414

Proposal To Observe the Proton Produced Dimuon Spectrum

FNAL Proposal #_____

(NU Proposal #359E)

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Summary

PROPOSAL TO OBSERVE THE PROTON PRODUCED DIMUON MASS SPECTRUM*

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It is proposed to study the production of forward dimuons produced by protons in a nuclear target:

$$p^+ + Z \rightarrow \mu^+ + \mu^- + X$$

with the major aims (a) of studying the dimuon and multi muon mass spectrum up to 24 GeV; (b) of comparison to production by K, π, $\bar{p}$; and (c) of obtaining better statistics on ψ meson production by protons in order to improve the study of the p_L and $p_\perp^2$ dependence.

Sufficient yield will be obtained to analyze the p_L and $p_\perp^2$ dependence of resonances with σB greater than 0.02 nanobarns. Five standard deviation observations of new peaks will be made for resonances with σB as low as 0.005 nanobarns.

The equipment consists of the fast arm of E365, including a solid target, and the gapless magnet, Genesis, constructed and tested in January 1975. The mass resolution will be about 9% for $M_{\mu\mu} < 8.0$ GeV and about 13% for $M_{\mu\mu} < 24$ GeV.

One hundred and fifty hours of data taking time in the M2 beam are required, in two sets of 75 hours each, separated by at least one day for rigging. Intensities of $\geq 10^7$ protons/pulse will be used at 400 GeV/c for half the data, and at 300 GeV/c for the other half. If this experiment is run sequentially with NUP359D, no additional setup time is needed. If it is run separately some parasite time and 20 additional hours of prime time are required for setup.

Summary prepared by
Roy Weinstein
Roy Weinstein, May 1975

*NU Proposal 359E

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 reaction

$$p^+ + Z \rightarrow \mu^+ + \mu^- + \ldots \qquad (1)$$

and to measure its $p_\perp^2$ and p_L dependence.

This experiment:

(a) will search for proton produced dimuon spectra up to 24 GeV with a sensitivity for discovering new particles of $\sigma B = 0.005$ nanobarns, and an ability to measure p_L and $p_\perp^2$ dependence for resonances for which $\sigma B \geq 0.02$ nanobarns.

(b) will be performed with the same apparatus as P359D, and from the results of both experiments the relative yields of dimuon resonances produced by K, π, $\bar{p}$ and p^+ will be measured;

(c) will add to the statistics of ψ production by p^+, observed in E365 in January 1975 and permit a better determination of $b_\perp$ and b_L.

(d) will also observe $\mu^+\mu^+$, $\mu^-\mu^-$, and other multimuon spectra.

We believe that the sensitivity and mass bite of this experiment are unique advantages for a mass search. The experiment can be run with

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

high beam rates. We know from tests in January 75 that we can run with 10^7 protons/pulse. This intensity gives us a sensitivity such that we can determine the existence of new particles, with $\sigma B = 0.005$ nanobarns, in 75 hours of running. The mass bite during such a run covers the mass spectrum up to 24 GeV. In the case of dimuon searches above 2.0 GeV, the backgrounds are negligible and will remain so until considerably longer runs are contemplated. Also, above 3.7 GeV there are no known resonances to be resolved. In such a case high yield and high mass bite provide the "goodness" parameter of a search experiment. Resolution does not enter until the background becomes significant or until resonances are discovered and must be resolved. This experiment provides a dimuon search which is extremely efficient in its use of beam time, and extremely sensitive.

A second advantage of this proposal is that the study of production ratios ($K: \pi: \bar{p}: p^+$) may provide important clues in the interpretation of the new particles, and that it is very useful to complete such a study with a single piece of apparatus.

II) Experimental Details

A. Equipment

The technique we propose to use is that discussed in P359 (November 74). The equipment is described in some detail in the Appendix of P365 (November 74), which has been recopied and submitted to the PAC in parallel with this proposal. However, the magnet, constructed in January '75, differs from that proposed in the November '74 Appendix, in that it is shorter, but has much higher field. This resulted in an overall 22% imporvement in resolution, compared to the proposed resolution. A possible new magnet is outlined in the E365 progress report submitted to the PAC (March 20). This magnet would further improve the resolution.

