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.

[1] Work supported by FCT grant PTDC/FIS/103902/2008, ERC StG No. 203175, OTKA NN83261 (EuroGENESIS) and OTKA K68801

Journal of Physics: Conference Series **337** (2012) 012030 doi:10.1088/1742-6596/337/1/012030

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].

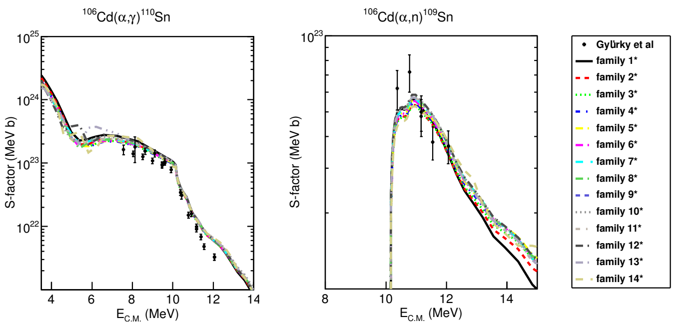

Figure 1. Astrophysical S-factor of the ^{106}Cd$(\alpha,\gamma)^{110}$Sn and ^{106}Cd$(\alpha$,n$)^{109}$Sn reactions [9] together with the results obtained from the 14 different potential families obtained in this study.

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].

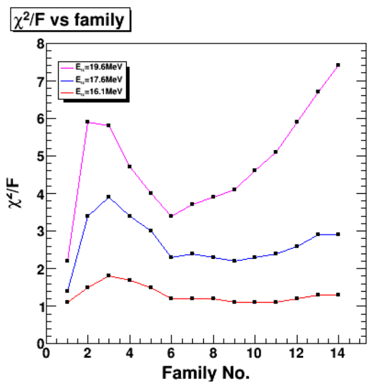

Figure 2. Normalized χ^2 obtained from the analysis of the elastic scattering data by all potential families considered in this work.

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.

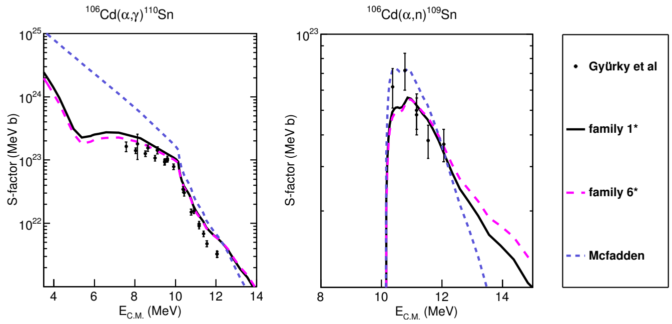

Figure 3. Astrophysical S-factor of the ^{106}Cd$(\alpha,\gamma)^{110}$Sn and ^{106}Cd$(\alpha$,n$)^{109}$Sn reactions [9] together with the results obtained from families 1*, 6* and from the global potential of [15].

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 $(\alpha$,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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