304

REVISED

PROPOSAL FOR A STUDY OF THE INTERACTION OF HIGH ENERGY $\pi^{\pm}$ WITH URANIUM

to

Fermi National Accelerator Laboratory

W. D. Walker, L. Fortney, J. Loos, A. T. Goshaw,
W. Robertson and J. Lamsa
Department of Physics
Duke University
Durham, North Carolina 27706

1 October 1975

Spokesman - W. D. Walker
F.T.S. - (919) 684-8228

PROPOSAL:

To study high energy π interactions in a plate of a high Z material (U or Pb) placed in the 30" bubble chamber filled with hydrogen and followed by a Pb-Glass Cerenkov counter array. We also propose to use the MWPC system and Pb-Glass spectrometer to increase the precision of measurements of the fast forward tracks and γ-rays that are produced.

PURPOSE:

1) To determine the multiplicity distribution produced in high energy π-Uranium interactions and to compare this data with data obtained in hydrogen and neon.
2) To measure the inclusive momentum distributions of produced pions and protons and compare these data with the distributions found for neon and hydrogen.
3) To measure nuclear coherent $\pi A \rightarrow MA$, $M \rightarrow 3\pi$, 5π, etc.
4) To look at high $P_\perp$ ($>$ 1 GeV) events that are produced in the heavy nucleus.
5) To do a feasibility study for looking at π-γ collisions. The γ's being the virtual gammas produced by the high charge of a heavy nucleus.
6) To measure direct electron pair rates in a dense medium.

METHOD:

We propose to use the 30" FNAL chamber filled with hydrogen and with two thin plates of Pb or U on the upstream side. We also propose to use the PHC consortiums PWC and shower detector systems downstream to enhance our ability to measure high energy secondaries.

MOTIVATION:

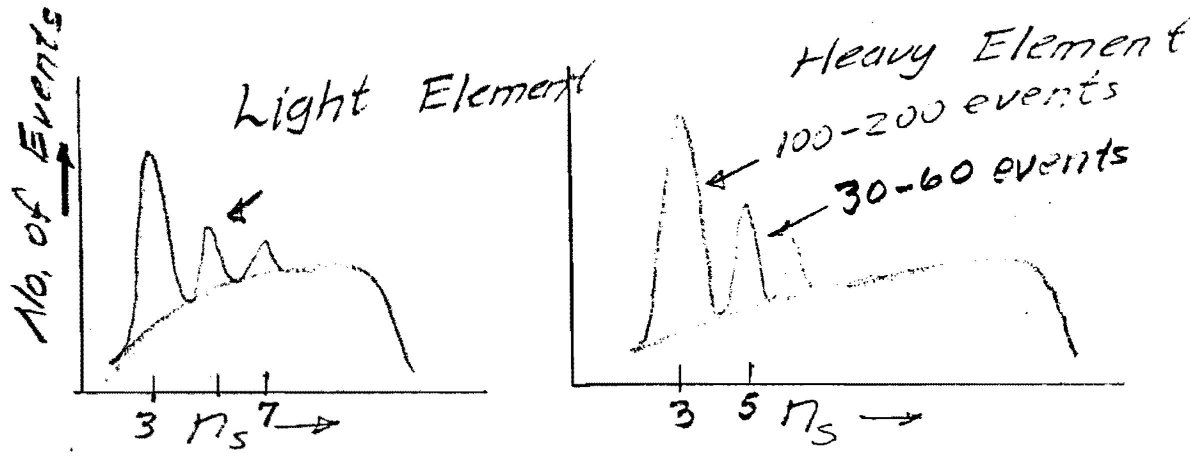
The purpose of this experiment is several fold. The first purpose is to study the incoherent π-U (or Pb) interactions. U is 7.7 nucleons thick which is over twice as thick as a Neon nucleus. We would measure the multiplicity of pions, K^o production in the heavy nucleus. We would also measure the rapidity spectrum of π's from the heavy nucleus. The importance of measurements of the rapidity distribution in distinguishing between different models of particle production has been stressed in recent papers by Koplik and Mueller.(1) Recent results of studies of 10 GeV π-Ne interactions are shown in Fig. 1. It is clearly necessary to extend these results both to higher energy -- to allow for a wider range of rapidity and to a heavier nucleus. We show in Fig. 2 the KNO multiplicity scaling curve for Neon and hydrogen. It is obviously important to see whether this scaling law holds for a heavy nucleus where the multiplicity will be nearly 2 times as great as in hydrogen.

INCLUSIVE DIFFRACTIVE:

In Fig. 3 we show the multiplicity distribution in π-Neon collisions at 200 GeV for cases with zero protons visible. There are prominent peaks visible for cases with 3, 5 and 7 prongs. These results suggest that it is possible to measure diffractive dissociation in an inclusive fashion. By going to a heavier nucleus, it may be possible to do this in a cleaner fashion since the incoherent interactions give rise to a peak in the multiplicity distribution at a higher multiplicity. This means that the background of

---

(1) High Energy Hadron - Nucleus Scattering by J. Koplik, A. H. Mueller (Columbia University preprint).



incoherent events should be less for a heavy nucleus than for the lighter nucleus such as Neon. This is an important point since we would select events on the basis of topology and lack of heavy tracks. This separation is much improved by having a higher multiplicity.

LARGE MOMENTUM TRANSFER EVENTS

In the last several years there has been great interest in the study of particles with large transverse momentum. As in any inclusive study, the bubble chamber possesses considerable merit. For interactions in Ne we find about 1 interaction in 5 has a particle with more than 1 BeV/c transverse momentum. The cross section for the production of high P_T particles is proportional to $A^{1.1}$ (A = No. of Nucleons). This means that it might be advantageous to look in Pb or U for high P_T events. We would like to look at high P_T (1 - 3 GeV/c) and find the relative frequency of single pions as compared with clusters of particles or resonances produced with high P_T. Also it would be very interesting to see whether high P_T events differ in a qualitative way from the average events. What can be done in a practical way is to look for particles with high P_T which occur outside of the forward jet of fast particles. This limits the momentum of the particles direct pair production is suppressed (because of multiple scattering or other dense medium effects) much more than predicted by theoretical calculations. This seems unlikely, but by measuring direct pair production in lead we can check this possibility. With 200K pictures (4 tracks/pulse) we would produce over 4000 direct pairs in the lead plates. After all cuts we would have a clean sample of approximately 1000 direct pairs (more than any previous experiment). This would allow us to make a good check of this basic Q. E. D. process in an unexplored physical domain.

