Fermilab Proposal No. 348

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PROPOSAL TO STUDY SCATTERING OF MUONS FROM PROTONS AND DUETERONS AT MOMENTUM TRANSFERS UP TO $q^2 = 150\ (\mathrm{Gev/c})^2$

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October 10, 1974

Introduction

The scattering of muons by protons and deuterons and nuclei in E26 and E98 has stimulated interest in studying the scattering at higher energies and momentum transfers.

E98, as presently configured, is limited in its ability to study high momentum transfers by the muon beam, and by the target length.

E26 uses a heavier target, which enables a respectable rate to be achieved, but at the expense of using a target which is a complex nucleus, with consequent corrections for Fermi motion.

We anticipate that only modest improvements in the muon beam intensity will become available in 1976, and that significant improvements in event rate at high momentum transfers can only be achieved by using a long liquid hydrogen or deuterium target.

The compensations which are inherent in the geometry of the muon spectrometer of the E26 type are not easy with a long liquid hydrogen target, and we therefore propose to use the basic E98 apparatus.

In experiment E98 there is limited data, even at moderate momentum transfers, on several interesting hadronic channels. We will improve the statistics on these channels concurrently with the main "single arm" experiment.

We propose that this experiment can be implemented in 1976 after E98 is complete.

The two target system

We plan to use two targets - the present one which is 2 meters long, preceded by a longer one of 10 meters. A set of proportional counters will be placed between the two targets. These and the counters and spark chambers downstream will enable us to identify, with some certainty, the vertex of the scattering event. This is already done in E98. With the higher momentum transfers envisaged in this proposal, the muon scatters at a larger angle and the vertex will be correspondingly easier to locate. We expect, therefore, to be able to distinguish from which of the two targets the event comes.

If, for example, we wish to measure the ratio of scattering from deuterium and from hydrogen to get scattering from the neutron by the equation $N/P = D/H - 1$, we can reduce systematic errors by exchanging hydrogen and deuterium in the two targets. Then normalization and reconstruction errors will be much reduced.

Location of target

The acceptance at large q^2 of the cyclotron spectrometer depends vertically on the M counter hodoscope, divided by the distance from the target; horizontally, primarily on the distance of the M counters from the cyclotron magnet. Thus we can consider two locations for the target which are equivalent for this purpose; one, approximately the present location for E98, stretching into the magnet, and one upstream of the present target. Both involve moving the veto wall, and the second involves moving the target through the front of the muon laboratory, and relocating the halo veto outside also. These are appreciable changes, but are possible.

The 10 metre target (construction)

We do not plan to study hadrons escaping from the sides of the 10 metre target. Therefore we can use a thick wall target cup, 5 inches in diameter, and 130 litres in volume. There can be a large vacuum space to prevent pressure rise in the unlikely event of a break in the inner vessel. A heat shield can be connected to a 50°K temperature. We believe such a target can be cooled by a 50 W (at 20°K) and 200 W (at 50°K) Philips heat engine, such as is used presently at NAL.

Construction, testing, and operation is clearly a matter which needs considerable thought and mutual discussion of responsibilities.

Trigger scheme

We will use basically the same trigger scheme as E98, which is fairly satisfactory, with a few modifications.

The basic trigger is shown in Fig. 1. A muon must be found in the beam, and must be found in the scattered particle hodoscope M. It must not be found in the halo veto, or remaining in the beam at the end of the experiment (beam veto). This double veto requirement reduces randoms to an acceptable level.

The region of momentum transfer open to the experiment is defined by the counter M. In present E98 running, this has included some low q^2 events where the scattered muon has low energy (high ν). We will now have ten times the rate, and will alter the trigger to cut out the low q^2 events (including μe events) so that the apparatus is not choked.

At the same time we anticipate that there may be some specific hadron channels of interest of quite low rate where we can accept events at low q^2 if a specific hadron signature is also present.

