IC/76/78
INTERNAL REPORT
(Limited distribution)

International Atomic Energy Agency

and

United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

T O P I C A L M E E T I N G

ON LEPTON INTERACTIONS AND NEW PARTICLES

6 - 9 July 1976

P A R T I

(Contributions)

MIRAMARE - TRIESTE
July 1976

μ - PHYSICS AT CERN SPS

E. Gabathuler

EP Division, CERN, 1211 Genève 23, Switzerland.

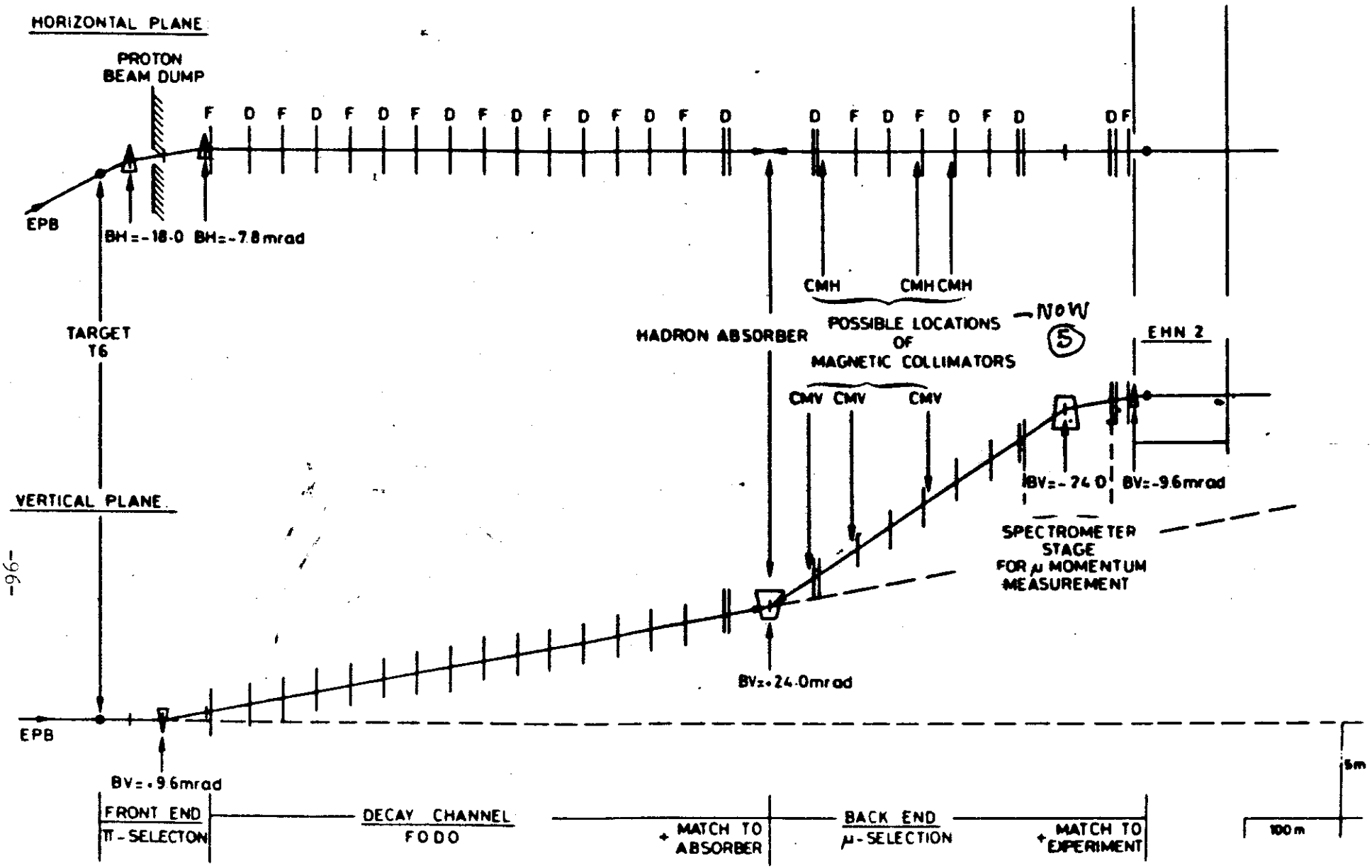
PLANS FOR MUON PHYSICS AT CERN · S P.S

by

ERWIN GABATHULER

CERN & RUTHERFORD LAB

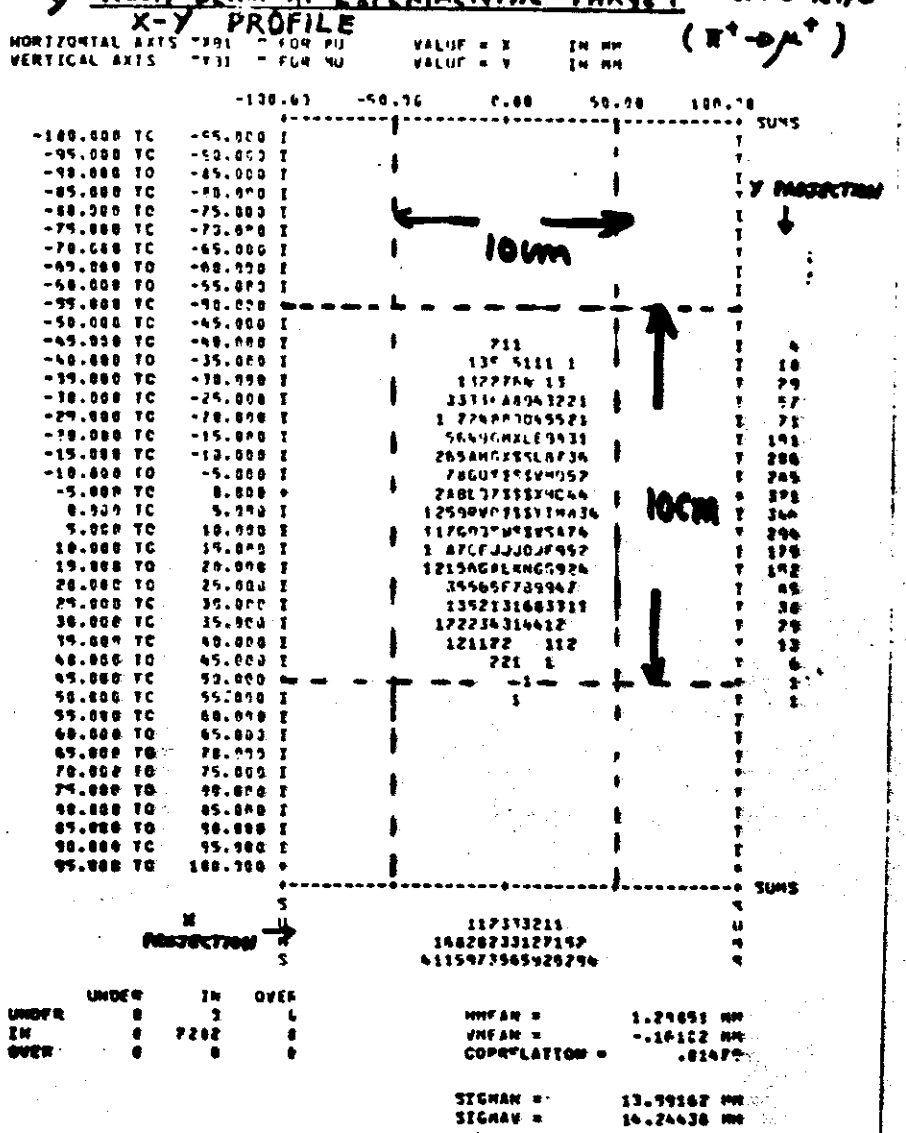
(SELECTION OF TRANSPARENCIES)
PRESENTED



SCHEMATIC LAYOUT OF BEAM M2

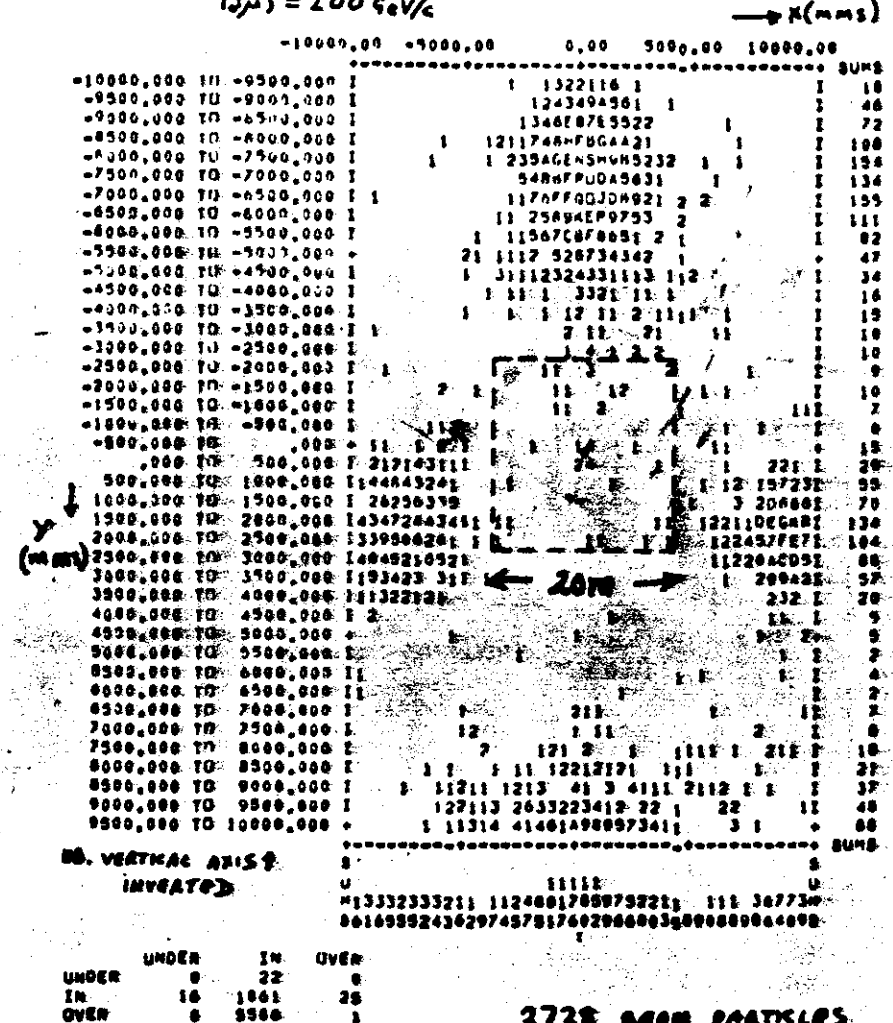
Fig. C.2.1

a) MUON BEAM AT EXPERIMENTAL TARGET 200 GeV/c
X-Y PROFILE ($\pi^+ \to \mu^+$)



