NAL PROPOSAL #224

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Study of Diffraction Dissociation (Coherent and Incoherent) and Inclusive Parameters of the Interaction of High Energy Pions and Protons on Nuclei Heavier than Hydrogen

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Purpose: To study inclusive parameters of the interaction of high energy pions and protons and diffraction dissociation (coherent and incoherent) on nuclei heavier than hydrogen: carbon, aluminum, iron, and lead.

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NAL Proposal (30-inch Bubble Chamber)

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Beam: 200 GeV/c, Protons and negative pions

Pictures: 50,000 with 200 GeV/c p,
50,000 with 200 GeV/c π^-

Chamber: 30-inch, with an internal target of 4 elements: carbon, aluminum, iron, and lead. The chamber filling could be hydrogen, or a mixture of neon-hydrogen.
Simultaneous use could be made of the downstream wide-gap spark chambers of Experiment 2B.

I. Introduction

We propose to study reactions of 200 GeV/c negative pions and of 200 GeV/c protons on nuclei heavier than hydrogen using the 30-inch hydrogen bubble chamber Hybrid system. Reactions which occur in a four-element metal target located within the chamber will be studied. The physics motivation is two-fold: to study diffraction dissociation processes on heavier nuclei and to systematically study inclusive reactions and topological cross sections in heavier nuclei for clues to the nature of the fundamental particle-particle interactions. Simple things like the multiplicity distributions for coherent diffractions and incoherent interactions are clearly of great interest.[1]

II. Background

At this time we are coming to know with excellent statistics the inclusive distributions of secondary reaction products from pp and from πp interactions from 20 to 2000 GeV. We also know, from electron scattering and a variety of other data, the parameters characterizing the size and shape of heavier nuclei.[2] It should be straightforward, then, to combine these two kinds of data in order to predict the various inclusive distributions for protons and pions incident on heavy nuclei. That the situation is not this simple has been known in cosmic ray physics for over two decades.[3] Specifically, the average charged prong multiplicities from protons on nuclei at a given energy increase as $A^{0.1}$ to $A^{0.25}$, whereas a simple model of intranuclear cas-

cading would predict a very much more rapid increase of prong multiplicity with atomic mass number. This slow dependence on nuclear size has been explained as due to the "tunneling" of secondaries through the nucleus. It has also been noted that most resonances have a width of about 100 MeV or less so that their characteristic lifetime is about 6×10^{-24} seconds. For masses of about 1 GeV and energies of 20 GeV, ($\gamma \simeq 20$) the decay mean free path of such resonances is about 3.6×10^{-12} cm or several times the diameter of the target nuclei. Hence excited states of the incident particle generally decay following emergence from the nucleus, thus limiting the intra nuclear cascade.[4]

Several concepts have been put forward, and recent theoretical calculations indicate that significant information could be obtained concerning hadron structure (i.e. partons) by studying hadron-nucleus collisions.[5] However, the data are thus far simply inadequate to test these hypotheses quantitatively.

On the other hand, K. Gottfried has remarked about the average multiplicity (private communication): "... my own concern with these questions is based on my conviction that there is no tenable explanation of the weak A dependence of $\bar{n}$. ... I suspect that the explanation of the A dependence of $\bar{n}$ will provide a very difficult and incisive test of theories of multiple production."

Diffraction dissociation is believed to be an important process at high energies. There are some bubble chamber studies on heavier nuclei which confirm these processes,[6] and limited spark chamber experiments on specific diffractive

states on a broader spectrum of nuclei.[7] However, we know of no systematic study over all diffractive final states from a range of target nuclei. It is important to note that studies to date demonstrate that coherent diffraction dissociation is at least non-trivial; both s- and t-channel helicity conservation are violated and there is evidence for high spin states even at near-threshold mass values.[8] We believe that it is important to survey diffraction dissociation processes on heavier nuclei, and we believe that the bubble chamber is the most suitable tool for this survey. It has the combination of good resolution and wide angle acceptance which is essential for such measurements. It is the best tool for measuring topological cross sections.

The energy dependence of the various inclusive parameters which in turn depend on A would also be of interest, and, depending on what is learned from this experiment, subsequent experiments at NAL might be pursued at other energies and with other particles.

III. Target

We propose to construct a target of about 5% of a nuclear interaction mean free path made of four elements: carbon, aluminum, iron, and lead. Each element would be a plate of one square inch, with the four plates supported in a stainless steel holder about 6 in. inside the visible volume of the bubble chamber (to permit clear visibility of the incident beam and measurement of backward-produced tracks). The 4 in. high vertical "ribbon" beam would be incident on the 4 targets

simultaneously; their locations would be accurately seen on the film so that the originating element for each event would be determined on the scanning table.

As almost nothing systematic is known so far, data with any chamber filling would be of interest. However, a light neon-hydrogen filling, permitting studies of γ-conversions, might enhance the interest and utility of the results.

IV. Exposure

With 7 tracks per photograph and .05 λ_I for each target, every third photograph would contain a nuclear interaction in a heavy nucleus. In order to have a sample of 4000 interactions in each of 4 nuclei for protons and pions, we would need 48,000 proton photographs and 48,000 pion photographs. Therefore we request 50,000 200 GeV/c proton photographs and 50,000 200 GeV/c pion photographs. As <u>no</u> other data exist, any high energy is interesting. Thus if 300 GeV protons better matches the running schedule, we would use them.

V. Measurement

The scanning and measuring facilities at the University of Michigan (which includes a POLLY) would be used for this experiment. From the experience of Bingham and others with high energy events in heavy liquid bubble chambers we conclude that measurements will be sufficiently accurate to separate coherent from incoherent diffraction events. The coherent events on heavier nuclei follow an exponential t' dependence similar to elastic scattering; exp $(10A^{2/3})t'$, while incoherent

events generally fall with t'(=t-t min) as exp (10t'). Hence, a sample of coherent events of about 80% purity can be obtained by making a small t' cut, where $P_{\perp} \approx \sqrt{-t'}$ is the transverse momentum of the diffractively produced state. (Events with viable nuclear boil-off prongs can be eliminated to help purify the sample.)

In order to improve the angular and momentum resolution for the coherent separation it will be valuable to make use of the downstream wide gap chambers of Experiment 2B. This system makes the 30-inch chamber at 200 GeV comparable in resolution to the 80-inch chamber at 25 GeV. The fact that fast tracks coming from our target traverse 80% of the chamber is a definite aid in measuring their momenta. The experiment is altogether justified without the downstream chambers, however the resolution they provide would greatly assist the analysis of diffraction events.

VI. Related Experiments

We have submitted a nearly identical proposal to this for the BNL 80 in. bubble chamber for similar data at 20 - 30 GeV, so that energy dependence of various processes may be studied. The same four target elements will be used.

An unpublished extenstion of the Echo Lake experiment was run where targets of heavy elements (C, Al, Fe, Sn, and Pb) replaced the hydrogen target. These data include about 200 events of over 100 GeV in each of the heavier elements and is still being analyzed. Preliminary results are to

be presented at the Denver International Cosmic Ray Conference.[9] So far, the results confirm the slow change in $\bar{n}$ with A and corresponding slow but definite shifts in rapidity distributions.

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