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# PION-DEUTERON INTERACTIONS

# at 200 GeV/c and 400 GeV/c

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## ABSTRACT

We propose to study $\pi^-$ d interactions at 200 and 400 GeV/c in the NAL 30-inch bubble chamber. We will measure cross sections, charged particle multiplicities and momentum and mass spectra for $\pi^-$ n inclusive reactions, pion diffractive dissociation and neutron diffractive dissociation. We will search for the increase in the deuteron "screening" effect correction as predicted by Sidhu and Quigg.

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## I. Introduction

We propose an exploratory experiment to study diffractive dissociation and $\pi^-n$ inclusive final states in $\pi^-d$ interactions at 200 GeV/c and 400 GeV/c. the experiment would be conducted in the NAL 30-inch bubble chamber filled with deuterium. A limited exposure of 50,000 pictures at each energy will yield important information on cross sections, charged particle multiplicities and the mass spectrum of diffractively produced systems. The bare 30-inch bubble chamber is sufficient for this experiment. However, if a downstream spectrometer system is available, we would propose to use it to detect fast outgoing tracks which cannot be accurately measured in the bubble chamber.

## II. Physics

The purpose of this experiment is to utilize the properties of a deuteron target to look at phenomena which cannot be easily studied on protons. These are: (1) inclusive reactions such as $\pi^- + n \rightarrow \pi^{\pm} +$ anything, (2) diffractive dissociation of the neutron, and (3) diffractive dissociation of pions on deuterons and (4) a possible increase in the deuteron "screening" correction.

### Inclusive Reactions

Despite the existence of data on $\pi^-p$ inclusive reactions, it is no less compelling that $\pi^-n$ processes should also be studied. The $\pi^-+n$ topological cross sections can supply missing information on the odd-number charged particle multiplicities. These results can be compared with the even-number distributions from $\pi^-p$ interactions to see if they fit into the odd-number gaps, consistent with KNO scaling.

The single $\pi$ inclusive spectrum can give information about the role of isospin in the inclusive dynamics. By studying the fragmentation of the neutron

$$n \rightarrow \pi^{\pm} + \text{anything} \qquad (1)$$

and the corresponding proton data, a comparison of

$$(n \rightarrow \pi^- + \text{anything}) = (p \rightarrow \pi^+ + \text{anything})$$
$$(n \rightarrow \pi^+ + \text{anything}) = (p \rightarrow \pi^- + \text{anything}) \qquad (2)$$

will provide a test of I=0 exchange dominance.

### Cross Sections and Statistics

The $\pi^-n$ inclusive cross sections should be comparable to the $\pi^-p$ data.

At 200 GeV/c, $\sigma_T$ ($\pi^- p$) is 24.0± 0.5 mb.[1] Subtracting the elastic cross section (3.26 mb) leaves ~21 mb. At 4-5 beam tracks per picture, we estimate ~10,000 interactions of all multiplicities at each energy. These $\pi^- n$ events are characterized by an odd number of charged tracks with or without a slow spectator proton. A large fraction of the spectator events can be easily distinguished from either proton or deuteron interactions since the spectator will be emitted at backward laboratory angles.

Diffractive Dissociation

Diffractive dissociation is one of the most interesting phenomena which has been encountered in strong interaction physics. It is a manifestly inelastic scattering process which has properties such as angular distribution and energy dependence that are nearly identical to those of elastic scattering. It does not fit neatly into either the purely elastic or inelastic categories and it is therefore one of the least well understood scattering reactions.

Recently, new experimental results from NAL, Serpukov and the ISR are beginning to suggest that the cross section for diffractive dissociation is as large as that for elastic scattering. In addition, the first NAL bubble chamber experiments indicate that the charged particle multiplicities of diffractive reactions may be extremely important for understanding new results in inclusive reactions. The diffractive multiplicity is found to be completely different from that of ordinary multiparticle production. This has led to the idea of two-component theoretical models which contain both a diffractive and a nondiffractive or multiperipheral part.[2] The multiperipheral component is thought to be understood theoretically but little is known about the very high energy behavior of the diffractive contribution, either theoretically or experimentally. These two components are difficult to separate in the present inclusive data; it is therefore important to perform new experiments in which only diffractive dissociation can occur in order to study the exact nature of this process at high energies.

