Dimuon Detection at CBM

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Outline

- Layout of the CBM Detector
- Schematic of dimuon measurements in different expt.
- Muon Chamber (MUCH) system of CBM
    - -- Muon Design Requirements
    - -- Simulation results
    - -- Detailed Detector R&D
- Summary

Why Dileptons ?

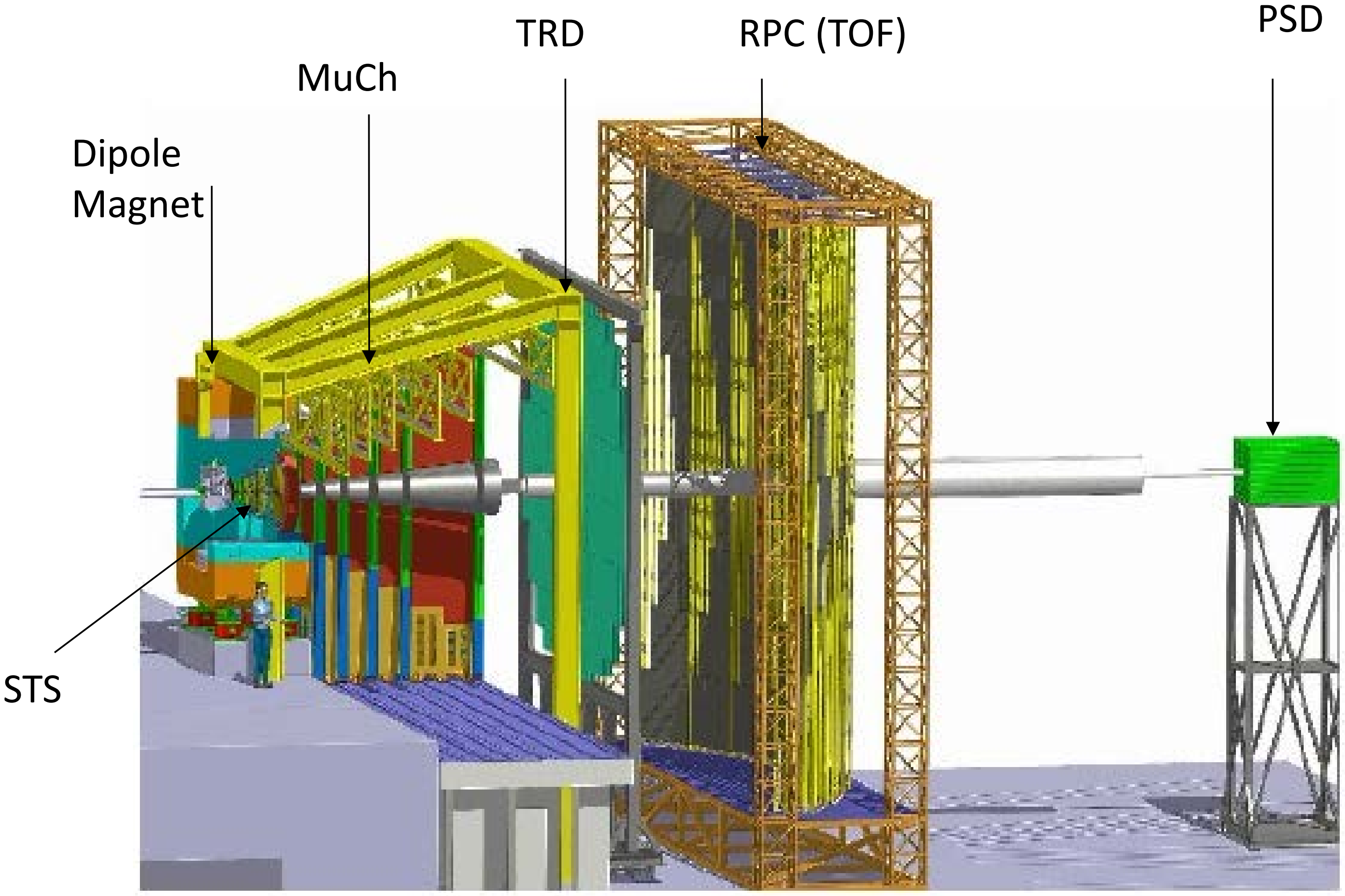
- Dilepton pairs **(e^+,e^-) and (μ^+,μ^-)** provide valuable information on the evolution and on the properties of the hot and dense fireball formed in the heavy ion collisions.

- These measurements in heavy-ion collisions will open a new era of dilepton experiments in the energy range between 2 and 40 A GeV where the highest net- baryon densities can be created in the laboratory.

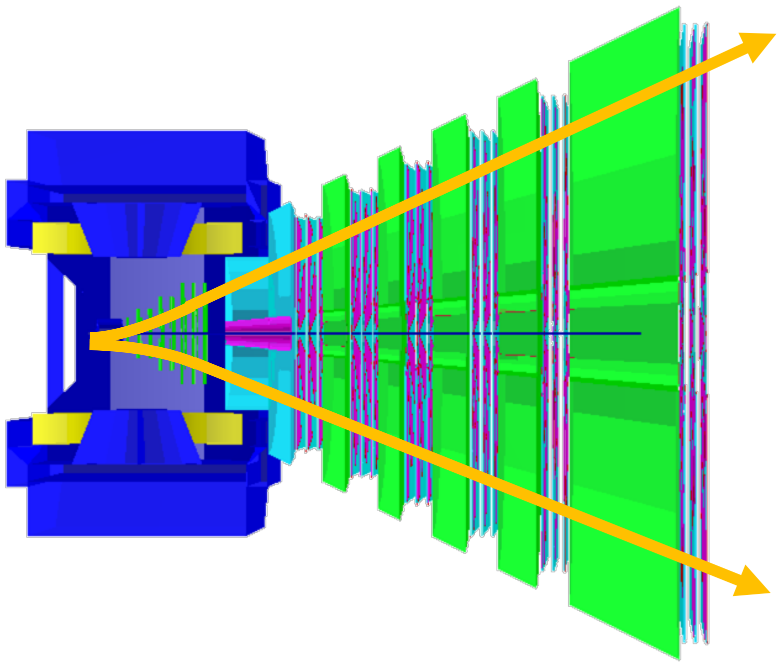
- ➔ physics issues : onset of deconfinement phase transition,
  search for critical end point, equation of state

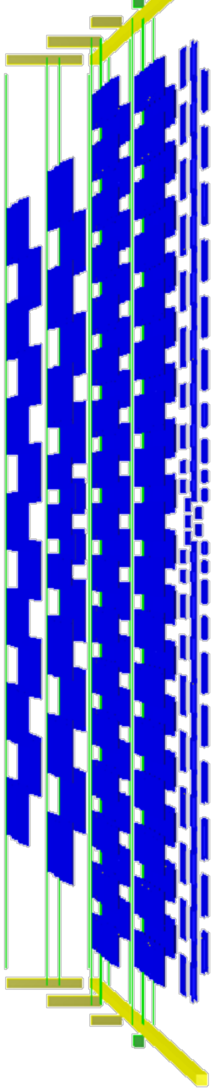
- The CBM collaboration will systematically measure both di-electrons and di-muons in p+p, p+A and A+A collisions as function of beam energy and size of the collision system.

CBM Experiment @ FAIR



Muon Chamber (MUCH) System @ CBM





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

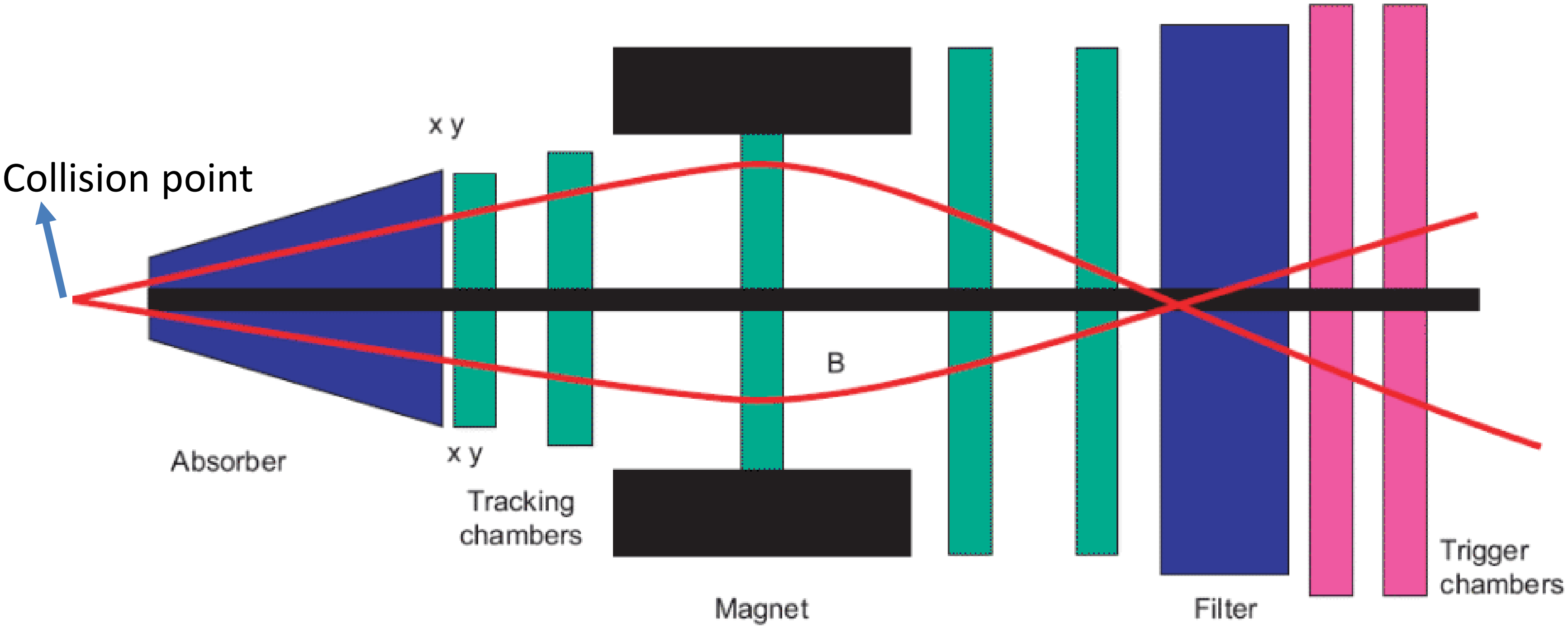
Novel subsystem of segmented absorbers and alternating detector stations,

design goal being to simultaneously identify low and high momentum muons over full phase space

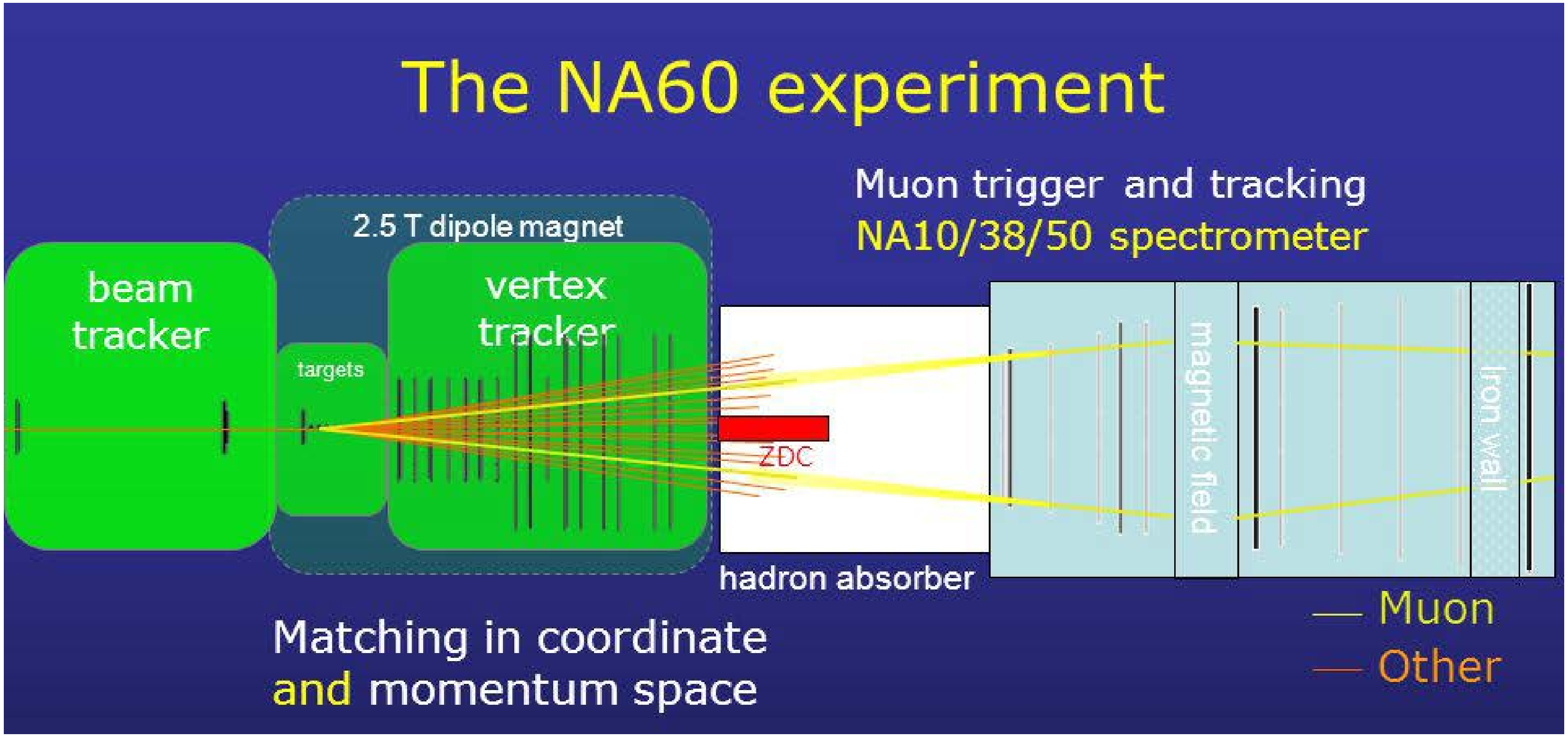
What is the typical configuration for dimuon detection in high energy physics ?

