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Investigation of α-nuclear potential families from elastic scattering experiments [1]

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Abstract.
In this work we present the continuation of the reported analysis [1] of the experimentally measured angular distributions of the reaction ^{106}Cd$(\alpha,\alpha)^{106}$Cd at several different energies around the Coulomb barrier. The difficulties that arise in the study of ^{106}Cd-α-nuclear potential and the so called Family Problem are addressed.

1. Introduction

The 35 stable elements located on the proton-rich side of the valley of β-stability that cannot be explained in the framework of slow and fast neutron capture are the so called the p-nuclei. These very low-abundant nuclei present one of the most interesting puzzles in nuclear astrophysics. One of the most accepted mechanisms for the synthesis of the p-nuclei is based on photon-disintegration reactions on neutron-rich seed nuclei [2, 3]. Possible scenarios for such nucleosynthesis are the C, O and Ne layers of a Type II SN [2].

2. The Family Problem in ^{106}Cd

The sensitivity of nuclear reaction network calculations to the nuclear physics input has been addressed [3, 4] with particular emphasis to the uncertainties related to the α-nuclear potentials in the heavy mass region (A>150). The sensitivity of α-nuclear potentials at high energies (far above the Coulomb barrier) has been extensively studied in the past (see for instance [5, 6]). The present report concentrates on the α-nuclear potential of the system α-^{106}Cd, starting from the 14 families of the potential previously obtained [1] from the analysis of elastic scattered angular distributions measured at energies around the Coulomb barrier [7, 8]. The analysis was performed within the framework of the Optical Model, considering parameterizations of the Woods-Saxon form for both real and imaginary parts of the nuclear potential.

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3. Description of existing α-induced reaction data

Considering as our starting point the 14 families of the real nuclear potential [1], a modified parameterization with an increased surface Woods-Saxon was adopted for the imaginary potential. The astrophysical S-factor for the processes ^{106}Cd$(\alpha,\gamma)^{110}$Sn and ^{106}Cd$(\alpha$,n$)^{109}$Sn [9], was determined for each of the considered potential families using the NON-SMOKER^{WEB} [10] application. The default settings for neutron and proton potential [11], default nuclear level density [12] and theoretical masses [13] were used in the calculations.

The results are shown in Figure 1 together with the experimental data from [9]. At this stage, our evaluation of the potential families is limited to these two reaction channels, since they are primarily dependent on the α-particle width at the considered energies [14].

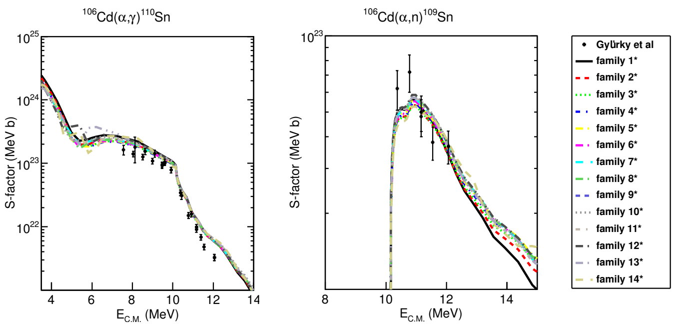

Figure 1. Astrophysical S-factor of the ^{106}Cd$(\alpha,\gamma)^{110}$Sn and ^{106}Cd$(\alpha$,n$)^{109}$Sn reactions [9] together with the results obtained from the 14 different potential families obtained in this study.

As it can be seen in the figures, both the (α,γ) and $(\alpha$,n$)$ processes are well reproduced by almost all of the considered potential families. In the case of the (α,γ) reaction, almost all families present a local minimum at the threshold energy for the $(\alpha$,p$)$ process, which needs to be further investigated. Any of these potentials could be thus used to calculate the reaction cross section at the energy range relevant for p-process calculations: T_9=2-3, with α-energies corresponding to 5.4 and 8.1 MeV [14].

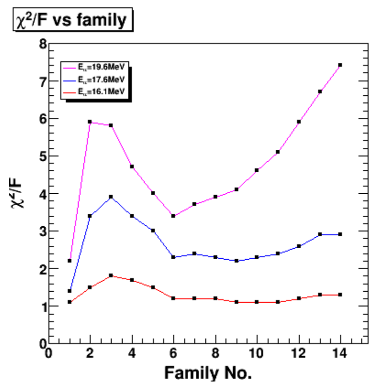

Figure 2. Normalized χ^2 obtained from the analysis of the elastic scattering data by all potential families considered in this work.

The results shown in Figure 2 provide a summary of the description of the different families of the experimental data of the ^{106}Cd$(\alpha,\alpha)^{106}$Cd at energies around the Coulomb barrier, presenting the normalized χ^2 obtained for each of the measured energies. A local minimum is observed around family number 6*, with another minima located on family 1*. The nature of these minima, as well as the particularities of these two families need to be further studied before any definite conclusions can be drawn.

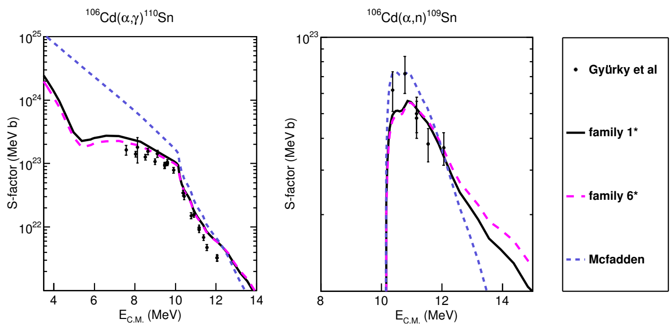

Figure 3. Astrophysical S-factor of the ^{106}Cd$(\alpha,\gamma)^{110}$Sn and ^{106}Cd$(\alpha$,n$)^{109}$Sn reactions [9] together with the results obtained from families 1*, 6* and from the global potential of [15].

4. Conclusions

At this stage, we compare the two selected families with the standard global α nuclear potential from [15]. The results are shown in Figure 3. Analysis and comparison to further global and local α nuclear potentials will be the topic of a dedicated paper. The results from this work, combined with those previously presented [1], highlight the processes that are more sensitive to each part of the considered nuclear potential. While the real part of the potential presents a clear sensitivity to elastic scattering data, induced α-particle capture reactions show a higher sensitivity to the imaginary part of the potential. When analyzing both processes in a coupled way, a minimum of χ^2/F in the description of the elastic scattering data appears. The reaction channels (α,n) and up to some extent (α,γ) at low energies, and elastic scattering reaction data at energies above the Coulomb barrier are necessary to achieve a full description of the potential.

5. Bibliography

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