



R&D for A High Eta Forward Muon Trigger and Tracking detector for CMS



RD 51 Collaboration Meeting May 24-27 2010

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
Yong Ban, Haiyun Teng, Jingxin Cai
Peking University Beijing China




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



Friday 04 September 2009








Next Meeting 20th November 2009


14:30    Introduction and discussion (20')







14:50    New Physics Potential and Detector Requirements - Albert (de Roeck) (40')







15:30    MPGD Experience and Expression of Interest from Frascati - Stefano Bianco / Benussi / Fabbri (20')

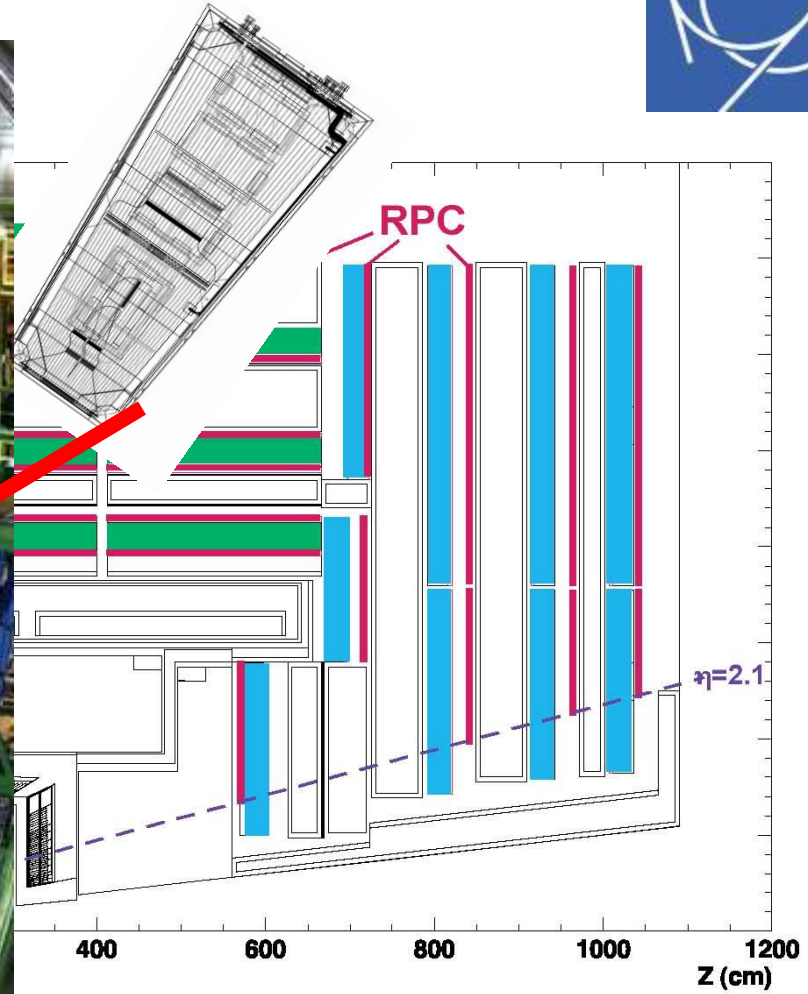
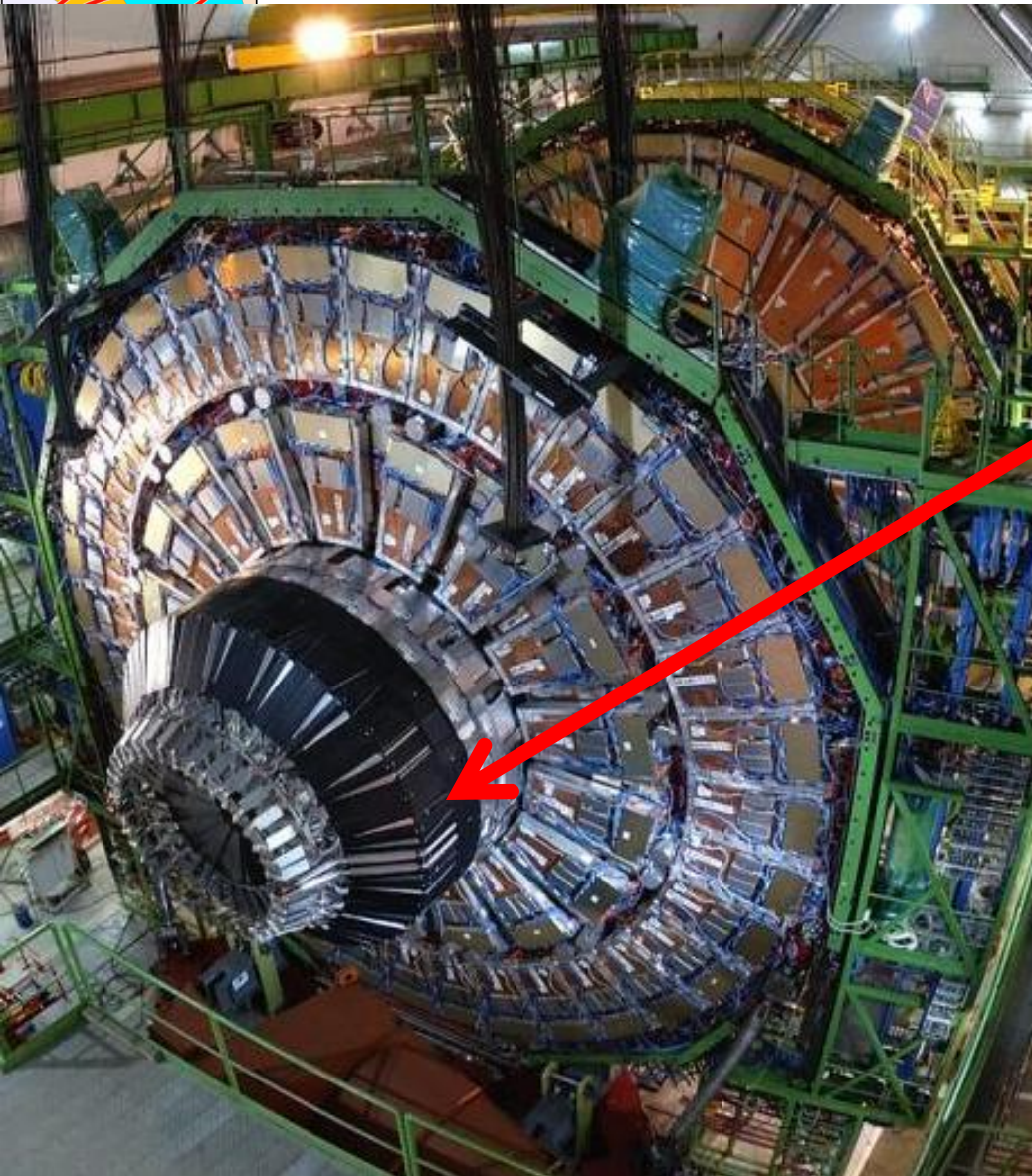
15:50    Current MPGD studies, CSC alignment work within CMS and interest in the high-eta MPGD upgrade from Florida (20') ( Slides  )

16:10    Current Experience, Expression of interest and (preliminary preparation for Simulations of Trigger Efficiency) - Arun K ( Slides   document )

16:30    Update on small prototype tests at CERN - Archana (20')

16:50    Preparation towards large prototype(s) - Andrey / Serguei / Serge (20') ( Slides  )

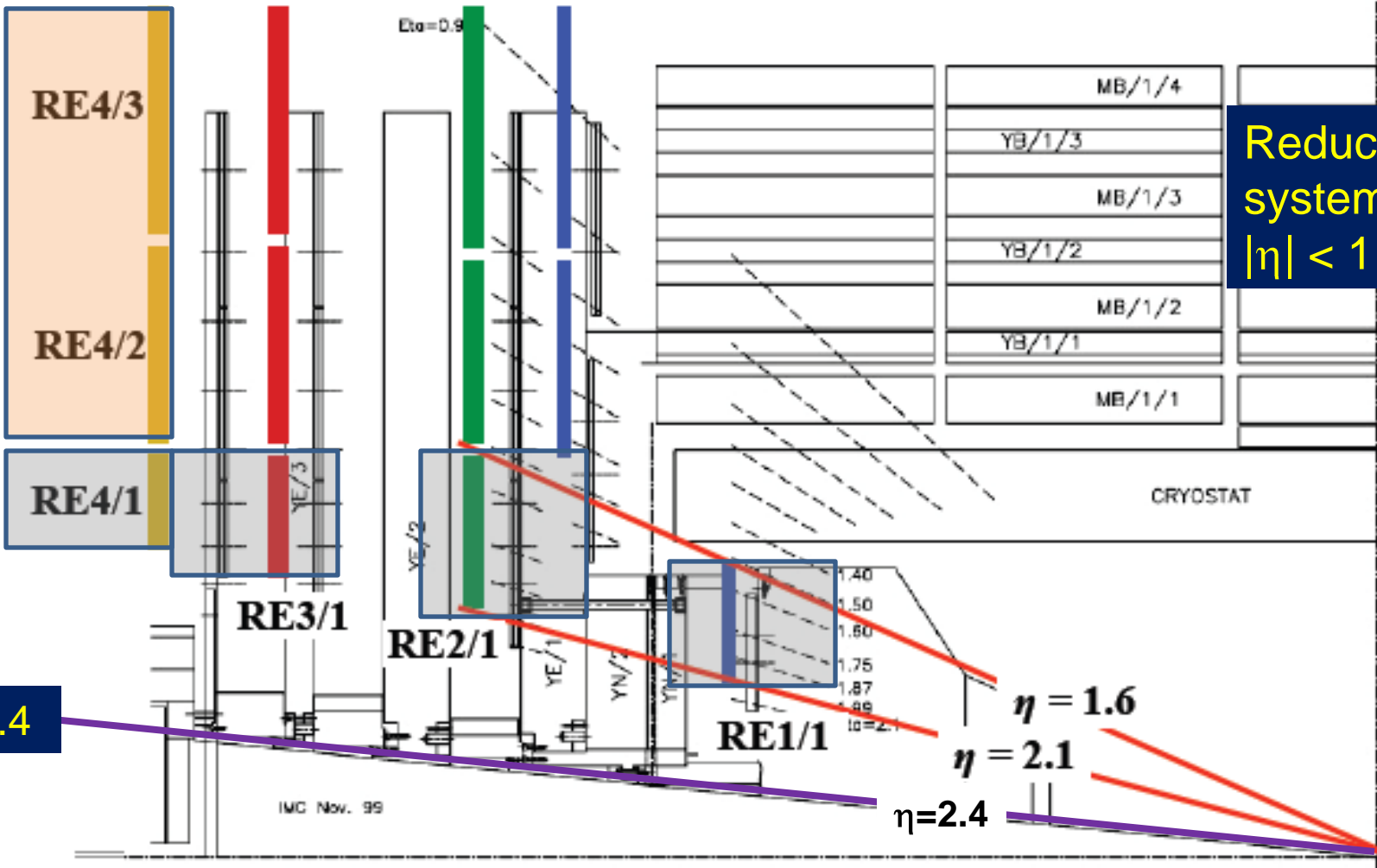
17:10    Update on Front End Readout - Nicola Turini (20') ( VFAT - Details  )



Endcap RPC:

- RE 1,2,3,4 = 1 layers
- 540 trapezoidal chambers
- 80 000 radial strips

Initial RE system –tailored to budget



STAGED

	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*

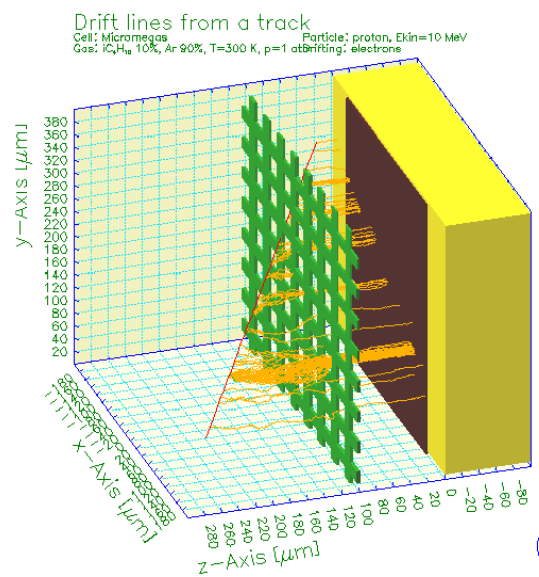
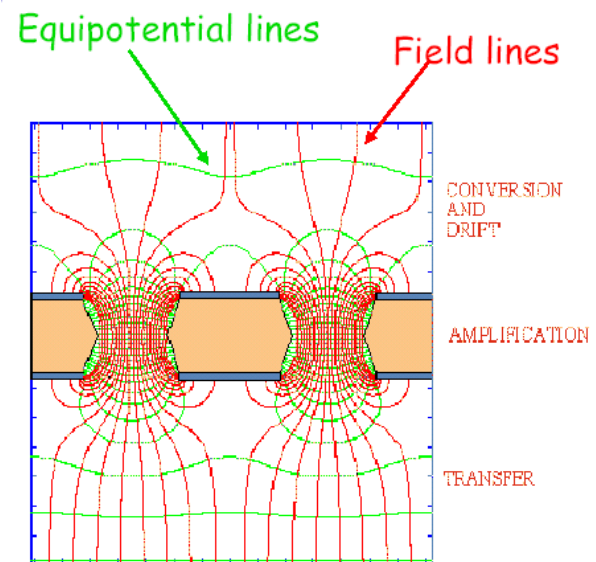
Estimated Particle rates in Forward CMS

RPC Region	Rates Hz/cm ² LHC (10 ³⁴ cm ² /s)	High Luminosity LHC 2.3 x LHC	(10 ³⁵ cm ² /s) Phase II SLHC ??
RB	30	Few 100	kHz (tbc)
RE 1, 2, 3,4 $\eta < 1.6$	30	Few 100	kHz (tbc)
Expected Charge in 10 years	0.05 C/cm ²	0.15 C/cm ²	~ C/cm ²
RE 1,2,3,4 $\eta > 1.6$	500Hz ~ kHz	Few kHz	Few 10s kHz
Total Expected Charge in 10 years	(0.05- 1) C/cm ²	few C/cm ²	Few 10s C/cm ²

MPGDs as candidate technology

Improve contribution to
 Muon Trigger Efficiency
 Combine triggering and
 tracking functions?

 Instrument the vacant
 (RE i/1) zone in CMS
 Forward
 $1.6 > \eta > 2.4$

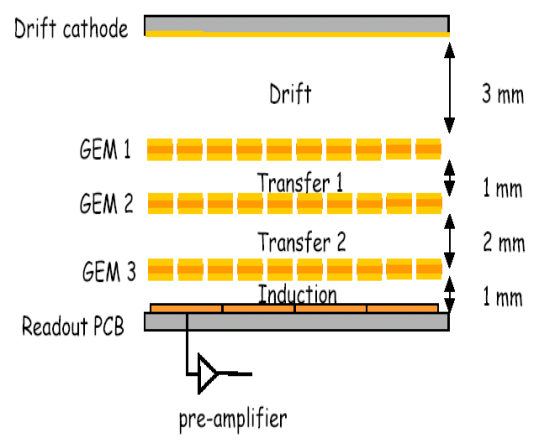
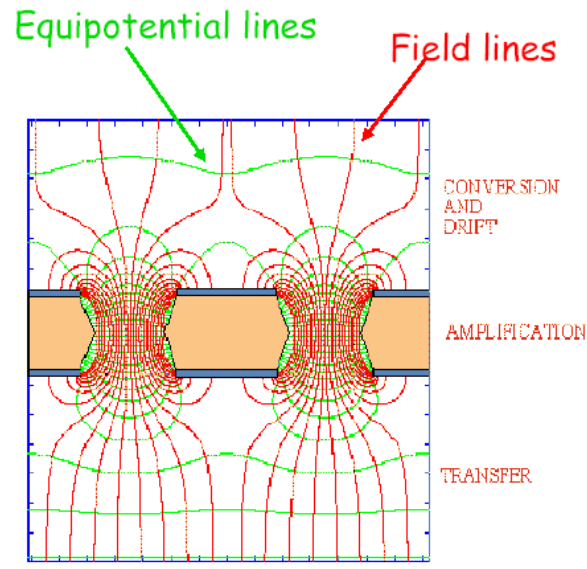


MPGDs as candidate technology

Enhance and optimize the readout ($\eta-\phi$) granularity by improved rate capability

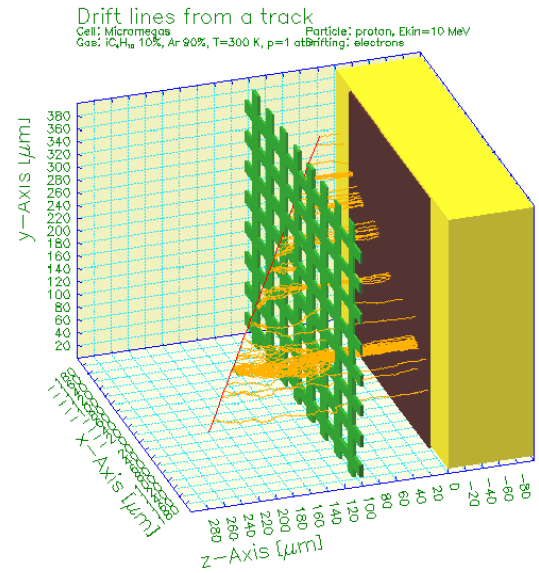
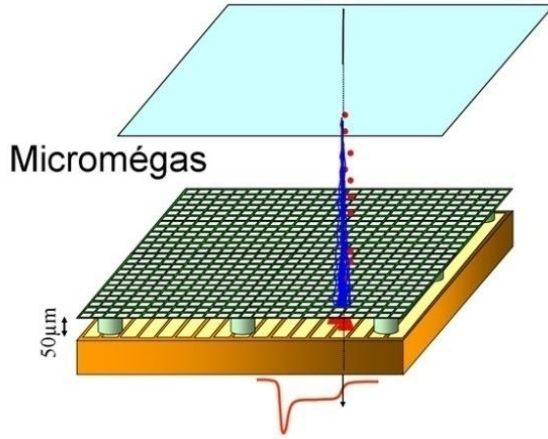
Rate capability – $10^4/\text{mm}^2$

- Spatial resolution $\sim 100 \mu\text{m}$
($\Theta_{\text{track}} < 45^\circ$)
- Time resolution $\sim 1\text{-}3 \text{ ns}$ (Gas!)
- Efficiency $> 98\%$
- Rate capability $> 5 \text{ kHz}/\text{cm}^2$
- Argon CO2 (non flammable mixture - big plus)



MPGDs as candidate technology

- Potential for going to large areas $\sim 1\text{m} \times 2\text{m}$ with industrial processes (cost effective)
- Long term operation experience in Compass
- Negligible Discharge probability with no consequence
- **Implemented for LHCb first muon station (4m^2) ~ 500 kHz/cm², operational in COMPASS for 10 years**
- **Proposed /in prep for ATLAS Muon upgrade (1000m^2)**



Printed at 03:28:25 on 15/02/08 with Octave version 0.20.

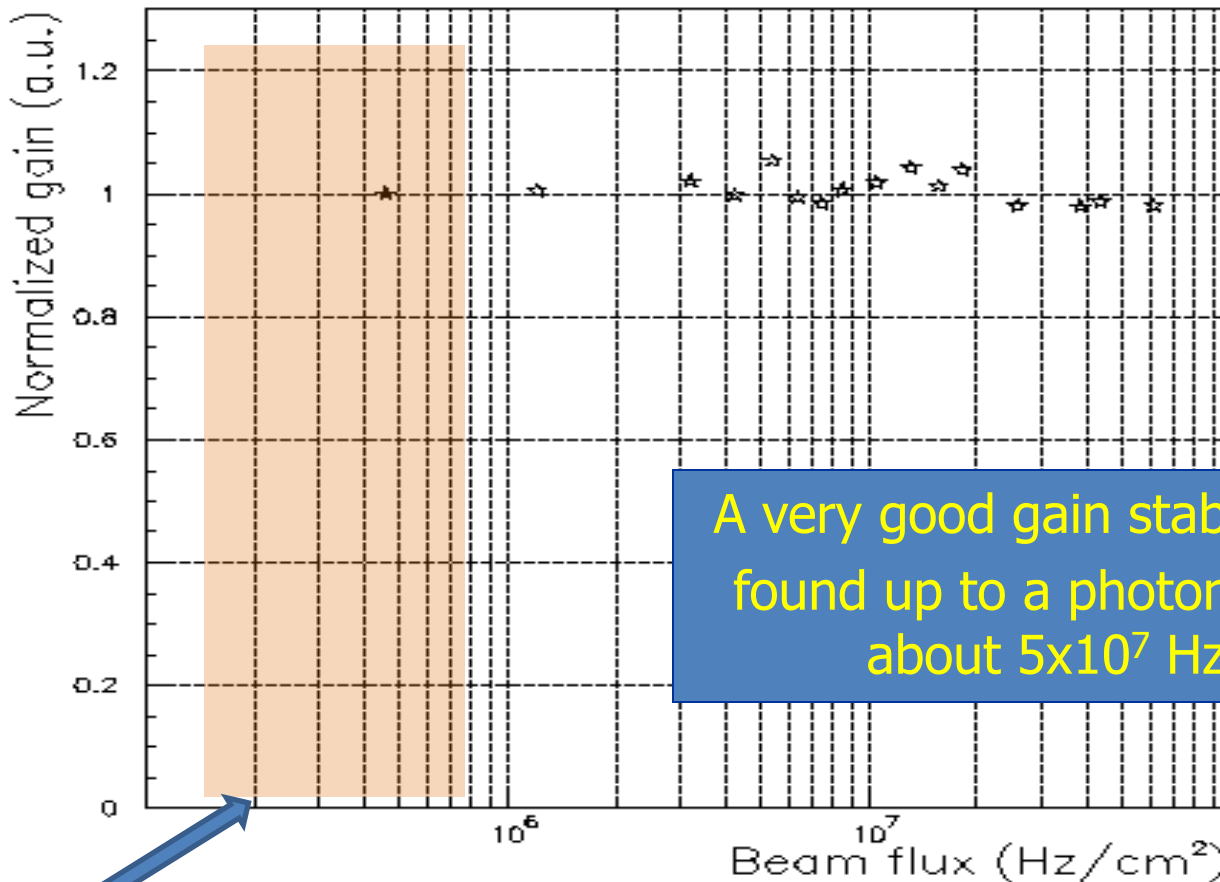


Rate capability

Measured with an X-ray (5.9 keV) tube;

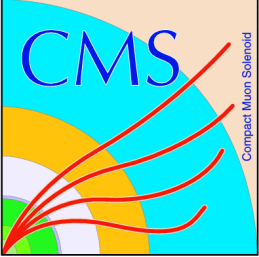
Ar/CO₂/CF₄ (60/20/20)

Gain of about 2×10^4 ;



CMS high η - maximum rate

LHCb meas

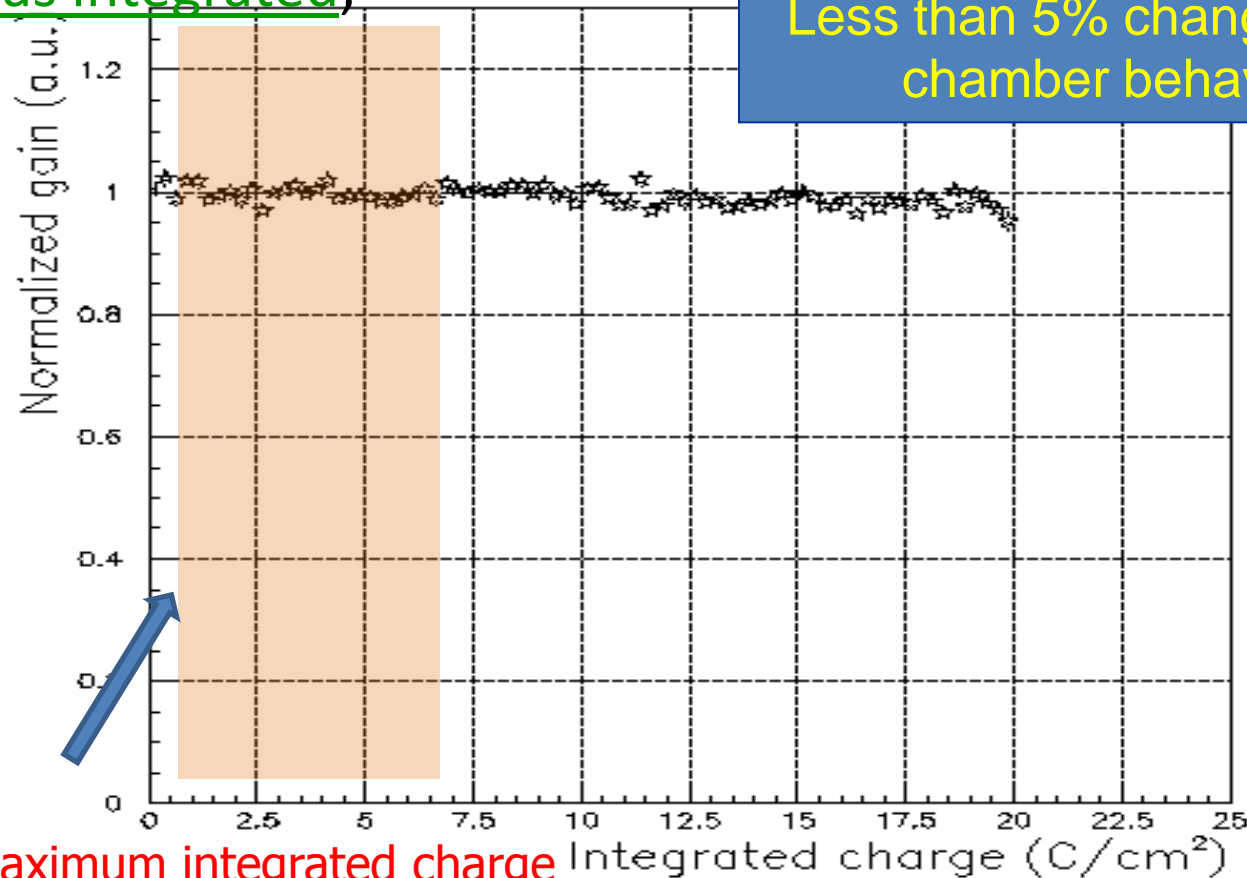


Triple GEM Ageing test

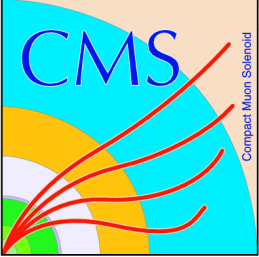
Gain of 2×10^4

Total integrated charge of 13 C/cm^2 is expected in 10 years of operation in LHCb

