Calculations of Induced Activity in the ATLAS Experiment for Nuclear Waste Zoning

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Abstract

Extensive calculations were performed with the general activation formula using the fluxes of high-energy hadrons and low-energy neutrons previously obtained from simulations with the GCALOR code of the ATLAS detector. Three sets of proton cross-sections were used for hadrons energy above 20 MeV: (a) one set calculated with the YIELDX code (i.e., the Silberberg-Tsao formula of partial proton spallation cross-sections), (b) one set calculated with the Rudstam formula, and (c) the 'best-estimate' dataset which was a compilation of the available experimental and calculated data. In the energy region below 20 MeV, neutron activation cross-sections were taken from evaluated nuclear data files. The activity of each nuclide for a predefined operation scenario (i.e., number and duration of irradiation and shutdown cycles) was normalized to reference values taken from the European or Swiss legislations, to obtain an aggregate estimate of the radiological hazard comparable with a nuclear waste zoning definition criteria that has been adopted by the LHC experiments. The impact of changing the operation scenario and hadrons spallation cross-sections datasets on the zoning was investigated for the 21 most common materials.

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1. Introduction

The installation of the CERN Large Hadron Collider (LHC) is under completion in a circular tunnel 27 km in circumference, previously housing the Large Electron Positron (LEP) collider. The tunnel, placed at a depth varying between 50 and 175 m, straddles the Swiss/French border on the outskirts of Geneva. LHC is designed to collide two counter rotating beams of protons or heavy ions. Proton-proton collisions are foreseen at an energy of 7 TeV per beam with a planned start-up in 2007. Each proton beam consists of 2808 bunches at full intensity, each bunch containing 1.15×10^{11} protons at the start of a nominal fill. The total energy stored in the nominal beam at top energy is 334 MJ. This enormous amount of energy will partly be deposited at the beam dumps at the end of each physics period, partly be dissipated in collimators and a certain fraction will convert into secondary particles following collisions at the centre of the experimental apparatus. Interaction of the primary and secondary particles with any material will generate induced radioactivity.

ATLAS (A Toroidal LHC ApparatuS), the biggest of the LHC experiments, is installed in an underground cavern. ATLAS is 42 m long, 11 m in radius and weighs approximately 7000 tons. It is one of the two high-luminosity, general-purpose LHC detectors (together with CMS). Beams of protons will collide at its centre with a centre of mass energy of 14 TeV and a design luminosity of 10^{34} cm^{-2} s^{-1}. The collisions will create a harsh radiation environment that will cause activation of material, some (and eventually all) of which will become radioactive waste.

The LHC machine and the experiments are classified as Nuclear Basic Installation (*Installation Nucléaire de Base*, INB) in France. The French legislation requires that INB installations provide – among other things – a radioactive waste study before starting operation. A compulsory part of the study is the identification of areas where radioactive waste may be produced from areas where only the production of conventional waste is expected. In case of the LHC experiments this translates into the identification of a boundary dividing the experimental cavern into two zones – a radioactive waste zone and a conventional waste zone.

The French legislation does not provide unconditional clearance levels, e.g., threshold values in terms of specific activity, below which a material can be released from the regulatory control into the public domain (after a proper radiation survey). A material can only be exempted from the regulatory control through a detailed theoretical study supported by experimental measurements. The aim of such a study is to establish a "zoning" (*zonage*) of the facility (accelerator tunnel, experimental areas, etc), i.e., a classification of areas where material may or may not have been activated to a level of concern. To demonstrate that a given component or material is "non-radioactive", i.e., "conventional", one has to prove that beam losses around the ring, or any other activation mechanism, can only produce "insignificant" amounts of radioactivity.

The present report describes methods, input data (including associated assumptions and potential sources of uncertainty), and results of the study performed in order to provide the basis for the choice of the nuclear waste zoning boundary in the ATLAS experiment.

The report is structured as follows. Section 2 describes the methodology generally applicable for an activation study and the basic criteria used for the classification of activated materials. Section 3 presents the compiled input data used for the study and is followed by Section 4, which describes specific techniques and adjustments necessary to implement the general methodology with respect to the format and deficiencies of available input data. Finally, Section 5 outlines the basic results obtained in the course of the study and the major findings are formulated in Section 6.

2. General approach

The primary aim of the ATLAS zoning study is to identify the experimental areas where material may or may not have been activated above a certain level.

The specific activity at a location $\vec{r}$ can be calculated according to the following formula, based on the prior knowledge of the particle fluxes and the nuclear reaction cross sections:

$$A^k(\vec{r}) = n(\vec{r}) \int_{E_{\min}}^{E_{\max}} \varphi(\vec{r}, E) \sigma^k(E) dE \times \mathrm{BuildUp}(T, t) \qquad (1)$$

where:
k is the index of the produced radionuclide;
$A^k(\vec{r})$, [Bq/g] is the activity of radionuclide k at location $\vec{r}$;
E, [MeV] is the energy of the incident particles;
$E_{\min}$, $E_{\max}$, [MeV] define the energy range of the particle spectrum;
$n(\vec{r})$, [10^{24}/g] is the concentration of target nuclei of interest at location $\vec{r}$;
$\varphi(\vec{r}, E)$, [1/(cm^2 s MeV)] is the particle flux spectrum at location $\vec{r}$;
$\sigma^k(E)$, [b] is the production cross section for radionuclide k;
$\mathrm{BuildUp}(T, t)$ is the function responsible for the activity build-up, which depends on the irradiation time T, cooling time t, and decay characteristics of radionuclide k and all its precursors in the decay chain.

For the zoning study of the LHC machine and experiments an operational limit was adopted for each radionuclide, equal to 1/10 of the exemption limit (LE) as given by the European Directive (EU) of 13 May 1996 [1], following the same approach adopted for the decommissioning of LEP [2]. For most radionuclides found in the accelerator components, the EU exemption limit is 10 Bq/g (exceptions are, e.g., tritium and ^{7}Be, for which the values are 10^6 Bq/g and 10^3 Bq/g, respectively). For radionuclides for which a value was not provided by the EU directive, the Swiss clearance levels (which essentially correspond to 1/10 of the EU values) [3] were adopted. The compilation of the LE values adopted for the study from these two regulations is given in Table 1. The reference zoning in ATLAS was chosen such that

$$\sum_k A^k(\vec{r}) / LE_k \le 0.1 \qquad (2)$$

Therefore, the goal of this study was to provide complete and reliable information about spatial distributions of induced activity in terms of LE values in the ATLAS experimental area.

3. Input data

Five types of input are generally required for any activation study. These are: (1) knowledge of geometry (design) and materials; (2) operational history (irradiation conditions); (3) flux spectra, e.g., calculated using FLUKA or another Monte Carlo transport code; (4) radionuclide decay data, i.e., half-life and decay branching ratios; (5) activation cross-sections. All the data collected and used in this study are described below.

3.1. Materials

Knowledge of geometry (design) and materials of an installation under study is crucial. First it is necessary for the fluxes/spectra calculations and then for the activity calculation based on the fluxes and concentrations of target materials. This last task usually requires a better quality of the knowledge of the materials. For example, in order to have a correct prediction of particle fluxes/spectra one usually needs only to account for the main components and structural materials (iron, copper, aluminum, carbon, lead, etc.), and this info can be extracted from engineering drawings and specifications. While for correct prediction of the induced activity, specifically in the low energy region (i.e., neutron capture reactions) one should pay special attention to important impurities like cobalt, silver, europium, cesium etc. with typical concentrations of only a few dozen ppm. As a rule, the impurities are not readily available for most materials.

For the purpose of the study, one can identify a representative set of individual materials that are the most common constituents of the ATLAS components and structures: Be, C, Al, Si, Ti, Cr, Mn, Fe, Ni, Co, Cu, Zn, Nb, Sn, Sb, Ag, W, Re, Au, Pb. The list includes:

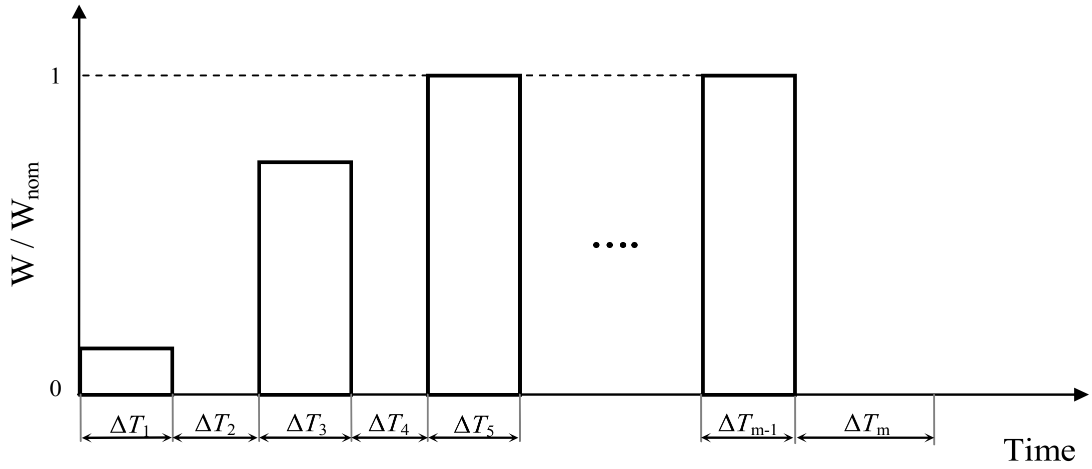
- base structural materials such as Be, C, Al, Fe, Ni, Cu, W, Pb;
- minor materials which are either alloying constituents or encountered as small components: Si, Ti, Cr, Mn, Zn, Nb, Sn, Ag, Sb, Re, Au;
- impurities in various materials at trace level: Co, Ag.

The only composite material considered in this study is stainless steel (69% Fe, 18% Cr, 11% Ni, 1.8% Mn, and 0.2% Co).

Despite the fact that the ATLAS detector is approaching its commissioning phase, there were not sufficiently complete and structured information on the material composition available that would meet requirements for a comprehensive activation study. In order to remain on the conservative side, a “dual” approach was followed. So in the first phase the best available description of the experiment and its materials was used to simulate the particle fluxes. In the second phase it was assumed that the experiment was made of all the pure materials listed above to calculate specific activity. Practically, one has to assume that the entire experimental volume is filled with the particular target material in question (e.g., beryllium, carbon, aluminum, etc.) and to provide separate considerations for each of the materials to define the largest zone.

3.2. Operating scenarios

In order to estimate induced activity, one needs to know at the minimum the period of operation, the average power (or luminosity in our case) during the operation period, and the cooling time. For a more correct modeling of the operational history one should account for all operational periods, variation of power, and shutdowns. For practical reasons, it is convenient to present the dependence of relative power (the ratio of real power W to nominal power W_{nom}) during the whole operation history as a step-wise function of time, i.e., as a sequence of m time intervals ΔT_j when the power is constant.



The real operation history is uncertain until the start of operation or until the final shutdown (decommissioning). Therefore, any study of activation prior to the final shutdown is dependent on possible scenarios of the future operation. Up to now there is no definitive knowledge of the lifecycle of the LHC and the experiments. As a result, one may consider several scenarios.

For the purpose of this study, the following two scenarios - baseline and alternative - were defined on the basis of recommendations provided in [4]:

- "the ATLAS operating scenario": an ATLAS year consists of 120 days of continuous running and 245 days of shutdown;
- "the CMS operating scenario": a CMS year is 60 days ON, 10 days OFF, 60 days ON, 10 days OFF, 60 days ON, 165 days OFF.

Also, based on the two baseline scenarios a number of modified scenarios were defined by changing the number of operating cycles, luminosity, and cooling time.

The ATLAS operating scenarios:

(A1) 10 years of operation at a luminosity of 10^{34} followed by 100 days of cooling
(A2) 2 years of operation at a luminosity of 10^{34} followed by 100 days of cooling
(A3) 2 years of operation at a luminosity of $2 \cdot 10^{33}$ followed by 100 days of cooling
(A4) 10 years of operation at a luminosity of 10^{34} followed by 2 years of cooling
(A5) 2 years of operation at a luminosity of $2 \cdot 10^{33}$ followed by 10 days of cooling

The CMS operating scenarios:

(C1) 13 years[i] of operation at a luminosity of $5 \cdot 10^{33}$ followed by 100 days of cooling
(C2) 13 years of operation at a luminosity of $5 \cdot 10^{33}$ followed by 2 years of cooling
(C3) 13 years of operation at a luminosity of $5 \cdot 10^{33}$ followed by 10 days of cooling

3.3. Fluxes

The fluxes of high-energy hadrons and low-energy neutrons in a fine spatial mesh were obtained from simulations carried out by Mike Shupe with the GCALOR code in a realistic 3D GEANT geometry implementation of the ATLAS detector [5]. The calculated fluxes in plain ASCII format together with a read-back procedure are available on the Activation Web Page [6]. The

[i] The 13 CMS years are structured in the following way: 1 CMS year at $0.5 \cdot 10^{33}$ followed by 1 CMS year at $1.7 \cdot 10^{33}$ followed by 1 CMS year at $3.3 \cdot 10^{33}$ followed by 10 CMS years at $5.0 \cdot 10^{33}$.

following information about the energy spectra and spatial distribution was available for the activation calculations:

- For each fine spatial bin (as defined below), the following flux information is available (see fig. 1-8):

  a. Thermal neutron flux (10^{-5} eV to 0.414 eV)
  b. Moderated neutron flux (0.414 eV to 3.78 keV)
  c. Intermediate neutron flux (3.78 keV to 2.19 MeV)
  d. Fast neutron flux (2.19 MeV to 20 MeV)
  e. High energy neutron flux (above 20 MeV)
  f. Proton flux (above 20 MeV)
  g. π^- flux (above 20 MeV)
  h. π^+ flux (above 20 MeV)

The fine spatial binning of the GCALOR calculation of particle fluxes

ΔZ = 10 cm (0<Z<2400 cm)	ΔR = 0.1 cm (0<R<4 cm)
	ΔR = 1 cm (4<R<120 cm)
	ΔR = 10 cm (120<R<1200 cm)

- The following flux information was in addition available for two sets of spatial binning:

  i. neutron flux spectra

ΔZ = 10 cm (0<Z<2400 cm)	ΔR = 10 cm (0<R<50 cm)
ΔZ = 100 cm (0<Z<2400 cm)	ΔR = 100 cm (0<R<1200 cm)

  j. proton flux spectra
  k. π^- flux spectra
  l. π^+ flux spectra

ΔZ = 10 cm (0<Z<2400 cm)	ΔR = 10 cm (0<R<50 cm)
ΔZ = 50 cm (0<Z<2400 cm)	ΔR = 50 cm (0<R<1200 cm)

Neutron energy spectra were calculated in 60 log-uniform bins within an energy range from 0.414 eV to 139 GeV. Charged particle spectra were calculated in 20 log-uniform bins within an energy range from 12.9 MeV to 89.3 GeV.

The available flux information in the fine and coarse spatial binning was interpolated in order to obtain the spatial and spectral flux information used in the activation calculations. A few examples of typical flux spectra are provided in figures 9-10.

3.4. Radionuclide decay data

Knowledge of basic nuclide characteristics, i.e., natural abundance of stable nuclides and half-lives and decay branching ratios of radionuclides, is necessary for the simulation of radionuclide build-up/decay processes. These characteristics have been evaluated for virtually all the known radionuclides and are distributed as evaluated nuclear structure data files ENSDF [7], with new evaluations published in the Nuclear Data Sheets monthly journal.

The basic decay characteristics of radionuclides are also available as specialized data-sets processed from the ENSDF files. These data-sets are easily available as web-based or downloadable databases and more user-friendly than sophisticatedly formatted evaluated files and thus more preferable for routine applications. For the purpose of this study, NuDat 2.1 [8] - a widely known database of this kind - was used as the single source of radionuclide decay data.

3.5. Activation cross-sections

When studying radionuclide production in high-energy hadron accelerator experiments, one may limit the consideration to the activation of stable target nuclei with hadrons only. Provided the accelerator energy is sufficiently high, most of the induced radioactivity is usually due to inelastic interactions of secondary particles – neutrons, protons and positive and negative pions [9]. Other particles rarely play any significant role. This is particularly true close to the beam-pipe where most of the induced activation is taking place. Energy spectra of secondary hadrons depend on the beam energy and, primarily, on the shielding and other surrounding material. The energy of hadrons extends from thermal energies (for neutrons) to hundreds of GeV. Up to now, the activation (i.e., radionuclide production) cross-sections are not readily available for all the particles and materials of interest within the entire energy range.

3.5.1. The energy region below 20 MeV

For most of the important materials, neutron activation cross-sections are well studied from thermal energies to 20 MeV since these data are widely used for nuclear reactor calculations and other important applications. The tabulated data are available from a number of evaluated nuclear data files (ENDF/B, JENDL, JEFF, etc.).

One should note that in the energy region below 20 MeV only neutrons make a significant contribution to activation. This is evident from the analysis of hadron spectra and inelastic cross-sections. First, the fraction of neutrons in hadron spectra below 20 MeV exceeds the fraction of charged particles (protons and pions) at least by an order of magnitude (see, fig. 9-10). Second, in the energy region above a few MeV, the activation is dominated by inelastic interactions of hadrons with nuclei. Inelastic cross-sections are smooth functions of energy and may vary for different hadrons within one order of magnitude (see, fig. 11 [10]) with neutrons dominating below 30 MeV. As a result, contribution of charged particles to the activation below 20 MeV is negligible. Accordingly, the need for nuclide production cross-sections below 20 MeV are fully satisfied with the already existing neutron nuclear data.

For the purpose of this study, neutron activation cross-sections were taken from both ENDFB-6.8 [11] and JEFF-3.0A [12] (in the order of preference). All the nuclear reactions that produce radioactive nuclides with half-life longer than 1 hour and shorter than 10^6 years are listed in Table 2.

3.5.2. The energy region above 20 MeV

For the second energy region - above 20 MeV - all the particles are important (neutrons, pions, protons - in the order of importance). There are almost no evaluated (or recommended) tabulated activation cross-sections up to the GeV region for neutrons or protons while tabulated data for pions are completely missing.

As a result, for the activation study one has first to compile and analyze the available activation cross-section data. A number of tabulated data libraries calculated with various nuclear model codes, semi-empirical formulas of spallation yields, and experimental data can be used as a source of activation cross-section data. A brief review of the data sources used is given below.

The tabulated data

The nuclide production processes are being actively studied for protons and neutrons from 20 MeV to 100-200 MeV. These data are used in the conceptual design of sub-critical nuclear energy installations with an external neutron source (Accelerator Driven Systems) and in the design of accelerators for long-lived nuclear waste transmutation. There are available several data libraries based on nuclear model code calculations, for example:

- New versions of ENDF/B files (since version 6.8) contain neutron and proton data for some materials up to 150 MeV. Unfortunately, the list of materials (stable target nuclides) is rather short. The data were calculated with a version of the ALICE code (i.e., the cross-section data may not be referred to as “evaluated”).
- Another widely used neutron and proton activation data library, the MENDL library, was calculated with the ALICE-IPPE code up to 100 MeV for neutrons [13] and up to 200 MeV for protons [14]. The main advantage of the library is an exhaustive list of target materials, including long-lived radionuclides.
- Recently, JAERI provided JENDL High Energy files for protons and neutrons up to 3 GeV for 40 materials [15]. However, both quality and applicability of the data for the purpose of this study are questionable.

The Medical isotope production library [16] is probably the only charged particle activation cross-section library, which is based on rigorous evaluation of experimental data. However, neither the energy range nor the list of evaluated reactions satisfy the needs for this study.

The compilation by Sobolevsky et al. [17], is an example of a good set of tabulated proton activation cross-sections up to 10 GeV based on experimental data. This compilation may be used in practical applications. However, the list of compiled cross-sections is limited to the most common materials for which sufficient amount of measured data were published (e.g., Al – 7 functions, Fe – 16, Ni – 15, Cu - 17). Other important target materials such as lead and tungsten are not compiled (Pb - 3 functions, W - 0). This compilation is based on experimental data included into the NUCLEX [18] database and, consequently, does not consider a large volume of experimental data published after 1998.

Cross section formulas

Historically, activation of accelerator components was studied with the use of semi-empirical formulas for proton cross-sections developed for astrophysics research. First of all, there is the Rudstam formula [19], which was developed in the middle of sixties, and then the Silberberg-Tsao formula [20-24] that was last updated in the late nineties. Rudstam is a simple and not very accurate formula, especially for deep spallation processes (i.e., when the atomic weight difference between the target and the product exceeds ~30 mass units) and for targets within 3-4 mass units of the product. The Silberberg-Tsao formula is rather complex and provides better results. It is implemented in FORTRAN and is available from the GSI site as the YIELDX code [25]. Both formulas have limitations:

- They work well for high energies (from about 50 MeV) and do not work near the reaction threshold;
- They are designed for protons only;
- One cannot calculate tritium production with them.

The last of the above limitations is not a significant deficiency since the contribution of tritium to the total LE equivalent is negligible. Production of tritium may furthermore be estimated using the semi-empirical formula by Konobeev and Korovin [26], which provides a relatively good prediction of the tritium production cross-section in interactions of protons, neutrons, and light nuclei (He-3, He-4) with materials ranging from carbon to bismuth.

<u>Experimental data</u>

There are a lot of experimental data published for radionuclide production cross-sections. A thorough analysis of thousands of individual publications would be impossible. In this study, we consider only two major compilations of experimental data - EXFOR and NUCLEX. EXFOR is readily available from IAEA [27] and NEA [28] web-sites. NUCLEX [18] is available both in printed form and as an ACCESS data-base. Most experimental data above 20 MeV are for protons while data for neutrons and pions are very sparse. The compilations are not yet exhaustive and are partially overlapping. However, in aggregate, these two sources seem to provide a rather thorough selection of published experimental results.

Analysis of the sources of cross-section data mentioned above has shown that:

- the available tabulated data from nuclear model code calculations for protons (up to 200 MeV) and neutrons (up to 100-150 MeV) do not cover the entire energy region of interest; the quality and applicability range of the data are also questionable;
- there is a number of semi-empirical formulas for protons which are usable for nearly all materials, but the applicability range in terms of atomic weight of produced nuclei and energies is also questionable;
- neither nuclear model codes nor formulas allow to separate yields for ground and isomeric states of the radionuclides produced;
- there is a vast collection of experimental data for proton cross-sections, however, the data cannot be directly used in simulations since it is necessary to evaluate the data and make interpolations in the energy regions not covered well by the experiments; the data are in any case useful for a qualitative assessment of the calculated data;
- there are no tabulated data for pions;
- experimental data for neutrons and pions is insufficient.

Taking into account the aforementioned deficiencies in the cross-section data, one has to use the following approach in the compilation and assessment of the **proton** cross-sections:

- The Silberberg-Tsao formula is used as a primary source of input data for protons;
- The Rudstam formula is used only to cross-check the Silberberg-Tsao formula;
- A “best estimate” dataset of proton cross-sections was compiled using all available information. This made it possible to benchmark the Silberberg-Tsao and Rudstam formulas, the MENDL-2p library, and other data (if necessary) against a representative pool of experimental data.

For **neutrons and pions**, the proton cross sections will have to be used within the energy region above 20 MeV. One can provide a reasonable motivation for such a substitution. Analysis of inelastic cross-sections (fig. 11) shows that the pion cross sections are several times higher than those for protons in the energy region 40-400 MeV. On the other hand, the fraction of pions in the aggregate hadron spectra in this energy region is usually much lower than that of protons (see fig. 9-10) and, consequently, the effect of the substitution will not be very high. For energy above 400 MeV, the behavior of inelastic cross-section for protons and pions is rather similar and the difference never exceeds 30%. In the case of the neutrons, the similarity of inelastic cross-section is even more evident – the difference does not exceed 10% in the entire energy region above 20 MeV. As a result, one may expect that the use of proton cross-sections for all hadrons, including neutrons and pions, may produce an 'additional' uncertainty of some 30-50%, which is acceptable when we take into consideration that the proton cross-sections themselves are not usually known with better accuracy.

A somewhat similar approach underlies the concept of ω–factors, which has been used for decades in evaluation of activation in accelerator materials [29]. The core of the concept is that hadron flux spectra above a certain energy limit (usually 20 or 50 MeV) are folded with corresponding inelastic cross-sections to obtain total number of inelastic interactions (so-called 'stars') per unit of volume; then the 'stars' are multiplied by $\omega(T,t)$ - a function of irradiation time T and cooling time t – to calculate dose rate on the surface of semi-infinite uniformly irradiated material. An implicit assumption behind the concept is that $\omega(T,t)$ does not strongly depend on the type of hadrons and their spectra above the specified energy limit. A more recent study of $\omega(T,t)$ for various spectra using FLUKA has shown that disregarding the real hadron spectra may lead to an uncertainty within a factor of 3-5 [9].

However, the issue of applicability of the proton cross-sections as a substitute to other hadrons is still open but some results recently provided with FLUKA simulations support the correctness of this approach. The resulting effect of merging all hadrons into the proton category on the predictions accuracy of P-32 and P-33 activity in liquid argon in the ATLAS electromagnetic calorimeters has been studied [30]. The outcome of the study is that in this particular case, the substitution incurs an additional inaccuracy of about 20%.

There were three sets of cross-sections prepared for the purpose of the present study. Each of the following sets includes cross-sections for all produced radionuclides with half-life longer than 1 hour and shorter than 10^6 years. If the product nuclei can be found in both ground and metastable states, then the m/(g+m) ratio was assumed to be equal 1/2. When necessary, the production of short-lived precursors was accounted for by increasing the respective cross-sections of 'long-lived' radionuclides (i.e., use was made of cumulative cross-sections).

(a) A cross-section dataset for all the 20 individual target materials based on the Silberberg-Tsao formula was calculated.
(b) A cross-section dataset for all the 20 individual target materials based on the Rudstam formula was calculated;
(c) A "best estimate" cross-section dataset for Be, C, Al, Si, Ar, Cr, Mn, Fe, Ni, Cu (see attachments to this report) based on the available data, including EXFOR, NUCLEX, MENDL-2p, the Medical library, the compilation of Sobolevsky et al., and finally the energy threshold data [31]. A simple 'by-hand' interpolation technique was used as proposed in [32].

A side effect of the "best estimate" cross-section dataset compilation is an additional confidence in the applicability of Silberberg-Tsao formula for all the studied radionuclides (within a factor 2-3 for energy above 50 MeV). A limited analysis of the results using the Rudstam formula has confirmed that it is a priori less accurate formula than the Silberberg-Tsao formula. It does, however, provide relatively good results for spallation products above 100 MeV where the difference between the target and product nuclide is between 3 and 30 atomic mass units. For most radionuclides, both the Silberberg-Tsao and the Rudstam formulas provide conservative results below 100 MeV. An extensive comparison has shown that the MENDL-2p library provides an acceptable accuracy (within a factor of 2-3) in the energy region from the reaction threshold up to 100 MeV.

4. The specific approach with respect to the available input data

While taking into consideration the actual volume, format and quality of the input data that have been compiled, one should identify the specific approach/techniques necessary to implement the general methodology formulated in Section 2.

The specific activity of individual radionuclides was calculated based on the flux spectra calculated in discrete spatial (in R and Z) and energy intervals (bins) using the realistic ATLAS geometry model (see Section 3.3). Section 4.1 below defines more exactly the activation formula (Equation 1) in order to account for the discrete format of the fluxes.

Specific activity of individual radionuclides produced in particular target material by low energy neutrons (E< 20 MeV) and high energy hadrons (i.e., neutrons, protons, positive and negative pions above 20 MeV) are calculated separately and then summed up. This is done because of the different formats of the available cross-section data in the two energy regions (see Section 3.5).

Another step required for the implementation of the activation formula (Equation 1) is the definition of a concrete technique to calculate the radionuclide build-up function. Section 4.2 below describes the simple analytical technique developed for the calculation of the build-up function with respect to the typical duration of the irradiation and cooling periods for the identified operating scenarios (see Section 3.2).

Since the precise distribution of target materials is not known within the entire ATLAS experiment area (i.e., it is impossible to exclude the possibility that a small item with high content of a target material may be situated at any location), the most general conservative assumption has to be used and that is that such a material can be located anywhere within the studied area. Practically, this was implemented by taking concentration of target nuclei n in equation (1) independent of location $\vec{r}$ and repeating calculations for each material (Be, C, Al, etc.) to define the material giving the largest zone.

Finally, the calculated specific activities of individual radionuclides are weighed by the LE values (Equation 2) and are plotted as 2D isoline graphs in R-Z coordinates for each target material. Within the $\Sigma_k(A_k/LE_k)=0.1$ isoline curve, the target material is considered as "nuclear waste" and beyond the isoline the material is considered as "conventional waste." The 0.1-isoline that is the most distant from the beam-line, i.e., the one enveloping all the other target materials, will be the "zoning boundary", beyond which no "radioactive" material is expected to be produced under the specific operation scenario.

4.1. Bin-averaged cross-sections

Equation (1) has to be reformulated into a more practical form to suit the discrete nature of the input information: the particle fluxes are calculated by the GCALOR code giving the average value in a spatial interval (volume) and the particle flux energy spectra are grouped into energy intervals (bins).

As a result, specific activity (a continuous function of $\vec{r}$ in Equation 1) will be calculated as an average value in each volume V_j :

$$\begin{aligned} A_j^k &= \frac{1}{V_j}\int_{Vj} A^k(\vec{r})d\vec{r} = \frac{n}{V_j}\int_{E_{\min}}^{E_{\max}}\int_{Vj}\varphi(\vec{r},E)\sigma^k(E)\,d\vec{r}\;dE \times \mathrm{BuildUp}(T,t) = \\ &= n\int_{E_{\min}}^{E_{\max}}\varphi_j(E)\sigma^k(E)dE \times \mathrm{BuildUp}(T,t) = \\ &= n\sum_i \varphi_{j,i}\,\sigma_{i,j}^k \times \mathrm{BuildUp}(T,t) \approx \\ &\approx n\sum_i \varphi_{j,i}\sigma^k{}_i \times \mathrm{BuildUp}(T,t) \end{aligned} \tag{3}$$

where:

$\varphi_j(E) = \frac{1}{V_j}\int_{V_j}\varphi(\vec{r},E)\,d\vec{r}$ [1/(cm^2 s MeV)] is the volume-averaged hadron flux spectrum in spatial interval (volume) *j*;

$\varphi_{j,i} = \int_{E_i}^{E_{i+1}}\varphi_j(E)dE$ [1/(cm^2 s)] is the flux in energy bin *i* averaged over spatial interval *j*;

The bin averaged cross section $\sigma_{i,j}$ is dependent on the energy spectrum $\varphi_{j,i}(E)$ in energy bin *i* and spatial interval *j*:

$$\sigma_{i,j} = \frac{\int_{E_i}^{E_{i+1}}\sigma(E)\varphi_j(E)dE}{\int_{E_i}^{E_{i+1}}\varphi_j(E)dE} \tag{4}$$

Since the explicit form of $\varphi_{j,i}(E)$ is unknown, a model spectrum has to be assumed. Such an assumption introduces an error in the calculations whose magnitude depends on the local properties of the functions $\sigma(E)$ and $\varphi_j(E)$, as well as on the width of energy interval. The larger the number of energy bins (smaller energy intervals) the less sensitive is the bin averaged cross-sections to a model spectrum. If the number of bins is large enough then a single 'universal' model spectrum in all spatial intervals can be used, thus a single set of bin averaged cross sections will be valid for all spatial intervals:

$$\sigma_{i,j} \approx \sigma_i = \frac{\int_{E_i}^{E_{i+1}} \sigma(E)\chi(E)dE}{\int_{E_i}^{E_{i+1}} \chi(E)dE} \quad (5)$$

The following model spectrum $\chi(E)$ was used for **neutrons** in this study:

$$\chi(E) = \begin{cases} C_1 E \exp(-\frac{E}{\theta_{th}}) & \text{for } E \le 0.414 \text{ eV} \\ \frac{C_2}{E} & \text{for } 0.414 \text{ eV} \le E \le 20 \text{ MeV} \\ C_3 & \text{for } 20 \text{ MeV} \le E \end{cases} \quad (6)$$

$\chi_1(E)$ - a Maxwellian spectrum used in the thermal energy region ($E \le 0.414$ eV), where $\theta_{th}=kT$ is the thermal energy that corresponds to the temperature of material (assumed 293 K).

$\chi_2(E)$ - a Fermian spectrum, slowing-down component at energies above thermal boundary and below 20 MeV.

$\chi_3(E)$ - flat, energy independent spectrum above 20 MeV.

It is only the flat spectrum that was used as the model spectrum for **charged hadrons**.

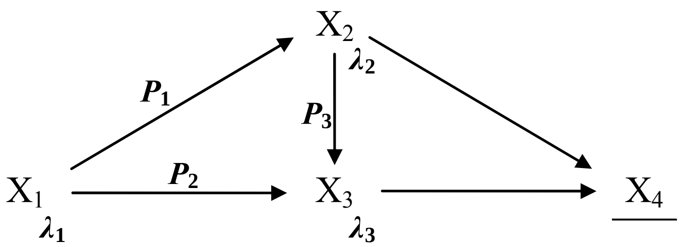
The selection of the first two components in the model spectrum $\chi_1(E)$ and $\chi_2(E)$ is a common (and usually the best) assumption, which is based on a general analysis of a neutron slowing down process in a media with low absorption.

The third component $\chi_3(E)$ for high-energy neutrons and charged particles is an arbitrary assumption. Considering that the major inaccuracy comes from the lack of knowledge of continuous cross-section function - $\sigma(E)$, it is reasonable to assume that the averaging using the flat model spectrum adds only an insignificant error to the bin-averaged cross section, especially if each energy bin is small (that is, the number of log-uniform bins for the whole energy region E_{min} - E_{max} is large).

4.2. The build-up function

The particle flux around an accelerator beam-line is relatively low (as compared to a reactor core). So, it is reasonable to disregard burn-up (depletion) of both stable target nuclides and activation products. This significantly simplifies the simulation of the radionuclide build-up. As a result, one can use analytical formulations deduced from balance equations for radioactive decay chains.

For the purpose of this study the consideration of all the possible radionuclide decay chains was limited to the following generalized chain with three radioactive nuclides:



Where, P_1, P_2, P_3 – are branching ratios; and λ_1, λ_2, λ_3 – are decay constants[ii] of the parent (X_1), daughter (X_2), and grand-daughter (X_3) nuclides.

Then the build-up of radionuclides after exposure at a constant luminosity during time T and cooling time t are calculated using the following equations:

$$\text{BuildUp}^1(T,t) = \lambda_1 N_1(T)\exp(-\lambda_1 t) \tag{7}$$

$$\text{BuildUp}^2(T,t) = \lambda_2 P_1 \lambda_1 N_1(T)\left[\frac{\exp(-\lambda_1 t)}{\lambda_2-\lambda_1}+\frac{\exp(-\lambda_2 t)}{\lambda_1-\lambda_2}\right]+\lambda_2 N_2(T)\exp(-\lambda_2 t) \tag{8}$$

$$\begin{aligned}\text{BuildUp}^3(T,t) = {} & \lambda_3 P_3 P_1 \lambda_2 \lambda_1 N_1(T)\left[\frac{\exp(-\lambda_1 t)}{(\lambda_3-\lambda_1)(\lambda_2-\lambda_1)}+\frac{\exp(-\lambda_2 t)}{(\lambda_1-\lambda_2)(\lambda_3-\lambda_2)}+\right.\\ & \left.+\frac{\exp(-\lambda_3 t)}{(\lambda_1-\lambda_3)(\lambda_2-\lambda_3)}\right]+\lambda_3 P_3 \lambda_2 N_2(T)\left[\frac{\exp(-\lambda_2 t)}{\lambda_3-\lambda_2}+\frac{\exp(-\lambda_3 t)}{\lambda_2-\lambda_3}\right]+\\ & +\lambda_3 P_2 \lambda_1 N_1(T)\left[\frac{\exp(-\lambda_1 t)}{\lambda_3-\lambda_1}+\frac{\exp(-\lambda_3 t)}{\lambda_1-\lambda_3}\right]+\lambda_3 N_3(T)\exp(-\lambda_3 t)\end{aligned} \tag{9}$$

$$N_1(T)=\frac{1-\exp(-\lambda_1 T)}{\lambda_1} \tag{10}$$

$$N_2(T)=P_1\left[\frac{1-\exp(-\lambda_2 T)}{\lambda_2}+\frac{\exp(-\lambda_1 T)-\exp(-\lambda_2 T)}{\lambda_1-\lambda_2}\right] \tag{11}$$

$$\begin{aligned}N_3(T)= {} & P_1 P_3\left[\frac{1-\exp(-\lambda_3 T)}{\lambda_3}+\frac{\lambda_2}{\lambda_2-\lambda_1}\frac{\exp(-\lambda_1 T)-\exp(-\lambda_3 T)}{\lambda_1-\lambda_3}+\right.\\ & \left.+\frac{\lambda_1}{\lambda_1-\lambda_2}\frac{\exp(-\lambda_2 T)-\exp(-\lambda_3 T)}{\lambda_3-\lambda_2}\right]+P_2\left[\frac{1-\exp(-\lambda_3 T)}{\lambda_3}+\frac{\exp(-\lambda_1 T)-\exp(-\lambda_3 T)}{\lambda_1-\lambda_3}\right]\end{aligned} \tag{12}$$

In the case, when the operation history is modeled by a stepwise function of time (see section 3.2), i.e., as a sequence of m time intervals ΔT_j with constant luminosity W_j, then the build-up is calculated using the following equation:

$$\text{BuildUp}^{\text{n}} = \sum_{j=1}^{m}\frac{W_j}{W_{nom}}\text{BuildUp}^{\text{n}}\left(\Delta T_j, \sum_{i=j+1}^{m}\Delta T_i\right) \tag{13}$$

where W_{nom} is nominal luminosity, i.e., luminosity at which the particle flux was calculated, and $\text{BuildUp}^{\text{n}}(T,t)$ is defined by equations (7-12) respectively for the activation product (n=1), its daughter (n=2), and grand-daughter (n=3) nuclide.

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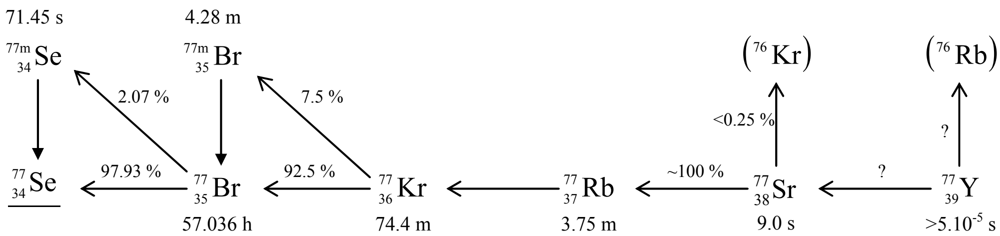
ii) $\lambda = \ln 2/\tau$, where τ is half-life of the radionuclide.

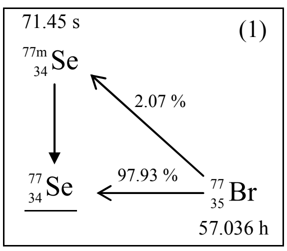
Parametric representations of decay chains of all explicitly accounted radionuclides produced from the irradiation of stable target nuclides (up to Pb-208) is provided in Table 3. All radionuclides with half-life from 1 hour to 10^6 years and their decay products are explicitly treated in this study. Taking into account the specifics of the studied case (the range of typical exposure and cooling time), an explicit treatment of short-lived activation products with half-life time less than 1 hour using equations (7-12) is unreasonable. However, production of the short-lived radionuclides cannot be completely disregarded because they contribute to the activity of long-lived nuclides down the decay chain. The contribution of the short-lived nuclides can be accounted for by an appropriate increase of the production cross sections for the explicitly treated nuclides. For the radionuclides marked with '+' in Table 3 use was made of the cumulative cross sections (i.e., the sum of production cross-sections for a given radionuclide and all its short-lived precursors, which have not been explicitly treated).

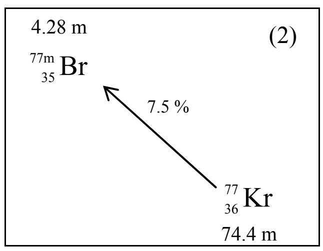
As a rule, most of the radionuclides with a half-life exceeding one hour have decay chains that include two or less progeny radionuclides. The rare exceptions to this 'rule' are considered case-by-case and the 'long' decay chains are divided into shorter ones. A correct simulation of build-up processes is thus achieved by a proper choice of short chains and the use of cumulative cross-sections.

Let us consider the following decay chain as an example.



According to the above described technique, one must take into consideration four radionuclides. These are ${}^{77}_{36}\mathrm{Kr}$ and ${}^{77}_{35}\mathrm{Br}$ (because their half-life exceed one hour) and their short-lived daughter nuclides ${}^{77m}_{35}\mathrm{Br}$ and ${}^{77m}_{34}\mathrm{Se}$. This chain is an example of an 'exception' because a chain of four nuclides cannot be immediately described by equations (7-12). Nonetheless, the build-up of all the nuclides still can be simulated using the equations if one considers the two following separate chains and properly calculates cumulative production cross-sections for radionuclides ${}^{77}_{36}\mathrm{Kr}$ and ${}^{77}_{35}\mathrm{Br}$.





The parametric representation of the decay chains according to the notations in equations (7-12) will be as follows.

(1) $X_1 = {}^{77}_{35}\mathrm{Br}$, $X_2 = {}^{77m}_{34}\mathrm{Se}$, $P_1 = 0.027$, τ_1 =57.036 h, τ_2 = 71.45 s

(2) $X_1 = {}^{77}_{36}\mathrm{Kr}$, $X_2 = {}^{77m}_{35}\mathrm{Br}$, $P_1 = 0.075$, τ_1 =74.4 m, τ_2 = 4.28 m

In addition, cumulative cross-section of ${}^{77}_{36}Kr$ is the sum of independent production cross-sections for ${}^{77}_{36}Kr$, ${}^{77}_{37}Rb$, ${}^{77}_{38}Sr$, and ${}^{77}_{39}Y$; cumulative cross-section of ${}^{77}_{35}Br$ is the sum of independent production cross-sections for ${}^{77}_{35}Br$, ${}^{77m}_{35}Br$, ${}^{77}_{36}Kr$, ${}^{77}_{37}Rb$, ${}^{77}_{38}Sr$, and ${}^{77}_{39}Y$.

In this exceptional case, the division of the chains does not produce any significant error to the ${}^{77}_{35}Br$ build-up (within a given range of typical exposure and cooling times) because its half-life is two orders of magnitude higher than half-lives of ${}^{77}_{36}Kr$ and ${}^{77m}_{35}Br$.

5. Results

The activation was calculated for an extensive list of materials, assuming each time a single material for all detector components. For each of the 20 chemical elements and 1 composite material studied, the high-energy hadron and low-energy neutron activation were calculated and the sum of the two was plotted over the detector volume in form of 2D maps showing the $\Sigma_k(A_k/LE_k)$ isolines. Taking into account the location and material composition of a detector component and the maps for each of the materials, it is possible to understand whether the component will be activated to more than 1/10 of the exemption limit.

Extensive calculations were repeated for several different assumptions on irradiation and cooling times, and using different cross section sets:

- a complete list of materials using Silberberg-Tsao cross-sections for all the operation scenarios identified in section 3.2;
- a complete list of materials using the Rudstam formula for operation scenario (A1);
- a limited list of materials (Be, C, Al, Si, Cr, Mn, Fe, Ni, Cu) using the “best-estimate” compilation of cross-sections for scenarios (A1), (A2), (C1), (C2);
- low-energy neutron activation for a limited list of materials (Re, W, Sb, Sn, Ag, Nb, Zn, Cu, Ni, Co, Fe, Mn, Cr and Ti) in which low-energy neutrons (E<20 MeV) produce a noticeable contribution to activation – for operating scenario (A1) only.

All the maps are now available from the “ATLAS Activation Web-page” [6]. Basic results for scenario (A1) are provided on figures 12-32 to show the difference of using Silberberg-Tsao, Rudstam, and the “best-estimate” sets of proton cross-sections.

Most ATLAS detector components will only become waste at the time of decommissioning of the LHC. Basic results are provided for 10 years of homogeneous irradiation, which corresponds to 10 years of LHC operation at a luminosity of 10^{34} cm^{-2} s^{-1} for 120 days per year. Other operation scenarios were explored but it was found that the duration of the irradiation did not exert a strong influence on the zoning. The length of the cooling time, however, makes a large difference on the zoning.

Analysis of results for the baseline scenario (A1) shows that if only aluminum components would be of concern, the 10^{-1} isoline of $\Sigma_k(A_k/LE_k)$, marking the radioactive waste zone, would reach a maximum radius of less than 3 meters at a distance of 3-4 m from the interaction point (and about 1 m beyond 3-4 m in Z). In the case of components made of nickel, the zone is larger, extending 4 meters at the location of this peak and including another broad peak, almost 5 meters in radius stretching between 6 and 13 meters from the interaction point. The second peak cuts through the End Cap Toroid. If one assumes that some components could have been made of pure cobalt, practically the whole cavern would fall within the radioactive waste zone. This is due to the low-energy neutron activation, particularly the reaction $^{59}Co(n, \gamma)^{60}Co$. For most of the other materials (Fe, Cu, Pb, Au, Re, W, Sn, Nb, Mn, Cr, Ti, Si, C and Be) the zoning boundary lies below that of nickel. Only alloys with more than 0.1% (wt.) cobalt, 1% antimony, 10% zinc and 1% silver have zoning boundaries larger than nickel.

The basic sources of uncertainty that affect results of this study originate from the uncertainty of calculated fluxes and the activation cross-sections for high-energy hadrons. A parallel zoning study using full-scale FLUKA simulations was conducted to provide more assurance in definition of ATLAS zoning [33]. FLUKA results are in good agreement with comparable results of the present report.

6. Conclusions

The results of the present calculations served as a source material for the decision on the zoning of the ATLAS experiment. Other aspects influencing the decision were the expected irradiation conditions and cooling times that the detector will experience, the likelihood and time horizon in which a component might become waste, the physical boundaries of the components, and the need to prevent a large overestimation of the radioactive waste zone while ensuring that to the current best knowledge it includes all areas where radioactive waste may be produced.

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References

[1] Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation, Official Journal of the European Communities L 159 (29 June 1996).

[2] M. Silari and L. Ulrici, Investigation of induced radioactivity in the CERN Large Electron Positron collider for its decommissioning, Nuclear Instruments and Methods A526, 510-536 (2004).

[3] Swiss "ORDONNANCE DU 22 JUIN 1994 SUR LA RADIOPROTECTION (ORaP)", 814.501

[4] L. Ulrici, "General Procedure For The Establishment of the Waste Study for the LHC Experiments", CERN-SC-2005-085-RP-TN

[5] M. Bosman, I. Dawson, V. Hedberg, M. Shupe, "Estimation of Radiation Background, Impact on Detectors, Activation and Shielding Optimization in ATLAS", ATL-GEN-2005-001

[6] ATLAS Zoning Study, http://atlas.web.cern.ch/Atlas/TCOORD/Activities/CommonSys/Shielding/Activation/act_zoning.html

[7] Evaluated Nuclear Structure Data File (ENSDF), http://nds121.iaea.org/ensdf/index.jsp

[8] NuDat 2.1 - selected evaluated nuclear data, http://www-nds.iaea.org/nudat2/index.jsp

[9] M. Huhtinen, L.Y. Nicolas, Advanced Method of Estimating Residual Dose Rates in a Hadron Environment. CMS NOTE-2002/019

[10] B.S.Sychev. Cross Sections of High Energy Hadrons Interactions with Nuclei. Moscow Radiotechnical Institute, 1995, 284 p. (in Russian)

[11] Evaluated Nuclear Data File - ENDF/B-VI release 8, http://www.nndc.bnl.gov/csewg/

[12] J-Ch. Sublet, A.J. Koning, R.A. Forrest and J. Kopecky, "The JEFF-3.0/A Neutron Activation File - EAF-2003 into ENDF-6 format", JEFF-DOC-982, 2003. http://www.nea.fr/html/dbdata/JEFF/

[13] Yu.N. Shubin, V.P. Lunev, A.Yu. Konobeyev, A.I. Ditjuk, "Cross-section data library MENDL-2 to study activation as transmutation of materials irradiated by nucleons of intermediate energies", report INDC(CCP)-385 (International Atomic Energy Agency, May 1995). http://www.nea.fr/dbforms/data/eva/evatapes/mendl_2/

[14] Yu.N. Shubin, V.P. Lunev, A.Yu. Konobeyev, A.I. Ditjuk, MENDL-2P Proton reaction data library for nuclear activation (Medium Energy Nuclear Data Library), IAEA-NDC-204, Nuclear Data Section, IAEA, Vienna (1998). http://www.nea.fr/dbforms/data/eva/evatapes/mendl_2p/

[15] JENDL High Energy File 2004, http://wwwndc.tokai-sc.jaea.go.jp/ftpnd/jendl/jendl-he-2004.html

[16] Charged Particle Cross-Section Database for Medical Radioisotope Production: Diagnostic Radioisotopes and Monitor Reactions IAEA, Vienna, 2001, IAEA-TECDOC-1211, http://www-nds.iaea.org/medical/

[17] V.G. Semenov, N.M. Sobolevsky, Approximation of Radionuclides Production Cross Sections in Proton Induced Nuclear reactions. Report on ISTC Project No. 187, Moscow, 1998

[18] Production of radionuclides at Intermediate Energies. Ed. H.Schopper. Landolt-Börnstein. Springer-Verlag Numerical data and functional relationships in science and

technology. New series. Subvolumes I/13a (1991), I/13b (1992), I/13c (1993), I/13d (1994), I/13i (1998)

[19] G. Rudstam, Systematics of spallation yields, Zeitschrift fur Naturforschung A21, 1027-1041 (1966).

[20] C.H. Tsao and R. Silberberg, Partial cross sections in high-energy nuclear reactions and astrophysical applications. 1. Targets with Z<=28**,** Astrophysical Journal Supplement, vol. 25, 315-333 (1973).

[21] C.H. Tsao and R. Silberberg, Partial cross sections in high-energy nuclear reactions and astrophysical Applications. 2. Targets heavier than nickel**,** Astrophysical Journal Supplement, vol. 25, 335-367 (1973).

[22] C.H. Tsao and R. Silberberg, Cross Sections for (p,xn) Reactions, and Astrophysical Applications" ApJS 129 (1977)

[23] Spallation Processes and Nuclear Interaction Products of Cosmic Rays" Physics Reports, 191(6), 351 1990.

[24] Updated Partial Cross Sections of Proton-Nucleus Reactions" ApJ 501, (1998 July 10)

[25] SILBERBERG systematics of isotopic cross sections in proton-induced spallation reactions, http://www-win.gsi.de/charms/silberbe.htm

[26] A.Yu. Konobeev and Yu.A. Korovin. Tritium production in materials from C to Bi irradiated with nucleons of intermediate and high energies. Nuclear Instruments and Methods in Physics research B82 (1993), 103-115

[27] Experimental Nuclear Reaction Data (EXFOR), http://nds121.iaea.org/exfor2/exfor00.htm

[28] EXFOR: Experimental nuclear reaction data, http://www.nea.fr/html/dbdata/x4/

[29] M. Barbier. Induced radioactivity. Amsterdam: North-Holland, 1969, -424 p.

[30] V. Hedberg et al., The comparison of the predicted activities of P-32 and P-33 in the liquid argon of the ATLAS End Cap Calorimeter calculated with two different cross-section sets. CERN-SC-2006-010-RP-TN, EDMS no. 751498.

[31] Qtool: Calculation of Reaction Q-values and Thresholds. http://t2.lanl.gov/data/qtool.html

[32] S.G. Mashnik, A.J. Sierk, K.A. Van Riper, and W.B. Wilson, Production and Validation of Isotop Production Cross Section Libraries for Neutrons and Protons to 1.7 GeV. LANL Report LA-UR-98-6000 (1998)

[33] V. Hedberg, M. Magistris, M.N. Morev, M. Silari and Z. Zajacová, “Radioactive waste study of the ATLAS detector”, Technical Note, CERN-SC-2005-141-RP-TN, Presented at the Eight Meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF-8), 22-24 May 2006, Pohang, Republic of Korea

Fig. 1. Thermal neutron flux, cm^{-2}s^{-1} (E < 0.414 eV)

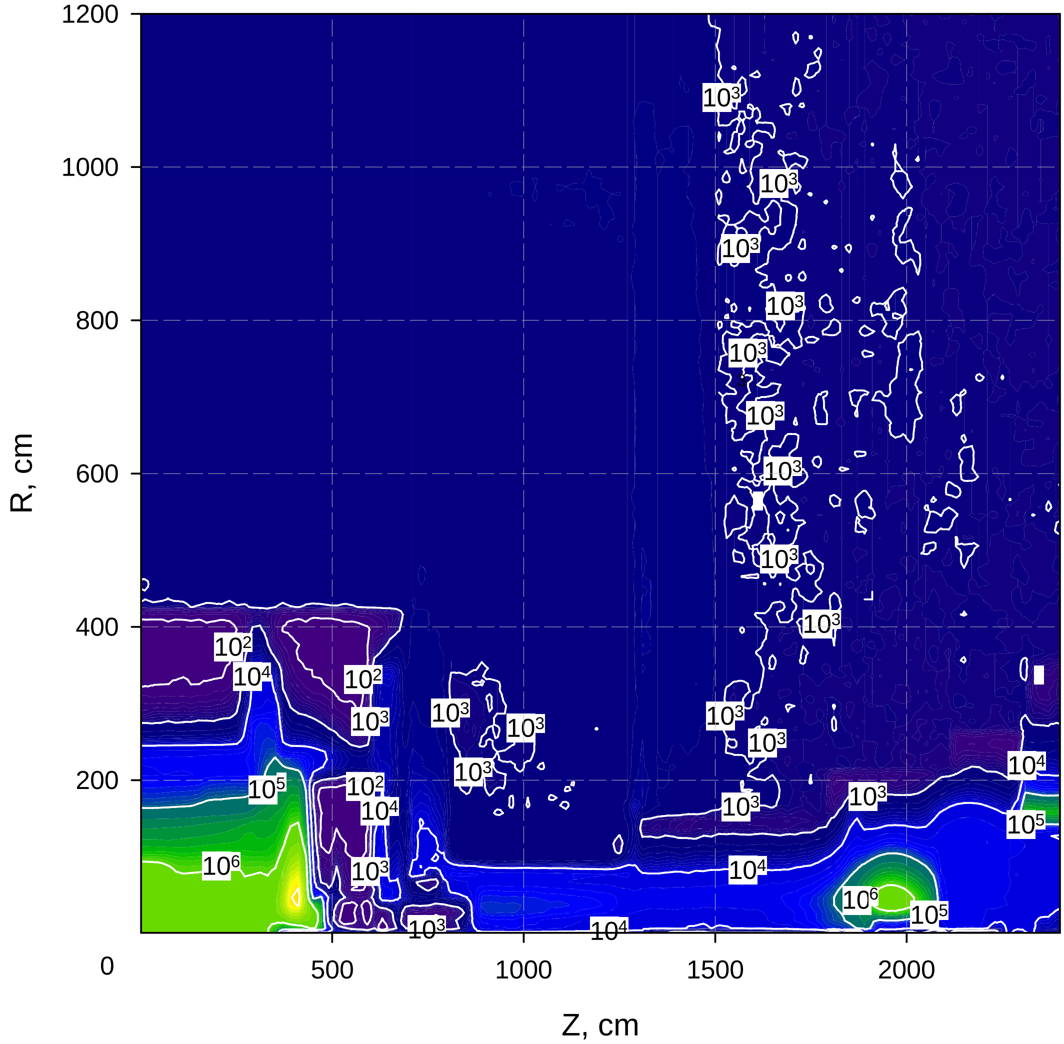


Fig. 2. Moderated neutron flux, $cm^{-2}s^{-1}$ (0.414 eV < E < 3.78 keV)

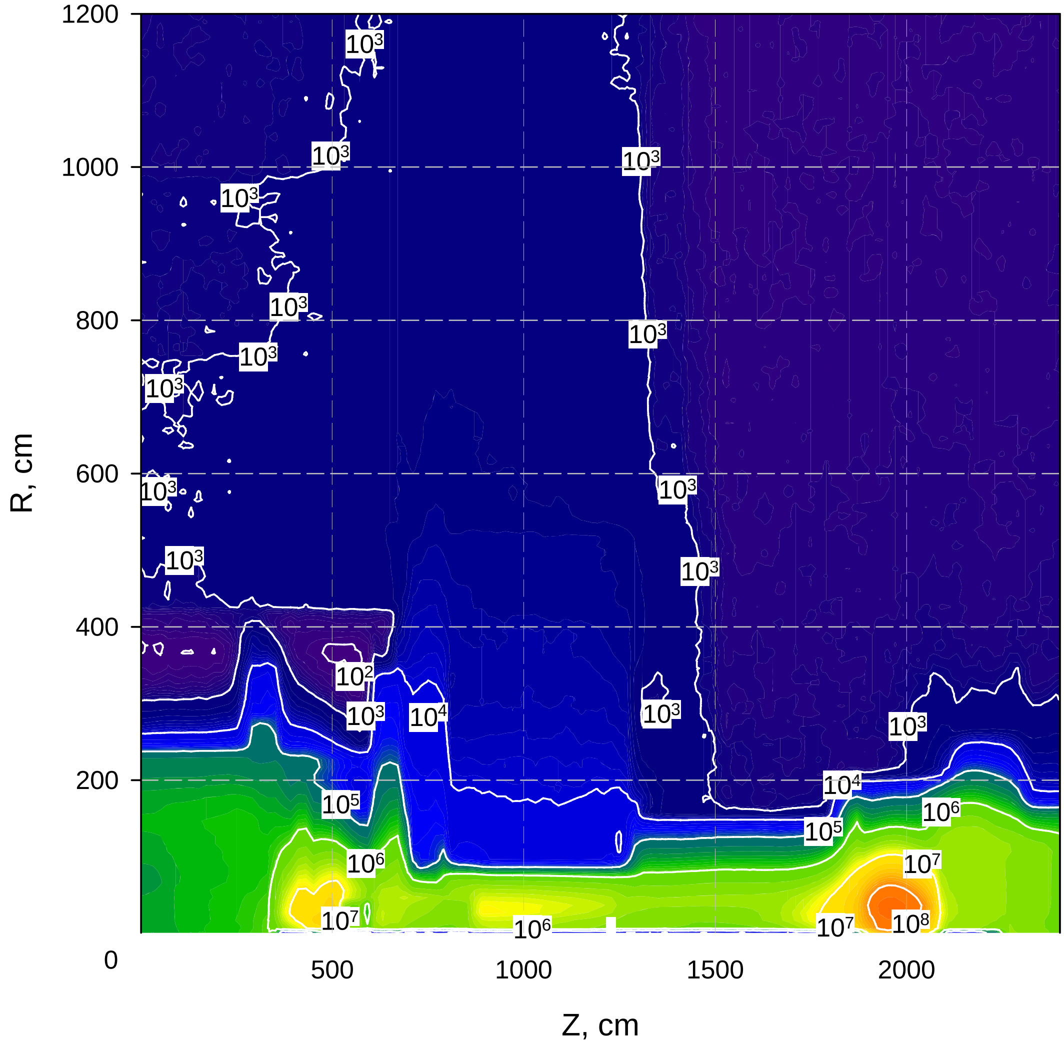


Fig. 3. Intermediate neutron flux, $cm^{-2}s^{-1}$ (3.78 keV < E < 2.19 MeV)

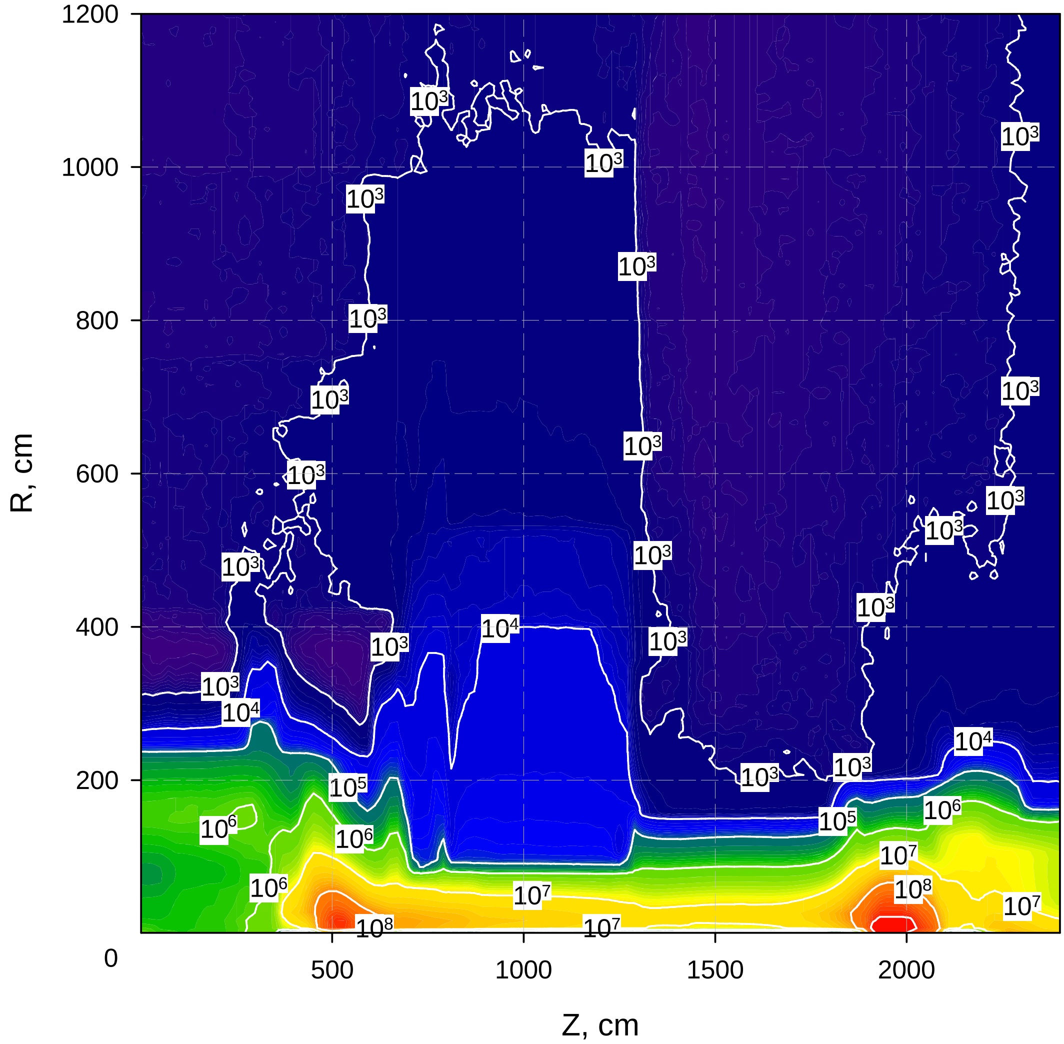


Fig. 4. Fast neutron flux, $cm^{-2}s^{-1}$ (2.19 MeV < E < 20 MeV)

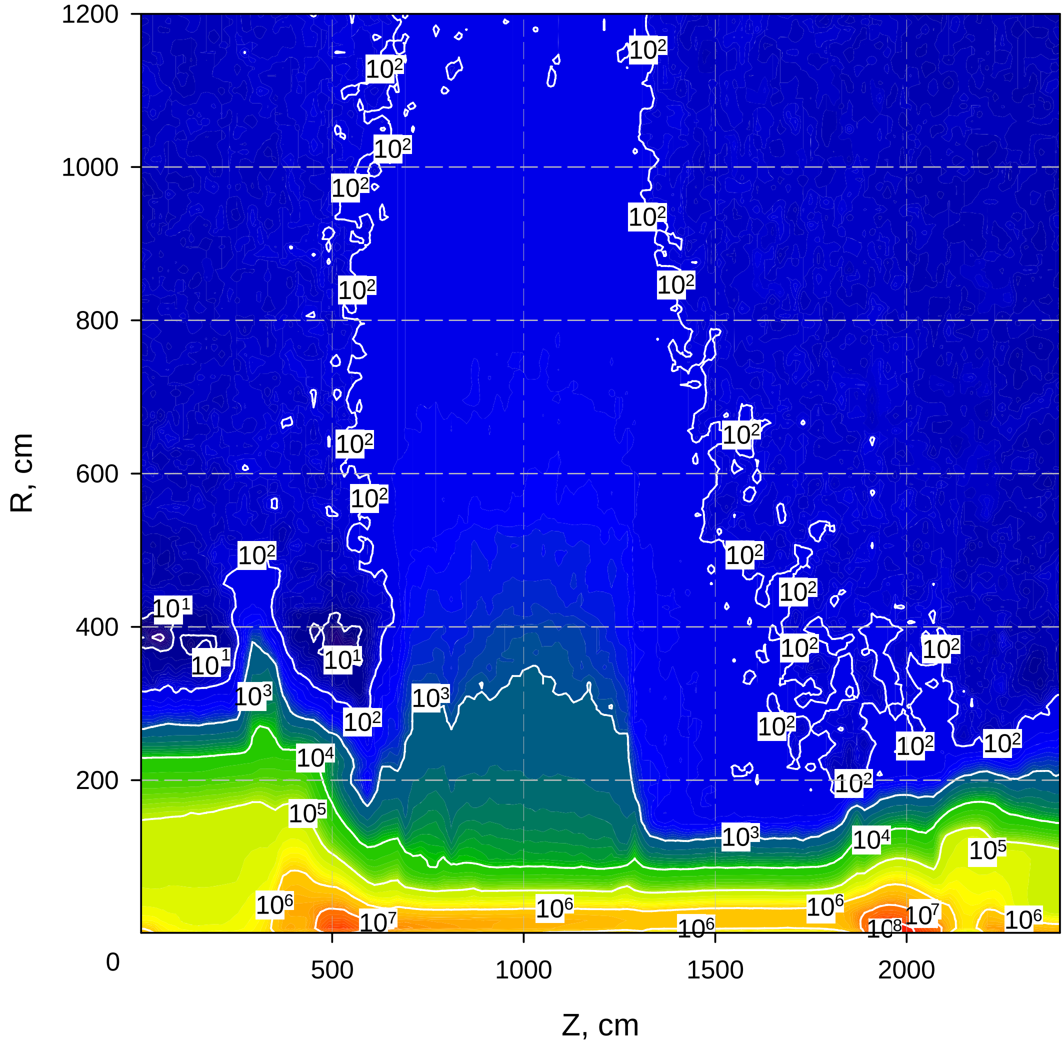


Fig. 5. High energy neutron flux, $cm^{-2}s^{-1}$ (20 MeV < E)

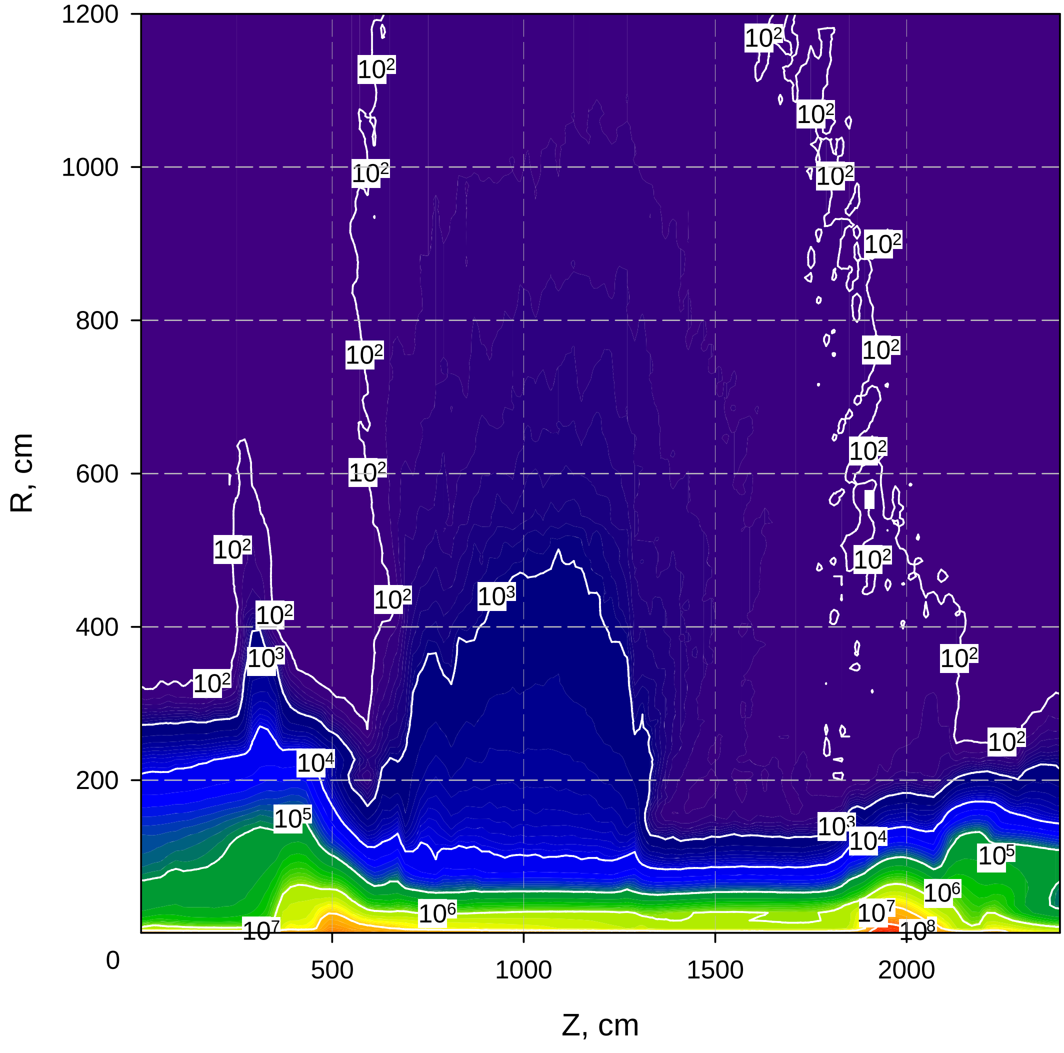


Fig. 6. Proton flux, $cm^{-2}s^{-1}$ (20 MeV < E)

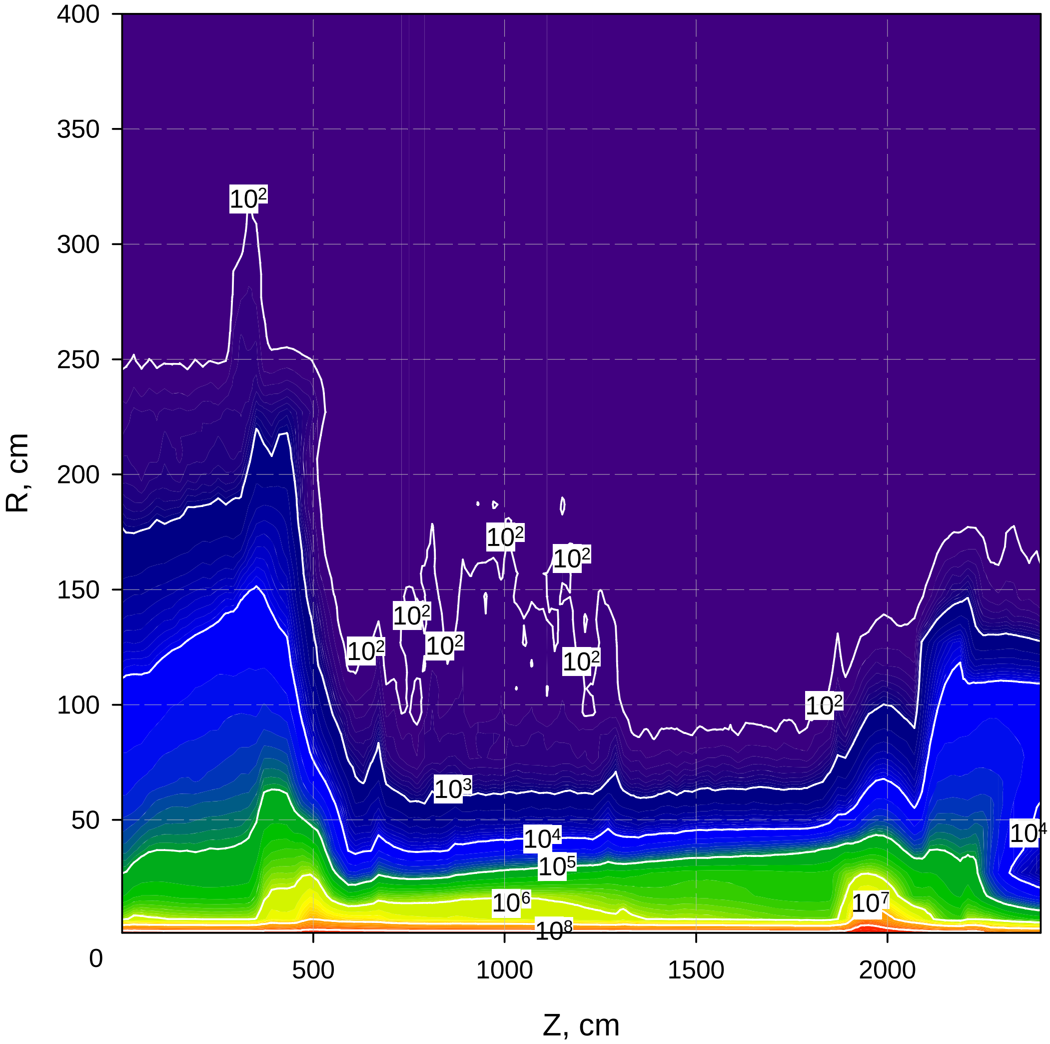


Fig. 7. Negative pion flux, $cm^{-2}s^{-1}$ (20 MeV <E)

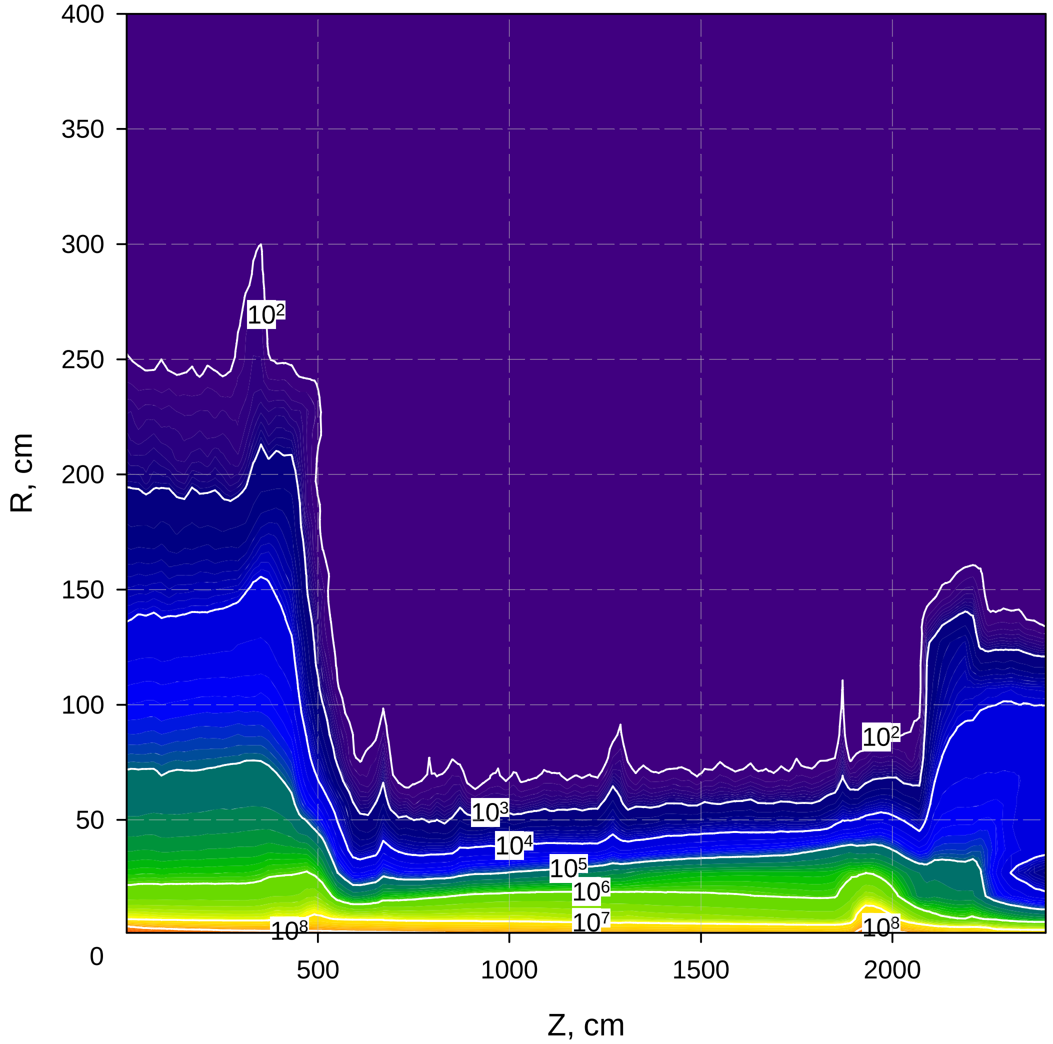
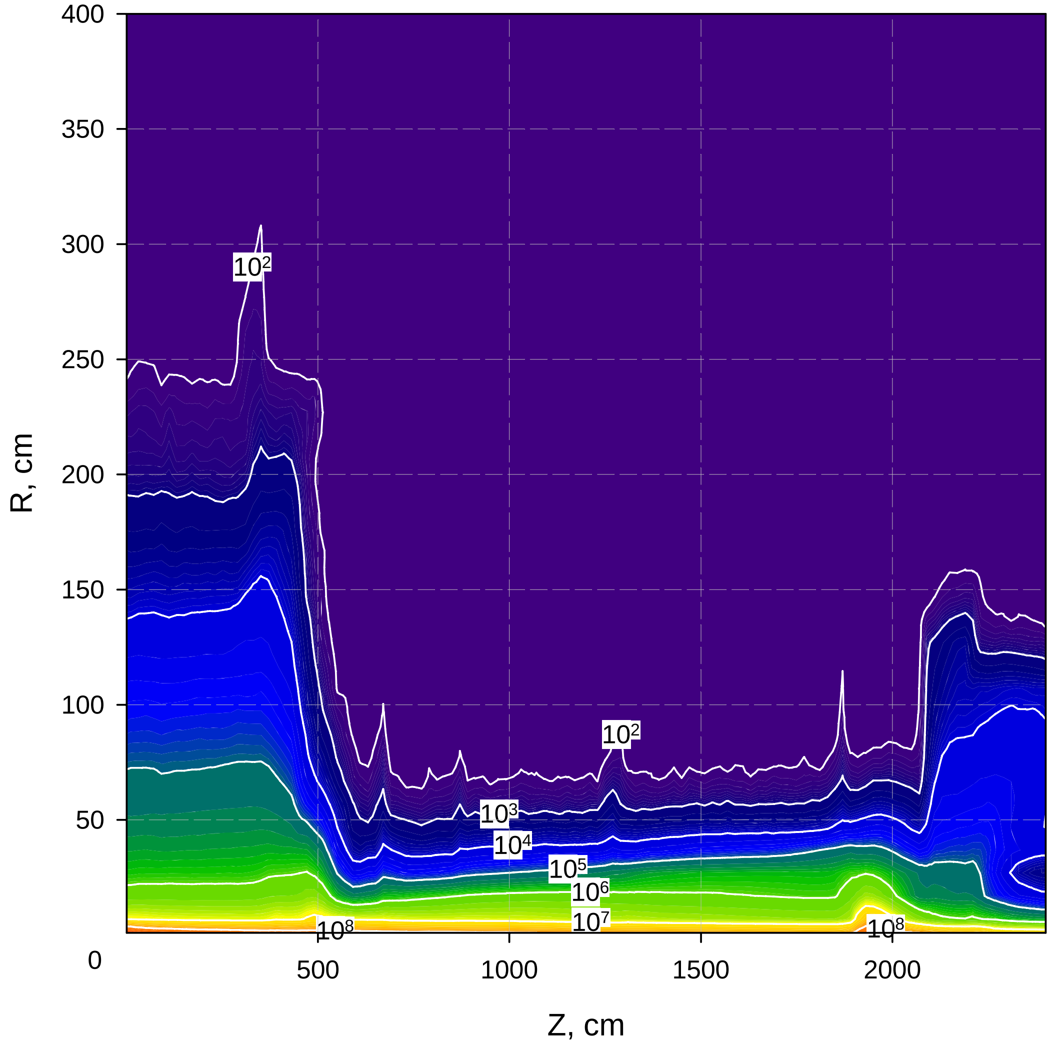


Fig. 8. Positive pion flux, $cm^{-2}s^{-1}$ (20 MeV < E)



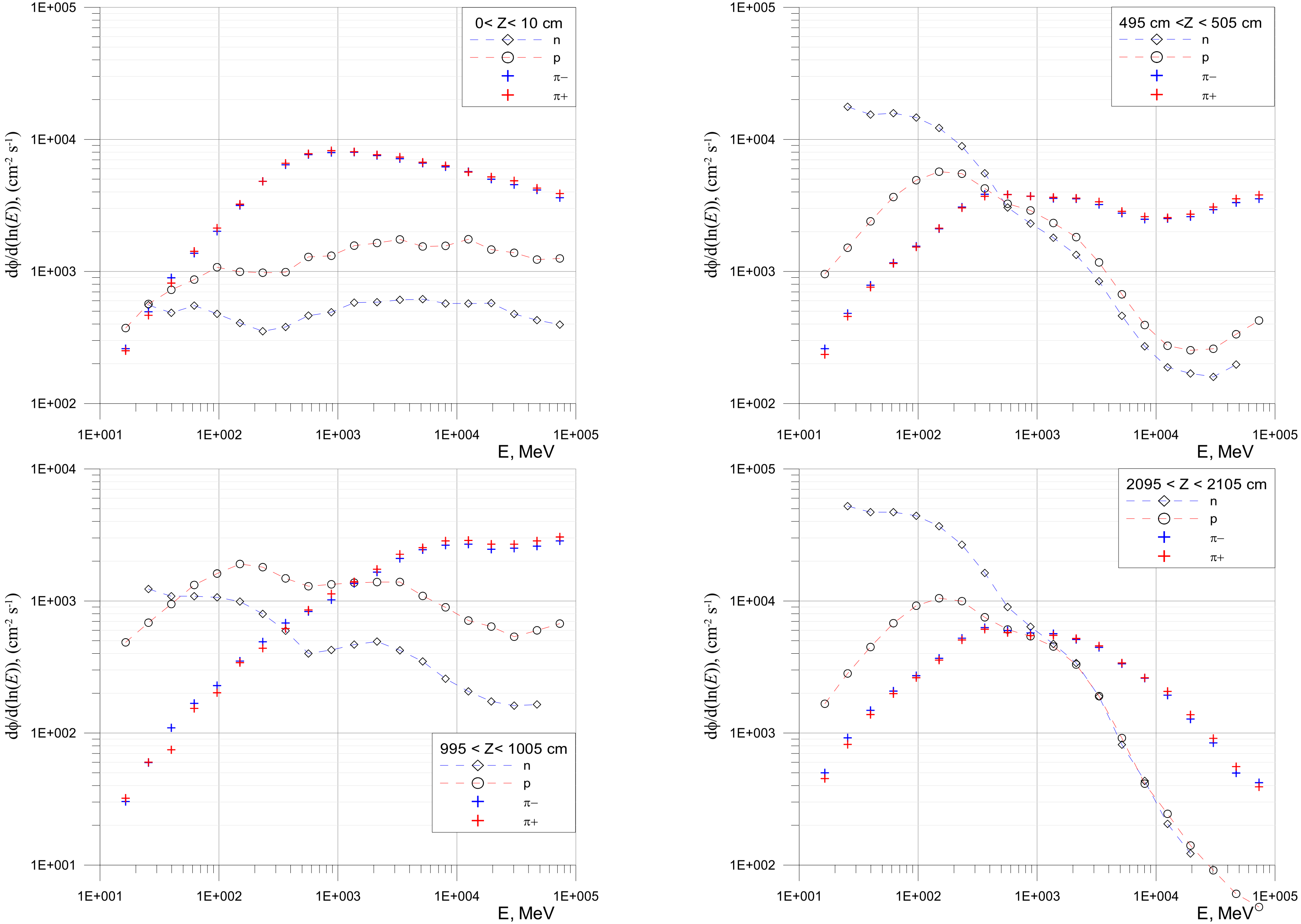


Fig. 9. High energy hadrons spectra at different points near the beam-line (0 < R < 10 cm).

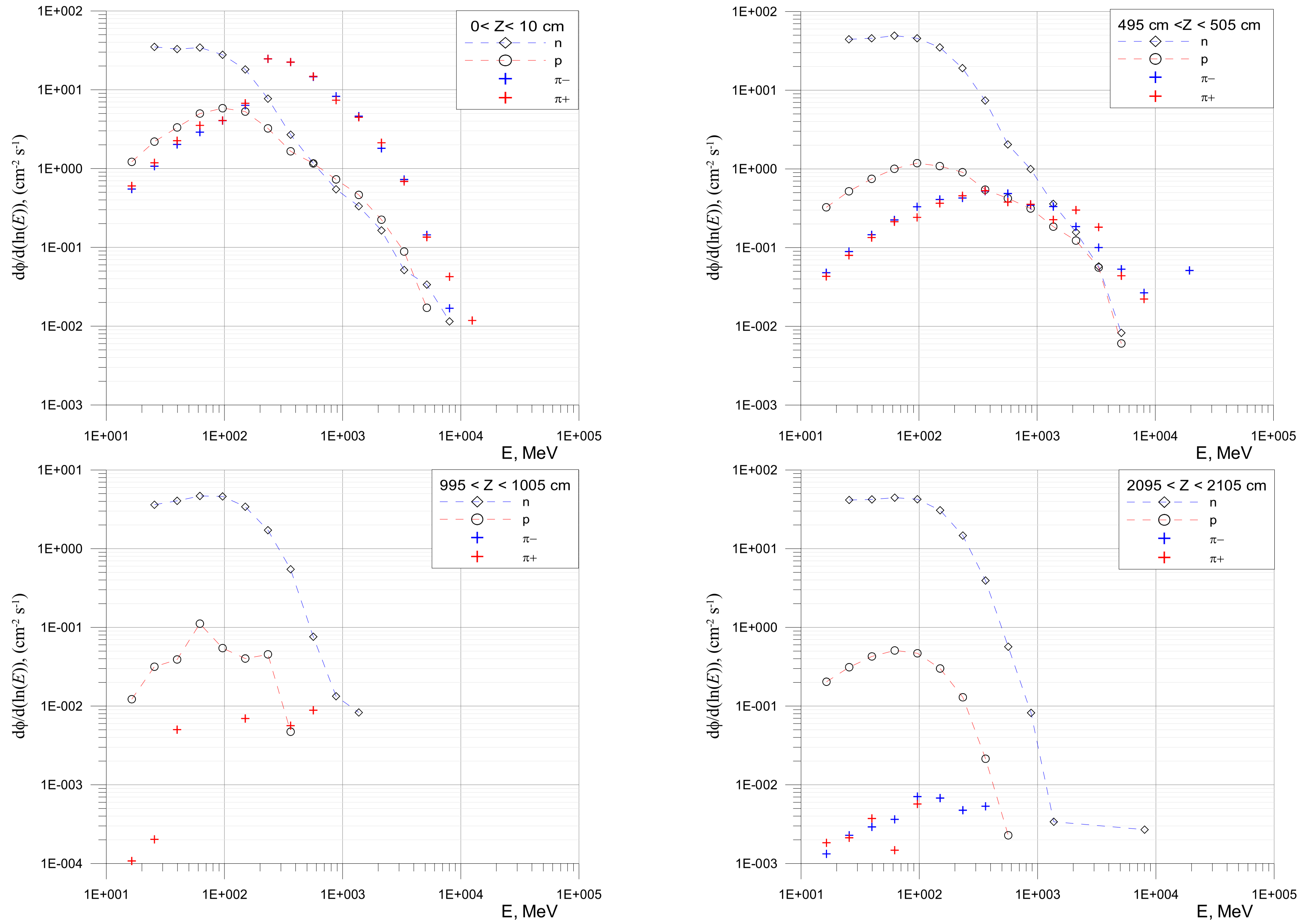


Fig. 10. High energy hadrons spectra at different points 1 meter far from the beam-line (95 < R < 105 cm).

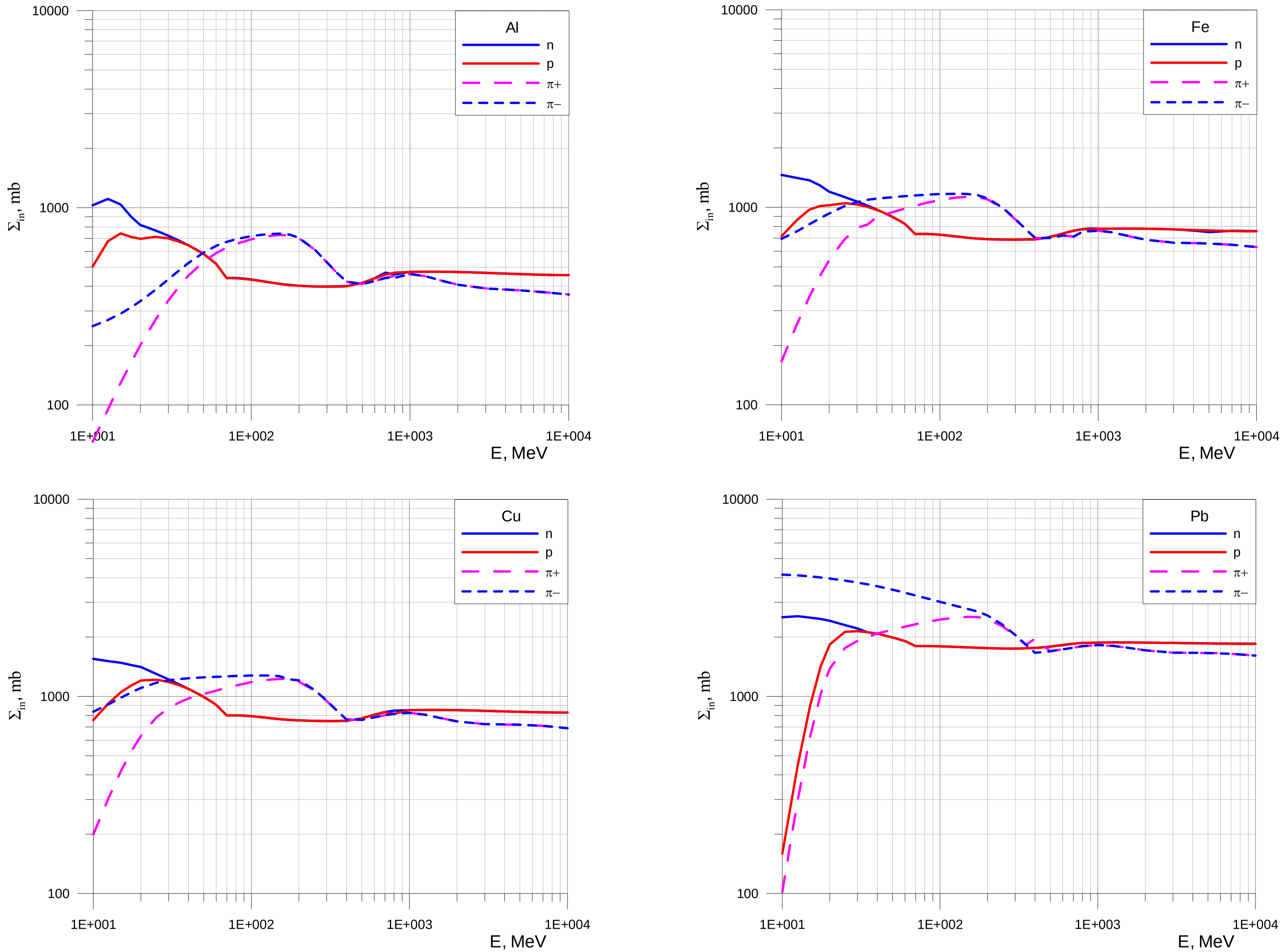


Fig. 11. Inelastic cross-sections for neutrons (n), protons (p), positive (π+) and negative (π-) pions in some materials [10]

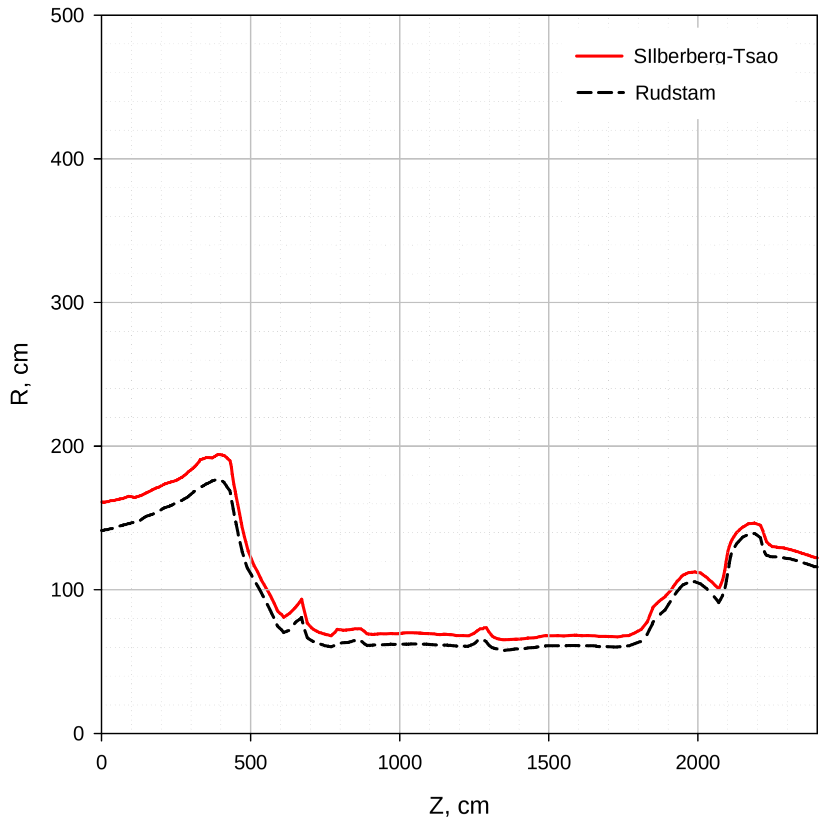


Fig. 12. The $\Sigma_k(A_k/LE_k)=0.1$ isoline for lead, scenario A1

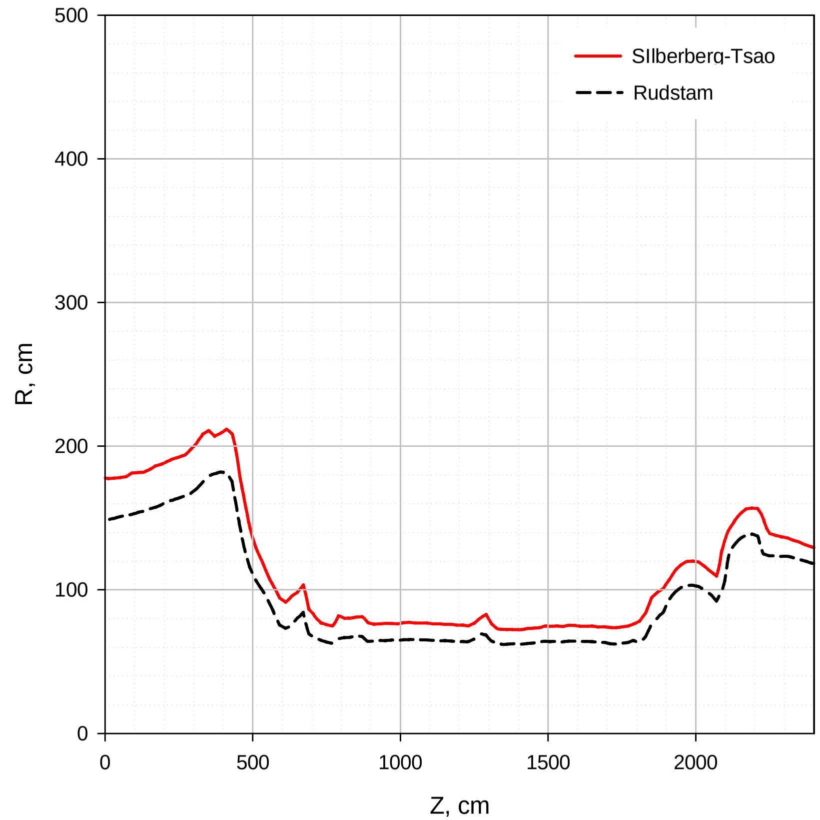


Fig. 13. The $\Sigma_k(A_k/LE_k)=0.1$ isoline for gold, scenario A1

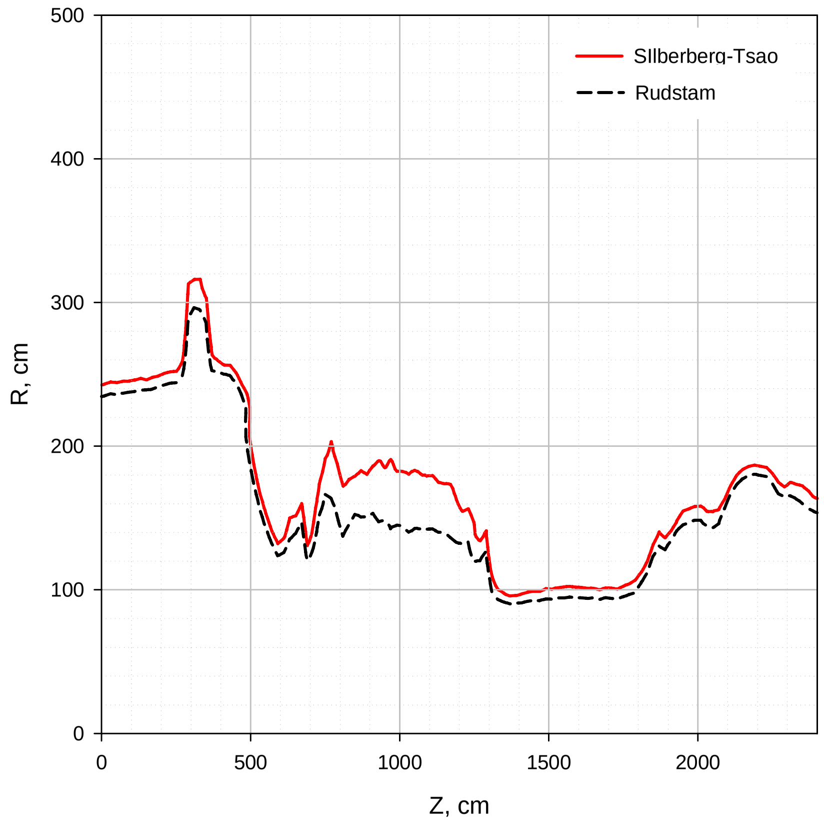


Fig. 14. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for rhenium, scenario A1

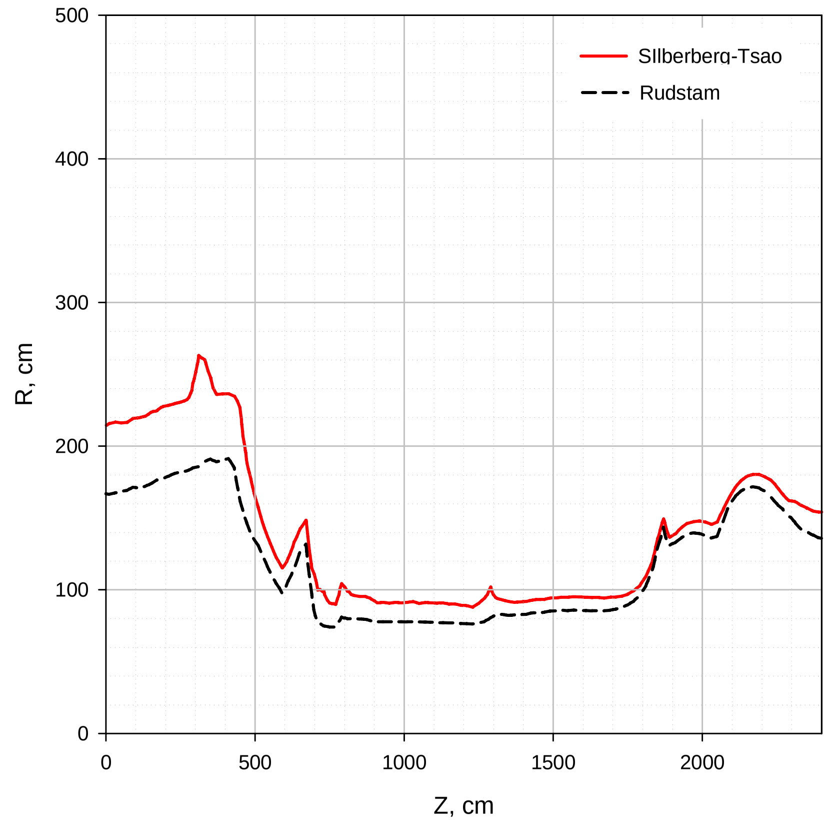


Fig. 15. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for tungsten, scenario A1

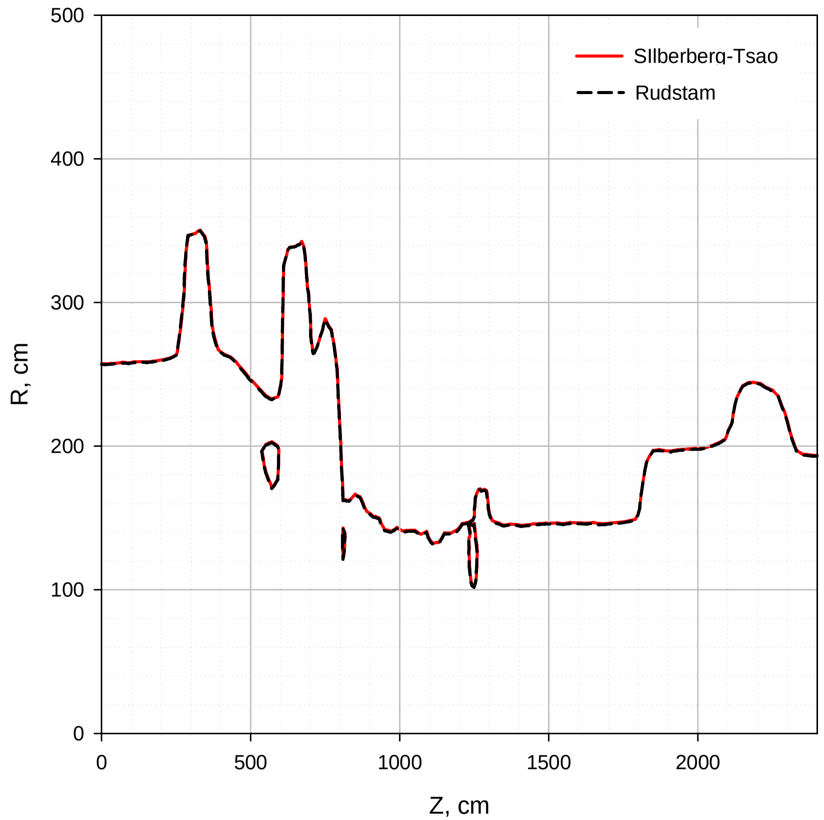


Fig. 16. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for antimony (1% wt.), scenario A1

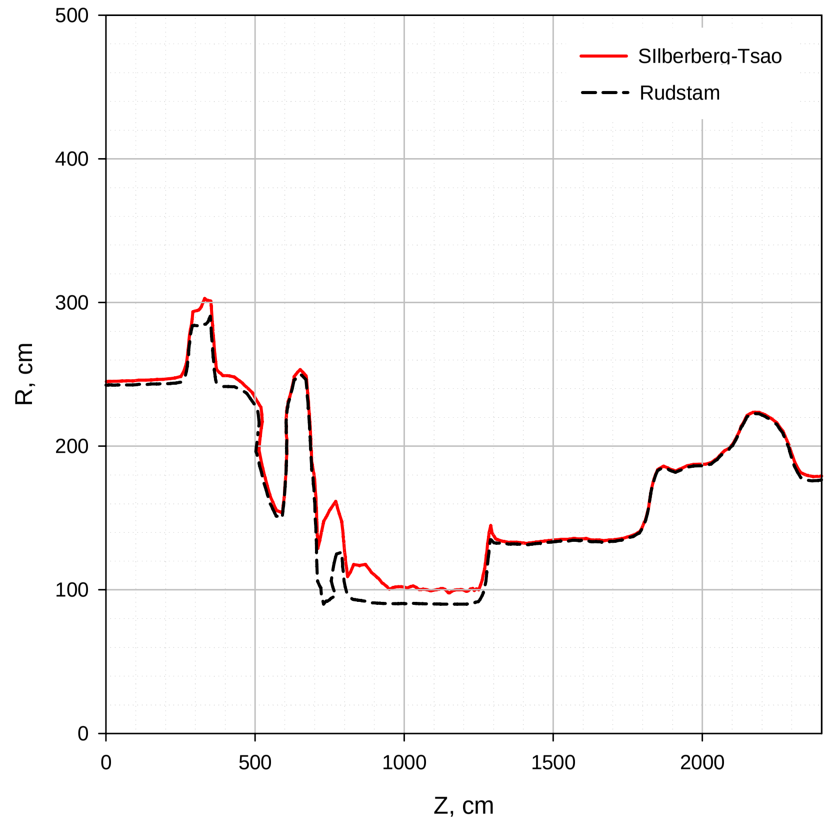


Fig. 17. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for tin, scenario A1

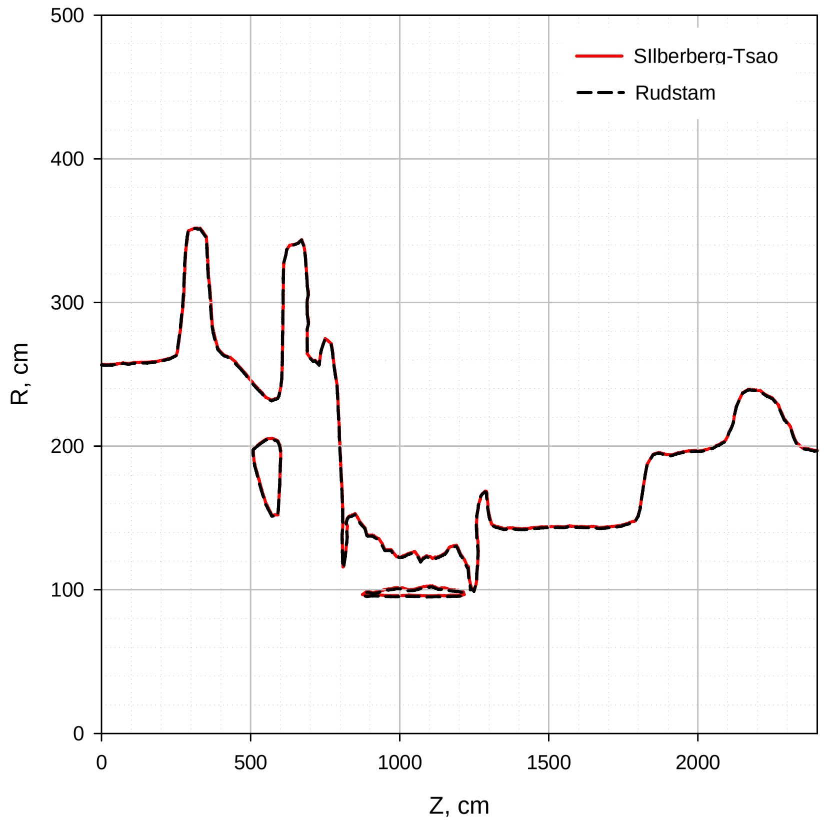


Fig. 18. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for silver (1% wt.), scenario A1

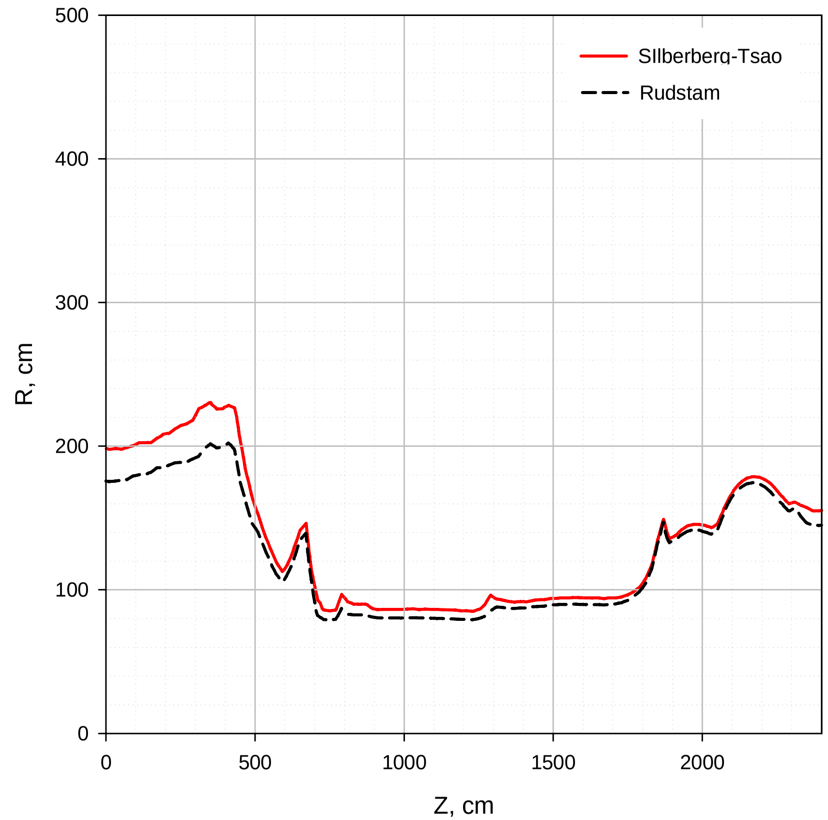


Fig. 19. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for niobium, scenario A1

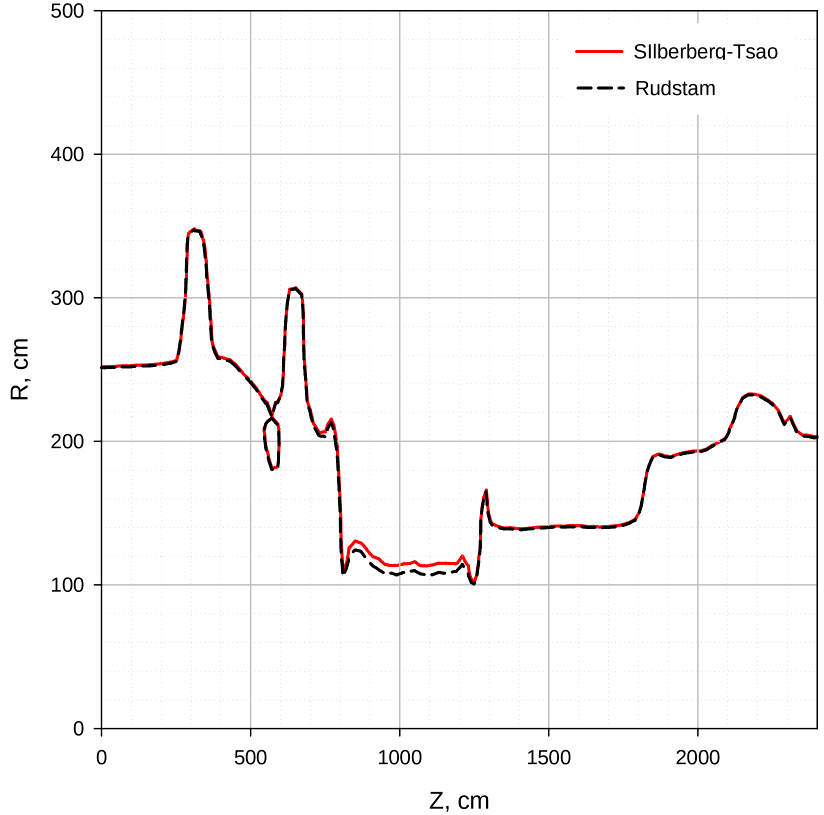


Fig. 20. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for zinc (10% wt.), scenario A1

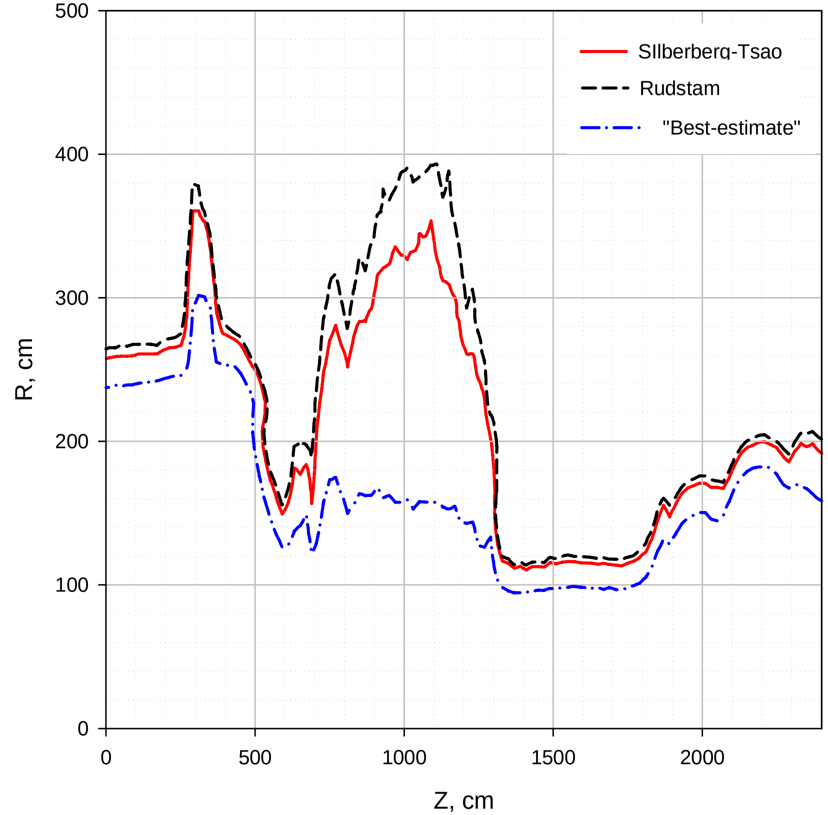


Fig. 21. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for copper, scenario A1

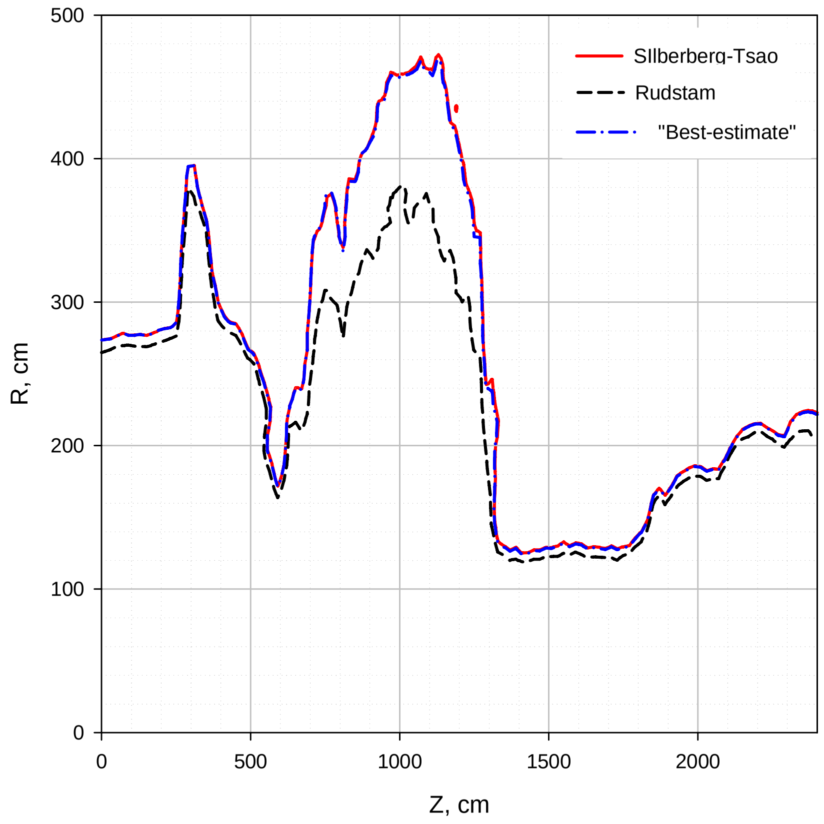


Fig. 22. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for nickel, scenario A1

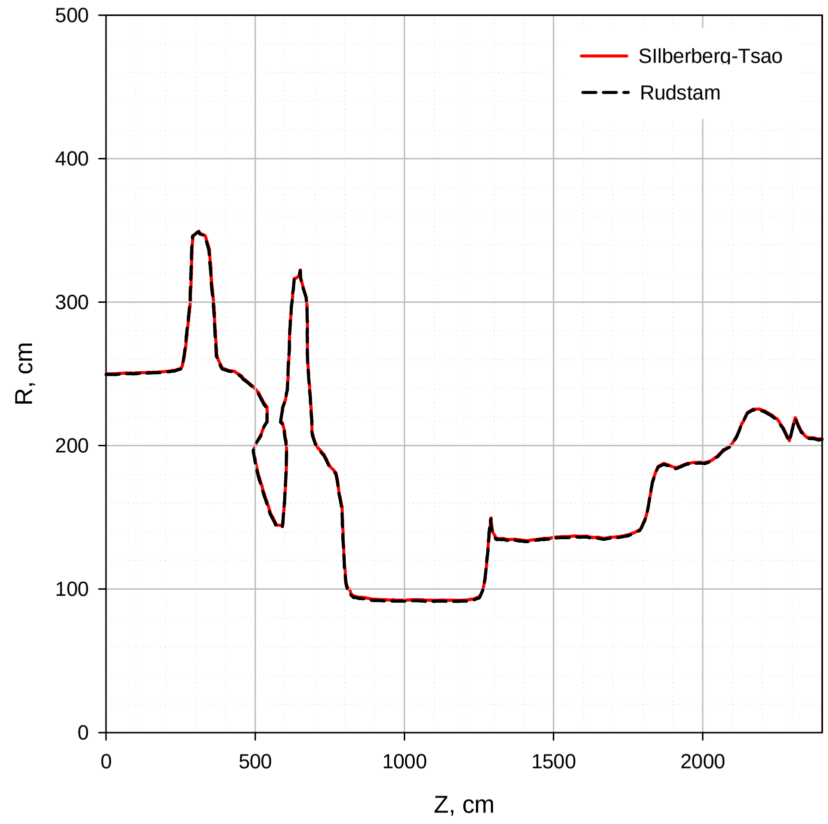


Fig. 23. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for cobalt (0.1% wt.), scenario A1

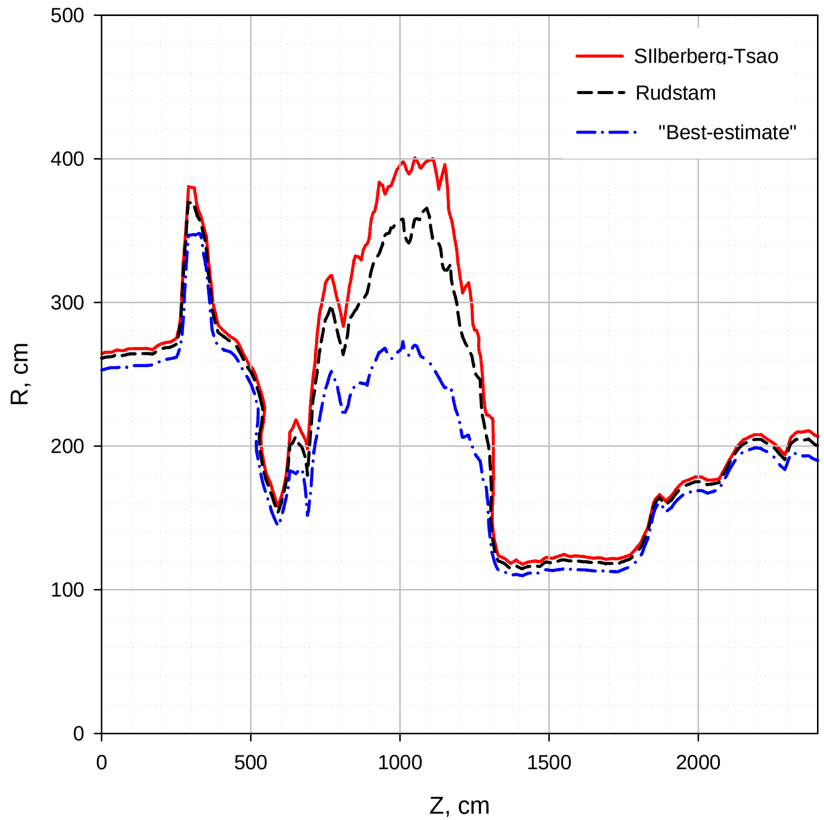


Fig. 24. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for iron, scenario A1

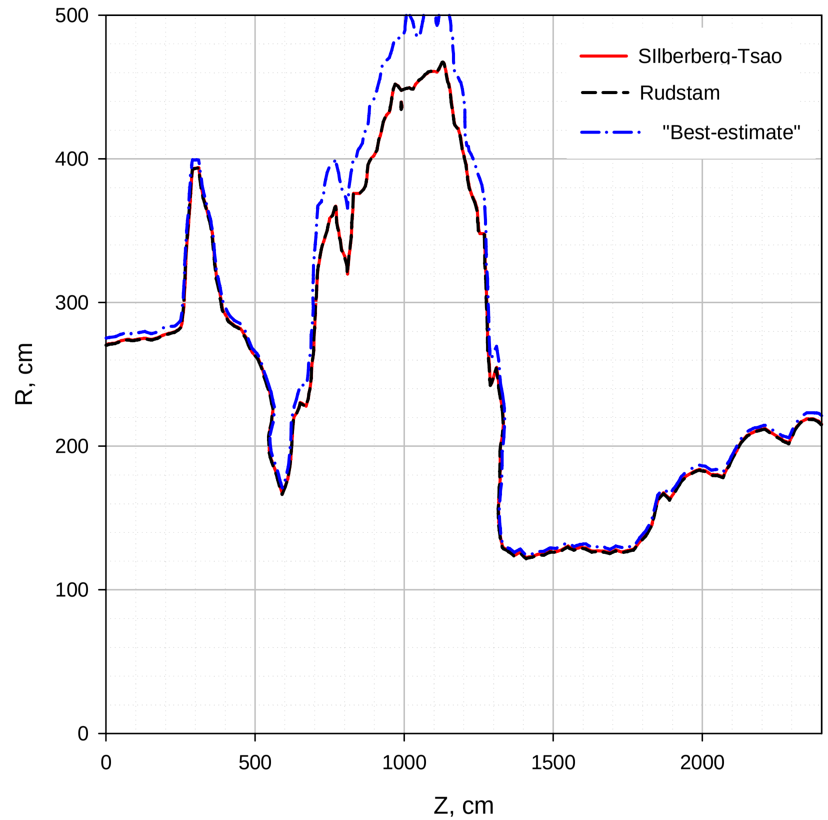


Fig. 25. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for manganese, scenario A1

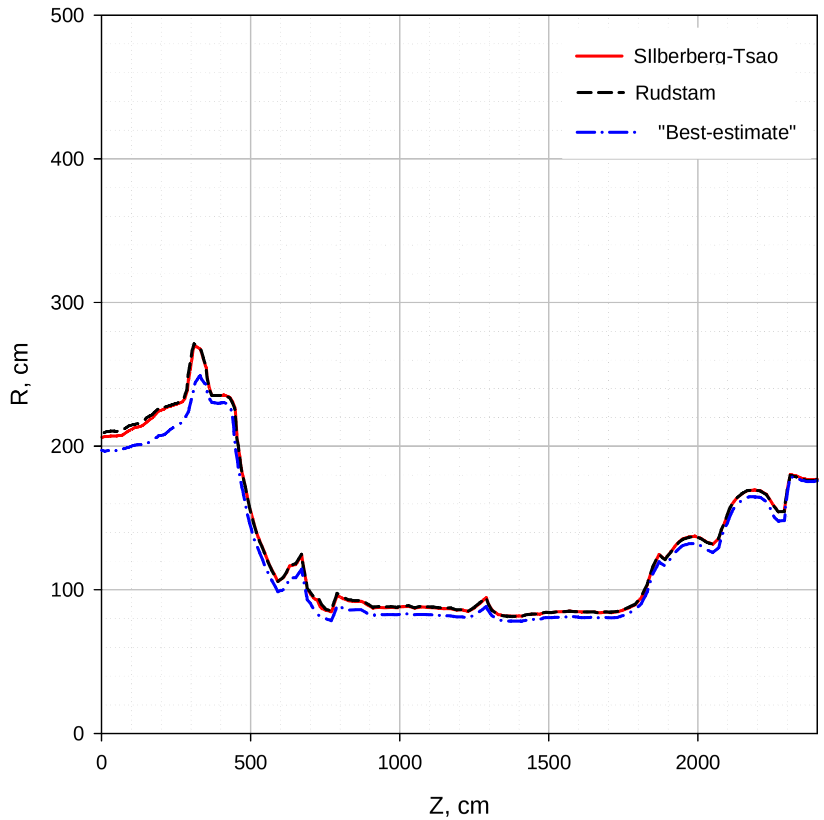


Fig. 26. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for chromium, scenario A1

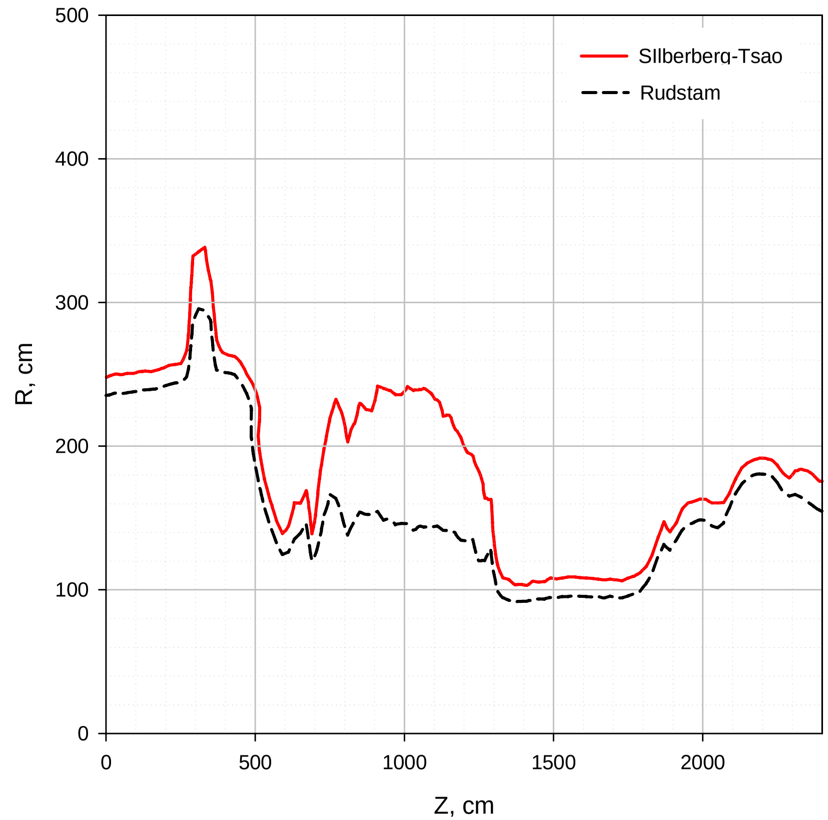


Fig. 27. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for titanium, scenario A1

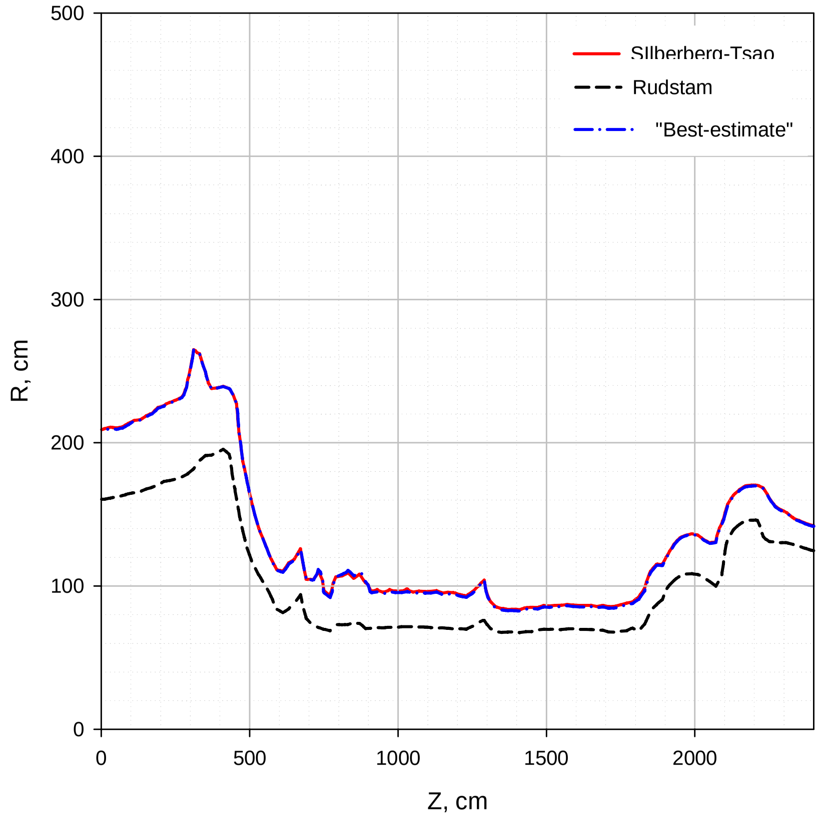


Fig. 28. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for silicon, scenario A1

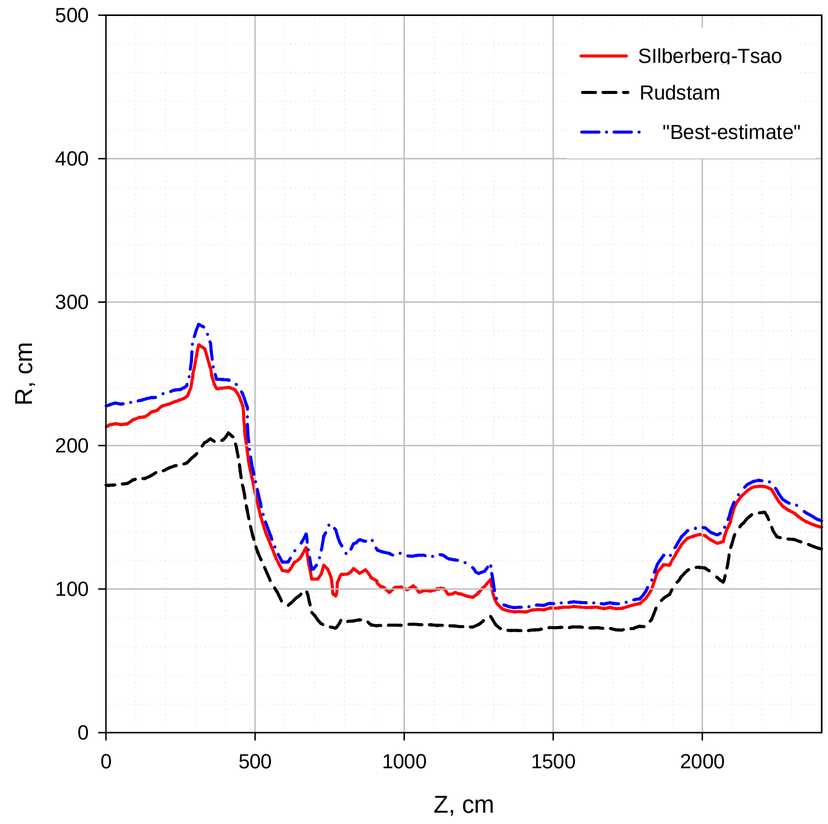


Fig. 29. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for aluminum, scenario A1

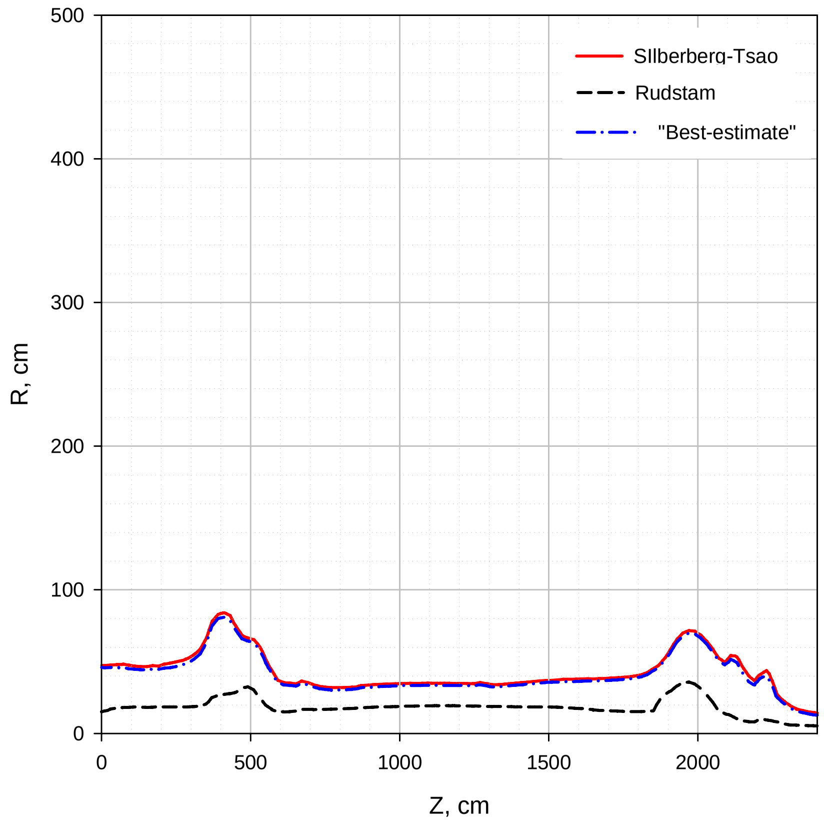


Fig. 30. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for carbon, scenario A1

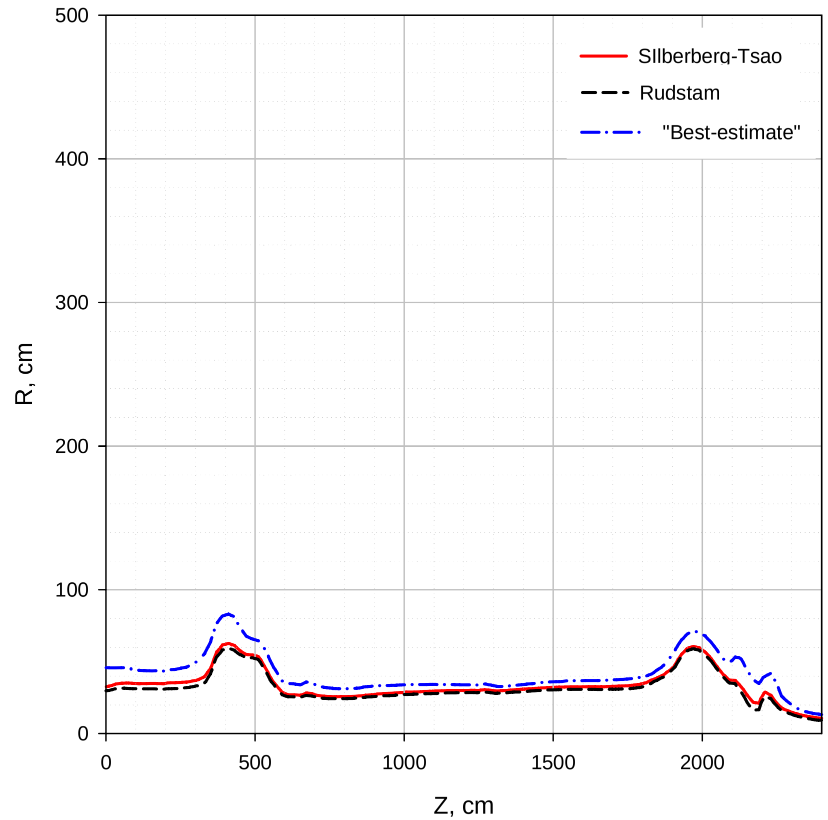


Fig. 31. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for beryllium, scenario A1

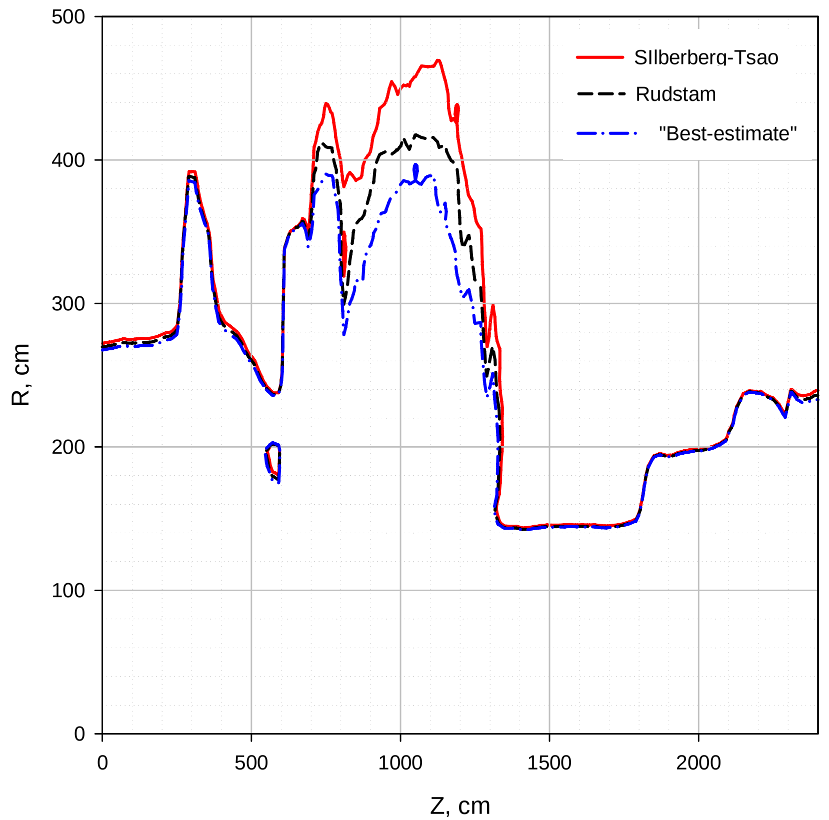


Fig. 32. The $\Sigma_k(A_k/LE_k)$=0.1 isoline for stainless steel (69% Fe, 18% Cr, 11% Ni, 1.8% Mn and 0.2% Co), scenario A1

Table 1

Limite'd exemption - LE values for radionuclides produced on stable nuclei up to Pb with half-live from 1 hour to 10^6 years and their short-lived daughter radionuclides

Nuclide	Limit, Bq/g	Half-life		Ref.
H-3	1.E+06	12.32	y	[1]*
Be-7	1000	53.22	d	[1]
Be-10	90	1510000	y	[3]**
C-11	4000	20.39	m	[3]
C-14	10000	5700	y	[1]
O-15	100	122.24	s	[1]
F-18	10	109.77	m	[1]
Na-22	10	2.6019	y	[1]
Na-24	10	14.959	h	[1]
Mg-28+ Al-28	50	20.915	h	[3]
Al-26	30	717000	y	[3]
Si-31	1000	157.3	m	[1]
Si-32	200	132	y	[3]
P-32	1000	14.262	d	[1]
P-33	100000	25.34	d	[1]
S-35	100000	87.51	d	[1]
S-38	N/A***	170.3	m	
Cl-36	10000	301000	y	[1]
Cl-38	10	37.24	m	[1]
Cl-39	1000	55.6	m	[3]
Ar-37	1000000	35.04	d	[1]
Ar-39	N/A	269	y	
Ar-41	100	109.61	m	[1]
Ar-42	N/A	32.9	y	
K-40	100	1.265e+9	y	[1]
K-42	100	12.36	h	[1]
K-43	10	22.3	h	[1]
K-44	1000	22.13	m	[3]
K-45	2000	17.3	m	[3]
Ca-41	300	102000	y	[3]
Ca-45	10000	162.61	d	[1]
Ca-47	10	4.536	d	[1]
Sc-43	500	3.891	h	[3]
Sc-44m	40	58.61	h	[3]
Sc-44	300	3.97	h	[3]
Sc-46	10	83.79	d	[1]
Sc-47	100	3.3492	d	[1]
Sc-48	10	43.67	h	[1]
Sc-49	1000	57.2	m	[3]
Ti-44	20	60	y	[3]
Ti-45	700	184.8	m	[3]
V-47	2000	32.6	m	[3]
V-48	10	15.9735	d	[1]
V-49	6000	330	d	[3]
Cr-48	500	21.56	h	[3]
Cr-49	2000	42.3	m	[3]
Cr-51	1000	27.7025	d	[1]
Mn-51	10	46.2	m	[1]
Mn-52	10	5.591	d	[1]
Mn-52m	10	21.1	m	[1]
Mn-53	10000	3740000	y	[1]
Mn-54	10	312.12	d	[1]
Mn-56	10	2.5789	h	[1]
Fe-52	10	8.275	h	[1]
Fe-55	10000	2.737	y	[1]
Fe-59	10	44.495	d	[1]
Fe-60	0.9	1500000	y	[3]
Co-55	10	17.53	h	[1]
Co-56	10	77.233	d	[1]
Co-57	100	271.74	d	[1]
Co-58	10	70.86	d	[1]
Co-58m	10000	9.04	h	[1]
Co-60	10	1925.3	d	[1]
Co-60m	1000	10.467	m	[1]
Co-61	100	1.65	h	[1]
Co-62m	10	13.91	m	[1]
Ni-56	100	6.075	d	[3]
Ni-57	100	35.6	h	[3]
Ni-59	10000	76000	y	[1]
Ni-63	100000	100.1	y	[1]
Ni-65	10	2.5172	h	[1]
Ni-66+ Cu-66	30	54.6	h	[3]
Cu-60	1000	23.7	m	[3]
Cu-61	800	3.333	h	[3]
Cu-64	100	12.7	h	[1]
Cu-67	300	61.83	h	[3]
Zn-62+ Cu-62	10	9.186	h	[1]
Zn-63	100	328.47	m	[1]
Zn-65	10	244.06	d	[1]
Zn-69	10000	56.4	m	[1]
Zn-69m	100	13.76	h	[1]
Zn-71	N/A	2.45	m	
Zn-71m	400	3.96	h	[3]
Zn-72	70	46.5	h	[3]

* exemption levels taken from DIRECTIVE 96/29/EURATOM 13th May 1996 [1]

** the clearance levels from Swiss "Ordonnance sur la radioprotection" (ORaP) 814.501 [3] are multiplied by 10 for convenience

*** N/A – not available from [1], [3]

Nuclide	Limit, Bq/g	Half-life		Ref.
Ga-66	80	9.49	h	[3]
Ga-67	500	3.2612	d	[3]
Ga-68	1000	67.61	m	[3]
Ga-72	10	14.1	h	[1]
Ga-73	400	4.86	h	[3]
Ge-66	1000	2.26	h	[3]
Ge-68	80	270.8	d	[3]
Ge-69	400	39.05	h	[3]
Ge-71	10000	11.43	d	[1]
Ge-73m	N/A	0.499	s	
Ge-75	2000	82.78	m	[3]
Ge-77	300	11.3	h	[3]
Ge-78	800	88	m	[3]
As-71	200	65.28	h	[3]
As-72	60	26	h	[3]
As-73	1000	80.3	d	[1]
As-74	10	17.77	d	[1]
As-76	100	1.0778	d	[1]
As-77	1000	38.83	h	[1]
As-78	500	90.7	m	[3]
Se-72	N/A	8.4	d	
Se-73	300	7.15	h	[1]
Se-75	100	119.779	d	[1]
Se-77m	N/A	17.45	s	
Se-79	30	295000	y	[1]
Br-75	1000	96.7	m	[3]
Br-76	200	16.2	h	[3]
Br-77	1000	57.036	h	[3]
Br-77m	N/A	4.28	m	
Br-80	3000	17.68	m	[3]
Br-80m	900	4.4205	h	[3]
Br-82	10	35.282	h	[1]
Br-83	2000	2.4	h	[3]
Kr-74	100	11.5	m	[1]
Kr-76	100	14.8	h	[1]
Kr-77	100	74.4	m	[1]
Kr-79	1000	35.04	h	[1]
Kr-81	10000	229000	y	[1]
Kr-81m	N/A	12.81	s	
Kr-83m	100000	1.83	h	[1]
Kr-85m	1000	4.48	h	[1]
Kr-85	100000	3934.4	d	[1]
Kr-87	100	76.3	m	[1]
Kr-88	100	2.84	h	[1]
Rb-81	2000	4.576	h	[3]
Rb-82m	800	6.472	h	[3]
Rb-83	50	86.2	d	[3]
Rb-84	40	32.77	d	[3]
Rb-86	100	18.642	d	[1]

Nuclide	Limit, Bq/g	Half-life		Ref.
Rb-88	1000	17.8	m	[3]
Sr-80+ Rb-80	300	106.3	m	[3]
Sr-82+ Rb-82	20	25.55	d	[3]
Sr-83	200	32.41	h	[3]
Sr-85m	100	67.63	m	[1]
Sr-85	100	64.84	d	[1]
Sr-87m	100	2.815	h	[1]
Sr-89	1000	50.53	d	[1]
Sr-90 + Y-90	100	28.79	y	[1]
Sr-91	10	9.63	h	[1]
Sr-92	10	2.66	h	[1]
Y-85m	N/A	4.86	h	
Y-85	N/A	2.68	h	
Y-86	100	14.74	h	[1]
Y-87m	N/A	13.37	h	
Y-87	200	79.8	h	[3]
Y-88	80	106.65	d	[3]
Y-89m	N/A	15.28	s	
Y-90m	600	3.19	h	[3]
Y-90	1000	64	h	[1]
Y-91	1000	58.51	d	[1]
Y-91m	100	49.71	m	[1]
Y-92	100	3.54	h	[1]
Y-93	100	10.18	h	[1]
Zr-86	100	16.5	h	[3]
Zr-87	N/A	1.68	h	
Zr-88	300	83.4	d	[3]
Zr-89	100	78.41	h	[3]
Zr-89m	N/A	4.161	m	
Zr-90m	N/A	0.809	s	
Zr-93 + Nb-93m	1000	1530000	y	[1]
Zr-95	10	64.032	d	[1]
Zr-97 + Nb-97m + Nb-97	10	16.744	h	[1]
Nb-89m	300	2.03	h	[3]
Nb-89	700	66	m	[3]
Nb-90	80	14.6	h	[3]
Nb-90m	N/A	18.8	s	
Nb-91m	200	60.86	d	[3]
Nb-91	2000	680	y	[3]
Nb-92m	200	10.15	d	[3]
Nb-93m	10000	16.13	y	[1]
Nb-94	10	20300	y	[1]
Nb-95m	200	3.61	d	[1]
Nb-95	10	34.991	d	[1]

Nuclide	Limit, Bq/g	Half-life		Ref.
Nb-96	90	23.35	h	[3]
Nb-97	10	72.1	m	[1]
Nb-98	10	51.3	m	[1]
Mo-90	10	5.56	h	[1]
Mo-93m	400	6.85	h	[3]
Mo-93	1000	4000	y	[1]
Mo-99	100	65.94	h	[1]
Mo-101	10	14.61	m	[1]
Tc-93	2000	2.75	h	[3]
Tc-94	600	293	m	[3]
Tc-95m	200	61	d	[3]
Tc-95	600	20	h	[3]
Tc-96	10	4.28	d	[1]
Tc-96m	1000	51.5	m	[1]
Tc-97m	1000	91.4	d	[1]
Tc-97	1000	4210000	y	[1]
Tc-98	40	4200000	y	[3]
Tc-99m	100	6.015	h	[1]
Tc-99	10000	211100	y	[1]
Ru-95	N/A	1.643	h	
Ru-97	100	2.791	d	[1]
Ru-103	100	39.26	d	[1]
Ru-105	10	4.44	h	[1]
Ru-106 + Rh-106	100	373.59	d	[1]
Rh-99m	2000	4.7	h	[3]
Rh-99	200	16.1	d	[3]
Rh-100	100	20.8	h	[3]
Rh-101m	500	4.34	d	[3]
Rh-101	200	3.3	y	[3]
Rh-102	40	2.9	y	[3]
Rh-102m	80	207	d	[3]
Rh-103m	10000	56.114	m	[1]
Rh-105	100	35.36	h	[1]
Rh-105m	N/A	45	s	
Rh-106m	600	131	m	[3]
Pd-100	100	3.63	d	[3]
Pd-101	1000	8.47	h	[3]
Pd-103	1000	16.991	d	[1]
Pd-109	1000	13.7012	h	[1]
Pd-111	N/A	23.4	m	
Pd-111m	N/A	5.5	h	
Pd-112	N/A	21.03	h	
Ag-103	2000	65.7	m	[3]
Ag-104	2000	69.2	m	[3]
Ag-105	100	41.29	d	[1]
Ag-106m	70	8.28	d	[3]
Ag-107m	N/A	44.3	s	
Ag-108m+ Ag-108	10	418	y	[1]

Nuclide	Limit, Bq/g	Half-life		Ref.
Ag-109m	N/A	39.6	s	
Ag-110m+ Ag-110	10	249.76	d	[1]
Ag-111	1000	7.45	d	[1]
Ag-111m	N/A	64.8	s	
Ag-112	200	3.13	h	[3]
Ag-113	N/A	5.37	h	
Cd-107	2000	6.5	h	[3]
Cd-109	10000	461.4	d	[1]
Cd-113m	4	14.1	y	[3]
Cd-115m	1000	44.56	d	[1]
Cd-115	100	53.46	h	[1]
Cd-117m	400	3.36	h	[3]
Cd-117	400	2.49	h	[3]
In-109	2000	4.2	h	[3]
In-110m	400	4.9	h	[3]
In-110	1000	69.1	m	[3]
In-111	100	2.8047	d	[3]
In-113m	100	99.476	m	[1]
In-114	N/A	71.9	s	
In-114m	100	49.51	d	[1]
In-115m	100	4.486	h	[1]
In-117	3000	43.2	m	[3]
In-117m	800	116.2	m	[3]
Sn-110	300	4.11	h	[3]
Sn-113	1000	115.09	d	[1]
Sn-117m	100	13.76	d	[3]
Sn-119m	300	293.1	d	[3]
Sn-121m	300	55	y	[3]
Sn-121	400	27.03	h	[3]
Sn-123	50	129.2	d	[3]
Sn-125	100	9.64	d	[1]
Sn-126	20	230000	y	[3]
Sn-127	500	2.1	h	[3]
Sb-116	4000	15.8	m	[3]
Sb-116m	1000	60.3	m	[3]
Sb-117	6000	2.8	h	[3]
Sb-118	N/A	3.6	m	
Sb-118m	500	5	h	[3]
Sb-119	1000	38.19	h	[3]
Sb-120m	80	5.76	d	[3]
Sb-122	100	2.7238	d	[1]
Sb-124	10	60.2	d	[1]
Sb-125	100	2.75856	y	[1]
Sb-126	40	12.35	d	[3]
Sb-126m	3000	19	m	[3]
Sb-127	60	3.85	d	[3]
Sb-128	100	9.01	h	[3]
Sb-129	200	4.4	h	[3]

Nuclide	Limit, Bq/g	Half-life		Ref.
Te-116	600	2.49	h	[3]
Te-117	N/A	62	m	
Te-118	N/A	6	d	
Te-119m	N/A	4.7	d	
Te-119	100	16.05	h	[3]
Te-121m	40	154	d	[3]
Te-121	200	19.16	d	[3]
Te-123m	100	119.25	d	[1]
Te-125m	1000	57.4	d	[1]
Te-127m	1000	109	d	[1]
Te-127	1000	9.35	h	[1]
Te-129m	1000	33.6	d	[1]
Te-129	100	69.6	m	[1]
Te-131m	10	30	h	[1]
Te-131	100	25	m	[1]
Te-132	100	3.204	d	[1]
Te-133	10	12.5	m	[1]
Te-133m	10	55.4	m	[1]
Te-134	10	41.8	m	[1]
I-120	300	81.6	m	[3]
I-121	1000	2.12	h	[3]
I-122	N/A	3.63	m	
I-123	100	13.27	h	[1]
I-124	8	4.176	d	[3]
I-125	1000	59.4	d	[1]
I-126	100	12.93	d	[1]
I-129	100	15700000	y	[1]
I-130	10	12.36	h	[1]
I-131	100	8.0207	d	[1]
I-132m	500	1.387	h	[3]
I-132	10	2.295	h	[1]
I-133	10	20.8	h	[1]
I-134	10	52.5	m	[1]
I-135	10	6.57	h	[1]
Xe-122	N/A	20.1	h	
Xe-123	N/A	2.08	h	
Xe-125	N/A	16.9	h	
Xe-127	N/A	36.4	d	
Xe-129m	N/A	8.88	d	
Xe-131m	10000	11.934	d	[1]
Xe-133	1000	5.243	d	[1]
Xe-133m	N/A	2.19	d	
Xe-135	1000	9.14	h	[1]
Xe-135m	N/A	15.29	m	
Cs-127	4000	6.25	h	[3]
Cs-129	100	32.06	h	[1]
Cs-131	1000	9.689	d	[1]
Cs-132	10	6.479	d	[1]
Cs-134m	1000	2.903	h	[1]

Nuclide	Limit, Bq/g	Half-life		Ref.
Cs-134	10	754.5	d	[1]
Cs-135	10000	2300000	y	[1]
Cs-136	10	13.16	d	[1]
Cs-137 + Ba-137m	10	30.07	y	[1]
Cs-138	10	33.41	m	[1]
Ba-126+ Cs-126	400	100	m	[3]
Ba-128+ Cs-128	40	2.43	d	[3]
Ba-129m	N/A	2.16	h	
Ba-129	N/A	2.23	h	
Ba-131	100	11.5	d	[1]
Ba-133m	200	38.9	h	[3]
Ba-133	100	3848.9	d	[3]
Ba-135m	200	28.7	h	[3]
Ba-136m	N/A	0.3084	s	
Ba-139	800	83.06	m	[3]
Ba-140 + La-140	10	12.752	d	[1]
La-132	300	4.8	h	[3]
La-133	N/A	3.912	h	
La-135	3000	19.5	h	[3]
La-137	1000	60000	y	[3]
La-140	10	1.6781	d	[3]
La-141	300	3.92	h	[3]
La-142	600	91.1	m	[3]
Ce-132	N/A	3.51	h	
Ce-133m	N/A	97	m	
Ce-133	N/A	4.9	h	
Ce-134+ La-134	40	3.16	d	[3]
Ce-135	100	17.7	h	[3]
Ce-137m	200	34.4	h	[3]
Ce-137	4000	9	h	[3]
Ce-139	100	137.641	d	[1]
Ce-141	100	32.508	d	[1]
Ce-143	100	33.039	h	[1]
Ce-144 + Pr-144m	100	284.91	d	[1]
Pr-137	3000	1.28	h	[3]
Pr-138m	800	2.12	h	[3]
Pr-139	3000	4.41	h	[3]
Pr-140	N/A	3.39	m	
Pr-142	100	19.12	h	[1]
Pr-143	10000	13.57	d	[1]
Pr-144	2000	17.28	m	[3]
Pr-145	300	5.984	h	[3]
Nd-138+ Pr-138	200	5.04	h	[3]
Nd-139	5000	29.7	m	[3]

Nuclide	Limit, Bq/g	Half-life		Ref.
Nd-139m	400	5.5	h	[3]
Nd-140	40	3.37	d	[3]
Nd-141	10000	2.49	h	[3]
Nd-147	100	10.98	d	[1]
Nd-149	100	1.728	h	[1]
Pm-143	400	265	d	[3]
Pm-144	100	363	d	[3]
Pm-145	900	17.7	y	[3]
Pm-146	100	5.53	y	[3]
Pm-147	10000	2.6234	y	[1]
Pm-148m	60	41.29	d	[3]
Pm-148	40	5.368	d	[3]
Pm-149	1000	53.08	h	[1]
Pm-150	400	2.68	h	[3]
Pm-151	100	28.4	h	[3]
Sm-142+ Pm-142	500	72.49	m	[3]
Sm-145	500	340	d	[3]
Sm-151	10000	90	y	[1]
Sm-153	100	46.284	h	[1]
Sm-156	400	9.4	h	[3]
Eu-145	100	5.93	d	[3]
Eu-146	80	4.61	d	[3]
Eu-147	200	24.1	d	[3]
Eu-148	80	54.5	d	[3]
Eu-149	1000	93.1	d	[3]
Eu-150m	80	36.9	y	[3]
Eu-150	300	12.8	h	[3]
Eu-152m	100	9.3116	h	[1]
Eu-152	10	13.516	y	[1]
Eu-154	10	8.593	y	[1]
Eu-155	100	4.7611	y	[1]
Eu-156	50	15.19	d	[3]
Eu-157	200	15.18	h	[3]
Gd-146	100	48.27	d	[3]
Gd-147	200	38.06	h	[3]
Gd-148	2	74.6	y	[3]
Gd-149	200	9.28	d	[3]
Gd-151	500	124	d	[3]
Gd-153	100	240.4	d	[1]
Gd-159	1000	18.479	h	[1]
Tb-147	600	1.7	h	[3]
Tb-148	N/A	60	m	
Tb-149	400	4.118	h	[3]
Tb-150	400	3.48	h	[3]
Tb-151	300	17.609	h	[3]
Tb-152	N/A	17.5	h	
Tb-153	400	2.34	d	[3]
Tb-154m	N/A	22.7	h	

Nuclide	Limit, Bq/g	Half-life		Ref.
Tb-154	200	21.5	h	[3]
Tb-155	500	5.32	d	[3]
Tb-156m	600	24.4	h	[3]
Tb-156	80	5.35	d	[3]
Tb-157	3000	71	y	[3]
Tb-158	90	180	y	[3]
Tb-160	10	72.3	d	[1]
Tb-161	100	6.906	d	[3]
Dy-152	N/A	2.38	h	
Dy-153	N/A	6.4	h	
Dy-155	800	9.9	h	[3]
Dy-157	2000	8.14	h	[3]
Dy-159	1000	144.4	d	[3]
Dy-165	1000	2.334	h	[1]
Dy-166	1000	81.6	h	[1]
Ho-158	N/A	10.3	m	
Ho-158m	N/A	28	m	
Ho-160	N/A	25.6	m	
Ho-160m	N/A	5.02	h	
Ho-161	8000	2.48	h	[3]
Ho-161m	N/A	6.76	s	
Ho-162	30000	15	m	[3]
Ho-162m	4000	67	m	[3]
Ho-163	N/A	4570	y	
Ho-163m	N/A	1.09	s	
Ho-166m	50	1200	y	[3]
Ho-166	1000	26.83	h	[1]
Ho-167	1000	3.1	h	[3]
Er-167m	N/A	2.269	s	
Er-158	N/A	2.29	h	
Er-160	N/A	28.58	h	
Er-161	1000	3.21	h	[3]
Er-163	N/A	75	m	
Er-165	5000	10.36	h	[3]
Er-169	10000	9.4	d	[1]
Er-171	100	7.516	h	[1]
Er-172	100	49.3	h	[3]
Tm-163	N/A	1.81	h	
Tm-164	N/A	2	m	
Tm-165	N/A	30.06	h	
Tm-166	400	7.7	h	[3]
Tm-167	200	9.25	d	[3]
Tm-168	N/A	93.1	d	
Tm-170	1000	128.6	d	[1]
Tm-171	10000	1.92	y	[1]
Tm-172	60	63.6	h	[3]
Tm-173	300	8.24	h	[3]
Yb-164	N/A	75.8	m	
Yb-166	100	56.7	h	[3]

Nuclide	Limit, Bq/g	Half-life		Ref.
Yb-169	100	32.026	d	[3]
Yb-169m	N/A	46	s	
Yb-175	1000	4.185	d	[1]
Yb-177	1000	1.911	h	[3]
Yb-178	800	74	m	[3]
Lu-169	200	34.06	h	[3]
Lu-170	100	2.012	d	[3]
Lu-170m	N/A	0.67	s	
Lu-171	100	8.24	d	[3]
Lu-171m	N/A	79	s	
Lu-172	80	6.7	d	[3]
Lu-172m	N/A	3.7	m	
Lu-173	400	1.37	y	[3]
Lu-174m	200	142	d	[3]
Lu-174	400	3.31	y	[3]
Lu-176m	600	3.664	h	[3]
Lu-177m	60	160.44	d	[3]
Lu-177	1000	6.647	d	[1]
Lu-178	2000	28.4	m	[3]
Lu-179	500	4.59	h	[3]
Hf-170	200	16.01	h	[3]
Hf-171	N/A	12.1	h	
Hf-172	100	1.87	y	[3]
Hf-173	400	23.6	h	[3]
Hf-175	200	70	d	[3]
Hf-178m	20	31	y	[3]
Hf-179m	80	25.05	d	[3]
Hf-180m	600	5.5	h	[3]
Hf-181	10	42.39	d	[1]
Hf-182m	2000	61.5	m	[3]
Hf-183	1000	1.067	h	[3]
Hf-184	200	4.12	h	[3]
Ta-173	500	3.14	h	[3]
Ta-174	2000	1.14	h	[3]
Ta-175	500	10.5	h	[3]
Ta-176	300	8.09	h	[3]
Ta-177	900	56.56	h	[3]
Ta-178m	1000	2.36	h	[3]
Ta-179	2000	1.82	y	[3]
Ta-180	2000	8.152	h	[3]
Ta-182	10	114.43	d	[1]
Ta-182m	8000	15.8	m	[3]
Ta-183	80	5.1	d	[3]
Ta-184	100	8.7	h	[3]
W-176	900	2.5	h	[3]
W-177	2000	132	m	[3]
W-178+ Ta-178	400	21.6	d	[3]
W-181	1000	121.2	d	[1]

Nuclide	Limit, Bq/g	Half-life		Ref.
W-183m	N/A	5.17	s	
W-185	10000	75.1	d	[1]
W-187	100	23.72	h	[1]
W-188	40	69.78	d	[3]
Re-181	200	19.9	h	[3]
Re-182m	70	64	h	[3]
Re-182	400	12.7	h	[3]
Re-183	100	70	d	[3]
Re-184m	70	169	d	[3]
Re-184	100	38	d	[3]
Re-186	1000	3.7183	d	[1]
Re-186m	50	200000	y	[3]
Re-188	100	17.004	h	[1]
Re-189	100	24.3	h	[3]
Re-190	N/A	3.1	m	
Re-190m	N/A	3.2	h	
Os-181m	1000	105	m	[3]
Os-182	200	22.1	h	[3]
Os-183m	N/A	9.9	h	
Os-183	N/A	13	h	
Os-185	10	93.6	d	[1]
Os-189m	6000	5.8	h	[3]
Os-190m	N/A	9.9	m	
Os-191m	1000	13.1	h	[1]
Os-191	100	15.4	d	[1]
Os-193	100	30.11	h	[1]
Os-194	40	6	y	[3]
Ir-184	600	3.09	h	[3]
Ir-185	400	14.4	h	[3]
Ir-186m	2000	1.9	h	[3]
Ir-186	200	16.64	h	[3]
Ir-187	800	10.5	h	[3]
Ir-188	200	41.5	h	[3]
Ir-189	400	13.2	d	[3]
Ir-190m	800	3.087	h	[3]
Ir-190	10	11.78	d	[1]
Ir-191m	N/A	4.94	s	
Ir-192m	300	241	y	[3]
Ir-192	10	73.827	d	[1]
Ir-193m	400	10.53	d	[3]
Ir-194m	50	171	d	[3]
Ir-194	100	19.28	h	[1]
Ir-195m	500	3.8	h	[3]
Ir-195	1000	2.5	h	[3]
Ir-196m	N/A	1.4	h	
Pt-185	N/A	70.9	m	
Pt-186	1000	2.08	h	[3]
Pt-187	N/A	2.35	h	
Pt-188	100	10.2	d	[3]

Nuclide	Limit, Bq/g	Half-life		Ref.
Pt-189	800	10.87	h	[3]
Pt-191	100	2.802	d	[1]
Pt-193m	1000	4.33	d	[1]
Pt-193	3000	50	y	[3]
Pt-195m	200	4.02	d	[3]
Pt-197m	100	95.41	m	[1]
Pt-197	1000	19.8915	h	[1]
Pt-200	80	12.5	h	[3]
Pt-202	N/A	44	h	
Au-191	N/A	3.18	h	
Au-192	N/A	4.94	h	
Au-193	800	17.65	h	[3]
Au-193m	N/A	3.9	s	
Au-194	200	38.02	h	[3]
Au-195	400	186.098	d	[3]
Au-195m	N/A	30.5	s	
Au-196m	N/A	9.7	h	
Au-196	200	6.183	d	[3]
Au-197m	N/A	7.73	s	
Au-198m	80	2.27	d	[3]
Au-198	100	2.69517	d	[1]
Au-199	100	3.139	d	[1]
Au-200	1000	48.4	m	[3]
Au-200m	90	18.7	h	[3]
Au-202	N/A	28.8	s	
Hg-192	N/A	4.85	h	
Hg-193m	300	11.8	h	[3]
Hg-193	1000	3.8	h	[3]
Hg-194	2	444	y	[3]
Hg-195m	200	41.6	h	[3]
Hg-195	1000	9.9	h	[3]
Hg-197m	100	23.8	h	[1]
Hg-197	100	64.14	h	[1]
Hg-203	100	46.612	d	[1]
Tl-195	4000	1.16	h	[3]
Tl-196m	N/A	1.41	h	
Tl-196	N/A	1.84	h	
Tl-197	4000	2.84	h	[3]
Tl-198m	2000	1.87	h	[3]
Tl-198	1000	5.3	h	[3]
Tl-199	4000	7.42	h	[3]
Tl-200	10	26.1	h	[1]
Tl-201	100	72.912	h	[1]
Tl-202	100	12.23	d	[1]
Tl-204	10000	3.78	y	[1]
Pb-198	1000	2.4	h	[3]
Pb-199	2000	90	m	[3]
Pb-200	300	21.5	h	[3]
Pb-201	600	9.33	h	[3]

Nuclide	Limit, Bq/g	Half-life		Ref.
Pb-201m	N/A	61	s	
Pb-202	10	52500	y	[3]
Pb-202m	800	3.53	h	[3]
Pb-203	100	51.873	h	[1]
Pb-203m	N/A	6.3	s	
Pb-204m	N/A	67.2	m	
Pb-205	400	0.00554	s	[3]
Pb-209	2000	3.252	h	[3]
Bi-201	800	108	m	[3]
Bi-202	1000	1.72	h	[3]
Bi-203	200	11.76	h	[3]
Bi-204	N/A	11.22	h	
Bi-205	100	15.31	d	[3]
Bi-206	10	6.243	d	[1]
Bi-207	10	32.9	y	[1]
Bi-208	70	368000	y	[3]
Po-203	10	36.7	m	[1]
Po-204	N/A	3.53	h	
Po-205	10	1.66	h	[1]
Po-206	0.8	8.8	d	[3]
Po-207	10	5.8	h	[1]
Po-208	0.1	2.898	y	[3]
At-207	400	1.8	h	[3]
At-208	N/A	1.63	h	

Table 2

Neutron activation reactions and source of cross-section

##	Reaction	Library	##	Reaction	Library
1	Be-9 (n,g) Be-10	ENDF/B-6.8	40	Ni-58 (n,a) Fe-55	ENDF/B-6.8
2	C-13 (n,a) Be-10	JEFF-3.0/A	41	Ni-58 (n,2n) Ni-57	ENDF/B-6.8
3	Al-27 (n,a) Na-24	ENDF/B-6.8	42	Ni-58 (n,p) Co-58	ENDF/B-6.8
4	Al-27 (n,2n) Al-26	ENDF/B-6.8	43	Ni-60 (n,2n) Ni-59	ENDF/B-6.8
5	Si-30 (n,a) Mg-28	ENDF/B-6.8	44	Ni-60 (n,p) Co-60	ENDF/B-6.8
6	Si-30 (n,g) Si-31	ENDF/B-6.8	45	Ni-61 (n,p) Co-61	ENDF/B-6.8
7	Ar-36 (n,g) Ar-37	JEFF-3.0/A	46	Ni-62 (n,g) Ni-63	ENDF/B-6.8
8	Ar-36 (n,p) Cl-36	JEFF-3.0/A	47	Ni-62 (n,a) Fe-59	ENDF/B-6.8
9	Ar-38 (n,g) Ar-39	JEFF-3.0/A	48	Ni-64 (n,g) Ni-65	ENDF/B-6.8
10	Ar-38 (n,a) S-35	JEFF-3.0/A	49	Ni-64 (n,a) Fe-61	ENDF/B-6.8
11	Ar-38 (n,2n) Ar-37	JEFF-3.0/A	50	Ni-64 (n,2n) Ni-63	ENDF/B-6.8
12	Ar-40 (n,g) Ar-41	ENDF/B-6.8	51	Cu-63 (n,g) Cu-64	ENDF/B-6.8
13	Ar-40 (n,2n) Ar-39	JEFF-3.0/A	52	Cu-63 (n,p) Ni-63	ENDF/B-6.8
14	Ti-46 (n,2n) Ti-45	JEFF-3.0/A	53	Cu-63 (n,a) Co-60	ENDF/B-6.8
15	Ti-46 (n,p) Sc-46	ENDF/B-6.8	54	Cu-65 (n,2n) Cu-64	ENDF/B-6.8
16	Ti-47 (n,p) Sc-47	ENDF/B-6.8	55	Cu-65 (n,p) Ni-65	ENDF/B-6.8
17	Ti-48 (n,a) Ca-45	ENDF/B-6.8	56	Zn-64 (n,g) Zn-65	JEFF-3.0/A
18	Ti-48 (n,p) Sc-48	ENDF/B-6.8	57	Zn-64 (n,2n) Zn-63	JEFF-3.0/A
19	Ti-50 (n,a) Ca-47	ENDF/B-6.8	58	Zn-64 (n,p) Cu-64	JEFF-3.0/A
20	Cr-50 (n,np) V-49	ENDF/B-6.8	59	Zn-66 (n,a) Ni-63	JEFF-3.0/A
21	Cr-50 (n,g) Cr-51	ENDF/B-6.8	60	Zn-66 (n,2n) Zn-65	JEFF-3.0/A
22	Cr-50 (n,2n) Cr-49	ENDF/B-6.8	61	Zn-67 (n,p) Cu-67	JEFF-3.0/A
23	Cr-52 (n,2n) Cr-51	ENDF/B-6.8	62	Zn-68 (n,g) Zn-69m	JEFF-3.0/A
24	Mn-55 (n,g) Mn-56	ENDF/B-6.8	63	Zn-68 (n,a) Ni-65	JEFF-3.0/A
25	Mn-55 (n,2n) Mn-54	ENDF/B-6.8	64	Zn-70 (n,a) Ni-67	JEFF-3.0/A
26	Fe-54 (n,np) Mn-53	ENDF/B-6.8	65	Zn-70 (n,2n) Zn-69m	JEFF-3.0/A
27	Fe-54 (n,g) Fe-55	ENDF/B-6.8	66	Nb-93 (n,g) Nb-94	ENDF/B-6.8
28	Fe-54 (n,a) Cr-51	ENDF/B-6.8	67	Nb-93 (n,a) Y-90	ENDF/B-6.8
29	Fe-54 (n,2n) Fe-53	ENDF/B-6.8	68	Nb-93 (n,2n) Nb-92	JEFF-3.0/A
30	Fe-54 (n,p) Mn-54	ENDF/B-6.8	69	Nb-93 (n,2n) Nb-92m	JEFF-3.0/A
31	Fe-56 (n,2n) Fe-55	ENDF/B-6.8	70	Nb-93 (n,p) Zr-93	ENDF/B-6.8
32	Fe-56 (n,p) Mn-56	ENDF/B-6.8	71	Ag-107 (n,g) Ag-108m	ENDF/B-6.8
33	Fe-58 (n,g) Fe-59	ENDF/B-6.8	72	Ag-107 (n,2n) Ag-106m	JEFF-3.0/A
34	Co-59 (n,g) Co-60	ENDF/B-6.8	73	Ag-107 (n,p) Pd-107	ENDF/B-6.8
35	Co-59 (n,a) Mn-56	ENDF/B-6.8	74	Ag-109 (n,g) Ag-110m	ENDF/B-6.8
36	Co-59 (n,2n) Co-58	ENDF/B-6.8	75	Ag-109 (n,a) Rh-106m	JEFF-3.0/A
37	Co-59 (n,p) Fe-59	ENDF/B-6.8	76	Ag-109 (n,2n) Ag-108m	JEFF-3.0/A
38	Ni-58 (n,np) Co-57	ENDF/B-6.8	77	Ag-109 (n,p) Pd-109	ENDF/B-6.8
39	Ni-58 (n,g) Ni-59	ENDF/B-6.8	78	Sn-112 (n,g) Sn-113	ENDF/B-6.8

##	Reaction			Library
79	Sn-112	(n,a)	Cd-109	JEFF-3.0/A
80	Sn-112	(n,2n)	Sn-111	JEFF-3.0/A
81	Sn-114	(n,2n)	Sn-113	JEFF-3.0/A
82	Sn-116	(n,g)	Sn-117m	JEFF-3.0/A
83	Sn-116	(n,a)	Cd-113m	JEFF-3.0/A
84	Sn-117	(n,p)	In-117m	JEFF-3.0/A
85	Sn-118	(n,g)	Sn-119m	JEFF-3.0/A
86	Sn-118	(n,a)	Cd-115	JEFF-3.0/A
87	Sn-118	(n,a)	Cd-115m	JEFF-3.0/A
88	Sn-118	(n,2n)	Sn-117m	JEFF-3.0/A
89	Sn-120	(n,g)	Sn-121	JEFF-3.0/A
90	Sn-120	(n,g)	Sn-121m	JEFF-3.0/A
91	Sn-120	(n,a)	Cd-117	JEFF-3.0/A
92	Sn-120	(n,a)	Cd-117m	JEFF-3.0/A
93	Sn-120	(n,2n)	Sn-119m	JEFF-3.0/A
94	Sn-122	(n,g)	Sn-123	JEFF-3.0/A
95	Sn-122	(n,2n)	Sn-121	JEFF-3.0/A
96	Sn-122	(n,2n)	Sn-121m	JEFF-3.0/A
97	Sn-124	(n,g)	Sn-125	JEFF-3.0/A
98	Sn-124	(n,a)	Cd-121	JEFF-3.0/A
99	Sn-124	(n,2n)	Sn-123	JEFF-3.0/A
100	Sb-121	(n,g)	Sb-122	ENDF/B-6.8
101	Sb-121	(n,2n)	Sb-120m	JEFF-3.0/A
102	Sb-121	(n,p)	Sn-121	JEFF-3.0/A
103	Sb-121	(n,p)	Sn-121m	JEFF-3.0/A
104	Sb-123	(n,g)	Sb-124	ENDF/B-6.8
105	Sb-123	(n,2n)	Sb-122	ENDF/B-6.8
106	W-180	(n,g)	W-181	JEFF-3.0/A
107	W-180	(n,2n)	W-179	JEFF-3.0/A

##	Reaction			Library
108	W-180	(n,p)	Ta-180	JEFF-3.0/A
109	W-182	(n,2n)	W-181	ENDF/B-6.8
110	W-182	(n,p)	Ta-182	ENDF/B-6.8
111	W-183	(n,p)	Ta-183	ENDF/B-6.8
112	W-184	(n,g)	W-185	ENDF/B-6.8
113	W-184	(n,a)	Hf-181	ENDF/B-6.8
114	W-184	(n,p)	Ta-184	ENDF/B-6.8
115	W-186	(n,g)	W-187	ENDF/B-6.8
116	W-186	(n,a)	Hf-182	ENDF/B-6.8
117	W-186	(n,2n)	W-185	ENDF/B-6.8
118	Re-185	(n,g)	Re-186	ENDF/B-6.8
119	Re-185	(n,a)	Ta-182	JEFF-3.0/A
120	Re-185	(n,2n)	Re-184	ENDF/B-6.8
121	Re-185	(n,p)	W-185	JEFF-3.0/A
122	Re-187	(n,g)	Re-188	ENDF/B-6.8
123	Re-187	(n,a)	Ta-184	JEFF-3.0/A
124	Re-187	(n,2n)	Re-186	ENDF/B-6.8
125	Au-197	(n,g)	Au-198	ENDF/B-6.8
126	Au-197	(n,a)	Ir-194	ENDF/B-6.8
127	Au-197	(n,a)	Ir-194m_2	ENDF/B-6.8
128	Au-197	(n,2n)	Au-196	ENDF/B-6.8
129	Au-197	(n,p)	Pt-197	ENDF/B-6.8
130	Pb-204	(n,g)	Pb-205	JEFF-3.0/A
131	Pb-204	(n,2n)	Pb-203	JEFF-3.0/A
132	Pb-204	(n,p)	Tl-204	JEFF-3.0/A
133	Pb-206	(n,2n)	Pb-205	JEFF-3.0/A
134	Pb-208	(n,g)	Pb-209	ENDF/B-6.8

