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MULTIPARTICLE PRODUCTION IN π-p COLLISIONS AT 100 GeV

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SUMMARY

We propose to study the meson showers produced in $\pi^+ + p \rightarrow p + X^{\pm}$ at 100 GeV. We measure the proton recoil to determine the momentum transfer and the mass of $X^{\pm}$ with proportional wire planes, using the Chicago 170" cyclotron magnet as a spectrometer. The same magnet also measures the number and momentum distribution of the particles comprising $X^{\pm}$. A special π^o detector measures the number of π^o's and their energy. Special attention will be given to coherent diffraction processes.

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Multiparticle Production in π-p Collisions
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We propose an experiment to examine in some detail the multiple production of pions in π-p collisions at 100 GeV. In our experiment we identify and measure the proton recoiling from the collision and then measure the multiplicity and the momentum distribution of the accompanying mesonic shower. We propose to measure:

1. The elastic πp cross-section over a wide range of momentum transfer $0.1 \leq -t \leq 15$ GeV^2 or until the cross-section $d\sigma/dt$ drops below 10^{-33} cm^2/GeV^2/c^2.

2. Using proton recoil measurements above, the mesonic missing mass cross-sections over a wide range of possible mass and momentum transfer.

3. The multiplicity and momentum distribution of the charged and neutral particles in the mesonic shower over a wide range of mass and momentum transfer. We should be able to identify completely a large class of such events.

4. Reactions of the type

$$\pi + p \rightarrow (2n+1)\ \pi + p$$

have a particular interest, inasmuch as such combinations of an odd number of pions might represent Regge recurrences of the pion which could be produced by a coherent diffraction process with substantial cross-section at 100 GeV.[1]

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[1] M. L. Good and W. D. Walker, Phys. Rev. 120, 1857 (1960). See also P. Franzini, "Third International Conference on High Energy Collisions", Stony Brook, New York (1969) Gordon and Breach, New York, p. 97.

ARRANGEMENT

Our arrangement is shown in Figure 1. It consists of a single magnet, the Chicago 170" cyclotron magnet, which serves the dual purpose of analyzing the recoil proton and the pionic shower at the same time. Extensive use is made of proportional wire planes to trace the orbits of the particles. These operate well in the magnetic field and are placed in different strategic locations, according to the momentum transfer range being covered.

PROTON RECOIL SPECTROMETER

Figure 1 indicates how we would measure the proton recoil corresponding to well defined values of momentum transfer from $-t = 0.13$ to $12.5\ (\mathrm{GeV/c})^2$. Higher values of momentum transfer are also accessible, but the trajectories have not been drawn in this figure. In the range $0.1 \leq -t \leq 2.0\ (\mathrm{GeV/c})^2$ the trajectories fall sufficiently within the magnet pole area to permit emission angle and momentum to be measured by measuring 3 points on the circular orbit by wire planes. For $-t \geq 2.0\ (\mathrm{GeV/c})^2$ we depend on 5 wire planes, two inside the magnet and three outside to establish the trajectory sufficiently well to determine θ_p and p_p with high precision.

In the range of small momentum transfers positive identification of the proton can be made by time of flight (together with the momentum measurement provided). For the high momentum transfers in which the trajectories leave the magnet, we will depend on Cerenkov counters (not shown) to identify the proton.

As an example, Figure 1 shows the arrangement that is suitable for measuring the proton recoil in the momentum transfer range near $-t = 0.5\ (\mathrm{GeV/c})^2$. The wire planes are arranged to measure the radius vector from the center of the orbit to the point of emission with high precision. In this example, assuming 1mm measurement accuracy for the wire planes we can establish the momentum to

