NAL PROPOSAL No. 117

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PHENOMENOLOGICAL STUDY OF 200 and 500 GeV/c PROTON-PROTON COLLISIONS IN EMULSION

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Phenomenological Study of 200 and 500 GeV/c proton-proton collisions in Emulsion

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Abstract

We propose to expose two stacks of nuclear emulsion to the 200 and 500 GeV/c protons. In these stacks, the following properties are examined. 1) energy dependence of total, elastic and inelastic cross sections, 2) contribution of diffraction dissociation, 3) energy dependence of mean multiplicity, 4) character of multiplicity distribution, 5) behaviors of backward particles for which momenta and masses are determined.

PHYSICS JUSTIFICATION

The following properties of the proton-proton collisions at momenta of 200 and 500 GeV/c are examined:

1) elastic and inelastic cross sections,

2) contribution of diffraction dissociation,

3) energy dependence of mean multiplicity,

4) character of multiplicity distribution,

5) behaviors of backward particles for which momenta and masses are determined.

What tendency is observed for the cross sections at very high energy, that is, whether they decrease down to zero or approach a constant or increase like a logarithmic way with energy, is one of the basic problems[1]. Though the emulsion experiment is somewhat weak to compete with the counter experiment about this problem, the cross sections and their energy dependences are at first checked through the selected events. According to π^--nucleus experiments in emulsion[2], the cross section per nucleon for diffraction dissociation increases roughly proportional to $P_0^{1/2}$ up to 60 GeV/c where P_0 is the incident momentum and is amounting to ~ 1 mb at 60 GeV/c. It is pointed out by Feynman[3] that at high energy limit this process should be 10 % of the elastic one. The second purpose of the present proposal is to derive the cross sections for this process of the proton at 200 and 500 GeV/c. The energy dependence of mean multiplicity of charged particles, $\langle n^{\pm} \rangle$, is also a basic problem to consider the structure of multiparticle process[3,4]. The recent results of accelerator experiments[5] show that $\langle n^{\pm} \rangle$ seems to have a power dependence with energy rather than logarithmic way. It is our third purpose to see this energy dependence of $\langle n^{*}\rangle$ for proton-proton collisions. The fourth aim is to examine whether the prong-number distributions at energies of hundreds GeV are pure Poissonian or not[1]. This gives us the information whether there exists any correlation between particles at their production stage. In recent cosmic ray experiment[6], it is reported that there seems to be some production correlation between secondaries[7]. The final is the main purpose of the present proposal. About 10 % of particles emitted backward in the proton-proton CMS should be determined their momenta by the single or relative scattering measurements. By along-the-track scanning of ~10 km in emulsion, ~3000 protpn-proton collisions (collisions with free and quasi-free protons) should be detected when the cross section for PP is 40 mb (corresponding mean free path ~ 3.1 m). Among the visible prongs associated with these collisions, about 1500 prongs should be determined their momenta (these prongs have track lengths per plate more than 5 mm). The maximum momentum of a recoil proton is estimated to be ~1.4 GeV/c under the assumptions of $P^{*} \gg M_p$ and $P^{*} \gg P_{\perp}$ where P^{*} and $P_{\perp}$ are momentum and transverse momentum of a proton in CMS and M_p the proton mass**).

**) Under these assumptions, the momentum of a proton in Lab. system, P, is written as,

$$P = \left\{ \frac{1}{4M_p^2} (P_{\perp}^2 + M_p^2)^2 + P_{\perp}^2 \right\}^{\frac{1}{2}}.$$

P_{max} comes from $P_{\perp max}$. Since $P_{\perp max}$ is ~1 GeV/c, we have $P_{max} \sim 1.4$ GeV/c.

Therefore, all of the recoil protons among the 1500 prongs could be identified. Since the situation of $P^* \gg M$ for pions and kaons is expected not to be so different for the case of the recoil proton and the mode value of $P_\perp$ of pions or kaons is also expected to be relatively smaller than P^*, the chance we can identify pions and kaons seems to be more than 50 %. Using these results, we can examine at first the features of angular and momentum distributions for protons, pions and kaons. Second, according to the parton model[3] or the hypothesis of limiting fragmentation[8], the longitudinal momentum distribution in Lab. system for special particles, that is, protons, pions or kaons, at fixed $P_\perp$ approaches a limiting one at very high energy. The tendency to approach a limit seems to be observed at the energies produced by accelerators now available[8]. Though much more statistics are needed, at high energy and also highly inelastic limits, we could observe the parton mass[9] if the model is correct. It is not clear at present that from where the condition of high energy and highly inelastic is satisfied. In order to proceed the study along this line, we are preparing a Helmholtz type pulsic magnet.