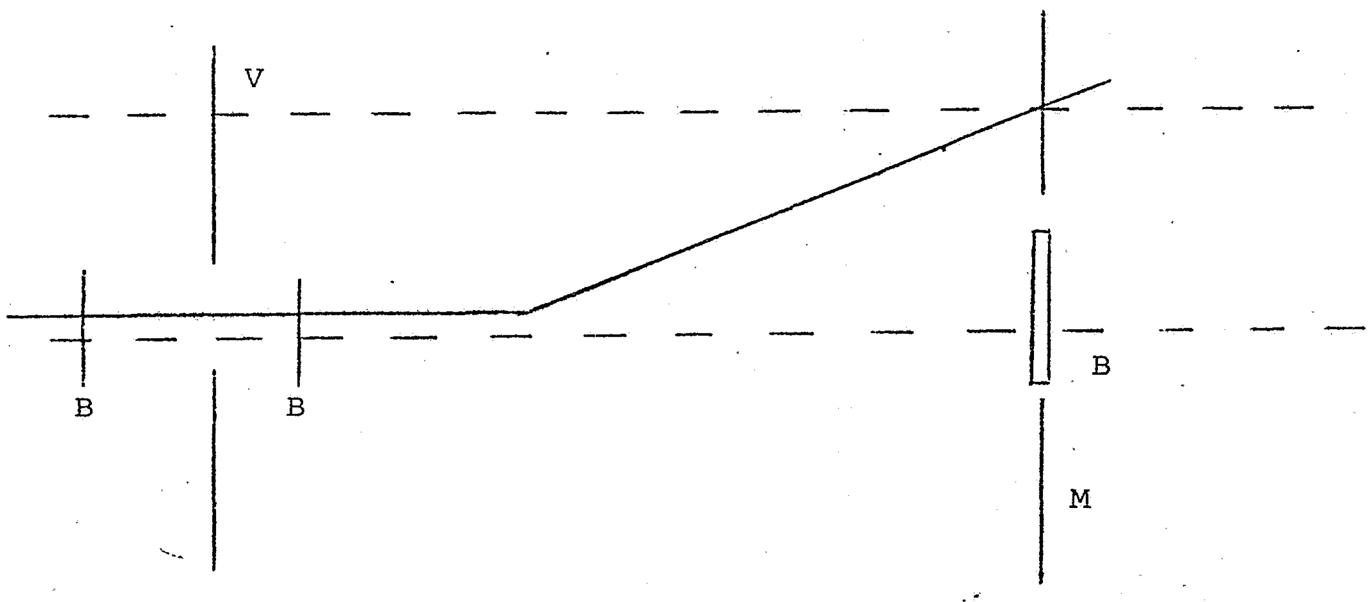


Fig. 1

Scattered muon ——— is detected

Halo muon ------ is vetoed, even if in random coincidence with B

Unscattered muon ------ is vetoed, even if in random coincidence with M.

