COHERENT GENERATION OF PARTICLES ON EMULSION NUCLEI BY 200 GeV/c PROTONS

Z.V. Anzon, M.G. Antonova, E.G. Boos, A.A. Goryachikh, P.V. Morozova, T.I. Mukhordova, N. P. Pavlova, Zh.S. Takibaev, A.V. Kholmetskaya, I.Ya. Chasnikov, Ts. I. Shakhova,
N.P. Bogachev[1], F.G. Lepekhin, B.B. Simonov,
V.G. Bogdanov, N.A. Perfilov, Z.I. Solov'eva,
M.I. Adamovich, N.A. Dobrotin, V. G. Larionova, M.I. Tret'yakova, S.P. Kharlamov, M.M. Chernyavskii,
K.I. Alekseeva,
S.A. Azimov, A.I. Bondarenko, K.G. Gulamov, U.G. Gulyamov, V.V. Lavkov, V.Sh. Novotnyi, V.I. Petrov, T.T. Riskiev, T.P. Trofimova, L.P. Chernova, and G.M. Chernov

Alma-Ata - Leningrad - Moscow - Tashkent Collaboration
Submitted 14 May 1973
ZhETF Pis. Red. 18, No. 1, 19 - 24 (5 July 1973)

Type BR-2 nuclear emulsions were bombarded in the NAL accelerator by 200 GeV/c protons. By comparing the multiplicity and angular-characteristics distributions of pp and pn interactions on 1438 m of primary tracks, it is found that the ranges for coherent generation of three and five charged particles are $\lambda_3 = (21.8^{+3.9}_{-2.8})$ and $\lambda_5 = (68^{+28}_{-15})$ meters, respectively.

In [1] there are given summary data on the cross sections of coherent reactions with production of one, three, and five charged particles on emulsion nuclei by protons and pions in the energy range 17 - 67 GeV.

We present in this paper data on the cross section for the production of three and five charged particles in coherent interactions of 200 GeV/c protons with emulsion nuclei.

In coherent proton interactions, the total number of generated particles can be arbitrary and the number of charged particles can be odd. The following reactions with production of charged particles in the final state are possible:

one
$$p + A \to p\pi^0 + k\pi^0 + A \quad (1)$$
$$p + A \to n\pi^+ + k\pi^0 + A \quad (2)$$

three
$$p + A \to p\pi^+\pi^- + k\pi^0 + A \quad (3)$$
$$p + A \to n\pi^+\pi^+\pi^- + k\pi^0 + A \quad (4)$$

five
$$p + A \to p2\pi^+2\pi^- + k\pi^0 + A \quad (5)$$
$$p + A \to n3\pi^+2\pi^- + k\pi^0 + A \quad (6)$$

etc., where k = 0, 1, 2, ...

The main characteristics of coherent hadron interactions on nuclei are: 1) narrowness of the angular distributions, owing to the smallness of the momentum transferred to the target nucleus; 2) absence of breakup or even excitation of the nucleus; 3) conservation of the quantum numbers of the initial and final systems in the diffraction mechanism of the process.

It should be noted that the high spatial resolution of the nuclear emulsions makes it possible to meaure small particle emission angles with high accuracy (angles $\sim 10^{-3}$ are measured with an error 10 - 20%) and to register very slow fragments ($E \geq 0.2$ MeV for protons and $E \geq 1$ MeV for carbon nuclei) and electrons from nuclear β decay, i.e., to select with assurance events without breakup or excitation of the nucleus.

Experiment

Two stacks (one liter each) of NIKFI type BR-2 emulsions with pellicles measuring 10 x 20 cm^2 and thickness 600 microns were bombarded by 200 GeV/2 in the NAL accelerator in Batavia. The emulsions were developed at the High Energy Laboratory of the Noint Institute for Nuclear Research. The irradiation density was (1 - 3) x 10^4 cm^{-2}.

[1] Joint Institute for Nuclear Research, Dubna.

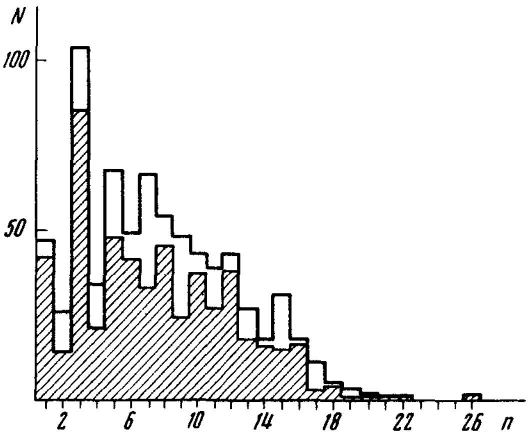

Fig. 1. Distribution with respect to the number of secondary charged particles in all proton-nucleon events (solid line) and "pure" stars of the $0 + 0 + n_{ch}$ type (shaded).

