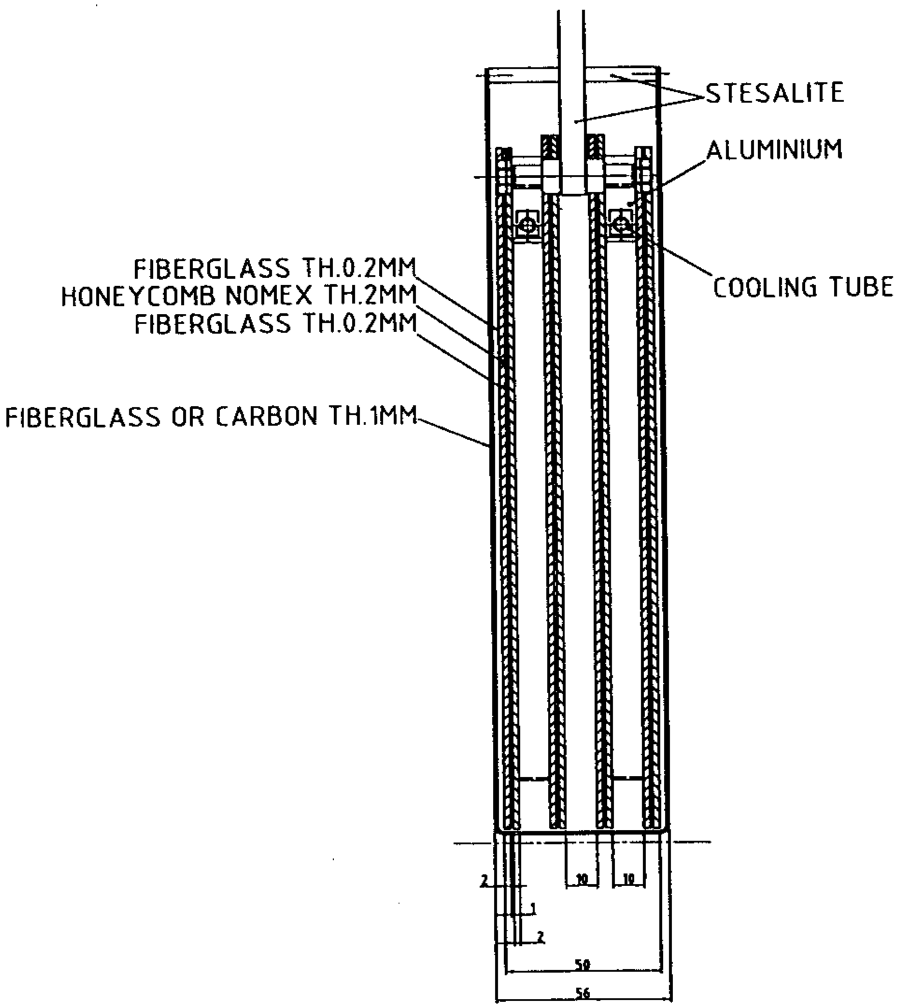
O. STEINKAMP
LHCb WEEK
CERN, 26-05-00

INNER TRACKER SUMMARY

- SIMULATION:
  - RADIATION ENVIRONMENT
  - DIGITIZATION / TRACKING
- 3GEM OPTION:
  - INVESTIGATION OF SPARKING BEHAVIOUR
  - DETECTOR OPTIMIZATION
- SILICON OPTION:
  - STATION LAYOUT
  - DETECTOR SPECIFICATIONS
  - MANUFACTURERS

V. Talanov
→ LHCb Note 2000-013



INNER TRACKER SILICON STATION

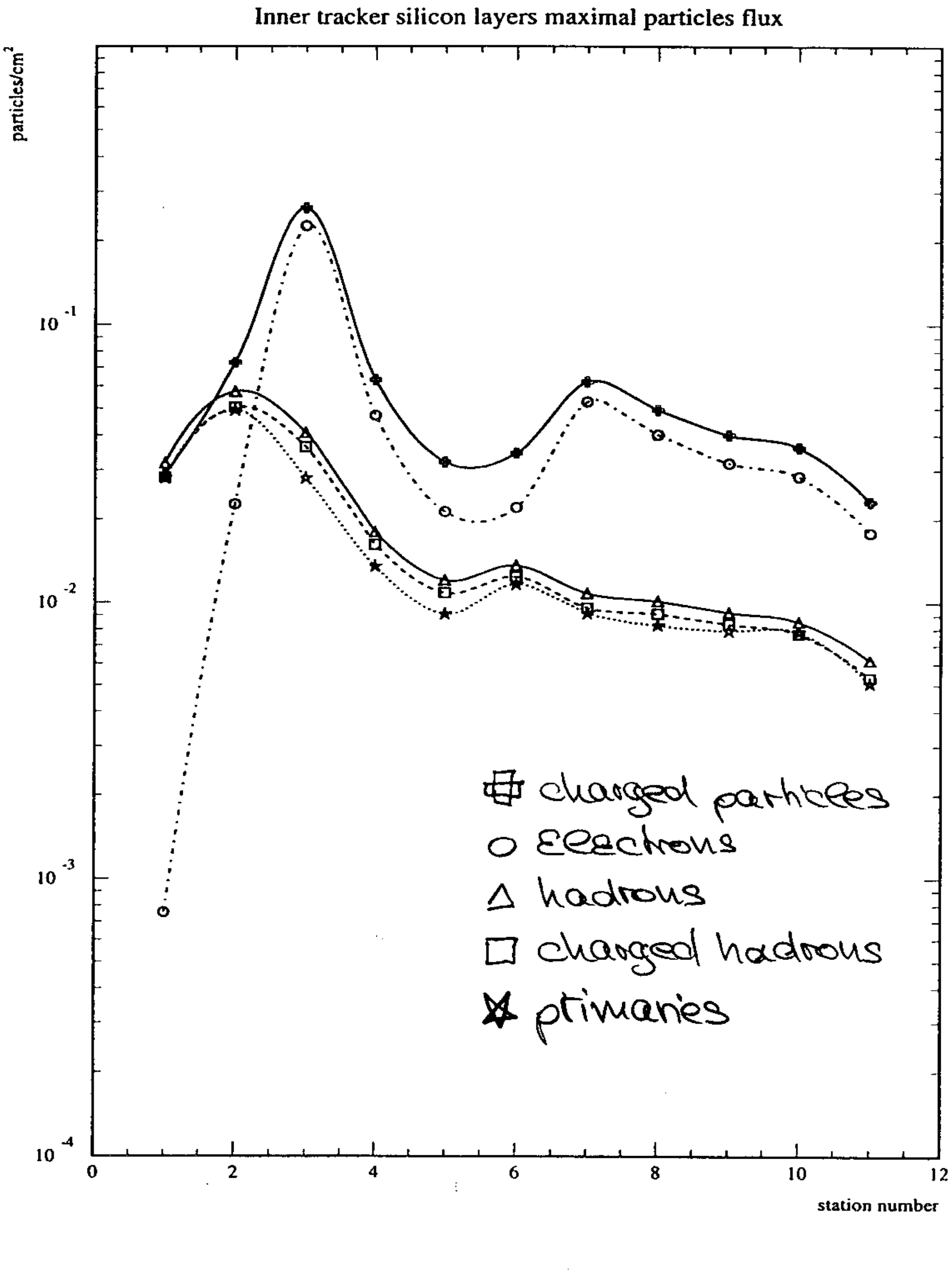
DETECTOR MODEL:

- 4 LAYER SILICON, 300 μm
- SUPPORTS
- FRAMES
- COOLING PIPES

SUMMARY

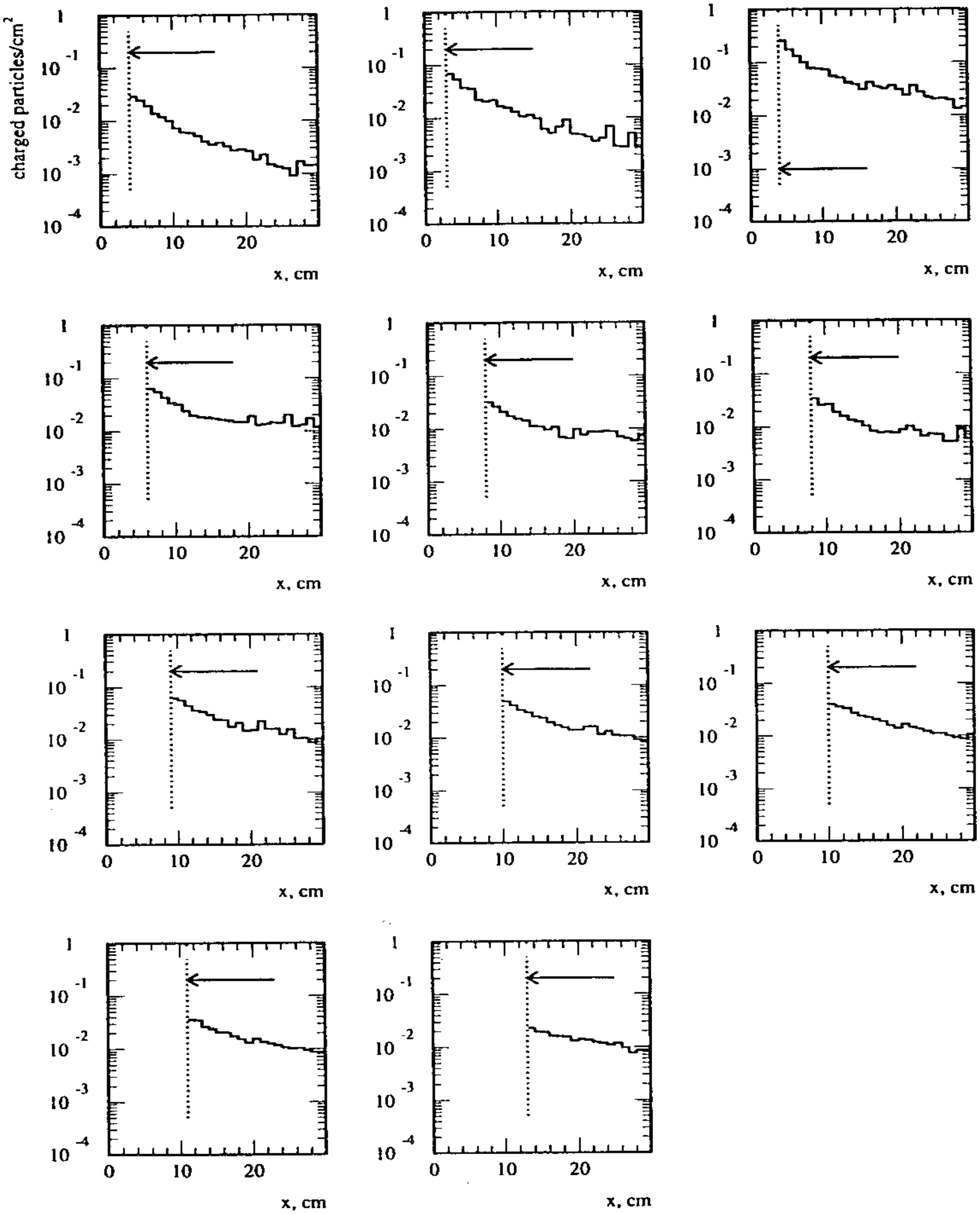
Value of	**per 1 int.**	**at 16 MHz**
charged hadrons ($\simeq$ primary charged)	5×10^{-2}	8×10^{5} /cm²/s
charged particles (charged hadrons + e)	3×10^{-1}	4.8×10^{6} /cm²/s
cumulatives		
charged hadrons	$\approx$10	1.6×10^{8} /station/
charged hadrons + e	$\approx$100	1.6×10^{9} /station/
dose level (per year)		
station 03	$\approx 10^{-8}$	1.6 Mrad /year
station 07	2×10^{-9}	320 krad /year
chip location	$\approx 10^{-9}$	160 krad /year

1 MeV-equivalent neutrons: $\sim 5\times10^{13}$/cm²/10y



Inner tracker silicon layers maximal particles flux
particles/cm^2
10 $^{-1}$
10 $^{-2}$
10 $^{-3}$
10 $^{-4}$
0
2
4
6
8
10
12
station number
⊞ charged particles
○ Electrons
△ hadrons
□ charged hadrons
✯ primaries

Inner tracker silicon layers charged particles flux



CONCLUSION :

- With the data provided by Vadim Talanov, we estimated the probability to have 2 or more particles in a strip
  (200 μm x 20cm) :
  - in the case of the maximum flux (tracker 03)
  - taking into account the probability to have several interactions in a bunch.

