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Charged Particle Spectra in Oxygen-Induced Reactions at 14.6 and 60 GeV/nucleon

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Multiplicity distributions and pseudo-rapidity distributions of charged particles from oxygen-induced nuclear reactions at 14.6 and 60 GeV/nucleon are presented. The data were taken from the EMU-01 emulsion stacks and compared to simulations from the Lund Monte Carlo Model (FRITIOF).

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In the present paper, we report our results on the charged particle spectra in 14.6 and 60 GeV/nucleon oxygen-induced reactions with emulsion nuclei (Em). As far as we know, nuclear emulsion has the highest spatial resolution among all the particle detectors. In this experiment, stacks of emulsion pellicles with dimensions 10 cm × 10 cm × 600 μm were exposed horizontally at the Brookhaven National Laboratory (BNL) to 14.6 and at CERN to 60 GeV/nucleon oxygen beam. At BNL[1] the link between the Tandem Van de Graff and the AGS (Alternating Gradient Synchrotron) was employed and at CERN[2] the acceleration complex consists of ECR (Electron Cyclotron

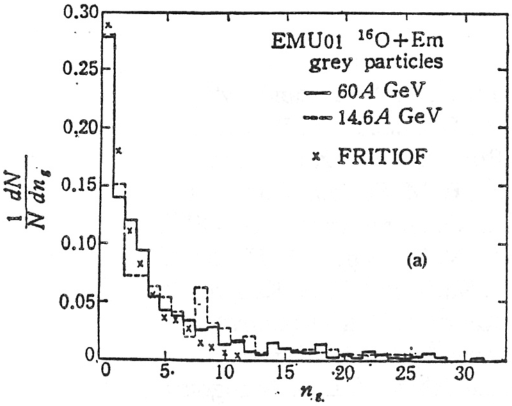

FIG.1 a Normalized multiplicity distributions of grey particles at 14.6 and 60 GeV/nucleon. The cross points are calculated from the Lund Monte Carlo Model (FRITIOF).

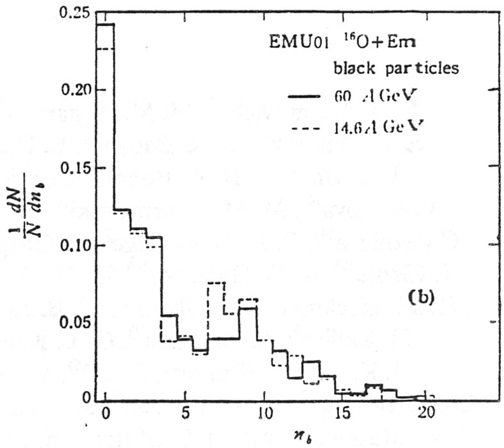

FIG.1 b Normalized multiplicity distributions of black particles at 14.6 and 60 GeV/nucleon.

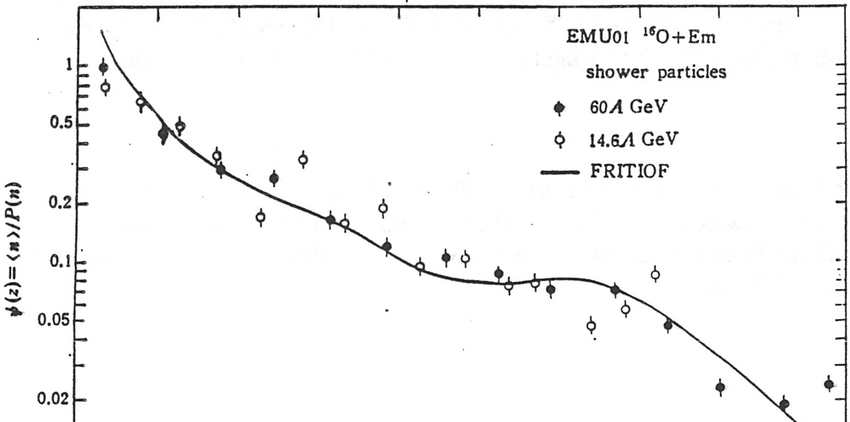

FIG.2 Scaled multiplicity distributions of shower particles at 14.6 and 60 GeV/nucleon. The curve is calculated from the Lund Monte Carlo Model (FRITIOF).

