S14

2nd ECFA/DESY Study on Physics and Detectors for a Linear Electron-Positron Collider

LAL - Orsay - France, April 5-7, 1998

Date : April 6, 1998 - 14:30

Parallel groups to plan tasks :

Detector Performance + R&D

S14

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M. Gruwé

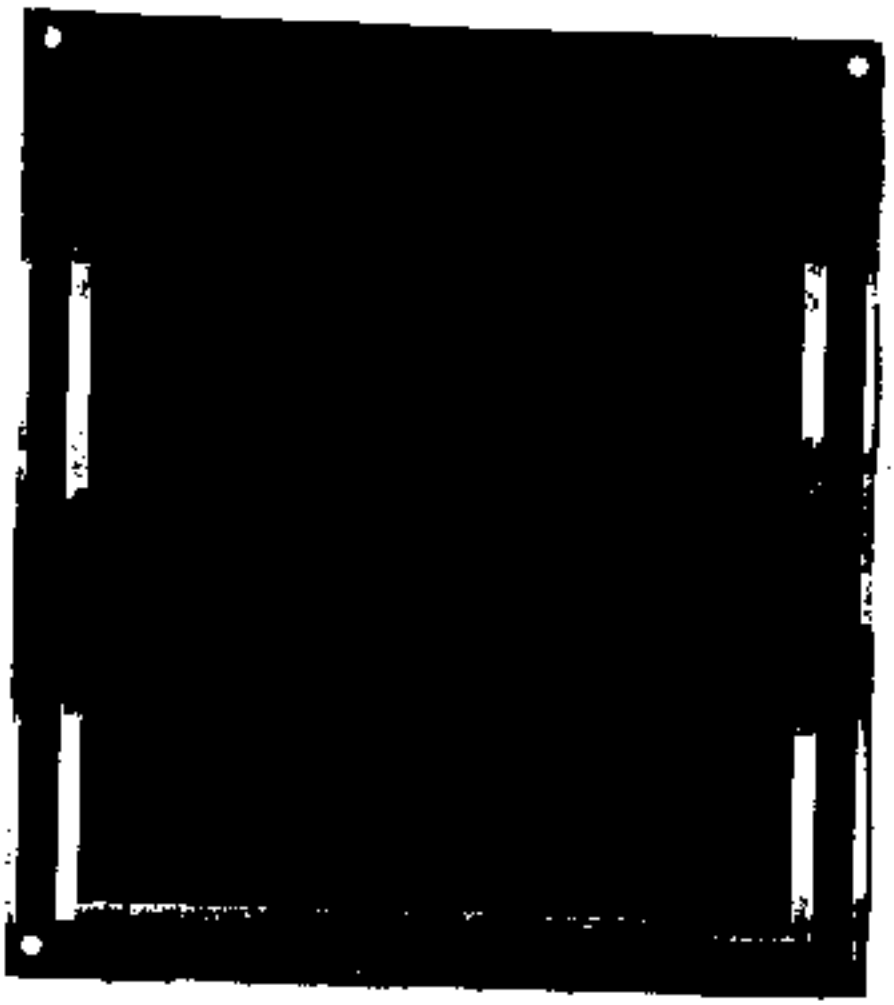
GEM

Gas Electrons Multiplier

- What is a GEM?
  And how does it work?
- Current status, performances
- Future works and developments

⇒ inputs

GEM 2



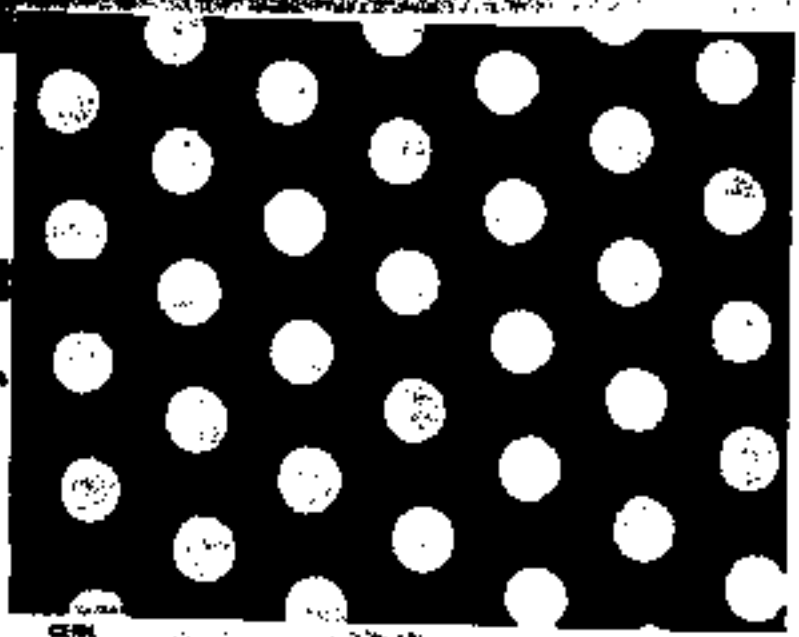
50 µm KAPTON
4 µm GOLD-PLATED COPPER ELECTRODES
140-200 µm PITCH
80-100 µm HOLES
100x100 mm^2 ACTIVE AREA

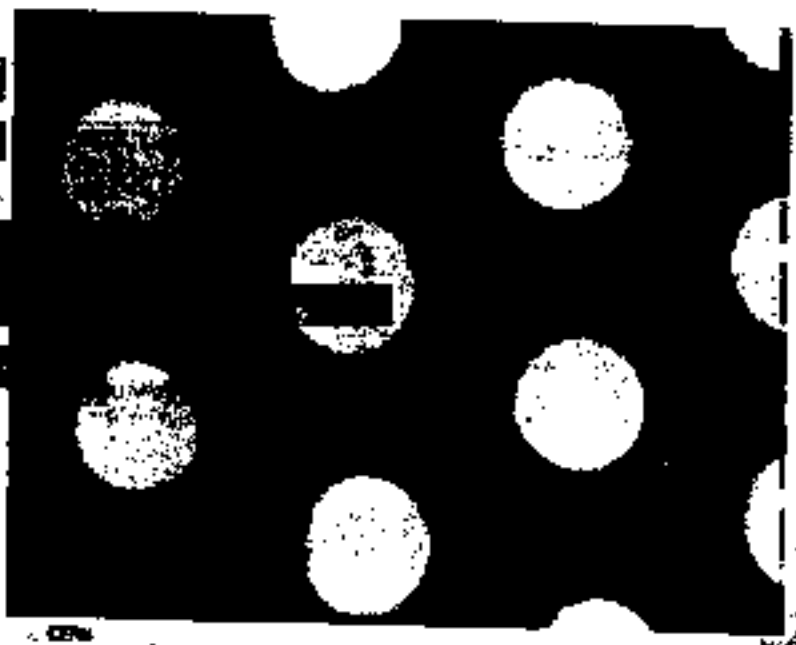
CERN-PPE-TA1-GD

GAS ELECTRON MULTIPLIER

GEM # 81

200/130/110





Plotted at 18:46:40 on 14/09/87 with Confield version 6.15.

Current status Performances

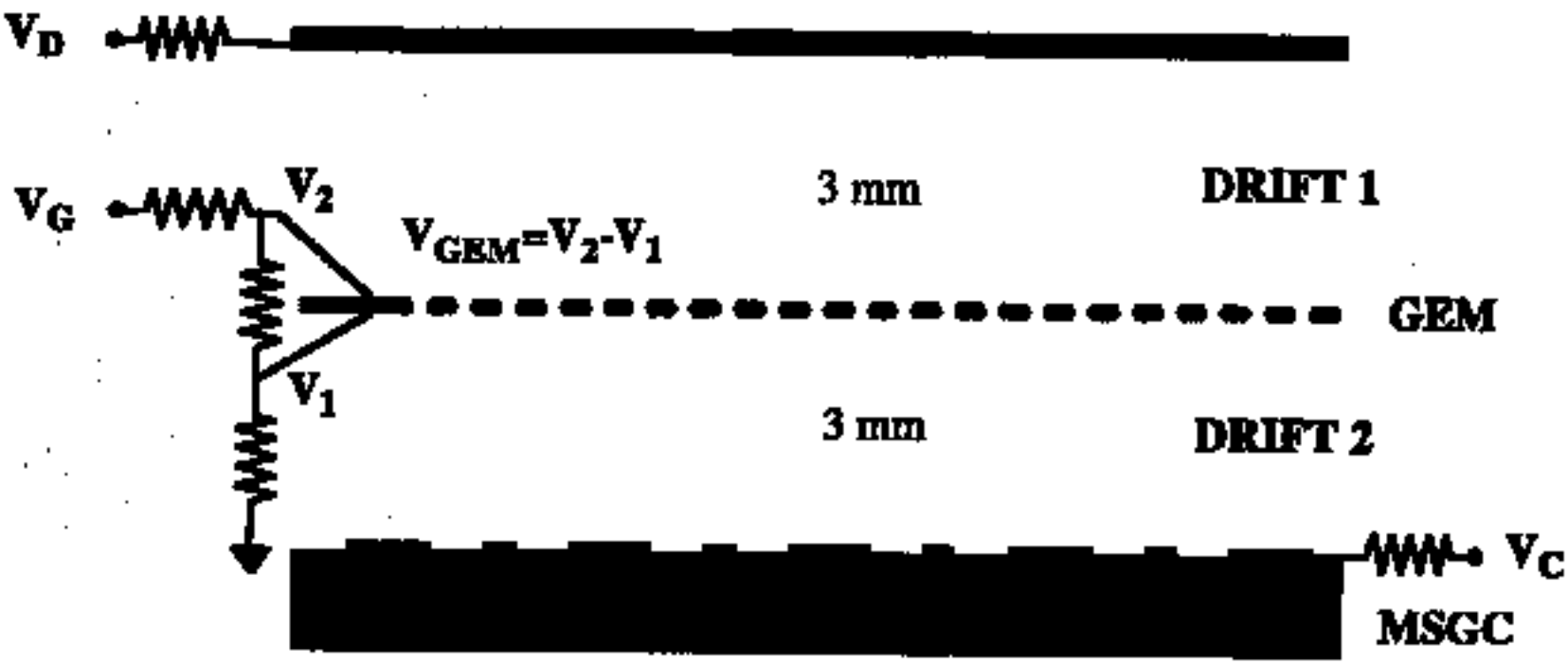
A. Coupled to an MSGC

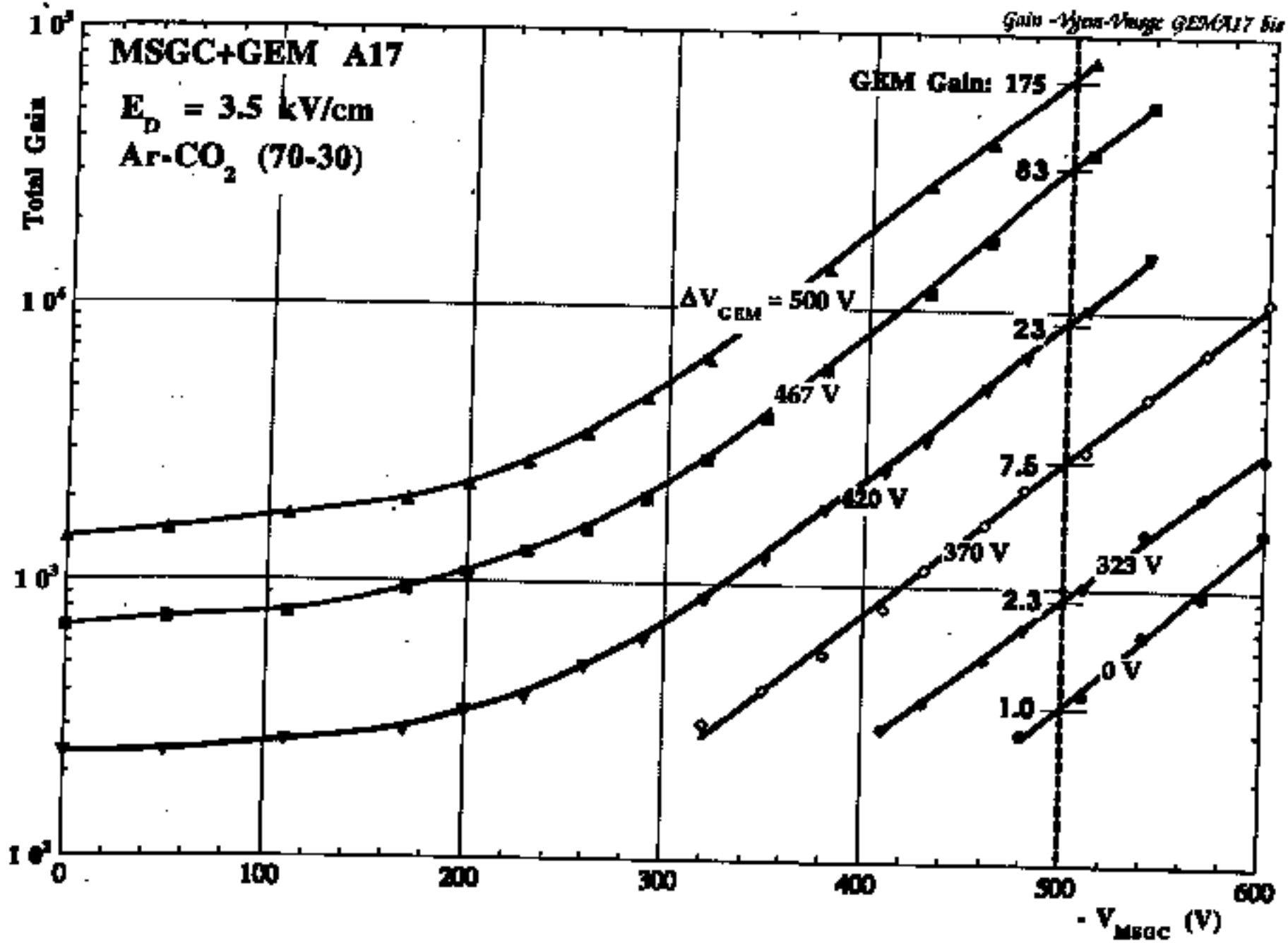
- → scheme
- → gain
- → efficiency plateaux
- → spatial resolution
- → time resolution
- → rate capability
- → ageing