ALICE MUON ARM

The ALICE forward muon spectrometer will study the complete spectrum of heavy quarkonia (J/Ψ, Ψ′, ϒ, ϒ′, ϒ′′) via their decay in the $\mu^+\mu^-$ channel.



The optimized design provides
--- a good shielding capability and
--- a limited multiple scattering (…mass resolution).
→ Using low-Z material in the absorber layers close to the vertex, and a high-Z shielding materials at the other end. => Pb + Boronated polyethylene & Pb + tungsten


The NA60 experiment
Muon trigger and tracking
NA10/38/50 spectrometer
2.5 T dipole magnet
beam tracker
targets
vertex tracker
ZDC
magnetic field
iron wall
hadron absorber
Muon
Other
Matching in coordinate and momentum space

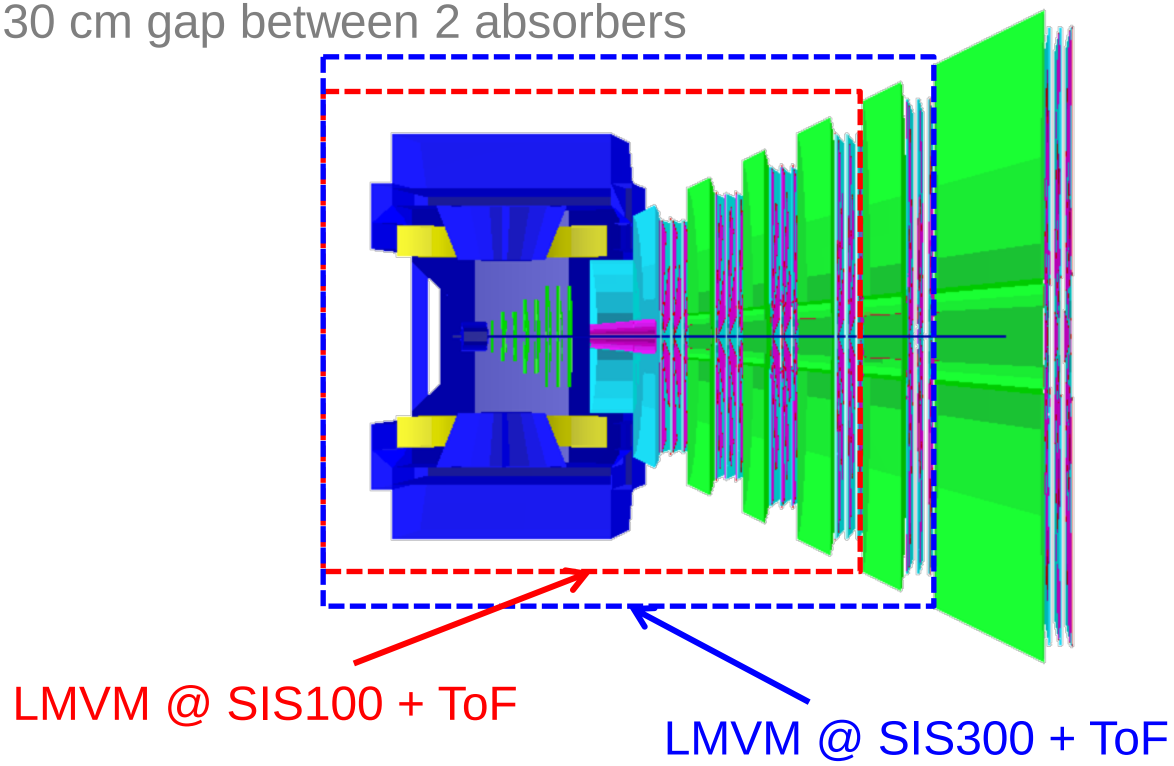
Muon detection system: MUCH

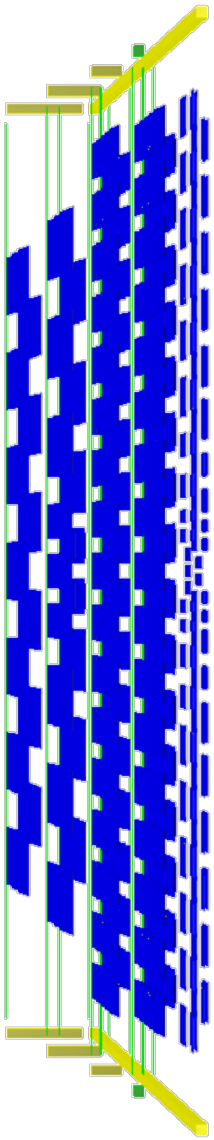
• ID after hadron absorber with intermediate tracking layers

• **major combinatorical background from π,K decays into μν, punch through of hadrons and track mismatches**

→ use excellent tracking to reject π,K decays in the STS

60 C + 20 Fe + 20 Fe + 30 Fe + 35 Fe + 100 Fe (cm)
30 cm gap between 2 absorbers



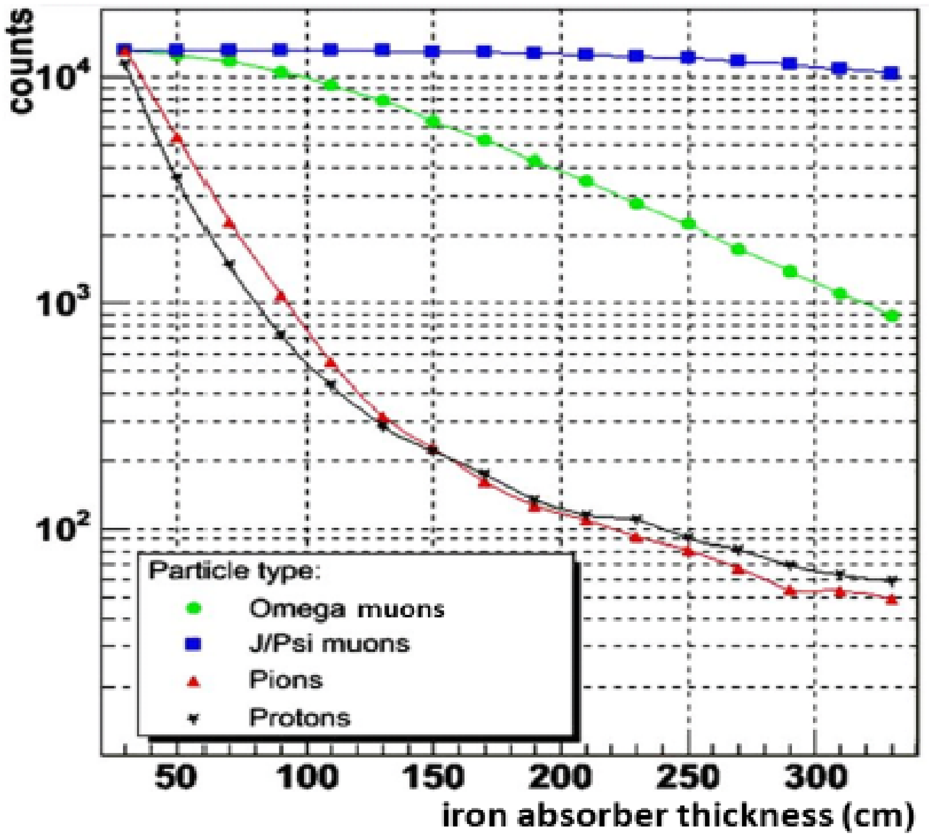


Optimizing Absorber thicknesses

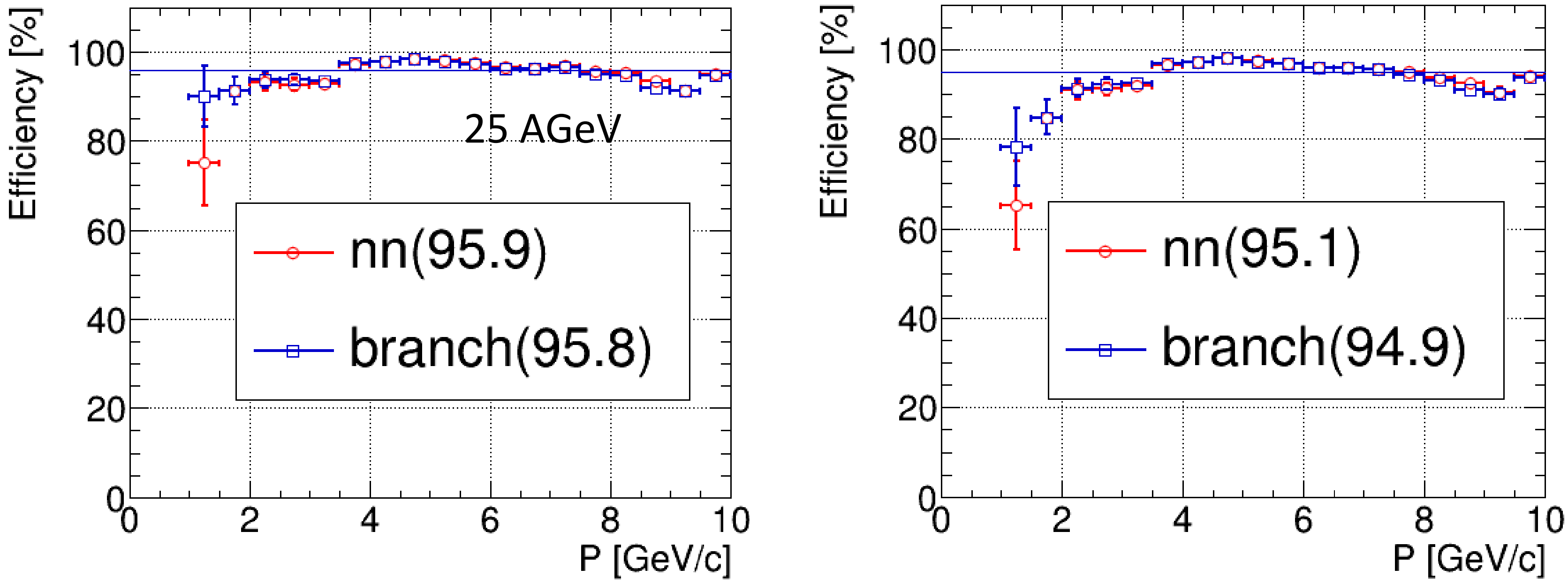
Inputs for Detector Optimization

URQMD background :
- **central Au+Au @8, 10 and 25 AGeV**
- **p+Au @ 30 GeV**

Pluto : signal distributions
- **LMVM @ 8 and 25 AGeV**
- **J/ψ @10 AGeV and 30 GeV**

