Proposal to Observe K^-, π^- and $\bar{p}$ Produced Dimuon Spectra

FNAL Proposal # 412

(NU Proposal #359D)

W. Faissler, D. Garelick, M. Glaubman, J. Johnson, M. Mallary, E. Pothier, D. Potter, M. Ronan, E. von Goeler, R. Weinstein*

Northeastern University, Boston, Mass. 02115

(19 May 1975)

*Spokesman. Telephone (617)-437-2939

Summary

PROPOSAL TO OBSERVE THE KAON, PION AND ANTI-PROTON PRODUCED DIMUON MASS SPECTRA*

W. Faissler, D. Garelick, M. Glaubman, J. Johnson, M. Mallary, E. Pothier, D. Potter, M. Ronan, E. von Goeler, R. Weinstein (Northeastern University).

It is proposed to study the production of forward dimuons produced by K, π, $\bar{p}$ in a nuclear target:

1) $K^- + Z \rightarrow \mu^+ + \mu^- + X$

2) $\pi^- + Z \rightarrow \mu^+ + \mu^- + X$

3) $\bar{p} + Z \rightarrow \mu^+ + \mu^- + X$

with the major aims (a) of studying K and $\bar{p}$ production of ψ mesons relative to π (and p^+) production, and (b) of searching for new dimuon or multi-muon states up to masses of 12 GeV with each projectile. The mass resolution will be 11%.

Sufficient yield will be obtained to analyze the p_L and $p_\perp^2$ dependence of any resonance with σB greater than 1.2 nanobarns for reaction (1), 0.02 nanobarns for reaction (2), and 4.0 nanobarns for reaction (3). Five standard deviation observations of new peaks will be made for resonances with σB one quarter of these values.

The experimental equipment consists of the fast arm of E365, including a solid target.

One hundred and fifty hours of beam time is required for data taking, in the M2 beam, with 3×10^6 π/pulse at about 200 GeV. Two weeks, with some parasite time, and 20 hours of prime time are needed for set up.

Summary prepared by

Roy Weinstein, May 19, 1975

*NU Proposal 359D

Forward

This is one of several proposals addressing themselves to the question of the existence of particles which decay under emission of one or more muons.[1] Common features of these proposals are the use of the same apparatus and the possibility of concurrent running. The physics goals, however, vary. This program has been submitted previously (FNAL Proposals 365 and 359 and addenda). It is resubmitted at the request of FNAL, broken up into several parts.

I) Introduction

We propose to observe the following reactions, and to measure their relative yields, $p_\perp^2$ and p_L dependence.

$$K^- + Z \rightarrow \mu^+ + \mu^- + \ldots \quad (1)$$

$$\pi^- + Z \rightarrow \mu^+ + \mu^- + \ldots \quad (2)$$

$$\bar{p} + Z \rightarrow \mu^+ + \mu^- \ldots \quad (3)$$

We believe that this experiment has important, unique features:

(a) Its ability to measure reactions (1) and (3) and

(b) Its unusual sensitivity.

Concerning (a) we wish to note that reactions (1) and (3) have not been observed yet. We believe that it is important to measure these reactions, and that this is the only proposed experiment which can measure them in a reasonable time. It is expected that there will be a hierarchy of production cross sections for vector mesons, depending upon the projectile

(1) NU Proposals 365A, 365B, 359D, 359E

used. Results recently obtained at FNAL show that π's produce ψ's more effectively than do p^+'s. (See March 20, 1975 report to the PAC by E365). K's may produce ψ's more effectively than do either π's or p^+'s. Any anomalies in the measured ratios of production cross sections may provide an important phenomenological clue to the quark structure of the new particles. We will measure these ratios of the production cross sections of ψ's, for π, K and $\bar{p}$. We will also obtain sufficient data to measure the p_L and $p_\perp^2$ behavior of the heretofore unobserved reaction (1) for ψ mesons.

Continuing with item (a), above, the $\bar{p}$ is also an interesting projectile. The ratio of π/p production of ψ's already observed may be due, in part, to the anti-quark component of the π, relative to the p^+. It would be most interesting to compare reaction (3) to reaction (2), and to p^+ production of ψ's, since we would then have data on nonstrange particles with ~ 0, ~ 1, and ~ 3 antiquarks. Data on reaction (3) will be taken during the proposed experiment.