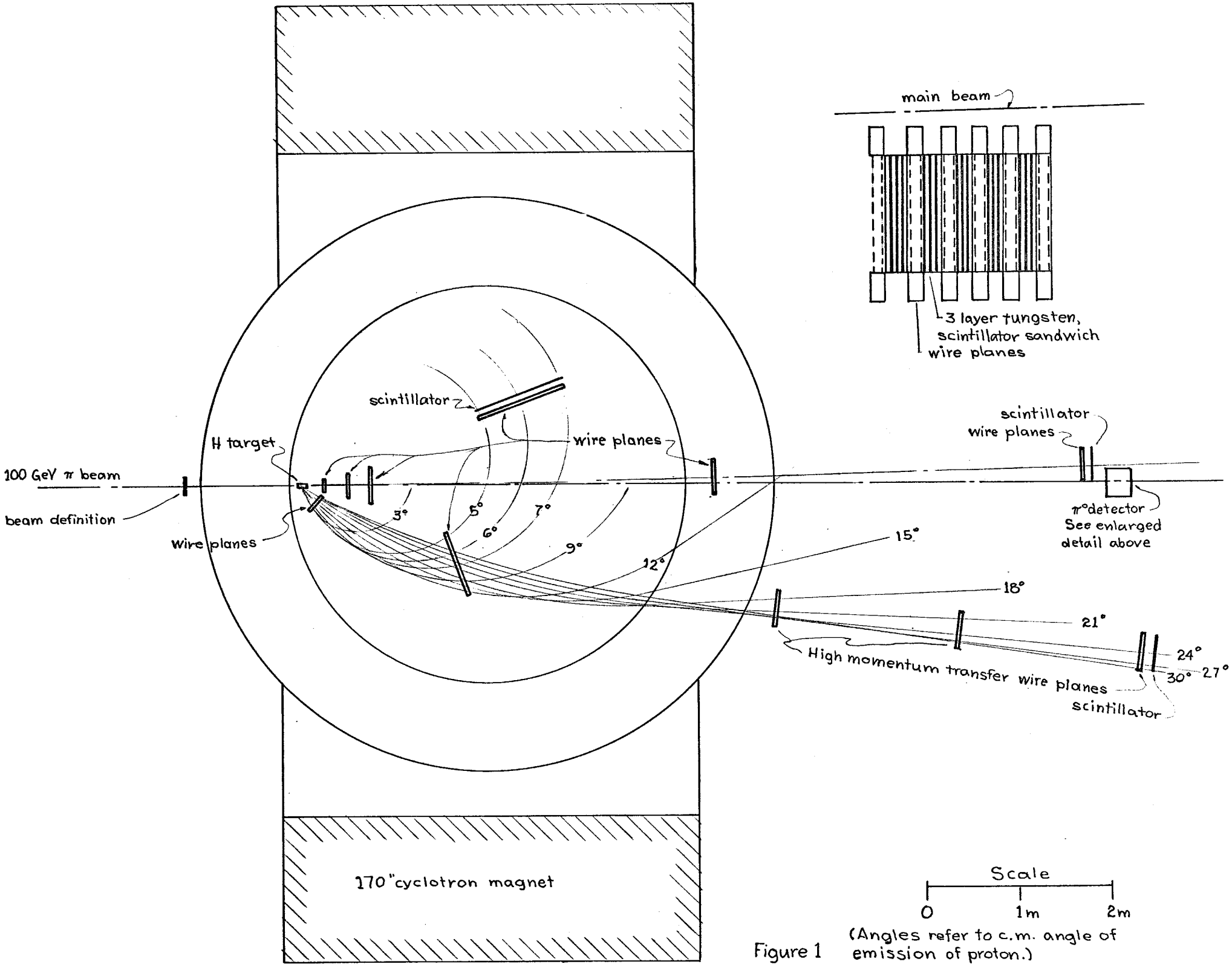

Figure 1 (Angles refer to c.m. angle of emission of proton.)

0.04% and the emission angle to 0.8 mrad. For a determination of the mesonic missing mass, multiple scattering in the liquid hydrogen of the target is a major limitation. Taking 10^{-3} radiation lengths as the amount of material traversed, the uncertainty in ΔM^2 amounts to 0.2 $(GeV/c)^2$. This requires that the beam direction be known to better than 1 mrad, and we intend to provide a set of small high resolution (0.2 mm) wire planes to measure this for each incoming particle that produces an event.

The resolution ΔM^2 improves for larger values of -t, but worsens for smaller values ($\Delta M^2 \simeq 0.6$ GeV^2 at $-t = 0.13$ $(GeV/c)^2$), but this is mainly due to the thickness of hydrogen traversed and this could be reduced if a special effort were made.

Time of flight is measured by means of a scintillator behind the final wire plane in the proton orbit. This requires a long light pipe to keep the photomultiplier out of the magnetic field. This should pose no special difficulty since there is plenty of light and the difference in flight time for a proton and a π of the same momentum is 7.5 ns, enough to accomodate a reasonable amount of time dispersion in the light pipe. The time of flight is referred to the time of the pulse at the far end of the pion spectrometer.

We use the wire planes in a decision making mode and ask them to accept as good events only those which give a signal from the single particle in the final pair of planes in the proton orbit. The planes are arranged to have 255 wires encoded into an 8 bit word. The calculation of θ_p and p_p can be done easily and quickly using a Sigma 3 computer on-line. Thus we will be able to accumulate a missing mass spectrum on-line from the proton recoil events alone. The time of flight requirement need not be imposed as a condition for accepting an event. This requires at least 1 pion with momentum large enough and emission angle small enough to enter the downstream counters. This should be the case most of the

time, but we will want to examine those events which manage to circumvent this condition.