Coherent Production

A well-known technique for cleanly separating pion diffractive dissociation from other processes is to study coherent production on a deuteron or other heavy nucleus target. For the inclusive reaction

$$\pi^- + d \rightarrow d + x^- \qquad (3)$$

the recoil deuteron remains intact only if the $x^-$ system is coherently produced. This imposes several very important restrictions on the $x^-$ system and the exchange mechanism. The internal quantum numbers of x must be the same as those of the incident $\pi$ and the spin-parity series must be the same. The G-parity of the pion is also conserved which means only odd numbers of pions are diffractively produced. These are just the known properties of diffractive dissociation. A much more important restriction is obviously that the momentum transfer to the deuteron,

$$q \simeq M_x^2/2P_{LAB} \tag{4}$$

must be small, where $M_x$ is the mass of x and $p_{LAB}$ is the incident beam momentum. The above two requirements preferentially enhance diffractive dissociation over all other mechanisms in coherent production. Any reaction which involves a change in quantum numbers or large momentum transfer (e. g. due to spin-flip coupling) is suppressed.

The requirement that q be small is also essential for identifying diffractive dissociation events. A significant fraction of the observed events will be interactions on a proton or neutron rather than the deuteron. Since it will be extremely difficult to measure the momenta of all outgoing tracks at 200 GeV/c, there will be some difficulty in identifying deuteron tracks in the bubble chamber pictures. The usual kinematic fits (e. g. SQUAW) may not be able to separate deuterons from protons. However, the momentum-transfer dependence

$$\frac{d\sigma}{dt} \sim e^{At} \tag{5}$$

for coherent production has a very steep slope, $A \simeq 40\ GeV^{-2}$, because of the deuteron form factor. The recoil protons, on the other hand, come from non-coherent reactions involving breakup of the deuteron and therefore have slopes of 8-10 GeV . Thus, the coherent deuteron events can be selected by choosing only small t values, e.g., $t < 0.05\ GeV^2$.

The properties of coherent production therefore make it well suited to study at very high energies in a relatively small bubble chamber. Most of the recoil deuterons are expected to stop in the chamber and their momenta can be accurately measured from range and curvature. The slope of $d\sigma/dt$ is thus very well determined by the measurement of a single slow track in the bubble chamber.

All previous experiments on coherent production have been limited in their ability to study high masses and therefore high multiplicities because of the low energy beam. However, at NAL energies, the requirement that q be small can be easily satisfied for very large masses of the diffracted system x. From eq. (4), we can see that at $P_{LAB}$=200 GeV/c, t can be restricted to values of 0.05 $GeV^2$ or smaller, and masses of 5 GeV and greater can be produced. This may be relevant for understanding the rise in the total cross section recently observed at the ISR. Since the cause of the rise is unknown, it is clearly important to see if it may be coming from processes which were inaccessible to study at low energies. Diffractive dissociation into high mass states is one of these processes since it is strongly suppressed by the nuclear form factor at low energies. This process has also never been studied in hydrogen because of the difficulty of separating it from the many inelastic channels.

The Seattle group has been studying diffractive dissociation in $\pi^- d$ interactions at 15 GeV/c.[3] The Polish groups have photos of 25 GeV/c $\pi^- d$ interactions in a 2m bubble chamber. Thus, in a simple bare-chamber experiment there will result preliminary information on the behavior of diffractive dissociation over the energy interval 15 GeV/c to 400 GeV/c. In particular, the quantity $d\sigma/dt\,ds'$ , where s' is the mass squared of the dissociated system, will be studied for inclusive diffractive dissociation. This double differential cross section is believed to be a measure of the three-Pomeron coupling. Thus, this experiment will give preliminary information about the three-Pomeron coupling. Because of the deuterium target, there will be no contribution from isotopic spin one exchanges, which fact considerably reduces the number of three-Reggeon couplings.