b) HALO WITHIN 20m x 20m AT THE POSITION OF AN EXPERIMENT NEAR THE FRONT OF EHN2

$P(\mu) = 200$ GeV/c



2728 BEAM PARTICLES

Fig. 8

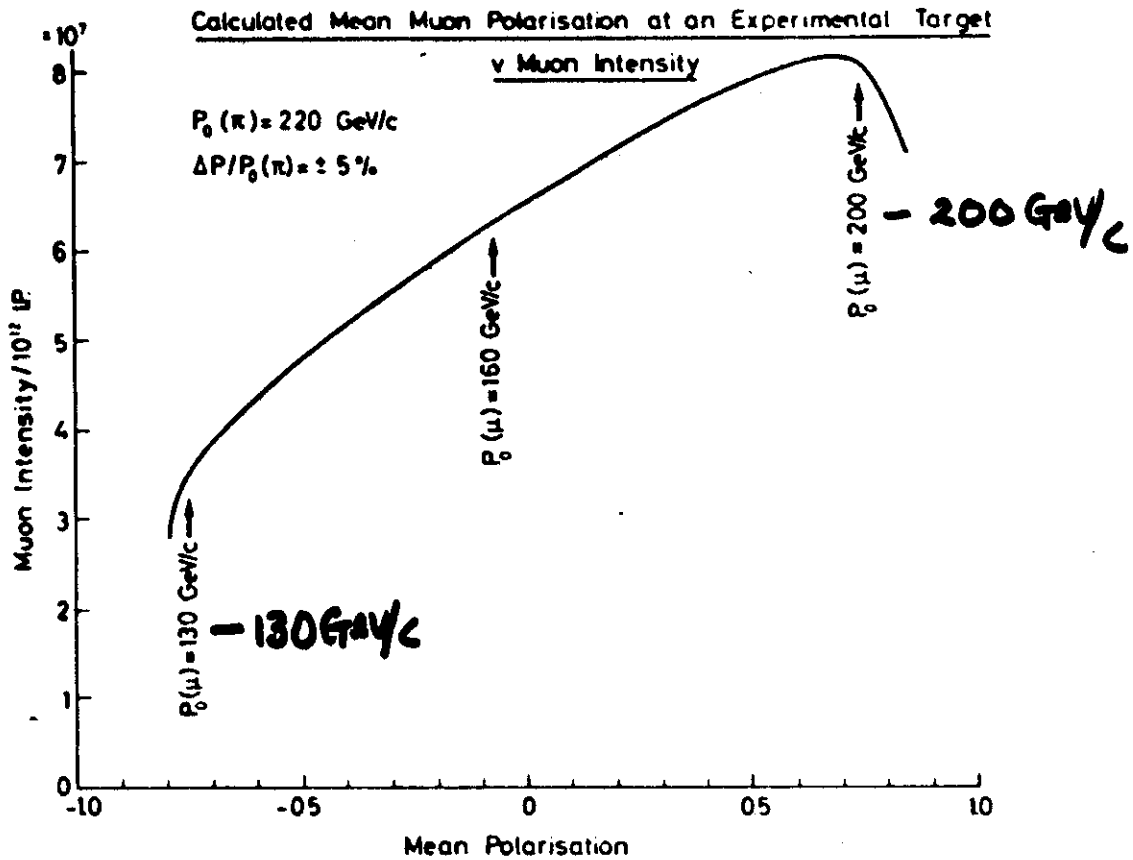

Calculated Mean Muon Polarisation at an Experimental Target
v Muon Intensity
$P_0(\pi) = 220$ GeV/c
$\Delta P/P_0(\pi) = \pm 5\%$
$P_0(\mu) = 130$ GeV/c
$P_0(\mu) = 160$ GeV/c
$P_0(\mu) = 200$ GeV/c
130 GeV/c
200 GeV/c
Muon Intensity/10^{12} iP
$\times 10^7$
0
1
2
3
4
5
6
7
8
-10
-05
0
05
10
Mean Polarisation

TABLE C.2.1.

MUON INTENSITY AT EXPERIMENTAL TARGET
(CALCULATED USING HAGEDORN-RANFT PRODUCTION FIGURES)

ENERGY (GeV)							CALC. HALO LEVEL %
PARENT PARTICLE	MUON	PARENT	MUON	INDIVIDUAL MUON INTENSITIES/10^{12} LB	BEAM INTENSITY 10^{12} I.P.	μ^+/μ^- RATIO	
300	280	π^+	μ^+	$1{\cdot}0 \times 10^7$	$1{\cdot}4 \times 10^7$	4·9	3%
300	280	K^+	μ^+	$3{\cdot}5 \times 10^6$			
300	280	π^-	μ^-	$2{\cdot}7 \times 10^6$	$2{\cdot}8 \times 10^6$		
300	280	K^-	μ^-	$3{\cdot}1 \times 10^4$			
220	200	π^+	μ^+	$1{\cdot}0 \times 10^8$	$1{\cdot}2 \times 10^8$	3·8	-1%
220	200	K^+	μ^+	$2{\cdot}2 \times 10^7$			
220	200	π^-	μ^-	$3{\cdot}2 \times 10^7$	$3{\cdot}3 \times 10^7$		
220	200	K^-	μ^-	$7{\cdot}9 \times 10^5$			
140	120	π^+	μ^+	$3{\cdot}0 \times 10^8$	$3{\cdot}1 \times 10^8$	2·3	2·6%
140	120	K^+	μ^+	$1{\cdot}1 \times 10^7$			
140	120	π^-	μ^-	$1{\cdot}3 \times 10^8$	$1{\cdot}4 \times 10^8$		
140	120	K^-	μ^-	$2{\cdot}2 \times 10^6$			
200	120	π^+	μ^+	$6{\cdot}8 \times 10^7$	$7{\cdot}1 \times 10^7$	3·0	3·3%
200	120	K^+	μ^+	$2{\cdot}8 \times 10^6$			
200	120	π^-	μ^-	$2{\cdot}3 \times 10^7$	$2{\cdot}3 \times 10^7$		
200	120	K^-	μ^-	$2{\cdot}0 \times 10^4$			

PPO HELICITY

FOR 220 - 200 GeV

	R.M.S	FULL WIDTH (99%)
HORIZ SIZE (x)	± 14 mm	± 34 mm
(x')	± 0·22 mr	± 0·50 mr
y	± 14 mm	± 34 mm
y'	± 0·44 m	± 1·0 mr
$\frac{\Delta P}{P}$	± 4·5%	± 9%
$\frac{\pi}{\mu}$	$\leq 10^{-6}$	

TWO EXPERIMENTS APPROVED

(1) EUROPEAN MUON COLLABORATION

a) FRANCE - ORSAY / ANNECY

b) GERMANY - D.E.S.Y / FREIBURG U. / KIEL U. / WUPPERTAL.

c) CERN

d) ITALY - TURIN

e) U.K - LANCASTER / LIVERPOOL / OXFORD SHEFFIELD / R. M. C / DARESBURY RUTHERFORD

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(2) a) CERN — C. FIRG. EXP

b) FRANCE - SACLAY

c) ITALY - ROME

d) RUSSIA - DUBNA.

e) GERMANY - MUNICH
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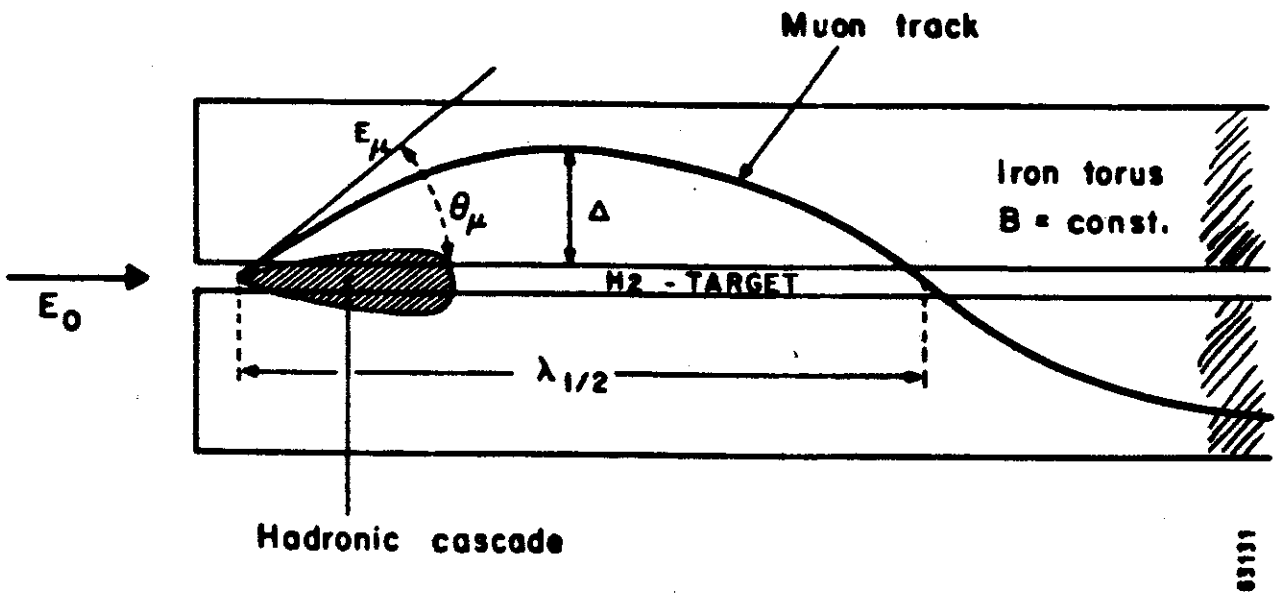
PHILOSOPHY OF C.F.I.R.G EXP

