Update of FNAL Proposal 477

Study of π,K and $\bar{p}$ Production Of High Mass Multi Muon States

W. Faissler, P. Gauthier, M. Mallary, J. Moromisato, E. Pothier, E. von Goeler, and R. Weinstein*

Northeastern University

Boston, Mass. 02115

(January 25, 1977)

*Spokesman. Telephone (617)-437-2902

Summary

Study of π, K, and $\bar{p}$ Production of High Mass Multi Muon States

W. Faissler, P. Gauthier, M. Mallary, J. Moromisato, E. Pothier, E. von Goeler, and R. Weinstein

It is proposed to study the reactions

$$\pi + A \rightarrow \mu + \mu + X$$

$$K + A \rightarrow \mu + \mu + X \quad .$$

$$\bar{p} + A \rightarrow \mu + \mu + X$$

The products X may also contain muons.

The experiment will investigate the high mass dimuon spectrum (Drell-Yan region) for both π and K produced dimuons. For π's this initial study will probe to at least 12 GeV, and for K's to at least 6 GeV. The experiment will also measure and compare π K and $\bar{p}$ production of $\rho(\omega)$, φ, and ψ mesons and will measure or set limits on multi muon processes. The five standard deviation sensitivity of the experiment to new vector mesons is $\sigma B_{\mu\mu} \geq 10^{-3}$ nanobarns. The experimental technique is that of gapless magnet spectrograph.

400 hours of data taking time in the M2 beam are requested with 5×10^6 π/pulse, and $E_\pi = 200$ GeV.

Summary prepared by
Roy Weinstein, January 26, 1977

I) Introduction

P477 was submitted in January 1974 and was postponed until now by mutual agreement between FNAL and the experimenters. The present addendum is intended to update the proposal, and is written as a self-contained document for ease of reference.[1]

We propose to observe the following reactions:

$$\pi + A \rightarrow \mu + \mu + X \quad . \qquad (1)$$

$$K + A \rightarrow \mu + \mu + X \qquad (2)$$

$$\bar{p} + A \rightarrow \mu + \mu + X \qquad (3)$$

The unspecified products, X, may contain one or more additional muons. Such multimuon events will be observed as part of these experiments.

Among the $\mu\mu$ final states observed will be the $\rho(\omega)$, φ, ψ, and the Drell-Yan region.

The technique proposed is the use of a magnetized iron spectrograph such as previously proposed in P359, and used in E365, and again being used in E439. This technique provides the greatest yield for any given beam intensity and running time. It is, we believe, ideal for observations of low cross section dimuon and multimuon final states.

II) Technique

A) Equipment

A gapless magnet technique for observing dimuons was proposed in P359, utilized in E365, and is again being used in E439. The "Genesis" magnet constructed for E365, and presently used in E439 will be used in this experiment. A second magnet of the Genesis type, now being utilized in E439 will also be used. These magnets have useful magnetized regions of approximately

3' x 3' x 4' and 2' x 2' x 10'. See Fig. 1. Muon detection will be accomplished by a counter hodoscope and wire chambers downstream of the magnets.

The identification of π , K and $\bar{p}$ beam particles will be accomplished using the two Cal Tech differential Cerenkov counters presently in the M2 beam plus one threshold Cerenkov counter provided by Northeastern. The beam will further be defined by horizontal and vertical hodoscopes.

B) Resolution

The resolution for $M_{\mu\mu} \geq M_{\psi}$ is limited by the $\Delta p/p$ resolution. For the geometry of this experiment, Fig. 1, this resolution is approximately $\frac{\Delta M}{M} = 9\%$. (For comparison, the resolution in E365 was 13%.) At lower masses the resolution is dominated by the angular resolution, and the mass resolution worstens.

C) Sensitivity; Values of $M_{\mu\mu}$ Probed

This experiment probes, at one setting, the entire mass spectrum from $M_{\mu\mu\,min}$ to 20 GeV. For a 400 hour run at $I_{\pi} = 5 \times 10^6$/pulse a five standard deviation signal will be observed for any cross section times branching ratio such that

$$\sigma\, B_{\mu\mu} \geq 10^{-3} \text{ nanobarns}$$

For comparison, the cross section times branching ratio for production of the ψ meson by pions is about 6 nanobarns. Thus a five standard deviation signal will be observed for cross sections about ten thousand times smaller than that for ψ production.

