PS/KHR/afm

PS/DL/Min 83-6
25 April 1983

SUMMARY OF CONSULTANTS MEETING OF 21st APRIL 1983

Present : V. Agoritsas, S. Battisti, J. Bovigny*, G. Gelato, C.D. Johnson, H. Koziol, J. Haffner*, L. Hoffmann*, K.H. Reich, M. Van Rooij, E. Schulte, D. Simon*, P. Têtu.

* * * * * *

Concerning PS/DL/Min. 83-5 : p should read $\bar{p}$ in paragraphs 1c) and 2c).

1. Wire chambers and FAT (V. Agoritsas)

a) Wire chambers

MWPCs (multiwire proportional chambers) are used for profile measurements in the LEAR beam lines. Their main advantage is the large dynamic range: from some thousand particles to the highest intensities expected, ejected fast or slow. For details see Annex 1.

b) FAT (fast activation techniques) are useful notably for calibrating (off-line") low intensity measurements devices. Mainly carbon, aluminium and copper foils are used (see Annex II). The latter is the least affected by beam "impurities" like neutrons) but needs more complex counting equipment.

The same technique may be used to measure partial distribution in particular of "small" beams (resolution down to ~5 μm).

2. Current work (of more general interest)

a) The LEAR instrumentation in the beam line (MWPCs, Argonions, SEM grids, etc.) seems to function all right. More detailed measurements will be made as beam becomes available.

---

* Point 1.

With MWPCs available for profile measurements, it would seem reasonable not to push further the sensitivity of the SEM grids.

b) The display of $\bar{p}$ intensities works for triple shots. The reading of the PS beam current transformer PR-TSW HI has been added (manual input to begin with.)

There are still certain discrepancies between transformer readings. Studies of statistics with p and $\bar{p}$ beams (in opposite directions) may shed some light on this question. One could also attempt to calibrate the same transformer with various calibration generators to make sure that an error has not crept in from that end.

c) The electrostatic and resistive WB PUs in the TT 70 line gave the same bunch length of 3 ns "at the base" to within a few hundred ps. As the resistive PU is passive and has higher sensitivity, introduction into the PS ring is being considered (possibly both a PSB and an SPS version to cover a wider frequency range). A measurement of the "high quality" cables to the BC and MCR showed that they are no longer linear. Corrosion is suspected (more than 20 years old).

d) Work on the electronics for the "Linac" (magnetic) for the PUs in the PSB injection line has started.

e) In a test of the PU in front of the AA target gave useable signals when passing through a digital filter (400 ms LeCroy measurement time). An analog filter will be looked into.

f) The parts for the AA fast wire have been ordered, the last orders for the new PS fast wire are imminent. The local computer controls for the latter are progressing.

3. Miscellaneous

a) C.D. Johnson reported briefly about his US trip. LeCroy will demonstrate their latest equipment at CERN end May 1983 and give a preview of ongoing developments. In case these would not satisfy our needs (not very likely though), and the LEP controls electronics is too far off, one might reconsider the question of commercial components for beam instrumentation, e.g. for LPI.

b) K.H. Reich reported some comments by the users of DESY beam instrumentation and a few additions by the makers to PS/LPI/Min. 83-3, particularly with regard to magnetic PUs. DESY has lent us one of their PUs for tests.

c) Next Meeting:

Thursday 5th May 1983, 9.00 h in Large PS Conference Room.

- Transformer calibration.
- Current work.

K.H. Reich

Distribution

Consultants, PS Group Leaders, C. Bovet, J. Bovigny, E. Brouzet, L. Burnod, C. Carter, J.P. Delahaye, R. Jung, J. Haffner, H. Koziol, A. Krusche, H. Kugler, J.J. Merminod, D.A.G. Neet, J.P. Riunaud, G.C. Schneider, D. Simon, D.J. Williams.

Annex 1

CERN 21.4.83

RADIATION DETECTORS
|||
PARTICLE DETECTORS
|||
EYES OF H. E. Ph.

ALMOST ALL DETECTORS ARE DEVICES WHICH EXPLOIT THE INTERACTIONS OF HARGED PARTICLES PASSING THROUGH MATTER: GAS, LIQUID, SOLID.

WE SHALL DISCUSS IN AN INTRODACTORY WAY THE "GASEOUS DETECTORS.":

- M W P C. [MultiWire Proportional Chambers]
- D. C. [Drift Chambers]
- T. P. C. [Time Projection Chambers].

1. GENERAL CONSIDERATIONS.

WHEN AN ENERGETIC CHARGED PARTICLE PASSES THROUGH A GASEOUS LAYER SUFFER ENERGY LOSS ON ACCOUNT OF ELECTROMAGNETIC INTERACTIONS WITH ORBIT ELECTRONS OF ATOMS OR MOLECULES [OF THE GAS].

$\Longrightarrow$ IONIZATION + EXCITATION. LOSSES

$\Downarrow$ $\Downarrow$

PRODUCTION OF IONS PRODUCTION OF PHOTONS

$\Downarrow$

Production of electrons [e^-] with few eV kinetic Energy and Positive Ions.

$\Rightarrow$ ENERGY LOSS $\propto$ Particle Parameters Medium

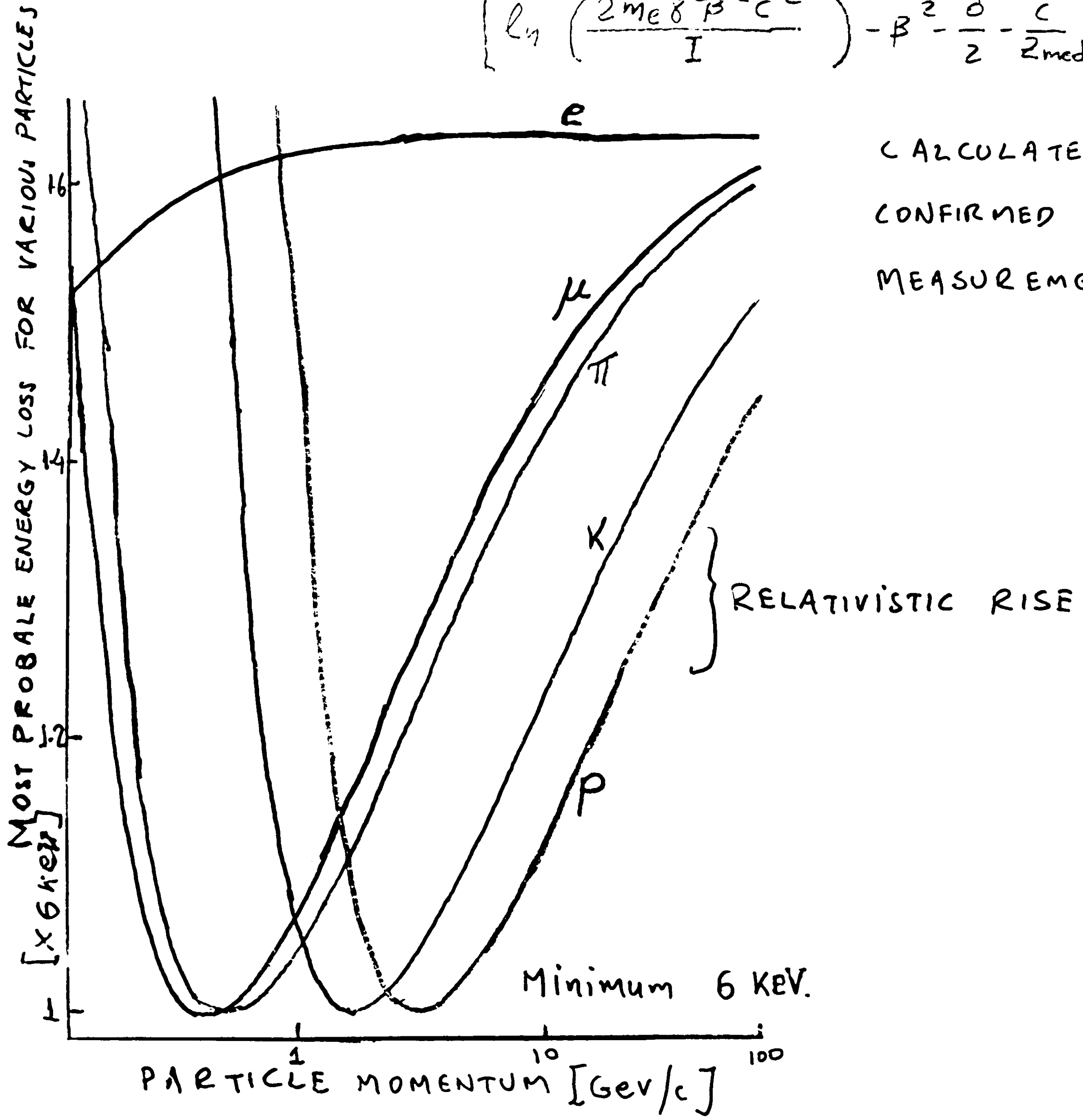
②

THE AVERAGE DIFFERENTIAL ENERGY LOSS (ENERGY LOSS PER UNIT LENGTH) IS GIVEN BY THE FORMULA OF BETHE AND BLOCH.

SEE REVIEW OF PARTICLE PROPERTIES
PARTICLE DATA GROUP. August 1982.
CERN ef.

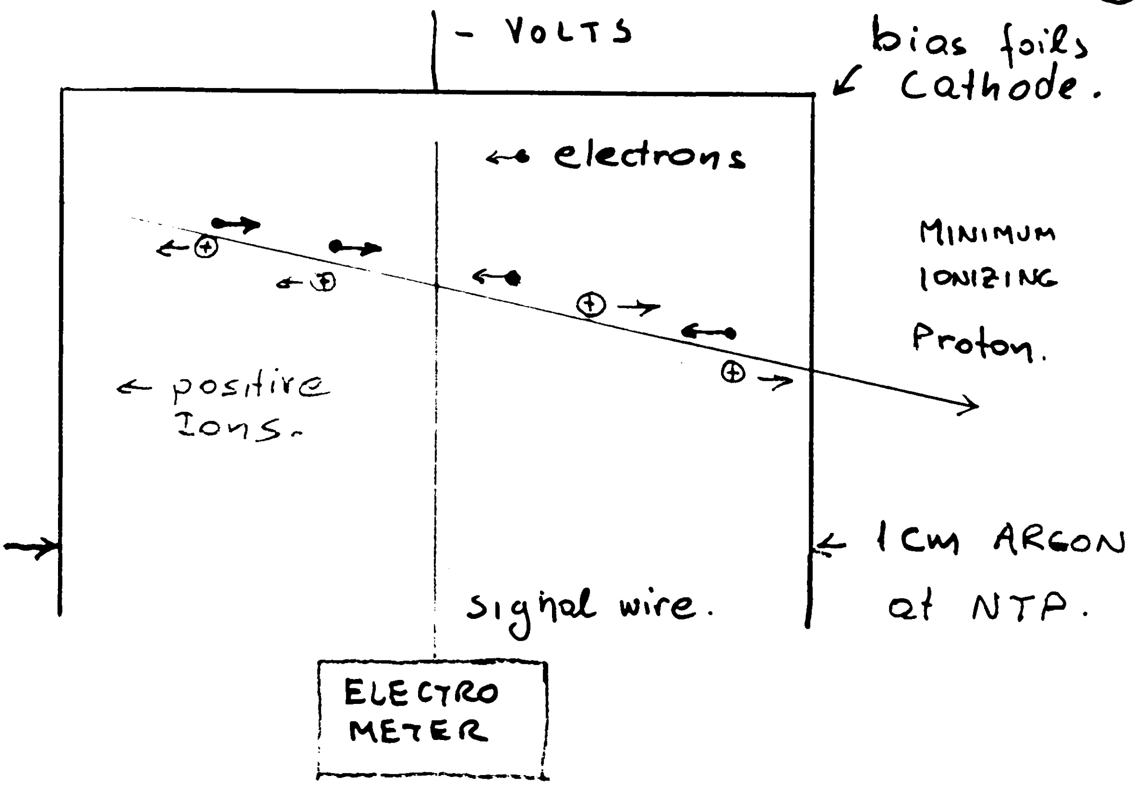
$$\left[\frac{dE}{dx}\right]_{inc} = \frac{D\, Z_{med}\, \rho_{med}}{A_{med}} \left[\frac{Z_{inc}}{\beta}\right]^2 \times$$

$$\left[\ln\left(\frac{2 m_e \gamma^2 \beta^2 c^2}{I}\right) - \beta^2 - \frac{\delta}{2} - \frac{C}{Z_{med}}\right] \{1 \cdot \cdot \}.$$



CALCULATED AND CONFIRMED BY MEASUREMENTS

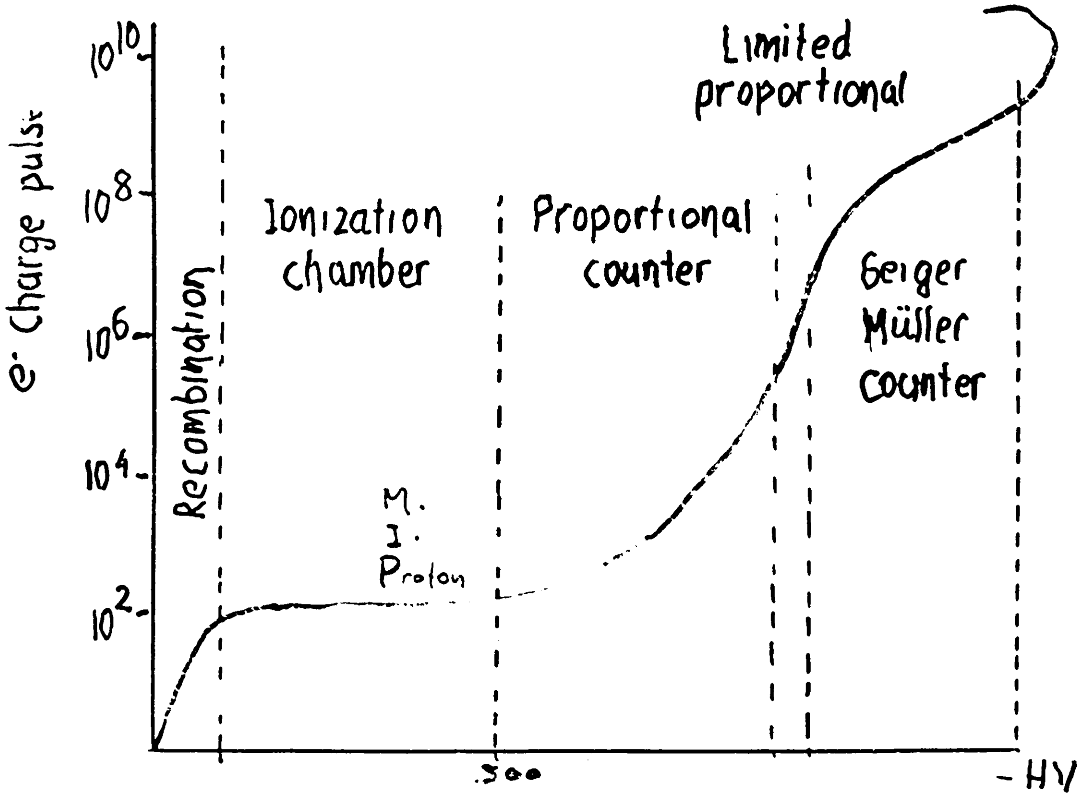
1 CM OF 80% ARGON + 20% METHANE AT STP.