50 MHz/cm² X-rays, in 10 days a total charge of 20 C/cm^2 was integrated;



CMS high η - maximum integrated charge

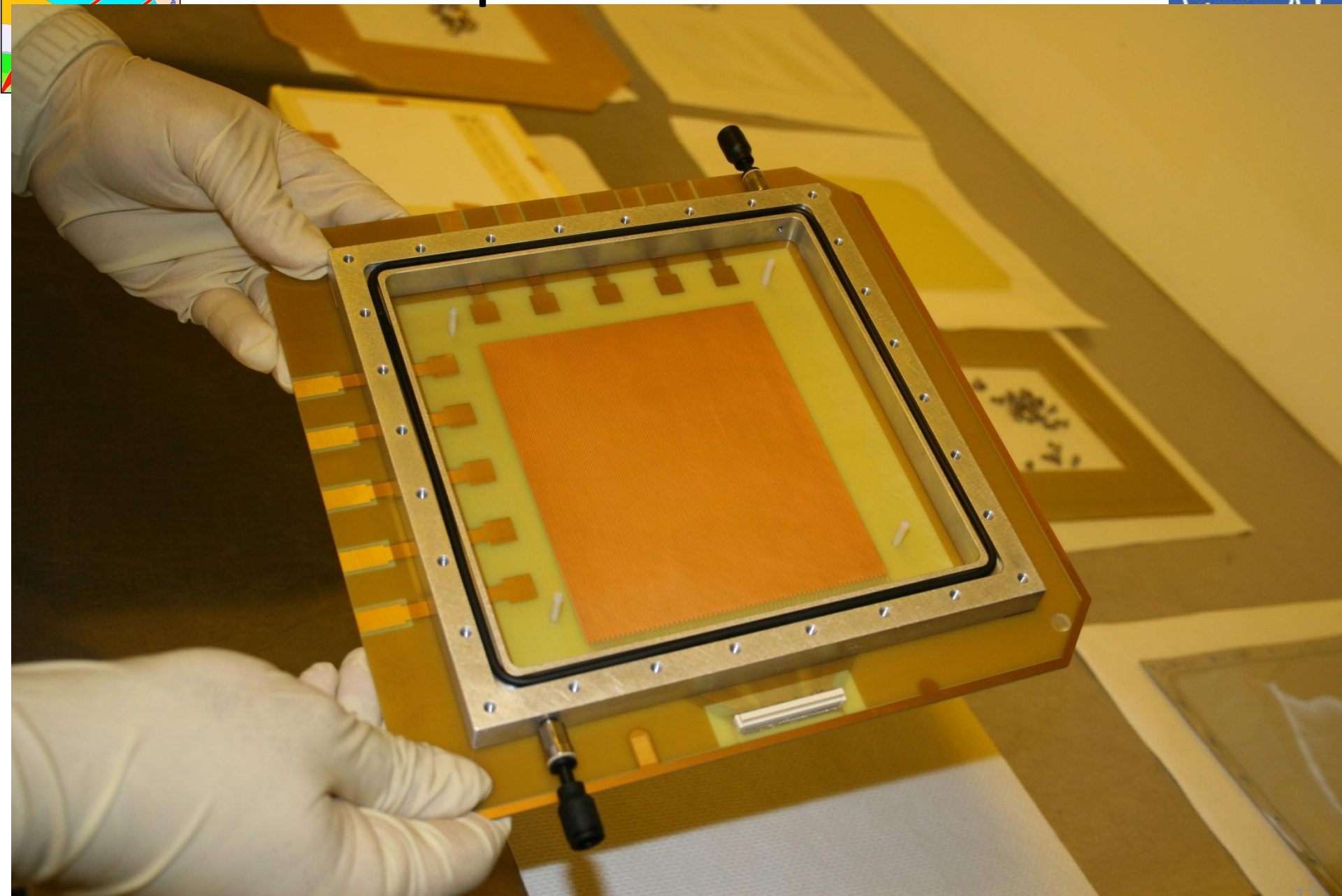


CMS MPGD High Eta Feasibility Studies - activities since August 2009

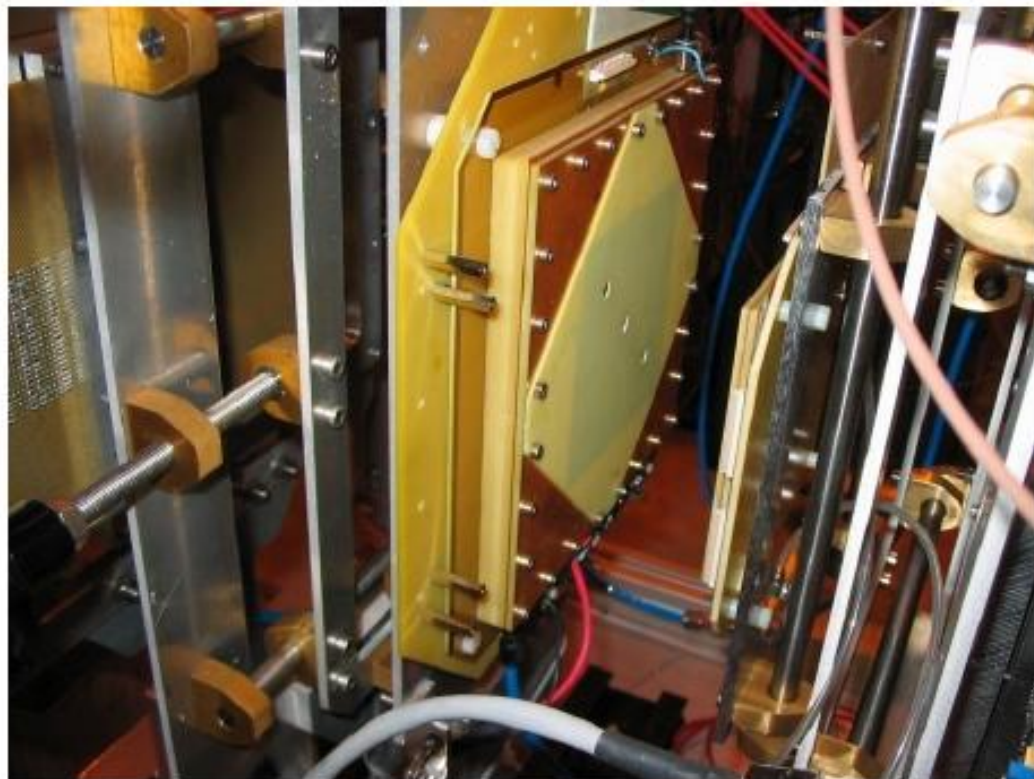


- 1. Assembly and test of two small MPGD prototypes**
- 2. Participated in Beam tests 2009**
- 3. Planned 2010 (with three different chambers)**
- 4. Mock ups of large prototype**
 - **Size and envelope limitations**
 - **Services and routing: HV, Gas, LV, Cooling**
 - **HV Divider**
 - **3D Model / Drawings**
- 4. Production of the prototype**

Small proto-CMS-TG-01

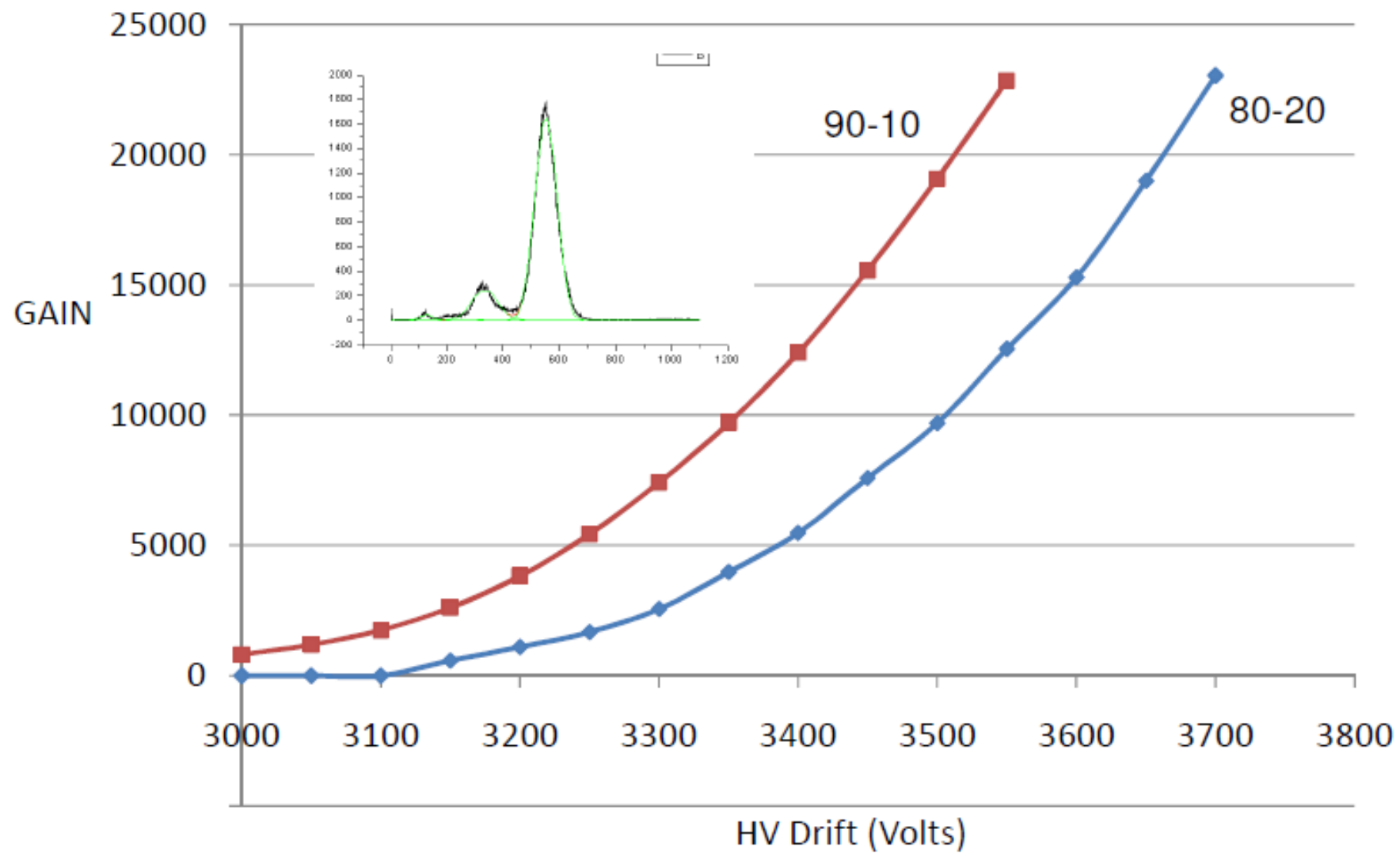


- Triple GEM Detector
- 10x10 cm² active area
- Gas Mixtures used: Ar/CO₂ 90%/10% and 70%/30%
- 1D Readout Strip (X-direction) and 1 VFAT connected to the only one connector
- Strip pitch = 0.8 mm;
1 connector → 128 strips

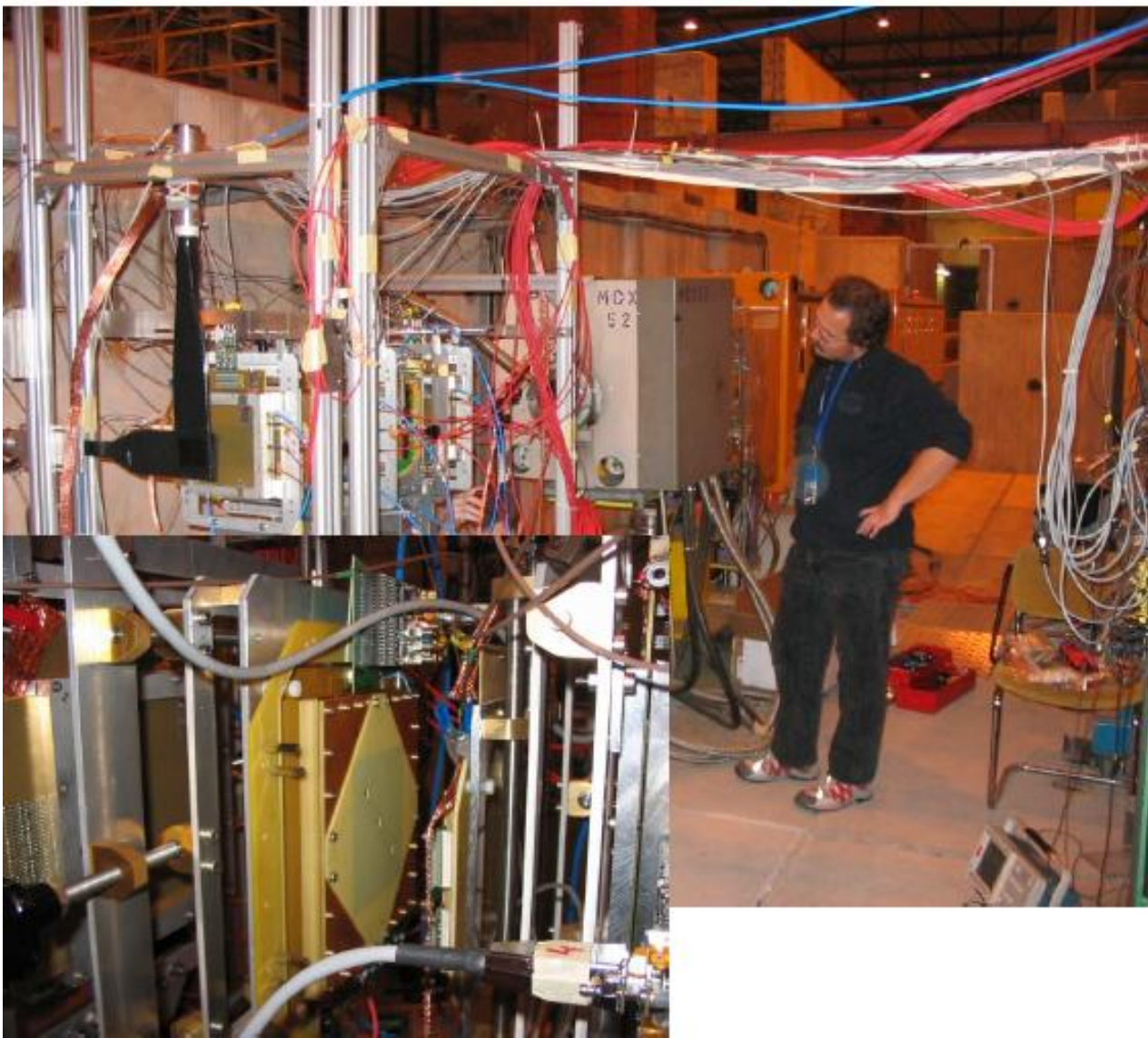




GAIN STUDIES WITH TRIPLE GEM ARGON CO2 CURRENT WITH Cu X-Rays



ONGOING Activities: BEAM TEST DATA ANALYSIS



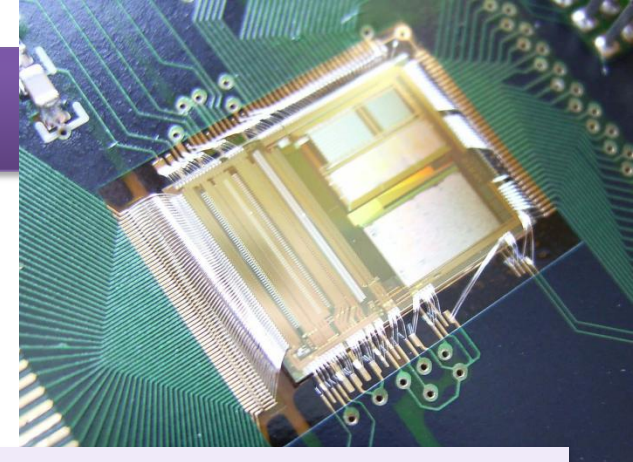
-During Beam Test and later in the lab the CMS GEM has been working fine, data has been taken.

-Unfortunately, lots of discharges have been observed during beam in the CMS μ Megas prototype

BACK IN THE LAB

- Read the CMS GEM with VFAT electronics and play with Gas mixture.
- Understand the timing performance of the detector.

Readout Electronics – VFAT



A digital on/off chip, with an adjustable threshold for each of 128 channels.

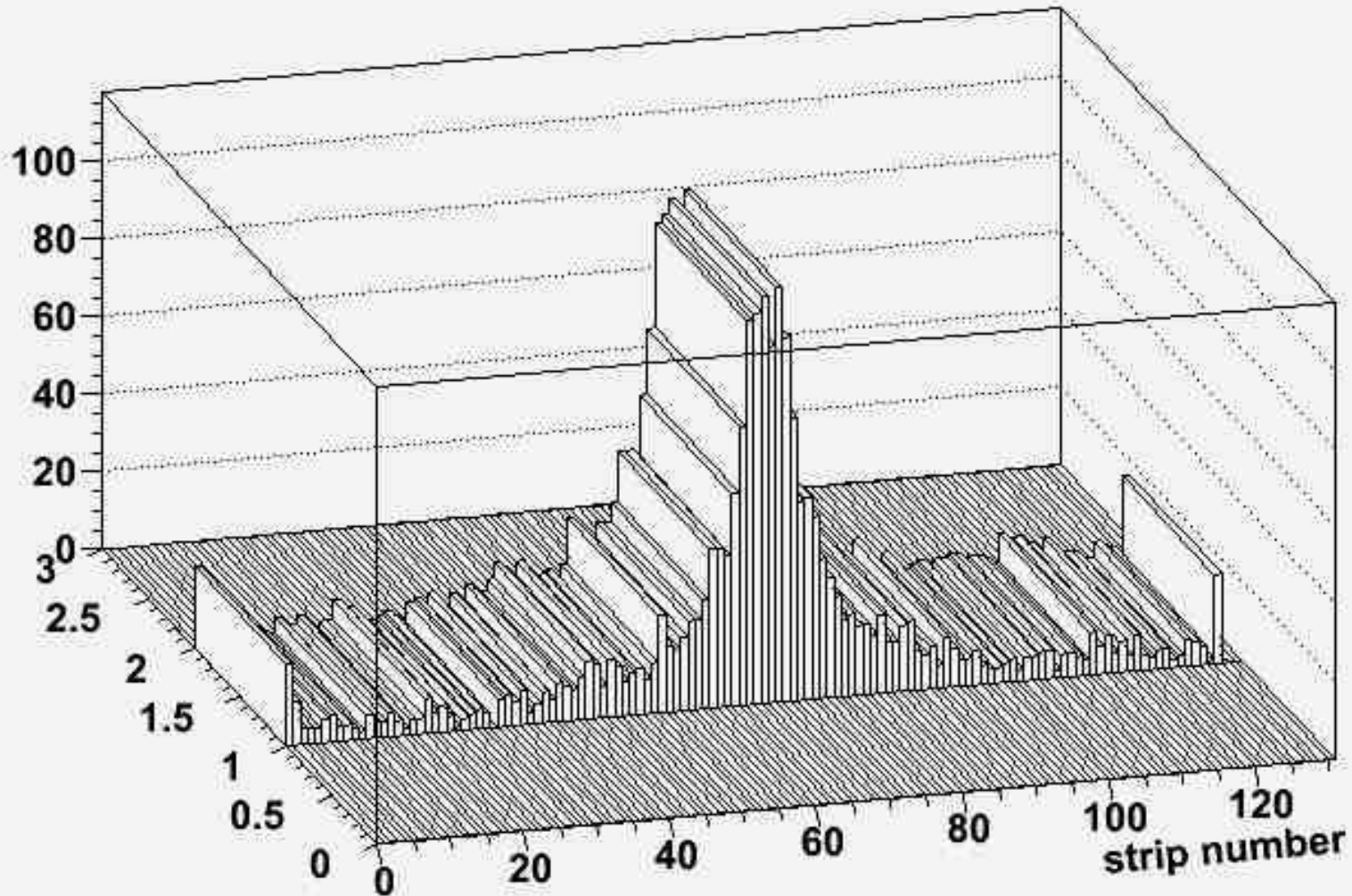
Used in all the Totem detectors, the GEMs and the CSCs to simplify the DAQ and Trigger design

Quarter micron CMOS technology and measures 9.43mm by 7.58mm.

Trigger function to provide programmable “fast OR” information based on the region of the sensor hit. This can be used for the creation of a trigger.

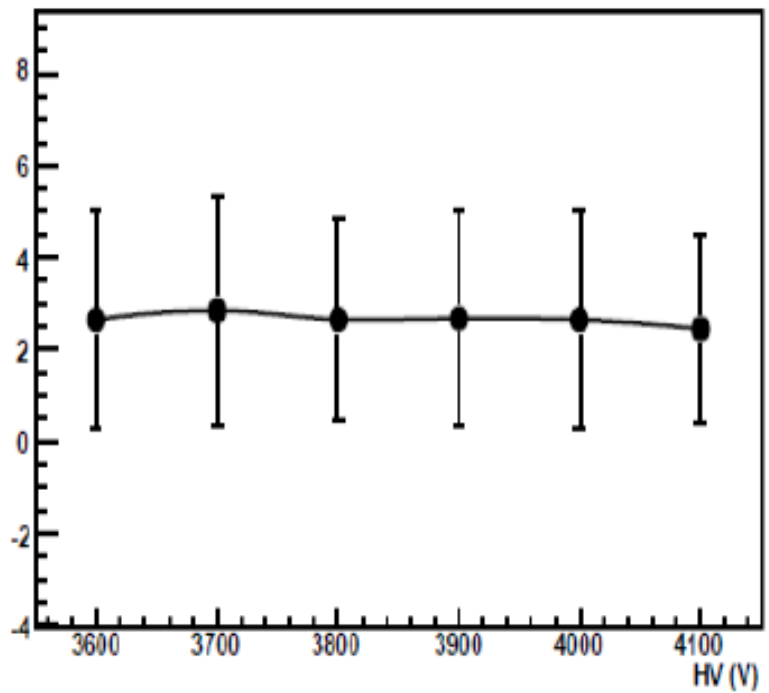
Tracking function for providing precise spatial hit information for a given triggered event.