EXPERIMENTAL DETAILS

We expect the order of 5×10^3 events in a 1 millimeter plate of Uranium for 100K pictures with four beam tracks per picture. The plate must be thin in order to limit the γ-conversion within the plate (1 mm is approximately 1/3 radiation length). For classes of events having low multiplicities, it would be possible to incorporate a second 1 mm plate a few inches downstream of the first and still obtain useful information from events produced in the first plate. Thus for some purposes we would expect 10^4 events per 100K pictures by using two 1 mm plates.

About one U event in 20 will be a π-γ interaction; thus we would expect 500 π-γ interactions per 10^5 pictures. It is important probably to have $\sim$1000 such events. For this reason it seems desirable to have 200K pictures with this set up.

CHAMBER SET-UP

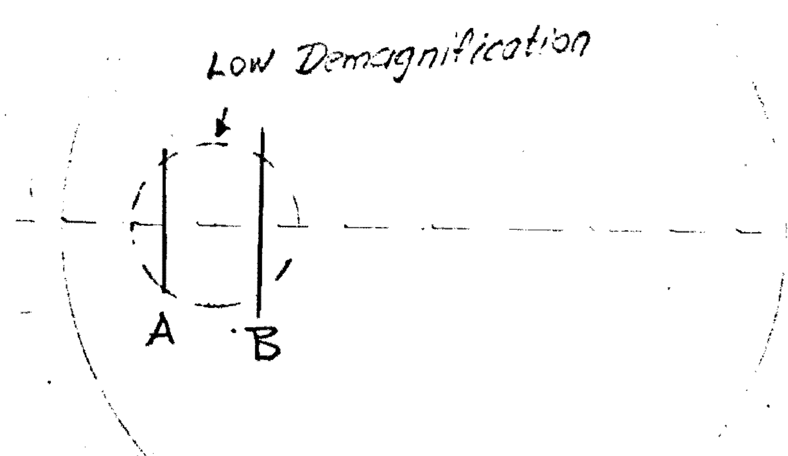


Plate A 6" high x 2" deep x 1 mm thick
Plate B 8" high x 4" deep x 1 mm thick

we look at to $\lesssim$10-15 GeV/c for $P_T \geq 1.0$ GeV/c. This means that we can efficiently search about 35% of the available phase space for high P_T tracks. For this domain we can do an interesting study of the characteristics of the events in which relatively large P_T tracks occur. With 200K pictures with two 1 mm thick pieces of Pb or U in the chamber, we can extend the search to a P_T of 3 GeV/c for interactions in the heavy nucleus.

π-γ INTERACTIONS

One of the uses of the high Z target would be as a source of virtual γ-rays. These virtual γ-rays are the target in this part of the proposed experiment. The total π-"γ" cross section should be approximately 100 mb for 300 GeV pions incident on U. This is to be compared to a total π-U cross section of 1500 - 2000 mb. One of the characteristics of such events might be a diffractive appearing event with an even G parity. The simplest example of such an event would be $\pi^- + \gamma \rightarrow \rho^- \rightarrow \pi^- + \pi^0$. Other more interesting (less studied) reactions would be $\pi + \gamma \rightarrow \pi + \omega^0$ or $\pi + \gamma \rightarrow \pi + \phi^0$. Note that both of these reactions can be well studied with the proposed apparatus and, in particular, the downstream γ-detection. The ϕ^0 could probably be detected because the dominant decay $\phi^0 \rightarrow K^+ + K^-$ will look like an electron pair but will not register in the Pb-Glass as an electron pair.

DIRECT PAIR PRODUCTION

Our group has recently measured direct pair production by 200 GeV π^- mesons from a hydrogen-neon mixture and found excellent agreement with Q. E. D. This result is in contrast to several emulsion experiments where large descrepancies with Q. E. D. have been reported. The emulsion targets used are about ten times as dense as the hydrogen-neon target we used. If the emulsion experiments are correct, the reason might be that