Table 3

Parametric radionuclide decay chains for buildup calculation

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
1	H-3	-	-	-	-	-	1.228E+1 Y	-	-
2	Be-7	-	-	-	-	-	5.329E+1 D	-	-
3	Be-10	-	-	-	-	-	1.151E+6 Y	-	-
4	C-14+	-	-	-	-	-	5.700E+3 Y	-	-
5	F-18+	-	-	-	-	-	1.098E+2 M	-	-
6	Na-22+	-	-	-	-	-	2.609E+0 Y	-	-
7	Na-24+	-	-	-	-	-	1.503E+1 H	-	-
8	Mg-28+	Al-28		1	-	-	2.092E+1 H	2.240E+0 M	-
9	Al-26	-	-	-	-	-	7.170E+5 Y	-	-
10	Si-31+	-	-	-	-	-	2.620E+0 H	-	-
11	Si-32+	P-32	-	1	-	-	1.620E+2 Y	1.426E+1 D	-
12	P-32	-	-	-	-	-	1.426E+1 D	-	-
13	P-33+	-	-	-	-	-	2.534E+1 D	-	-
14	S-35+	-	-	-	-	-	8.732E+1 D	-	-
15	S-38+	Cl-38	-	1	-	-	2.840E+0 H	3.724E+1 M	-
16	Cl-36	-	-	-	-	-	3.010E+5 Y	-	-
17	Ar-37+	-	-	-	-	-	3.504E+1 D	-	-
18	Ar-39+	-	-	-	-	-	2.690E+2 Y	-	-
19	Ar-41+	-	-	-	-	-	1.096E+2 M	-	-
20	Ar-42+	-	-	-	-	-	3.290E+1 Y	-	-
21	K-42	-	-	-	-	-	1.236E+1 H	-	-
22	K-43+	-	-	-	-	-	2.230E+1 H	-	-
23	Ca-41+	-	-	-	-	-	1.020E+5 Y	-	-
24	Ca-45+	-	-	-	-	-	1.626E+2 D	-	-
25	Ca-47+	Sc-47	-	1	-	-	4.536E+0 D	3.349E+0 D	-
26	Sc-43+	-	-	-	-	-	3.891E+0 H	-	-
27	Sc-44m	Sc-44	-	0.9861	-	-	2.440E+0 D	3.927E+0 H	-
28	Sc-44	-	-	-	-	-	3.927E+0 H	-	-
29	Sc-46	-	-	-	-	-	8.381E+1 D	-	-
30	Sc-47	-	-	-	-	-	3.349E+0 D	-	-
31	Sc-48	-	-	-	-	-	4.370E+1 H	-	-
32	Ti-44	Sc-44	-	1	-	-	6.000E+1 Y	3.927E+0 H	-
33	Ti-45+	-	-	-	-	-	1.848E+2 M	-	-
34	V-48	-	-	-	-	-	1.597E+1 D	-	-
35	V-49+	-	-	-	-	-	3.380E+2 D	-	-
36	Cr-48+	V-48	-	1	-	-	2.156E+1 H	1.597E+1 D	-
37	Cr-51+	-	-	-	-	-	2.770E+1 D	-	-
38	Mn-52	-	-	-	-	-	5.591E+0 D	-	-
39	Mn-53+	-	-	-	-	-	3.740E+6 Y	-	-
40	Mn-54	-	-	-	-	-	3.120E+2 D	-	-
41	Mn-56+	-	-	-	-	-	2.579E+0 H	-	-
42	Fe-52	Mn-52m	Mn-52	1	0	0.0175	8.275E+0 H	2.110E+1 M	5.59E+0 D
43	Fe-55	-	-	-	-	-	2.737E+0 Y	-	-
44	Fe-59+	-	-	-	-	-	4.449E+1 D	-	-

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
45	Fe-60+	-	-	-	-	-	1.500E+6 Y	-	-
46	Co-55+	Fe-55	-	1	-	-	1.753E+1 H	2.730E+0 Y	-
47	Co-56	-	-	-	-	-	7.722E+1 D	-	-
48	Co-57	-	-	-	-	-	2.718E+2 D	-	-
49	Co-58m	-	-	-	-	-	9.040E+0 H	-	-
50	Co-58+	-	-	-	-	-	7.082E+1 D	-	-
51	Co-60	-	-	-	-	-	5.270E+0 Y	-	-
52	Co-61+	-	-	-	-	-	1.650E+0 H	-	-
53	Ni-56	-	-	-	-	-	6.075E+0 D	-	-
54	Ni-57+	-	-	-	-	-	3.565E+1 H	-	-
55	Ni-59+	-	-	-	-	-	7.600E+4 Y	-	-
56	Ni-63+	-	-	-	-	-	1.001E+2 Y	-	-
57	Ni-65+	-	-	-	-	-	2.517E+0 H	-	-
58	Ni-66+	Cu-66	-	1	-	-	5.460E+1 H	5.100E+0 M	-
59	Cu-61+	-	-	-	-	-	3.333E+0 H	-	-
60	Cu-64	-	-	-	-	-	1.270E+1 H	-	-
61	Cu-67+	-	-	-	-	-	6.183E+1 H	-	-
62	Zn-62+	Cu-62	-	1	-	-	9.186E+0 H	9.740E+0 M	-
63	Zn-63+	-	-	-	-	-	3.285E+2 M	-	-
64	Zn-65+	-	-	-	-	-	2.439E+2 D	-	-
65	Zn-69m	Zn-69	-	1	-	-	1.376E+1 H	5.640E+1 M	-
66	Zn-71m	Zn-71	-	1	-	-	3.940E+0 H	2.450E+0 M	-
67	Zn-72+	Ga-72	-	1	-	-	4.650E+1 H	1.410E+1 H	-
68	Ga-66	-	-	-	-	-	9.490E+0 H	-	-
69	Ga-67+	-	-	-	-	-	3.261E+0 D	-	-
70	Ga-68	-	-	-	-	-	6.761E+1 M	-	-
71	Ga-72	-	-	-	-	-	1.410E+1 H	-	-
72	Ga-73+	Ge-73m	-	0.998	-	-	4.860E+0 H	4.990E-1 S	-
73	Ge-66+	Ga-66	-	1	-	-	2.260E+0 H	9.490E+0 H	-
74	Ge-68+	Ga-68	-	1	-	-	2.708E+2 D	6.763E+1 M	-
75	Ge-69+	-	-	-	-	-	3.905E+1 H	-	-
76	Ge-71	-	-	-	-	-	1.143E+1 D	-	-
77	Ge-75+	-	-	-	-	-	8.278E+1 M	-	-
78	Ge-77+	As-77	Se-77m	1	0	0.0032	1.130E+1 H	3.883E+1 H	1.75E+1 S
79	Ge-78+	As-78	-	1	-	-	8.800E+1 M	9.070E+1 M	-
80	As-71+	Ge-71	-	1	-	-	6.528E+1 H	1.143E+1 D	-
81	As-72	-	-	-	-	-	2.600E+1 H	-	-
82	As-73	Ge-73m	-	1	-	-	8.030E+1 D	4.990E-1 S	-
83	As-74	-	-	-	-	-	1.777E+1 D	-	-
84	As-76	-	-	-	-	-	1.078E+0 D	-	-
85	As-77	Se-77m	-	0.0032	-	-	3.883E+1 H	1.745E+1 S	-
86	As-78	-	-	-	-	-	8.800E+1 M	-	-
87	Se-72+	As-72	-	1	-	-	8.400E+0 D	2.600E+1 H	-
88	Se-73+	As-73	Ge-73m	1	0	1	7.150E+0 H	8.030E+1 D	4.99E-1 S
89	Se-75	-	-	-	-	-	1.198E+2 D	-	-
90	Se-79+	-	-	-	-	-	2.950E+5 D	-	-

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
91	Br-75+	Se-75	-	1	-	-	9.670E+1 M	1.198E+2 D	-
92	Br-76	-	-	-	-	-	1.620E+1 H	-	-
93	Br-77+	Se-77m	-	0.0207	-	-	5.704E+1 H	1.745E+1 S	-
94	Br-80m	Br-80	-	1	-	-	4.421E+0 H	1.768E+1 M	-
95	Br-82	-	-	-	-	-	3.530E+1 H	-	-
96	Br-83+	Kr-83m	-	1	-	-	2.400E+0 H	1.830E+0 H	-
97	Kr-76+	Br-76	-	1	-	-	1.480E+1 H	1.620E+1 H	-
98	Kr-77+	Br-77m	-	1	-	-	7.440E+1 M	4.280E+0 M	-
99	Kr-79+	-	-	-	-	-	3.504E+1 H	-	-
100	Kr-81	-	-	-	-	-	2.290E+5 Y	-	-
101	Kr-83m	-	-	-	-	-	1.830E+0 H	-	-
102	Kr-85m+	Kr-85	-	0.214	-	-	4.480E+0 H	1.076E+1 Y	-
103	Kr-85	-	-	-	-	-	3.934E+3 D	-	-
104	Kr-87+	-	-	-	-	-	7.630E+1 M	-	-
105	Kr-88+	Rb-88	-	1	-	-	2.840E+0 H	1.780E+1 M	-
106	Rb-81+	Kr-81m	Kr-81	0.96	0.04	1	4.576E+0 H	1.281E+1 S	2.29E+5 Y
107	Rb-82m	-	-	-	-	-	6.472E+0 H	-	-
108	Rb-83	Kr-83m	-	0.76	-	-	8.620E+1 D	1.830E+0 H	-
109	Rb-84	-	-	-	-	-	3.277E+1 D	-	-
110	Rb-86	-	-	-	-	-	1.863E+1 D	-	-
111	Sr-80+	Rb-80	-	1	-	-	1.063E+2 M	3.400E+1 S	-
112	Sr-82+	Rb-82	-	1	-	-	2.555E+1 D	1.273E+0 M	-
113	Sr-83+	Rb-83	Kr-83m	1	0	0.76	3.240E+1 H	8.620E+1 D	1.83E+0 H
114	Sr-85m	Sr-85	-	0.866	-	-	6.763E+1 M	6.484E+1 D	-
115	Sr-85	-	-	-	-	-	6.484E+1 D	-	-
116	Sr-87m	-	-	-	-	-	2.811E+0 H	-	-
117	Sr-89+	-	-	-	-	-	5.053E+1 D	-	-
118	Sr-90+	Y-90	-	1	-	-	2.879E+1 Y	6.400E+1 H	-
119	Sr-91+	Y-91m	Y-91	0.576	0.424	1	9.630E+0 H	4.971E+1 M	5.85E+1 D
120	Sr-92+	Y-92	-	1	-	-	2.660E+0 H	3.540E+0 H	-
121	Y-85m+	Sr-85m	Sr-85	0.04	0.96	0.866	4.860E+0 H	6.763E+1 M	6.48E+1 D
122	Y-85	Sr-85m	Sr-85	0.5	0.5	0.866	2.680E+0 H	6.763E+1 M	6.48E+1 D
123	Y-86	-	-	-	-	-	1.474E+1 H	-	-
124	Y-87m+	Y-87	Sr-87m	0.984	0	1	1.337E+1 H	7.980E+1 H	2.82E+0 H
125	Y-87	Sr-87m	-	1	-	-	7.981E+1 H	2.815E+0 H	-
126	Y-88	-	-	-	-	-	1.066E+2 D	-	-
127	Y-90m	Y-90	-	1	-	-	3.190E+0 H	6.410E+1 H	-
128	Y-90	-	-	-	-	-	6.400E+1 H	-	-
129	Y-91	-	-	-	-	-	5.851E+1 D	-	-
130	Y-92	-	-	-	-	-	3.540E+0 H	-	-
131	Y-93+	Zr-93	Nb-93m	1	0	0.95	1.020E+1 H	1.530E+6 Y	1.61E+1 Y
132	Zr-86+	Y-86	-	1	-	-	1.650E+1 H	1.474E+1 H	-
133	Zr-87+	-	-	-	-	-	1.680E+0 H	-	-
134	Zr-88+	Y-88	-	1	-	-	8.340E+1 D	1.067E+2 D	-
135	Zr-89+	Y-89m	-	0.0013	-	-	7.841E+1 H	1.528E+1 S	-
136	Zr-93	-	-	-	-	-	1.530E+6 Y	-	-

##	Nuclide			Branching ratio			Half-life					
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1		τ_2		τ_3	
137	Zr-95+	Nb-95m	Nb-95	0.009	0.991	0.994	6.402E+1	D	3.610E+0	D	3.50E+1	D
138	Zr-97+	Nb-97m	Nb-97	0.973	0.027	1	1.690E+1	H	5.810E+1	S	7.20E+1	M
139	Nb-89m+	Zr-89m	-	0.0126	-	-	2.030E+0	H	4.161E+0	M	-	
140	Nb-89+	Zr-89m	-	0.9874	-	-	6.600E+1	M	4.161E+0	M	-	
141	Nb-90+	Zr-90m	-	0.981	-	-	1.460E+1	H	8.090E-1	S	-	
142	Nb-91m+	Nb-91	-	0.95	-	-	6.086E+1	D	6.800E+2	Y	-	
143	Nb-91+	-	-	-	-	-	6.800E+2	Y	-		-	
144	Nb-92m	-	-	-	-	-	1.015E+1	D	-		-	
145	Nb-93m	-	-	-	-	-	1.613E+1	Y	-		-	
146	Nb-94	-	-	-	-	-	2.030E+4	Y	-		-	
147	Nb-95m	Nb-95	-	0.994	-	-	3.610E+0	D	3.498E+1	D	-	
148	Nb-95	-	-	-	-	-	3.498E+1	D	-		-	
149	Nb-96	-	-	-	-	-	2.335E+1	H	-		-	
150	Nb-97	-	-	-	-	-	7.210E+1	M	-		-	
151	Mo-90+	Nb-90m	-	0.935	-	-	5.560E+0	H	1.880E+1	S	-	
152	Mo-93m	-	-	-	-	-	6.850E+0	H	-		-	
153	Mo-93+	Nb-93m	-	0.96	-	-	4.000E+3	Y	1.610E+1	Y	-	
154	Mo-99+	Tc-99m	Tc-99	0.8751	0.1249	1	6.594E+1	H	6.012E+0	H	2.11E+5	Y
155	Tc-93+	Mo-93	Nb-93m	1	0	0.96	2.750E+0	H	4.000E+3	Y	1.61E+1	Y
156	Tc-94	-	-	-	-	-	2.930E+2	M	-		-	
157	Tc-95m	Tc-95	-	0.04	-	-	6.100E+1	D	2.000E+1	H	-	
158	Tc-95	-	-	-	-	-	2.000E+1	H	-		-	
159	Tc-96	-	-	-	-	-	4.280E+0	D	-		-	
160	Tc-97m	Tc-97	-	1	-	-	9.140E+1	D	4.210E+6	Y	-	
161	Tc-97	-	-	-	-	-	4.210E+6	Y	-		-	
162	Tc-98	-	-	-	-	-	4.200E+6	Y	-		-	
163	Tc-99m	Tc-99	-	1	-	-	6.015E+0	H	2.111E+5	Y	-	
164	Tc-99	-	-	-	-	-	2.111E+5	Y	-		-	
165	Ru-95+	Tc-95m	Tc-95	0.026	0.974	0.04	1.643E+0	H	6.100E+1	D	2.00E+1	H
166	Ru-97+	Tc-97	-	1	-	-	2.791E+0	D	4.210E+6	Y	-	
167	Ru-103+	Rh-103m	-	0.9973	-	-	3.925E+1	D	5.611E+1	M	-	
168	Ru-105+	Rh-105m	Rh-105	0.28	0.72	1	4.440E+0	H	4.500E+1	S	3.54E+1	H
169	Ru-106+	Rh-106	-	1	-	-	3.736E+2	D	2.890E+1	S	-	
170	Rh-99m+	-	-	-	-	-	4.700E+0	H	-		-	
171	Rh-99+	-	-	-	-	-	1.610E+1	D	-		-	
172	Rh-100	-	-	-	-	-	2.080E+1	H	-		-	
173	Rh-101m	Rh-101	-	0.064	-	-	4.340E+0	D	3.300E+0	Y	-	
174	Rh-101	-	-	-	-	-	3.300E+0	Y	-		-	
175	Rh-102m	Rh-102	-	0.0023	-	-	2.900E+0	Y	2.070E+2	D	-	
176	Rh-102	-	-	-	-	-	2.070E+2	D	-		-	
177	Rh-105	-	-	-	-	-	3.536E+1	H	-		-	
178	Rh-106m	-	-	-	-	-	1.310E+2	M	-		-	
179	Pd-100+	Rh-100	-	1	-	-	3.630E+0	D	2.080E+1	H	-	
180	Pd-101+	Rh-101	-	1	-	-	8.470E+0	H	3.300E+0	Y	-	
181	Pd-103	Rh-103m	-	0.99975	-	-	1.699E+1	D	5.611E+1	M	-	
182	Pd-109+	-	-	-	-	-	1.346E+1	H	-		-	

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
183	Pd-111m+	Pd-111	Ag-111m	0.21	0.73	0.994	5.500E+0 H	2.340E+1 M	6.48E+1 S
184	Pd-112+	Ag-112	-	1	-	-	2.103E+1 H	3.140E+0 H	-
185	Ag-103+	Pd-103	Rh-103m	1	0	1	6.570E+1 M	1.699E+1 D	5.61E+1 M
186	Ag-104+	-	-	-	-	-	6.920E+1 M	-	-
187	Ag-105+	-	-	-	-	-	4.129E+1 D	-	-
188	Ag-106m	-	-	-	-	-	8.460E+0 D	-	-
189	Ag-108m	Ag-108	-	1	-	-	4.180E+2 Y	2.370E+0 M	-
190	Ag-110m	Ag-110	-	0.0136	-	-	2.498E+2 D	4.100E-1 M	-
191	Ag-111+	-	-	-	-	-	7.450E+0 D	-	-
192	Ag-112	-	-	-	-	-	3.130E+0 H	-	-
193	Ag-113+	-	-	-	-	-	5.370E+0 H	-	-
194	Cd-107+	Ag-107m	-	1	-	-	6.500E+0 H	4.430E+1 S	-
195	Cd-109	Ag-109m	-	1	-	-	4.626E+2 D	3.960E+1 S	-
196	Cd-113m	-	-	-	-	-	1.410E+1 Y	-	-
197	Cd-115m	In-115m	-	0.27	-	-	4.460E+1 D	4.468E+0 H	-
198	Cd-115+	In-115m	-	1	-	-	5.346E+1 H	4.468E+0 H	-
199	Cd-117m+	In-117m	In-117	0.01	0.99	0.471	3.360E+0 H	1.162E+2 M	4.31E+1 M
200	Cd-117+	In-117m	In-117	0.9156	0.0844	0.471	2.490E+0 H	1.162E+2 M	4.31E+1 M
201	In-109+	Cd-109	Ag-109m	1	0	1	4.200E+0 H	4.614E+2 D	3.96E+1 S
202	In-110m	-	-	-	-	-	4.900E+0 H	-	-
203	In-110	-	-	-	-	-	6.910E+1 M	-	-
204	In-111+	-	-	-	-	-	2.807E+0 D	-	-
205	In-113m	-	-	-	-	-	9.948E+1 M	-	-
206	In-114m	In-114	-	0.995	-	-	4.951E+1 D	7.190E+1 S	-
207	In-115m	-	-	-	-	-	4.486E+0 H	-	-
208	In-117m	In-117	-	0.471	-	-	1.162E+2 M	4.320E+1 M	-
209	Sn-110+	In-110	-	1	-	-	4.110E+0 H	6.910E+1 M	-
210	Sn-113+	-	-	-	-	-	1.151E+2 D	-	-
211	Sn-117m+	-	-	-	-	-	1.361E+1 D	-	-
212	Sn-119m	-	-	-	-	-	2.931E+2 D	-	-
213	Sn-121m+	Sn-121	-	0.776	-	-	5.500E+1 Y	2.703E+1 H	-
214	Sn-121+	-	-	-	-	-	2.703E+1 H	-	-
215	Sn-123+	-	-	-	-	-	1.292E+2 D	-	-
216	Sn-125+	Sb-125	-	1	-	-	9.640E+0 D	2.730E+0 Y	-
217	Sn-126+	Sb-126m	Sb-126	1	0	0.14	1.000E+5 Y	1.900E+1 M	1.24E+1 D
218	Sn-127+	-	-	-	-	-	2.100E+0 H	-	-
219	Sb-116m	-	-	-	-	-	6.030E+1 M	-	-
220	Sb-117	-	-	-	-	-	2.800E+0 H	-	-
221	Sb-118m	-	-	-	-	-	5.000E+0 H	-	-
222	Sb-119	-	-	-	-	-	3.819E+1 H	-	-
223	Sb-120m	-	-	-	-	-	5.760E+0 D	-	-
224	Sb-122	-	-	-	-	-	2.724E+0 D	-	-
225	Sb-124	-	-	-	-	-	6.020E+1 D	-	-
226	Sb-125+	Te-125m	-	1	-	-	2.730E+0 Y	5.740E+1 D	-
227	Sb-126	-	-	-	-	-	1.235E+1 D	-	-
228	Sb-127+	Te-127m	Te-127	0.174	0.826	0.976	3.850E+0 D	1.070E+2 D	9.35E+0 H

##	Nuclide			Branching ratio			Half-life					
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1		τ_2		τ_3	
229	Sb-128+	-	-	-	-	-	9.010E+0	H	-		-	
230	Sb-129+	Te-129m	Te-129	0.166	0.834	0.634	4.400E+0	H	3.360E+1	D	6.96E+1	M
231	Te-116+	Sb-116	-	1	-	-	2.490E+0	H	1.580E+1	M	-	
232	Te-117+	Sb-117	-	1	-	-	6.200E+1	M	2.800E+0	H	-	
233	Te-118+	Sb-118	-	1	-	-	6.000E+0	D	3.600E+0	M	-	
234	Te-119m	Sb-119	-	1	-	-	4.690E+0	D	3.819E+1	H	-	
235	Te-119+	Sb-119	-	1	-	-	1.605E+1	H	3.810E+1	H	-	
236	Te-121m	Te-121	-	0.886	-	-	1.540E+2	D	1.916E+1	D	-	
237	Te-121	-	-	-	-	-	1.916E+1	D	-		-	
238	Te-123m	-	-	-	-	-	1.197E+2	D	-		-	
239	Te-125m	-	-	-	-	-	5.740E+1	D	-		-	
240	Te-127m	Te-127	-	0.976	-	-	1.070E+2	D	9.350E+0	H	-	
241	Te-127	-	-	-	-	-	9.350E+0	H	-		-	
242	Te-129m	Te-129	-	0.634	-	-	3.360E+1	D	6.960E+1	M	-	
243	Te-129+	-	-	-	-	-	6.960E+1	M	-		-	
244	Te-131m+	Te-131	I-131	0.222	0.778	1	3.000E+1	H	2.500E+1	M	8.05E+0	D
245	Te-132+	I-132	-	1	-	-	7.860E+1	H	2.300E+0	H	-	
246	I-120+	-	-	-	-	-	8.160E+1	M	-		-	
247	I-121+	Te-121	-	1	-	-	2.120E+0	H	1.916E+1	D	-	
248	I-123	-	-	-	-	-	1.331E+1	H	-		-	
249	I-124	-	-	-	-	-	4.180E+0	D	-		-	
250	I-125	-	-	-	-	-	5.937E+1	D	-		-	
251	I-126	-	-	-	-	-	1.301E+1	D	-		-	
252	I-130+	-	-	-	-	-	1.236E+1	H	-		-	
253	I-131+	Xe-131m	-	0.0109	-	-	8.051E+0	D	1.193E+1	D	-	
254	I-132m	I-132	-	0.86	-	-	1.378E+0	H	2.295E+0	H	-	
255	I-132	-	-	-	-	-	2.295E+0	H	-		-	
256	I-133+	Xe-133m	Xe-133	0.0288	0.9712	1	2.080E+1	H	2.188E+0	D	5.24E+0	D
257	I-135+	Xe-135m	Xe-135	0.155	0.845	1	6.570E+0	H	1.529E+1	M	9.14E+0	H
258	Xe-122+	I-122	-	1	-	-	2.010E+1	H	3.630E+0	M	-	
259	Xe-123+	I-123	Te-123m	1	0	0.000115	2.080E+0	H	1.331E+1	H	1.20E+2	D
260	Xe-125+	I-125	-	1	-	-	1.690E+1	H	5.937E+1	D	-	
261	Xe-127	-	-	-	-	-	3.640E+1	D	-		-	
262	Xe-129m	-	-	-	-	-	8.880E+0	D	-		-	
263	Xe-131m+	-	-	-	-	-	1.190E+1	D	-		-	
264	Xe-133m	Xe-133	-	1	-	-	2.188E+0	D	5.234E+0	D	-	
265	Xe-133	-	-	-	-	-	5.243E+0	D	-		-	
266	Xe-135	Cs-135	-	1	-	-	9.140E+0	H	2.300E+6	Y	-	
267	Cs-127+	Xe-127	-	1	-	-	6.250E+0	H	3.640E+1	D	-	
268	Cs-129	-	-	-	-	-	3.206E+1	H	-		-	
269	Cs-131	-	-	-	-	-	9.690E+0	D	-		-	
270	Cs-132	-	-	-	-	-	6.479E+0	D	-		-	
271	Cs-134m	Cs-134	-	1	-	-	2.903E+0	H	7.545E+2	D	-	
272	Cs-134	-	-	-	-	-	7.545E+2	D	-		-	
273	Cs-135+	-	-	-	-	-	2.300E+6	Y	-		-	
274	Cs-136	Ba-136m	-	0.148	-	-	1.316E+1	D	3.084E-1	S	-	

##	Nuclide			Branching ratio			Half-life		
	X1	X2	X3	p1	p2	p3	τ1	τ2	τ3
275	Cs-137+	Ba-137m	-	0.946	-	-	3.021E+1 Y	2.552E+0 M	-
276	Ba-126+	Cs-126	-	1	-	-	1.000E+2 M	1.640E+0 M	-
277	Ba-128+	Cs-128	-	1	-	-	2.430E+0 D	3.620E+0 M	-
278	Ba-129m	Cs-129	-	1	-	-	2.160E+0 H	3.206E+1 H	-
279	Ba-129+	Cs-129	-	1	-	-	2.230E+0 H	3.206E+1 H	-
280	Ba-131+	Cs-131	-	1	-	-	1.155E+1 D	9.690E+0 D	-
281	Ba-133m	Ba-133	-	1	-	-	3.890E+1 H	1.054E+1 Y	-
282	Ba-133+	-	-	-	-	-	1.053E+1 Y	-	-
283	Ba-135m	-	-	-	-	-	2.870E+1 H	-	-
284	Ba-139+	-	-	-	-	-	8.306E+1 M	-	-
285	Ba-140+	La-140	-	1	-	-	1.275E+1 D	4.028E+1 H	-
286	La-132+	-	-	-	-	-	4.800E+0 H	-	-
287	La-133	Ba-133m	Ba-133	0.0003	0.9997	1	3.912E+0 H	3.890E+1 H	3.85E+3 D
288	La-135	-	-	-	-	-	1.940E+1 H	-	-
289	La-137	-	-	-	-	-	6.000E+4 Y	-	-
290	La-140	-	-	-	-	-	4.028E+1 H	-	-
291	La-141+	Ce-141	-	1	-	-	3.920E+0 H	3.251E+1 D	-
292	La-142+	-	-	-	-	-	9.110E+1 M	-	-
293	Ce-132+	La-132	-	1	-	-	3.510E+0 H	4.800E+0 H	-
294	Ce-133m+	La-133	Ba-133	1	0	1	9.700E+1 M	3.912E+0 H	3.85E+3 D
295	Ce-133	La-133	Ba-133	1	0	1	4.900E+0 H	3.912E+0 H	3.85E+3 D
296	Ce-134+	La-134	-	1	-	-	7.590E+1 H	6.450E+0 M	-
297	Ce-135+	La-135	-	1	-	-	1.780E+1 H	1.940E+1 H	-
298	Ce-137m	Ce-137	La-137	0.9922	0.0078	1	3.440E+1 H	9.000E+0 H	6.00E+4 Y
299	Ce-137	La-137	-	1	-	-	9.000E+0 H	6.000E+4 Y	-
300	Ce-139+	-	-	-	-	-	1.376E+2 D	-	-
301	Ce-141	-	-	-	-	-	3.250E+1 D	-	-
302	Ce-143+	Pr-143	-	1	-	-	3.300E+1 H	1.356E+1 D	-
303	Ce-144+	Pr-144m	Pr-144	0.017	0.983	1	2.849E+2 D	7.200E+0 M	1.73E+1 M
304	Pr-137+	Ce-137	La-137	1	0	1	1.280E+0 H	9.000E+0 H	6.00E+4 Y
305	Pr-138m+	-	-	-	-	-	2.120E+0 H	-	-
306	Pr-139+	Ce-139	-	1	-	-	4.410E+0 H	1.386E+2 D	-
307	Pr-142	-	-	-	-	-	1.912E+1 H	-	-
308	Pr-143	-	-	-	-	-	1.356E+1 D	-	-
309	Pr-145+	-	-	-	-	-	5.984E+0 H	-	-
310	Nd-138+	Pr-138	-	1	-	-	5.040E+0 H	1.450E+0 M	-
311	Nd-139m	Nd-139	Pr-139	0.118	0.882	1	5.500E+0 H	2.970E+1 M	4.41E+0 H
312	Nd-140+	Pr-140	-	1	-	-	3.370E+0 D	3.390E+0 M	-
313	Nd-141+	-	-	-	-	-	2.490E+0 H	-	-
314	Nd-147+	Pm-147	-	1	-	-	1.098E+1 D	2.623E+0 Y	-
315	Nd-149+	Pm-149	-	1	-	-	1.728E+0 H	5.308E+1 H	-
316	Pm-143+	-	-	-	-	-	2.650E+2 D	-	-
317	Pm-144	-	-	-	-	-	3.630E+2 D	-	-
318	Pm-145	-	-	-	-	-	1.770E+1 Y	-	-
319	Pm-146	-	-	-	-	-	5.530E+0 Y	-	-
320	Pm-147	-	-	-	-	-	2.623E+0 Y	-	-

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
321	Pm-148m	Pm-148	-	0.046	-	-	4.129E+1 D	5.370E+0 D	-
322	Pm-148	-	-	-	-	-	5.370E+0 D	-	-
323	Pm-149	-	-	-	-	-	5.308E+1 H	-	-
324	Pm-150	-	-	-	-	-	2.680E+0 H	-	-
325	Pm-151+	Sm-151	-	1	-	-	2.840E+1 H	9.000E+1 Y	-
326	Sm-142+	Pm-142	-	1	-	-	7.249E+1 M	4.050E+1 S	-
327	Sm-145	Pm-145	-	1	-	-	3.400E+2 D	1.770E+1 Y	-
328	Sm-151	-	-	-	-	-	9.000E+1 Y	-	-
329	Sm-153+	-	-	-	-	-	4.627E+1 H	-	-
330	Sm-156+	Eu-156	-	1	-	-	9.400E+0 H	1.519E+1 D	-
331	Eu-145+	Sm-145	Pm-145	1	0	1	5.930E+0 D	3.400E+2 D	1.77E+1 Y
332	Eu-146	-	-	-	-	-	4.490E+0 D	-	-
333	Eu-147	-	-	-	-	-	2.400E+1 D	-	-
334	Eu-148	-	-	-	-	-	5.450E+1 D	-	-
335	Eu-149	-	-	-	-	-	9.310E+1 D	-	-
336	Eu-150m	-	-	-	-	-	3.580E+1 Y	-	-
337	Eu-150	-	-	-	-	-	1.260E+1 H	-	-
338	Eu-152m	-	-	-	-	-	9.274E+0 H	-	-
339	Eu-152	-	-	-	-	-	1.354E+1 Y	-	-
340	Eu-154	-	-	-	-	-	8.592E+0 Y	-	-
341	Eu-155+	-	-	-	-	-	4.680E+0 Y	-	-
342	Eu-156	-	-	-	-	-	1.519E+1 D	-	-
343	Eu-157+	-	-	-	-	-	1.518E+1 H	-	-
344	Gd-146+	Eu-146	-	1	-	-	4.827E+1 D	4.590E+0 D	-
345	Gd-147+	Eu-147	-	1	-	-	3.806E+1 H	2.400E+1 D	-
346	Gd-148+	-	-	-	-	-	7.460E+1 Y	-	-
347	Gd-149+	Eu-149	-	1	-	-	9.400E+0 D	9.310E+1 D	-
348	Gd-150+	-	-	-	-	-	1.790E+6 Y	-	-
349	Gd-151+	-	-	-	-	-	1.240E+2 D	-	-
350	Gd-153	-	-	-	-	-	2.416E+2 D	-	-
351	Gd-159+	-	-	-	-	-	1.856E+1 H	-	-
352	Tb-147+	Gd-147	Eu-147	1	0	1	1.700E+0 H	3.806E+1 H	2.41E+1 D
353	Tb-148+	Gd-148	-	1	-	-	6.000E+1 M	7.460E+1 Y	-
354	Tb-149+	Gd-149	Eu-149	0.842	0	1	4.130E+0 H	9.400E+0 D	9.31E+1 D
355	Tb-150+	Gd-150	-	1	-	-	3.480E+0 H	1.790E+6 Y	-
356	Tb-151+	Gd-151	-	1	-	-	1.761E+1 H	1.239E+2 D	-
357	Tb-152+	-	-	-	-	-	1.750E+1 H	-	-
358	Tb-153	Gd-153	-	1	-	-	2.340E+0 D	2.416E+2 D	-
359	Tb-154m	-	-	-	-	-	2.270E+1 H	-	-
360	Tb-154	-	-	-	-	-	2.150E+1 H	-	-
361	Tb-155	-	-	-	-	-	5.320E+0 D	-	-
362	Tb-156m	Tb-156	-	1	-	-	2.440E+1 H	5.350E+0 D	-
363	Tb-156	-	-	-	-	-	5.350E+0 D	-	-
364	Tb-157	-	-	-	-	-	7.100E+1 Y	-	-
365	Tb-158	-	-	-	-	-	1.800E+2 Y	-	-
366	Tb-160	-	-	-	-	-	7.230E+1 D	-	-

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
367	Tb-161+	-	-	-	-	-	6.880E+0 D	-	-
368	Dy-152+	Tb-152	-	1	-	-	2.380E+0 H	1.750E+1 H	-
369	Dy-153+	Tb-153	Gd-153	1	0	1	6.400E+0 H	2.340E+0 D	2.42E+2 D
370	Dy-154+	Gd-150	-	1	-	-	3.000E+6 Y	1.800E+6 Y	-
371	Dy-155+	Tb-155	-	1	-	-	1.000E+1 H	5.320E+0 D	-
372	Dy-157+	Tb-157	-	1	-	-	8.100E+0 H	7.100E+1 Y	-
373	Dy-159+	-	-	-	-	-	1.444E+2 D	-	-
374	Dy-165+	-	-	-	-	-	2.334E+0 H	-	-
375	Dy-166	Ho-166	-	1	-	-	8.150E+1 H	2.680E+1 H	-
376	Ho-160m	Ho-160	-	0.65	-	-	5.020E+0 H	2.560E+1 M	-
377	Ho-161	-	-	-	-	-	2.480E+0 H	-	-
378	Ho-162m	Ho-162	-	0.62	-	-	6.700E+1 M	1.500E+1 M	-
379	Ho-163	-	-	-	-	-	4.570E+3 Y	-	-
380	Ho-166m	-	-	-	-	-	1.200E+3 Y	-	-
381	Ho-166	-	-	-	-	-	2.683E+1 H	-	-
382	Ho-167+	Er-167m	-	0.62	-	-	3.100E+0 H	2.269E+0 S	-
383	Er-158+	Ho-158m	Ho-158	1	0	0.81	2.290E+0 H	2.800E+1 M	1.03E+1 M
384	Er-160+	Ho-160m	Ho-160	1	0	0.65	2.858E+1 H	5.020E+0 H	2.56E+1 M
385	Er-161+	Ho-161m	Ho-161	0.28	0.72	1	3.210E+0 H	6.760E+0 S	2.48E+0 H
386	Er-163	Ho-163m	Ho-163	0.00016	0.99984	1	7.500E+1 M	1.090E+0 S	4.57E+3 Y
387	Er-165	-	-	-	-	-	1.040E+1 H	-	-
388	Er-169+	-	-	-	-	-	9.400E+0 D	-	-
389	Er-171+	Tm-171	-	1	-	-	7.520E+0 H	1.920E+0 Y	-
390	Er-172	Tm-172	-	1	-	-	4.930E+1 H	6.360E+1 H	-
391	Tm-163+	Er-163	Ho-163	1	0	1	1.810E+0 H	7.500E+1 M	4.57E+3 Y
392	Tm-165+	Er-165	-	1	-	-	3.022E+1 H	1.040E+1 H	-
393	Tm-166	-	-	-	-	-	7.700E+0 H	-	-
394	Tm-167+	Er-167m	-	0.984	-	-	9.250E+0 D	2.269E+0 S	-
395	Tm-168	-	-	-	-	-	9.310E+1 D	-	-
396	Tm-170	-	-	-	-	-	1.286E+2 D	-	-
397	Tm-171	-	-	-	-	-	1.920E+0 Y	-	-
398	Tm-172	-	-	-	-	-	6.360E+1 H	-	-
399	Tm-173+	-	-	-	-	-	8.240E+0 H	-	-
400	Yb-164+	Tm-164	-	1	-	-	7.880E+1 M	2.000E+0 M	-
401	Yb-166+	Tm-166	-	1	-	-	5.670E+1 H	7.700E+0 H	-
402	Yb-169	-	-	-	-	-	3.203E+1 D	-	-
403	Yb-175+	-	-	-	-	-	4.190E+0 D	-	-
404	Yb-177+	Lu-177	-	1	-	-	1.911E+0 H	6.647E+0 D	-
405	Yb-178	Lu-178	-	1	-	-	7.400E+1 M	2.840E+1 M	-
406	Lu-169+	Yb-169m	Yb-169	0.51	0.49	1	3.406E+1 H	4.600E+1 S	3.20E+1 D
407	Lu-170	-	-	-	-	-	2.020E+0 D	-	-
408	Lu-171	-	-	-	-	-	8.240E+0 D	-	-
409	Lu-172	-	-	-	-	-	6.740E+0 D	-	-
410	Lu-173	-	-	-	-	-	1.370E+0 Y	-	-
411	Lu-174m	Lu-174	-	0.9935	-	-	1.420E+2 D	3.310E+0 Y	-
412	Lu-174	-	-	-	-	-	3.310E+0 Y	-	-

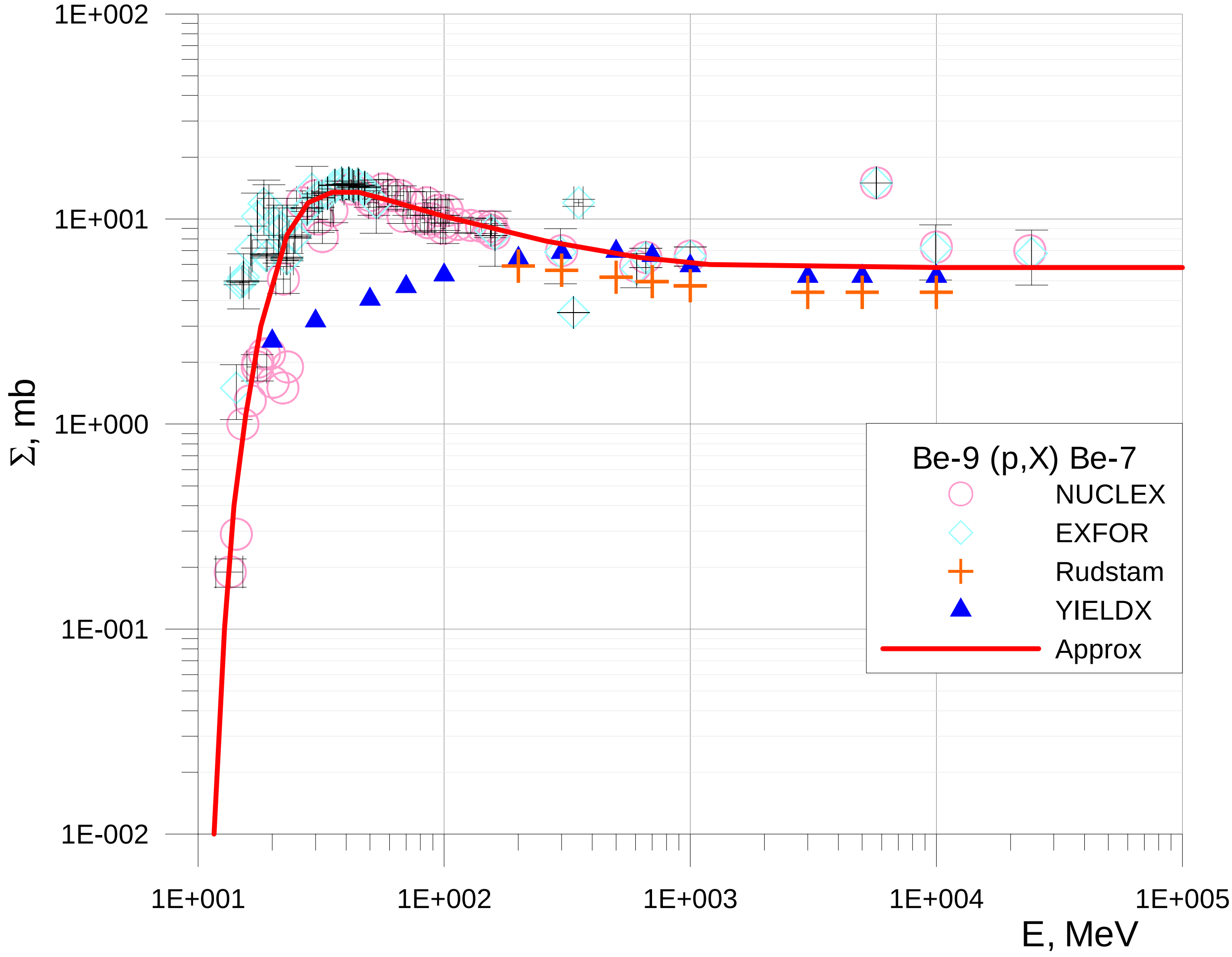
##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
413	Lu-176m	-	-	-	-	-	3.664E+0 H	-	-
414	Lu-177m	Lu-177	-	0.0224	-	-	1.604E+2 D	6.645E+0 D	-
415	Lu-177	-	-	-	-	-	6.645E+0 D	-	-
416	Lu-179+	-	-	-	-	-	4.590E+0 H	-	-
417	Hf-170+	Lu-170m	Lu-170	0.054	0.946	1	1.600E+1 H	6.700E-1 S	2.02E+0 D
418	Hf-171+	Lu-171m	Lu-171	0.0092	0.9908	1	1.210E+1 H	7.900E+1 S	8.24E+0 D
419	Hf-172+	Lu-172m	Lu-172	1	0	1	1.870E+0 Y	3.700E+0 M	6.70E+0 D
420	Hf-173	Lu-173	-	1	-	-	2.360E+1 H	1.370E+0 Y	-
421	Hf-175	-	-	-	-	-	7.000E+1 D	-	-
422	Hf-178m	Hf-178m	-	1	-	-	3.100E+1 Y	4.000E+0 S	-
423	Hf-179m	-	-	-	-	-	2.505E+1 D	-	-
424	Hf-180m	Ta-180	-	0.014	-	-	5.500E+0 H	8.152E+0 H	-
425	Hf-181+	-	-	-	-	-	4.239E+1 D	-	-
426	Hf-182m+	Ta-182m	Ta-182m	0.014	0.466	1	6.150E+1 M	1.580E+1 M	2.80E-1 S
427	Hf-183+	Ta-183	W-183m	1	0	0.053	1.067E+0 H	5.100E+0 D	5.17E+0 S
428	Hf-184+	Ta-184	-	1	-	-	4.120E+0 H	8.700E+0 H	-
429	Ta-173+	Hf-173	Lu-173	1	0	1	3.140E+0 H	2.360E+1 H	1.37E+0 Y
430	Ta-174+	-	-	-	-	-	1.140E+0 H	-	-
431	Ta-175+	Hf-175	-	1	-	-	1.050E+1 H	7.000E+1 D	-
432	Ta-176	-	-	-	-	-	8.090E+0 H	-	-
433	Ta-177	-	-	-	-	-	5.656E+1 H	-	-
434	Ta-178m	Hf-178m	-	1	-	-	2.360E+0 H	4.000E+0 S	-
435	Ta-179+	-	-	-	-	-	6.650E+2 D	-	-
436	Ta-180	-	-	-	-	-	8.152E+0 H	-	-
437	Ta-182+	-	-	-	-	-	1.150E+2 D	-	-
438	Ta-183	W-183m	-	0.053	-	-	5.100E+0 D	5.170E+0 S	-
439	Ta-184	-	-	-	-	-	8.700E+0 H	-	-
440	W-176+	Ta-176	-	1	-	-	2.500E+0 H	8.090E+0 H	-
441	W-177+	Ta-177	-	1	-	-	1.320E+2 M	5.656E+1 H	-
442	W-178+	Ta-178	-	1	-	-	2.160E+1 D	9.300E+0 M	-
443	W-181	-	-	-	-	-	1.212E+2 D	-	-
444	W-185+	-	-	-	-	-	7.510E+1 D	-	-
445	W-187	-	-	-	-	-	2.372E+1 H	-	-
446	W-188	Re-188	-	1	-	-	6.940E+1 D	1.698E+1 H	-
447	Re-181+	W-181	-	1	-	-	1.990E+1 H	1.212E+2 D	-
448	Re-182m	-	-	-	-	-	6.400E+1 H	-	-
449	Re-182	-	-	-	-	-	1.270E+1 H	-	-
450	Re-183	-	-	-	-	-	7.000E+1 D	-	-
451	Re-184m	Re-184	-	0.754	-	-	1.650E+2 D	3.800E+1 D	-
452	Re-184	-	-	-	-	-	3.800E+1 D	-	-
453	Re-186m	Re-186	-	0.9	-	-	2.000E+5 Y	9.064E+1 H	-
454	Re-186	-	-	-	-	-	3.718E+0 D	-	-
455	Re-188	-	-	-	-	-	1.698E+1 H	-	-
456	Re-189+	Os-189m	-	0.109	-	-	2.430E+1 H	5.800E+0 H	-
457	Re-190m+	Re-190	-	0.456	-	-	3.200E+0 H	3.100E+0 M	-
458	Os-181m+	Re-181	W-181	1	0	1	1.050E+2 M	1.990E+1 H	1.21E+2 D

##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
459	Os-182+	Re-182	-	1	-	-	2.210E+1 H	1.270E+1 H	-
460	Os-183m+	Os-183	Re-183	0.15	0.85	1	9.900E+0 H	1.300E+1 H	7.00E+1 D
461	Os-183+	Re-183	-	1	-	-	1.300E+1 H	7.000E+1 D	-
462	Os-185	-	-	-	-	-	9.630E+1 D	-	-
463	Os-189m	-	-	-	-	-	5.800E+0 H	-	-
464	Os-191m	Os-191	Ir-191m	1	0	1	1.310E+1 H	1.540E+1 D	4.94E+0 S
465	Os-191+	Ir-191m	-	1	-	-	1.540E+1 D	4.940E+0 S	-
466	Os-193	Ir-193m	-	0.0035	-	-	3.011E+1 H	1.053E+1 D	-
467	Os-194	Ir-194	-	1	-	-	6.000E+0 Y	1.915E+1 H	-
468	Ir-184+	-	-	-	-	-	3.090E+0 H	-	-
469	Ir-185+	Os-185	-	1	-	-	1.440E+1 H	9.360E+1 D	-
470	Ir-186m	Ir-186	-	0.15	-	-	1.900E+0 H	1.664E+1 H	-
471	Ir-186	-	-	-	-	-	1.664E+1 H	-	-
472	Ir-187	-	-	-	-	-	1.050E+1 H	-	-
473	Ir-188	-	-	-	-	-	4.150E+1 H	-	-
474	Ir-189	Os-189m	-	0.088	-	-	1.320E+1 D	5.800E+0 H	-
475	Ir-190m	Os-190m	-	0.944	-	-	3.087E+0 H	9.900E+0 M	-
476	Ir-190	-	-	-	-	-	1.178E+1 D	-	-
477	Ir-192m	Ir-192	-	1	-	-	2.410E+2 Y	7.383E+1 D	-
478	Ir-192	-	-	-	-	-	7.383E+1 D	-	-
479	Ir-193m	-	-	-	-	-	1.053E+1 D	-	-
480	Ir-194m	-	-	-	-	-	1.710E+2 D	-	-
481	Ir-194	-	-	-	-	-	1.928E+1 H	-	-
482	Ir-195m	Pt-195m	-	0.443	-	-	3.800E+0 H	4.020E+0 D	-
483	Ir-195+	-	-	-	-	-	2.500E+0 H	-	-
484	Ir-196m+	-	-	-	-	-	1.400E+0 H	-	-
485	Pt-185+	Ir-185	Os-185	1	0	1	7.090E+1 M	1.440E+1 H	9.36E+1 D
486	Pt-186+	Ir-186	-	1	-	-	2.080E+0 H	1.664E+1 H	-
487	Pt-187+	Ir-187	-	1	-	-	2.350E+0 H	1.050E+1 H	-
488	Pt-188+	Ir-188	-	1	-	-	1.020E+1 D	4.150E+1 H	-
489	Pt-189+	Ir-189	Os-189m	1	0	0.088	1.089E+1 H	1.320E+1 D	5.80E+0 H
490	Pt-191	Ir-191m	-	1	-	-	2.802E+0 D	4.940E+0 S	-
491	Pt-193m	Pt-193	-	1	-	-	4.330E+0 D	5.000E+1 Y	-
492	Pt-193+	-	-	-	-	-	5.000E+1 Y	-	-
493	Pt-195m	-	-	-	-	-	4.020E+0 D	-	-
494	Pt-197m+	Pt-197	Au-197m	0.967	0.033	0	9.541E+1 M	1.989E+1 H	7.73E+0 S
495	Pt-197+	-	-	-	-	-	1.989E+1 H	-	-
496	Pt-200	Au-200	-	0.033	-	-	1.250E+1 H	4.840E+1 M	-
497	Pt-202	Au-202	-	0.033	-	-	4.400E+1 H	2.880E+1 S	-
498	Au-191+	Pt-191	-	1	-	-	3.180E+0 H	2.802E+0 D	-
499	Au-192	-	-	-	-	-	4.940E+0 H	-	-
500	Au-193	Pt-193	-	1	-	-	1.765E+1 H	5.000E+1 Y	-
501	Au-194	-	-	-	-	-	3.802E+1 H	-	-
502	Au-195+	-	-	-	-	-	1.861E+2 D	-	-
503	Au-196m_2	Au-196m_1	Au-196	1	0	1	9.700E+0 H	8.200E+0 S	6.18E+0 D
504	Au-196	-	-	-	-	-	6.183E+0 D	-	-

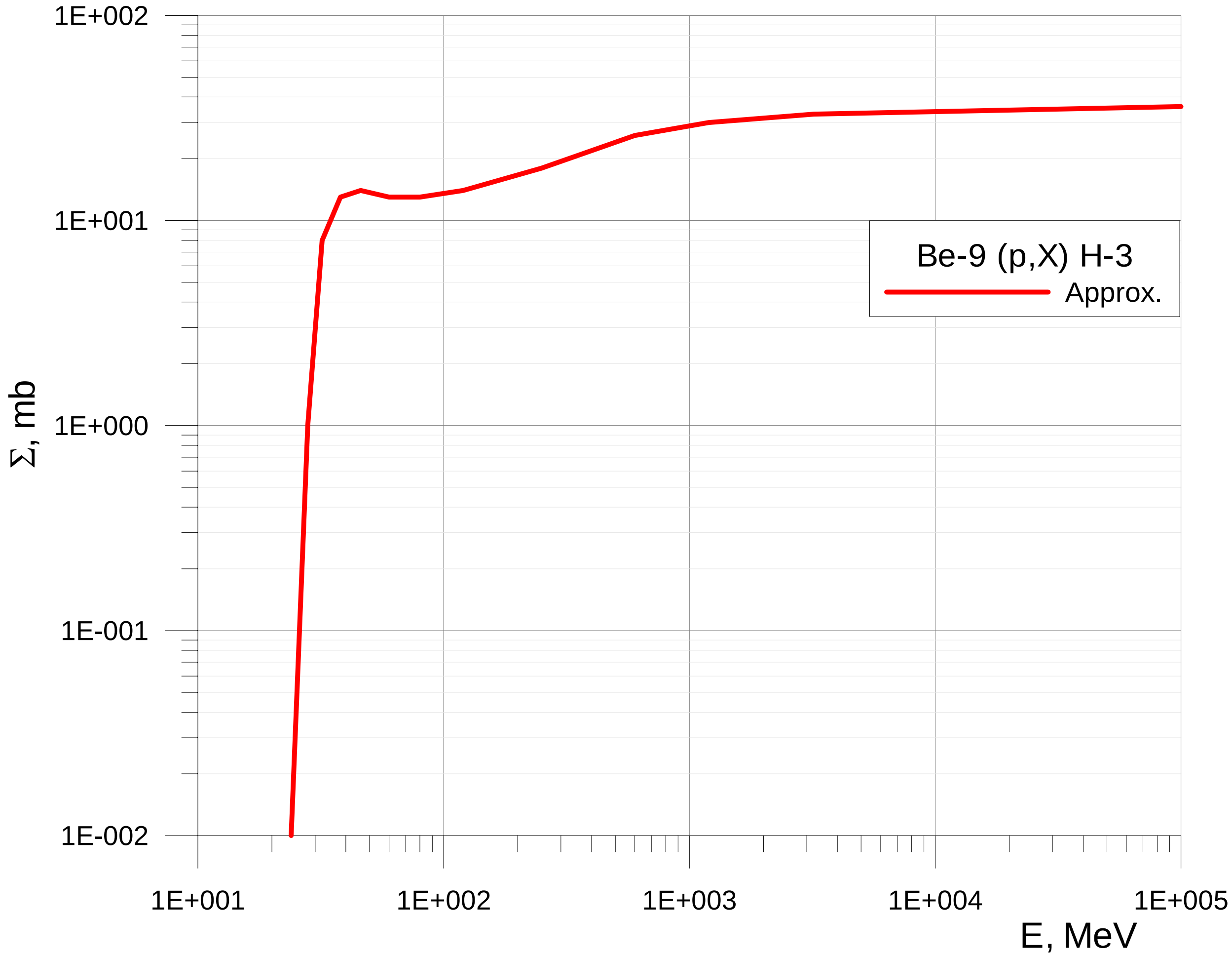
##	Nuclide			Branching ratio			Half-life		
	X_1	X_2	X_3	p_1	p_2	p_3	τ_1	τ_2	τ_3
505	Au-198m	Au-198	-	1	-	-	2.270E+0 D	2.695E+0 D	-
506	Au-198	-	-	-	-	-	2.695E+0 D	-	-
507	Au-199+	-	-	-	-	-	3.139E+0 D	-	-
508	Au-200m	Au-200	-	0.18	-	-	1.870E+1 H	4.840E+1 M	-
509	Hg-192+	Au-192	-	1	-	-	4.850E+0 H	4.940E+0 H	-
510	Hg-193m	Hg-193	Au-193	0.078	0.922	1	1.180E+1 H	3.800E+0 H	1.77E+1 H
511	Hg-193+	Au-193		1			3.800E+0 H	1.765E+1 H	
512	Hg-194+	Au-194	-	1	-	-	4.440E+2 Y	3.802E+1 H	-
513	Hg-195m	Hg-195	Au-195m	0.542	0.4569	0	4.160E+1 H	9.900E+0 H	3.05E+1 S
514	Hg-195	-	-	-	-	-	9.900E+0 H	-	-
515	Hg-197m	Hg-197	Au-197m	0.93	0.07	0	2.380E+1 H	6.414E+1 H	7.73E+0 S
516	Hg-197	-	-	-	-	-	6.414E+1 H	-	-
517	Hg-203+	-	-	-	-	-	4.661E+1 D	-	-
518	Tl-195+	Hg-195		1			1.130E+0 H	9.900E+0 H	
519	Tl-196m	Tl-196	-	0.045	-	-	1.410E+0 H	1.840E+0 H	-
520	Tl-196+	-	-	-	-	-	1.840E+0 H	-	-
521	Tl-197+	Hg-197	-	1	-	-	2.840E+0 H	6.414E+1 H	-
522	Tl-198m	Tl-198	-	0.46	-	-	1.870E+0 H	5.300E+0 H	-
523	Tl-198	-	-	-	-	-	5.300E+0 H	-	-
524	Tl-199+	-	-	-	-	-	7.420E+0 H	-	-
525	Tl-200	-	-	-	-	-	2.610E+1 H	-	-
526	Tl-201	-	-	-	-	-	7.298E+1 H	-	-
527	Tl-202	-	-	-	-	-	1.223E+1 D	-	-
528	Tl-204	-	-	-	-	-	3.780E+0 Y	-	-
529	Pb-198+	Tl-198	-	1	-	-	2.400E+0 H	5.300E+0 H	-
530	Pb-199+	Tl-199	-	1	-	-	1.500E+0 H	7.420E+0 H	-
531	Pb-200+	Tl-200	-	1	-	-	2.150E+1 H	2.610E+1 H	-
532	Pb-201+	Tl-201	-	1	-	-	9.330E+0 H	7.298E+1 H	-
533	Pb-202m	Pb-202	Tl-202	0.905	0.095	1	3.530E+0 H	5.250E+4 Y	1.22E+1 D
534	Pb-202	Tl-202	-	1	-	-	5.250E+4 Y	1.223E+1 D	-
535	Pb-203	-	-	-	-	-	5.187E+1 H	-	-
536	Pb-204m	-	-	-	-	-	6.720E+1 M	-	-
537	Bi-201+	Pb-201m	-	0.77	-	-	1.800E+0 H	6.100E+1 S	-
538	Bi-202+	Pb-202	Tl-202	1	0	1	1.720E+0 H	5.250E+4 Y	1.22E+1 D
539	Bi-203+	Pb-203m	Pb-203	0.23	0.77	1	1.173E+1 H	6.300E+0 S	5.19E+1 H
540	Bi-204	Pb-204m	-	0.153	-	-	1.122E+1 H	6.720E+1 M	-
541	Bi-205	Pb-205	Pb-205m	0.096	0.904	1	1.531E+1 D	5.540E-3 S	1.52E+7 Y
542	Bi-206	-	-	-	-	-	6.243E+0 D	-	-
543	Bi-207	-	-	-	-	-	3.290E+1 Y	-	-
544	Bi-208	-	-	-	-	-	3.680E+5 Y	-	-

Summary of experimental and calculated cross-section data used for beryllium

Nuclide	Half-life			Decay Mode	Source		Comment
					NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-			
Be-7	53.22	D	0.06	EC	x	x	



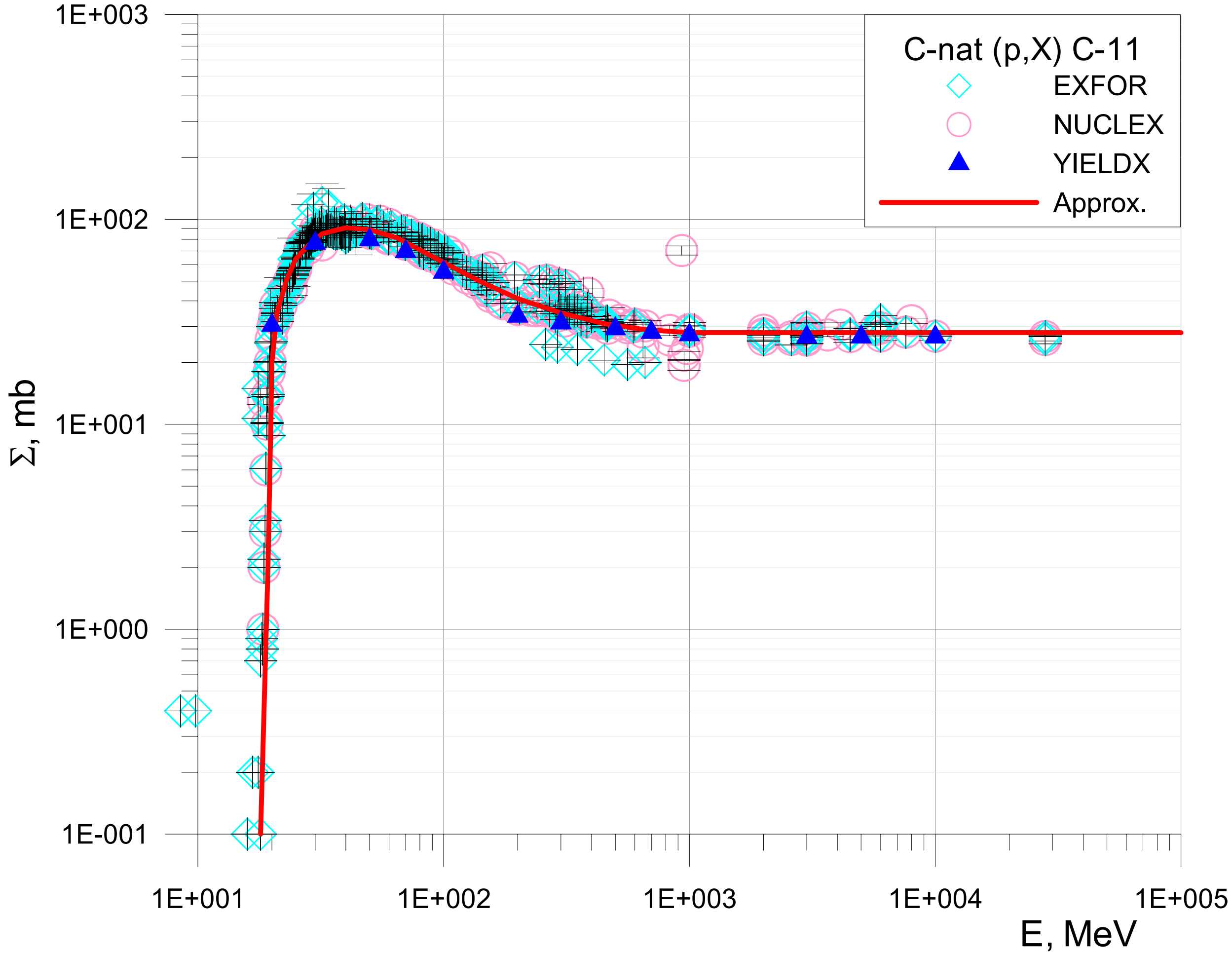
##	E, MeV	Σ, mb
1	11.6	0.01
2	12.8	0.10
3	14.0	0.40
4	15.6	1.10
5	18	3.00
6	23	8.40
7	28	12.0
8	35	13.5
9	45	13.5
10	60	12.3
11	100	10.3
12	260	7.8
13	620	6.5
14	1200	6.0
15	10000	5.8
16	100000	5.8
17		
18		



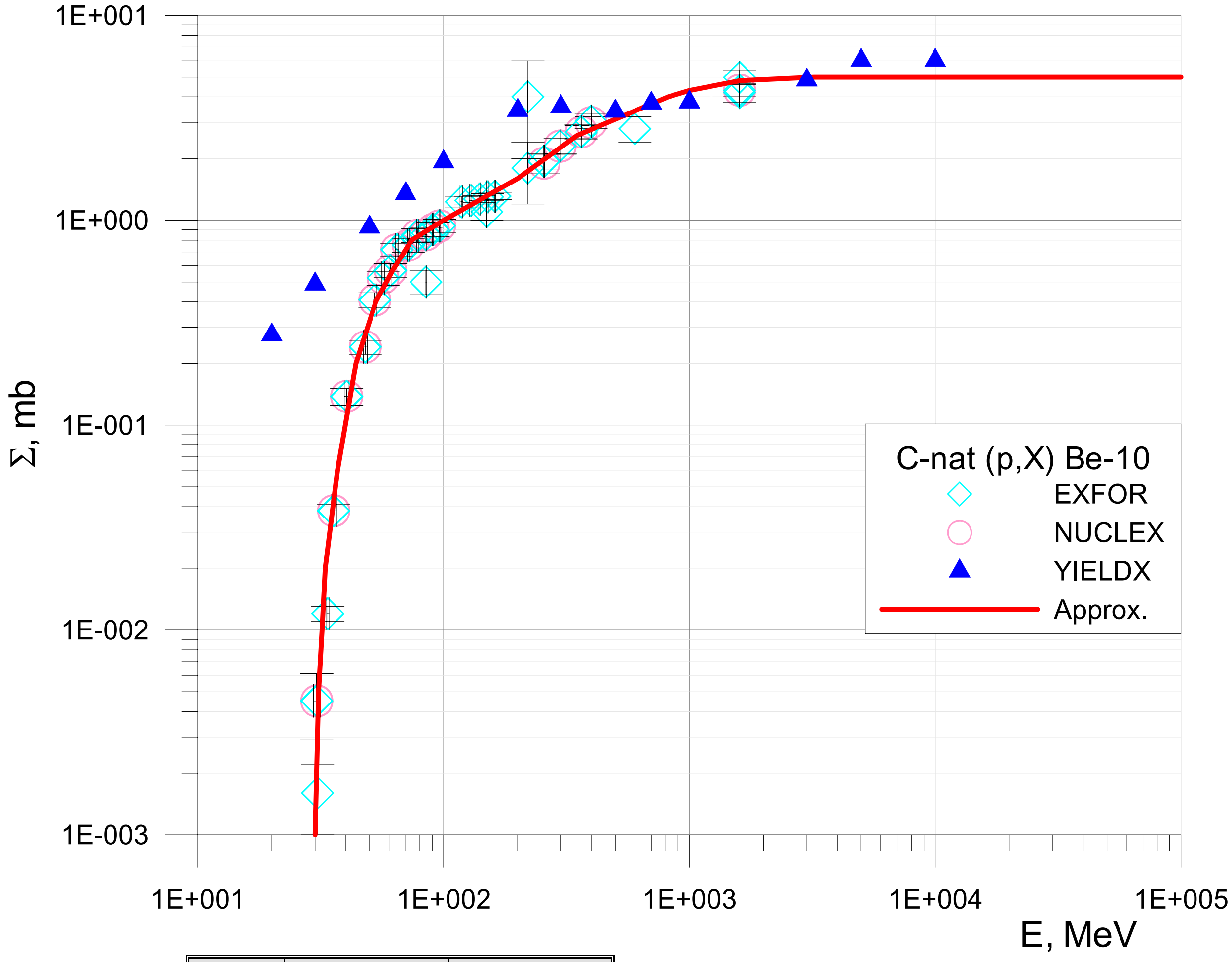
##	E, MeV	Σ, mb
1	11.2	0.00
2	24	0.01
3	28	1.0
4	32	8.0
5	38	13
6	46	14
7	60	13
8	80	13
9	120	14
10	250	18
11	600	26
12	1200	30
13	3200	33
14	10000	34
15	100000	36
16		
17		
18		
19		

Summary of experimental and calculated cross-section data used for carbon

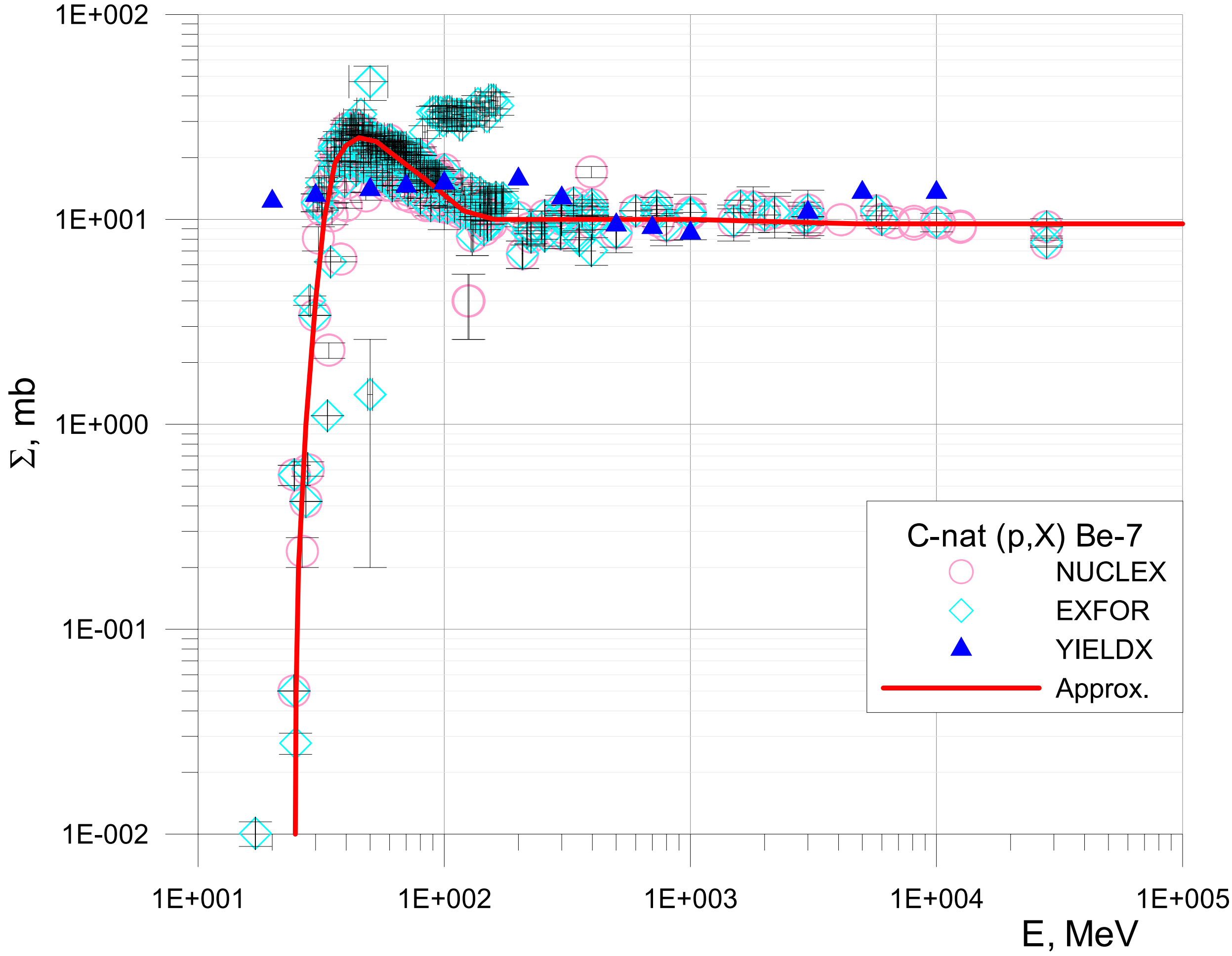
Nuclide	Half-life			Decay Mode	Source		Comment
					NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-	x	x	
Be-7	53.22	D	0.06	EC	x	x	
Be-10	2E+06	Y	60000	B-	x	x	
C-11	20.39	M	0.02	B-	x	x	



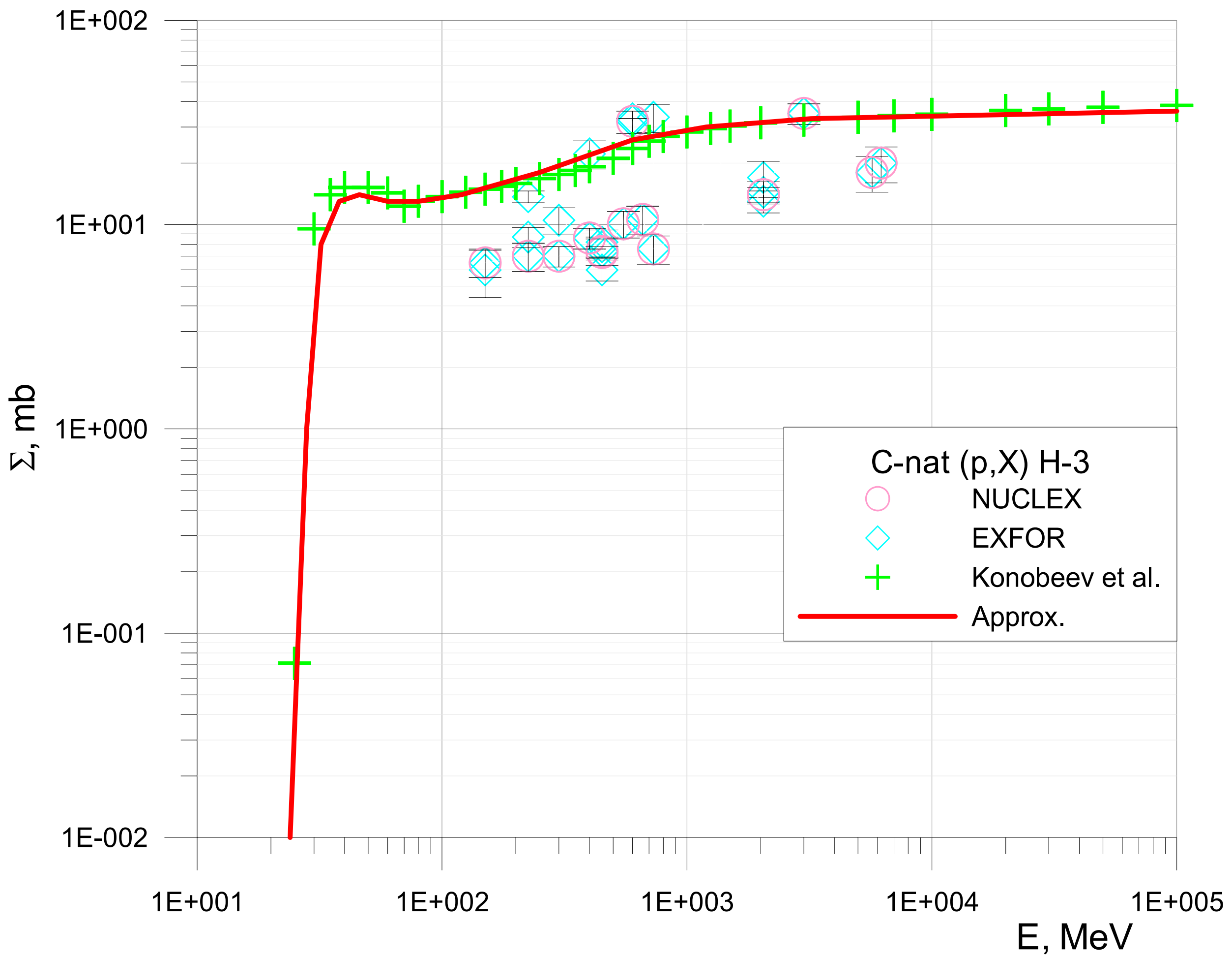
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	16.4	0.0	19	450	31
2	18.0	0.1	20	660	29
3	18.6	0.4	21	1000	28
4	19.3	2.0	22	10000	28
5	19.8	10	23	100000	28
6	20	20			
7	21	35			
8	23	51			
9	25	64			
10	28	74			
11	32	85			
12	40	91			
13	50	89			
14	65	81			
15	90	66			
16	140	50			
17	200	41			
18	300	35			



##	E, MeV	Σ, mb
1	26.3	0.000
2	30	0.001
3	31	0.005
4	32	0.01
5	33	0.02
6	37	0.06
7	44	0.20
8	53	0.40
9	62	0.57
10	74	0.80
11	100	1.0
12	200	1.6
13	350	2.6
14	560	3.3
15	820	4.0
16	1000	4.3
17	1600	4.8
18	3200	5.0
19	100000	5.0



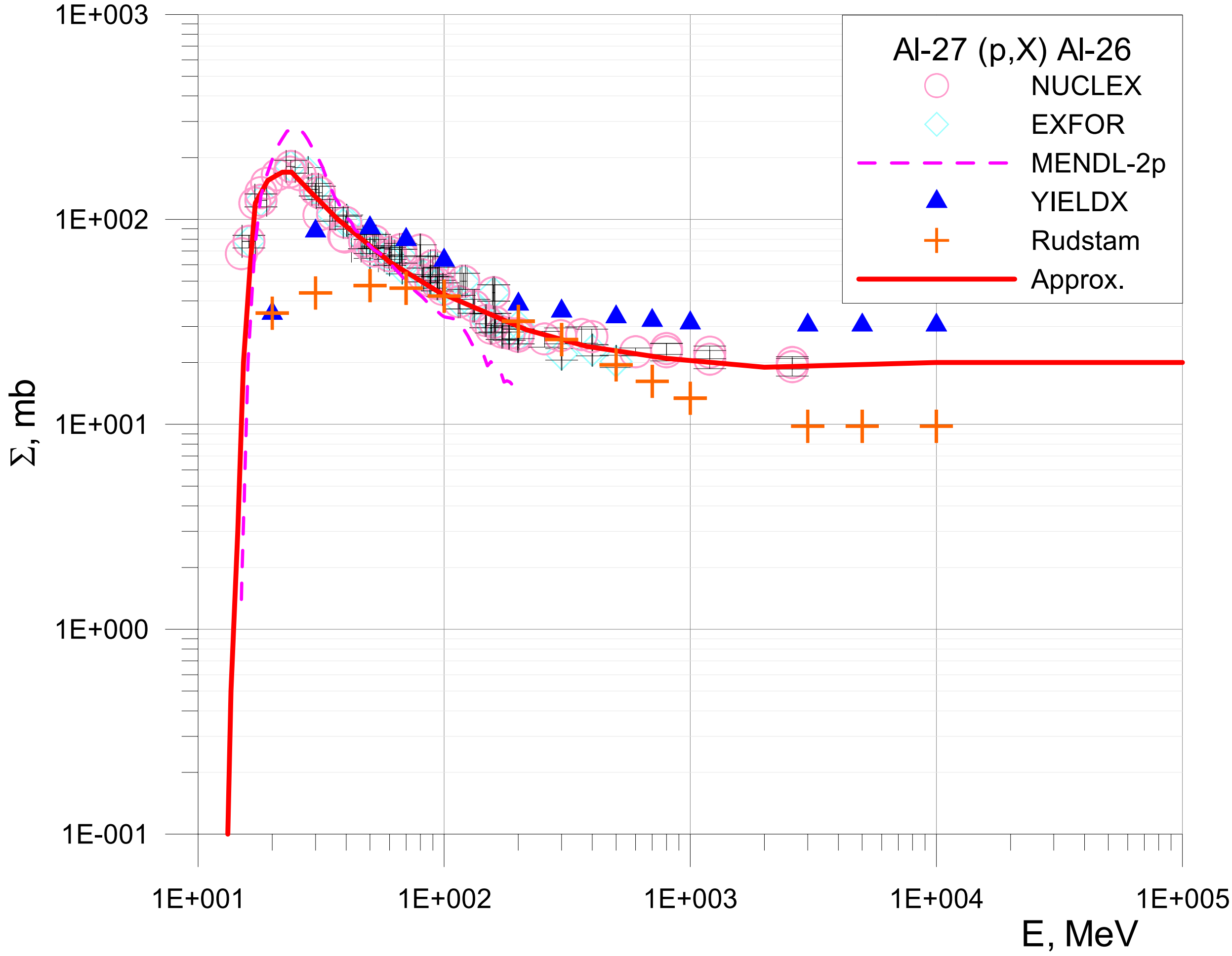
##	E, MeV	Σ, mb
1	24.5	0.00
2	24.8	0.01
3	25.0	0.05
4	25.6	0.20
5	27.4	1.0
6	30.0	4.0
7	32.5	10
8	36	19
9	40	23
10	45	25
11	53	24
12	61	21
13	82	16
14	120	11
15	160	10.
16	1000	10.
17	4800	9.5
18	100000	9.5



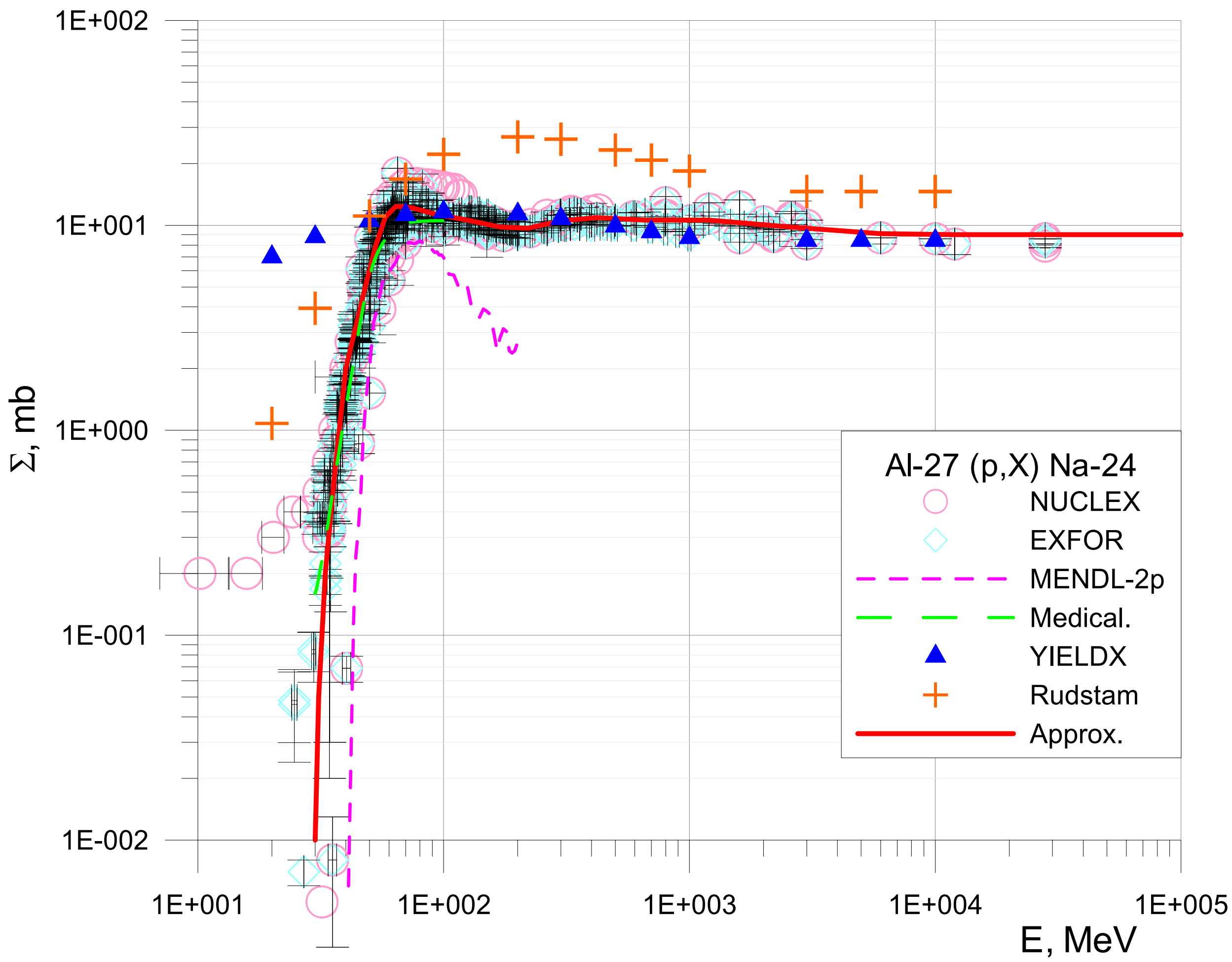
##	E, MeV	Σ, mb
1	16.4	0.00
2	24	0.01
3	28	1.0
4	32	8.0
5	38	13
6	46	14
7	60	13
8	80	13
9	120	14
10	250	18
11	600	26
12	1200	30
13	3200	33
14	10000	34
15	100000	36
16		
17		
18		
19		

Summary of experimental and calculated cross-section data used for aluminum

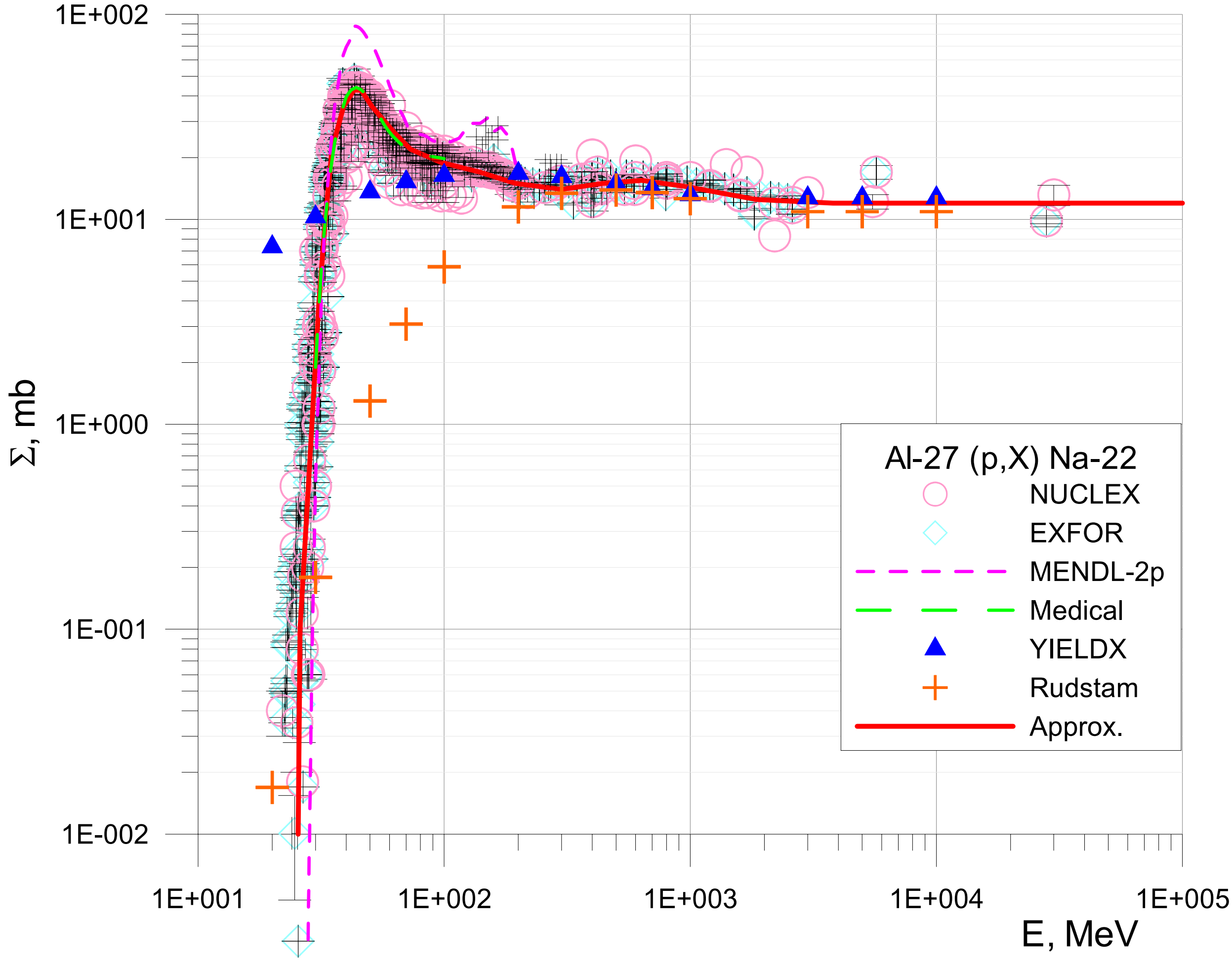
Nuclide	Half-life			Decay Mode	Source				Comment
					Medical	Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-			x	x	
Be-7	53.22	D	0.06	EC			x	x	
Be-10	2E+06	Y	60000	B-			x	x	
C-14	5700	Y	30	B-		x		x	cum
F-18	109.77	M	0.05	EC		x	x	x	cum
Na-22	2.6019	Y	4E-04	EC	x	x	x	x	cum
Na-24	14.959	H	0.001	B-	x	x	x	x	cum
Al-26	717000	Y	24000	EC		x	x	x	



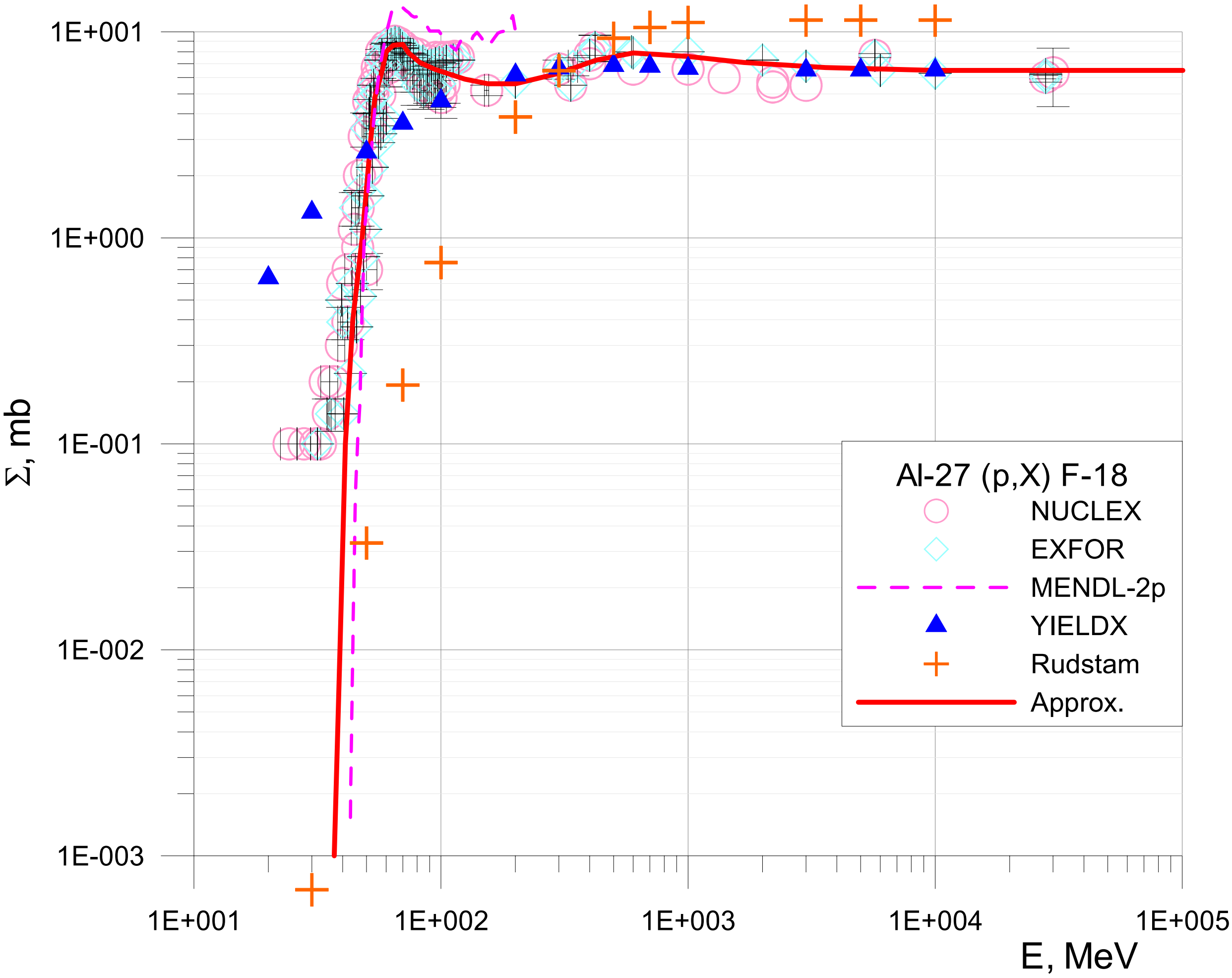
##	E, MeV	Σ, mb
1	11.2	0.00
2	13.2	0.10
3	13.6	0.50
4	14.5	3.00
5	15.3	20.0
6	16.3	60.0
7	17.1	120
8	19.2	155
9	22	170
10	24	170
11	28	140
12	37	100
13	60	62
14	96	44
15	215	29
16	380	24
17	800	21
18	2000	20
19	100000	20



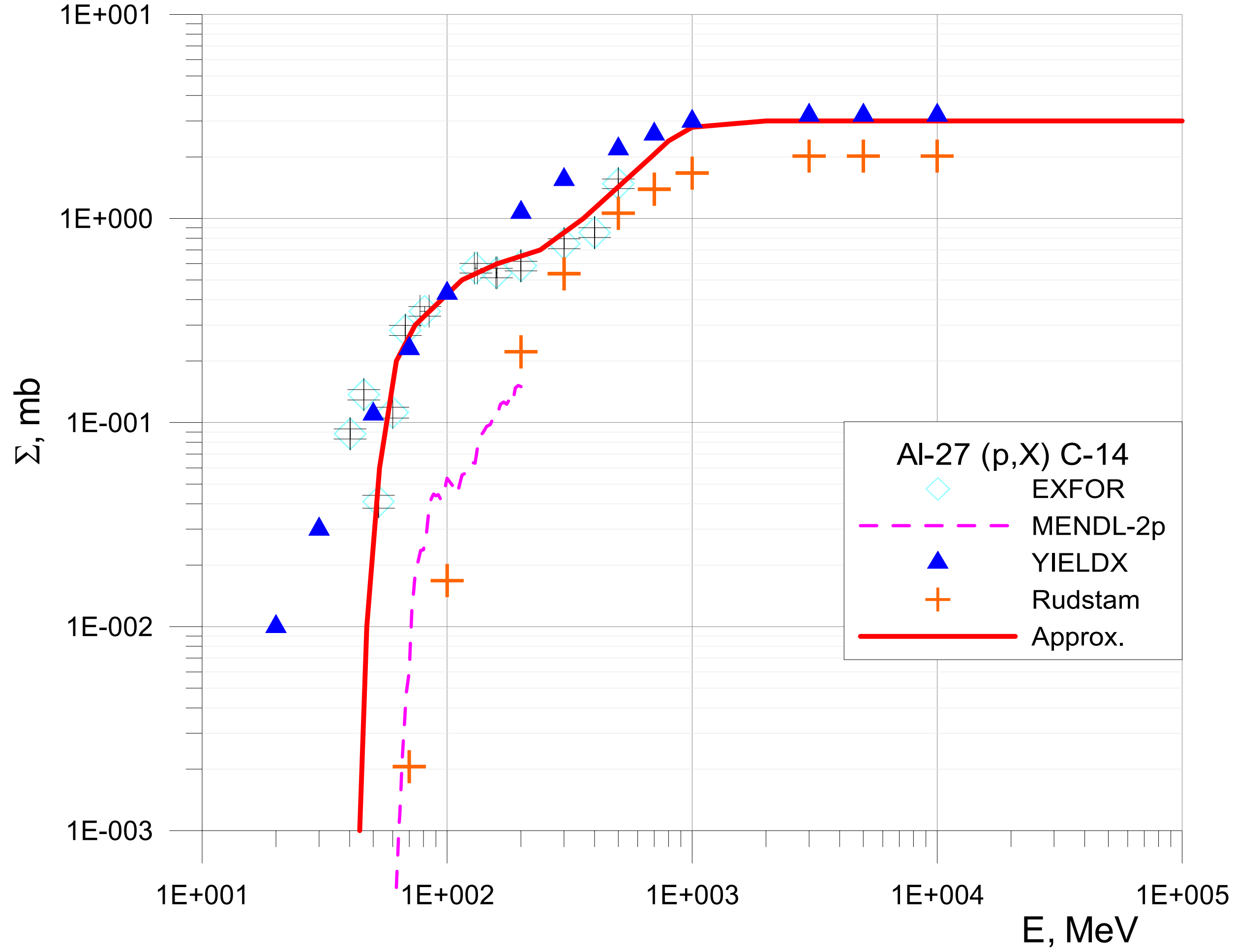
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	24.6	0.00	19	1200	10.6
2	30	0.01	20	2600	9.8
3	31	0.04	21	6000	9.1
4	33	0.20	22	12000	9.0
5	36	0.60	23	100000	9.0
6	40	2.00	24		
7	48	5.00	25		
8	53	8.00	26		
9	58	11.0			
10	64	12.4			
11	74	12.2			
12	93	11.3			
13	125	10.6			
14	170	9.80			
15	220	9.70			
16	300	10.5			
17	420	10.9			
18	660	10.6			



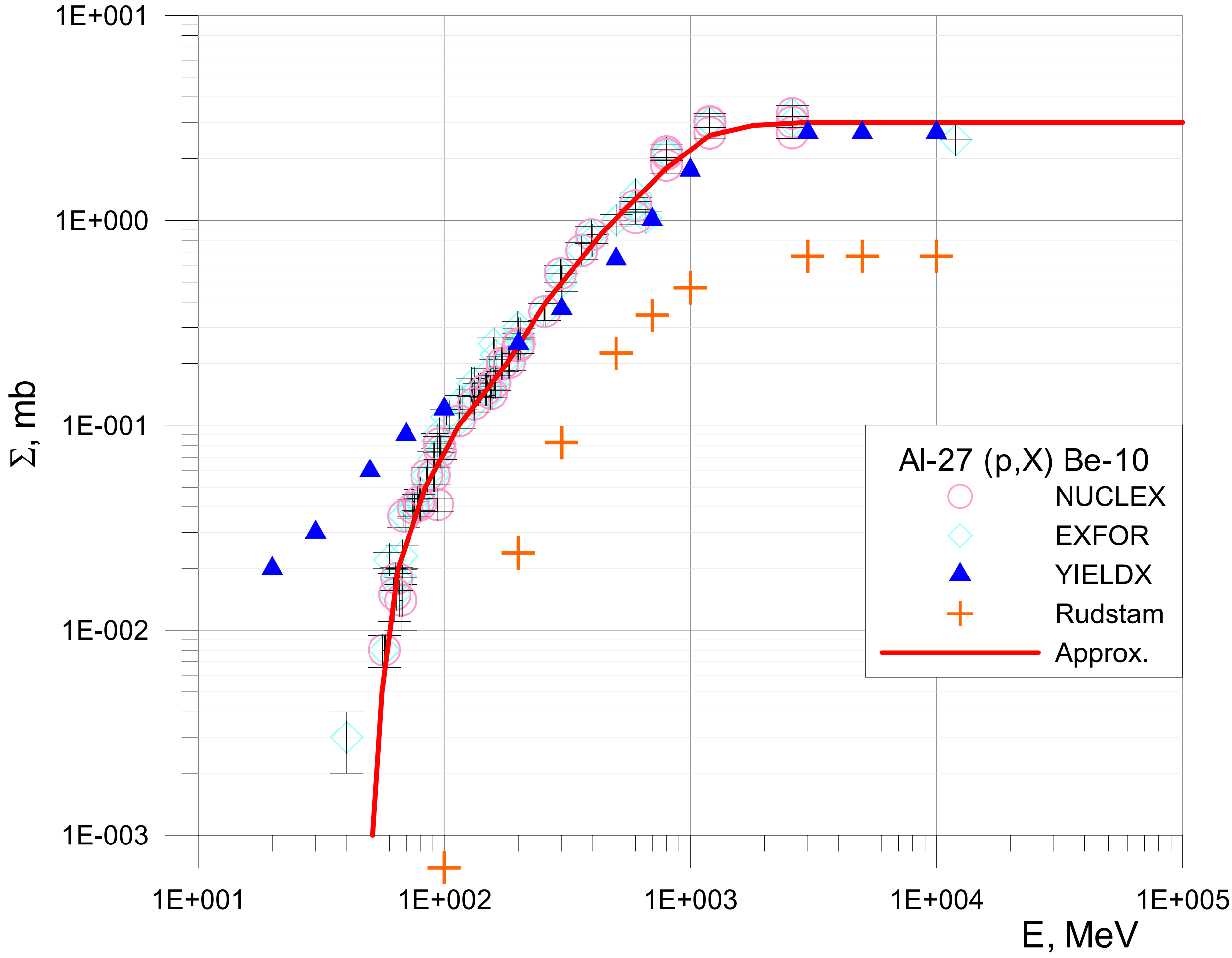
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	21.0	0.00	19	635	15.5
2	25.5	0.01	20	945	14.5
3	26	0.10	21	1860	12.5
4	29	1.00	22	3800	12.0
5	31	4.00	23	10000	12.0
6	33	10.5	24	100000	12.0
7	35	22.0	25		
8	39	35.5	26		
9	43	42.8			
10	46	42.7			
11	51	35.4			
12	63	26.4			
13	73	22.0			
14	97	19.0			
15	140	17.0			
16	195	15.0			
17	300	14.0			
18	440	15.0			



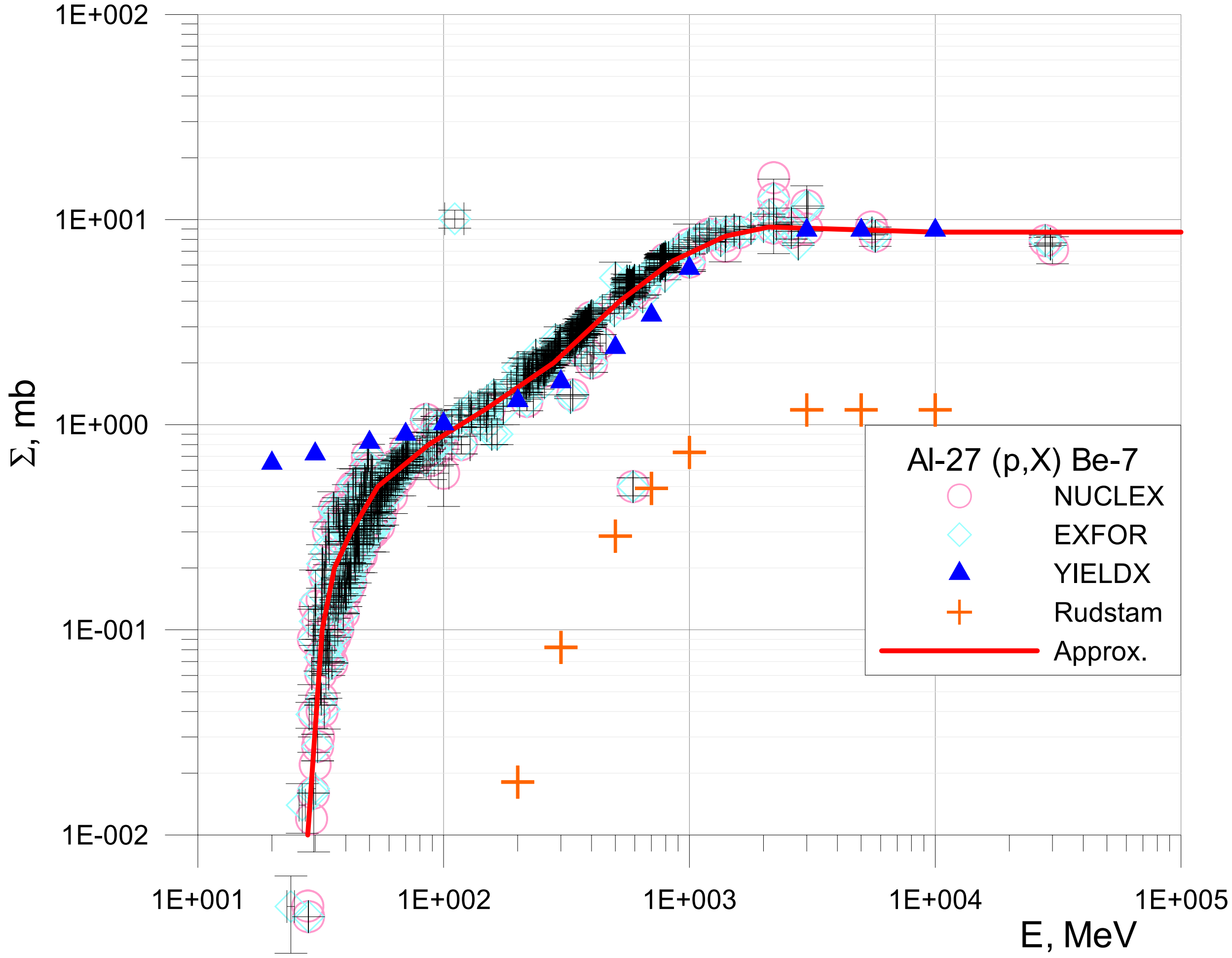
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	29.8	0.000	19	300	6.3
2	37.0	0.001	20	425	7.3
3	39.0	0.010	21	600	7.9
4	41	0.10	22	1000	7.6
5	44	0.40	23	1680	7.1
6	48	1.0	24	3600	6.7
7	52	3.0	25	10000	6.5
8	54	4.8	26	100000	6.5
9	58	6.6			
10	60	8.0			
11	64	8.6			
12	70	8.7			
13	74	7.9			
14	82	7.1			
15	94	6.6			
16	125	5.9			
17	155	5.6			
18	200	5.6			



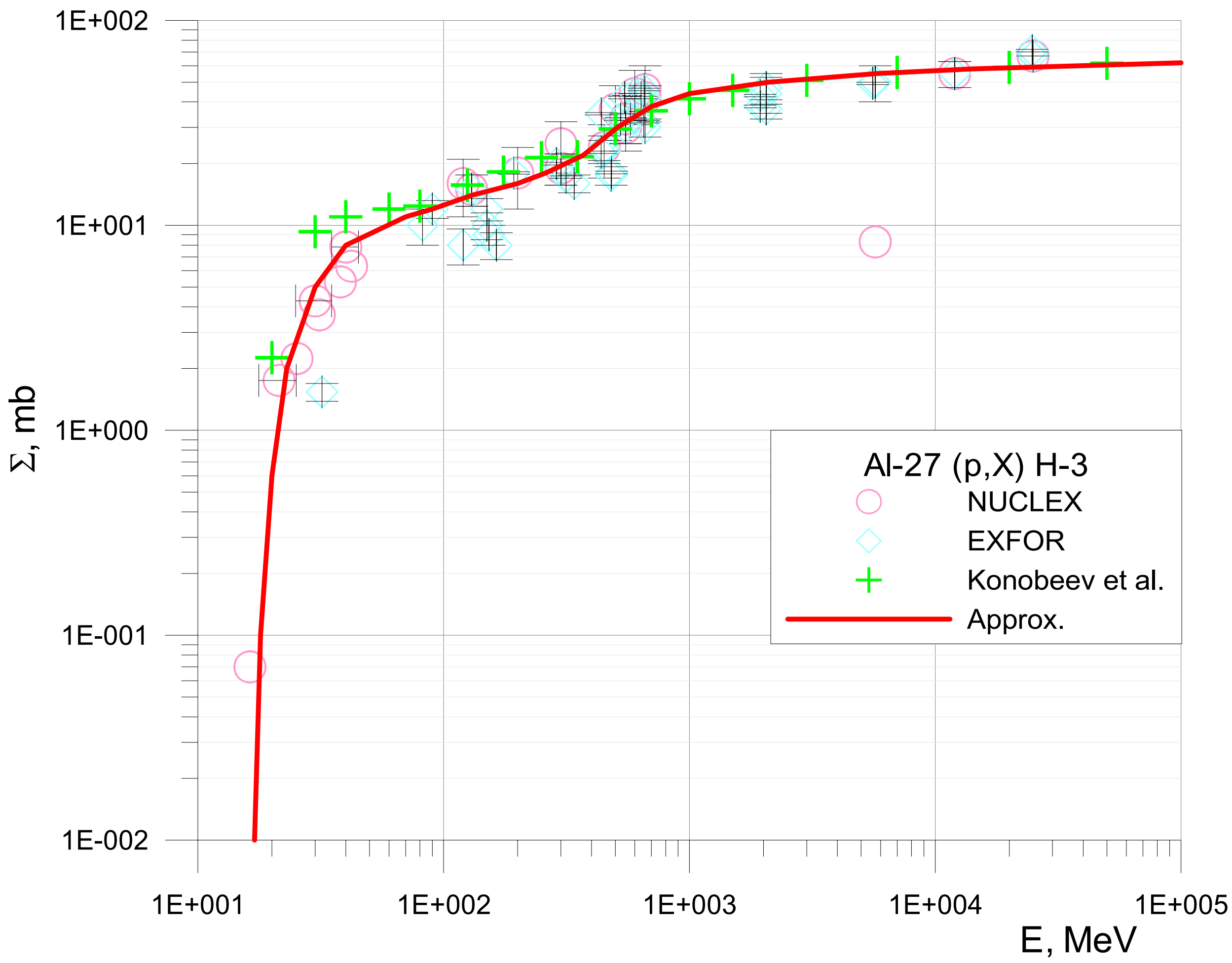
##	E, MeV	Σ, mb
1	36.1	0.000
2	44	0.001
3	47	0.01
4	53	0.06
5	62	0.2
6	74	0.3
7	115	0.5
8	160	0.6
9	240	0.7
10	360	1.0
11	680	2.0
12	800	2.4
13	1000	2.8
14	2000	3.0
15	100000	3.0
16		
17		
18		



##	E, MeV	Σ, mb
1	48.5	0.000
2	51.3	0.001
3	56	0.005
4	65	0.02
5	84	0.05
6	115	0.10
7	180	0.20
8	260	0.40
9	450	0.90
10	800	1.8
11	1200	2.6
12	1800	2.9
13	3000	3.0
14	10000	3.0
15	100000	3.0
16		
17		
18		



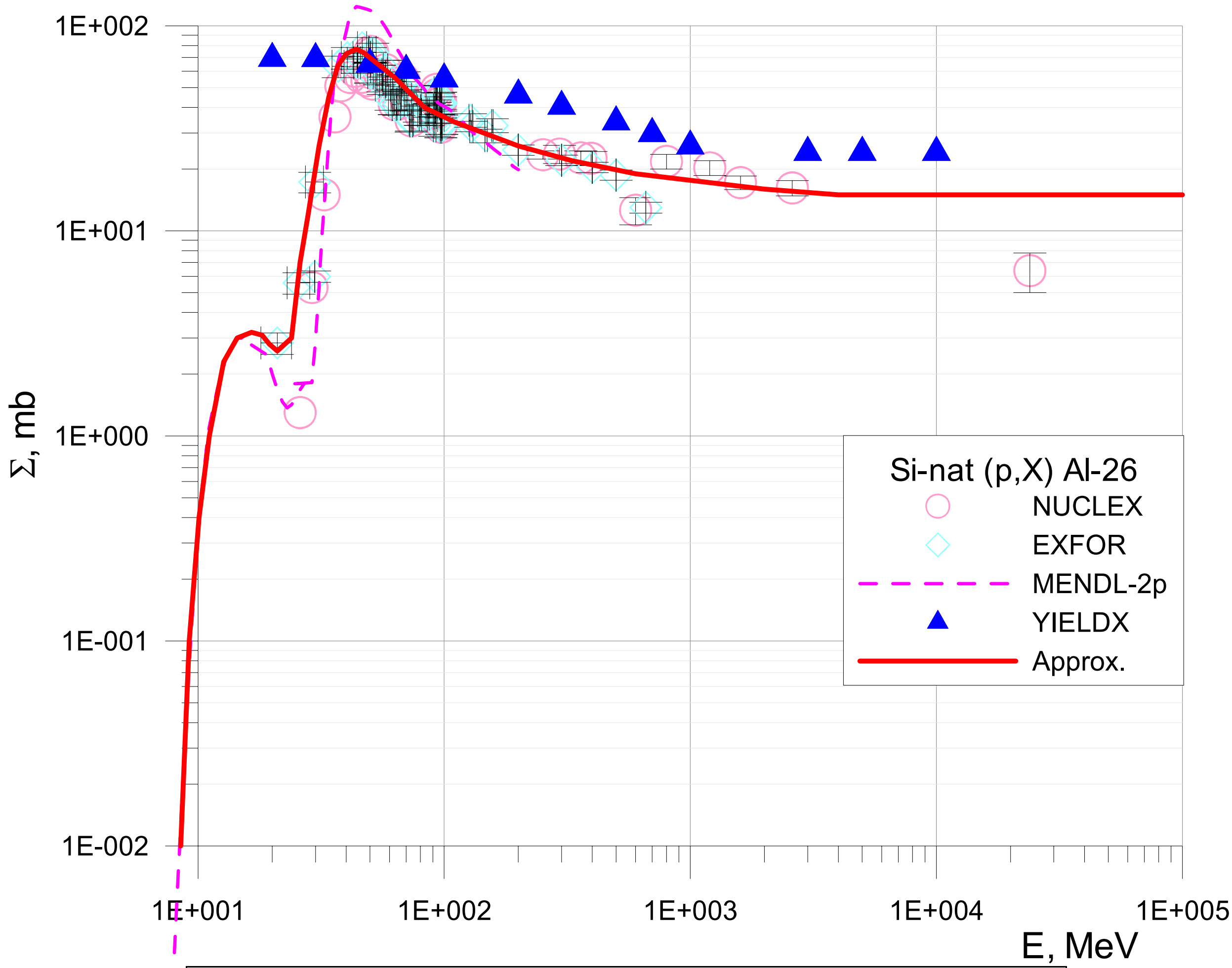
##	E, MeV	Σ, mb
1	28	0.01
2	32	0.1
3	36	0.2
4	42	0.3
5	54	0.5
6	87	0.8
7	150	1.2
8	280	2.0
9	520	4.0
10	860	6.3
11	1400	8.3
12	2100	9.2
13	10000	8.7
14	100000	8.7
15		
16		
17		
18		



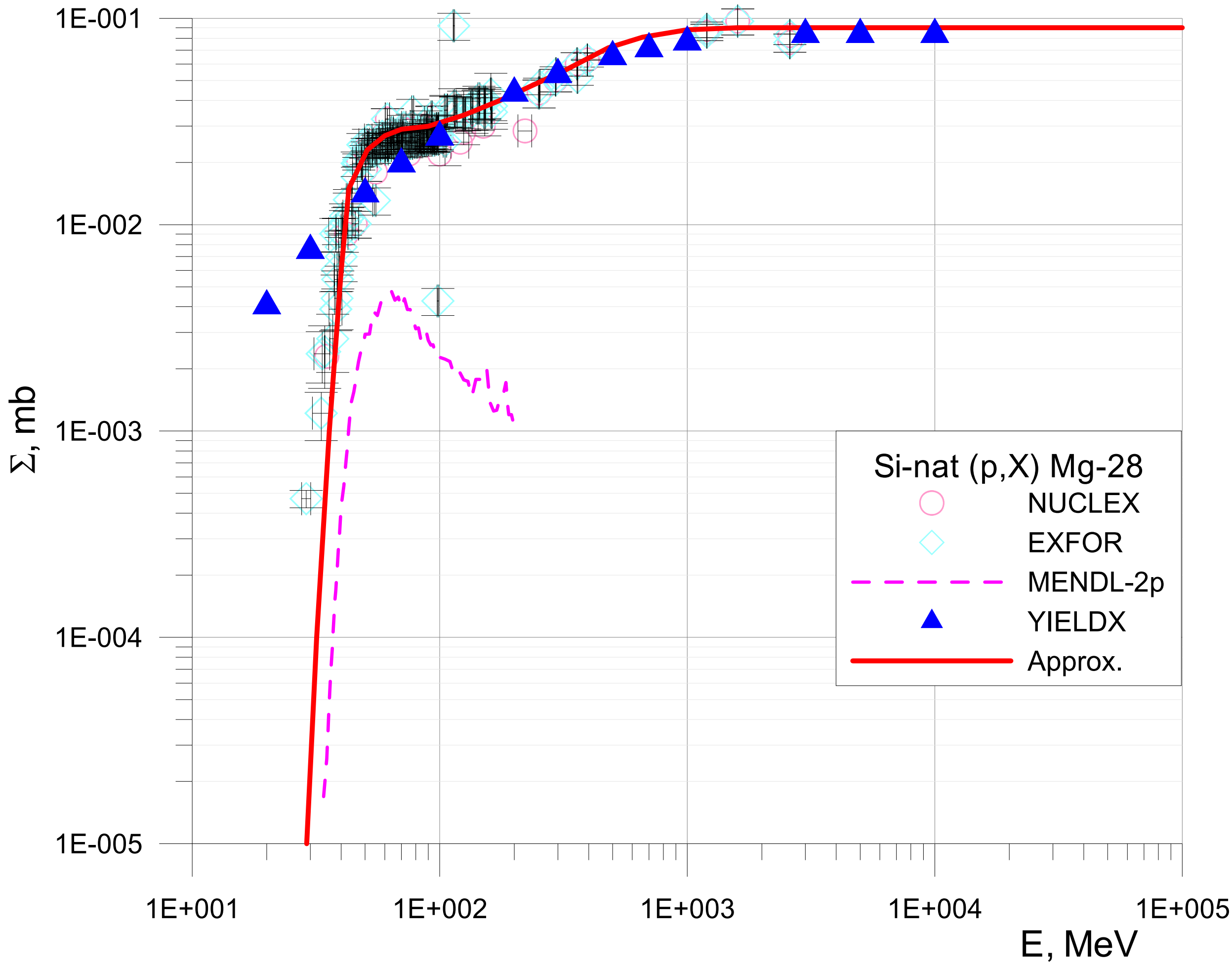
##	E, MeV	Σ, mb
1	15.5	0.00
2	17.0	0.01
3	18.0	0.10
4	20	0.6
5	23	2.0
6	30	5.0
7	40	8.0
8	70	11
9	90	12
10	130	14
11	200	16
12	260	18
13	370	22
14	510	30
15	700	38
16	1000	44
17	2100	50
18	5800	55
19	14000	58
20	100000	62

Summary of experimental and calculated cross-section data used for silicon

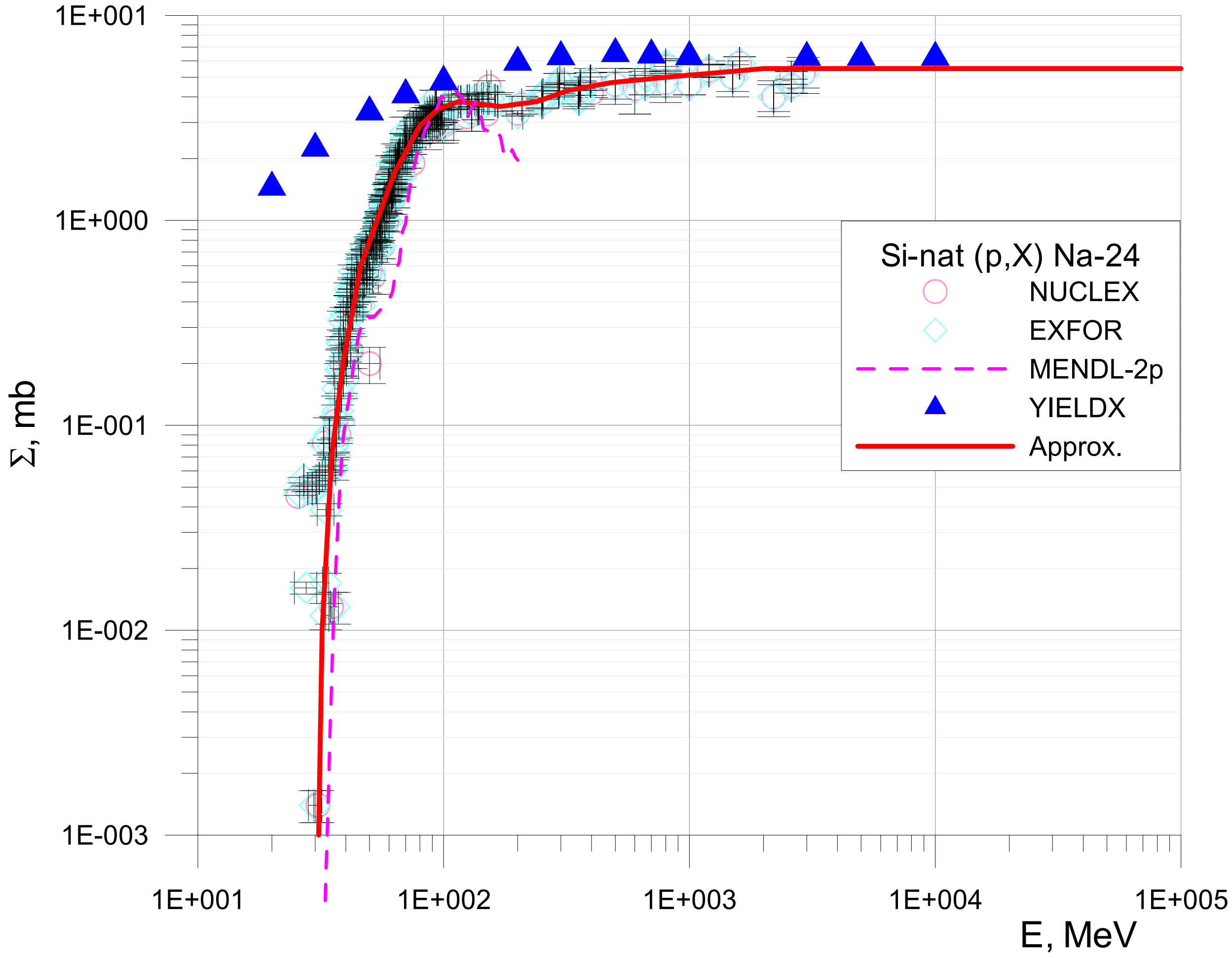
Nuclide	Half-life			Decay Mode	Source			Comment
					Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-		x	x	
Be-7	53.22	D	0.06	EC		x	x	
Be-10	2E+06	Y	60000	B-		x	x	
C-14	5700	Y	30	B-			x	cum
F-18	109.77	M	0.05	EC	x	x	x	cum
Na-22	2.6019	Y	4E-04	EC	x	x	x	cum
Na-24	14.959	H	0.001	B-	x	x	x	cum
Mg-28	20.915	H	0.009	B-	x	x	x	cum
Al-26	717000	Y	24000	EC	x	x	x	



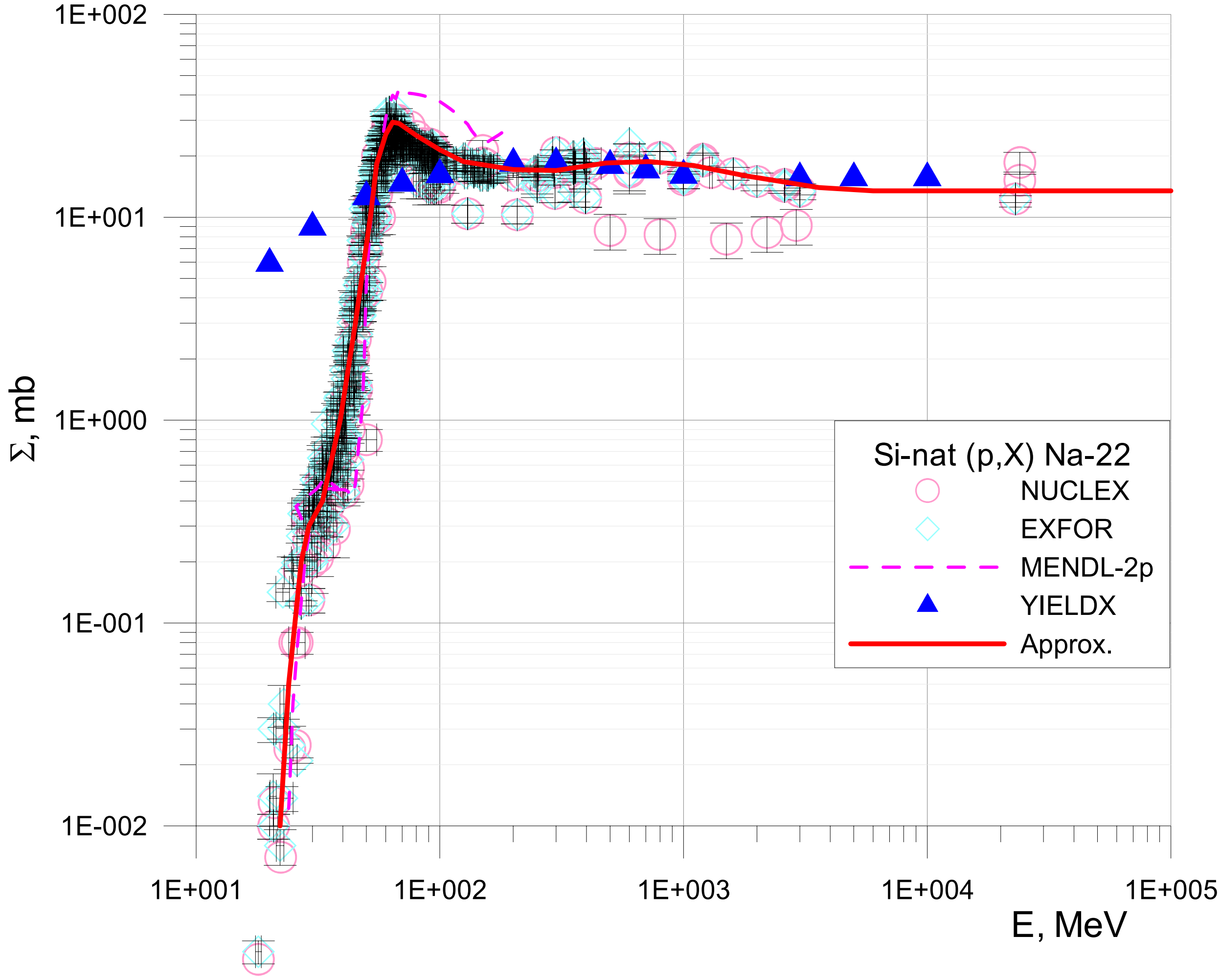
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	5.0	0.00	19	44	77
2	8.5	0.01	20	47	74
3	9.2	0.1	21	63	56
4	10.1	0.4	22	83	40
5	11.1	1.0	23	110	34
6	12.7	2.3	24	200	26
7	14.4	3.0	25	330	22
8	16.5	3.2	26	600	19
9	18.2	3.1	27	2000	16
10	19.5	2.8	28	4000	15
11	21.0	2.6	29	100000	15
12	24.0	3.0			
13	26.0	7.0			
14	28.0	12			
15	31	26			
16	34	45			
17	37	64			
18	40	73			



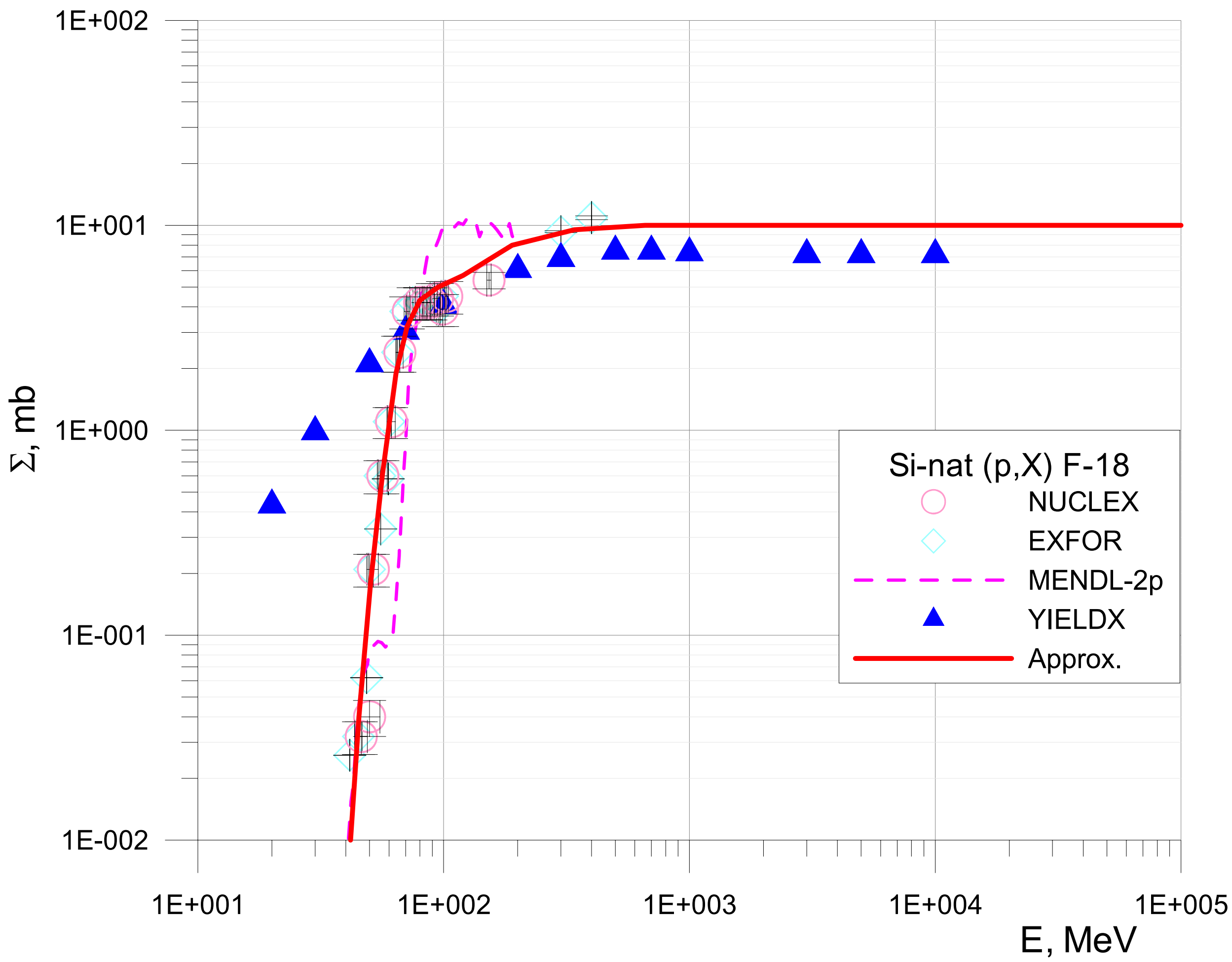
##	E, MeV	Σ, mb
1	24.8	0.0000
2	31.8	0.0001
3	35.8	0.001
4	40	0.006
5	43	0.015
6	51	0.023
7	60	0.027
8	70	0.029
9	90	0.030
10	125	0.034
11	175	0.040
12	320	0.056
13	480	0.072
14	660	0.081
15	1000	0.088
16	1600	0.090
17	100000	0.090
18		



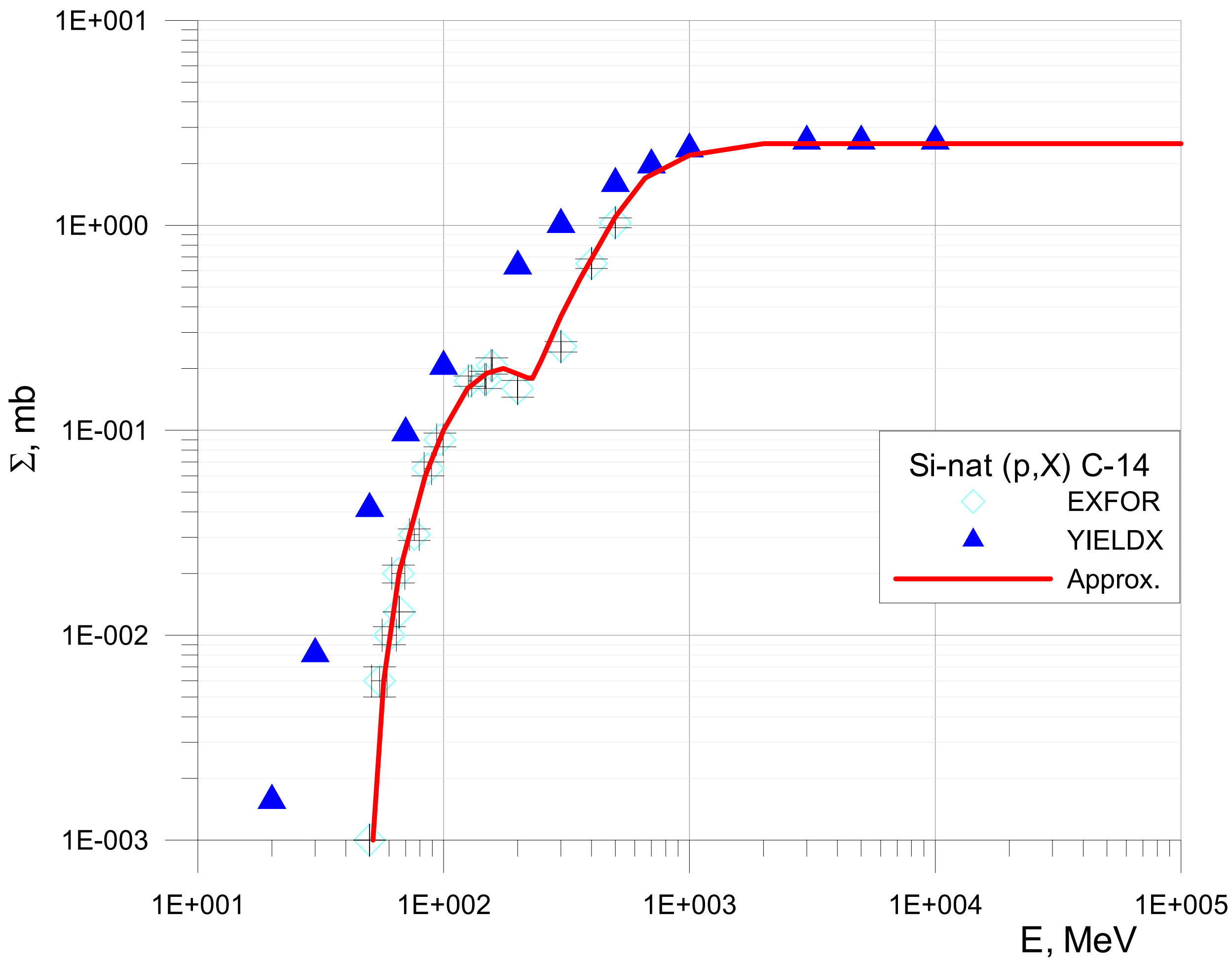
##	E, MeV	Σ, mb
1	24	0.000
2	31	0.001
3	32	0.01
4	35	0.07
5	39	0.2
6	46	0.6
7	52	0.9
8	63	1.7
9	80	2.9
10	95	3.5
11	115	3.8
12	170	3.6
13	240	3.8
14	320	4.3
15	480	4.7
16	800	5.0
17	2000	5.5
18	100000	5.5



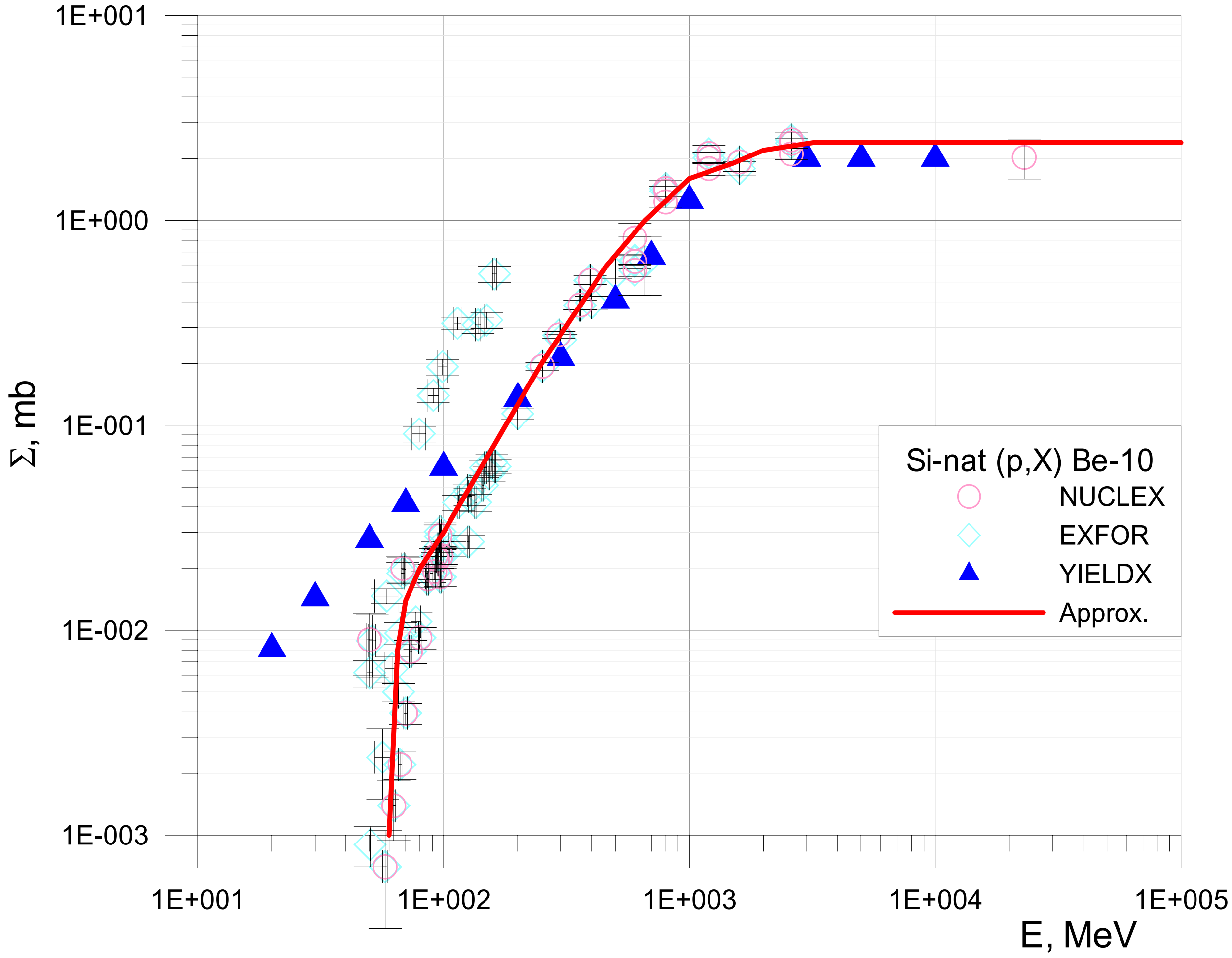
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	14.8	0.00	19	480	18.5
2	22.1	0.01	20	720	18.8
3	24	0.05	21	1100	18.0
4	27	0.2	22	1800	16.0
5	29	0.3	23	3600	14.0
6	33	0.4	24	6000	13.5
7	39	1.0	25	100000	13.5
8	45	3.0	26		
9	52	10.2	27		
10	55	18.3	28		
11	60	25.6			
12	64	29.4			
13	68	29.0			
14	80	25.3			
15	100	21.5			
16	125	18.8			
17	200	17.2			
18	300	17.0			



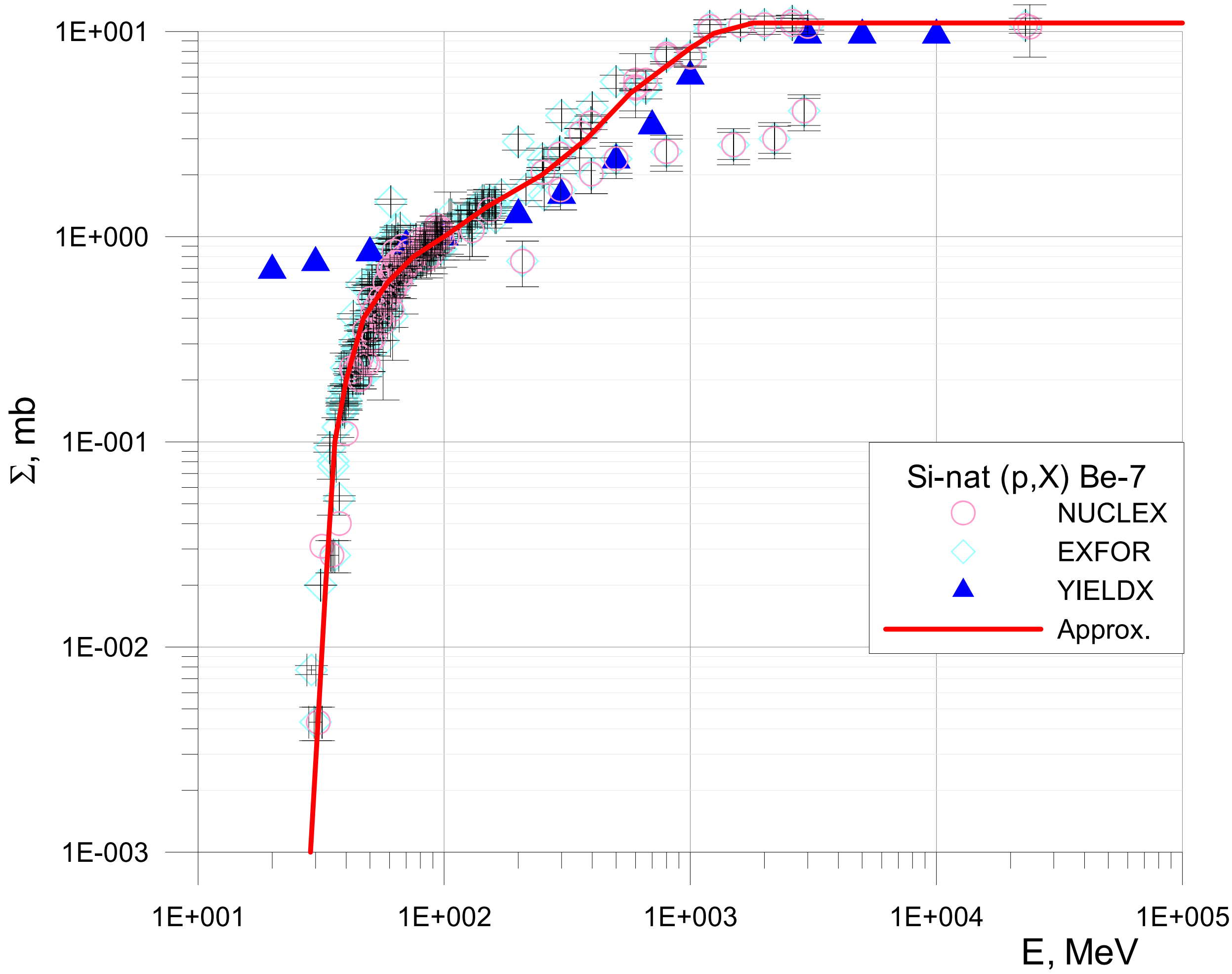
##	E, MeV	Σ, mb
1	23.6	0.00
2	41.8	0.01
3	45.2	0.04
4	50.4	0.18
5	56.4	0.61
6	64	1.9
7	71	3.2
8	80	4.3
9	95	5.0
10	120	5.7
11	190	8.0
12	340	9.5
13	660	10
14	100000	10
15		
16		
17		
18		



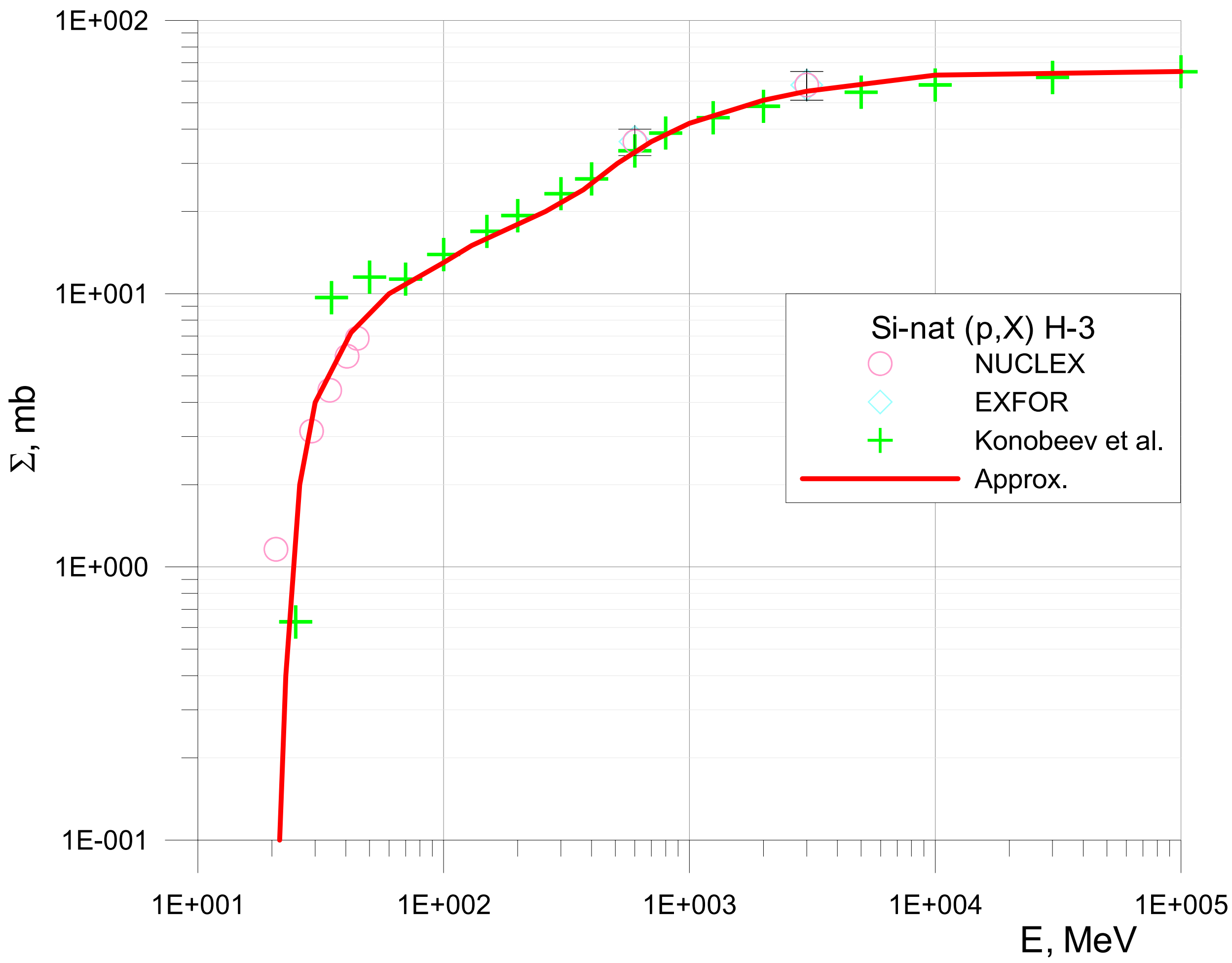
##	E, MeV	Σ, mb
1	38.4	0.000
2	51.6	0.001
3	57.0	0.01
4	65.9	0.02
5	84.2	0.06
6	100	0.10
7	125	0.16
8	150	0.19
9	175	0.20
10	220	0.18
11	230	0.18
12	250	0.22
13	300	0.36
14	360	0.6
15	500	1.1
16	660	1.7
17	1000	2.2
18	2000	2.5
19	100000	2.5



##	E, MeV	Σ, mb
1	50.8	0.000
2	60	0.001
3	65	0.008
4	70	0.01
5	80	0.02
6	100	0.0
7	250	0.2
8	460	0.6
9	660	1.0
10	1000	1.6
11	1500	1.9
12	2000	2.2
13	3200	2.4
14	100000	2.4
15		
16		
17		
18		



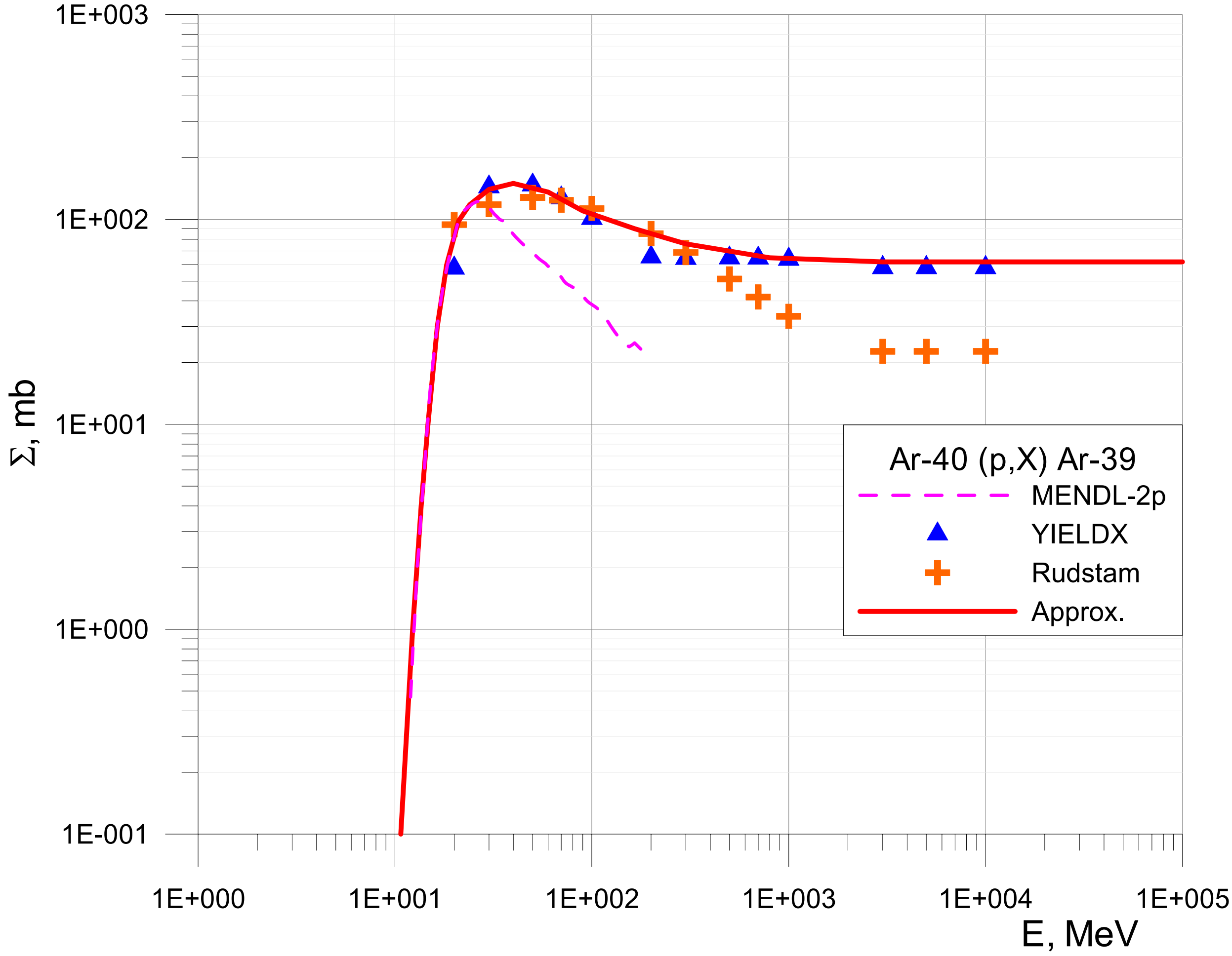
##	E, MeV	Σ, mb
1	28.6	0.001
2	30.6	0.004
3	33	0.02
4	36	0.1
5	40	0.2
6	47	0.4
7	59	0.6
8	75	0.8
9	100	1.0
10	150	1.4
11	250	2.0
12	380	3.0
13	570	5.0
14	1000	8.3
15	1250	9.8
16	1800	11
17	3000	11
18	6000	11
19	100000	11



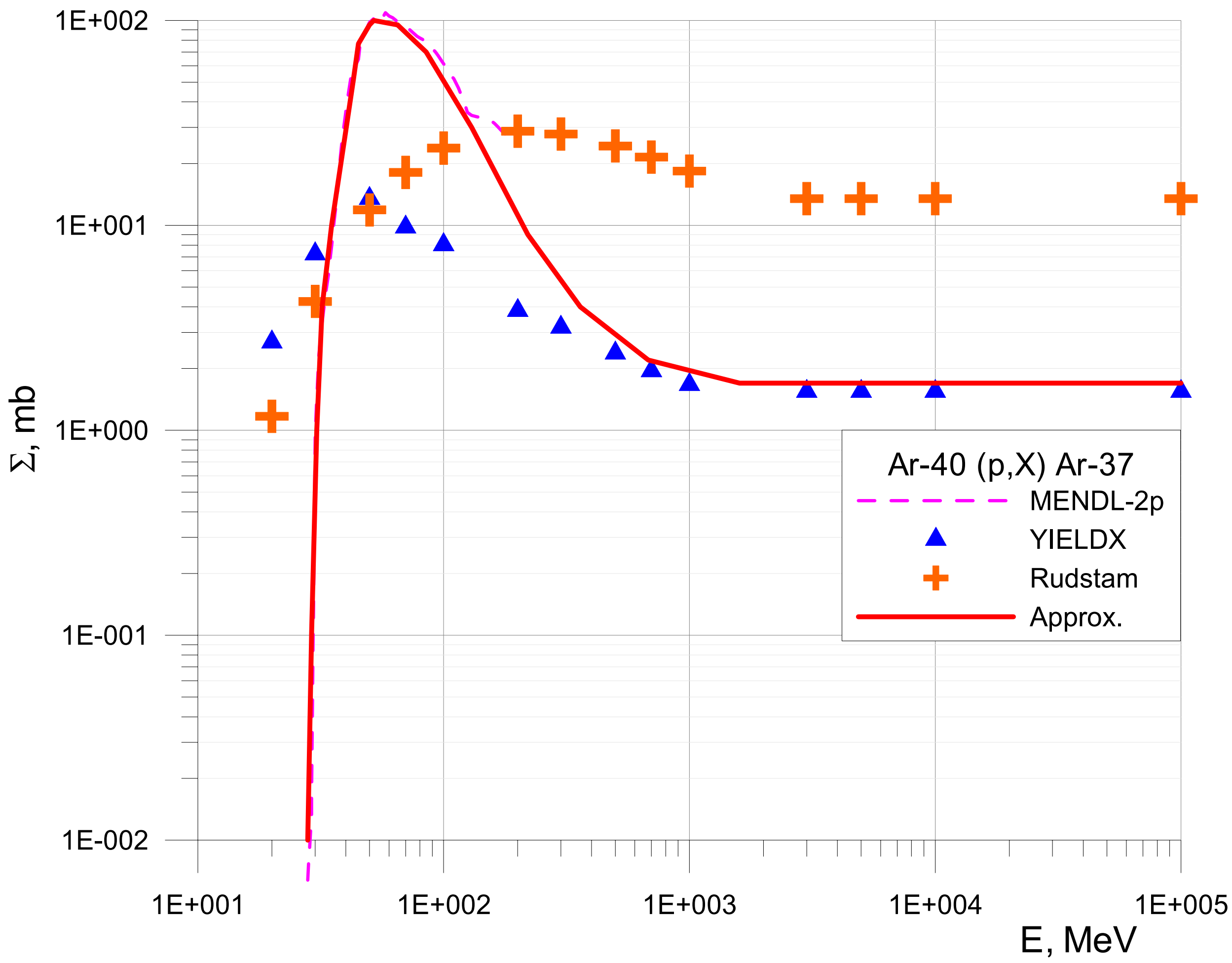
##	E, MeV	Σ, mb
1	11.0	0.00
2	20.0	0.01
3	21.5	0.1
4	22.8	0.4
5	26	2.0
6	30	4.0
7	42	7.2
8	60	10
9	100	13
10	130	15
11	260	20
12	370	24
13	510	30
14	700	36
15	1000	42
16	2000	51
17	3000	55
18	10000	63
19	100000	65

Summary of experimental and calculated cross-section data used for argon

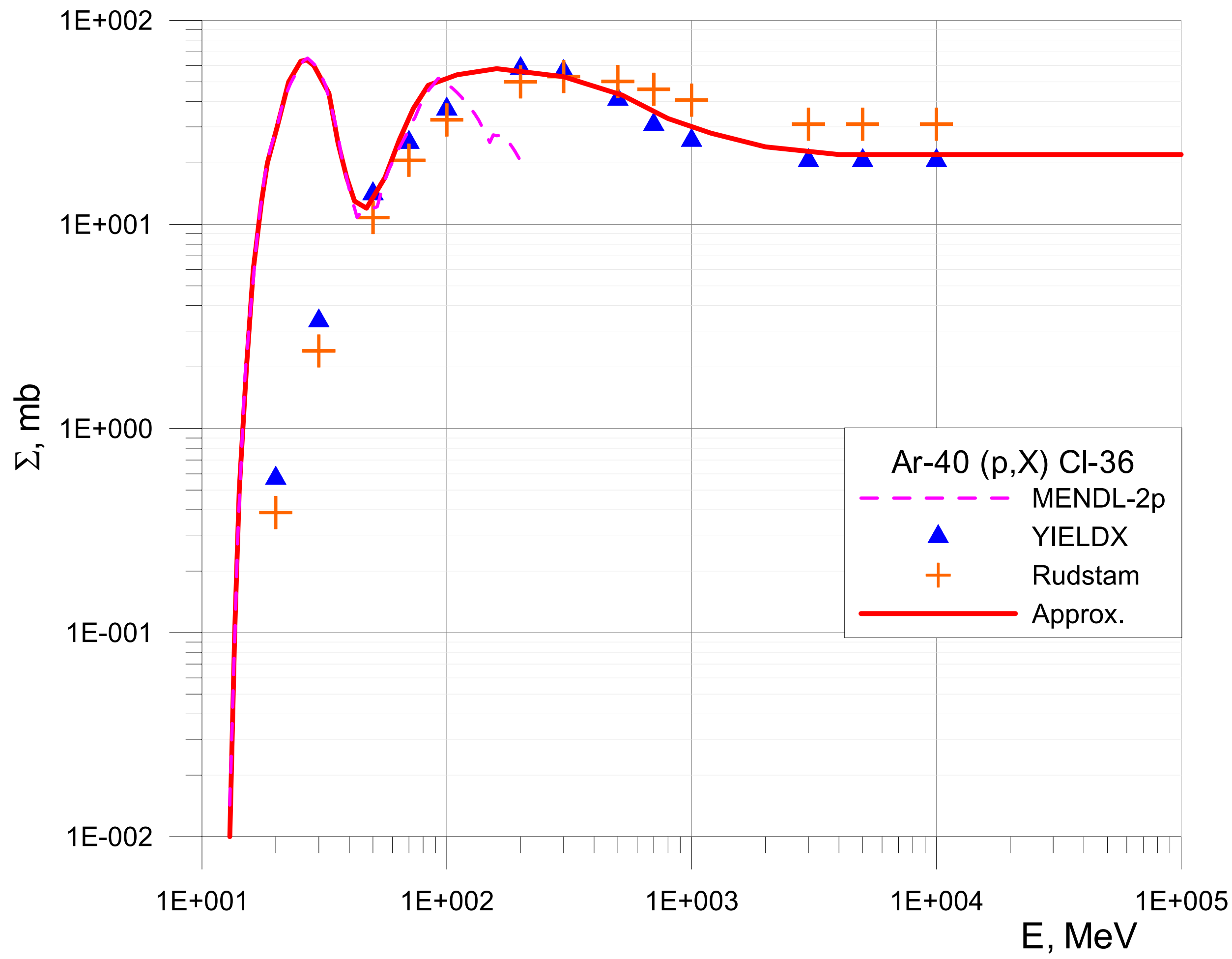
Nuclide	Half-life			Decay Mode				Comment
					Mendl-2p	EXFOR	NUCLEX	
H-3	12.32	Y	0.02	B-				
Be-7	53.22	D	0.06	EC			x	
Be-10	2E+06	Y	60000	B-				
C-14	5700	Y	30	B-				cum
F-18	109.77	M	0.05	EC			x	cum
Na-22	2.6019	Y	4E-04	EC			x	cum
Na-24	14.959	H	0.001	B-	x		x	cum
Mg-28	20.915	H	0.009	B-	x	x	x	cum
Al-26	717000	Y	24000	EC	x		x	
Si-31	157.3	M	0.3	B-	x		x	cum
Si-32	132	Y	13	B-	x			cum
P-32	14.262	D	0.014	B-	x		x	
P-33	25.34	D	0.12	B-	x		x	cum
S-35	87.51	D	0.12	B-	x			cum
S-38	170.3	M	0.7	B-	x	x	x	cum
Cl-36	301000	Y	2000	B-	x			
Ar-37	35.04	D	0.04	EC	x			cum
Ar-39	269	Y	3	B-	x			cum



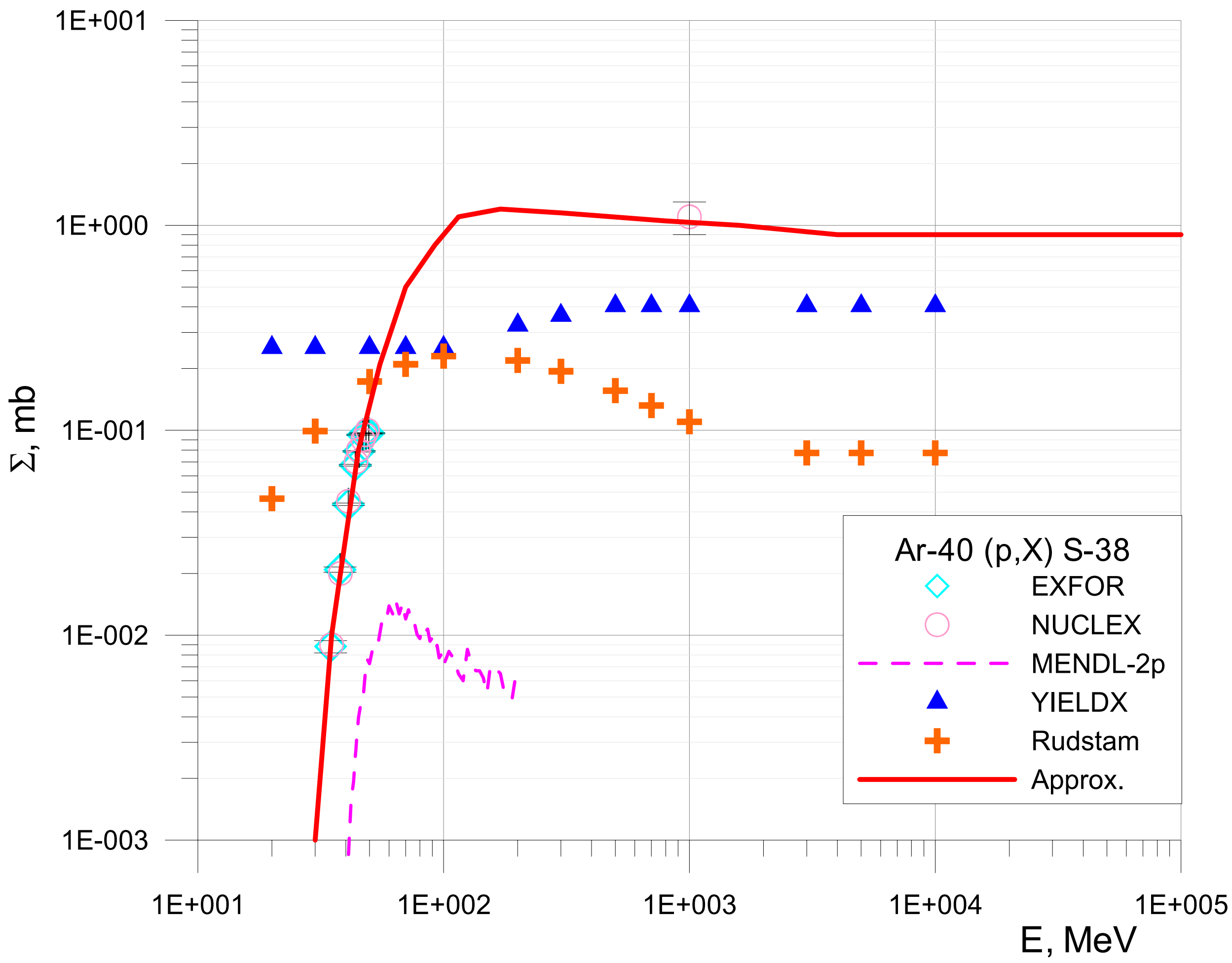
##	E, MeV	Σ, mb
1	7.84	0.0
2	10.7	0.1
3	12.3	1.0
4	13.6	4.0
5	14.7	10
6	16.4	30
7	18.3	60
8	21	98
9	24	118
10	30	140
11	40	150
12	60	136
13	90	110
14	165	90
15	300	76
16	800	65
17	3000	62
18	100000	62



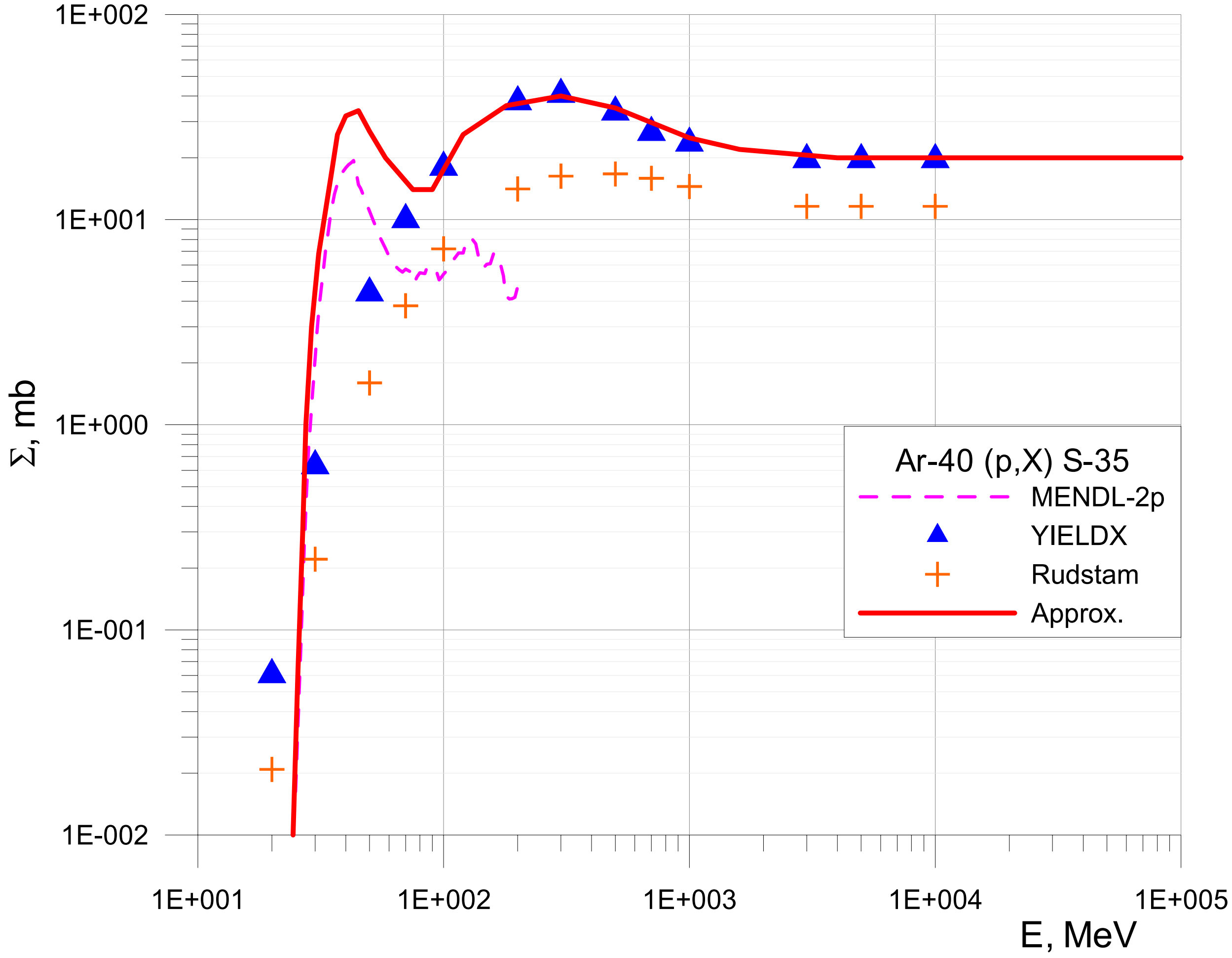
##	E, MeV	Σ, mb
1	20.32	0.00
2	28.0	0.01
3	29.0	0.1
4	30.5	1.0
5	32	4.0
6	35	10
7	40	29
8	43	52
9	45	77
10	50	95
11	52	100
12	65	95
13	85	70
14	130	30
15	220	9.0
16	360	4.0
17	680	2.2
18	1600	1.7
19	100000	1.7



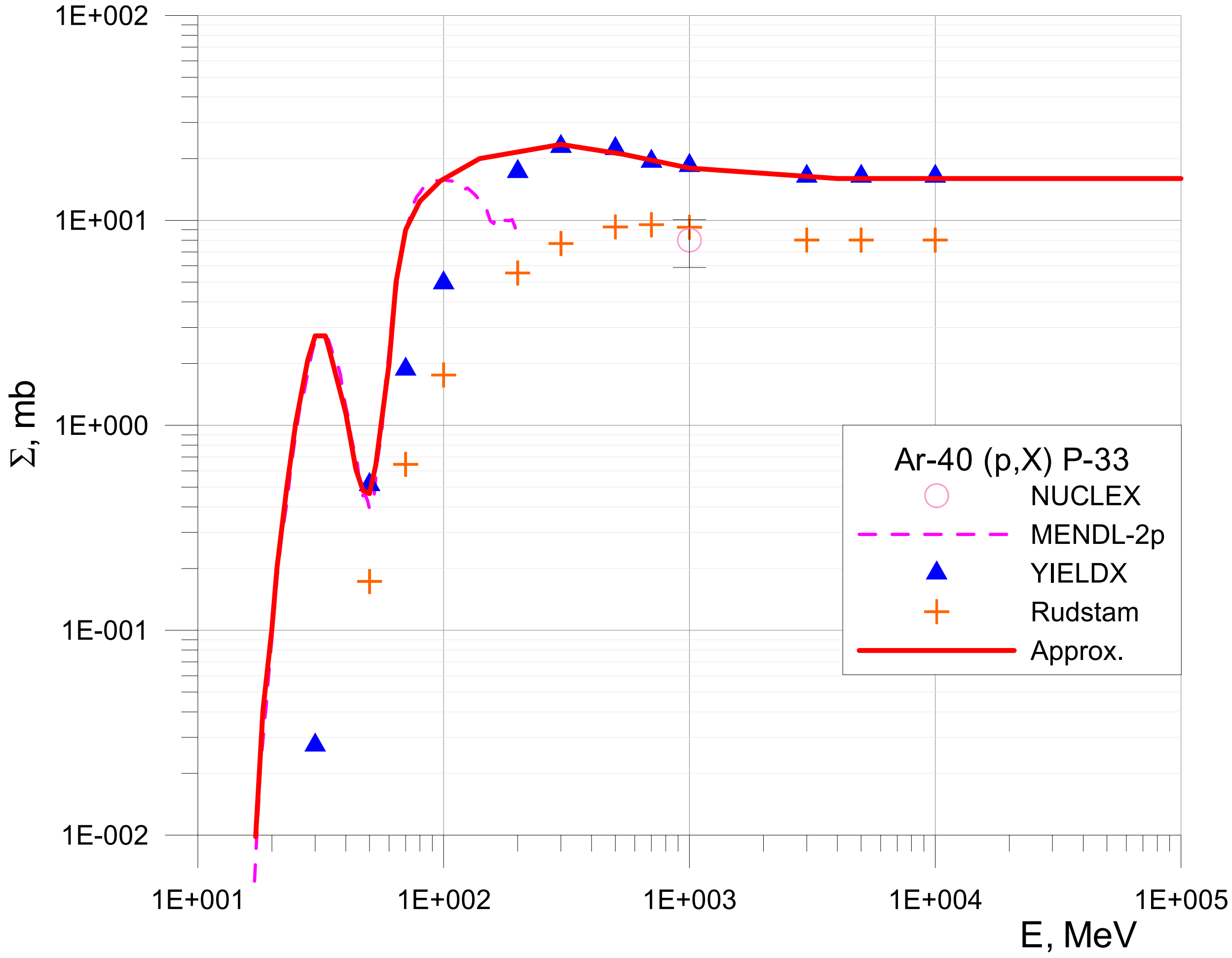
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	8.95	0.00	19	56	17
2	13.0	0.01	20	64	26
3	13.6	0.1	21	73	37
4	14.2	0.5	22	84	48
5	15.2	2.0	23	110	54
6	16.2	6.0	24	160	58
7	17.5	13	25	300	53
8	18.5	20	26	520	43
9	20.3	30	27	800	33
10	22.6	50	28	1200	28
11	25.3	63	29	2000	24
12	26.8	64	30	4000	22
13	28.6	60	31	100000	22
14	33	44			
15	36	25			
16	39	17			
17	42	13			
18	47	12			



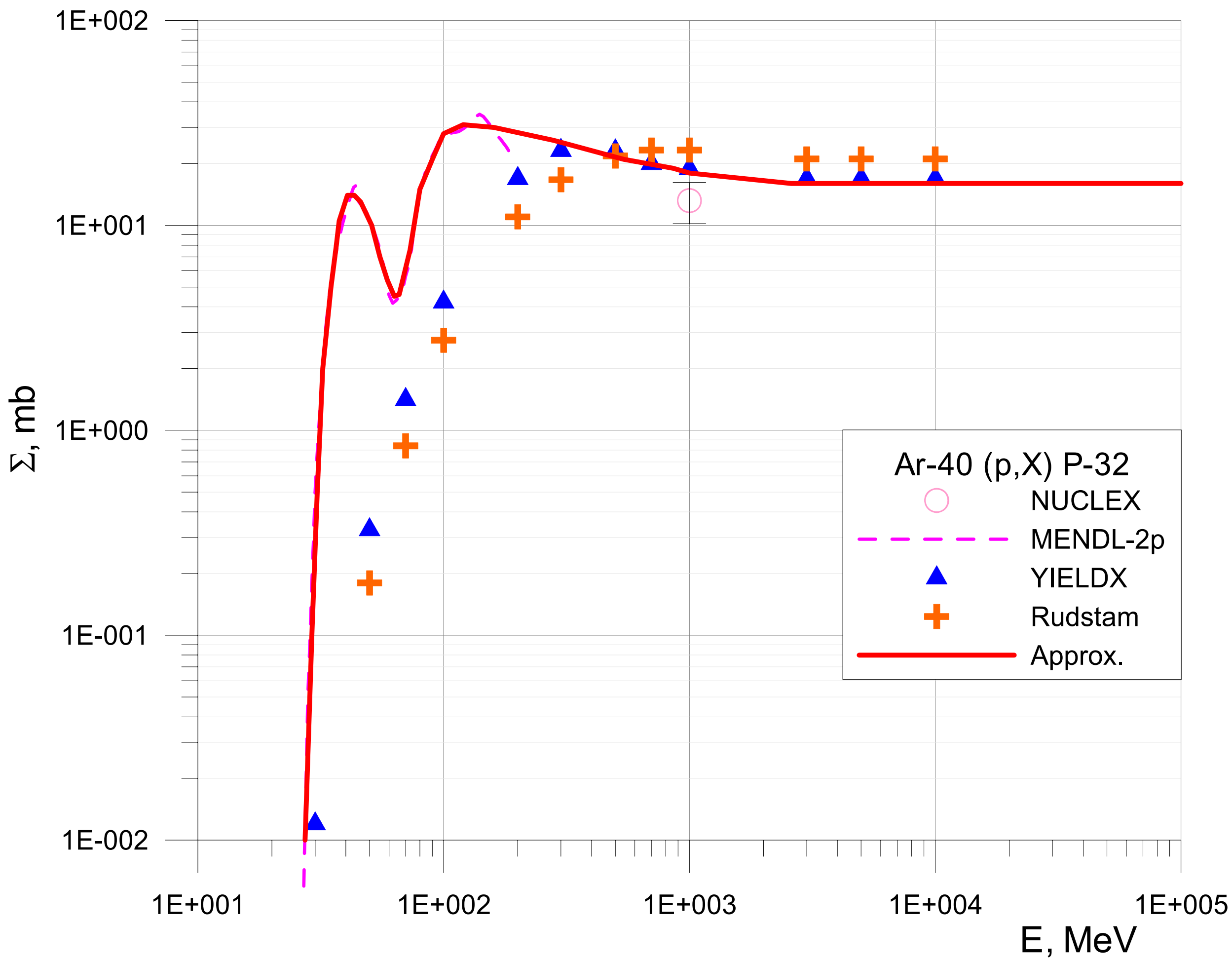
##	E, MeV	Σ, mb
1	23.3	0.000
2	30	0.001
3	35	0.01
4	38	0.02
5	45	0.08
6	55	0.21
7	70	0.50
8	92	0.80
9	115	1.10
10	170	1.20
11	300	1.15
12	800	1.05
13	1600	1.00
14	4000	0.90
15	100000	0.90
16		
17		
18		



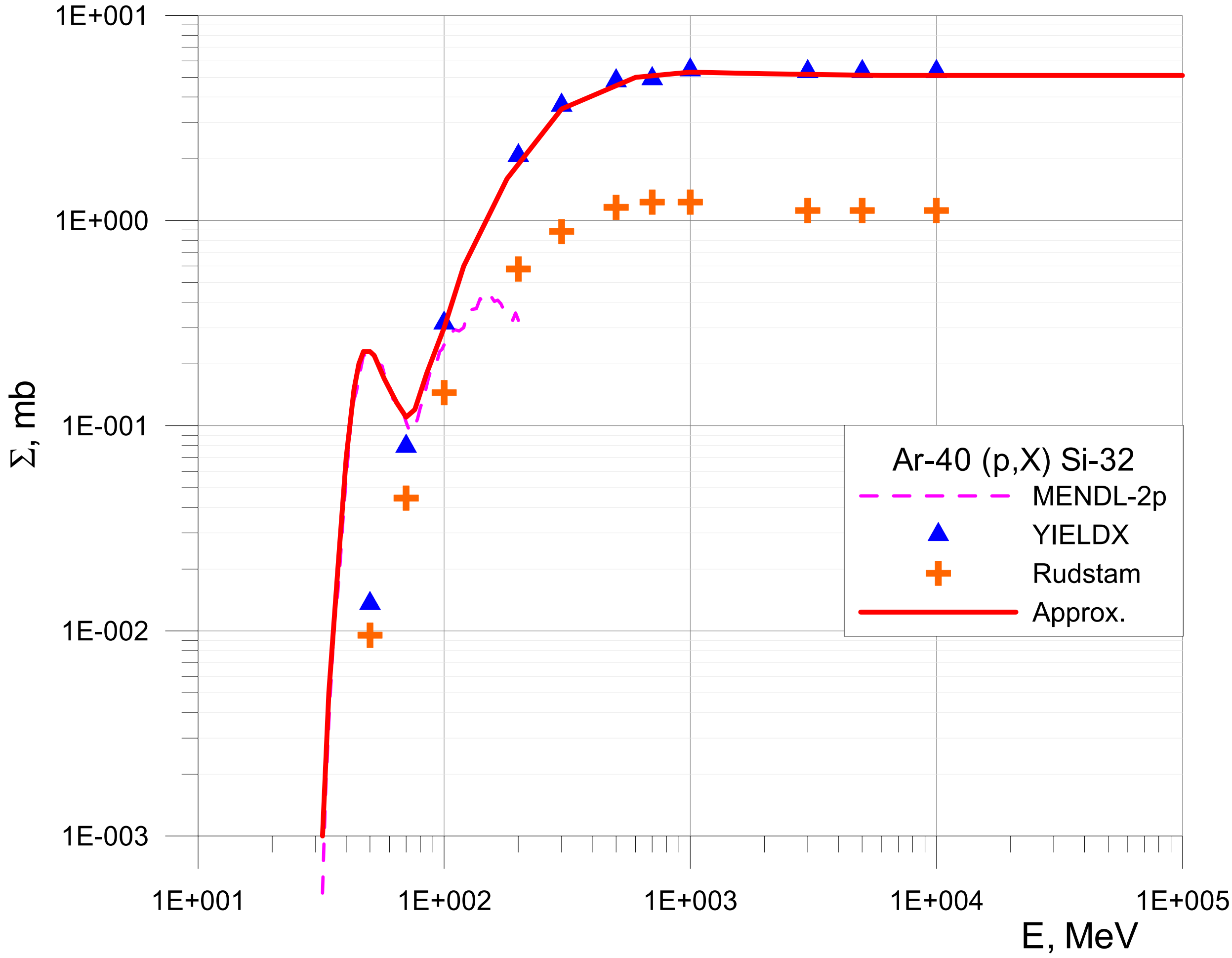
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	14.83	0.00	19	500	35
2	24.4	0.01	20	1000	25
3	25.5	0.06	21	1600	22
4	26.7	0.3	22	4000	20
5	27.5	1.0	23	100000	20
6	29	3.0			
7	31	6.8			
8	35	17			
9	37	26			
10	40	32			
11	45	34			
12	50	27			
13	58	20			
14	75	14			
15	90	14			
16	120	26			
17	180	36			
18	300	40			