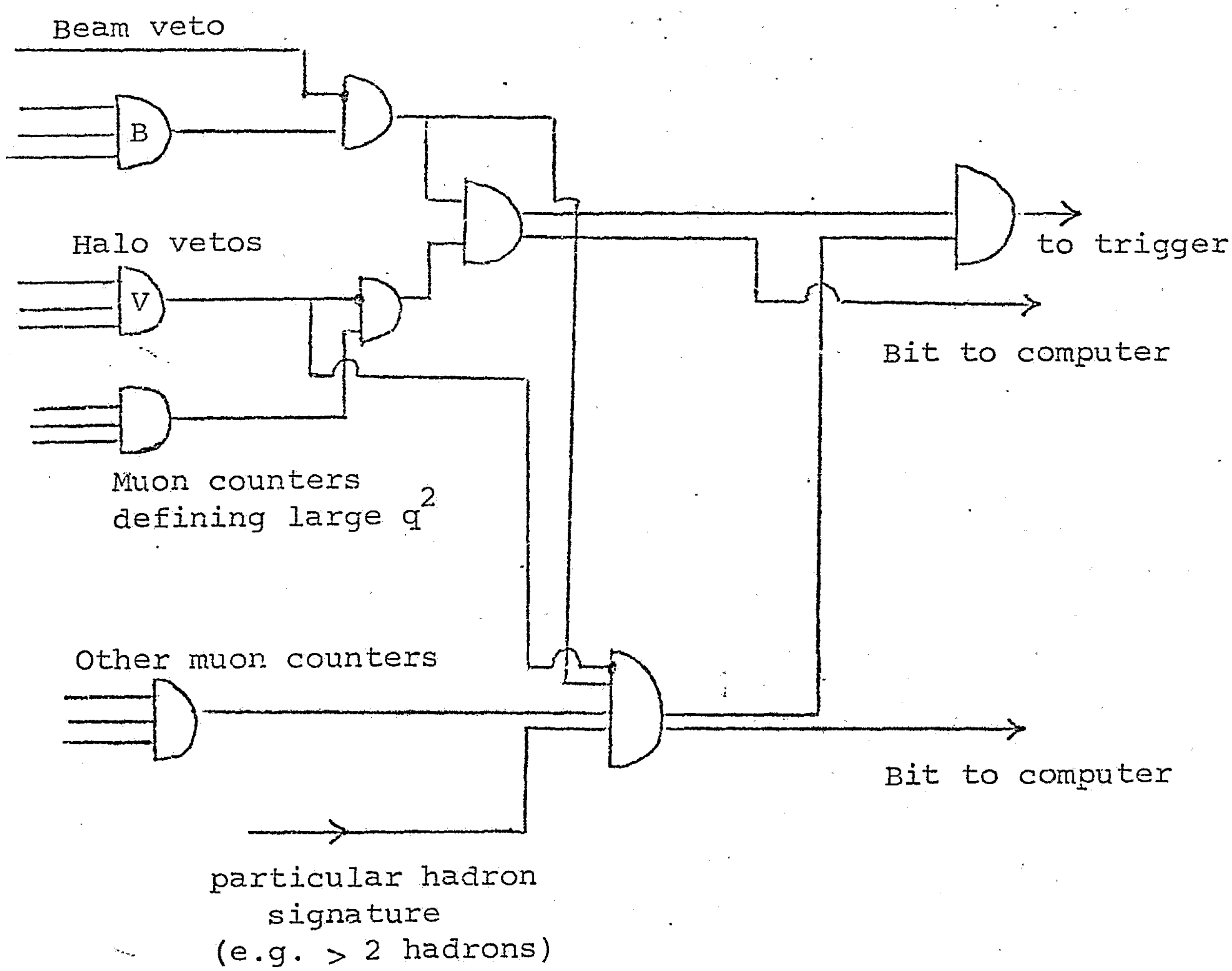


Fig. 2

Schematic trigger scheme

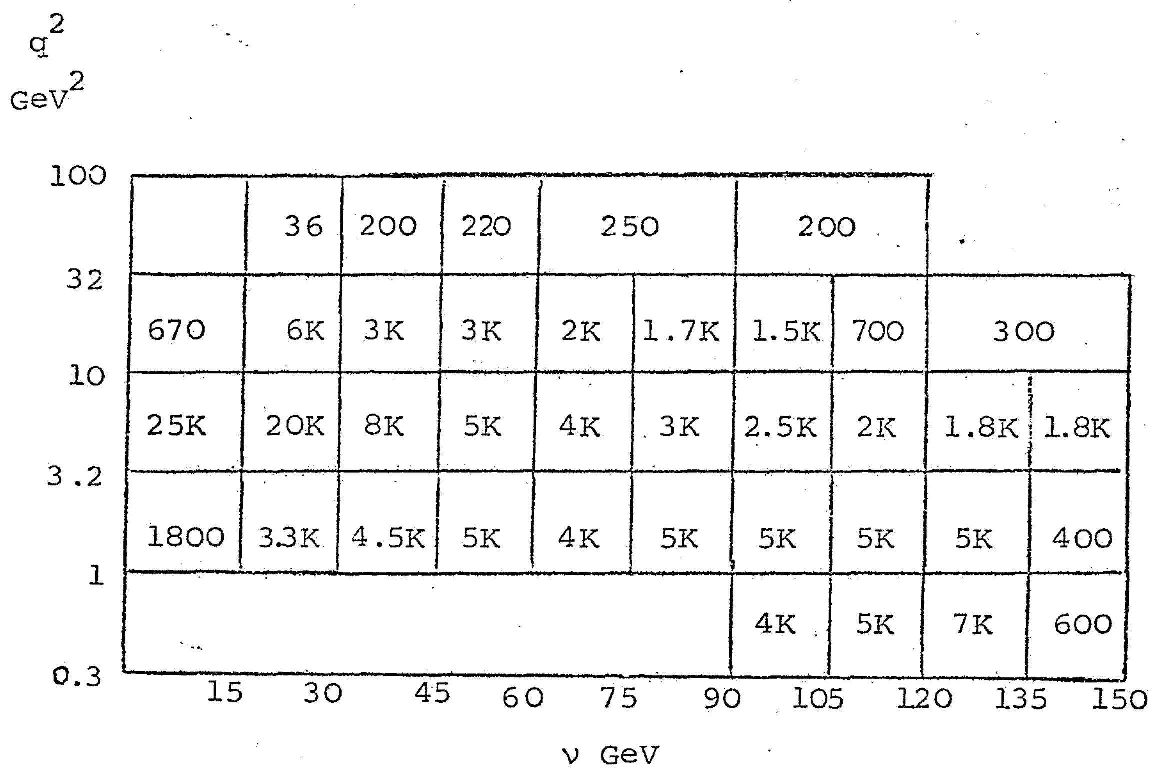
Acceptance and count rate

The present configuration of E98 is limited at high momentum transfers by the size of the spark chamber and counters, and principally the muon detector. In E98 it has been found that at high momentum transfers, identification of a track in these spark chambers is unnecessary; so, accordingly, we can increase the acceptance by adding counters only; which is comparatively simple.

We calculate the count rate for 0.6×10^{11} muons at each of three energies, 150, 300, and 500 GeV, on a 10 metre LH_2 target. We present these in Figs. 3 and 4.

