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Proposed Charm Search with Muon Trigger

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Abstract

We propose to add a muon detector system onto a double arm spectrometer to be able to search for (charm) pair production with very high sensitivity.

Physics

Should the newly discovered particles[1] J(3.1), ψ(3.7), etc. be explained as particles of hidden charm[2] content, mesons and baryons with quantum number charm = ±1 must exist.[3] It is therefore of primary interest to find these particles. They may be produced in pairs[2]:

$$p\,p \rightarrow D\,\bar{D} + X \qquad (a)$$

$$D \rightarrow K\pi \text{ or } K^-p \text{ if baryon}$$

$$D \rightarrow K\mu\nu \text{ or } \Lambda\mu\nu$$

The decay modes $K\pi$ and the semileptonic modes $K\mu\nu$ have been predicted to be of substantial[2] size (8%). Measurements of $K\pi$ and Kp mass spectra so far show [4] no such evidence. However an event selection for $K\pi$ with a μ as fragment from the other charm partner detected will be a much more selective signature of (a) to happen. However the production (a) may be very energy dependent as the J(3.1) production is. The measured[5,6,7] cross sections of Fig. 1 display an increase of ~100 for production from BNL to FNAL energies. The ψ(3.7) production is already [5,6,7,8] suppressed in hadron production. Many models[9] expect the production cross section has a strong dependence on the mass produced. Therefore, high production energies for (a) seem necessary.

An experimental advantage comes from the fact that at FNAL the emitted muons from charmed particle decays will be on the average three times more energetic than those at BNL. This allows thicker shielding to suppress hadrons.

Muon Detector

One of the unique features of the double arm spectrometer proposed in 372 is that it can withstand a very intense beam. Hence, the proposed muon detector should have the following properties:

1) operate under as intense hadron fluxes as the double arm spectrometer can.

2) detect muons with CM momentum $p^* \geq \frac{M_D}{3} = 700$ MeV, where the mass of charmed mesons is expected to be $M_D \sim 2$ GeV.

3) cover a large solid angle.

4) absorb kaons and pions right next to the target, to reduce muon background from decays.

Such a large solid angle detector has been built and tested at BNL at a target station in an intense external proton beam. Figure 2a, b shows the plan and side view of detector. Tungsten blocks are piled around the beam 1" away from the target. A sealed one cubic meter box of uranium surrounds the tungsten collimator to further absorb the hadron shower. Beyond the uranium is one meter of lead concrete sandwich reducing the number of neutrons to a tolerable level. The detector covers a solid angle of 2 sr. and accepts muon momenta greater than 2.8 GeV in the laboratory or .7 GeV in the center of mass.

The coincidence between two banks of scintillation counters registers muon candidates. With 4×10^{10} protons per pulse incident upon a 2% collision length target, we established that the

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and PRL 33, 1453 (1974)

2) M.K. Gaillard, B.W. Lee, J.L. Rosner, Fermilab 74/86 and references there, also Rev. of Mod. Physics.
A. deRujula, S.L. Glashow, PRL 34, 46 (1975)

3) B.J. Bjorken, S.L. Glashow, P.L. 11, 255 (1964)

4) J.J. Aubert et al., PRL 35, 416 (1975)
A.M. Boyarski et al. PRL 35, 196 (1975)

5) B. Knapp et al., PRL 34, 1044 (1975)

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K.J. Anderson et al., contribution to SLAC Conf. (1975)

7) F.W. Büsser et al., P.L. 56B, 482 (1975)

8) J.J. Aubert et al., PRL 33, 1624 (1974)

9) J. Ranft and G. Ranft, CERN TH 75/ and KMU-HEP 75-03
see ref 3), too

single rate of all counters is less than 4 MC. The coincidence rate of the two scintillation counters is about 100 KC.

The muon production at Fermilab averages about 3 times more energetic than those at BNL. Therefore, one can increase the thickness of the degrader by a factor of 2-3, which will greatly cut down the number of hadrons punching through. With the detector as sketched in Fig. 3, we estimated using a MC technique developted by Ranft, that the detector will be able to handle at least 1 or 2 orders of magnitude more intense beam than at BNL. The sensitivity for charm search is therefore improved by several orders of magnitude.

Time:

There are several possiblities of adding such a system to the double arm spectrometer. If linked to the MIT apparatus of Experiment 372, data taking could start after completion of the installment in 1977. Because of the big interest in the basic ingredients of current theoretical conjectures, one might also view this specific search in connection with existing facilities. In this case data taking as early as mid 1976 can be envisioned. In any such case we propose a

test set up in spring 1976

preferably in the proton center beam.

