PROTON EMISSION TIMES IN SPECTATOR FRAGMENTATION

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Proton-proton correlations from spectator decays following ^{197}Au+^{197}Au collisions at 1000 AMeV have been measured with an highly efficient detector hodoscope. The constructed correlation functions indicate a moderate expansion and low breakup densities similar to assumptions made in statistical multifragmentation models. In agreement with a volume breakup rather short time scales were deduced employing directional cuts in proton-proton correlations.

1 Introduction

Densities lower than ground state density of nuclei are a prerequisite of statistical models describing multifragmentation [1,2]. While static statistical models assume fragment formation in an expanded volume breakup, the dynamic statistical model[3,4] combines surface emission during expansion with volume breakup of the remaining source. Interferometry-type methods are widely considered as valuable tools in determining the space-time extent of such sources and, recently, spectator remnants of the reaction Au + Au at 1 AGeV incident energy were found to break up at densities considerably lower than ground state density [5]. In that analysis a instantaneous volume breakup was assumed.

In this article we report on results of a directional analysis of the measured proton-proton correlations of protons from the target spectator following the collisions of Au + Au at 1 AGeV incident energy. The results are found to be consistent with low breakup densities with values close to those assumed in the statistical multifragmentation models and short emission time differences with values close to those anticipated for volume breakup.

2 Experiment

Targets, consisting of 25 mg/cm^2 of ^{197}Au were irradiated by an 1 AGeV Au beam delivered by the Schwerionen-Synchrotron (SIS) at GSI in Darmstadt. For the results presented here, we employed one multi-detector hodoscope, consisting of a total of 96 Si-CsI(Tl) telescopes in closely packed geometry. The hodoscope covered an angular range Θ_{lab} from 122^0 to 156^0 with the aim of selectively detecting the products of the target-spectator decay. Each telescope consisted of a 300 μm Si detector with 30 x 30 mm^2 active area, followed by a 6 cm long CsI(Tl) scintillator with photodiode readout. The distance to the target was 60 cm. The products of the projectile decay were measured with the time-of-flight wall of the ALADIN spectrometer [6] and the quantity Z_{BOUND} was determined event-by-event. Z_{BOUND} is defined as the sum of the atomic numbers Z_i of all fragments with $Z_i \geq 2$. It reflects the variation of the charge of the primary spectator system and serves as a measure of the impact parameter.

3 Data analysis

The correlation functions were constructed dividing the spectrum of relative momenta of two coincident particles by the spectrum of pairs from different events. At a relative momentum of $q \approx 20$ MeV/c, one observes a maximum of the correlation function the height of which is inversely related to the diameter of the source for simultaneous emission [7,8]. Directional cuts on the angle between sum momentum and relative momentum allow the determination of the spatial and temporal separation of the two protons at emission[7,9]. Instead of using sharp cuts on the angle between sum momentum and relative momentum we employed harmonic weights (sin^2 and cos^2) for the generation of transversal and longitudinal correlation functions[10]. The analysis of the

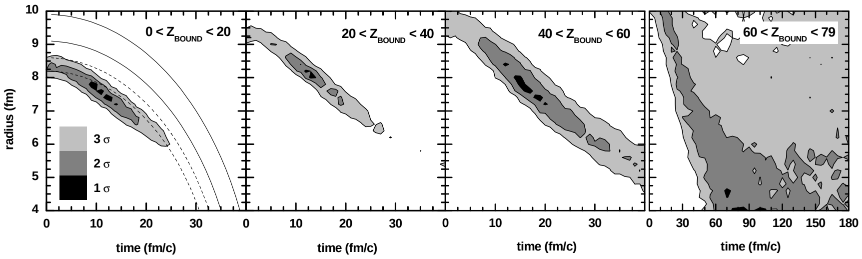

Figure 1. χ^2 distributions as a function of radius and emission time of the emitting source for four impact parameter ranges indicated by the Z_{BOUND} ranges in the panels. The lines in the left panel are explained in the text.

p-p correlation functions was performed with the Koonin-Pratt formalism [7,8]. Particles were chosen to be randomly emitted from the volume of an uniform sphere and their velocities were sampled according to a Maxwell-Boltzmann distribution. An additional velocity component was added in order to simulate the Coulomb repulsion corresponding to the location of the particle within the source. An experimentally observed anisotropy in the proton-energy spectra was modeled by assuming a sideward movement (bounce) of the source perpendicular to the beam. This causes a reaction plane which was included in the Monte-Carlo calculations.

4 Results and Discussions

We varied the radius of an uniform density distribution and the Gaussian emission time of the protons. The simulated correlation functions were used to perform a χ^2-test in the region of relative momentum region $10 \leq q \leq 35$ MeV/c. The results are presented in Fig. 1, where the shadings denote the deviation from the data. The minima of χ^2 yield approximately constant source radii of ≈ 8 fm and short emission times of $\approx 10 - 15$ fm/c. For the most peripheral bin a radius and emission time could not be deduced due to the low statistics of the correlation function. The experimental correlation functions (symbols) and the simulations (lines) for the parameters corresponding to the minimum of χ^2 are shown in Fig. 2, left panel. They agree well

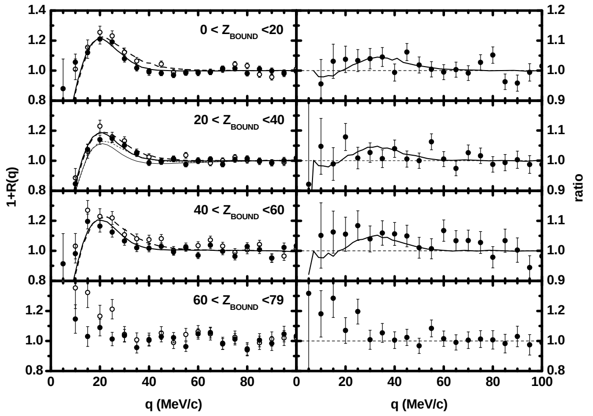

Figure 2. The left panel shows experimental longitudinal (open symbols) and transversal (closed symbols) correlation functions and results of MC-simulations (lines). The right panel compares the their experimental ratios (symbols) with the results of the MC-simulation (lines).

with each other. The minimum χ^2 values per degree of freedom are within the range of $1.3 \leq \chi^2/d.o.f. \leq 2.4$. The right panel in Fig. 2 presents the ratios between longitudinal and transversal correlation functions. One recognizes the weak enhancement of about 5% above unity (dashed line) of data (symbols) and simulations (solid line) for relative momenta $q < 50$ MeV/c. For a source size of ≈ 8 fm the quantum suppression is expected at $q = \sqrt{\mathbf{q}^2} < \sqrt{3} * \hbar/r \approx 40$ MeV/c.

5 Conclusions

We constructed correlation functions for pairs of protons detected at backward angles in the reaction Au+Au at 1000 AMeV incident beam energy. Using high energy cuts of $E > 20$ MeV we selected protons which are only little affected by sequential feeding [11]. Comparing the results with Monte-Carlo simulations within the Koonin-Pratt formalism fairly constant freeze-out radii of $R \approx 8$ fm are deduced and emission times of $\tau = 10 - 15$ fm/c are surprisingly short of the order of the passing time of the projectile through the target. The extracted radii are larger than the ground state radii of target spectators and show expansion. Because of the short emission times in the order of the passing time of both spectators we cannot exclude that the protons come from first stage scattering of the nuclear cascade.

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