With an anticipated improvement in beam we might obtain 2×10^6 muons per pulse within the 4" diameter acceptance area. (Outside this area the muons may have scattered from magnet walls and must be excluded). With 10 pulses per minute, 0.6×10^{11} muons are obtained (in principle) in 50 hours. This, with the usual allowance for inefficient beam usage, can be obtained in 100 hours beam time. 400 hours overall can give these results at each of 150 GeV and 300 GeV energies, and each of H_2 and D_2 (or 300 and 500 GeV if the energy of the accelerator has been increased).

Fig. 3



150 GeV 6×10^{10} muons. 10 metres liquid H_2

q^2_{min} adjusted to give 3 counts / pulse.

Liquid hydrogen target in present position.

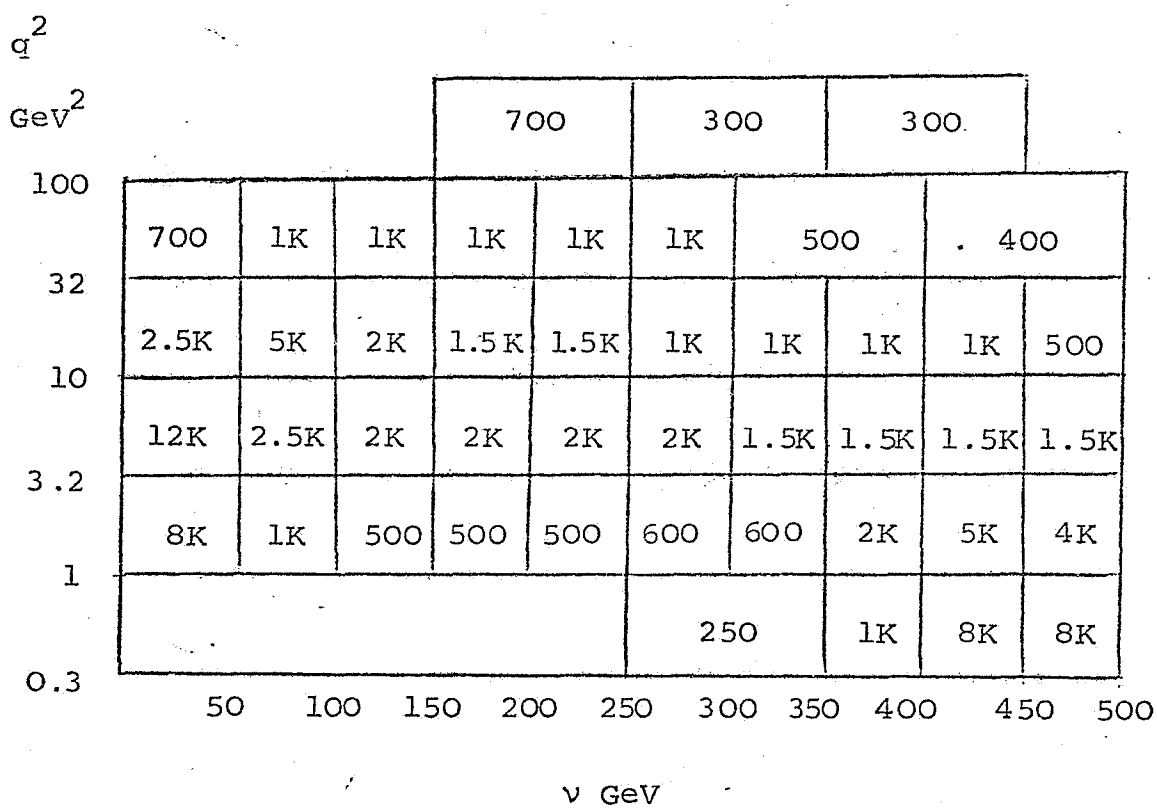
Fig. 4

q^2 GeV^2 \ ν GeV	–30	30–60	60–90	90–120	120–150	150–180	180–210	210–240	240–270	270–
> 100				105		900		100		
32–100		140	500	500	500	600	250	270	900	15
10–32	3K	3K	3K	3K	1K	1K	1K	1K	500	200
3.2–10	16K	9K	6K	4K	3K	3K	2.5K	2.5K	2.5K	800
1–3.2					300	1300	4000	10K	13K	5K
0.3–1							1500	10K	15K	4K