III) Yields

We request 5×10^6 π^-/pulse in the M2 beam for 200 GeV π's. We expect the K^- beam to be 2%, and the $\bar{p}$ beam to be 0.3% of this value. The

yields of various reactions which will be studied in this experiment are shown in Table I, in matrix form. Many of the reactions listed in Table I have not yet been observed. In each such case an unobserved cross section has been replaced by a cross section which has been observed and which should conservatively approximate the yield of the unobserved cross section.

Table I Estimates of Yields. These assume a 400 hour run at $I_\pi = 5 \times 10^6$/pulse, with $K^-/\pi^- = 0.02$ and $\bar{p}/\pi^- = 0.003$

Beam → Products ↓	π^-	K^-	$\bar{p}$
$(\rho + \omega)$	1.8×10^6	3.6×10^4 (1)	5×10^3 (2)
φ	2.0×10^5	$> 4 \times 10^3$	5×10^2
ψ	1.2×10^5	2.4×10^3 (1)	2×10^2 (2)
ψ + other μ	probe to 5×10^{-5}	probe to 10^{-3}	-
[Upsilon]	~ 100	-	-
Drell-Yan	probe to $\geqslant$ 12 GeV (3)	Probe to $\geqslant$ 6 GeV	-

(1) Assumes $\sigma_{\rho,\psi}^{K} = \sigma_{\rho,\psi}^{\pi}$

(2) Assumes $\sigma_{\rho,\psi}^{\bar{p}} = \sigma_{\rho,\psi}^{p^+}$

(3) Assumes $\sigma_{DY}^{\pi} = \sigma_{DY}^{K} = \sigma_{DY}^{p^+}$

IV) Motivation

There is a great deal of physics which will be observed in the proposed experiment, as seen in Table I. We do not plan to review here each of the interesting measurements, but will mention our motivation in only a few. (All of the observations we find interesting are underlined in Table I.)

1) Drell-Yan. The presence of the $\bar{p}$ quark in the π^- means that $p\bar{p}$ quark annihilation in a π-nucleon collision can proceed without requiring the creation of a $p\bar{p}$ quark pair from the sea. The Drell-Yan dimuon yield from pions should therefore greatly exceed that for p-nucleon collisions.[2] The K^- Drell-Yan yield will equal that of the π^- if no sea quarks are involved. When sea quarks are involved $\lambda\bar{\lambda}$ pairs must be created. The K^+ on the other hand should behave much more like the proton. A study of Drell-Yan yields for available beam particles appears to be a rich source of information on quark structure. We note that the Oct 75 NALREP pointed out that "the comparison of pion and proton production of these (massive dilepton) pairs is very important."..."It is important to stress that a comparison of those processes which probe the granularity of the hadrons with different projectiles is very significant since the quark or parton content is quite different in each case." "As long as free quark beams are not available, the only way to test for quark effects will be by using particle beams with different quark and anti-quark compositions". We very much agree.

The comparison of particle beams with different quark and anti-quark components requires (a) intense $\pi^{\mp}$, $K^{\mp}$ and $\bar{p}$ beams, (b) an observation technique with great sensitivity and (c) a resolution consistent with the process being investigated. The gapless magnet technique is unsurpassed for sensitivity.

In addition, its resolution is considerably better than is required for observation of an $M_{\mu\mu}^{-4}$ or $M_{\mu\mu}^{-5}$ spectrum. The same basic technique was used by some of us at CEA as a test of QED, in which an $M_{\mu\mu}^{-4}$ spectrum was successfully investigated with a markedly worse resolution than is proposed here.

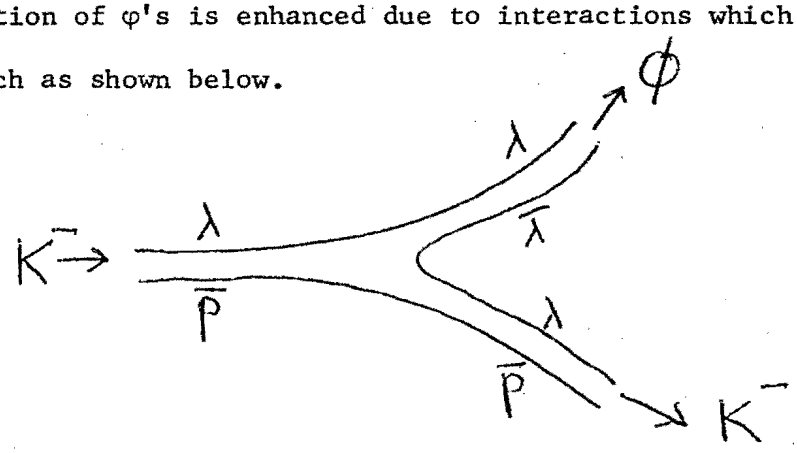
2) <u>ψ production</u>. This experiment will investigate the reactions

