NAL PROPOSAL No. 253

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NEUTRINO-ELECTRON SCATTERING AT NAL

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October 15, 1973

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Proposal

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Submitted by

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I. INTRODUCTION

The reactions of scattering neutrinos from electrons,

$$\nu_\mu + e^- \rightarrow \nu_\mu + e^-,$$
$$\nu_e + e^- \rightarrow \nu_e + e^-$$

and their anti-neutrino counter parts, have not been observed experimentally. These reactions are predicted in the conventional V-A theory of weak interactions.[1] They also play an important role in some cosmological theories.

During the past few years, a great deal of theoretical effort has been concentrated on the development of a renormalizable gauge field theory which manifestly unifies the electromagnetic and the weak interactions.[2] In the context of this theory, there should exist a massive neutral boson, Z°, mediating the weak interactions in the same manner as the photons for the electromagnetic interactions. Both the V-A theory and the gauge theory give definite predictions on the cross sections of neutrino-electron scatterings. Specifically, the Z°-exchange makes the νe scatterings a first order process; while the W-boson exchange makes the reaction a second-order process.

The latest experimental development in high energy physics is the observation of events in neutrino-nucleus interactions in which no muons are produced.[3] This important discovery indicates the existence of hadronic weak currents.

These important developments in physics give us a strong incentive to study neutrino-electron scattering at NAL where strong sources of high energy neutrinos are available. Such experiments will answer the following fundamental questions:

1. The existence of lepton-lepton current interactions.
2. The distinction between various weak interactions theories, such as;
    a. The 4 fermion local V-A theory.

b. Gauge theories.

c. The W-boson theory.

3. The existence of a lepton neutral current.

II. EXPERIMENTAL DESIGN

The basic experimental arrangement is shown in Figure 1. It is conceptually simple and novel. The main elements are specially designed multiple wire proportional chambers interlaced with steel radiators of ~ 1 r.ℓ. in thickness. Neutrino-electron interaction can be uniquely identified by the observation of an electron shower with no hadrons present. We expect to measure the shower energy with about 15% accuracy and the shower mean direction to about 1 mr. The whole arrangement presents several hadron interaction lengths to the beam so that events with hadrons can be isolated. The accuracy of the shower direction measurement will enable us to sort out other types of backgrounds.

Two main types of background are:

1. π° production, and

2. $\nu n \rightarrow ep$.

The first one can be discriminated against by the presence of accompanying hadrons. The second process gives the same order of magnitude as the νe rate but such events can be recognized by the broader angular distribution.

A. The MWPC

The construction of the MWPC's is shown in Figure 2. In this construction, the anode wires are connected together to give information on the pulse-height induced by the electron shower. Signals at the anode wires will also provide the trigger. The two cathode planes are used to measure the position of the electron shower. The "induced" signal on the cathode planes will be read out by a novel "delay-line" technique.[4] The active area of the chamber is 1m x 1m. The mechanical construction is made easier by the use of aluminum plates to support the cathode-wires, which also serve as part of the radiators. The cathode-wires are glued on and insulated from the aluminum plates.

Our laboratory has already built 12 MWPC's 1m x 1m in size for the μ-p inelastic scattering experiment at NAL. The required electronics and mechanical techniques for building these chambers are now fully developed. We estimate the cost of the chambers for the proposed ν-e experiment at $3000 each.

B. The Target

The steel plates between the chambers and the aluminum walls of the MWPC's will serve both as the target for the neutrino interactions and as the radiators for the recoil electrons. The total thickness will be 1 r.ℓ. per cell.

Initially, we would like to build 50 cells, made of one MWPC and one steel plate each, to do the experiment. Later, this number can be increased to 100. If economy permits, we will replace a few steel plates with Pb-glasses. This should enable us to double check the electron energy measurement of the MWPC's.

C. The Trigger

Since the chambers are operating in the proportional mode we will use the anode signals to sample the electron shower energy. If the anode signals from several adjacent chambers show the characteristics of such an electron shower this signal will be used as a trigger to latch the information in all the equipment preparatory to data readout.

Details of electronic logic, cosmic ray vetoes, etc., will not be discussed here.

D. Counting Rate

To estimate the event rate we use the neutrino spectrum shown in Figure 3 and a basic cross section

$$\sigma_0(E_\nu) = 10^{-41}\ E_\nu(\text{in GeV})\ \text{cm}^2.$$

For 50 cells 1m x 1m in size each with 1.38 cm of steel and 2 cm of aluminum

$$N_e = 6 \times 10^{23} \times \left(\frac{10.8\text{x}26}{56} + \frac{5.4\text{x}13}{27}\right) \times 50 = 3 \times 10^{26}\ \text{electrons/cm}^2.$$

From Figure 3, the integral

$$\int_5^{120} N_\nu(E)\ E\ dE = 1.7 \times 10^{11}\ \text{neutrinos/m}^2\ .$$

The counting rate is given by

$$N = N_e \int_5^{120} N_\nu(E)\ \sigma_0(E)\ dE = 0.3 \quad \text{events/hour},$$

for 10^{13} protons of 350 GeV on target, 600 pulses per hour. At 1000 hours running, this will provide 137 events.

The expected cross-sections from different theories are shown in Figures 4 and 5. It is quite clear that 1000 hours running should provide a very significant amount of information in this totally unknown area of physics.

E. Beam

The neutrino beam at NAL can be reused many times. This proposed experiment can be set up behind Exp. 1A and run in parallel with other neutrino experiments under any beam conditions. ,

III. EXPERIMENTAL PLAN AND REQUEST TO NAL

Upon approval of this experimental proposal, we can immediately start the construction work of the MWPC's. The job can be completed within a year and the experiment can be started 3 months after.

The cost for the MWPC's and the associated electronics will be borne by the investigators from the Enrico Fermi Institute of the University of Chicago. We anticipate requesting some supplementary equipment funding from the NSF.

We request NAL to supply the following items:

1) 50 steel plates, 1m x 1m x 1.4 cm in size.
2) A suitable enclosure for the equipment.
3) Fast trigger electronics from PREP.
4) A PDP-11 computer for data acquisition.

Finally, we request 1,000 hours of running time, all parasitic.

REFERENCES

1. R. P. Feynman and M. Gell-Mann, Phys. Rev. 109, 193 (1958).

2. The theoretical review on this subject and original references can be found in the Rapporteur's talk given by B. W. Lee, and the experimental review by D. H. Perkins; Proceedings of the XVI International Conference on High Energy Physics at Chicago and Batavia, U. S. A., 1972.

3. The experimental results from CERN and NAL were recently announced at the International Symposium on Photons and Electrons, Bonn, Germany, 1973.

4. This technique has been developed by T. A. Nunamaker at the Enrico Fermi Institute.

FIGURE CAPTIONS

Figure 1: Schematic arrangement of the experimental setup.

Figure 2: Schematic diagram of the construction of the multiple-wire proportional chamber.

Figure 3: Neutrino spectrum at NAL.

Figure 4: Cross sections for νe scatterings given by different theories. The parameter e^2/g^2 is defined as $\sin^2\theta$ in Weinberg's theory.

Figure 5: The energy dependence of νe scattering cross sections.

