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Benchmarking of multiple preequilibrium routines in GNASH

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We compare two different models for multiple preequilibrium emission (MPE) in GNASH: the older exciton MPE model ; and a new "generalized MPE" model which is parameter-free. We analyze the proton-induced reactions on zirconium and lead, which were the focus of a recent NEA intermediate-energy code intercomparison, using both the MPE models. We find that the new generalized MPE model better describes the measurements.

Multiple preequilibrium emission (MPE) refers to processes in which more than one fast preequilibrium particle can be emitted in a nuclear reaction. Once the incident energy in nucleon-induced reactions exceeds about 50 MeV, MPE becomes increasingly important. When comparing calculations with experimental data there are two types of phenomena which are impacted by MPE processes: (1) nucleon emission spectra (specifically, accounting for the high-energy differential spectra while simultaneously maintaining flux conservation); and (2) describing excitation functions, where the population of a particular residual nucleus is dramatically influenced by the MPE modeling.

The nuclear modeling code GNASH was modified to include MPE processes in 1991, using an exciton model description [1]. This version of GNASH was used to analyze the LAMPF/WNR $(n,xn\gamma)$ measurements of excitation functions, and MPE was shown to be very important [2]. In addition, this version was also used to calculate (p,xn) and (p,xp) reactions on ^{90}Zr and ^{208}Pb for the NEA intermediate-energy code intercomparison [3], organized by Blann and Nagel. Again, the modeling described the data fairly well when MPE was included [4]. However, some weaknesses in the exciton MPE modeling were noticed – the MPE emission spectra in some cases appeared too hard, overpredicting the highest energies, and underpredicting the lower emission energies. This follows from the simplifying assumption about the dominance of $1p1h$ in MPE made in the exciton model MPE algorithm [1]. Also, this algorithm requires the input of a parameter describing the preequilibrium damping processes which is not always well known, and in practice it is often treated as a free parameter with which to optimize the fit to measurements.

Due to the above-mentioned limitations of the original exciton-model MPE algorithm, we developed a new "generalized MPE" model, which is parameter free. It is "generalized" since it can always be used to determine MPE, whatever preequilibrium model is used for the primary preequilibrium emission (whether exciton model, or FKK). We described this model in detail in Ref. [5]. Since this model accounts for preequilibrium emission from the various $p-h$ configurations, it gives a softer spectrum compared to the original exciton model MPE algorithm, and tends to describe emission spectra more accurately.

In this report we compare the two MPE model's ability to account for the emission spectra for the reactions studied in the NEA code intercomparison. The figures show the GNASH composite spectrum results for inclusive nucleon emission in the proton-induced reactions on lead and zirconium, compared with experimental data where they exist. We show the total spectrum results obtained using both the new and the older MPE models, as well as the MPE contribution from the new model. The old MPE model contributions can be found in our report of the GNASH calculations for the NEA code intercomparison [4]. We have the following general observations:

- For the 160-MeV induced reactions, the old MPE model underpredicts the measurements in the 20-50 MeV emission energy region. The new generalized MPE model better describes the measurements here. This same underprediction of the lower emission-energy data also occurs in the 80-MeV induced reactions, but to a lesser extent.

- At the higher emission energies, in the 80 and 160-MeV induced reactions, there are cases where the old MPE model results are too high. Again, the new generalized MPE model better describes the measurements.

- In the 25 and 45-MeV induced reactions, the total spectrum results are almost identical when using the two MPE models. This is because in both cases the MPE contributions are small compared to primary preequilibrium emission.

In summary, the new generalized MPE model provides an improvement to the modeling of emission spectra in higher-energy reactions. The softer spectral shape of the generalized MPE model, compared to that found with the older exciton model routine, agrees better with measurements. Also, the new generalized MPE has the advantage of being parameter-free. As a further test, we intend to assess our new generalized MPE model's ability to describe the LAMPF/WNR $(n,xn\gamma)$ excitation functions.

REFERENCES

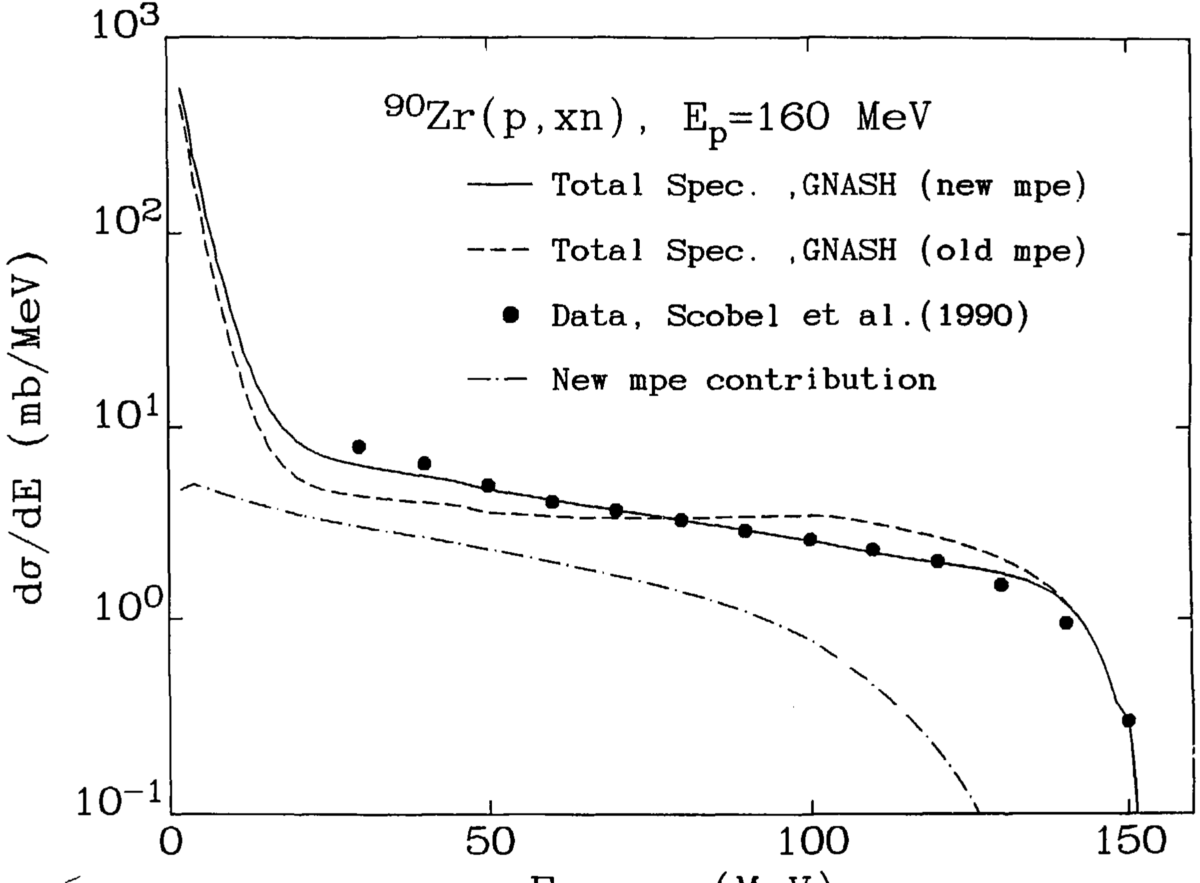
[1] P.G. Young, E.D. Arthur, and M.B. Chadwick, *Comprehensive Nuclear Model Calculations: Introduction to the Theory and Use of the GNASH Code*, Los Alamos National Laboratory Document LA-12343-MS (1992).