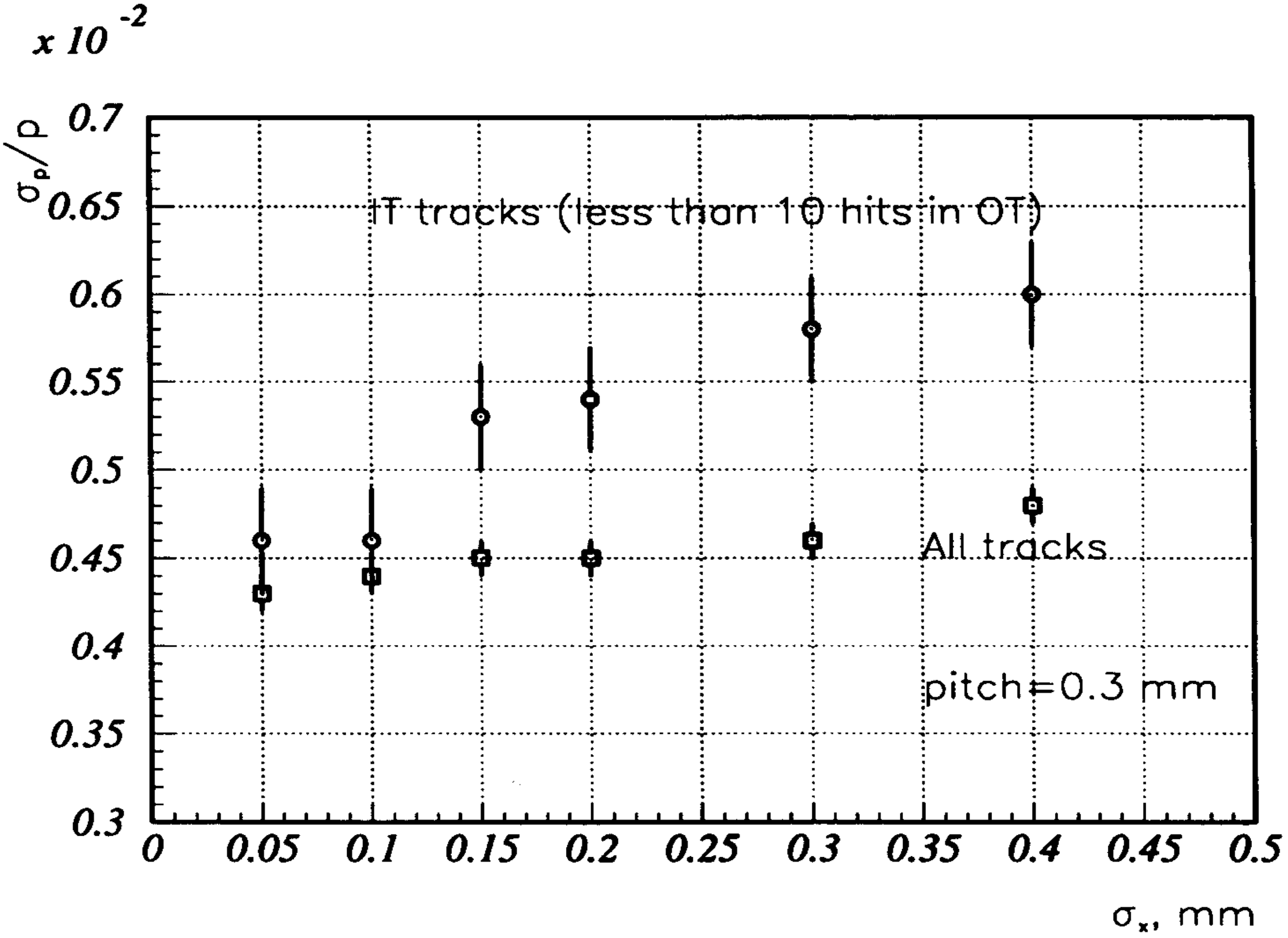
→

$P_{Cor}(N \geq 2) = 1.28\ 10^{-3}$ acceptable

- We have tried to define a geometry

  But we still have to think about
  - the transition to the outer tracker (T2, T10,T11)
  - where to put the electronic
  - test the cooling system and change it if needed, ...
  - ...