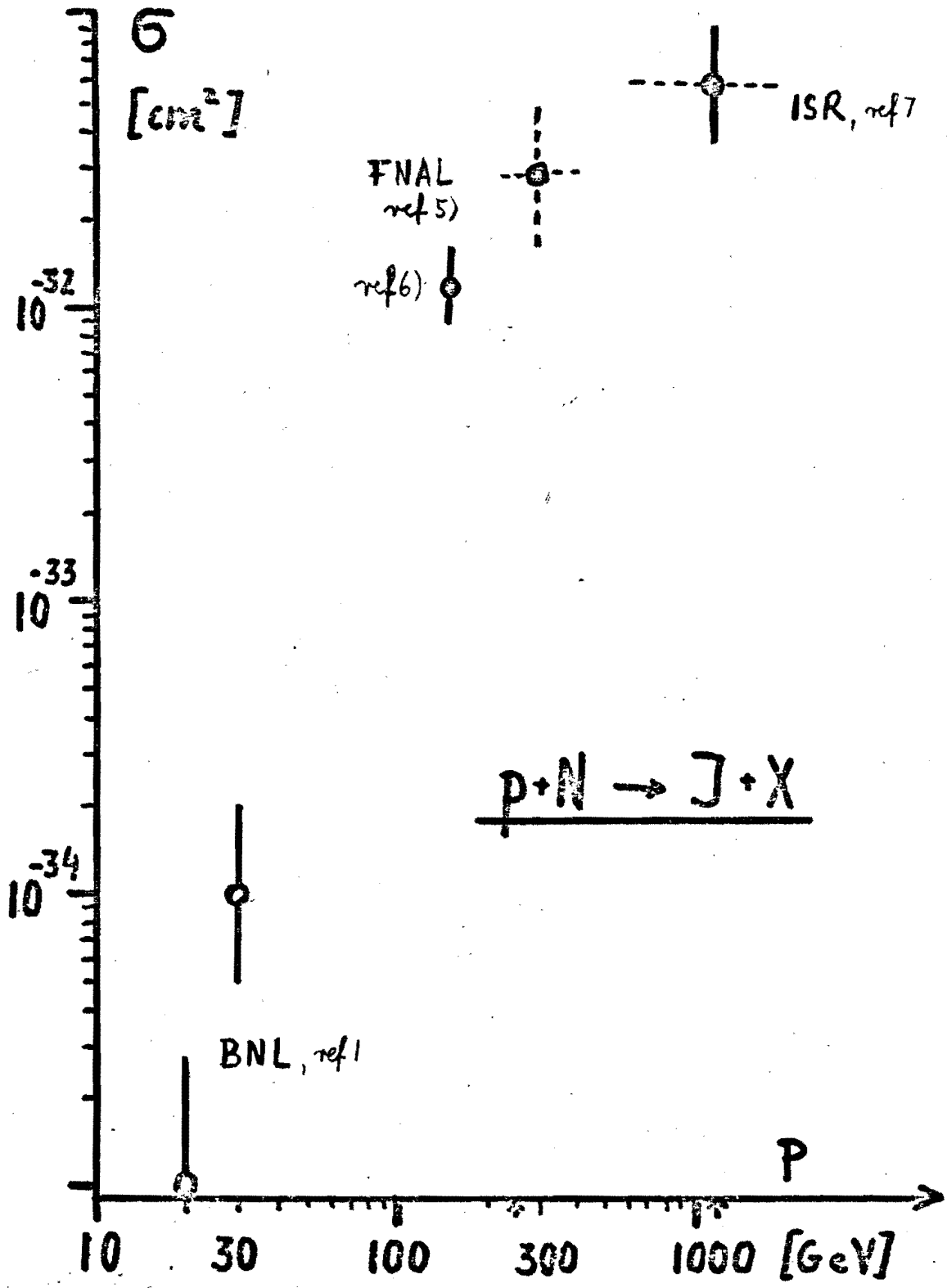
σ
[cm²]
ISR, ref 7
FNAL
ref 5)
ref 6)
10^-32
10^-33
10^-34
p+N → J+X
BNL, ref 1
P
10
30
100
300
1000 [GeV]

