OLAF [redacted]
LHCb week
CERN 24-2-2000

SUMMARY OF INNER TRACKER MEETINGS

* GAS OPTIONS (TUE MORNING, WED AFTERNOON)
  - ⇒ PRESENTATION OF RESULTS FROM DEC'99 PSI TEST BEAM
  - ⇒ AGREE ON <u>ONE</u> GAS TECHNOLOGY
  - ⇒ DISTRIBUTE RESPONSIBILITIES
* SILICON OPTION (TUE AFTERNOON)
  - ⇒ PRESENTATIONS BY INVITED EXPERTS (CMS, ATLAS, HERA-B, LHCb)
  - ⇒ FIRST LOOK AT RADIATION ENVIRONMENT

PSI TEST

DETECTORS:

MICRO-MEGA (LAUSANNE)

- WIRE (SANTIAGO)

- GROOVE (+GEM) (NOVOSIBIRSK)

DOUBLE-GEMS (GDD/COMPASS)

TRIPLE-GEMS (NOVOSIBIRSK, ZÜRIC

MEASURE:

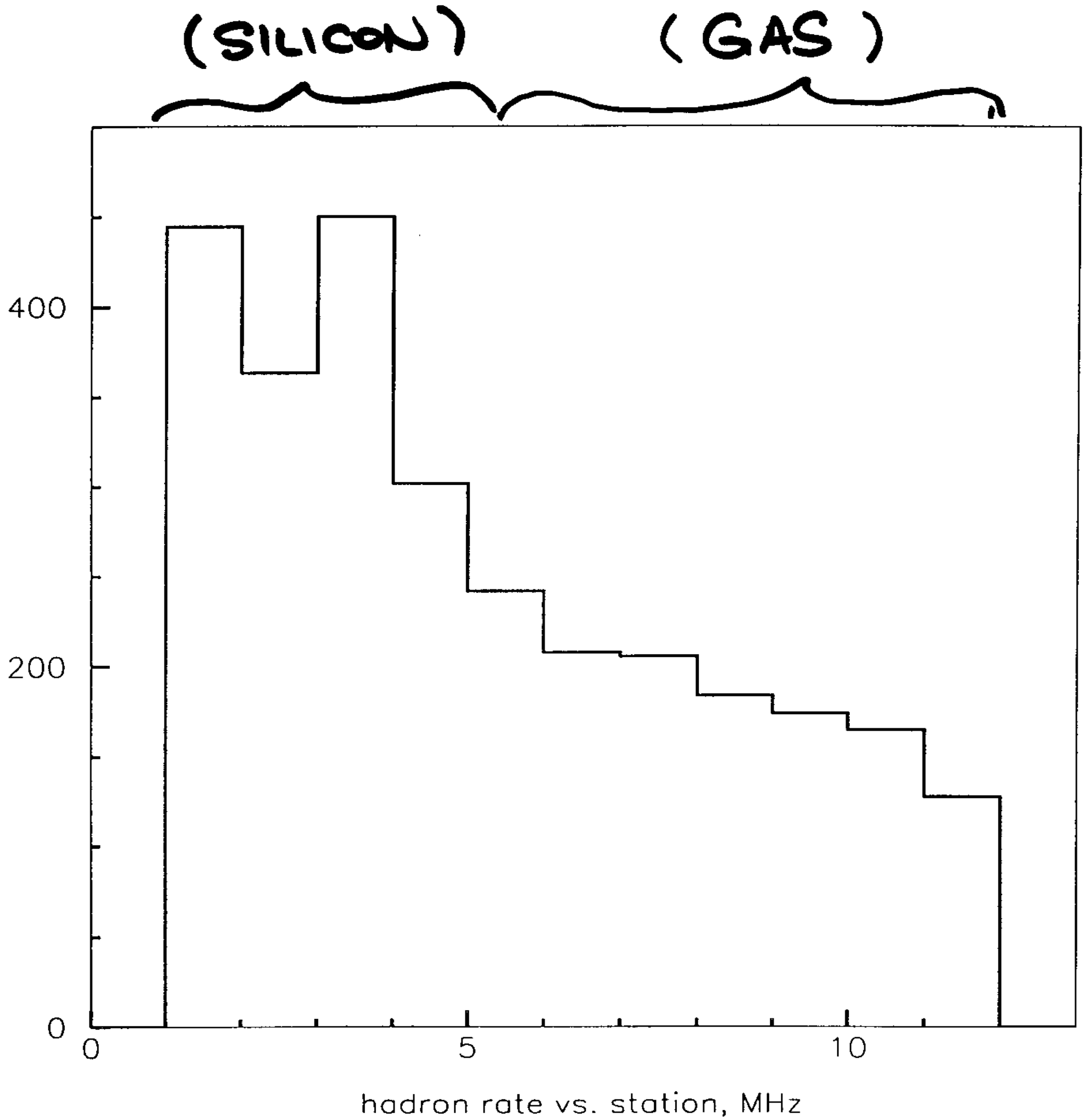
1) EFFICIENCY PLATEAU

WITH "REALISTIC" (=FAST) READOUT CHIP
(PREMUX, STAR4, HELIX)

2) SPARK / DISCHARGE RATE

AT FULL EFFICIENCY

REMARK: ALL EFFICIENCIES MEASURED
RELATIVE TO 2-SCINTILLATOR COINCIDENCE
→ PLATEAU NOT AT 100% DUE TO FAKE TRIG



$$\Rightarrow \frac{0.1\ \text{Hz total spark rate}}{6\ \text{station} \times 2\ \text{planes} \times 200\ \text{MHz}} = \underline{4 \cdot 10^{-11}\ \text{sparks per hadron}}$$

IPHE

OUTLINE

Setup

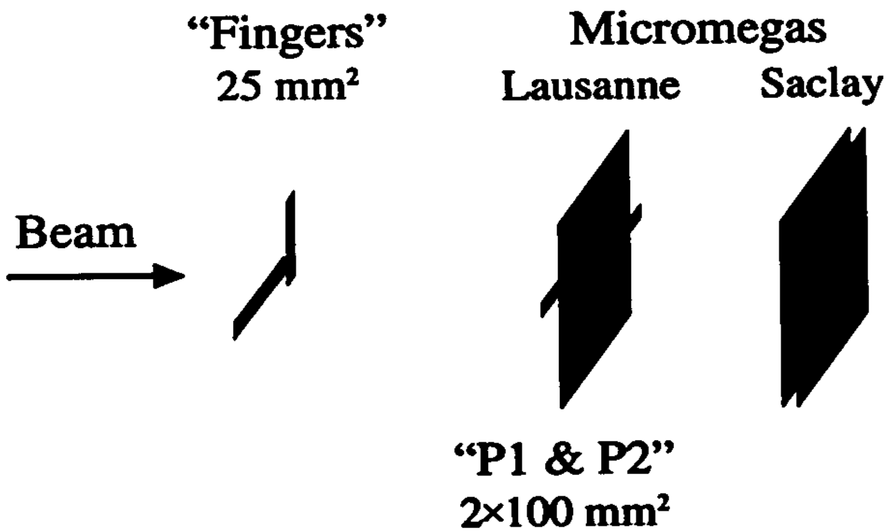
Results

- Discharge probability
- Off-line analysis
- Charge spectrum

Conclusion and outlook

Raymond Frei
Jean-Baptiste Mosset
Jean-Pierre Perroud
Frédéric Ronga

Experimental Setup



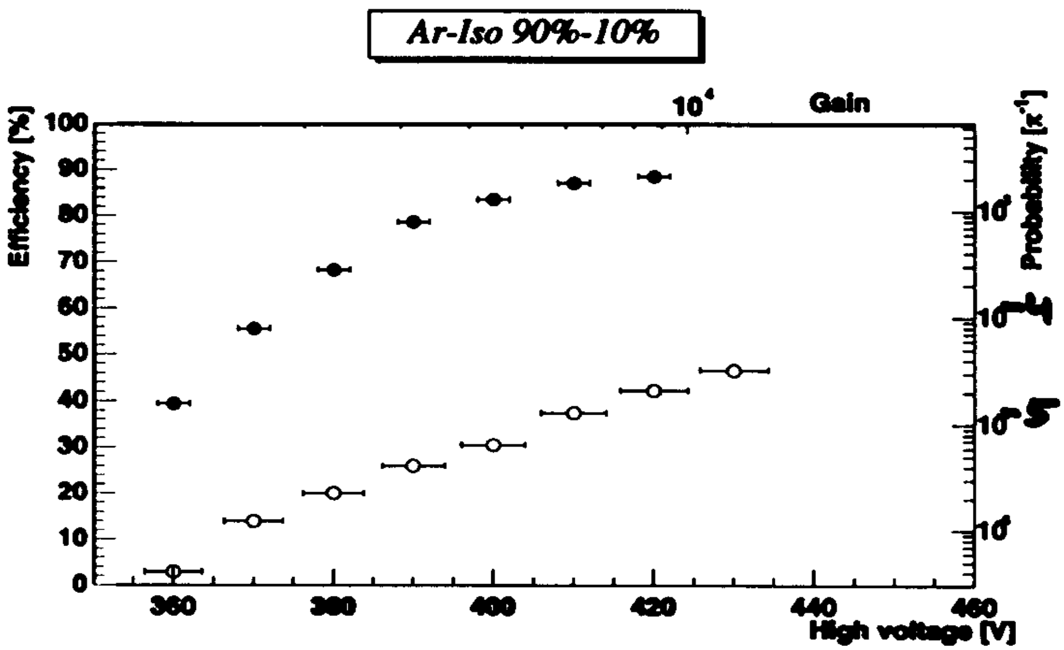
Detectors:

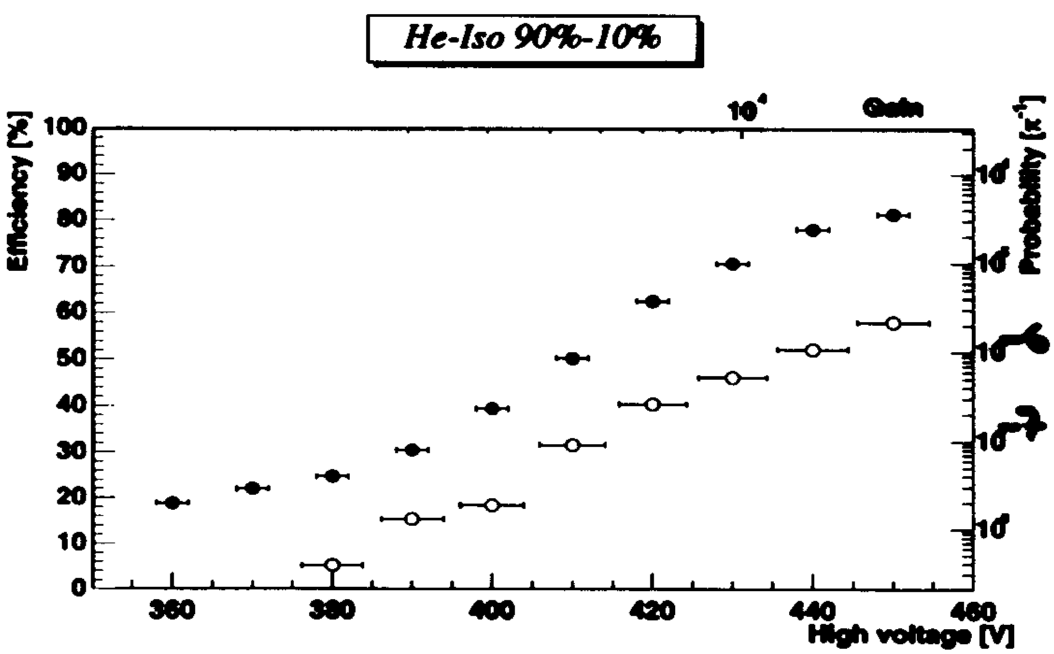
- $15x15\ cm^2$ active area
- 6 mm – 75 μm
  3 mm – 75 μm
  3 mm – 100 μm
  3 mm – 100 μm (Saclay)

Gases:

