Internal Report
DESY F15/01
November 1977

Meeting on DORIS Experiments
10th and 11th October 1977
at D E S Y

Collection of Transparencies used by the Speakers

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Collection of transparencies used by the speakers

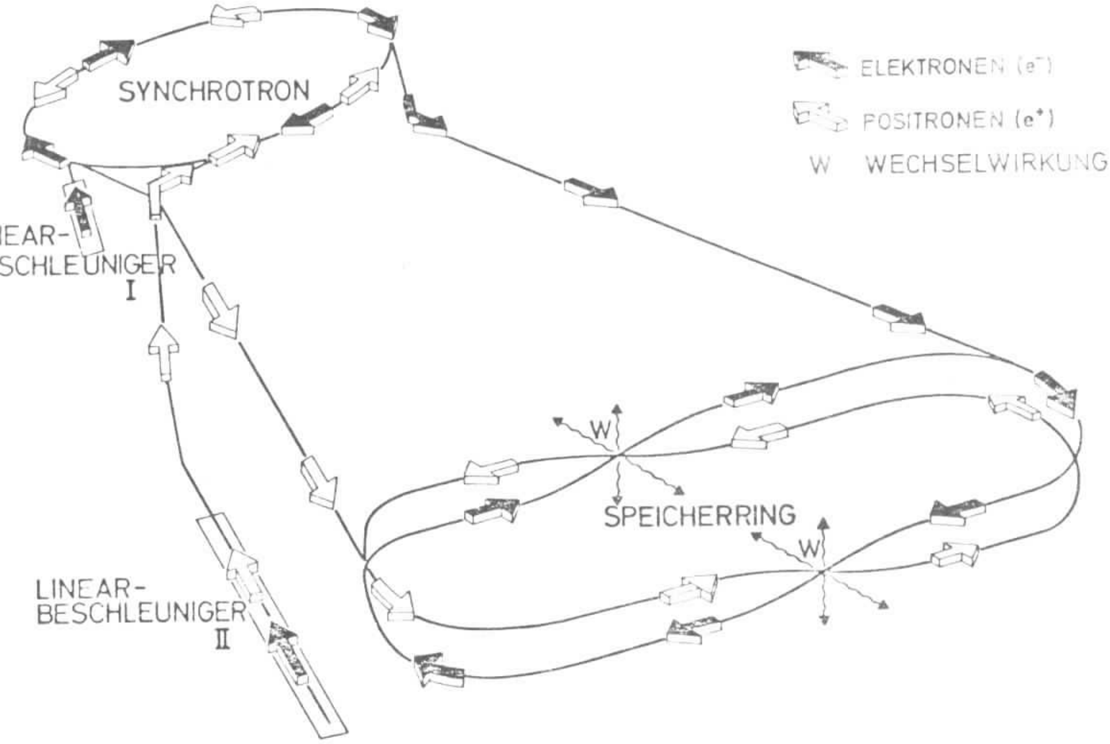
A

10.10.1977

D O R I S a t H i g h E n e r g i e s

by

D. Degèle



The DORIS double ring (maximum energy 2 x 3.5 GeV)

History of DORIS

Date of proposal:	summer	1967
Excavation work starts:	spring	1970
First stored beam:	December	1973
Begin of experiments:	autumn	1974
Reconstruction for single ring operation	autumn	1977

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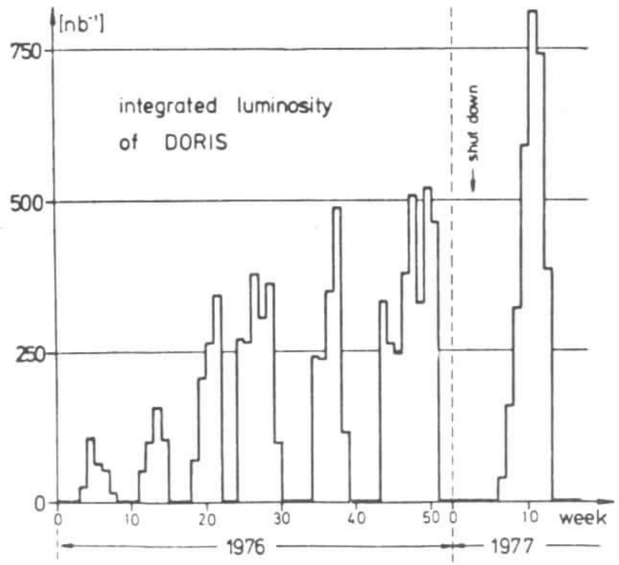


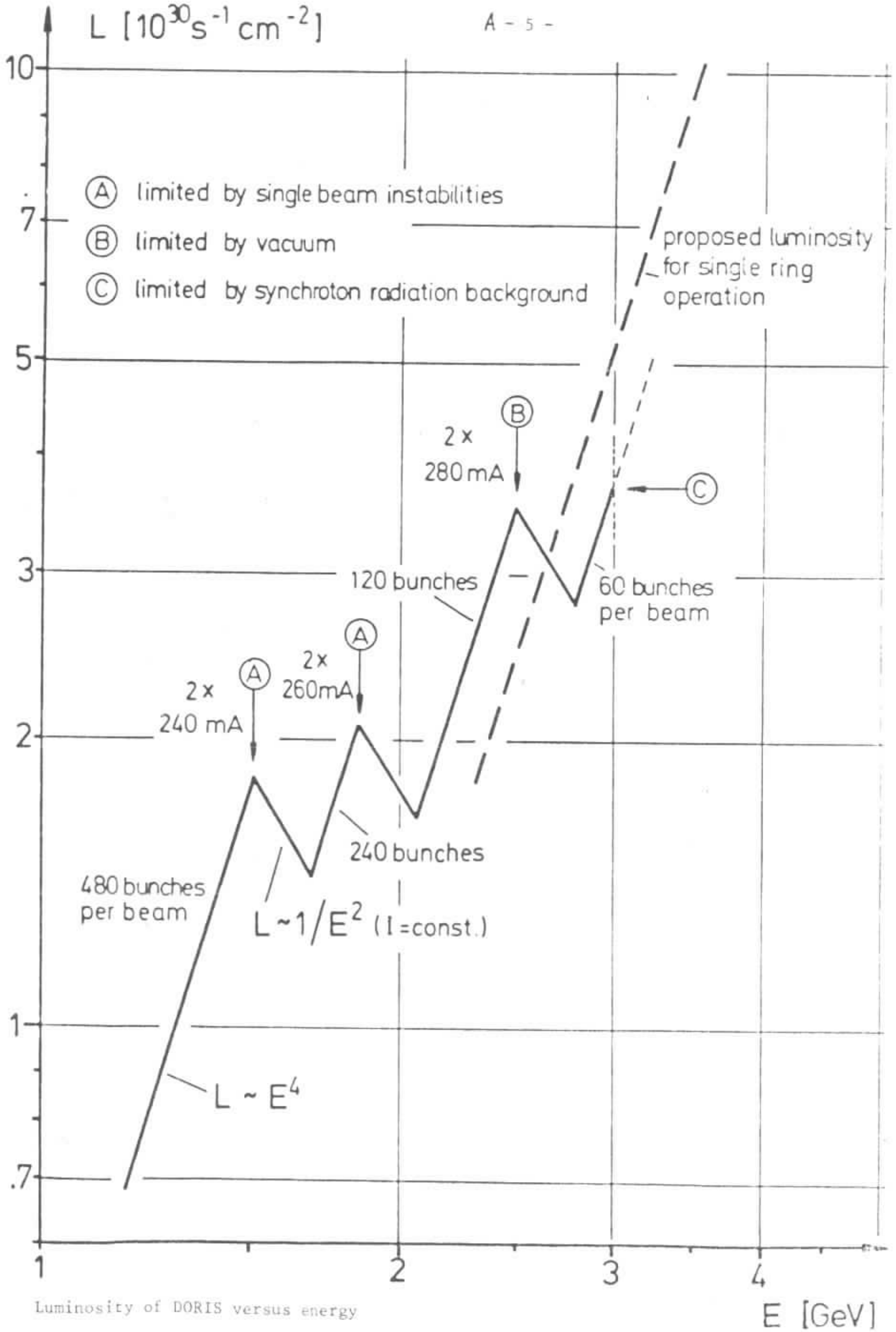
Integrated luminosity per interaction point averaged over one week.
Gaps are due to maintainance and machine studies.

Operation schedule

(average of the last two years)

Time for high energy experiments:	45 %
Time for machine studies:	18 %
Maintenance:	17 %
Shut down:	20 %
	100 % ≙ 365 days

During 80 % of experimentaltime, luminosity was available.
The remaining 20 % were due to injektion and breakdowns.



Luminosity of DORIS versus energy

Limitations for the DORIS luminosity

1.) Instabilities:

Single beam currents usuable for luminosity $\leq$ .3 A

2.) Beam-beam limit:

Maximum ΔQ shift observed at DORIS: .01

3.) Vacuum:

Background in the experiments limits usuable currents to $\leq$ .3 A

Single beam instabilities observed at DORIS

1.) Head tail instability starting at .2 mA/bunch

cure: chromaticity positiv

2.) Transverse multiturn modes induced by parasitic cavity modes

cure: resonance damping of cavity modes +
rf-quadrupole

3.) Transverse multimodes induced by low Q resonators in the ring

cure: rf-quadrupole + increased Landau-damping
by octupole fields

4.) Longitudinal multiturn modes induced by parasitic cavity modes

cure: resonance damping of cavity modes +
additional rf-transmitter at a different
harmonic number

5.) Bunch shape oscillations with bunchlengthening and energy widening

cure: increase of longitudinal Landau-damping

Vacuum conditions at DORIS

Average pressure $\bar{p}_{torr} = 1 \cdot 10^{-9} + 1 \cdot 10^{-11}\, I_{mA}$ at 2 GeV

At 2 x 2 GeV and 2 x 200 mA beam current

$\bar{p} = 3 \cdot 10^{-9}$ torr

and beam lifetime $\tau \approx 8^h$

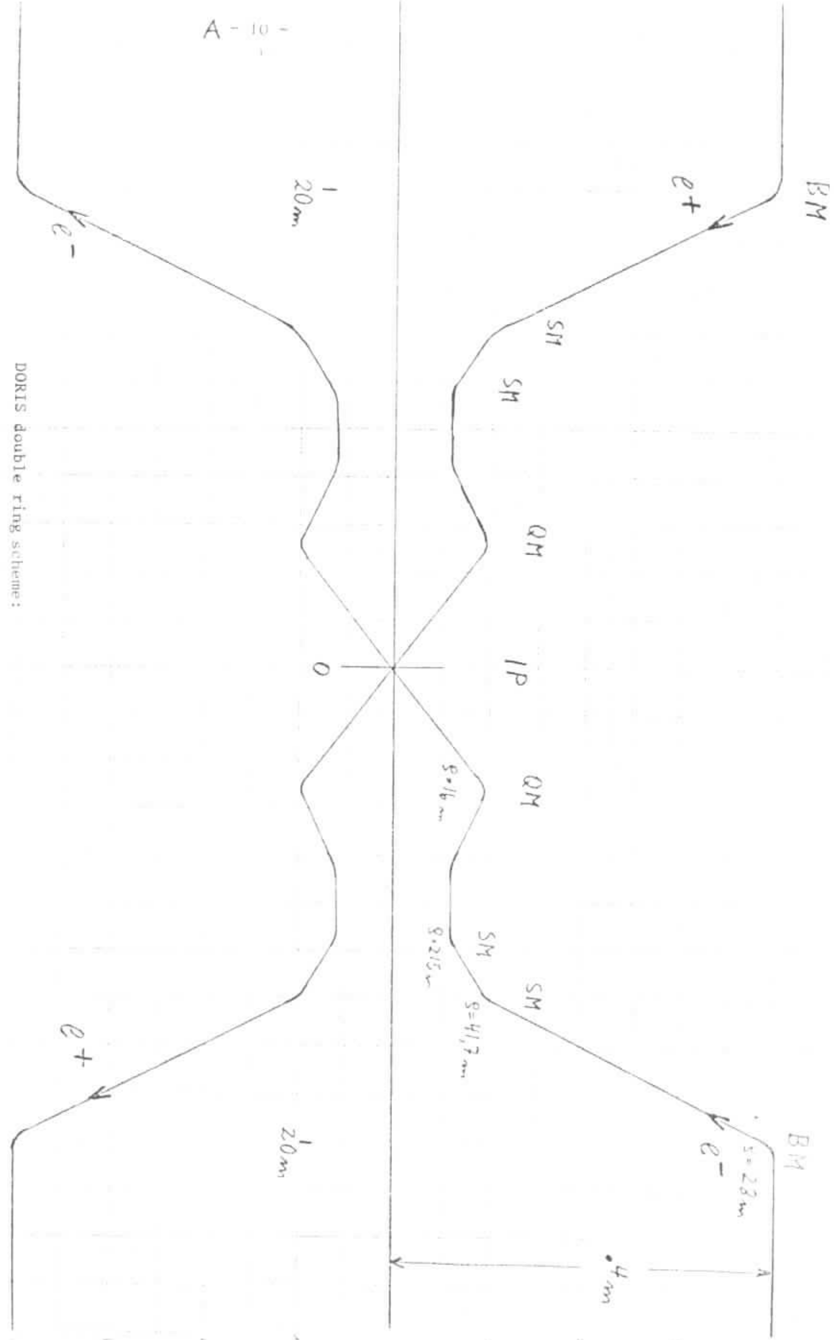
Reconstruction of DORIS for single bunch-
single ring operation

Technical implications:

- 4 additional bending magnets
- electrostatic beam separators
- additional synchrotron radiation absorbers
- 2 additional fivecell cavities

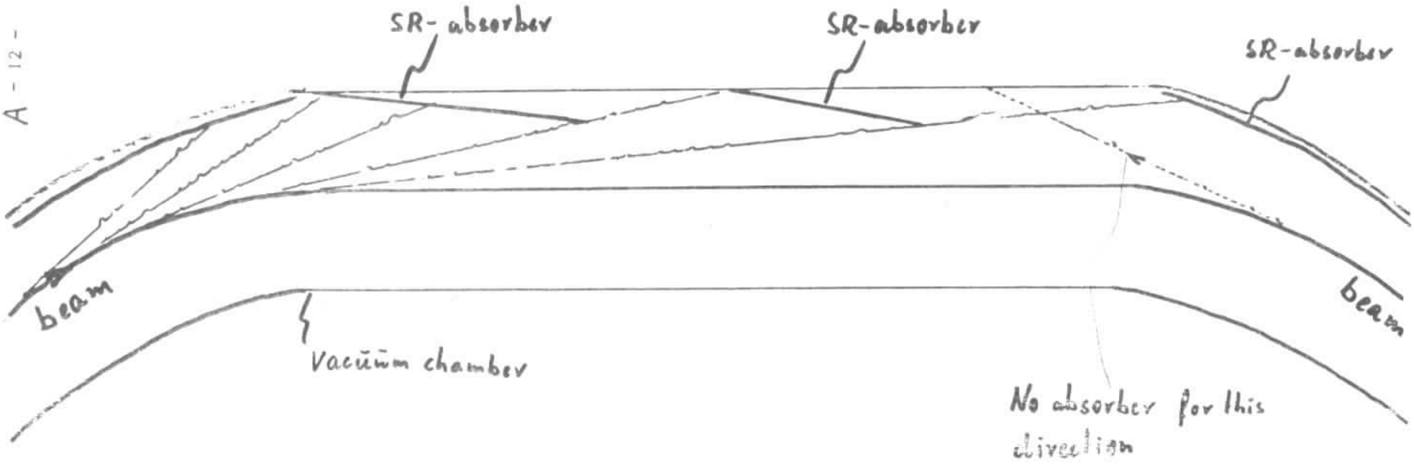
Possible problems:

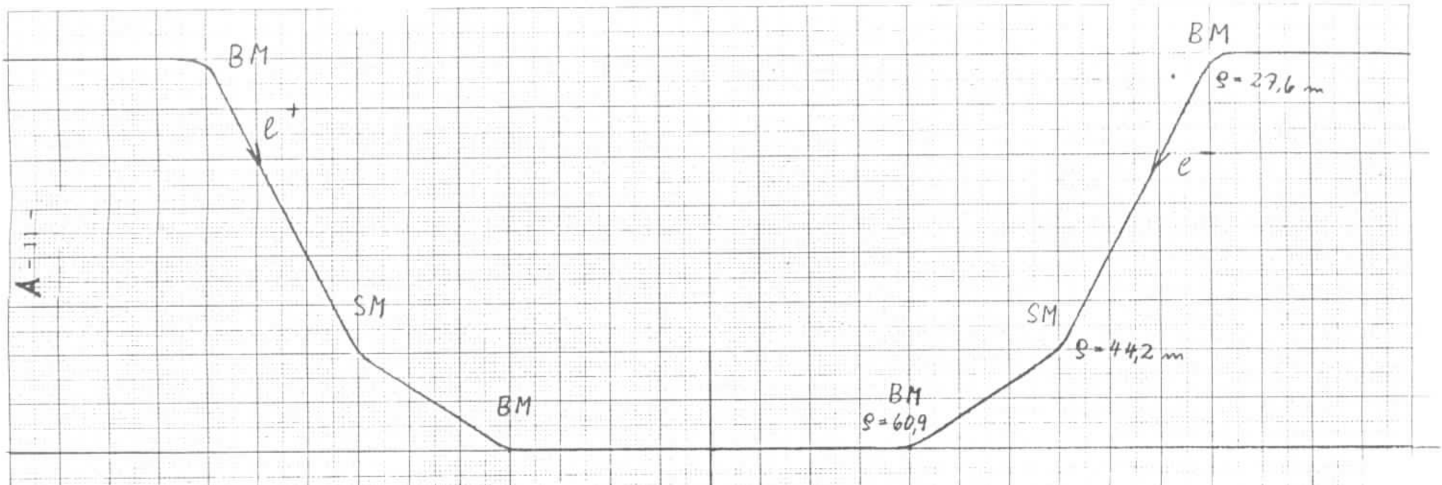
- instabilities due to the new rf-structure
- saturation of magnets
- acceptance to small
- higher order mode losses



DORIS double ring scheme:
Vertical bending near the interaction point
crossing angle 2 x 12 mrad
BM: bending magnet, SM: septum magnet, QM: quadrupole magnet

Synchrotron radiation absorbers in a straight section of the DORIS double ring





The DORIS single ring scheme:
Vertical bending near the interaction point.
Head on collision

RF for 4.3 GeV single ring operation

2 PETRA cavities:

shunt impedance	:	2 x 18 MΩ
rf-power	:	250 kW
⤳ rf-voltage	:	$4{,}2 \cdot 10^6$ Volt

plus

4 DORIS cavities:

shunt impedance	:	4 x 3 MΩ
rf-power	:	250 kW
⤳ rf-voltage	:	$2{,}4 \cdot 10^6$ Volt
summa	:	$6{,}4 \cdot 10^6$ Volt

Energy loss per turn	$2{,}6 \cdot 10^6$ Volt
⤳ phase angle	24°
⤳ lifetime against quantum fluctuations	~ 100^h

⤳ 4,3 GeV is the maximum energy with zero current.

At 4,0 GeV the rf can keep 2 x 50 mA.

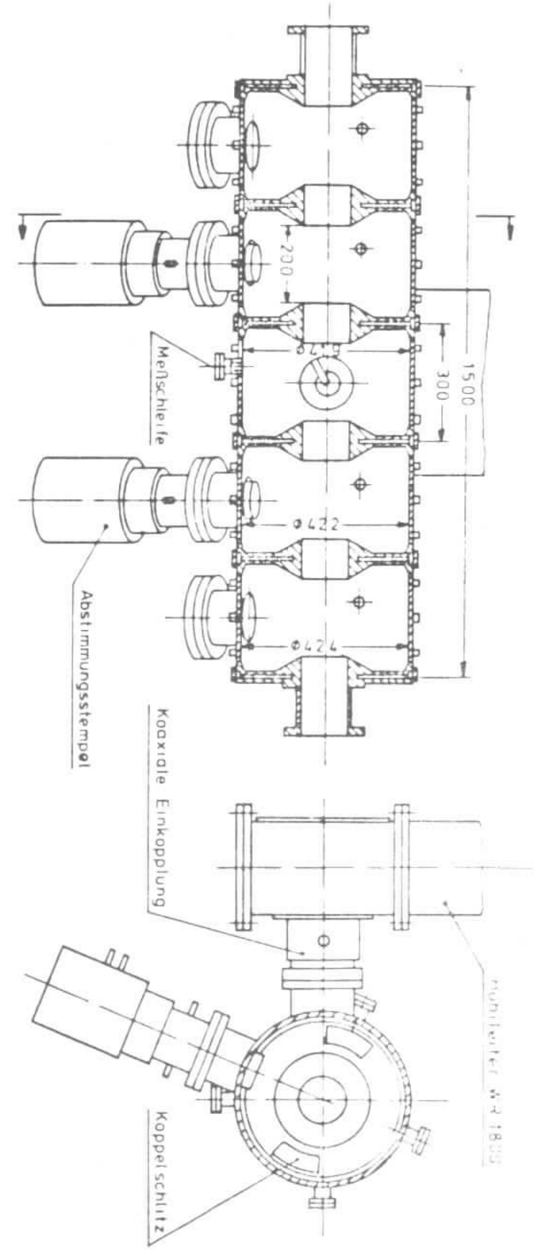
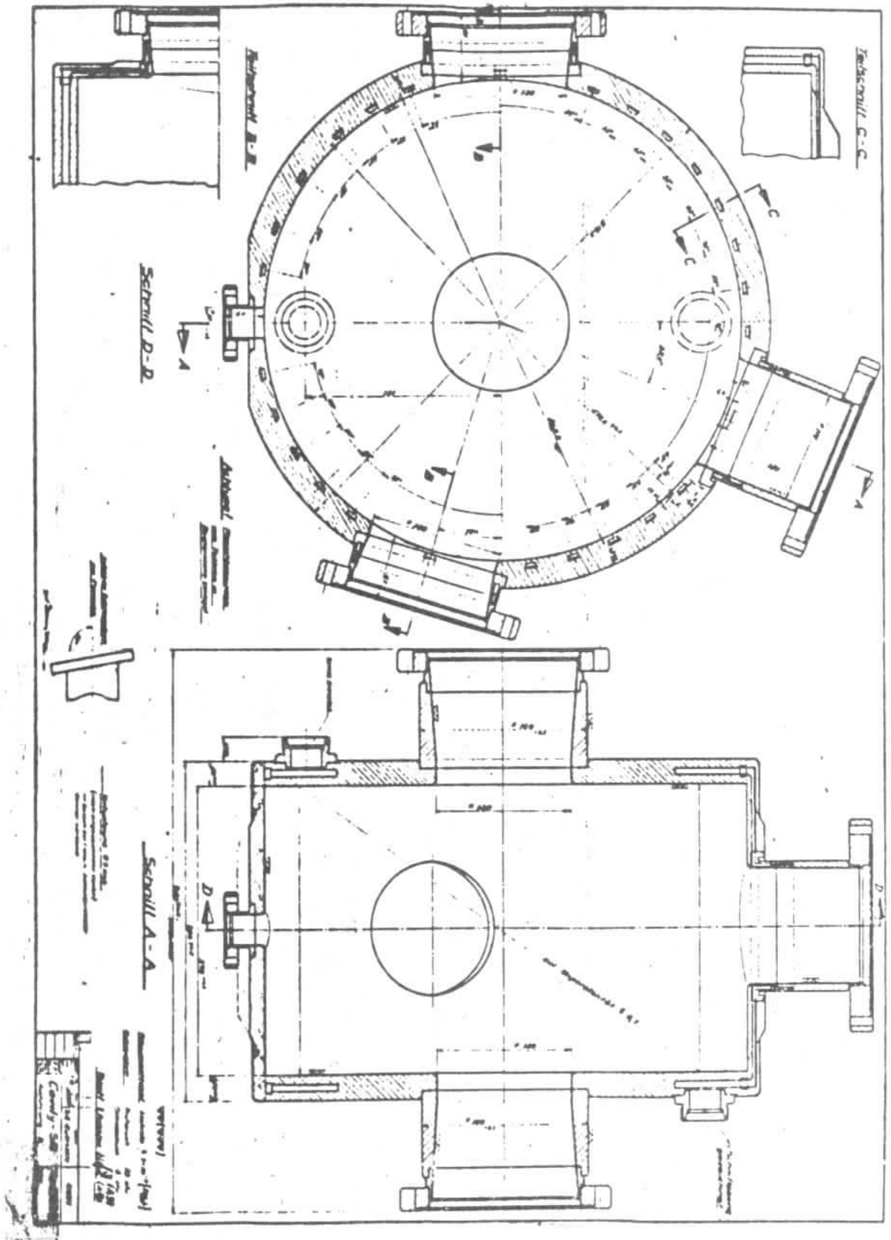


Abb. 1 PETRA Beschleunigungsstruktur



[[illegible] comparison: One of the normal DORIS cavities]

DORIS magnets at higher excitation

type	saturation at	
	4,3 GeV	5 GeV
Main bending magnet DM	1,2 %	7,7 %
Vert. bending magnet VM	3,0 %	9,0 %
large quadrupole near interaction point WQ	8,3 %	- 5 % x)

x) mechanical position changed.

Acceptance requirements at DORIS

Experience at 2 GeV:

Measured beam emittance	ε_x = .17 π mrad mm
6 standard deviations	$36 \cdot \varepsilon_x$ = 6,12 π mrad mm
+ space for injection (7 mm, β=10 m)	A_x = 22 π mrad mm

Beam widening in the tails due to
beam-beam interaction:

increasing lifetime up to	A_x = 40 π mrad mm

Scaling to 4,3 GeV:

beam emittance	ε_x = .79 π mrad mm
6 standard deviations	$36 \cdot \varepsilon_x$ = 28,3 π mrad mm
+ space for injection (5 mm, β=10 m)	A_x = 48 π mrad mm

Measured acceptance in DORIS at 2,2 GeV A_x = 65 π mrad mm.

Expected properties of the single bunch mode

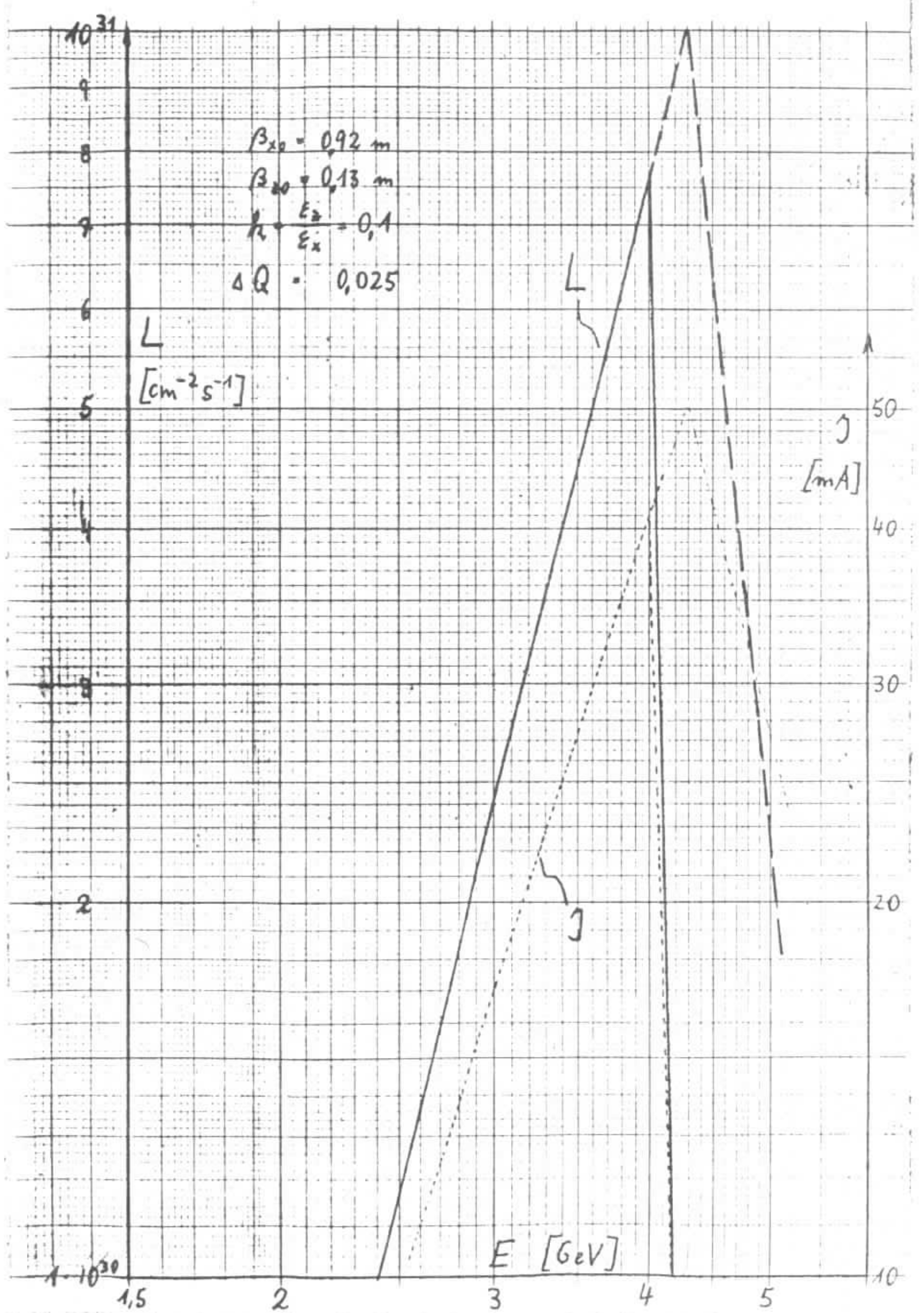
luminosity up to $7 \cdot 10^{30}$ $cm^{-2}s^{-1}$ at 2 x 4 GeV

synchrotron radiation much smaller

same vacuum conditions as before

longer injection time for e^+ : up to 20 min
(2 mA/min)

strong polarisation of the stored beams ?



Luminosity and current per beam in the single ring - single bunch mode.

Synchrotron radiation into the interaction region

		last bending point	
		double ring	single ring
distance from interaction point		3,2 m	8,0 m
bending radius		~ 16 m	60,8 m
λ_c	at 2,0 GeV	11,2 Å	42,5 Å
	3,0 GeV	3,3 Å	12,6 Å
	4,0 GeV	1,4 Å	5,3 Å
	5,0 GeV	0,7 Å	2,7 Å

Arrangements for 2 x 5 GeV

1.) 4 additional fivecell PETRA cavities with 2 x 250 kW rf-power

2.) Large quadrupoles near interaction point have to be shifted by 1 m.

Expected operation schedule of DORIS

Dec. 77	start of experiments, - 300^h / month available for HEP
spring 78	3 week shut down + 4 week test for 2 x 5 GeV extension
	after that: - 300^h / month for HEP
Oct. 78	short interruptions for PETRA-injection
spring 79	PIA comes in operation, 400^h / month available for HEP

Additional informations:

Power consumption of DORIS at 5 GeV : 17 MW
Power costs during the summer months : DM 1000,-/h
Shut down time to rebuild DORIS for double ring operation : 3 weeks

B

PHYSICS PRIORITIES AT DORIS

1. IDENTIFY 2ND GENERATION GOALS
   - USE CURRENT THEORY, "REALISTIC" MODELS AS TOOLS

2. ESTABLISHED ISSUES

TALK IS ON POINT 1

B

*** PHYSICS AT LEVEL

$\sigma \cdot \int \mathcal{L} dt \cdot$ EFFICIENCY

$\sim 10^2 \times$ PRESENT DATA

PRIORITIES

ISSUES	PARADIGM	TOPIC
WEAK INTERACTIONS	GAUGE (Q.A.D) THEORIES + QUARKS	τ { $e\mu$ UNIVERSALITY, RARE DECAYS } D { θ_c^2 ISM, $D^0\bar{D}^0$ MIXING, NONLEPTONIC }
STRONG INTERACTIONS	GAUGE (QCD) THEORIES + QUARKS	NONSCALING JETS GLUE SPECTROSCOPY
EM INTERACTIONS	QUARKS, OLD IDEAS	$\gamma\gamma$ { $\eta' \to \gamma\gamma$, $f^0 \to \gamma\gamma$, $\sigma_{\gamma\gamma}$ }

1. τ: $\to e\gamma, \mu\gamma$ + $e\mu$ UNIVERSALITY
2. D: $\to e\nu\pi, \pi\pi$ + $D^0 \bar{D}^0$ MIXING
3. QCD: $\Upsilon \to$ 3 JETS, $\sigma_{TOT}(e^+e^-)$
4. SPECTROSCOPY: $c\bar{c}$, MOLECULES, $c\bar{q}$ ATOM
5. $\gamma\gamma$: $\to \eta'$, $\to f^0$ $E_{CM} < 2$ GEV

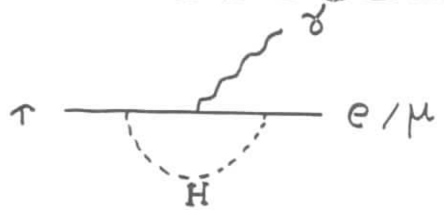
1. "NEW" MACHINE + 2. NEW DETECTOR ...... 5. OLD MACHINE BONANZA

1. $\tau \to e\gamma, \mu\gamma$

$\mu \to e\gamma$ NATURALLY SUPPRESSED IN GAUGE THEORIES, BR $< 10^{-9}$

ONE LOOP HIGGS ESTIMATE

BJ + WEINBERG $\mu \to \tau$



MANY HIGGS / SCALES AS M_{LEPTON}^4

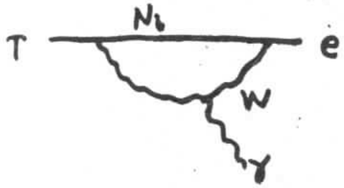
$$\frac{\Gamma(\tau \to e\gamma/\mu\gamma)}{\Gamma(\tau)} \sim \frac{12}{N_F}\,\frac{\alpha}{\pi}\left(\frac{M_\tau}{M_H}\right)^4 < 3\times10^{-4}$$

FOR TYPICAL HIGGS $M_H > 5$ GEV

[DEPENDS ON # HIGGS, COUPLING PATTERNS: CONNECTION OF $\mu \to e\gamma$ AND $\tau \to e\gamma/\mu\gamma$ NOT CLEAR]

ONE LOOP W ESTIMATE

CHENG-LI
$\mu \to \tau$



$$N_e = N_1 \cos\phi + N_2 \sin\phi$$
$$N_\tau = N_2 \cos\phi - N_1 \sin\phi$$
$$N_\mu = N_3$$

$$\frac{\Gamma(\tau \to e\gamma)}{\Gamma(\tau)} = \frac{75}{128 N_F} \frac{\alpha}{\pi} \sin^2 2\phi \left(\frac{M_{N_\tau}}{M_W}\right)^4 < 3\times10^{-4}$$

[IF $M_{N_e} \ll M_{N_\tau} < M_W$]

ANOTHER τ NO. VIOLATING DECAY

$\tau^- \to e^- e^+ e^- \;/\; e^- \mu^+ \mu^- \;/\; e^- \pi^+ \pi^-$

$\to \mu^-$ " μ^- " μ^- "

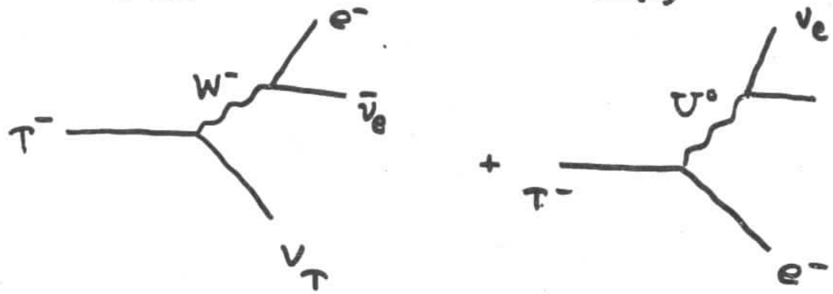
	$e\gamma + \mu\gamma$		$e\mu\mu$ + 2CH
SLAC/LBL	< 4%	<	<.6%
PLUTO	< 12%	<	1%

ACTIVITY IN NEXT FACTOR 10^{-2} ?

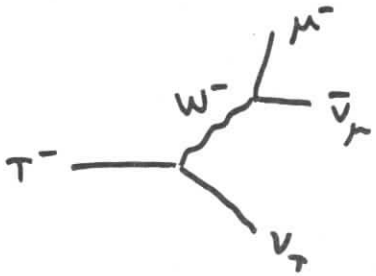
$\tau \to \mu\nu\nu,\ e\nu\nu$

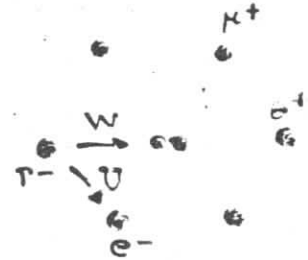
BIG GAUGE GROUPS : $\underbrace{W^\pm, W_3, B, V^\pm, U^0, \overline{U^0}}_{SU(3)}$

EXAMPLE:



$\tau \to e\nu\nu$





$\tau \to \mu\nu\nu$

$$\frac{\Gamma(\tau \to e\nu\nu) - \Gamma(\tau \to \mu\nu\nu)}{\Gamma(\tau \to \mu\nu\nu)} = O\left(\frac{M_W^4}{M_V^4}\right)$$

IF $\nu' \neq \nu_e$

2. $D \to e\nu\pi$, $\pi\pi$

[illegible]

$$\begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} c \\ s \end{pmatrix}_L \begin{pmatrix} t \\ b \end{pmatrix}_L ; \begin{pmatrix} \nu_e \\ e \end{pmatrix}_L \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}_L$$

CURRENT:

$$J^{CH} = (\bar{u} \ \bar{c}' \ \bar{t}') \begin{pmatrix} \cos\chi & 0 & \sin\chi \\ 0 & e^{i\delta} & 0 \\ -\sin\chi & 0 & \cos\chi \end{pmatrix} \begin{pmatrix} d' \\ s' \\ b' \end{pmatrix}$$

$$\begin{pmatrix} Q_1' \\ Q_2' \end{pmatrix} = \begin{pmatrix} \cos\xi & \sin\xi \\ -\sin\xi & \cos\xi \end{pmatrix} \begin{pmatrix} Q_1 \\ Q_2 \end{pmatrix}$$

$\theta, \phi \ \chi \ \oplus$

δ: CP VIOLATING PHASE

$$\left| \frac{c \to d}{c \to s} \right|^2 \text{FACTOR} = \tan^2\theta_c F = \tan^2\theta_c \left| \frac{1 - e^{-i\delta} t_\phi c_\theta s_\chi}{1 + e^{-i\delta} t_\phi t_\theta s_\chi} \right|$$

IGNORE δ ($1 \to c$)

$$\boxed{F \approx |1 - .5 \tan\phi|^2}$$

INPUT: $\theta = \theta_c = .23$; $\lesssim .1$ FROM ... UNIVERSALITY

RESULTS:

(i) $$\frac{\Gamma(D^0 \to e^+\nu\pi^-)}{\Gamma(D^0 \to e^+\nu K^-)} = [\text{KIN. FACTOR}] \tan^2\theta_c F$$

(ii) $$\frac{\Gamma(D^0 \to \pi^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)} = [\text{KIN FACTOR}] \tan^2\theta_c F$$

(iii) $$\frac{\Gamma(D^+ \to \pi^+\pi^0)}{\Gamma(D^+ \to \bar{K}^0\pi^+)} = [\text{KIN. FACTOR}] \tfrac{1}{2} \tan^2\theta_c F$$

⋮

F POORLY KNOWN: DIMUONS $\nu_\mu d \to c\mu^-$ ($\hookrightarrow \mu^+$ vs) ARE $\propto \cos^2\phi \sin^2\theta_c$

$$\Rightarrow \cos^2\phi \gtrsim \tfrac{1}{2} - \tfrac{3}{4}$$

F COULD BE ½ → 2 IN THIS MODEL

$D^0 - \bar{D}^0$ MIXING

GIM MODEL

$\propto (m_s - m_d)^2 \theta_c^2$

KM MODEL HAS ADDITIONAL TERM

$\propto \; m_b^2 \sin^2\chi \sin^2\phi + \dots$

$\sin\chi \approx \chi \lesssim .1$

ESTIMATE RATIO KM/GIM:

$$OM \sim \left(\frac{m_b}{m_s - m_d}\right)^2 \left(\frac{\chi}{\theta_c}\right)^2 \sin^2\phi$$

$\left(\frac{m_b}{m_s - m_d}\right)^2 \gtrsim 10^2$; $\left(\frac{\chi}{\theta_c}\right)^2 \lesssim \frac{1}{4}$; $\sin^2\phi \lesssim \frac{1}{2} - \frac{1}{4}$

AMPLITUDE COULD BE ~ 10 * GIM [illegible]

MEASURE:
$$\frac{\sigma(e^+e^- \to \psi(3770) \to D^0\bar{D}^0 \to e^\pm e^\pm + \dots)}{\sigma(e^+e^- \to \psi(3770) \to D^0\bar{D}^0 \to e^+e^- + \dots)}$$

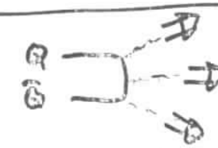
NOTE:
$$\frac{N(e^+e^+) - N(e^-e^-)}{N(e^+e^+) + N(e^-e^-)} \neq 0$$

IS SIGNAL FOR CP VIOLATION
ACTIVITY IN NEXT FACTOR 10^{-2}? $(\sim \theta_c^2)$

K. KOLLER + TUS

3. $\Upsilon(9.5) \to$ 3 GLUONS $\to$ 3 JETS

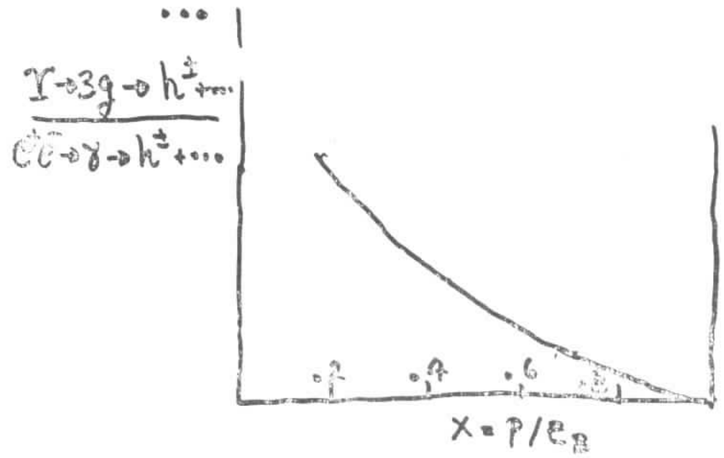
QCD:



$\Upsilon \to e\bar{e} + \mu\bar{\mu}$	:	$\Upsilon \to \gamma \to$ 2 JETS	:	$\Upsilon \to 3g \to$ 3 JETS
2	:	5	:	5 ($e_Q = 2/3$); 20 ($e_Q = -1/3$)
$N^{CH} = 2$	:	$\bar{N}^{CH} \simeq 5$	:	$\bar{N}^{CH} \simeq 10$

CALORIMETRY / FIT PLANE (EXCLUDE 2 JET) / FIND $N_{HAD}^{EG.} = 7$

...



CROSS SECTION $\Upsilon \to g_1(\vec{k}_1)\, g_2(\vec{k}_2)\, g_3(\vec{k}_3)$

$\vec{k}_i = \vec{P}_{JET,i} \qquad |\vec{k}_i| / (E_\Upsilon/2) = x_i$

$$\frac{d\sigma}{dx_1 dx_2 d^3R} = \frac{\text{CONST}}{x_1^2 x_2^2 x_3^2} W(\vec{x}_1, \vec{x}_2, \vec{x}_3)$$

ORE-POWELL 1948

$$W = 4\Big\{\big[x_1^2(1-x_1)^2 + x_2^2(1-x_2)^2 + x_3^2(1-x_3)^2\big]\Big\}$$
$$+ 2S(x_1-1)(x_2-1)(x_3-1)\big[x_1^2+x_2^2+x_3^2\big]$$
$$+ \sum_{i=1}^{3} S_{ii} F_i(x_1, x_2 x_3) + \sum_{i<j=1}^{3} S_{ij} F_{ij}(x_1 x_2 x_3)$$

$$F_3 = 2(x_1^2+x_2^2) + 4(x_1^2 x_2 + x_1 x_2^2) + x_1^2 x_2^2 - 6x_1 x_2$$

$$F_{12} = 2(x_1+x_2)(x_3+x_3^2) + x_1 x_2 (4 - 8x_3 - x_3^2)$$

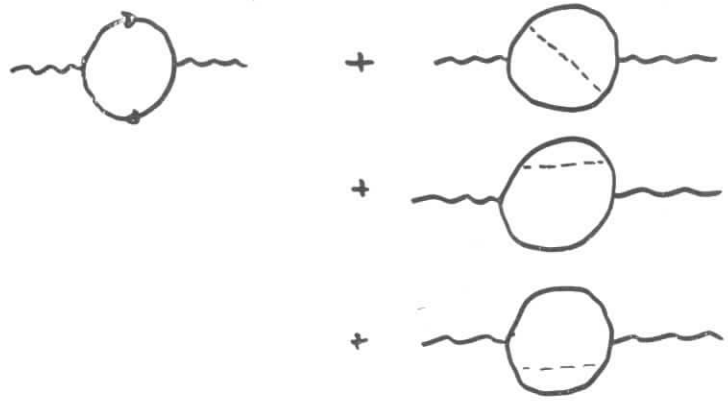
$$S_{ij} = k_i^\mu S_{\mu\nu} k_j^\nu \qquad S_{\mu\nu} = \tfrac{1}{2}(s^+_\mu s^-_\nu + s^-_\mu s^+_\nu)$$

$s^\pm_\mu$ = Q / Q̄ SPIN VECTOR

$$S_{\mu\nu} = \begin{pmatrix} -\frac{1-P^2}{2} & 0 & 0 & 0 \\ 0 & -\frac{1+P^2}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$ FOR TRANS POL. BEAM

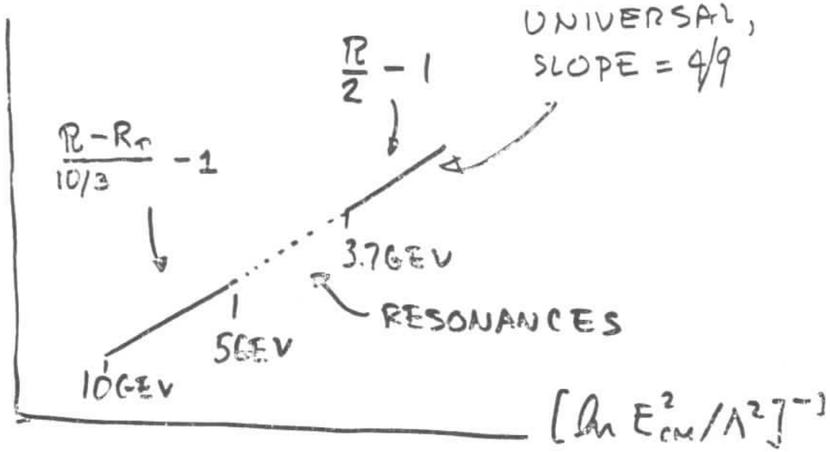
$\sigma_{TOT}(e^+e^-)$

"PARTON" TERM　　　　QCD RADIATIVE CORRECTIONS



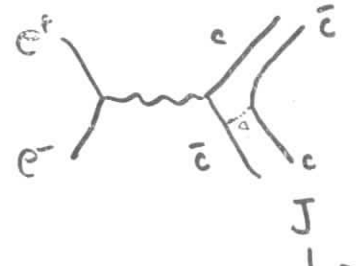
CAN BE CUT + $\Delta\sigma$ POSITIVE

$N_{COLOR} \sum_i e_i^2 \qquad N_{COLOR} \sum e_i^2 \dfrac{4}{9 \ln E_{cm}^2/\Lambda^2}$



MORE SOPHISTICATED: DISPERSION METHODS

4. $e^+e^- \to J$ + [C = + CHARMONIUM], "MOLECULES"

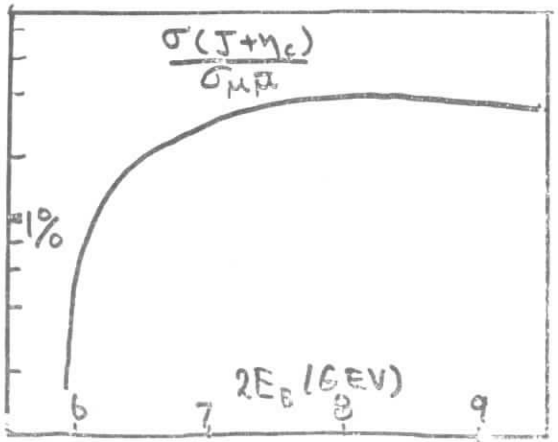


C = + $c\bar{c}$: X(2.8)? η_c(3.0)?
X(3.45)?? ...

SEE STATES IN MISSING MASS

CRUDE MODEL 

VDM



MOLECULAR STATES

3.88 $J^P I^G = 1^+ 1^-$

$c\bar{q}\,qc$ [illegible]

→ MUCH STRUCTURE IN σ_{TOT} $\sigma(D\bar{D})$, [illegible]

DeRújula + Jaffe : ψ 4.03 A MOLECULE

→ 3.88 MOLECULE + π

1% BR

MOLECULE → $D^*\bar{D}$

OTHER MOLECULES → J + η, ETC

[illegible]

[illegible]

[illegible]

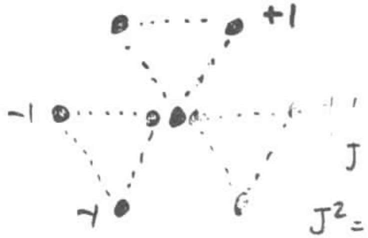
5. $\gamma\gamma \to \eta'$, $\gamma\gamma \to f^0$

$\eta' \to \gamma\gamma$: QUARK CHARGES

GMZ

HAN-NAMBU PATI-SALAM

$\langle \eta | Q^2 | 0 \rangle$



$J = \underset{\sim}{8} + \underset{\sim}{8}^c$

$J^2 = \underset{\sim}{8} \times \underset{\sim}{8} + \cdots + \underset{\sim}{8}^c \times \underset{\sim}{8}^c$ (1)

$A(\pi^0 \to \gamma\gamma) = \frac{1}{\sqrt{6}}$ ⟷ $A(\pi^0 \to \gamma\gamma) = \frac{1}{\sqrt{6}}$

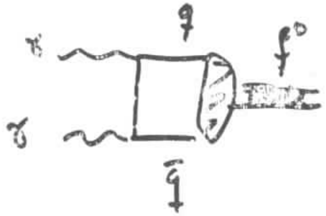
$A(\eta_8 \to \gamma\gamma) = \frac{1}{\sqrt{6}}\,\frac{1}{\sqrt{3}}$ ⟷ $A(\eta_8 \to \gamma\gamma) = \frac{1}{\sqrt{3}}\,\frac{1}{\sqrt{3}}$

$A(\eta_1' \to \gamma\gamma) = \frac{1}{\sqrt{6}}\,(2)\sqrt{2}$ ⟷ $A(\eta_1' \to \gamma\gamma) = \frac{1}{\sqrt{6}}\,(4)\sqrt{2}$

$\Gamma(\eta' \to \gamma\gamma) \cong 6$ KEV $\Gamma(\eta' \to \gamma\gamma) \cong 24$ KEV

TESTS FUNDAMENTAL CHARGE STRUCTURE

$f^0 \to \gamma\gamma$: SPIN STRUCTURE



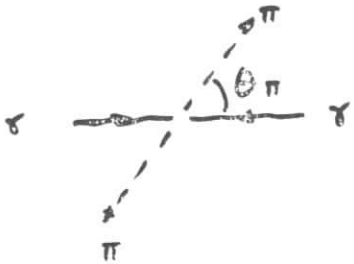
$\Gamma(f \to \gamma\gamma) \cong 5\text{-}8$ KEV

$\gamma\gamma \to q\bar{q}$ TAKES PLACE FROM $J_z = \pm 2$

TEST THIS VIA

$$\gamma\gamma \to f^0 \to \pi^+\pi^-$$

$$\frac{d\sigma}{d\Omega_\pi} \propto |Y_2^{\pm 2}|^2 \propto (1 - \cos^2\theta_\pi)^2$$



PEAKED TOWARD 90°

BASIC ISSUES

C 1

EXPERIMENTS AT DASP
IN THE $\Upsilon(9.4)$ - REGION

NEW DASP GROUP:

- C. W. DARDEN
- H. HASEMANN
- W. SCHMIDT-PARZEFALL
- H. SCHRÖDER
- H. D. SCHULZ
- F. SELONKE

+ HARDWARE SUPPORT BY F51 (8)
+ SOFTWARE SUPPORT BY R2 (6)

C2

CHARMONIUM SPECTROSCOPY

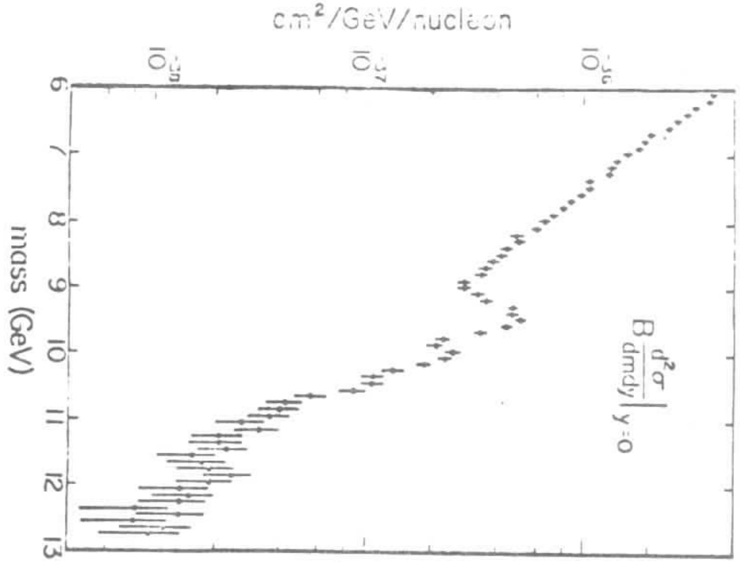
CHARMED MESON & BARYONS

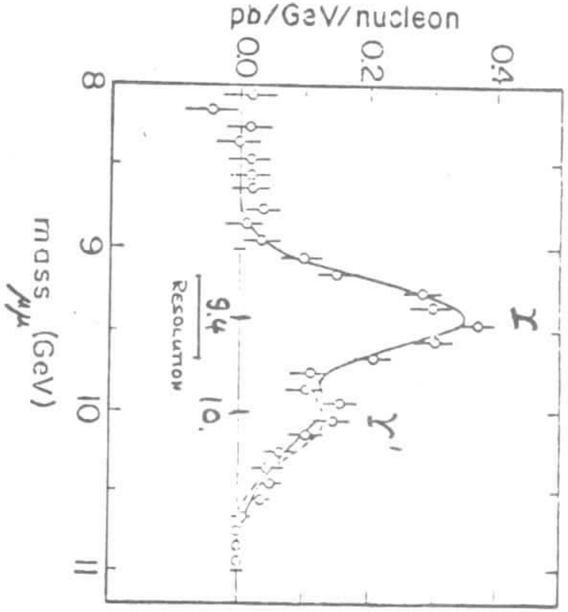
TOTAL CROSS SECTION, R

INCLUSIVE PARTICLE PRODUCTION

HEAVY LEPTON DECAYS

⋮



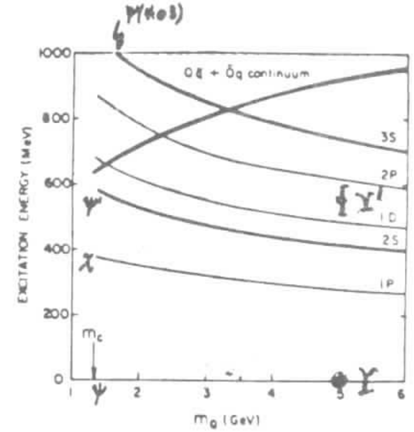


LEDERMANN:

$p\,(400\text{ GeV}) + \text{Nucleus} \to \mu^+\mu^- + X$

⇒ Υ's SHOULD BE NARROW
SHOULD BE SEEN IN e^+e^-

$$V(r) = -\frac{4}{3}\alpha_s \frac{1}{r} + \frac{r}{a^2}$$



EICHTEN & GOTTFRIED

MASS SPLITTING $\Delta M = M_\Upsilon - M_{\Upsilon'}$

EXPERIMENT : $\Delta M = 590 \pm 50$ MeV
$\approx M_\psi - M_{\psi'}$?

