GEM based R&D for Muon Chambers of CBM experiment at FAIR

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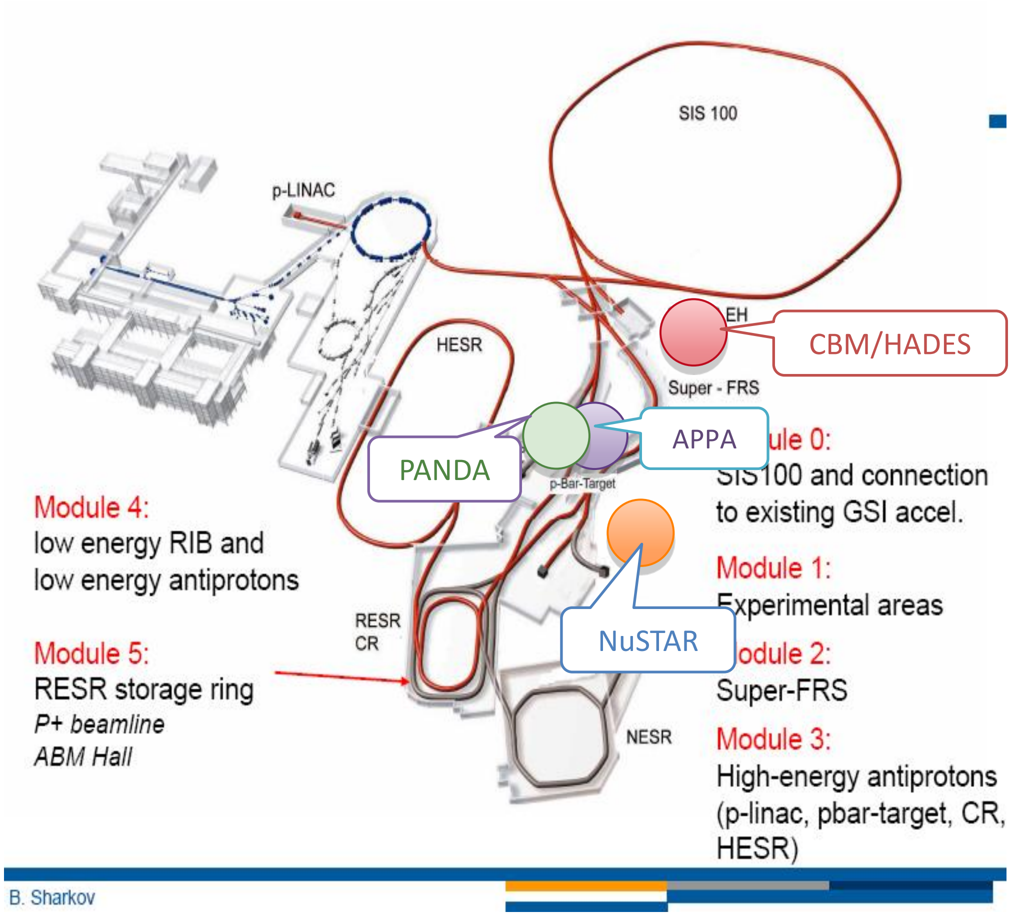
(for CBM collaboration)

FAIR: **the international Facility for Antiproton and Ion Research**



primary beams

- $5 \cdot 10^{11}$/s; 1.5-2 GeV/u; $^{238}U^{28+}$
- factor 100-1000 increased intensity
- 4×10^{13}/s 90 GeV protons
- 10^{10}/s ^{238}U 35 GeV/u (Ni 45 GeV/u)

secondary beams

- rare isotopes 1.5 - 2 GeV/u;
- factor 10 000 increased intensity
- antiprotons 3(0) - 30 GeV

accelerator technical challenges

- rapidly cycling superconducting magnets
- high energy electron cooling
- dynamical vacuum, beam losses

FAIR will provide intense beams of rare isotopes, relativistic heavy ions and antiprotons for a wide range of expts. in particular, nuclear and atomic physics

Compressed Baryonic Matter (CBM) Experiment

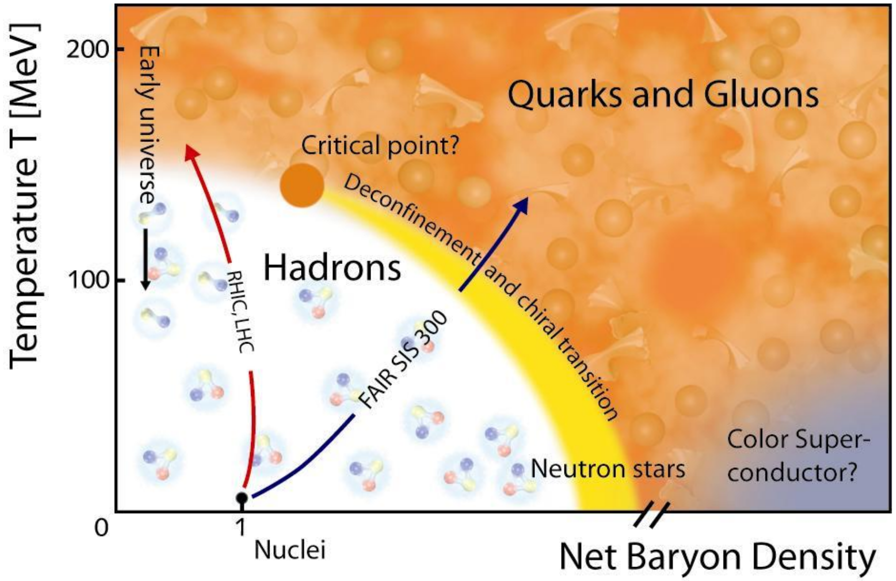
- **Fixed target heavy ion expt.**
- **Energy range 2-45 GeV/u**
- **Expected to begin in 2017.**

CBM physics program:

- Equation-of-state at high ρ_B
- Deconfinement phase transition
- QCD critical endpoint
- Chiral symmetry restoration

Diagnostic probes of the high-density phase:

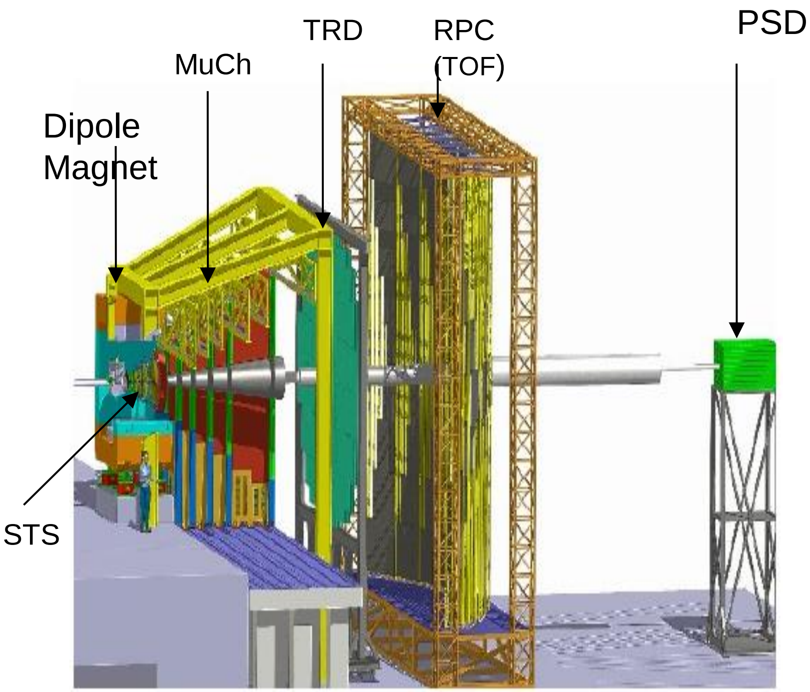
- open charm, charmonia
- low-mass vector mesons
- multistrange hyperons
- flow, fluctuations, correlations



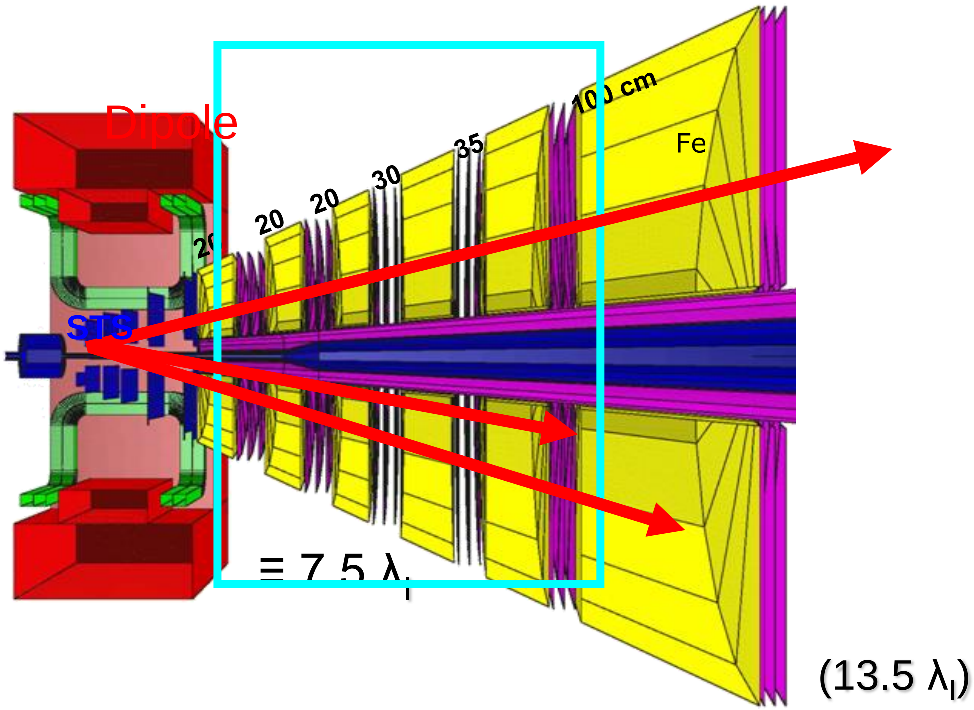
Exploring the QCD Phase Diagram

Rare Probes
→ high interaction rates
→ selective triggers

CBM Experiment @ FAIR



Muon Chamber (MUCH)



Aim: to detect dimuon signals from low mass vector mesons and J/ψ

For the first few stations, micropattern detectors--- GEMs, Micromegas.

Challenges in Muon detection

Main issues:

- High collision rates ~ 10 MHz/cm^2
  The first plane(s) have a high density of tracks
- High granularity ~ average hit rate is about 1 hit/cm^2
- Should be radiation resistant –
  high neutron flux → ~10^{13} n.eq./sq.cm/year
- Large area detector – with modular arrangement
- Data to be readout in a self triggered mode
  -- a must for all CBM detectors.

detectors based on micropattern technology

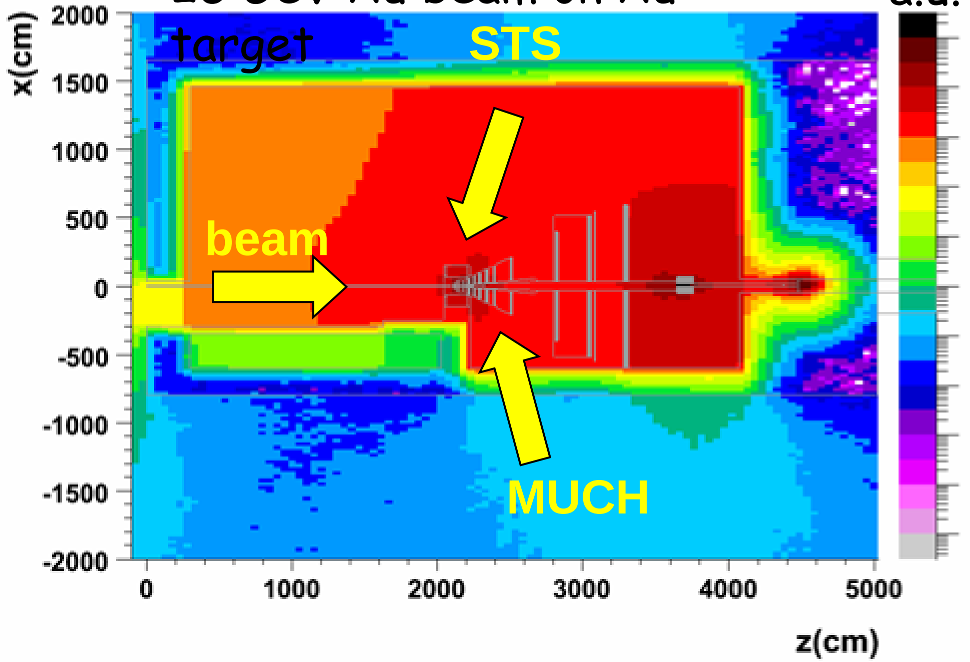
--- GEMs, THGEMs and Micromegas

At VECC, we are pursuing R&D with GEMs for MuCH

CBM Radiation Environment

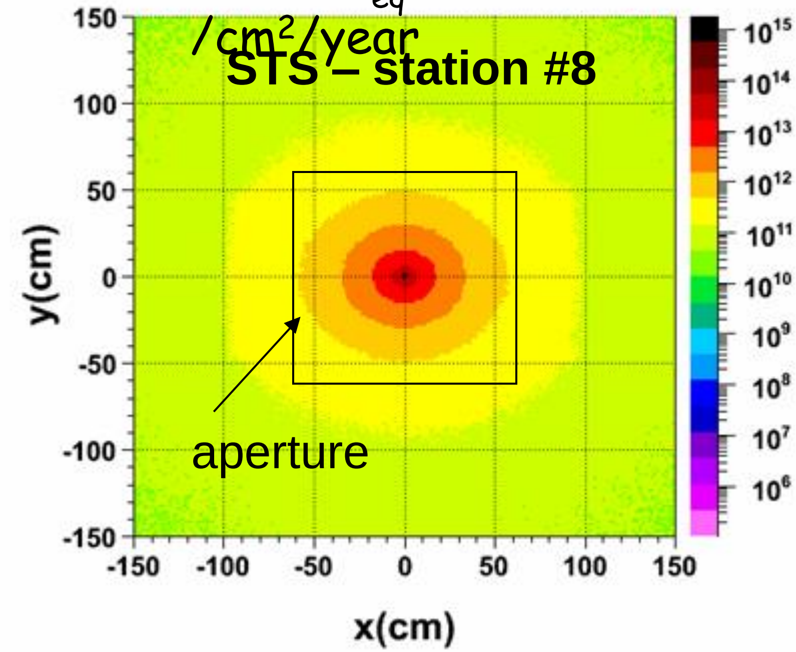
Neutron fluence in CBM cave

UrQMD + FLUKA simulation,
25 GeV Au beam on Au target



Neutron fluence through Silicon Tracking System

1-MeV n_{eq} /cm²/year

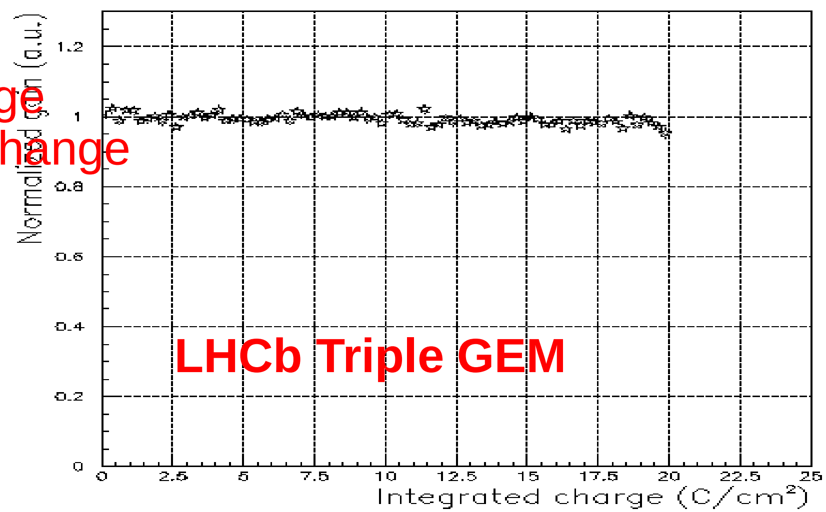


Hottest part of Silicon tracker: 6 years ⇒ up to 10^{15} n_{eq}/cm^2 in STS
⇒ radiation hardness regime of LHC/SuperLHC experiments

