Proximity decay effect in ^{28}Si + ^{12}C at 35 MeV/u using FAUST

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In heavy-ion collisions near the fermi-energy, some collisions may result in an excited projectile-like fragment that may de-excite via light charged particle emission [1]. If the light charged particle is emitted in an excited state (LCP*), itself will further de-excite according to the decay pathways available. Given short enough lived LCP* states, the LCP* decay will on average occur in very close proximity to the source that emitted it. These decay products experience the coulomb field of the source remnant, affecting the distribution of relative energies between the LCP* decay products depending on the LCP* emission velocity (Ecm) distribution, lifetime, decay energy (ERel), and decay orientation (β). This effect for the 2+ excited state of ^{8}Be emitted from sources with 14 < Z < 47 has been previously studied using LASSA [2]. The position sensitive FAUST (Forward Array Undertaking Search for Toroids) was recently used to measure reaction products from collisions of ^{28}Si at 35 MeV/u on ^{12}C. The excellent angular information afforded by FAUST has allowed for this effect to be studied in more detail.

The decay orientation angle, β, is defined as the angle between the center-of-mass energy vector (between the source remnant and the two LCP* decay products) and the relative energy vector between the two LCP* decay products as shown in Fig. 1. Events were selected that contain two ^{4}He(α)-particles and an isotope of Ne (Z = 10) to observe the proximity decay effect of ^{8}Be(2+) emission from an excited

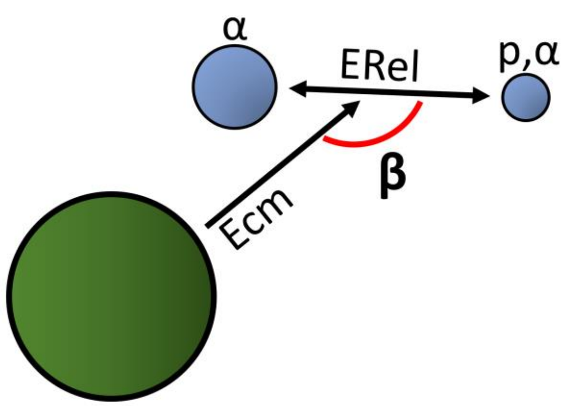

Fig. 1. (a) Diagram depicting the decay of an LCP* emitted from an excited projectile-like source. In this work, ^{8}Be(0+, 2+) → α + α and ^{5}Li(3/2-) → p + α LCP* decays are studied.

Si source. The α- α relative energy distributions in 5° ranges of β were produced from 0° to 90°, with the β = 20° - 25° range shown in blue in Fig. 2(a). The ^{8}Be(2+) state of interest can be seen as the broad peak centered at ~3 MeV, having an intrinsic width of 1.5 MeV. To extract the mean of this distribution, the uncorrelated background must be accounted for. One way to do this is by producing a mixed event distribution [3]. Here, two α-particles were chosen from different events and the relative energy between them was calculated. To obtain the mixed event β, the velocity vector of each α-particle relative to the remnant measured in each respective event was first obtained. These remnant frame α-particle velocities were then joined to produce a mixed event decay where β could be calculated. The mixed event distribution with β = 20° - 25° is shown in red in Fig. 2(a). The mixed event distribution is then normalized to the real distribution in a range where there are no expected states (5 – 8 MeV relative energy in this case). By subtracting the mixed event distribution from the real event distribution, yield associated with excited state decays emerge as shown in Fig. 2(b). To obtain the mean relative energy of the ^{8}Be(2+) state, a gaussian fit is performed. This analysis procedure is repeated for all 5° ranges of β.