300 GeV 6 x 10^{10} muons. 10 metres liquid H_2

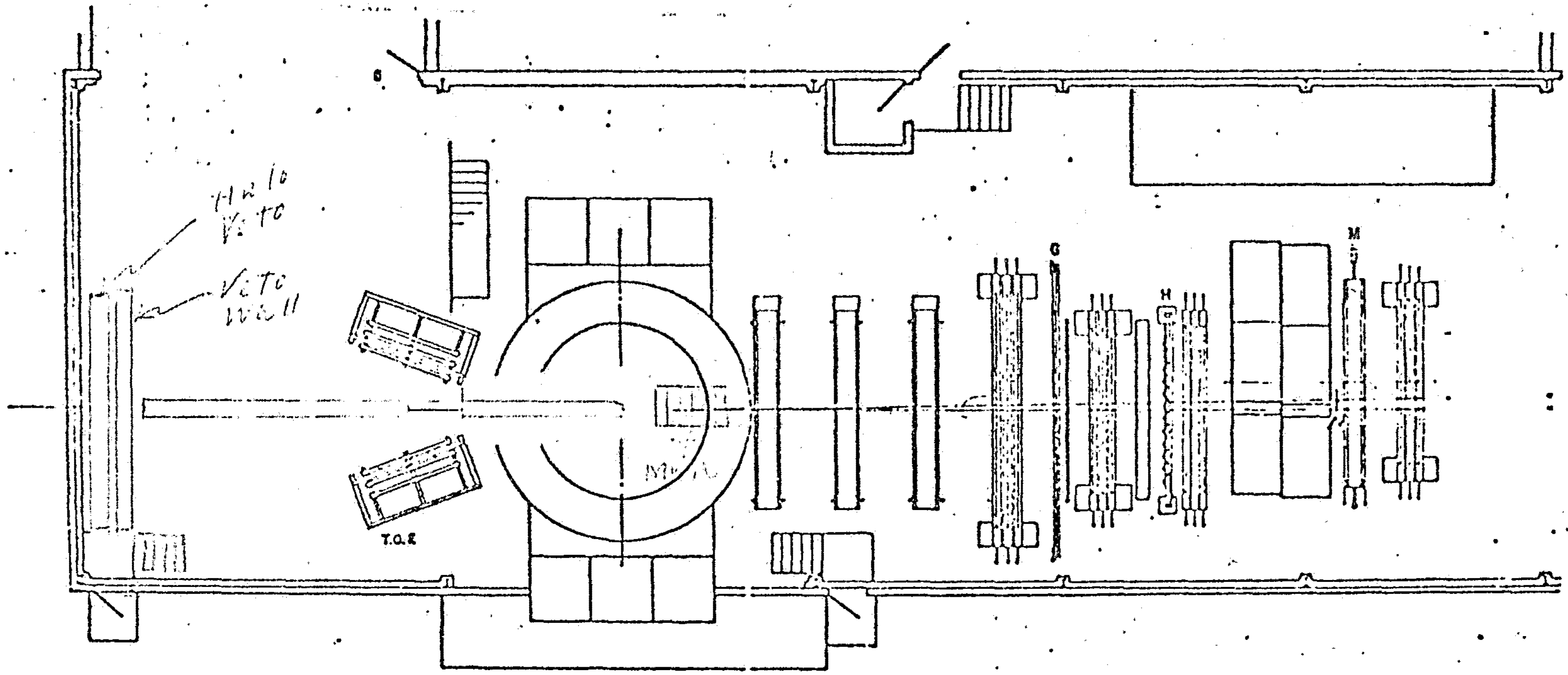
q^2 min. adjusted to give 10 counts / pulse