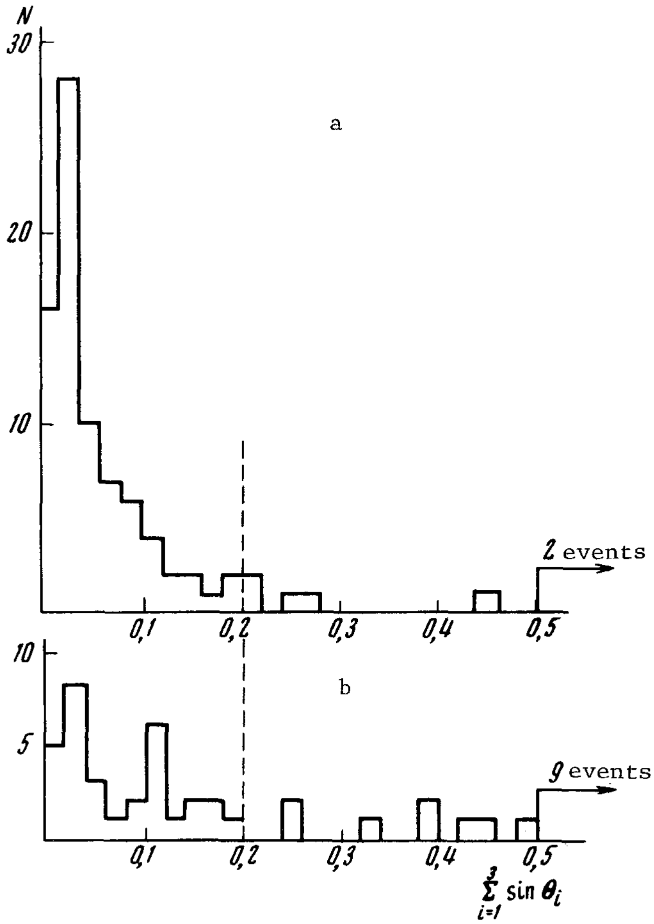

Fig. 2. Distribution relative to $\sum_{i=1}^{3}\sin\theta_i$ in "pure" stars 0 + 0 + 3p (a) and in background three-prong events (b). The latter group consists of: 1) three-prong stars accompanied by an electron (pn interactions), 2) four-prong pp collisions with exclusion of the recoil proton, or (for events of the 0 + 0 + 4p type) of one relativistic particle with maximum emission angle θ.

On a total of 1438 m of primary-proton tracks, we selected 294 pp interactions (the criteria for the selection of pp and pn interactions are given in [2]) and 442 pn and coherent pA interactions. The number of coherent reactions was obtained by comparing the distributions with respect to the multiplicities and angular characteristics of the secondary particles in inelastic pp and pn interactions.

Multiplicity Distribution

Figure 1 shows the distribution with respect to the number of charged particles (n_{ch}) for all the selected interactions (solid line) and the so-called "pure" events (shaded), i.e., events without slow charged particles and without excitation of the nuclei, where some of the events may be coherent. A noticeable excess of events with n_{ch} = 1, 3, 5 is observed and is due to "pure" stars.

Whereas at $n_{ch} \geq 8$ the number of "pure" pp events noticeably exceeds the number of "pure" pn events (owing to the presence of free hydrogen in the emulsion), in the region of small n_{ch} the situation is reversed, a fact naturally attributable to the admixture of coherent reactions.

A rough estimate of the number of coherent events with production of one, three, or five charged particles assuming a linear growth of the number of events with increasing n_{ch} in the region $0 < n_{ch} \leq 6$ yields the respective values $N_1 = 34 \pm 13$, $N_3 = 73 \pm 12$, and $N_5 = 25 \pm 10$. It should be noted that the number of coherent events with $n_{ch} = 1$ is noticeably underestimated, since all events with a secondary-particle emission angle less than 2×10^{-3} are attributed to elastic interactions.

