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TO STUDY ψ PRODUCTION

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ABSTRACT

We propose to study ψ production in the reaction $\pi^- + p \rightarrow \mu^+\mu^- + X$ using a hydrogen target in a 2 x 1 x 0.6 m^3 streamer chamber. The streamer chamber placed in a large magnet will provide the momentum measurements of the charged secondaries produced in association with the ψ. A fast trigger selecting $\mu^+\mu^-$ pairs in the ψ region will be developed.

I. Introduction

From the FNAL results, we know that the ψ (3.1) appears to be produced centrally at small x in hadronic reactions, but almost nothing else is known about the reaction mechanism. It has been proposed that the ψ mesons are evidence for the existance of a new quantum number (charm) which should result in new multiplets of charmed resonances. The failure of the first-round of searches to find these resonances clearly indicates the importance of a detailed study of the ψ production mechanism at FNAL energies with both pion and proton beams. In fact, because of its narrow width, there is still some question of whether or not it should be classified as a strongly interacting particle, despite the very nice measurements by Knapp, et al.(1) who measured the absortion cross section in nuclear matter. A detailed knowledge of the production mechanism may help to clarify this point.

We are proposing to study the reaction $\pi^{\pm}(p) + p \rightarrow \psi$ + anything using a streamer chamber with a hydrogen target. The streamer chamber provides the detection efficiency necessary for studying the charged particles produced in association with a ψ meson. The trigger will be provided by two muons whose invariant mass is greater than ∿ 1 GeV.

In order to perform this experiment, we propose to construct a new streamer chamber. This new chamber and the magnet into which it would be placed could provide a useful detector for many experiments.

II. ψ Rate Calculation

We calculate the expected rate for the production of ψ (3.1) and detection of the $\mu^+\mu^-$ decay. We consider a 1 foot long H_2 target with an incident flux of 10^6 pions or protons per pulse. The cross section used is: $\sigma_{\psi}\ (\Gamma_{\mu\bar{\mu}}/\Gamma_{tot}) = 20$ nb.

The hadron absorber and trigger hodoscope assembly are considered as optimized for detecting all positive x events. With these assumptions, the expected yield of ψ (3.1) for one month of running is approximately 2000 events (based on 400 hours/month). This value will be reduced by the detection efficiency of the final trigger system which is under study. In any case, we expect something between a few hundred and a few thousand events.

A summary of the rate calculation is given below.

ψ Rate

$\sigma_\psi \frac{\Gamma}{\Gamma_{TOT}} (\psi \to \mu^+\mu^-)$ ∿ 20 nb (2 x 10^{-8} b)

1 ft. H_2 target; incid flux ∿ 10^6/pulse

$\longrightarrow 2 \times 10^{-8} \times 10^{6} = 2 \times 10^{-2}\ \psi \to \mu^+\mu^-$/pulse

10 sec/pulse

$6 \times 60 \times 24 = 8.6 \times 10^{3}$ pulses/day

$\longrightarrow 2 \times 10^{-2} \times 8.6 \times 10^{3} \simeq \boxed{170\ \psi_{\mu\bar{\mu}}/\text{day}}$ 170/day

1 month (∿ 400 hrs.?)

$\Longrightarrow \sim 2000\ \psi_{\mu\bar{\mu}}$/month (produced)

detector

$x_{\parallel} \geq 0$ only = 1/2X

$\longrightarrow \boxed{\sim 2000\ \psi_{\mu\bar{\mu}}/\text{month}}$

X efficiency of trigger

if eff. is only 15% $\Longrightarrow 300\ \psi_{(\mu\bar{\mu})}$

III. Trigger

A possible detector arrangement is shown in Fig. 1. It consists of a streamer chamber with magnet followed by a large magnetized iron absorber (the SOD magnet used in E-416 would be suitable) and hodoscope arrays H_1, H_2, H_3. The streamer chamber will be triggered by detecting the muons from the decay ψ (3.1) $\rightarrow \mu^+\mu^-$ which penetrate the absorber. The hodoscope will be in coincidence with scintillation counters P which indicate an interaction has occurred inside the streamer chamber.

The magnetic fields of the streamer chamber and the absorber are used to momentum analyze the muons. The hodoscopes provide the exit position and angles. This information is processed by fast electronics to determine the invariant mass of the dimuon system for selecting ψ events.