SPATIAL RESOLUTION



A. Poloueltov / F. RONGA
using "TrackingTest"

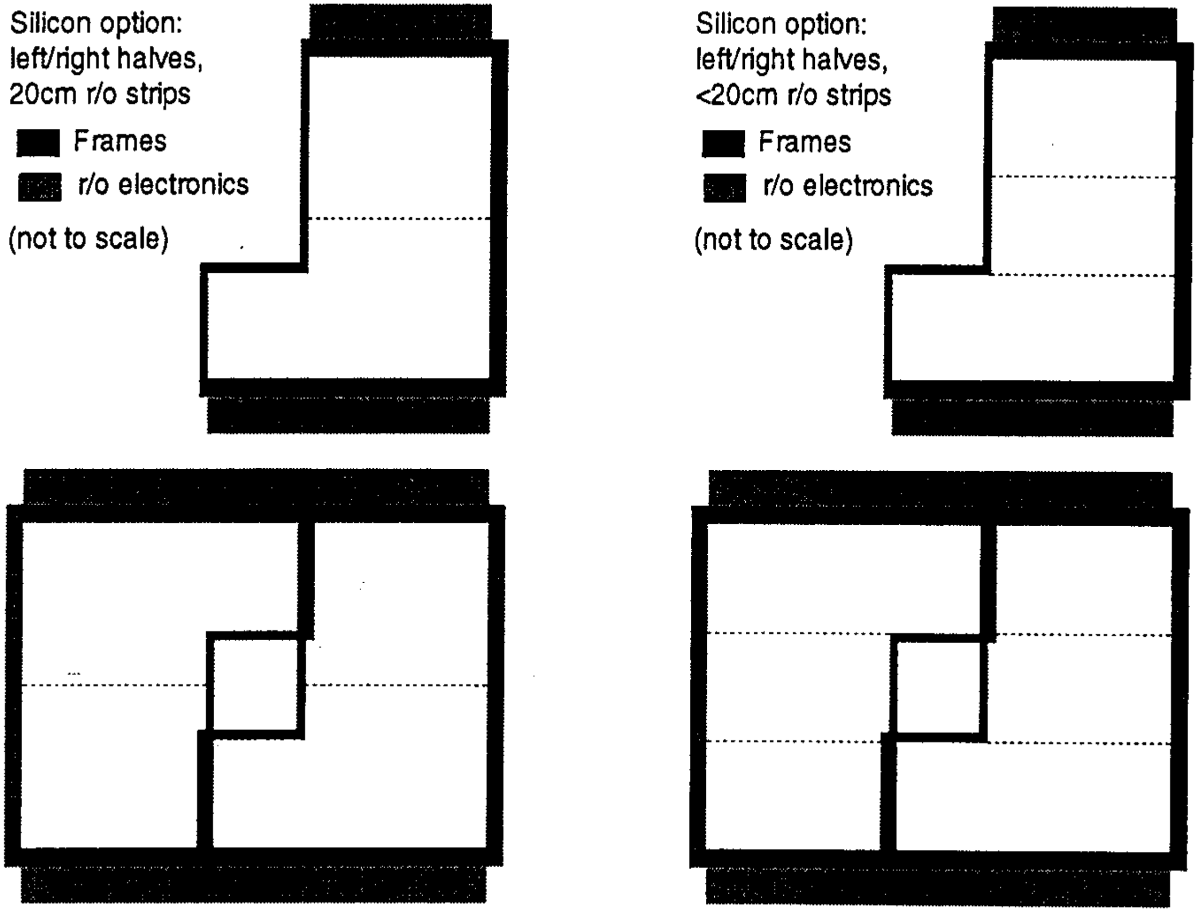


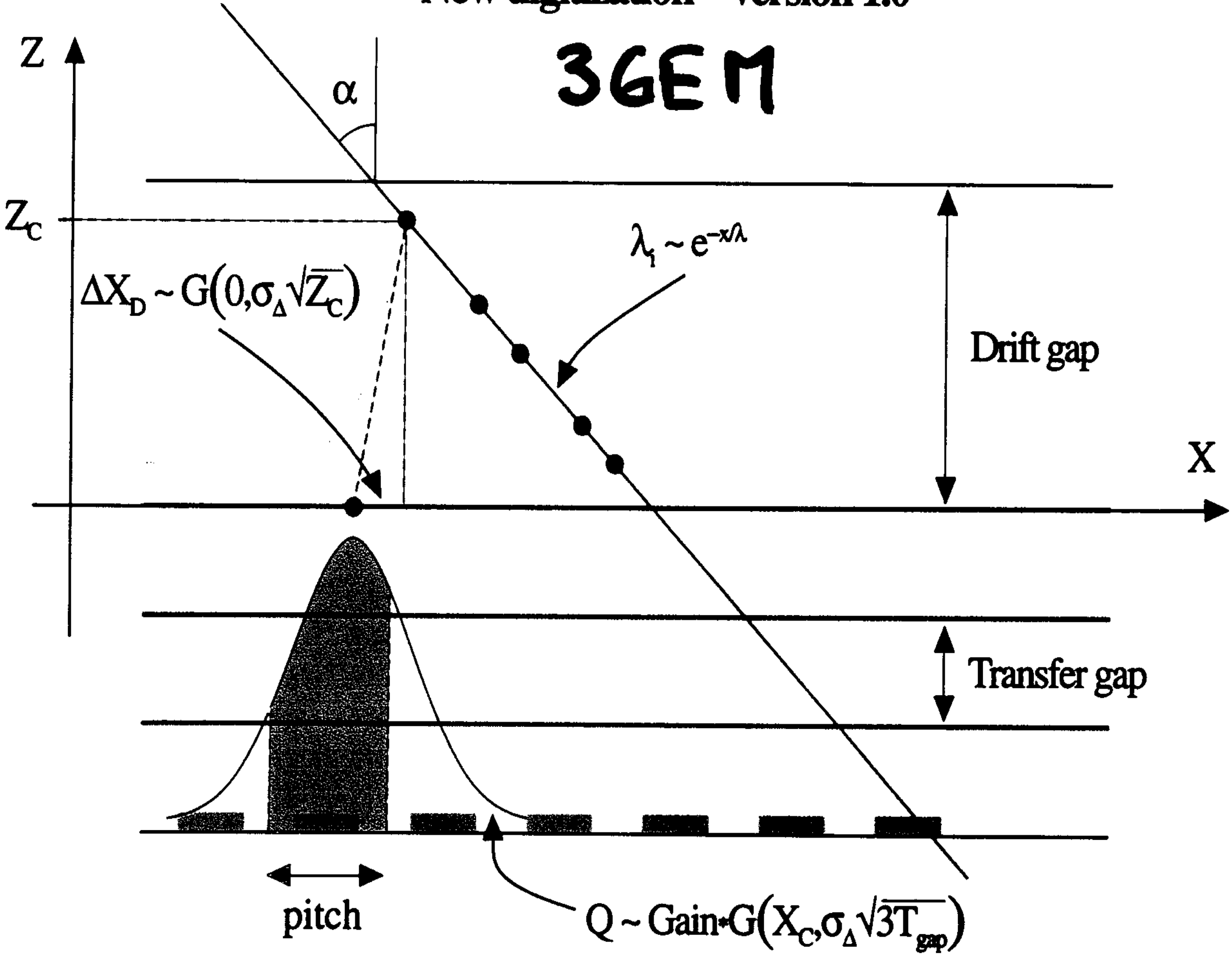
Figure 4: Possible layout of Silicon detector with left/right half-stations: sketch on left assumes two vertical r/o sectors (the preferred solution), sketch on right with three vertical r/o sectors (necessary if r/o strips cannot be made long enough due to S/N limitation)

PREFERED

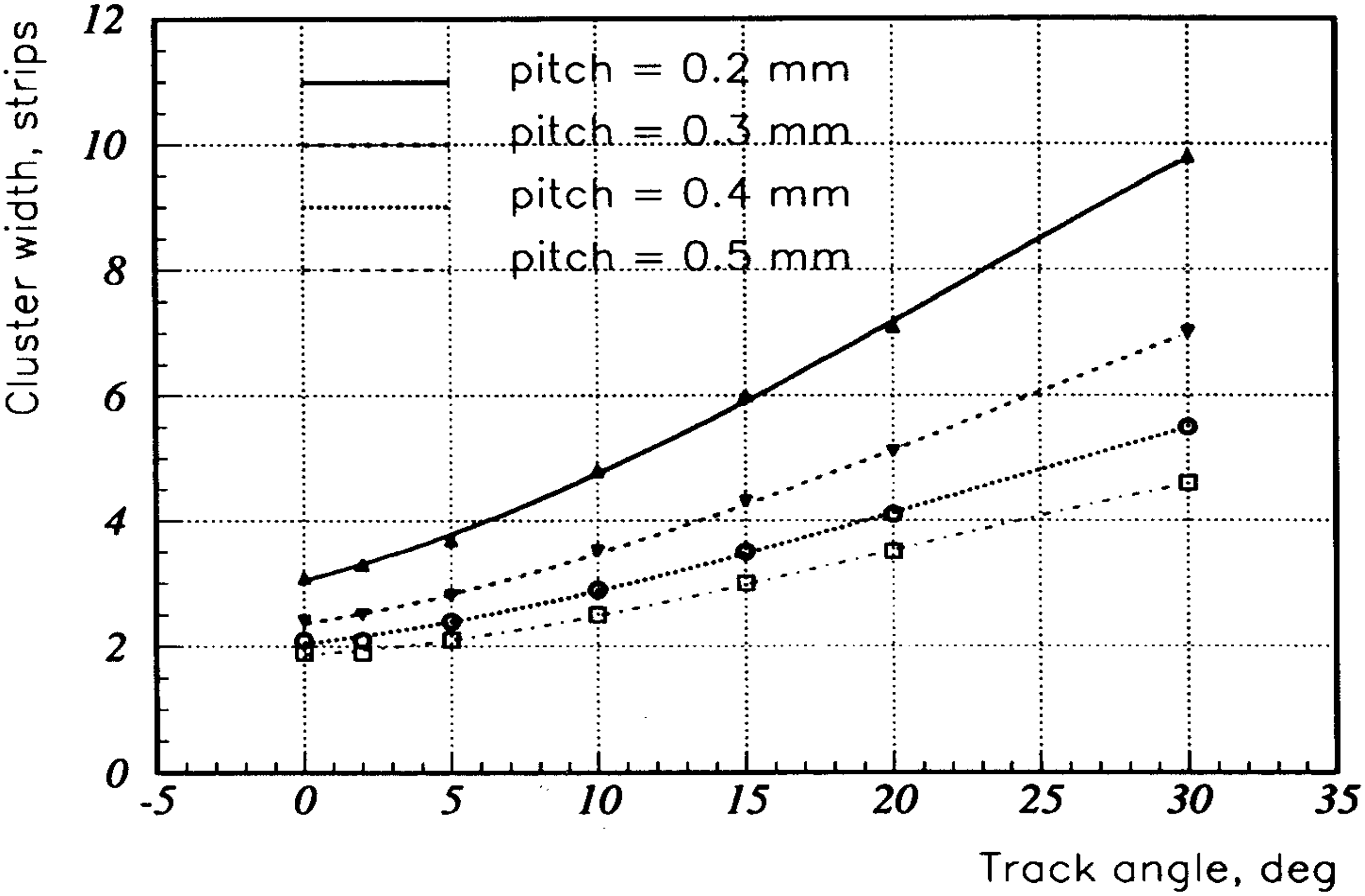
⇒ FRAMES OUT OF MAX. FLUX
⇒ FIXATION TO OTR HALF-STATIONS
⇒ 3GEM OPTION

New digitization – version 1.0

3GEM



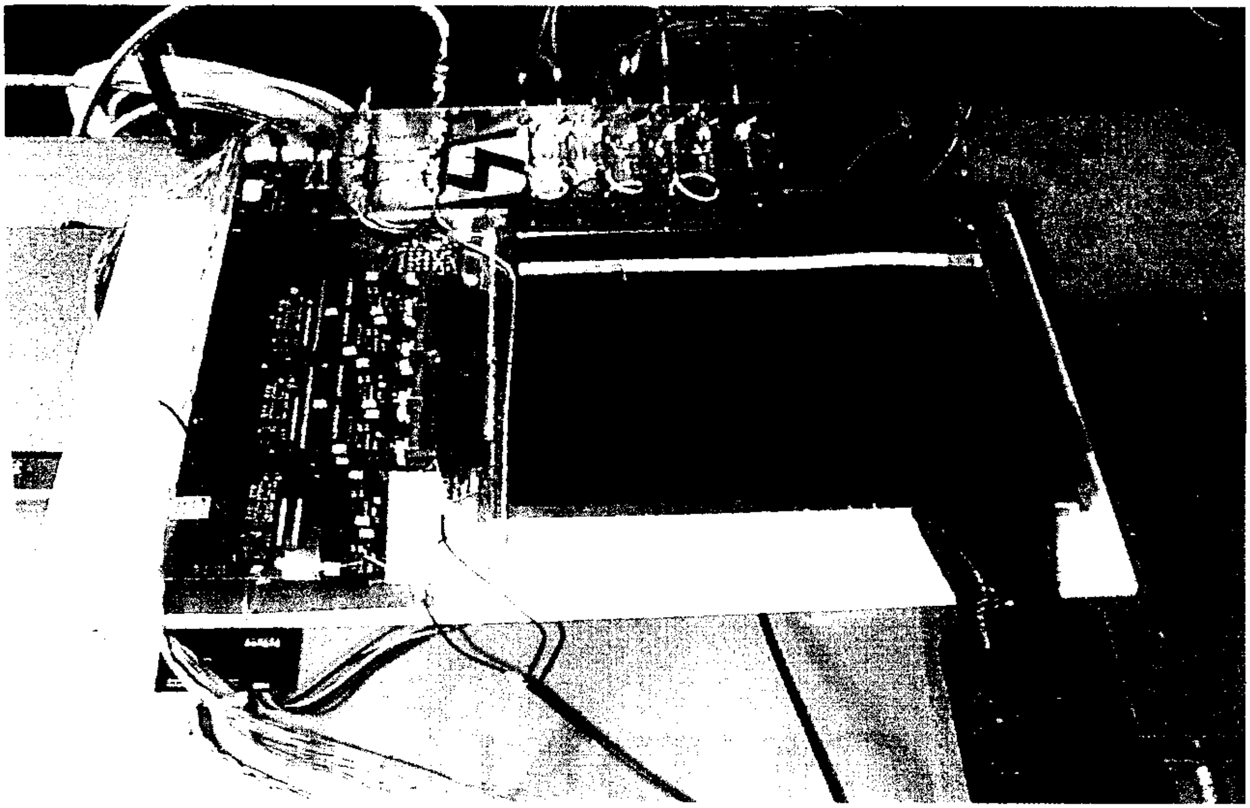
CLUSTER WIDTH



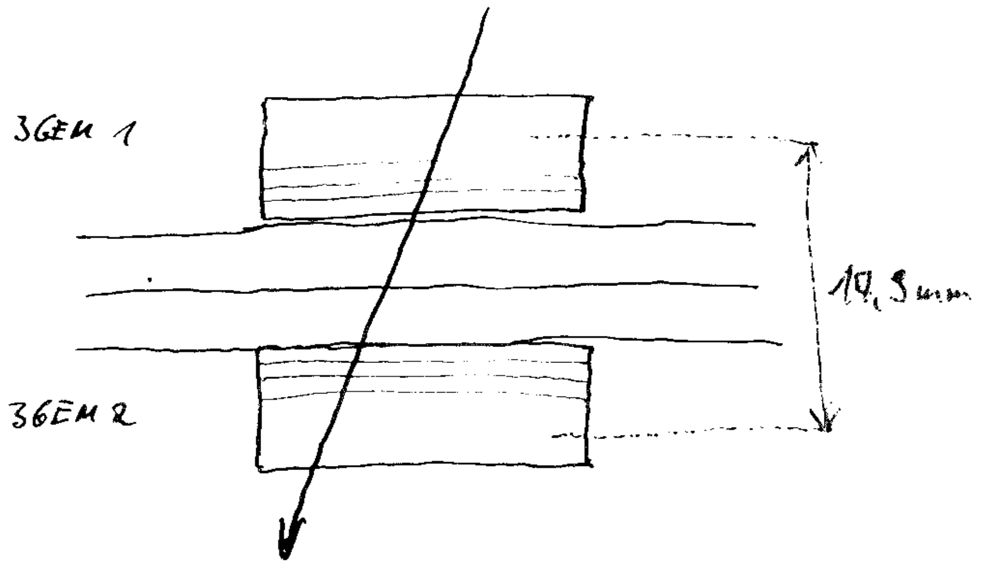
Need interaction with hardware IT group to tune settings