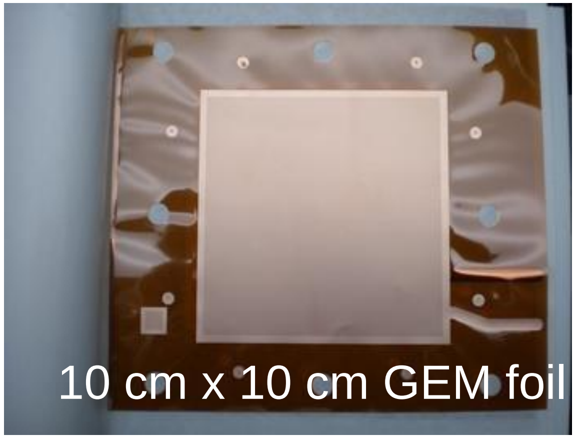
MUCH: Accumulated Charge

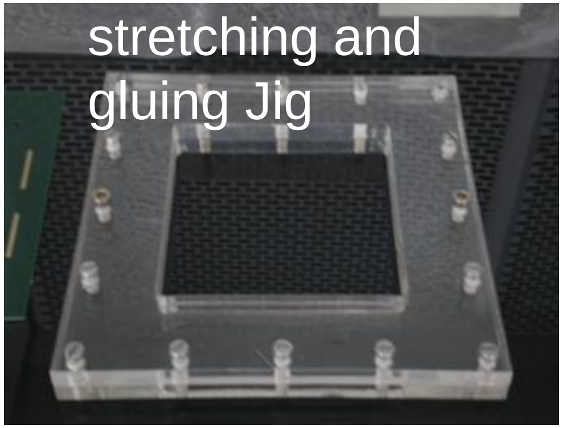
H	hits/cm^2/event	~1 (first GEM Layer)
R	event rate [Hz]	10^7
P	primary electrons/track	~30
G	detector gas gain	10^3
N_e	$=H \times R \times P \times G$ (no. of electrons)	3×10^{11} cm^2/s
Q_y	$=N_e \times Q_e \times y$ (acc. charge/year)	1.5 C/cm^2/y
Q_{10y}	acc. charge over exp. lifetime	15 C/cm^2

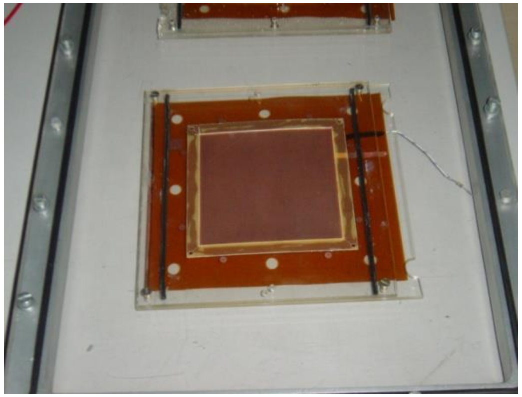
50 MHz/cm^2 X-rays, in 10 days a total charge of <u>20 C/cm^2 was integrated</u>; less than 5% change in the chamber behavior

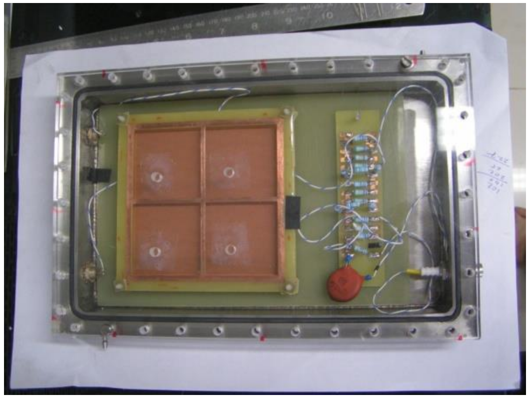


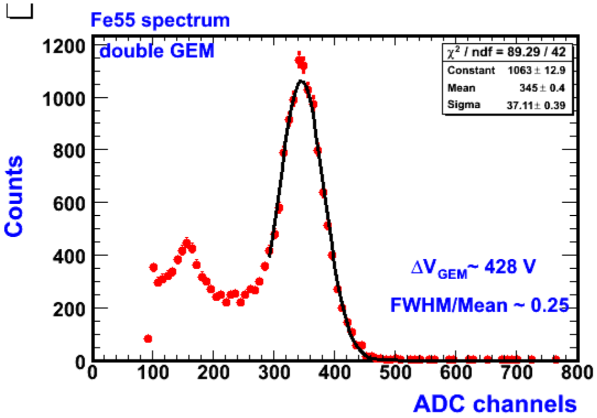
GEM ASSEMBLY at VECC, the first attempt







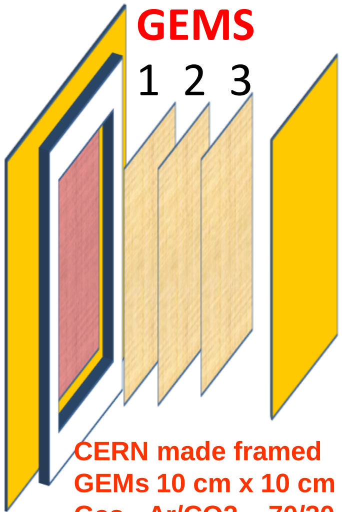




Gas mixture: Ar/CO2 – 70/30

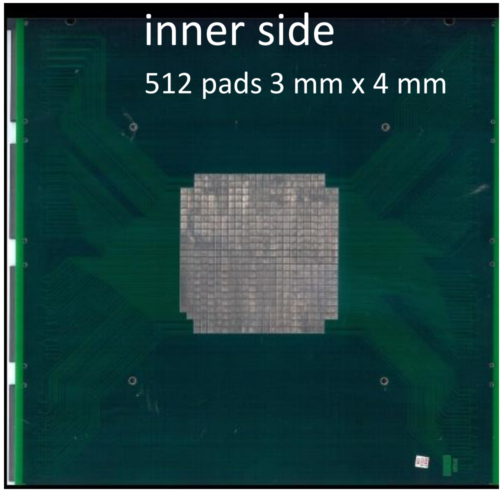
Readout : single pad 1cm x 1cm

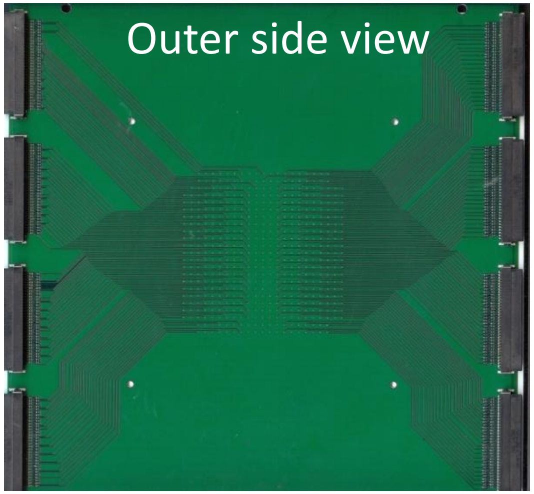
Prototype fabrication at VECC for beam test

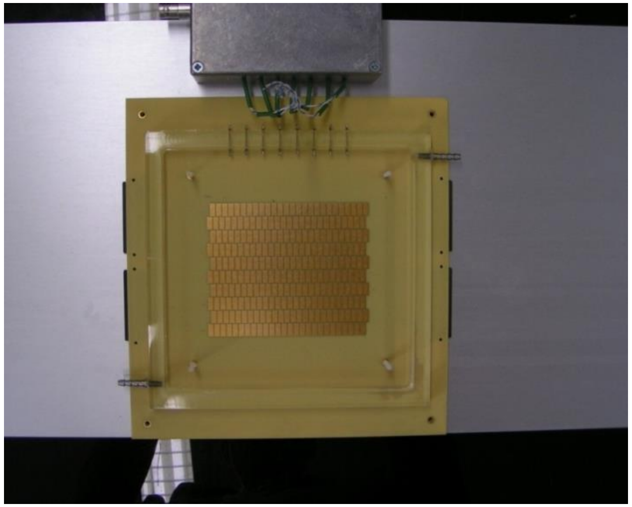


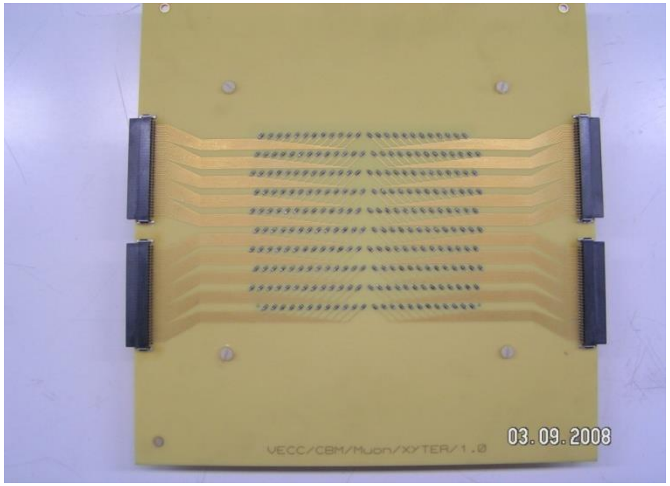
CERN made framed
GEMs 10 cm x 10 cm
Gas - Ar/CO2 – 70/30

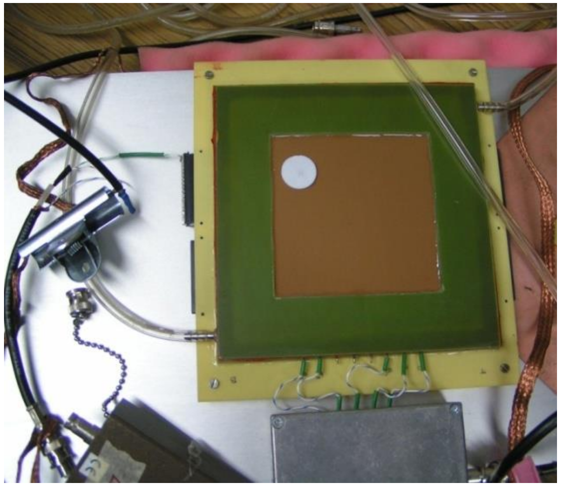
Multilayered Readout PCB







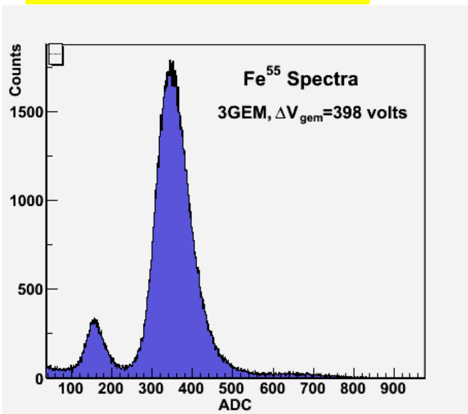


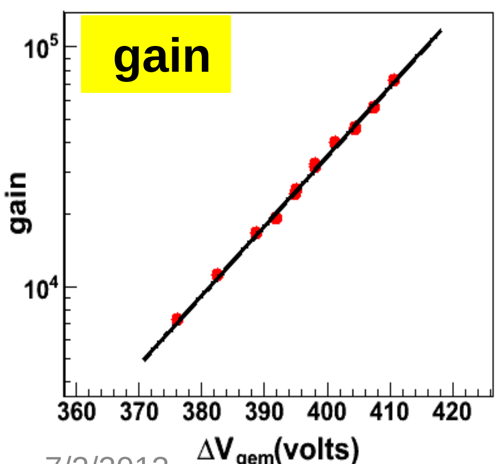


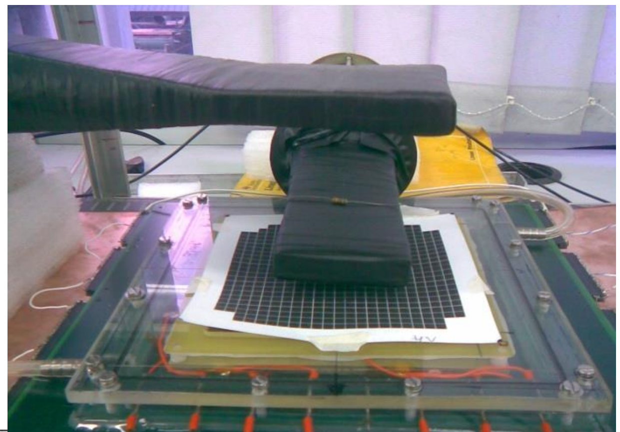
Results from Lab tests (using conventional Ortec electronics)

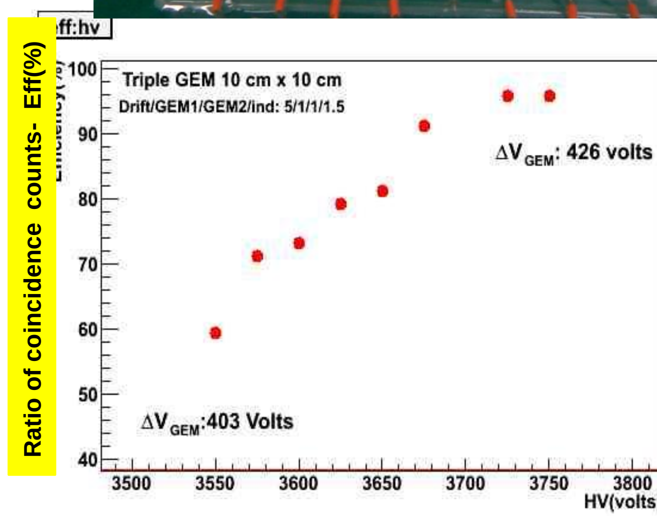
Test with Cosmic muons in VECC lab

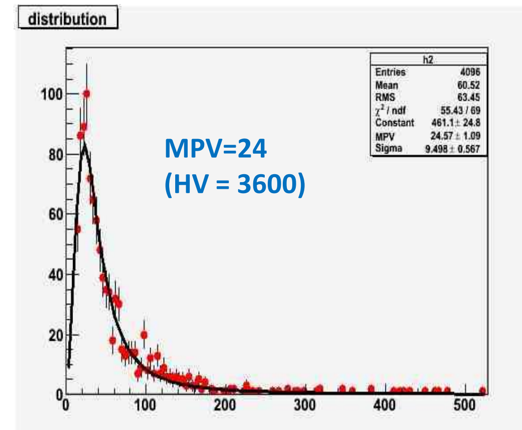
X-ray source

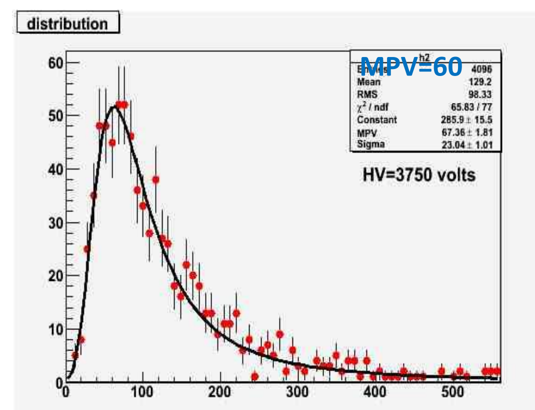












Beam test of GEM prototype chambers

Aim :

-- to test the response of the detector to charged particles. mainly in terms of efficiency, cluster size, gain uniformity, rate handling capability

-- testing with actual electronics for CBM : nXYTER

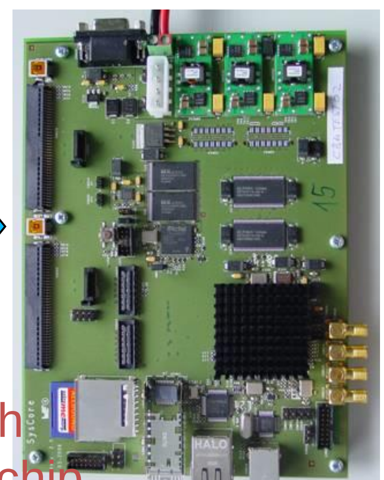
-- nXYTER is a 32 MHz, 128 channel self triggered ASIC first developed by DETNEE collaboration for neutron measurements.

– coupled to ROC(ReadOut Controller) and then fed to the DAQ.