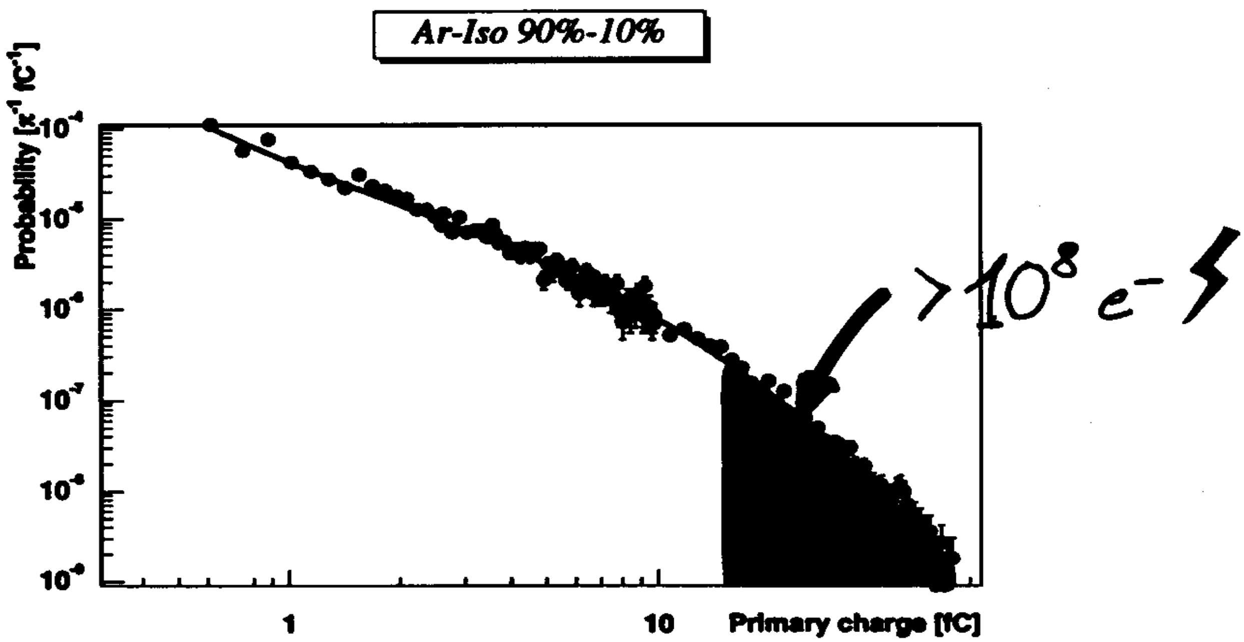
Ar–Iso	90%–10%	95%–05%	
He–Iso	90%–10%	95%–05%	85%–05%
Ne–Iso	90%–10%		
Ar–Iso–CF_4	90%–05%–05%		

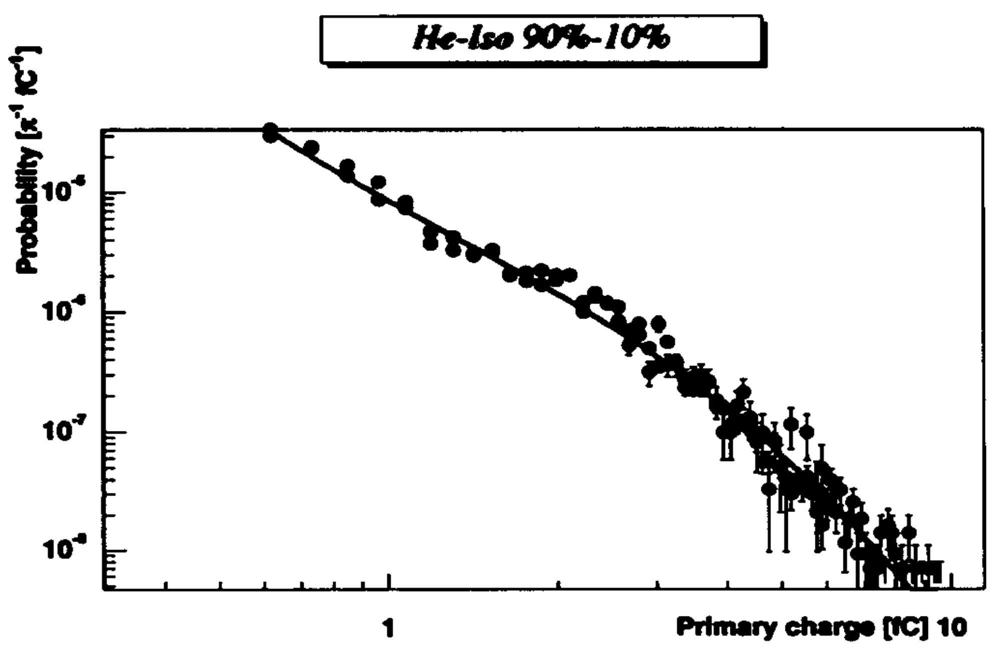
EFFICIENCY & DISCHARGE



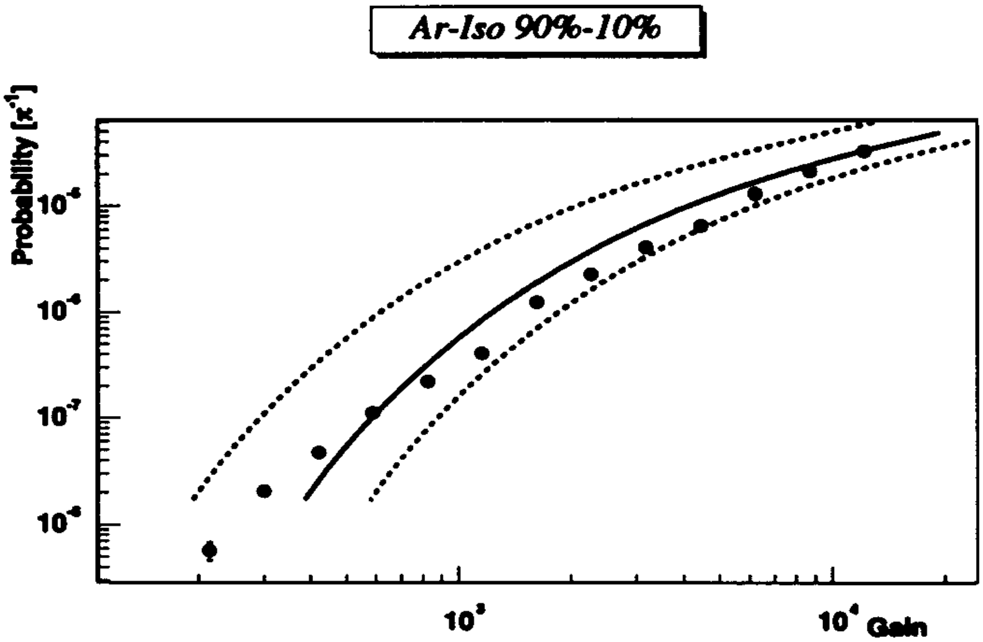


HIGH IONIZATION

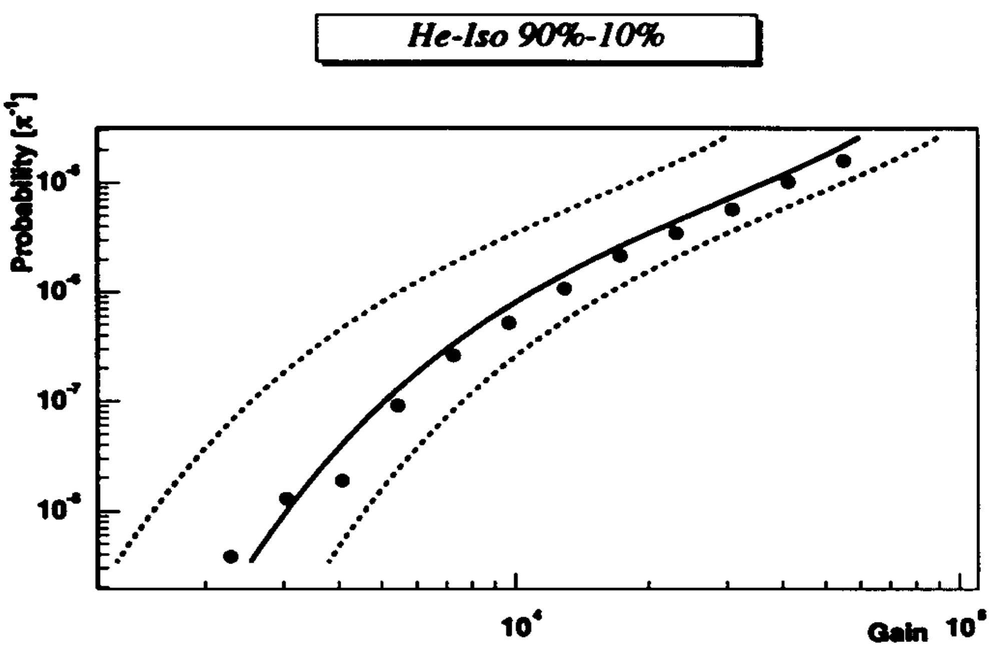




DISCHARGE PROBABILITY



Raether limit: $\sim 10^8$ charge carriers



CONCLUSION & OUTLOOK

Summary:

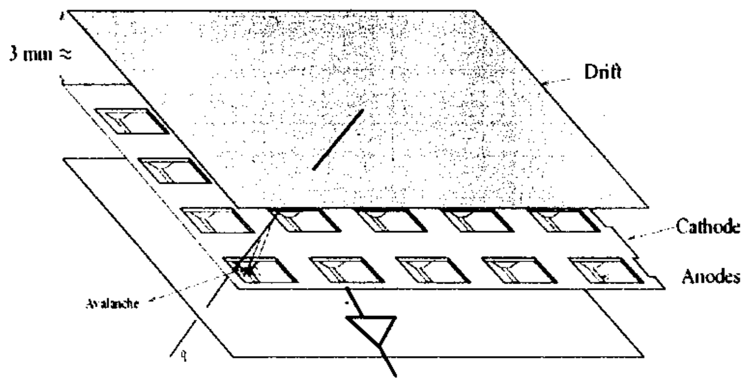
- satisfactory results
  charge distribution, S/N, efficiency
- detailed discharge study
  Ar–He–Ne, energy, beam rate, particles
- origin understood
- discharge rate too high!

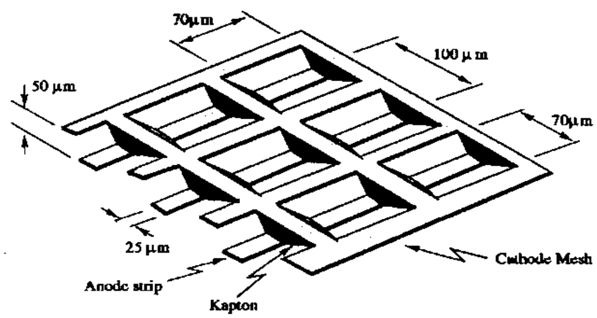
Outlook:

- multi-stage “GEMicromegas”. . . ?