$\left[\frac{dE}{dx}\right]_{m.i.p}$ in Argon at NTP = 2.44 KeV/cm.

⇒ n primary Ion pairs/cm = 29.4.

⇒ n Total Ion pairs/cm = 94.



Pulse Height versus Applied High voltage of a Gaseous

DRIFT VELOCITY

"VERY IMPORTANT PARAMETER"

AS WE HAVE SEEN THE MINIMUM IONIZING PROTO WILL PRODUCE ~ 100 ION PAIRS i.e ~ 100 e^- and ~ 100 heavy Ion:

THEY WILL DRIFT TOWARD THE CORRESPONDING ELECTRODES.

ELECTRONS TOWARDS THE SIGNAL WIRE.

POSITIVE HEAVY IONS TOWARDS THE - BIAS FOILS.

THE AVERAGE DRIFT VELOCITY OF ELECTRONS IS GIVEN BY

$$V = \mu_e \frac{E}{p}.$$

E = electric field strength V/cm. p = gas pressure

μ_e = mobility, depending strongly on E and p as well as on the medium gas.

At NORMAL TEMPERATURE AND PRESSURE, THE DRIFT VELOCITY OF ELECTRONS AT E = 1 KV/cm IS

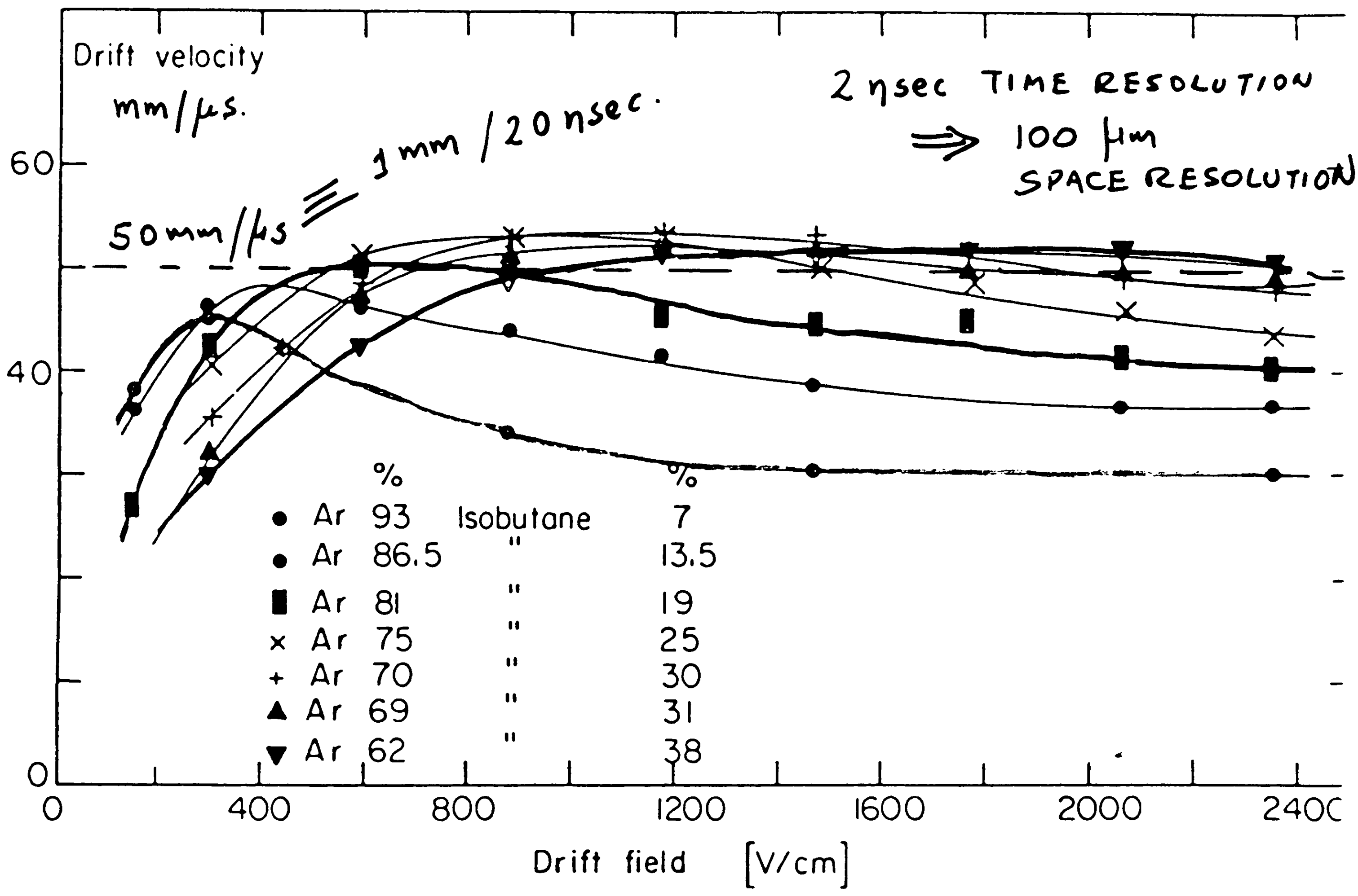
$\underline{10^6 - 10^7 \text{ cm/sec} \equiv 10 - 100 \text{ mm}/\mu\text{sec.}}$

THE VELOCITY OF IONS IS ABOUT 10^3 TIMES SLOWER

$\underline{10^3 - 10^4 \text{ cm/s} \equiv 10 - 100 \text{ mm/msec.}}$

EXPERIMENTAL MEASUREMENTS OF DRIFT VELOCITIES OF ELECTRONS IN ARGON - ISOBUTANE MIXTURES AT NORMAL TEMPERATURE AND PRESSURE AND AT DRIFT FIELDS, E = 1 KV/cm. ~ 2,5 KV/cm ARE.

				DRIFT VELOCITIES
Ar	93 %	+ ISOBUTANE	7 %	35 - 40 mm / μsec.
Ar	81 "	"	19 %	~ 50 constant mm/μsec
Ar	70 "	"	30	~ 55 " "



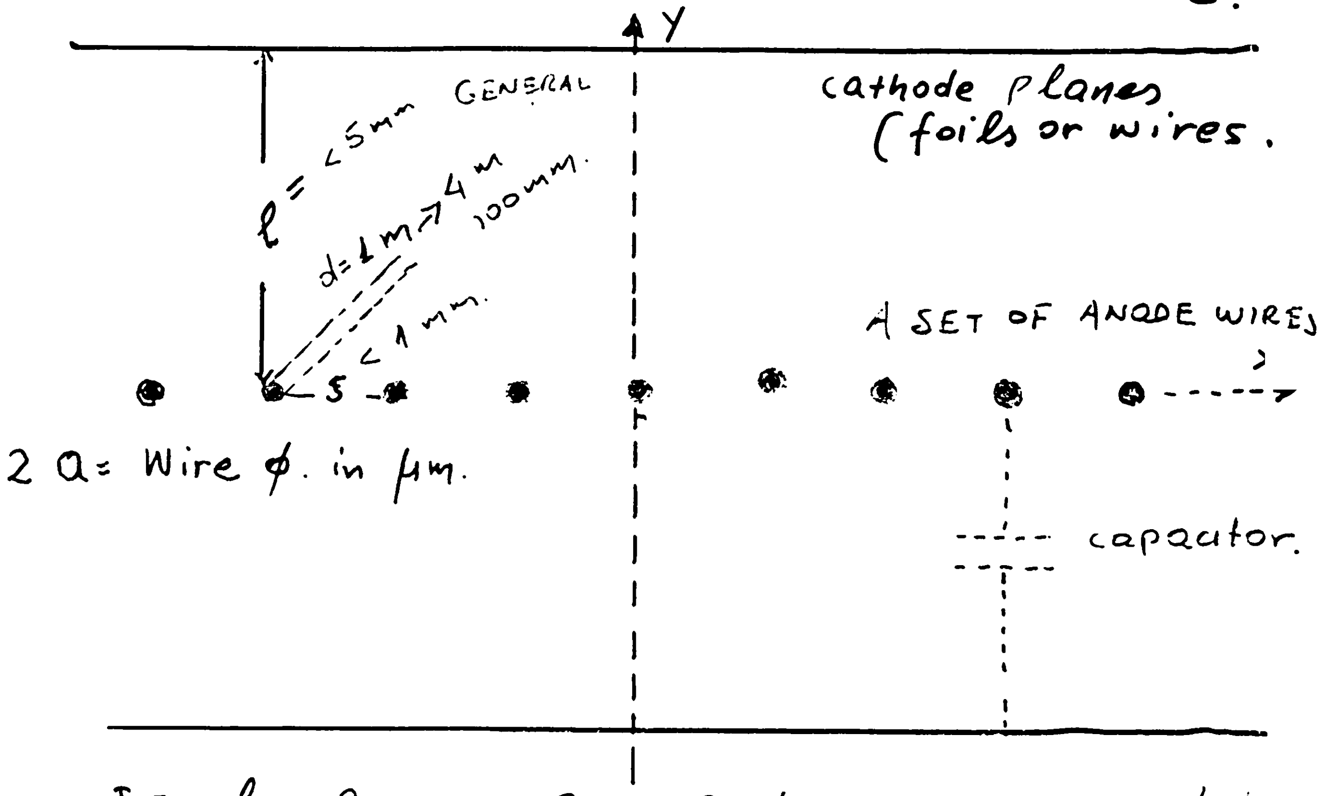
Drift velocity of electrons in argon-isobutane mixtures, at normal conditions

M - W. P. C. from. F. Sauli CERN 77-09. yellow report.

MULTIWIRE PROPORTIONAL CHAMBER.

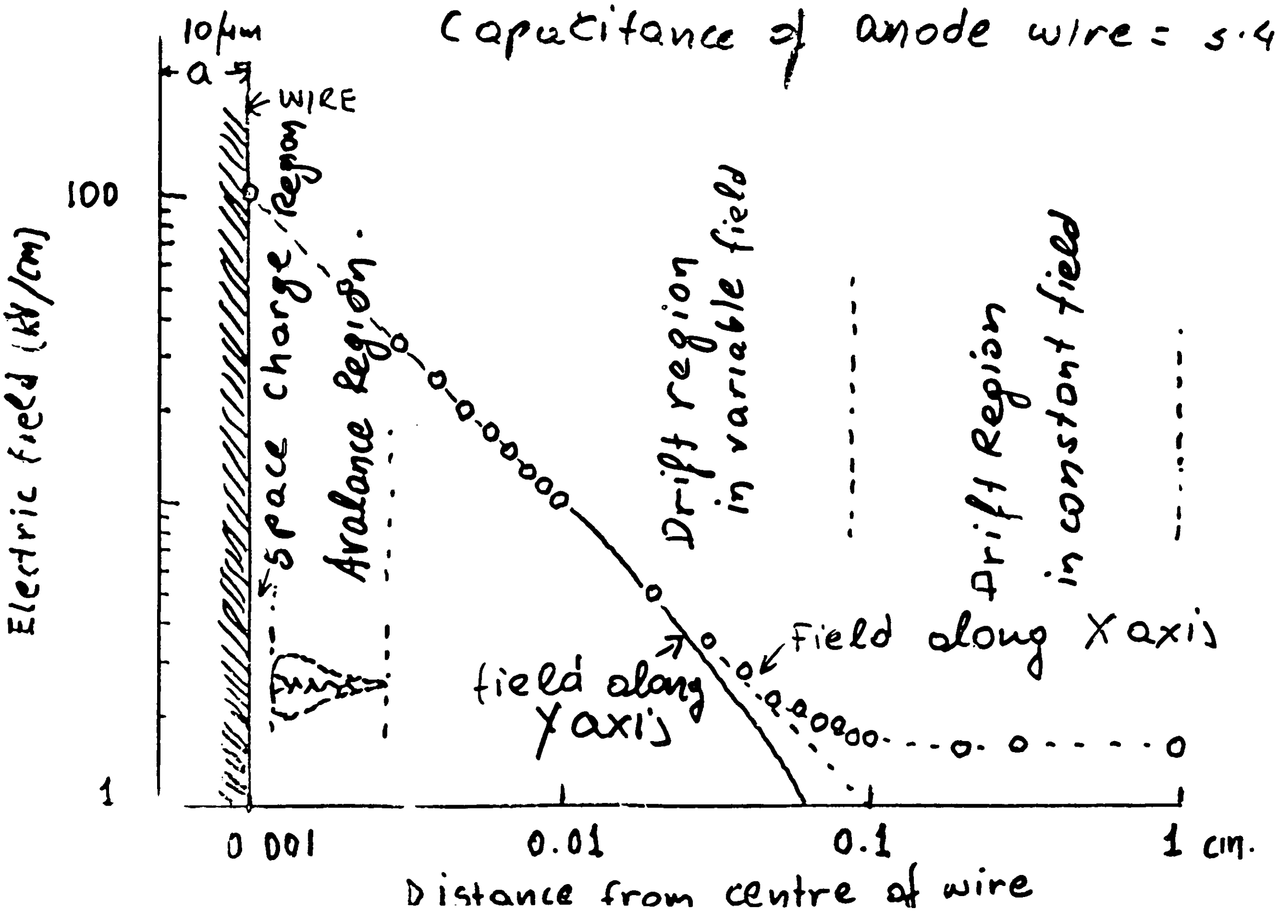
PRINCIPLE OF CONSTRUCTION AND DEFINITION OF PARAMETERS.