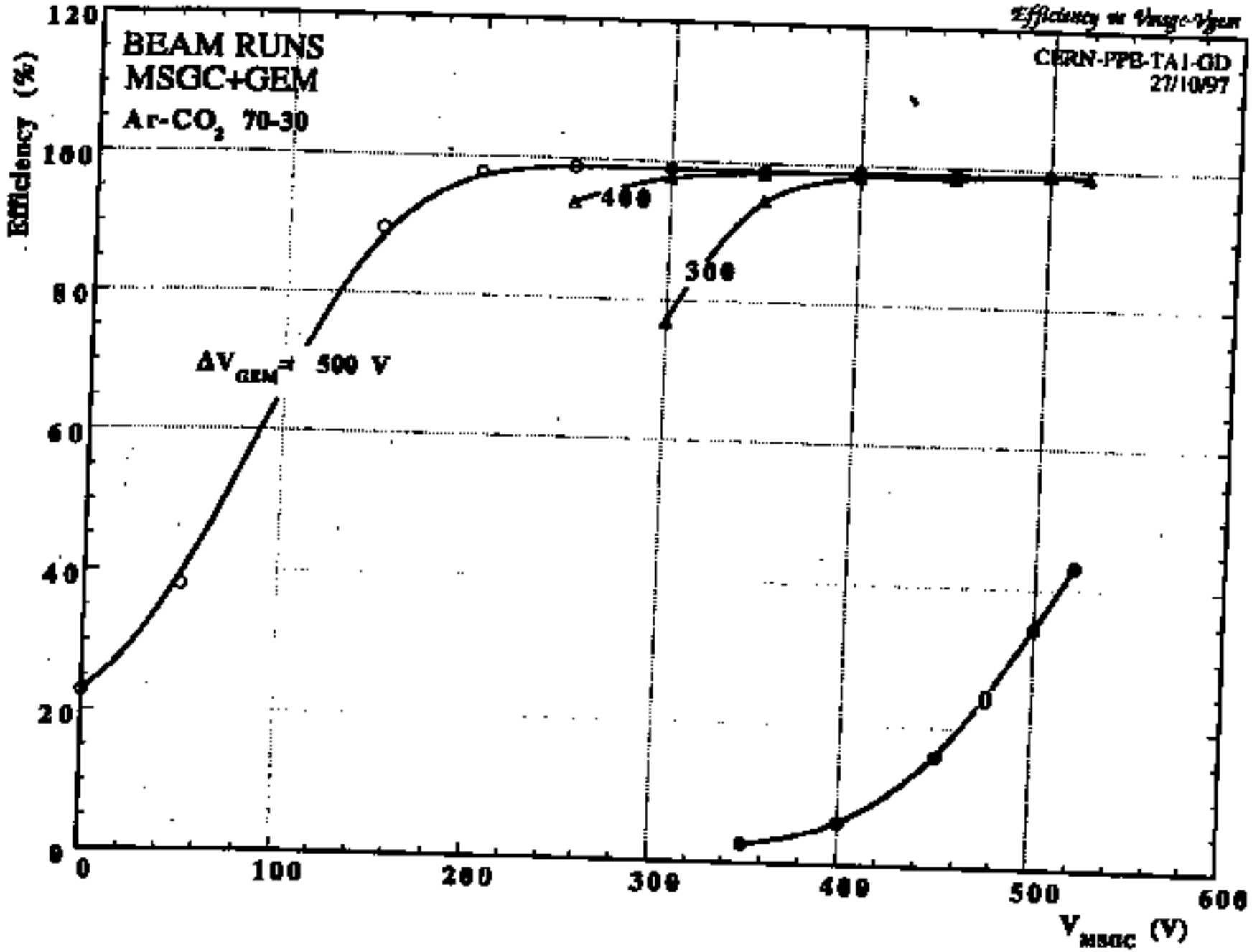
B. GEM alone

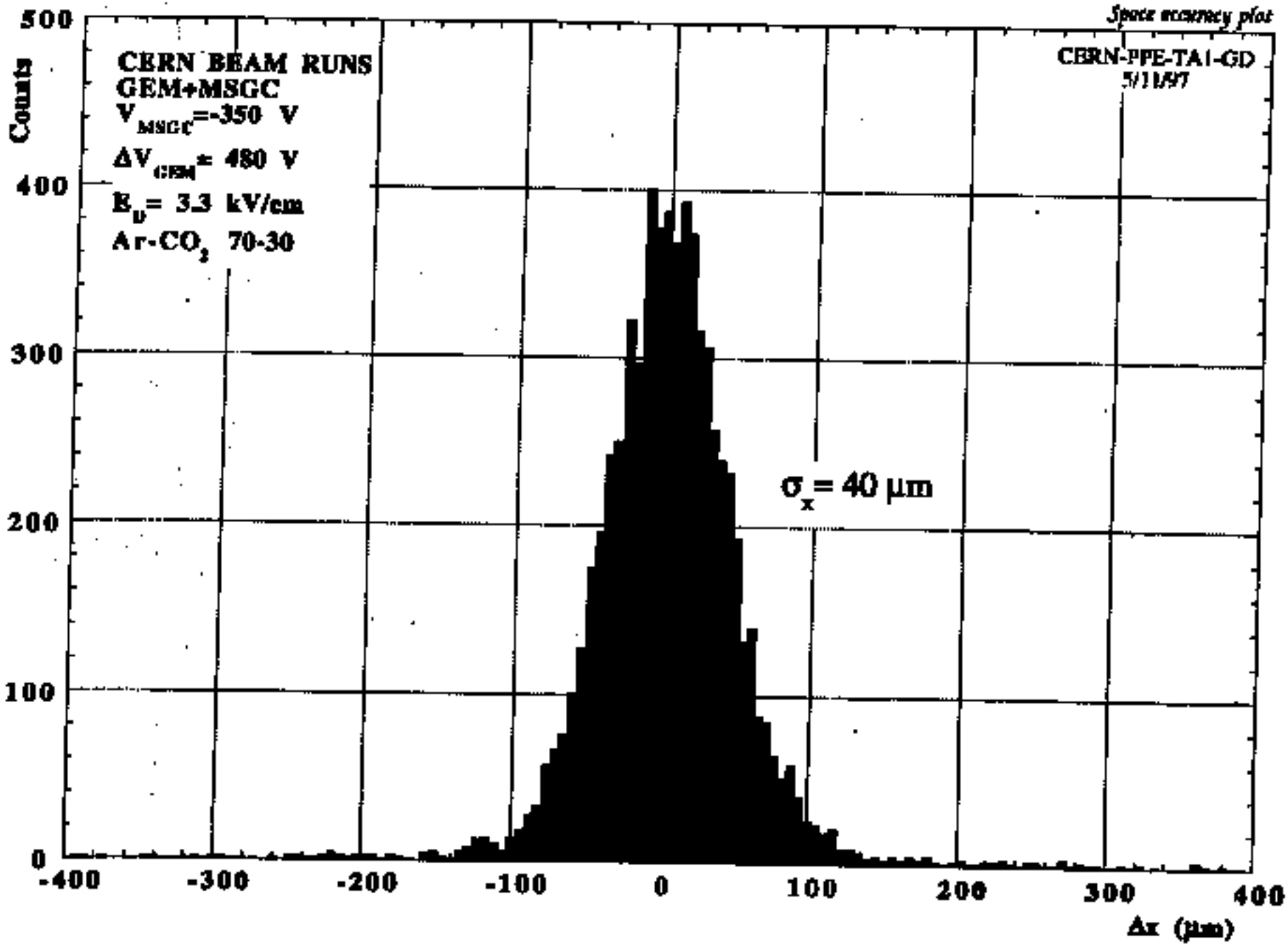
- → scheme
- → gain
- → efficiency plateaux

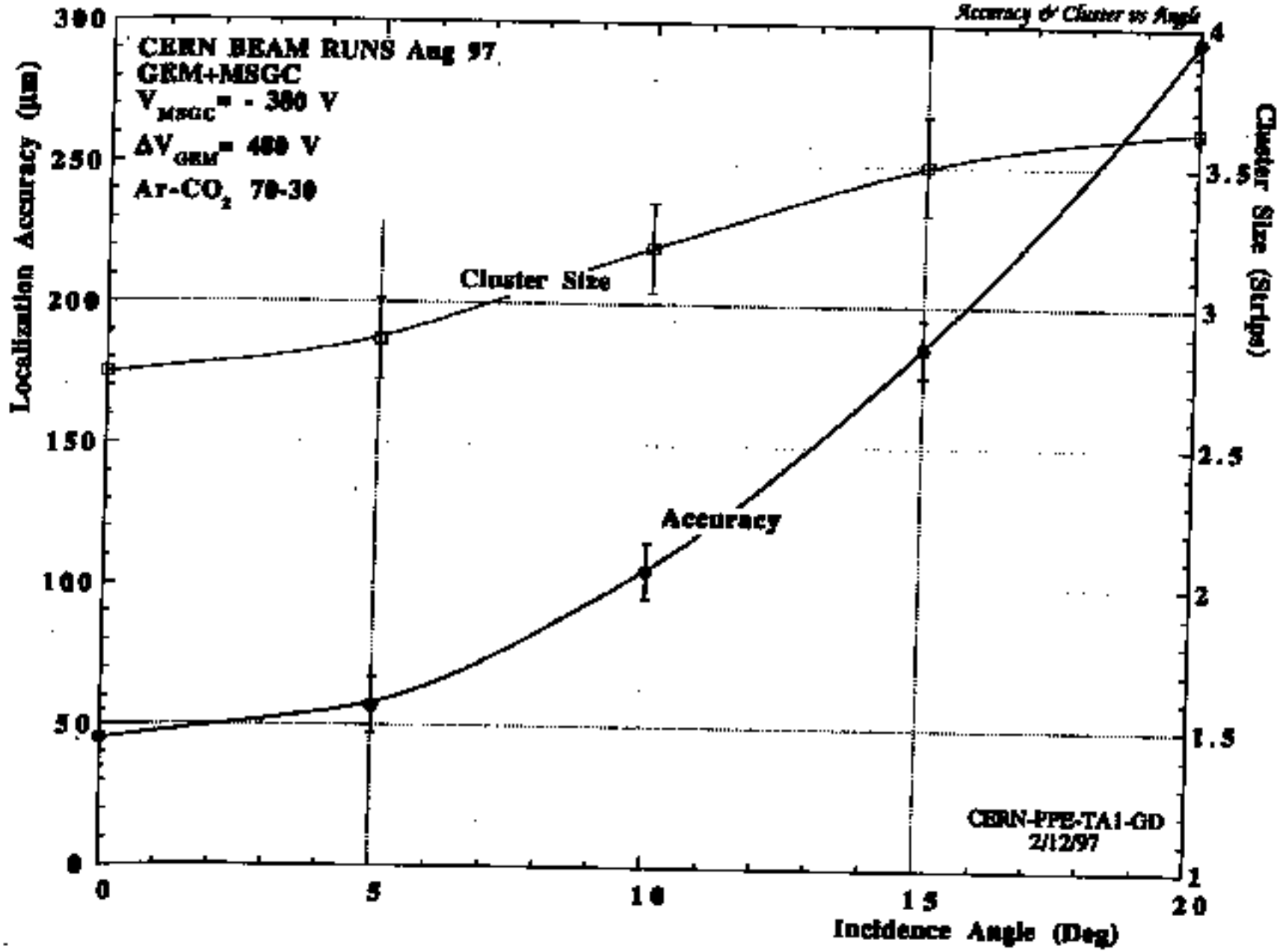
GEM + MSGC




Gain -Vgem-Vmsgc GEM17 5a
MSGC+GEM A17
E_D = 3.5 kV/cm
Ar-CO_2 (70-30)
Total Gain
GEM Gain: 175
83
23
7.5
2.3
1.0
ΔV_{GEM} = 500 V
467 V
420 V
370 V
329 V
0 V
10^5
10^4
10^3
10^2
0
100
200
300
400
500
600
$-V_{MSGC}$ (V)

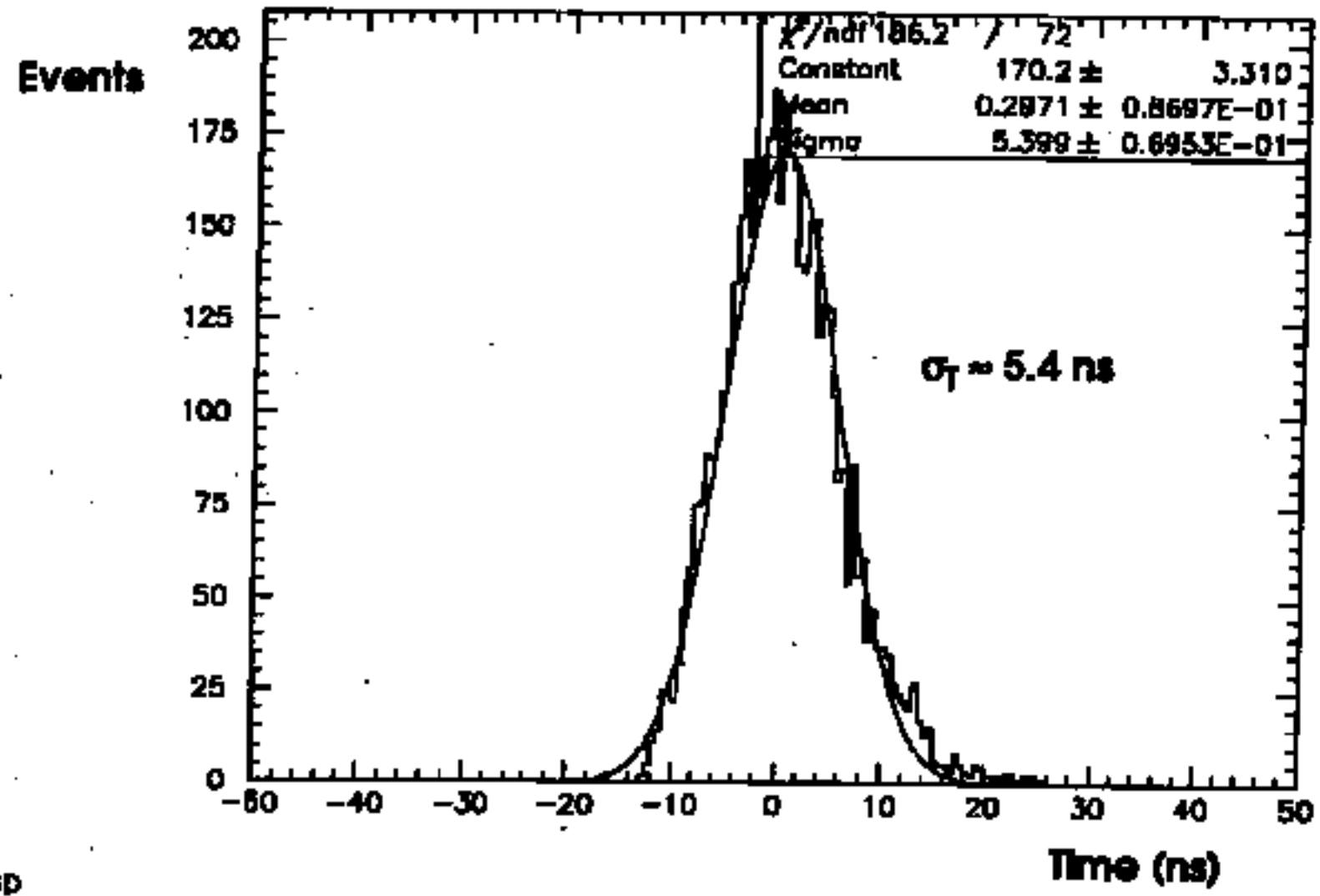

BEAM RUNS
MSGC+GEM
Ar-CO2 70-30
Efficiency vs Vmsgc-Vgem
CERN-PPE-TA1-GD
27/10/97
Efficiency (%)
120
100
80
60
40
20
0
0
100
200
300
400
500
600
VMSGC (V)
ΔVGEM= 500 V
400
300


Space accuracy plot
CERN-PPE-TA1-GD
5/11/97
CERN BEAM RUNS
GEM+MSGC
V_{MSGC}=-350 V
ΔV_{GEM}= 480 V
E_D= 3.3 kV/cm
Ar-CO_2 70-30
σ_x= 40 µm
Counts
500
400
300
200
100
0
-400
-300
-200
-100
0
100
200
300
400
Δx (µm)

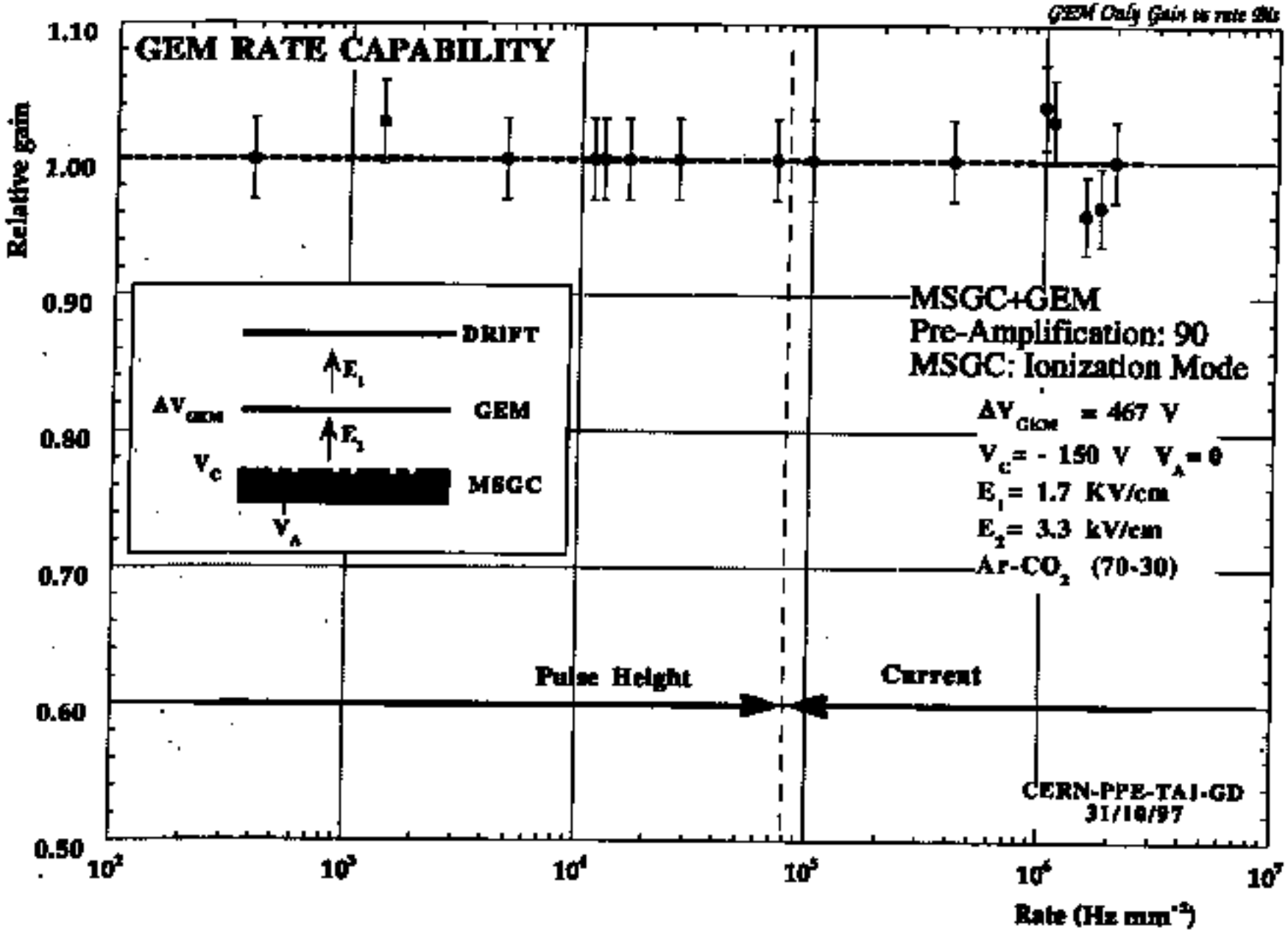

Accuracy & Cluster vs Angle
CERN BEAM RUNS Aug 97
GEM+MSGC
V_{MSGC} = - 380 V
ΔV_{GEM} = 480 V
Ar-CO_2 70-30
Cluster Size
Accuracy
Localization Accuracy (µm)
Cluster Size (Strips)
Incidence Angle (Deg)
CERN-PPE-TA1-GD
2/12/97
300
250
200
150
100
50
0
4
3.5
3
2.5
2
1.5
1
0
5
10
15
20