[2] H. Vonach, A. Pavlik, M.B. Chadwick, R.C. Haight, P.O. Nelson, S.A. Wender, and P.G. Young, $^{207,208}Pb(n, xn\gamma)$ *reactions for neutron energies from 3 to 200 MeV*, submitted to Physical Review C, (1994).

[3] M. Blann, H. Gruppelaar, P. Nagel, and J. Rodens, *International Code Comparison for Intermediate Energy Nuclear Data*, Nuclear Energy Agency, OECD, (1994).

[4] P.G. Young and M.B. Chadwick, *Calculation of Proton and Neutron Emission Spectra From Proton Reactions With* ^{90}Zr *and* ^{208}Pb *to 160 MeV with the GNASH Code*, in the *Proceedings of the Specialist Meeting on Intermediate Energy Nuclear Data*, Issy-les-Moulineaux, Paris, France, 30 May - 1 June, 1994, edited by P. Nagel (OECD, Paris, 1994), in print.

[5] M.B. Chadwick, P.G. Young, D.C. George, Y. Watanabe, *Multiple Preequilibrium Emission in Feshbach-Kerman-Koonin Analyses*, Physical Review C, in print, (1994).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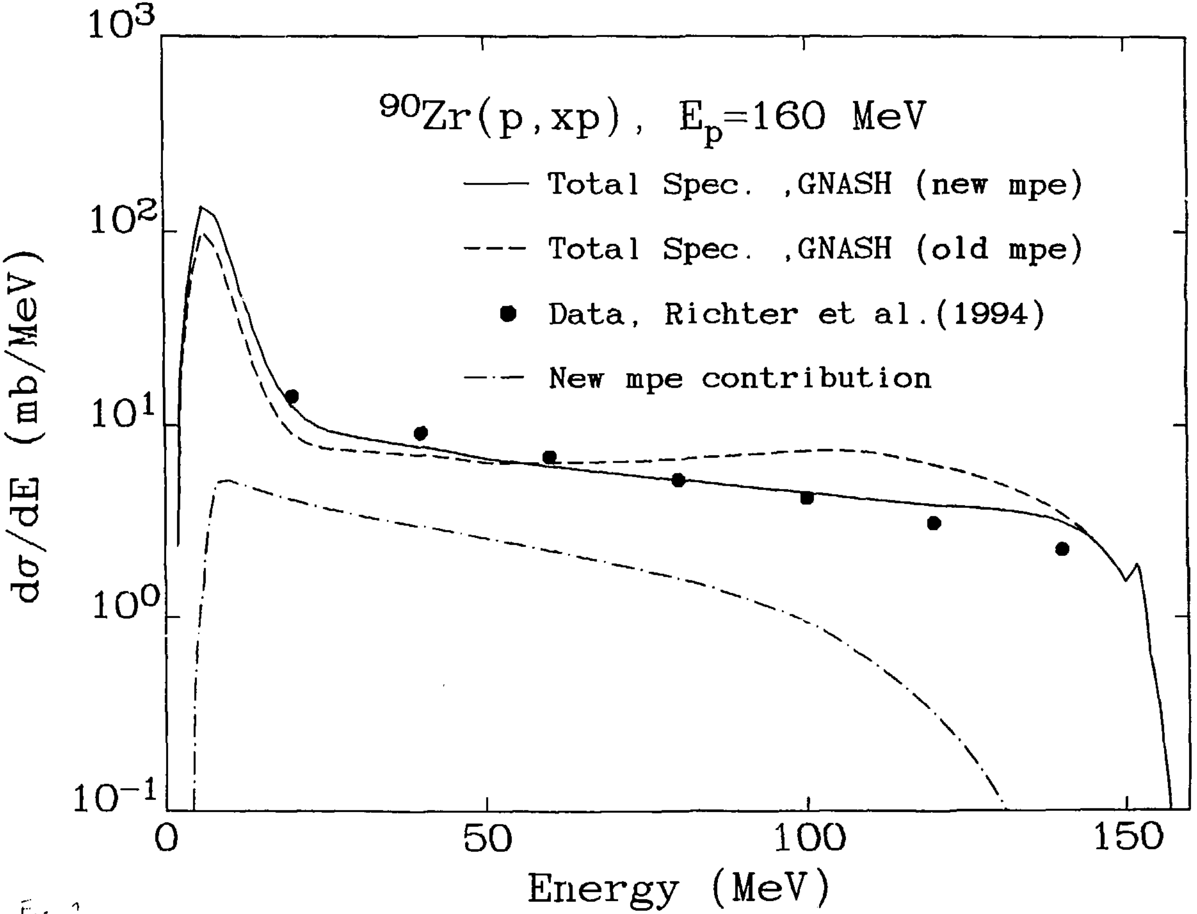
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
● Data, Scobel et al.(1990)
New mpe contribution
$d\sigma/dE$ (mb/MeV)
10^3
10^2
10^1
10^0
10^{-1}
0
50
100
150
Energy (MeV)

Fig 1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Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
Data, Richter et al.(1994)
New mpe contribution
dσ/dE (mb/MeV)
10^3
10^2
10^1
10^0
10^{-1}
0
50
100
150
Energy (MeV)