THEORY : $\Delta M = 420$ MeV

QUESTIONS: WHAT POTENTIAL,
NATURE OF QUARK CONFINEMENT?
$\alpha_s = ?$

CROSS SECTION FOR $e^+e^- \to \Upsilon \to$ hadrons:

ASSUME: Υ IS A VECTOR MESON LIKE THE ψ

Υ IS NARROW ($\Gamma_{had} \ll \Delta E \sim 14$ MeV)

$\Gamma_{had} \approx \Gamma$

$$\Rightarrow \sigma_{Peak} = \frac{12\pi}{M^2} \frac{\Gamma_{ee}}{\Delta E}$$

RADIATIVE CORRECTIONS ARE ABOUT THE SAME FOR Υ AND ψ.

$$\Rightarrow \sigma^{\Upsilon}_{Peak} = \underbrace{\sigma^{\psi}_{Peak}}_{3000 nb} \cdot \frac{\Delta E_\psi}{\Delta E_\Upsilon} \cdot \left(\frac{M_\psi}{M_\Upsilon}\right)^2 \cdot \frac{\Gamma^{\Upsilon}_{ee}}{\Gamma^{\psi}_{ee}}$$

3000 nb · .1 · .1

$\Gamma_{ee} \sim Q^2$

PREDICTIONS FOR $Q = -1/3$

Γ^{Υ}_{ee}	= .7 keV	EICHTEN & GOTTFRIED
	= 1.2 keV	WALSH
	= .7 keV	QUIGG & ROSNER
	= 1.9 keV	" "
	= 1.5 keV	FNOSUZ

TAKE $\Gamma^{\Upsilon}_{ee} = 1.3$ keV

$\Rightarrow \sigma^{\Upsilon}_{Peak} = 8 nb \quad Q = -1/3$

$\sigma^{\Upsilon}_{Peak} = 32 nb \quad Q = 2/3$

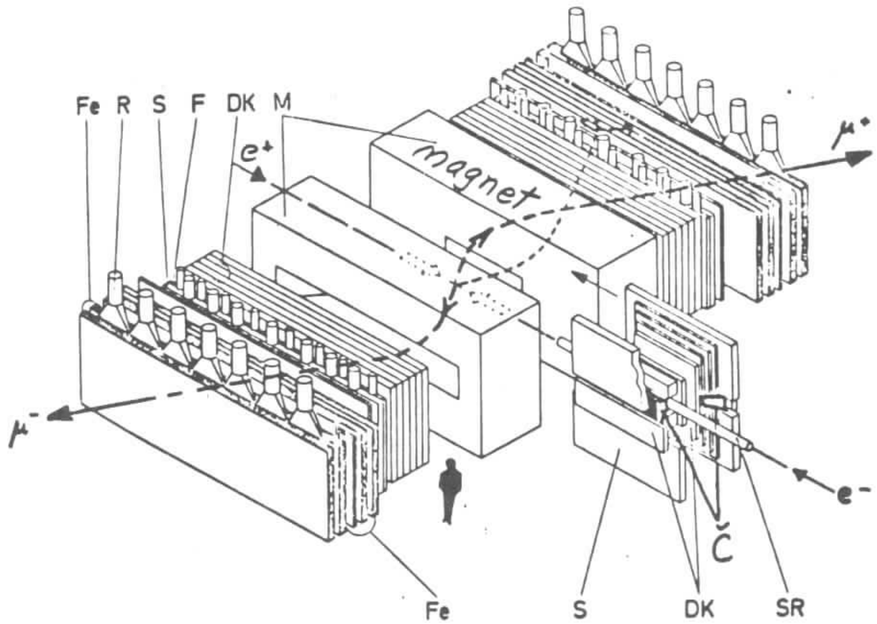
$\sigma_{Background} = R \cdot \sigma_{\mu\mu} = 5 nb$

Υ' $\quad \Gamma^{\Upsilon'}_{ee} \approx 1/3\, \Gamma^{\Upsilon}_{ee}$

$\Rightarrow \sigma^{\Upsilon'}_{Peak} = 3 nb \quad Q = -1/3$

$\sigma^{\Upsilon'}_{Peak} = 11 nb \quad Q = 2/3$

DASP



SPECTROMETER

$\Delta\Omega = 7\%$ OF 4π

e, μ, π, k, p IDENTIFICATION

$\varepsilon_{HADRONS}$ AT $E_{cm} = 9.5$ GeV:

$\langle n_{ch} \rangle \sim 5$

$\langle p_{mean} \rangle \sim .8$ GeV/c

P-CUT-OFF ~ .2 GeV FOR 4 kGM

$\Rightarrow \varepsilon_{HAD} \sim 25\%$

$\varepsilon_{\mu\mu} \sim 3\%$

INNER DETECTOR

(NON MAGNETIC)

$\Delta\Omega = 70\%$ OF 4π

C7

BACKGROUND CONDITIONS

- COSMIC BACKGROUND REDUCED BY BUNCH GATE
- LESS SYNCHROTRON RADIATION
- LESS BEAM-GAS-INTERACTIONS

HOWEVER, AT HIGHER ENERGIES AGAIN MORE SYNCHROTRON RADIATION

C8

COUNTING RATES

YIELD = $\mathcal{L} \times \sigma \times \varepsilon$

$\mathcal{L} \approx 220\,nb^{-1}$/DAY ($\hat{=}$ 50% OF TOP LUMINOS. AT $E_{cm} = 9.4\,GeV$)

$\varepsilon_h \approx 25\%$ FOR HADRONS IN THE SPECTRO

$\varepsilon_\mu \approx 3\%$ FOR μ-PAIRS — " —

EVENTS / DAY IN THE Υ-RESONANCE:

	σ(nb)	TOTAL RATE	RATE IN THE SPECTRO	
$e^+e^- \to$ HADRONS	5	1100	280	
$e^+e^- \to \Upsilon \to$ HADRONS	8	1800	450	$Q = -1/3$
"	32	7000	1750	$Q = 2/3$

EVENT RATE FOR A 10 DAYS SCAN OVER THE RESONANCE (SPECTROMETER)

	$Q = -1/3$	$Q = 2/3$	
$e^+e^- \to$ HADRONS	2800	2800	
$e^+e^- \to \Upsilon \to$ HADRONS	2250	8750	
⟹ $e^+e^- \to \mu\mu$ ($\sigma \sim 1\,nb$)	70	70	
$e^+e^- \to \Upsilon \to \mu\mu$	10	90	!
BR($\Upsilon \to \mu\mu$)	3.7%	8.2%	[illegible]

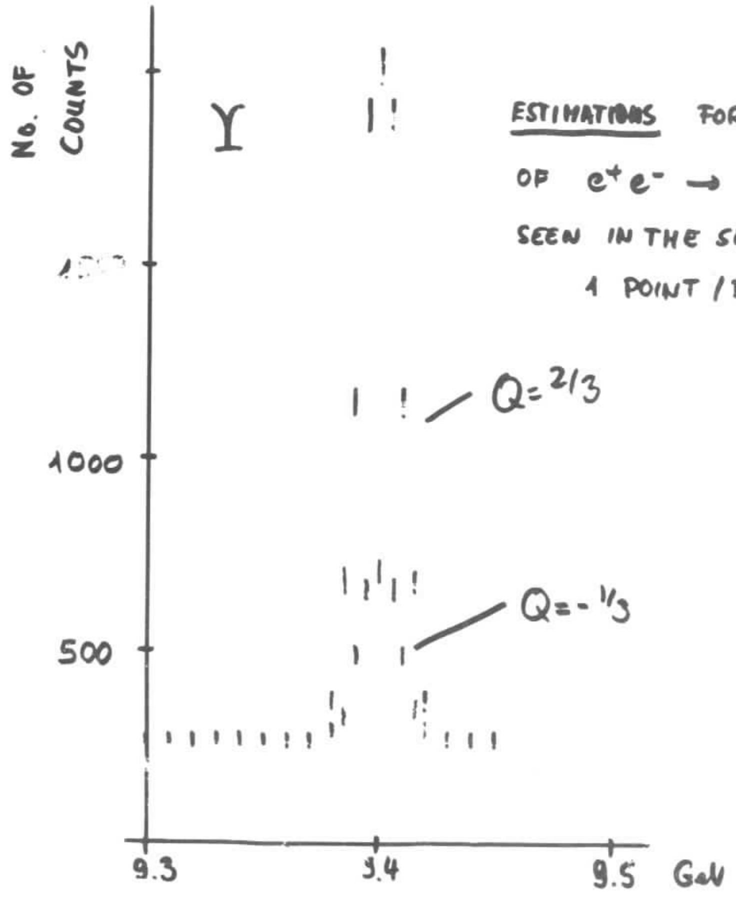
$$BR_{\mu\mu} = \frac{Q^2}{\frac{10(\pi^2-9)\alpha_s^3}{81\pi\alpha^2} + (R+2)\,Q^2} \Rightarrow \left.\begin{matrix} Q \\ \alpha_s \\ \Gamma \end{matrix}\right\}$$

FOR Υ'(10 GeV): $\mathcal{L} \sim 100\,nb^{-1}$/DAY

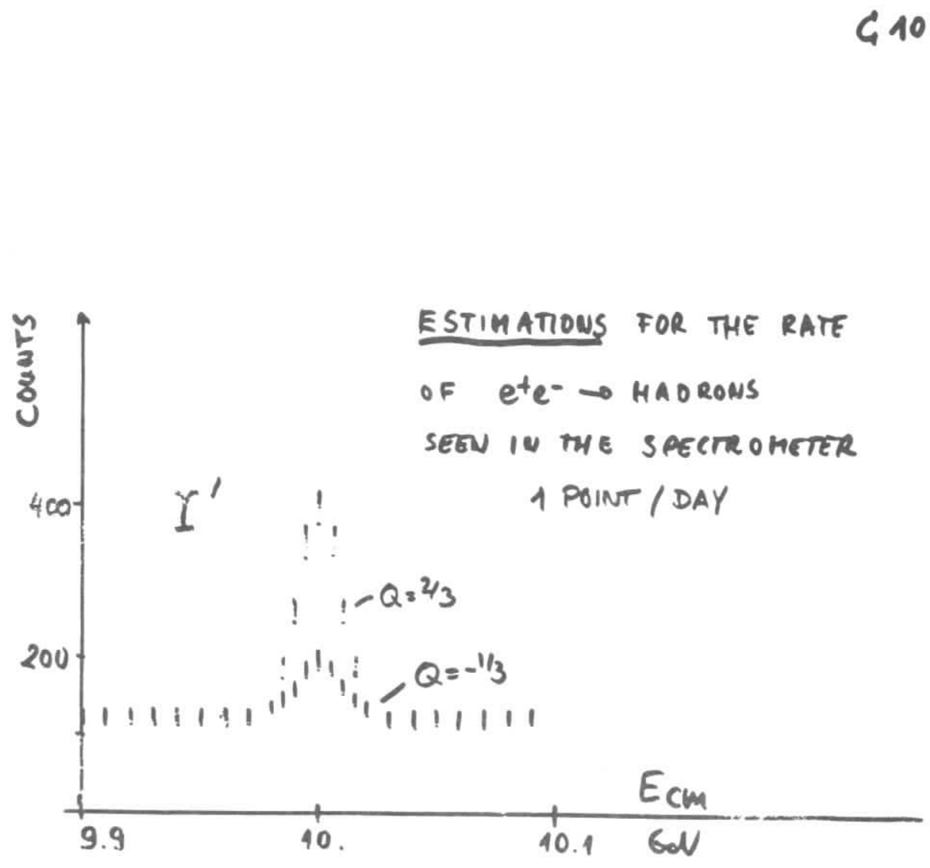
⇒ EVENTS PER DAY

	σ(nb)	TOTAL RATE	SPECTRO-RATE	
$e^+e^- \to$ HADRONS	5	500	125	
$e^+e^- \to \Upsilon' \to$ HADRONS	3	300	75	[illegible]
"	11	1100	275	Q = [illegible]

⇒ STILL FEASIBLE



C9
No. OF COUNTS
Υ
ESTIMATIONS FOR THE RATE
OF e+e- → HADRONS
SEEN IN THE SPECTROMETER
1 POINT / DAY
Q=2/3
Q=-1/3
1000
500
9.3
9.4
9.5 GeV



C 10
COUNTS
ESTIMATIONS FOR THE RATE
OF e+e- → HADRONS
SEEN IN THE SPECTROMETER
1 POINT / DAY
Υ'
400
Q=2/3
200
Q=-1/3
Ecm
9.9
40.
10.1
GeV

C 11

CONCLUSIONS

* UPSILON'S ARE DETECTABLE AT DASP (FOR Υ ~ 2 WEEKS)
* BR ($\Upsilon \to \mu\mu$) WILL GIVE US INFORMATION ON Q_h, $\Gamma(\Upsilon)$.
* OTHER DECAYS OF Υ ?
* A CAREFUL SCAN OF THE e^+e^- - CROSS SECTION COULD REVEAL MORE STRUCTURES BETWEEN 9 AND 10 GeV (2 - 3 MONTH ≙ 10 - 15000 nb^{-1} = K)
* HEAVY LEPTON (~500) AND THEIR DECAYS
* INCLUSIVE SPECTRA

  ⋮

* ???

D

Meeting on Doris Experiments

PROPOSAL OF THE PLUTO - COLLABORATION TO SCAN THE UPSILON - REGION

10 / 10 / 77

J. Bürger

Proposal of the PLUTO - Collaboration to scan the Υ - energy - region

- PLUTO has been aproved to be the first running detector at PETRA. PLUTO will move to PETRA at May 78.
- Whatever happens at DORIS, PLUTO will move to PETRA.

⇒ The future of DORIS is not the future of PLUTO

Why does PLUTO propose a measurement in the Υ - region in spite of the above mentioned constraints?

⇒ cf. PLUTO - Proposal (# 144)

printed version was completed before the Υ - resonances:

- At utmost high energies ($\sqrt{s} = 8.6$ GeV)
- testing the full detektor & software (which will go to PETRA)
- measuring R, τ - physics and probably new resonances.

After the discovery of the Υ, we made an addendum to our proposal:

- If the DORIS - group is able to push the energy up to the Υ-region, we like to measure in this region, although we should have less int. luminosity due to more machine studies.

1^{st} PROPOSAL to measure Υ at DORIS

- Only DORIS must be changed.
- No special requests of PLUTO for a program in the Υ - region.

  ⇒ PLUTO has
  - → experience at DORIS
  - → a well understood detektor
  - → a complete software system (from on-line pgms. to data analysis and physics)
  - → PLUTO is at an interaction-region of DORIS (till May 78)
  - → PLUTO's preparation for PETRA are not influenced

- If there is a <u>general interest</u> to measure the Υ - energy - region in e^+e^- - annihilation <u>as soon as possible</u>, DORIS should reach the Υ region in the early 78 and <u>PLUTO will do the job!</u>

What can one expect ?

1. Status of PLUTO's equipment in the early '78 (→ fig)

⇒ detection of charged tracks within 85% * 4π

⇒ Photon detection in 95% * 4π

⇒ Myon detection in ~ 60% * 4π (p_μ > 1 GeV)

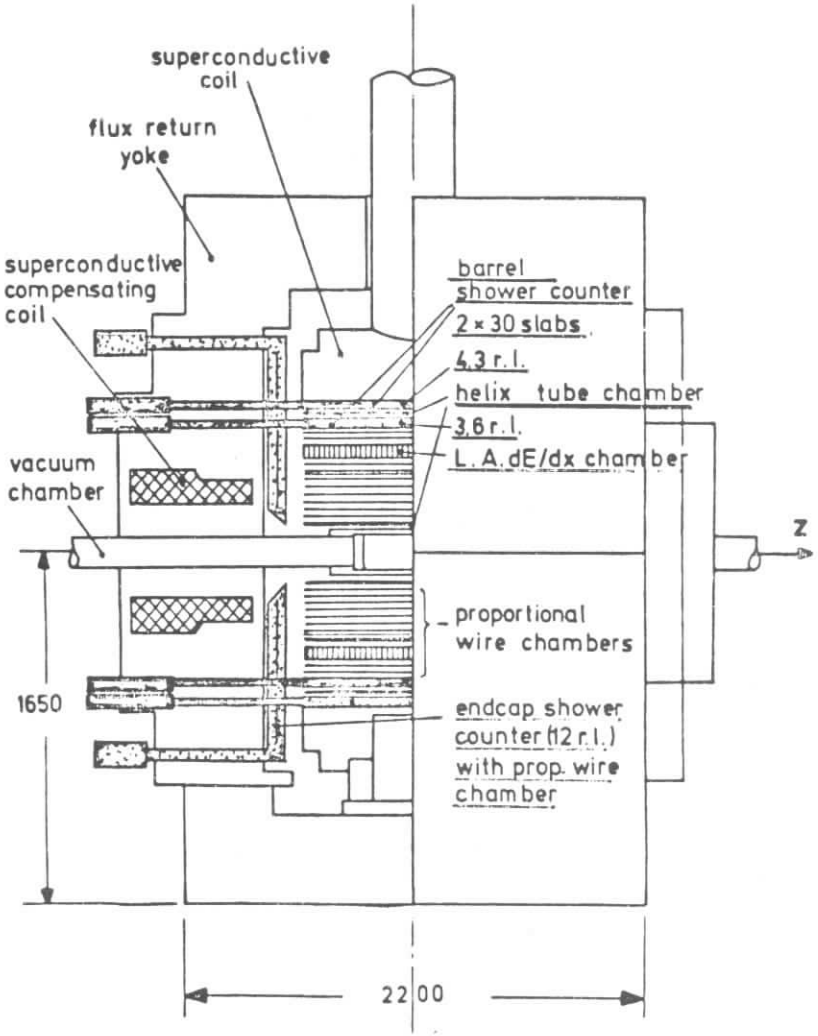
⇒ e, μ, hadron separation

PLUTO is a reasonable detector for measuring

→ σ_{tot}

→ leptonic channels

D 4a →D



Cross sectional half view of PLUTO 1977

1. Knowledge on the Υ - family
(ask theorists !)

2 possibilities:

⇒ Υ enhancement is a broad resonance

⇒ Υ enhancement is a family of ≥ 2 small resonances

<u>1st alternative</u> : nobody expects something like this

If Υ also broad in e^+e^-

⇒ No chance to see anything if $\Gamma_{res} \gg \sigma(E_{beam})$

<u>2nd alternative</u> : „Standard" – assumption:

$\Upsilon, \Upsilon', \Upsilon'', \ldots$ are vector mesons like $J/\psi, \psi'$ with new heavier quarks $Q\bar{Q}$.

⇒ a lot of models

„Standard" assumption № 2.:

Add a 3rd quark dublett to the old ones

$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$ top ($q = 2/3$) bottom ($q = 1/3$)

$J_B = (b\bar{b})$
$J_T = (t\bar{t})$

Decay modes of bottomonia and toponia

Mode \ State	J_B	J'_B	J''_B	J_T	J'_T	J''_T
e^+e^-	0.7	0.4+	0.4-	2.7	1.7	1.5
$\mu^+\mu^-$	0.7	0.4+	0.4-	2.7	1.7	1.5
$\tau^+\tau^-$	0.7	0.4+	0.4-	2.7	1.7	1.5
$\gamma^* \to$ hadrons	2.8	1.7	1.5	10.8	6.8	6.0
direct hadrons	13.7	8.8	7.8	13.7	8.8	7.8
$\gamma\chi_{B,T}$	-	8	12.5	-	30	50
$J_{B,T}\pi\pi$	-	$\lesssim$ 0.3	small?	-	$\lesssim$ 0.3	small?
$J'_{B,T}\pi\pi$	-	-	$\lesssim$ 0.1	-	-	$\lesssim$ 0.1
Total	~ 19	~ 20	~ 23	~ 33	~ 51	~ 68
BR $\to \mu^+\mu^-$	3.5%	2.1%	1.6%	8.2%	3.3%	2.2%

Decay widths in keV

Only take the last two lines seriously! -- see text.

(from J. Ellis TH2365 -CERN)

Lederman's data $\quad pp \to \mu^+\mu^- + X$

	M (GeV) (2 res.)	M (GeV) (3 res.)
Υ	9.41 ± 0.02	9.40 ± .02
Υ'	10.06 ± 0.04	9.99 ± .05
Υ''	-	10.41 ± .12

(from Hamburg talk)

$\chi^2 = 18.7/18 \qquad \chi^2 = 12.0/16$

Calculations are made : (Eichten & Gottfried / Appelquist & Politzer) → table

	$(t\bar{t})$	$(b\bar{b})$	
Γ_{ee}	2.7	0.7	keV
Γ_{tot}	33	19	keV
BR($\mu\mu$)	8.2	3.5	%

⇒ Υ is a small resonance $(\sigma(E_{beam}) \gg \Gamma_{res})$

$$\Rightarrow \int_\Upsilon \sigma \, d\sqrt{s} = \begin{cases} \sim 160 \text{ nb keV} & \text{for } (b\bar{b}) \\ \sim 620 \text{ nb keV} & \text{for } (t\bar{t}) \end{cases}$$

Assuming an energy-resolution of ~ 5 MeV per beam

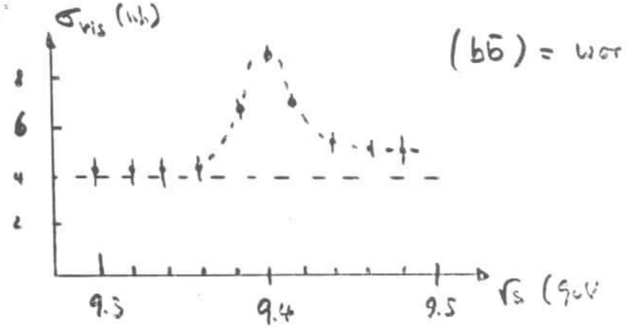
$$\sigma_{\text{peak visible}} = \begin{cases} 9 \text{ nb} & \text{for } (b\bar{b}) \\ 35 \text{ nb} & \text{for } (t\bar{t}) \end{cases} \quad \text{(no rad. correct.)}$$

$\sigma_{tot}(\sqrt{s} = 9.4 \text{ GeV}) \approx 4.3$ nb $\quad (\sigma_{tot} = \sigma(\to \text{hadr.} + \tau\tau))$

To measure the resonance curve with $O(10\%)$ statistical error:

$\Rightarrow$ 10 points of ~ 100 evts. nonresonant
or ~ ≳200 evts resonant

e.g.



$(b\bar{b})$ = worse case

Assume $\langle L \rangle = 0.43 \cdot 10^{+30}\ cm^{-2}\ sek^{-1}$
$= 50\ nb^{-1}/day$

$\Rightarrow$ 2 data-points per day

$\Rightarrow$ Minimal program in <u>5 days</u>

Next step: Measuring $BR(\Upsilon \to e^+e^-, \mu^+\mu^-, \tau^+\tau^-)$

$\sigma_{\mu\mu}(\text{nonres}) \approx 1\ nb$

$\sigma(\Upsilon \to \mu\mu)_{\text{peak vis.}} = \begin{cases} 0.32\ nb & (b\bar{b}) \\ 2.83\ nb & (t\bar{t}) \end{cases}$

BR ± 10% error: 3 * more luminosity

Conclusion

Min. Program (5 days)

- → $\int \sigma\, d\sqrt{s}$ (± 10 %)
- → $M(\Upsilon)$ (Error due to DORIS-energy calibration)
- → decision $(t\bar{t})$ or $(b\bar{b})$

with more integrated luminosity:

- → BR into lepton pairs ($\mu\mu$, $\tau\tau$ (?))
- → Γ_{tot}

→ We can supply some physical parameters of great importance for further theoretical development.

→ Even if no resonance is seen in e^+e^--annihilation this will be a remarkable result.

The higher states Υ', Υ'' and their transitions to the lower Υ-state are beyond the possibilities of DORIS!

Time schedule for PLUTO

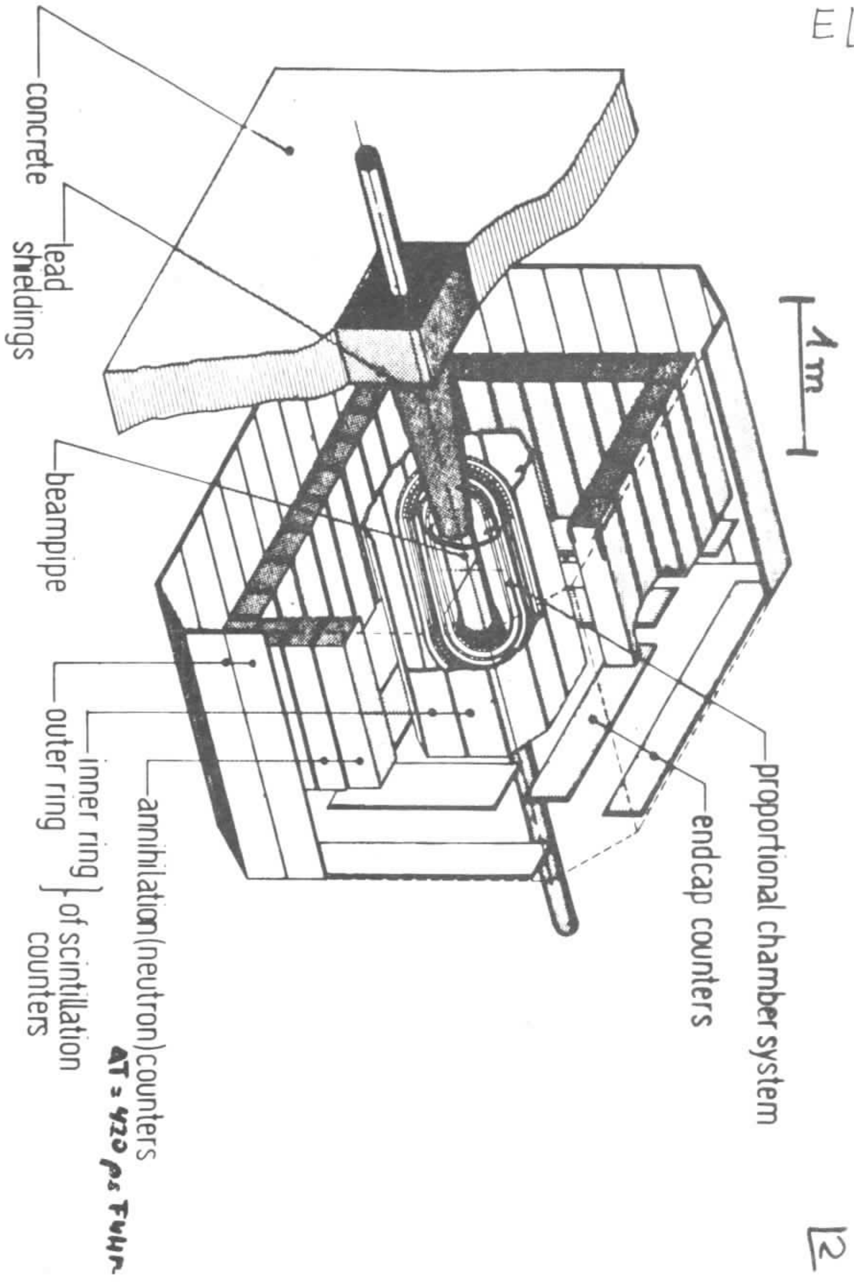
Nov. 77	PLUTO tests
Nov/Dec. 77	PLUTO moves into DORIS interaction region
until Feb. 78	Runperiod
Feb. 78	Shut down to install the PLUTO endcaps
until May 78	Runperiod

- Timeschedule fixed for PETRA purposes
- Completely independent of DORIS energy
- If DORIS goes up to 10 GeV, the necessary shutdown must be matched.

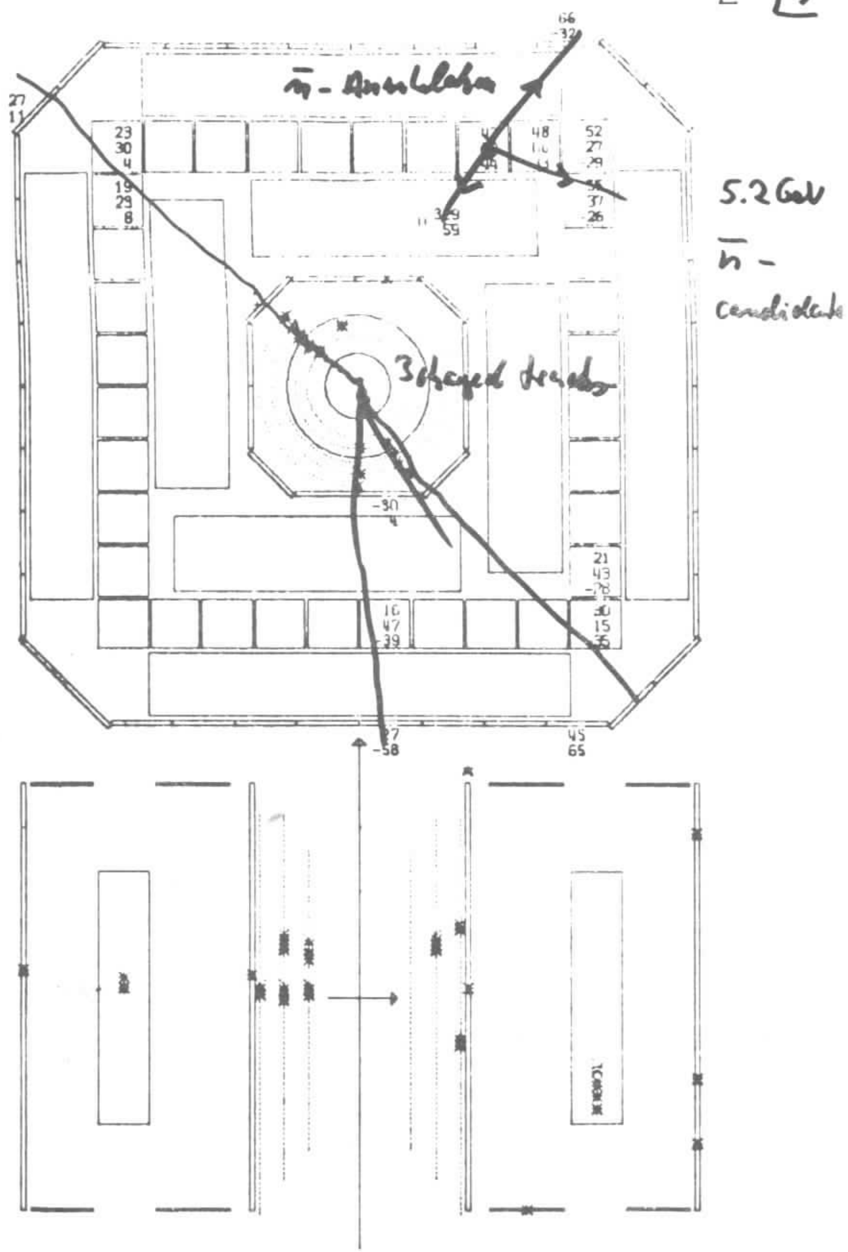
Experimental Possibilities of
BONANZA at DORIS

1. Apparatus
2. Charmed Baryons
3. Proton Form Factor. $B\bar{B}$-Resonances
4. Two Photon Physics

E12


1m
concrete
lead sheldings
beampipe
proportional chamber system
endcap counters
annihilation (neutron) counters
inner ring
outer ring
of scintillation counters
ΔT = 420 ps FWHM
12

E13


5.2 GeV
n̄ - candidate

Charmed Baryon Threshold

$$e^+e^- \to \Lambda_c \bar{\Lambda}_c$$
$$\to \Sigma_c \bar{\Sigma}_c$$
$$\to \Sigma_c \bar{\Sigma}_c^* \quad \text{etc}$$

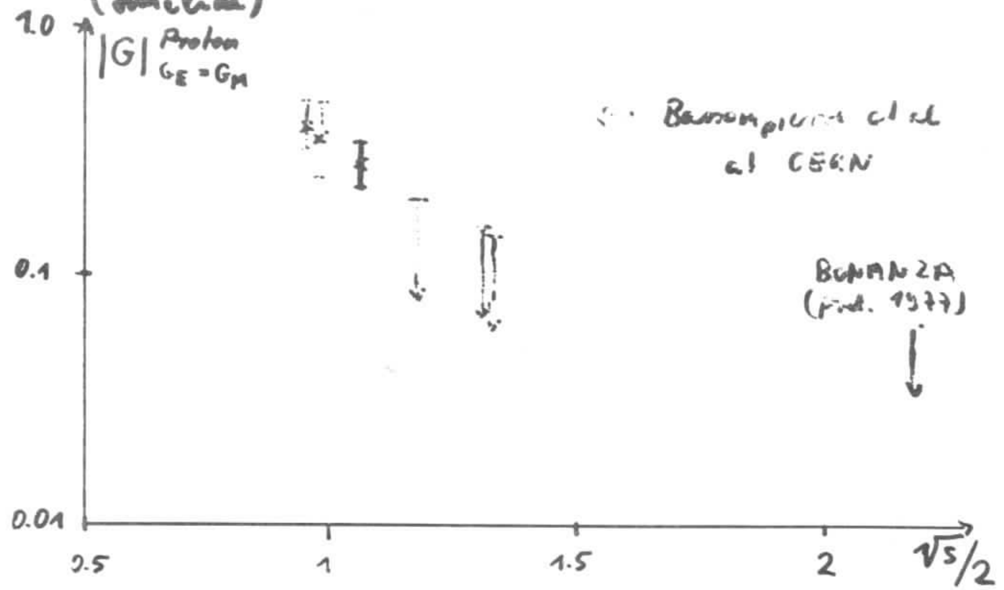
Threshold at ~ $s = 4.5$ GeV should be seen in inclusive $\bar{p}$, $\bar{n}$, (or $\Lambda, \bar{\Lambda}$) - Production.

Spear Data were presented at the Hamburg Conference Aug. 77.

Ours will - hopefully - become available late this year.

We would like to wait for our error bars before discussing a continuation of this Experiment.

Formfactors $e^+e^- \to p\bar{p}$
(timelike)



Expected counting rates:

$\frac{1}{2}\sqrt{s}$	$L \cdot nb \cdot day$	$\varepsilon_{p\bar{p}}$	$\dot{N}_{p\bar{p}} \cdot day$	$\dot{N}_{n\bar{n}} \cdot day$
1	2	0.3?	1.0	0.05
1.1	2.4	0.35	0.6	0.04
1.5	20	0.43	0.09	0.01

Machine improvement? longitudinal damping.

New low lying $p\bar{p}$ - Resonances are not expected to contribute significantly.

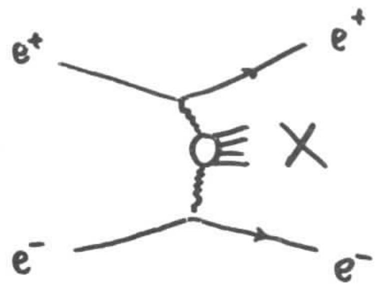
a) Spin

b) Zweig rule

E 7

γγ - Physics with BONANZA.

$e^+e^- \rightarrow e^+e^- X$ $\quad X = e^+e^-$, $\mu^+\mu^-$ QED



$= \eta$ (lifetime without Primakoff)

η' (quark charges)

f

G

$\pi\pi$

(total cross section)

Sharp peaks at very small angles ($\ll 1$ mrad)

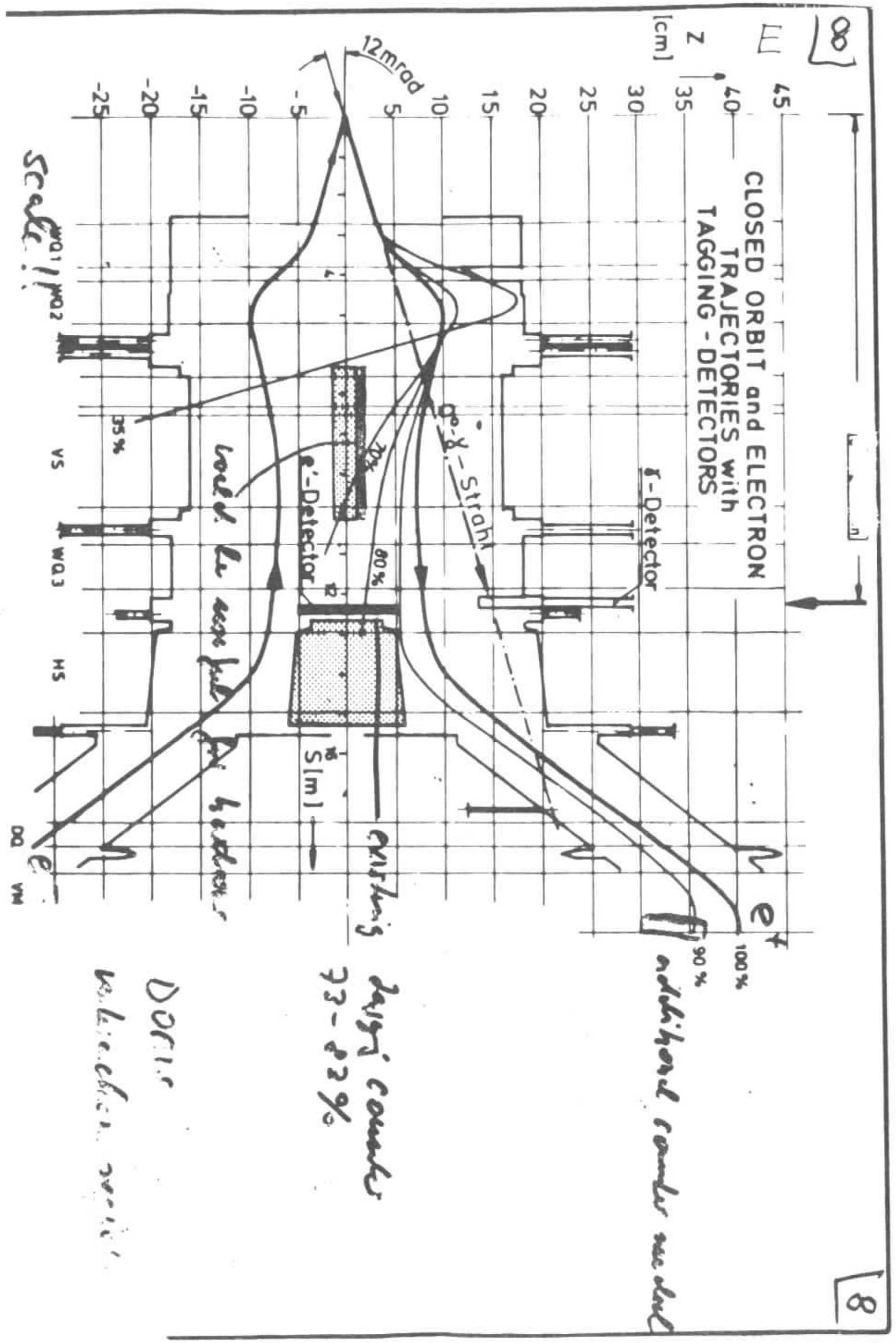
Equivalent photon approximation. (~ real photons)

Detect:

1. e^+e^- in tagging system
2. X in BONANZA

BONANZA results for $e^+e^- \rightarrow e^+e^-e^+e^-$ and $e^+e^- \rightarrow e^+e^-\eta'$ were shown here last week.

P.W.



Cross sections are small.

$e^+e^- \to e^+e^- e^+e^-$

$\vartheta < 8$ mrad

$|\cos\vartheta| < .47$ (BONANZA)

tagging \ E_{beam}	1.5	2.2	2.6 GeV	
73-83%	14 pbarn	8	6	measured by BONANZA
73-90%	133	73	56	
35-50%	143	77	60	

← X-sections increasing that way !!

~ 5 Events / day

$e^+e^- \to e^+e^- \mu^+\mu^-$ rate ~ the same.

Narrow Resonances, tagged X-sections

Particle	γγ-Width (keV)	1.5	2.2	2.4	2.6	4.3 GeV
η(550)	0.4		34	21	9 pbarn	
η'(960)	6 (?)	185	270	260	240	41
f(1260)	1 (??)				107	66

tagging from 35 - 50% of E_{beam}.

Counting rates depend on BONANZA - Trigger;

0.2 - 5 / day

Production of $\mu\mu$, $\pi\pi$, (σ) can be expected at roughly the same rates, using Brodsky's, Kinoshita's and Terazawa's formulae

Remarks:

1. ~2% resolution of tagging system
2. $s = 4\, k_1 \cdot k_2$; consider lab. moment
3. Single tagging*) and $e^-e^- \to e^-e^- X$
4. neutral decays should give clear signal

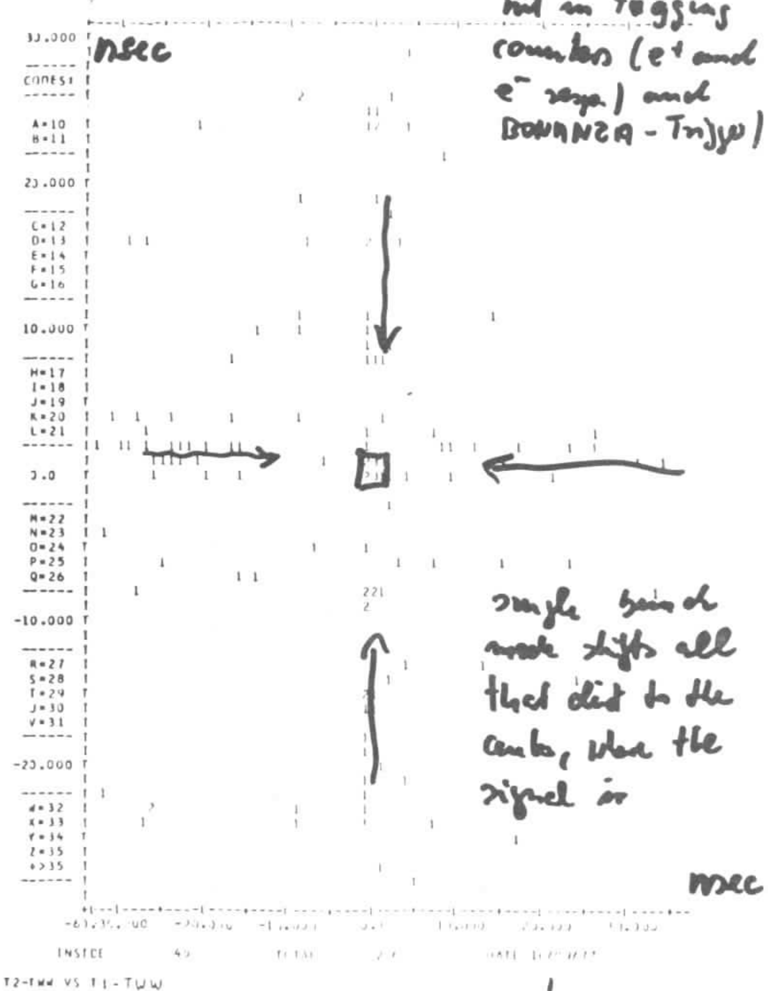
*) [illegible] trigger

E. 10

Why many bunches?

Why small current/bunch

T_{e^-} vs T_{e^+} (Time between hit in tagging counters (e^+ and e^- resp.) and BONANZA-Trigger)



single bunch mode shifts all that dirt to the center, where the signal is

Trigger: $e^+ * e^- *$ 15 MeV in Bonanza gives ~ 1 Trigger / Minute

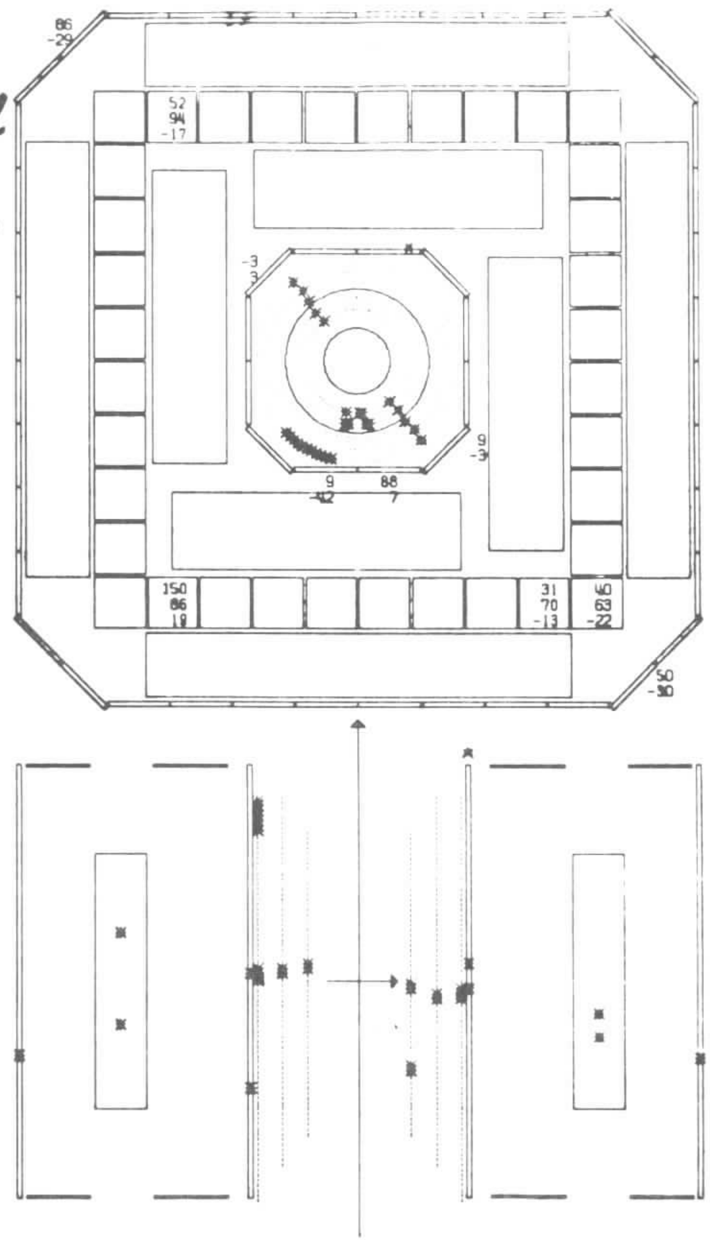
E. 11

Bonanza most unclear double-tagged event with correct timing.

26312
T 8489

$\gamma\gamma$ 4.48 GeV

T_{a3} 39.0 nsec
T_{a4} 37.5
A_{a3} 234 units
A_{a4} 172



γγ - Physics in the

η, η', f, σ

range.

1. Cross sections are small.
   Visible cross sections do not rise significantly with energy.

2. Tagging system should cover ~60% to at least 90% of beam energy.

3. Momentum resolution should be sufficient to separate η, η', f; that means ~ 2%.
   Good monitors for crossing angle and WWP.

4. Use DORIS as a multibunch machine at the energy of maximum luminosity.

5. e^-e^- does not pay out for this Prisoner. (loss of luminosity)

Bonanza can do new γγ-Physics at rates of several Events per day and process, if DORIS is returned to multibunch-mode and if the tagging system is extended.

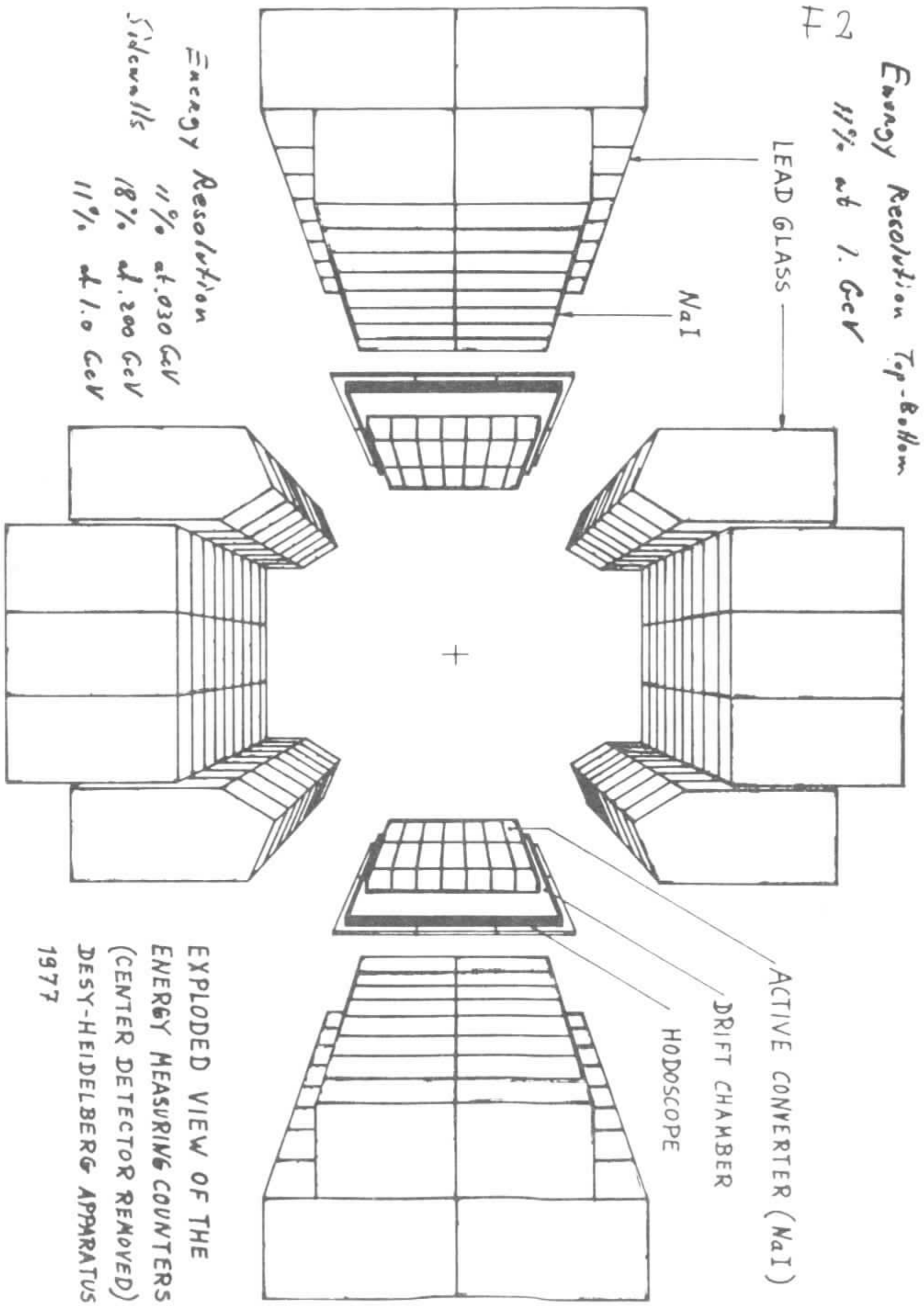
F 1

SOME REMARKS
about the DESY-HEIDELBERG Apparatus

① DESY-HEIDELBERG GROUP
→ JADE

② DESY-HEIDELBERG APPARATUS
is sitting there
- open for proposals from outside

F 2



EXPLODED VIEW OF THE ENERGY MEASURING COUNTERS (CENTER DETECTOR REMOVED) DESY-HEIDELBERG APPARATUS 1977

SOLID ANGLES + ANGULAR RESOLUTIONS

	$\frac{\Omega}{4\pi}$	$\delta\varphi$ FWHM	$\delta\vartheta$ FWHM	
Internal Detector 3×128 anode wires 3×80 cathode strips	86%	4 mr	30 mr	unambigous φ-ϑ correl.!
Small ∢ Hodoscope 32 elements	7%	22.5°	15°	$\frac{\Delta\Omega}{4\pi} \sim 3 \times 10^{-3}$ per element
Side walls 28 converter slabs 24 NaJ-blocks 40 Lead Glass " + conv. chambers	21%	70 mr 240 mr	80 mr 100 mr	conv. photons unconv. phot.
top & bottom ctrs. 86 L.G. blocks	67%	75 mr 80 mr	65 mr 45 mr	conv. phot. unconv. phot.
muon chambers 4×2 double driftch. (ϑ, φ)	60%	limited by mult. scat.		

Physics

1) Total crossections of Υ, Υ'....

2) Two lepton decay modes

3) $\Upsilon' \to \gamma\gamma\Upsilon$

Trigger

n tracks + E_m

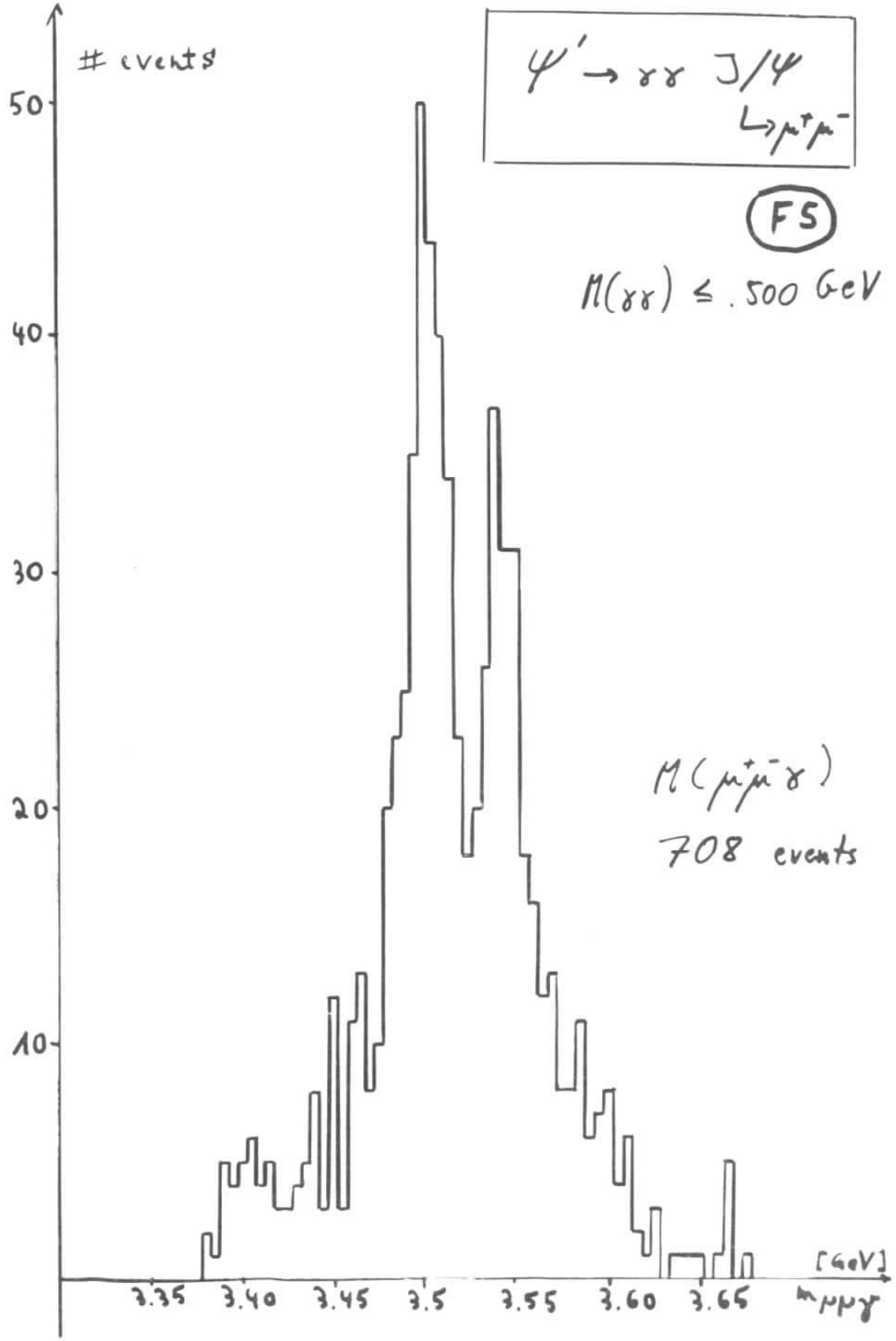
E_m → from Energy ctrs.

n tracks → from hodoscopes

--→ on line drift chamber analysis

n = 0, 1, 2 ...

At 2×5 GeV | No problem for n = 0, n > 2.
For n = 2: no problem if one μ ove requested.

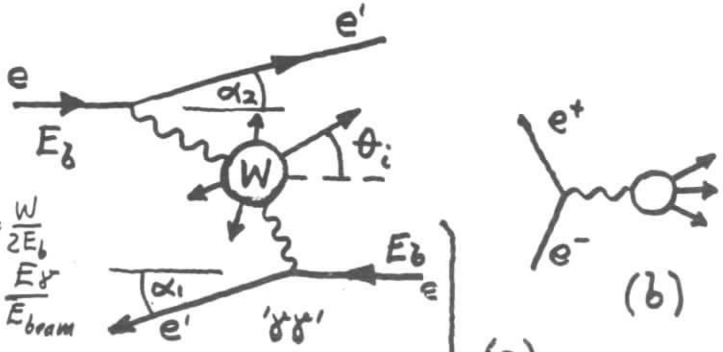


P. WALOSCHEK

WHY γ-γ PHYSICS AT DORIS ?

① INTRODUCTION; NOTATION.

AS PAUL KESSLER FIRST POINTED OUT IN 1969:



$Z = \frac{W}{2E_b}$

$X = \frac{E_\gamma}{E_{beam}}$

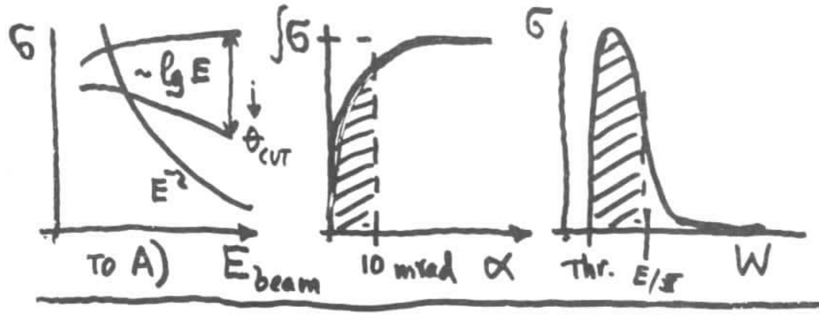
+ OTHER 'QED' SAME ORDER } (a)

A) AT HIGHER ENERGIES: $\sigma(a) > \sigma(b)$

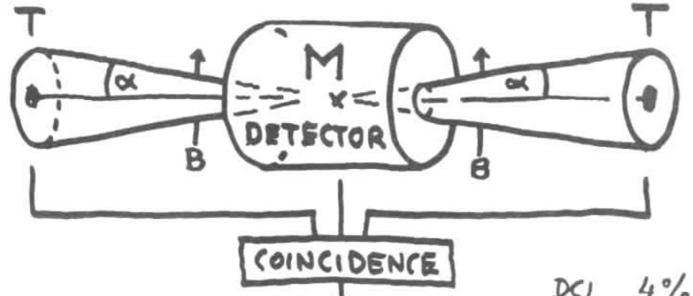
B) TO SEPARATE 'γγ' FROM 'QED' $\alpha < \sim 10°$

C) ANYWAY ~80% OF $\sigma_{\gamma\gamma}$ IS AT $\alpha < 10$ mrad

D) BEST W-REGION → $\lesssim$ 20% OF $2E_{beam}$



EXPERIMENTAL PROBLEMS:



CHANCE COINC. DUE TO:

- 1-γ-EVENTS (b)
- BEAM-GAS EVENTS } IN M, WITH
- BEAM-BEAM
- BEAM-GAS } BREMSSTRAHLUNG IN T ($\alpha \lesssim 5$ mrad)

DCI 4%
DORIS 1%
PETRA ~1
DORIS OLD: 10^{-5}

TO REDUCE THIS BACKGROUND:

→ ① CUT-OUT SMALL α TAGGING (PETRA PROP.)
  - → LESS γγ EVENTS (FACTOR 3 TO 10)
  - → MORE 'QED' BACKGROUND

→ OR: ② GO TO LOW LUMINOSITY PER BUNCH-CROSSING.