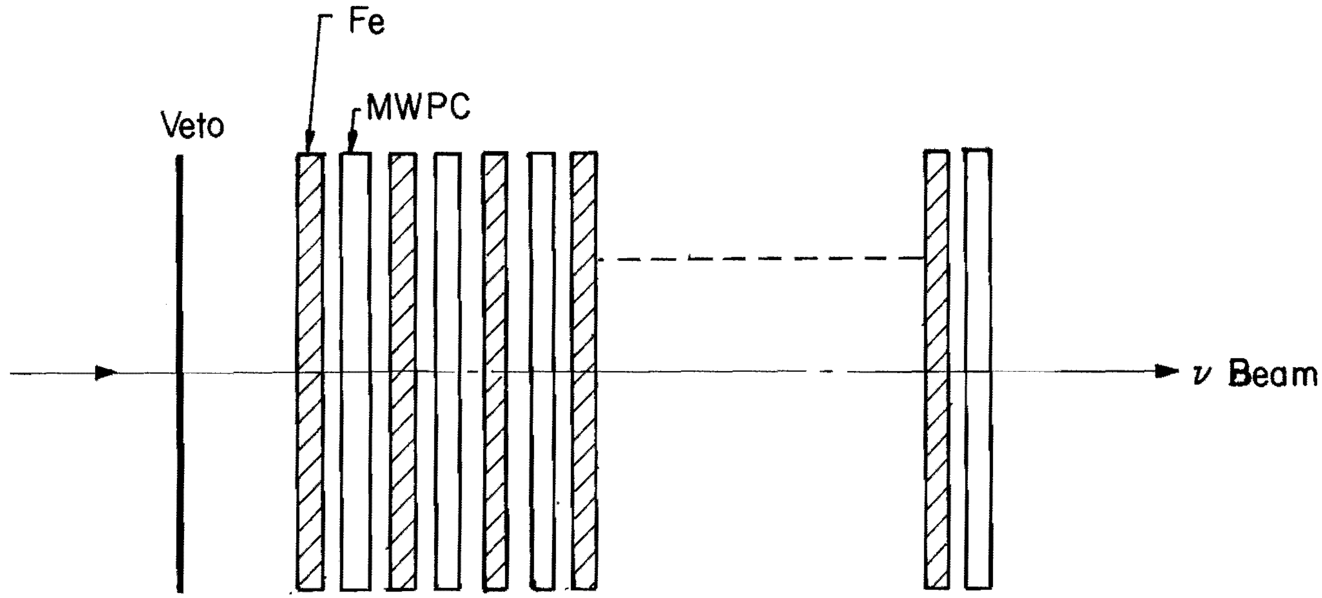

Figure I Schematic Arrangement of the Experimental Setup

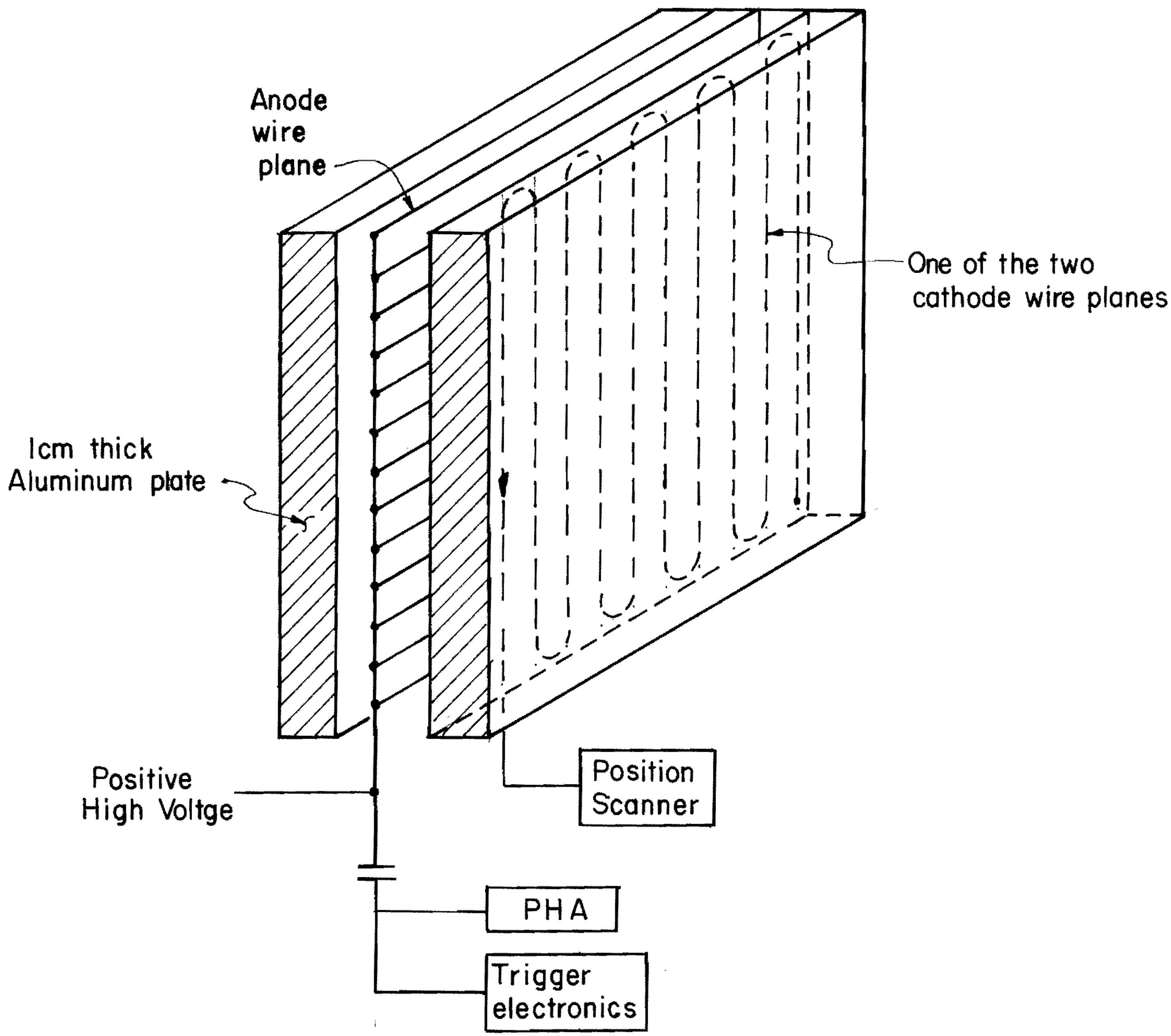

Figure 2 Schematic diagram of the MWPC construction

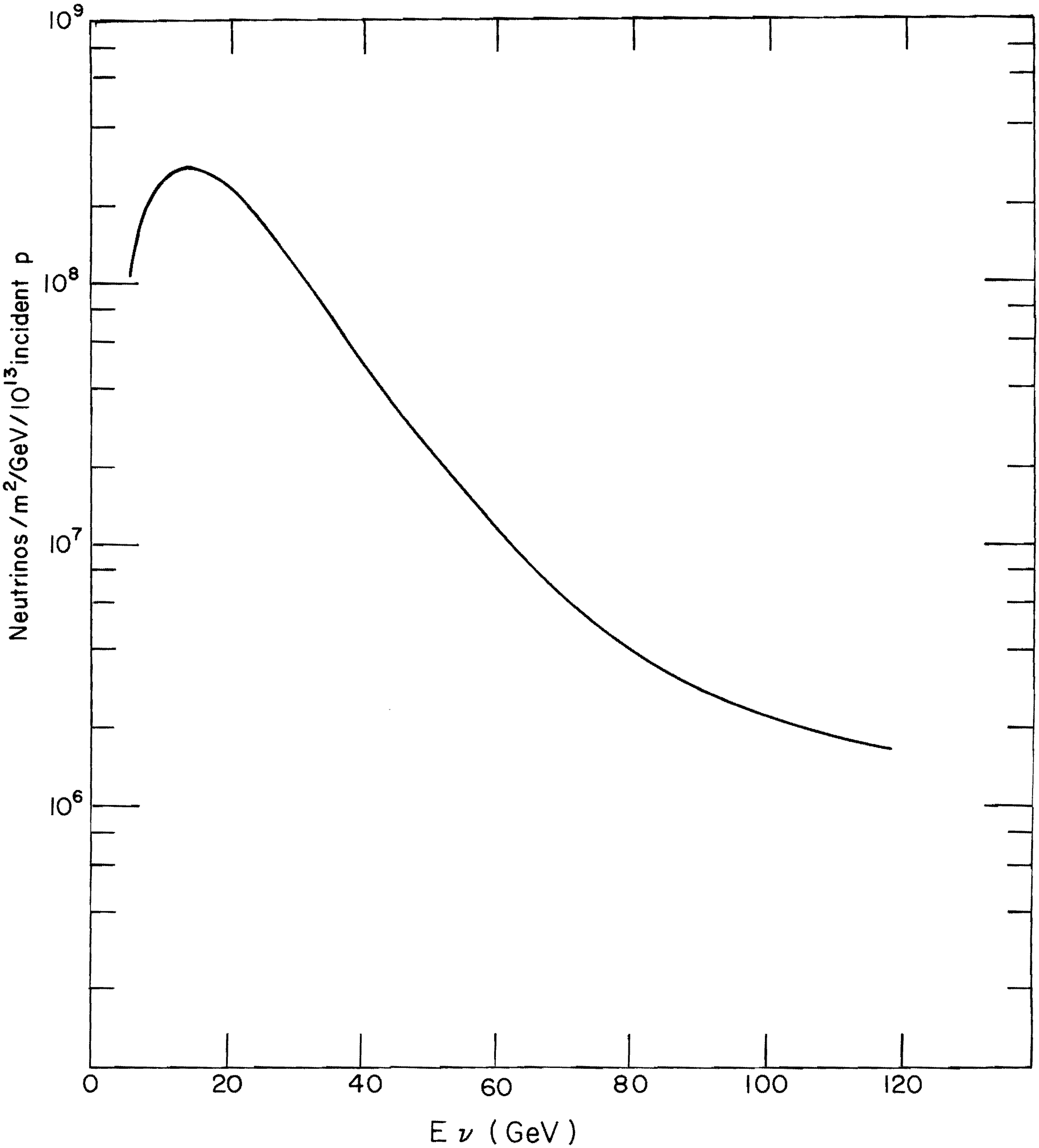

Figure 3 Neutrino Flux Produced by 350 GeV Protons at NAL

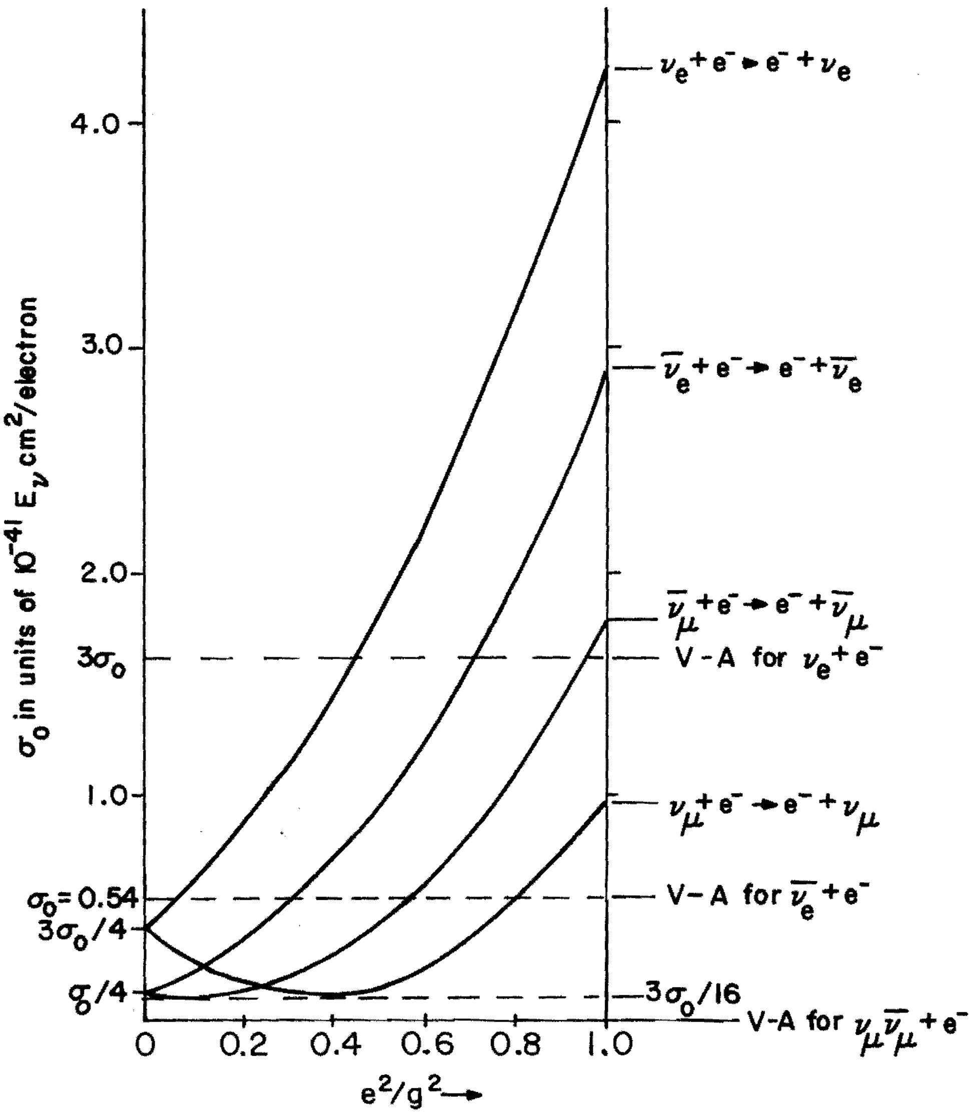

Figure 4 Neutrino-Electron Scattering Cross-Sections in Weinberg Model

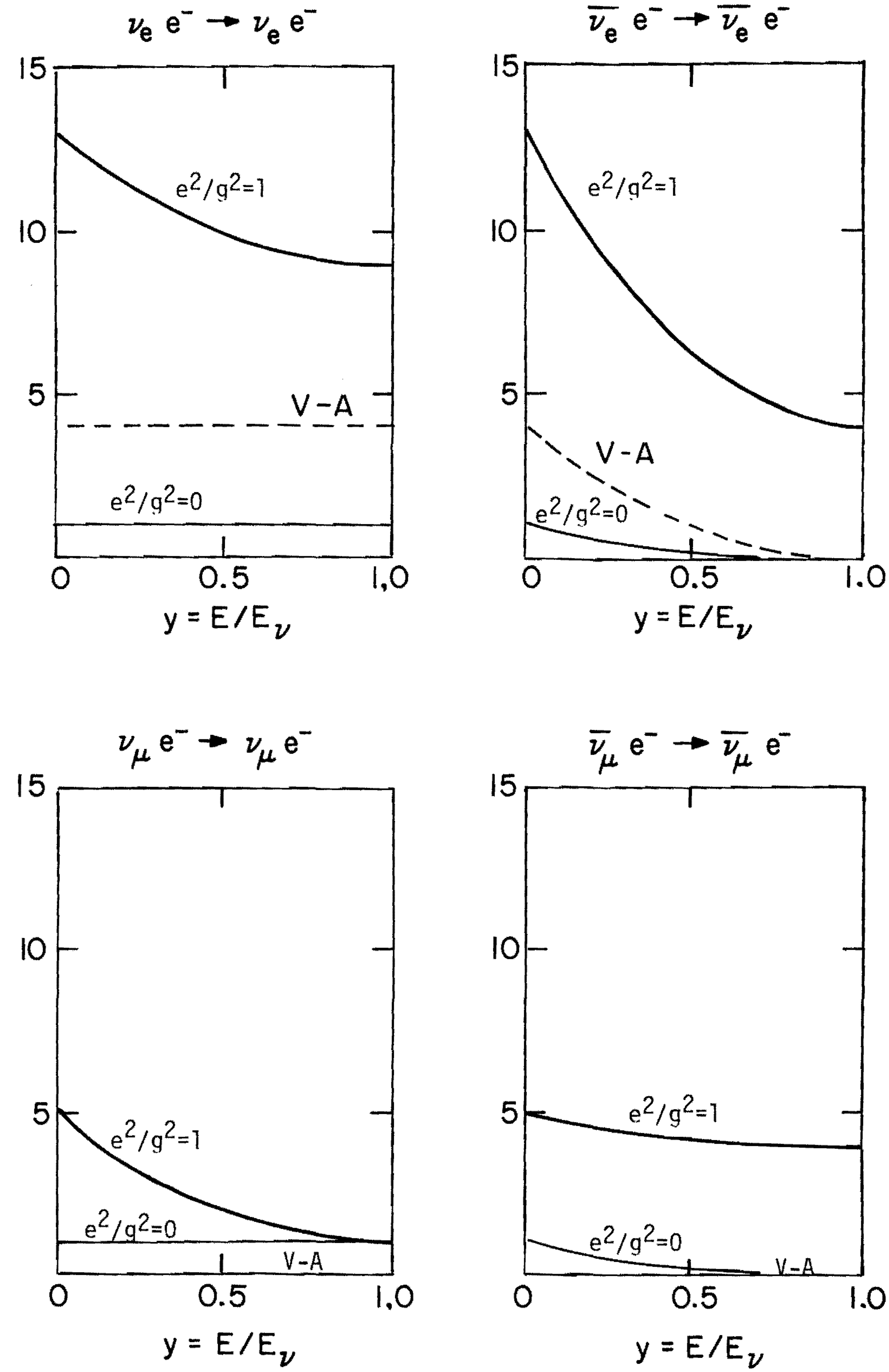

Figure 5 $d\sigma/dE$ for ν-e scattering
(units are 0.4×10^{-41} cm^2/GeV)

Addendum to Proposal 253

Detection Technique

In this addendum, we describe the technique to be used in detecting the recoil electrons from high energy νe scattering. Experience at SLAC is reported, as well as the test we recently made at the Wilson Synchrotron Laboratory of Cornell University.

A. Principle of Detection

To identify νe scatters, events which occur at the 10^{-3} level of the dominant νN interactions, a detector which unambiguously singles out electromagnetic interactions is clearly necessary. Moreover, since hadronic reactions produce electromagnetic showers via neutral pions, the extreme forward going character of the electrons from νe scatterings must be recognized by this detector.

It is well established now that the energies of high energy electrons or photons can be measured very well by an electromagnetic shower detector of approximately 20 radiation lengths in thickness. The energy of the incident particle is fully contained in the detector. However, such a detector is not thick enough to contain the high energy hadronic cascade because 20 r.l. is equivalent to approximately only 2 strong interaction collision lengths. In the initial 3 r.l. of the detector, the energy loss of the electromagnetic particles is several times that of the minimum ionizing particles. Therefore, an EM shower detector in conjunction with a $(\frac{dE}{dX})$ measurement at its front end can determine the energy of an electron or photon and at the same time reject hadrons.

In Proposal #253, we try to apply this simple principle to detect the recoil electrons from νe scattering. The detector we plan to use is sensitive only to the electromagnetic showers induced by high energy electrons or photons. It should be "blind" to the nuclear scattering events because it capitalizes on the radical differences between electromagnetic and hadronic shower development. Of course, as in all neutrino experiments, the detector is part of the target. After a description of a SLAC detector in (B), our solution is described in (C).

B. Experience at SLAC

At SLAC, two large size shower detectors were built for the 8- and 20-GeV/c spectrometers. Each one of these detectors was 20 r.l. thick. It consisted of 20 slabs of Pb-plate and lucite sandwich, 1 r.l. thick each. The first 3 slabs were used also for $(\frac{dE}{dX})$ measurement. Signals from the whole assembly were electronically added to provide the total energy determination. The arrangement is shown schematically in Figure 1.

For the SLAC deep inelastic electron scattering experiment, the π/e ratio accepted by the heavily shielded spectrometer was at times as bad as 400/1. Therefore, pion rejection was very important to the success of the experiment. For a typical run, the raw pulse height spectrum is shown in Figure 2. The minimum ionization peak was greatly suppressed by strong attenuation, but $\sim$ 30% still remained. The pulse height spectrum of the front (dE/dX) detector is shown in Figure 3. If one demands a (dE/dX) cut, as shown in the Figure, then all the pion contamination vanishes in the total energy spectrum. The resultant total energy spectrum of the electrons is shown in Figure 4. We found that pions could be rejected to the level of $\sim 10^{-3}$, with an overall electron detection efficiency ranging from 67% at 2 GeV to 89% at energies above 4 GeV.

It should be remarked that the SLAC shower detectors were built in 1965 and have successfully operated since 1966. Although no details were ever published, the technique has been widely adopted in high energy physics. For example, a similar system was used at SPEAR for the Ψ discovery.