In order to obtain good quality tracks in the streamer chamber, the memory time must be limited to a few μsecs. This rules out the possibility of any sophisticated pattern recognition of the hodoscope data as part of the trigger. The simplest trigger system would be separate left and right hodoscope arrays which would accept only a single muon passing through.

A novel system is presently being designed for fast processing of the hodoscope trigger information. The muon track location in $H_1 - H_3$ is determined directly by cascaded priority encoder IC's tied directly to each hodoscope element. This information is then fed into a programmable read only memory (PROM) which checks if the track is a straight line. The PROM is basically a look-up table pre-coded with the parameters of the detector system. The arithmetic for computing the dimuon mass can be performed by standard electronics or further PROM's. The use of PROM's has the advantage of high speed and great versatility. They can be programmed for multiple outputs involving non-linear functions which would be difficult to implement with standard hardware.

The hodoscope resolution is limited by the muon multiple scattering in the iron absorber. For high energy muons (> 50 GeV), the lateral error is on the order of 1 to 2 cm. The number of hodoscope elements required can be estimated from the angular coverage needed for the ψ decay. A decay muon emitted at 90° in the ψ rest frame will have a lab angle of less than 150 mr for a 20 GeV ψ. For the hadron absorber and the dimensions of Exp. 416, this would require a maximum of 100 hodoscope elements for minimum resolution. The hodoscopes could thus be PWC's with relatively large wire spacing.

IV. Streamer Chamber

In order to perform this experiment, we propose to build a chamber of $2.0 \times 1.0 \times 0.6\ m^3$. This chamber could be of the usual conventional design. We are also looking into a three-gap chamber where the volume would be achieved by two 15 centimeter and one 30 centimeter gap. A similar scheme has been proposed by the Munich Group for the CERN SPS.(2) This has an advantage that there is no material in the center of the chamber where the forward-going jet is most likely to occur. The one foot hydrogen target would be provided and situated at the upstream end of the chamber in the central plane. From our experience in the M-1 beam line, we can easily tune a beam of a few millimeters in diameter; therefore, we should be able to construct a target of a useful diameter

of 1 1/4 inches. This small diameter would provide good vertex reconstruction. The streamer chamber body is not complicated to build.
Typically most streamer chamber facilities, such as SLAC and Argonne, construct a new chamber body for each experiment in order to accommodate the geometry dictated by the physics.

The advantages of a streamer chamber is that one has very good detection efficiency near the vertex of the interaction even though the interaction occurs inside of a hydrogen target. At the high energy accelerators, beams can be made very, very tiny and therefore the hydrogen target can be made quite thin in the direction perpendicular to the beam. This allows for rather good determination of vertex position as well as elimination of double interactions by being able to localize the vertex. The 2 meter volume also gives rather high efficiency for observing neutral strange particle decays which is of particular advantage for the experiment involving ψ production since it is possible that new quantum numbers would be produced more copiously with psi's.

V. Magnet

We would propose to place this chamber in a magnet which would provide an $\int$Bdl of some 40 kilogaus-meter. This implies fields of 25 kilogaus or more. Because of power requirements, it seems advantageous to think in terms of a large, super-conducting magnet. Final design requires a more complete study; however, we can approximately estimate that the cost of such a magnet would be in the neighborhood of $200,000. The final size of the magnet and therefore streamer chamber cell would require an optimization of several parameters; one important one being cost. Another being other user's interest in the streamer chamber. If there were other groups who had experiments which would effect the size of the magnet in particular, one would want to take this into account and try to design a system which would accommodate as many possible future experiments as one could foresee.