-- testing with the actual CBM DAQ

Detector

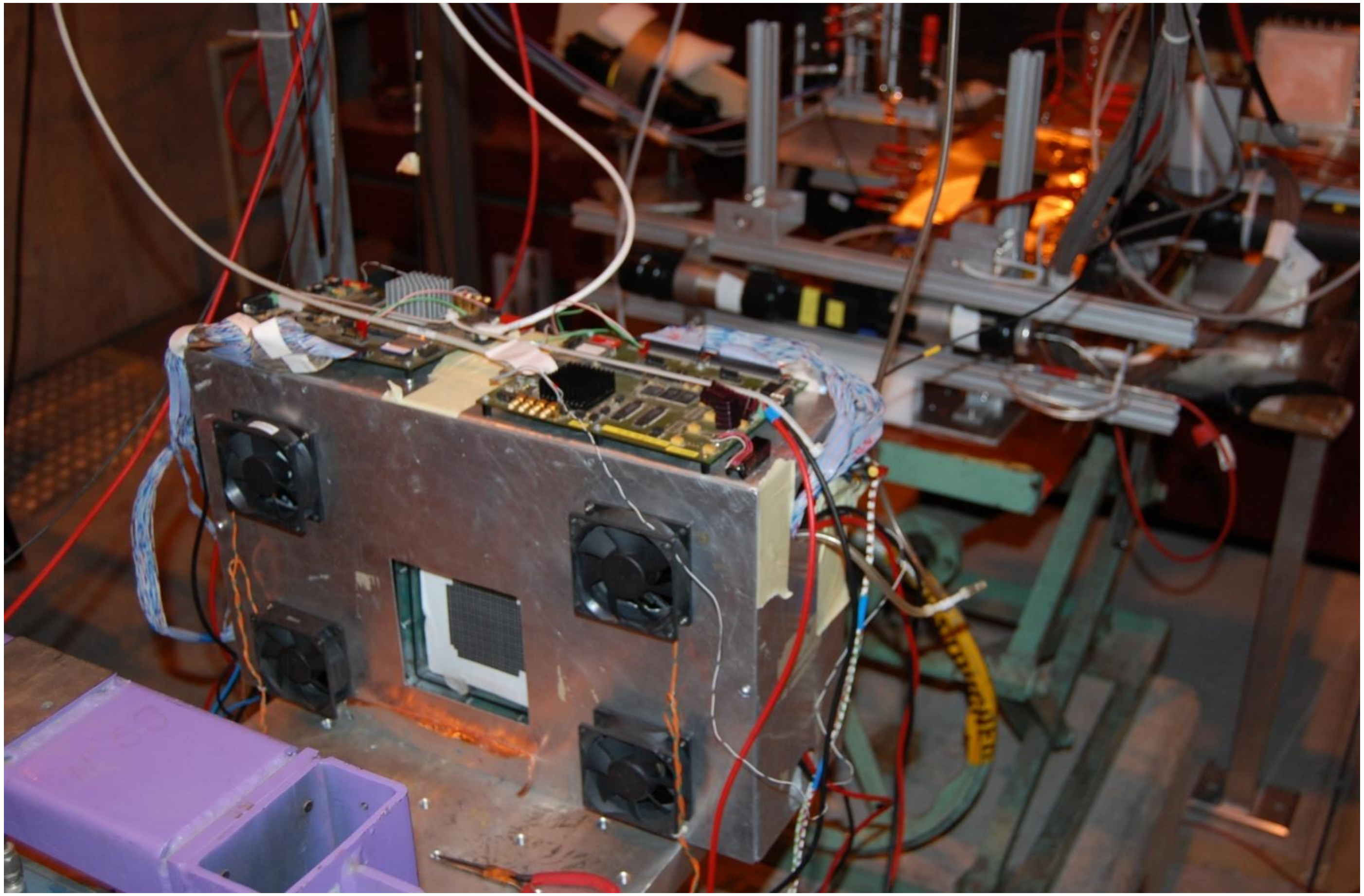
FEE board with Self triggered chip



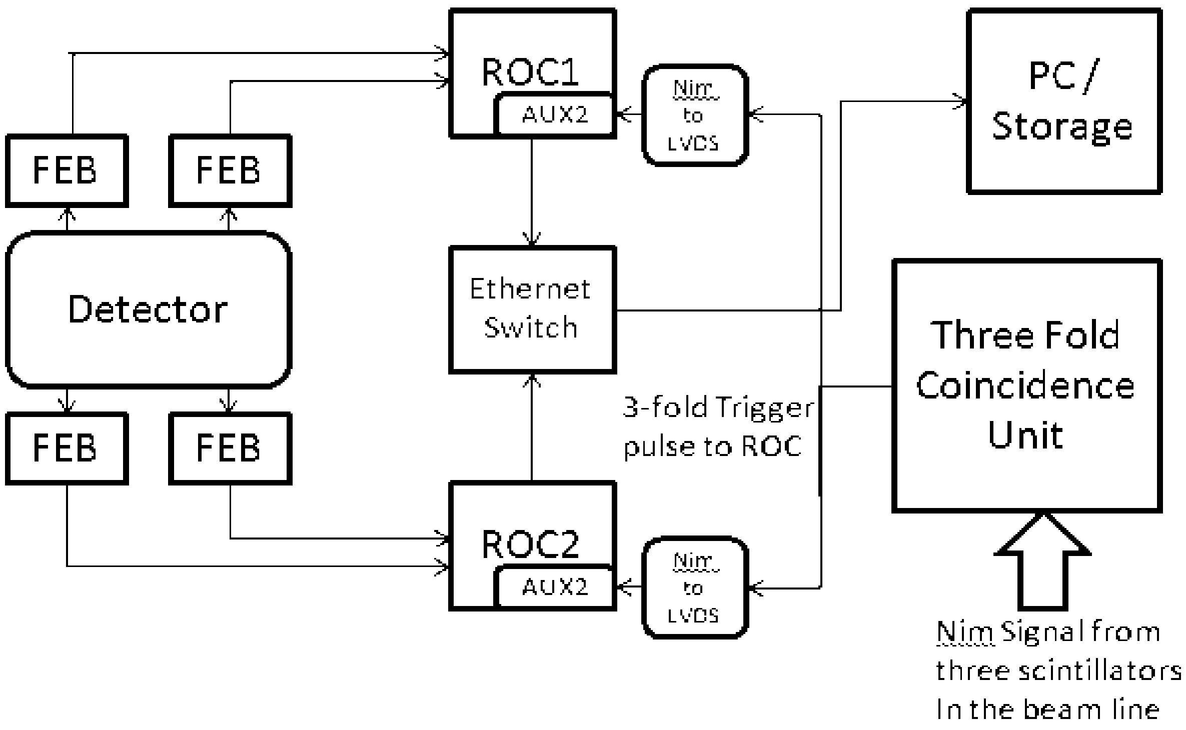
DABC

GO4
FAIR Root

Test Beam Set Up (CERN/ H4 beam line)

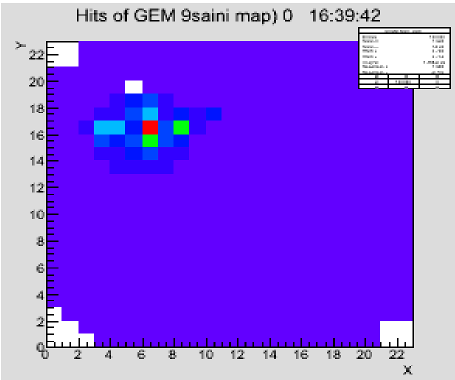


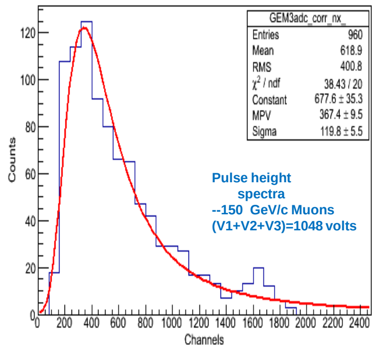
DAQ Schematic during the beamtest

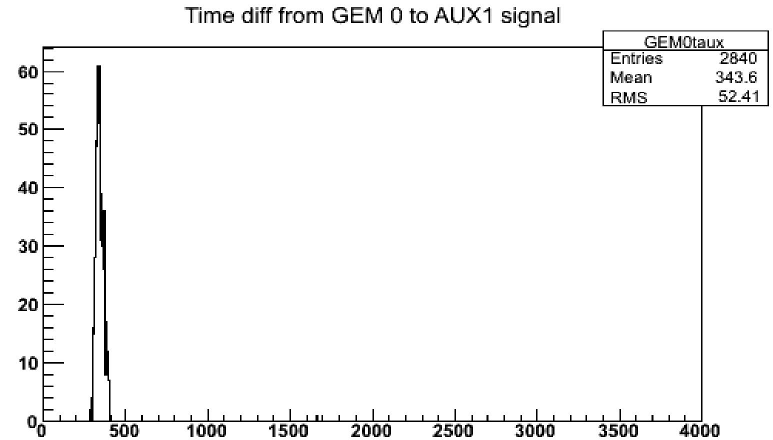


The nXYTER ADC spectra is inverted as compared to conventional picture, this has to be subtracted from a baseline value channel by channel