$$K^- + A \rightarrow \psi + \ldots, \quad \psi \rightarrow \mu\mu$$

$$\bar{p} + A \rightarrow \psi + \ldots, \quad \psi \rightarrow \mu\mu$$

These reactions are to date unreported. Based on π^- and p^+ production cross sections, the yields will be about 2400 K^- produced ψ's, and 200 $\bar{p}$ produced ψ's. These yields are quite sufficient to accurately determine the $p_\perp$ and X dependence of the reactions.

3) <u>φ production</u>. Although the mass resolution in the φ mass region is poor φ yields can be observed by using the ratio of π^- to K^- production. The K^- production of φ's is enhanced due to interactions which are absent for the π, such as shown below.



The contribution of such added terms can be investigated as a function of X (and $p_\perp$) in this experiment.

4) Particle Search. The 9-10 GeV vector meson which would result from the quark of mass ~ 5 GeV, recently proposed to account for the high y anomaly, should be observable in this experiment if it is produced with a cross section $\geq 10^{-3}$ nanobarns. If such a quark exists, its vector meson will probably be observed first in E439. However we know of no experiment other than that proposed here capable of confirming the existence of such a particle in a reasonable amount of time under different physical conditions.

V) Beam Requirements and FNAL Support

We propose to use the M2 beam for this work.

We need 400 hours in a 200 GeV π^- beam at 5×10^6 π/pulse. The amount of set-up time, parasite time, and rigging needed depends strongly upon whether this experiment is run contiguously with one of our other experiments. If this experiment is contiguous, no set-up or parasite time, and little or no rigging, will be needed. If it is run alone, about two to three days of rigging, two weeks of set-up time, and about 40 hours of parasite time will be needed.

The electronics required is approximately the same as that used by E439. A few additional latches and discriminators are required.

In addition, we request 50 hours of CDC6600 time.

VI) Subsequent Experiments

The motivation of the experiment described above carries through to other measurements. We note three of these below, which we feel will be desirable.

477': In order to pursue the study of the high mass dimuon continuum to the kinematic limits of mass available at FNAL, a high intensity pion beam

is desirable. Such an experiment would be carried out in the future high intensity pion beam at intensities between 10^9 and 10^{10}.

477'': If the comparisons of K^- to π^- yields and $\bar{p}$ to π^- yields in the $\rho(\omega)$ or φ region show behavior of interest, an experiment with better mass resolution in the low mass region is desirable. This requires a geometry which yields a better angular resolution. A geometry has been investigated which provides a resolution in the low mass region of about 8% (at the expense of acceptance at high mass). A small 1' x 4' magnet is required in addition to those shown in Fig. 1, and also wire chambers are required between this small magnet and the 10' magnet. Multi μ events may also need such a geometry.

477''': The Drell-Yan process predicts several interesting results involving K^+ and π^+ mesons. For example, if no sea antiquarks are involved the ratio of K^+ to K^- dimuons should be zero. An extension of the experiment proposed here to a beam of positive secondaries is therefore useful.

Footnotes

1) This update of P477 also contains physics previously discussed in P412.
2) For this reason our estimated yields for the Drell-Yan region are almost certainly considerably understated. For example if $\sigma_{DY}^{\pi} = 4\sigma_{DY}^{p}$, we will be able to probe the pion Drell-Yan background to about 16 GeV.