Fig. 5

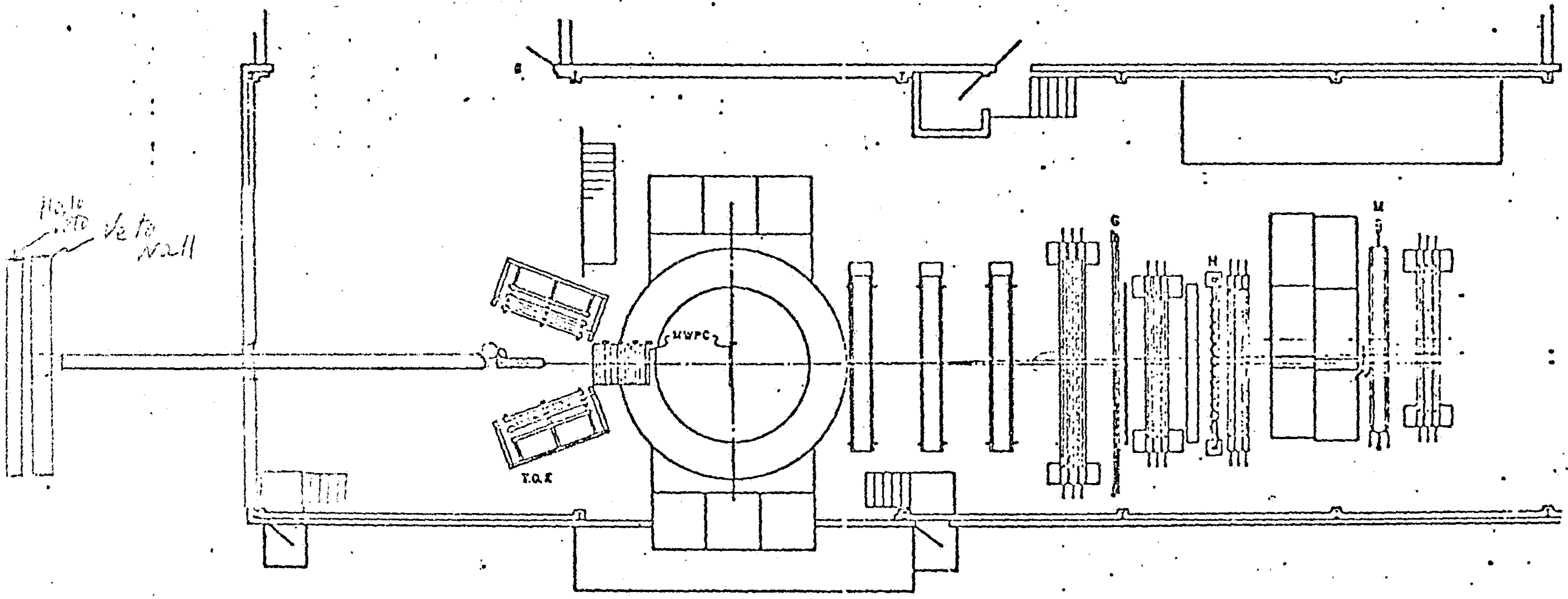


500 GeV 6×10^{10} muons. 10 metres liquid H_2

q^2 min adjusted to give 5 counts / pulse



Scale 1" = 4 m
Single target scheme



Scale 1" = 4 meters
Two Target Geometry

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T. Loomis, F. M. Pipkin, A. Sessoms, R. Wilson
Harvard University

W. Francis, T. Kirk
University of Illinois

REVISED

October 8, 1976

Introduction

The violations of scaling in the scattering of muons by protons and deuterons and nuclei in E26 and E98 has stimulated interest in studying the scattering at higher energies and momentum transfers.

E398, as presently configured, is limited in its ability to study high momentum transfers by the muon beam, and by the target length.

E319 uses a heavier target, which enables a respectable rate to be achieved, but at the expense of using a target which is a complex nucleus, with consequent corrections for Fermi motion.

We anticipate that only modest improvements in the muon beam intensity will become available in 1977, and that significant improvements in event rate at high momentum transfers can only be achieved by using a long liquid hydrogen or deuterium target.

The compensations which are inherent in the geometry of the muon spectrometer of the E26/E319/E203 type are not easy with a long liquid hydrogen target, and we therefore propose to use the basic E98 apparatus.

We propose that this experiment can be implemented in 1977 after E398 is complete and concurrently with E203.

The Target System

We plan to use a long target of 12 meters. A set of proportional counters will be placed after the target. These and the counters and spark chambers downstream will enable us to identify, with certainty, the vertex of the scattering event. This is already done in E98/398. With the higher momentum transfers envisaged in this proposal, the muon scatters at a larger angle and the vertex will be correspondingly easier to locate. We will, therefore, be able to distinguish from where the event comes.