BEAM RUNS
MSGC+GEM

TIME RESOLUTION

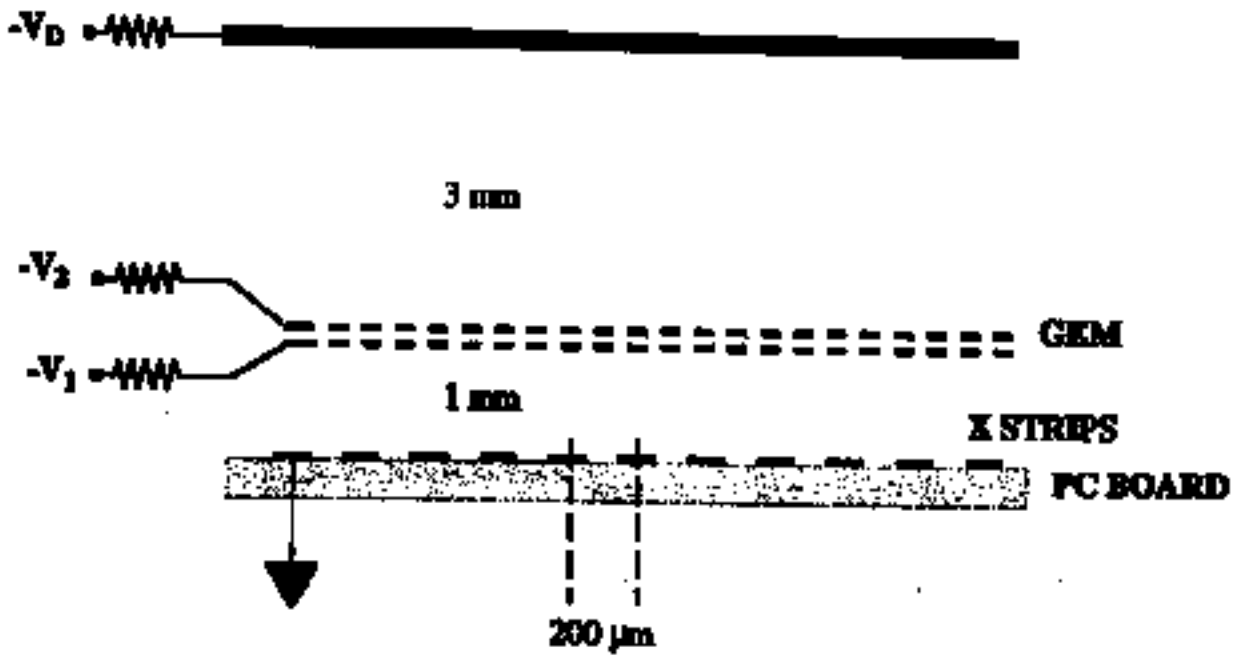


CERN-PPE-TA1-GD
27/10/97


GEM Only Gain vs rate Ok
GEM RATE CAPABILITY
Relative gain
1.10
1.00
0.90
0.80
0.70
0.60
0.50
DRIFT
E_1
ΔV_{GEM}
GEM
E_2
V_C
MSGC
V_A
MSGC+GEM
Pre-Amplification: 90
MSGC: Ionization Mode
ΔV_{GEM} = 467 V
V_C = - 150 V V_A = 0
E_1 = 1.7 KV/cm
E_2 = 3.3 kV/cm
Ar-CO_2 (70-30)
Pulse Height
Current
CERN-PPE-TA1-GD
31/10/97
10^2
10^3
10^4
10^5
10^6
10^7
Rate (Hz mm^{-2})

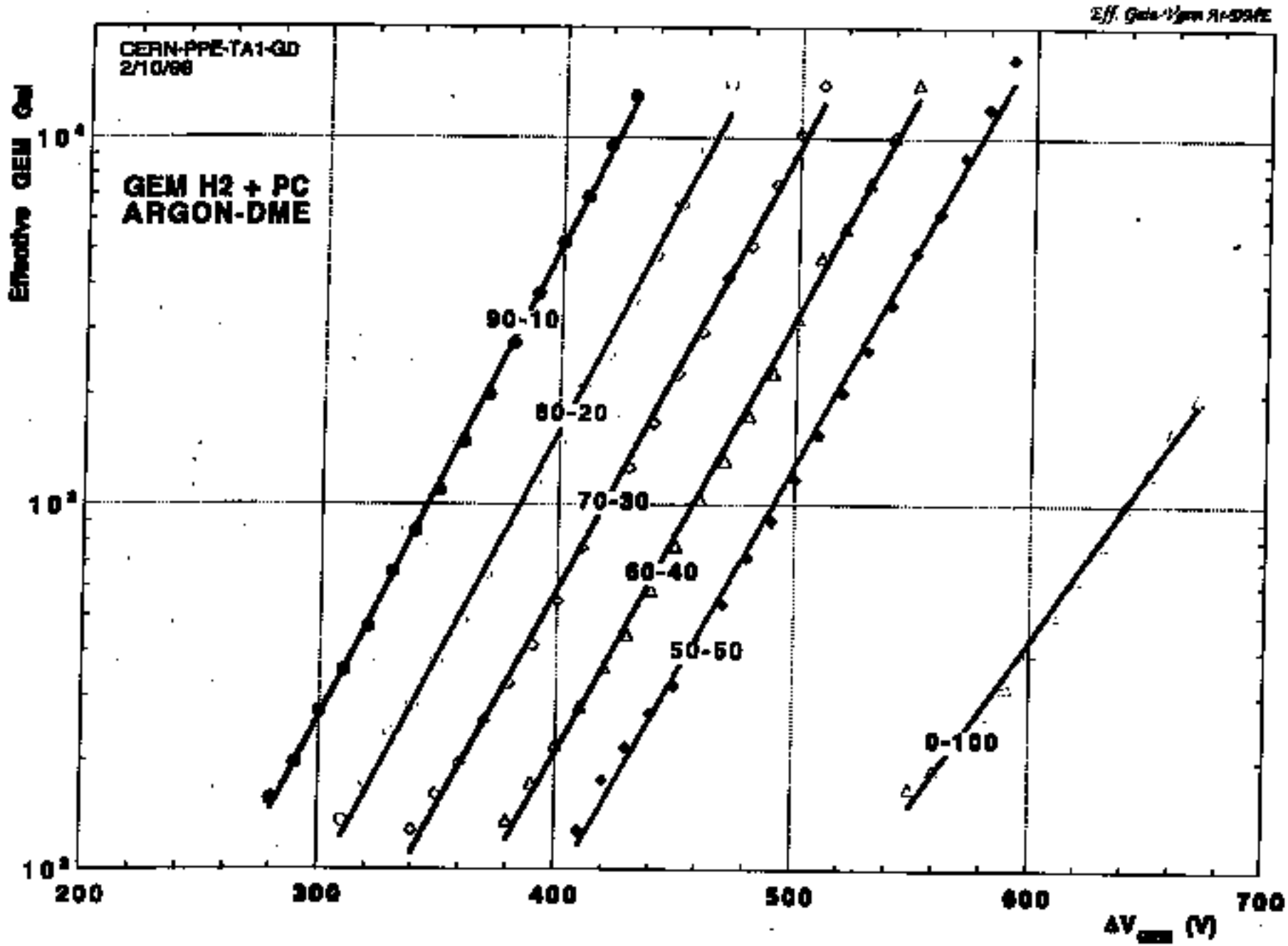
MSGC+GEM
MSGC: Gold on DLC-Coated D-263
GEM A17A 140/50/60
V_{MSGC} = -540 V
V_{GEM} = -355 V
V_d = -1500 V
Ar-CO_2 (70-30)
I= 5 nA mm^{-2}
CERN-PPE-TA1-GD
27/10/97
GEM Preamplification Factor
Charge (mC cm^{-2})
8
7.5
7
6.5
6
5.5
5
4.5
4
0
2
4
6
8
10
12

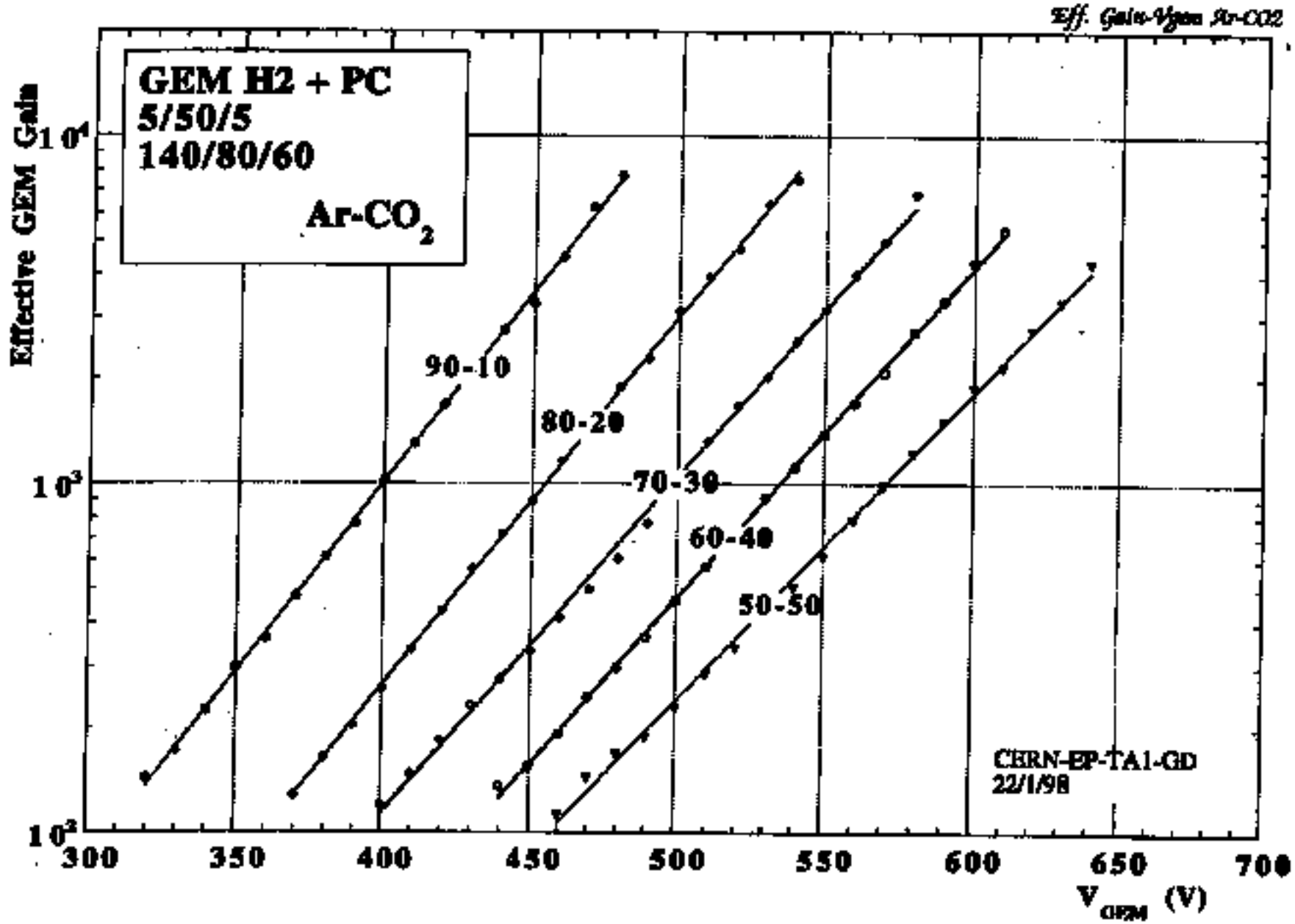
HI-GEM + PC BOARD

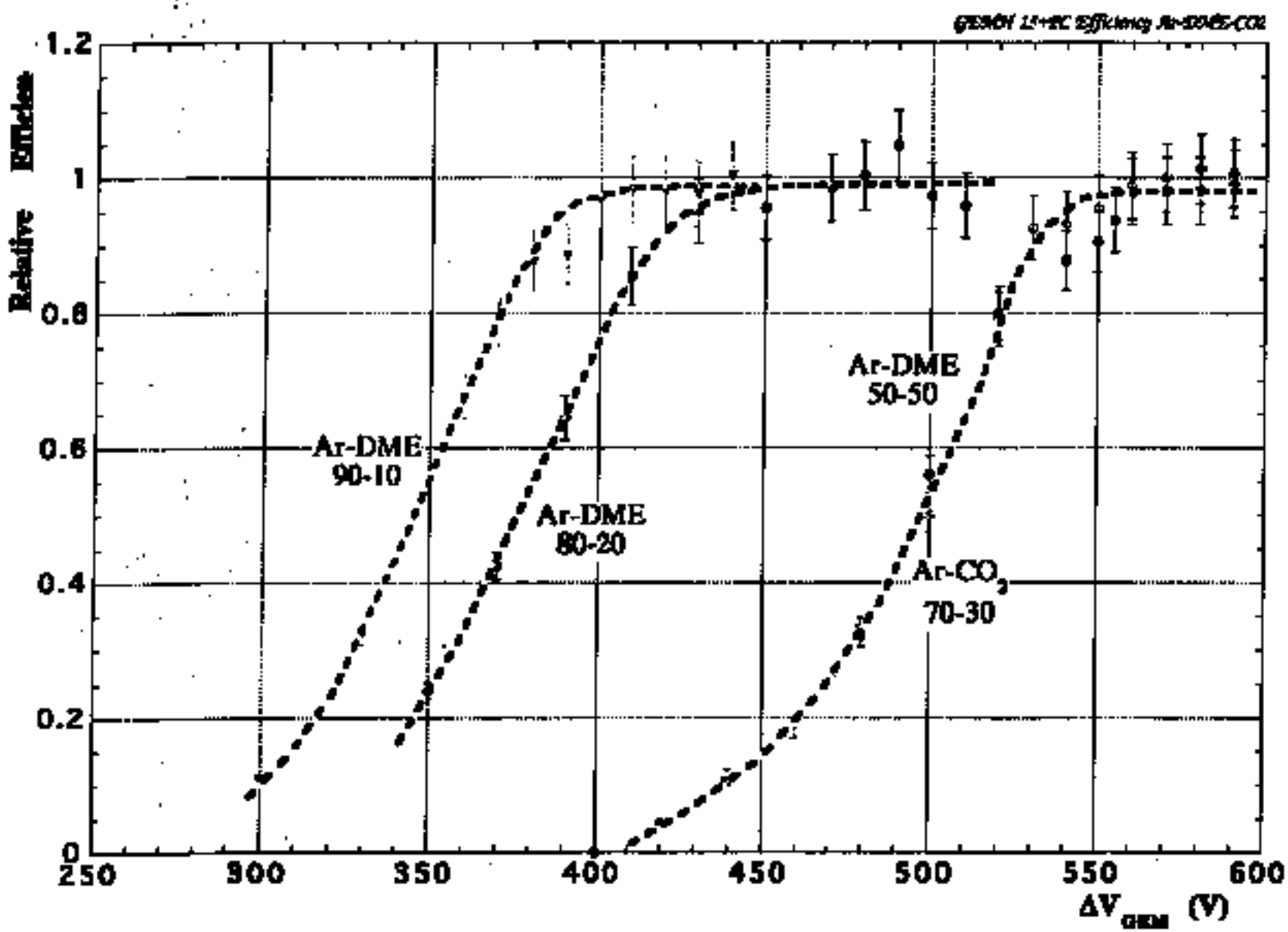


ADVANTAGES:

- No fragile elements (all pc boards)
- HV elements completely decoupled from read-out
- Possibility of 2-D readout (thin, double-sided pc board)
- Non-critical, light mechanics
- Flexible (allows non-planar geometry)
- Rugged and cheap


Eff. Gain-Vgem Ar-DME
CERN-PPE-TA1-GD
2/10/98
GEM H2 + PC
ARGON-DME
Effective GEM Gain
10⁴
10³
10²
90-10
80-20
70-30
60-40
50-50
0-100
200
300
400
500
600
700
ΔV_GEM (V)


Eff. Gain-Vgem Ar-CO2
GEM H2 + PC
5/50/5
140/80/60
Ar-CO2
Effective GEM Gain
1 0^4
1 0^3
1 0^2
90-10
80-20
70-30
60-40
50-50
CERN-EP-TA1-GD
22/1/98
300
350
400
450
500
550
600
650
700
V_GEM (V)