IN ADDITION ③ KILL 1-γ-EVENTS USING e^+e^+ OR e^-e^-.

BOTH SATISFIED IN

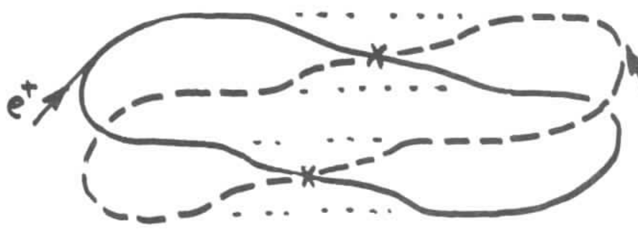
DORIS-MULTIBUNCH

BEST W-REGION: ~1 TO 3 GeV

→ TO WORK AT $\alpha \lesssim 10$ mrad: MAGNETIC TAGGING NEEDED.

AT DORIS AND DCI THIS IS POSSIBLE USING THE MAGNET STRUCTURE OF THE MACHINES.

DORIS MULTIBUNCH, UP TO 1977:



CHANCE COINC
$\sim 10^{-5}$

WE LEARNED:

+ → TAGGING NEAR TO THE BEAM IS POSSIBLE.
(BEAM MAGNETS USED) (COUNTERS IN BEAM PIPE)

+ → DEHNE'S VETO USING 0^0-γ-COUNTER: O.K.
ALL RATES ARE REASONABLE.

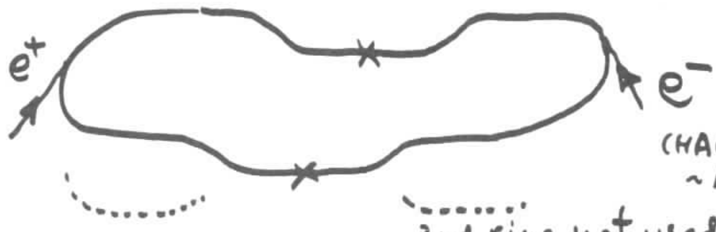
- → IMPROVEMENTS NEEDED:
  - LUMINOSITY
  - MAGNET SYSTEM (?) (FOR TAGGING ACCEPTANCE)
    (AT PRESENT ONLY SMALL WINDOWS)
  - e^+e^+ BEAMS → LESS GAS (CLOUD)

QUADRUPOLES PROVIDE BENDING (!)

→ NEW DORIS '77' SATISFYES (HOPEFULLY) THESE REQUIREMENTS.

→

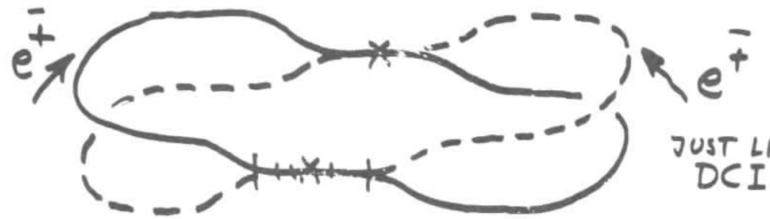
DORIS SINGLE BUNCH SINGLE RING



CHANCE C.
$\sim 10^{-2}$

2nd ring not used for e^+e^-

BUT:
THE SAME MAGNETIC SYSTEM
CAN BE USED FOR e^-e^- OR e^+e^+:



JUST LIKE
DCI

→ - PROVIDING HEAD-ON COLLISIONS (BETTER LUMIN.)

→ - BETTER POSSIBILITIES FOR MAGN. TAGGING
(BENDING LIKE IN A SPECTROMETER)

→ - VACUUM ON BEAM (e^+e^+) PERHAPS BETTER.

→ - >20 BUNCHES MAY BE KEPT IN e^+e^+ MODE,
or e^-e^- " .

EXCELENT FACILITY FOR $\gamma\gamma$ PHYSICS.

STILL, COMPARE TO PETRA

γ-γ-PHYSICS AT PETRA

⇒ O.K. FOR W > 3 GeV (NO COMPETITION)

FOR **W < 3 GeV**:

- ANY INCREASE OF σ IS COMPENSATED BY THE LOSS DUE TO TAGGING AT α > 10 mrad
- NO TAGGING RESOLUTION (SHOWER COUNTERS) AT 20 GeV

*) - EV. TOO MUCH e+GAS (ELASTIC) BACKGR. IN TAG. CTRS.

- ALL BACKGROUNDS HERE DISCUSSED 'QED' '1-γ-EVENTS' ARE "IN".

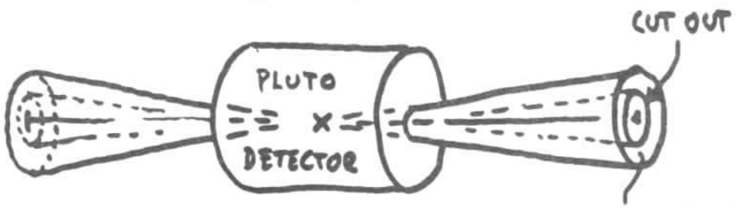
FOR W < 2-3 GeV

→ NO ADVANTAGE GOING TO PETRA,

→ MAY BE EVEN IMPOSSIBLE TO TAG FOR M < 2 GeV.

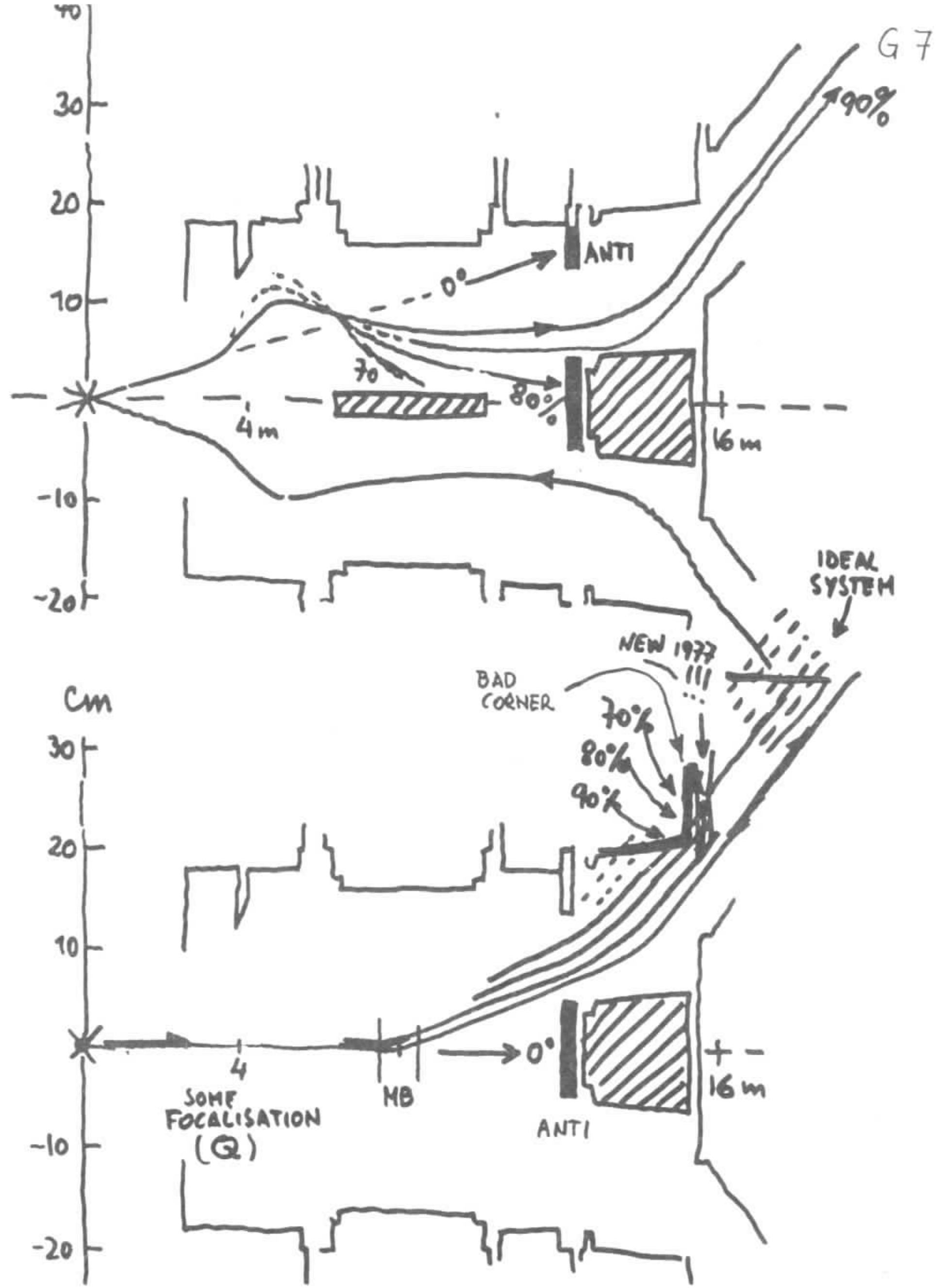
SEE NEXT COMUNIC...

*) PETRA - PLUTO - SYSTEM:



SINGLE BREMSSTR. BACKGR. OUT

BUT, FOR SMALL M → *



G 8

CONCLUSION:

DORIS OFFERS AT PRESENT THE BEST CHANCES FOR AN ACCURATE MEASUREMENT OF γ-γ INTERACTIONS IN THE ENERGY → REGION OF ~1 TO ~3 GeV (γ-γ-CMS).

A CENTRAL DETECTOR COVERING ~4π SHOULD BE COMPLEMENTED WITH A DOUBLE → TAGGING SYSTEM OF GOOD ACCEPTANCE. THIS SEEMS PARTICULARLY FEASABLE WITH THE NEW MAGNET STRUCTURE (S.B.-S.R.) EXTENDED TO BOTH RINGS → AS e^+e^+ FACILITY.

BUT EVEN USING e^+e^- IT IS NOT BAD. (SAME IMPROVED TAGGING SYSTEM IS O.K.)

H 1

A. COURAU

γ-γ - PHYSICS AT DCI

H 2

The γ-γ LUMINOSITY, IN W-W-APPROXIM. :

$$\frac{1}{\mathcal{L}(ee)} \frac{d\mathcal{L}(\gamma\gamma)}{dx_1\, dx_2} \sim \frac{1}{x_1} \frac{1}{x_2} S(x_1) S(x_2)$$

with $x_{1,2} = E_{\gamma_{1,2}} / E_0$

WHICH CAN BE WRITTEN :

$$\frac{1}{\mathcal{L}(ee)} \frac{d\mathcal{L}(\gamma\gamma)}{dz\, d\beta} = \left(\frac{2\alpha}{\pi}\right)^2 \frac{1}{1-\beta^2} S\left(z\sqrt{\frac{1+\beta}{1-\beta}}\right) S\left(z\sqrt{\frac{1-\beta}{1+\beta}}\right)$$

$z = \frac{W}{2E}$ (W is the invariant mass of the γγ-system)

$\beta = \left|\frac{x_2 - x_1}{x_2 + x_1}\right|$ (β is the velocity of the γγ-system in the Lab.) // to the incident beams

W.W. Approximation Limits :

$q^2_{12} \ll W^2$

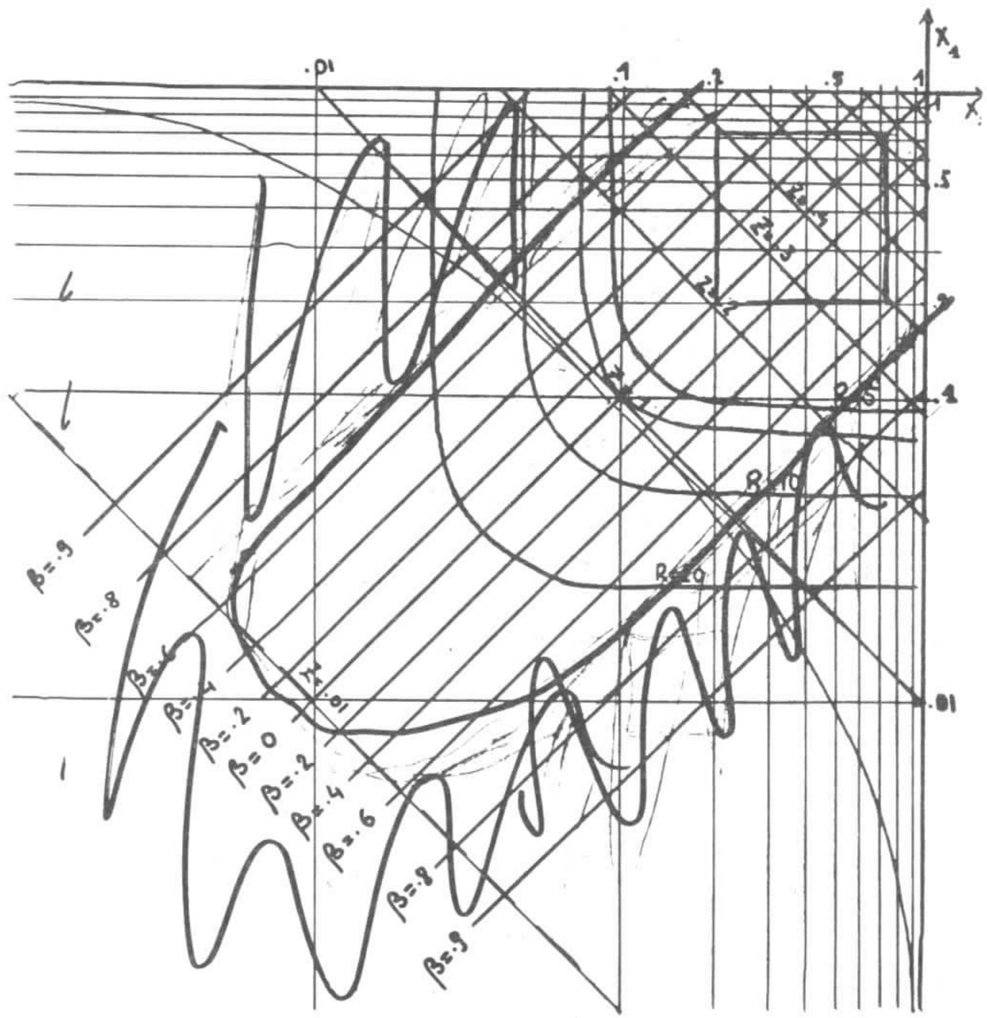
↓

$\Theta_e \ll \frac{4z}{\sqrt{1-x}}$

1/9 . A. COURAU

H 3

$X = \frac{E_\gamma}{E_0}$, $Z = \frac{W}{2E_0}$, $\frac{d\mathcal{L}}{dx_1 dx_2} \propto \frac{1}{x_1} \cdot \frac{1}{x_2} \cdot S(x_1) S(x_2)$



γ-γ-MASS RESOLUTION :

$R = (dW/W)/(dE'/E')$

2/9 A. COURAU

H 4

$$\frac{dS(x)}{d\theta_\gamma} \propto \frac{\theta_\gamma}{\theta_\gamma^2 + \left(\frac{m_e}{E}\right)^2} \qquad (\gamma\text{-ANGULAR DISTR.})$$

Integrate over all angles $\longrightarrow \ Ln\left(\frac{E}{m_e}\right)$

The E dependance comes only from the very small θ_γ

when $\theta_\gamma \gg \frac{m}{E}$

$$\frac{dS(x)}{d\theta_\gamma} \sim \frac{1}{\theta_\gamma} \qquad (\text{NO DEPENDENCE ON } E)$$

Then:

without tagging $\quad S(x) = (1-x+x^2/2)\, Ln\,(E/m) - (1-x)$

with a zero. tagging $0 \leq \Theta_e < \Theta_0$ $\quad S(x) = (1-x+x^2/2)\, Ln\left(E/m\, \frac{1-x}{x}\Theta_0\right) - (1-x)$

with a Angle Tagging $\Theta_m \leq \Theta_e \leq \Theta_M$ $\quad S(x) = (1-x+x^2/2)\, Ln\,(\Theta_M/\Theta_m)$

* Remarks on x acceptance

1) Seem more drastic at zero degré

2) but $\theta_\gamma = \frac{1-x}{x}\Theta_e$ $\qquad x \searrow \quad \Theta_e$ constant : $\theta_\gamma \nearrow$

Θ_m and Θ_M becomes outside the range of validity of W.W.

and $S(x)$ decay more fast than $1/\theta_\gamma$

Rough approximation to see the effect,

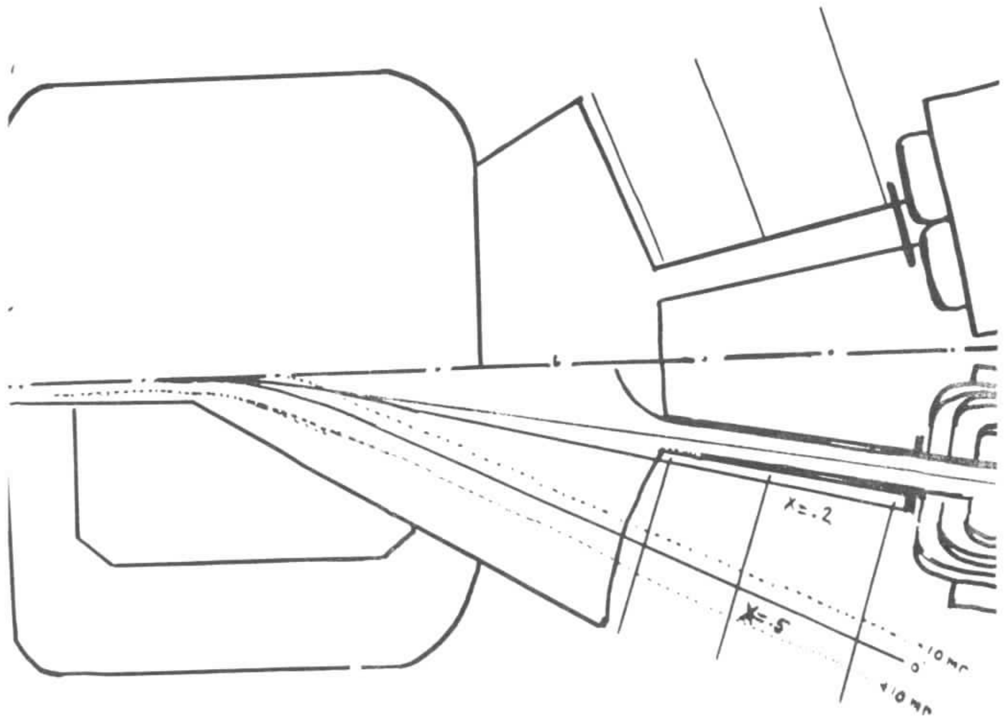
$S(x) = \frac{1}{\theta_\gamma}$ for: $q^2_{1,2} < \frac{W^2}{4}$ $\quad \longrightarrow \quad \Theta < \frac{z}{\sqrt{1-x_1}}, \frac{z}{\sqrt{1-x_2}} \sim z$ inside cuts

$S(x) = 0$ for $q^2_{1,2} > \frac{W^2}{4}$

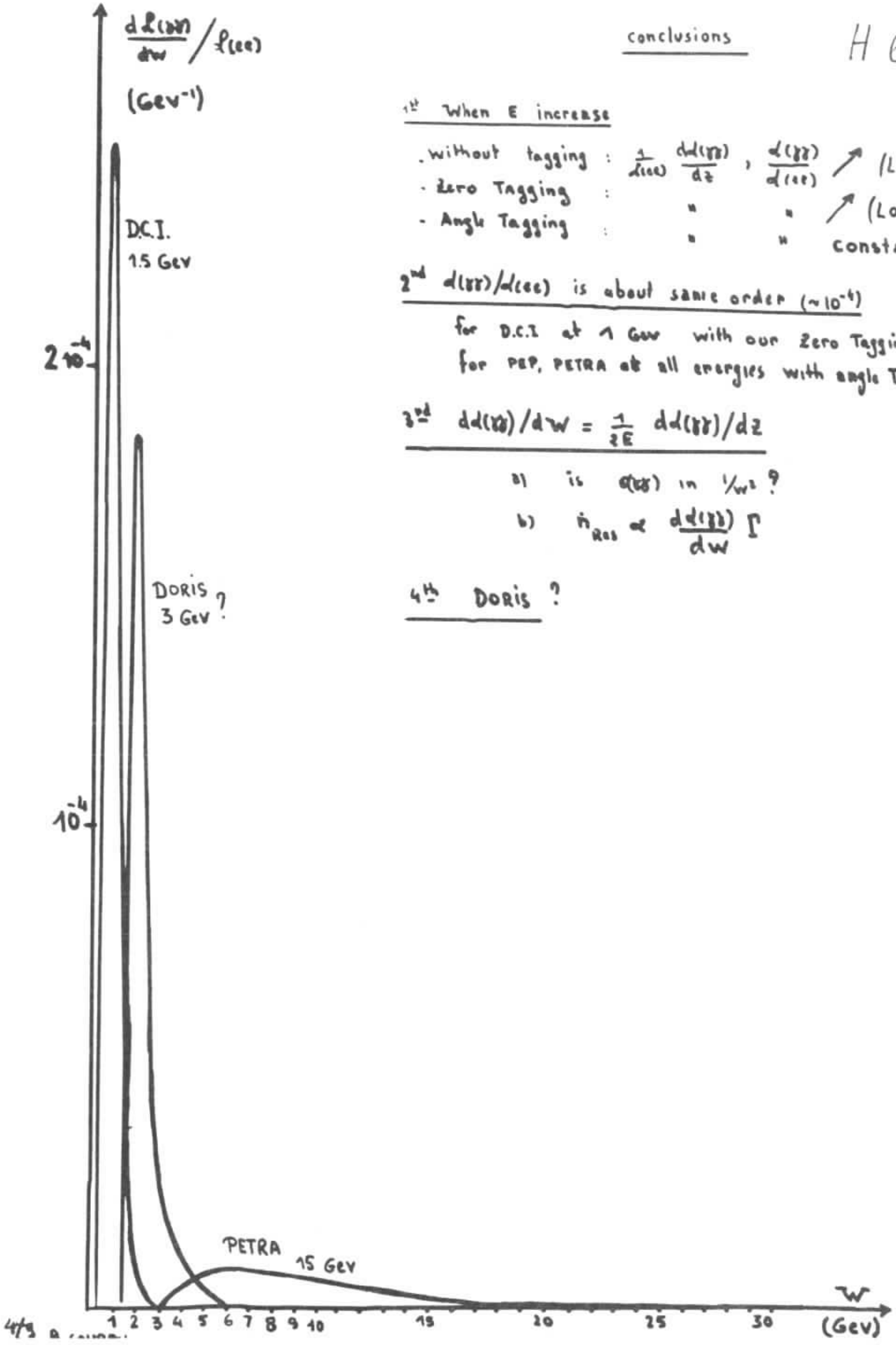
$$Ln\,\frac{\text{MAX}\,(z, \Theta_M)}{\text{MAX}\,(z, \Theta_m)}$$

H 5

$(D_1 \cup D_2) \cap (G_1 \cup G_2)$



H 6



conclusions

1st When E increase

- without tagging : $\frac{1}{\mathcal{L}(ee)} \frac{d\mathcal{L}(\gamma\gamma)}{dz}$, $\frac{\mathcal{L}(\gamma\gamma)}{\mathcal{L}(ee)}$ ↗ $(\mathrm{Log}\,\frac{E}{m})$
- Zero Tagging : " " ↗ $(\mathrm{Log}\,\frac{E}{m})'$
- Angle Tagging : " " constant

2nd $\mathcal{L}(\gamma\gamma)/\mathcal{L}(ee)$ is about same order ($\sim 10^{-4}$)

for D.C.I at 1 Gev with our Zero Tagging
for PEP, PETRA at all energies with angle Tagging

3rd $d\mathcal{L}(\gamma\gamma)/dW = \frac{1}{2E}\, d\mathcal{L}(\gamma\gamma)/dz$

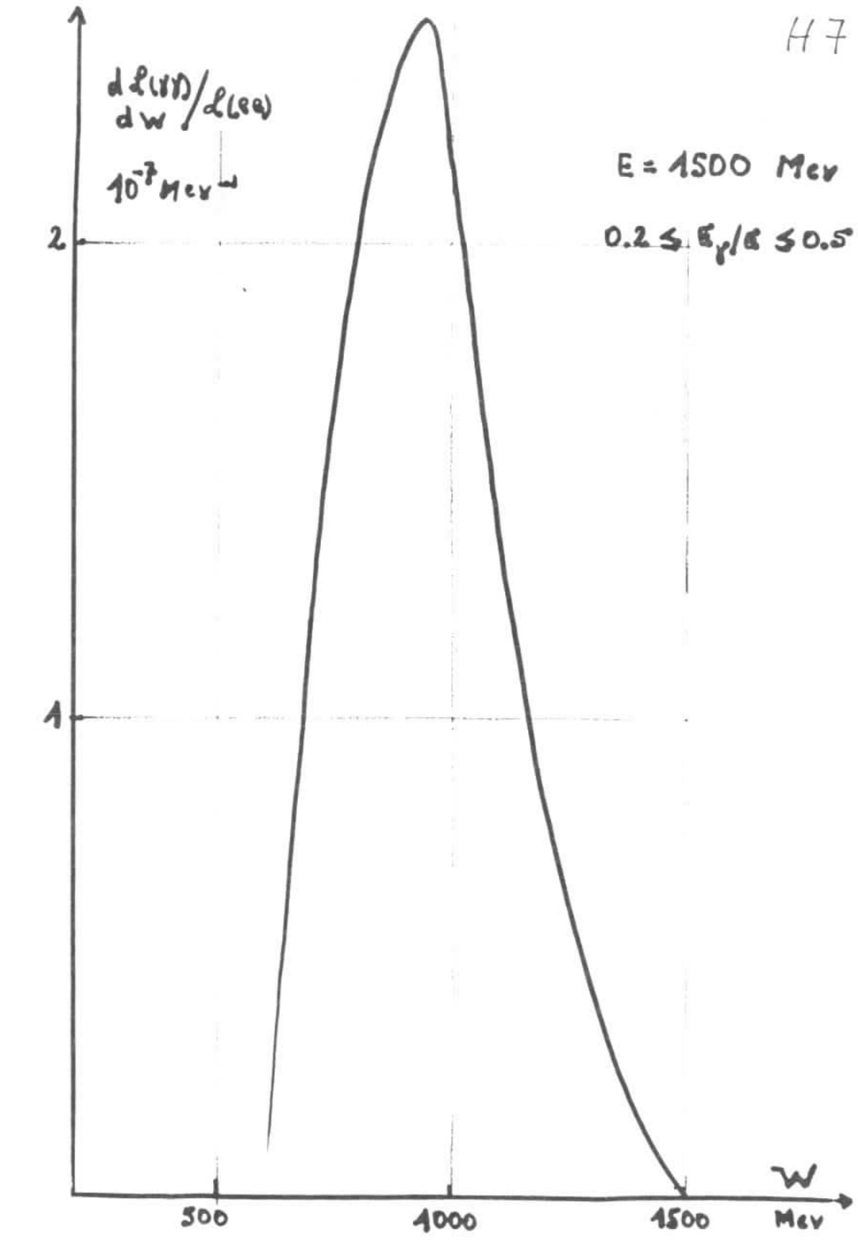
a) is $\sigma(\gamma\gamma)$ in $1/w^2$?

b) $\dot{n}_{Res} \propto \frac{d\mathcal{L}(\gamma\gamma)}{dw}\,\Gamma$

4th DORIS ?

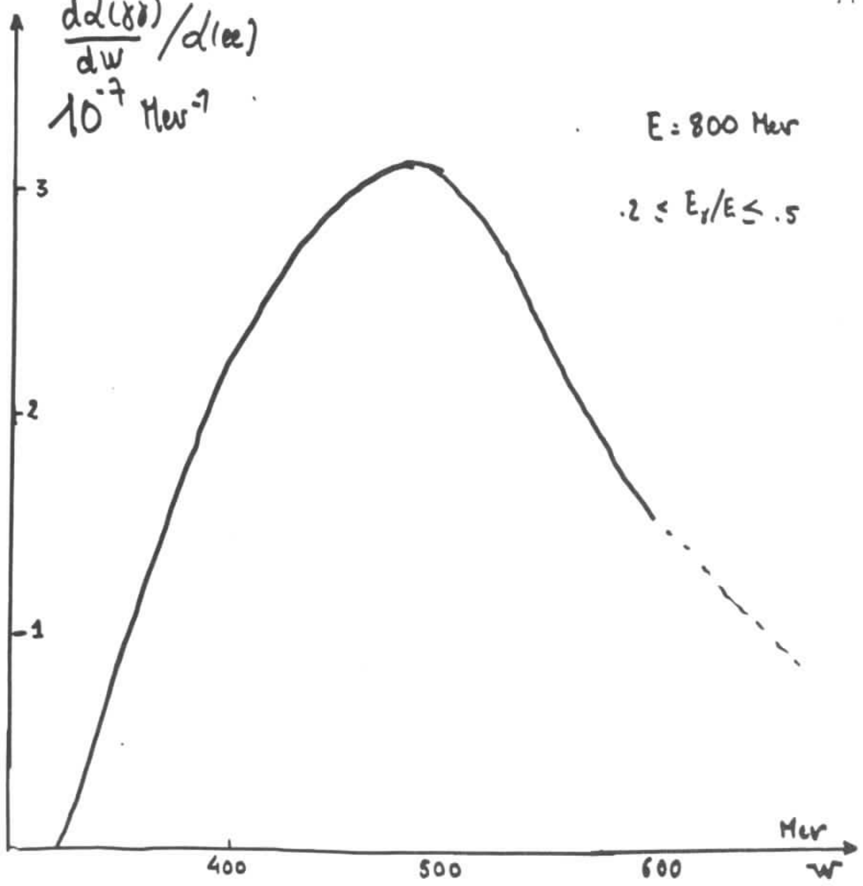
4/3 A. Courau

H 7 "

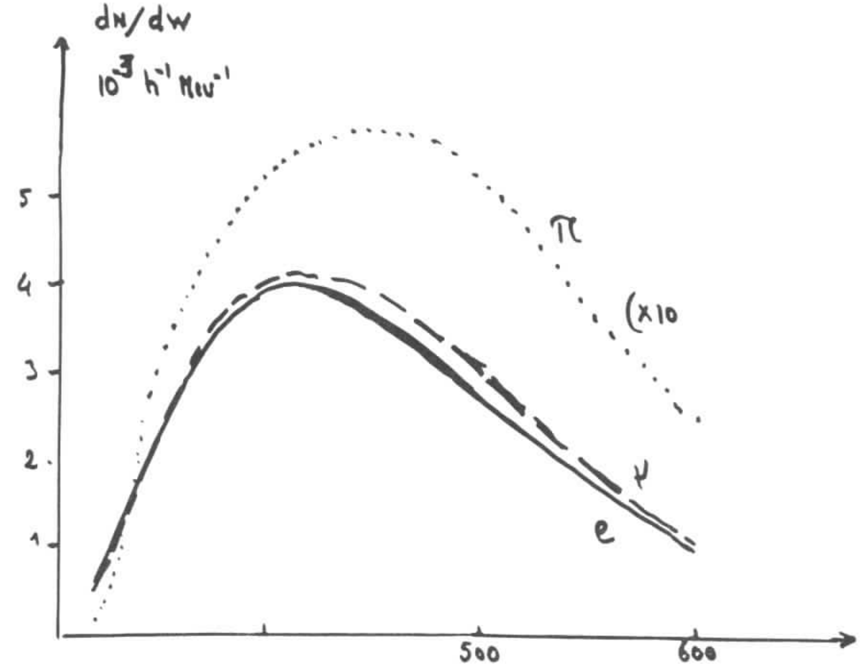


7/3 A. COURAU

H 8



H 9



	events/hour
ππ	.5
μμ	3
ee	3

E = 800 MeV

$\mathcal{L}(e^+e^-) = 8\ 10^{30}\ cm^{-2}s^{-1}$

$(\mathcal{L}(ee) = 2\ \mathcal{L}(e^+e^-))$

$.2 \leq E_\gamma/E \leq .5$

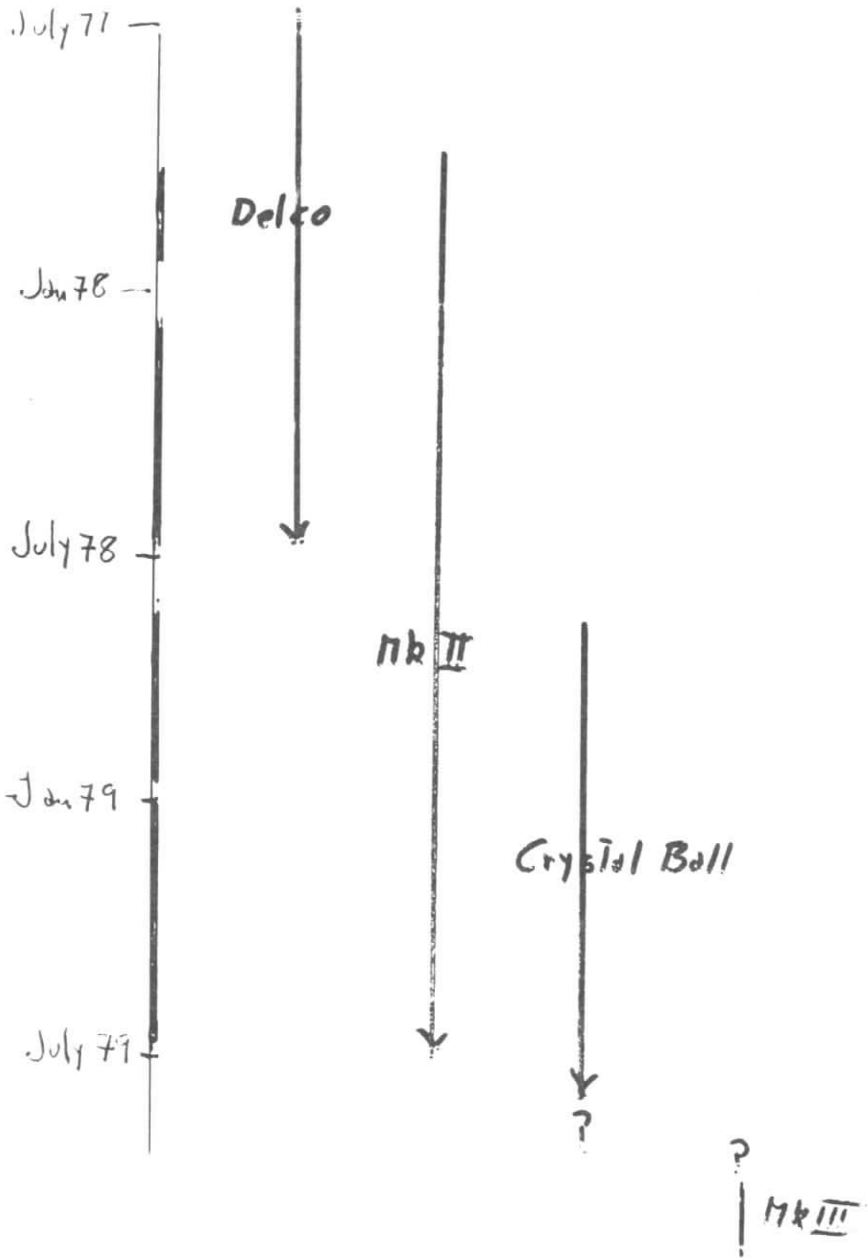
4.4 Counting rates

Counting rates, taking into account the acceptance of the experimental set-up, are summed up in the following table :

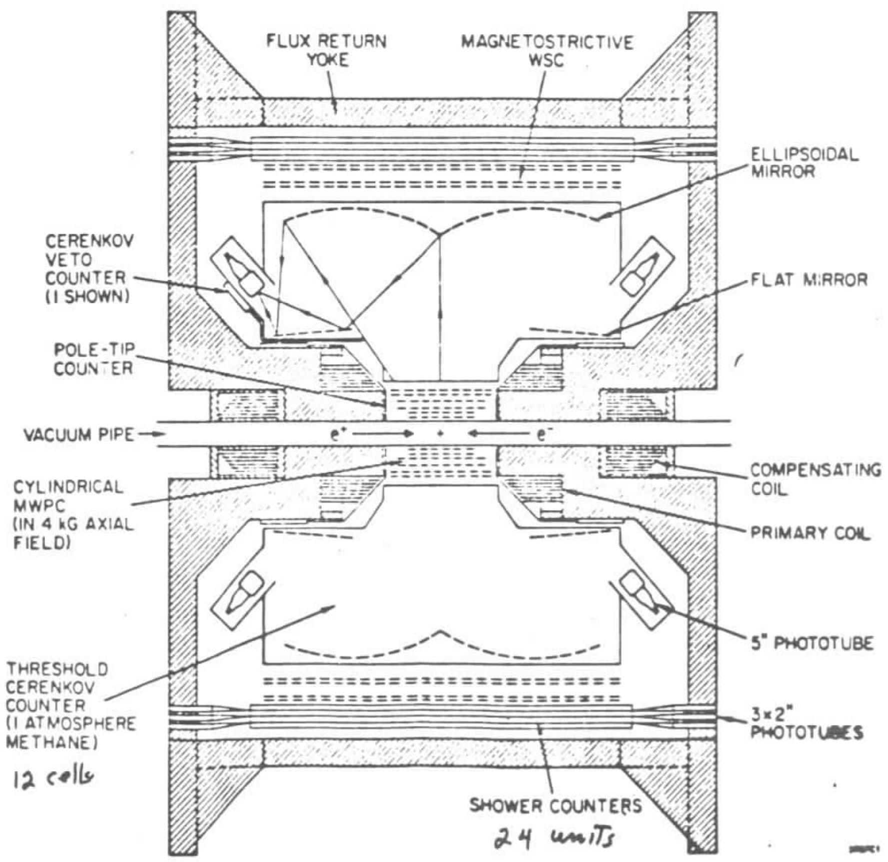
$E = 800$ MeV $320 < W < 600$ MeV $0.2 < \frac{W}{E} < 0.5$ $50° < \theta_{DMI} < 130°$	$ee \to ee + e^+e^-$	$ee \to ee + \mu^+\mu^-$	$ee \to ee + \pi^+\pi^-$
	$\langle q_m^2 \rangle = 1522\ MeV^2$ DMI accept. 0.055	$\langle q_m^2 \rangle = 1465\ MeV^2$ DMI accept. 0.321	$\langle q_m^2 \rangle = 1461\ MeV^2$ DMI accept. 0.493
<u>Maximal expected luminosity</u> $\mathcal{L}(e^+e^-) = 0.8.10^{31}\ cm^{-2}\ s^{-1}$ $\mathcal{L}(ee) = 1.6.10^{31}\ cm^{-2}\ s^{-1}$ $\mathcal{L}(\gamma\gamma) = 9.6.10^{26}\ cm^{-2}\ s^{-1}$	$\dot{N} = 3.04$ /h	$\dot{N} = 3.15$ /h	$\dot{N} = 0.47$ /h
<u>Integrated luminosity</u> $\mathcal{L}(ee) = 1.4.10^{37}\ cm^{-2}$ (80 sessions of 12 h with $\mathcal{L} = \mathcal{L}_{max}/4$)	$N = 723$	$N = 758$	$N = 115$

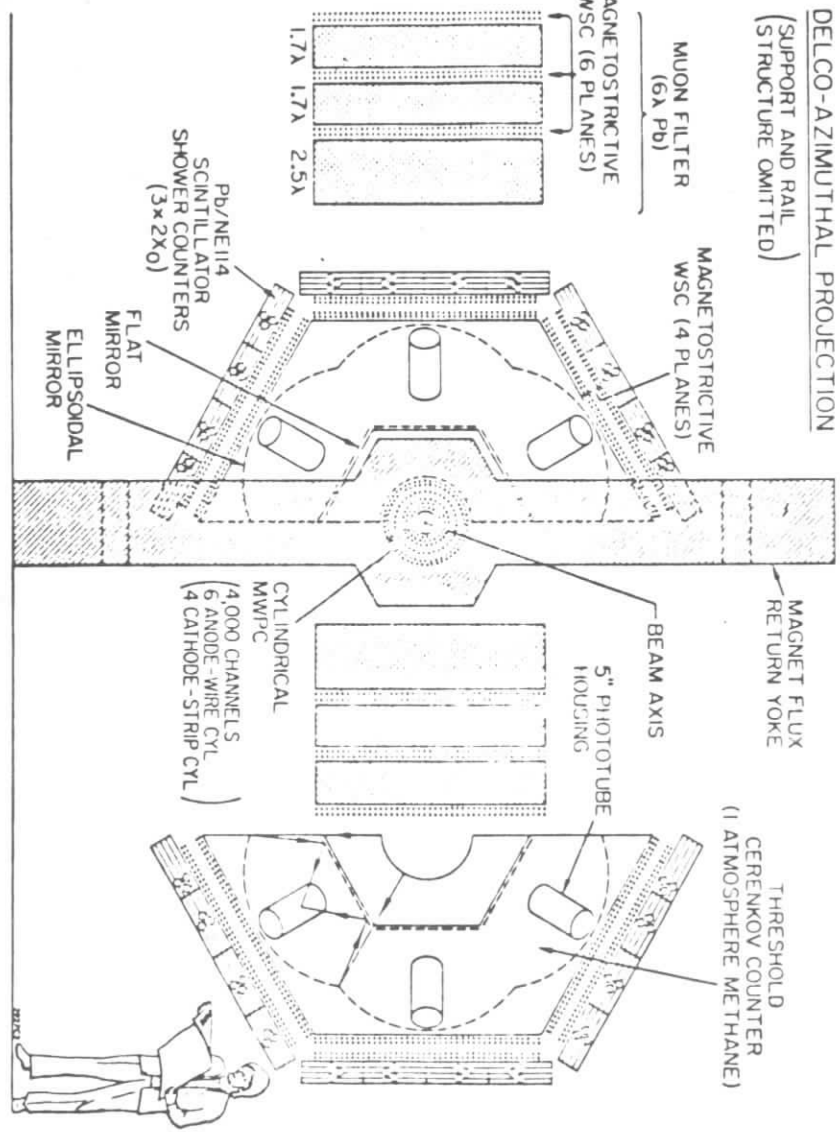
Figure 8 gives the events distribution as a function of W.

SPEAR SCHEDULE



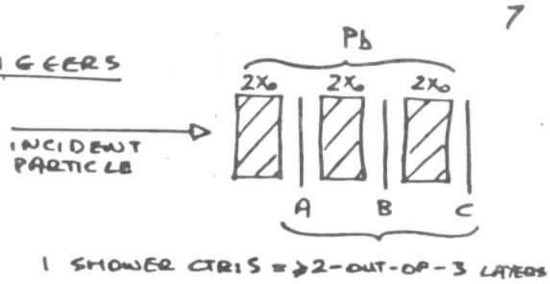
DELCO-POLAR PROJECTION





7

TRIGGERS



1 SHOWER CTRIS = ≥2-OUT-OF-3 LAYERS FIRE

2S . Q_{12} CHARGED

3S
2S . 8

} ALLOWS IN ADDITION ALL-NEUTRAL FINAL STATES

Σ RATE = 0.7 Hz

COMPOSITION: 85% COSMICS
10% BHABHAS
4% HADRONS (10^{-4} CEA)

8

SUMMARY OF DELCO'S CHARACTERISTICS

1) SOLID ANGLES: $\left.\begin{matrix} C^{\circ} \\ \text{SHOWER CTRS} \\ \text{WSC} \end{matrix}\right\} \sim 0.65 \times 4\pi$

MWPC #6 0.74 × 4π
#2 0.90 × 4π

2) π → e REJECTION < 10^{-3} (C° ALONE)
ϵ_e (BHABHAS) ≥ 98%

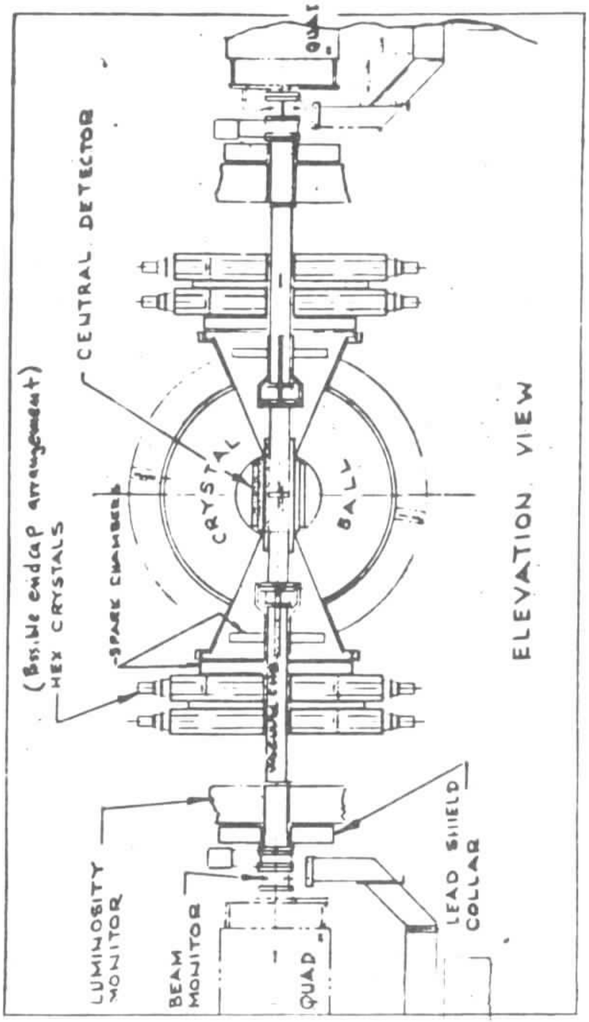
3) $\Delta p/p$ = 10 p(GeV) % (p > 1GeV)

4) Δθ ~ Δφ ~ 5 mrads

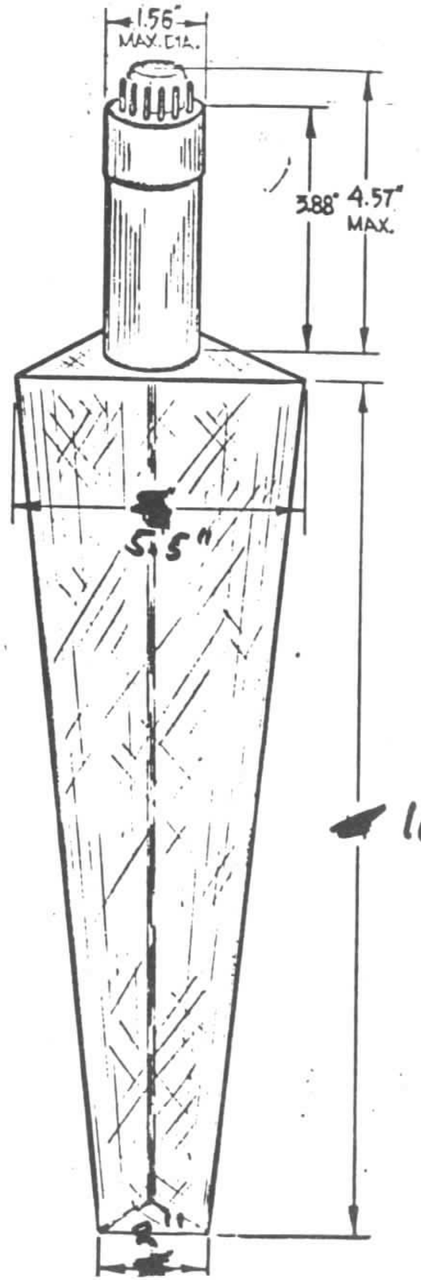
5) HADRONIC TRIG. ε = 0.85

6) LARGE-SOLID ∠ NEUTRAL TRIGGER + CRUDE PHOTON MEASUREMENTS – $(\Delta E/E)_\gamma$ ~ 30% AT 1GeV
Δ ANGLE ~ 40-100 mrads

7) μ's NEXT CYCLE – 21% × 4π
(WSC + COUNTERS) – 2.5 λ_{abs}. Pb



I 6



(6)

I 7

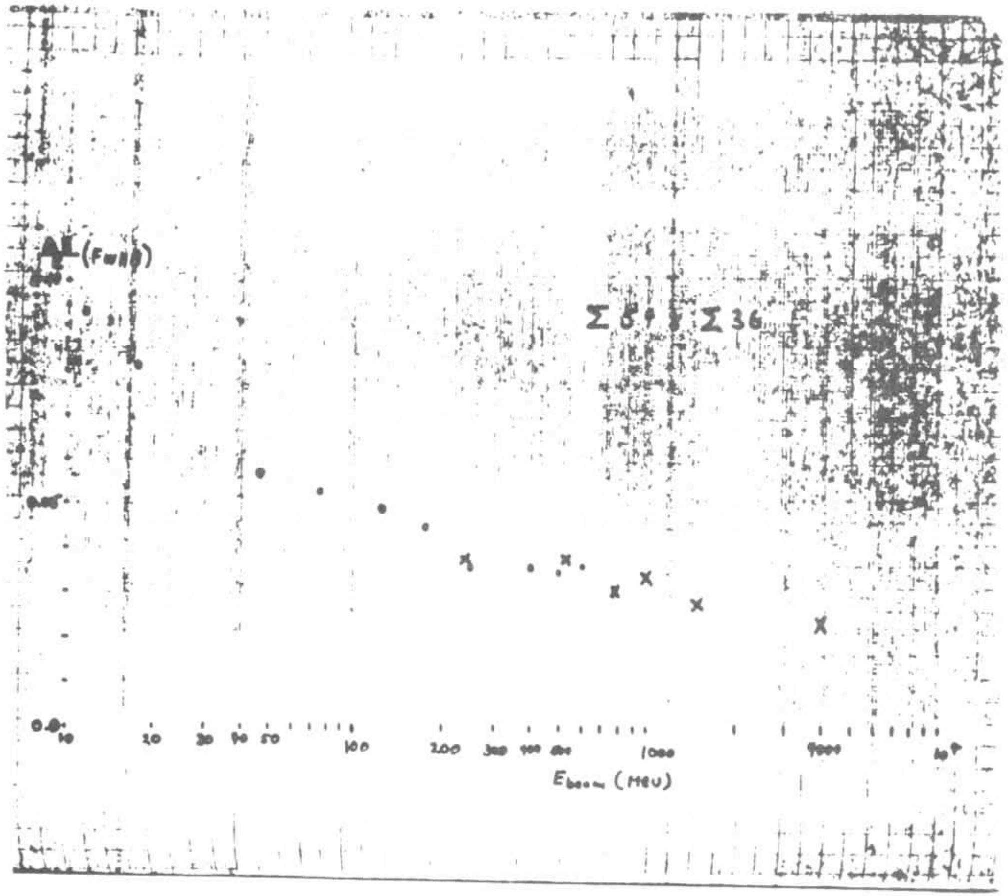
672 Modules.

16 $\bar{X}_0$

Photon ∡ res ~ 1° for k > 200 MeV

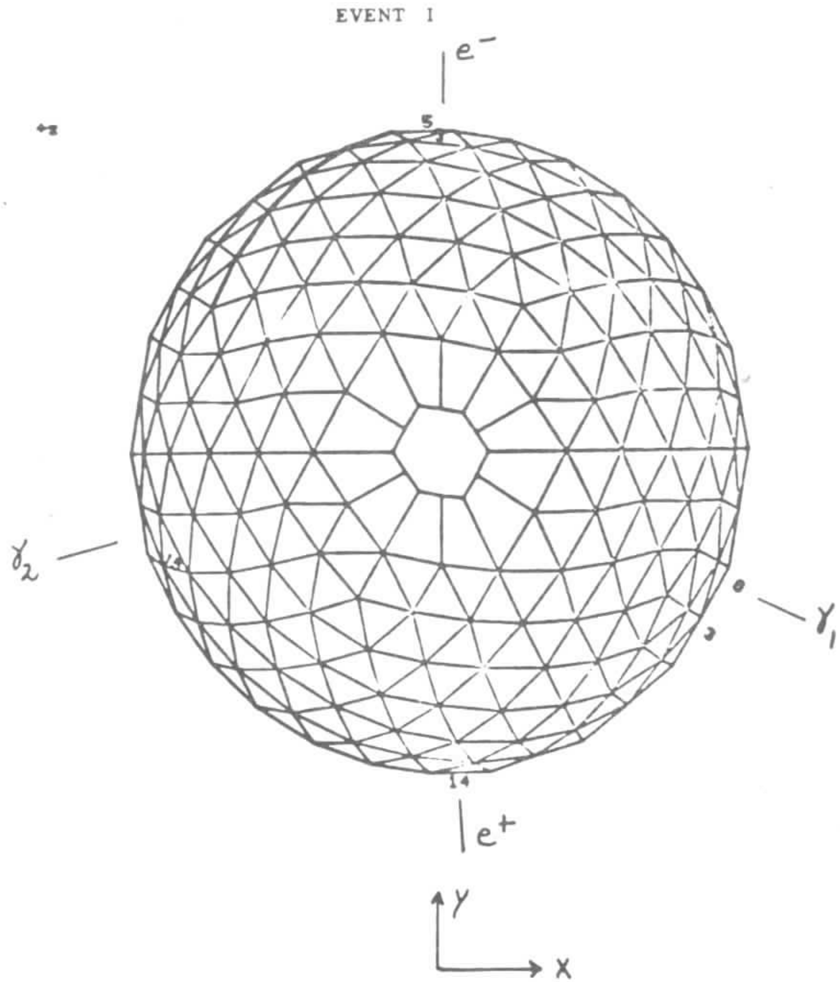
$\sigma_M(\pi^0)$ = 9 MeV @ 700 MeV

for $p(\pi^0)$ > 2-3 GeV no mass meas but can tell 2γ from 1.



Electronics?