In the studies aforementioned, the nuclear emulsion is essentially useful, because at the energies few hundred GeV about 10 charged particles are produced by a collision and emitted in a very narrow cone and therefore a fine spacial resolving power is generally required.

References

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7) C.P.Wang, Phys. Rev. 180 1463 (1969).

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Experimental Arrangement

1) Beam: Protons of 200 and 500 GeV/c.
2) Intensity: 10^4 - 10^5 protons/cm^2. We would desire two test exposure of intensities 10^4 and 10^5 and then determine the final value.
3) Emulsion: Ilford K-5 pellicle of 600 micron thick and 10 x 20 cm^2, 47 sheets/stack. Beam parallel to the 20 cm side.
4) Alignment: as accurate as possible.

Apparatus

1) Emulsion storage facilities protecting from background radiations, high humidity and high temperature.
2) Processing facilities: grid-printing, adhesion of pellicle and backing glass, developing and drying.

NAL PROPOSAL No. 117-A

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ADDENDUM NO. 1

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We wish to propose the exposures of our proposal no. 117 to split into two parts, namely, the one is the exposures described in the proposal, but we use somewhat smaller sizes of stacks, and the other one is the five kinds of sandwich stacks, each having a Be, Al, Ni, Ag or W foil between pellicles. The latter is used to get the total cross section for the proton-nucleus collision on each nucleus and to see what the energy and mass number dependences are.

At present, we have not any definite information about the proton-nucleus collision in the energy range more than 100 GeV. Therefore, it is fruitful to obtain the general features on it as much as possible, for example, for the total cross section, diffraction dissociation, and their mass number dependences and so on. The sandwich stacks are suitable and convenient to derive this information efficiently.

We use the sandwich stack made up by three pellicles of 5 cm x 5 cm, 600 μ thick and one metal foil of 200 $\sim$ 400 μ thick and expose vertically to the emulsion plane with a beam density of $\sim 5 \times 10^4$ particles/cm^2. This exposure can afford us more than 10^3 events of the desired proton-nucleus collision when the cross section is assumed to be 50 $A^{2/3}$ millibarns. The scanning rate is about one sandwiched stack per scanner-month.

The ordinary stack is composed of 3 dozen pellicles of 7.5 cm x 15 cm, 600 microns thick each, in which we expect the number of the proton-proton collisions to be about 8 x

10^3 under the condition of the exposed density of 10^4 particles/ cm^2 and of the cross section of pp, 40 mb.

The purpose we wish to add to those of the proposal no. 117 is the short-lived particle hunting. Recently Niu found an event which might be a decay of a new particle with a supposed lifetime around 10^{-13} sec in his cosmic ray study. The emulsion has an essential advantage to search such a short-lived particle because of its fine spacial resolving power. If the Lorentz factor of the particle is 100, we can derive the information about the lifetime of that particle down to 10^{-16} sec. The hunting of any short-lived particle is done by inspecting near the vertex point of the proton or pion hitting to the nucleon or nucleus. This analysis is mutually complementary with Niu's experiment (proposal no. 156).

According to the recent theoretical works[1] based on the Glauber theory[2], if heavy mass resonances with masses up to 2P/R on Regge recurrences where P is the incident proton momentum and R is the nuclear radius of the target, contributes in the intermediate stage of the collision, that is, in the stage that the impinging proton passes through the nucleus, the total elastic cross section has a strong energy dependence especially in the light nuclei. The emulsion has a value of mean mass number ($\bar{A}$), 48.5 and $\overline{A^{2/3}}$, 13.2 where the contribution of the free hydrogen is excluded. The calculation of Trefil[1] shows that in this case the total elastic cross section ($P + A \rightarrow P + A$) has a difference $\sim$ 10% between impinging proton energies

100 and 300 GeV. Therefore, we can have a chance to check the contribution of the higher mass resonances.

In addition to the proton exposures with energies more than 100 GeV, we wish to propose the exposures of the same kind of an ordinary and the five sandwich stacks for pions with the same energies of protons. The same kind of analysis as the protons is applied and the results are compared with those of protons, for example, target fragmentation, diffraction dissociation, and short-lived particle hunting, and so on.

Therefore, we would like to change the subject of our proposal to "Phenomenological Study of Proton and Pion Interactions at Energies More Than 100 GeV Using Emulsion". The proposal includes the studies as:

1. proton or pion - nucleon interactions
2. proton or pion - nucleus interactions
3. short-lived particle hunting

and requires the exposures of ordinary and sandwich stacks to each proton or pion beam at least in two different energies more than 100 GeV.

We add the following collaborators to the original group:

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REFERENCES

1. J. S. Trefil, Phys. Rev. D3 1615 (1971), other references included therein.

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