MICRO-WIRE DETECTOR

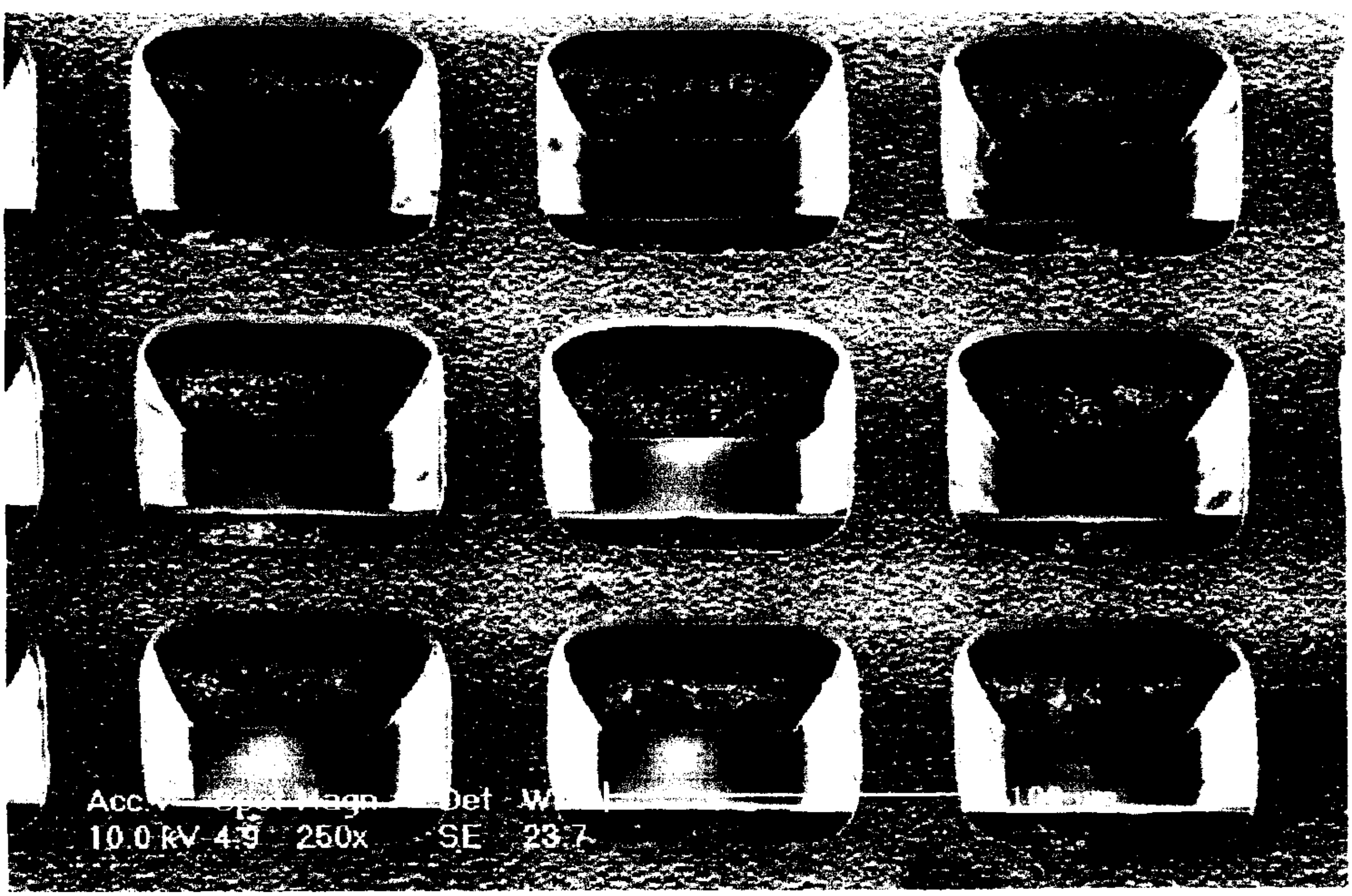
B. Adeva et al., NIM A435 (1999) 402





$C_{\text{anode strip}} = \mathbf{0.28\ pF/cm}$

$X_0 = \mathbf{0.037\%}$



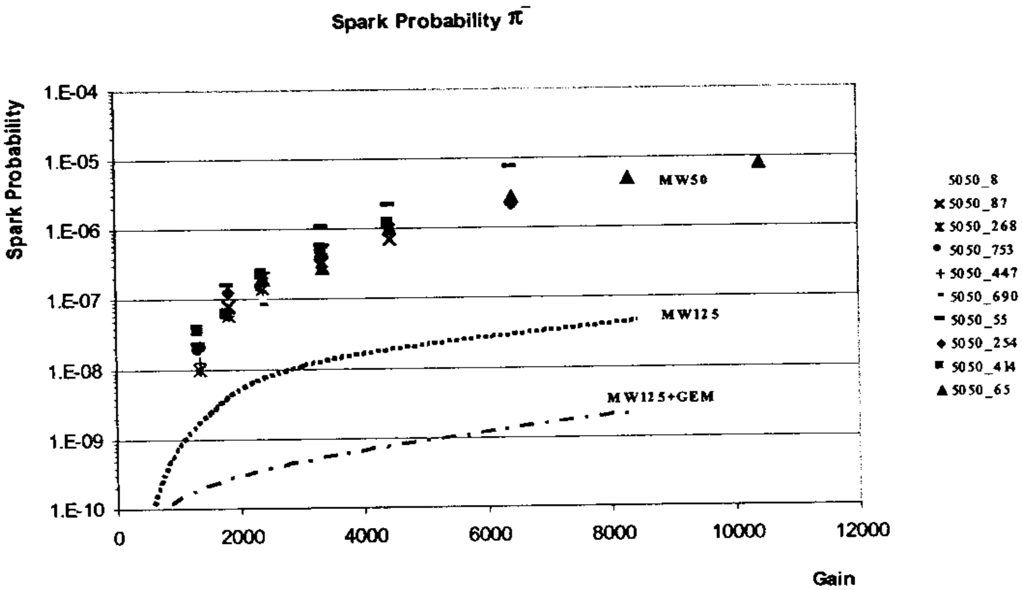
B. Adeva, F. Gómez, A. Iglesias, J.C. Labbé, A. Pazos, M. Pló, X. Rodríguez, P. Vázqu
Universidade de Santiago de Compostela
CERN

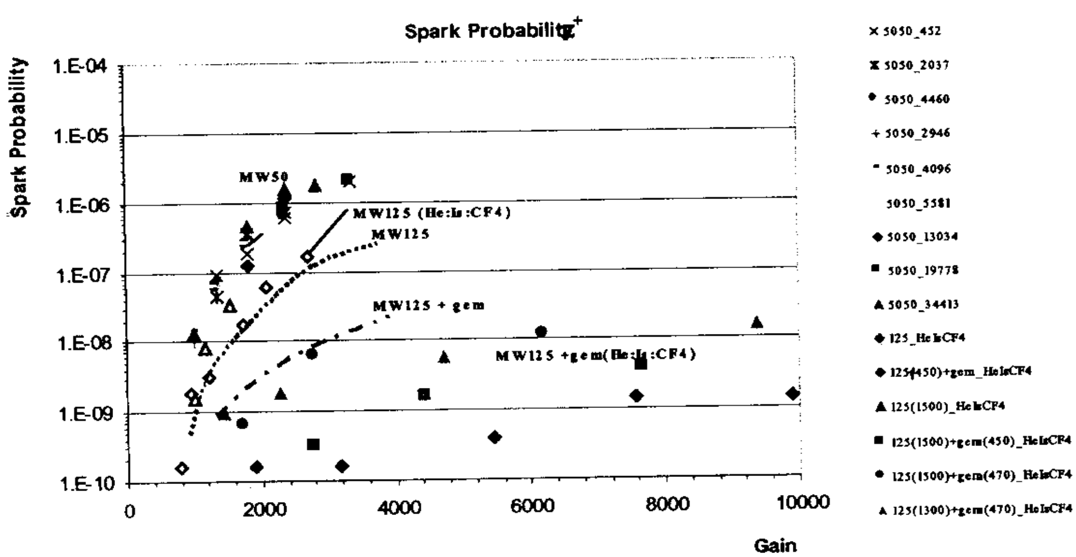
MWD operating point

	MSGC	MWD	3 GEM
Detector capacitance			
Specific capacitance	0.5 pF/cm	0.28 pF/cm	
25 cm strip	13 pF	7 pF	~30 pF
Noise			
Premux Noise = 500e+40e*Cp[F]	1020 e-	780 e- (0.7 * MSGC noise)	1700 e- (1.7*MSGC noise)
Gain			
Visible gain @ full eff	900	630 (0.7 * MSGC gain)	1530 (1.7*MSGC gain)
Operating gain @ full eff ~ 2 times visible gain	1800	1260	3060 ↑
Safe operating point ~ 3 times full eff gain	3960 ~4000	2772 ~ 3000	6732 ↑ ~7000

Dec. 99 PSI Test-beam results

Spark probability and gas mixture





Conclusions

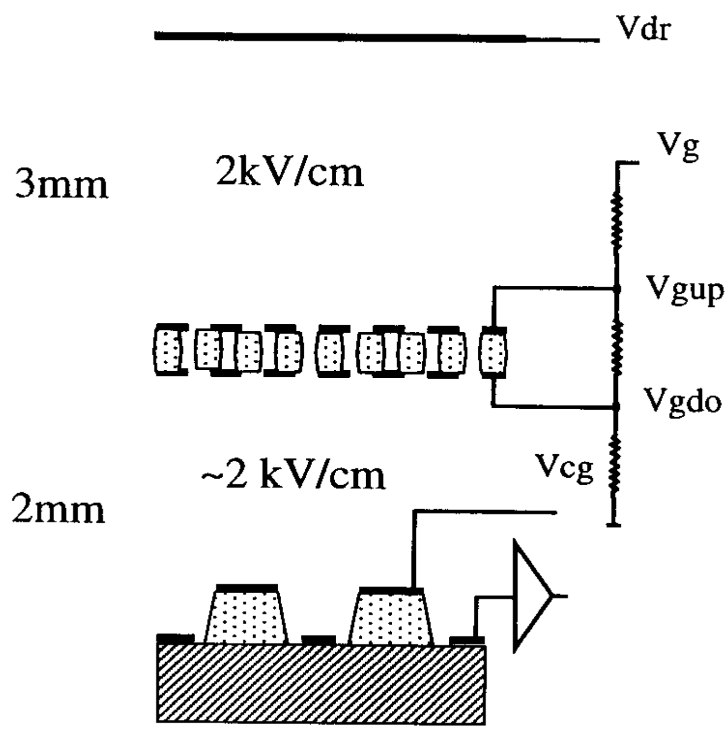
- It is perfectly feasible to operate MWD at LHCb inner tracker with a spark probability < 10^{-8}
- MWD allows safe operation in the presence of HIPs
- MWD smallest anode capacitance among all gas options allows the lowest operating gain.

RESULTS FROM PSI-99.