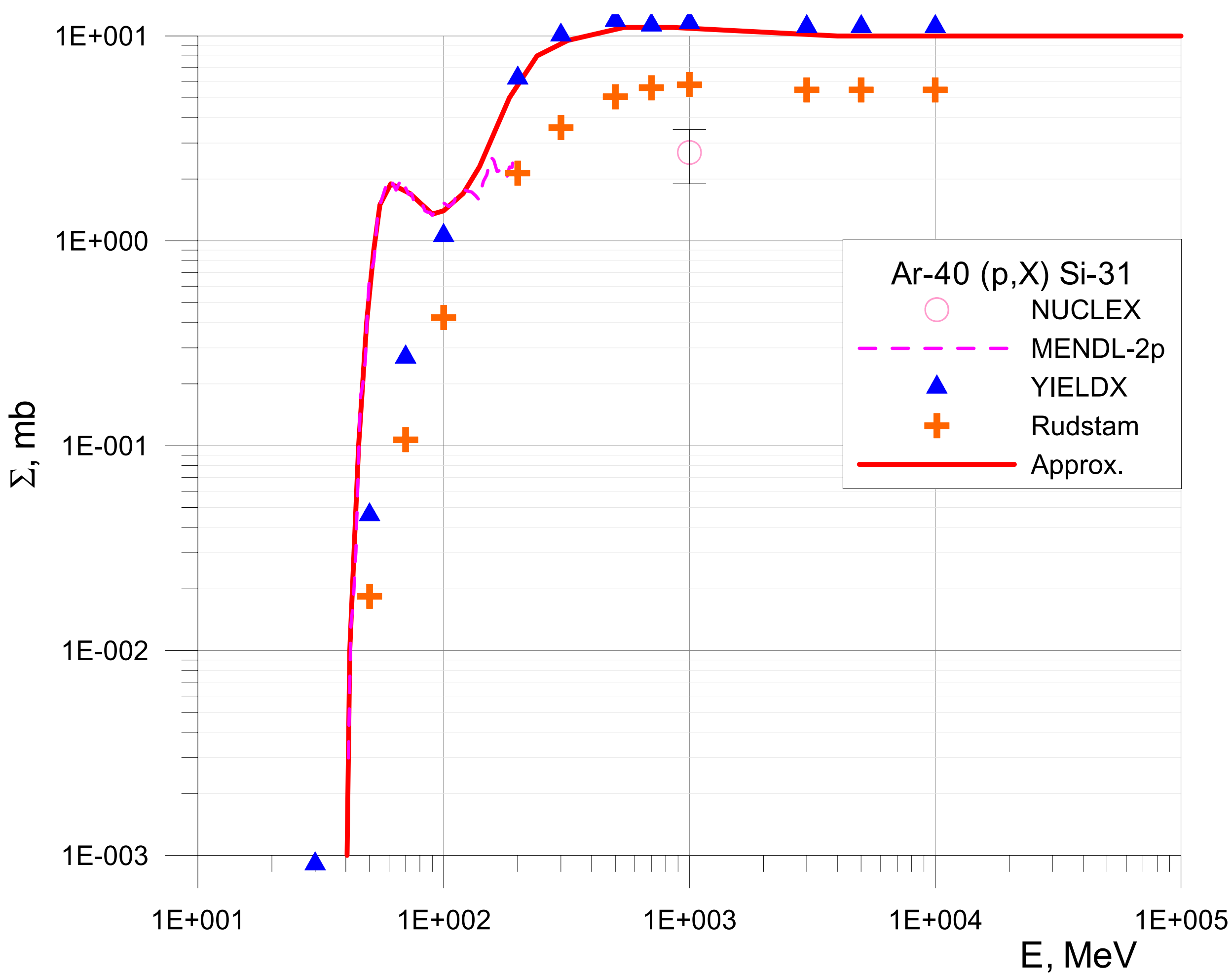
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	6.42	0.00	19	70	9.0
2	17.2	0.01	20	80	13
3	18.4	0.04	21	97	15
4	20	0.10	22	145	15
5	21	0.20	23	290	13
6	23	0.50	24	540	12
7	25	1.00	25	1000	11
8	28	2.08	26	3000	10
9	30	2.73	27	100000	10
10	33	2.73			
11	34	2.43			
12	40	1.15			
13	44	0.61			
14	47	0.48			
15	50	0.46			
16	53	0.64			
17	60	2.0			
18	64	5.0			



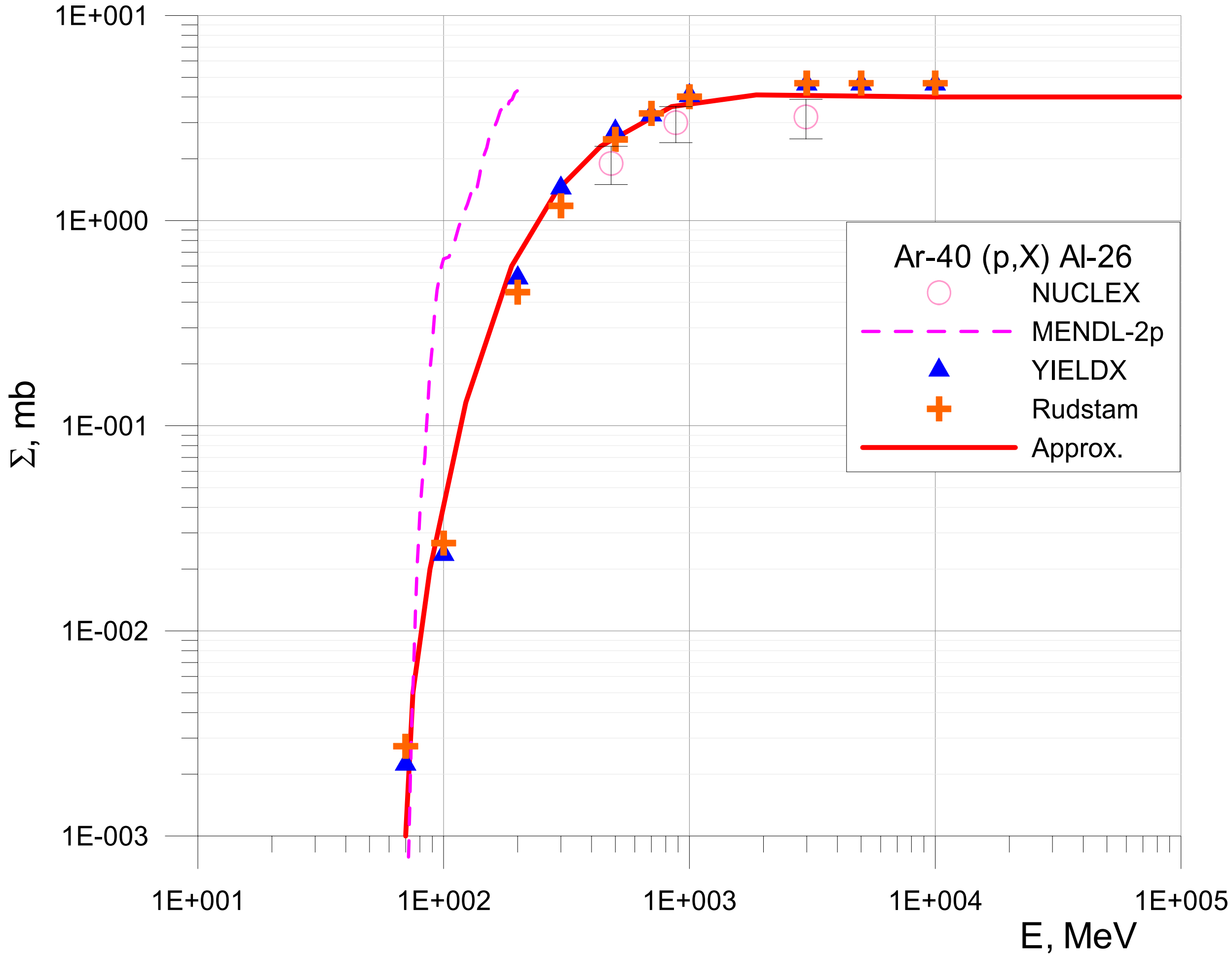
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	16.78	0.00	19	90	21
2	27.3	0.01	20	100	28
3	29.1	0.10	21	120	31
4	30.6	0.50	22	160	30
5	32.2	2.00	23	280	26
6	34.8	5.00	24	540	21
7	36.6	8.00	25	860	19
8	37.6	10.5	26	1000	18
9	40.6	14.0	27	2600	16
10	43.3	14.0	28	100000	16
11	46	13.0			
12	51	10.0			
13	55	7.0			
14	59	5.4			
15	63	4.5			
16	66	4.6			
17	73	7.6			
18	80	15			



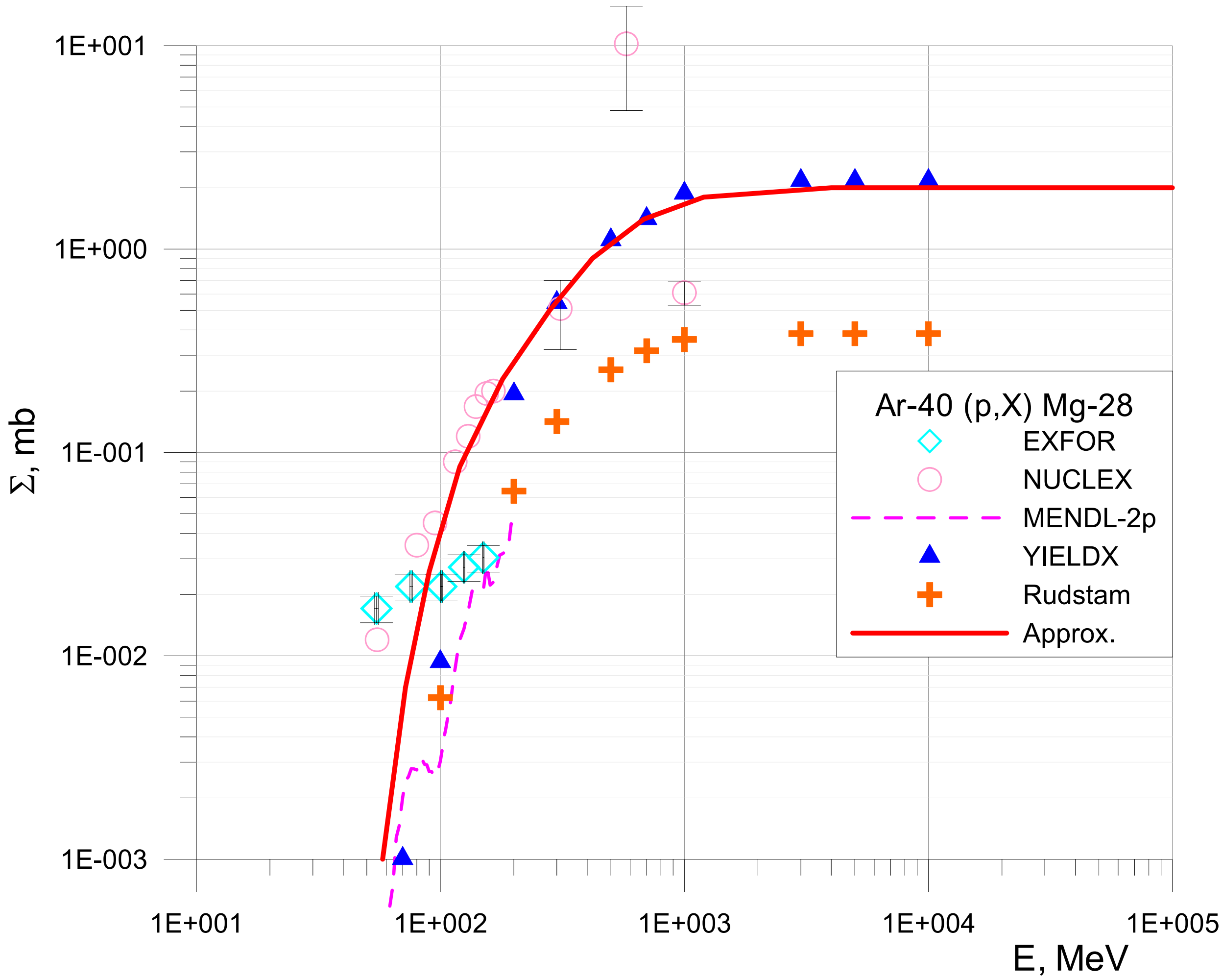
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	16.2	0.000	19	300	3.5
2	32	0.001	20	600	5.0
3	34	0.005	21	1000	5.3
4	37	0.02	22	2000	5.2
5	40	0.07	23	6000	5.1
6	43	0.15	24	100000	5.1
7	45	0.20			
8	47	0.23			
9	50	0.23			
10	52	0.22			
11	57	0.17			
12	64	0.13			
13	70	0.11			
14	76	0.12			
15	85	0.18			
16	100	0.3			
17	120	0.6			
18	180	1.6			



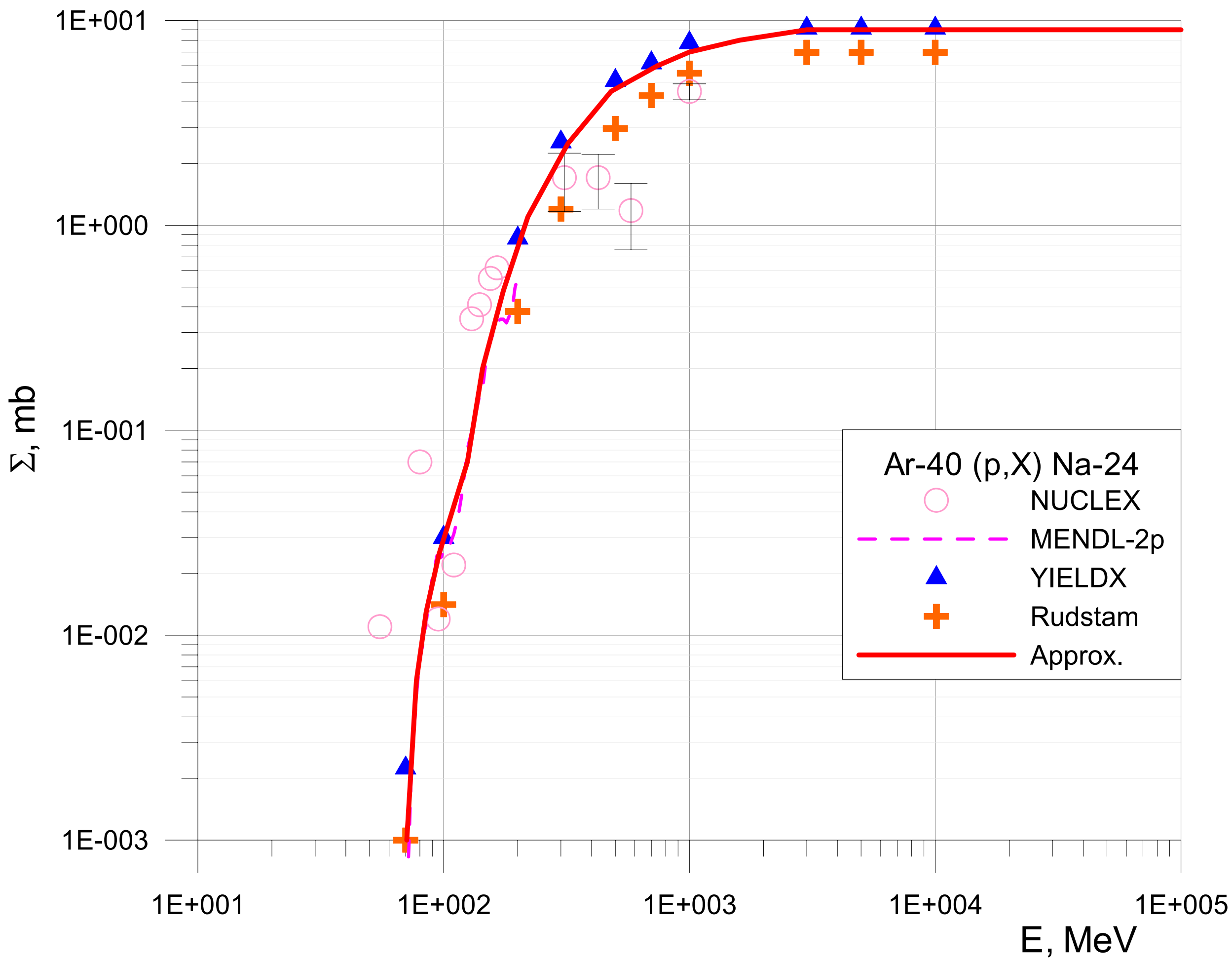
##	E, MeV	Σ, mb
1	23.36	0.000
2	40.5	0.001
3	41.5	0.01
4	45.1	0.10
5	48.6	0.40
6	52	0.90
7	55	1.50
8	61	1.90
9	73	1.70
10	90	1.35
11	100	1.4
12	120	1.7
13	140	2.3
14	185	5.0
15	240	8.0
16	320	9.5
17	540	11
18	860	11
19	4000	10
20	100000	10



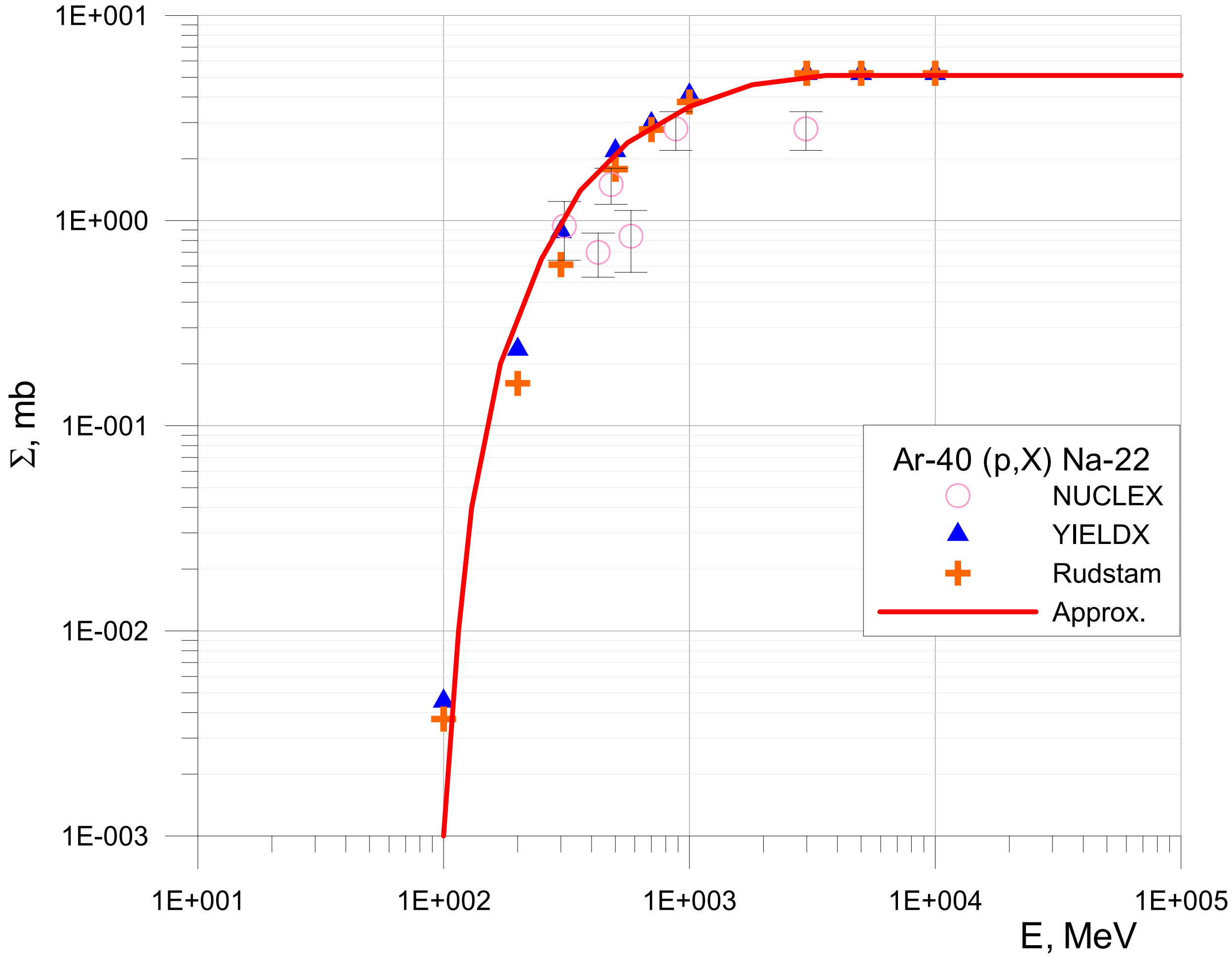
##	E, MeV	Σ, mb
1	48.2	0.000
2	70	0.001
3	76	0.005
4	88	0.02
5	125	0.13
6	200	0.60
7	300	1.40
8	440	2.20
9	860	3.40
10	1200	3.80
11	2000	4.00
12	100000	4.00
13		
14		
15		
16		
17		
18		



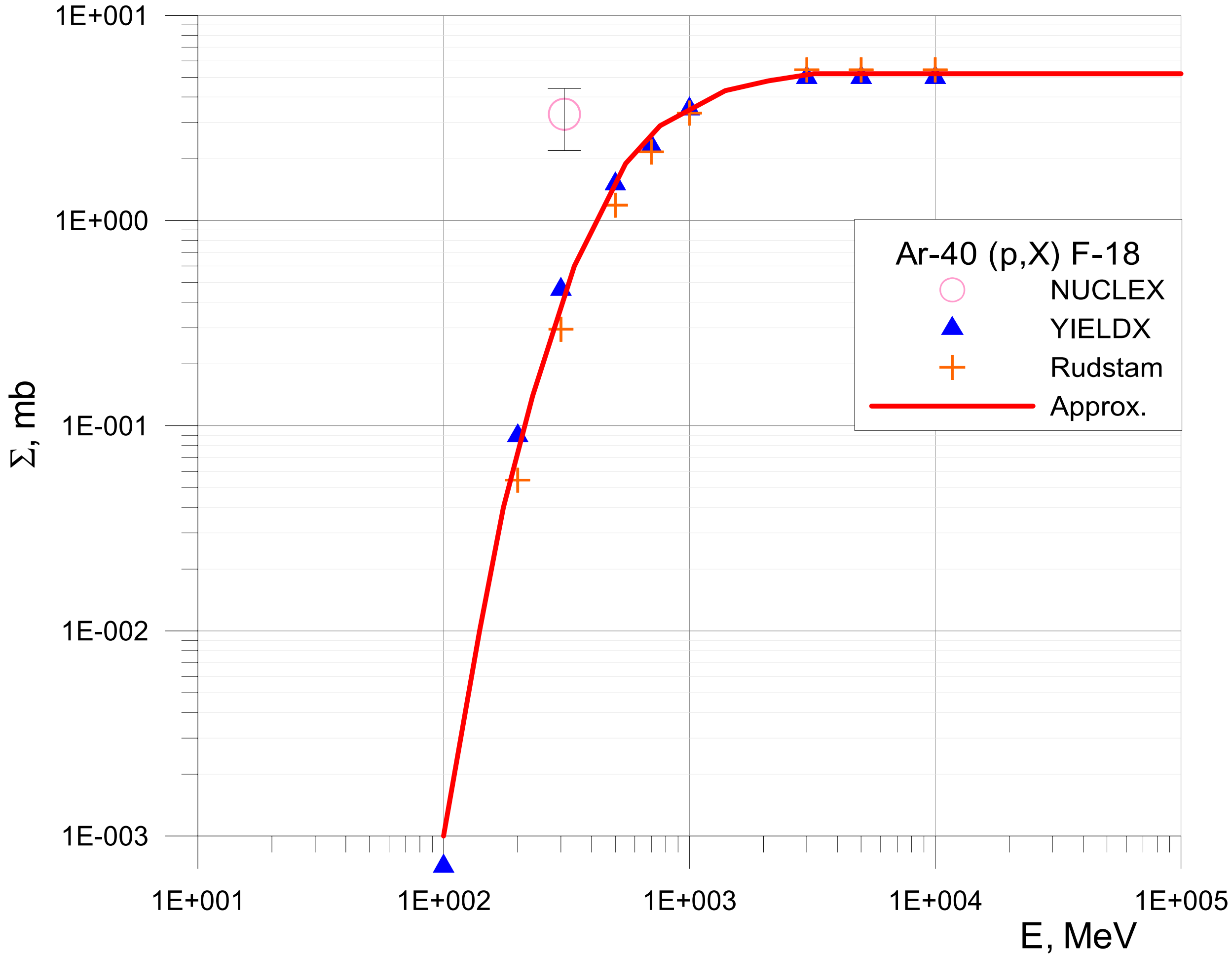
##	E, MeV	Σ, mb
1	28	0.0000
2	53	0.0001
3	58	0.001
4	72	0.007
5	90	0.026
6	120	0.085
7	180	0.23
8	280	0.50
9	420	0.90
10	680	1.40
11	1200	1.80
12	4000	2.00
13	100000	2.00
14		
15		
16		
17		
18		
19		



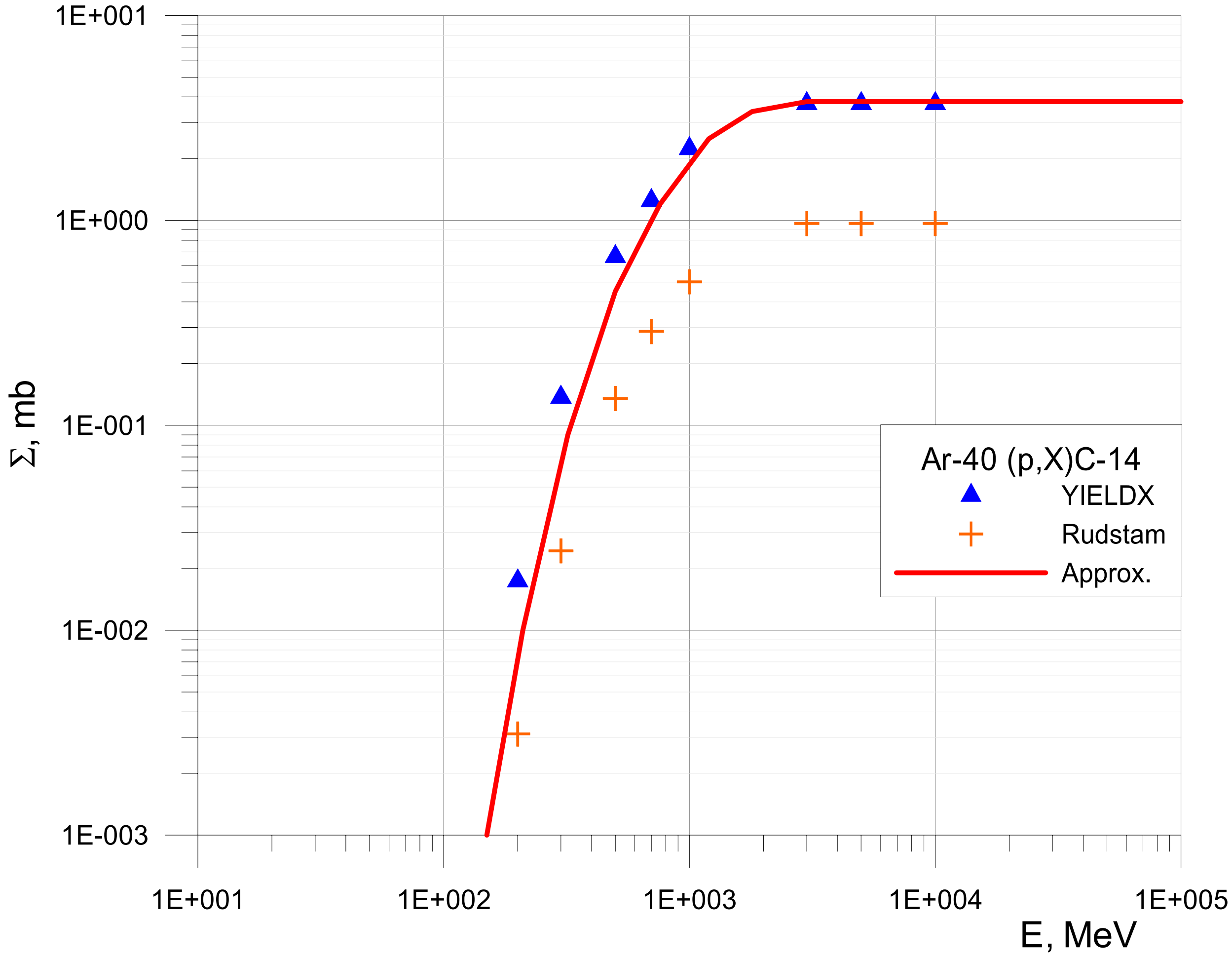
##	E, MeV	Σ, mb
1	38.04	0.000
2	70.8	0.001
3	77.5	0.006
4	85	0.013
5	96	0.025
6	125	0.07
7	144	0.20
8	175	0.48
9	220	1.10
10	320	2.5
11	480	4.5
12	740	6.0
13	1000	7.0
14	1600	8.0
15	3000	9.0
16	10000	9.0
17	100000	9.0
18		
19		



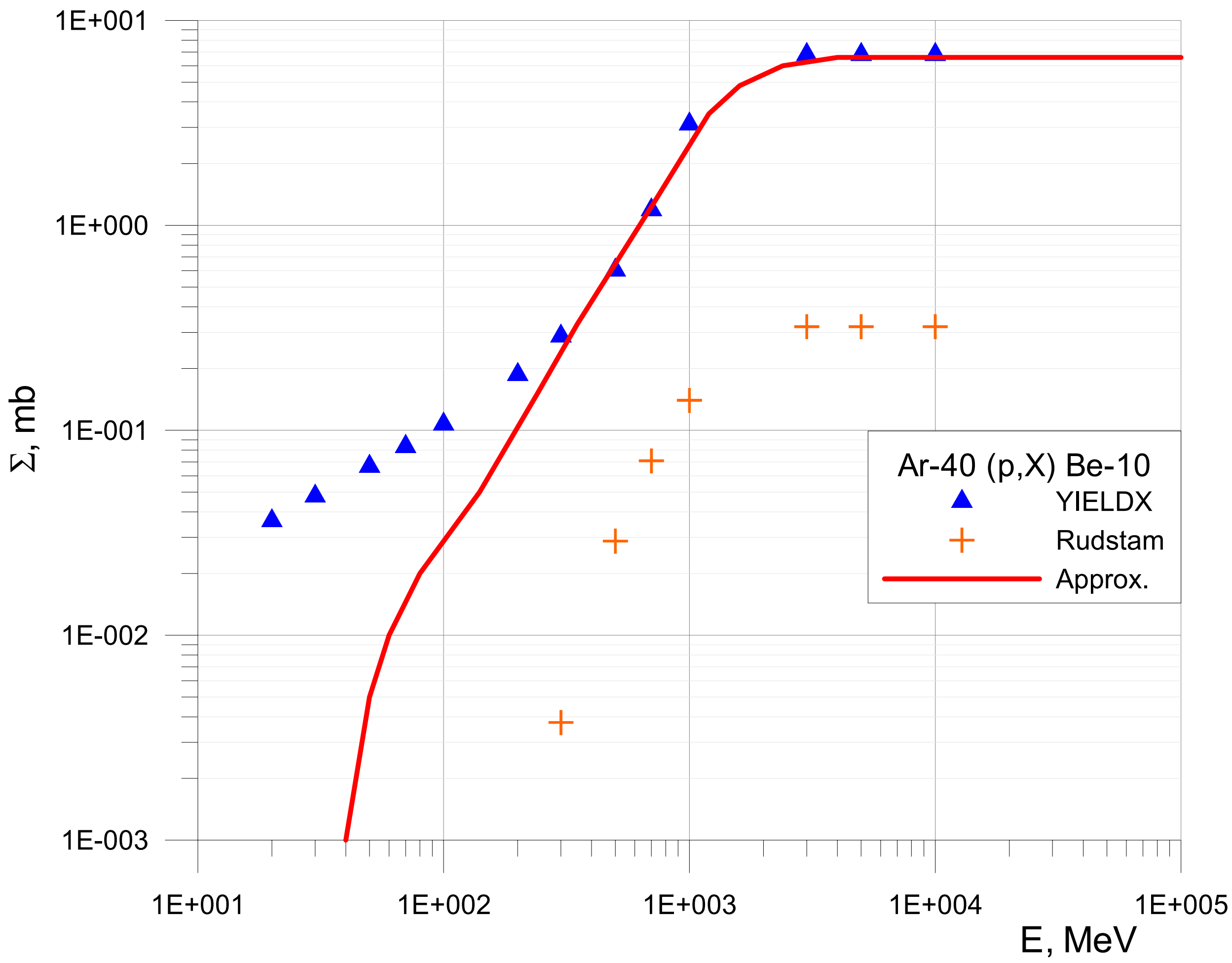
##	E, MeV	Σ, mb
1	69.5	0.000
2	100	0.001
3	115	0.01
4	130	0.04
5	170	0.2
6	250	0.7
7	360	1.4
8	560	2.4
9	1000	3.6
10	1800	4.6
11	3600	5.1
12	10000	5.1
13	100000	5.1
14		
15		
16		
17		
18		
19		



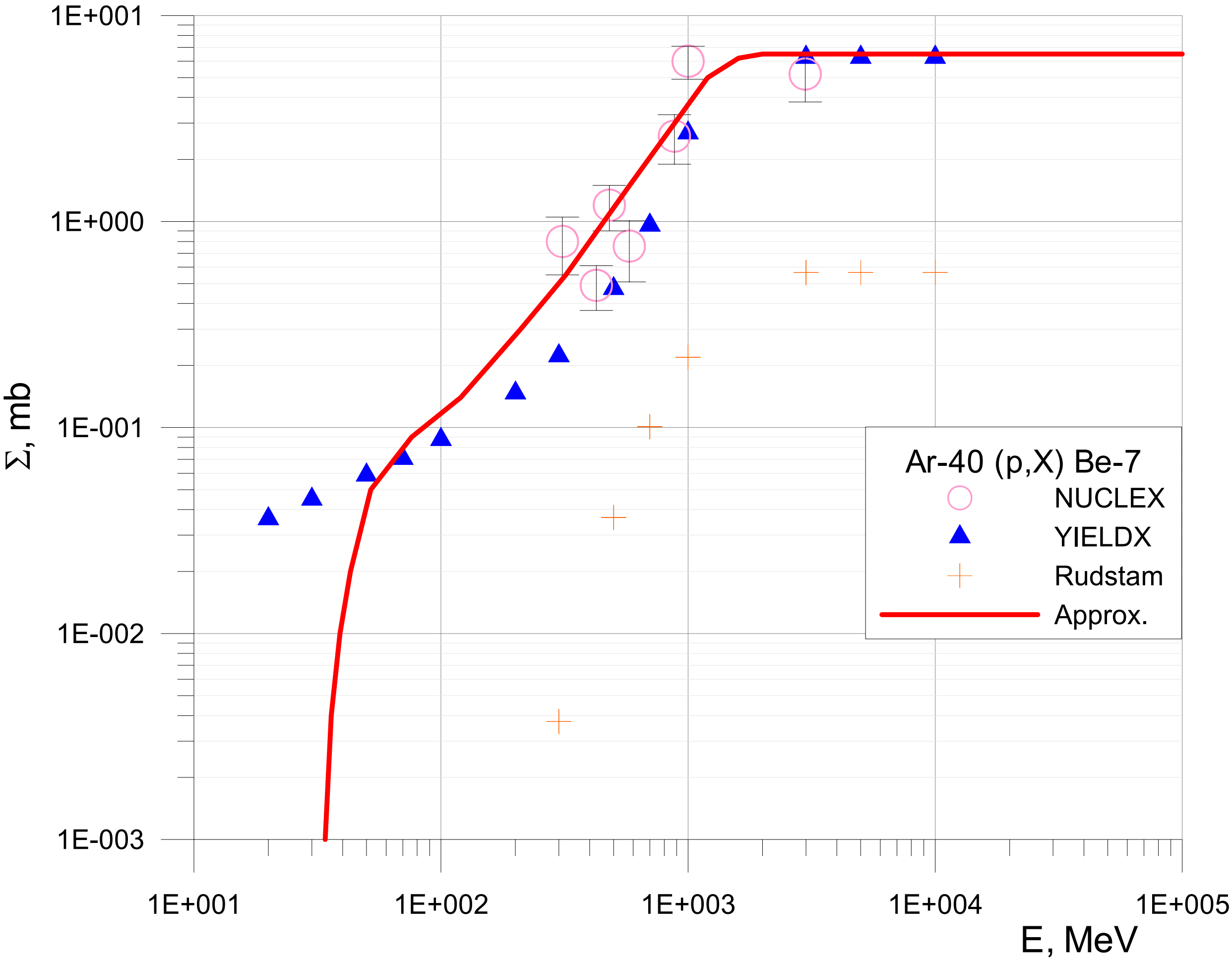
##	E, MeV	Σ, mb
1	100	0.001
2	140	0.01
3	175	0.04
4	230	0.14
5	340	0.6
6	550	1.9
7	760	2.9
8	1400	4.3
9	2100	4.8
10	3200	5.2
11	10000	5.2
12	100000	5.2
13		
14		
15		
16		
17		
18		
19		



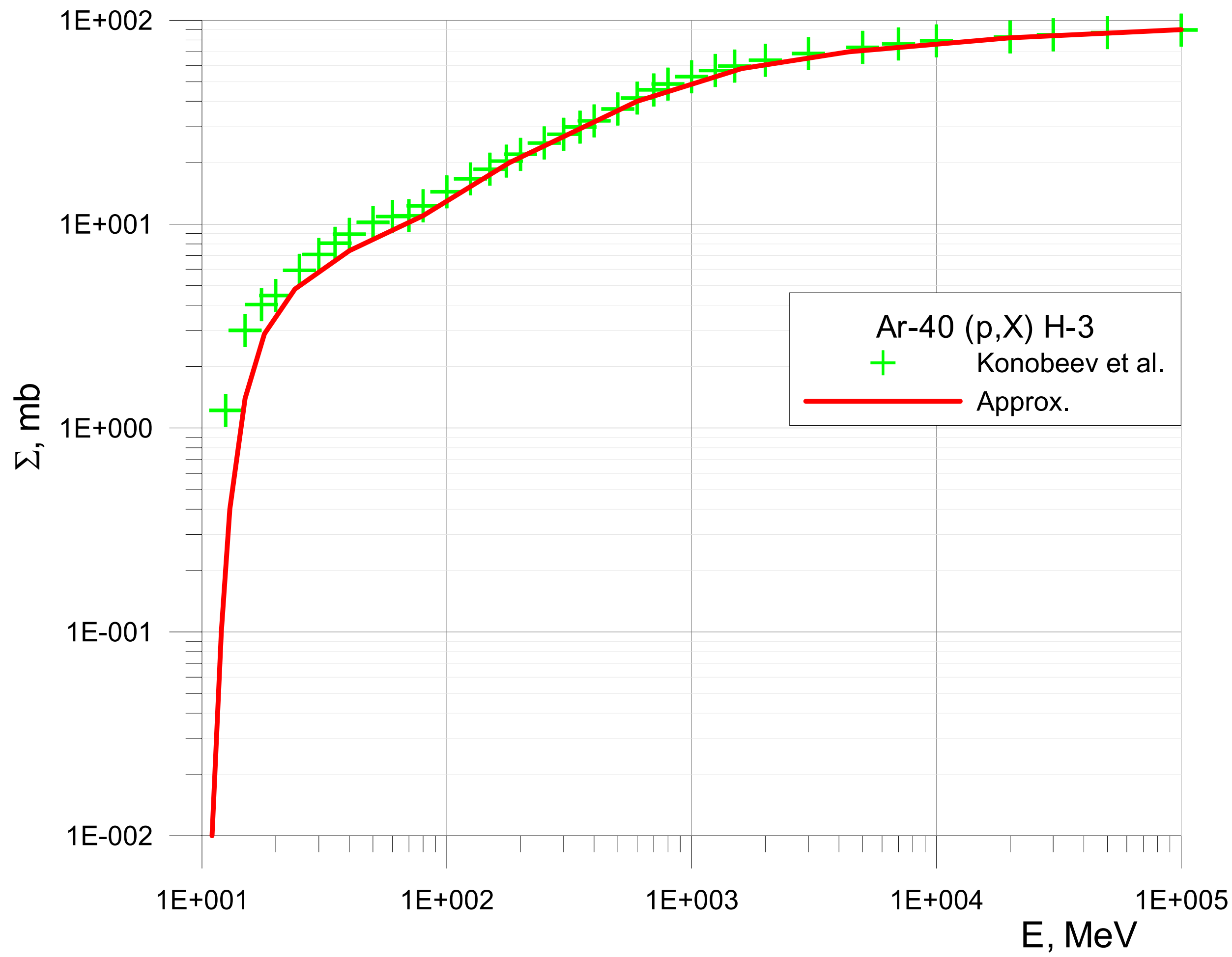
##	E, MeV	Σ, mb
1	150	0.001
2	210	0.01
3	320	0.09
4	500	0.45
5	760	1.2
6	1200	2.5
7	1800	3.4
8	3000	3.8
9	100000	3.8
10		
11		
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	40	0.001
2	50	0.005
3	60	0.01
4	80	0.02
5	140	0.05
6	240	0.15
7	350	0.33
8	720	1.3
9	1200	3.5
10	1600	4.8
11	2400	6.0
12	4000	6.6
13	100000	6.6
14		
15		
16		
17		
18		



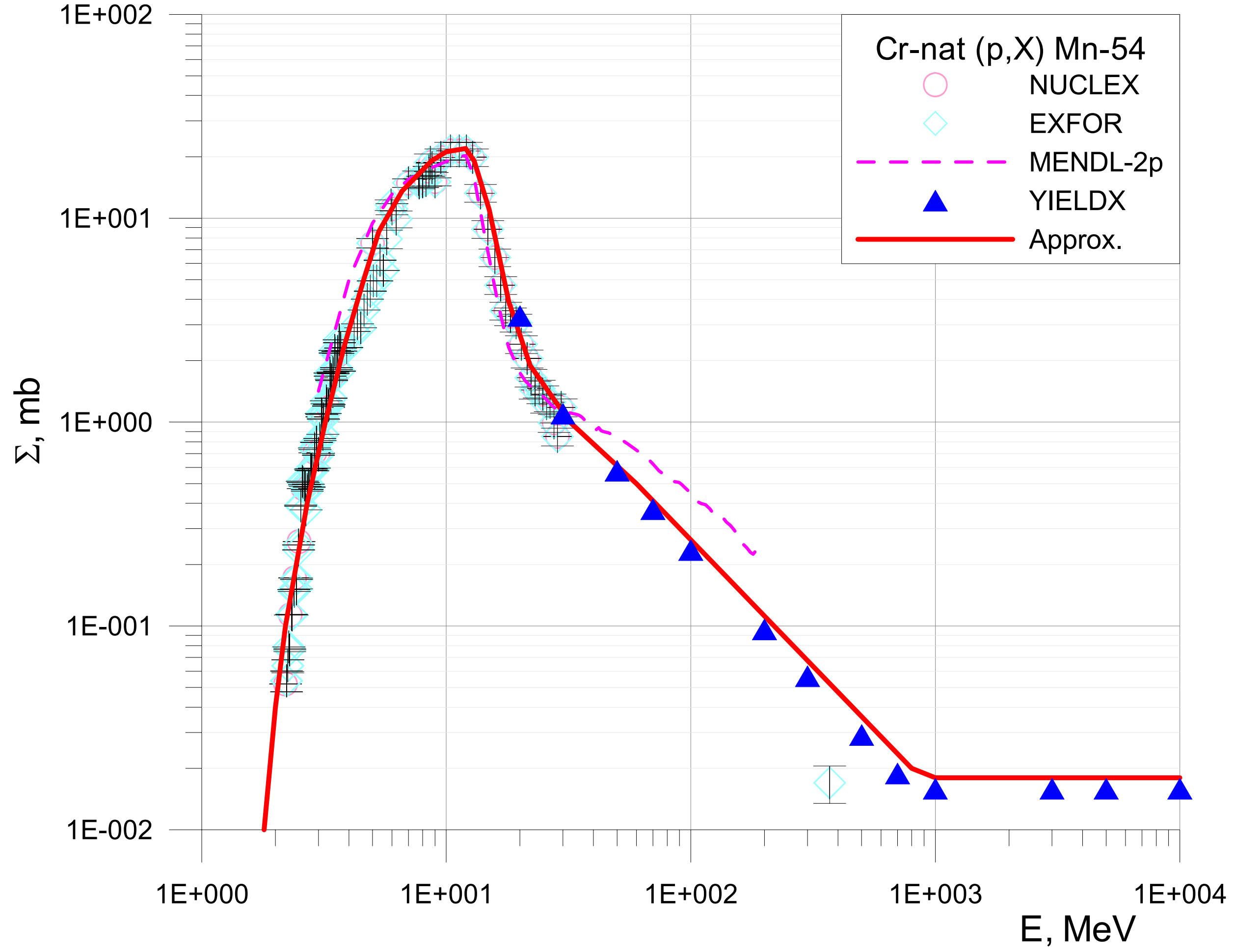
##	E, MeV	Σ, mb
1	34	0.001
2	36	0.004
3	39	0.01
4	43	0.02
5	52	0.05
6	76	0.09
7	120	0.14
8	210	0.3
9	320	0.6
10	580	1.5
11	1200	5.0
12	1600	6.2
13	2000	6.5
14	100000	6.5
15		
16		
17		
18		



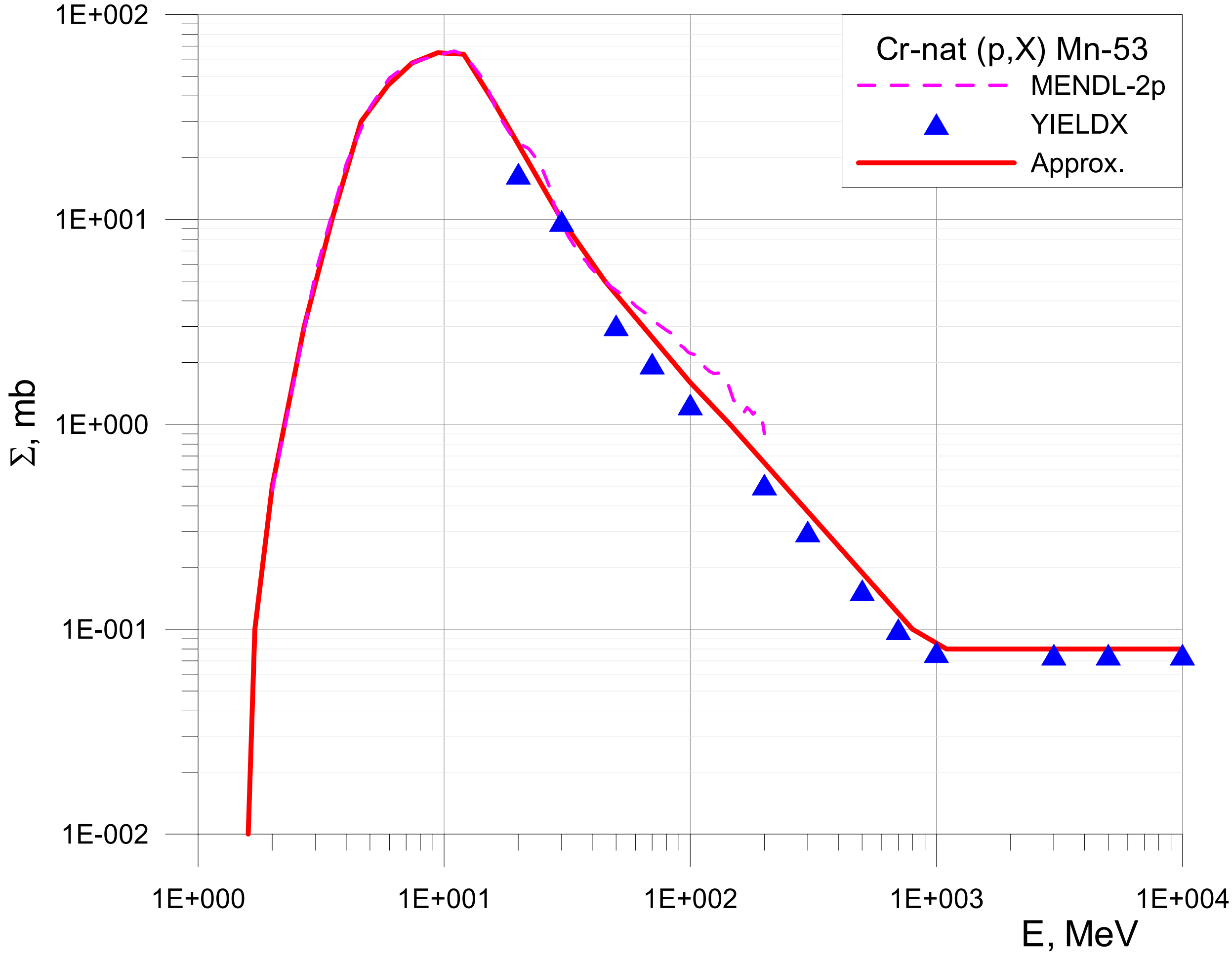
##	E, MeV	Σ, mb
1	8.2	0.00
2	11	0.01
3	12	0.1
4	13	0.4
5	15	1.4
6	18	2.9
7	24	4.8
8	40	7.4
9	80	11
10	180	20
11	600	40
12	1600	58
13	4400	70
14	20000	82
15	100000	90
16		
17		
18		

Summary of experimental and calculation cross-section data used for chromium

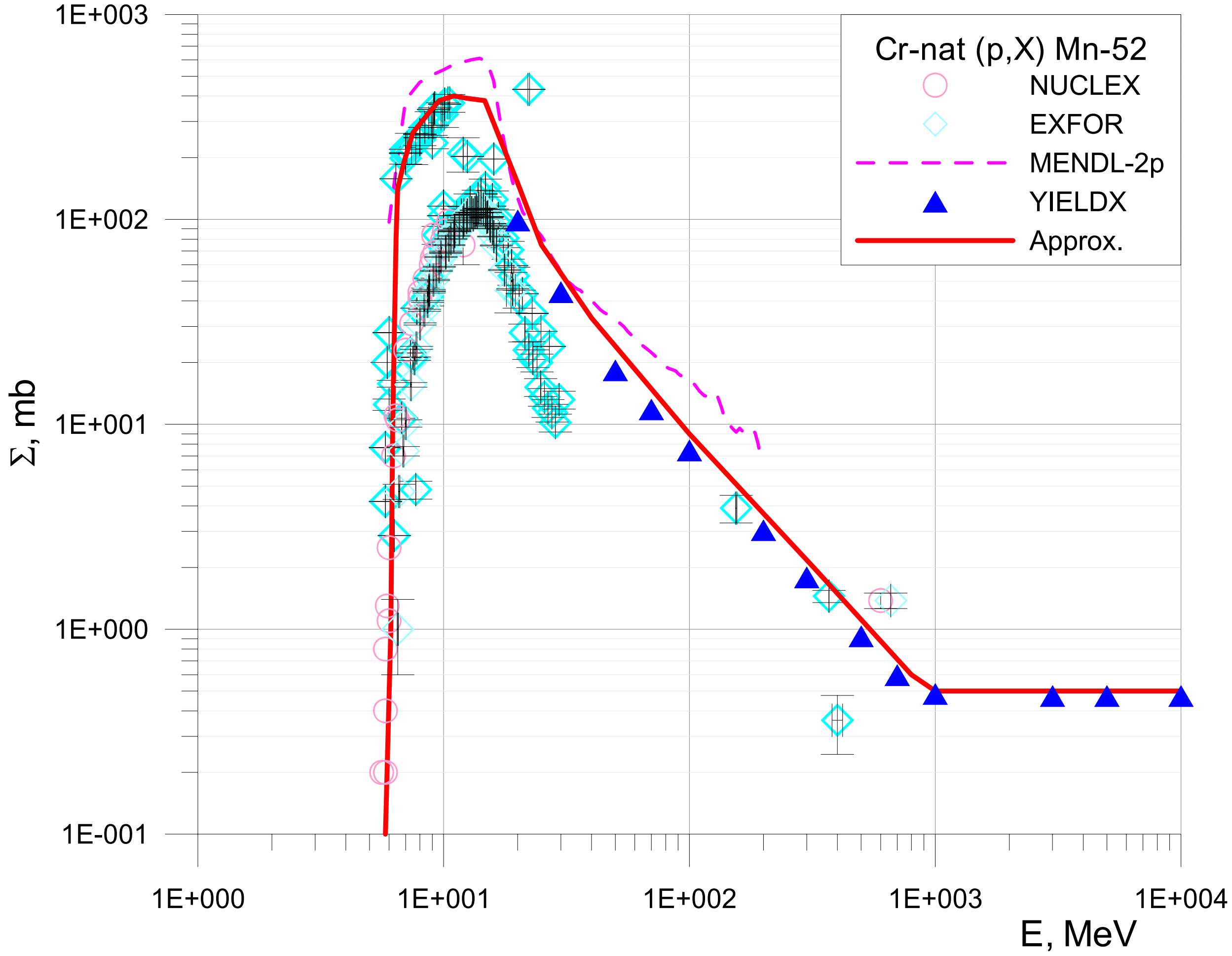
Nuclide	Half-life			Decay Mode	Source			Comment
					Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-				
Be-7	53.22	D	0.06	EC				
Be-10	2E+06	Y	60000	B-				
C-14	5700	Y	30	B-				cum
F-18	109.77	M	0.05	EC				cum
Na-22	2.6019	Y	4E-04	EC		x	x	cum
Na-24	14.959	H	0.001	B-			x	cum
Mg-28	20.915	H	0.009	B-				cum
Al-26	717000	Y	24000	EC				
Si-31	157.3	M	0.3	B-				cum
Si-32	132	Y	13	B-				cum
P-32	14.262	D	0.014	B-				
P-33	25.34	D	0.12	B-				cum
S-35	87.51	D	0.12	B-				cum
S-38	170.3	M	0.7	B-				cum
Cl-36	301000	Y	2000	B-, EC	x			
Ar-37	35.04	D	0.04	EC	x			cum
Ar-39	269	Y	3	B-	x			cum
Ar-41	109.61	M	0.04	B-	x			cum
Ar-42	32.9	Y	1.1	B-	x			cum
K-42	12.36	H	0.012	B-	x			
K-43	22.3	H	0.1	B-	x	x	x	cum
Ca-41	102000	Y	7000	EC	x			cum
Ca-45	162.61	D	0.09	B-	x			cum
Ca-47	4.536	D	0.003	B-	x	x	x	cum
Sc-43	3.891	H	0.012	EC	x			cum
Sc-44	3.97	H	0.04	EC	x			
Sc-44m	58.61	H	0.1	IT, EC	x			
Sc-46	83.79	D	0.04	B-	x	x	x	
Sc-47	3.3492	D	6E-04	B-	x	x	x	
Sc-48	43.67	H	0.09	B-	x	x	x	
Ti-44	60	Y	1.1	EC	x			cum
Ti-45	184.8	M	0.5	EC	x		x	cum
V-48	15.974	D	0.003	EC	x	x	x	
V-49	330	D	15	EC	x			cum
Cr-48	21.56	H	0.03	EC	x	x	x	cum
Cr-51	27.703	D	0.002	EC	x	x	x	cum
Mn-52g	5.591	D	0.003	EC	x	x	x	cum
Mn-53	4E+06	Y	40000	EC	x			
Mn-54	312.12	D	0.06	EC	x	x	x	



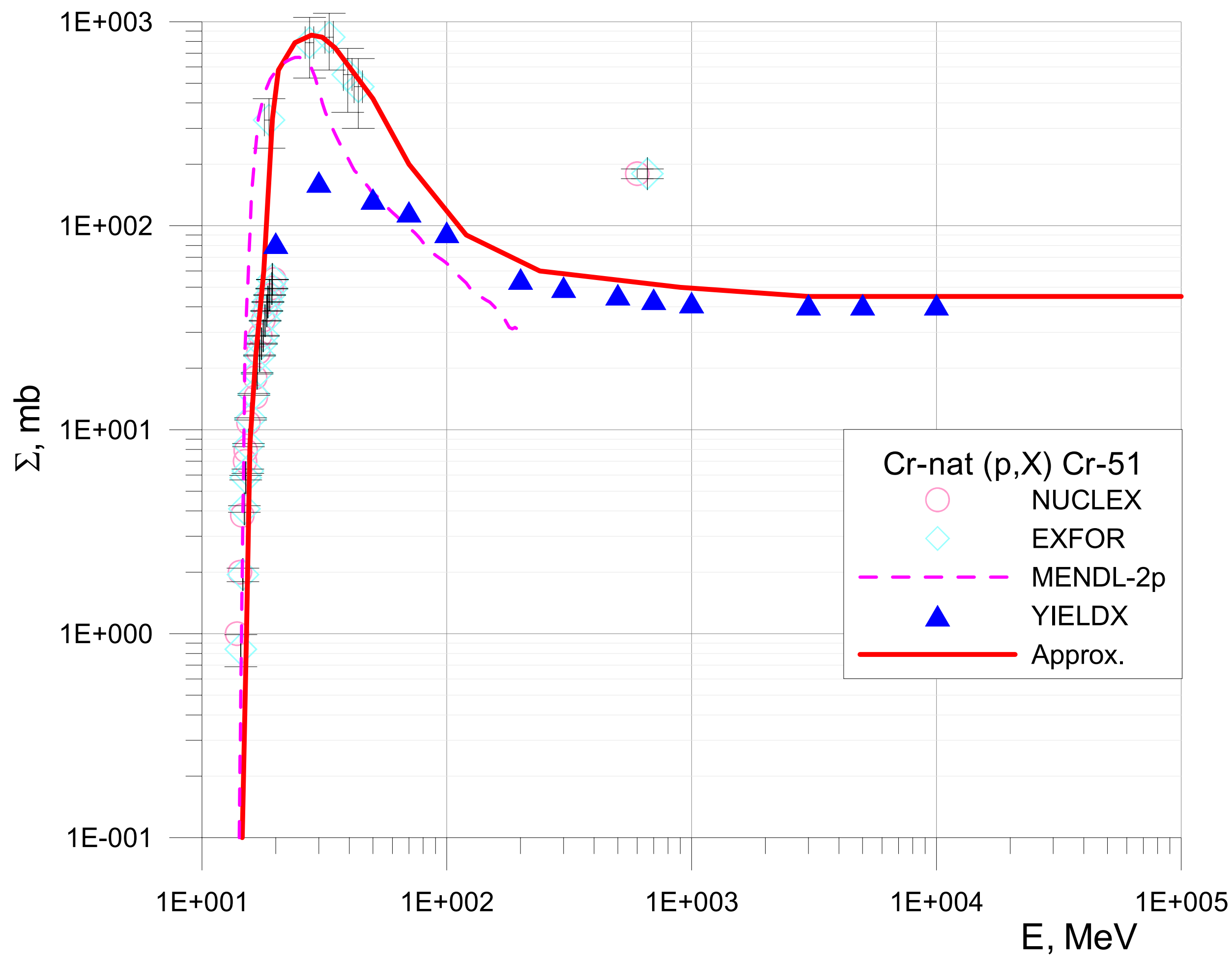
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	1.8	0.01	19	150	0.16
2	2.0	0.04	20	800	0.020
3	2.2	0.10	21	1000	0.018
4	2.7	0.40	22	10000	0.018
5	3.2	1.00	23	100000	0.018
6	3.8	2.30	24		
7	4.6	5.00	25		
8	5.3	8.60	26		
9	6.6	13.6	27		
10	8.7	19.1			
11	10	21.2			
12	12	22.0			
13	13	19.1			
14	15	11.0			
15	18	3.90			
16	22	1.90			
17	32	1.00			
18	60	0.50			



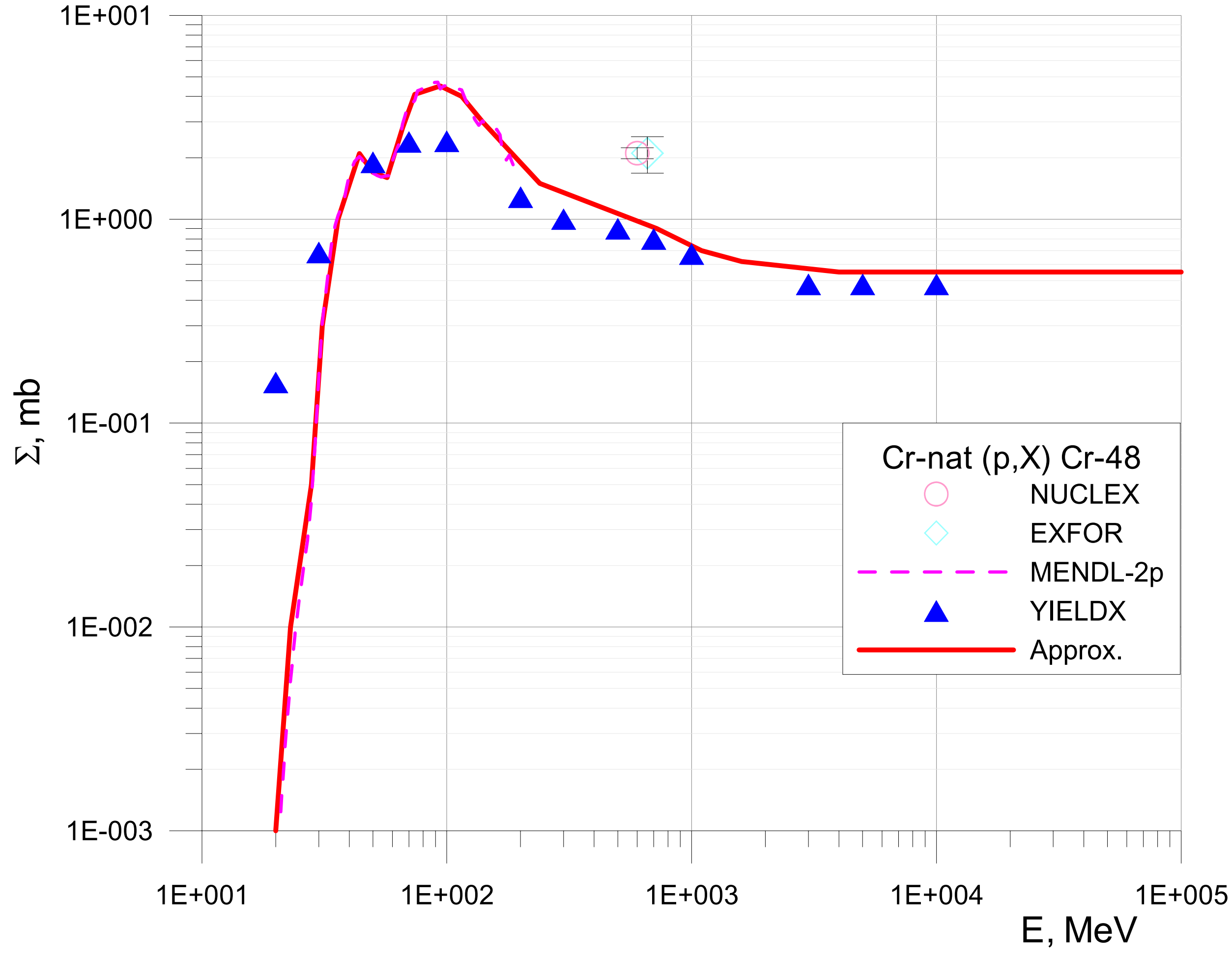
##	E, MeV	Σ, mb
1	1.6	0.01
2	1.7	0.10
3	2.0	0.50
4	2.7	3.00
5	3.5	10
6	4.6	30
7	5.9	45
8	7.4	58
9	9.4	65
10	12	64
11	16	37
12	30	10
13	45	5.0
14	100	1.6
15	145	1.0
16	800	0.10
17	1100	0.08
18	10000	0.08
19	100000	0.08



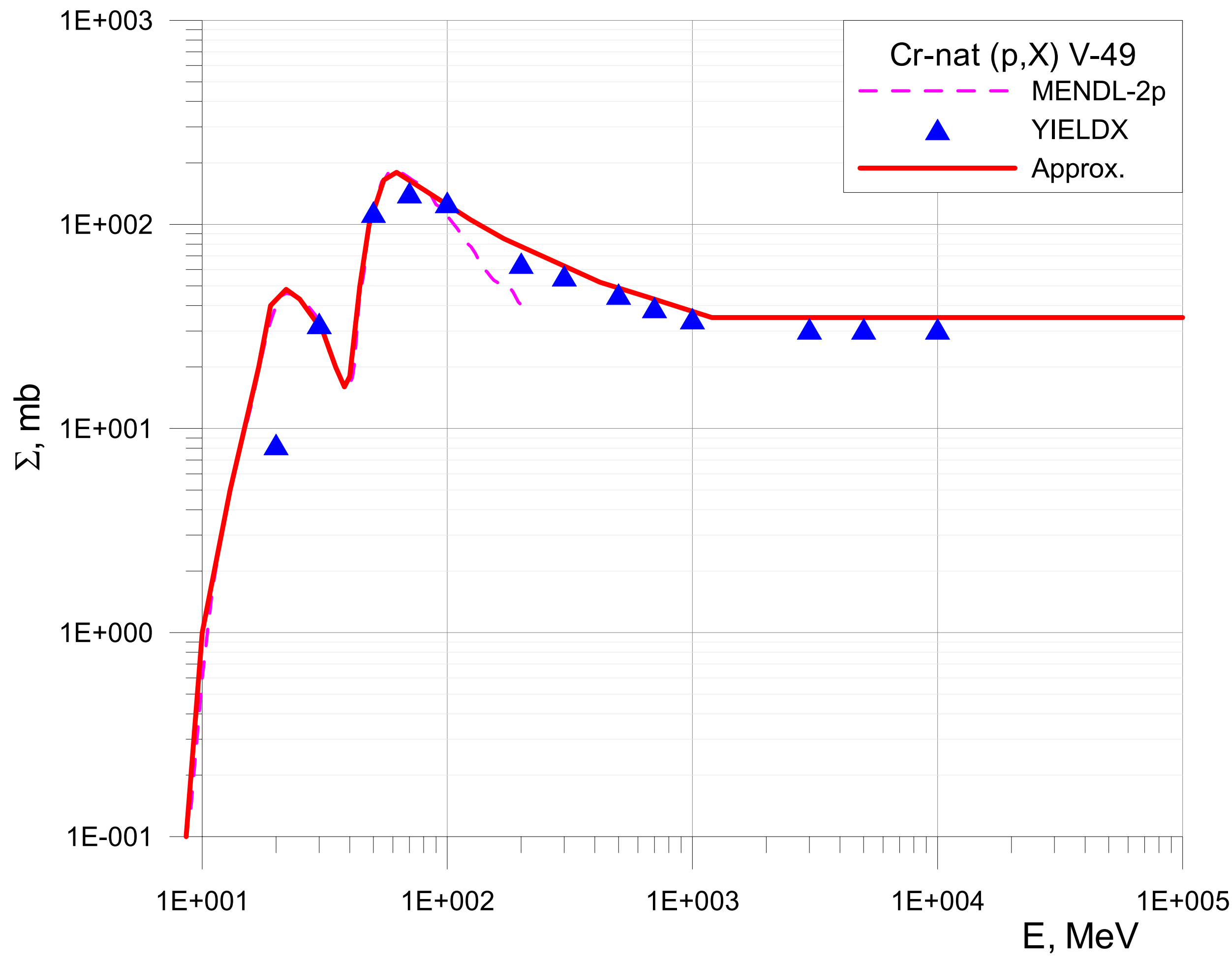
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	5.6	0.00	19	800	0.6
2	5.8	0.1	20	1000	0.5
3	6.1	1.0	21	10000	0.5
4	6.2	10	22	100000	0.5
5	6.4	80	23		
6	6.5	140	24		
7	6.9	190	25		
8	7.5	265	26		
9	8.7	330	27		
10	9.6	380			
11	11.0	400			
12	12.4	390			
13	14.7	380			
14	20	150			
15	25	75			
16	40	33			
17	100	9.0			
18	320	2.0			



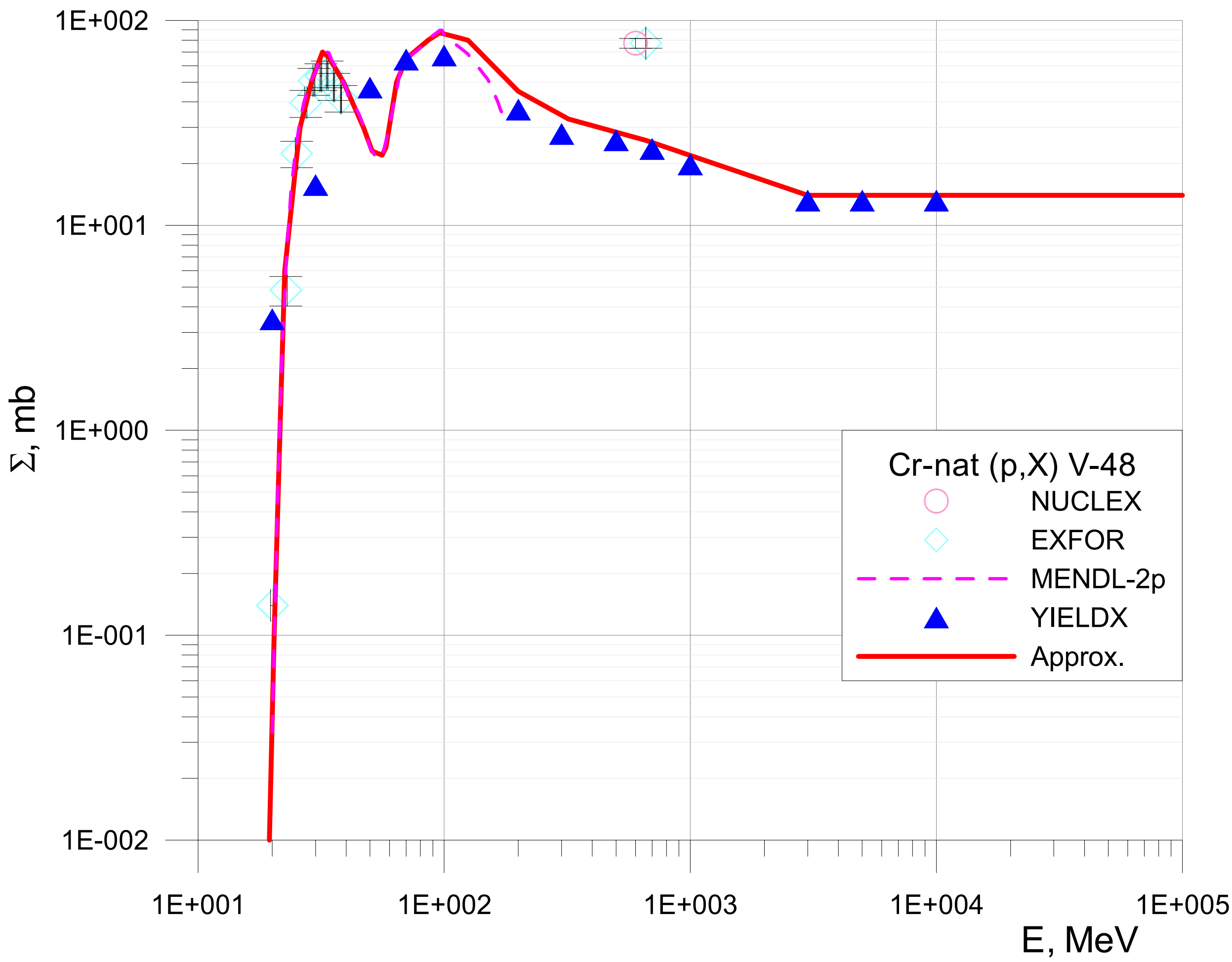
##	E, MeV	Σ, mb
1	10.0	0.00
2	14.6	0.10
3	15.2	1.0
4	15.7	8.5
5	16.6	23
6	17.9	60
7	19.4	335
8	20.5	580
9	24	790
10	28	860
11	31	840
12	35	745
13	50	420
14	70	200
15	120	90
16	240	60
17	900	50
18	3000	45
19	100000	45



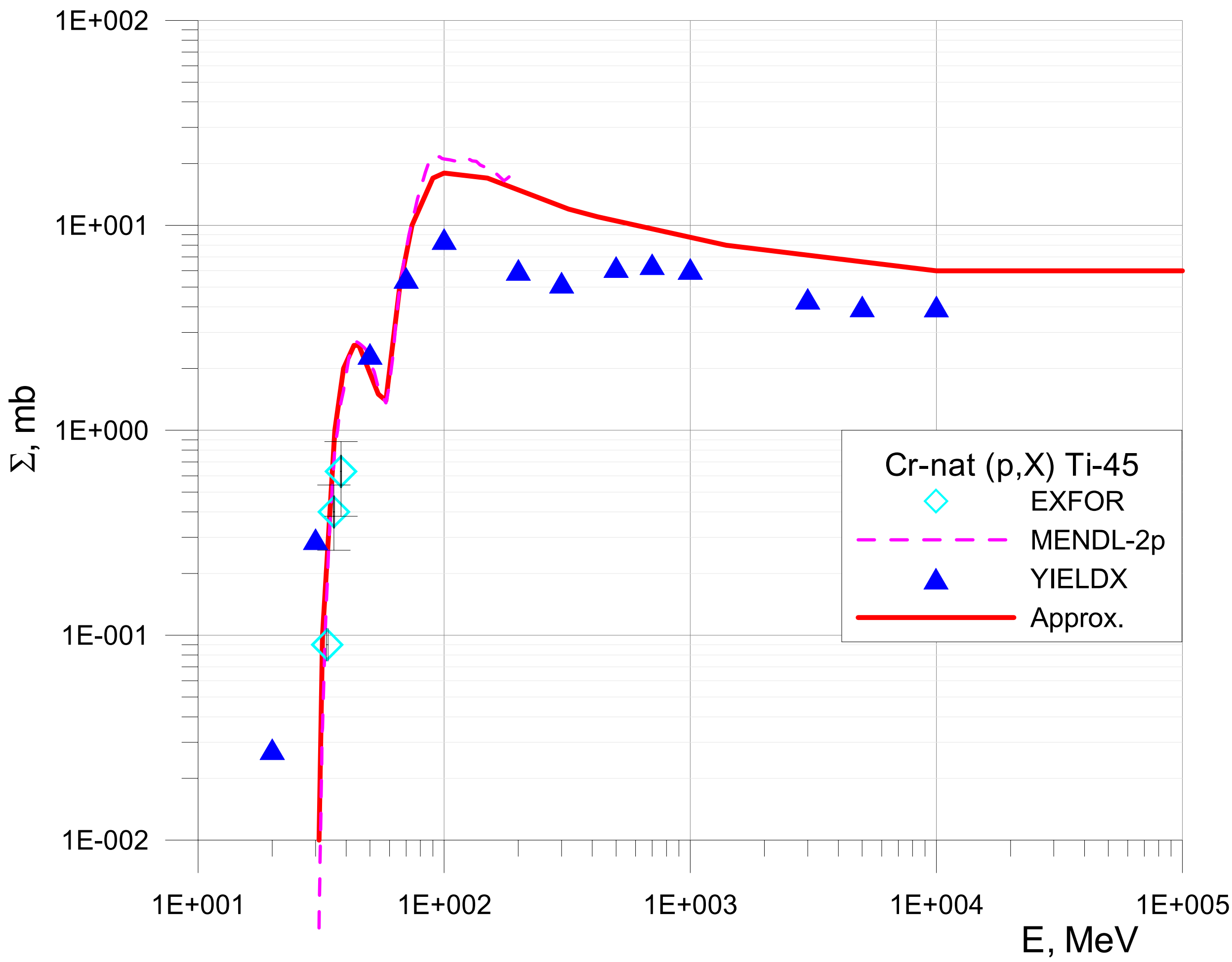
##	E, MeV	Σ, mb
1	15.4	0.000
2	20	0.001
3	23	0.01
4	28	0.05
5	31	0.30
6	36	1.0
7	44	2.1
8	50	1.7
9	57	1.6
10	66	2.8
11	74	4.1
12	94	4.5
13	115	4.0
14	140	3.0
15	240	1.5
16	720	0.9
17	1100	0.7
18	1600	0.62
19	4000	0.55
20	100000	0.55



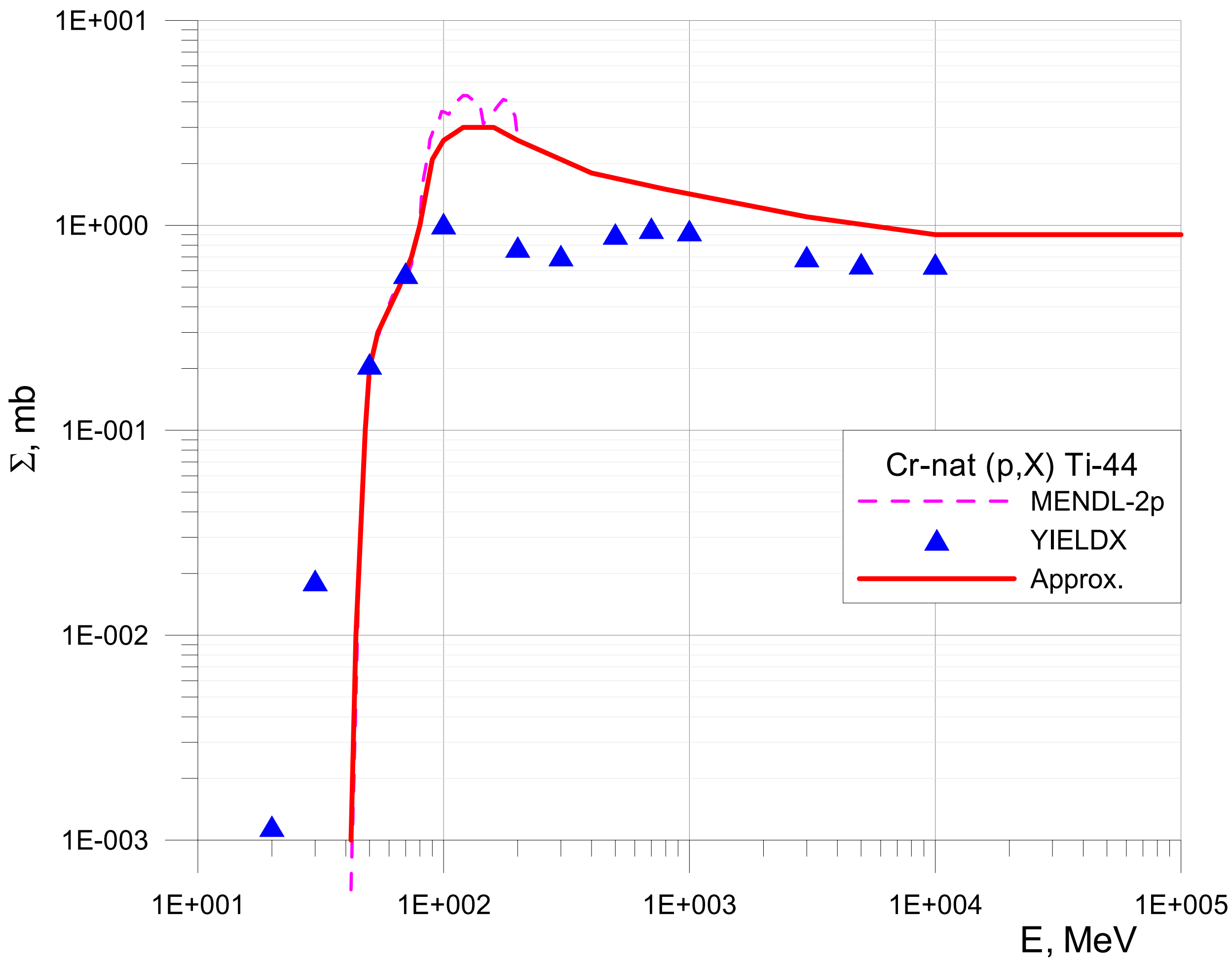
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	2.64	0.0000	19	125	105
2	6.95	0.0005	20	170	85
3	8.6	0.10	21	420	52
4	10	1.0	22	660	44
5	13	5.0	23	1200	35
6	17	20	24	10000	35
7	19	40	25	100000	35
8	22	48	26		
9	25	43	27		
10	31	30			
11	35	20			
12	38	16			
13	40	18			
14	44	50			
15	48	100			
16	55	165			
17	62	180			
18	86	140			



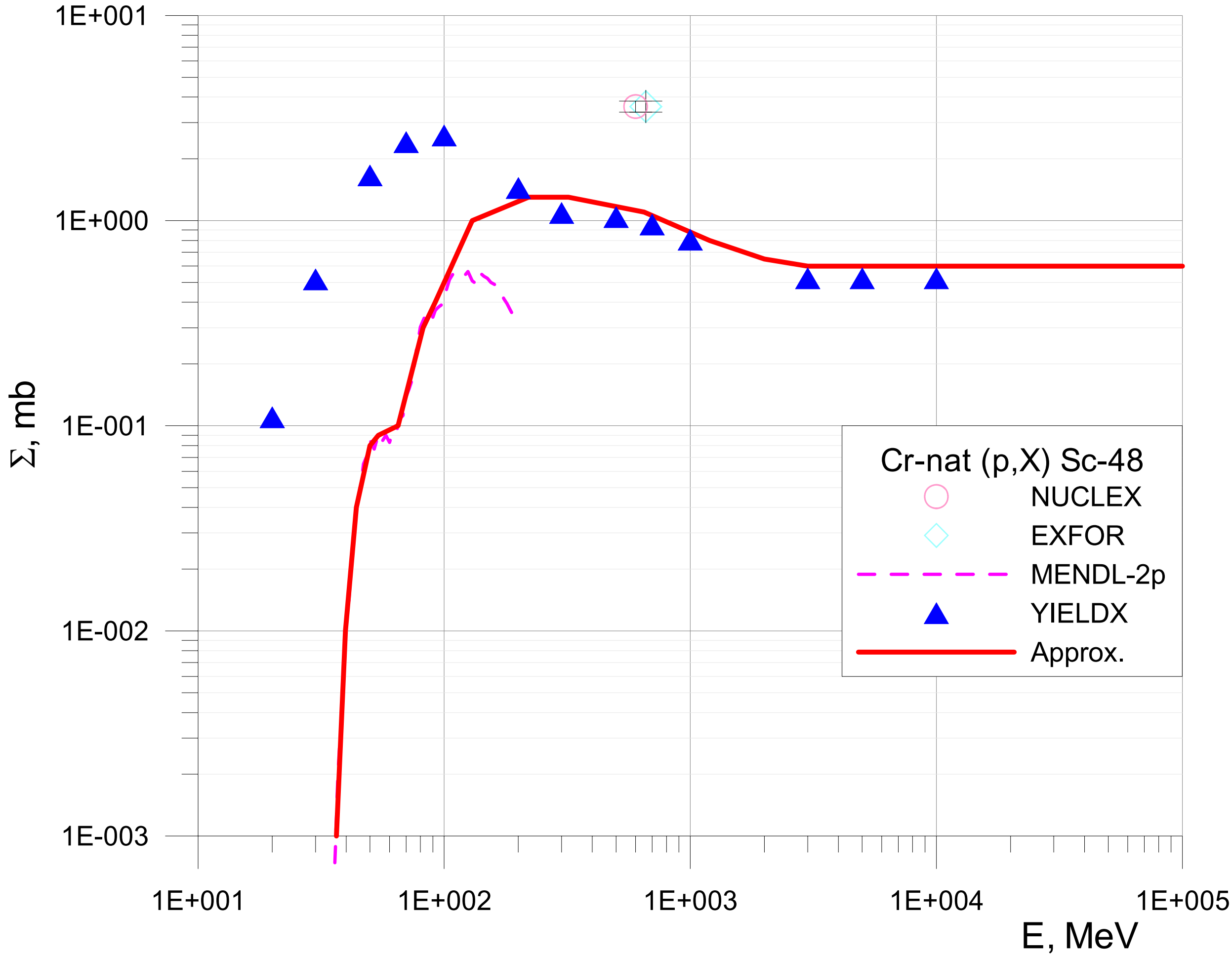
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	13.7	0.00	19	96	87
2	19.5	0.01	20	125	80
3	20.4	0.10	21	200	45
4	21.5	1.0	22	320	33
5	22.5	6.0	23	660	26
6	25	20	24	3000	14
7	26	30	25	100000	14
8	29	51	26		
9	32	70	27		
10	34	66			
11	39	50			
12	47	30			
13	51	23			
14	56	22			
15	58	24			
16	64	50			
17	70	65			
18	86	80			



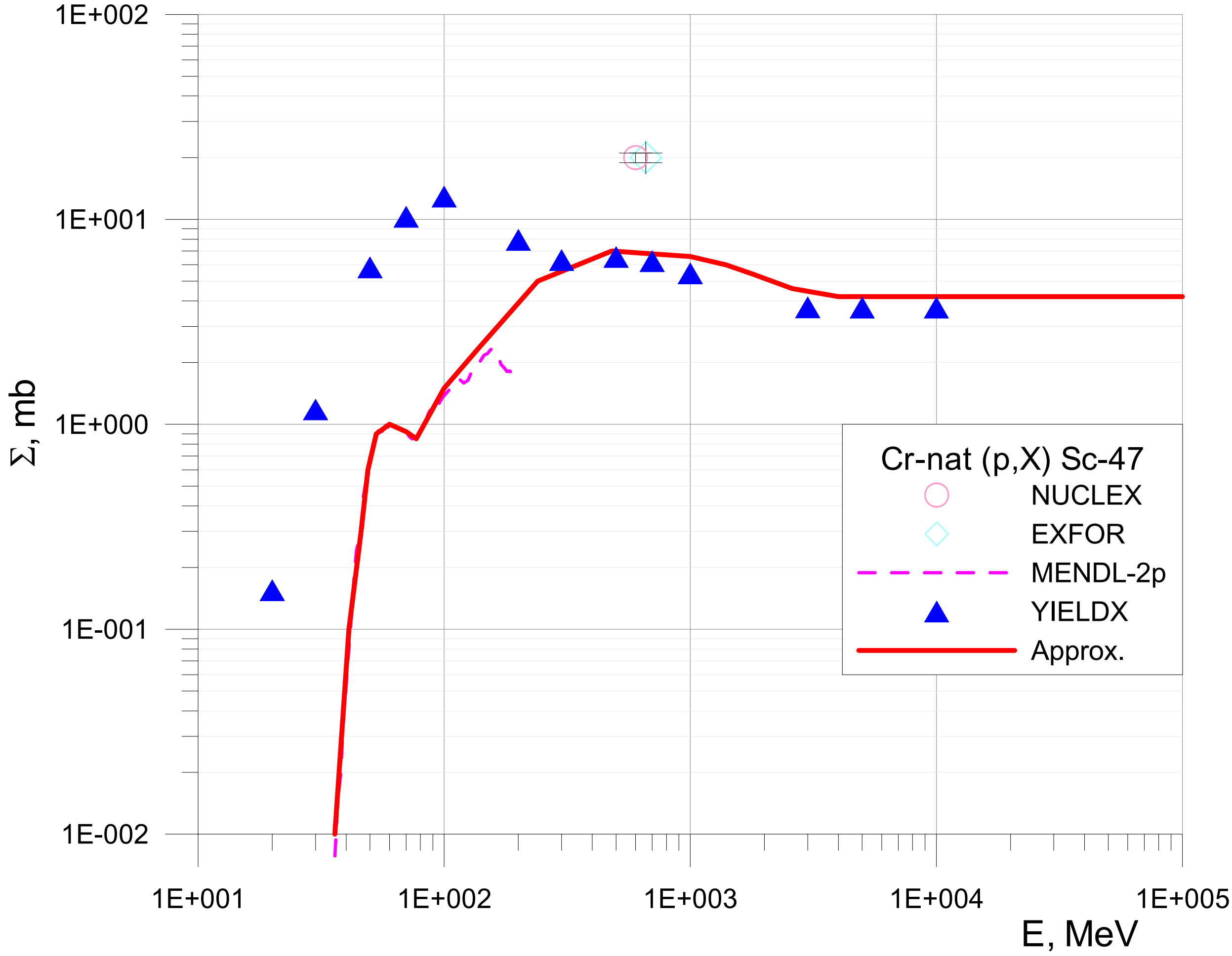
##	E, MeV	Σ, mb
1	19.9	0.00
2	31	0.01
3	32	0.1
4	36	1.0
5	39	2.0
6	43	2.6
7	45	2.6
8	54	1.5
9	58	1.4
10	66	5.0
11	74	10
12	90	17
13	100	18
14	150	17
15	320	12
16	420	11
17	1400	8.0
18	10000	6.0
19	100000	6.0



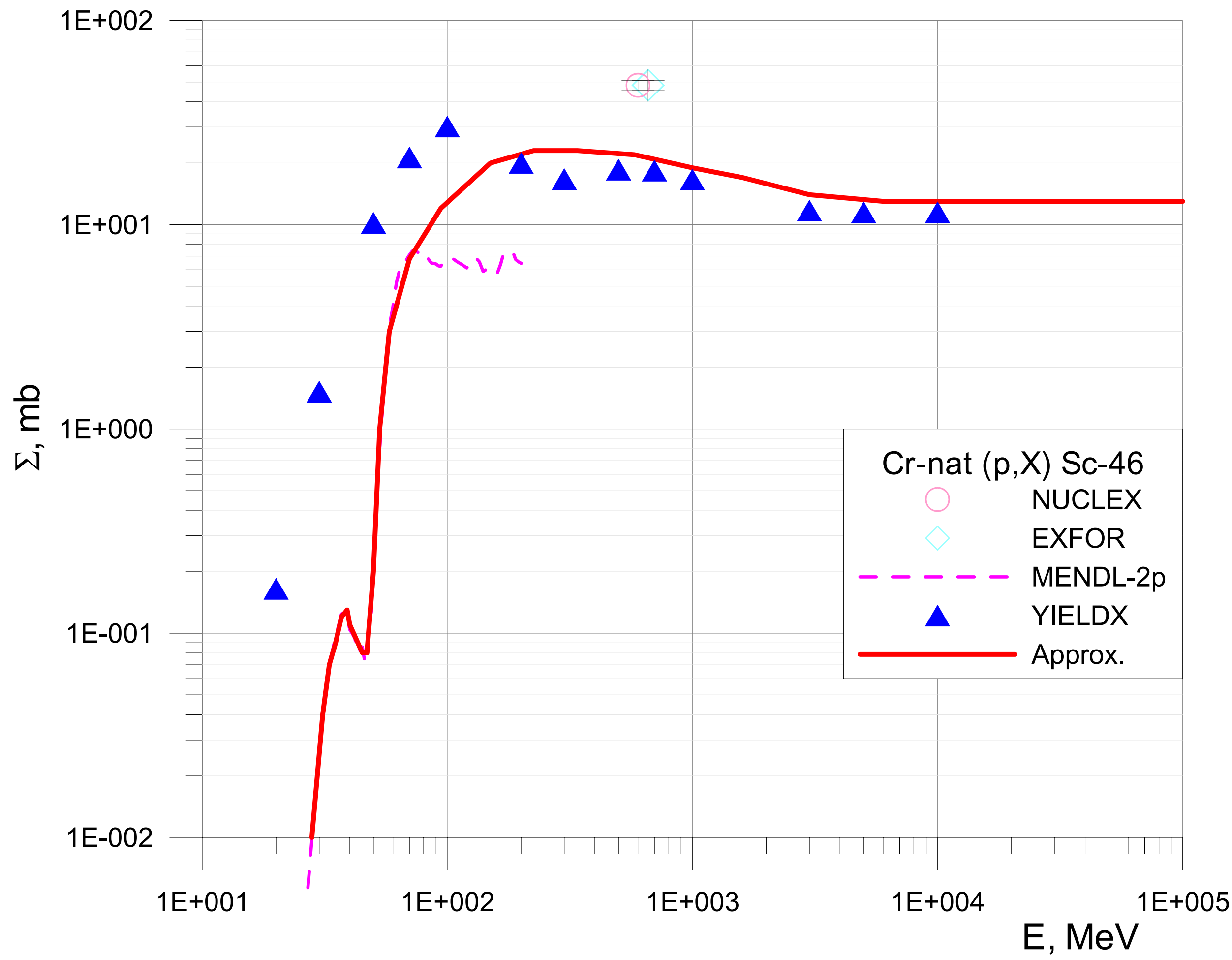
##	E, MeV	Σ, mb
1	23.3	0.000
2	42	0.001
3	44	0.01
4	48	0.1
5	50	0.2
6	54	0.3
7	66	0.5
8	74	0.7
9	80	1.0
10	90	2.1
11	100	2.6
12	110	2.8
13	120	3.0
14	160	3.0
15	200	2.6
16	400	1.8
17	800	1.5
18	3000	1.1
19	10000	0.9
20	100000	0.9



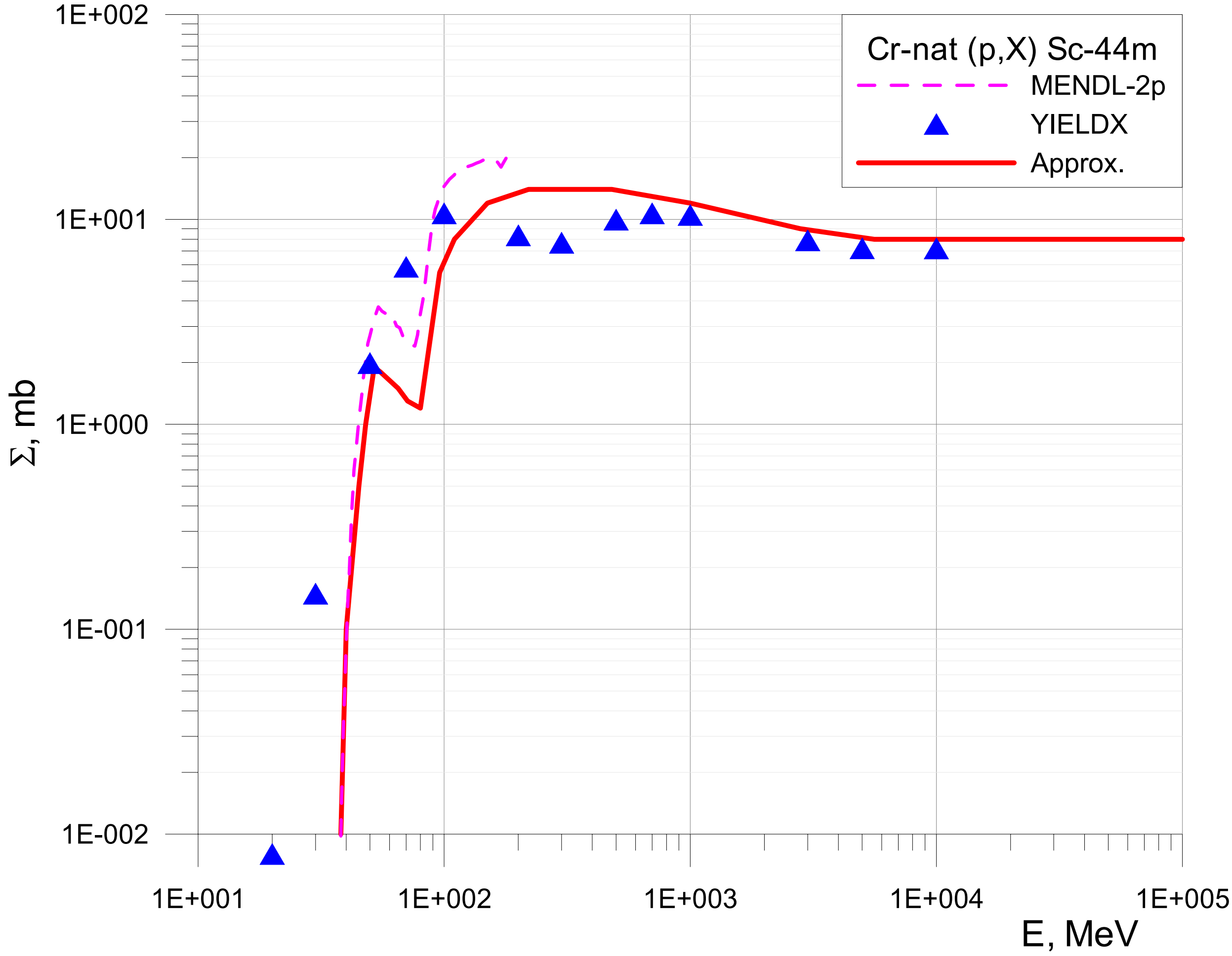
##	E, MeV	Σ, mb
1	20.9	0.000
2	36.5	0.001
3	39.7	0.01
4	44	0.04
5	50	0.08
6	54	0.09
7	65	0.1
8	82	0.3
9	92	0.4
10	130	1.0
11	220	1.3
12	320	1.3
13	650	1.1
14	1200	0.8
15	2000	0.7
16	3000	0.6
17	100000	0.6
18		



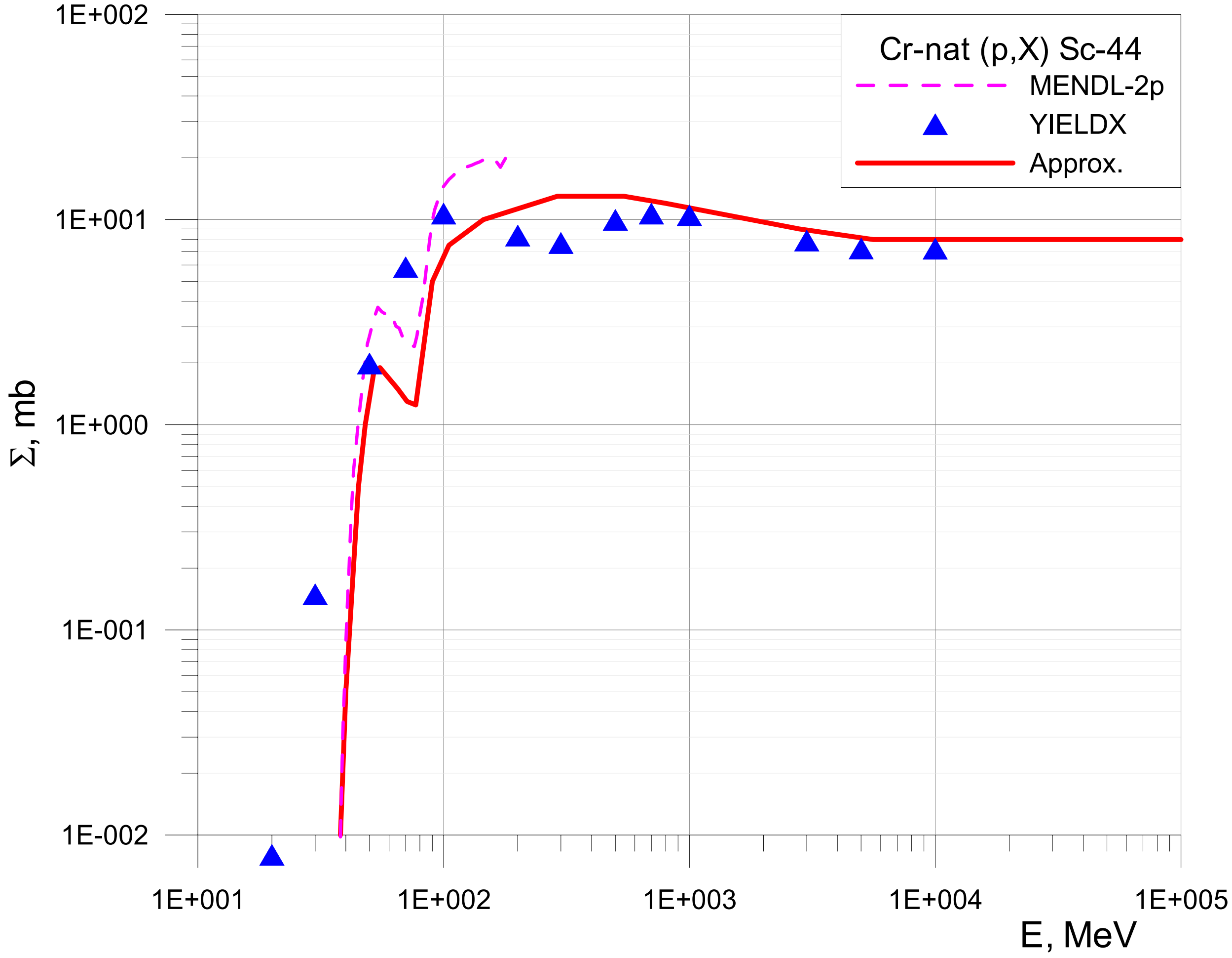
##	E, MeV	Σ, mb
1	10.4	0.00
2	36	0.01
3	41	0.10
4	46	0.30
5	49	0.60
6	53	0.90
7	60	1.00
8	70	0.92
9	77	0.85
10	100	1.5
11	140	2.4
12	240	5.0
13	480	7.0
14	680	6.8
15	1000	6.6
16	1400	6.0
17	1800	5.4
18	2600	4.6
19	4000	4.2
20	100000	4.2



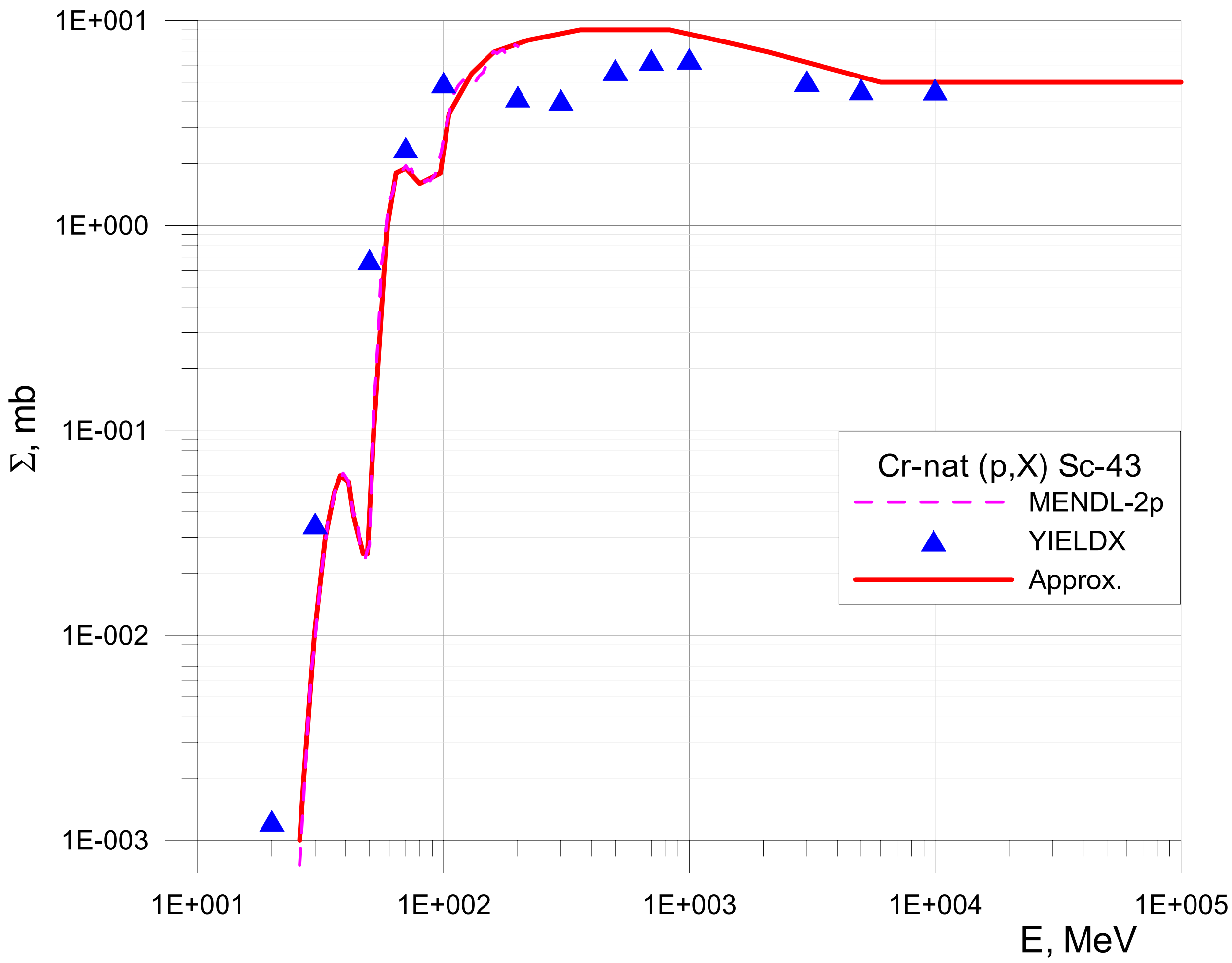
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	11.3	0.00	19	580	22
2	28	0.01	20	1000	19
3	31	0.04	21	1600	17
4	33	0.07	22	3000	14
5	35	0.09	23	6000	13
6	37	0.12	24	100000	13
7	39	0.13	25		
8	40	0.11	26		
9	45	0.08	27		
10	47	0.08			
11	50	0.20			
12	53	1.0			
13	58	3.0			
14	70	6.8			
15	94	12			
16	150	20			
17	225	23			
18	340	23			



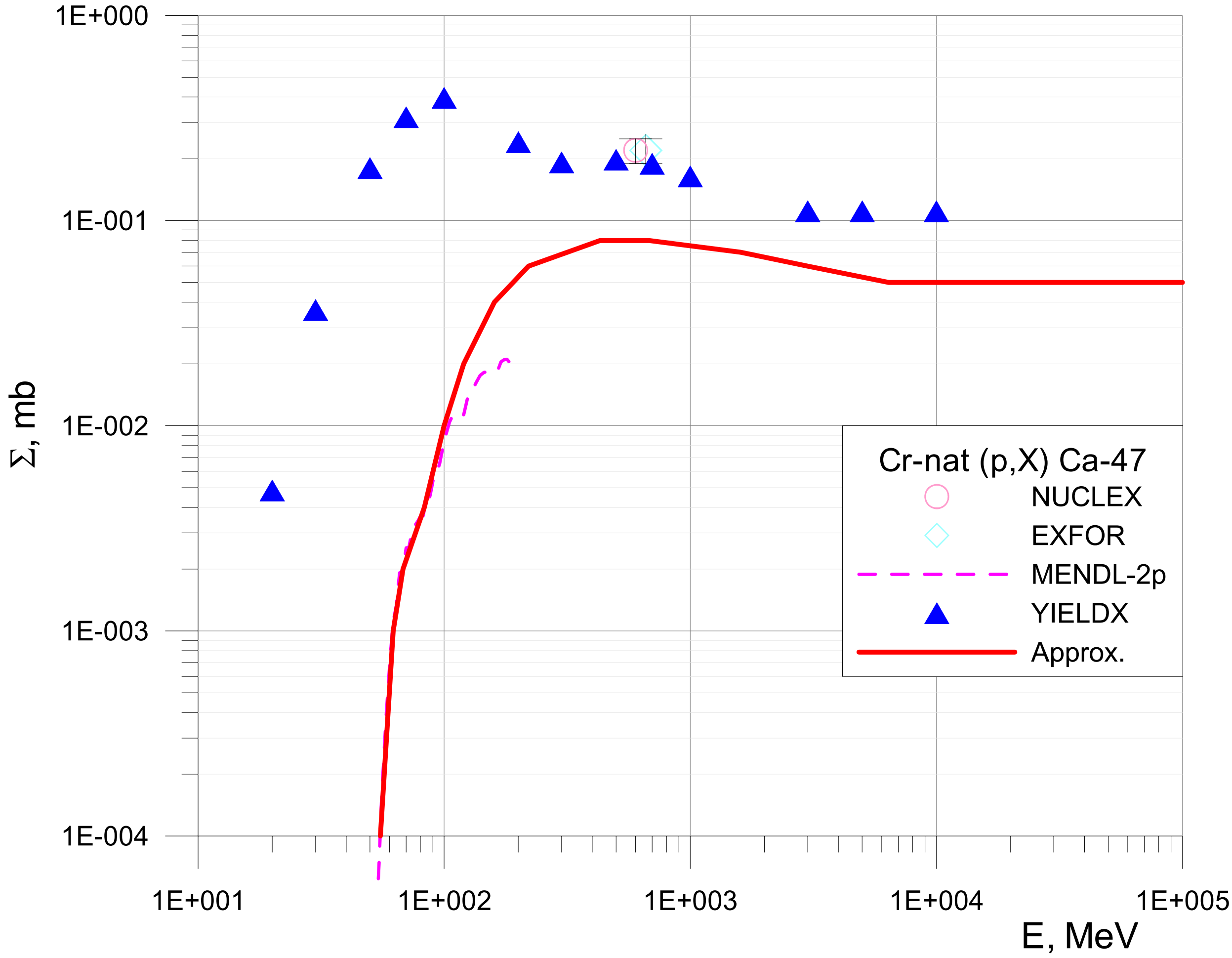
##	E, MeV	Σ, mb
1	23	0.00
2	38	0.01
3	40	0.10
4	45	0.5
5	48	1.0
6	52	1.9
7	55	1.8
8	65	1.5
9	71	1.3
10	80	1.2
11	96	5.5
12	110	8.0
13	150	12
14	220	14
15	480	14
16	1000	12
17	2800	9
18	5600	8
19	100000	8



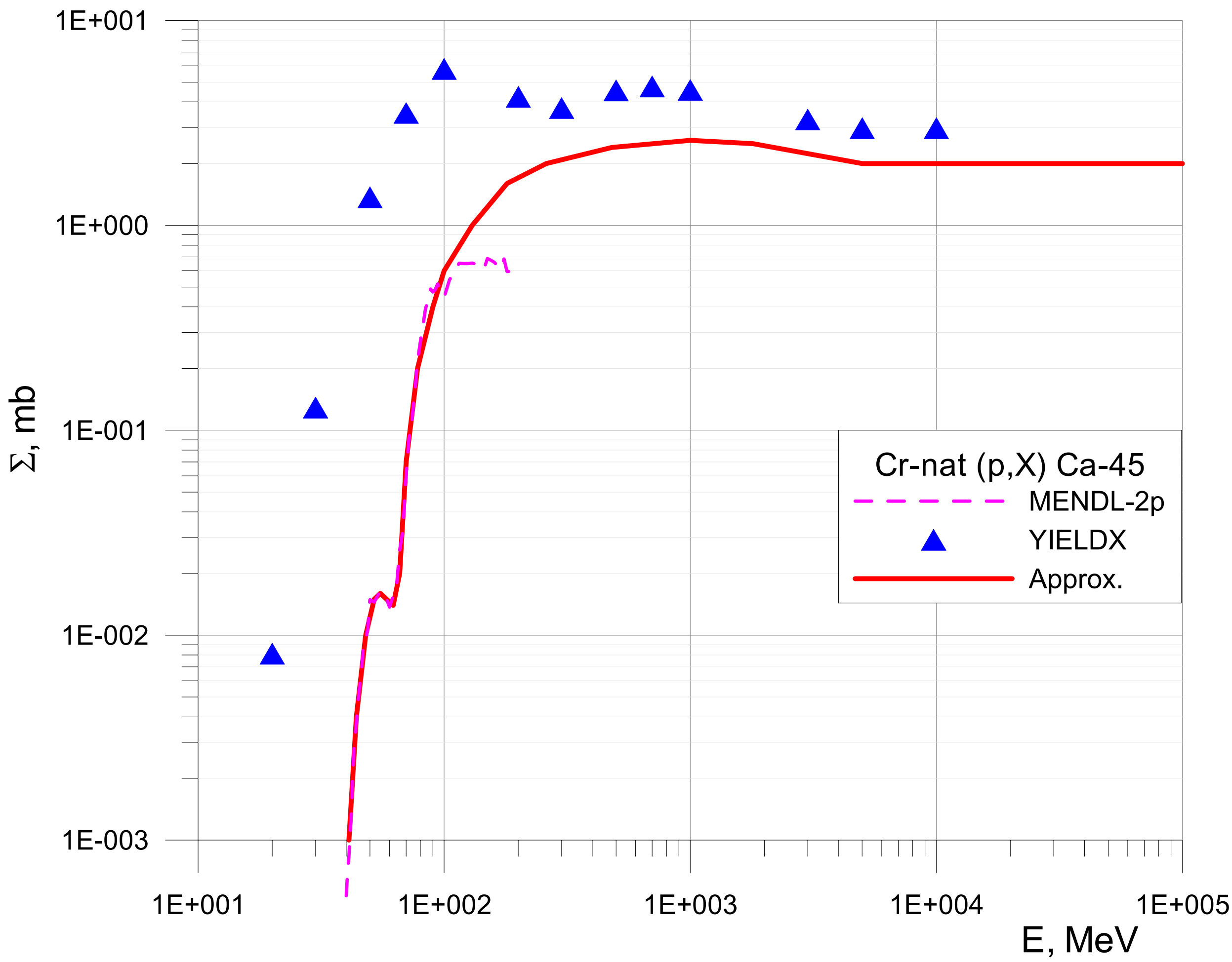
##	E, MeV	Σ, mb
1	23	0.00
2	38	0.01
3	40	0.05
4	45	0.5
5	48	1.0
6	52	1.8
7	55	1.9
8	65	1.5
9	71	1.3
10	77	1.3
11	90	5.0
12	105	8.0
13	145	10
14	290	13
15	540	13
16	800	12
17	2800	9
18	5600	8
19	100000	8



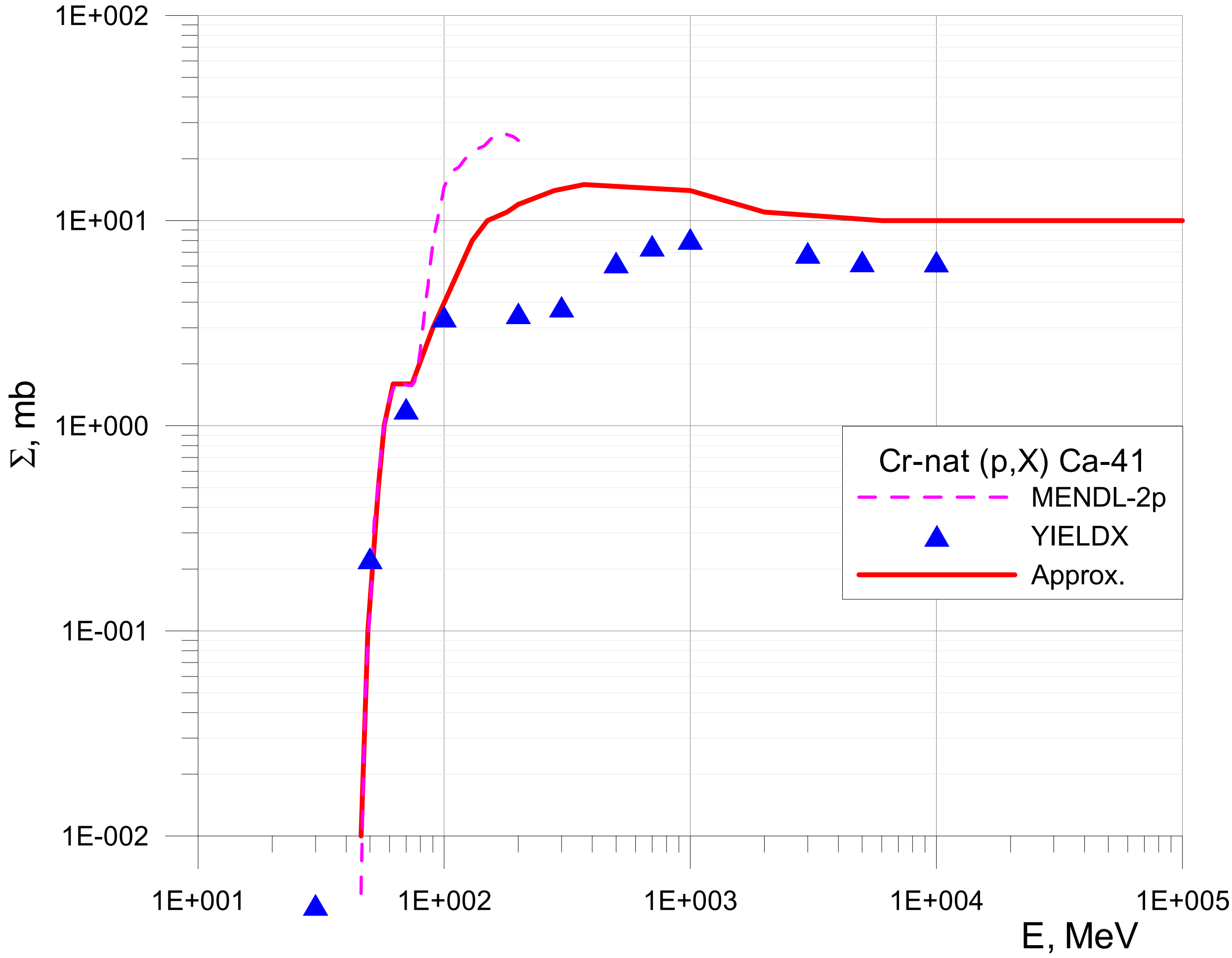
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	11.9	0.000	19	130	5.5
2	26.0	0.001	20	160	7.0
3	27	0.002	21	220	8.0
4	30	0.010	22	360	9.0
5	33	0.030	23	830	9.0
6	36	0.050	24	1300	8.0
7	38	0.060	25	2100	7.0
8	41	0.056	26	6000	5.0
9	43	0.038	27	100000	5.0
10	47	0.03			
11	49	0.0			
12	52	0.1			
13	59	1.0			
14	64	1.8			
15	70	1.9			
16	80	1.6			
17	97	1.8			
18	105	3.5			



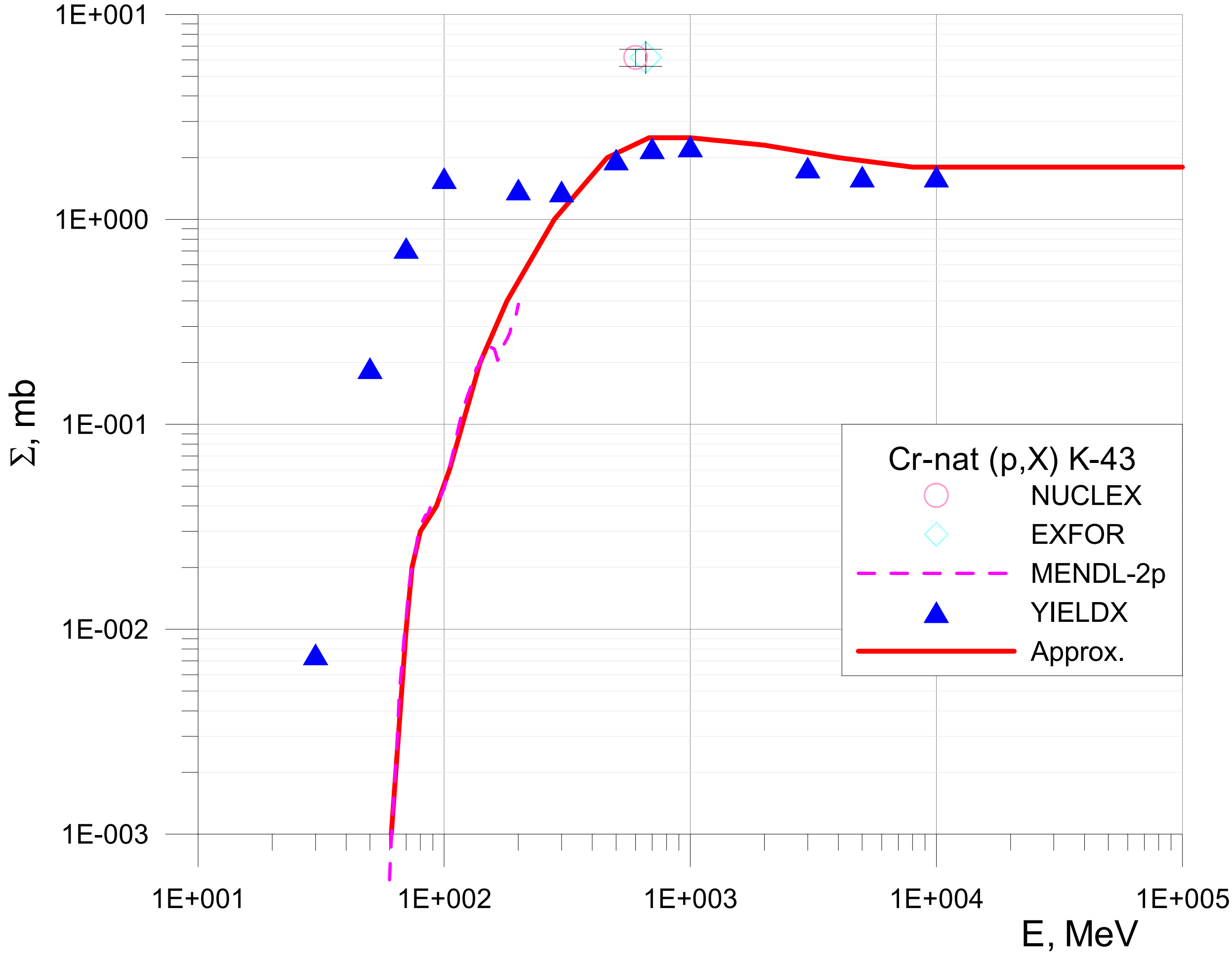
##	E, MeV	Σ, mb
1	30.5	0.0000
2	55	0.0001
3	62	0.001
4	68	0.002
5	83	0.004
6	100	0.01
7	120	0.02
8	160	0.04
9	220	0.06
10	430	0.08
11	680	0.08
12	1600	0.07
13	3000	0.06
14	6400	0.05
15	100000	0.05
16		
17		
18		



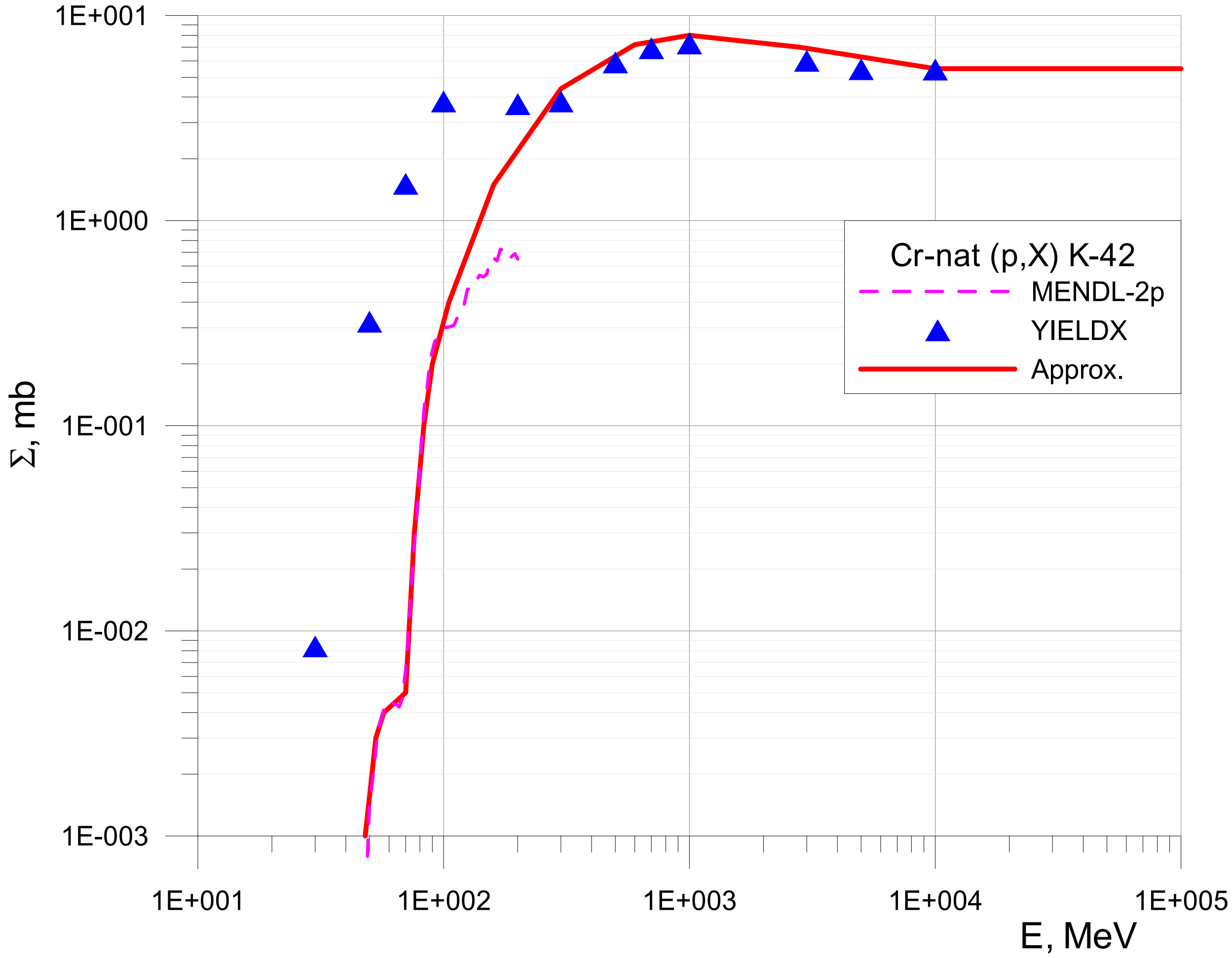
##	E, MeV	Σ, mb
1	19.7	0.000
2	41	0.001
3	44	0.004
4	48	0.010
5	52	0.015
6	55	0.016
7	62	0.014
8	66	0.020
9	70	0.07
10	78	0.20
11	90	0.40
12	100	0.60
13	130	1.0
14	180	1.6
15	260	2.0
16	480	2.4
17	1000	2.6
18	1800	2.5
19	5000	2.0
20	100000	2.0



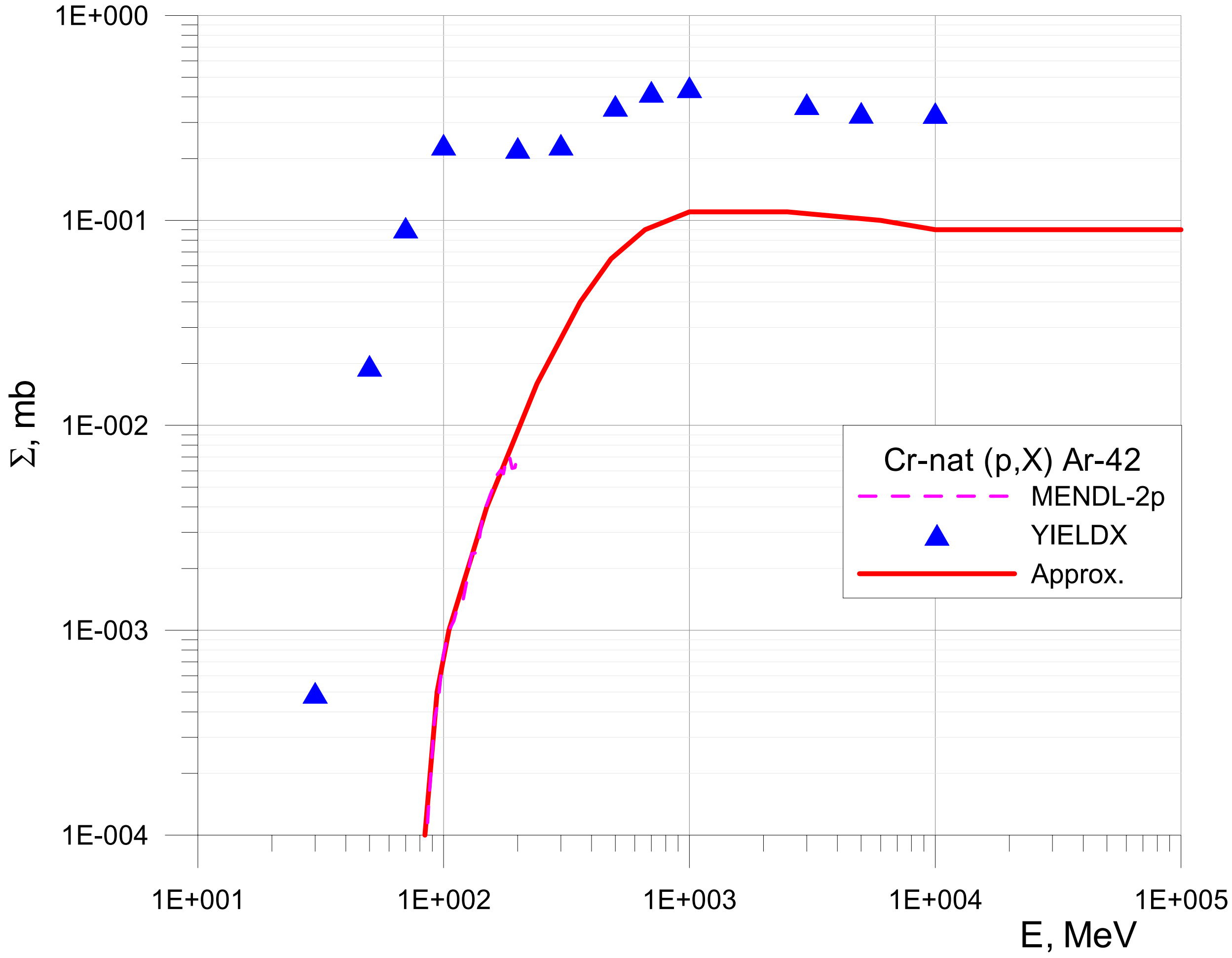
##	E, MeV	Σ, mb
1	26.3	0.00
2	46	0.01
3	49	0.10
4	54	0.50
5	57	1.0
6	62	1.6
7	74	1.6
8	90	3.0
9	130	8.0
10	150	10
11	180	11
12	200	12
13	280	14
14	370	15
15	1000	14
16	2000	11
17	6000	10
18	100000	10



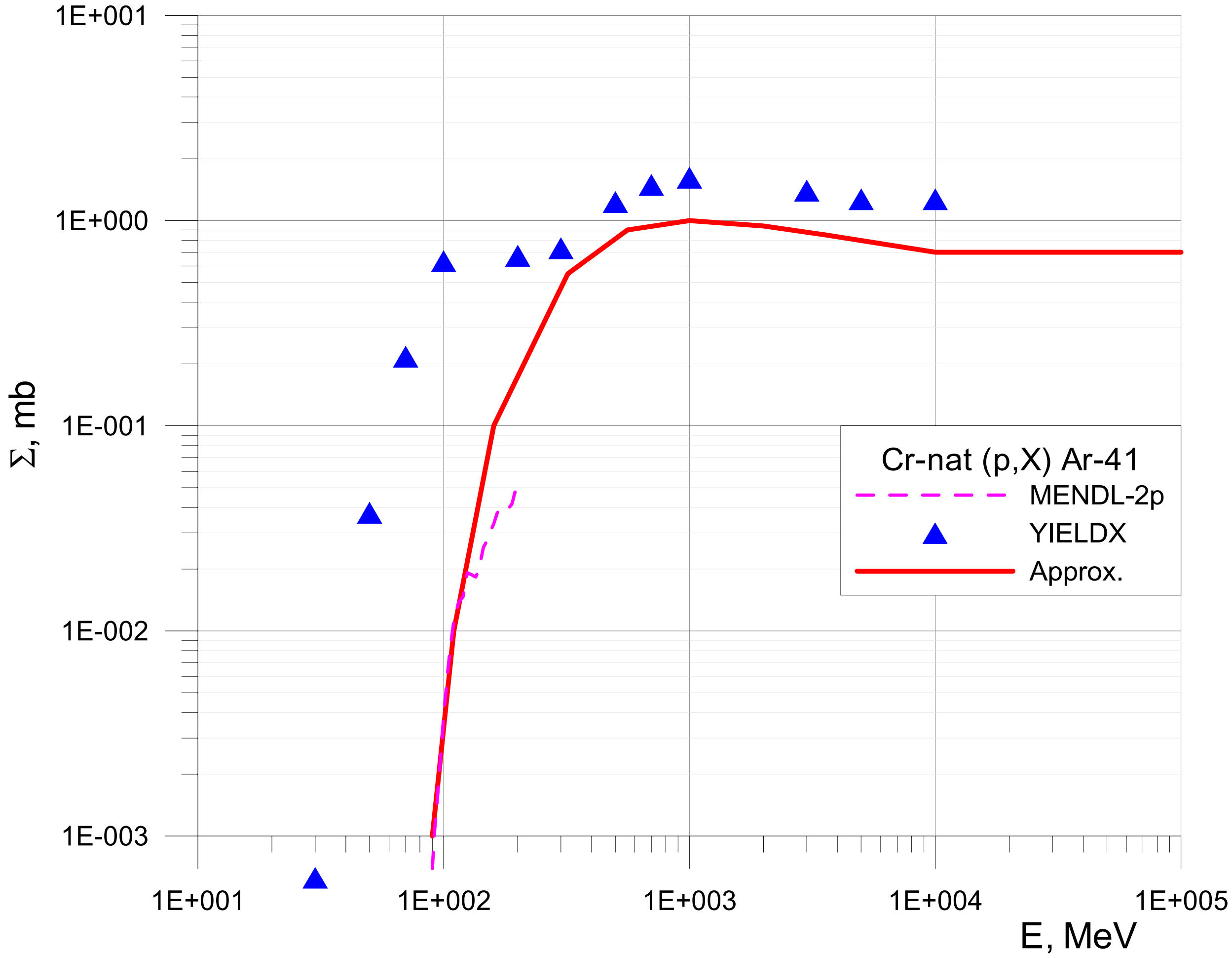
##	E, MeV	Σ, mb
1	20.7	0.000
2	61	0.001
3	70	0.01
4	74	0.02
5	80	0.03
6	93	0.04
7	105	0.06
8	140	0.20
9	180	0.4
10	280	1.0
11	460	2.0
12	680	2.5
13	1000	2.5
14	2000	2.3
15	4000	2.0
16	8000	1.8
17	100000	1.8
18		



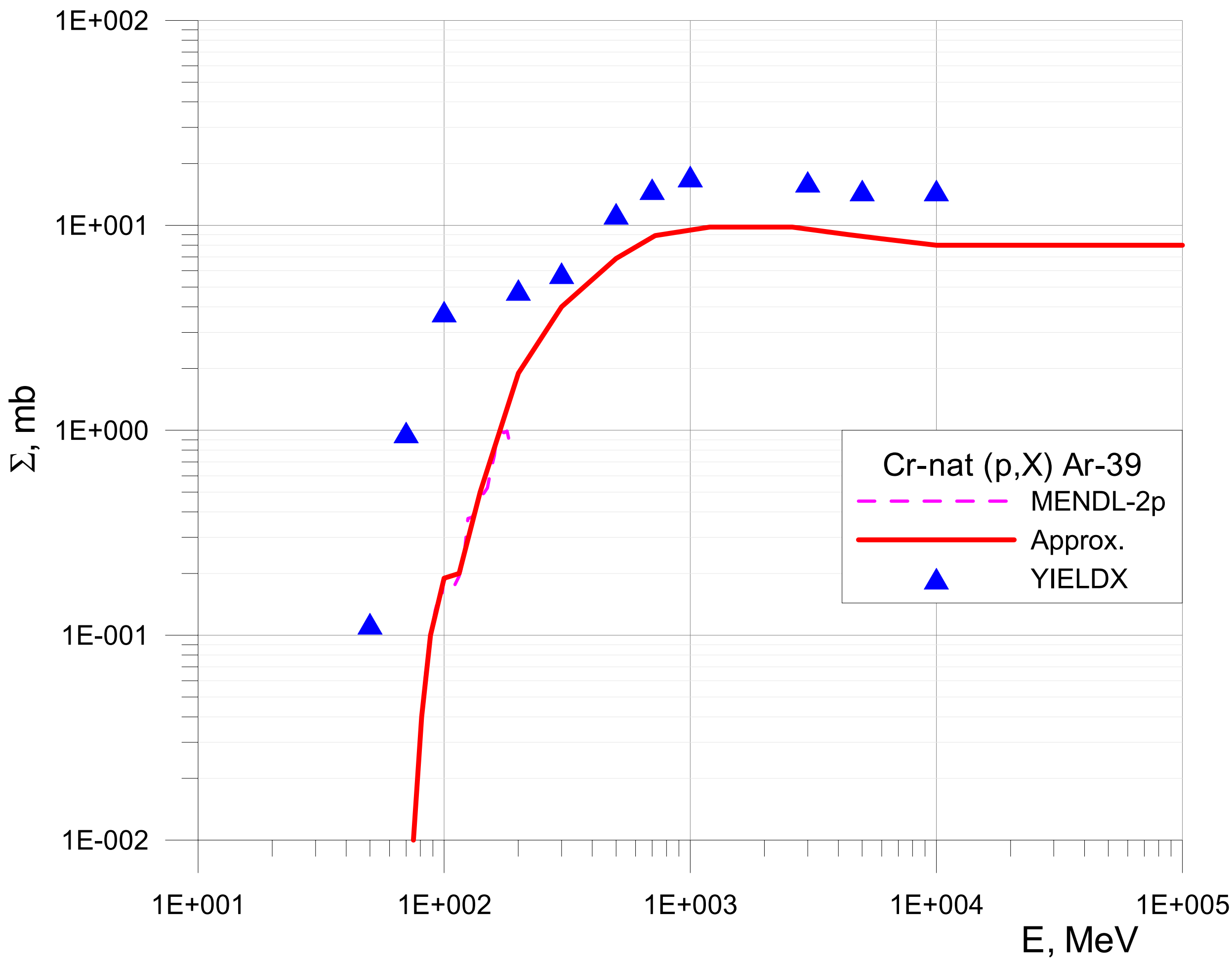
##	E, MeV	Σ, mb
1	20.6	0.000
2	48	0.001
3	53	0.003
4	57	0.004
5	70	0.005
6	76	0.03
7	83	0.10
8	90	0.20
9	105	0.40
10	160	1.5
11	300	4.4
12	600	7.2
13	1000	8.0
14	2800	7.0
15	10000	5.5
16	100000	5.5
17		
18		



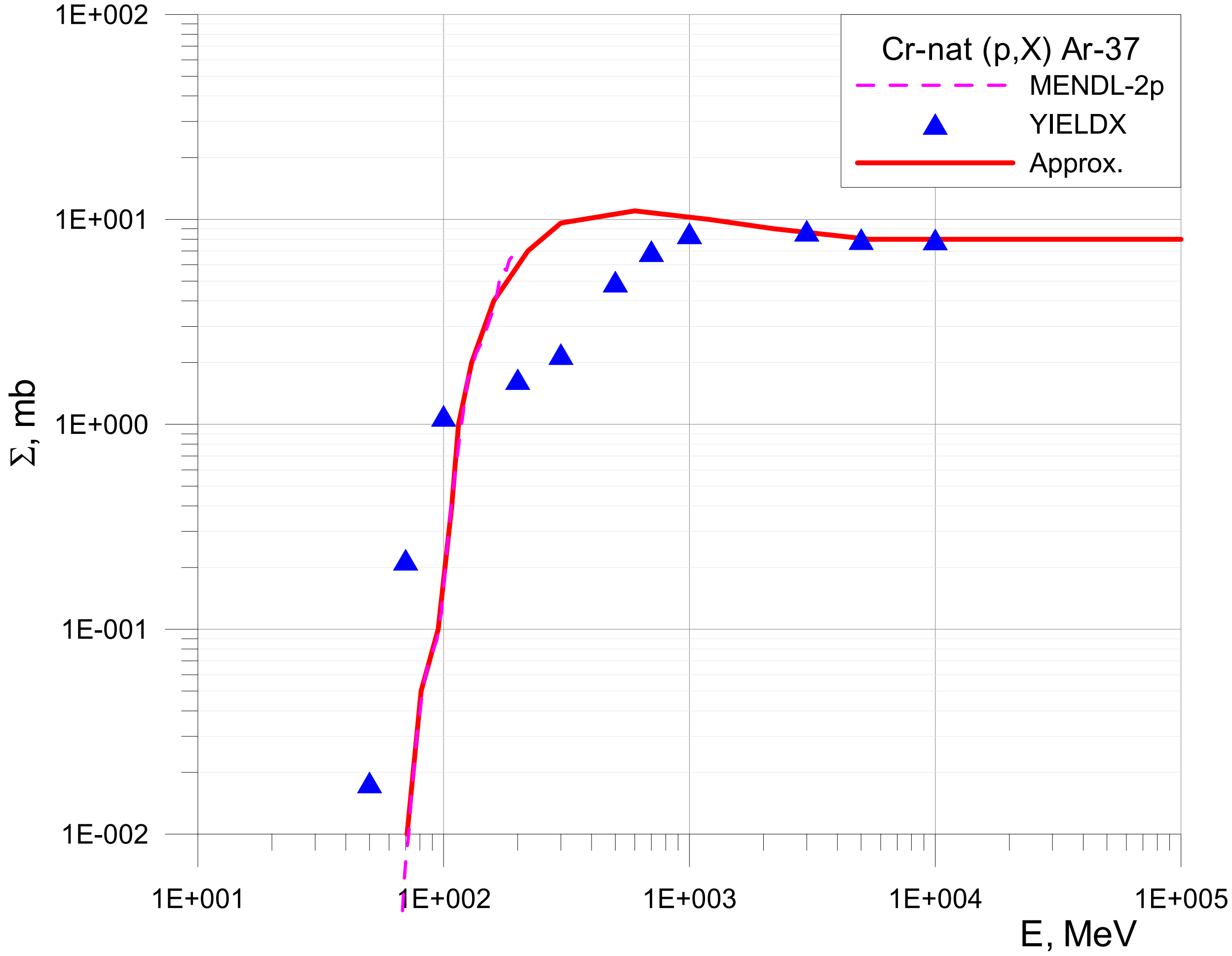
##	E, MeV	Σ, mb
1	30.3	0.00000
2	76	0.00001
3	84	0.0001
4	94	0.0005
5	105	0.0010
6	150	0.004
7	240	0.016
8	360	0.040
9	480	0.065
10	660	0.090
11	1000	0.11
12	2500	0.11
13	6000	0.10
14	10000	0.09
15	100000	0.09
16		
17		
18		



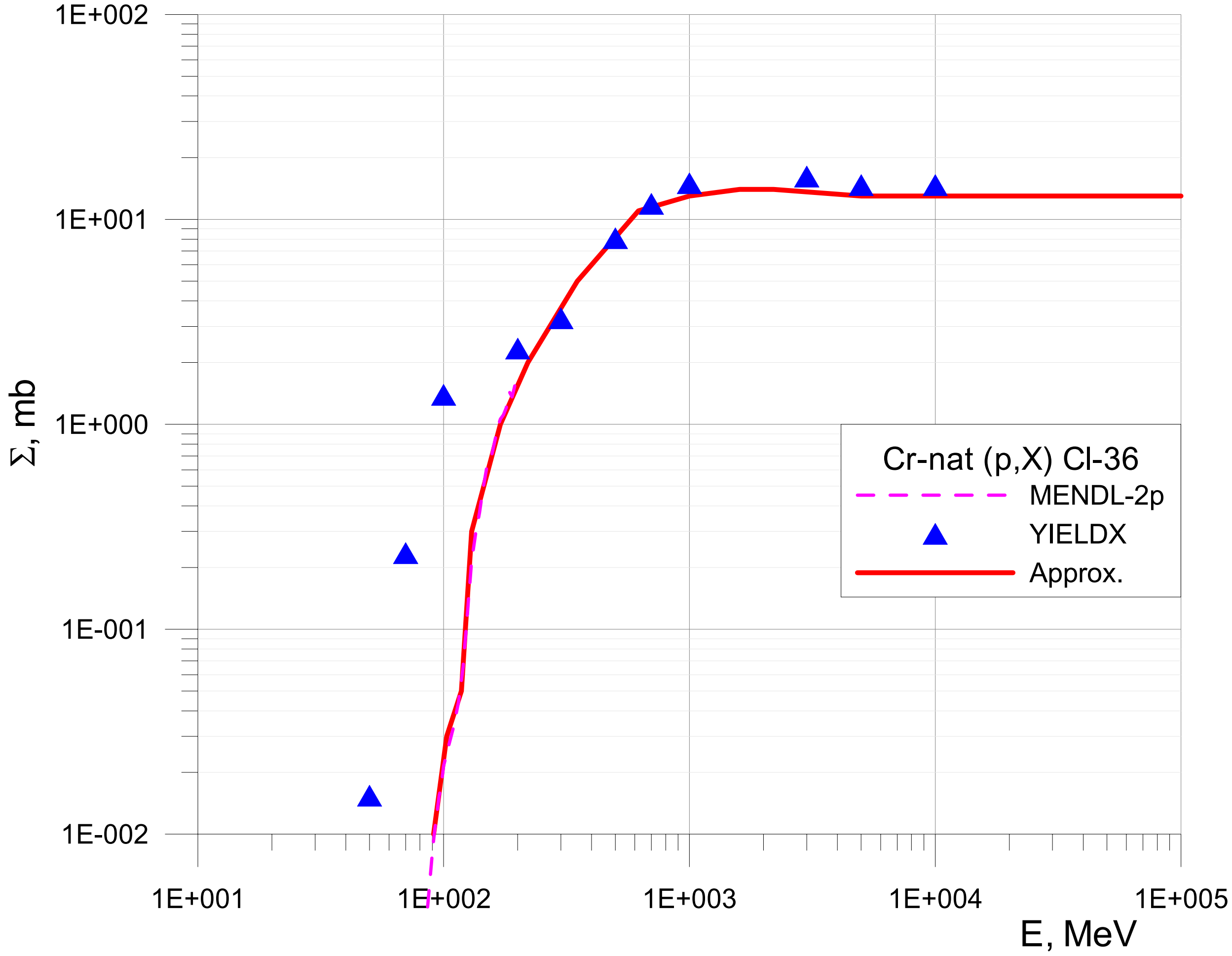
##	E, MeV	Σ, mb
1	30.1	0.0000
2	68	0.0001
3	83	0.0003
4	90	0.0010
5	110	0.010
6	160	0.10
7	320	0.55
8	560	0.90
9	1000	1.00
10	2000	0.94
11	3600	0.85
12	10000	0.70
13	100000	0.70
14		
15		
16		
17		
18		



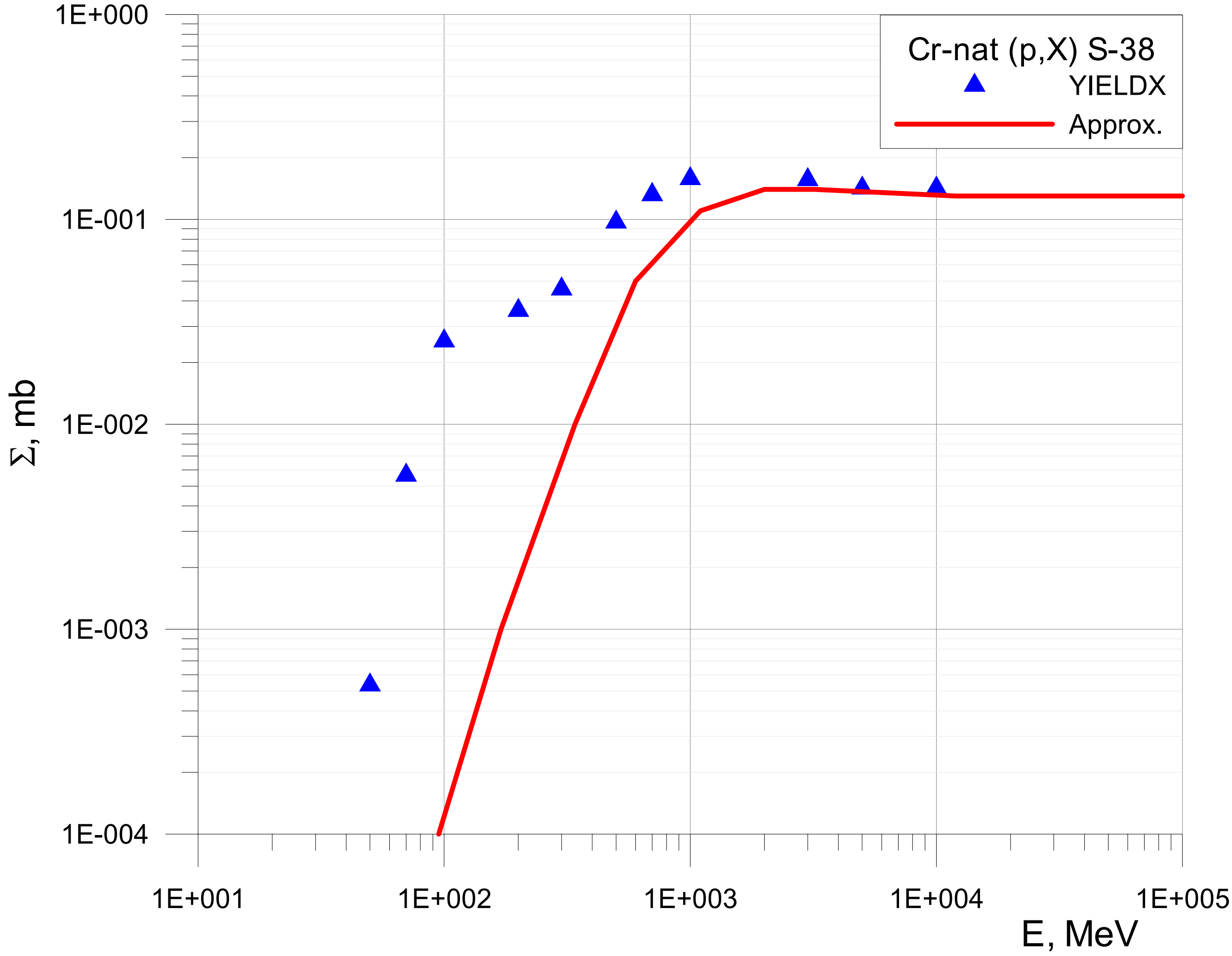
##	E, MeV	Σ, mb
1	30.1	0.000
2	69	0.001
3	75	0.01
4	81	0.04
5	88	0.10
6	100	0.19
7	115	0.20
8	140	0.50
9	200	1.9
10	300	4.0
11	500	6.9
12	720	8.9
13	1200	9.8
14	2600	9.8
15	4400	9.0
16	6000	8.6
17	10000	8.0
18	100000	8.0



##	E, MeV	Σ, mb
1	33.1	0.00
2	71	0.01
3	81	0.05
4	95	0.1
5	108	0.4
6	115	1.0
7	130	2.0
8	160	4.0
9	220	7.0
10	300	9.6
11	600	11
12	1200	10
13	2200	9
14	5400	8
15	100000	8
16		
17		
18		



##	E, MeV	Σ, mb
1	36.4	0.00
2	91	0.01
3	103	0.03
4	118	0.05
5	130	0.30
6	170	1.0
7	220	2.0
8	350	5.0
9	620	11
10	1000	13
11	1600	14
12	2200	14
13	5000	13
14	100000	13
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	40.51	0.0000
2	95	0.0001
3	170	0.001
4	340	0.01
5	600	0.05
6	1100	0.11
7	2000	0.14
8	3200	0.14
9	12000	0.13
10	100000	0.13
11		
12		
13		
14		
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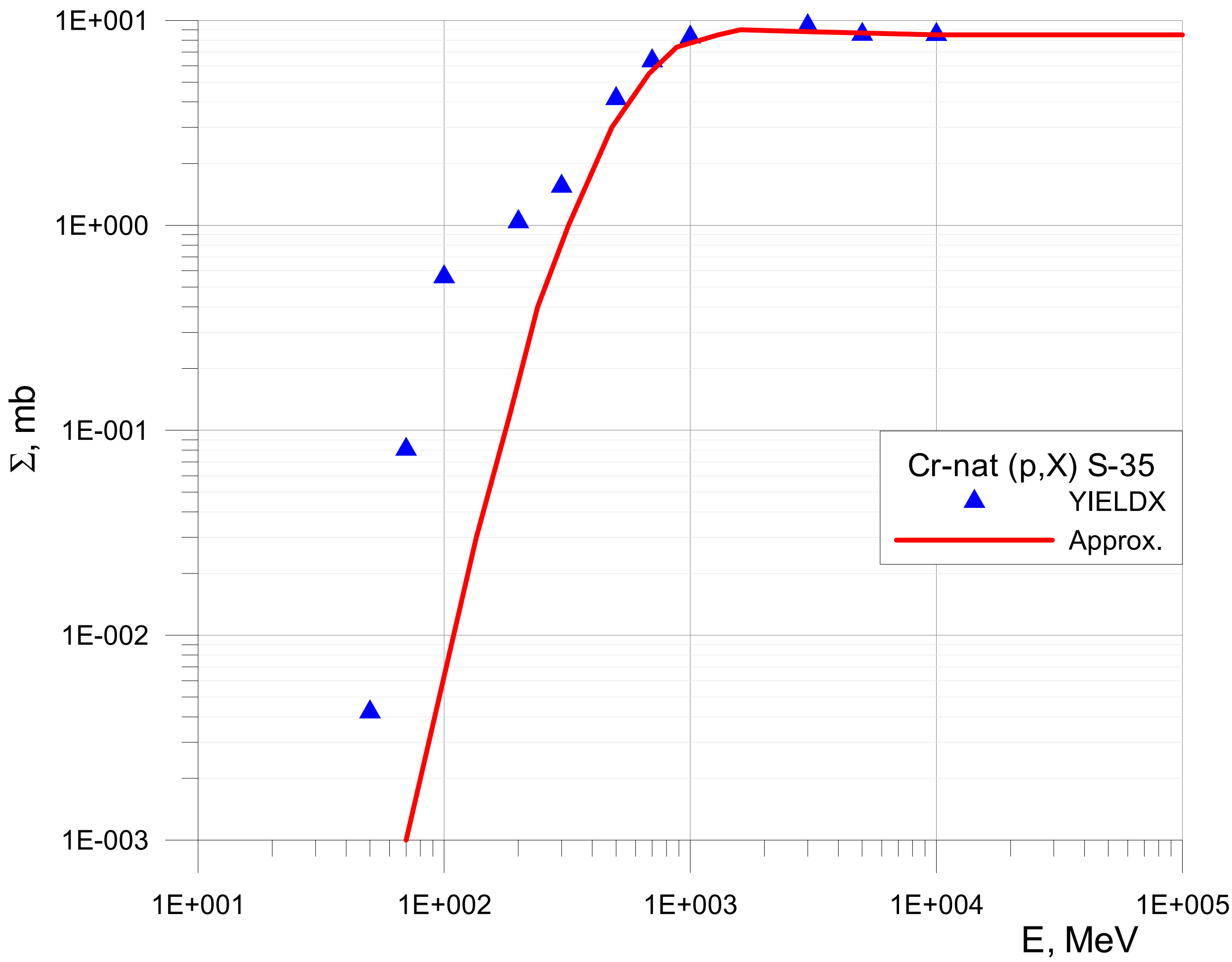
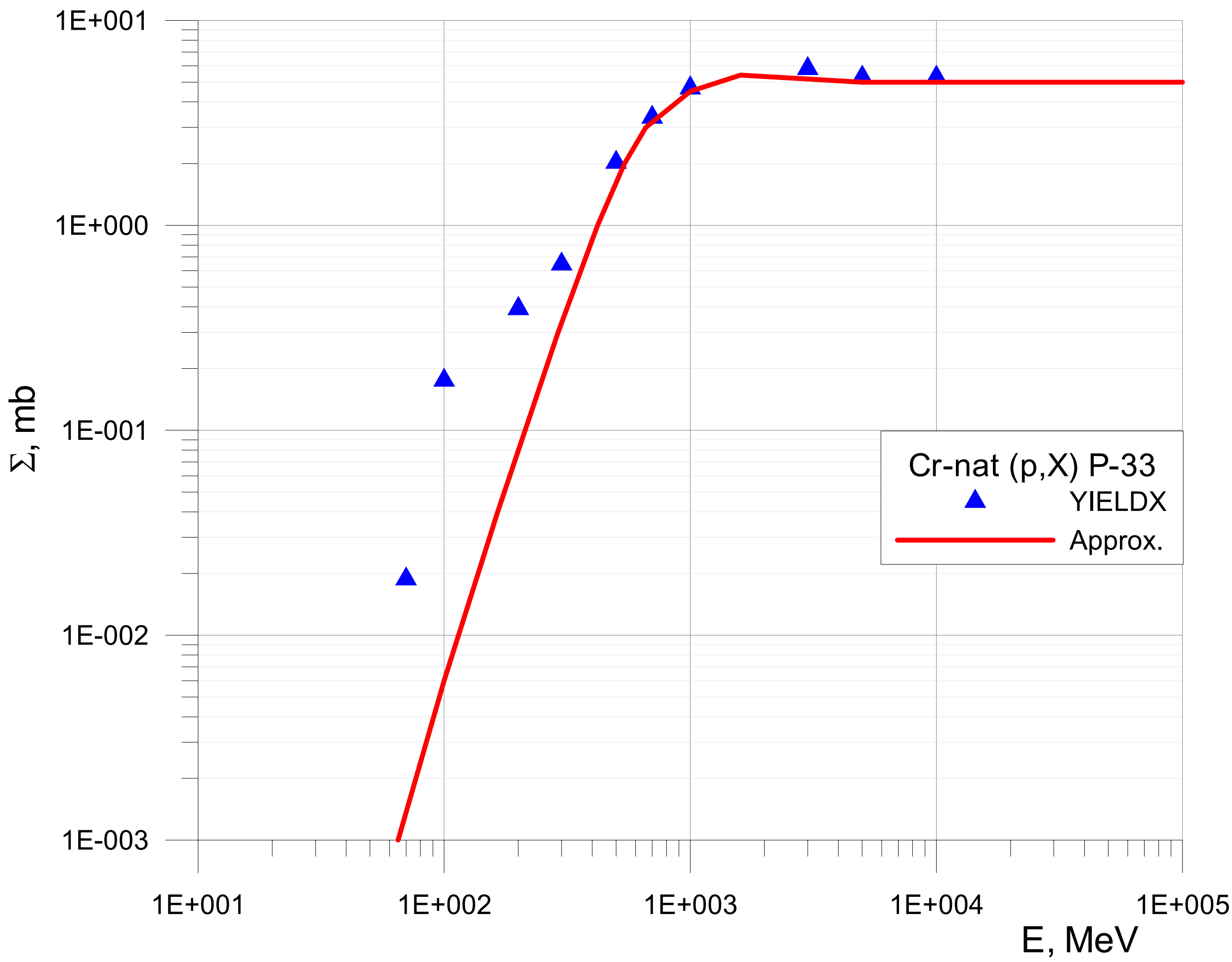
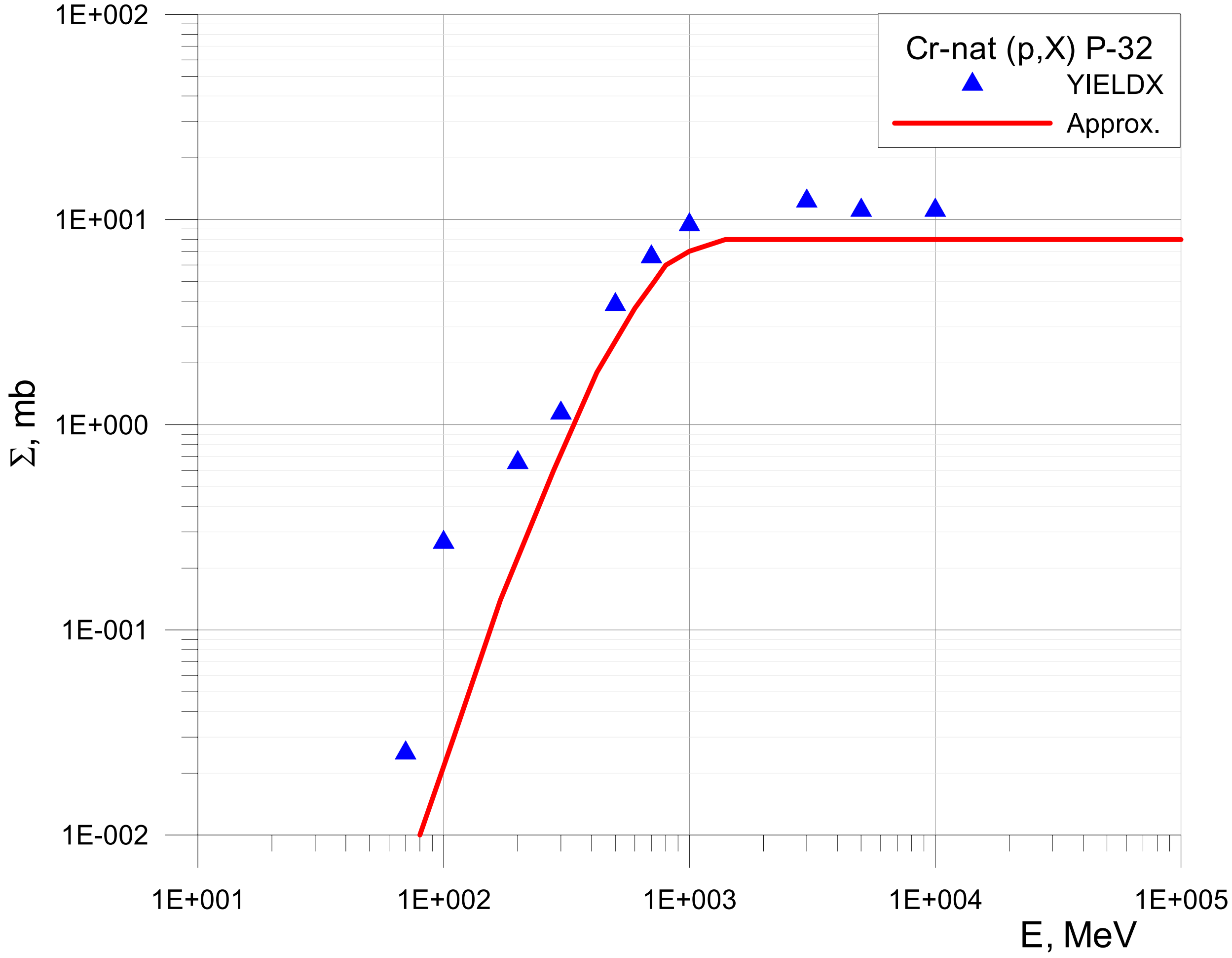
17		
18		



##	E, MeV	Σ, mb
1	42.93	0.0000
2	70	0.0010
3	135	0.030
4	185	0.12
5	240	0.40
6	320	1.0
7	480	3.0
8	680	5.5
9	880	7.4
10	1300	8.5
11	1600	9.0
12	3000	8.8
13	10000	8.5
14	100000	8.5
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	34.57	0.0000
2	65	0.0010
3	100	0.006
4	165	0.04
5	290	0.30
6	420	1.0
7	540	2.0
8	660	3.0
9	1000	4.5
10	1600	5.4
11	5000	5.0
12	100000	5.0
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	44.16	0.0000
2	80	0.0100
3	110	0.030
4	170	0.14
5	280	0.60
6	420	1.8
7	600	3.7
8	720	5.0
9	800	6.0
10	1000	7.0
11	1400	8.0
12	4000	8.0
13	100000	8.0
14		
15		
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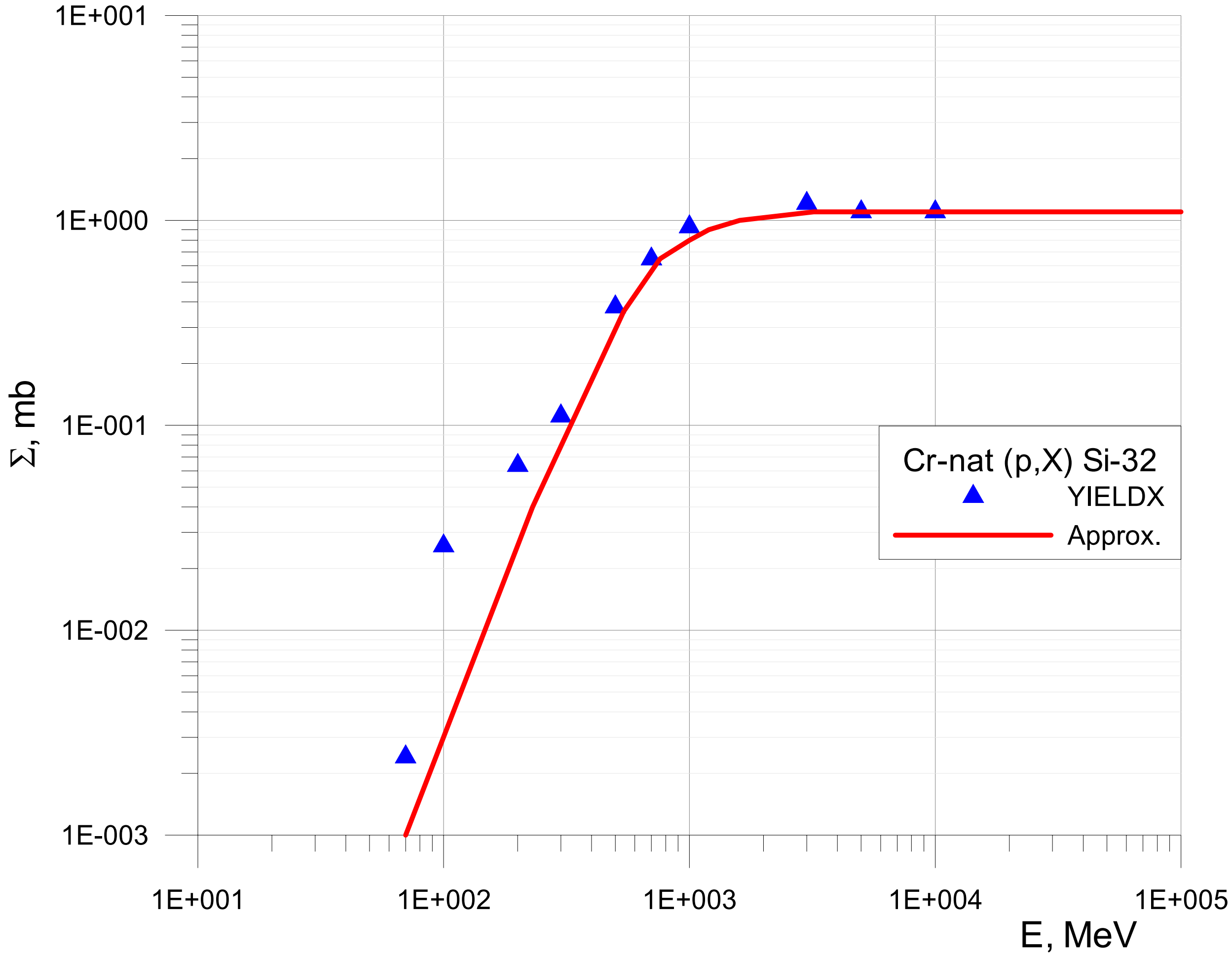
18		



##	E, MeV	Σ, mb
1	44.3	0.0000
2	70	0.0010
3	230	0.040
4	540	0.36
5	760	0.65
6	1000	0.8
7	1200	0.9
8	1600	1.0
9	3200	1.1
10	100000	1.1
11		
12		
13		
14		
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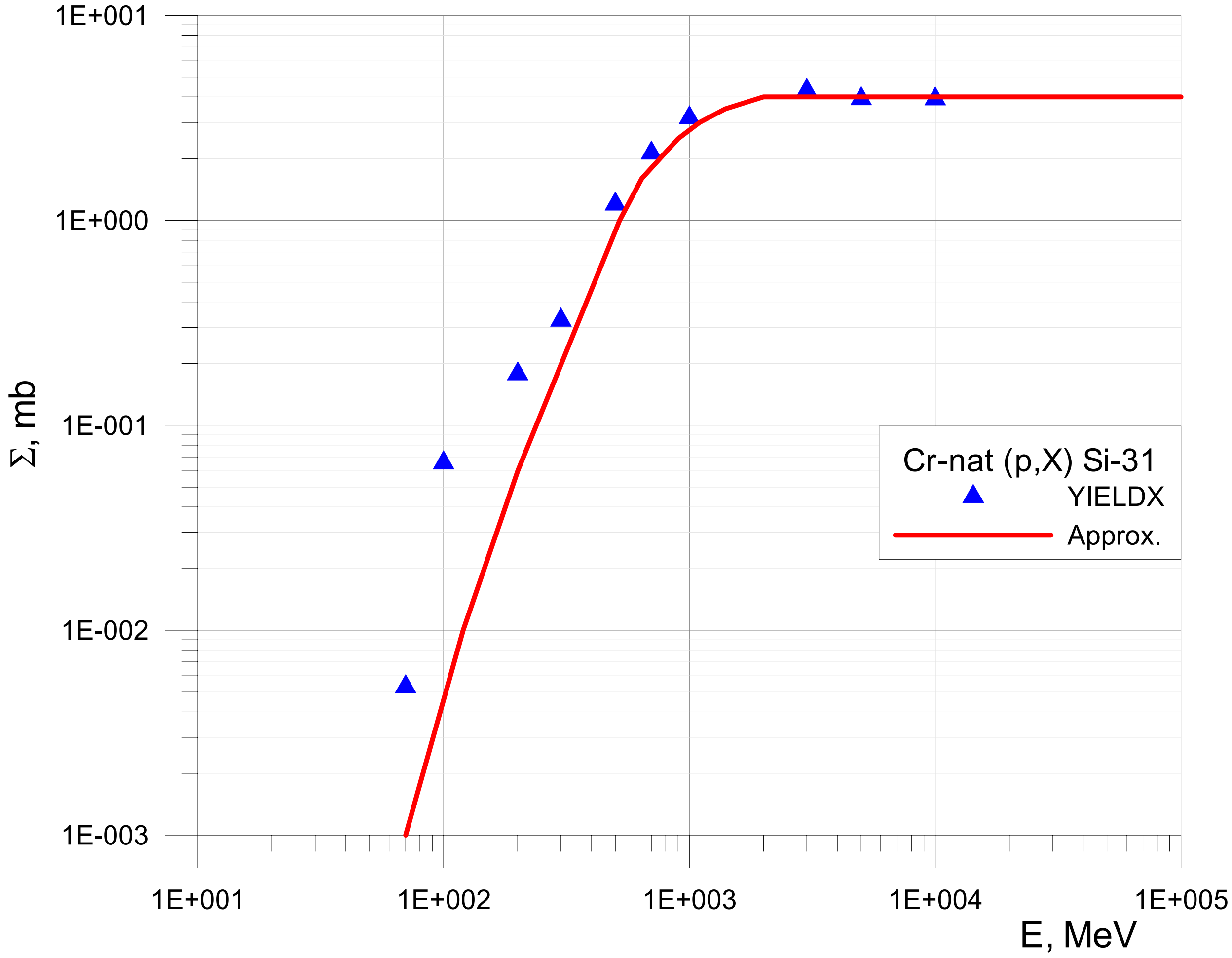
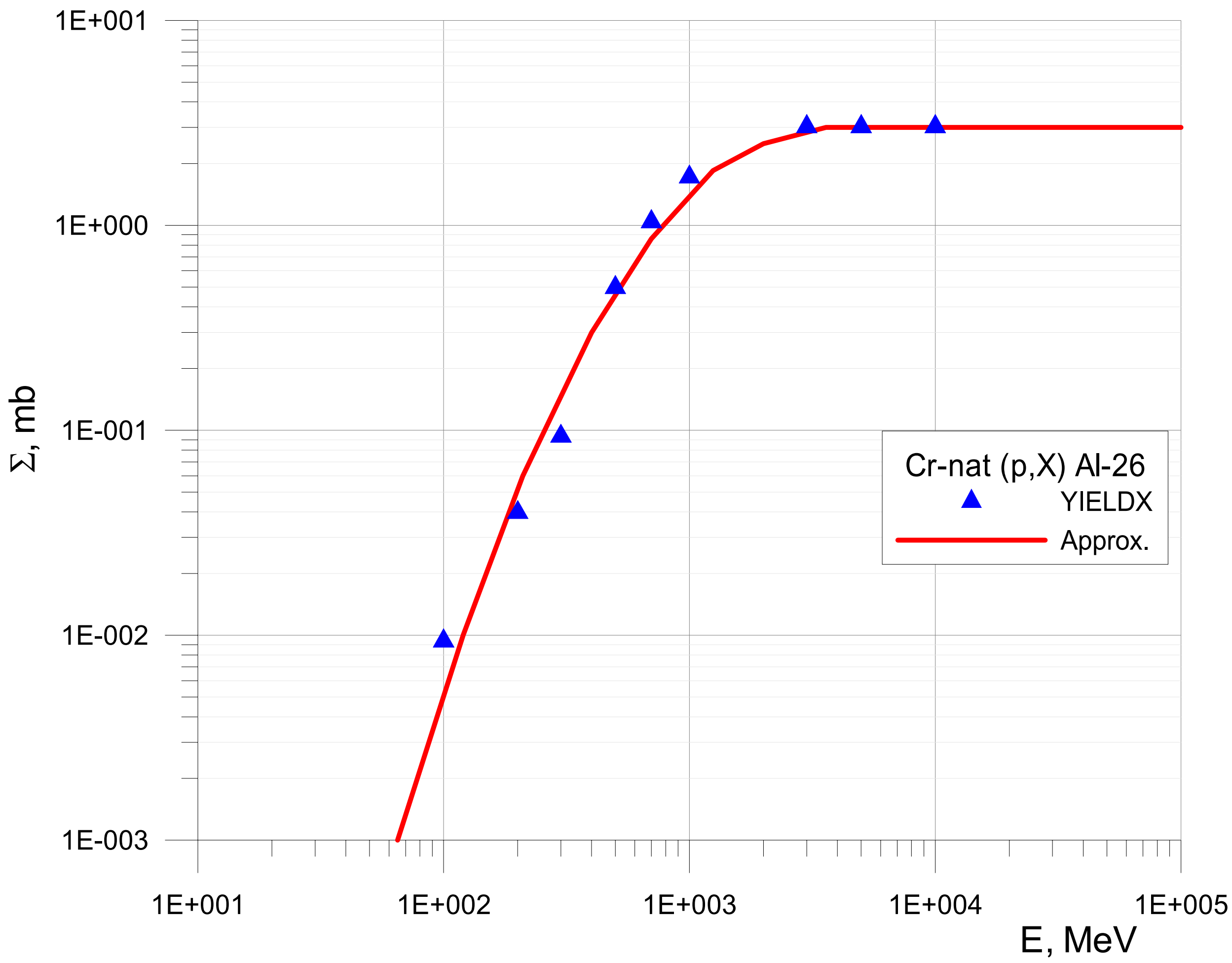
18		



##	E, MeV	Σ, mb
1	51.41	0.0000
2	70	0.0010
3	120	0.010
4	200	0.06
5	520	1.00
6	640	1.6
7	900	2.5
8	1100	3.0
9	1400	3.5
10	2000	4.0
11	100000	4.0
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	65	0.001
2	120	0.01
3	210	0.06
4	400	0.30
5	700	0.86
6	1250	1.85
7	2000	2.5
8	3600	3.0
9	100000	3.0
10		
11		
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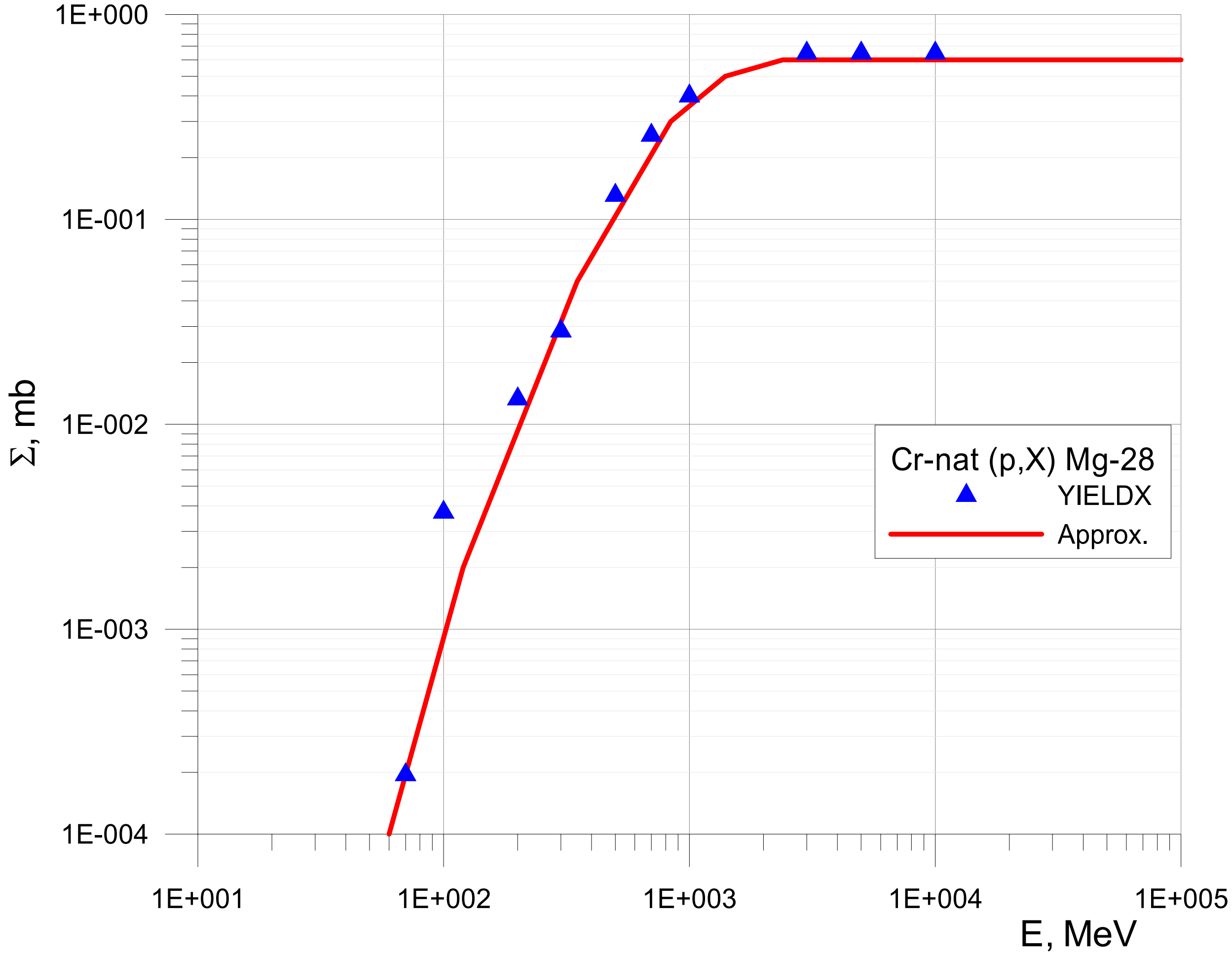