PRINCIPLE OF q^2 - FOCUSSING SPECTROMETER



$$\lambda_{1/2} = 6.66\, p_\perp / B \qquad (p_\perp = p \sin\theta)$$

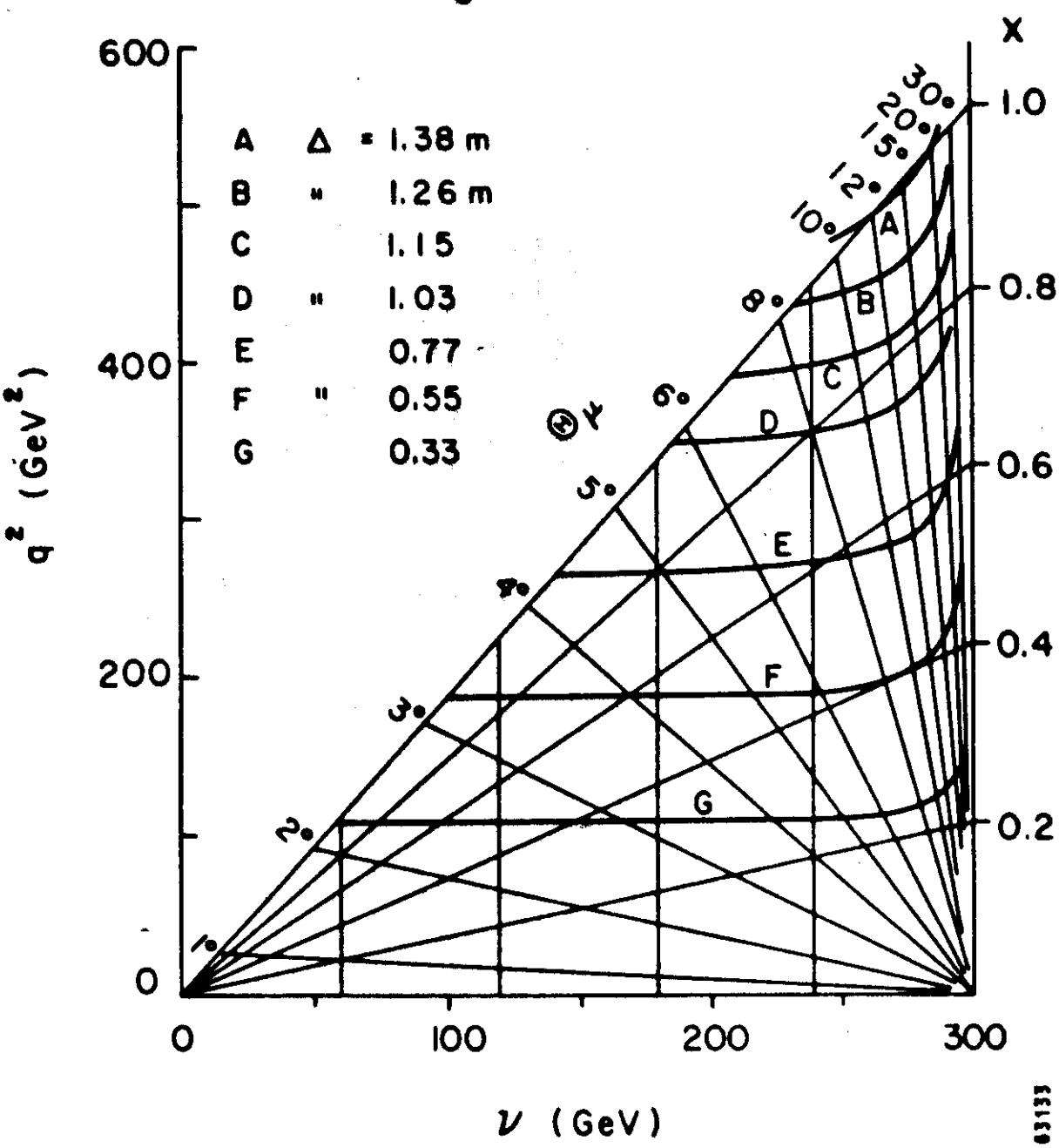
$$\Delta = \frac{Mp}{0.3B}\,\frac{q^2}{q^2_{max}} \qquad (q^2_{MAX} = 2mE_0)$$

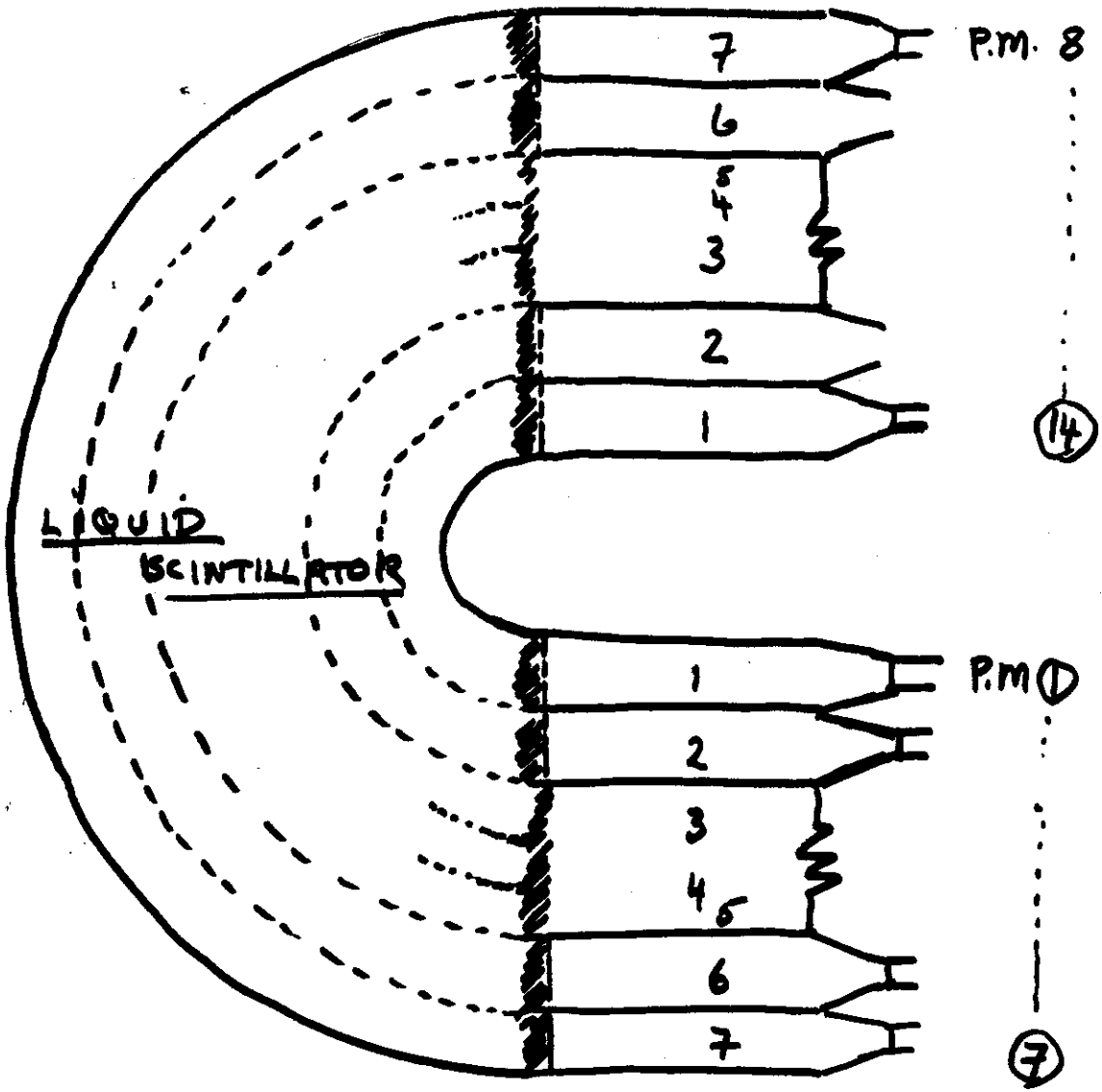
MUON DESCRIBES ↝ IN IRON

ONLY μ SEEN — PUSH FOR MAX LUMINOSITY

SHORT π-DECAY PATH.

Lines of constant sagitta Δ taking into account energy-loss in the iron





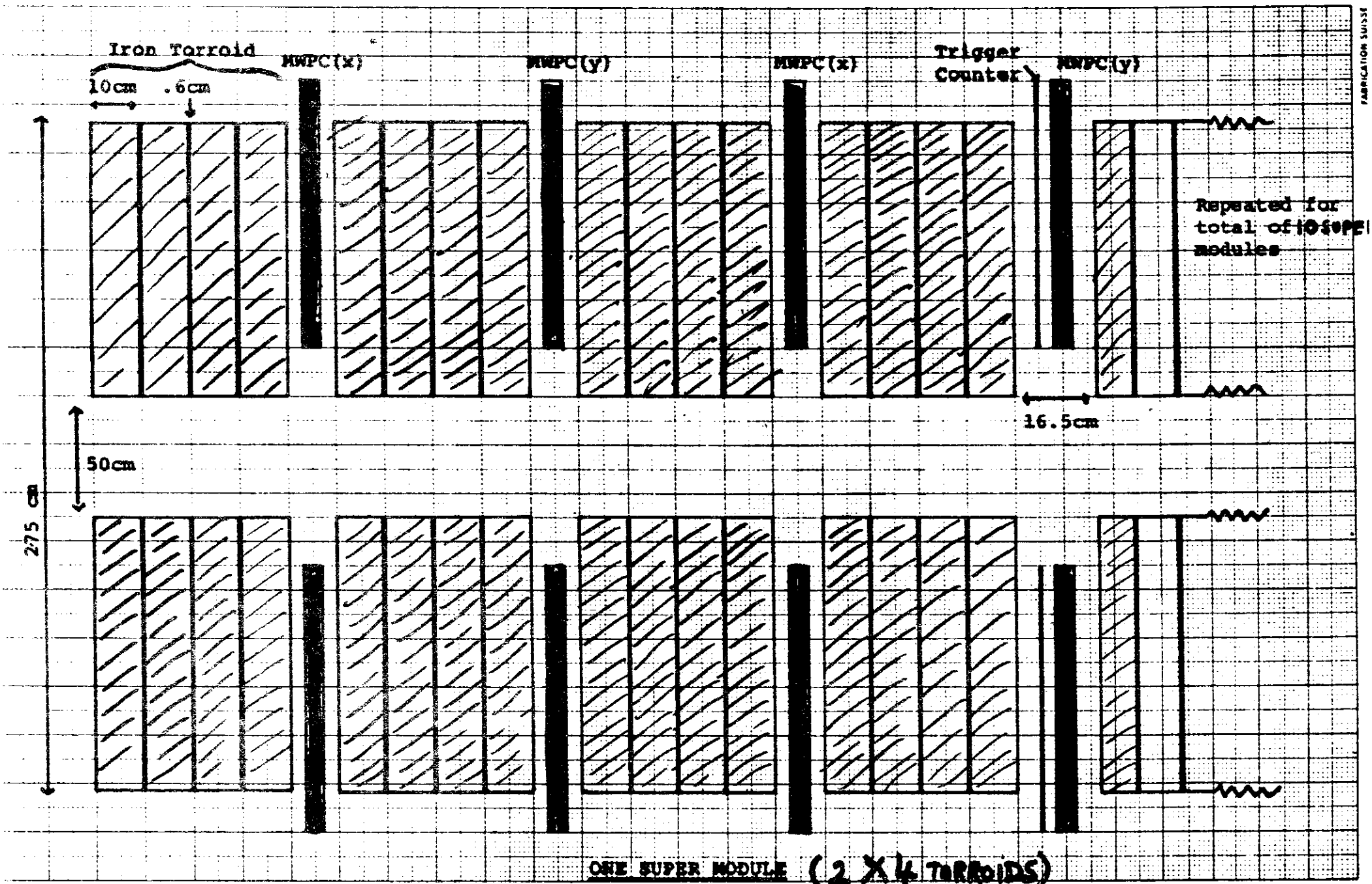
θ - EACH ELEMENT

φ - T.I.MING BETWEEN P.M's (Ly. 1-14)

TRIGGER COUNTER

EACH MUON WILL GIVE TRIGGER PATTERN

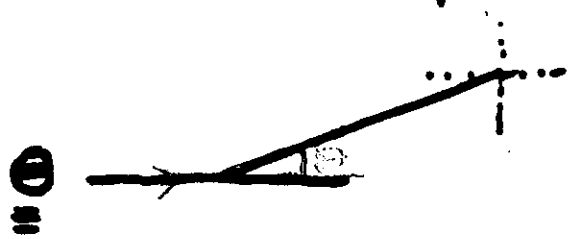
e.g. 0,0, 1, 2, 3, 4, 3, 2, 1 ...