First Results – to be studied in detail

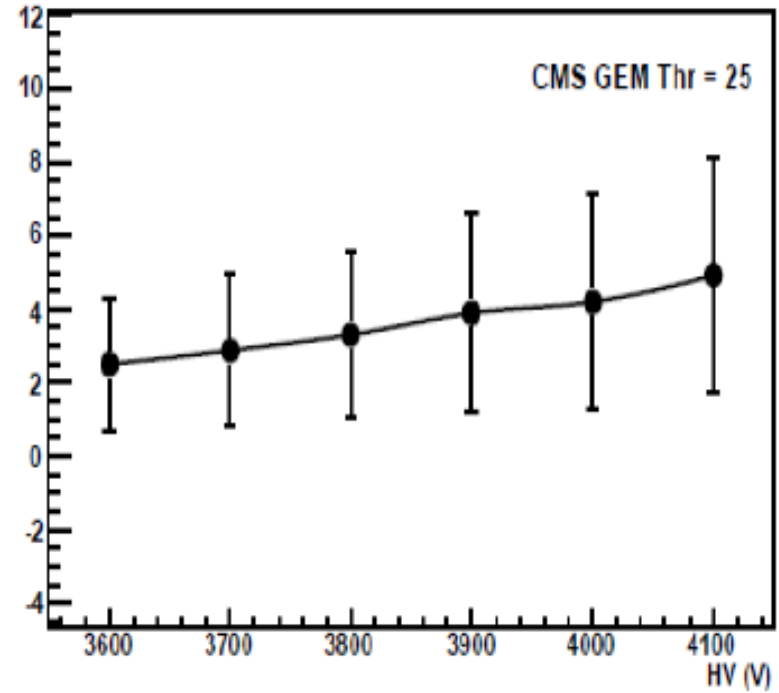


CLUSTER SIZE & CLUSTER MULTIPLICITY

Cluster multiplicity

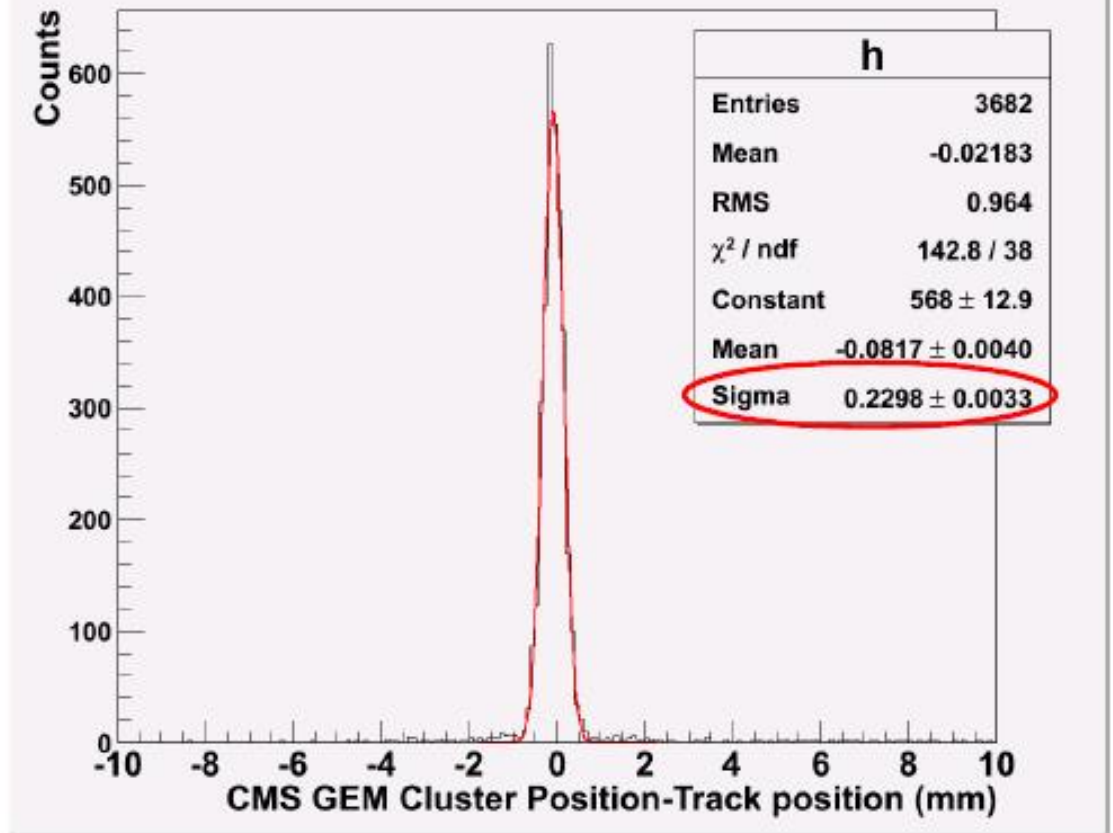


Cluster size (#channels)



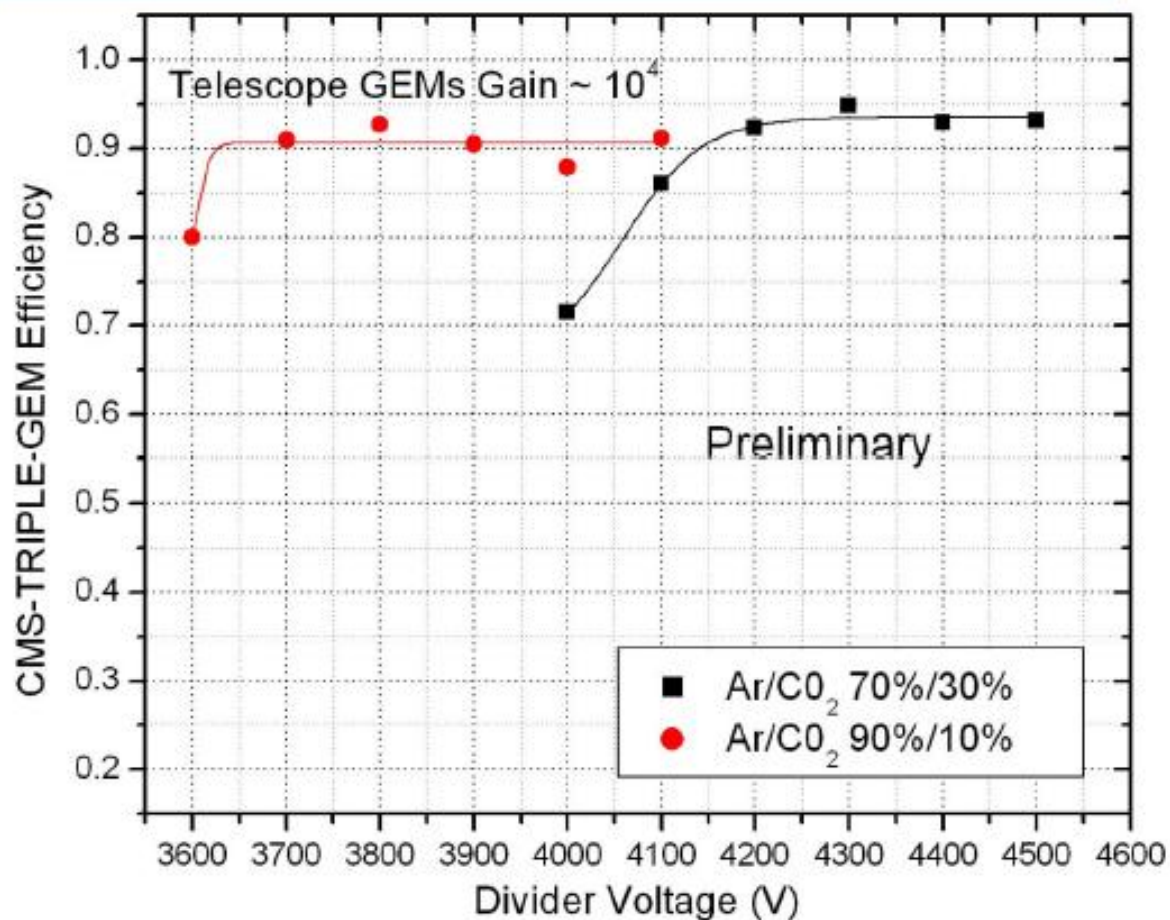
M. Tytgat

CMS GEM SPACE RESOLUTION



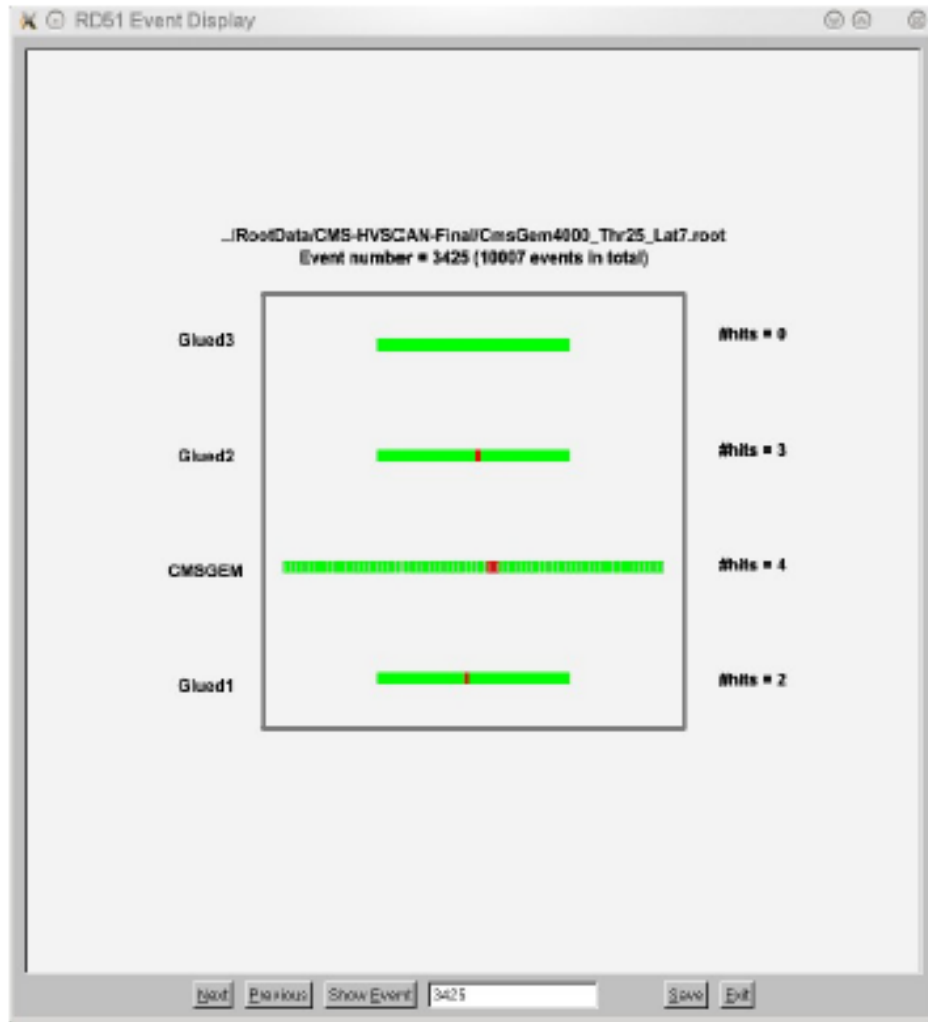
The expected resolution due to a digital readout is $\text{pitch}/\sqrt{12} = 0.8\text{mm}/\sqrt{12} = 230 \mu\text{m}$
 The measured space resolution is $\sim 230 \mu\text{m}$

CMS GEM Preliminary Efficiency .. Ongoing analyses



Efficiency = $\frac{\text{Cluster in CMS GEM close to track crossing point}}{\text{number of tracks}}$

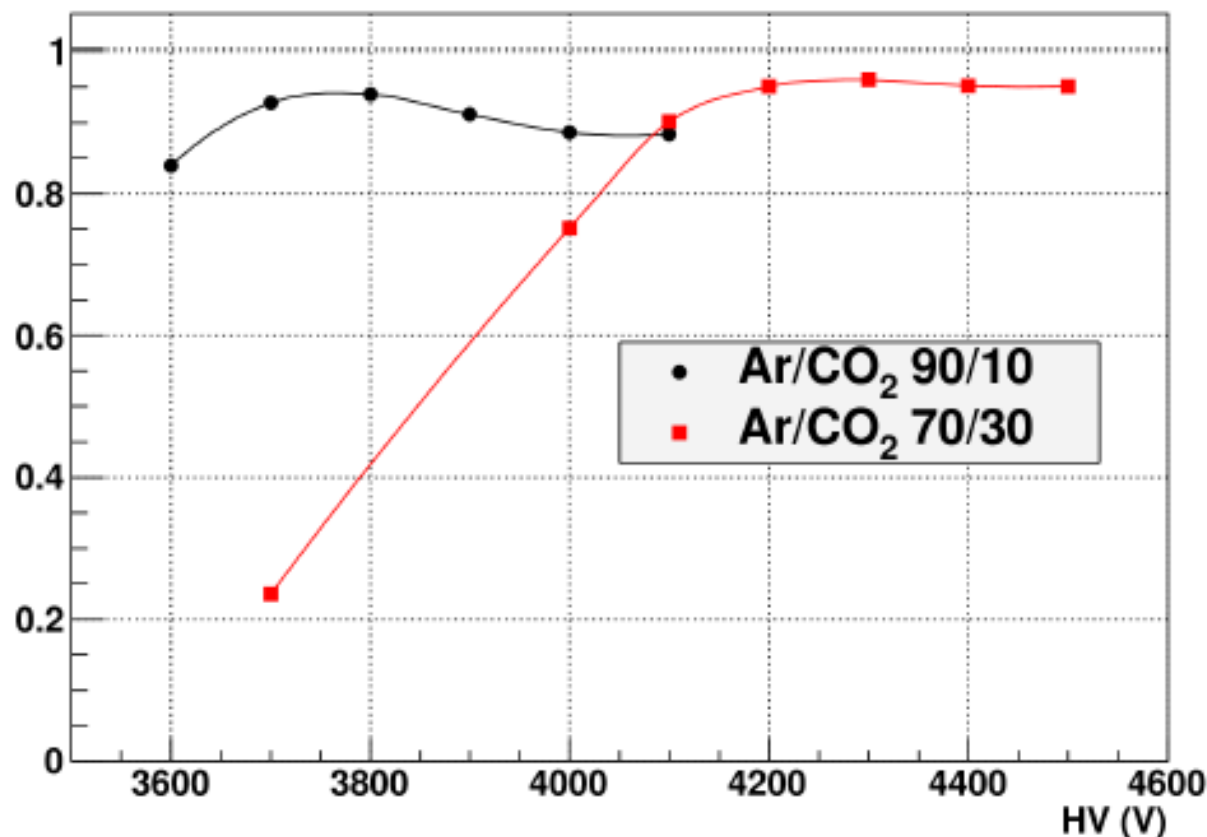
Event Display (I)



- Event display for GEM telescope
- Takes **raw detector hits** as input
- Ability to :
 - › Scan through entire data file event by event
 - › Select specific event
 - › Save event display
- Nice for debugging ...

CMSGEM Efficiencies

CMS GEM Efficiency

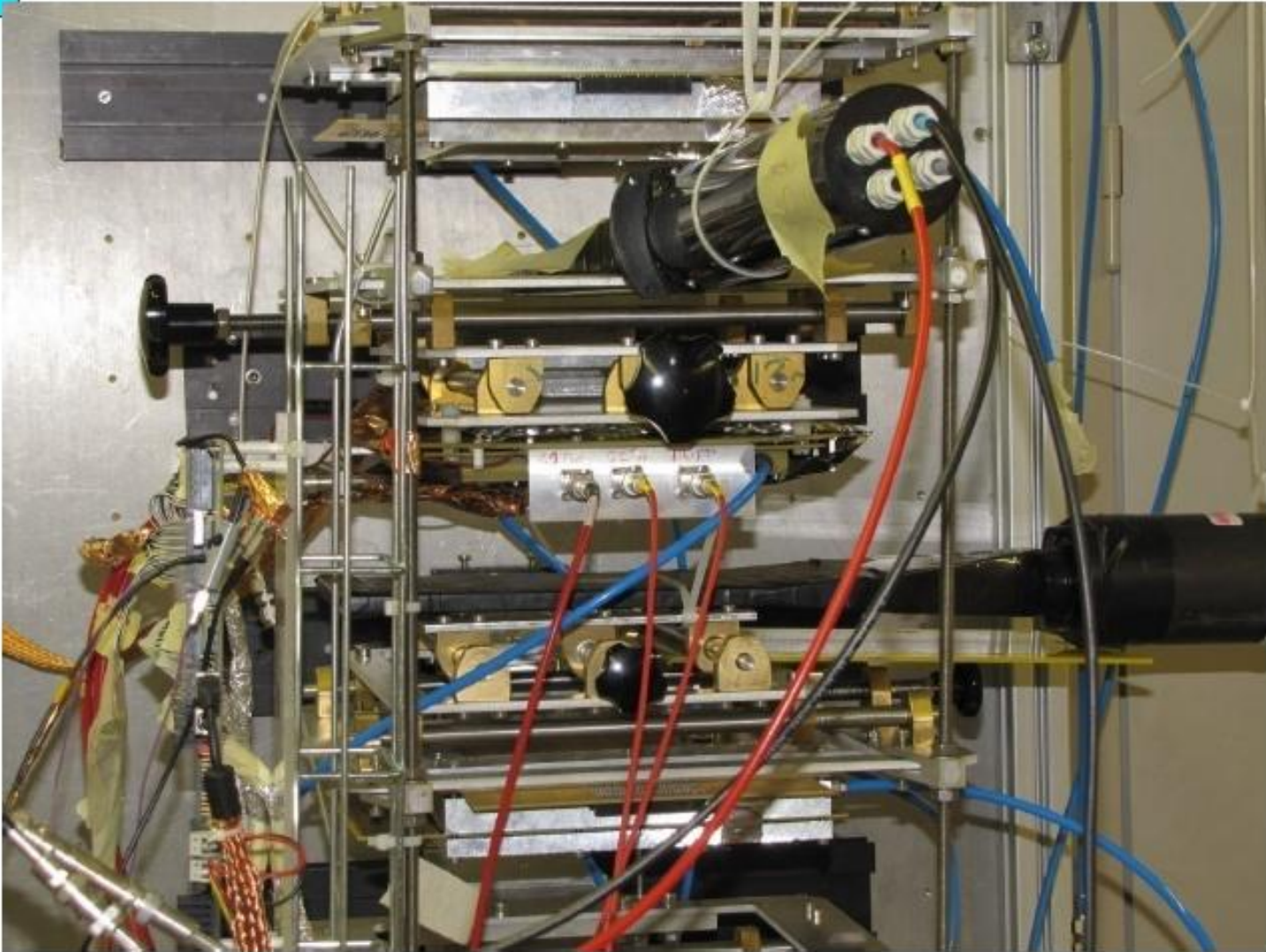


- Efficiency computed using events with 1 track (ie. exactly 1 cluster in glued GEMs), no restriction on number of clusters in CMS GEM