[First M.W.PC constructed and operated in 1967-1968 by CHARPAK AND COLLABORATORS.].

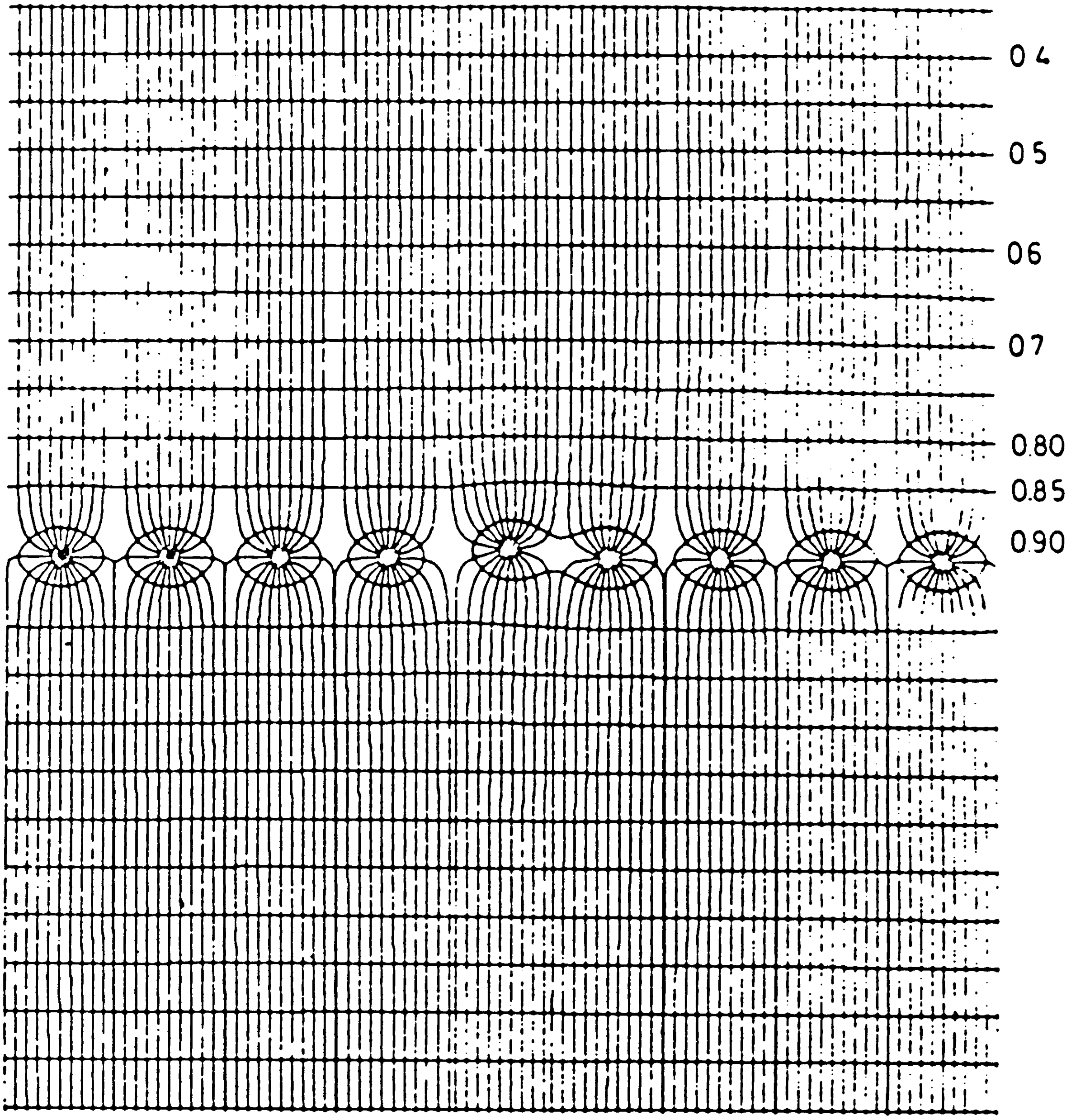


IF l = 8 mm 2a = 20 μm. s = 2 mm. d = 1m.

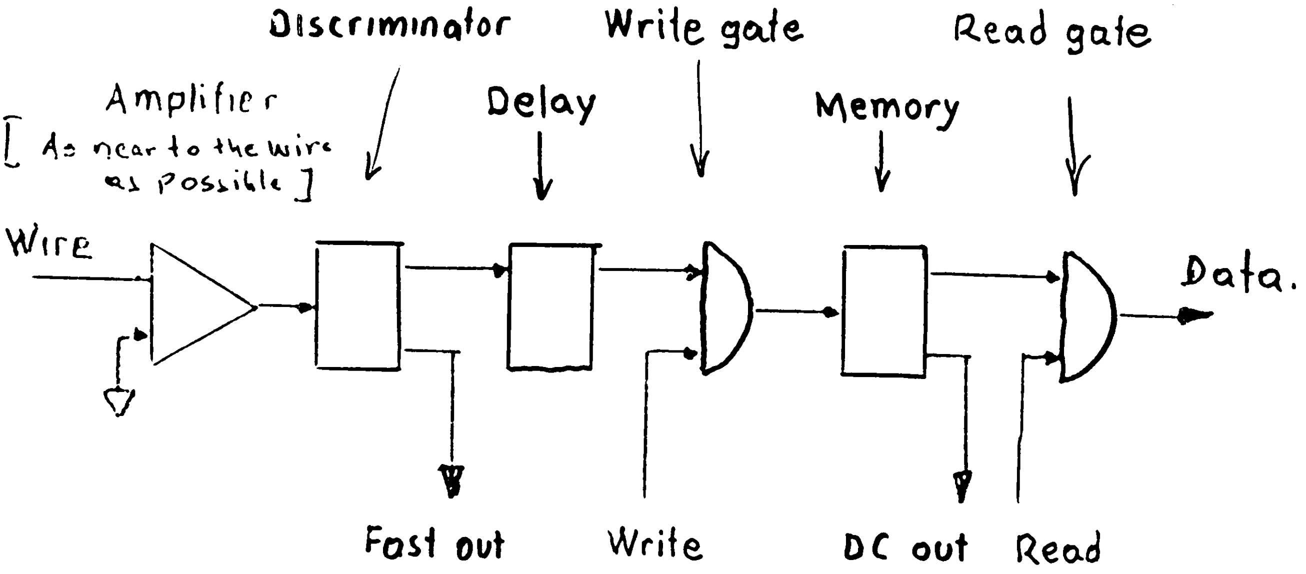
Capacitance of anode wire = 5.47 pF.



6′



Electric field equipotentials and field lines in a multiwire proportional chamber. The effect on the field of a small displacement of one wire is also shown[37].

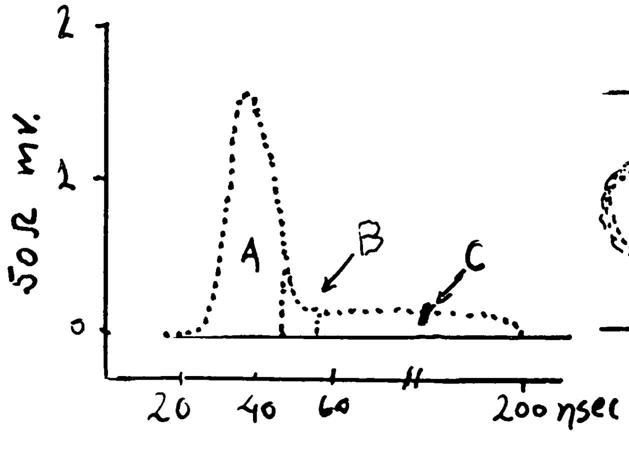


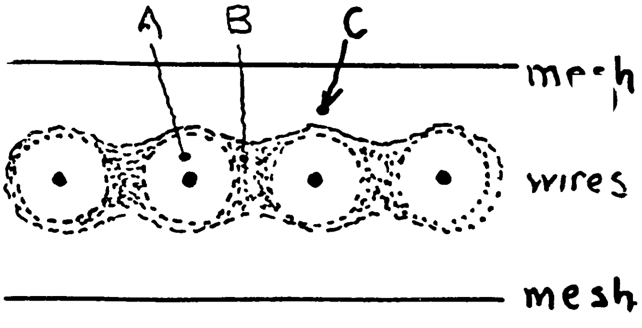
BASIC SCHEME OF THE ELECTRONICS REQUIRED FOR EACH WIRE IN A MODERN PROPORTIONAL CHAMBER.

30 - 1000 Depends what is included.
{~ 300 Fr. S per channel!}

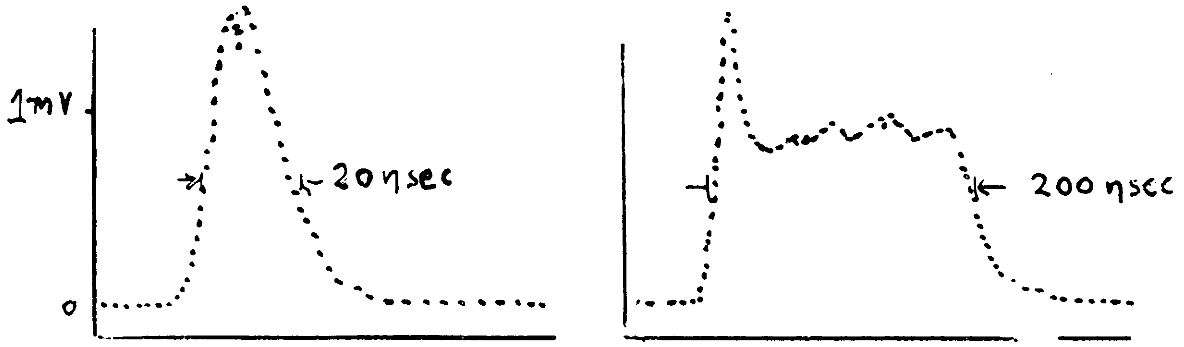
SIGNAL CHARACTERISTICS OF A M.W.P.C.

As seen on 50Ω impedance one two two meters from the wire.





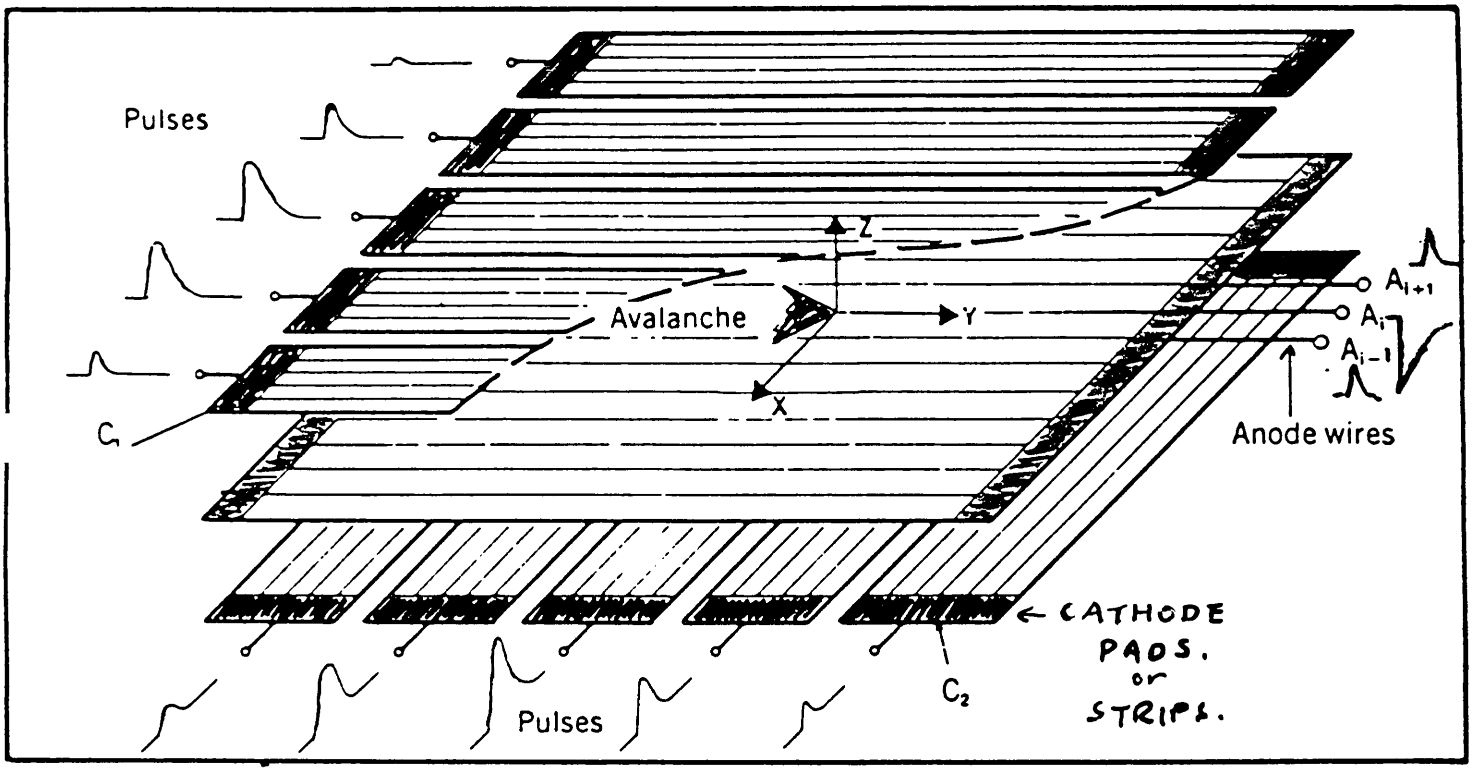
Best performance.
(10 - 20 μA)!