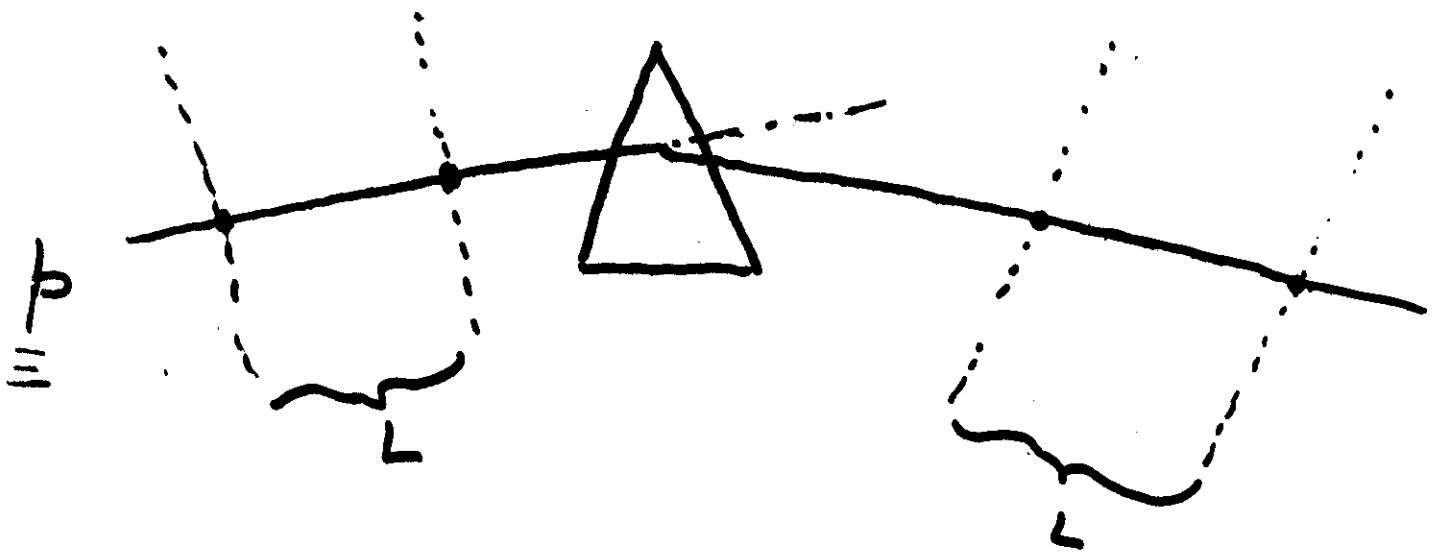
CERN/DUBNA/MUNICH/ROME/SACLAY EXPT

PHILOSOPHY OF E M C

1) MEASURE p θ ϕ DIRECTLY



0·5mm SPATIAL RESOLN
→ 0·1 mrad.



LEVER ARMS

$\frac{\Delta p}{p} \sim \pm 10^{-4} p$ GeV/c ($\frac{\Delta p}{p} \sim 1\%$ @ 100 GeV/c)

2) FLEXIBILITY

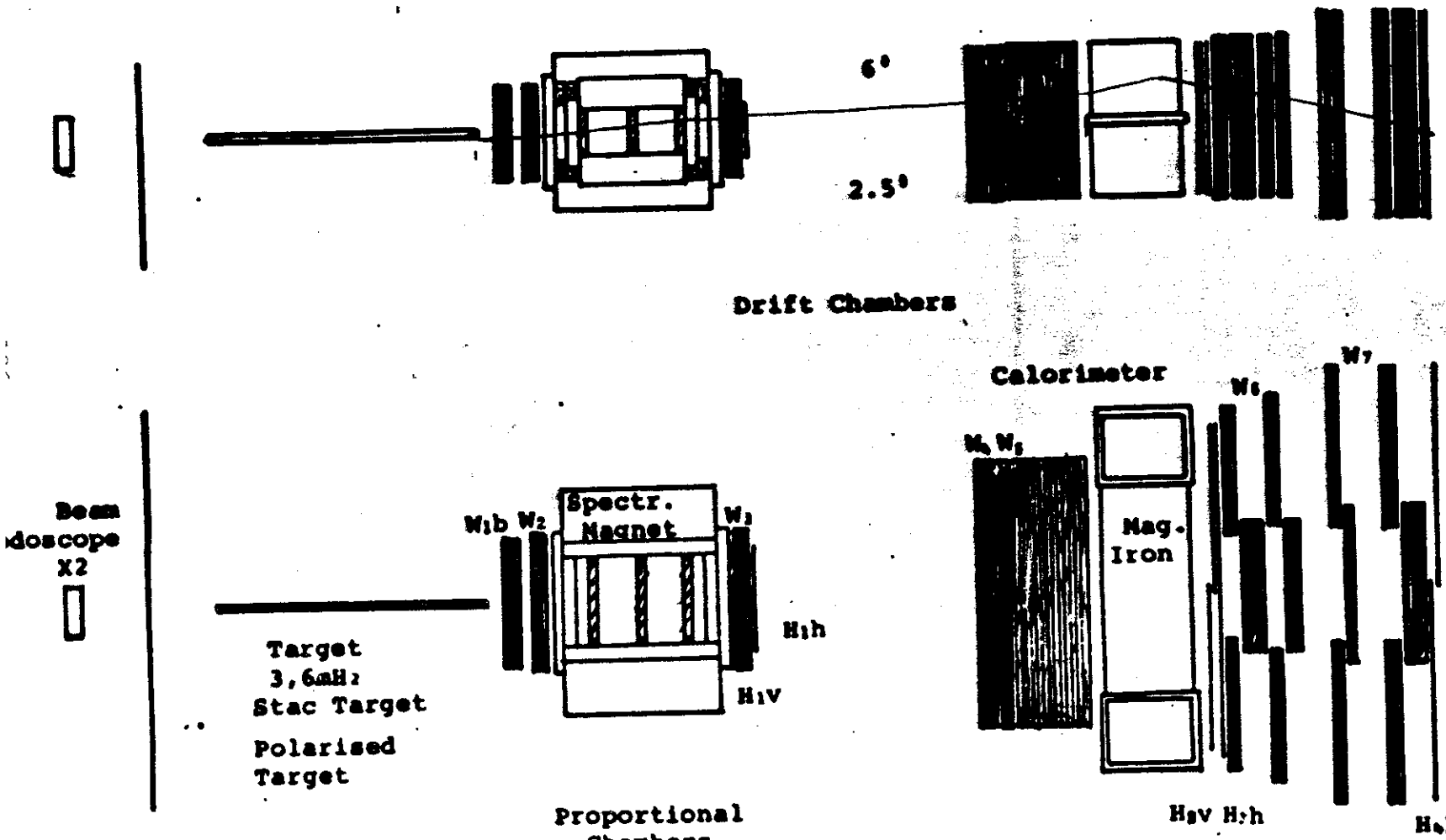
LOOK AT HADRONS (IDENTIFY)

" " PHOTONS, ELECTRONS

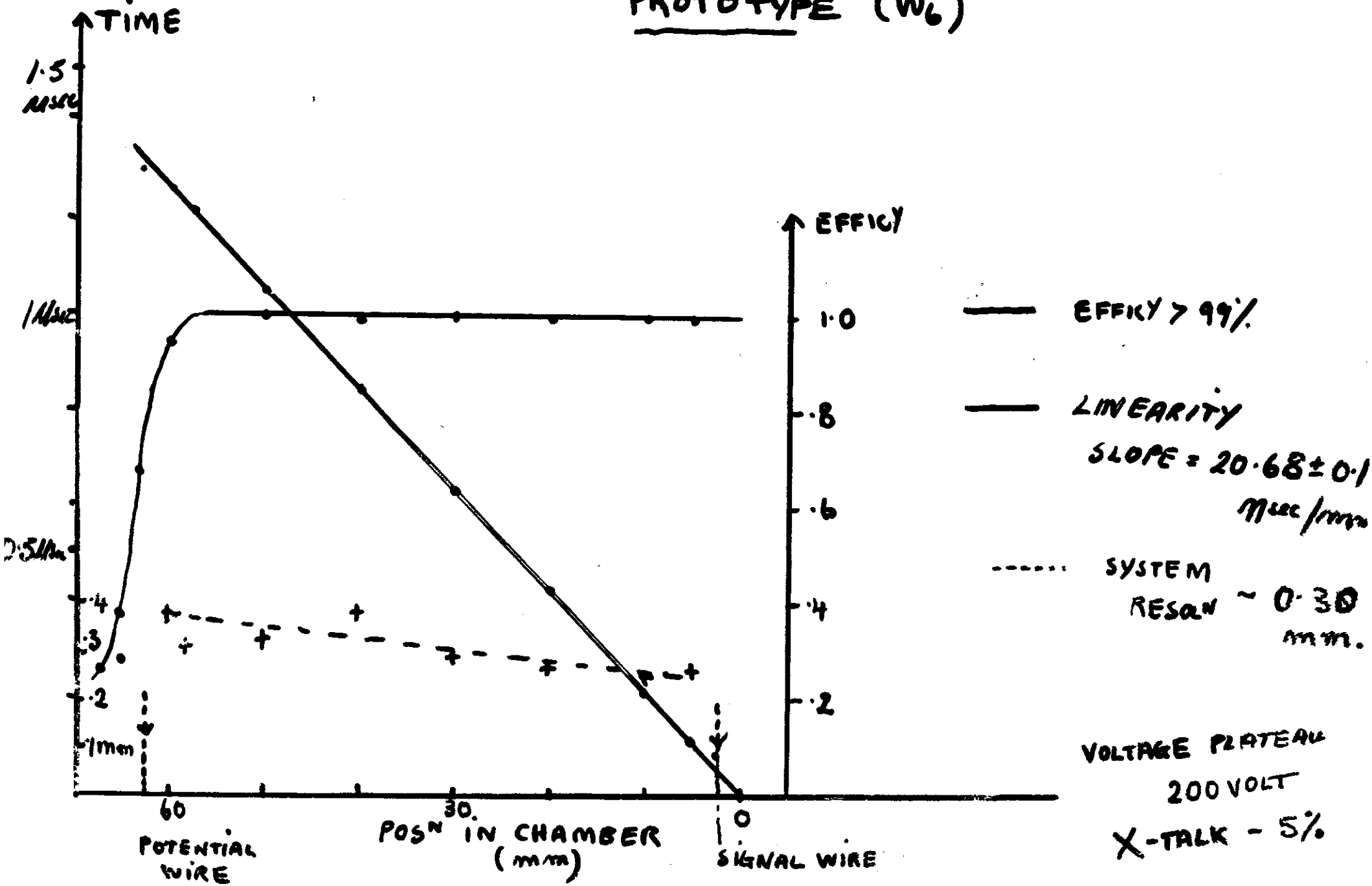
3) DIFFERENT TARGETS (HEAVY TARGETS
X1000 LUMINOSITY)

