Study of α-α correlation functions in $^{40}Ar+^{58}Fe$ at 30 MeV/u

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Correlation functions have the potential to give interesting information about the resonant states of a fragment produced in a heavy ion reaction as the shape and size will allow one to understand the lifetime and energy state of the fragment [1]. Large correlation at a specific relative momentum would indicate a strong interaction between α particles at a specific energy which would refer to a distinct state of ^{8}Be, as shown in Fig. 1. In order to calculate correlation functions experimentally, the ratio of the

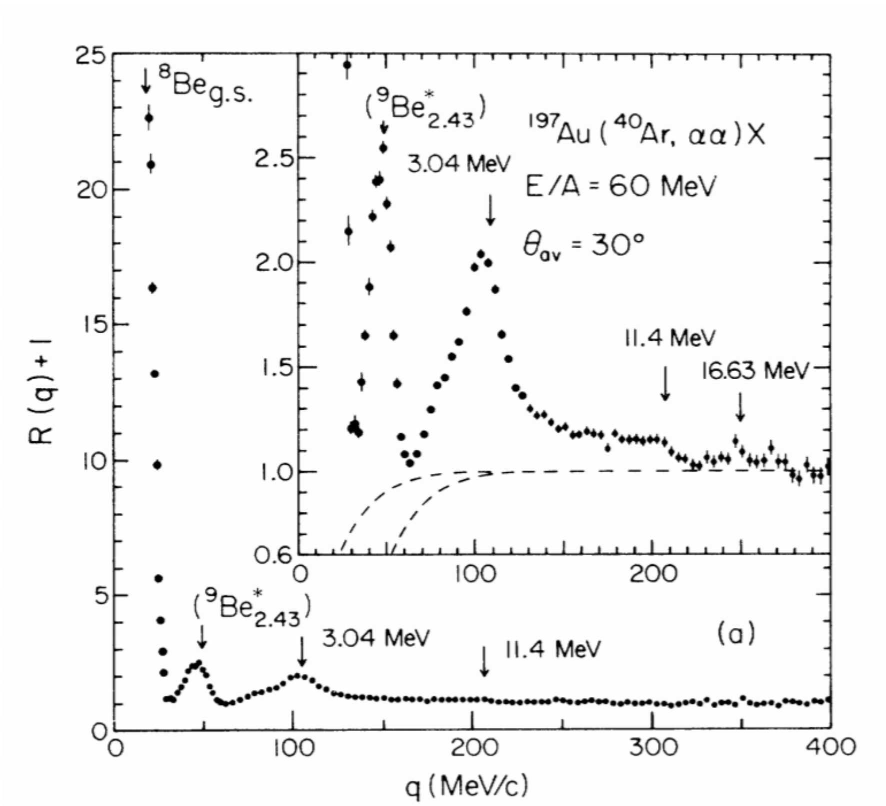

FIG. 1. Reprinted from Ref. [2]. Alpha-alpha correlation function from ^{40}Ar $+^{197}Au$. Illustrates the correlation between two alphas from different resonant states produced in the reaction. Shows correlation as a function of relative momentum in MeV/c.

yields

of correlated and uncorrelated particles' relative momenta are used (see Eq. 1)

$$1 + R(q) = N\left(\frac{Y(q)}{ucorr\,Y(q)}\right) \tag{1}$$

and is plotted as a function of the relative momentum, an example of which is listed as Fig. 1 and was reprinted from Ref. [2]. Particles from the same event are considered correlated while the uncorrelated yield is calculated through the use of a technique called "event mixing" where the relative momentum is calculated between two α particles detected in separate events [1-3]. $Y(q)$ and $ucorr\ Y(q)$ are the yields of the correlated and uncorrelated relative momenta and N is a normalization constant that requires $R(q)$=0 at large relative momenta because particles are expected to have little to no interaction when separated largely in space [1-4].

Fig.1 gives information about the fragments produced in the reaction that decay into alpha particles. The plot is dominated by the large peak around 25 MeV/c shows the emitting source of the two alphas to be the ground state of ^{8}Be. The decay of the 3.04 MeV and 11.4 MeV excited states of ^{8}Be can also be seen despite having very short lifetimes. Even an excited state of ^{9}Be can be determined to have emitted alphas in this system. The energy uncertainty, or width, for the peaks gives indications for the lifetime of those states as defined by Heisenberg uncertainty principle.

The experiment was performed using the Forward Array Using Silicon Technology (FAUST), which was used to detect particles emitted from the excited projectile-like fragments (PLF*) produced from the collision between the beam and target [1]. Due to the requirement of precise position detection for the calculation of correlation functions, the telescopes utilized dual-axis duo-lateral (DADL) Si detectors with a CsI(Tl) crystal coupled to a photodiode. This allowed for the determination of the angle at which the particle left the target and for the measurement of the particle energy. The current short term goal is to construct an alpha-alpha correlation function using the known energies and angles of the alpha particles emitted from the decay of excited projectile-like fragments produced by ^{40}Ar+^{58}Fe at 30 MeV/u. Using these values, the velocity vectors for the alpha particles are determined and used to calculate their relative momentum both for particles from the same event, and particles from different events. Calculating the uncorrelated relative momenta involves filling an array with 200 alpha particles and randomly selecting pairs. In order for the pair of particles to be used, they must pass certain restrictions including occurring in different events, having not been paired before, and having not hit the same detector. Once pairs have been made, the array is cleared and filled with the next 200 particles. The relative momentum is calculated according to Eq. 2

$$P_{rel} = \mu(\nu_1 - \nu_2) \tag{2}$$

where ν_1 and ν_2 are the velocity vectors of the alpha particles in m/s and μ is the reduced mass.

