ON THE MECHANISM OF ANOMALOUS NUCLEUS-NUCLEUS INTERACTIONS AT ENERGIES ABOVE 1 TEV/NUCLEON

S.Sh.Ameev, V.L.Shmonin

High Energy Physics Institute of the Kazakh SSR
Academy of Sciences, Alma-Ata, 82, USSR

Abstract. Two anomalous interactions of cosmic ray nuclei with photoemulsion nuclei are considered within the framework of the nuclear pionization model. It is shown that the observed regularities of nuclear collisions at the given energy range are satisfactorily reproduced by the model.

The observation and determination of the number of the characteristics of the two heavy ion collisions at energies of 4 TeV/nucleon (Si+Ag) and of 100 TeV/ nucleon (Ca+C) [1] allow to examine roughly the notions of the mechanism of nuclear interactions at the given energy range. The most interesting features of these events are follows. The mean transverse momentum $\langle P_T \rangle_\pi$ of π-mesons produced is significantly higher than that for pp-collisions at approximately the same energies of ISR[2] and of SPS[3] (see Table 1). High multiplicity of secondaries and low number of h-tracks do not agree within the existing classification scheme of events according to which the number of nonrelativistic products of target disintegration in the central collisions should be large.

In this report we analyse the possibility of an interpretation of such events within the framework of the nuclear pionization model [4÷6].

According to this model an interaction of relativistic nuclei occurs through the stages of the formation, development and decay of the three intermediate systems : the central pionization cluster and two baryon ones formed by leading components of interacting nucleons. Later a similar scheme was used as the base of the model [7]. The numbers of interacting nucleons of the projectile, N_1, and target, N_2 , are determined for a fixed impact parameter b from the formulae:

$$N_1=\int dx_1 dy_1 T_1(x_1,y_1,b)\left[1-\exp(-\alpha\sigma^{in}_{NN}T_2(x_2,y_2,b))\right]$$
$$N_2=\int dx_2 dy_2 T_2(x_2,y_2,b)\left[1-\exp(-\alpha\sigma^{in}_{NN}T_1(x_1,y_1,b))\right] \qquad (1)$$

Here $\alpha=1$, $x_2=x_1-b$, $y_2=y_1$, $T_i=\int\rho(b,x_i,y_i,z)dz,(i=1,2)$, ρ is the Fermi distribution of the nucleon density in a nucleus. It was pointed out [8] that the existence of the channel of the total compound-system formation in nucleon-nucleon interactions [9,10] leads to the fact that the part of the interacting nucleons in A-A collisions turns out to be captured into the central pionization cluster. The numbers of such nucleons, N_1' and N_2', are also determined in terms of (1) with $\alpha=1/3÷1/4$. The numbers of nucleons entered the baryon clusters can be found from the equations :

$$N_1''=N_1-N_1' \qquad N_2''=N_2-N_2' \qquad (2)$$

In the system where the nuclei collide with equal speeds the energies, masses and momenta of the baryon clusters are defined by the expressions :

$$E_i''=N_i''\left[(1-\langle\delta\rangle)^2p^2+m_N^2\right]^{1/2},\ M_i''=N_i''(m_N+\varepsilon_K),\ P_i''=(E_i''^2-M_i''^2)^{1/2}\ (i=1,2) \qquad (3)$$

In (3) $\langle\delta\rangle=0.3$ is a part of a baryon cluster nucleon momentum spent on the central cluster production. $\varepsilon_K\approx0.2$ GeV is an average kinetic energy of the nucleon in a baryon cluster rest system.

Taking into account the conservation laws one can determine the energy, momentum and mass of the central cluster $E_c=E_1+E_2-E_1''-E_2''$ $P_c=P_1+P_2-P_1''-P_2''$ $M_c=(E_c^2-P_c^2)^{1/2}$, (4) where E_1 and E_2 are the energies of the interacting parts of the nuclei before their collision.

The thermodynamical model [4÷6,8] is used to describe the decay of the clusters. The pionization cluster decay temperature is determined from the equation of the energetic balance with an account of π-, K-, ρ-, ω-mesons, nucleons and antinucleons among the secondaries. The decay volume is defined by formula from [11]

$$V=\frac{4}{3}\pi(R_0+\varkappa\tau_h)^2(2R_0/\gamma+\varkappa\tau_h)$$

Here R_0 is the initial size of the central cluster Lorentz compressed in longitudinal direction (γ is the Lorentz-factor of the motion of a nucleus in the equal speed system). The parameter Ro is taken to be equal to the radius of the smaller colliding nucleus for the central collisions. τ_h =1.2 GeV·fm/c [12] is the hadronization time of the quark-gluon plasma forming the cluster matter. The value $\varkappa \geqslant 1$ takes into account the possible increase of τ_h in nuclear collisions in comparison with hadronic ones [13]. According to [14] the contribution of longitudinal collective motion in cluster is taken into account in the energetic balance. The results of the calculation of the multiplicity and average transverse momentum $\langle P_T\rangle_\pi$ for π -mesons from the considered events are given in the Table 1.