Fig 2

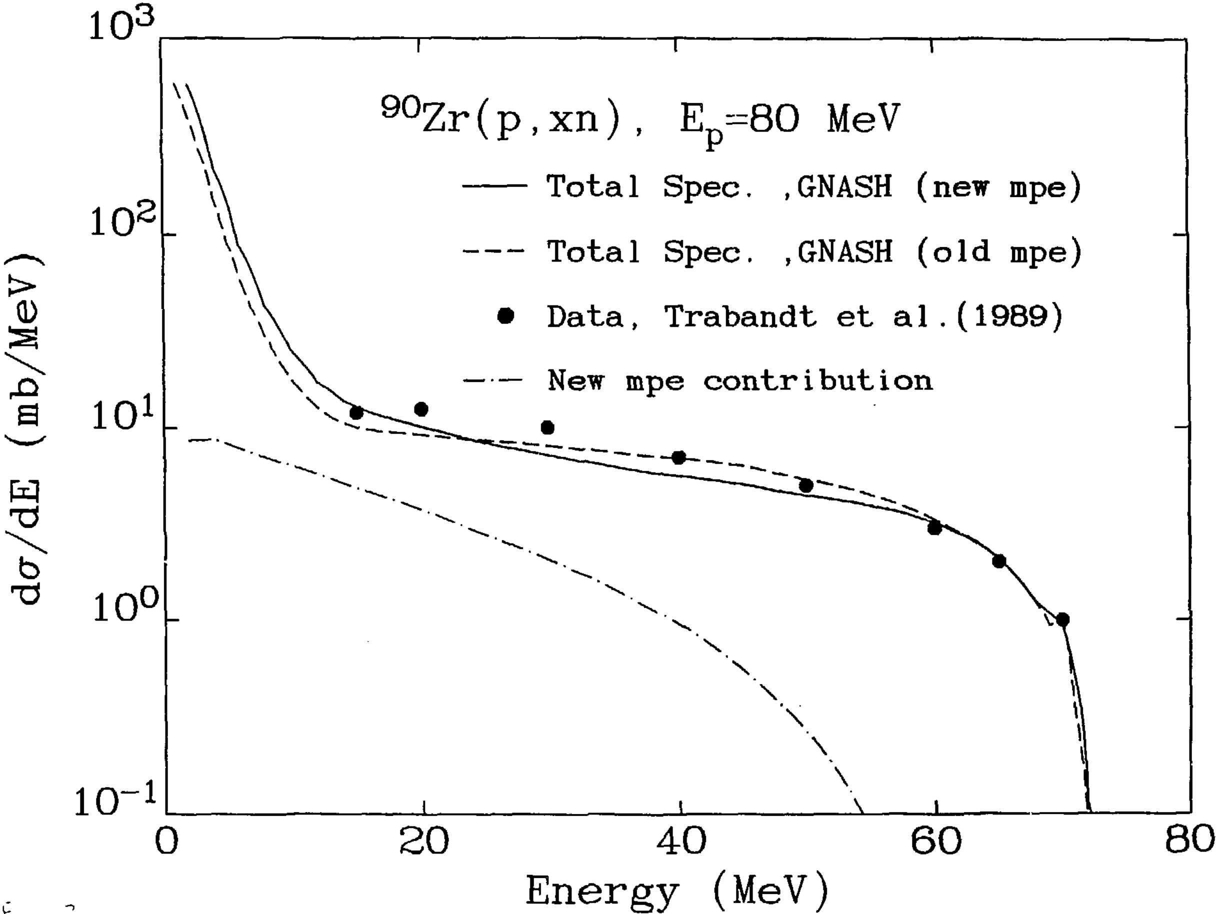
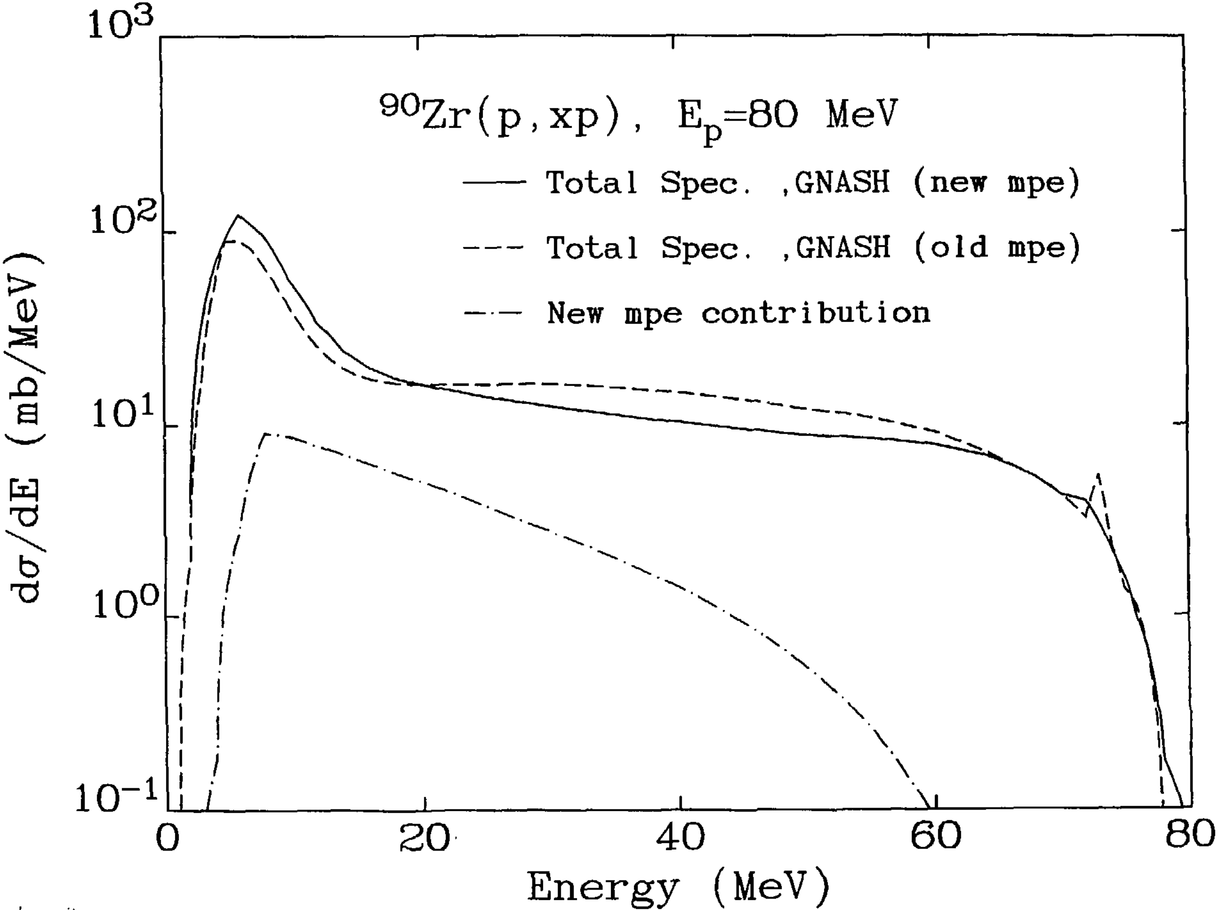