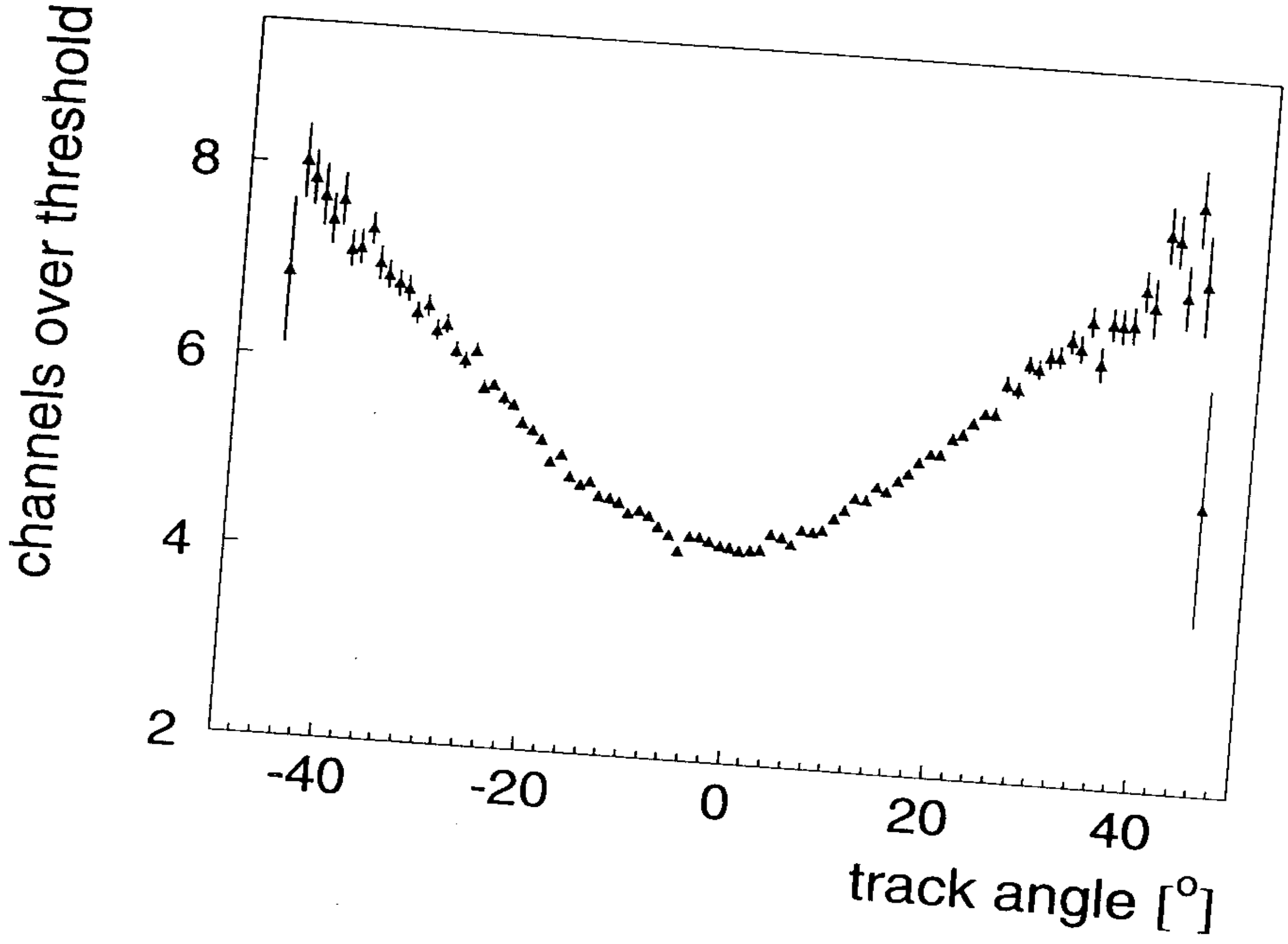
3GEM

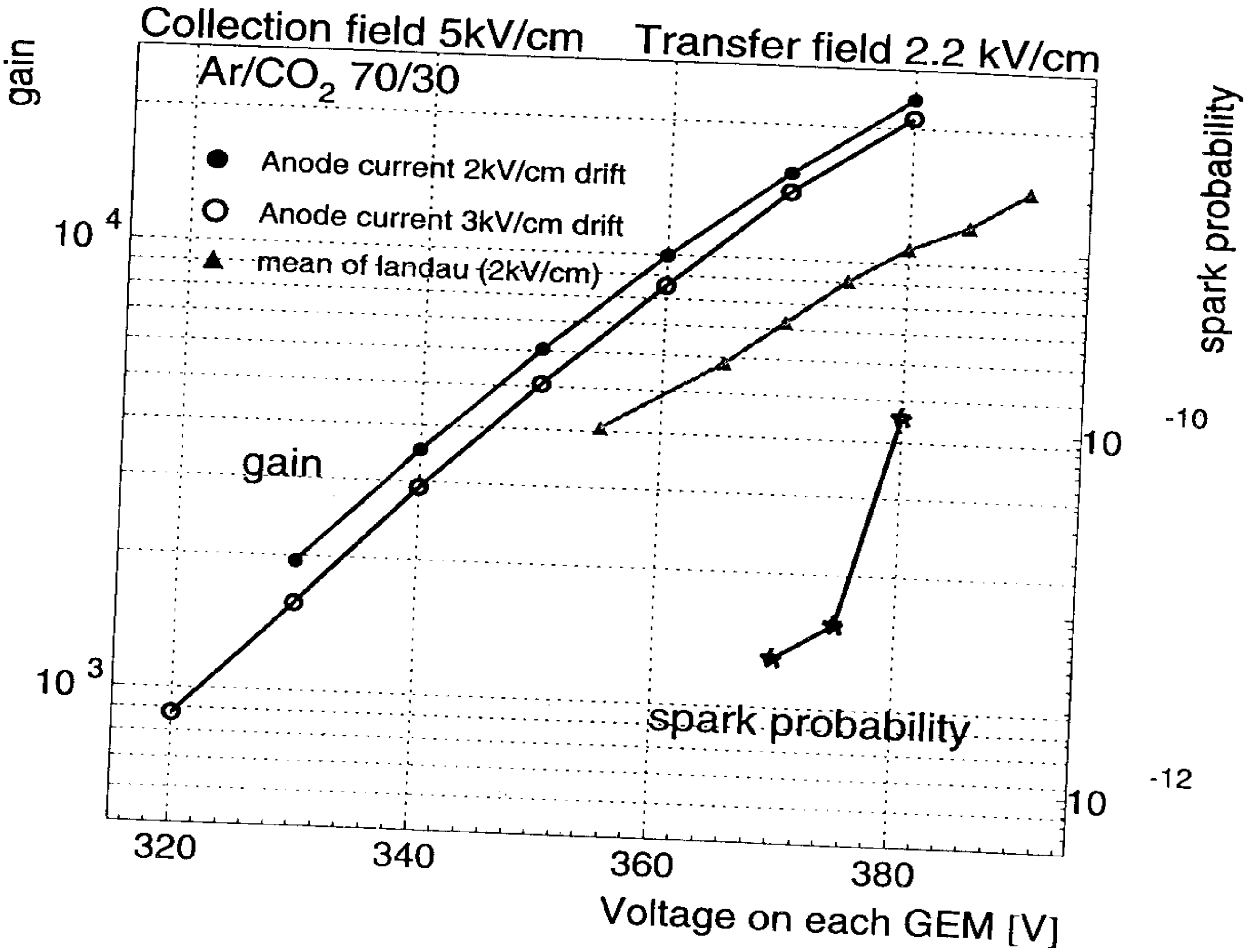
Cosmics setup



two 10cm x 10cm scintillators




channels over threshold
8
6
4
2
-40
-20
0
20
40
track angle [°]



PSI test / "Zürich" 3GEM

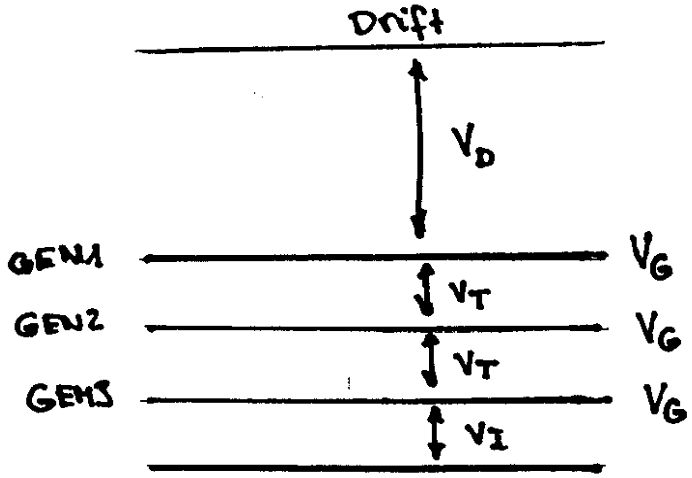
SPARK PROBABILITY 1 ORDER OF MAGNITUDE SMALLER THAN PRESENTED IN FEBRUARY!