Fig 1

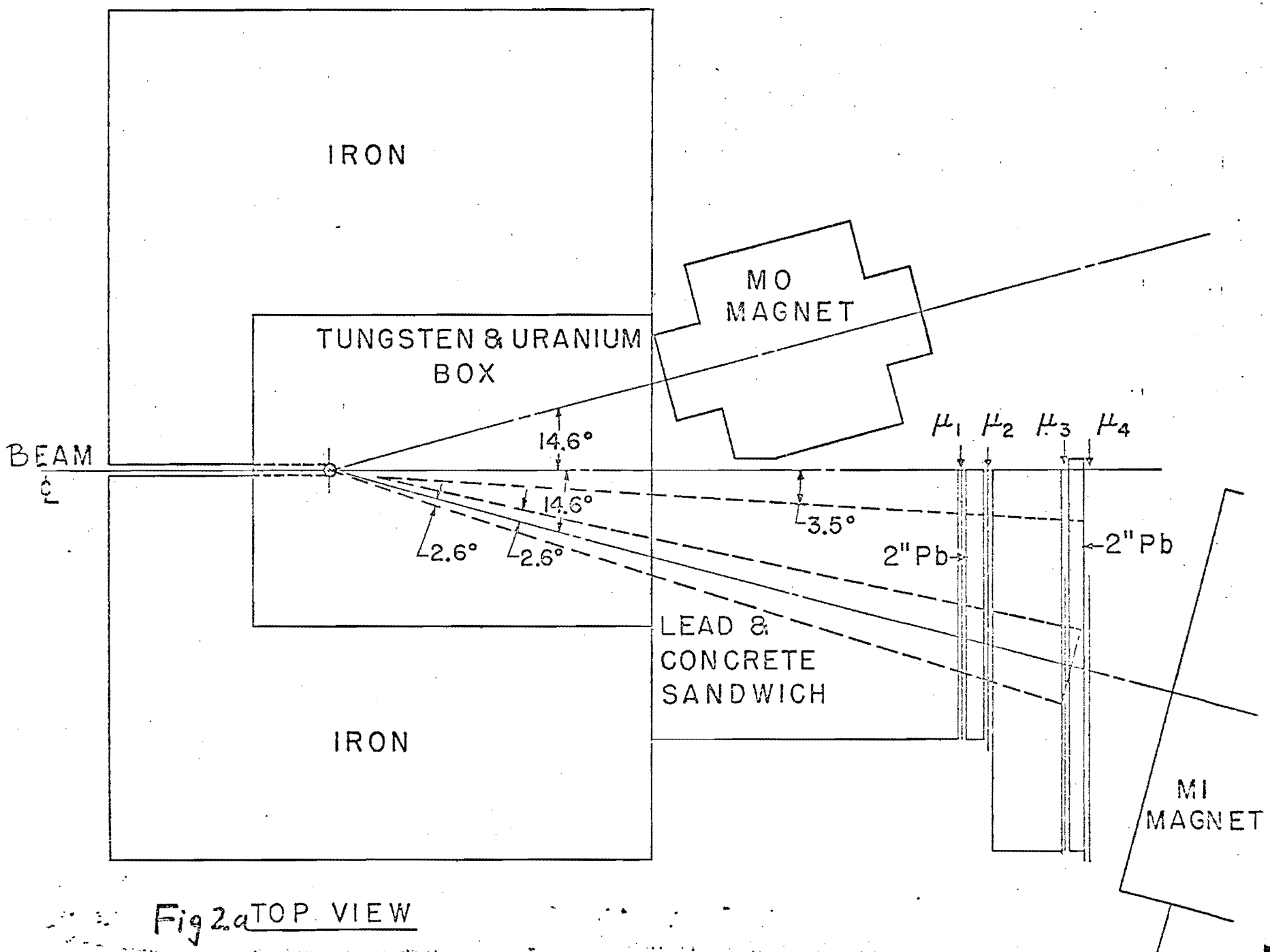

Fig 2.a TOP VIEW

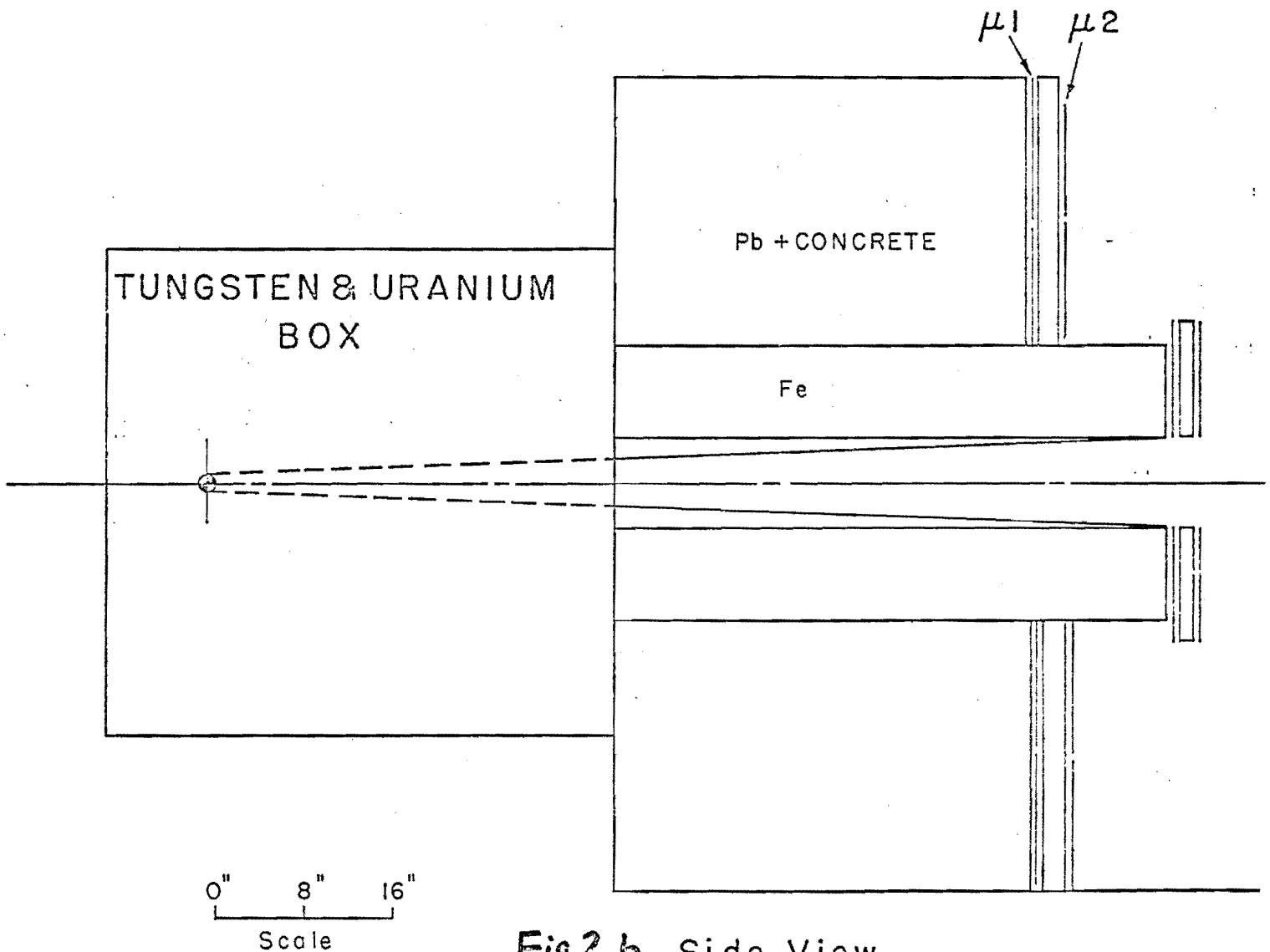

Fig 2b Side View

MUON DETECTOR AT BNL
FOR $P + P \rightarrow \mu + h^{+} + h^{-} + x$

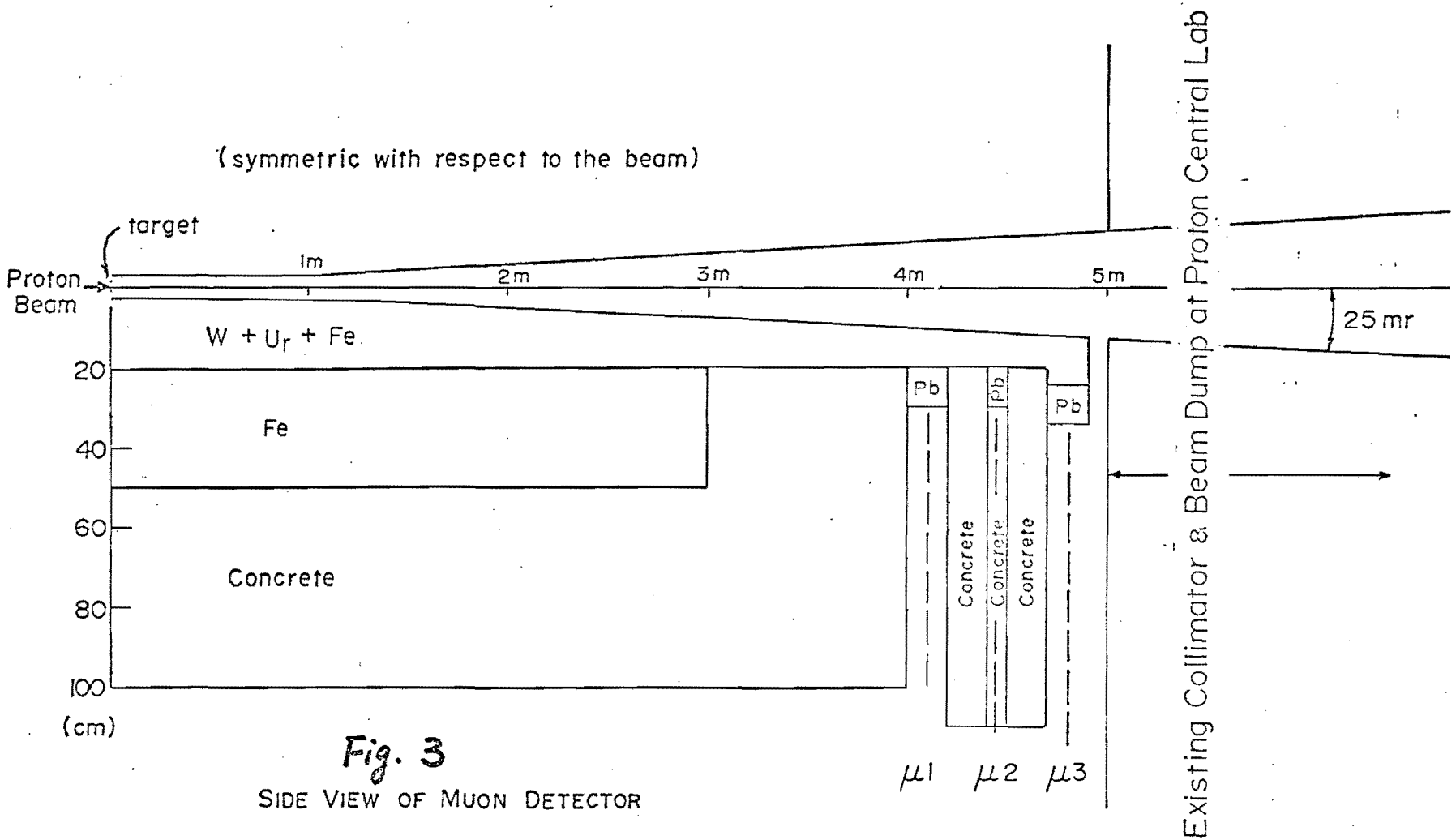

Fig. 3

SIDE VIEW OF MUON DETECTOR

PROPOSED CHARM SEARCH WITH MUON TRIGGER, P465

ADDENDUM

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APPENDIX I: SPECIFIC FEATURES OF PROPOSED MUON DETECTOR

At BNL we have observed muons in coincidence with particles detected by the MIT-BNL double arm spectrometer. Figure 4 shows the pulse height distribution of the muon scintillation counters. Figure 5a shows the coincidence of two muon counters and fig. 5b displays the triple coincidence between a muon and particles in each of the spectrometer arms at high beam intensities.

For the purpose of clarity, the proposed detector is illustrated again in fig. 6a. We plan to use three banks of scintillation counters to further reduce random coincidences (ref. fig. 5) and obtain better time resolution. Their arrangement is detailed in fig. 6b. We estimate a hadron punch through of less than 10^{-4} and approximately 1 in 10^4 pions decaying to contaminate the muon rate when the walls of the absorber start two centimeters from the target.

In the center of mass frame the detector covers a solid angle of roughly 5 s.r. The c.m.s. production angle of detected muons, θ^*, ranges from 80° - 140°, with a minimum required momentum, p^*, of approximately 500 MeV at 80° and 1000 MeV at 140°. The minimum muon momentum accepted by the proposed detector as a function of production angle in the laboratory is shown in fig. 8.