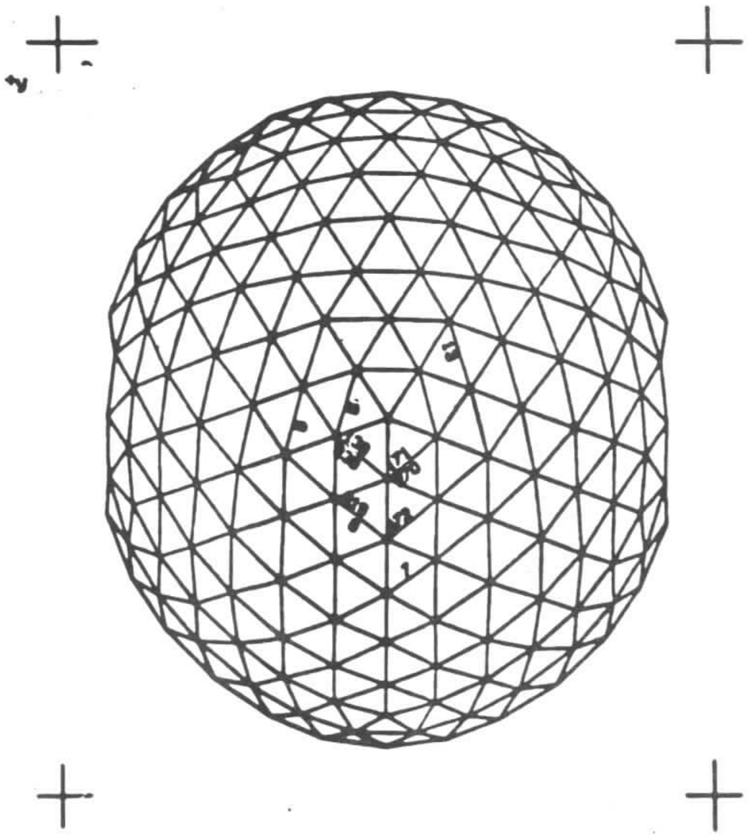
$\psi' \to \gamma\gamma\psi$
$\hookrightarrow e^+e^-$



I 10

one of e

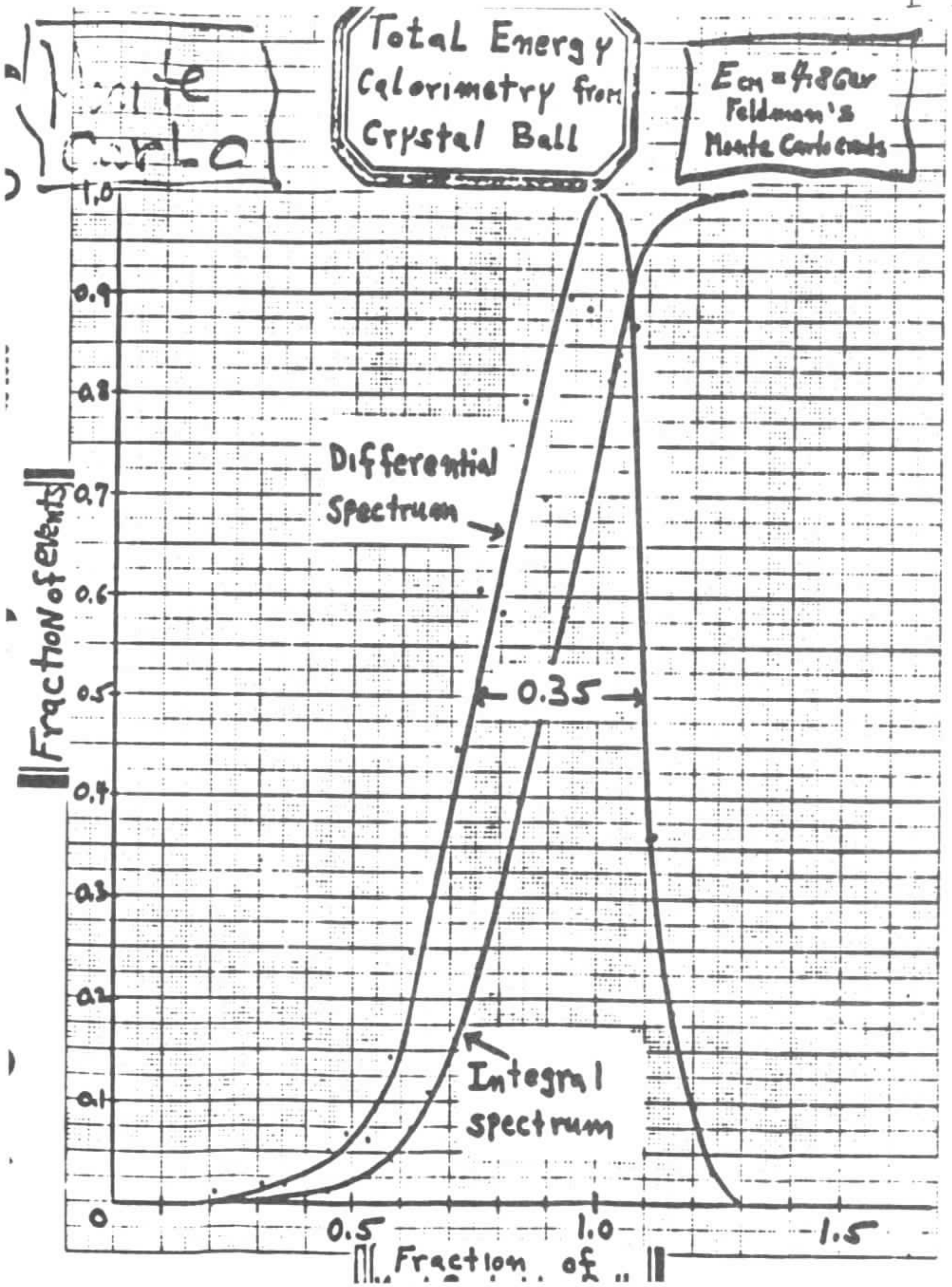
EVENT I

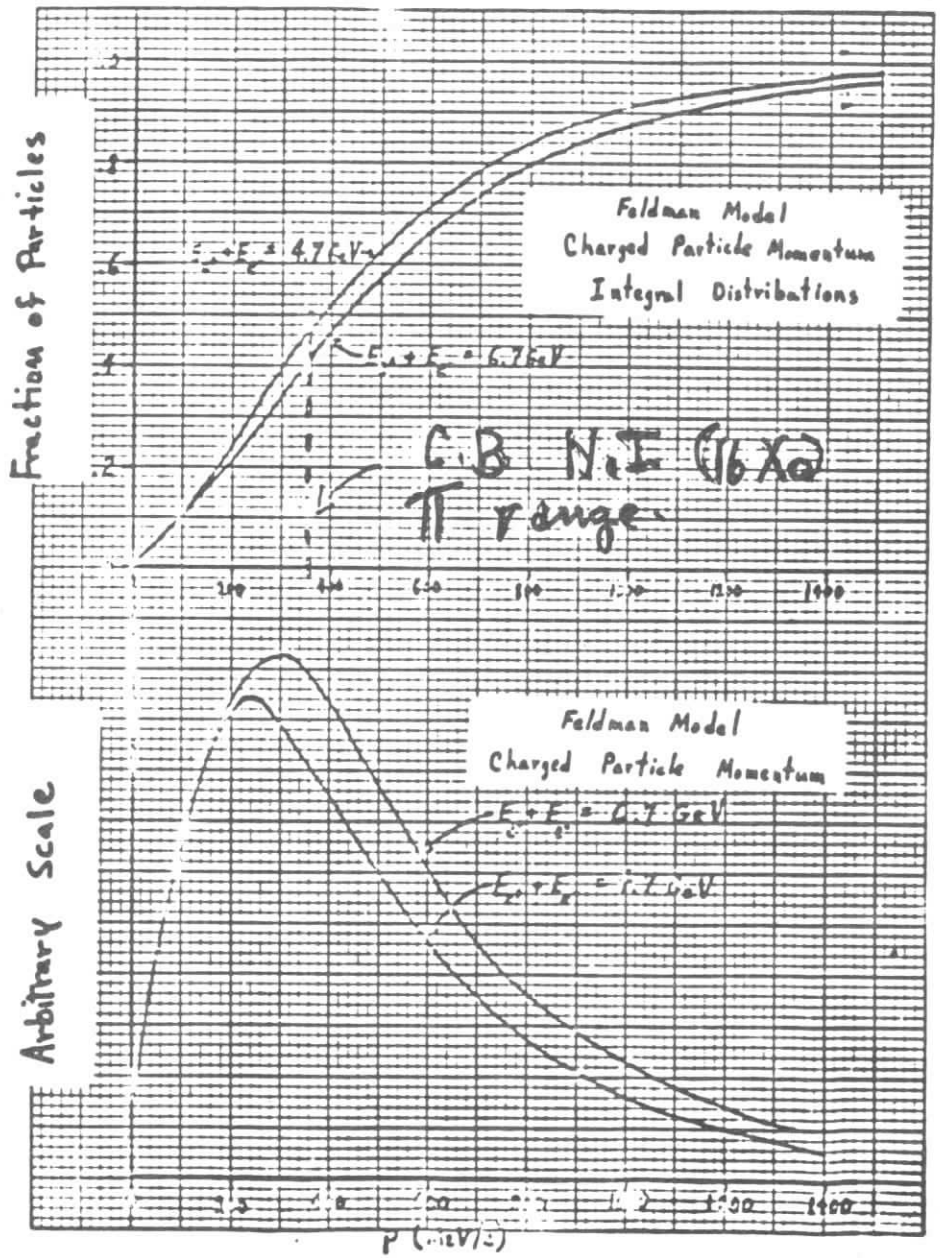


I 11

Energy Contributions From various types of Particles in the Feldman Model with $E_{CM} = 4.8$ Gev.

Particle type	Fraction of Total E_{CM}
$\pi^{\pm}$	0.41
γ	0.38
$K^{\pm}$	0.11
K^0_L	0.06
$p\bar{p}$	0.02
$n\bar{n}$	0.02
	1.00


Monte Carlo
Total Energy Calorimetry from Crystal Ball
E_{cm} = 4.8 GeV Feldman's Monte Carlo events
Differential Spectrum
0.35
Integral spectrum
Fraction of events
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0.5 1.0 1.5
Fraction of


Fraction of Particles
Feldman Model
Charged Particle Momentum
Integral Distributions
C.B NaI (16 X0)
π range
Feldman Model
Charged Particle Momentum
Arbitrary Scale

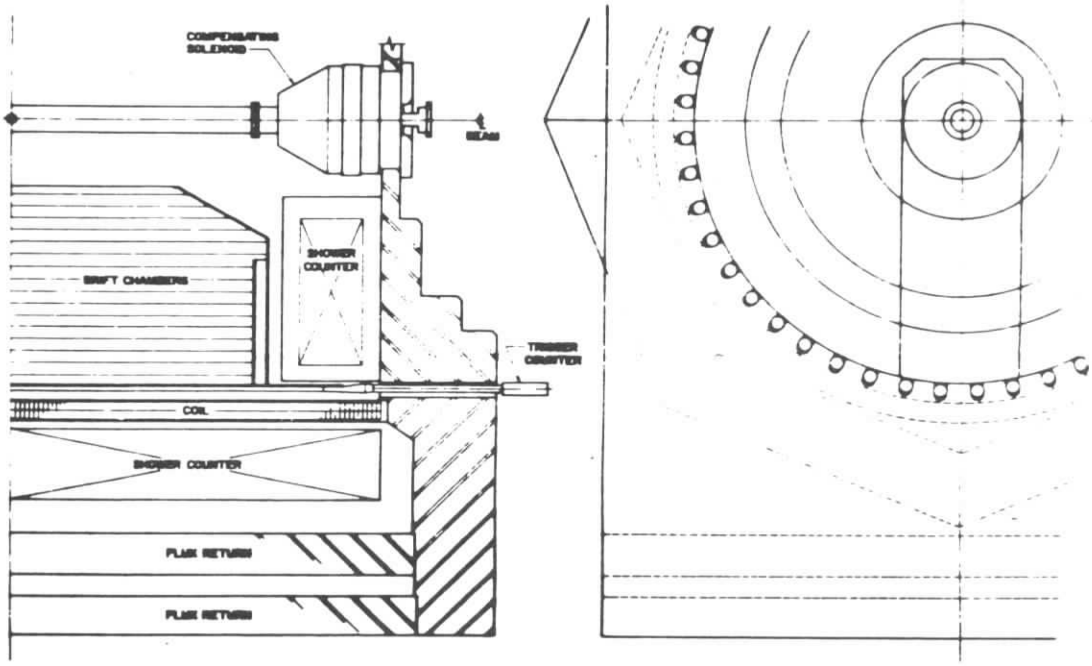

COMPENSATING SOLENOID
BEAM
SHOWER COUNTER
DRIFT CHAMBERS
TRIGGER COUNTER
COIL
SHOWER COUNTER
FLUX RETURN
FLUX RETURN

FIG. 2

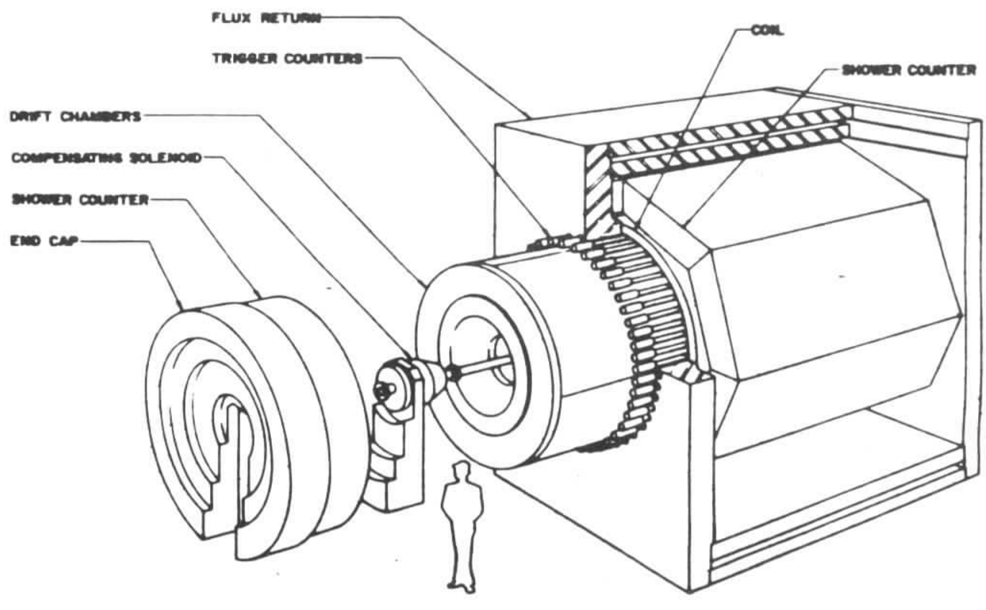
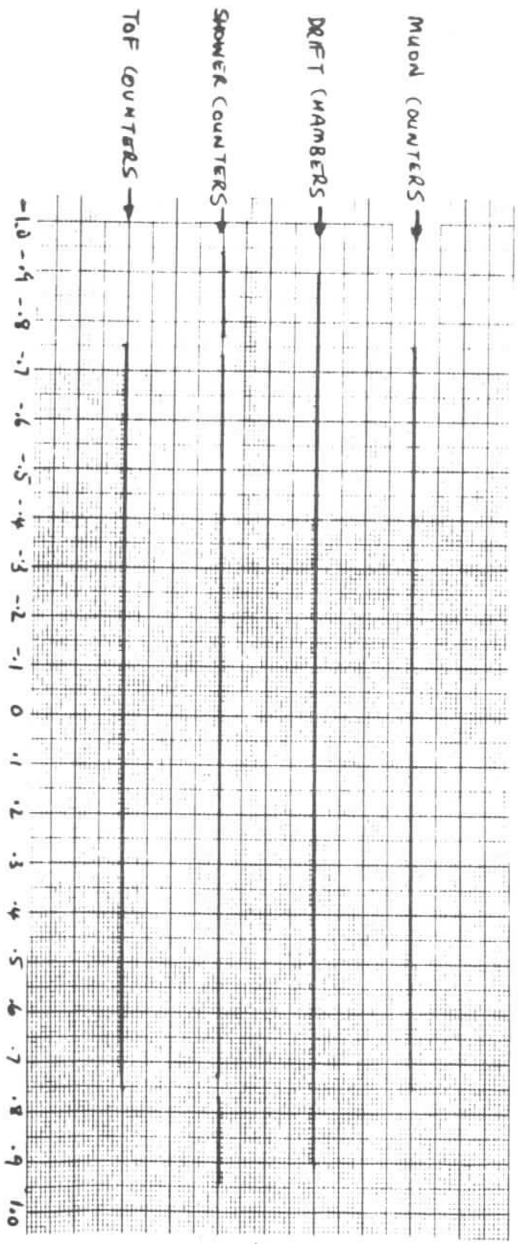

FLUX RETURN
TRIGGER COUNTERS
COIL
SHOWER COUNTER
DRIFT CHAMBERS
COMPENSATING SOLENOID
SHOWER COUNTER
END CAP

FIG.1



COVERAGE OF MARK II DETECTOR IN COSθ

FIG. 3

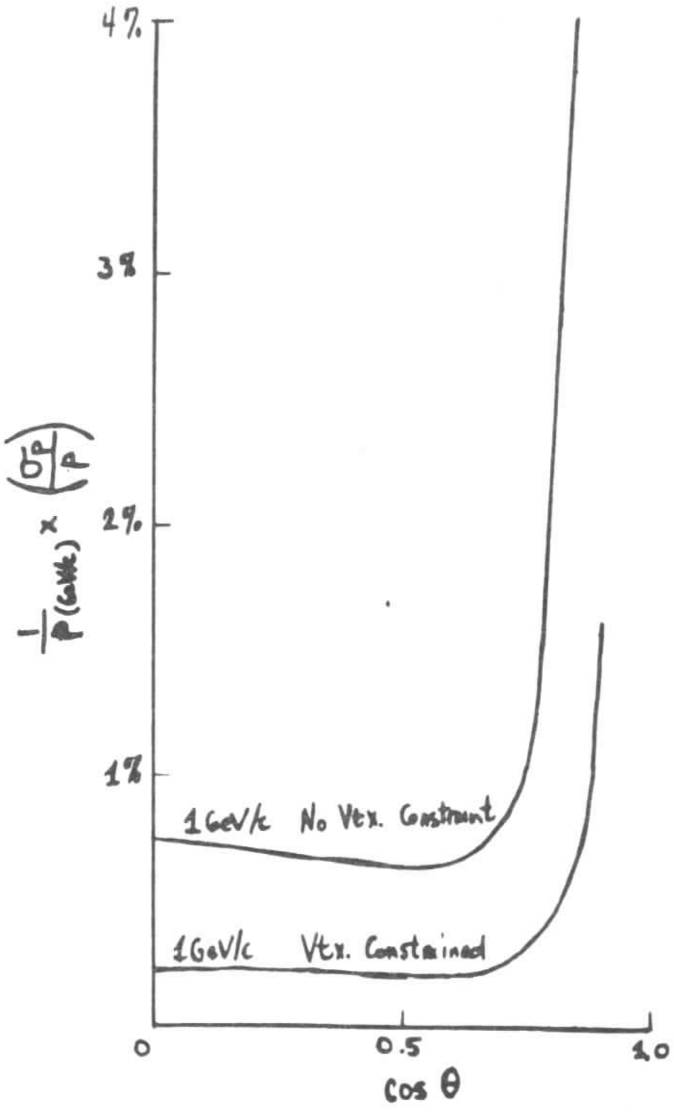


FIG. 7

I 18

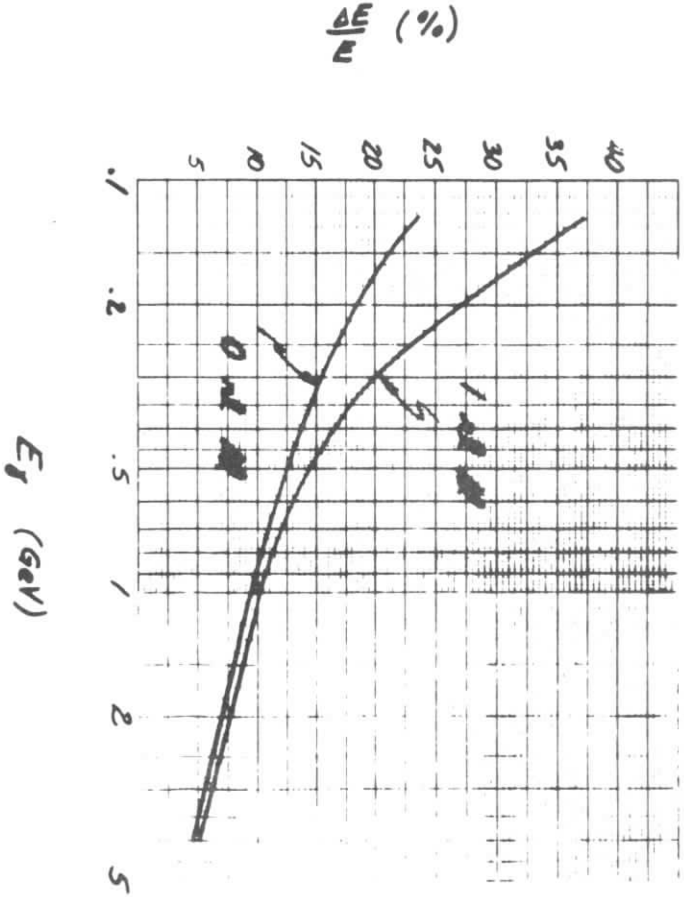


FIG. 12

I 19

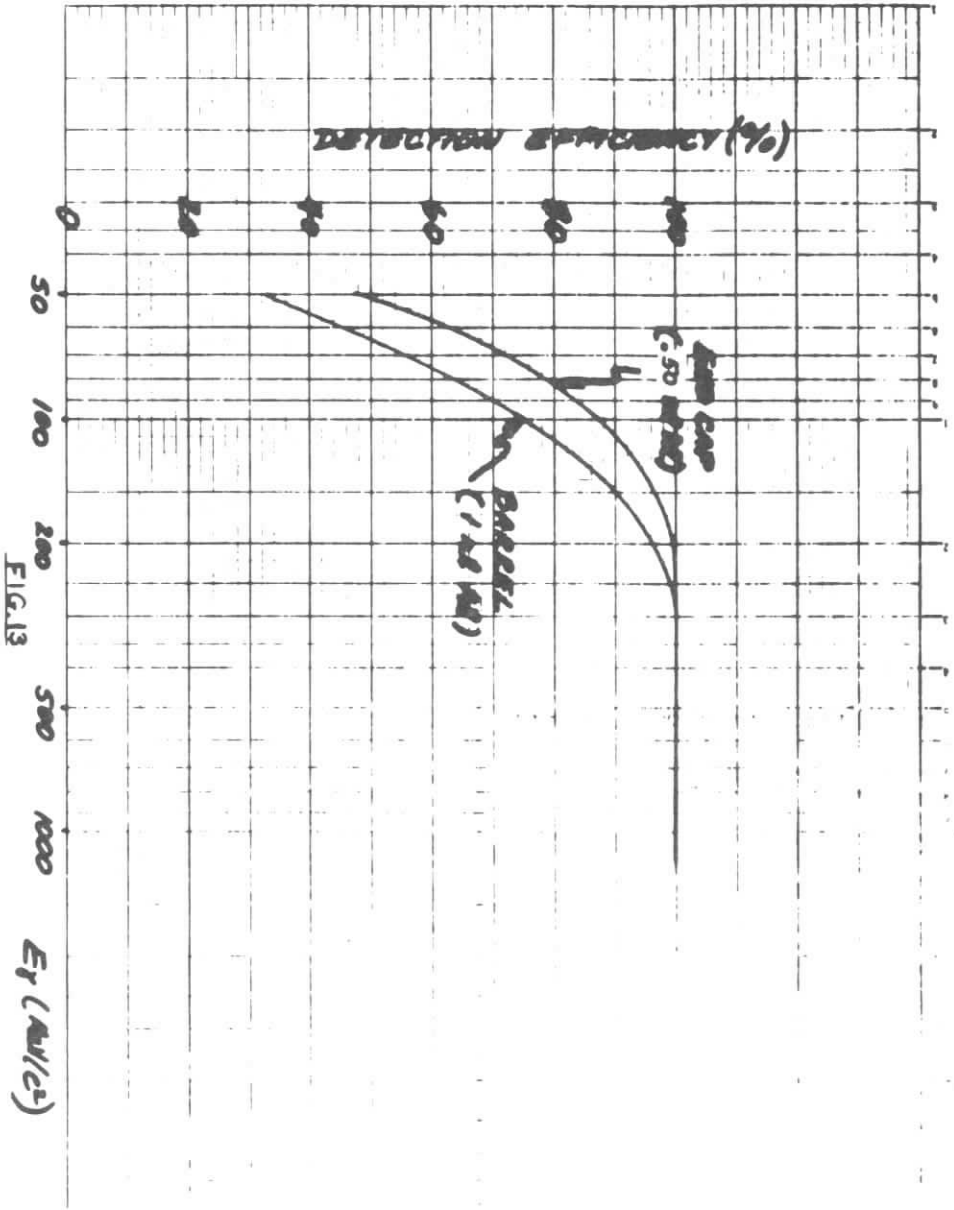


FIG. 13

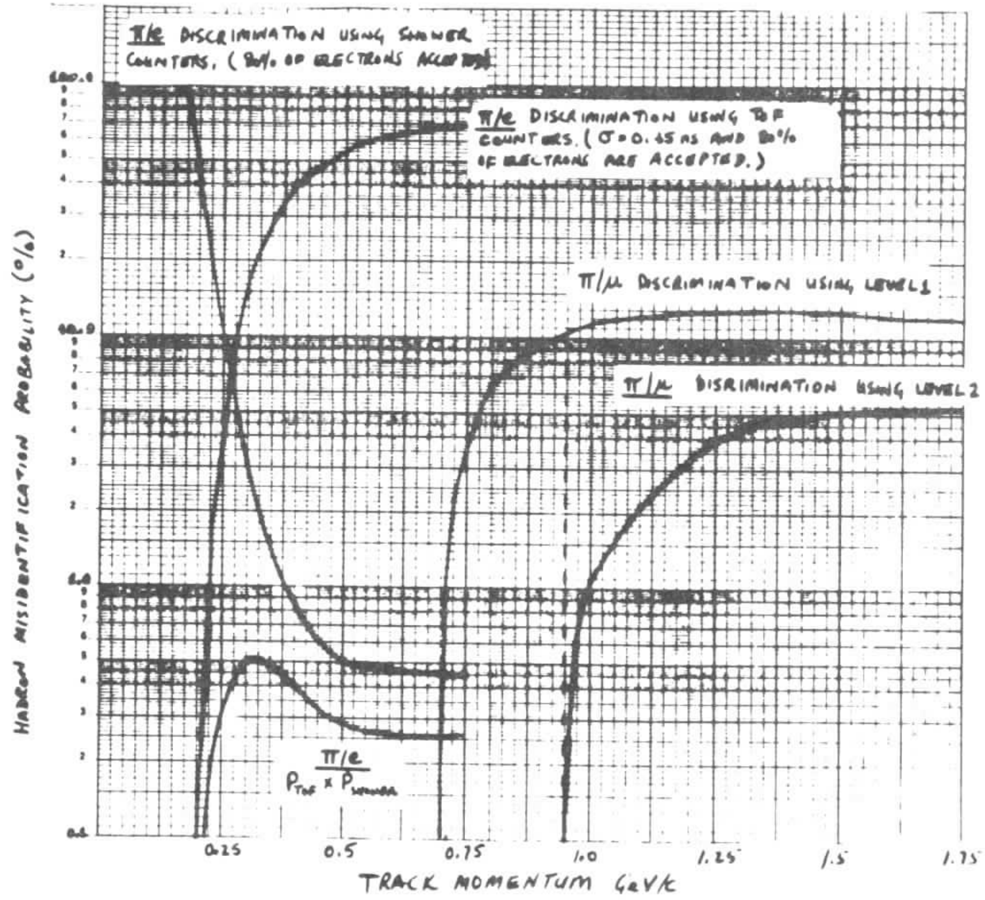
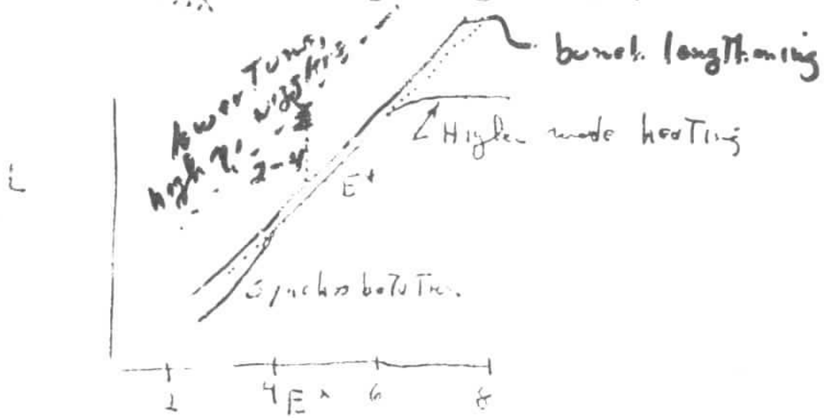


FIG 11.

Informal Workshop on SPR in 80s
25 & 26 July

Consider Machine
Phys Prog
New Detector

Emax ≈ 8.5 GeV cm.



I 22

Physics.

Charmed Meson, Baryon, τ

Decay modes

Spectroscopy.

Form Factors in wk decays

Detector Requirements

$\frac{\sigma_P}{P} \simeq$ Mk I $\approx$ 2x Mk II

Photon Det $\frac{\sigma_E}{E} \simeq 20\%/\sqrt{E}$ O.K. (2x M II)

eff - good low en eff reg (better than M II)

Photon position $\sigma \sim 1$ cm (5-10 mrad) Same as M II

I 23

Detector (cont)

K/π/P Sep   TOF $\sigma \sim 0.35$ ns (Same as M II)

e/π sep   ~1% π mis I.D.

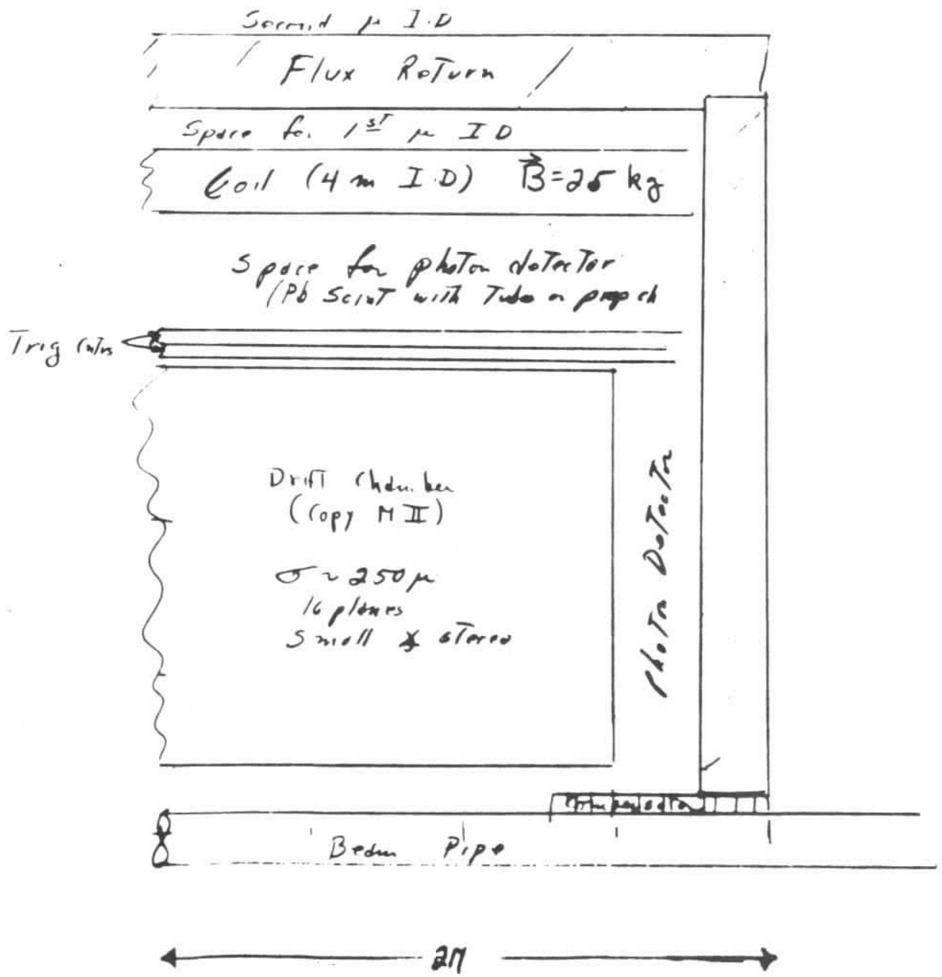
Mag power < ½ M II

K 1

J. Heintze

Jet chambers as Internal Detector for storage ring experiments

M III Schematic

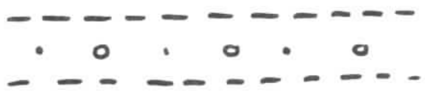


I. Jet chambers

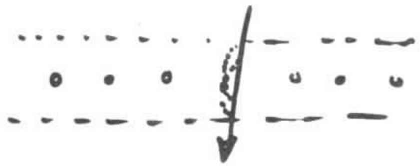
II. Drift chambers at high pressure
- space resolution
- mass resolution

III. Test results

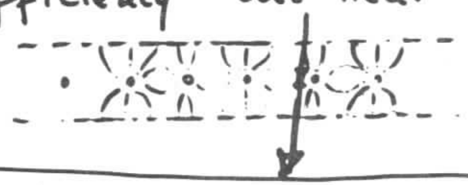
Possible sources of trouble in ordinary drift chambers:



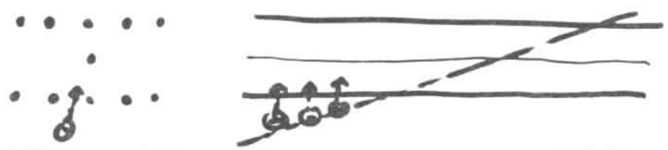
① Large drifttime differences near anode wire



② Efficiency loss near Pot. wire



③ Electrons leaking out of dead corners



④ Z - coordinates?
double track resolution?
t, z correlation?
track reconstruction?

I. Jet chambers

Ad ① + ②: Reduce the number of anode and potential wires

→ Large drift spaces

Ad ③ Eliminate dead corners

Ad ④: z coordinates by current division:

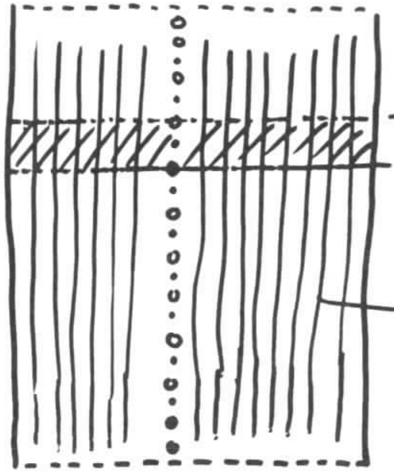
$$\frac{z}{\ell} = \frac{A_L - A_R}{A_L + A_R}$$

\+ Digitalisation of t, A_L, A_R for each hit using a multiple hit electronics

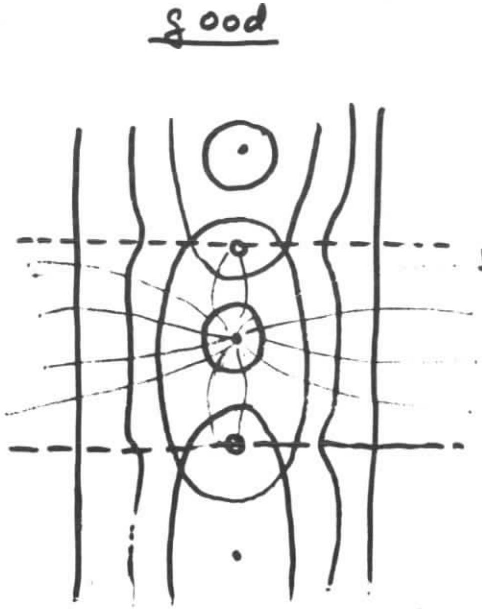
→ measure also
$A_L + A_R \sim \Delta E$

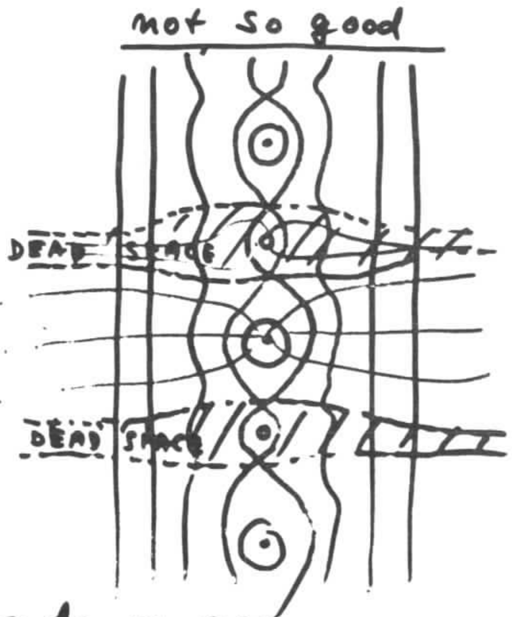
↷ $\frac{dE}{dx}$ [illegible]

Structure of a Jet chamber



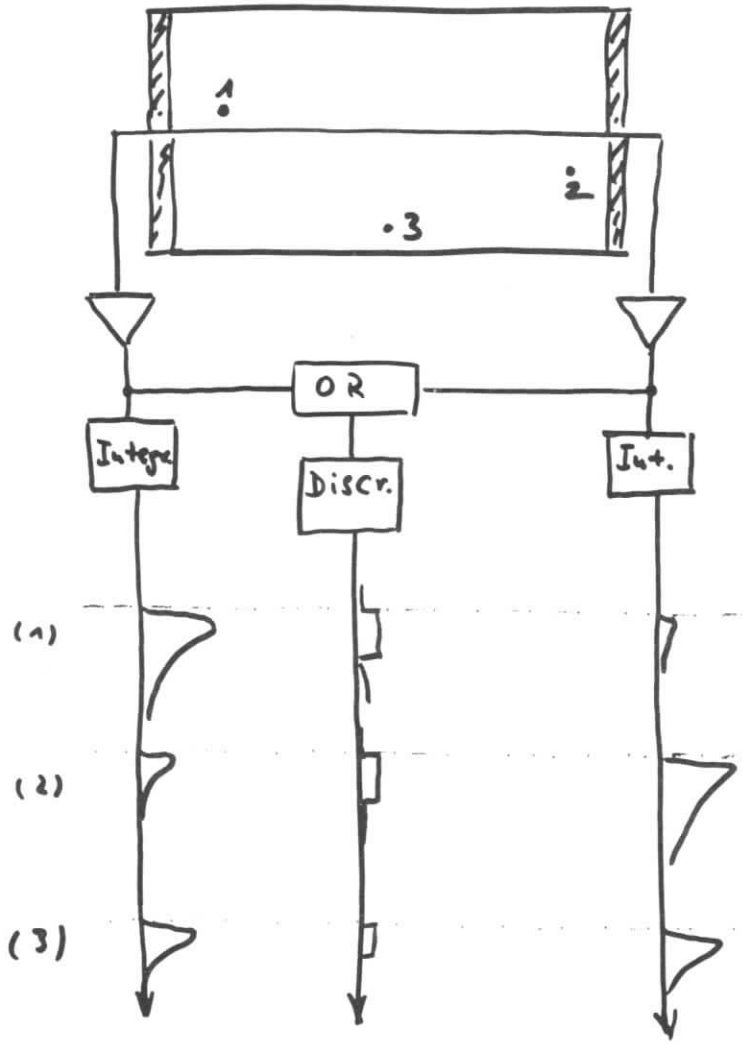
watch out for saddle points!





- situation depends on GAS

Read out of one wire:



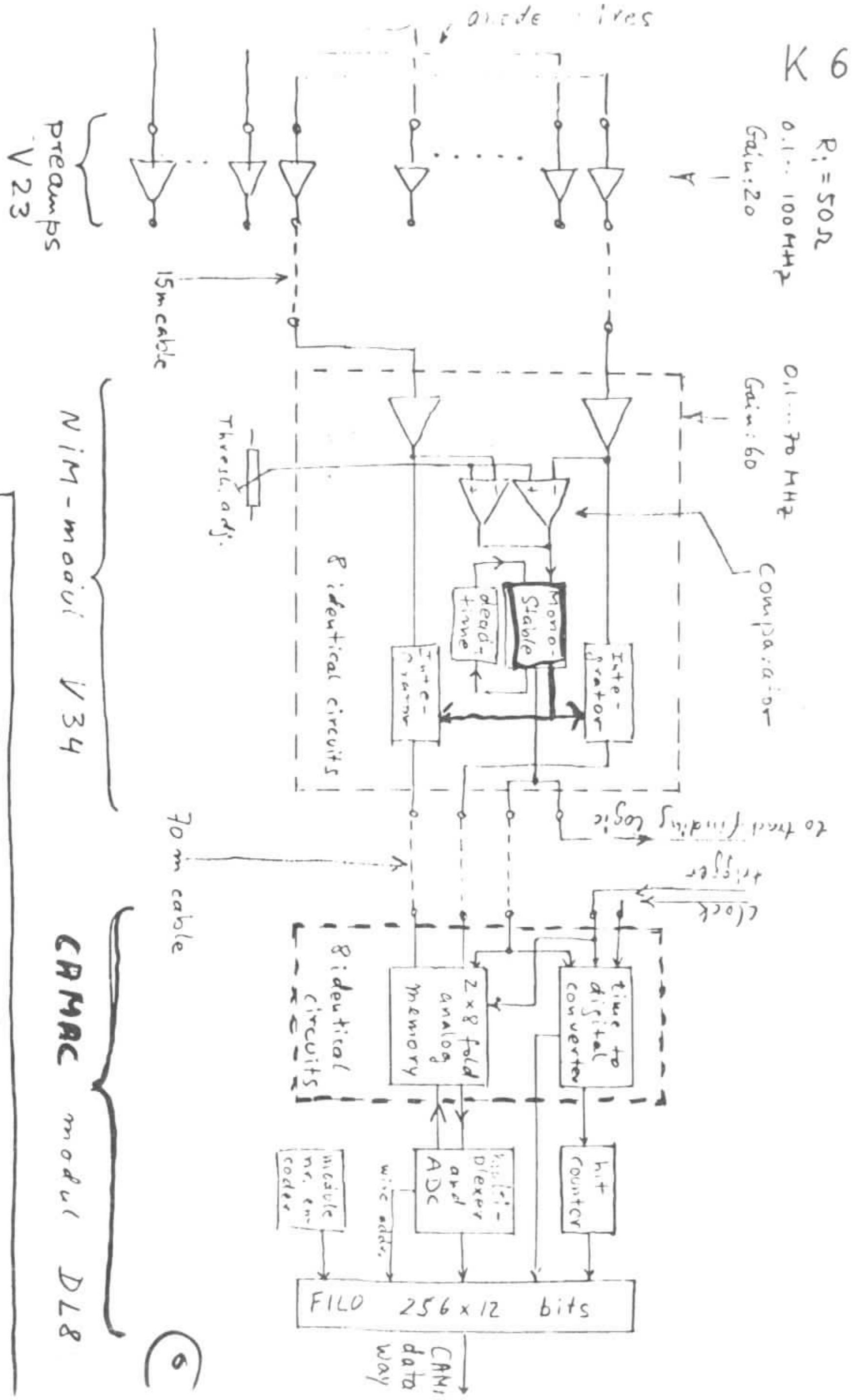
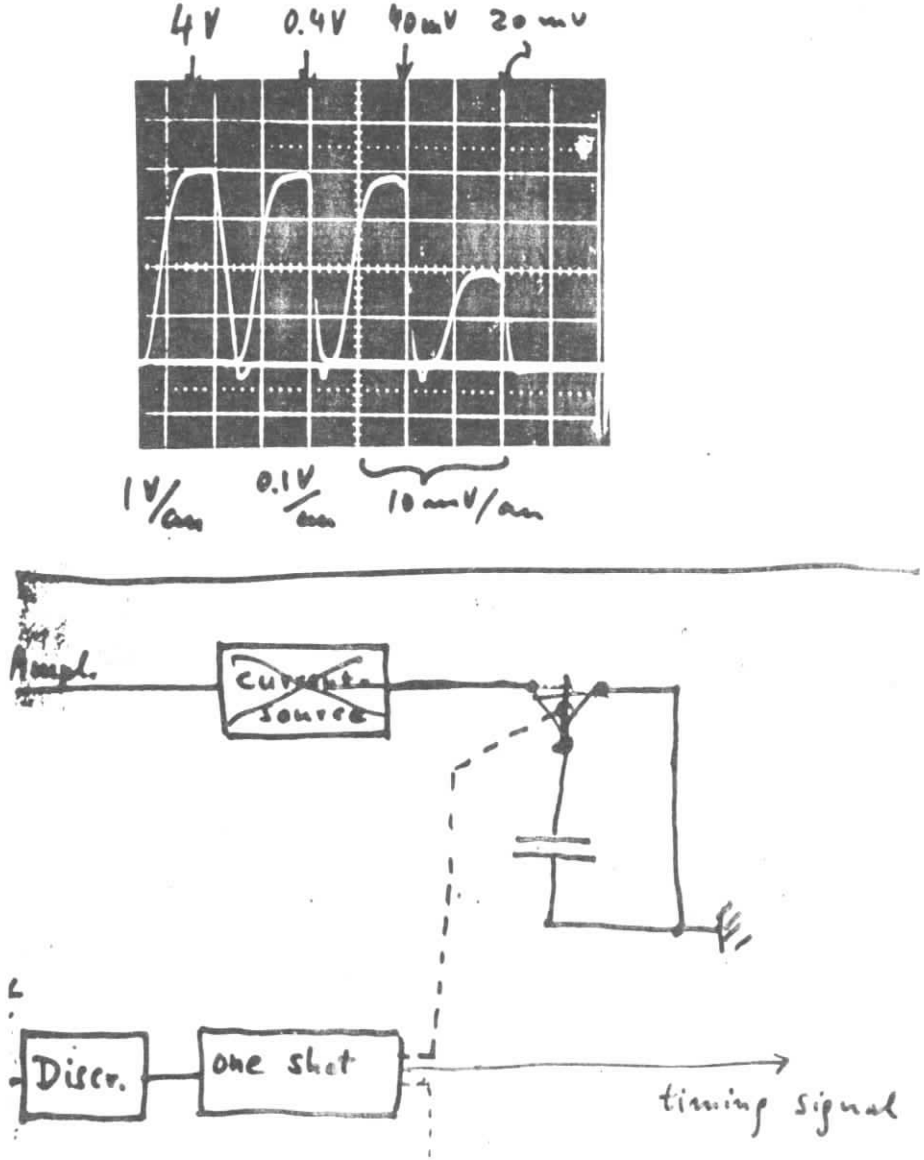
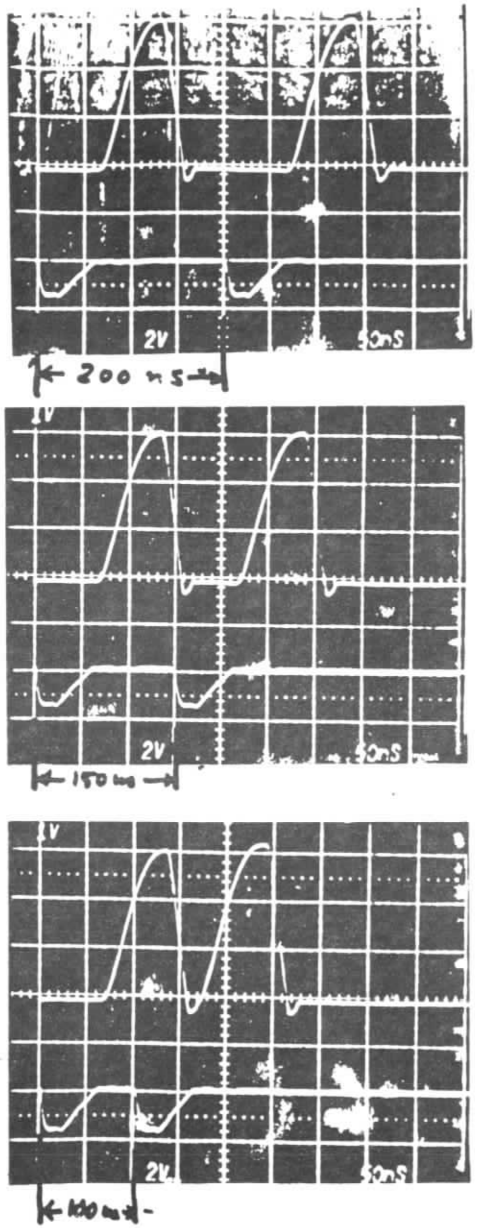


Fig. 2: Block diagram of jet chamber electron

Switchable Integrator K(+

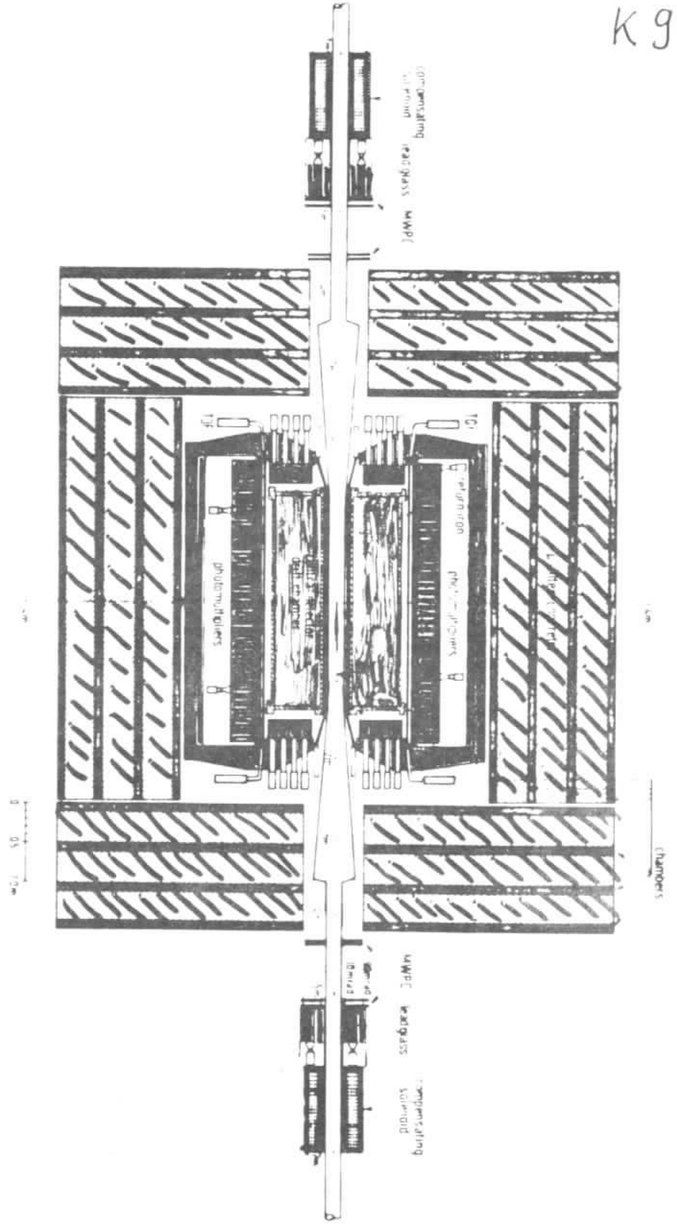


K18



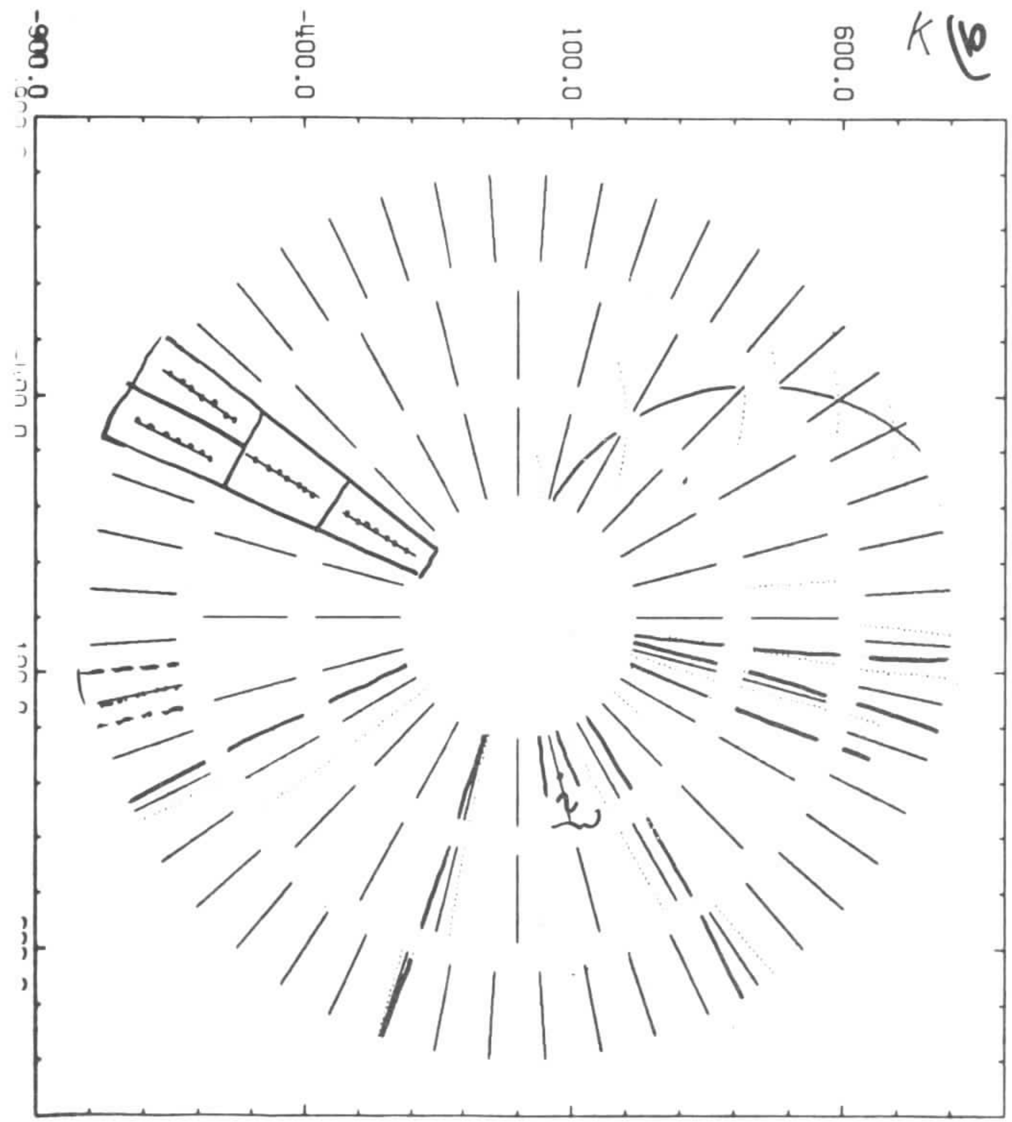
Double poulse resolution of Switchable Integrator.