Figure 2 shows the geometry, for the experiment proposed here, for the high mass search. The low mass portion of this experiment will be run with the same geometry as the fast arm of E365 (See March 20 PAC report.) This is shown in Fig. 1.

B. Sensitivity

One interesting "sensitivity" is the cross section x branching ratio for which we will collect 100 dimuons in the proposed experiment. We call this yield the "measurement sensitivity", 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. For reaction 1, the measurement sensitivity of this experiment is $\sigma B = 0.02$ nanobarns.

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 section x dimuon branching ratio as small as 1/4 of the "measurement sensitivity" listed above will satisfy the 5 standard deviation condition. As argued in Section I, in the absence of noise background, or nearby resonances this 5 standard deviation sensitivity, and not resolution, is the significant experimental parameter of merit in a mass search.

In this experiment, the existence of an object with $\sigma B = 0.005$ nanobarns can be established to five standard deviations. This sensitivity is a function of the dimuon momentum and mass. For brevity, we have given, above, typical sensitivites at about 15 GeV dimuon mass.

C. Mass and Resolution

With the existing Genesis magnet, built and tested by this group in January '75, this experiment will probe up to 24 GeV in invariant mass

with a resolution of about 13%. It will probe to 8 GeV with a mass resolution of 9%. It is planned to do a mass search with the first set of conditions, and a ψ measurement with the second set.

Depending upon the scheduling of this experiment, we may construct a second gapless magnet. This would enable us to improve our high mass resolution to about 9%.

III) Beam Requirements

We propose to use the M2 beam for this work. We need 75 hours to measure at 9% resolution to 8 GeV and 75 hours to measure at 13% resolution to 24 GeV. In addition, for set up, about 2 weeks of calendar time, with some parasite time available, and about 20 hours of prime time are needed. If, however, this experiment is run immediately after NU proposal 359D, then no checkout time is required.

A proton beam of $\geq 10^7$ protons/pulse at 400 GeV is required for the high mass probe and the same intensity at 300 GeV is required for the low mass run.

IV) Results of January Run

In a brief initial run (15 hours) on this experiment in January '75, proton produced ψ mesons were observed. Fig. 3 shows the observed mass spectrum in the ψ region. The early analysis of these results appears in the report on E365 submitted to the PAC on March 20, 1975. More recent analysis 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 published results of E87. These results will be published in the near future.