Concerning item (b), our high sensitivity, we wish to note that in a search for new vector mesons, or other multi-muon objects, it is important to have the maximum possible yield and mass range, so that a scan of a large mass range may be done in a reasonable time. In the absence of significant backgrounds, which is the case here, high yield, and not resolution, is the important design parameter in a search. Resolution does not appear as a search parameter except when backgrounds or separation of nearby resonances must be considered. ("Nearby" is measured in terms of the resolution width.) In particular, in the experiment proposed here the backgrounds are negligible. In addition, it would be a major discovery if, above the ψ', 2 resonances even exist for us to confuse.

Under these circumstances yield and mass bite are the significant measures of a search experiment. We propose, in the experiment described here,

to search for new vector mesons up to 12 GeV rest mass, with very high yields. For example, for the π produced dimuon spectrum, a five standard deviation observation of the "existence" of a new resonance will be made for resonances with a cross section x branching ratio into dimuons of $\sigma B \geq 0.005$ nanobarns. In addition, a detailed measurement of $p_\perp^2$ and p_L behavior will be made for any resonance with $\sigma B \geq 0.02$ nanobarns. We believe that this is a uniquely high sensitivity.

For each of reactions (1) - (3), in addition to detecting $\mu^+\mu^-$, we will also detect $\mu^-\mu^-$, and $\mu^+\mu^+$ dimuons, and higher multi muon states, thus also searching for more exotic phenomena. We have seen both $\mu^+\mu^+$ and $\mu^-\mu^-$ signals in our early data.

II) Experimental Details

A. Equipment

The technique we propose to use is essentially that proposed in P359 in November 1974. The equipment is described in some detail in the Appendix of the E365 proposal (November '74) which has been recopied and submitted to the PAC in parallel with this proposal. However, the magnet which we constructed in January '75, differs from that proposed in the November '74 Appendix, in that it is shorter, and has much higher field. This resulted in an overall 22% improvement in resolution compared to the resolution proposed. A possible replacement magnet is outlined in the E365 report submitted to the PAC (March 20). This magnet would allow a larger mass bite (24 GeV) to be investigated, and would further improve the resolution.

B. Sensitivity

In the table below, the "measurement sensitivity" is the cross section x branching ratio for which we will collect 100 dimuons in the proposed

experiment. We choose this yield since it is sufficient to measure not only cross section, in order to test production ratios, but is also sufficient to measure the p_L and $p_\perp^2$ behavior of the observed resonance.

In a mass search, however, in order to show that an object "exists", it is usually sufficient to establish a 5 standard deviation signal above background. In the absence of background, as is the case here, objects with cross sections x dimuon branching ratios as small as 1/4 of the "measurement sensitivity" listed below will satisfy this condition. These values of σB are shown below as "existence sensitivity".

As argued in Section I, in the absence of noise background, or nearby resonances, (as is the case here) the existence of sensitivity, and not resolution, is the significant experimental parameter of merit in a mass search.

Reaction	$(\sigma B)_{min}$ (Measurement Sensitivity)	$(\sigma B)_{min}$ (Existence Sensitivity)
K production	1.2 nanobarns	0.3 nanobarns
π production	0.02 nanobarns	0.005 nanobarns
$\bar{p}$ production	4.0 nanobarns	1.0 nanobarns

The sensitivities are functions of the dimuon momentum and the observed mass. For brevity we give, above, typical sensitivities at about 8 GeV dimuon mass.

C. Mass, and Resolution

With the existing Genesis magnet, built and tested by our group in January '75, this proposed experiment will cover up to 12 GeV in invariant mass, with a resolution of 11%. Depending upon the scheduling of this experiment, and logistics, we may use the Genesis magnet, or we may construct a second

gapless magnet. Such a second magnet, if constructed, will accomplish two things. It will extend the mass range investigated to 24 GeV, and improve the resolution to 9%.

III) Beam Requirements and NAL Support

We propose to use the M2 beam for this work. We need 150 hours of prime beam time to measure to the sensitivity outlined in IIB. In addition, we need about two calendar weeks of set up time, with some parasite time available, and 20 hours of prime time, in order to set up. The measurements will be done with an incident beam of 3×10^6 π/pulse, at 200 GeV/c.

The only significant equipment needed from FNAL is the electronics which had previously been loaned by FNAL to E365. We will also need a small amount of rigging and survey time.