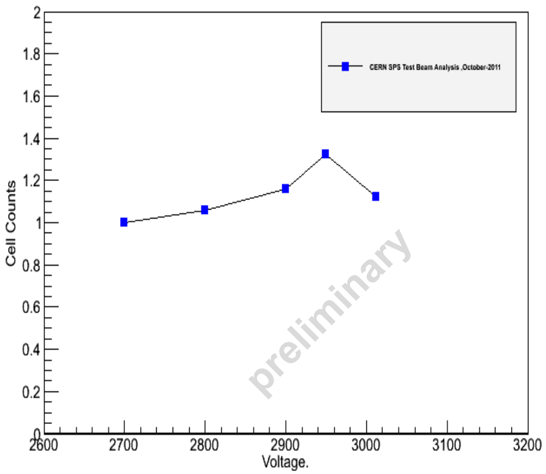
Test with Muons

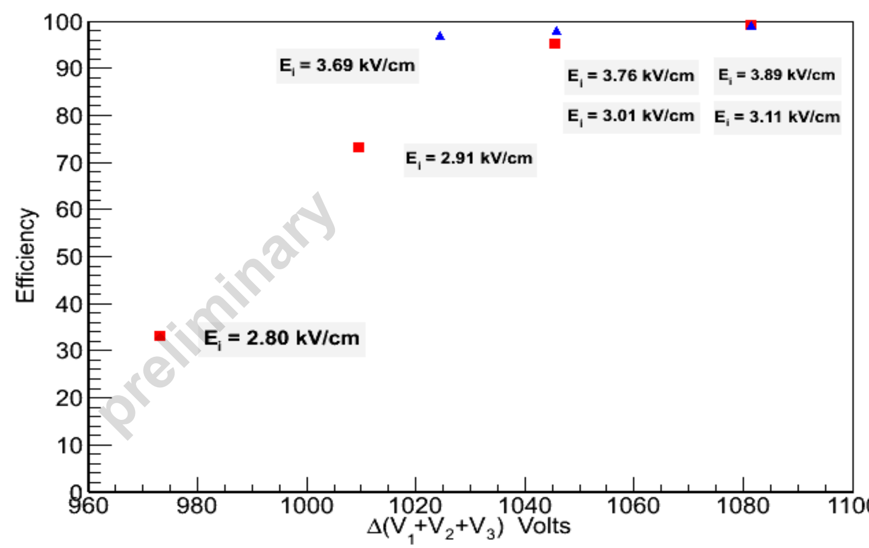






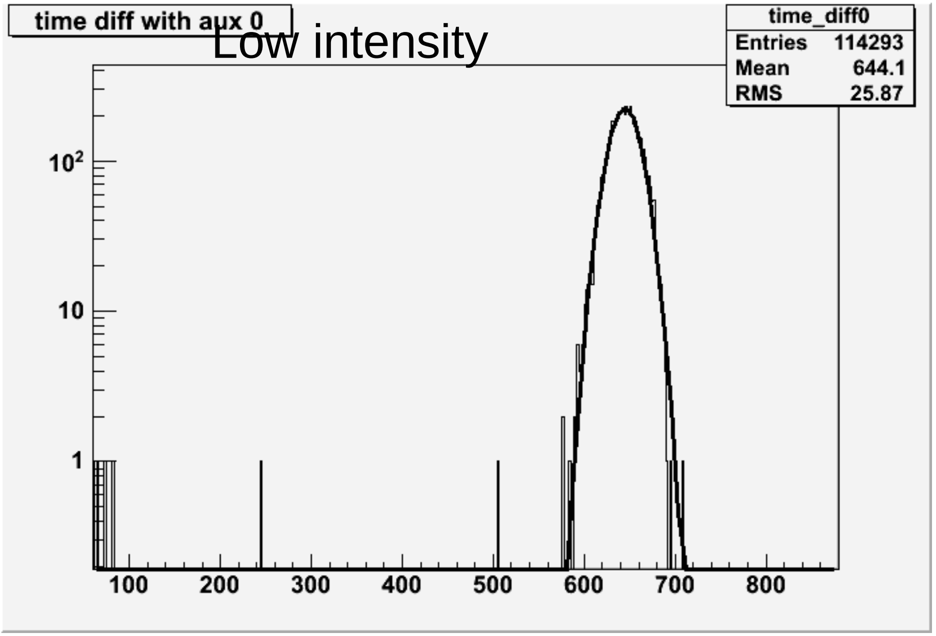
nsec

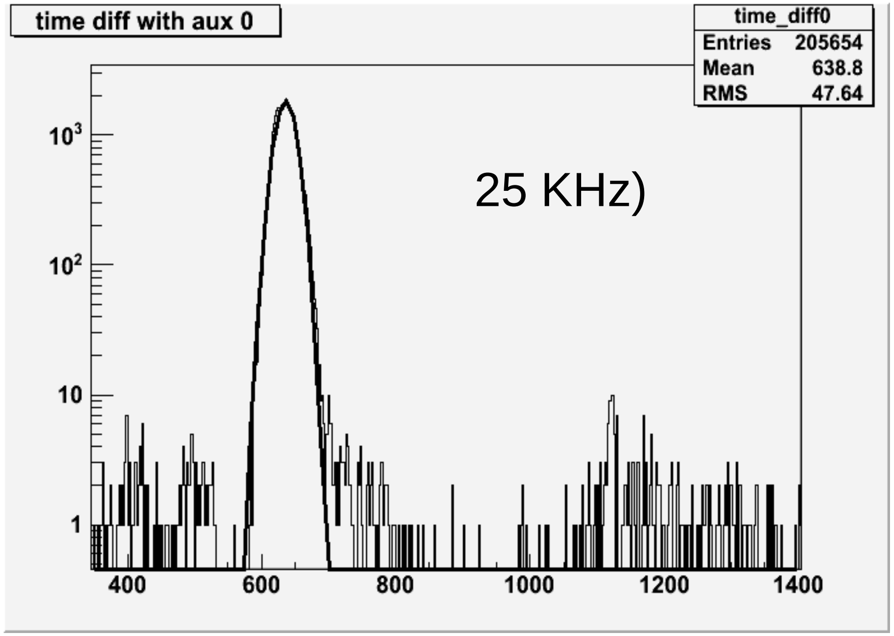


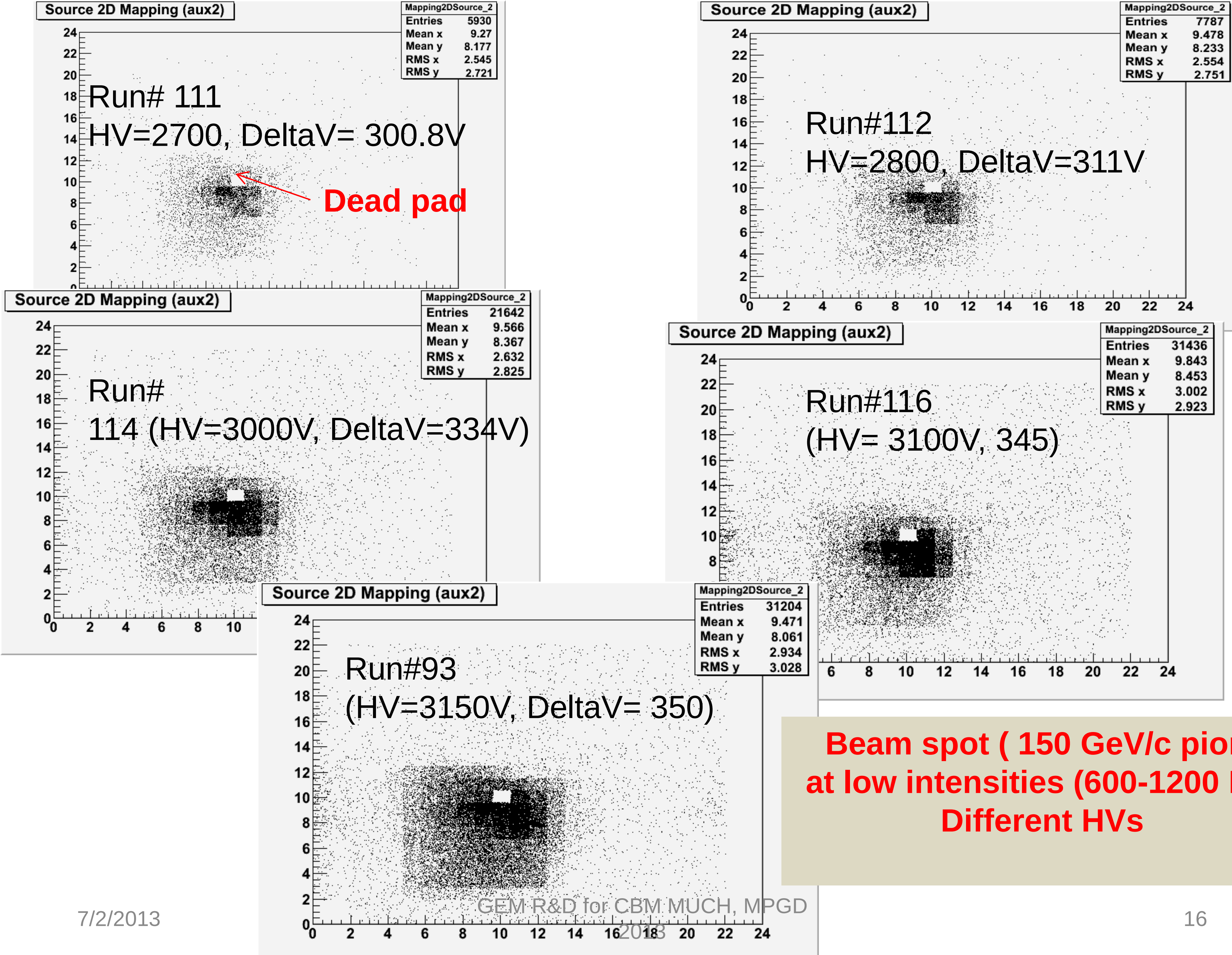


Cluster Size **Efficiency(using 150 GeV/c muons)**

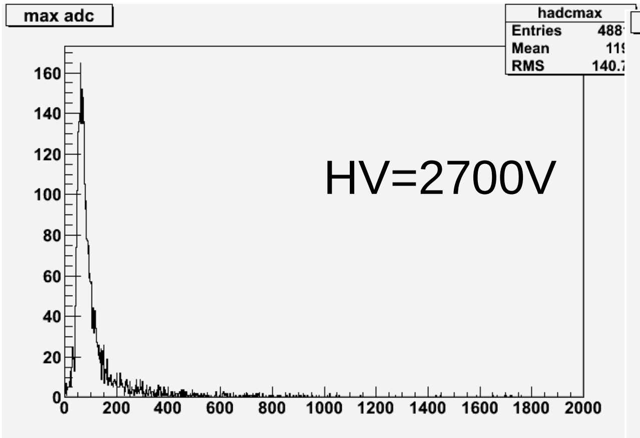
Time correlation spectra

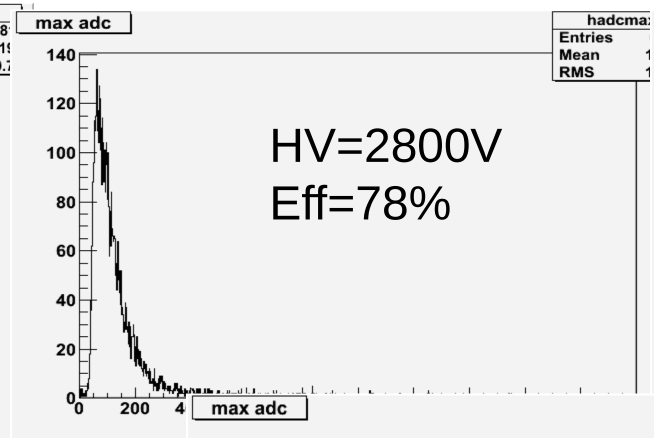


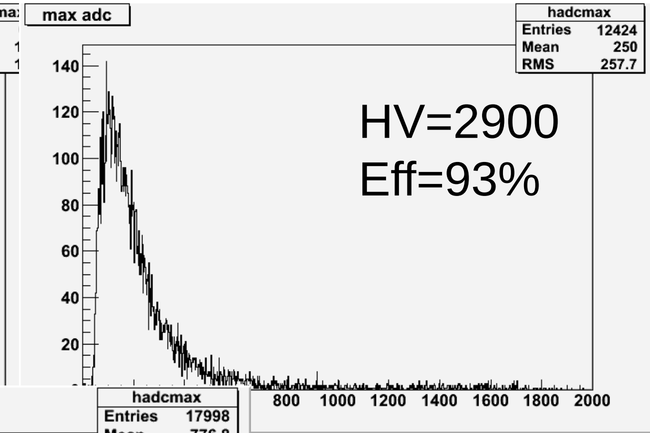


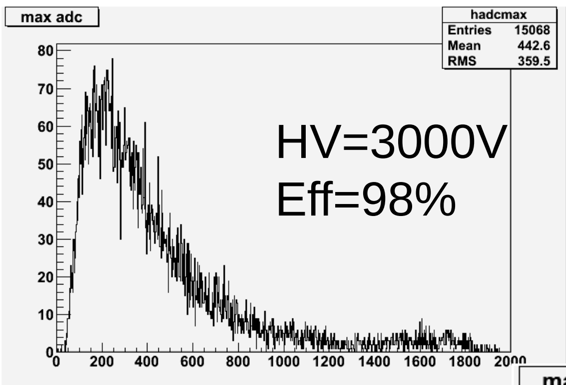


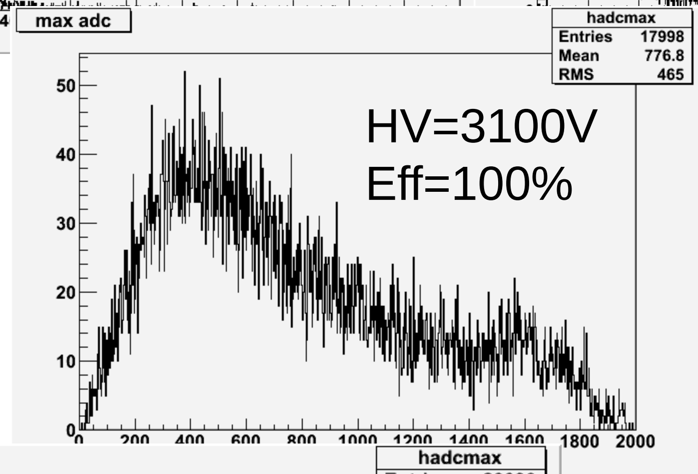
Beam spot (150 GeV/c pion)
at low intensities (600-1200 Hz),
Different HVs

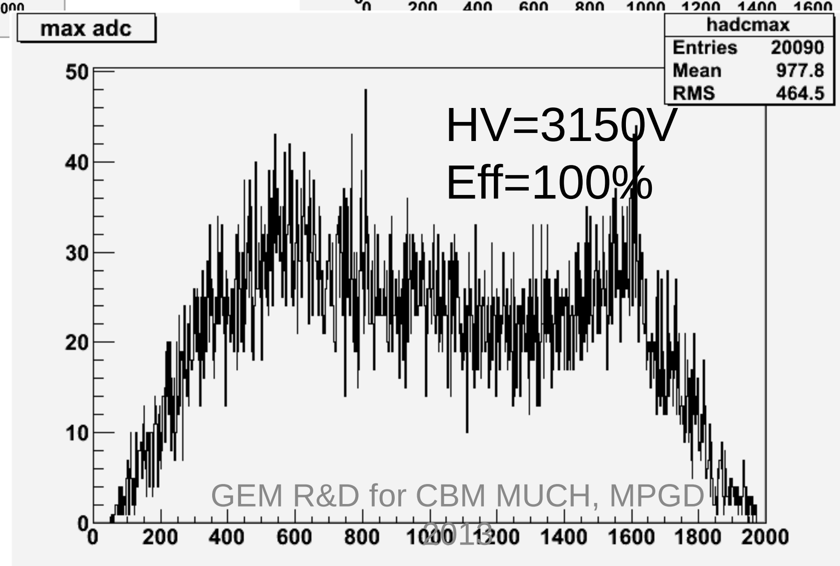




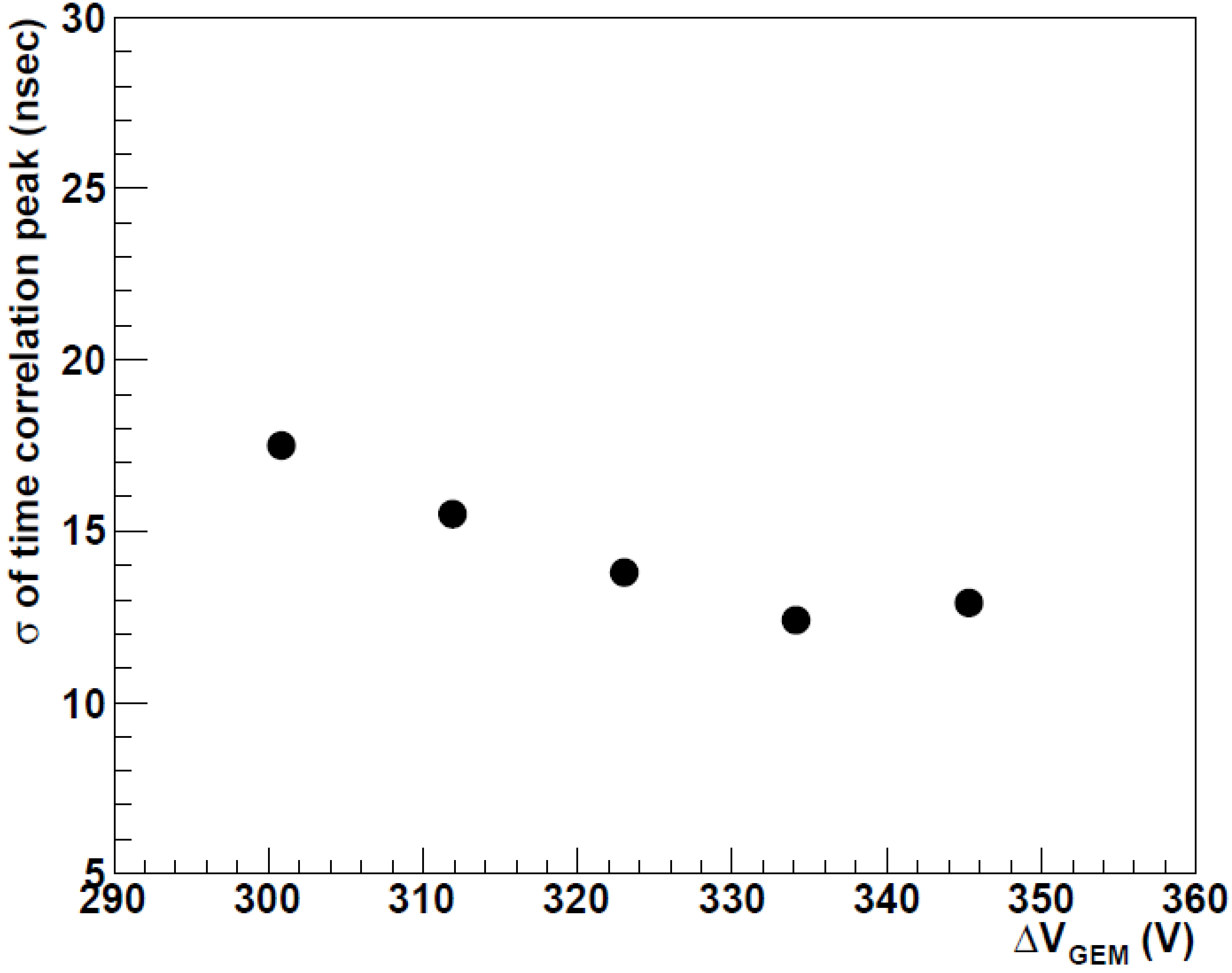






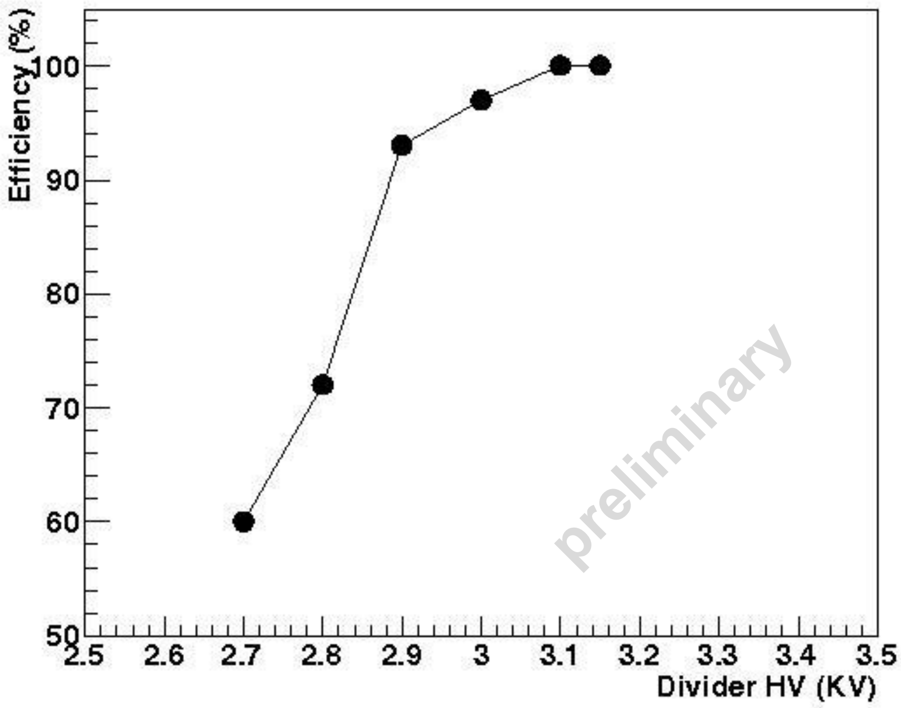


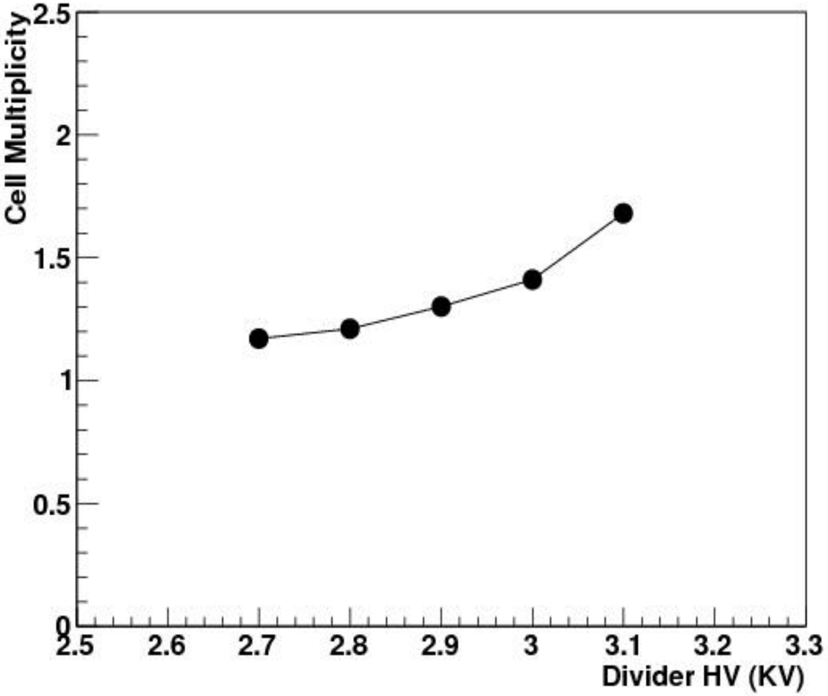
Highest cell ADC
Different for diff HVs



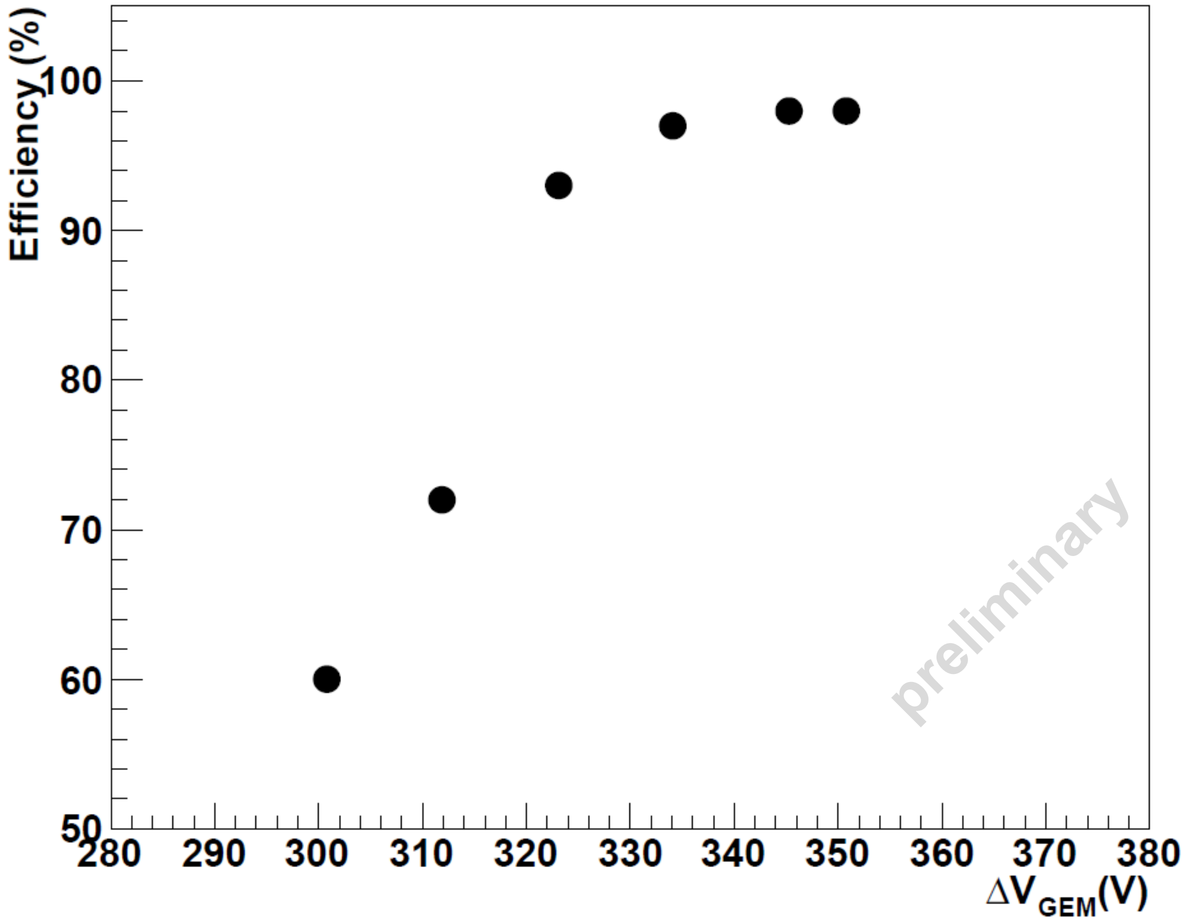
σ of time correlation peak (nsec)
30
25
20
15
10
5
290
300
310
320
330
340
350
360
ΔV_{GEM} (V)