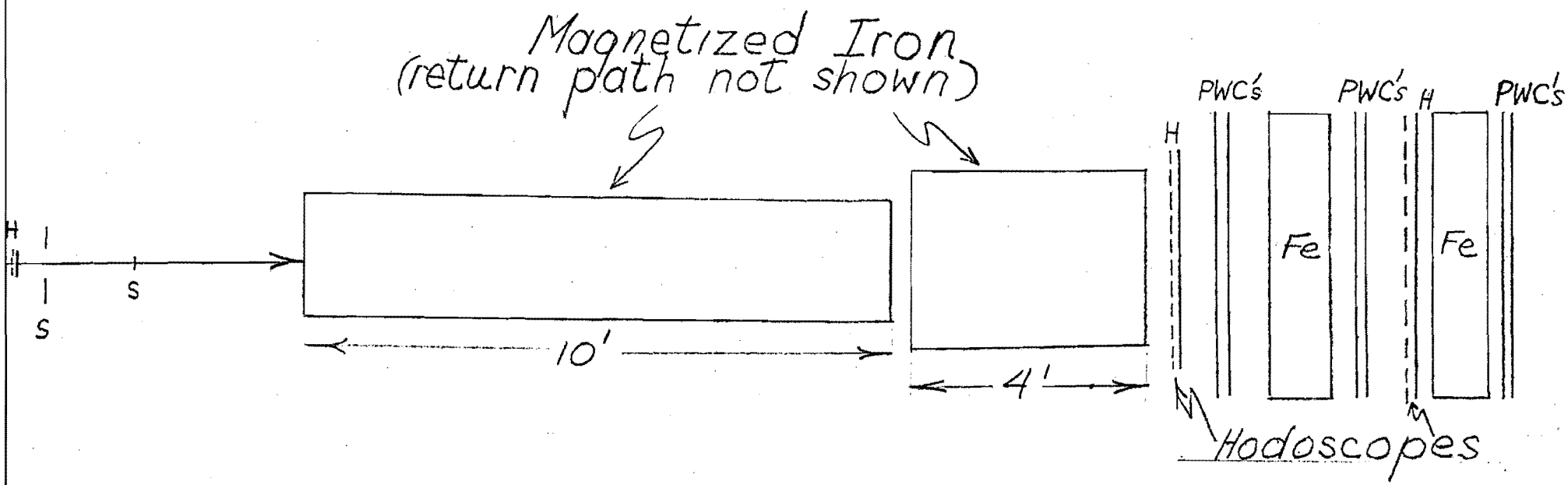


Figure 1 Geometry

FNAL Proposal # 477

Study of π, K, and $\bar{p}$ Production Of High Mass Multi Muon States

W. Faissler, D. Garelick, P. Gauthier, J. Johnson, M. Mallary, E. Pothier, E. von Goeler, R. Weinstein*

Northeastern University, Boston, Mass. 02115

(January 23, 1976)

*Spokesman. Telephone (617)-437-2902

Abstract

The reactions $(\pi, K, \bar{p})$ + Fe $\longrightarrow$ muons + anything will be observed in order to measure σ and its dependence on X and $p_\perp$,and to compare to equivalent proton production cross sections. For example, a dimuon resonance at 7 GeV, with a production cross section 1000 times smaller than the ψ would result in a yield of 200 events. A beam dump method with improved resolution is employed. 400 hours of data taking and 100 hours of testing with 200 to 250 GeV pions at an intensity of 10^7 π / pulse is requested.

Introduction

We propose to measure the inclusive pion production cross sections of high mass resonances which are capable of decaying into two or more muons. The experiment will not only observe the existence but will determine the X and $p_\perp$ dependence of such objects. For example, for two mesons of mass 6 and 7.5 GeV, with production cross sections 10^3 smaller than the ψ, we would collect about 200 events per resonance, and measure the X and $p_\perp$ of each resonance. The experiment is designed to have a resolution of better than 10%.

It is known[1] that the pion production of ψ mesons differs markedly from the proton production in the magnitude of the cross section as well as in its dependence on X. The data taken in this experiment, when compared to the data of E439, will also permit a measurement of the ratio of π to p production as a function of X (or $p_\perp$) for such high mass resonances.

At the same time as we observe production of high mass resonances by pions, kaons and antiprotons, production of "low mass" ψ mesons by K and $\bar{p}$, and π will be measured. This will permit us to compare ψ production by K and $\bar{p}$ to that by pions.

The Experiment

We propose to use a variation of the beam dump-gapless magnet technique[1] which we have used previously. This technique is most conservative of machine time and is attractive for the investigation of small cross sections. Yields of 12 ψ/hour have already been obtained at π beam intensities of 6×10^5 π/pulse[2], and we have run tests at beam intensities of 10^7, the intensity proposed here.

