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Review article

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Variation of the Source Velocity in Collisions of 2.1 GEV Protons with Gold Target

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ABSTRACT

The invariant cross-sections of fragments from lithium to oxygen in terms of longitudinal versus transversal velocity components are investigated for p + Au collisions at 2.1 GeV which allowed the source velocity to be measured in each case. It was found that fragments are emitted by one slowly moving source and source velocity of target spectator decreasing with increasing fragment charge.

Introduction

The main decay mode of very excited nuclei (E* ≥ 4 MeV/nucleon) is copious emission of intermediate mass fragments (IMF), which are heavier than α-particles but lighter than fission fragments. An effective way to produce hot nuclei is reactions induced by heavy ions with energies up to hundreds of MeV per nucleon. But in this case the heating of the nuclei may be accompanied by compression, rotation, and shape distortion, which can essentially influence the decay properties of hot nuclei. The picture becomes clearer when light relativistic projectiles are used. In this case, fragments are emitted by only one source – the slowly moving target spectator. Its excitation energy is almost entirely thermal. Light relativistic projectiles provide therefore a unique possibility for investigating thermal multifragmentation.

In the present paper the source characteristics of multifragmentation are investigated for the p + Au collisions at 2.1 GeV.

Results of Measurements

Beam of 2.1 GeV protons were obtained from the Dubna superconducting accelerator NUCLOTRON. Intermediate-mass fragments spectra from target spectator were measured with the 4π setup FASA, which contains thirty ΔE–E telescopes and 58 CsI (Tl) detectors, covering 81% of 4π. The experimental details are described in the [1,2].

In order to interpret multifragmentation observables, it is essential to understand the degree of equilibration involved in the disassembly process. One way of evaluating the degree of equilibration in a reaction, as well as determining the average source velocity, is through a longitudinal versus transversal velocity components analysis. Figure 1 shows the longitudinal versus transverse velocity plots ($\beta_\perp$ vs $\beta_\parallel$) along points of constant invariant cross section $(1/p)d^2\sigma/dEd\Omega$ for fragments from lithium to oxygen with energy E and momentum p obtained in solid angle Ω with cross section σ. The symbols in the figures indicate the projections of the velocities of fragments obtained in different telescopes. The points corresponding to one telescope lie on the same line passing through zero values $\beta_\perp$ and $\beta_\parallel$ sins they have

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the same laboratory angle. The lines in Figure 1 are the result of fitting the experimental data for a constant value of invariant cross section in the in the ($\beta_\perp$ vs $\beta_\parallel$) plane with circles, for which the source velocity (positions of the circle centers) and the fragments velocity (circle radius) were free parameters.

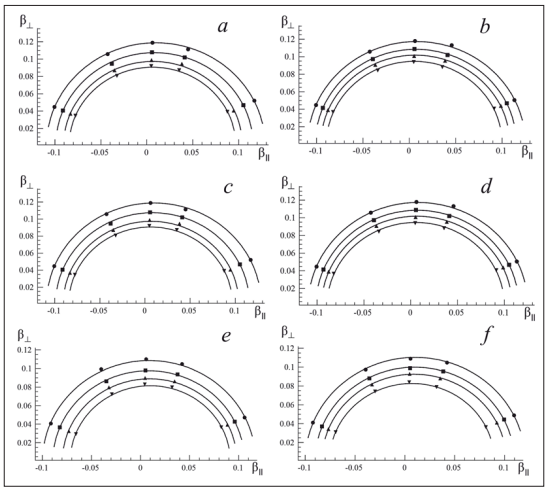

Figure 1: Longitudinal ($\beta_\parallel$) versus transverse ($\beta_\perp$) velocity plot along points of constant invariant cross section $(1/p)d^2\sigma/dEd\Omega$, for fragments produced in the p(2.1 GeV) + Au reaction. Points – experimental data. Circles are drawn through points of equal invariant cross section corresponding to isotropic emission of the fragments in the moving source frame. a – Lithium, b – Beryllium, c – Boron, d – Carbon, e – Nitrogen, f – Oxygen

For an isotropically emitting source, the points of invariant cross section should fall on a locus centered at the laboratory velocity of the source. To a good approximation, the data for a given invariant cross section are isotropic; i.e., they can be described by a circle with fixed locus, corresponding to a single average source velocity. This suggests that the system is at least in "kinetic equilibrium" prior to fragment emission. The source velocities as a function of fragment charges are shown at Figure 2. It can be seen that the source velocity decreases with increasing fragment charge.

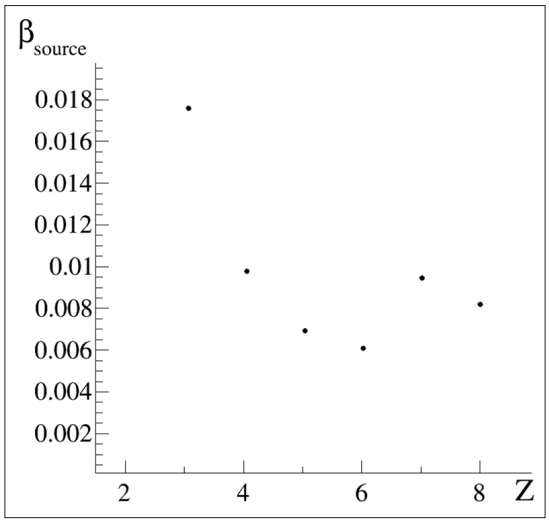

Figure 2: The source velocities (β_{source})of target spectator in units of the speed of light as a function of fragment charge Z

Conclusions

The p + Au system have been studied for bombarding energies 2.1 GeV using the 4π FASA detector on Dubna superconducting accelerator NUCLOTRON.

Evidence that at least "kinetic equilibrium" of the system is achieved before fragmentation take place is found in the results of longitudinal versus transversal velocity components analyses. Data in p(2.1 GeV) + Au reaction can be described by one source with fixed velocity, and source velocity decreasing with increasing fragment charge.

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