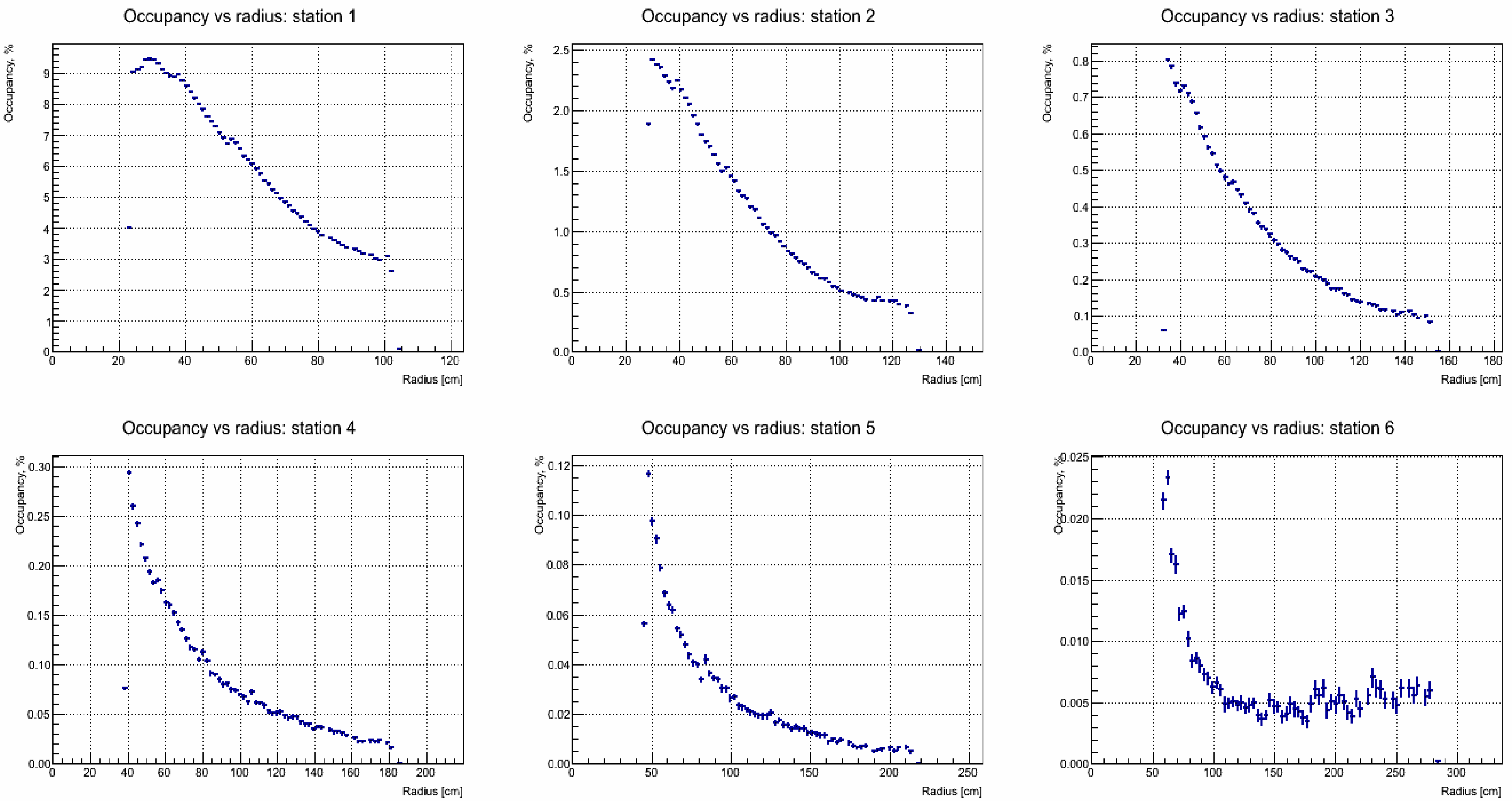


Total number of particles as a function of the traversed length in iron. The particle momenta have been taken from the simulation of central Au+Au collisions at 25 A GeV, their numbers have been normalized.



Track reconstruction efficiency for primary muon tracks from J/psi as a function of momentum for two tracking algorithms: nearest neighbor (red) and branching (blue). Left plot shows MUCH tracking efficiency, right plot shows STS-MUCH tracking efficiency. Horizontal lines represent numbers integrated over momentum.

Occupancy (25 AGeV central collisions)

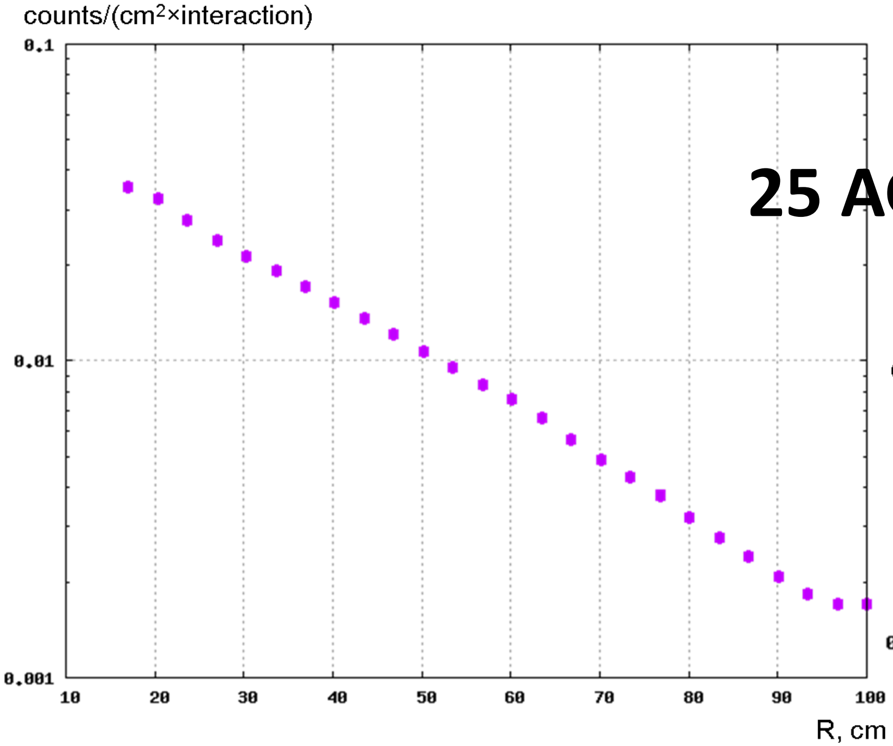


Geant3 + segmentation + GEM profile implemented

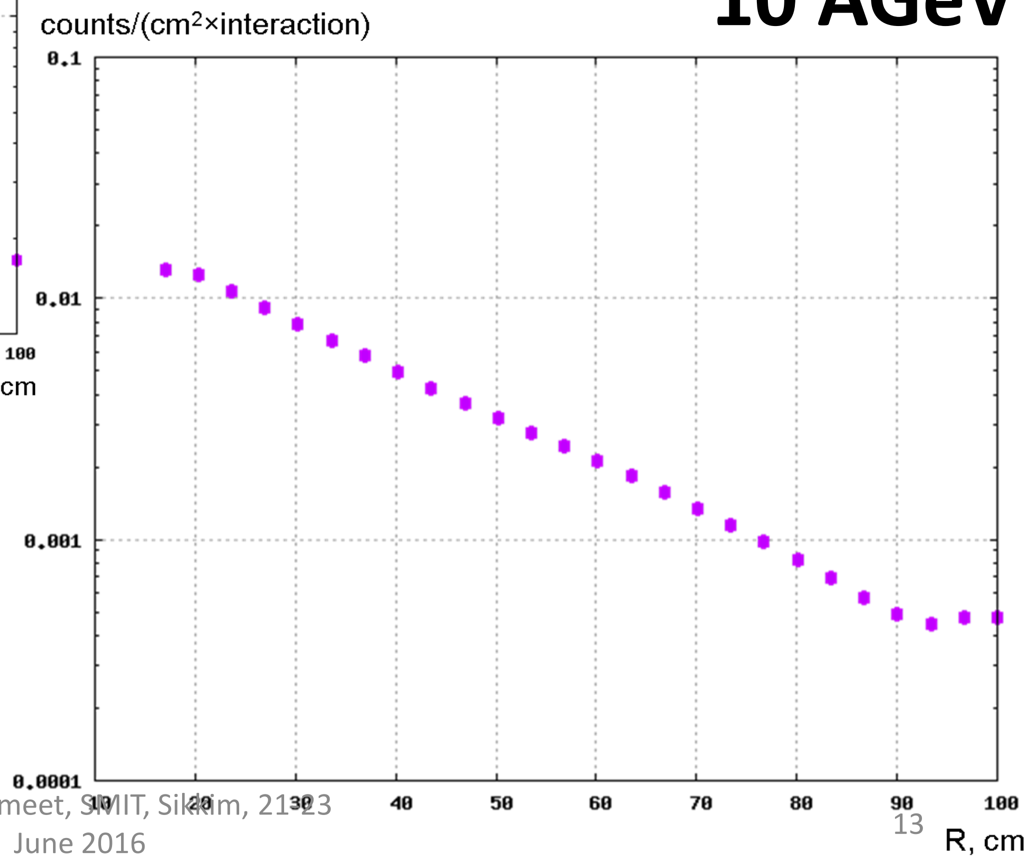
Hit density on 1st station (Carbon as first absorber)

400 KHz/cm^2

25 AGeV

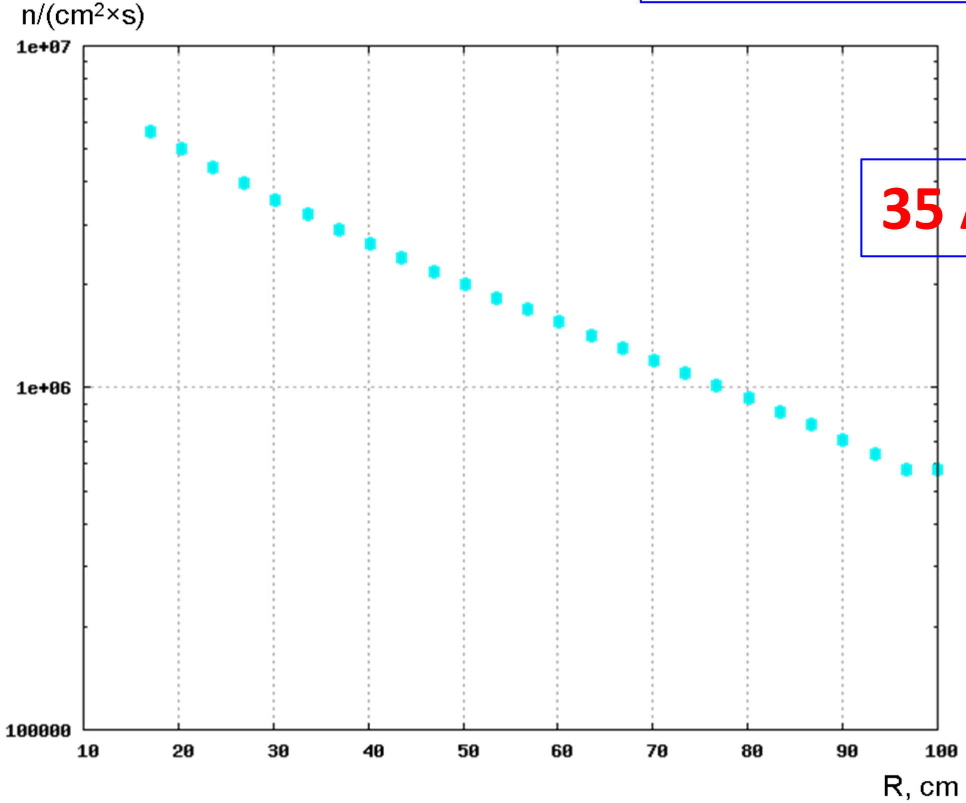


10 AGeV



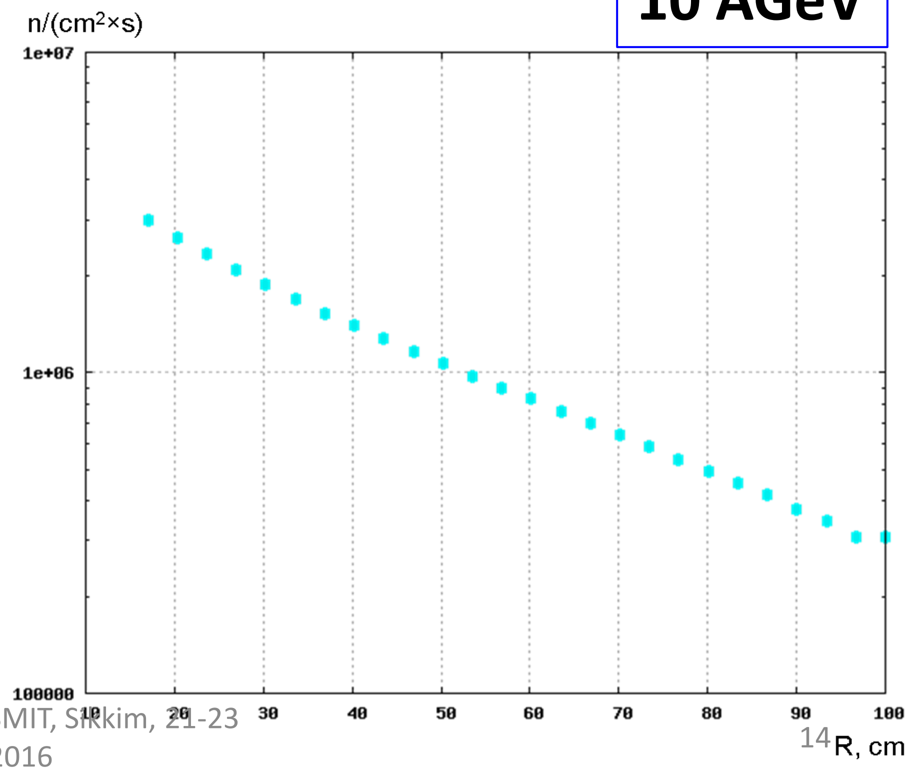
FLUKA calculations (min-bias collisions)