<u>Neutron Diffractive Dissociation</u>

Deuterium is useful for the study of diffractive dissociation of neutrons. The dissociation

$$n \to p + \pi^- \qquad (6)$$

is known to have a large cross section ($>200\,\mu b$) at lower energies. The related processes in hydrogen,

$$\begin{aligned} p &\to p + \pi^0 \\ p &\to n + \pi^+ \end{aligned} \qquad (7)$$

are both 2-prong final states and much more difficult to separate from elastic scattering at 200 GeV/c. The neutron dissociation will be easier to identify since it will satisfy a 4-C fit in most cases. This will also make it easier to measure the higher multiplicity states, such as $n \to p\pi\pi, p\pi\pi\pi$ , etc.

At lower energies, meson diffractive cross sections are known to be larger than nucleon diffractive cross sections. The study of higher multiplicity states for both the pion and neutron at 200 GeV/c may provide further information that has been missing at lower energies.

<u>Cross Sections and Statistics</u>

According to various two-component model analyses of NAL and Serpukov data, the total diffractive cross-section may be as large as 3-4 mb in $\pi^- p$ [illegible] at 200 GeV/c. Less than 1 mb of this has been identified in 2 and 4-charged prong final states in a recent NAL bubble chamber experiment.[1)]

Lower energy data indicate that 1/3 are nucleon dissociation and 2/3 are pion dissociation. Thus we expect ~ 1 mb for nucleon diffractive states and ~ 4 mb for pions, where we have scaled by a factor of 2 for the deuteron target. At 4-5 beam tracks per picture, we estimate ~500 nucleon events and ~2000 pion events at each energy. Approximately 1/2 of the latter will have a deuteron recoil which is too short to be seen in the bubble chamber.

Deuteron Screening Corrections

Serpukov data show a rise with incident energy in the deuteron screening correction, $\delta\sigma$, defined by

$$\sigma_T(\pi d) = \sigma_T(\pi p) + \sigma_T(\pi n) - \delta\sigma \qquad (8)$$

The rate of increase form 20 to 60 GeV/c incident momentum may be parameterized by

$$\delta\sigma = \left(1.39 + 0.004\,(P_{LAB}/1.\ GeV/c)^{1.05}\right)\ mb$$

Sidhu and Quigg have computed the additional screening corrections that would arise from inelastic rescattering involving intermediate states reached by diffractive excitation. Their result for the rate of increase is in agreement with the trend of the data. Additional data at higher energies would help to clarify this effect.

The difference between $\delta\sigma$ at 400 GeV/c and its minimum value at ~30 GeV/c is about 3 mb if the trend continues. We expect that the total $\pi d$ cross section can be measured to an absolute uncertainty of ±2 1/2 percent, or ±1 mb. Thus we can expect to confirm this continued rise to 400 GeV/c at a confidence level of about 3 standard deviations.

## III. Experimental Apparatus

The film will be scanned in parallel at the four laboratories. Among them, there are 10 scanning tables available. These scanning tables will be operated 40 hours per week and we estimate the total experiment can be double-scanned in less than 2 months.

The VTL owns an Astrodata PEPR measuring machine connected to a PDP-10 computer. This system is used exclusively for bubble chamber data processing by the VTL. The PEPR system has already measured 40,000 $\pi^- d$ events from the SLAC 82-inch bubble chamber, so that no changes will be needed to measure the NAL experiment. By using the new VTL vertex guidance technique, we can measure 40 events an hour if all tracks need to be measured. The low multiplicity pion-diffraction events can readily be handled by PEPR.

In addition, the Institute of Nuclear Physics at Cracow has a "Sweepnik" automatic measuring device, and the Davis group has access to the LBL spiral reader.

Special classes of events may be measured on manually operated machines if necessary. Among the four collaborating groups, there exist 6 film-plane measuring projectors and 4 image-plane digitizers. Four of the film-plane devices have automatic track-following features.

Thus, the collaboration possesses the entire spectrum of measuring devices available today. If any one of them offers particular advantages for this film, that device is available to us.

Adequate computer facilities are available. The Cracow group and the Warsaw group each has a CDC 6500; the VTL has its own PDP-10, and the Davis group has a remote batch terminal accessing the LBL CDC7600 system.

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