##	E, MeV	Σ, mb
1	60	0.0001
2	120	0.002
3	350	0.05
4	840	0.3
5	1400	0.5
6	2400	0.6
7	100000	0.6
8		
9		
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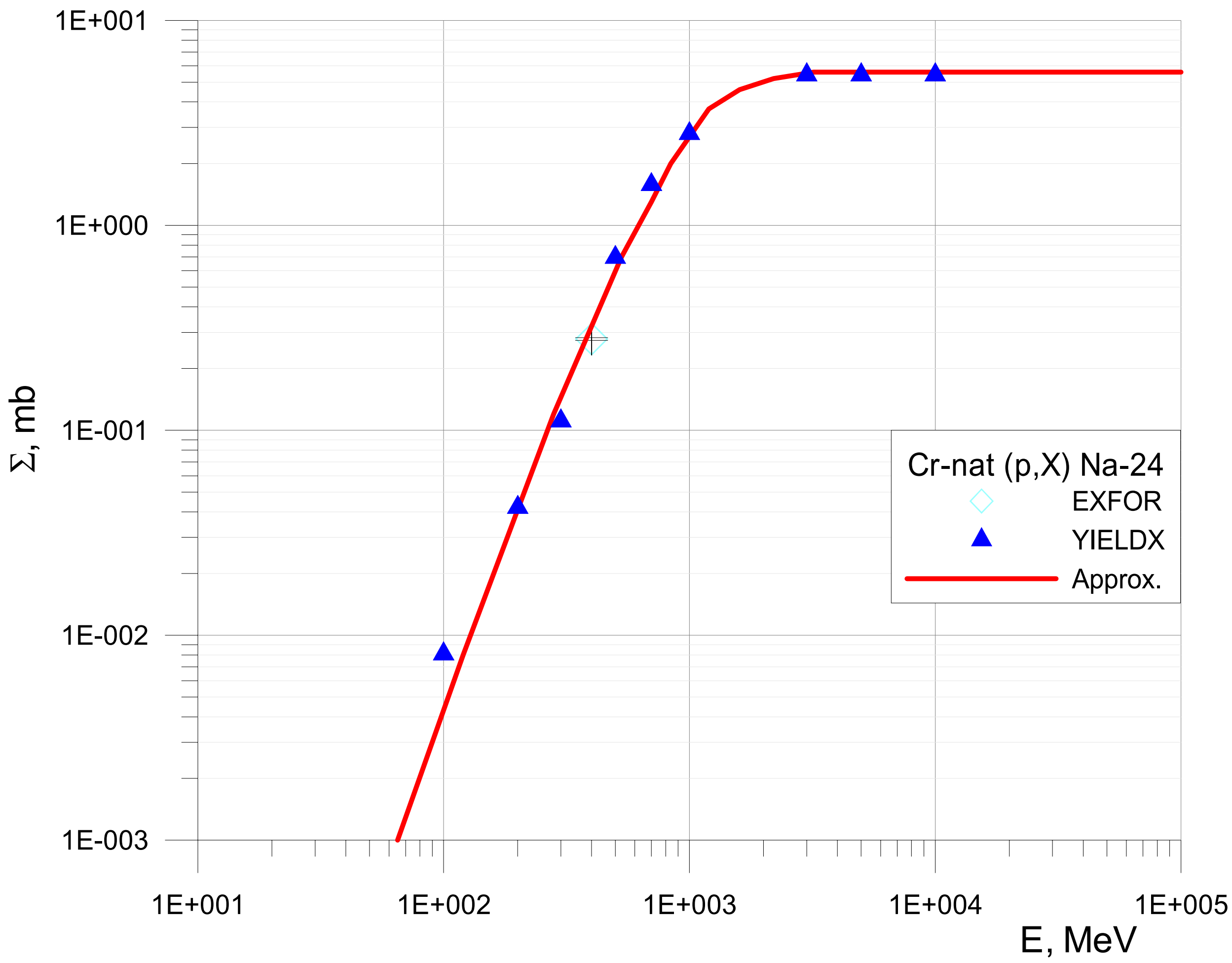
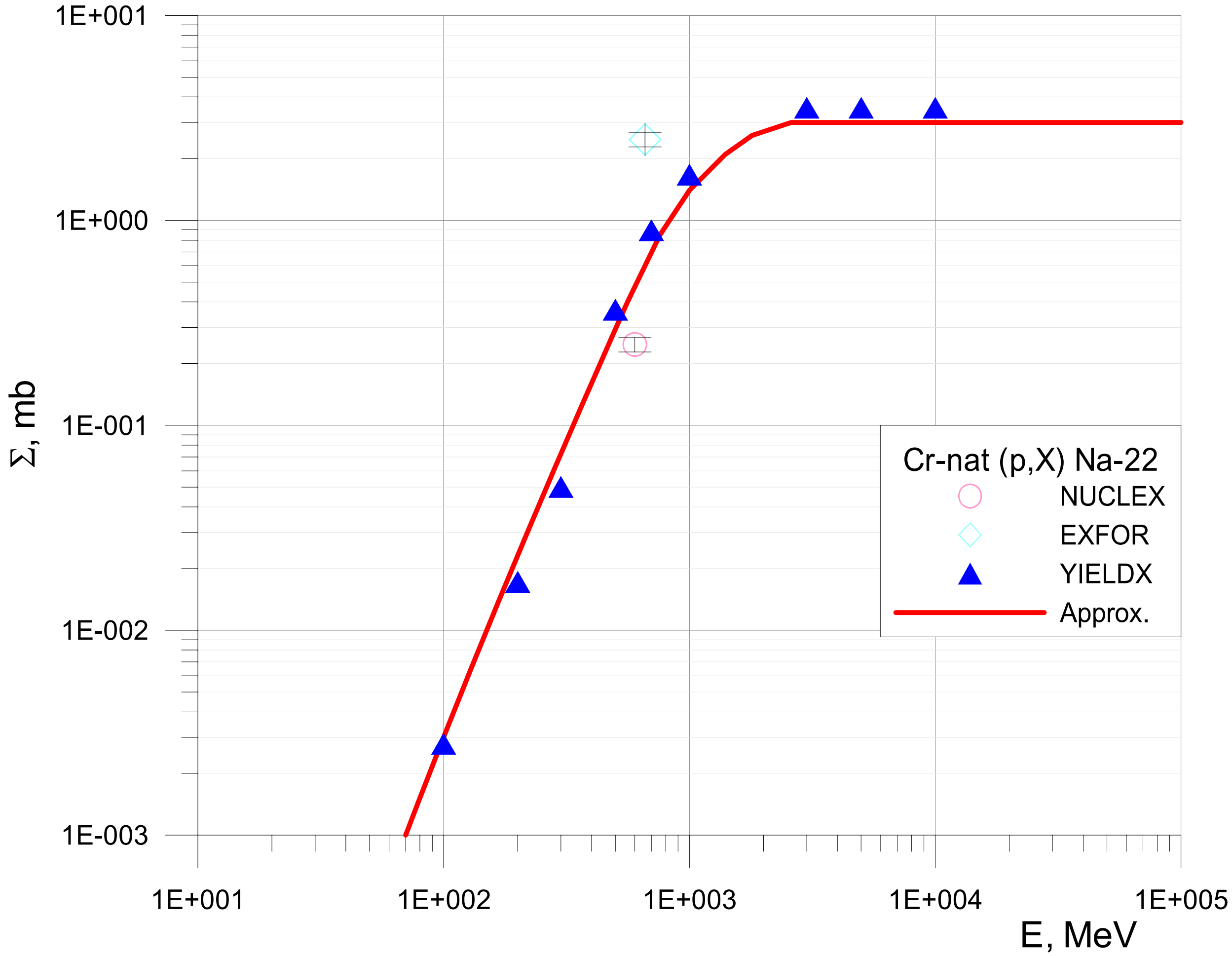
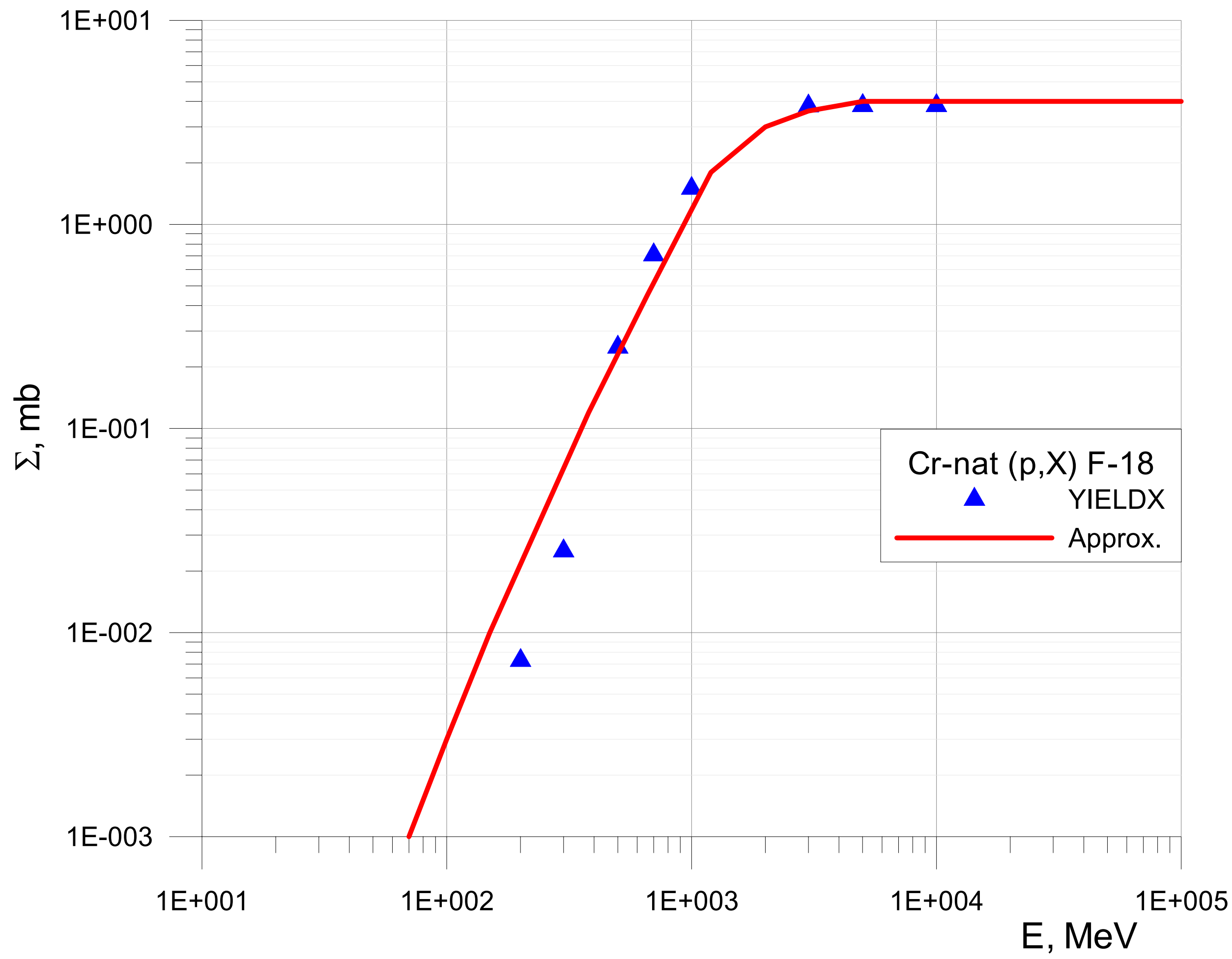


##	E, MeV	Σ, mb
1	65	0.001
2	120	0.008
3	280	0.12
4	530	0.7
5	700	1.3
6	840	2.0
7	1200	3.7
8	1600	4.6
9	2200	5.2
10	3200	5.6
11	100000	5.6
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	70	0.001
2	100	0.003
3	150	0.01
4	190	0.02
5	280	0.06
6	380	0.14
7	560	0.40
8	760	0.85
9	1000	1.4
10	1400	2.1
11	1800	2.6
12	2600	3.0
13	100000	3.0
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	70	0.001
2	100	0.003
3	150	0.01
4	380	0.12
5	660	0.45
6	1200	1.8
7	2000	3.0
8	3000	3.6
9	5000	4.0
10	100000	4.0
11		
12		
13		
14		
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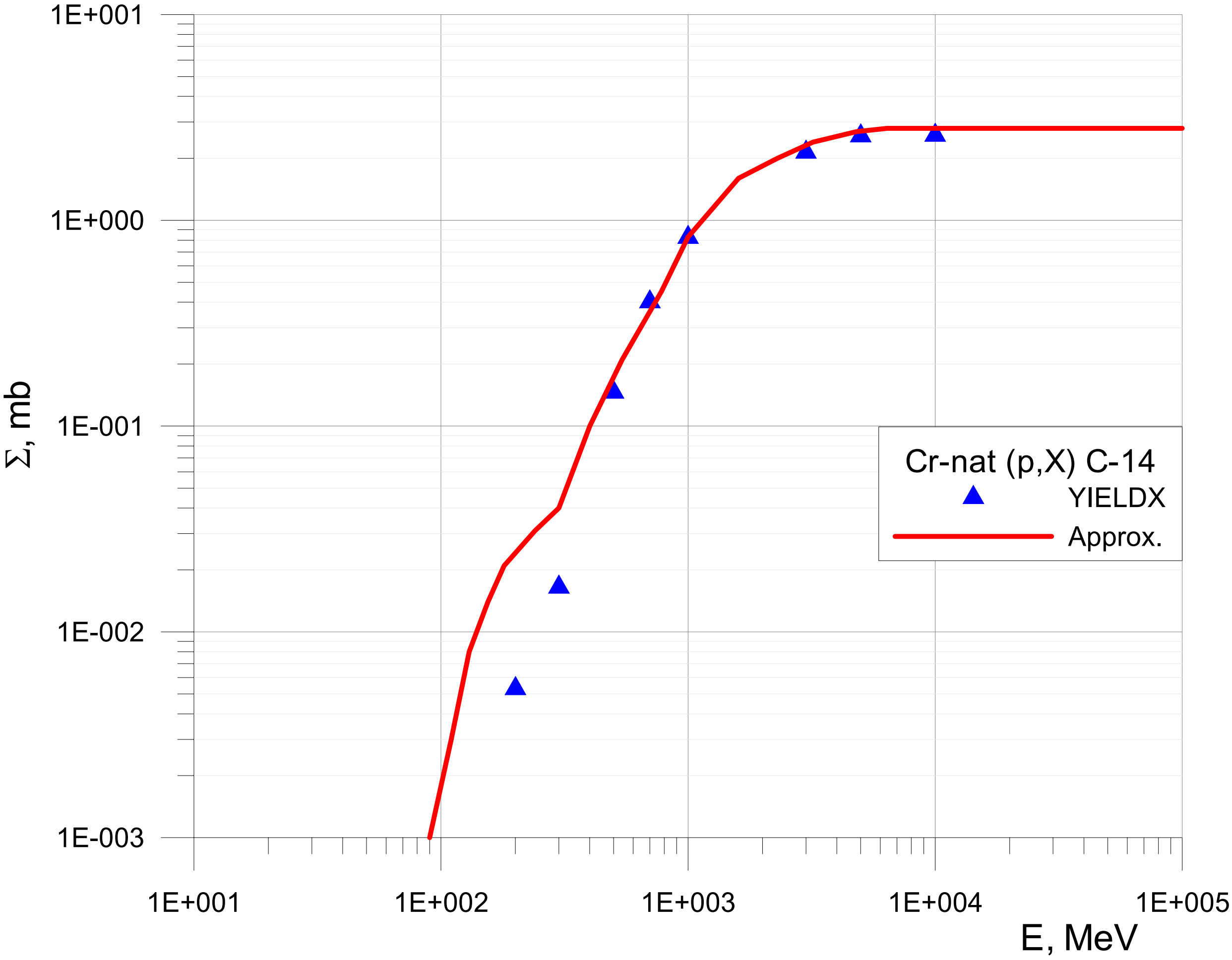
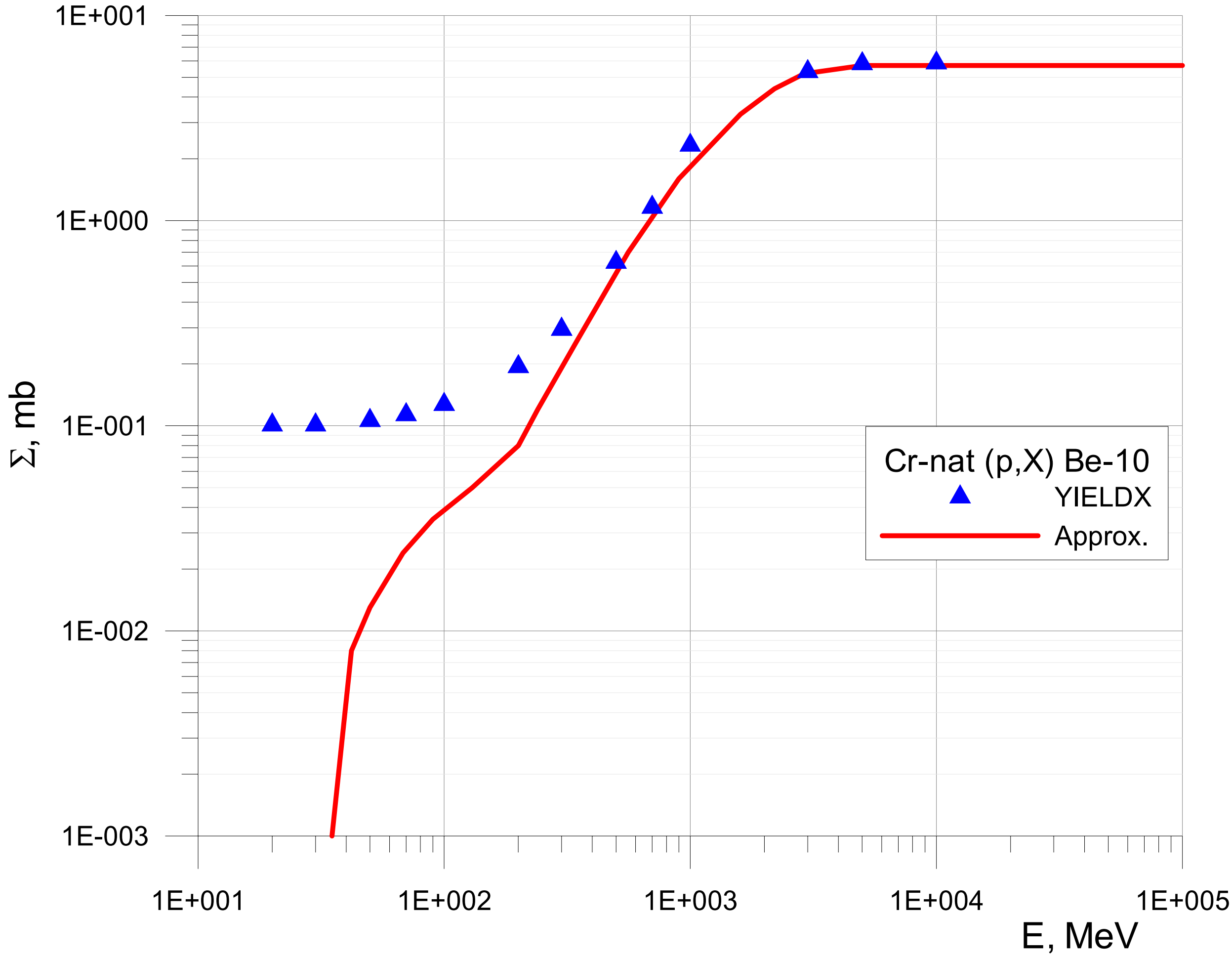
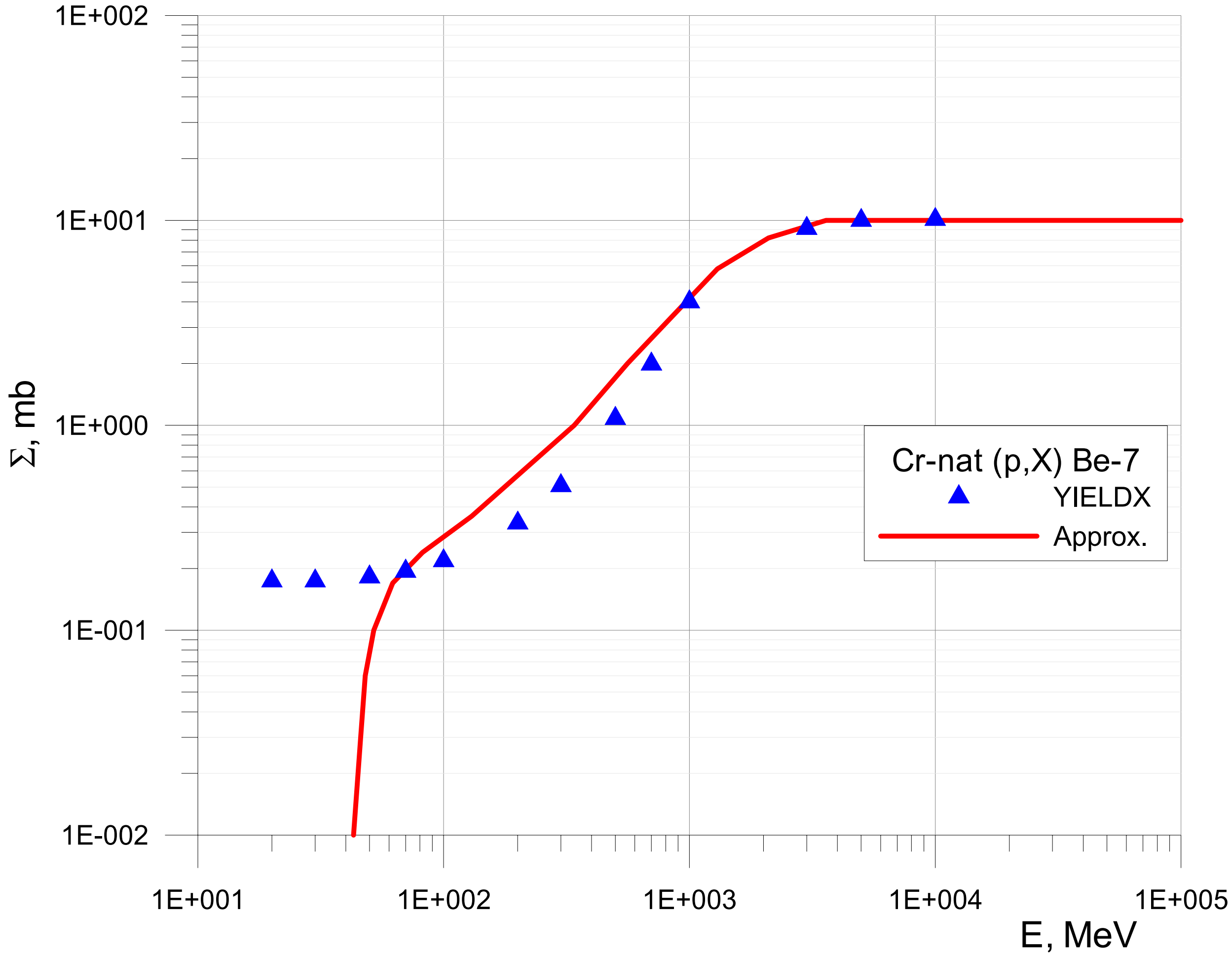
16		
17		
18		



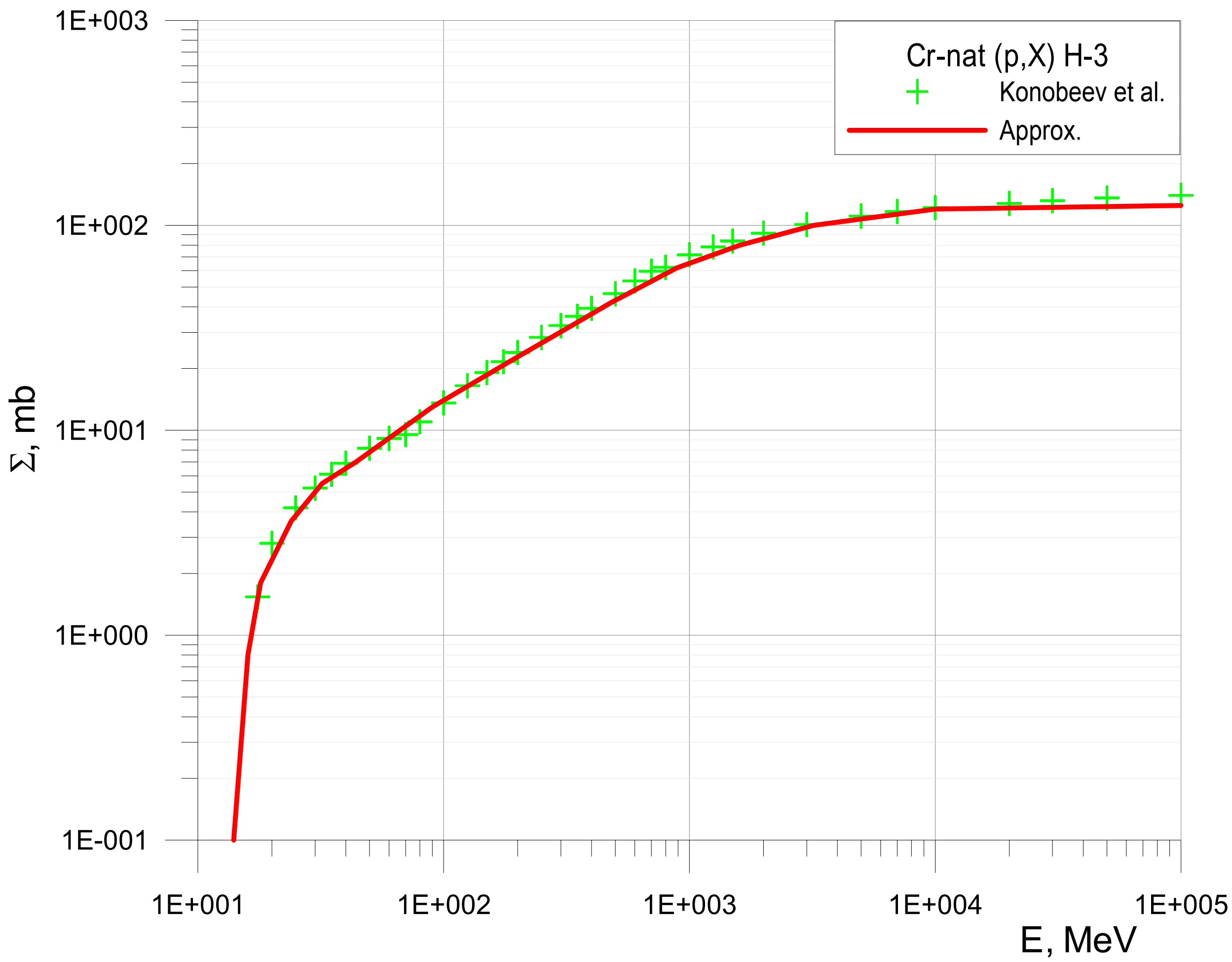
##	E, MeV	Σ, mb
1	90	0.001
2	110	0.003
3	130	0.008
4	155	0.014
5	180	0.021
6	240	0.031
7	300	0.04
8	400	0.10
9	540	0.21
10	780	0.45
11	1000	0.83
12	1600	1.6
13	2300	2.0
14	3200	2.4
15	4800	2.7
16	6400	2.8
17	100000	2.8
18		



##	E, MeV	Σ, mb
1	35	0.001
2	42	0.008
3	50	0.013
4	68	0.024
5	90	0.035
6	130	0.05
7	200	0.08
8	240	0.12
9	340	0.25
10	560	0.7
11	900	1.6
12	1600	3.3
13	2200	4.4
14	2900	5.2
15	5000	5.7
16	100000	5.7
17		
18		



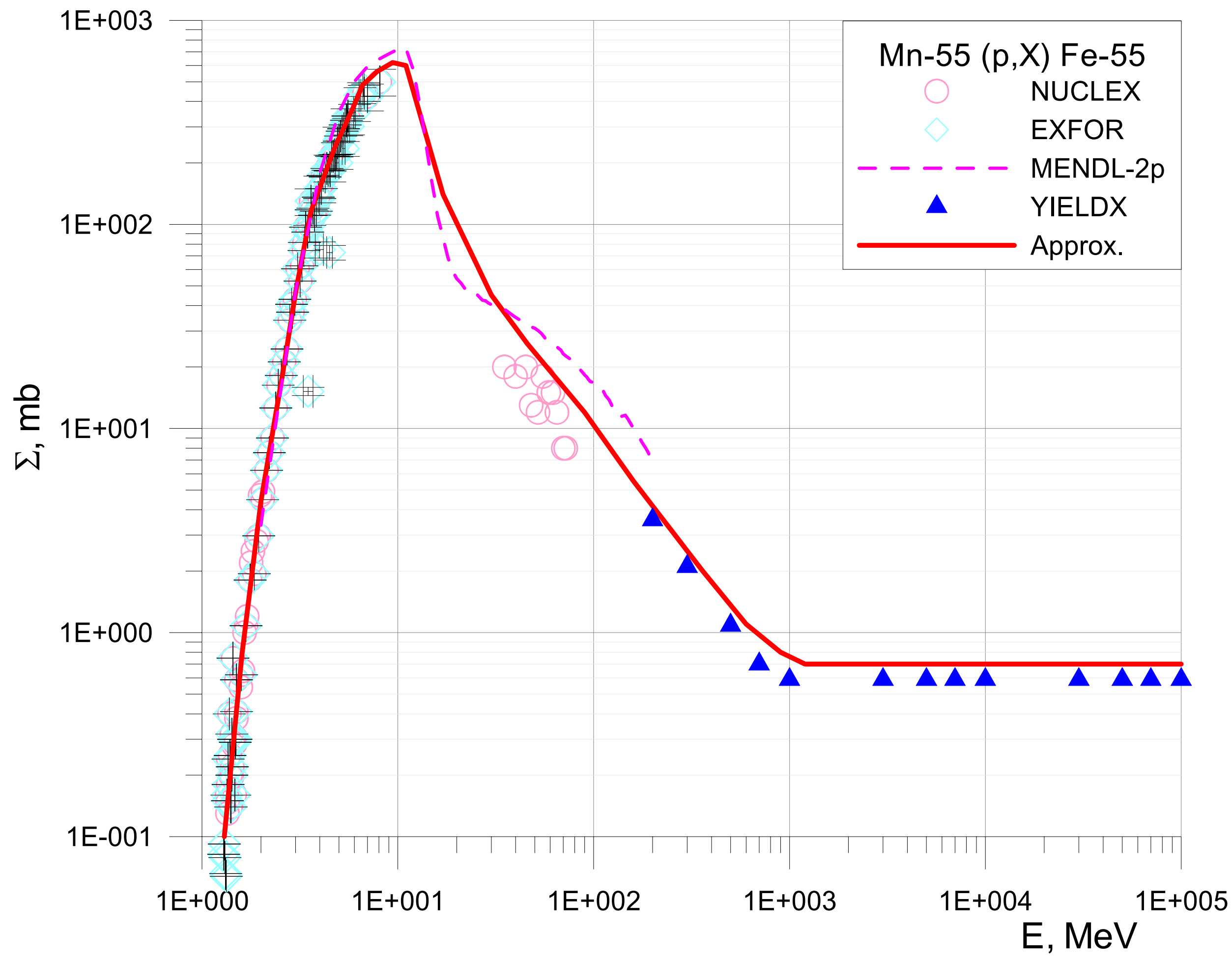
##	E, MeV	Σ, mb
1	43	0.01
2	46	0.03
3	48	0.06
4	52	0.10
5	62	0.17
6	82	0.24
7	130	0.36
8	200	0.57
9	340	1.0
10	560	2.0
11	870	3.5
12	1300	5.8
13	2100	8.2
14	3600	10
15	100000	10
16		
17		
18		



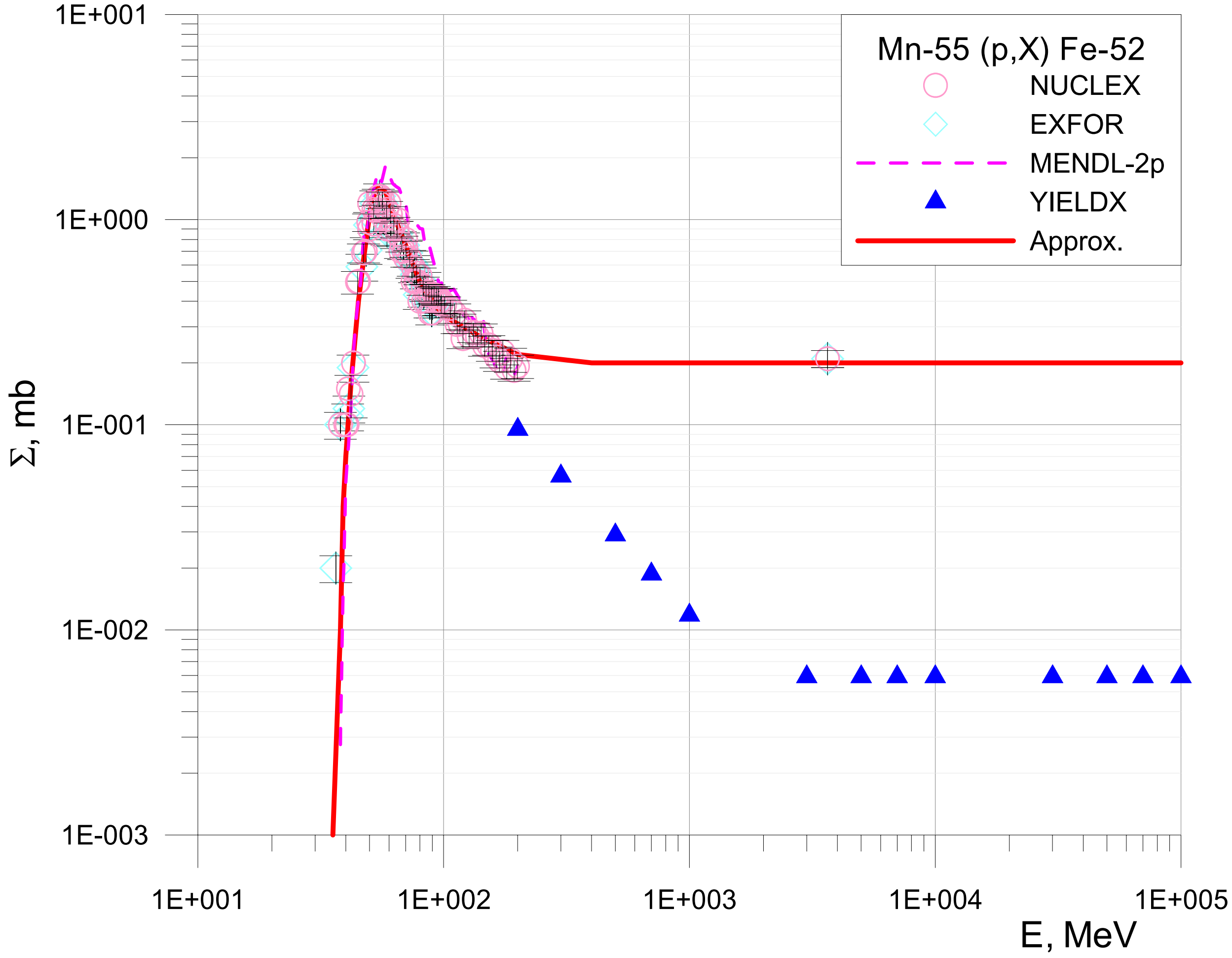
##	E, MeV	Σ, mb
1	9.34	0.0
2	14	0.1
3	16	0.8
4	18	1.8
5	24	3.6
6	32	5.5
7	44	7.0
8	90	13
9	190	22
10	340	33
11	480	42
12	890	62
13	1600	80
14	3200	100
15	10000	120
16	100000	125
17		
18		

Summary of experimental and calculated cross-section data used for manganese

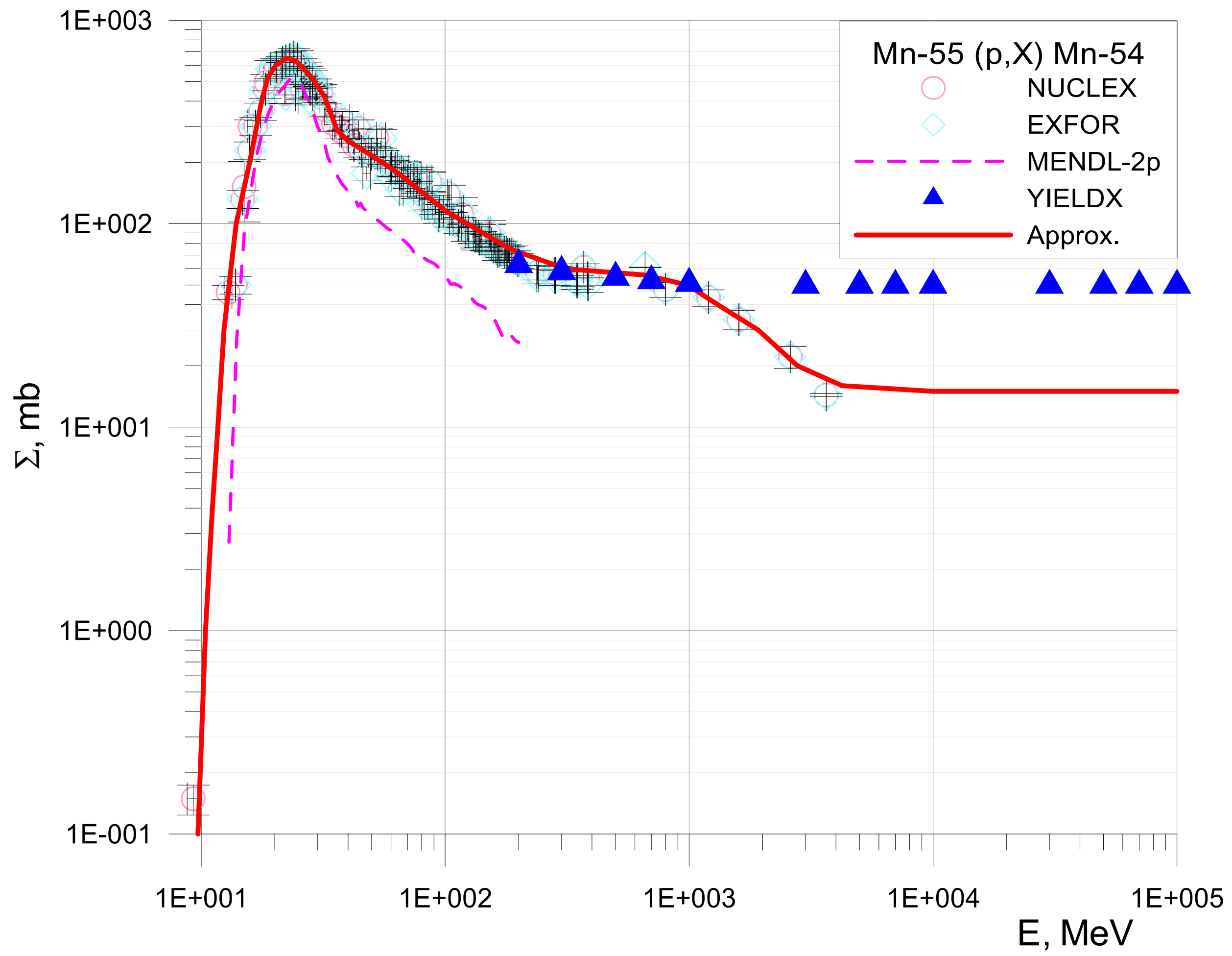
Nuclide	Half-life			Decay Mode	Source			Comment
					Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-				
Be-7	53.22	D	0.06	EC		x	x	
Be-10	2E+06	Y	60000	B-		x	x	
C-14	5700	Y	30	B-				cum
F-18	109.77	M	0.05	EC				cum
Na-22	2.6019	Y	4E-04	EC		x	x	cum
Na-24	14.959	H	0.001	B-		x	x	cum
Mg-28	20.915	H	0.009	B-		x	x	cum
Al-26	717000	Y	24000	EC		x	x	
Si-31	157.3	M	0.3	B-				cum
Si-32	132	Y	13	B-				cum
P-32	14.262	D	0.014	B-				
P-33	25.34	D	0.12	B-				cum
S-35	87.51	D	0.12	B-				cum
S-38	170.3	M	0.7	B-				cum
Cl-36	301000	Y	2000	B-, EC		x	x	
Ar-37	35.04	D	0.04	EC	x			cum
Ar-39	269	Y	3	B-	x			cum
Ar-41	109.61	M	0.04	B-	x			cum
Ar-42	32.9	Y	1.1	B-	x			cum
K-42	12.36	H	0.012	B-	x	x		
K-43	22.3	H	0.1	B-	x	x	x	cum
Ca-41	102000	Y	7000	EC	x		x	cum
Ca-45	162.61	D	0.09	B-	x			cum
Ca-47	4.536	D	0.003	B-	x	x	x	cum
Sc-43	3.891	H	0.012	EC	x	x	x	cum
Sc-44	3.97	H	0.04	EC	x	x	x	
Sc-44m	58.61	H	0.1	IT, EC	x	x	x	
Sc-46	83.79	D	0.04	B-	x	x	x	
Sc-47	3.3492	D	6E-04	B-	x	x	x	
Sc-48	43.67	H	0.09	B-	x	x	x	
Ti-44	60	Y	1.1	EC	x	x		cum
Ti-45	184.8	M	0.5	EC	x			cum
V-48	15.974	D	0.003	EC	x	x	x	
V-49	330	D	15	EC	x			cum
Cr-48	21.56	H	0.03	EC	x	x	x	cum
Cr-51	27.703	D	0.002	EC	x	x	x	cum
Mn-52g	5.591	D	0.003	EC	x	x	x	cum
Mn-53	4E+06	Y	40000	EC	x			cum
Mn-54	312.12	D	0.06	EC	x	x	x	
Fe-52	8.275	H	0.008	EC	x	x	x	
Fe-55	2.737	Y	0.011	EC	x	x	x	



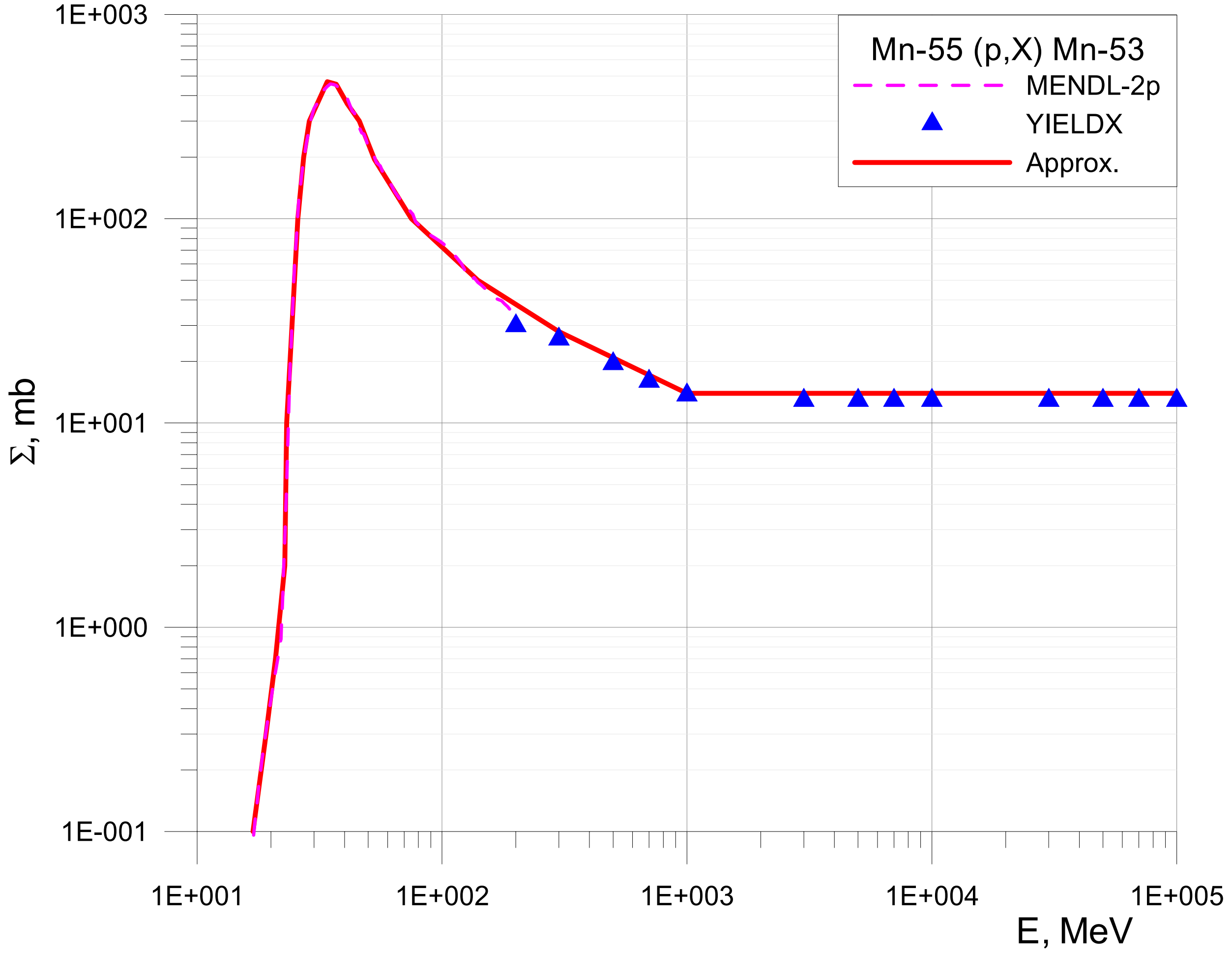
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	1.03	0.000	19	46	26.0
2	1.05	0.001	20	90	12.0
3	1.08	0.004	21	160	5.5
4	1.15	0.020	22	360	2.0
5	1.3	0.10	23	600	1.1
6	1.6	0.78	24	900	0.8
7	2.0	4.40	25	1200	0.7
8	2.6	19.4	26	100000	0.7
9	3.0	46.2			
10	3.6	116			
11	4.8	242			
12	5.9	372			
13	6.6	480			
14	7.8	560			
15	9.4	620			
16	11	600			
17	17	140			
18	30	45.0			



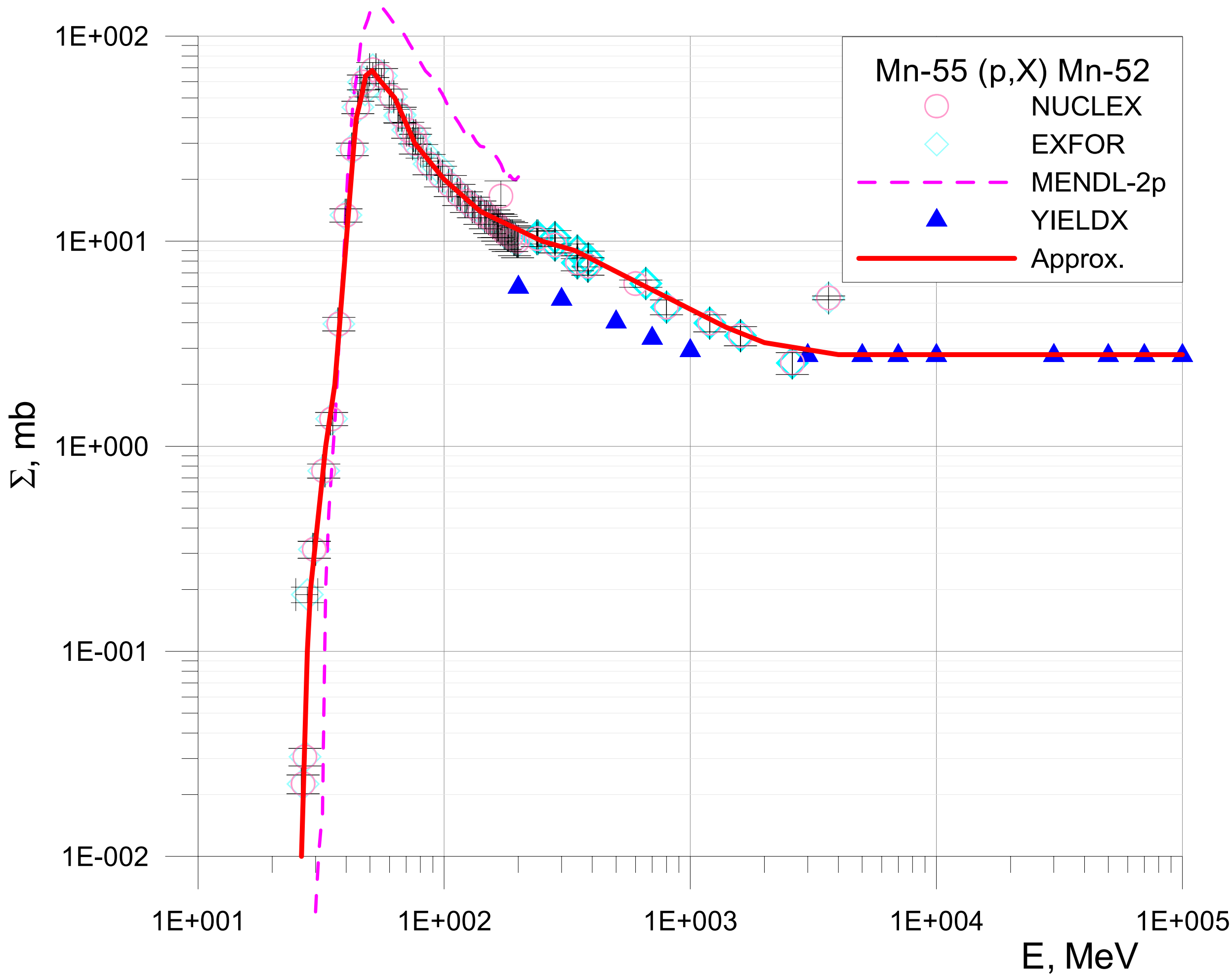
##	E, MeV	Σ, mb
1	35.0	0.000
2	35.4	0.001
3	38	0.01
4	39	0.04
5	40	0.07
6	42	0.16
7	45	0.40
8	48	0.74
9	50	1.05
10	51	1.25
11	54	1.42
12	58	1.37
13	62	1.08
14	70	0.75
15	81	0.48
16	100	0.34
17	140	0.27
18	200	0.22
19	400	0.20
20	100000	0.20



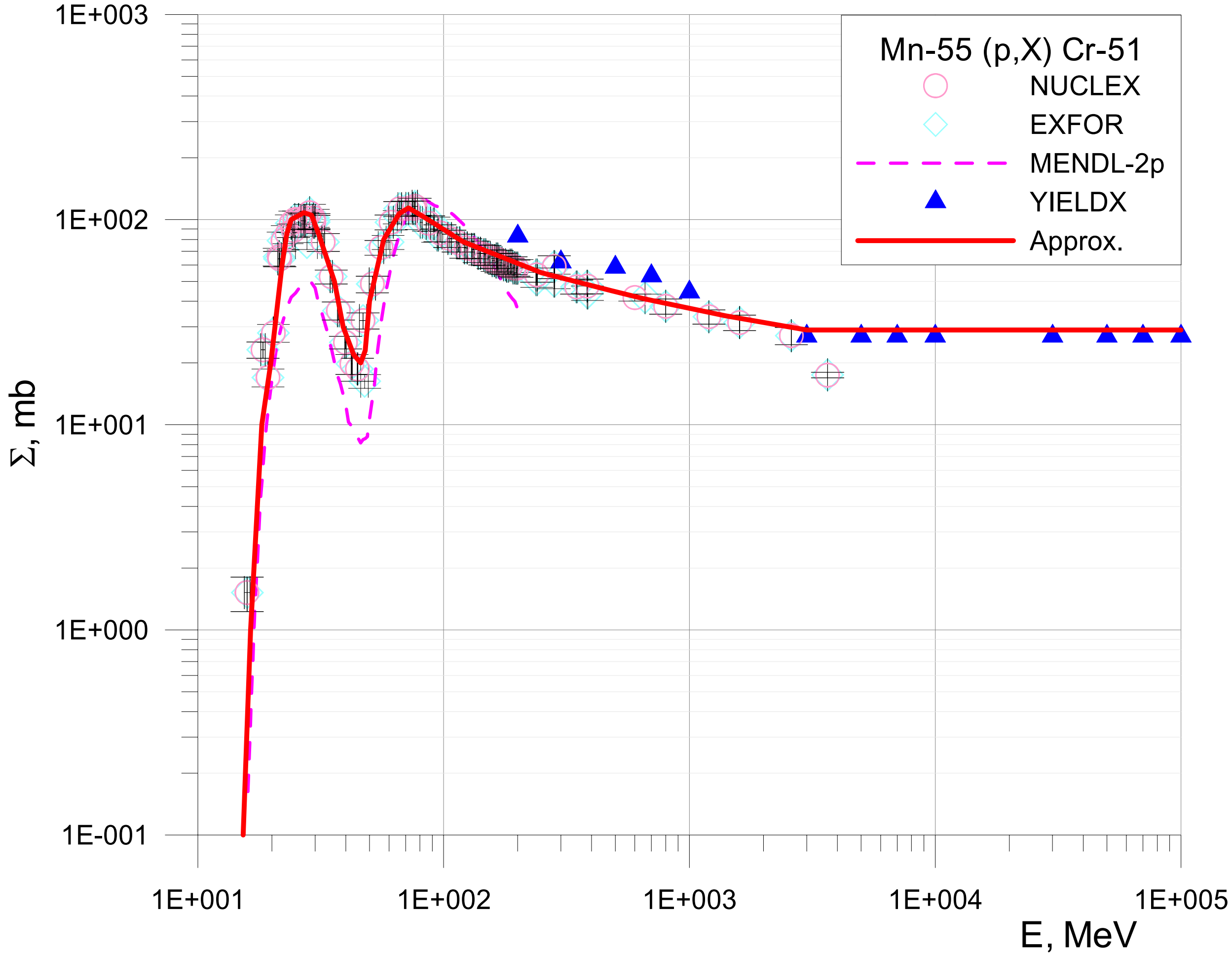
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	8.15	0.0	19	49	220
2	9.75	0.1	20	63	180
3	10.4	1.0	21	101	115
4	11.1	4.0	22	185	75
5	11.7	10	23	312	60
6	12.4	30	24	656	56
7	13.6	80	25	986	50
8	13.9	100	26	1308	40
9	15.8	200	27	1920	30
10	17.5	380	28	2780	20
11	18.7	520	29	4240	16
12	20.2	600	30	10000	15
13	22.4	650	31	100000	15
14	24.5	630			
15	28.5	520			
16	32	420			
17	36	290			
18	40	255			



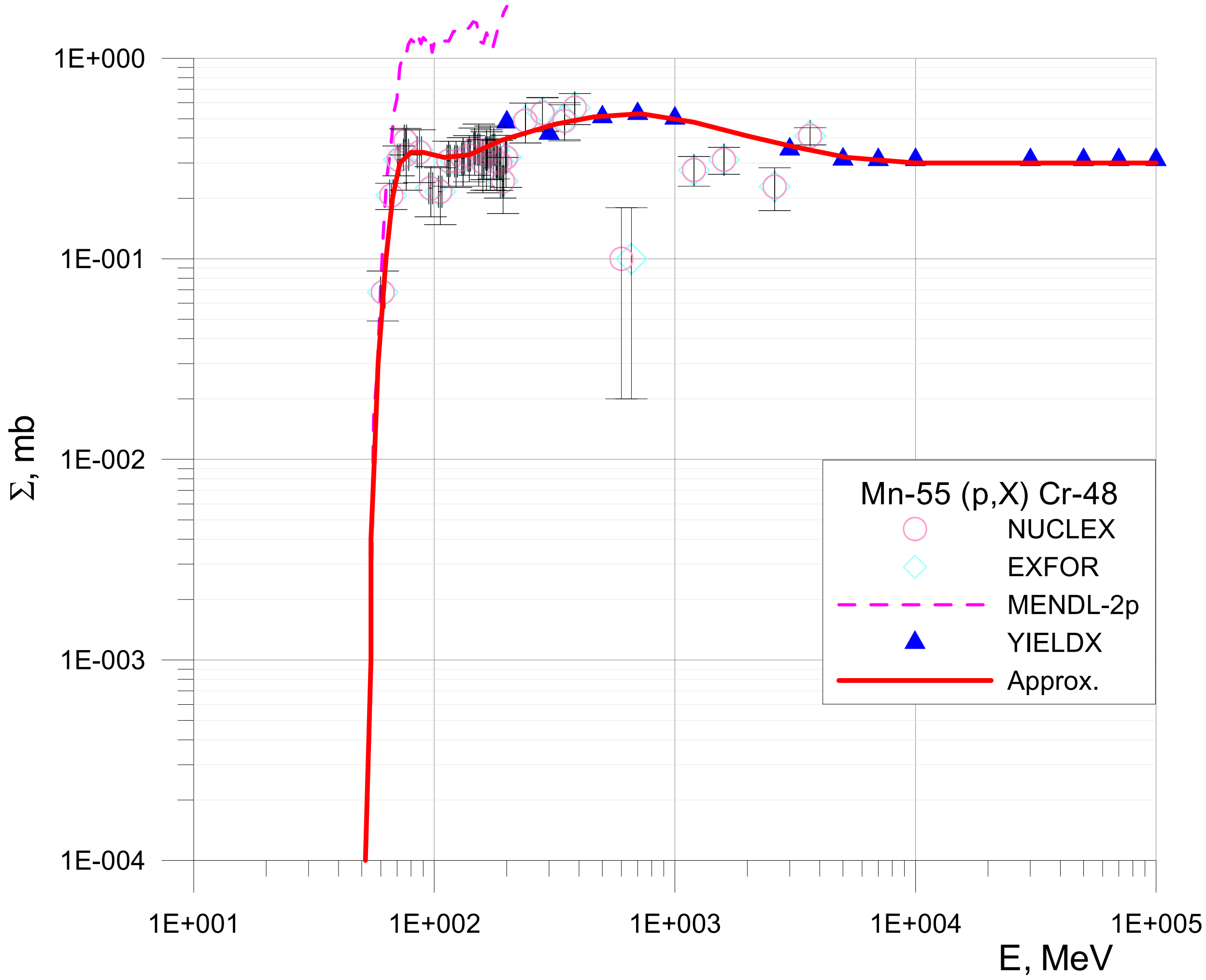
##	E, MeV	Σ, mb
1	10.88	0.0
2	16.9	0.1
3	19.1	0.3
4	20.9	0.7
5	22.8	2.0
6	23.2	10.0
7	25.8	100
8	27.2	200
9	28.7	300
10	32	400
11	34	468
12	37	456
13	41	365
14	46	300
15	53	195
16	75	100
17	140	50
18	300	28
19	1000	14
20	100000	14



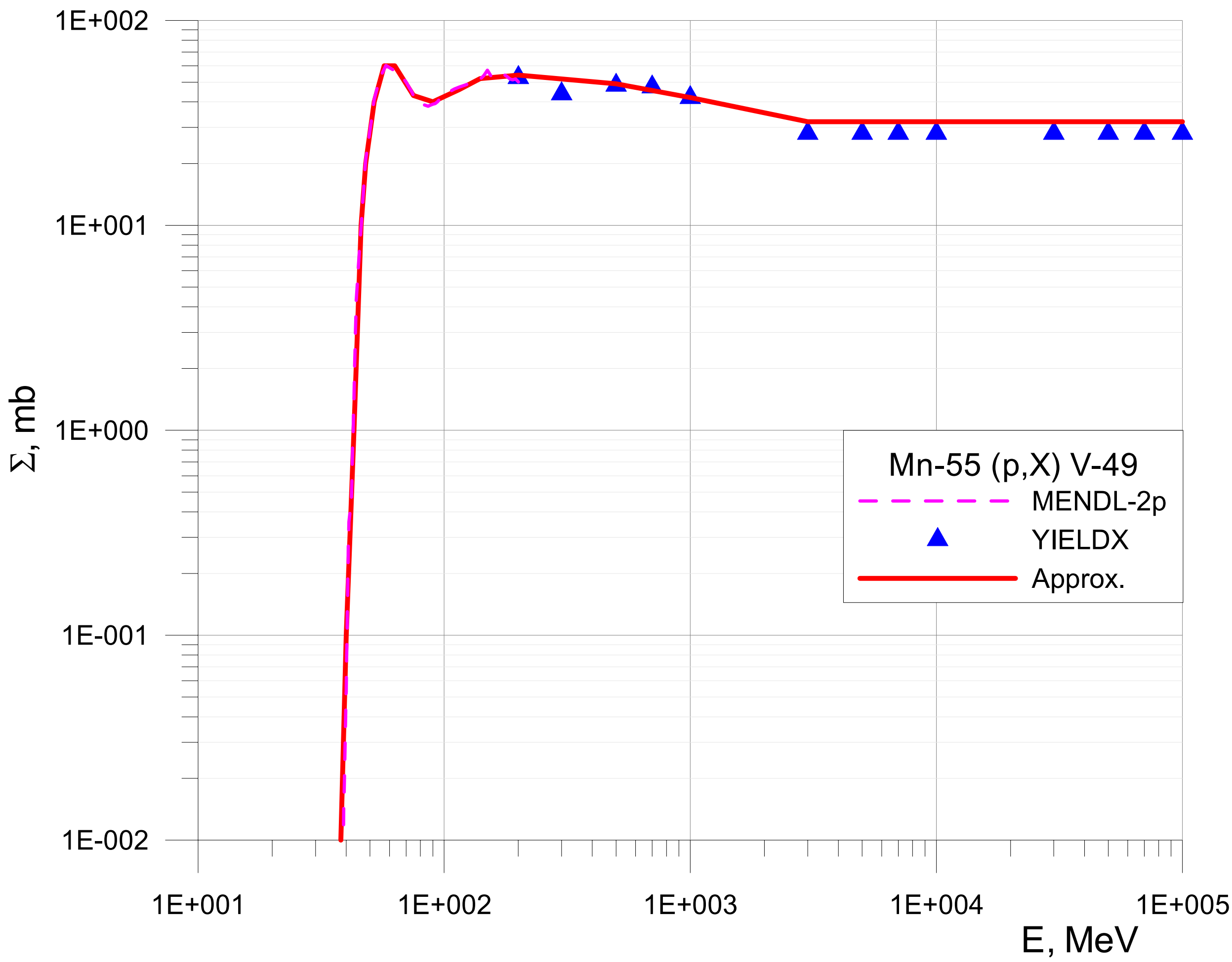
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	23.15	0.00	19	340	9.0
2	26.3	0.01	20	660	6.0
3	27.8	0.10	21	1400	3.8
4	28.6	0.20	22	2000	3.2
5	33	1.0	23	4000	2.8
6	36	2.0	24	100000	2.8
7	40	10.			
8	43	30.			
9	44	40.			
10	46	50.			
11	48	64.			
12	51	68.			
13	54	62.			
14	63	50.			
15	76	30.			
16	100	20.			
17	140	14.			
18	250	10.			



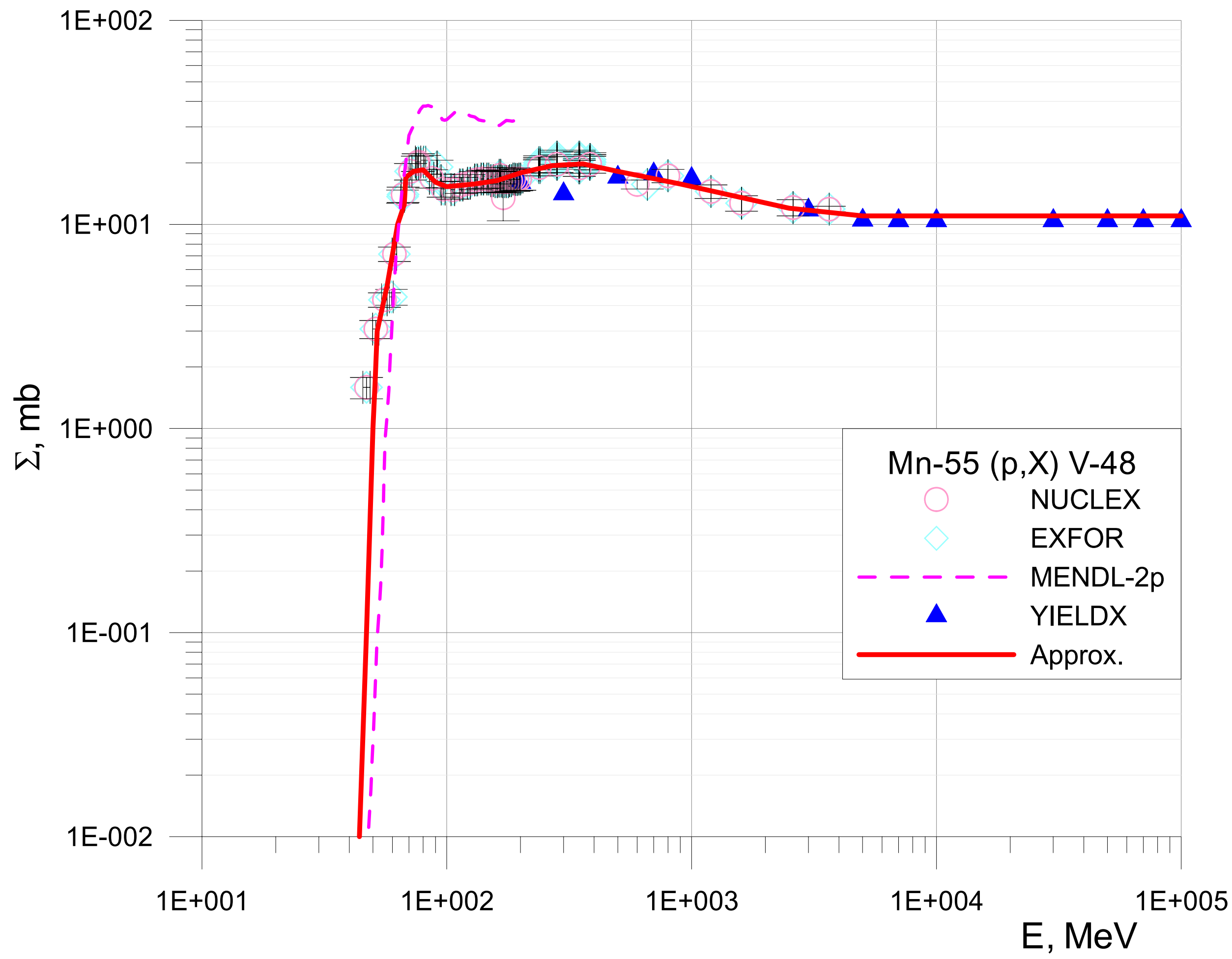
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	9.64	0.0	19	66	107
2	15.3	0.1	20	72	114
3	16.4	1.0	21	83	103
4	18.2	10	22	120	78
5	19.8	20	23	250	55
6	22	60	24	480	45
7	23	85	25	660	41
8	24	100	26	1400	34
9	27	108	27	3000	29
10	29	105	28	100000	29
11	31	85			
12	36	50			
13	39	30			
14	43	22			
15	46	20			
16	48	23			
17	50	40			
18	57	80			



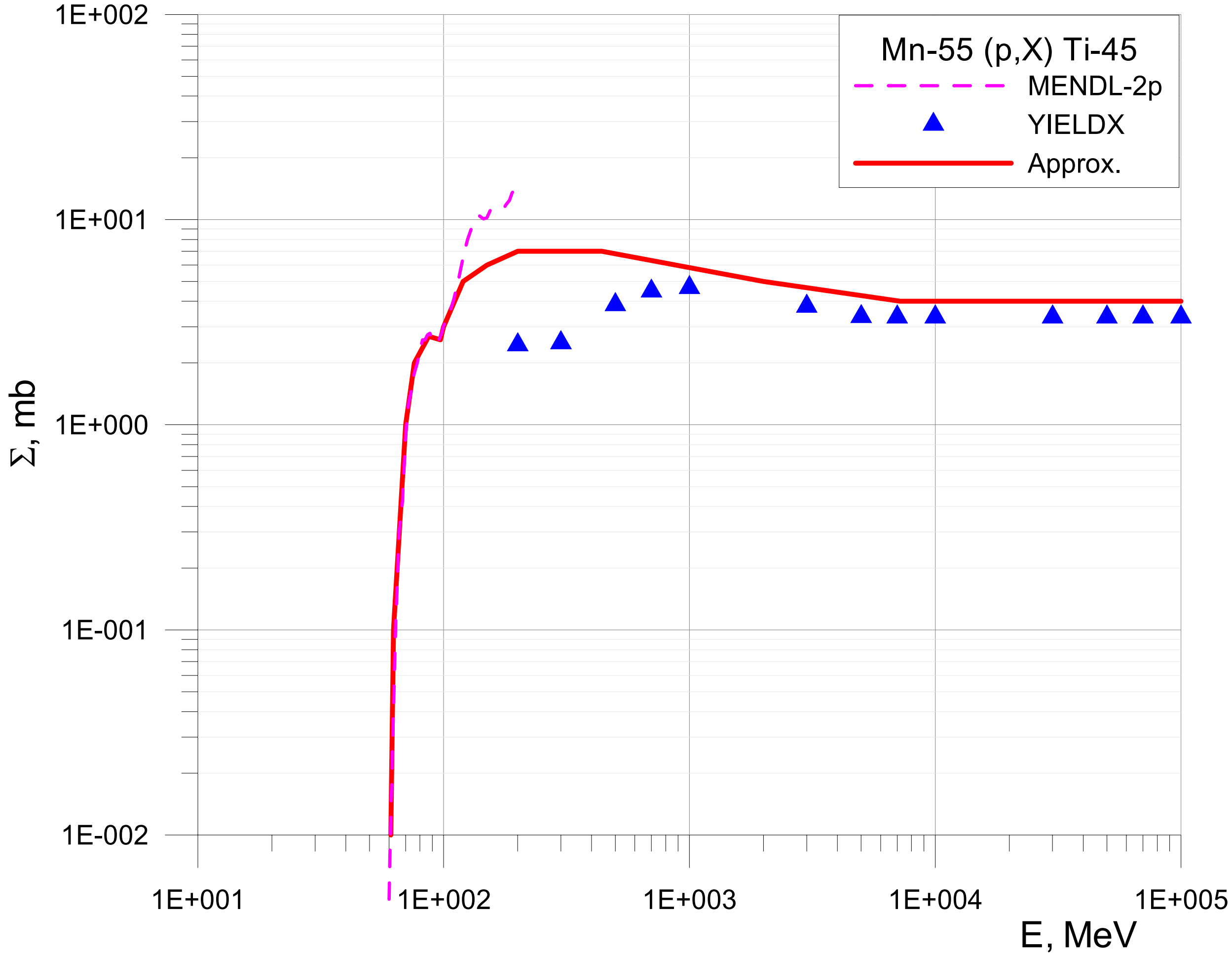
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	43.1	0.0000	19	2000	0.41
2	51.8	0.0001	20	3200	0.36
3	54.5	0.001	21	5200	0.32
4	54.5	0.004	22	10000	0.30
5	56.4	0.01	23	100000	0.30
6	58.4	0.03			
7	63	0.10			
8	67	0.20			
9	72	0.30			
10	80	0.34			
11	90	0.34			
12	110	0.32			
13	140	0.33			
14	190	0.39			
15	320	0.47			
16	460	0.51			
17	720	0.53			
18	1200	0.48			



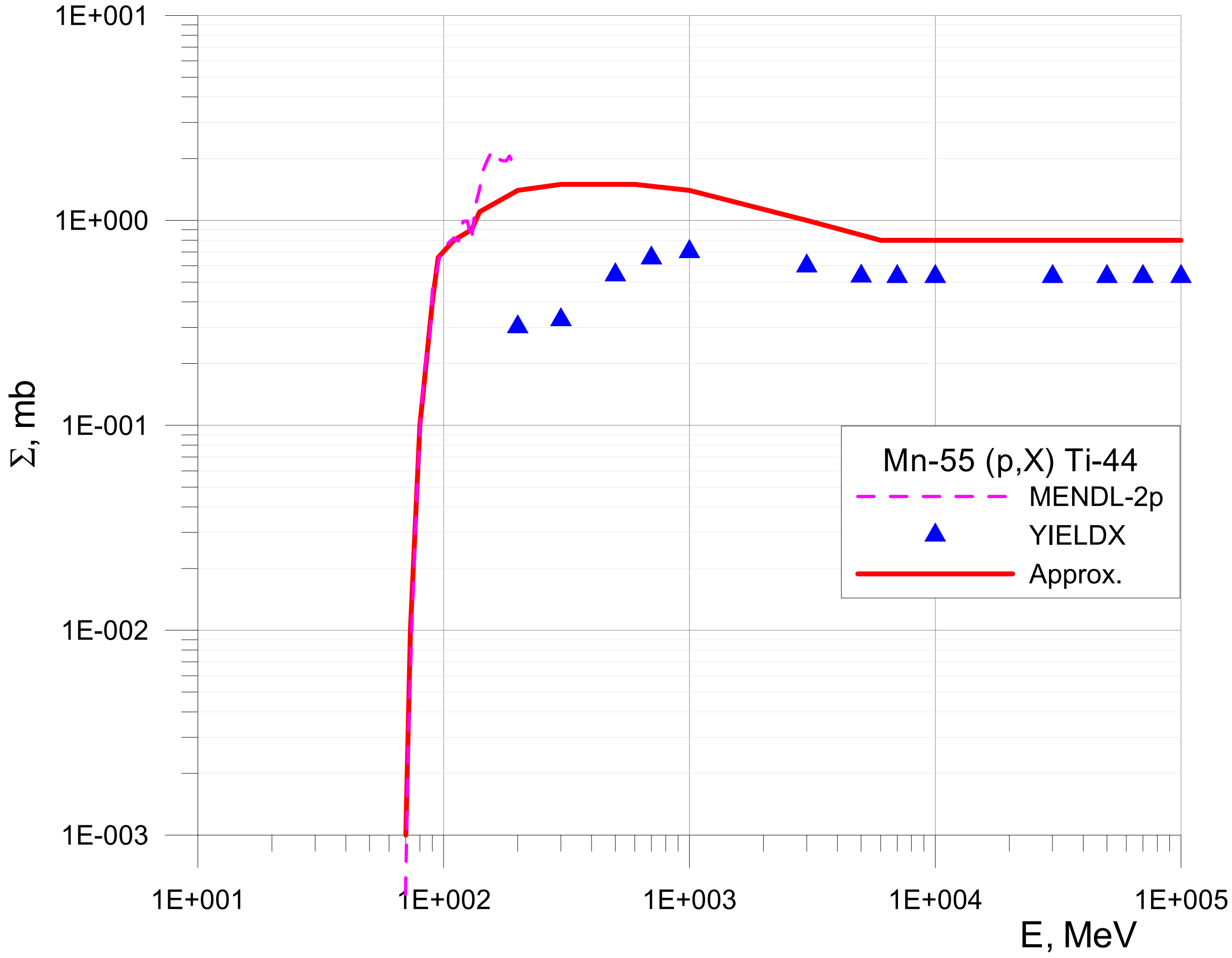
##	E, MeV	Σ, mb
1	20.2	0.00
2	38	0.01
3	40	0.1
4	43	1.0
5	46	10
6	48	20
7	52	40
8	57	60
9	63	60
10	75	43
11	90	40
12	115	46
13	140	52
14	200	54
15	500	49
16	1000	42
17	3000	32
18	100000	32



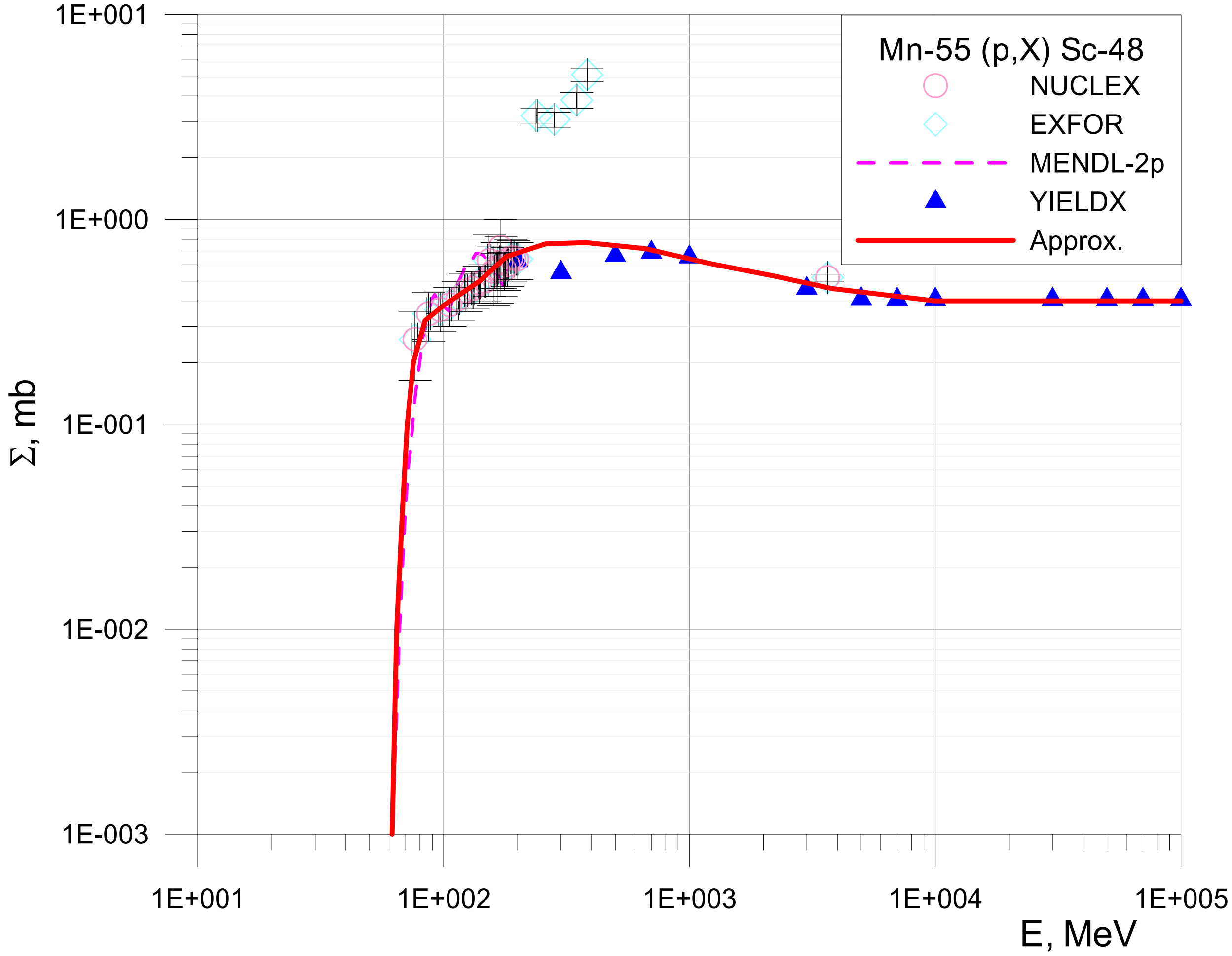
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	32.0	0.00	19	360	19.8
2	44.0	0.01	20	500	18.2
3	47.0	0.1	21	900	15.8
4	50.0	1.0	22	2500	12.0
5	51.0	1.7	23	5000	11.0
6	52	3.0	24	100000	11.0
7	57	5.0			
8	63	10.0			
9	67	12.5			
10	68	17.0			
11	73	18.2			
12	80	18.5			
13	90	16.1			
14	100	15.3			
15	130	15.8			
16	160	16.4			
17	200	17.9			
18	270	19.4			



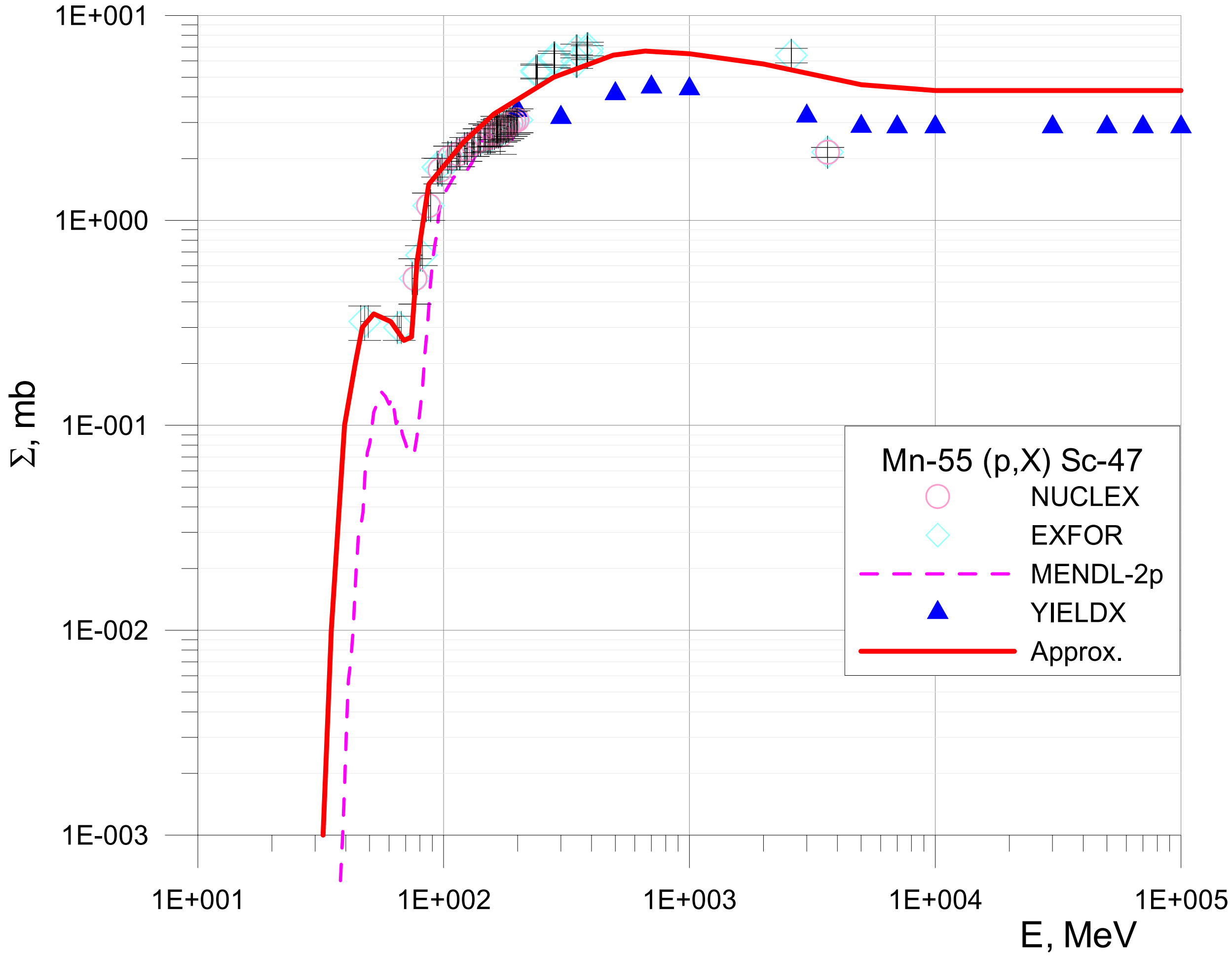
##	E, MeV	Σ, mb
1	41.2	0.00
2	61.0	0.01
3	62.5	0.1
4	70	1.0
5	76	2.0
6	87	2.7
7	97	2.6
8	100	3.0
9	120	5.0
10	150	6.0
11	200	7.0
12	440	7.0
13	2000	5.0
14	7200	4.0
15	100000	4.0
16		
17		
18		



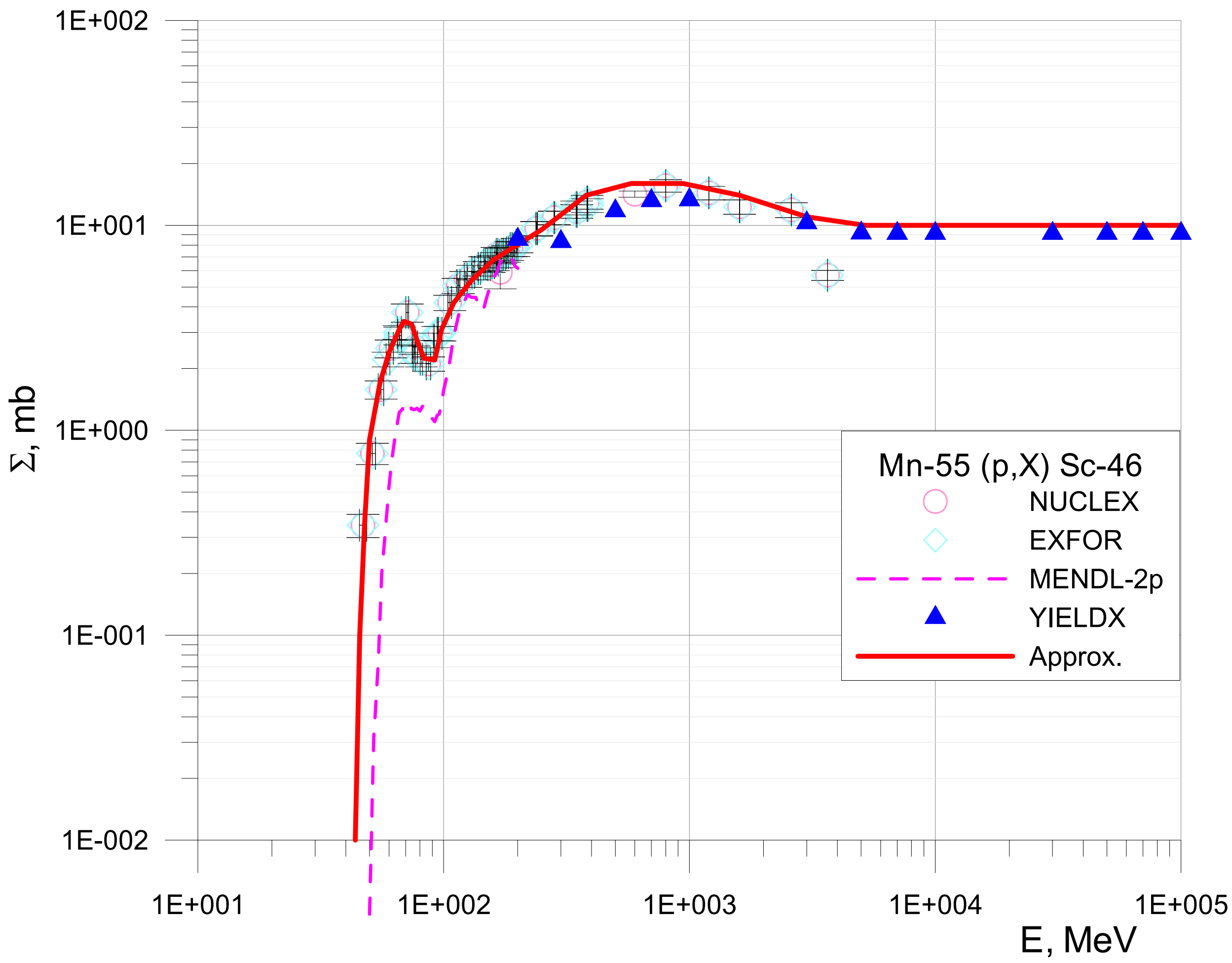
##	E, MeV	Σ, mb
1	50.9	0.000
2	70.1	0.001
3	73.2	0.01
4	80	0.10
5	90	0.40
6	95	0.66
7	110	0.80
8	130	0.90
9	140	1.10
10	200	1.40
11	300	1.50
12	600	1.50
13	1000	1.40
14	3000	1.00
15	6000	0.80
16	100000	0.80
17		
18		



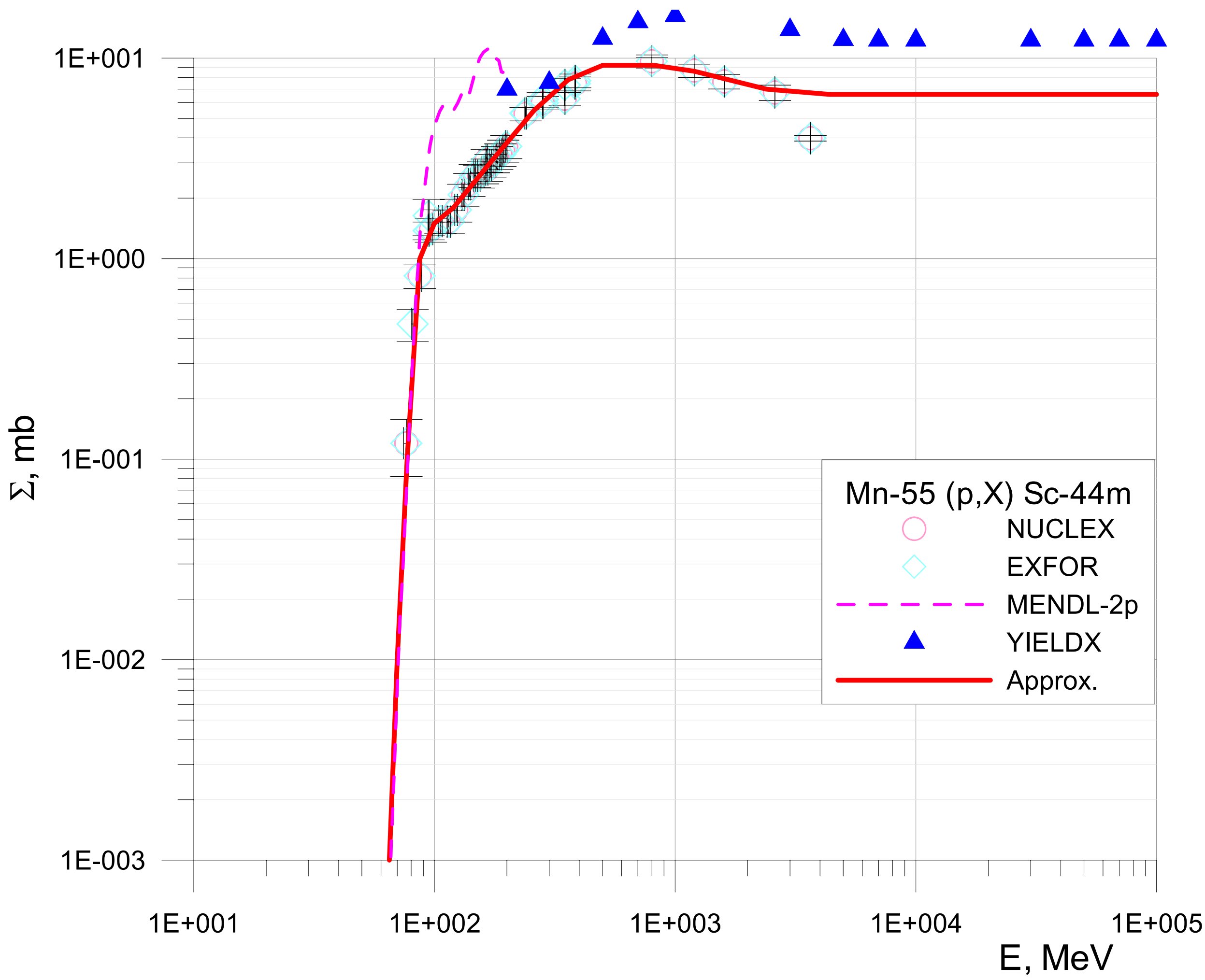
##	E, MeV	Σ, mb
1	31.1	0.000
2	61.7	0.001
3	64.4	0.01
4	68.1	0.04
5	71.1	0.10
6	75.3	0.20
7	84	0.32
8	100	0.38
9	140	0.50
10	180	0.66
11	260	0.76
12	380	0.77
13	660	0.72
14	1200	0.61
15	2200	0.53
16	3800	0.46
17	10000	0.40
18	100000	0.40



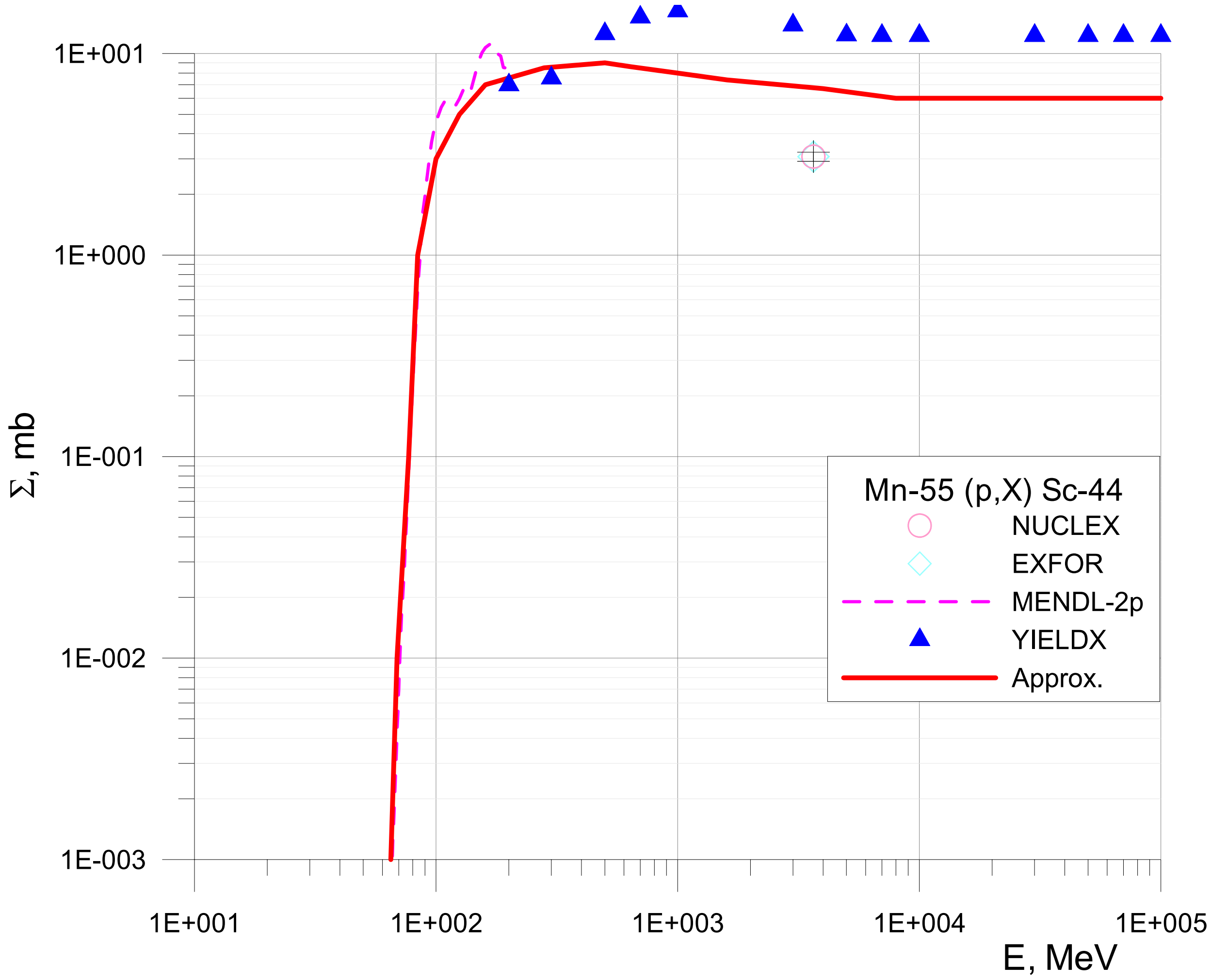
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	18.6	0.000	19	2000	5.8
2	32.3	0.001	20	5000	4.6
3	34.9	0.01	21	10000	4.3
4	39.5	0.10	22	100000	4.3
5	43.7	0.20			
6	46.6	0.30			
7	52	0.35			
8	61	0.32			
9	69	0.26			
10	74	0.27			
11	78	0.63			
12	87	1.5			
13	120	2.4			
14	160	3.3			
15	280	5.0			
16	490	6.4			
17	660	6.7			
18	1000	6.5			



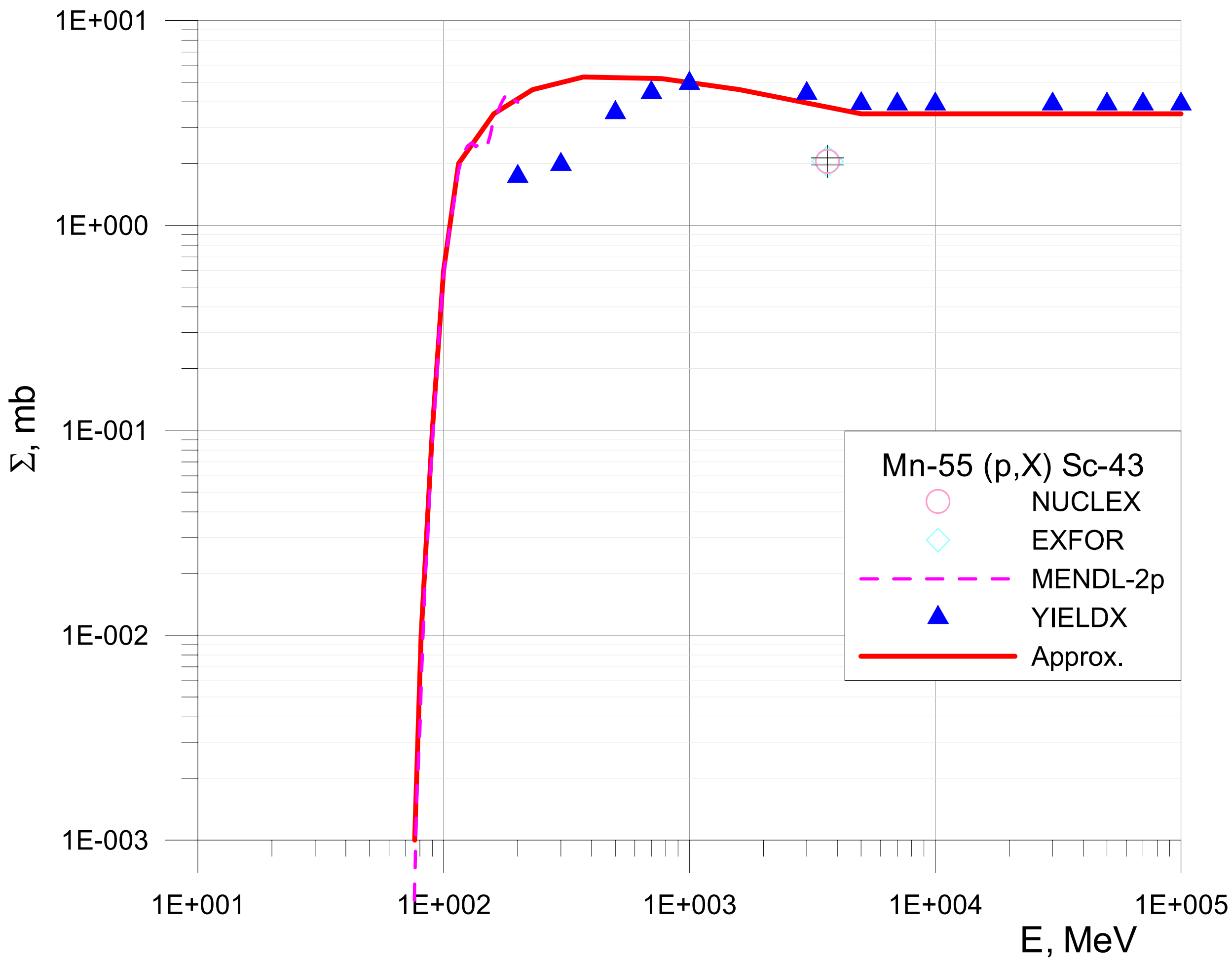
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	27.1	0.00	19	380	14
2	43.7	0.01	20	580	16
3	45.6	0.10	21	940	16
4	47.7	0.35	22	1600	14
5	50	0.90	23	3000	11
6	55	1.70	24	5200	10
7	60	2.40	25	100000	10
8	66	3.10			
9	69	3.40			
10	74	3.30			
11	78	2.75			
12	83	2.25			
13	92	2.20			
14	98	3.1			
15	110	4.2			
16	130	5.4			
17	160	6.8			
18	250	9.5			



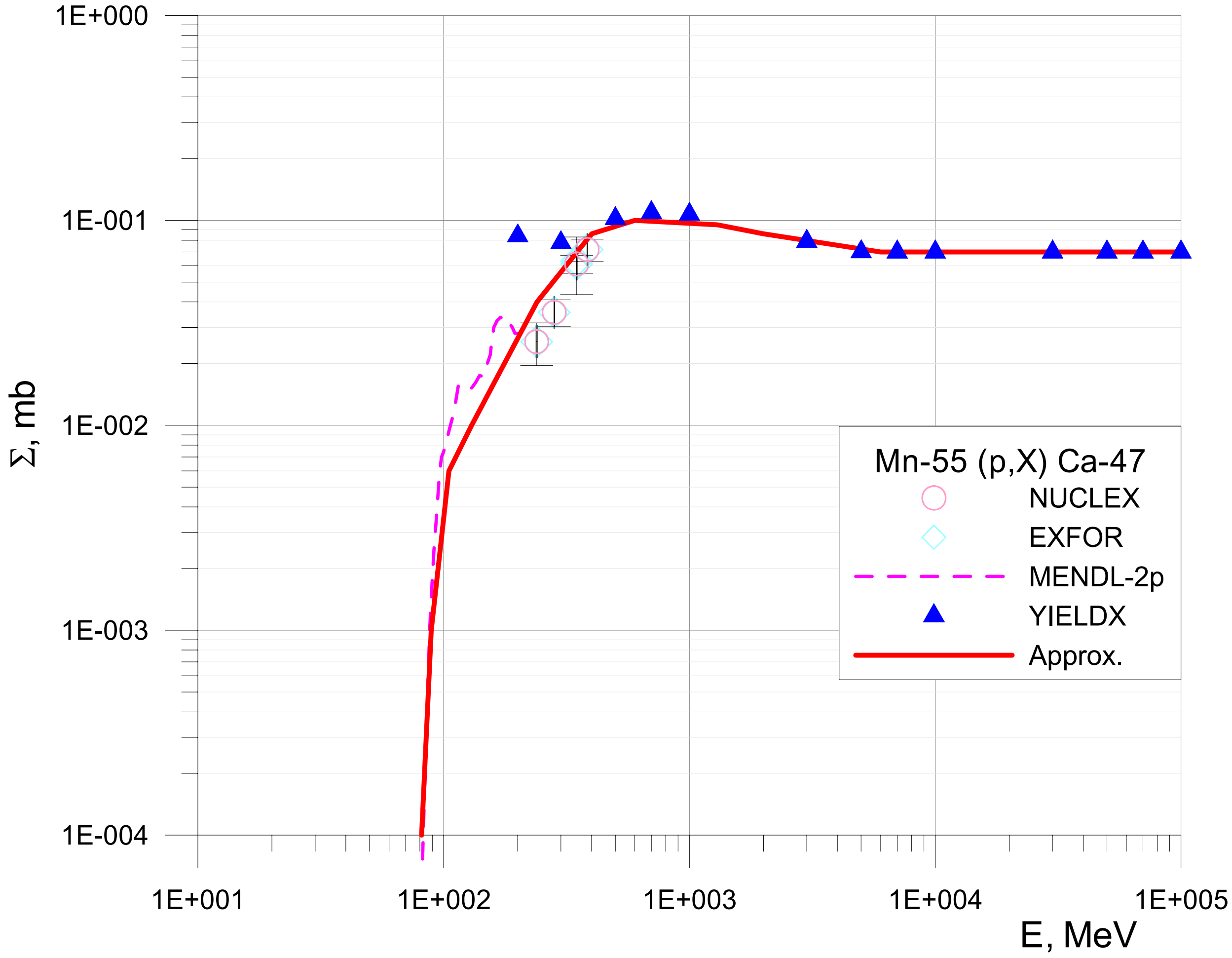
##	E, MeV	Σ, mb
1	41.2	0.000
2	65	0.001
3	70	0.01
4	77	0.1
5	87	1.0
6	100	1.5
7	120	1.8
8	170	3.0
9	260	5.5
10	360	7.8
11	500	9.2
12	820	9.2
13	1200	8.6
14	2400	7.0
15	4400	6.6
16	100000	6.6
17		
18		



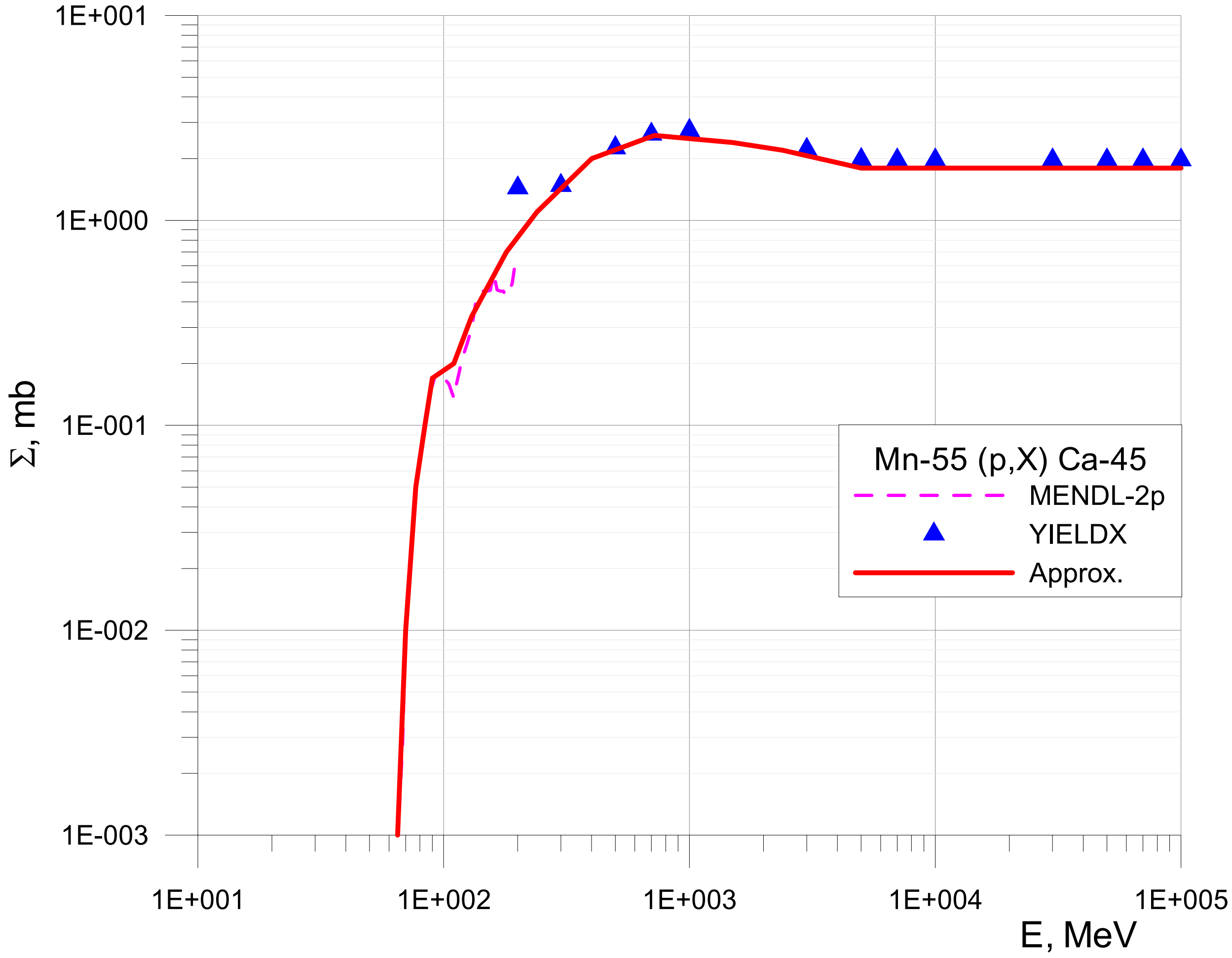
##	E, MeV	Σ, mb
1	41.2	0.000
2	65	0.001
3	69	0.01
4	77	0.10
5	84	1.00
6	100	3.00
7	125	5.00
8	160	7.0
9	280	8.5
10	500	9.0
11	640	8.6
12	1000	8.0
13	1600	7.4
14	4000	6.7
15	8000	6.0
16	100000	6.0
17		
18		



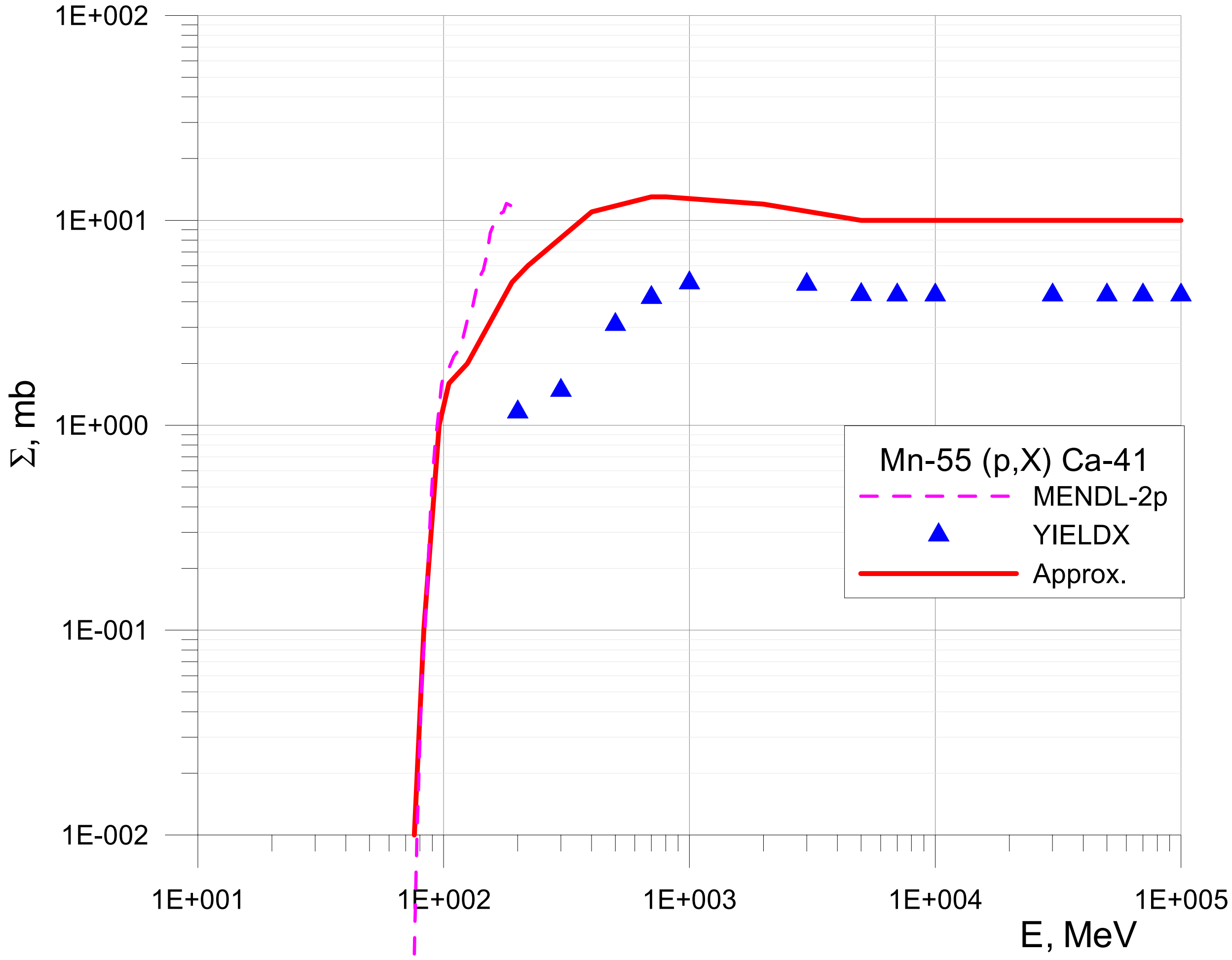
##	E, MeV	Σ, mb
1	51.1	0.000
2	76.2	0.001
3	81	0.01
4	90	0.1
5	100	0.6
6	115	2.0
7	160	3.5
8	230	4.6
9	370	5.3
10	770	5.2
11	1600	4.6
12	5000	3.5
13	100000	3.5
14		
15		
16		
17		
18		



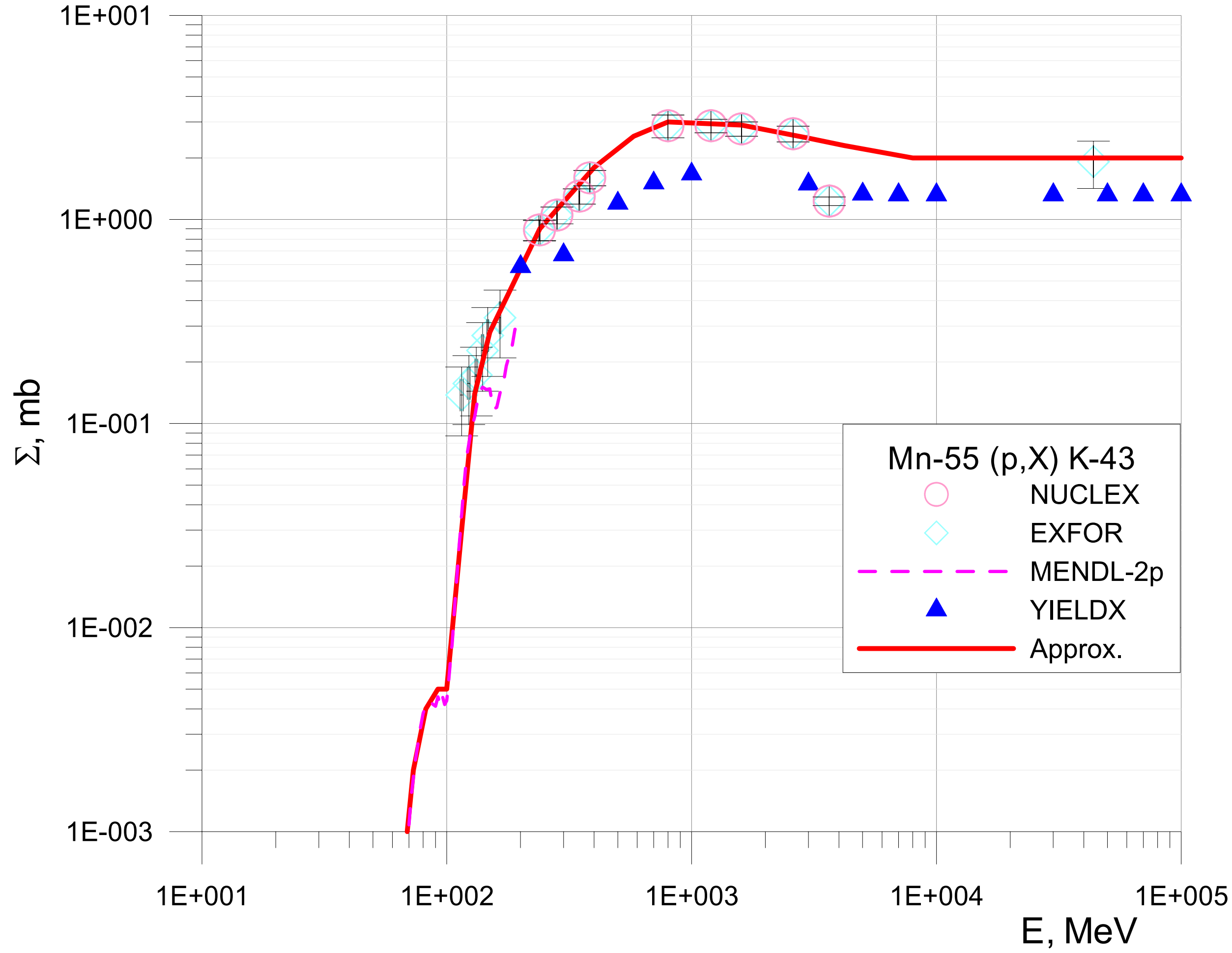
##	E, MeV	Σ, mb
1	40.74	0.0000
2	81.4	0.0001
3	89	0.001
4	105	0.006
5	130	0.01
6	240	0.04
7	400	0.09
8	600	0.10
9	1300	0.10
10	2000	0.09
11	6000	0.07
12	100000	0.07
13		
14		
15		
16		
17		
18		



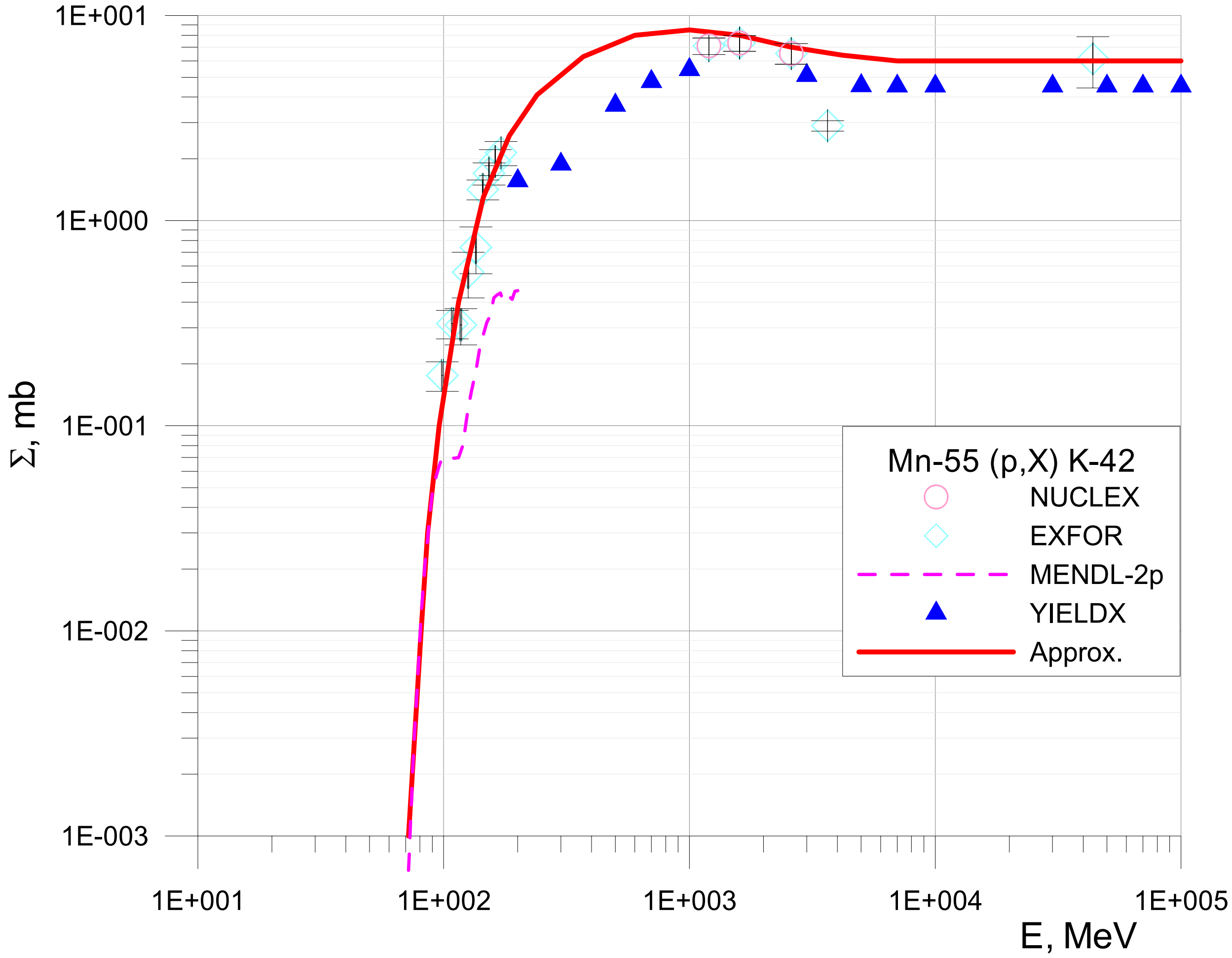
##	E, MeV	Σ, mb
1	29.9	0.0000
2	62	0.0001
3	65	0.001
4	70	0.01
5	77	0.05
6	84	0.10
7	90	0.17
8	110	0.20
9	130	0.34
10	180	0.70
11	240	1.10
12	400	2.00
13	720	2.60
14	1500	2.40
15	2400	2.20
16	5000	1.80
17	100000	1.80
18		



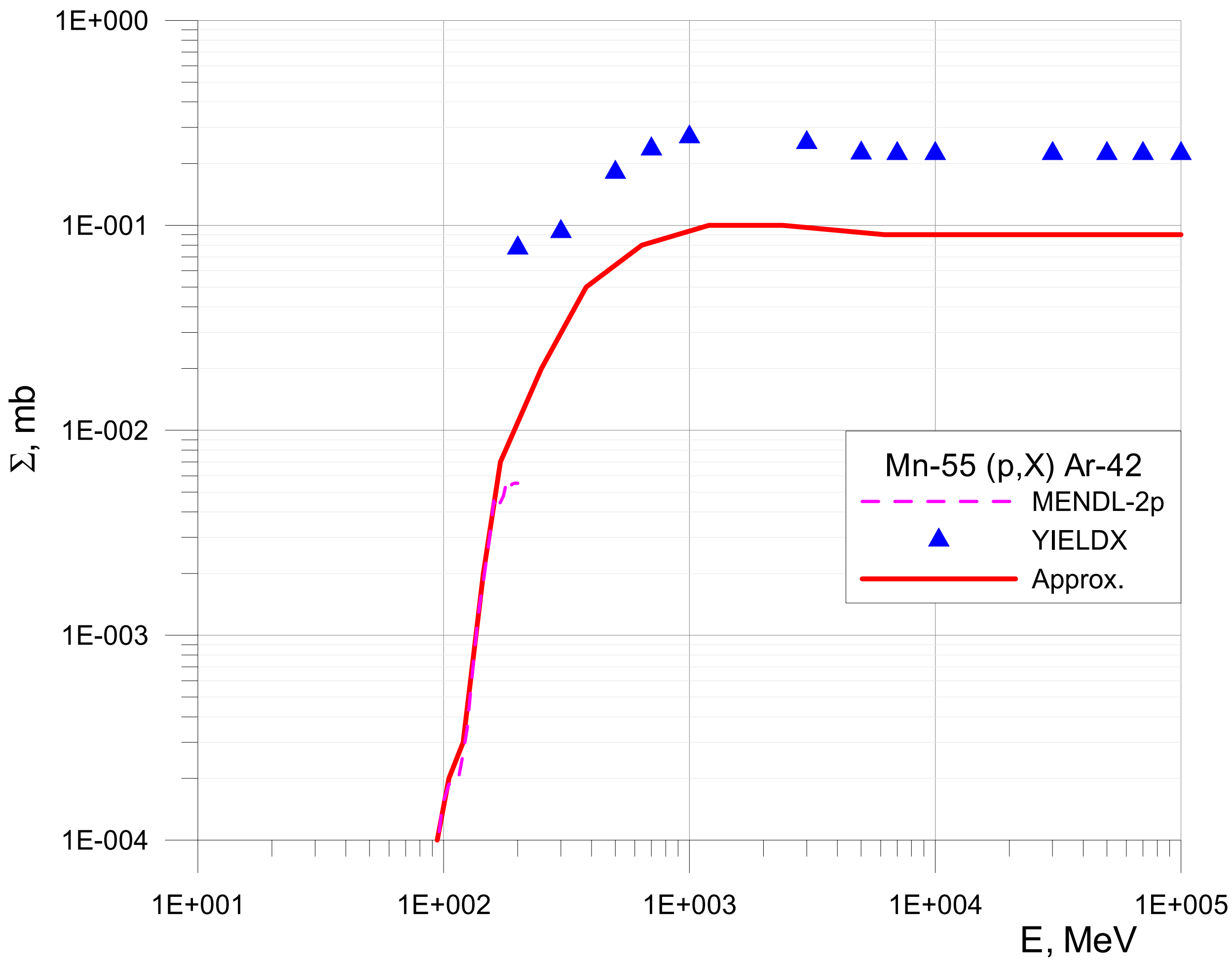
##	E, MeV	Σ, mb
1	47.6	0.00
2	76	0.01
3	83	0.1
4	96	1.0
5	105	1.6
6	125	2.0
7	190	5.0
8	220	6.0
9	400	11
10	700	13
11	800	13
12	2000	12
13	5000	10
14	100000	10
15		
16		
17		
18		



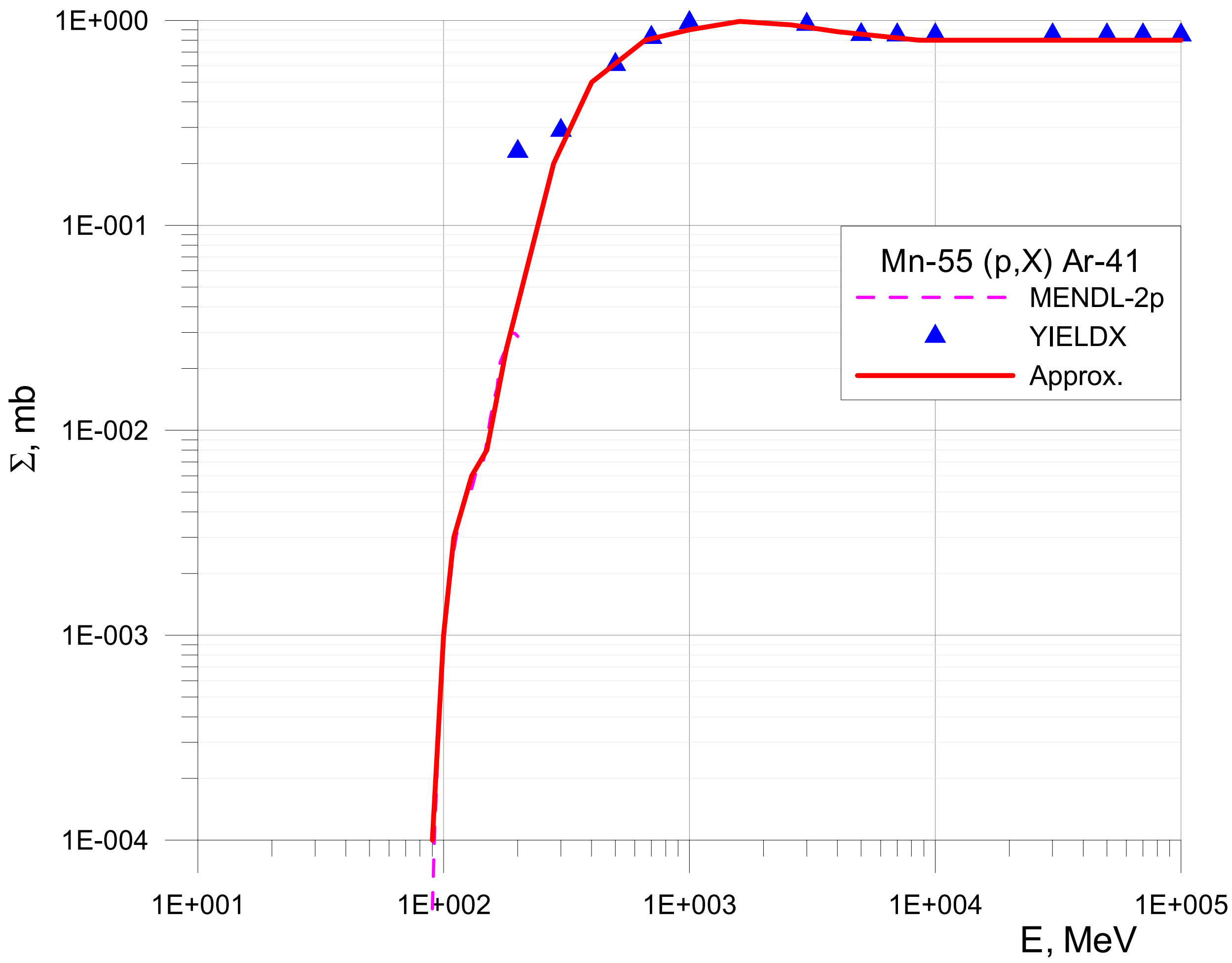
##	E, MeV	Σ, mb
1	28.9	0.000
2	69	0.001
3	73	0.002
4	82	0.004
5	92	0.005
6	100	0.005
7	115	0.03
8	130	0.14
9	150	0.28
10	240	0.90
11	400	1.80
12	580	2.56
13	800	3.00
14	1600	2.90
15	3000	2.50
16	4200	2.30
17	8000	2.00
18	100000	2.00



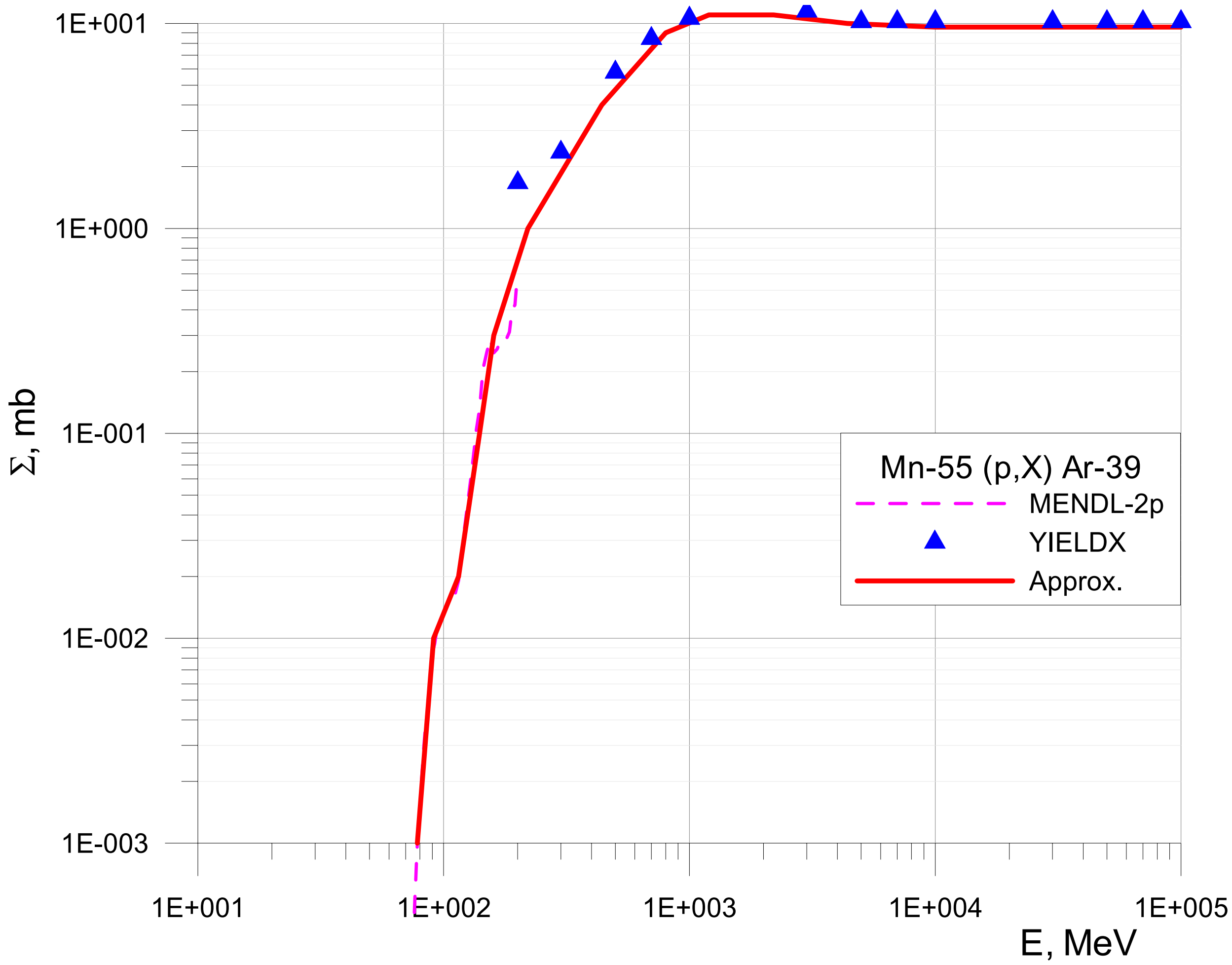
##	E, MeV	Σ, mb
1	36.5	0.000
2	72	0.001
3	81	0.01
4	86	0.03
5	96	0.10
6	115	0.40
7	145	1.3
8	185	2.6
9	240	4.1
10	370	6.3
11	600	8.0
12	1000	8.5
13	1600	8.0
14	2600	7.0
15	4200	6.4
16	7000	6.0
17	100000	6.0
18		



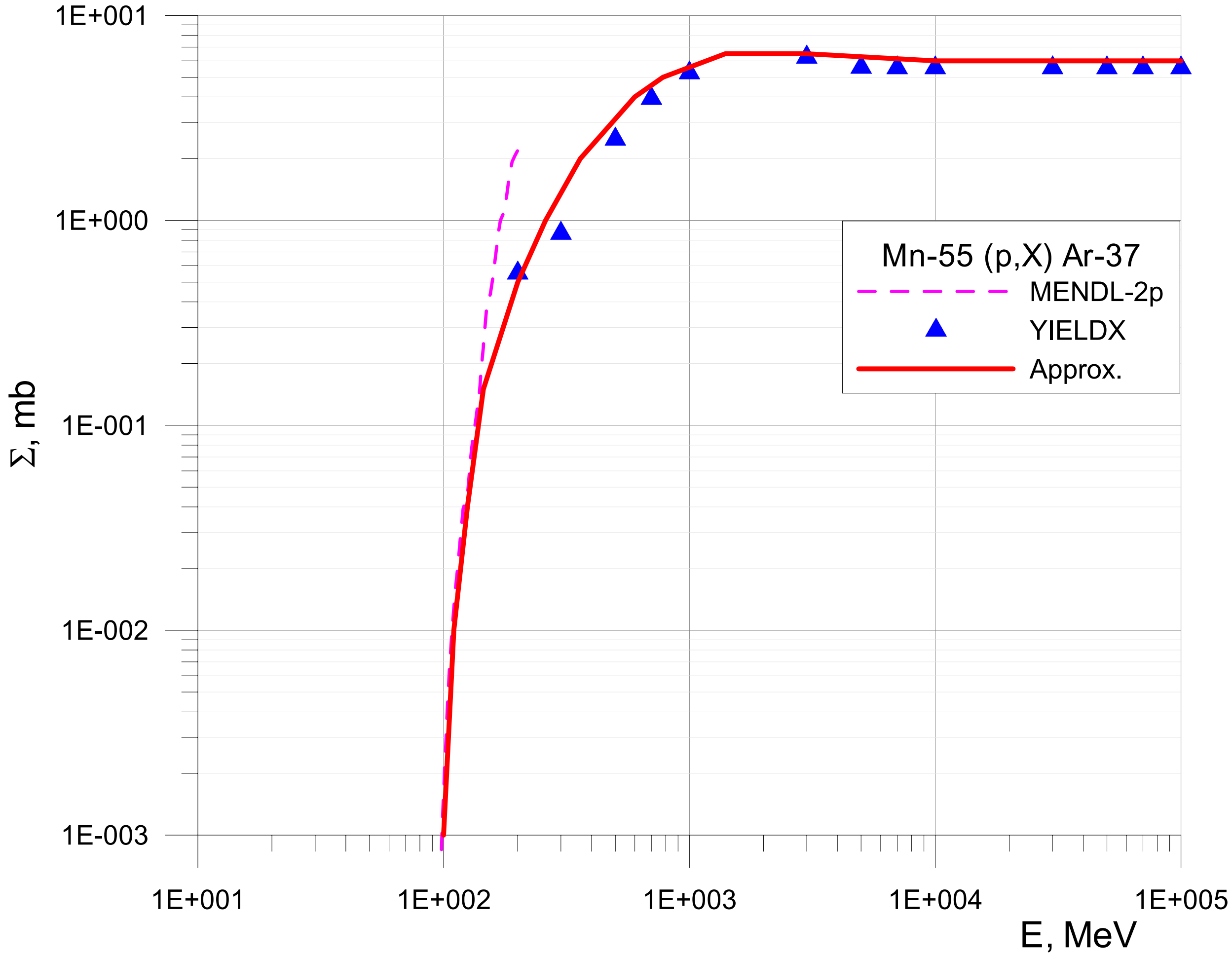
##	E, MeV	Σ, mb
1	38.5	0.00000
2	84.6	0.00001
3	94.2	0.0001
4	105	0.0002
5	120	0.0003
6	145	0.002
7	170	0.007
8	250	0.02
9	380	0.05
10	640	0.08
11	1200	0.10
12	2400	0.10
13	6200	0.09
14	10000	0.09
15	100000	0.09
16		
17		
18		



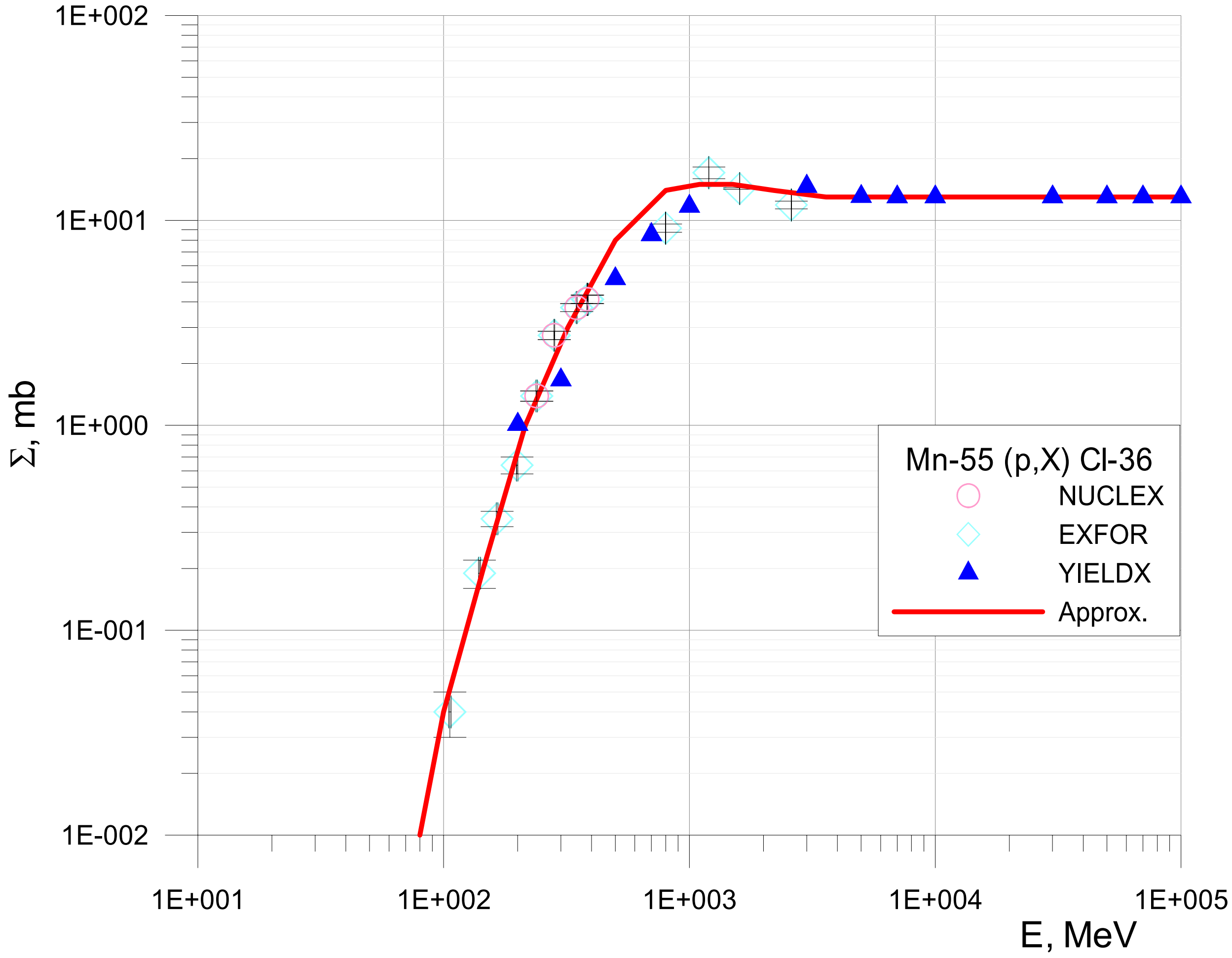
##	E, MeV	Σ, mb
1	40.3	0.00000
2	87	0.00001
3	90	0.0001
4	100	0.001
5	110	0.003
6	130	0.006
7	150	0.008
8	180	0.025
9	280	0.2
10	400	0.5
11	660	0.8
12	1000	0.9
13	1600	1.0
14	2600	1.0
15	4000	0.9
16	8600	0.8
17	100000	0.8
18		



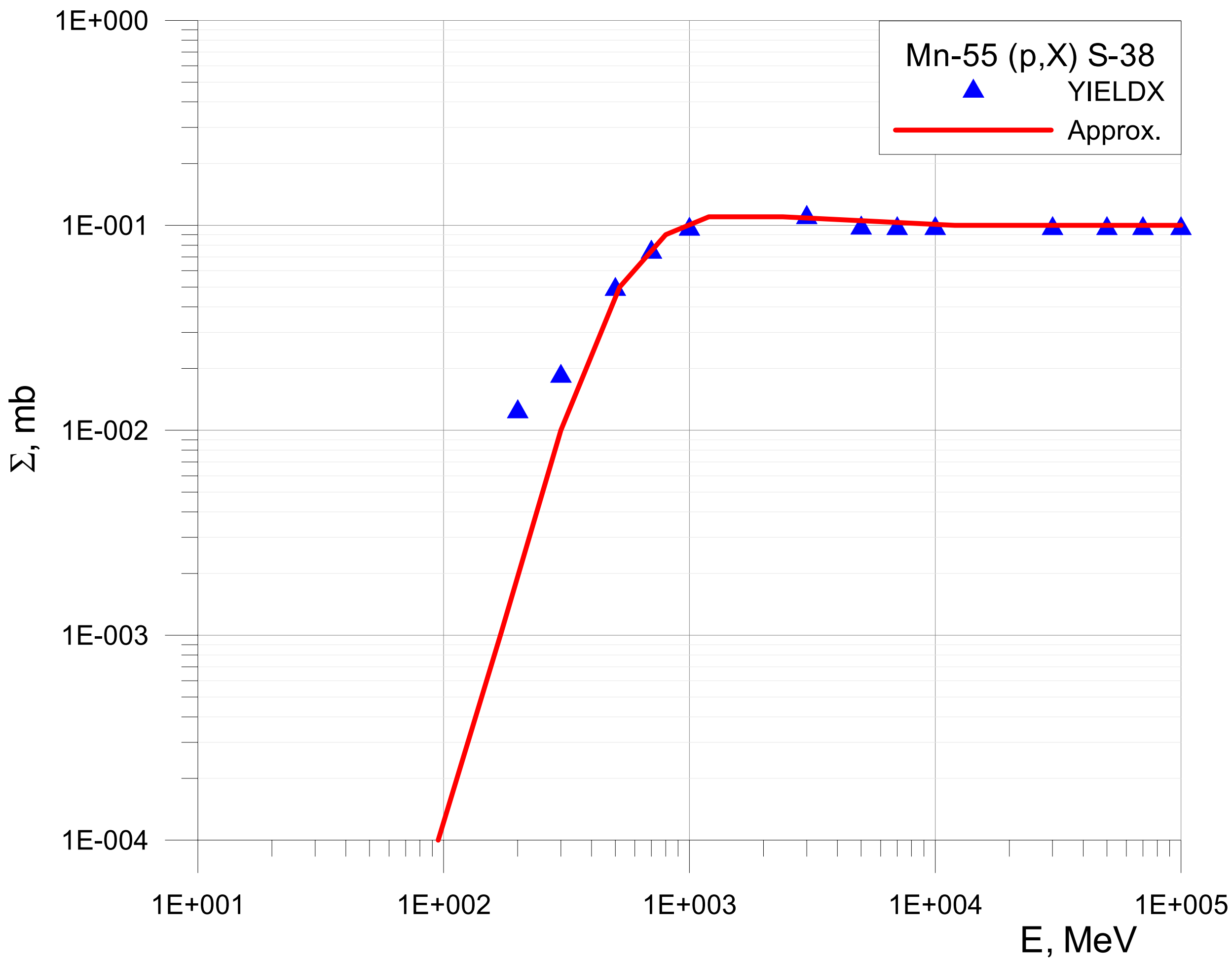
##	E, MeV	Σ, mb
1	35.6	0.000
2	78.2	0.001
3	91	0.01
4	115	0.02
5	140	0.10
6	160	0.30
7	220	1.0
8	440	4.0
9	800	9.0
10	1200	11.0
11	2200	11.0
12	4400	10.0
13	10000	9.6
14	100000	9.6
15	35.6	0.000
16		
17		
18		



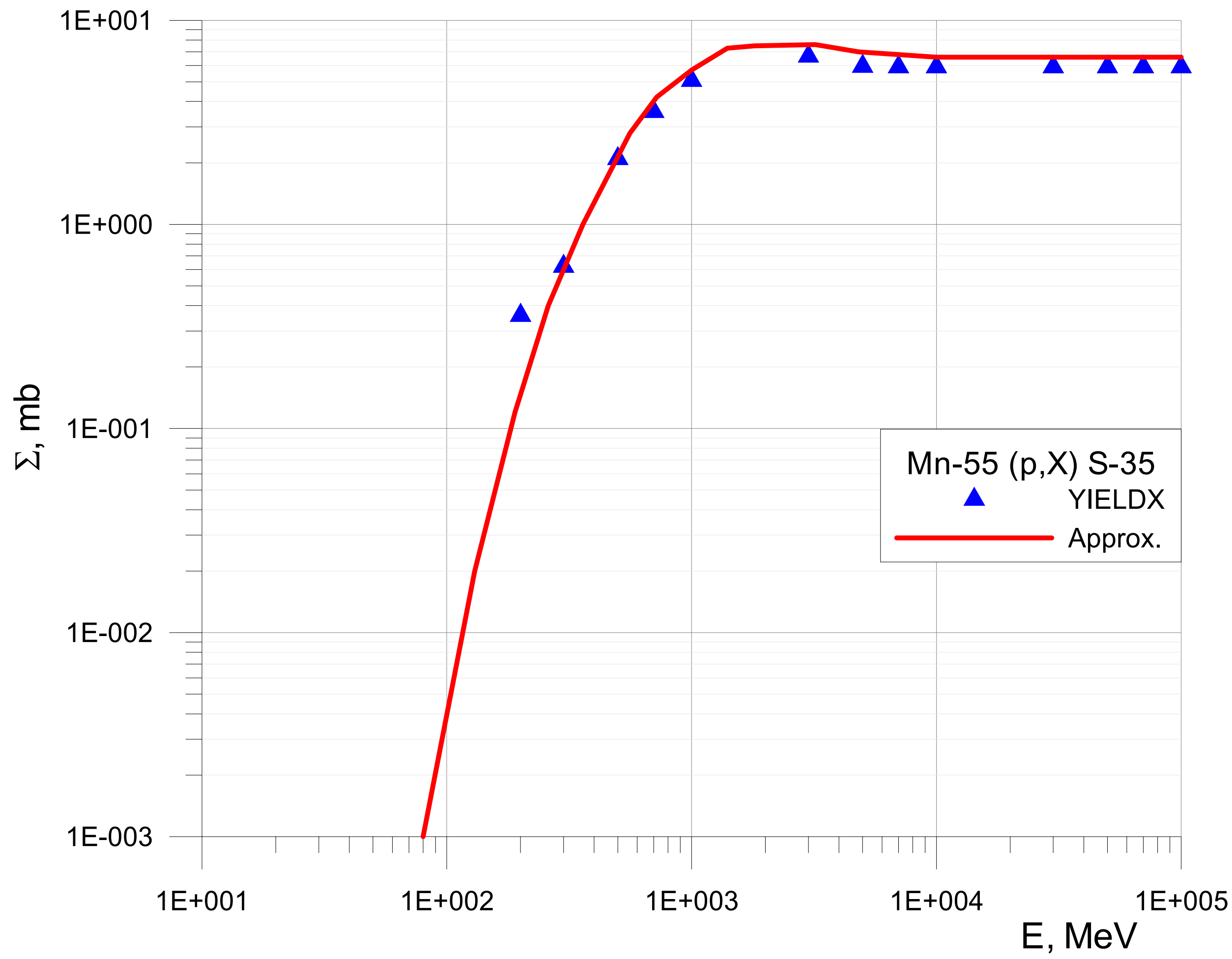
##	E, MeV	Σ, mb
1	65.9	0.000
2	100	0.001
3	110	0.01
4	125	0.04
5	145	0.2
6	200	0.5
7	260	1.0
8	360	2.0
9	600	4.0
10	780	5.0
11	1400	6.5
12	3000	6.5
13	10000	6.0
14	100000	6.0
15		
16		
17		
18		



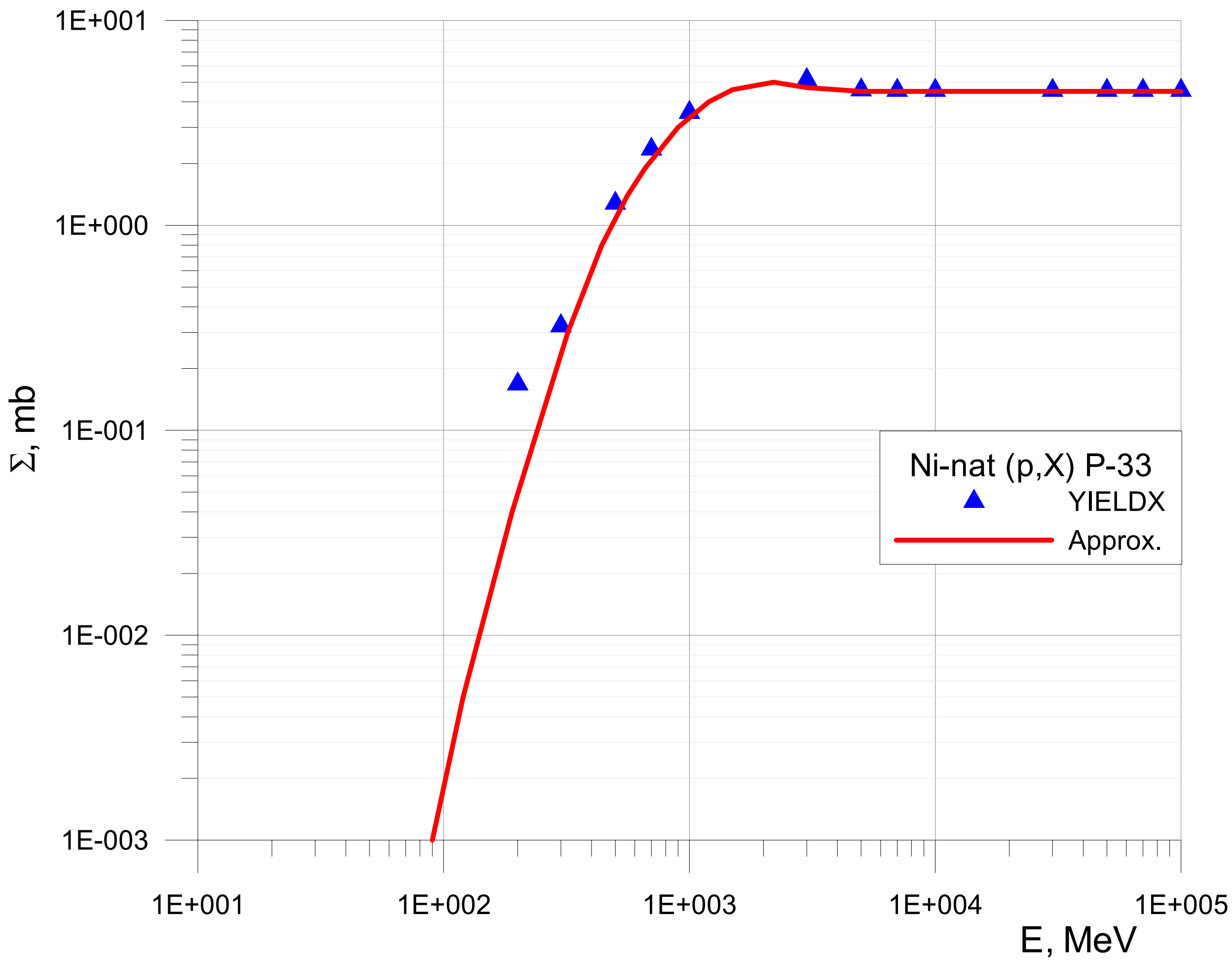
##	E, MeV	Σ, mb
1	54.6	0.00
2	80	0.01
3	100	0.04
4	145	0.2
5	215	1.0
6	320	3.0
7	500	8.0
8	800	14
9	1100	15
10	1500	15
11	2200	14
12	3600	13
13	100000	13
14		
15		
16		
17		
18		



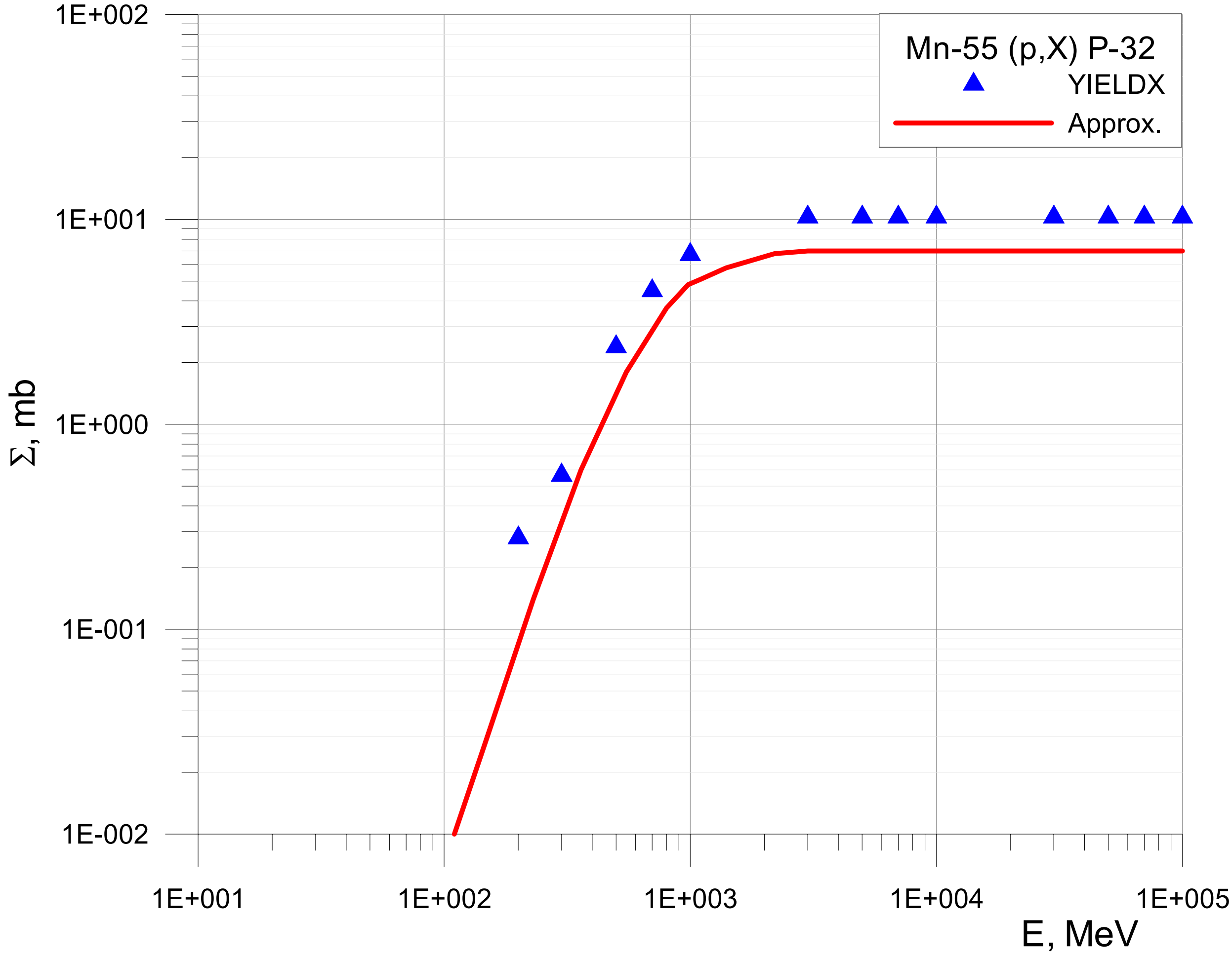
##	E, MeV	Σ, mb
1	48.71	0.0000
2	95	0.0001
3	170	0.001
4	300	0.01
5	520	0.05
6	800	0.09
7	1200	0.11
8	2400	0.11
9	12000	0.10
10	100000	0.10
11		
12		
13		
14		
15		
16		
17		
18		



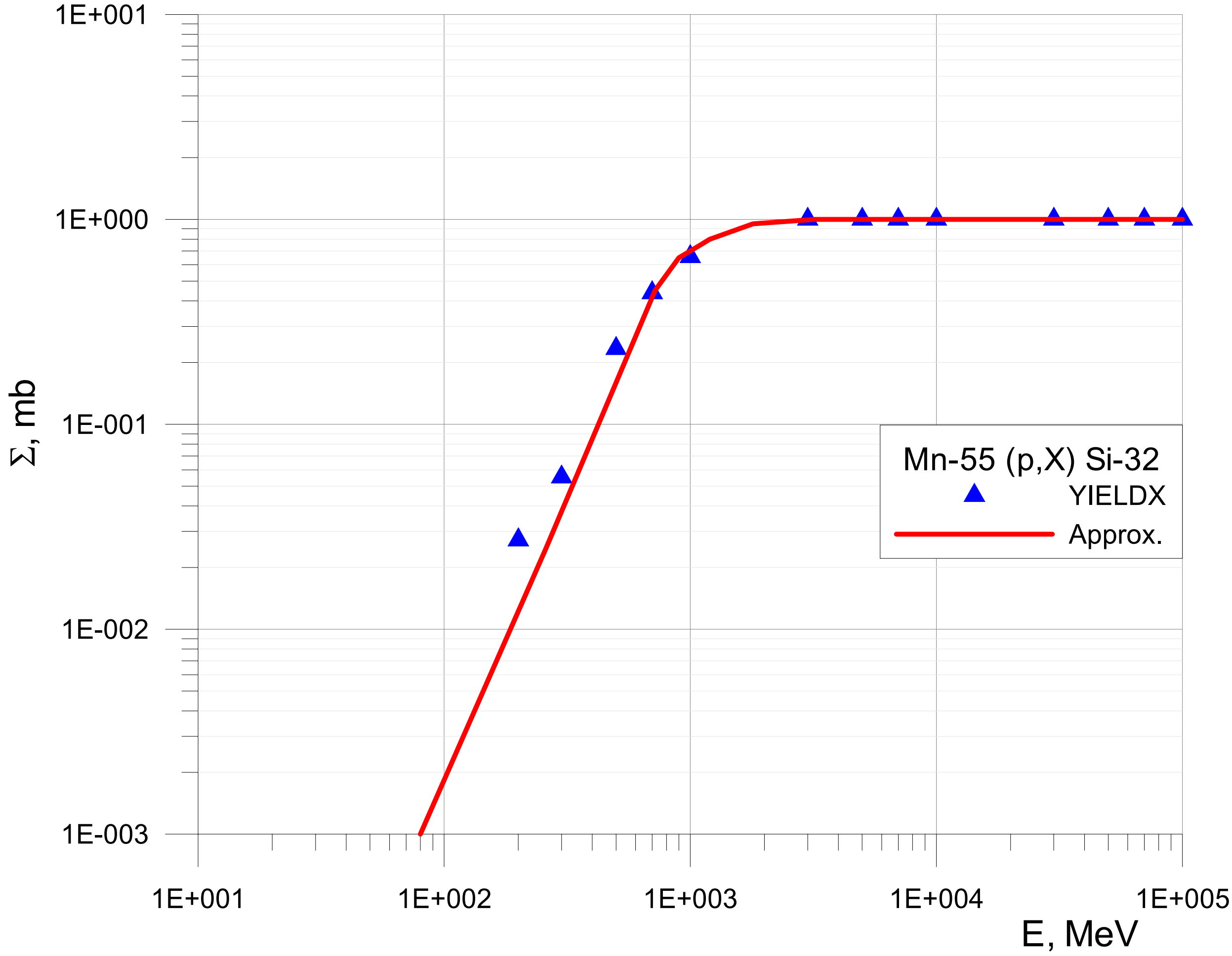
##	E, MeV	Σ, mb
1	42.53	0.000
2	80	0.001
3	130	0.02
4	190	0.12
5	260	0.40
6	360	1.00
7	560	2.80
8	720	4.20
9	1000	5.70
10	1400	7.30
11	1800	7.50
12	3200	7.60
13	4800	7.00
14	10000	6.60
15	100000	6.60
16		
17		
18		



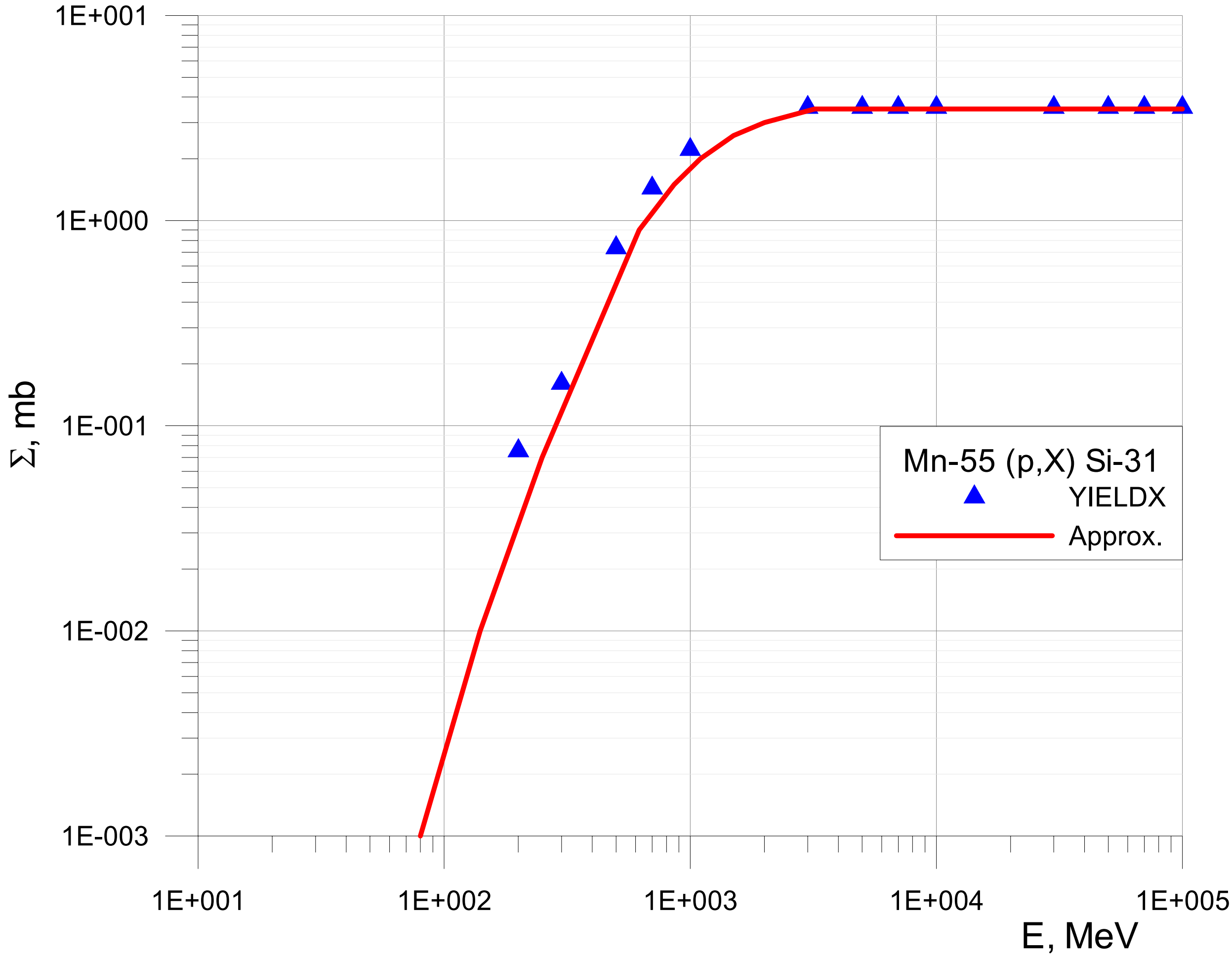
##	E, MeV	Σ, mb
1	52.09	0.000
2	90	0.001
3	120	0.005
4	190	0.04
5	320	0.30
6	440	0.80
7	560	1.4
8	660	1.9
9	900	3.0
10	1200	4.0
11	1500	4.6
12	2200	5.0
13	3000	4.7
14	5000	4.5
15	100000	4.5
16		
17		
18		



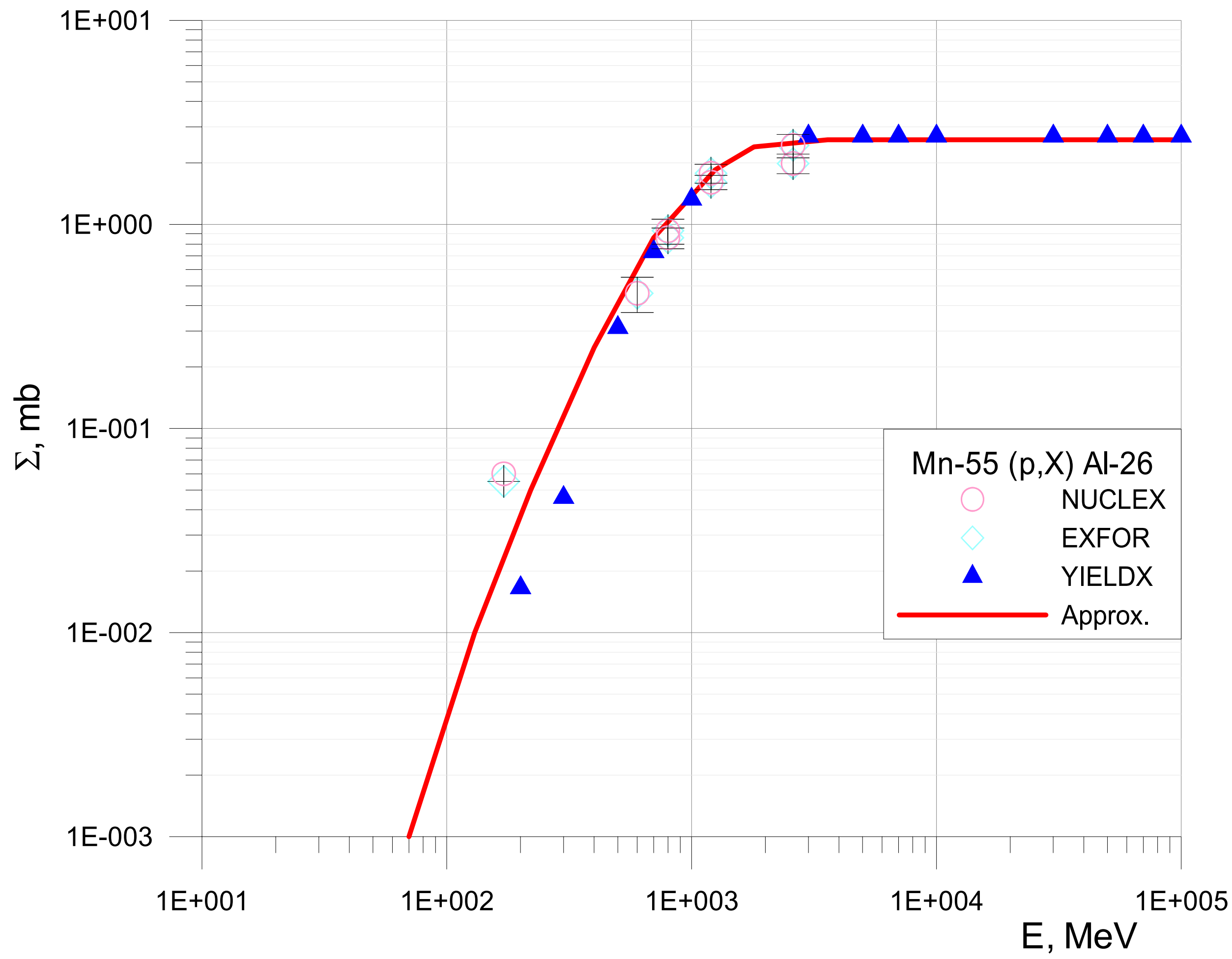
##	E, MeV	Σ, mb
1	110	0.01
2	150	0.03
3	230	0.14
4	360	0.6
5	550	1.8
6	800	3.7
7	980	4.8
8	1100	5.1
9	1400	5.8
10	2200	6.8
11	3000	7.0
12	100000	7.0
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	80	0.001
2	260	0.025
3	720	0.45
4	900	0.65
5	1100	0.75
6	1200	0.80
7	1800	0.95
8	3200	1.00
9	100000	1.00
10		
11		
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	80	0.001
2	140	0.01
3	250	0.07
4	620	0.90
5	860	1.50
6	1100	2.00
7	1500	2.60
8	2000	3.00
9	3200	3.50
10	100000	3.50
11		
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	70	0.001
2	130	0.01
3	220	0.05
4	400	0.25
5	700	0.86
6	1250	1.85
7	1800	2.4
8	3600	2.6
9	100000	2.6
10		
11		
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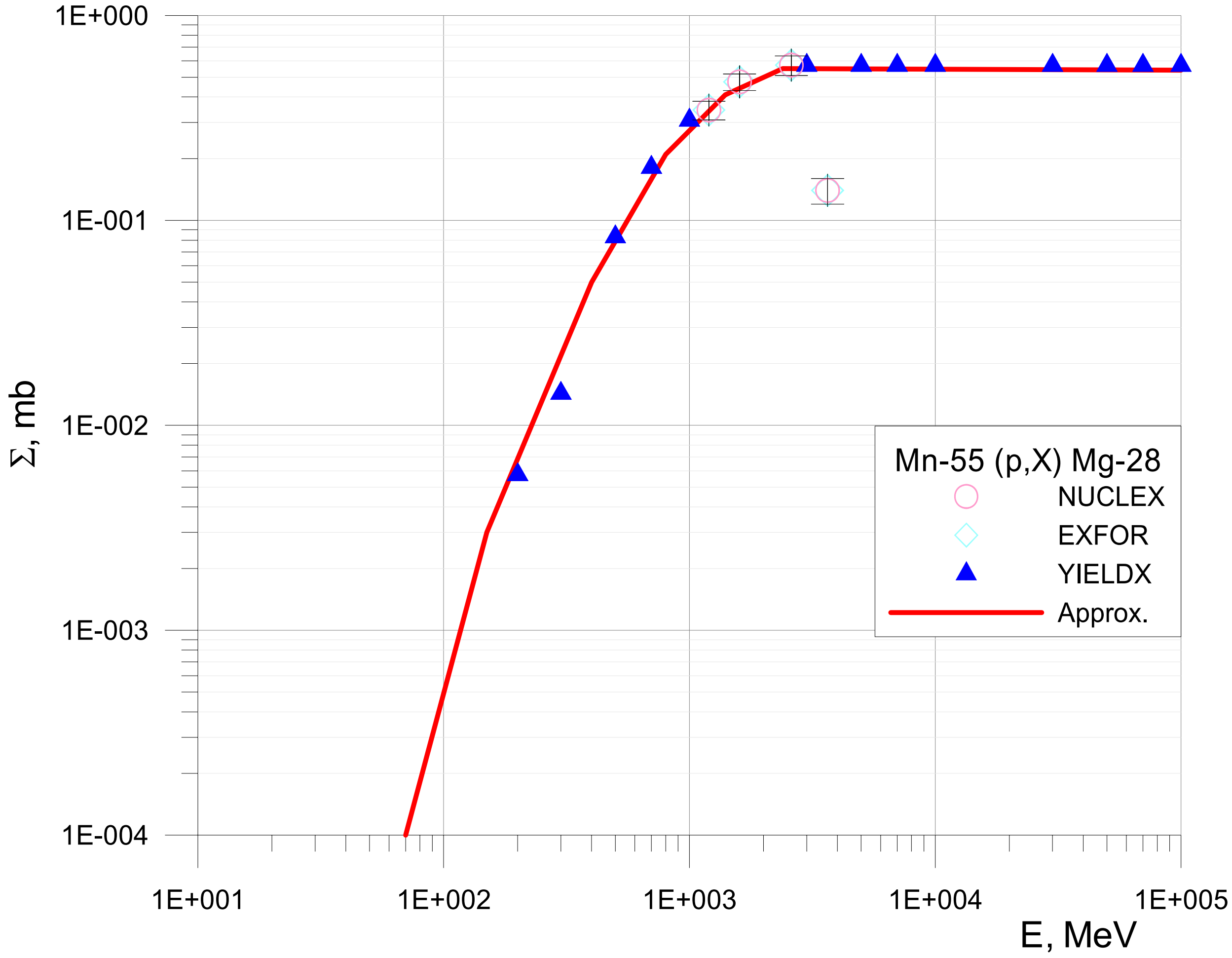

##	E, MeV	Σ, mb
1	70	0.0001
2	150	0.003
3	400	0.05
4	800	0.21
5	1400	0.41
6	2400	0.55
7	100000	0.54
8		
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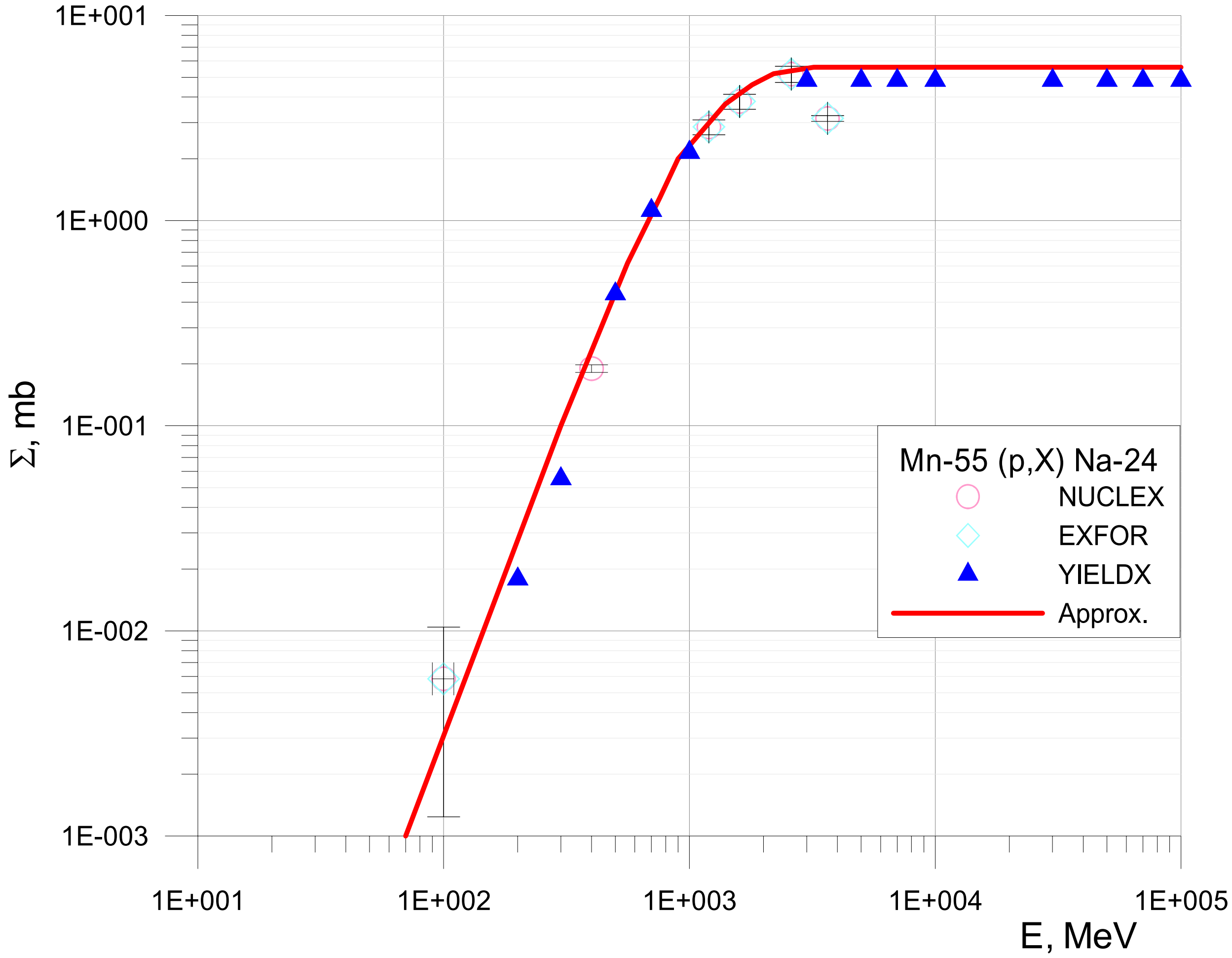