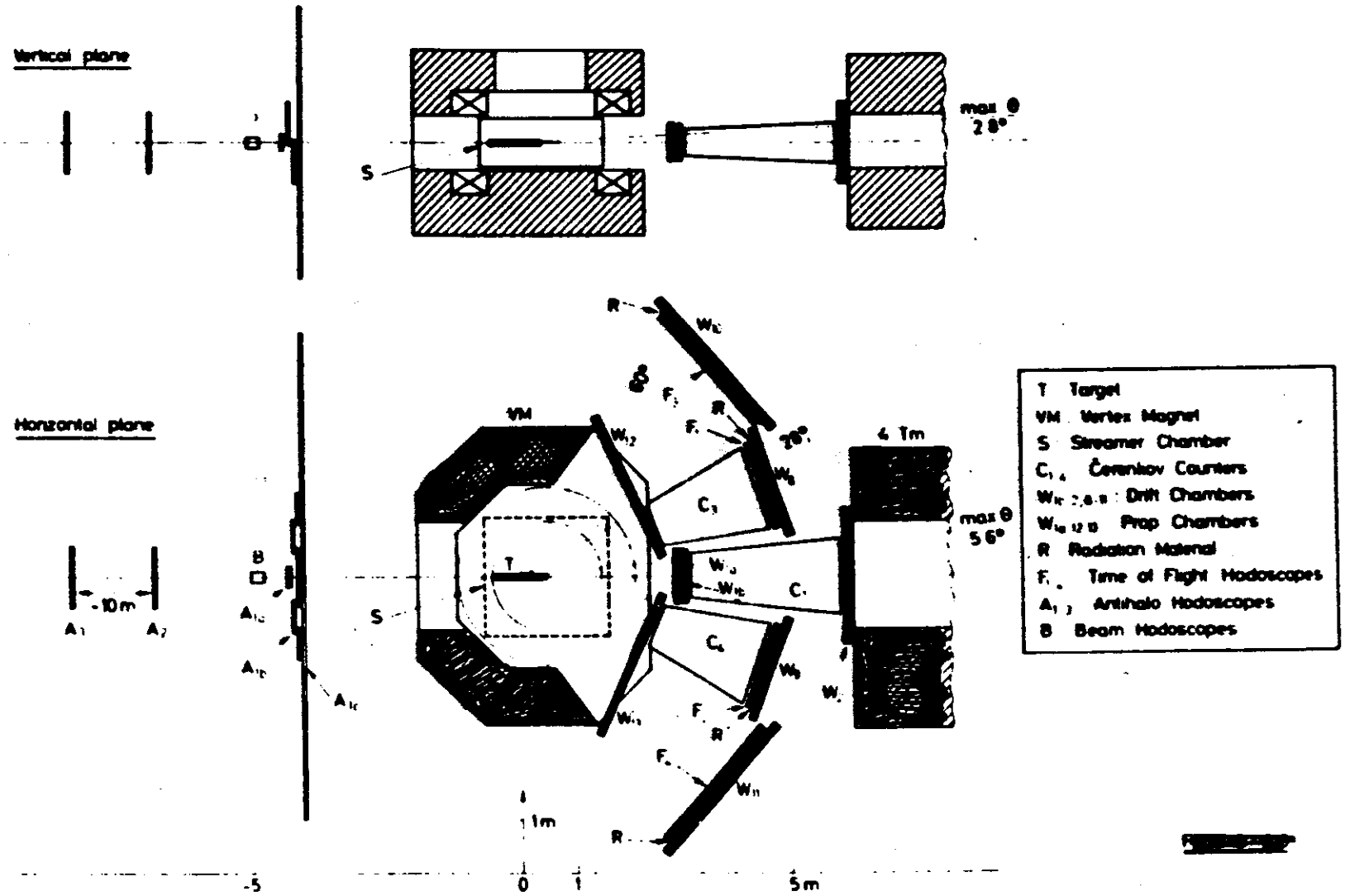
FORWARD SPECTROMETER

(EUROPEAN MUON COLLABORATION)



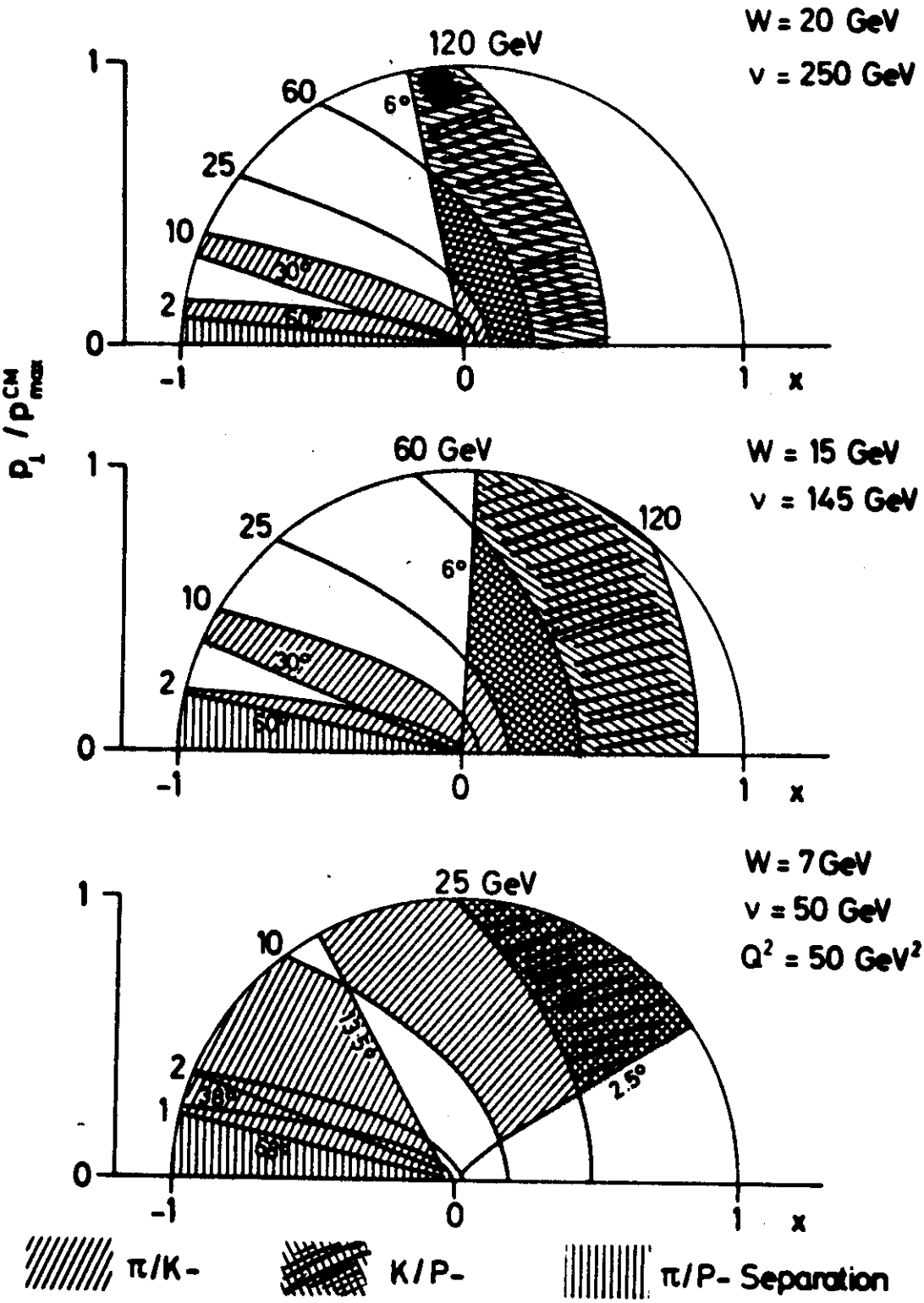
PRELIMARY RESULTS ON FULL SIZE PROTOTYPE (W_6)





VERTEX DETECTION SYSTEM
TO BE ADDED TO
FORWARD SPECTROMETER

HADRON SEP^N



ACCEPT. FOR PIONS/KAONS & PROTONS GIVING SEPARATION

FIG. B.6.10

(G. W.)

PHYSICS (?) - ONLY DISCUSS THAT OF E.M.C. EXPT

(1) SINGLE ARM. MEAS. - H_2, D_2, Z

TO DETERMINE $\{W_1\}$ and W_2.

BY MEASURING CROSS-SECTIONS

(2) INCLUSIVE HADRON. DISTRIBUTIONS

NEUTRAL + CHARGED HADRONS

↓ INCLUDES (PHOTONS)

COMPTON. (D.I.C)

(3) SINGLE ARM. POLARISED TARGET. (200cc - 2000cc)

STRUCTURE FUNCTIONS (ANSWER TO L. HAND)

(4) "ATTEMPT." NEUTRAL Z^0/γ INTERFERENCE

(ANSWER TO L. HAND)

(5) NEW. PHYSICS

↓ .....

CHARM. ETC.

+

?

