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Emission Feature of the Heavily Ionized Charged Particles Released from the Interaction of ^{84}Kr + Em at 1 A GeV

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Abstract
Since the quark–gluon plasma prediction and the discovery of nuclear matter properties, such as quarks, gluon, and nuclear matter density, which are crucial in comprehending a cardinal equation in nuclear and sub-nuclear physics, as a new phase of matter, the nucleus–nucleus (A–A) and Hadrian–nucleus (H–A) interactions have attracted more interest from physicists worldwide. A fascinating component of heavy-ion collisions is the alteration of the response characteristics with the collision shape. The collision of two nuclei with relativistic energy is well explained by the participant spectator (PS) model, according to which, two interacting nuclei can be divided into three distinct regions. The overlapping portion is called the participant region (PR), from which shower particles are released. The remaining portions of the projectile and target, which do not interact with one another, are called the projectile spectator region (pCR) and the target spectator region (TSR). The TSR is where the black and gray particles are spewing. Heavily ionized charged particles are the total of all the black and gray particles. In this article, we discuss the correlation between the shower and the highly ionized charge particles created when ^{84}Kr interacted with an emulsion containing nucleons with 1 GeV per nucleon.

Keywords Relativistic heavy-ion collision · Emulsion technology · Target fragmentation

Introduction

Scientists have been very interested in relativistic nucleus–nucleus (A–A) and hadrian–nucleus (H–A) collisions in the decade since the quark–gluon plasma phase of matter was predicted.[1–6] The various nuclear physics concepts have been extrapolated through the investigation of heavy-ion collisions with relativistic energy. Nuclear fragmentation, which provides information on the equation of state, emission mechanics, and phase transition of nuclear matter, is one of the most important outcomes of heavy-ion collisions. The interaction between two interacting nuclei is explained by the participant spectator (PS) model.[7–9] The PR, target spectator region (TSR) and projectile spectator region (PCR) are three separate areas that can be created as a result of the collision of two nuclei in this model, as shown in Fig. 1. The fireball region is another name for the PR. Shower particles are the particles that are emitted from this area.

Target fragments are the particles that are released from the TSR. The velocity of the fragments emitted by TSR in the laboratory frame is almost zero. The region of the TSR closest to the PR is responsible for creating gray particles, also known as fast target fragments, whereas the region of the TSR furthest from the PR is primarily responsible for producing the slowest target fragments, also known as black fragments. Heavily ionized charged particles are the collective term for the black and gray particles. Projectile fragments are the particles that are released from the PCR, which is the second region, and these PCR-released fragments move almost as quickly as a projectile beam.[8,9]

In this work, the correlation between the heavily charged particles released from the TSR and the shower particles released from the PR following the interaction of ^{84}Kr with an emulsion at 1 GeV per nucleon has received the majority of our focus.

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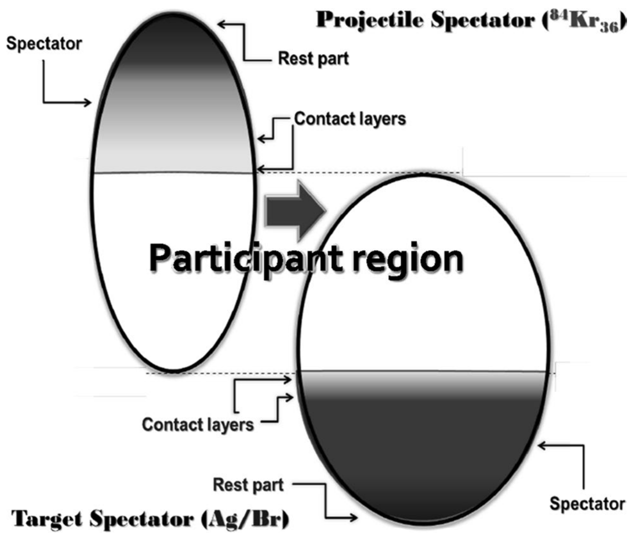

Fig. 1 Schematic of two (projectile and target) colliding nuclei to explain the concept of the PS model.