From our experience at BNL we know that the event rate with the muon trigger requirement is a factor of a thousand lower than that of the double arm spectrometer alone. At NAL we estimate that a suppression factor of 10^4 is possible due to the higher energy of the muons. So as to achieve a higher sensitivity in cross section, it would be desirable to run at greater beam intensities than ordinarily used for double arm detection. We feel the considerations presented here make this a very real possibility. We would therefore like to emphasize the importance of a test as soon as possible in order to determine exactly what increase in incident beam flux can be accomodated.

APPENDIX II: COST ESTIMATE

Instrumentation for muon detector

48 Scintillation counters, phototubes, bases					MIT $ 28,000
12 existent; require 36 more					
Fast Electronics					FNAL
14 Discriminators	LRS 621	or	equivalent	(4 inputs)	
2 Two-fold Coinc.	LRS 370	or	"	(2x8 inputs)	
6 Gated Coinc.	LRS 370T	"	"	(2x8 inputs)	
2 Fan-in	LRS 127	"	"	(16 inputs)	
2 Fan-out	LRS 128	"	"	(16 inputs)	
12 TDC units	LRS 226A	"	"	(4 inputs)	
1 CAMAC crate & controller - 78					
2 ADC units	LRS 2248			(8 inputs)	
10 Double Scalers					
3 Nim Bins					
Beamscope and Moniters					FNAL
Uranium (could be acquired from BNL on loan) $<$ 20 tons					
Test data recording system with magnetic tape unit					MIT $ 20,000

FIGURE CAPTIONS

4. Pulse height spectrum of a muon counter at BNL.
5. (a) Coincidence between front and back muon counters as observed at BNL.

   (b) Coincidence of 2 arms of hadron spectrometer with the muon detector.
6. (a) Side view of detector proposed for FNAL.

   (b) Schematic arrangement of muon scintillation banks.
7. Number of collision lengths required for a 10^{-4} suppression of E^{*}=1 GeV pions produced in the center of mass plotted as a function of laboratory angle (broken line) and actual shielding provided versus laboratory angle (solid line).
8. Momentum acceptance of proposed detector as a function of laboratory angle.