Neutron Flux on 1st station



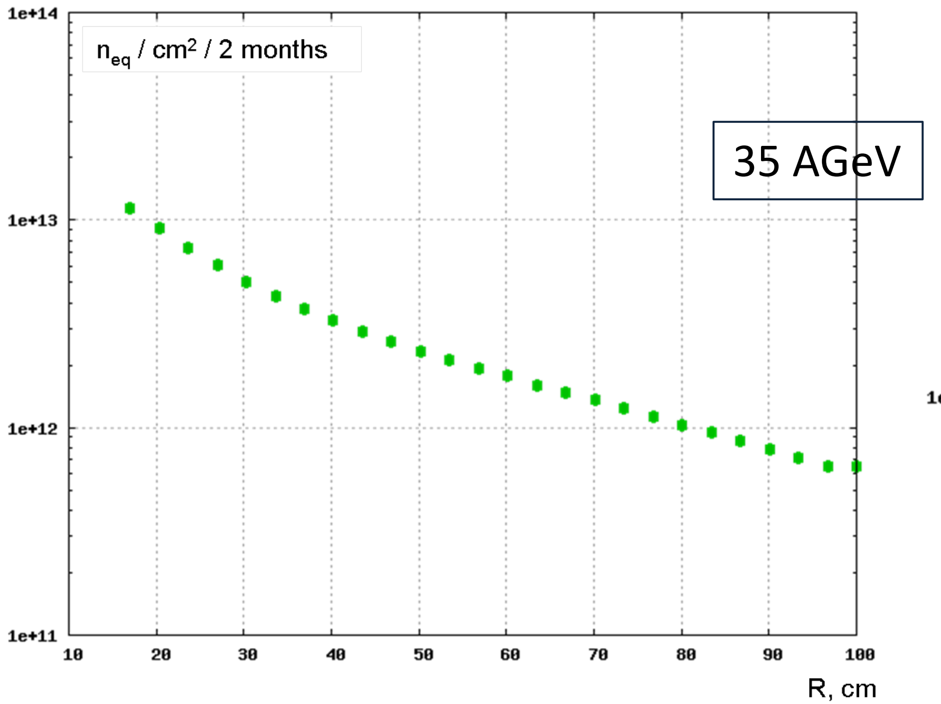
35 AGeV

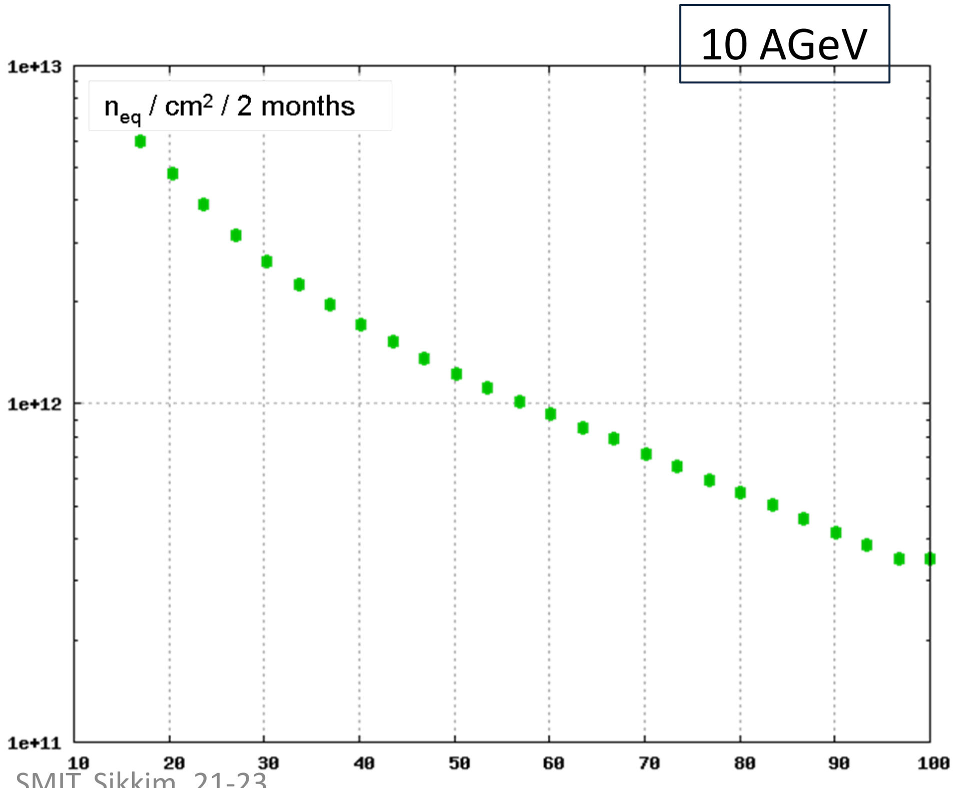
10 AGeV



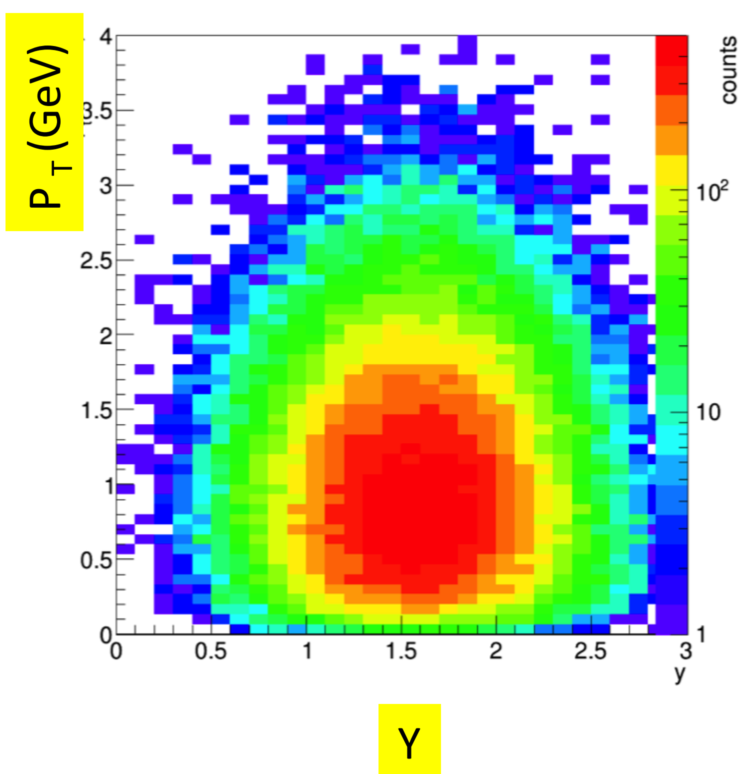
FLUKA calculations

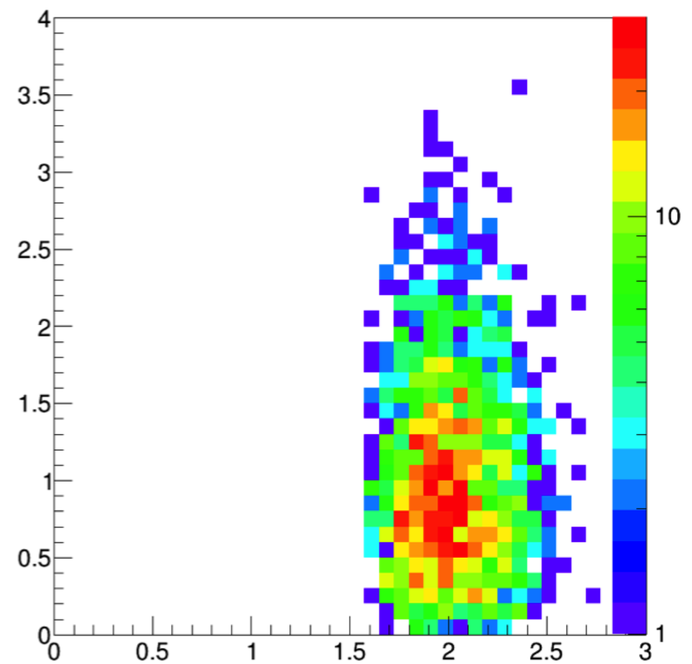
Neutron-equivalent dose





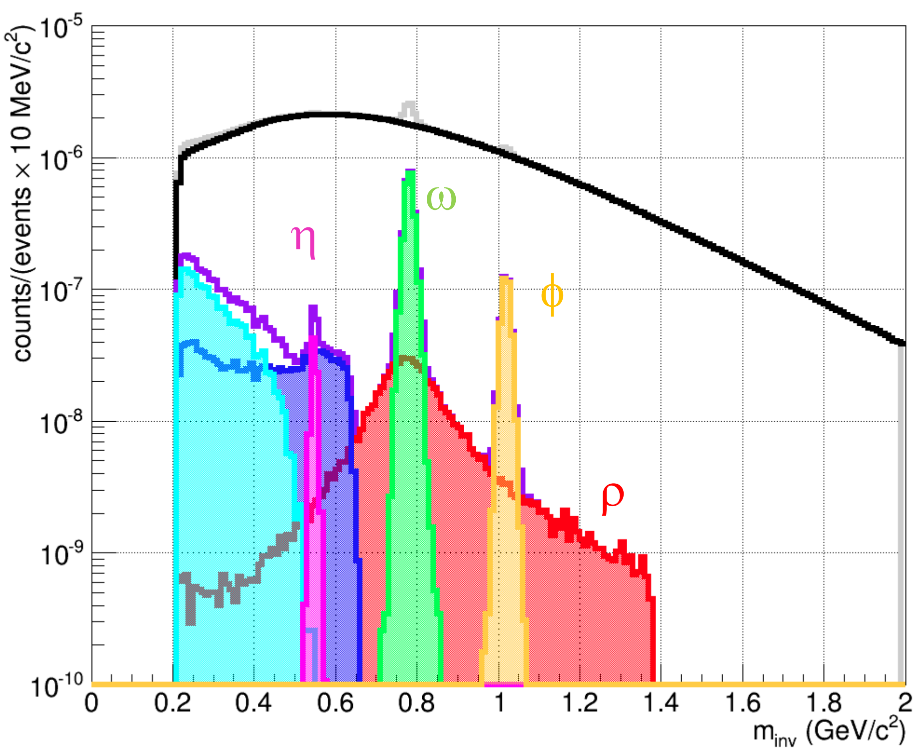
Acceptance plots for J/psi mesons simulated for Au + Au collisions at 10 A GeV for the PLUTO input (left) and after reconstruction (right).

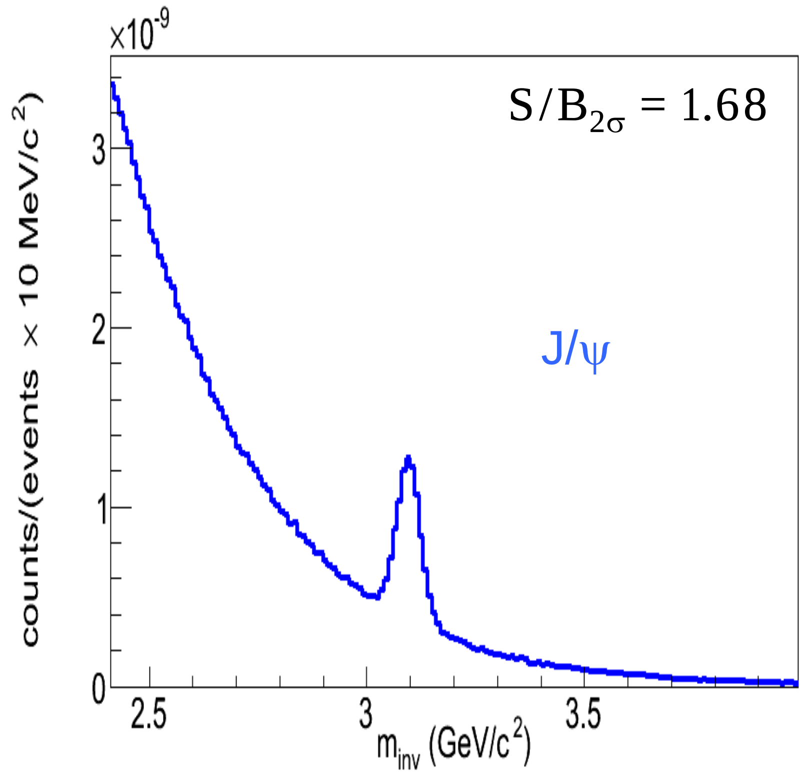




Invariant mass spectra – muons

- Shown: central (b=0fm) Au+Au collisions at 25 AGeV
- Mass resolution: <u>12 MeV (ω) and 29 MeV (J/ψ)</u> only due to momentum determination in STS
- LMVM spectra for SIS100 show similar quality
- J/ψ in central pAu at 30GeV with superb S/B ratio