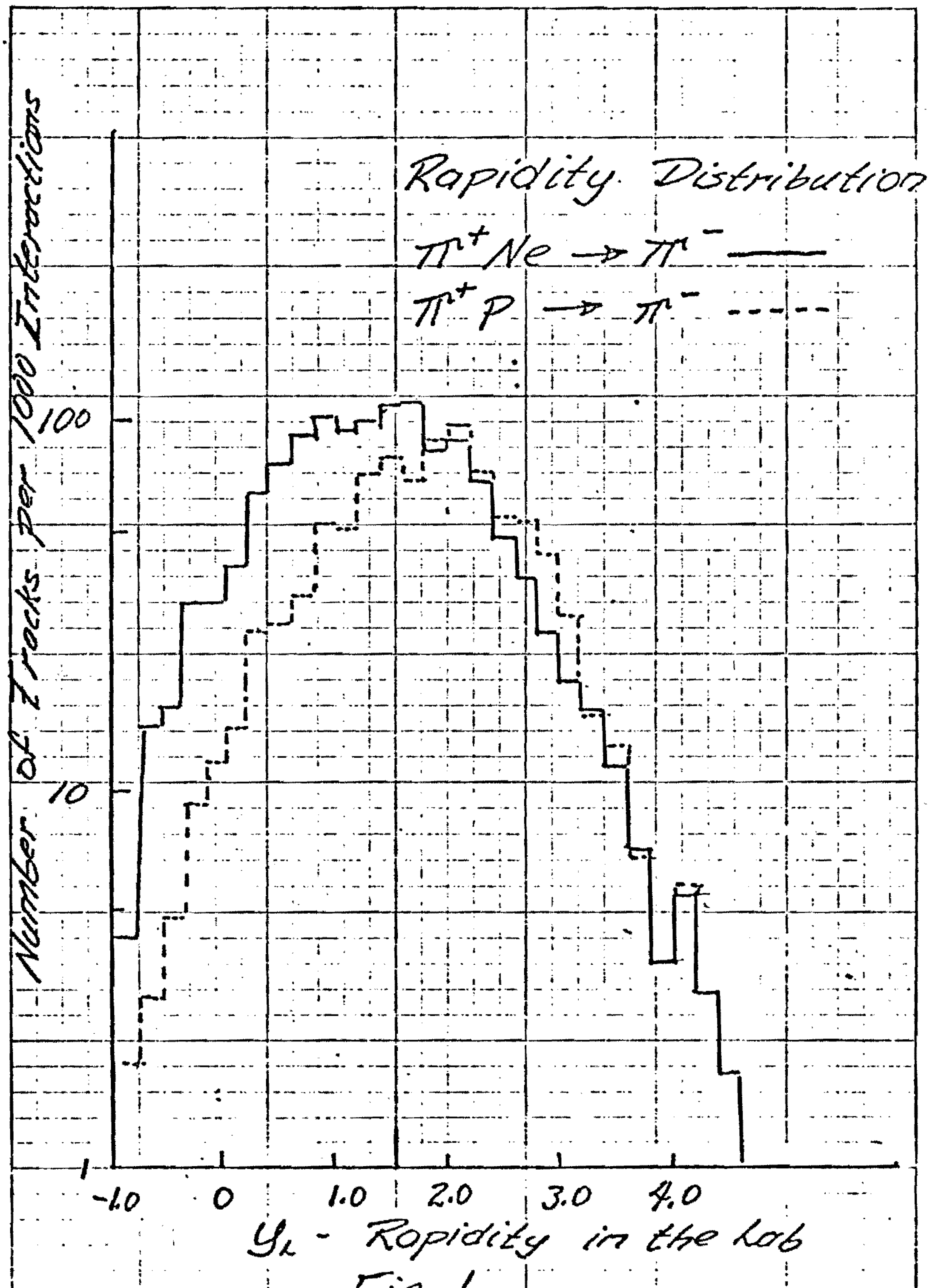
In order to be able to have better track determination between plates and close to the vertex, we would propose a fourth camera at the normally unused upstream port. This camera would have a lens which would view only the vertex region and would have a demagnification of perhaps 6/1. We would also propose to run the camera at a lower f-stop to decrease the bubble diameter. This would allow close scrutiny of the vertex region and allow a more accurate ionization determination and of track count between the plates. It will also allow the possibility of examining the interactions closer to the main vertex to look for evidence of very short lived objects (charmed particles).

In summary we want:

1) 200K pictures of 300 GeV π^-.

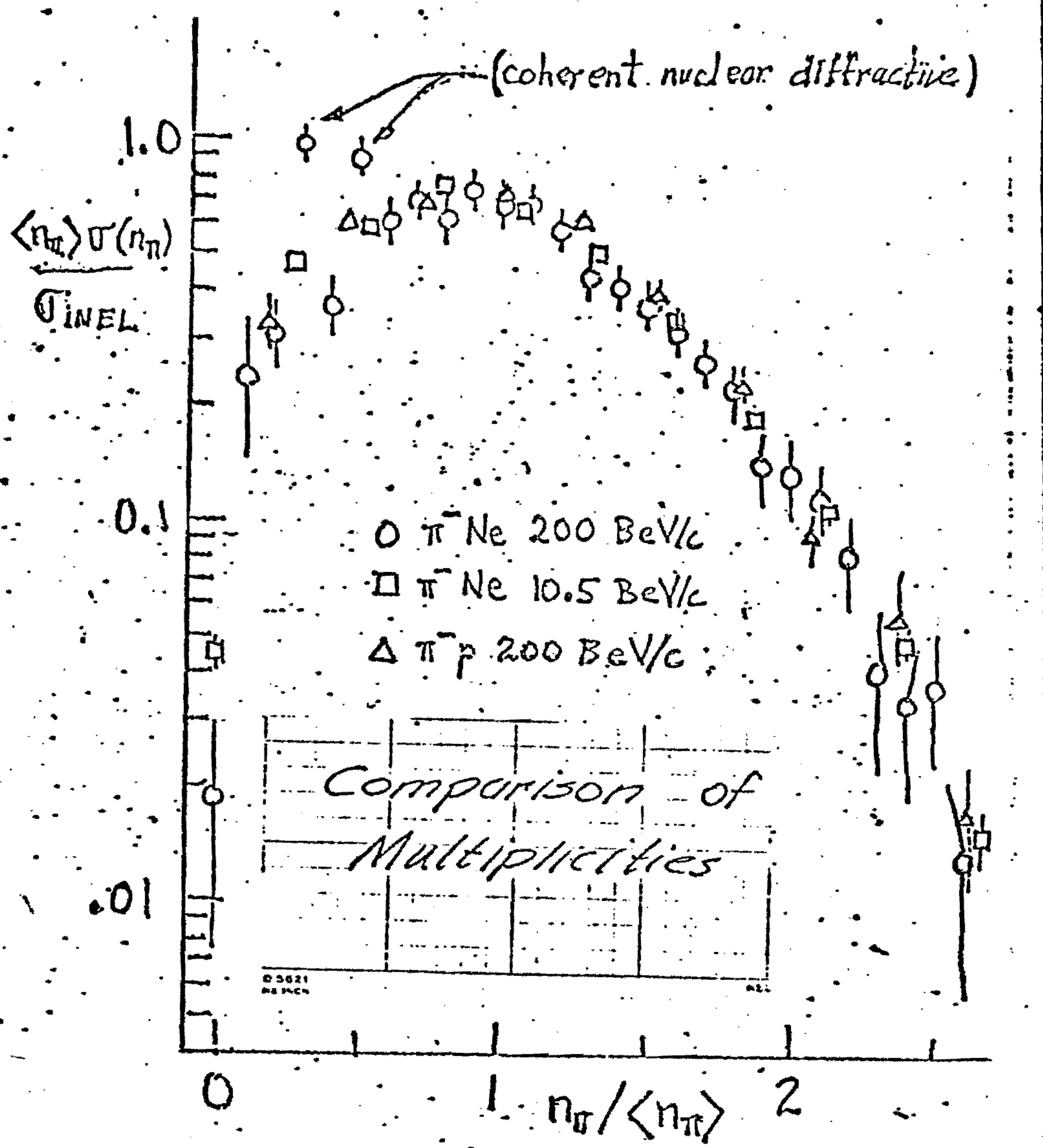
2) Two thin heavy metal plates in the chamber. The working fluid should be hydrogen to allow better measurements and ionization determination.

