NAL PROPOSAL NO. 209

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A Study of 300 GeV/c pd Interactions in the Thirty-inch Bubble Chamber

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ABSTRACT

We are requesting 50,000 photographs in the bare deuterium-filled 30" bubble chamber exposed to a 300 GeV/c proton beam. A rapid, complete and systematic study of high energy pd interactions will complement similar studies of pp interactions which already have proved to be fruitful. In addition to studying the characteristics of pn interactions, a detailed comparison will be made between the acquired data and already existing 300 GeV/c pp data.

INTRODUCTION

The bare 30" bubble chamber studies of 100, 200 and 300 GeV/c pp interactions have already yielded interesting physics results.[1-7] In particular, the charged particle multiplicity distributions at high energies provide an opportunity to determine the validity of various multiparticle production theories such as the fragmentation model or the multiperipheral model. These pp studies have provided inclusive data which are used to test scaling in different reactions at these high energies. In addition, correlations between particles in the final state are studied.

This program of bare 30" bubble chamber studies of high energy hadron physics serves a twofold purpose. First of all, the data, which can be acquired rather simply and rapidly, can be used to test existing theories and to inspire new theories. Secondly, while these data do not represent high statistics, they are taken over the entire solid angle. This latter feature is extremely important in a new energy region so that reasonably unbiased survey experiments may be performed.

As a continuation of these bare bubble chamber studies, we are requesting 50,000 pictures of an exposure of the deuterium-filled 30" bubble chamber to 300 GeV/c protons. The choice of incident beam momentum and target are motivated by the following considerations:

a. The deuteron target allows one to study both pp and pn interaction, the latter complementing the pp and πp studies. (The details of the physics we will study are outlined below).

b. It is unlikely that high energy pd experiments will be performed either at the ISR or with Mirabelle in the near future.

c. Several members of this collaboration have already measured and analyzed pictures from the 300 GeV/c pp experiment.[5,6] This should greatly facilitate a detailed comparison of the pp and pd physics at the same incident beam momentum.

d. If the 30" chamber deuterium fill is coincident with sustained 300 GeV/c accelerator running, then a 300 GeV/c proton beam should technically be the easiest beam to supply to the 30" chamber.

ESTIMATES of YIELDS

The "exposure size" of the proposed experiment is ~1 ev/μb. This assumes a deuteron target, 50 K pictures, an average of 5 beam particles into the chamber per expansion, and a fiducial volume of 2 feet along the beam direction. For the yield estimate in the discussion that follows, we use the published 300 GeV/c pp[5,6] results which are based on a 6 K picture exposure in hydrogen with an average beam flux of 5 particles/expansion. We will also make the assumption, based on lower energy measurements, that the total pn and pp cross sections are equal.

THE DEUTERON TARGET

Use of deuterium as a ... ws us to look at reactions with pd, pp and pn initial ... se studies, especially those involving high multi ... reaction will be non-coherent, i.e., the beam p ... t with the p or n of the deuteron but not with t

Based on the total pp ... t at 300 GeV/c of 40 mb, we expect a total of 40,00 ... be divided into three categories:

a. Events which are clea ... e will be characterized by an even number of p ... oton track with momentum < 300 MeV/c (the maxi ... he spectator proton). This selection should inclu ... nts.

b. Events which are clea ... e will be characterized either by:

   i. an odd number of ... is unseen (~ 70% of true pn events).

   ii. an even number of ... rongs is a stopping proton of momentum < 300 ... ward direction in the laboratory systen ... .

   The percentages are ba ... pe of the momentum distribution of the spectat ... 70% of the spectator protons have a momentum below ... eshold for bubble chamber detection of the proto ... ion of the emitted spectator is, of course, isotrop

c. Ambiguities: These are events which cannot be unambiguously identified as pp or pn interactions. One source of ambiguities will arise from an inability to identify protons with momenta below 300 MeV/c emitted in the forward hemisphere as being recoil protons or spectator protons.

Of course, we realize that there will be other sources of ambiguities. For example, if a secondary interacts very close to the production vertex, the resulting event could incorrectly be classified as an odd or even prong if the secondary scatter is not identified. We emphasize that the availability of the 300 GeV/c pp data will be crucial in helping to untangle some of the confusion.

PHYSICS JUSTIFICATION

The specific type of physics we will initially study will parallel, to a great extent, the physics studied in the high energy pp experiments. In summary, we will study:

a. charged particle multiplicity distributions, both odd and even prong;

b. inclusive reactions involving diffractive dissociation of the neutron into two or more charged particles;

c. neutral V^0 production (including γ's);

d. study of inclusive distributions and correlations among final state particles for all particles in all events;

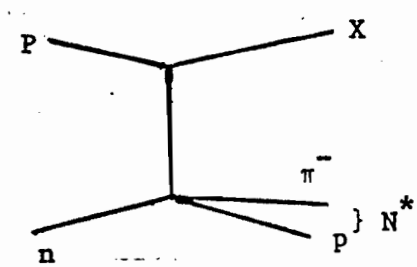
e. search for new phenomena.