Fig. 1

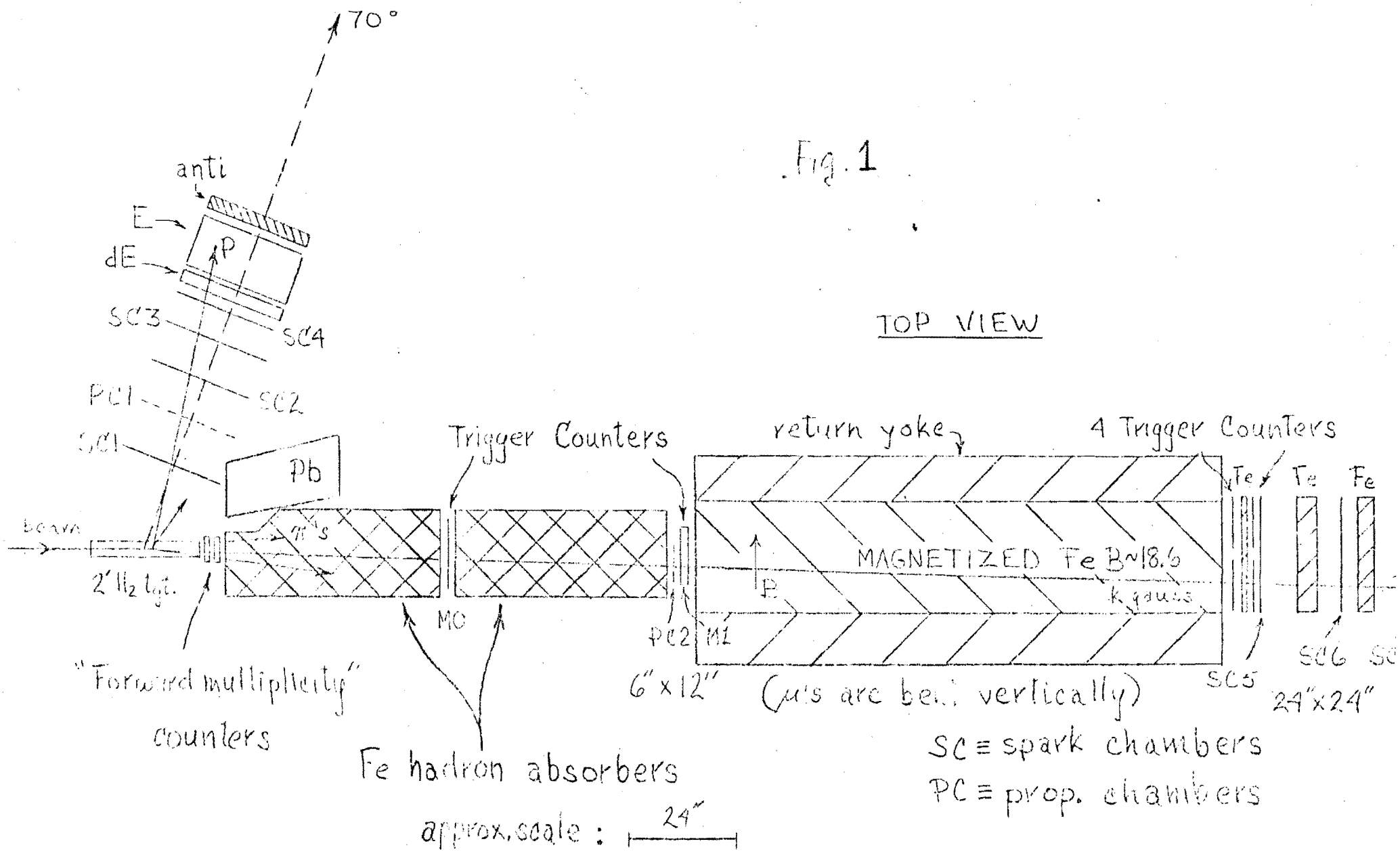
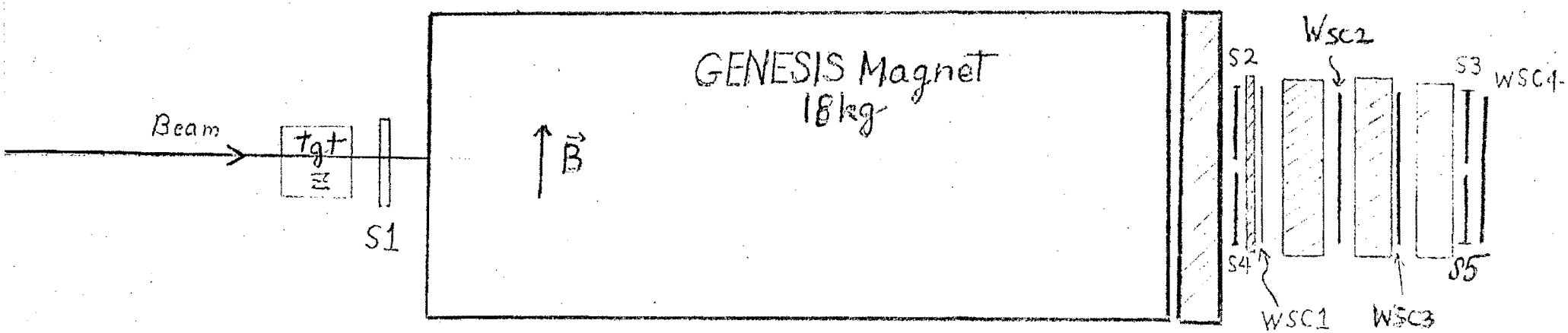

TOP VIEW
70°
anti
E
dE
P
SC3
SC4
PC1
SC2
SC1
Pb
beam
2' 1/2 tgt.
π's
"Forward multiplicity" counters
Trigger Counters
MC
Fe hadron absorbers
PC2
M1
6" x 12"
return yoke
B
MAGNETIZED Fe B~18.6 k gauss
(μ's are bent vertically)
4 Trigger Counters
Fe
Fe
Fe
SC5
SC6
24"x24"
SC ≡ spark chambers
PC ≡ prop. chambers
approx. scale : 24"

