NAL PROPOSAL No. 173

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Proton-Deuteron Interactions in the Thirty-inch Bubble Chamber

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Abstract

We propose two exposures in the thirty-inch chamber filled with deuterium, using protons of 100 and 200 GeV/c, with 50,000 pictures at each momentum. We plan to study various properties of p-n interactions including odd-prong multiplicity cross section, single and double dissociation, average π° multiplicity, inclusive pion production, and correlations.

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I. Physics Justification

There are several reasons why it is important that such an experiment be done. There is currently great interest, but very little solid data, in high multiplicity hadron interactions above 70 GeV. It is important to compare p-n interactions with currently planned studdies of p-p and π-p interactions using the same techniques. The bubble chamber appears to be the best way to extract a sizeable fraction of the physics involved. Moreover, p-n interactions are of particular present interest for NAL since it is not likely they will be studied at the ISR or in Mirabel (at least not in the very near future).

Details of the main topics of interest in these exposures are as follows:

A. Odd-prong Multiplicities

Current bubble chamber data on charged multiplicity cross sections, $\sigma_n(E)$, from p-p interactions are shown in Figure 1. The following questions are of particular interest.

(1) What are the ratios of the various σ_n at a given E? The Hwa-Jacob-Slansky (HJS) type models predict $\sigma_n \propto n^{-2}$. Clearly such ratios must be tested at energies where the cross sections have already reached their limiting values and this apparently requires NAL energies. It also requires at least two energies in order to see to what extent the limits have been reached.

(2) In what manner are limits approached and what happens after that? There is some evidence already that σ_4 is decreasing with E. (see Fig. 1) It is important to measure the rate of decrease. The present experiment will allow us to investigate the other low-n cross sections, σ_3 and σ_5, for such behavior.

(3) H-J-S models predict $\langle n^2 \rangle$ grows as $\sqrt{s}$ whereas other models predict a slower ($\ell n\, s$) dependence. p-n interactions give <u>independent</u> evidence to compare with p-p and π-p data on all these questions.

We believe we can obtain reliable p-n data by restricting to those events where the spectator proton range is less than a few millimeters in the bubble chamber. Including the unseen spectators this should comprise about 75-80% of the p-n interactions. Low energy data indicate that such protons are truly Hulthén-like. We will, of course, need to study the energy and prong-number dependence of spectator protons in order to <u>test</u> the extent to which the spectator approximation can be believed.

It is our opinion that the requested exposures are justified on the basis of the physics described so far. We point out also that this physics requires essentially no measuring and can be done reliably and quickly. It would be best to do it concurrently with the analysis of our two similar p-p exposures (on which we are collaborating with Rochester).

B. <u>Single and Double Dissociation</u>

(1) A completely unanswered question at present is whether inelastic interactions can be described in terms of a "dissociation"

or "fragmentation" of the beam and/or the target particles. If such a description is possible it may occur with no quantum number exchange between beam and target clusters. In the language of H-J-S, the beam would produce n_1 particles and the target n_2 particles with the same net charge as the beam and target respectively. Such "allowed" values of n_1 and n_2 are listed in the table below. (In the table n_1 and n_2 refer to charged particles)

n	$= n_1 + n_2$ = number of charged prongs
2(pp)	1+1
3(pn)	3+0, 1+2
4(pp)	3+1
5(pn)	5+0, 3+2, 1+4
6(pp)	5+1, 3+3
7(pn)	7+0, 5+2, 3+4, 1+6
8(pp)	7+1, 5+3
9(pn)	9+0, 7+2, 5+4, 3+6, 1+8

As can be seen from the table, the study of p-n greatly enriches the possibility of finding and studying such behavior. (We note that σ_2 is difficult to measure in hydrogen because of the elastic background.)