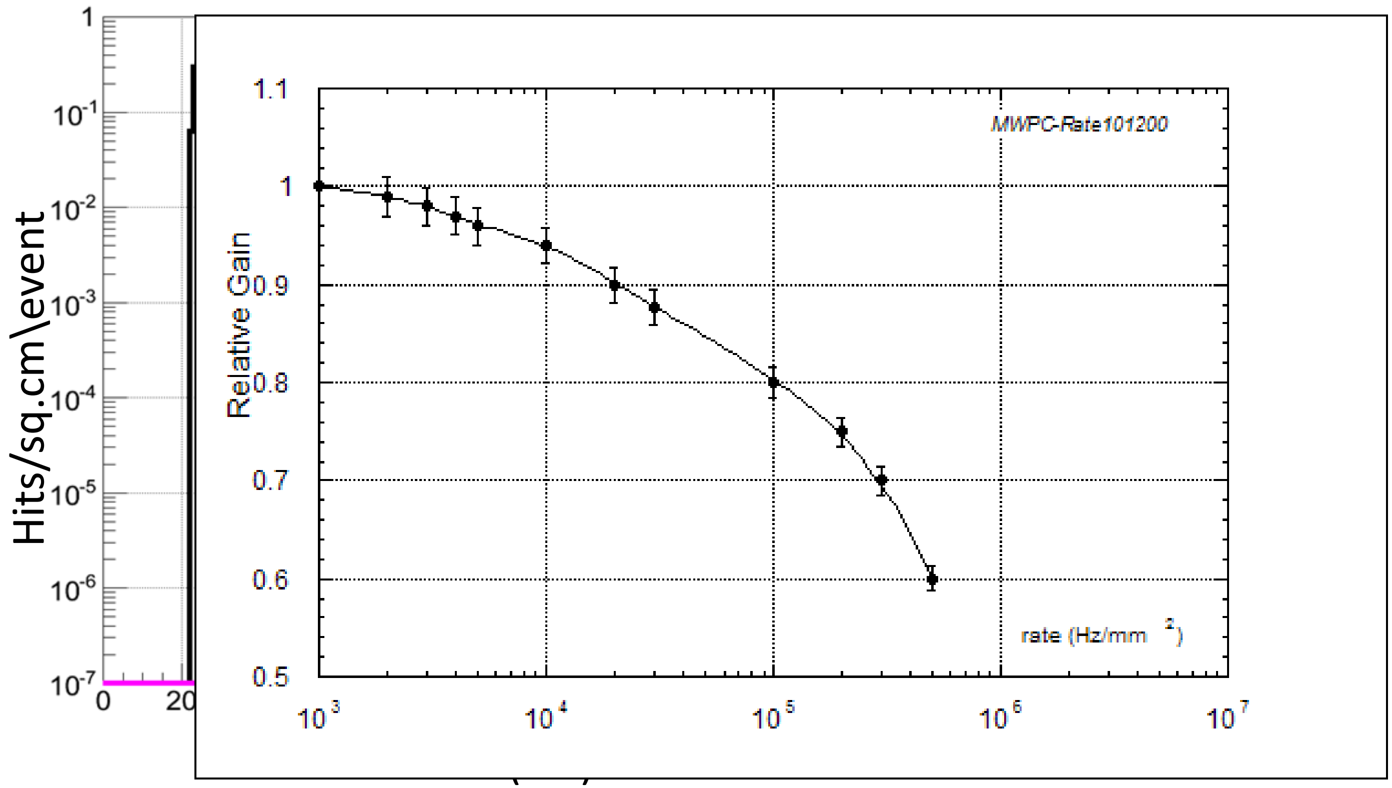


Challenges in Muon detection

Main issues:

- High collision rates ~ 10 MHz
- The first plane(s) have a high density of tracks
  High granularity ~ average hit rate is about 0.4 hit/cm^2
- Should be radiation resistant –
  high neutron dose → ~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.
  -- and event reconstructed offline by grouping
  the timestamps of the detector hits.

Particle Density at Different MUCH stations



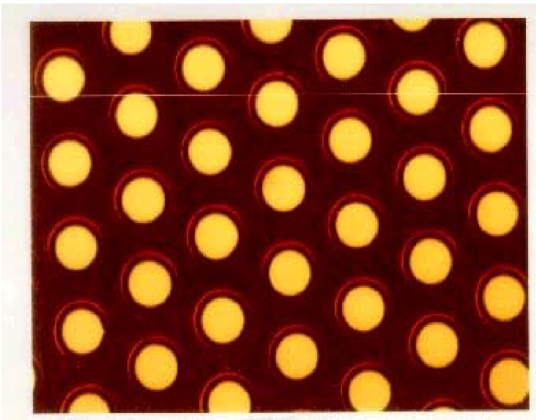
Different detector technologies for different stations

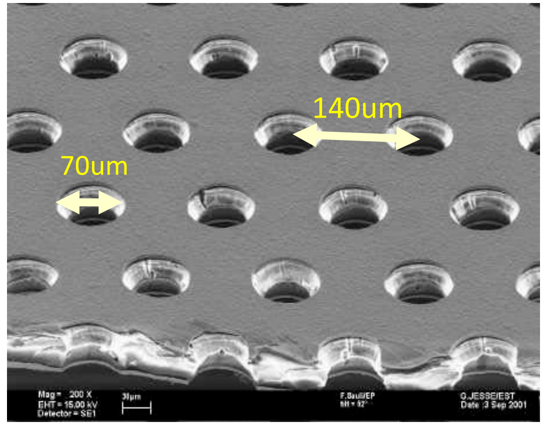
-- For the first two stations, which demand a high rate capability, Gas Electron Multiplier technology (GEM) would be used.

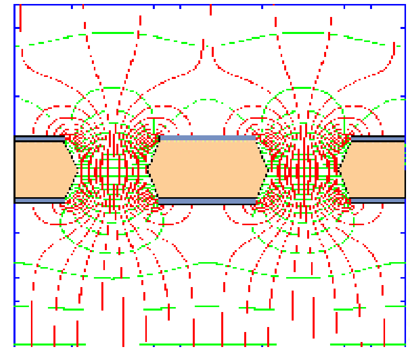
-- Straw tube and TRD for the other layers.

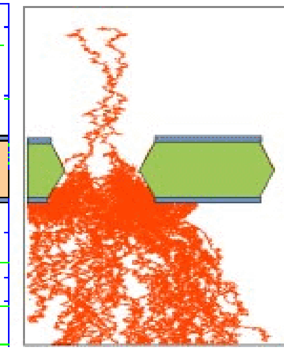
Triple GEM module for the first Two stations of MUCH

Gas Electron Multiplier (GEM) and its working principle









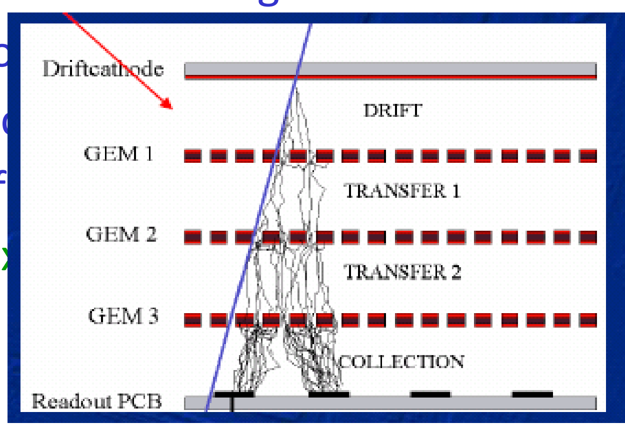
a 50 micron polyimide foil with a 5 micron Cu layer deposited on both sides of polyimide

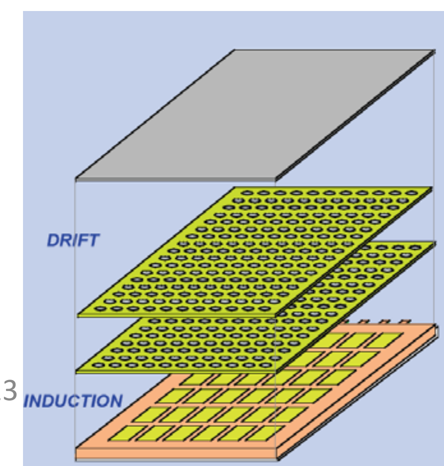
Basic elements of a GEM chamber:

1. Drift plane
2. Amplifying element – GEM
3. Readout Plane

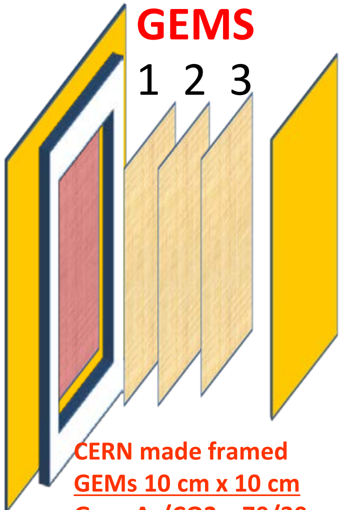
Cascaded GEMs can give higher gains and have lesser spark proability

- Active medium is a gas mixture.
- electro ... oles of two ... n
- Amplif
  - Ma ... 0 cm

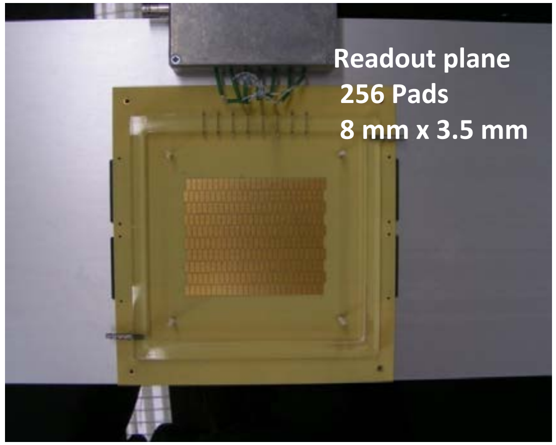


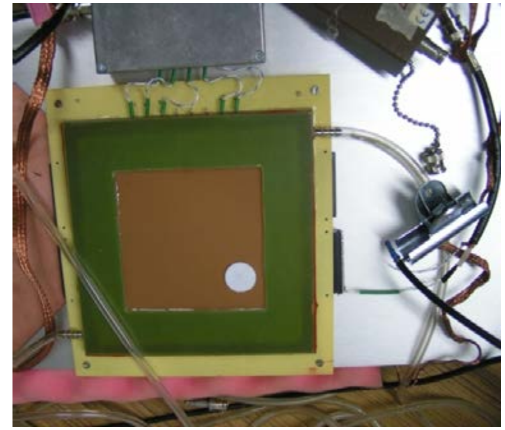


Prototype fabrication at VECC

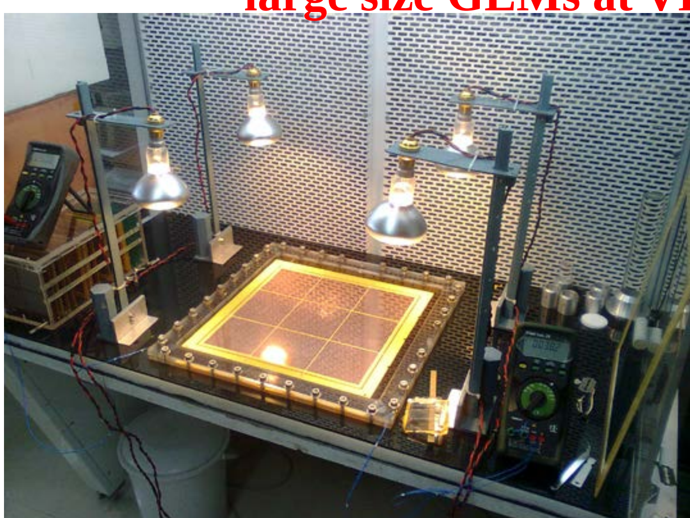


CERN made framed
GEMs 10 cm x 10 cm
Gas - Ar/CO2 – 70/30





Thermal stretching and framing of 31 cm x 31 cm large size GEMs at VECC



Beam test of GEM prototype chambers

Aim :

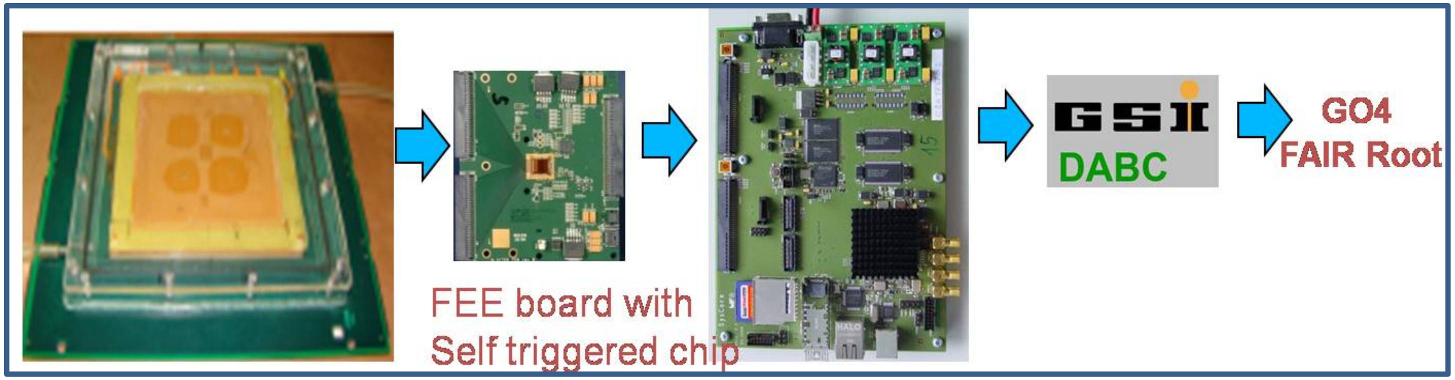
-- to test the response of the detector to charged particles. mainly in terms of efficiency, cluster size, gain uniformity, rate handling capability

-- 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.