Location of Target

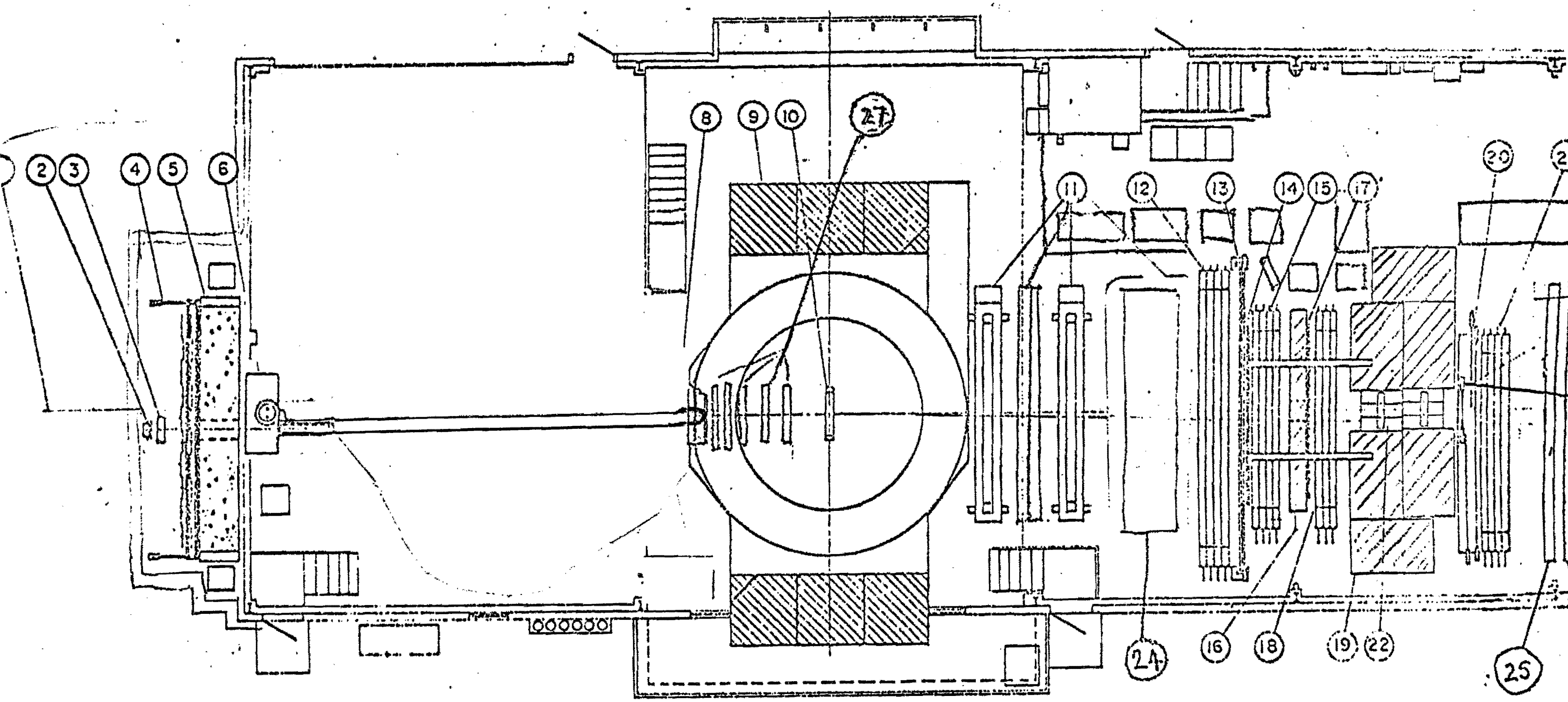
The acceptance at large q^2 of the cyclotron spectrometer depends vertically on the M counter hodoscope, divided by the distance from the target; horizontally, primarily on the distance of the M counters from the cyclotron magnet. Thus we can consider two locations for the target which are equivalent for this purpose; one, approximately the present location for E98/398, stretching into the magnet, and one upstream of the present target. Both involve moving the veto wall, and the second involves moving the target through the front of the muon Laboratory, and relocating the halo veto outside also. These are appreciable changes, but are possible.

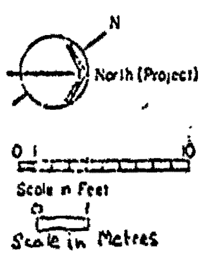
The 12 Meter Target (Construction)

We do not plan to study hadrons escaping from the sides of the 12 meter target. Therefore we can use a thick wall target cup, 5 inches in diameter, and 150 liters in volume. There can be a large vacuum space to prevent pressure rise in the unlikely event of a break in the inner vessel. A heat shield can be connected to a 50°K temperature. We believe such a target can be cooled by a 50 W (at 20°K) and 200 W (at 50°K) Philips heat engine, such as is used presently at Fermilab.

Discussions on construction, testing, and operation have begun with the cryogenic group. If this experiment is approved

EXPERIMENT 398





1 Cerenkov Counter Omitted
2 8"x8" Proportional Chamber (2 prs)
3 Hodoscope
4 Halo Veto Counter
5 Backward Scattering Shield
6 ~~Liquid H_2 Target (1m Long)~~
~~7 [illegible]~~
8 ~~8 1m x 1m Proportional Chambers~~
9 Cyclotron Magnet (4.3m dia. Poletip)
10 1m x 1m Proportional Chamber
11 3-2m x 4m Spark Chamber
4 Shift Readout Planes/Chamber
12 2m x 6m Spark Chambers
(5 Magnetostrictive Delay Readout Planes)
13 2m x 6m G Hodoscope
14 2m x 6m x 2" Steel Plate
15 2m x 4m Spark Chambers
(8 Magnetostrictive Delay Line Readout Planes)
16 2m x 4m x 40.6 cm Pb Absorber
17 2m x 4m H Hodoscope
18 2m x 4m Spark Chambers
(6 Magnetostrictive Delay Line Readout Planes)
19 Steel Hadron Shield
20 2m x 4m M Hodoscope
21 2m x 4m Spark Chambers
(8 Magnetostrictive Delay Line Readout Planes)
22 Removable Shutters
23 N Hodoscope
24 Cerenkov counter
25 lead wall
26 P hodoscope
27 80 cm x 80 cm M4
28 Electronics racks

in November it is probable that the target would be ready in August, 1978.

Trigger Scheme

We will use basically the same trigger scheme as E98, which is fairly satisfactory, with a few modifications.