$^{90}Zr(p,xn)$, E_p=80 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
Data, Trabandt et al.(1989)
New mpe contribution
$d\sigma/dE$ (mb/MeV)
Energy (MeV)
10^3
10^2
10^1
10^0
10^{-1}
0
20
40
60
80

Fig 3



^{90}Zr(p,xp), E_p=80 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
New mpe contribution
$d\sigma/dE$ (mb/MeV)
10^3
10^2
10^1
10^0
10^{-1}
0
20
40
60
80
Energy (MeV)

Fig 4

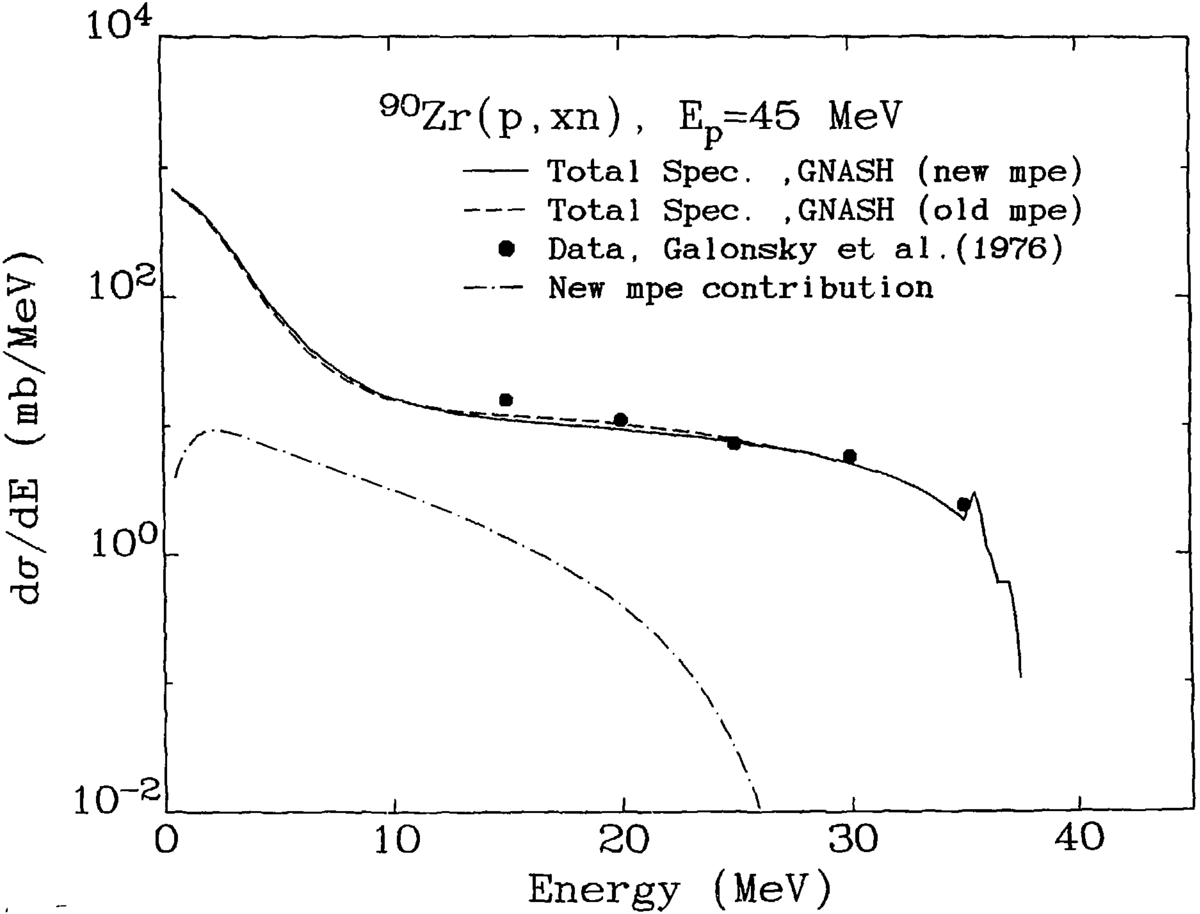

^{90}Zr(p,xn), E_p=45 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
Data, Galonsky et al.(1976)
New mpe contribution
10^4
10^2
10^0
10^{-2}
dσ/dE (mb/MeV)
0
10
20
30
40
Energy (MeV)

