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Possible signatures of short range correlations in intermediate energy heavy ion collisions

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Summary. — Forward angle proton spectra from min-bias collisions in the reactions of various 47 MeV/u projectiles on Sn targets are analyzed. Energy Spectra transformed to momentum space in the projectile frame reveal a $1/k^4$ dependence indicating a possible signature that short range correlations are observed

Short range correlations (SRC) in nuclei are fluctuations that occur when nucleons form pairs with high relative momentum and small center of mass momentum for short periods of time. They are important in the investigation of large relative momentum and short distance properties of nuclear wave functions. They provide information on the domain of transition from baryonic to quark-gluon degrees of freedom revealing new phenomenon inherent to QDC dynamics that are not visible to long-range nuclear forces as well as the practically unexplored dynamics of the nuclear repulsive core [1]. Theoretical studies suggest that information regarding neutron star masses can be obtained when SRC are included in nucleon interactions in dark matter calculations [2] suggesting the intriguing possibility to obtain information on neutron star masses from experiments in the lab.

SRC have typically been studied at high energies [3,4] using proton knockout reactions at 6-9 GeV/c p + ^{12}C [3] and high energy (5.014 GeV) beams of electrons incident on ^{12}C, ^{27}Al, ^{56}Fe, ^{208}Pb targets. Investigations at lower energies have to date been mostly theory investigations. Calculations at intermediate energies [5] was a theoretical study of the interplay of SRC and symmetry energy. These calculations indicate that with the inclusion of high momentum tails (HMT) in the calculation that the effects of SRC overwhelm those of symmetry energy. Another theoretical study [6] involves comparisons to photon spectra produced in the reactions of ^{14}N + ^{12}C at 20, 30 and 40 MeV/u [7] that were described by a thermal bremsstrahlung model in that work. Incorporating HMTs into the formalism of these calculations allowed to describe the photon spectra and angular distributions of the earlier work [7].

Motivated by the suggestions of these calculations and the effects HMTs show on photon observables for intermediate energy heavy ions we began an investigation to ascertain whether charged particles may show signatures of SRC. To that end we analyzed forward angle proton spectra from min bias collisions of 47 MeV/u ^{4}He, ^{10}B, ^{20}Ne, ^{40}Ar, ^{64}Zn on Sn targets as well as forward angle spectra from ^{40}Zn on Ti, Mo and Au targets

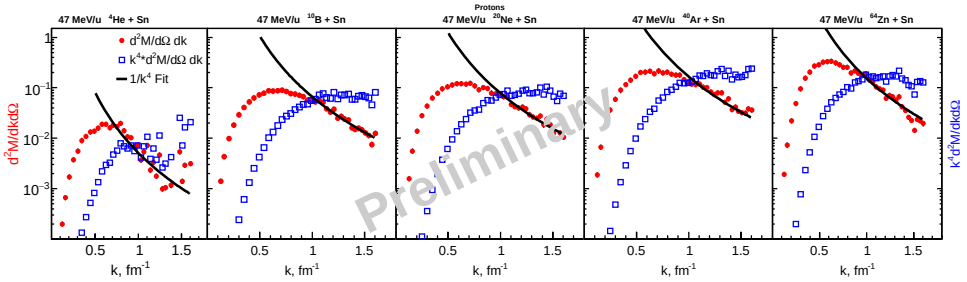

Fig. 1. – Wavenumber spectra in the projectile frame for the 47 MeV/u beams

at 26, 35 and 47 MeV/u. Such an analysis may shed light on whether charged particles which suffer final state interactions carry information on SRCs at these energies that are significantly lower than the heretofore reported experiments on charged particles at higher energies.

1. – Experimental procedures

The experiment was performed at Texas A & M University Cyclotron Institute using beams 47 MeV/u beams of ^{4}He, ^{10}B, ^{20}Ne, ^{40}Ar, as well as 26, 35 and 47 MeV/u ^{64}Zn beams produced by the K500 superconducting cyclotron at the Cyclotron Institute at Texas A & M University. The reaction products for the study reported here were measured using ring 2 of the 4π array, NIMROD (Neutron Ion Multidetector for Reaction Oriented Dynamics) [8]. Protons were identified using pulse shape analysis of signals from the CsI detectors in NIMROD. The measured proton energy spectra collected from reactions of the above mentioned beams on Ti, Mo, Sn and Au targets were transformed to momentum space in the frame of the projectile.