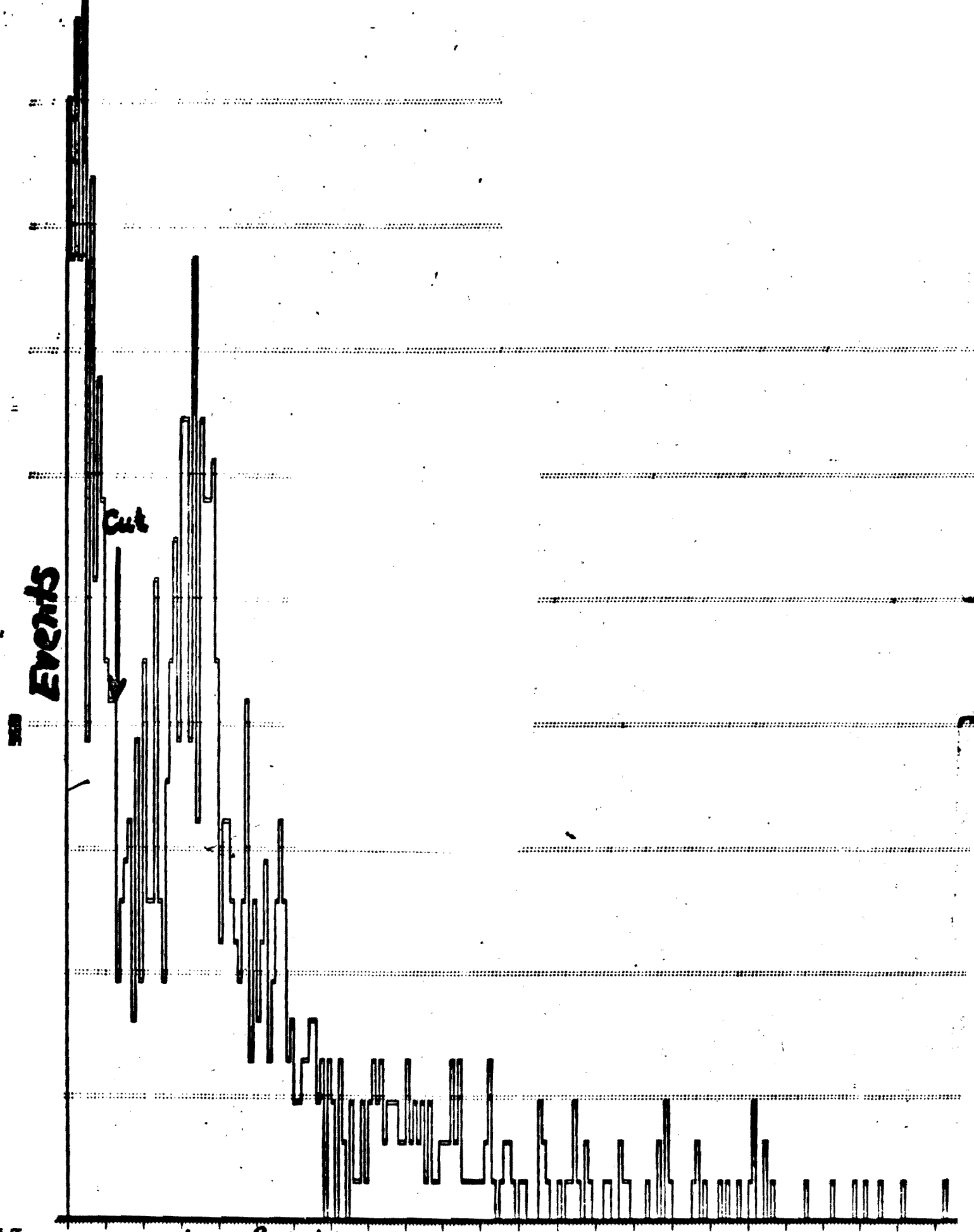


Fig 4 pulse height of muon counters

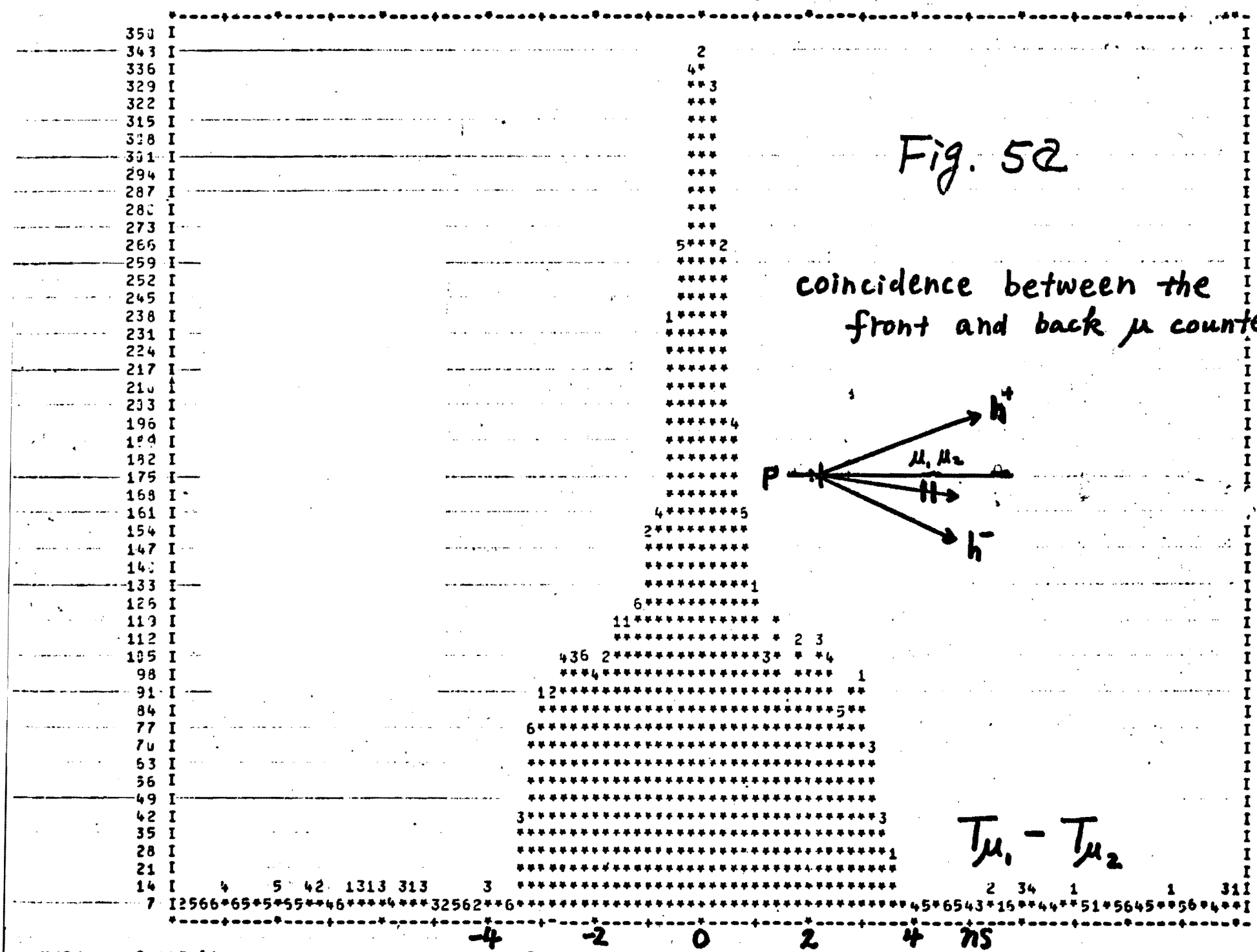
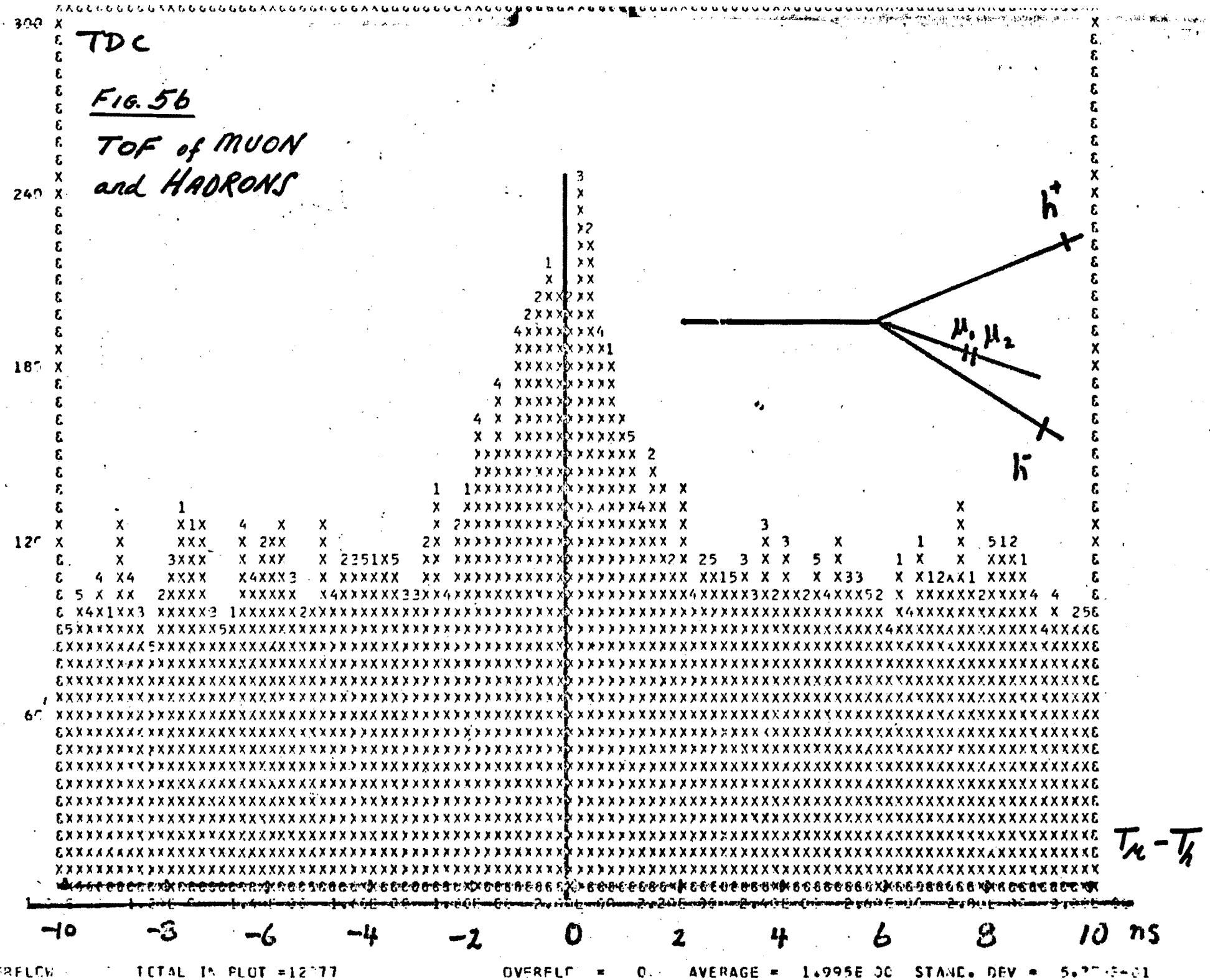


Fig. 52
coincidence between the front and back μ counters
p
h+
μ1 μ2
h−
Tμ1 − Tμ2
-4 -2 0 2 4 ns
XMIN = -5.00E+01
BIN WIDTH = 1.00E+00
XMAX = 5.00E+01
TOTAL = 5.315E+03
PLOTTED = 5.199E+03
UNDERFLOWS = 5.50E+01
OVERFLOWS = 6.10E+01