K9



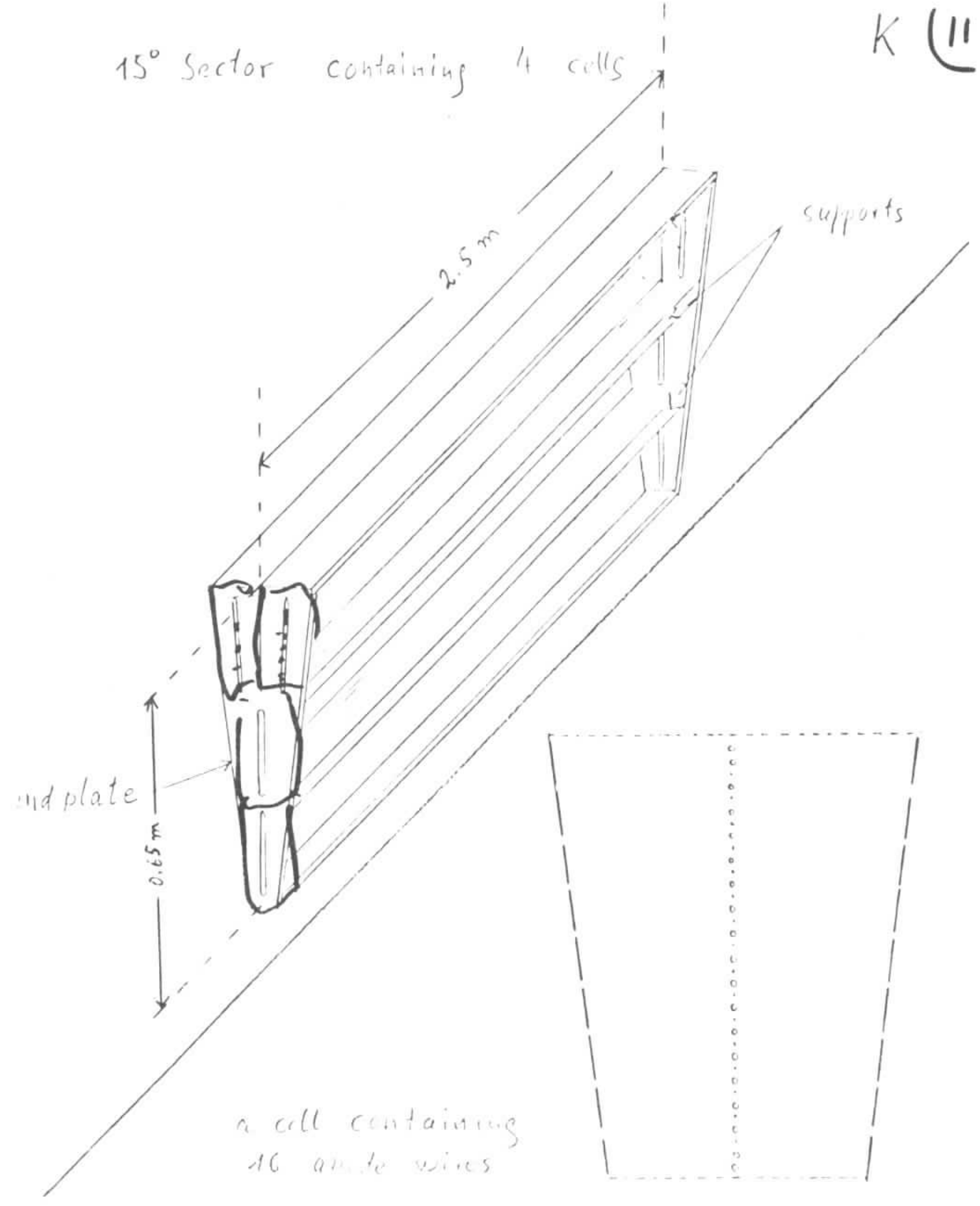
JADE

K (10



-900.0
-400.0
100.0
600.0

K (11



15° Sector containing 4 cells
2.5 m
supports
nd plate
0.65 m
a cell containing
16 anode wires

Fig 1

II. Drift chambers at high pressure K 13

Factors affecting the space resolution in drift chambers:

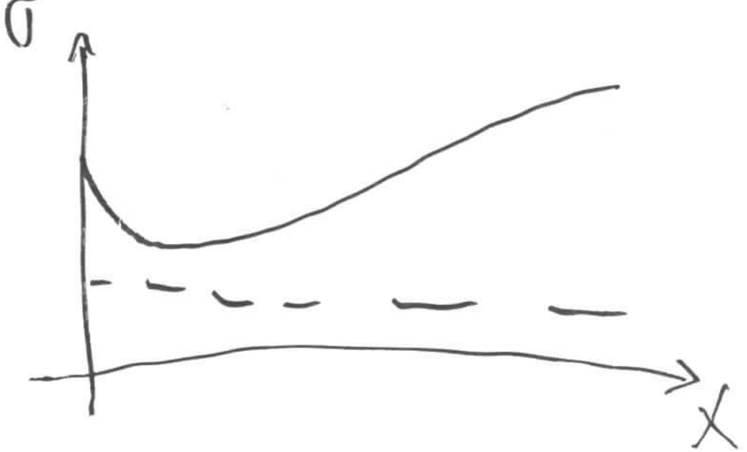
(1) Electron diffusion

(2) Fluctuations of primary ionisation density

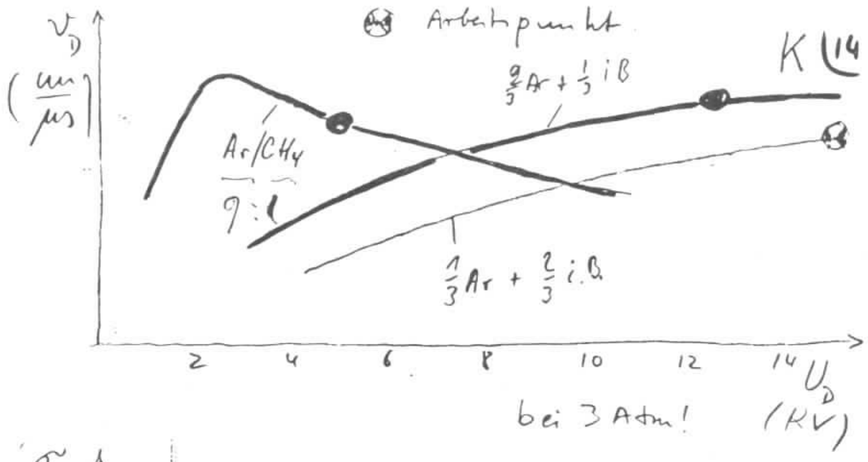
(3) Range of δ-rays

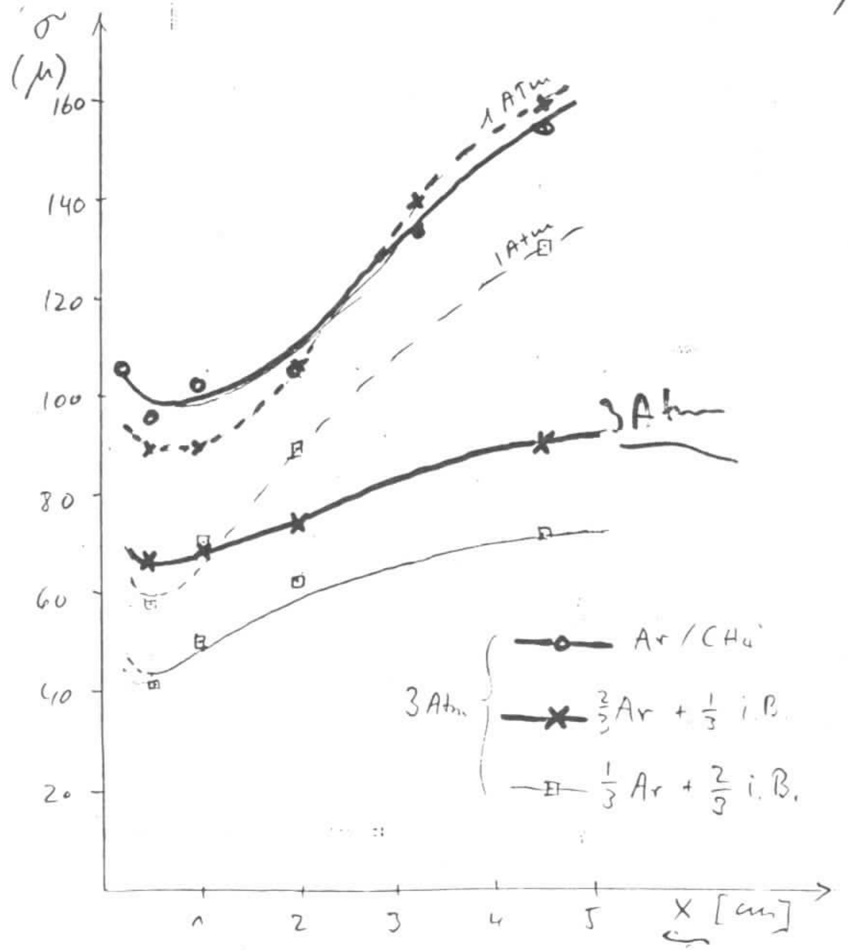
(4) Accuracy of drift time measurement

(5) Uncontrolled variations of drift velocity

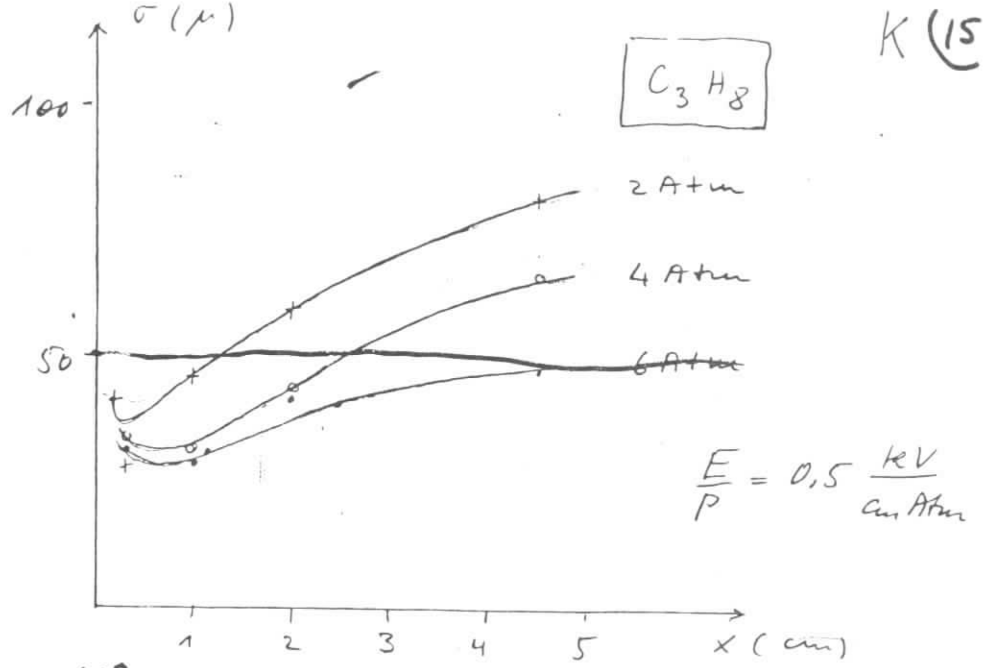


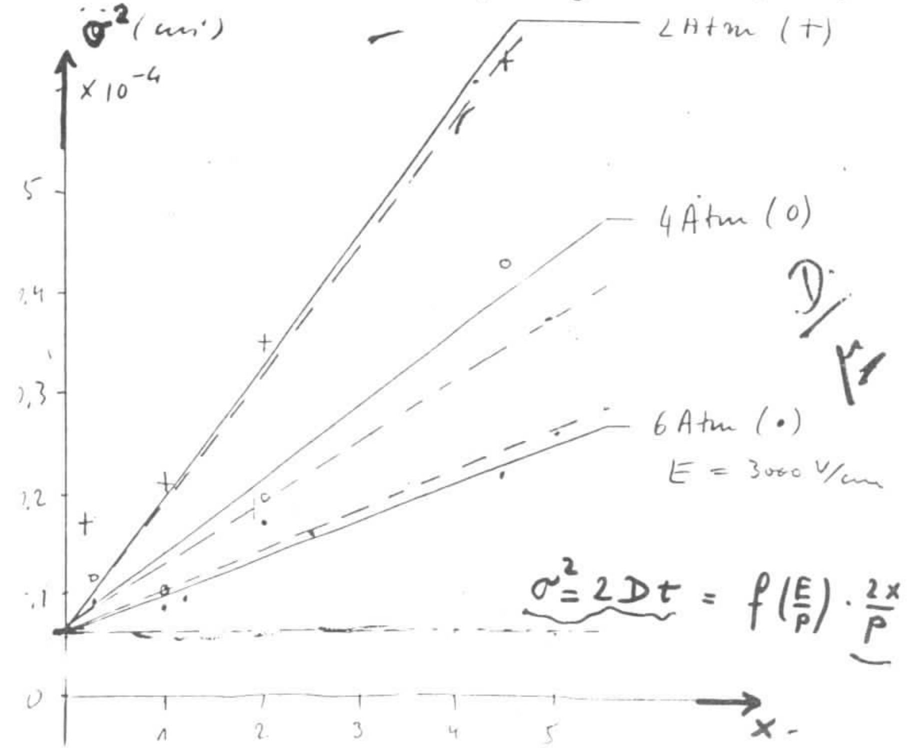
K 14





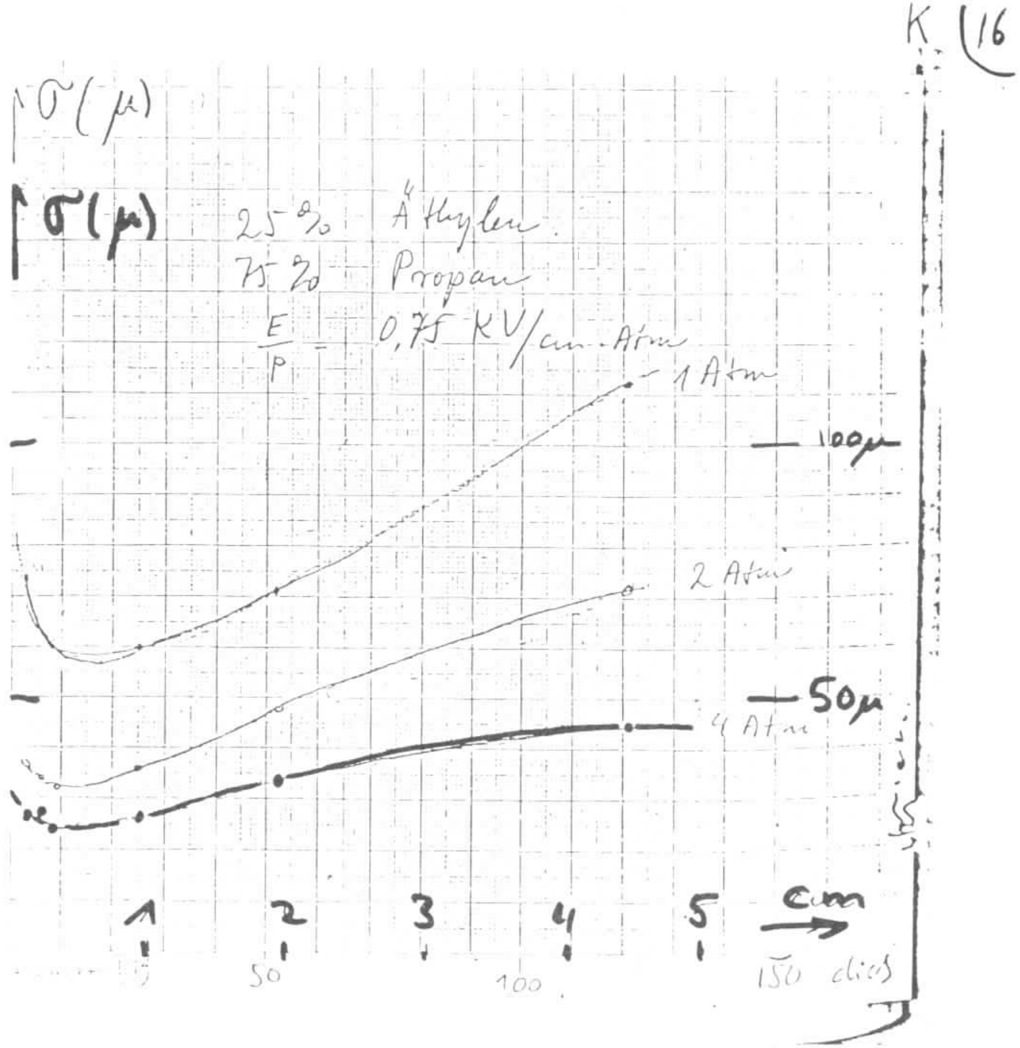
K 15

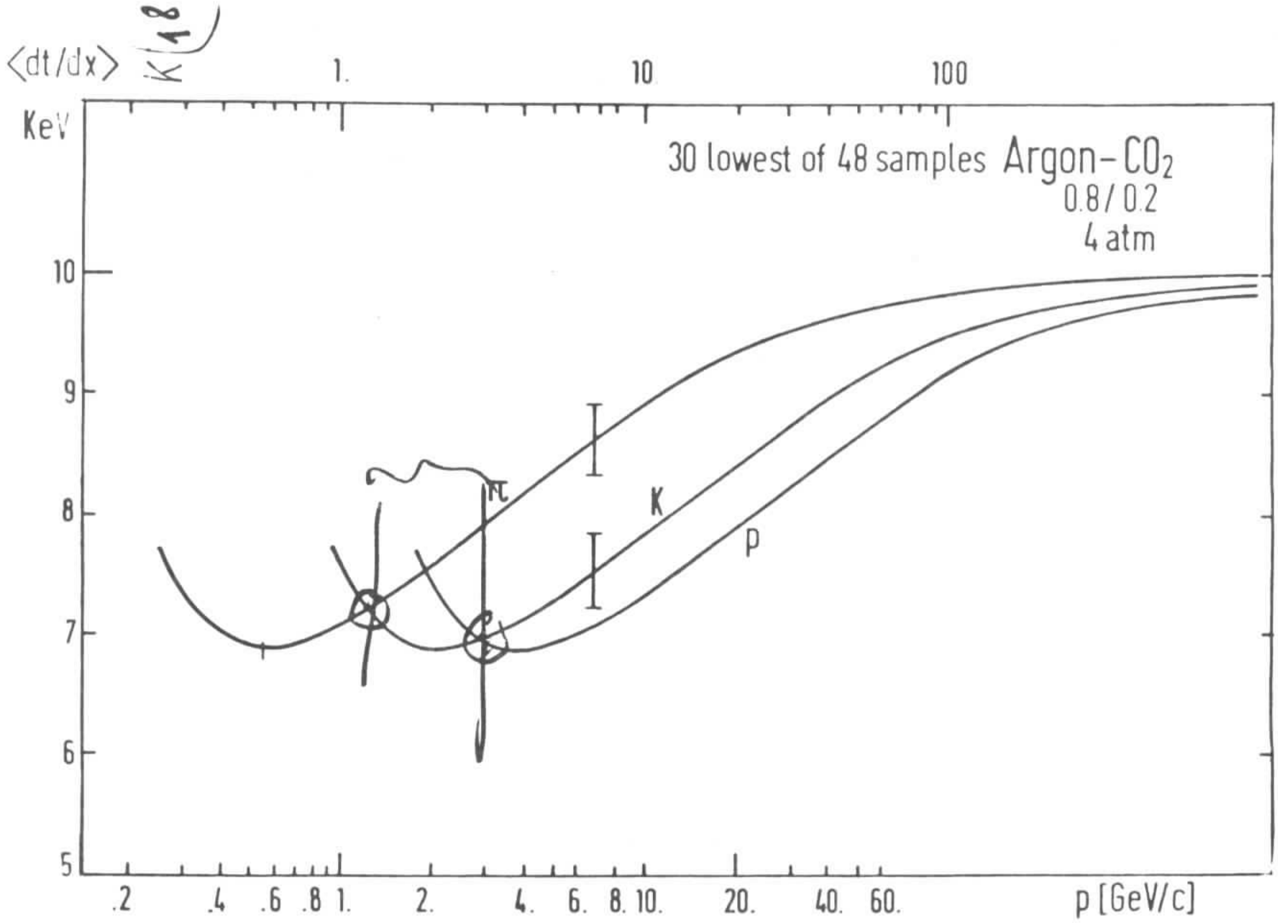




$$\sigma^2 = 2Dt = f\left(\frac{E}{p}\right) \cdot \frac{2x}{p}$$

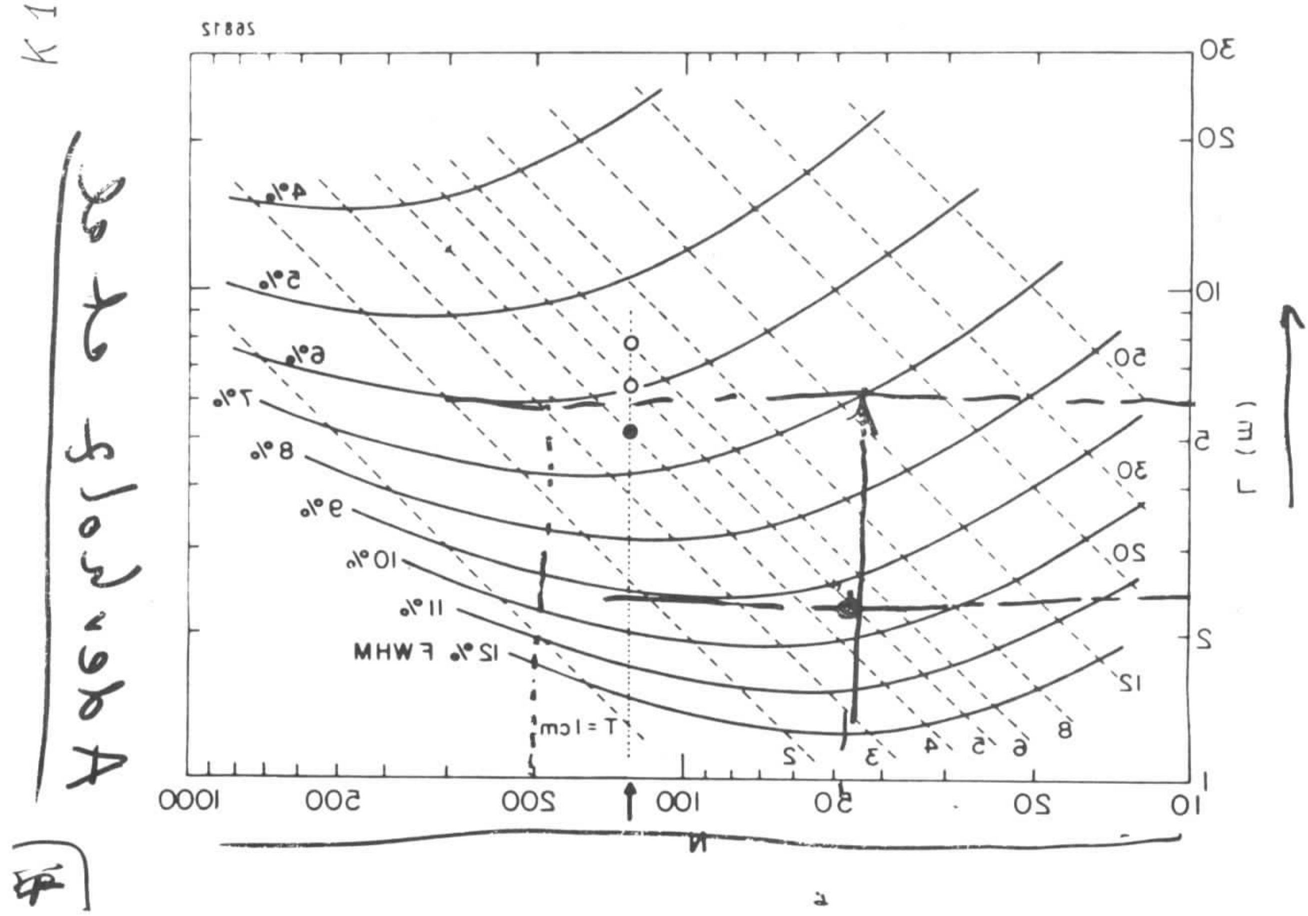
K 16



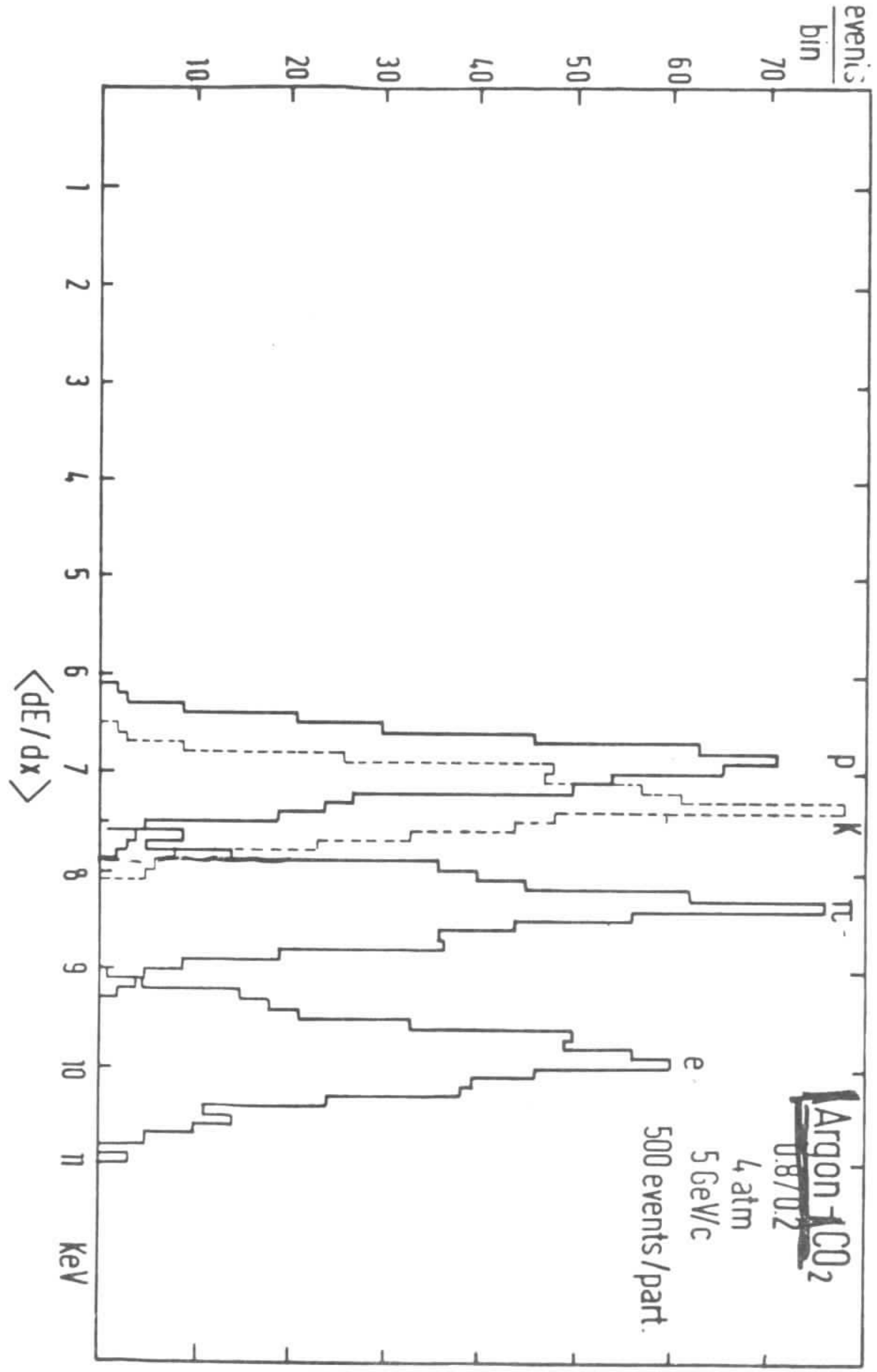


K 18
⟨dt/dx⟩
KeV
30 lowest of 48 samples Argon-CO_2
0.8/0.2
4 atm
π
K
p
p [GeV/c]

K 17



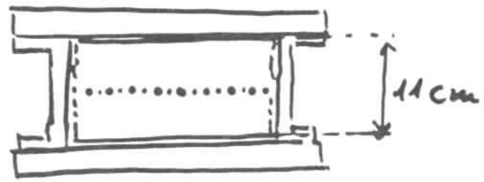
K 19



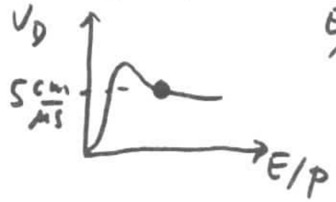
K 20

III. Test Results

Test chamber:



- 16 anode wires, 2.4 m long (20μ φ W, 300 Ω/m)
- Gas: 4 Atm Ar/CH_4 (9:1)
- Drift field: E = 1000 V/cm

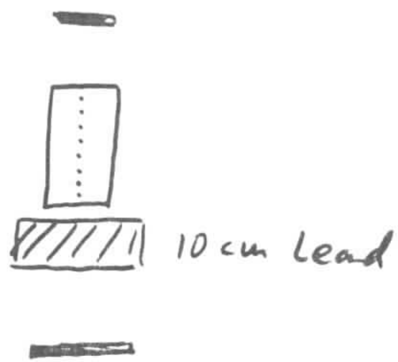


$E/p = 0.33 \frac{V}{cm \cdot torr}$

- Gas Amplification **$m = 3 \cdot 10^4$**

drift time measurement:

1 time bin ≙ 300 μm



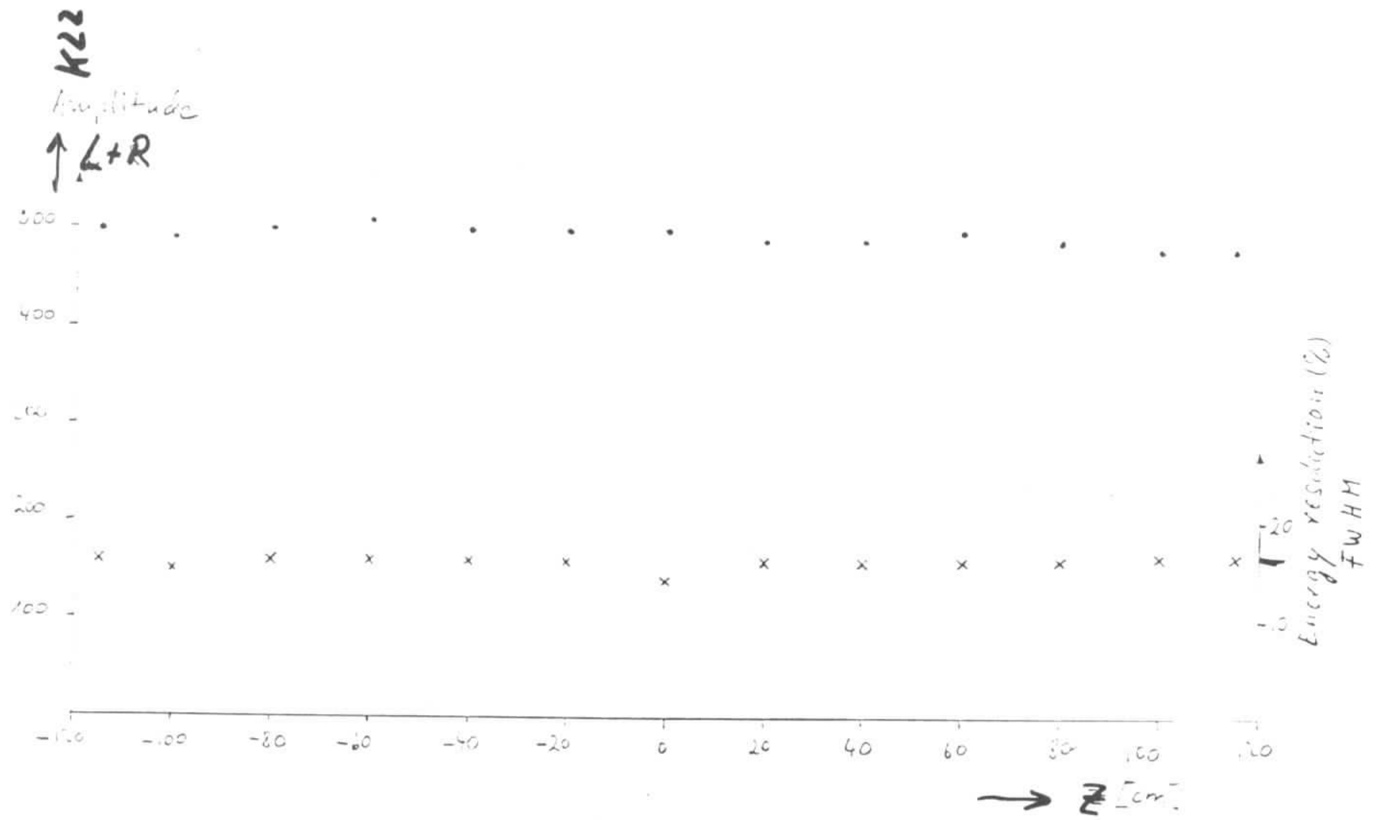


Fig 5 Testchamber: Amplitude and Energy resolution (6.0 keV X-rays)

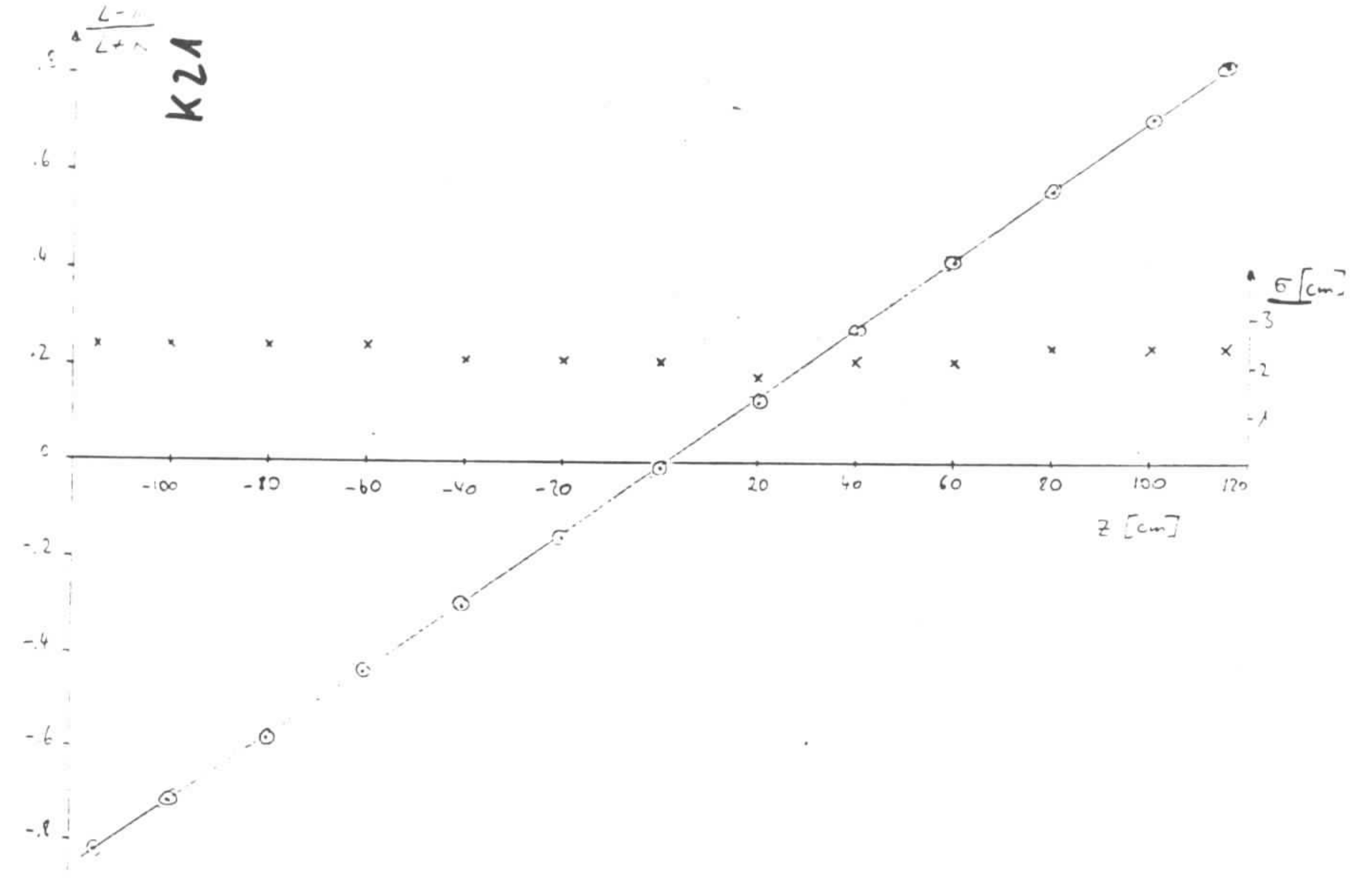


Fig 6 Testchamber: Determination of z-coordinate linearity and resolution

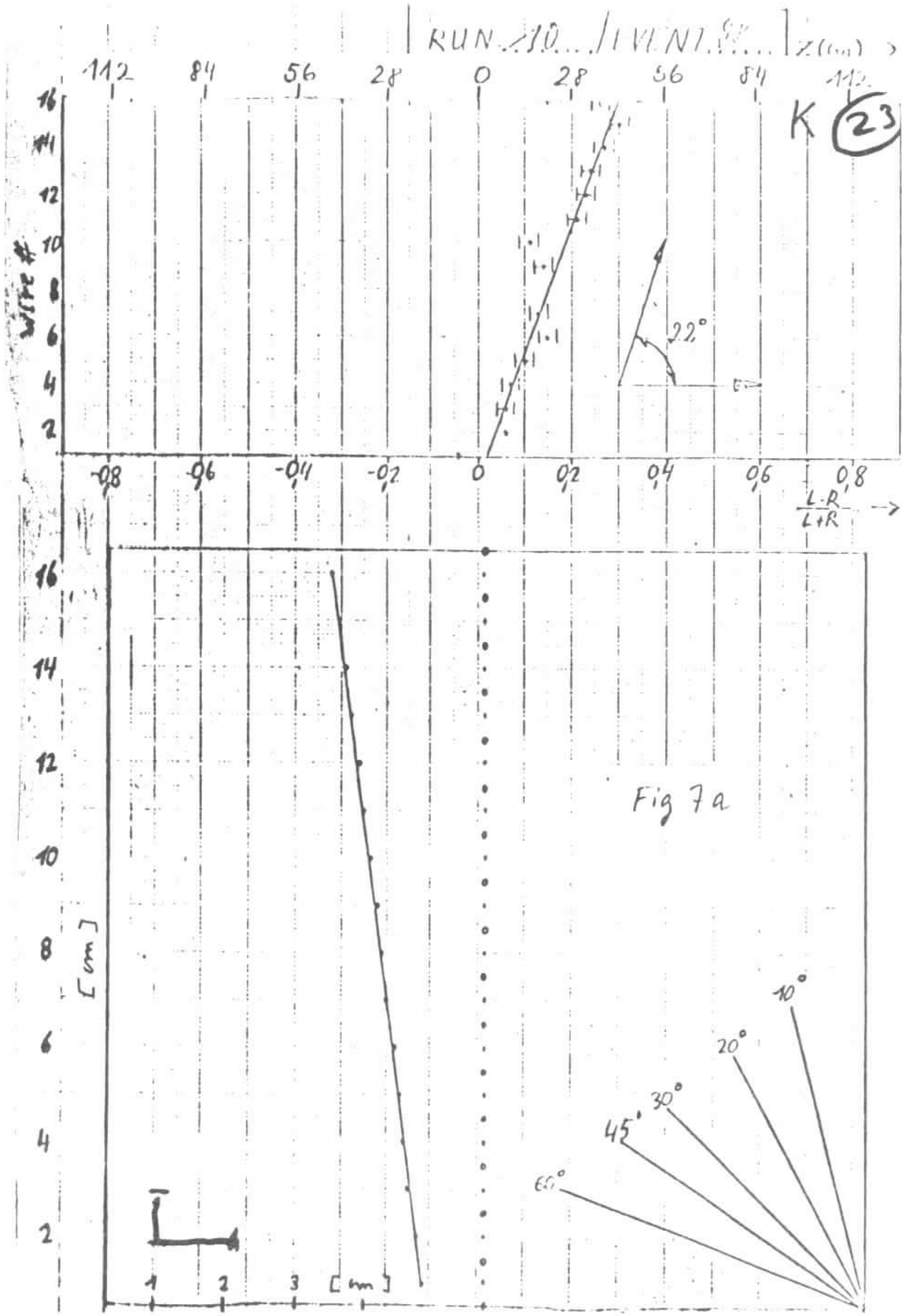

K 23
RUN 10
z (cm)
112 84 56 28 0 28 56 84 112
wire #
22°
-0,8 -0,6 -0,4 -0,2 0 0,2 0,4 0,6 0,8
(L-R)/(L+R)
[cm]
1 2 3 [cm]
10° 20° 30° 45° 60°

Fig 7a

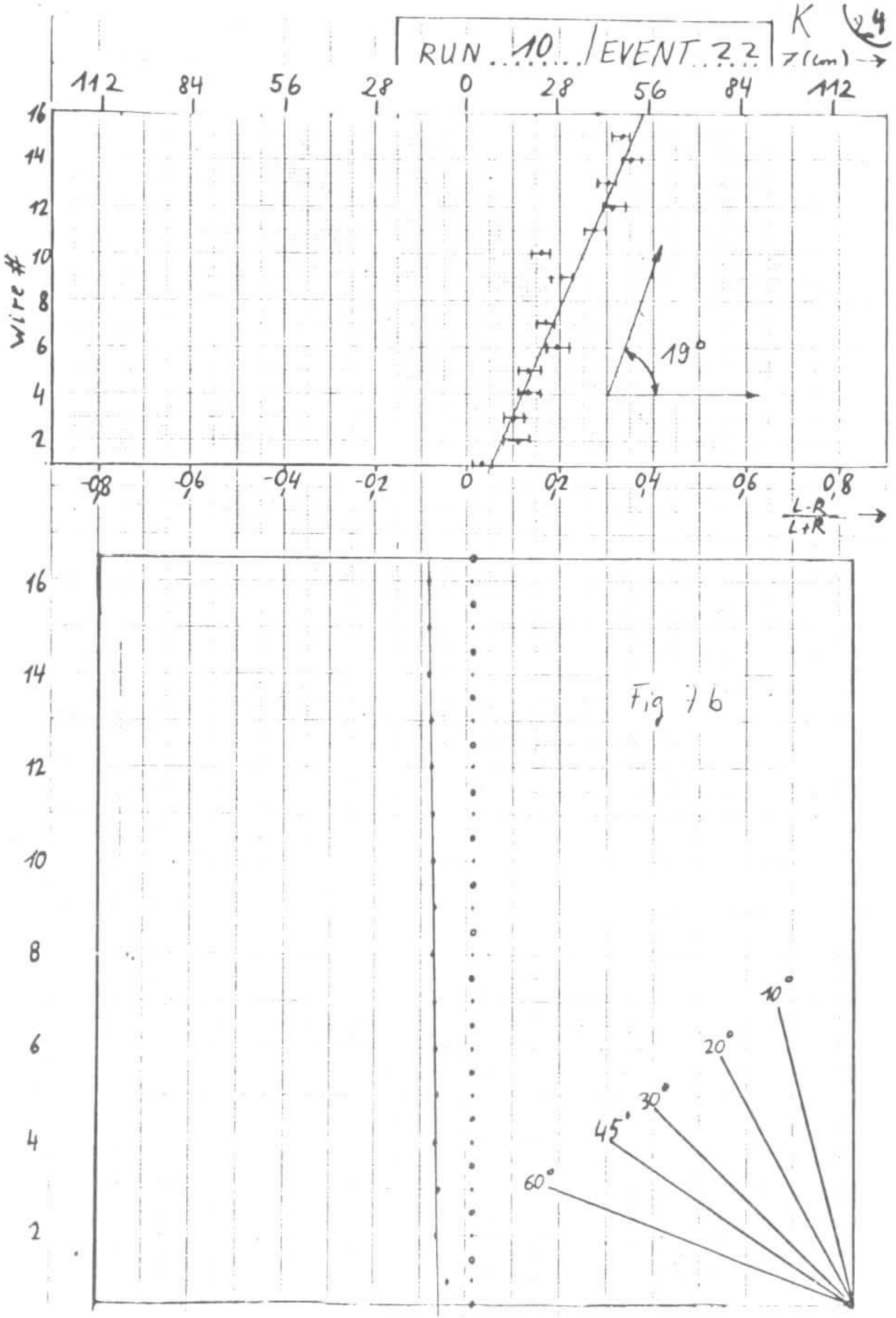
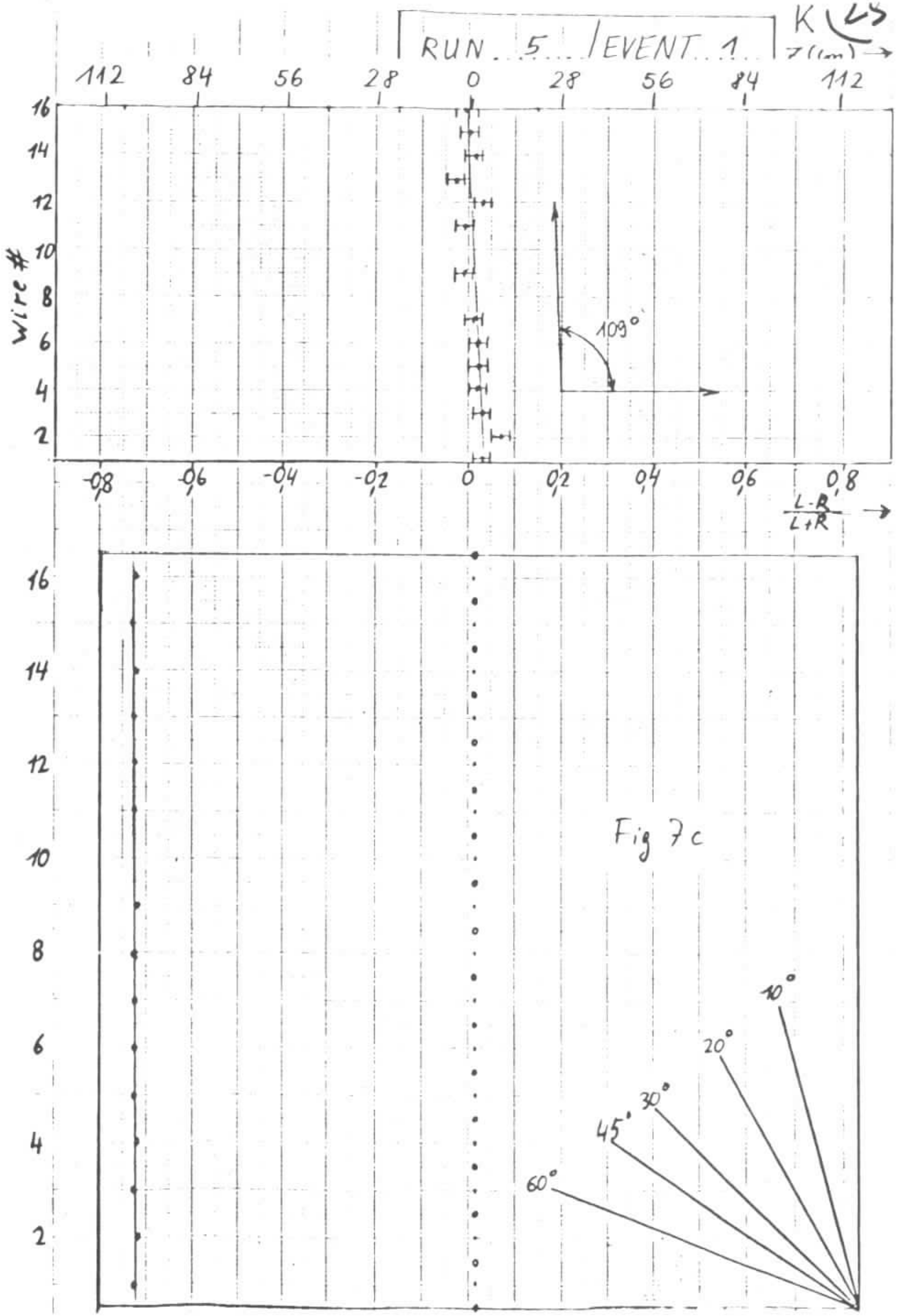
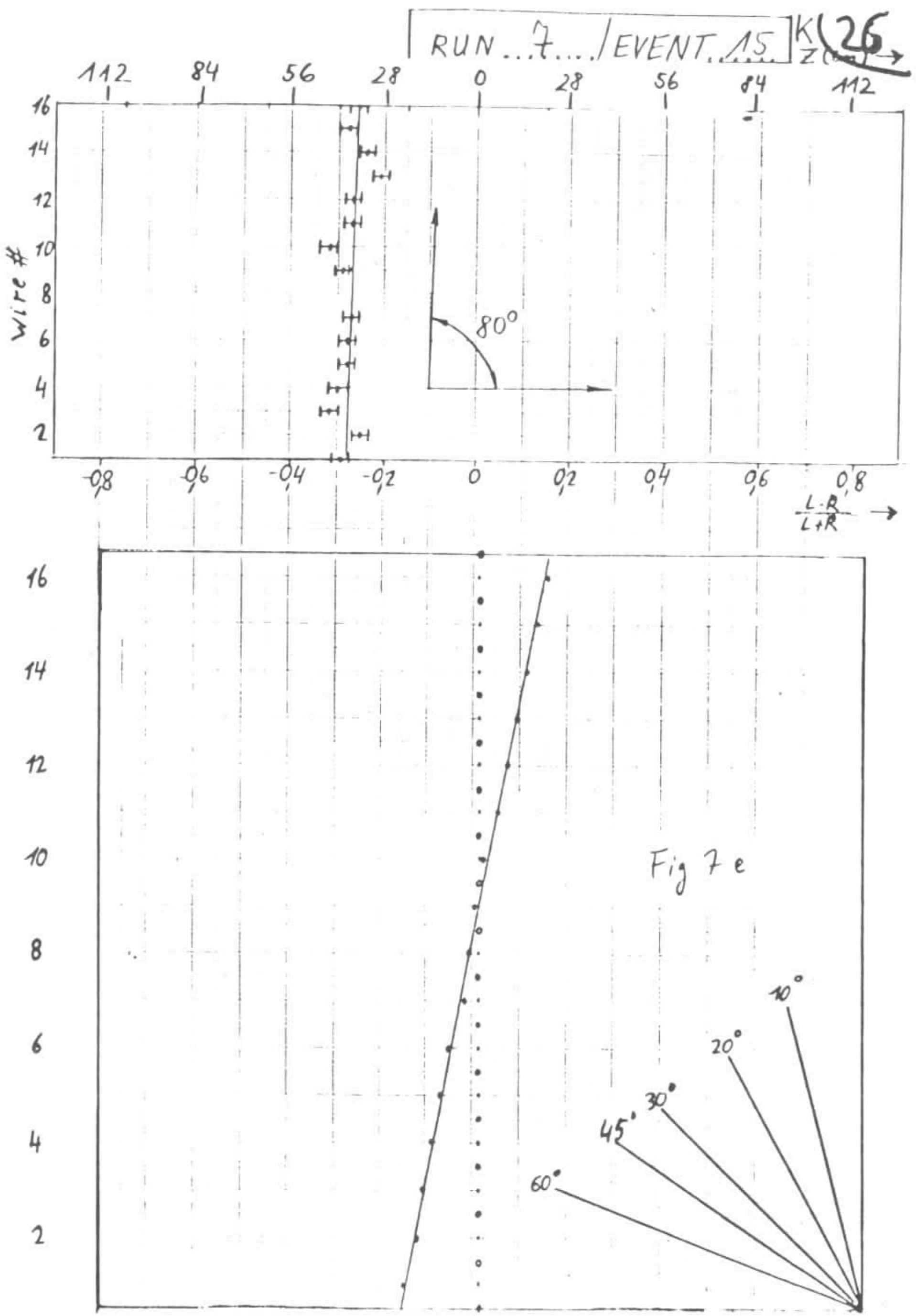

K 24
RUN 10 EVENT 22
z (cm)
112 84 56 28 0 28 56 84 112
wire #
19°
-0,8 -0,6 -0,4 -0,2 0 0,2 0,4 0,6 0,8
(L-R)/(L+R)
10° 20° 30° 45° 60°

Fig 7b



RUN 5 / EVENT 1
K 25
z (cm)
wire #
109°
L-R / L+R
Fig 7c
10°
20°
30°
45°
60°



RUN 7 / EVENT 15
K 26
z (cm)
wire #
80°
L-R / L+R
Fig 7e
10°
20°
30°
45°
60°

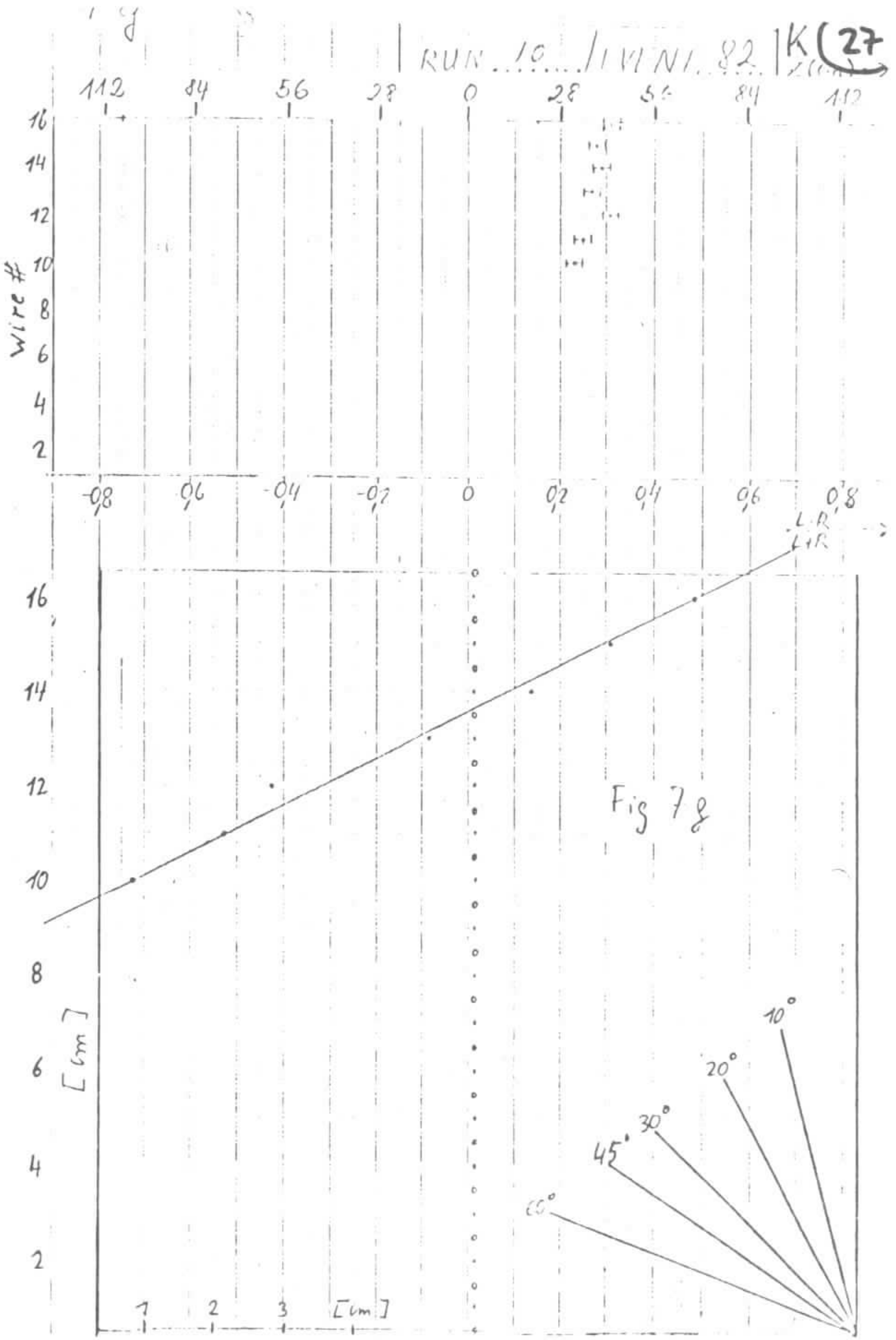


Fig 7g

K 28

summary of jet-chamber test results.

item	threshold [mV] 2	3	6	9
inefficiency	$< 10^{-3}$	$< 10^{-3}$	$\sim 10^{-3}$	$3 \cdot 10^{-2}$
displaced signals		$\sim 4 \cdot 10^{-3}$		
after pulses	$5 \cdot 10^{-3}$	~ 0		
rms displacement from straight line	120 μm			
double pulse resolution	5 mm			

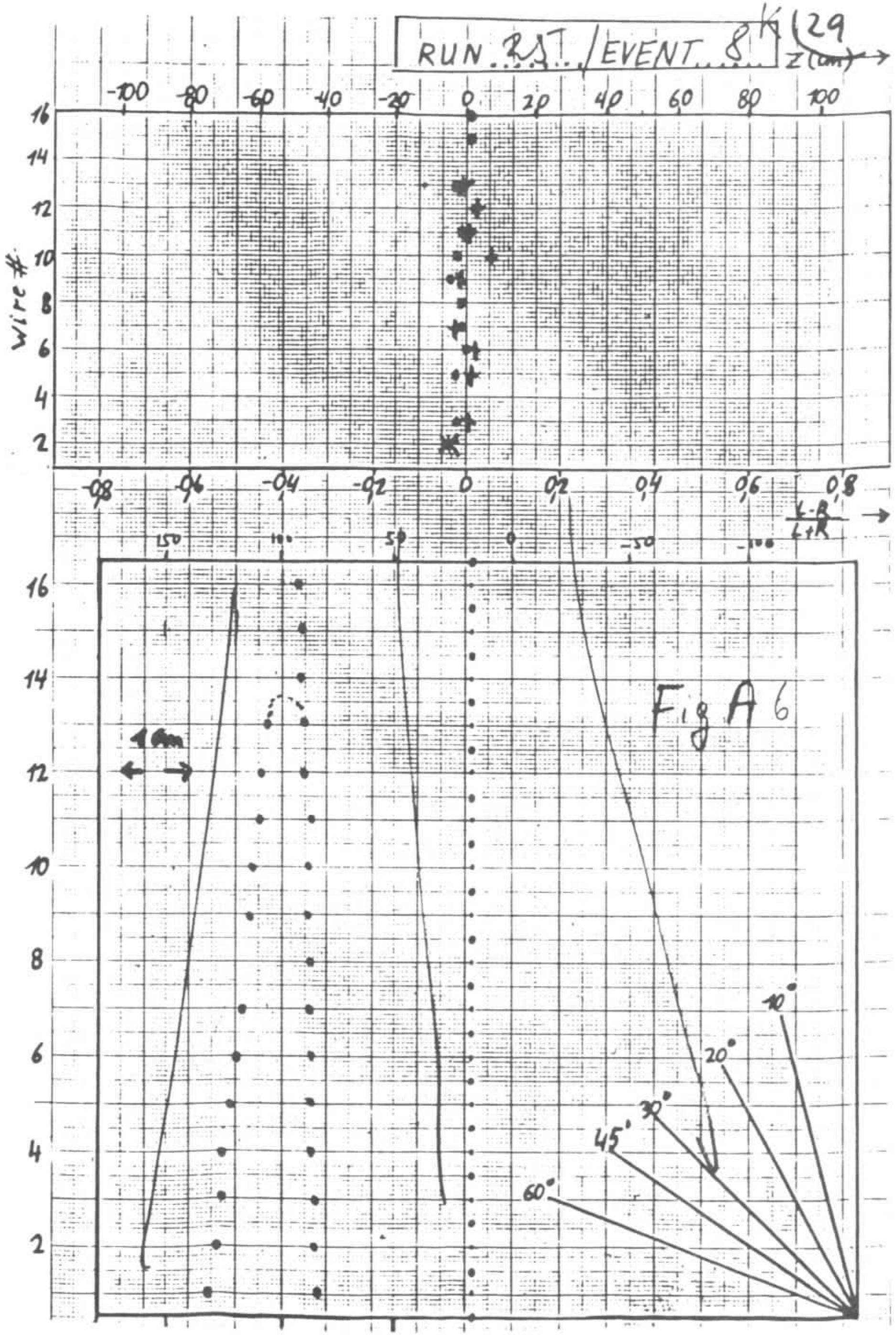
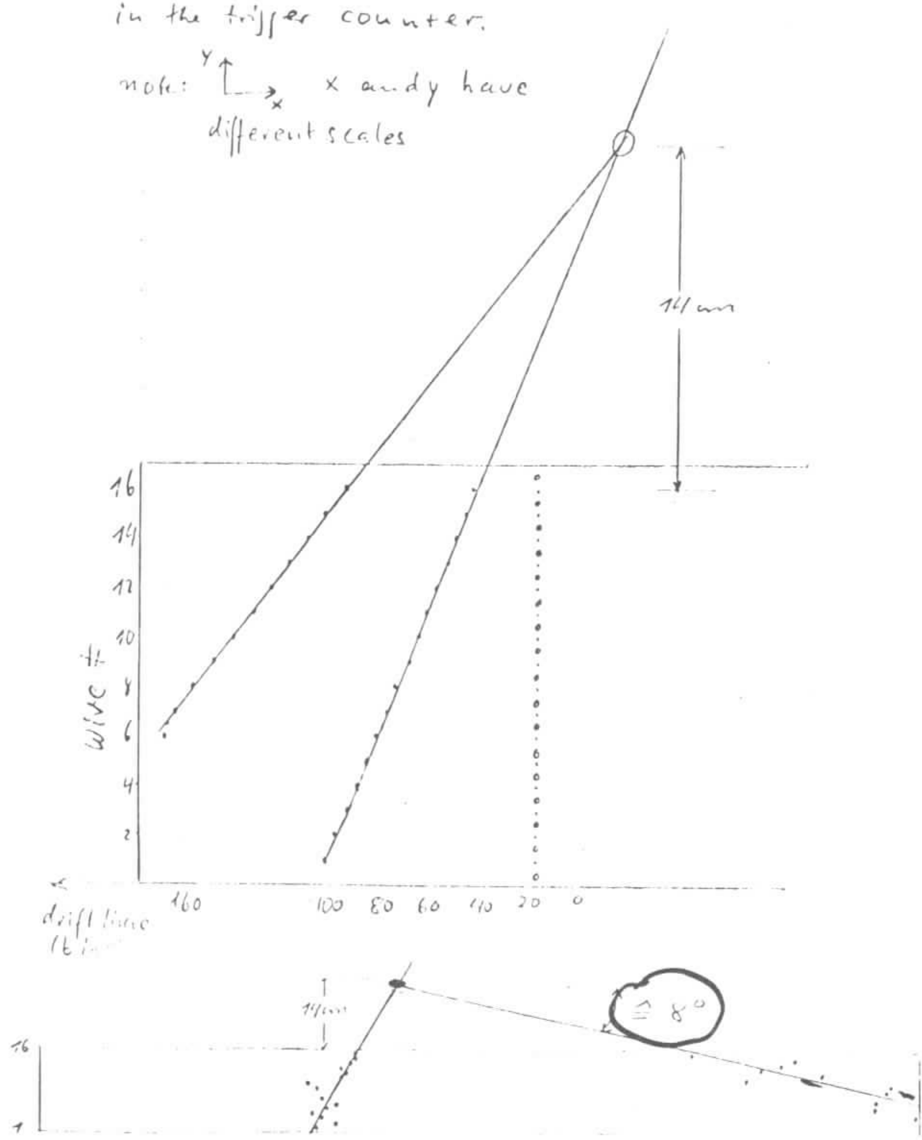