##	E, MeV	Σ, mb
1	70	0.001
2	145	0.01
3	300	0.10
4	560	0.62
5	760	1.3
6	900	2.0
7	1400	3.7
8	1800	4.6
9	2200	5.2
10	3200	5.6
11	100000	5.6
12		
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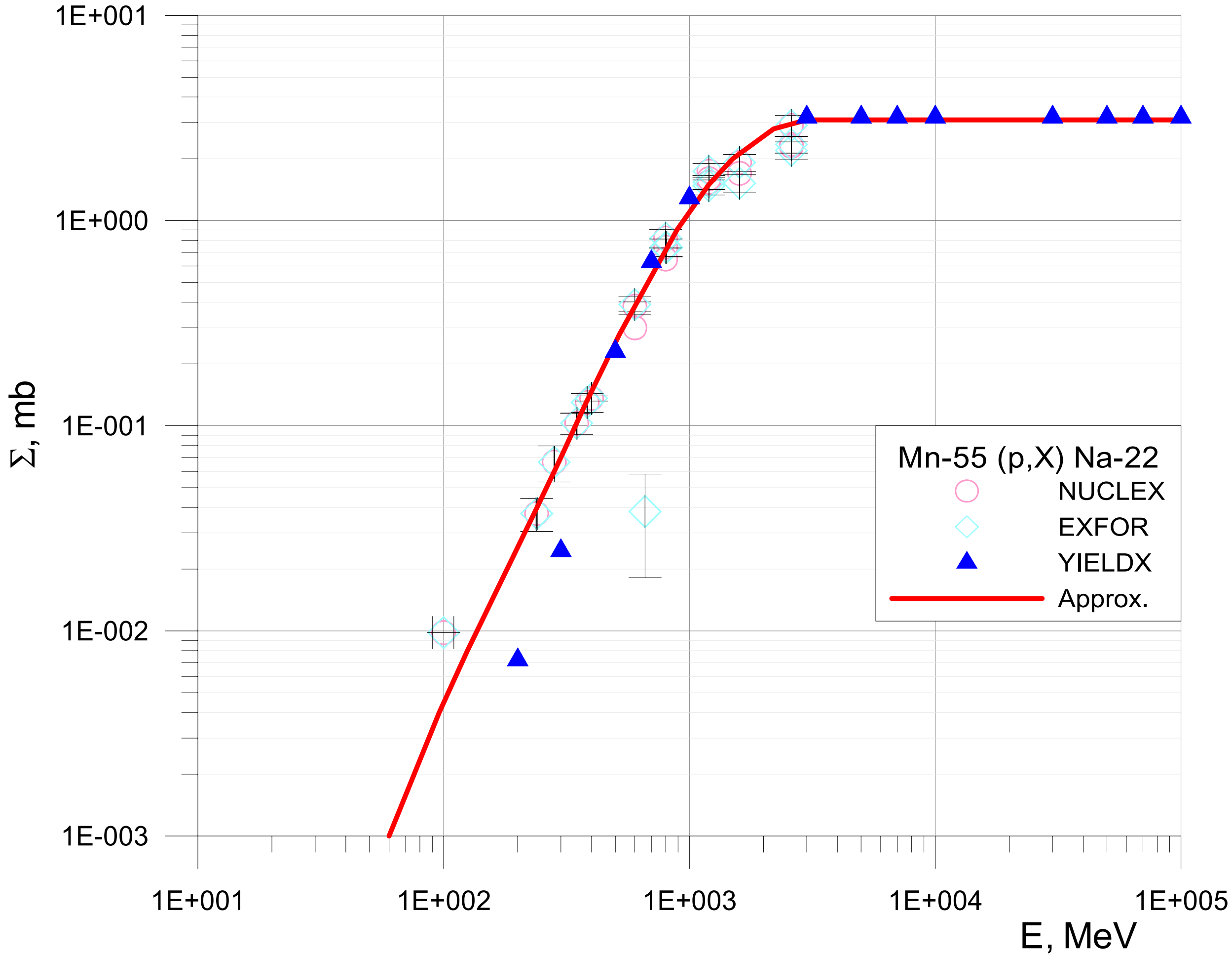
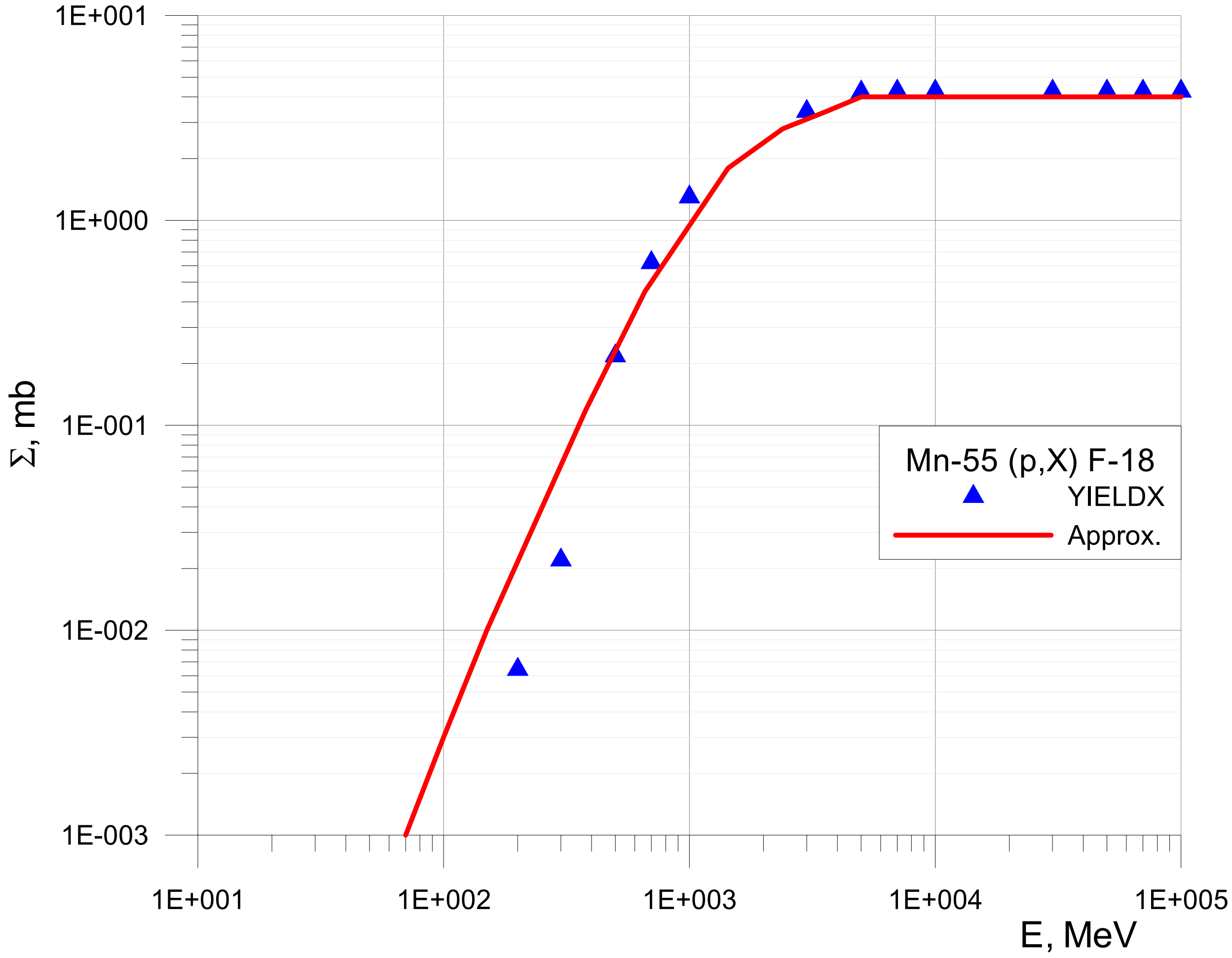


##	E, MeV	Σ, mb
1	60	0.001
2	96	0.004
3	125	0.01
4	240	0.04
5	300	0.07
6	380	0.13
7	520	0.28
8	890	0.90
9	1200	1.5
10	1500	2.0
11	2200	2.8
12	3000	3.1
13	5400	3.1
14	100000	3.1
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	70	0.001
2	100	0.003
3	150	0.01
4	380	0.12
5	660	0.45
6	1437	1.8
7	2400	2.8
8	3600	3.4
9	5000	4.0
10	100000	4.0
11		
12		
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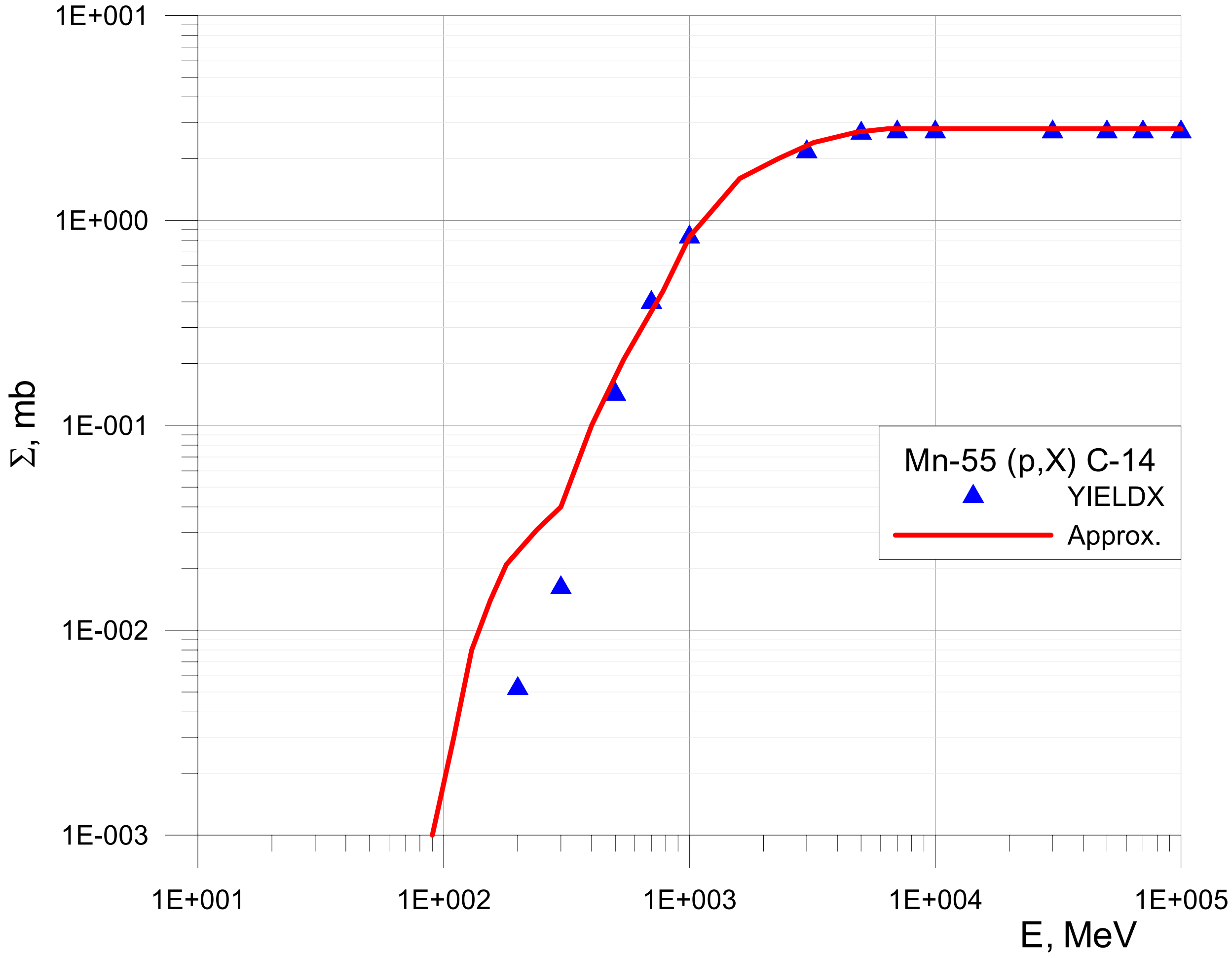
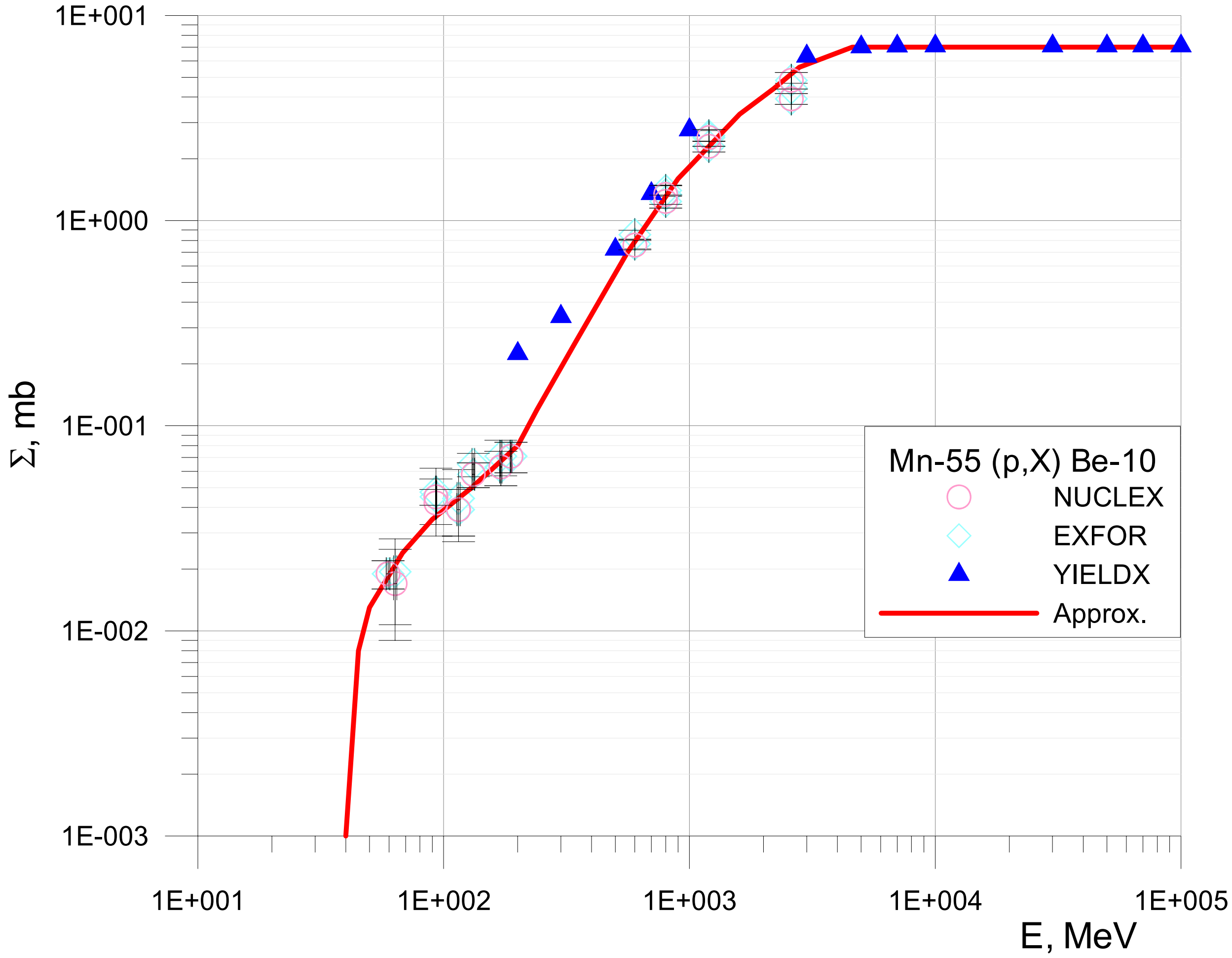
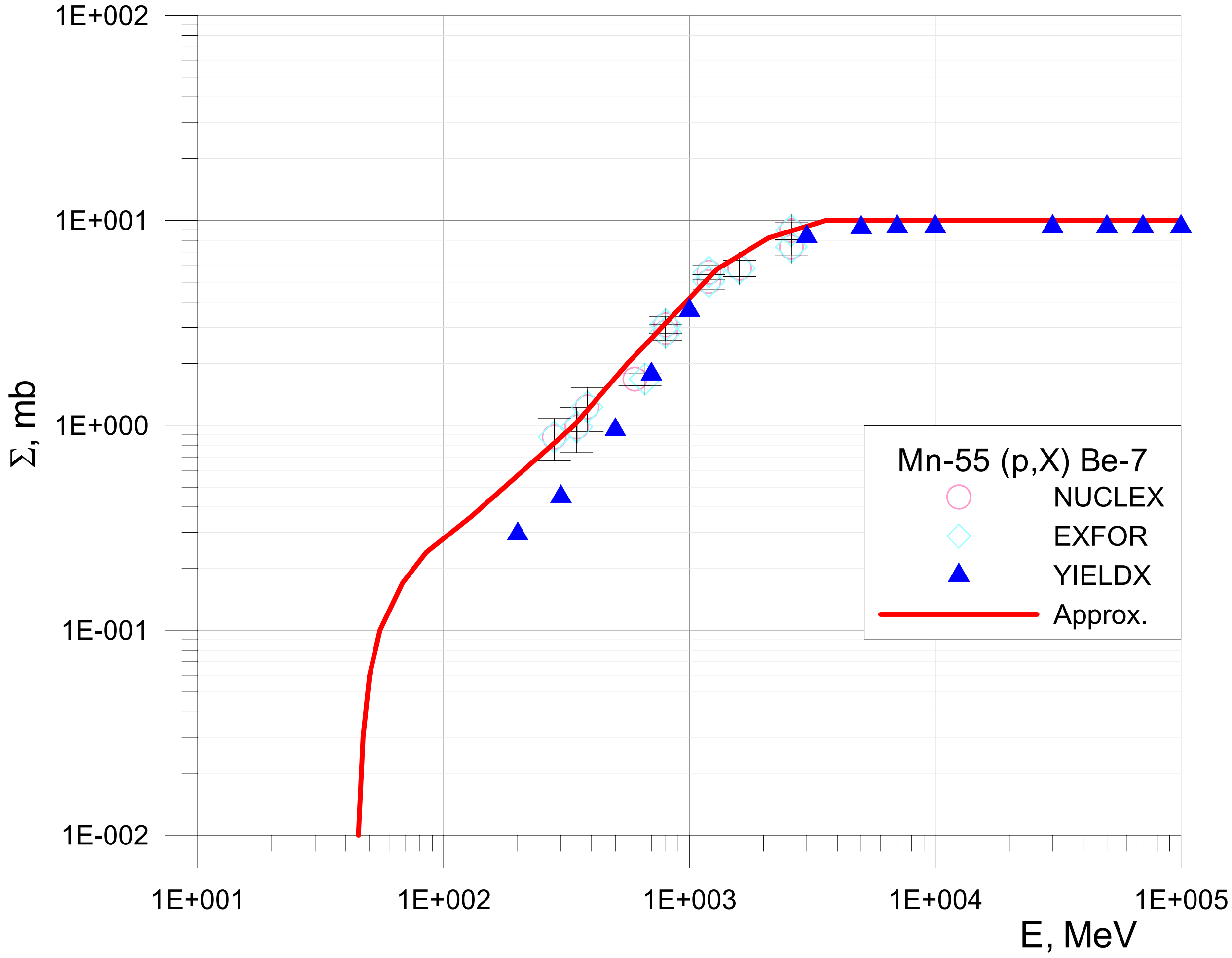


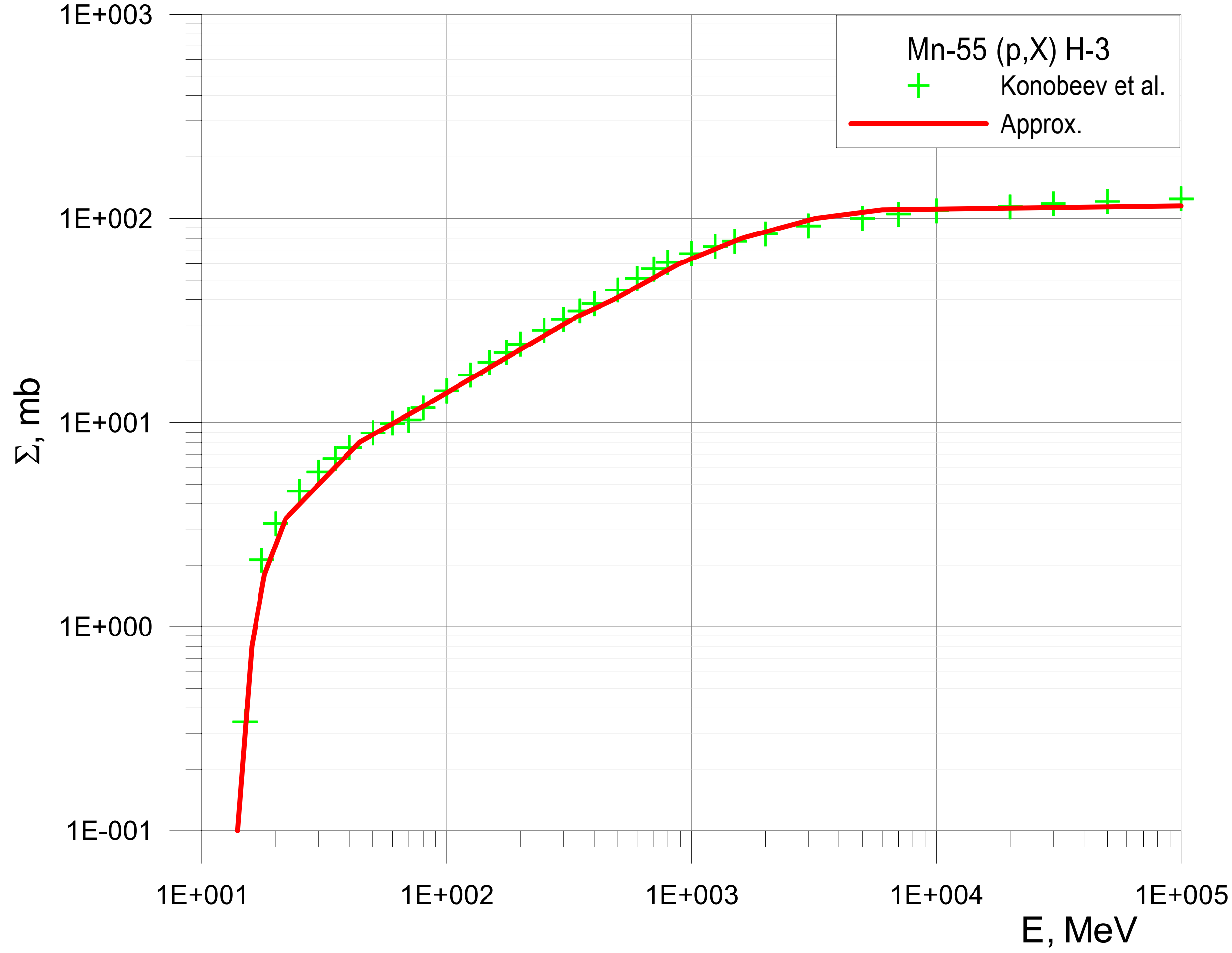
##	E, MeV	Σ, mb
1	90	0.001
2	110	0.003
3	130	0.008
4	155	0.014
5	180	0.021
6	240	0.031
7	300	0.04
8	400	0.10
9	540	0.21
10	780	0.45
11	1000	0.83
12	1600	1.6
13	2300	2.0
14	3200	2.4
15	4800	2.7
16	6400	2.8
17	100000	2.8
18		



##	E, MeV	Σ, mb
1	40	0.001
2	45	0.008
3	50	0.013
4	68	0.024
5	90	0.035
6	130	0.05
7	200	0.08
8	240	0.12
9	340	0.25
10	560	0.70
11	900	1.6
12	1600	3.3
13	2200	4.4
14	2800	5.6
15	4600	7.0
16	100000	7.0
17		
18		



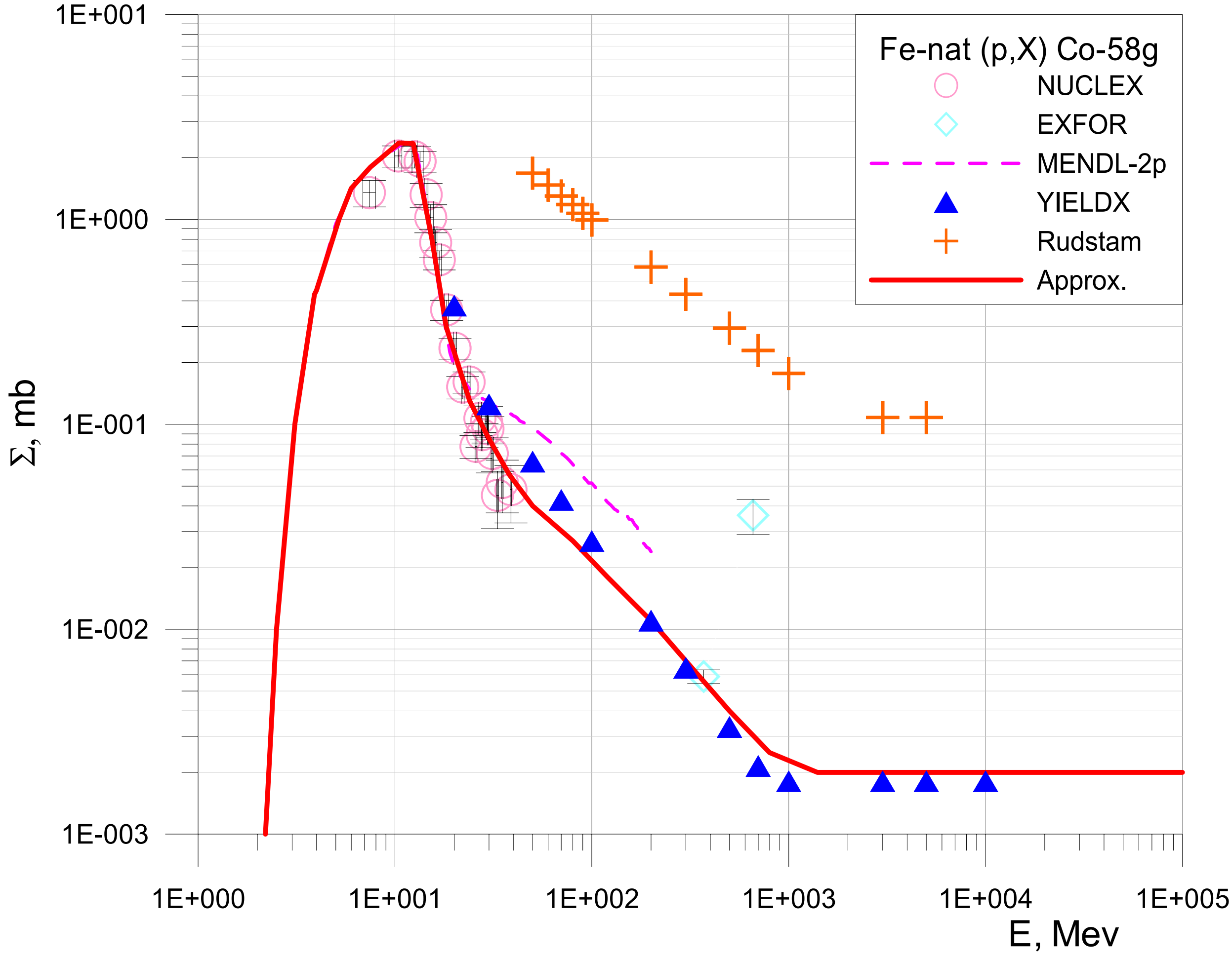
##	E, MeV	Σ, mb
1	45	0.01
2	47	0.03
3	50	0.06
4	55	0.10
5	68	0.17
6	85	0.24
7	130	0.36
8	200	0.57
9	340	1.0
10	560	2.0
11	870	3.5
12	1300	5.8
13	2100	8.2
14	3600	10
15	100000	10
16		
17		
18		



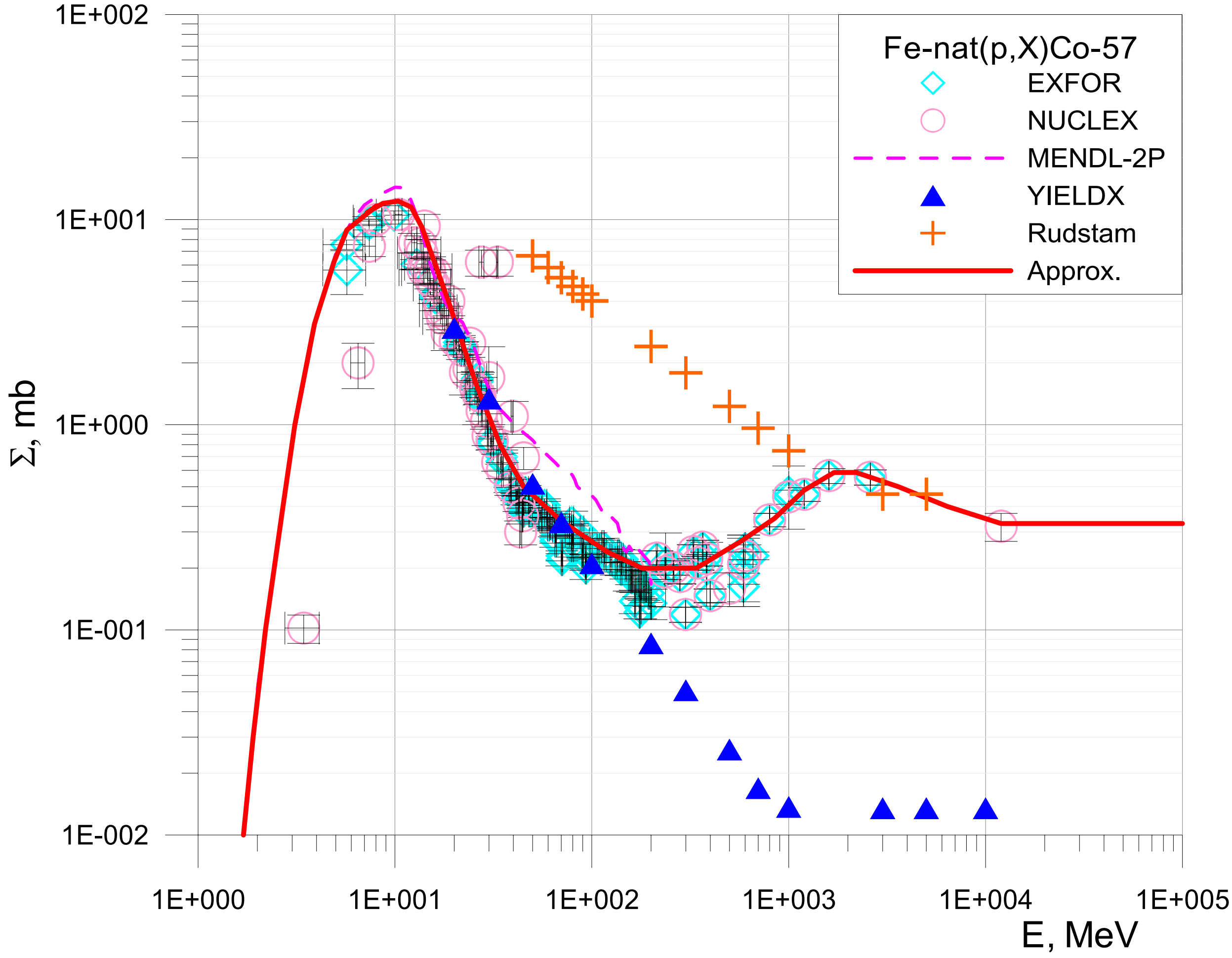
##	E, MeV	Σ, mb
1	10.88	0.0
2	14	0.1
3	16	0.8
4	18	1.8
5	22	3.4
6	44	8.0
7	90	13
8	190	22
9	340	33
10	480	40
11	890	60
12	1600	80
13	3200	100
14	6000	110
15	100000	115
16		
17		
18		

Summary of experimental and calculated cross-section data used for iron

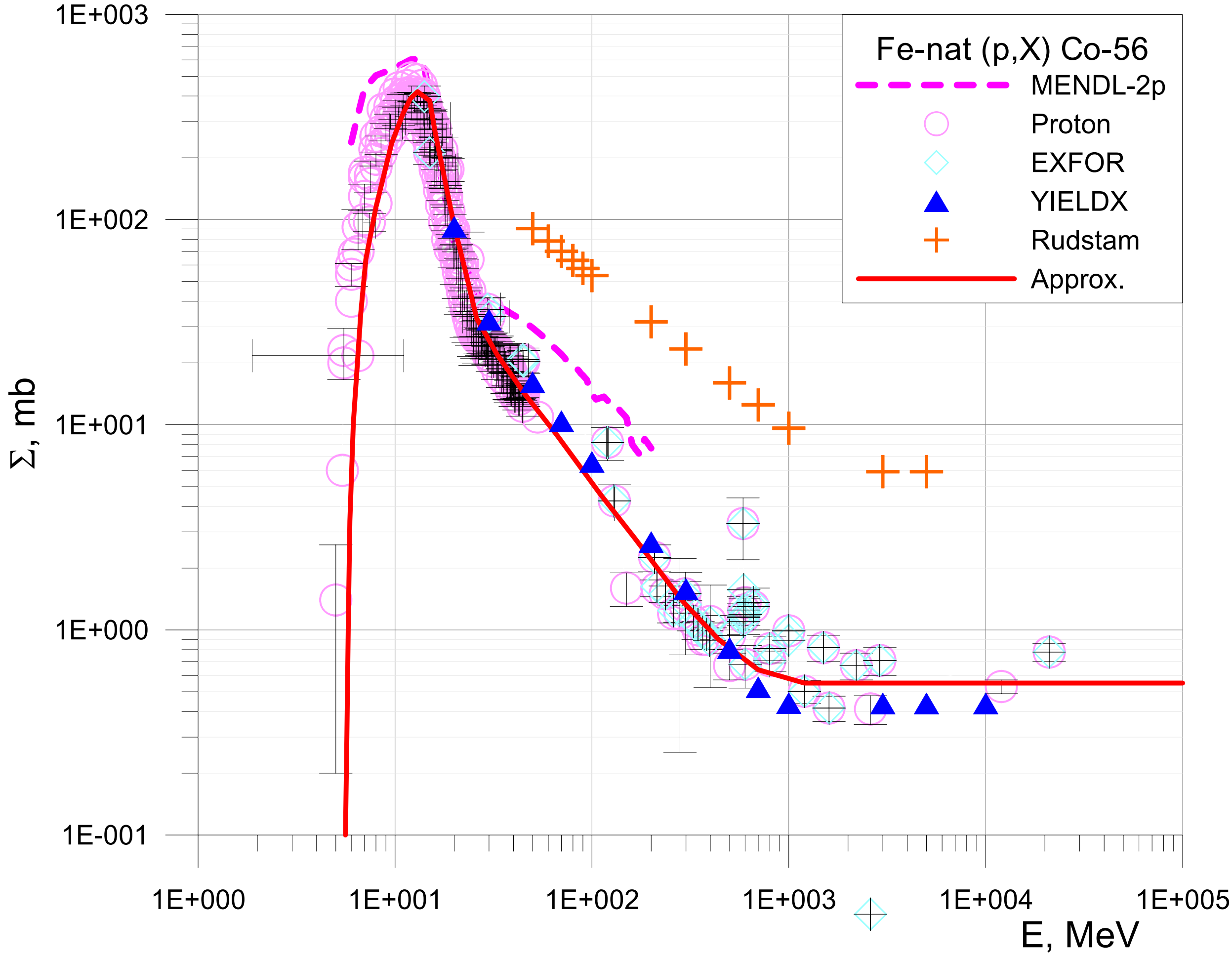
Nuclide	Half-life			Decay Mode	Source			Comment
					Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-		x	x	
Be-7	53.22	D	0.06	EC		x		
Be-10	2E+06	Y	60000	B-		x		
C-14	5700	Y	30	B-				cum
F-18	109.77	M	0.05	EC		x		cum
Na-22	2.6019	Y	4E-04	EC		x	x	cum
Na-24	14.959	H	0.001	B-		x	x	cum
Mg-28	20.915	H	0.009	B-		x	x	cum
Al-26	717000	Y	24000	EC		x	x	
Si-31	157.3	M	0.3	B-		x	x	cum
Si-32	132	Y	13	B-			x	cum
P-32	14.262	D	0.014	B-		x	x	
P-33	25.34	D	0.12	B-		x	x	cum
S-35	87.51	D	0.12	B-		x	x	cum
S-38	170.3	M	0.7	B-		x	x	cum
Cl-36	301000	Y	2000	B-, EC		x	x	
Ar-37	35.04	D	0.04	EC		x	x	cum
Ar-39	269	Y	3	B-		x	x	cum
Ar-41	109.61	M	0.04	B-		x	x	cum
Ar-42	32.9	Y	1.1	B-			x	cum
K-42	12.36	H	0.012	B-	x	x	x	
K-43	22.3	H	0.1	B-	x	x	x	cum
Ca-41	102000	Y	7000	EC	x		x	cum
Ca-45	162.61	D	0.09	B-	x	x	x	cum
Ca-47	4.536	D	0.003	B-	x	x	x	cum
Sc-43	3.891	H	0.012	EC	x	x	x	cum
Sc-44	3.97	H	0.04	EC	x	x	x	
Sc-44m	58.61	H	0.1	IT, EC	x	x	x	
Sc-46	83.79	D	0.04	B-	x	x	x	
Sc-47	3.3492	D	6E-04	B-	x	x	x	
Sc-48	43.67	H	0.09	B-	x	x	x	
Ti-44	60	Y	1.1	EC	x		x	cum
Ti-45	184.8	M	0.5	EC	x	x	x	cum
V-48	15.974	D	0.003	EC	x	x	x	
V-49	330	D	15	EC	x		x	cum
Cr-48	21.56	H	0.03	EC	x	x	x	cum
Cr-51	27.703	D	0.002	EC	x	x	x	cum
Mn-52g	5.591	D	0.003	EC	x	x	x	cum
Mn-53	4E+06	Y	40000	EC	x		x	cum
Mn-54	312.12	D	0.06	EC	x	x	x	
Mn-56	2.5789	H	1E-04	B-		x	x	cum
Fe-52	8.275	H	0.008	EC	x	x	x	
Fe-55	2.737	Y	0.011	EC	x	x	x	
Co-55	17.53	H	0.03	EC	x	x	x	cum
Co-56	77.233	D	0.027	EC	x	x	x	
Co-57	271.74	D	0.06	EC	x	x	x	
Co-58g	70.86	D	0.06	EC	x	x	x	cum



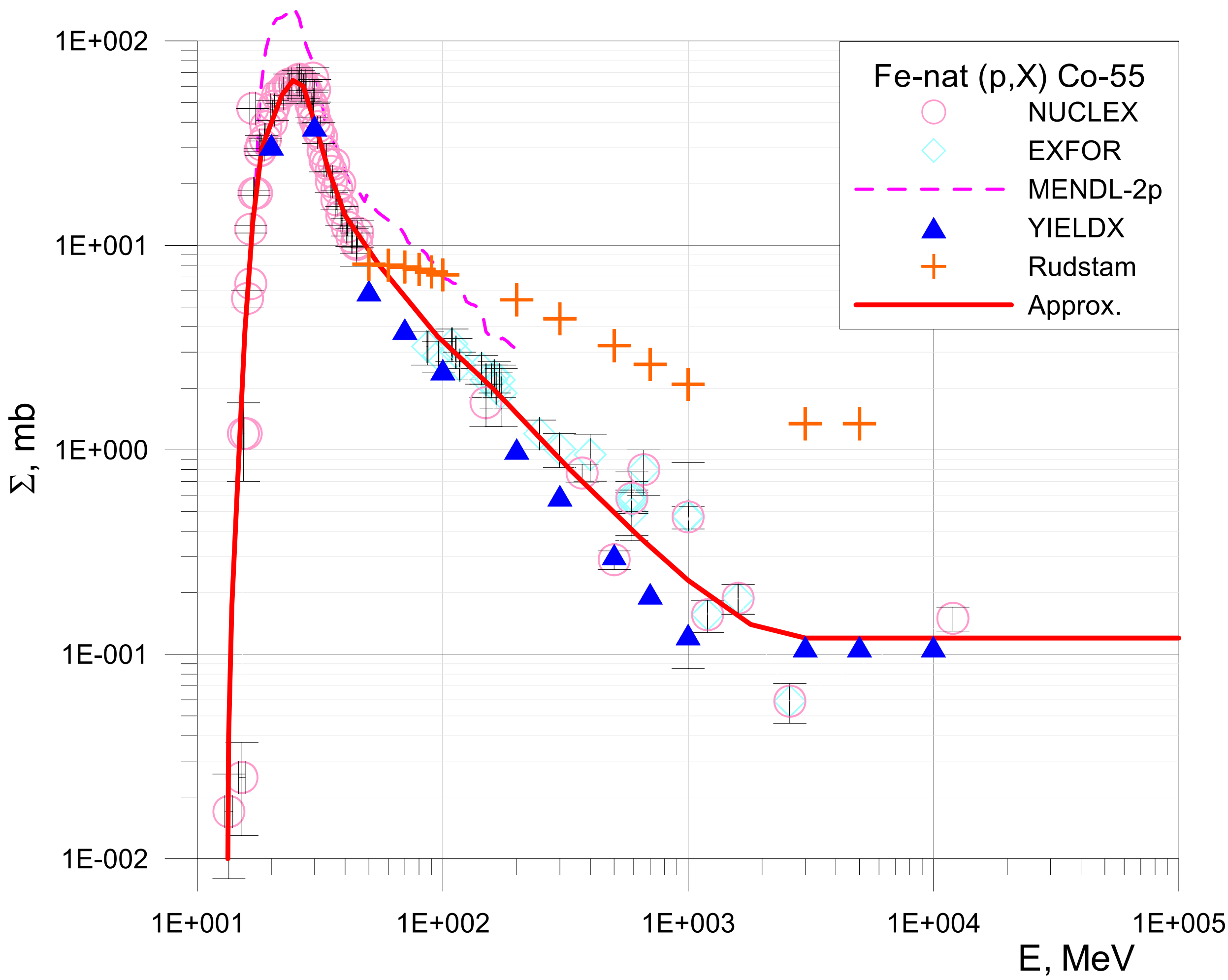
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	2.2	0.001	19	120	0.018
2	2.5	0.01	20	200	0.011
3	3.1	0.10	21	300	0.0070
4	3.9	0.43	22	500	0.0040
5	4.0	0.45	23	800	0.0025
6	5.2	1.00	24	1400	0.0020
7	6.0	1.42	25	10000	0.0020
8	7.5	1.80	26	100000	0.0020
9	10.5	2.36			
10	12.4	2.34			
11	15.4	0.80			
12	18.2	0.30			
13	18.5	0.285			
14	24	0.130			
15	30	0.085			
16	38	0.057			
17	50	0.040			
18	80	0.027			



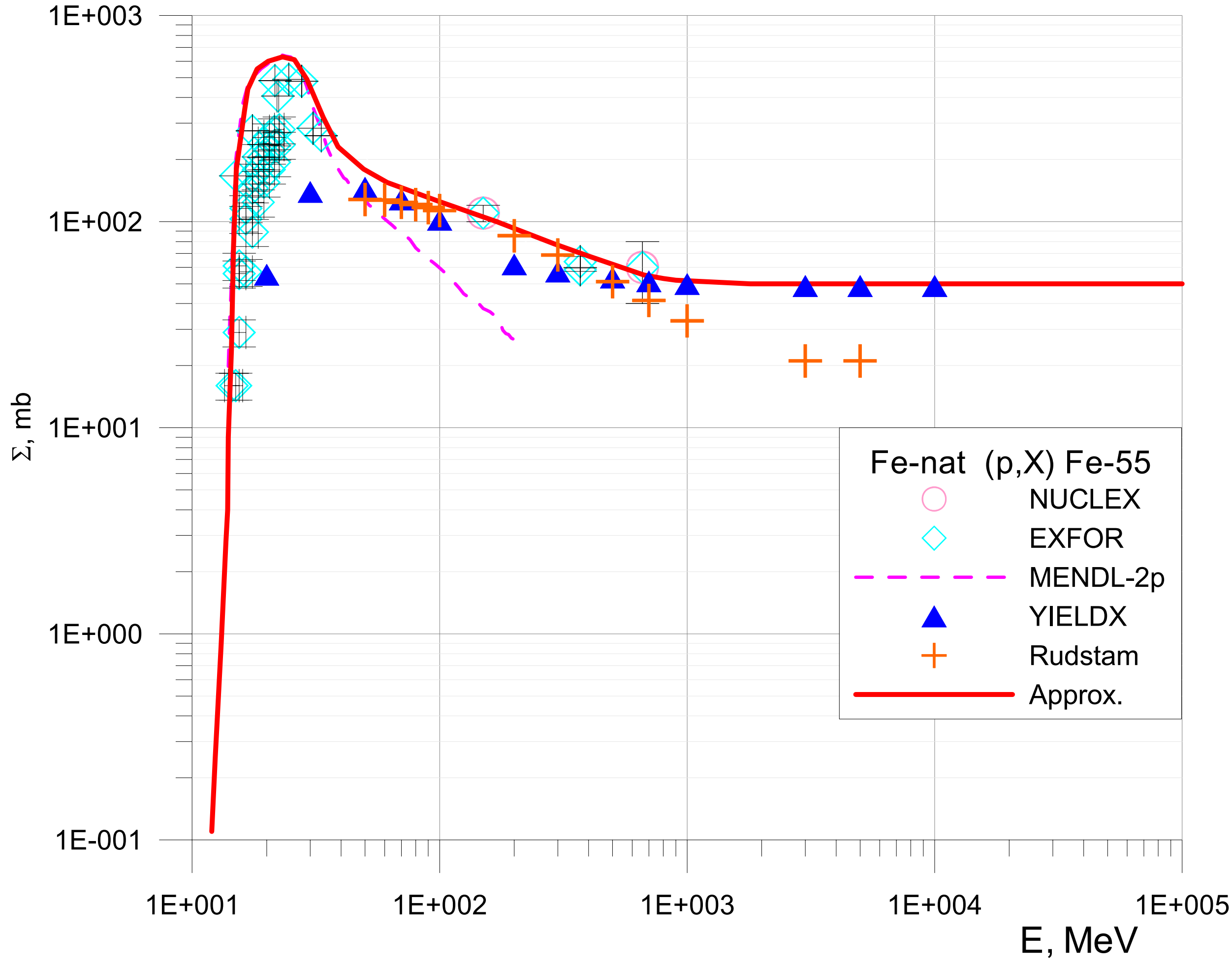
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	1.7	0.01	19	70.0	0.34
2	1.9	0.03	20	120	0.24
3	2.2	0.10	21	180	0.20
4	2.7	0.40	22	260	0.20
5	3.1	1.00	23	340	0.20
6	3.9	3.10	24	570	0.27
7	4.9	6.20	25	850	0.35
8	5.7	8.90	26	1200	0.48
9	8.1	11.7	27	1700	0.59
10	7.2	10.8	28	2200	0.59
11	8.7	12.0	29	3600	0.50
12	10.4	12.3	30	6400	0.40
13	12.1	11.5	31	12000	0.33
14	13.7	9.20	32	100000	0.33
15	18.7	4.00			
16	25.7	1.60			
17	34.4	0.79			
18	45.0	0.50			



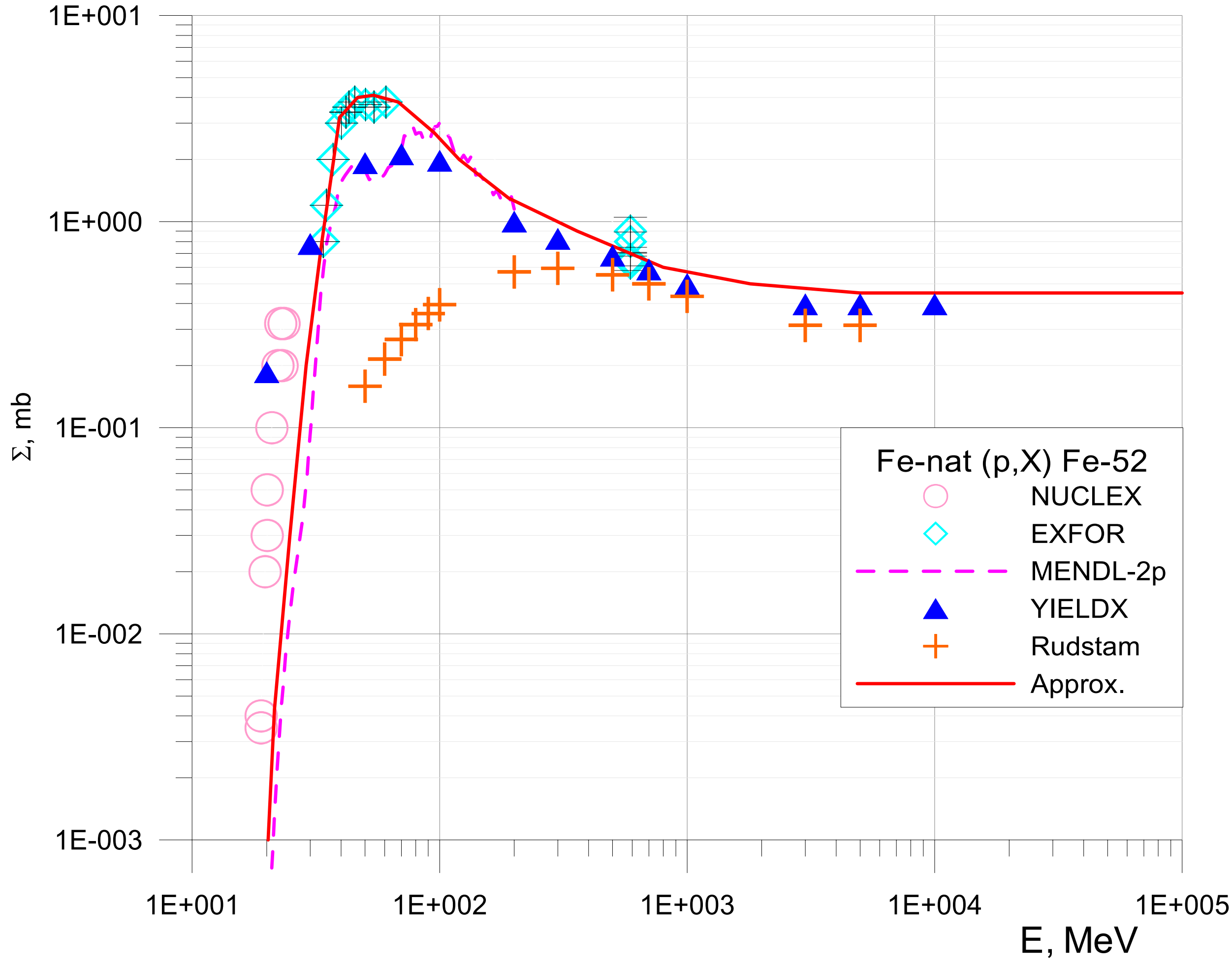
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	5.44	0.00	19	33	22.0
2	5.60	0.10	20	46	14.0
3	5.70	0.30	21	66	9.00
4	5.80	1.22	22	110	4.60
5	5.90	3.40	23	165	2.80
6	6.14	10.2	24	285	1.40
7	6.70	35.0	25	440	0.90
8	7.10	64.0	26	700	0.64
9	8.0	115	27	1200	0.55
10	9.6	235	28	10000	0.55
11	11	330	29	100000	0.55
12	12	390			
13	13	420			
14	15	380			
15	16	265			
16	20	93.0			
17	23	54.0			
18	26	33.0			



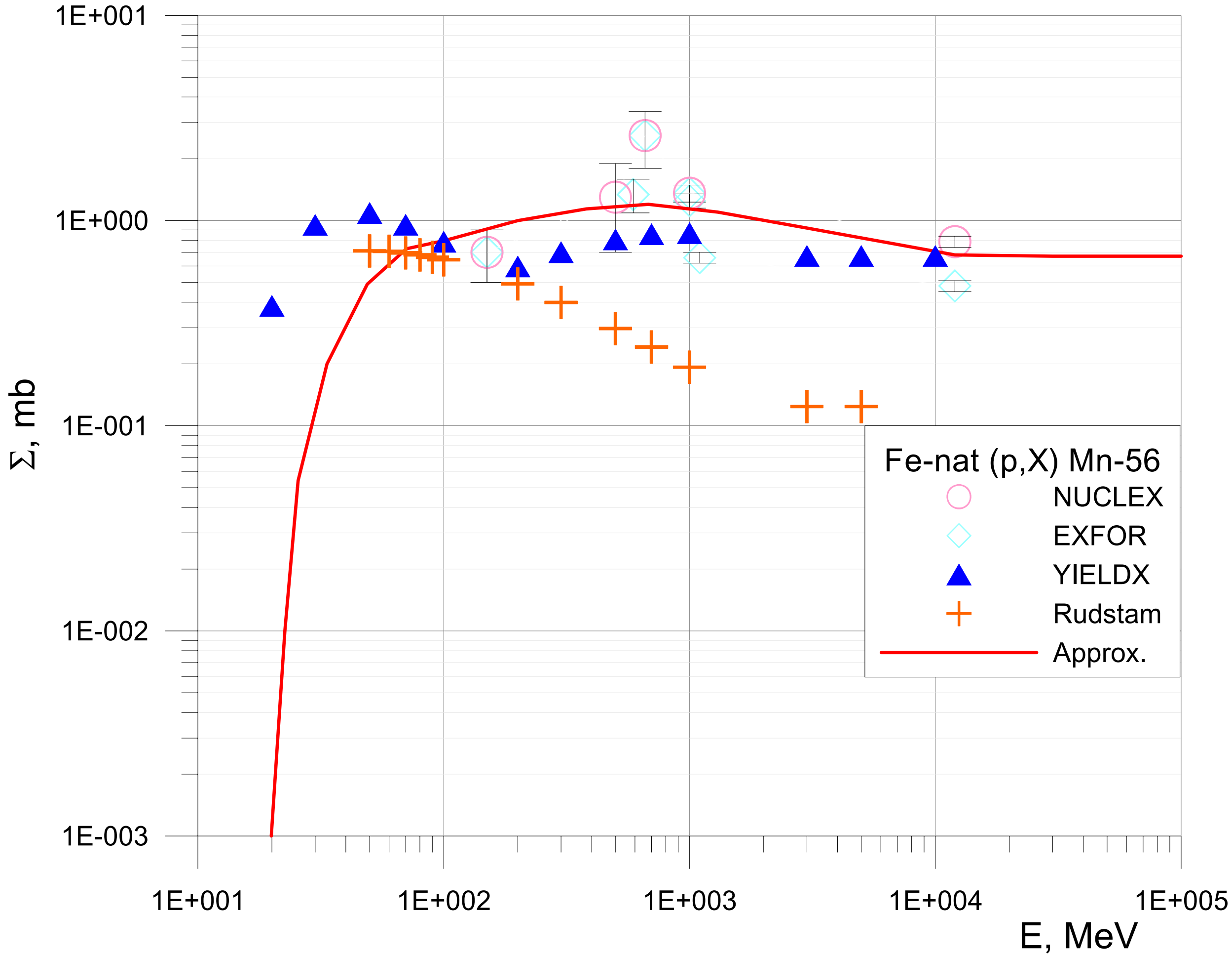
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	13.3	0.01	19	1000	0.23
2	13.4	0.04	20	1800	0.14
3	13.8	0.17	21	3000	0.12
4	14.6	0.75	22	100000	0.12
5	15.6	3.80			
6	16.8	13.0			
7	18.3	30.0			
8	22.0	54.0			
9	24.5	64.0			
10	27.0	60.0			
11	30.0	40.0			
12	34.0	24.0			
13	40.0	14.0			
14	55.0	8.00			
15	95.0	3.60			
16	160	2.00			
17	330	0.80			
18	640	0.37			



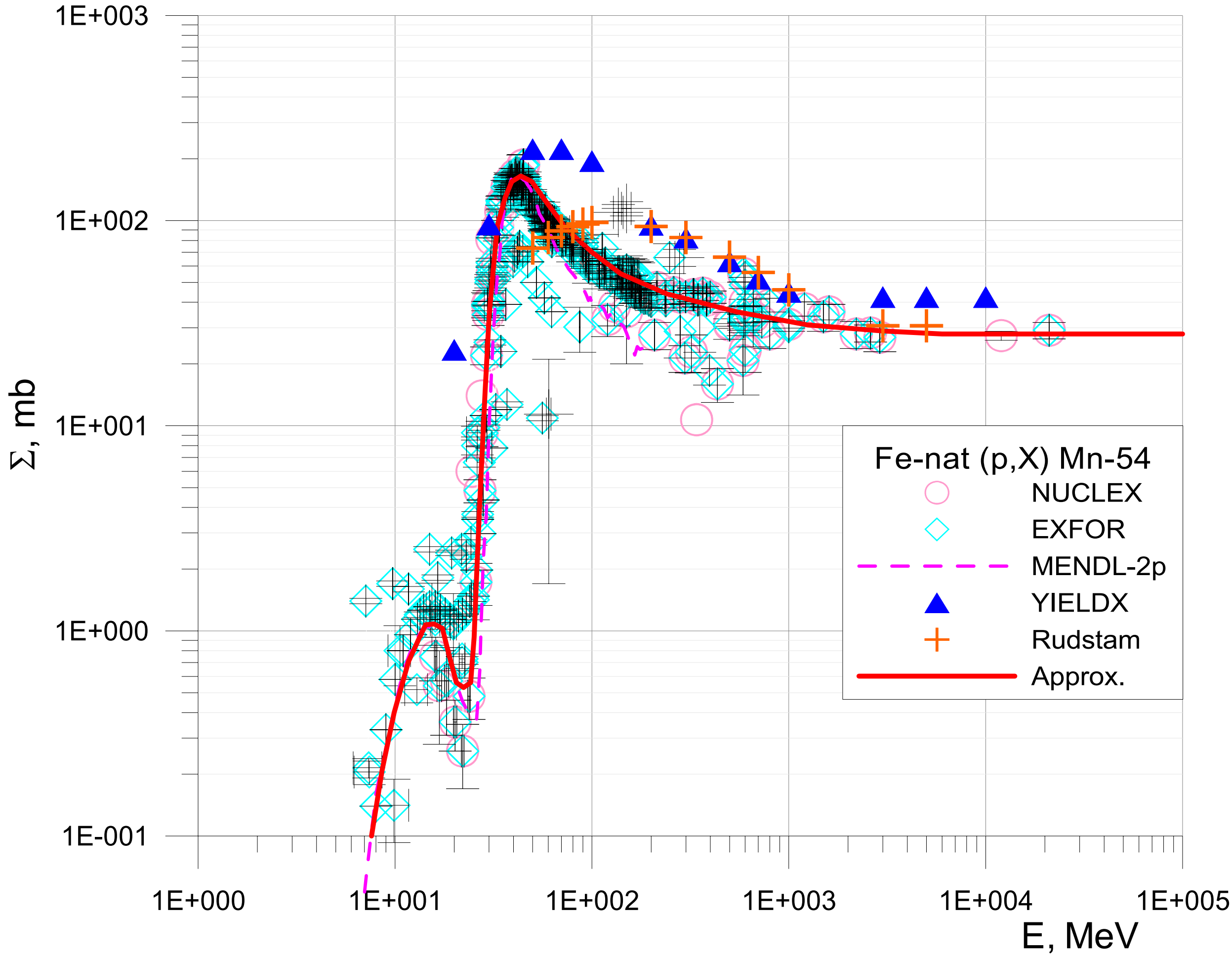
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	9.13	0.00	19	38.9	230
2	12.0	0.11	20	49.3	180
3	12.4	0.25	21	61.4	155
4	13.1	0.9	22	100	125
5	13.7	2.8	23	170	100
6	13.9	4.0	24	290	78
7	14.0	9.0	25	400	68
8	14.4	24.0	26	670	55
9	14.7	75.0	27	800	53
10	15.1	180	28	900	52
11	16.3	350	29	1800	50
12	16.8	440	30	2800	50
13	18.3	550	31	10000	50
14	20.3	600	32	100000	50
15	23.2	630			
16	25.9	610			
17	29.1	490			
18	33.9	320			



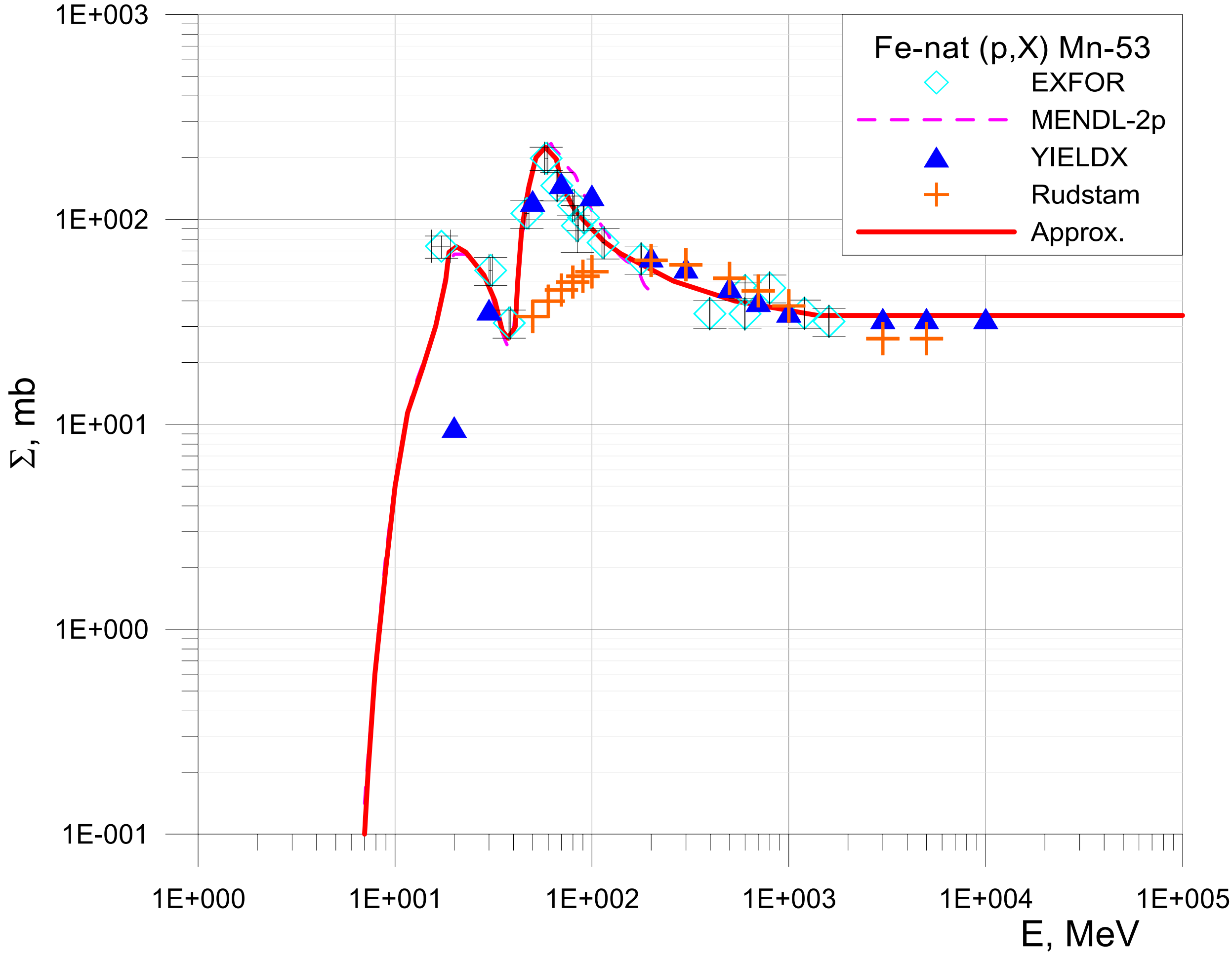
##	E, MeV	Σ, mb
1	15.9	0.0000
2	20.3	0.0010
3	21.5	0.0043
4	24.8	0.030
5	28.9	0.20
6	33.4	0.80
7	37.3	2.00
8	39.4	3.20
9	46.6	4.00
10	54.0	4.10
11	68.0	3.80
12	95.0	2.70
13	120	2.00
14	190	1.30
15	360	0.90
16	800	0.60
17	1800	0.50
18	5000	0.45
19	100000	0.45



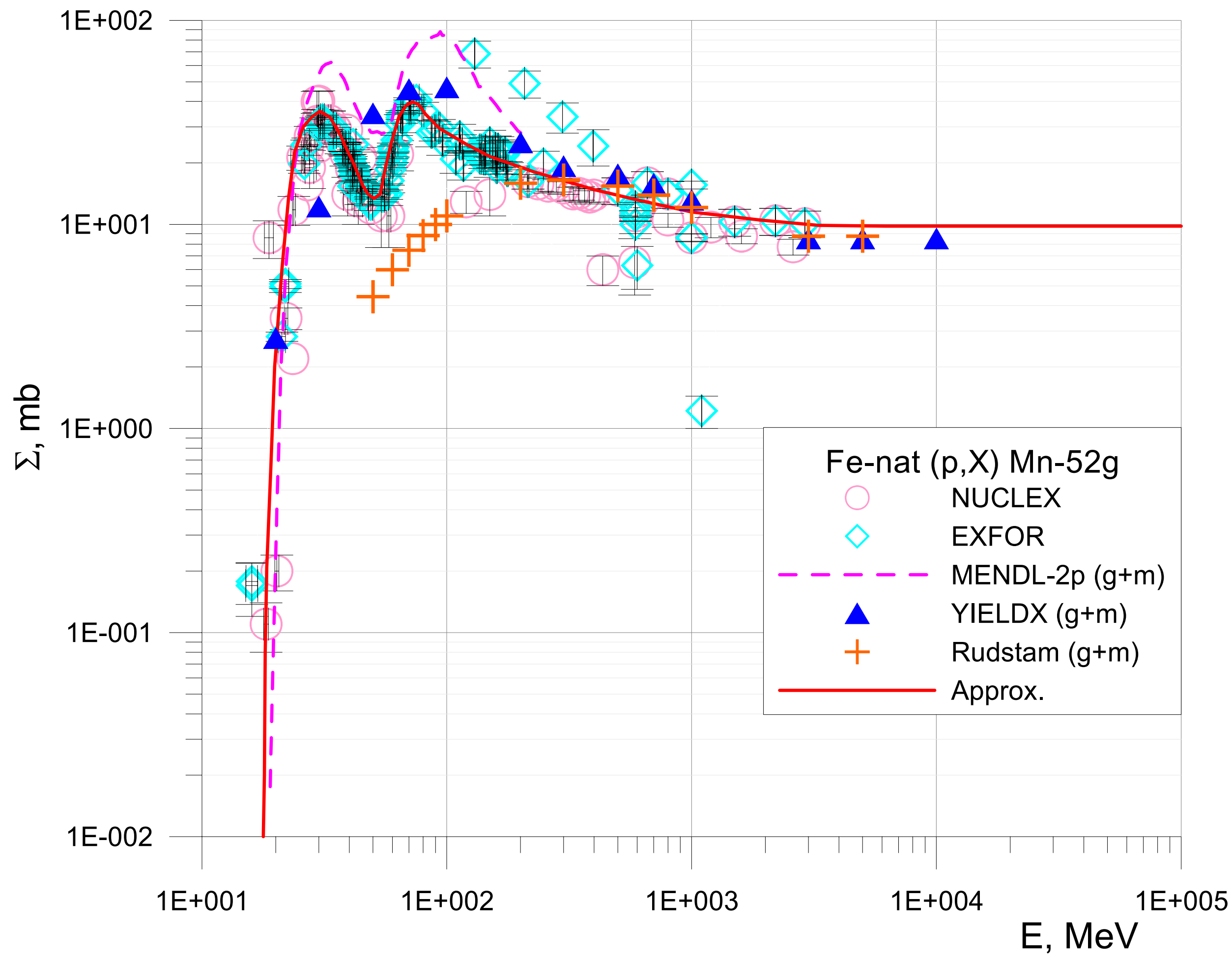
##	E, MeV	Σ, mb
1	10.8	0.000
2	19.9	0.001
3	22.6	0.010
4	25.6	0.054
5	33.5	0.20
6	48.9	0.49
7	70.6	0.73
8	101	0.80
9	200	1.00
10	380	1.14
11	680	1.20
12	1300	1.10
13	3000	0.92
14	6800	0.77
15	12000	0.68
16	30000	0.67
17	100000	0.67
18		



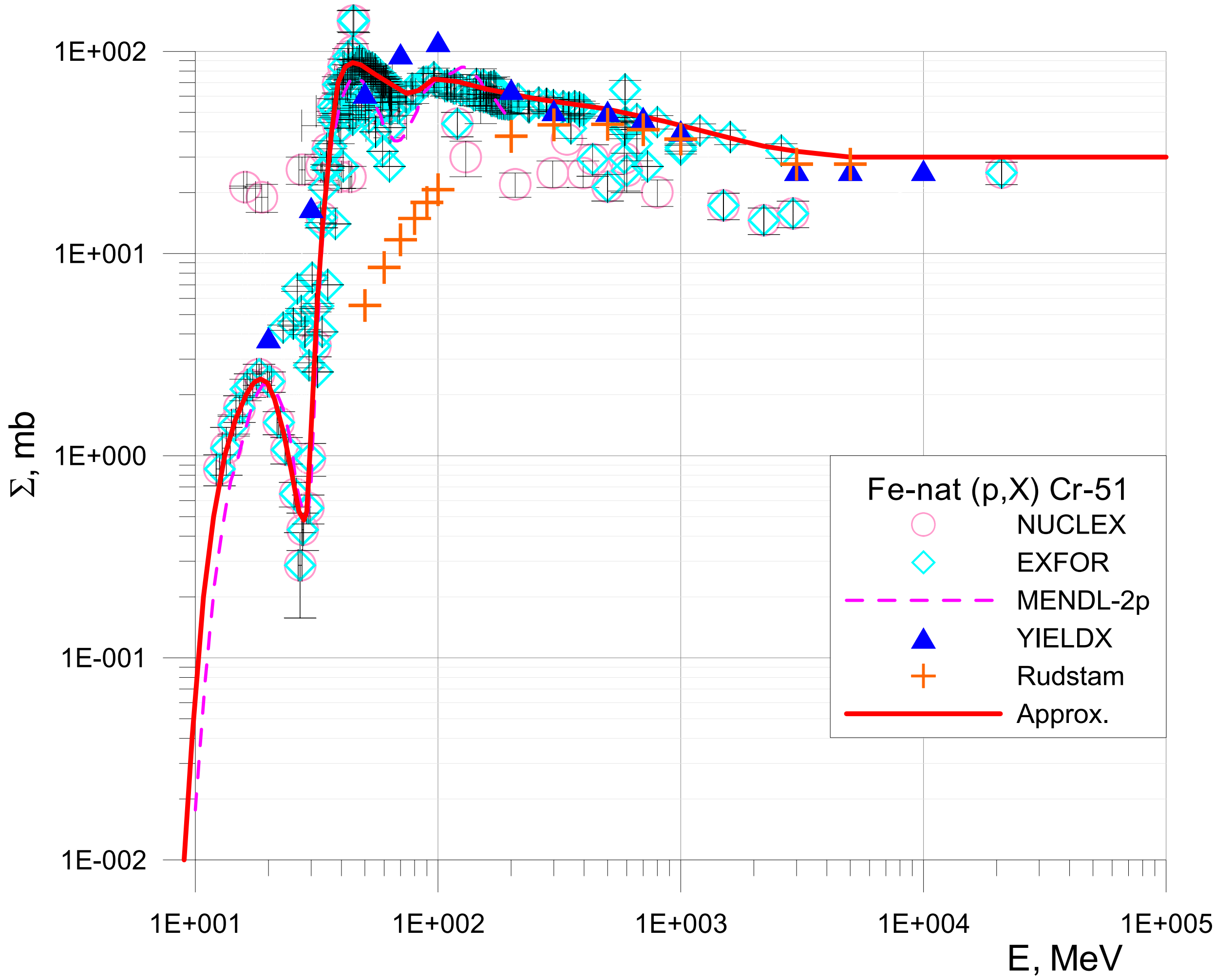
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	7.6	0.10	19	31.7	60.0
2	8.6	0.21	20	33.2	95.0
3	9.9	0.40	21	36.3	130
4	11.7	0.71	22	39.2	155
5	13.4	0.94	23	43.5	165
6	14.3	1.07	24	49.5	155
7	15.8	1.08	25	58	125
8	17.4	1.03	26	75	90
9	18.7	0.78	27	100	70
10	20.5	0.56	28	140	55
11	22.3	0.53	29	240	44
12	24.2	0.56	30	540	36
13	25.2	0.93	31	1250	31
14	25.8	1.60	32	3000	29
15	26.7	3.50	33	6000	28
16	27.2	5.00	34	100000	28
17	28.7	14.5			
18	30.1	34.5			



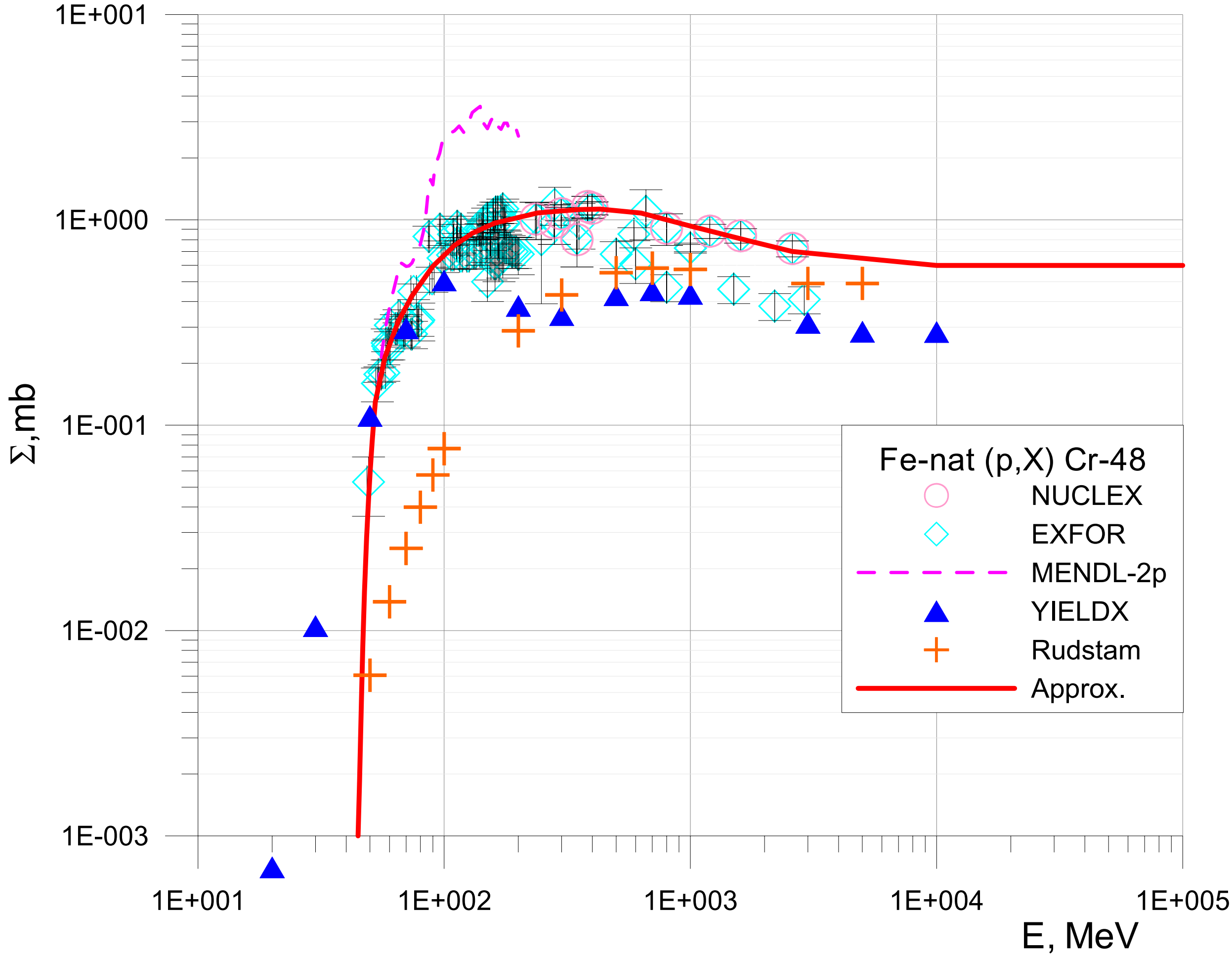
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	1.1	0.00	19	42.0	50.3
2	7.0	0.10	20	44.0	89.5
3	7.3	0.20	21	48.0	145
4	7.9	0.60	22	52.0	200
5	9.0	2.00	23	58.0	225
6	10.0	5.00	24	66.0	197
7	11.6	11.4	25	70.0	148
8	13.8	18.8	26	80.0	115
9	16.1	30.2	27	90.0	100
10	18.1	50.3	28	115	78
11	18.8	69.2	29	140	68
12	20.5	73.4	30	260	50
13	22.9	69.2	31	530	40
14	28.3	53.5	32	1400	34
15	32.1	40.2	33	2600	34
16	35.1	28.6	34	100000	34
17	37.6	26.3	35		
18	40.8	30.0	36		



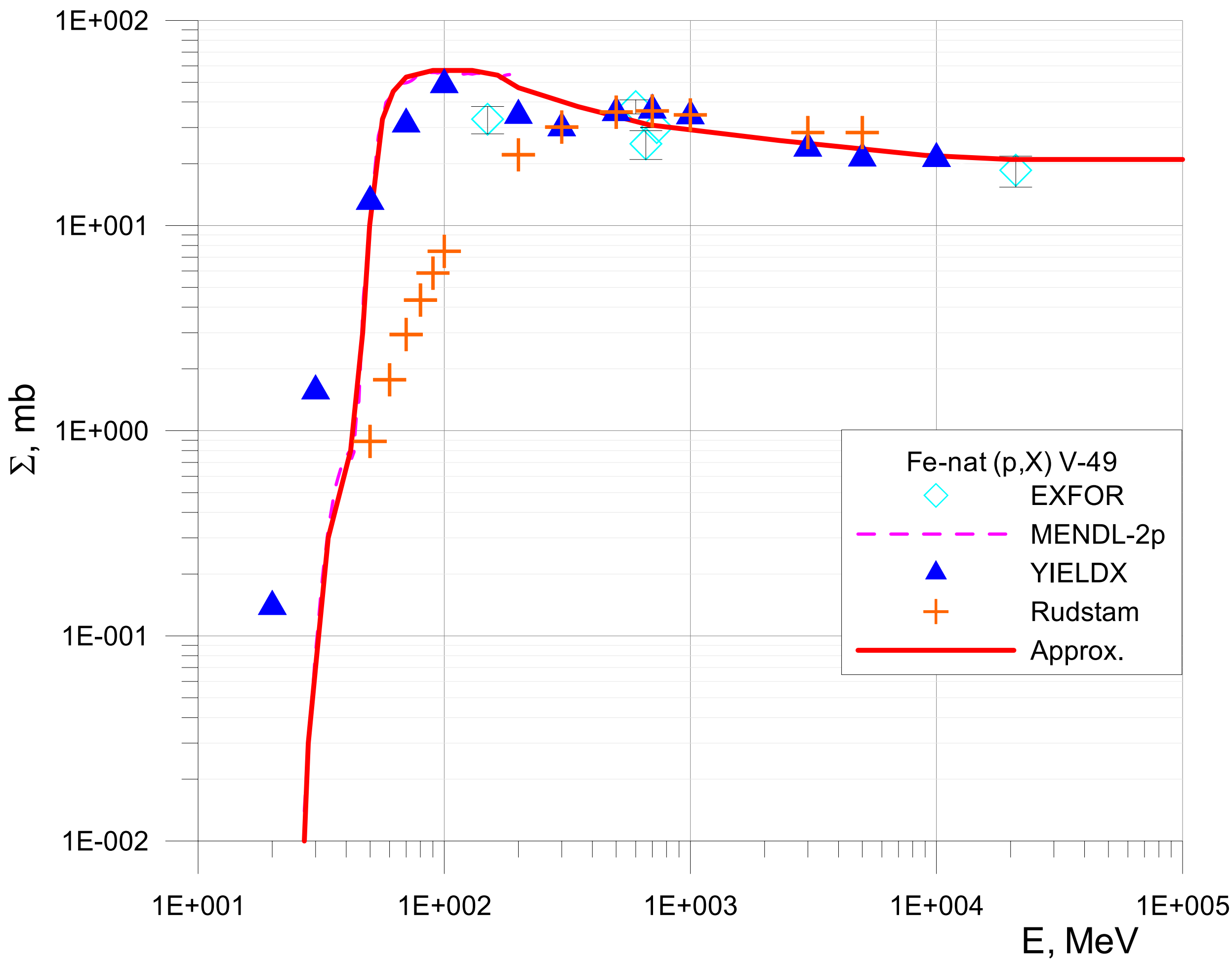
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	13.3	0.00	21	53.5	14.1
2	17.8	0.01	22	55.9	18.5
3	18.0	0.02	23	59.1	24.7
4	18.1	0.08	24	63.8	33.7
5	18.4	0.21	25	68.5	38.5
6	19.1	0.65	26	72.4	39.8
7	19.8	2.00	27	76.6	38.8
8	21.2	6.00	28	81.8	34.7
9	22.6	13.6	29	93.5	29.5
10	23.9	22.5	30	120	24.7
11	25.9	30.0	31	150	21.5
12	28.2	33.7	32	230	18.0
13	30.3	36.0	33	400	14.8
14	33.3	33.5	34	580	13.3
15	36.1	28.6	35	1000	11.5
16	38.4	24.4	36	1900	10.5
17	41.9	19.6	37	3300	9.9
18	45.3	15.6	38	6200	9.8
19	47.6	14.1	39	100000	9.8
20	50.4	13.4			



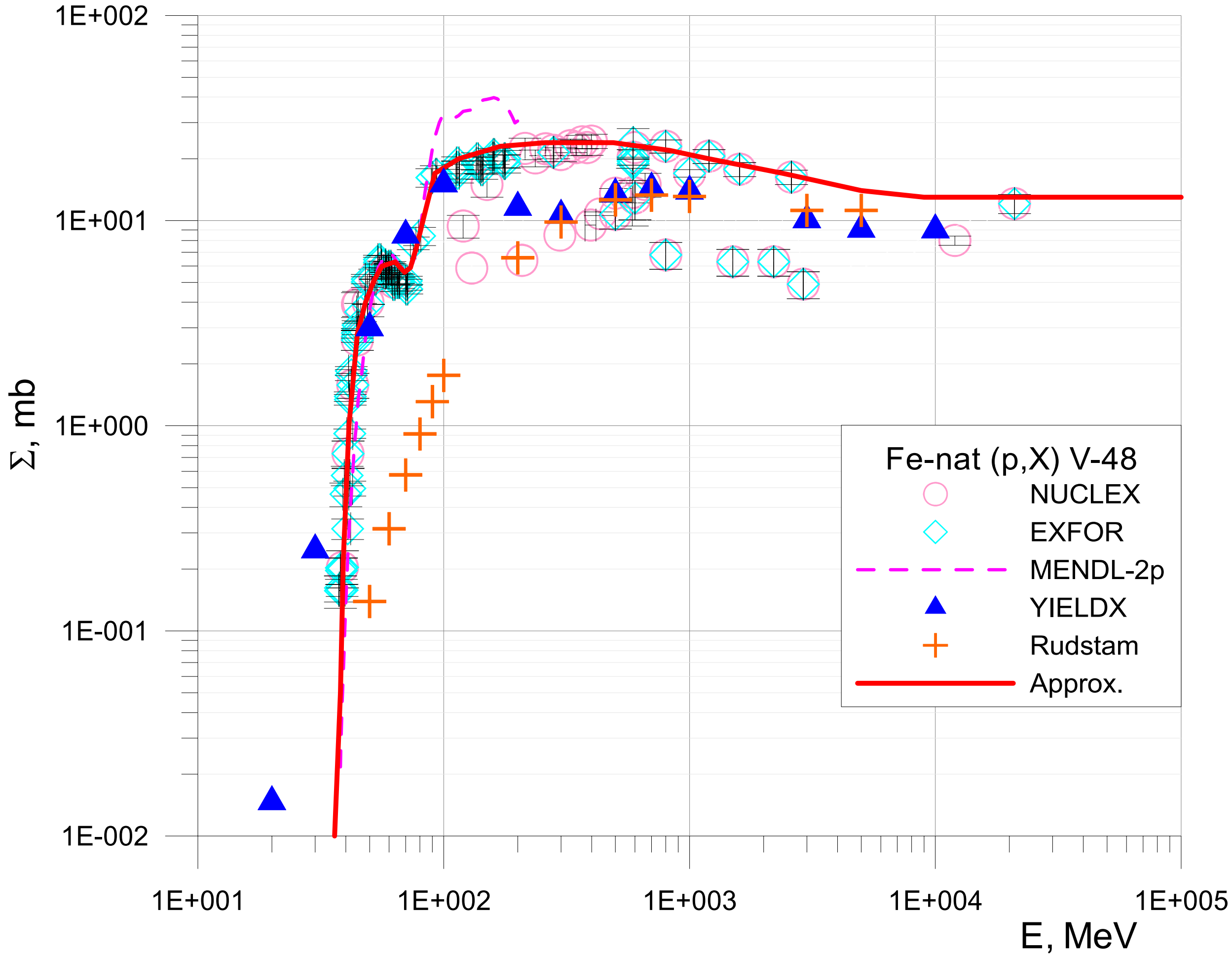
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	9.0	0.01	21	36.4	40
2	9.7	0.04	22	38.7	70
3	10.8	0.20	23	41.4	84
4	11.9	0.50	24	44.4	88
5	13.2	1.00	25	48.0	86
6	14.6	1.50	26	55.0	77
7	16.2	2.00	27	64.0	69
8	17.4	2.30	28	74.0	62
9	18.5	2.40	29	83.0	64
10	19.8	2.30	30	96.0	73
11	21.2	1.90	31	120	71
12	23.1	1.30	32	160	65
13	24.9	0.84	33	260	58
14	26.7	0.53	34	490	52
15	28.0	0.48	35	860	45
16	28.8	0.53	36	1800	36
17	29.6	1.00	37	2200	34
18	30.6	2.20	38	3000	32
19	31.9	6.00	39	5000	30
20	33.5	14.5	40	100000	30



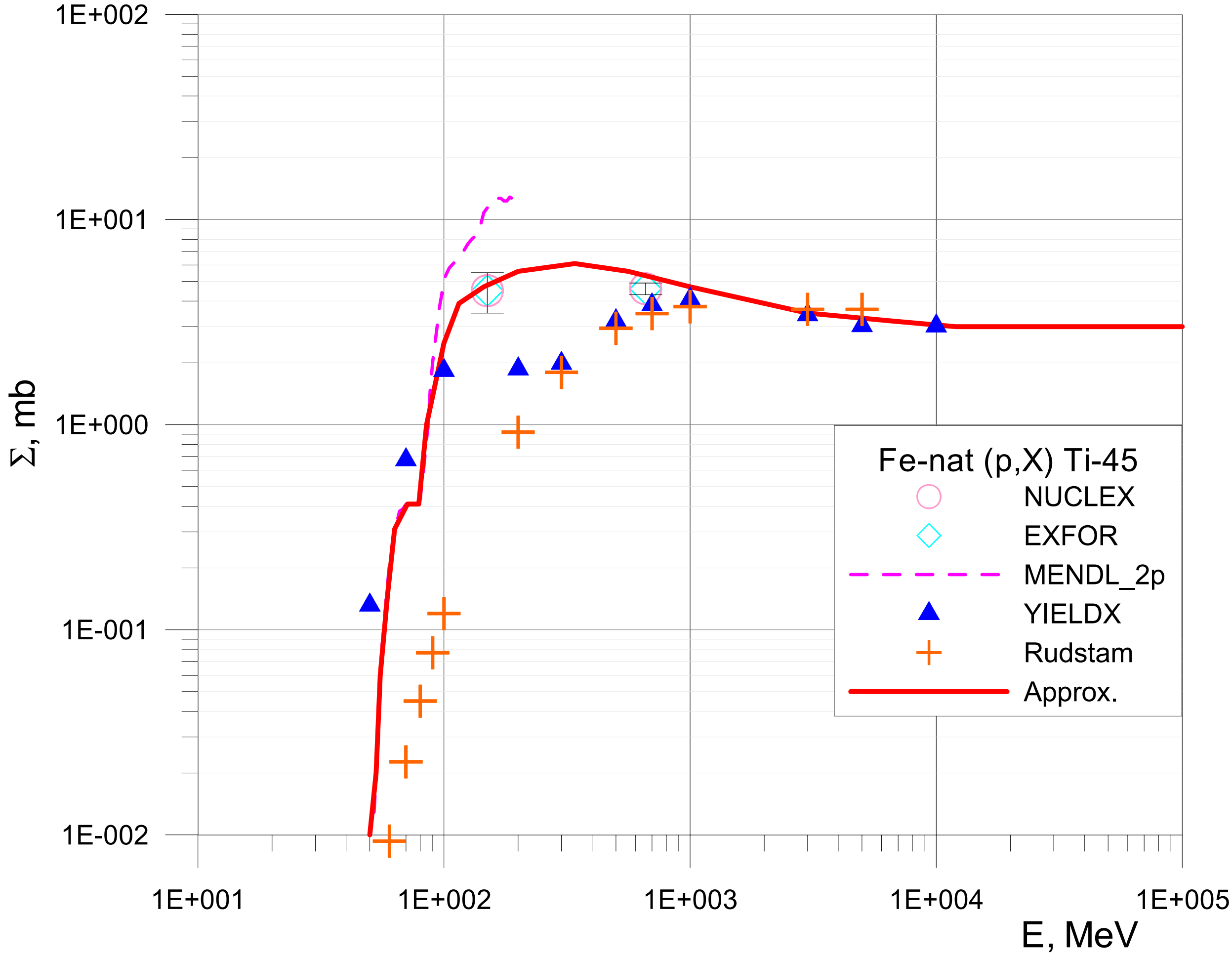
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	24.0	0.000	19	630	1.08
2	44.7	0.001	20	1000	0.93
3	45.4	0.002	21	1700	0.79
4	46.3	0.006	22	2600	0.70
5	47.2	0.012	23	10000	0.60
6	47.9	0.022	24	100000	0.60
7	49.8	0.053			
8	52.5	0.13			
9	57.5	0.22			
10	65.0	0.32			
11	74.0	0.43			
12	90.0	0.60			
13	110	0.75			
14	130	0.86			
15	160	0.96			
16	240	1.08			
17	350	1.12			
18	430	1.13			



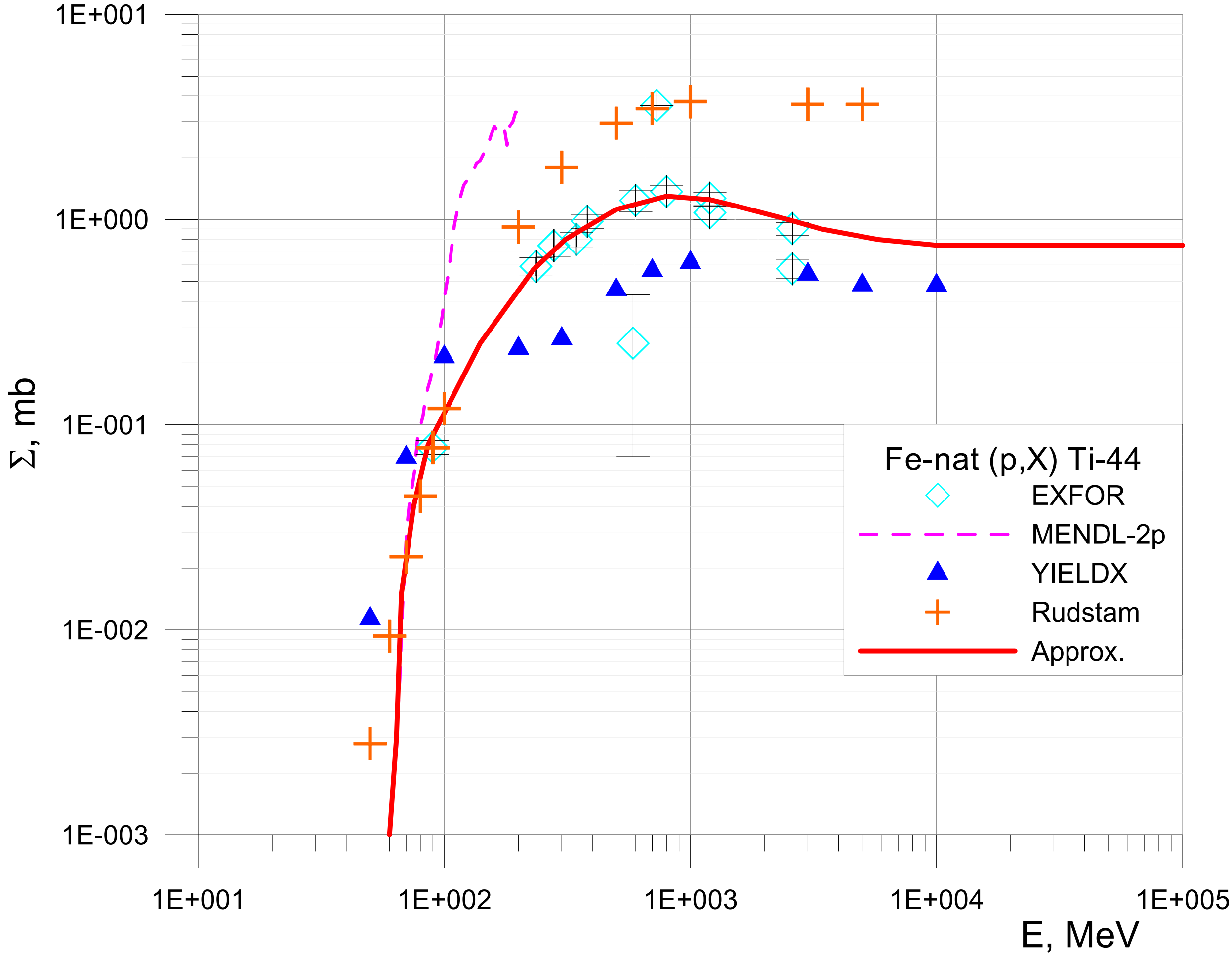
##	E, MeV	Σ, mb
1	10.4	0.00
2	27.0	0.01
3	28.0	0.03
4	30.0	0.07
5	33.8	0.30
6	41.7	0.80
7	46.6	3.0
8	49.7	10
9	56.1	33
10	62.0	45
11	70.0	53
12	90.0	57
13	130	57
14	165	54
15	200	47
16	350	38
17	680	31
18	2300	26
19	9000	22
20	20000	21
21	100000	21



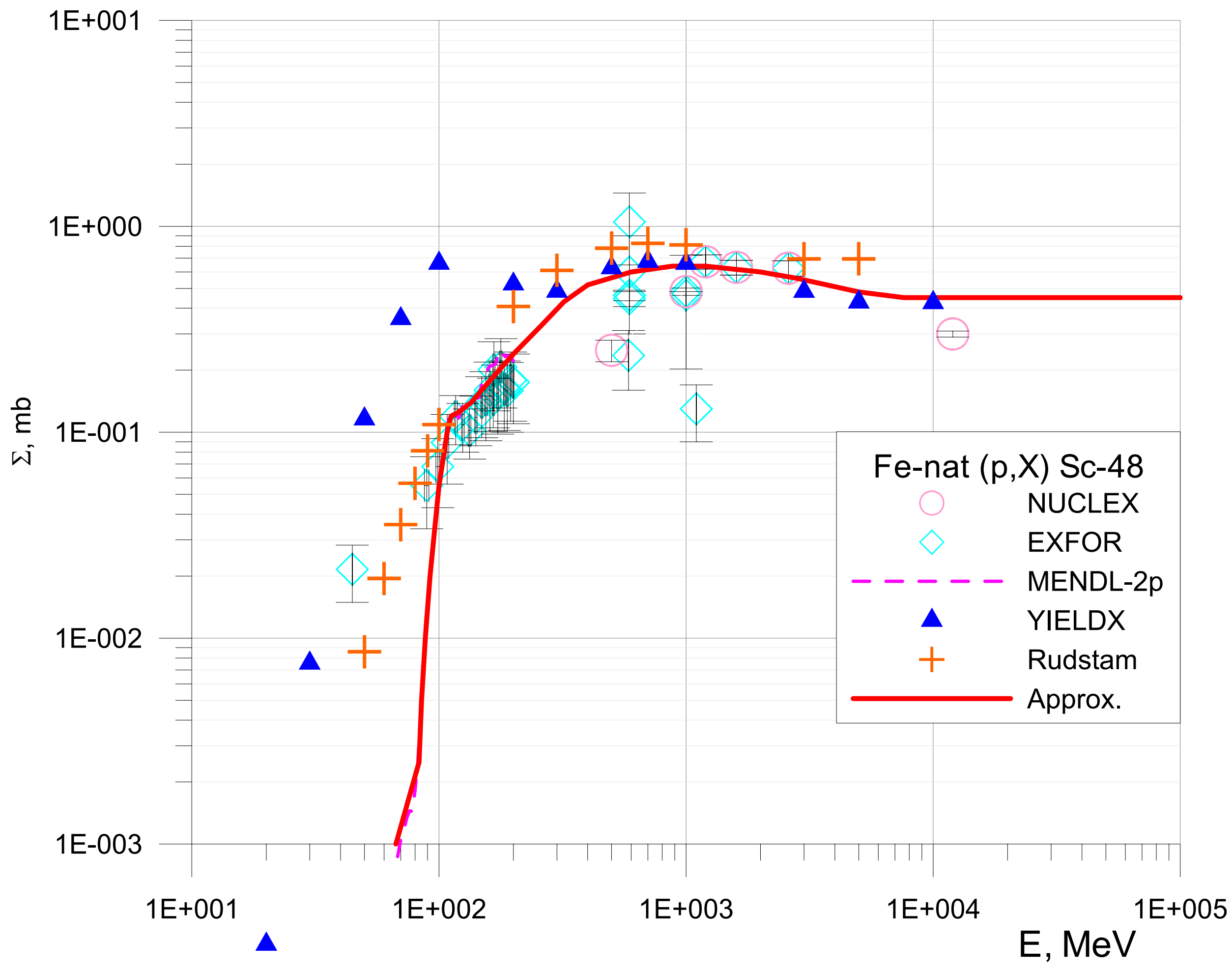
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	22.2	0.00	19	490	24
2	36.0	0.01	20	830	22
3	38.0	0.05	21	1200	20
4	39.0	0.22	22	2400	17
5	41.2	1.0	23	5000	14
6	44.5	2.8	24	9000	13
7	48.1	4.0	25	100000	13
8	52.0	5.1			
9	56.1	6.0			
10	63.4	6.3			
11	69.3	5.6			
12	73.2	5.9			
13	77.4	7.4			
14	84.0	11			
15	92.0	17			
16	115	20			
17	170	23			
18	260	24			



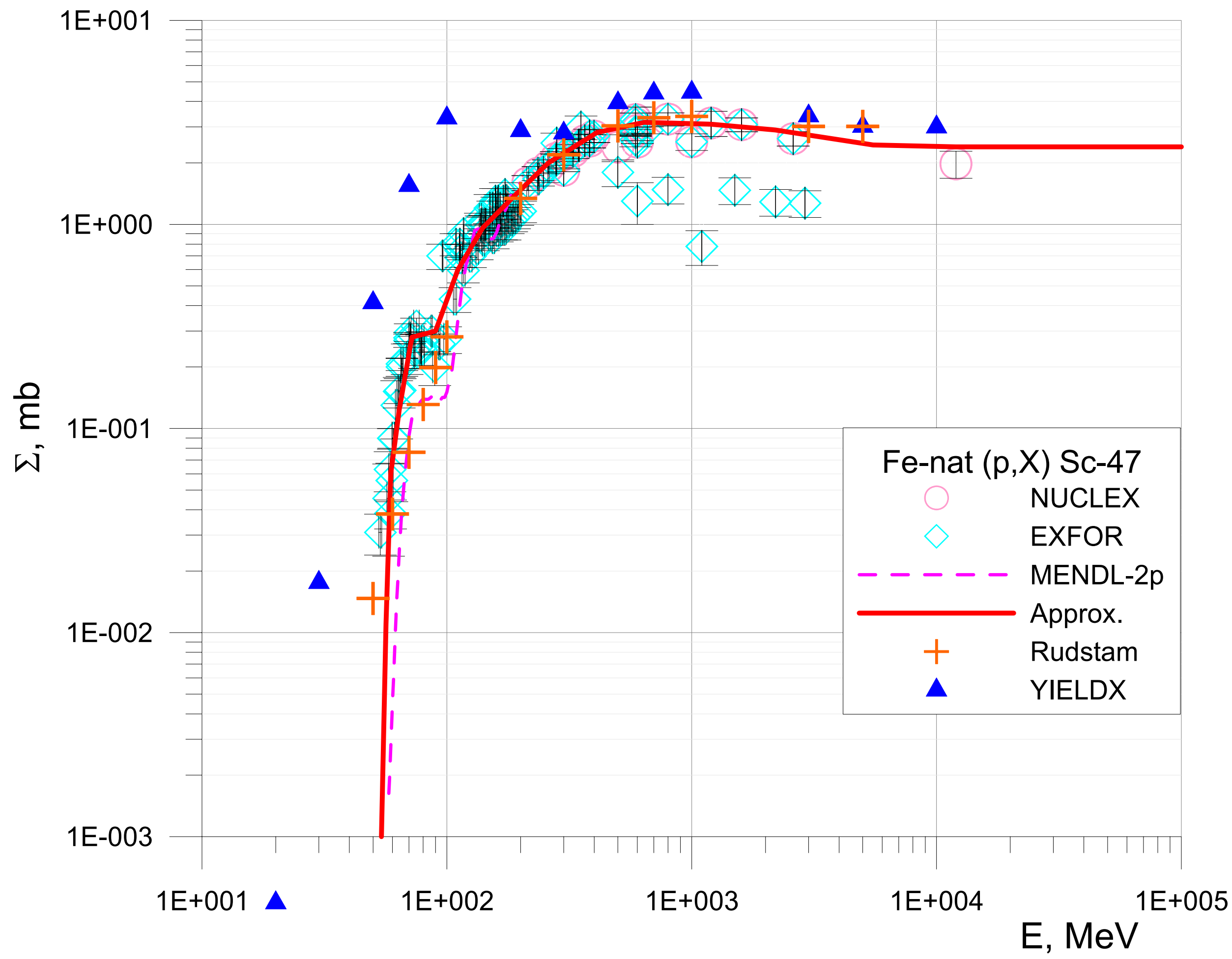
##	E, MeV	Σ, mb
1	28	0.00
2	50	0.01
3	53	0.02
4	55	0.06
5	59	0.15
6	63	0.31
7	71	0.41
8	79	0.41
9	85	1.00
10	100	2.5
11	115	3.9
12	145	4.7
13	200	5.6
14	340	6.1
15	560	5.6
16	1000	4.7
17	3000	3.5
18	6600	3.2
19	12000	3.0
20	100000	3.0



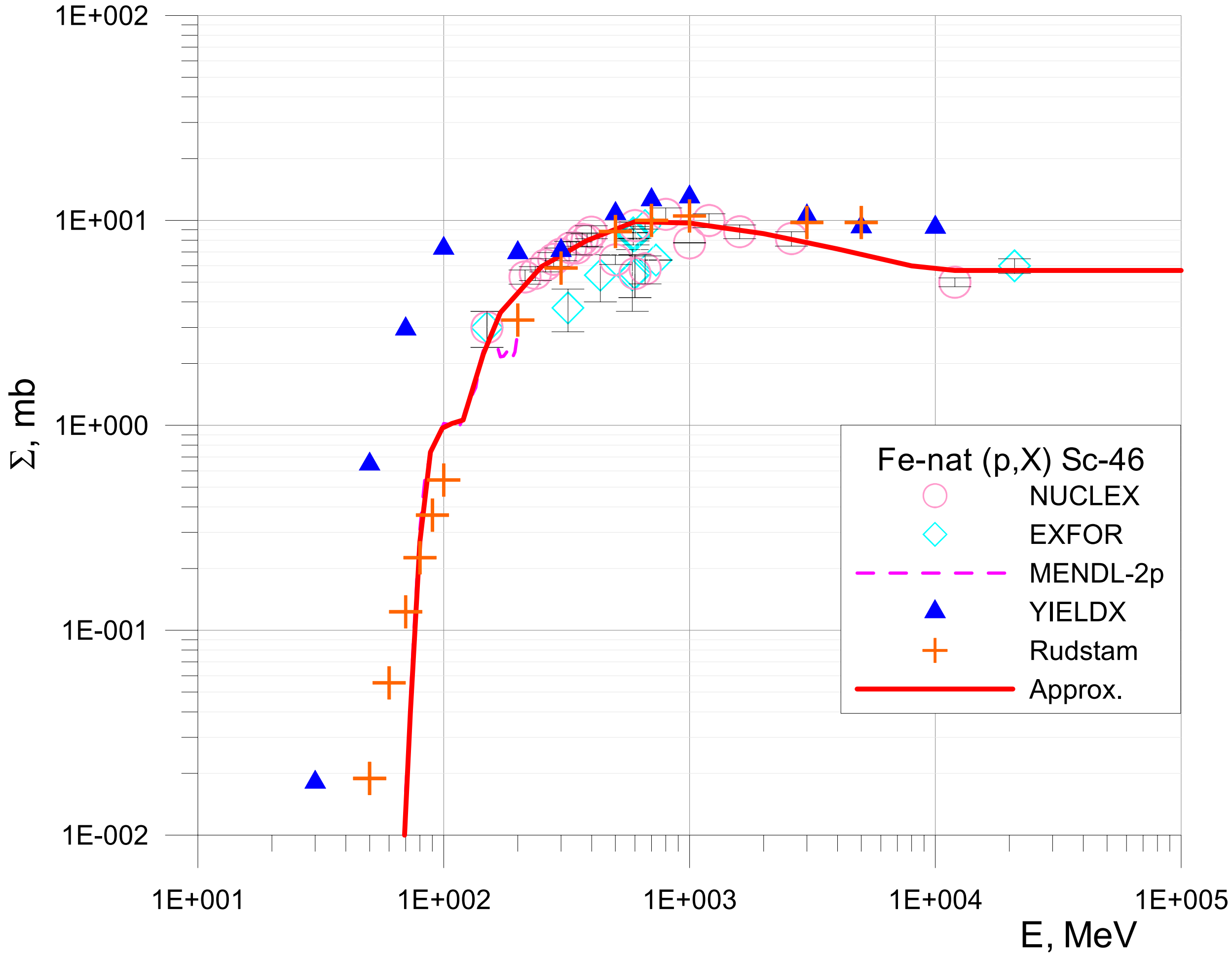
##	E, MeV	Σ, mb
1	31.8	0.000
2	60	0.001
3	64	0.003
4	67	0.015
5	75	0.04
6	86	0.08
7	140	0.25
8	230	0.57
9	310	0.80
10	500	1.12
11	800	1.30
12	1200	1.25
13	1600	1.15
14	2500	1.00
15	3400	0.90
16	5800	0.80
17	10000	0.75
18	100000	0.75



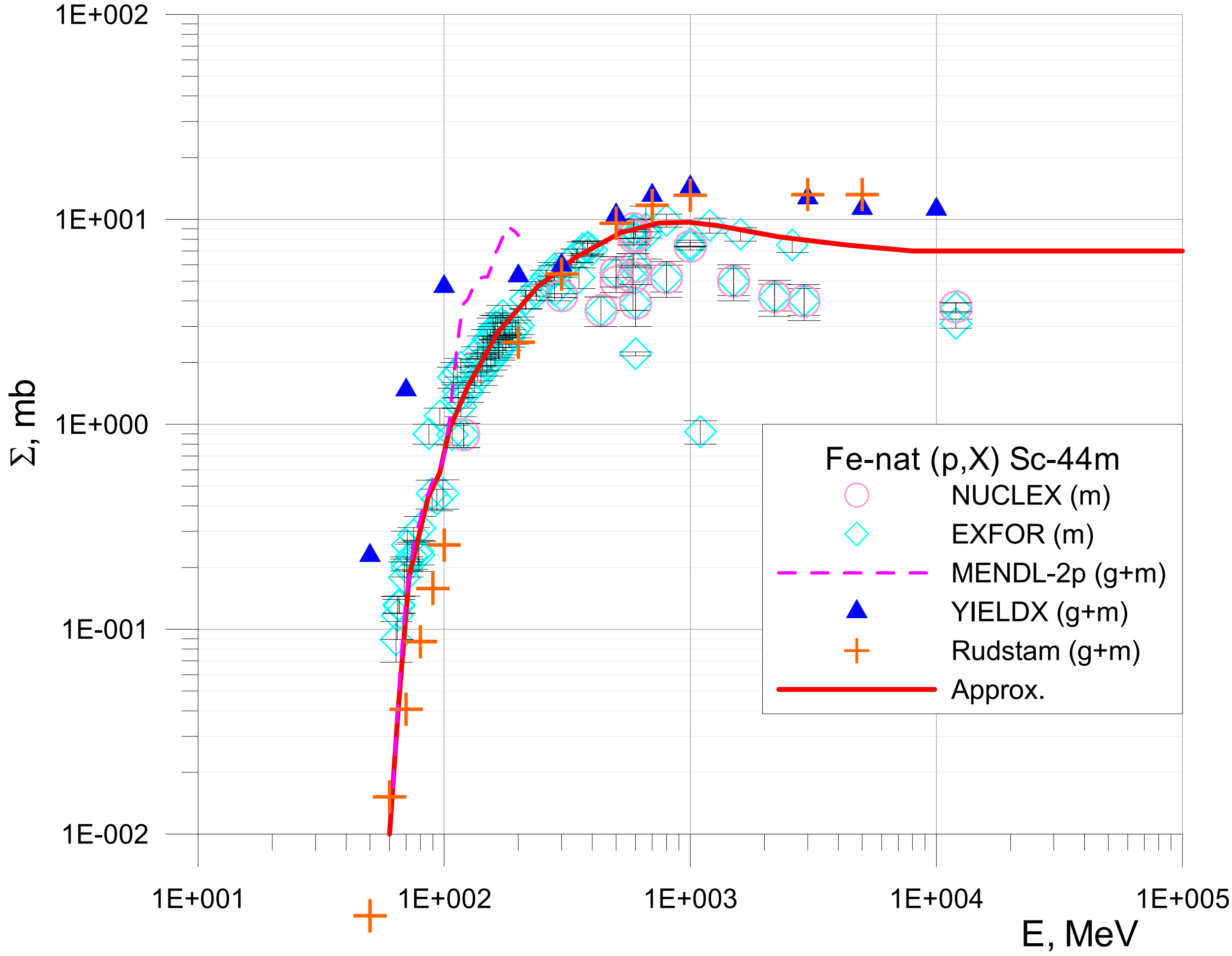
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	28.3	0.000	19	1200	0.64
2	67	0.001	20	2000	0.60
3	83	0.003	21	2800	0.56
4	85	0.005	22	5000	0.48
5	88	0.010	23	7600	0.45
6	92	0.020	24	100000	0.45
7	100	0.055			
8	108	0.10			
9	112	0.12			
10	120	0.13			
11	135	0.14			
12	175	0.20			
13	200	0.24			
14	260	0.33			
15	320	0.43			
16	400	0.52			
17	600	0.60			
18	880	0.64			



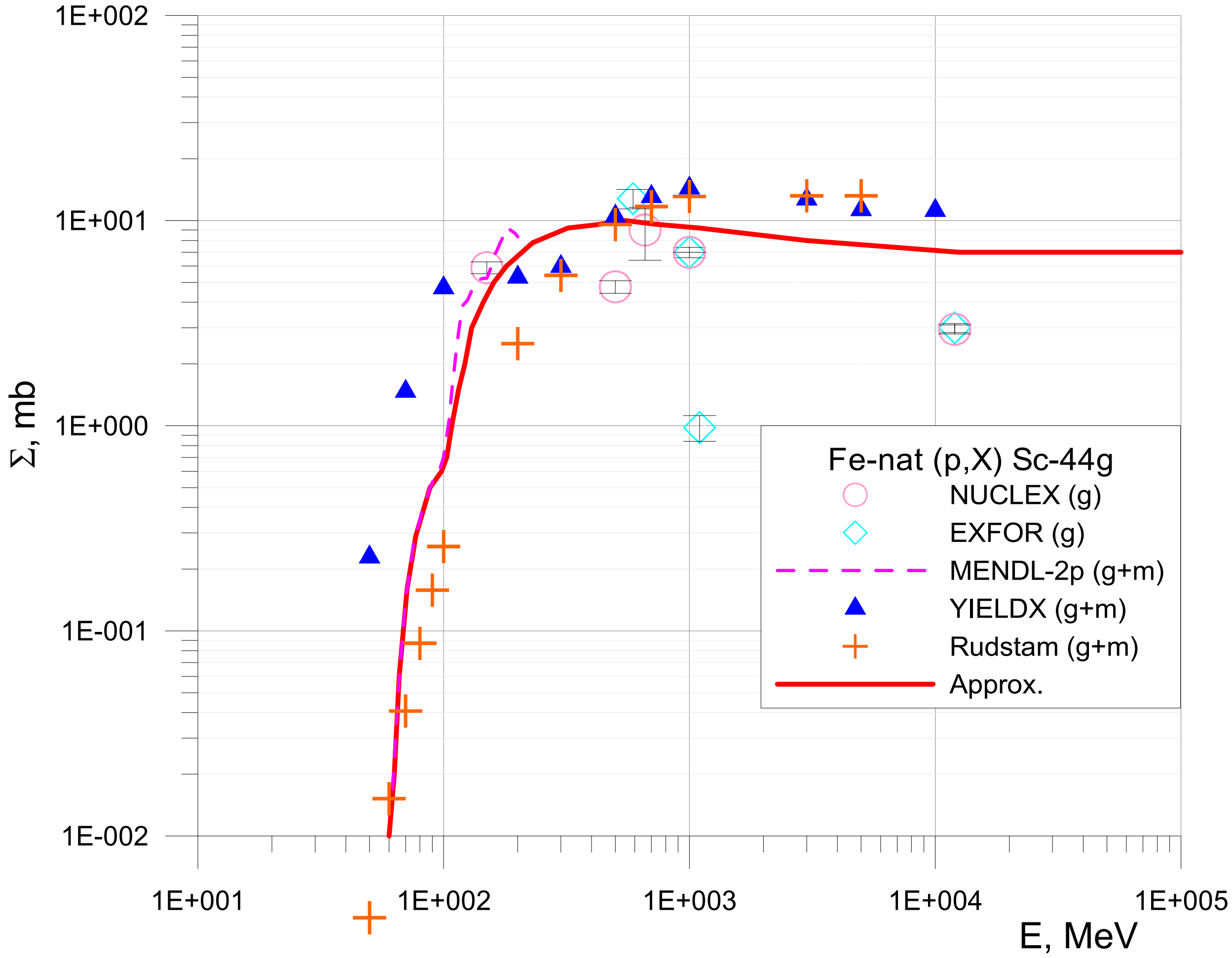
##	E, MeV	Σ, mb
1	28.8	0.000
2	54.0	0.001
3	56.4	0.011
4	59.0	0.060
5	64.0	0.125
6	72.0	0.28
7	90.0	0.30
8	111	0.60
9	140	0.96
10	190	1.39
11	260	2.00
12	410	2.82
13	640	3.16
14	1200	3.10
15	2200	2.90
16	5500	2.45
17	12000	2.40
18	100000	2.40



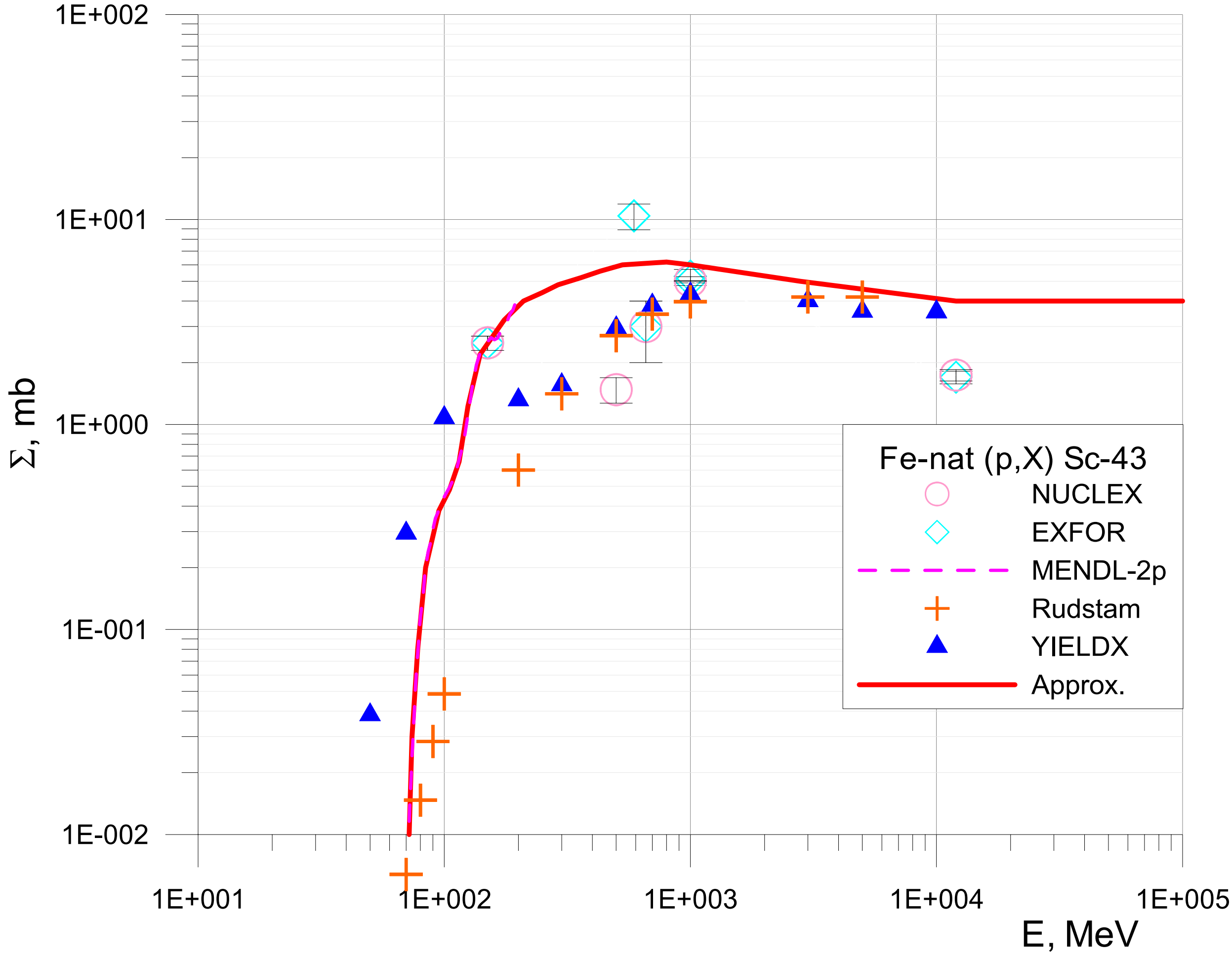
##	E, MeV	Σ, mb
1	18.73	0.00
2	69.3	0.01
3	73.2	0.04
4	80.0	0.27
5	88.3	0.74
6	98.6	0.97
7	108	1.02
8	120	1.06
9	145	2.23
10	170	3.54
11	250	5.95
12	380	7.96
13	600	9.85
14	1000	9.70
15	2000	8.60
16	4000	7.25
17	8000	6.00
18	12000	5.70
19	100000	5.70



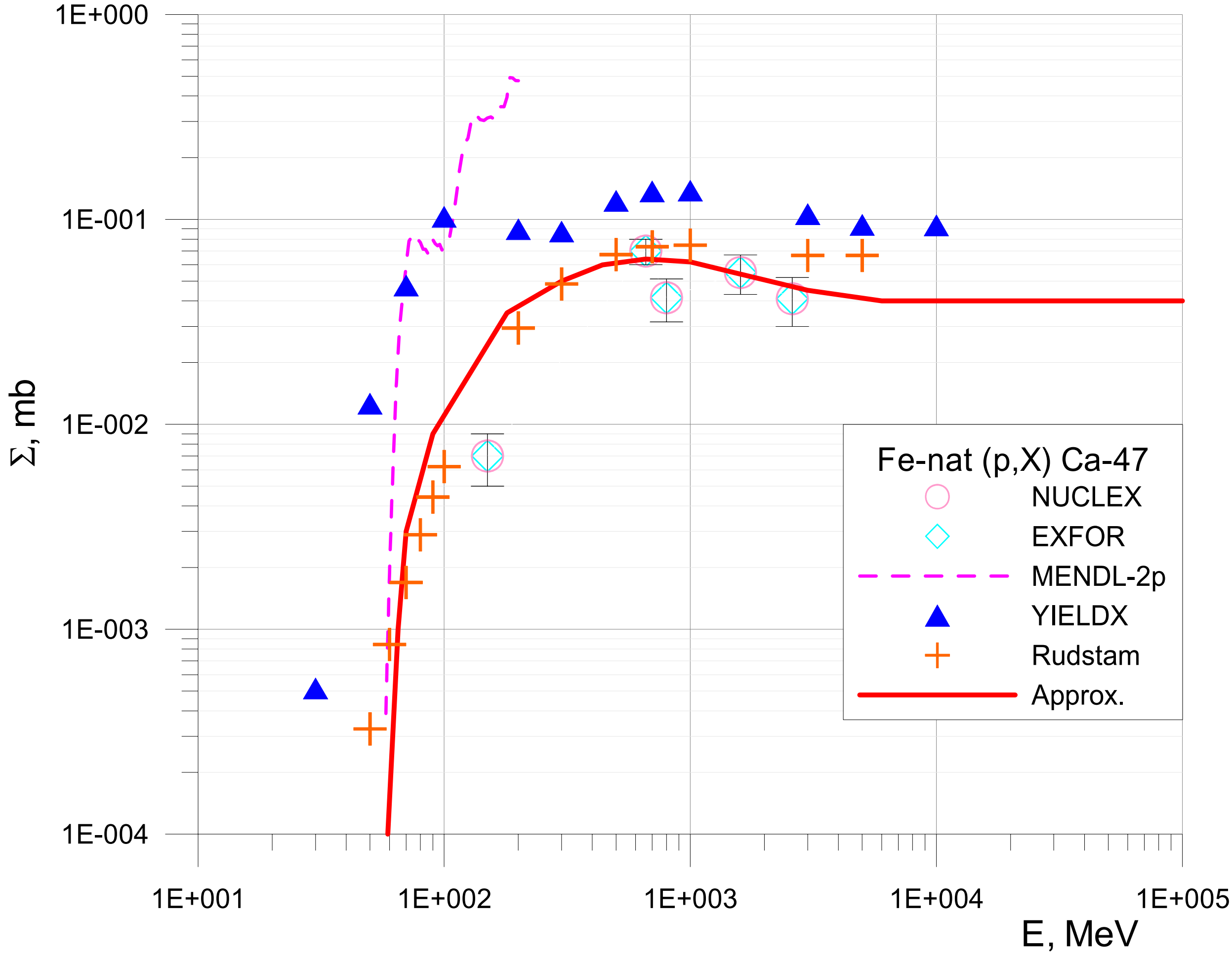
##	E, MeV	Σ, mb
1	31	0.00
2	60	0.01
3	65	0.04
4	72	0.18
5	86	0.44
6	96	0.58
7	105	0.95
8	125	1.5
9	165	2.8
10	240	4.7
11	340	6.5
12	520	8.6
13	745	9.6
14	990	9.7
15	1300	9.3
16	2300	8.2
17	4300	7.5
18	8000	7.0
19	100000	7.0



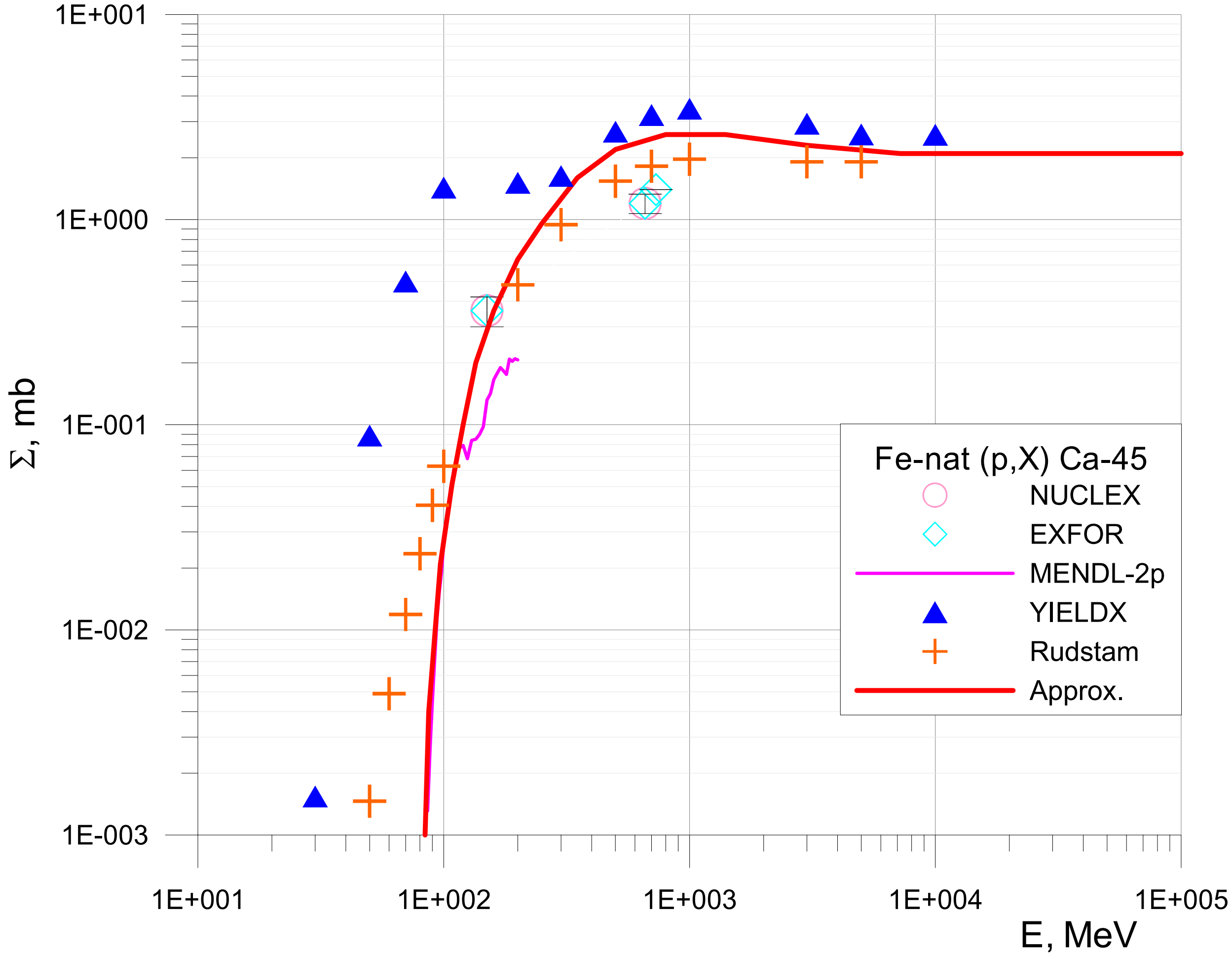
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	31	0.00	19	410	9.5
2	60	0.01	20	550	10
3	63	0.02	21	730	9.6
4	66	0.06	22	1100	9.2
5	71	0.16	23	3000	8.0
6	77	0.29	24	12500	7.0
7	88	0.50	25	100000	7.0
8	98	0.60			
9	103	0.70			
10	108	1.0			
11	115	1.5			
12	122	2.0			
13	130	3.0			
14	145	4.0			
15	160	5.0			
16	180	6.0			
17	230	7.8			
18	320	9.2			



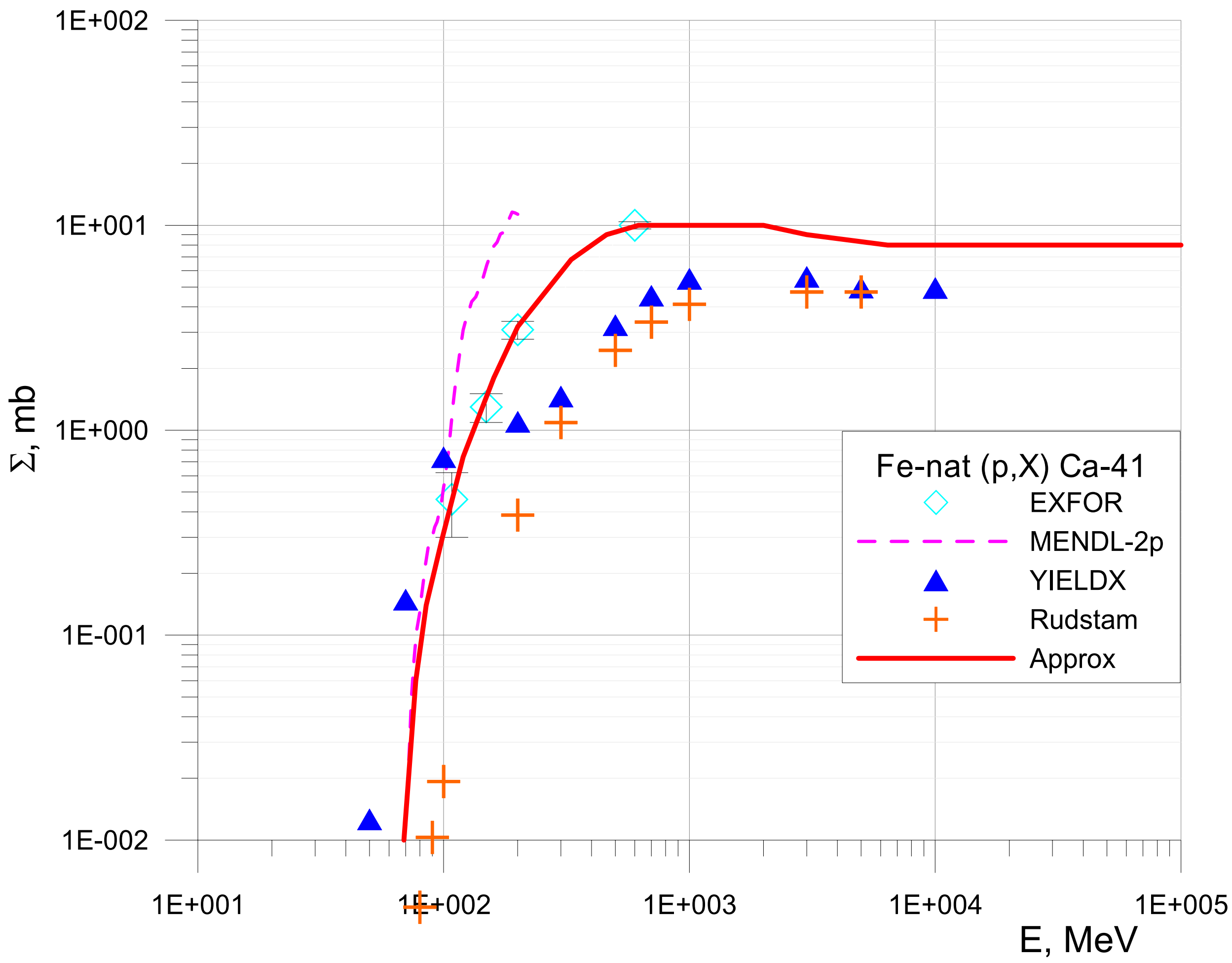
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	20.4	0.00	19	1000	6.0
2	72	0.01	20	2800	5.0
3	74	0.03	21	12000	4.0
4	78	0.08	22	100000	4.0
5	84	0.20			
6	95	0.38			
7	105	0.48			
8	115	0.66			
9	125	1.2			
10	140	2.2			
11	175	3.2			
12	210	4.0			
13	250	4.4			
14	290	4.8			
15	360	5.2			
16	430	5.6			
17	530	6.0			
18	800	6.2			



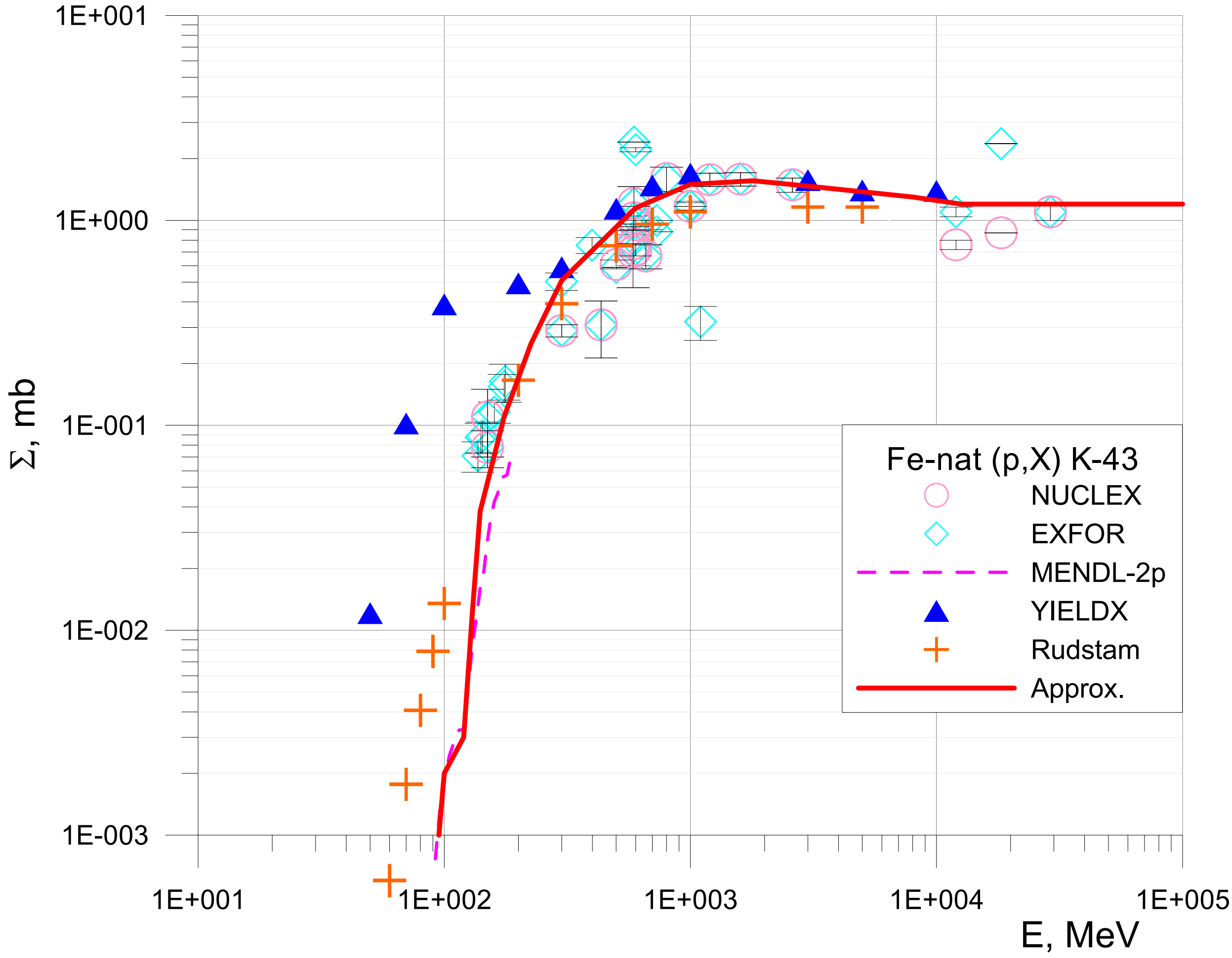
##	E, MeV	Σ, mb
1	37.9	0.0000
2	80	0.0001
3	94	0.001
4	115	0.003
5	150	0.009
6	210	0.035
7	300	0.050
8	440	0.060
9	660	0.064
10	1000	0.062
11	1500	0.055
12	3000	0.045
13	6000	0.040
14	100000	0.040



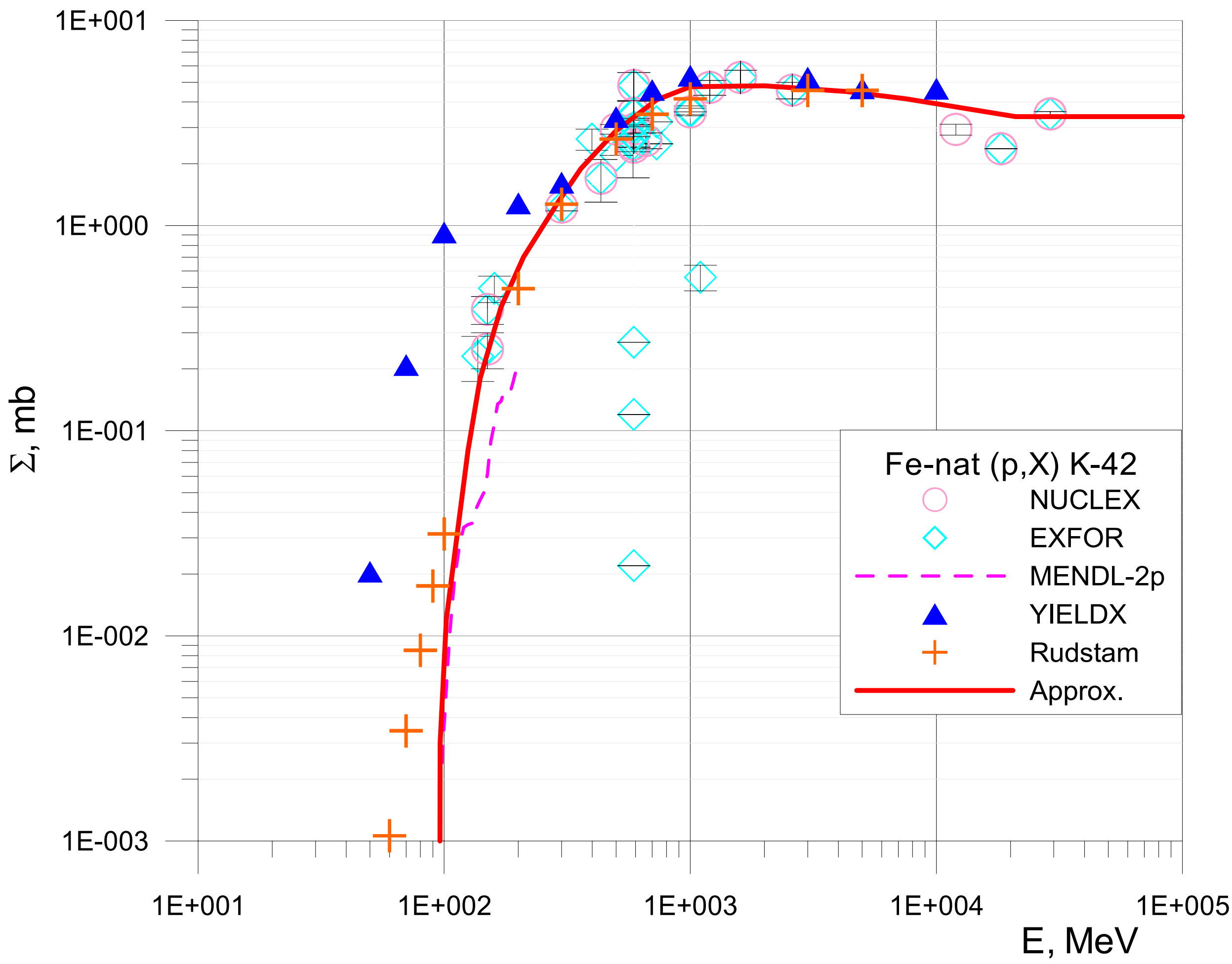
##	E, MeV	Σ, mb
1	27	0.000
2	84	0.001
3	87	0.004
4	97	0.021
5	108	0.051
6	120	0.100
7	135	0.20
8	160	0.36
9	200	0.64
10	250	0.95
11	350	1.60
12	500	2.20
13	800	2.60
14	1400	2.60
15	3000	2.30
16	7200	2.10
17	100000	2.10



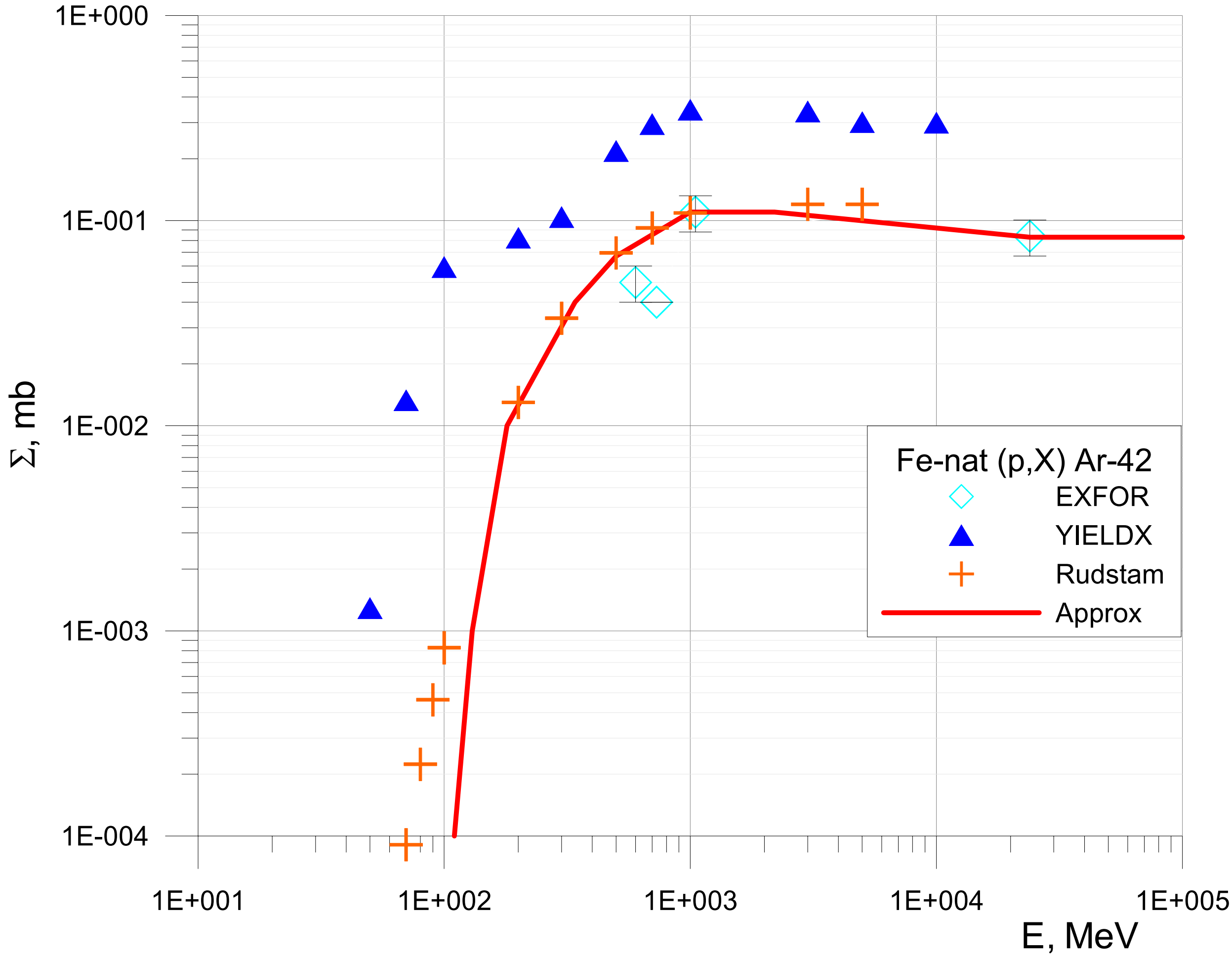
##	E, MeV	Σ, mb
1	34.9	0.00
2	69	0.01
3	77	0.06
4	85	0.14
5	99	0.30
6	120	0.74
7	160	1.80
8	200	3.20
9	330	6.80
10	460	9.00
11	620	10.0
12	2000	10.0
13	3000	9.00
14	6400	8.00
15	100000	8.00



##	E, MeV	Σ, mb
1	39.2	0.000
2	95	0.001
3	100	0.002
4	120	0.003
5	130	0.014
6	140	0.04
7	175	0.15
8	225	0.30
9	300	0.50
10	600	1.15
11	1000	1.50
12	1800	1.56
13	3000	1.45
14	8000	1.25
15	12600	1.20
16		



##	E, MeV	Σ, mb
1	28.1	0.000
2	96.1	0.001
3	96.2	0.003
4	102	0.012
5	115	0.037
6	125	0.08
7	140	0.18
8	170	0.40
9	210	0.70
10	290	1.30
11	360	1.90
12	500	2.90
13	730	4.10
14	1000	4.75
15	2000	4.80
16	4300	4.50
17	7500	4.15
18	21000	3.40
19	100000	3.40



##	E, MeV	Σ, mb
1	38.1	0.0000
2	110	0.0001
3	130	0.001
4	180	0.010
5	340	0.040
6	500	0.067
7	1000	0.110
8	2200	0.110
9	24000	0.083
10	100000	0.083
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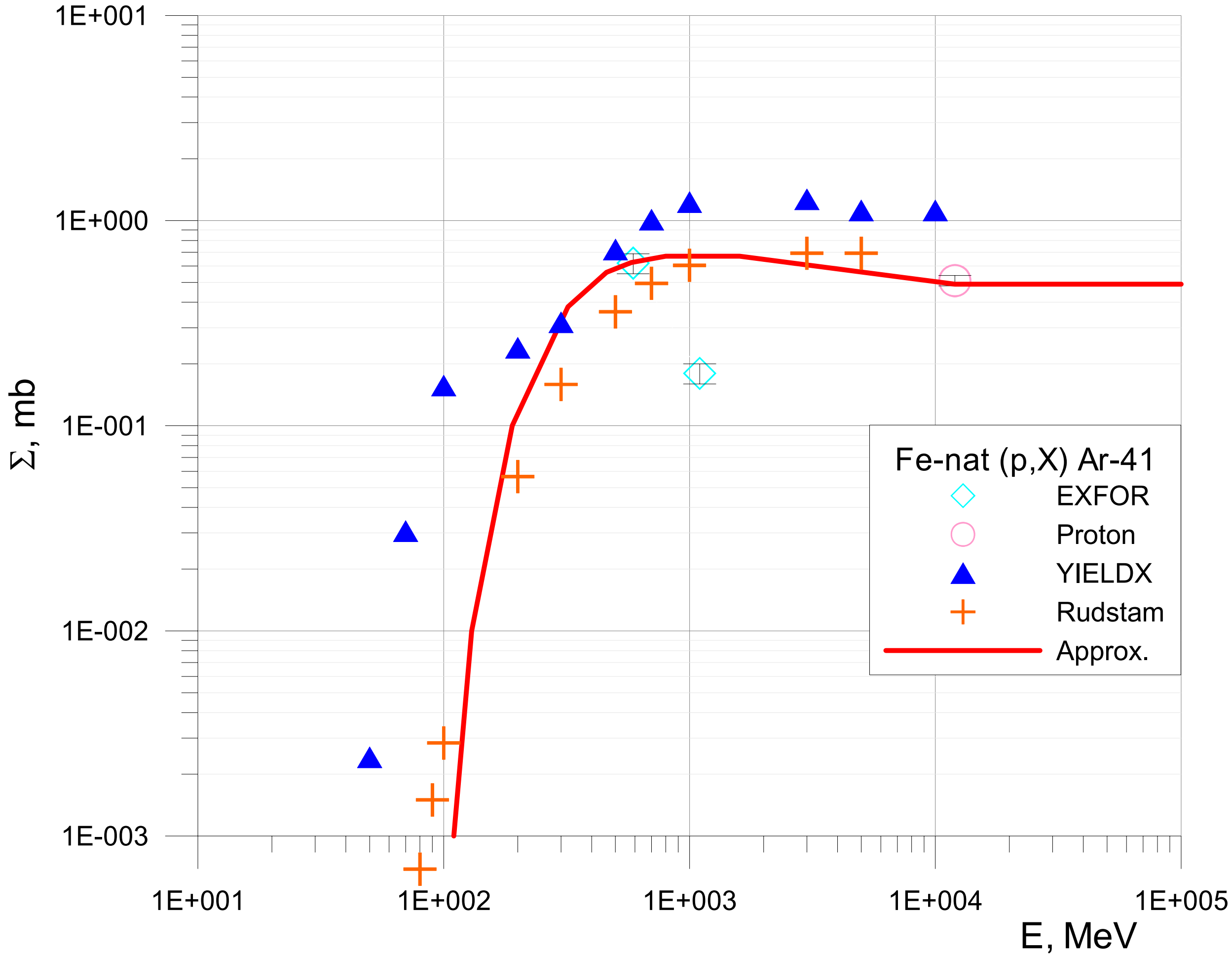
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	37.5	0.000
2	110	0.001
3	130	0.010
4	190	0.100
5	320	0.380
6	460	0.560
7	580	0.625
8	800	0.670
9	1600	0.670
10	12000	0.490
11	100000	0.490
12		
13		
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15		
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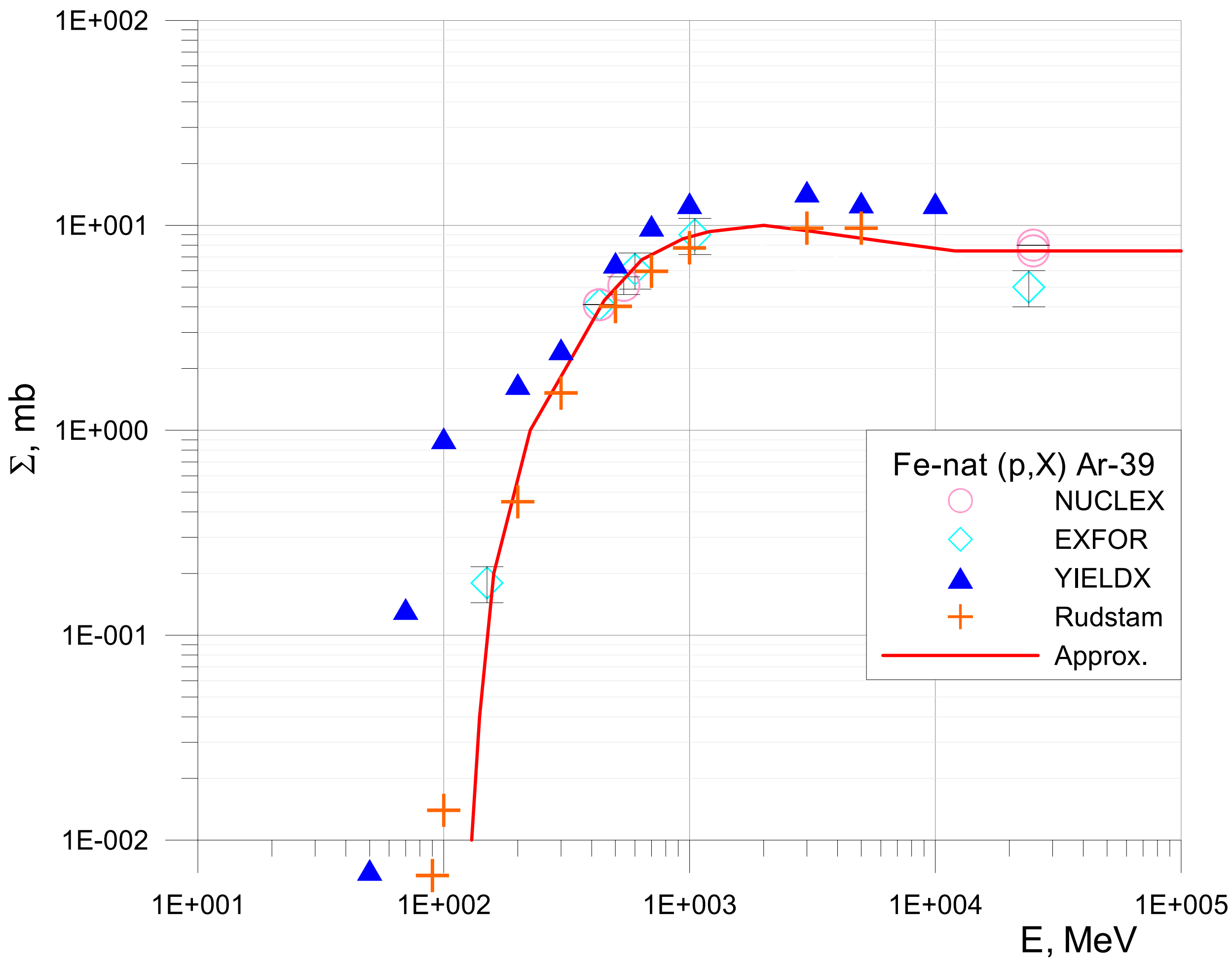
17		
18		



##	E, MeV	Σ, mb
1	44	0.00
2	130	0.01
3	140	0.04
4	160	0.20
5	225	1.00
6	320	2.10
7	450	4.30
8	640	6.80
9	940	8.60
10	1200	9.30
11	2000	10.0
12	3000	9.40
13	6000	8.40
14	12000	7.50
15	100000	7.50
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17		
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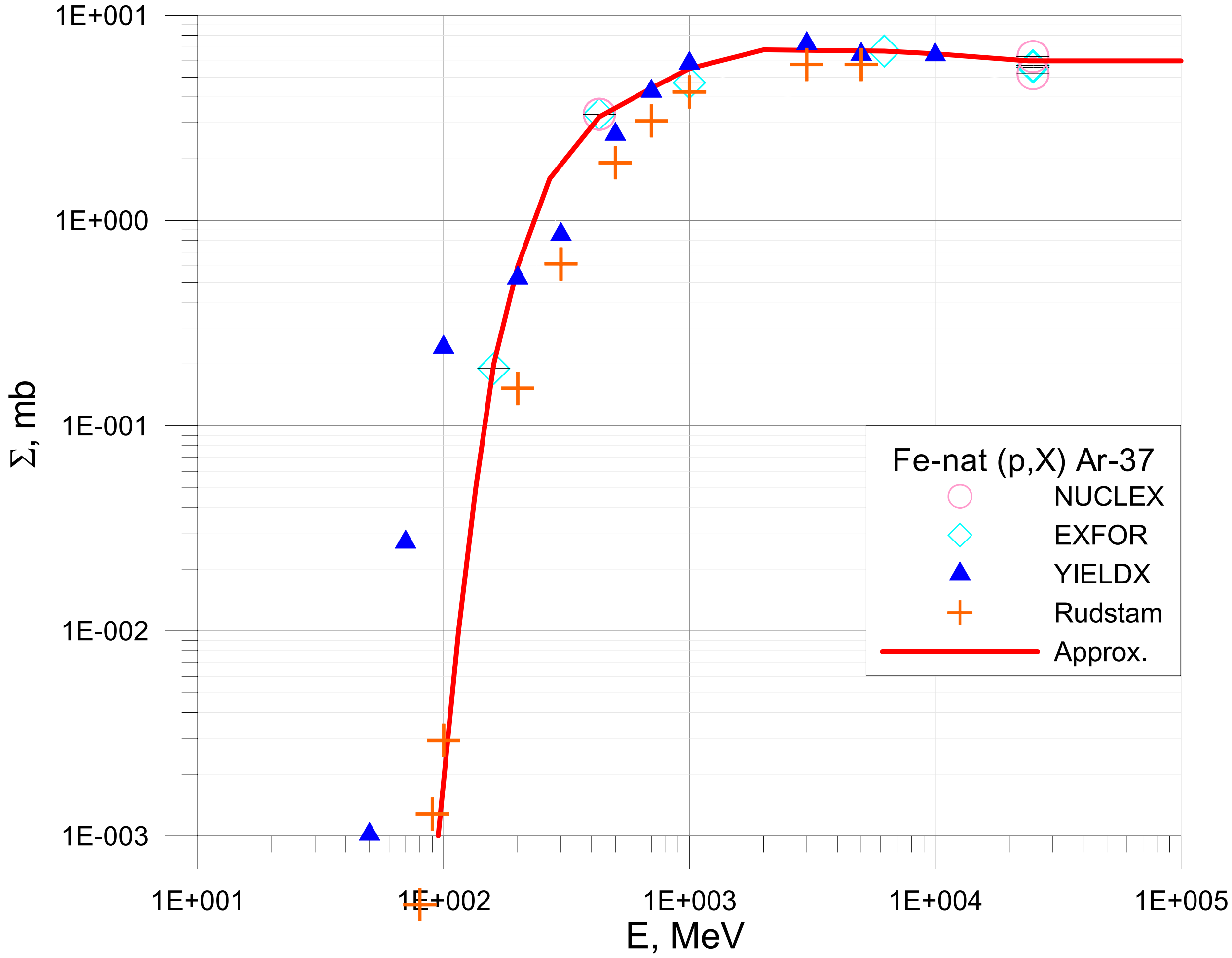
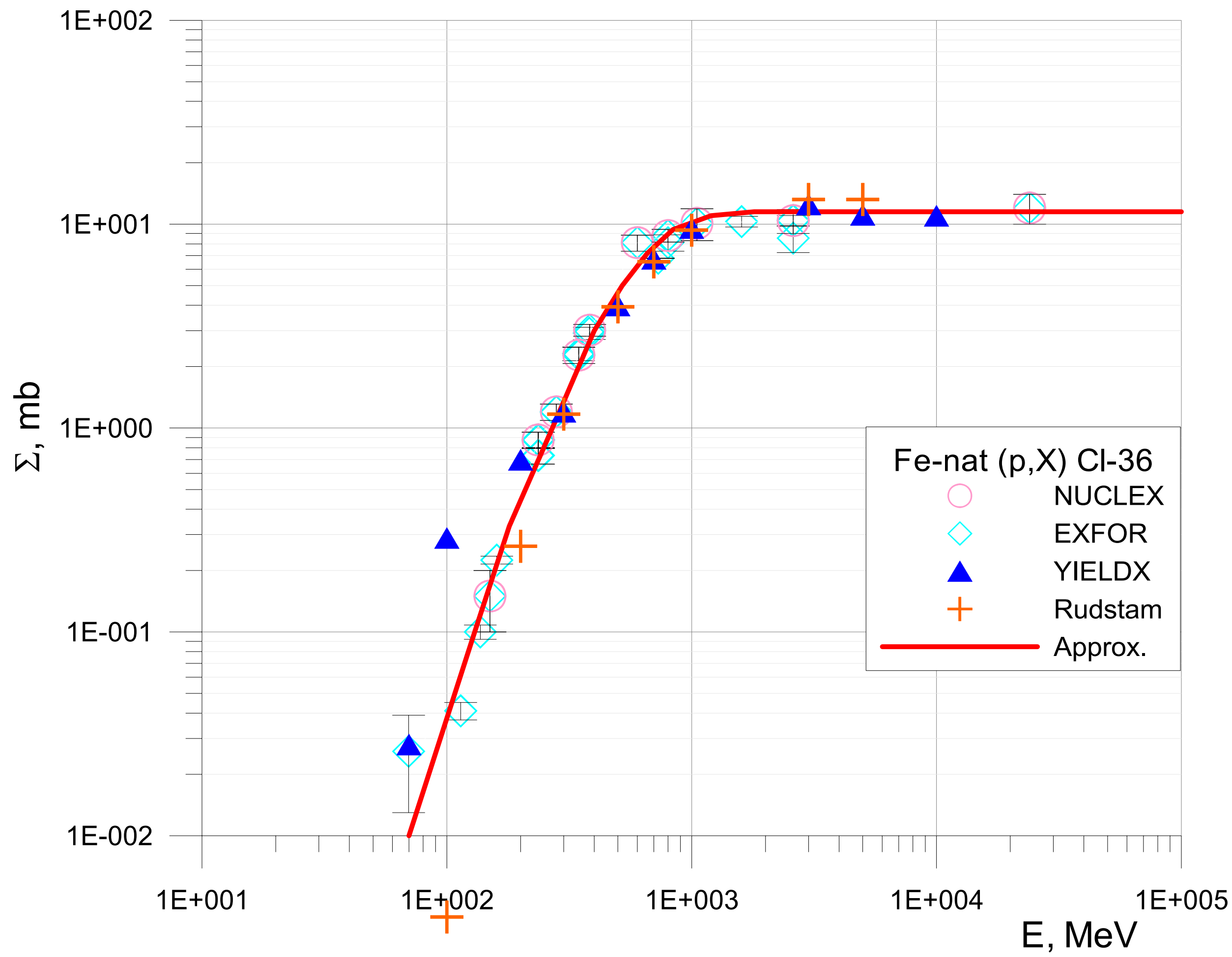
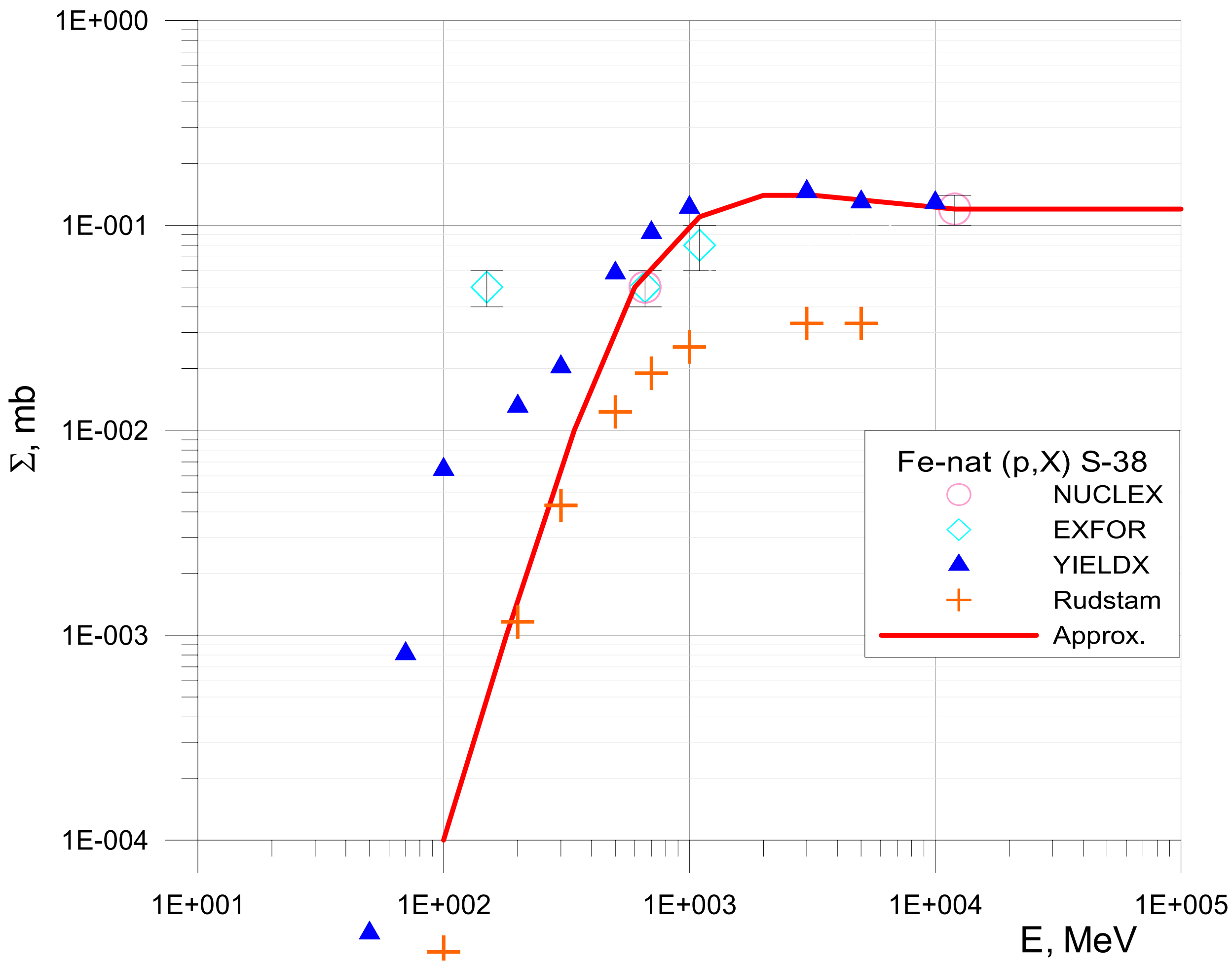


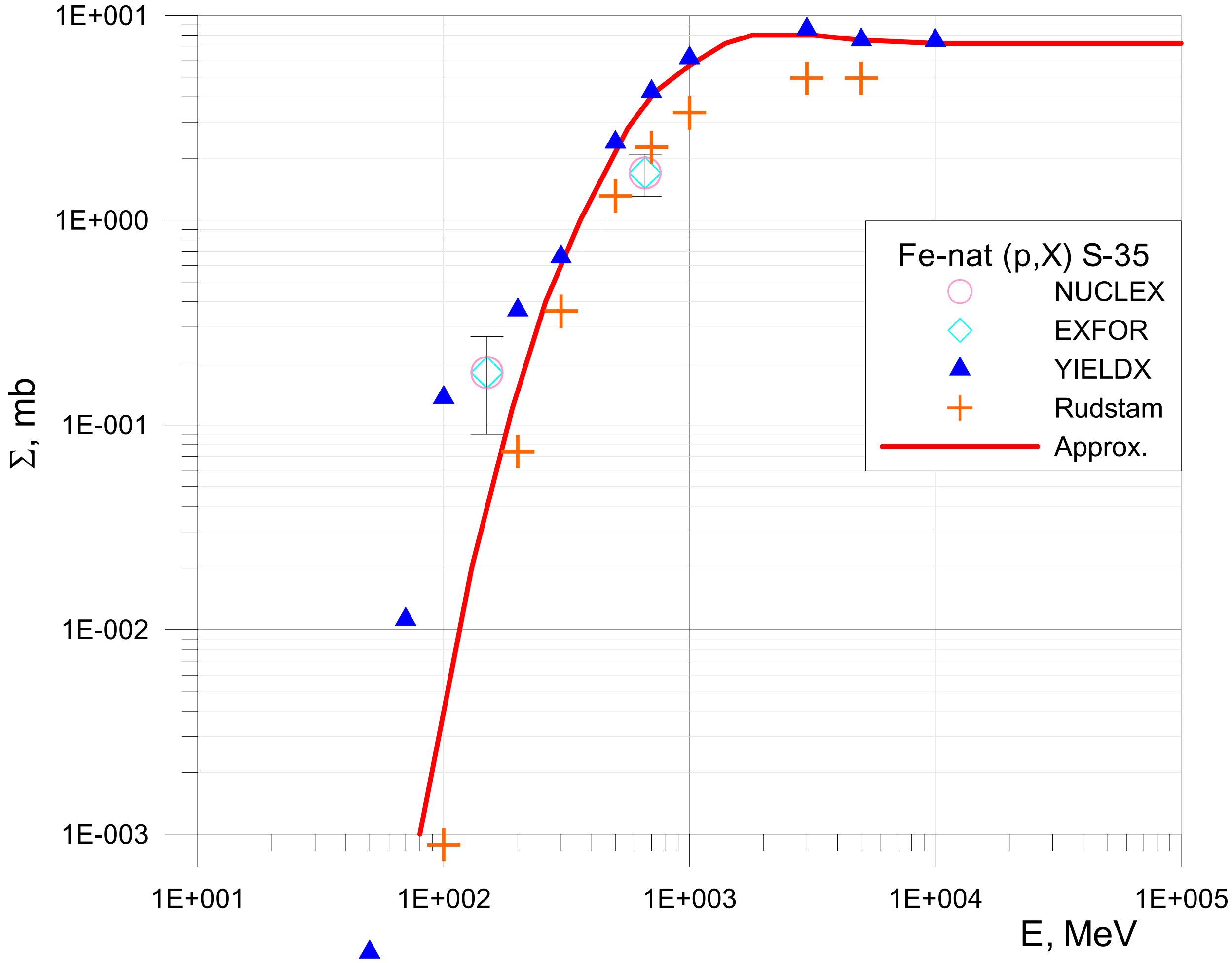
##	E, MeV	Σ, mb
1	42	0.000
2	95	0.001
3	115	0.01
4	135	0.05
5	160	0.20
6	200	0.60
7	270	1.60
8	430	3.2
9	720	4.5
10	1000	5.5
11	2000	6.8
12	6200	6.7
13	10000	6.5
14	24000	6.0
15	100000	6.0
16		
17		
18		



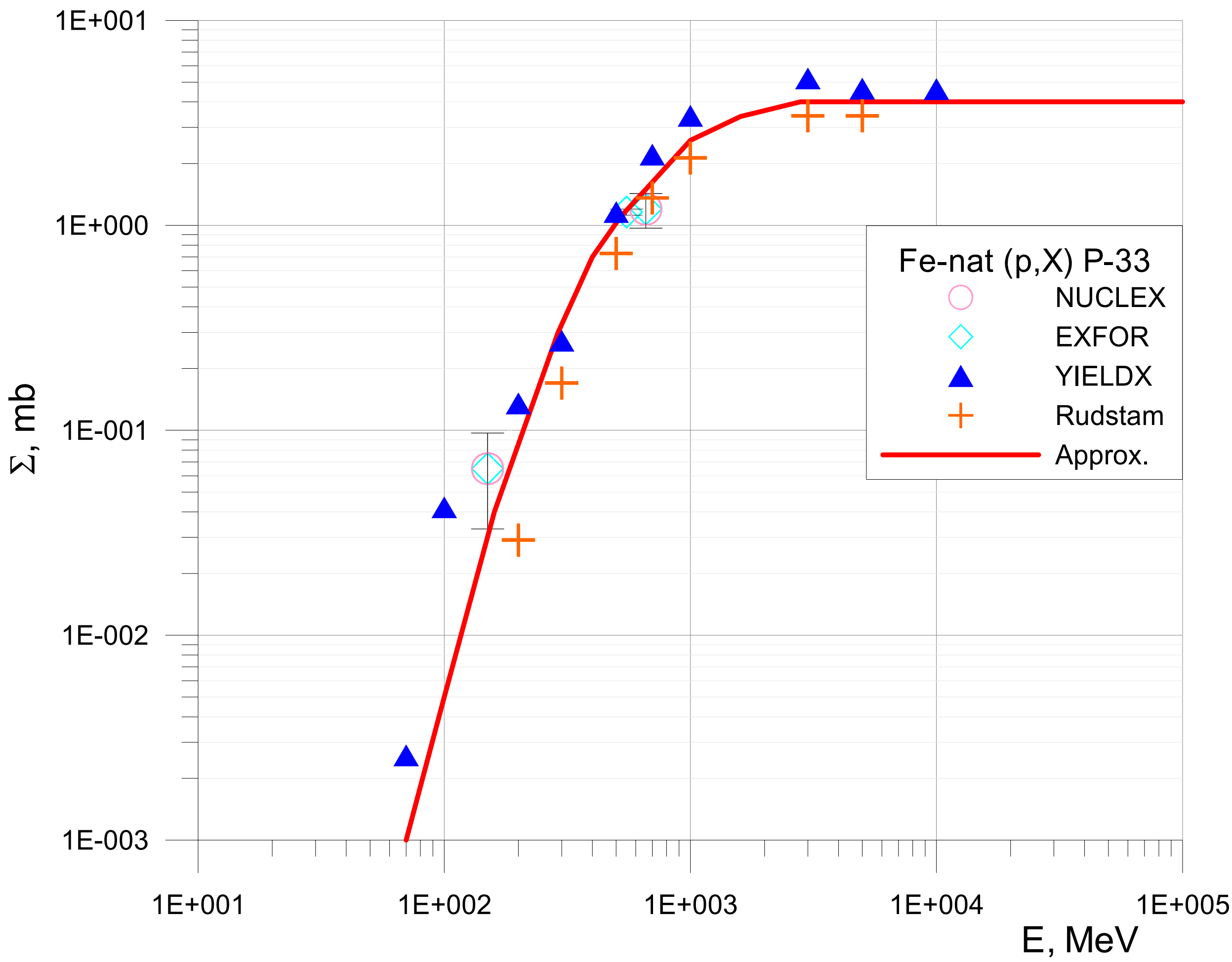
##	E, MeV	Σ, mb
1	44.8	0.00
2	70	0.01
3	130	0.10
4	180	0.33
5	270	1.00
6	400	3.00
7	520	5.00
8	660	7.20
9	840	9.40
10	1200	11.0
11	1800	11.5
12	3600	11.5
13	24000	11.5
14	100000	11.5
15		
16		
17		
18		



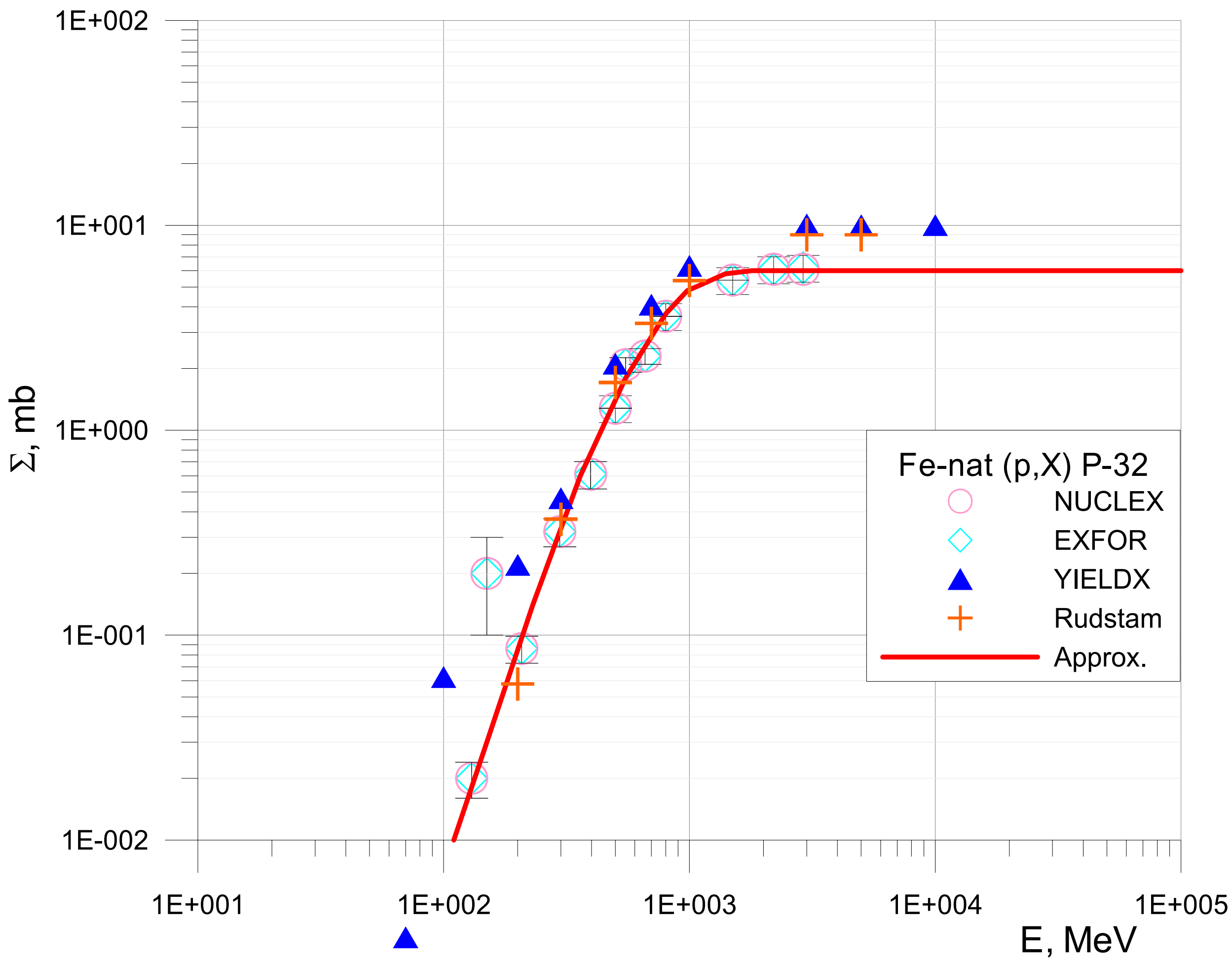
##	E, MeV	Σ, mb
1	48.24	0.0000
2	100	0.0001
3	180	0.001
4	340	0.01
5	600	0.05
6	1100	0.11
7	2000	0.14
8	3200	0.14
9	12000	0.12
10	100000	0.12
11		
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	50.6	0.000
2	80	0.001
3	130	0.02
4	190	0.12
5	260	0.4
6	360	1.0
7	560	2.8
8	720	4.2
9	1000	5.7
10	1400	7.3
11	1800	8.0
12	3200	8.0
13	4800	7.6
14	10000	7.3
15	100000	7.3
16		
17		
18		



