Coalescence Studies of the Participant Region in Heavy Ion Collisions at Intermediate Energy

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Recently, we applied a coalescence model analysis to intermediate energy heavy ion collisions to explore the early particle emission which carries essential information on the early collision dynamics and on the degree of equilibration at different reaction stages [1, 2]. We are presently focusing on the emission of mid-rapidity particles to explore properties of the participant zone as a function of impact parameter.

Recently, a large number of experiments have been performed at TAMU with the NIMROD multidetector. In this work, we focus on the lightest system reactions, namely, ^{40}Ar + ^{27}Al, ^{48}Ti and ^{58}Ni at 47 MeV/nucleon.

Five impact parameter bins were sorted using the total multiplicity of charged particles and neutrons. In each impact parameter, the kinetic energy spectra of light particles (p, d, t, ^{3}He, α, Li) were reproduced by three source fits (Target-like component, Nucleon-nucleon component and Projectile-like component). The Nucleon-nucleon component is dominated by the early dynamical emission and it can be analyzed with the coalescence model. The coalescence model assumes that the composite particles are composed from the neutrons and protons via final-state interaction. In this picture, produced neutrons and protons can merge to form light clusters if they are in the same momentum phase space during the kinetic freeze-out. In the low-intermediate energy range, the Coulomb corrected Coalescence model [1] is expressed by

$$d^2N(Z,N,E_A)/dE_A d\Omega = R^N{}_{np}/A/N!/Z!$$
$$\times [(4/3)\pi P^3{}_0/[2m^3(E\text{-}Ec)]^{1/2}]^{(A-1)}$$
$$\times [d^2N(1,0,E)/dEd\Omega]^A$$

where the double differential multiplicity for a cluster of mass number A containing Z protons and N neutrons and having a Coulomb-corrected energy E_A, is related to the proton double differential multiplicity at the same Coulomb-corrected energy per nucleon E - E_c, where E_c is the Coulomb barrier for proton emission and R_{np} is the free neutron to proton ratio in the participant region, which can be replaced by the triton to ^{3}He ratio [2]. From the laboratory frame differential multiplicities, the coalescence radius in momentum space, P_0 , can be extracted. Then the coalescence radius R of coordinate space can be deduced from Mekjian's thermal model [3].

Fig. 1 shows the preliminary results for Mekjian Model radii R extracted from spectra of alpha versus the surface velocity (V_{surf}) at $\theta_{lab} \sim 60°$ where both PLF and TLF components are very low in comparison with the NN component. Cleanly, the radius at larger surface velocity decreases with the impact parameter, from ~6 fm at the most central collisions to ~3 fm at the most peripheral collisions. This evolution appears basically indicative of the geometry of the participant zone of the collision partners. On the other hand, the radius evolves with surface velocity. From QMD simulations, we know that the surface velocity is related to the reaction time: the larger the surface velocity, the earlier the emission time. In this context, the evolution of radius with V_{surf} can be explained as the later stage expansion as V_{surf} becomes smaller.

Similar behaviors have been observed for the radii extracted from spectra of deuterons, tritons, ^{3}He and Li. In addition, the same conclusion was drawn for reactions with ^{48}Ti and ^{27}Al targets. Detailed analysis is still underway.

In summary, the coalescence model was applied to 47 MeV/nucleon ^{40}Ar + ^{27}Al, ^{48}Ti and ^{58}Ni data. The coalescence radii in both momentum and coordinate spaces are extracted. The coordinate space radius shows an increase with decreasing impact parameter.

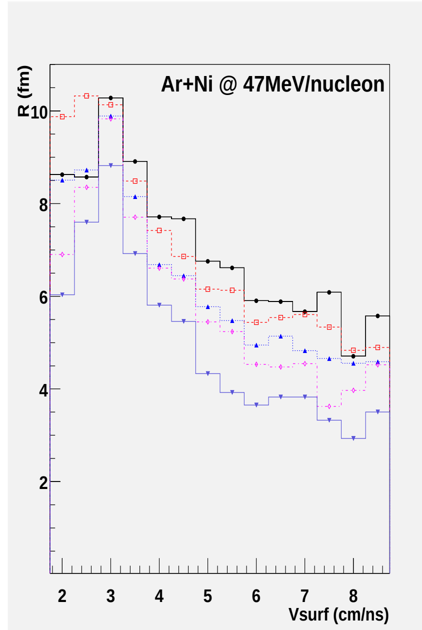

Figure 1: The Mekjian thermal model radii for 47MeV/nucleon Ar+Ni at $\theta_{lab} \sim 60°$ vs the surface velocity. The circles, squares, triangles, diamonds and downtriangles represent different collision centrality from the most central to the most peripheral collision.

References

[1] T. C. Awes *et al.*, Phys. Rev. C **24**, 89 (1981).

[2] K. Hagel *et al.*, Phys. Rev. C **62**, 034607 (2000).

[3] A. Z. Mekjian *et al.*, Phys. Rev. C **17**, 1051 (1978); Phys. Rev. Lett. **38**, 640 (1977).