C. <u>νe Detection at Fermilab</u>

In order to do the νe scattering experiment at the Fermilab successfully, one has to measure (1) the recoil electron energy,

(2) the recoil electron direction. Also one has to be able to reject the nuclear scattering events which will be $\sim 10^3$ times more abundant as mentioned before. The Pb-lucite sandwich described above is a device much less expensive than Pb-glass or NaI(Tl) crystals. However, the cost for using it to do a νe scattering experiment is still formidable. In addition, it does not have good spatial resolution. The economic consideration led us to the development of a shower detector as described in Proposal #253. It basically works the same way as a Pb-lucite sandwich does. The only difference is that instead of the lucite-photomultiplier tube assembly, less expensive proportional chambers are used to allow accurate shower direction measurements. In each module, the signal from the anode will be used for pulse height analysis. The delay-line readout from the cathode planes will determine the centroid position of the electron shower.

The signature of a possible νe scattering event is also provided by the anode signals of the proportional chambers. The trigger scheme is illustrated in Figure 5. The analog signals from every ten or so successive anode planes are added together. The triggering threshold is adjusted by the calibrated attenuator in front of the discriminator which will accept electrons above a certain energy and reject most of the signals caused by nuclear scatterings. We plan to build the electronic logic required for this purpose at the Enrico Fermi Institute.

D. The Test at Cornell University

During November, 1974, five members of the collaboration (R. Fine, R. Heisterberg, L. Mo, T. Nunamaker, and S. C. Wright) did a test run with 5 MWPC's at the Wilson Synchrotron Laboratory, Cornell University.

The test set-up at Cornell University is shown in Figure 6. The bremsstrahlung from the 12 GeV electron synchrotron was incident upon a thin converter in front of a dipole magnet. The asymmetrically produced electron pair was energy selected by a magnet and a collimation channel to an energy resolution of $\sim$ 10%. This electron beam was used to test the shower detector we intend to use for the νe scattering experiment at Fermilab.

We installed five 1m X 1m MWPC's exactly the way we intent to do the νe scattering experiment as shown in Figure 7. Since there were only five chambers, the assembly was not thick enough to contain all the electron shower energy. Hence, the energy resolution was consequently not ideal. We recorded the pulse height spectrum of each individual chamber. The total energy spectrum was obtained by software addition. Figure 8 shows the pulse height spectrum at 8 GeV from the first chamber. Figure 9 shows the total energy spectrum at 8 GeV from the sum of five chambers. Figure 10 gives the energy calibration from 2.5 through 9.5 GeV.

As shown in Figure 11, on each cathode plane there are five tap points to measure the partacle trajectory position. Because of time and financial limitations, we did not build the electronic centroid finder. Instead we use standard commercial start-stop type, time-to-digital converters (TDC) to measure the transit time. By doing it this way, the positions measured were actually the edges, instead of the center, of the shower core. A typical picture of a shower induced by 8 GeV electrons is shown in Figure 12. Figure 13 shows the spatial resolution which was obtained by taking the average values as the centroid positions and fit with a straight line.

E. <u>Conclusion</u>

The test run at Cornell University indicated that the proposed detector is a sound one. One can measure the electron energy and determine simultaneously the shower direction to better than 8 mr. If the centroid finders are used instead of the TDC's, we anticipate a factor of $\sim$4 improvement in direction determination.

We wish to thank Dr. R. Humphrey, Dr. M. Tigner, Professor B. McDaniel, and the staff of the Wilson Synchrotron Laboratory for their help and hospitality. It has always been a pleasure to visit Cornell University.