3) Use of the MWPC and γ-detector downstream.



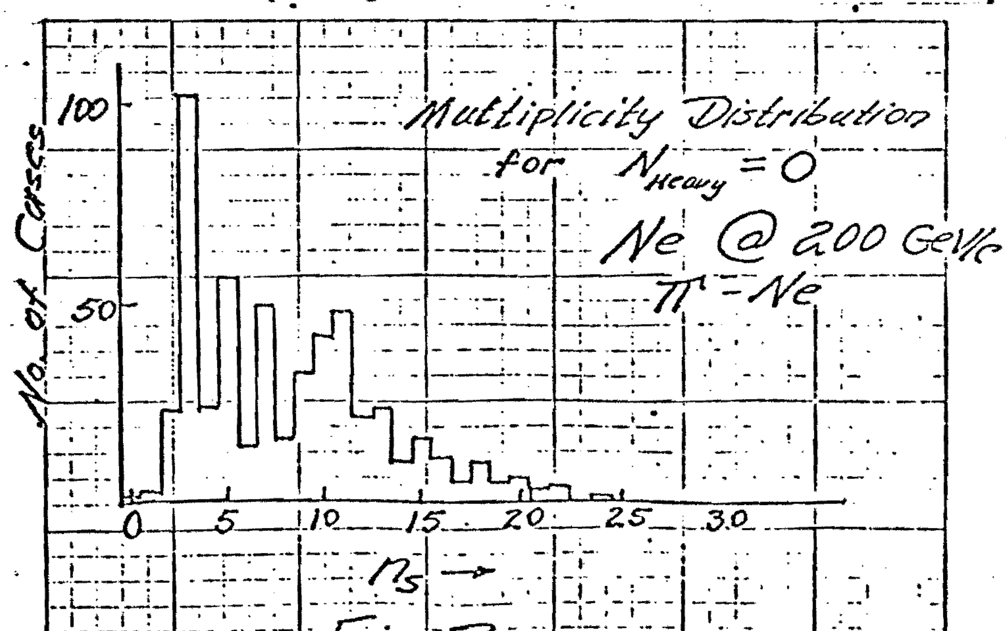
Rapidity Distribution
$\pi^+ Ne \rightarrow \pi^-$
$\pi^+ p \rightarrow \pi^-$
Number of Tracks per 1000 Interactions
100
10
1
-1.0
0
1.0
2.0
3.0
4.0
y_L - Rapidity in the lab

Fig. 1



(coherent nuclear diffractive)
1.0
0.1
.01
$\langle n_\pi \rangle \sigma(n_\pi) / \sigma_{INEL}$
O π⁻ Ne 200 BeV/c
□ π⁻ Ne 10.5 BeV/c
Δ π⁻p 200 BeV/c
Comparison of Multiplicities
0
1
2
$n_\pi / \langle n_\pi \rangle$

Fig. 2.



Multiplicity Distribution for $N_{Heavy} = 0$
Ne @ 200 GeV/c
π⁻-Ne
No. of Cases
100
50
0
5
10
15
20
25
30
n_s →

Fig. 3.

DIFFRACTION DISSOCIATIONS OF THE COULOMB FIELD
BY HIGH ENERGY HADRONS ON HIGH Z TARGETS[+]

W. D. Walker

Department of Physics, Duke University, Durham, North Carolina 27706

We propose a set of experiments to measure the cross section of vector mesons on various projectiles. By using Fermilab energy π's incident on U cross sections of the order of a millibarn are likely.

[+] Work supported in part by the U. S. Atomic Energy Commission under Contract No. AT-(40-1)-3065.

In the last twelve years high energy physicists have become quite used to considering the collisions of high energy particles with virtual pions in the peripheral regions of the nucleon. The use of the concept of the virtual pion has opened up the whole field of pion-pion physics. In this note we point out the possibility of a similar sort of investigation that may be undertaken using the virtual quanta associated with the Coulomb field of a high Z nucleus.[1] We know that the photon is intimately coupled to the vector mesons ρ^o, ω^o, ϕ^o, the ρ'[2] and the recently discovered ψ[3] mesons. From a study of the diffraction production of ρ^o, ω^o, ϕ^o in γ + nucleon $\rightarrow$ ρ^o, ω^o, ϕ^o + Nucleon, we know approximately the strength of the coupling of these objects to the photon. Thus if we can use the Coulomb field as a virtual source of ρ^o, ω^o, ϕ^o's, this would, in principle, be a means of studying the interactions of the vector bosons with elementary particles.

The idea involved in such a process is simple enough. The Coulomb field associated with the nucleus appears as a cloud of photons when viewed from the rest frame of the projectile. By using the idea of vector dominance we know that some of the virtual photons will appear as ρ^o, ω^o, ϕ^o, etc. There may be either elastic or inelastic collisions between the projectile and the vector meson. The kinematics are fairly simple. Imagine a case of π incident which produces a ρ^o collinear with itself. In the special case of collinear π and ρ^o the momentum that must be transferred to the nucleus is

$$\Delta_{\parallel} = \frac{m_\rho^2}{2P_\rho} + \frac{m_\pi^2}{2(P_i - P_\rho)} - \frac{m_\pi^2}{2P_i} .$$

P_ρ, P_i are the momentum of the ρ^o and the momentum of the incident π, respectively. Note that usually $\Delta_{/\!/} = \frac{m_\rho^2}{2P_\rho}$. Also note that the mass of the π-ρ system is approximately $=\sqrt{\frac{P_i}{P}}\ m_\rho$.