Fig 5

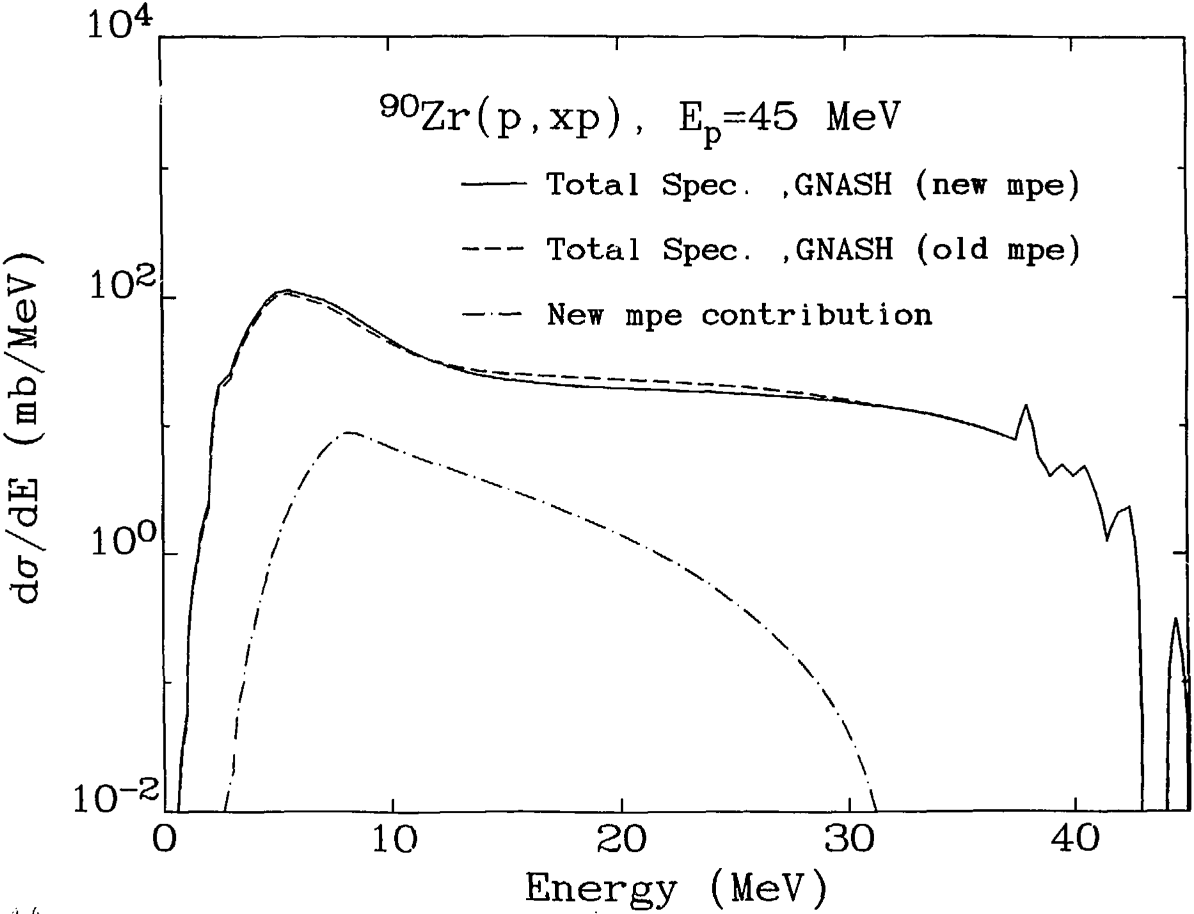