(a) Charged Particle Multiplicity Distributions

We will measure σ_n, the cross-section for producing n charged particles in the final state, as a function of n. Present data do not strongly favor any one particular model predicting σ_n. The two most popular of these models are the fragmentation model and the two-component picture in which both diffractive and multiperipheral processes contribute to the production of multiparticle final states. In the proposed experiment, we will be measuring σ_n for both the pp and pn initial states. It will be interesting to explicitly compare the nature of the prong distributions for pn and pp interactions insofar as any significant differences would be extremely surprising from the point of view of all existing theories.

(b) Study of the Reaction $pn \rightarrow XN^*$

In order to gain an understanding of the diffractive processes, we will measure the reaction



by selecting those events with two slow protons and one (or three) slow tracks. We define slow tracks as those having $P_{LAB} < 1.4$ GeV/c, the momentum at which pions and protons can still be distinguished by ionization.

The reaction will further be identified by requiring that the mass recoiling against the slow tracks be small. Use of deuterium uniquely allows

one to study the πN decay of the N^* in this way since the neutron can diffractively dissociate into two charged particles. The relevant questions concerning us here are:

i. What is the cross section for diffraction dissociation at 300 GeV/c?

ii. What is the shape of the $\pi^- p$ mass distribution?

iii. What is the charged particle multiplicity of the X?

We expect about 10,000 events in this category.

(c) Study of V^0 and γ Production

As in the 200 and 300 GeV/c experiments, we will measure neutral strange particle decays, Λ^0, $\overline{\Lambda^0}$ and K_s^0, as well as γ's. The range of laboratory momenta thus measured will allow a study of the inclusive process

$$p\begin{pmatrix} p \\ n \end{pmatrix} \rightarrow V^0 + \text{anything}$$

for Λ^0, $\overline{\Lambda^0}$ and K_s^0 produced in the backward hemisphere, separately for different multiplicities. We expect to find $\sim$ 6000 events with neutral decays. We will use the measured γ's to estimate π^0 inclusive cross sections.

(d) Study of General Features of Multiparticle Production

There has been a lot of interest recently in looking for general features of multiparticle production. Current theoretical ideas fall into two categories, the fragmentation picture and multiperipheral picture of multiparticle production. In understanding how these multiparticle final states arise and in trying to choose which models the experiments favor, various distributions have been advocated as objects of study. These include inclusive distributions in

rapidities and correlations in these distributions in for various prong counts, for example. Berger[8] et al. advocate distributions in δ, the dispersion in particle rapidities in an event, as being particularly useful in choosing between multiperipheral and fragmentation models.

In this experiment, we will measure all tracks in three views for all events. In the 30" chamber particle momenta can be measured up to 15 GeV/c. For these particles rapidity can be measured exactly. For particle momenta greater than 15 GeV/c, the rapidity, y, can be calculated from a measurement of the particle's production angle θ to a good approximation as

$$y = -\log(\tan\theta/2)$$

These data will be used to:

a. look at inclusive distributions in rapidity and correlations in these distributions;

b. search for clustering phenomena and study the mass distribution of any clusters;

c. study distributions in δ, dispersion in rapidities in an event;

d. compare the characteristics of multiparticle production in the backward hemisphere with the forward hemisphere.

ANALYSIS

Scanning

Our plans are to scan the 50 K pictures carefully in at least two passes the first of which will be a physicist scan. Based on experience with the 300 GeV/c pp experiment, we estimate that 16 weeks should be sufficient to scan all of the film. Tentatively we plan to do all the scanning at NAL. During this 16-week period, one full-time physicist from Caltech will be at NAL.

Measuring

Again based on results of the pp experiment, we expect to measure slow tracks and V's in about 16,000 events. We expect that the measuring will be divided between NAL and Caltech. The measuring facilities at these institutions include:

NAL:	4 Micrometric Image-Plane-Digitizers
	2 MOM Film Plane Digitizers
Caltech:	POLLY (now starting "production" measuring)

We expect to complete measuring diffraction dissociation physics and events with V^0's in about 5-6 months from the end of the scanning period. Measurement of the projected angles will mean measuring about 400,000 tracks in 3 views based on $\langle n_c \rangle = 8.86$ measured at 300 GeV/c. This should require about 2 months of measuring time.

REFERENCES

1. J. W. Chapman *et al.*, Phys. Rev. Letters *29*, 1686 (1972).
2. G. Charlton *et al.*, Phys. Rev. Letters *29*, 1759 (1972).
3. G. Charlton *et al.*, Phys. Rev. Letters *29*, 515 (1972).
4. G. Charlton *et al.*, Phys. Rev. Letters *30*, 574 (1973).
5. F. T. Dao *et al.*, Phys. Rev. Letters *29*, 1627 (1972).
6. F. T. Dao *et al.*, Phys. Rev. Letters *30*, 34 (1973).
7. E. I. Malamud, "Recent Experimental Results at N. A. L." Paper presented at the 1972 Winter Meeting of the American Physical Society, Los Angeles, December 27, 1972.
8. E. L. Berger, G. C. Fox and A. Krzywicki, Phys. Letters *43B*, 132 (1973).