Let us consider the simplest experiment, namely, π-ρ scattering. A uranium or lead target could be illuminated by pions of 300 or 400 GeV at Fermilab or CERN II; the virtual ρ^o's in the Coulomb field can be scattered by the incident π. The lowest momentum ρ that can be made coherently on uranium is about 12 GeV/c. (This corresponds to having $\Delta_{/\!/} = \frac{\hbar}{R}$ for a nuclear radius $R = 1.3\ A^{1/3}$.) For a 300 GeV π, the π-ρ system has a mass 3.8 GeV/c^2. Thus one can study π-ρ systems of up to 3.8 GeV/c^2 in mass. This means, likewise, that one could study any system of π + vector meson by such an experiment. If, for example, a ψ(3100) were produced, the minimum momentum of the produced ψ would be 200 GeV/c.

The potential interest and utility of this sort of experiment is really quite great. One can imagine illuminating a photon target with various projectiles π, K, μ, ν, γ, Σ^-, Λ^o. Each projectile listed allows the possibility of an initial state that is unattainable in any other way. What we specifically stress, however, is the possibility of measuring the elastic vector-meson-projectile cross sections. By measuring $\frac{d\sigma}{dt}$ and extrapolating to $t = 0$ and using the optical theorem, one can estimate (or at least determine an upper bound) for projectile-vector meson cross section. It is interesting to contemplate looking at projectile-vector meson scattering in an inclusive fashion;

this, however, is complicated by the mixture of ρ^o, ω^o, ϕ^o, etc. in the target. In the case of a π incident, one could separate the target particles in part by using the G-parity quantum number. A particularly intriguing possibility would be that of doing ρ^o- ρ^o, ρ^o-ω^o scattering by using photons on a high Z target. The competition with electromagnetic processes would limit the target thickness to a few millimeters of the high Z material. Such scatterings would be in two substates of $m_z = 0, 2$.

The real possibility of such experiments will ultimately depend on the size of the nuclearly induced background. Incoherent interactions between projectile and target will tend to produce rather high multiplicity interactions which should be easy to discriminate against. The coherent interactions of the projectile with the nucleus will be the main source of background. The cross section for such interactions tend to be of the order of 5 per cent of the inelastic projectile-nucleus cross section.[4] We are concerned with a special part of that cross section, namely, that part in which a sizeable rapidity gap exists between the vector meson and the projectile, and with the vector meson the slower particle in the laboratory. A hadronic process of this sort has a cross section which is probably between 1 and 10 per cent of the total coherent cross section. Clearly, it will be necessary to study the nuclear background. An additional cut can be made requiring a helicity of $\pm$ 1 for the recoiling vector meson. The coherent nuclear processes which have the same kinematic characteristics are interesting processes in their own right. They might represent elastic diffractive scattering off a ρ^o, ω^o, etc. in the nuclear field of the nucleus.

One can estimate the cross section for photon processes fairly simply. In Fig. 1 we show the result of a Weiszacker-Williams[5] calculation which gives the effective number of photons per GeV/c, N(K), in the π rest frame. The overall energy of the π-γ system is $\sqrt{2Km_\pi}$. The cross section per GeV/c for a given process would be $(g_{\gamma v})^2 \times \sigma_{v-\pi}(K)\, N(K)$.[6] The differential cross section for elastic scattering would be given by $\frac{d\sigma}{dt} = (g_{\gamma v})^2 \times (\frac{1}{4\pi})^2 \sigma_{v-\pi}^2 e^{At} \times N(K)$. In Fig. 1 we also give an estimate for the cross section for $\pi + U \rightarrow \pi + \rho + U$ from the virtual photons.[7]

We believe that if these experiments are feasible (that is, if the nuclear background is low enough) then this type of experiment would add a new dimension to hadronic physics.

These considerations were stimulated by conversations with Professor J. Rosen.

REFERENCES

[1] The idea of using the Coulomb field as a source of virtual photons is an old one dating back to the original work of E. J. Williams and C. F. von Weizsacker. In this case, we are particularly concerned with the diffractive scattering of these photons on various projectiles rather than the dissociation of projectiles by photons as stressed by M. L. Good and W. D. Walker, Phys. Rev. 120, 1855 (1960).

[2] Vector dominance has been particularly stressed by Sakurai, J. J. Sakurai, Ann. Phys. (New York) 11, 1 (1960).

[3] J. E. Augustin et al., Phys. Rev. Letters 33, 1406, 1453 (1974); J. J. Aubert et al., Phys. Rev. Letters 33, 1404 (1974).

[4] J. Elliott et al., Phys. Rev. Letters 34 (March 1975).