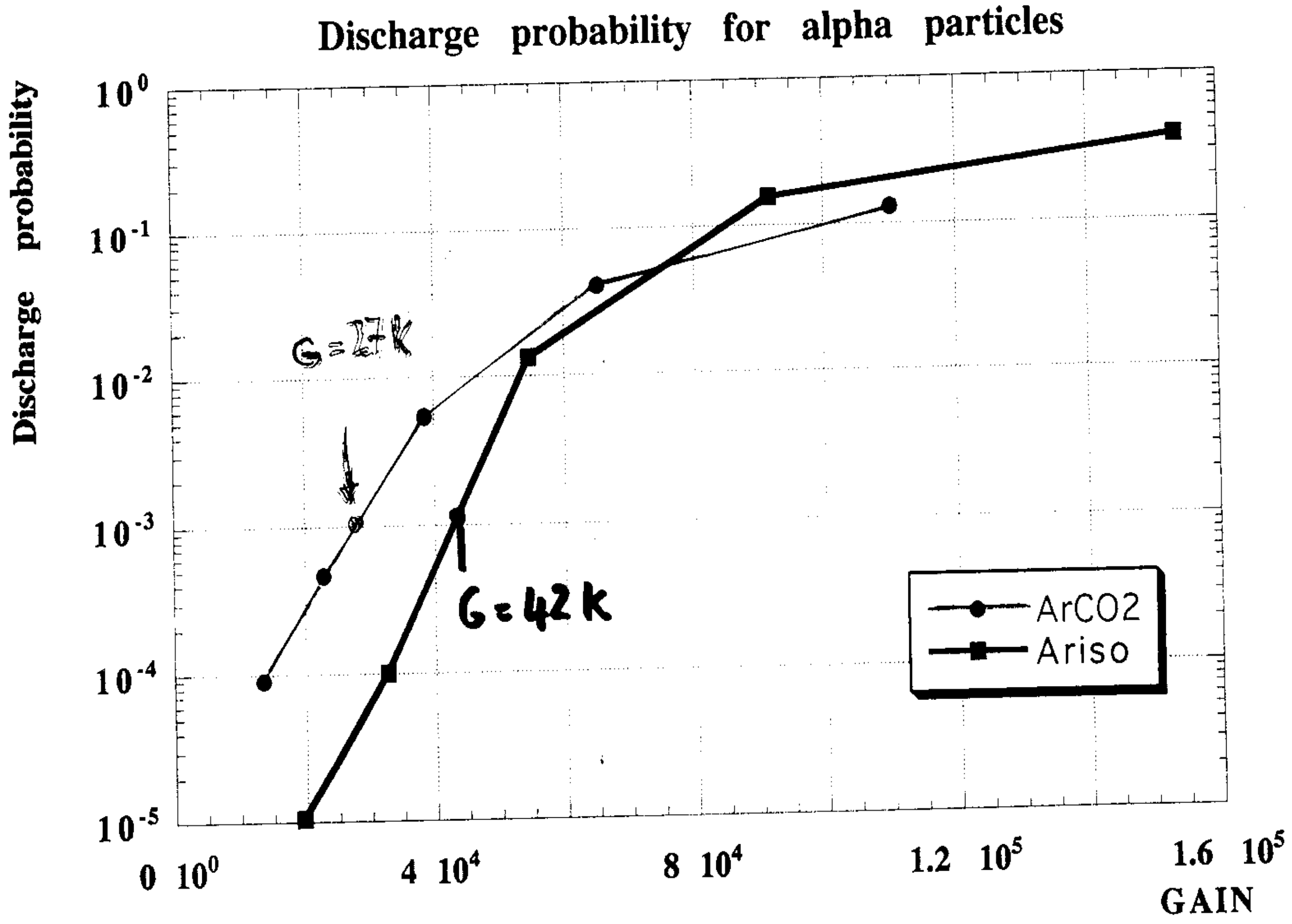
Study of discharges in triple GEM prototype

J.P.Perroud, IPHE, Lausanne

24, may, 2000

- Standard GEM pitch 140 μm, holes 70 μm, 5 μm Cu
- Size 30x30 mm^2
- Spacing drift 3 mm, transfer 1mm, induction 1mm
- Readout anode of 8 mm in diameter
- Discharges triggered by alpha particles
- Two gas mixtures tested argon-isobutane and argon-CO$_2$




Discharge probability for alpha particles
Discharge probability
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
0 10^0
4 10^4
8 10^4
1.2 10^5
1.6 10^5
GAIN
ArCO2
Ariso
G=27K
G=42K

Argon-isobutane (90,10)

- **Vg = 315 V**
- **average discharge size 6.7 nC or 4.2×10^{10} electrons**

Number of discharges	Defect
25042	GEM3
422400	GEM2
11067	GEM3
136200	GEM3
57630	GEM2
500	GEM3
257000	GEM3
Total 909800 Average 130000	

Argon-CO2 (70,30)

- **Vg = 415 V**
- **average discharge size 9.4 nC or 5.9×10^{10} electrons**

Number of discharges	Defect
100	GEM3
19810	GEM1
2160	GEM3
481	GEM3
15227	GEM1
22870	GEM2
41790	GEM2
Total 102400 Average 14600	

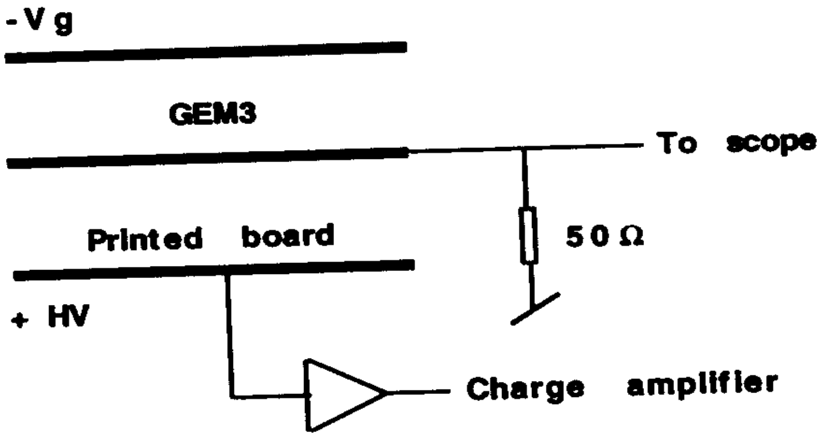
Hot spot: 8×10^{5} hadrons/cm^2/s
Spark probability: $\lesssim 10^{-11}$/hadron
$\Rightarrow$ ~100 sparks/cm^2/year