Efficiency and hit multiplicity



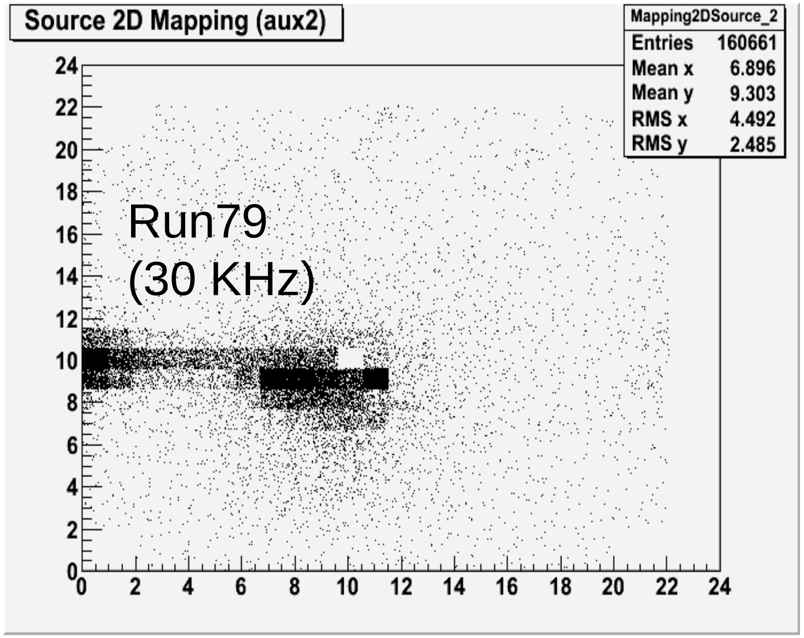


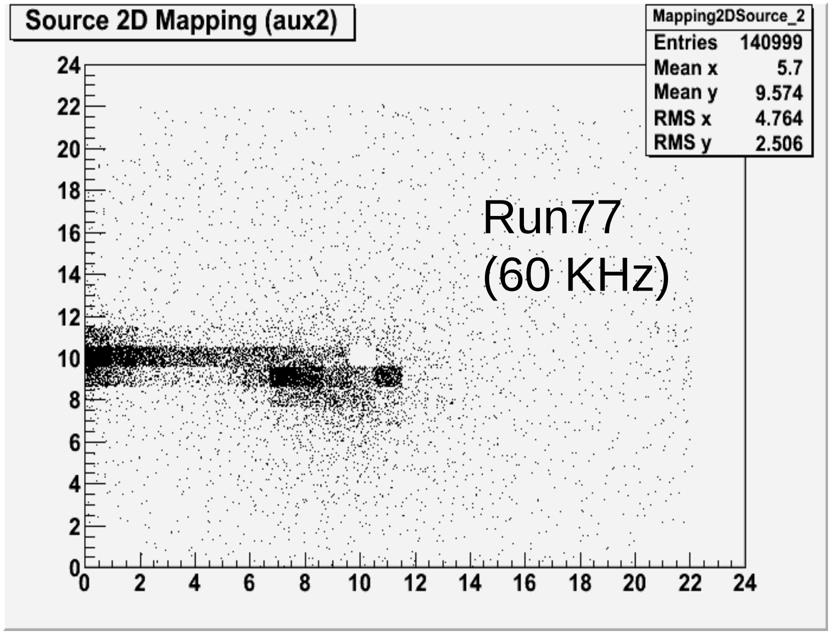
Efficiency



150 GeV/c pion Beams, CERN SPS

self triggered mode

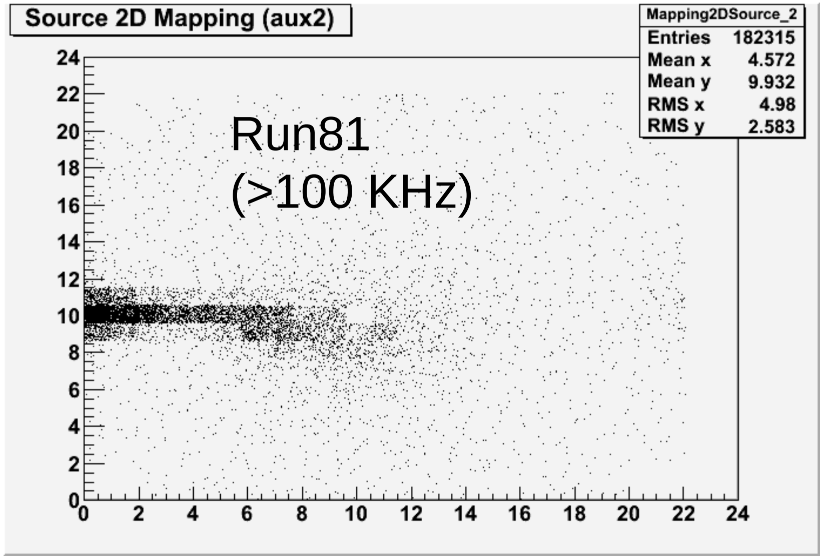




Beam spots at High Rates

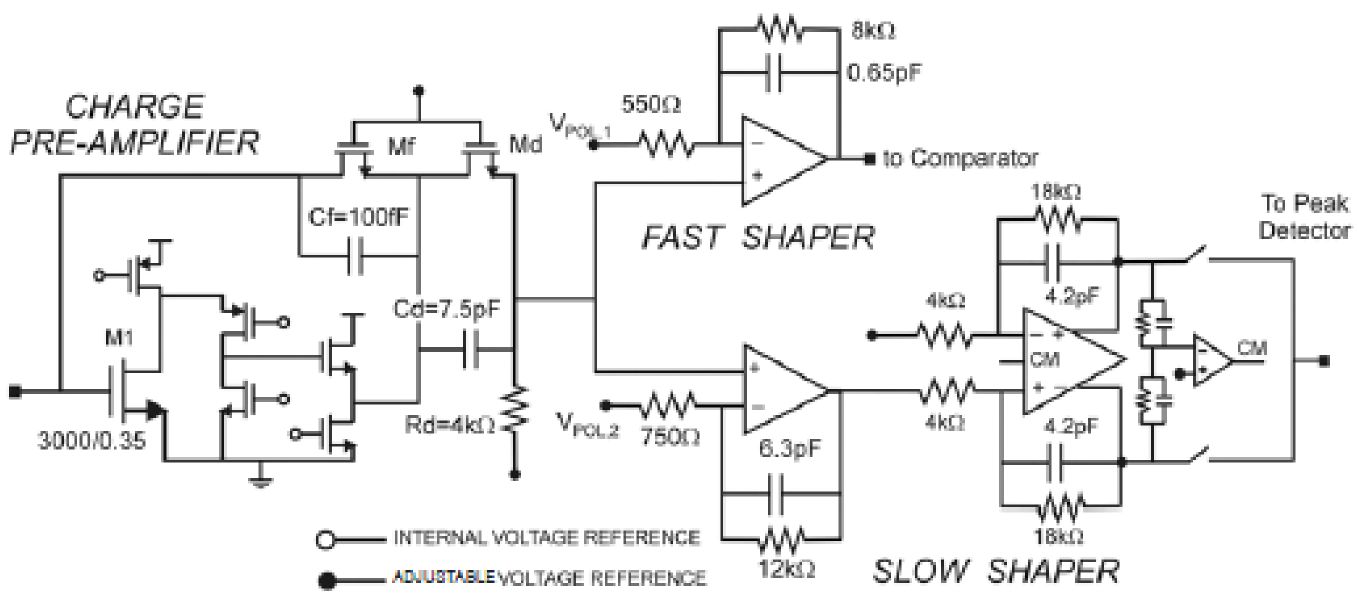
The structure
as investigated offline was
due to wrong settings of the nXYTER
Parameter –>discharge time was large.

The issue is hopefully solved.

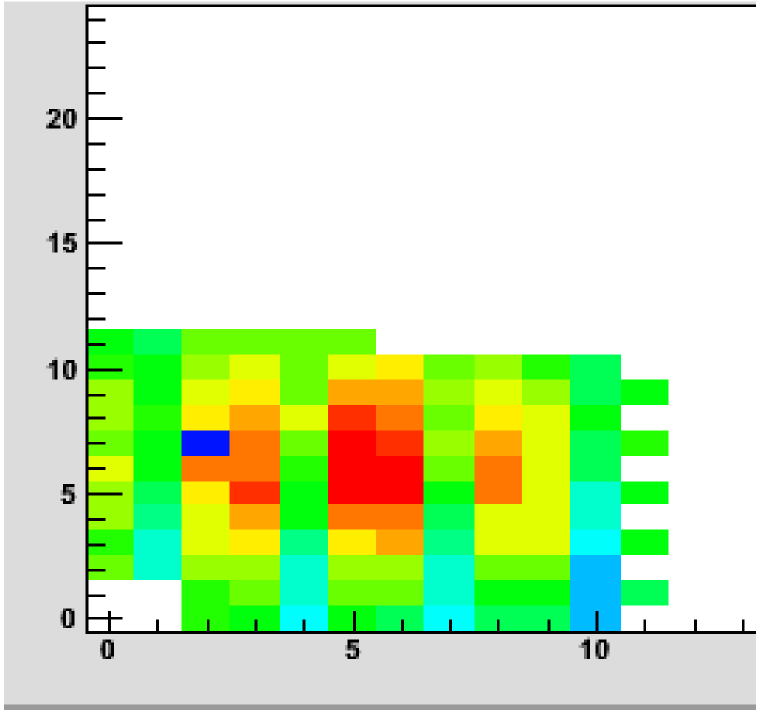


nXYTER parameter which might play a role

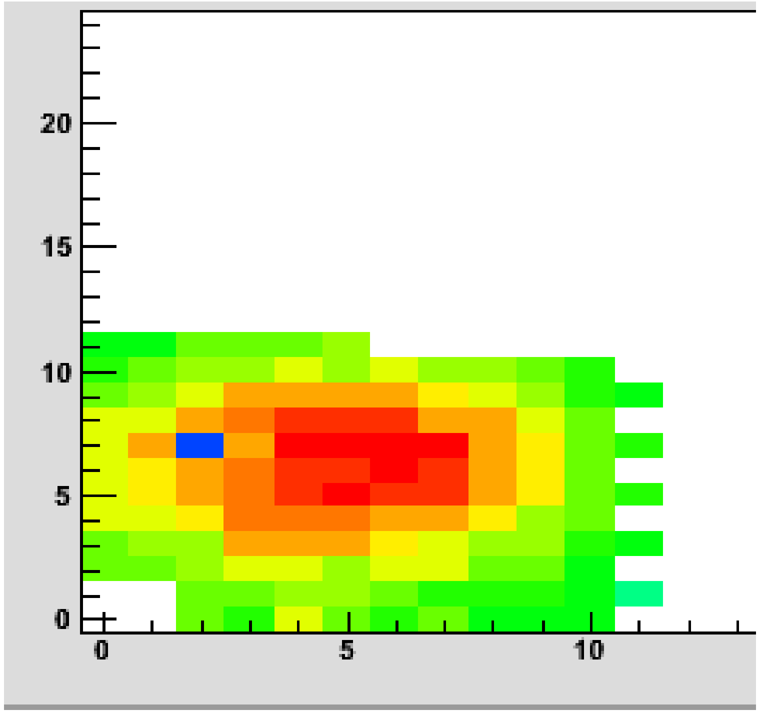
Vbfb (19) Sets the discharge time for the preamplifier by controlling the resistance of the transistors Mfb and Mpz. Vbfb is also the upper limit for the output voltage. A large negative charge as input produces a large positive output signal that might be cut through if Vbfb is set too low. Nevertheless, increasing Vbfb will decrease the discharge resistance and result in greater noise and undershoot. It also decreases the rise and discharge time.



Co60 source test showing distorted beam spot with lower Vbfb



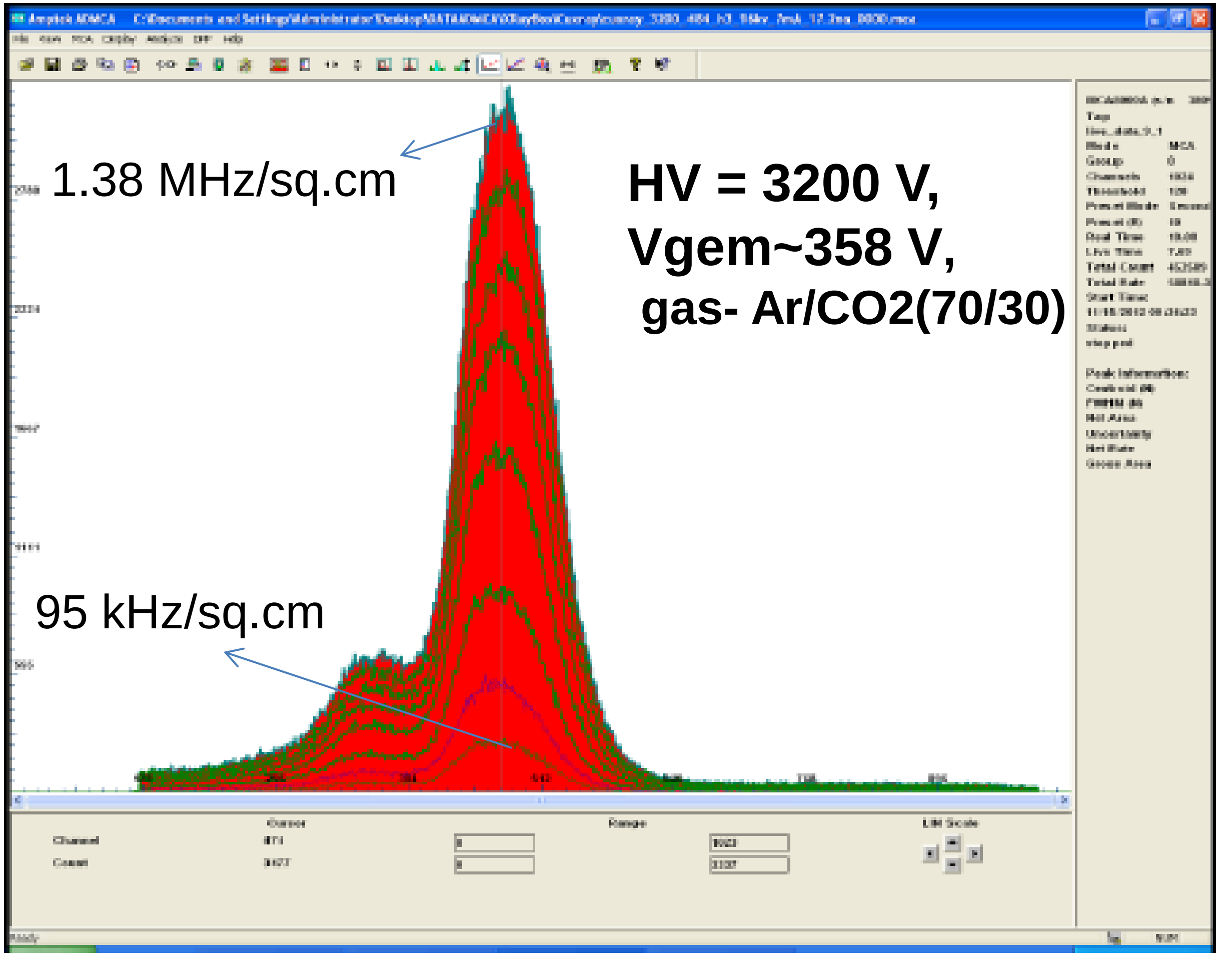
DAQ 2D plot with Co60 Vbfb=25, hits are missing in Central region



DAQ 2D plot with Co60 Vbfb=55, well defined beam spot

Rate test using high intensity Cu X-ray source in RD51 lab at CERN, with conventional electronics

