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FRAGMENTATION IN ^{16}O – AgBr INTERACTIONS AT 60 GeV/N, EVAPORATION MODEL REVISITED

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We present new data on the target fragment model in ^{16}O – AgBr interactions at 60 GeV/n. The data do not favour the evaporation model; instead, they indicate a preferential backward emission of black tracks.

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1. Introduction

The relativistic heavy-ion collisions allow the study of the extended state of matter under extremes of density of energy, matter and temperature which occured in the hot stage of the early Universe and in certain astrophysical situations of strong gravitational collapse. In particular, such collisions can possibly create regions of deconfined matter so highly energetic that the normal forces that confine quarks and gluons in a hadron are overcome and the matter in the interaction region takes the form of an extended quark-gluon plasma [1]. There have been considerable speculations on the types of exotic matter which may be formed in central relativistic heavy-ion collisions. At high barion density, the conjectures are pion condensation, Lee-Wick nuclear matter, delta isomer and quark matter, while at still higher temperatures, one might encouter a temperature limit.

Using the relativistic heavy-ion collisions, we want to reach very high temperature over a domain many times larger than the size of a single hadron. Quantum chromodynamics (QCD) suggests that the colour confinement prevails under normal circumstances, but at sufficiently high density and/or temperature, deconfinement should occur, leading to a new phase of matter, the quark-gluon plasma.

If a thermalized quark-gluon plasma is formed during the collision, it will rapidly destroy itself through instabilities, expansion and cooling. One should search for specific signals which could be associated with the transient presence of the plasma. The key point is a deciding fluctuation of some parameters on an event-to-event basis.

Recently, much work on nuclear fragmentation in collisions of ions at relativistic energies has been reported. Since the true dynamics of low-energy particles evaporated from the target is not known, the study of "black tracks" still remains interesting. Most articles have concentrated on the collective flow of particles from the target and they are the richest source of information on nuclear reactions and reaction dynamics [1–9]. In the present work, black tracks are in fact identified as target evaporation particles in a model referred to as the "evaporation model" [10]. According to this model, the particles corresponding to the "shower" and "grey" tracks leave the hot residual nucleus and are emitted from the nucleus immediately after the instant of impact. The emisisom of particles is relatively slow. In order to escape from the residual nucleus, a particle must await a favourable statistical fluctuation which is a result of random collisions among nucleons within the nucleus which takes the particle close to the nuclear boundary, travelling in the outward direction. After the evaporation of a particle, another particle comes to a favourable condition for evaporation, etc., until the excitation energy of the residual nucleus is reduced to values that emission of γ-rays to the ground state prevails. In the rest system of the nucleus, the emission of evaporation particles is isotropic. A description of the process is the evaporation model which is based on the assumption that a statistical equilibrium is established in the decaying system, and that the lifetime of the system is much longer than the time needed for a distribution of energy among the nucleons within the nucleus. The evaporation model has not been generally accepted. Barkas [11] suggested a different mechanism to explain the emission of heavy fragments from highly excited nuclei. The emission of slow target-associated particles indicates the existence non-equilibrium states, as supported by many experimental data, while measurements od Dalkhazheaev et al. indicate non-equilibrium processes in the energy spectrum of slow particles in interactions of 70A GeV protons and 9.4A GeV deuterons with different nuclei in the emulsions. By analyzing the experimental data from proton-emulsion experiment at incident energy from 76 to 400 GeV, Takibaev and Adamovich [13] observed the dominance of non-statistical fluctuations over the statistical of angular distribution of "black" particles. In this work, we present new data on black tracks produced in ^{16}O – AgBr interactions at 60 GeV/n. The data do not favour the evaporation model.

2. *Experimental method*

At CERN SPS, a stack of G5 emulsion plates was irradiated by a ^{16}O beam of 60 GeV per nucleon [14]. A Leitz Metalloplan microscope with a 10× objective and 10× occular lens, provided with a semiautomatic scanning stage, was used to scan the plates. The scanning was done independently by at least two persons with the aim to increase the efficiency to 98%. The criteria for the selection of events were:

i) The particle track may not exceed more than 3° from the main beam direction in the pellicle.

ii) Events showing interactions within 20 μm from the top or bottom surface of the pellicle were rejected.

iii) The tracks of incident particles which induced a reaction were followed in the backward direction to ensure that the selected events did not include interactions by secondary particles from a previous interaction.