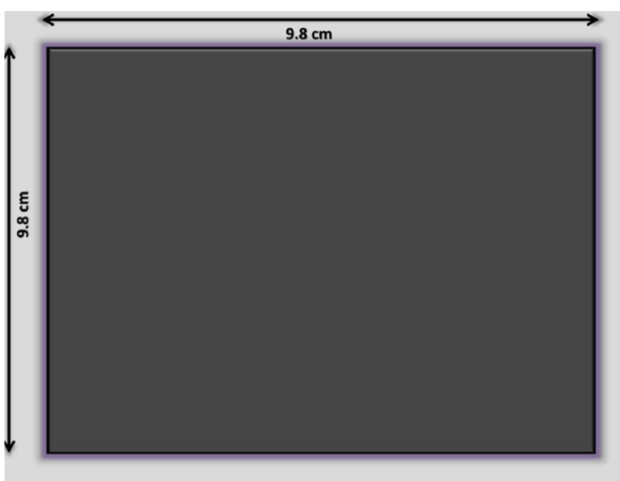

Fig. 2 Schematic of the nuclear emulsion plate.

Experimental

The present analysis utilized the nuclear emulsion detector (NED), which was created at GSM in Darmstadt, Germany.[9,10] NED is a composite target detector containing a combination of Ag, Br, O, N, C, and H, with very small amounts of I and S. Figure 2 shows a schematic of the NED plate's dimensions of 9.8 × 9.8 × 0.06 cm^3.[10] ^{84}Kr, which has 1 GeV per nucleon, was used as a projectile during the development of NED. The recovered ^{84}Kr beam at that energy had a composition of 95–98% ^{84}Kr and no more than 5–2% impurities, indicating that the beam was extremely clean.[10]

The particle tracks in the NED are magnified and measured using a high-power transmitted-light optical binocular microscope. The NED is scanned to find physics events using an Olympus BH-2 binocular microscope with a ×100 oil immersion objective and ×15 eyepieces.[3,7] Events are gathered using the two most popular scanning methods from the NED plate: line scanning and volume scanning. The latter method uses a strip-by-strip search, whereas the former employs a track-by-track search all the way to the last point of the encounter.[9,10]

Using characteristics like the relativistic range (L), normalized grain density (g^*), and relative velocity (β), we divided the events into different groups.[5,9]

Gray Particles

Gray particles, denoted by N_g , come from the TSR and have the properties of $0.7 < \beta > 0.3$, $L > 3$ mm and $6.0 > g^* > 1.4$.

Black Particles

Black particles, denoted by N_b , come from the TSR and have the properties of $\beta < 0.3$, $L < 3$ mm and $g^* > 6.0$.

Heavily Ionized Charged Particles

The term N_h refers to highly ionized charged particles, which are sum of the black and gray particles.

Shower Particles

Shower particles, also known as freshly formed particles, are created in the PR of two interacting nuclei and are denoted by the symbol N_s, with $g^* < 1.4$, $\beta > 0.7$.

Results and Discussion

Two separate mechanisms can create the hadrons released in A–A collisions at a relativistic energy.[11] Once the projectile departs the area of overlap between the target and the projectile, they only participate in the primary reaction. These kinds of hadrons are viewed as shower particles in an emulsion. The second possibility is that they contribute to rescattering by releasing more nucleons when they penetrate spectator areas of the nucleus.[11]

Collisions of two nuclei may be categorized into three main groups, peripheral, quasi-central and central, based on their geometry, which was described in our previous work.[12] In this investigation, we have selected the events coming from central and quasi-central collisions only. A NED with high spatial resolution can be used to detect short-lived