Figure Captions

Figure 1	Electron shower detector used in the 20-GeV/c spectrometer at SLAC. The detector is a Pb-lucite sandwich.
Figure 2	Pulse height spectrum of the SLAC shower detector with a mixture of pions and scattered electrons of 6.4 GeV.
Figure 3	Pulse height spectrum of the third slab of the SLAC shower detector at 6.4 GeV. The cut used for electron-pion separation is also shown.
Figure 4	Pulse height spectrum of the SLAC shower detector at 6.4 GeV. Pion contaminations has been removed by imposing a (dE/dX) cut as shown in Figure 3.
Figure 5	Trigger scheme for the proposed νe scattering experiment at Fermilab.
Figure 6	Arrangement of the test setup at the Wilson Synchrotron Laboratory of Cornell University.
Figure 7	Details of the test setup. The steel radiator is 3/8 in thick each. The distance between chambers is 13". Each chamber consists of two aluminum plates, 1/4 in thick each.
Figure 8	Pulse height spectrum of the first proportional chamber with 8 GeV electrons.
Figure 9	Total energy spectrum given by 5 MWPC's and 8 GeV electrons. This spectrum was obtained by software addition of spectra from five chambers.
Figure 10	Energy calibration curve of the 5-MWPC assembly. The channel numbers are those of the centroids of the total energy spectra as shown in Figure 9.
Figure 11	Schematic of the delay-line readout on the cathode plane. The positions seen by the TDC's are the edges of the shower.

Figure 12 A typical picture from the cathode plane delay-line readout. In this illustration, the triangles indicate the outer edges of the shower measured by the TDC's, and the crosses their average values which were taken as the centroids.

Figure 13 Typical spatial resolution given by the electron shower.

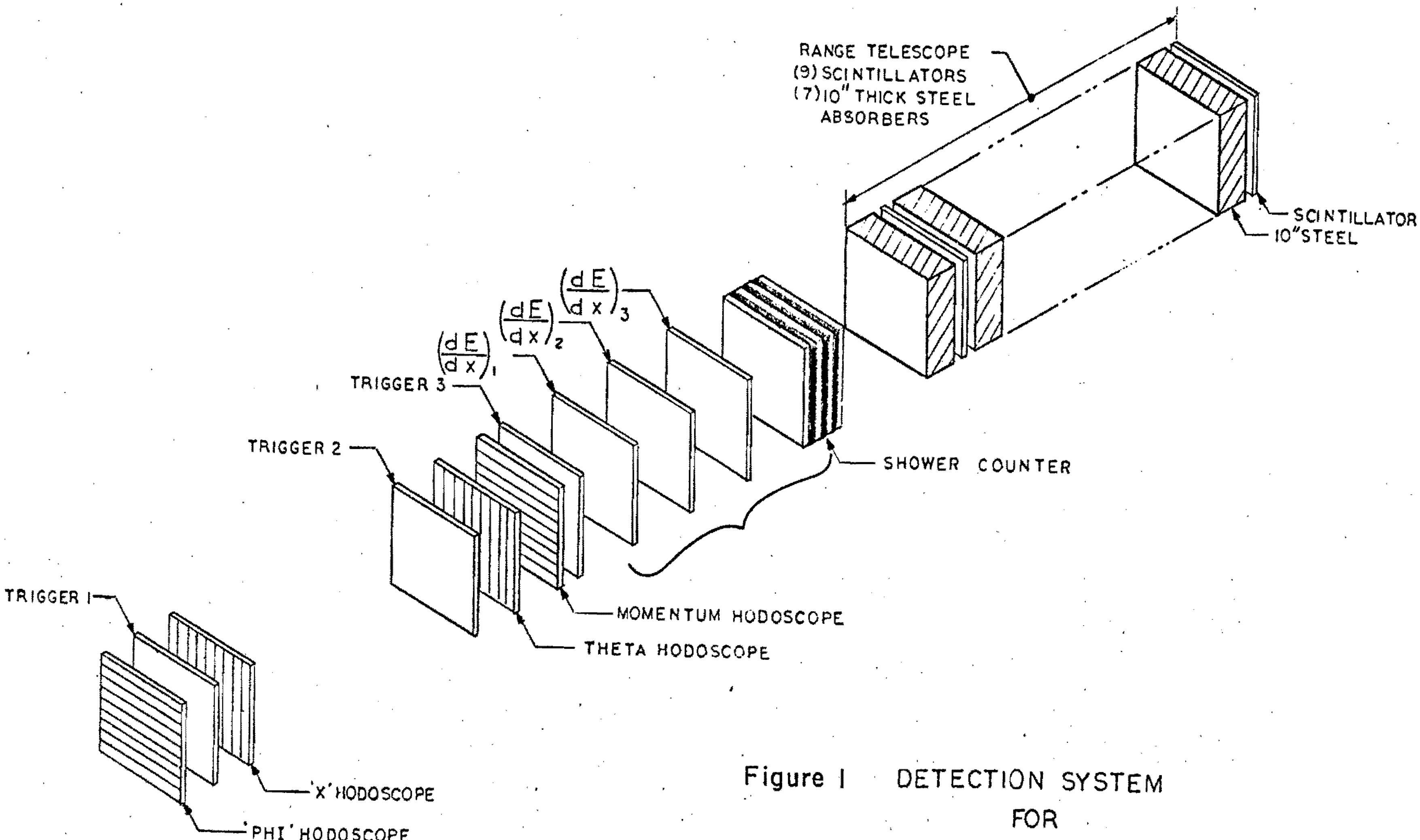

Figure 1 DETECTION SYSTEM FOR 20 GeV/c SPECTROMETER

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                              PH4
                                                       Y(I)                         X E  2
 INTEG  HIST(I) I  X(I)          2         4         6         8        10        12        14        16        18        20
                            +---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
                                                                     ***NO COUNTS RECORDED BELOW CHANNEL     35***
  1039  1039     6    35IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  1993   954     7    42IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  3112  1219     8    49IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  3448   336     9    56IXXXXXXXXXXXXXXX
  3679   231    10    63IXXXXXXXXXXX
  3933   254    11    70IXXXXXXXXXXXX
  4135   202    12    77IXXXXXXXXXX
  4326   191    13    84IXXXXXXXXX
  4482   156    14    91IXXXXXXX
  4628   146    15    98IXXXXXXX
  4728   100    16   105IXXXXX
  4821    93    17   112IXXXX
  4902    81    18   119IXXXX
  4970    68    19   126IXXX
  5040    70    20   133IXXX
  5090    50    21   140IXX
  5146    56    22   147IXX
  5196    50    23   154IXX
  5261    65    24   161IXXX
  5322    61    25   168IXXX
  5388    66    26   175IXXX
  5500   112    27   182IXXXXX
  5694   194    28   189IXXXXXXXXX
  6073   379    29   196IXXXXXXXXXXXXXXXXXX
  6758   695    30   203IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  7854  1096    31   210IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  9382  1528    32   217IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 11134  1752    33   224IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 12644  1510    34   231IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 13622   978    35   238IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 14111   489    36   245IXXXXXXXXXXXXXXXXXXXXXXXX
 14275   164    37   252IXXXXXXXX
 14325    50    38   259IXX
 14339    14    39   266I
 14340     1    40   273I
 14342     2    41   280I
 14344     2    42   287I
 14344     0    43   294I
 14344     0    44   301I
 14344     0    45   308I
 14344     0    46   315I
 14346     2    47   322I
 14347     1    48   329I
 14348     1    49   336I
 14349     1    50   343I