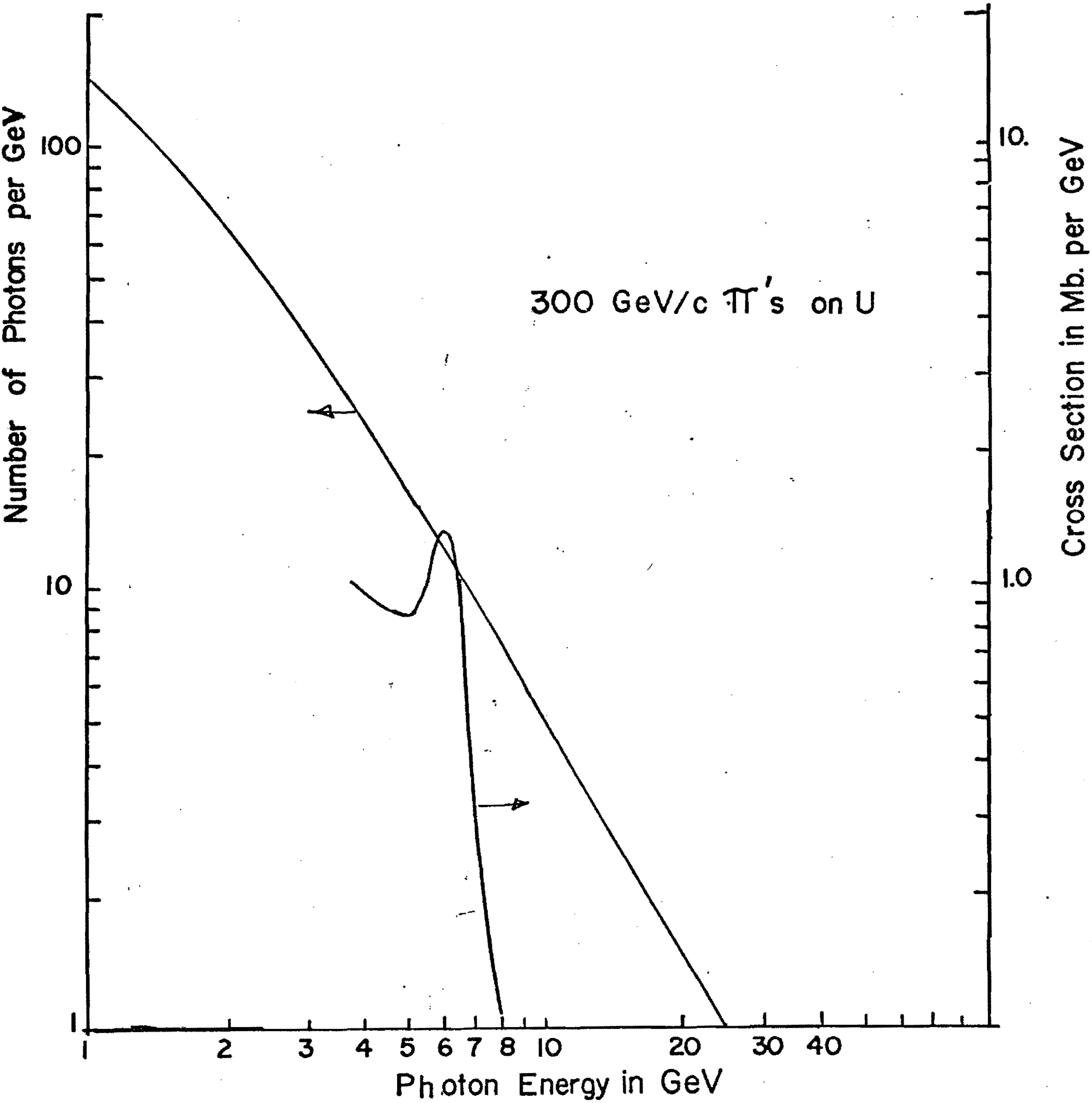
[5] J. D. Jackson, Electrodynamics, (John Wiley, New York, 1962). We used the formulae as given by this source to calculate N(K) the effective number of photons.

[6] We used the same notation as in M. Ross and L. Stodolsky, Phys. Rev. 149, 1172 (1966). We have used coupling constants etc. as summarized by G. Wolf in Proc. 1971 Conference on Electron and Photon Interactions at High Energy, Lab of Nuclear Studies, Cornell Univ. p. 190.

[7] The estimate of the π-ρ cross section is estimated on the basis of the elastic π-π in the same energy range. The A_2 π-ρ scattering is assumed to be 70% elastic in the A_2 region. The fall-off on the high side of the A_2 in addition to the decrease in the resonant 2^+ amplitude the falling elastic cross section because of the onset of inelasticity in the scattering process.

FIGURE CAPTION

Fig. 1. The effective number of virtual photons is plotted against the photon energy in the π rest frame with the ordinate on the left side. The cross section for $\pi + U \longrightarrow \pi + \rho + U$ is plotted against photon energy with the ordinate on the right.



300 GeV/c π's on U
Number of Photons per GeV
Cross Section in Mb. per GeV
Photon Energy in GeV
100
10
1
10.
1.0
1
2
3
4
5
6
7
8
10
20
30
40

ADDENDUM TO PROPOSAL No. 304

π - γ Scattering

Since our proposal was submitted we have taken 50K pictures in a Ne-H_2 mixture in the 30" chamber. We have worked quite intensively on these pictures. Our preliminary findings influence our proposal with U or Pb in the 30" chamber.

One of the things we propose to do in the U experiment is to look at the diffractive-appearing events in which relatively slow ρ^o, ω^o, ϕ^o's are produced. Since diffractive events form a topological background, it becomes important to do a careful study of the diffractive events in neon and hydrogen. Because the average multiplicity of incoherent events is much higher ($\sim 11\ \pi^{\pm}$) we know the incoherent background in such events to be quite small. We have a sample of about 200 - 3π events which seem to be coherent Ne diffractive events. We need to separate these into $(3\pi)^-_{ch}$, $(3\pi)^-_{ch}\,\pi^o$, $(3\pi)^-\,2\pi^o$ states on the basis of the number of γ's found. We believe this study is important in its own right. In any event, we need more pictures in neon to do a useful piece of work on this subject. We also find that a small fraction of the 3π events look qualitatively like $\pi + (\rho^o)_{slow}$. We need more neon pictures for this aspect of the study as well.

Large Momentum Transfer Events

In the last couple of years there has been great interest in the study of particles with large transverse momentum. As in any inclusive study the bubble chamber possesses considerable merit. For interactions in Ne we find about 1 interaction in 5 has a particle with more than 1 BeV/c transverse momentum. The cross section for the production of high P_T particles is proportional to $A^{1.1}$ (A = No. of Nucleons). This means that it might be advantageous to look in Pb or U for high P_T events. What we would like to do is to look at high P_T (1 - 3 GeV/c) and find the relative frequency of single pions as compared with clusters of particles or resonances produced with high P_T. What can be done in a practical way is to look for particles with high P_T which occur outside of the forward jet of fast particles. This limits the momentum of the particles we look at to $\lesssim$ 10 - 15 GeV/c for $P_T \gtrsim 1.0$ GeV/c. This means that we can efficiently search about 35% of the available phase space for high P_T tracks. For this domain we can do an interesting study of the characteristics of the events in which relatively large P_T tracks occur. With 150K pictures in Neon we can search up to a P_T of about 3.0 GeV/c. With 150K pictures with an 8 mm piece of Pb or U in the chamber we can extend the search to a P_T of 3 GeV/c for interactions in the heavy nucleus.