IV Results of Early Run

In a brief initial run (25 hours) on this experiment in January 1975 a yield of about 120 ψ mesons, produced by π mesons, was achieved. Fig 1 shows the geometry of the January run, and Fig. 2 shows the geometry for this proposal. Fig. 3 shows the π induced mass spectrum from the January run. The early analyses of these results, on 1/2 of the data, appears in the report on E365 given to the PAC (March 20, 1975). More recent analyses has corrected for efficiency, and fitted the yields to a form $e^{-b_\perp p_\perp^2 - b_L p_L}$. The efficiency calculation and fitting were done by two methods, one analytical and one monte carlo. The results agree well, and are also in agreement with the preliminary results of the March 20 report. The proton induced ψs are in agreement also with the results of E87. However the results for ψ's produced

by π's are <u>not</u> in agreement with ψ's produced by p^+'s. For example, for values of X between about 0.5 and 1.0, the π's are 5 times more effective in producing ψ's than are protons. Fig. 4 shows the p_L spectrum observed. These results will be published in the near future.

Fig. 1

TOP VIEW

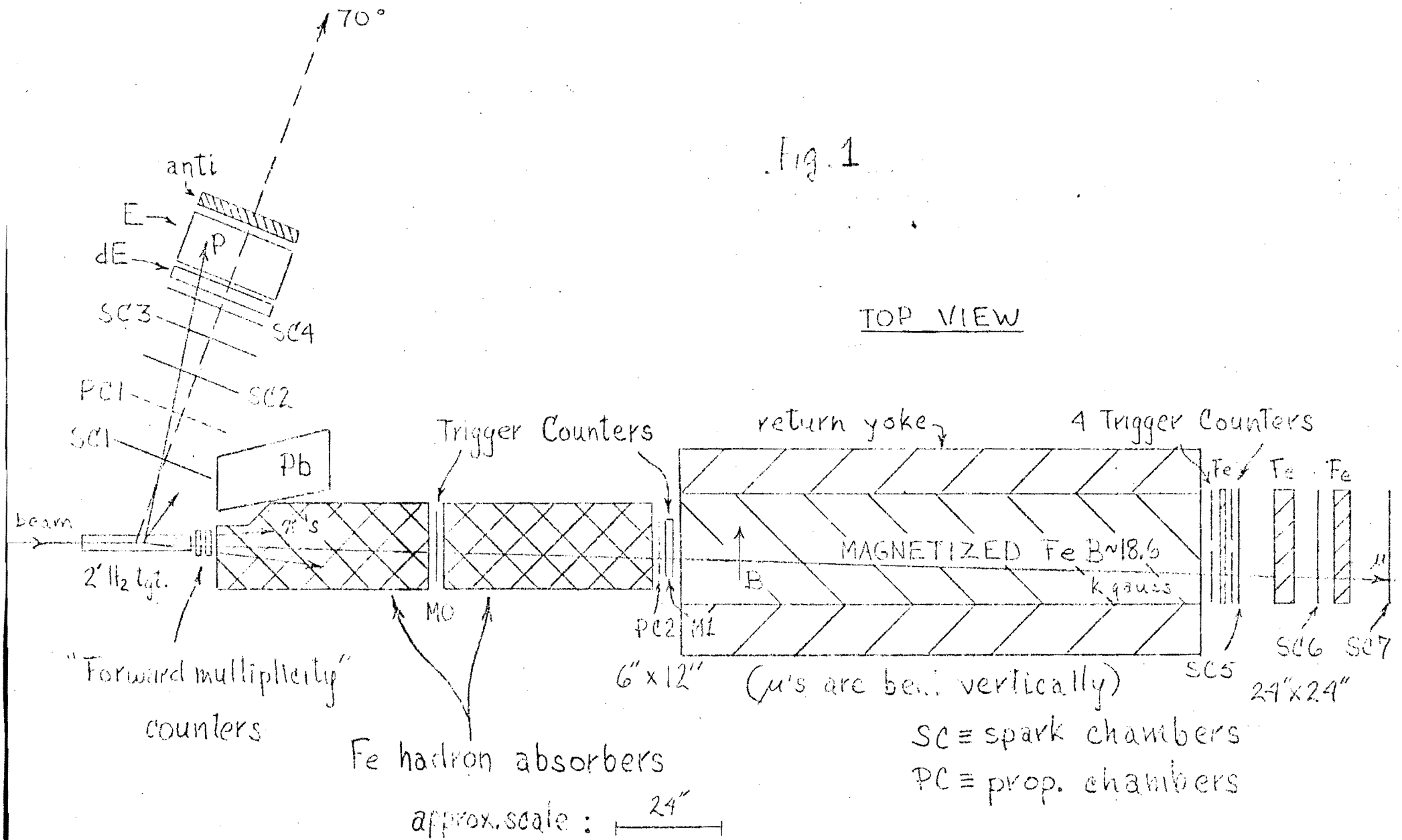
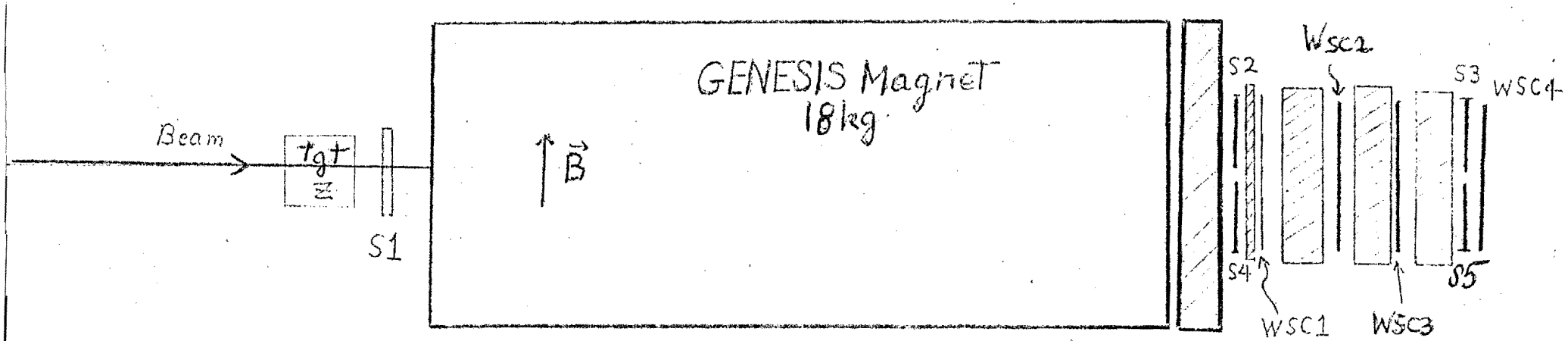