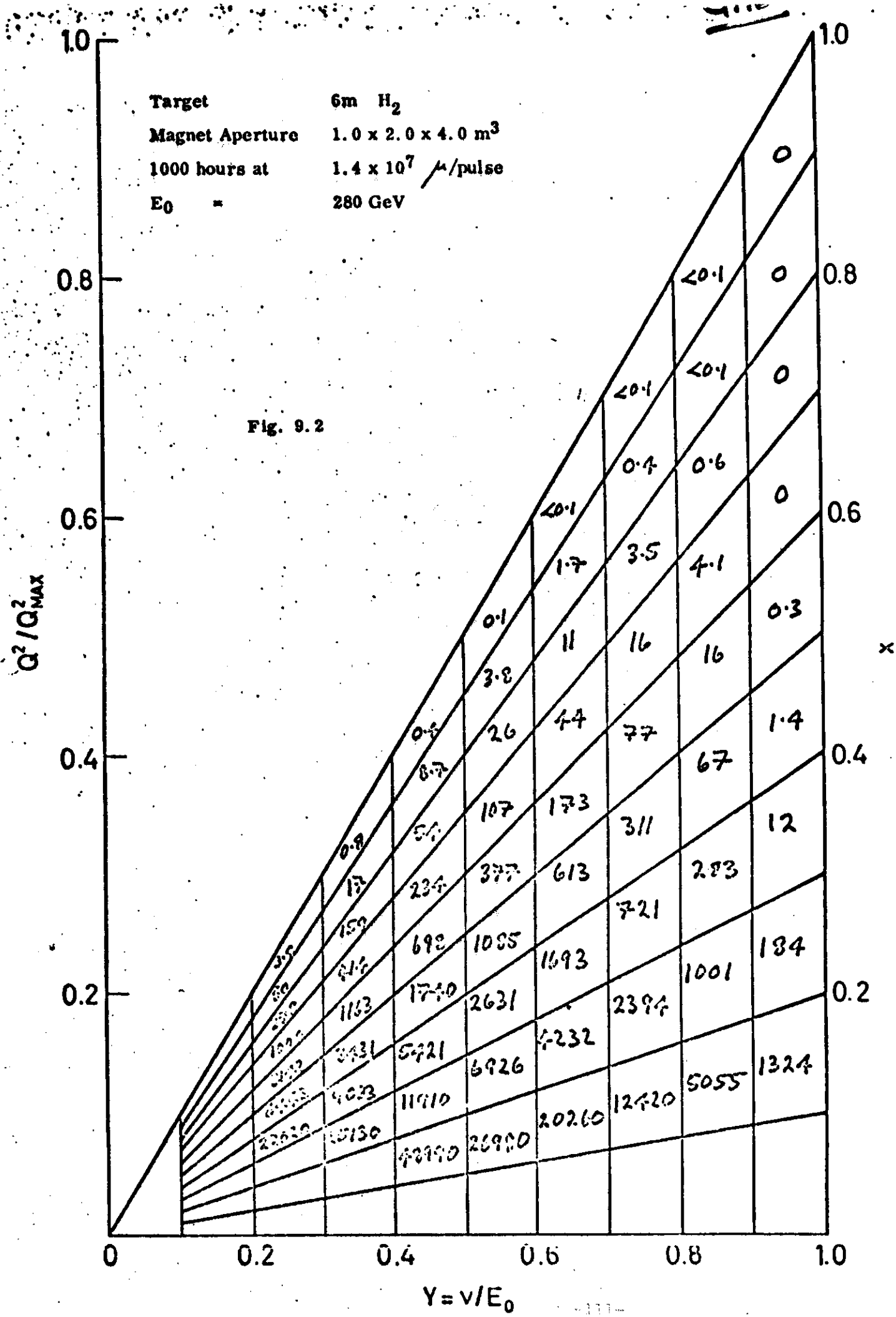
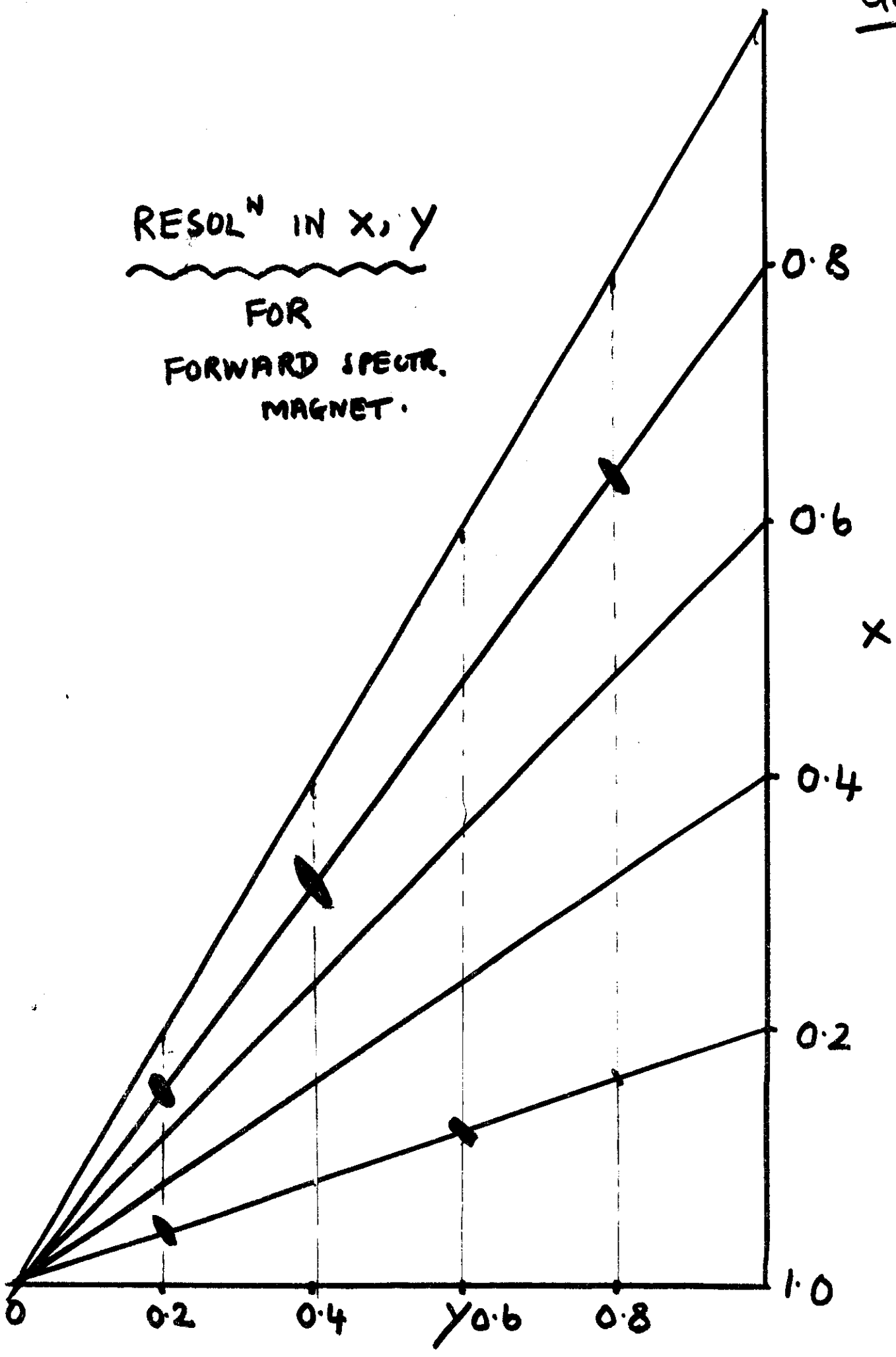

Target 6m H_2
Magnet Aperture 1.0 x 2.0 x 4.0 m^3
1000 hours at 1.4×10^7 μ/pulse
E_0 = 280 GeV
Q^2/Q^2_{MAX}
$Y = \nu/E_0$
x
0
0.2
0.4
0.6
0.8
1.0

Fig. 9.2


RESOL^N IN X, Y
FOR
FORWARD SPECTR.
MAGNET.
0·8
0·6
0·4
0·2
1·0
X
0
0·2
0·4
Y 0·6
0·8

REGION OF (q^2, ν)

CORRESP TO. 6m. H_2.
TARGET.

ERROR PURELY STAT.AL

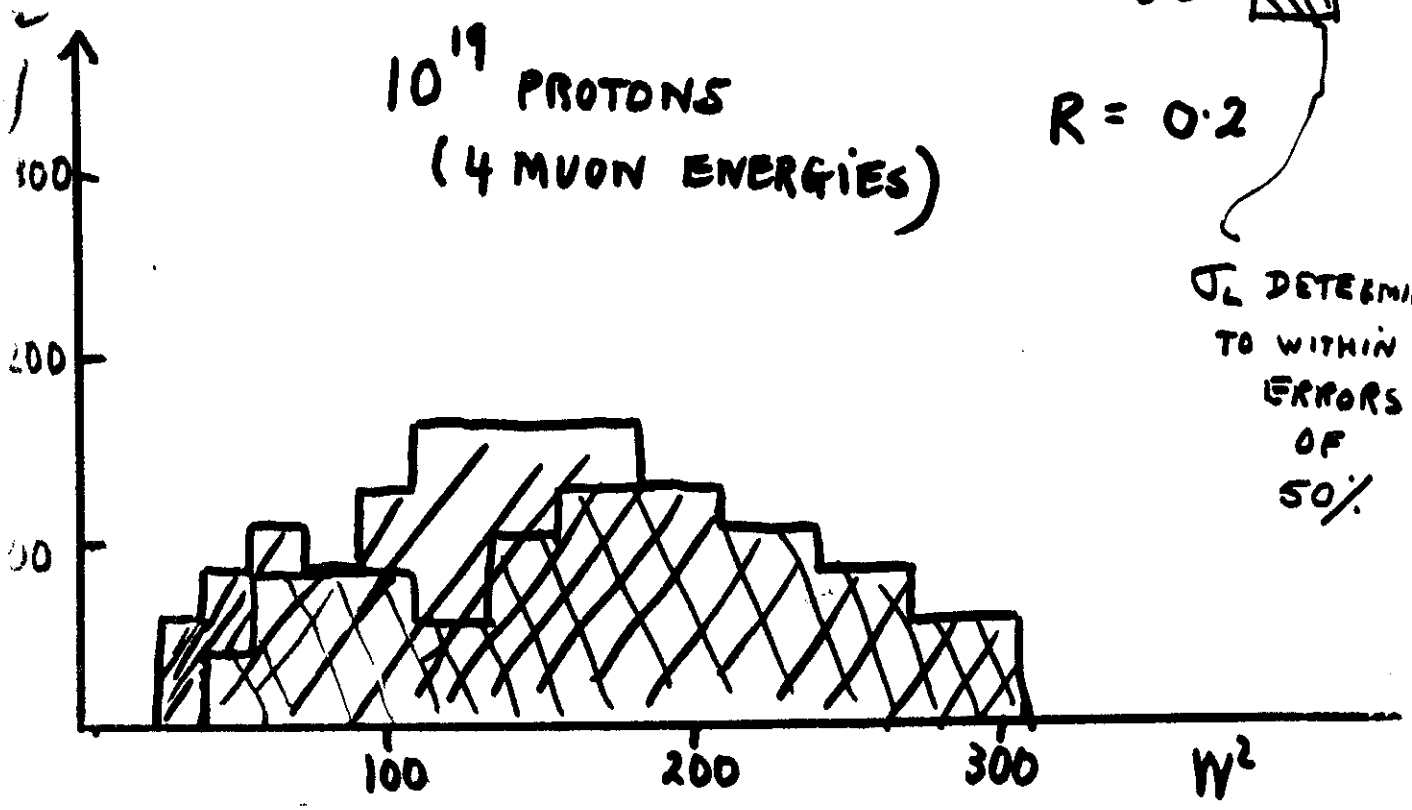
10^{19} PROTONS
(4 MUON ENERGIES)