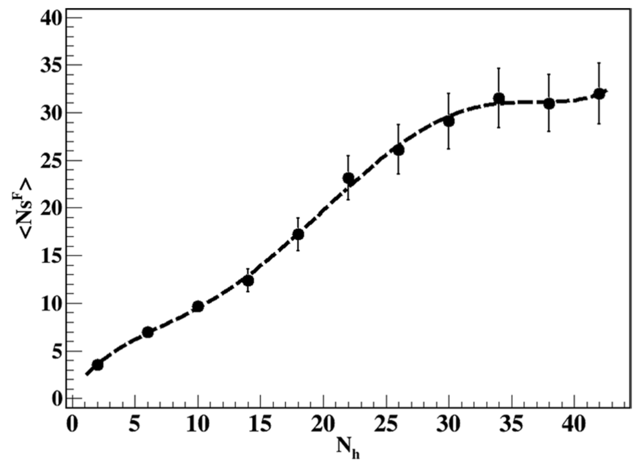

Fig. 3 The variation of $< N_S{}^F >$ with N_h for events produced in the interaction of the ^{84}Kr with emulsion at 1 A GeV; *points* are the experimental data and the *curved line* is just to guide the eye for the data variation.

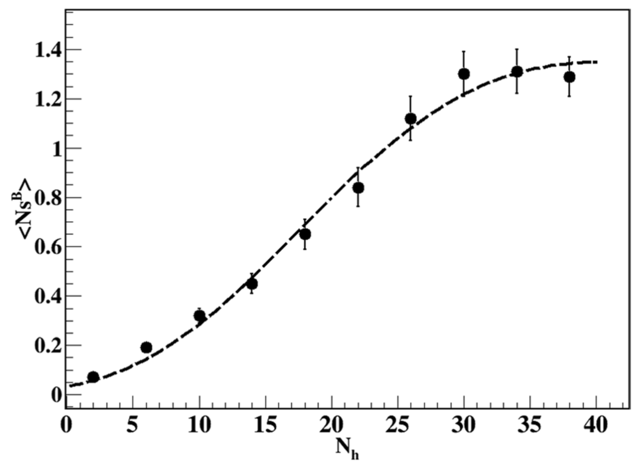

Fig. 4 The variation of $< N_S{}^B >$ with N_h for events produced in the interaction of the ^{84}Kr with emulsion at 1 A GeV; *points* are the experimental data and the *curved line* is just to guide the eye for the data variation.

particles. In this work, we have reported the correlation of the ^{84}Kr + emulsion contact events (N_s and N_h) emitted in the forward ($\theta \leq 90°$) and backward ($\theta > 90°$) hemispheres.[13]

The variation of average value of shower particles emerging in the forward hemisphere ($< N_S{}^F >$) with N_h for events produced in the interaction of the ^{84}Kr with emulsion at 1 A GeV is depicted in Fig. 3, which shows that the values of $< N_S{}^F >$ are growing linearly with N_h up to 30. And, for the value of N_h more than 30, $< N_S{}^F >$ shows the independent nature on N_h which becomes almost constant. This demonstrates that it is the highest value of $< N_S{}^F >$ for N_h in the forward hemisphere.[13]

Figure 4 shows the correlation of the average value of the shower particles emerging in the backward hemisphere ($<N_S{}^B>$) with N_h for events produced in the interaction of the ^{84}Kr with emulsion at 1 A GeV. From this figure, we can again observe that the values of $< N_S{}^B >$ are growing linearly with N_h up to 30, while after that, it shows an independent nature and become almost constant, demonstrating that it is the highest value of $< N_S{}^B >$ for N_h in the backward hemisphere. From Figs. 3 and 4, we have also observed that the emission probability of shower particles emitted in the forward hemisphere is higher compared to the emission probability of shower particles emitted in the backward hemisphere.

Conclusions

The correlation between the quantity of shower particles generated at a relativistic energy in the forward and backward hemispheres has been observed. The emission characteristic of the shower particles in the forward hemisphere is stronger than that in the backward hemisphere. Additionally, we have seen that the emission characteristics of shower particles in the forward and backward hemispheres exhibit a linear connection that is independent of the incident energy of the projectiles.

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Conflict of interest The authors declare that they have no conflict of interest.

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