TABLE 1 Mean Values $<n>$, Dispersions D and $D/<n>$ Values of Multiplicity Distributions for Shower, Grey and Black Particles at 14.6 and 60 GeV/nucleon

Energy (A GeV)		Type of particles		
		Shower particles	Grey particles	Black particles
14.6	$\langle n \rangle$	20.89±1.02	4.52±0.22	4.43±0.22
	D	20.35±1.47	5.54±0.29	4.32±0.31
	$D/\langle n \rangle$	0.97±0.09	1.23±0.06	0.98±0.09
60	$\langle n \rangle$	37.77±1.55	4.47±0.18	4.32±0.18
	D	39.60±2.15	6.14±0.23	4.49±0.25
	$D/\langle n \rangle$	1.05±0.06	1.37±0.04	1.03±0.07

Resonance source), RFQ (Radio-Frequency Quadrupole), Linac I, PSB, PS and SPS (Super Proton Synchrotron). The emulsions were developed and then scanned by the along-the-track method with optical microscopes. The following attention has been paid in the process of scanning: only primary tracks with ionization corresponding to the usual ionization of oxygen nuclei in a given stack were selected visually for scanning. Any primary track with doubt was not followed. So far, 417 events of 14.6 GeV/nucleon and 592 events of 60 GeV/nucleon have been measured under a 100 × oil objective. To each event the secondary charged particles are identified as shower, heavy and forward particles respectively in the following ways:

(1) Shower particles (denoted by N_s) are defined as single charged relativistic particles with grain density $g > 1.4\, g_0$, which are mainly pions with energies above 70 MeV and protons with energies above 400 MeV. g_0 corresponds to the minimum ionization.

(2) Heavy prongs as target fragments are divided into two groups: grey tracks and black tracks (expressed by $N_h = N_g + N_b$). Grey particles are defined as heavily ionizing particles ($1.4 < g/g_0 < 8$) and most of them are recoiled protons from target nuclei. Black particles are the evaporated fragments out of target nuclei defined as heavily ionizing particles ($g/g_0 > 8$).

(3) Forward particles (denoted by N_f) are projectile fragments, which are defined as relativistic particles with emission angles $\theta < 14$ mrad at 14.6 GeV/nucleon and $\theta < 3$ mrad at 60 GeV/nucleon. The ionization of these particles does not change considerably within the range of $L < 2$ cm. They are also classified into several types according to their charge Z: alpha particles (N_α) with $1.4 < g/g_0 < 4$ for $Z = 2$, lightly-ionizing fragments (N_l) and medium-ionizing fragments (N_m) for $Z > 3$.

Table 1 gives the mean value $<n>$, the dispersion $D = (<n^2> - <n>^2)^{1/2}$, and the characteristic parameter $D/<n>$ of multiplicity distributions for shower, grey and black particles at each energy. The normalized multiplicity distributions of grey and black particles at 14.6 and 60 GeV/nucleon are plotted in Figs.1a and 1b. Also indicated in Fig.1a is the distribution for grey particles obtained from the Lund Monte Carlo Model (FRITIOF) [3] for high energy nucleus-nucleus interactions.

The fragmentation of the target-nucleus might be still independent of the energy in the present experiment. Shown in Fig.2 is the approximate scaling of the multiplicity distributions of shower particles in term of the variable $Z = n/<n>$ for nucleus-nucleus collisions in the present energy region. Data are in good agreement with the geometry of FRITIOF [3], as shown in Fig.2.