Fig A6

Fig 7h

Event with nuclear reaction in the trigger counter.

note: x and y have different scales



wire staggering K(3

$\delta = 0$

$$t_i = A \cdot i + B$$

$\delta \neq 0$

$$t_i\,(\text{odd}) = A i + B + \delta$$

$$t_i\,(\text{even}) = A i + B - \delta$$

$$\Delta_S = \frac{\sum t(\text{odd})}{n_{odd}} - \frac{\sum t(\text{ev})}{n_{ev.}} + A = 2\delta$$

Aim: make δ as small as possible

a) No pattern recognition trouble

b) No trouble with additional electrostatic wire deflection ($\sim \delta$)

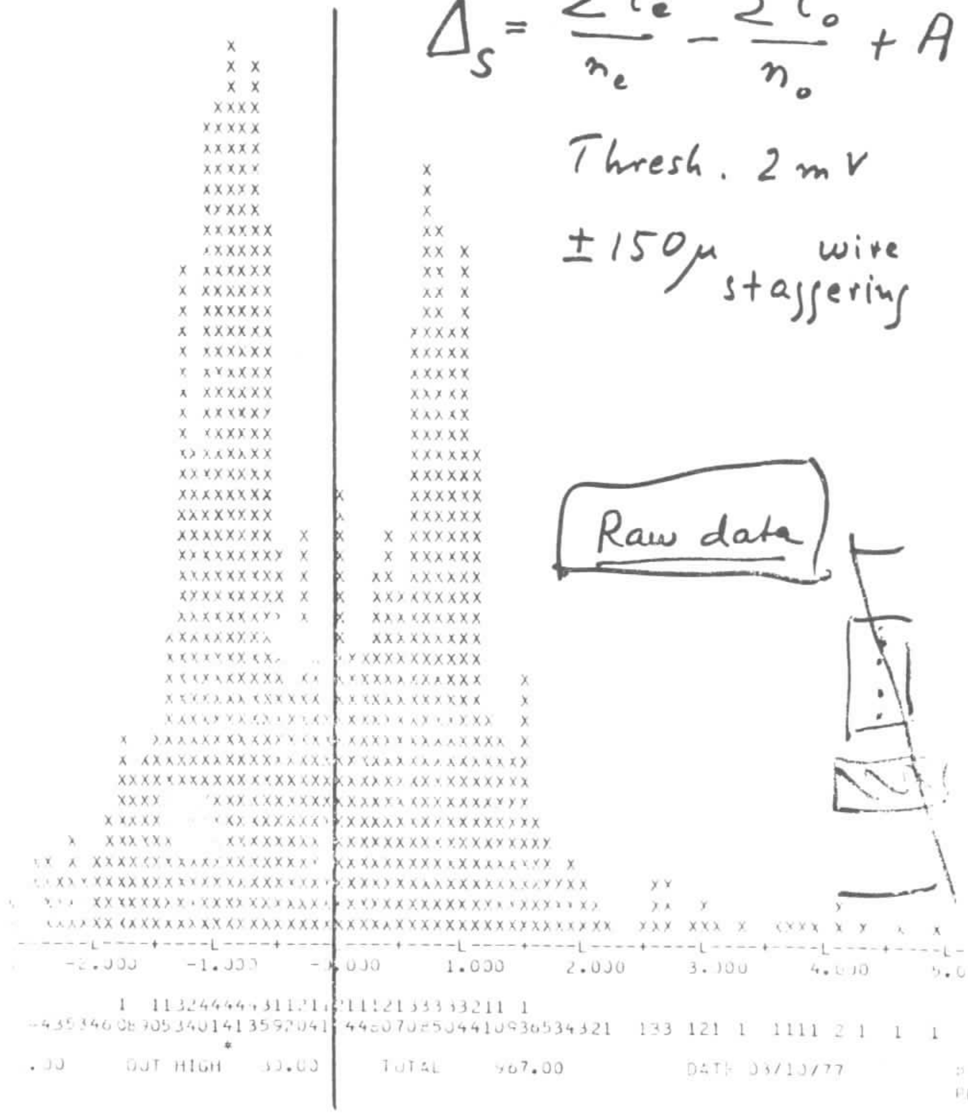
K(32

$$\Delta_S = \frac{\sum t_e}{n_e} - \frac{\sum t_o}{n_o} + A$$

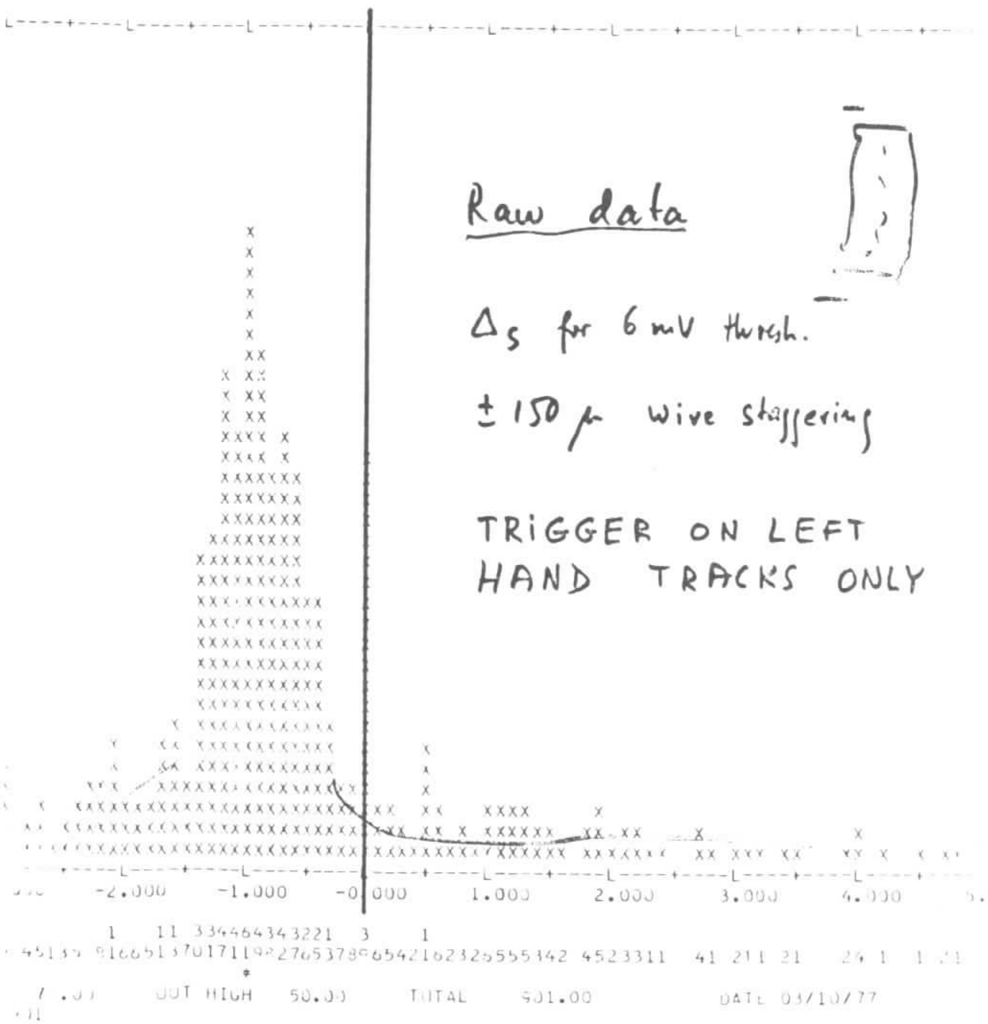
Thresh. 2 mV

±150μ wire staggering

Raw data

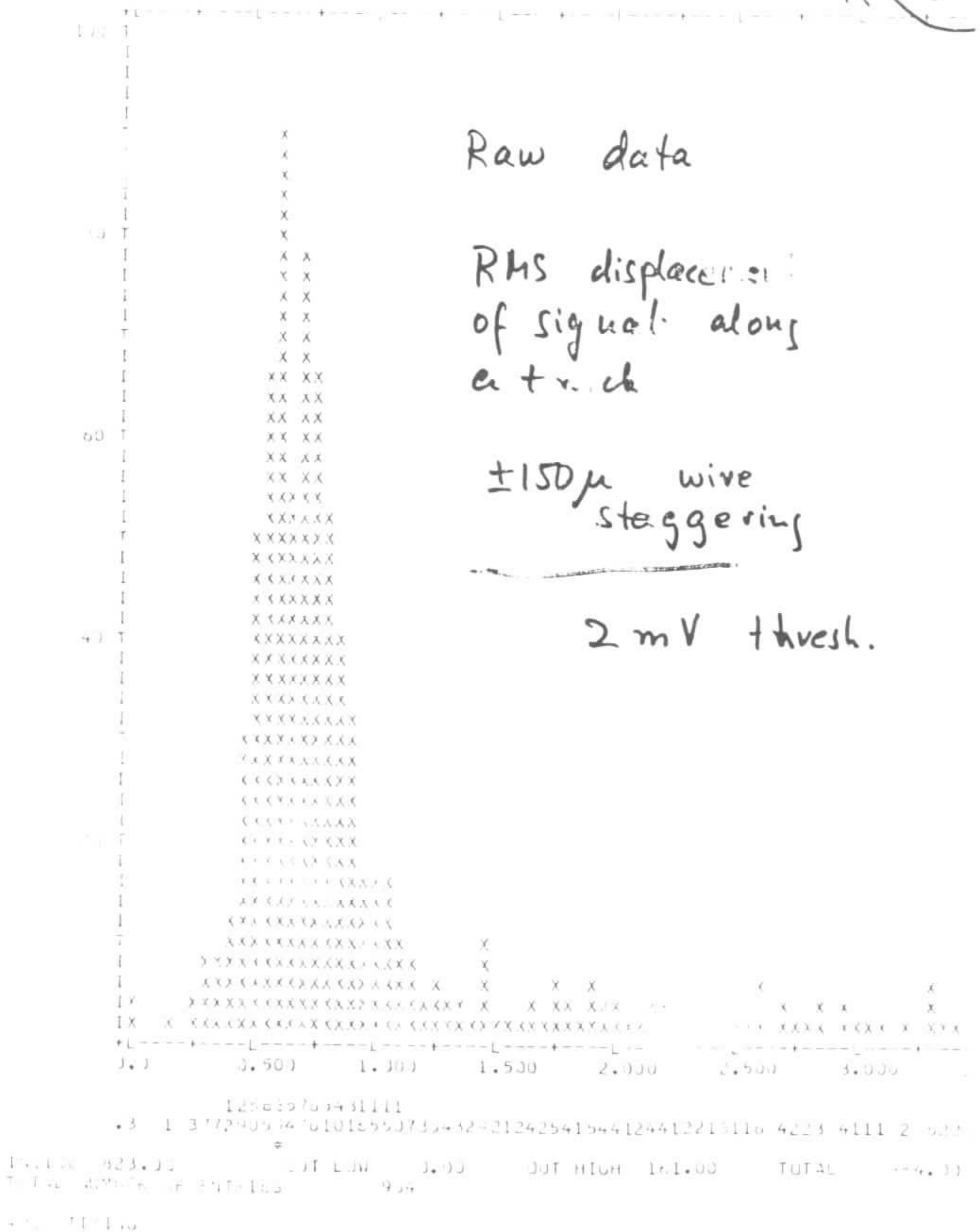


K(33



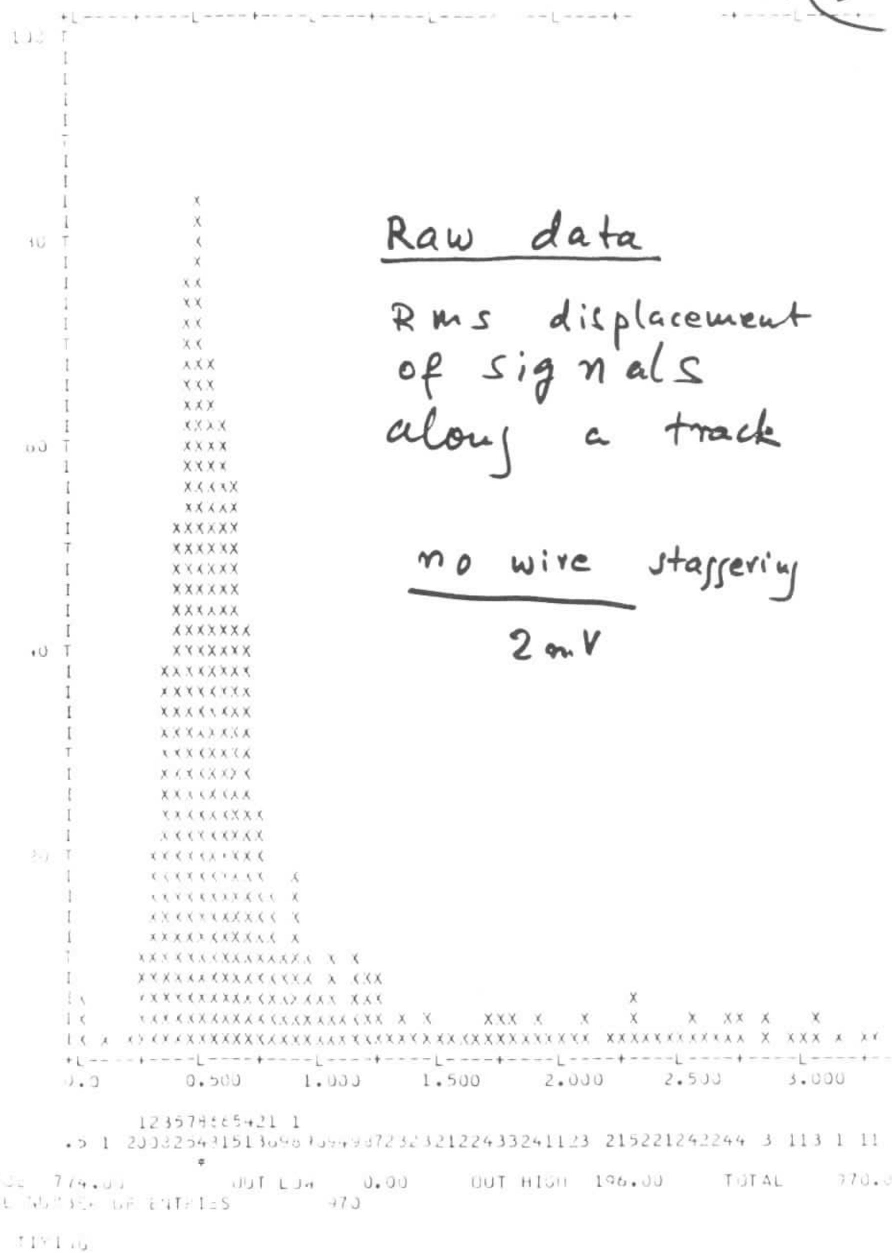
Raw data
Δs for 6 mV thresh.
± 150 μ wire staggering
TRIGGER ON LEFT HAND TRACKS ONLY
-2.000
-1.000
-0.000
1.000
2.000
3.000
4.000
OUT HIGH 50.00
TOTAL 401.00
DATE 03/10/77

K(3



Raw data
RMS displacement of signal along a track
±150μ wire staggering
2 mV thresh.
0.500
1.000
1.500
2.000
2.500
3.000
OUT HIGH 161.00
TOTAL

K(35



L 1

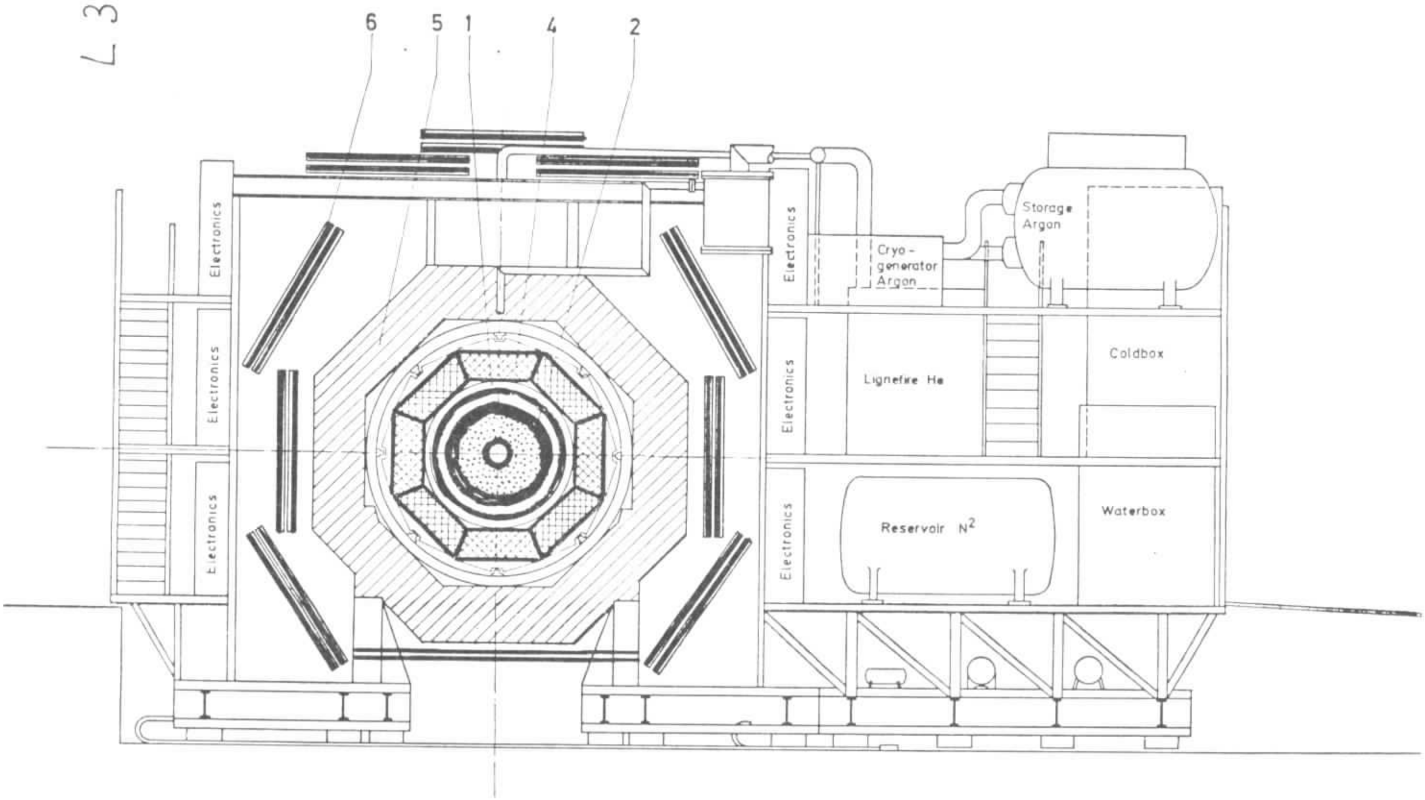
CELLO LAr Calorimeter TEST

Involved groups and their experimenters:

Karlsruhe: D. Apel, J. Engler, H. Keim, F. Mönnig, H. Schneider, M. Süsser

MPI: B. Gunderson, D. Lüers, T. Meyer, H. Oberlack, P. Schacht, M. Schachter, H. Steiner (LBL)

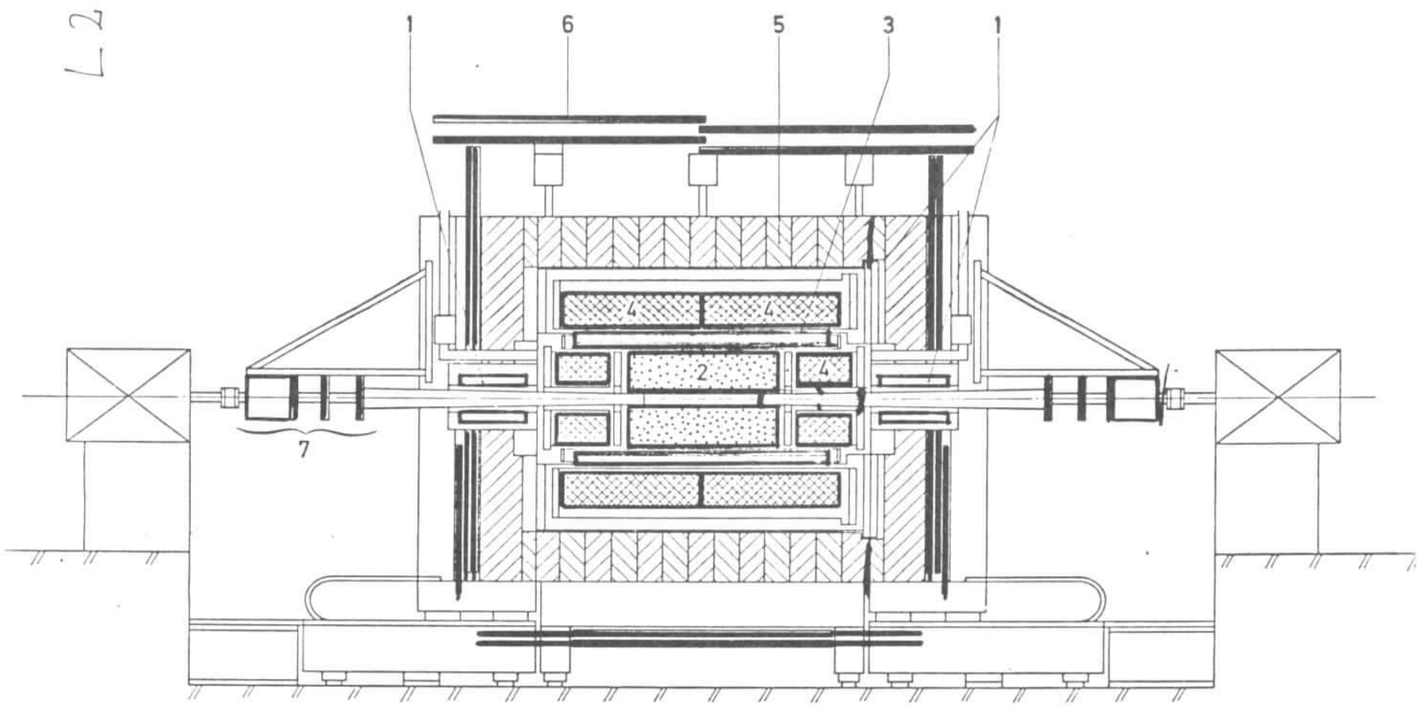
Saclay: G. Cozzika



CELLO

Fig. 2

1m



1 Magnets
2 Tracking Device
3 End Cap Chambers
4 L. Ar. Calorimeters
5 Hadron Filter
6 μ-Chambers
7 Forward Spectrometers

CELLO

Fig.1

1m

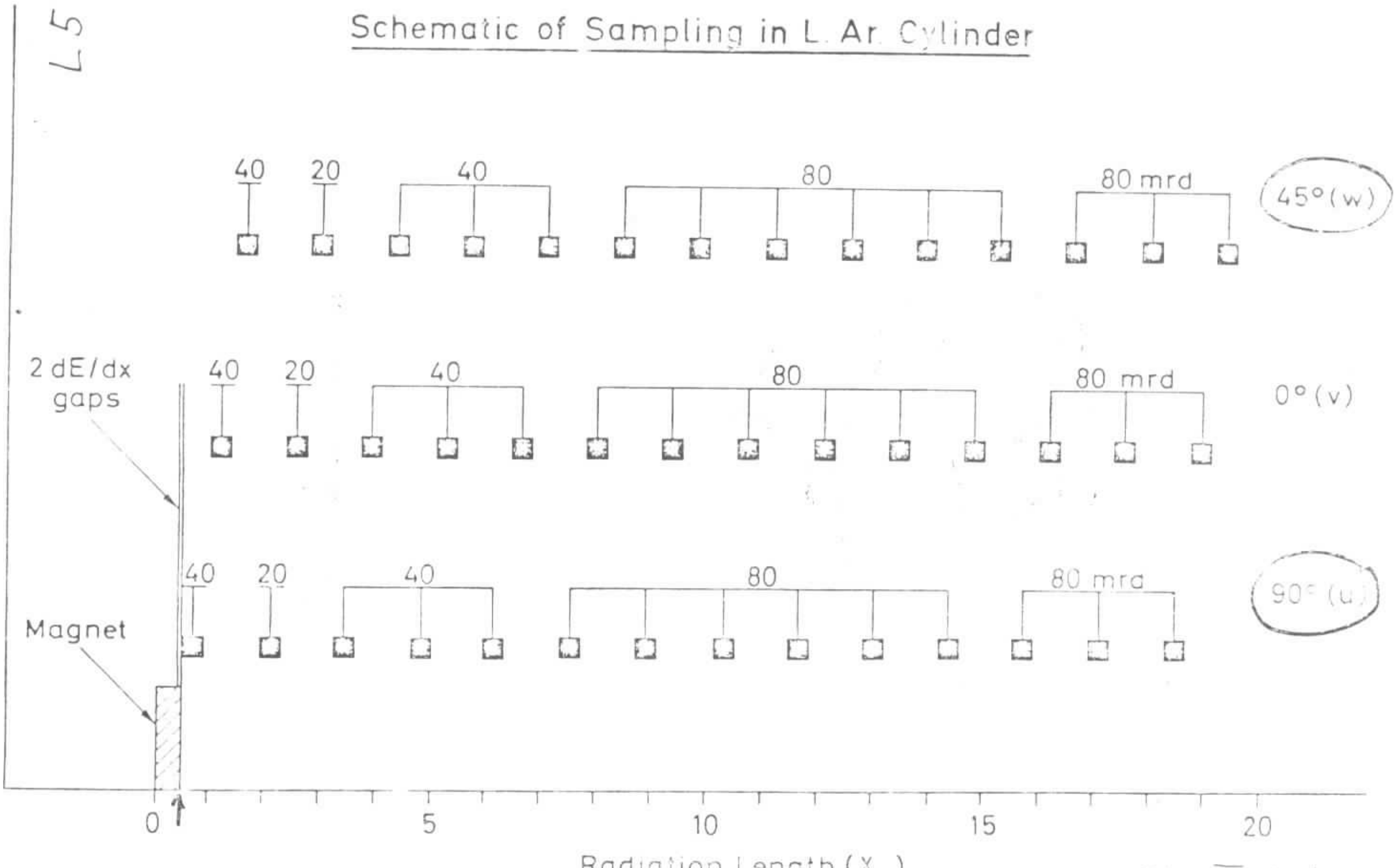


Fig. II-4-4

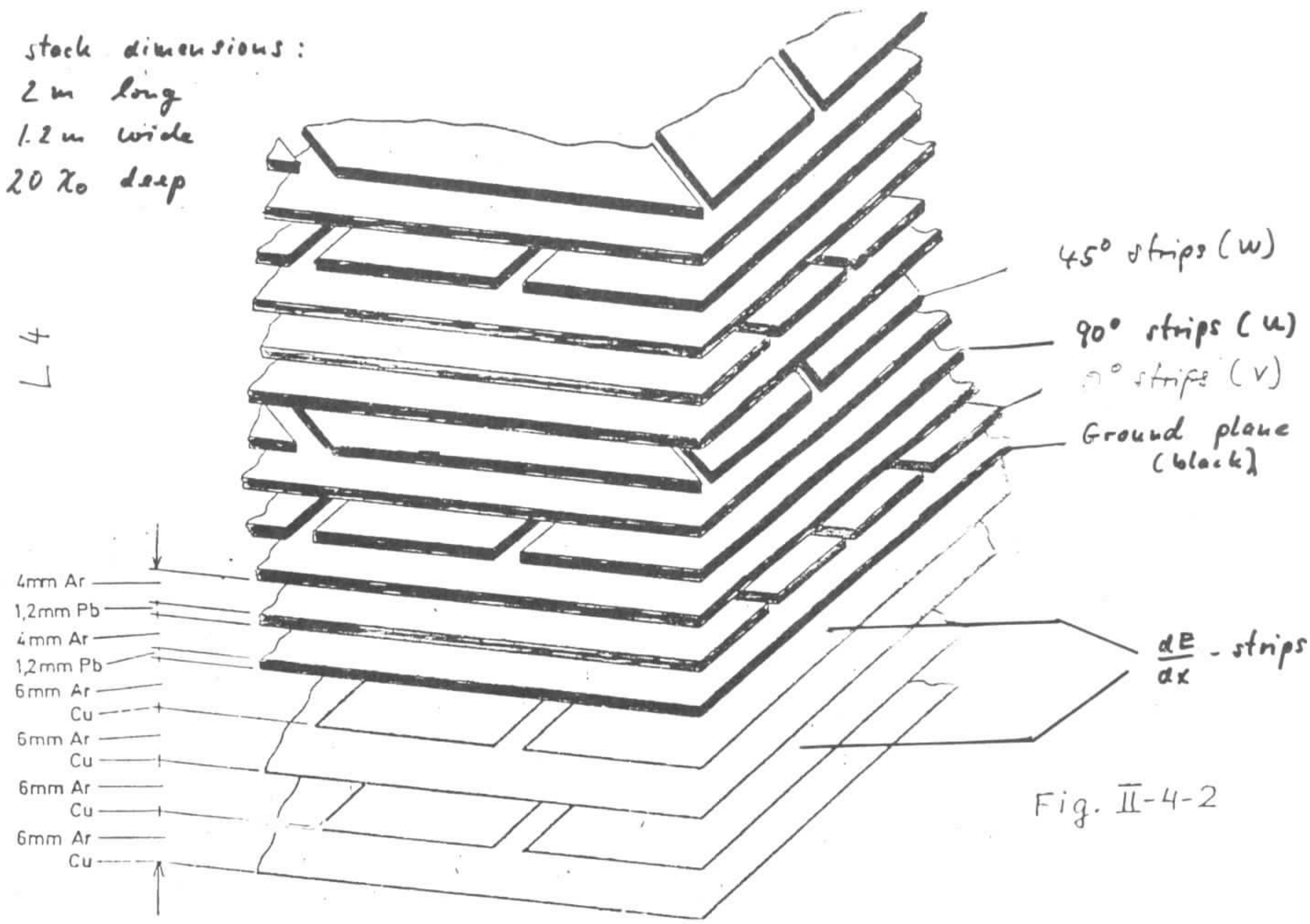
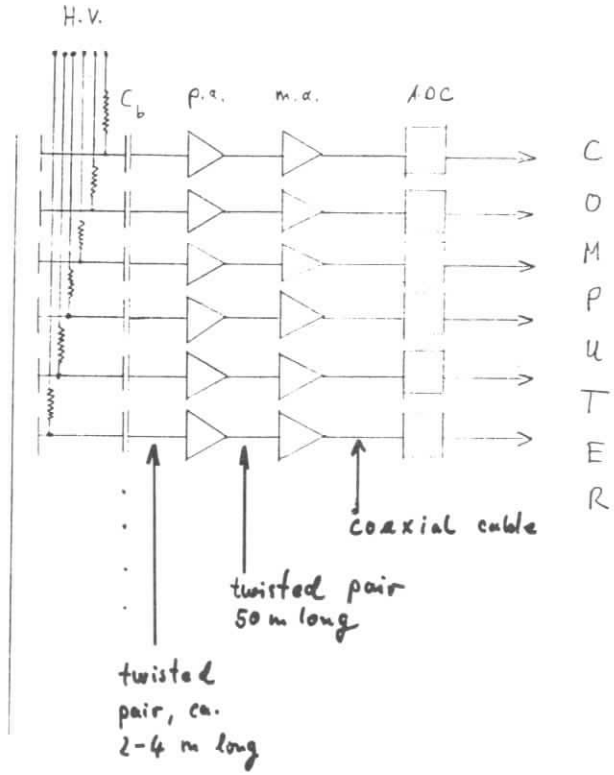


Fig. II-4-2

Block diagram of electronics



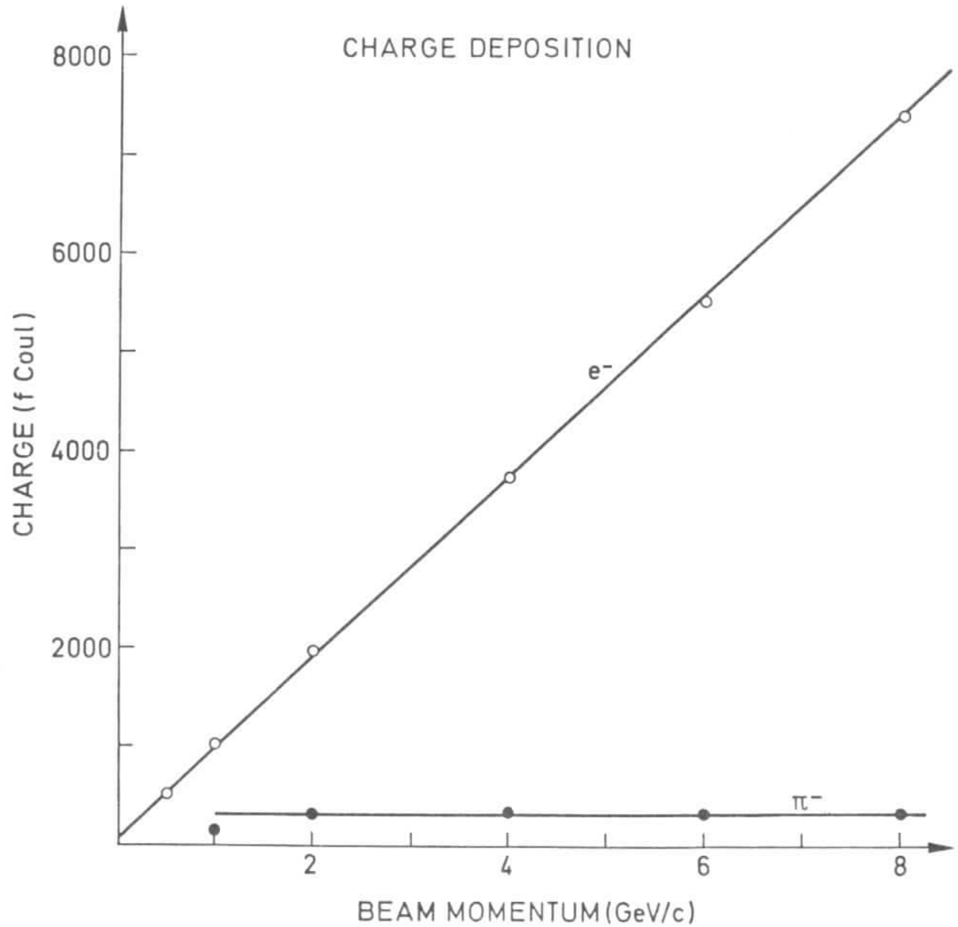


FIG. 3

DEPENDENCE OF ENERGY RESOLUTION ON MATERIAL THICKNESS

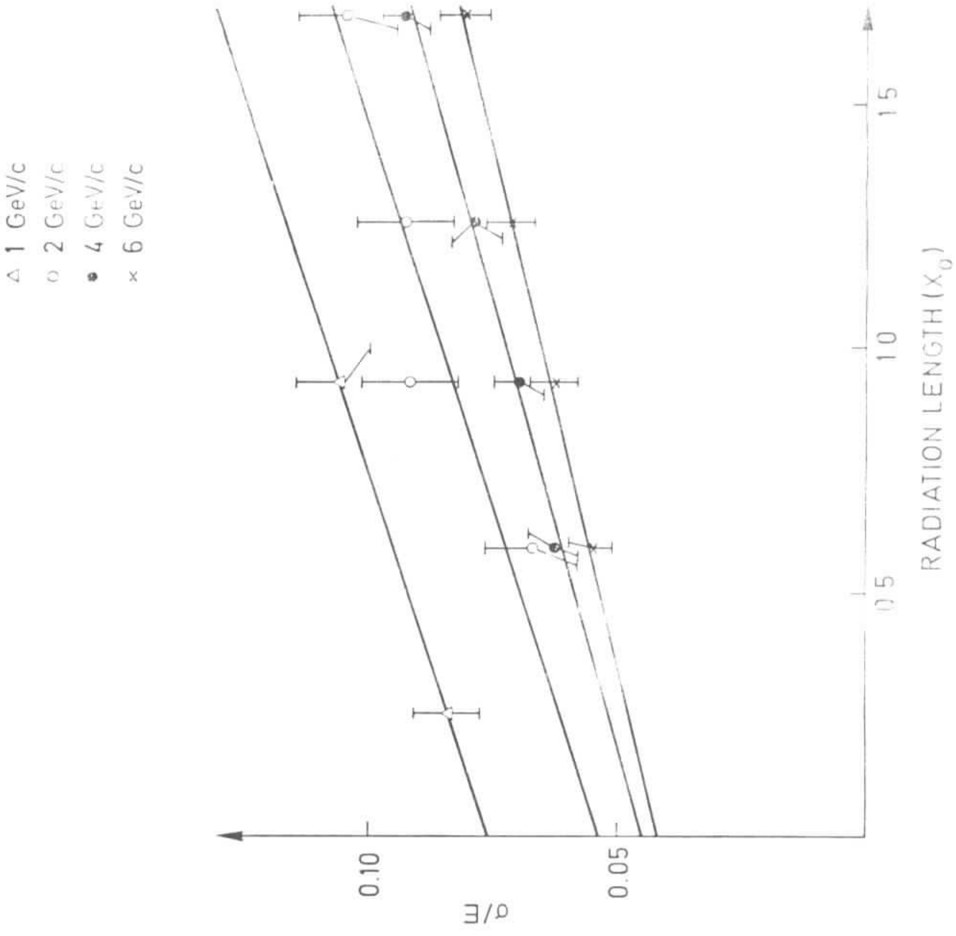


FIG 4

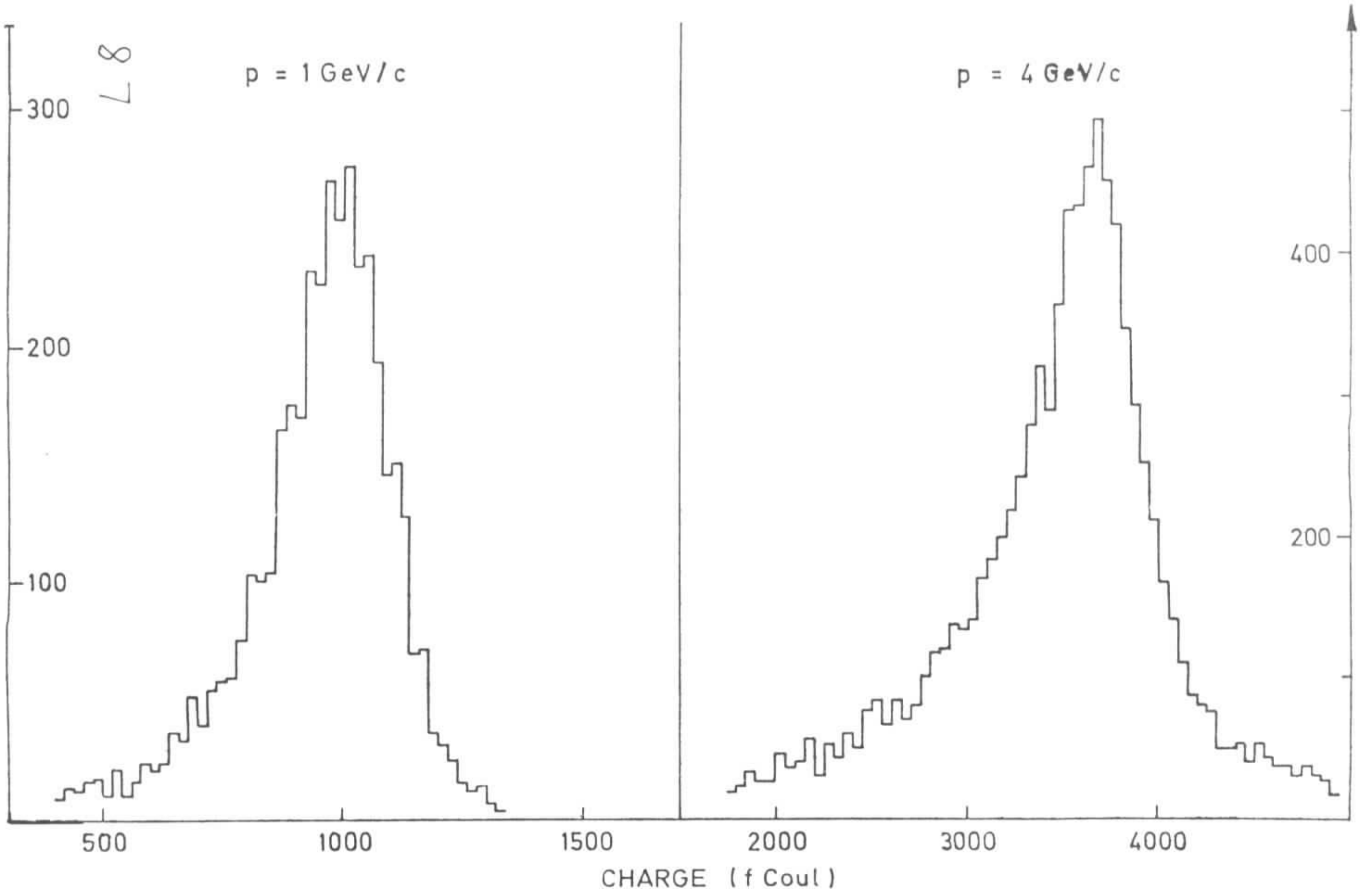


FIG. 6

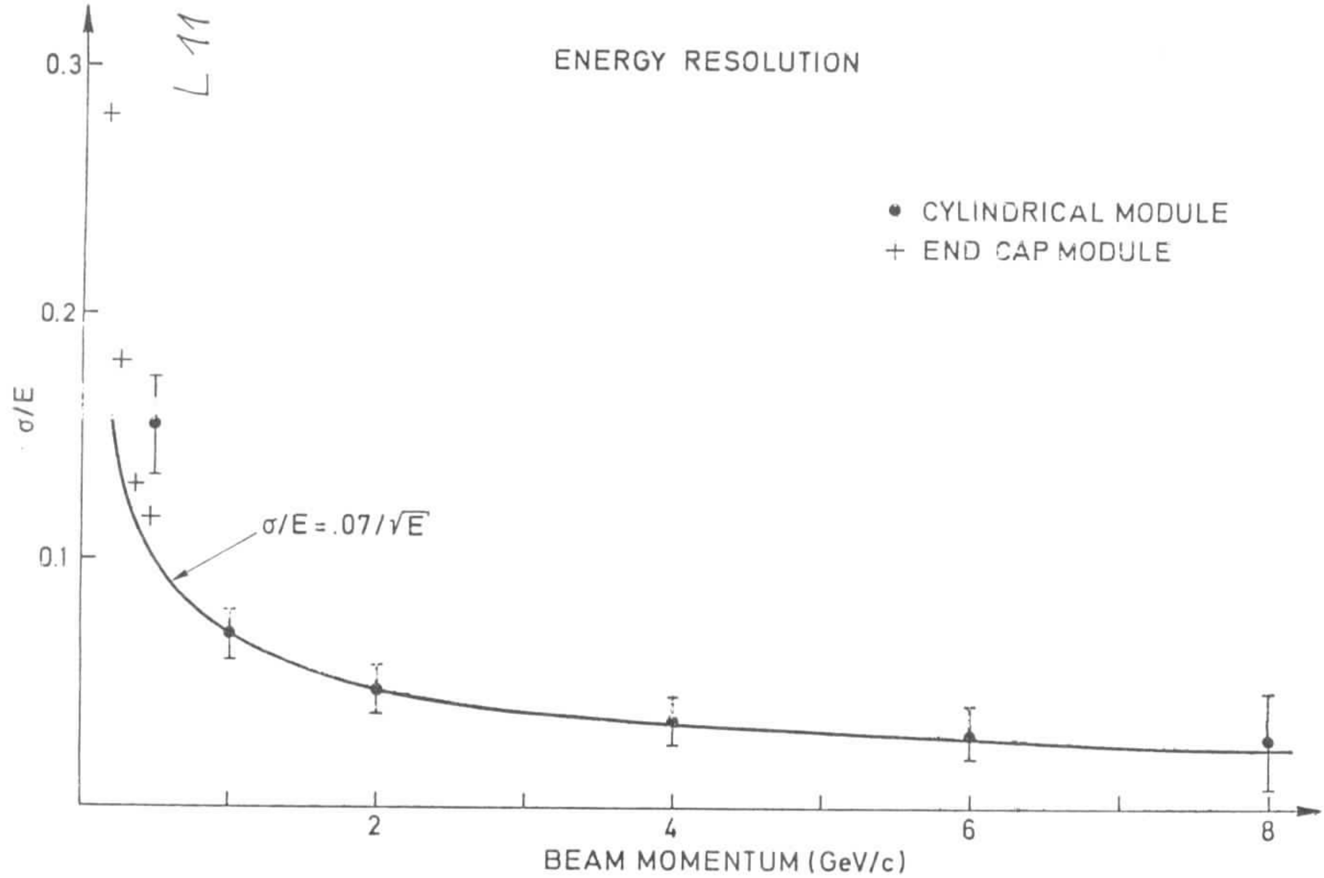

L 11
ENERGY RESOLUTION
0.3
0.2
0.1
σ/E
● CYLINDRICAL MODULE
+ END CAP MODULE
σ/E = .07/√E
2
4
6
8
BEAM MOMENTUM (GeV/c)

FIG. 3.1.1

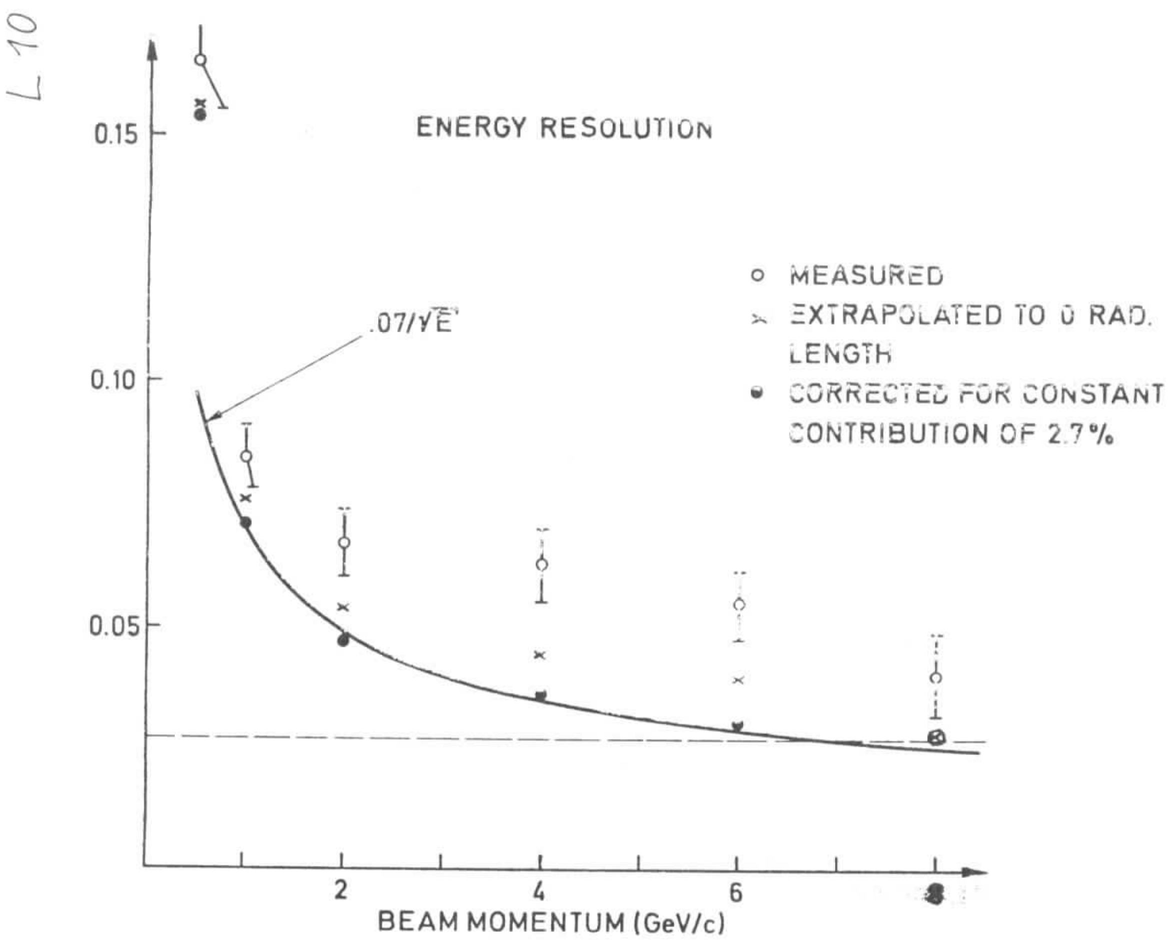

L 10
ENERGY RESOLUTION
0.15
0.10
0.05
○ MEASURED
× EXTRAPOLATED TO 0 RAD. LENGTH
● CORRECTED FOR CONSTANT CONTRIBUTION OF 2.7%
.07/√E
2
4
6
BEAM MOMENTUM (GeV/c)

FIG. 5

L 12

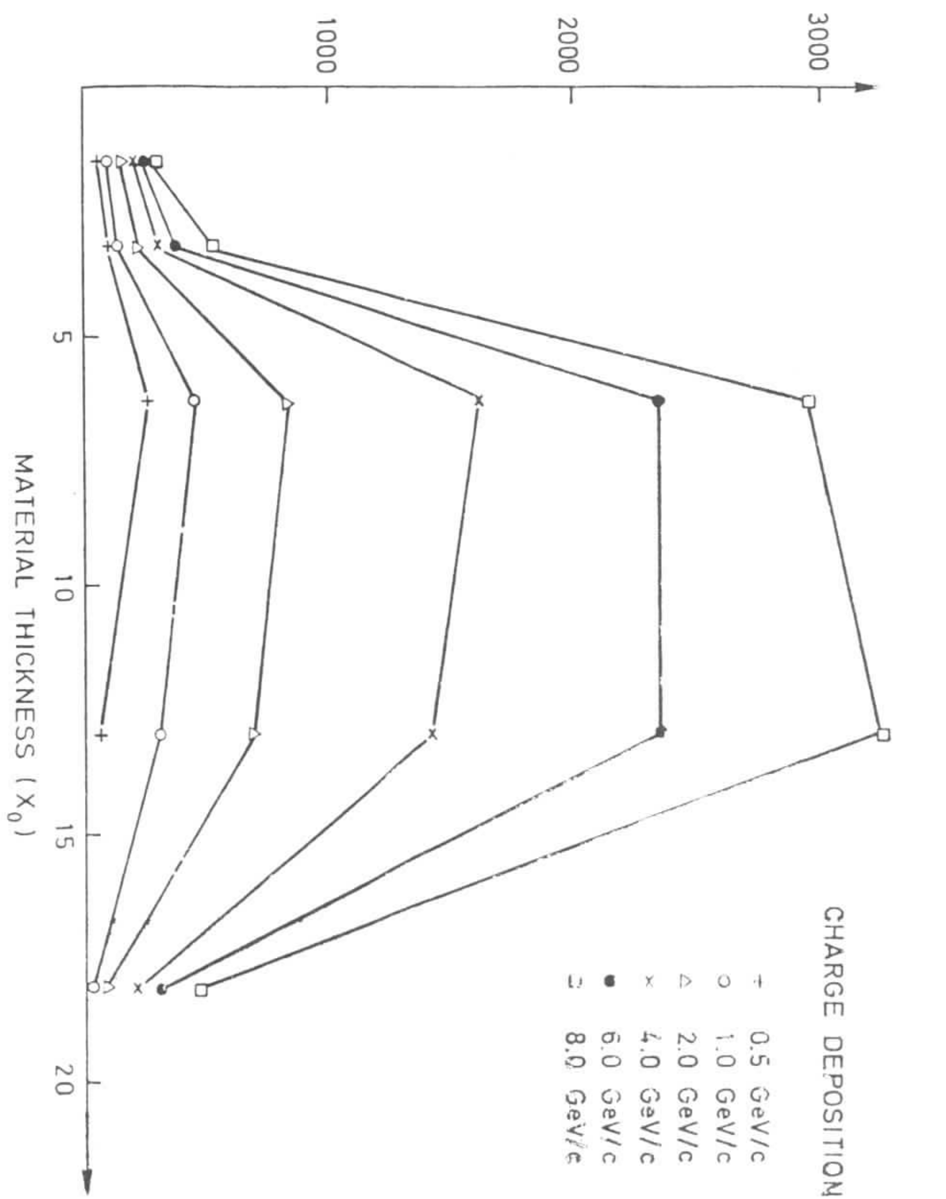


FIG. 3.1.2.

