NAL PROPOSAL No. 105

Correspondent P. K. Malhotra and
S. N. Ganguli
Tata Institute of
Fundamental Research
Homi Bhabha Road
Bombay 5, India

Telephone 213141

A PROPOSAL TO STUDY SOME CHARACTERISTICS OF PROTON-NUCLEON AND PROTON-NUCLEUS COLLISIONS AT 400 GEV USING NUCLEAR EMULSIONS

R. R. Daniel, S. N. Ganguli, P. K. Malhotra

Tata Institute of Fundamental Research

December 31, 1970

A PROPOSAL

TO STUDY SOME CHARACTERISTICS OF PROTON-NUCLEON AND PROTON-NUCLEUS COLLISIONS AT 400 GEV USING NUCLEAR EMULSIONS

Exp. Group: R. R. Daniel, S. N. Ganguli and P. K. Malhotra
Tata Institute of Fundamental Research
Colaba, Bombay 5, India

Spokesman: Dr. P. K. Malhotra and Dr. S. N. Ganguli

Beam: 200-500 GeV (the highest energy possible) protons at NAL, U.S.A.

Intensity: $(1 \pm 0.5) \times 10^4$ protons/cm^2

Emulsion stack: 80 pellicles, 40 of normal G5 and 40 of hypersensitive G5 emulsion, each 15cm x 12cm x 0.06cm. The 15cm edge along the beam.

We understand that the Batavia Accelerator (National Accelerator Laboratory, U.S.A.) may have a beam in mid-1971 and perhaps a low-intensity beam of about 500 GeV not long after. It also seems that a majority of the proposed experiments could only be undertaken about 6 months to a year later as they require facilities which may not be ready when the first high energy internal beam is available. This has prompted us to propose an experiment which can be carried out employing nuclear emulsion soon after an external or even internal proton beam becomes available.

While it is true that the role of nuclear emulsion as a detector in accelerator work has, during recent years declined considerably, it can still be used with advantage in the present situation to get

......2

important information in a relatively short time. Such information might also be used with advantage in designing and implementing complex and sophisticated experiments later. The simplicity of the general lay out , the small machine time required and the fact that the present experiment can be carried out during the early period when the NAL accelerator comes into operation, are factors which may be mentioned in favour of this proposal.

1. Aim of the Experiment

The prime aim of the experiment is to obtain information on the general characteristics of proton-nucleon collisions at the highest energy possible soon after the first internal or external beam at NAL becomes available. The type of information that this experiment is expected to yield can be summarised as follows:

1.1 Multiplicity

One of the important quantities that can be determined from this simple experiment is the multiplicity and its distribution in proton-nucleon collisions at 400 GeV. The dependence of multiplicity on primary energy has not yet been well established[1] mainly because of the unreliable nature of the cosmic ray data. The machine results available so far are only upto 70 GeV and an extension of this to 400 to 500 GeV would be very valuable.

1.2 Composition of Secondary Particles

We hope to get some important information on the proportion of charged **kaons** amongst the secondary particles by identifying them as outlined in Section 2.2.

When one examines the existing information on the composition of secondary particles in proton collisions with light nuclei, it is seen that sufficient information from accelerator work is available only for energies less than 30 GeV; the data from Serpukhov exists only at a few angles and for a limited range of secondary energies. Extensive data [2,3] is however available at primary energies of 12.5 GeV and 30 GeV. We have integrated the data over angles covering the respective forward cones, 0° to 20° at 12.5 GeV and 0° to 14° at 30 GeV, and the results obtained on K to π ratio are given in the following table.

E_p (GeV)	K^+/π^+	K^-/π^-	$K^{\pm}/\pi^{\pm}$
12.5	0.06	0.02	0.045
30	0.15	0.06	0.11

We have also carefully analysed [4] the available data from cosmic-ray investigations. This analysis indicates that in the region of a few TeV, $K^{\pm}/\pi^{\pm} = 0.40 \pm 0.07$. It thus seems that $K^{\pm}/\pi^{\pm}$ increases from about 0.045 at 12.5 GeV through 0.11 at 30 GeV to about 0.40 at a few thousand GeV.

It is therefore of considerable interest to determine $K^{\pm}/\pi^{\pm}$ at around 400-500 GeV from an accelerator investigation.

1.3 Energy Distribution and Transverse Momentum Distribution of Secondary Particles

It is generally agreed that the best known feature of particle production is the distribution of P_t.

$$N(P_t) \sim P_t \cdot e^{-P_t/c}$$

with $\langle P_t \rangle = 2c =$ 0.35 GeV/c, almost independent of primary energy. Accelerator data seems to indicate furthermore a slow increase of $\langle P_t \rangle$ with primary energy from 10–30 GeV. There are also indications[5] from cosmic ray work that in the region of a few TeV, $\langle P_t \rangle$ for π^o is 0.51 $\pm$ 0.024 GeV/c. It is therefore not unlikely that $\langle P_t \rangle$ does increase slowly with energy. Therefore it would be interesting to obtain P_t distribution at 400 GeV; we propose to do this by carrying out measurements on secondary particles emitted in the backward hemisphere in the C.M. System.

1.4 Quarks

Nuclear emulsion is in some ways a better and unambiguous detector to search for quarks, as it permits very accurate and reliable ionisation measurements. We plan to use hypersensitive G5 emulsion for half of the stack. The relativistic singly charged particles will have a grain-density of about 35/100 μ and the quark with charge 2e/3 will therefore have a g.d. of 15.5/100 μ which is sufficiently large to enable the quarks to be identified uniquely from single events. Counting of just 500 grains on the quark and the same number on a neighbouring beam track yields a resolution of 7 standard deviations. The measurements are therefore relatively simple. However, as it is not practical in such an experiment to look at perhaps more than 10,000 interactions, the search for quarks is limited to a production cross-section of greater than about 30 μb at the relevant energies.