In analogy with [1, 2], the number of coherent events with production of three and five charged particles was determined by analyzing the distribution of the events with respect to the parameter $\sum_{i=1}^{n_{ch}} \sin\theta_i$, which is approximately proportional to the longitudinal momentum ($q_{\parallel}$)

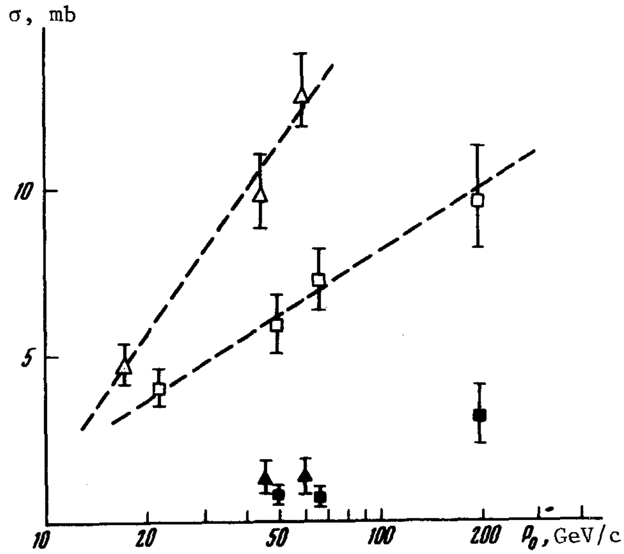

Fig. 3. Momentum dependence of the cross section (per average emulsion nucleus) of coherent generation of three (light symbols) and five (dark) charged particles. The squares and triangles represent primary protons and pions, respectively.

transferred to the nucleus. Here θ is the secondary particle emission angle relative to the direction of the incident proton beam.

Figure 2 shows the distribution with respect to $\sum_{i=1}^{3} \sin\theta_i$ for three-prong events. We see that for "pure" events (Fig. 2a) this distribution is much narrower than for the background proton-nucleon interactions (Fig. 2b). If the distributions of Figs. 2a and 2b are normalized to $\sum\sin\theta_i > 0.2$, the number of coherent events with production of three charged particles (reactions 3 and 4 amounts to $N_3' = 66 \pm 10$, corresponding to a mean range $\lambda_3 = 21.8^{+3.9}_{-2.8}$) m. A similar procedure yields for the number of coherent events with production of five charged particles $N_5' = 21 \pm 6$, corresponding to $\lambda_5 = (68^{+28}_{-15})$ m. Figure 3 shows the data (per average emulsion nucleus) on the coherent reactions with production of three and five charged particles at 200 GeV/c, and the corresponding data for the primary protons and pions in the energy region 17 - 67 GeV [1]. As seen from Fig. 3, the cross section for the production of three and five charged particles by protons increases with energy up to 200 GeV. For reactions of production of events with three charged particles by pions, the cross section likewise increases with the momentum, and the rate of this increase differs from that for the protons.

To determine the character of the dependence of the cross section of the pion reactions with production of three and five charged particles on the momentum and for its comparison with the analogous proton reactions, further experiments are necessary.

The authors are deeply grateful to the Division of Nuclear Physics of the USSR Academy of Sciences, to the Management and Staff of NAL (Batavia, Ill), to V. A. Nikitin for help with the experiment, and to the members of S. I. Lyubomilov's group for developing the emulsions. The authors are also grateful to the laboratory staff for emulsion scanning and measurements.

[1] R. Khoshmukhamedov, G. S. Sharbatova, K. D. Tolstov, et al., JINR Preprint E1-6598, 1972; Submitted to 16-th Internat. Conf. on High Energy Physics, Batavia.

[2] Alma-Ata - Dubna - Cracow - Leningrad - Moscow (FIAN and MGU) - Tashkent - Ulan-Bator Collaboration, JINR Communication R1-6504, 1972; Phys. Lett. 39B, 285 (1972).

CERTAIN CONSIDERATIONS CONCERNING THE THERMONUCLEAR POSSIBILITIES OF A ZETA PINCH

I. F. Kvartskhava and Yu. V. Matveev
Submitted 16 May 1973
ZhETF Pis. Red. 18, No. 1, 24 - 27 (5 July 1973)

As is well known, attempts to use strong-current plasma systems in thermonuclear (TN) purposes encounter great difficulties because the discharge is prone to a certain self-organization that counteracts the containment of the hot plasma in the magnetic fields. According to the theoretical concepts, these difficulties are connected mainly with the instabilities of the contained plasma. According to the experimental data, on the other hand, other processes are also responsible, including plasma processes that develop both inside and outside the containment region.

Thus, for example, the theory of an idealized pinch, in which the phenomena next to the electrodes and the walls are taken into account and the presence of rarefied plasma around the pinch is neglected, predicts rather rapid instabilities with modes m = 0 and m = 1; the theory relates the "singularities" of the current-voltage characteristics of the discharge only with