We desire to run at a beam momentum, p_π, between 200 and 250 GeV, with an intensity of 10^7 π/pulse, for 400 hours. If we assume, for example,

a 7.5 GeV dimuon resonance with a production cross section x branching ratio of 10^{-36} cm^2, then we expect a yield of about 90 events. Alternatively stated we could measure the magnitude of a cross section as small as 3×10^{-37} cm and demonstrate its existence to better than 5 standard deviations. At the same time we are sensitive to K produced cross sections of 5×10^{-35} cm^2 and $\bar{p}$ produced cross sections of 10^{-33} cm^2.

The gapless magnet technique is capable of markedly better resolutions than we have, to date, obtained. If, for example we desired to observe two resonances at about 7 GeV, separated by about 1.5 GeV, then a resolution of about 11% is needed. In our previous work resolutions of 13% were obtained. We propose to use a geometry which provides a resolution of better than 10%.

One way to do this is to add one magnet segment of active volume 4' x 4' x 6' to the configuration of E439. The resulting system, shown in Fig. 1, subtends lab angles of about $\pm$ 100 mrad, and detects production in the range $0 \lesssim X \leq +1$. In addition we utilize chambers between the first and second magnet segments. Other geometries, capable of coupling the high yields of the beam dump technique with better resolutions, are under study.

Requirements for this experiment

If we run in the geometry noted above, we desire FNAL to supply the new gapless magnet segment of 4' x 4' x 6' active volume, in addition to the magnets and electronics already provided for E439. We desire a maximum intensity π^- beam of 200 to 250 GeV for 400 hours of data taking and 100 hours of testing. Fifty hours of CDC 6600 time are also requested. We will either build drift chamber detectors for the downstream detector, or seek a collaborator willing to supply such detectors.

1) G. J. Blanar, et al., Phys. Rev. Lett. 35, 346, (1975).

M. Ronan, et al., SLAC Topical Conference, Stanford, July 1975.

R. Weinstein, et al., SLAC Electron Photon Conference, Stanford, August 1975.

2) The total yield of ψ's produced by π's, in 25 hours at 6×10^5 π/pulse was 300. Of these, analysis of about 150 have been published.

3) For the region $0.5 \leq X \leq +1$, the ratio of pion to proton produced ψ's is about 5. For $0 \leq X \leq +1$ the ratio is nearer to 1.

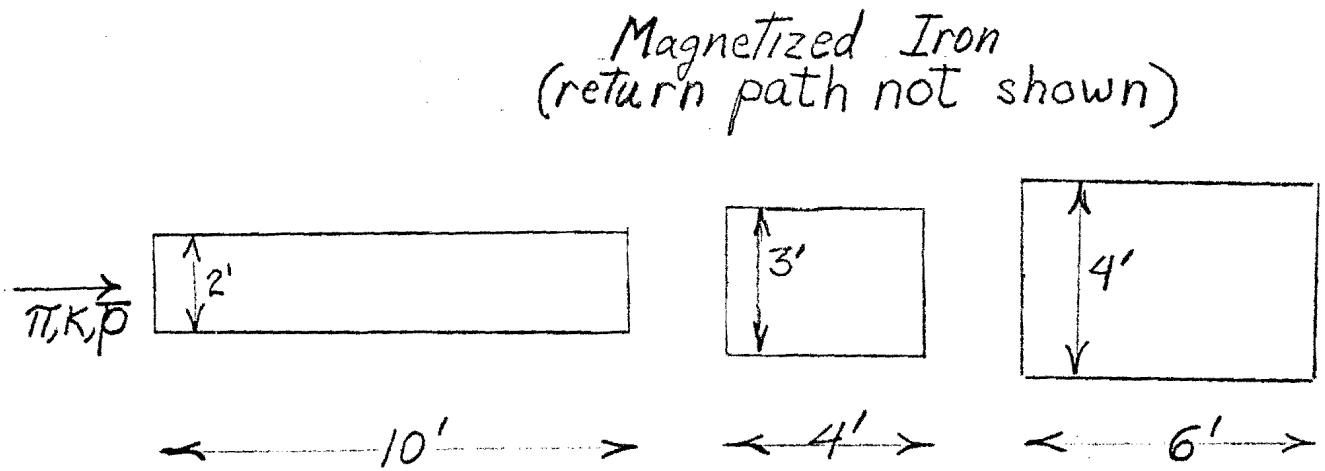


Fig 1 Magnet Geometry