The relative momentum yields for both are shown below and labeled Fig. 2 and Fig. 3 respectively. The ratio of these two plots gives the correlation function plot shown below as Fig. 4, where the dominant 20 MeV/c peak referring to the ground state of ^{8}Be can be observed. The idea of this project is to generate correlation functions for many light charged particles in order to obtain information about the specific system. More work is being done to normalize the plot in Fig. 4 at high relative momenta, to investigate possible restrictions to be added to the event mixing process and to produce an alpha-alpha correlation function for the system at a different energy so that excited states can be observed.

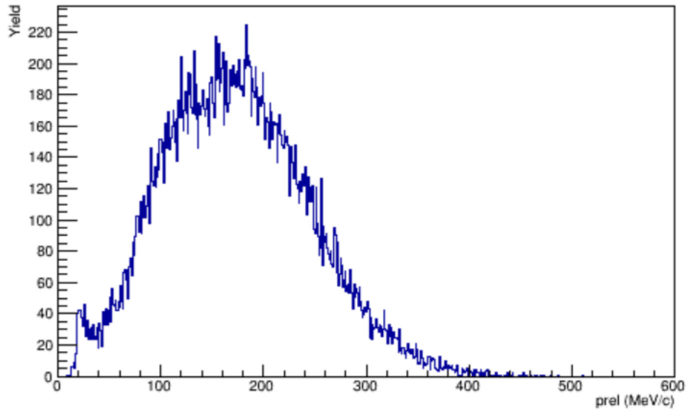

FIG. 2. Alpha-alpha correlated relative momentum. Shows the yield as a function of the relative momentum in MeV/c.

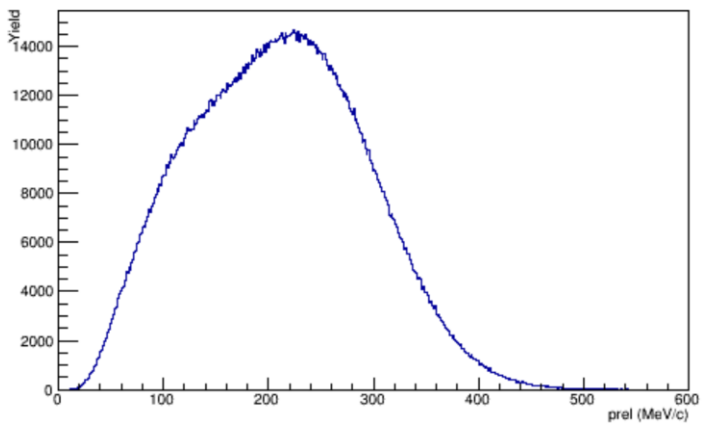

FIG. 3. Alpha-alpha uncorrelated relative momentum. Illustrates the yield of the calculated relative momentum between two alpha particles from separate events as a function of the relative momentum in MeV/c.

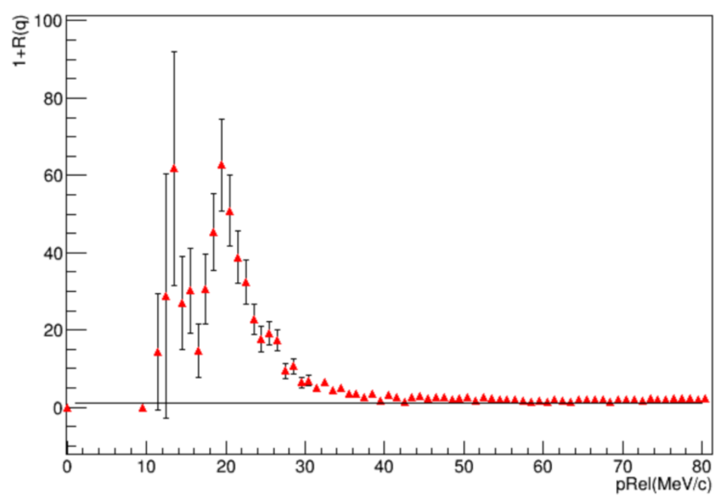

FIG. 2. Low relative momentum alpha-alpha correlation function. The strong peak at 20 MeV/c indicates the ^{8}Be ground state. The solid black line placed at 1+R(q) = 1 corresponds to no correlation.

[1] L. Heilborn, Ph.D. Thesis, Texas A&M University, 2018.
[2] J. Pochodzalla *et al.*, Phys. Rev. C **35**, 1695 (1987).
[3] G. Verde *et al.*, Eur. Phys. J. A **30**, 81 (2006).
[4] L. Heilborn *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2011-2012), p. II_36.