High energy neutron production and high momentum tail in intermediate heavy ion collisions

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Short range correlation (SRC) between two nucleons in a nucleus, especially np pair, has been intensively studied in the knockout reactions of (e,e'p), (e,e'np) and (p,pnp) on various targets at GeV incident energies [1-3]. In heavy ion collisions, the same SRC process may enhance the high energy nucleon emissions and as the result the production cross section show K-4 power dependence in the high momentum tail (HMT), where K=p/PF and PF is Fermi momentum [4].

In our previous report in 2021, the simulated results of AMD/D-FM [5] and AMD/D-3NC [6] for ^{12}C+^{12}C, ^{12}C+^{16}O at 290 MeV/nucleon are presented where the high energy neutron productions are rather well reproduced by AMD/D-3NC. This study is extended to the higher incident energy. For ^{12}C+^{12}C at 400 MeV/nucleon, the simulated results are compared with the experimental data [7] in Fig.1. On the left, the neutron energy spectra are compared at different measured angles. AMD/D-3NC results (red histograms) start to underpredict the experimental high energy neutron tails. On the right, the weighted cross section $K^4 d\sigma^2/dKd\Omega$ is plotted as a function of the relative momentum $\boldsymbol{K}$. The experimental data indeed show K^{-4} power dependence as a more or less constant distribution at the high momentum side.

An attempt is made to reproduce the experimental high momentum tail distribution with K^{-4}

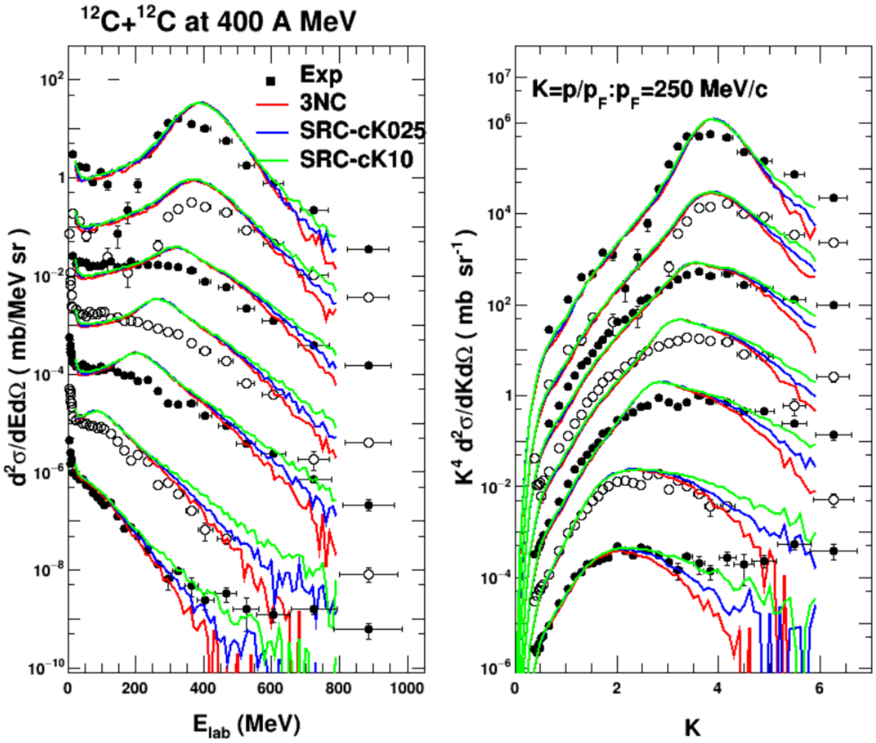

Fig. 1. AMD simulated results are compared with the experimental data from Ref.[7] at angles from 5o, 10o, 20o, 30o, 40o, 60o, 80o, from top to bottom. The red histograms are with AMD/D-3NC. Blue and green histograms are those with HMT in the Fermi distributions shown in Fig.2 with same color lines, respectively.

dependence with AMD/D-3NC. When Fermi boost is applied to the three nucleons in the 3NC process, HMT component is added to the original Gaussian distribution as shown below.

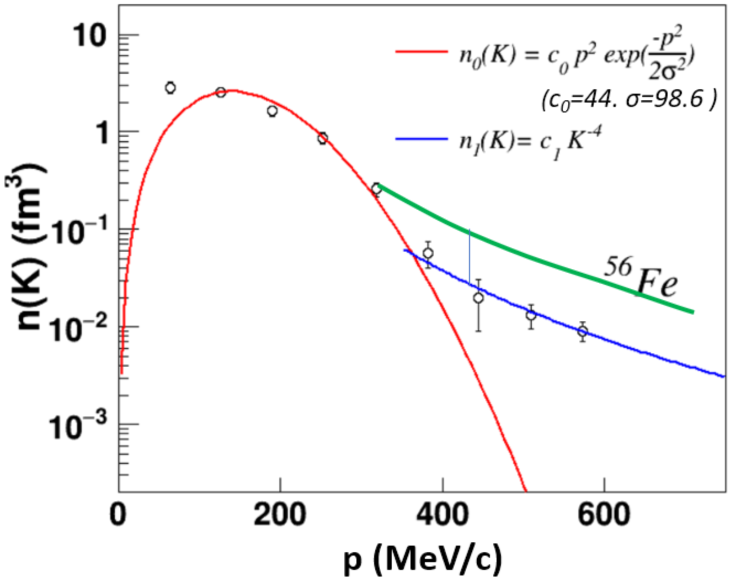

Fig. 2. Fermi momentum distribution incorporated with the Fermi boost. Circles are the experimental data from Ref.[9] and red curve corresponds to the Gaussian distribution, blue and green to the added HMTs with c1/c0=0.0057 and 0.023, respectively.

In the Fermi boost, the new momentum $\boldsymbol{P'}$ with a momentum fluctuation is given as

$$\boldsymbol{P'} = \boldsymbol{P} + \Delta\boldsymbol{P'},$$

$$\Delta\boldsymbol{P} = (h/2\pi)\sqrt{}\, v(\rho/\rho0)^{1/3}G(1) \qquad for\ \boldsymbol{p} < \boldsymbol{P}_K$$

$$= c_1\, (\boldsymbol{p}/\boldsymbol{P}_F)4 \qquad for\ \boldsymbol{p} \geq \boldsymbol{P}_K$$

$$\Delta\boldsymbol{P'} = \Delta\boldsymbol{P} - c_R\, \boldsymbol{P}_F$$

$G(1)$ is a random number generator along the Gaussian distribution with σ=1 and c_R is a reduction factor (c_R=0.3) as described earlier. c_0, c_1 are relative strength between the Gaussian and K^{-4} term shown in the figure. $\boldsymbol{P}_K$ is the crossing momentum between the two curves. When c1/c0=0.023 is used, the experimental HMTs are reasonably well reproduced.

At present the relation between SRC and HMT in heavy ion collisions is not clear. In Refs. [4,8], HMT in heavy ion reactions is attributed to SRC based on the resemblance of K^{-4} power dependence of the cross sections. However in the knockout reaction of np pairs by the GeV electron and proton beams, these pairs are at T~ 0 before they are knocked out and the HMT is reasonably attributed to SRC. On the other hand in the heavy ion collisions studied here, the high energy neutrons are dominantly produced from 3NC process at hot-high density nuclear matter at an early stage of the reactions. If the high temperature for the Fermi-liquid governs the Fermi distribution, HMT originates from the Pauli-blocking. If the high density governs the behavior, it may reflect SRC. Further studies are underway.

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