- CMSGEM is "efficient" when

$$|x_{\text{cluster}} - x_{\text{track}}| < 0.8 \text{ mm}$$

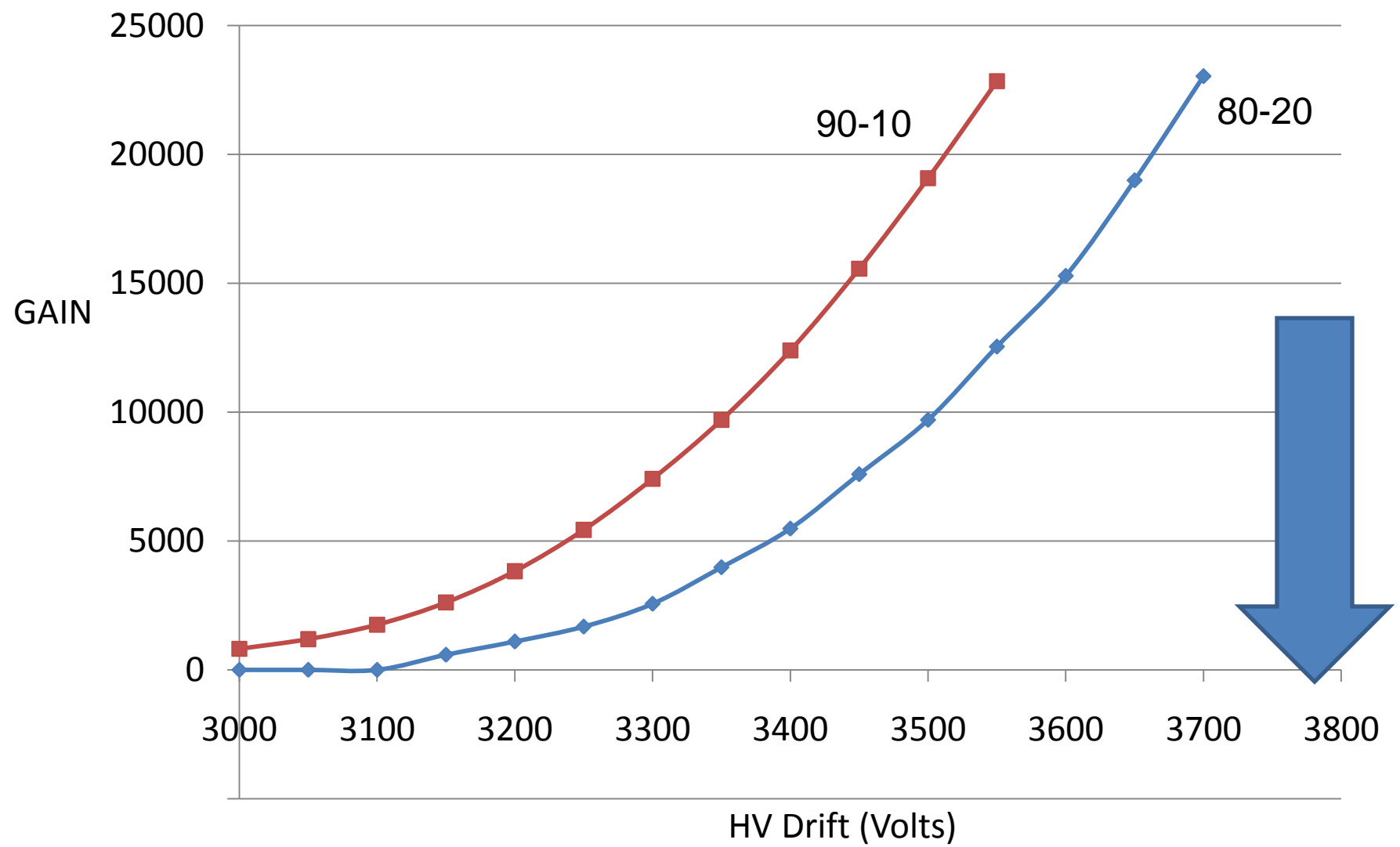
BACK IN THE LAB..Cosmic Stand



Andrey Marinov

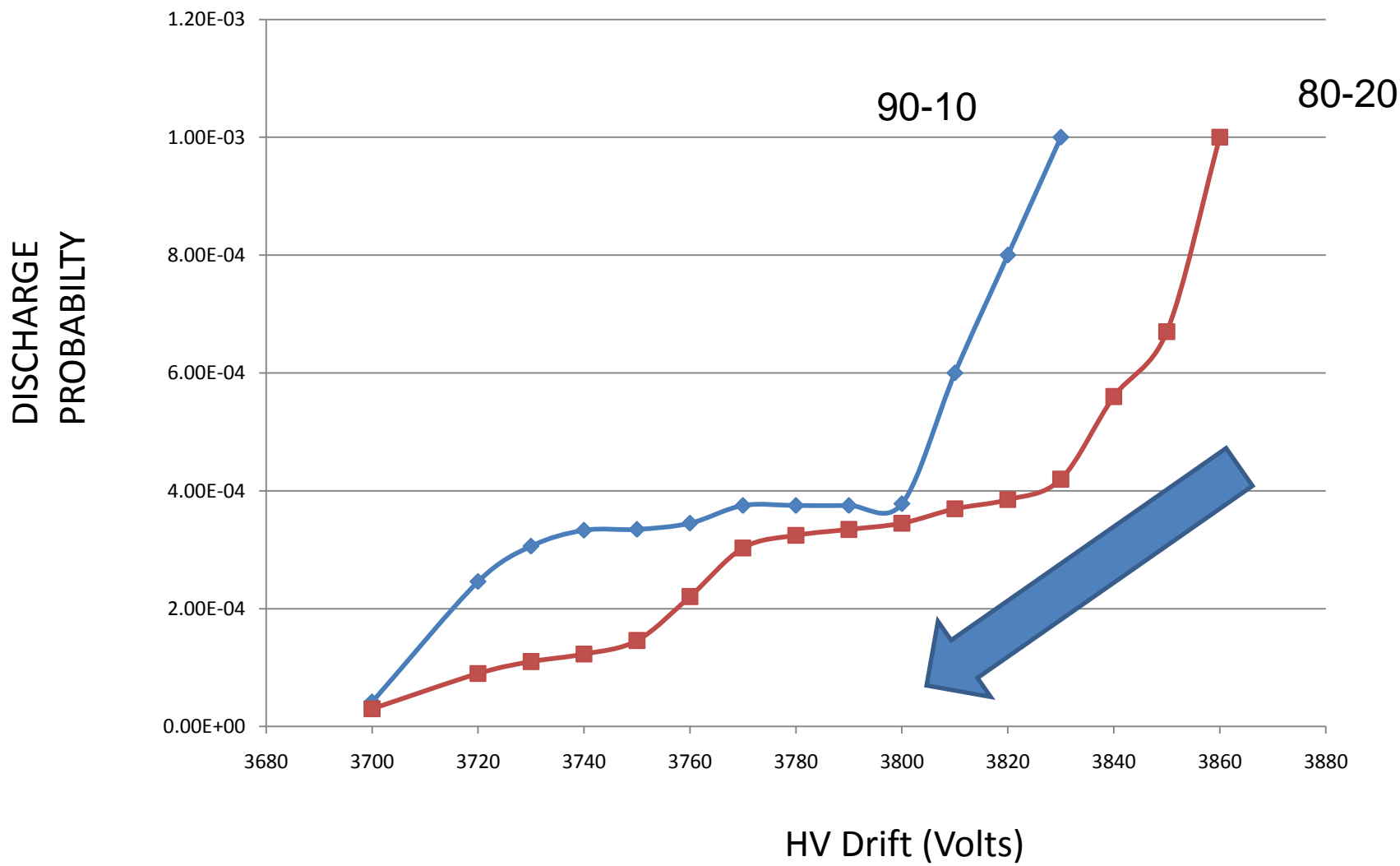


GAIN STUDIES WITH TRIPLE GEM ARGON CO2 CURRENT WITH Cu X-Rays



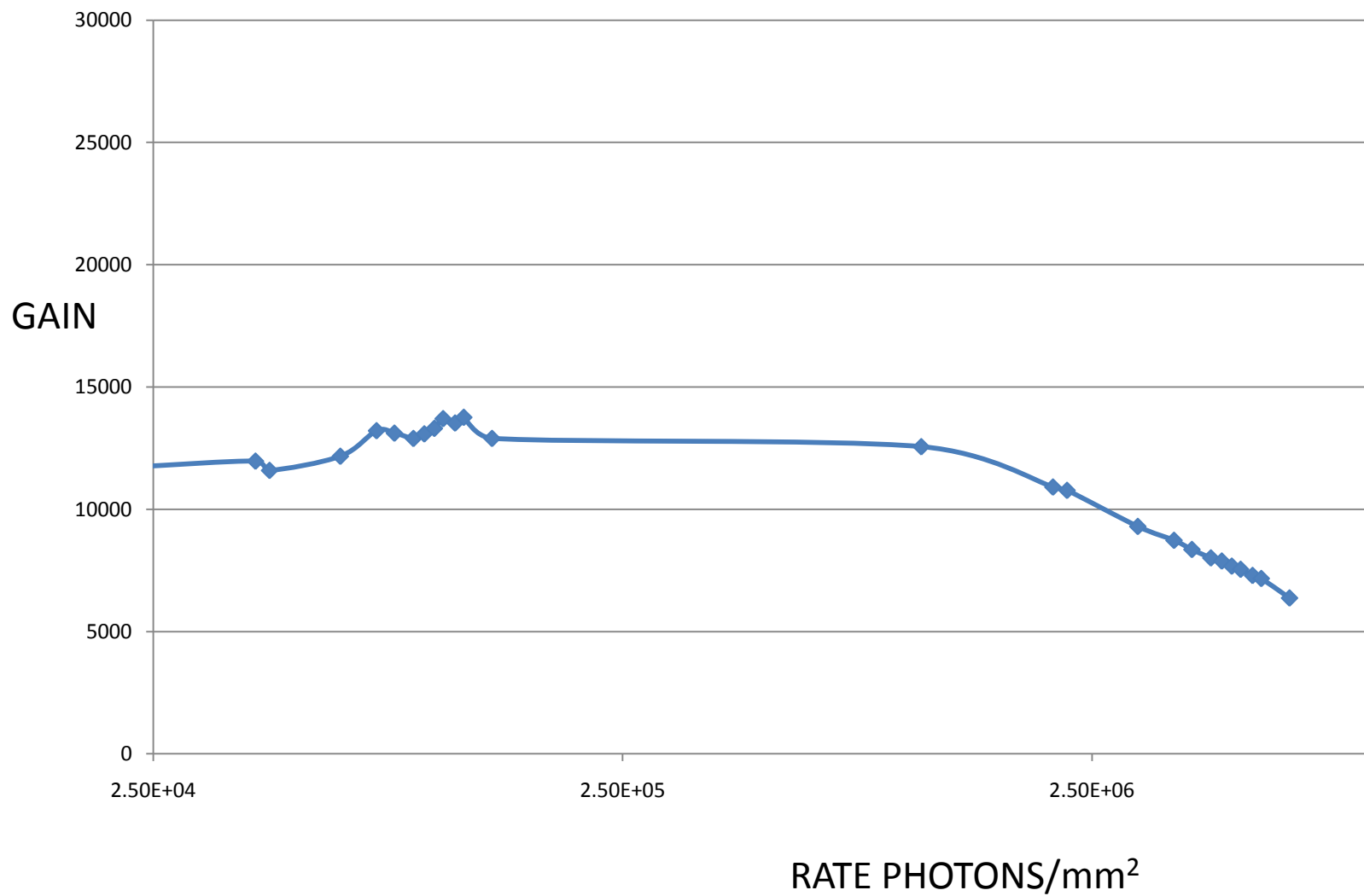


DISCHARGE STUDIES WITH TRIPLE GEM ARGON CO2



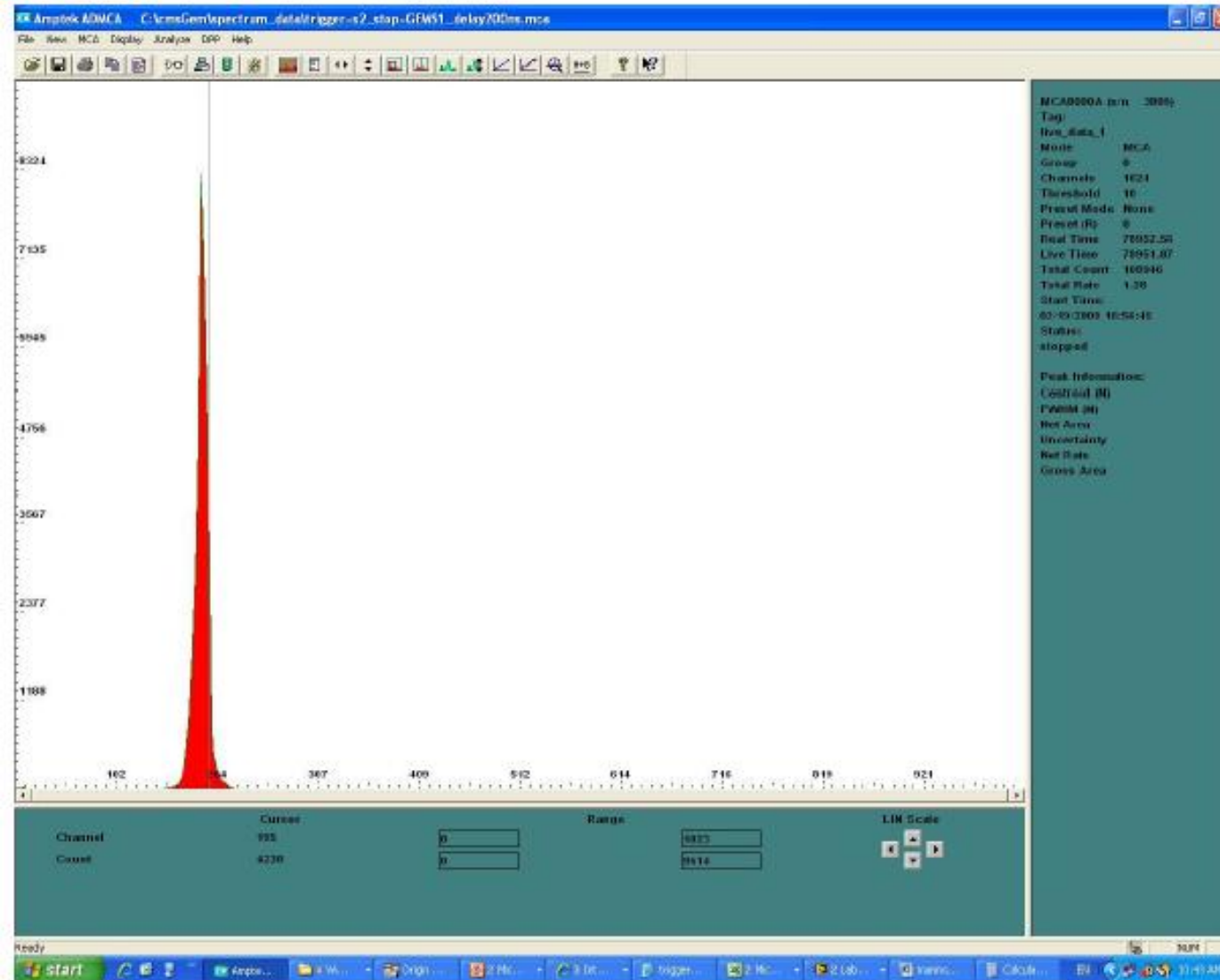


RATE CAPABILITY STUDIES WITH CMS TRIPLE GEM Prototype ARGON CO2 90-10





Timing Studies..



Ar-CO2 70-30
VFAT

Field Configuration:
Ed – 2.5 kV/cm

ET1 – 3.7 kV/cm
ET2 – 3.7 kV/cm
ET3 – 3.7 kV/cm

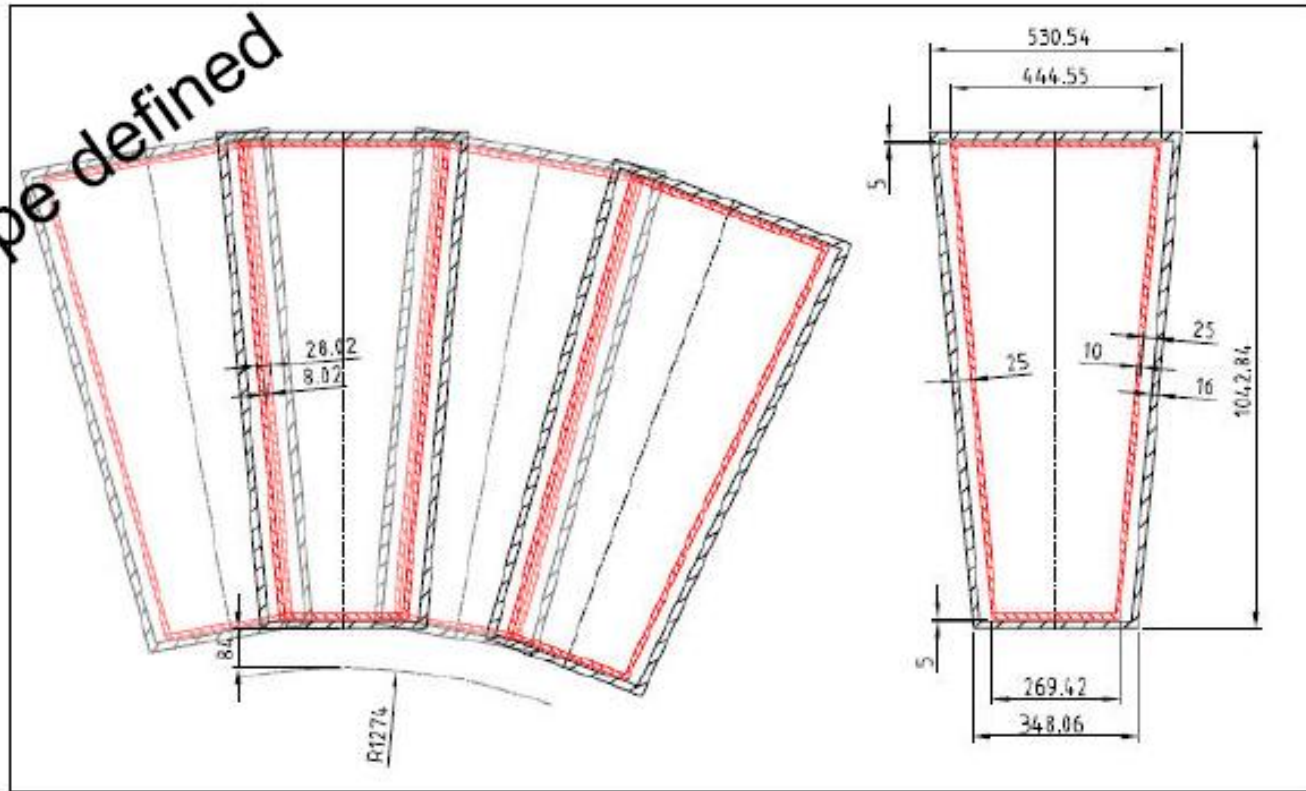
GEM1 – 416 V
GEM2 – 378 V
GEM 3 – 332 V

FWHM – 10.89 ns
RMS – 4.25 ns

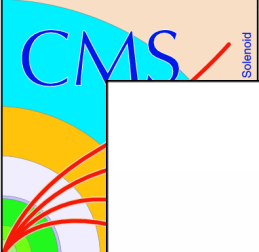
Noise to be reduced

Is it possible to increase the eta coverage from 2.1 to > 2.2 ?
There are mechanical (and installation) constraints to be understood.

Envelope defined



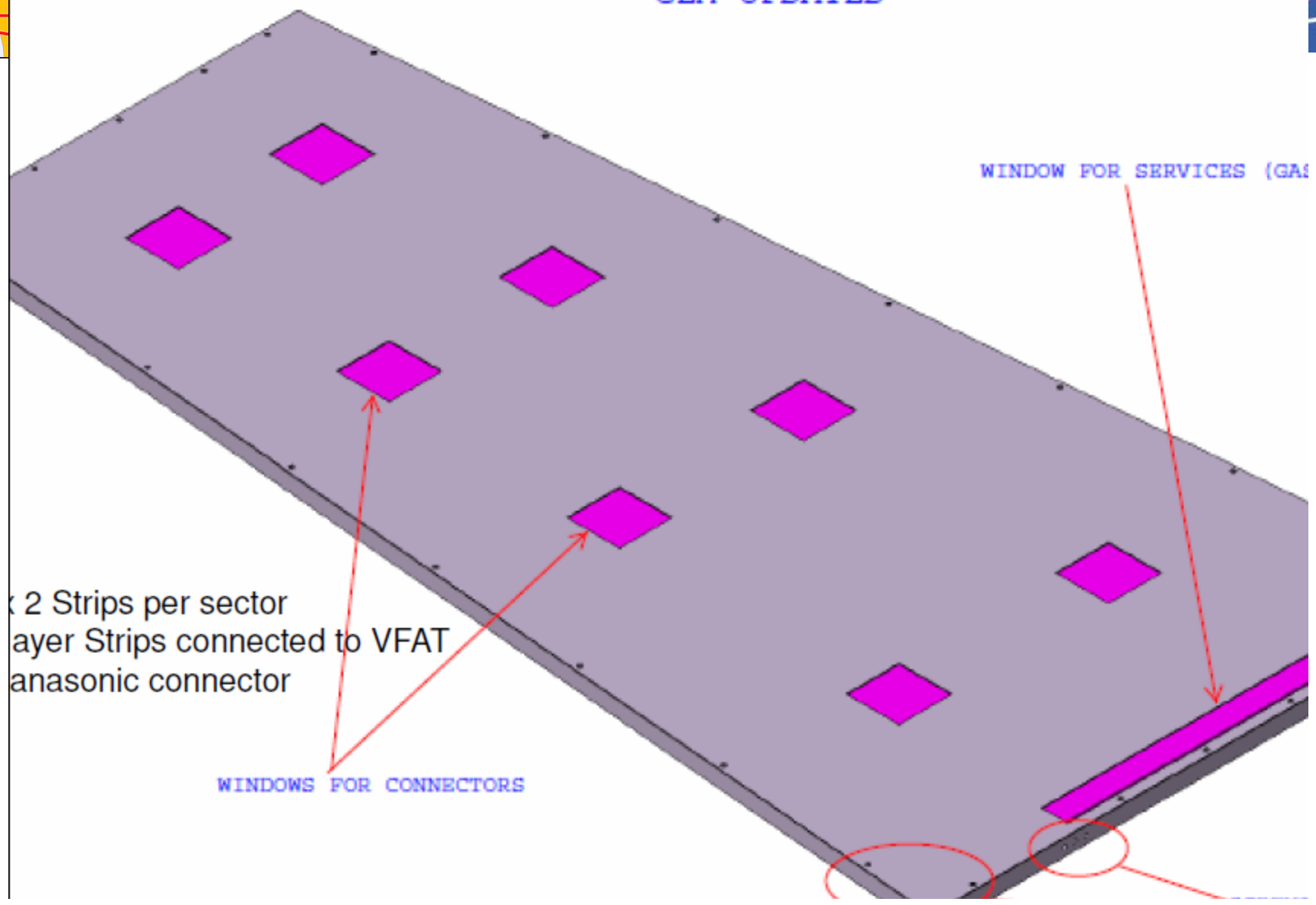
Hans Postema, Stephane Bally, Antonio Conde, Gerard Faber, Jean-Paul Chatelain



CONSTRUCTION OF LARGE PROTOTYPE



GEM UPDATED

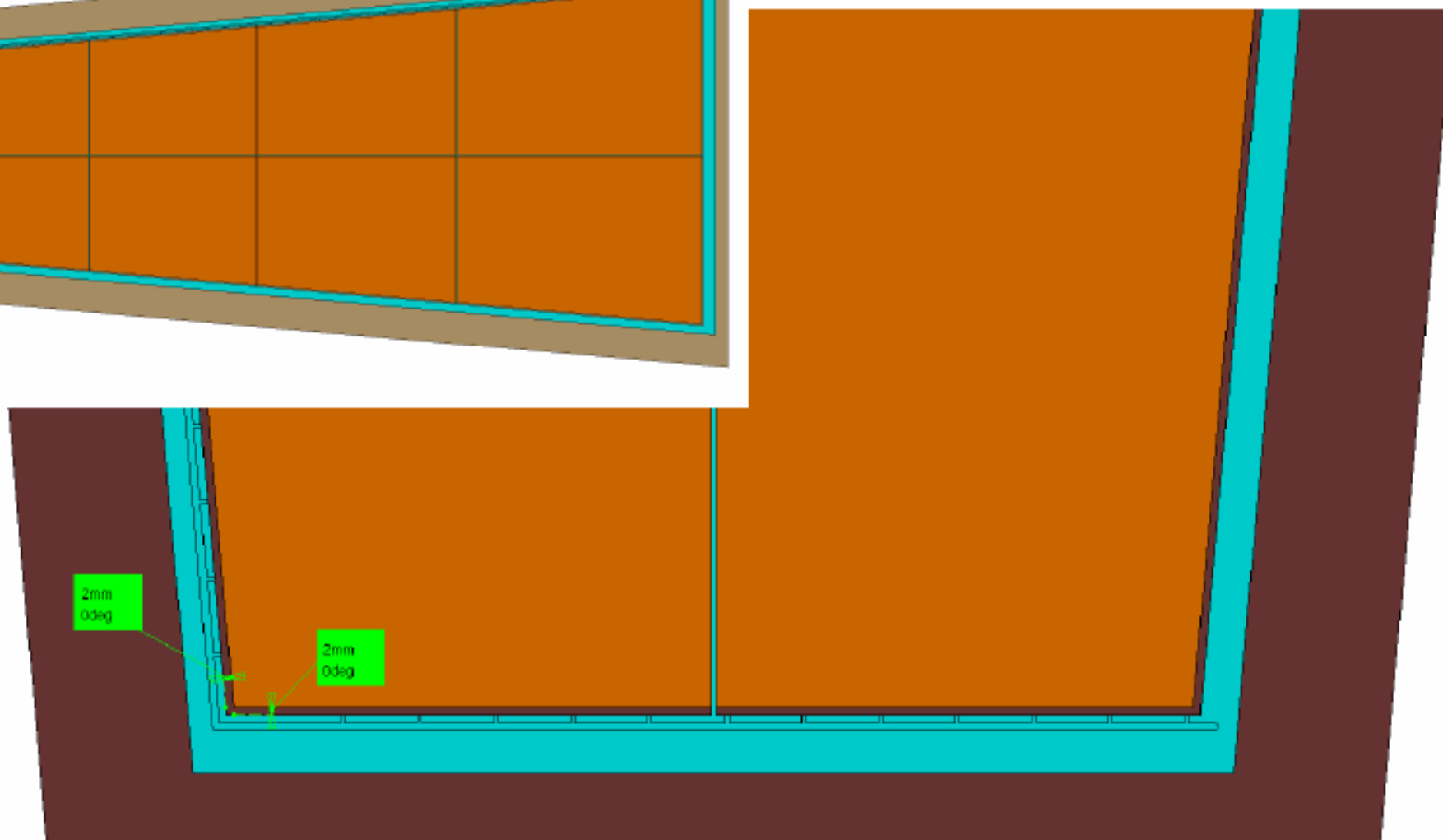
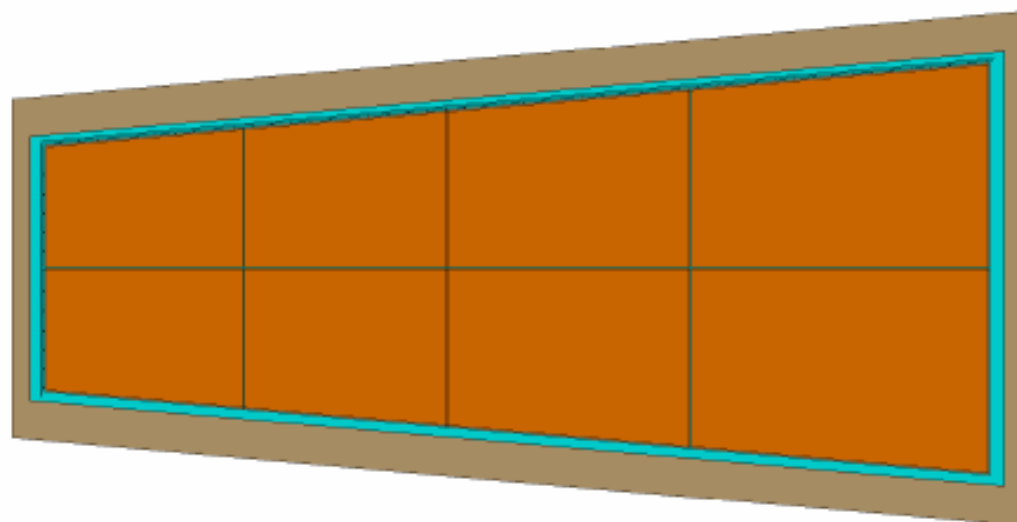


WINDOW FOR SERVICES (GAS)

2 Strips per sector
layer Strips connected to VFAT
anasonic connector

WINDOWS FOR CONNECTORS

Frames, spacers and grooves for gas



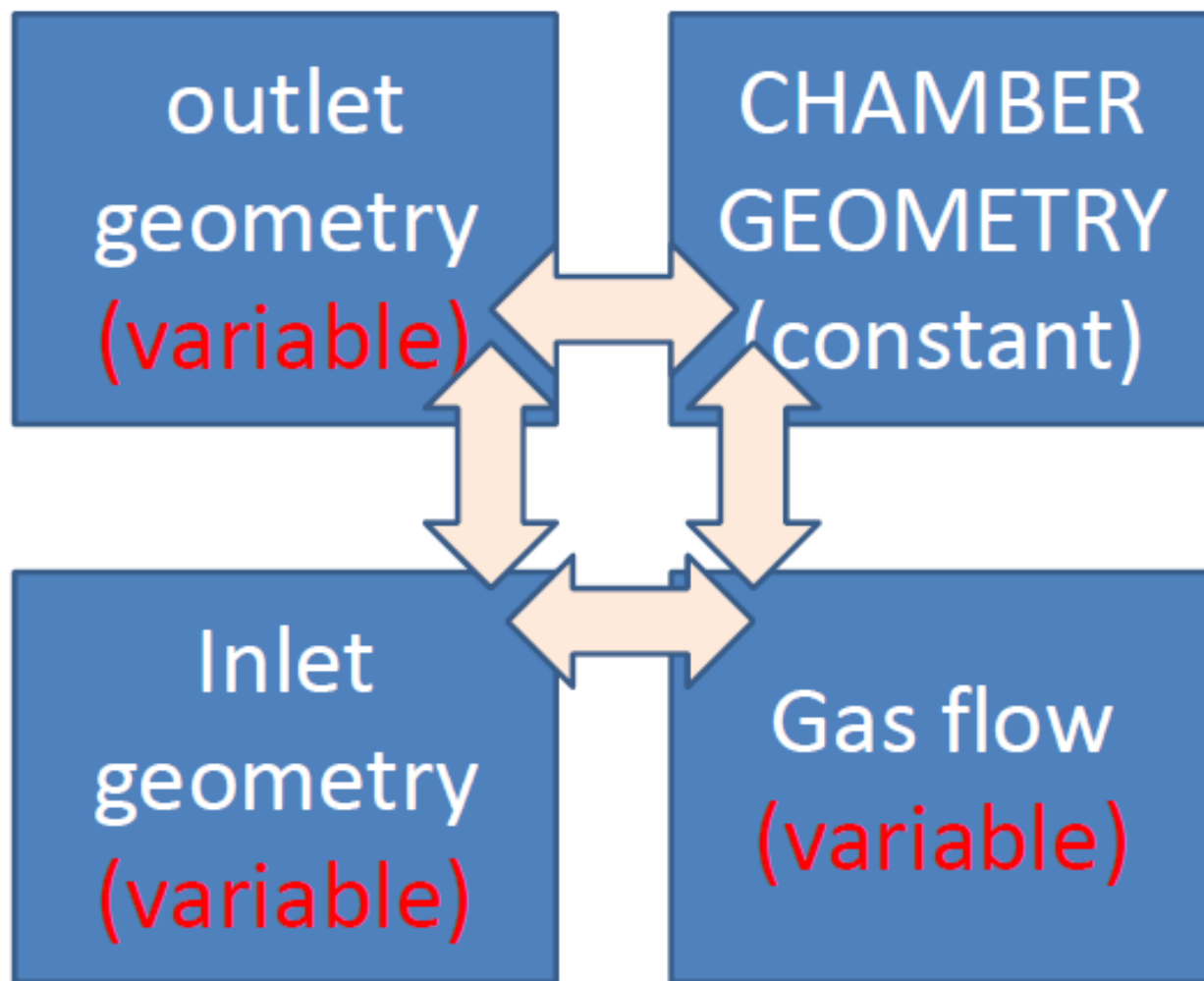


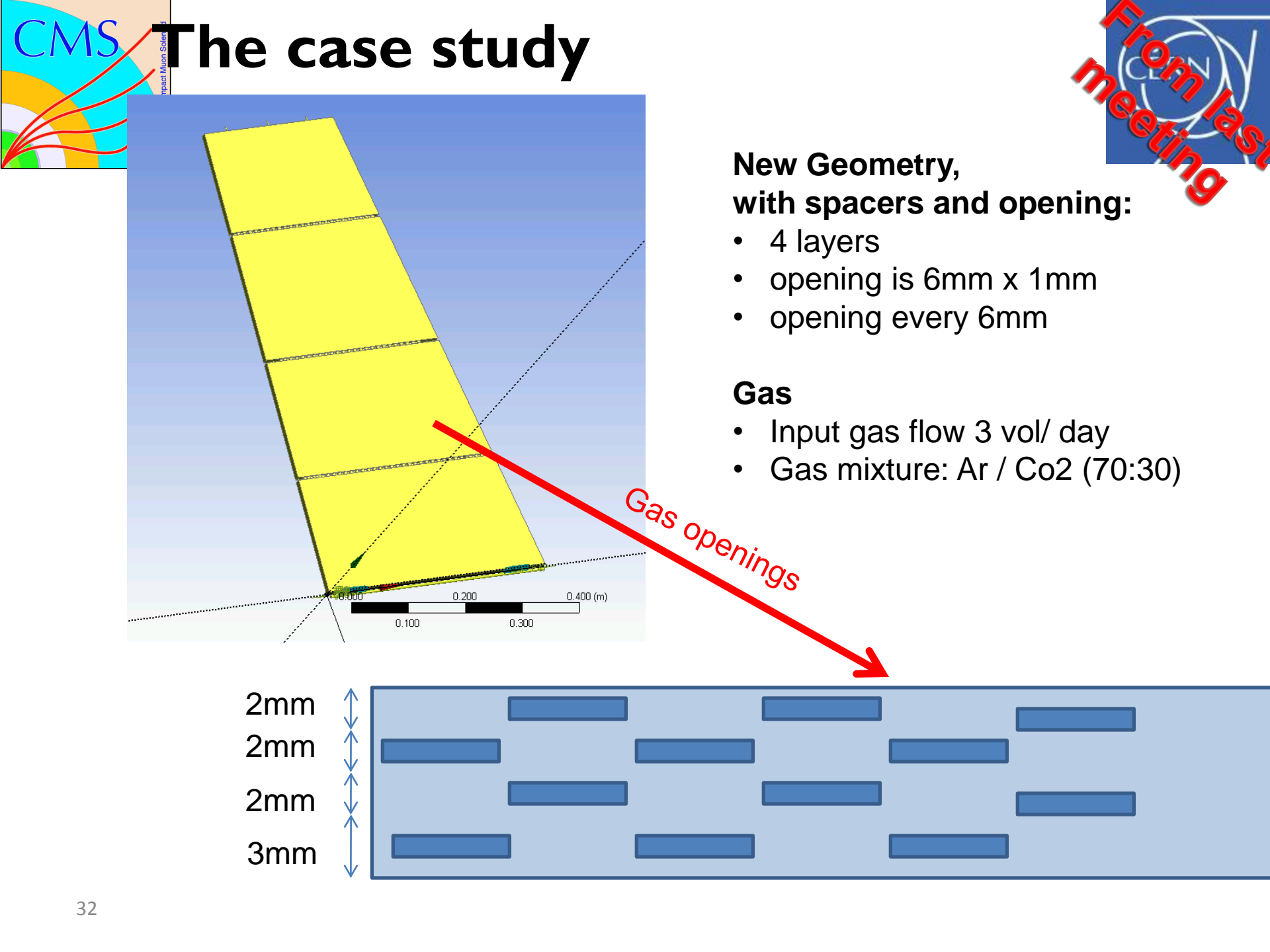
Fluid Dynamics for GEM Preliminary studies