1.5 Other Information

In addition to the above important features (1.1 to 1.4), this experiment would also lead to useful information such as the angular distribution of created particles, the interaction mean free path which would give some indication whether cross section is increasing or decreasing with energy, and inelasticity in p-N interactions at 400-500 GeV.

It is therefore obvious that while this "old fashioned" experiment can't furnish the detailed information which one can get from sophisticated accelerator experiments, it can lead to valuable information in about 6 months after the exposure to the first beam at NAL.

2. Exposure and Experimental Details

2.1 Exposure Details

The stack would consist of 80 pellicles of nuclear emulsion, the top 40 being Ilford normal G5 and the remaining 40, Ilford hypersensitive G5; each pellicle will have dimensions of 15cm x 12cm x 0.06cm. The stack dimensions would therefore be 15cm x 12cm x 4.8 cm. The 15cm edge would be along the beam. The alignment of the stack with respect to the beam should be better than 6×10^{-3} radian.

External beams of course would be ideal as one can then ensure excellent alignment of the stack with respect to the beam line. As suggested by Prof. E. L. Goldwasser one can perhaps produce a beam of low intensity by placing a very fine wire in the internal proton beam. The exposure could then be made at a suitably large distance from the scattering source so that the intensity of protons is low enough ($10^4/\text{cm}^2$) and also the background due to the secondary particles would be small. If, however, this is not possible for some reason (or it might take too long before this is possible) and only an internal beam is available we propose the exposure to be made in the following way. The emulsion stack could be located close to the straight section of the vacuum pipe. The exposure would be made by letting the upstream ring magnet drop its magnetic field, enabling the beam to come out of the vacuum pipe. (If this is not feasible then an alternate method similar to putting the target in the beam could be tried. In this case the stack mounted on guide rails is allowed to drop such that as it reaches the beam line it is synchronised with the beam). Since in emulsion work one cannot work with an intense exposure, the overall exposure should lie between 5×10^3 and $2 \times 10^4/\text{cm}^2$, the optimum value to aim at should be $1 \times 10^4/\text{cm}^2$. The beam should preferably have a diameter of at least 5cm as it hits the stack.

As mentioned above, the alignment of the stack with respect to the beam should preferably be better than 6×10^{-3} radian so that the length of the beam tracks is at least 10cm per emulsion plate. As the beam has to pass through the walls of the vacuum pipe before entering the stack, there would be some background of secondary tracks depending upon the thickness of the vacuum pipe and the angle at which the beam hits it while emerging from the ring.

2.2 Experimental Details

The interactions would be obtained by the "along the track" scanning procedure to ensure an unbiased sample. Suitable criteria would be employed to select a sample of proton-nucleon type of collisions. Angular measurements would be made on all secondary tracks from this sample of p-N collisions.

All reasonably flat tracks emitted at angles greater than 4.0°, the median angle, would be followed through successive emulsions.

The secondary particles will have energies right from less than 100 MeV to few hundred GeV. While the high energy particles in the laboratory system are those emitted in the forward direction in the C.M. system, the low energy ones are those produced mainly in the backward direction in the C.M. system. At 400 GeV primary energy, the median angle which roughly demarks the forward cone from the backward cone is given by $\eta = \tan^{-1} 1/\gamma_c$ and as $\gamma_c = 14.14$, $\eta = 4.0^{\circ}$. If $\langle P_t \rangle = 0.35$ GeV/c $\langle p \rangle = 0.35/\sin 4.0^{\circ} = 5.0$ GeV/c. Therefore if we restrict to particles in the backward cone in the C. M. System, we would be dealing with particles which have momenta on the average less than 5.0 GeV/c. From the transverse momentum distribution we estimate that among the backward cone particles, there should be less than 2 or 3% particles with momentum greater than 10 GeV/c. It therefore seems that it should be possible to identify a major fraction of all the secondary particles emitted in the backward hemisphere by a combination of multiple Coulomb scattering, grain density and range measurements.

A quick scan would also be carried out to collect a large sample of events for the quark 'hunt'.

3. Scientific and Technical Competence

The Tata Institute of Fundamental Research has been carrying out extensive work on high energy physics using nuclear emulsions for a long time. Therefore adequate competence and facilities exist for all phases of this proposal such as design of experiment, processing of emulsions, scanning and data reduction, and interpretation.

REFERENCES

1. P. K. Malhotra, Nuclear Physics, 46, 559, 1963.

P. K. Malhotra, Proc. Int. Conf. Cosmic Rays, Jaipur, 5, 40, 1963.

2. R. A. Lundy, T. B. Novey and D. D. Yovanovitch

V. L. Telegdi, Proc. Informal Conf. on Experimental Neutrino Physics, CERN 65-32, 109, 1965.

3. W. F. Baker, R. L. Cool, E. W. Jenkins, T. F. Kycia, S. J. Lindenbaum, W. A. Love, D. Luers, J. A. Niederer, A. Ozaki, A. L. Read, J. J. Russel and L. C. Yuan, Phys. Rev. Letters, 7, 101, 1961.

4. P. K. Malhotra, P. G. Shukla, S. A. Stephens, B. Vijayalakshmi, J. Boult, M. G. Bowler, P. H. Fowler, H. L. Hackforth, J. Keereetaveep, V. M. Mayes and S. N. Tovey, Nuovo Cim., 40A, 404, 1965.

PKM/ssb.30.12.70