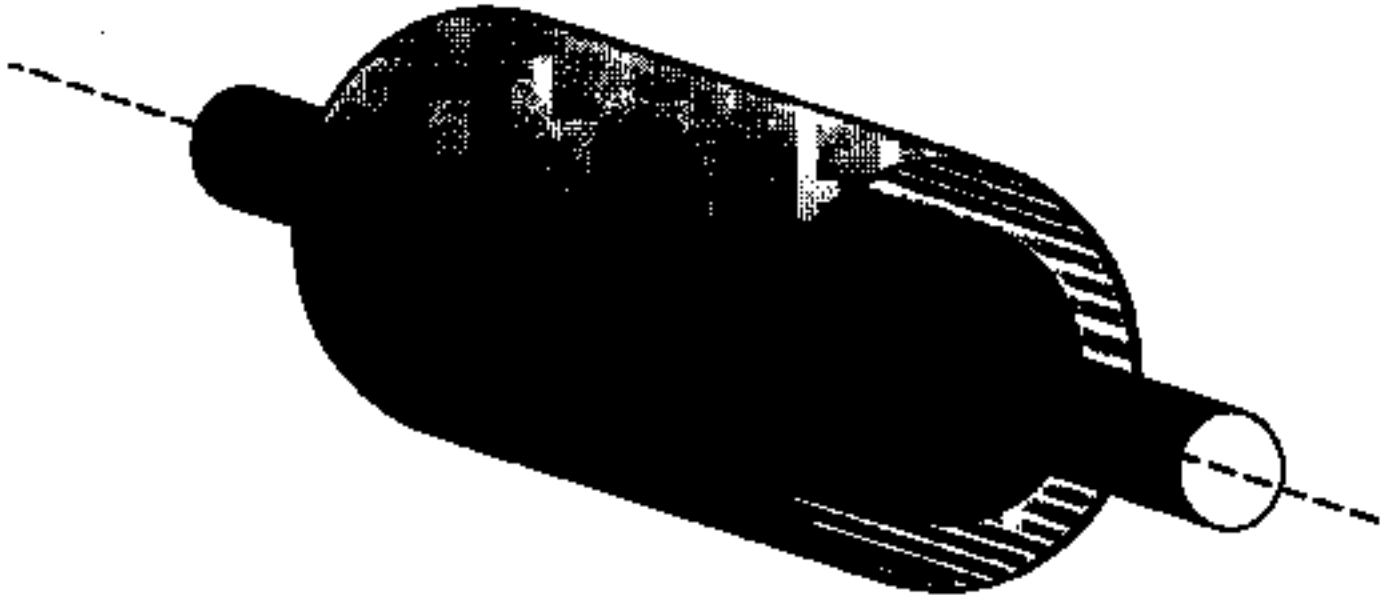

Relative Efficiency
1.2
1
0.8
0.6
0.4
0.2
0
250
300
350
400
450
500
550
600
ΔV_{GEM} (V)
Ar-DME
90-10
Ar-DME
80-20
Ar-DME
50-50
Ar-CO_2
70-30

Developments

- Thickness of material
  go to 5 μm thick Cu ?
- Type of material
  Al instead of Cu ?
- Shape: cylindrical?
- Size: as large as 50 x 50 cm² ?
- 2-dimensional readout: soon
- Other gases ?
- TPC + GEM

CYLINDRICAL GEM FOR FELIX

L. Dick, K. Eggert, V. Karapetian, W. Kienzle.....



FELIX GEM

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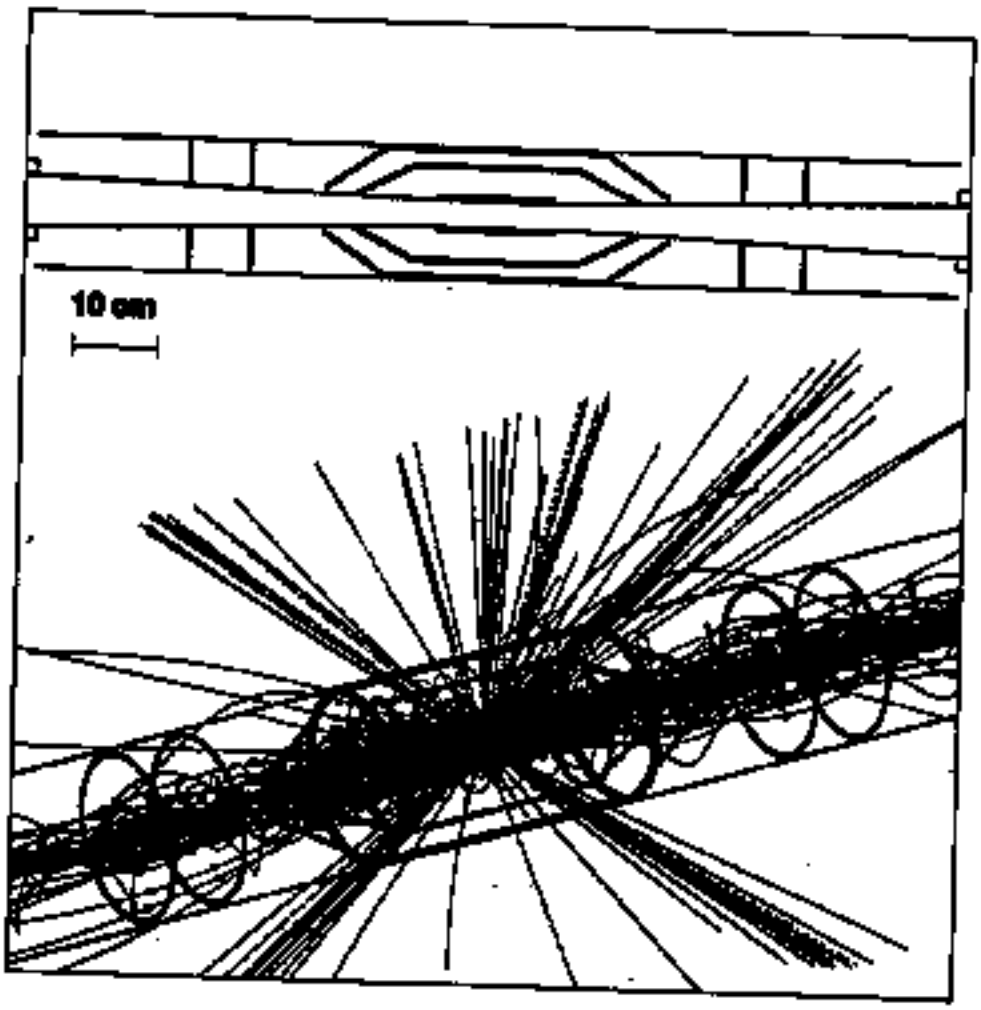
M. Battaglia

The Vertex Tracker Design

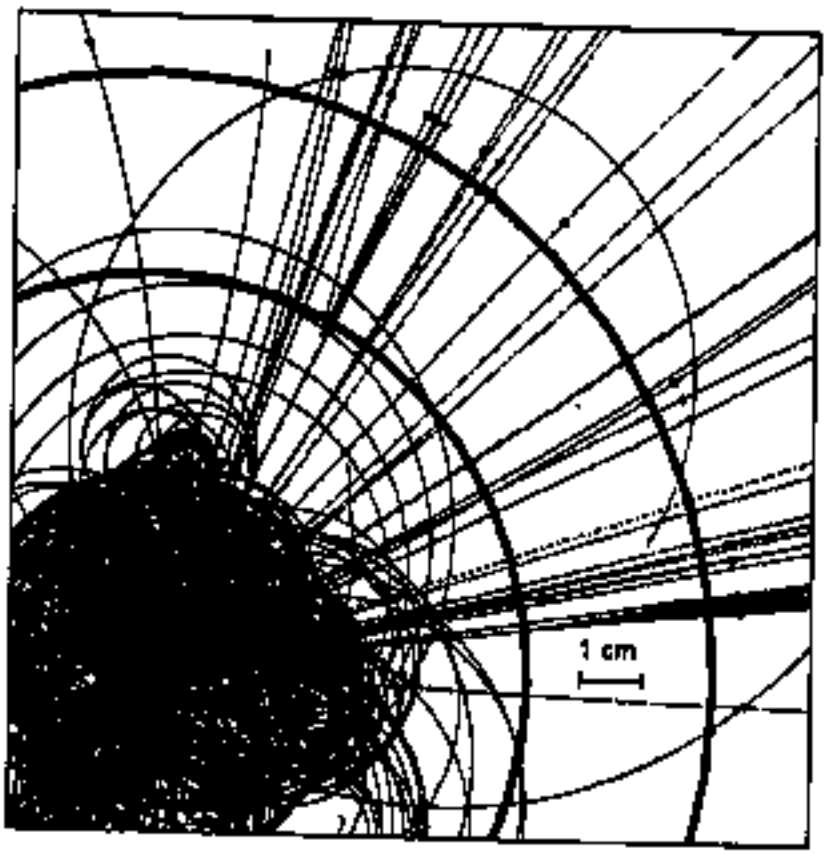
A. Andreazza, M. Battaglia and M. Caccia

- Extend present LEP/SLC experience on silicon Vertex Detectors and jet flavour tagging.
- Obtain optimal values for Vertex Tracker geometry and single point resolution from studies of machine induced backgrounds, track density in hadronic jets and requirements for c and b tagging.



- Compare with realistic silicon detector technologies.

- Tagging of c and b particles relies on the identification of their decay products originating at a point displaced from the beam collision region.

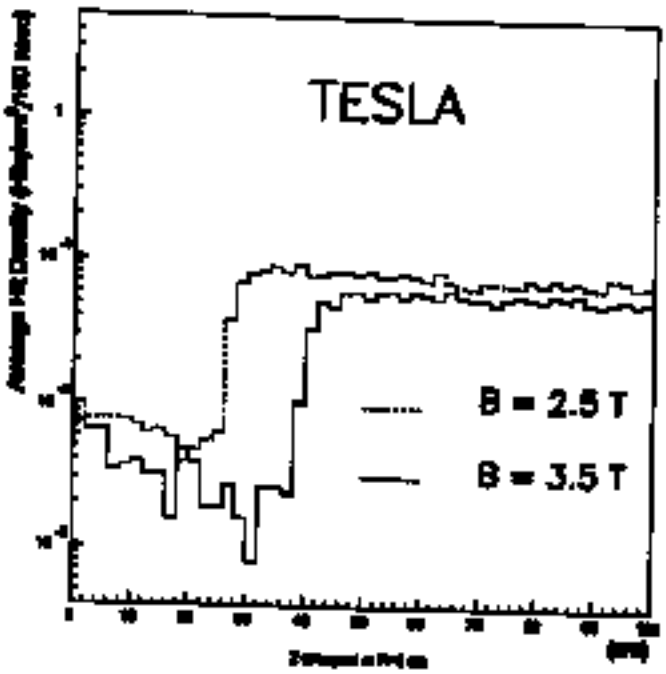


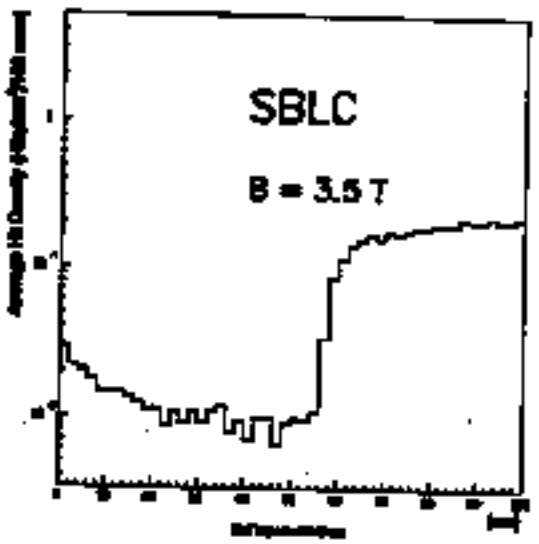
- Useful figure of merit is the resolution σ_{IP} on distance of closest approach to the beam interaction region (**impact parameter**)
- For a detector with single point resolution σ_{point} and measurements at inner and outer radii Rin and R_{out}:

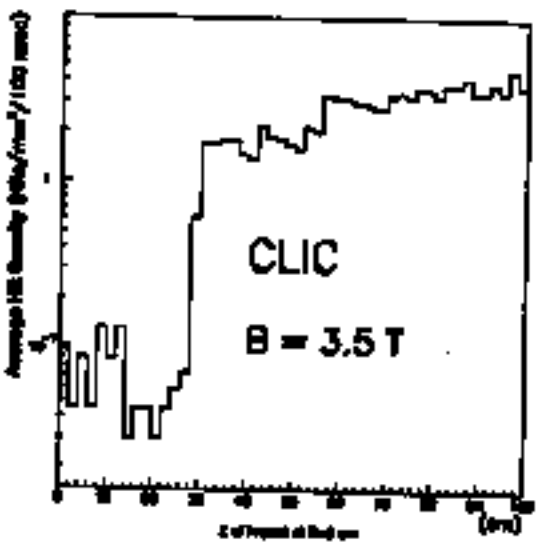
$$\sigma_{IP} = \sqrt{(n+1)^2 + n^2}\sigma_{point} \text{ with } n = \frac{R_{in}}{R_{out} - R_{in}}$$

- After the choice of the detector technology has fixed σ_{point}, it is necessary to minimize R_{in} for optimizing the impact parameter resolution and thus the Tracker tagging performances.

Hit density as a function of longitudinal position at R=3 cm for $\sqrt{s}$=500 GeV

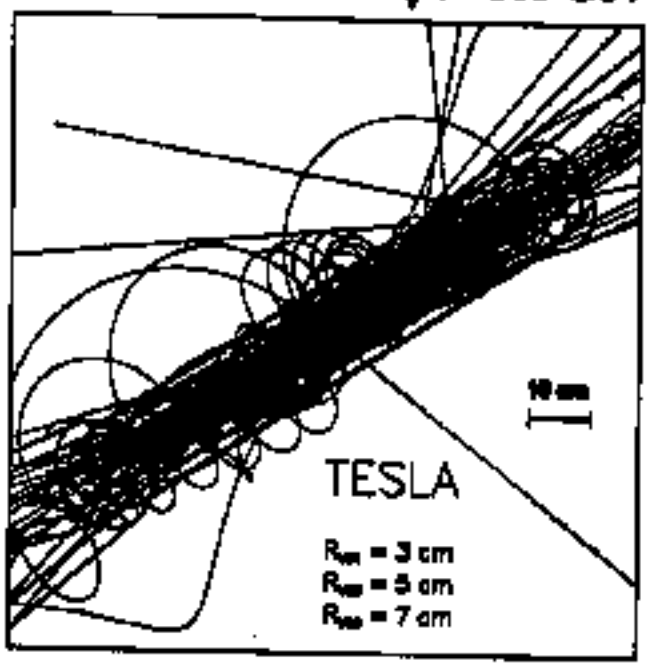




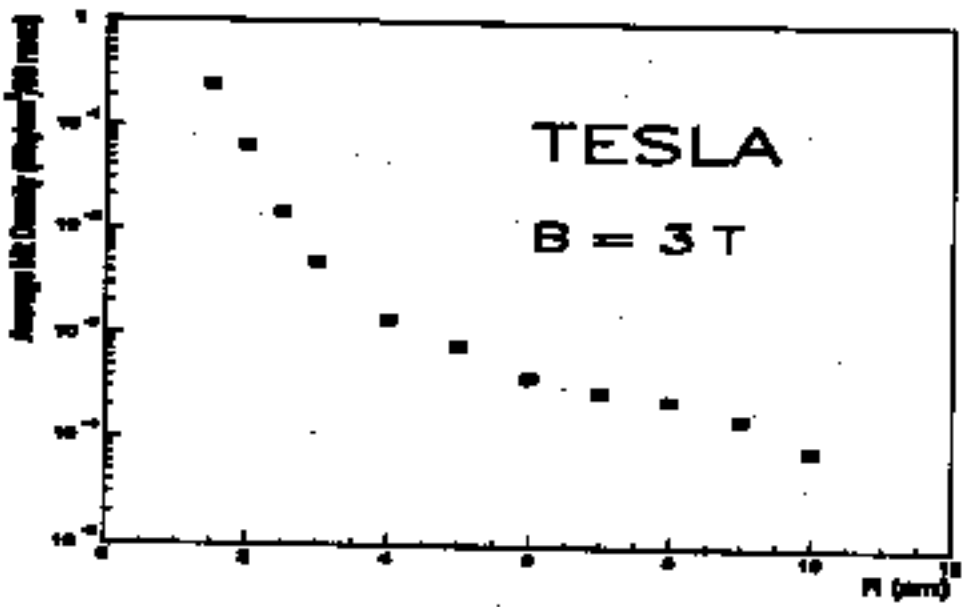


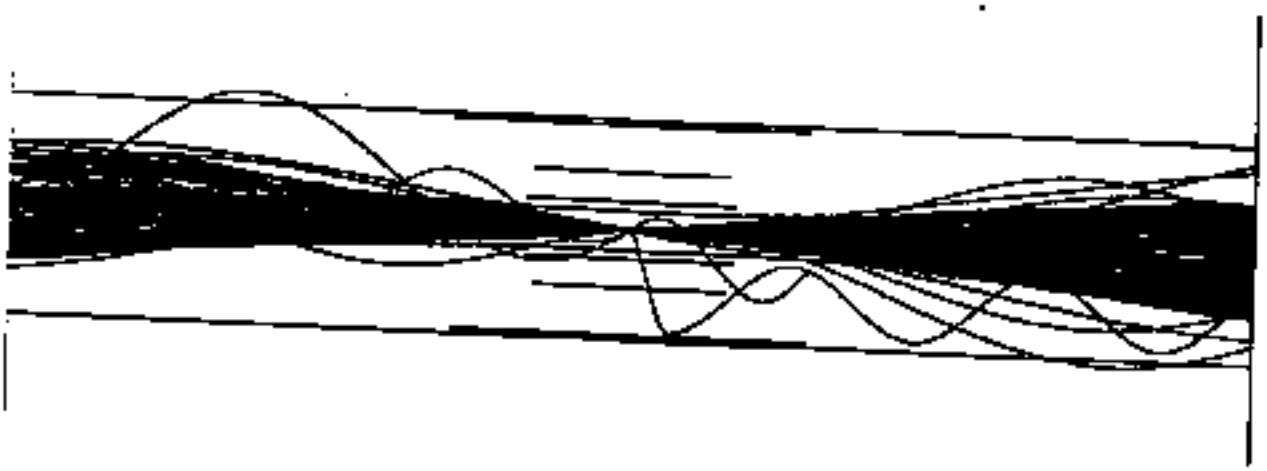
- Study primary $e^{\pm}$ hit density at reference radial surfaces using full GEANT simulation for transport of particles in solenoidal magnetic field and particle interactions.