Stefano Colafranceschi



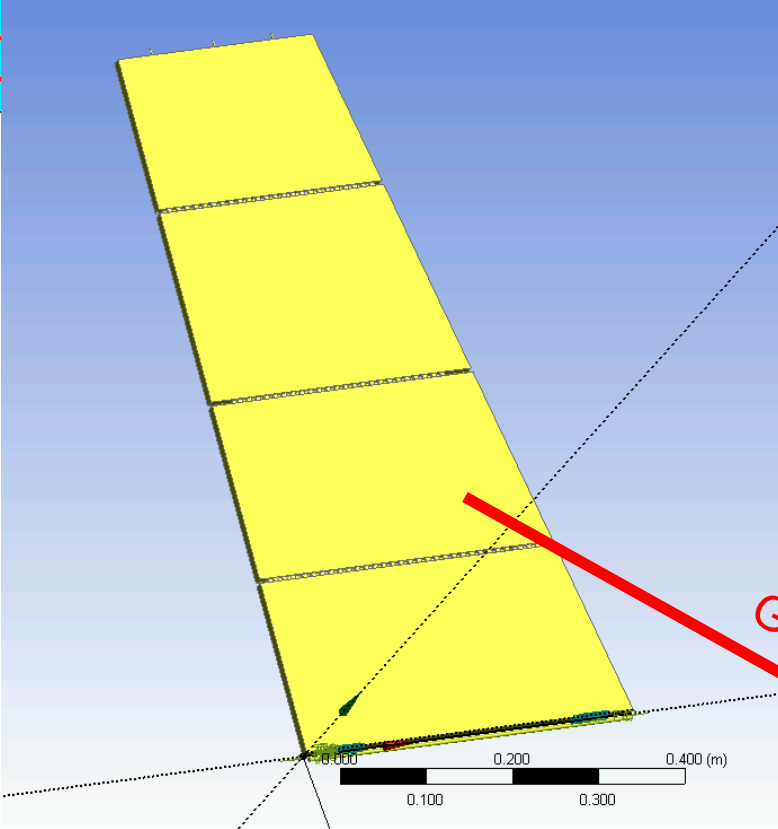
Details in WG4
Gas Flow Simulations





The case study

From last meeting



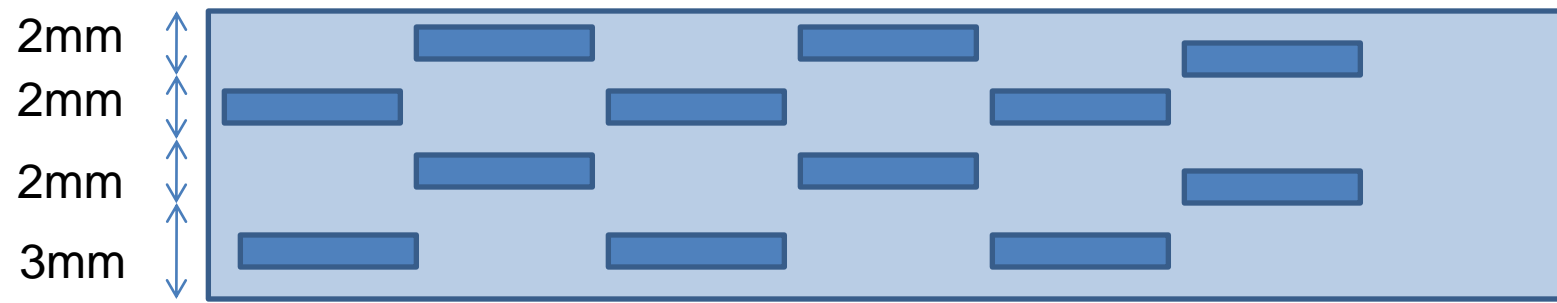
New Geometry, with spacers and opening:

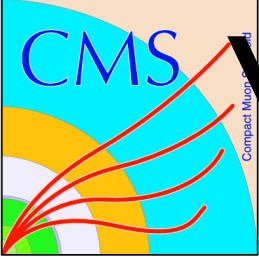
- 4 layers
- opening is 6mm x 1mm
- opening every 6mm

Gas

- Input gas flow 3 vol/ day
- Gas mixture: Ar / Co2 (70:30)

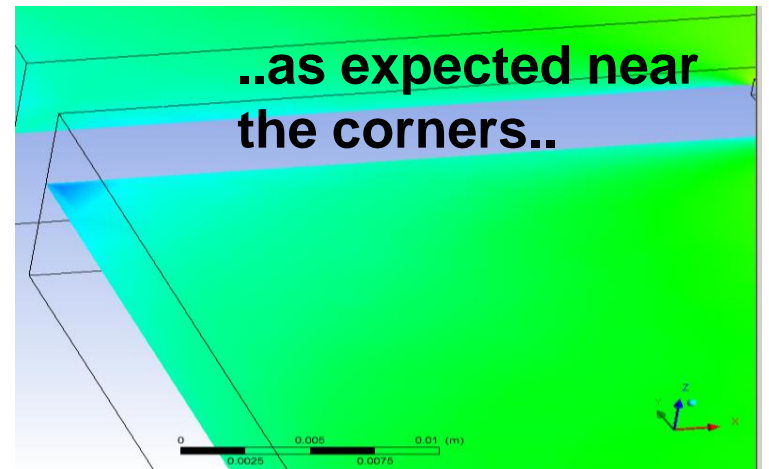
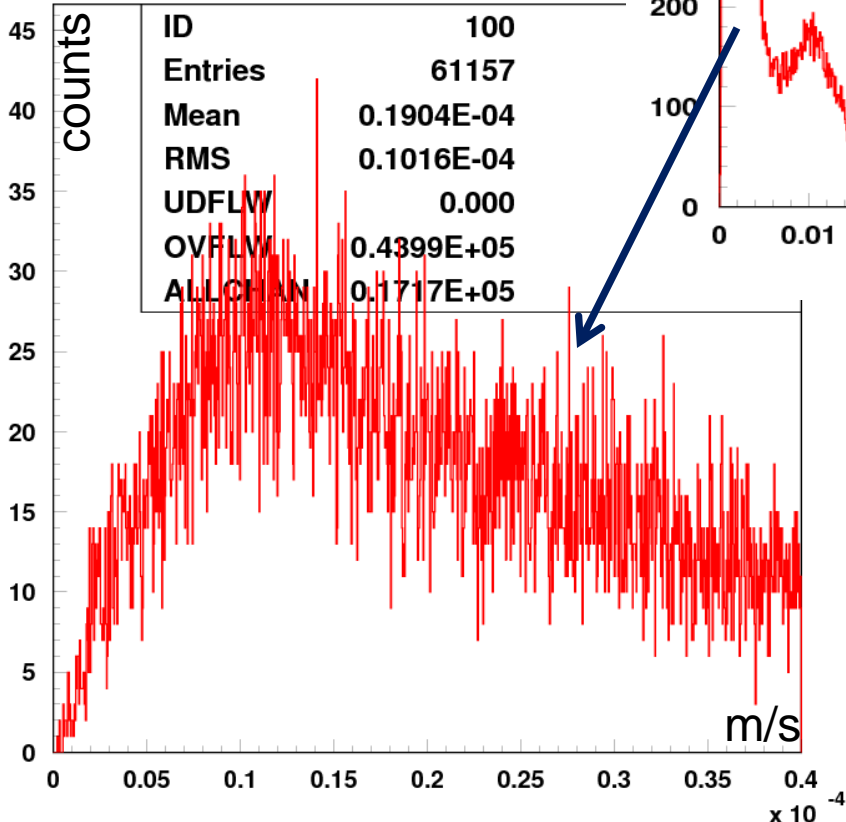
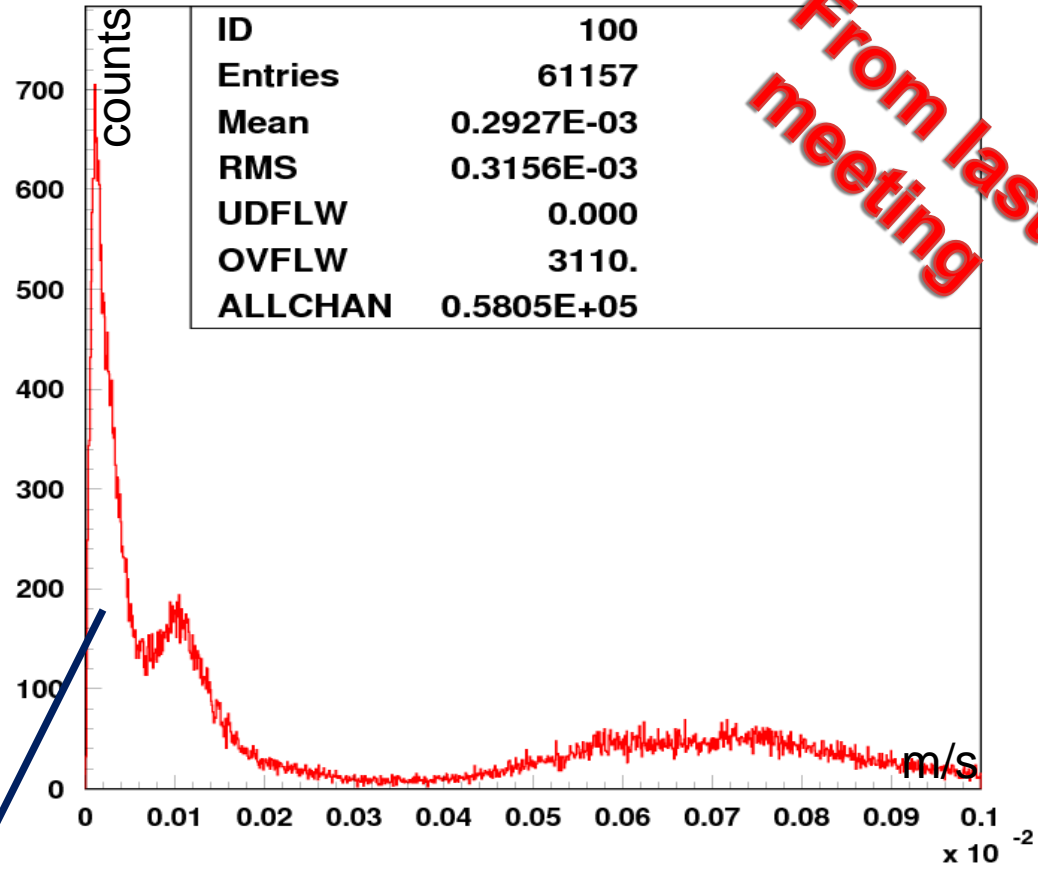
Gas openings

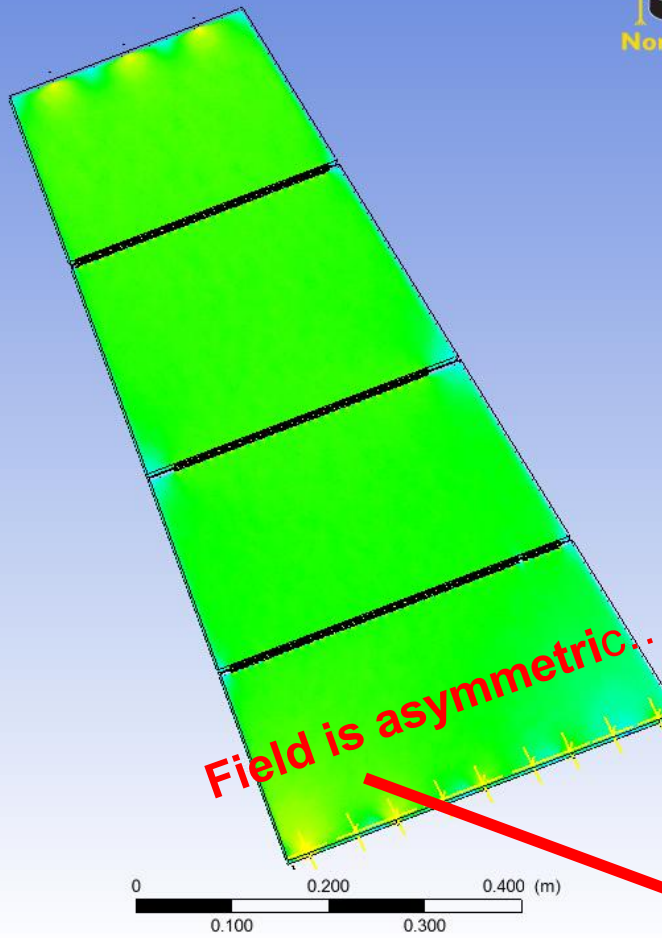
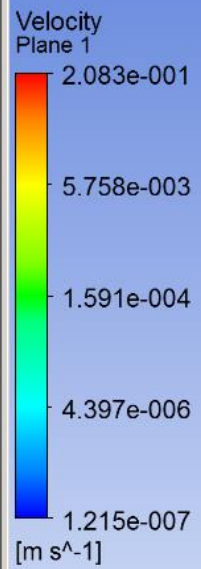




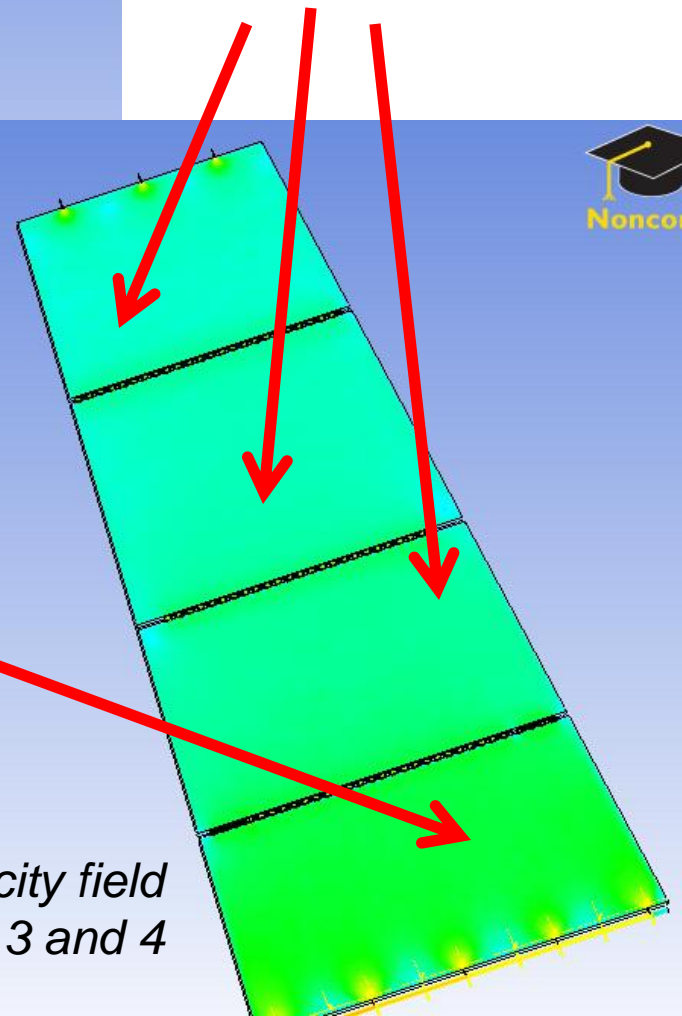
Velocity field

30% chamber
has velocity field 5
times slower with
respect to the mean
value



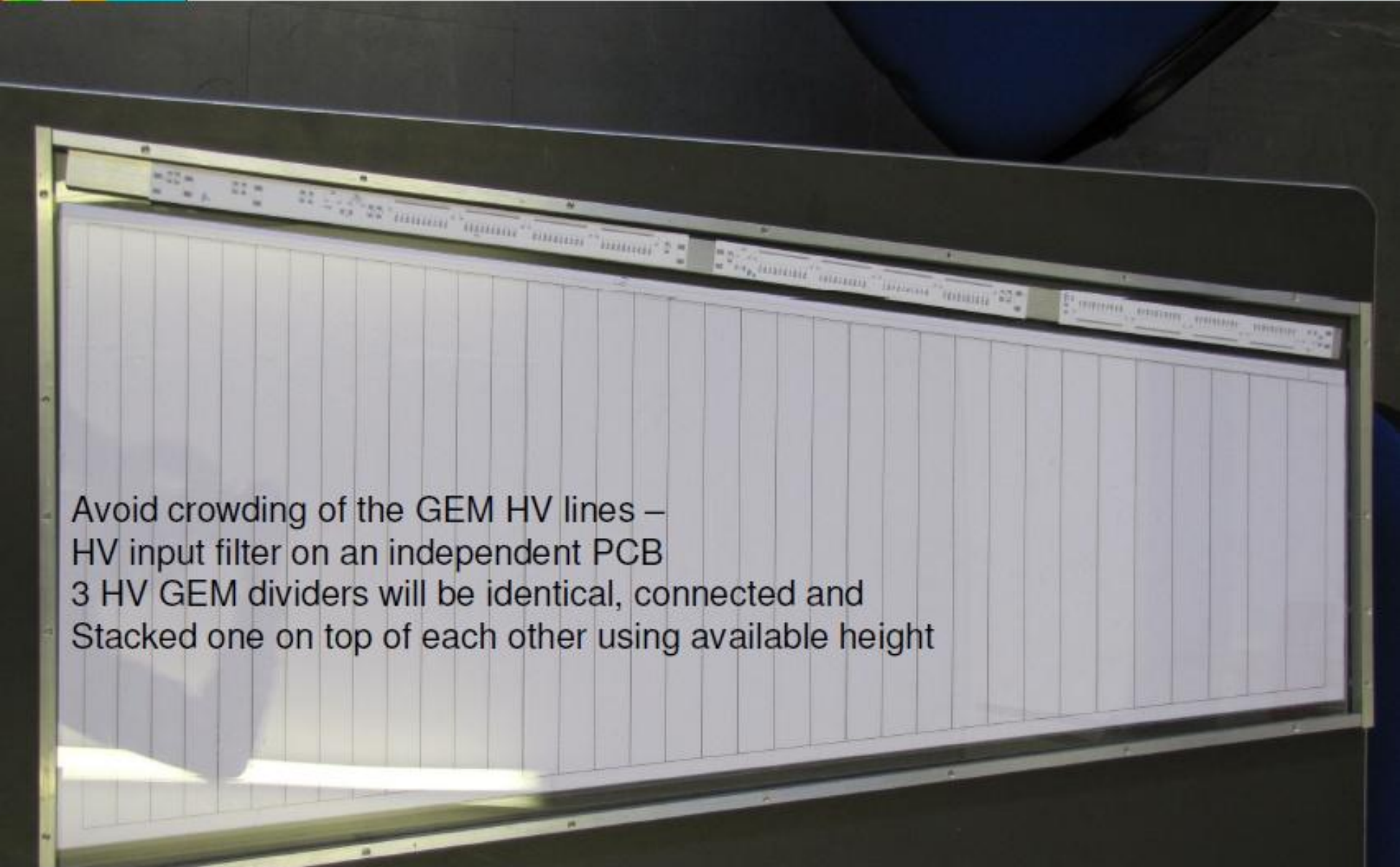


PROBLEMS..



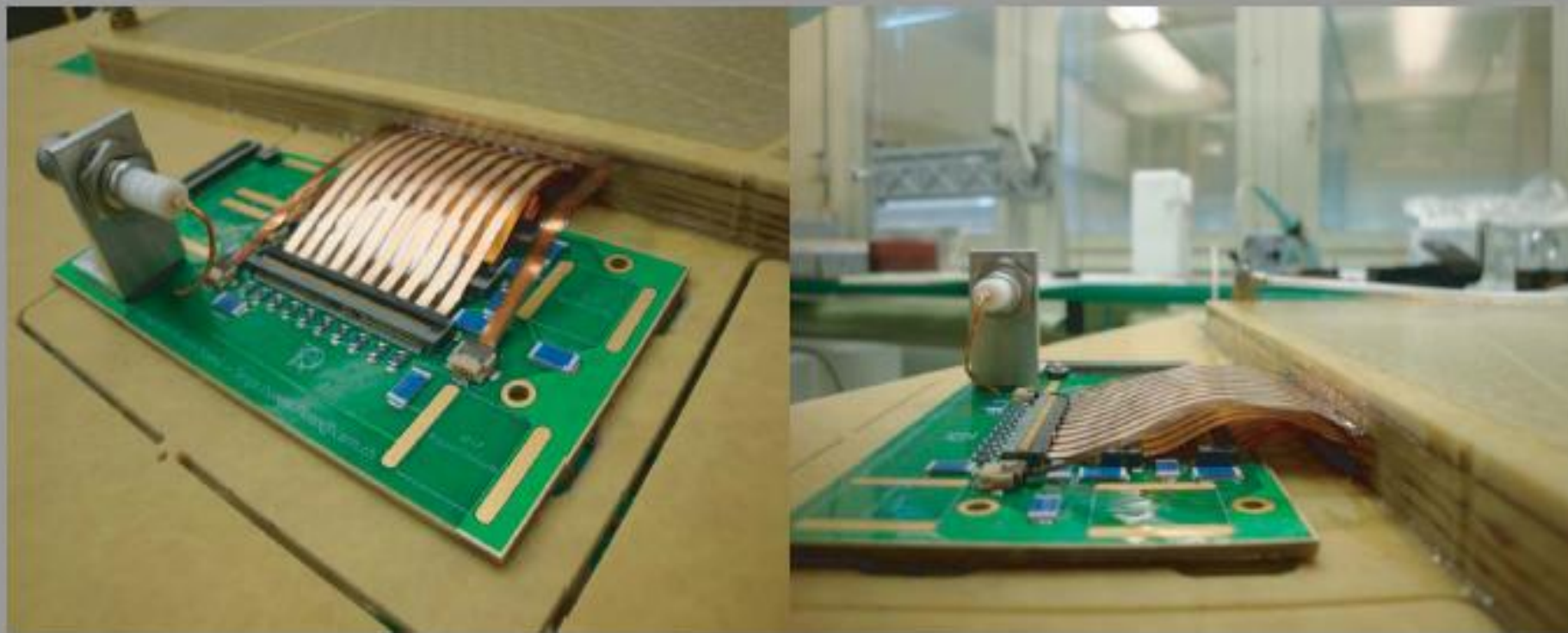
Reducing inlets diameters (1mm) the velocity field is more uniform but slower in the sector 3 and 4

CMS GE1/1 Mock up



Avoid crowding of the GEM HV lines –
HV input filter on an independent PCB
3 HV GEM dividers will be identical, connected and
Stacked one on top of each other using available height