A.Buzulutskov, L.Shekhtman, A.Sokolov, A.Tatarinov

BINP, Novosibirsk

Micro-groove/GEM



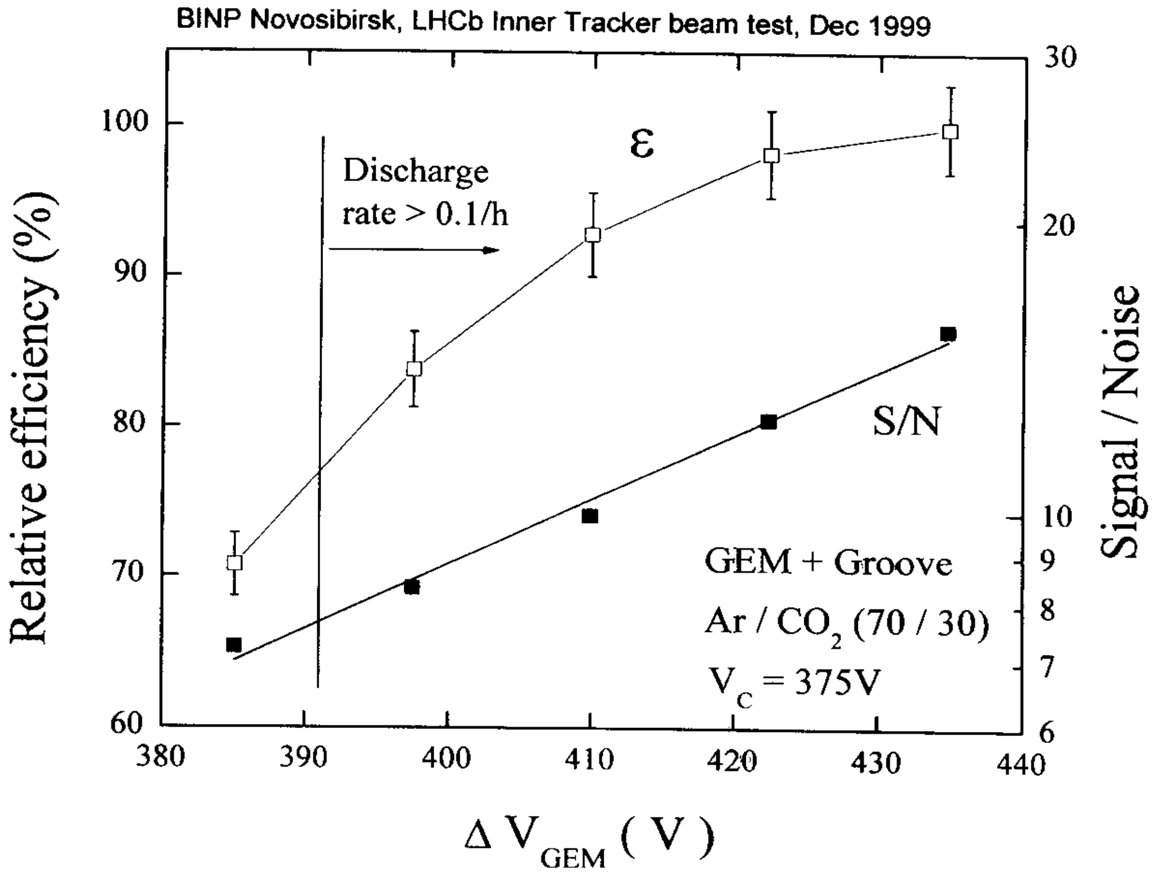
GEM

pitch - 140um
hole diameter - 80/60um

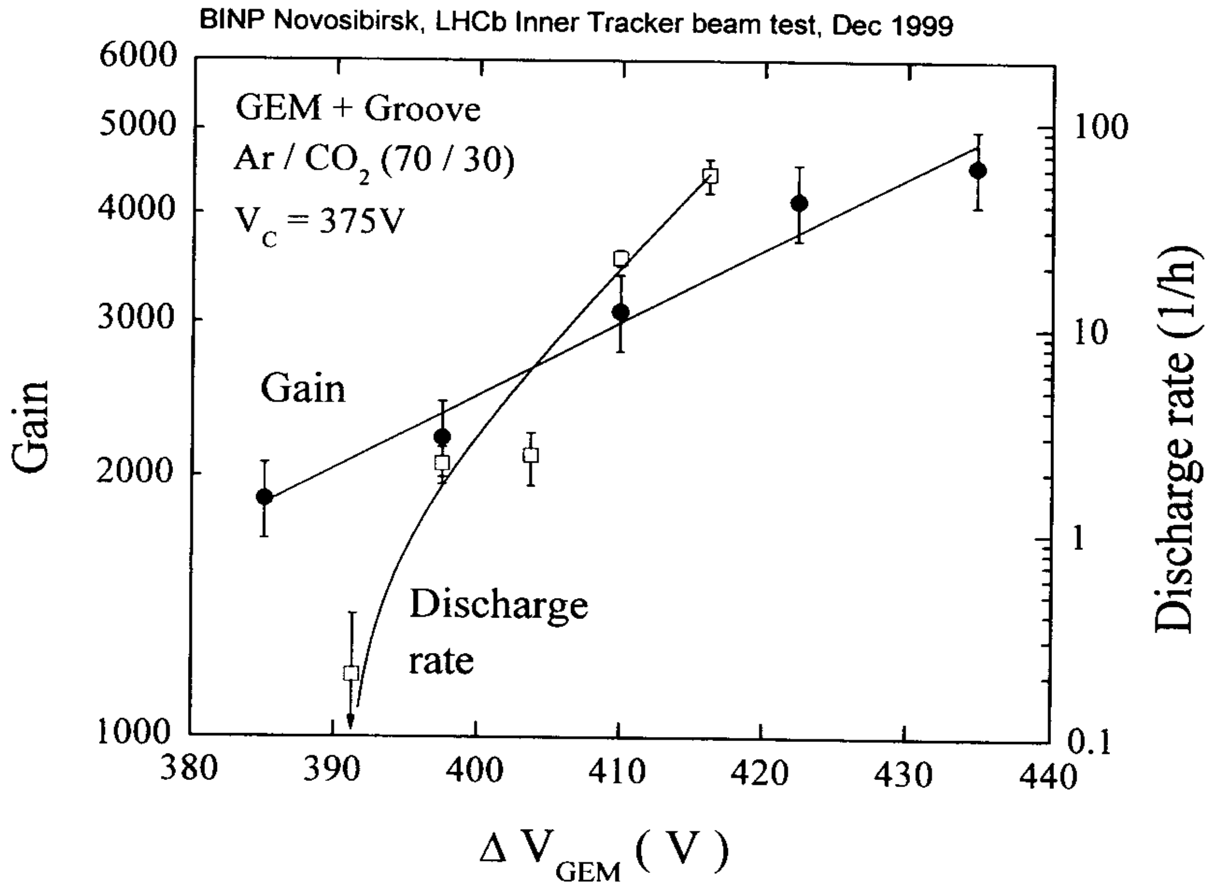
MICRO-GROOVE(wedge)

pitch - 180-200um
anode - 30um
cathode - 90-100um

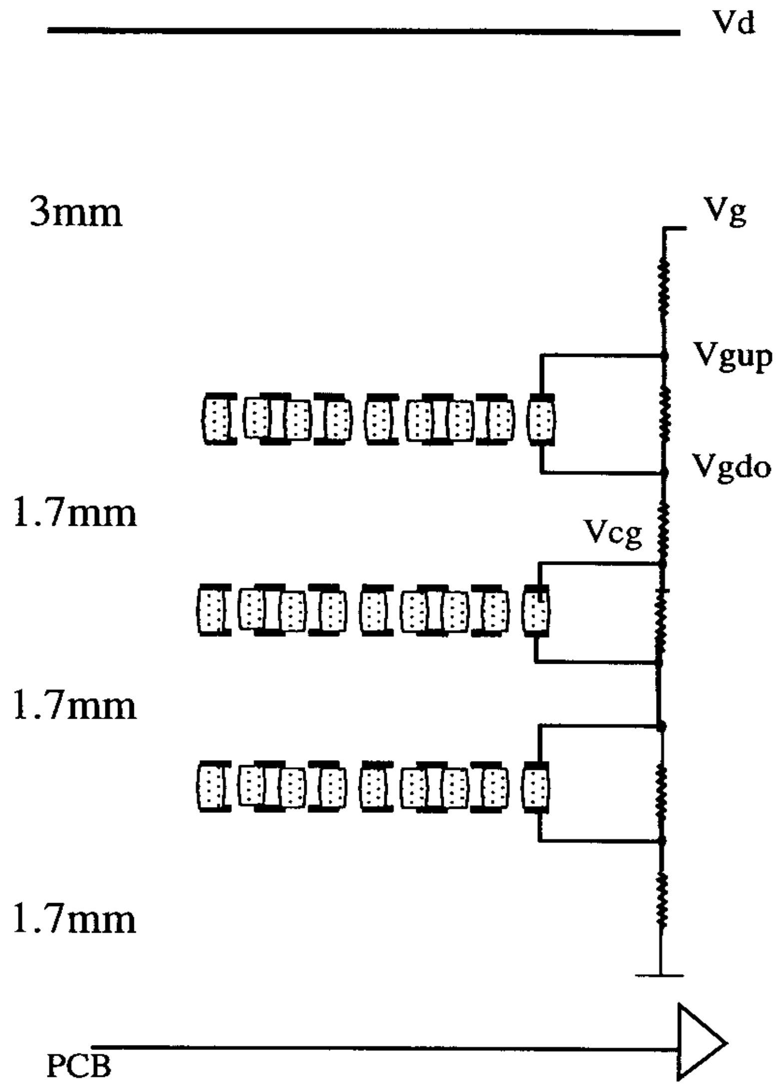
10*10 cm



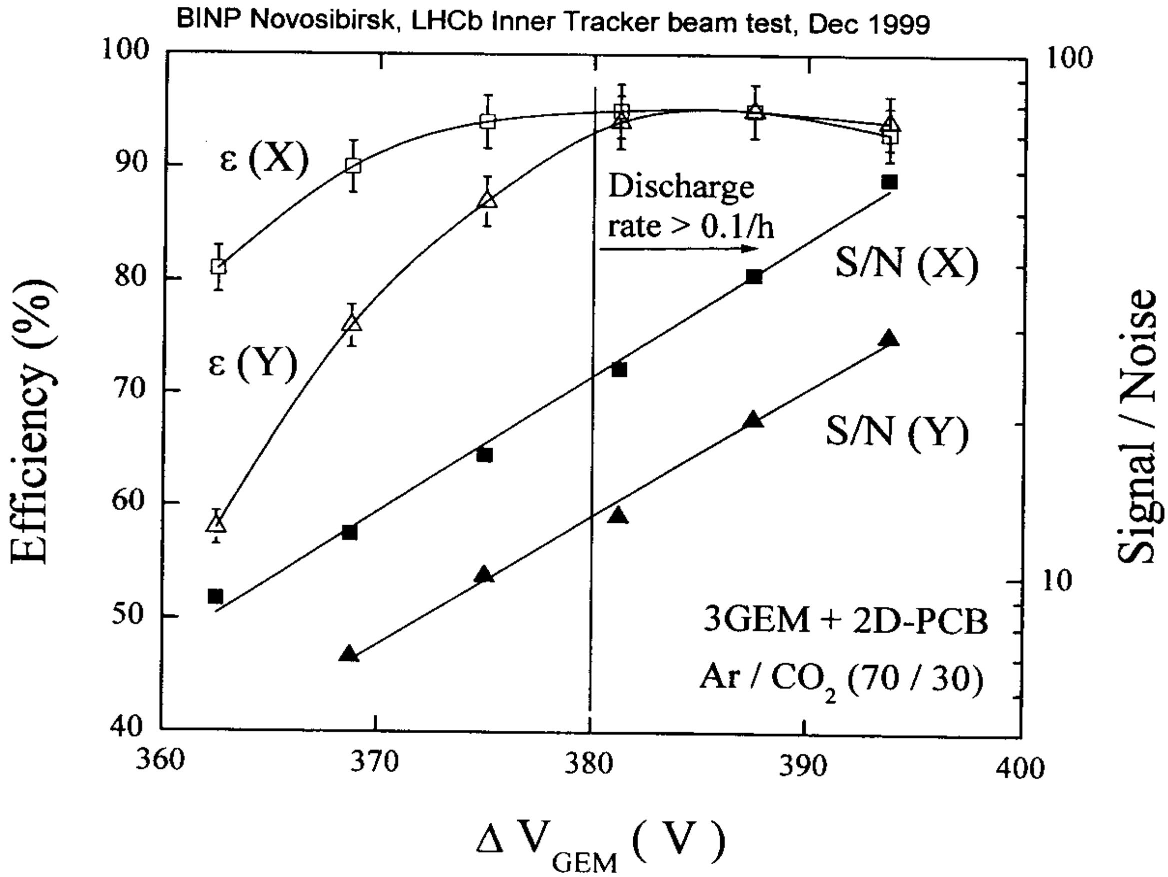
BINP Novosibirsk, LHCb Inner Tracker beam test, Dec 1999
Relative efficiency (%)
Signal / Noise
ε
Discharge rate > 0.1/h
S/N
GEM + Groove
Ar / CO2 (70 / 30)
VC = 375V
100
90
80
70
60
30
20
10
9
8
7
6
380
390
400
410
420
430
440
Δ VGEM (V)


BINP Novosibirsk, LHCb Inner Tracker beam test, Dec 1999
GEM + Groove
Ar / CO2 (70 / 30)
VC = 375V
Gain
Discharge rate
Gain
Discharge rate (1/h)
Δ VGEM (V)
6000
5000
4000
3000
2000
1000
100
10
1
0.1
380
390
400
410
420
430
440

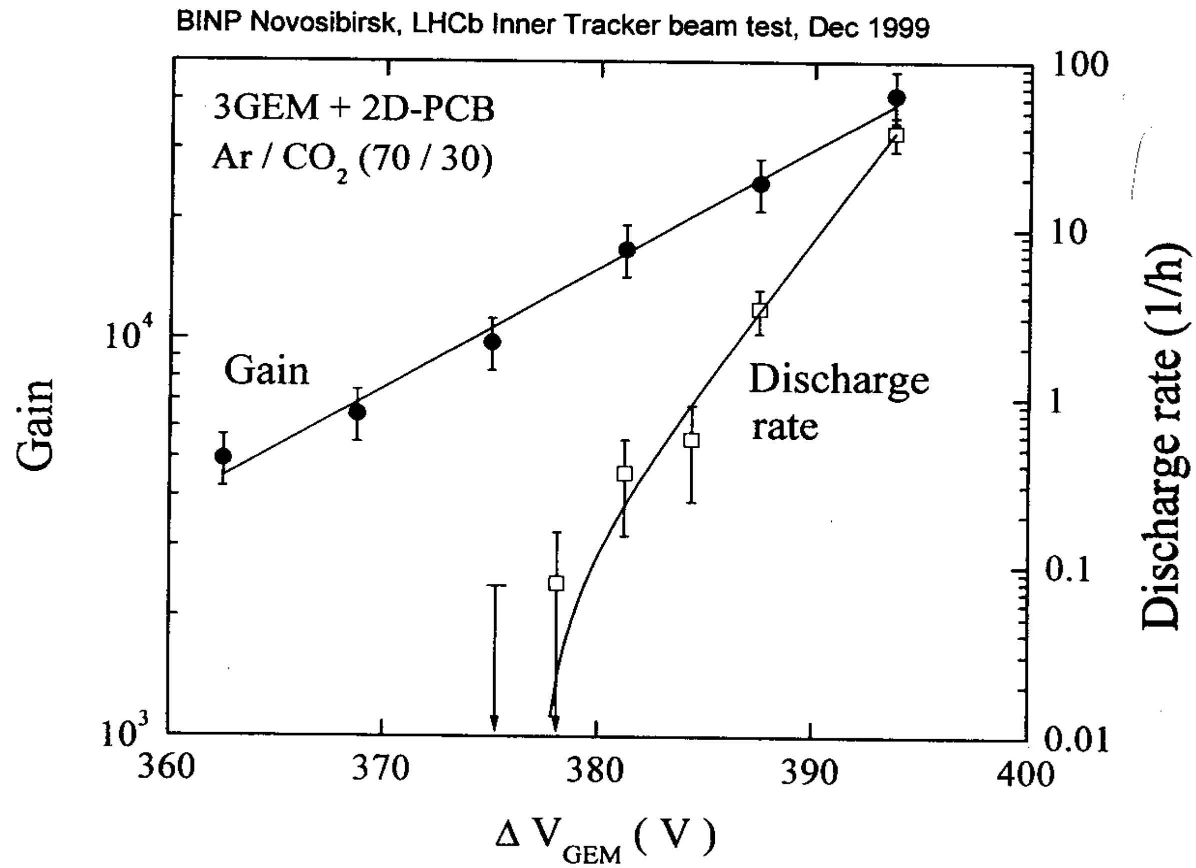
3GEM-PCB



Pitch - 200um
strip width - 80um (top)
140um (bottom)
signal ratio - 1.7 (top/bottom)
10*10 cm