        14376          14349              0              0              0
OBSERVED PEDESTAL LIES AT CHANNEL NO. =     35
TA-CUT=  176.6449 ,ICUT=    7 ,BY MOMENTS(ON CHANNELS  176 TO    301):PEAK CENTRE=  220,SIGMA= 15.94 PEAK TOTAL(OBS)=     9083
SHOWER COUNTER FOR CONDITION  9     = ALL EVENTS INCLUDING PIONS
```

Figure 2

PULSE HEIGHT SPECTRUM OF SHOWER COUNTER (NO CUT)

E_o = 15.6 GeV

θ = 1.5 DEGREE

E' = 6.4 GeV

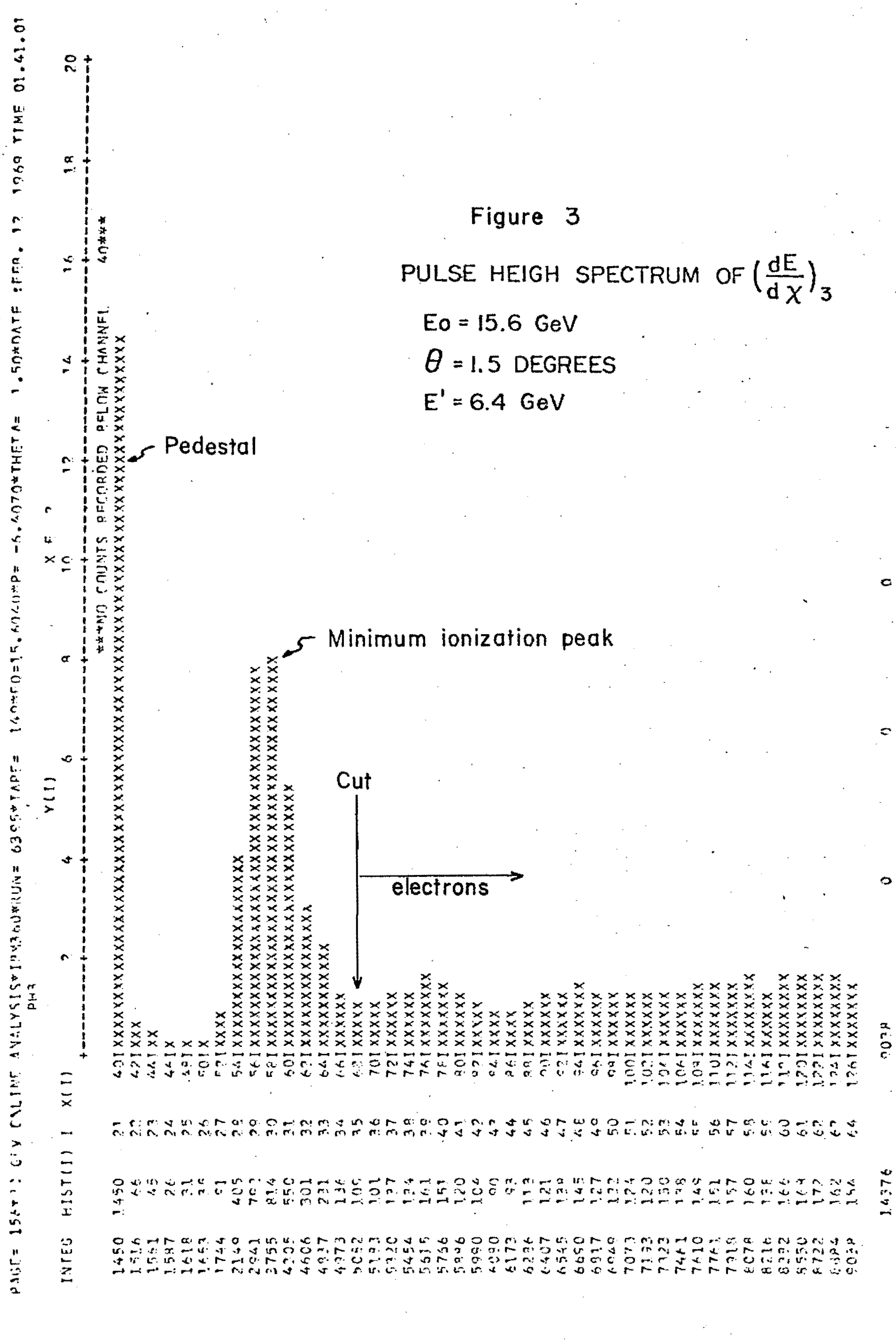

Figure 3

PULSE HEIGH SPECTRUM OF $\left(\frac{dE}{d\chi}\right)_3$

Eo = 15.6 GeV

θ = 1.5 DEGREES

E' = 6.4 GeV

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                                                         Y(I)                       X E  2
 INTEG  HIST(I) I  X(I)          2         4         6         8        10        12        14        16        18        20
                            +---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
                                                              ***NO COUNTS RECORDED BELOW CHANNEL    42***
     5      5     7    42I
    19     14     8    49I
    24      5     9    56I
    26      2    10    63I
    28      2    11    70I
    31      3    12    77I
    35      4    13    84I
    38      3    14    91I
    42      4    15    98I
    43      1    16   105I
    47      4    17   112I
    47      0    18   119I
    51      4    19   126I
    52      1    20   133I
    54      2    21   140I
    57      3    22   147I
    64      7    23   154I
    73      9    24   161I
    86     13    25   168I
   107     21    26   175IX
   159     52    27   182IXX
   269    110    28   189IXXXXX
   535    266    29   196IXXXXXXXXXXXXX
  1049    514    30   203IXXXXXXXXXXXXXXXXXXXXXXXXX
  1929    880    31   210IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  3156   1227    32   217IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  4592   1436    33   224IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  5793   1201    34   231IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  6546    753    35   238IXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  6930    384    36   245IXXXXXXXXXXXXXXXXXXX
  7047    117    37   252IXXXXX
  7081     34    38   259IX
  7090      9    39   266I
  7091      1    40   273I
  7093      2    41   280I
  7094      1    42   287I
  7094      0    43   294I
  7094      0    44   301I
  7094      0    45   308I
  7094      0    46   315I
  7095      1    47   322I
  7095      0    48   329I
  7095      0    49   336I
  7096      1    50   343I

          7112             7096             0                0                0
TA-CUT=  176.6449 ,ICUT=   7 ,BY MOMENTS(ON CHANNELS  176 TO  301):PEAK CENTRE=  221,SIGMA= 14.59 PEAK TOTAL(OBS)=    7021
SHOWER COUNTER FOR CONDITION  3    = YES CC1 YES DE/DX AND GOOD P-T CODES
```

Figure 4

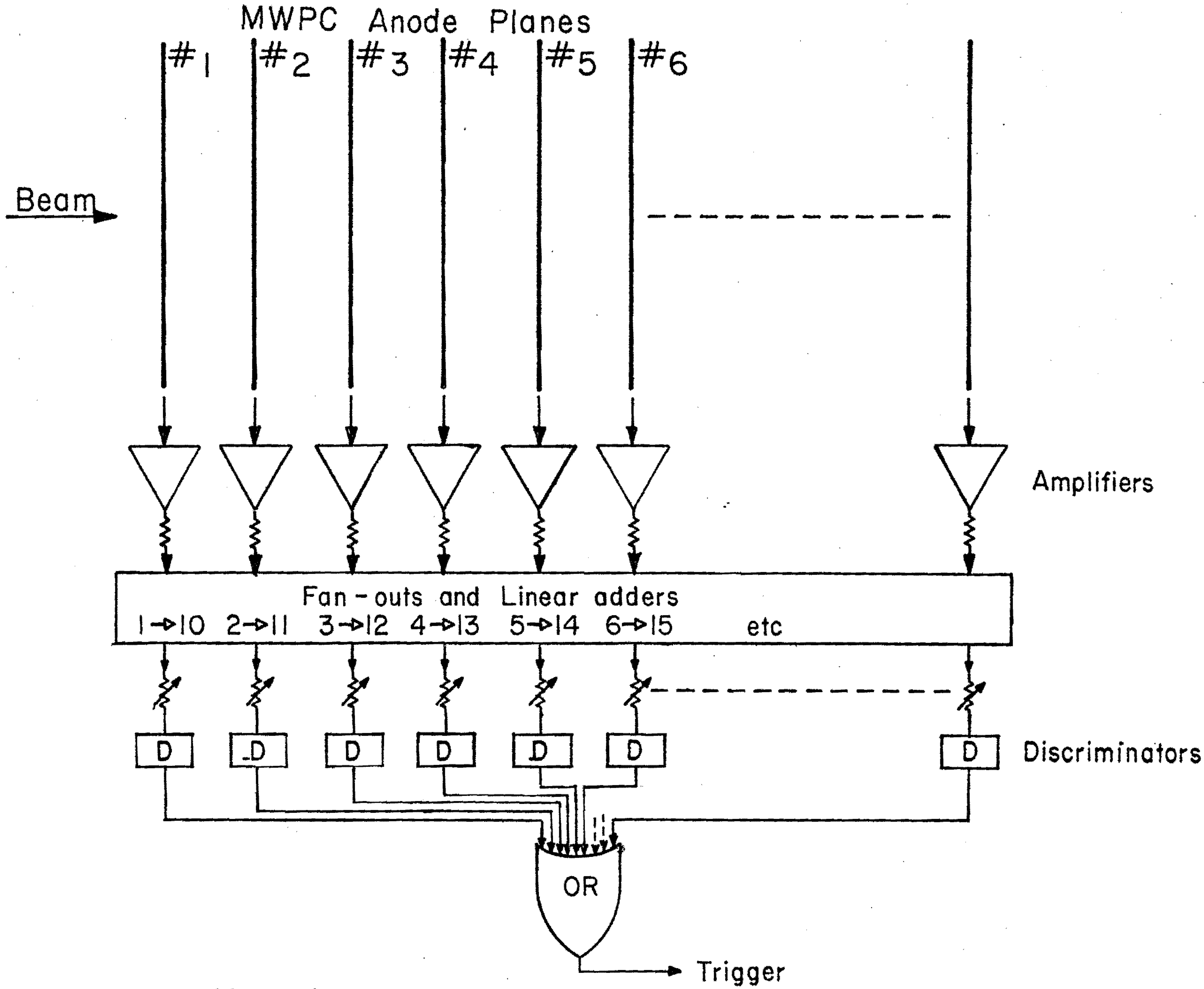
PULSE HEIGHT SPECTRUM OF SHOWER COUNTER

(CUT BY $\frac{dE}{dX}$)