##	E, MeV	Σ, mb
1	42	0.000
2	70	0.001
3	100	0.005
4	160	0.04
5	290	0.30
6	400	0.70
7	520	1.10
8	660	1.50
9	1000	2.60
10	1600	3.40
11	2800	4.00
12	100000	4.00
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	52.7	0.00
2	110	0.01
3	150	0.03
4	230	0.14
5	360	0.60
6	550	1.80
7	800	3.70
8	980	4.80
9	1100	5.10
10	1400	5.80
11	1800	6.00
12	4000	6.00
13	100000	6.00
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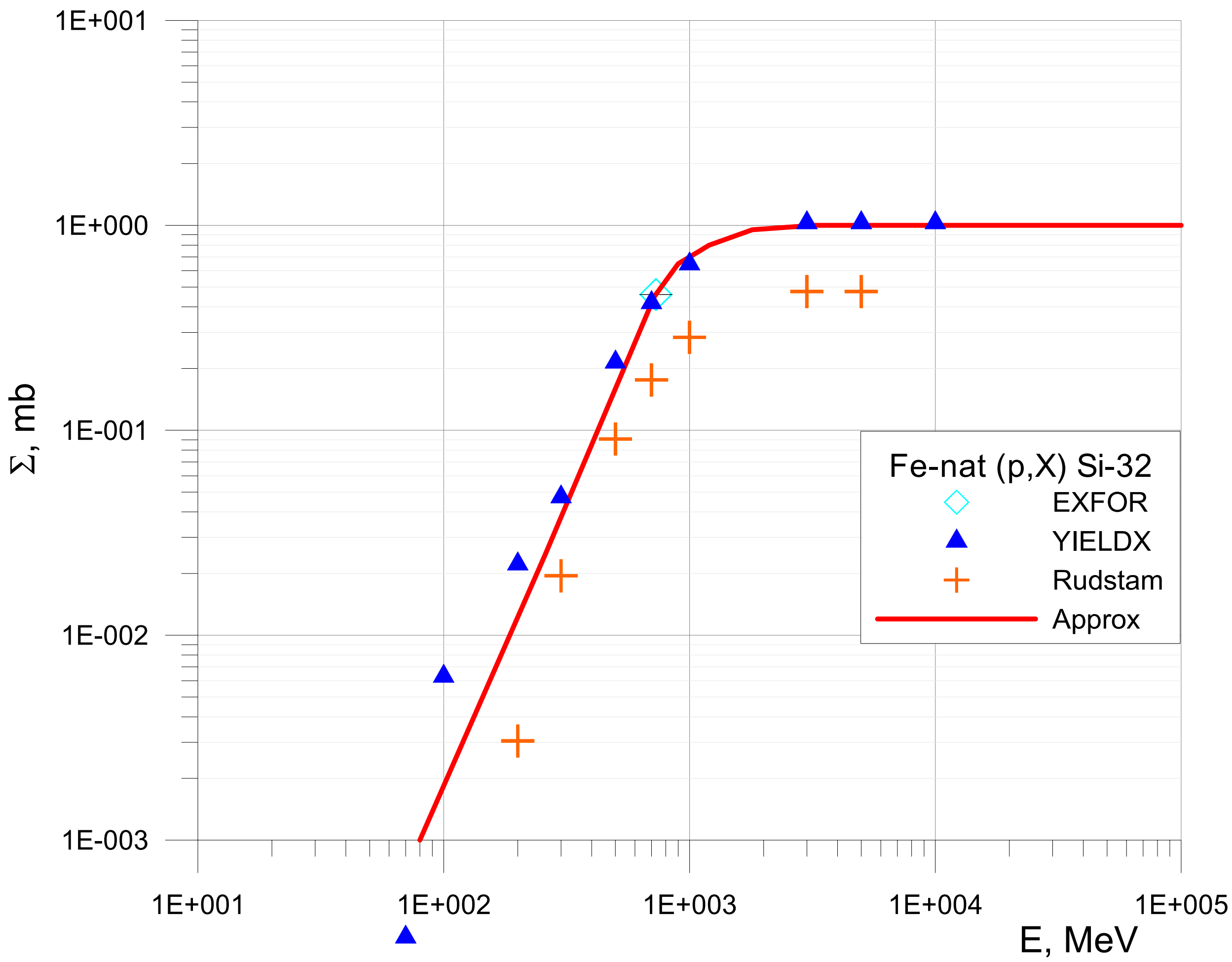
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	80	0.001
2	260	0.025
3	720	0.45
4	900	0.65
5	1100	0.75
6	1200	0.80
7	1800	0.95
8	3200	1.00
9	100000	1.00
10		
11		
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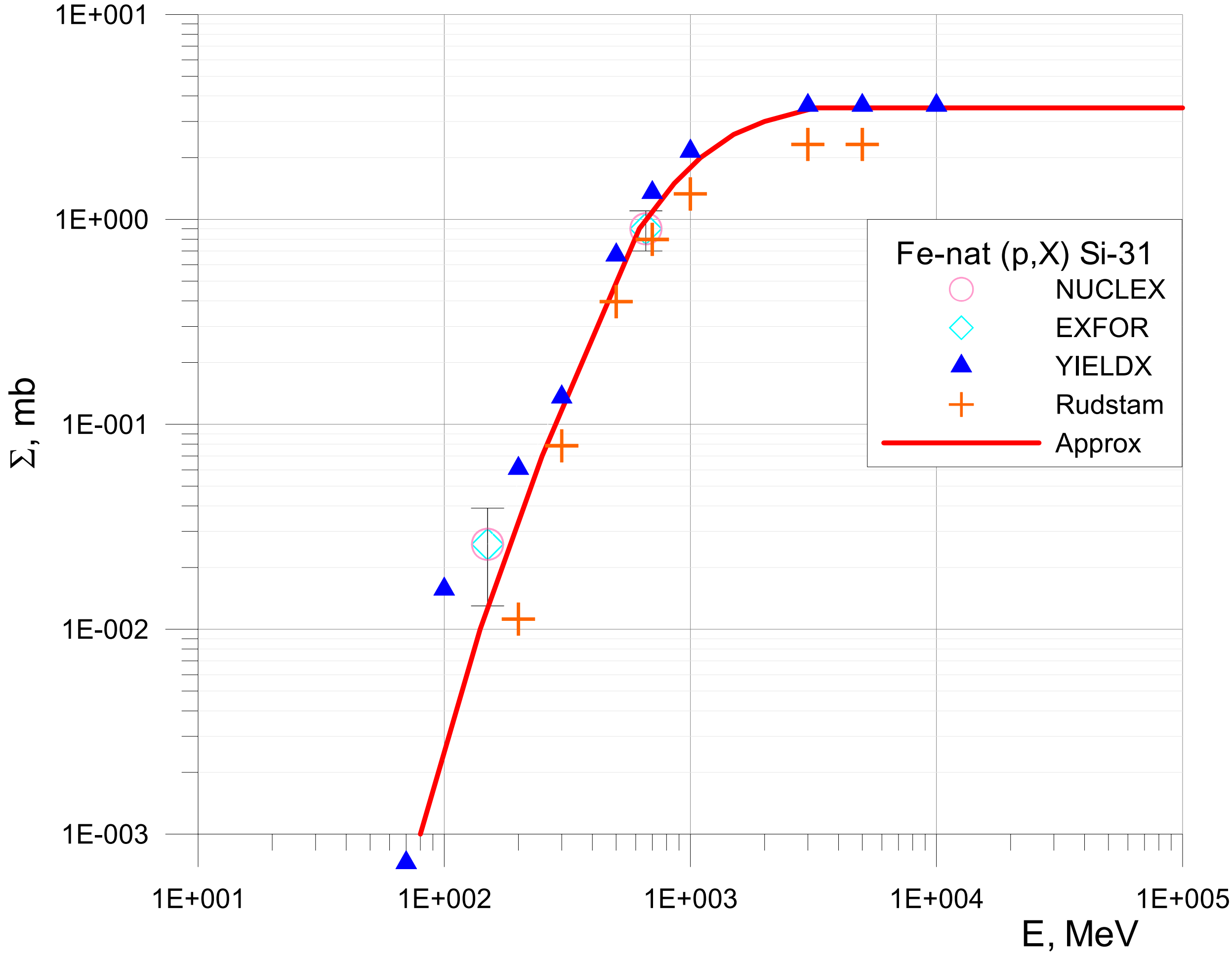
17		
18		



##	E, MeV	Σ, mb
1	80	0.001
2	140	0.010
3	250	0.07
4	620	0.90
5	860	1.50
6	1100	2.00
7	1500	2.60
8	2000	3.00
9	3200	3.50
10	100000	3.50
11		
12		
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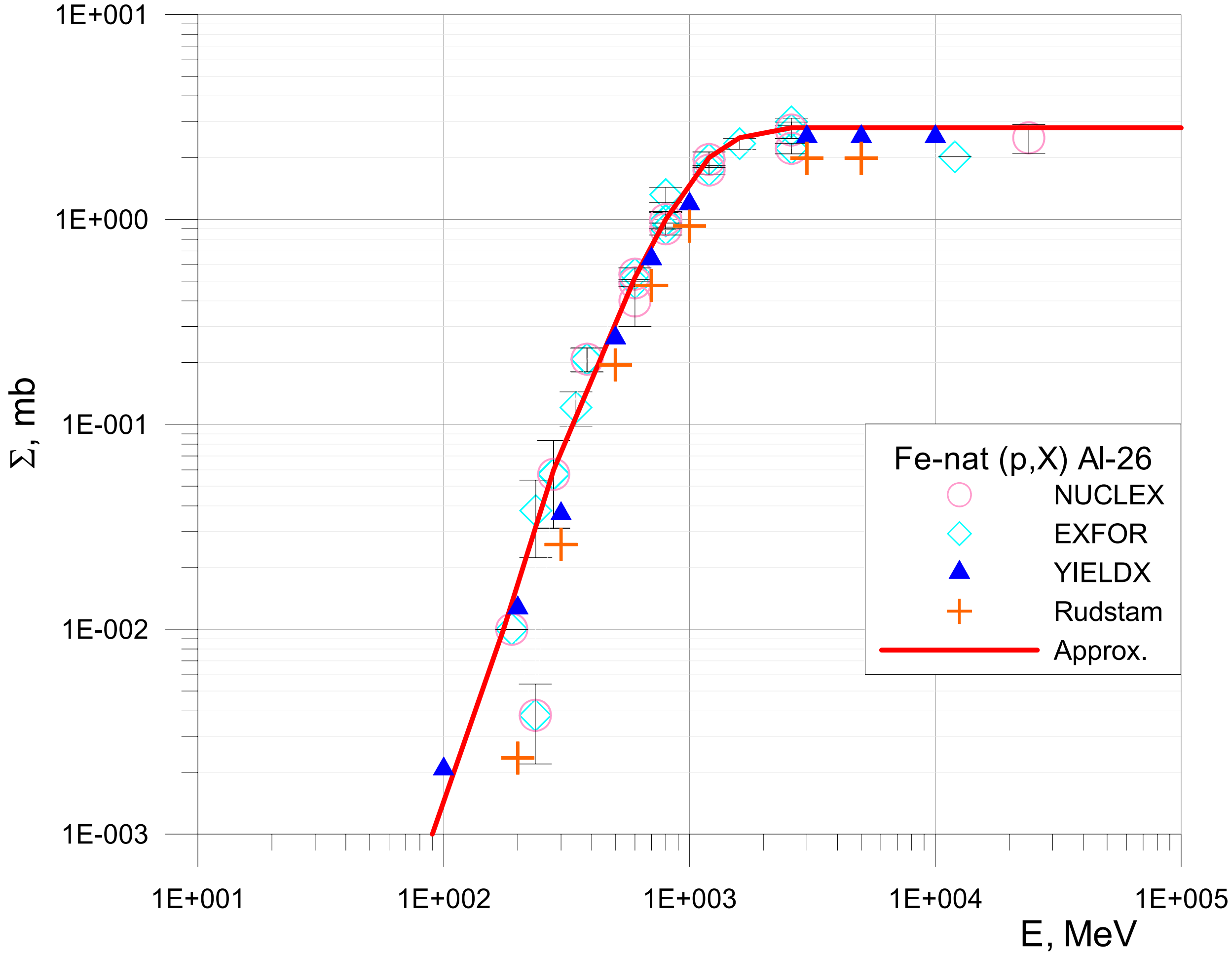
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	90	0.001
2	175	0.010
3	280	0.06
4	600	0.52
5	800	1.00
6	1200	2.00
7	1600	2.50
8	2600	2.80
9	24000	2.80
10	100000	2.80
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12		
13		
14		
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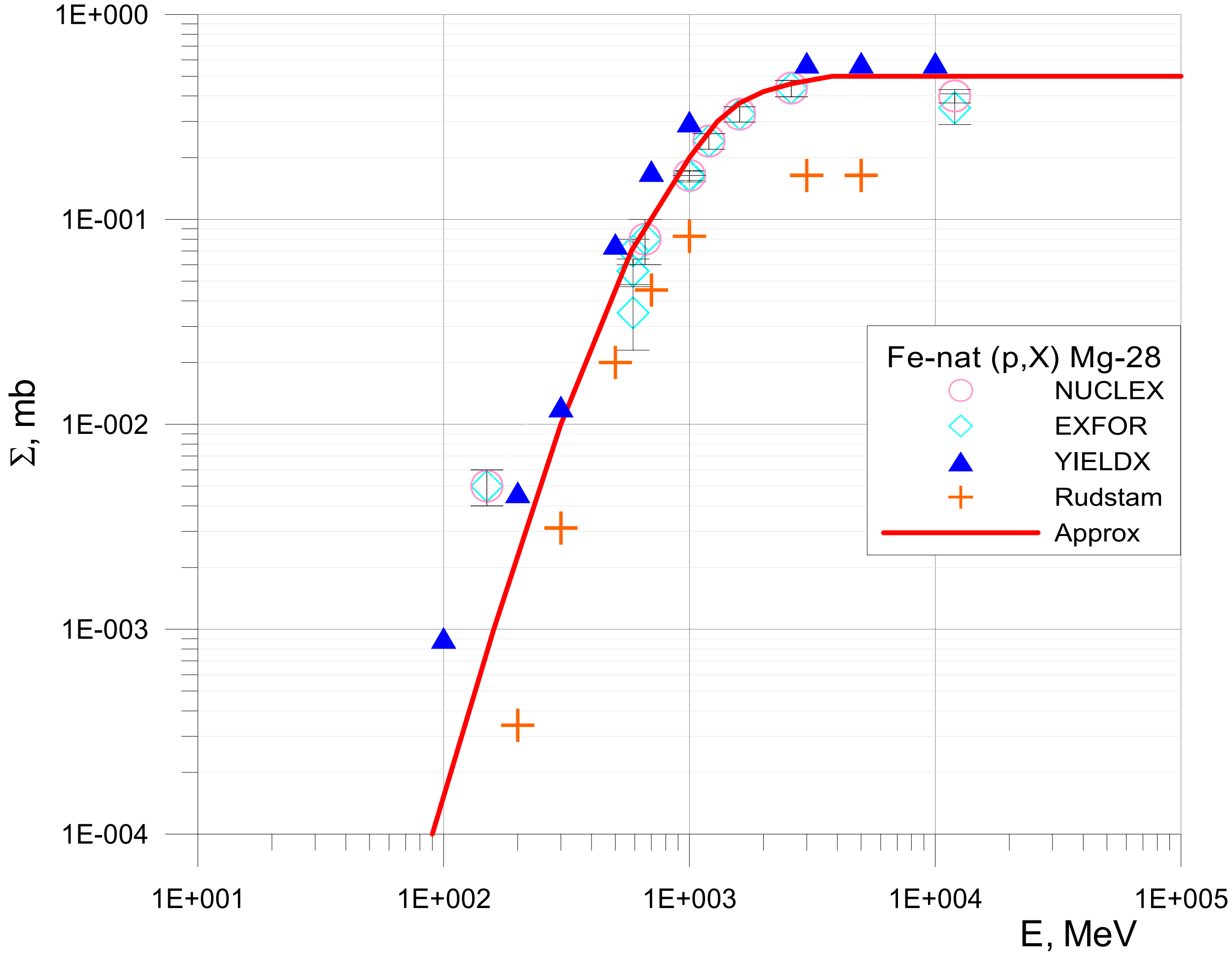
17		
18		



##	E, MeV	Σ, mb
1	90	0.0001
2	160	0.001
3	300	0.01
4	580	0.07
5	1000	0.20
6	1300	0.30
7	1600	0.37
8	2000	0.42
9	2600	0.46
10	3800	0.50
11	100000	0.50
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13		
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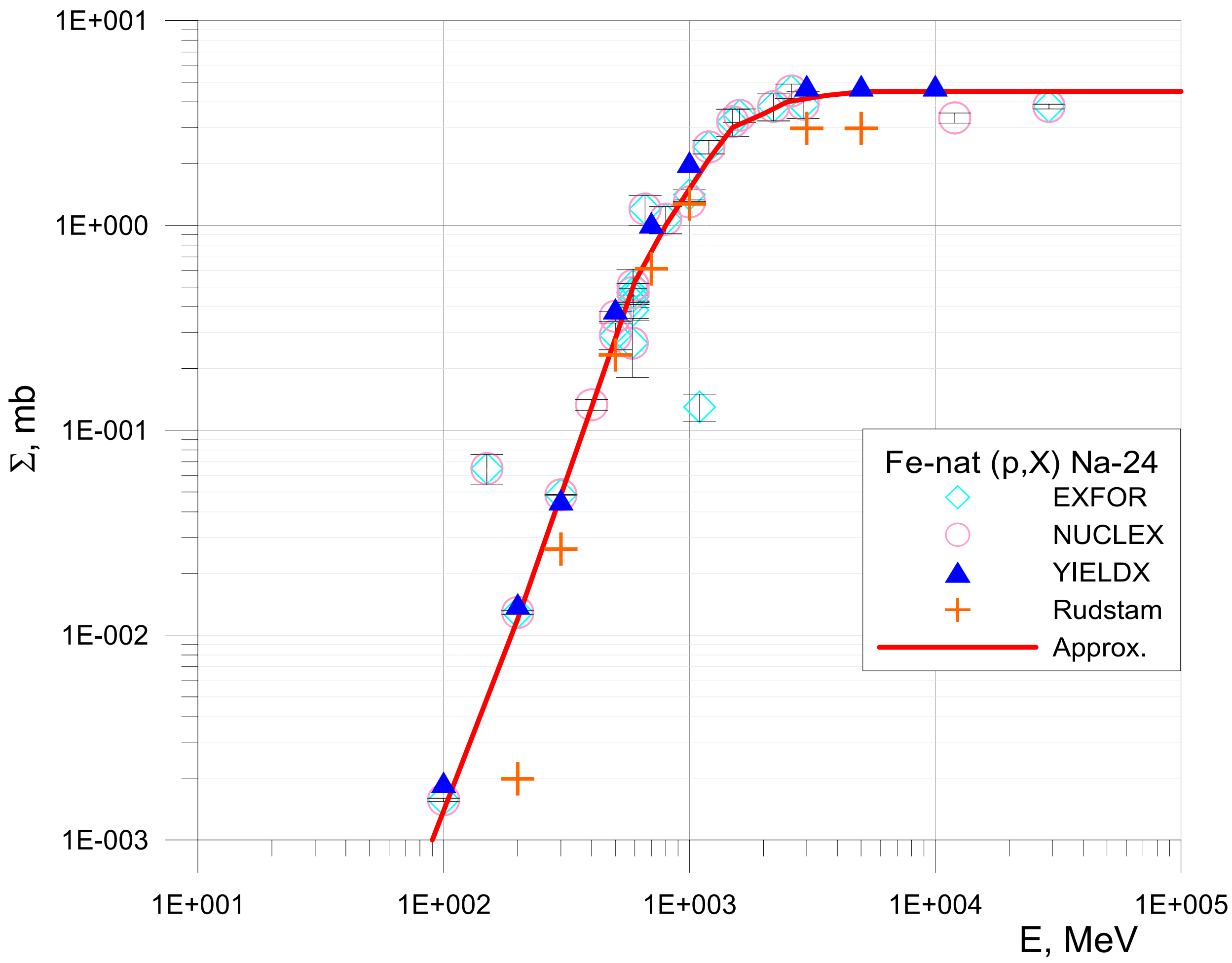
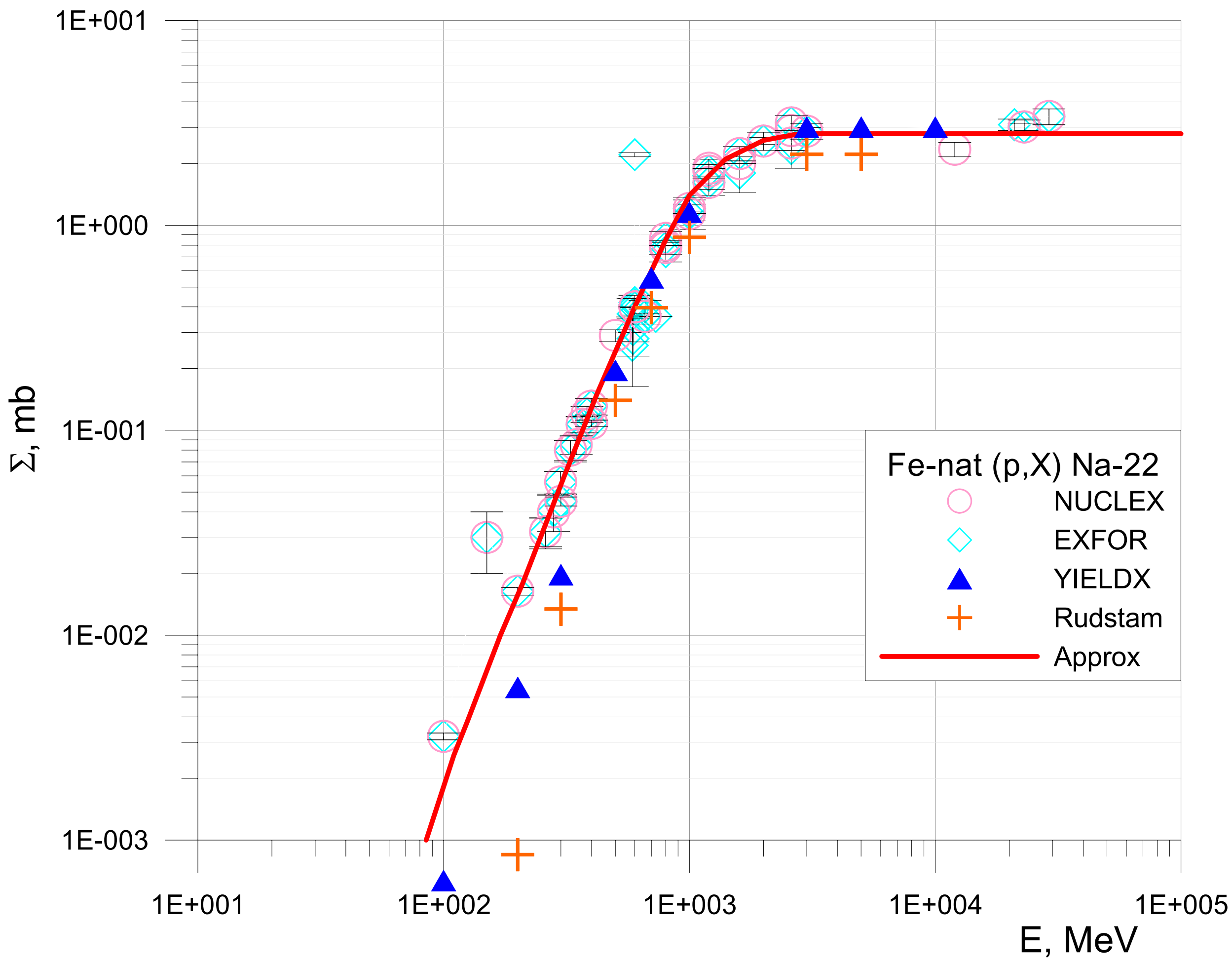
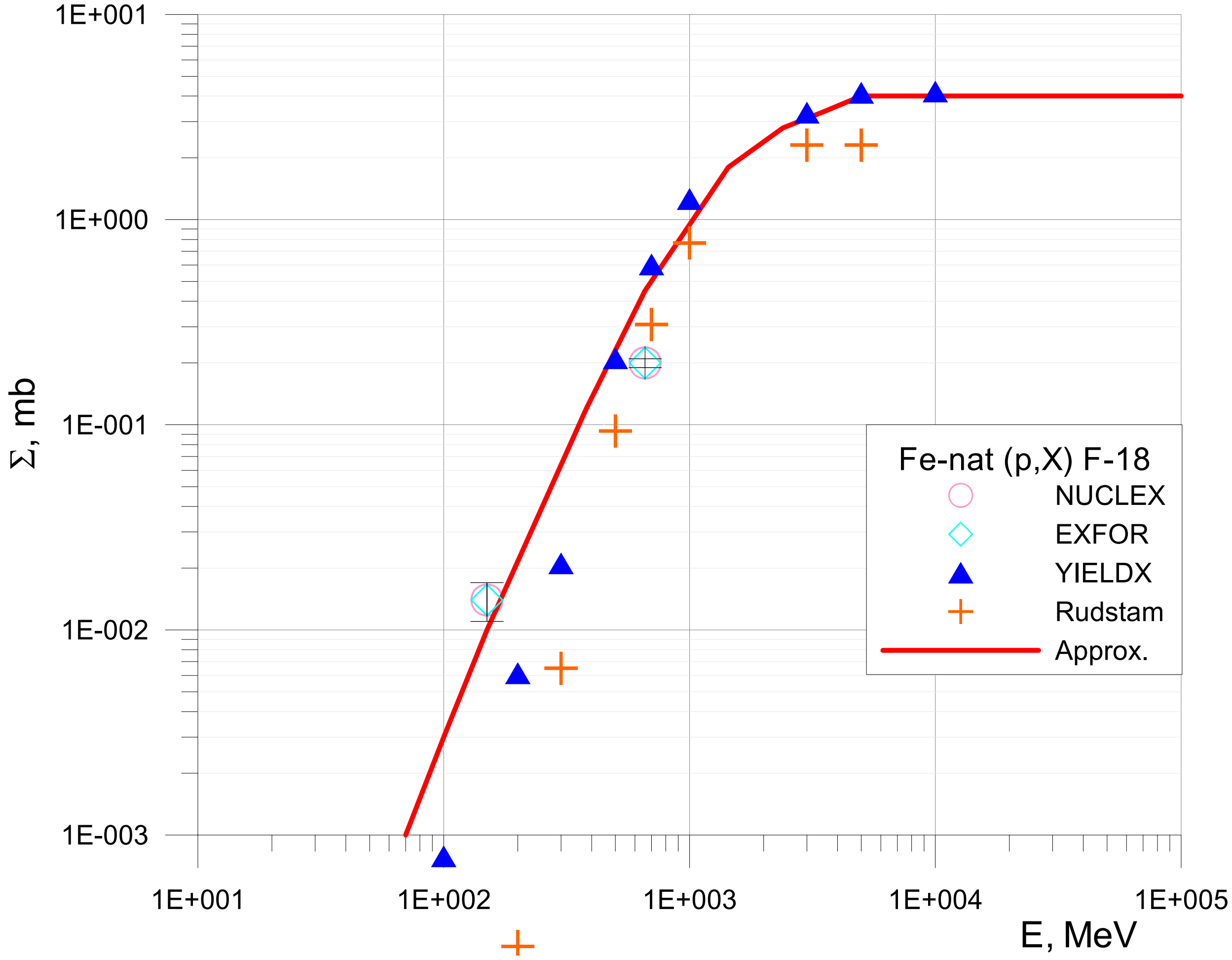
17		
18		



##	E, MeV	Σ, mb
1	90	0.001
2	200	0.012
3	400	0.13
4	600	0.53
5	800	1.00
6	1200	2.10
7	1500	3.00
8	2000	3.50
9	2500	4.00
10	3600	4.30
11	5200	4.50
12	100000	4.50
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	85	0.001
2	110	0.003
3	125	0.004
4	170	0.010
5	210	0.018
6	310	0.060
7	420	0.15
8	600	0.40
9	800	0.85
10	1000	1.40
11	1400	2.10
12	2000	2.60
13	2800	2.80
14	100000	2.80
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	70	0.001
2	100	0.003
3	150	0.010
4	380	0.12
5	660	0.45
6	1437	1.80
7	2400	2.80
8	3600	3.40
9	5000	4.00
10	100000	4.00
11		
12		
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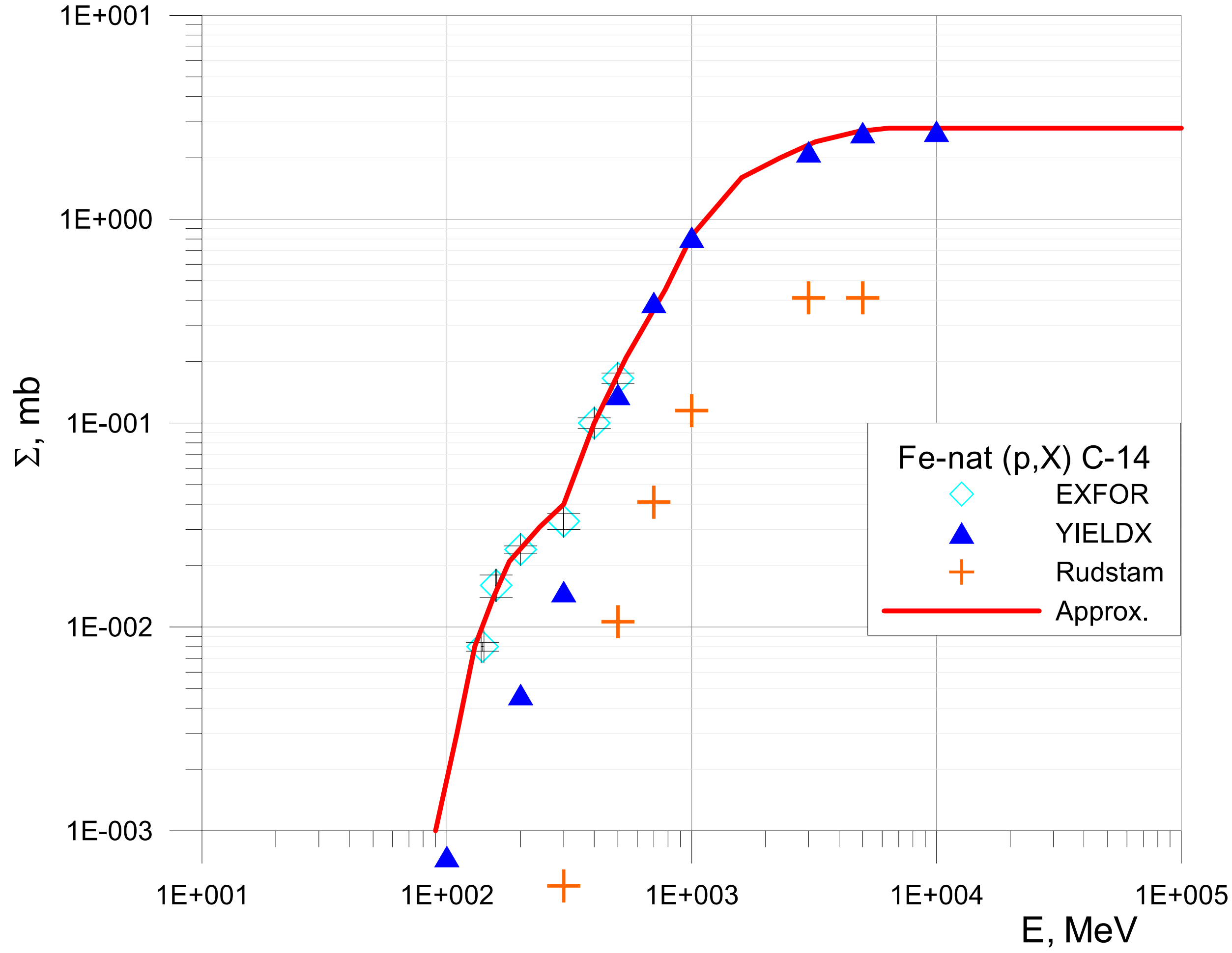
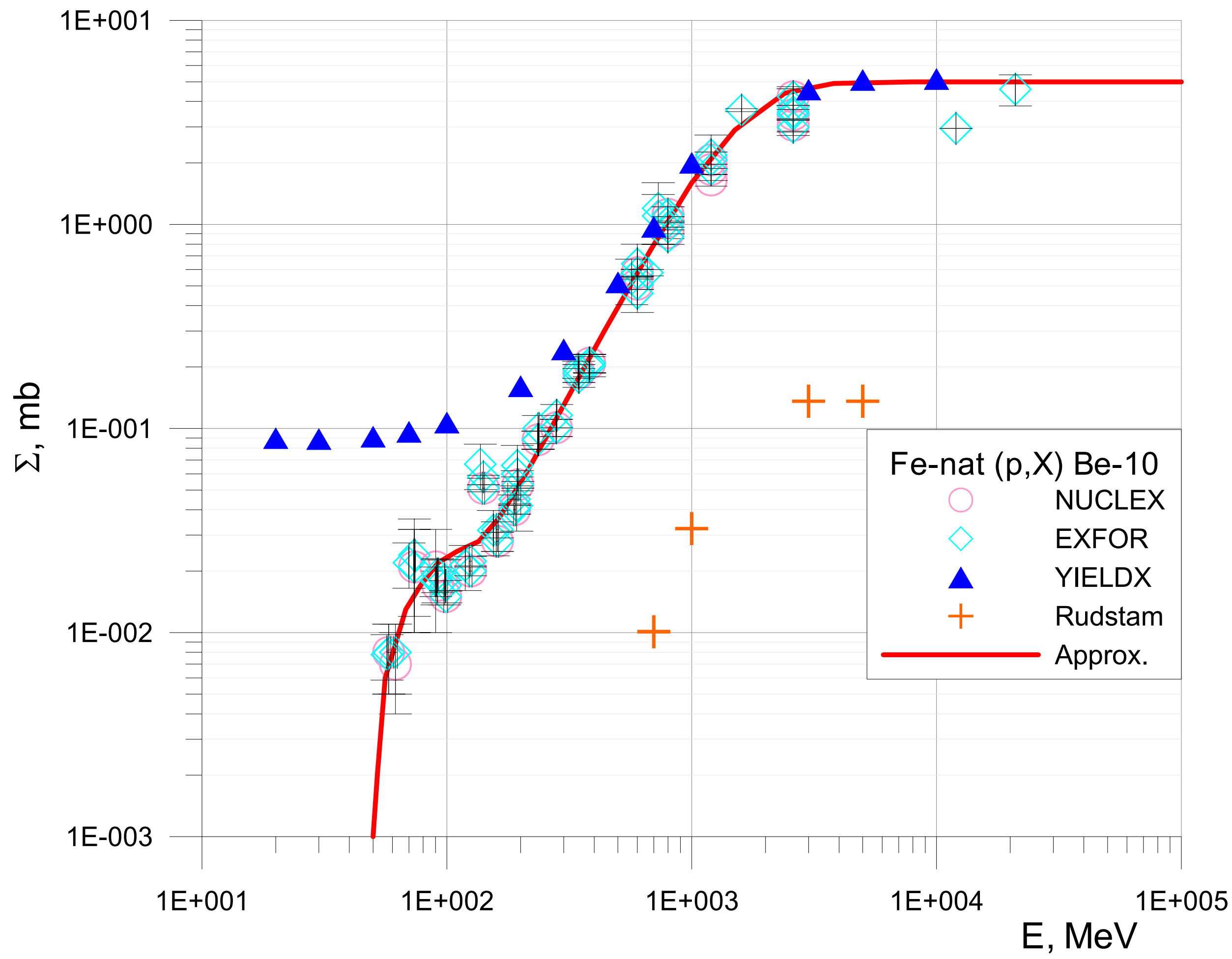
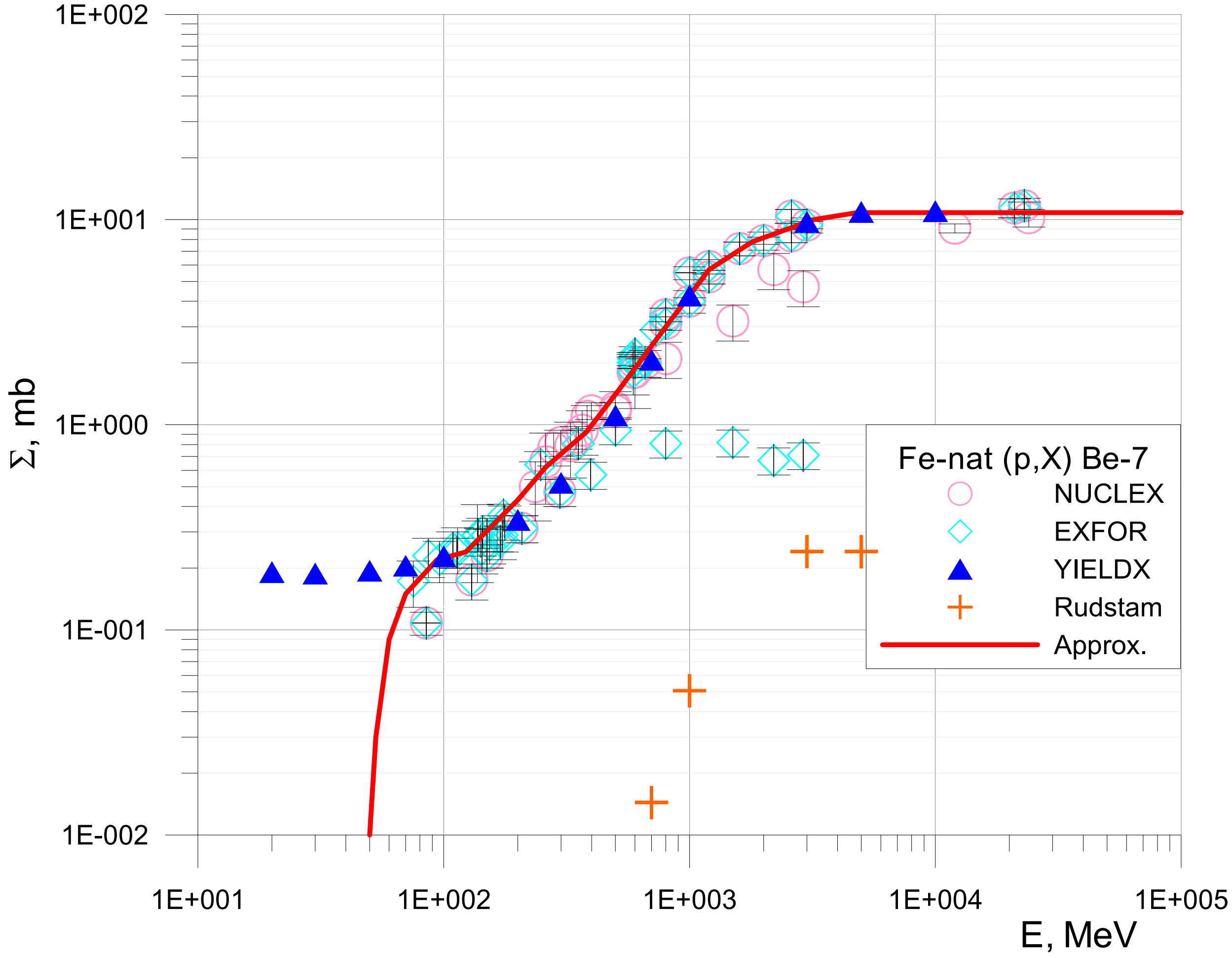


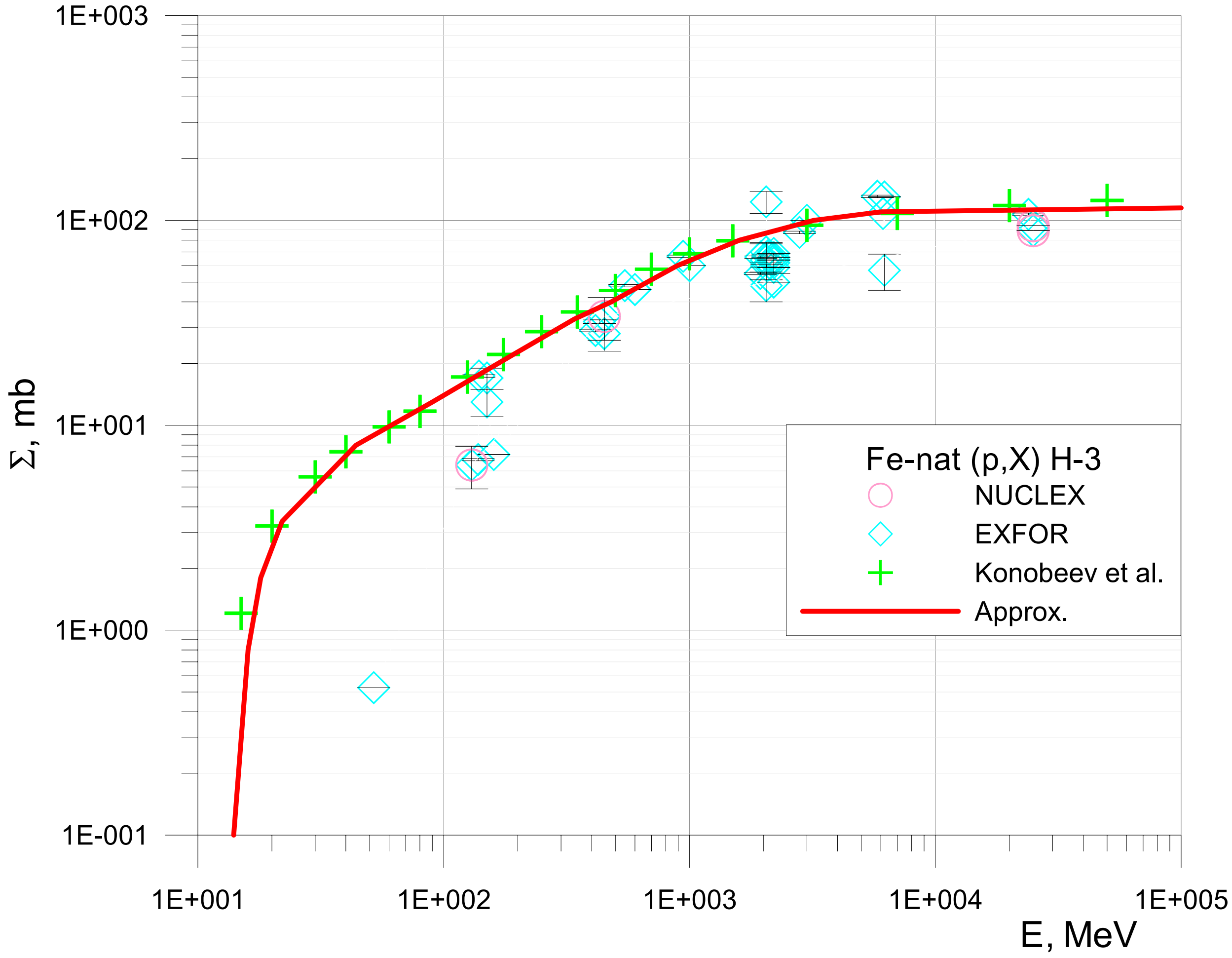
##	E, MeV	Σ, mb
1	90	0.001
2	110	0.003
3	130	0.008
4	155	0.014
5	180	0.021
6	240	0.031
7	300	0.040
8	400	0.10
9	540	0.21
10	780	0.45
11	1000	0.83
12	1600	1.60
13	2300	2.00
14	3200	2.40
15	4800	2.70
16	6400	2.80
17	100000	2.80
18		



##	E, MeV	Σ, mb
1	50	0.001
2	52	0.002
3	56	0.006
4	62	0.009
5	68	0.013
6	78	0.017
7	92	0.022
8	110	0.025
9	135	0.028
10	165	0.037
11	220	0.066
12	440	0.30
13	680	0.75
14	1000	1.60
15	1500	2.90
16	2400	4.40
17	3800	4.90
18	8000	5.00
19	100000	5.00



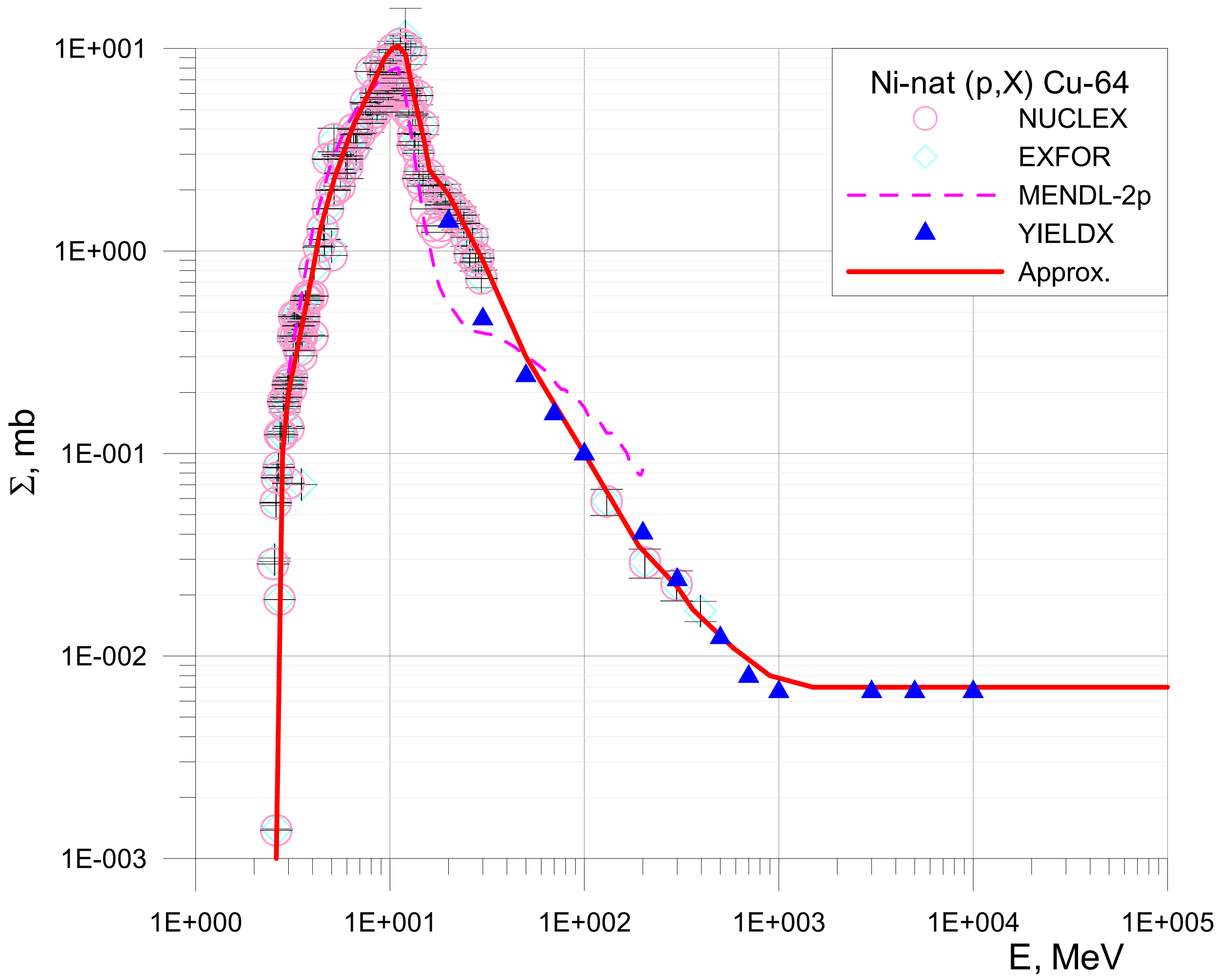
##	E, MeV	Σ, mb
1	50	0.01
2	53	0.03
3	60	0.09
4	70	0.15
5	94	0.22
6	123	0.24
7	200	0.43
8	260	0.62
9	380	0.92
10	520	1.50
11	800	3.00
12	1200	5.70
13	1800	7.80
14	3200	10.0
15	4800	10.8
16	7400	10.8
17	100000	10.8
18	100000	10.8



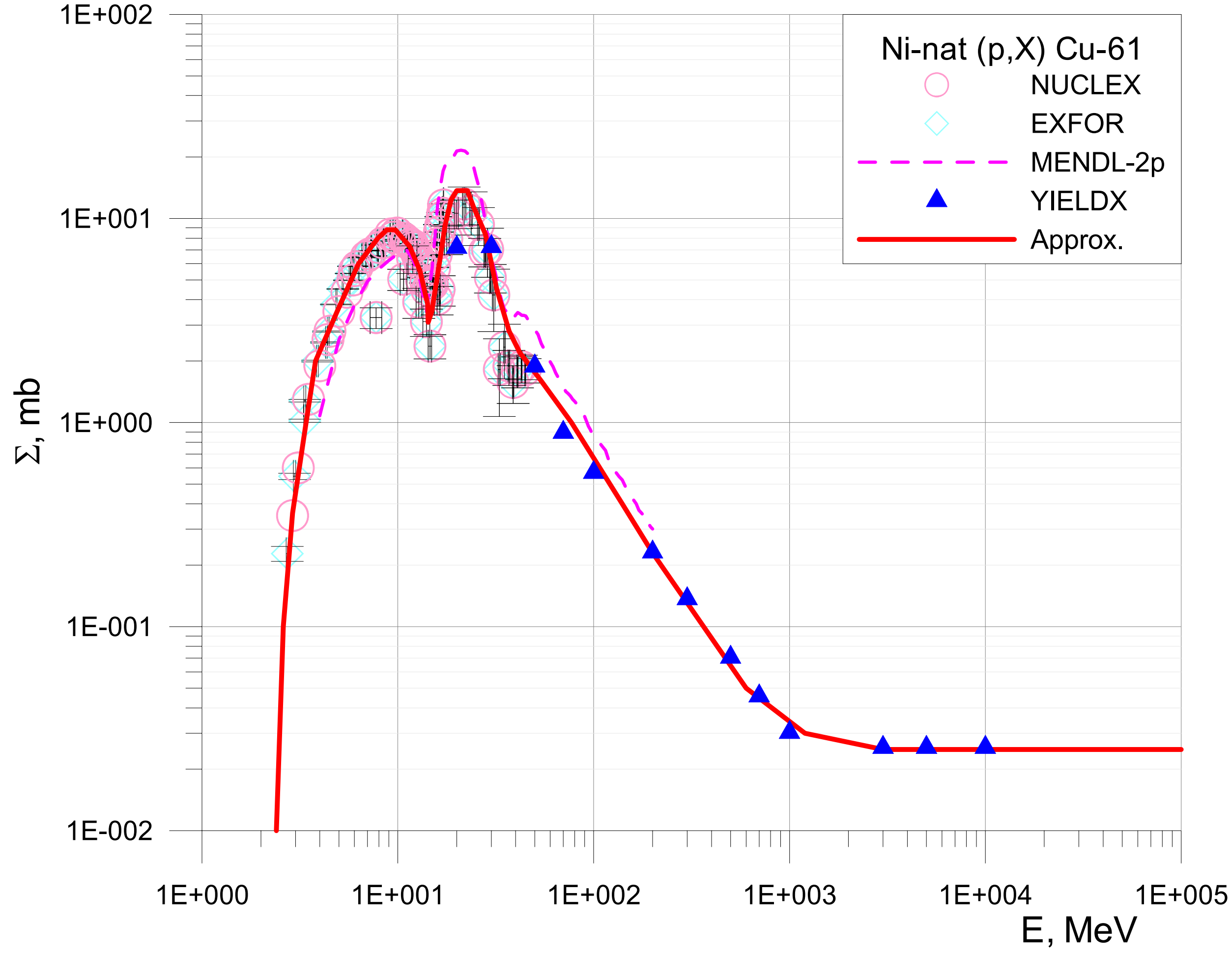
##	E, MeV	Σ, mb
1	9.4	0.0
2	14	0.1
3	16	0.8
4	18	1.8
5	22	3.4
6	44	8.0
7	90	13
8	190	22
9	340	33
10	480	40
11	890	60
12	1600	80
13	3200	100
14	6000	110
15	100000	115
16		
17		
18		

Summary of experimental and calculated cross-section data used for nickel

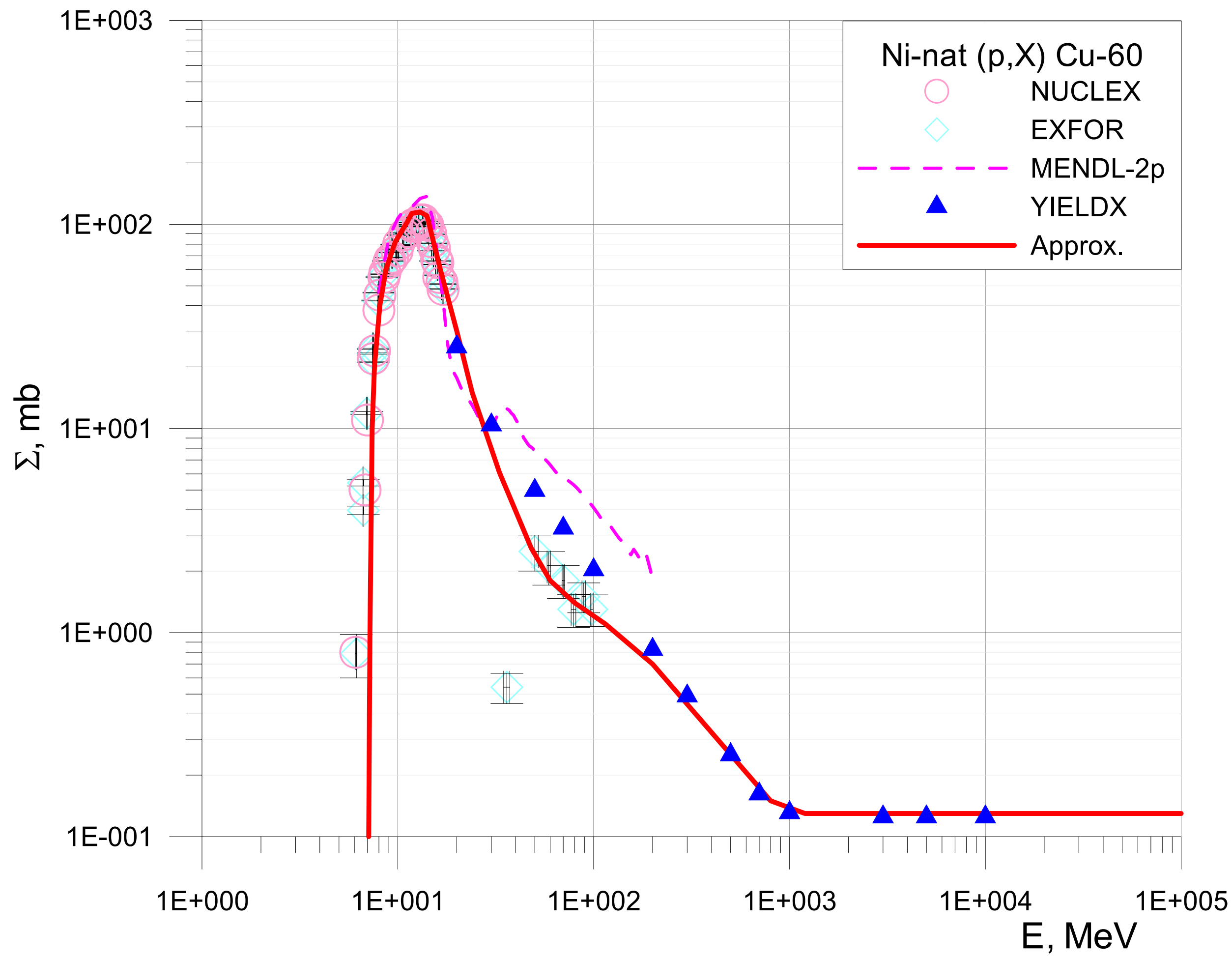
Nuclide	Half-life			Decay Mode	Source				Comment
					Medical	Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-				x	
Be-7	53.22	D	0.06	EC			x	x	
Be-10	2E+06	Y	60000	B-			x	x	
C-14	5700	Y	30	B-				x	cum
F-18	109.77	M	0.05	EC					cum
Na-22	2.6019	Y	4E-04	EC			x	x	cum
Na-24	14.959	H	0.001	B-			x	x	cum
Mg-28	20.915	H	0.009	B-			x	x	cum
Al-26	717000	Y	24000	EC			x	x	
Si-31	157.3	M	0.3	B-					cum
Si-32	132	Y	13	B-					cum
P-32	14.262	D	0.014	B-			x	x	
P-33	25.34	D	0.12	B-				x	cum
S-35	87.51	D	0.12	B-					cum
S-38	170.3	M	0.7	B-					cum
Cl-36	301000	Y	2000	B-, EC			x	x	
Ar-37	35.04	D	0.04	EC					cum
Ar-39	269	Y	3	B-			x	x	cum
Ar-41	109.61	M	0.04	B-			x		cum
Ar-42	32.9	Y	1.1	B-				x	cum
K-42	12.36	H	0.012	B-			x	x	
K-43	22.3	H	0.1	B-			x	x	cum
Ca-41	102000	Y	7000	EC				x	cum
Ca-45	162.61	D	0.09	B-					cum
Ca-47	4.536	D	0.003	B-					cum
Sc-43	3.891	H	0.012	EC		x	x	x	cum
Sc-44	3.97	H	0.04	EC		x	x	x	
Sc-44m	58.61	H	0.1	IT, EC		x	x	x	
Sc-46	83.79	D	0.04	B-		x	x	x	
Sc-47	3.3492	D	6E-04	B-		x	x	x	
Sc-48	43.67	H	0.09	B-		x	x	x	
Ti-44	60	Y	1.1	EC		x		x	cum
Ti-45	184.8	M	0.5	EC		x			cum
V-48	15.974	D	0.003	EC		x	x	x	
V-49	330	D	15	EC		x		x	cum
Cr-48	21.56	H	0.03	EC		x	x	x	cum
Cr-51	27.703	D	0.002	EC		x	x	x	cum
Mn-52g	5.591	D	0.003	EC		x	x	x	cum
Mn-53	4E+06	Y	40000	EC		x		x	cum
Mn-54	312.12	D	0.06	EC		x	x	x	
Mn-56	2.5789	H	1E-04	B-		x	x	x	cum
Fe-52	8.275	H	0.008	EC		x	x	x	
Fe-55	2.737	Y	0.011	EC		x	x	x	
Fe-59	44.495	D	0.009	B-		x	x	x	cum
Co-55	17.53	H	0.03	EC		x	x	x	cum
Co-56	77.233	D	0.027	EC		x	x	x	
Co-57	271.74	D	0.06	EC		x	x	x	cum
Co-58g	70.86	D	0.06	EC		x	x	x	cum
Co-60	1925.3	D	0.3	B-		x	x	x	
Co-61	1.65	H	0.005	B-		x		x	cum
Ni-56	6.075	D	0.01	EC		x	x	x	
Ni-57	35.6	H	0.06	EC	x	x	x	x	cum
Ni-59	76000	Y	5000	EC		x			cum
Ni-63	100.1	Y	2	B-		x	x		cum
Cu-60	23.7	M	0.4	EC		x	x	x	
Cu-61	3.333	H	0.005	EC		x	x	x	
Cu-64	12.7	H	0.002	EC, B-		x	x	x	



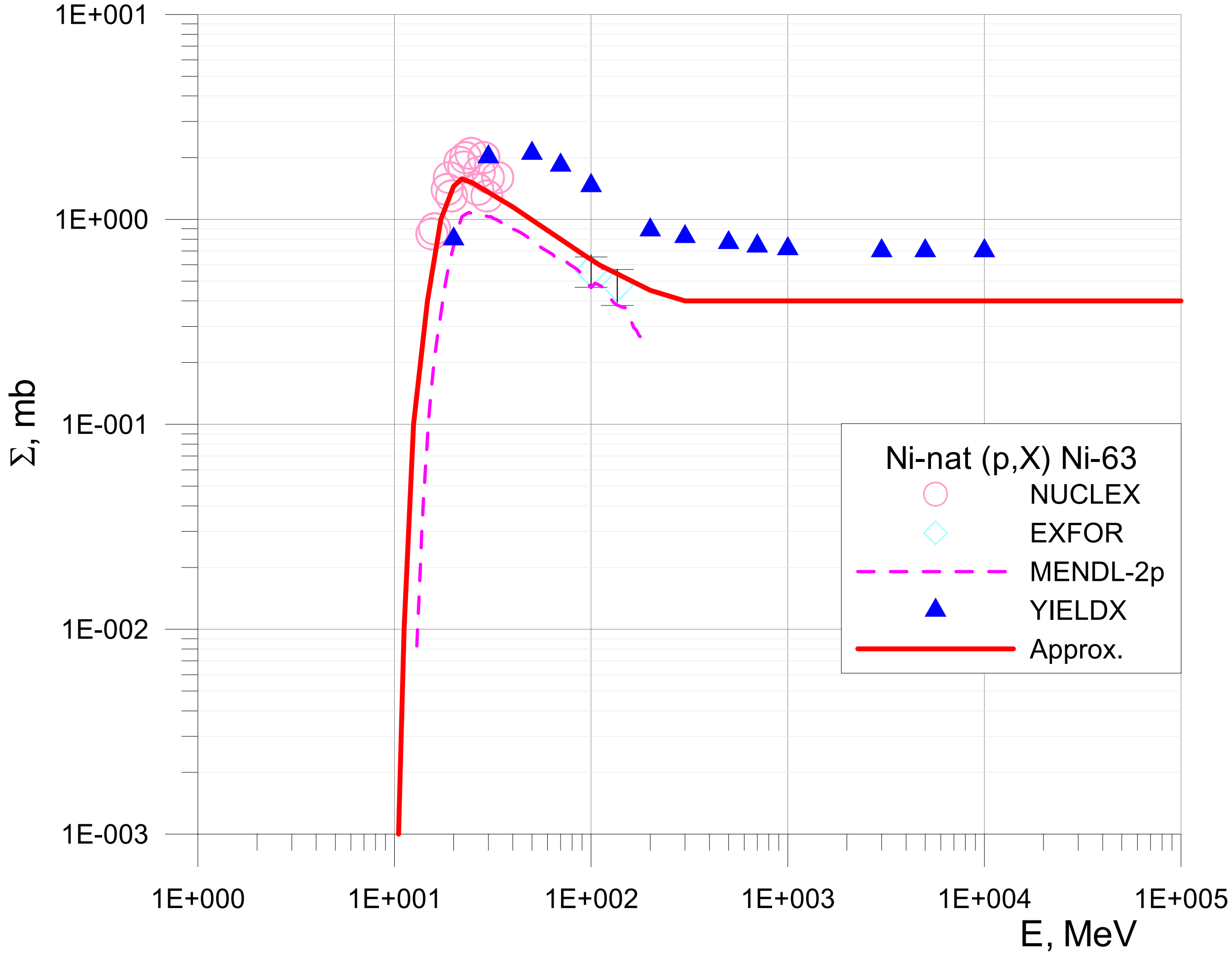
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	2.50	0.000	19	30	0.90
2	2.60	0.001	20	50	0.30
3	2.7	0.01	21	100	0.10
4	2.8	0.1	22	190	0.035
5	3.0	0.2	23	300	0.022
6	3.8	0.6	24	360	0.017
7	4.4	1.3	25	580	0.011
8	5.2	2.3	26	900	0.008
9	6.5	4.2	27	1500	0.007
10	8.3	6.9	28	100000	0.007
11	9.4	9.0			
12	10.3	10.0			
13	11	10.3			
14	12	9.4			
15	13	6.4			
16	15	3.5			
17	16	2.5			
18	20	1.9			



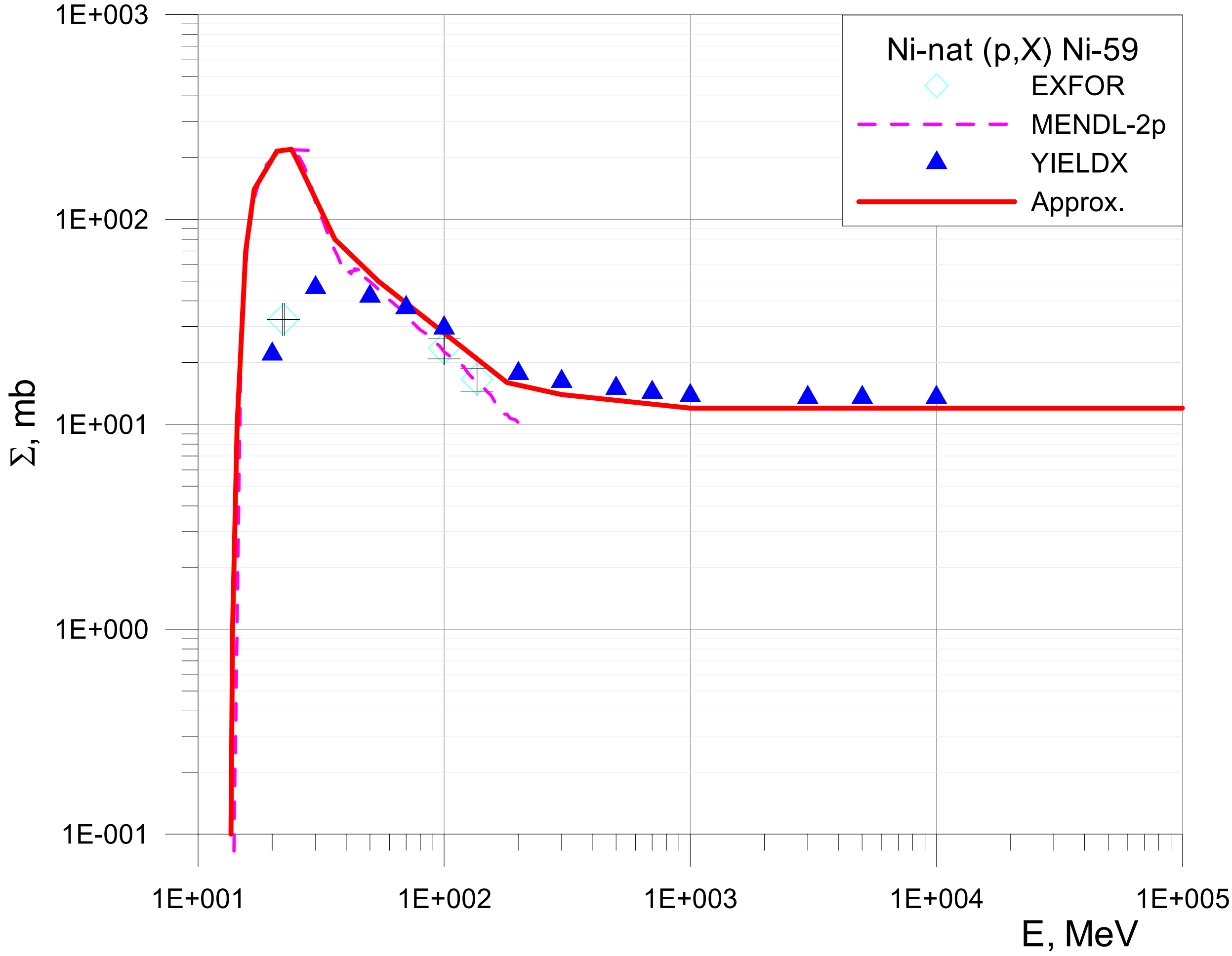
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	2.4	0.01	19	20.0	13.70
2	2.6	0.10	20	22.7	13.70
3	2.9	0.36	21	24.3	11.40
4	3.4	1.00	22	28	8.40
5	3.8	2.00	23	32	4.50
6	4.9	3.50	24	37	2.80
7	6.3	6.00	25	42	2.20
8	7.9	8.00	26	54	1.60
9	8.8	8.80	27	77	1.00
10	9.7	8.80	28	140	0.40
11	11.5	7.30	29	200	0.23
12	13.0	5.50	30	600	0.05
13	14.2	3.80	31	1200	0.03
14	14.3	3.10	32	3000	0.025
15	14.9	3.50	33	100000	0.025
16	16.2	5.80			
17	17.4	9.20			
18	18.7	12.3			



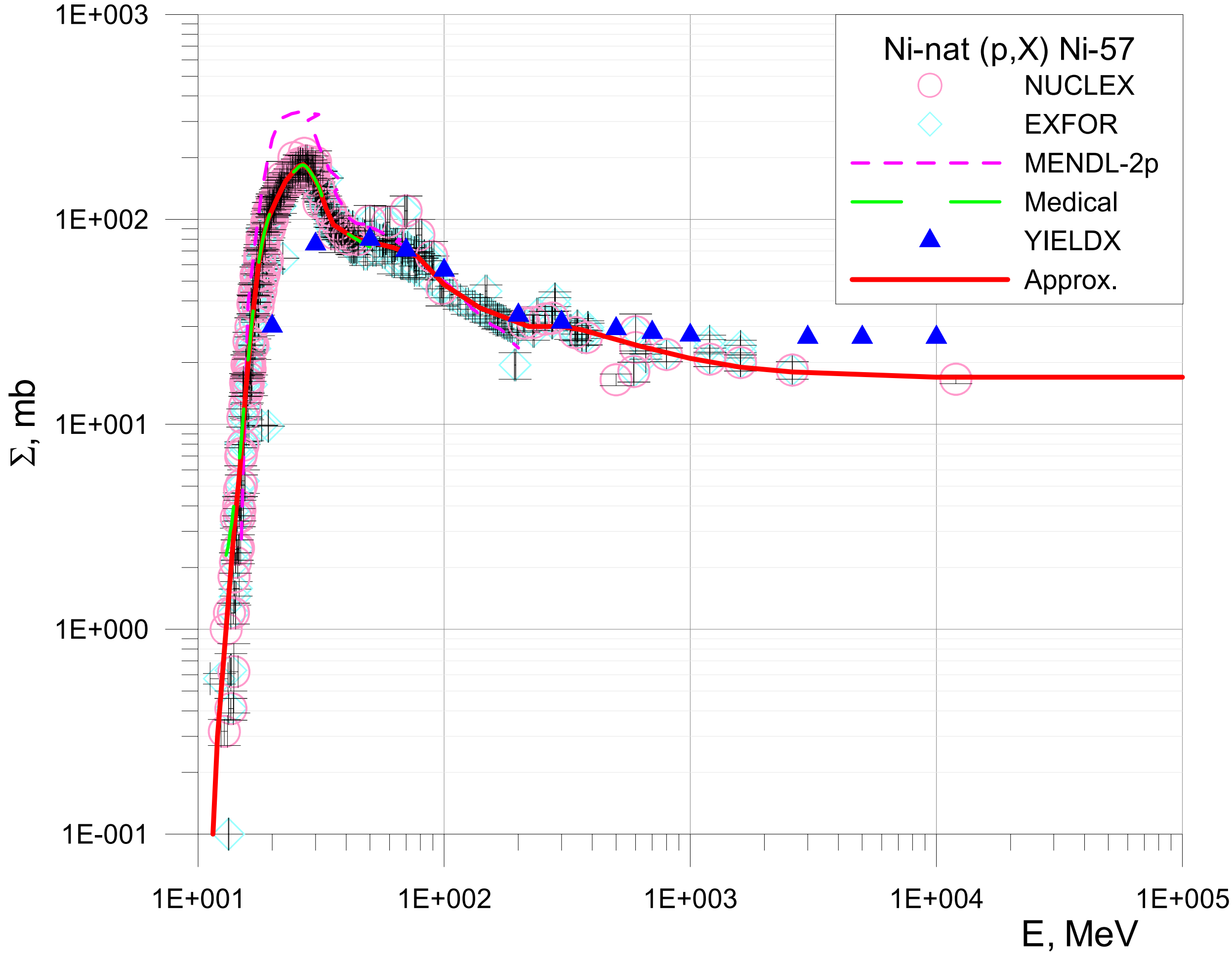
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	7.03	0.0	19	80	1.4
2	7.1	0.1	20	115	1.1
3	7.2	1.0	21	200	0.7
4	7.4	10	22	800	0.15
5	7.6	20	23	1200	0.13
6	8.1	40	24	100000	0.13
7	8.7	60	25		
8	9.7	82	26		
9	11.2	103	27		
10	11.8	113	28		
11	13.0	115	29		
12	14.1	110	30		
13	16.5	60	31		
14	20.0	30			
15	24	15			
16	33	6.1			
17	48	2.6			
18	60	1.8			



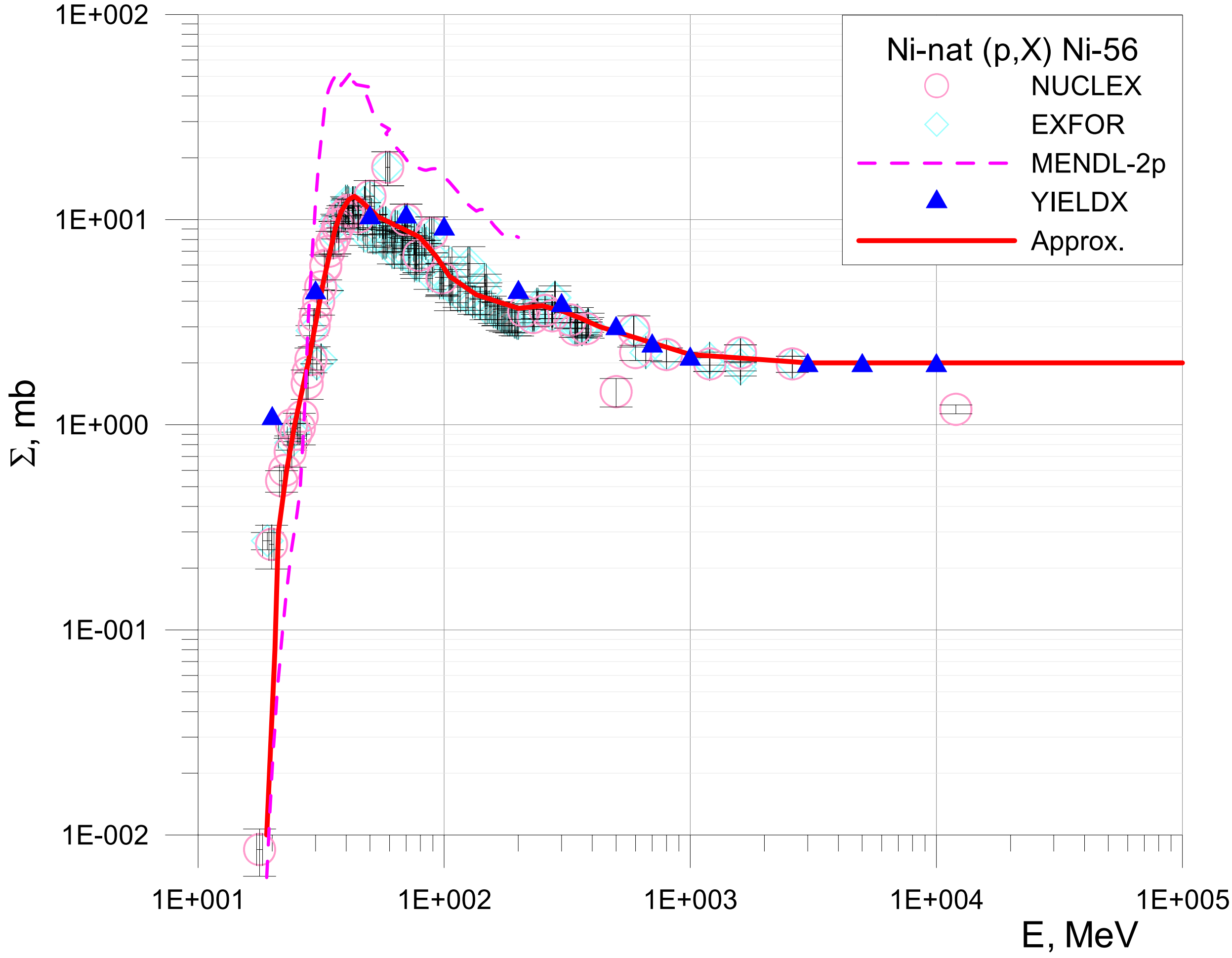
##	E, MeV	Σ, mb
1	7.55	0.000
2	10.5	0.001
3	11.2	0.01
4	12.5	0.10
5	14.7	0.40
6	17.2	1.00
7	20	1.45
8	22	1.58
9	25	1.51
10	40	1.15
11	90	0.68
12	110	0.60
13	200	0.45
14	300	0.40
15	100000	0.40
16		
17		
18		



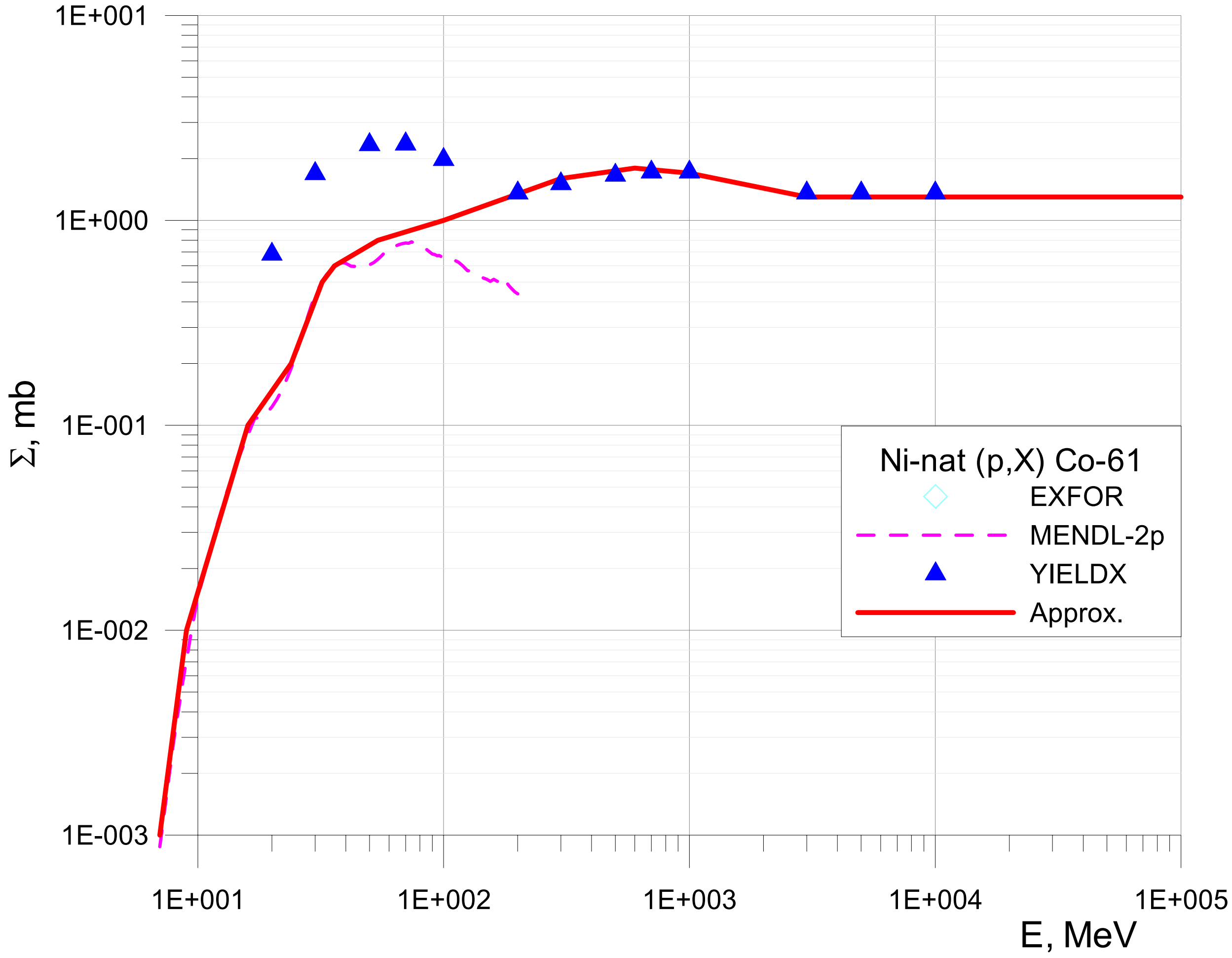
##	E, MeV	Σ, mb
1	9.3	0.0
2	13.6	0.1
3	13.8	1.0
4	14.4	10
5	15.6	70
6	16.9	140
7	20.9	215
8	24.0	220
9	25.5	190
10	36.0	80
11	54.0	50
12	180	16
13	300	14
14	1000	12
15	100000	12
16		
17		
18		



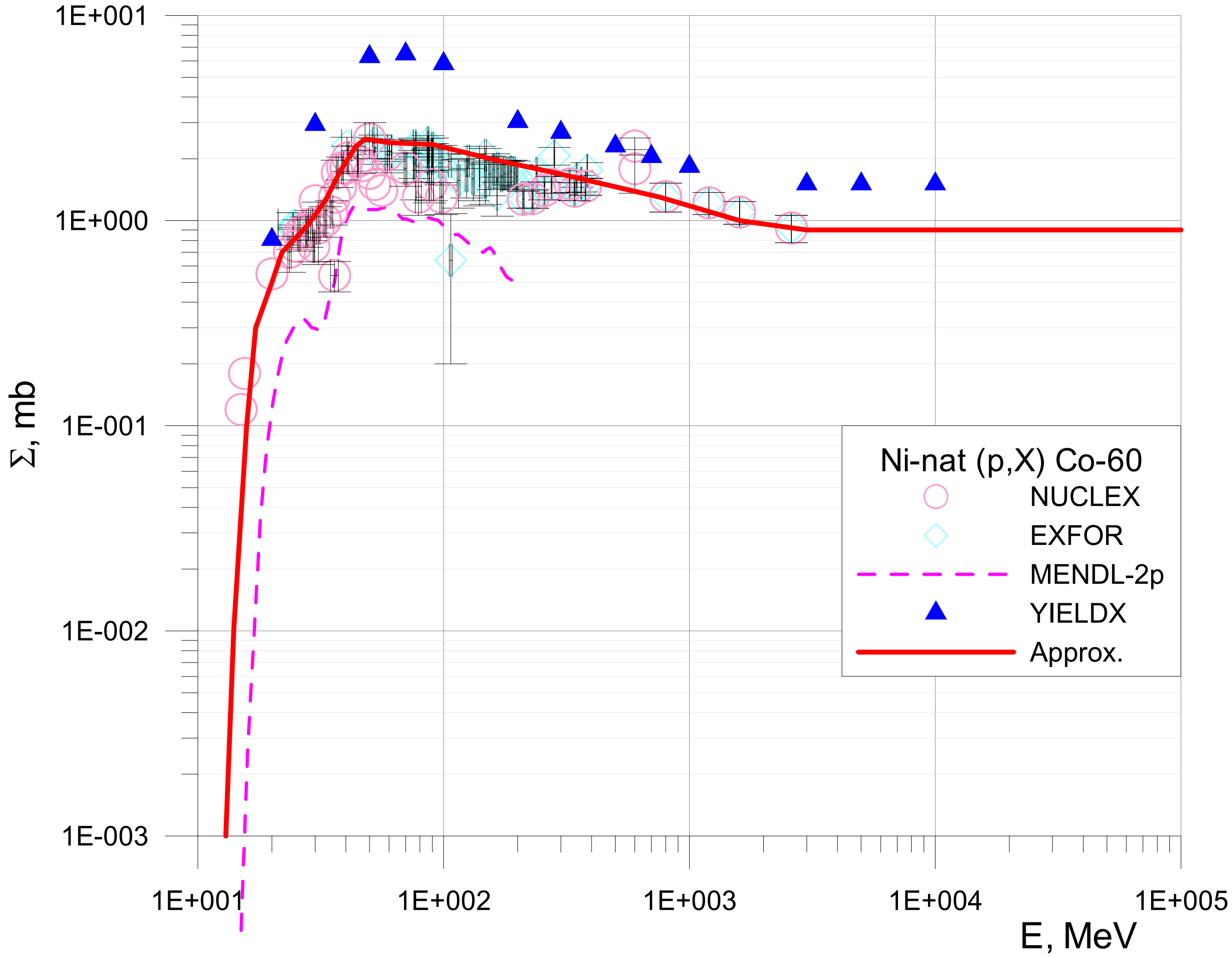
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	10.2	0.0	19	33.1	113
2	11.0	0.1	20	35.5	94
3	12.0	0.3	21	43	81
4	13.0	1.0	22	62	73
5	14.0	3.0	23	78	66
6	14.8	6.1	24	100	48
7	15.6	14.5	25	140	37
8	16.5	30.0	26	220	30
9	17.6	60.0	27	300	30
10	18.3	80.0	28	360	29
11	19.2	100	29	630	24
12	21.0	127	30	1000	21
13	22.7	154	31	1600	19
14	24.5	172	32	2600	18
15	25.7	182	33	10000	17
16	26.8	185	34	100000	17
17	28.1	176			
18	31.0	144			



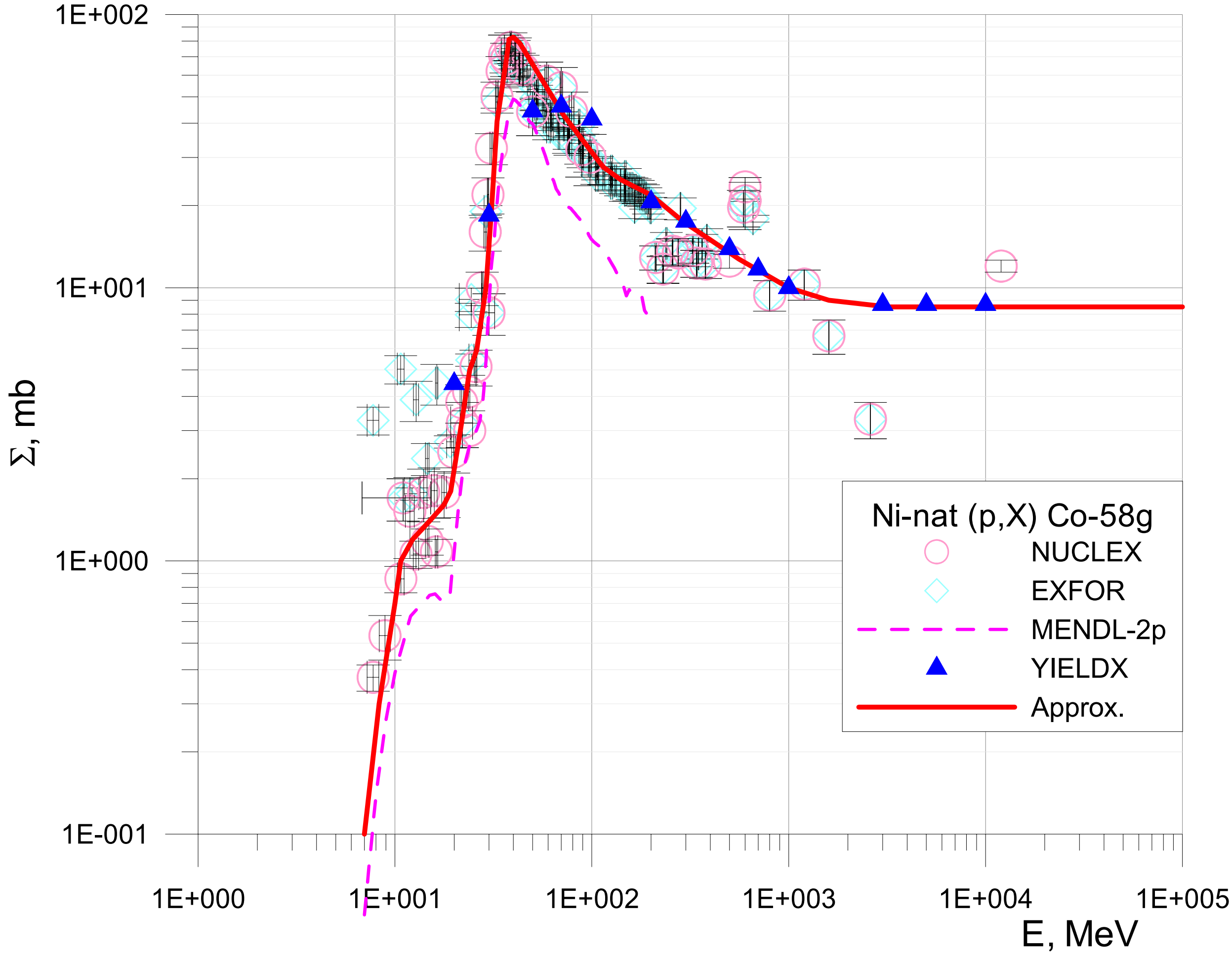
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	14.2	0.00	19	135	4.3
2	19.0	0.01	20	200	3.7
3	20.5	0.08	21	250	3.8
4	21.2	0.3	22	300	3.6
5	22.9	0.6	23	360	3.3
6	24.7	1.0	24	430	3.0
7	28.0	2.0	25	1000	2.2
8	32.3	5.0	26	3000	2.0
9	36.1	9.0	27	10000	2.0
10	38.2	11.0	28	100000	2.0
11	40.9	12.5			
12	43.2	13.0			
13	46.6	12.1			
14	54.0	10.3			
15	68.1	9.0			
16	79.6	8.2			
17	93.0	6.6			
18	105	5.3			



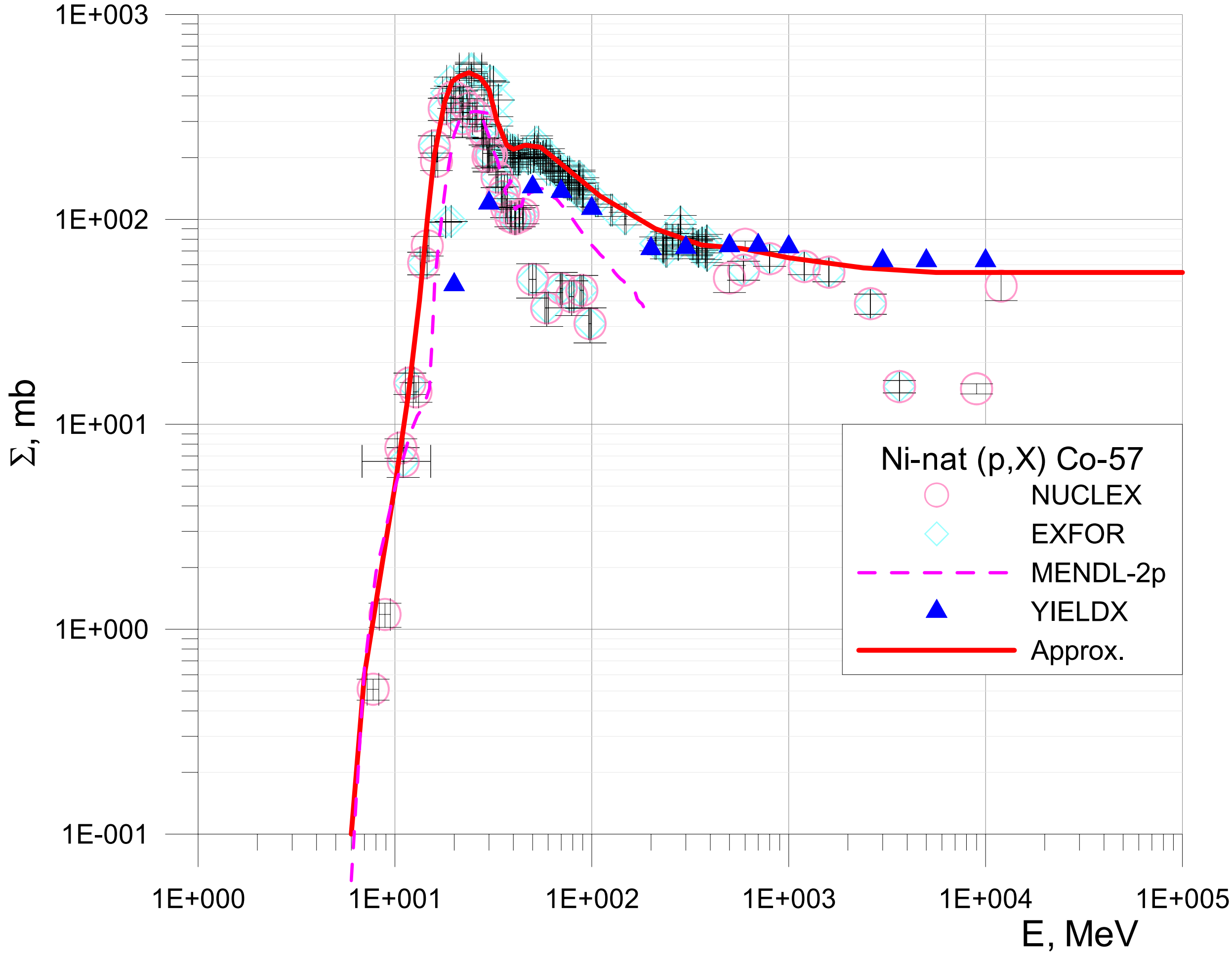
##	E, MeV	Σ, mb
1	7	0.001
2	9	0.01
3	16	0.1
4	24	0.2
5	32	0.5
6	36	0.6
7	54	0.8
8	100	1.0
9	300	1.6
10	600	1.8
11	1000	1.7
12	3000	1.3
13	100000	1.3
14		
15		
16		
17		
18		



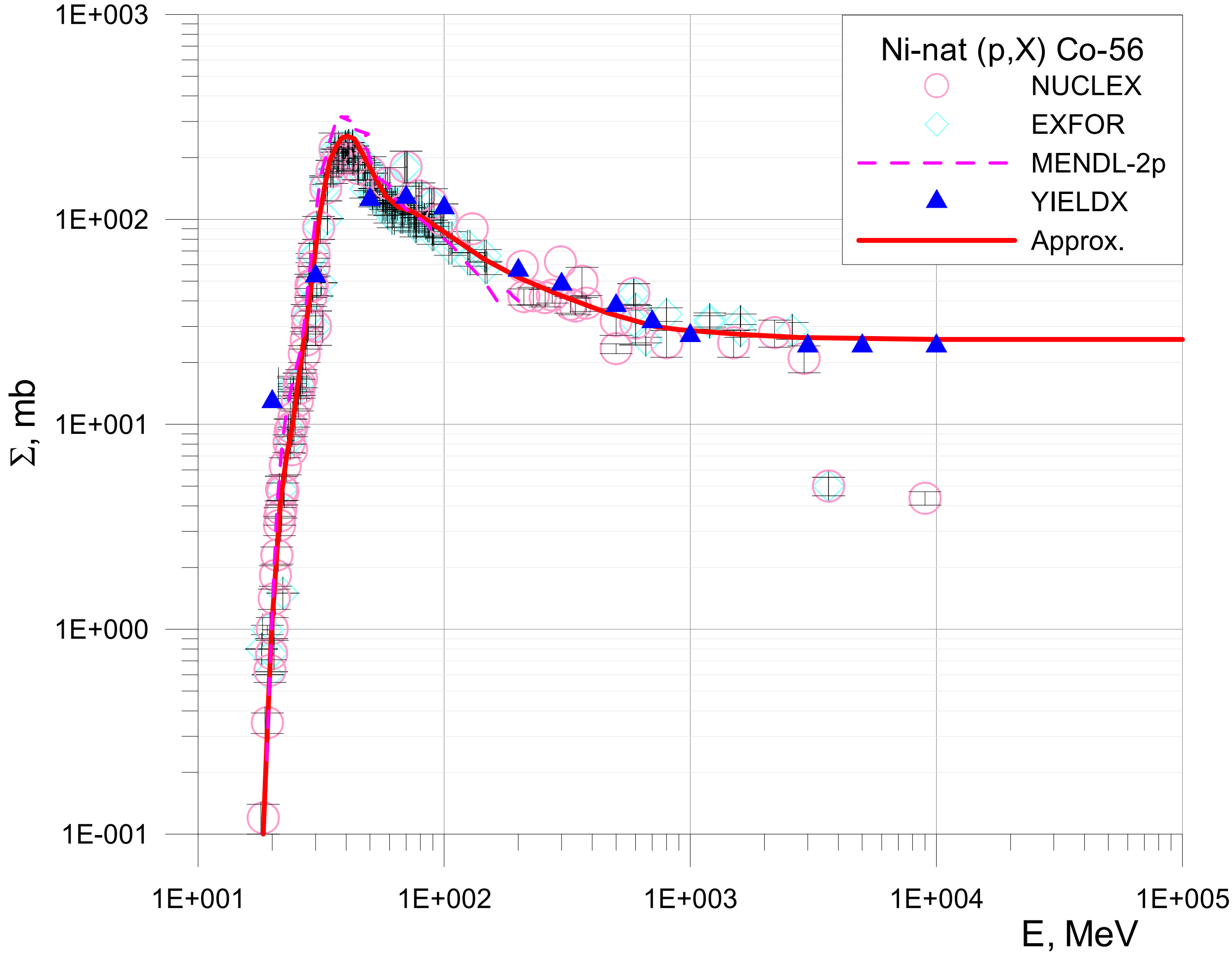
##	E, MeV	Σ, mb
1	8.8	0.000
2	13.0	0.001
3	14.0	0.01
4	15.8	0.10
5	17.2	0.30
6	20	0.50
7	22	0.70
8	28	0.95
9	33	1.25
10	38	1.75
11	44	2.30
12	48	2.50
13	60	2.40
14	90	2.35
15	155	2.00
16	290	1.70
17	760	1.30
18	1600	1.00
19	3000	0.90
20	100000	0.90



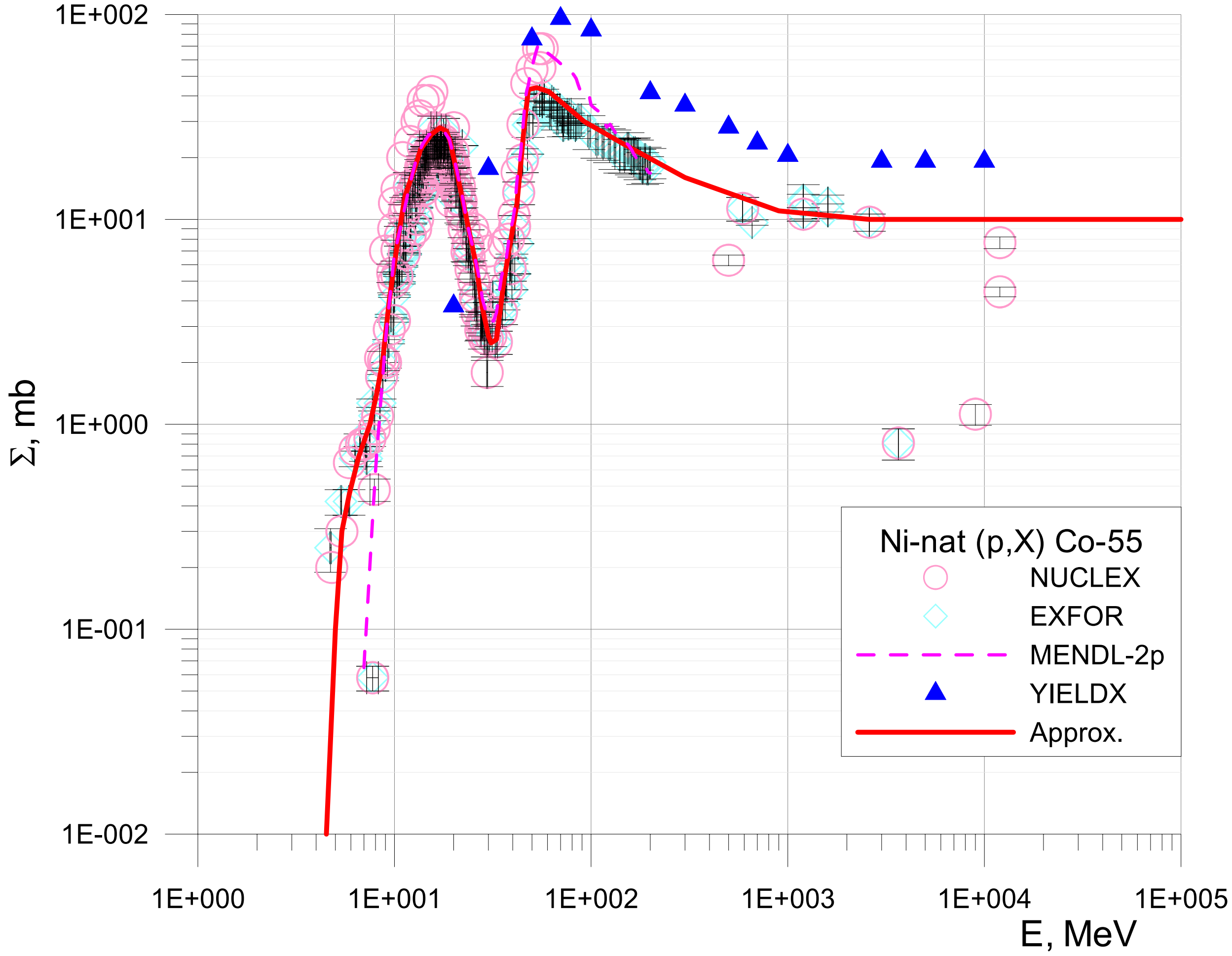
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	7.0	0.1	19	72	42.7
2	8.3	0.3	20	114	27.7
3	10.0	0.7	21	140	24.9
4	10.7	1.0	22	200	21.8
5	12.3	1.2	23	290	17.5
6	15.0	1.4	24	560	12.7
7	17.7	1.6	25	1000	10.0
8	19.2	1.8	26	1600	9.0
9	21.5	3.0	27	3200	8.5
10	24.0	5.0	28	100000	8.5
11	26.0	5.9			
12	29	10.0			
13	31	19.8			
14	33	40.6			
15	37	70.4			
16	38	81.1			
17	40	82.6			
18	43	78.6			



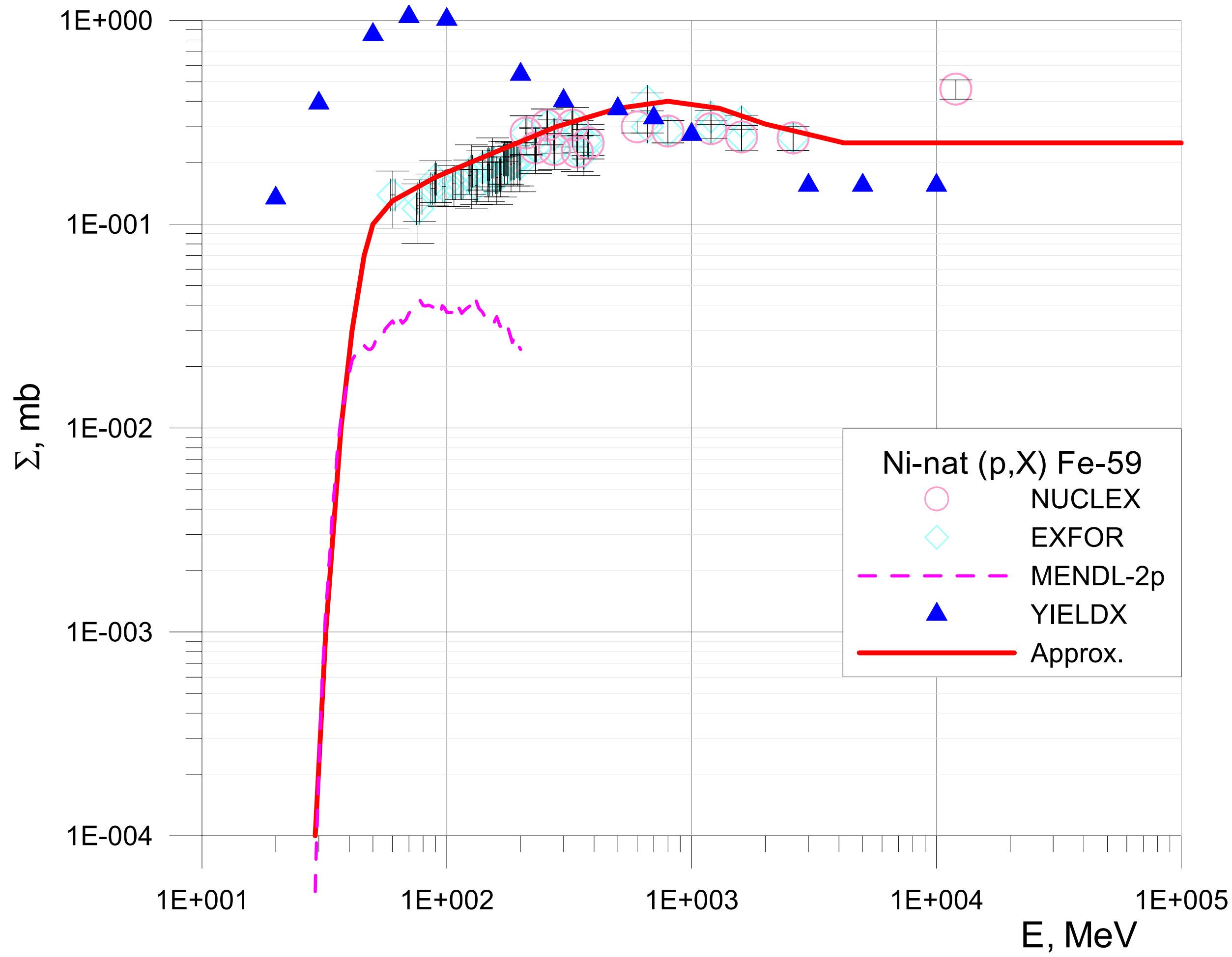
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	2.6	0.0	19	46	230
2	6.0	0.1	20	55	225
3	7.0	0.6	21	66	195
4	8.7	2.2	22	110	130
5	10.0	5.0	23	210	90
6	11.7	14	24	360	75
7	13.3	40	25	580	72
8	14.6	100	26	1000	65
9	15.8	200	27	2400	58
10	17.8	370	28	5600	55
11	19.5	470	29	10000	55
12	21.2	500	30	100000	55
13	23.8	520			
14	27.2	490			
15	30	430			
16	33	300			
17	37	230			
18	40	220			



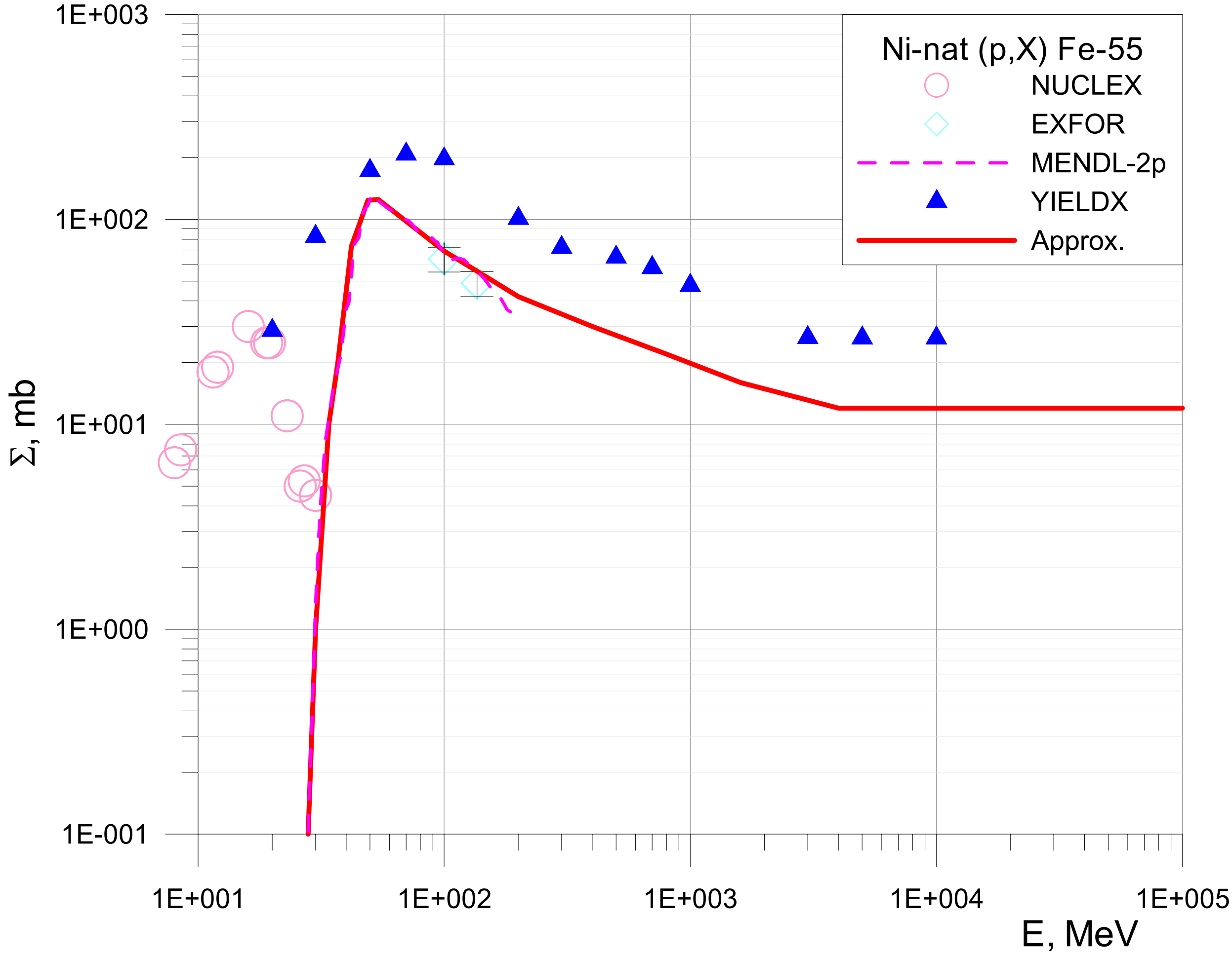
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	11.8	0.00	19	48	200
2	17.8	0.01	20	54	150
3	17.9	0.03	21	58	130
4	18.4	0.10	22	65	115
5	19.4	0.50	23	73	110
6	19.9	1.0	24	84	100
7	21.6	4.2	25	100	87
8	22.9	7.0	26	145	64
9	24.2	10.0	27	200	52
10	26.1	20.0	28	290	43
11	28.3	40.0	29	460	35
12	31.0	100	30	720	30
13	32.7	145	31	900	29
14	34.3	193	32	1600	28
15	36.7	230	33	2800	27
16	38.5	250	34	10000	26
17	40.4	255	35	100000	26
18	43.2	247			



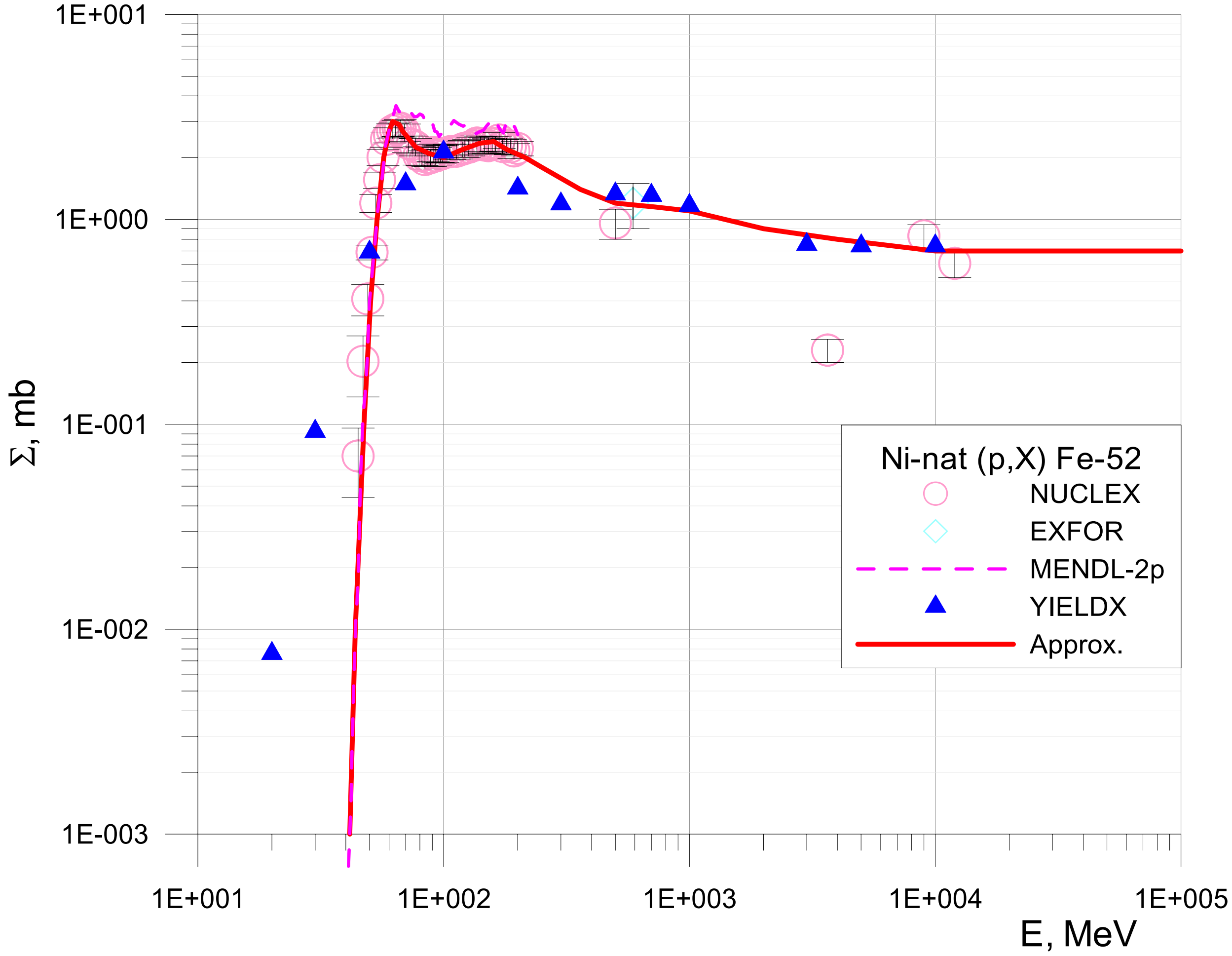
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	1.4	0.00	19	26	6.0
2	5.0	0.10	20	28	3.7
3	5.4	0.30	21	30	2.7
4	5.9	0.46	22	31	2.5
5	6.6	0.70	23	33	2.6
6	7.5	1.00	24	36	5.0
7	8.1	1.4	25	42	12
8	8.7	2.0	26	46	30
9	9.4	4.0	27	48	43
10	10.4	7.9	28	53	44
11	11.3	13.	29	61	42
12	12.7	18.	30	92	30
13	13.6	22.	31	150	23
14	15.4	26.	32	300	16
15	17.0	28.	33	900	11
16	18.4	27.	34	2600	10
17	19.2	24.	35	10000	10
18	22.4	12.	36	100000	10



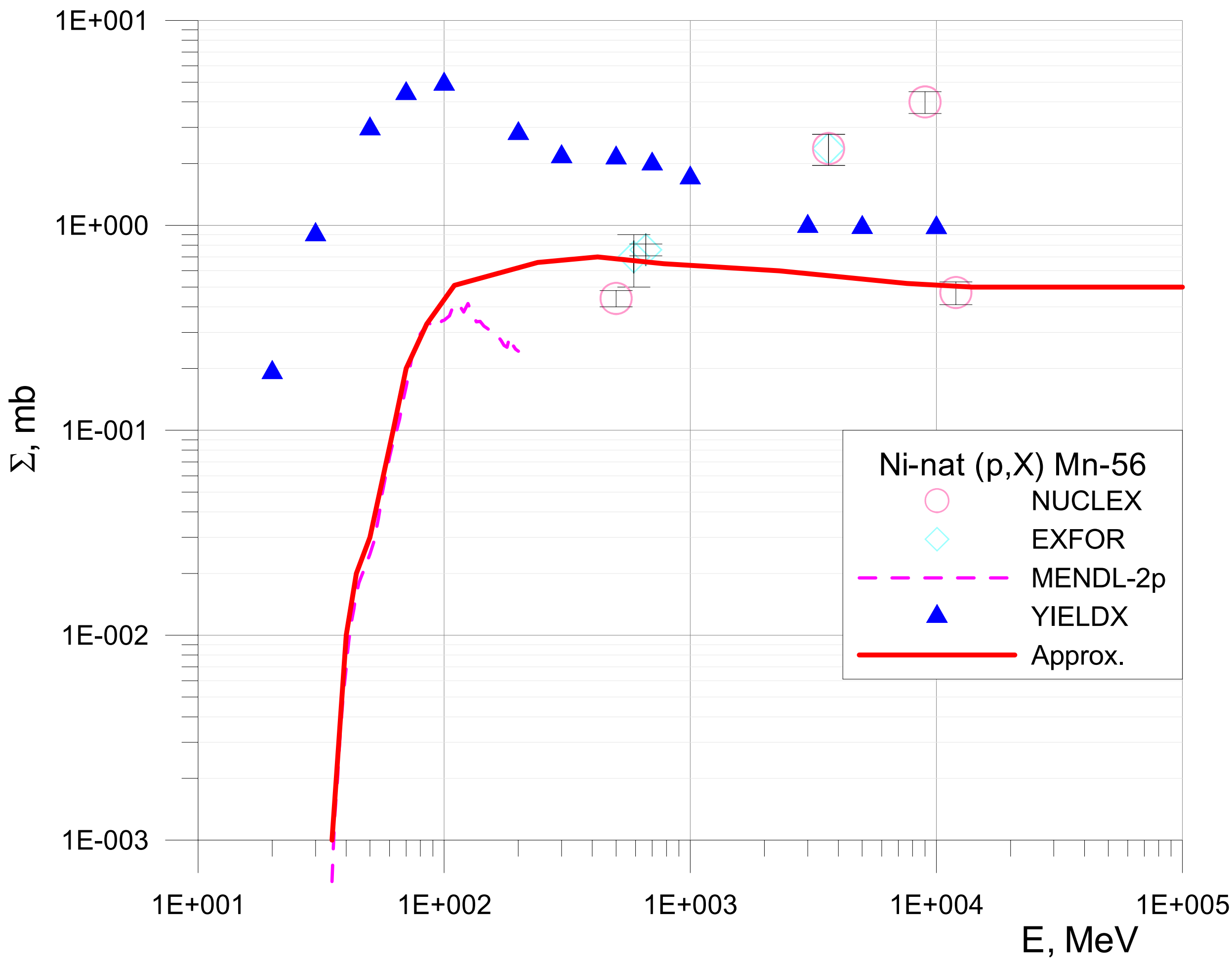
##	E, MeV	Σ, mb
1	14.9	0.0000
2	29	0.0001
3	32	0.001
4	37	0.01
5	41	0.03
6	46	0.07
7	50	0.10
8	60	0.13
9	90	0.17
10	150	0.22
11	280	0.30
12	500	0.37
13	800	0.40
14	1300	0.37
15	2000	0.31
16	4200	0.25
17	100000	0.25
18		



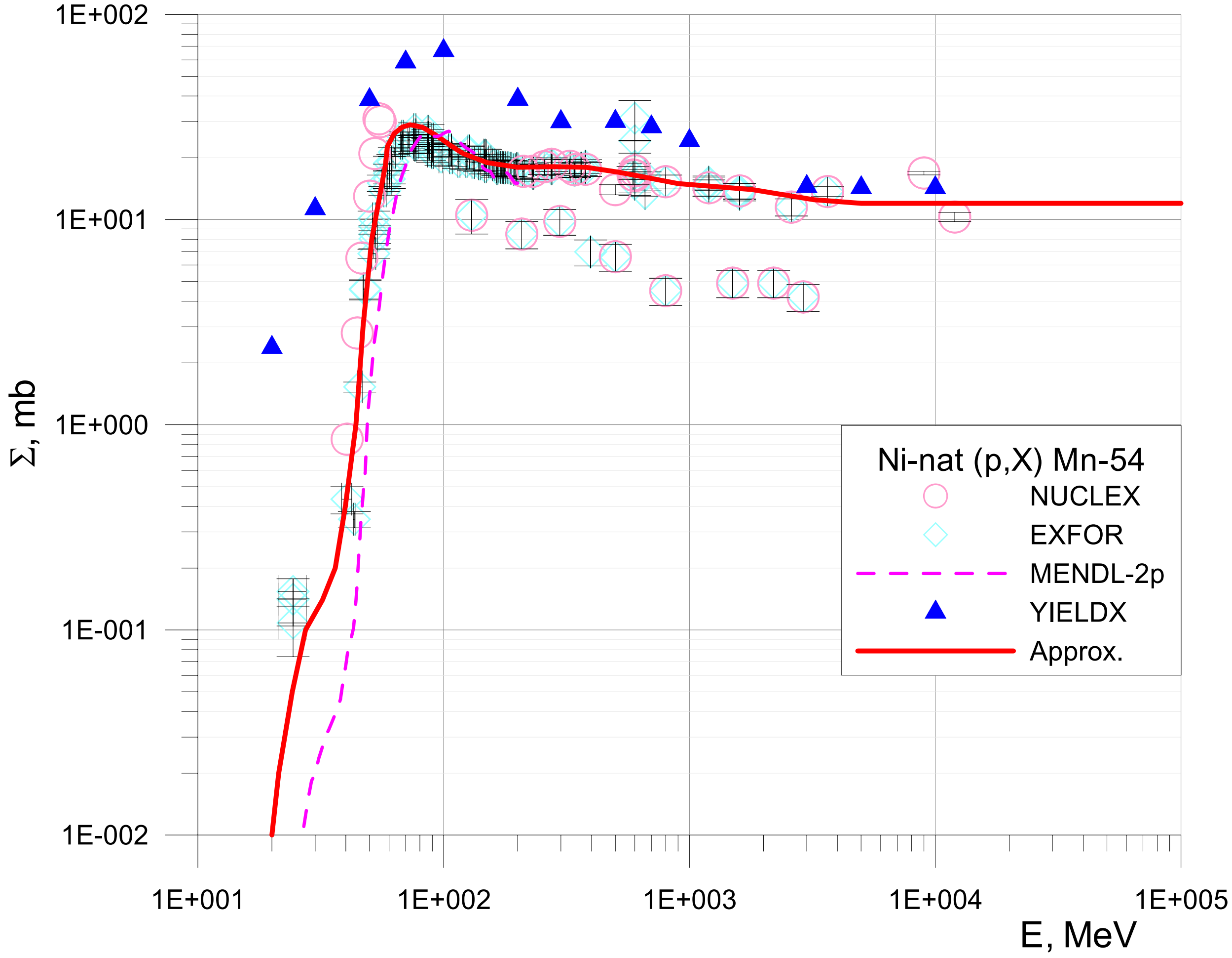
##	E, MeV	Σ, mb
1	15.5	0.0
2	28	0.1
3	30	1.0
4	34	10
5	37	20
6	42	74
7	46	100
8	49	124
9	54	125
10	100	70
11	200	42
12	400	30
13	800	22
14	1600	16
15	4000	12
16	100000	12
17		
18		



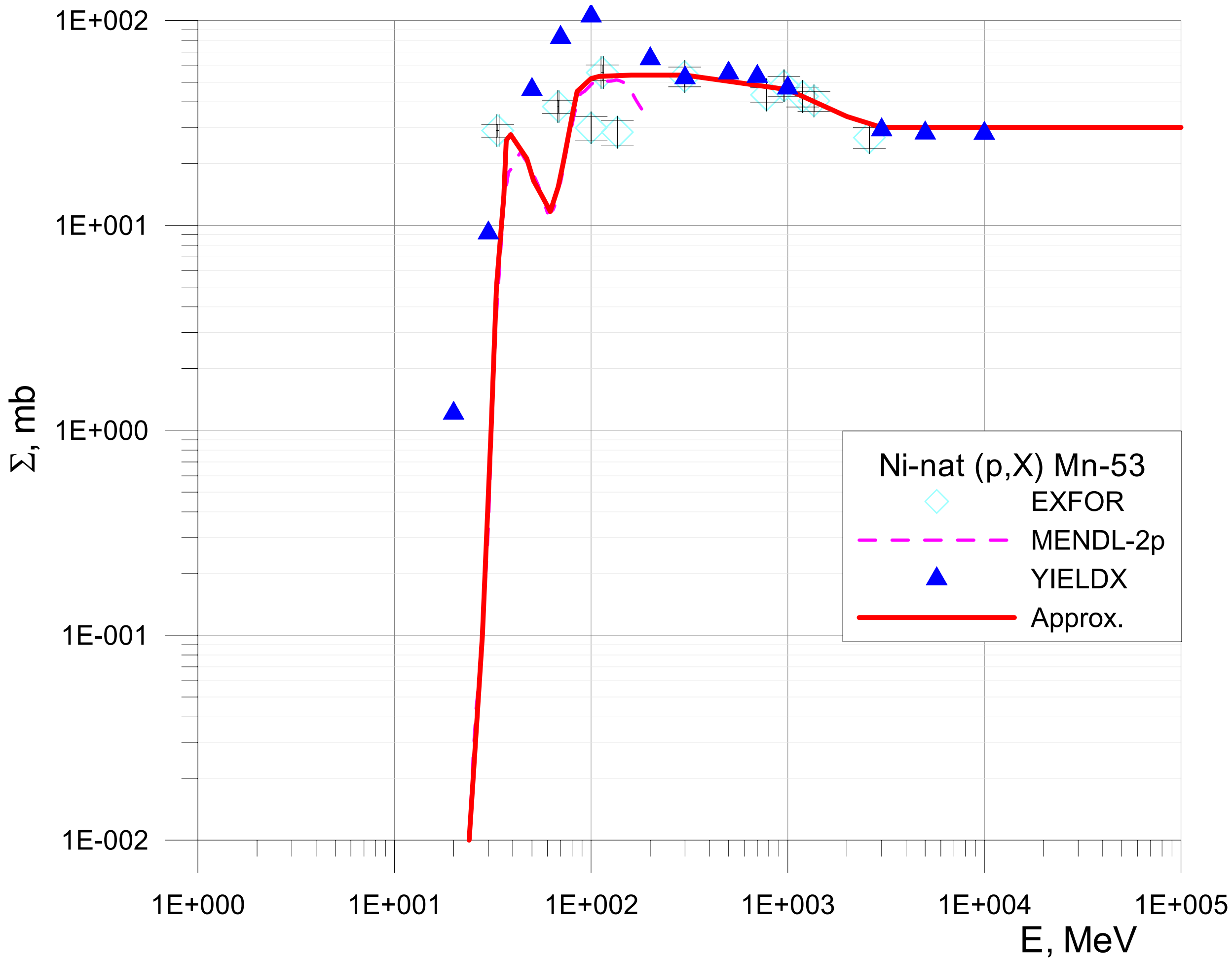
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	22.4	0.000	19	215	2.00
2	41.5	0.001	20	250	1.80
3	43.7	0.01	21	360	1.40
4	47.4	0.10	22	500	1.20
5	50.4	0.40	23	720	1.15
6	53.6	1.00	24	1000	1.10
7	57.0	2.00	25	2000	0.90
8	60	2.70	27	4000	0.80
9	62	3.00	28	10000	0.70
10	66	2.90	29	100000	0.70
11	68	2.70			
12	77	2.25			
13	87	2.10			
14	100	2.00			
15	120	2.20			
16	140	2.35			
17	160	2.40			
18	180	2.20			



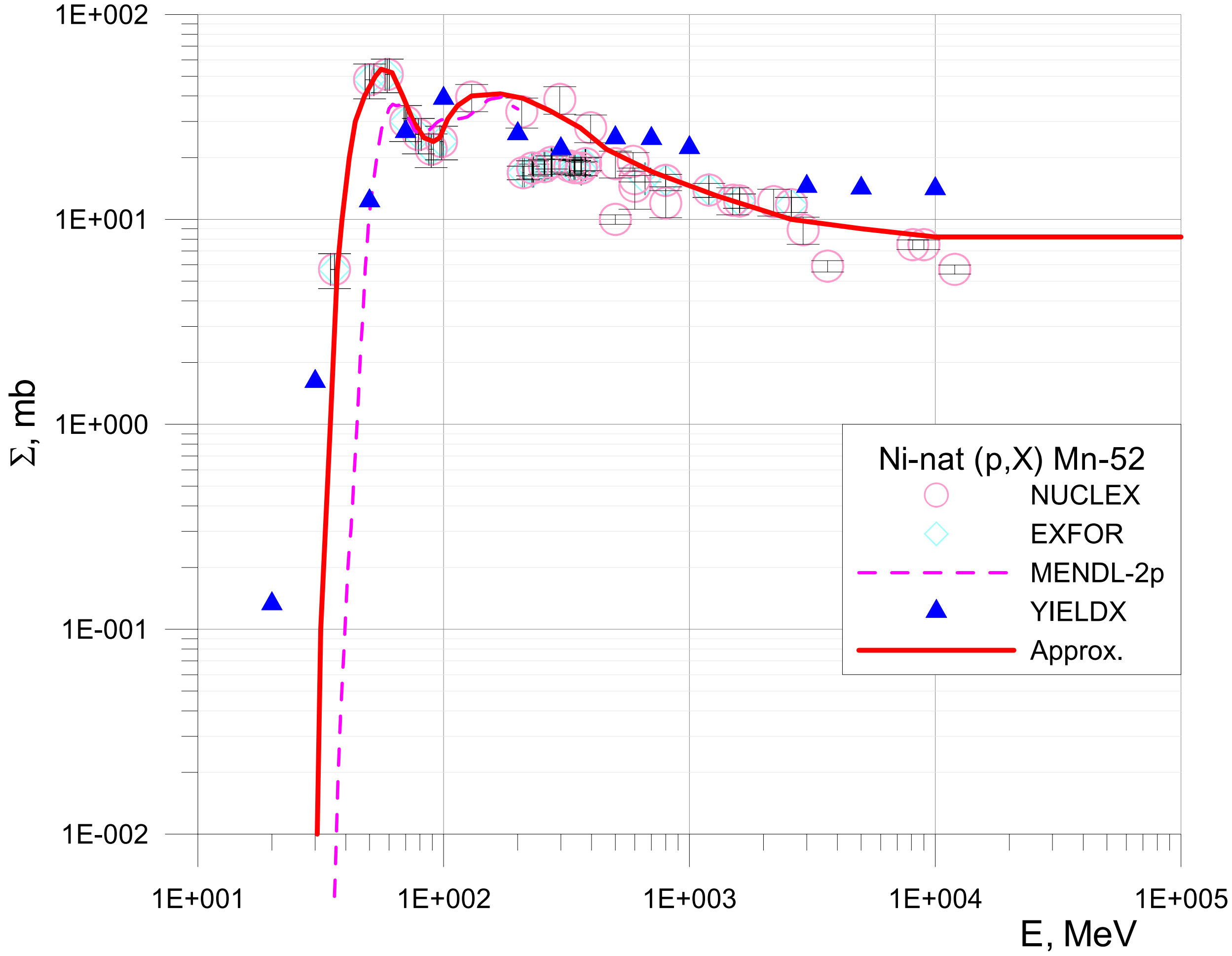
##	E, MeV	Σ, mb
1	16.1	0.000
2	35	0.001
3	40	0.01
4	44	0.02
5	50	0.03
6	62	0.10
7	70	0.20
8	85	0.33
9	110	0.51
10	240	0.66
11	420	0.70
12	780	0.65
13	2300	0.60
14	7600	0.52
15	14000	0.50
16	100000	0.50
17		
18		



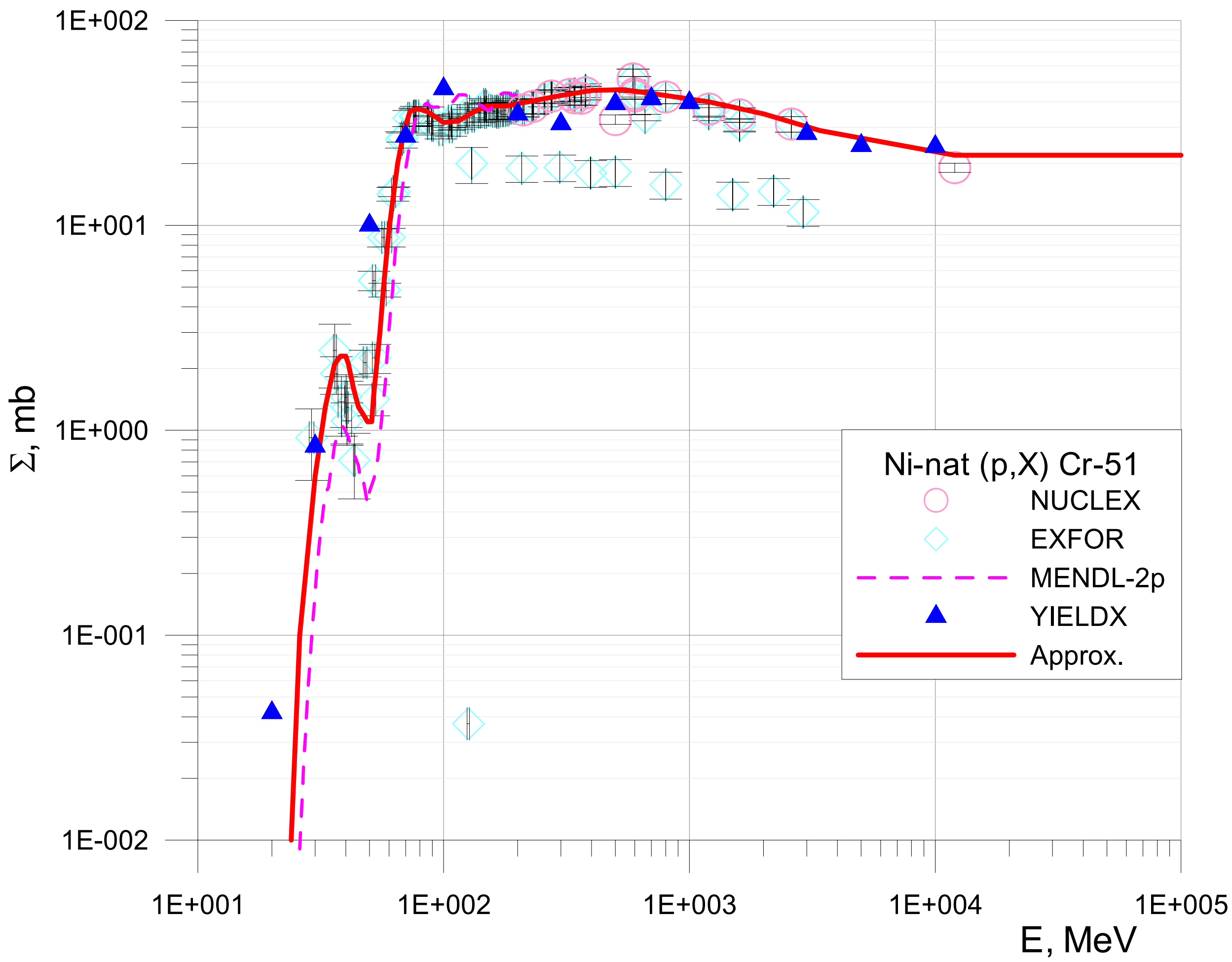
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	6.33	0.00	19	105	23.3
2	20.0	0.01	20	120	21.0
3	21.3	0.02	21	150	19.0
4	24.2	0.05	22	200	18.0
5	27.4	0.10	23	280	18.1
6	32.1	0.14	24	380	18.0
7	36.2	0.2	25	520	17.0
8	39.8	0.4	26	900	15.0
9	44	1.0	27	1800	14.0
10	47	3.0	28	3200	12.5
11	51	8.0	29	5000	12.0
12	58	18.5	30	100000	12.0
13	59	22.7			
14	63	26.3			
15	68	28.3			
16	73	29.0			
17	82	28.2			
18	95	25.4			



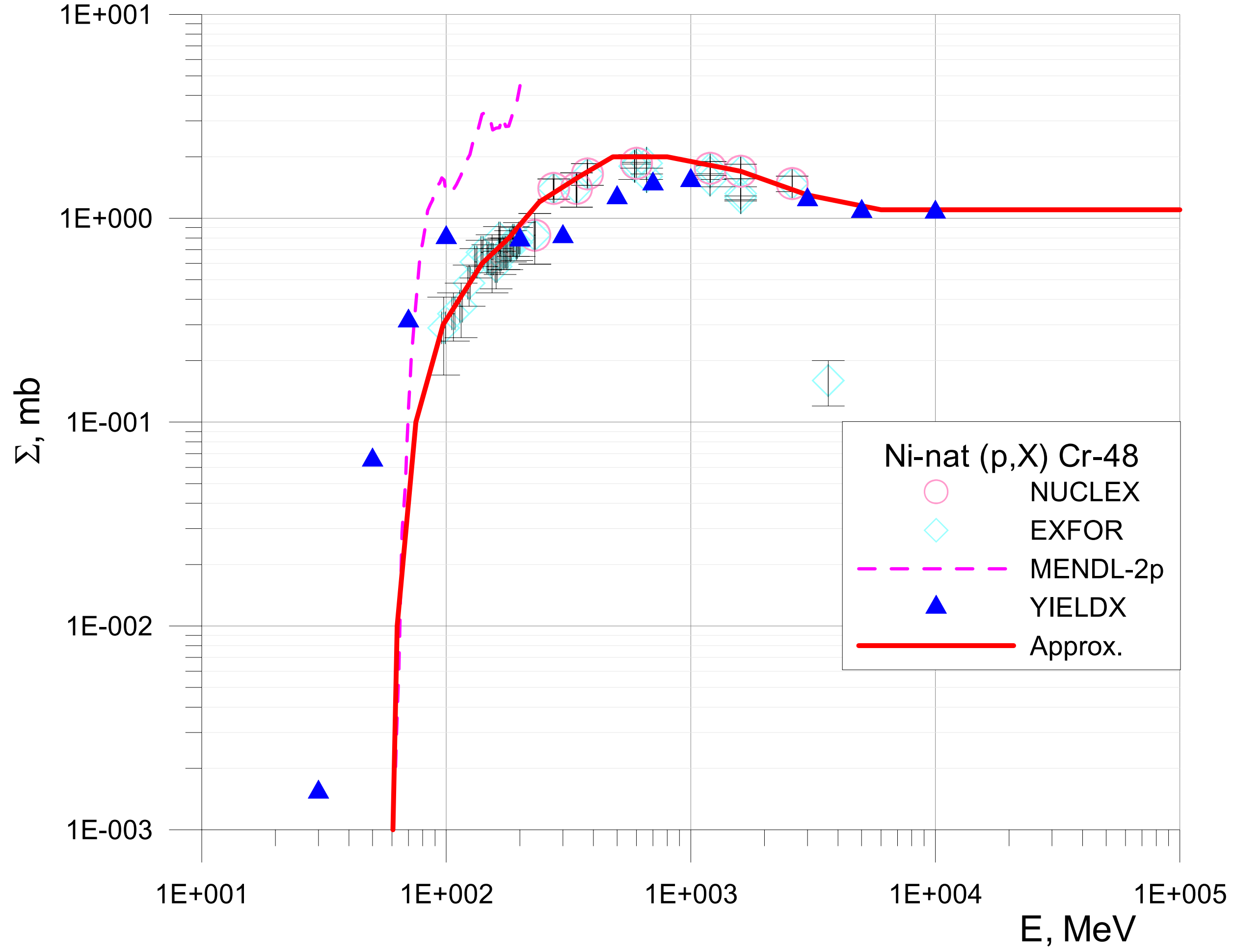
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	7.5	0.00	19	160	54.
2	24	0.01	20	300	54.
3	28	0.1	21	1000	46.
4	31	1.0	22	2000	34.
5	33	5.0	23	3000	30.
6	36	14.0	24	100000	30.
7	37	26.0			
8	39	27.7			
9	47	21.2			
10	51	16.5			
11	56	14.0			
12	62	11.7			
13	68	15.4			
14	72	20.0			
15	81	36.2			
16	85	45.0			
17	100	52.0			
18	110	53.4			



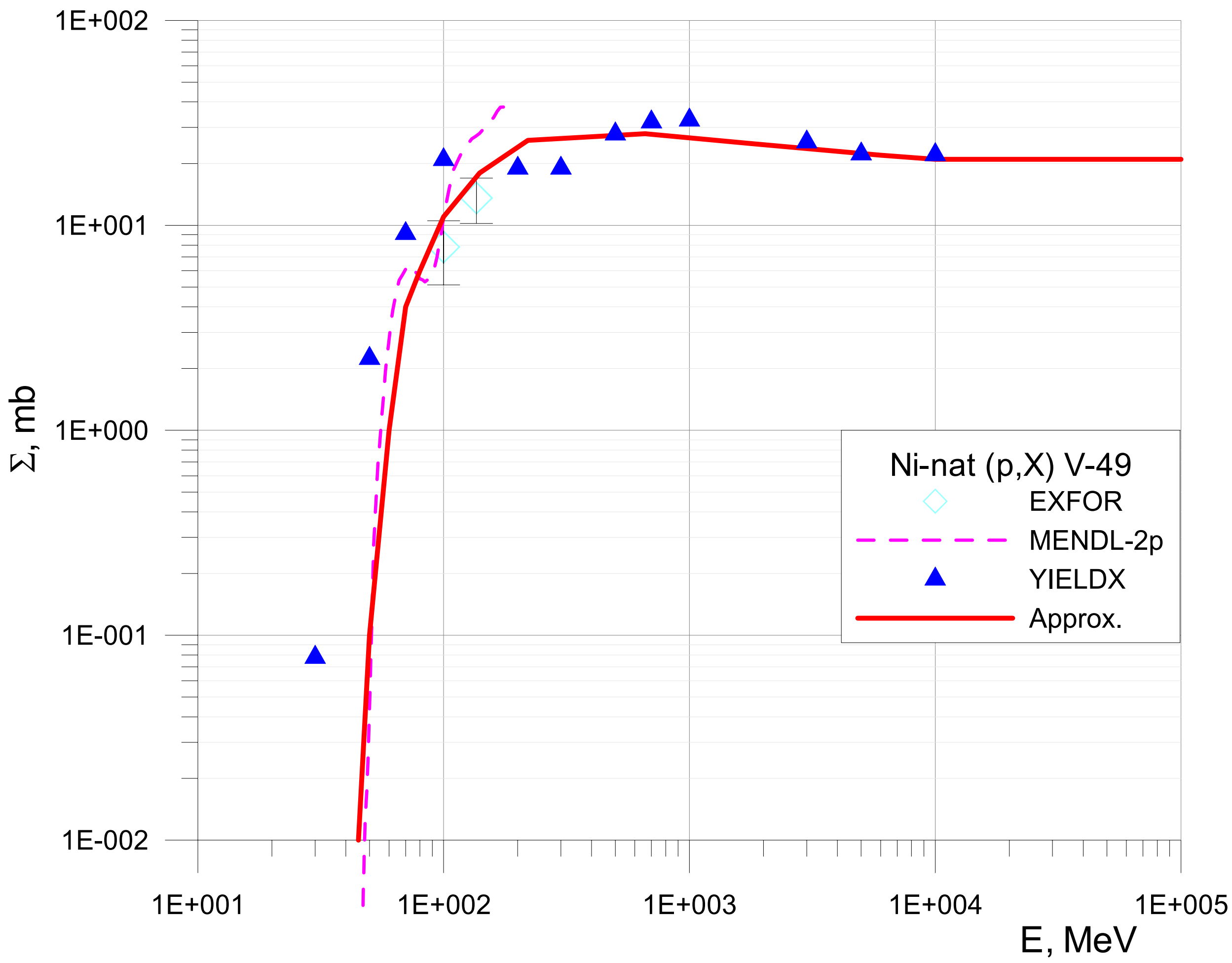
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	19.7	0.00	19	114	36.
2	30.6	0.01	20	130	40.
3	31.6	0.10	21	170	41.
4	34.6	1.0	22	210	39.
5	36.9	5.7	23	270	34.
6	38.6	10.	24	360	28.
7	41.3	20.	25	460	22.
8	43.7	30.	26	710	17.
9	47.7	40.	27	1300	13.
10	52.7	50.	28	2600	10.
11	55.7	54.	29	5000	9.0
12	61.7	52.	30	10000	8.2
13	68.1	40.	31	100000	8.2
14	75.3	30.			
15	83.2	25.			
16	90.9	24.			
17	96.2	25.			
18	104.0	31.			



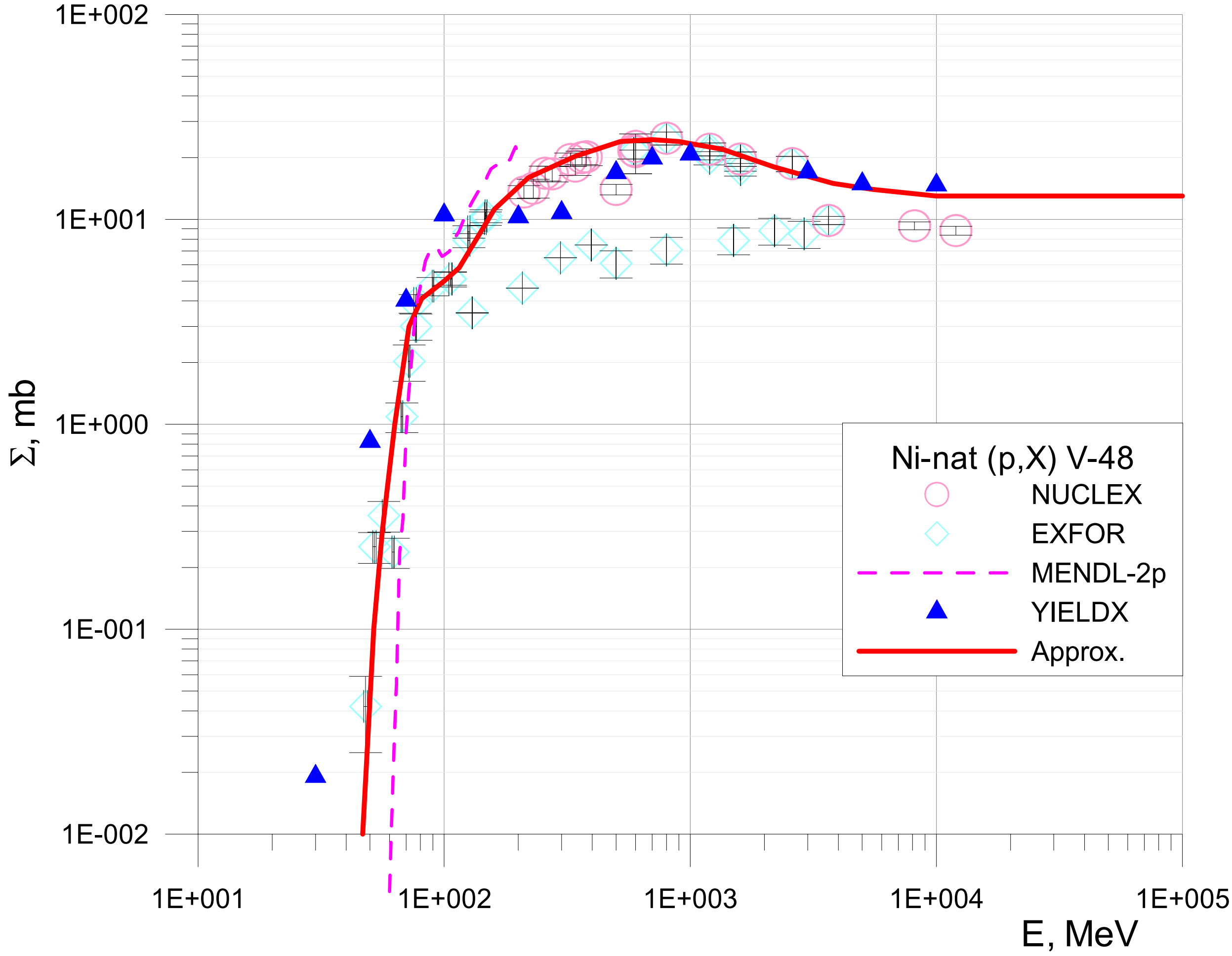
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	9.7	0.00	21	69	28.7
2	24	0.01	22	73	36.2
3	26	0.1	23	79	37.0
4	30	0.6	24	86	35.8
5	33	1.3	25	94	33.4
6	35	1.8	26	100	31.7
7	36	2.1	27	115	32.3
8	38	2.3	28	130	35.3
9	40	2.3	29	150	38.2
10	41	2.1	30	180	38.2
11	43	1.6	31	220	40.0
12	45	1.3	32	300	43.0
13	47	1.2	33	400	45.5
14	49	1.1	34	540	46.0
15	51	1.1	35	800	43.0
16	52	1.5	36	1200	40.0
17	55	3.0	37	2000	35.0
18	57	5.1	38	3400	29.0
19	60	9.6	39	12000	22.0
20	65	20.	40	100000	22.0



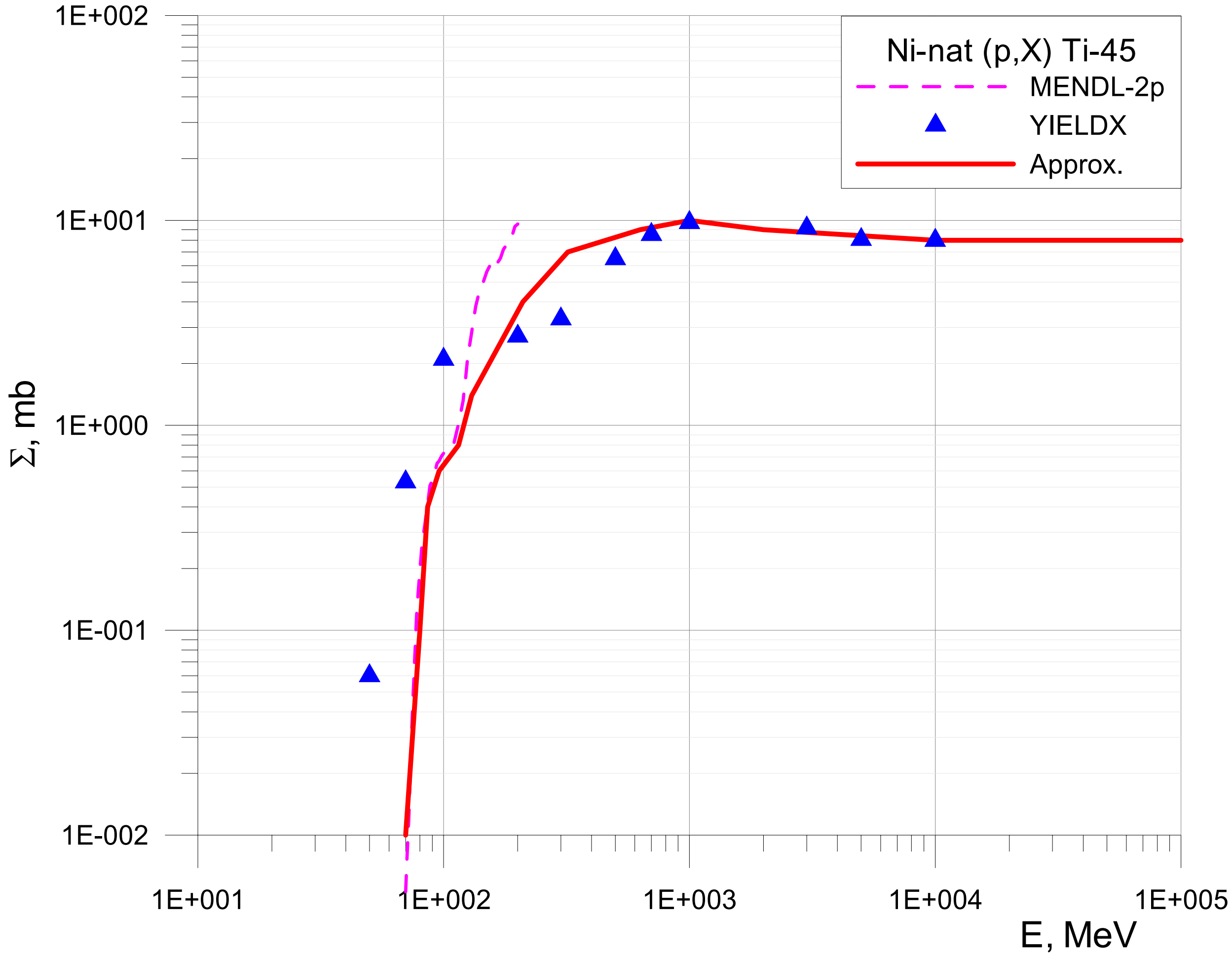
##	E, MeV	Σ, mb
1	30.4	0.0000
2	61	0.0010
3	63	0.010
4	75	0.10
5	97	0.30
6	140	0.60
7	180	0.80
8	240	1.2
9	350	1.6
10	480	2.0
11	800	2.0
12	1600	1.7
13	3000	1.3
14	6000	1.1
15	100000	1.1
16		
17		
18		



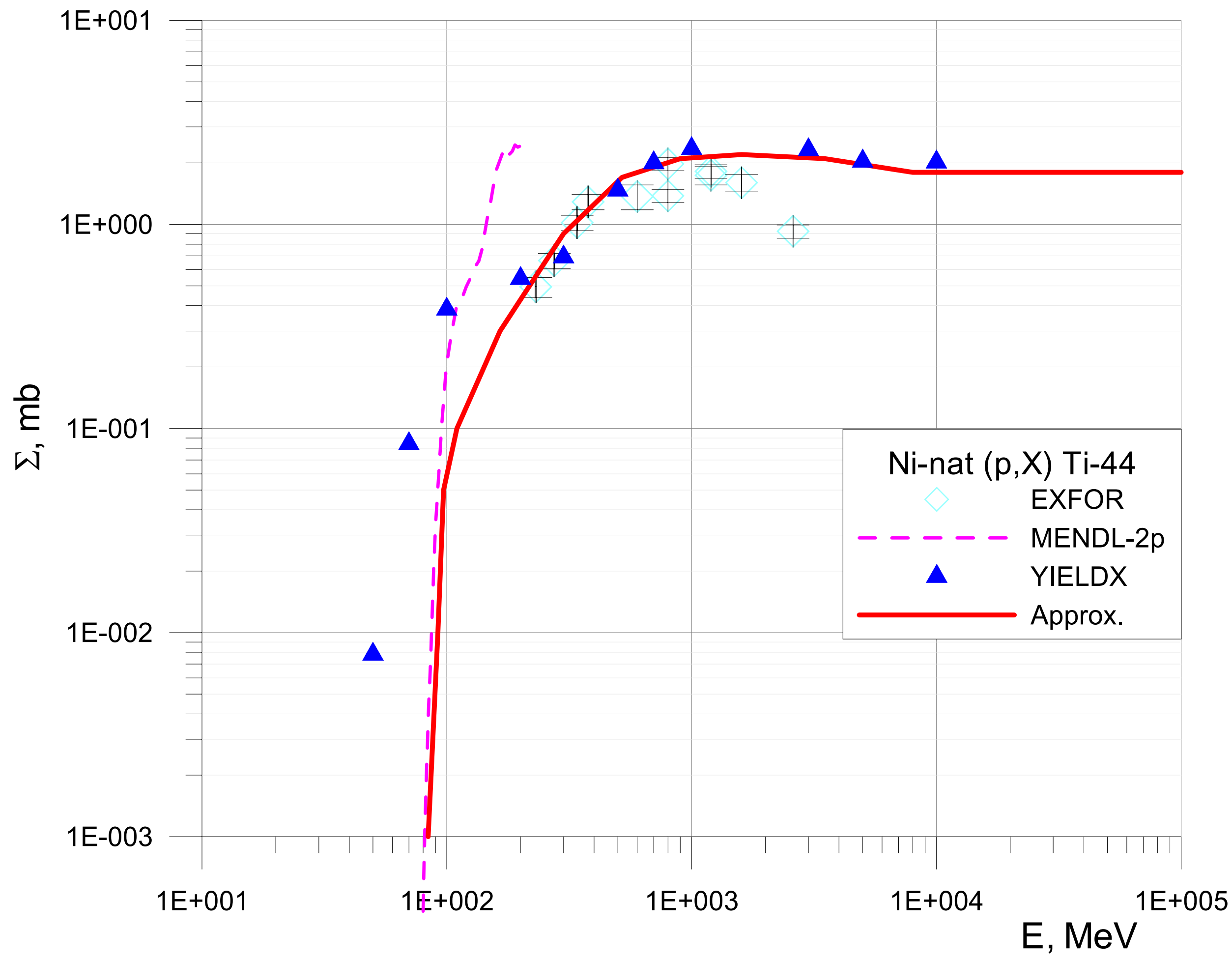
##	E, MeV	Σ, mb
1	16.8	0.00
2	45	0.01
3	50	0.1
4	60	1.0
5	70	4.0
6	80	6.0
7	100	11
8	140	18
9	220	26
10	660	28
11	1800	25
12	6000	22
13	10000	21
14	100000	21
15		
16		
17		
18		



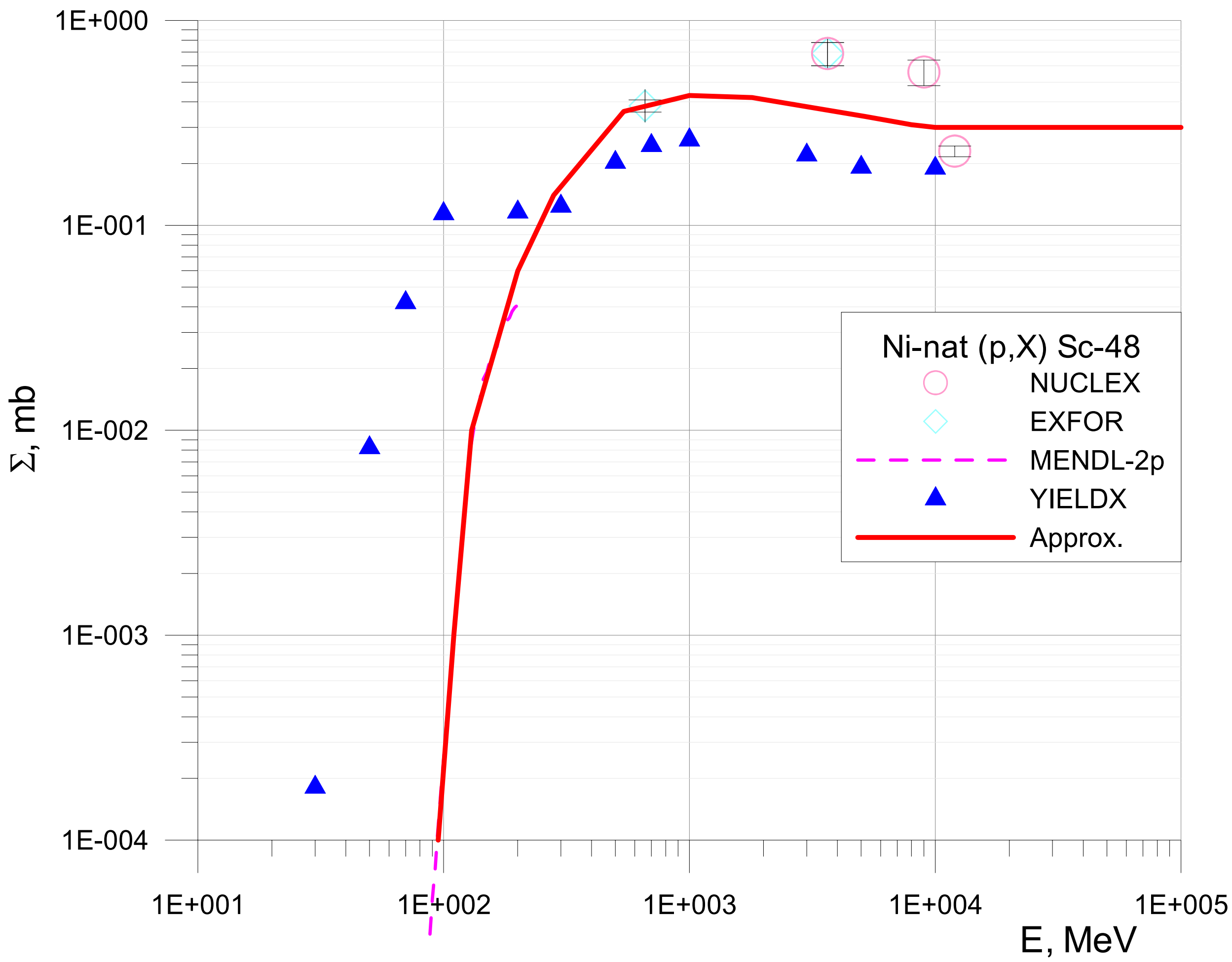
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	28.5	0.00	19	5500	14.0
2	46.6	0.01	20	10000	13.0
3	51.8	0.10	21	100000	13.0
4	56.1	0.30			
5	63	1.00			
6	72	3.00			
7	81	4.10			
8	100	5.00			
9	115	5.80			
10	160	11.2			
11	220	16.0			
12	340	20.3			
13	520	24.0			
14	700	24.5			
15	900	24.0			
16	1350	22.0			
17	2200	18.0			
18	3800	15.0			



##	E, MeV	Σ, mb
1	35	0.00
2	70	0.01
3	80	0.1
4	86	0.4
5	96	0.6
6	115	0.8
7	130	1.4
8	160	2.2
9	210	4
10	320	7
11	630	9
12	1000	10
13	2000	9
14	10000	8
15	100000	8
16		
17		
18		



##	E, MeV	Σ, mb
1	38.3	0.000
2	84	0.001
3	92	0.01
4	97	0.05
5	110	0.10
6	165	0.30
7	300	0.90
8	520	1.7
9	900	2.1
10	1600	2.2
11	3500	2.1
12	8000	1.8
13	100000	1.8
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	30.4	0.0000
2	95	0.0001
3	110	0.001
4	130	0.01
5	200	0.06
6	280	0.14
7	540	0.36
8	1000	0.43
9	1800	0.42
10	5200	0.34
11	8000	0.31
12	10000	0.30
13	100000	0.30
14		
15		
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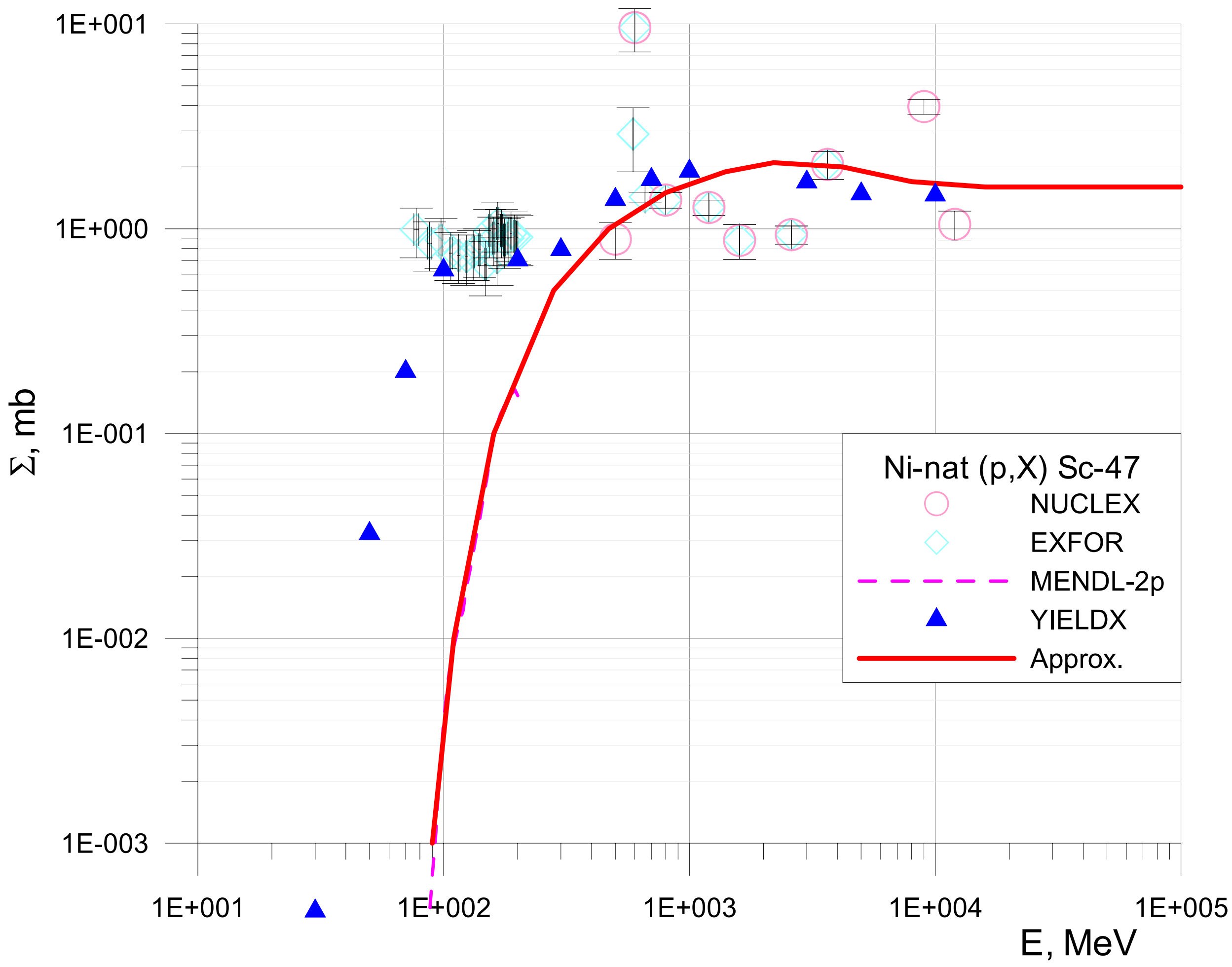
17		
18		



##	E, MeV	Σ, mb
1	25.2	0.000
2	90	0.001
3	110	0.01
4	160	0.1
5	280	0.5
6	470	1.0
7	800	1.5
8	1400	1.9
9	2200	2.1
10	4200	2.0
11	8000	1.7
12	16000	1.6
13	100000	1.6
14		
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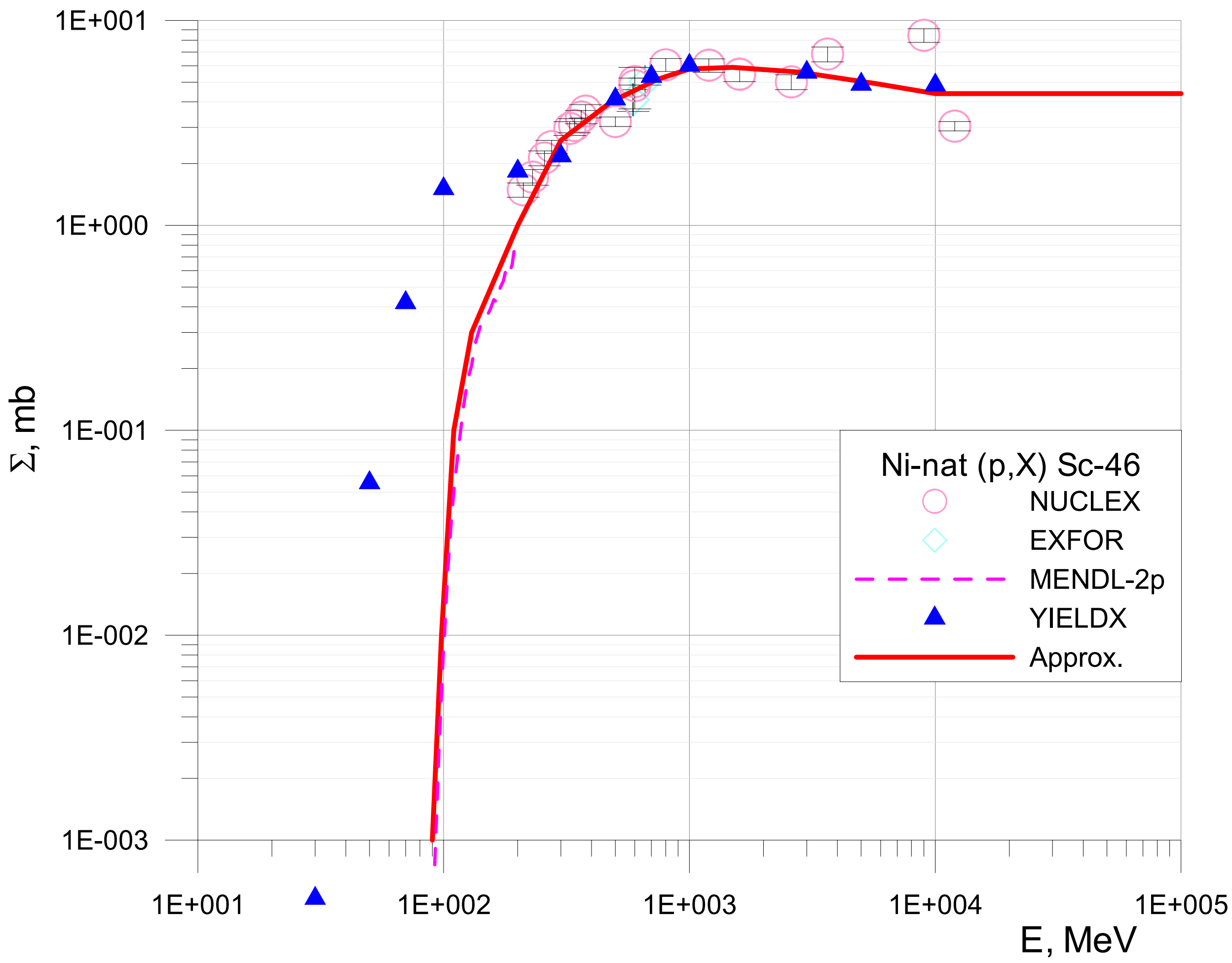
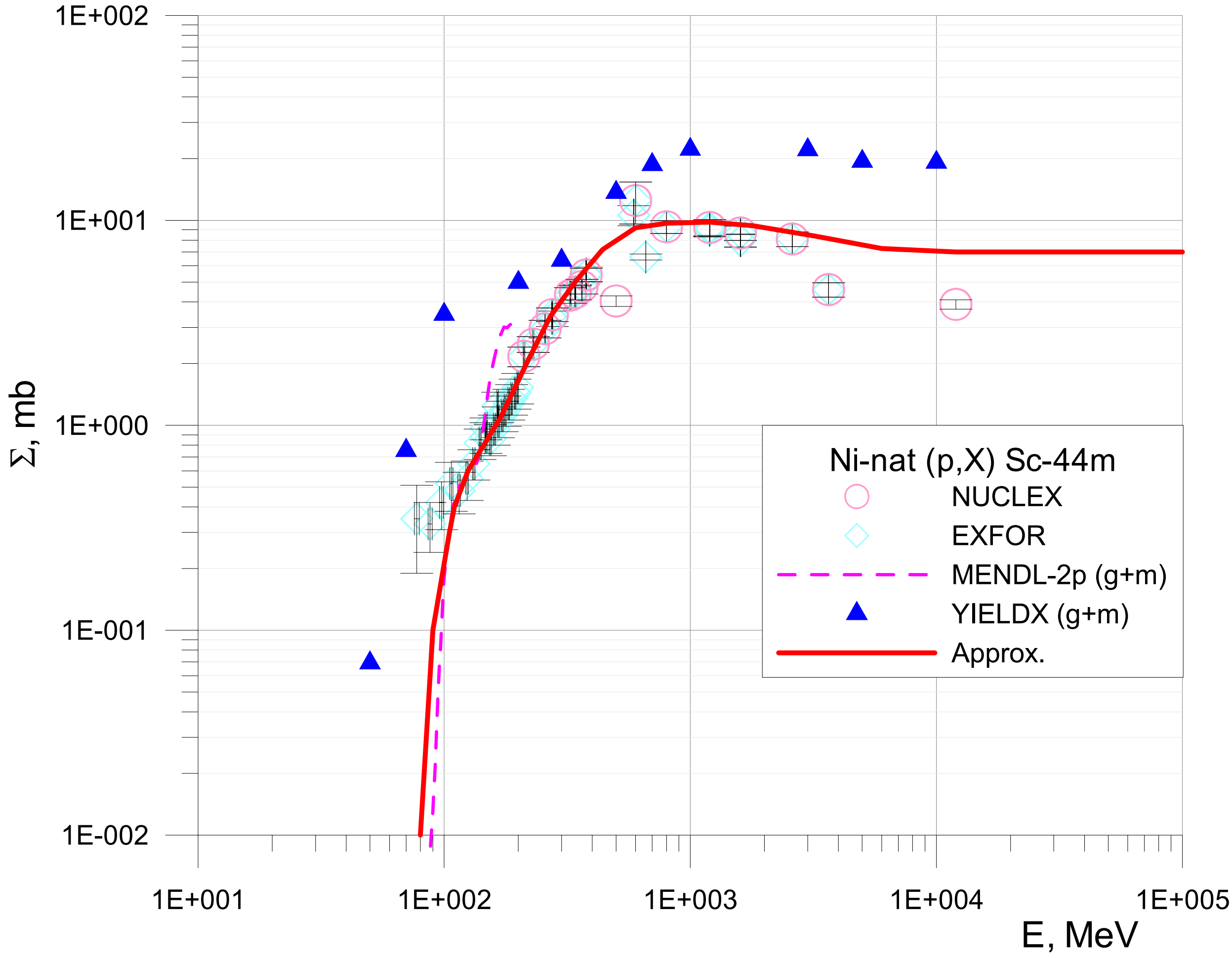
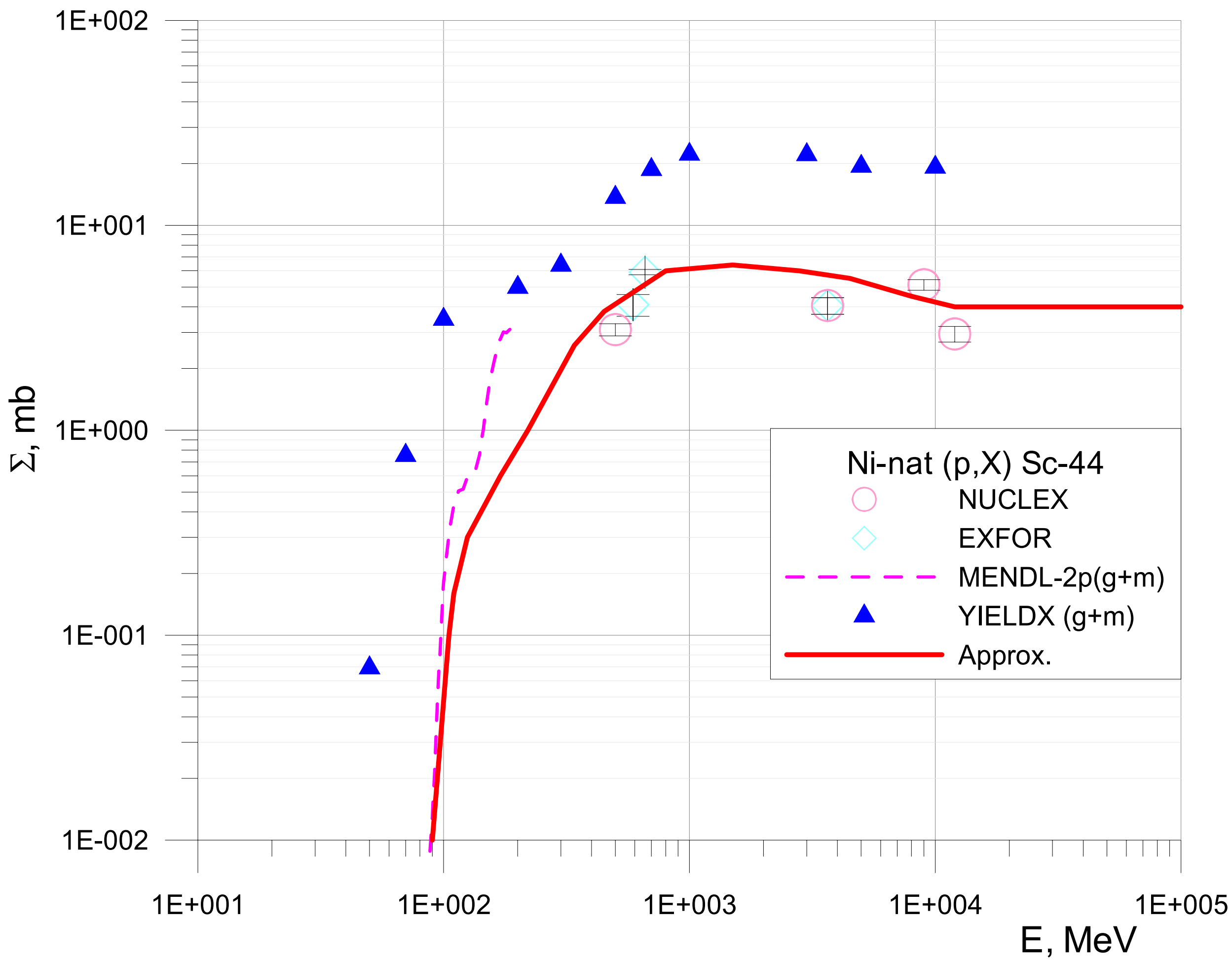
17		
18		



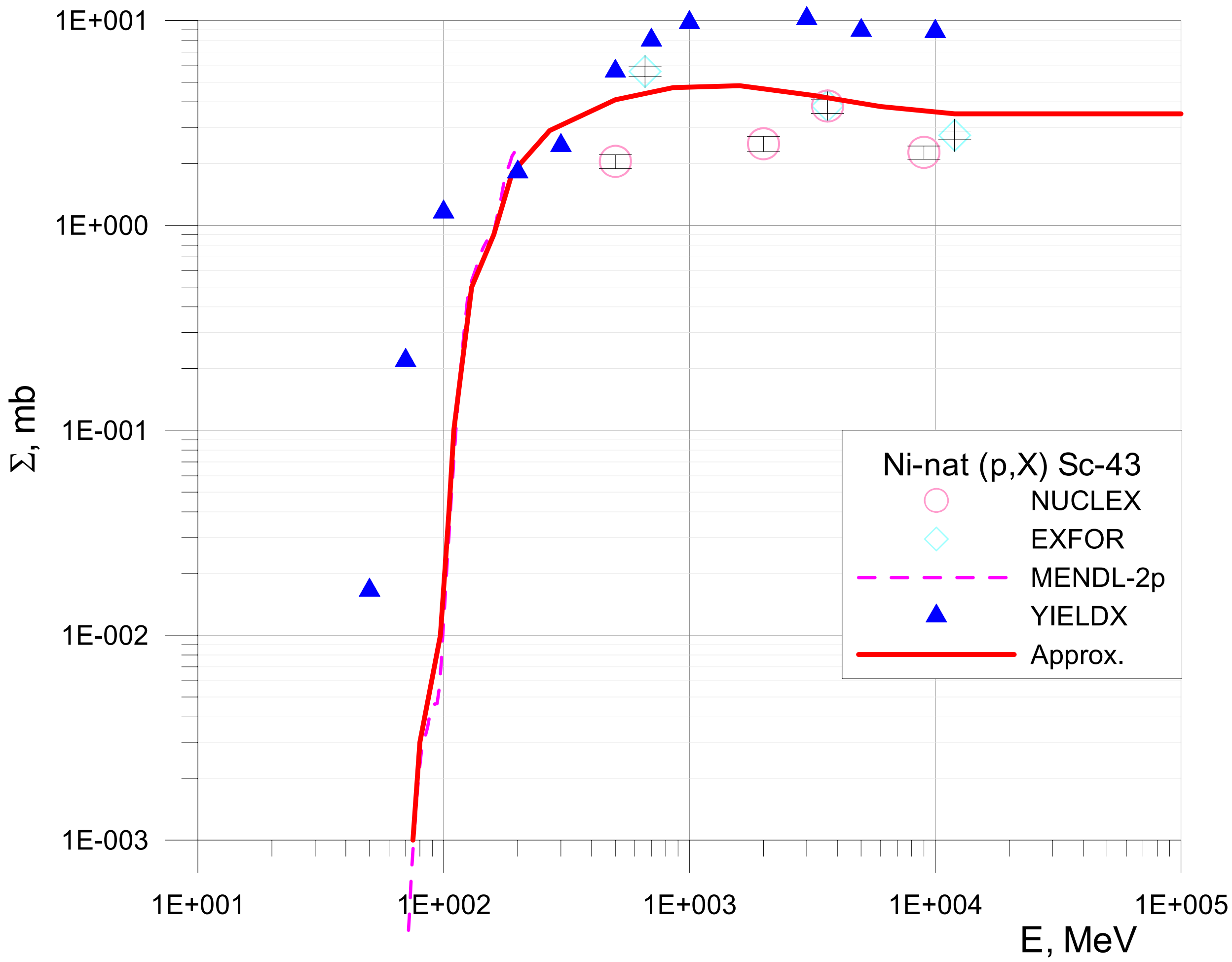
##	E, MeV	Σ, mb
1	25.3	0.000
2	90	0.001
3	98	0.01
4	110	0.1
5	130	0.3
6	200	1.0
7	300	2.6
8	480	4.0
9	740	5.2
10	1000	5.8
11	1500	5.9
12	2800	5.6
13	5800	4.9
14	10000	4.4
15	100000	4.4
16		
17		
18		