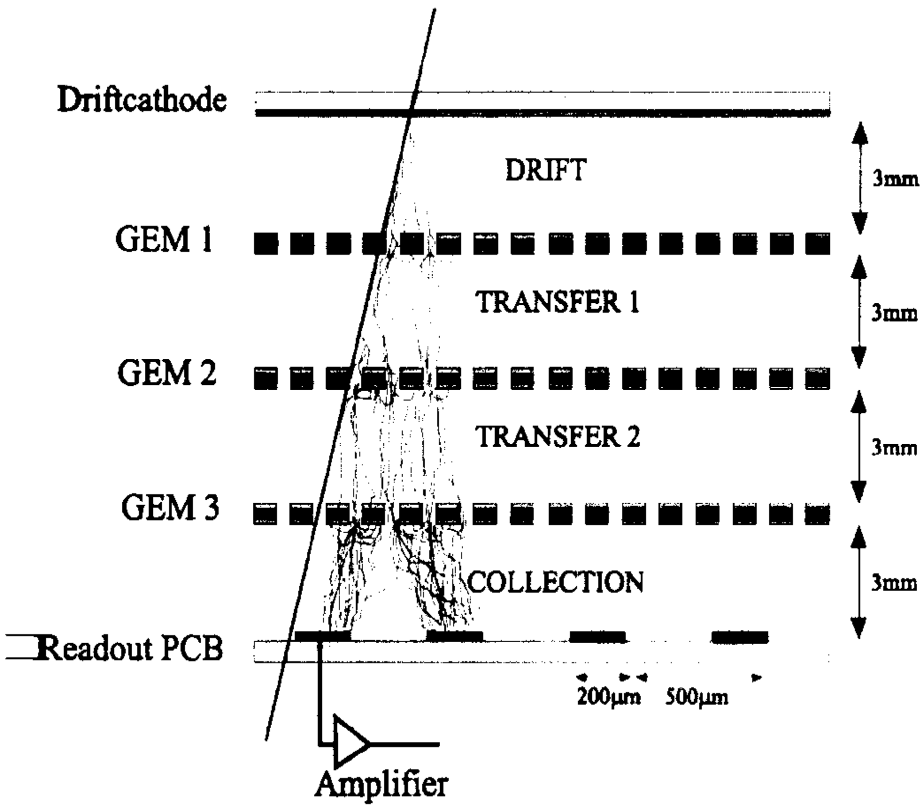
BINP Novosibirsk, LHCb Inner Tracker beam test, Dec 1999
ε (X)
ε (Y)
Discharge rate > 0.1/h
S/N (X)
S/N (Y)
3GEM + 2D-PCB
Ar / CO_2 (70 / 30)
Efficiency (%)
Signal / Noise
ΔV_{GEM} (V)
100
90
80
70
60
50
40
10
360
370
380
390
400



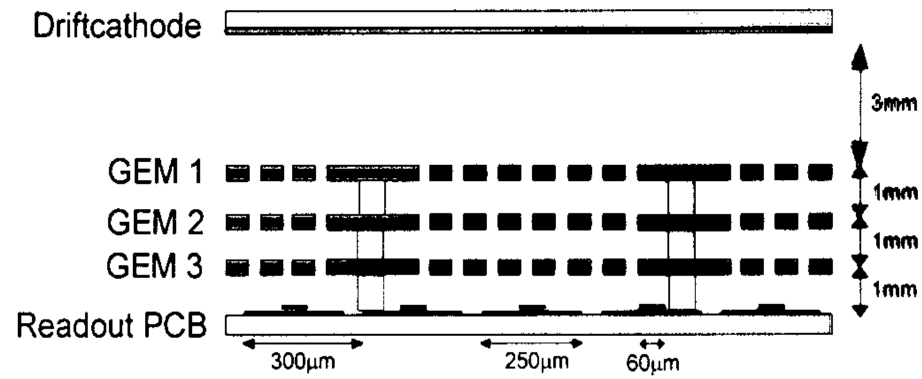
$(1/Q \leq 5 \times 10^{-12}/\pi)$

Testbeam results from a Triple-GEM with 2D-Readout

PSI Dez 99 (M. Ziegler, P. Sievers, U. Straumann)



1st prototype



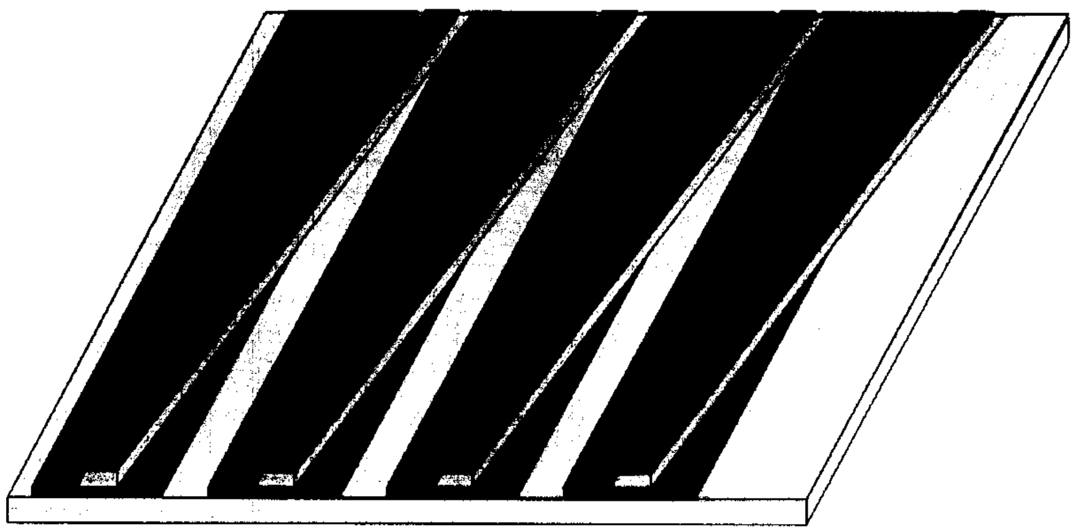
Improvements:

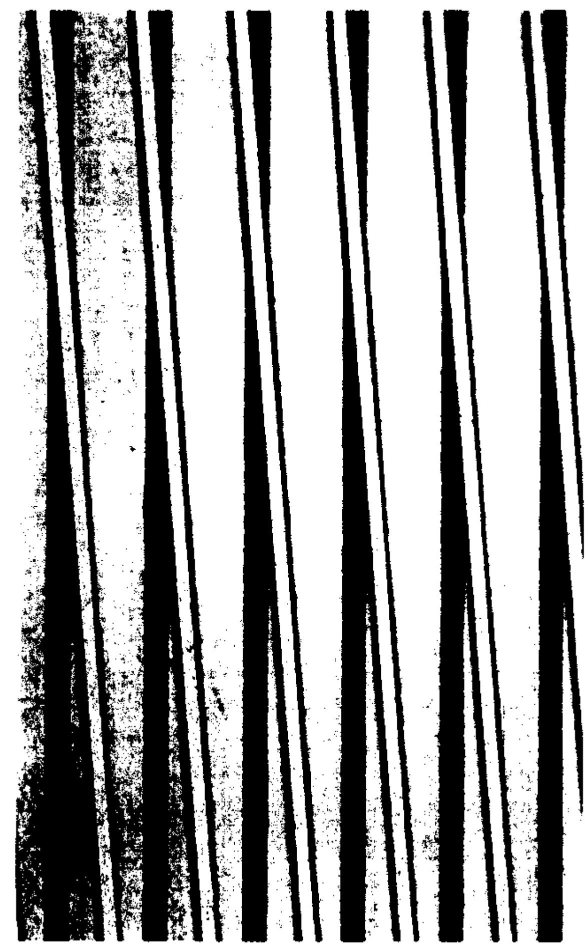
spacers on the GEM
segmentated GEM
2dimensional readout

2nd prototype

2 dimensional readout

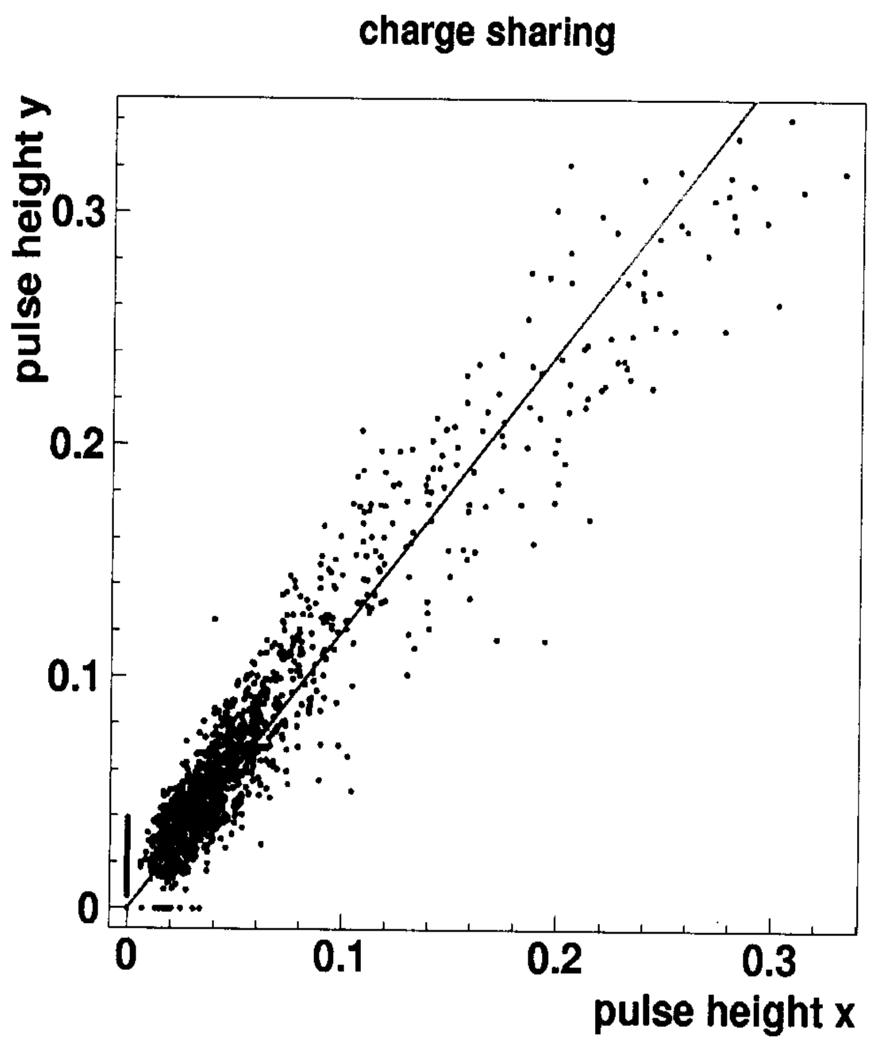
the readout PCB has two layers of strips, wich have an angle of 5°