TDC
FIG. 5b
TOF of MUON and HADRONS
EVENTS
300
240
180
120
60
-10
-8
-6
-4
-2
0
2
4
6
8
10 ns
h^+
μ_1 μ_2
h^-
$T_\mu - T_h$
UNDERFLOW TOTAL IN PLOT =12077 OVERFLOW = 0. AVERAGE = 1.995E 00 STAND. DEV = 5.

same Arrangement above the beam

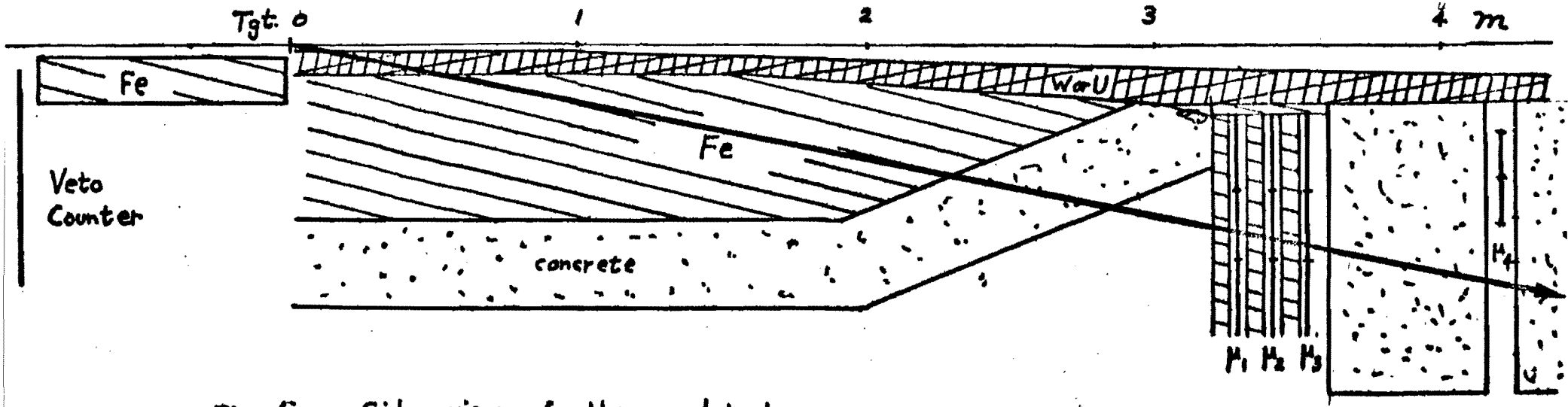


Fig. 6a. Side view of the μ-detector.

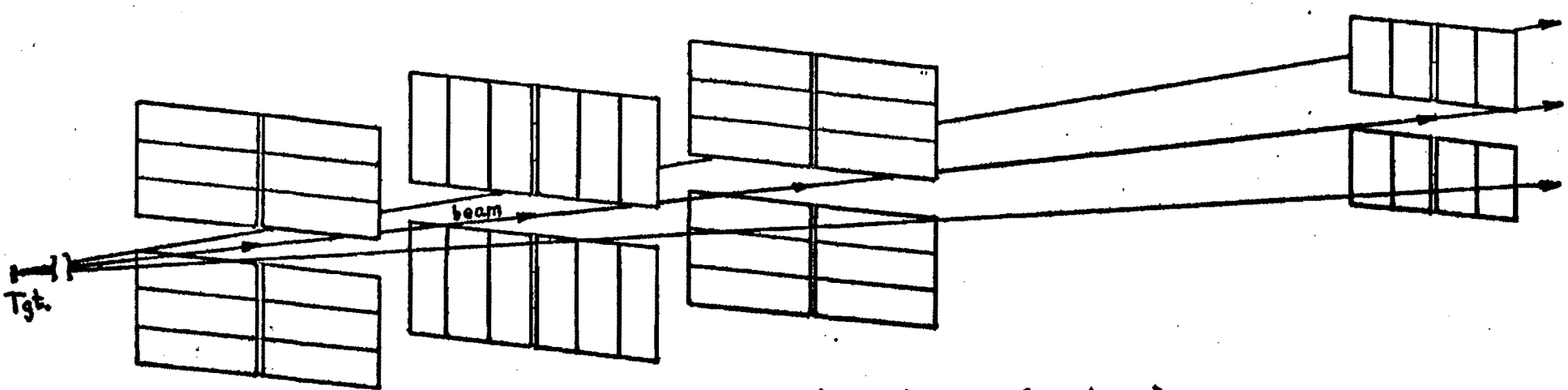


Fig. 6b. μ-counter arrangement schematic (spread apart for clarity).