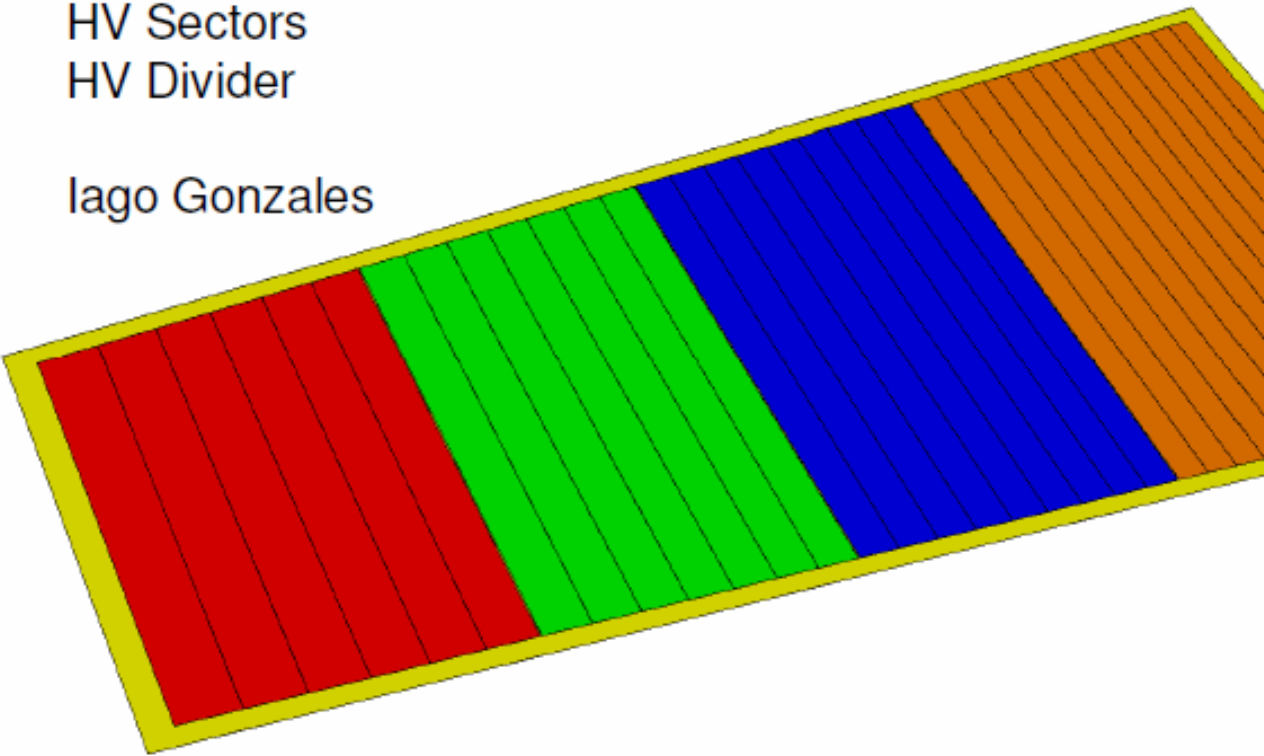
Compact high voltage divider board



- Based on only SMD components
- Using ZIF sockets to connect to GEM terminals
- Traces that lead to GEM sectors are embedded in frame
- Easy to make, and to replace or debug

HV Sectors
HV Divider

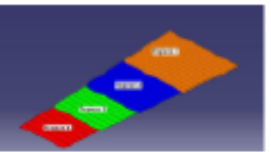
Iago Gonzales



DIMENSION OF THE TRAPEZES

Trapez 1

	a (mm)	A (mm/2)	b (mm)	h (mm)
1.000	419.054	9200.300	416.080	22.000
2.000	418.297	9200.300	415.180	22.110
3.000	417.540	9200.300	404.280	22.220
4.000	408.183	9200.300	404.379	22.640
5.000	404.700	9200.300	400.500	22.870
6.000	400.174	9200.300	396.131	23.100
7.000	396.105	9200.300	392.020	23.340
8.000	391.594	9200.300	387.860	23.590
9.000	387.230	9200.300	383.560	23.840
10.000	383.045	9200.300	379.430	24.100
11.000	379.364	9200.300	375.170	24.360
12.000	375.120	9200.300	370.790	24.630
13.000	370.758	9200.300	366.340	24.910



Trapez 2

	a (mm)	A (mm/2)	b (mm)	h (mm)
1.000	365.180	9200.300	361.600	26.100
2.000	361.775	9200.300	356.940	26.440
3.000	358.021	9200.300	352.230	26.780
4.000	354.209	9200.300	347.480	27.130
5.000	349.620	9200.300	342.610	27.500
6.000	345.488	9200.300	337.630	27.880
7.000	341.637	9200.300	332.530	28.280
8.000	338.080	9200.300	327.650	28.700
9.000	334.825	9200.300	322.680	29.140



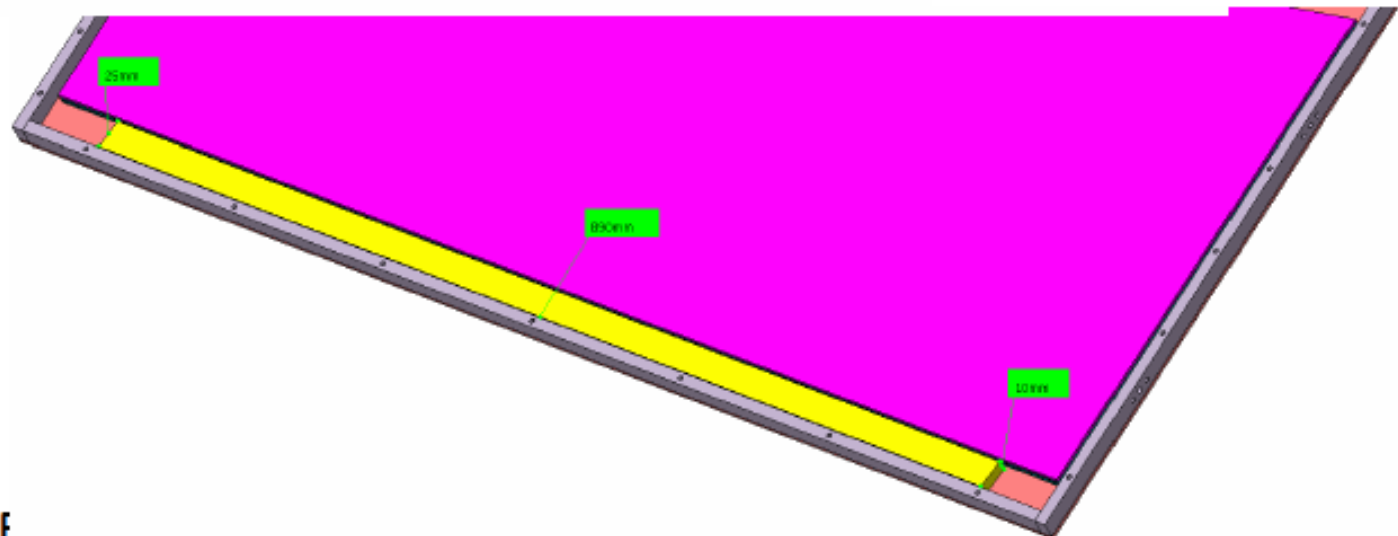
Trapez 3

	a (mm)	A (mm/2)	b (mm)	h (mm)
1.000	312.500	9200.300	317.570	28.100
2.000	312.540	9200.300	311.510	28.840
3.000	312.580	9200.300	305.420	29.580
4.000	307.380	9200.300	300.200	30.410
5.000	307.181	9200.300	294.910	30.130
6.000	298.881	9200.300	291.510	30.870
7.000	291.480	9200.300	286.000	31.620

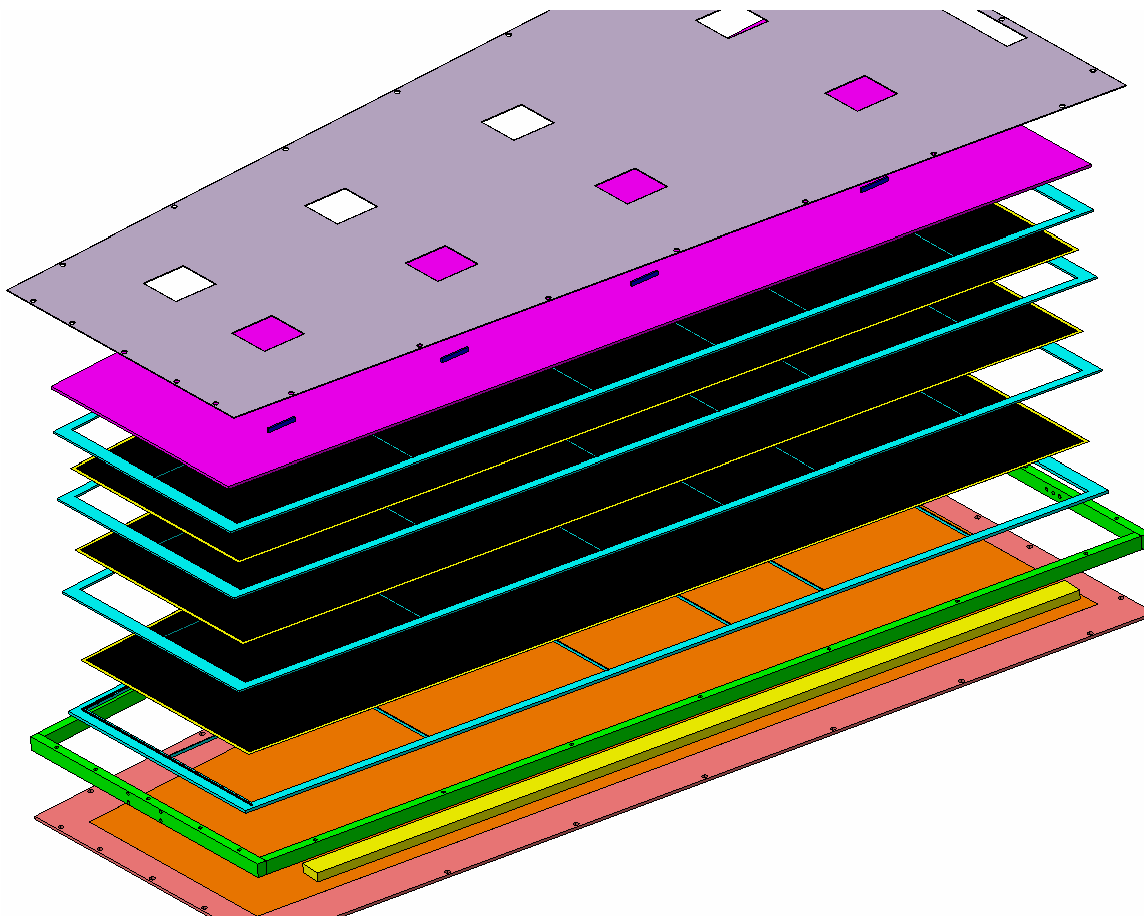
Trapez 4

	a (mm)	A (mm/2)	b (mm)	h (mm)
1.000	257.334	9200.300	263.210	31.910
2.000	258.334	9200.300	257.820	32.420
3.000	259.477	9200.300	252.440	32.930
4.000	258.620	9200.300	247.070	33.060
5.000	247.633	9200.300	246.510	34.800
6.000	246.500	9200.300	240.230	35.230

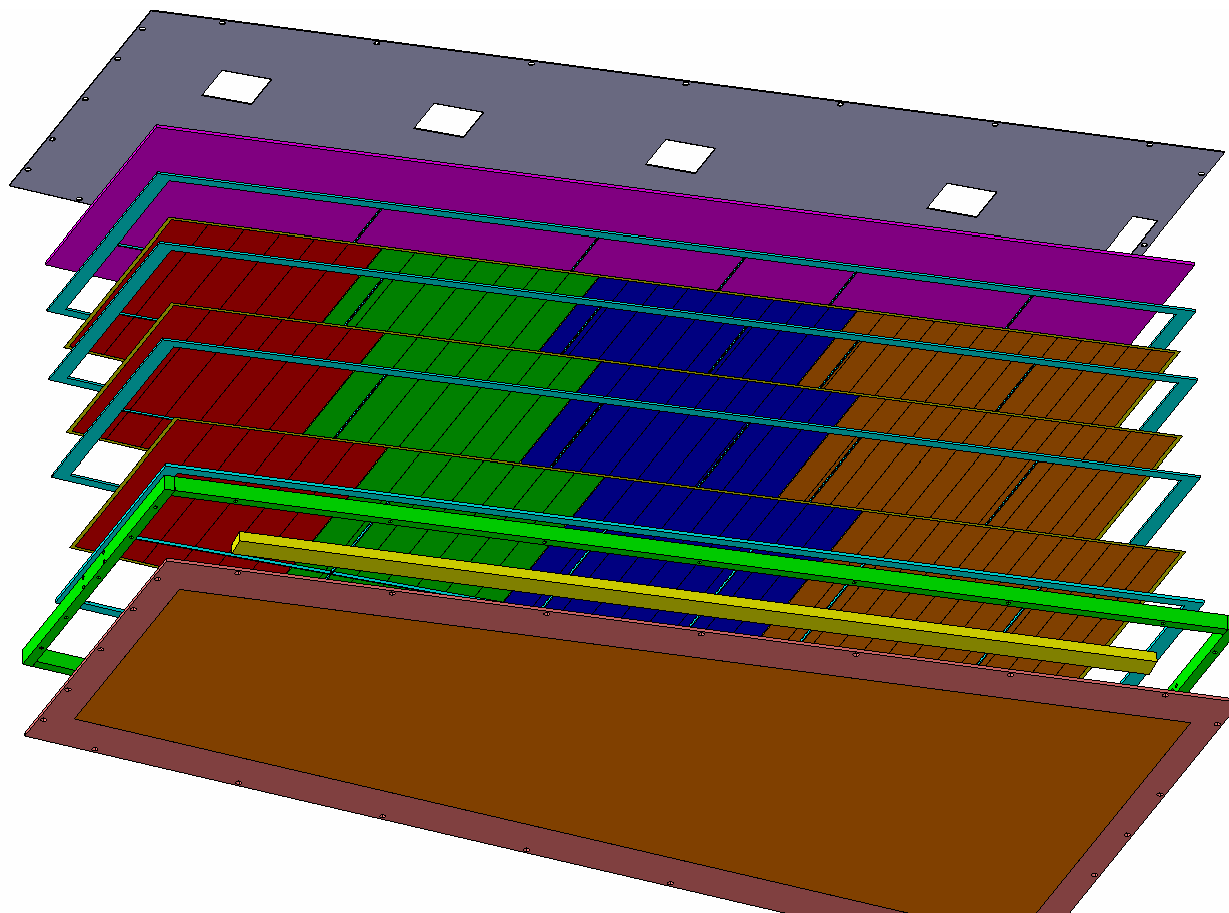
Iago Gonzales Tabares
PH-CMX-05
12/1/2010