pitch in each layer	300 μm
upper strips width	60 μm
lower strips width	250 μm

Carge sharing between upper and lower strips



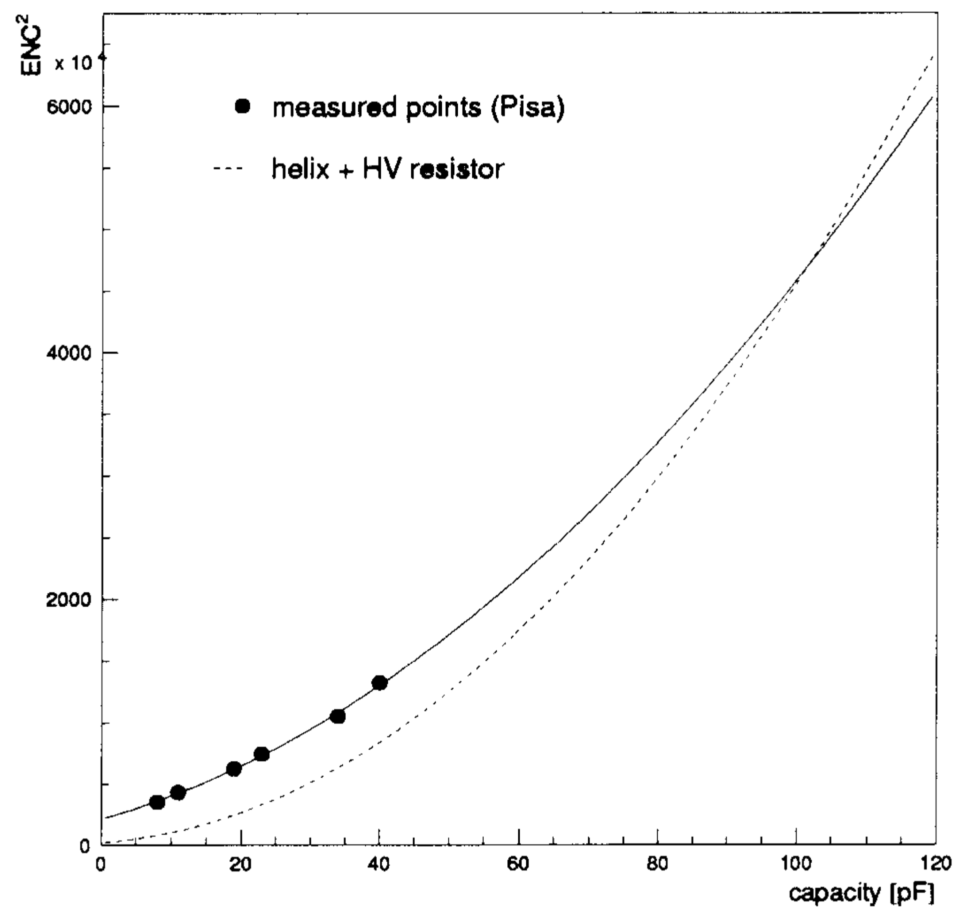
=> upper strips collect 1.25 times more charge than lower strips

Measurement of the strip capacity

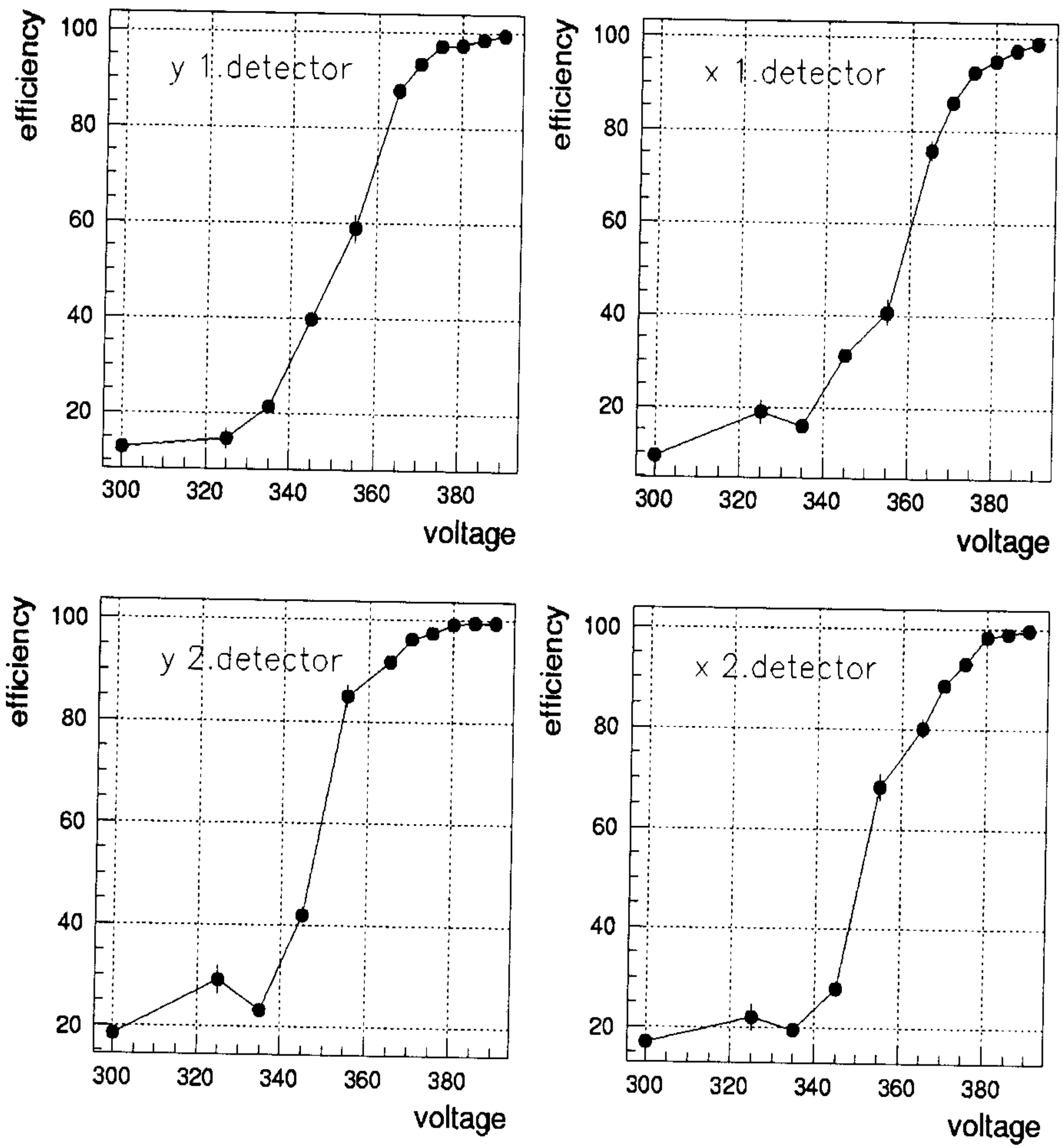
all neighbouring strips are connected to the amplifier

1. Capacity derived from pulse rise time => 86 pF

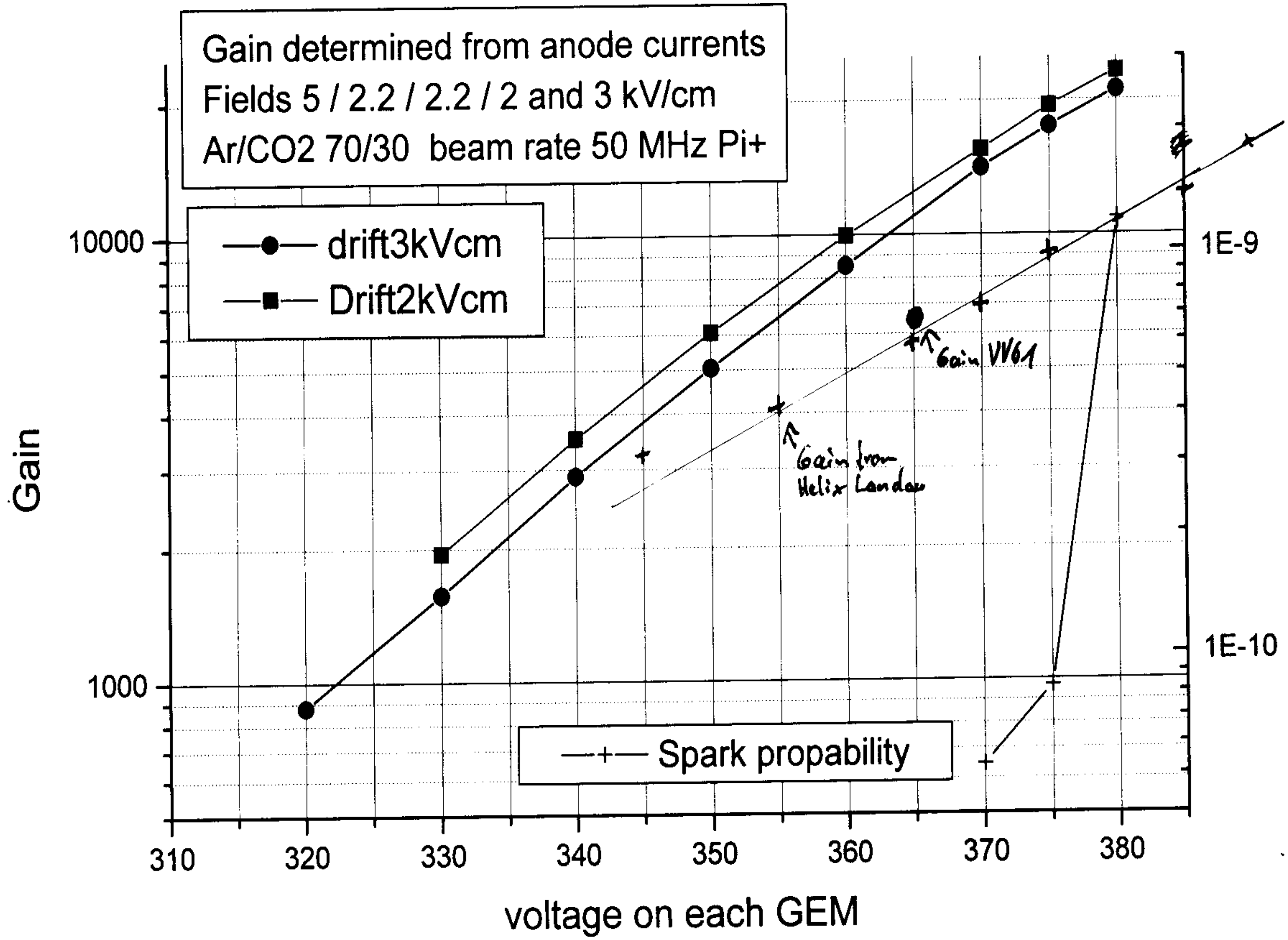
2. Capacity derived from 5 mV noise level => 100 pF



Efficiency



y 1.detector
x 1.detector
y 2.detector
x 2.detector
efficiency
voltage
100
80
60
40
20
300
320
340
360
380


Gain determined from anode currents
Fields 5 / 2.2 / 2.2 / 2 and 3 kV/cm
Ar/CO2 70/30 beam rate 50 MHz Pi+
drift3kVcm
Drift2kVcm
Spark propability
Gain VV61
Gain from Helix Landau
Gain
10000
1000
1E-9
1E-10
310
320
330
340
350
360
370
380
voltage on each GEM