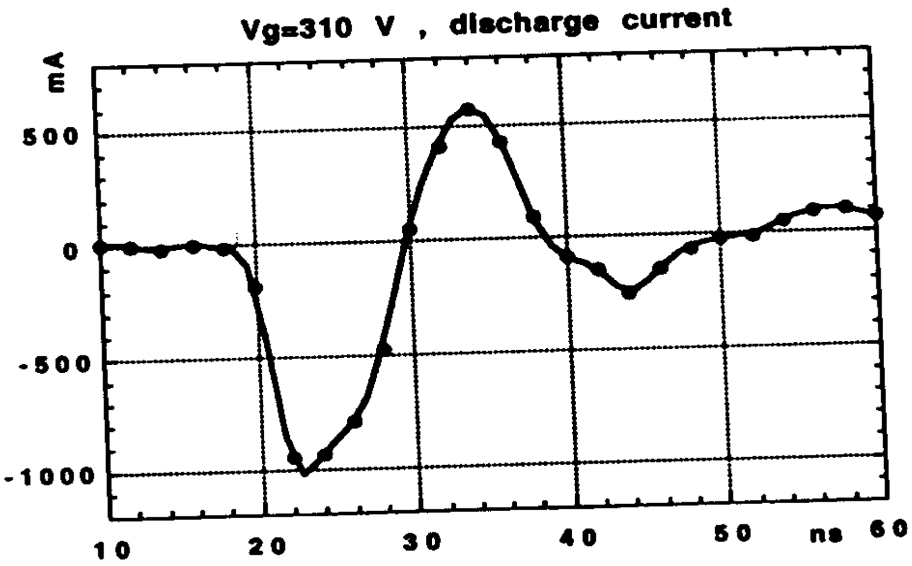
Measurement of discharge current

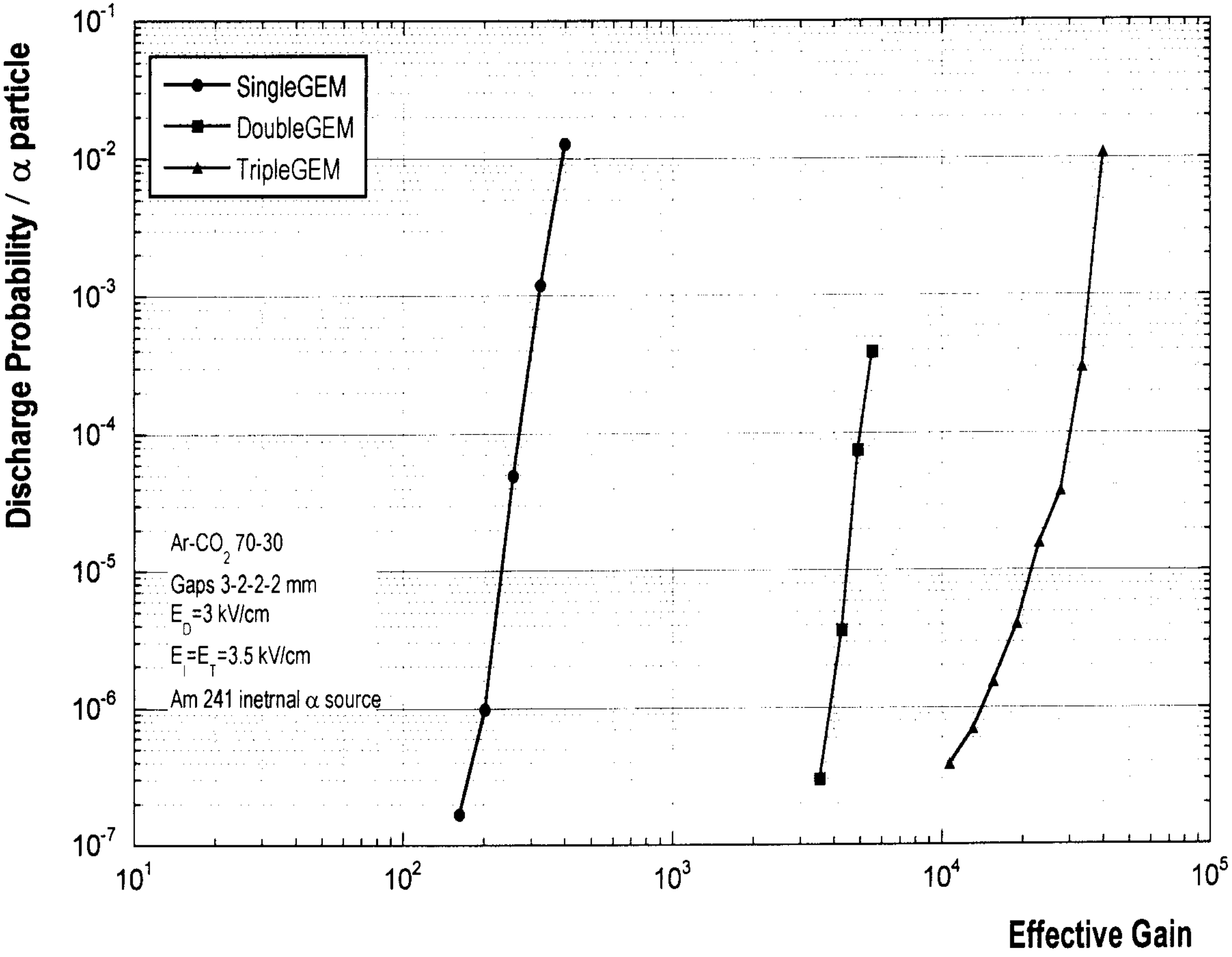
GEM capacity 450 pF

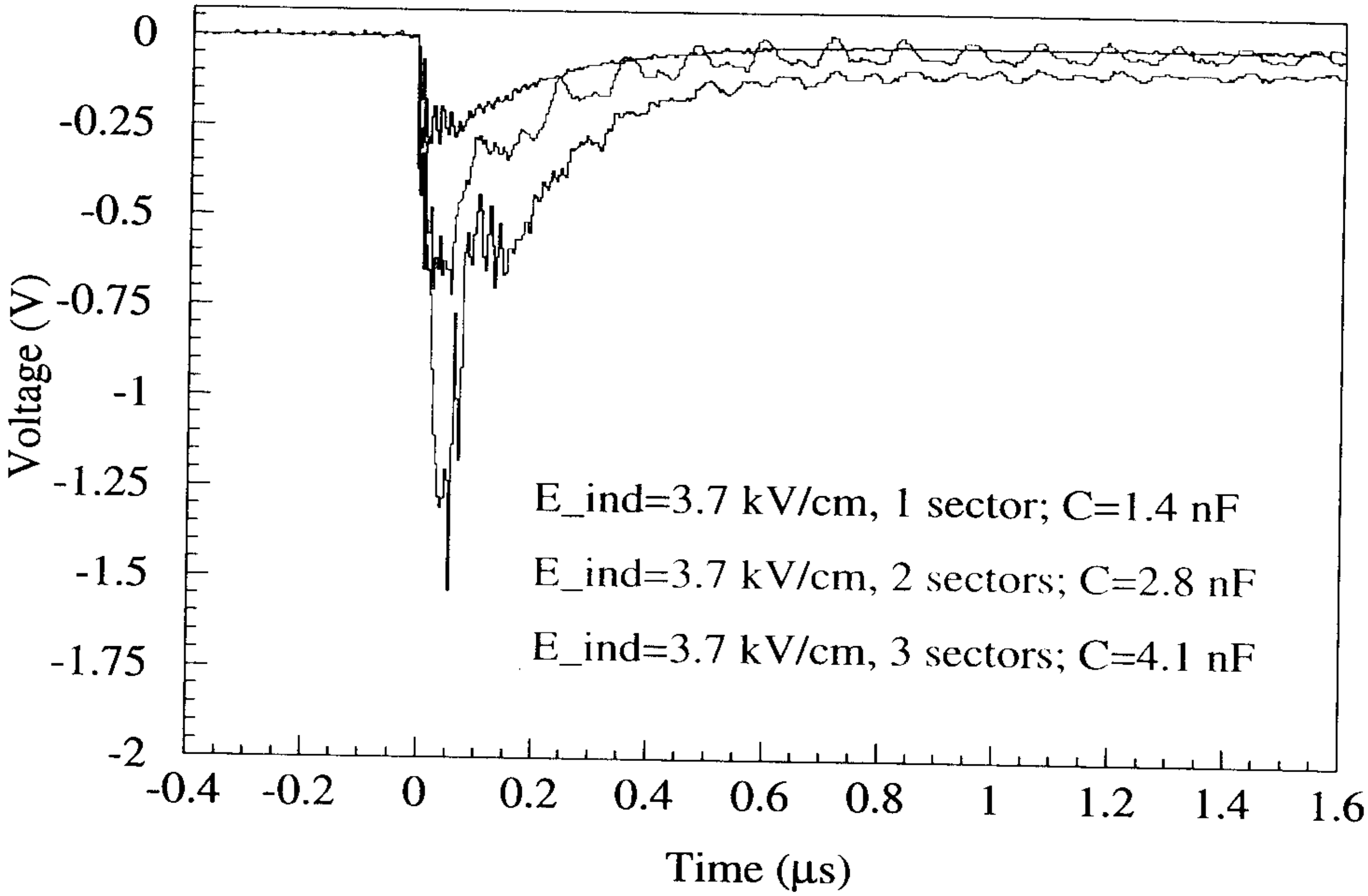
	Ar-CO2	**Ar-Isobutane**
Discharge size:	**9.4 nC**	**6.7 nC**
GEM voltage	**415 V**	**315 V**
Equivalent capacity	**22.6 pF**	**21.3 pF**

seems not to depend on the GEM capacity
Only a small fraction of the GEM capacity is discharged

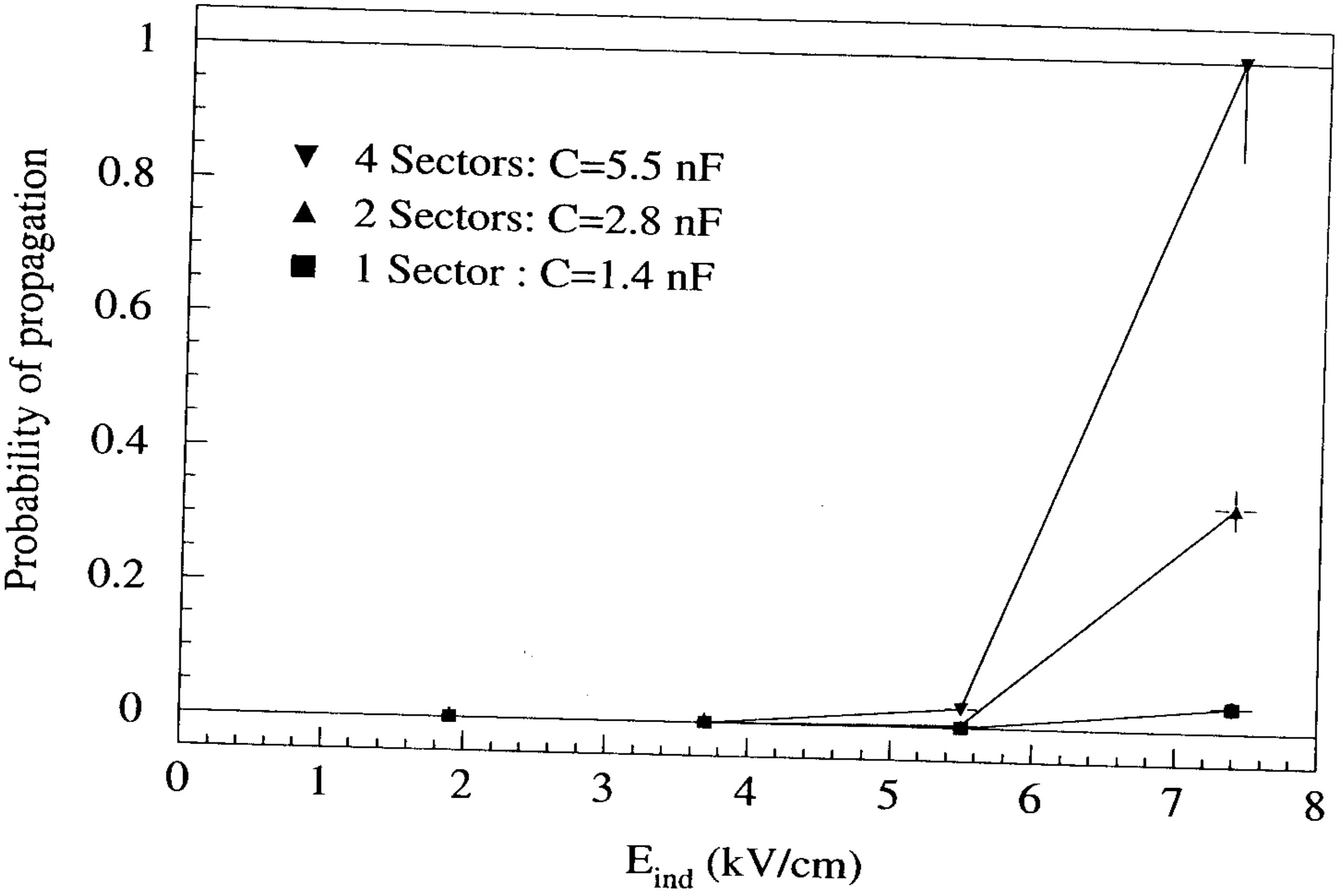




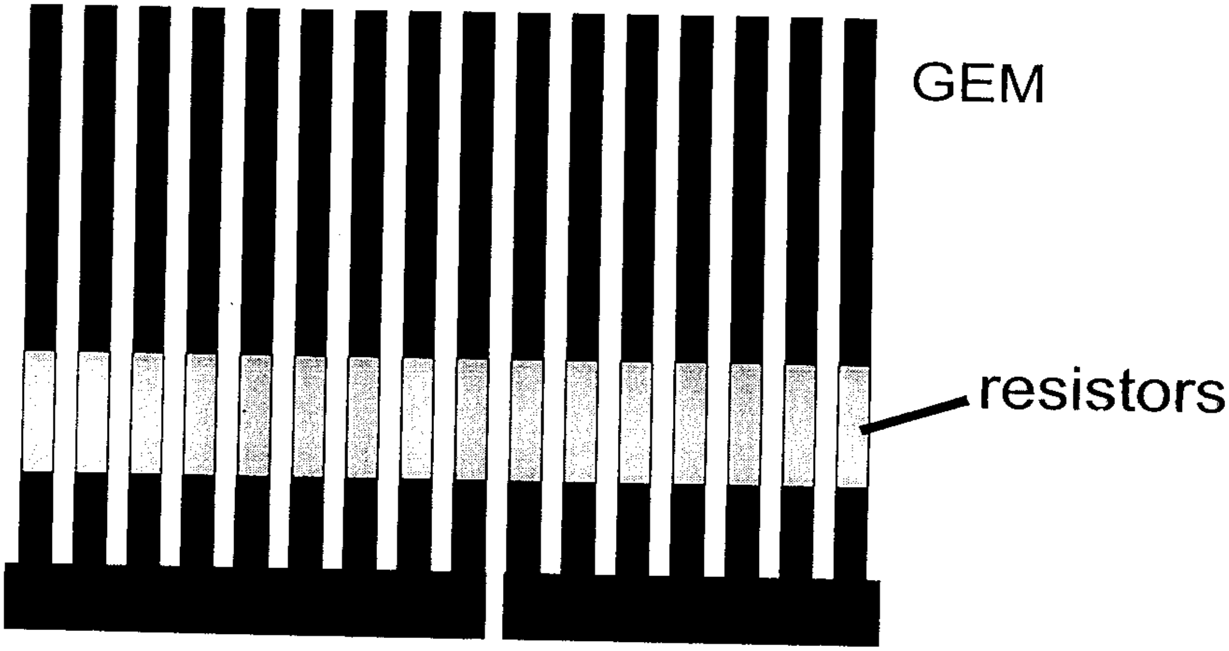

Discharge Probability / α particle
Effective Gain
SingleGEM
DoubleGEM
TripleGEM
Ar-CO2 70-30
Gaps 3-2-2-2 mm
ED=3 kV/cm
EI=ET=3.5 kV/cm
Am 241 inetrnal α source
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^1
10^2
10^3
10^4
10^5

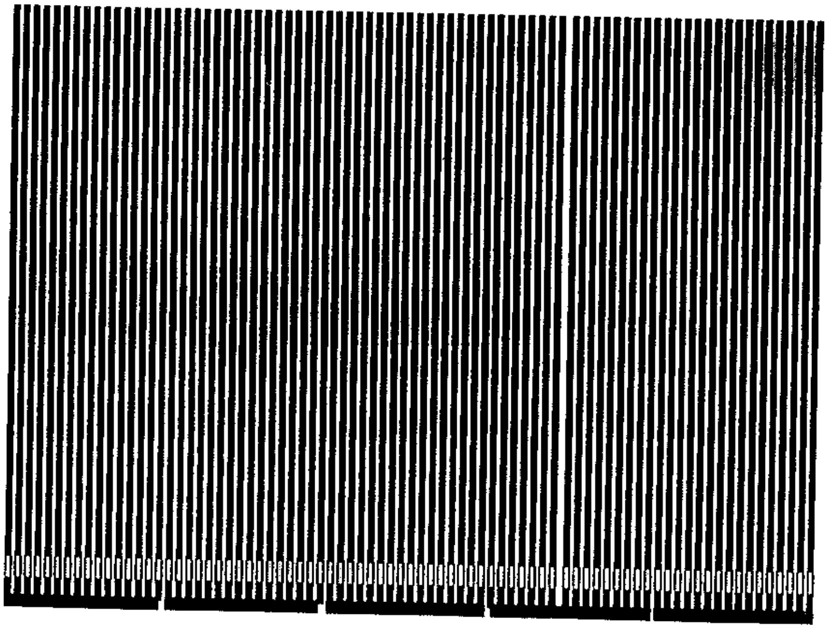


0
-0.25
-0.5
-0.75
-1
-1.25
-1.5
-1.75
-2
Voltage (V)
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time (µs)
E_ind=3.7 kV/cm, 1 sector; C=1.4 nF
E_ind=3.7 kV/cm, 2 sectors; C=2.8 nF
E_ind=3.7 kV/cm, 3 sectors; C=4.1 nF


