Effects of different NN potentials on ^{120}Te nucleus

C. Lahiri[1],* S. K. Biswal[1], and S. K. Patra[1]
[1]Institute of Physics, Sachivalaya Marg, Bhubaneswar 751005, India

Introduction

In nature 35 nuclei, commonly termed as p nuclei, can be found on the proton-rich side of the nuclear landscape ranging between ^{74}Se to ^{196}Hg. One can find a detailed study related to the p process in the review article[1]. In this paper we concentrate on a fully microscopic calculation for a specific p-nucleus ^{120}Te. The framework is based on microscopic optical model utilizing the theoretical density profile of the nucleus.

The nonlinearity in the scalar field[2, 3] in RMF theory has been proved very successful in reproducing various observables like nuclear ground state including nuclear matter properties and the surface phenomena like proton radioactivity etc. In the present work, we intend to study the effect of microscopic optical potentials obtained from nonlinear NN interactions also in addition to the conventional linear NN interactions for ^{120}Te isotope.

Technique

In this work we have used the RMF formalism in both direct and indirect way. Directly we have calculated the nuclear density, which is an essential quantity to calculate the optical potential. Indirectly we used RMF Lagrangian to derive NN interactions also along with the phenomenologically availed NN interaction model. Here we have used different types of NN interactions, namely the density dependent M3Y interaction (DDM3Y) and nonlinear R3Y interactions(NR3Y)[4]. In order to perform astrophysical calculations nuclear densities from different sets of parameters like NL3 and TM1 have been utilized and we have folded them with corresponding NN interactions respectively. In case of DDM3Y interaction, which is not obtained from the RMF theory, we folded it with RMF density from FSUGold.

In [3], Sahu *et al.* introduced a simple form of nonlinear self-coupling of the scalar meson field and suggested a new NN potential in relativistic mean field theory (RMFT) analogous to the M3Y interaction. According to their prescription, the effective nucleon-nucleon interaction takes the form

$$v_{eff}(r) = \frac{g_\omega^2}{4\pi}\frac{e^{-m_\omega r}}{r} + \frac{g_\rho^2}{4\pi}\frac{e^{-m_\rho r}}{r} - \frac{g_\sigma^2}{4\pi}\frac{e^{-m_\sigma r}}{r} + \frac{g_2^2}{4\pi} r e^{-2m_\sigma r} + \frac{g_3^2}{4\pi}\frac{e^{-3m_\sigma r}}{r} - \frac{\xi^2}{4\pi}\frac{e^{-3m_\omega r}}{r} + J_{00}(E)\delta(r).$$

where all the terms carry their usual meanings.

Therefore the folded potential can be expressed as

$$V(E,\vec{R}) = \int \rho(\vec{r'}) v_{eff}(r,\rho,E) d\vec{r'},$$

with $\vec{r} = \vec{r'} - \vec{R}$ in fm.

Finally reaction cross-sections and astrophysical reaction rates are calculated in the Hauser-Feshbach formalism using the computer package TALYS1.2[5].

Results

In figure 1, S factors for ^{120}Te obtained from NR3Y(NL3) and NR3Y(TM1) potentials are compared with the experimental data taken from reference[6]. The S- factor with DDM3Y interaction folded with FSUGold density is also given for comparison.

One can see that our calculation with folded DDM3Y potential shows a very nice agreement with experimental values throughout

*Electronic address: clahiri@iopb.res.in

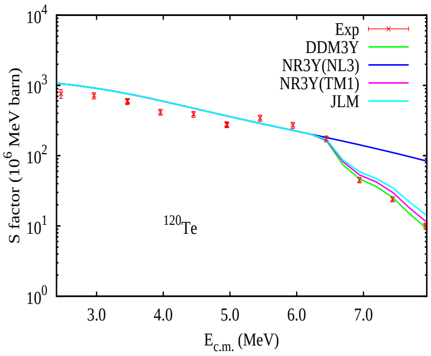

FIG. 1: (Color online) S factors extracted from our calculations compared with experimental measurements for ^{120}Te.

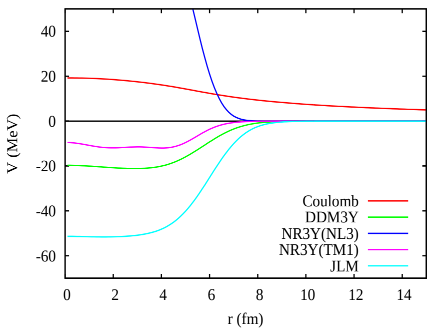

FIG. 2: (Color online) Real central part of folded potentials and Coulomb potential for 7 MeV proton(Lab) incident on ^{120}Te

the energy range. In contrary, in case of NR3Y(NL3)folded potential, there is a wide deviation of the theory with experimental data after 6 MeV whereas the TM1 folded potential NR3Y(TM1) shows a decrease in S factor value around 6 MeV energy unlike the NR3Y(NL3)case.

The rapid drop of S factor values with increasing energy actually takes place due to the increasing contribution of higher angular momentum channels (l>0). Therefore, if the center of mass energy becomes larger than the Coulomb barrier for a specific set of nucleon-nucleus reaction, as a result the S factor will decrease rapidly with the growth of energy[7].

A graphical representation of the real part of the microscopic potentials for ^{120}Te after folding the interactions is represented in figure 2. One can see that the DDM3Y folded potential provides an attractive potential, whereas in case of NR3Y(NL3) folded potential, the repulsive part overpowers the attractive part, as well as the Coulomb part of the potential. Therefore the penetrability of the higher angular momentum channels get reduced and as a obvious consequence, the desirable sharp drop in S factor values has not been achieved.

This scenario can be explained from the numerical value of the nonlinear coupling constants g_2 and g_3. We find that with the decreasing values of the nonlinear coupling constants g_2 and g_3, the repulsive component of the optical potential also gets reduced. So from the above observations we can comment that there should be an upper cut-off for the coupling constants of the nonlinear components.

Acknowledgments

The authors thank IOP, Bhubaneswar for providing computer support and want to acknowledge DAE for financial support.

References

[1] M. Arnould and S. Goriely, *Phys. Rep.* **384** (2003) 1.

[2] P.-G. Reinhard, *Z. Phys. A - Atomic Nuclei* **329** (1988) 257.

[3] B. B. Sahu, S. K. Singh, M. Bhuyan, S. K. Biswal and S. K. Patra, *Phys. Rev. C* **89** (2014) 034614.

[4] Bir Bikram Sing, M. Bhuyan, S. K. Patra and Raj K Gupta, *Journal of Phys. G* **39** (2012) 069501.

[5] A.J. Koning *et al.*, *Proc. Int. Conf. Nucl. Data Science Tech., April 22-27, 2007, Nice, France, EDP Sciences*, (2008) p. 211.

[6] R. T. Güray it et al., *Phys. Rev. C* **80** (2009) 035804.

[7] D. G. Yakovlev, M. Beard, L. R. Gasques and M. Wiescher, *Phys. Rev. C* **82** (2010) 044609.