Table 1.

	E_o, TeV	Nch		$\langle P_T\rangle_\pi$, GeV/c			
		exper.	theor.	exper.	theor.	ISR*	SPS**
Si+AgBr	4	1010 ±30	835	0.550 ±.100	0.541	0.340 ±.002	
Ca+C	100	760 ±30	597	0.700 ±.050	0.708		0.424 ±.001

* - data from Ref.[2]

** - data from Ref.[3]

For the second event the energy, transverse momentum and pseudorapidity restrictions for photons have been accounted in the same way as in the experiment[1]. All calculations were carried out for $\varkappa$ =3. The relativistic particle pseudorapidity distributions for these two events are shown in the Figs. 1. and 2.(histogram (experiment[1]), curves (this model)).

Taking into account that fact that the considerable fluctuations are possible in these unique events one can conclude that the nuclear pionization model satisfactorily reproduces the observed regularities of nuclear interactions at the given energy range.

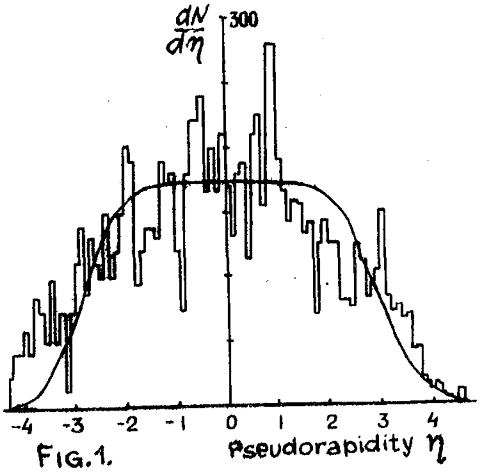

FIG.1.

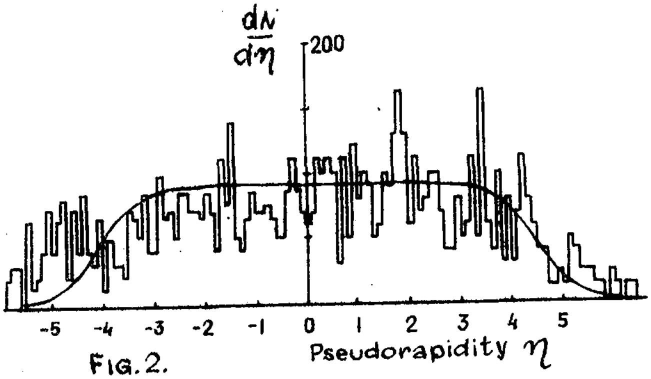

FIG.2.

FIG.1. The CMS pseudorapidity distribution of charged particles in the Si+AgBr event.

FIG.2. The CMS pseudorapidity distribution of charged particles in the Ca+C event.

References

1. Burnett T.H. et al., 1983, Phys.Rev.Lett.,v50,26,2062
2. Alper B. et al., 1975, Nucl.Phys., B100,237
3. Arnison G. et al., 1982, Phys. Lett., 118B, 167
4. Kalinkin B.N., Koltochnick S.N., Shmonin V.L., 1978 Preprint HEPI 61-78,Alma-Ata; 1980,Phys.Scr.,v21,792
5. Baranov D.G. et al., 1978, Pis'ma v JETP, v28, 7, 475 Varyukhin V.V. et al., 1979, Proc.16th ICRC, Kyoto, v6, 154-159
6. Ameev S.Sh. et al., 1982, Preprint HEPI 81-16,Alma-Ata
7. Bjorken J.D., 1983, Phys. Rev., D27, 140
8. Ameev S.Sh. et al., 1981, Proc.17th ICRC, Paris, 5, 80
9. Kalinkin B.N., Cherbu A.V., Shmonin V.L., 1980,Fortschr. Phys., 28, 35
10. Kalinkin B.N., Shmonin V.L., 1981, Phys.Scr.,v24, 3, 498
11. Ameev S.Sh., Shmonin V.L., 1984,J.Phys.G.,v10,1311-1317
12. Kalinkin B.N., Cherbu A.V., Shmonin V.L.,1979,Acta Phys. Austr. v50, 165; 1980, Phys.Scr., v21, 797-801
13. Kalinkin B.N., Gagarin Yu.F., 1984, FTI im A.F.Ioffe Preprint, 848, Leningrad
14. Varyukhin V.V. et al., 1982, FTI im A.F.Ioffe Preprint, 756, Leningrad.