(2) The possible <u>independence</u> of n_1 or n_2 is also of importance. This can be tested by relations such as

$$\sigma_{2+5} \stackrel{?}{=} \frac{(\sigma_{2+3})(\sigma_{1+5})}{\sigma_{1+3}} .$$

These relations can be tested with lower n values in p-n than in p-p. The cross-checks between p-p and p-n (such as above) are clearly of interest, and in fact necessary, if such relations are to be confirmed.

C. Average π° Multiplicity

This can be measured in p-d interactions by making use of a general theorem which states that (assuming I-spin is conserved) for any system with total initial I-spin 0 or 1/2, the average number of π° produced must equal 1/2 the sum of the average π^+ and π^-. In our case this will also hold for the subset of "spectator" proton events, so that in the spectator approximation the average π° number can be obtained for p-n interactions. Of course, one must count fast π^+ in order to do this but there will generally be at most one fast proton per event and their frequency can probably be fairly accurately determined. Thus in the relation

$$\langle\pi^\circ\rangle = \frac{1}{2}\langle\text{charged}\rangle - \frac{1}{2}\langle\text{protons}\rangle$$

a small uncertainty in the knowledge of $\langle$protons$\rangle$ will not significantly affect the meaningfulness of the result.

D. Inclusive and Semi-inclusive $\pi^\pm$ Production

(1) If no-isospin-exchange between beam and target clusters is a valid concept then the following relations between neutron and proton fragmentation must hold:

$$(p \to \pi^+ + \text{anything}) = (n \to \pi^- + \text{anything})$$

$$(p \to \pi^- + \text{anything}) = (n \to \pi^+ + \text{anything})$$

We should be able to test these relations, at least for low-n events, to see if no-isospin-exchange is indeed valid, and in what kinematic regions.

(2) The beam energy dependence of π^- production for each n value is straightforward and of great importance. Cosmic ray data indicate that the "tails" of the rapidity (y) distributions at high energy are depopulated. If this is true it is probably due to a fairly rapid fall with energy of the low-n cross sections in the large y region, and $n \to \pi^-$ may be one of the main culprits. The study of single pion production is much easier in $n \to \pi^- p$ than in $p \to \pi^+ n$.

E. Correlations

One wants to measure, for example, $\pi_1^- \pi_2^-$ transverse and longditudinal correlations as a function of $\Delta y = y_1 - y_2$. Do correlations fall as $\exp(-\Delta y/2)$ as some theories suggest? To do this one wants as large as possible Δy values. A reaction like

$$pn \to (p\pi^+\pi^-) + (p\pi^-)$$

requires one less pion than the p-p reaction

$$pp \to (p\pi^+\pi^-) + (p\pi^+\pi^-)$$

so a wider kinematic region is available.

We should be able to measure the y (related to log $\tan\theta_{lab}$) and φ_{lab} of the fast π^- with sufficient accuracy to make such tests.

II. Film Analysis

At present we have four scanning-measuring film plane projectors which handle 30-inch film. This should be sufficient to analyze the film in reasonably short time. We are also building a POLLY system which will start making its first useful measurements in January 1973, and this may turn out to be very useful in extracting more detailed information from the film at a later stage.

We believe that this experiment should be given as high priority as the other approved bare chamber p-p exposures and we would hope to obtain the film soon enough so that it can be more-or-less concurrently analyzed with our p-p exposures.

III. Special Equipment

The physics outlined above can be done using the "bare" 30-inch chamber and the emphasis for these exposures should be to operate in the normal bubble chamber mode. However it is possible that certain features of the data could be improved and additional useful information obtained by the simultaneous use of down-stream spark chambers. The usefulness of such additional data from both technical and physics standpoints is yet to be determined, but if the equipment is available we would, of course, like to make use of it.