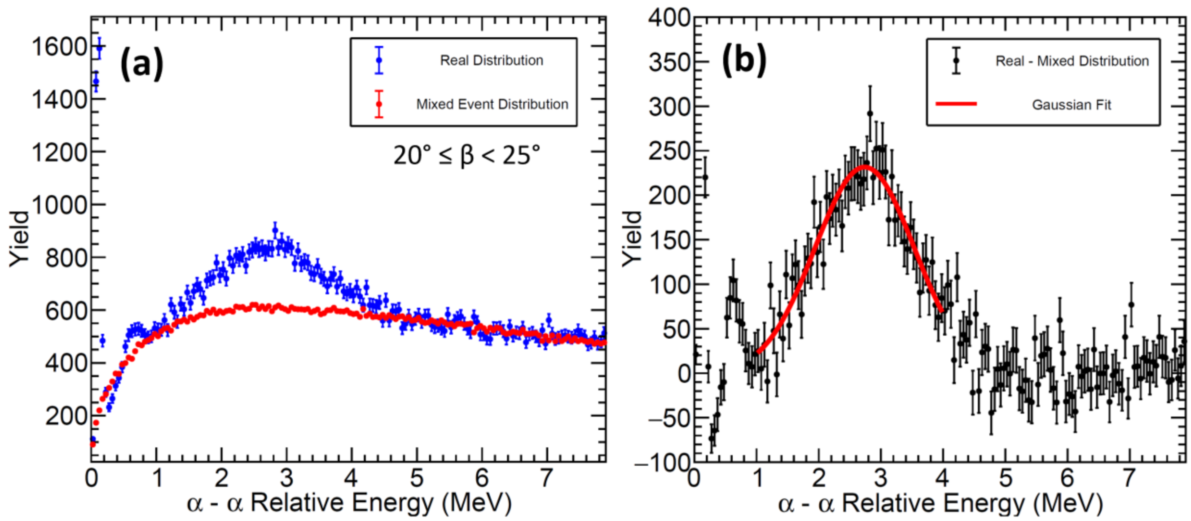

Fig. 2. Procedure for obtaining the ^{8}Be(2+) excited state relative energy mean for β = 20° - 25° in events with a measured Ne remnant. (a) Real (blue) and mixed (red) α – α relative energy distribution in MeV. (b) Real – mixed α – α relative energy distribution in MeV. Gaussian fit of the ^{8}Be(2+) peak is shown in red.

To examine the proximity decay effect for ^{8}Be(2+) emitted from a Si PLF*, the mean ^{8}Be(2+) relative energy is plotted as a function of the decay orientation in Fig. 3(a). For decays that occur in-line with the remnant Ne (β = 0°), the α-particle that is emitted back towards the Ne remnant experiences its coulomb field, kicking this α-particle away from the remnant towards the other α-particle. This reduces the measured α-α relative energy for this decay orientation by ~650 keV compared to the literature value of 3.12 MeV [4]. The results from this study show a similar trend to the LASSA result (blue open circles), however further modeling is necessary to make direct comparisons due to differences in detector acceptance, resolution, remnant mass, remnant charge, and event selection. One way to further test the validity of the proposed mechanism for this effect is to look for a lack of β-dependence on the mean energy for long-lived LCP* states. The same analysis is performed for the 0+ ground state of ^{8}Be (5.5 eV width), as emitted ^{8}Be(0+) decays will occur far from the remnant (~1 X 10^{6} fm for 8Be(0+) compared to ~5 fm for ^{8}Be(2+)). There is no observed β-dependence for the mean energy of this decay as shown by the black triangles in Fig. 1(a).

To further characterize and understand the interplay between the coulomb field, LCP* decay energy, LCP* lifetime, and decay orientation, it would be useful to observe this effect for asymmetric LCP* decays. The 1.23 MeV width (3/2-) ground state decay of ^{5}Li to p + α with a decay energy of 1.97 MeV is an excellent candidate. Events were selected that contained a proton, α, and heavy remnant with 7 < Z < 12, and the analysis procedure was repeated. Due to the decay producing two different isotopes, the decay orientation can be probed from β = 0° - 180°, showing the effect of having either the proton or α-particle emitted back towards the remnant as shown in Fig. 3(b). Decays where the proton is emitted backwards have a larger reduction in the mean relative energy than for decays where the α-particle is emitted backwards (~940 keV (β = 0°) compared to ~600 keV (β = 180°) less than the 1970 keV literature value) [5]. A coulomb trajectory model is currently being developed to better understand the contribution of all pertinent factors that may influence the degree of mean relative energy deviation as a function of β, as well as how the measured β relates to the initial β.