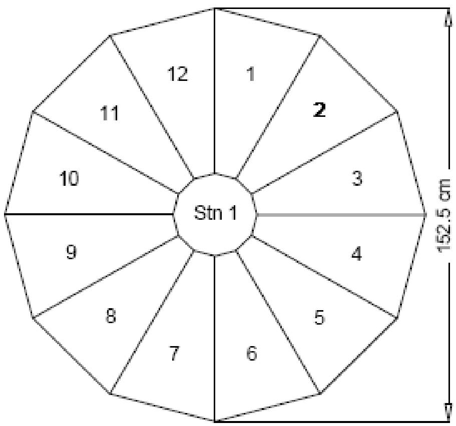
X-ray study with VEC chamber in RD51 lab

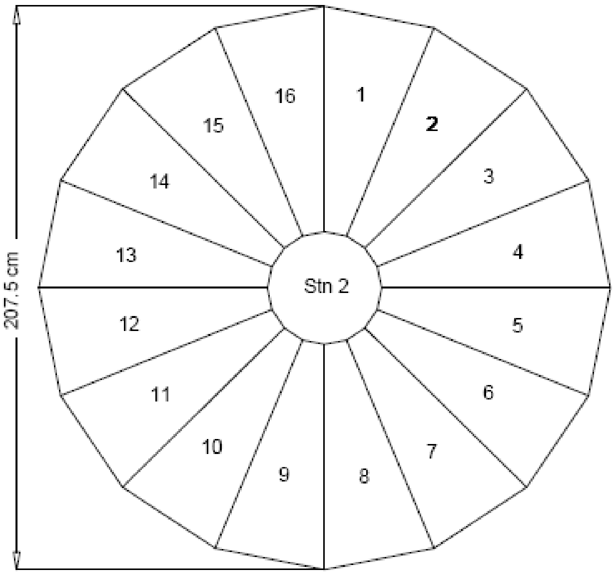


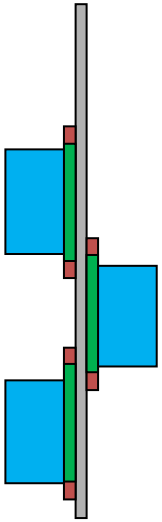
Gain does not change with rate

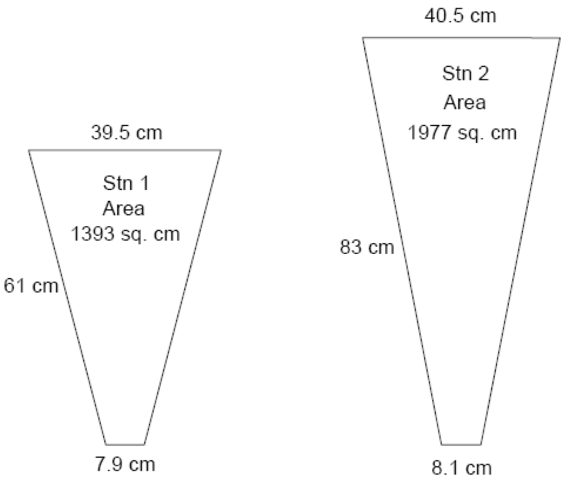
Highest Rate in this picture ~ 1.4 MHz/cm^2

Sector layout of GEM chambers





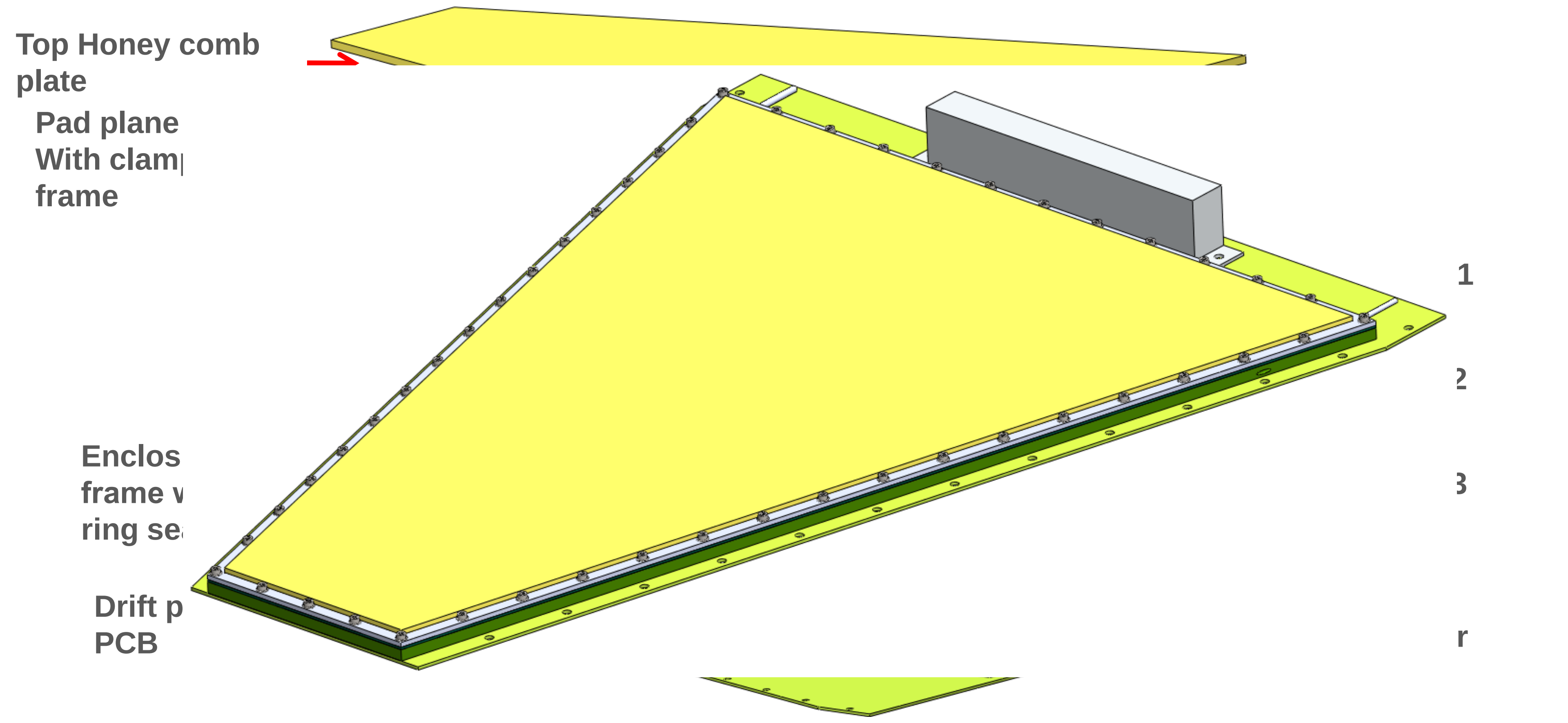




Station #	Layer #	R1 (cm)	R2 (cm)	Area (sq.mt)
1	1	13.25	66.25	1.32
	2	14.25	71.25	1.53
	3	15.25	76.25	1.75
2	1	18.75	93.75	2.65
	2	19.75	98.75	2.94
	3	20.75	103.75	3.24
3	1	24.25	121.25	4.43
	2	25.25	126.25	4.80
	3	26.25	131.25	5.19

Total area = ~28 x 3 = 84 sq. m + spares, For SIS 100 → 42 sq. m. + spares

Sector Chamber elements – exploded view



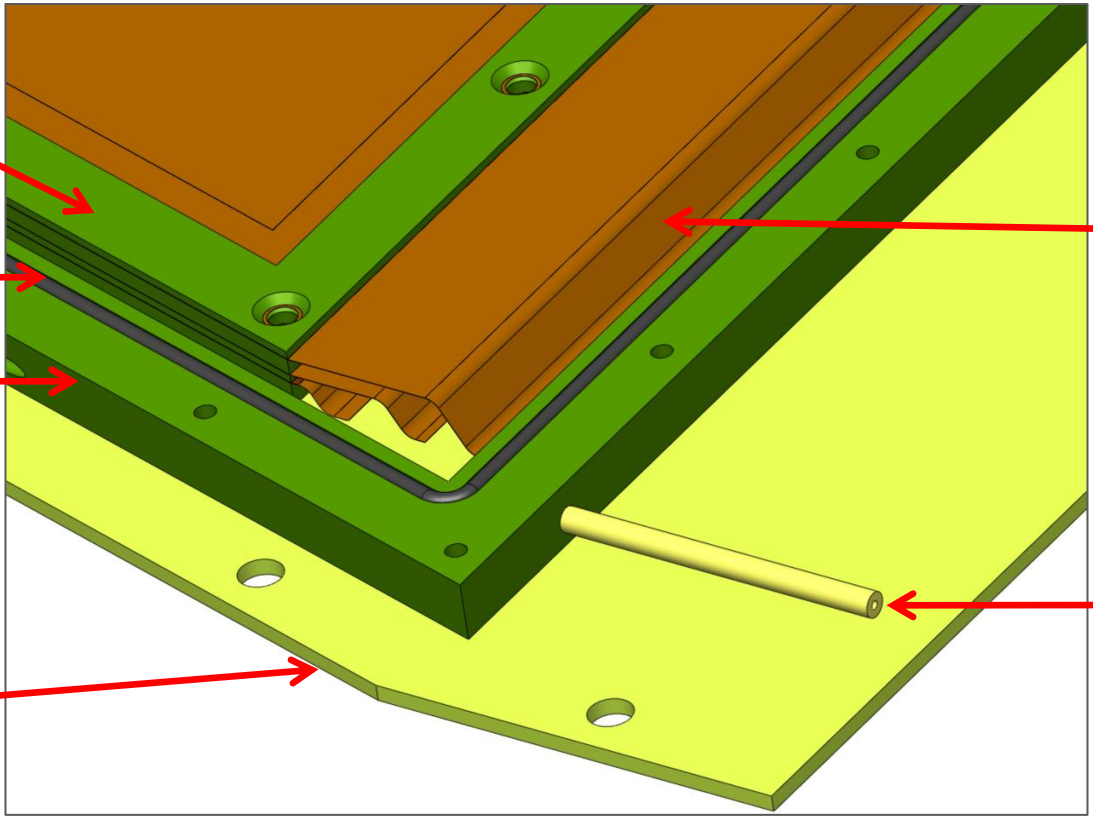
Gem foil stack inside the chamber

Framed GEMs

'O' ring seal

Gas tight boundary frame

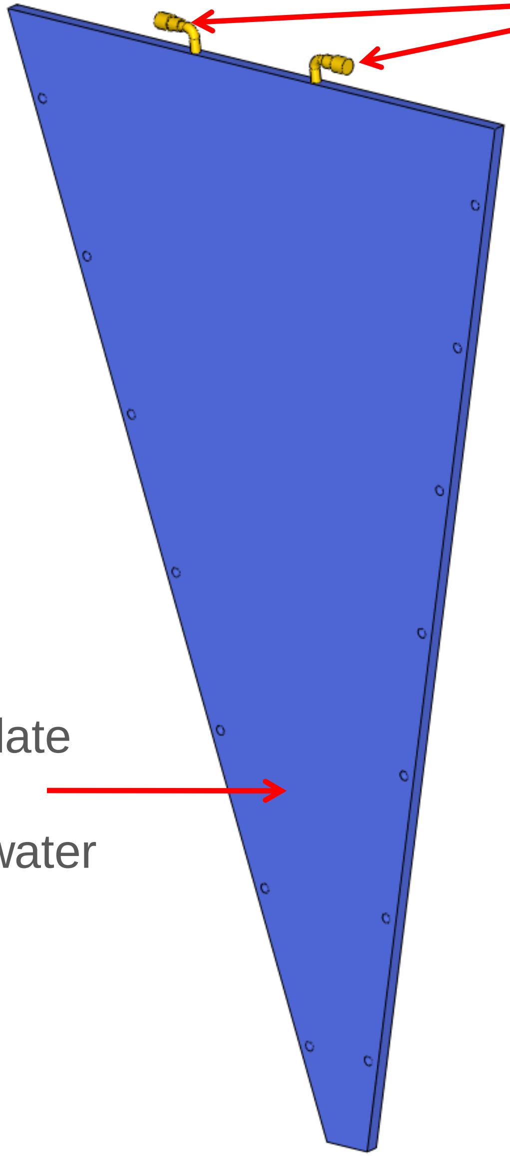
Drift plane PCB



HV tails on kapton

Gas connection

Cooled plate for FEB cooling



Chilled water In/Out connections

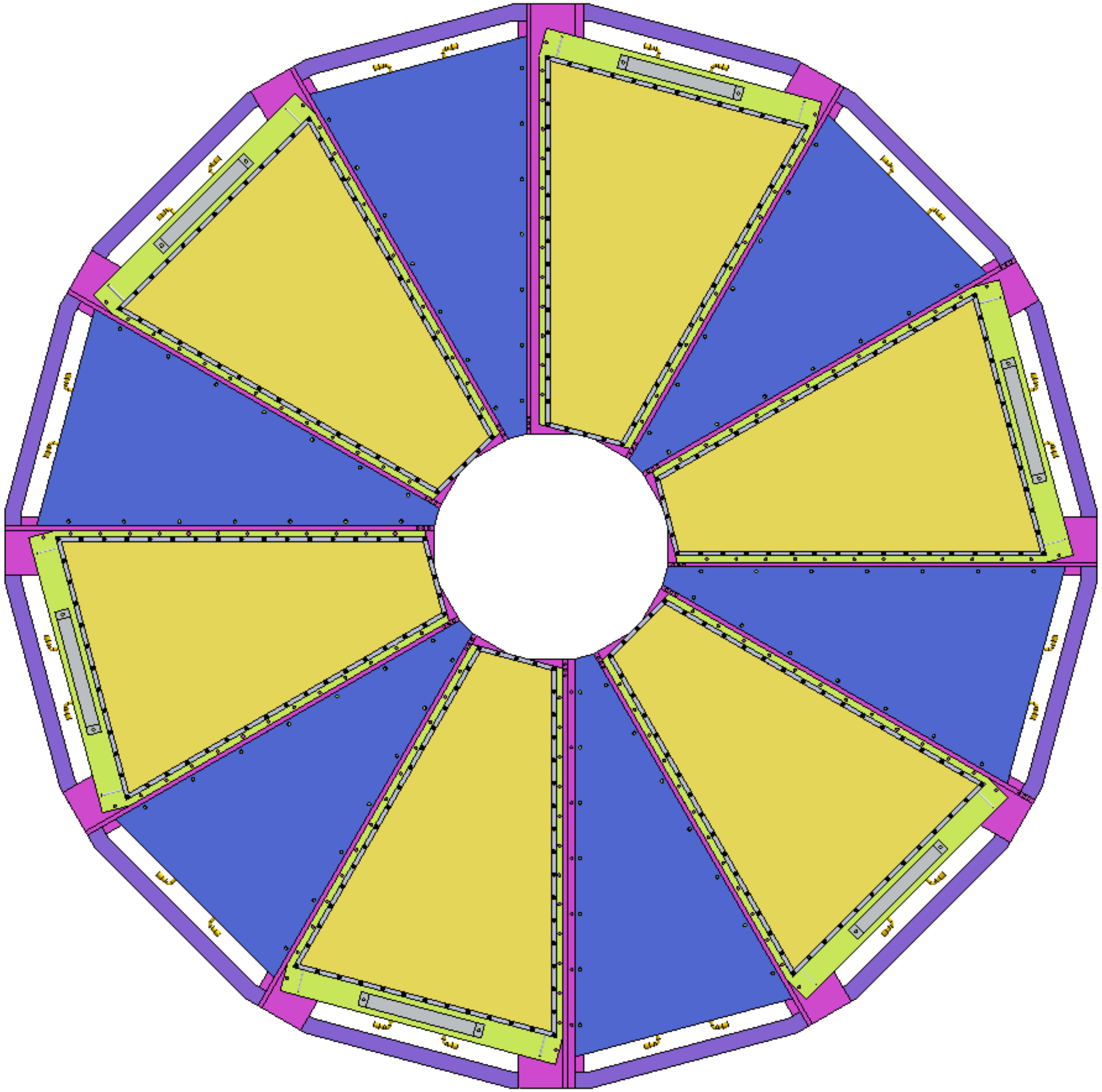
8mm thick Alluminum plate with internal channel for water flow

Front view of an assembled layer – Station1

- The chambers are assembled on the support structure at alternate positions on both sides of the plane.

- 12-chambers, 6 on each side of the support plane are shown in the figure.