▼ 4 Sectors: C=5.5 nF
▲ 2 Sectors: C=2.8 nF
■ 1 Sector : C=1.4 nF
Probability of propagation
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
5
6
7
8
E_{ind} (kV/cm)

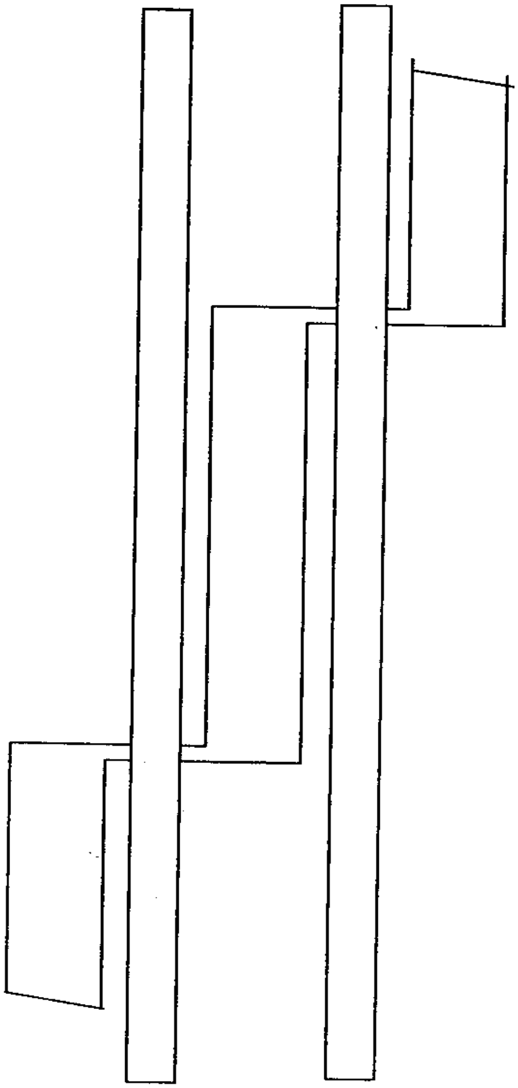
1mm segmentation





L. Chekhtman

PCB design

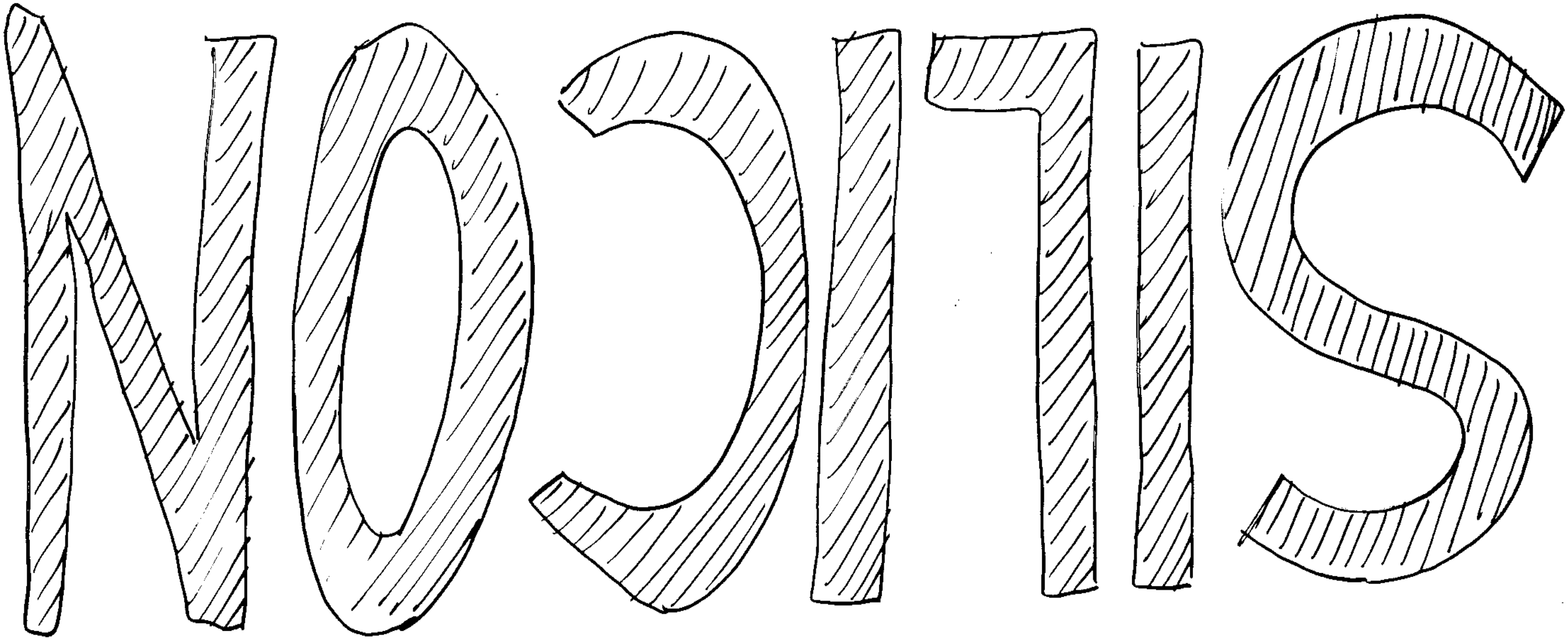


150um - bottom strip
60 um - top strip

50um kapton
400um pitch
4mm - zigzag pitch

capacitance (pF/cm):

	Meas.	Calc.
Top	0.54	0.32
bottom	0.73	0.62


SILICON

Status report on the Beetle development

Testchips (2mm x 2mm)

- BeetleMA (frontend for multianode-readout)
- BeetleCO (comparator)
- BeetlePA (pipeline amplifier)

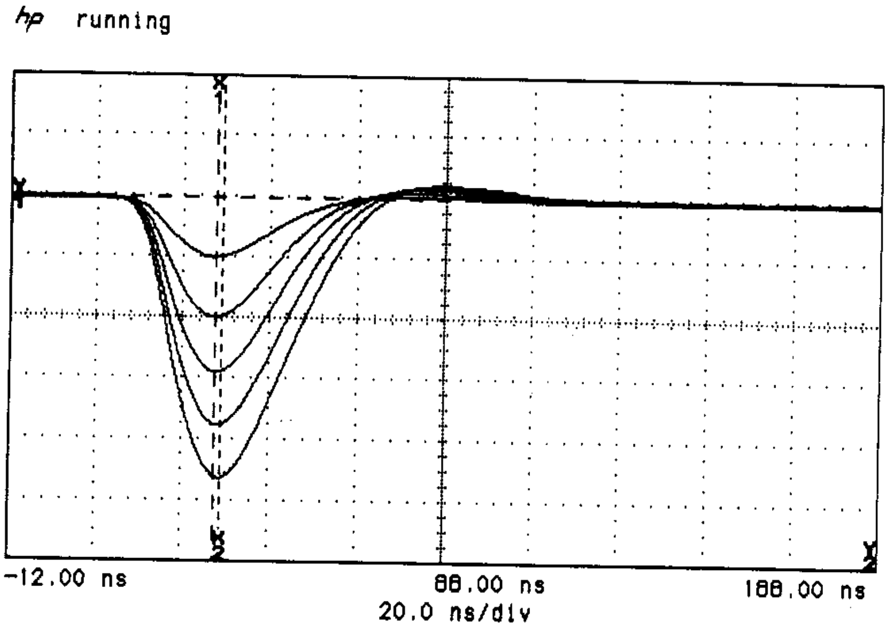
First prototyp readout chip

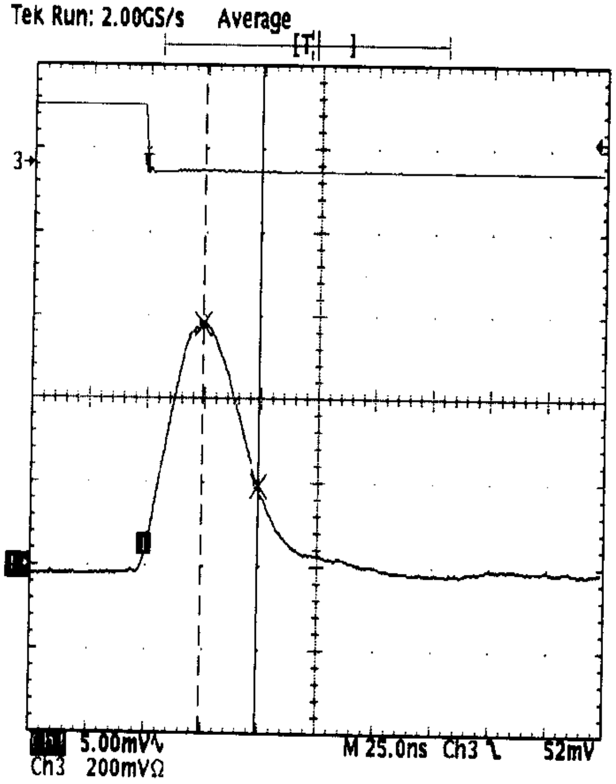
- Beetle 1.0

all submitted to CERN in april 2000

Beetle 1.0 Frontend Amplifier

Same like on BeetleFE testchip





measured noise = 303e$^-$+ 33.6e$^-$/pF

dynamic range: +- 10 MIP = +- 110.000e$^-$

no peakshift for higher signals

power consumption: 1.88mW / channel

risetime = 25ns

gain = 14.5 mV / 11.000e$^-$

remainder after 25ns = 30%

Pitch = 200 µm
Thickness = 300 µm
lenght = 20 cm
<S> = 32 000 e-h pairs
- 30% (Ballistic deficit)
= 22400 e-h pairs
divided by 2
<S> = 11200 e-h pairs

