Proton-proton correlations in distinguishing the two-proton emission mechanism of ^{23}Al and ^{22}Mg[†]

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Two-proton emission is a very interesting but complicated process occurring in nuclei close to the proton drip line. However, it is difficult to distinguish between the two-body sequential and three-body simultaneous emission mechanism in two-proton emission processes.[1)] In these two mechanisms, the emission time of the two protons is quite different. For the three-body simultaneous emission, the two protons are emitted almost simultaneously, while the two protons are emitted one by one in sequential emission. In heavy-ion collisions, two-particle interferometry is a well-recognized and powerful method to extract the source size and particle emission time and to probe and disentangle different reaction mechanisms.

An experiment was performed to study the proton-proton momentum correlation function for the three-body decay channels $^{23}\mathrm{Al} \to \mathrm{p} + \mathrm{p} + {}^{21}\mathrm{Na}$ and $^{22}\mathrm{Mg} \to \mathrm{p} + \mathrm{p} + {}^{20}\mathrm{Ne}$ using the RIPS beamline at the RI Beam Factory (RIBF) operated by RIKEN Nishina Center and Center for Nuclear Study, the University of Tokyo.

The proton-proton momentum correlation function (C_{pp}) was obtained by the event-mixing method with an iterative calculation. The source size and proton emission time information was extracted by comparing the CRAB calculation with the experimental C_{pp} data.[2)] In the calculation, the space and time profile of the source was assumed to be a Gaussian as $S(r,t) \sim \exp(-r^2/2r_0^2 - t/\tau)$, with r_0 referring to the source size and τ referring to the emission-time difference between the protons. As shown in Fig. 1, the source sizes were approximately $2 \sim 3$ fm for both ^{23}Al and ^{22}Mg based on the minimun reduced chi-square. However, the parameter τ is quite different for these two nuclei. For the reaction channel $^{23}\mathrm{Al} \to \mathrm{p} + \mathrm{p} + {}^{21}\mathrm{Na}$, as shown in Fig. 1(a), τ is very large ($>$ 600 fm/c), while for the reaction channel $^{22}\mathrm{Mg} \to \mathrm{p} + \mathrm{p} + {}^{20}\mathrm{Ne}$, as shown in Fig. 1(b), τ is very small ($<$ 50 fm/c). This implies that the emission-time difference between two protons for ^{23}Al and ^{22}Mg was quite different. For ^{23}Al, the two protons were emitted at very different times, i.e., the mechanism is sequential emission. For ^{22}Mg, the two protons were emitted almost simultaneously, i.e., the mechanism was essentially simultaneous. Based on the previous results[1)] and this work, it is possible to distinguish clearly the mechanism of two-proton emission by investigating on the proton-proton momentum correlation function, the two-proton relative momentum, and opening-angle distributions. The method presented in this work was applied for the first time to two-proton emitters, and was shown to provide new and valuable information on the mechanism of two-proton emission.

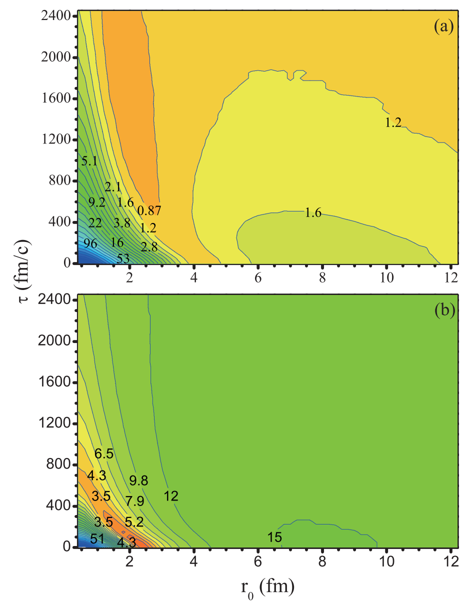

Fig. 1. Contour plot of the reduced chi-square (χ^2/ν, where ν is the number of degrees of freedom) obtained from fitting the experimental C_{pp} data by the CRAB calculation for the reaction channel of $^{23}\mathrm{Al} \to \mathrm{p} + \mathrm{p} + {}^{21}\mathrm{Na}$ (a) and $^{22}\mathrm{Mg} \to \mathrm{p} + \mathrm{p} + {}^{20}\mathrm{Ne}$ (b).

References
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