TESLA DESIGN AT $\sqrt{s}$=500 GeV



HIT DENSITY AS A FUNCTION OF DETECTOR RADIUS





- Derive simple scaling law for the position of crossing of the deflected particle envelope:
  - ongitudinal position of crossing z_c with a cylinder of radius R:

$$z_c = 1.1\ R^2\ \frac{B}{2\ Tesla}\ \frac{\sigma_z}{0.01\ cm}\ \frac{10^{10}}{N}$$

  - outer radius of crossing r_{max} with a plane a position z:

$$r_{max} = 9.5\sqrt{\frac{N}{10^{10}}\ \frac{2\ Tesla}{B}\ \frac{z}{100\ cm}\ \frac{0.01\ cm}{\sigma_z}}$$

- Optimal background conditions require large solenoidal magnetic field B and large values for the bunch lenght σ_z.
- For each value of B and accelerator parameters there is a **inward bound for the first detector layer** defined by the steep increse of the pair hit density and a **maximum length of the sensitive area** defined by the longitudinal position of crossing of the envelope of deflected particles at a given detector radius.

The Silicon Vertex Tracker

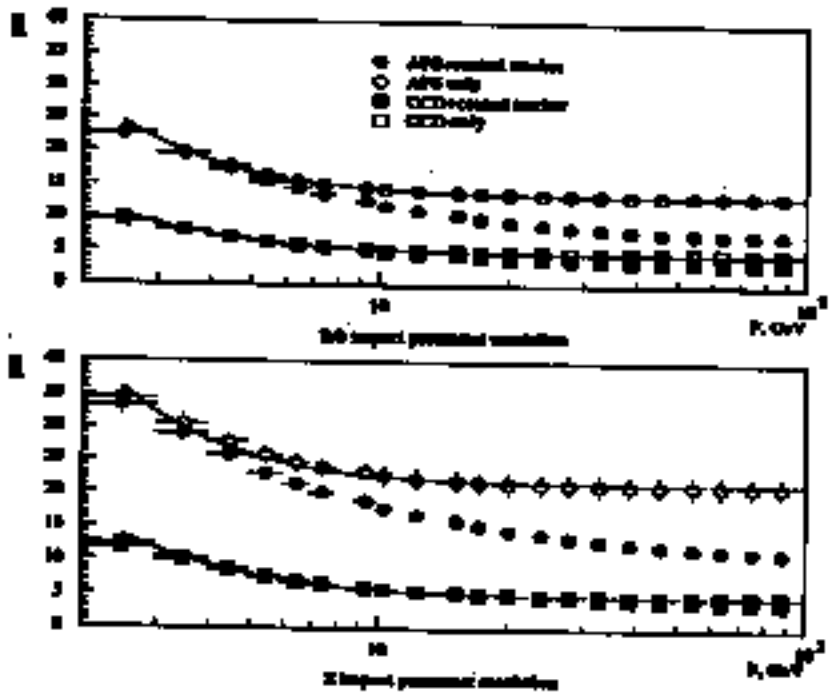
- Detector Geometry
  - Three layers of **pixel detectors** at radii of 2.5, 5 and 10 cm
  - Two Forward crowns of pixel detectors.
  - Two Forward disks of pixel detectors and three disks of **microstrip detectors** providing accurate track reconstruction down to 100 μm

- Detector Technology
  - **Active Pixel Sensors** (APS) and **Charge Coupled Devices** (CCD) have appealing features for the use in the Silicon Vertex Tracker at a Linear Collider.

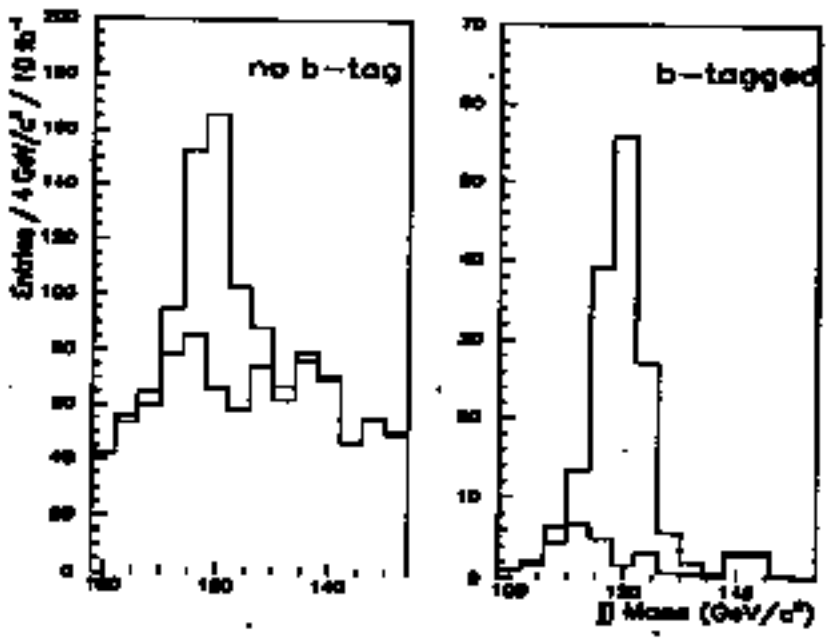
	APS	CCD
Pixel size (μm^2)	100 × 100	20 × 20
σ_{point} (μm)	10	5
Integration time	25 ns	30 ms
Occupancy at 2.5 cm (hits/mm^2)	0.007	8
Maximum neutron flux (n/cm^2)	10^{15}	3×10^9

  - Fraction of background hits associated to particle tracks extrapolated to the Vertex Tracker $\simeq$ 5 % for APS detectors.

– APS detectors are more tolerant of backgrounds; poorer space point resolution to be compensated by combined tracking including main tracking chamber.



SIGNAL FROM $H^0 \to b\bar{b}$



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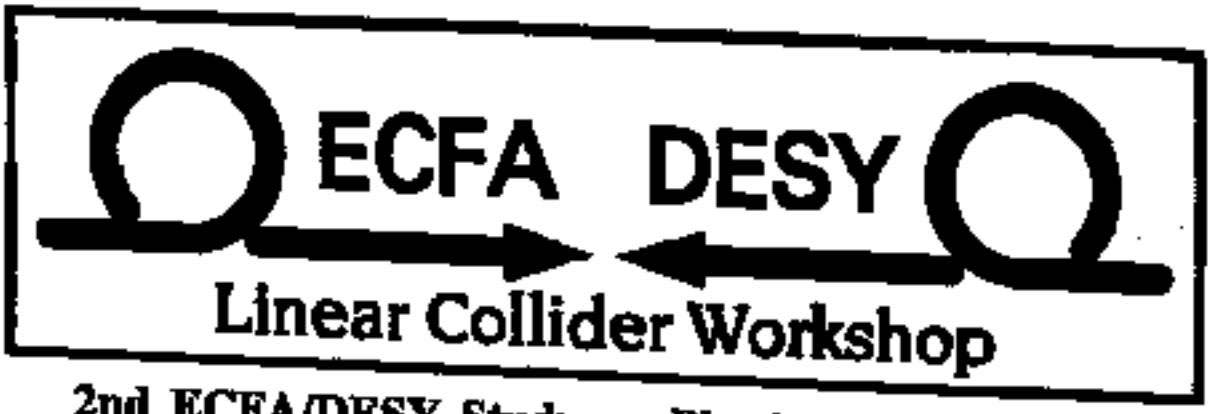

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R. Nahnhauer

Activities at DESY-Zeuthen in 1997

- publish proposal for
  - fiber trigger + TEC DESY-97-123E
  - preshower DESY 98-002

- tests of a fiber detector concept for high rate particle tracking
  (a possible inner tracker for HERA-B)

  - lot of material studies
  - lot of radiation hardness tests
  - full size prototypes (3) one produced at Zeuthen! Ex. 20 μm
    7× 480 μm fibers, pitch 360 μm
    size: 20×25 cm (660 channels)
    + 3m long light guides, 1.7mm diameter
    + R 5900-M64

    - 8-10 photoelectrons
    - ε > 99%
    - σ = 85 μm

    beam test results

detectors seem to work properly for HERA-B environment
DESY 97-[illegible], DESY 98-001, NCM A ?

Future R+D program:

FIRST

Feasibility and Implications of a high Rate Scintillating fiber Trigger

together with
- ETH Zürich
- (Univ. Tbilissi)

aim:

⇒ develop topological Jet-Trigger
$t_{trig} \leq 10$ nsec

- precision of detector prod. technology
- long term stability
- alignment of components rad. hard
- mass production
- couplings
- radiation hardness
- Opto-electronics (PSPM, HPD, VLPC
- Fast readout elect. + DAQ (bitmap proc
- Prototyping – long term studies

ask just now for manpower + money program under consideration at DESY + ETH

Long term study of prototypes

- combine with challenging experimental question

⇓ ⇓ ⇓

FAST

fiber active scintillator target (Kirkby 97)

CERN, DESY Berlin, ETH Zürich, PSI ?

- measure μ^+ lifetime with 20 fold better precision
- decrease exp. error of G_F by factor 10

build target with cell size 4x4 mm ?
out of scintillating fibers
use first electronics to get bitmaps for different time slices

identify π^+ stopping point
" μ^+ stopping point
" e^+ appearance
} measure corresp. time

all in 1 MHz beam of 135 MeV/c π

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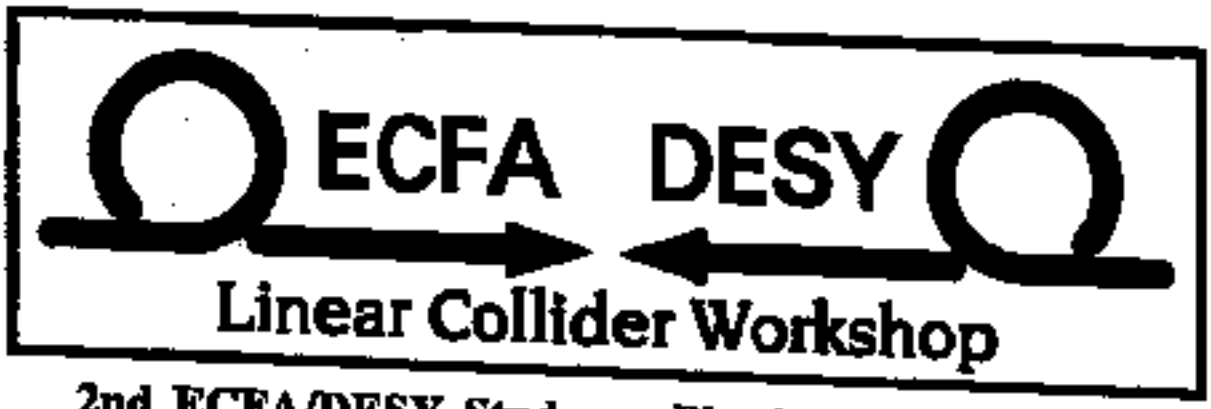

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P. Checchia

P.C.

DESY 88-

PRODUCTION AND TEST OF ELECTROMAGNETIC CALORIMETER

REQUIREMENTS FOR LC (SEE REF. DETECTOR)

- HIGH GRANULARITY
- GOOD RESOLUTION @ HIGH ENERGY ($D(E)/E$)
- LONGITUDINAL SEGMENTATION (E/π ; γ DIRECTION)

- WORKING IN HIGH MAGNETIC FIELD
- REASONABLE LENGTH ($\sim 25-30\ X_0$ IN ~ 50 cm)
- REASONABLE COST

BEAM TEST IN JUNE + SEPTEMBER @ CERN

COLLABORAZIONE CALEIDO

CAlorimeter with Light Emission and Internal Division Optimization

- MILANO: S A T
  M.Paganoni, F.Terranova.
- PADOVA: M E T A
  P.Checchia, M.Margoni, M.Mazzucato, F.Simonetto.
- ROMA: S T
  C.Luci.
- CERN: A T
  T.Camporesi.
- SERPUKOV: M A O T
  I. Britvich, V. Lishin, V. Obraztsov, V. Polyakov, V. Romanovsky, R. Shuvalov, V. Vasilchenko, E.Vlassov

A: ASSEMBLAGGIO E: ELETTRONICA M: MECCANICA O: ON-LINE
S: SIMULAZIONE T: TEST

CMS SHASHLIK*

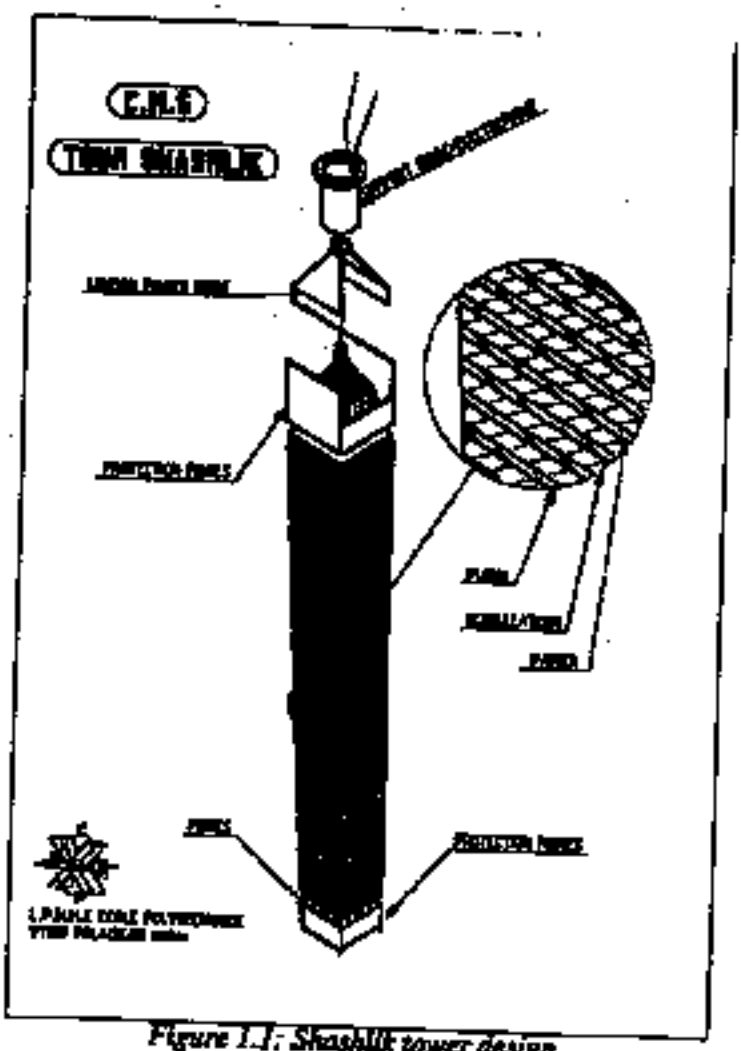


Figure 1.1: Shashlik tower design.

This technical note describes a Shashlik calorimeter solution for the CMS Barrel. The interferences with a preshower detector placed in front of the calorimeter will be also studied. The successive subdivisions of the paper are:

- The calorimeter performances needed to fulfill the LHC physic goals will be first discussed.

[1] factor of 2
[2] $PbWO_4$ radiation length is 0.9 cm

A SREWER, SPIEDO, BROCHETTE', ...