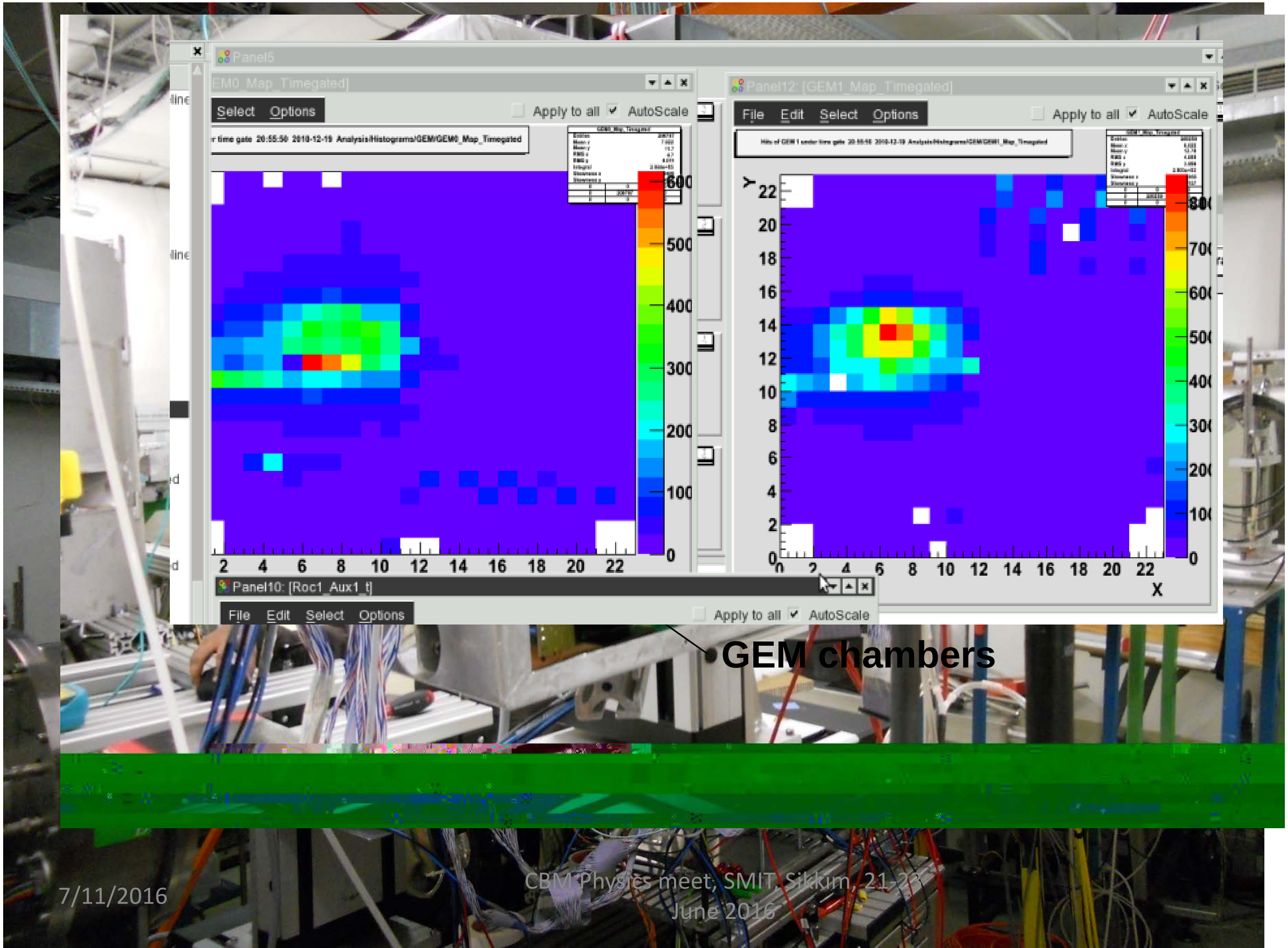
– coupled to ROC(ReadOut Controller) and then fed to the DAQ.

-- testing with the actual CBM DAQ

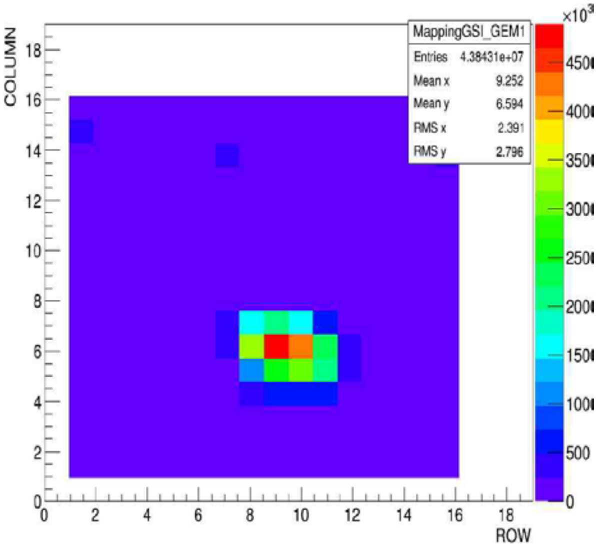


The nXYTER ADC spectra is inverted as compared to conventional picture, this has to be subtracted from a baseline value channel by channel

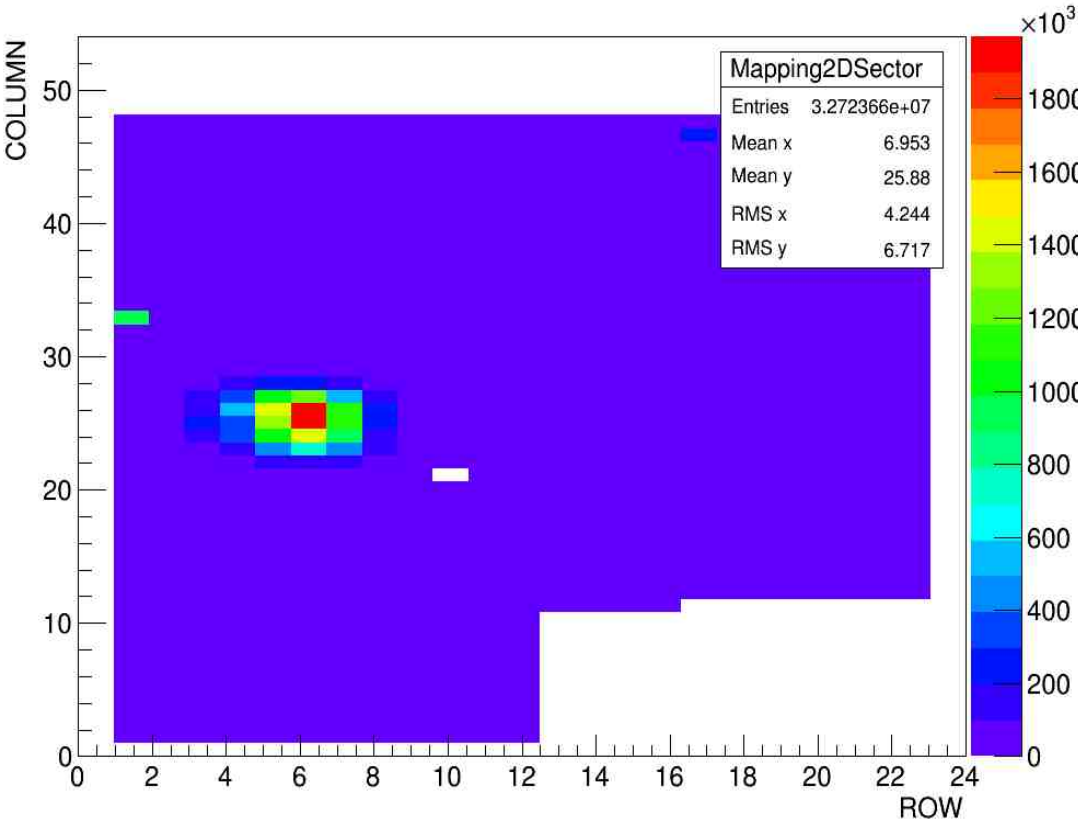
Test setup at Jessica beamline at COSY (Julich)



Beam spot (for high intensity runs), 2.3 GeV/c protons



GEM 2(10 cm x 10 cm)

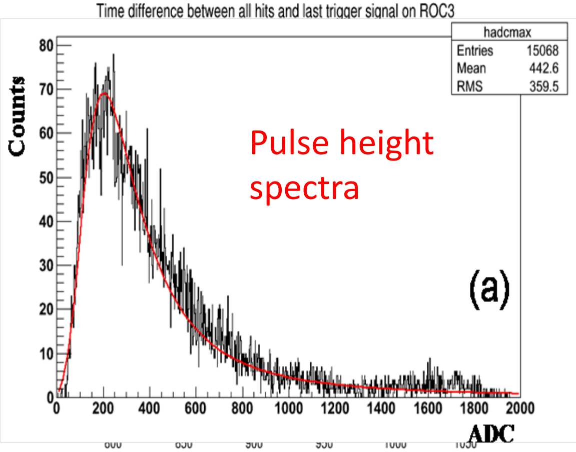


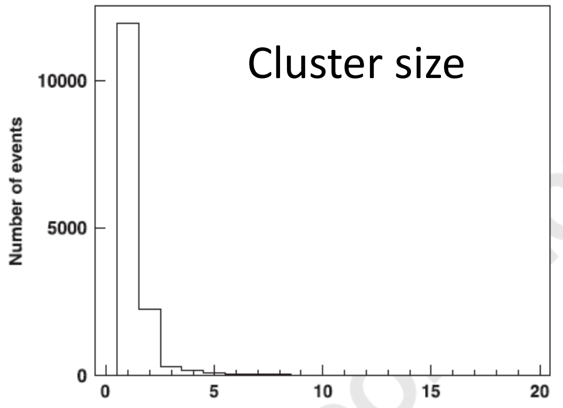
GEM 3 (31cm x 31 cm)

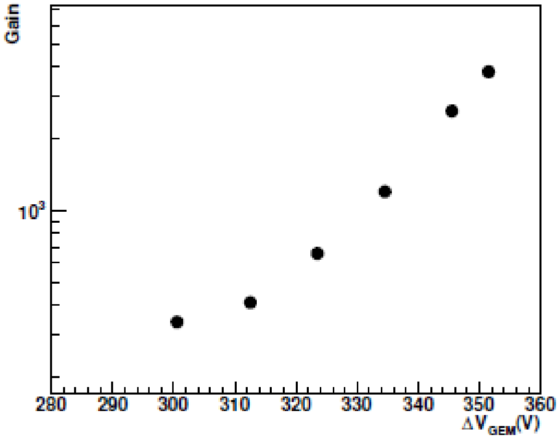
Beam profiles as seen by 10 cm x 10 cm prototype and 31 cm x 31 cm prototype (right)