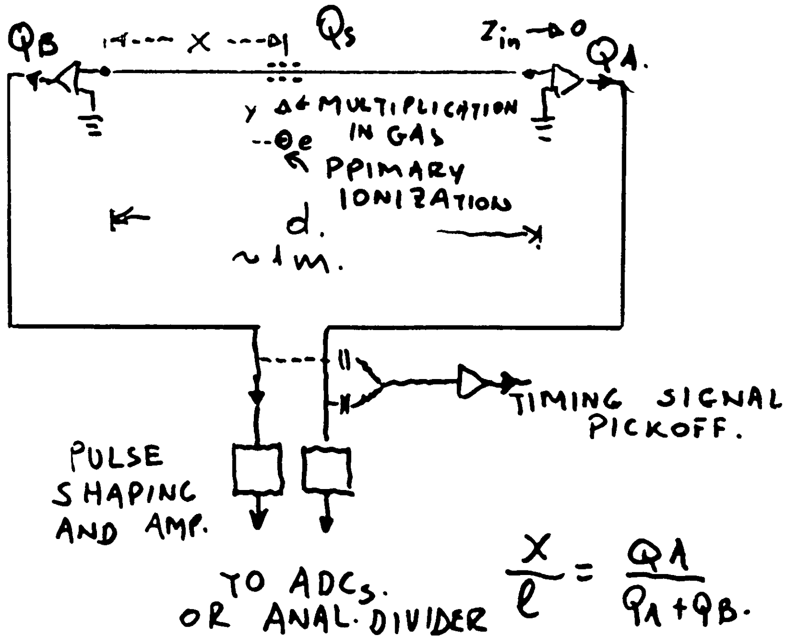
NEGATIVE POLARITY SIGNALS!!

MODERN CONCEPTION OF A M.W.P.C.

AND MORE COMPLEX READ OUT



Localization by center of gravity of the induced pulses. The motion of ions leaving the vicinity of the anode wires in a multiwire proportional counter induces positive pulses on all surrounding electrodes. The centroid of the pulses is centered on the avalanche. For a coordinate x, the centroid $\bar{x} = \sum x_i X_i / \sum X_i$, where X_i is the charge induced on the strip centered at x_i. Figure 3



$$\frac{X}{\ell} = \frac{Q_A}{Q_A + Q_B}.$$

LOCALIZATION OF THE AVALANCHE COODINATES USING THE CHARGE DIVISION METHOD.

PARAMETERS OF THE M.W.P.C FOR LEAR BEAMS.

SPS CONSTRUCTION.

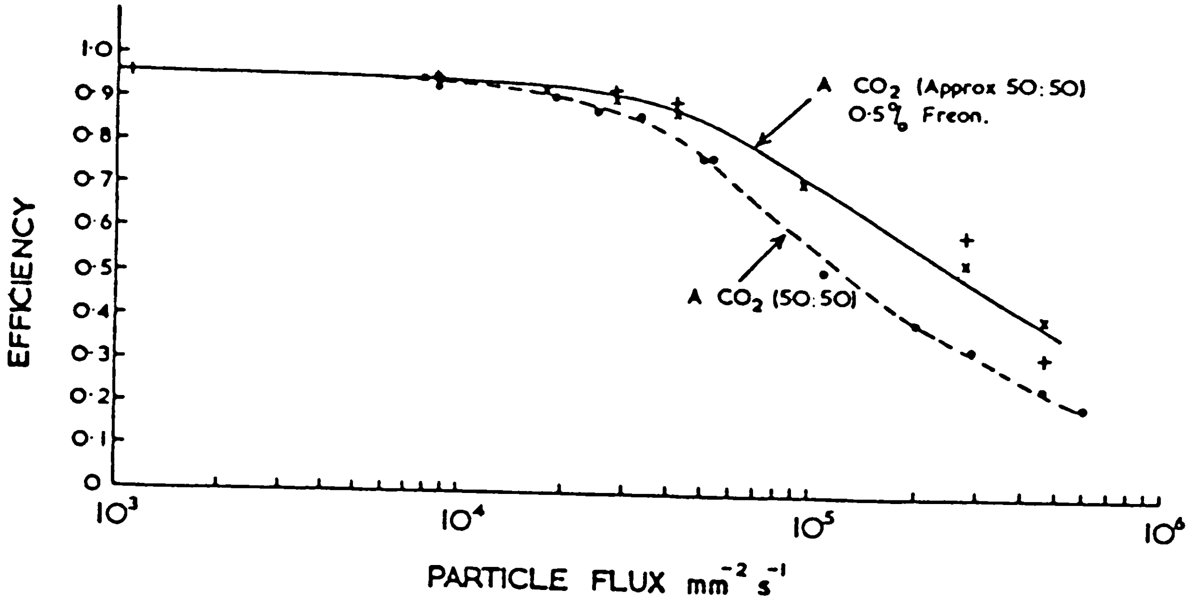
SIZE (SURFACE AREA	100×100 mm²
SIGNAL WIRE φ	10 µm.
SIGNAL WIRE SPACING.	1 mm.

⇒ 100 wires per plane

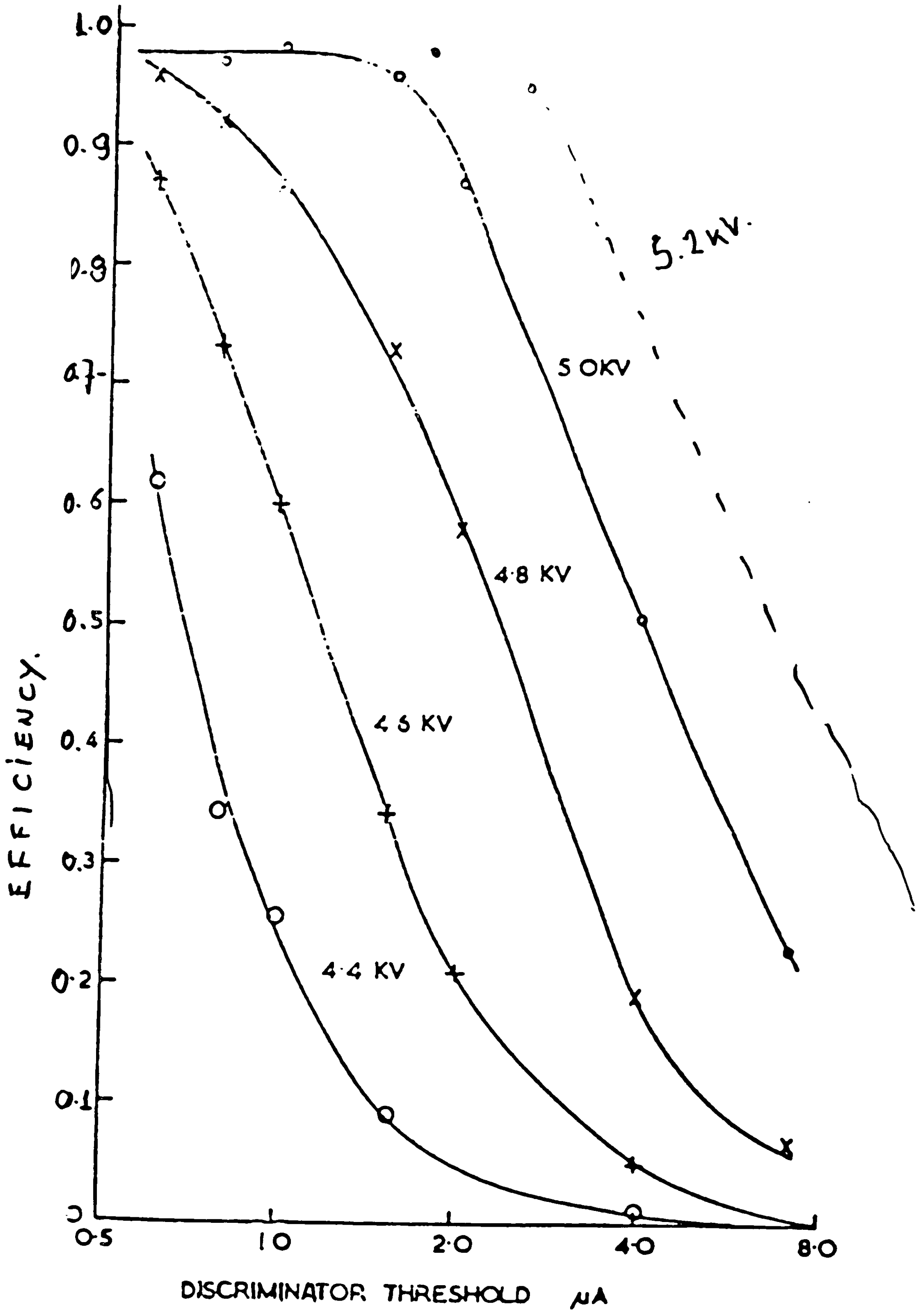
VERTICAL PLANE.

HORIZONTAL PLANE.

SPACING BETWEEN H.V AND SIGNAL PLANES	5 mm.
HIGH VOLTAGE PLANE Al foil thickness	10 µm.
END WINDOWS CAPTON	25 µm < 20 mg/cm²
VACUUM END WINDOWS stainless steel. For retractable operation	25 µm.



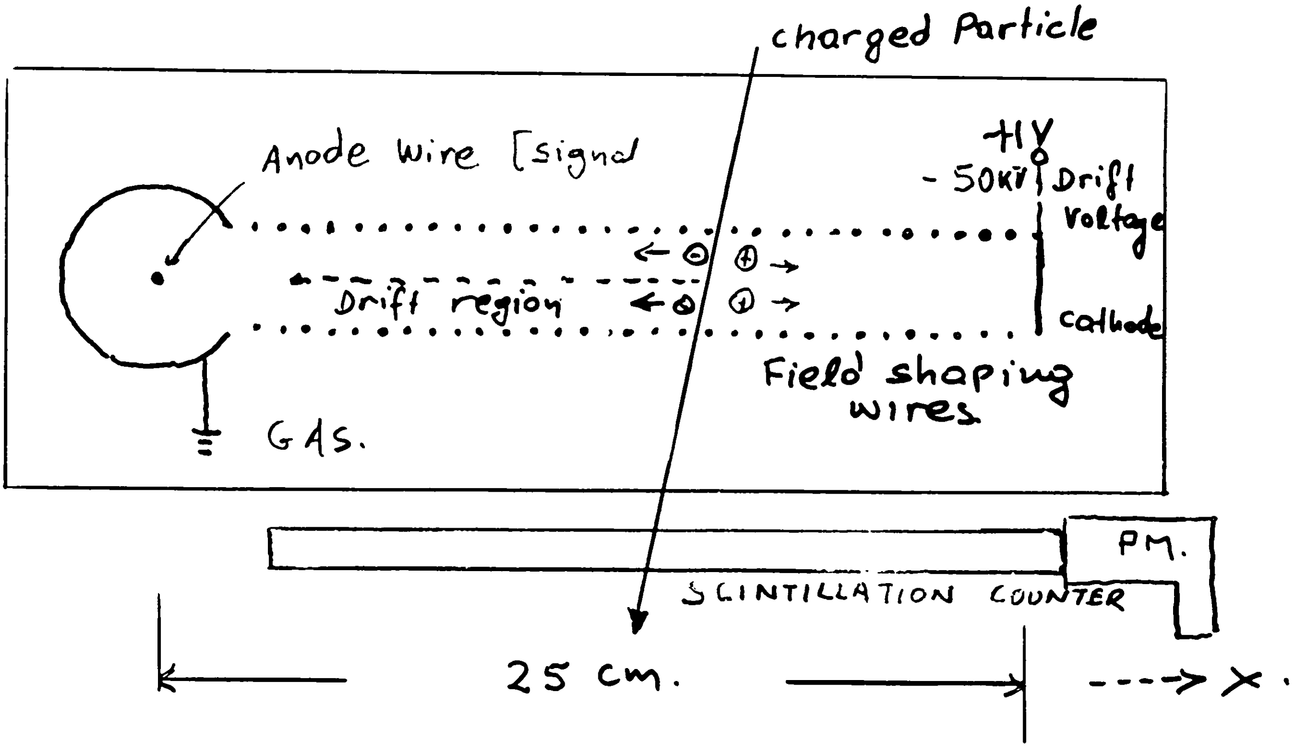
8.2.



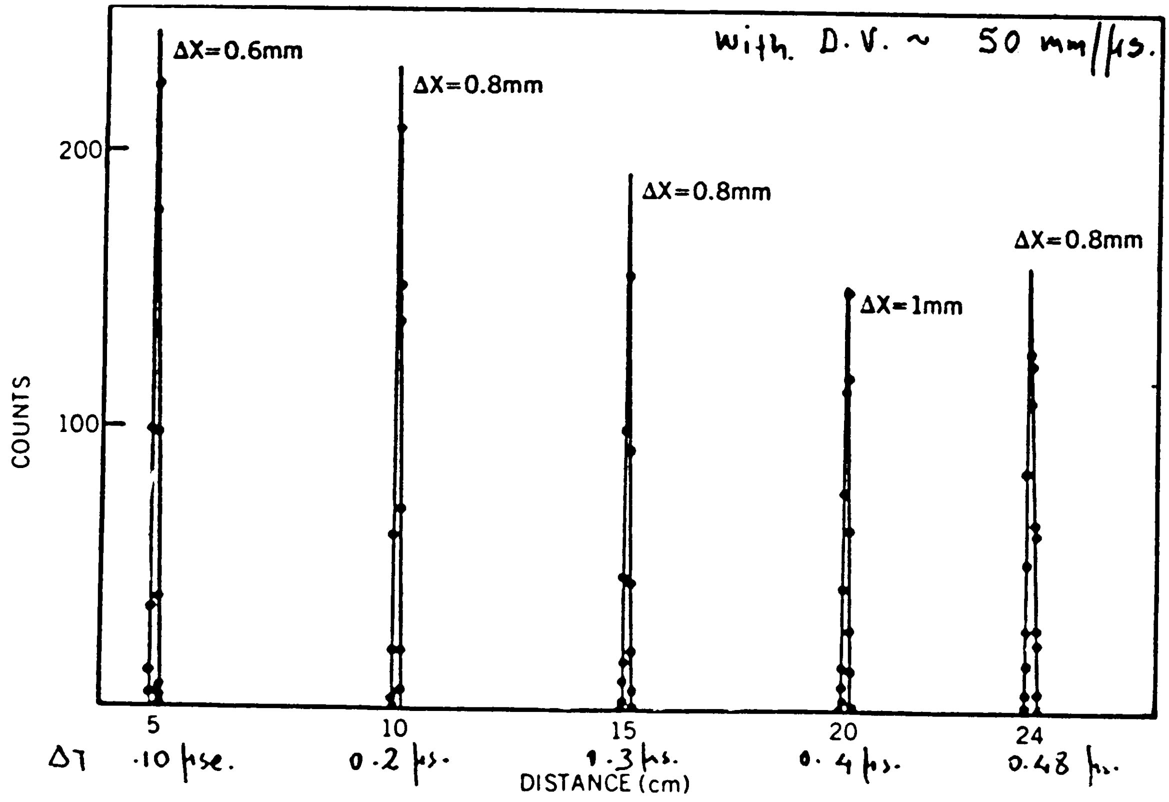
Plateau curves. The gas was approximately a 50:50 mi re of argon and CO_2 and the data was taken at a rate of $\sim 2 \times 10^3$ particles/mm^{-2} s^{-1}.