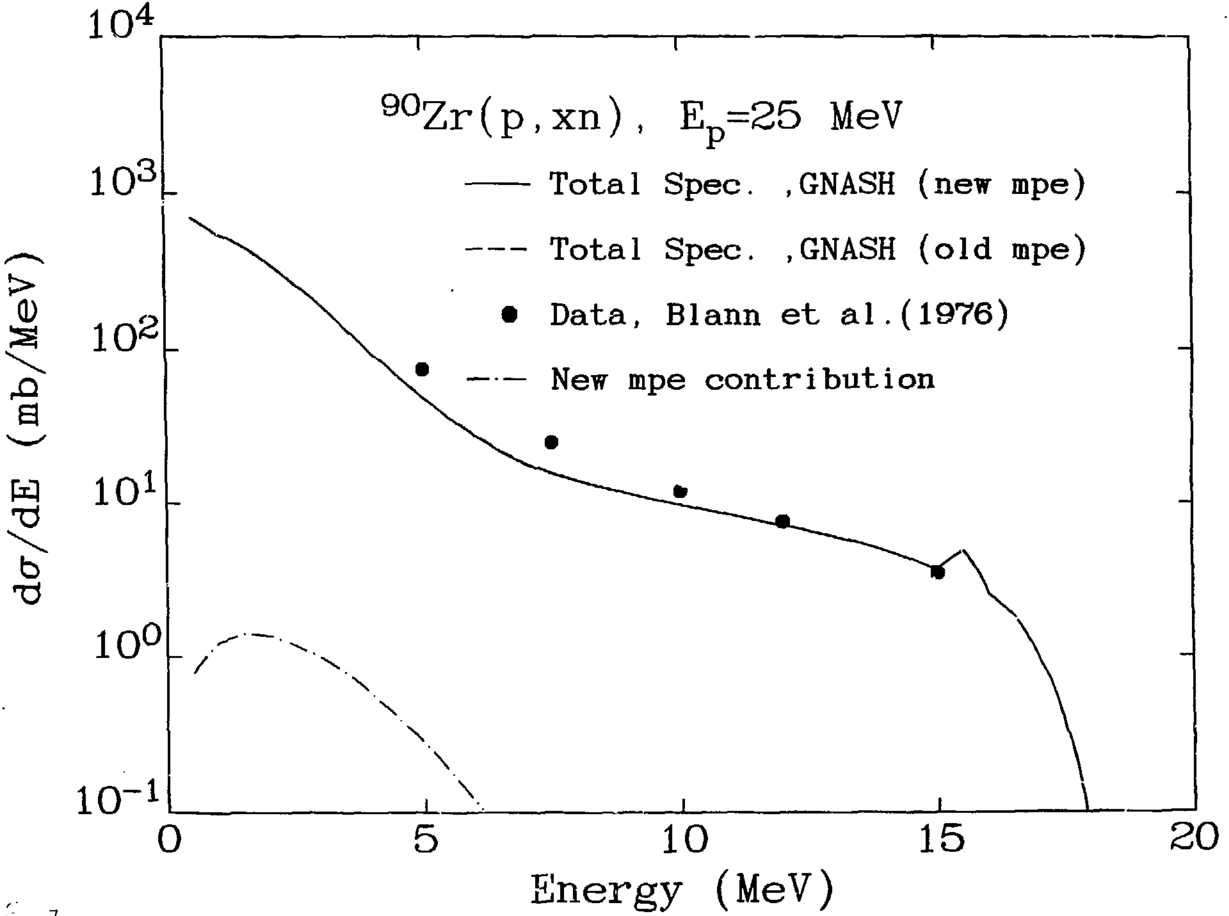
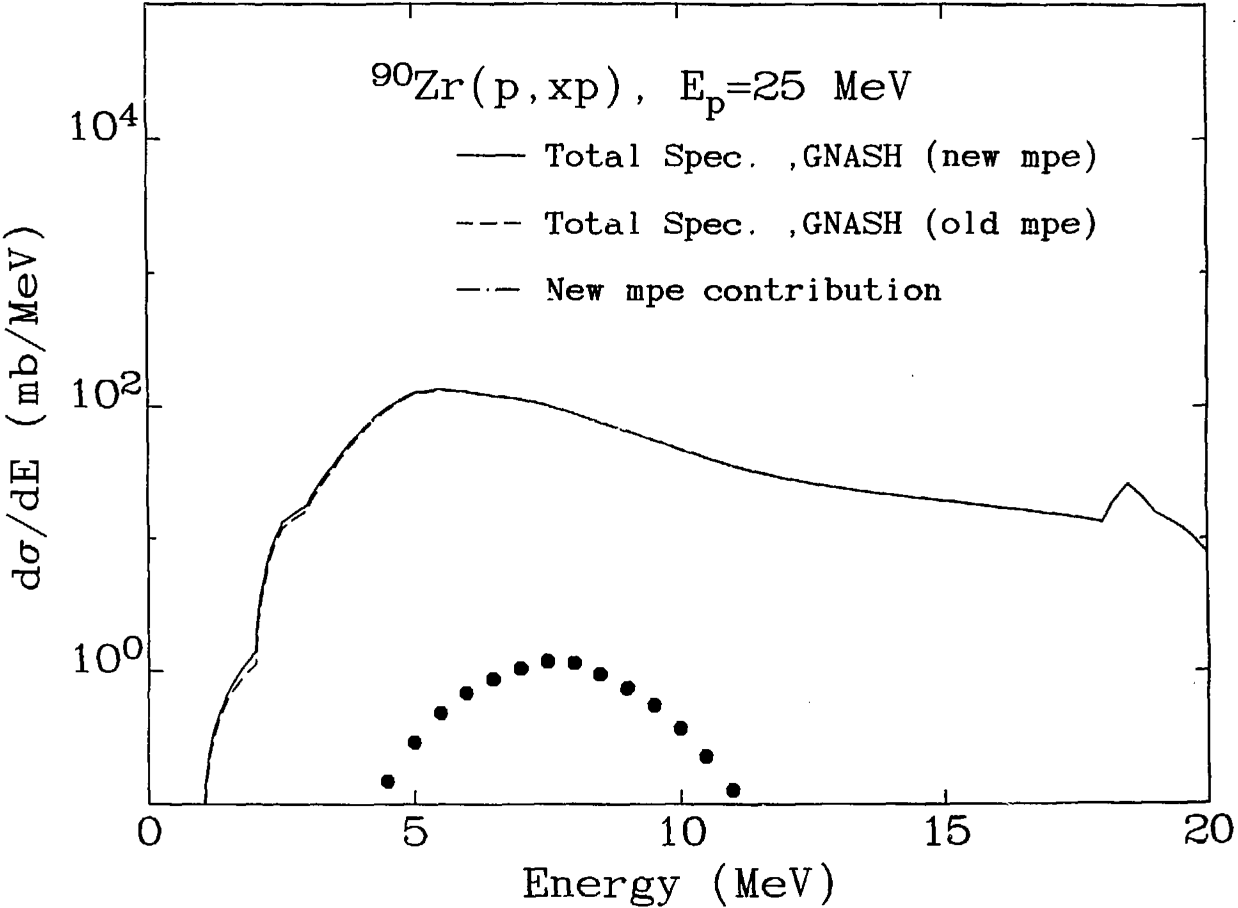