The normalized pseudo-rapidity ($\eta = -\ln \tan\theta/2$) distributions in the rest frame of the projectile-nucleon for the shower particles produced in ^{16}O-Em interaction at 14.6 and 60

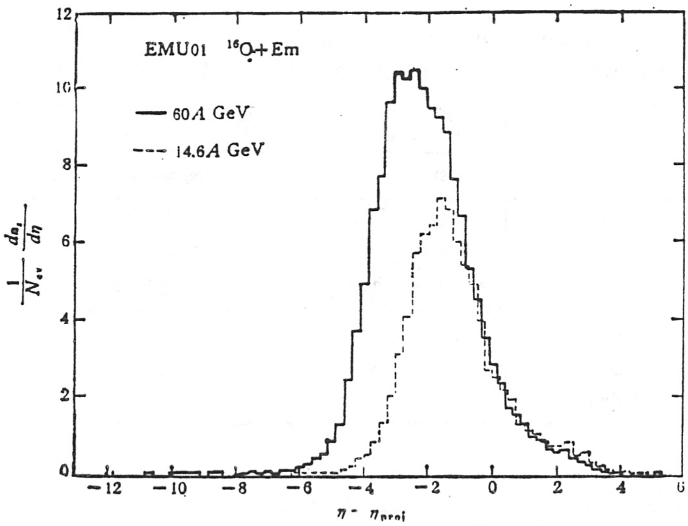

FIG.3 Pseudo-rapidity distributions in the rest frame of the projectile-nucleon for shower particles at 14.6 and 60 GeV/nucleon.

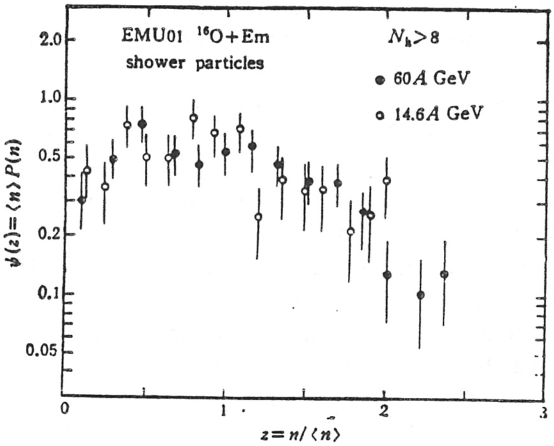

FIG.4 Scaled multiplicity distributions of shower particles for events with $N_h > 8$ at 14.6 and 60 GeV/nucleon.

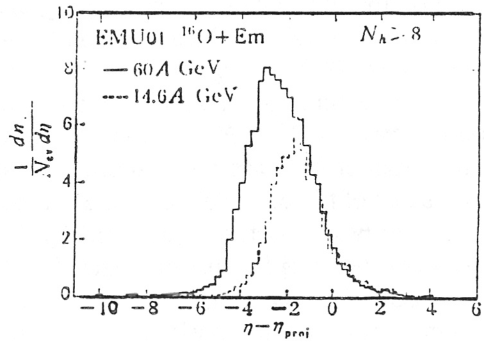

FIG.5 Pseudo-rapidity distributions of shower particles in the rest frame of the projectile-nucleon for events with $N_h > 8$ at 14.6 and 60 GeV/nucleon.

GeV/nucleon are shown in Fig.3. There is an obvious scaling property in the projectile fragmentation region. The limiting fragmentation behavior[4] is also observed in heavy-ion collisions in the present energy range.

During a high energy collision the target nucleus is left in a highly excited state, which subsequently breaks up as heavy fragments N_h. We selected events with the number of the heavy prong $N_h > 8$, which are taken for the events induced by the interactions of projectile with AgBr, the heavy elements of emulsion. The scaled multiplicity distributions for shower particles measured from these events at 14.6 and 60 GeV/nucleon are shown in Fig.4. We also observed the property of approximate scaling.

Pseudo-rapidity distributions in the rest frame of the projectile-nucleon at 14.6 and 60 GeV/nucleon indicate that the shape of curves in the projectile fragmentation region are independent of beam energy, as seen in Fig.5.

In conclusion, we feel that data on the multiplicity distributions and pseudo-rapidity distributions of the charged particles presented in this paper in oxygen-induced nuclear reaction with emulsion at 14.6 and 60 GeV/nucleon explored many features, such as, scaling properties in high energy heavy-ion collisions. But, the availability of the conditions for the formation of QGP at the present energy region is still an open question because of the lack of reliable quantitative predications for the experimental observations.

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