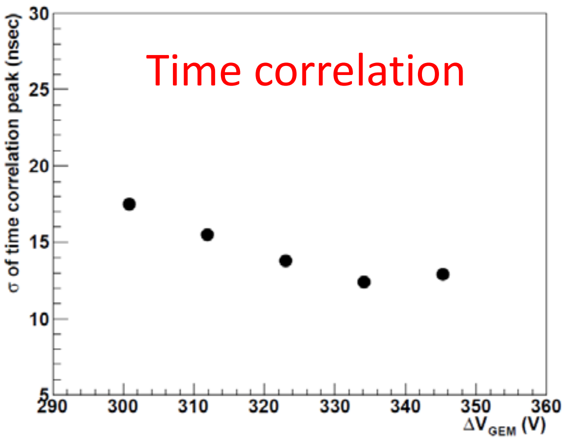
Test Results

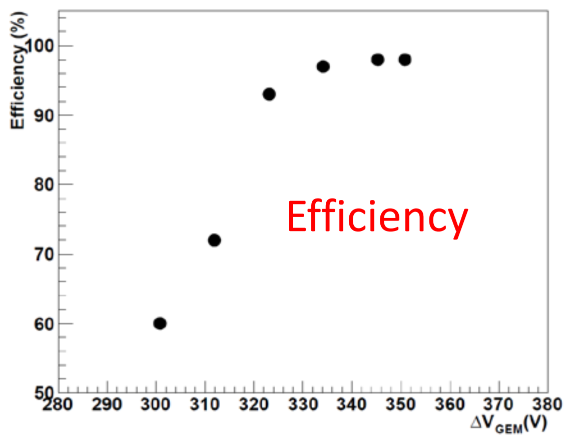
self triggered mode

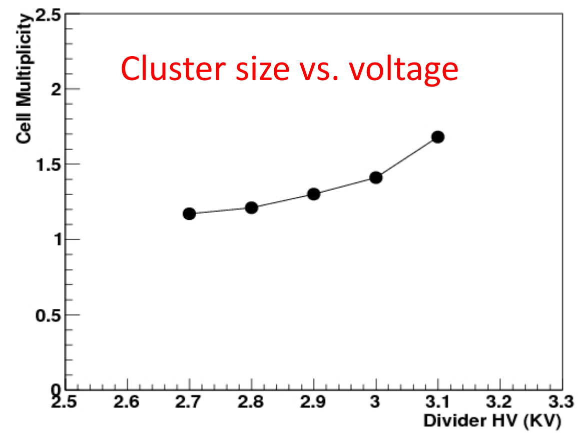






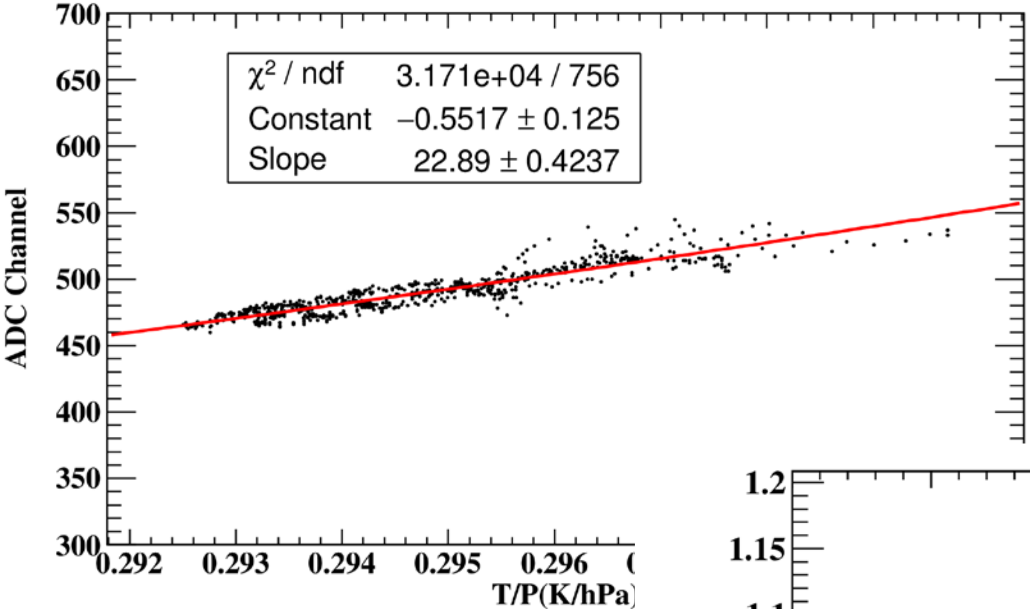


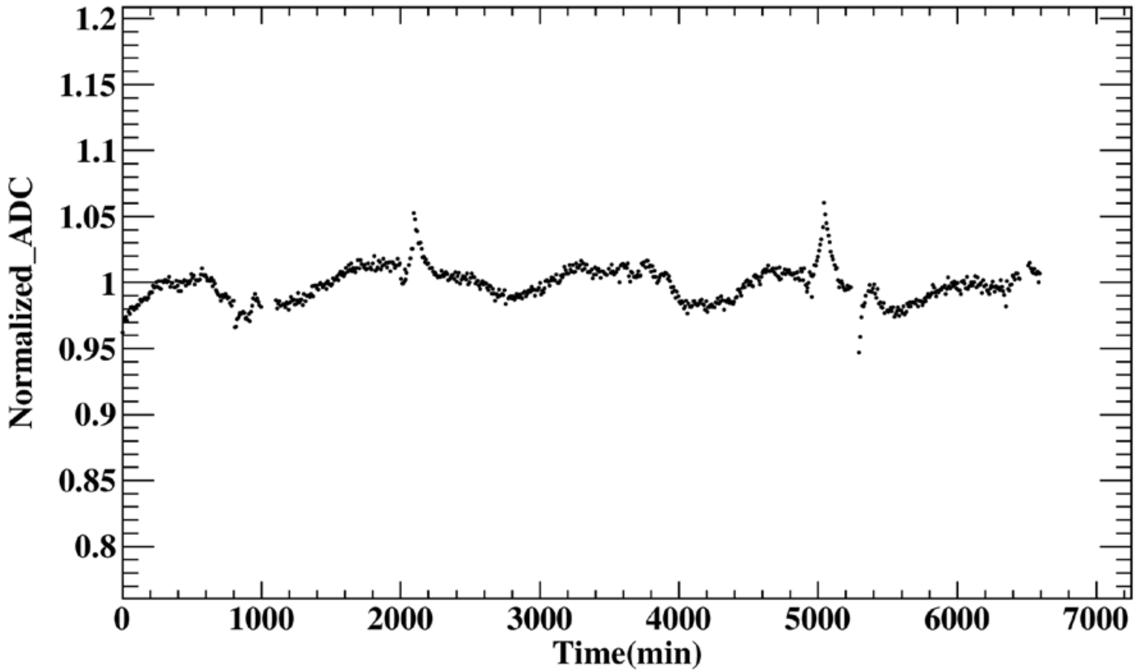




Published in NIMA

Gain stability with time (at VECC, using ^{55}Fe 5.9 keV X-ray source)

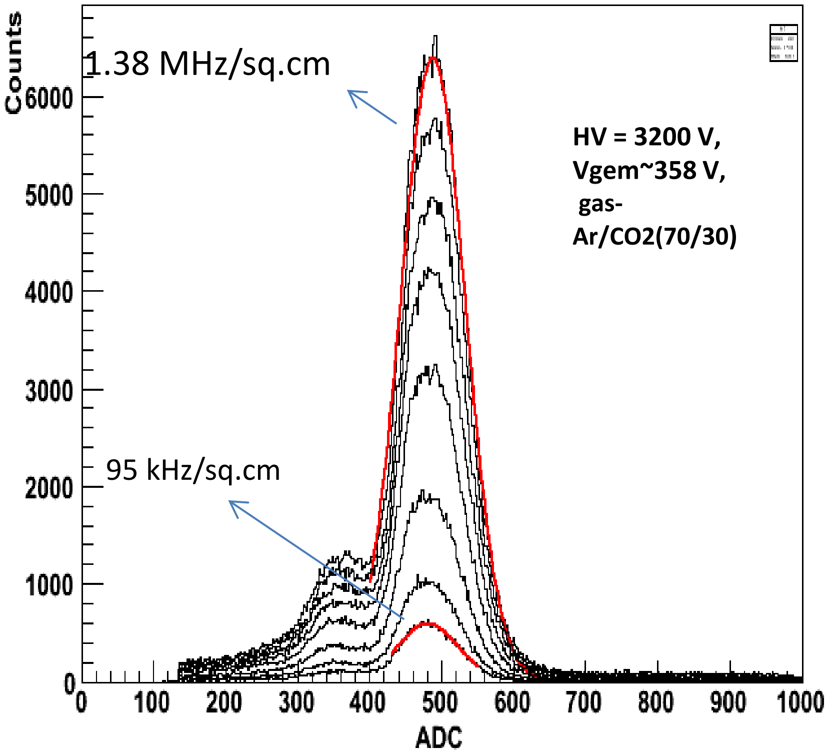




Ajit Kumar, VECC

Rate test

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

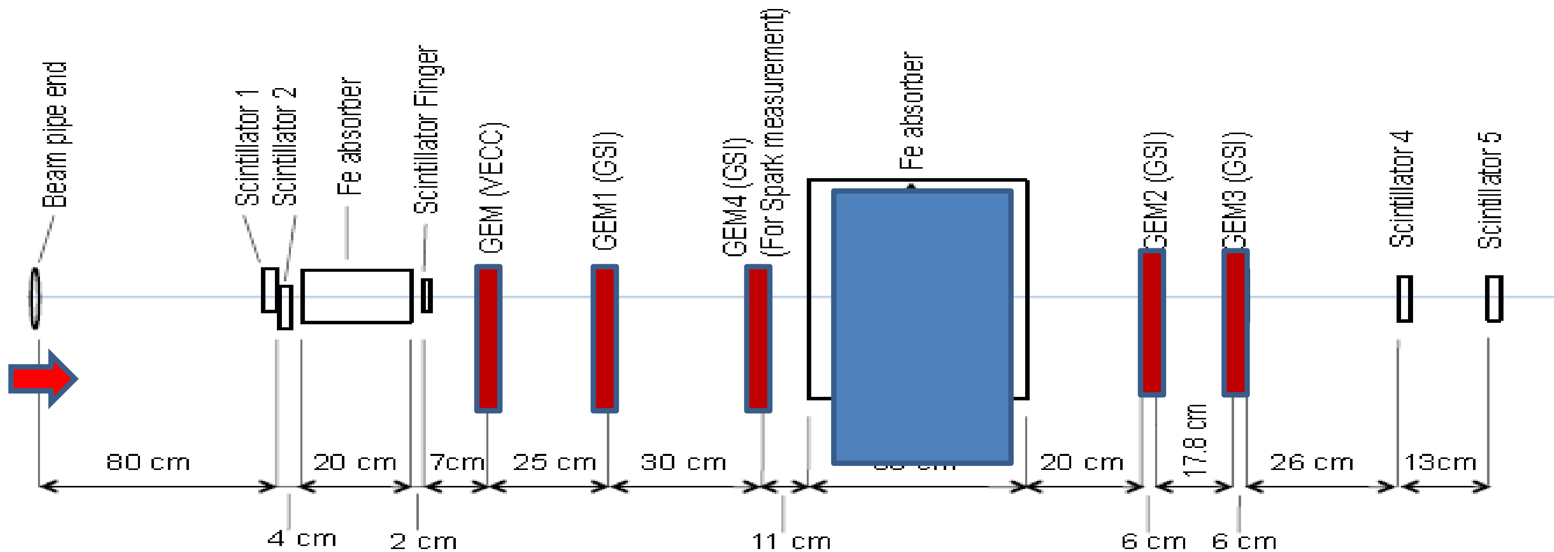


Published in JINST-2014

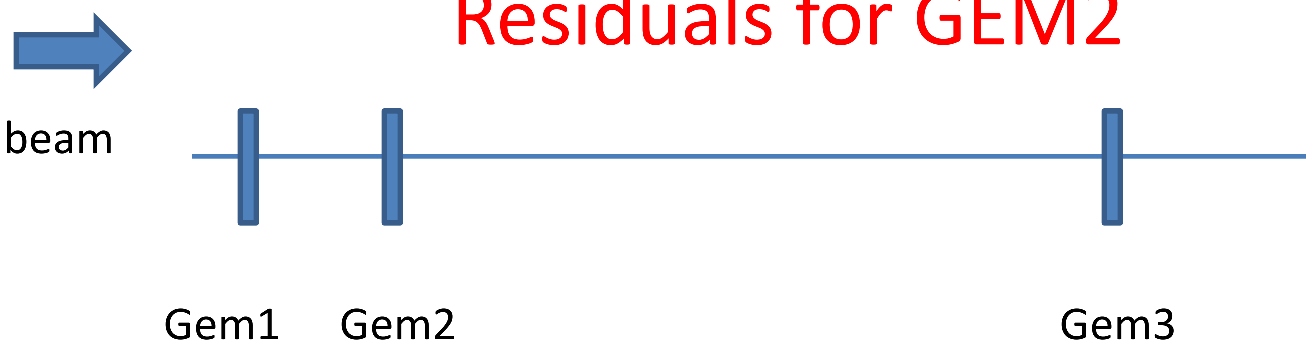
Gain remains almost stable with rate

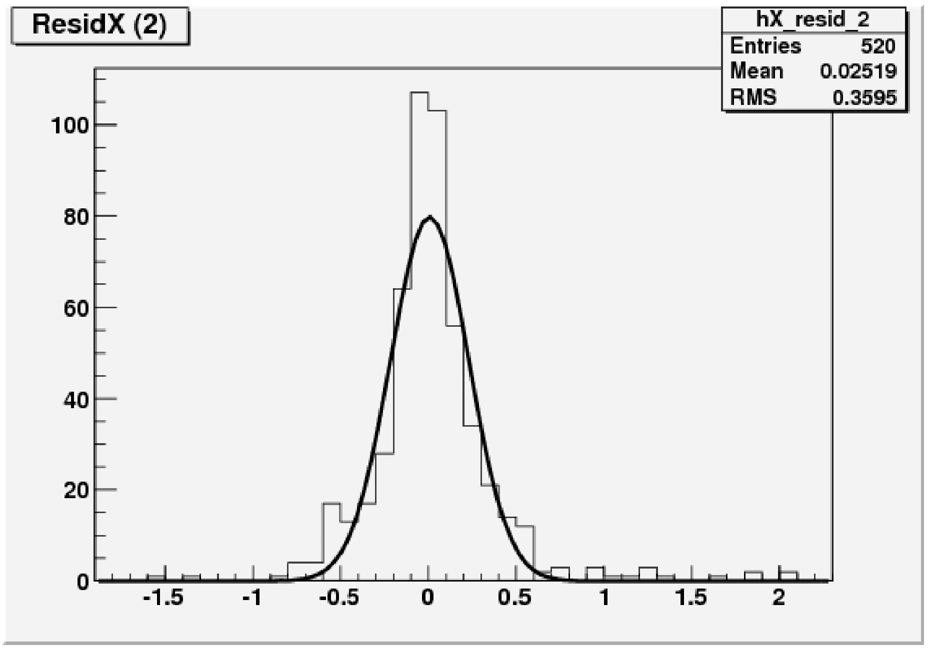
Highest Rate in this picture ~ 1.4 MHz/cm^2

