Some Energy-Angular Correlations of Secondary Charged Particles Produced in Relativistic Heavy Ion Collisions

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Introduction

In the present paper an attempt has been made to find out some energy-angular correlations of relativistic charged particles produced in the collisions of ^{28}Si (projectile) + Emulsion (target) at an approximate energy ≈ 409 GeV. A theoretical model, based on the statistical thermodynamic assumptions has been anticipated to find out the correlations between the energy of the produced particles to their emission angles so that it becomes easy to estimate the energy distribution in terms of measured emission angle.

The Particle Physics is a science of the fundamental structure of matter, which leads to the study of the properties of subatomic particles and the mechanism of their interactions. Its ultimate aim is to find a complete description of the elementary constituents of matter and of the forces acting between them, a description, which should be as simple as possible. It is appropriate to study the field in terms of theoretical and the experimental points of view. Theory predicts phenomenon, which can be verified by experiments, and experiments very often provide new insight through unexpected results, which in turn lead to the improvement in theoretical description.

The nuclear emulsion experiment is a versatile detector for the study of nuclear reactions in high energy heavy ion collisions. It has the ability to detect and identify the secondary charged particles in the outlet channel of nuclear reactions. The dynamic characteristics of all such reactions can be determined absolutely by carry on the precise measurement of the angular distribution, the energy spectra as well as the charge distribution of the produced particles which carry information about the mechanism of the interaction. Unfortunately, the measurement of the energy of secondary charged particles is a difficult task and also it requires pursuing their path through the emulsion plates for enough long distance to get accurate results. On the other hand it is possible to measure the angular distribution to a high extent of accuracy. For this understanding, we believe that the findings of a kind of correlation between the angular and energy distribution of the emitted charged particles will be a better evidence to improve the performance of the emulsion detector as a tool in the determination of the energy spectra of the produced particles.

Used Experimental Data

In the present experiment, FUJI nuclear emulsion pellicles were irradiated horizontally with a beam of ^{28}Si nuclei at 14.6A GeV at Alternating Gradient Synchrophasotron (AGS) of Brookhaven National Laboratory (BNL), USA. The interactions collected from line scanning were scrutinized under an optical microscope (Semi-Automatic Computerized, Leica DM6000M). Some more details related to present experimental data have been presented in our recent publications [1-2].

Interpretation of the Model

It is predicted that during the high energy heavy collisions, a fast projectile nucleus (P) i.e.^{28}Si hit the target nucleus (T) i.e heterogeneous mixture of nuclear emulsion (Em) at some particular impact parameter (b), and a result of this, a large amount of energy is transferred from the projectile to target and the nucleons of both the nuclei rescue through each other. It is believable to work with a parameter that defines the fraction of the projectile nucleons in the formed nuclear system such as:

$$\eta(b) = \frac{\rho_P(b)}{\rho_P(b) + \rho_T(b)} \quad (1)$$

where $\rho_P(b)$ and $\rho_T(b)$ are the projectile and target nuclei densities respectively at some particular impact parameter "b = 1.2". And the pseudo-rapidity "η" has a continuous values in the order of 0-1. If "η" is zero, so it is called target region and "η = 1" belongs to the projectile region. Therefore it is assumed that in such collision three spectator regimes formed. These are the projectile spectator, the target spectator and an overlap region. The parameter "η" plays an important role in understanding the physics inside each part of the interacting medium. The quantity of energy transferred and the activity of nuclear collisions whether it was a strong collision or even elastic or Coulomb dissociation is controlled by the value of "η".

The conservation of energy at a particular location during nuclear collisions requires that:

$$\sqrt{[m^2 + 2\eta(1-\eta)mt_i]} = 3T + m\frac{K_1\,(m/T)}{K_2\,(m/T)} \quad (2)$$

where; m is the nucleon rest mass, t_i is the incident kinetic energy per nucleon in the Lab system and K_1 and K_2 are the Mc Donald's functions of first and second orders respectively.

The final form of the energy distribution for the produced secondary charged particle in nuclear collisions is found by integration over the η and all the θ values so that:

$$F_L(t) = \int_0^{2\pi}\int_0^1 F(t,\eta,\theta)\chi(\eta)Y(\theta)d\eta d\theta \quad (3)$$

where, all symbols has some significant meanings also have some particular values.

Results and Discussions

From Eqn. (2), one can get the value of the local temperature at some specific "η" value. The dependence of the temperature as a function of projectile fraction (η) during high energy heavy ion collisions in the present experimental work has been depicted in Fig.1. It is clear from this Fig. that the maximum value of the temperature is found approximate 0.4 GeV corresponding the "η" value ≈ 1.5. The temperature (T) transfers towards both the projectile and the target regions. It is assumed that at each local equilibrium point for the grey track producing particles (with energy 30-400 MeV) are produced in Maxwellian form subjected to the corresponding temperature.

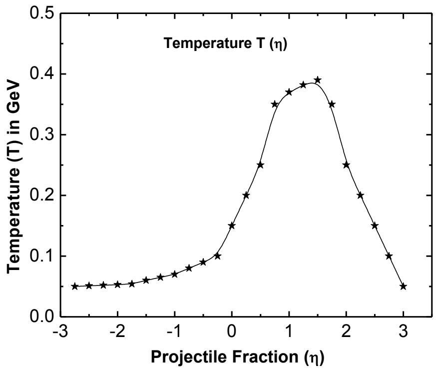

Fig. 1 Dependence of the temperature (T) of thermodynamical system as a function of projectile fraction (η) during high energy heavy ion collisions.

The outcomes / results of Eqn. (3) have been depicted in Fig. 2. These results give us an authorized confidence to apply Eqn. (3) successfully to get the energy distribution of the grey track particles produced within an angular band.

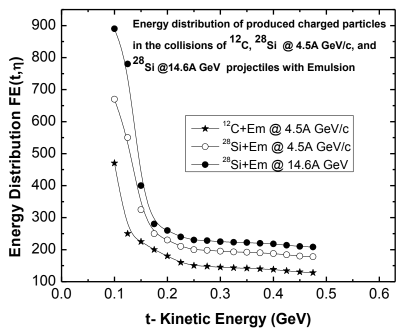

Fig. 2 The energy distribution of grey track producing particles for the collisions of ^{12}C, ^{28}Si at energy 4.5A GeV/c and ^{28}Si at energy 14.6A GeV. The solid line is the prediction of the thermodynamic model which is calculated in terms of the measured angular distribution of the corresponding reactions.

References

[1] M. Ayaz Ahmad et.al., Proc.DAE Symp. on Nucl. Physics, (60), 2015, pp. 736-737.
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