C_coupling négligé car en série

Width W µm	X = W/P	C_coup	C_tot [pF/cm]	C_tot [pF]				
10	0.05	500	0.89	[illegible]	898	1795	24.95	6.24
20	0.10	1000	0.97	19.40	955	1910	23.46	5.86
30	0.15	1500	1.06	[illegible]	1012	2024	22.14	5.53
40	0.20	2000	1.14	[illegible]	1069	2138	20.95	5.24
50	0.25	2500	1.23	24.50	1126	2252	19.89	4.97
60	0.30	3000	1.31	26.20	1183	2367	18.93	4.73
70	0.35	3500	1.40	27.90	1240	2481	18.06	4.51
80	0.40	4000	1.48	29.60	1298	2595	17.26	4.32
90	0.45	4500	1.57	[illegible]	1355	2709	16.54	4.13
100	0.50	5000	1.65	[illegible]	1412	2824	15.87	3.97
110	0.55	5500	1.74	[illegible]	1469	2938	15.25	3.81
120	0.60	6000	1.82	36.40	1526	3052	14.68	3.67

ENC Beetle : 303 + 33.6*C_tot

ENC+ = 2.*ENC

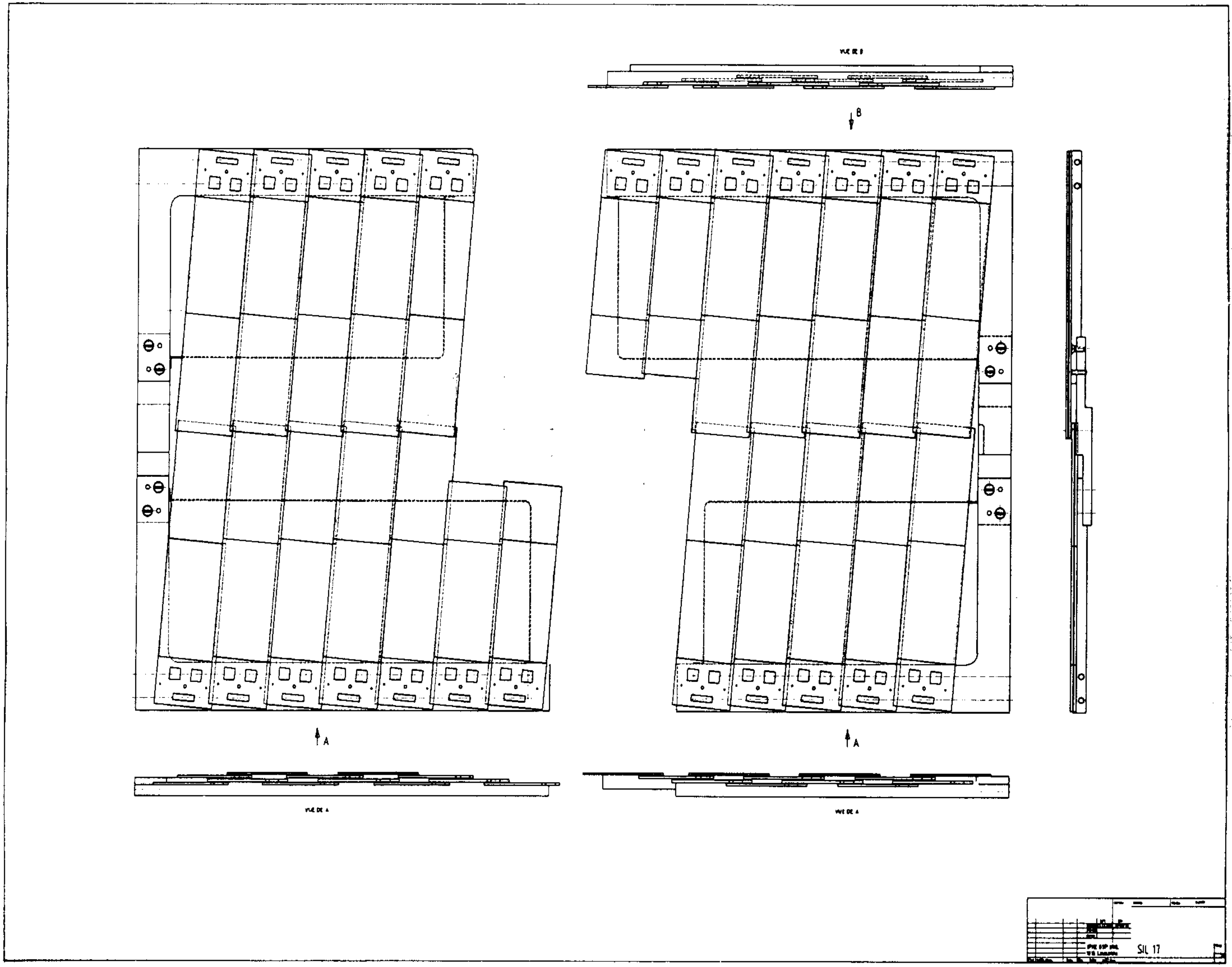
S_m = Minimum gauche de la distribution de Landau

C_tot = 0.8 + 1.7 X

C_tot selon l'article de CMS, <100> et <111> avant irradiation	
C_back	Non utilisé
C_interstip = (0.9 + 1.7*X)	Non utilisé

Ref: CMS Note 2000/011

↳ no deterioration up to ~24×10^{14} equiv. 1MeV N for <100> low-resistivity silicon


VUE DE B
B
A
A
VUE DE A
VUE DE A
SIL 17

COOLING :

- REMOVE HEAT FROM R/O ELECTRONICS
- OPERATE DETECTORS AT -5 TO -10°C
  (CMS / ATLAS)

APPROACH 1 :

LIQUID COOLING CIRCUIT FOR R/O ELECTR.
+ "AIR" COOLING FOR DETECTORS

INTERESTING: "VORTEX" COOLING, ~~TESTED~~ TESTED
BY HERA-B FOR "STATION 8"

⇒ ALLOWS TO REACH ~ -40°C

⇒ ENOUGH POWER FOR LARGE VOLUMES ?

APPROACH 2 :

LIQUID COOLING CIRCUIT FOR R/O ELECTR.
AND DETECTORS

RELY ON THERMAL CONDUCTIVITY OF SUPPORT
STRUCTURE ⇒ USED IN CMS TRACKER

⇒ APPROPRIATE FOR "OPEN GEOMETRY" ?

⇒ FOLLOW BOTH APPROACHES

DOUBLE-SIDED SILICON :

MANY DISADVANTAGES

- HANDLING
- COST
- PRODUCTION YIELD / QUALITY
  - CNM: "too complex"
  - HAMAMATSU: "afraid cannot meet specifications"
- R/O OF STEREO VIEWS ?
- INFRASTRUCTURE, MOUNTING OF R/O ELECTRONICS ?

ONE BIG ADVANTAGE

+ RADIATION LENGTH

(+ 300μm → 400μm FOR BETTER SIGNAL/NOISE ?)

ON THE OTHER HAND:

* CURRENT PERFORMANCE STUDIES ASSUME
0.4% X^0 / COORDINATE MEASUREMENT

300μm SILICON $\triangleq$ 0.3% X^0

* CURRENT SIMULATIONS SHOW
62% OF SECONDARIES FROM BEAM PIPE
27% OF SECONDARIES FROM TRACKING DET.

⇒ VERY LITTLE ENTHUSIASM

⇒ NEED STRONG ARGUMENTS FROM SIMULATION

⇒ START WITH SINGLE-SIDED PROTOTYPES

Alfredo Iglesias

Technical proposal of Si microstrip detector prototype for LHCb-ITR

1. Main parameters:

Technological Parameters	Value	Comments
Semiconductor type	N type Oxigenated Si ✓	Better rad hardness. Ref ROSE
Cristal	< 100 > ✓	Better rad hardness. Ref ROSE
Resistivity	Low: ~ 1kΩ · cm ✓	Better rad hardness. Ref ROSE
Wafer thickness	D ~ 300 μm ✓	Commercially available Oxigenation uniformity: OK
	D > 300 μm?? (⇒ ONLY IF DOUBLE-SIDED)	Oxigenation uniformity: possible Better S/N? Better efficiency?? Lower Cback?
Size (wafer diam)	4" ⇒ FOR PROTOTYPES	4" wafer oxigenation: done at IMB-CNM
	6" ⇒ FOR PRODUCTION	6" wafer oxigenation: not yet done
Implant type	P+ on n ✓	Ref CMS, ATLAS
	N+ on n	Old baseline
Breakdown protection	Guard ring structures Number of rings: 16? DISCUSSION WITH EXPERTS	Only on strip side
Individual strip biassing (AC readout)	Implanted resistors	Ref MPI
	Polisilicon resistors	More lithography steps
Backplane biassing	Edge contact	No backplane passivation removal Ref MPI: http://www.hll.mpg.de/atlas/bias/topBias.html
	Metal contact: N+ / Al / bonding	Open backplane passivation
Photolithography	Single sided 5 steps	1 passivation openings 2 p+ strip implant 3 resistors implant 4 metalization (Al) 5 contacts

PRODUCERS :

* HAMAMATSU
- \+ RUN MASS PRODUCTION FOR ATLAS / CMS
- \+ KNOWN FOR RELIABLE QUALITY
- \+ ONLY MINOR MODIFICATIONS TO CMS DESIGN
- \+ WE PROVIDE SPECS, THEY TAKE CARE OF DETAILS
- \+ ATTRACTIVE PRICE : < 10 CHF/cm² FOR CMS
- − TURNAROUND / COST FOR PROTOTYPING ?

* "CNM" / BARCELONA
- \+ EXPERIENCE WITH DETECTORS FOR HIGH-RADIATION ENVIRONMENT (MEMBERS OF RD48/ROSE COLL.)
- \+ HAVE CAPACITY FOR MASS PRODUCTION
  "is really a big institute of micro-electronics, Olaf"
- − WE HAVE TO PROVIDE FULL SET OF MASKS
- − QUALITY / YIELD IN MASS PRODUCTION ?

* "DETEKTOR" / KIEV
- \+ LONG-ESTABLISHED CONTACT TO V. PUGATCH
  "their boss ~~is~~ was a PhD student of mine..."
- \+ HAVE CAPACITY FOR MASS PRODUCTION
- \+ WE PROVIDE SPECS, THEY TAKE CARE OF DETAILS
- \+ ATTRACTIVE PRICE FOR PROTOTYPE
- − QUALITY / YIELD IN MASS PRODUCTION ?

⇒ KEEP OPTIONS OPEN, TRY TO GET PROTOTYPES FROM ALL THREE

SUMMARY

- DETECTOR SIMULATION / TRACKING STUDIES STARTED
  - * AIM :
    - ~ DETERMINE DETECTOR PARAMETERS
    - ~ CHECK INFLUENCE OF MATERIALS
  - * INTEGRATED INTO TRACKING GROUP
- 3GEM OPTION
  - * DETECTOR OPTIMIZATION :
    - ~ GEM FOILS → LESS MATERIAL, SEGMENTATION
    - ~ READOUT PCB → CAPACITANCE
    - ~ GAS MIXTURES → DIFFUSION, CLUSTER SIZE, SPARKING
  - * STUDY OF SPARKING PROPERTIES & DAMAGE
- SILICON OPTION
  - * WORK HAS STARTED :
    - ~ STATION LAYOUT
    - ~ COOLING
    - ~ SPECS FOR PROTOTYPE DETECTORS
    - ~ CONTACTS TO MANUFACTURERS (→HAMAMATSU!)
- ... ALSO STARTING TO WORRY ABOUT SUPPORTS/FRAMES...