All tracks were classified in the standard way, i.e.:

i) The target fragments with ionization density $I > 1.4I_0$, where I_0 is the ionization plateau, were divided into "black" and "gray" tracks. The black tracks with a range < 3 mm are due to singly or multiply charged light nuclei evaporated from the target nucleus with a velocity $\beta < 0.3$.

ii) The gray tracks with a range ≥ 3 mm and having velocities $0.7 \geq \beta \geq 0.3$ mm are mainly tracks of fast target recoil protons in the energy range up to 400 MeV.

iii) The relativistic shower tracks with ionization density $< 1.4I_0$ were mainly produced by pions and generally are not confined within the emulsion pellicle. They are believed to carry important information about nuclear reaction dynamics.

iv) The projectile fragments wich are a different class of tracks, with constant ionization, long range and small emission angle.

To ensure the targets in the emulsion to be Ag and Br nuclei, we have chosen only the events with at least eight heavily-ionizing tracks. The heavily-ionizing particles of types (i) and (ii) are due to the target fragmentation, and those of type (iv) to the projectile nucleus. Particles of type (iii) are produced in the final state of the interaction.

Following the above selection procedure, we have chosen 250 events of ^{16}O–AgBr interactions at the quoted energy of 60A GeV. The spacial angle of emission (θ) in the laboratory frame of all black tracks was measured by taking the space coordinates (X, Y, Z) of a point on the track, a point on the track of the incident beam and a point at the production (collision) site. The microscope was used with the oil immersion objective 100× and a 10× occular lens. The azimuthal angles of all black tracks were also calculated from the measured coordinates.

3. Results and discussion

The data from the ^{16}O–AgBr interactions at 60 GeV/n have been presented in the two-dimensional cos $-\phi$ plot shown in Fig. 1. The scale was properly shifted to improve the figure.

The following conclusions can be drawn from the data:

1) The data indicate an overall azimuthal symmetry.

2) The plot indicates a clustering of target fragments in an angular emission zone of 180°.

3) The azimuthal angle of those particles decreases in the entire region of ϕ.

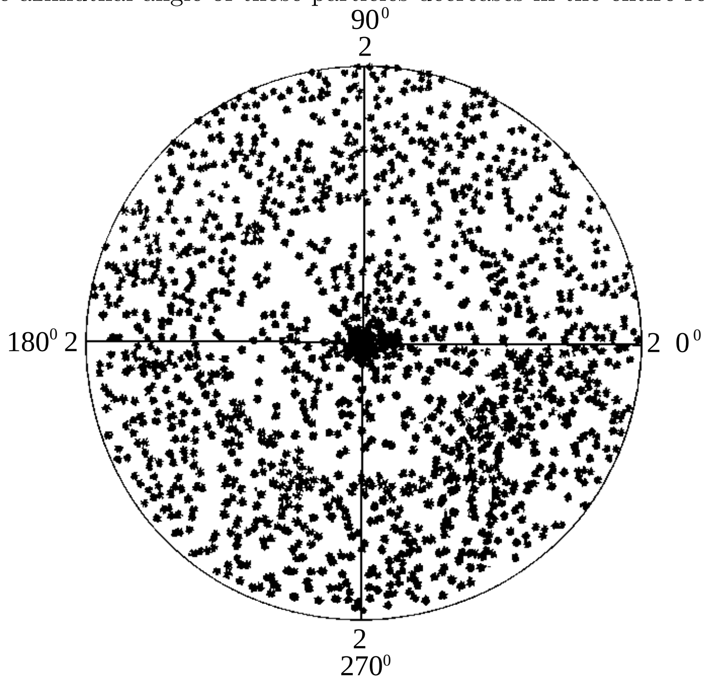

Fig. 1. $(1-\cos\theta)-\phi$ *plot of emission angles* $(0 \leq (1-\cos\theta) \leq 2$ *and* ϕ $0°$ *to* $360°)$ *of target fragments from* ^{16}AgBr *interactions at 60A* GeV.

These results are interesting because they do not favour the evaporation model which predicts an isotropic angular distribution. Further, the data indicate a preferential emission of target fragments in the backward direction. The angular distribution of target fragments produced in ultra-high-energy nuclear collisions can possibly throw some light on the emission mechanism of the target fragments.

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ODLAMANJE U SUDARIMA ^{16}O – AgBr NA 60 GeV/n, NAPOMENE O MODELU ISPARAVANJA

Predstavljamo nove podatke o modelu odlamanja u sudarima ^{16}O – AgBr pri 60 GeV/n. Ti podaci nisu u skladu s modelom isparavanja; umjesto toga nalazi se pretežno izbacivanje unatrag čestica koje daju "crne" tragove.