Fig 2

Top View; 12 GeV Dimuon Particle Search

Note: Beam Hodoscopes, Vetos and Cerenkovs not shown.

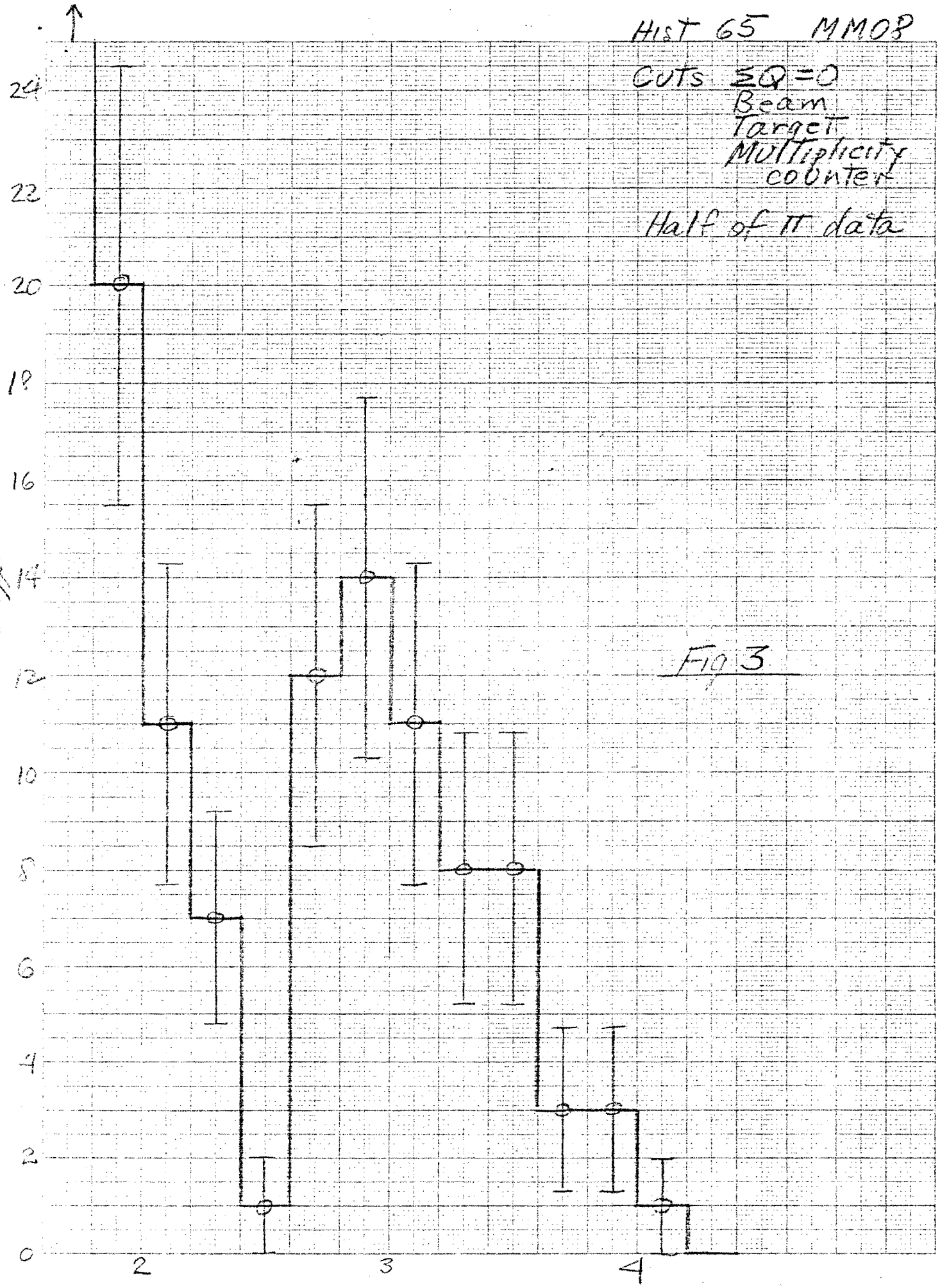