TWO PROPOSED SOLUTION FOR LONGITUDINAL SEGMENTATION

1) CALORIMETER 1

FLAT VACUUM PHOTODIODE
LATERAL READ OUT

1 PH.D $\Delta\theta = 5 \times 0.5$ cm^2 READS
$0 < \theta < 3$ $\theta = 4^\circ 5$ X

2) CALORIMETER 2

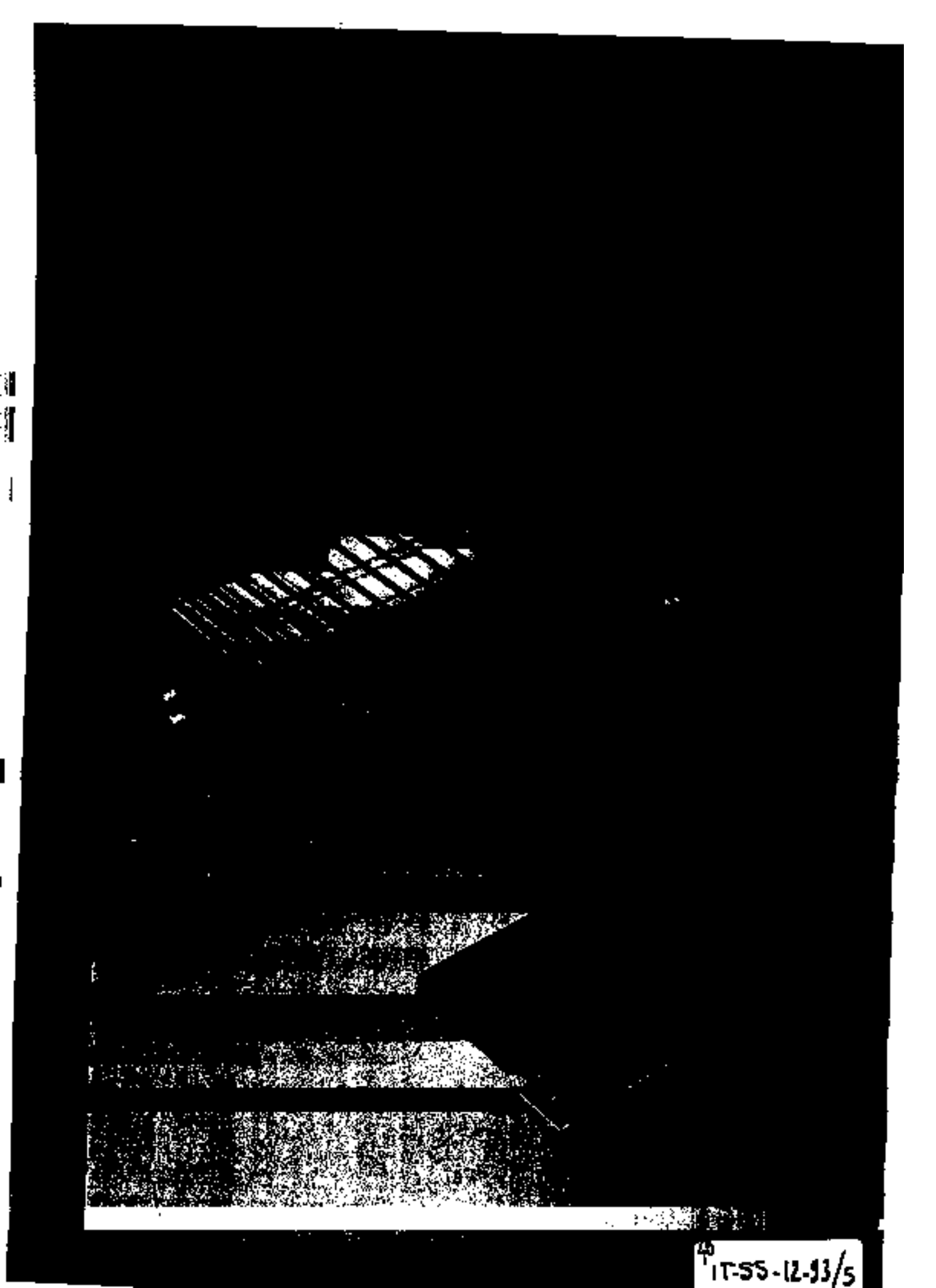
SCINTILLATOR WITH LONG DECAY TIME

$\tau \sim 200$ ns ON $0 < \theta < 5$
BC 444 (FROM BYCRON)

BOTH PROTOTYPES: 5×5 CELLS

5×5×32 cm^3 MADE WITH 160 PAIRS OF
4 mm Pb 4 mm SCINTILLATOR

SOLUTION 1



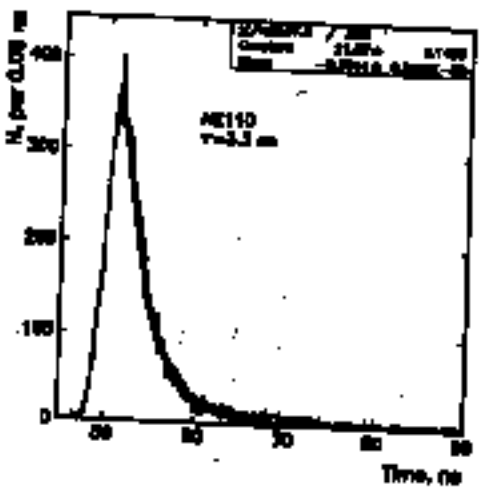
CALORIMETRO 1

FASCIO

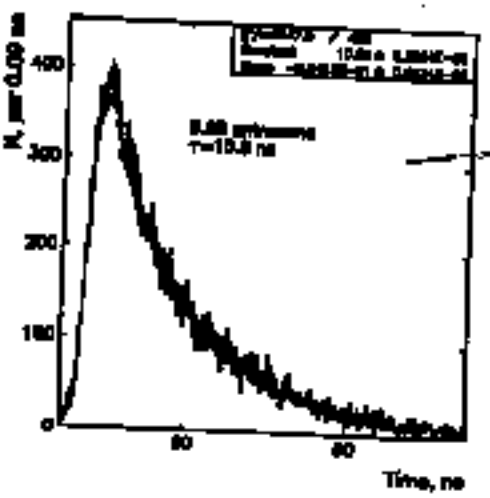
SOLUZIONE 'A,

CALORIMETRO 2

Scintillatore standard *

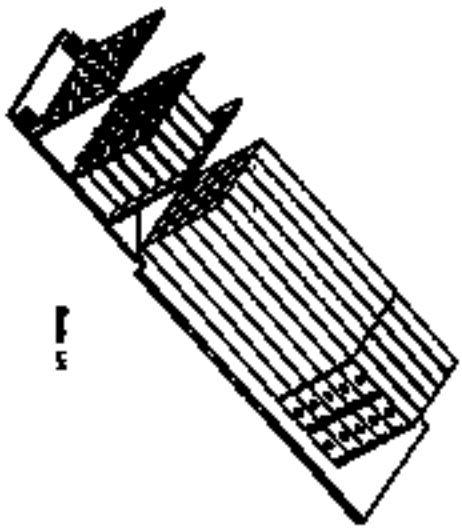


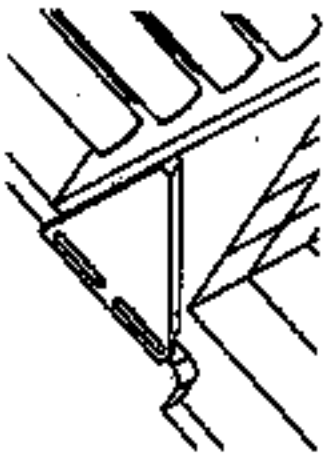
Scintillatore lento * *

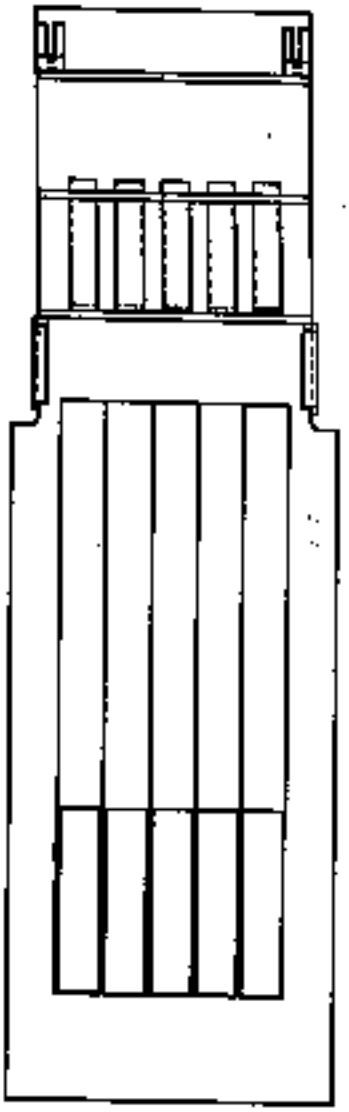


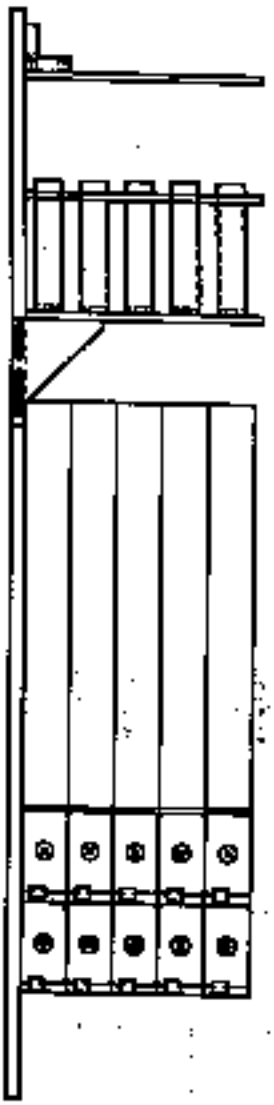
→ 200 μs

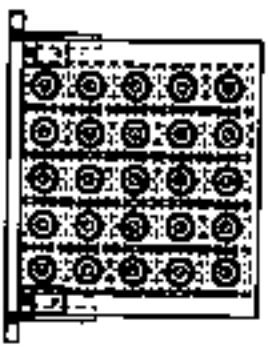
* PRONTO PER 'PRODUZIONE', ULTERIORI SVILUPPI POSSIBILI
+ FAST BCF BEA FIBERS τ = 2.3 μs











http://www.cern.ch/~checchia/caleido

CALEIDO

Homepage

General information

People involved and e-mail adresses
Minutes of the 971030 meeting

Mechanics

Mechanics

Simulation

Available software
Montecarlo plots

Scintillator studies

Scintillator emission time

APD studies (by G. Rampazzo)

Gain vs Bias
ENC/Gain vs Gain
ENC vs Bias

CONCLUSIONS

- ..SGE AFTER TESTS

- CALEIDO IS OPEN TO PEOPLE/GROUPS WISHING TO JOIN .....

S14

2nd ECFA/DESY Study on Physics and Detectors for a Linear Electron-Positron Collider

LAL - Orsay - France, April 5-7, 1998

Date : April 6, 1998 - 14:30

P. Steffen

Impact of Calorimeter Parameters 6.4.98

on Physics : jet-jet- mass resolution

- energy resolution
  granularity
  longitudinal segmentation
  } E-cal, H-cal

present approach based on optimistic extrapol.
of Aleph-type detector:

tracking
Ecal
} + Hcal-correction

Is this the best solution?

OK at 90 GeV BUT worse resolution at
high energies (tracking $\frac{\sigma_{p_T}}{p_T} \propto p_T$)

Alternative: explore ZEUS/H1 inspired type
of energyflow meas.:

Ecal
Hcal
} + correction (tracking)

advantage: $\sigma_{E/E} \sim 1/\sqrt{E}$

Program:

- simulate parametrized detector:
  cylindrical calorimeter: $\sigma_{E/E}$ for Ecal/Hcal granularity
  tracking: p_t-resolution
  ⇒ easy to change parameters, flexible & fast ⇒ Calo-cells: E / tracks: $\vec{p}$
- try exisiting algorithms for energy flow, develop improvements
- start with $e^+e^- \to \begin{cases} W^+W^- \\ Z^0Z^0 \end{cases}$
  - determine jet-jet-mass resolution,
  - separation of the two processes (parameters)
- later: analyse more complicated processes like Z-H / $t\bar{t}$ final states

Further Questions to be attacked:

- mixing of jets
- gluon radiation between $q\bar{q}$-jets
- charged particle bent by magnetic field
- loss/ignoring of low energy particles
  (may be caused/dominated from background: minijets)
- loss in beam pipe

Status:

- started (P.St.) with def. sim. (H.J. Schreiber)
- expecting Japanese collaborators
- further contributors welcome...

email : steffcap@desy.de

S14

2nd ECFA/DESY Study on Physics and Detectors for a Linear Electron-Positron Collider

LAL - Orsay - France, April 5-7, 1998

Date : April 6, 1998 - 14:30

R. Settles

DETECTOR PERFORMANCE and R&D ISSUES

- TRACKING (incl. VERTEXING)
- CALORIMETRY (incl. LUMI. MEAS.)
- MUON SYSTEM (incl. FORWARD DET.)
- DAQ / TRIGGER (incl. ANALYSIS FARM)
- ANALYSIS TOOLS (DET. SIM. GROUP)
- BACKGROUNDS (MACH. - DET. INTERF. GROUP)

PLANS FOR WORK

FOR TODAY'S MEETING,

TRACKING

Chris Damerell (CCD)
Ron Settles (TPC)
Magali Gruwe (LCAL)
Elizabeth Rulikowska (Gas Studies)
Marco Battaglia (Vertex)

CALORIMETRY

Volker Korbel (Shaslik/Crystals)
Paolo Checchia (Shaslik R&D)
Peter Steffen

MUON

DAQ/TRIGGER

Rolf Nahnhauer (Fibre Trigger)

SIMULATION

Silicon Aid

VDET

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APS ↔ CCD Technology

2 cm ↔ 1 cm $r_{beam-pipe}$

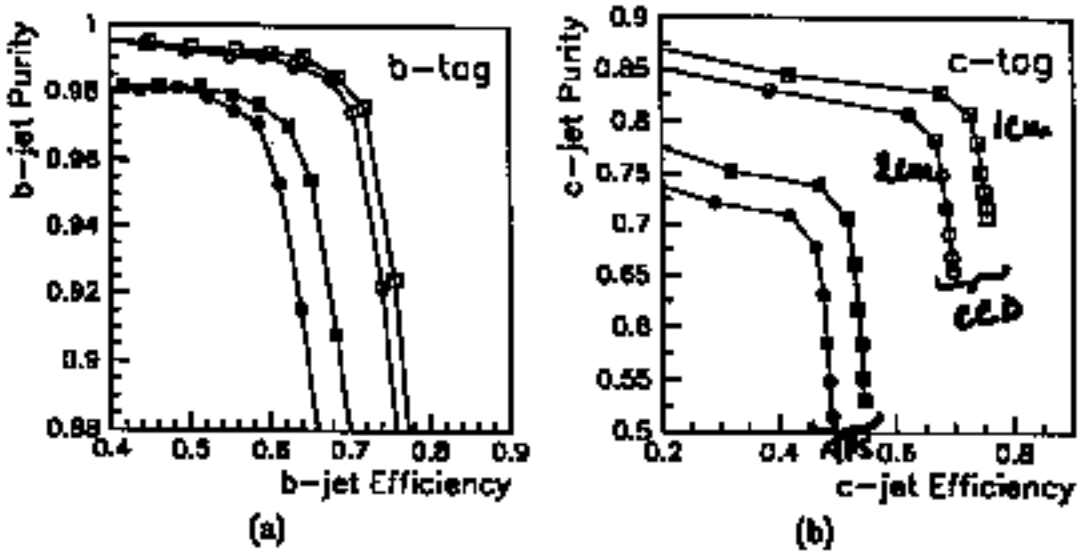


Figure 2.2.2: *Purity vs efficiency for (a) beauty and (b) charm identification in 50 GeV jets. Open squares and circles refer to the CCD option, with respectively* $r_{beam-pipe}$ = *10 and 22 mm. The filled squares and circles refer to the APS option for the same* $r_{beam-pipe}$ *values.*

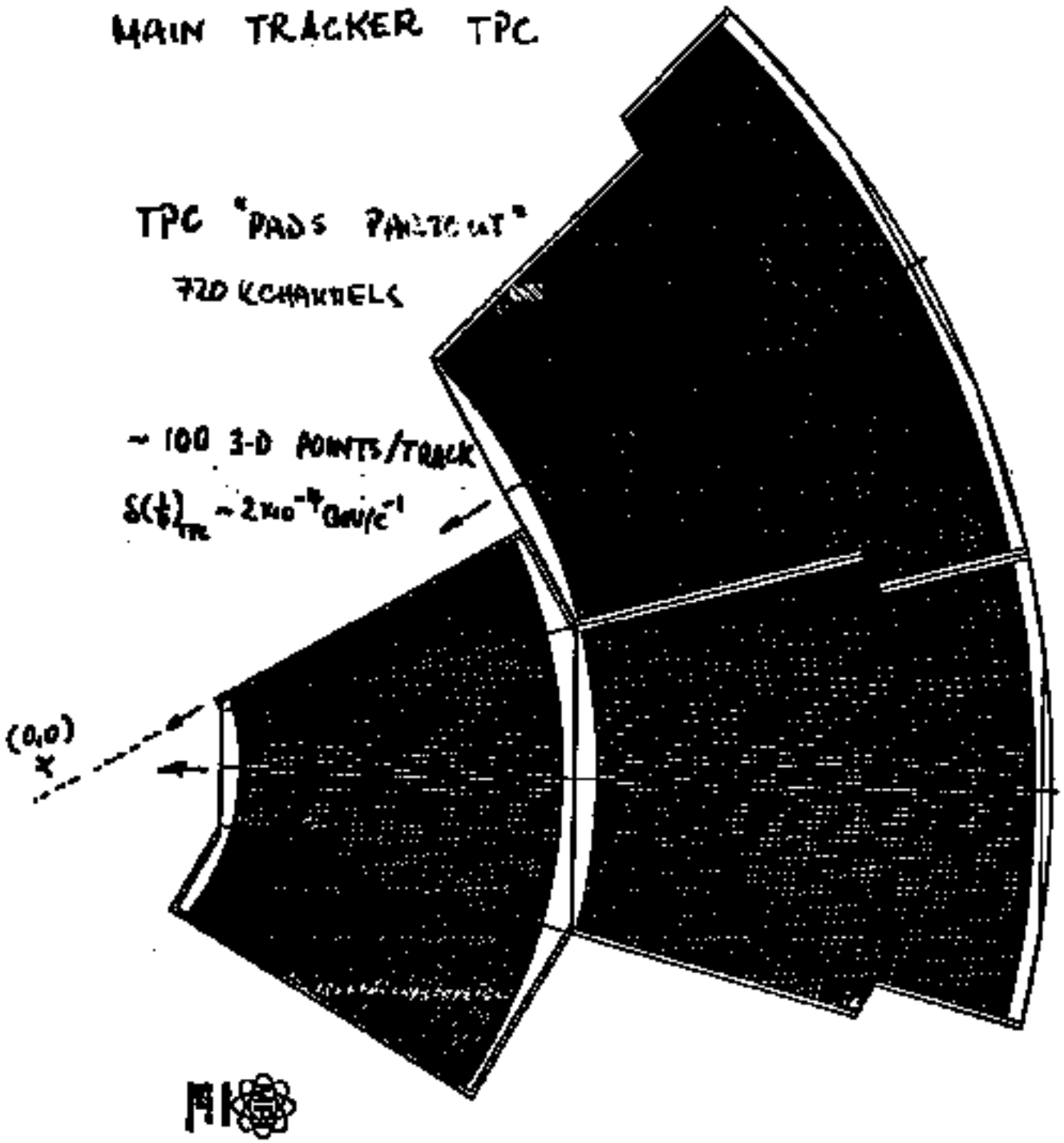
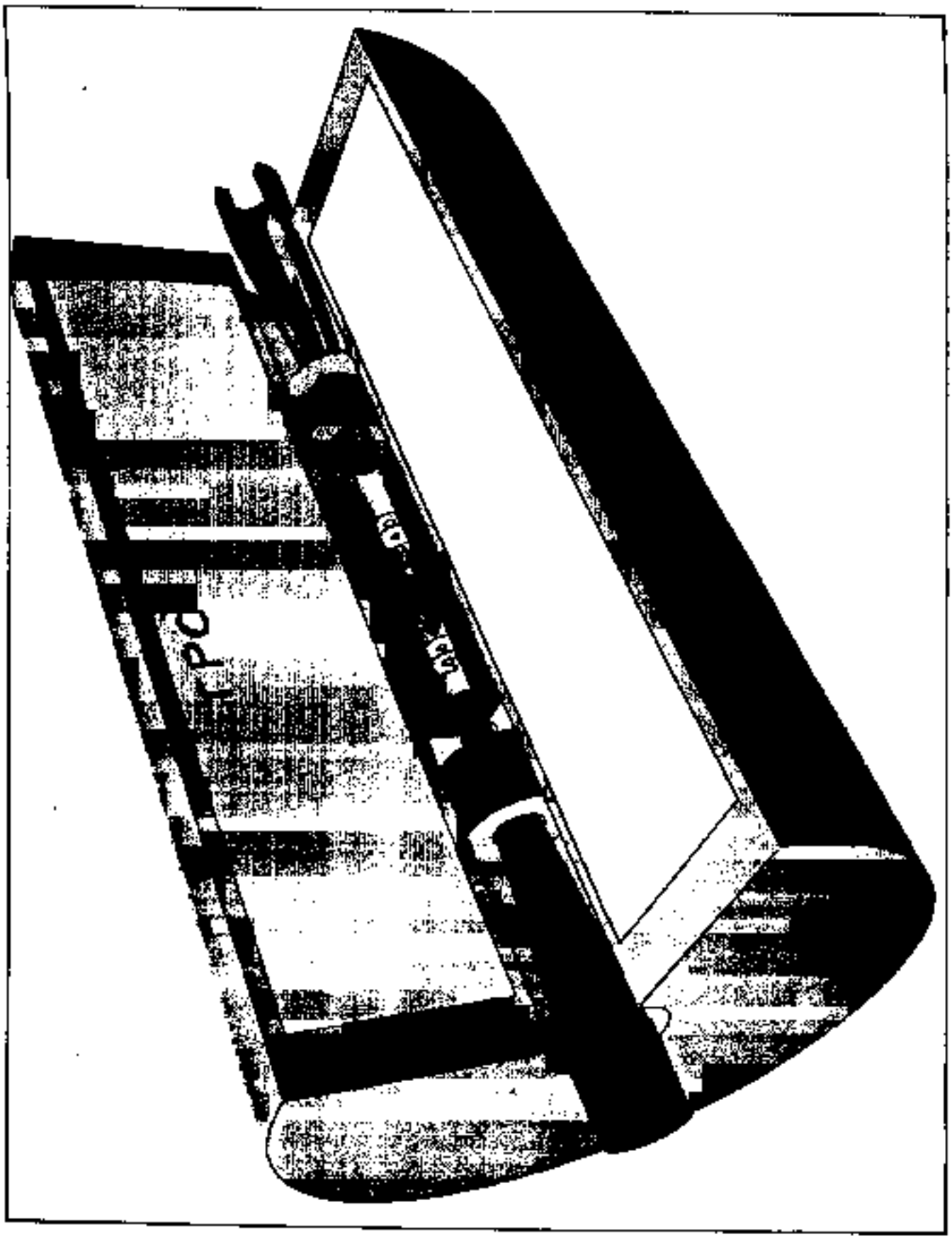


