Measurements of α-α-n coincidence in ^{9}Be+^{198}Pt reaction

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In recent times, the decay mechanisms of ^{9}Be from its continuum and resonances have received much attention due to its implication on research related to nucleosynthesis of ^{12}C via ^{9}Be(α,n)^{12}C reaction, which is considered to be a trigger to the r-process for the synthesis of heavy elements. There are extensive study on structure of ^{9}Be, both theoretical and experimental [1–3]. Although the theoretical calculations are able to reproduce the energy levels reasonably well, their decay properties have not been established yet. From measurement point of view, though, there are several measurements, which are quantifying the contribution of different decay components for the low-lying continuum, very limited $\alpha-\alpha-n$ triple coincidence measurements are available to understand the decay mechanisms directly [4]. In our earlier measurements, from a precise elastic scattering data and coupled channel calculations for ^{9}Be+^{208}Pb system, we have shown that the nucleus ^{9}Be appears as n+^{8}Be rather than α+^{5}He cluster [5]. In the present study, we have aimed to understand the decay mechanism of ^{9}Be from direct $\alpha-\alpha-n$ coincidence measurements.

An experiment to measure $\alpha-\alpha-n$ triple coincidence was carried out for the ^{9}Be+^{198}Pt system at the BARC-TIFR Pelletron-LINAC facility, Mumbai. The measurements were performed at beam energy of 45 MeV. An enriched ($\sim$95.7%) self-supporting $\sim$ 1.3 mg/cm^{2} thick ^{198}Pt foil was used as target. The experimental setup is shown in Fig. 1. Five segmented large area Si-telescopes of active area 5 x 5 cm^{2} were used for the measurement of the energy and scattering angle of the outgoing α-particles. The telescopes were mounted at angles 40°, 70°, 115°, 145° and -55° in a compact scattering chamber of diameter 32 cm. Three of the ΔE detectors were $\sim$50 μm thick, while other two were $\sim$20 μm thick. Both the thinner (Thickness 20 μm) detectors were kept at backward angles to increase the dynamical energy range of α-particles. All the five E-detectors were of thickness of 1.5 mm and double sided with 16 strips allowing a maximum of 256 pixels. Thin tantalum foils of thickness $\sim$5 mg/cm^{2} were placed in front of the two forward angle telescope (40° and -55°) to prevent elastically scattered ^{9}Be to reach E-detectors. The purpose of the of the tantalum foils was to reduce the coincident count rate due to the random of elastic events. Fifteen liquid scintillator detectors (EJ-301) were used to measure neutrons over an angular coverage of 30°-145°. The time-of-flight (TOF) distances of the neutron detectors were 72.5 cm. Concrete blocks and lead bricks were used for proper

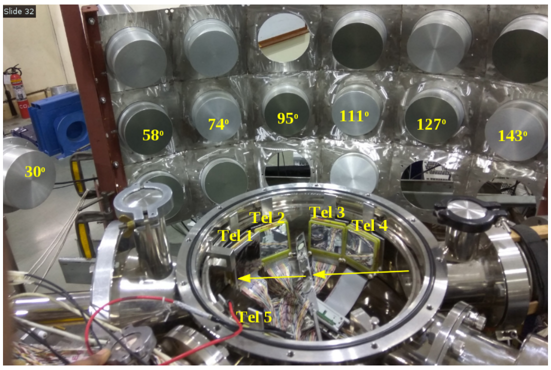

FIG. 1: The experimental setup, which consists of five segmented large area Si-telescopes for charged particles and fifteen liquid scintillator for neutron detection.

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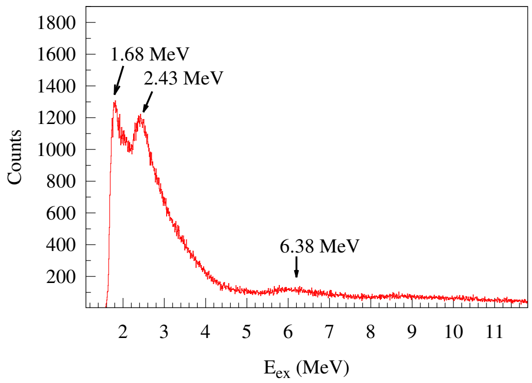

FIG. 2: The reconstructed ^{9}Be excitation energy spectra from measured $\alpha-\alpha-n$ triple coincidence for ^{9}Be+^{198}Pt system at E_{beam} = 45 MeV.

shielding to reduce the scattered background neutrons from the beam dump and collimators [6]. One Si surface barrier detector of a thickness $\sim$ 300 μm was fixed at 20° to monitor Rutherford scattering for absolute normalization purposes. The data were collected in event by event mode for two or higher fold coincidence in 120 ns time window from any strips out of all the E-detectors. The filtered RF (logically ANDed with two or higher fold coincidence of charged particles) was used as reference to measure time of flight of the neutrons. The Si-detectors were calibrated using the known α energies from ^{239}Pu-^{241}Am and ^{229}Th sources. The energy loss information from ΔE and E detectors were used to identify the α-particles. The $n-\gamma$ separation achieved with the standard pulse shape discrimination technique.

An preliminary analysis of the data has been carried out. Energy of the detected neutrons were determined from the measured time-of-flight. The measured energies (E_α^1, E_α^2, E_n) and scattering angles (θ_α^1, ϕ_α^1; θ_α^2, ϕ_α^2; θ_n, ϕ_n) were used to reconstruct the energy ($E_{^9Be}$) and angel ($\theta_{^9Be}$) of the scattered ^{9}Be prior to breakup. The energy (E^*) of the excited states of ^{9}Be were extracted from conservation of energy

$E_{^9Be} + E^* - E_{th} = E_\alpha^1 + E_\alpha^2 + E_n$

where, E_{th}=1.57 MeV is the breakup threshold. The reconstructed ^{9}Be excitation energies are shown in Fig. 2. The excited states at 1.68 ($\frac{1}{2}^+$), 2.43 ($\frac{5}{2}^-$), and 6.38 ($\frac{7}{2}^-$) are observed in the excitation energy spectra. The further analysis is in progress. The breakup mechanisms from different resonance states will be presented.

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References

[1] T. A. D. Brown, P. Papka, B. R. Fulton, D. L. Watson, S. P. Fox, D. Groombridge, M. Freer, N. M. Clarke, N. I. Ashwood, N. Curtis, et al., Phys. Rev. C **76**, 054605 (2007).

[2] P. Papka, T. A. D. Brown, B. R. Fulton, D. L. Watson, S. P. Fox, D. Groombridge, M. Freer, N. M. Clarke, N. I. Ashwood, N. Curtis, et al., Phys. Rev. C **75**, 045803 (2007).

[3] R. Álvarez-Rodríguez, A. S. Jensen, E. Garrido, and D. V. Fedorov, Phys. Rev. C **82**, 034001 (2010).

[4] B. R. Fulton, R. L. Cowin, R. J. Woolliscroft, N. M. Clarke, L. Donadille, M. Freer, P. J. Leask, S. M. Singer, M. P. Nicoli, B. Benoit, et al., Phys. Rev. C **70**, 047602 (2004).

[5] S. K. Pandit, V. Jha, K. Mahata, S. Santra, C. S. Palshetkar, K. Ramachandran, V. V. Parkar, A. Shrivastava, H. Kumawat, B. J. Roy, et al., Phys. Rev. C **84**, 031601 (2011).

[6] P. Rout, A. Gandhi, T. Basak, R. Thomas, C. Ghosh, A. Mitra, G. Mishra, S. Behera, R. Kujur, E. Mirgule, et al., JINST **13**, P01027 (2018).