MESONIC SHOWER

The mesonic shower will be recorded using a triplet of wire planes close to the target to detect the low momentum particles and an additional triplet of wire planes to provide a measurement of the momentum and emission angles of the high momentum particles. By and large, most of the momentum will be carried by particles emitted at angles less than 10 mrad. So this array should be able to detect almost all of the charged particles in the pion shower. High momentum (100 GeV) π's can be measured with an accuracy of about 3%.

π^0 DETECTOR

The π^0's will be detected using a total absorption γ ray detector placed on the beam axis. The magnet deflects the 100 GeV beam particles so that these miss this array of counters. The detector measures the total energy of the γ rays with a tungsten-scintillator sandwich. We provide 15 radiation lengths of tungsten and use wire planes to determine the origin of each shower (if there are more than 1). Thus, we should be able to determine how many π^0's there are and determine how much energy they carry.

With this combination of momentum and energy measurements we should be able to account for the total available energy, 13.7 GeV in the center of mass, in a substantial fraction of the events.

DATA ANALYSIS

The information from the wire planes in the meson shower spectrometer may be quite complex. We plan to read them out on tape for analysis off line on a

large computer. We should be able to handle certain simple types of information, such as the number of particles traversing each plane on line on our Sigma 3 computer. Simple events such as the elastic scattering and the proton recoil missing mass spectrum will be handled on-line and the results displayed as the run proceeds.

RATES

In the arrangement as shown for the measurement near $-t = 0.5\ (\mathrm{GeV/c})^2$ the range of momentum transfer covered is $0.45 \leq -t \leq 0.58\ (\mathrm{GeV/c})^2$. In this momentum range we expect a cross-section, for elastic scattering alone, $\frac{d\sigma}{dt} = 1\ \mathrm{mb/(GeV/c)^2}$ with a 10 cm liquid hydrogen target and 10^6 π's / pulse. This gives 1.8 events per pulse. Rates for inelastic events will be comparable. Rates will be higher (especially for elastic scattering) at lower values of -t. They will decrease rapidly, at least for the elastic scattering, at higher values of -t. However, because of the large acceptance in -t at $-t = 12(\mathrm{GeV/c})^2$, we can expect 1 event/day for a cross-section of $10^{-33}\ \mathrm{cm}^2\ (\mathrm{GeV/c})^2$. The inelastic processes of interest here should have cross-sections considerably greater than this because of the large number of detectable channels.

REQUIREMENTS

The experiment has been designed for the high energy high resolution pion beam with 10^6 pions/pulse assuming 1 second spill. We can manage 10^7 pions/second and would improve our rates by a factor of 10 if this could be provided so that the high intensity pion beam is also a possibility. We prefer a small beam spot of 1-2 mm diameter and small dispersion. The angular dispersion is of primary importance, but we plan to install small high resolution wire chambers in the incident beam line to measure this for the beam particles that produce our events.

We will provide a Cerenkov counter in the beam to identify K's and $\bar{p}$'s if it turns out that the contamination of these particles is more than 1-2%.

We will want to do the experiment with π^- as well as π^+. (The figure has been drawn assuming π^+).

CYCLOTRON MAGNET

The 170" Chicago cyclotron magnet is made of steel forgings and can be readily disassembled, trucked to the NAL site where it would have to be assembled again. It has its own power supply - a 1000 kw motor generator set and would require power and water cooling (200 gal/min) at NAL. The Chicago cyclotron is currently in operation, and the suggestion implied in this proposal that it will be closed down and the magnet installed at NAL will require the approval of the Enrico Fermi Institute.

READINESS

Assuming that the cyclotron magnet can be released for this experiment by January 1972, we should be ready by July 1972 to accept beam if it is available then. The development of proportional wire chambers in the Fermi Institute is sufficiently advanced that we foresee no difficulty in providing what is required here. We are currently preparing the same type of chambers for a somewhat similar experiment planned for the Bevatron in early 1971.

We anticipate no difficulty in assembling a group of competent collaborators from the Enrico Fermi Institute, The National Research Council of Canada, and Carleton University, Canada, to help prepare and carry out this experiment if it is approved. A list of collaborators will be supplied in due course.

TIME REQUIRED

We estimate 1 month for tuning and 1 month to do a reasonable initial survey. Due to the novelty of much that we would expect to find, we would want to analyze and examine our results, modify the design of the experiment and return in 6 months or so for a follow-up run of 1 month. We consider the general arrangement quite versatile and would expect that other experiments might be carried out using all or part of the equipment in the interim.