CMS Prototype GEM - Stack

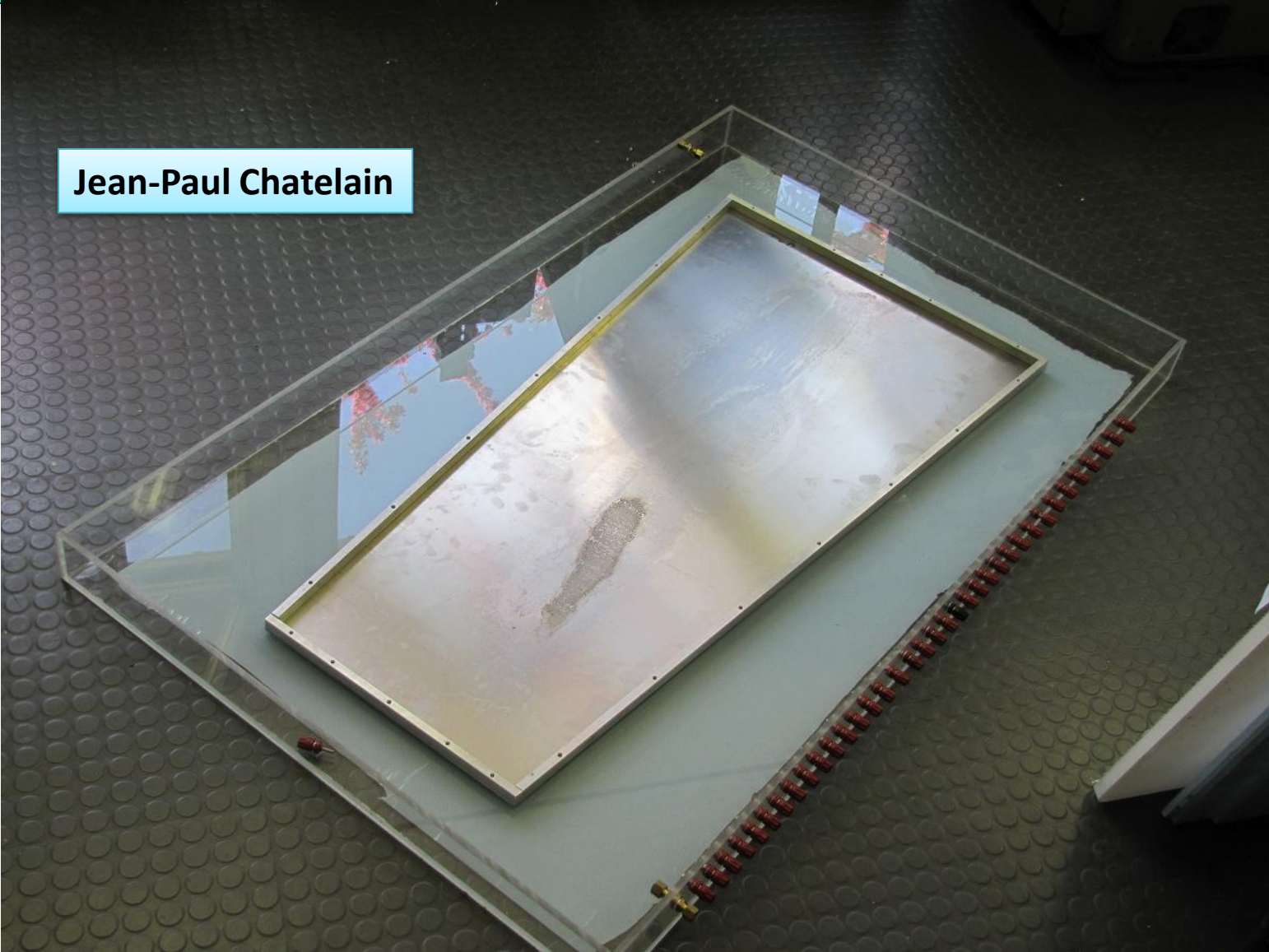


CMS Prototype GEM - Stack

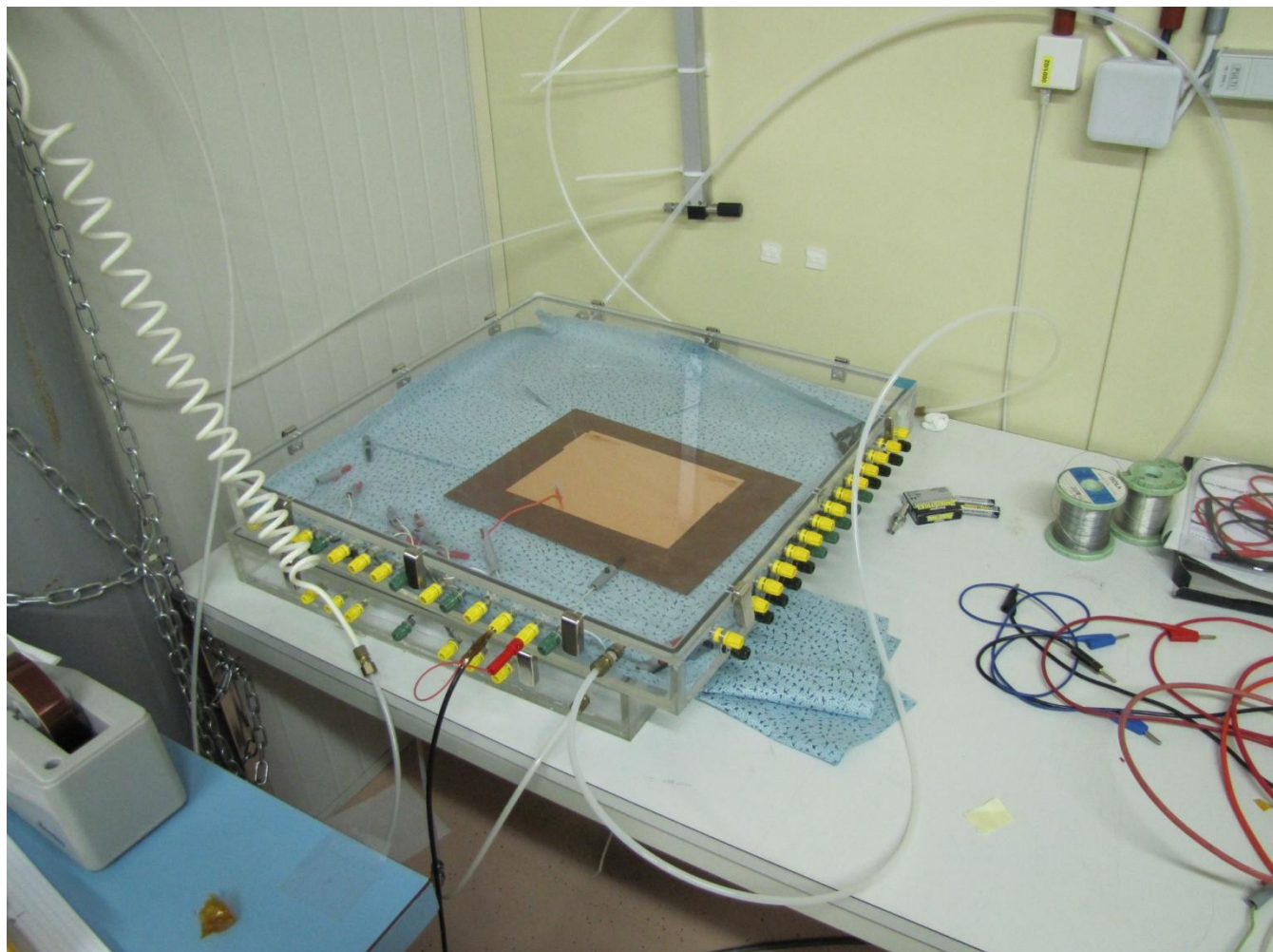


CMS Prototype GEM - Test Box

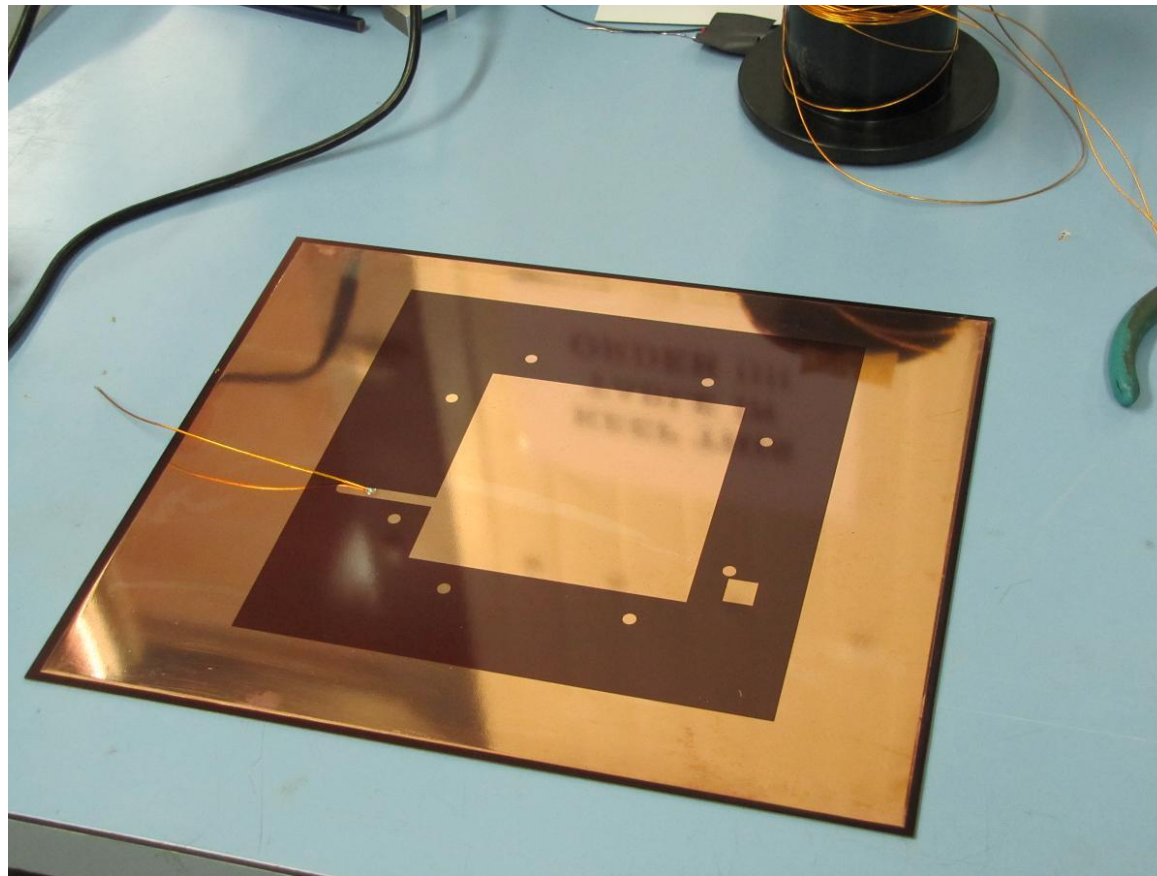
Jean-Paul Chatelain



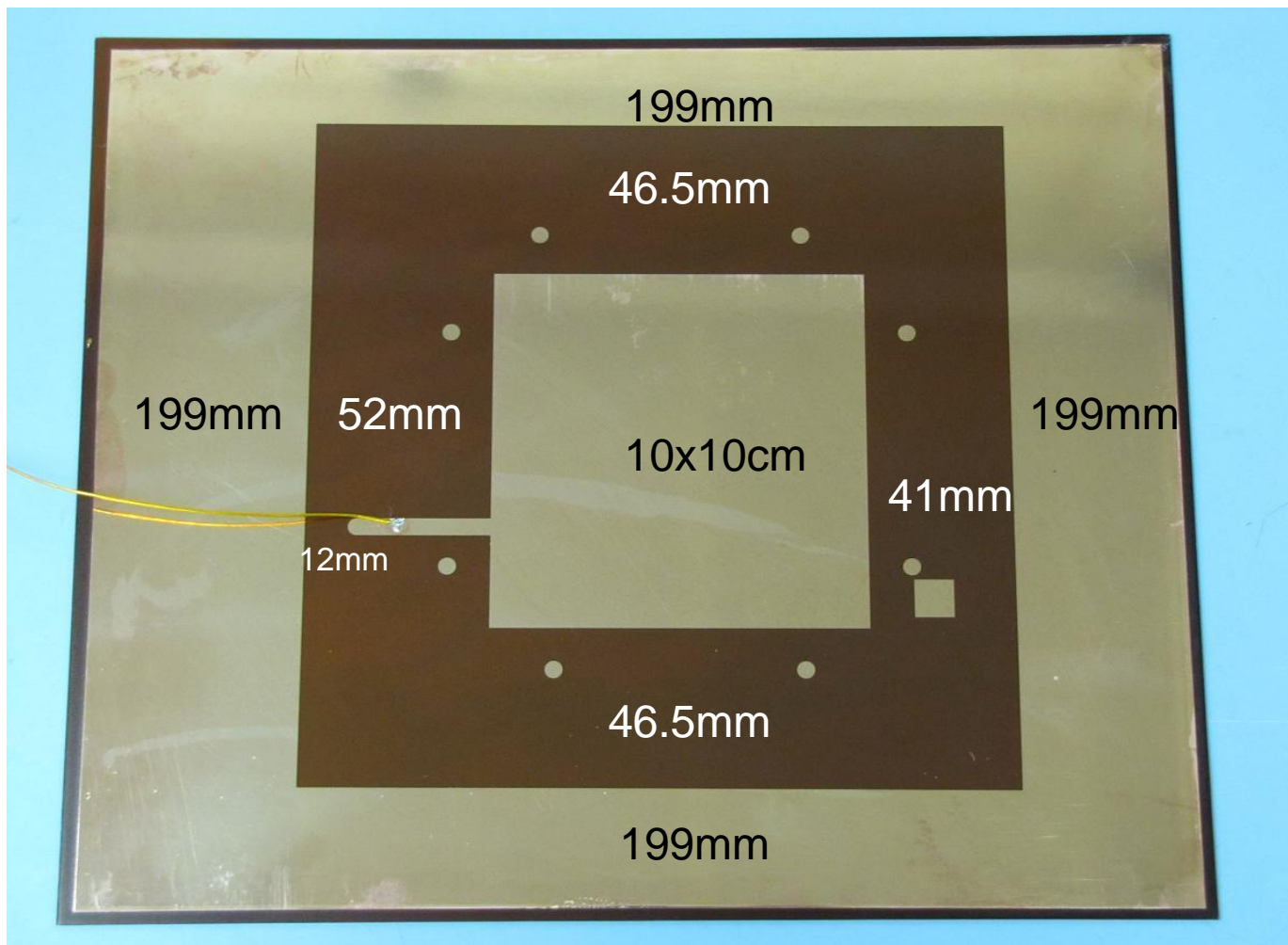
Ongoing Drift Electrode Tests



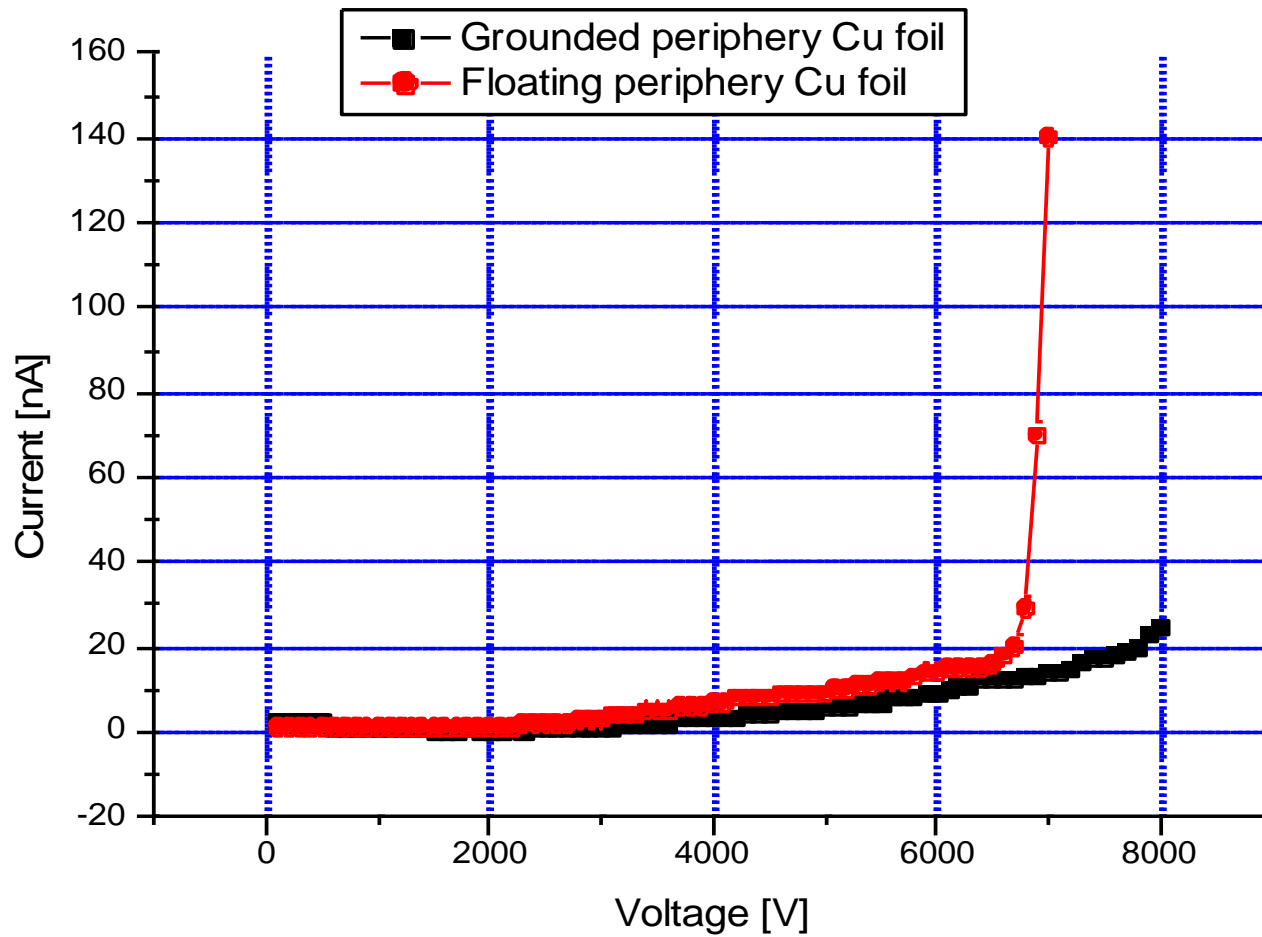
Drift Sample



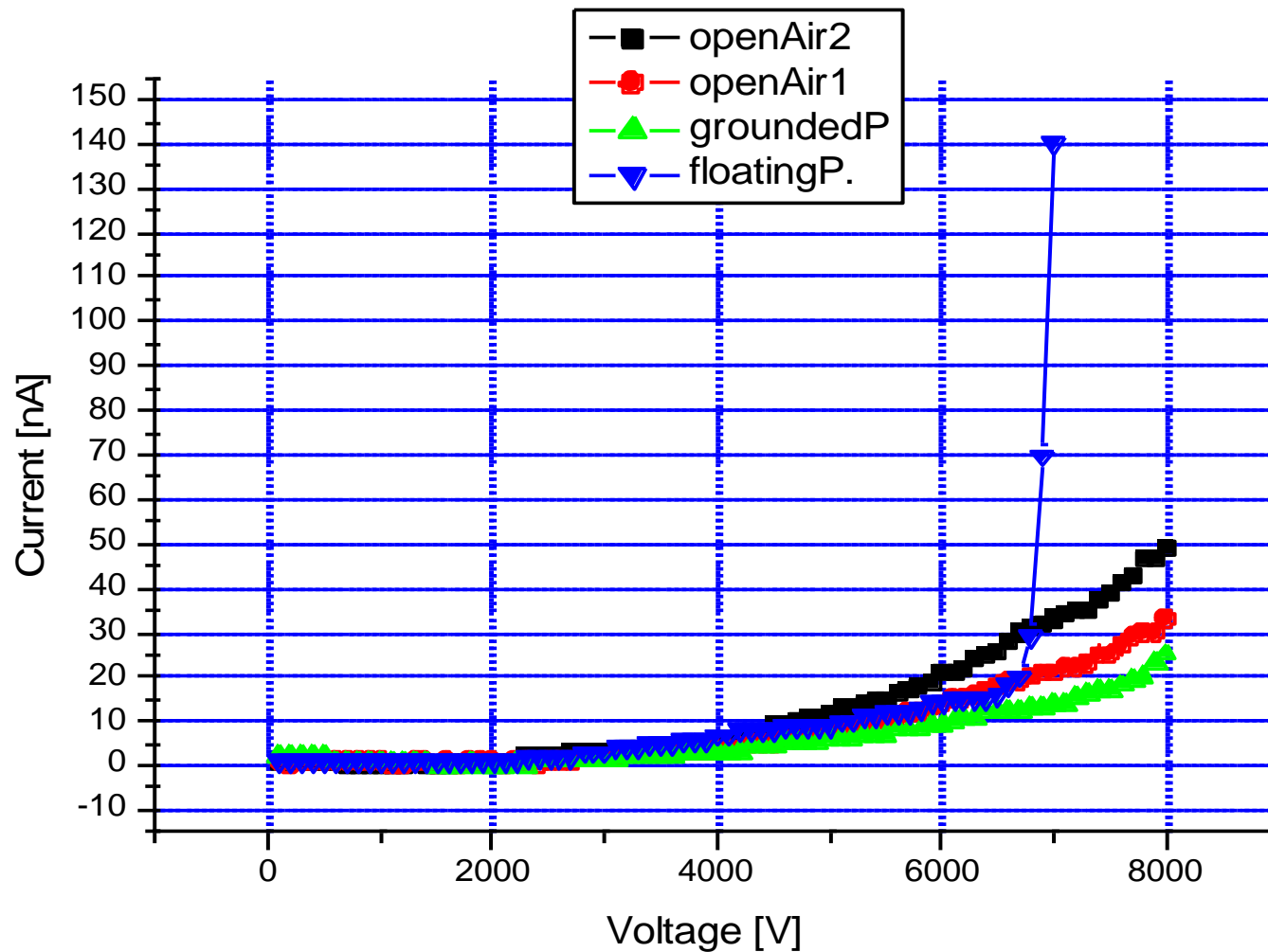
Picture and dimensions



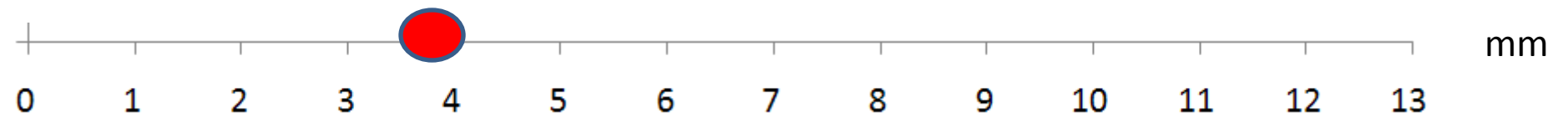
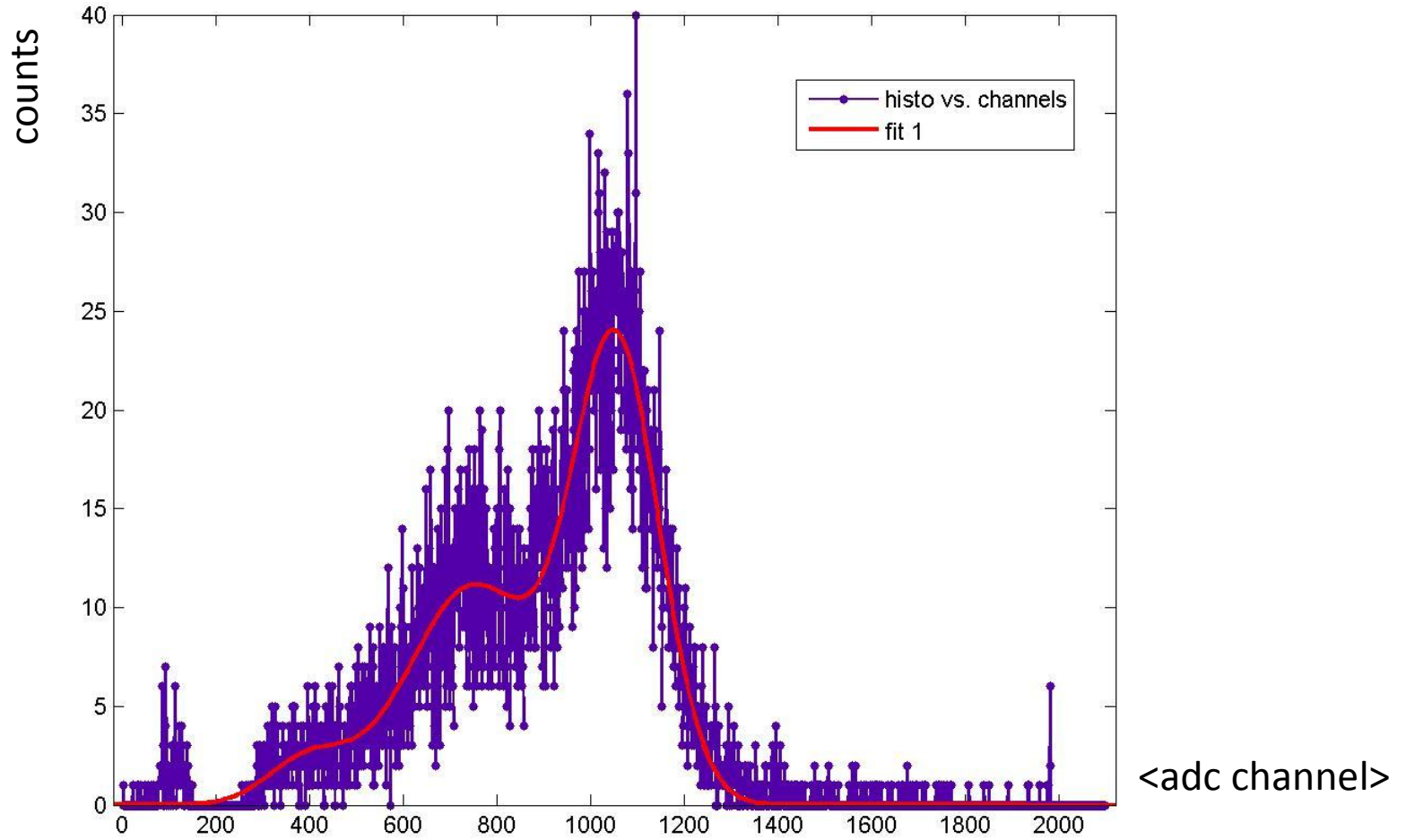
I/V scan in Nitrogen environment

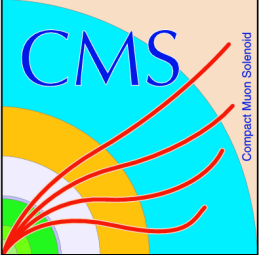


All I/V scans

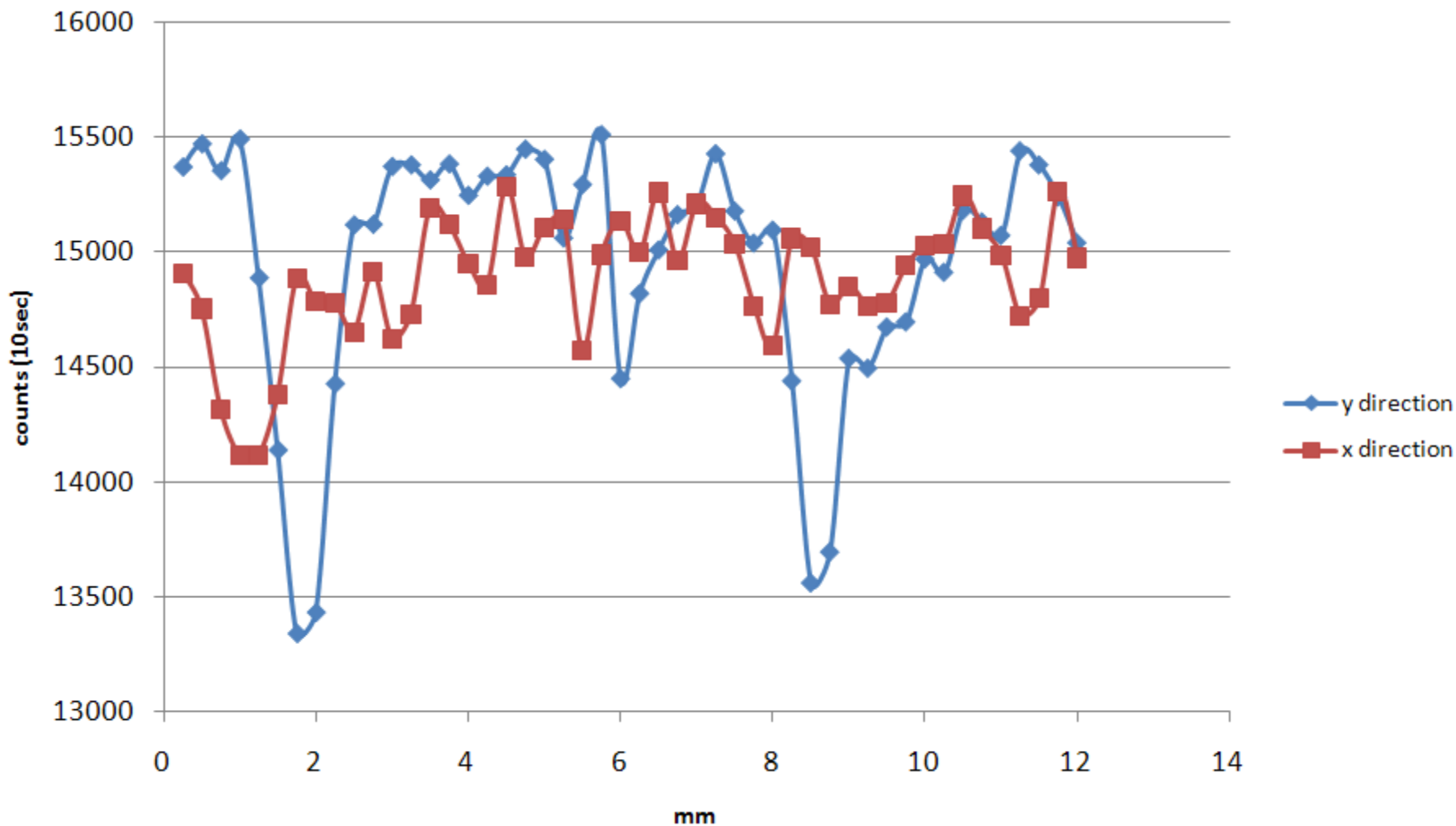


Analysis of GEM spectrum 'X displacement'