D.C [DRIFT CHAMBER]. 1968 →

PRINCIPLE OF OPERATION OF A SINGLE CELL DRIFT CHAMBER.

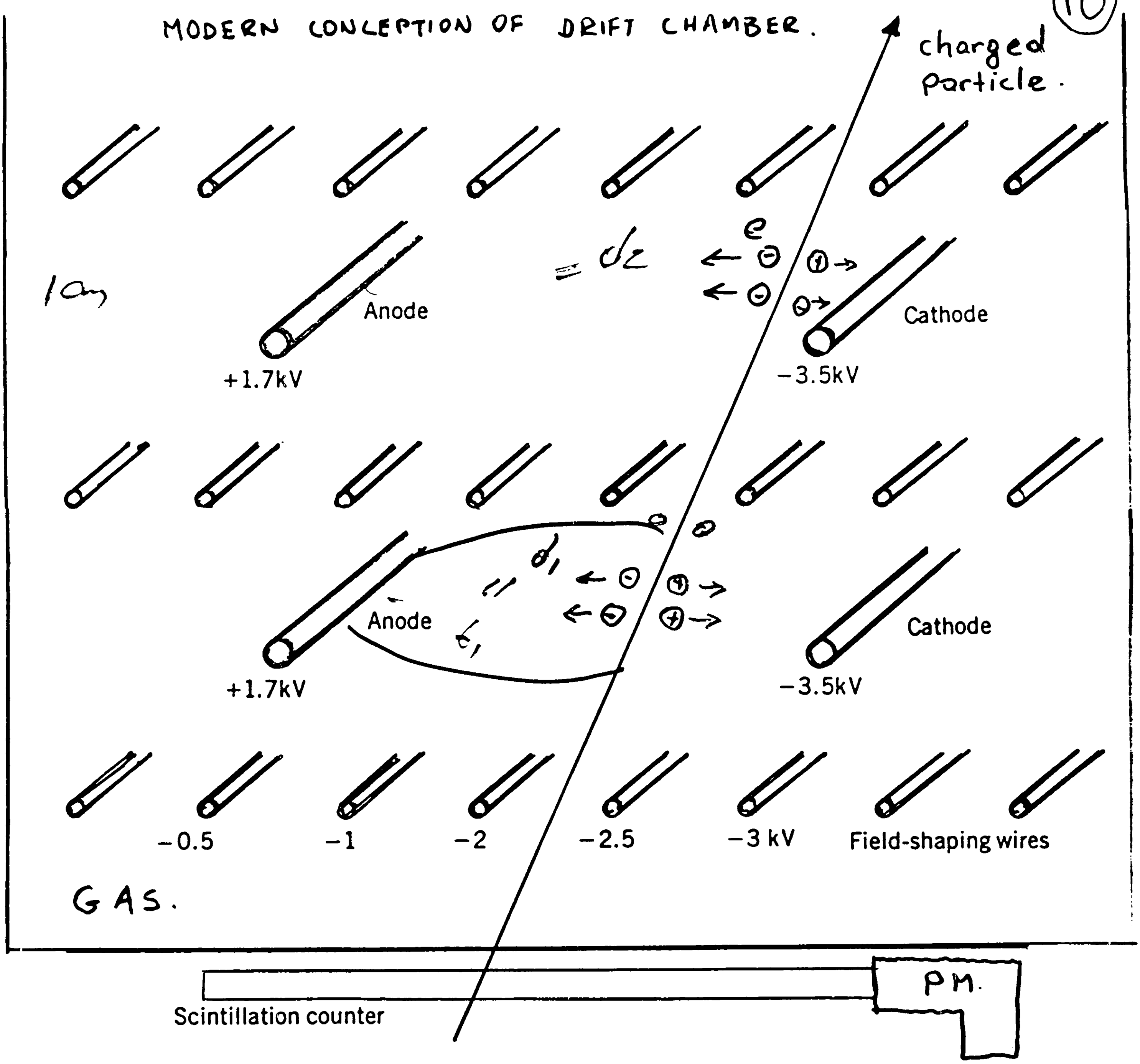


KNOWING THE DRIFT VELOCITY Xmm/sec AS WELL THE T_0 GINEN BY THE SCINT. COUNTER. THEN THE $\Delta T = (T_1 - T_0)$. GIVES DIRECTLY THE X CORDINATE OF THE CHARGED PARTICLE OF THE CELL.



Drifting electrons over large distances in a uniform field. Beam width is 0.6 mm. Almost no broadening is observed over the entire 25-cm drift length, showing that the intrinsic accuracy is much better than the beam width. From references 10 and 11. Figure 7

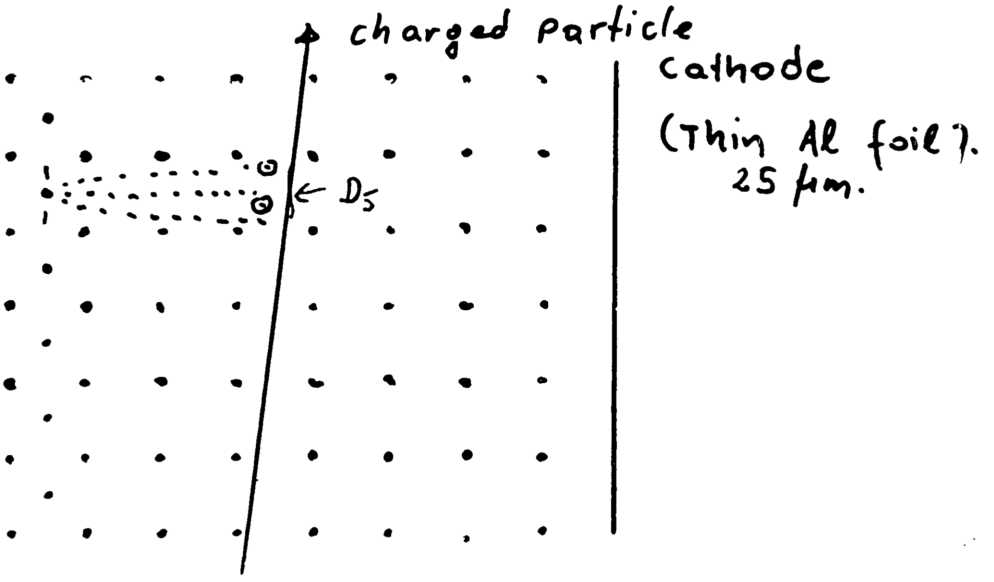
MODERN CONCEPTION OF DRIFT CHAMBER.



Construction principle of a multiwire drift chamber is seen in this schematic view. Cathode wires are connected to uniformly decreasing potentials, starting from ground in front of the anode. Field wires reinforce the field in the transition region to the next cell. The time between detection by a scintillation counter and the pulse on the anode wire gives the trajectory position. Figure 8

ϕ 200 μm Field shaping wires.

ϕ 20 μ Anode wires



$D_5 = V_e \cdot t_{min}$.

$[\,V_e = 1\,mm/20\,nsec\,]$

$D_5 = D \pm 50\,\mu m$.

Typical Detector Characteristics:

Detector Type	Accuracy (rms)	Resolution Time	Dead Time
Bubble chamber	≈ ±10 to ≈ ±150μ	≃ 1 ms	≈1/20 s[a]
Streamer chamber	+300μ	≈ 2 μs	≈100 ms
Optical spark chamber	±200μ[b]	≈ 2 μs	≈ 10 ms
Magnetostrictive spark chamber	±500μ	≈ 2 μs	≈ 10 ms
Proportional chamber	≥ ±300μ[c][d]	≈ 50 ns	≈200 ns
Drift chamber	±50 to 300μ	≈ 2 ns[e]	≈100 ns
Scintillator	1to2 mm.	≈150 ps	≈ 10 ns
Emulsion	±1μ		

see also transparency 11″

[a] Multiple pulsing time.

[b] 60μ for high pressure.

[c] 300μ is for 1 mm pitch.

[d] Delay line cathode readout can give ±150μ parallel to anode wire.

[e] For two chambers.