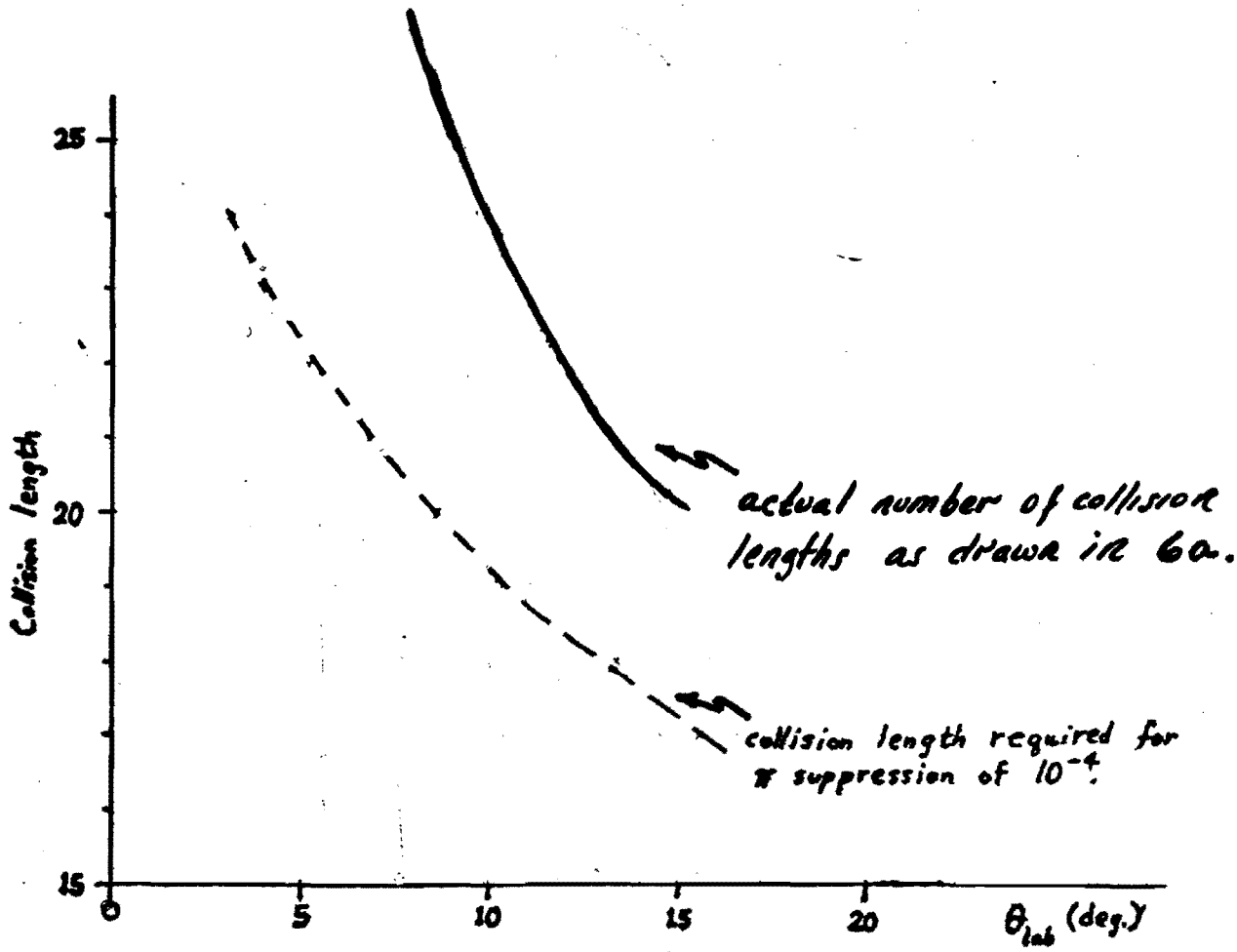


Fig. 7 π-suppression.

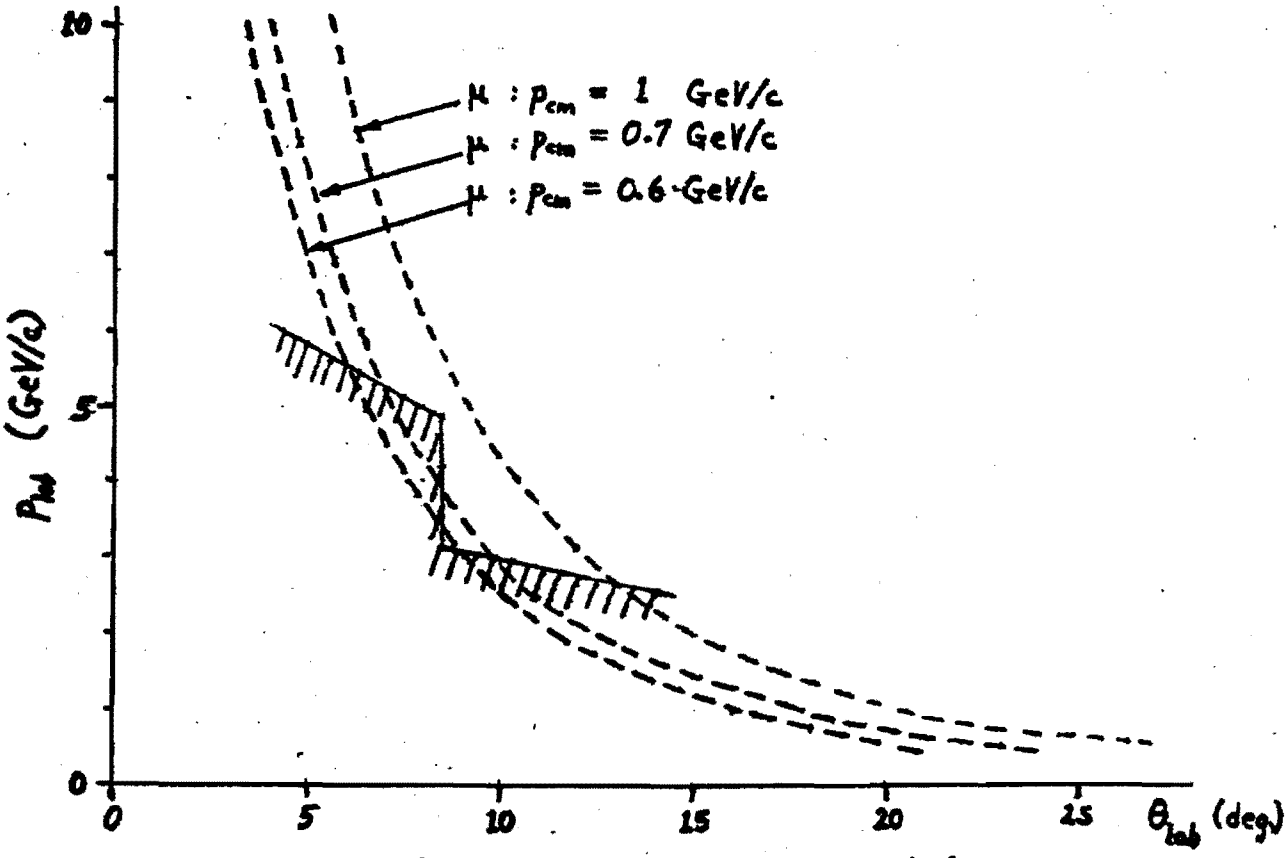


Fig. 8 Minimum μ momentum accepted.