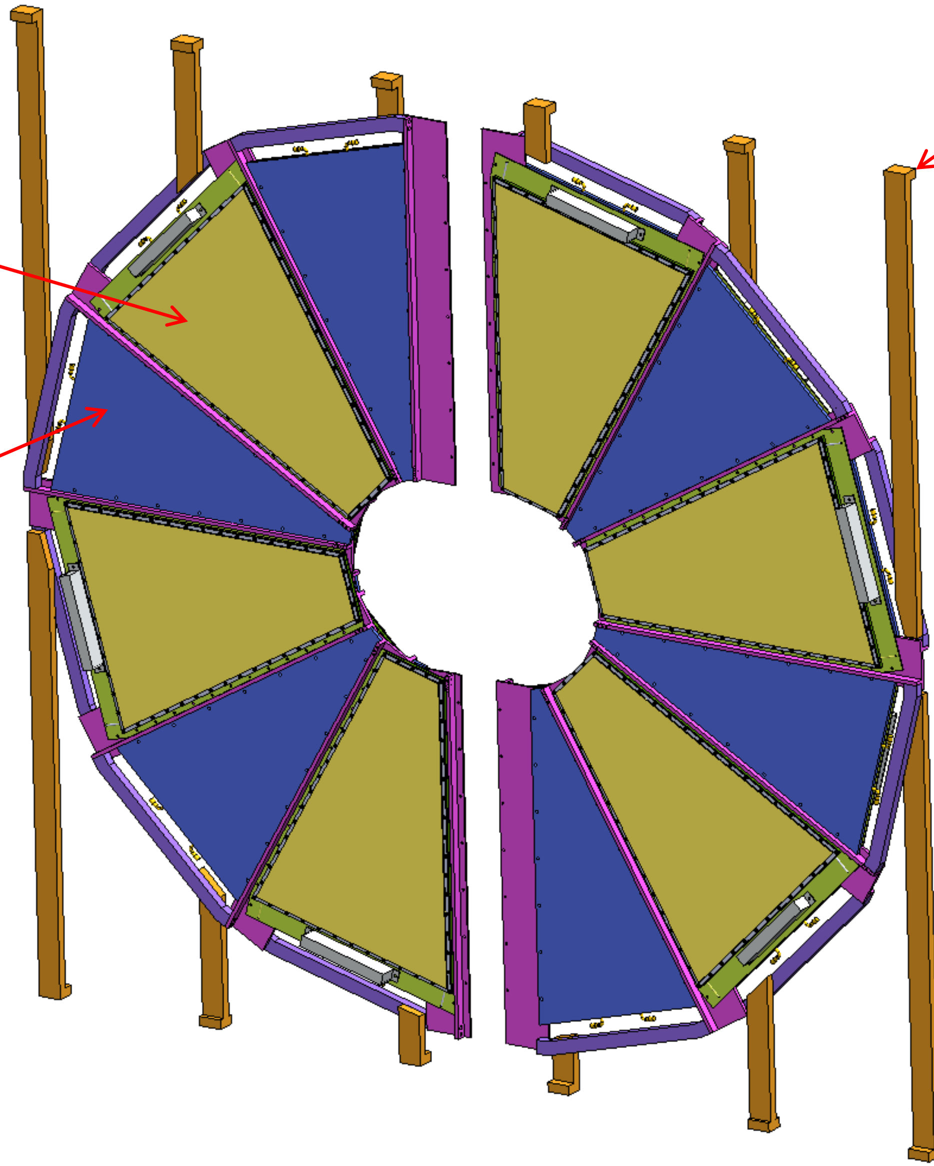
- The chamber frame areas are overlapped to make a seamless active area of the pad plane.



Sector chambers on the support structure

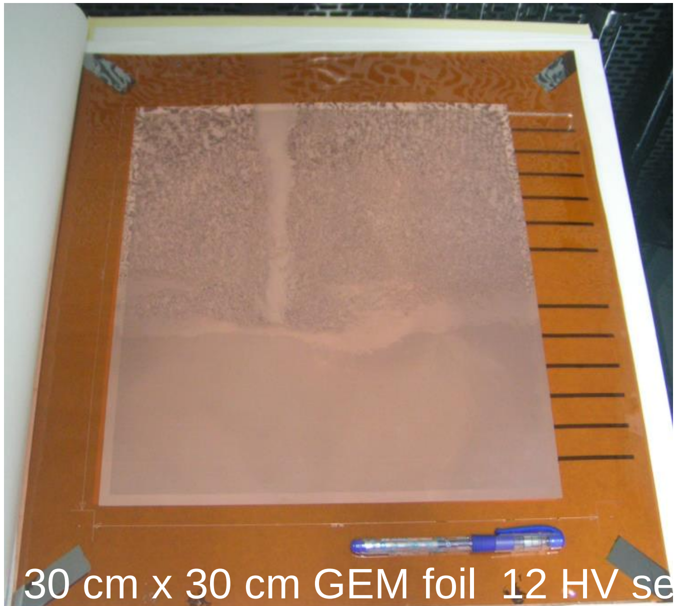
Sector GEM chamber module

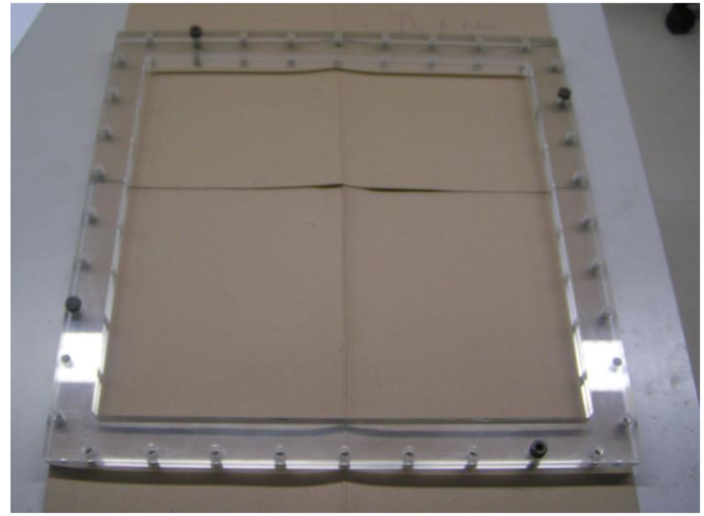
Water cooled Allluminum plate

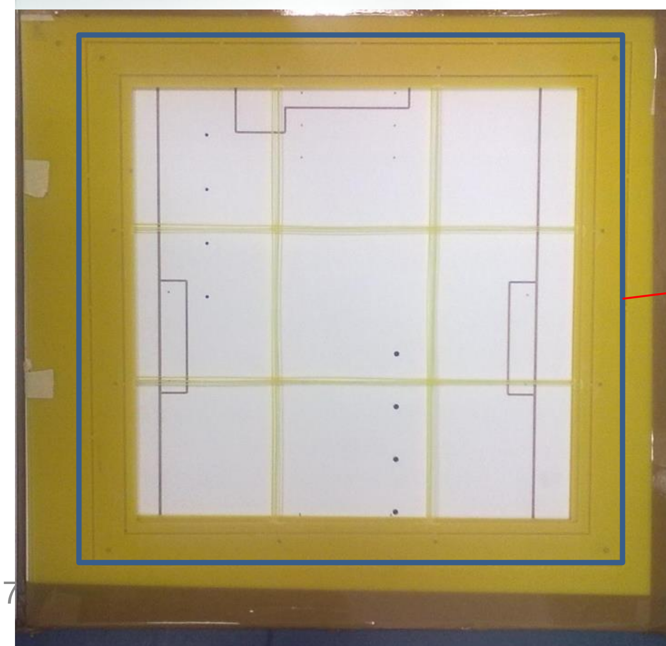


To be attached to slide rail carriages

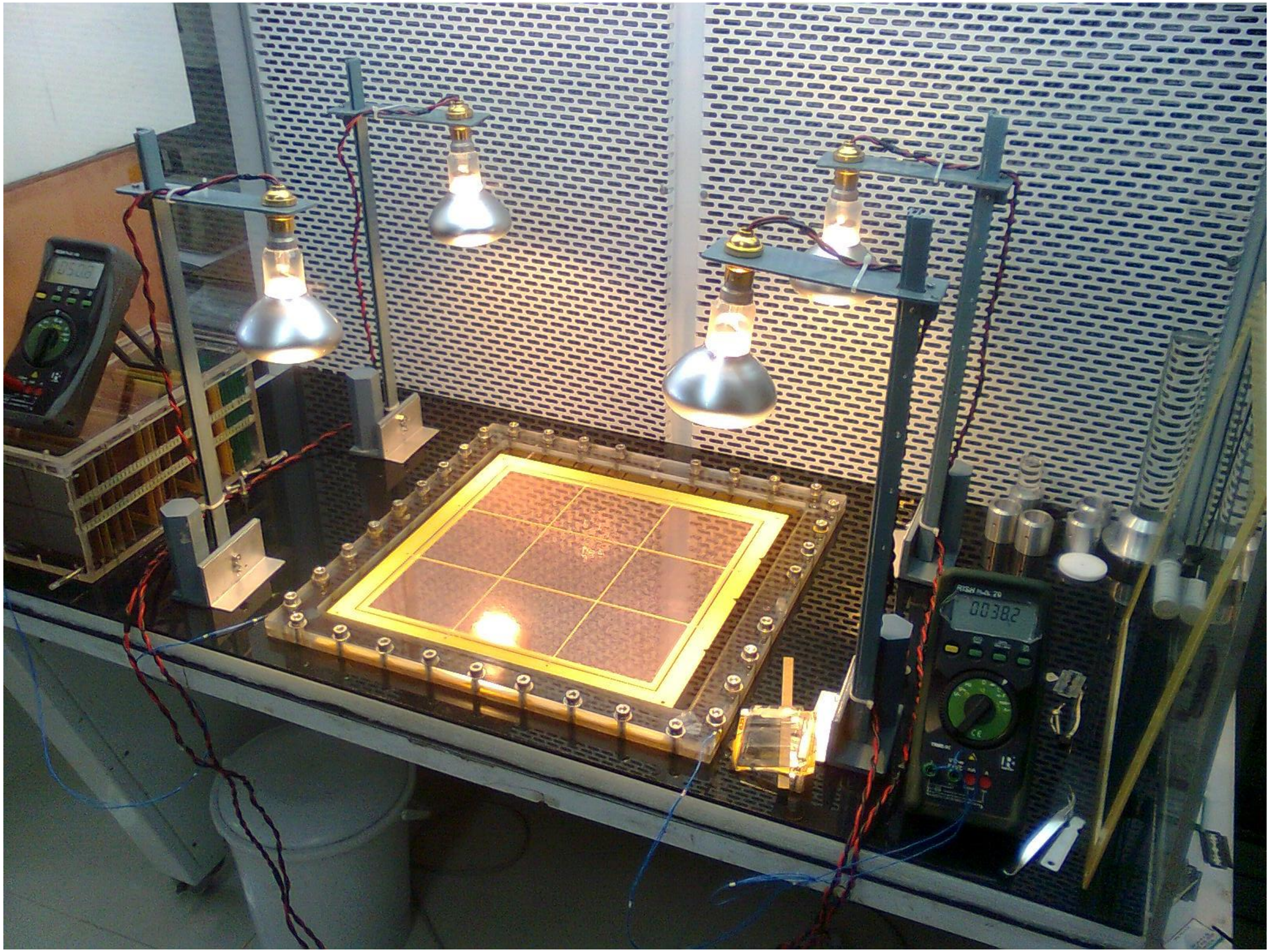
Towards making a large size GEM chamber



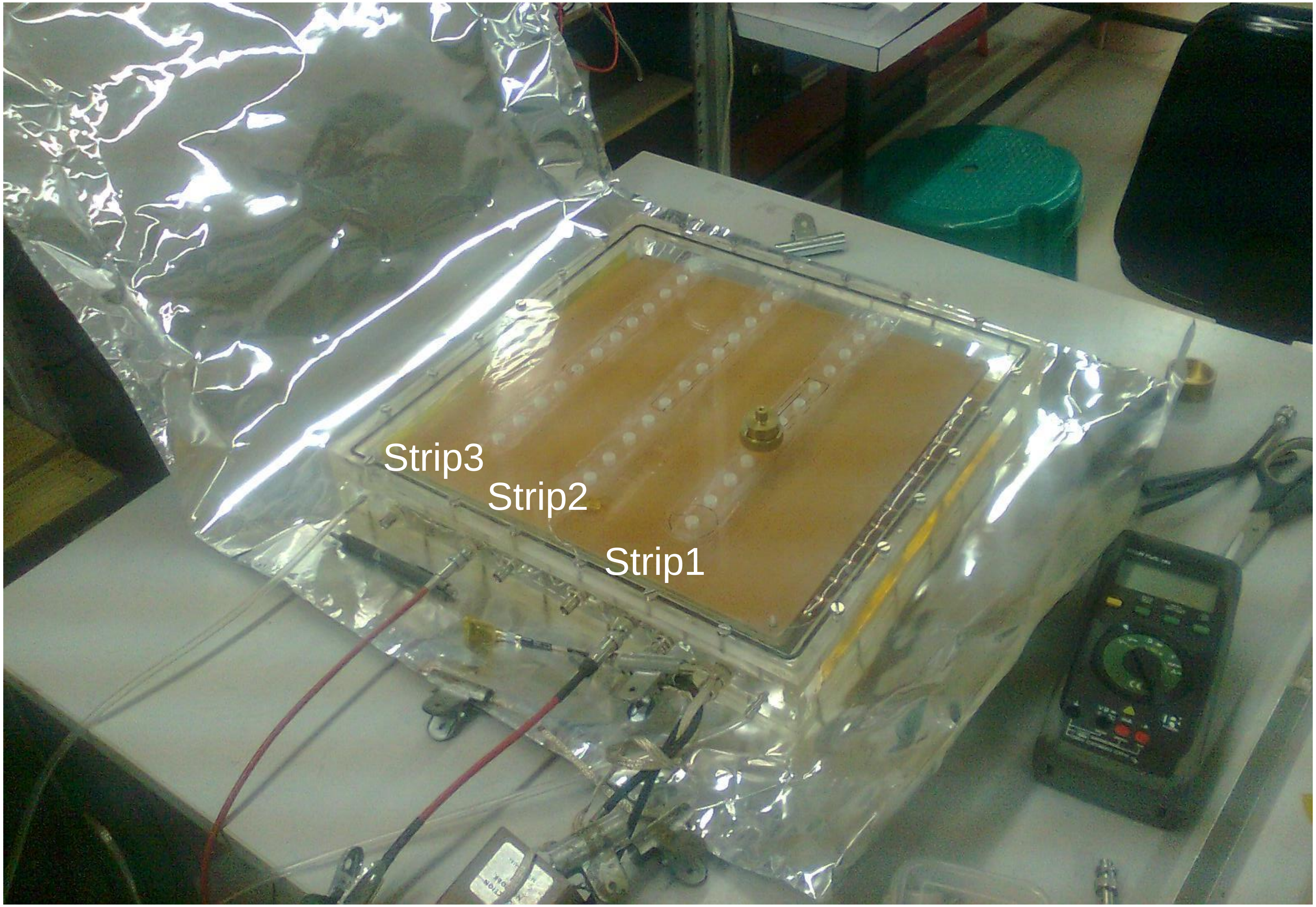




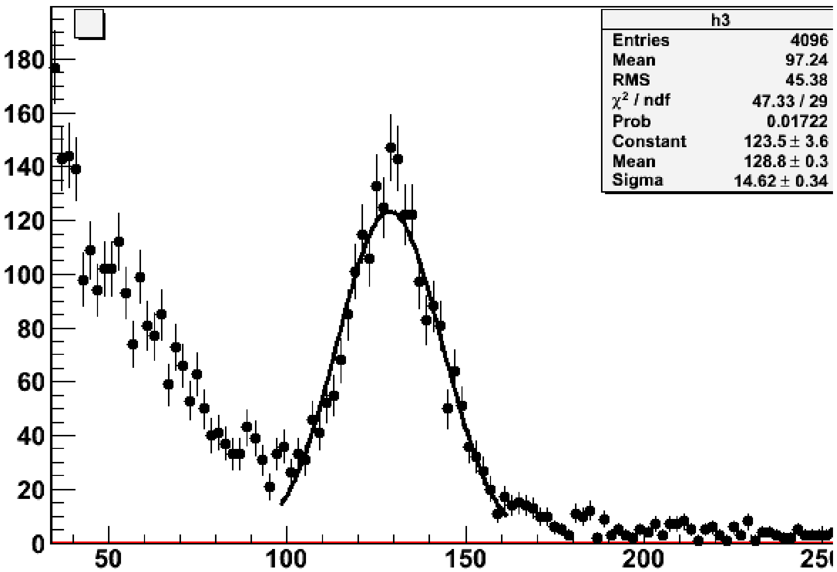
Thermal stretching and framing of 30 cm x 30 cm large size GEMs at VECC