^{90}Zr(p,xp), E_p=45 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
New mpe contribution
10^4
10^2
10^0
10^{-2}
dσ/dE (mb/MeV)
0
10
20
30
40
Energy (MeV)

Fig.6



10^4
10^3
10^2
10^1
10^0
10^{-1}
$d\sigma/dE$ (mb/MeV)
0
5
10
15
20
Energy (MeV)
$^{90}Zr(p,xn)$, E_p=25 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
Data, Blann et al.(1976)
New mpe contribution

F. 7


^{90}Zr(p,xp), E_p=25 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
New mpe contribution
10^4
10^2
10^0
dσ/dE (mb/MeV)
0
5
10
15
20
Energy (MeV)

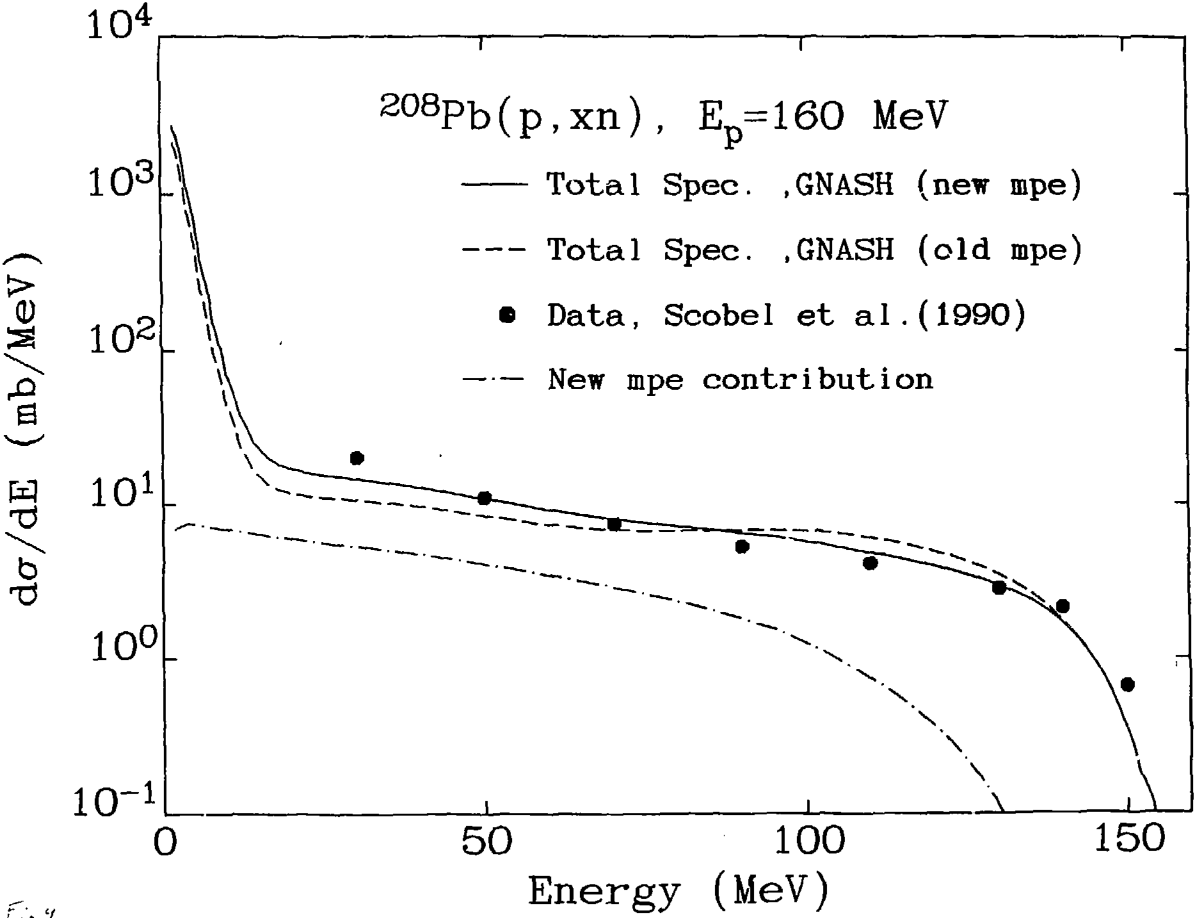

$^{208}Pb(p,xn)$, E_p=160 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
Data, Scobel et al.(1990)
New mpe contribution
10^4
10^3
10^2
10^1
10^0
10^{-1}
dσ/dE (mb/MeV)
0
50
100
150
Energy (MeV)

Fig 4

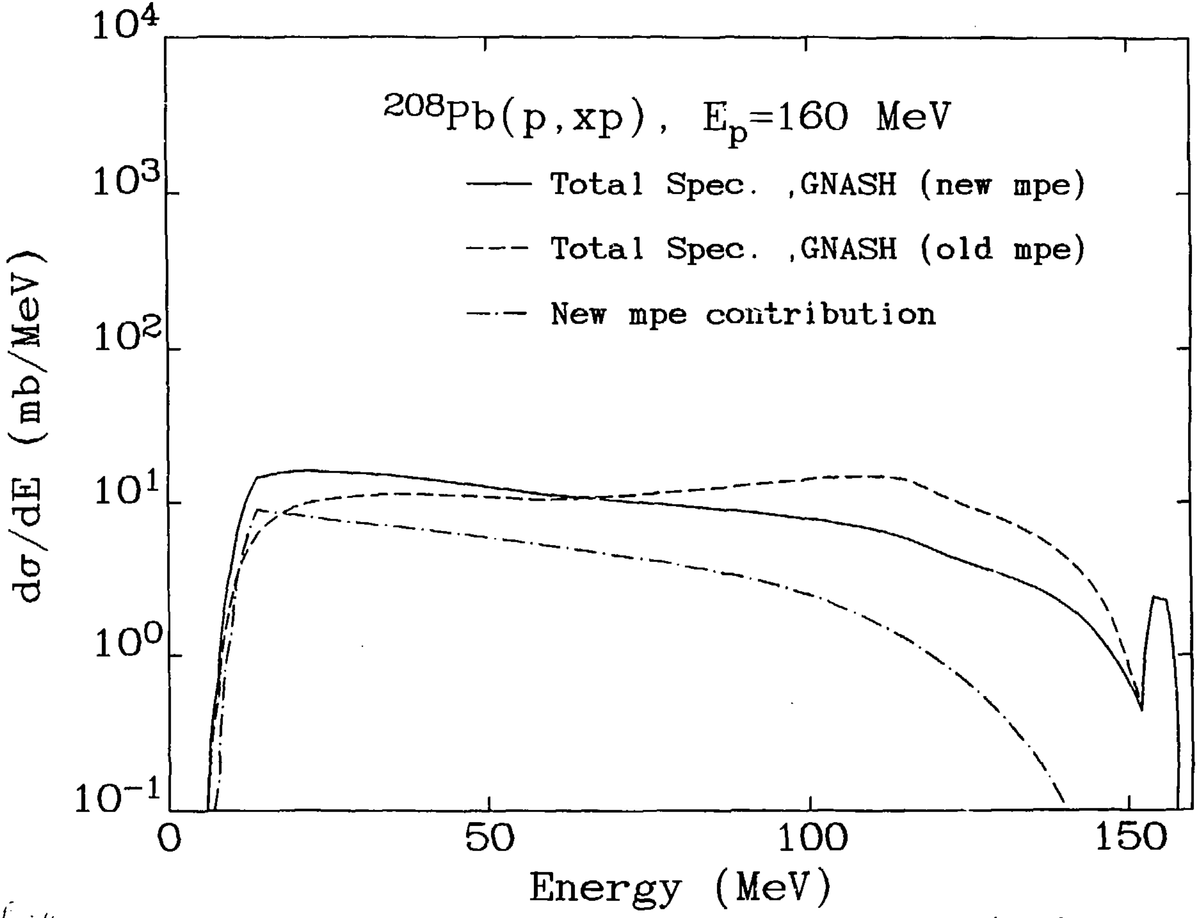

^{208}Pb(p,xp), E_p=160 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
New mpe contribution
10^4
10^3
10^2
10^1
10^0
10^{-1}
dσ/dE (mb/MeV)
0
50
100
150
Energy (MeV)