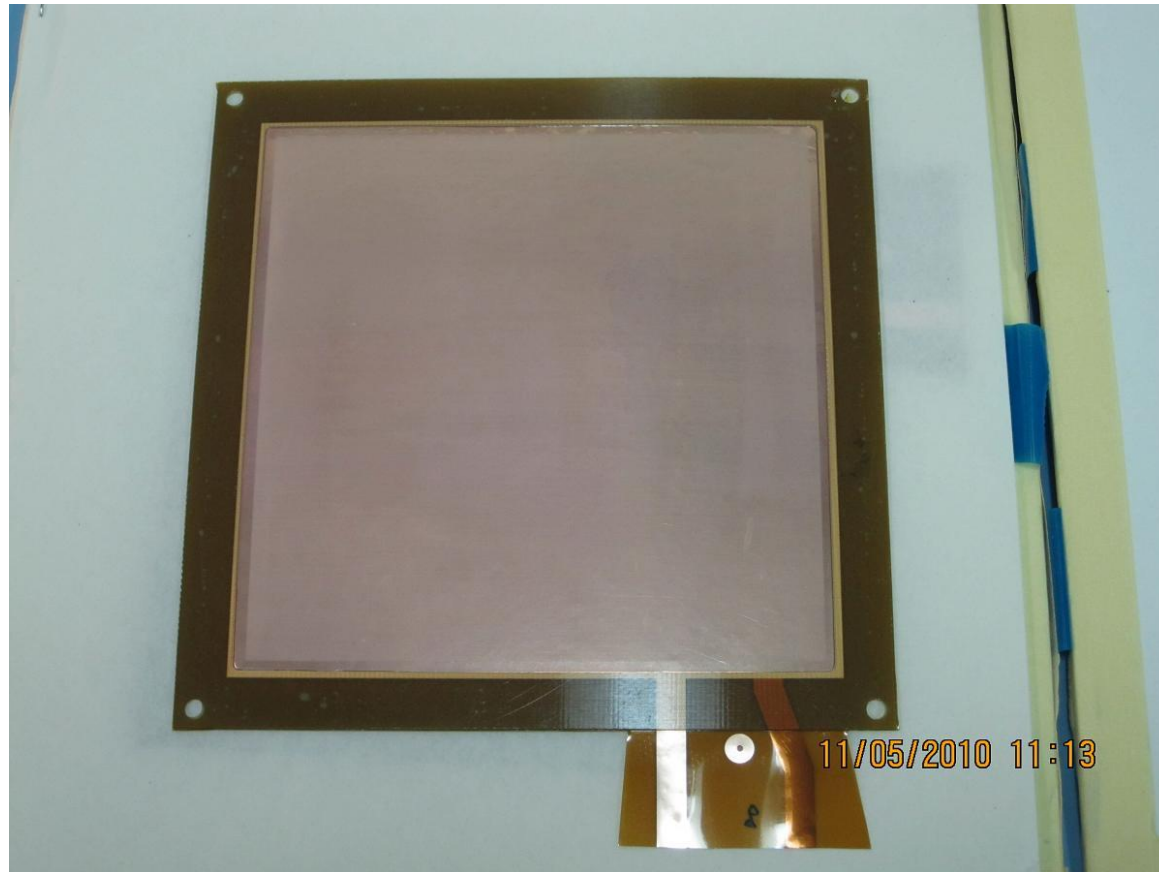




Moving the GEM (under x rays) along x,y direction with 0,25mm steps

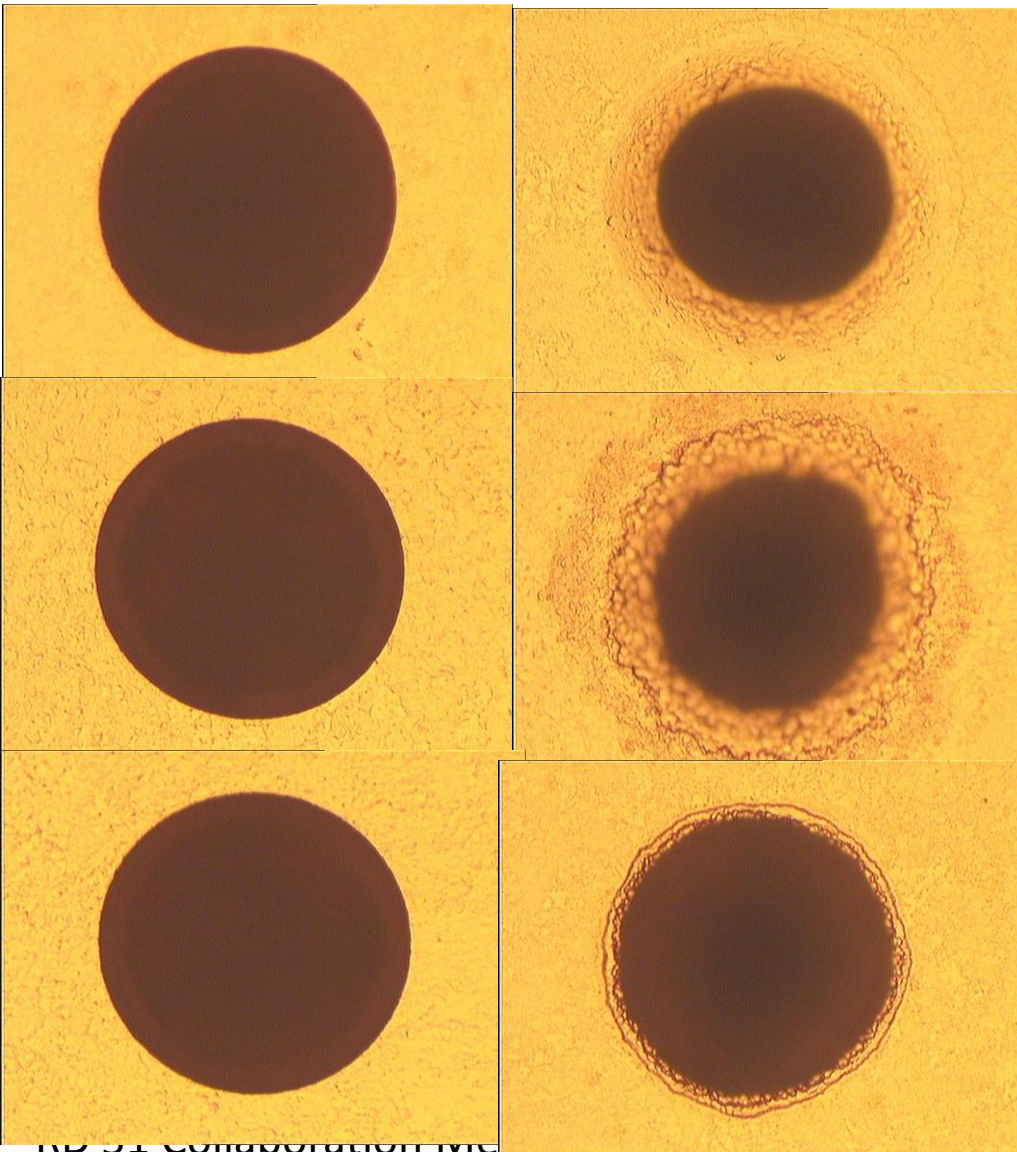


CMS single mask GEM1



Marco Villa

Single GEM Electrodes



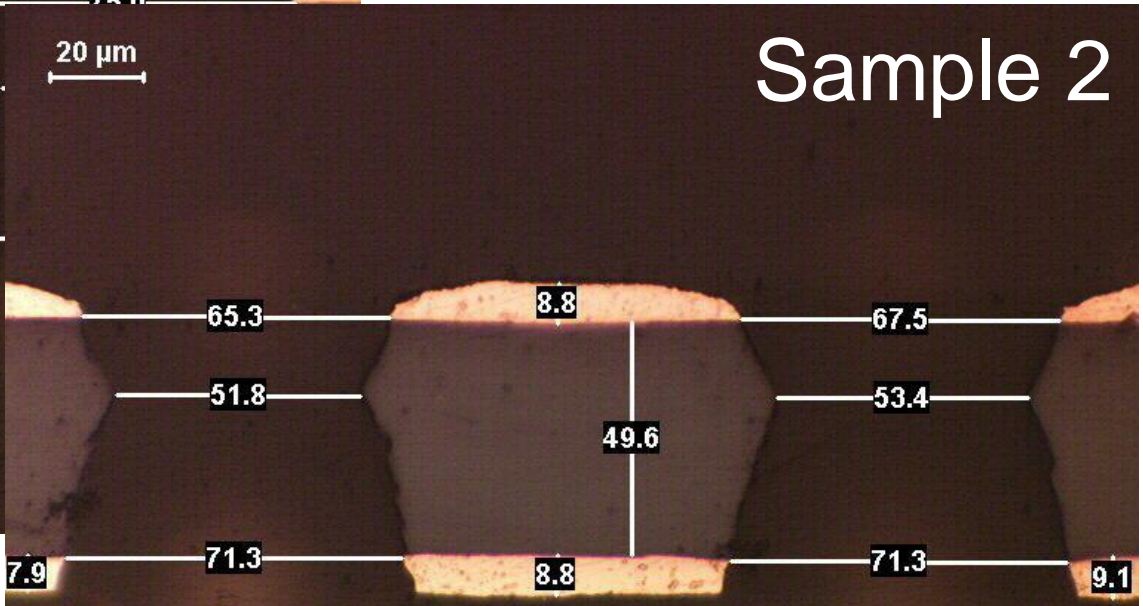
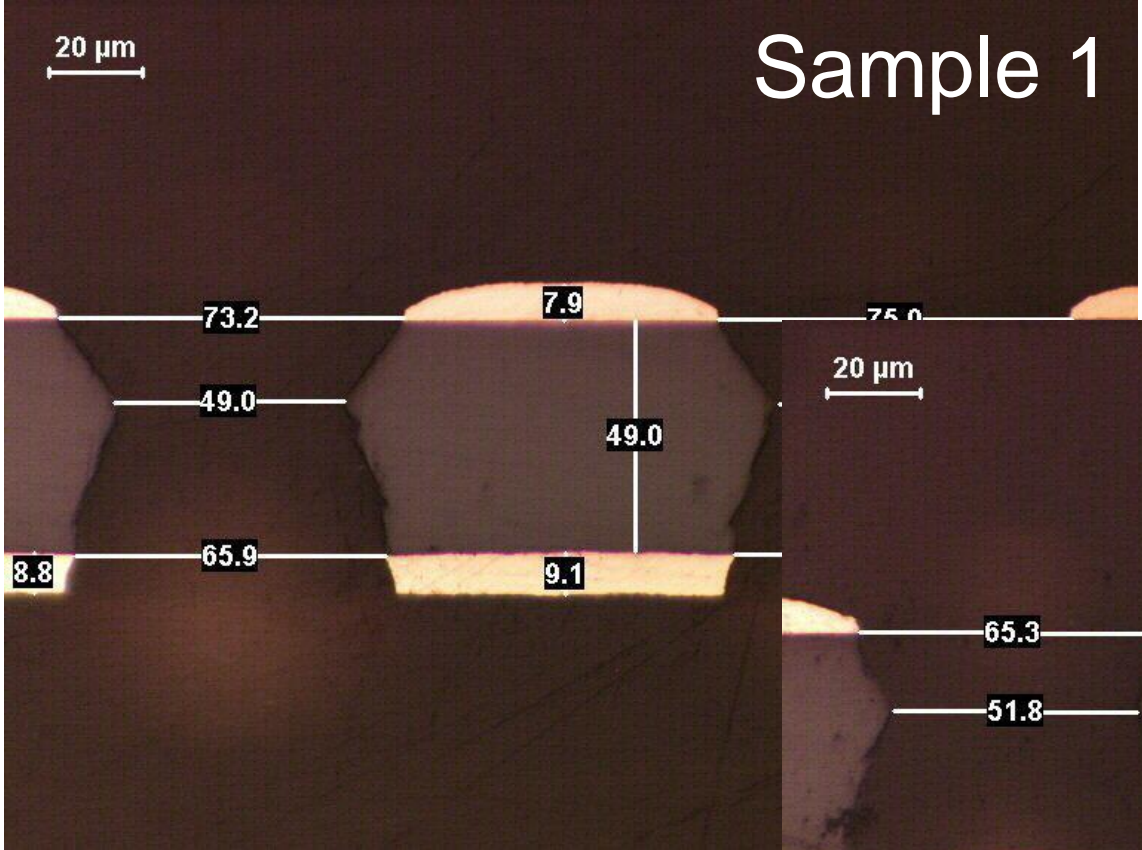
GEM 1

GEM 2

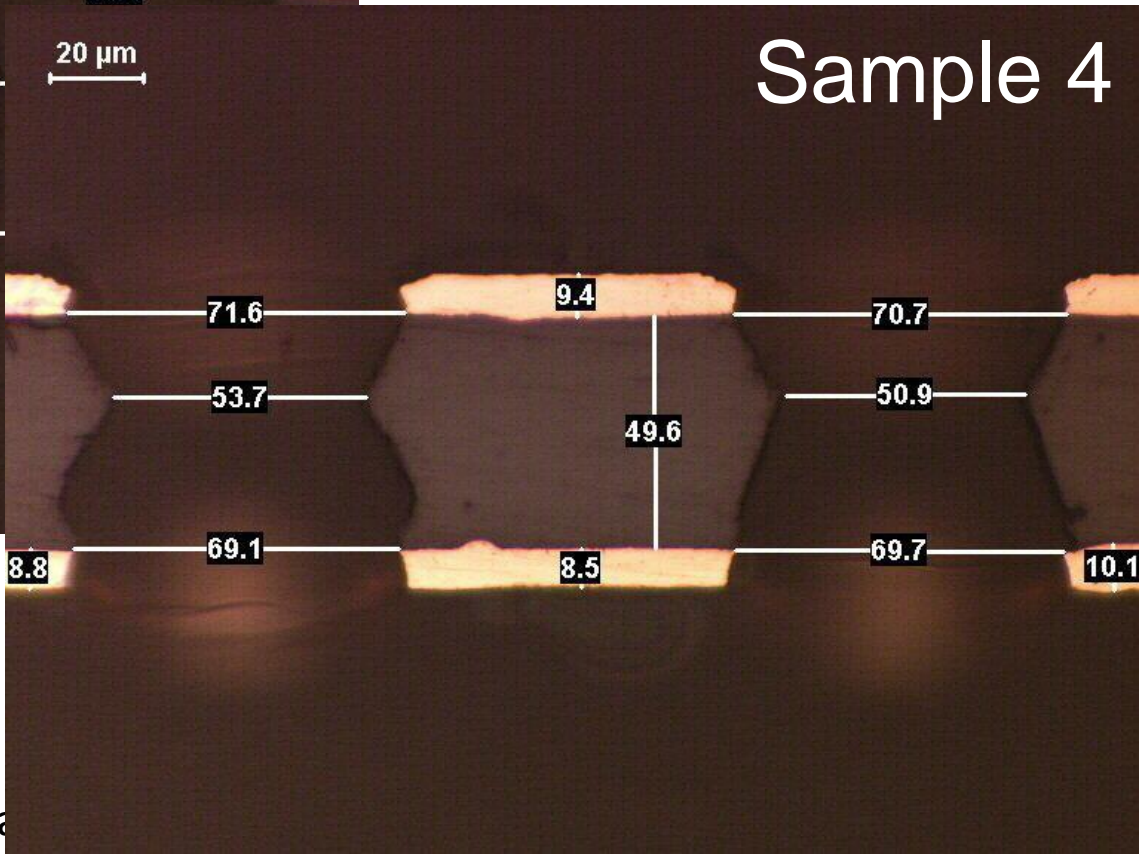
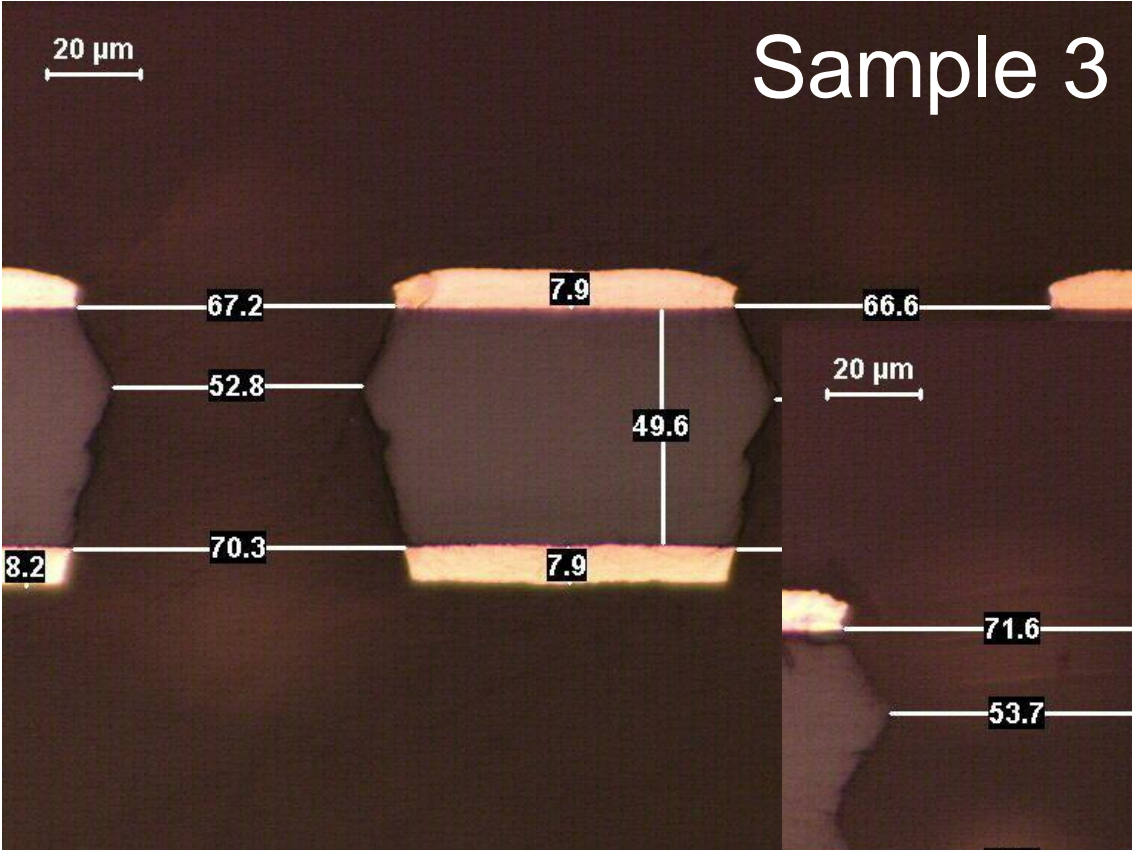
GEM 3

Top – Left
Bottom - Right

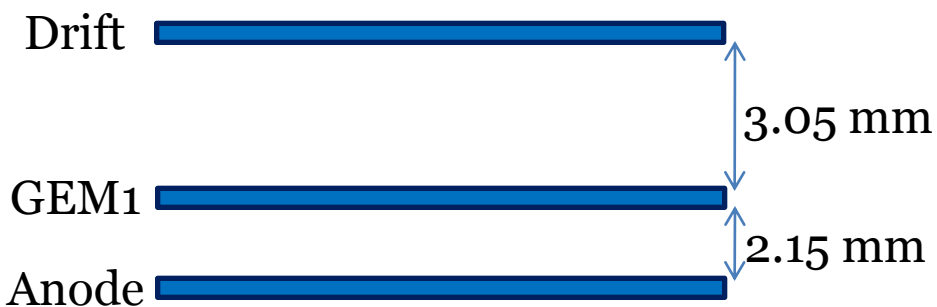
...and cross section pictures (1)



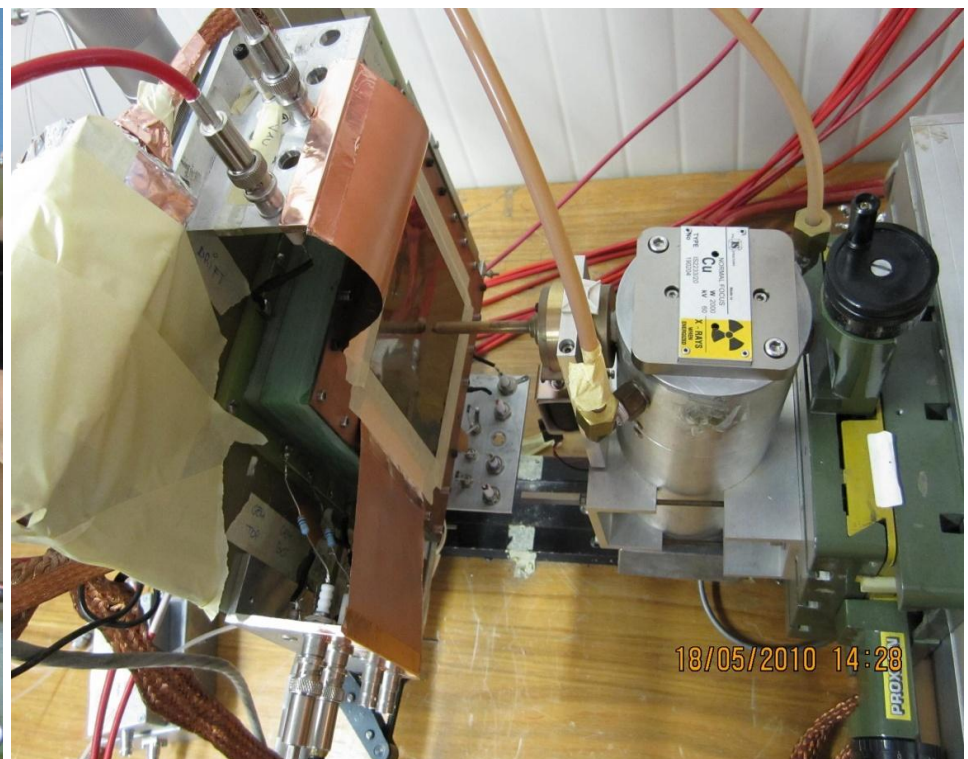
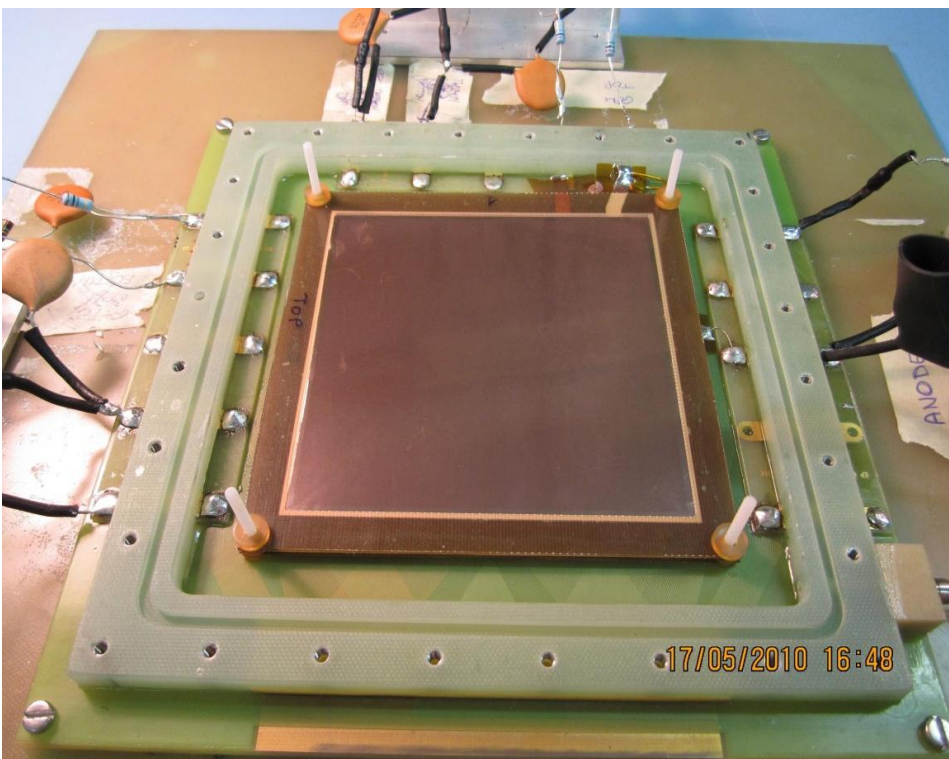
...and cross section pictures (2)



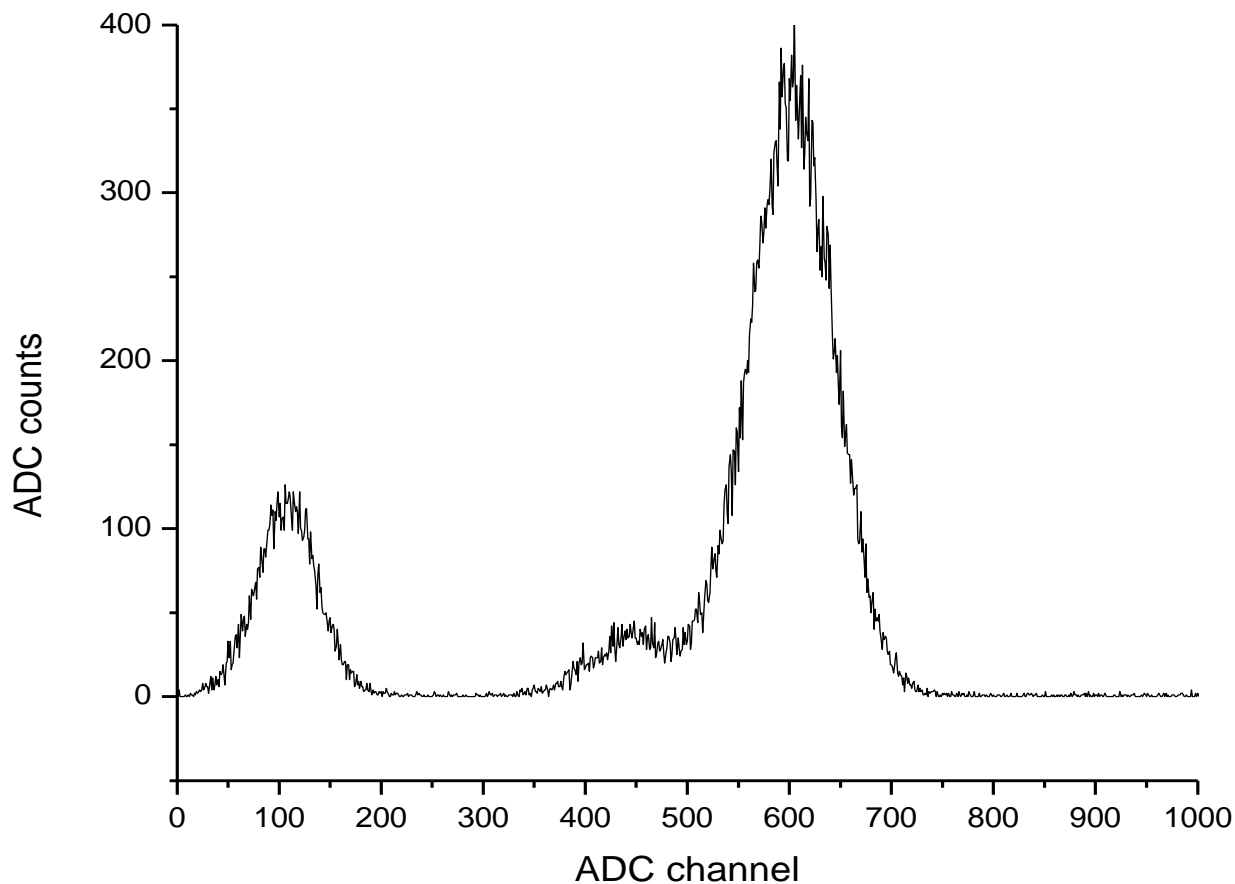
Preparing the experimental setup



- GEM active area: 10 x 10 cm²
- Gas mixture: Ar/CO₂ 70/30
- Gas flow: ~ 5 l/h
- Water content: ~ 100 ppm H₂O
- Radiation source: Cu X-ray tube

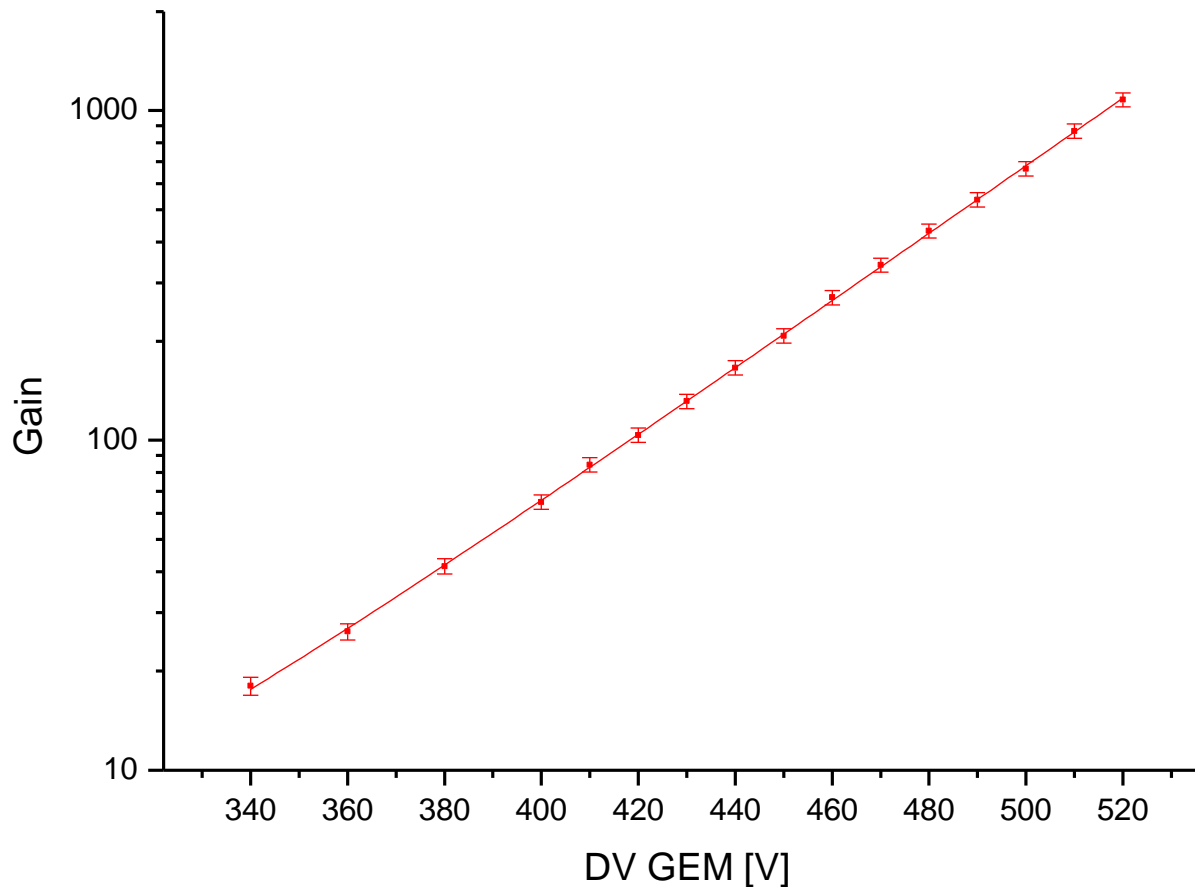


Taking spectra



- $E_d = 2$ kV/cm
- $E_i = 3$ kV/cm
- DV GEM = 480 V
- Rate ~ 32 Hz/mm²
- Energy resolution @ 8.04 keV ~ 19.6 % FWHM/peak

Measuring the gain curve



- $E_d = 2$ kV/cm
- $E_i = 3$ kV/cm
- Rate ~ 180 kHz/mm²
- Spark voltage ~ 530 V
- Max gain ~ 1080



CMS High Eta Upgrade Studies Test Beam Plan 2010



Chambers for June:

CMS Triple GEM prototype 10 x 10 cm

Honeycomb Triple GEM

Single Mask GEM

1. Measure Efficiency for perpendicular tracks
2. Measure Efficiency for inclined tracks with tracking
3. Optimization of time resolution
4. Tests with Front End electronics for mips
5. Space and time resolution

1. Gas Studies
2. Magnetic Field Operation
3. Large Prototype test



OUTLOOK



1. Prototype (standard, honeycomb, single mask) tests in lab, beam - **continue**
 2. Beam tests 2010 – **continue**
 3. Detail mechanical design for mock up and proto
~ **final**
 4. Definition of readout electronics and its mechanical support
- **ongoing**
- Services and routing HV, Gas, LV, cooling - **ongoing**
5. Mockup realization of detector
Done, some details missing
 6. Production of prototype
– **expected to be completed by end of June**