VI. Beam Requirements

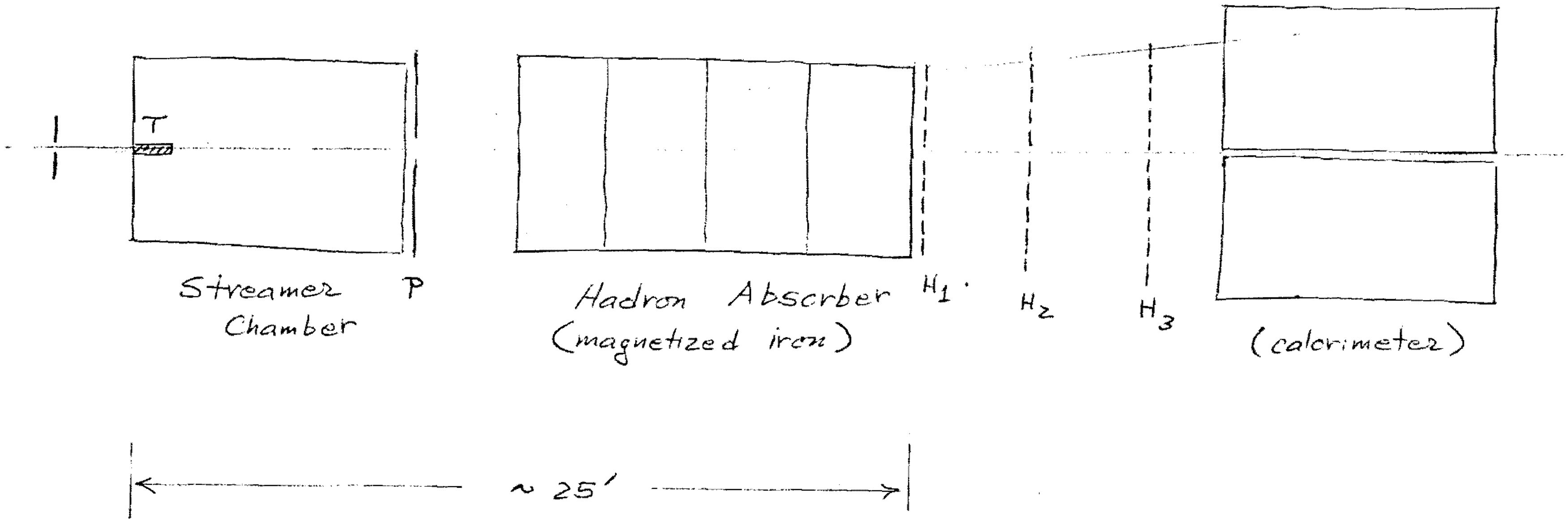
We would require a beam line which can provide both negative and positive pions at energies of 100 GeV and greater with intensities of 10^6 particles/pulse. The beam should also have a very small diameter (a few mm) and a momentum resolution ($\Delta p/p$) of a few percent or less. The present M1 beam line in the Meson Lab would be ideal for this purpose. Due to the space limitations in the M1 area, we are investigating the possibility of adding further transport elements to extend the beam downstream of the E61 experiment.

VII. New Technological Possibilities

Considerable attention has been focused recently on the possibility of filmless readout of streamer chambers. The Stanford group has investigated the possibility of using charged coupled devices to readout on-line the information.(3) These devices are now commercially available from Fairchild in a grid size of 100 x 100 (∿ 20 μ center to center) for ∿ $1500. We, at the University of Washington, are planning to study these devices over the next year in order to determine their practicality and possibility for implementing in a streamer chamber system. The advantage on paper of these devices is that they may be more sensitive than the streamer chamber film which is currently used and that they may be readout at very high data rates. Typically, one can clock out the information at megacycle rates so an array of 190 x 244 could be readout in tens of milliseconds. Another possibility is the use of high sensitivity T.V. tubes. Badier, et al.(4) have studied Tivicon and Nocticon tubes and found in particular that the Nocticon seems quite suitable for reading out the streamer chamber. The Nocticon has 256 lines and the interval between two consecutive lines is 60 microns on the photocathode. They claim that the Nocticon is about 60 to 100 times more sensitive than Kodak SO-265 film. This suggests the exciting possibility that the streamer chamber could be run in the avalanche mode.

In the avalanche mode, one could essentially eliminate the possibility of breakdown or flaring in the chamber. In addition, the size of the emitting region along the electric field lines would be one or two mm and thus we could use that information for position measurement. In addition, this has the advantage that the high-voltage pulse system could be slowed down and would not have to be the very sharp one or two nanosecond rise time with full width of five to eight nanoseconds which is currently employed for chambers operating in the streamer mode. Most of this is still very much in the stage of discussion; however, the advances in charge coupled device technology and in T.V. tube technology suggest that within a short time (2-3 years) filmless readout of streamer chambers will become practical. In any case, standard film, cameras, and lenses would be used at the outset and filmless readout only if it were a working system.

Fig. 1


T
Streamer Chamber
P
Hadron Absorber (magnetized iron)
H1
H2
H3
(calorimeter)
~ 25'

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