11¹

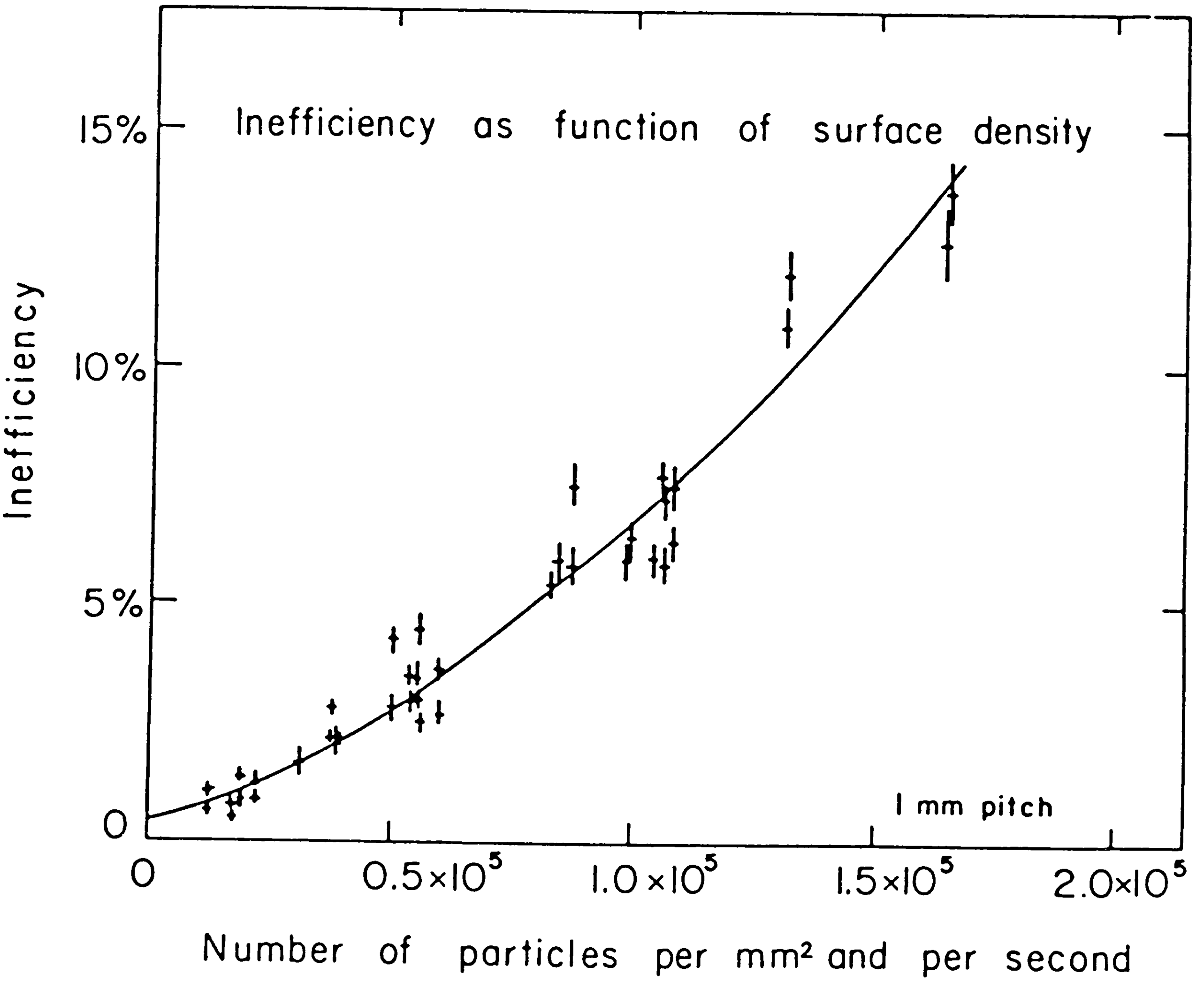
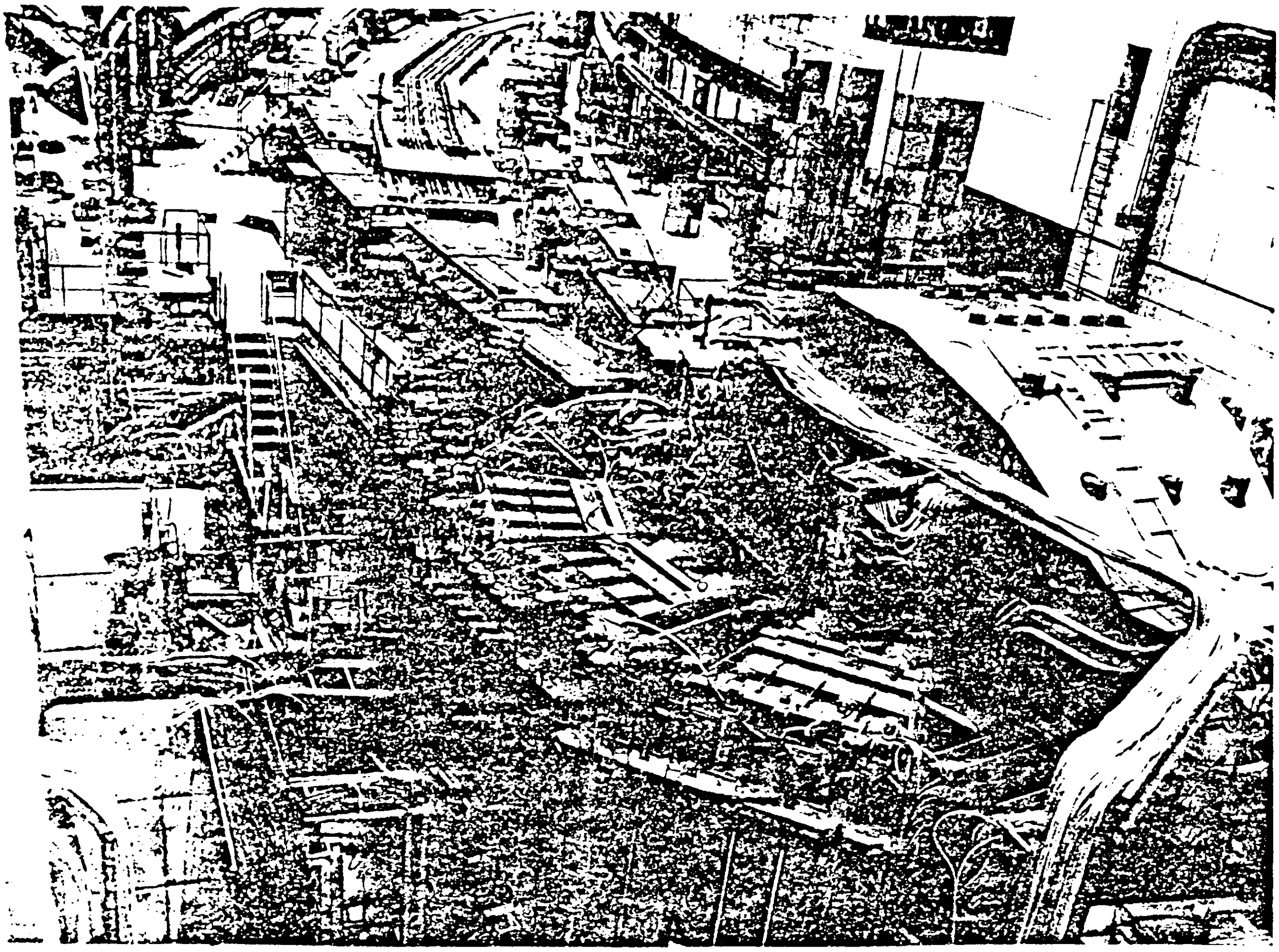
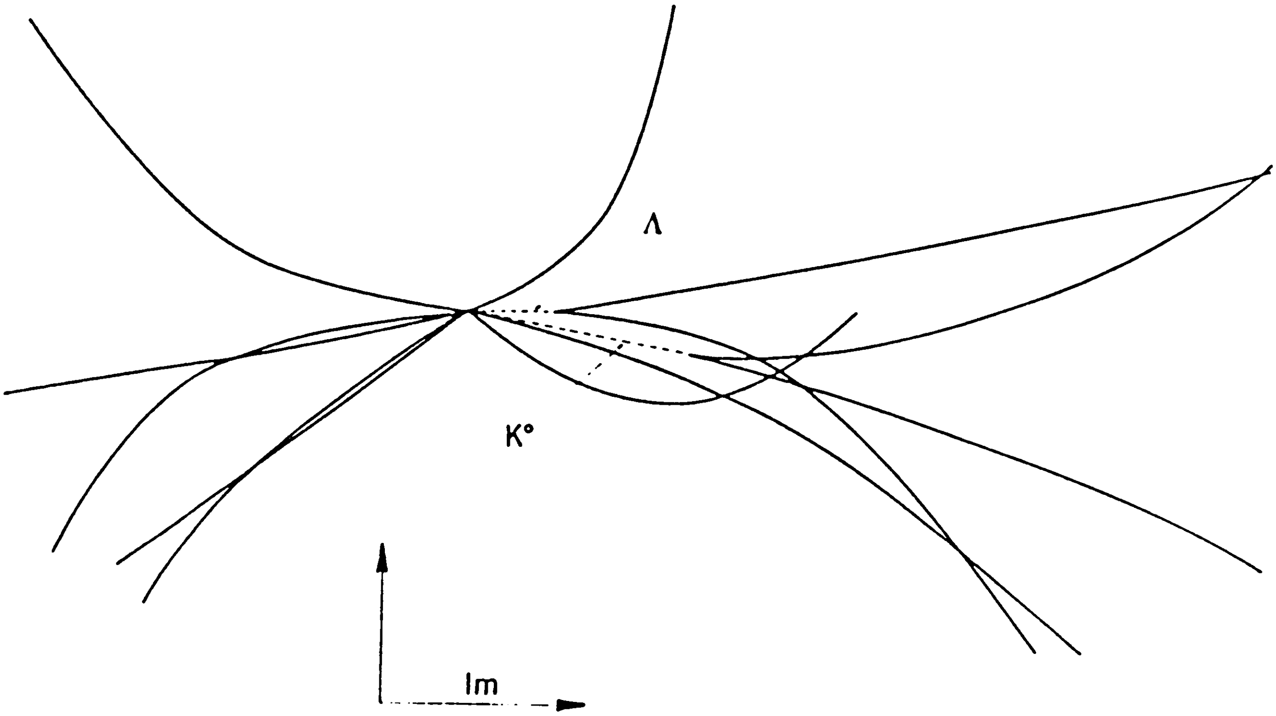
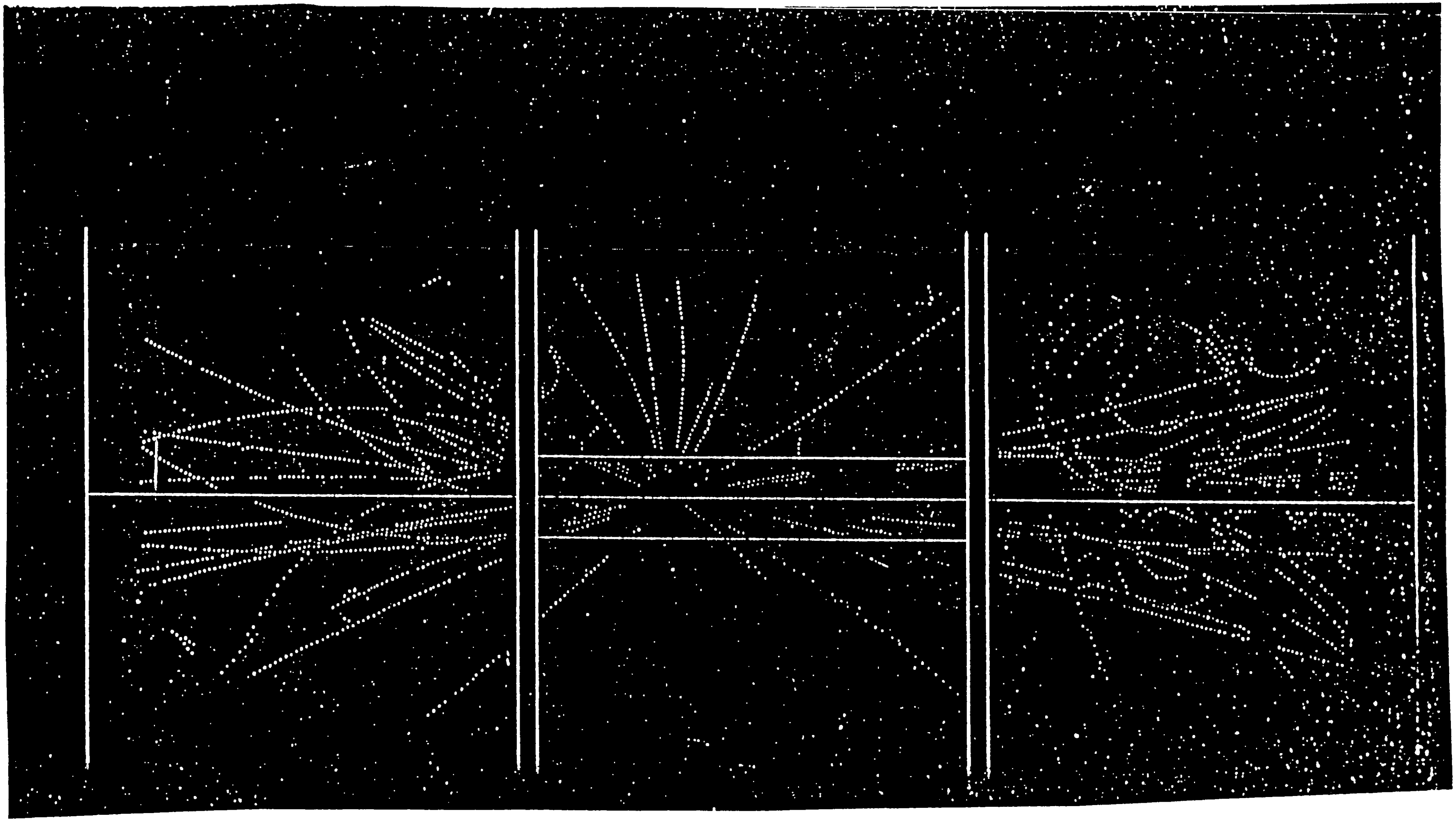


Fig. 75 Space-charge effect on chamber efficiency. Measured inefficiency on a s = 1 mm chamber, operating in magic gas, as a function of beam intensity[54].





Computer display of a high-energy interaction viewed by a system of multiwire chambers. At an intersection of the CERN proton storage rings, a system of 70 000 wires in a magnetic field detects the coordinates of the particles from one interaction. Typical rates are 150 000 interactions per sec; background, 10^6 per sec per chamber; resolution time about 100 nanosec. Figure 9



UA1 COMPUTER DISPLAY
OF $p\bar{p}$ EVENT.

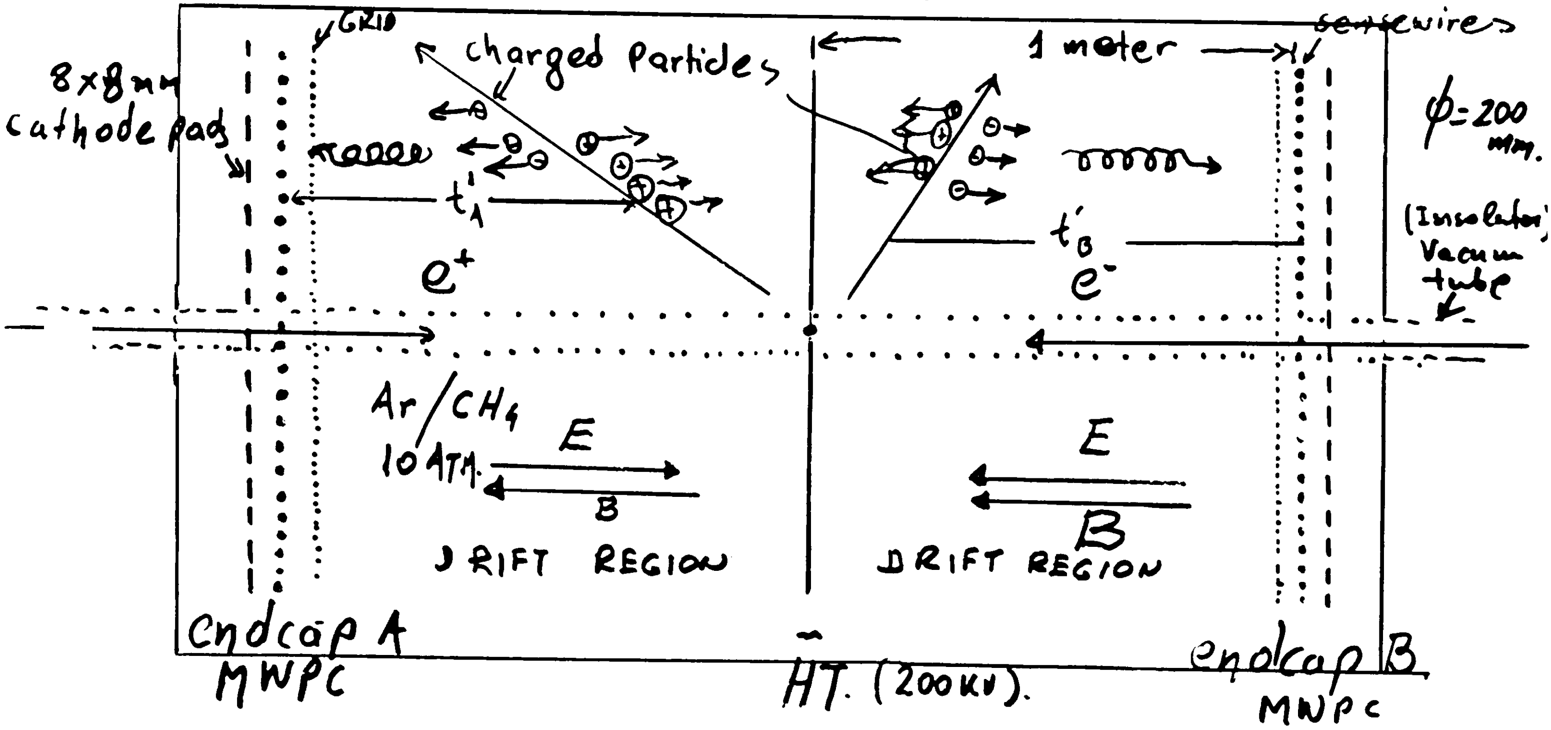
TPC

(Dev. at BERKLEY → PEP).

TIME PROJECTION CHAMBER.

[VOLUME DRIFT CHAMBER].

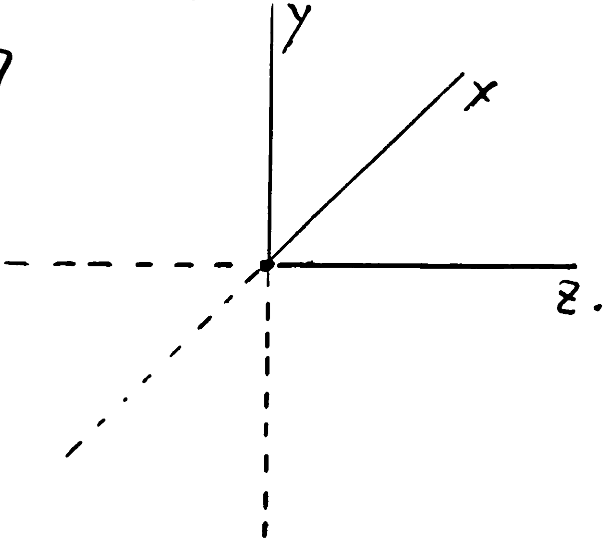
Parallel Electric and Magnetic fields in the direction of the electron drift.