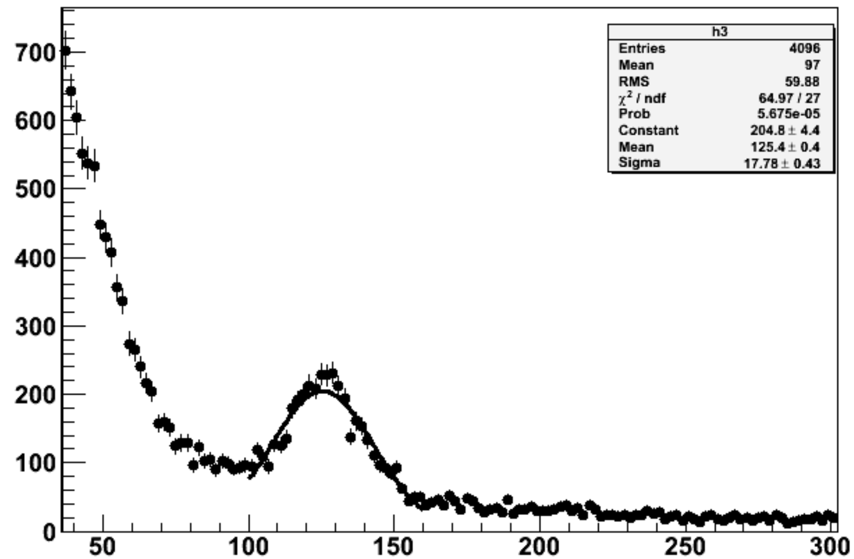
A Large size 30 cm x 30 cm single GEM chamber under test



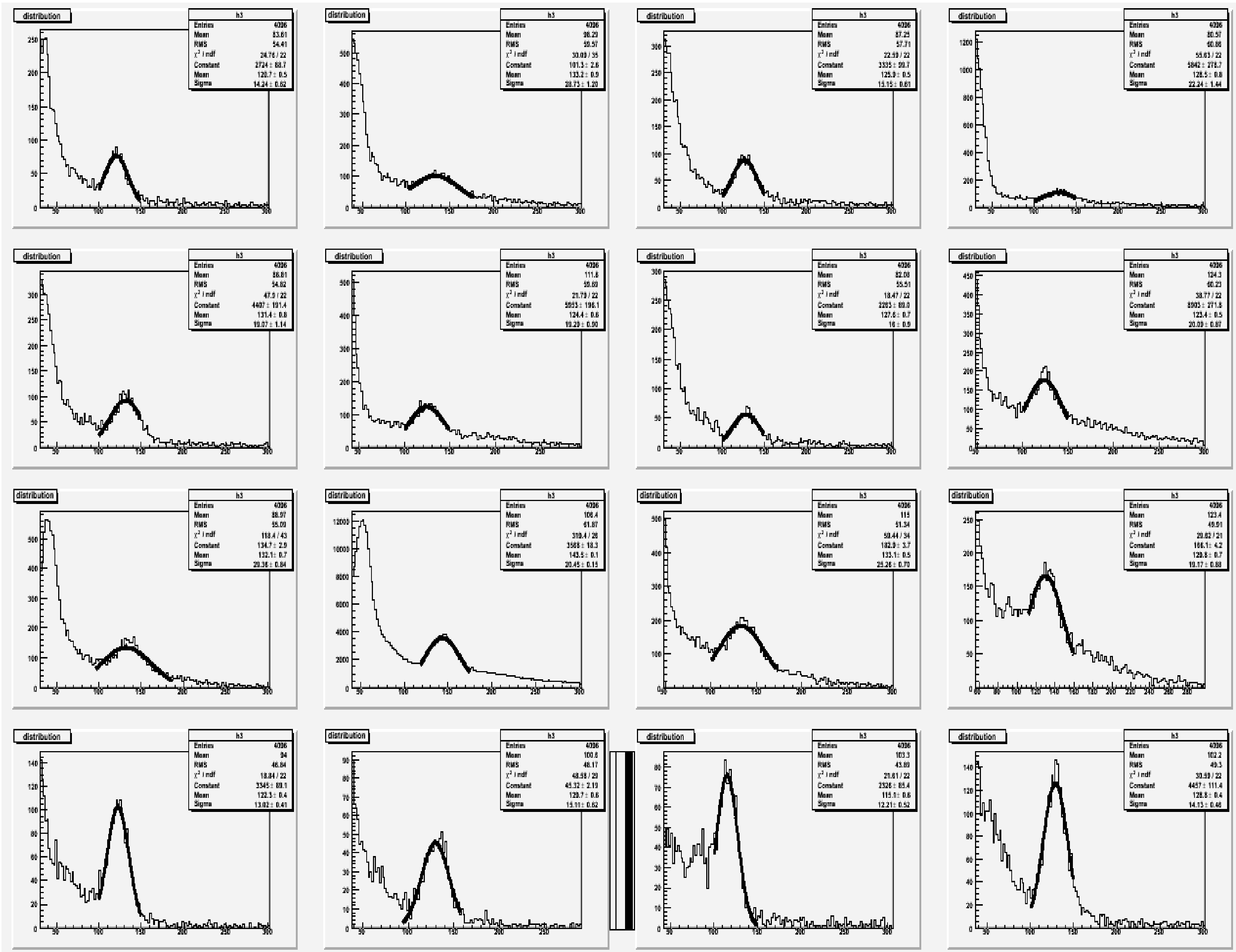
Xray test (Fe55) of Single GEM chamber
gas– Ar/CO2, Vgem ~525 V



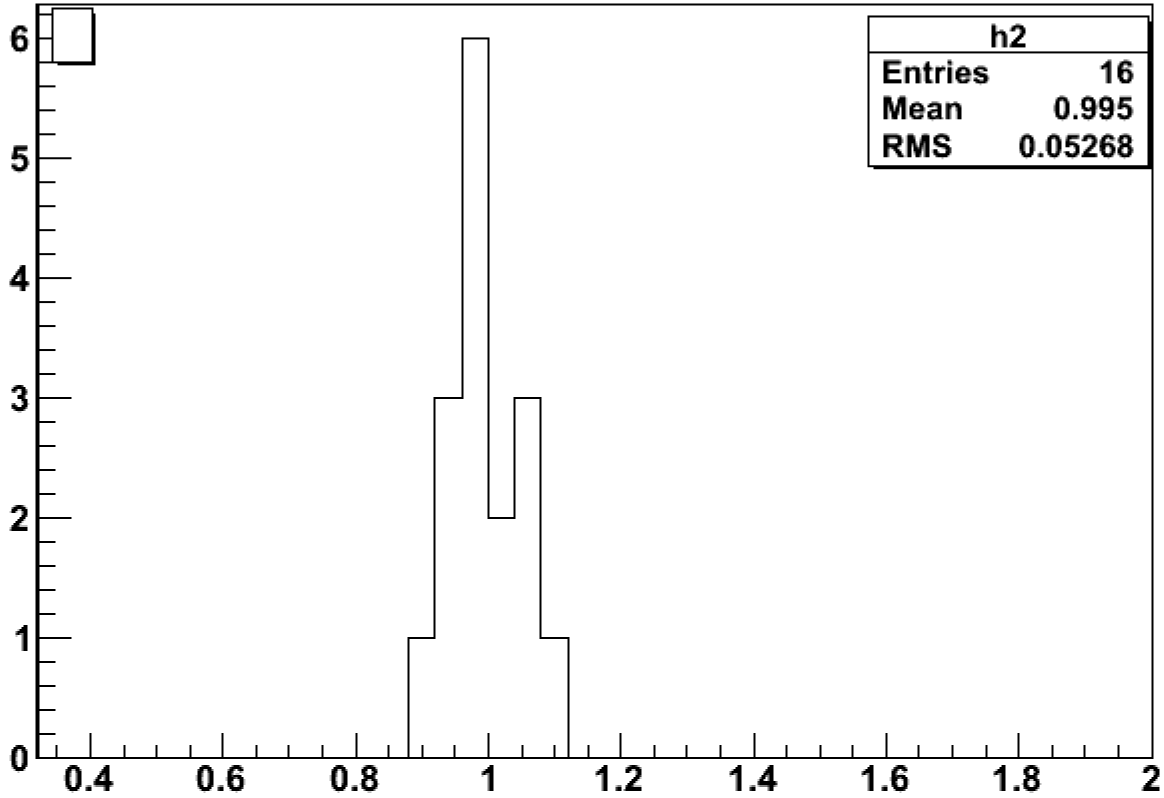
ADC



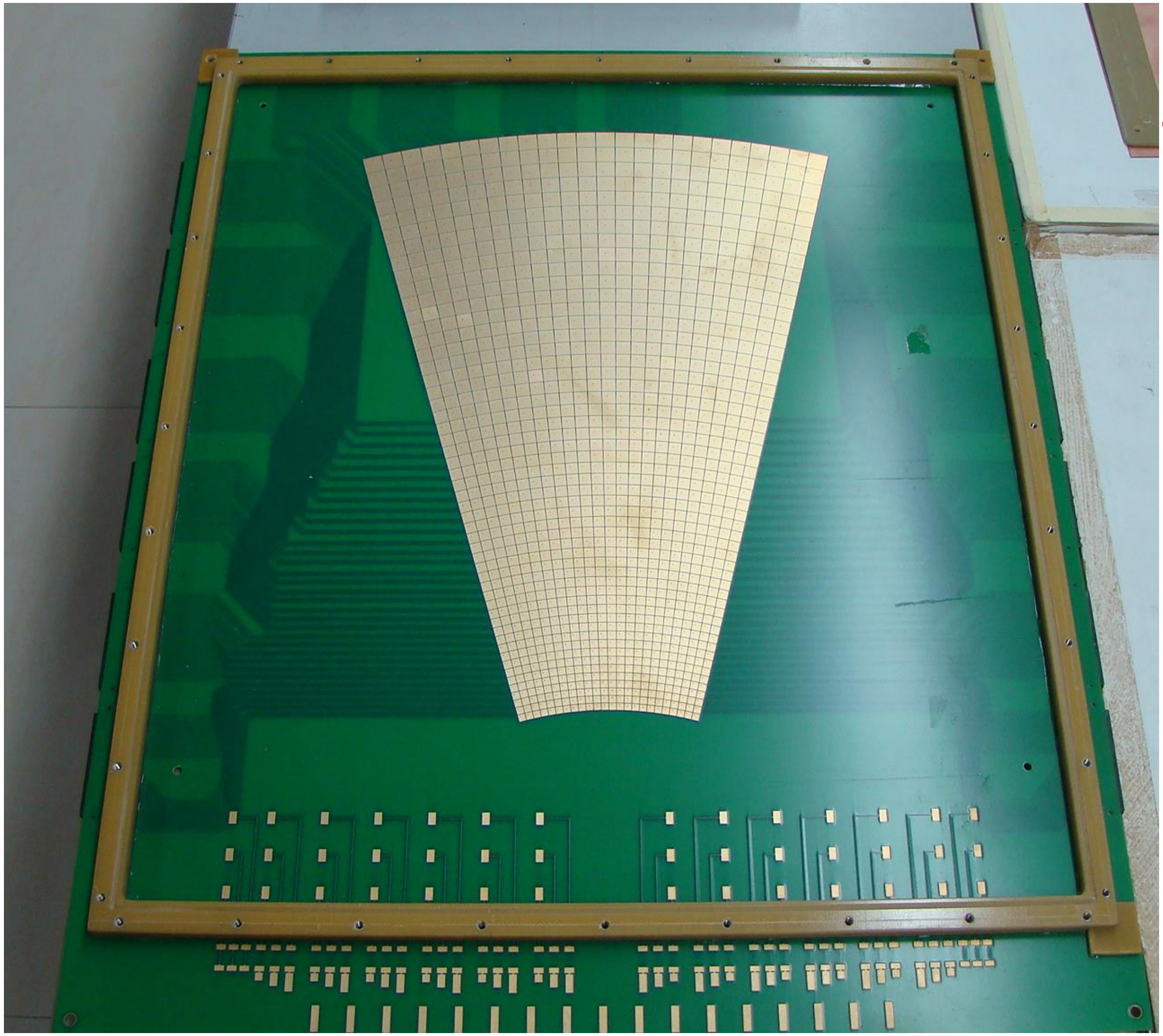
ADC


distribution
h3
Entries
Mean
RMS
Constant
Mean
Sigma

Relative gain as measured at 16 different regions over the entire area



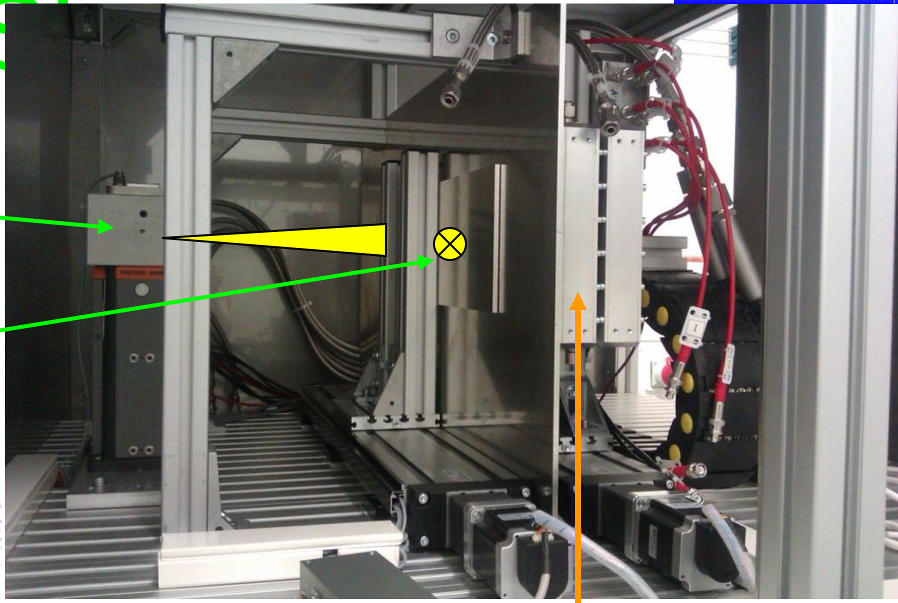
A large size triple GEM chamber under fabrication

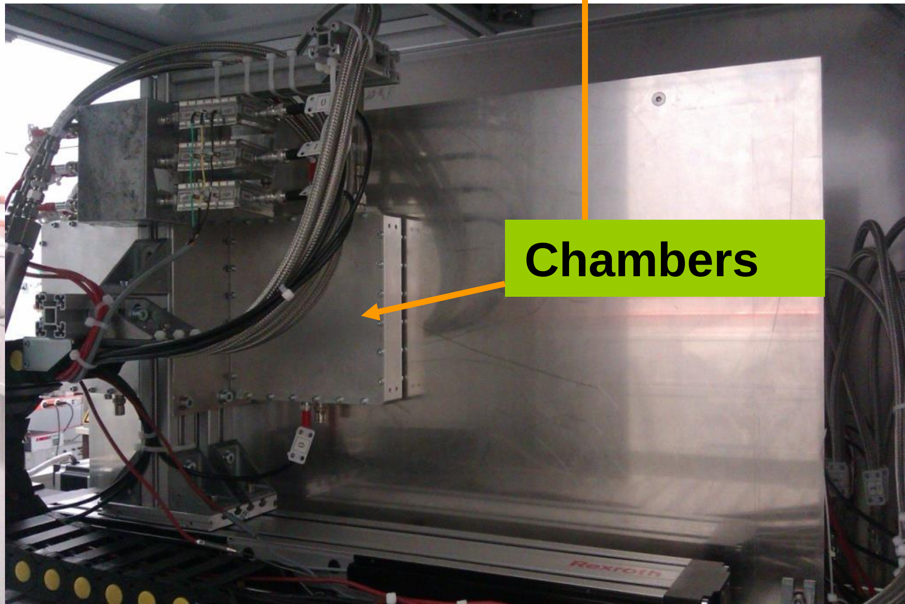


~ **Sector based readout.**
 1200 pads with progressive increasing size
-- **9 FEBs placed at the three sides of the board**
-- **5 ROC's would be needed**

Alhussain: GSI

New ageing setup at GS





SUMMARY

- We have built and tested several multi GEM prototypes at VECC.
- Response to MIPs: using cosmics an efficiency of 95 % achieved using conventional electronics. Prototypes tested with proton, pions, muon beams.
- Preliminary results suggest an efficiency of ~95 % with muon beams using self trigered readout, more analysis underway.
- First attempts at stretching, framing and testing large size GEM (30cm x 30 cm) – produced 3 framed GEMS so far – gain uniformity reasonable.
  - -- temperature control is quite critical, to prevent overstretching
  - -- the technique needs to be perfected, we are on the job.
  - -- mechanical stretching methods to be tried in the coming months
  - -- may adopt "ns2" stretching technique being developed by RD51 for CMS
- Next Steps:
  - -- Building a large size GEM (30 cm x 30 cm) chamber. Solving issues concerning design, stretching/gluing, optimizing jigs, etc.
  - -- Radiation test with neutrons at VECC, although at low rates.
  - -- Rate capability test to be performed using protons, at Julich test facility in this fall.
- FEE – has been nXYTER so far, an ASIC similar to nXYTER is under production.
- MUCH TDR is targeted to be written by the end of the year.

Collaborators

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Anton Lymanets, Hans Rudolf Schmidt

-
- BACKUPS

MUCH-XYter: specifications

- Input signal range of 1.5-100 fC
- Charge polarity – negative
- ENC – less than 0.3 fC
- Detector capacitance up to 100 pF
- maximum hit rate/channel – 2 MHz
- Power consumption – 2 mW/ch