Results from the Double GEM

S.Bachmann, A.Bressan, B.Ketzer,
L.Ropelewski, F.Sauli
CERN

E.Schulte
Helsinki Institute of Physics

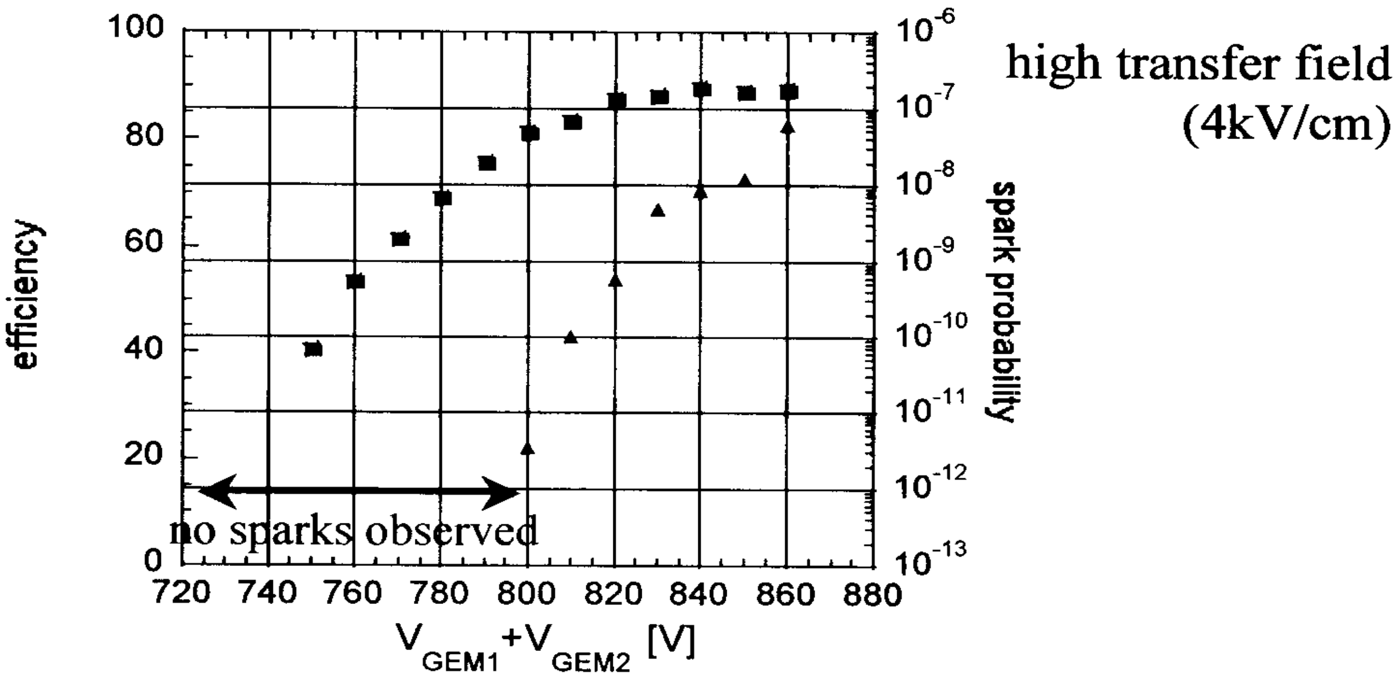
S.Keppler
University Karlsruhe

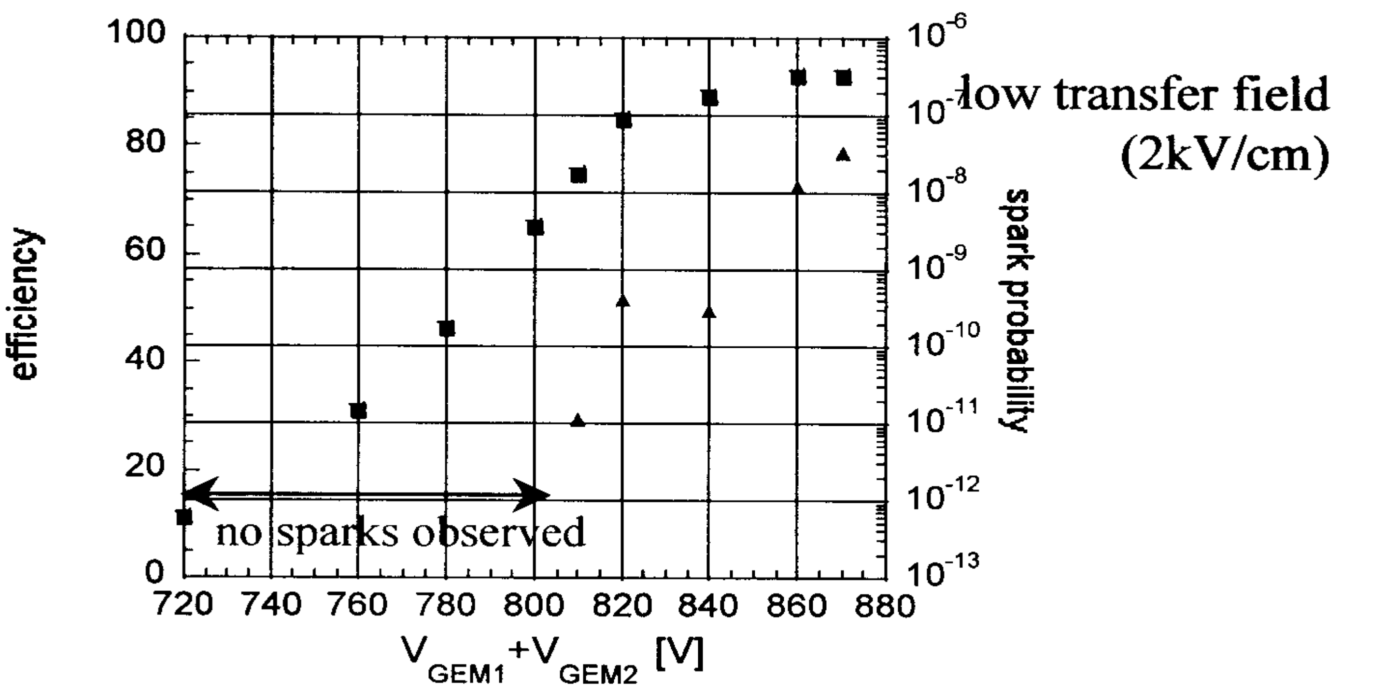
inner tracker meeting 23.2.2000
inner tracker meeting 23.2.2000

Construction of the Compass-prototype

- The construction procedure for the large size prototype has been optimized to allow the production of the Double GEM detectors for the COMPASS experiment
- 20 doubled sided modules will be built (4 until May '00, 10 until August '00, rest until April '01)
- In COMPASS the APV25 is used as readout chip (same characteristics as PreMux128, but with additional deconvolution-filter and buffer)

Results from the small chamber at PSI





Conclusion from measurements of the discharge rates:

We measured discharge rates of about $10^{-9\pm 1}$ sparks/hadron at the beginning of the efficiency plateau in different environments (M2 at CERN, mπ1 at PSI) using two different Double GEM detectors with 2 dim. readout.

- OK for COMPASS 2 dim readout (few sparks per hour for 10^6 particles per spill)
- Probably OK for 1dim. readout at LHC-B
- Not OK for 2 dim. readout at LHC-B (spark rate of $\simeq$0,1Hz for 10^4 Hz/mm^2)

Conclusions:

- we propose to concentrate on
  3GEM/2D-PCB (2GEM/1D-PCB)

- gas mixture need optimization
    - smaller cluster
    - higher discharge threshold

- noise optimization (with final electronics, with final geometry)

- tests of tracking properties at x7 (efficiency vs gain, S/N; spatial resolution;

- survivability at PSI with optimized noise and gas.

Further plans

-Try to reduce the cpapacity of 86 pF
  is it better to use 125 μm Kapton instead of 50 μm
  what is the thinest save strip width
  => Simmulation required to find the optimum

- Reduce radiation length
  5 μm copper on each GEM side is possible
  can GEMs with aluminium clad Kapton be produced

- Mecanical problems to be solved
  Test with XL GEMs of (30 cm x 60 cm)
  Mechanical stability, frames, support structure,
  Glueing procedure

- Aging test

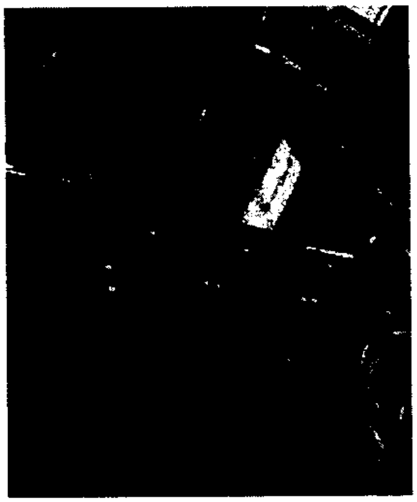
- Test with final readout electronic

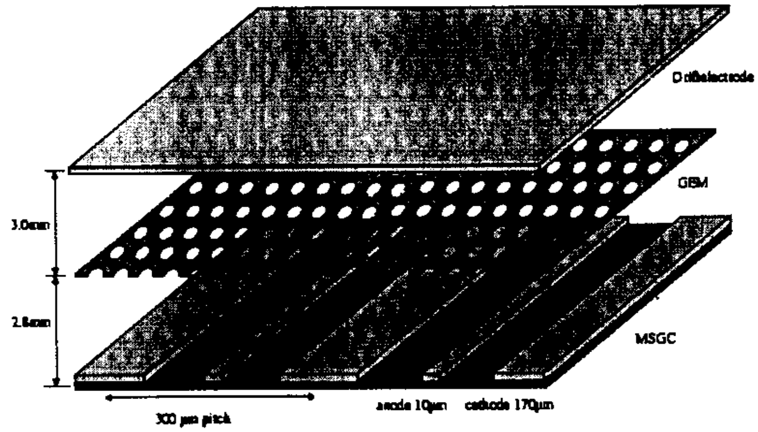
Possible improvements:

1. Use 1dim readout…
2. Choice of gas (see next transparencies)
3. Try optimization of GEM production (e.g. second etching)
4. Increase of drift gap (higher number of primaries, more diffusion, but worse time resolution, larger cluster widths)
5. Adapt strip pitch to cluster width (to reduce cluster noise)
6. Careful optimization of readout electronics for high input capacity possible?
7. Go to Triple GEM?

The HERA–B Inner Tracker

MSGC–GEM





– particle flux : ~ 10^4 mips / mm^2s

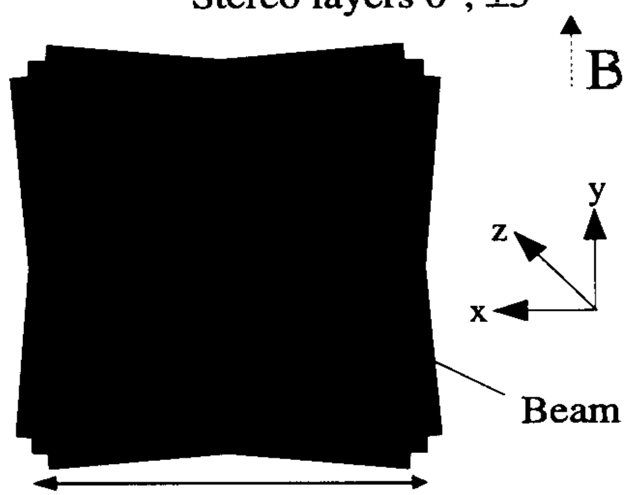
– radiation dose : ~ 1Mrad / year

Stereo layers 0°, ±5°

angular coverage : 10 – 100 mrad

4 chambers per plane

resolution : < 100 μm (x)
< 1 mm (y)



Torsten Zeuner, 22.02.00
zeuner@elfi1.physik.uni–siegen.de

Detector status of installed MSGC-GEM

(status 02/00)

out of 120 installed detectors

- ~ 20 are still in training phase
- ~ 10 show HV problems (frequent GEM sparks, high drift currents) -> need further training
- all other detectors have been trained and were operated (up to max. 200h at 8-10 MHz, few short rate scans -> 40 MHz)
- 20 detectors have cathode shorts (mostly 1 short/chamber) half of these shorts occured during HV test before installation (2 shorts disappeared during operation)
  -> these chambers can be normally operated!
- 2 GEM shorts (1 during operation, 1 during tests) in addition 2 chambers with GEM shorts have been exchanged (1 GEM short has been removed, probably another GEM short can be removed)
- 5 chambers gathered more (3-5) cathode shorts and are disconnected.

Most of the HV problems (GEM shorts, cathode shorts) appeared during training or first hours of operation
(-> Hope: chambers reach stable operation after training phase)

But: accumulated run time up to now is not ~~sufficient~~ to guaranty that long term behaviour is ~~stable~~!

How harmful are sparks to GEM or electronics -I-

A. The GEM foils:

During 2 weeks at PSI and 4 weeks at M2 and extensive discharge measurements we did not loose a GEM or a segment of a GEM.
The total GEM surface irradiate was about 0.2m.