The basic trigger is shown if Fig. 1. A muon must be found in the beam, and must be found in the scattered particle hodoscope M. It must not be found in the halo veto, or remaining in the beam at the end of the experiment (beam veto). This double veto requirement reduces randoms to an acceptable level.

The region of momentum transfer open to the experiment is defined by the counter M. In present E98 running, this has included some low q^2 events where the scattered muon has low energy (high ν). We will now have ten times the rate, and will alter the trigger to cut out the low q^2 events (including μe events) so that the apparatus is not choked.

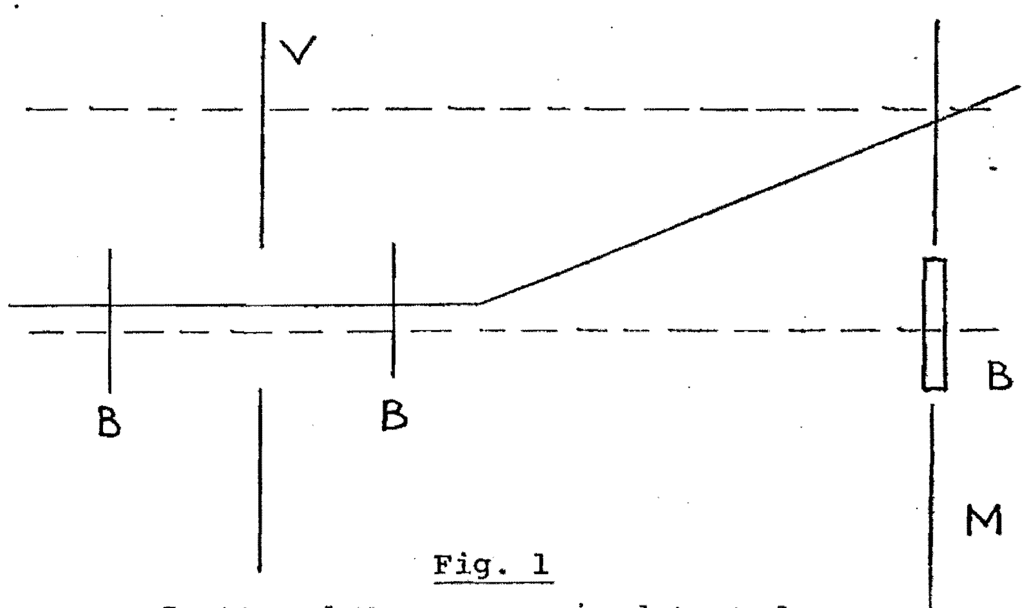


Fig. 1

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Unscattered Muon ----- is vetoed, even if in random coincidence with M.

Acceptance and Count Rate

The present configuration of E98 is limited at high momentum transfers by the size of the spark chamber and counters, and principally the muon detector. In E98 it has been found that at high momentum transfers, identification of a track in these spark chambers is unnecessary; so, accordingly, we can increase the acceptance by adding counters only; which is comparatively simple.

To make the most of the increased luminosity we would expect a total exposure equivalent to that of E398. Nominally this is 4×10^{11} muons but more likely is 800 hrs. of muons with 1.2×10^{13} ppp.—1.6×10^{11} muons after taking account of wastage and dead time. The tables show event rates for 6×10^{10} muons incident on 10 meters of hydrogen.

Enclosure

We enclose the report to the Tbilisi conference on a part of the E98 data. These statistics were obtained with 5×10^{10} muons/pulse on a 1.2 meter target. We expect to reduce the errors by at least a factor of 3.

Fig. 2

q^2 (GeV^2) \ ν (GeV)	0–15	15–30	30–45	45–60	60–75	75–90	90–105	105–120	120–135	135–150
32–100		36	200	220	250		200			
10–32	670	6K	3K	3K	2K	1.7K	1.5K	700	300	
3.2–10	25K	20K	8K	5K	4K	3K	2.5K	2K	1.8K	1.8K
1–3.2	1800	3.3K	4.5K	5K	4K	5K	5K	5K	5K	400
0.3–1							4K	5K	7K	600

150 GeV 6×10^{10} muons. 10 metres liquid H_2

q^2_{min} adjusted to give 3 counts / pulse.

Liquid hydrogen target in present position.

Fig. 3

q^2 GeV^2 \ ν GeV	0–30	30–60	60–90	90–120	120–150	150–180	180–210	210–240	240–270	270–300
> 100				105		900		100		
32–100		140	500	500	500	600	250	270	900	15
10–32	3K	3K	3K	3K	1K	1K	1K	1K	500	200
3.2–10	16K	9K	6K	4K	3K	3K	2.5K	2.5K	2.5K	800
1–3.2					300	1300	4000	10K	13K	5K
0.3–1							1500	10K	15K	4K

300 GeV 6×10^{10} muons. 10 metres liquid H_2

q^2 min. adjusted to give 10 counts / pulse