Number of Pictures

We believe that we have made a good case for a study of interactions in a heavy nucleus such as Uranium. We also realize that some effort will be involved in mounting a pair of plates in the chamber (although this was done at Argonne on the desired side of the chamber). If, in spite of our arguments, the committee would defer our U run we would like to continue our work in neon - H_2 with the same mixture as before. If there are plates in the chamber, we can continue our present work with a more restricted fiducial volume.

With pieces of U or Pb in the chamber the fiducial volume of the chamber would be reduced by about a factor of 2 so far as studies of π interactions with Ne and H are concerned. We believe additional pictures would be essential for completing our studies of these interactions. We thus request either 150K pictures with the U or Pb plates in the chamber or 100K pictures in the chamber with no plates. We would plan to use either the MWPC system or the wide-gap chambers for downstream measurements. We would propose to use 200 GeV/c π^- as the incident particle in either case.

FERMILAB PROPOSAL No. 304

Scientific Spokesman:

W. D. Walker
Department of Physics
Duke University
Durham, North Carolina 27706

FTS/Comm: (919) 684-8228

Proposal for a Study of the Interaction of High Energy $\pi^{\pm}$ with Uranium

W. D. Walker, L. Fortney, J. Loos, A. T. Goshaw, W. Robertson, J. Lamsa

Duke University

May 21, 1974

PROPOSAL FOR A STUDY OF THE INTERACTION OF HIGH ENERGY $\pi^{\pm}$ WITH URANIUM

to

National Accelerator Laboratory

W. D. Walker, L. Fortney, J. Loos, A. T. Goshaw,

W. Robertson and J. Lamsa

Department of Physics

Duke University

Durham, North Carolina 27706

21 May 1974

Spokesman - W. D. Walker

F.T.S. - (919) 684-8228

PROPOSAL:

To study high energy π interactions in a plate of a high Z material (U or Pb) placed in the 30" bubble chamber filled with a hydrogen-neon mixture. We also propose to use the wide gap spark chamber spectrometer to increase the precision of measurements of the fast forward tracks that are produced.

PURPOSE:

1) To determine the multiplicity distribution produced in high energy π-uranium interactions and to compare this data with data obtained in hydrogen and neon.
2) To measure the inclusive momentum distributions of produced pions and protons and compare these data with the distributions found for neon and hydrogen.
3) To do a feasibility study for looking at π-γ collisions. The γ's being the virtual gammas produced by the high Z charge of a heavy nucleus.
4) To look for higher order electromagnetic effects.

METHOD:

We propose to use the 30" NAL chamber filled with a hydrogen-neon mixture (30 percent mol/fraction neon) to give a radiation length of about 1.5 meters. We also propose to use the existing wide gap chamber system downstream to enhance our ability to measure high energy secondaries. We propose to place a thin plate (3 mm) of U on the upstream side of the bubble chamber. We need about 100,000 pictures of this sort.

MOTIVATION:

The purpose of this experiment is threefold. One purpose is to study the background of nuclear origin which is produced by high energy π interacting with a heavy nucleus such as that of lead or uranium. We propose eventually to do an experiment to look at π-γ interactions, depending on the outcome of this work.* The interaction would consist, for example, of the collisions between π and ρ^o meson, π and ω^o, and π and ϕ^o mesons. The simplest conceivable experiment would be to look at the elastic scattering of π's by these various vector mesons. The vector mesons would come from the virtual quanta in the field of the uranium or lead nucleus.

The second motivation for the experiment comes from our desire to follow up our work which consists of a systematic study of the collisions of high energy particles with medium and heavy nuclei. This study has been done to date using neon as a target in a neon-hydrogen mixture in a bubble chamber. By using either lead or uranium, we would approximately double the thickness of the nucleus which is one of the relevant parameters in a systematic study of this subject. Our main target to date has been neon with

---

*On the Use of High Z Targets

A = 20, which nucleus has a thickness of 3.4 nucleons. We propose in this run to use U^{238} as our target. This nucleus is 7.7 nucleons thick at the center -- thus a bit more than two times as thick as the neon.

A third possible motivation comes from the observation of fantastic showers occasionally emerging from the stainless windows of the bubble chamber. We see 200 - 400 particles emerging from the window. These are probably just electromagnetic showers, but it is worthwhile seeing if these might not be produced in a single interaction rather than a cascade phenomenon. No one has really looked for higher order electromagnetic phenomena (multi-electron production by γ's).

LOW ENERGY RESULTS

We will summarize our results to date which come from an experiment we have done with 10.5 GeV/c π^+ and π^-. The multiplicity of pions produced is slightly higher in neon than in hydrogen (approximately 20 percent). The momentum distribution of the π's is essentially the same for hydrogen and neon for the fast π's ($p \gtrsim 1.5$ GeV/c). For very slow π's ($p \lesssim 0.15$ GeV/c) the number of π's in Ne is 3 - 6 times higher in Ne than in H. This produces an interesting picture of the interactions in Ne. The incident π goes through the nucleus interacting one or more times. The fragments of the incident particle are not terribly different from those produced in a hydrogen collision although some absorption undoubtedly occurs. The slow π's are radiated from the various nucleons excited along the path of the incident pion. The distribution in angle of the slow π's is nearly isotropic in the laboratory and their intensity is 3 - 6 times as great as the number produced in a single π-nucleon collision. This radiation seems somewhat similar to Cerenkov radiation in nature (i.e., a degree of coherence between various source points).

Another interesting characteristic of π-Ne collisions seems to be the production of relatively high momentum nucleons (2 - 3 GeV/c).

It will be very interesting to see if the isotropic, low energy radiation increases very much as the thickness of the target nucleus is increased. This might be of some practical significance in building intense beams of very low energy pions for medical purposes, for example.

We can also expect to see if the number of fast protons increase proportionally as the nuclear thickness increases.