S = scintillation counter

WSC = wire spark chamber

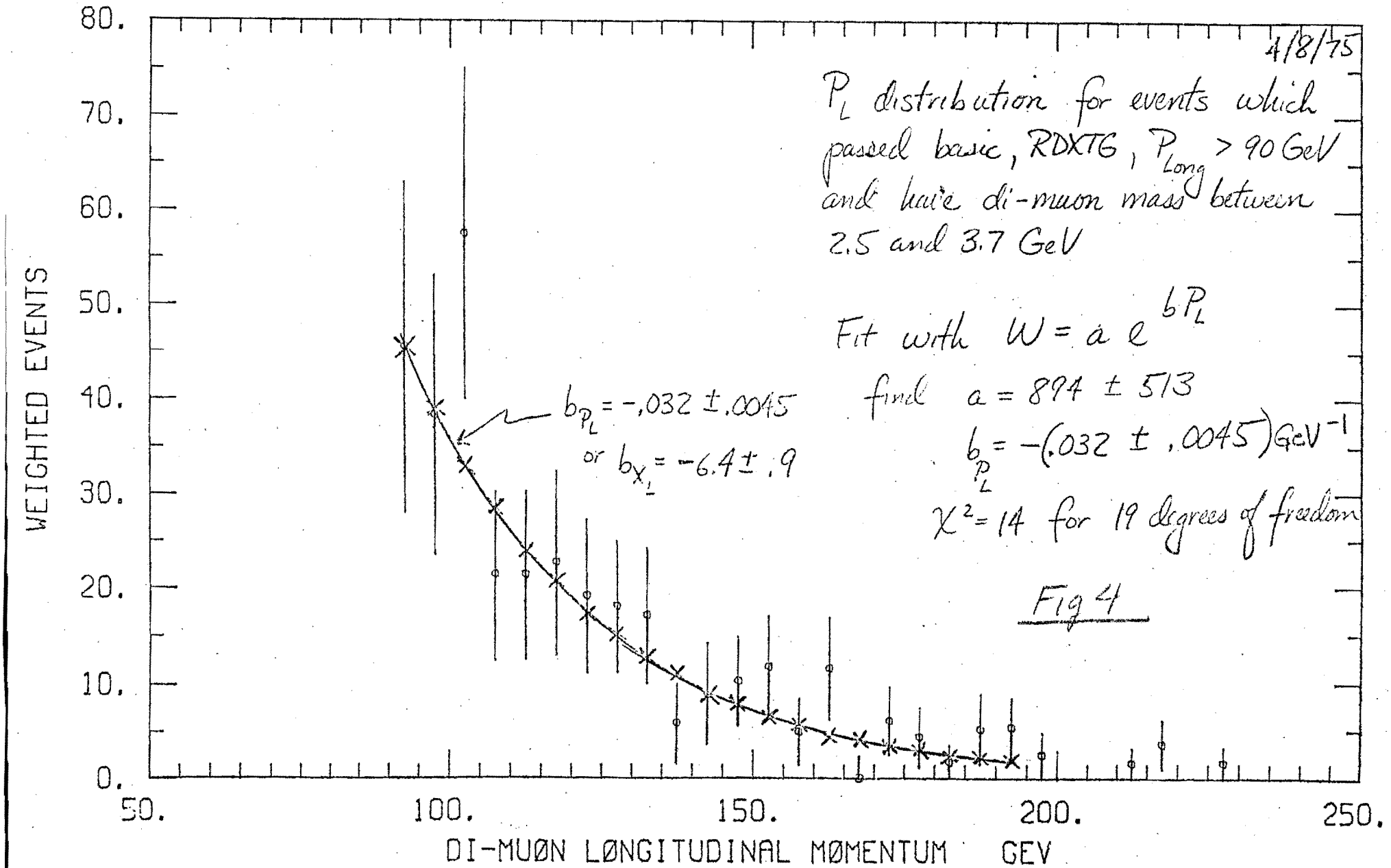
scale : 24"