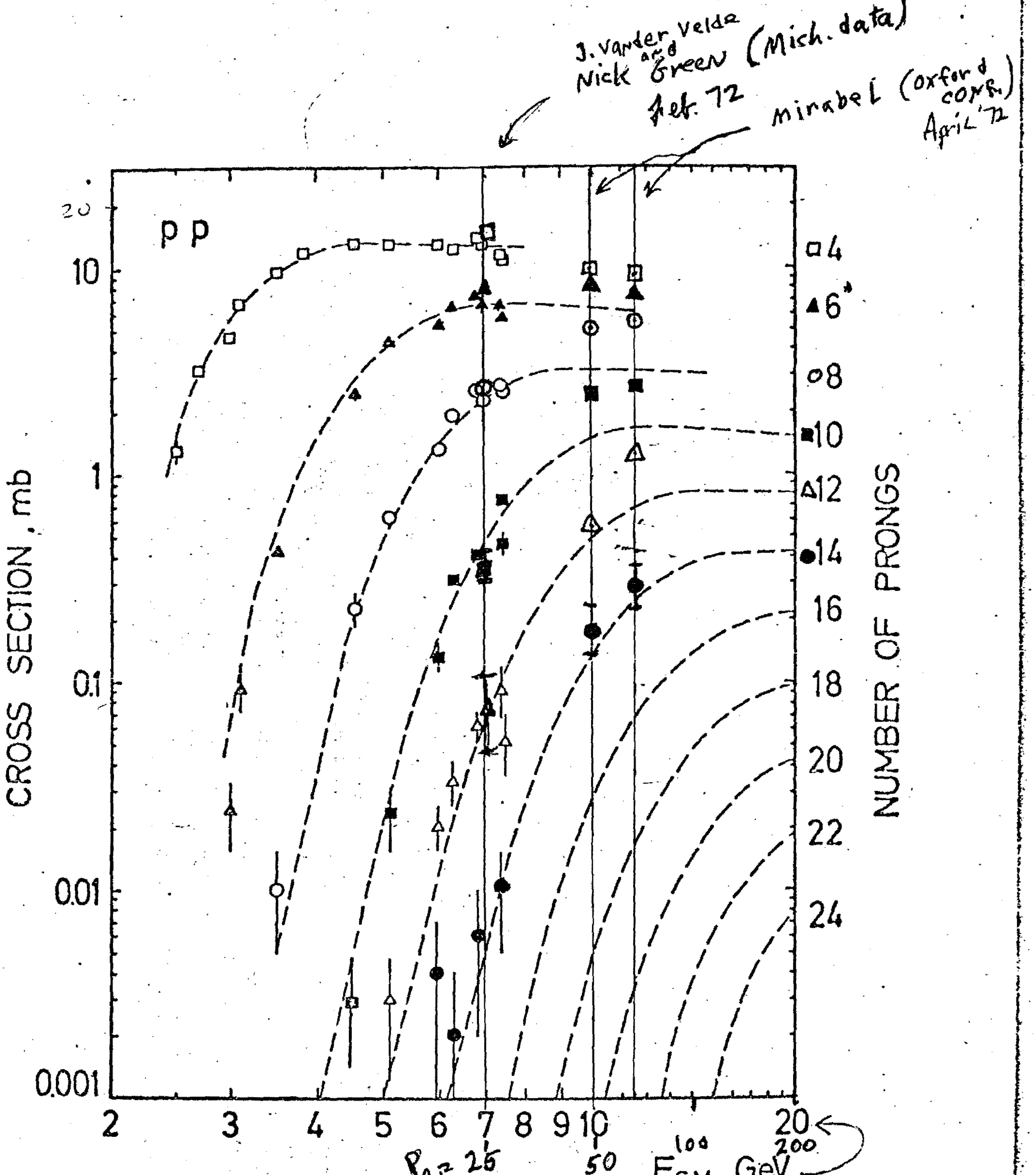
J. Vander Velde and Nick Green (Mich. data) Feb. 72
Mirabel (Oxford conf.) April '72
pp
CROSS SECTION, mb
NUMBER OF PRONGS
4
6
8
10
12
14
16
18
20
22
24
20
10
1
0.1
0.01
0.001
2
3
4
5
6
7
8
9
10
20
P_{lab} = 25
50
100
200
E_{CM}, GeV

Fig.1