# A simultaneous R-matrix analysis of $\alpha - \alpha$) elastic scattering and capture reaction data.

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## Introduction

Production of $^8$Be by fusing two alpha particles is the first reaction of He burning stage of a star and is the first step in the synthesis of $^{12}$C by triple alpha process in star. The ground state of $^8$Be is a resonance state of two alpha with energy of 0.092 MeV. It has a lifetime $6.7\times10^{-17}$s. This is considered a *sufficiently* long time for a small amount of $^8$Be to survive in the star for further reaction $^8$Be$(\alpha,\gamma)^{12}$C to take place. Besides the $2\alpha$ cluster ground state, $^8$Be has two other resonant states which are at $E_x$=3.04 MeV and $E_x$=11.4 MeV having spin parity $J^\pi=2^+$ and $4^+$ respectively forming a rotational band based on a dumbell-shaped structure for the nucleus. In 2005 and 2013 in two different experiments [2, 3] Datar *et al.* studied the radiative capture of $2\alpha$-s in the resonant $4^+$ excited state and reported the $4^+$ to $2^+$ electromagnetic transition as a test for the cluster structure of the excited states. future for better estimation we are planning to extend our R-matrix analysis by introducing more reaction channels leading to $^8Be$, which will help us to generate proper extrapolation of capture cross section at low energy region as well as it will help us to understand $\alpha$ cluster structure of

The present work reports a simultaneous R-matrix analysis of capture reaction $\alpha(\alpha,\gamma)^8$Be data of Ref. [3] along with the available low energy $\alpha-\alpha$ resonant elastic scattering data from Tombrello *et al.*[4] to probe the resonant parameter values.

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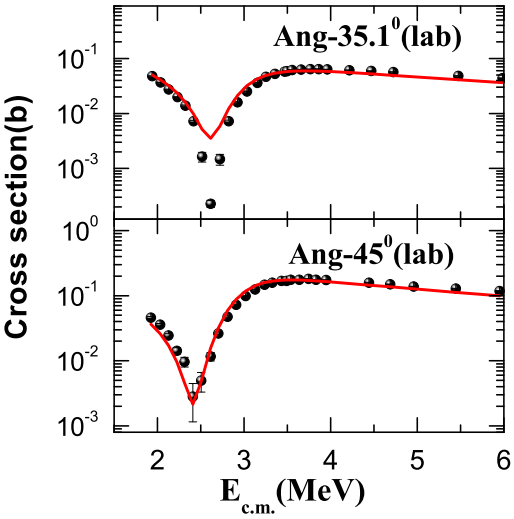


FIG. 1: R-matrix fit to the $\alpha-\alpha$ scattering data from Ref.[4].

## Analysis

We have performed the R-matrix analysis using the multi-channel, multi-level code AZURE2[5]. The channel radius value of 4.2 $fm$ has been chosen for $\alpha+\alpha$ channel. The fit of the elastic data of $\alpha-\alpha$ scattering has been shown in Fig. 1 for the two different angles. The elastic scattering data over the measured energy region actually constrain the parameters of the $2^+$ resonance state. On the other hand the excitation function data of Refs [2, 3] tests the parameters of $4^+$ and $2^+$ states. The fit to the $4^+\rightarrow2^+$ $\gamma$-transition data from the radiative capture reaction $\alpha(\alpha,\gamma)^8$Be is shown in Fig. 2. The resultant resonant parameters

TABLE I: The resonance parameters obtained from the $R$ matrix fits

| $J^\pi$ | $E_x$ (MeV) | $\Gamma_p$ (MeV) | $\Gamma_\Upsilon$ R→0.0 (eV) | $\Gamma_\Upsilon$ R→3.04 (eV) |
|---|---|---|---|---|
| $0^+$ | 0.00 | $6.17\times10^{-6}$ | | |
| $2^+$ | 3.04 | 1.57 | $8.3\times10^{-3}$ | |
| $4^+$ | 11.4 | 3.5 | 0.71 | 0.61 |
| $2^+$ | 20.0 | 5.0 | 100 | 0.34 |
| $4^+$ | 20.0 | 5.0 | 5.07 | 47.96 |

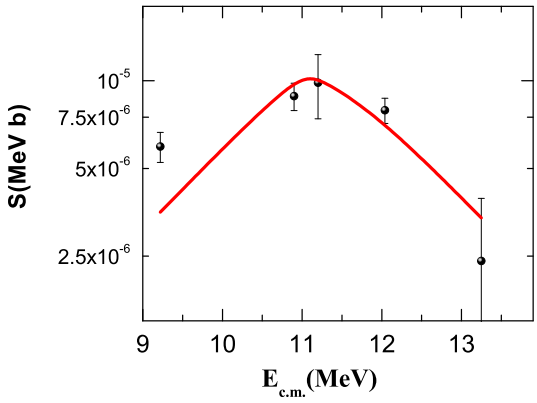


FIG. 2: Fit to the $4^+ \rightarrow 2^+$ transition cross section data from Refs.[2, 3]

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from the simultaneous fitting are tabulated in Table I. To simulate the non-resonant part in the excitation function, two high energy background poles having same spin parity as the two resonant states have been introduced with pole energy of $E_x$=20 MeV.

## Results & Discussions

The parameters obtained from R-matrix analysis agree well with the previous calculations[6, 7]. In our simultaneous analysis, the resultant parameter set is unable to reproduce the dip in the excitation function of $\alpha - \alpha$ scattering at the angle $\theta_{lab} = 35.1^o$. A possible reason could be the unavailability of capture cross section data to the $2^+$ resonance state.

Further calculation is in progress to generate proper extrapolation of capture cross section at low energy region through the phenomenological R-matrix modeling. Details of the calculation with the inclusion of more number of channels will be presented in the symposium.

## References

[1] C.E. Rolfs and W.S. Rodney, *Cauldrons in Cosmos: Nuclear Astrophysics*, University of Chicago press, Chicago, 1988

[2] V.M. Datar, Suresh Kumar, D.R. Chakraborty, V. Nanal, E.T. Mirgule, A Mitra and H.H Oza Phys. Rev. Lett.**94**, 122502 (2005).

[3] V.M. Datar, D.R. Chakraborty *et al.* Phys. Rev. Lett.**111**, 062502 (2013).

[4] T.A. Tombrello and L.S. Senhouse Phys. Rev. **129**, 2252 (1963)

[5] R. E. Azuma, E. Uberseder *et al.*, Phys. Rev. C **81**, 045805 (2010).

[6] K. Langanke and C. Rolfs, Phys. Rev. C **33**, 790 (1986).

[7] K. Langanke and C. Rolfs, Z. Phys. A 324, 307 (1986).