A NEW SHOWER DETECTOR

MOTIVATION:

1) INVOLVED IN DESIGNING A DETECTOR FOR PEP WHICH REQ. A LARGE SHOWER COUNTER [illegible]
(100 - 150 m^2)

2) LIQUID ARGON: TOO EXPENSIVE
@ \$50K / m^2 ⇒ \$ 5 M

THE SEARCH: (THINGS TRIED)

1) LEAD GLASS BEADS IN INDEX [illegible]
MATCHED LIQUID SCINT.
(CHEAP NaI ? [illegible]

2) LEAD PLATES / P.W.C. PLANES
- VERTICLE WIRES
- HORIZONTAL WIRES
- [illegible] ALMOST THERE

3) LEAD PLATES / SCINT. SANDWICH
- LIGHT COLLECTION VIA [illegible]

PEOPLE INVOLVED

W. B. ATWOOD* }
C. Y. PRESCOTT } SLAC
L. S. ROCHESTER }

* NOW AT CERN

B. C. BARISH } CIT (THE PLASTICS EXPERT)

REF.'s

1) THIS SHOWER COUNTER:
SLAC - TN - 76-7
W. B. ATWOOD et al, DEC., 1976

2) SAMPLING SHOWER FORMULAS
T. KATSURA et al, NIM, 105, (1972), 245

TOPICS OF THIS TALK

I. COUNTER REQUIREMENTS

II. THE WAVE-BAR SHOWER COUNTER DESIGN

III. BEAM TESTS

IV. CONCLUSIONS AND FUTURE DEVELOPMENT

I. COUNTER REQUIREMENTS

1) SPACIAL (ANGULAR) RESOLUTION
2) ENERGY RESOLUTION
3) GRANULARITY

$M_0 \rightarrow 2\gamma$

FOR $\frac{\Delta E}{E} = \frac{K}{\sqrt{E}} \Rightarrow \frac{\Delta M_0}{M_0} = \frac{K}{(2P_0)^{1/2}}\left[\ln\left(\frac{E_0+P_0}{E_0-P_0}\right)\right]^{1/2}$

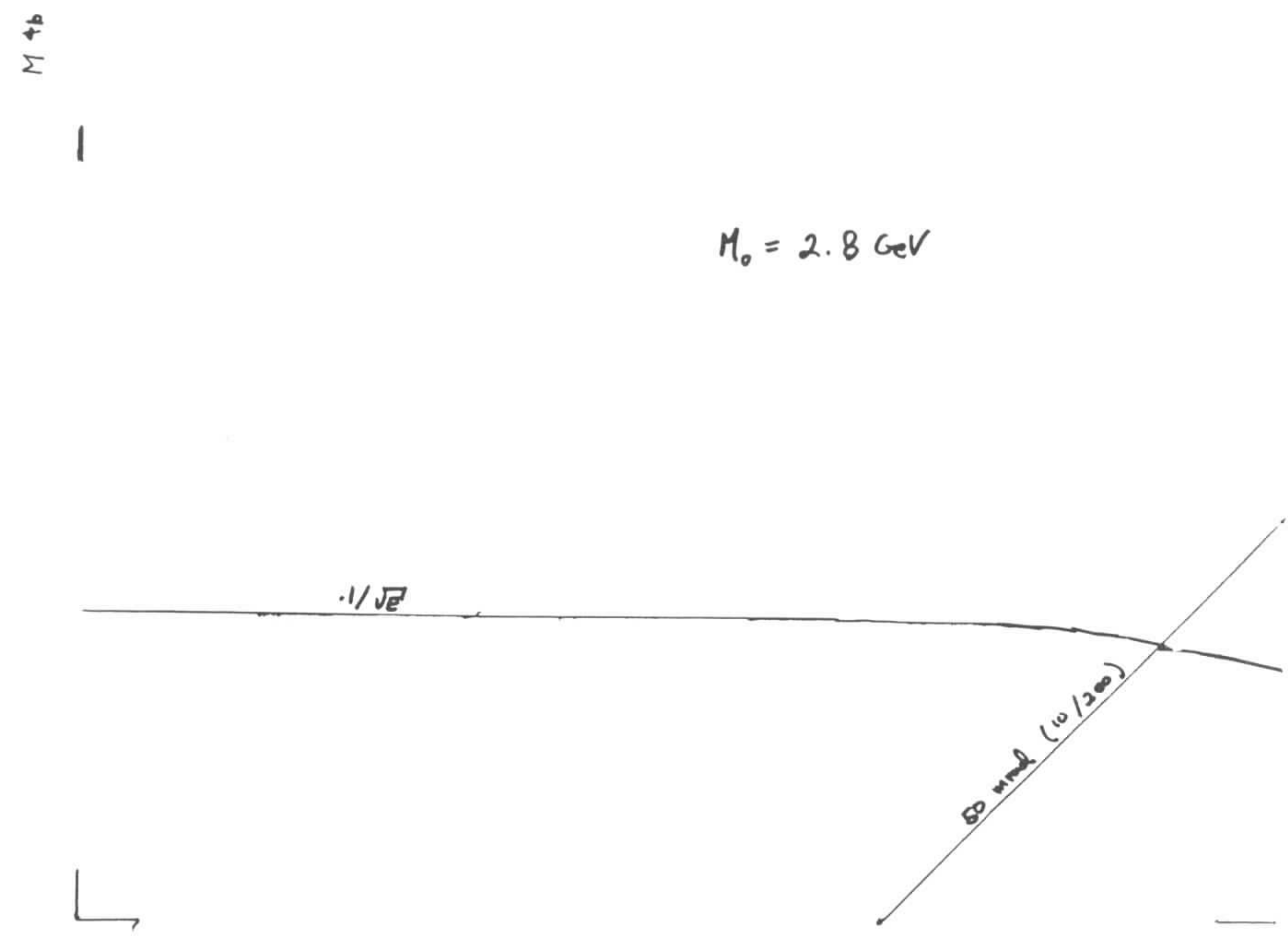
$\frac{\Delta M_0}{M_0} \simeq \frac{K}{\sqrt{M_0}}$; $P_0 \lesssim M_0$

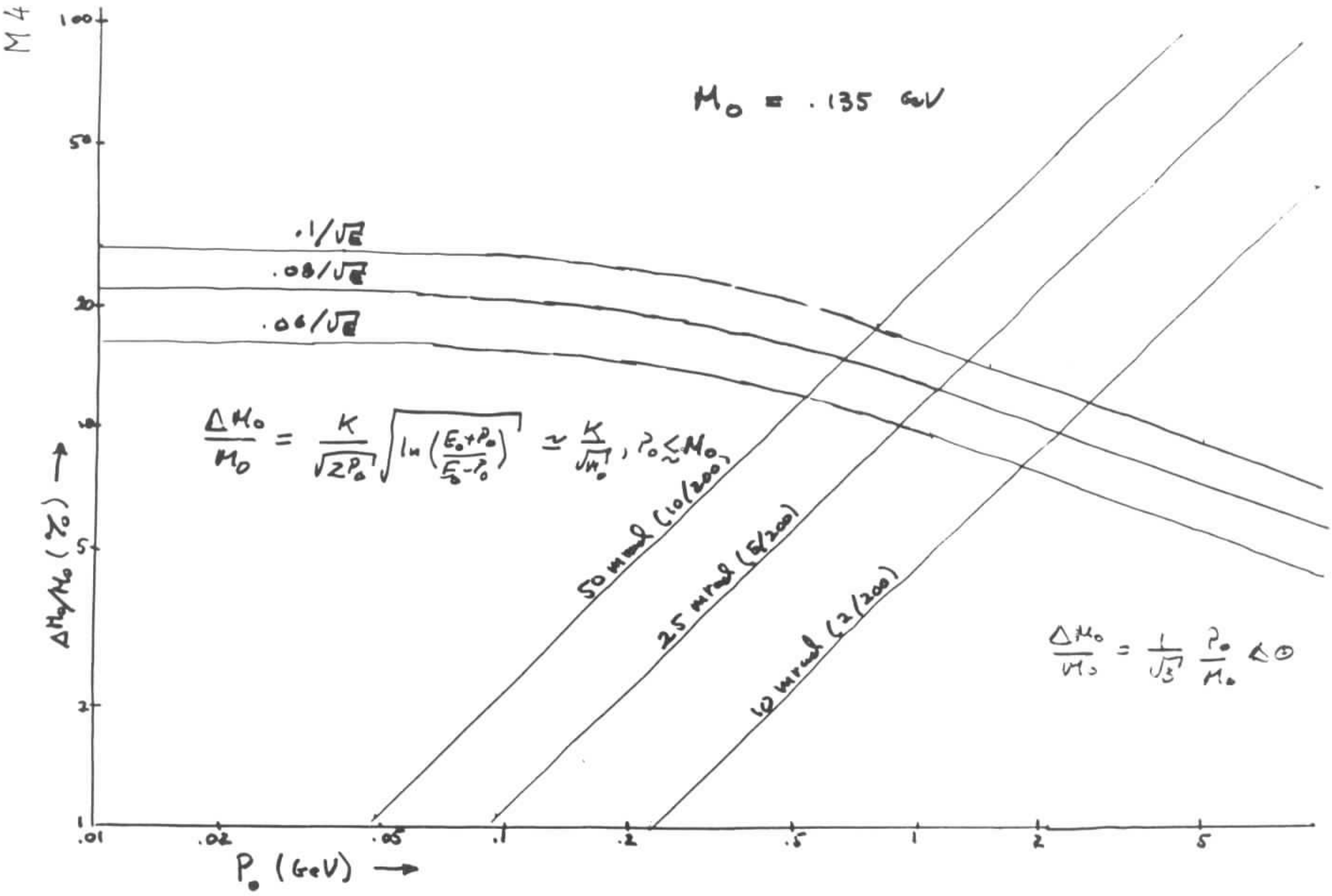
FOR $\Delta\theta = \frac{\Delta x}{R} \Rightarrow \frac{\Delta M_0}{M_0} = \frac{1}{\sqrt{3}} \frac{P_0}{M_0} (\Delta\theta)$

GRANULARITY

NO. OF CELLS INCREASES $\sim E_{cm}^2$
FOR JET MODELS

AT $E_{cm} = 30$ GeV $\Rightarrow$ 4π INTO $> 10^3$ CELLS


M 4b
M₀ = 2.8 GeV
.1/√E
50 mrad (10/200)


M 4
M₀ = .135 GeV
.1/√E
.08/√E
.06/√E
ΔM₀/M₀ = K/√(2P₀) √(ln((E₀+P₀)/(E₀−P₀))) ≃ K/√M₀ , P₀ ≲ M₀
50 mrad (10/200)
25 mrad (5/200)
10 mrad (2/200)
ΔM₀/M₀ = 1/√3 P₀/M₀ Δθ
ΔM₀/M₀ (%) →
P₀ (GeV) →
100
50
20
10
5
2
1
.01
.02
.05
.1
.2
.5
1
2
5

DESIGN: SHOWER SAMPLING FORMULAS

NO. OF GAP CROSSINGS = $N_G \simeq \dfrac{50\ E_0\,(\text{GeV})}{t_{\text{r.l. sample}}}$

THE "50" DEPENDS ON THE "CUT OFF ENERGY"

RESOLUTION = $R\ (= \frac{\sigma}{\mu}) = \left[\frac{1}{N_G} \left(1 + r^2_{\text{sample}} \right) \right]^{1/2}$

r_{sample} = RESOLUTION OF A SINGLE GAP CROSSING

$\cong (1/n_e)^{1/2}$ WHERE n_e = NO. PHOTO ELECTRONS

APPLICATION: TO "MATCH" LIQUID ARGON

WE USE 2 mm Pb

WITH 1/2" PLASTIC

$\Rightarrow t \cong .4$ r.l.

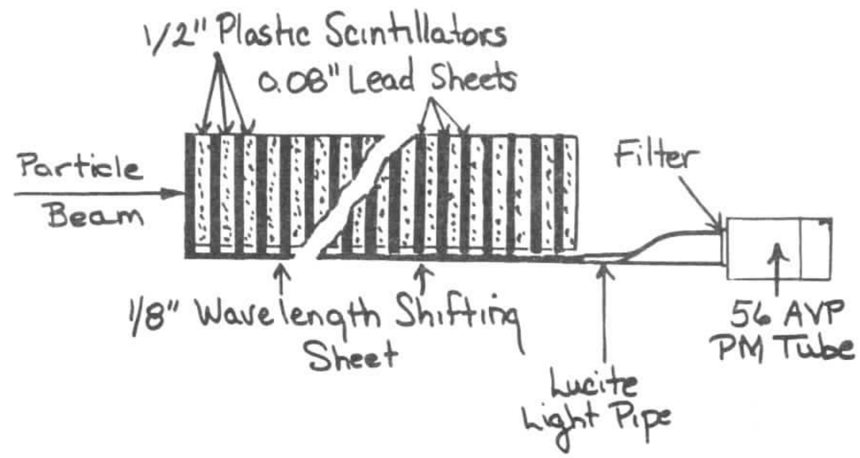
$\Rightarrow N_G = 125\ E_0$ (GeV)

WE EXPECTED TO HAVE

~ 4 PHOTO-ELECTRONS / G.C.

$\Rightarrow R \simeq \dfrac{.1}{\sqrt{E_0}}$

THE FIRST COUNTER



- 35 LAYERS OF PLASTIC / LEAD
  (13 r.l. OF LEAD
  1.3 r.l. OF PLASTIC)

- ENTRANCE APERTURE 10 cm x 10 cm

- COUNTER LENGTH (NOT INCLUDING P.M. + LIGHT PIPE) = 53 cm

CHEAP PLASTIC SCINTILLATOR

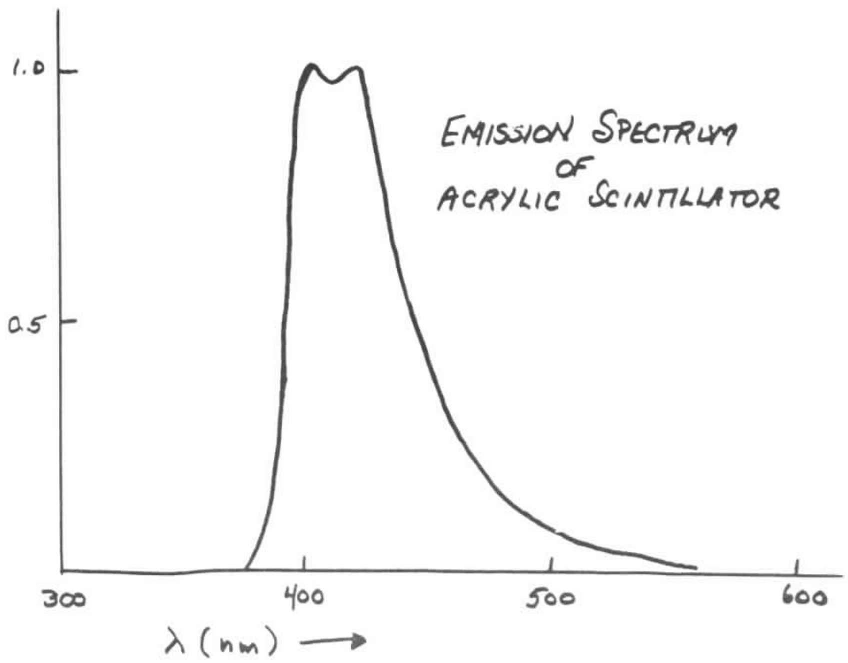
M 7

(DEVELOPED BY [illegible] & [illegible])

- SIMILAR TO "PLEXIPOP"
- ACRYLIC BASE

  3% NAPHTHALENE } (TO DISSOLVE THE PPO IN ACR[illegible]
  1% PPO } BY WEIGHT
  .01% POPOP }

- PPO + NAPH SCINT. ⇒ 360 nm LIGHT
- POPOP SHIFTS 360 nm → 420 nm LIGHT
- LIGHT OUTPUT ~ 30% NE 110
- COST (1976): \$53 (PLASTIC) + \$30 (CHEMICALS) / m^2 FOR ½" SHE[illegible]



WAVE SHIFTER SHEET

M 8

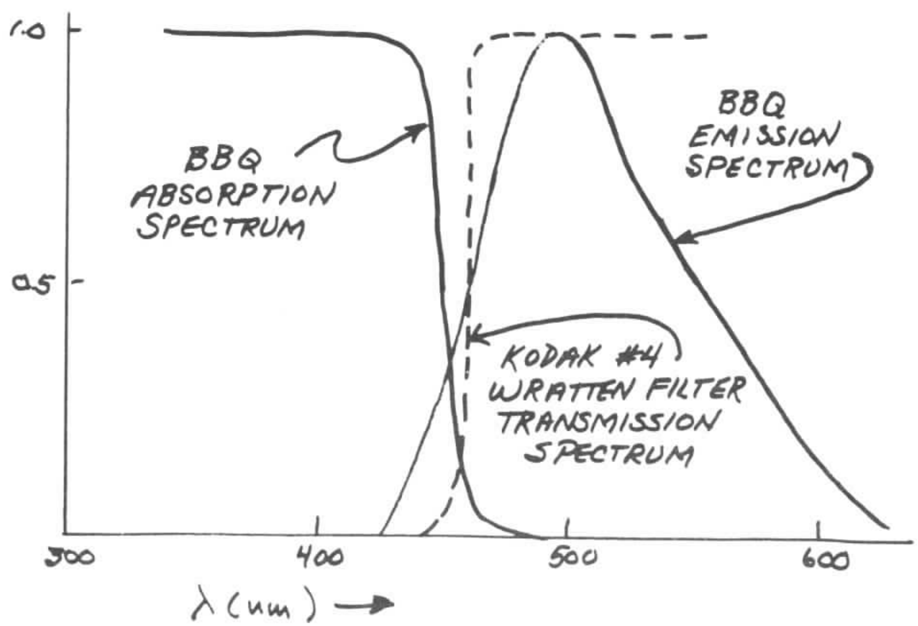
(DEVELOPED BY BARISH & ROHM)

- ACRYLIC BASED
- ACTIVE AGENT:

  BBQ (140 mg / liter)

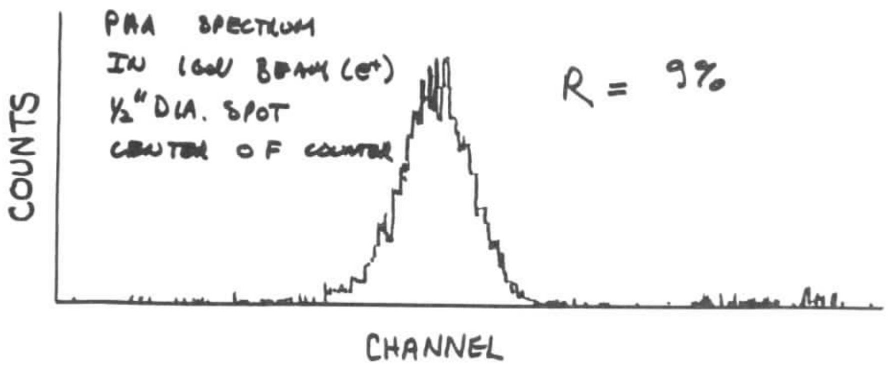
- ABSORPTION LENGTH FOR λ ≲ 450 nm
  - 90% IN ¼"
- ABSORPTION LENGTH FOR λ > 470 nm
  ~ 1 m.

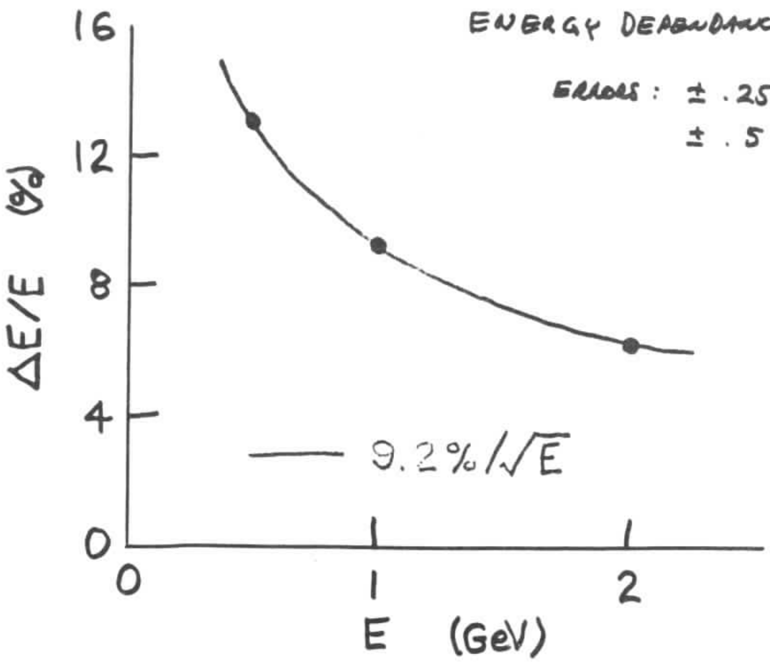
  (FILTER USED)



III BEAM TESTS

INITIAL TESTS





- POSITION DEPENDANCE:
  - PULSE HEIGHT MAX. AT CENTER OF COUNTER (NO PLATEAU)
  - SHOWER LEAKAGE OUT SIDES + BACK ~ 15% (MONTE CARLO INDICATED THIS WORSENED THE RESOLUTION BY ~ 2%)
- COUNTER WORKED AS EASY AS COMMON SCINTILLATORS

LATER TESTS

- 3 × 3 MODULE ARRAY (USING RCA 6342A P.M.'s) 10 STAGE
  - EACH MODULE SAME AS 1st COUNTER
  - FIRST TEST: ALL MODULES GAVE ~ 11% AT 1GeV, (POOR BEAM) AND WORKED IMMEDIATELY. BEAM IN CENTER MODULE
    - ADDING IN ADJ. MODS. IMPROVED RESOL. BY 2%
- ¼" PLASTIC MODULE:

$$R_{1/4} = 11.2\% \ @ \ 1 \text{ GeV}$$

$$R_{1/2} = 10.0\% \ @ \ 1 \text{ GeV}$$

$$n_e = 2.5 \quad \text{FOR } 1/4"$$

$$N_G = 112$$

- POSITION DEPENDANCE ~ 1%/cm. (LATER FOUND THAT THESE COUNTERS WERE MADE WITH BAD PLASTIC!)

IV CONCLUSIONS

ADVANTAGES

1) COST: ~ $10K / m² FOR 15 r.l. / 30 cm x 30 cm c
2 mm Pb

2) SIMPLE, RUGGED DESIGN
→ NON-CRITICAL ASSEMBLY

3) ADAPTABLITY –
- LARGE MODULES EASILY "RE-ARRANGED"
- PLASTIC + Pb REUSEABLE

4) "FLY'S EYE" GEOMETRY – GOOD GRANULARITY

DISADVANTAGES

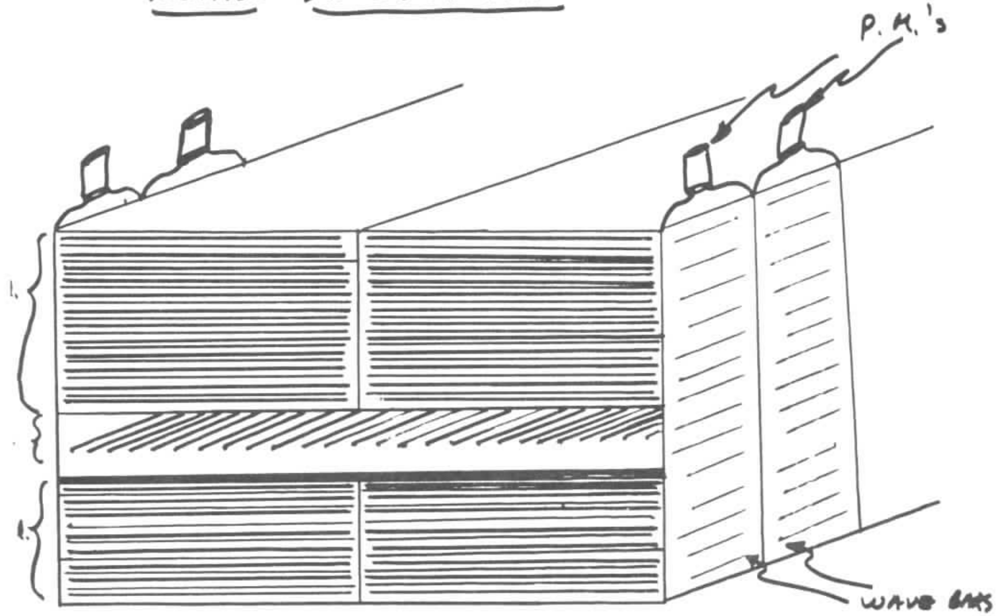
1) "FOREST" OF PHOTOTUBES
- CALIBRATION
- MAGNETIC FIELDS
- LONG TERM CHANGES IN P.M.'S

2) POOR SPACIAL RESOLUTION

3) POOR SHOWER DEVELOPEMENT INFO.

FUTURE

POSITION DETERMINATION



PWC: SENSE WIRES + 2 CROSSED CATHOD PLANES

LONGITUDINAL INFORMATION

READ OUT "PRE RADIATOR" WITH ONE WAVE BAR AND BACK RADIATOR WITH A 2ND WAVE BAR.

HADRON CALORIMETER

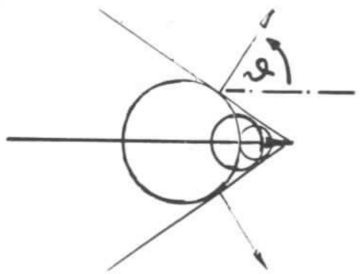
1" Fe PLATES / ½" PLASTIC

(BEING BUILD AND TESTED AT SLAC)

Properties of "Aerogel" in Cherenkov Counters

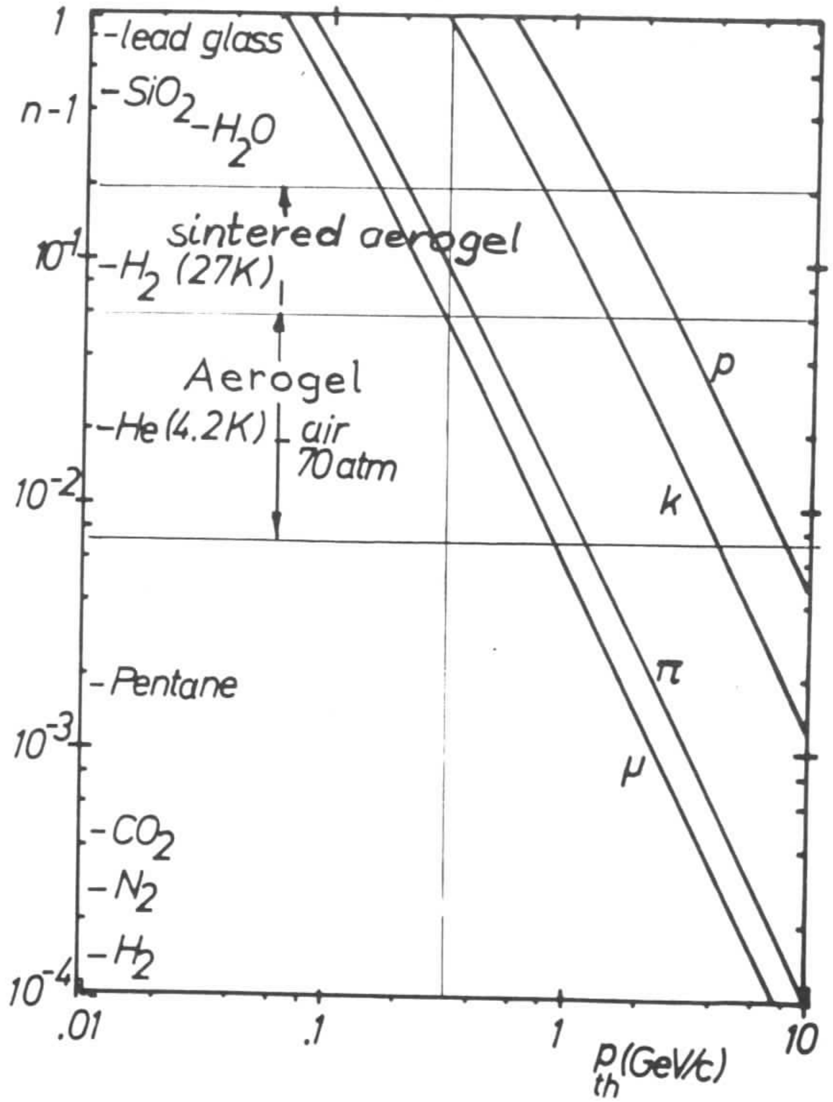
"Aerogel" = aerogel of silica (quartz)

≈ foam of silica

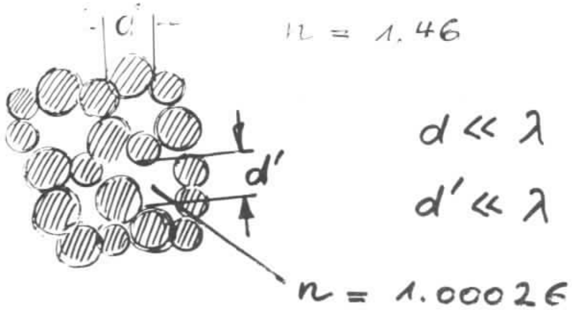


$$\cos\vartheta = \frac{1}{n\beta} = \frac{c_n}{v}$$

n = refr. Ind.
v = part. veloc.
c_n = Light veloc. in n



N3



$d \ll \lambda$

$d' \ll \lambda$

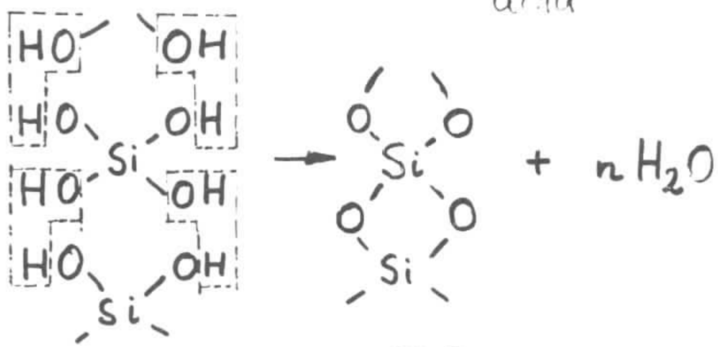
$n - 1 \approx .25\,\rho$ $\quad \rho$ = Density [g/cm^3]

N4

Chemistry

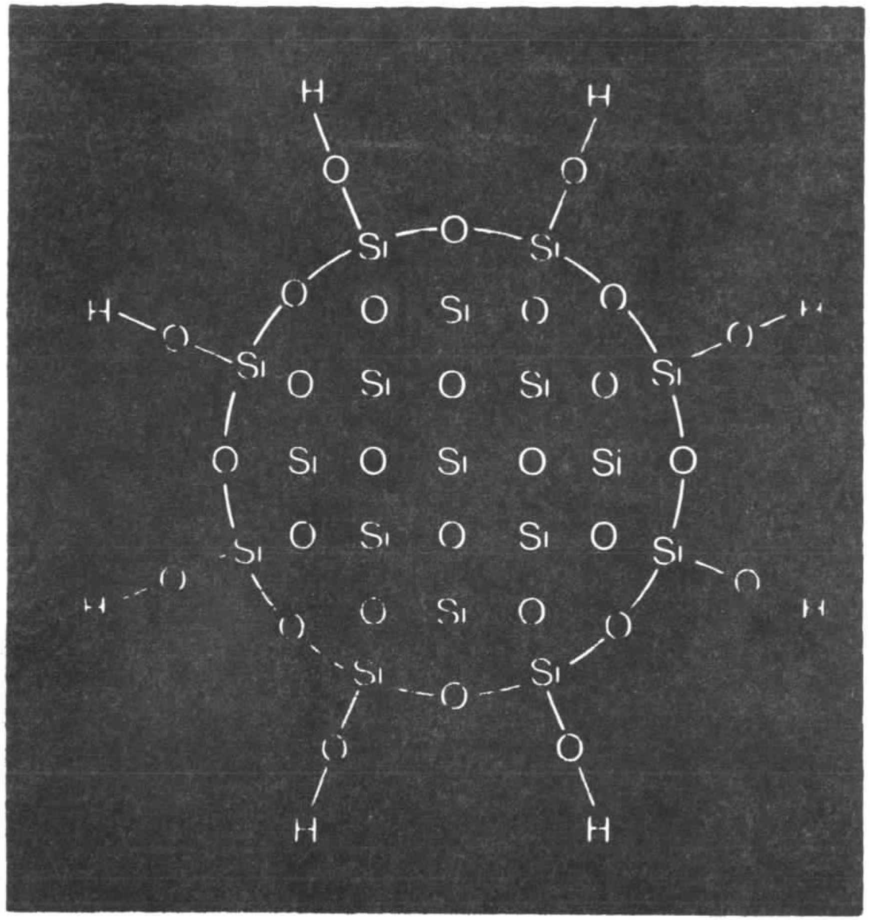
$$Si(OCH_3)_4 + 4H_2O \rightarrow Si(OH)_4 + 4CH_3OH$$

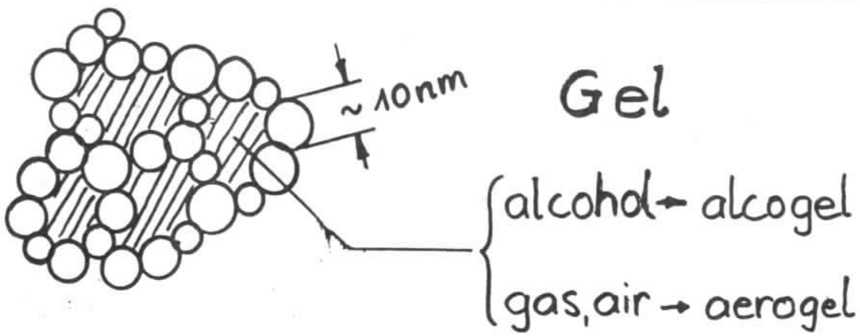
Tetramethoxysilan Orthosilicic acid Methanol



$\approx SiO_2$

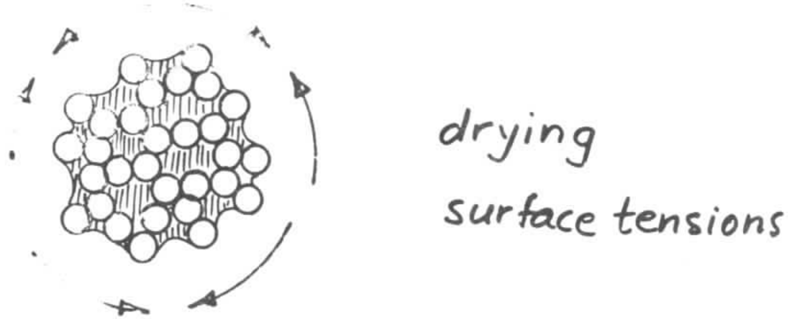
polymerisation → colloidal particles

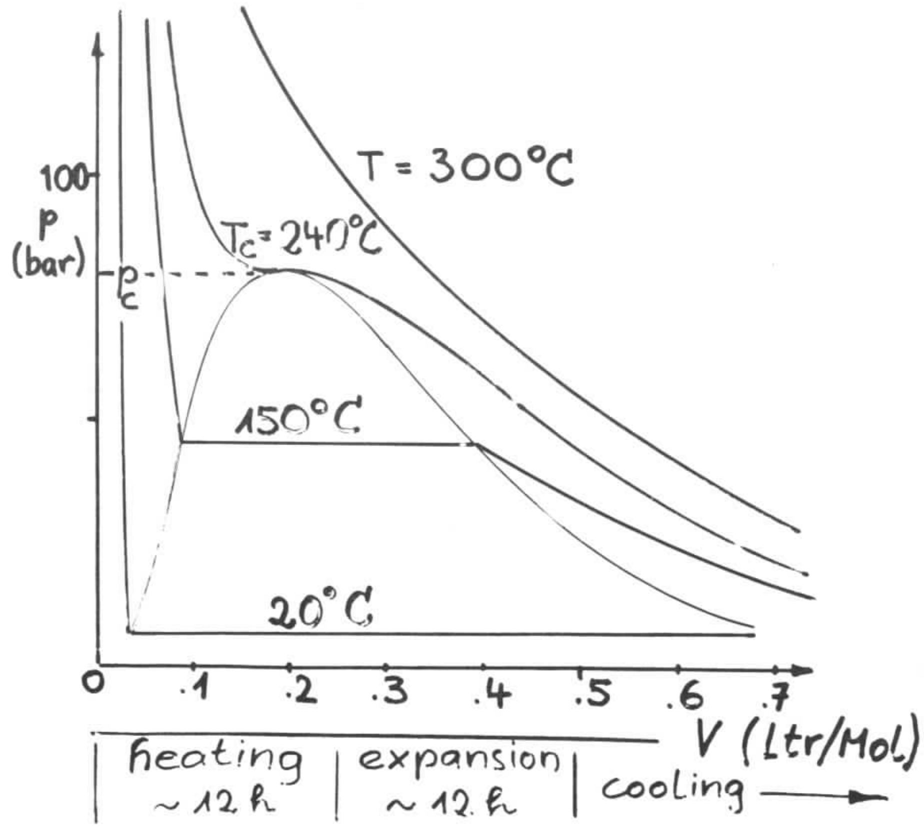




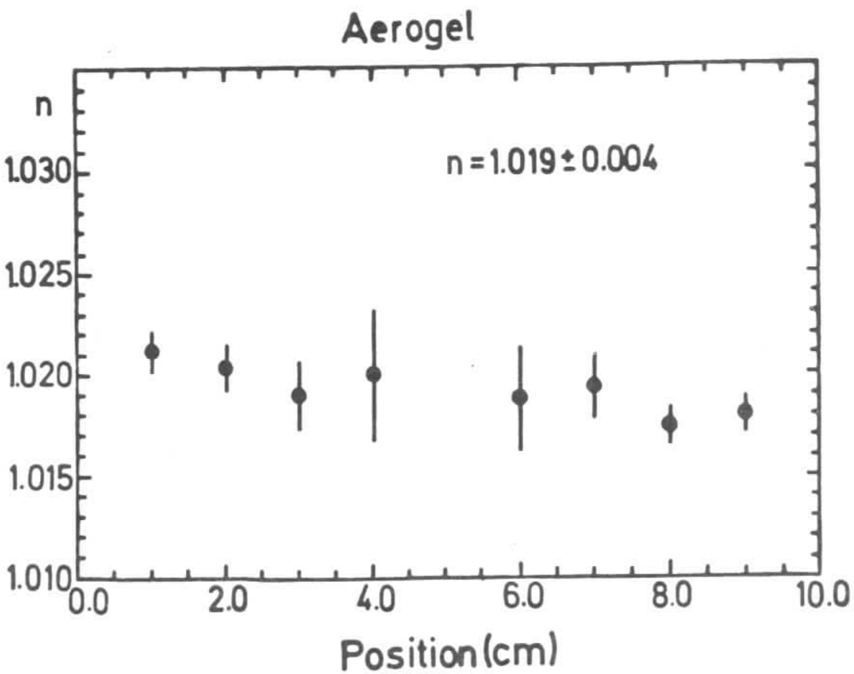
addition of alcohol → lower density

Alcogel → Aerogel





N 7



N 8

Properties

Diffraction

Rayleigh scattering

$$d = (0.1 \div 0.2)\lambda \approx 40 \div 100 \text{ nm}$$

$$I = I_0 \frac{128 \pi^5 N \alpha^2}{3} \, 1/\lambda^4$$

Absorption

$$\mu_a \approx 0.1 \, \mu_d$$

$$N_\gamma = 2\pi\alpha \sin^2\vartheta \int_{\lambda_1}^{\lambda_2} \frac{d\lambda}{\lambda^2}$$

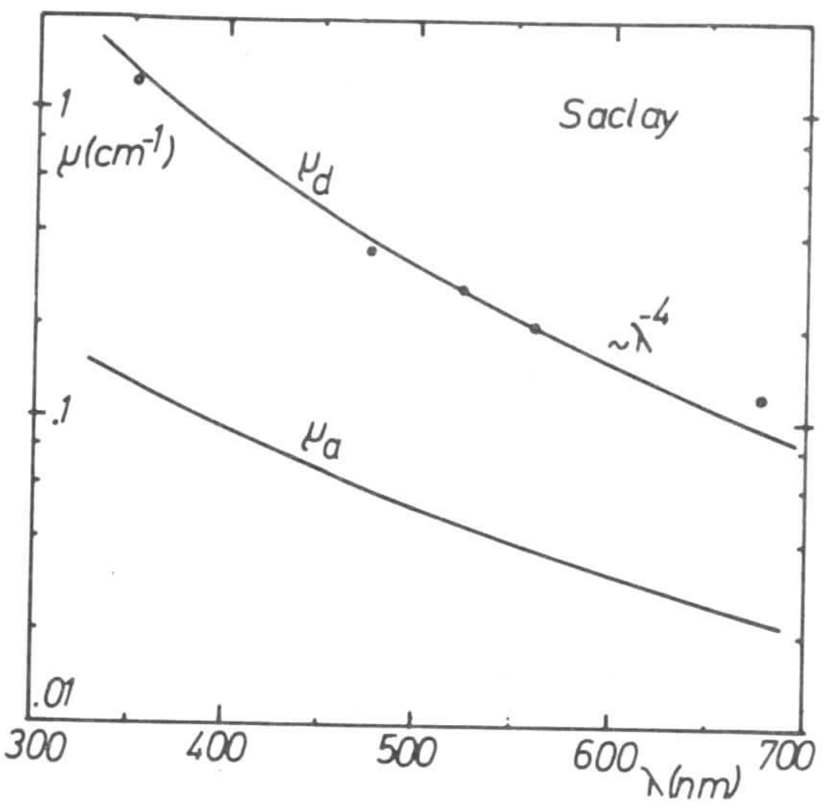
$$\approx 500 \sin^2\vartheta \; [cm^{-1}]$$

$$N_e \approx 100 \sin^2\vartheta \; [cm^{-1}]$$

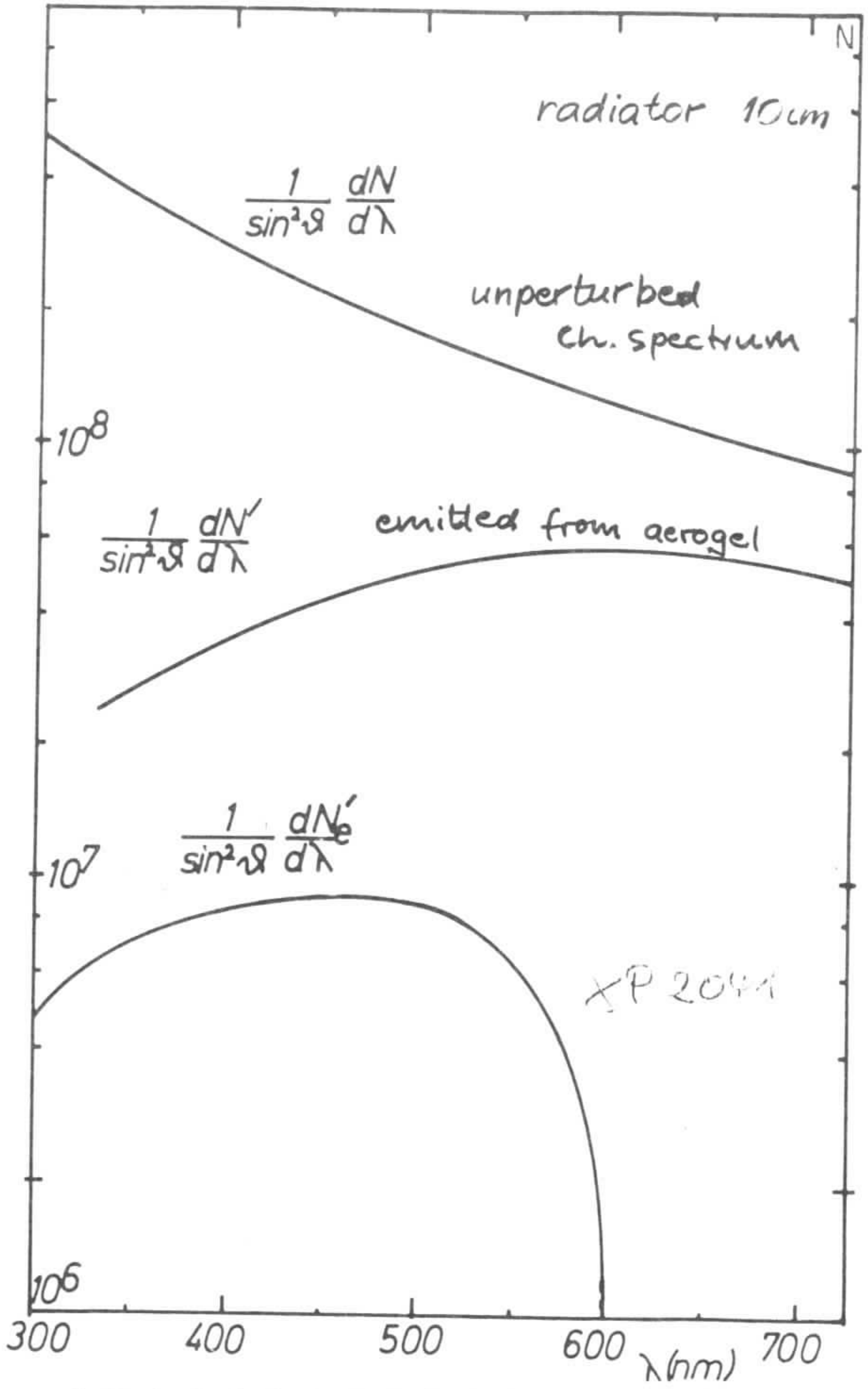
(both: gas)

$$N_e' \approx (10 \div 30) \sin^2\vartheta \; [cm^{-1}]$$ aerogel

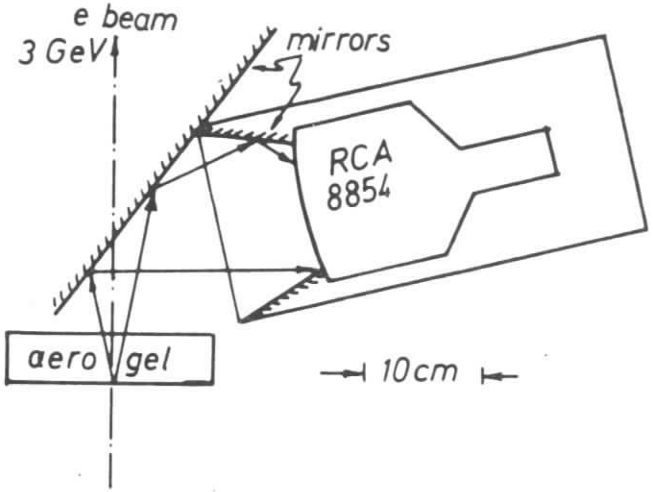
N9

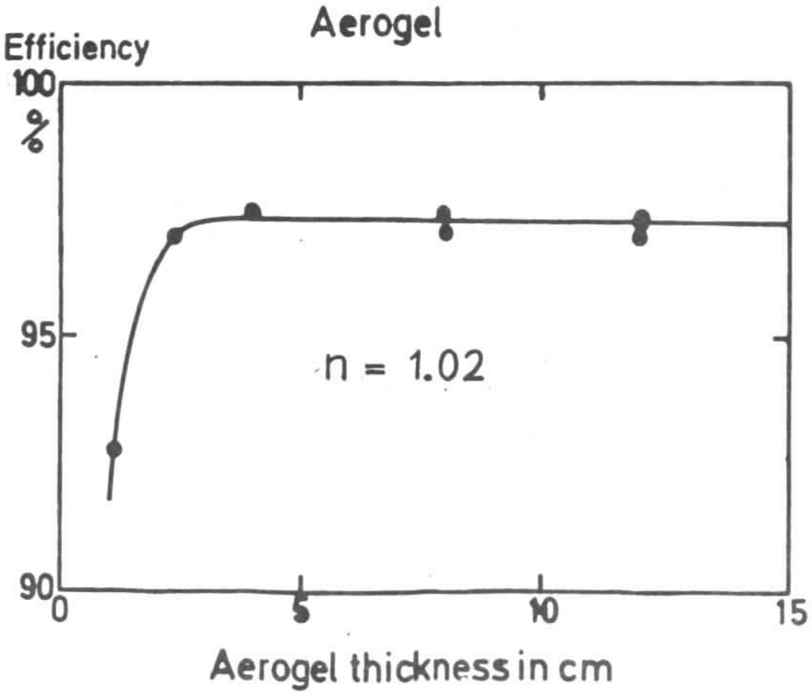

Saclay
1
μ(cm⁻¹)
μd
~λ^-4
.1
μa
.01
300
400
500
600
700
λ(nm)

N10

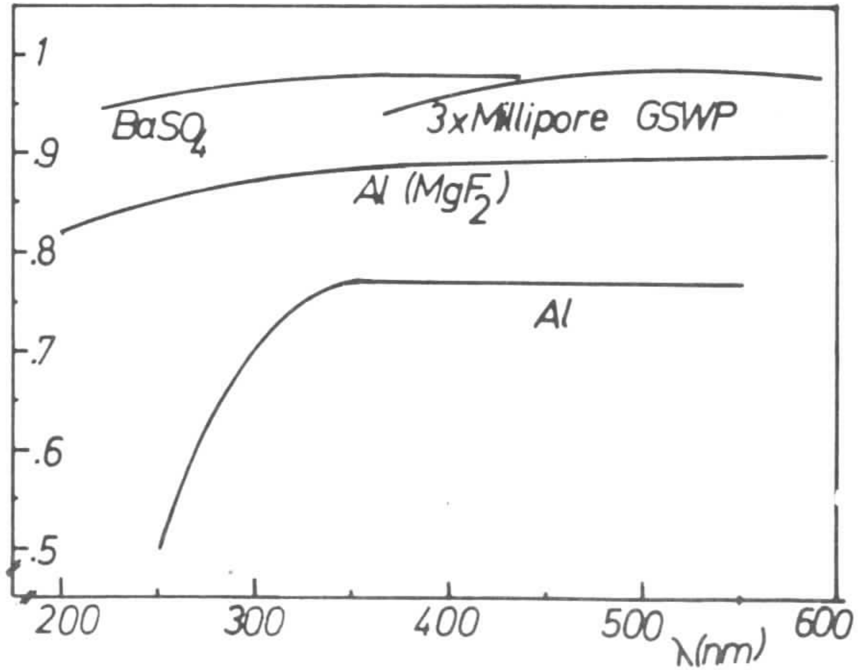

radiator 10cm
1/sin²ϑ dN/dλ
unperturbed ch. spectrum
10^8
1/sin²ϑ dN'/dλ
emitted from aerogel
1/sin²ϑ dN'e/dλ
10^7
XP 2041
10^6
300
400
500
600
700
λ(nm)

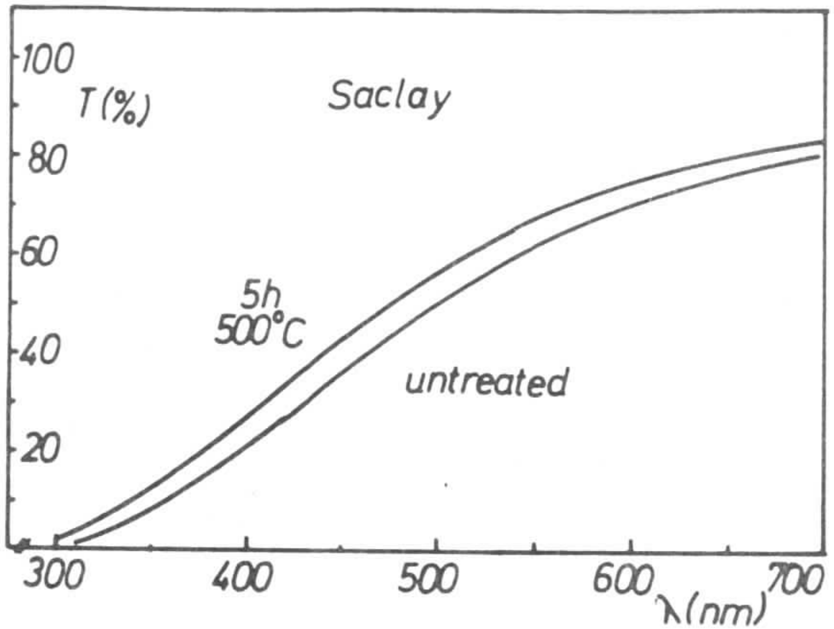
N 11


e beam
3 GeV
mirrors
RCA
8854
aero gel
10cm

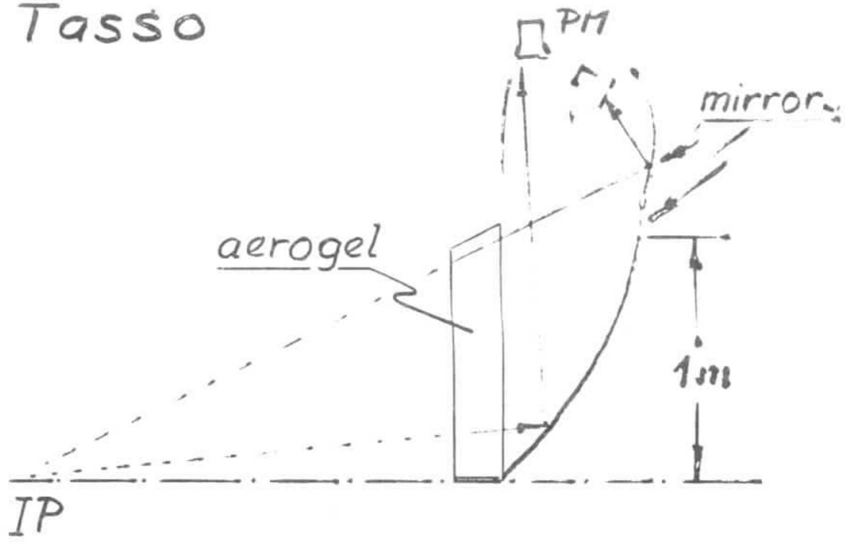

Aerogel
Efficiency
100
%
95
90
0
5
10
15
n = 1.02
Aerogel thickness in cm

N 12


1
.9
.8
.7
.6
.5
BaSO4
3xMillipore GSWP
Al (MgF2)
Al
200
300
400
500
600
λ(nm)