Fe Absorber


Hist 65 MM08
Cuts ΣQ=0
Beam
Target
Multiplicity
counter
Half of π data
Fig 3
ΔNν / ΔMyer (Rev Interval)
0
2
4
6
8
10
12
14
16
18
20
22
24
2
3
4

MR 4/8/75 Report

DI-MUØN LØNGITUDINAL MØMENTUM WEIGHTED PI BEAM



Addendum to Proposal 412

W. Faissler, D. Garelick, M. Glaubman, J. Johnson, M. Mallary, E. Pothier,
D. Potter, M. Ronan, E. von Goeler, R. Weinstein*

Northeastern University, Boston, MA 02115

(25 September 1975)

*Spokesman. Telephone (617) 437-2939

Addendum to Proposal 412

PROPOSAL TO OBSERVE K^-, π^- AND $\bar{p}$ PRODUCED DIMUON SPECTRA

1) We request that the PAC reconsider Proposal 412.

2) The request is based upon the following:

a) We know of no other experiment capable of performing the K^- and $\bar{p}$ studies of ψ production at yield rates comparable to this proposal. The communication we received regarding the PAC decision stated, as a reason for rejection, that "the difference between the physics and instrumentation of your proposals and those of approved experiment E331 are not sufficiently great to warrant approval." If by this the PAC means that K^- and $\bar{p}$ production of dimuons and of ψs in particular does not warrant experiments, then we strongly disagree. There are many interesting problems in such a study. To mention only two, the ψ production by K^- and $\bar{p}$, and a φ' search using K^-s.

If by its comment the PAC means that there are other experiments capable of investigating the K^- and $\bar{p}$ induced dimuons (ψ in particular), then we disagree. As noted in the attached letter which covered P412 and P414, all other experiments known to us provide this data, if at all, about one order of magnitude more slowly than P412.

b) We note, also, that our proposal investigates dimuon production at energies of about 1 1/2 times those achievable by E331.

c) The very high acceptance and rates of our technique have been proved. The differences in $d\sigma/dX$ favoring pions over protons, which we have measured, make it reasonable to probe high masses not only with protons but with pions. Yields per unit beam time are an order of magnitude better in E365 than other experiments which have reported data. In addition, we believe that no higher rates can be achieved than by the techniques we have used. It makes good sense, we believe, to see if any dimuon structure exists above 5 GeV by utilizing our techniques. This would be the most efficient use of beam time.

3) We ask that 100 hours be appended to our request in P412 for the purposes of a π beam dimuon mass search up to 24 GeV.

We are prepared to run this experiment in May 1976. It is natural to run it after the fast muon arm has been set up and tested for E411 and E413 and before the proton arm of those experiments is set up.

4) Publications since P412 was submitted include

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

2) M. Ronan, Proceedings of the SLAC Summer Inst. on Particle Physics, July 1975, in press.

3) R. Weinstein, International Conference on Photon and Electron Interactions at High Energy, Stanford, August 1975.