Figure 2.2.5: *TPC sectors with pad structure. The inner sector boundaries do not point to the origin.*

TRACKING



BACKGROUNDS

1. ? CURRENTS ?
2. ? OCCUPANCY ?

SOURCES

	a) PHOTONS	b) CHARGED PARTICLES
1) BEAM-BEAM	✓	✓
2) NEUTRONS		✓
3) SYNCH. RAD. QUADS	0	0
4) DEBRIS	?	?

ASSUME

TRIGGER RATE = 5 kHz

GATE OPEN 50 μs, CLOSE

⇒ "SEE" 70 BUNCHES TESLA

333 BUNCHES S-Band

BACKGROUND CURRENTS

	TESLA		S-BAND	
	a) PHOTONS	b) CHGD	a)	b)
1) BEAM-BEAM	0.08μA	0.06μA	0.08μA	0.04μA
2) NEUTRONS	0.43μA		0.35μA	

ALEPH: 0.5 – 5 μA TYPICAL.
@ LEP ~ 9μA MAX

LAB TESTS: ⇒ ≥ 100 μA SHOULD BE ASSUME

(HV TRIP AT LEP SET AT 1μA/SECTOR × 36 SECTORS)

BACKGROUND FREQUENCY (HEAD TRIGGER)

	TESLA		S-BAND	
	a) γ_s	b) CHGD	a)	b)
1) BEAM-BEAM	.012%	1%	.01%	.8%
2) NEUTRONS	.8%		.4%	

ALICE: 10%/EVENT → N.K
(HEAVY ION @ LHC) ECTOC TRACKS

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TRACKING OVERALL

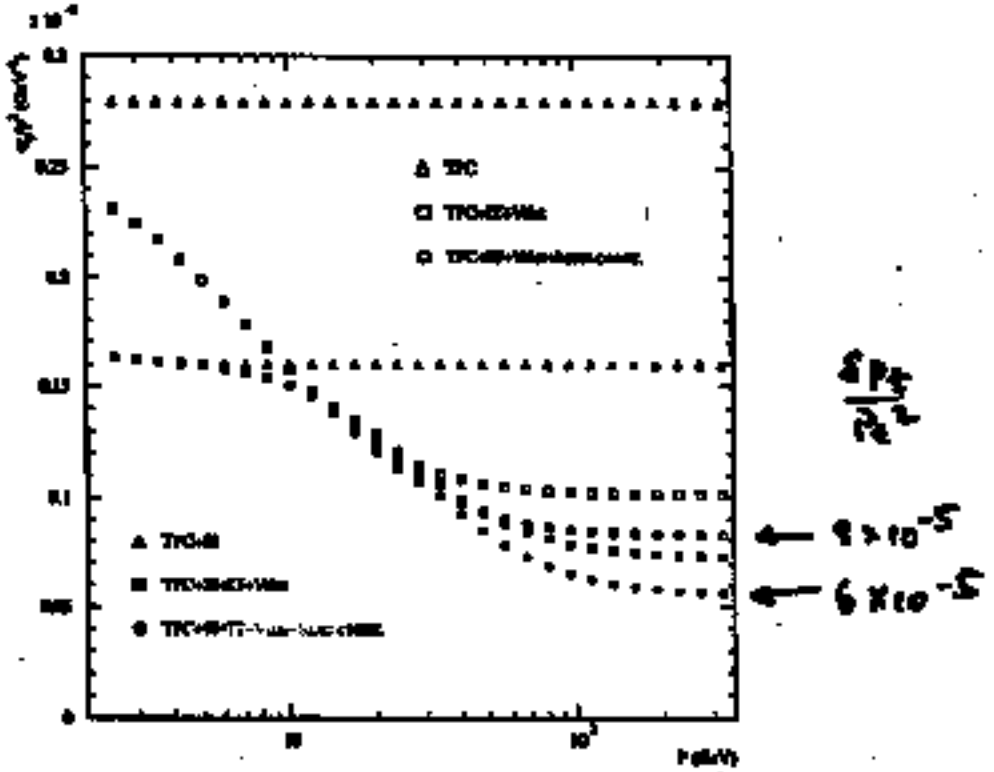

Figure 2.2.6: *Resolution of $1/p_t$ for 90° tracks assuming an APS vertex detector. Symbols: Vdet = vertex detector, IT = intermediate tracker, Si = intermediate silicon layer.*

< 10 μm Systematic error ?!!

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2nd ECFA/DESY Study on Physics and Detectors for a Linear Electron-Positron Collider

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Date : April 6, 1998 - 14:30

C. Damerell

Suggested UK LCFI Group Programme

- Current informal composition
  - Brunel
  - Glasgow
  - Lancaster
  - Liverpool
  - Oxford
  - RAL

- Aiming to work closely with other European, US and Japanese groups by interactions between those interested, entirely at the working level.

- ~~'Hawaii meeting' next month to begin inter-regional coordination~~

- 3-part programme suggested
  - physics studies and simulations
  - vertex detector design
  - vertex detector R&D

Physics Studies and Simulations

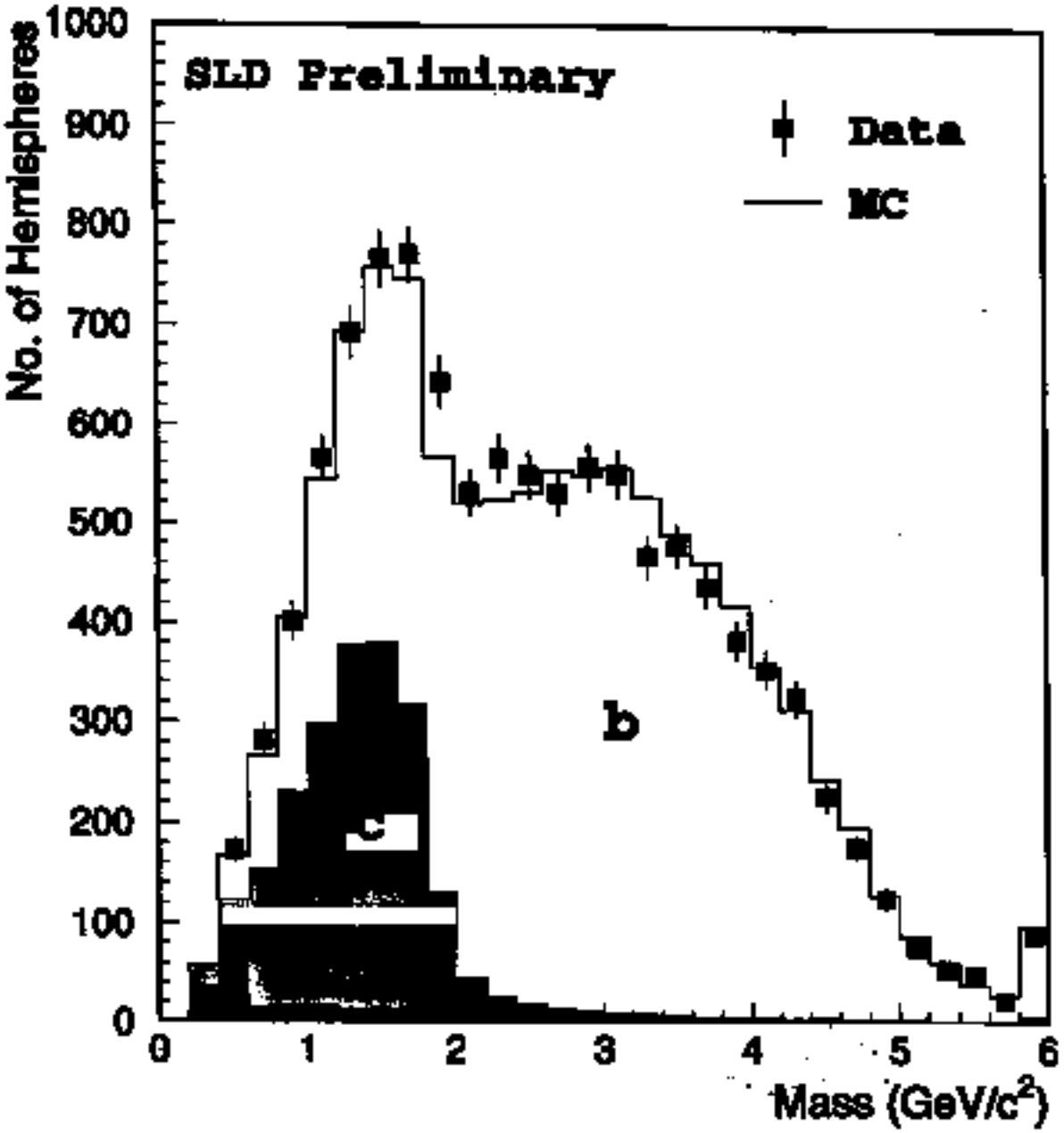
- Apply 'Snowmass' b and c tag to specific physics channels and evaluate S/N improvements
- Update b and c tagging with latest SLD procedures, and new ideas (eg resolved vertex-related π^0s)
- Prove stand-alone track finding capability of proposed detector with simulated backgrounds. Effects of 2-hit resolution in layer 1.
- CCD signal simulation; design variations aiming towards 1 μm precision ($\sigma_x \approx \sigma_y \approx 3.5$ μm in SLD)
- VXD and local electronics in GEANT. Implications for performance of overall LC detector
- Other parameters that impinge on accelerator and overall detector design

  layer 1 radius (accelerator and masking)
  solenoid field (final focus, overall detector)