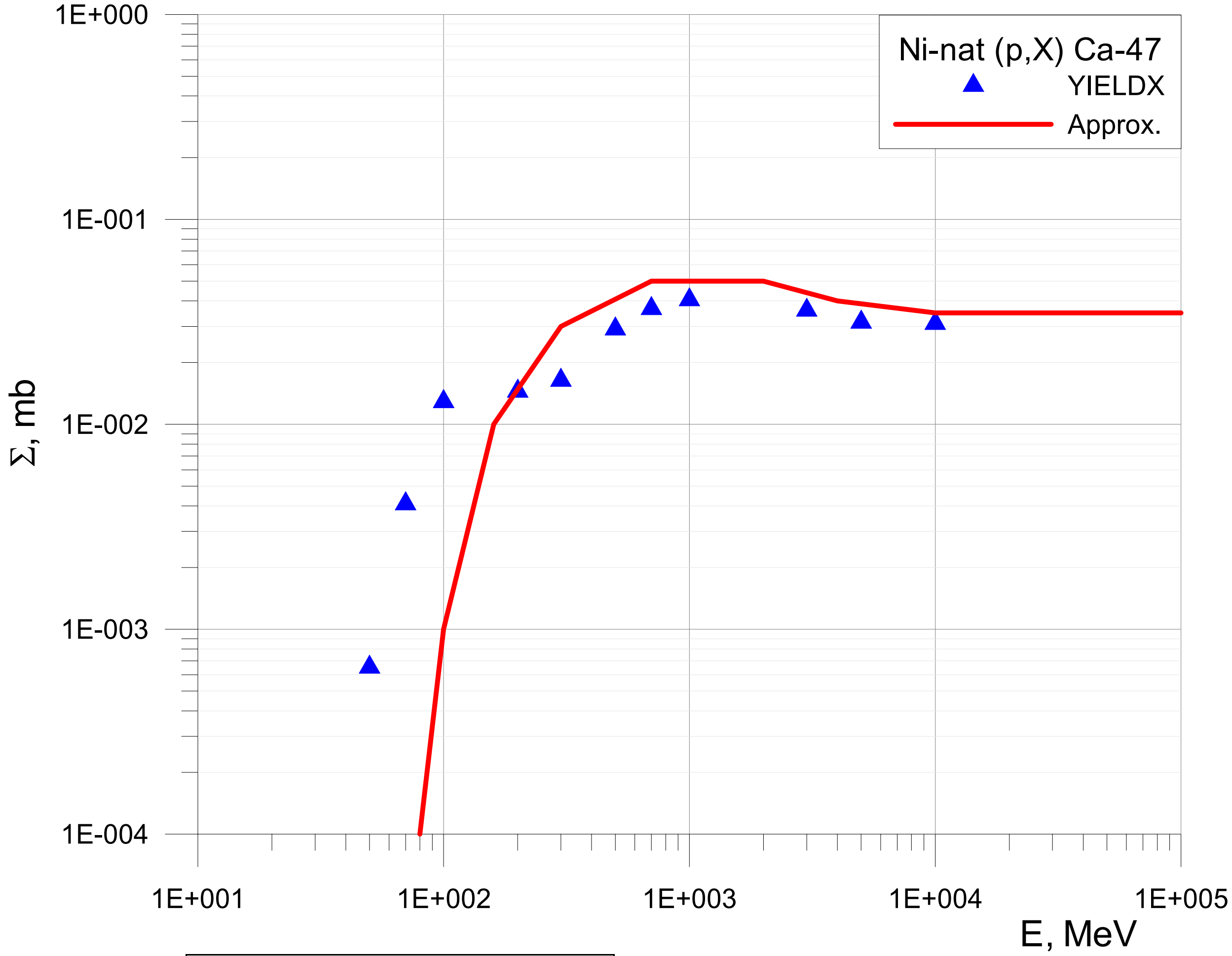
##	E, MeV	Σ, mb
1	37.8	0.00
2	80	0.01
3	90	0.1
4	105	0.3
5	110	0.4
6	125	0.6
7	170	1.1
8	220	2.1
9	270	3.4
10	340	5.0
11	440	7.2
12	600	9.2
13	800	9.7
14	1200	9.8
15	1800	9.4
16	3200	8.4
17	6000	7.3
18	12000	7.0
19	100000	7.0



##	E, MeV	Σ, mb
1	37.8	0.000
2	80	0.001
3	90	0.01
4	105	0.1
5	110	0.2
6	125	0.3
7	170	0.6
8	220	1.0
9	340	2.6
10	450	3.8
11	800	6.0
12	1500	6.4
13	2800	6.0
14	4500	5.5
15	8000	4.5
16	12000	4.0
17	100000	4.0
18		



##	E, MeV	Σ, mb
1	26.9	0.000
2	75	0.001
3	80	0.003
4	97	0.01
5	105	0.04
6	110	0.1
7	130	0.5
8	160	0.9
9	190	1.8
10	270	2.9
11	500	4.1
12	860	4.7
13	1600	4.8
14	3200	4.3
15	6000	3.8
16	12000	3.5
17	100000	3.5
18		



##	E, MeV	Σ, mb
1	80	0.0001
2	100	0.001
3	160	0.01
4	300	0.03
5	700	0.05
6	1000	0.05
7	2000	0.05
8	4000	0.04
9	10000	0.035
10	100000	0.035
11		
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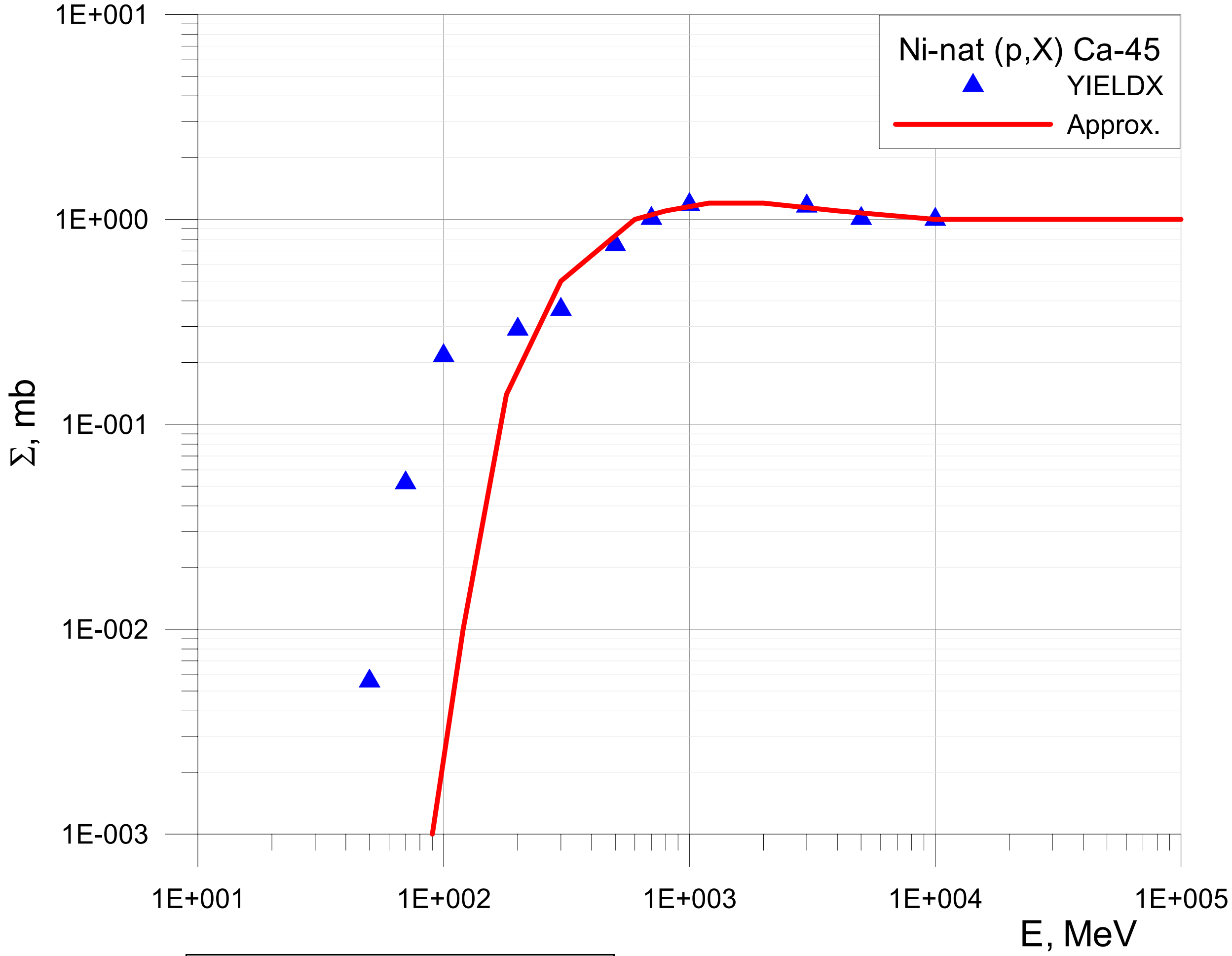
18		



##	E, MeV	Σ, mb
1	90	0.001
2	120	0.01
3	180	0.14
4	300	0.5
5	600	1.0
6	800	1.1
7	1200	1.2
8	2000	1.2
9	4000	1.1
10	10000	1.0
11	100000	1.0
12		
13		
14		
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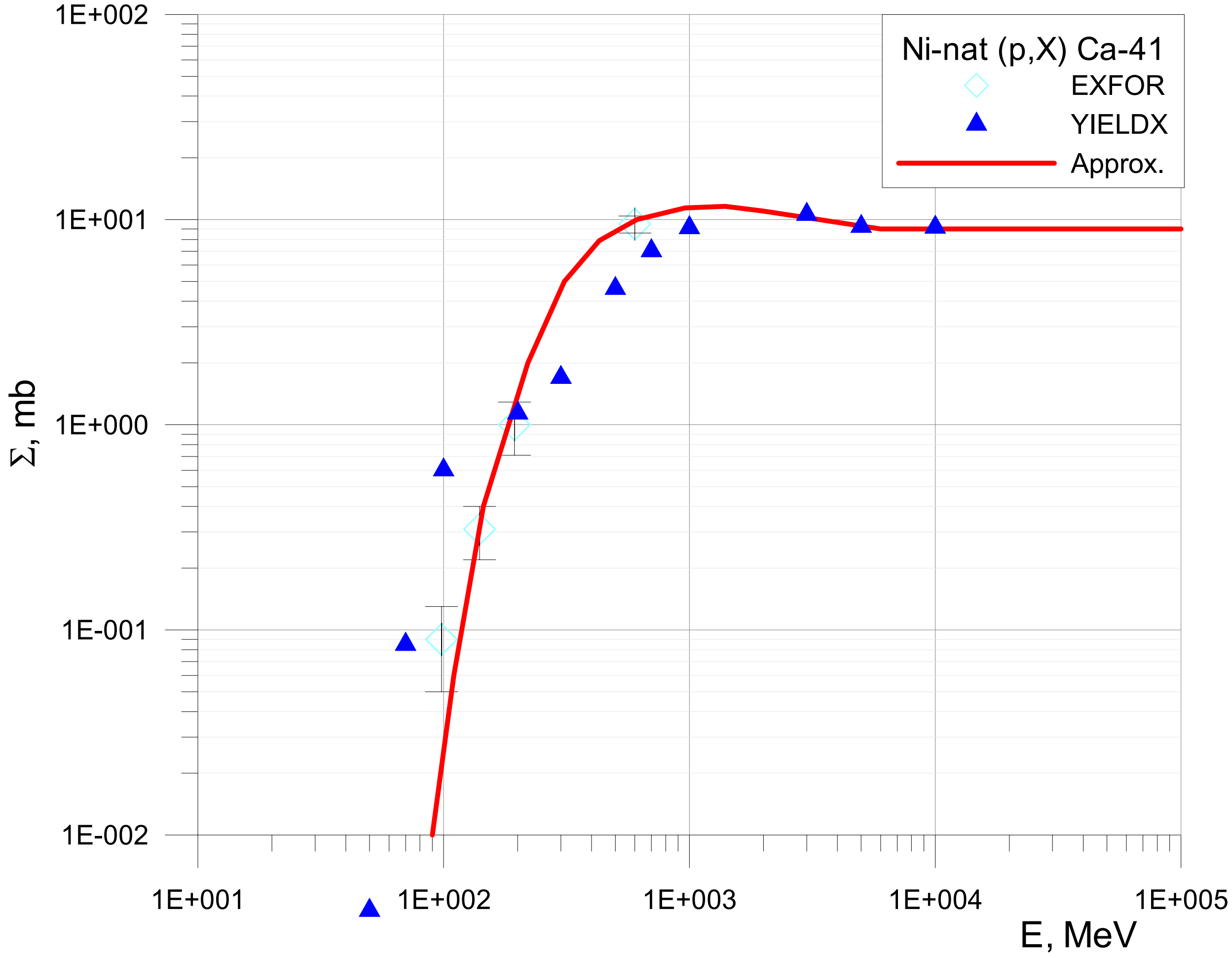
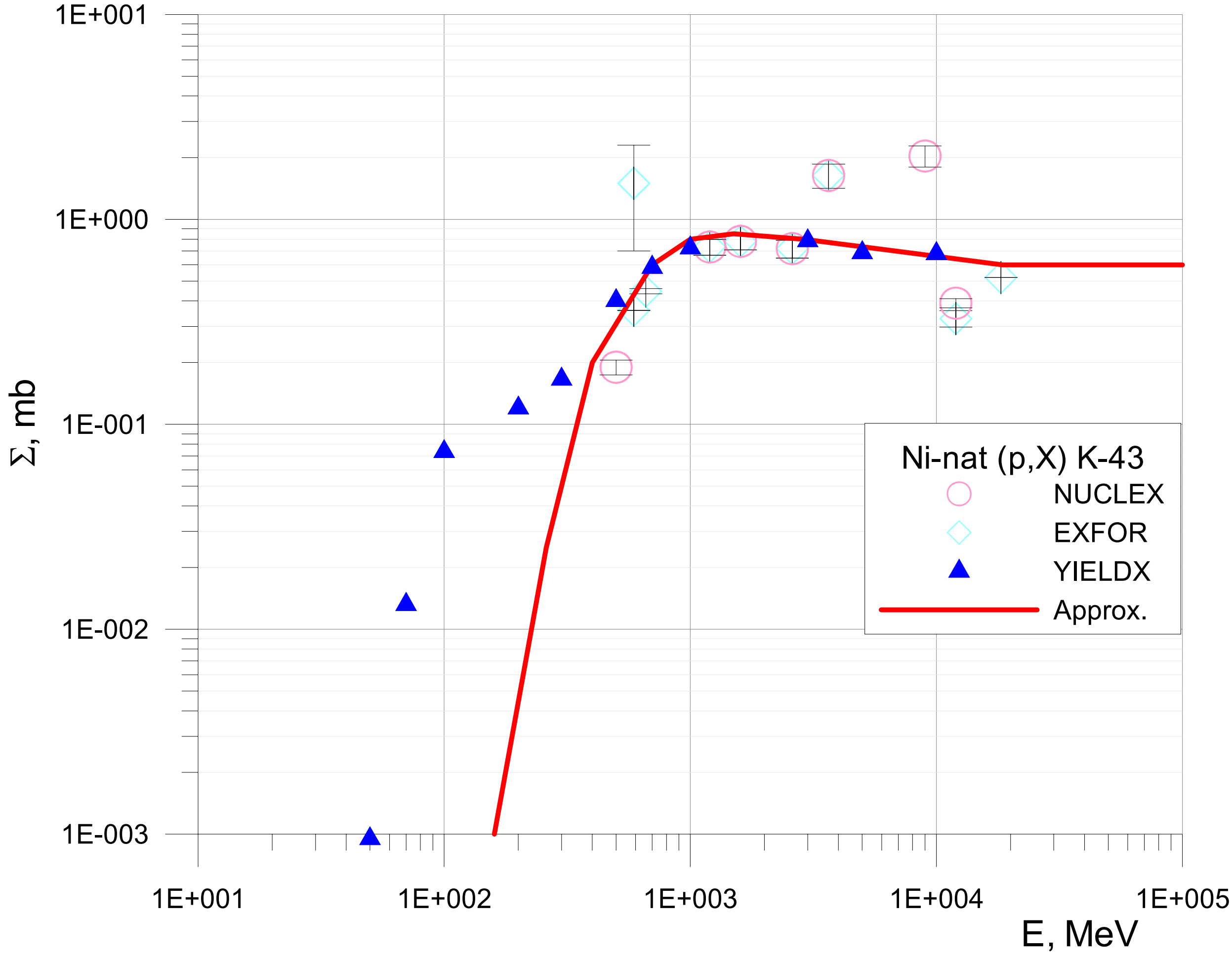
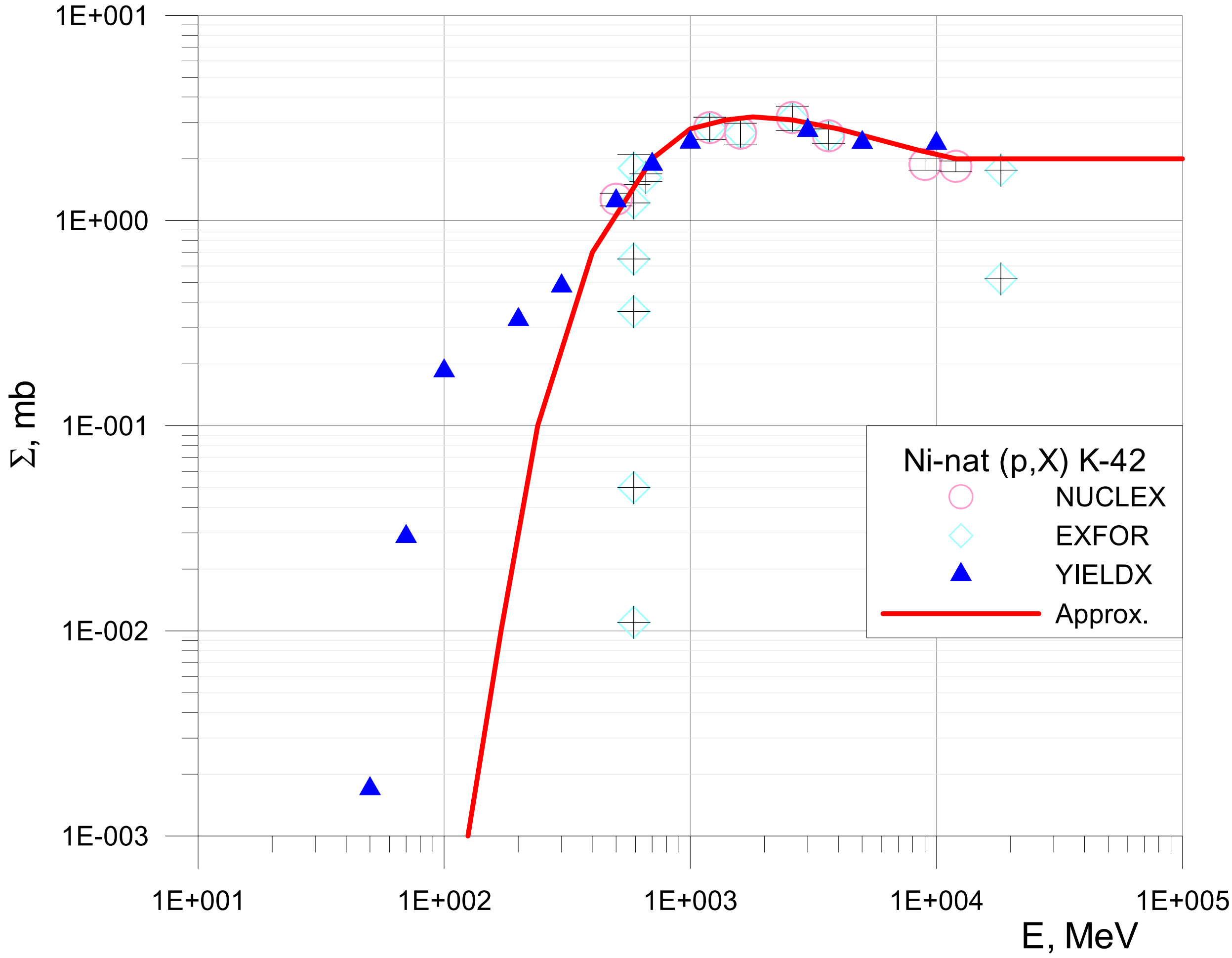
18		



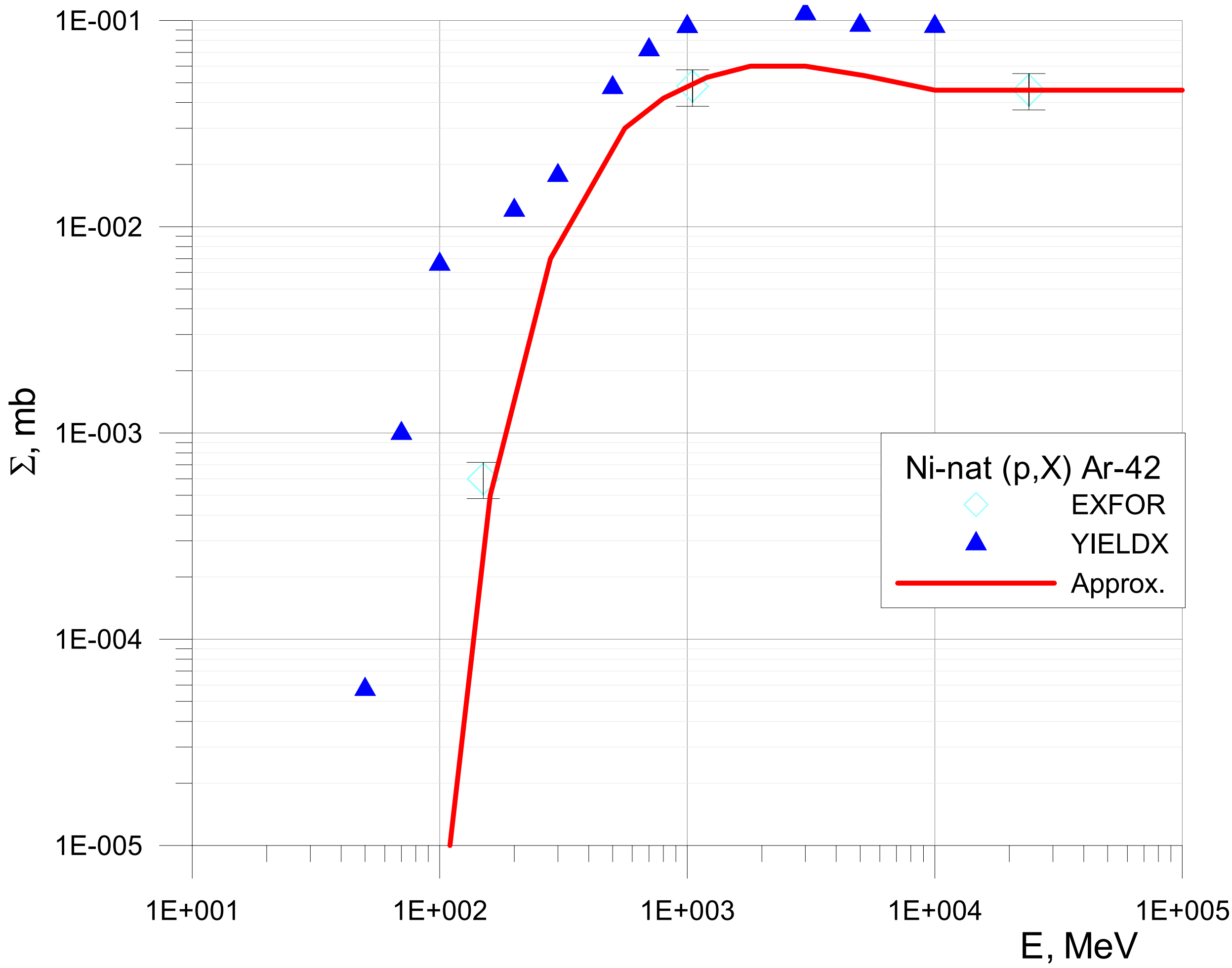
##	E, MeV	Σ, mb
1	41.3	0.00
2	90	0.01
3	110	0.06
4	145	0.40
5	220	2.00
6	310	5.00
7	430	7.90
8	610	10.0
9	960	11.4
10	1400	11.6
11	2000	11.0
12	6000	9.0
13	100000	9.0
14		
15		
16		
17		
18		



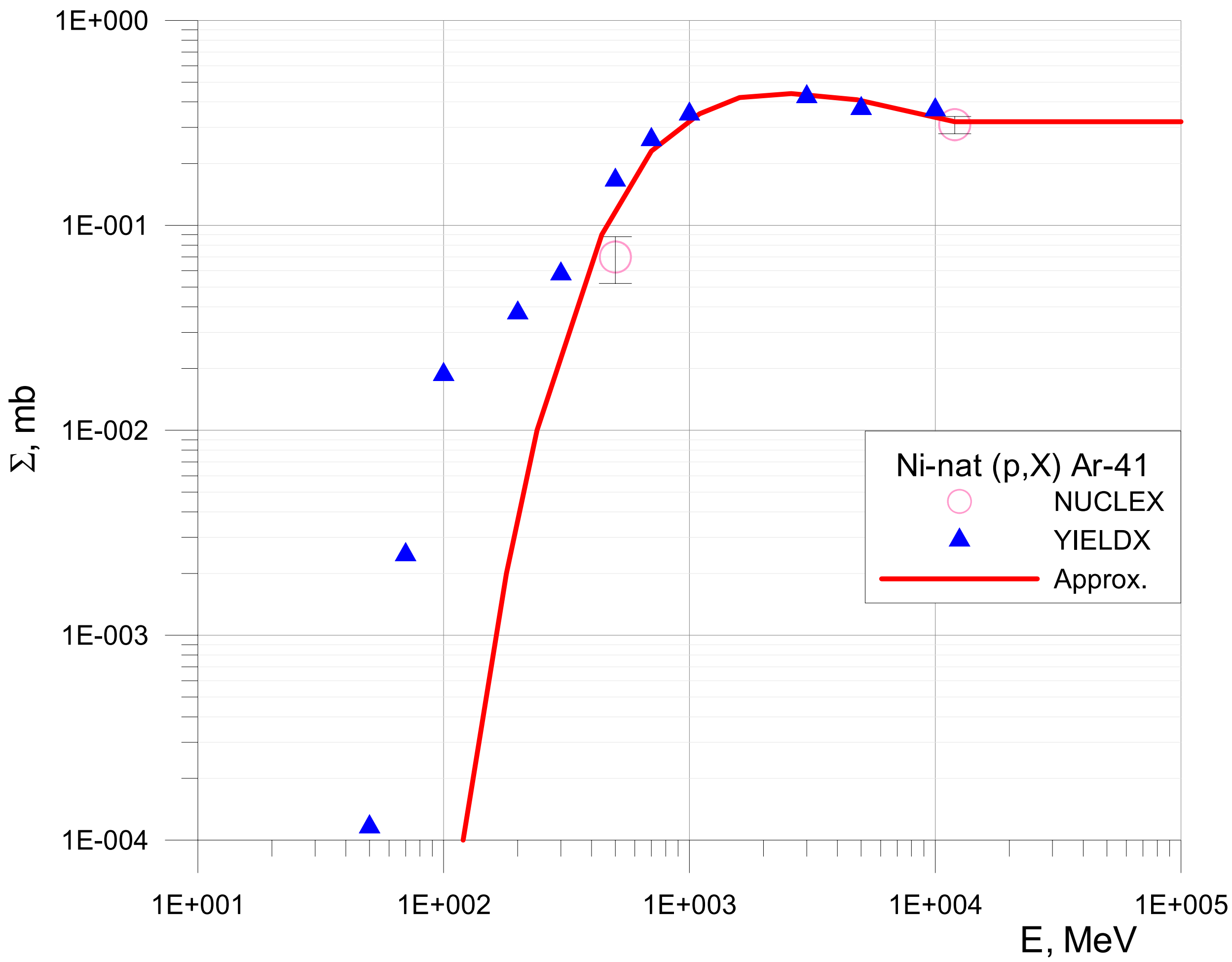
##	E, MeV	Σ, mb
1	35.6	0.000
2	160	0.001
3	260	0.03
4	400	0.20
5	700	0.60
6	1000	0.80
7	1500	0.85
8	2900	0.80
9	6800	0.70
10	18600	0.60
11	100000	0.60
12		
13		
14		
15		
16		
17		
18		



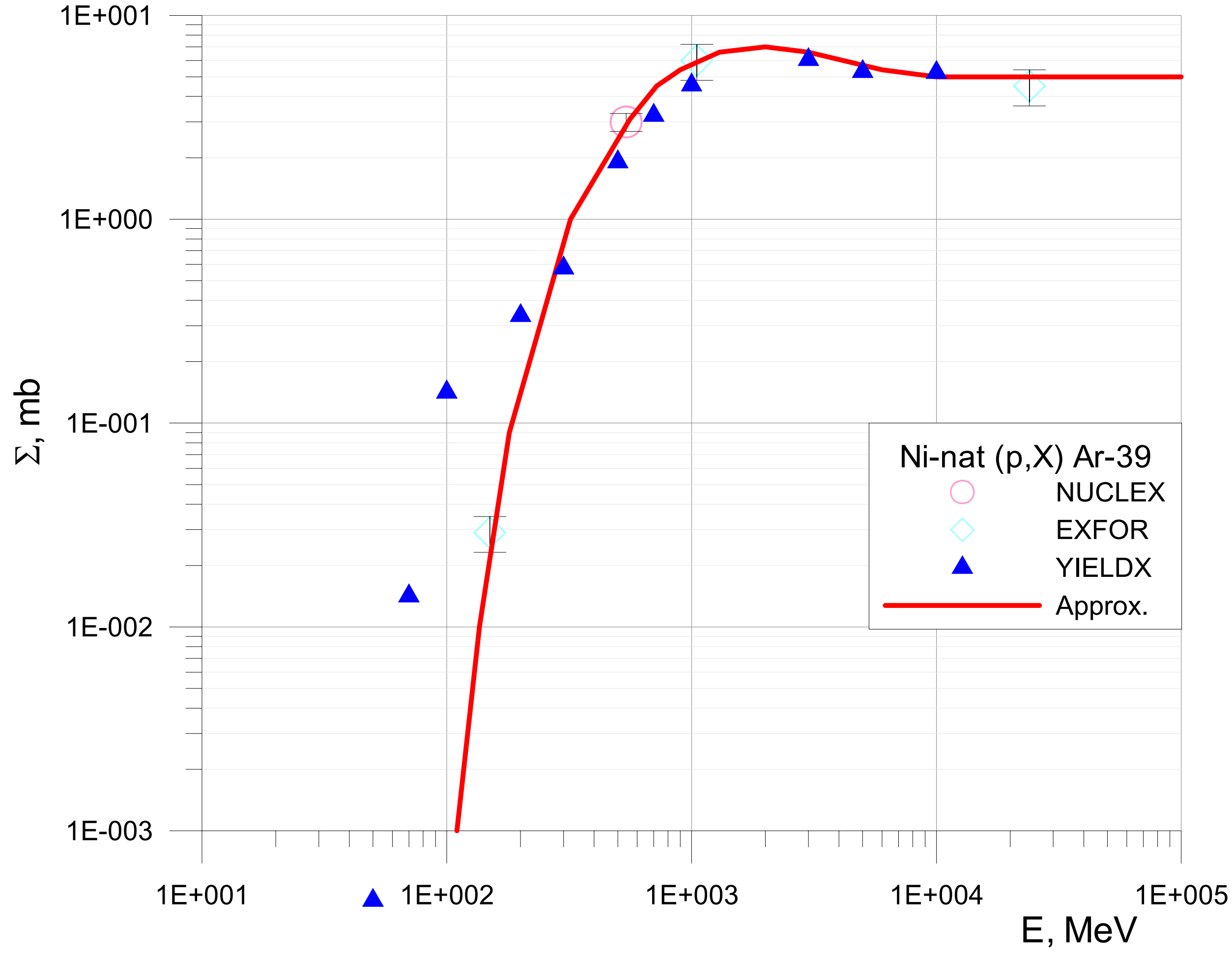
##	E, MeV	Σ, mb
1	34.6	0.000
2	125	0.001
3	170	0.01
4	240	0.10
5	400	0.7
6	700	2.0
7	1000	2.8
8	1400	3.1
9	1800	3.2
10	2600	3.1
11	4000	2.8
12	8500	2.2
13	12000	2.0
14	100000	2.0
15		
16		
17		
18		



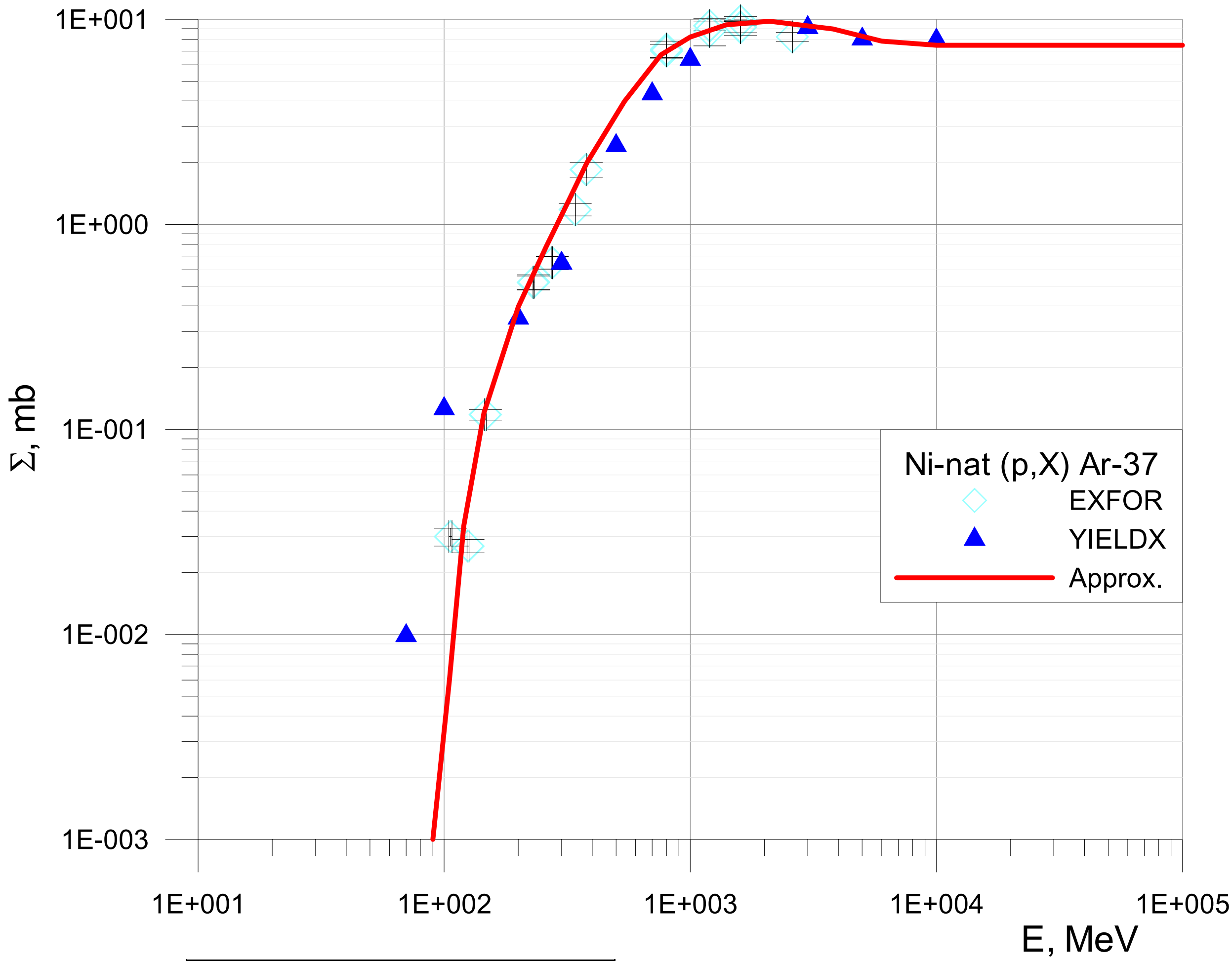
##	E, MeV	Σ, mb
1	45.2	0.00000
2	110	0.00001
3	160	0.0005
4	280	0.007
5	560	0.030
6	800	0.042
7	1200	0.053
8	1800	0.060
9	3000	0.060
10	5200	0.054
11	10000	0.046
12	100000	0.046
13		
14		
15		
16		
17		
18		



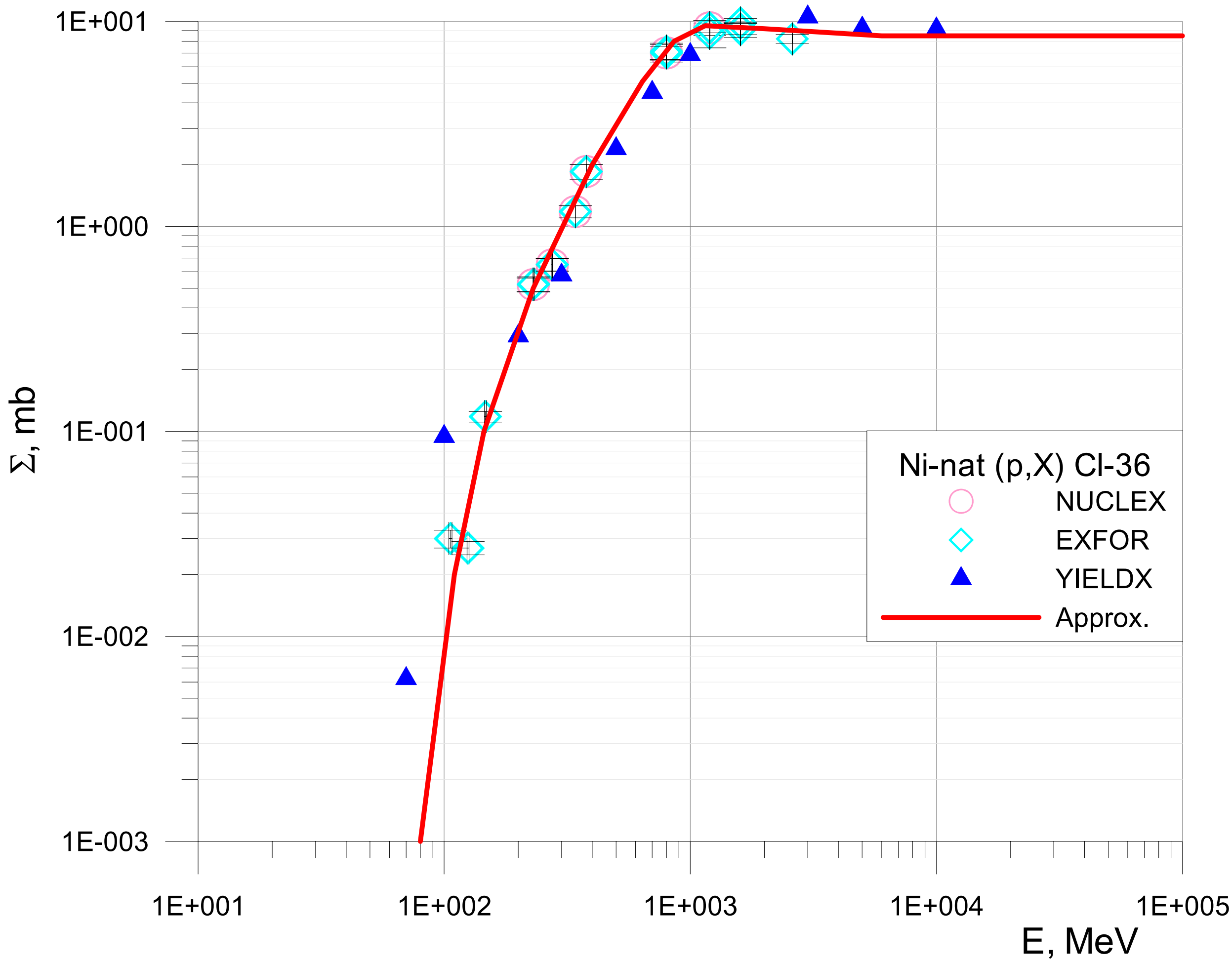
##	E, MeV	Σ, mb
1	44	0.0000
2	120	0.0001
3	180	0.002
4	240	0.01
5	440	0.09
6	700	0.23
7	1100	0.35
8	1600	0.42
9	2600	0.44
10	4800	0.41
11	12000	0.32
12	100000	0.32
13		
14		
15		
16		
17		
18		



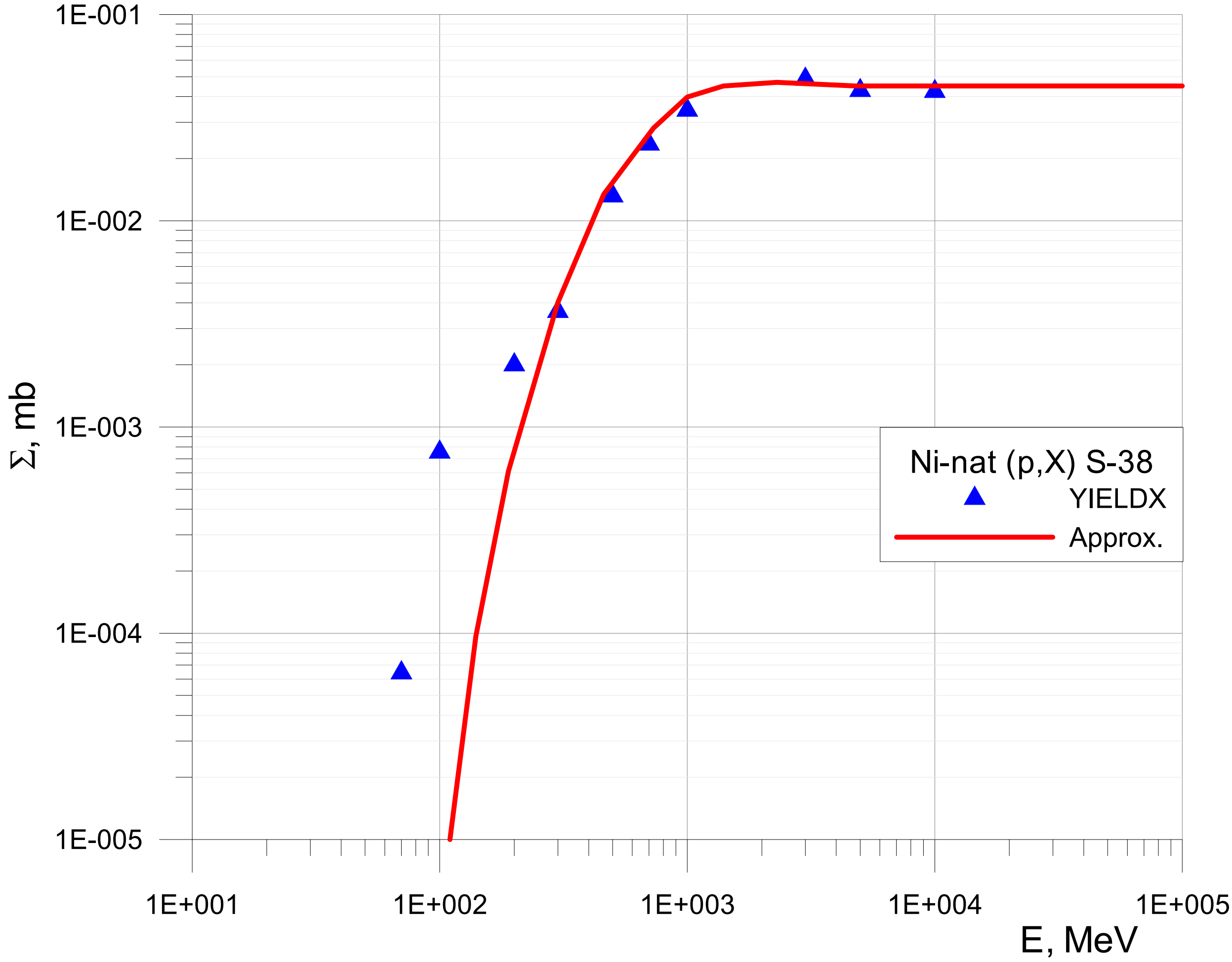
##	E, MeV	Σ, mb
1	50	0.000
2	110	0.001
3	136	0.010
4	180	0.09
5	320	1.0
6	560	3.1
7	720	4.5
8	900	5.4
9	1300	6.6
10	2000	7.0
11	3000	6.6
12	6000	5.4
13	10000	5.0
14	100000	5.0
15		
16		
17		
18		



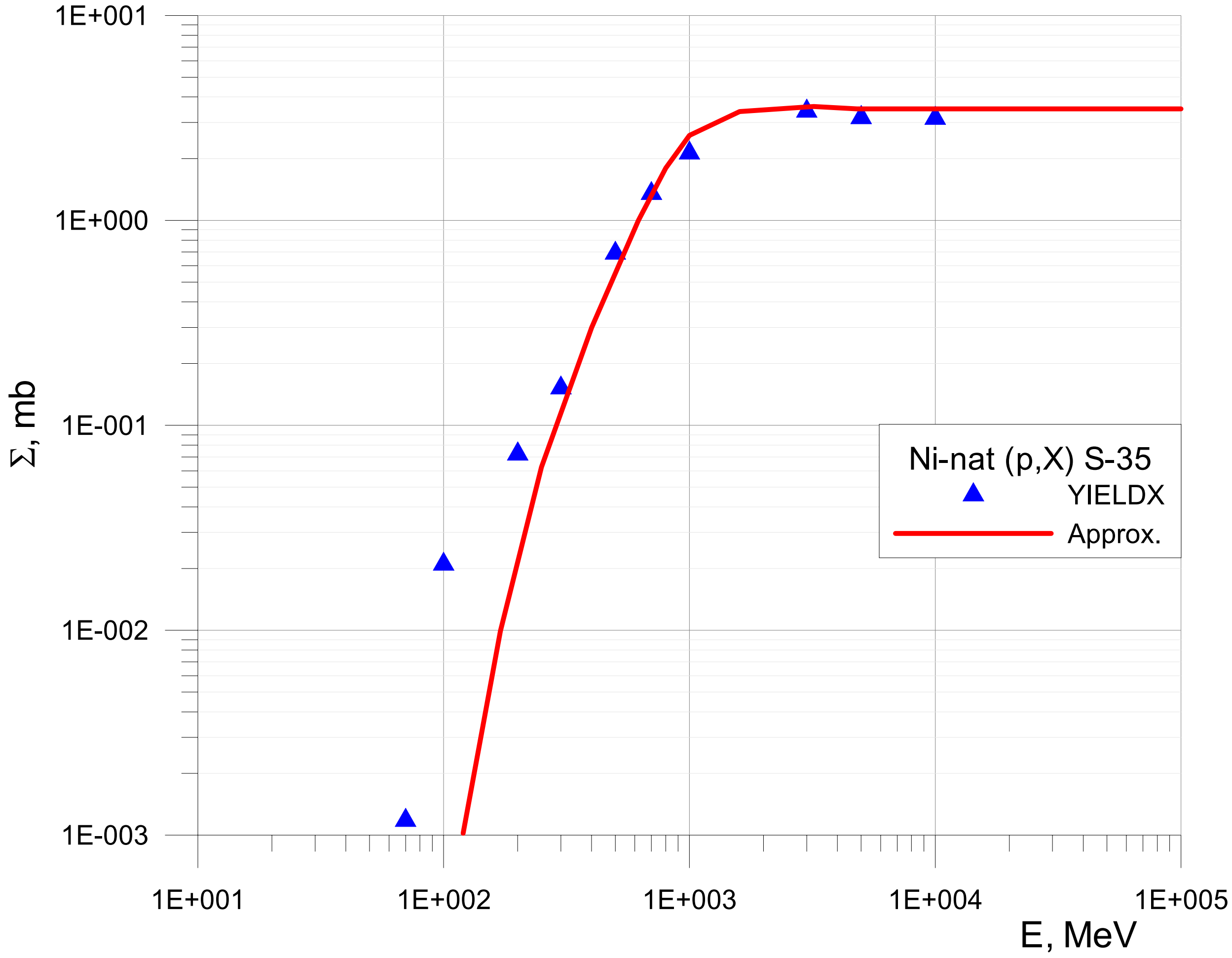
##	E, MeV	Σ, mb
1	48.1	0.000
2	90	0.001
3	105	0.006
4	120	0.034
5	145	0.12
6	200	0.40
7	260	0.78
8	320	1.3
9	380	2.0
10	540	4.0
11	760	6.7
12	1000	8.2
13	1400	9.4
14	2100	9.8
15	3800	9.0
16	6000	7.8
17	10000	7.5
18	100000	7.5



##	E, MeV	Σ, mb
1	51.4	0.000
2	80	0.001
3	110	0.02
4	145	0.1
5	230	0.5
6	400	2.0
7	640	5.1
8	860	8.0
9	1150	9.5
10	2000	9.2
11	6000	8.5
12	100000	8.5
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	110	0.00001
2	140	0.0001
3	190	0.0006
4	300	0.004
5	460	0.013
6	730	0.028
7	1000	0.040
8	1400	0.045
9	2300	0.047
10	4800	0.045
11	100000	0.045
12		
13		
14		
15		
16		
17		
18		



##	E, MeV	Σ, mb
1	120	0.001
2	170	0.010
3	250	0.06
4	400	0.3
5	620	1.0
6	800	1.8
7	1000	2.6
8	1600	3.4
9	3200	3.6
10	4800	3.5
11	100000	3.5
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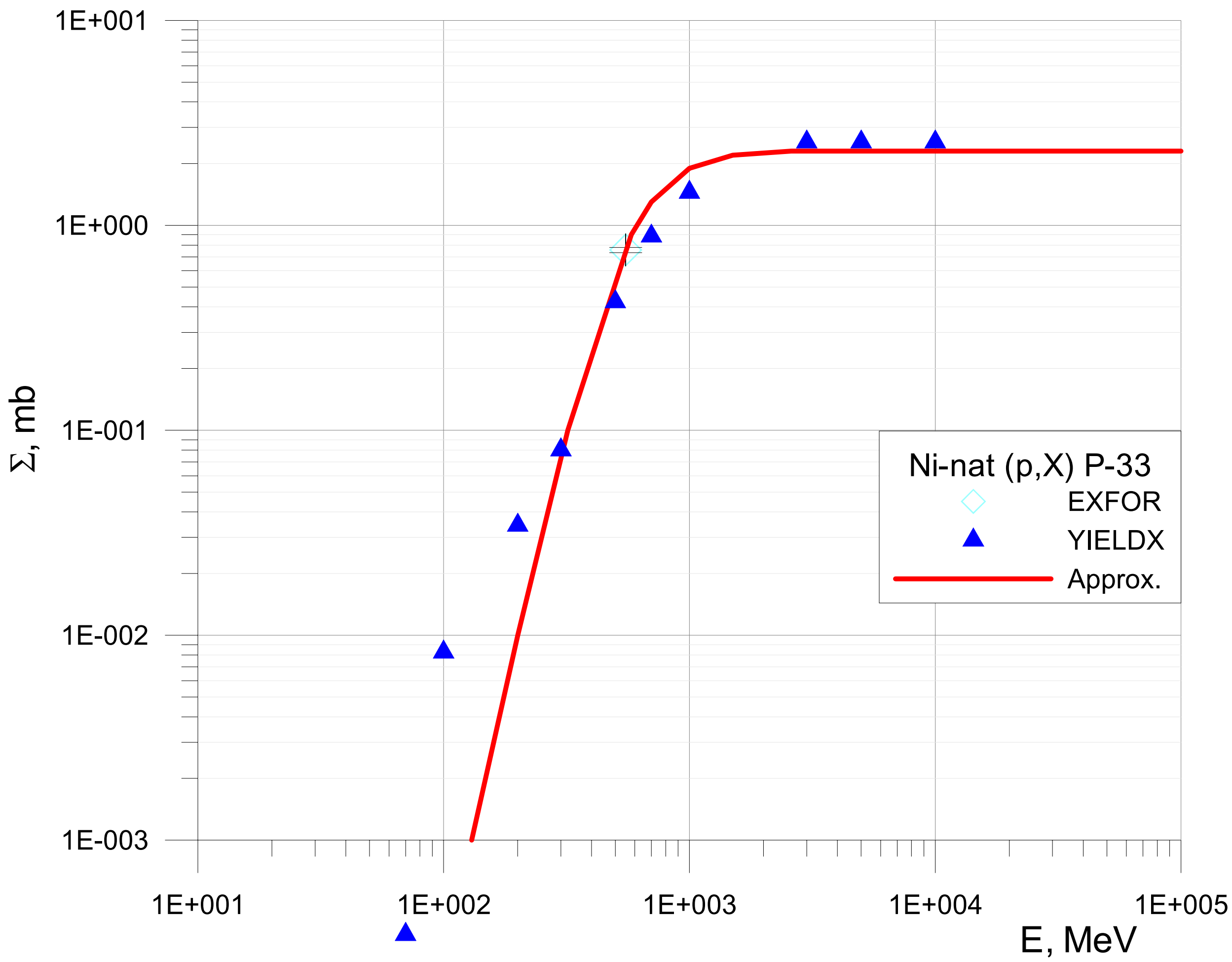

##	E, MeV	Σ, mb
1	130	0.001
2	200	0.01
3	320	0.10
4	580	0.90
5	700	1.3
6	1000	1.9
7	1500	2.2
8	2600	2.3
9	100000	2.3
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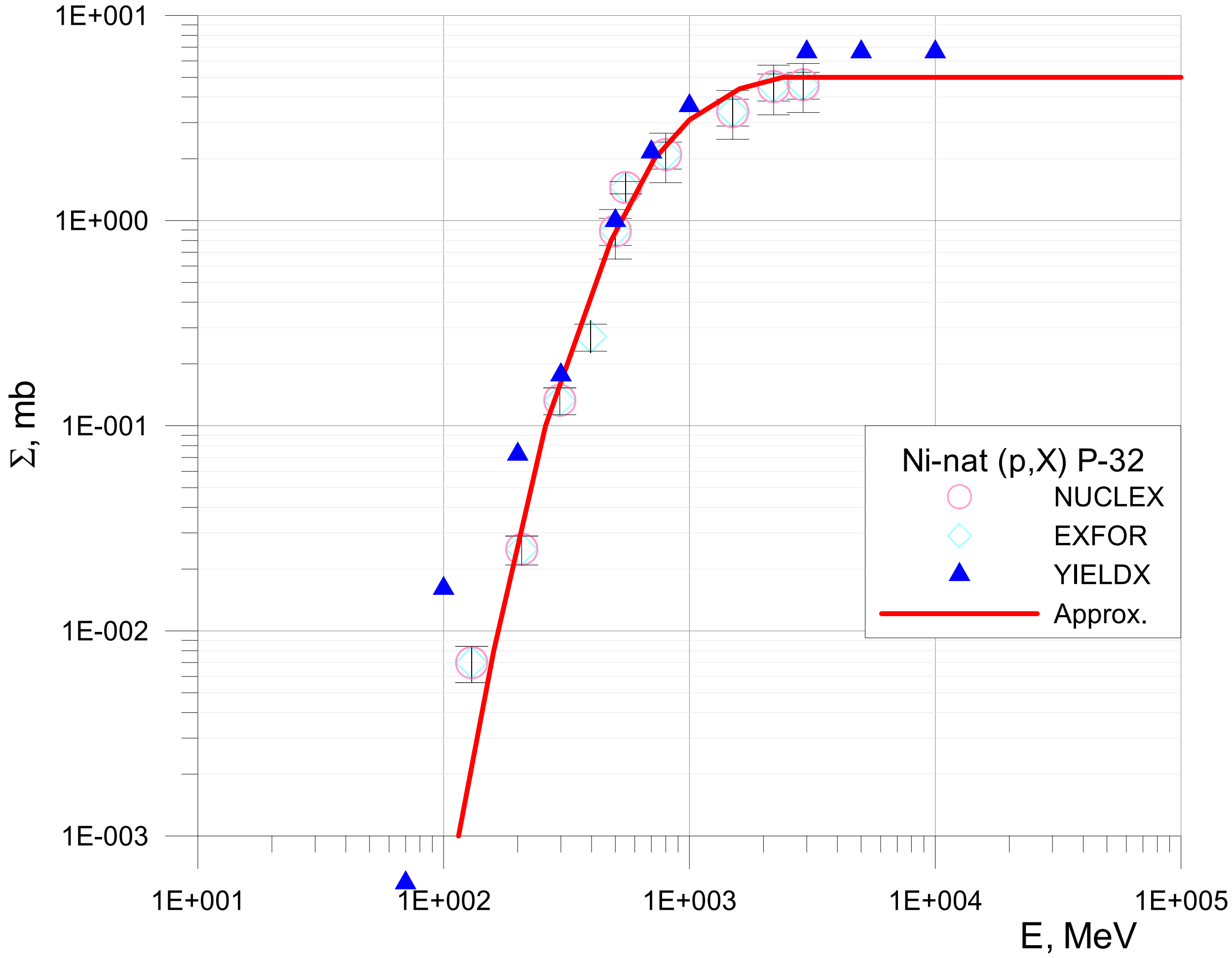

##	E, MeV	Σ, mb
1	115	0.001
2	160	0.008
3	260	0.10
4	480	0.80
5	720	2.0
6	1000	3.1
7	1600	4.4
8	2400	5.0
9	100000	5.0
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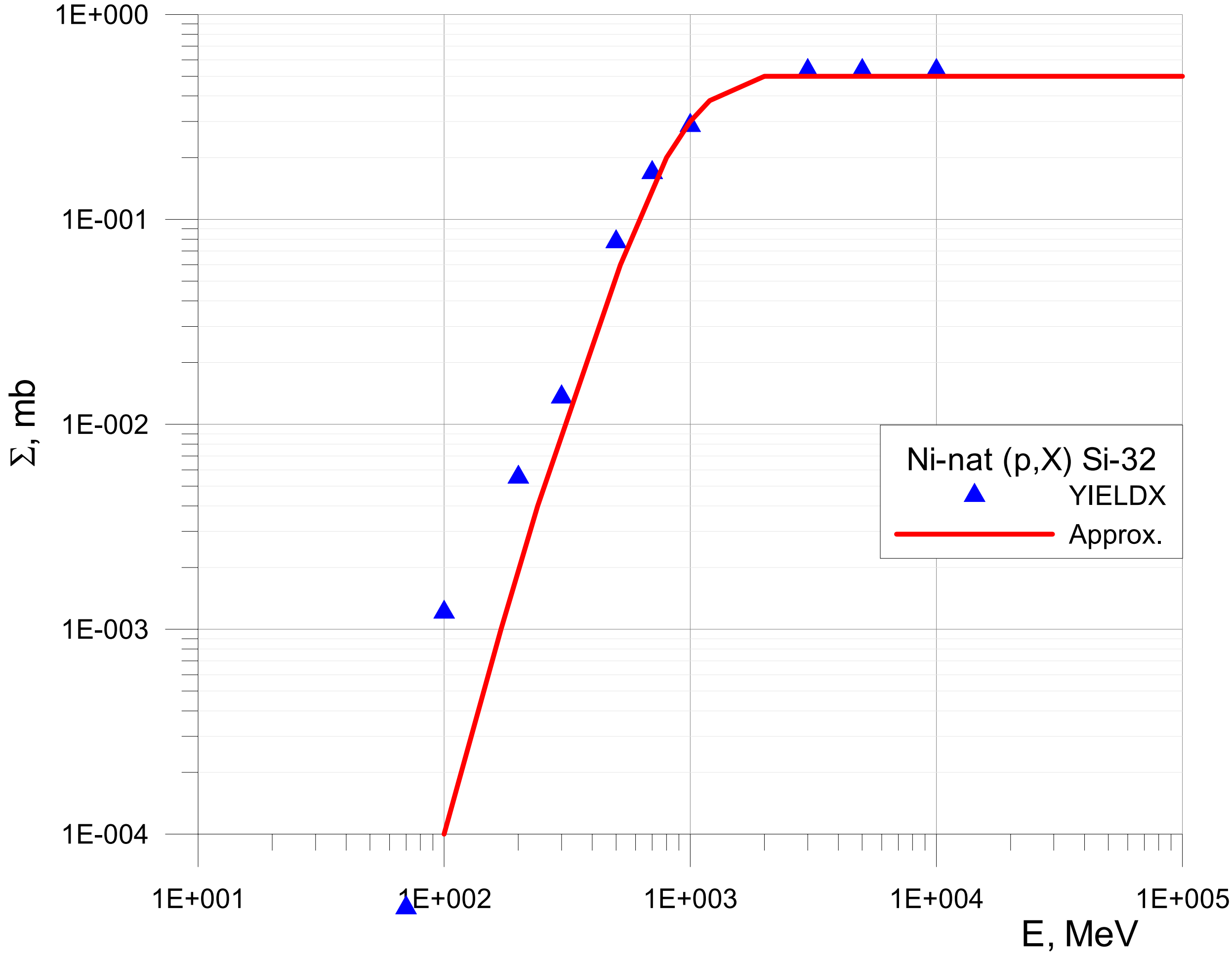

##	E, MeV	Σ, mb
1	100	0.0001
2	170	0.001
3	240	0.004
4	520	0.06
5	800	0.20
6	1000	0.30
7	1200	0.38
8	2000	0.50
9	10000 0	0.50
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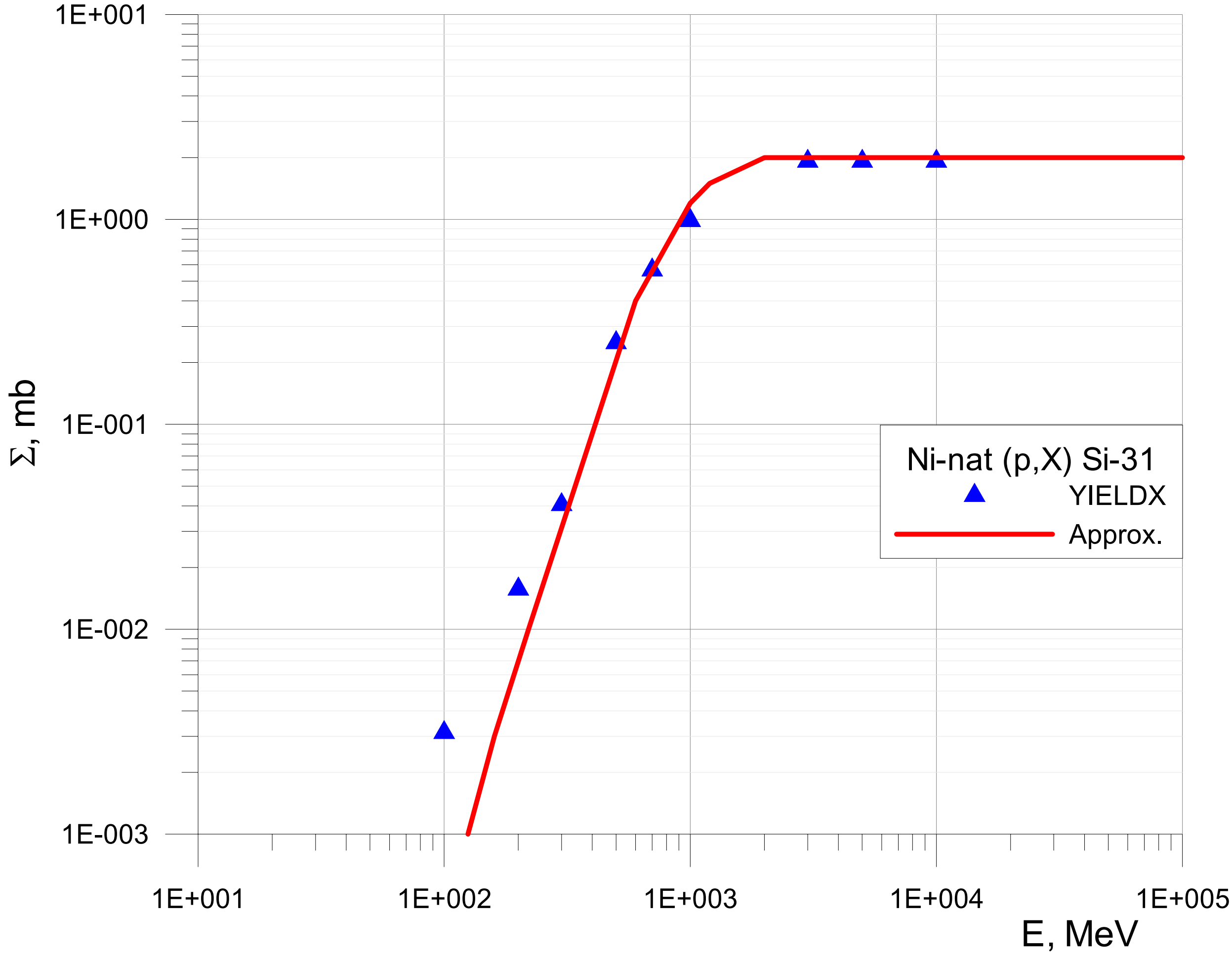

##	E, MeV	Σ, mb
1	125	0.001
2	160	0.003
3	220	0.01
4	600	0.40
5	1000	1.2
6	1200	1.5
7	2000	2.0
8	100000	2.0
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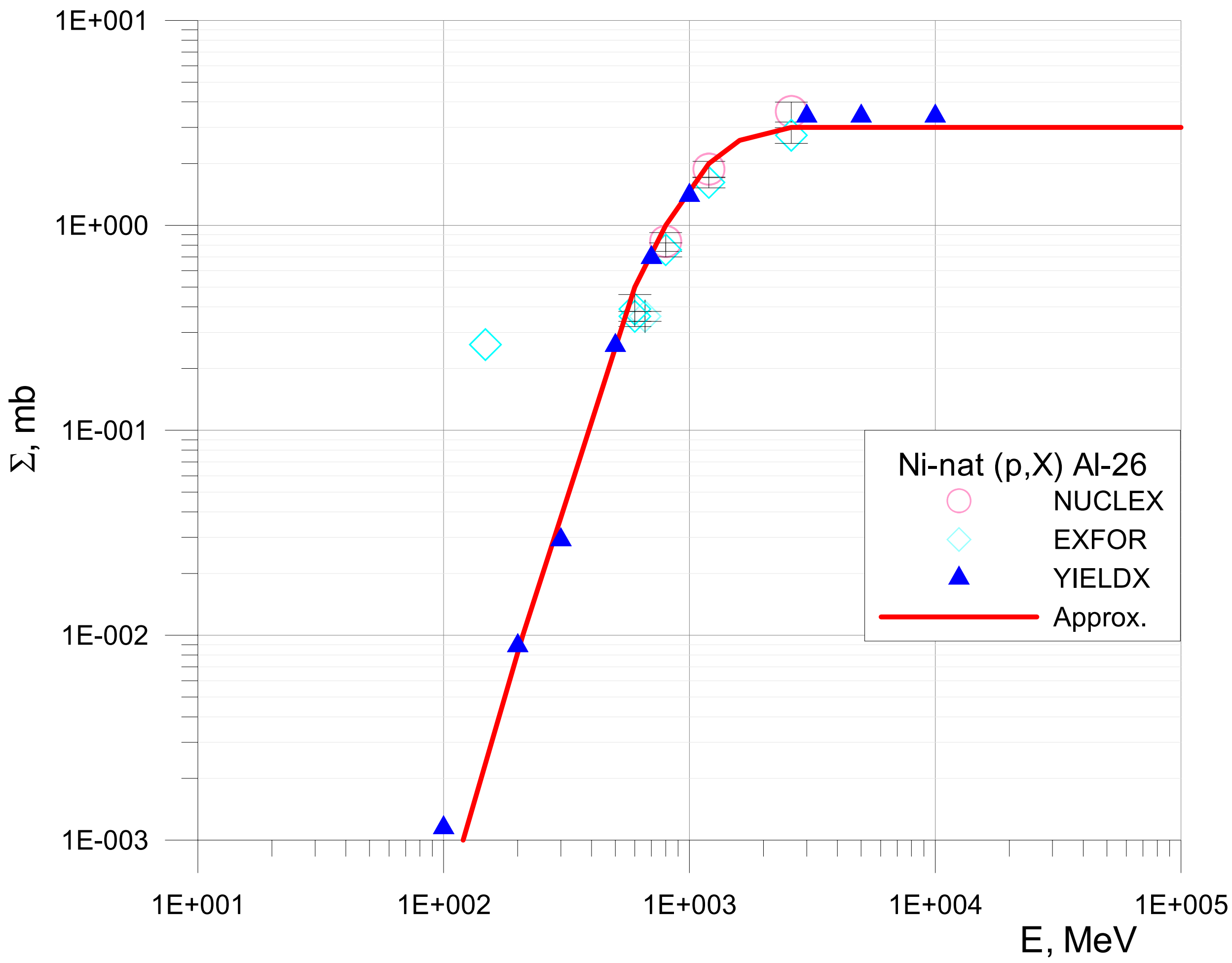

##	E, MeV	Σ, mb
1	120	0.001
2	210	0.01
3	340	0.06
4	600	0.5
5	800	1.0
6	1200	2.0
7	1600	2.6
8	2600	3.0
9	100000	3.0
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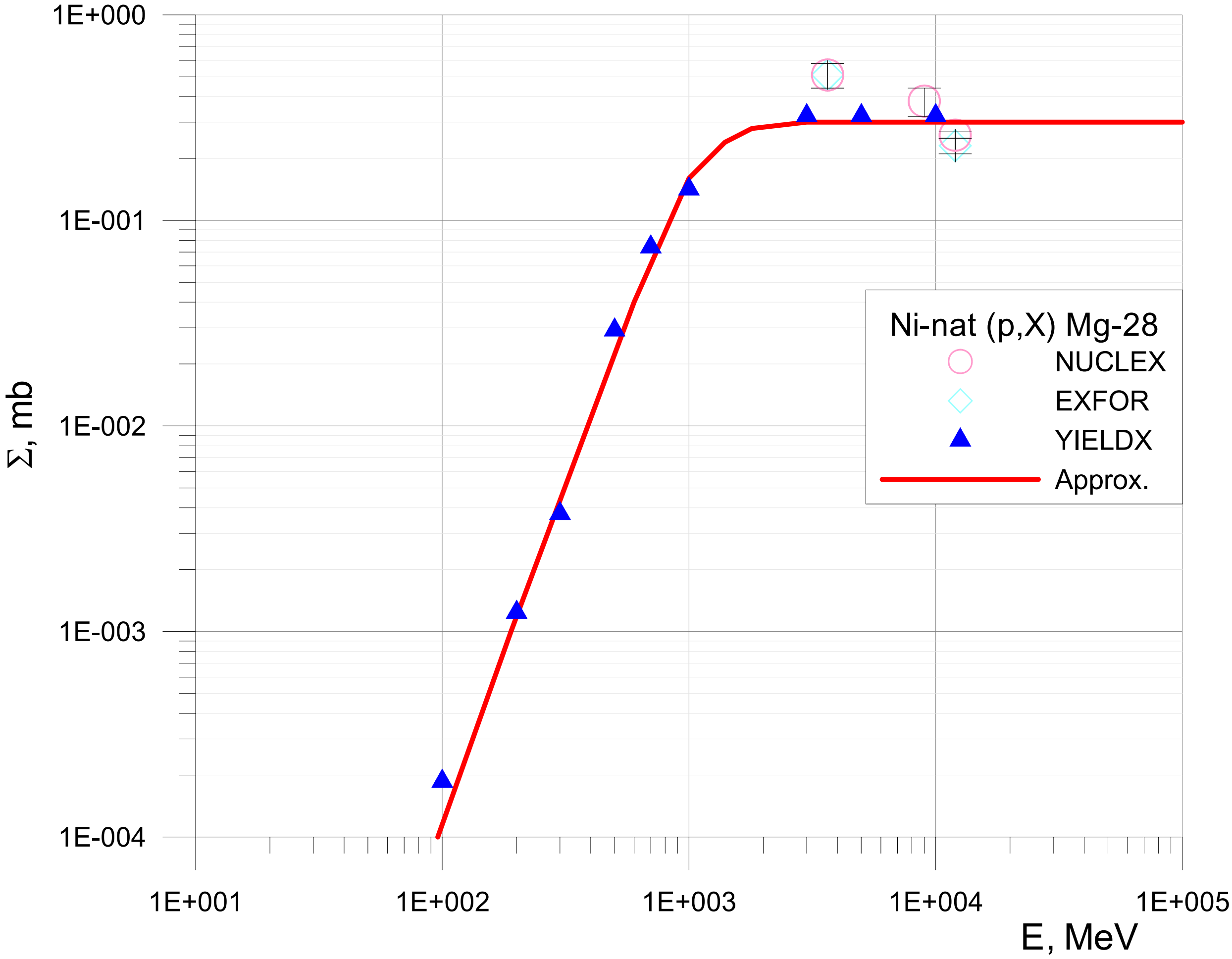

##	E, MeV	Σ, mb
1	96	0.0001
2	190	0.001
3	600	0.04
4	1000	0.16
5	1400	0.24
6	1800	0.28
7	3000	0.30
8	100000	0.30
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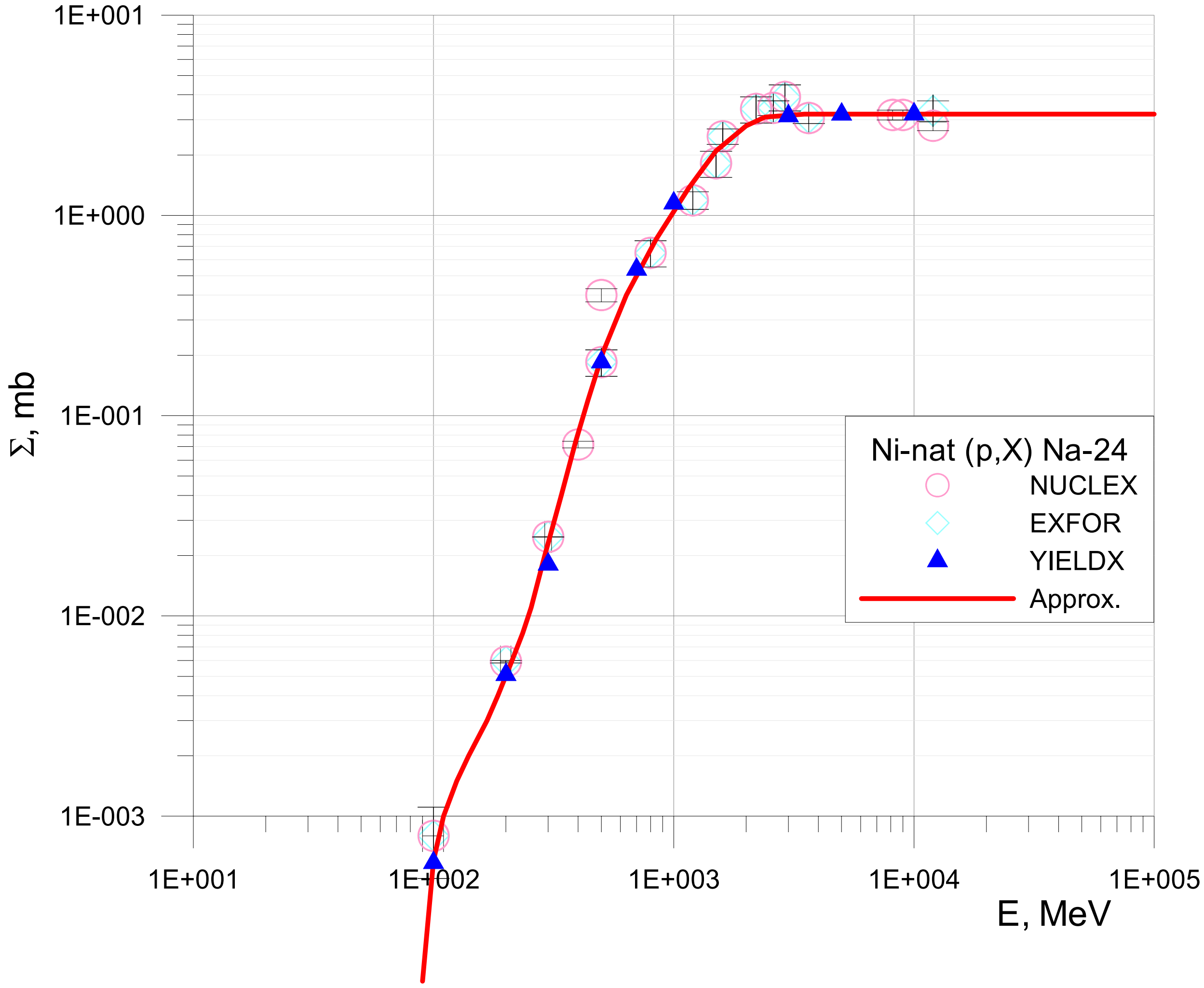
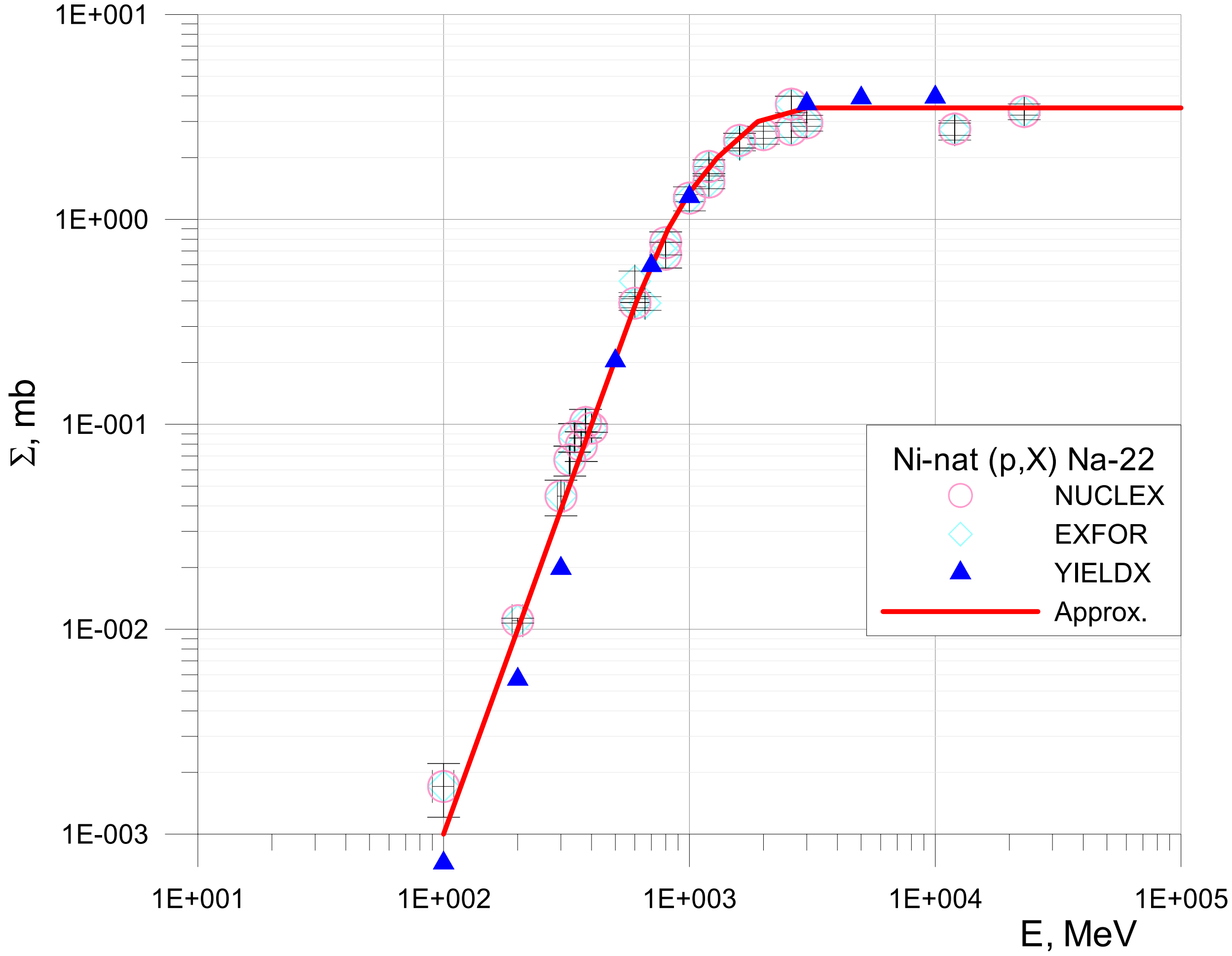


##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	90	0.00015	19	1500	2.10
2	100	0.0006	20	2000	2.80
3	110	0.0010	21	2400	3.10
4	125	0.0015	22	3500	3.20
5	140	0.0020	23	100000	3.20
6	167	0.0030			
7	185	0.0040			
8	210	0.0058			
9	235	0.0082			
10	255	0.011			
11	290	0.020			
12	340	0.040			
13	390	0.074			
14	440	0.12			
15	510	0.21			
16	635	0.40			
17	845	0.76			
18	1150	1.36			



##	E, MeV	Σ, mb
1	100	0.001
2	200	0.01
3	400	0.10
4	610	0.40
5	820	0.90
6	1000	1.35
7	1300	2.00
8	1900	3.00
9	3000	3.50
10	100000	3.50
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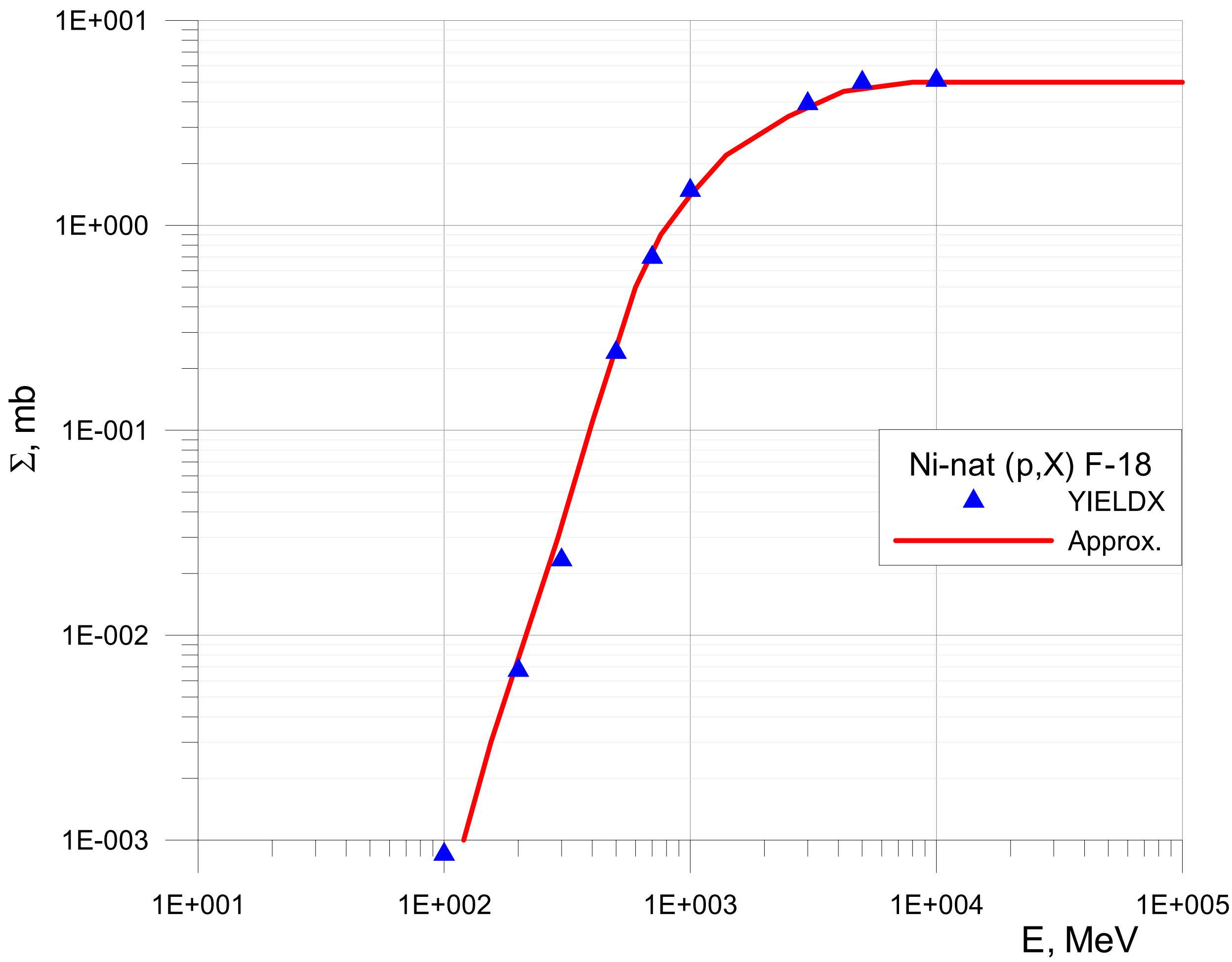

##	E, MeV	Σ, mb
1	120	0.001
2	155	0.003
3	290	0.03
4	400	0.11
5	600	0.50
6	760	0.90
7	1000	1.4
8	1400	2.2
9	2500	3.4
10	4200	4.5
11	8000	5.0
12	100000	5.0
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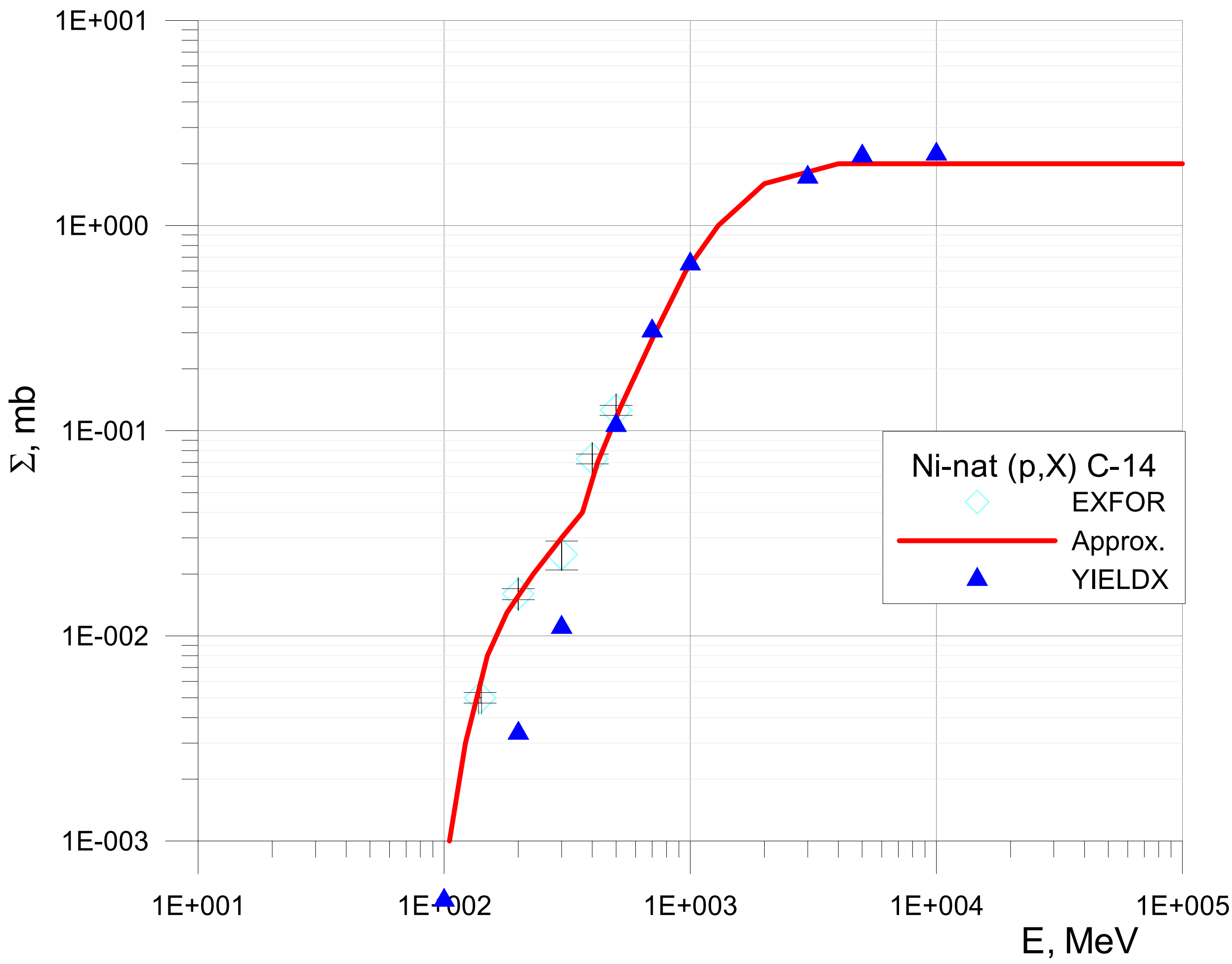

##	E, MeV	Σ, mb
1	105	0.001
2	122	0.003
3	150	0.008
4	180	0.013
5	230	0.020
6	300	0.03
7	365	0.04
8	420	0.07
9	520	0.13
10	720	0.30
11	960	0.60
12	1300	1.0
13	2000	1.6
14	4000	2.0
15	100000	2.0
16		
17		
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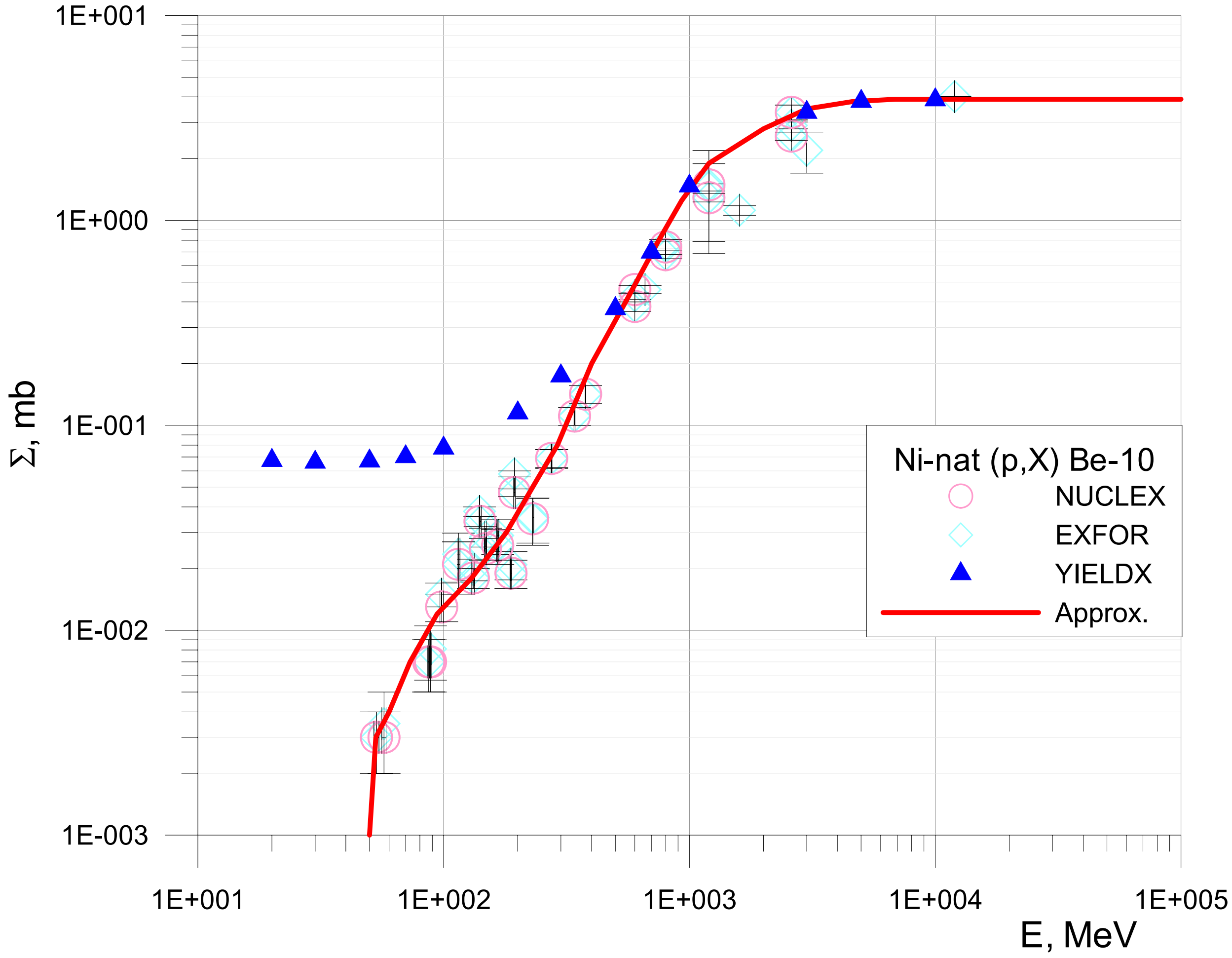
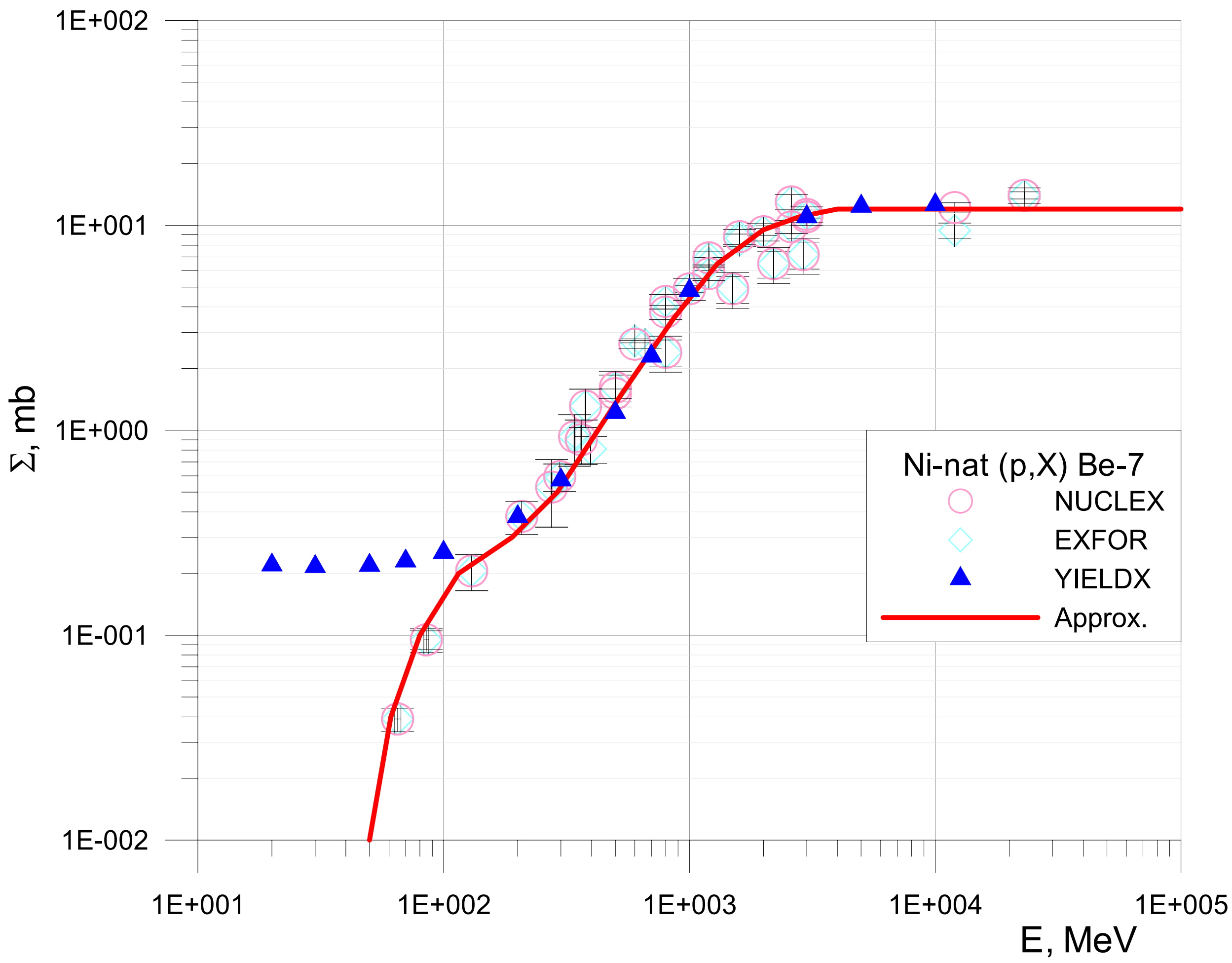


##	E, MeV	Σ, mb
1	50	0.001
2	53	0.003
3	60	0.004
4	73	0.007
5	94	0.012
6	130	0.018
7	180	0.03
8	230	0.05
9	290	0.08
10	400	0.20
11	550	0.40
12	750	0.80
13	930	1.25
14	1200	1.90
15	2000	2.80
16	3000	3.50
17	4600	3.80
18	6900	3.90
19	100000	3.90



##	E, MeV	Σ, mb
1	50	0.01
2	61	0.04
3	80	0.1
4	115	0.2
5	190	0.3
6	290	0.5
7	530	1.5
8	860	3.5
9	1300	6.5
10	2000	9.5
11	2800	11
12	4000	12
13	100000	12
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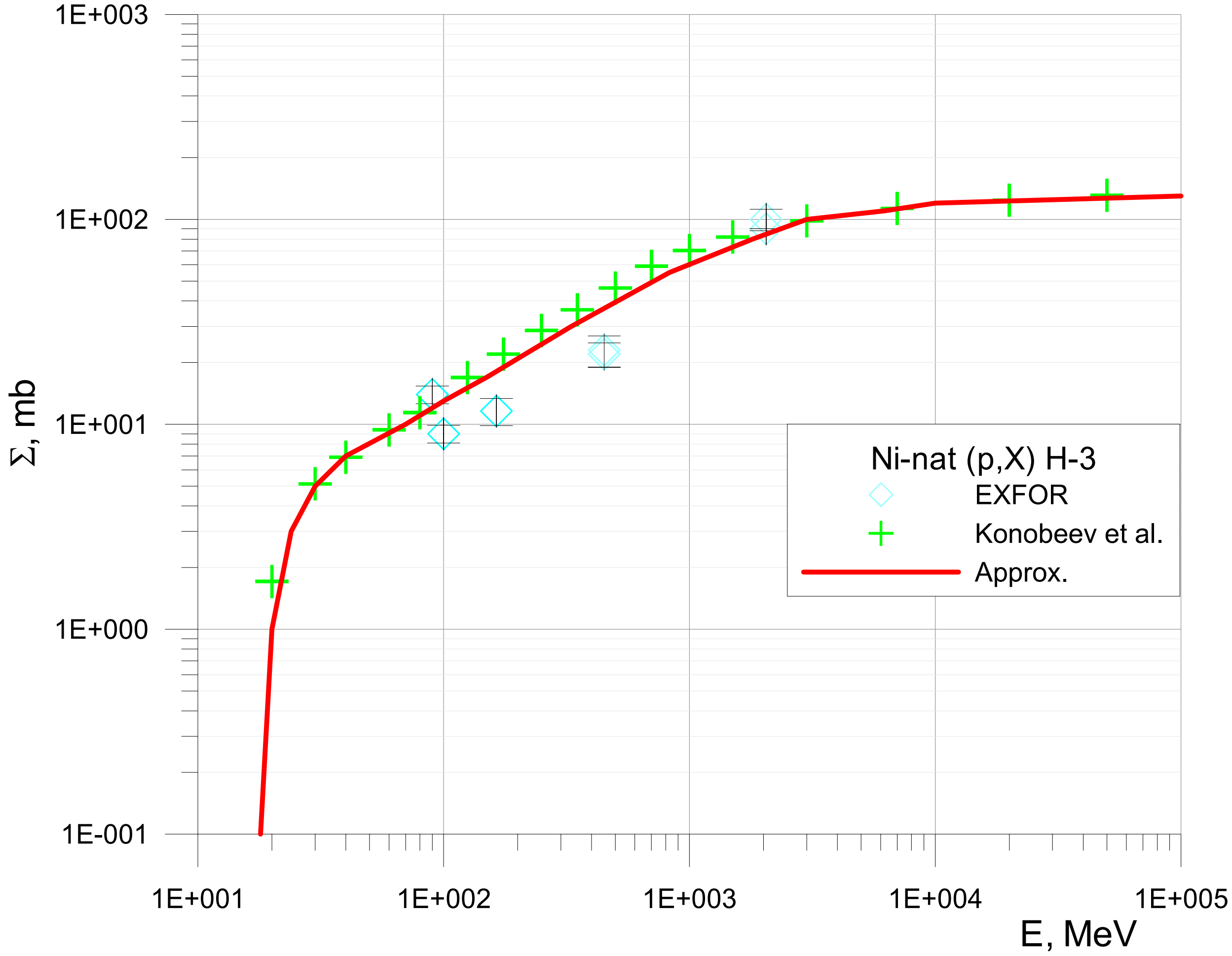
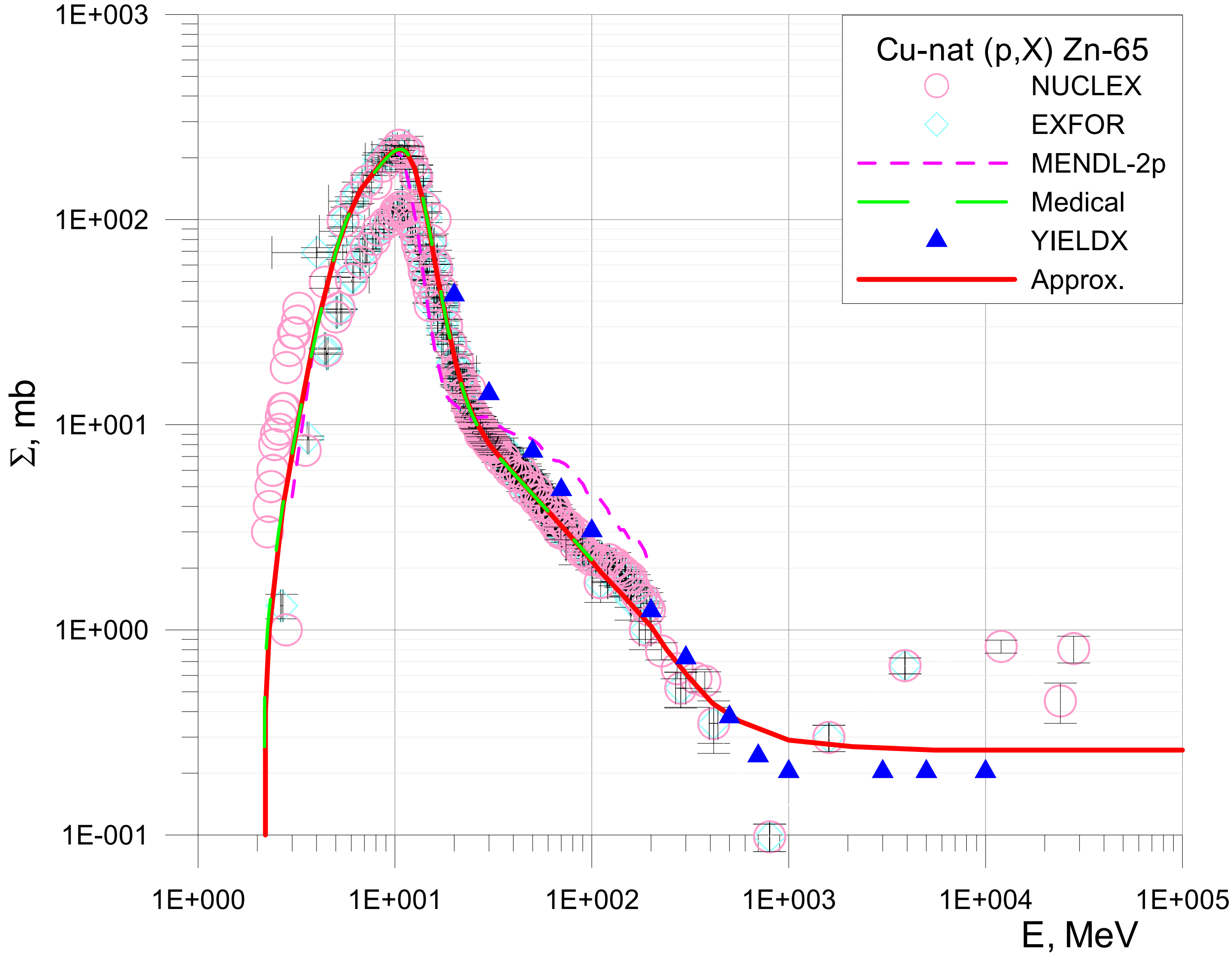


##	E, MeV	Σ, mb
1	8.1	0.0
2	18	0.1
3	20	1.0
4	24	3.0
5	30	5.0
6	40	7.0
7	70	10
8	100	13
9	150	17
10	330	30
11	830	55
12	1800	80
13	3000	100
14	6200	110
15	10000	120
16	100000	130
17		
18		

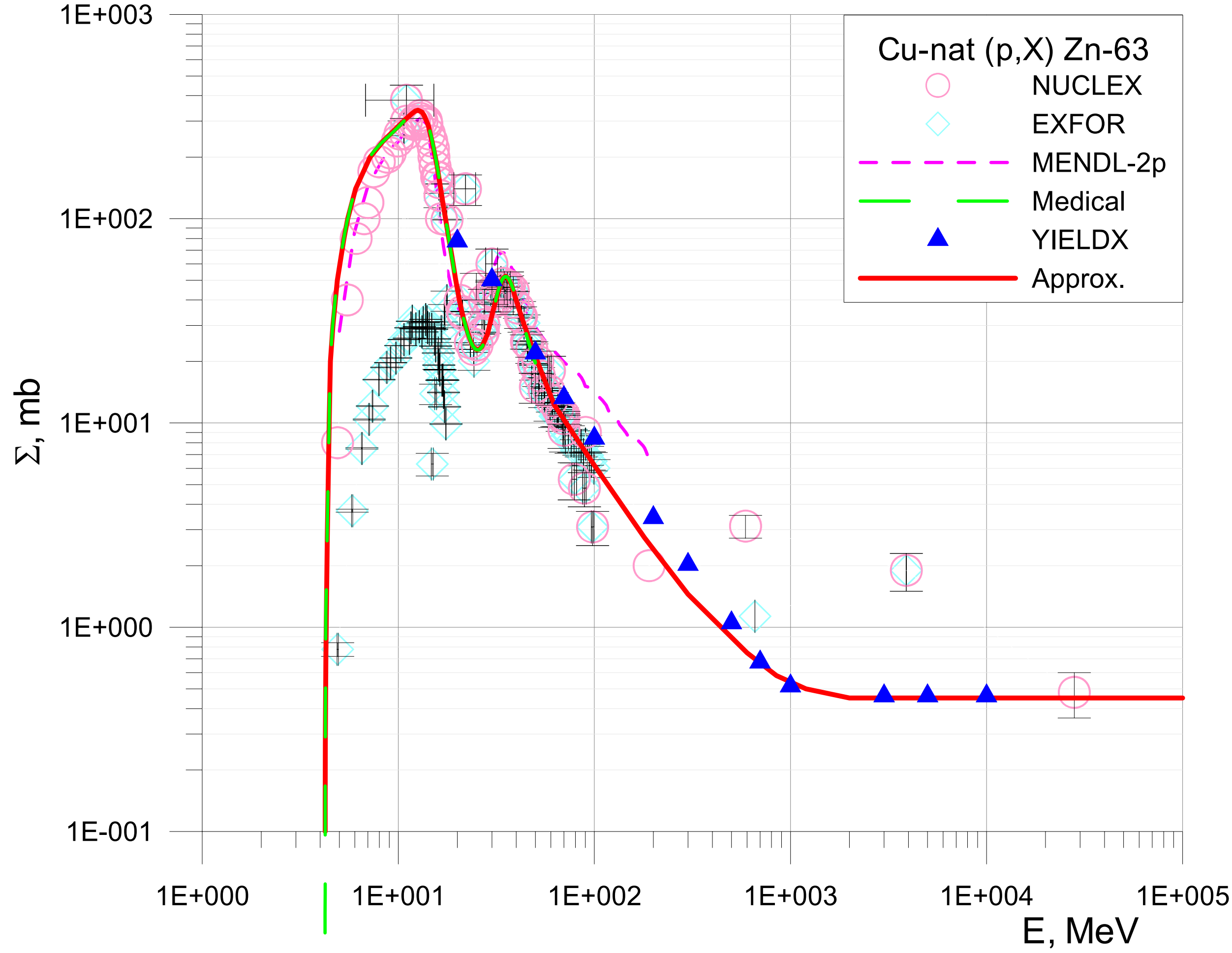
Summary of experimental and calculated cross-section data used for copper

Nuclide	Half-life			Decay Mode	Source				Comment
					Medical	Mendl-2p	NUCLEX	EXFOR	
H-3	12.32	Y	0.02	B-			x	x	
Be-7	53.22	D	0.06	EC			x	x	
Be-10	2E+06	Y	60000	B-				x	
C-14	5700	Y	30	B-					cum
F-18	109.77	M	0.05	EC			x	x	cum
Na-22	2.6019	Y	4E-04	EC			x	x	cum
Na-24	14.959	H	0.001	B-			x	x	cum
Mg-28	20.915	H	0.009	B-			x	x	cum
Al-26	717000	Y	24000	EC					
Si-31	157.3	M	0.3	B-					cum
Si-32	132	Y	13	B-					cum
P-32	14.262	D	0.014	B-			x	x	
P-33	25.34	D	0.12	B-			x	x	cum
S-35	87.51	D	0.12	B-			x		cum
S-38	170.3	M	0.7	B-			x	x	cum
Cl-36	301000	Y	2000	B-, EC					
Ar-37	35.04	D	0.04	EC			x	x	cum
Ar-39	269	Y	3	B-			x	x	cum
Ar-41	109.61	M	0.04	B-			x	x	cum
Ar-42	32.9	Y	1.1	B-			x	x	cum
K-42	12.36	H	0.012	B-			x	x	
K-43	22.3	H	0.1	B-			x	x	cum
Ca-41	102000	Y	7000	EC					cum
Ca-45	162.61	D	0.09	B-			x		cum
Ca-47	4.536	D	0.003	B-			x	x	cum
Sc-43	3.891	H	0.012	EC			x	x	cum
Sc-44	3.97	H	0.04	EC			x	x	
Sc-44m	58.61	H	0.1	IT, EC			x	x	
Sc-46	83.79	D	0.04	B-			x	x	
Sc-47	3.3492	D	6E-04	B-			x	x	
Sc-48	43.67	H	0.09	B-			x	x	
Ti-44	60	Y	1.1	EC		x			cum
Ti-45	184.8	M	0.5	EC		x	x		cum
V-48	15.974	D	0.003	EC		x	x	x	
V-49	330	D	15	EC		x	x		cum
Cr-48	21.56	H	0.03	EC		x	x	x	cum
Cr-51	27.703	D	0.002	EC		x	x	x	cum
Mn-52g	5.591	D	0.003	EC		x	x	x	cum
Mn-53	4E+06	Y	40000	EC		x	x	x	cum
Mn-54	312.12	D	0.06	EC		x	x	x	
Mn-56	2.5789	H	1E-04	B-		x	x	x	cum
Fe-52	8.275	H	0.008	EC		x	x	x	
Fe-55	2.737	Y	0.011	EC		x	x	x	
Fe-59	44.495	D	0.009	B-		x	x	x	cum
Co-55	17.53	H	0.03	EC		x	x	x	cum
Co-56	77.233	D	0.027	EC	x	x	x	x	
Co-57	271.74	D	0.06	EC		x	x	x	cum
Co-58g	70.86	D	0.06	EC		x	x	x	cum
Co-60	1925.3	D	0.3	B-		x	x	x	
Co-61	1.65	H	0.005	B-		x	x	x	cum
Ni-56	6.075	D	0.01	EC		x	x	x	
Ni-57	35.6	H	0.06	EC		x	x	x	cum
Ni-59	76000	Y	5000	EC		x			cum
Ni-63	100.1	Y	2	B-		x		x	cum
Ni-65	2.5172	H	3E-04	B-		-	x	x	cum

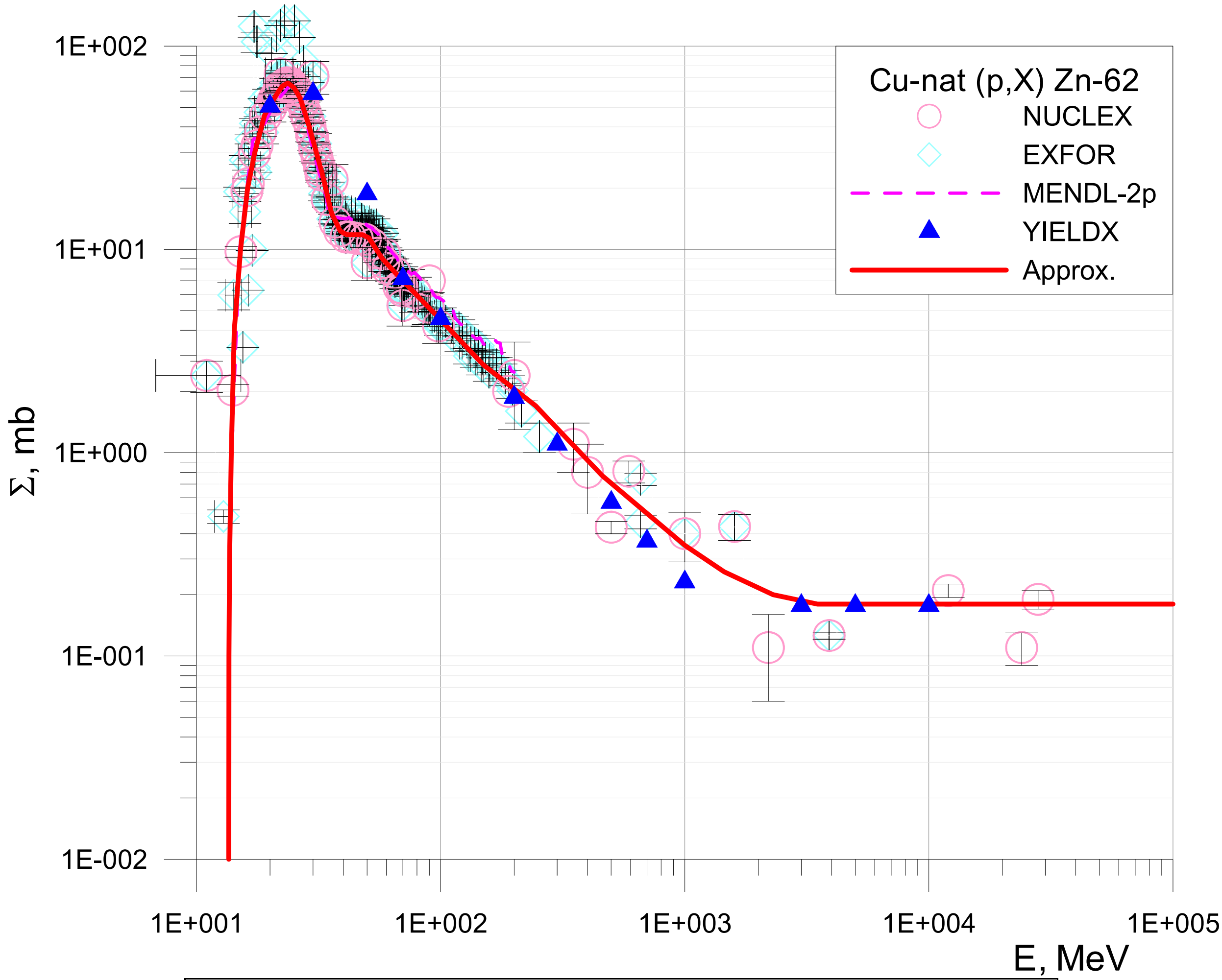
Cu-60	23.7	M	0.4	EC		x	x	x	cum
Cu-61	3.333	H	0.005	EC		x	x	x	cum
Cu-64	12.7	H	0.002	EC, B-		x	x	x	
Zn-62	9.186	H	0.013	EC	x	x	x	x	
Zn-63	328.47	M	0.05	EC	x	x	x	x	
Zn-65	244.06	D	0.1	EC	x	x	x	x	



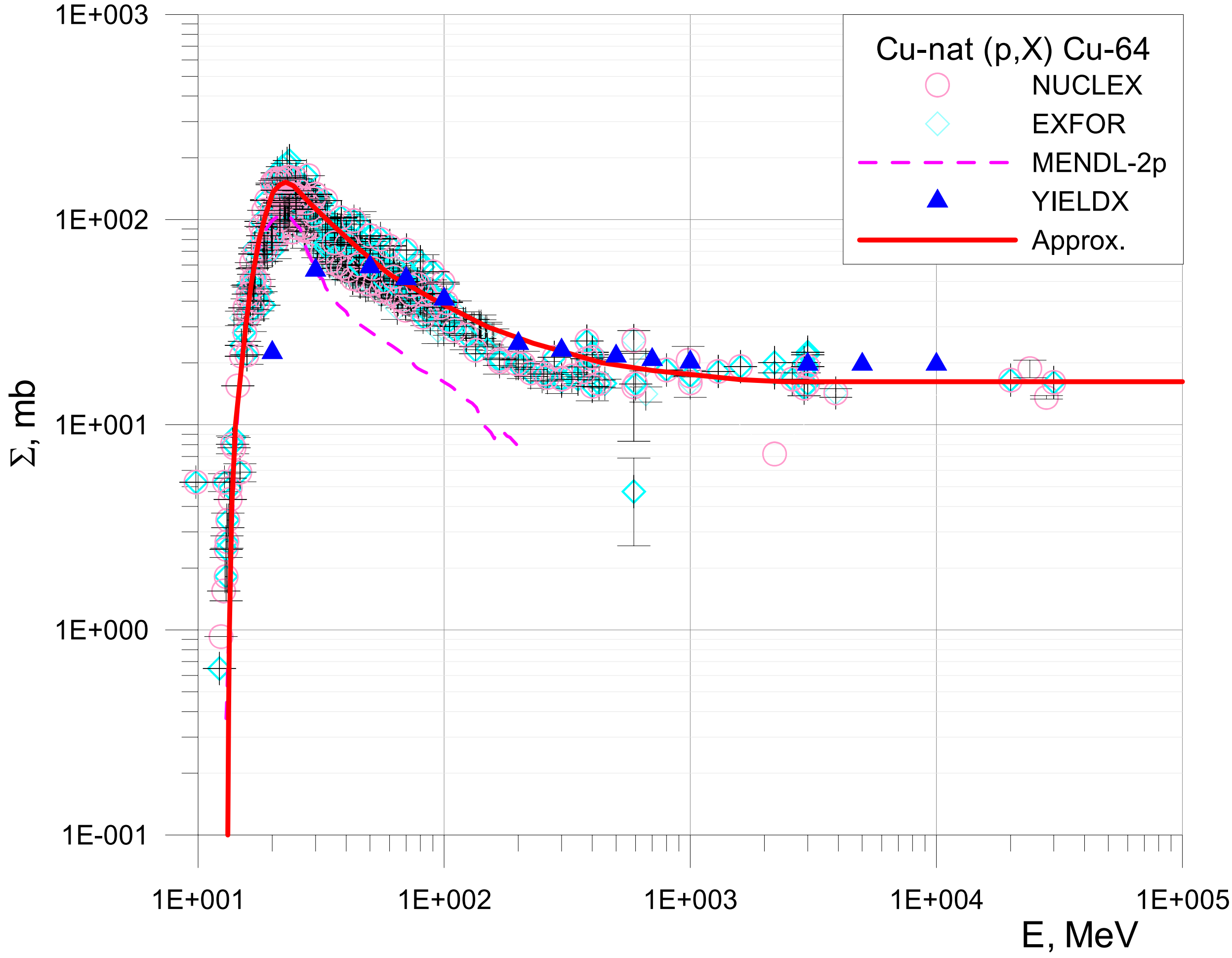
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	2.17	0.0	21	20.4	19.8
2	2.18	0.1	22	22.6	14.0
3	2.20	0.4	23	25.5	10.5
4	2.27	1.0	24	30.0	8.08
5	2.70	4.0	25	37.3	6.29
6	3.17	10.0	26	48.5	4.74
7	4.00	30.0	27	64.0	3.55
8	5.00	69.7	28	84.0	2.64
9	5.70	100.	29	110	1.93
10	6.70	140.	30	145	1.46
11	8.40	185.	31	200	1.04
12	9.31	207.	32	240	0.80
13	10.0	217.	33	310	0.59
14	10.6	220.	34	410	0.44
15	11.3	217.	35	560	0.36
16	11.7	205.	36	1000	0.29
17	12.6	178.	37	2100	0.27
18	14.5	104.	38	5500	0.26
19	16.6	50.2	39	10000	0.26
20	18.6	29.9	40	100000	0.26



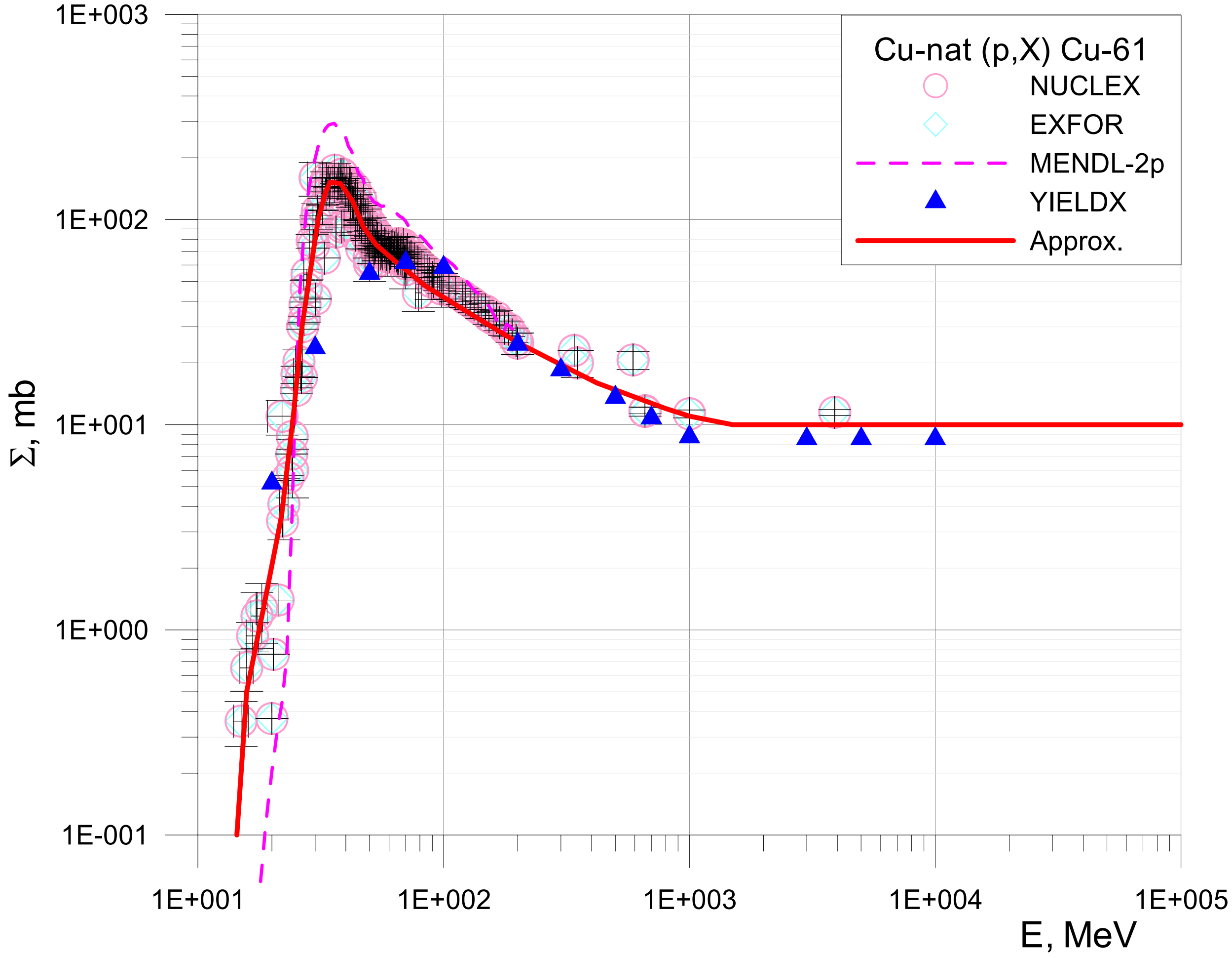
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	4.220	0.00	21	14.20	287	41	35.26	52.2
2	4.245	0.10	22	14.90	236	42	36.25	51.1
3	4.258	0.20	23	15.73	184	43	37.8	47.6
4	4.259	0.60	24	16.90	120	44	39.9	40.3
5	4.358	3.00	25	18.10	80.0	45	44.0	30.0
6	4.440	10.0	26	19.65	50.0	46	49.1	22.4
7	4.500	20.0	27	20.50	40.0	47	54.4	17.2
8	4.640	30.0	28	22.00	30.0	48	61.2	13.0
9	4.890	50.0	29	23.40	25.1	49	62.6	12.2
10	5.280	80.0	30	24.10	23.7	50	100	6.20
11	5.520	100	31	25.10	22.8	51	180	2.75
12	6.060	140	32	25.90	23.0	52	300	1.45
13	7.178	200	33	26.70	23.6	53	600	0.75
14	8.370	240	34	27.40	25.0	54	850	0.58
15	11.00	310	35	28.50	27.3	55	1200	0.50
16	11.70	326	36	30.30	35.0	56	2000	0.45
17	12.20	337	37	31.48	40.2	57	100000	0.45
18	12.60	340	38	32.90	46.6	58		
19	13.20	332	39	33.70	50.0	59		
20	13.55	320	40	34.30	51.3	60		



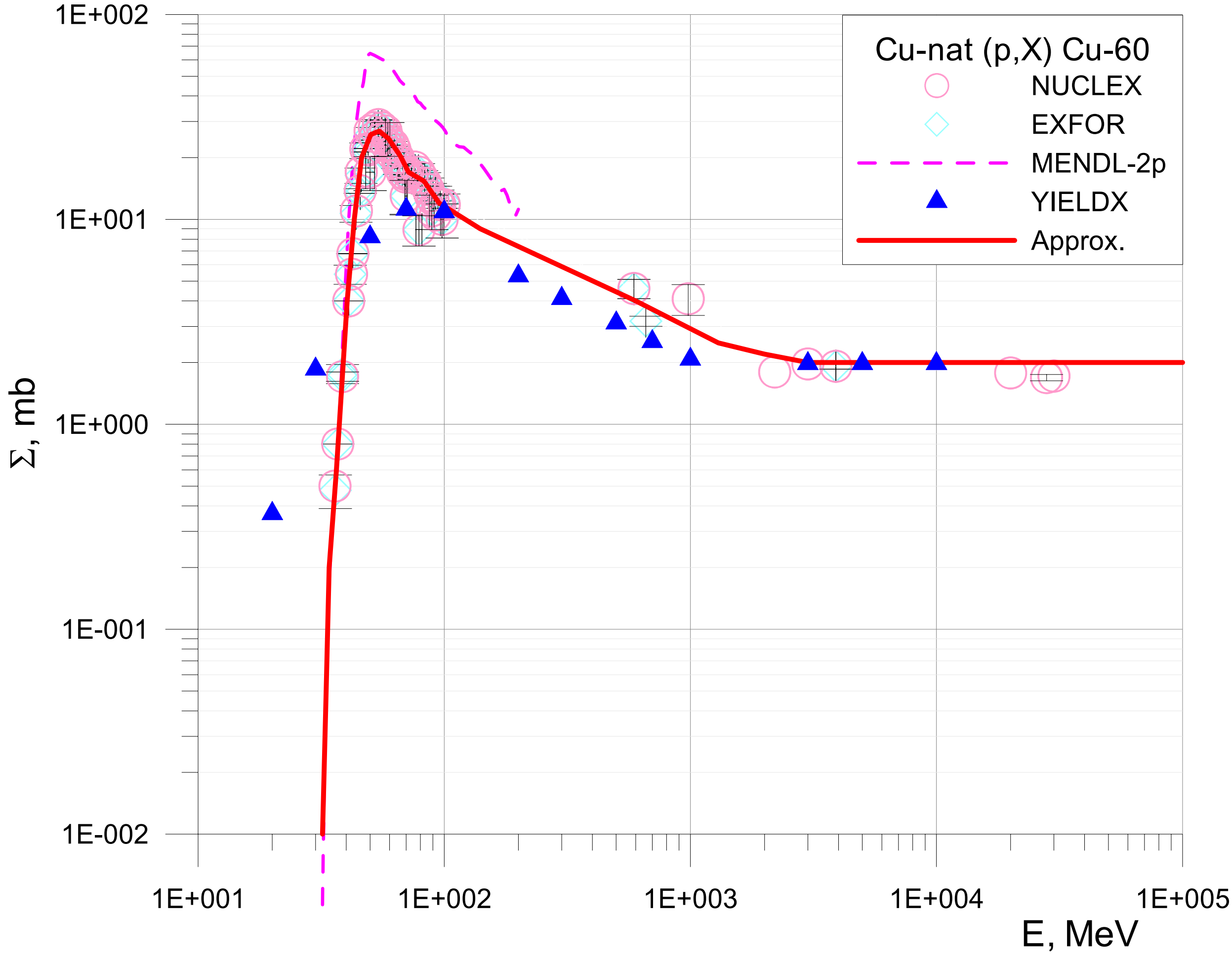
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	13.47	0.00	19	35.7	15.1
2	13.56	0.01	20	38.8	12.3
3	13.57	0.10	21	41.2	11.8
4	13.66	0.30	22	47.8	11.8
5	13.89	1.00	23	50.8	11.4
6	14.28	4.00	24	57.7	9.00
7	15.16	10.0	25	67.0	7.40
8	16.19	20.0	26	100	4.50
9	17.32	30.0	27	150	2.70
10	19.00	45.7	28	245	1.70
11	20.00	51.0	29	460	0.77
12	21.60	59.5	30	1000	0.35
13	22.50	63.7	31	1450	0.26
14	23.70	65.8	32	2300	0.200
15	25.1	62.4	33	3500	0.18
16	26.6	55.4	34	100000	0.18
17	28.9	40.3	35		
18	32.9	23.2			



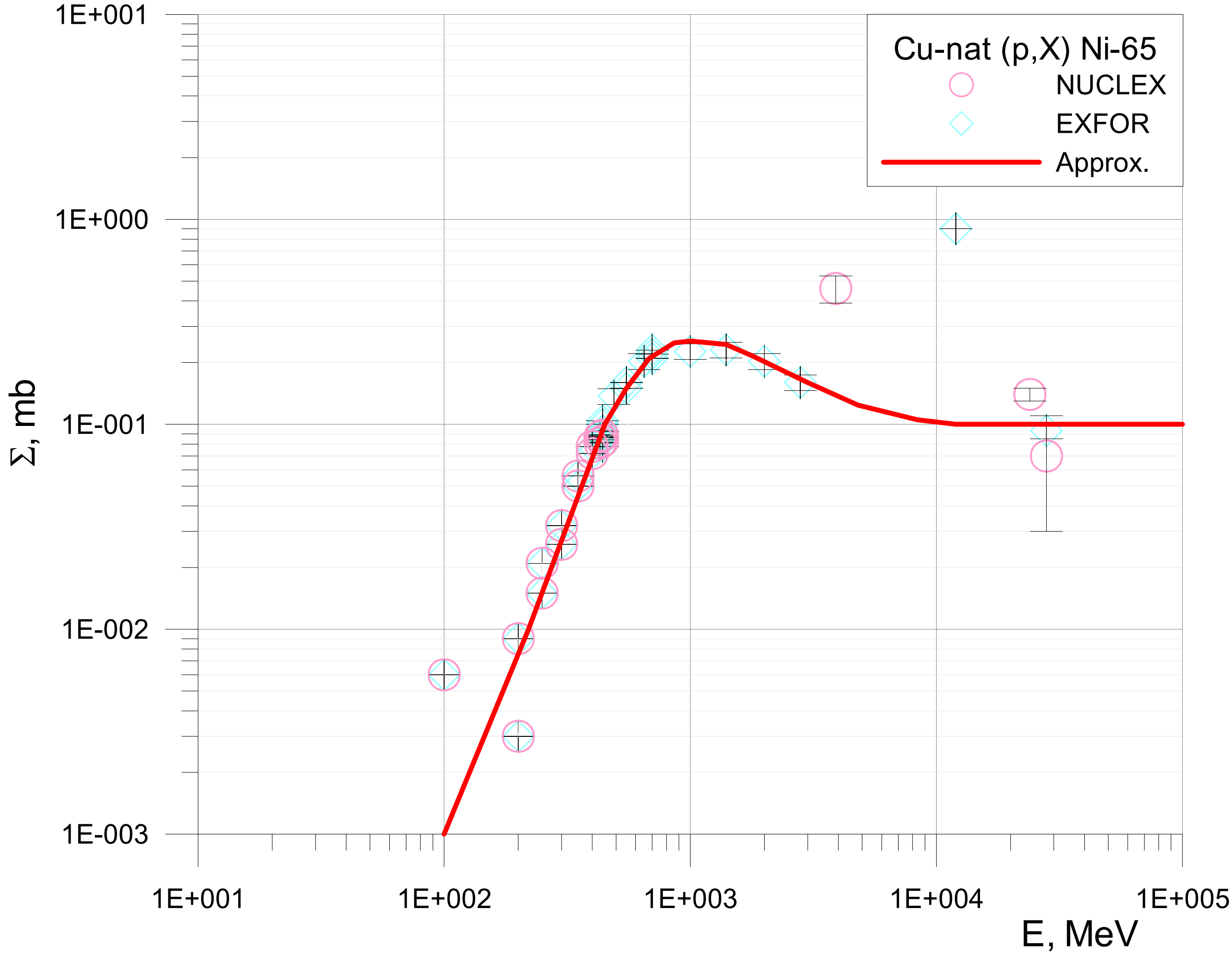
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	7.81	0.0	19	90.0	41.0
2	13.2	0.1	20	150	30.0
3	13.3	0.4	21	230	25.0
4	13.4	1.0	22	440	20.0
5	13.7	4.0	23	700	18.4
6	14.2	10.0	24	1600	16.6
7	15.6	30.0	25	2400	16.2
8	16.5	50.0	26	100000	16.2
9	17.7	80.0			
10	18.8	105.			
11	20.2	137.			
12	21.5	148.			
13	22.7	152.			
14	24.4	146.			
15	28.7	119.			
16	34.6	96.0			
17	45.0	72.0			
18	60.0	54.0			



##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	11.4	0.0	19	200	25.1
2	14.4	0.1	20	420	16.0
3	15.8	0.5	21	800	12.0
4	18.8	1.4	22	1000	11.0
5	21.9	3.6	23	1500	10.0
6	24.5	11.3	24	10000	10.0
7	26.5	29.8	26	100000	10.0
8	29.9	78.6			
9	30.9	101			
10	33.0	135			
11	34.5	152			
12	38.1	150			
13	42.6	123			
14	47.1	92.0			
15	53.1	75.4			
16	62.7	63.4			
17	84.5	47.4			
18	110	38.9			



##	E, MeV	Σ, mb
1	23.3	0.00
2	32.0	0.01
3	33.1	0.05
4	34.1	0.20
5	36.5	0.60
6	40.3	4.00
7	43.1	10.0
8	46.1	20.0
9	50.3	26.0
10	54.4	27.0
11	59.3	24.8
12	66.3	20.4
13	71.6	17.0
14	82.7	15.4
15	95.4	12.0
16	140	9.0
17	600	4.0
18	1300	2.5
19	2000	2.2
20	3000	2.0
21	100000	2.0



##	E, MeV	Σ, mb
1	100	0.001
2	220	0.010
3	450	0.100
4	550	0.150
5	680	0.210
6	860	0.250
7	1000	0.255
8	1400	0.245
9	1800	0.215
10	3000	0.160
11	4800	0.124
12	8400	0.105
13	12000	0.100
14	100000	0.100
15		
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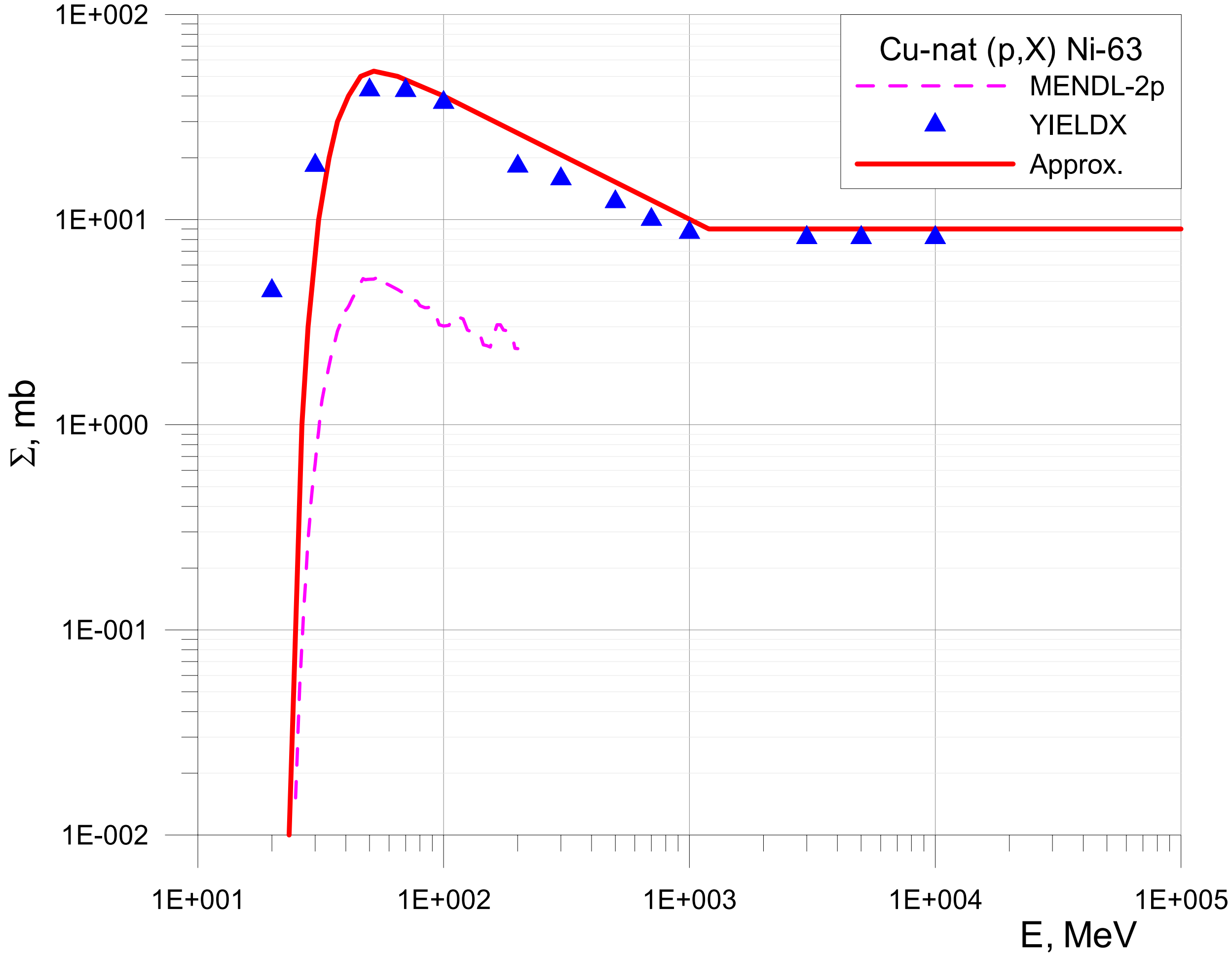
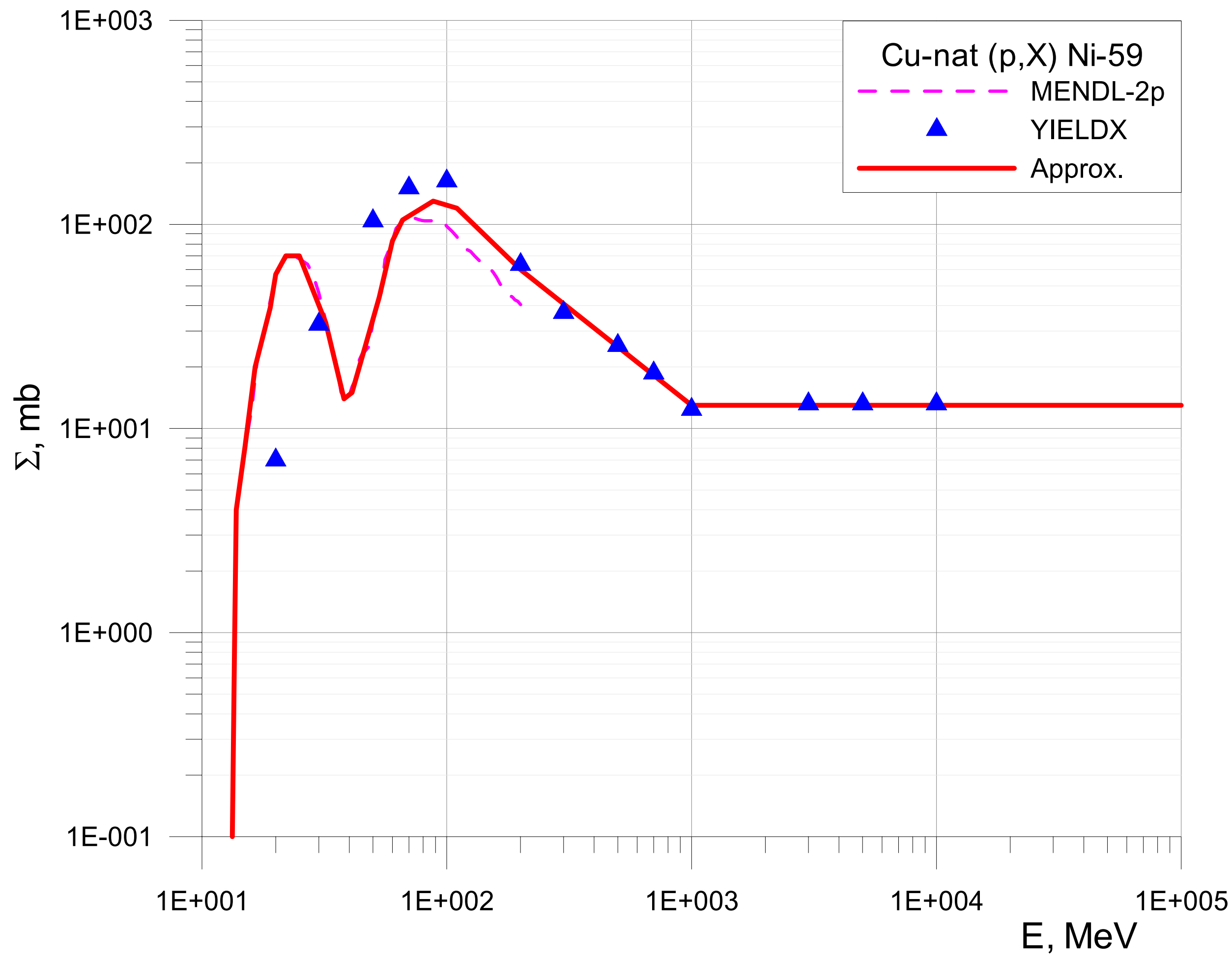
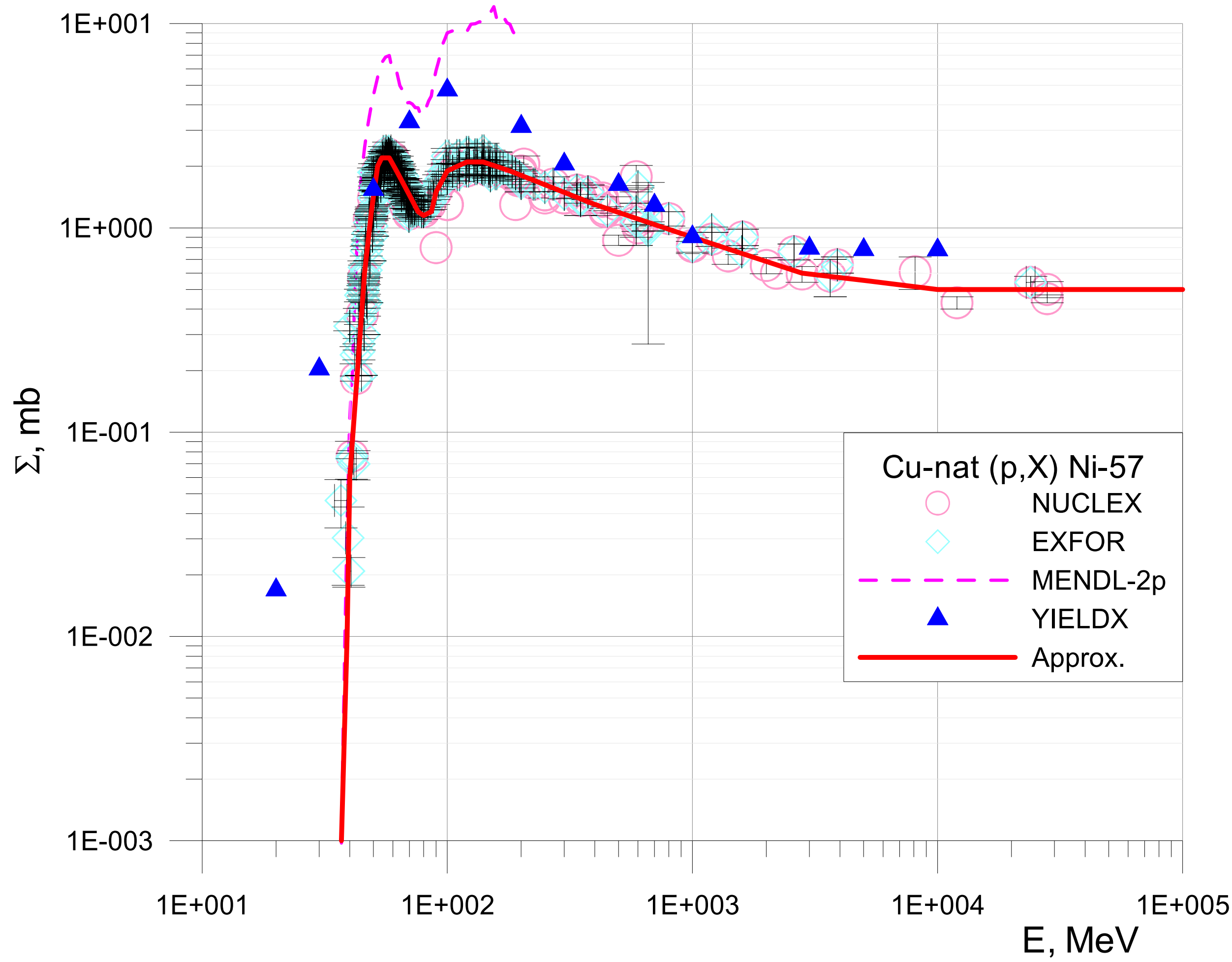
17		
18		



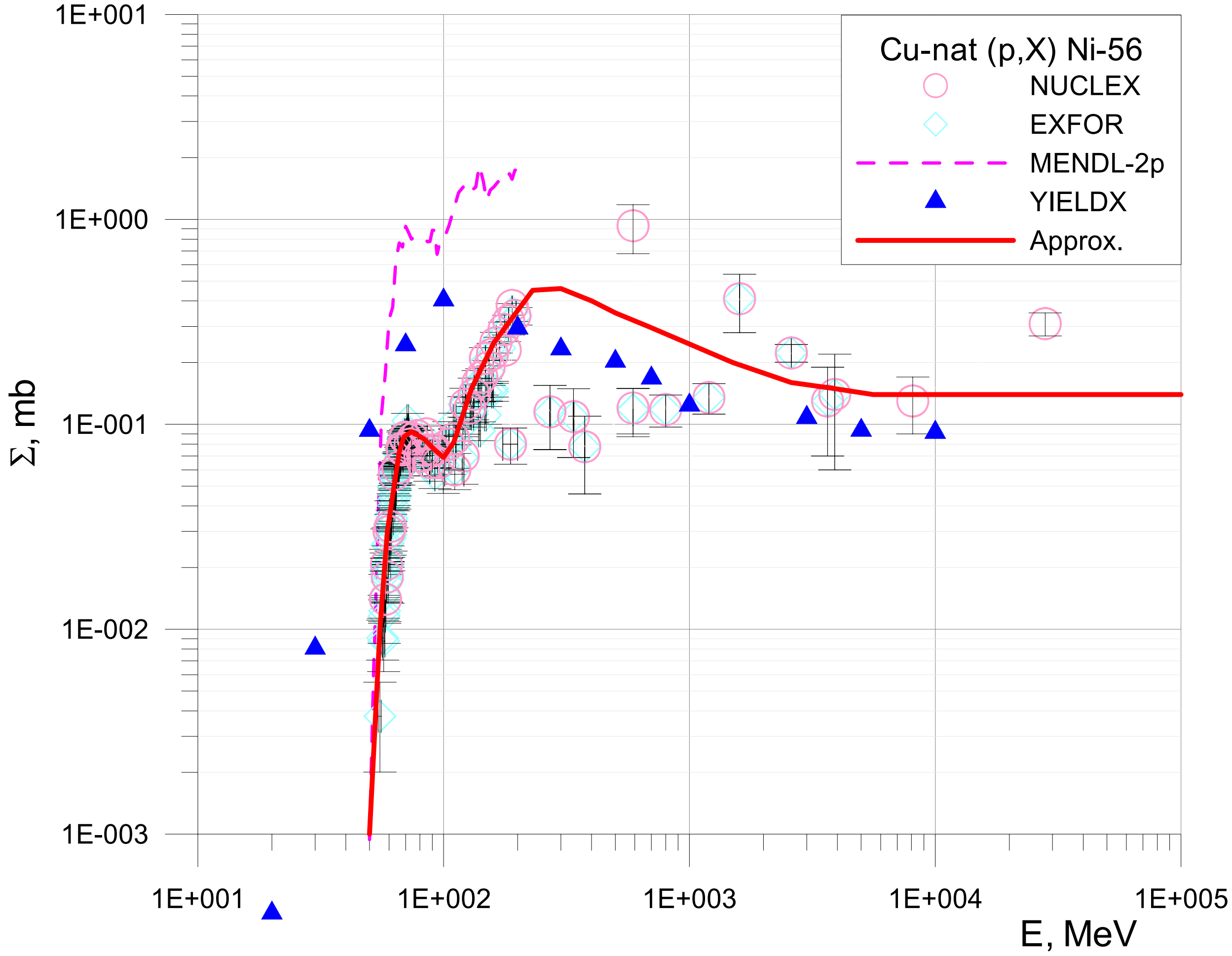
##	E, MeV	Σ, mb
1	9.5	0.00
2	23.5	0.01
3	25.0	0.1
4	26.5	1.0
5	28.1	3.0
6	31.0	10
7	34.2	20
8	37	30
9	41	40
10	46	50
11	52	53
12	65	50
13	100	40
14	1200	9.0
15	100000	9.0
16		
17		
18		



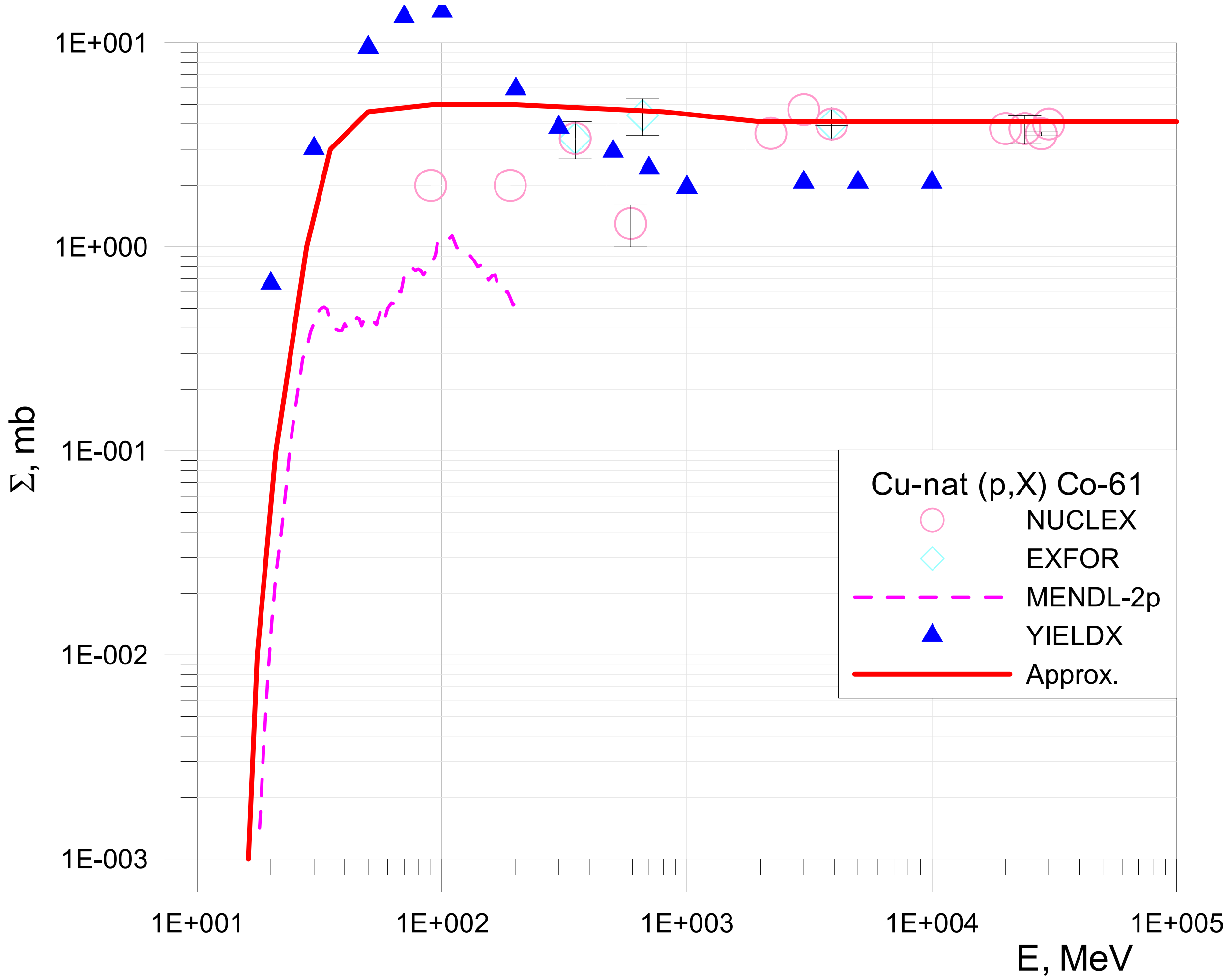
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	7.75	0.00	19	110	120
2	13.0	0.01	20	200	60
3	13.3	0.1	21	1000	13
4	13.6	1.0	22	100000	13
5	13.8	4.0			
6	15.0	8.2			
7	16.5	20			
8	19.0	39			
9	20	57			
10	22	70			
11	25	70			
12	32	33			
13	38	14			
14	41	15			
15	53	44			
16	60	83			
17	66	105			
18	88	130			



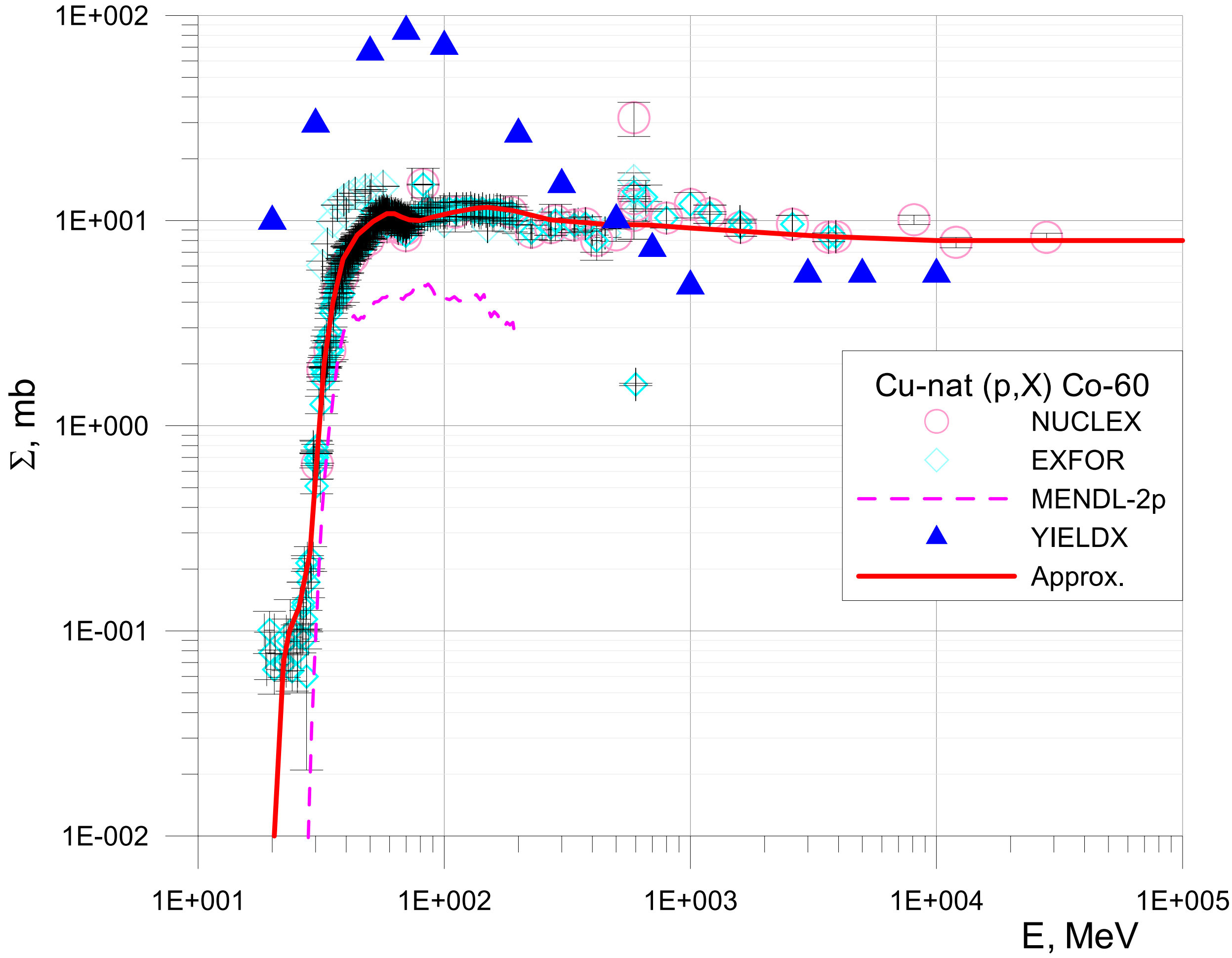
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	29.3	0.000	19	120	2.1
2	37	0.001	20	140	2.1
3	39	0.010	21	180	1.9
4	40	0.06	22	400	1.3
5	43	0.20	23	1000	0.9
6	46	0.60	24	2800	0.6
7	49	1.2	25	5200	0.55
8	51	1.7	26	10000	0.5
9	52	2.0		100000	0.5
10	54	2.2			
11	58	2.2			
12	62	1.9			
13	69	1.5			
14	76	1.2			
15	80	1.2			
16	86	1.15			
17	90	1.5			
18	100	1.9			



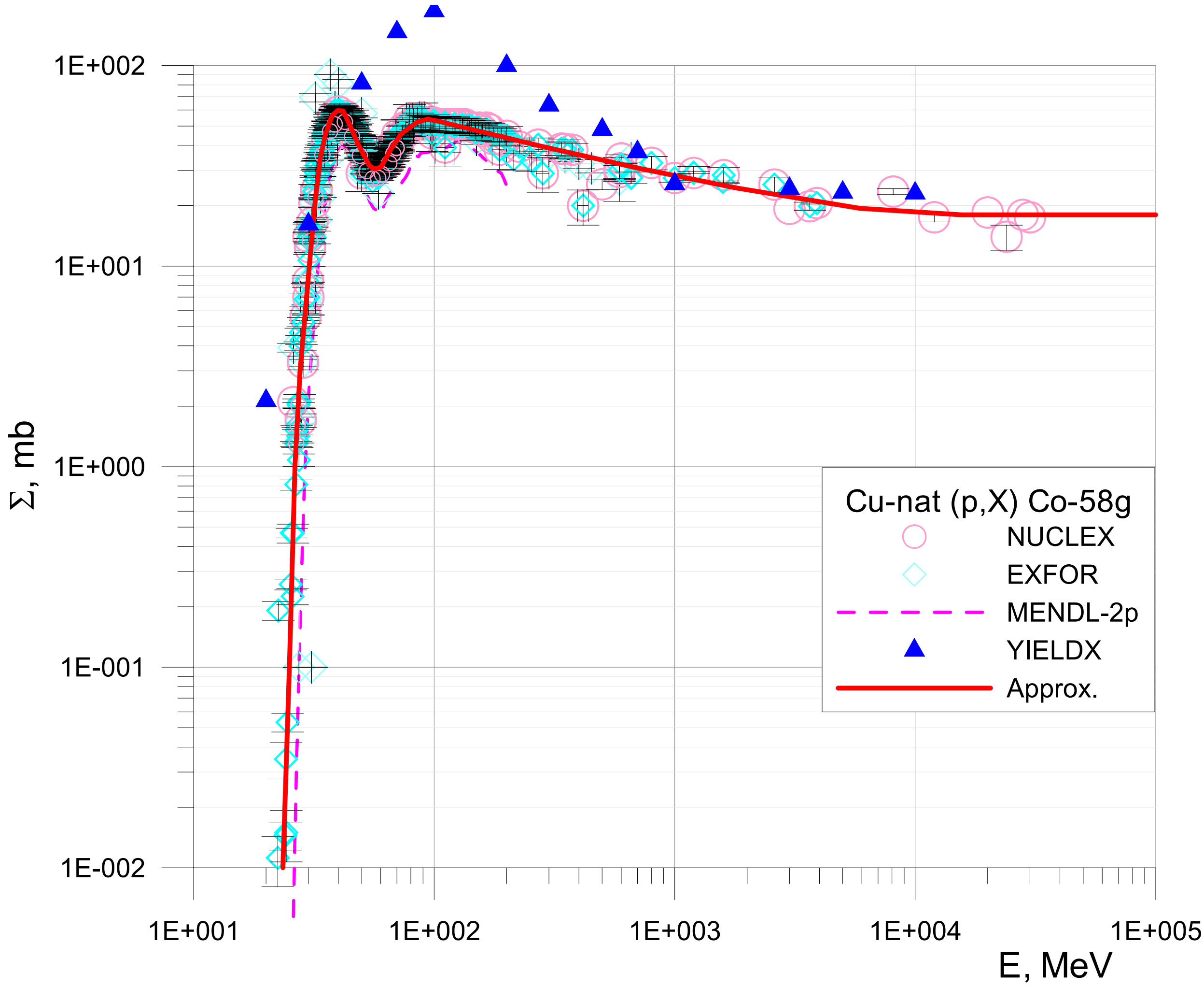
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	39.7	0.000	19	1500	0.20
2	50	0.001	20	2600	0.16
3	55	0.010	21	3800	0.15
4	59	0.030	22	5600	0.14
5	66	0.073	23	100000	0.14
6	69	0.087			
7	74	0.092			
8	83	0.085			
9	92	0.075			
10	100	0.069			
11	110	0.082			
12	130	0.15			
13	160	0.25			
14	230	0.45			
15	300	0.46			
16	400	0.40			
17	500	0.35			
18	680	0.30			



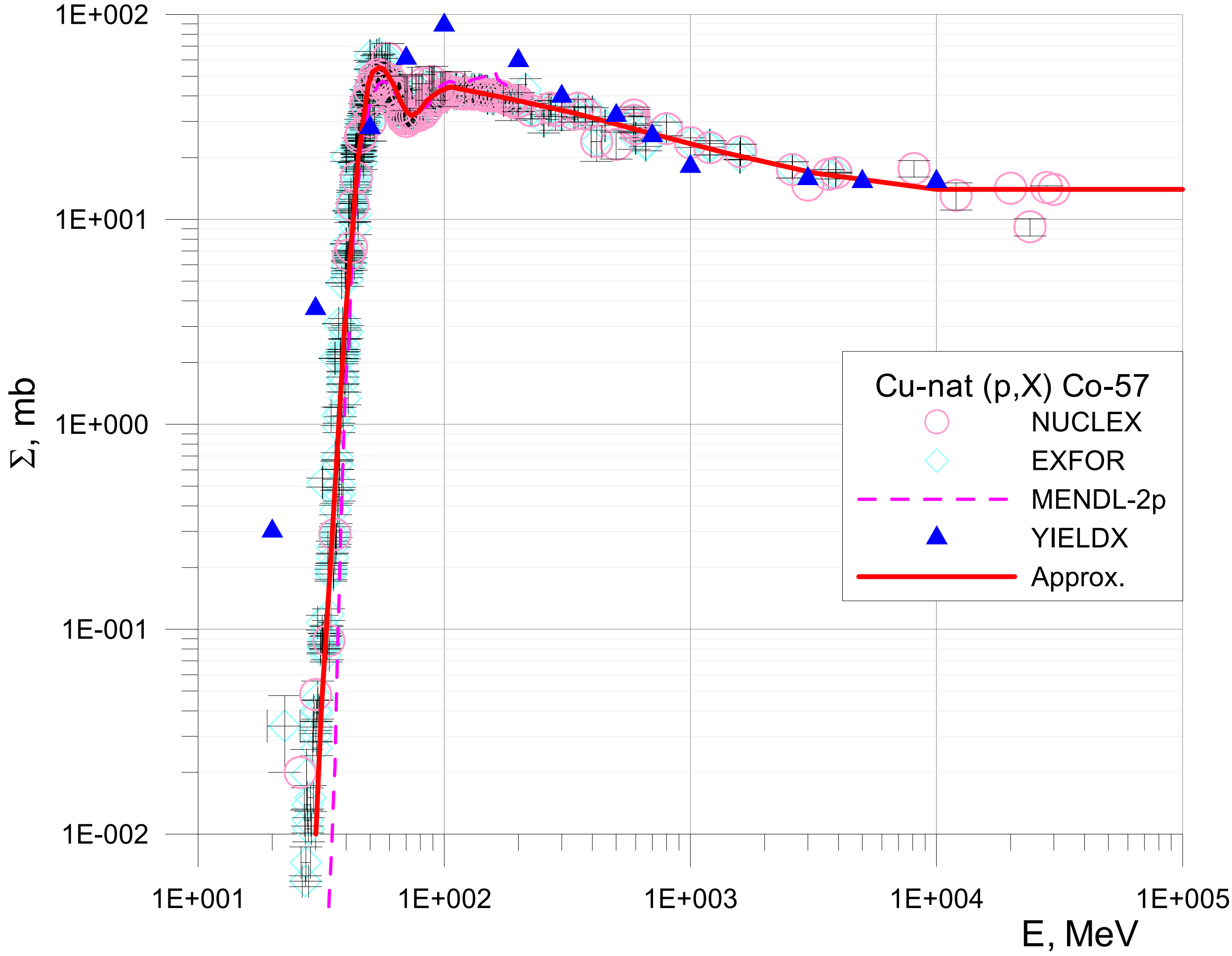
##	E, MeV	Σ, mb
1	6.9	0.000
2	16.2	0.001
3	17.6	0.01
4	21.0	0.1
5	28.0	1.0
6	35.0	3.0
7	50.0	4.6
8	93.0	5.0
9	190	5.0
10	800	4.6
11	2000	4.1
12	100000	4.1
13		
14		
15		
16		
17		
18		



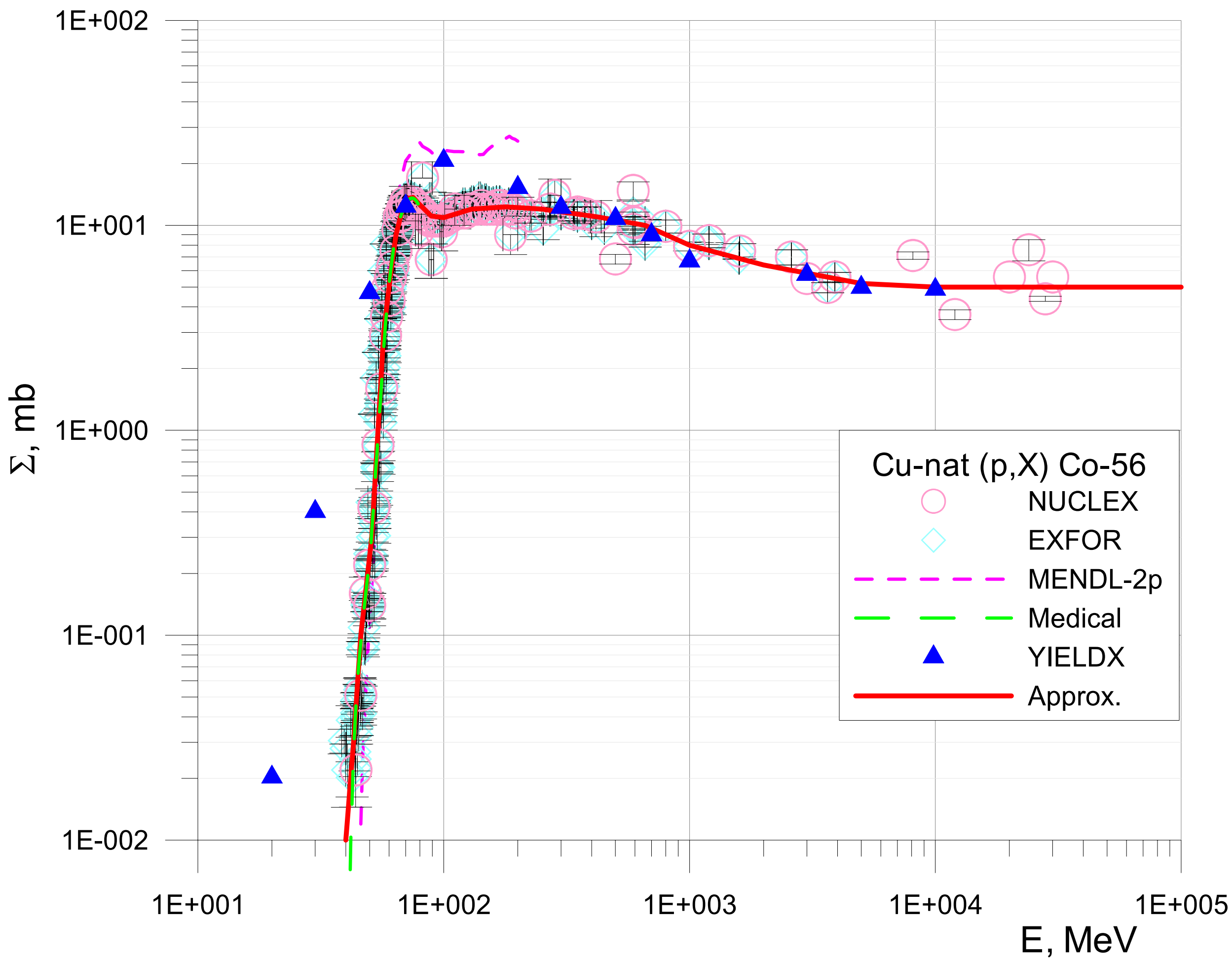
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	14.1	0.00	19	110	11.0
2	20.4	0.01	20	135	11.5
3	22.2	0.07	21	150	11.6
4	23.5	0.10	22	190	11.2
5	25.7	0.13	23	270	10.1
6	28.5	0.24	24	450	9.6
7	30.4	0.70	25	680	9.5
8	32.5	2.00	26	1000	9.2
9	35.3	4.00	27	3400	8.4
10	38.8	6.50	28	10000	8.0
11	44.3	8.50	29	100000	8.0
12	51.4	9.90			
13	58.4	10.8			
14	62.7	10.8			
15	67.0	10.4			
16	72.0	10.1			
17	80	10.0			
18	90	10.4			



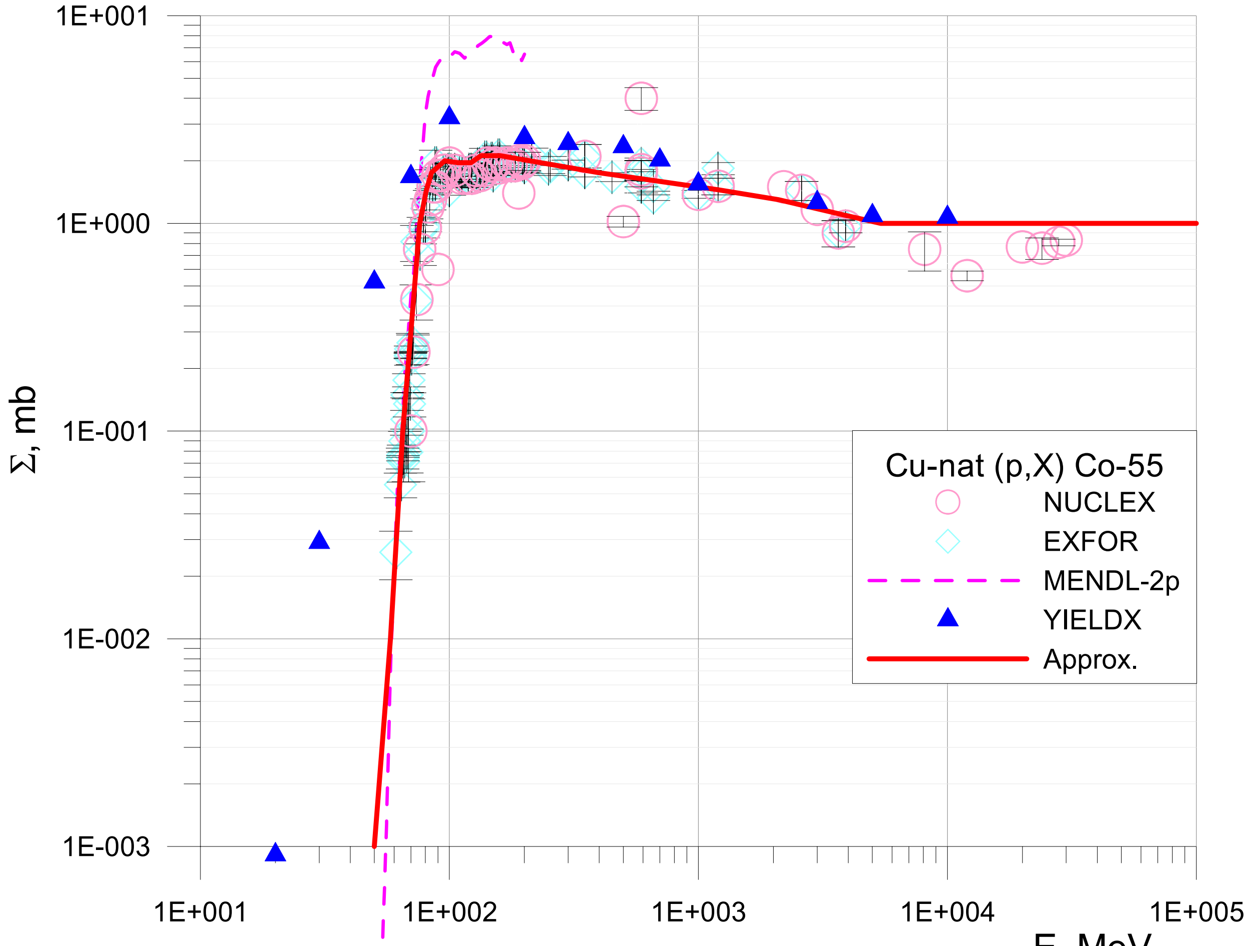
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	14.23	0.00	19	73.0	45.7
2	23.5	0.01	20	85.0	52.2
3	25.0	0.1	21	94.0	54.0
4	26.4	1.0	22	105	52.6
5	27.7	3.0	23	130	49.5
6	30.3	10.0	24	280	39.5
7	31.8	19.8	25	700	30.8
8	33.6	34.4	26	1800	24.5
9	35.2	44.5	27	5900	19.4
10	37.6	56.2	28	15600	18.0
11	39.7	59.6	29	100000	18.0
12	41.9	59.3			
13	43.6	53.7			
14	48.2	40.6			
15	53.8	31.6			
16	56.5	30.5			
17	60.3	31.2			
18	66.0	38.2			