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

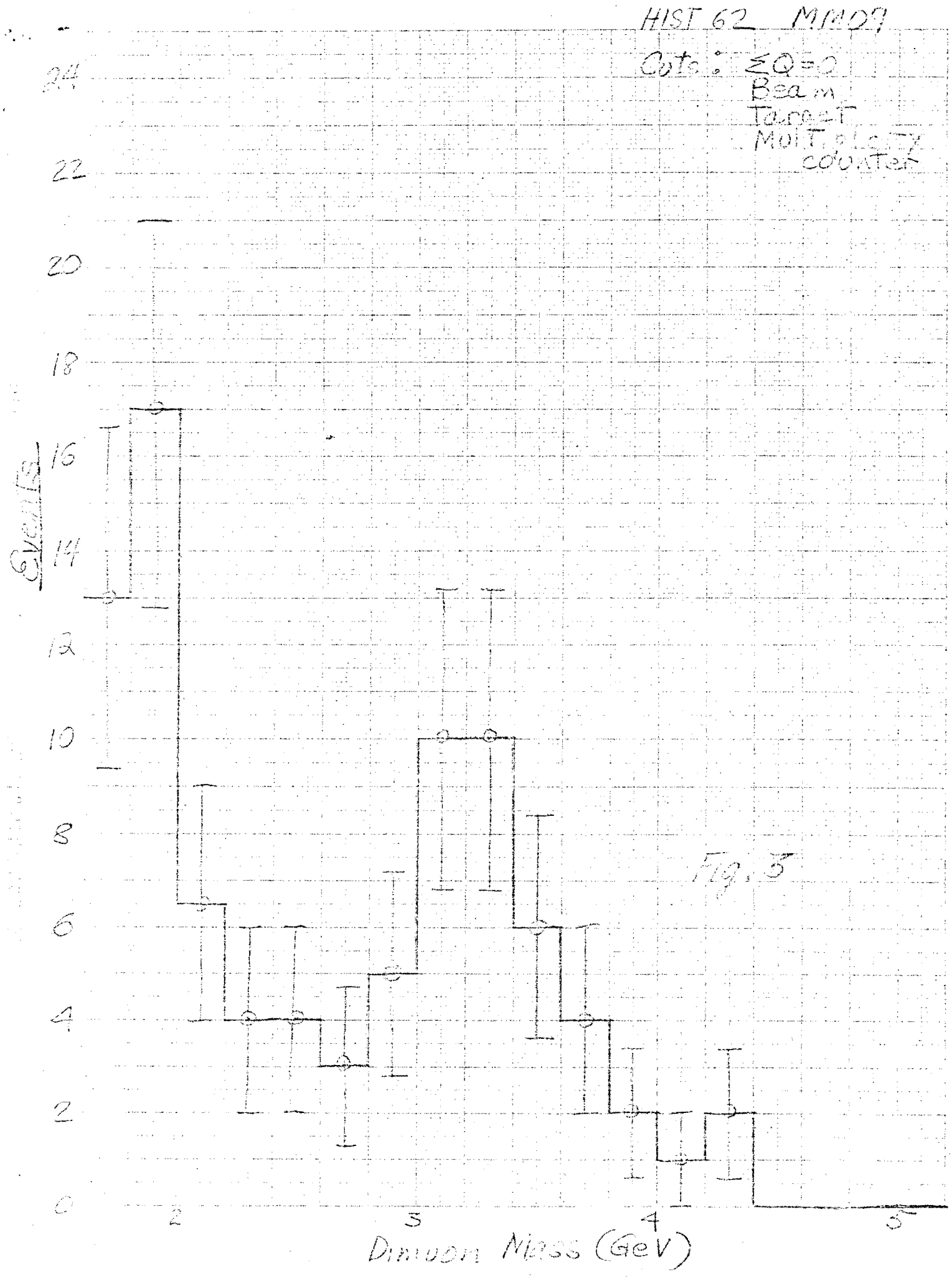

HIST 62 MM09
Cuts: ΣQ=0
Beam
Target
Multiplicity
counter
Events
Dimuon Mass (GeV)
0
2
4
6
8
10
12
14
16
18
20
22
24
2
3
4
5

Fig. 3

Addendum to Proposal 414

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Addendum to Proposal 414

PROPOSAL TO OBSERVE THE PROTON PRODUCED DIMUON SPECTRUM

1) We request that the PAC reconsider Proposal 414.