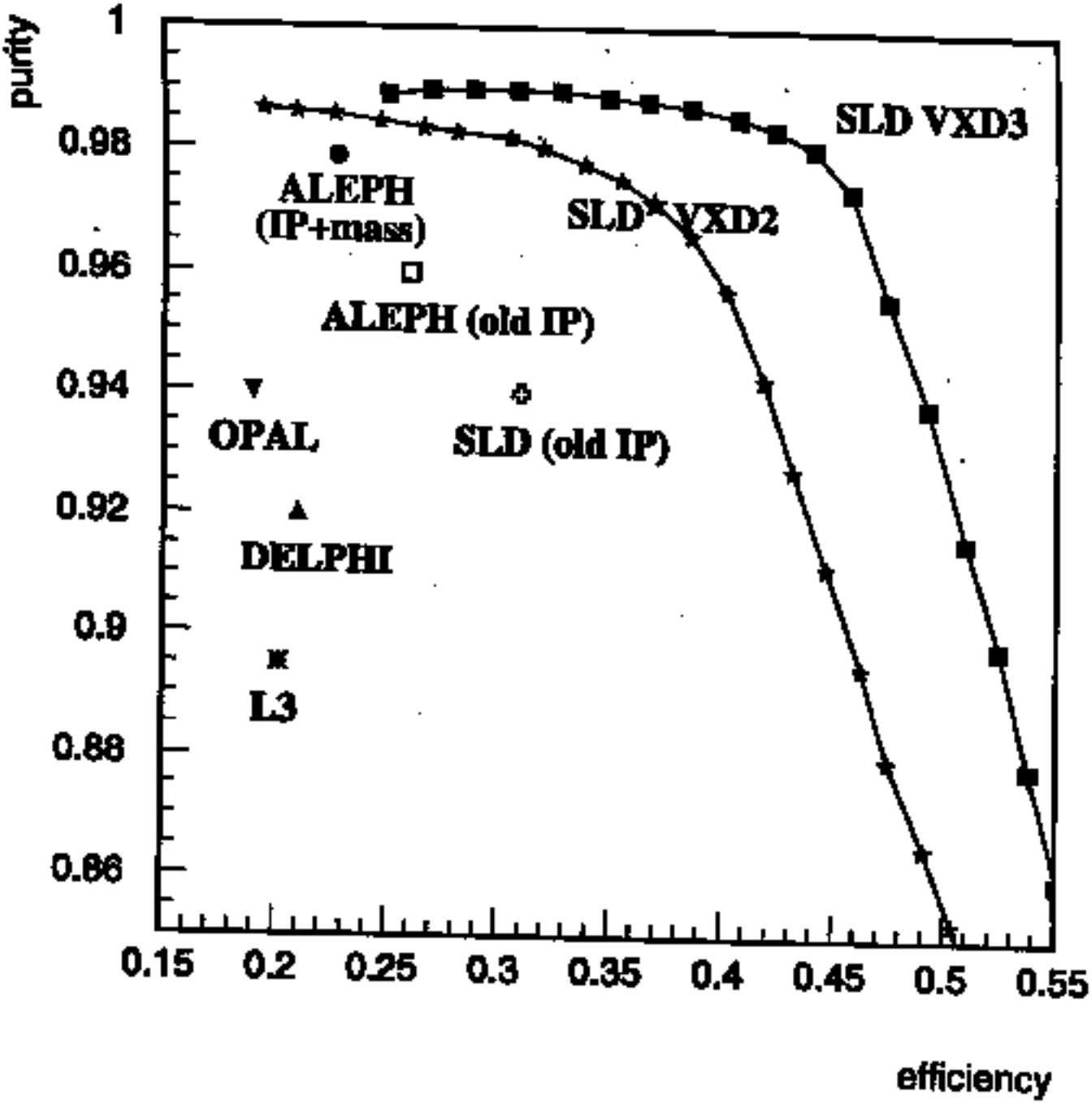
Vertex Detector Design

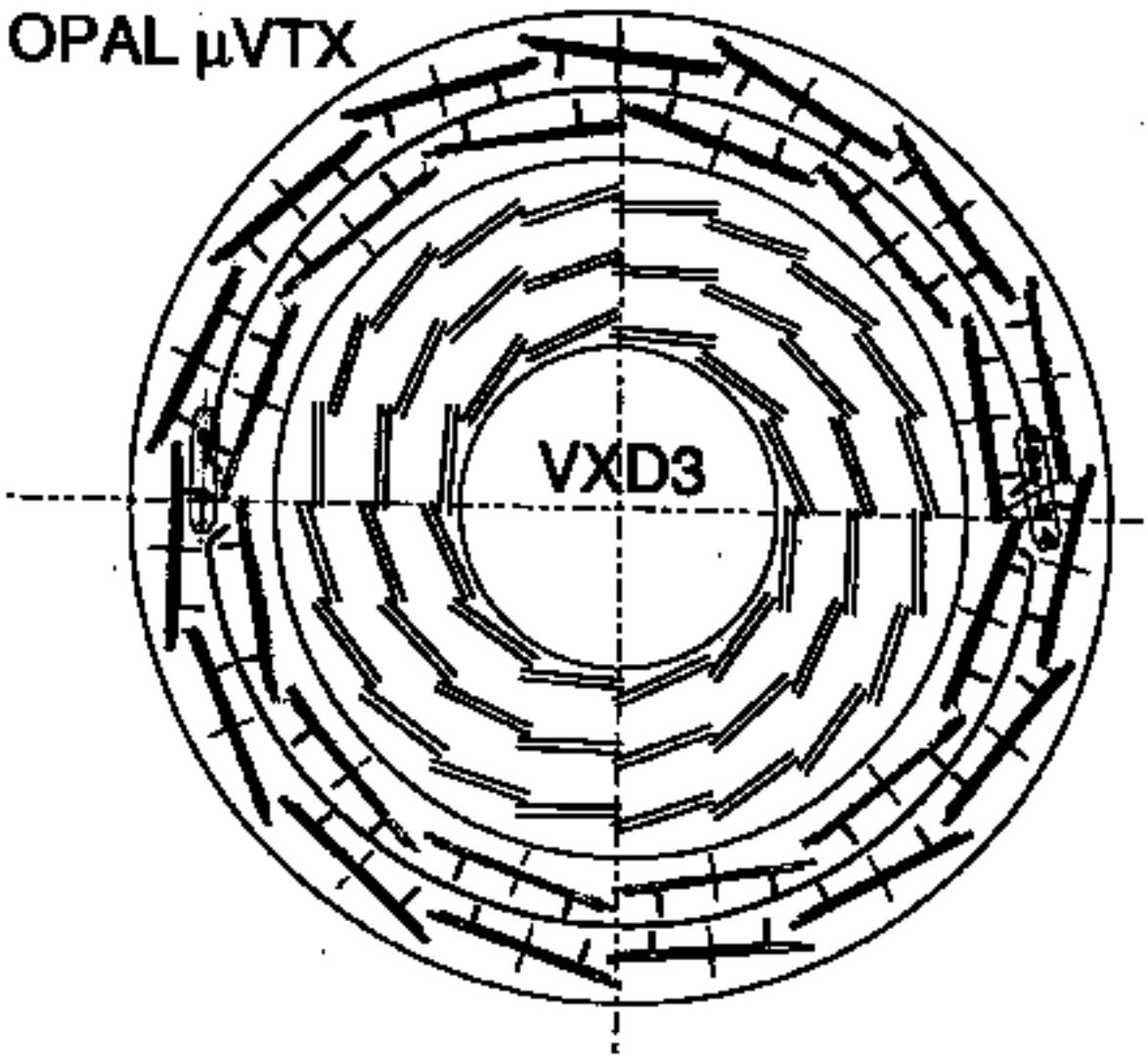
- Overall requirements
  - maximum precision $\sigma_x, \sigma_y < 5\ \mu m$
  - minimal layer thickness ($1.2\% \rightarrow 0.4\% \rightarrow 0.12\% X_0$)
  - minimal layer 1 radius ($28 \rightarrow 12$ mm)
  - polar angle coverage to $\cos\theta_p \approx 0.9$
  - standalone track finding, perfect linking to outer tracking detector
  - complete layer 1 readout between bunch trains, more relaxed beyond (4.6 ms $\rightarrow$ 115 ms)
  - deadtimeless readout (permitting high trigger rate)

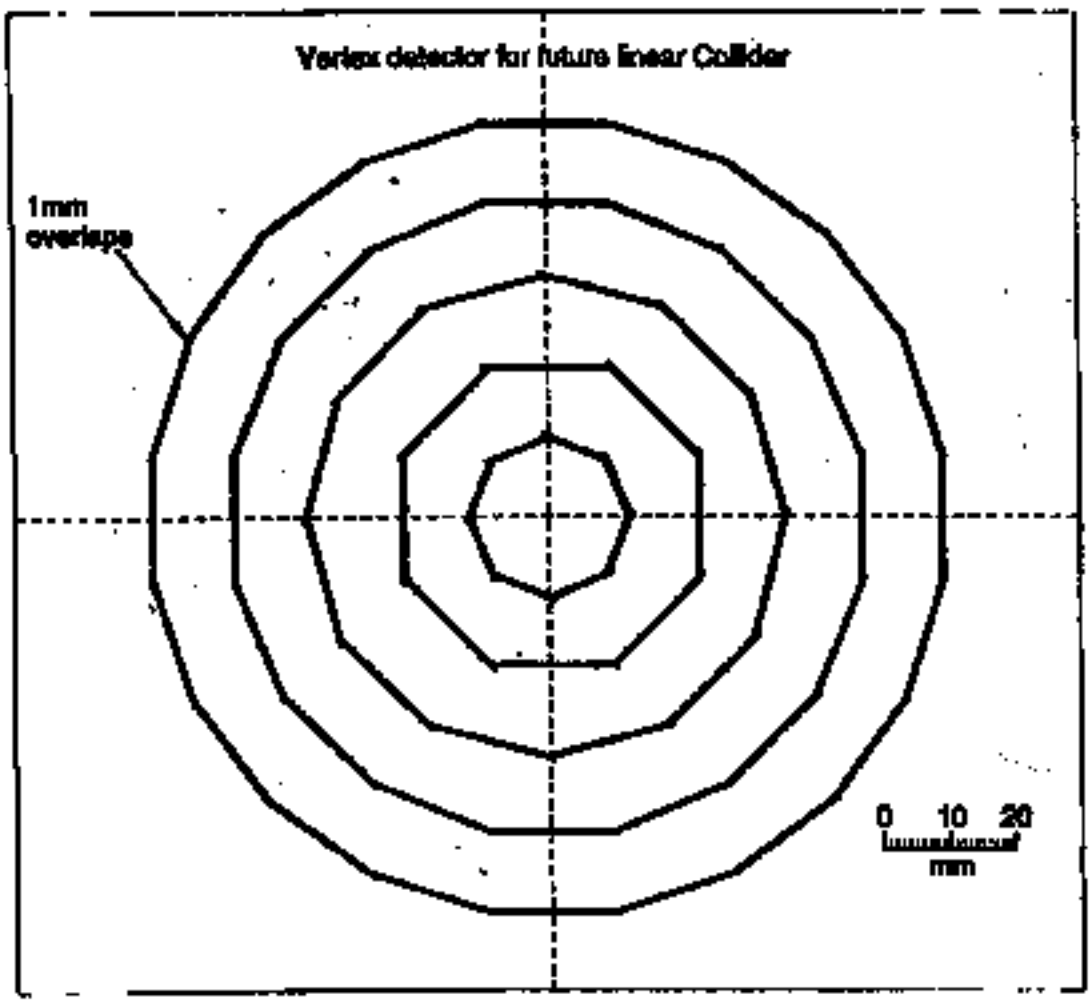
P_t Corrected Mass (VXD3 96)



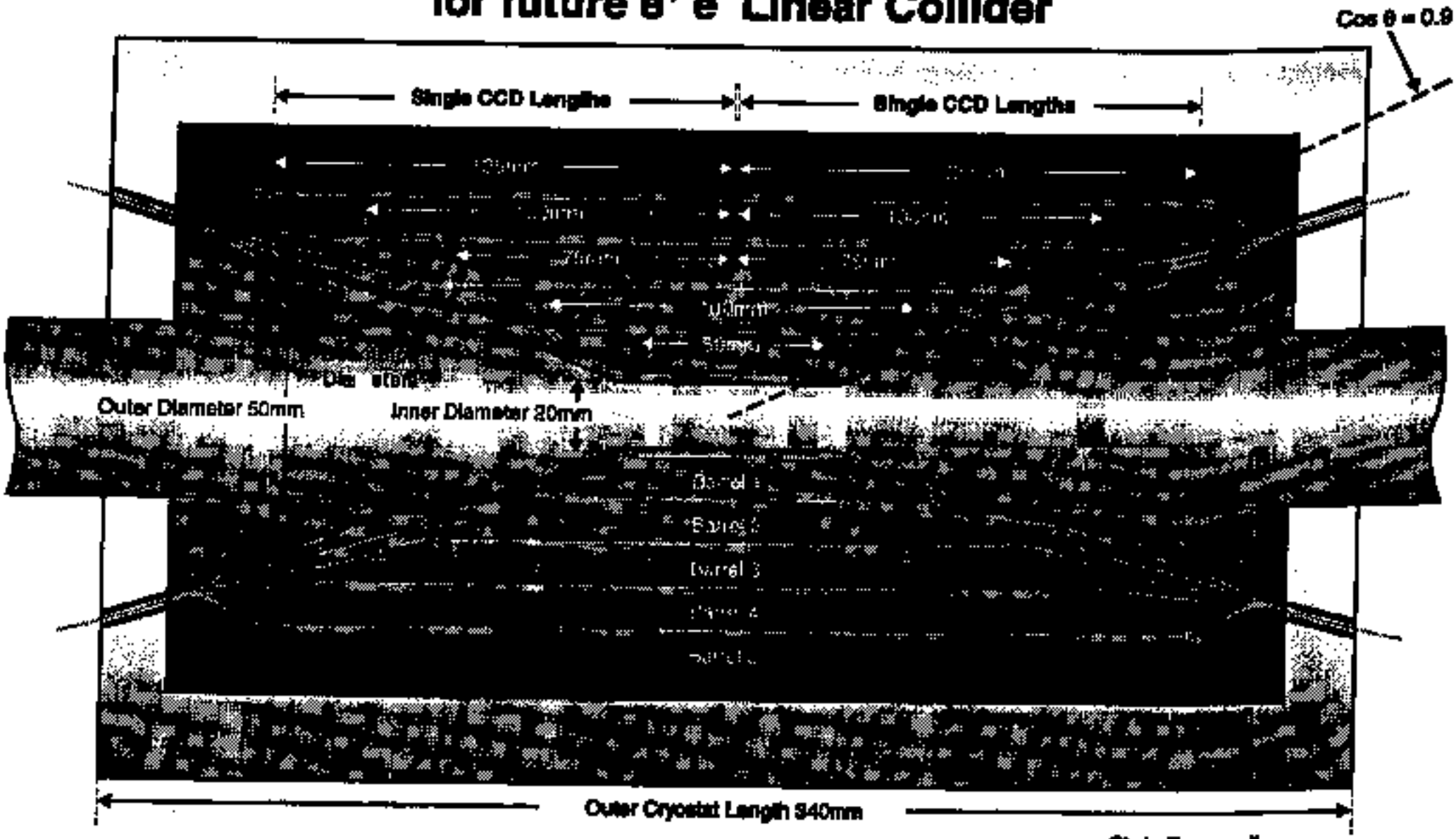
Hemisphere b-tag Performance




OPAL μVTX
VXD3


Vertex detector for future linear Collider
1mm
overlaps
0 10 20
mm

Suggested layout of Vertex Detector for future $e^+ e^-$ Linear Collider



Chris Damerell
Rutherford Appleton Laboratory
May 1996

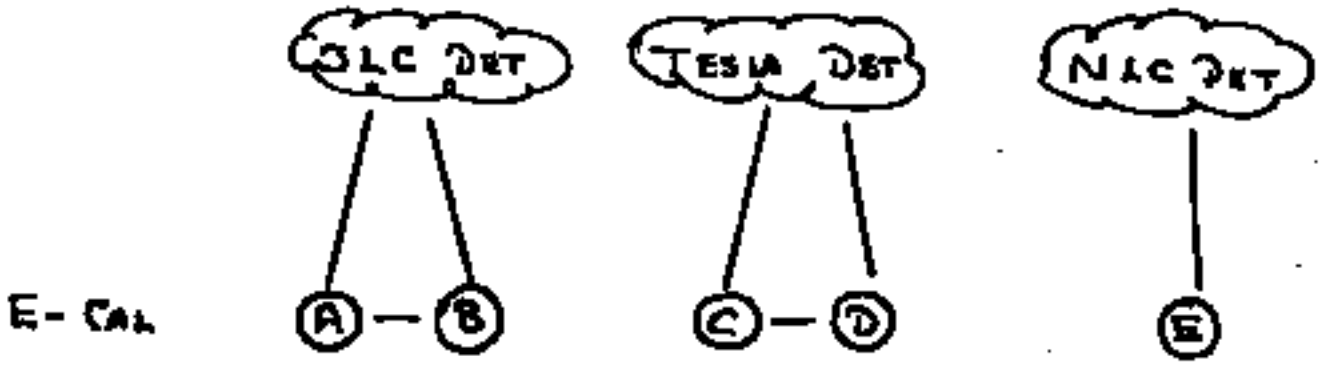
Suggestions For Detector R&D Groups

- Primary Organization:

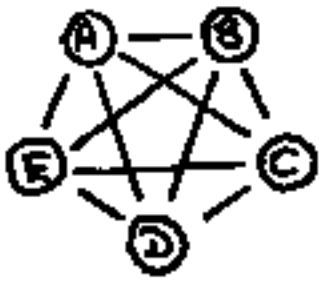
  National, According To Funding Sources

- Secondary Organization:

  Some Hypothetical Detector Designs



- Encourage Tertiary Organization:



Sharing Ideas, Software, Hardware, Problems
→ Optimised Output

$\boxed{\text{AND}}$ Eventual Re-Grouping In ~2 Real Collaborations

- While Not Attempting To Impose This Global Network, Should We Actively Assist In Some Ways,

  Eg A Web Site &/or News Group To Which People Can Sign Up?
  (Like CCD-World Of Astronomy)

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E. Rulikowska

GAS STUDIES

ELISABETH RULIKOWSKA @

UNIV. OF MINING & METALLURGY,
FACULTY OF PHYSICS

5 SCIENTISTS
4 TECHNICIANS

- PAST EXPERIENCE: STUDIES OF GAS SYSTEMS for ATLAS and ZEUS

- PROPOSAL for FUTURE STUDIES:
  GAS SYSTEM for LC DETECTOR
  (TPC, HONEYCOMB CE., MSGC, GEM...)

  → STUDY GAS MIXTURES TO IMPROVE SUB-DETECTOR PERFORMANCE

  → TAKE PART IN DESIGN and CHOICE of GAS-SUBDETECTORS

  → PREPARE SECTION for the TDR on GAS SYSTEMS

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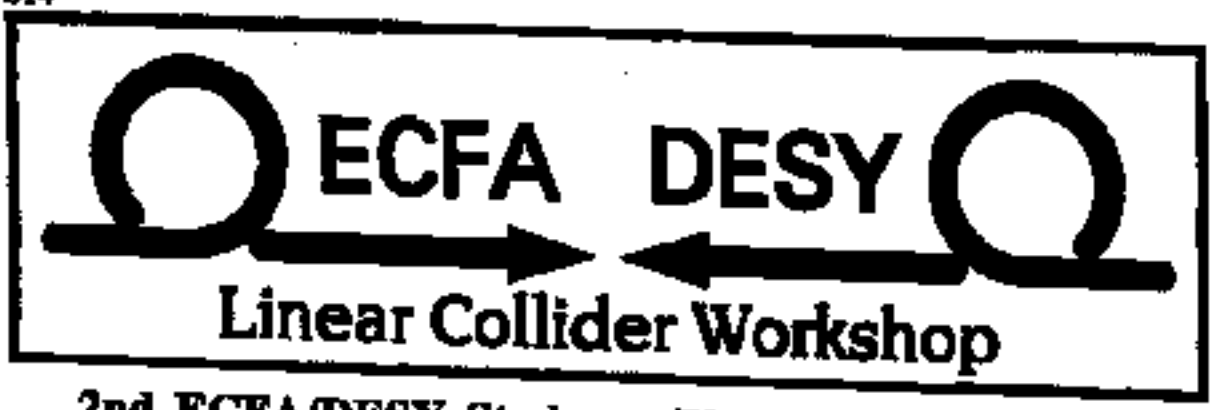

2nd ECFA/DESY Study on Physics and Detectors for a Linear Electron-Positron Collider

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V. Korbel

•20.3.98, V. Korbel, DESY

Calorimeter Studies

1. Monte Carlo simulations to improve geometry and sampling of shaslik type calorimeter cells in order to

- **improve light yield,**
- **density in X_0 and λ,**
- **electron/hadron response ratio,**
- **improve lateral impact measurement,**
- **improve homogeneity,**
- **read out in magnetic field,**
- **calibration precision,**
- **monitoring.**

The studies will be made at:
DESY, Lebedev-Inst. and LUND Univ.
by N. Konovalova, V. Korbel, S. Kotelnikov, P. Steffen and students.

•20.3.98, V. Korbel, DESY

Homogeneous calorimetry:

Crystal/glass studies:
Aim is to improve performance of

--$PbWO_4$ -- a crystal,
•as proposed by CMS

--$NaBi(WO_4)_2$ – a glass,
•as used by HERMES
with respect to:
•light yield, Cerenkov and Scintill.
•transparency and homogeneity
•radiation hardness
•price !

Studies:
- crystal growing conditions,
- glass casting for NBW,
- scintillating additives,
- tests in e-beams,
- comparison with shashlyk.

Groups involved (Intas Project):
Lebedev Physical Institute, Moskow,
University of Lund,
Institute of Nuclear Physics, Tashkent,
DESY