The $^{19}F(p,\alpha)^{16}O$ reaction in Nuclear astrophysics

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Introduction

Nuclear process plays a vital role in the evolution of universe after Big Bang.At astrophysical scenario the energy released from nuclear reaction prevents the star from gravitational collapse.Thermonuclear cross section need careful attention in astrophysical environment to predict the stellar phenomena.Since the cross section at such low energy is very low involving large error bar, we need theoretical extrapolation (R-matrix [1]) to Gamow region. In this work we are interested in one of the crucial reaction $^{19}F(p,\alpha)^{16}O$ which is a reaction in fourth branch of CNO cycle and the distinction between experimental data and theoretical models.Since the reaction has a controversy whether it is a direct process or compound nucleus process,H.Herndl[2] observed that direct part is also important using the Wirzba data[3].The Indirect Trojan horse method[4] can be important to study this reaction at Gamow region (27-94 KeV)[5].

Phenomenological R-matrix Calculation

R-matrix is one of the reliable tool for theoretical extrapolation to Gamow region at which direct measurements are quite impossible due to high uncertanity.The R-matrix formalism for angular mommentum l is given by

$$R_l = \sum_\lambda \frac{\Gamma^2_{\lambda\ l}}{E_\lambda - E}$$

where, $\Gamma_{\lambda\ l}$ is reduced width amplitude for the level λ and angular momentum l and E_λ is the R-matrix pole.

$$\Gamma^2_{\lambda\ l} = \sqrt{\frac{\hbar^2}{2ma}}\ \Phi_l(E_\lambda, a)$$

Both E_λ and Γ_λ are the unknown parameters of the R matrix which can be evaluated by examining the measured cross sections.

Result and Discussion

The R-matrix code Azure 2[1] is used to fit the recent and lowest energy data of Lombardo et.al. [6, 7] . In this fit procedure, the input parameters are level energies and spin parities of the ^{20}Ne nucleus.A background pole level is also introduced for considering the continuum. The levels considered in the fitting of Lombardo et.al 2013 [6] and Lombardo et. al. 2015 [7] are given below table.We got the ground state ANC of Lombardo [6] from R-matrix fitting is 37606.67 $fm^{-0.5}$.The background pole of 18 MeV and 20 MeV for Lombardo[6] and [7] data are added respectively for contribution from continuous level.

The fitting parameters and the fitting of the Lombardo [6, 7] data are shown below.

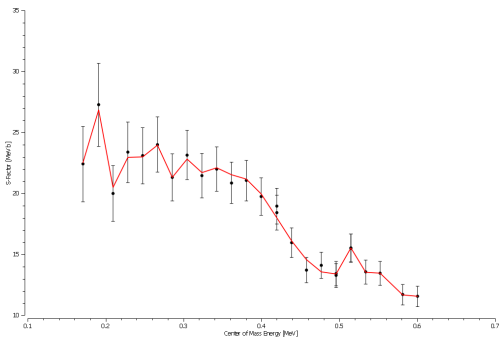

FIG. 1: R-matrix fit of Lombardo et.al. 2015 data

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TABLE I: Fitting parameters of Lombardo 2015 data

J^π	E (MeV)	$\Gamma(KeV)/C(fm^{-0.5})$
0^+	0	0.002
0^+	13.222	1.5
1^-	12.836	1.0
2^+	12.221	73.91
2^+	12.592	13.38
2^+	12.5143	55.19
2^+	12.953	192.20
2^+	13.104	6.68×10^{-3}
2^+	14.033	33.82
3^-	13.137	8.86
3^-	13.226	135.59
3^-	13.691	135.59
4^+	13.048	54.30×10^{-3}
4^+	14.215	2.56
1^-	20	1
3^-	20	8.105
4^+	20	4985.18

TABLE II: Fitting parameters of Lombardo 2013 data

J^π	$E^*(MeV)$	Γ(KeV)	$C(fm^{-0.5})$
0^+	0		36707.67
2^+	13.529	844.098	
2^+	13.5864	811.49	
0^+	13.691	$4.91 * 10^{-3}$	
2^+	18.60	2483.6	

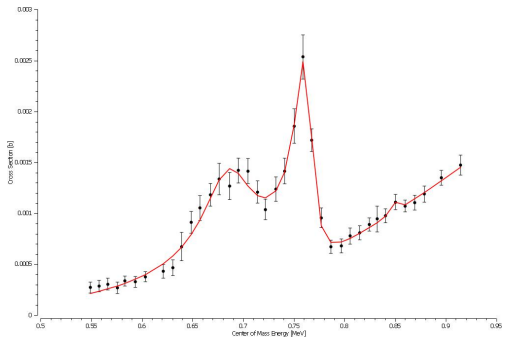

FIG. 2: R-matrix fit of Lombardo et.al. 2013 data

Conclusion

The Lombardo 2013 and 2015 data is well fitted by R-matrix program Azure 2.The ground state ANC value for the Lombardo 2013 data is 37606.67 $fm^{-0.5}$. The fitting value can be used to extrapolate to astrophysical region by Azure 2.

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