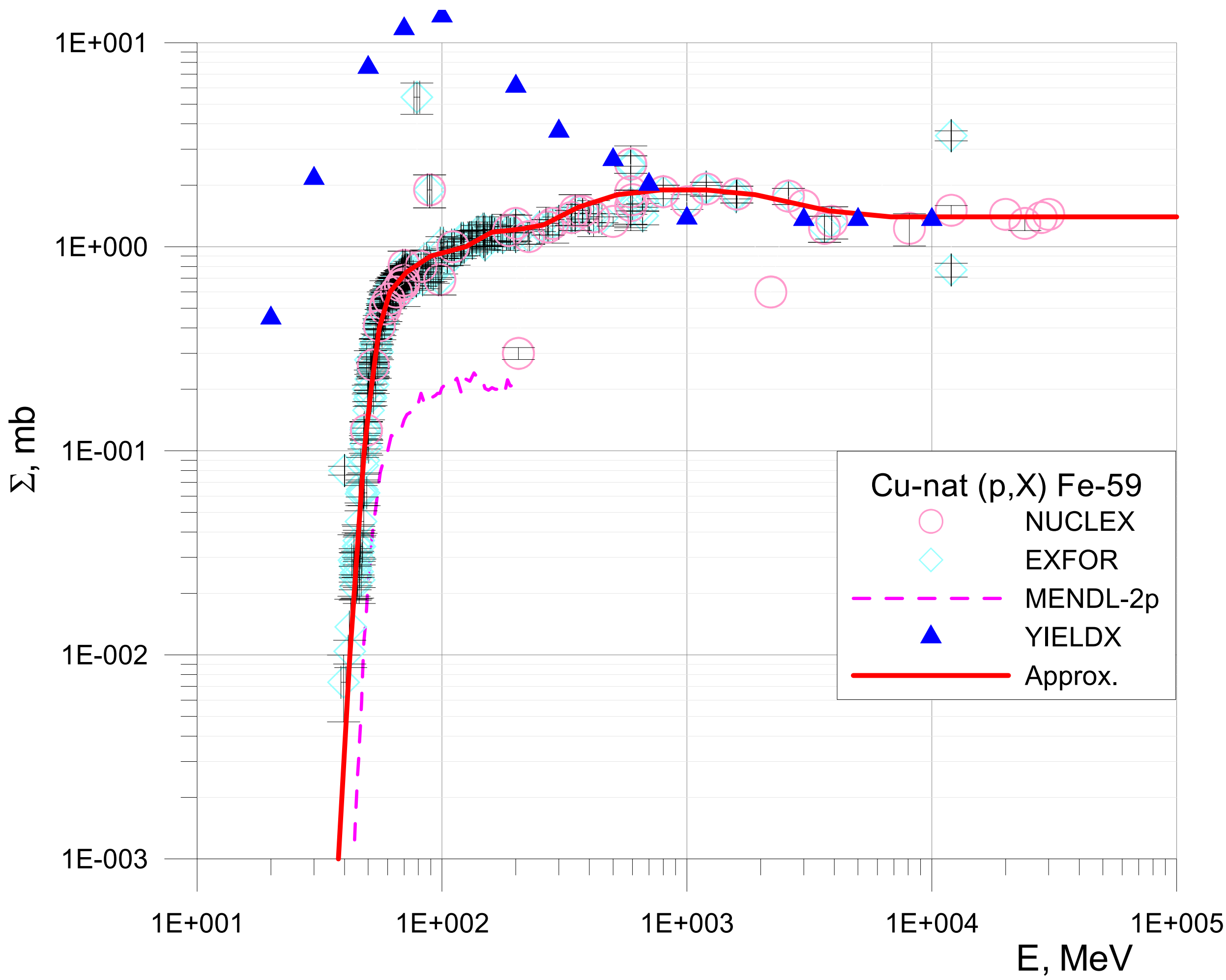
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	16.6	0.00	19	120	42.9
2	30.0	0.01	20	180	39.0
3	31.6	0.04	21	340	32.9
4	34.4	0.20	22	680	26.4
5	39.4	3.00	23	1400	21.1
6	44.7	20.0	24	3200	16.8
7	49.2	45.8	25	10000	14.0
8	51.4	52.6	26	100000	14.0
9	54.3	55.1			
10	56.8	54.0			
11	62.0	46.0			
12	66.5	37.7			
13	70	33.7			
14	74	32.0			
15	79	33.7			
16	85	38.0			
17	95	42.0			
18	106	44.3			



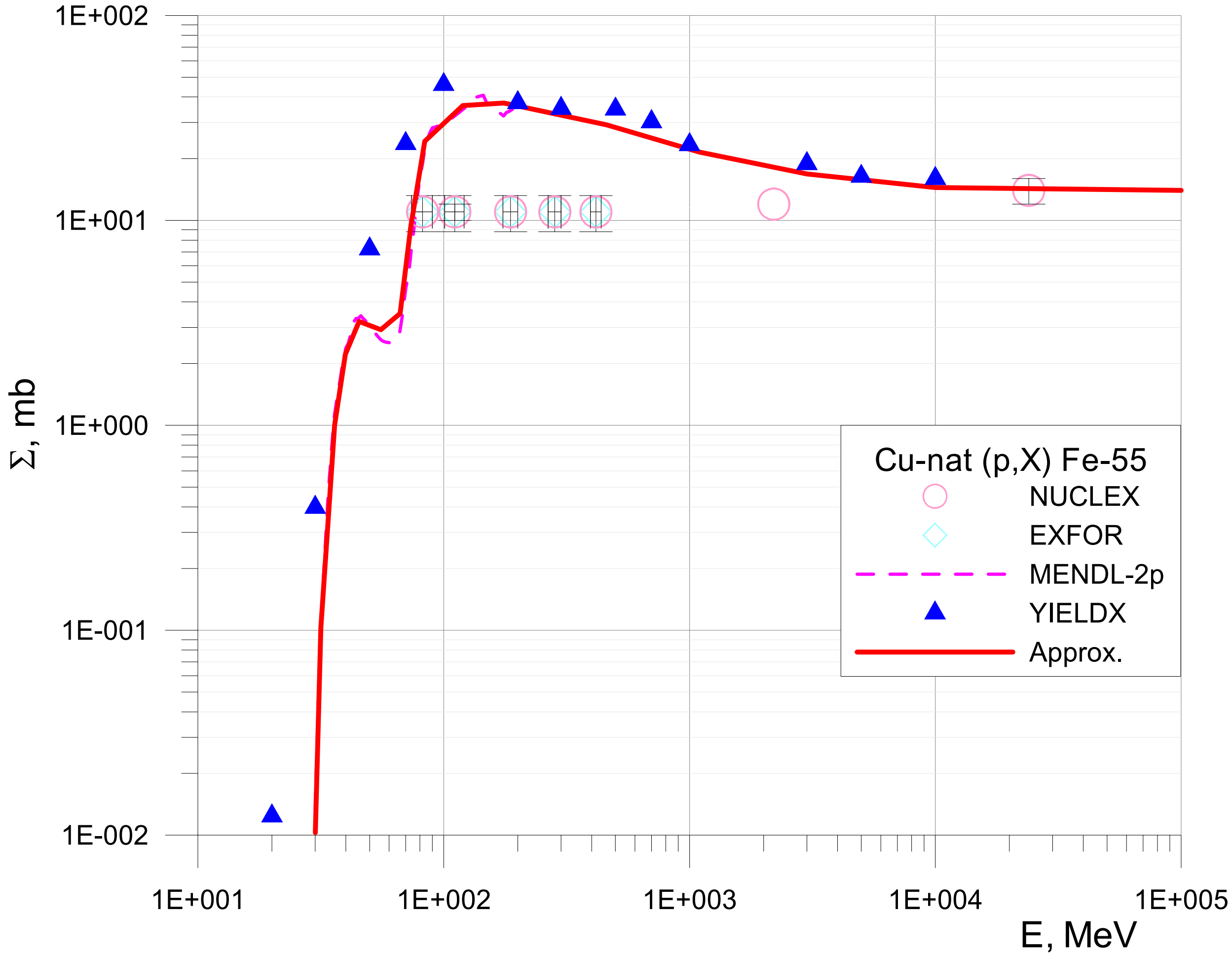
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	28.1	0.00	19	420	11.
2	40	0.01	20	660	10.
3	43	0.03	21	1000	8.0
4	46	0.1	22	2000	6.4
5	51	0.3	23	5000	5.2
6	54	1.0	24	10000	5.0
7	57	3.0	25	100000	5.0
8	61	6.0			
9	64	9.0			
10	68	12.0			
11	71	13.5			
12	75	13.7			
13	79	12.8			
14	89	11.1			
15	100	10.9			
16	130	12.0			
17	180	12.3			
18	250	12.0			



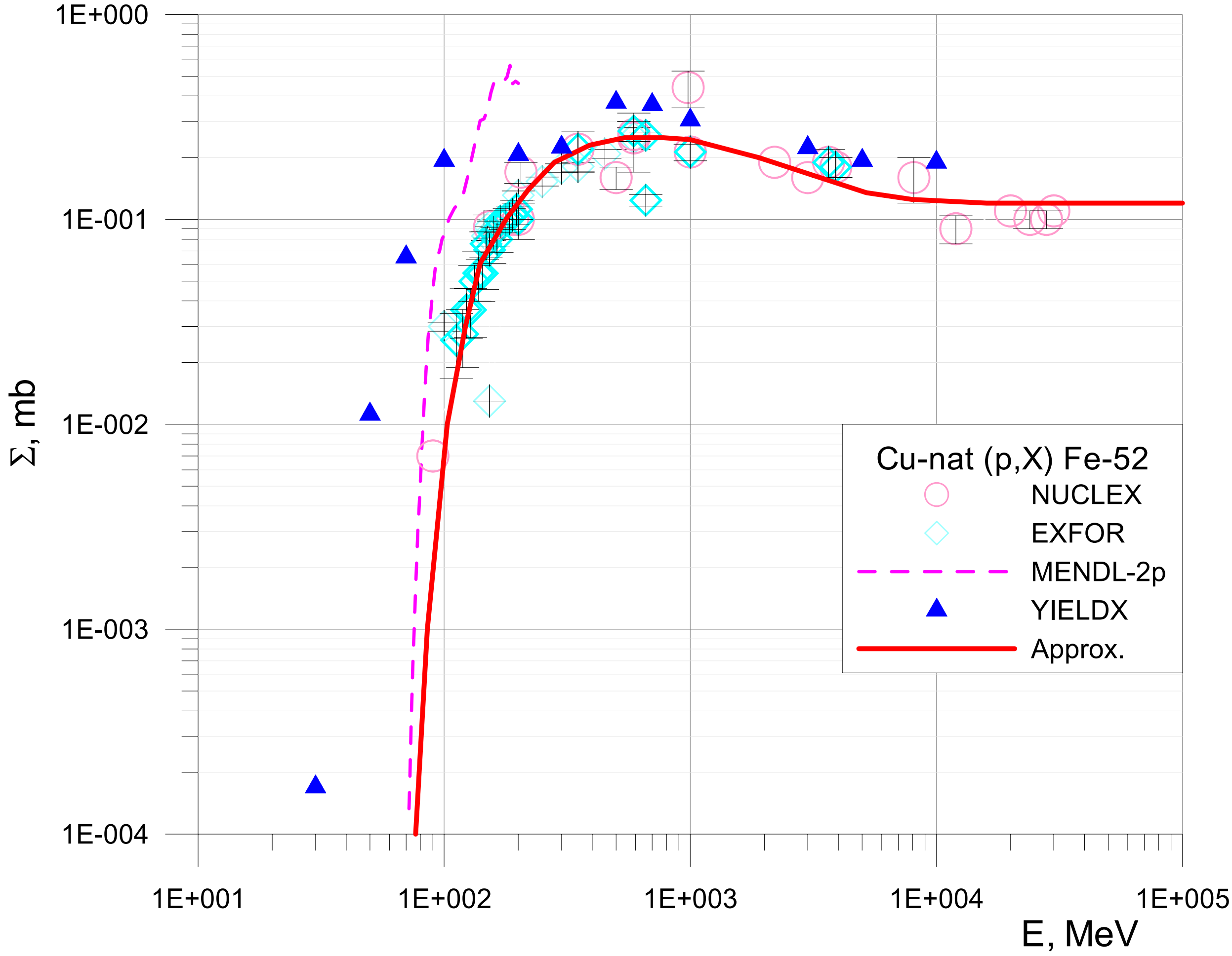
##	E, MeV	Σ, mb
1	38	0.000
2	50	0.001
3	58	0.01
4	65	0.10
5	76	1.00
6	81	1.46
7	85	1.76
8	96	2.00
9	108	1.96
10	122	1.96
11	134	2.12
12	160	2.12
13	210	2.00
14	400	1.75
15	680	1.60
16	1200	1.45
17	2100	1.30
18	3800	1.10
19	5400	1.00
20	100000	1.00



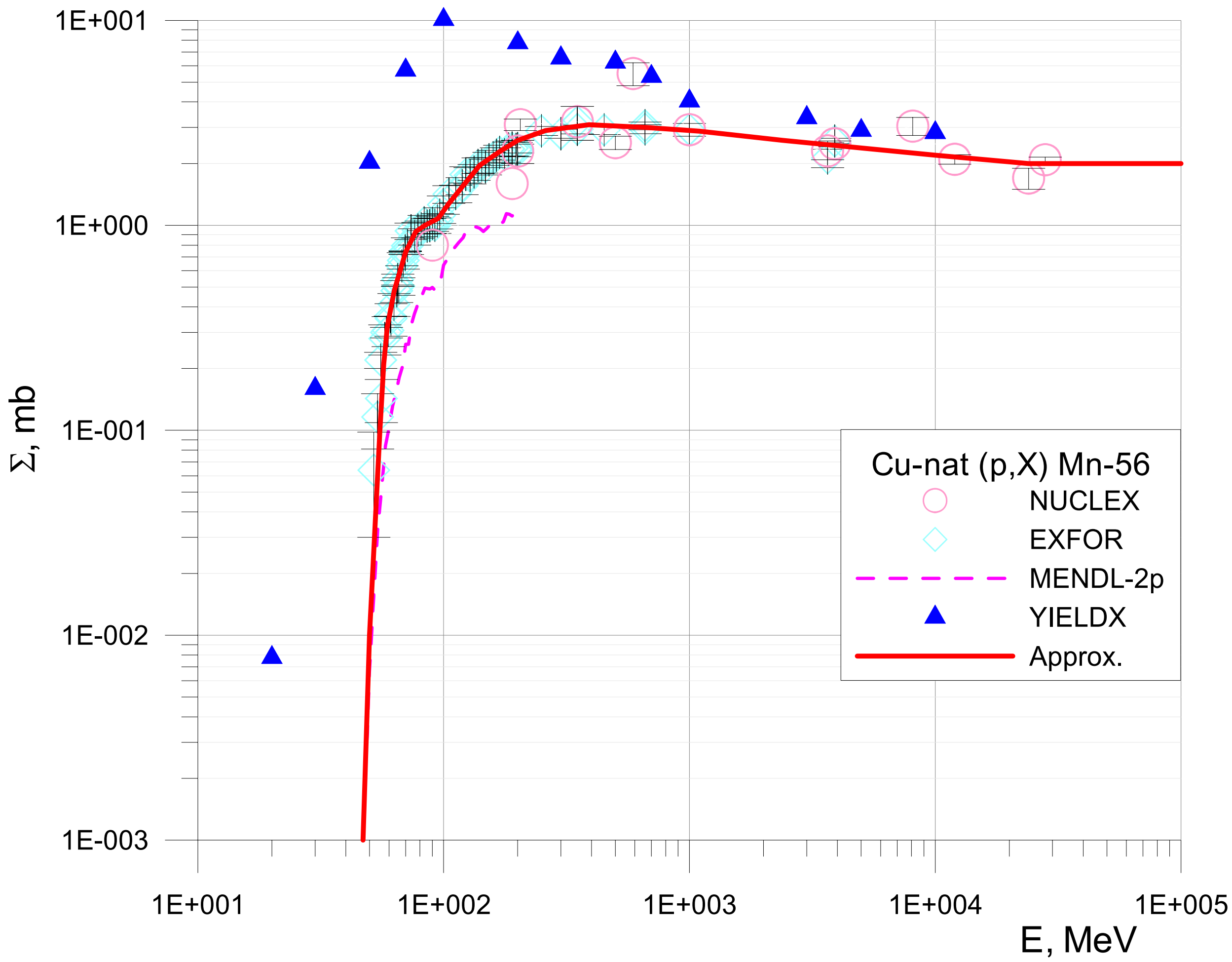
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	16.93	0.000	19	3800	1.50
2	37.7	0.001	20	6800	1.40
3	42.1	0.01	21	100000	1.40
4	48.1	0.10			
5	51.4	0.20			
6	55.5	0.40			
7	61.3	0.60			
8	71.6	0.75			
9	90	0.90			
10	125	1.00			
11	160	1.18			
12	210	1.22			
13	260	1.28			
14	360	1.56			
15	520	1.80			
16	780	1.90			
17	1200	1.90			
18	1900	1.80			



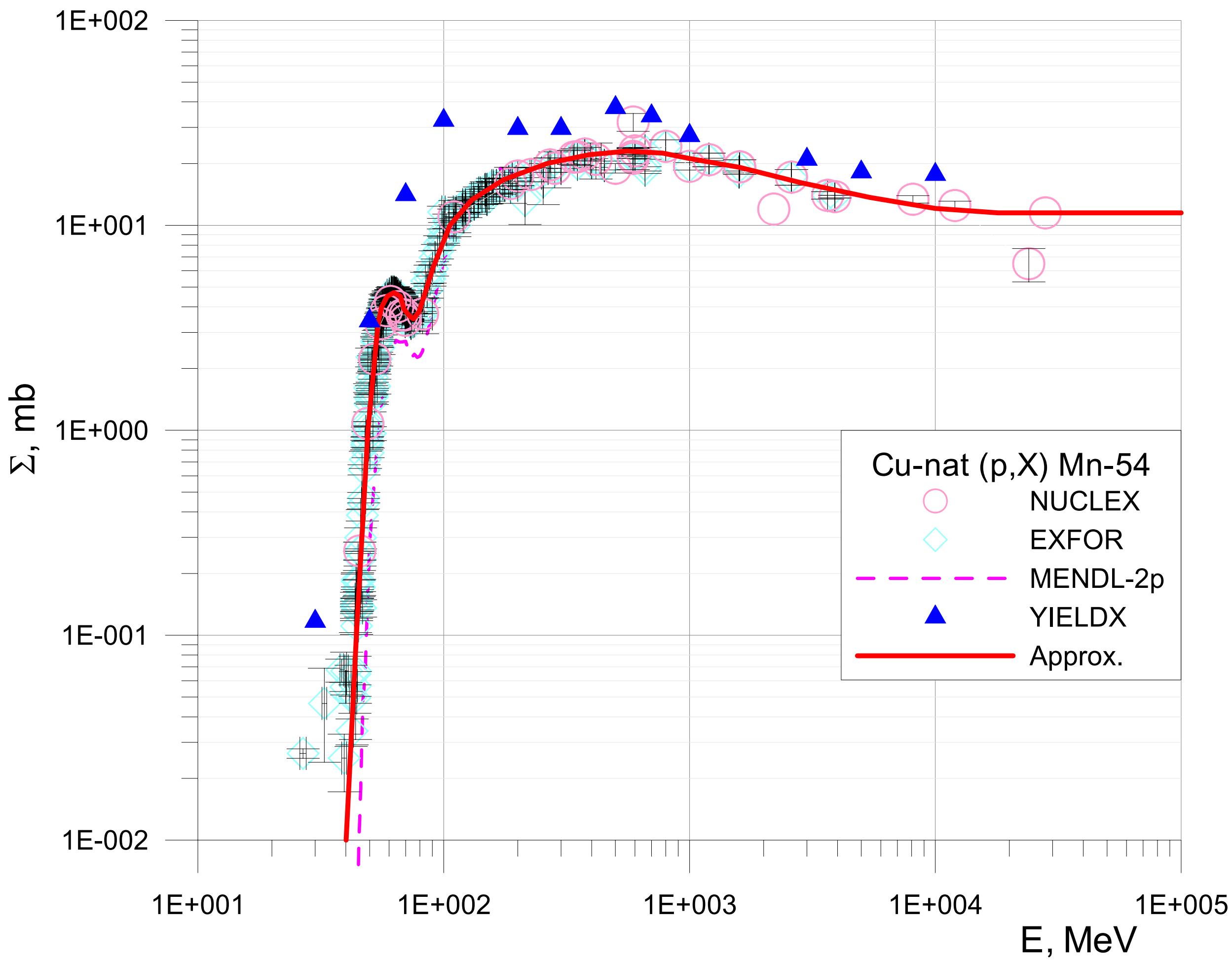
##	E, MeV	Σ, mb
1	30	0.01
2	32	0.1
3	36	1.0
4	40	2.2
5	45	3.2
6	56	2.9
7	66	3.5
8	74	9.4
9	84	24
10	120	36
11	176	37
12	460	29
13	1100	22
14	3000	17
15	10000	14
16		
17		
18		



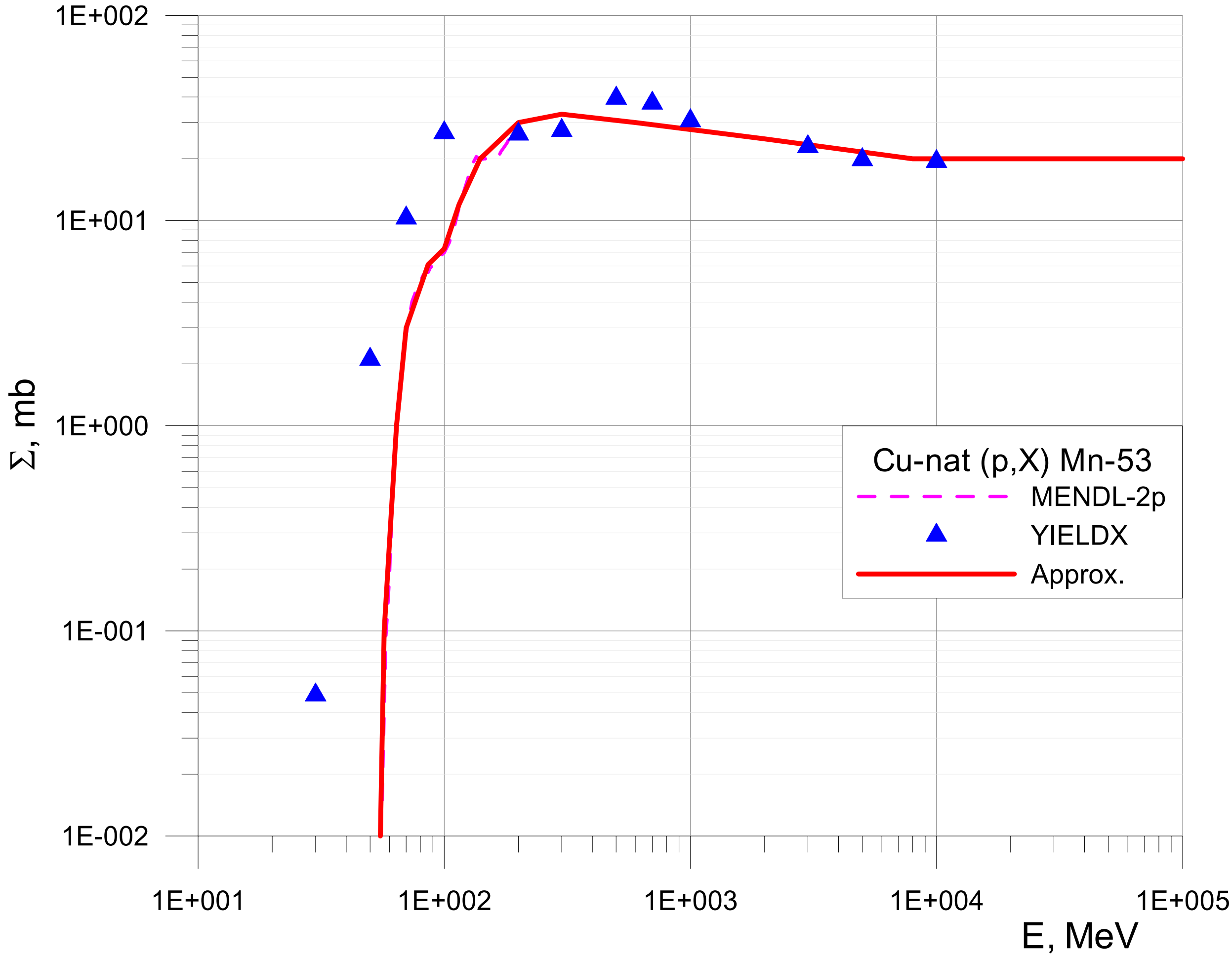
##	E, MeV	Σ, mb
1	47.8	0.0000
2	76.6	0.0001
3	85.4	0.001
4	103	0.010
5	122	0.030
6	140	0.061
7	180	0.102
8	220	0.140
9	280	0.190
10	390	0.230
11	540	0.250
12	780	0.250
13	1000	0.245
14	1900	0.200
15	5200	0.135
16	8000	0.125
17	16000	0.120
18	100000	0.120



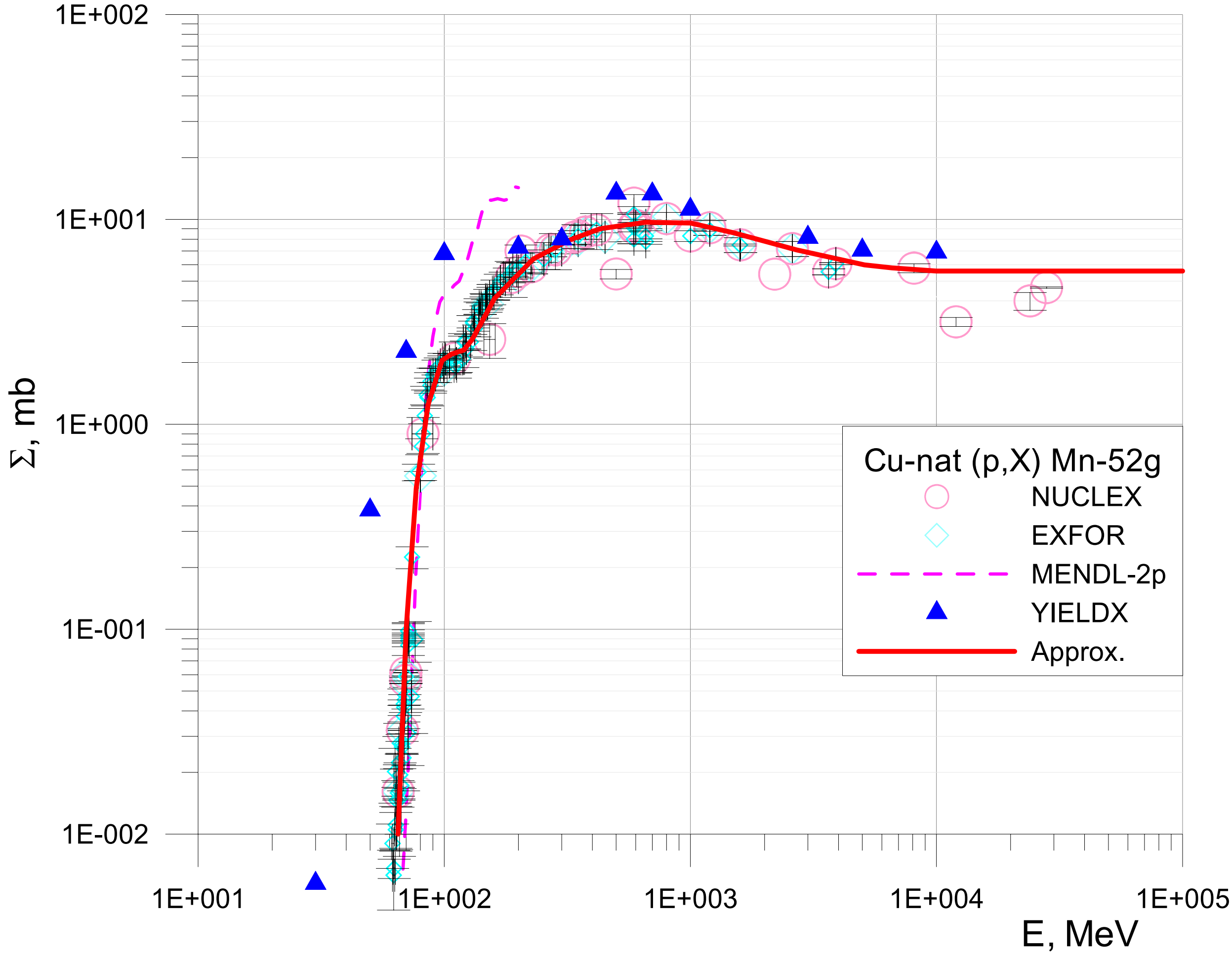
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	21.4	0.000	19	660	3.00
2	47	0.001	20	1100	2.88
3	50	0.01	21	2400	2.60
4	55	0.10	22	10000	2.20
5	57	0.21	23	24000	2.00
6	59	0.32	24	100000	2.00
7	63	0.48			
8	70	0.74			
9	77	0.93			
10	84	1.00			
11	95	1.08			
12	105	1.28			
13	120	1.56			
14	140	1.96			
15	170	2.30			
16	200	2.60			
17	260	2.90			
18	390	3.10			



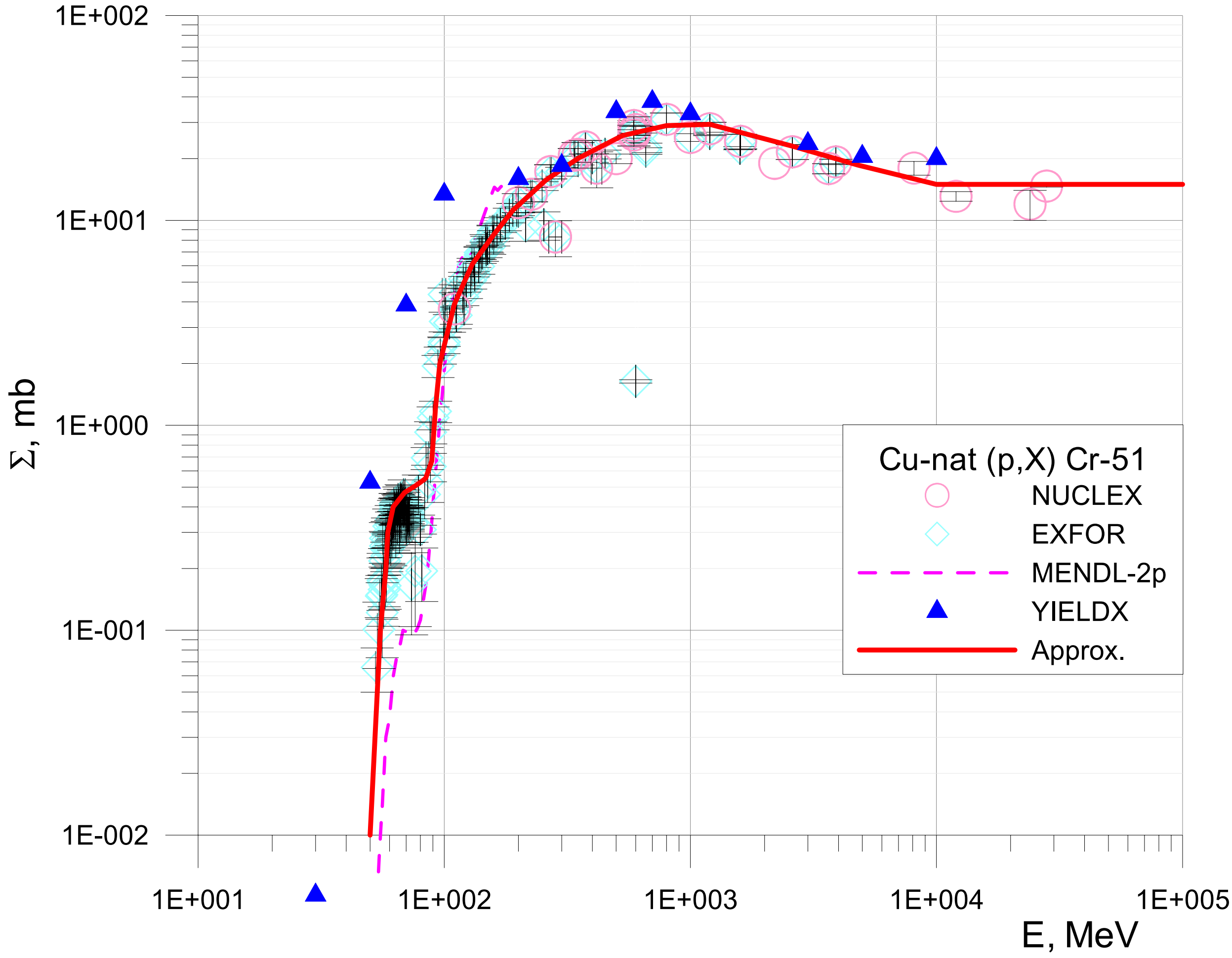
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	21.0	0.00	19	390	22.1
2	40.1	0.01	20	560	23.0
3	44.1	0.10	21	780	22.5
4	49.2	1.0	22	1000	21.2
5	54.0	3.3	23	1600	19.2
6	55.9	4.0	24	2800	16.2
7	59.0	4.5	25	5400	13.7
8	62.7	4.7	26	10000	12.1
9	66.7	4.5	27	18000	11.5
10	68.9	3.9	28	100000	11.5
11	72.8	3.6			
12	75.3	3.5			
13	79.6	3.8			
14	90.8	6.3			
15	106	10.0			
16	130	13.3			
17	175	16.7			
18	265	20.1			



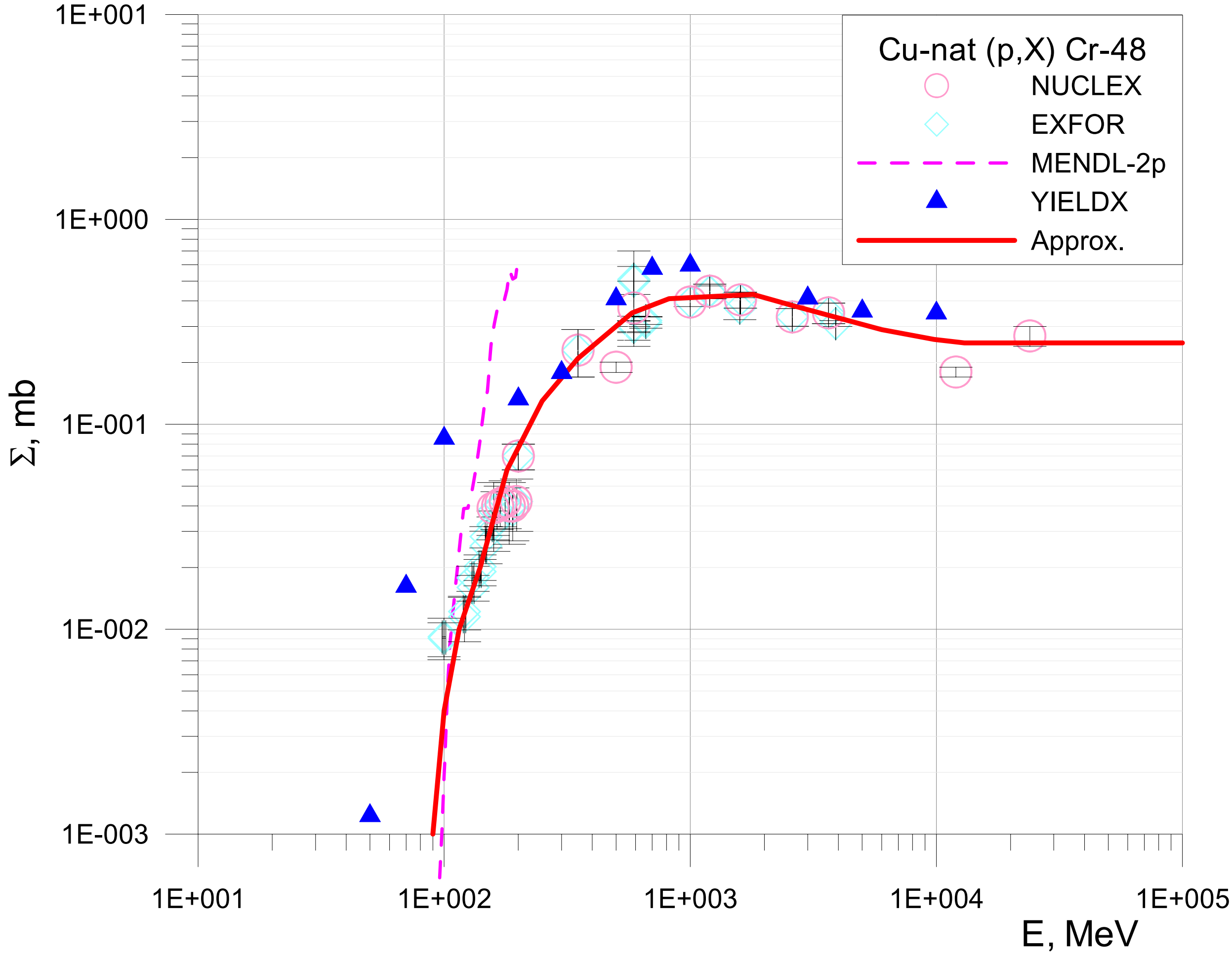
##	E, MeV	Σ, mb
1	23.8	0.00
2	55	0.01
3	57	0.10
4	64	1.0
5	70	3.0
6	86	6.1
7	100	7.3
8	115	12
9	140	20
10	200	30
11	300	33
12	600	30
13	2000	25
14	8000	20
15	100000	20
16		
17		
18		



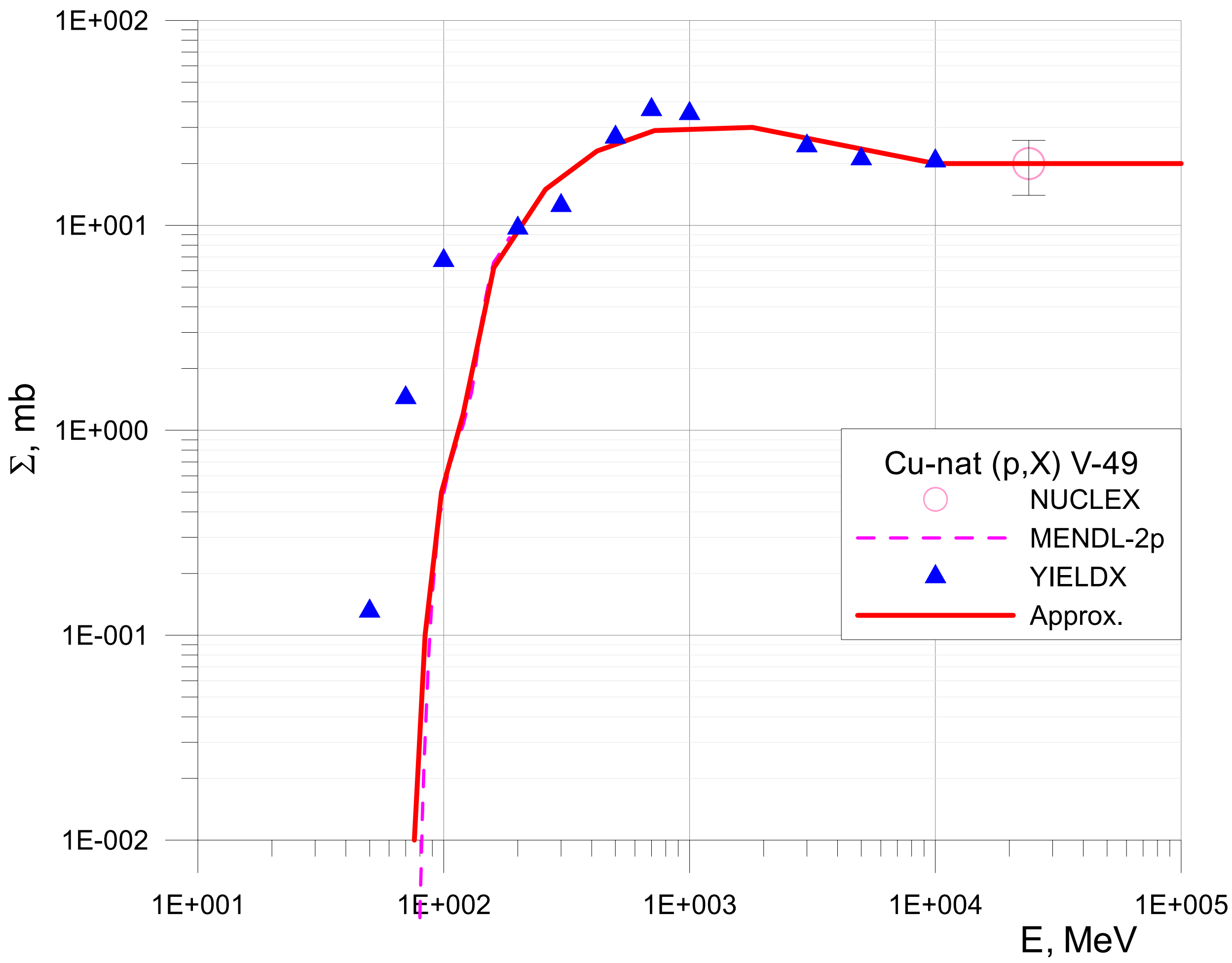
##	E, MeV	Σ, mb
1	36	0.00
2	65	0.01
3	70	0.10
4	77	0.49
5	86	1.25
6	98	2.05
7	107	2.2
8	120	2.3
9	130	2.6
10	160	4.1
11	230	6.4
12	320	7.9
13	430	9.0
14	660	9.7
15	1000	9.6
16	1500	8.6
17	2700	7.1
18	5100	6.0
19	6600	5.8
20	10000	5.6
21	100000	5.6



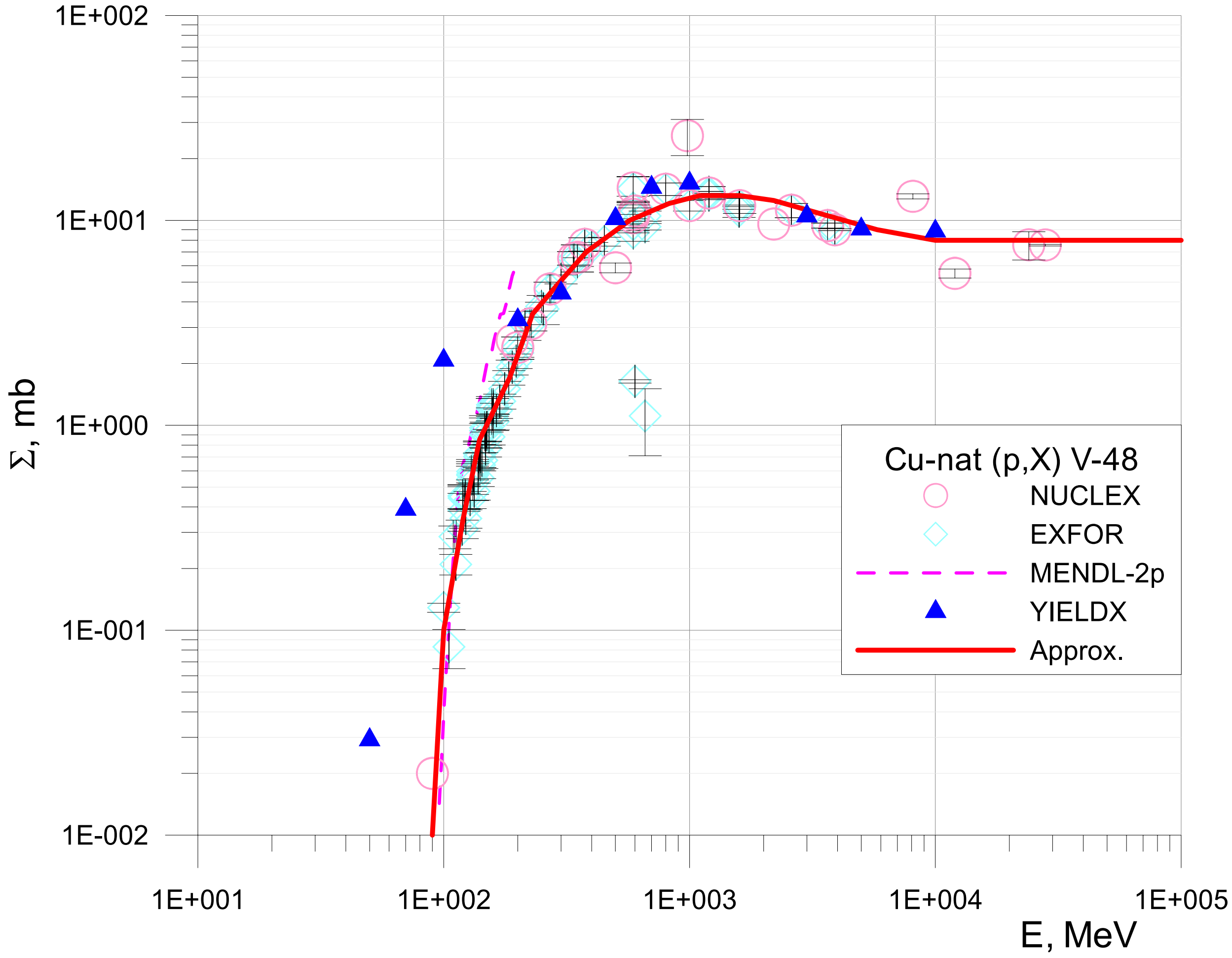
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	40.4	0.00	19	530	25.9
2	50	0.01	20	800	29.0
3	55	0.10	21	1200	29.4
4	58	0.20	22	2600	23.0
5	59	0.30	23	4800	18.6
6	62	0.40	24	13000	15.0
7	69	0.47	25	100000	15.0
8	77	0.51			
9	84	0.55			
10	89	0.67			
11	92	1.2			
12	96	2.0			
13	110	3.9			
14	130	6.1			
15	160	8.6			
16	190	11.2			
17	260	15.8			
18	350	20.1			



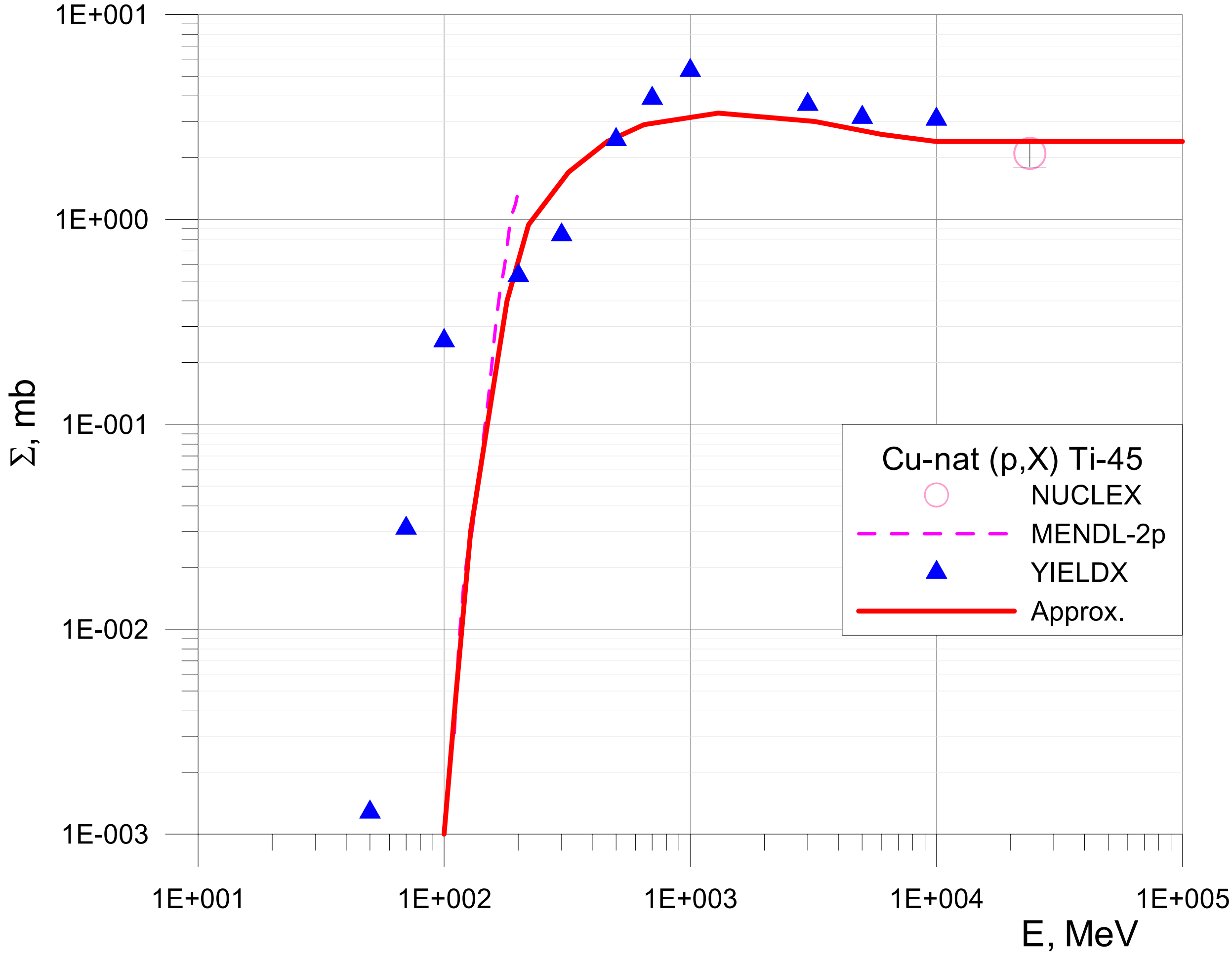
##	E, MeV	Σ, mb
1	67.4	0.000
2	90	0.001
3	100	0.004
4	115	0.01
5	140	0.02
6	180	0.06
7	250	0.13
8	350	0.21
9	580	0.35
10	820	0.41
11	1200	0.42
12	1800	0.43
13	2600	0.38
14	6000	0.29
15	9800	0.26
16	13000	0.25
17	100000	0.25
18		



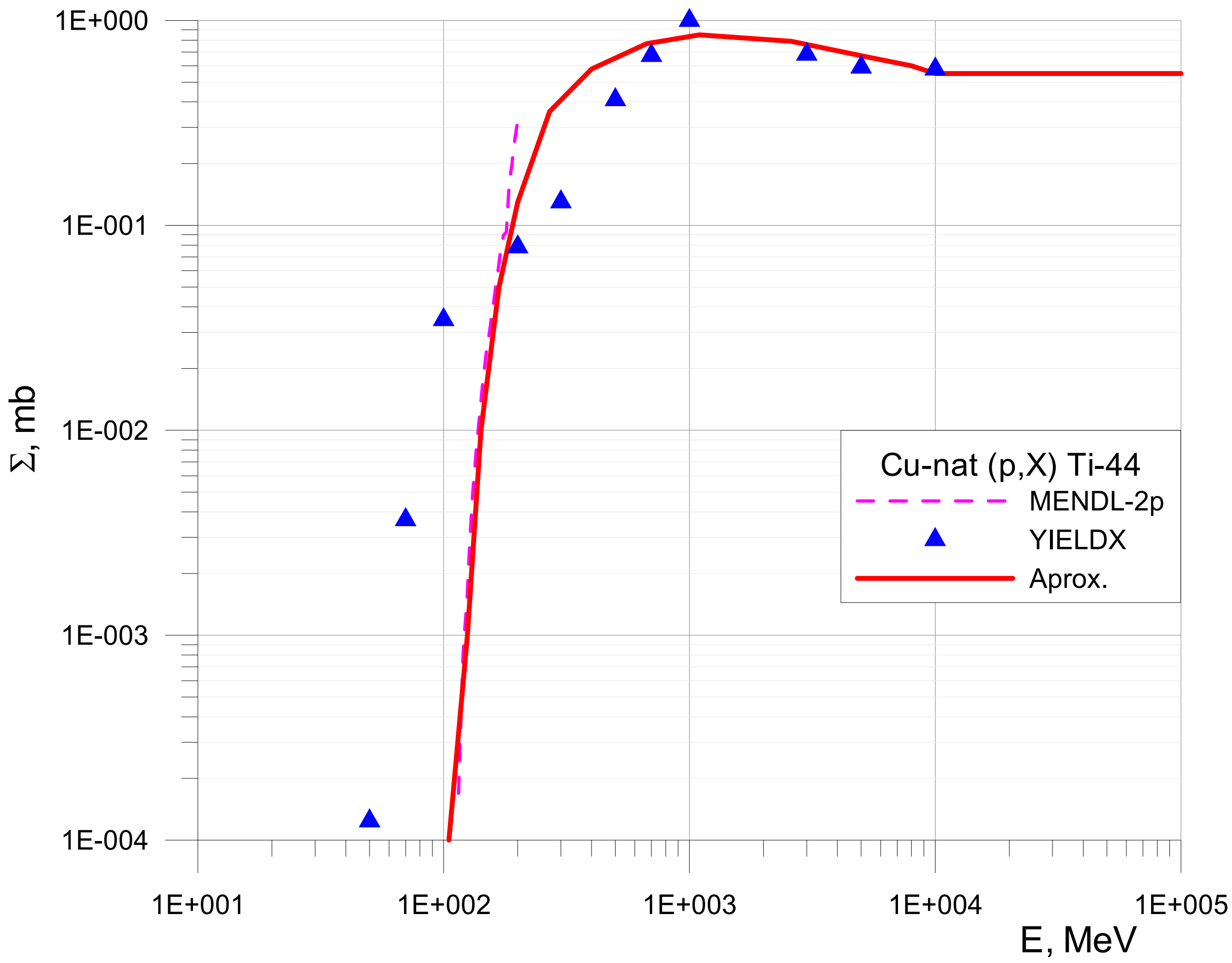
##	E, MeV	Σ, mb
1	33.1	0.00
2	76	0.01
3	84	0.1
4	98	0.5
5	120	1.2
6	160	6.2
7	260	15
8	420	23
9	720	29
10	1800	30
11	10000	20
12	100000	20
13		
14		
15		
16		
17		
18		



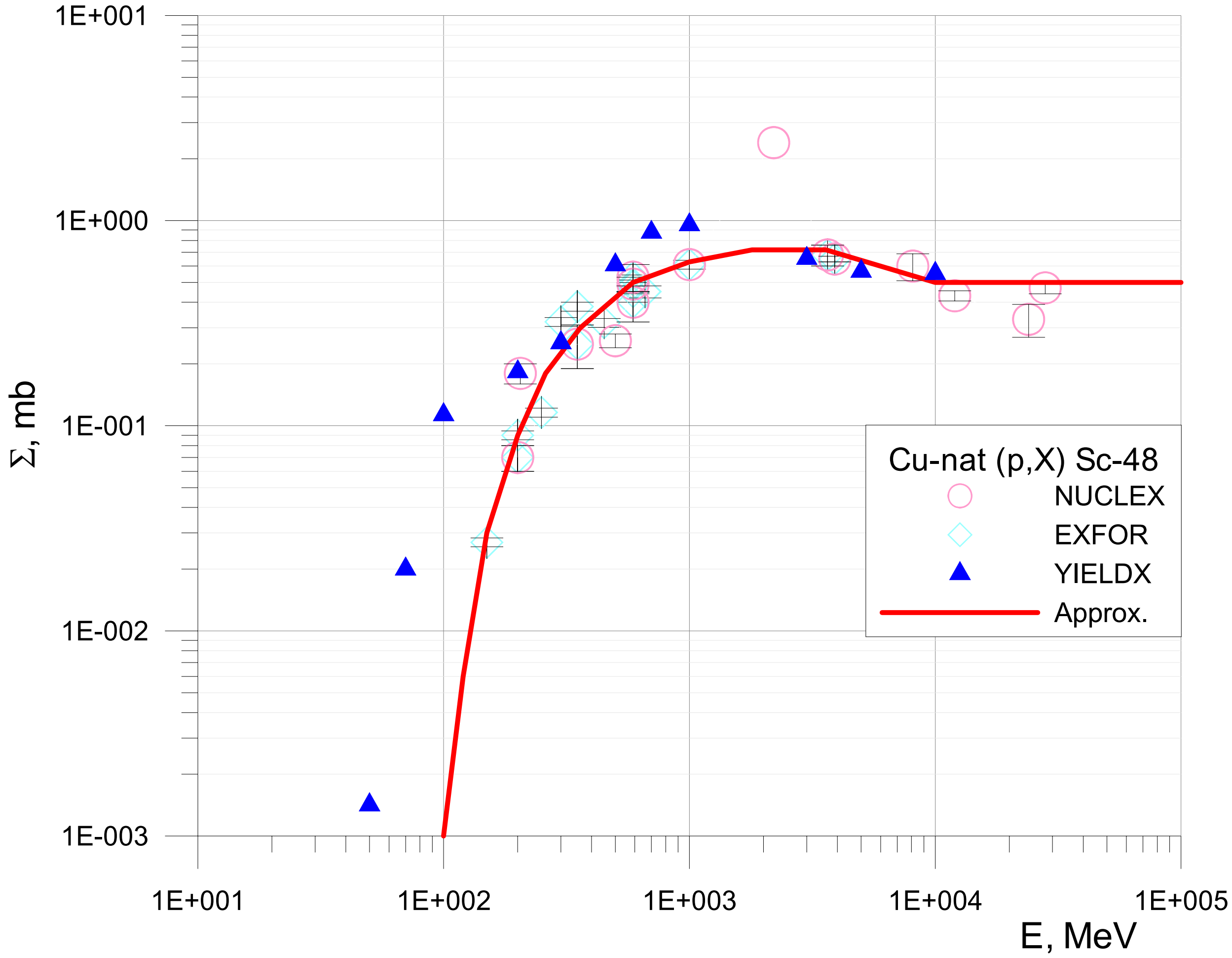
##	E, MeV	Σ, mb
1	45	0.00
2	90	0.01
3	100	0.10
4	120	0.35
5	140	0.85
6	185	1.70
7	230	3.50
8	290	4.85
9	380	7.00
10	570	10.0
11	825	12.1
12	1100	13.2
13	1600	13.2
14	2200	12.5
15	5800	9.0
16	10000	8.0
17	100000	8.0
18		



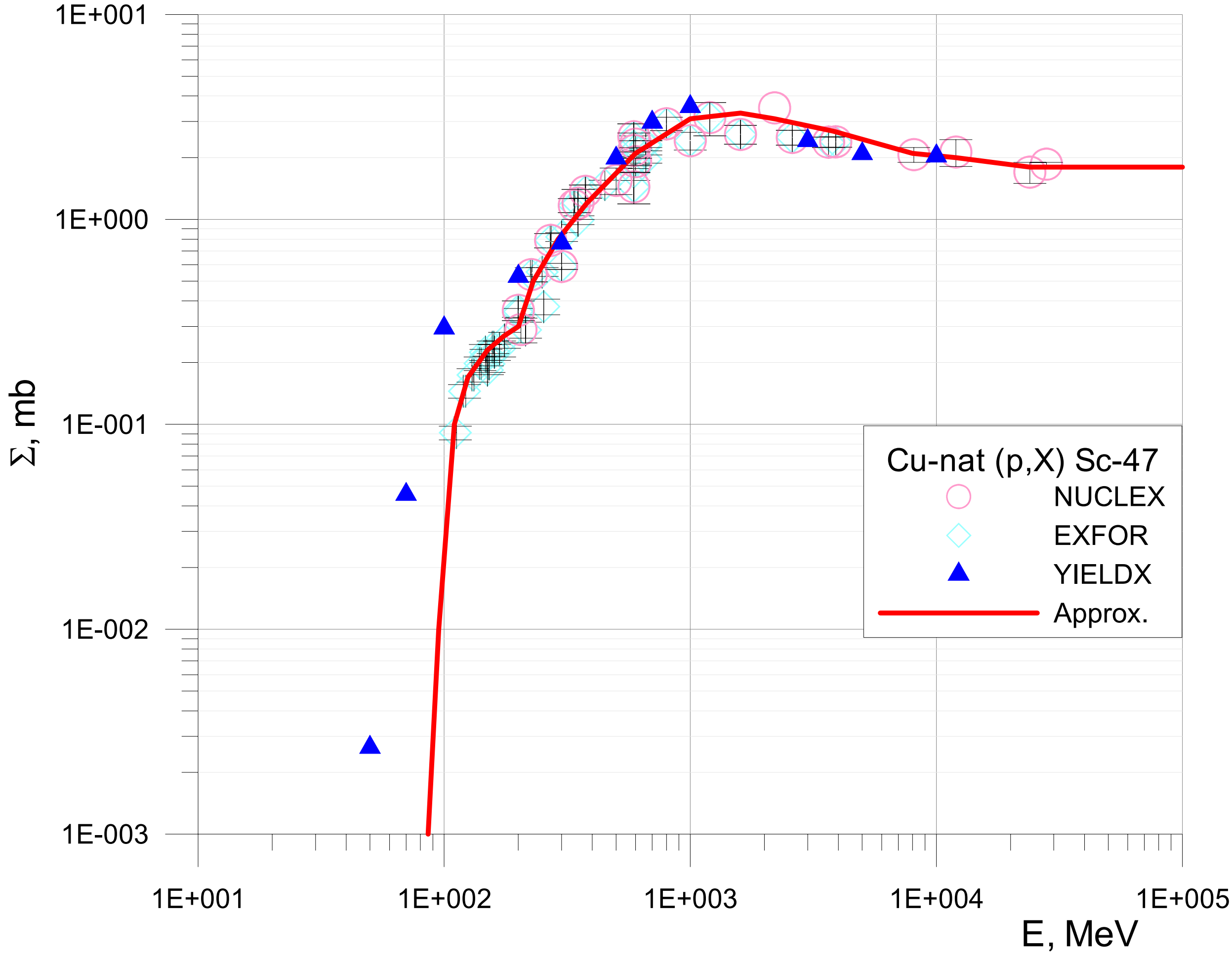
##	E, MeV	Σ, mb
1	66	0.000
2	100	0.001
3	112	0.005
4	128	0.03
5	150	0.10
6	180	0.40
7	220	0.94
8	320	1.7
9	460	2.4
10	650	2.9
11	1300	3.3
12	3200	3.0
13	6000	2.6
14	10000	2.4
15	100000	2.4
16		
17		
18		



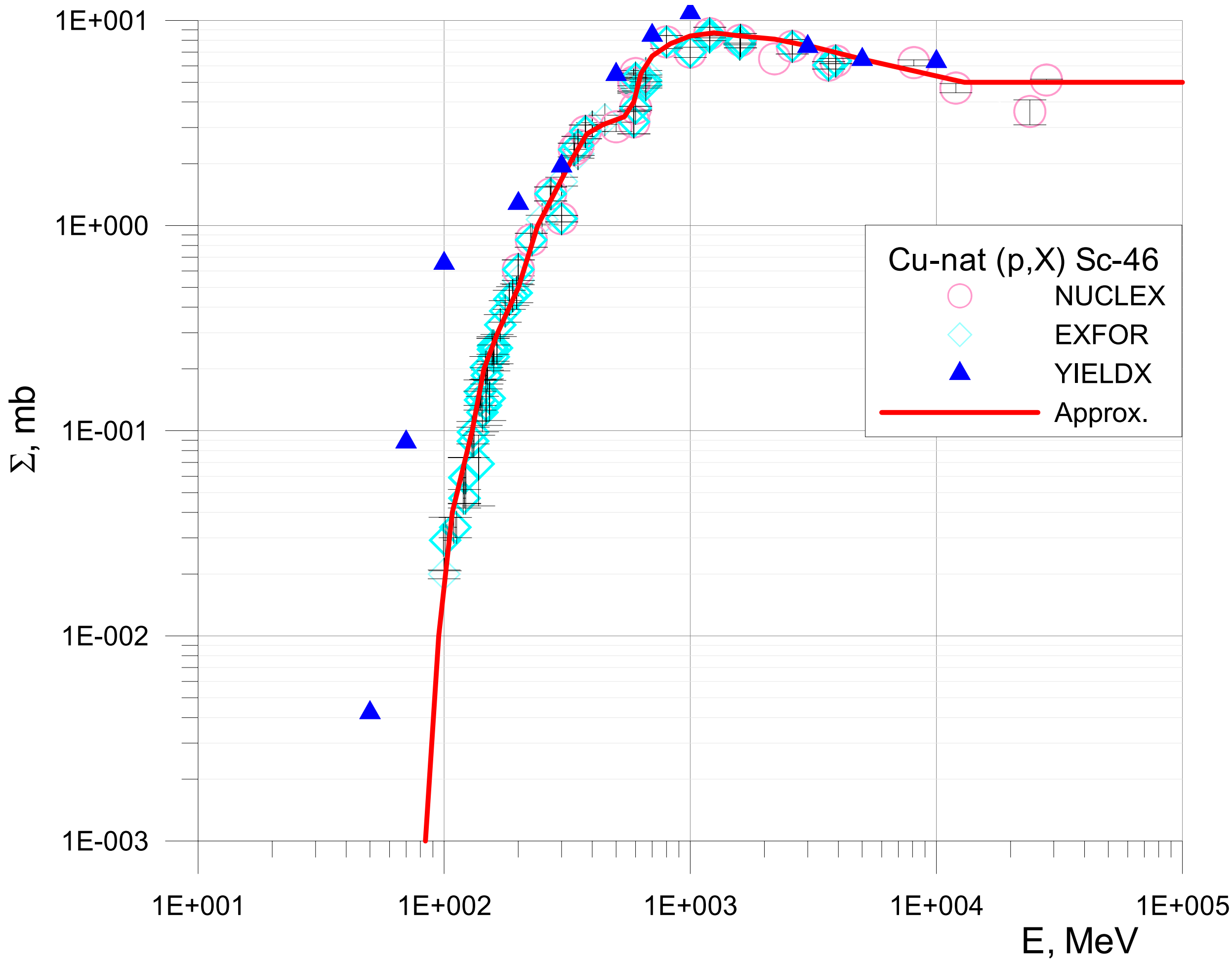
##	E, MeV	Σ, mb
1	86.8	0.0000
2	105	0.0001
3	125	0.001
4	142	0.01
5	168	0.05
6	200	0.13
7	270	0.36
8	400	0.58
9	670	0.77
10	1100	0.85
11	2600	0.79
12	5400	0.66
13	8000	0.60
14	10000	0.55
15	100000	0.55
16		
17		
18		



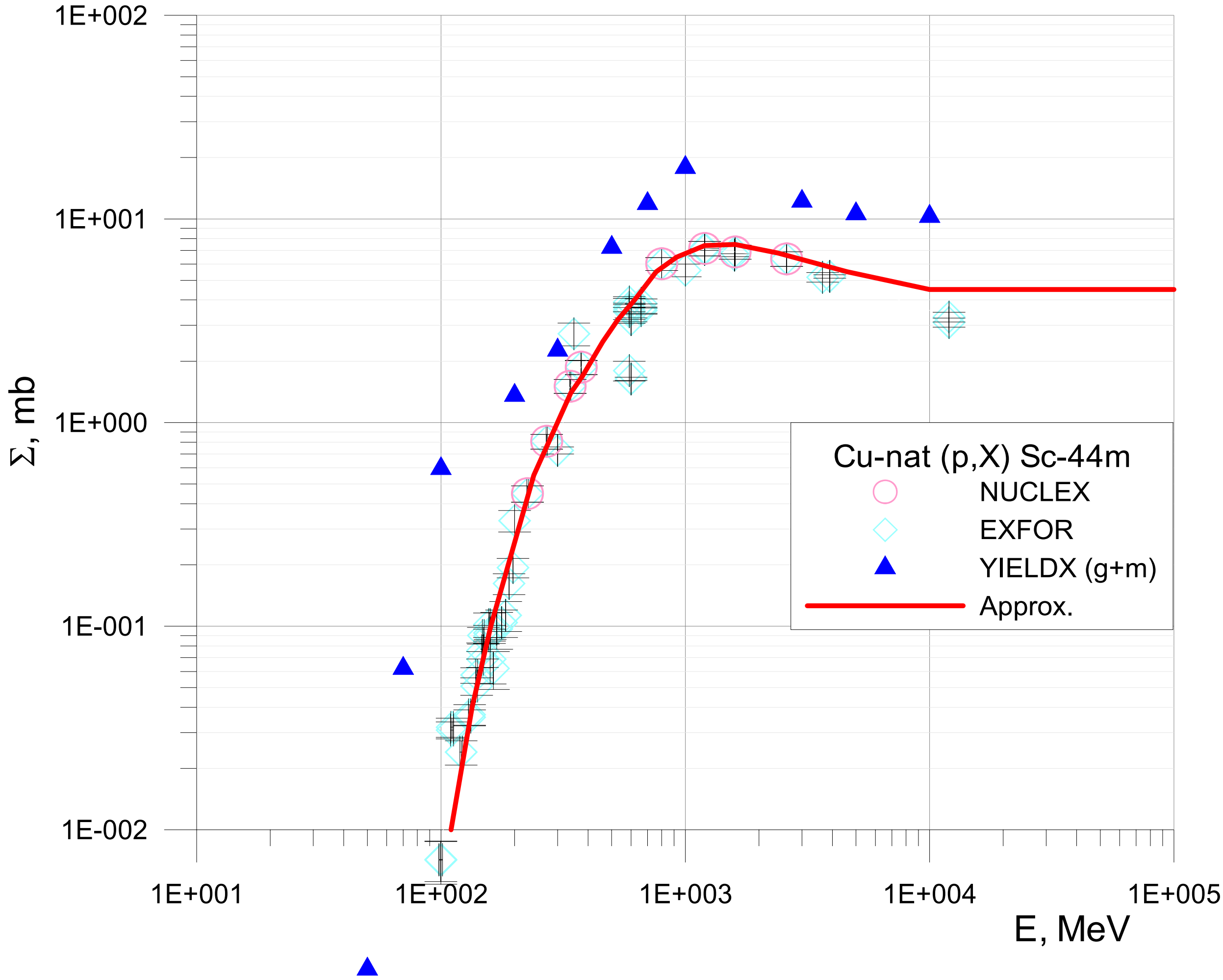
##	E, MeV	Σ, mb
1	38.9	0.000
2	100	0.001
3	120	0.006
4	150	0.03
5	200	0.09
6	260	0.18
7	360	0.30
8	590	0.50
9	1000	0.63
10	1800	0.72
11	3600	0.72
12	6000	0.60
13	10000	0.50
14	100000	0.50
15		
16		
17		
18		



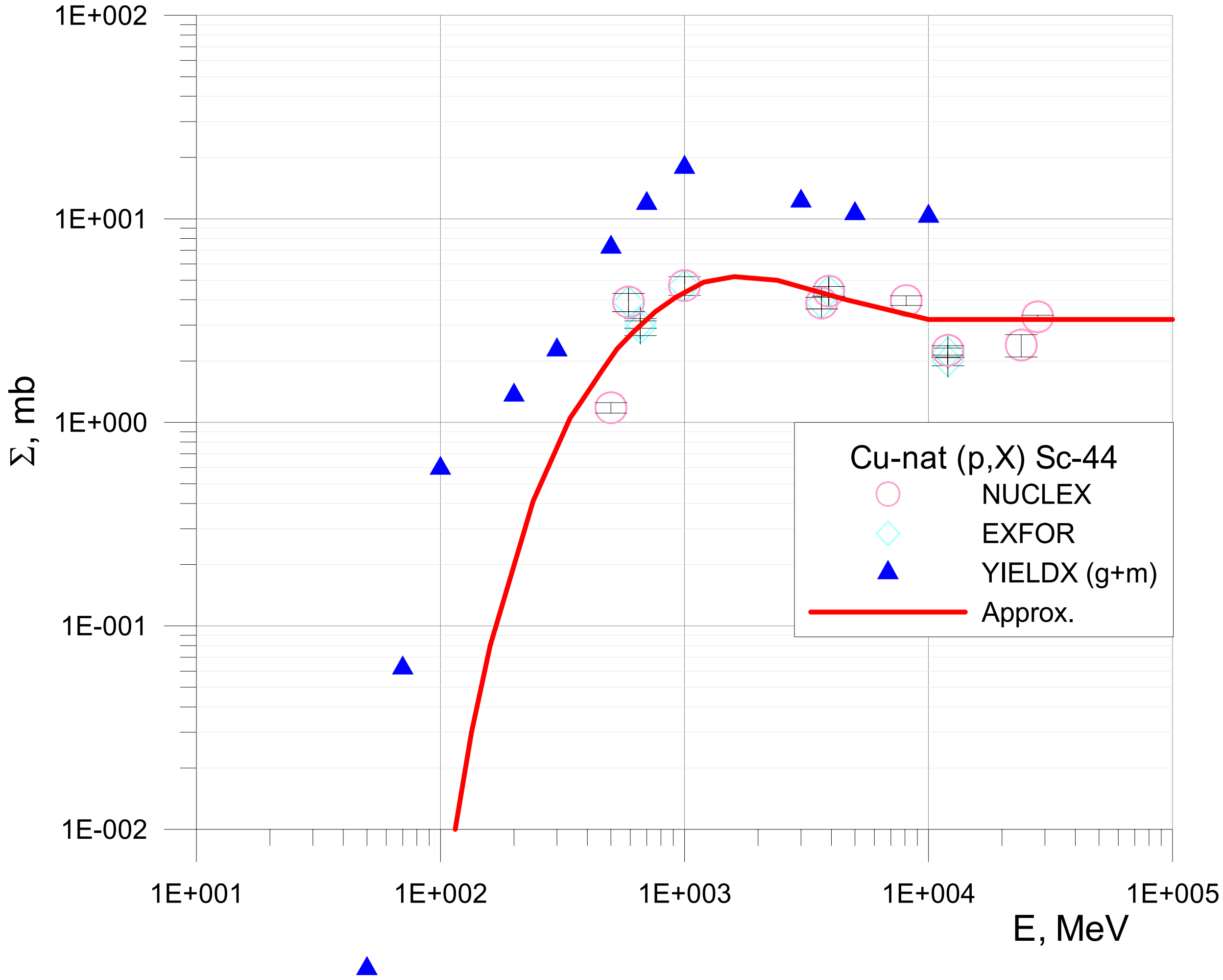
##	E, MeV	Σ, mb
1	31	0.000
2	86	0.001
3	95	0.01
4	110	0.10
5	125	0.17
6	150	0.23
7	175	0.27
8	200	0.30
9	230	0.50
10	290	0.80
11	380	1.2
12	600	2.1
13	1000	3.1
14	1600	3.3
15	2200	3.1
16	3800	2.7
17	8000	2.1
18	12000	2.0
19	24000	1.8
20	100000	1.8



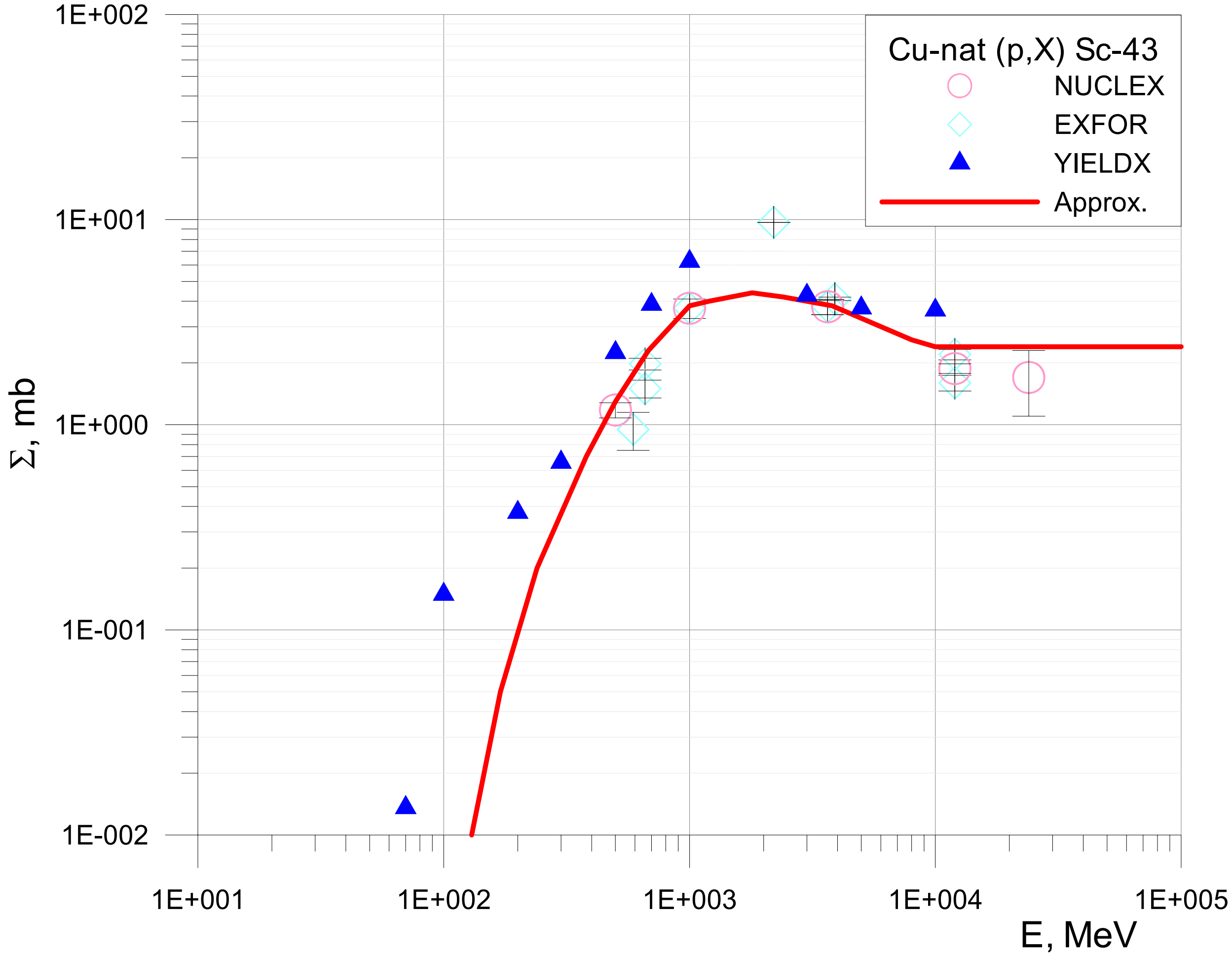
##	E, MeV	Σ, mb	##	E, MeV	Σ, mb
1	40	0.000	19	1250	8.7
2	84	0.001	20	1600	8.4
3	95	0.01	21	2200	8.1
4	108	0.04	22	3200	7.4
5	130	0.10	23	5200	6.4
6	145	0.20	24	13000	5.0
7	165	0.30	25	100000	5.0
8	200	0.5			
9	240	1.0			
10	330	2.1			
11	380	2.8			
12	440	3.1			
13	540	3.4			
14	590	4.0			
15	630	5.5			
16	700	6.7			
17	830	7.7			
18	1000	8.4			



##	E, MeV	Σ, mb
1	54	0.00
2	110	0.01
3	134	0.04
4	160	0.10
5	240	0.55
6	340	1.4
7	380	1.7
8	460	2.5
9	530	3.2
10	620	4.0
11	760	5.5
12	920	6.5
13	1200	7.4
14	1600	7.5
15	2400	6.8
16	4600	5.5
17	10000	4.5
18	100000	4.5



##	E, MeV	Σ, mb
1	54	0.00
2	115	0.01
3	134	0.03
4	160	0.08
5	240	0.41
6	340	1.05
7	380	1.3
8	460	1.8
9	530	2.3
10	620	2.8
11	760	3.5
12	920	4.1
13	1200	4.9
14	1600	5.2
15	2400	5.0
16	4600	4.0
17	10000	3.2
18	100000	3.2



##	E, MeV	Σ, mb
1	75.4	0.00
2	130	0.01
3	170	0.05
4	240	0.20
5	380	0.70
6	500	1.3
7	680	2.3
8	1000	3.8
9	1200	4.0
10	1800	4.4
11	2400	4.2
12	3800	3.8
13	8000	2.6
14	10000	2.4
15	100000	2.4
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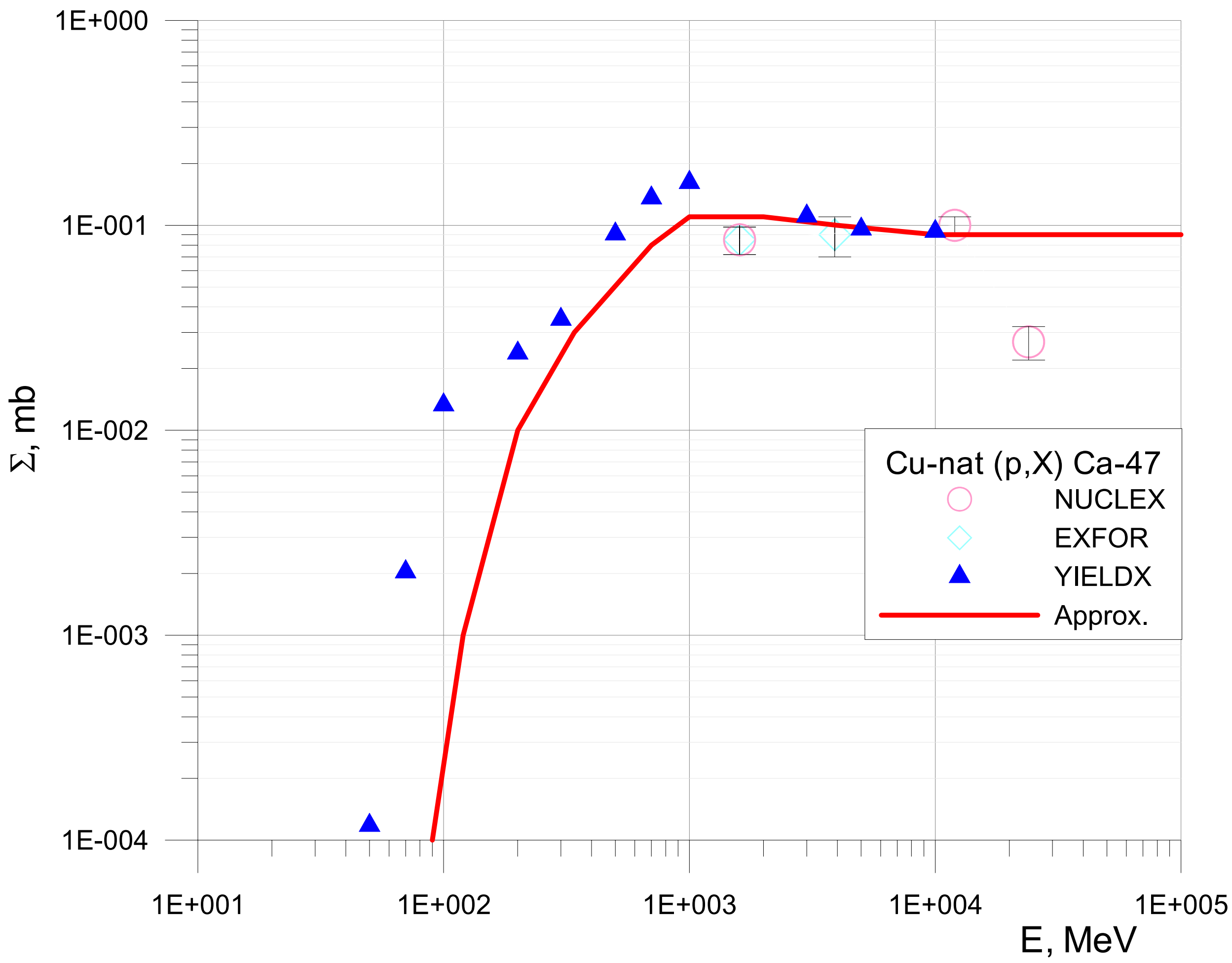

##	E, MeV	Σ, mb
1	42.9	0.0000
2	90	0.0001
3	120	0.001
4	200	0.01
5	340	0.03
6	700	0.08
7	1000	0.11
8	2000	0.10
9	4000	0.09
10	10000	0.09
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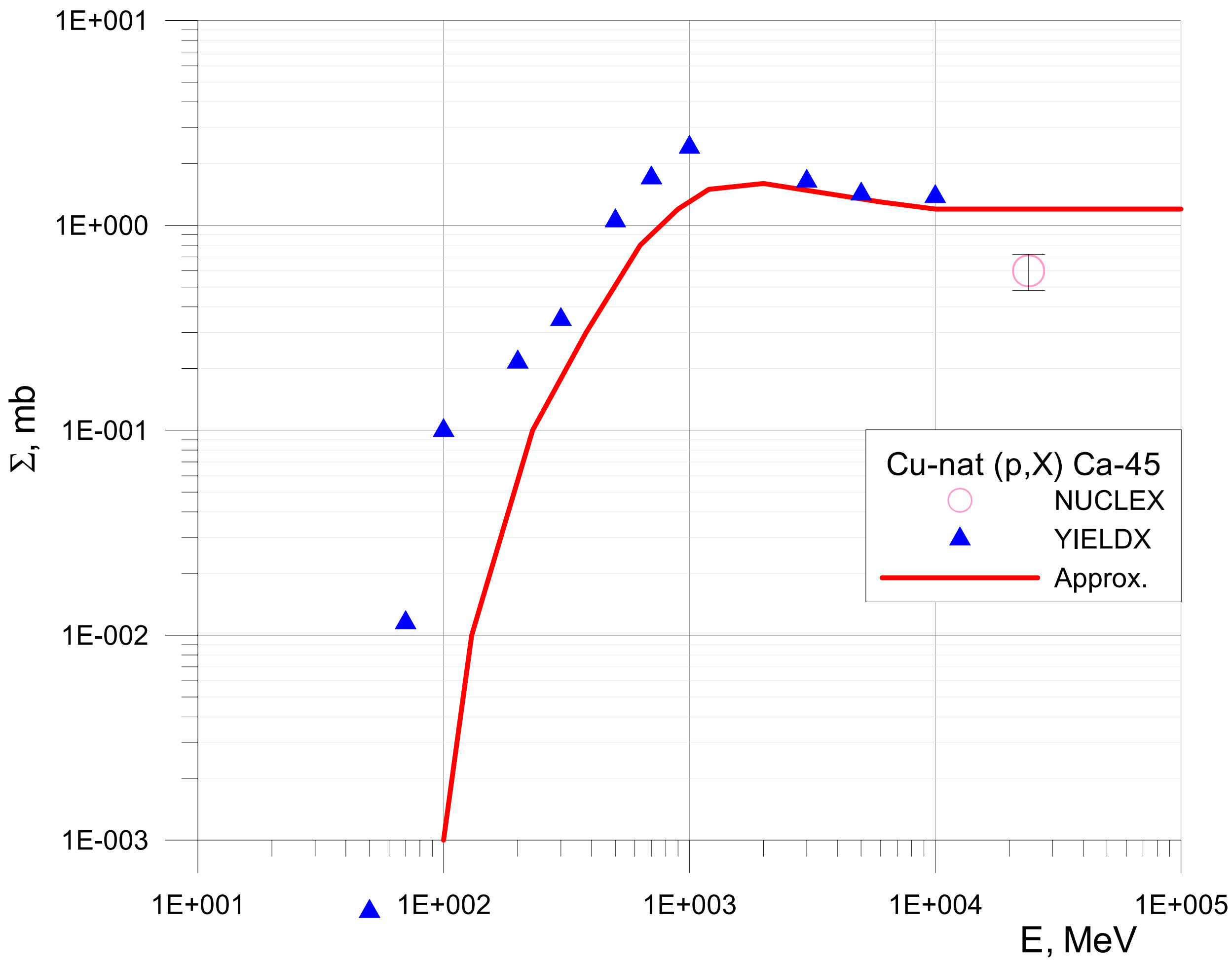

##	E, MeV	Σ, mb
1	40	0.000
2	100	0.001
3	130	0.01
4	230	0.10
5	380	0.30
6	630	0.80
7	900	1.2
8	1200	1.5
9	2000	1.6
10	6000	1.3
11	10000	1.2
12	100000	1.2
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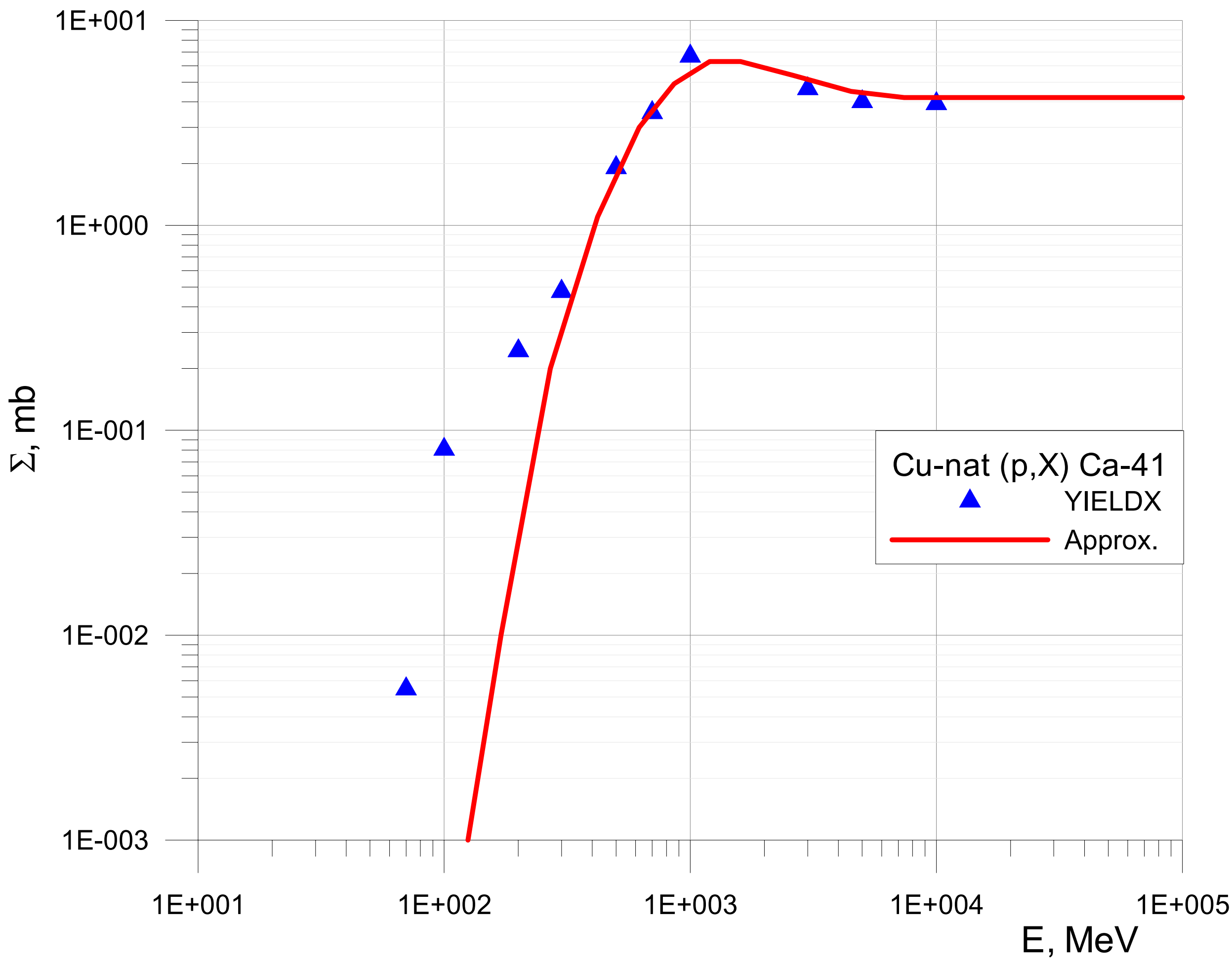

##	E, MeV	Σ, mb
1	125	0.001
2	170	0.01
3	270	0.2
4	420	1.1
5	620	3.0
6	860	4.9
7	1200	6.3
8	1600	6.3
9	2600	5.4
10	4500	4.5
11	7400	4.2
12	100000	4.2
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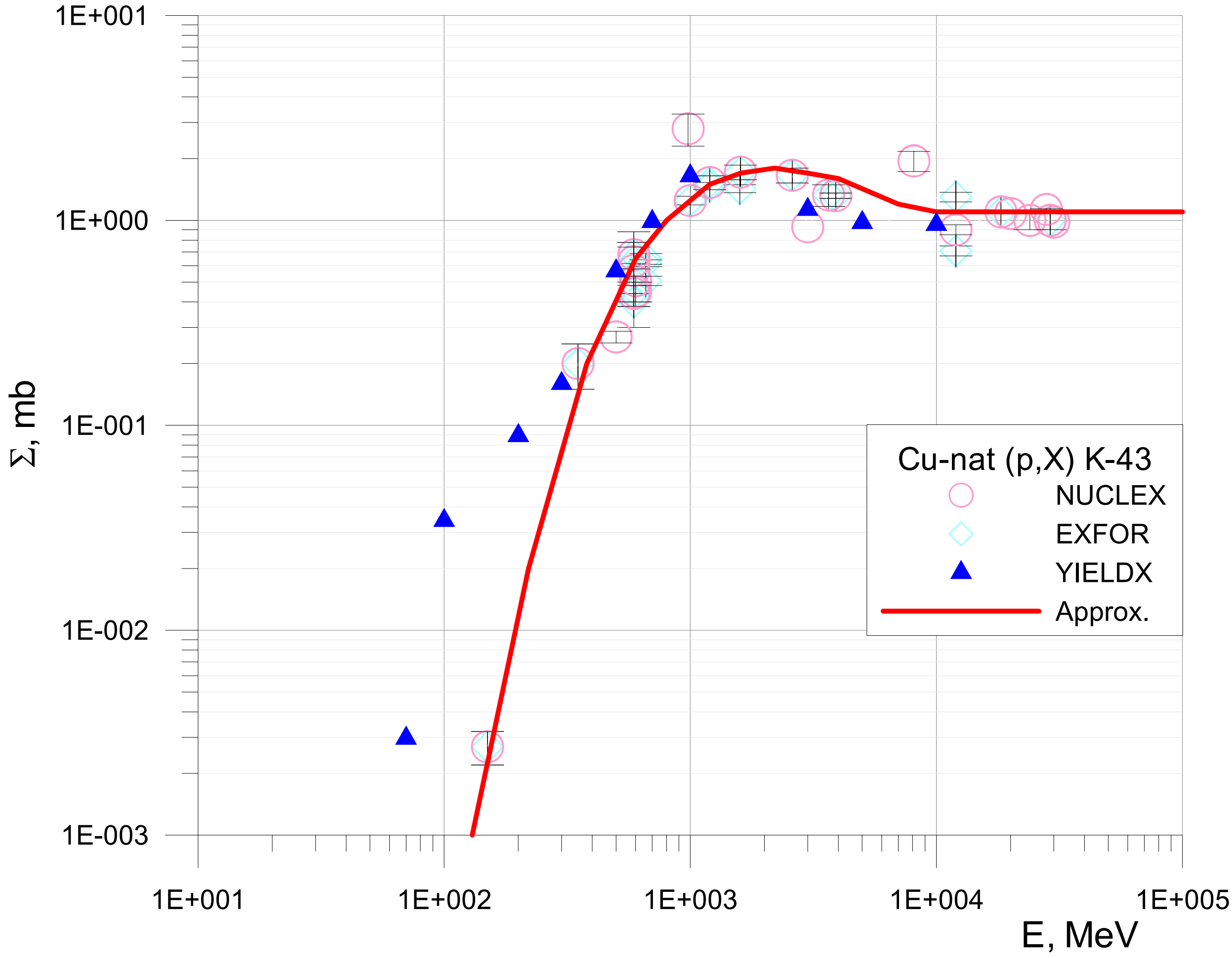

##	E, MeV	Σ, mb
1	42	0.000
2	130	0.001
3	220	0.02
4	380	0.20
5	600	0.65
6	800	1.0
7	1200	1.5
8	1600	1.7
9	2200	1.8
10	3000	1.7
11	4000	1.6
12	7000	1.2
13	10000	1.1
14	100000	1.1
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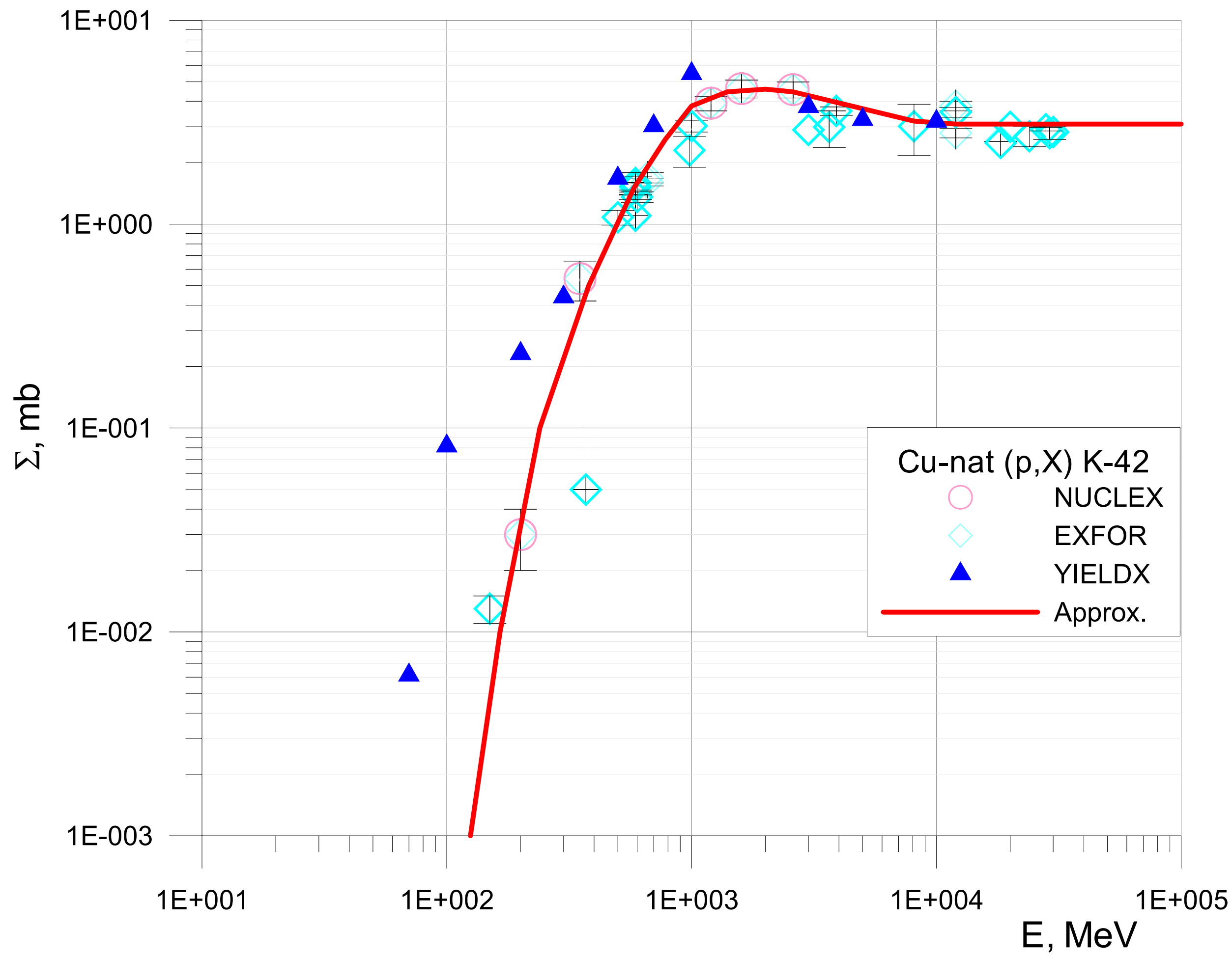

##	E, MeV	Σ, mb
1	49.3	0.000
2	125	0.001
3	165	0.01
4	240	0.10
5	380	0.50
6	580	1.50
7	780	2.60
8	1000	3.80
9	1400	4.45
10	2000	4.60
11	2600	4.45
12	4700	3.75
13	8100	3.20
14	12000	3.10
15	100000	3.10
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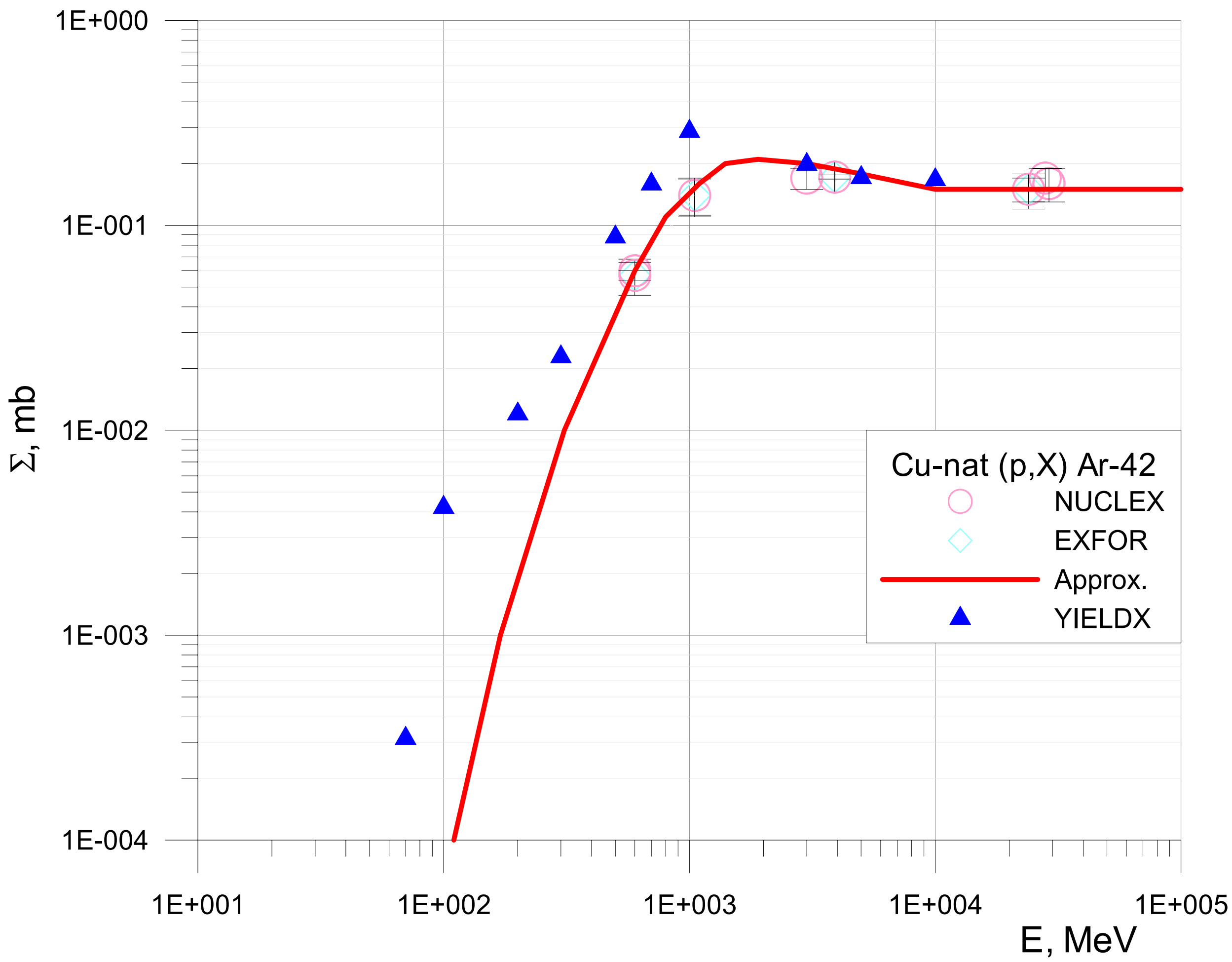

##	E, MeV	Σ, mb
1	40.7	0.0000
2	110	0.0001
3	170	0.001
4	310	0.010
5	600	0.06
6	800	0.11
7	1100	0.16
8	1400	0.20
9	1900	0.21
10	3000	0.20
11	4800	0.18
12	10000	0.15
13	100000	0.15
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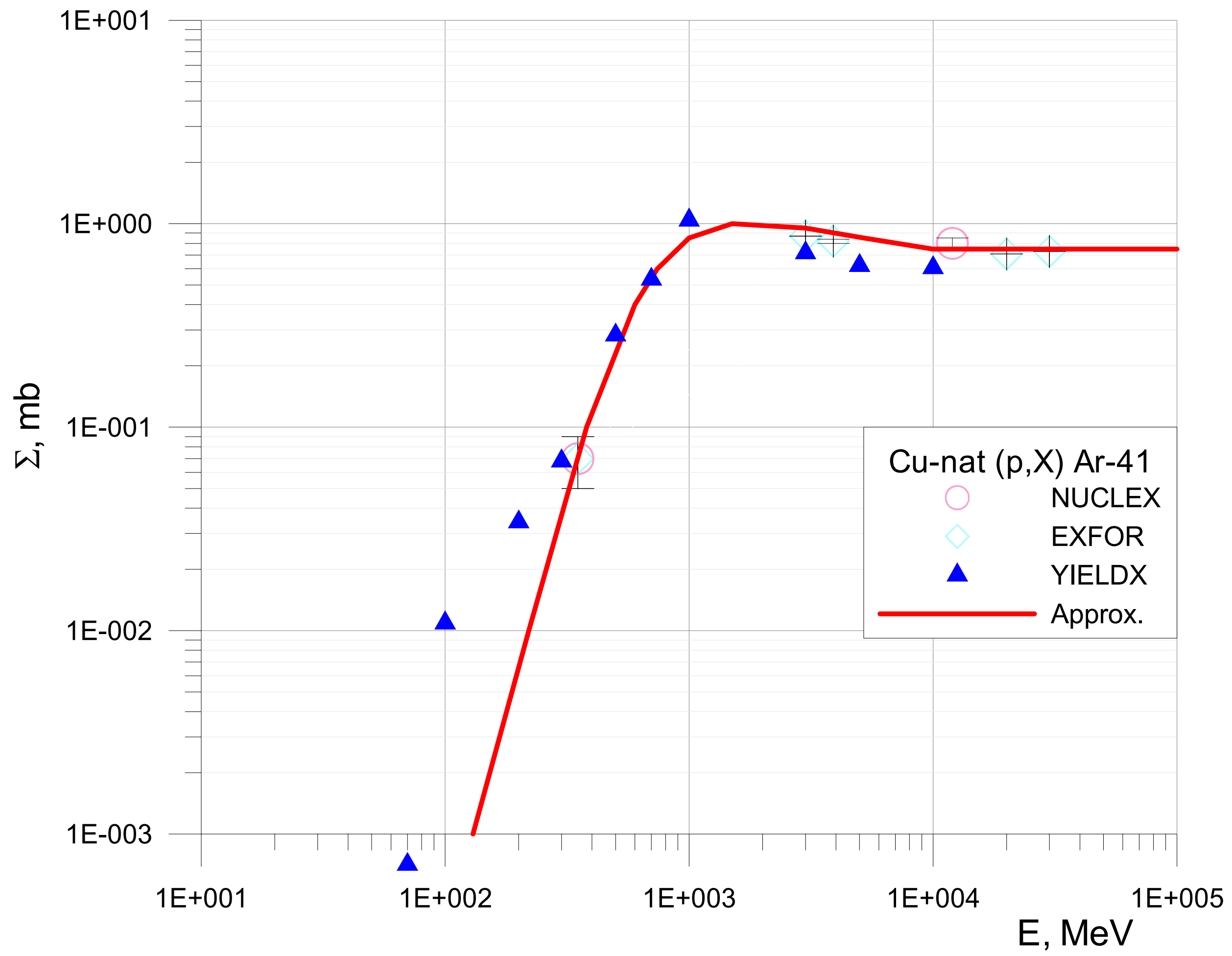

##	E, MeV	Σ, mb
1	53.1	0.000
2	130	0.001
3	220	0.01
4	380	0.10
5	600	0.40
6	740	0.60
7	1000	0.85
8	1500	1.00
9	3000	0.95
10	5200	0.85
11	10000	0.75
12	100000	0.75
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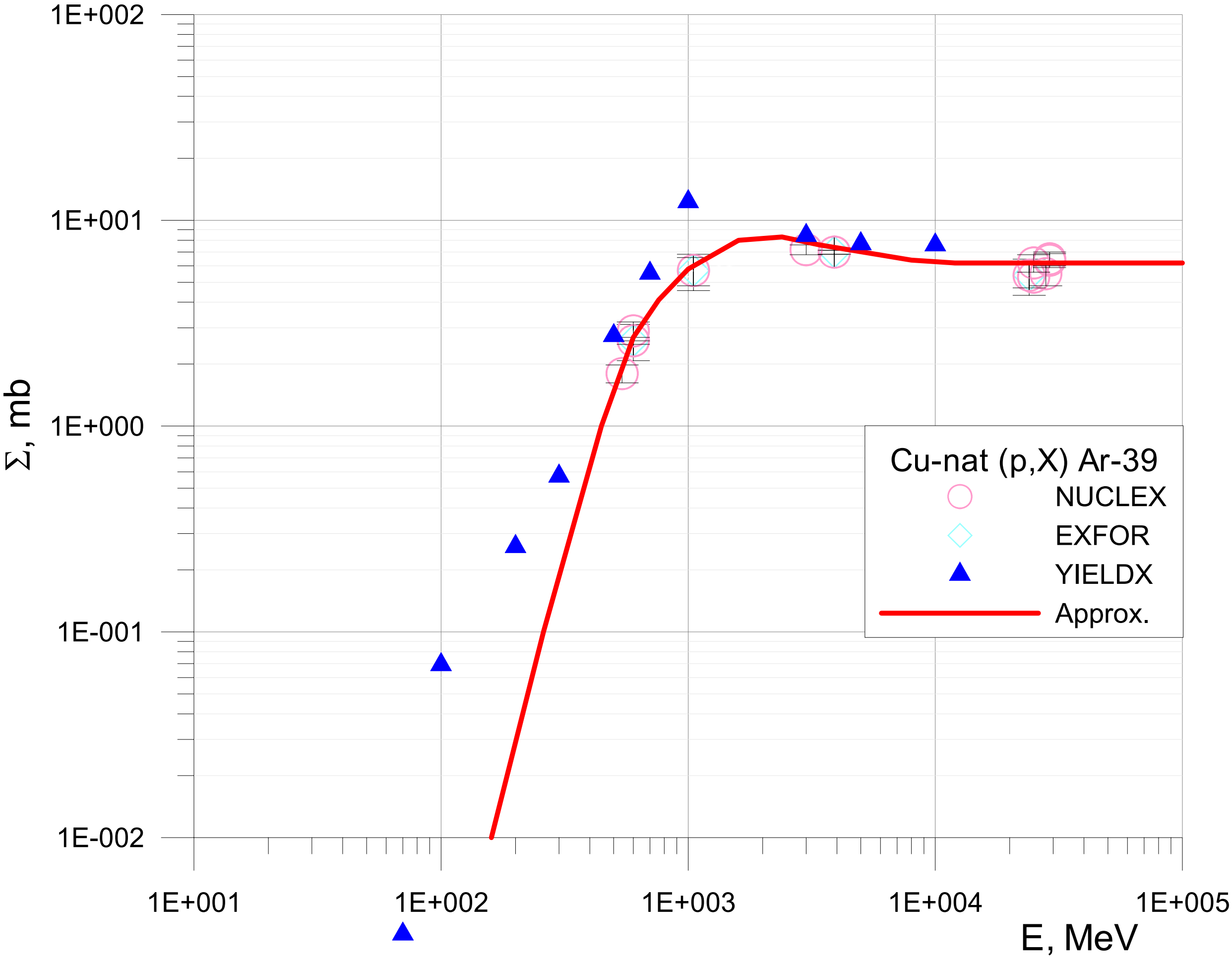

##	E, MeV	Σ, mb
1	160	0.01
2	260	0.1
3	445	1.0
4	600	2.7
5	760	4.1
6	1000	5.8
7	1600	8.0
8	2400	8.3
9	3400	7.6
10	8000	6.4
11	12000	6.2
12	100000	6.2
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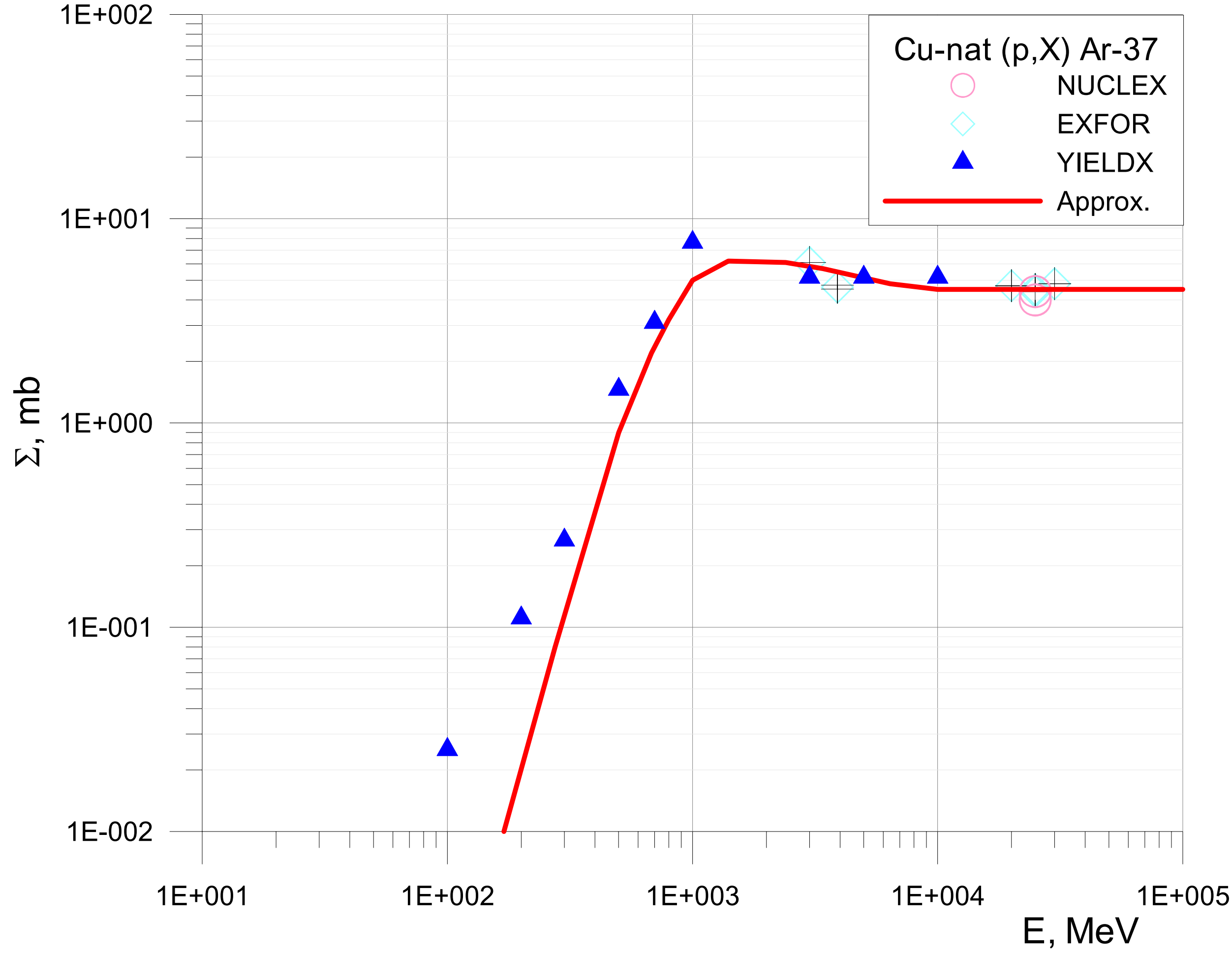

##	E, MeV	Σ, mb
1	170	0.01
2	275	0.08
3	500	0.9
4	680	2.2
5	800	3.2
6	1000	5.0
7	1400	6.2
8	2400	6.1
9	3400	5.7
10	6400	4.8
11	10000	4.5
12	100000	4.5
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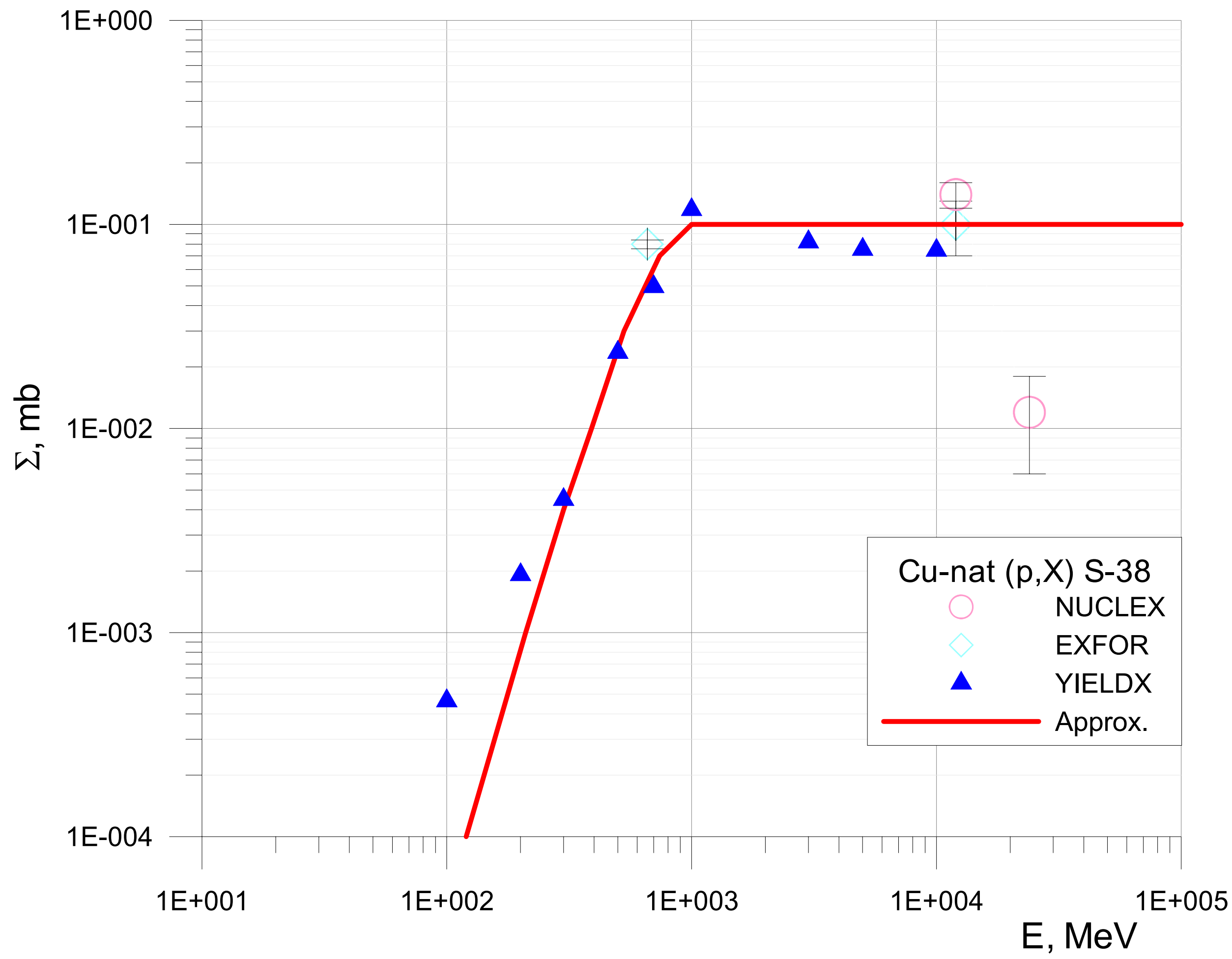

##	E, MeV	Σ, mb
1	120	0.0001
2	210	0.001
3	300	0.004
4	390	0.01
5	560	0.03
6	740	0.07
7	1000	0.10
8	10000	0.10
9	100000	0.10
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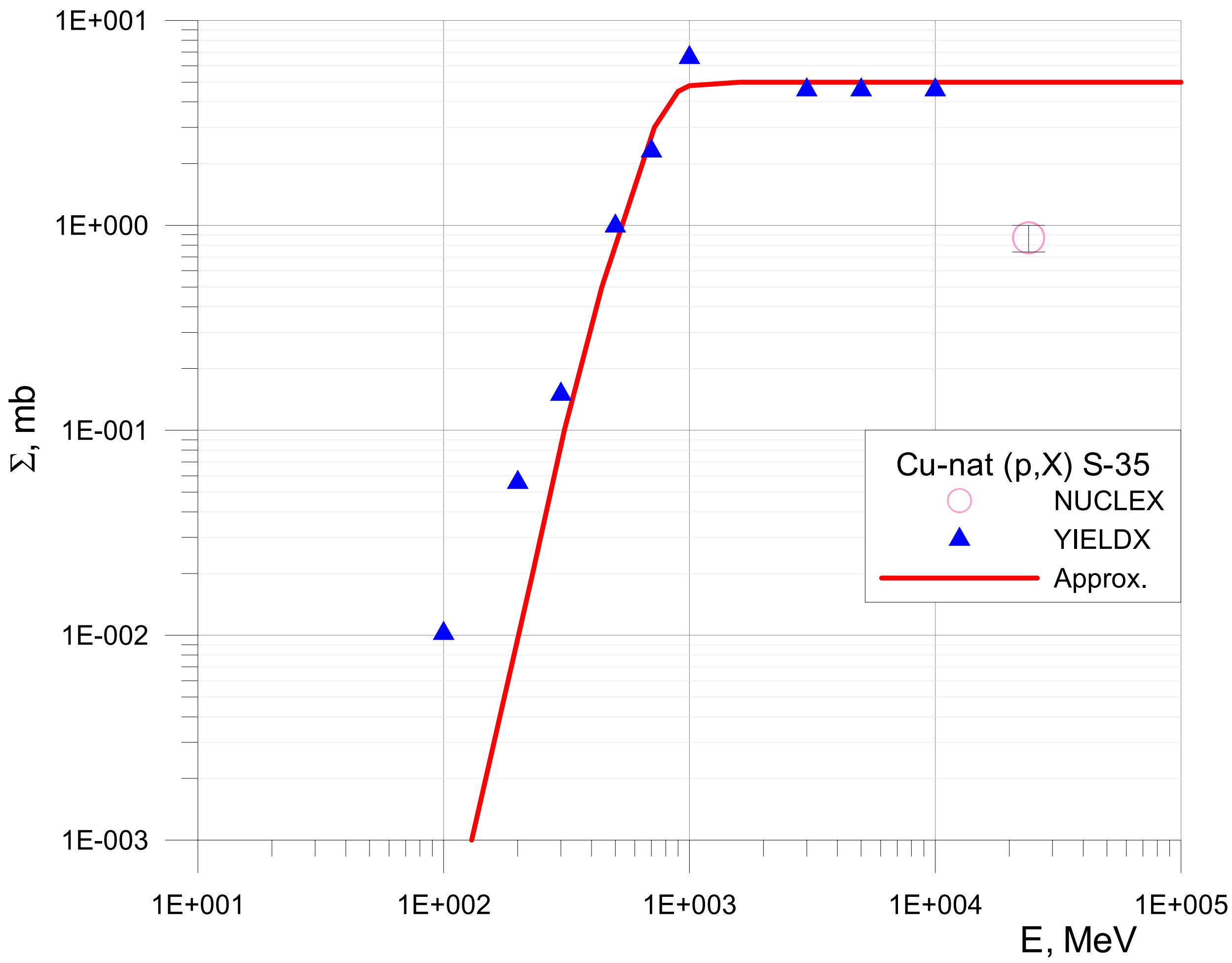

##	E, MeV	Σ, mb
1	130	0.001
2	230	0.02
3	310	0.1
4	440	0.5
5	720	3.0
6	900	4.5
7	1000	4.8
8	1600	5.0
9	10000	5.0
10	100000	5.0
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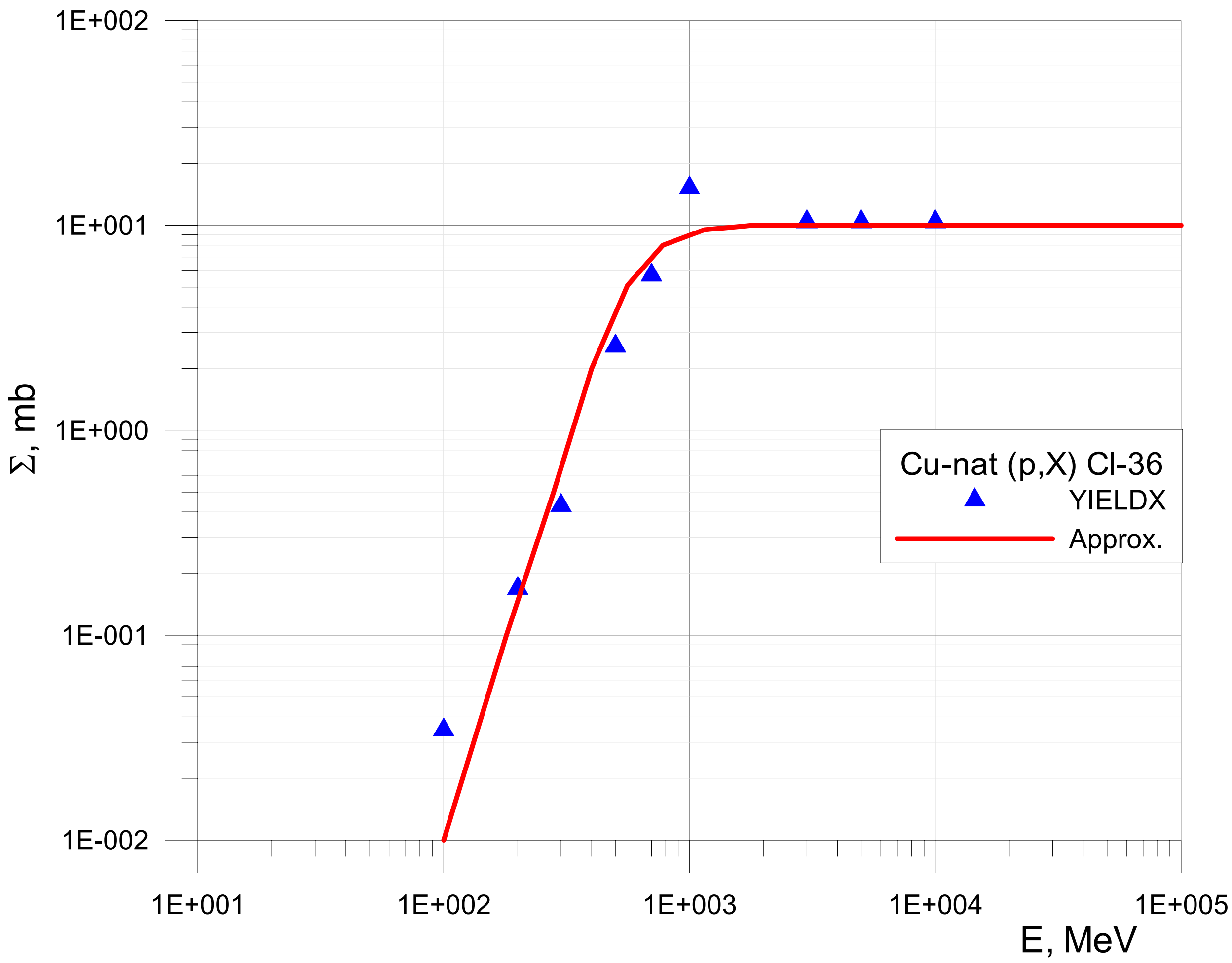

##	E, MeV	Σ, mb
1	100	0.01
2	180	0.1
3	280	0.5
4	400	2.0
5	560	5.1
6	780	8.0
7	1150	9.5
8	1800	10
9	100000	10
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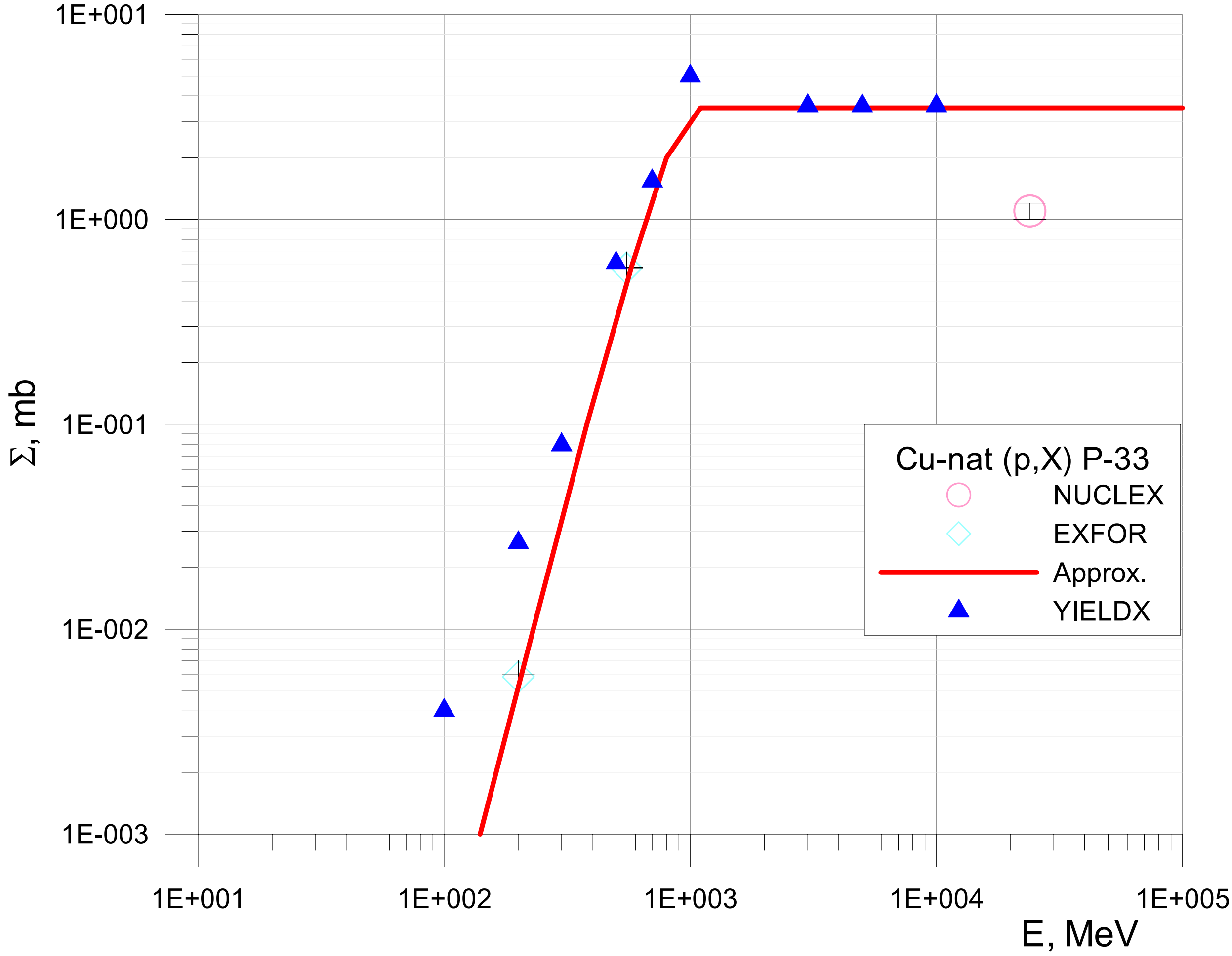

##	E, MeV	Σ, mb
1	140	0.001
2	230	0.01
3	380	0.10
4	580	0.6
5	800	2.0
6	1100	3.5
7	10000	3.5
8	100000	3.5
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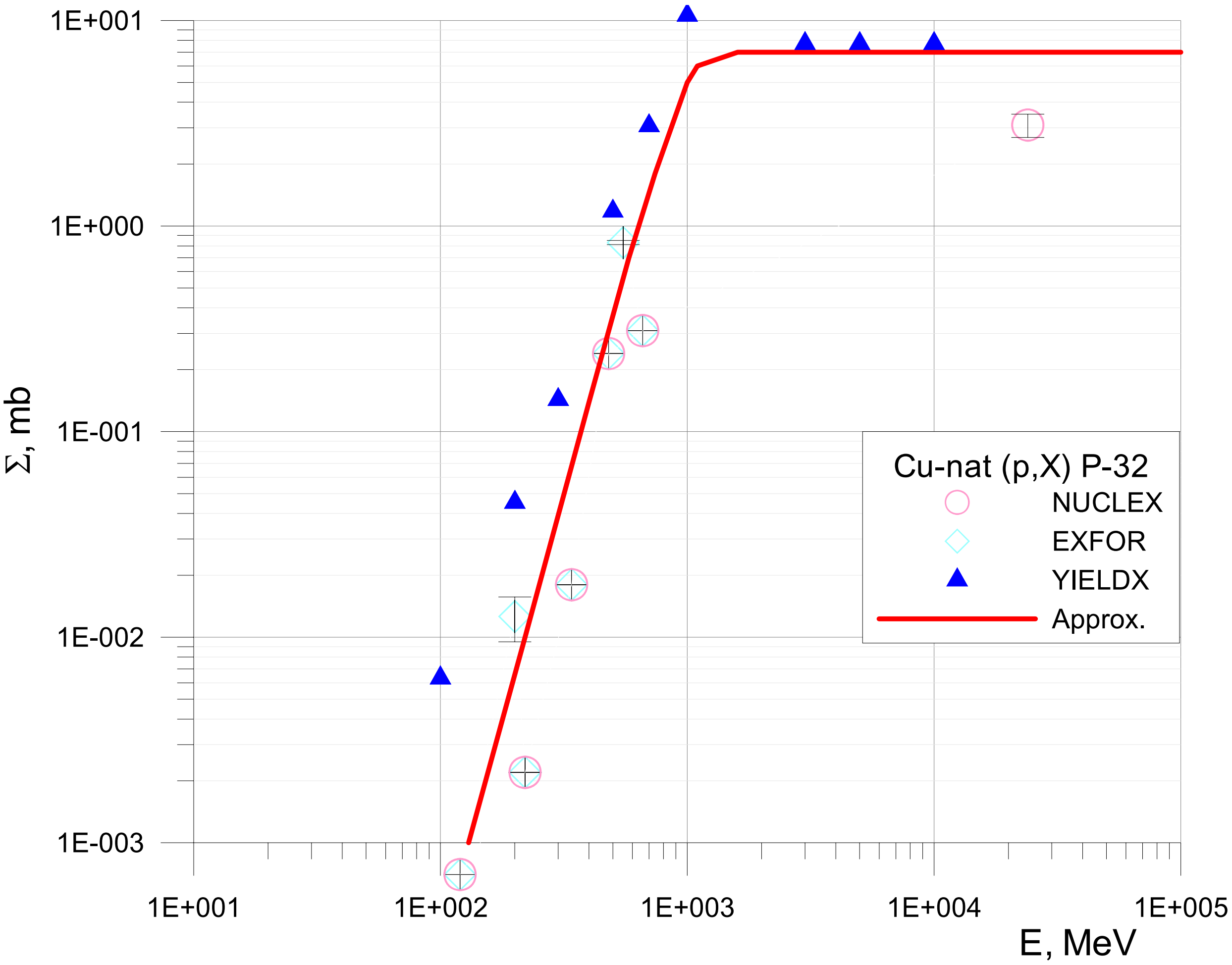

##	E, MeV	Σ, mb
1	130	0.001
2	220	0.01
3	400	0.1
4	580	0.7
5	740	1.8
6	1000	5.0
7	1100	6.0
8	1600	7.0
9	100000	7.0
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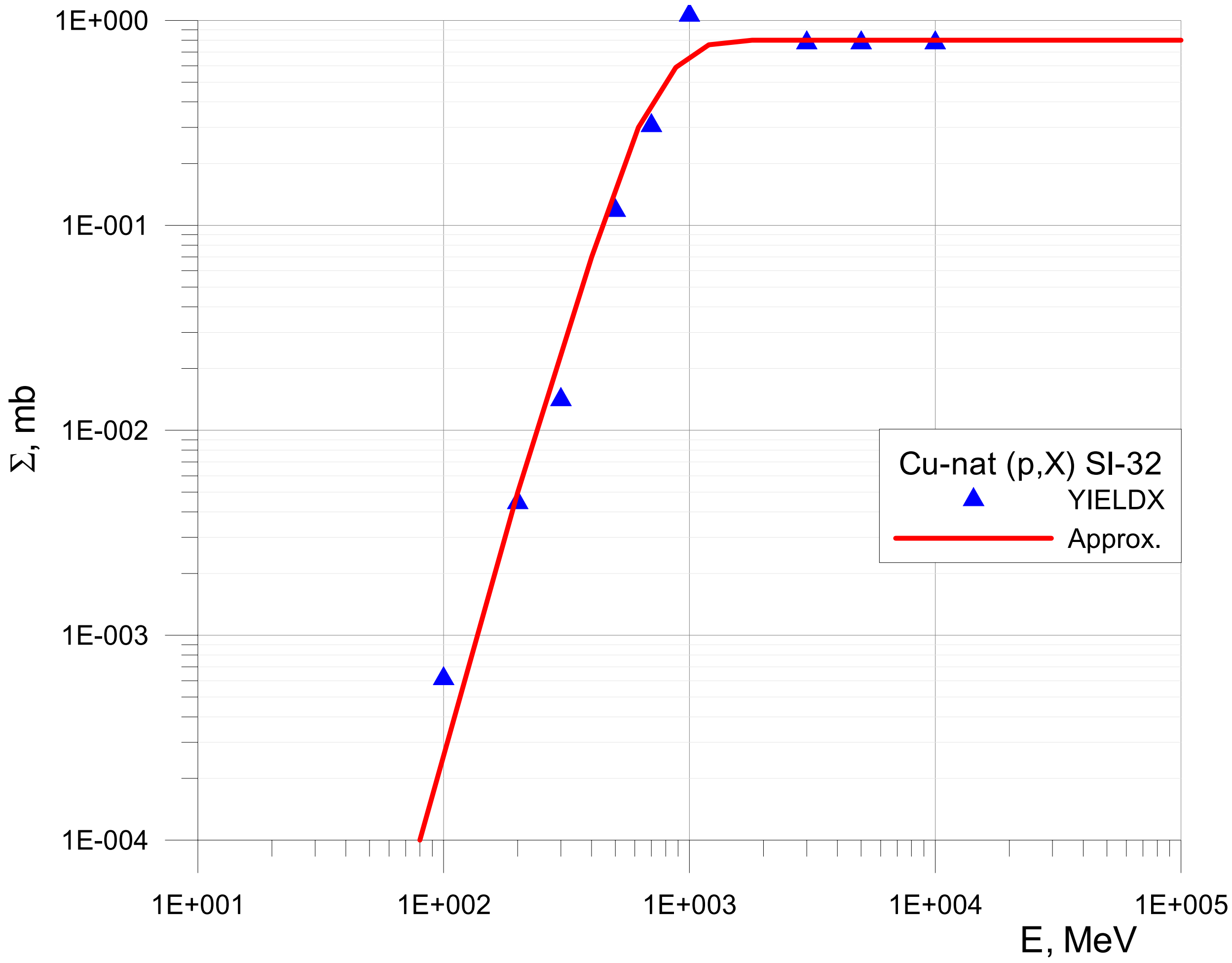

##	E, MeV	Σ, mb
1	80	0.0001
2	200	0.005
3	400	0.07
4	620	0.30
5	880	0.59
6	1200	0.76
7	1800	0.80
8	100000	0.80
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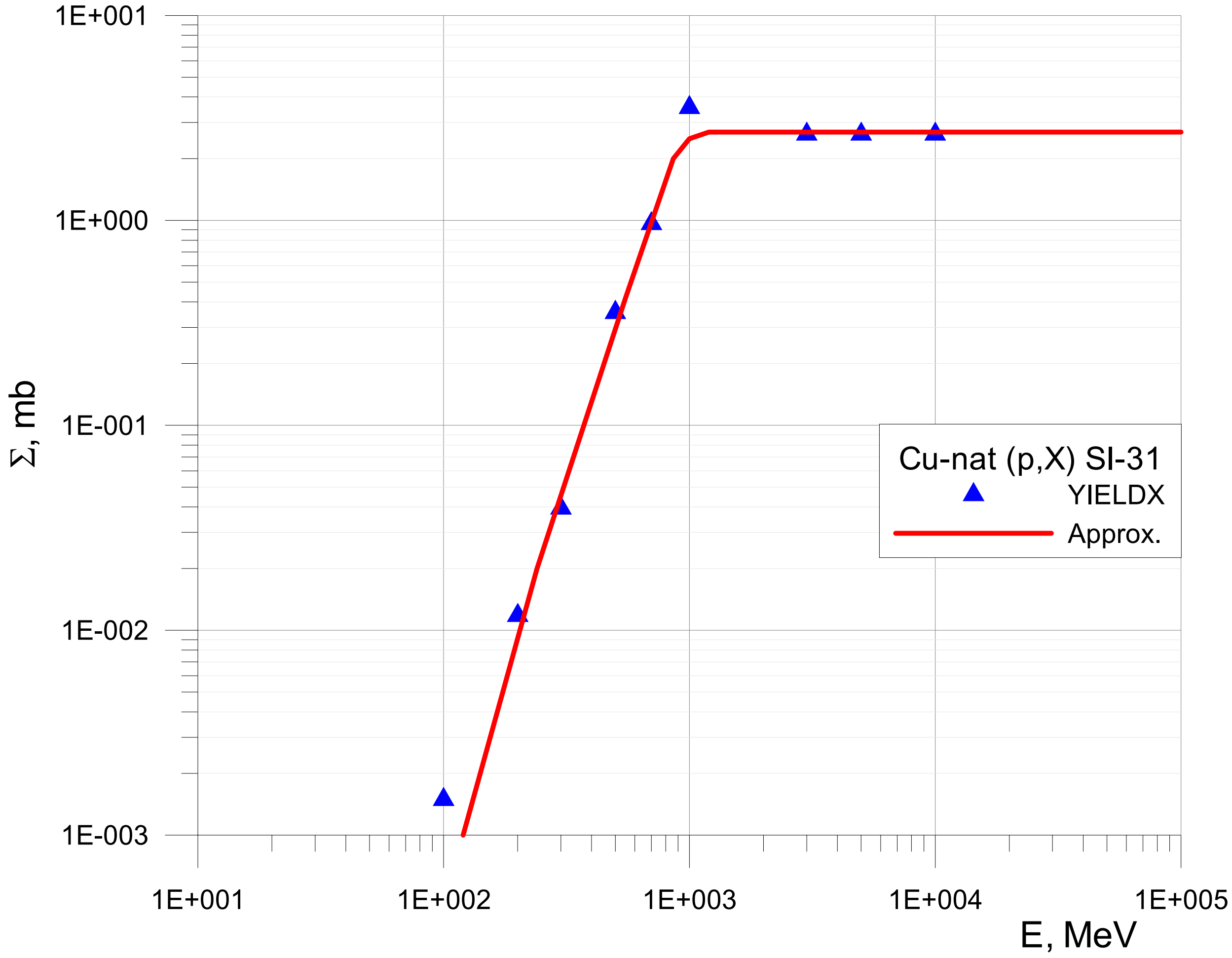

##	E, MeV	Σ, mb
1	120	0.001
2	240	0.02
3	550	0.42
4	860	2.0
5	1000	2.5
6	1200	2.7
7	100000	2.7
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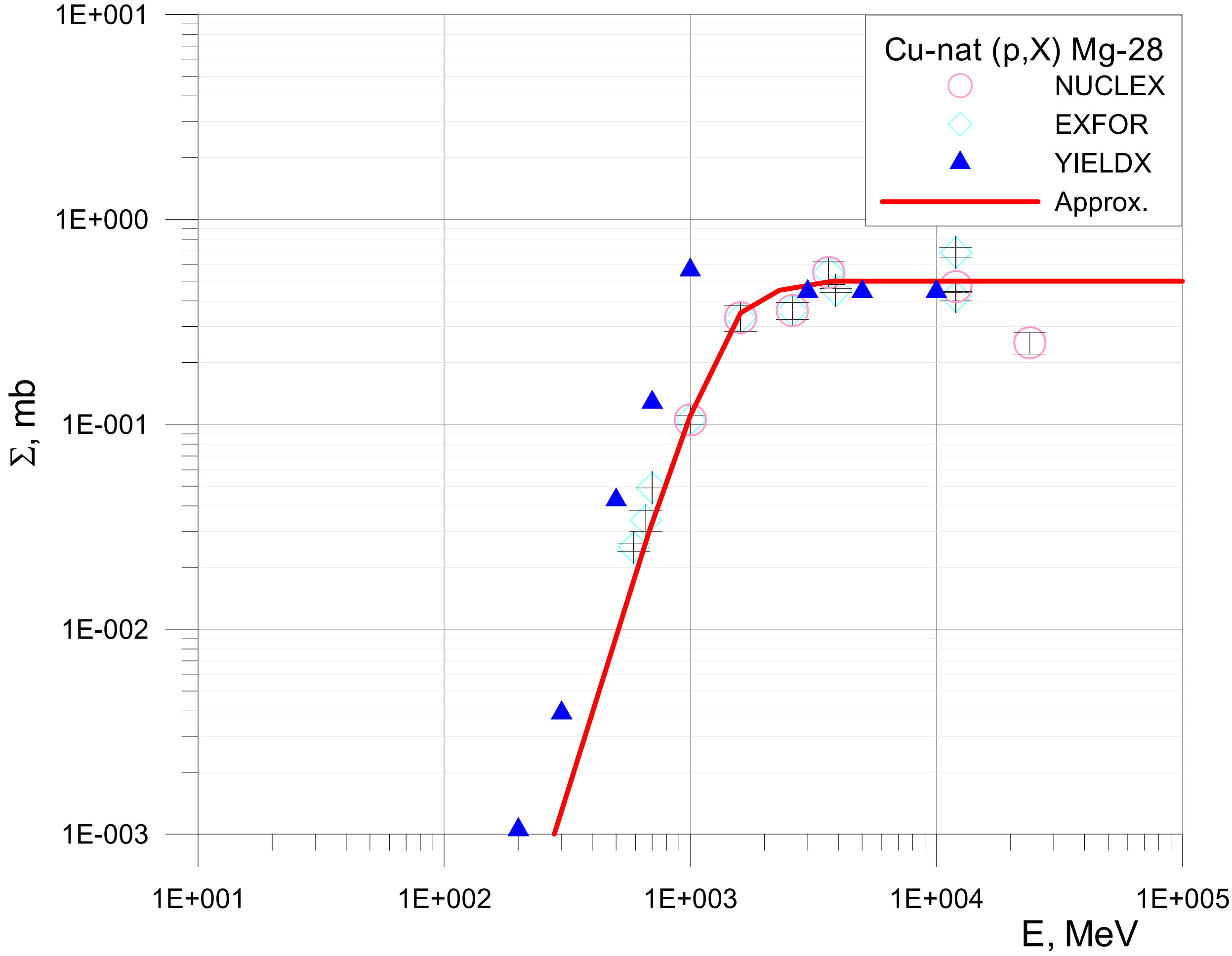

##	E, MeV	Σ, mb
1	280	0.001
2	680	0.03
3	1000	0.11
4	1600	0.35
5	2300	0.45
6	3800	0.50
7	100000	0.50
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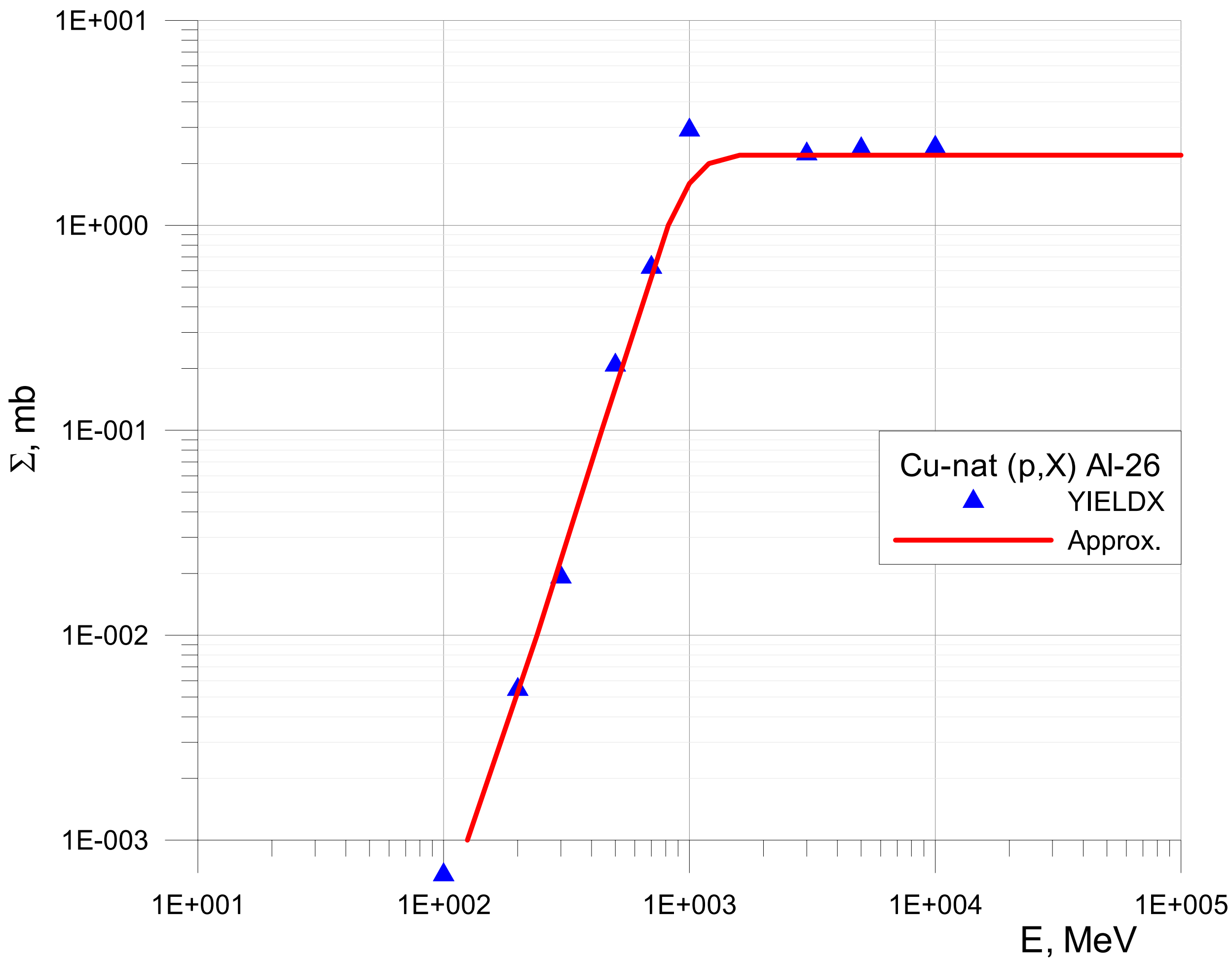

##	E, MeV	Σ, mb
1	125	0.001
2	240	0.01
3	440	0.1
4	820	1.0
5	1000	1.6
6	1200	2.0
7	1600	2.2
8	100000	2.2
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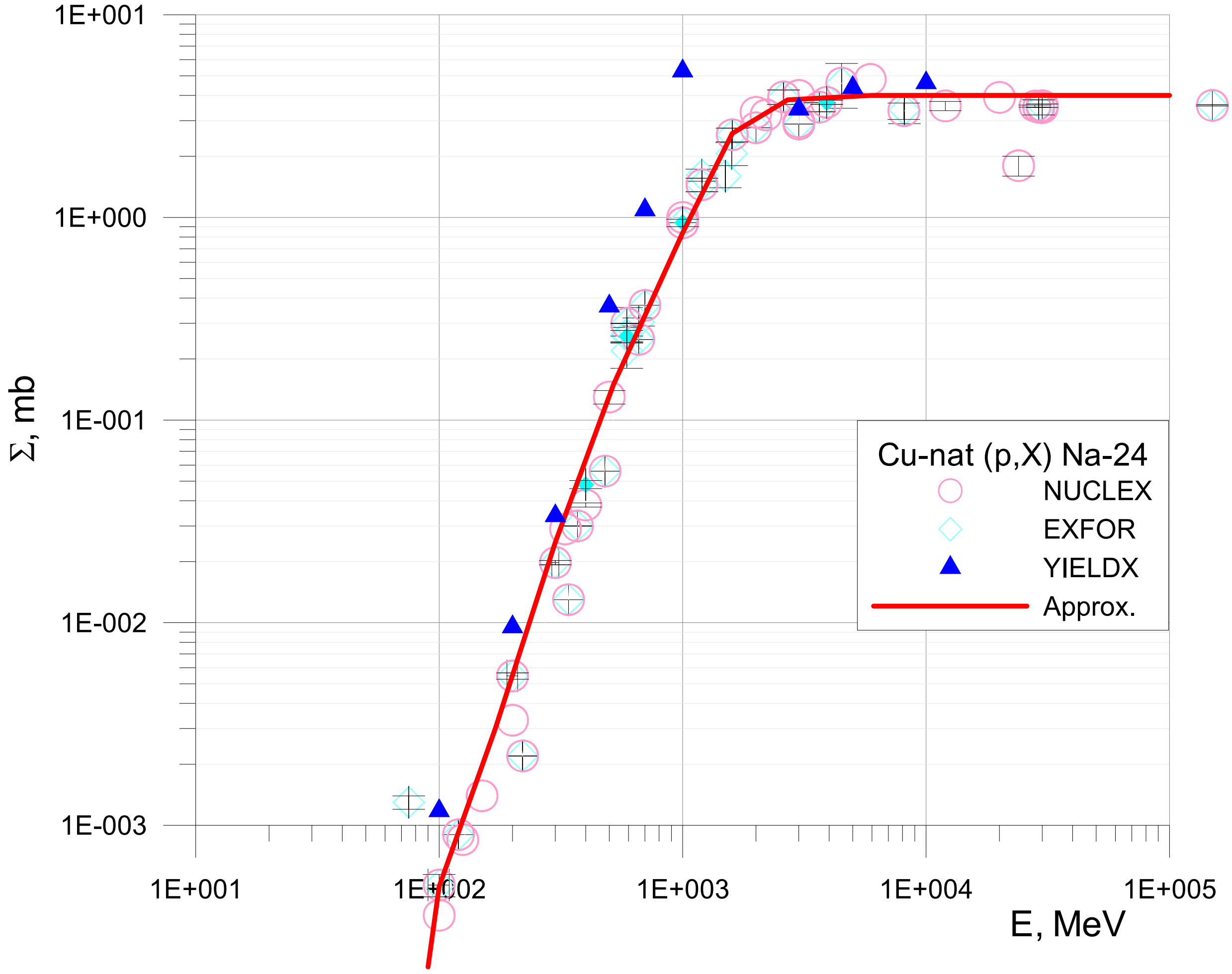

##	E, MeV	Σ, mb
1	90	0.0002
2	100	0.0005
3	170	0.0030
4	300	0.025
5	520	0.150
6	1000	0.84
7	1600	2.6
8	2700	3.8
9	6000	4.0
10	100000	4.0
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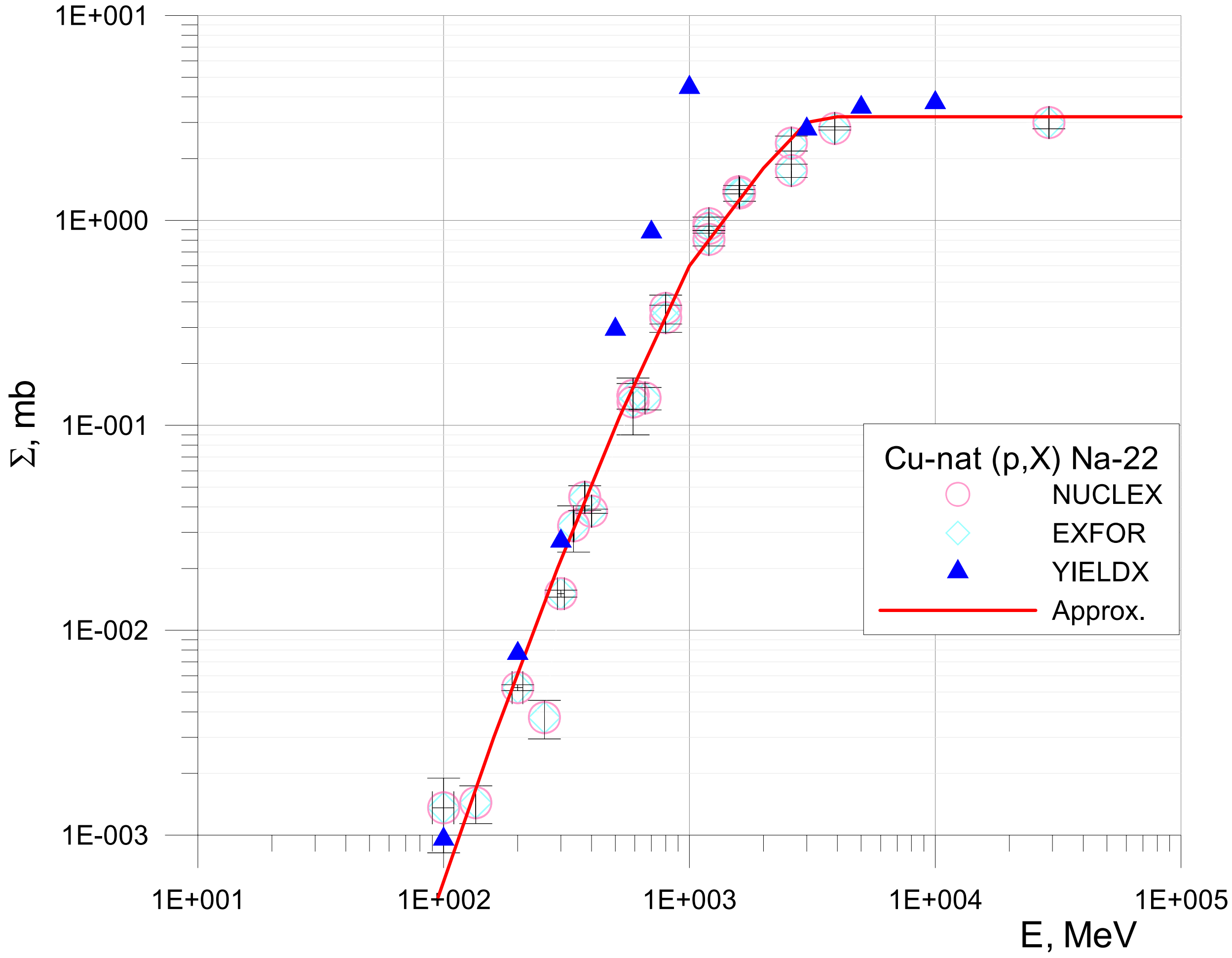

##	E, MeV	Σ, mb
1	90	0.0001
2	95	0.0005
3	160	0.003
4	290	0.02
5	520	0.11
6	1000	0.60
7	2000	1.8
8	3000	3.0
9	4000	3.2
10	100000	3.2
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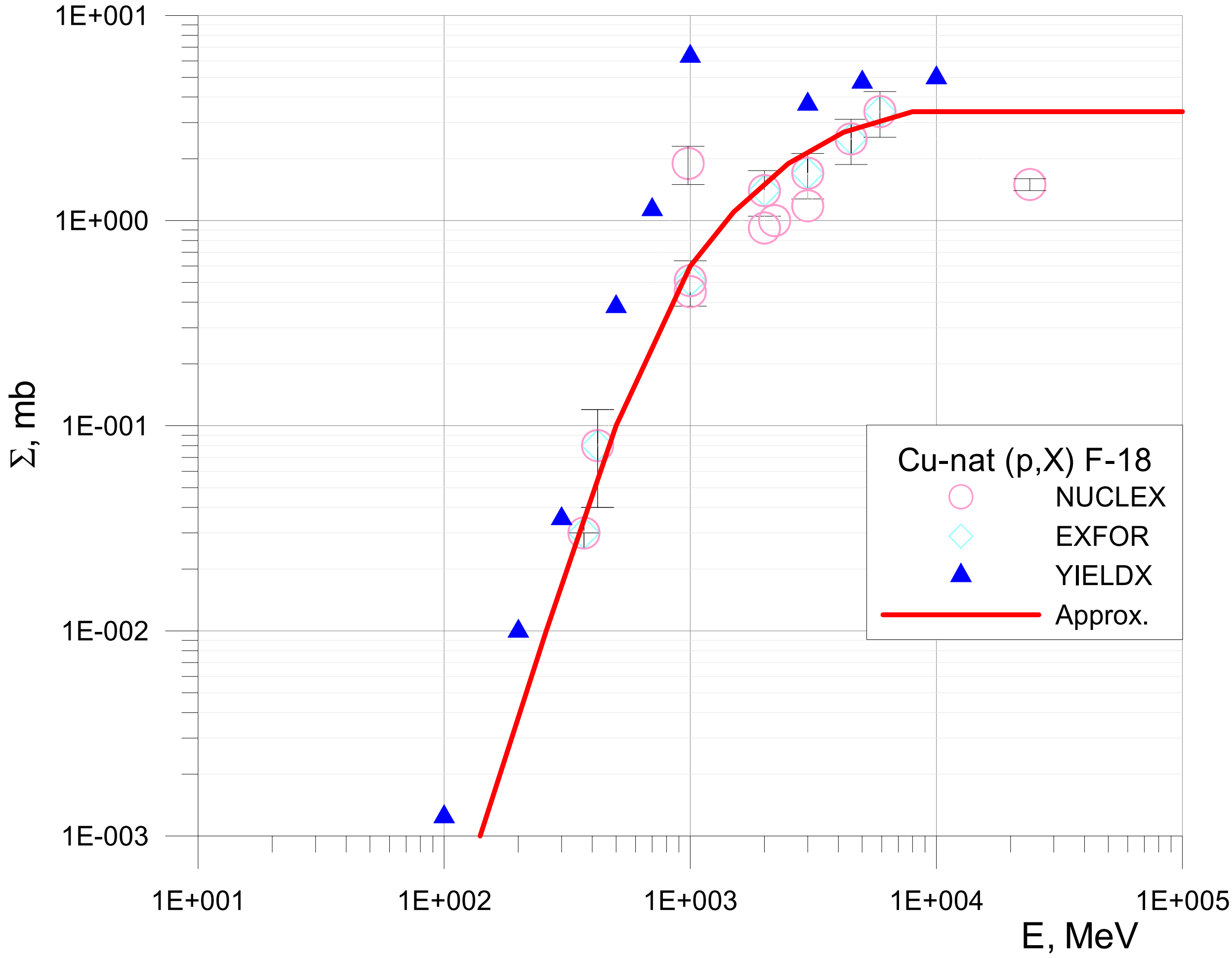

##	E, MeV	Σ, mb
1	140	0.001
2	260	0.01
3	500	0.1
4	1000	0.6
5	1500	1.1
6	2500	1.9
7	4200	2.7
8	8000	3.4
9	100000	3.4
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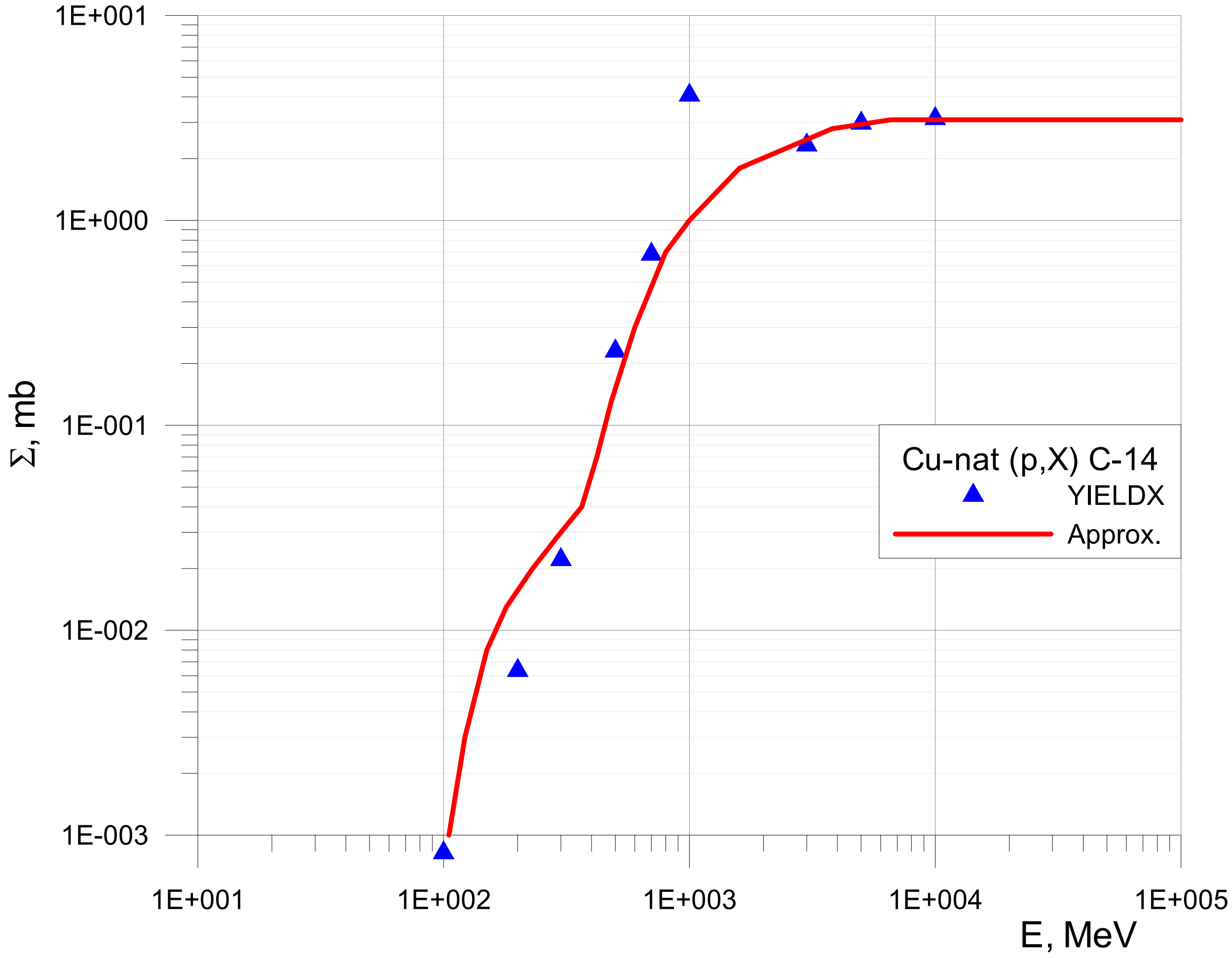

##	E, MeV	Σ, mb
1	105	0.001
2	122	0.003
3	150	0.008
4	180	0.013
5	230	0.02
6	300	0.03
7	365	0.04
8	420	0.07
9	480	0.13
10	600	0.3
11	800	0.7
12	1000	1
13	1600	1.8
14	3800	2.8
15	6600	3.1
16	10000 0	3.1
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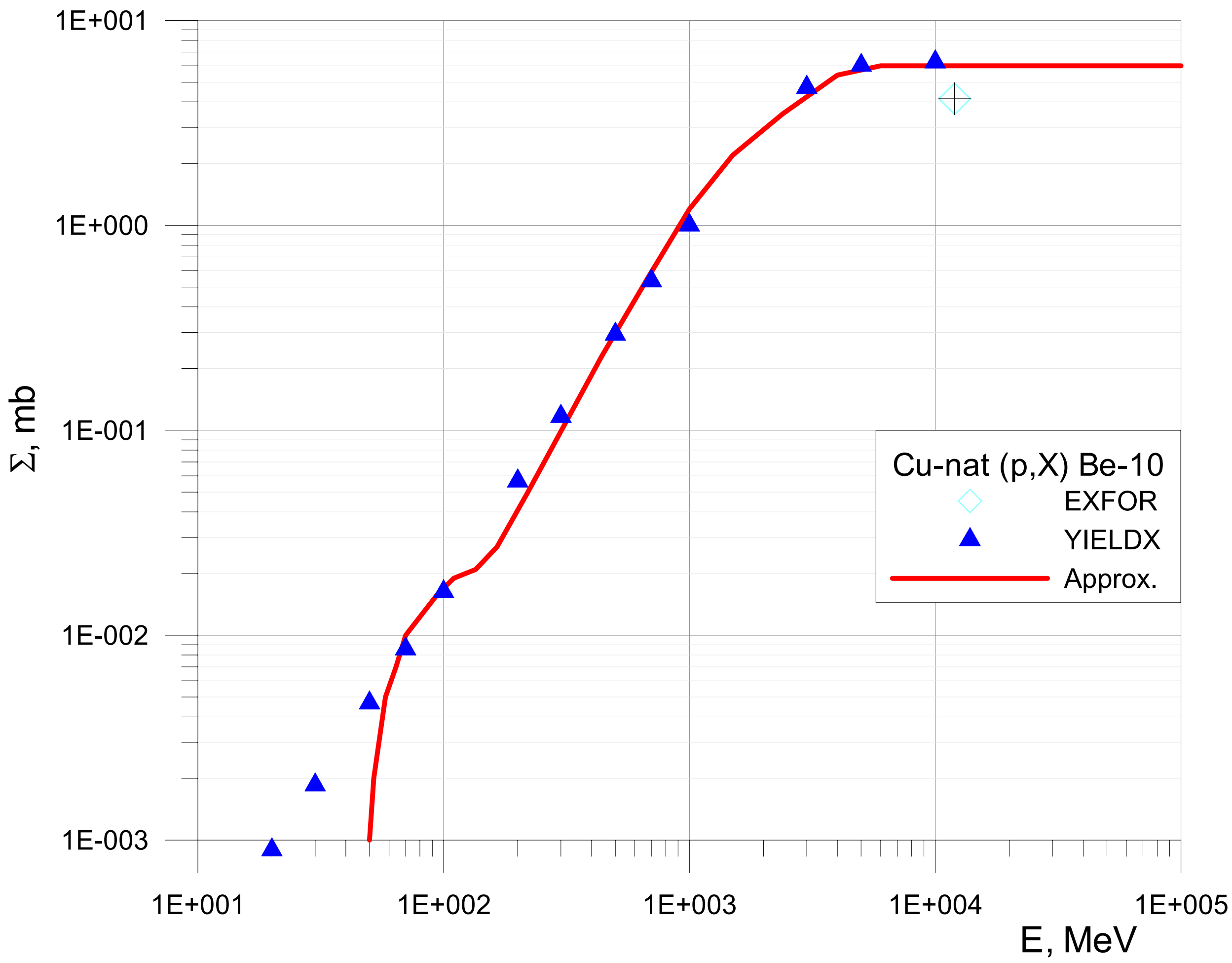
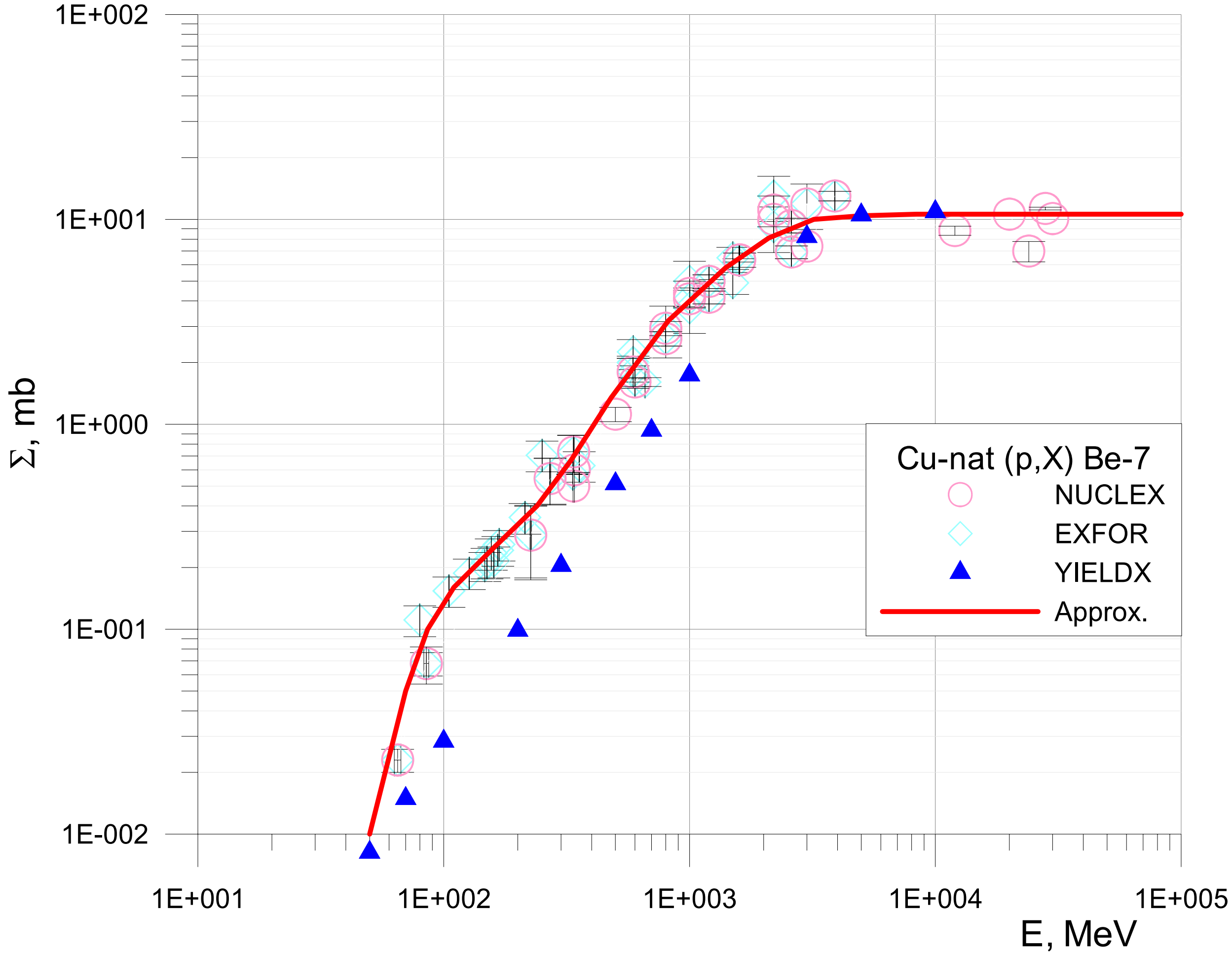
18		



##	E, MeV	Σ, mb
1	50	0.001
2	52	0.002
3	58	0.005
4	64	0.007
5	70	0.010
6	83	0.013
7	95	0.016
8	110	0.019
9	135	0.021
10	165	0.027
11	220	0.050
12	440	0.23
13	680	0.56
14	1000	1.2
15	1500	2.2
16	2400	3.5
17	4000	5.4
18	6000	6.0
19	100000	6.0



##	E, MeV	Σ, mb
1	50	0.01
2	70	0.05
3	86	0.10
4	110	0.16
5	160	0.25
6	240	0.40
7	330	0.67
8	480	1.35
9	820	3.20
10	1400	5.80
11	2100	8.10
12	3200	10.0
13	5000	10.4
14	8400	10.6
15	100000	10.6
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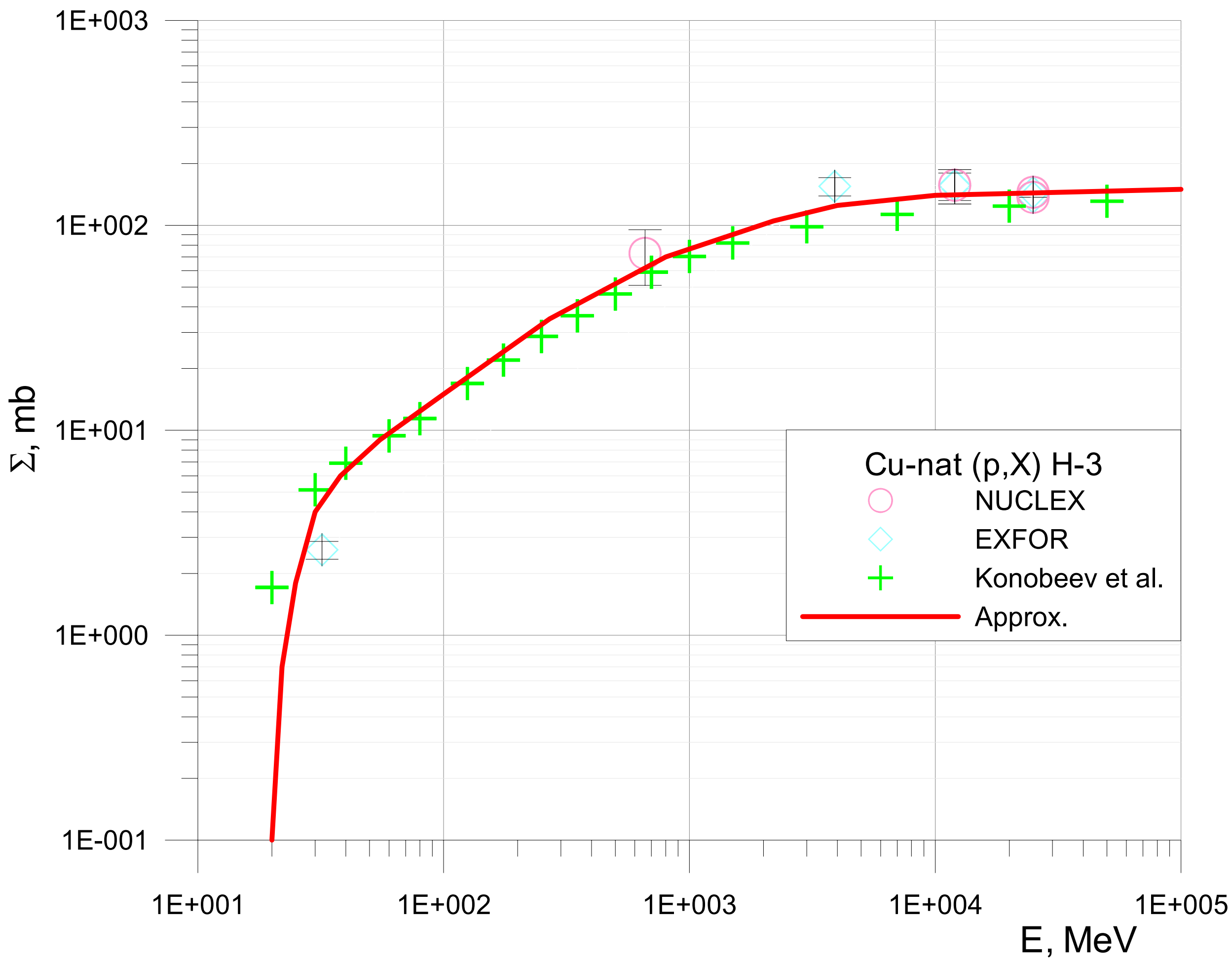

##	E, MeV	Σ, mb
1	9.5	0.0
2	20	0.1
3	22	0.7
4	25	1.8
5	30	4.0
6	38	6.0
7	55	9.0
8	100	15
9	270	35
10	800	70
11	2200	105
12	4000	125
13	10000	140
14	100000	150
15		
16		
17		
18		