T·P CHAMBER IS VERY PROMISING.

⇓

[2 proposals for LEP]



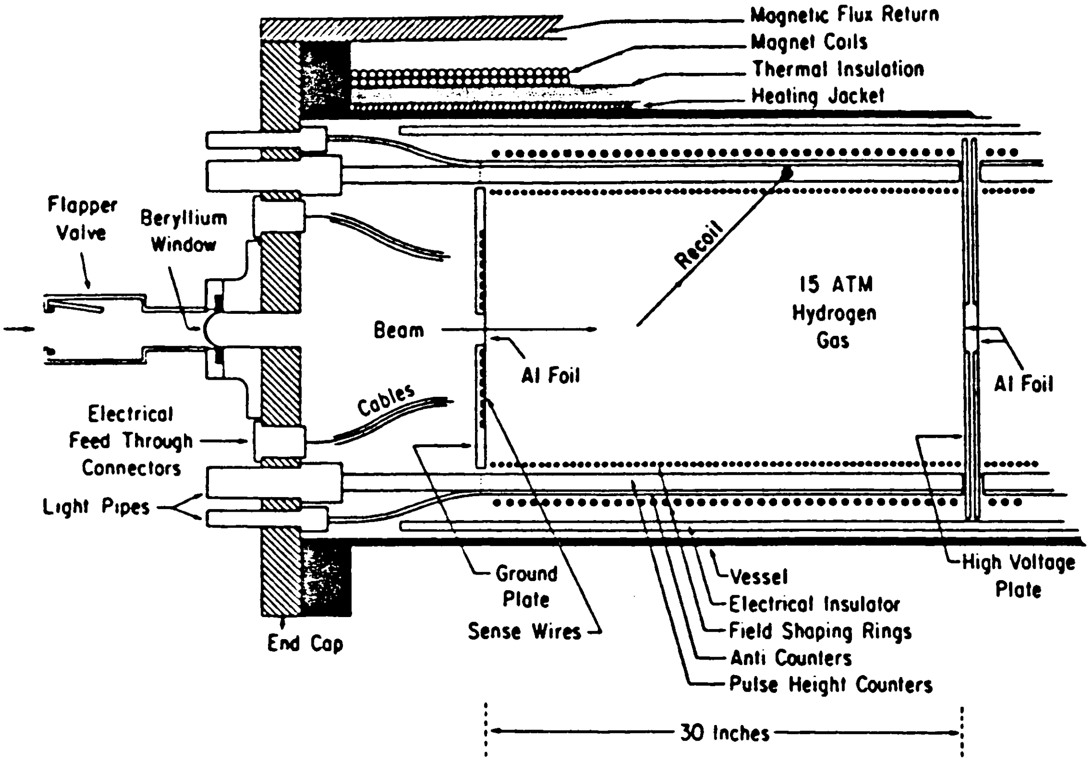
CORDINATES

z : from drift times (Drift velocity very well known). $\sigma \simeq 300\ \mu$.

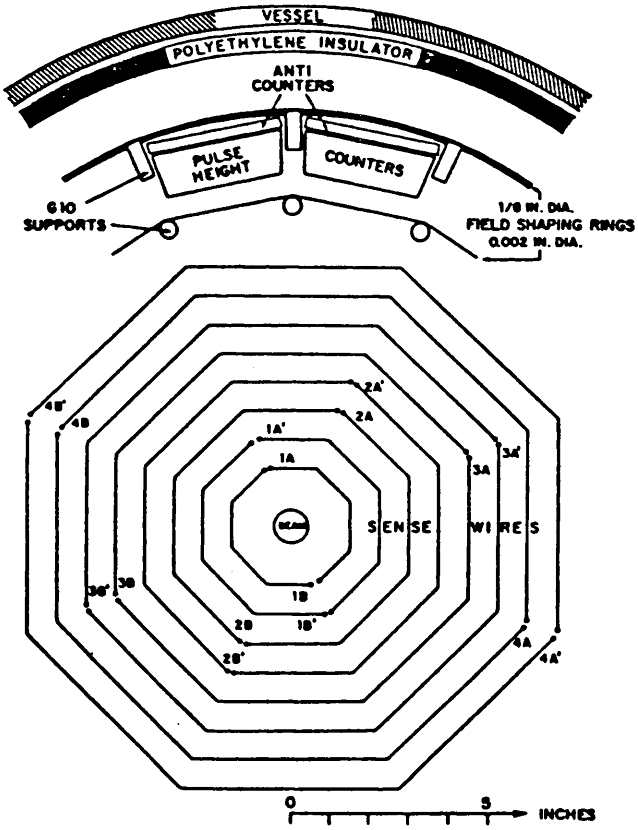
x, y : from centroids on cathode pads $\sigma \simeq 200\ \mu$.

$\frac{dE}{dx}\Big]_{\text{particle}}$ ÷ from amplitude analysis

FERMILAB TPC (Proton Recoil studies).

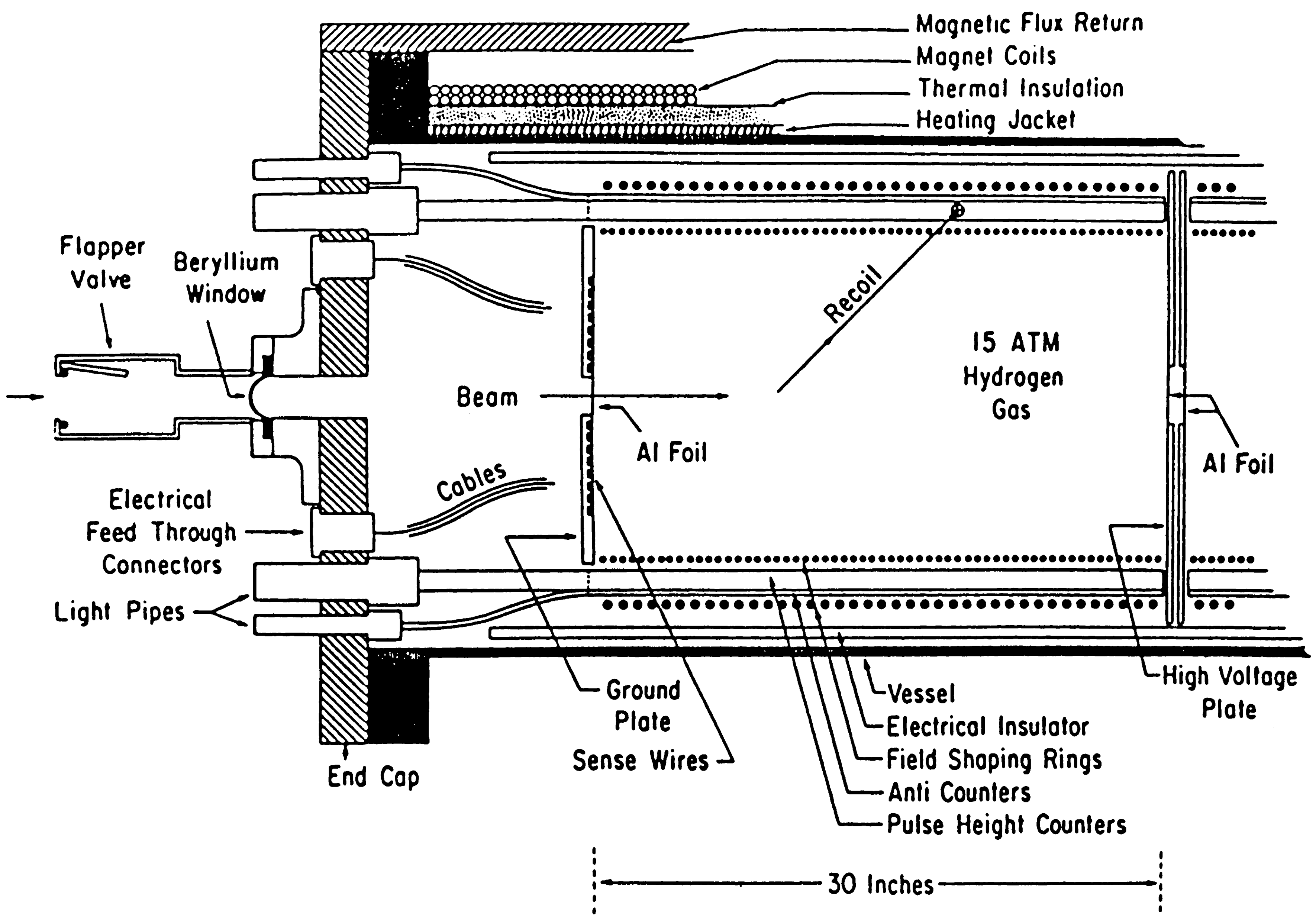


Side view of apparatus.



End view of apparatus.

Fermilab T1



Side view of apparatus.

Annex 2

CERN 21.4.83

FAT.

(FOIL ACTIVATION TECHNIQUE).

FOIL ACTIVATION IS A WELL-ESTABLISHED TECHNIQUE FOR MEASURING THE INTENSITY OR FLUX OF HIGH ENERGY PROTON BEAMS. Also PION BEAMS.

IT IS AN "OFF LINE" MONITOR.

THE FAT HAS PROVEN PARTICULARLY CONVENIENT IN BEAMS WHERE OTHER "ON LINE" MONITORING SYSTEMS ARE QUITE DIFFICULT.

THE FAT HAS BEEN LARGELY USED FOR "IN SITU" CALIBRATION OF "ON LINE" BEAM INTENSITY MONITORS SUCH AS

BEAM CURRENT TRANSFORMERS.	BCTs.
SECONDARY EMISSION CHAMBERS	SECs.
IONIZATION CHAMBERS	ARGONIONS.
TARGET COUNTER TELESCOPES.	

Cross-secti

AND VICE VERSA: MEASUREMENT OF THE NUCLEAR INTERACTION σ.

......

IF AN Al THIN FOIL ($\sim 50\,\mu m$) IS TRAVERSED BY A HIGH ENERGY PROTON BEAM THEN A NUMBER OF RADIOISOTOPES* WILL BE PRODUCED WITH PARTICULAR RADIOACTIVE CONSTANTS:

HALF LIFE	$T_{1/2}$.
RADIATION	α $\beta^{\pm}$ γ.
ABUNDANCE.	%.

---

* ALSO CALLED RADIOACTIVE NUCLIDES.

CHARACTERISTICS OF NUCLEAR REACTIONS AND CORRESPONDING INDUCED RADIOISOTOPES USED FOR PROTON FLUX MEASUREMENTS.

Proton Momentum. ≥ 10 Gev/c.

$^{12}_{6}C\,(p,\,pn)\,^{11}_{6}C$ $\sigma \simeq$ 25 mb: $= 25 \times 10^{-27}$ cm^2.
$T_{1/2}$ = 20.4 min.
β^+ 100%
γ .511 mev 200%

$^{12}_{6}C\,(p,\,3p3n)\,^{7}_{4}Be$ $\sigma \simeq$ 9 mb
$T_{1/2}$ = 53.6 Days.
γ: .477 Mev 10%

$^{27}_{13}Al\,(p,\,5p5n)\,^{18}_{9}F$ $\sigma \simeq$ 6 mb.
$T_{1/2}$ = 110 min.
β^+ 97%

$^{24}_{11}Na$: γ 1.37 Mev 100%
2.75 " 100%

$^{27}_{13}Al\,(p,\,3pn)\,^{24}_{11}Na$ σ = 8,6 mb.
$T_{1/2}$ = 15 Hrs.
BNL
(7.8 ± 0.1) mb.
J. CUMMING
V. AGORITSAS
R. WITKOVER.

VERY LARGE USE.

HOWEVER VULNERABLE TO LOW ENERGY NEUTRONS.

σ for L.E.N 10-20 times Higher than a 24 GeV Proton beam. SIMPLE COUNTERS + GeLi

BNL, FNAL, CERN

$^{64}_{29}Cu\,(p,\,\text{SPALLATION})\,^{24}_{11}Na$ σ = 4 mb
$\sigma \simeq (3.7 \pm 0.1)$ mb.
V. AGORITSAS
S. BAKER
J. CUMMING.

VERY LARGE USE
AT FNAL AND CERN.

ONLY NEUTRONS OF 600 MeV and above CAN PARTICIPATE IN THE REACTION. GeLi counters ONLY

VERY IMPERATIVE TO POSSESS PURE MATERIAL AND HOMOGENEOUS IN THICKNESS. !!!

A NUMBER OF OTHER NUCLEAR REACTIONS ARE ALSO USED TO MONITOR HIGH ENERGY PROTON FLUXES, HOWEVER, THE MEASUREMENT OF ACTIVITY NECESSITATES A MORE SOPHISTICATED COUNTING EQUIPMENT.

THE FOLLOWING FORMULA IS USED TO COMPUTE THE PROTON FLUX

$$\text{Proton flux} = \frac{\Delta t\, A(t)\, e^{(t-\Delta t)\lambda}}{N \sigma (1 - e^{-\lambda \Delta t})}. \quad \text{protons}$$

IF $\Delta t << \tau$ (very short duration of bombardment) where $\tau = \frac{T^{1/2}}{\text{Ln}\,2}$ then. $\lambda = \frac{1}{\tau} = \frac{\text{Ln}\,2}{T^{1/2}}$

Decay constant.

$$\Rightarrow \text{proton flux} = \frac{A(t)\, e^{t\lambda}}{N \sigma \lambda} \quad \text{protons.}$$

IF THE PROTON FLUX IS KNOWN BY A RELIABLE MONITOR SAY IJ BCT in 1 FEB. THEN THE CROSS SECTION CAN BE COMPUTED

$$\Rightarrow \sigma = \frac{A(t)\, e^{t\lambda}}{N\, [\text{proton flux}]\, \lambda}$$

Δt = Duration of bombardment in minutes.