LHCb WEEK
CERN, 21/25-02-00

INNER TRACKER SILICON MEETING
22-02-2000, 2:00 pm

INTRODUCTION	(OLAF)
CMS SILICON STRIP DETECTOR	(M.MANNELLI)
ATLAS SEMICONDUCTOR TRACKER	(G.LUTZ)
HERA-B VERTEX DETECTOR	(M.SCHMELLING)
LHCb VERTEX DETECTOR	(T.BOWCOCK)
"CONCEPTUAL DESIGN"	(R.FREI)
RADIATION ENVIRONMENT	(V.TALANOV)

WHICH TECHNOLOGY ?

DOUBLE SIDED	+ MATERIAL BUDGET + CHARGE CORRELATION	– HANDLING – NEED FULL DEPLETION FOR GOOD EFFICIENCY – HV ON STRIPS
N ON N	+ GOOD EFFICIENCY IF NOT FULLY DEPLETED	– MORE EXPENSIVE
P ON N	+ CHEAP + ADOPTED BY CMS/ATLAS	– NEED FULL DEPLETION FOR GOOD EFFICIENCY

MATERIAL BUDGET GAS OPTION (PER COORDINATE):

$0.55\% \ X_0$ SENSITIVE AREA
$1\% \ X_0$ FRAMES
} FROM LHCb T.P.

(COMPARE: $300 \mu m$ SILICON $\hat{=} \ 0.28\% X_0$)

PITCH ?

- 250 μm OK FOR RESOLUTION / OCCUPANCY
- >250 POSSIBLE WITHOUT EFFICIENCY LOSS ?
- OPTIMIZE W/P FOR CAPACITANCE / EFFICIENCY / H

INTERMEDIATE STRIPS ?

+ BETTER RESOLUTION (NOT NEEDED)
- SIGNAL LOSS

  ⇒ PROBABLY NOT ...

STRIP LENGTH ?

- 20 CM WOULD BE NICE (LAYOUT, # R/O CHANNELS
- LIMITED BY CAPACITANCE (1.2-1.5 pF/cm ?)
  - → SIGNAL SHAPE OK FOR ≤ 20 pF
  - → SIGNAL / NOISE: 300 e⁻ + 33 e⁻/pF

  } BEETLE CHIP (2/2000)
- DEPENDS ON RADIATION DOSE / TECHNOLOGY

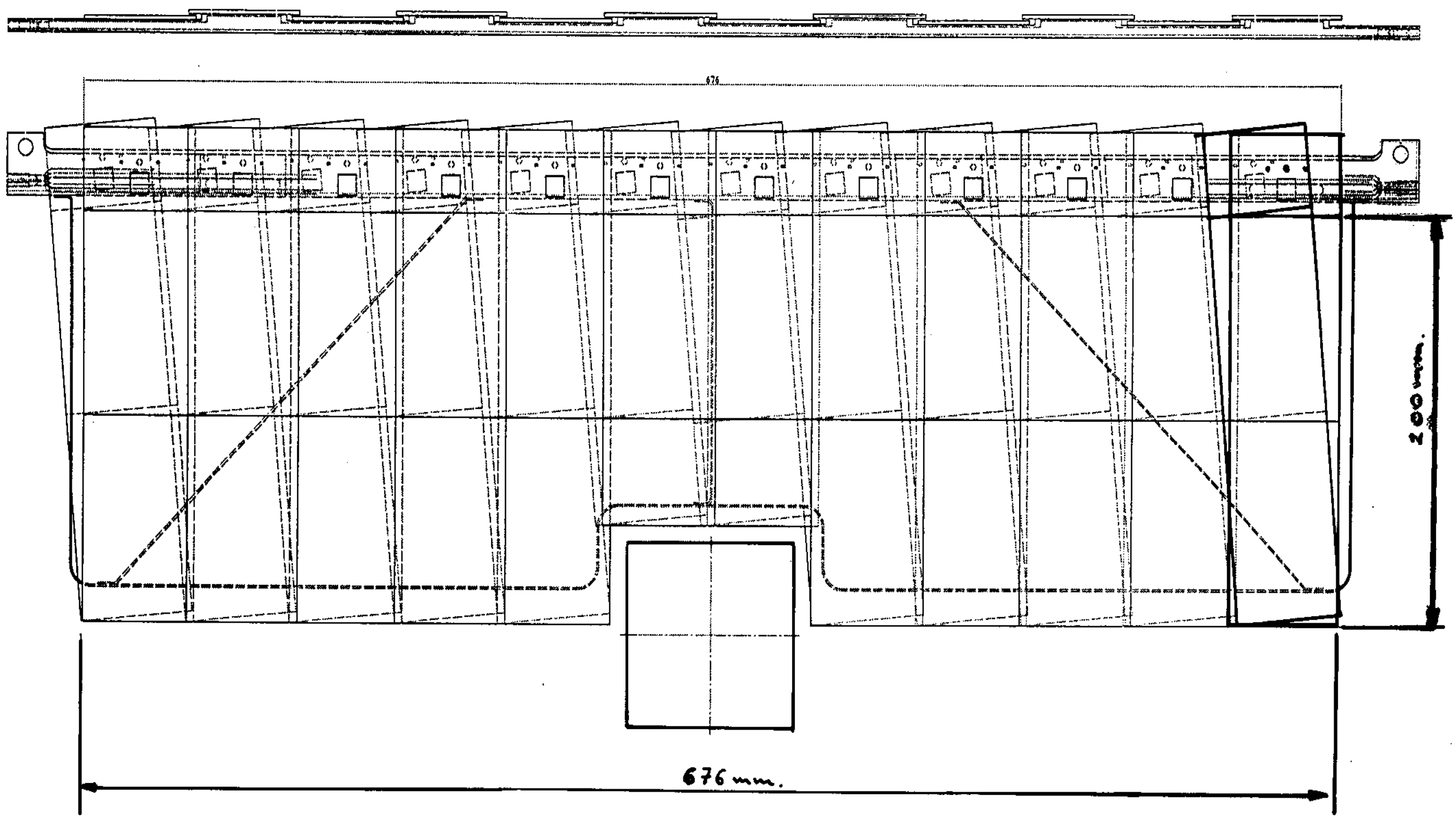
THICKNESS ?

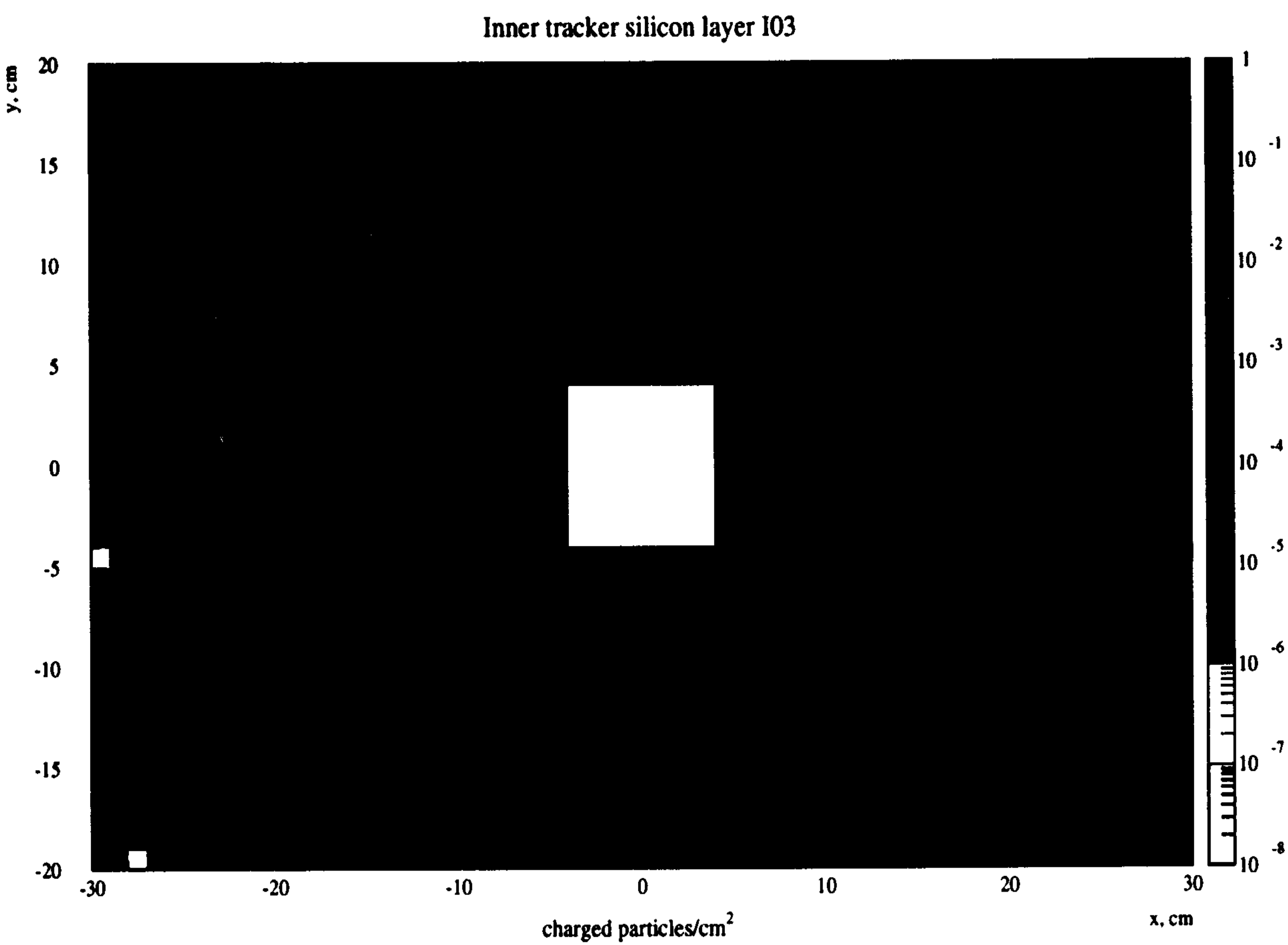
- 300 μm DEFAULT ?
- THICKER GIVES BETTER EFFICIENCY, CAN SAVE DETECTION LAYERS (3 STEREO VIEWS) ?

COOLING :

- CRUCIAL FOR EXPECTED RADIATION DOSES
- MATERIAL BUDGET NEEDS OPTIMIZATION.

support + 2 silicon layers.




Inner tracker silicon layer I03
y, cm
20
15
10
5
0
-5
-10
-15
-20
-30
-20
-10
0
10
20
30
x, cm
charged particles/cm^2
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}

Primary particles contribution

Minimal expected rate!

Simulation done without material of beam pipe and IT (no source of secondaries along beam line)

Estimated flux:

Mostly (99%) charged hadrons (no electrons)

Calculation gives (in maximum for inner tracker 03) (using the safety factor 3 [CMS] ... 5 [ATLAS]):

$3\times10^{-2} \times 1.3 \times 1.6\times10^{7} \times 3 \ldots 5 =$

$\approx \mathbf{2 \ldots 3 \times 10^{6}}$ **charged particles/cm^2/s**

Total charged particles flux

Material of the beam pipe and IT taken into account

Pratically all the increase is due to the electrons:

the flux consists of 10% charged hadrons and 90% electrons

Calculation gives (in maximum for inner tracker 03):

$3\times10^{-1} \times 1.3 \times 1.6\times10^{7} \times 3 \ldots 5 =$

$\approx \mathbf{2 \ldots 3 \times 10^{7}}$ **charged particles/cm^2/s**

CONCLUSIONS

GAS OPTION:

* AGREED ON <u>ONE</u> GAS TECHNOLOGY

  TRIPLE-GEM WITH 2D READOUT

* DISTRIBUTION OF RESPONSIBILITIES

  LAUSANNE / NOVOSIBIRSK / ZÜRICH
  (SANTIAGO WILL JOIN SILICON GROUP)

SILICON OPTION:

* STUDY GROUP GETTING STARTED

  HEIDELBERG / LAUSANNE / SANTIAGO / ZÜRICH

* NEED TO BUILD UP EXPERIENCE / INFRASTRUCTURE

  CONTACTS TO EXPERTS

* DEFINE REQUIREMENTS

  RADIATION DOSE / TRACKING / F/E ELECTRONICS

INNER TRACKER IN LHCb:

* REPRESENTATION IN TRACKING GROUP

  F. RONGA (LAUSANNE) + STUDENT FROM NOVOSIBIRSK

* INFRASTRUCTURE / SUPPORTS / FRAMES...

  LAUSANNE