Two methods for invariant mass reconstruction from events with multiple charged particles

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Invariant mass spectroscopy is one of the techniques to explore unbound states of nuclei. Relative energy (E_r) or the energy above threshold energy is reconstructed from four-momenta of decay particles. Experimental resolution is important since the level density above particle thresholds is higher than that below particle thresholds and unbound states have finite width. Another important aspect is acceptance. These two aspects often compete with each other.

The SAMURAI spectrometer is developed to investigate unbound states of nuclei. In the standard setup with the SAMURAI magnet, we install four multi-wire drift chambers, BDC1, BDC2, FDC1, and FDC2, to measure the four-momentum of a charged particle.[1] FDC1 is placed between the target and the SAMURAI magnet, while FDC2 is placed at the downstream of the magnet. By using positions and angles measured by these detectors, we can deduce the direction vector and the magnetic rigidity of a charged particle, which is converted to the four-momentum. For invariant mass reconstruction from events with multiple charged particles such as α decay into 2 charged particles of α + residue, positions of each charged particle have to be deduced with both FDC1 and FDC2. The positions are separated at FDC2 for particles with different A/Z values, while the positions can be close at FDC1. The cell size of FDC1 is 10 mm, and the requirement of deducing 2 positions with FDC1 can limit the acceptance, especially for a small opening angle corresponding to a low E_r. The four-momenta of charged particles can be deduced only from the reaction point on the target, positions and angles deduced from FDC2, and the magnetic field map of the SAMURAI magnet[2] without FDC1, though the resolution of the direction vector is worse than with FDC1. Therefore, we performed two different methods to deduce E_r, without FDC1 and with FDC1. The former yields a worse resolution but full acceptance, while the latter achieves a better resolution but with biased acceptance for two particles, especially for a small spatial separation at the FDC1 location.

We analyzed the data of the SAMURAI08 experiment[3] in which the α decay of ^{16}C* is investigated. We used known unbound states of ^{12}B and ^{11}B to compare the two methods. Figure 1 shows E_r spectra of ^{12}B reconstructed from the ^{8}Li + α decay channel. A clear peak is visible at $E_r = 2.75$ MeV in both spectra, without FDC1 (black line) and with FDC1 (red line). The better resolution with FDC1 allows us to find another peak at $E_r = 0.90$ MeV, while the corresponding peak is not so clear without FDC1. Figure 2 shows E_r spectra of ^{11}B reconstructed from the ^{7}Li + α decay channel. ^{11}B has doublet unbound states at $E_r = 0.52$ and 0.61 MeV with negligible width. The doublet peaks are not well separated without FDC1, while a dip between the doublet peaks can be seen with FDC1. With FDC1, the resolution (σ) of E_r is approximately $0.04\sqrt{E_r}$ MeV, while the acceptance is approximately 80% of that without FDC1.

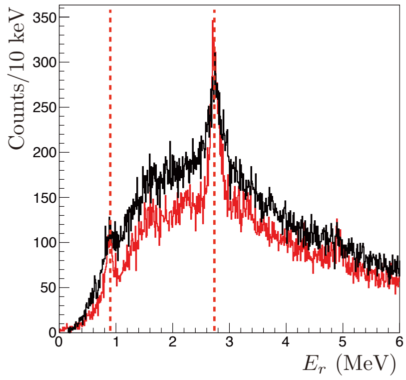

Fig. 1. E_r spectra for ^{12}B$^* \rightarrow {}^8$Li + α. The black line represents the E_r reconstructed without FDC1, while the red line represents that reconstructed with FDC1.

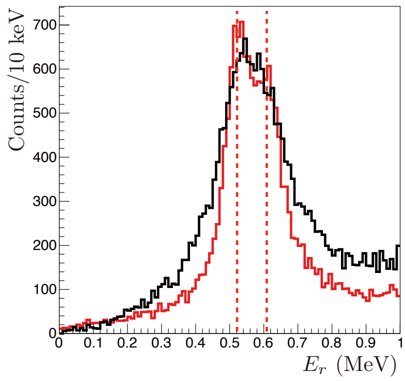

Fig. 2. Same as Fig. 1 but for ^{11}B$^* \rightarrow {}^7$Li + α.

In summary, two methods to reconstruct invariant mass were evaluated. Both methods have advantages and disadvantages. They should be used as per the intended application.

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References
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