2) The request is based upon the following:

a) High sensitivity is the leading criterion for a mass search. We have proposed and previously utilized the gapless magnet-iron absorption technique and are convinced that highest sensitivity for dimuons is achievable by this technique. We intend to run at the highest intensities possible to achieve the highest sensitivities possible.

Our experiment will ultimately utilize drift chambers behind the Genesis magnet. We intend to replace our wire spark chambers with drift chambers in order to achieve high sensitivity. We believe that another run with wire spark chambers at beam intensity of 10^7/pulse would be very useful prior to going to the highest beam intensities. However, we are prepared to go directly to faster chambers if that is a condition of our acceptance by the PAC. It would delay us for only about three months.

It is proved (by completed measurements)[1] that we can run with a beam of protons $\geq 10^7$/pulse with our wire spark chambers. Our opinion is that 10^9/pulse is a usable proton flux with faster chambers and we so stated in our March 1975 written report to the PAC (E365 part F). Higher proton fluxes may be achievable. We will run at the highest flux possible. We believe that no experiment can run at higher intensities than are achievable by our basic technique.

Our first preference is to run again in the M2 beam, with or without drift chambers, with a beam of $\geq 10^7$/pulse. Following this we would go to our sensitivity limit with fast chambers and with a new magnet as proposed in E365F to the March 1975 PAC meeting.

We note that in the first round of dimuon experiments published, our signal

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

rates were more than an order of magnitude higher than other experiments. We believe that when higher rates are desired techniques will be modified so as to approach the technique we have developed; we would enjoy being among those using this technique.

b) Mass resolution is not important for a mass search. The problem is not whether one can resolve two resonances separated by 20% in mass, but whether any resonances exist. It is clear from our published data that we have successfully studied the ψ resonance with our present resolution. We believe our present resolution, about $\sigma_M = 10\%$, is more than adequate for a mass search, and that our technique conserves beam time most effectively.

When a second magnet of the Genesis type is built (such as proposed on March 1975 to the PAC in E365F), this will improve the resolution by 25 to 40%.

c) In your letter of rejection for P412 and P414 it was stated that "the differences between the physics and instrumentation of your new proposals and those of E331 are not sufficiently great to warrant approval... ." We take issue with this conclusion.

1) We can run at about $1\frac{1}{2}$ × the beam energy of E331

2) P414 has a sensitivity which is far better than E331. The absence of chambers in front of the iron magnet (See Fig. 2 of P414) allows far higher beam intensities. Even the scintillation counter shown in Fig. 2 is used only for beam studies at lower intensities.[(2)] It is, of course, possible to modify the geometry of E331 to achieve the rates proposed in P414, but then, essentially, it would be P414.

d) Using wire spark chambers, in the running time requested below we will achieve a sensitivity of $\sigma B = 0.002$nb. With faster chambers, assuming that

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(2) The trigger counters S_2, S_4 have a gap which is adjustable to eliminate the profuse low mass triggers. A more sophisticated mass trigger is being considered. Also, our apparatus is capable of accepting up to 150 triggers per pulse.

nature allows us to run at 10^9, the sensitivity will be $\sigma B = 0.00002$nb.

3) We request 200 hours of beam time in place of the 150 requested previously. Also, we plan to spend all of this time in the mass search geometry (previously we planned to spend half studying the ψ region).

We are prepared to assemble the equipment starting in March, for a run at $\geq 10^7 p^+$/pulse. Alternatively we will be prepared to assemble equipment about 3 months later for a run with fast chambers and higher intensities.

In conclusion, we believe that our technique allows the most sensitive dimuon mass probe. Our plans are limited by scheduling uncertainties, not by our willingness to build new chambers or magnets. We prefer to run in two stages up to the sensitivity limit, but are willing to do in one stage if that is a condition of acceptance.