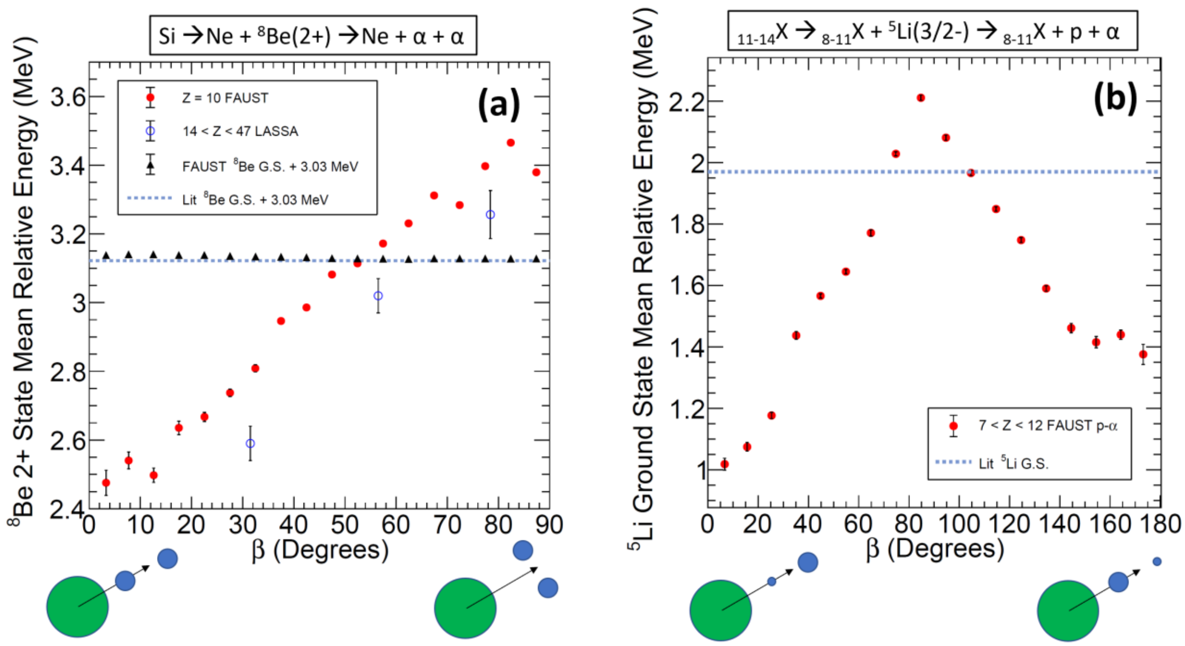

Fig. 3. Mean relative energy of LCP* decay in MeV as a function of decay orientation β in degrees. Diagrams depicting the physical orientation that each extreme of β corresponds to is shown below the x-axis. Event selection requirements are displayed in the legend. Errors on the means are obtained from the gaussian fits. (a) Mean α- α relative energy for the decay of ^{8}Be(2+) (red circles) and the decay of ^{8}Be(0+) (black triangles). Literature ^{8}Be(2+) mean relative energy is shown by the blue dashed line [4]. Results from the LASSA experiment is shown by the blue open circles [2]. (b) Mean p-α relative energy for the decay of ^{5}Li(3/2-) (red circles) with a measured remnant of 7 < Z < 12. Literature ^{5}Li(3/2-) mean relative energy is shown by the blue dashed line [5].

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