2. – Results and discussion

The solid points in fig. 1 show the differential multiplicity proton spectra transformed into momentum space and then wave number in the frame of the projectile for 47 MeV/u ^{4}He, ^{10}B, ^{20}Ne, ^{40}Ar and ^{64}Zn projectiles, respectively, incident on Sn. We note wavenumbers that reach 1.5 fm^{-1} which is the point in momentum space of the highest energy protons measured. The solid line shows a fit of $1/k^4$ to the wavenumber spectra. We note a good fit for wavenumber above 1 fm^{-1}. To observe this more visually, we transform the wavenumber spectra (solid points) in fig. 1 to $k^4d^2M/d\Omega dk$ which would lead to a flat line in the case of a $1/k^4$ dependence. The open squares in fig. 1 show this transformation. It is easy to observe the flattening of the spectra above 1 fm^{-1}, consistent with the fit to the $1/k^4$ function. This $1/k^4$ dependence extends for the light ^{4}He projectiles to the much heavier ^{64}Zn projectiles.

Figure 2 shows proton the same type of data as fig. 1, but ^{64}Zn projectiles at 26, 35 and 47 MeV/u on Ni, Mo and Au targets. We note for the 47 MeV/u systems that the spectra deviate from $1/k^4$ for the more symmetric systems, ie Zn + Ni as well as Zn + Mo to a lesser extent whereas the Zn + Au system shows a much closer dependence to $1/k^4$ at the largest wavenumbers. As the energy is decreased, the high momentum part of the spectrum deviates more and more from a $1/k^4$ dependence.

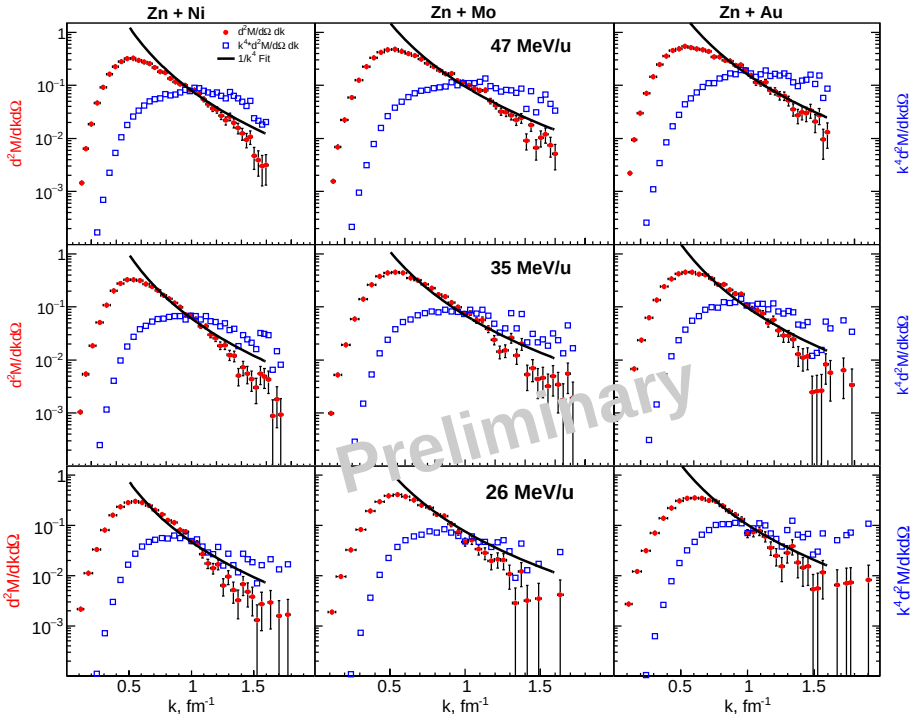

Fig. 2. – Wavenumber spectra in the projectile frame for the ^{64}Zn beams at the various energies indicated in the legends

In summary, we have observed possible signatures of SRC by observing a $1/k^4$ dependence of forward angle proton spectra for 47 MeV/u projectiles. The $1/k^4$ dependence appears to be more signficant for more asymmetric systems. In addition we observed a dependence on energy as well as the asymmetry of the reacting system when studying Zn projectiles at 26, 35 and 47 MeV/u on different targets.

We plan to extend this study by mounting an experiment where we can search for SRC n-p or p-p pairs and to study their characteristics.

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