$\frac{\Delta\sigma_L}{\sigma_L} < 1$

< 0.5

$R = 0.2$

σ_L DETERMINED TO WITHIN ERRORS OF 50%



S.P.S. = 10^{13} PROTONS $\times 10^{3}$ P/DAY

= 10^{16} PROTONS/DAY

G 18

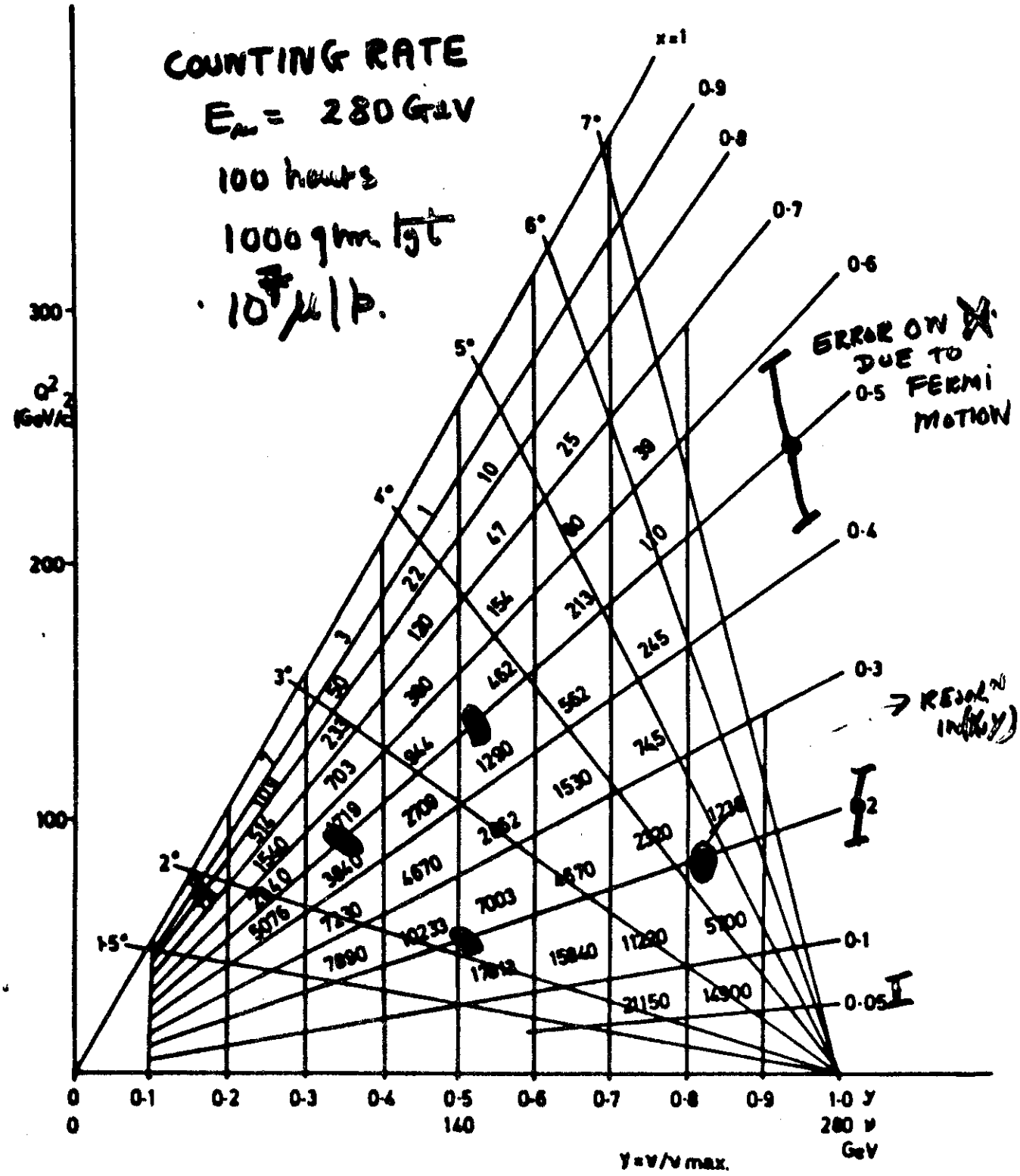

COUNTING RATE
E_{μ} = 280 GeV
100 hours
1000 gm. liq. H
$\cdot 10^{13}$ μ/p.
x=1
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·05
7°
6°
5°
4°
3°
2°
1·5°
300
200
100
Q^2 (GeV/c)^2
ERROR ON X DUE TO FERMI MOTION
RESOLN IN (X,Y)
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0 y
0
140
280 ν GeV
y = ν/ν max.

Fig. B. 3(a). 3

CALCULATED MOMENTUM SPECTRUM OF SINGLE PHOTONS DETECTED

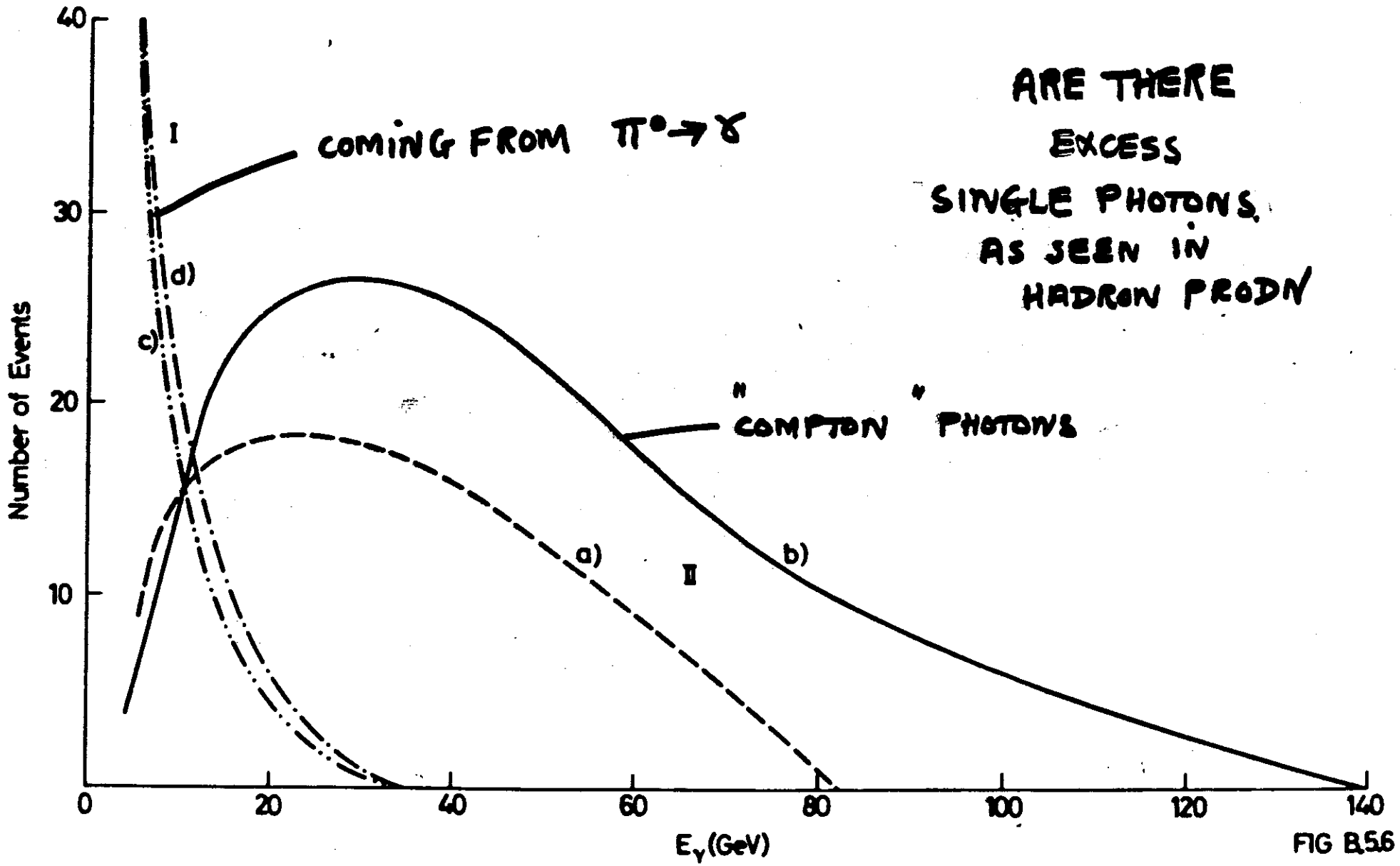


FIG B.5.6

MUONS – HIGHLY POLARISED → 70% ($\frac{\Delta P_\mu}{P_\mu} = \pm 6\%$)

DEFINE $A = \dfrac{d\dot{\sigma}(\overset{\rightarrow}{\uparrow}\overset{\leftarrow}{\downarrow}) - d\dot{\sigma}(\uparrow\uparrow)}{d\dot{\sigma}(\uparrow\downarrow) + d\dot{\sigma}(\uparrow\uparrow)}$

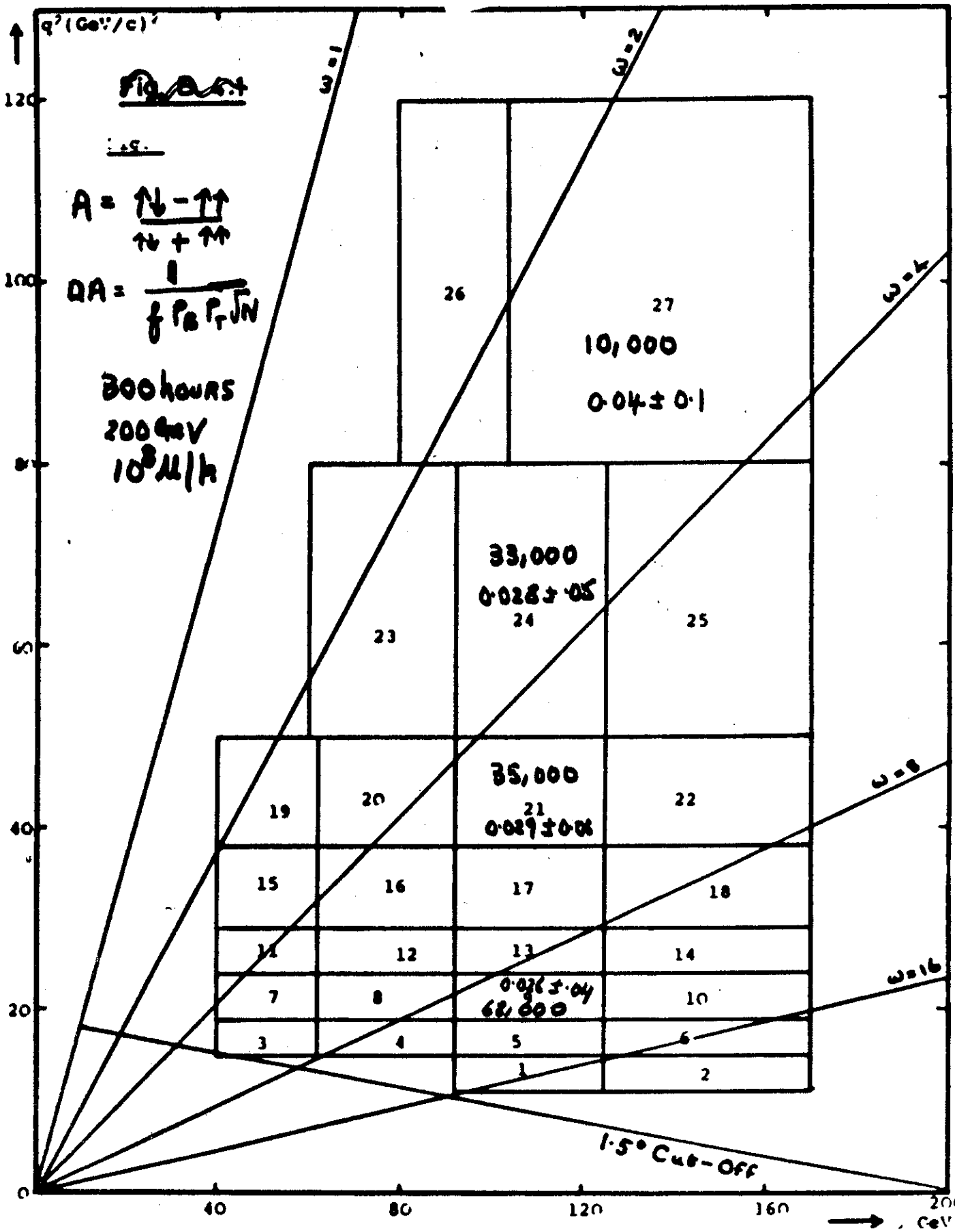
$$\approx \left[\frac{(E + E'\cos\theta) M G_1(q,\nu) + q\, G_2(q,\nu)}{W_2(q,\nu) + 2 W_1(q,\nu) \tan^2\theta/2} \right]$$

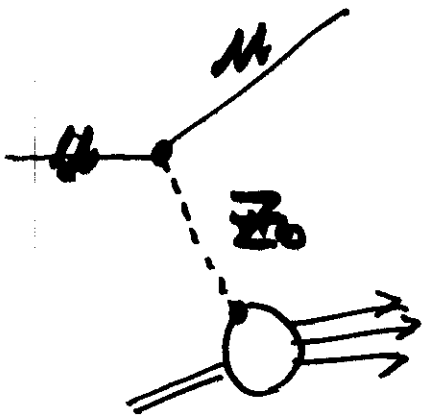
MEASURE. NEW. STRUCTURE FUN G_1 & G_2 (PROBABLY SMALL)

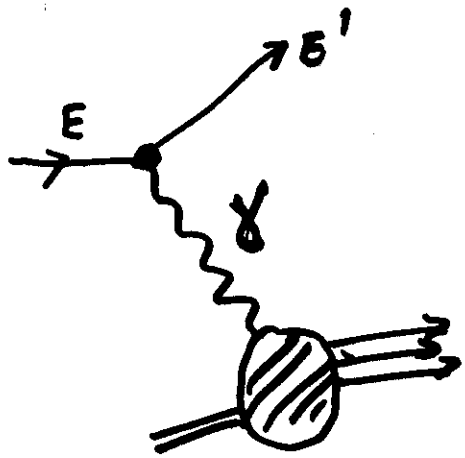
DO THEY SCALE?