USE OF THE NEON-H CHAMBER:

We propose to fill the chamber with a neon-hydrogen (30 percent mole/fraction Ne) in addition to having a thin U (or Pb) plate in the chamber. This will have a number of useful purposes.

1) Make it possible to determine the average number of π^0's produced in the heavy nucleus.

2) To identify electrons emerging from the U plate. For example, a π - ϕ collision would give rise to a 10 - 15 GeV/c ϕ^0 which might decay into a closely correlated pair of K^+ - K^-. This K pair would look like an electron

pair. The neon-hydrogen mixture would help identify and remove the $e^+ - e^-$ pairs.

3) A direct comparison of diffractive cross-sections in Pb and Ne. A comparison may be made of $\pi \rightarrow 3\pi$ on Pb and Ne and hydrogen. This comparison would be relatively independent of scanning and triggering efficiencies.

PLATE GEOMETRY:

We propose putting a thin U plate perhaps 5" from the upstream edge of the bubble chamber. Since U has a short radiation length ($\sim$ 3 mm) we would propose making a slice of the plate quite thin ($\sim$ 1 mm) to cut down on the γ-conversion in the plate. Alternatively we might have two plates, a thick one (6 - 7 mm) followed by a thin one (1 mm) with a 1" separation. The thin plate would be used in the multiplicity study whereas the thick plate would be used for the γ-ray study.

We propose to fabricate the plate assembly so that it could be removed through the piston cylinder in the top of the chamber. The idea being to remove the plate without having to pull off the bubble chamber window.

ON THE USE OF HIGH Z TARGETS

W. D. Walker
Department of Physics
Duke University
Durham, North Carolina 27706

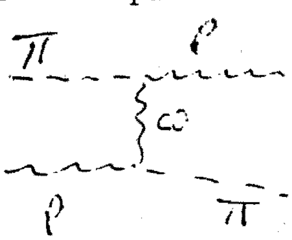
In the last twelve years high energy physicists have become quite used to considering the collisions of high energy particles with virtual pions in the peripheral regions of the nucleon. The use of the concept of the virtual pion has opened up the whole field of pion - pion physics. In this note we point out the possibility of a similar sort of investigation that may be undertaken using the virtual quanta associated with the Coulomb field of a high Z nucleus. We know that the photon is intimately coupled to the vector mesons ρ^o, ω^o, ϕ^o and perhaps the ρ'. From a study of the diffraction dissociation of ρ^o, ω^o, ϕ^o we know approximately the relative strength of the coupling of these objects to the photon. Thus if we can use the Coulomb field as a virtual source of ρ^o, ω^o, ϕ^o's, this would in principle be the simplest means of studying the interactions of the vector bosons with elementary particles.

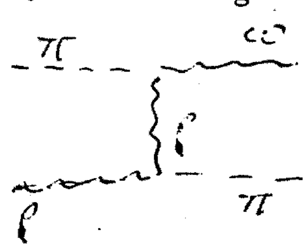
Let us discuss shortly the simplest system, namely, the π-ρ. What seems feasible is to illuminate a Pb or U target with NAL energy pions. The simplest experiment in some ways would be to look at π-ρ elastic scattering. The produced system would be a G = -1 system and would be mixed with the G = -1 diffractively produced system. The difference between these two systems at least in the A_1 region has to do with the helicity of the ρ. The ρ's associated with the A_1 tend to be helicity 0 whereas the ρ's associated with photons have helicity $\pm$ 1.

The cross sections for the diffractively produced and electro-produced ρ's seem to be rather comparable if one uses the Weizsacker-Williams method of calculating the effective γ-ray flux produced by a lead nucleus and extrapolates the CERN-AGS cross sections on diffractively produced $\pi \rightarrow 3\pi$.

This technique should allow one to measure π-ρ (and π- ω^o and π-ϕ^o) total cross sections up to 3 to 4 GeV total energy if one uses 300 GeV π's at NAL by measuring the elastic cross section and using the optical theorem. In the mass range above the A_2 the elastic scattering is probably diffractive with the ρ^o going backward which means that it ends up with relatively low energy in the laboratory (10-30 GeV). In the energy region below the A_2, if there is an A_1 one might expect to see it rather clearly in such a reaction.

π- ω^o scattering is presumably as interesting as π- ρ^o scattering and does not have the diffractive background to complicate the reaction. The comparison of π-ρ^o and π- ω^o scattering is a very interesting topic





by itself, presumably the same matrix element involved in π^o decay would be involved in U-channel scattering. π-ϕ^o scattering is probably feasible also although this has the smallest production cross section because of the γ - ϕ coupling constant. As to the possibility of doing inclusive π-ρ, π- ω^o, π-ϕ^o scattering is more difficult to judge feasibility, since we have no priori way of guessing whether there are simple signatures allowing one to discriminate against background readily.

One can certainly imagine doing similar experiments with other hadronic projectiles. It would be of considerable interest to do $K + Pb \rightarrow K + \rho + Pb$. One can probably measure K-ρ^o, K-ω^o, K-ϕ^o total cross section in the manner described above. In an inclusive study the separation of K-ρ^o, K-ω^o, K-ϕ^o collisions is not possible because the G-parity quantum number is not helpful in discriminating the three different reactions. One can also imagine doing similar experiments using photons and neutrinos. Both these projectiles have special interest. Photons as projectiles are particularly interesting in that they can be considered as ρ^o, ϕ^o, ω^o which scatter from the target ρ^o, ϕ^o, ω^o in all combinations. (Super Delbrück Scattering!) The competition of the usual electromagnetic processes in the case of the photons would make it necessary to use a rather thin target of the high Z material.

The interaction of ν's with photons seems to be a nearly unexplored domain. Such reactions as $\nu + \rho^o \rightarrow \mu^- + \rho^+$ would be expected for a charged current. On the other hand $\nu + \phi^{o} \rightarrow \nu + \phi^{o}$ might be expected to have a larger cross section for neutral currents.

In conclusion we believe that the ideas presented are worthy of considerable interest and indeed open some new vistas for experimentation at NAL and higher energies.