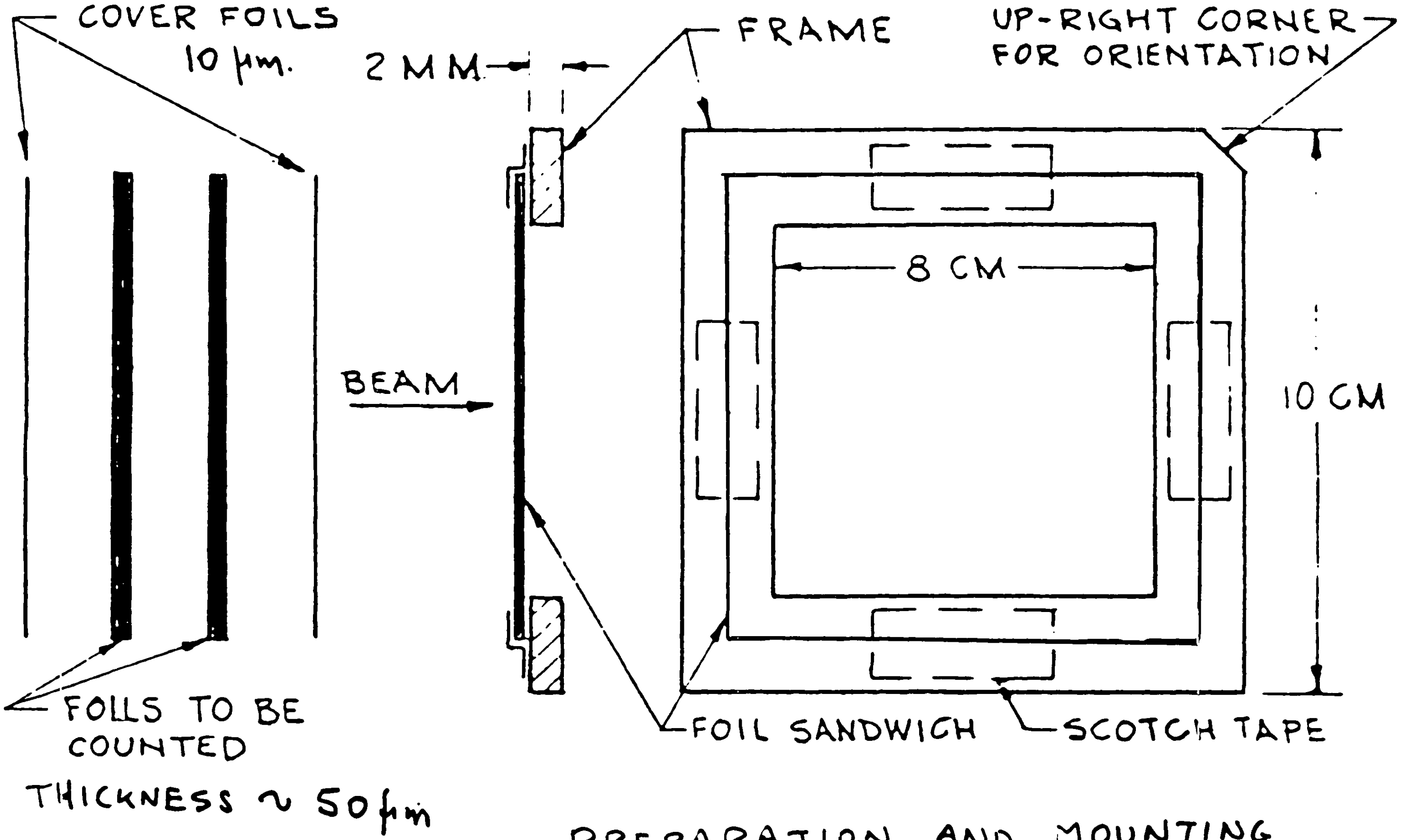
$T^{1/2}$ = half life in minutes.

$A(t)$ = Counting rate per minute of activated foil t minutes from beginning of bombardment. background subtracted and the efficiency of the counting equipment considered.

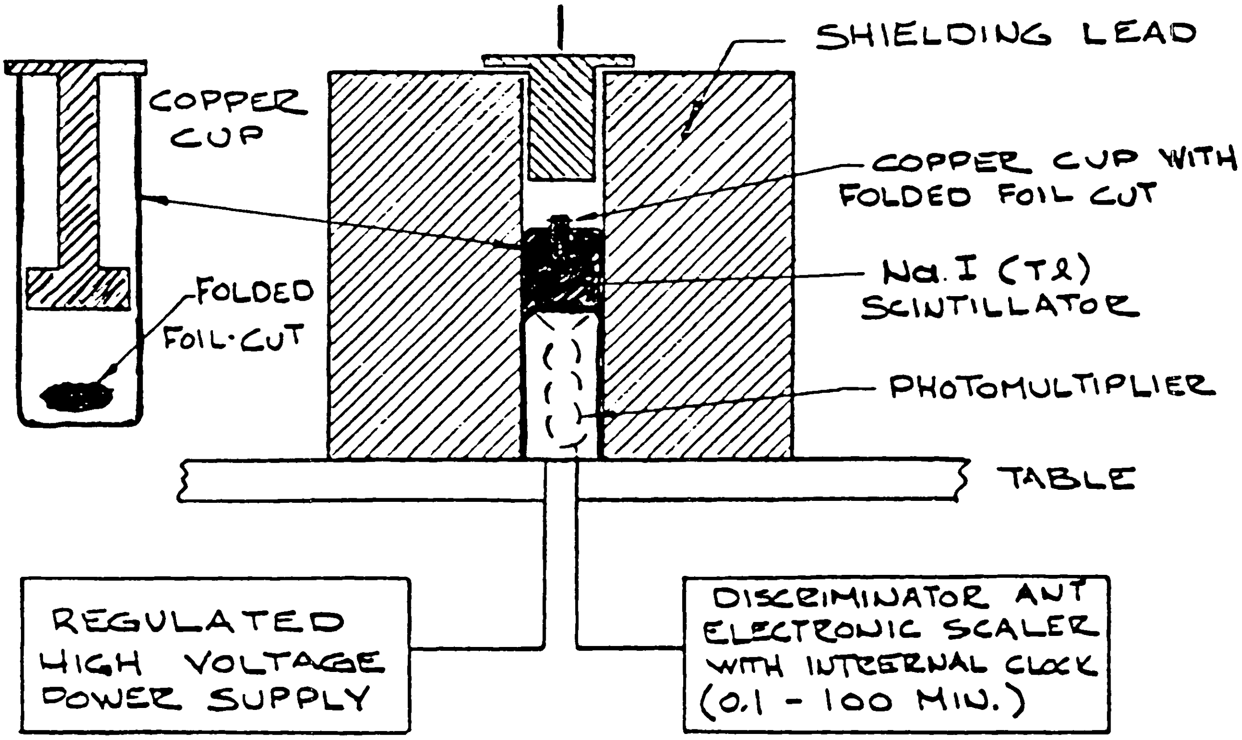
N = Number of atoms/cm^2 of the foil material.

$$= \frac{6.023 \times 10^{20} \times [mg/cm^2] \text{ of foil cut (activated)}}{\text{molecular weight}}$$

σ = Cross section of the Nuclear reaction used in cm^2



PREPARATION AND MOUNTING OF FOILS FOR ACTIVATION.



WELL COUNTER OR γ-ray COUNTER.

PROTON FLUX MEASUREMENT BY FOIL ACTIVATION DATA SHEET

GENERAL DATA

Foil Activation #. 18-A1-2 Date 9-23-76 Machine Pulses 10

Start 8:02:34 Stop 8:02:58 T(min) 0.25

Beam location CE 012 Energy (GeV) 28 Machine cycle (sec) 2.4

Beam Intensity Monitor SEC CE010 Reading (protons) 5.13×10^{13}

Foil Material ALUMINUM Mole: M(g) 26.98 Density 2.7

Foil-cut: Area (cm^2) 5.9 Weight (mg) 76.5 Thickness(mg/cm^2) 12.796

N($atoms/cm^2$) = $(6.023 \times 10^{20}/M) \times$ thickness = 2.857×10^{20}

Radioisotope ^{24}Na σ(mb) 8 Half life $T_{\frac{1}{2}}$(min): 900 (15h.)

τ = half life/ln2 (min) 1298 $\lambda = 1/\tau = 7.7016 \times 10^{-4}$

Well Counter: # 3 Counting efficiency: 0.515

Counting Data

Date	Time Scaler On	Counting Period Δt(min)	Cool-off Period t(min)	Total Counts	BKG per min.	Net and Corrected A_t(CPM)	$A_o = A_t e^{\lambda(t-\Delta t)}$	
9-24-76	9:29	1	1527	18728	108	18600	6.029×10^4	
..	9:41	..	1541	19079	..	19000	6.225 ..	
.	9:52	..	1550	18602	..	18500	6.104 ..	
..	15:37	..	1895	14141		14050	6.045 ..	
..	15:45	..	1903	14175		14100	6.105 ..	
..	15:53	..	1911	13960		13900	6.056 ..	

$\bar{A}_o = (6.094 \pm .0713) \times 10^4$

Proton flux = $\dfrac{\Delta t \; \bar{A}_o}{N\sigma\epsilon\,(1-e^{-\lambda\Delta t})}$ or if $\Delta t \ll \tau$ Proton flux = $\dfrac{\bar{A}_o}{N\sigma\lambda\epsilon} = 6.74 \times 10^{13} \pm 1.2\,\%$

BEAM SIZE MEASUREMENTS USING FAT.

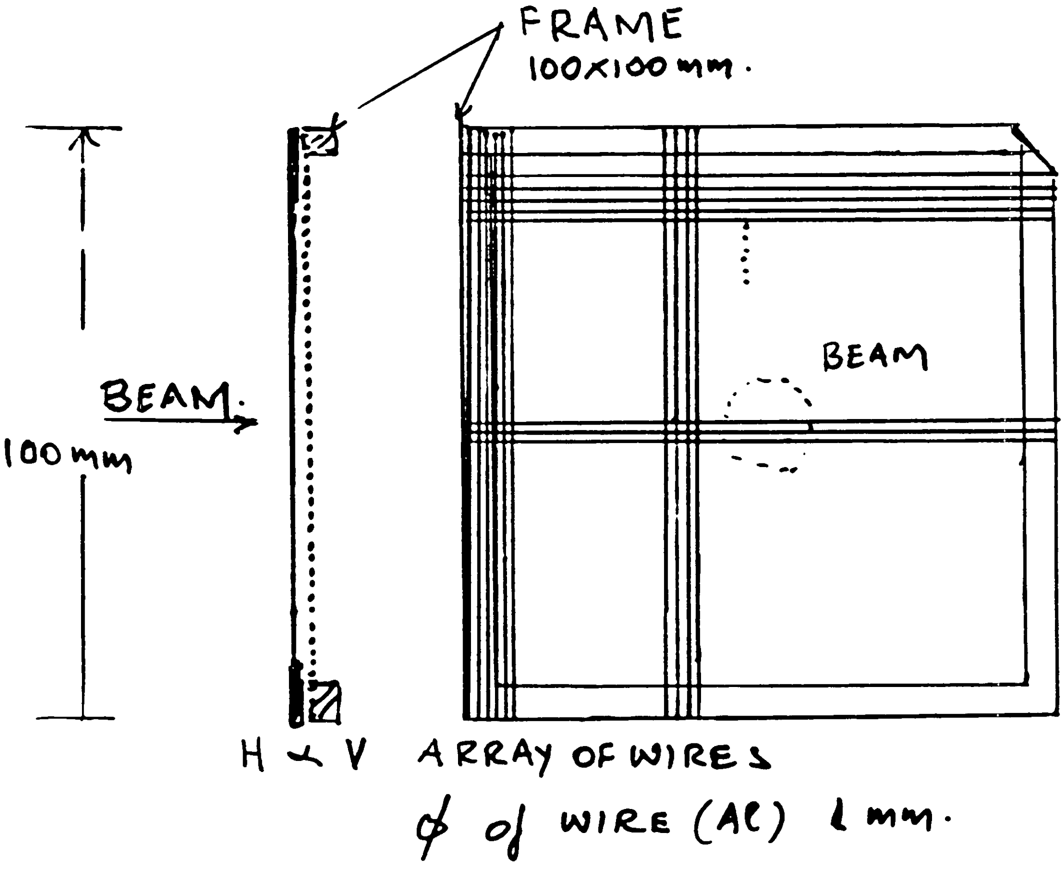
INTERCHANGING THE PLAIN FOILS WITH A FINE MESH THE SIZE OF THE BEAM CAN BE MESURED BY PLOTTING THE ACTIVITY OF EACH WIRE OF THE MESH. (OFF LINE MEASUREMENT).

⟹ BEAM DISTRIBUTION IN THE HORIZONTAL PLANE
SPATIAL RESOLUTION BETTER THAN 1 mm.

⟹ BEAM DISTRIBUTION IN THE VERTICAL PLANE.

HERE ONLY RELATIVE WIRE ACTIVITIES ARE NECESSARY. ⟹ MORE EASY

Instead of a MESH Arrays of WIRES OR BARS CAN BE USED. (Aluminium or Carbon or even iron wires, bars.).



H & V ARRAY OF WIRES
ϕ of WIRE (Al) 1 mm.

LAST YEAR WE FREQUENTLY USED THE FOIL ACTIVATION TECHIQUES TO CALIBRATE. THE "ARGONIONS" OF THE NA 10 EXPERIMENT (IN THE NORTH AREA OF SPS.).

RESULTS:

1. GOOD LONG TERM STABILITY OF THE TWO "ARGONIONS" FOR BOTH PION AND PROTON HIGH INTENSITY BEAMS

2. $^{12}_{6}C\,(\pi^{\pm}, pn)\,^{11}_{6}C \Rightarrow \sigma_{\pi} = 15\ mb.$

   π momentum = 250 GeV/c.

   $^{12}_{6}C\,(p, pn)\,^{11}_{6}C \Rightarrow \sigma_{p} = 25\ mb.$

   p momentum = 400 GeV/c.

$$\Rightarrow \quad \frac{\sigma_{\pi}}{\sigma_{p}} \approx \frac{15}{25} \simeq \frac{2}{3}.$$

Does this implies that: $\pi \Rightarrow$ Two quarks?

$p \Rightarrow$ three quarks?

3. BEAM SIZES. (CARBON BARS)

	H	V.
a. THEORETICAL (Phase-space).	1.618 mm	1.558 mm.
b M.W.P.C ($> 10^{9}\,\pi\ cm^{-2}\,s^{-1}$).	4.09 "	4.20 ".
c FAT (Carbon Bars).	1.50 mm	(1.70-1.90) mm !!