SPIN DEPENDENT.

$A_M \ll A$.

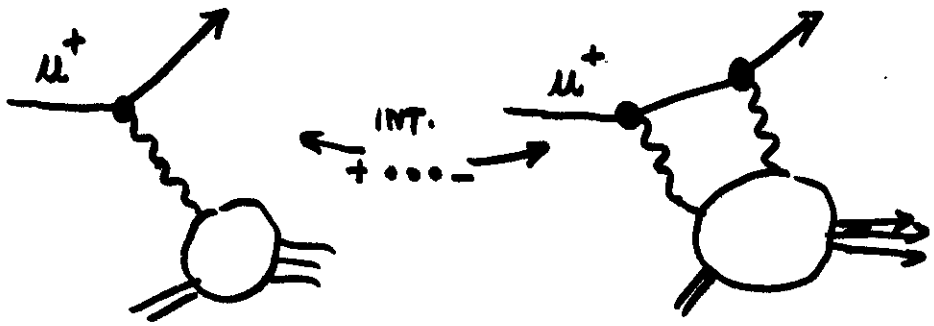

q² (GeV/c)²
Fig. 8.6.1
ω=1
ω=2
ω=4
ω=8
ω=16
1.5° Cut-Off
A = (↑↓ − ↑↑) / (↑↓ + ↑↑)
δA = 1 / (f P_B P_T √N)
300 hours
200 MeV
10^8 μ/h
26
27
10,000
0.04 ± 0.1
23
24
33,000
0.028 ± .05
25
19
20
21
35,000
0.029 ± 0.06
22
15
16
17
18
11
12
13
14
7
8
0.026 ± .04
68,000
10
3
4
5
6
1
2
120
100
80
60
40
20
0
40
80
120
160
200
GeV





$$A^{\pm} = \frac{\sigma_{\mu^+_L} - \sigma_{\mu^-_R}}{\sigma_{\mu^+_L} + \sigma_{\mu^-_R}} \approx 10^{-4}\, Q^2\ (\mathrm{GeV}/c)^2$$

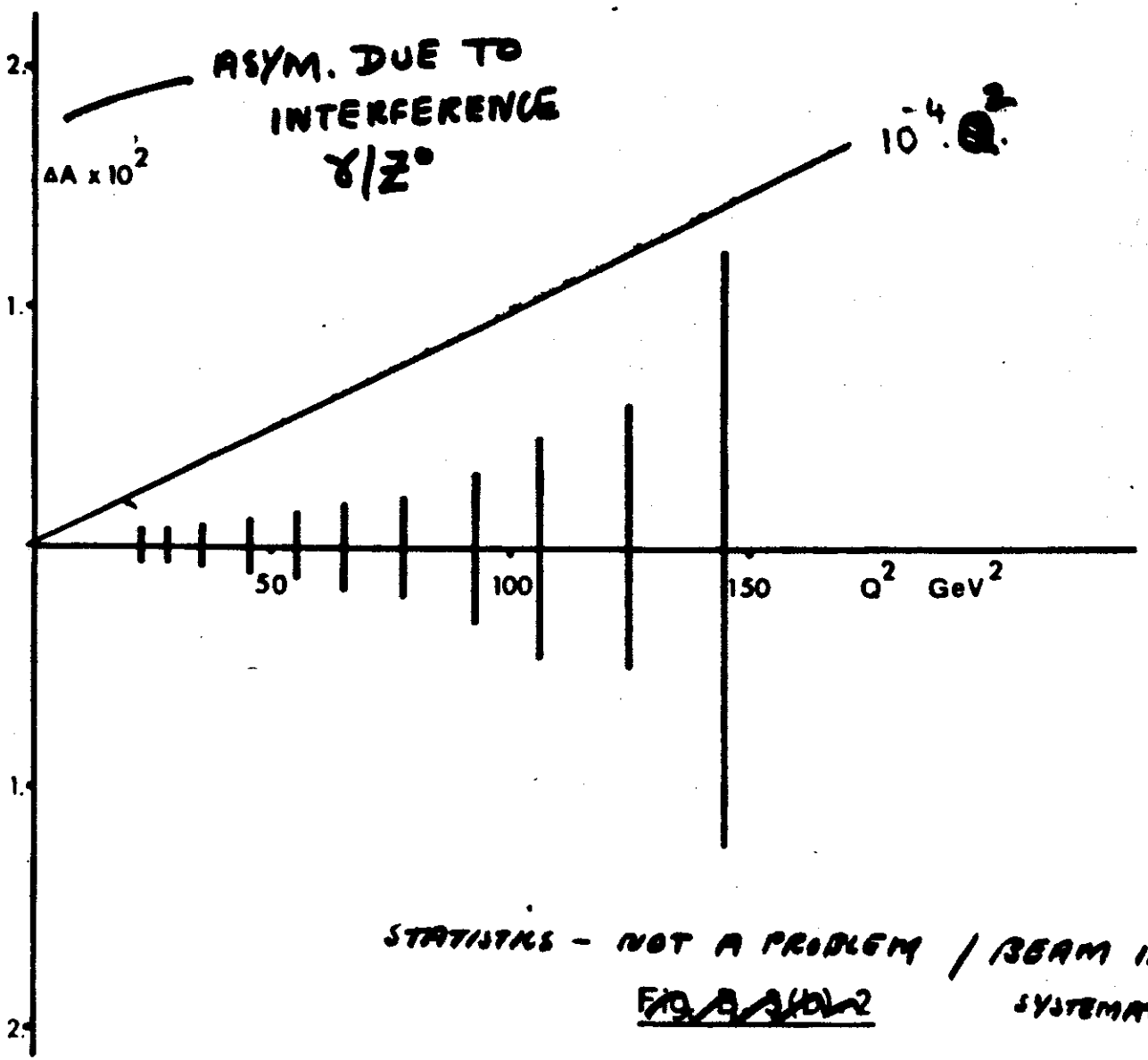
$\mu_+ \rightarrow \mu^-$ changes helicity but also changes charge.



$A^{\pm} \propto \log Q^2$.

STATISTICS NOT PROBLEM

HOW DO YOU RETAIN NORMALISATION TO ?

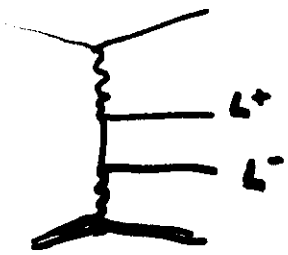


STATISTICS - NOT A PROBLEM / BEAM INTRODUCES SYSTEMATIC UNCERTY. + + -

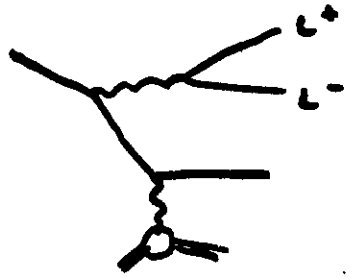
- HOLD TO ~ 0·2%

- HOW?

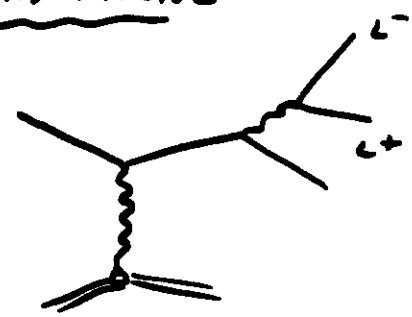
HEAVY LEPTON. PROD^N BY MUONS



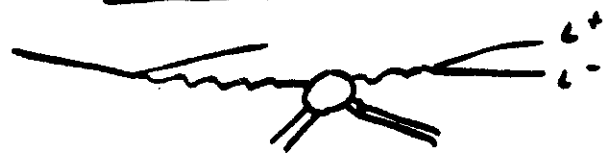
SPACE-LIKE



TIME-LIKE



TIME-LIKE



COMPTON.

MASS(L^+ GeV/c^2)	σ(P, 200GeV) $\times 10^{-36}$/cm^2	σ_{Co}(Fe, 200)	$\sigma_{Co.}$(Pb, 200)
0·5	82 (2·6)	15,000 (680)	75,000 (4600)
1·0	8 (0·38)	710 (62)	2,800 (280)
1·5	1·7 0·10	78·0 (8·3)	190 (27)
2	0·44 0·037	9·8 (1·5)	19 (3·1)
3	0·04 0·005	0·23 (·053)	02 0·05

HEAVY LEPTON YIELDS (Acc = 100%, 100hours

MASS $L^\pm$ (GeV/c^2)	6 m. H_2	1m. Fe	1m Pb
1·0	827	34,900	52,000
1·5	190	4700	5,000
2·0	51	840	845
3·0	4·7 [2500]	51 [$1.8\,10^5$]	54. [$4.1.\,10^5$]

[$\phi J \to \mu^+\mu^-$]

ΔM = 16MeV/c^2 ... 150MeV/c^2 — 250 MeV

MAIN SOURCE OF BACKGROUND
L = MUON

WHAT CAN WE DO ABOUT "CHARM" {FORWARD SPECTR.}

ASSUMPTION $\frac{\ell^{\pm}}{\pi^{\pm}} \simeq 10^{-4}$ DUE TO CHARM. ($\gamma \to \bar{p}/\pi$ - SLAC)

CALCULATE NO OF PIONS (X, $P_\perp$)

" " " $D^{\pm}$'s (10% $\to \ell^{\pm}$)

ASSUME D − VECTOR DECAY $\to K \ell \nu$

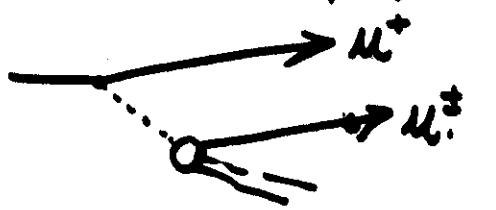
No of $D^{\pm}$ / 10^8 Mons in 3m. H_2 = 20 / burst
[200 GeV]

No of EVENTS ($\mu \ell$) SEEN AT ABSORBER = $10^{-2} \times 20$

= 0·2 / burst
(80 / hour)

FRACTION OF THESE WHERE "K" IS SEEN = 0·02 / burst.
(8 / hour)

FOR HEAVY TARGET (1000 gms)



} 4000/hour Q² dep.? "4-Lth"

FOR H_2 TARGET

} 80 / hour + WHAT ELSE?