E_o = 15.6 GeV

θ = 1.5 DEGREE

E' = 6.4 GeV



The trigger schematic for νe scatterings

FIGURE 5

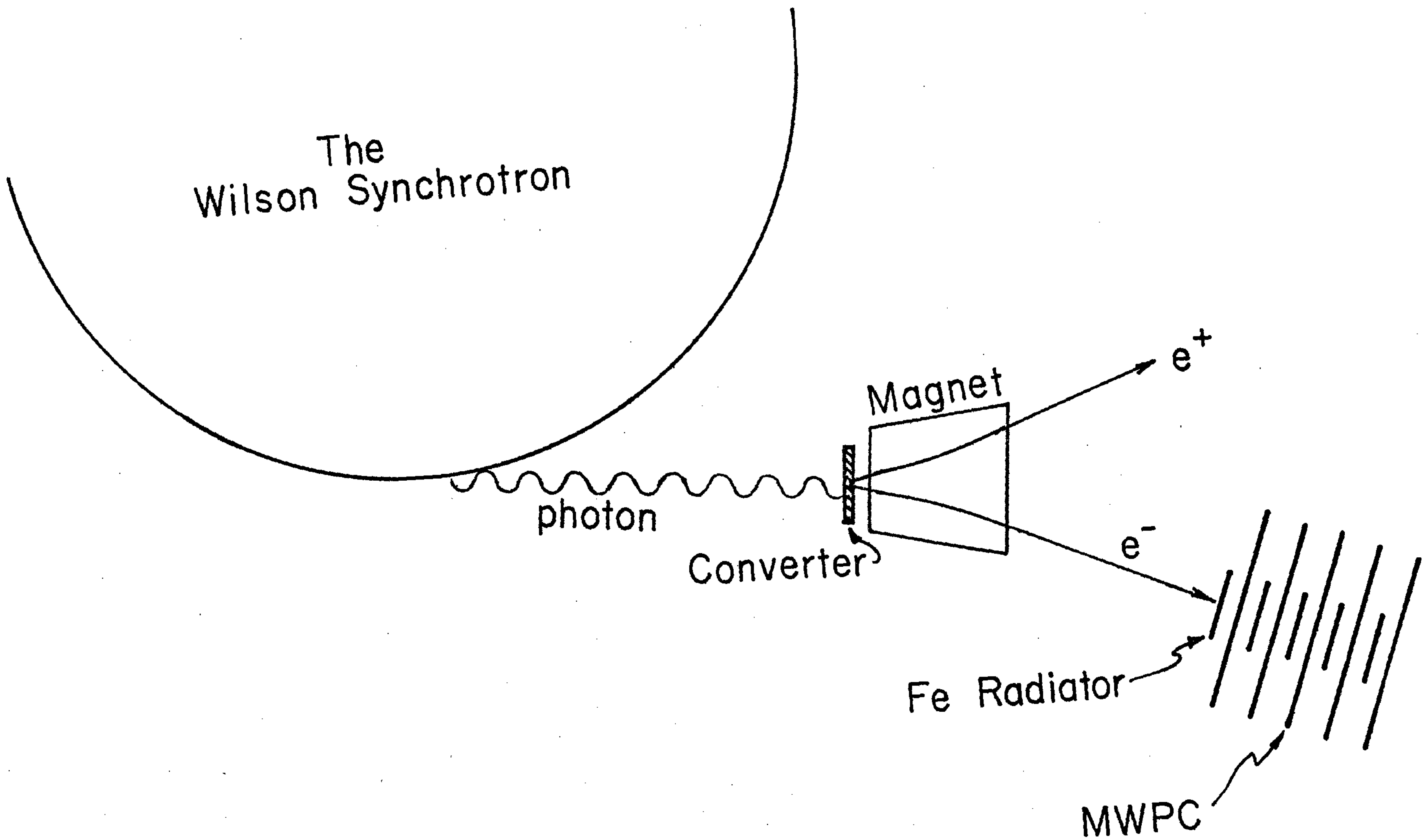
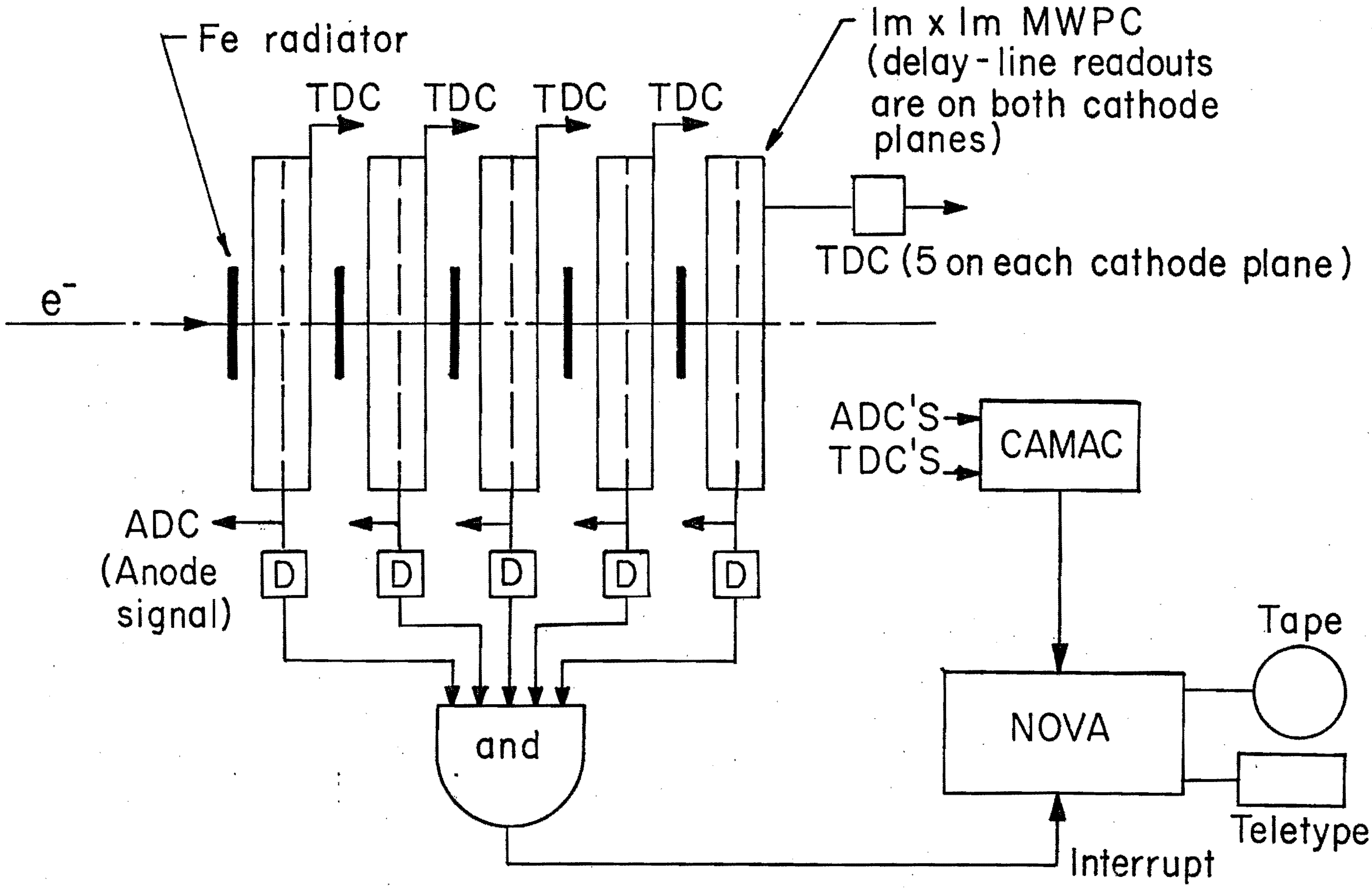
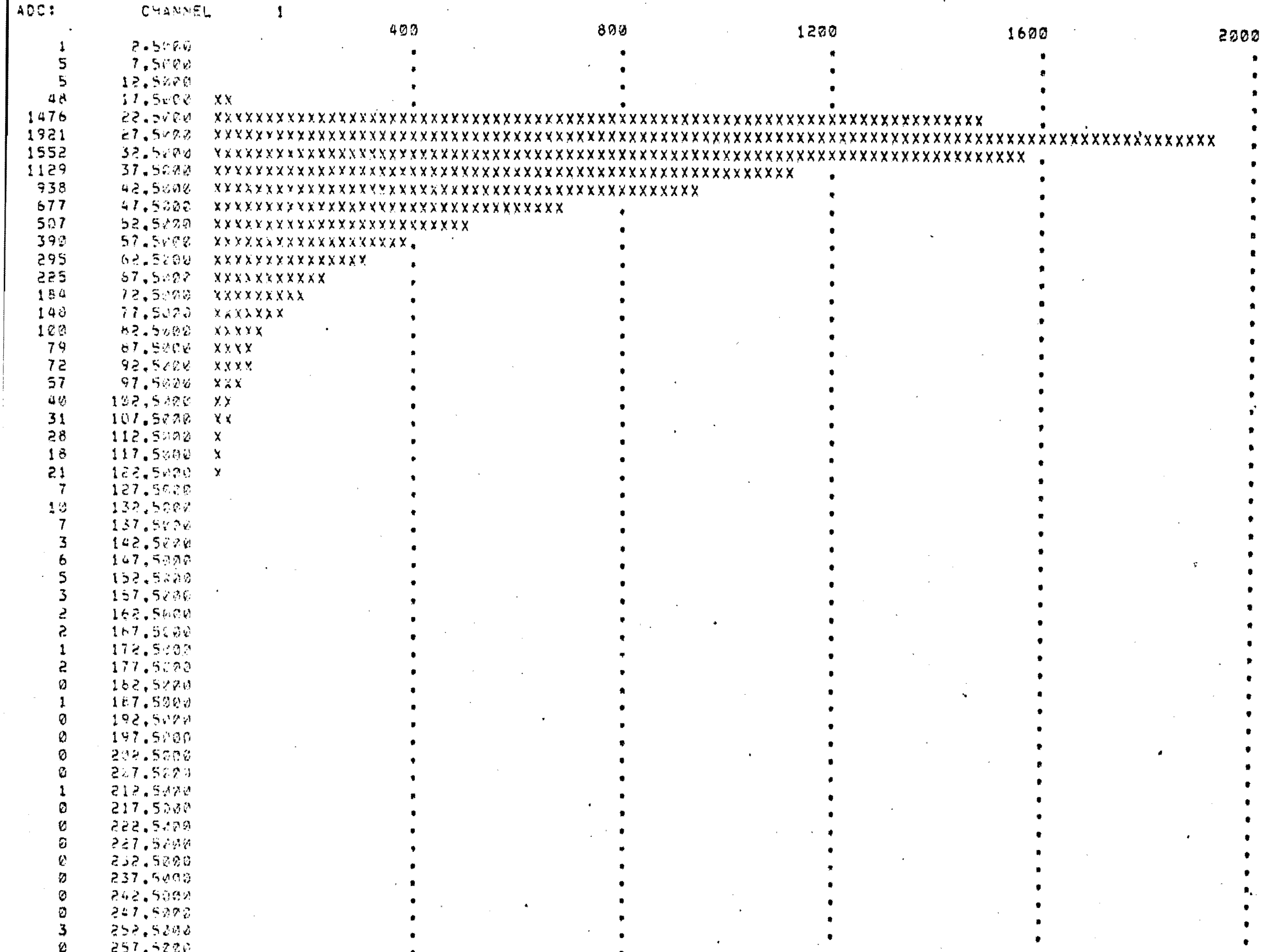

The
Wilson Synchrotron
Magnet
e+
photon
Converter
e-
Fe Radiator
MWPC

FIGURE 6



Fe radiator
Im x Im MWPC
(delay-line readouts
are on both cathode
planes)
TDC
TDC
TDC
TDC
TDC (5 on each cathode plane)
e⁻
ADC'S
TDC'S
CAMAC
ADC
(Anode
signal)
D
D
D
D
D
Tape
NOVA
and
Teletype
Interrupt