Fig 1c

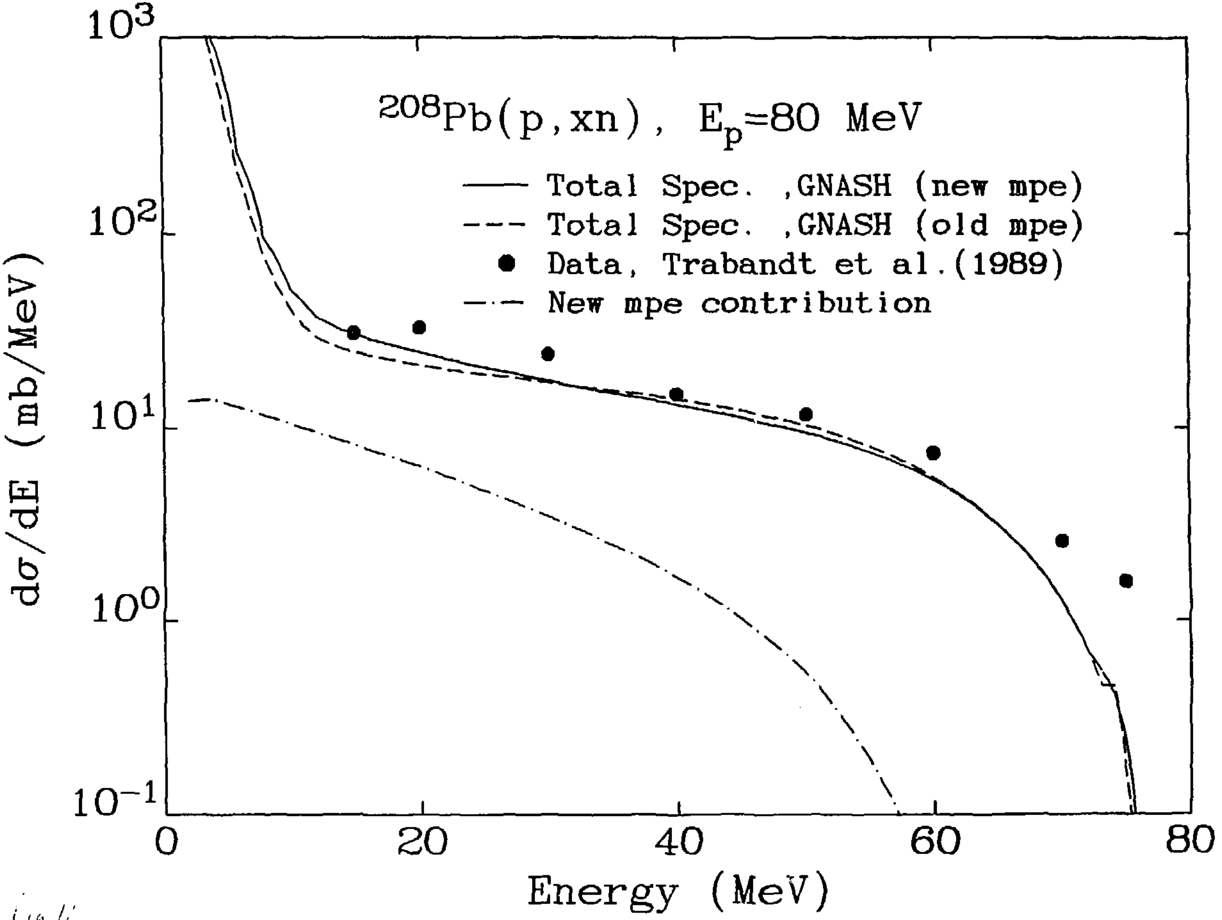

^{208}Pb(p,xn), E_p=80 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
● Data, Trabandt et al.(1989)
New mpe contribution
10^3
10^2
10^1
10^0
10^{-1}
0
20
40
60
80
Energy (MeV)
$d\sigma/dE$ (mb/MeV)

Fig 15

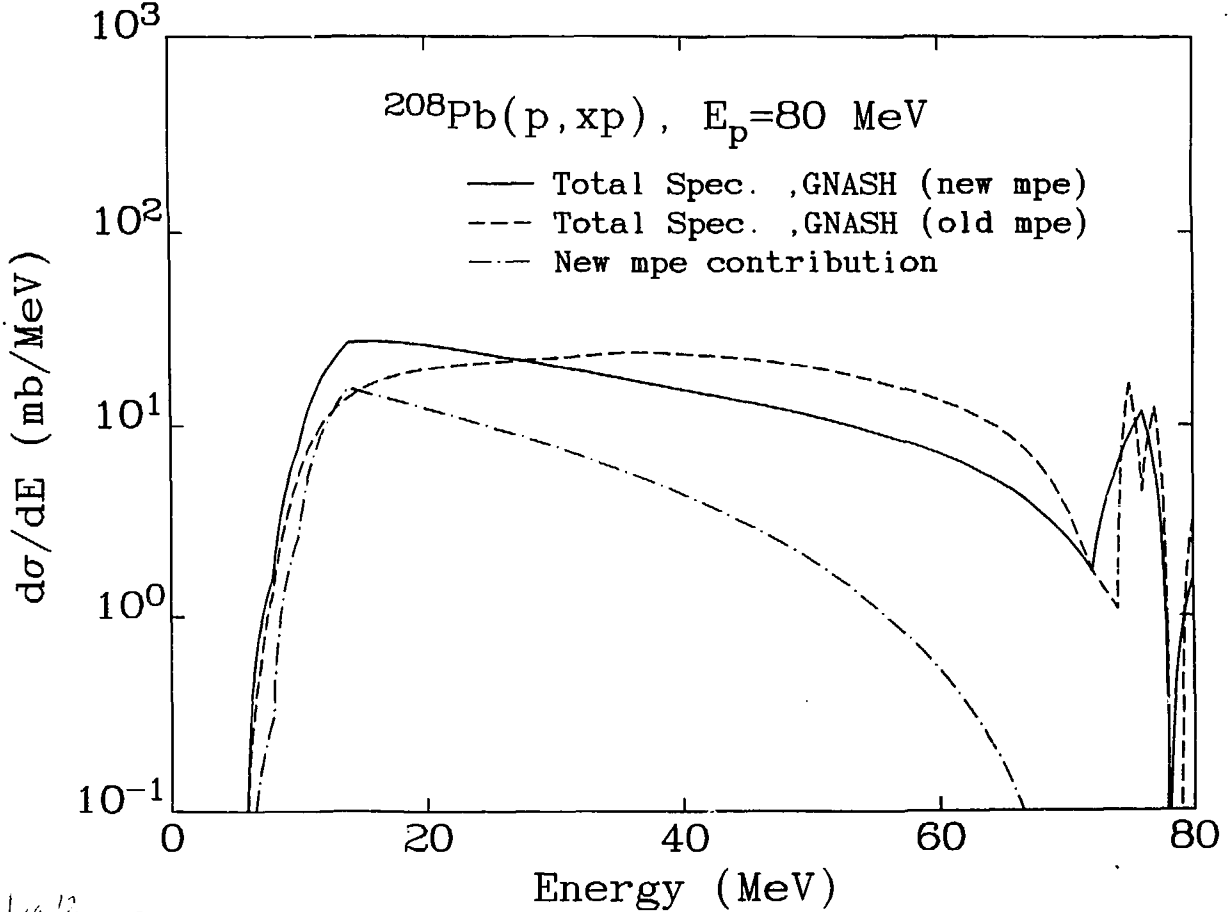

^{208}Pb(p,xp), E_p=80 MeV
Total Spec. ,GNASH (new mpe)
Total Spec. ,GNASH (old mpe)
New mpe contribution
$d\sigma/dE$ (mb/MeV)
10^3
10^2
10^1
10^0
10^{-1}
0
20
40
60
80
Energy (MeV)

Fig 12