Tasso



aerogel: 1 m × 40 cm, 20 cm thick
32 cells

P 1

Detector Design Study

C. W. Darden
H. Hasemann
A. Krolzig
W. Schmidt-Parzefall
H. Schröder
H.-D. Schulz
F. Selonke
R. Wurth

F 15 F 51 R 2

C. Fabjan
H. Hoffmann
A. Minten

CERN

P 2

Why

DORIS = gold mine

Charm Spectroscopy
Heavy Lepton (non sequential?)
Upsilon region

Cornell, SPEAR

What

Solid angle
Resolution
Identification

Second Generation $\stackrel{?}{=}$ Last Generation

Constraints
PETRA DASP

How

Particle Identification

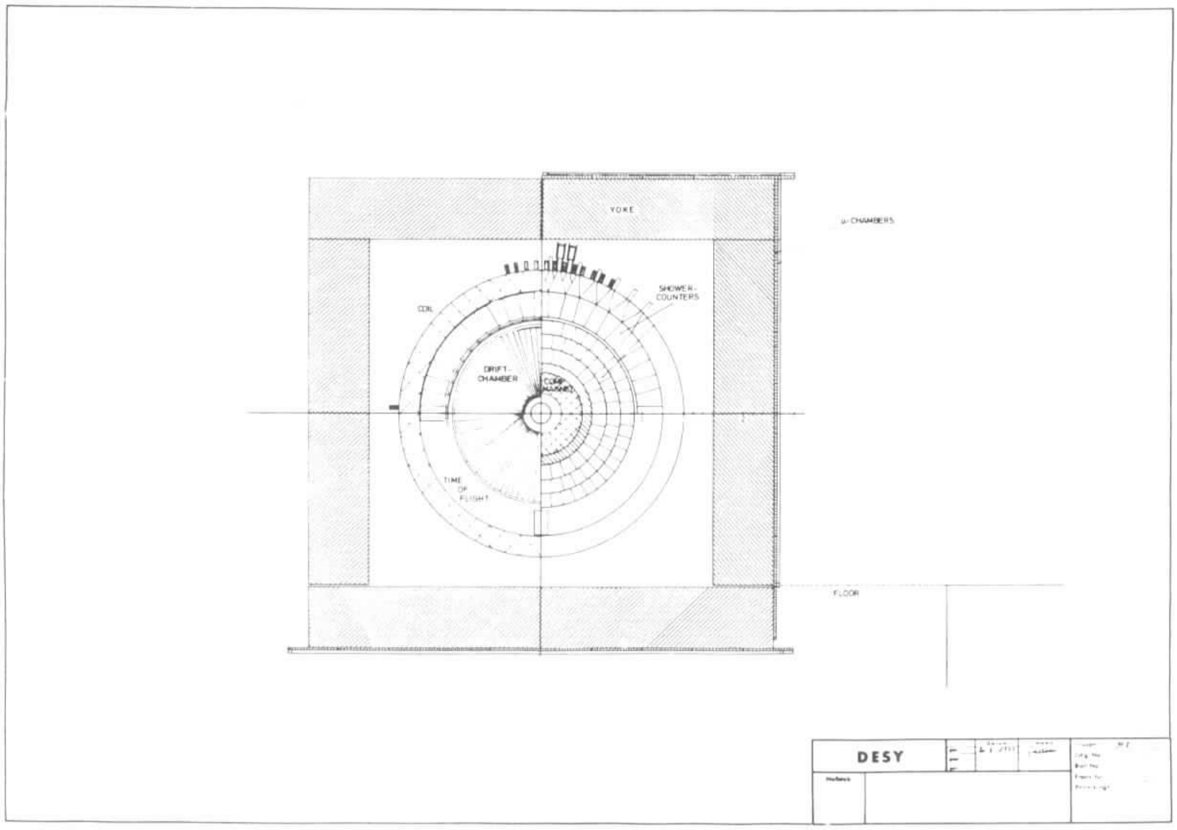
→ Čerenkow: Open inhomogenous field

→ $\frac{dE}{dx}$: Solenoid

P4

DESY

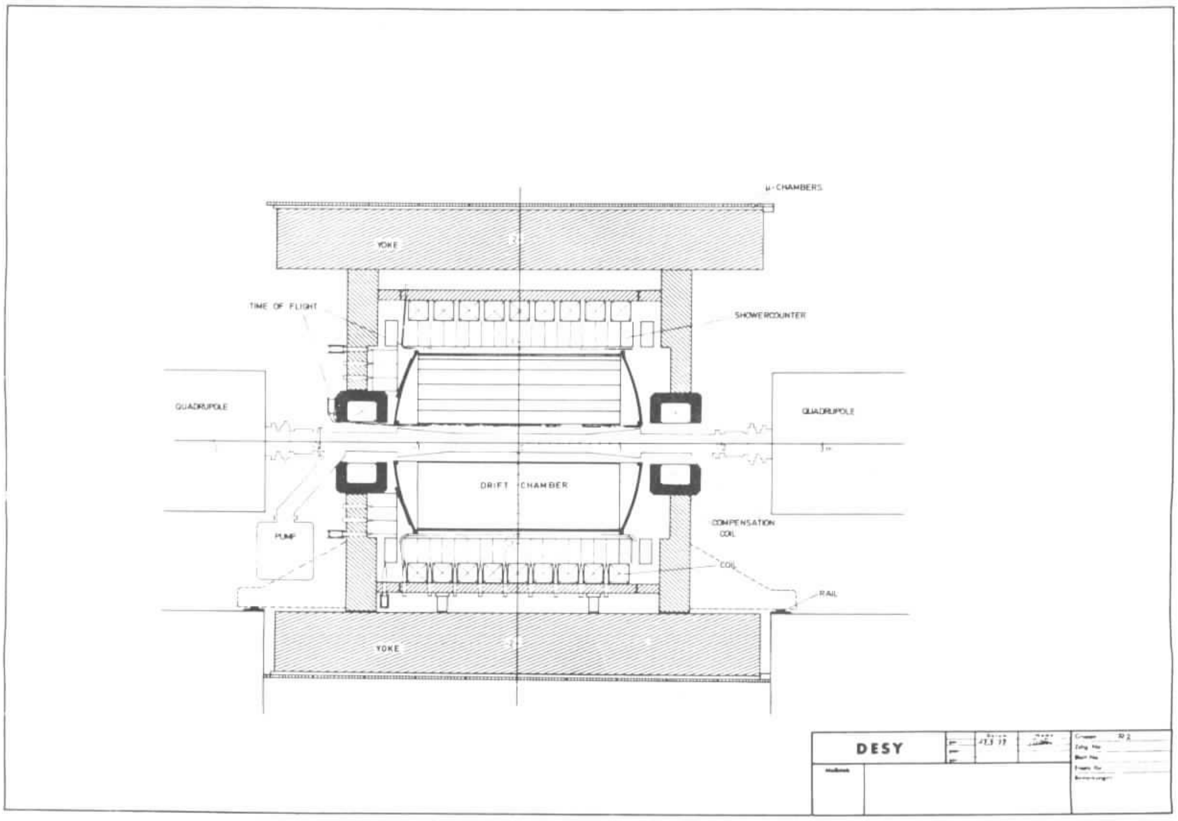
26802



P3

DESY

26803

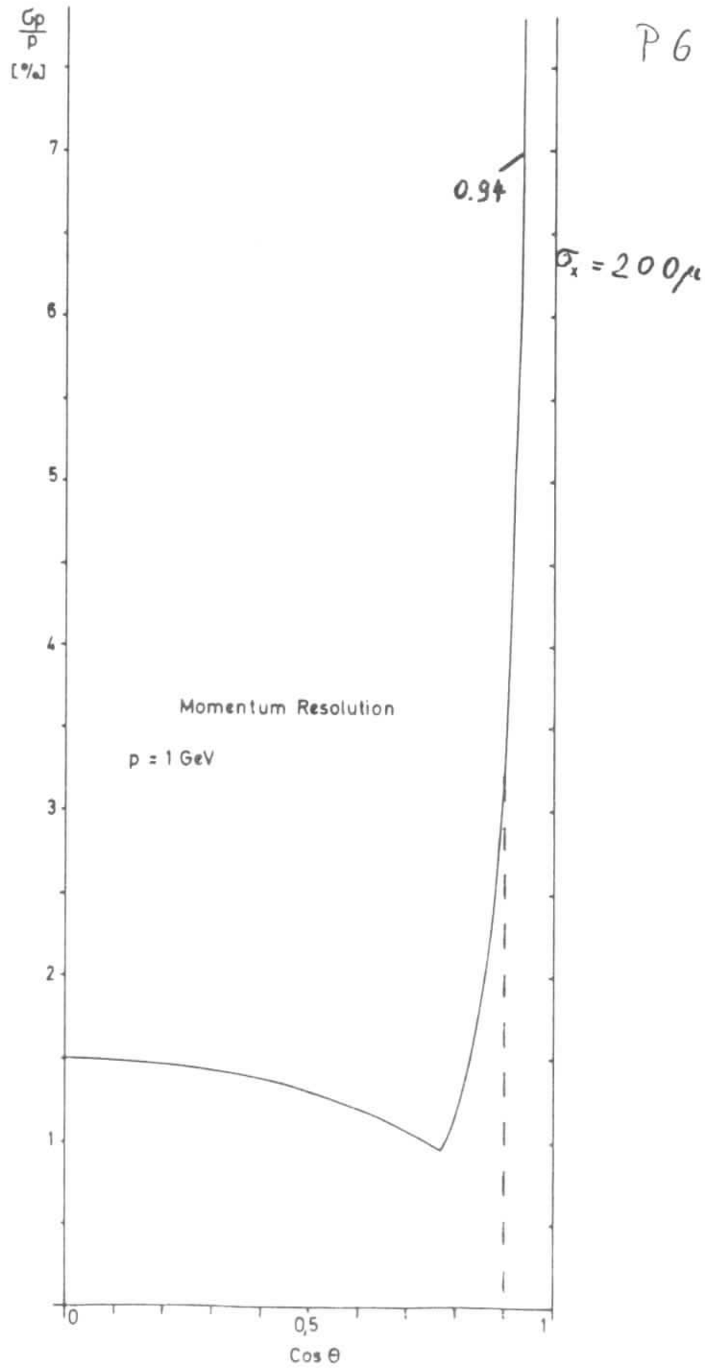


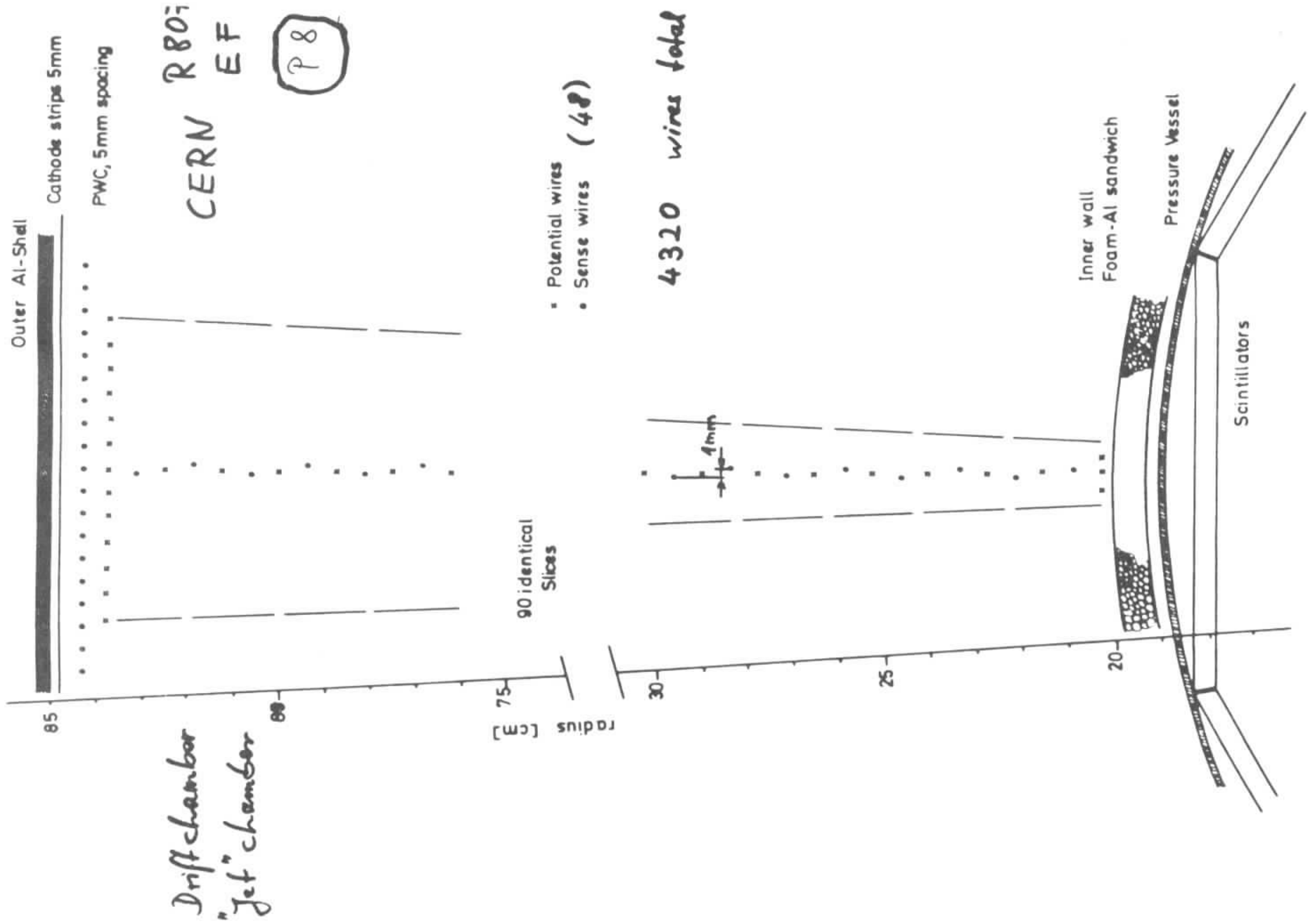
P. 5

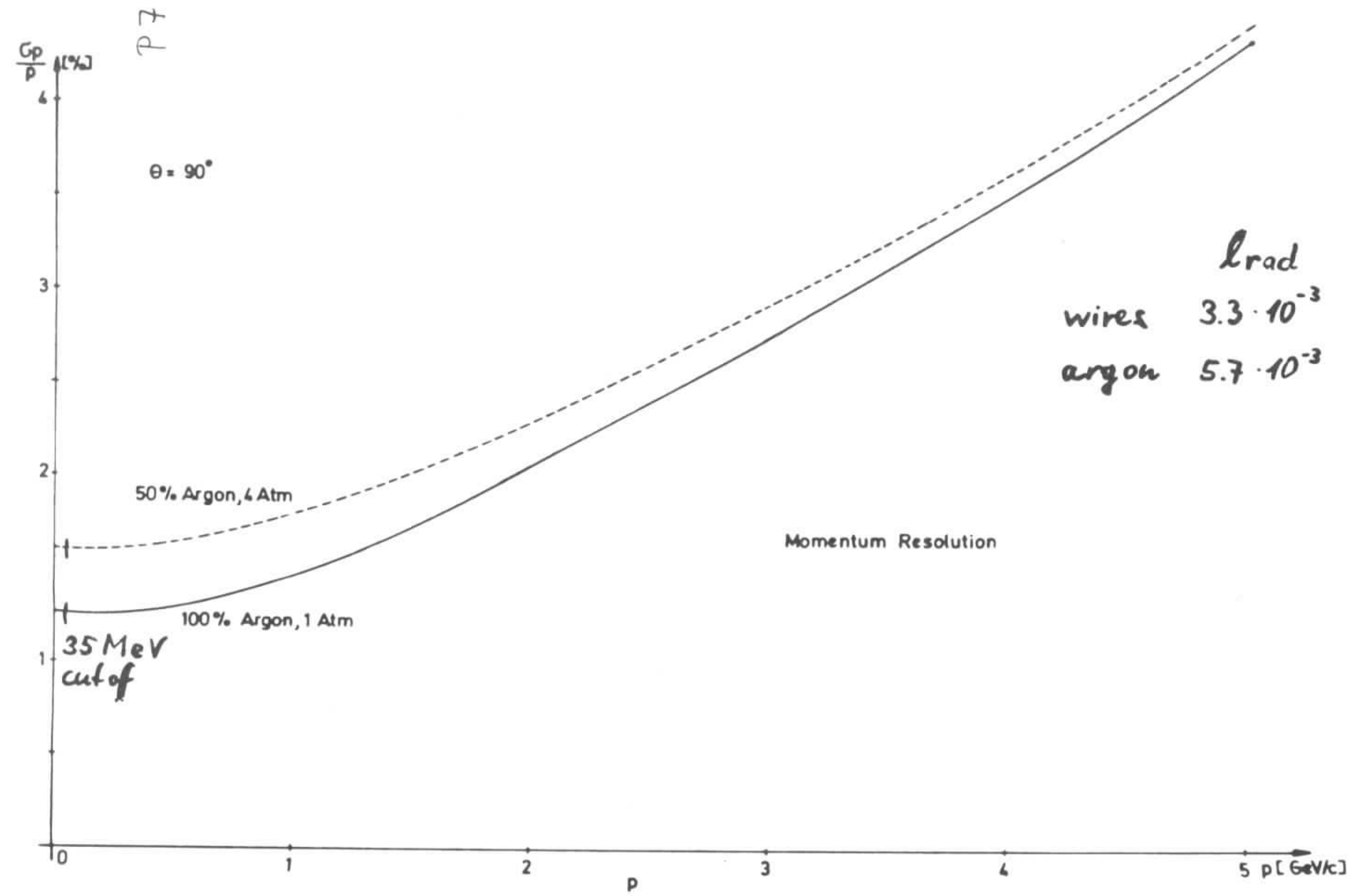
M a g n e t

Nominal field	8 kG
Nominal ~~field~~ power	1.9 MW
Conductor material	copper
Conductor weight	21.5 t
Conductor cross section	1.5 x 1.5 cm^2
Number of coils	9
Number of turns	9 x 169 = 1521
Current	1260 A
Power supply	DASP
Weight of iron yoke and muon filter	420 t

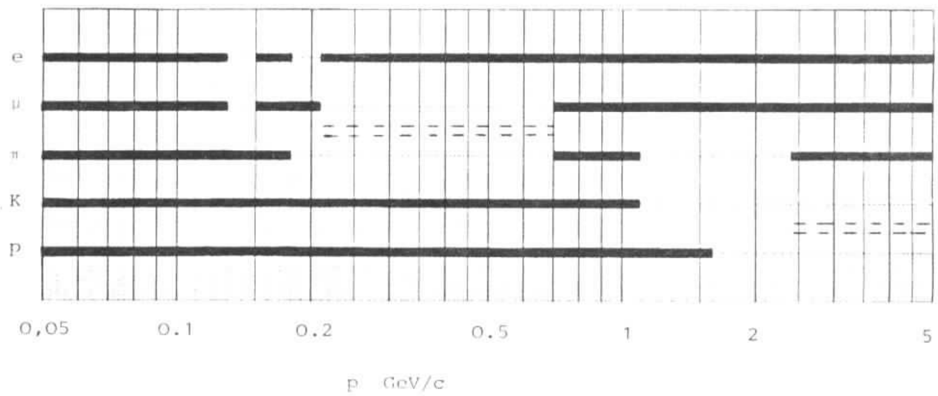
P 6




CERN R807
EF
P8
Outer Al-Shell
Cathode strips 5mm
PWC, 5mm spacing
Driftchamber
"Jet" chamber
90 identical Slices
Potential wires
Sense wires (48)
4320 wires total
1mm
Inner wall
Foam-Al sandwich
Pressure Vessel
Scintillators
85
80
75
radius [cm]
30
25
20


P7
σp/p [%]
θ = 90°
50% Argon, 4 Atm
100% Argon, 1 Atm
35 MeV cutof
Momentum Resolution
lrad
wires 3.3 · 10⁻³
argon 5.7 · 10⁻³
p
p [GeV/c]
0
1
2
3
4
5

P10


e
μ
π
K
p
0,05
0.1
0.2
0.5
1
2
5
p GeV/c

P9

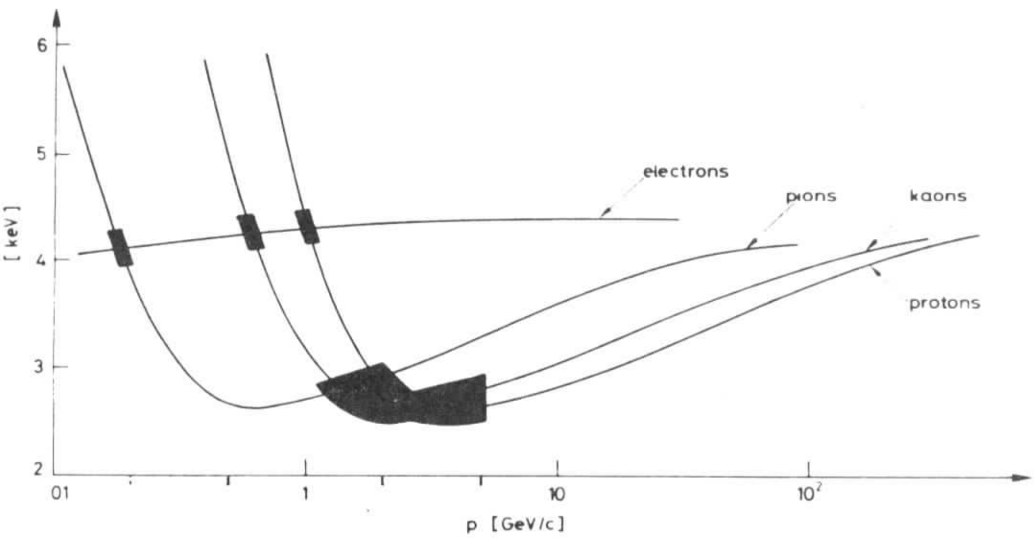
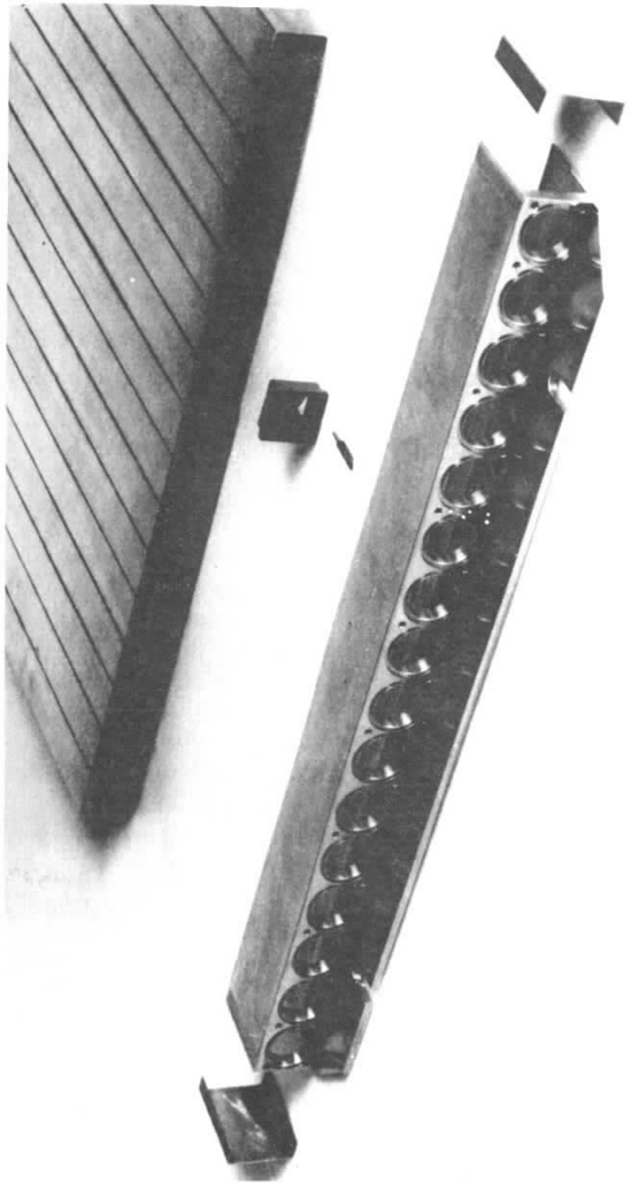

6
5
4
3
2
[keV]
electrons
pions
kaons
protons
01
1
10
10^2
p [GeV/c]

Fig. 12



μ - Chamber
CERN WA 18

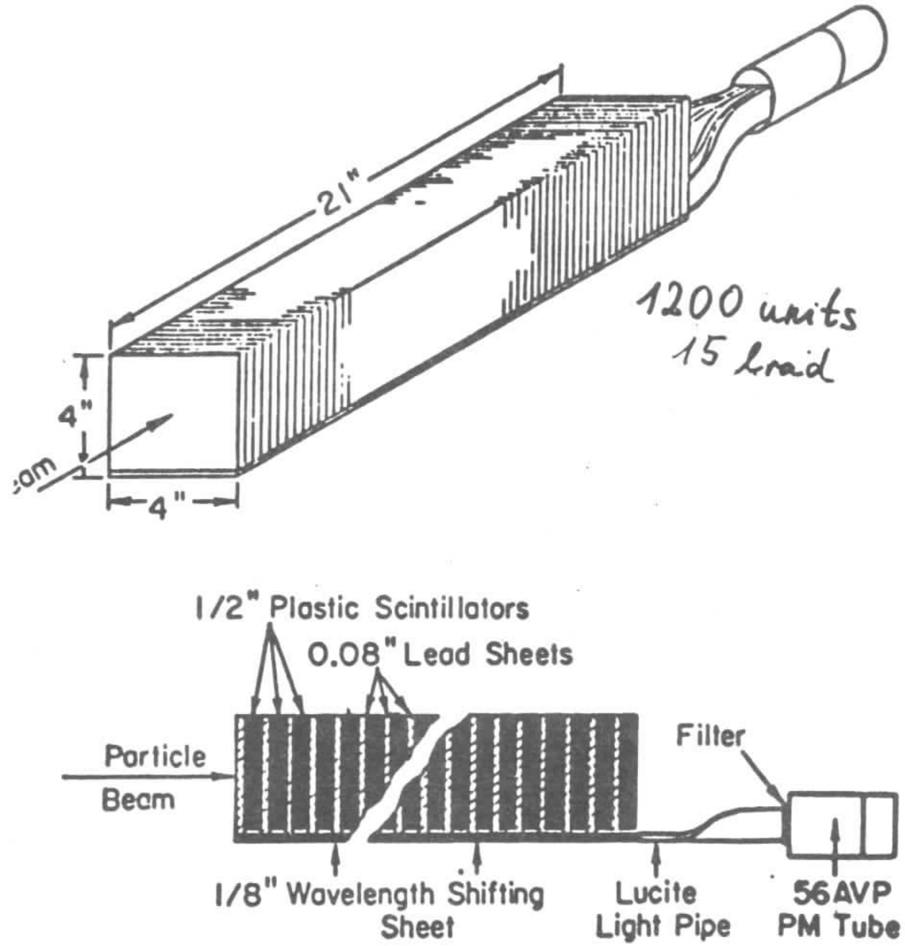
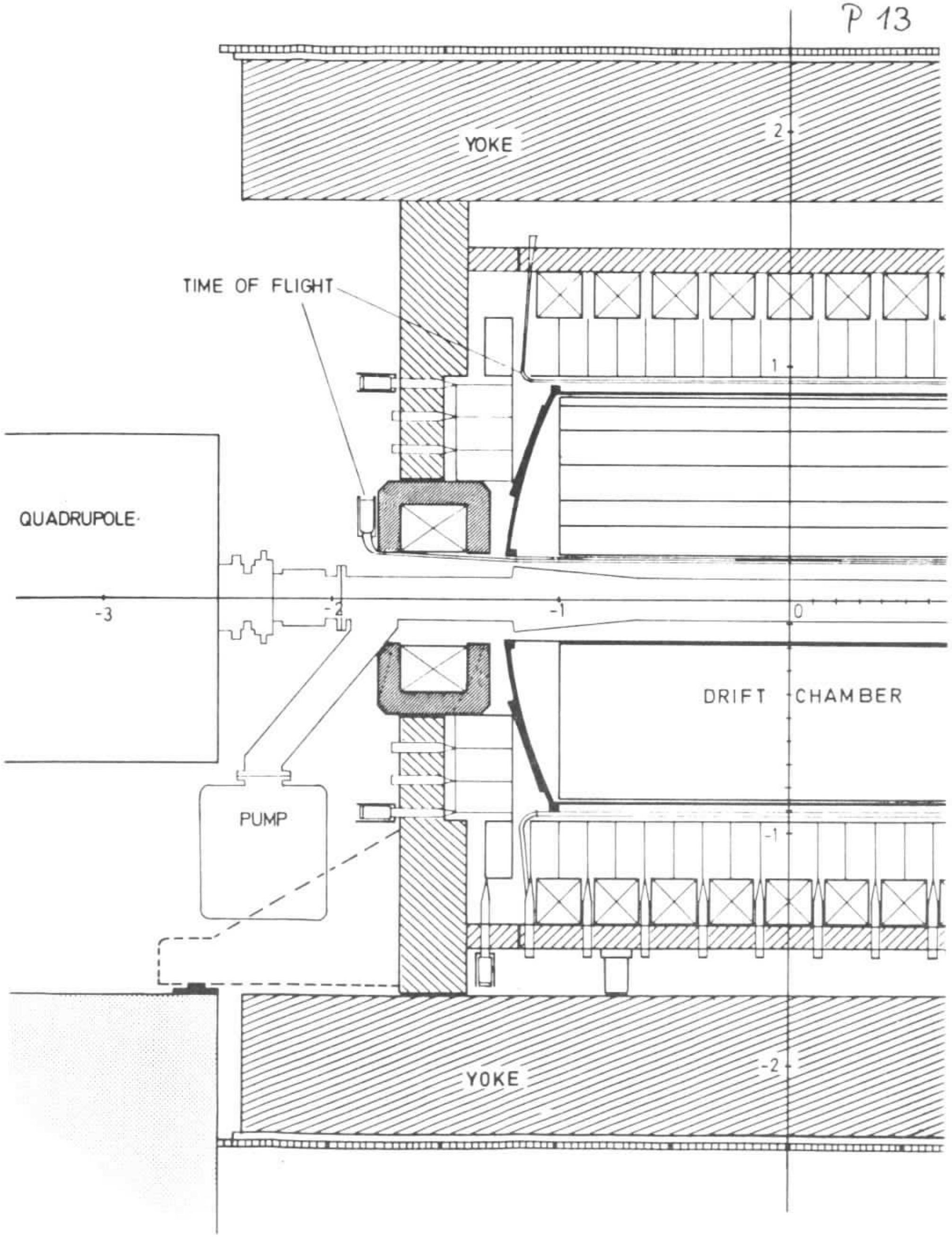


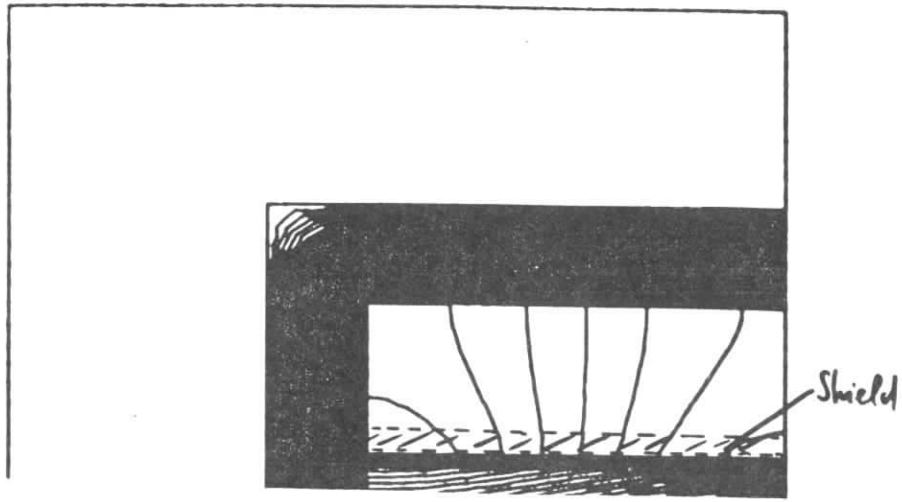
FIGURE 1

P 13

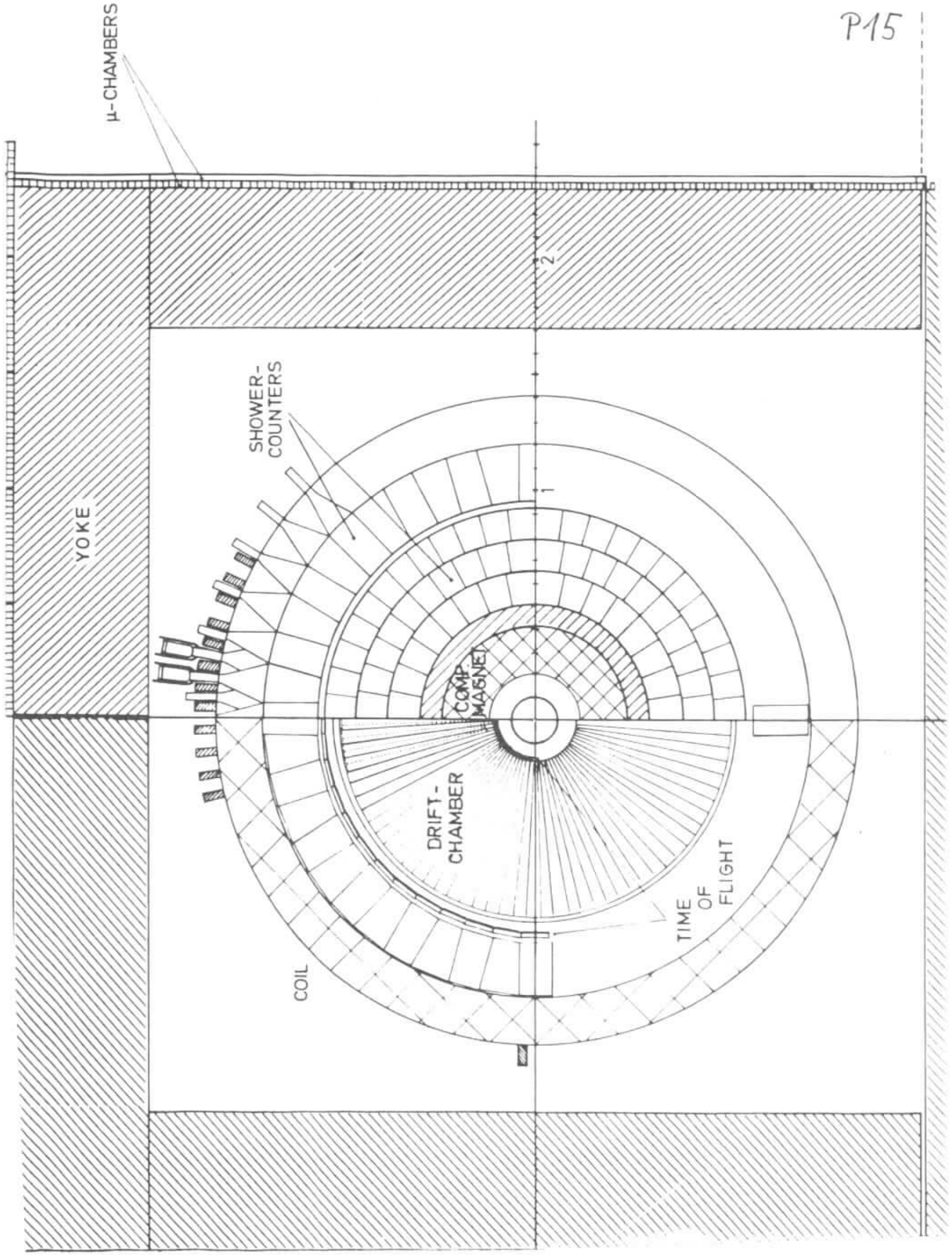


P 14

Stray-field



P15



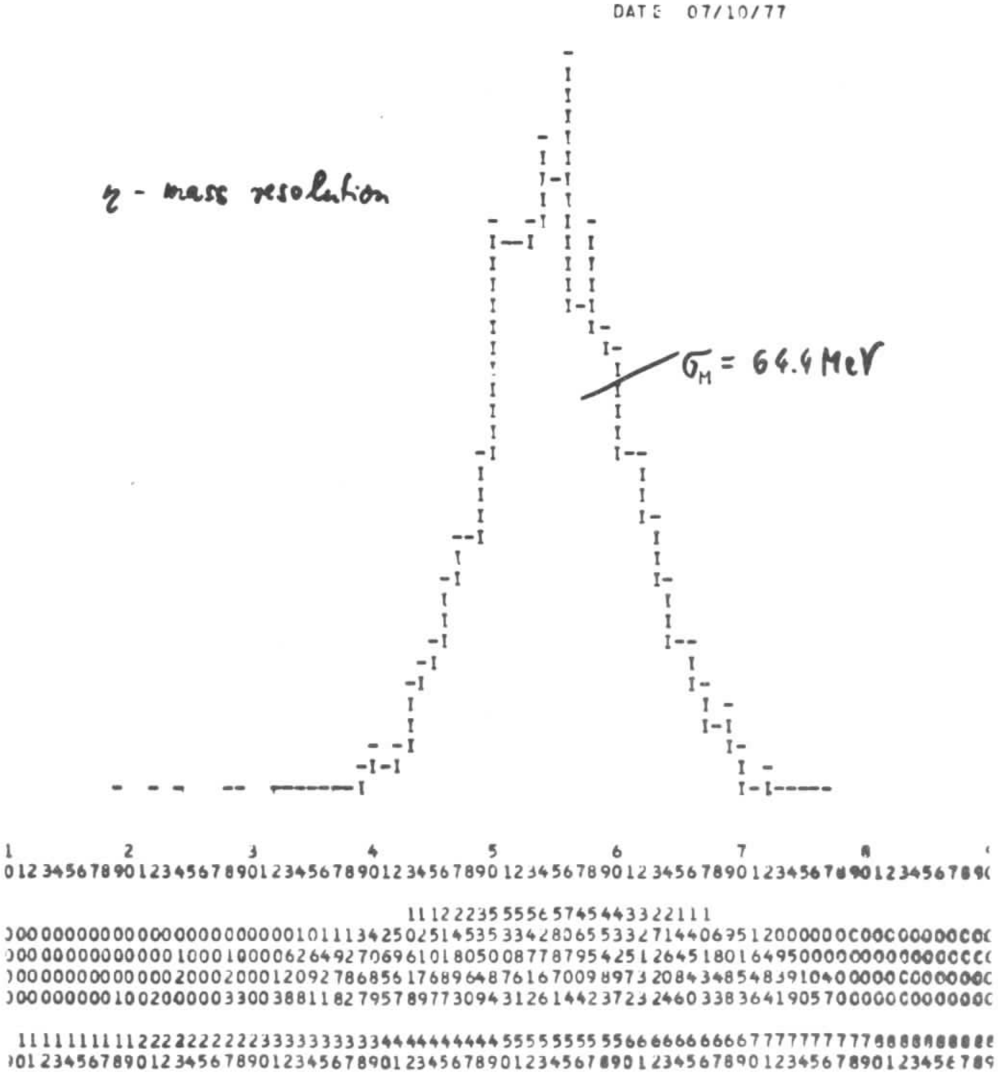
P16

Monte Carlo

Mass resolution for µ - pairs

```
( JAN 73 )                                    OS/360  FORTRAN H
COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=66,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
          COMMON //HMEMOR(5000)
          SIGE = 0.06
          SIGTH = 0.04
          T = 0.19
          PM = 0.55
          PO = 0.5*PM
          EBEAM = 5.
          CALL HBOOK1(1,16H    SMEARED MASS,100,0.,1.,0.)
          DO 100 I=1,10000
          P = RN(X)*EBEAM
          PSQ = P*P
          E = SQRT(PSQ+PM*PM)
          W = EXP(-E/T)*PSQ/E
          COSTH = RN(X)
          PL1 = PO*COSTH
          PL2 = -PL1
          PT1 = PO*SQRT(1.-COSTH*COSTH)
          PT2 = -PT1
          BETA = P/E
          GAMMA = 1./SQRT(1.-BETA*BETA)
          PL1S = GAMMA*(PL1+BETA*PO)
          PL2S = GAMMA*(PL2+BETA*PO)
          TH1 = ATAN(PT1/PL1S)
          TH2 = ATAN(PL2S/PT2) + 1.57
          P1 = SQRT(PL1S*PL1S+PT1*PT1)
          P2 = SQRT(PL2S*PL2S+PT2*PT2)
          P1M = P1 + FNORM(X)*SIGE*SQRT(P1)
          P2M = P2 + FNORM(X)*SIGE*SQRT(P2)
          TH1M = TH1 + FNORM(X)*SIGTH
          TH2M = TH2 + FNORM(X)*SIGTH
          AMSQ = 2.*P1M*P2M*(1.-COS(TH1M+TH2M))
          IF (AMSQ.LT.0.) AMSQ = 0.
          AM = SQRT(AMSQ)
          CALL HFILL(1,AM,0.,W)
      100 CONTINUE
          CALL HPRINT(1)
          STOP
          END
 EFFECT       NAME=  MAIN,OPT=00,LINECNT=66,SIZE=0000K,
 EFFECT       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
     SOURCE STATEMENTS =      39 ,PROGRAM SIZE =     1384
   NO  DIAGNOSTICS GENERATED
 F COMPILATION                                        145K BYTES OF COR
```

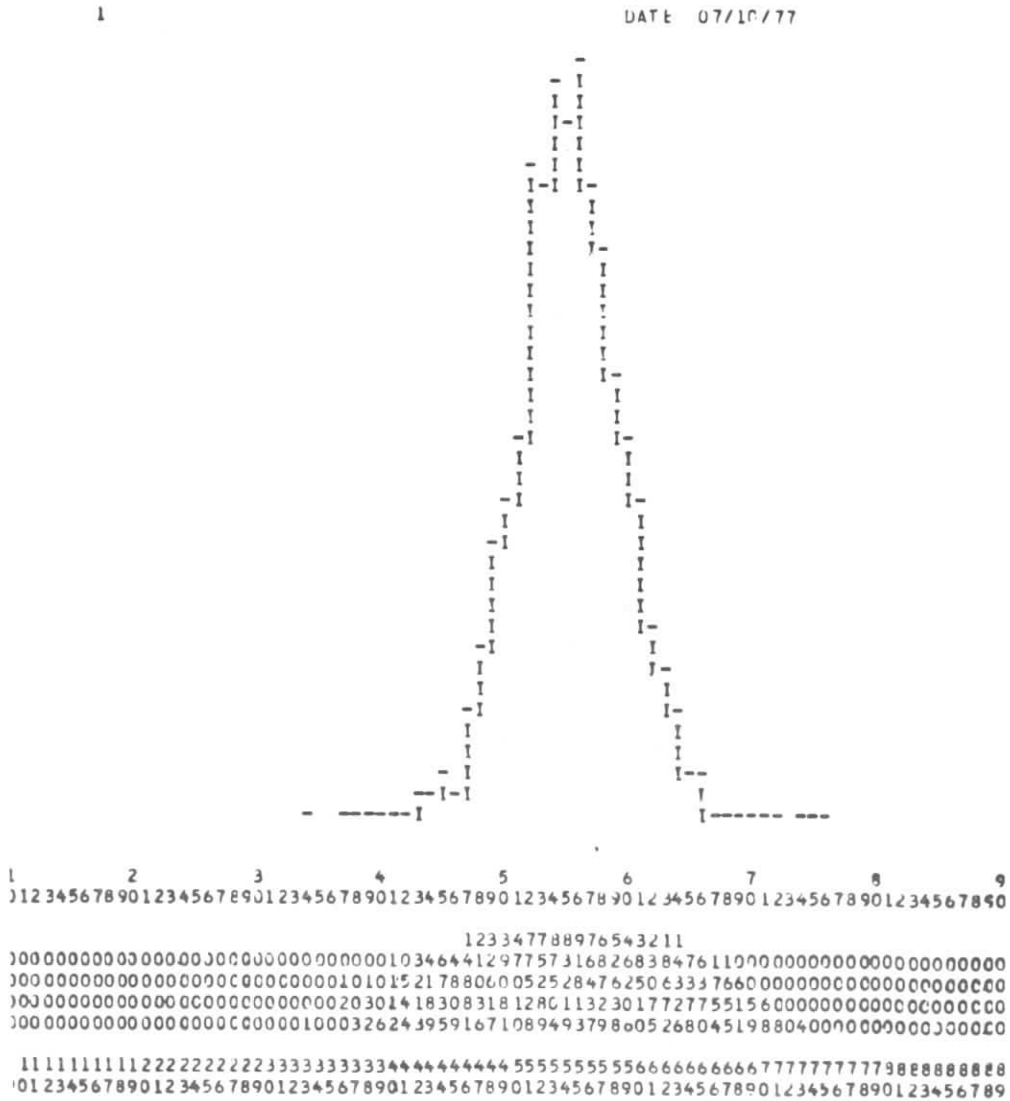
P 17



ALL CHANNELS = 0.9473E+01   UNDERFLOW = 0.0   OVERFLOW = 0
MEAN VALUE = 0.5448E+00   R . M . S = 0.6444E-01   ABNOR CHA= 0

$\sigma_E = \frac{9\%}{\sqrt{E}}$; $\sigma_\theta = 40$ mrad

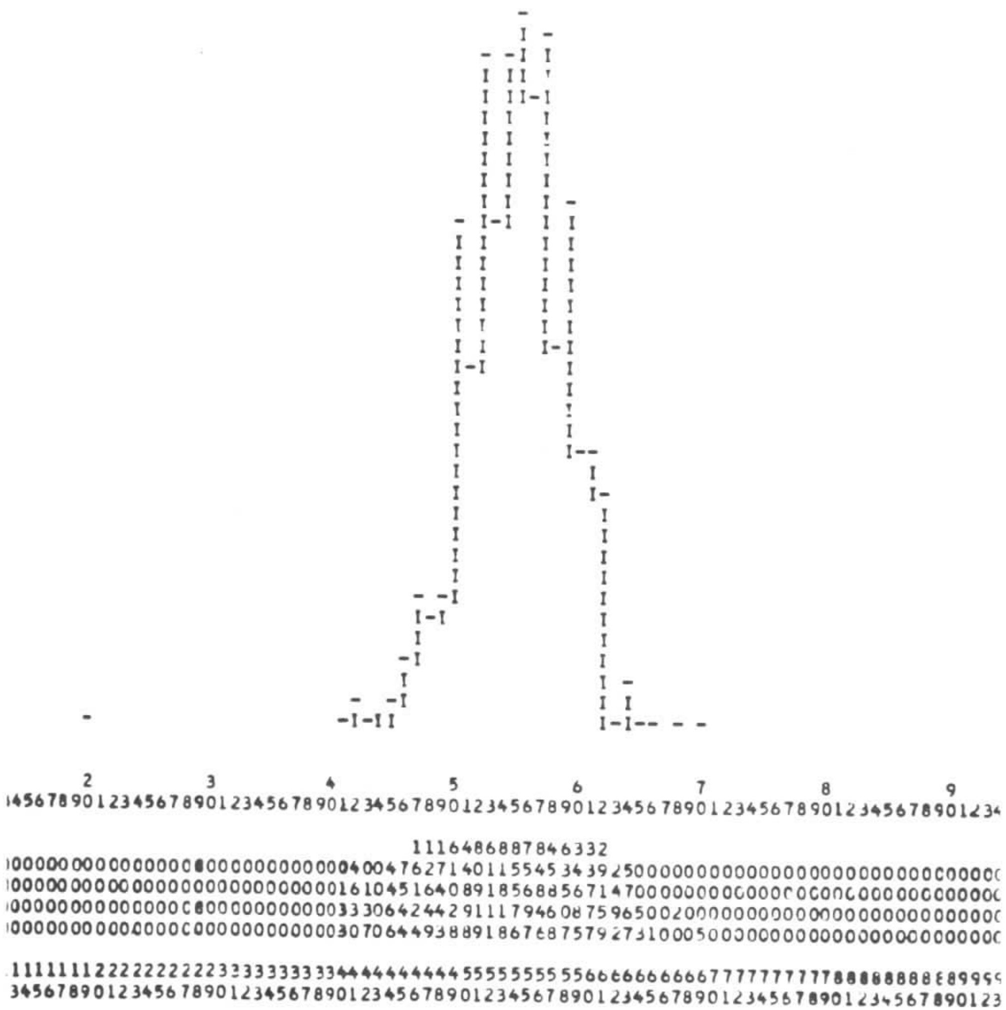
P 18



ALL CHANNELS = 0.9473E+01   UNDERFLOW = 0.0   OVERFLOW = 0
MEAN VALUE = 0.5471E+00   R . M . S = 0.4488E-01   ABNOR CHA= 0

$\sigma_E = \frac{6\%}{\sqrt{E}}$; $\sigma_\theta = 40$ mrad

1 DATE 29/09/77 NO



* ALL CHANNELS = 0.8544E+00
* MEAN VALUE = 0.5433E+00
* UNDERFLOW = 0.0
* R . M . S = 0.3960E-01
* OVERFLOW = 0.0
* ABNOR CHA= 0.0

$$\sigma_E = \frac{6\%}{\sqrt{E}} \; ; \; \sigma_\theta = 20\,\text{mrd}$$

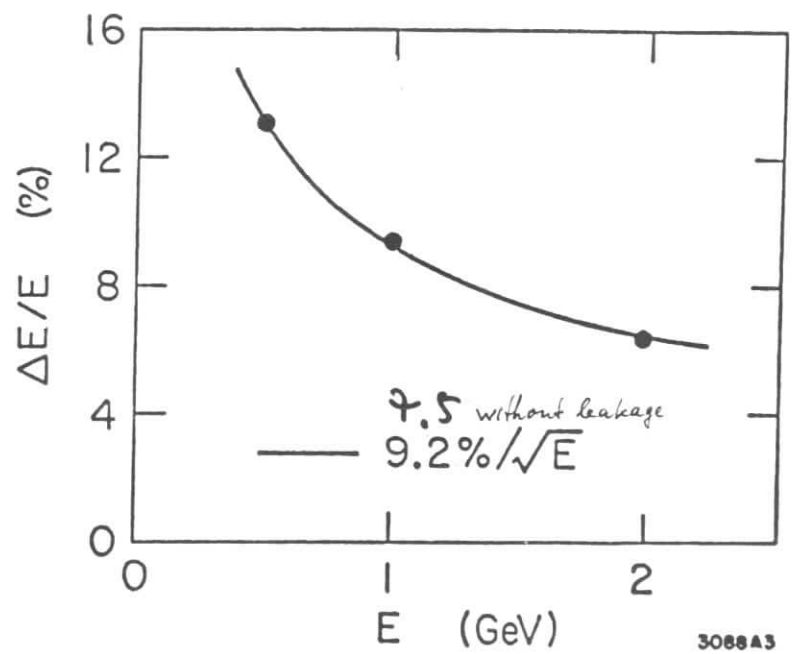


FIGURE 4

P 21

JADE

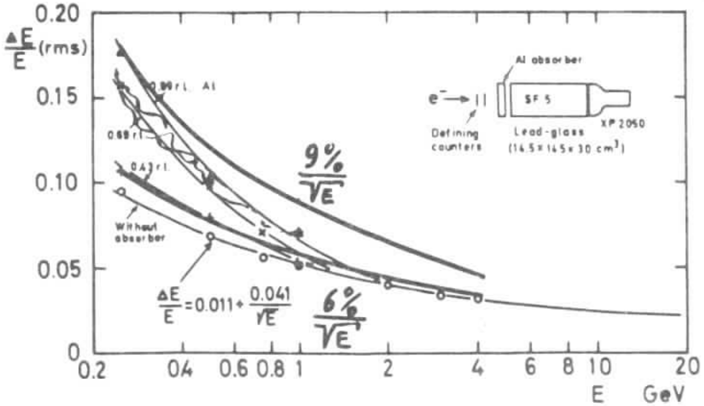
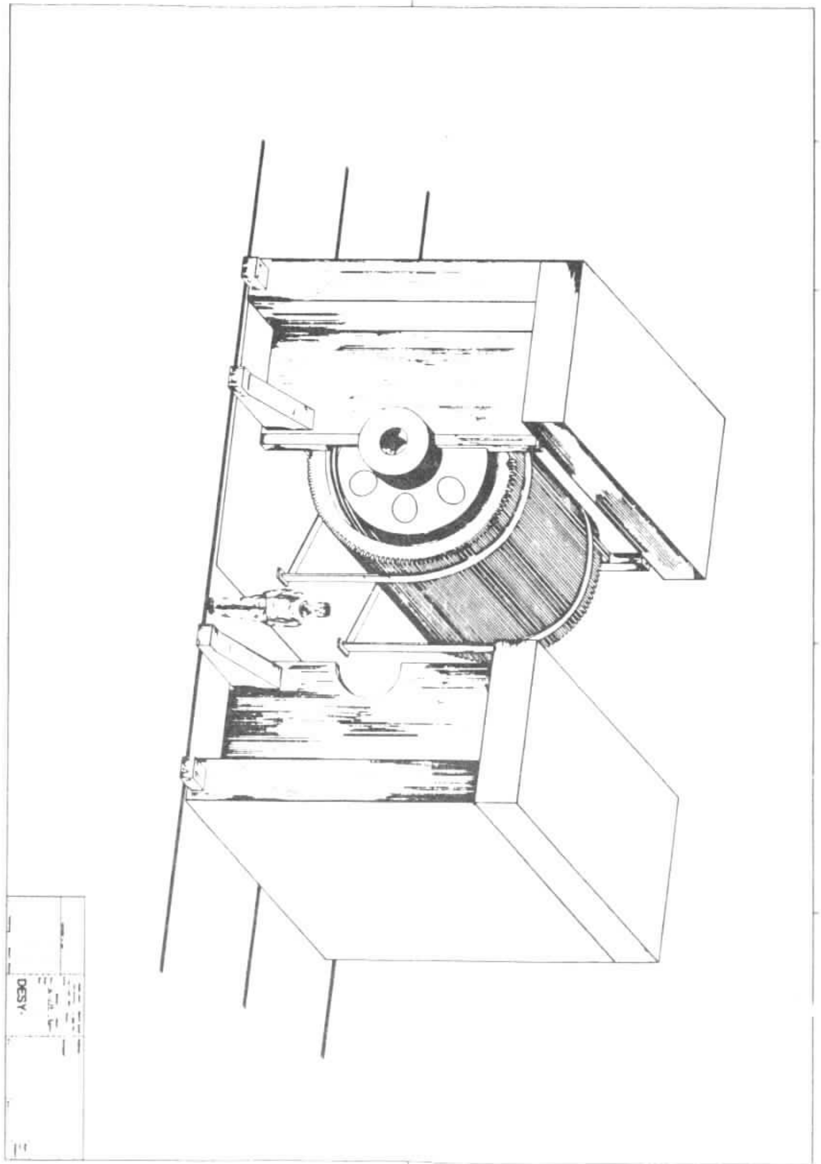


Fig. 2.11

P 22



DESY
26804

Detector Components — tentative

Driftchamber + Preamps	CERN	R 807, EF / EP
Pressure Vessel	JADE design	
TOF : PM + Electr.	DASP	
Shower Counters	POLIVAR	Rome
μ - Chambers	MBB	WA18 design
+ MWPC Electr.	DASP	

Trigger Electronics
Cables
Computer
Counting room — DASP
Pit , Rails
Hydraulics . . .

COST

Name

J. K. BIENLEIN

[illegible] for measuring [illegible]
[illegible]

very preliminary

Contents
- motivation
- basic requirements
- detector
- trigger
- data reduction
- data evaluation
- other topics, future development

Q 2

1. Motivation

Aim is to test numerical QCD predictions.

Where do they show up? QCD is a gauge theory, i.e. it predicts "radiative" corrections.

Eq. graphs in QCD picture

$$\sigma_{tot} = \frac{4\pi}{3} \cdot \frac{\alpha^2}{s} \cdot \sum Q_i^2 \cdot \left(1 + \frac{3C_3}{4\pi} \cdot \alpha_s(Q^2)\right) \qquad C_3 = \frac{1}{2} \sum_i \lambda_i^2 = \frac{4}{3}$$

(Gell-Mann SU(3) structure constants)

$$\alpha_s(Q^2) = \frac{12\pi}{25 \cdot \ln \frac{Q^2}{\Lambda^2}}$$

$\Lambda = 0.5\,GeV$ from deep-inelastic scattering

$\Delta R_{QCD} \approx 0.35$

These measurements have to be done in the Doris energy range

Q 3

2. Basic requirements

2.1. Which accuracy is needed?

now: $\frac{\Delta \sigma_{tot}}{\sigma_{tot}} = 12\% \Rightarrow \Delta R \approx 0.6$

needed: $\Delta R = 0.1 \Rightarrow \frac{\Delta \sigma}{\sigma} = 2\% \Rightarrow$ aim at 1%

absolute measurement in asymptotic region

can the $\ln Q^2$-dependence be seen?

between 5 and 10 GeV_{cm} ΔR decreases ~30%

2.2. Measuring time

$$rate = 10^{31}\,cm^{-2}s^{-1} \cdot \left(\frac{E_{beam}}{5\,GeV}\right)^4 \cdot \frac{25\,nb}{(E_{cm}/GeV)^2} \cdot R = 300 \cdot R \ \frac{events}{d} \ \text{at } 4\,GeV_{cm}$$

$\approx 1'500$ "

1% statistics ≙ 10'000 events ⇒ 7.5 d

≈ 10 d / point

2.3. Strategy

successive approaches: 5% accuracy at various energies

3% " " few "

1% " " selected "

reasons for a successive approach

measurement of energy dependence to verify that one is sitting in an asymptotic region and not in a resonance region

a sufficiently large energy range has to be chosen for the radiative corrections

details of acceptance calculations depend on experimentally measured quantities

⇒ [illegible], modular [illegible]

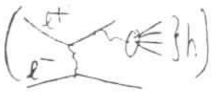
Q 4

2.4 Systematic effects

$N = L \cdot \sigma_{tot} \cdot acc$ + (heavy lepton)

+ (Bhabha) + (μ-pairs) + ($e^+e^- \to \gamma\gamma$)

+ (beam-gas) + (cosmics)

+ ($\gamma\gamma$ - events) + ()

good part has to be measured, other contributions have to be subtracted

requirements:

4π - detector

low momentum cut-off

good particle identification: e/h - discrimination

μ - identification

γ - detection

luminosity measurement:

calibration in detector by μ-pairs

wide-angle Bhabha's

" " $\gamma\gamma$ - events

monitor by small angle Bhabha's

neutral energy detection

measurement of z-coordinate

time measurement

Q 5

3. Detector

3.1. Components

magnet

track chamber

shower detector

μ- "

end cap "

3.2. Scheme of detector

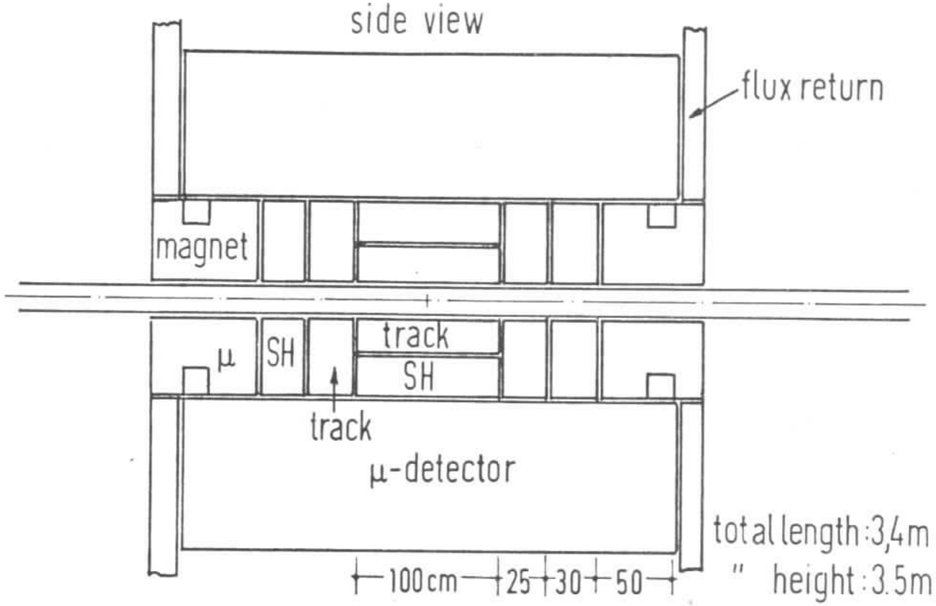
remarks: 1. modular set-up $\Rightarrow$ Helmholtz-coils

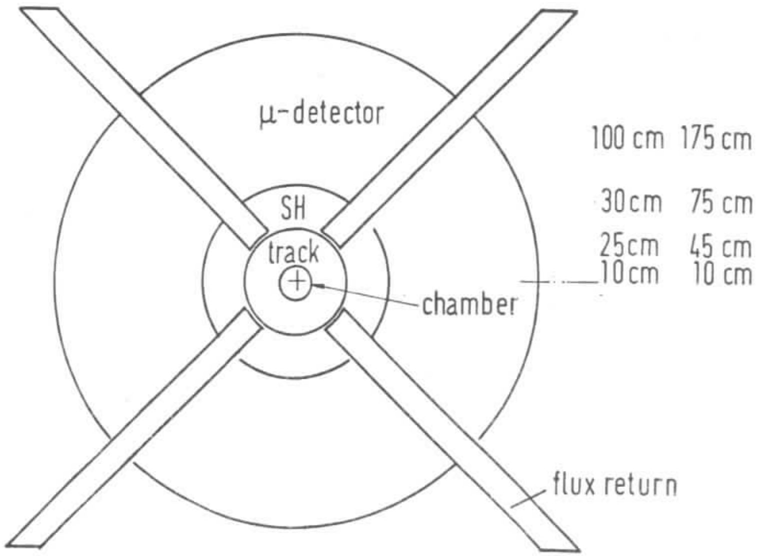
2. 4-fold symmetry from flux return

necessary for polarization measurements

flux return can be used as support for equipment

(e.g. Cerenkov-counters)





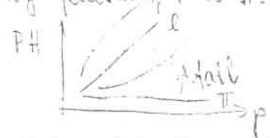
3.3. Magnetic field

The magnetic field is designed such that particle identification is possible. It will not be suited for "jet physics".

It should be small to accept also low momentum particles.

As a by-product no requirements on field homogeneity are made. This is the basic choice for this detector.

Which $\frac{\Delta p}{p}$ is necessary? One wants to discriminate e/π by pulseheight in shower counters.



From our experience:
at 1.5 GeV a $\frac{\Delta p}{p} \approx \pm 10\%$ is needed.

Calculation of bending and field strength from:

$$\alpha_{mrad} = 30 \cdot \frac{\int B_T\, dl_m}{p_{GeV}}$$

$$\frac{\Delta p}{p} = \frac{\Delta\alpha}{\alpha} = \frac{1}{30 \cdot \int B_T\, dl_m} \cdot p_{GeV} \cdot \Delta\alpha_{mrad}$$

Which accuracy for the measurement of α is possible?
position measurement: ±0.5 mm
track length: 25 cm
} ⇒ $\Delta\alpha = 3$ mrad

Magnetic field: $B \approx 4$ kT, $l = 25$ cm

Low momentum cut-off from bending in magnetic field: ≈ 30 MeV/c
(⇒ always, but not an important effect!)

3.4. Track chamber

6 chambers à 2 coordinates (minimum needed is 3·2)

The construction of the chambers has still to be discussed.

alternatives: helicoidal chambers

strip read-out for z-coordinate (like Pluto)

hexagonal or quadratic arrangement

technical requirement: use of a chamber gas which does not deteriorate in a high radiation level

(F-31 gas (60% Ar + 40% CO_2) is OK, but needs ~4'200 V)

A possible solution seems to be: drift chambers, but small drift length.

12 planes (helicoidal) ⇒ thickness ≈ 25 cm of track chamber

can the whole track chamber be put into a single gas volume?

(⇒ low multiple scattering)

wires ≈ 2'700

Solid angle of track chamber

length	1 m	1.5 m
θ_{min}	42°	31°
$\Omega/4\pi$	74%	86%

Beam pipe scintillator: 12 counters (= 24 scintillators)

3.5. Shower detector

Purpose: e/h-discrimination } some spatial resolution needed
γ-detection }

Construction: 3 segments position + PH, 5 segments PH only

| Sc | Pb $1X_0$ position Sc | ... | ... | Pb $2X_0$ Sc | 5 X

95% detection efficiency
for γ's with good position

total thickness: $13\ X_0$
30 cm

~600 multipliers, equipped with ADC's and TDC's.

3.6. μ-detector

Fe or concrete

Which thickness is needed?

E_μ	0.1	0.5	1	2	GeV
range (in Fe)	9	45	90	180	cm
range / Λ_0	0.9	4.5	9	18	

$\sim 9\ \Lambda_0 = 90$ cm

Construction: 9 sheets à 10 cm
position measurement between the sheets.

Mass: ~200 t

Q 10

3.6. End cap detector

Aim is to increase the solid angle

to measure small angle Bhabha's and μ-pairs

The set-up repeats the inner detector

track chamber, preceded by a scintillator

shower detector

μ-detector (magnet iron yoke is used)

multipliers: scintillation counter : 24

shower " : 48

Solid angle $\Omega = 4\pi \cdot 98\%$ $(\Theta_{min} = 11.3°)$

Total length of detector is 3.4 m

Problem: end cap detector is preceded by material for the mechanical construction and the read-out of the inner detector

Q 11

<u>Other topics, future developments</u>

1. F_{tot} in resonance region
2. τ-decays, e.g. μe decay channel to verify (V–A) interaction, esp. with transverse polarized beams)
3. γγ-physics. Add a beam tagging system. Measure $\sigma_{tot}(\gamma\gamma \to h)$
4. calorimetric measurements
5. jets

6. add Cerenkov counters (needs change of shower and μ-detectors)

7. add spectrometer arms