Figure 7



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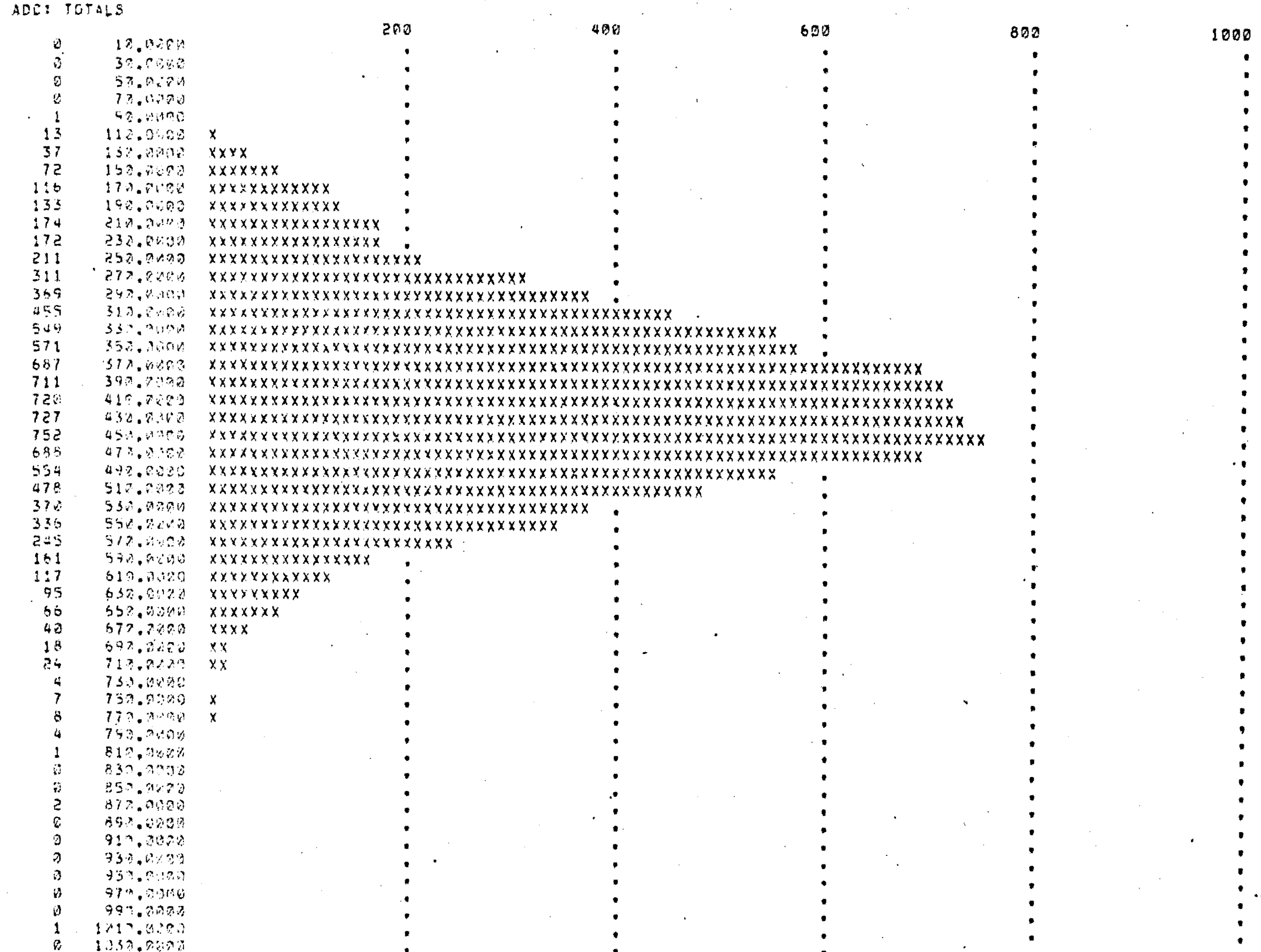
TOTAL	9601.	MEAN	38.278044 +-	0.147226	SIGMA	14.425925 +-	0.104120	CHIDF&NDF	1634.0157	14
TOTAL	9601.	MEAN	38.278044 +-	0.147226	SIGMA	14.425925 +-	0.104120	CHIDF&NDF	1634.0157	14

Figure 8

Pulse Height spectrum of the first chamber with 8 GeV electrons



10000 EVENTS IN PLOT. MEAN= 408.231998 AND SIGMA= 110.247476

TOTAL	9977.	MEAN	407.853062	+-	1.090729	SIGMA	108.947441	+-	0.771379	CHIDF&NDF 3.7045 30
TOTAL	9977.	MEAN	407.853062	+-	1.090729	SIGMA	108.947441	+-	0.771379	CHIDF&NDF 3.7045 30
TOTAL	9977.	MEAN	407.853062	+-	1.090729	SIGMA	108.947441	+-	0.771379	CHIDF&NDF 3.7045 30

Figure 9

Total energy spectrum with 5 MWPC's and 8 GeV electrons

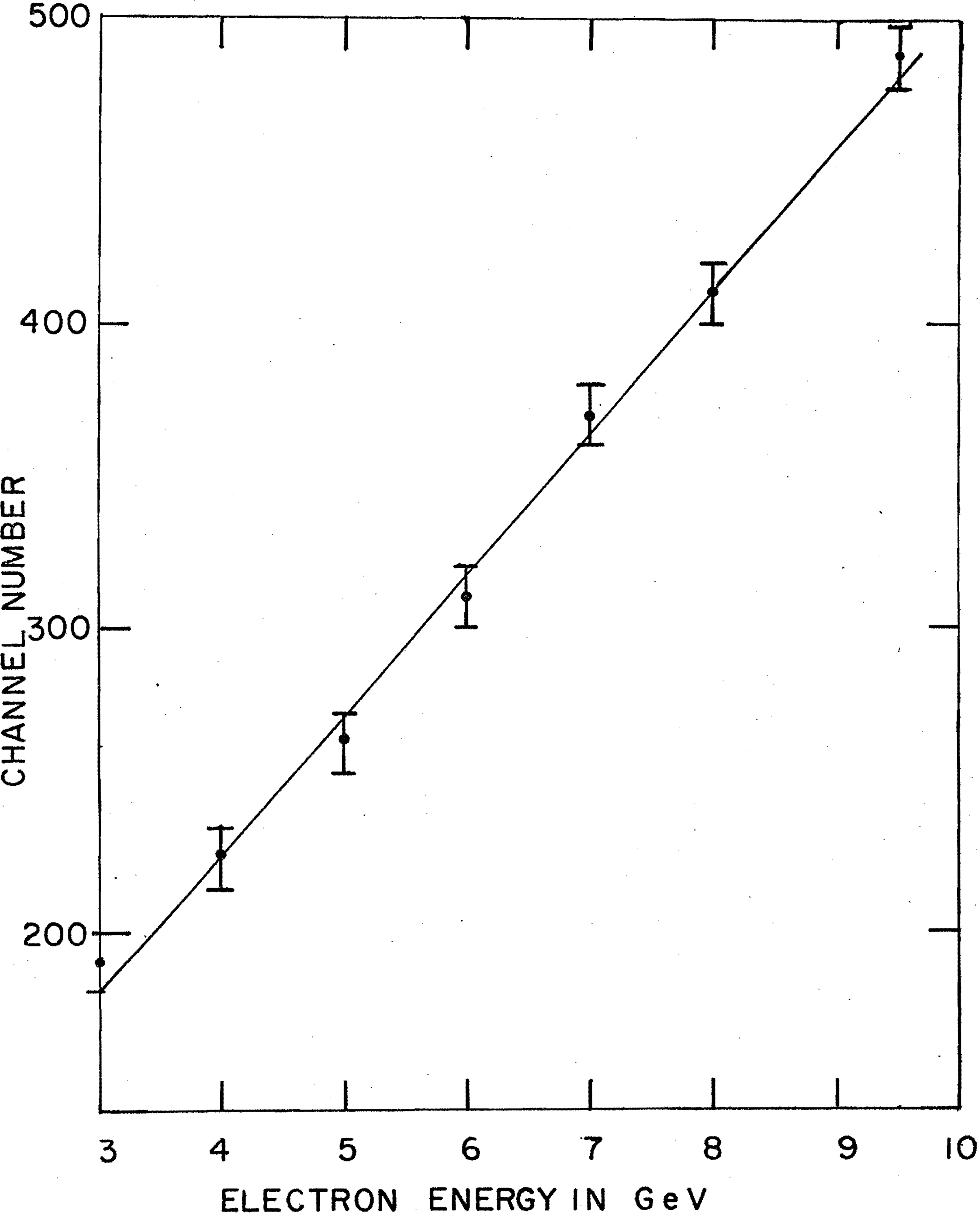
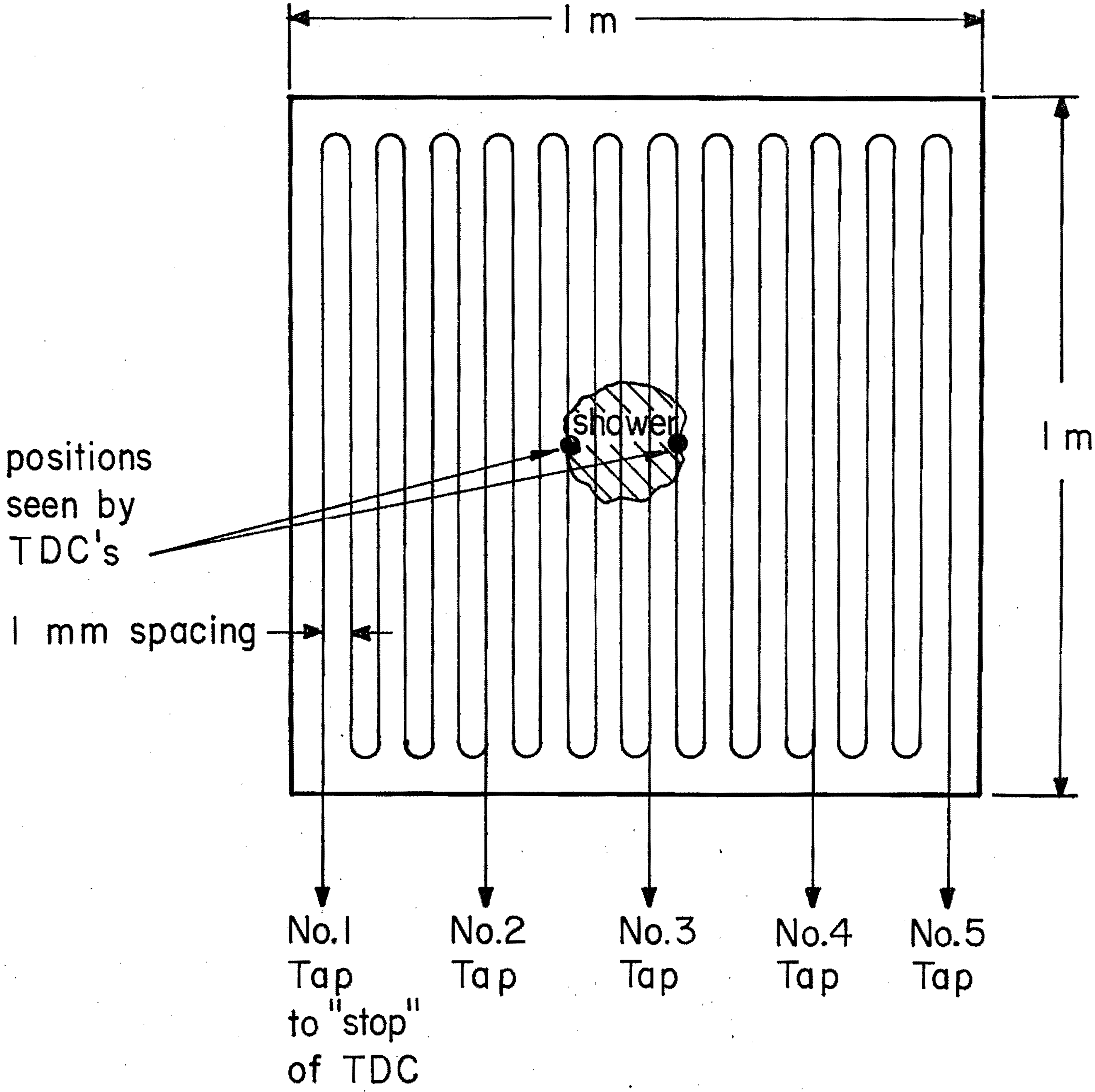

500
400
300
200
CHANNEL NUMBER
3
4
5
6
7
8
9
10
ELECTRON ENERGY IN GeV

FIGURE 10



1 m
1 m
shower
positions seen by TDC's
1 mm spacing
No.1 Tap to "stop" of TDC
No.2 Tap
No.3 Tap
No.4 Tap
No.5 Tap

FIGURE 11

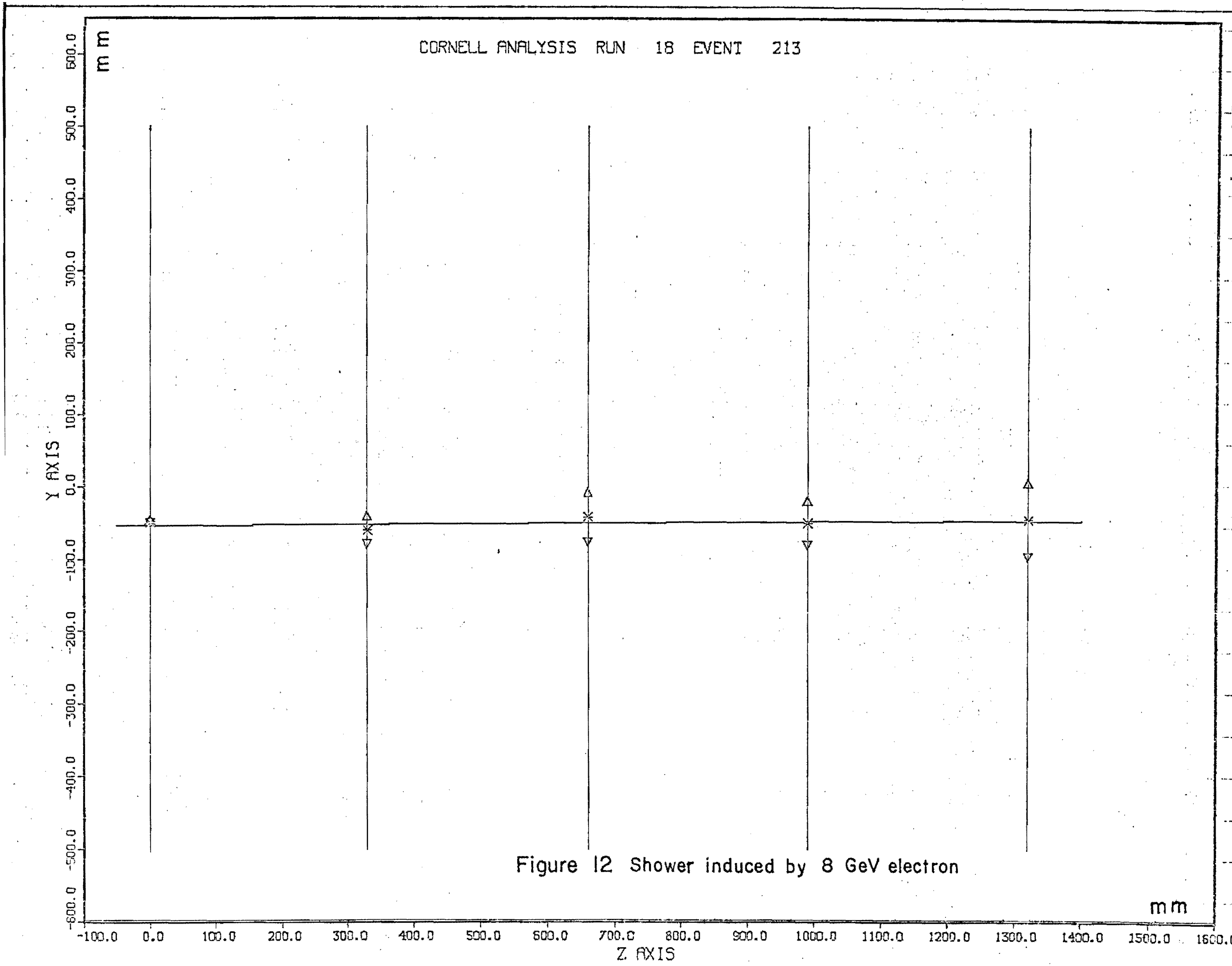


Figure 12 Shower induced by 8 GeV electron

END OF FILE ENCOUNTERED ON EVENT: 10000 CORNELL ANALYSIS

RMF & RHH DATE: 2/19/75 TIME: 01.20.31 PAGE: 1

HISTOGRAM # 1 DEVIATION HISTOGRAMS

SUM X10 [1]	Y X10 [1]	I	X	2 4 6 8 10 12 14 16 18 20
0.0	0.0	1	-50.00	:
0.0	0.0	2	-48.00	:
0.0	0.0	3	-46.00	:
0.0	0.0	4	-44.00	:
0.0	0.0	5	-42.00	:
0.0	0.0	6	-40.00	:
0.0	0.0	7	-38.00	:
0.0	0.0	8	-36.00	:
0.0	0.0	9	-34.00	:
0.0	0.0	10	-32.00	:
0.0	0.0	11	-30.00	:
0.0	0.0	12	-28.00	:
0.0	0.0	13	-26.00	:
0.0	0.0	14	-24.00	:
0.0	0.0	15	-22.00	:
0.100	0.100	16	-20.00	:X
0.200	0.100	17	-18.00	:X
0.500	0.300	18	-16.00	:XX
0.800	0.300	19	-14.00	:XX
1.600	0.800	20	-12.00	:XXXX
2.500	0.900	21	-10.00	:XXXXX
5.000	2.500	22	-8.00	:XXXXXXXXXXXXX
10.400	5.400	23	-6.00	:XXXXXXXXXXXXXXXXXXXXXXXXXXXX
16.200	5.800	24	-4.00	:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
23.300	7.100	25	-2.00	:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
31.800	8.500	26	0.0	:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
41.400	9.600	27	2.00	:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
52.500	11.100	28	4.00	:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
59.700	7.200	29	6.00	:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
62.600	2.900	30	8.00	:XXXXXXXXXXXXXXX
64.400	1.800	31	10.00	:XXXXXXXXX
65.300	0.900	32	12.00	:XXXXX
65.700	0.400	33	14.00	:XX
66.100	0.400	34	16.00	:XX
66.100	0.0	35	18.00	:
66.100	0.0	36	20.00	:
66.200	0.100	37	22.00	:X
66.200	0.0	38	24.00	:
66.200	0.0	39	26.00	:
66.200	0.0	40	28.00	:
66.200	0.0	41	30.00	:
66.200	0.0	42	32.00	:
66.200	0.0	43	34.00	:
66.200	0.0	44	36.00	:
66.200	0.0	45	38.00	:
66.200	0.0	46	40.00	: mm
66.200	0.0	47	42.00	:
66.200	0.0	48	44.00	:
66.200	0.0	49	46.00	:
66.200	0.0	50	48.00	:

UNDER: 0.0 < AVG > = 1.7556

OVER: 0.0 < SIG > = 5.5134

HISTOGRAM SHOWN FOR PLANE # 1

Figure 13

Spatial resolution with 4 GeV electrons

ADDENDUM III TO E-253

N. Booth, R. Heisterberg, L. Mo, A. Skuja

The setting up of E-253 is now almost complete in the Wonder Building and parasitic tuning is underway. The apparatus consists of 41 multi-wire proportional chambers, 1 m^2 in active area, with 1 r.l. of Al between successive chambers. In addition we have a scintillation hodoscope at the upstream end to veto/tag incoming muons and two hodoscopes at the downstream end separated by 4 ft of steel to veto/tag muons produced in the apparatus. At present we have no capability to measure the momenta of these muons. Now that we are ready to start our $\nu_\mu e$ scattering experiment we feel that it is time to reconsider the supplemental request which we made in Addendum II to our proposal.

We would like to supplement this setup with an iron magnet and drift chambers to measure the momenta of forward-going muons. Not only will this help us to better understand the background to our primary reaction of interest, $\nu_\mu e$ scattering, but will enable us to study as byproducts several interesting processes in a unique way. In particular, our apparatus is well suited to measure coincidences between electromagnetic showers and muons With a small amount of additional equipment, we will be able to measure the following two reactions:

1) Single π^o production by charged and neutral currents,

$$\nu_\mu + n \to u^- + p + \pi^o$$
$$\to \nu_\mu + n + \pi^o$$

This provides information on the isospin structure of the weak current.

2) Inverse muon decay,

$$\nu_\mu + e^- \rightarrow \nu_e + \mu^-$$

$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_e + \mu$$

These reactions have not yet been observed and have rates comparable to $\nu_\mu e$ elastic scattering. They can only be done at Fermilab because the threshold energy is 10 GeV. Since the muons go very forward our apparatus has very good acceptance. The study of these reactions answers the question of the additive or multiplicative law of lepton conservation.

We wish to stress that these measurements should not cost us additional effort.

We should also mention that once we can measure muon momenta we can also examine events of the following types in our data:

a) Muon-electron pair production,

$$\nu_\mu + N \rightarrow \mu^- + e + X$$

b) Multi-lepton production,

$$\nu_\mu + N \rightarrow \mu^-\mu^+\mu^- + X$$

$$\rightarrow \mu^-e^+e^- + X$$

$$\rightarrow e^-\mu^+\mu^- + X$$

$$\rightarrow e^-e^+e^- + X$$

We have begun to construct 10 drift chambers. We ask Fermilab to supply two iron dipole magnets each 1.5 m long and 8 ft X 8 ft in active cross-section. This requires an additional 15' of space in the Wonder Building. We do not envisage that this program will interfere with our approved $\nu_\mu e$ scattering experiment. Besides the additional physics which we can gain we consider it to be a necessary improvement to enable us to understand the many background processes which will trigger our apparatus.