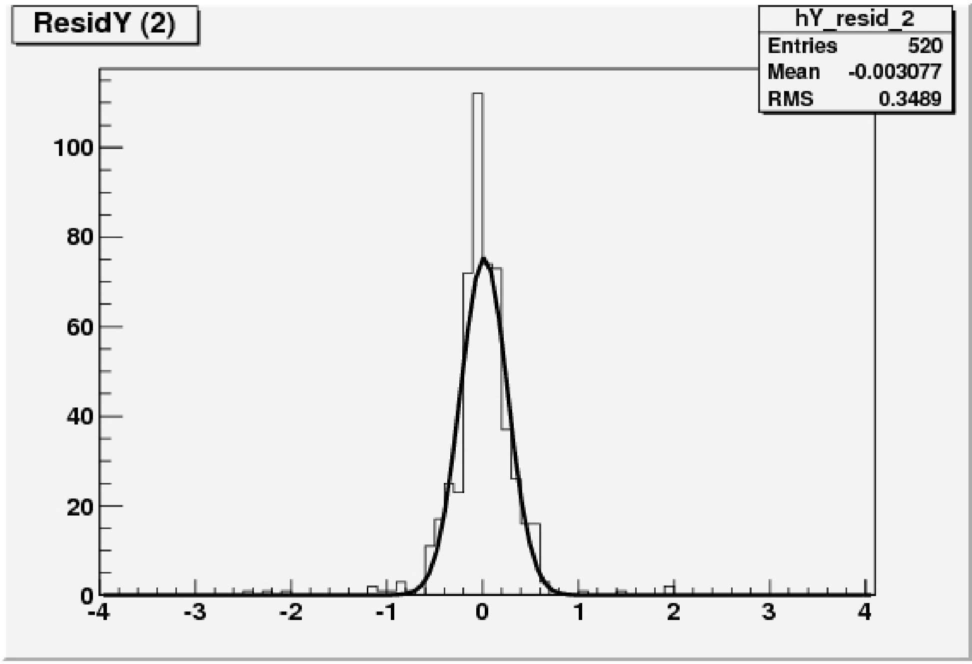
Test with absorbers – MiniMUCH
at CERN SPS, H4 beamline. Pion beams of GeV/c(with some muons and electrons)



Residuals for GEM2



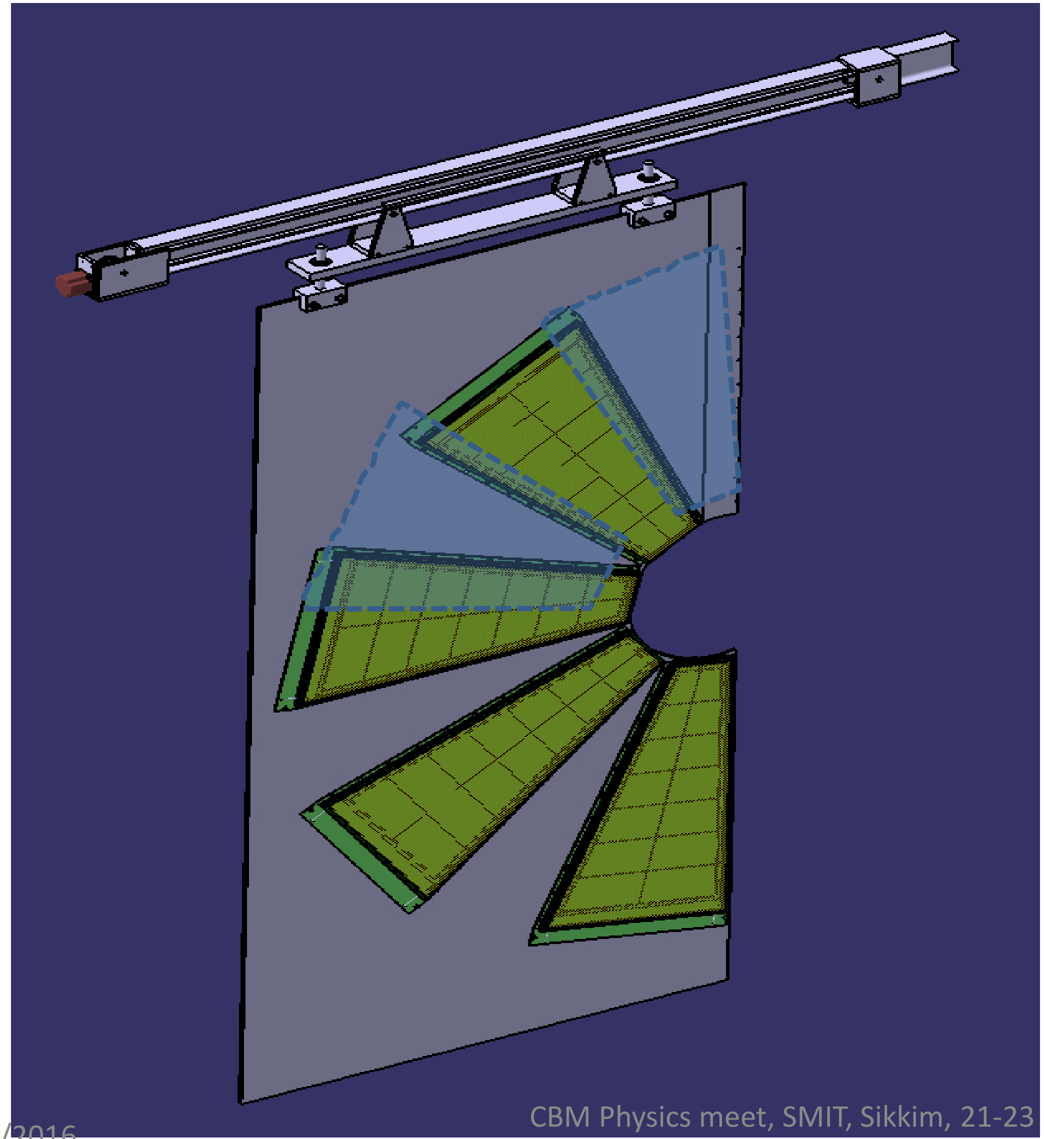


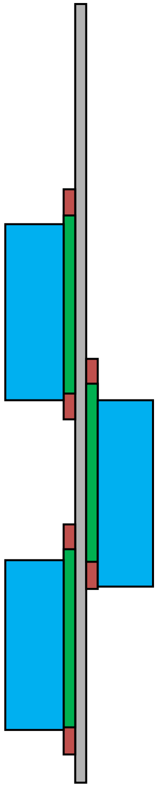


Reconstructing the track using GEM1 and GEM3 and Projecting the hits at plane_GEM2 and finding the distribution of residuals

Building a Real size MUCH sector prototype

Layout --one layer of MUCH on a Drive



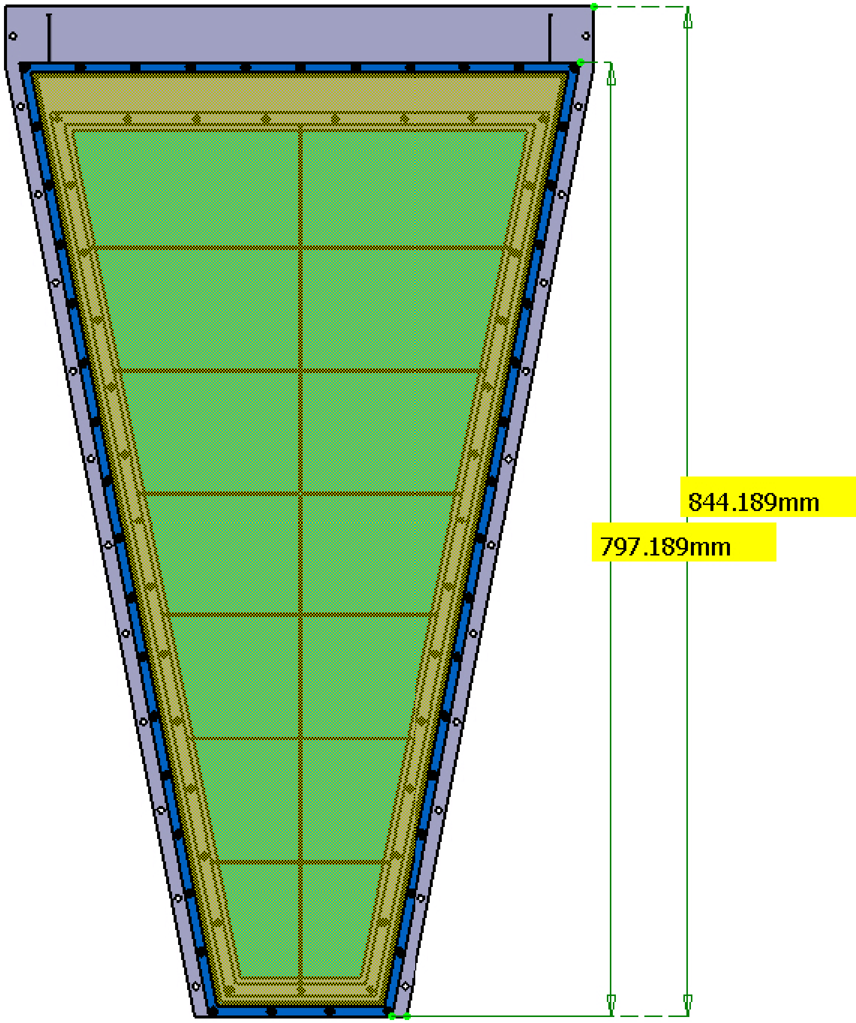


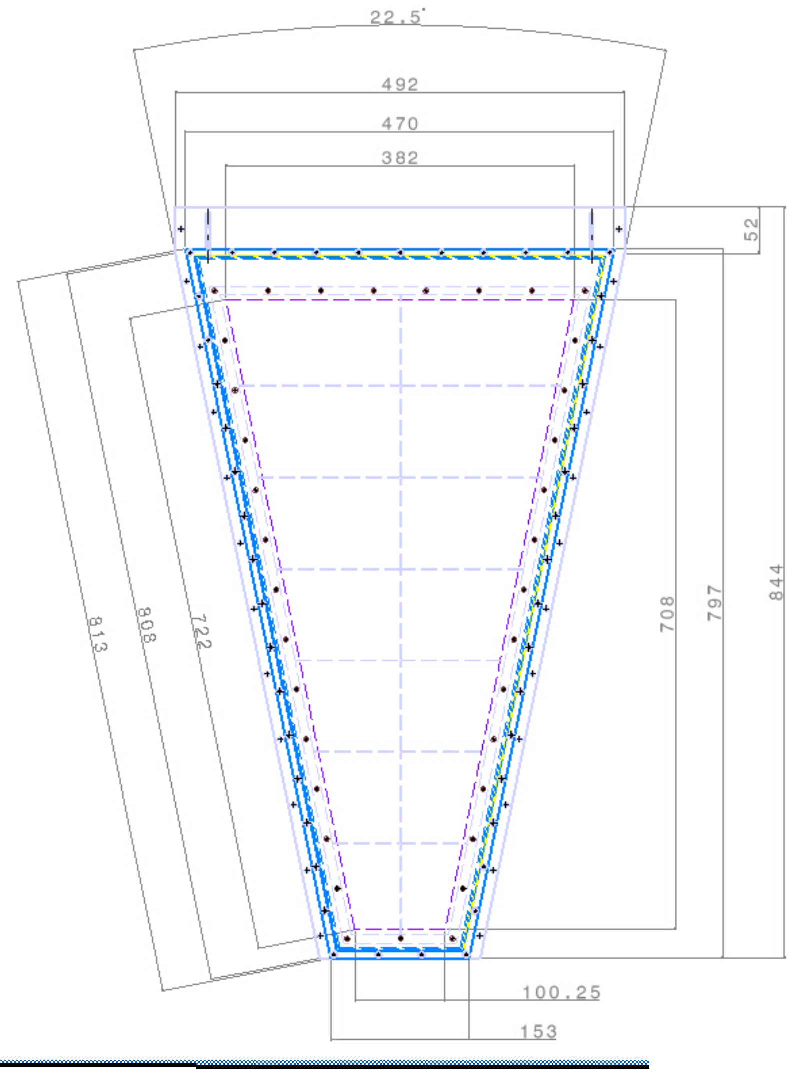
of sectors, FEB, area, etc.

~85 K + 90 K
Electronic channels

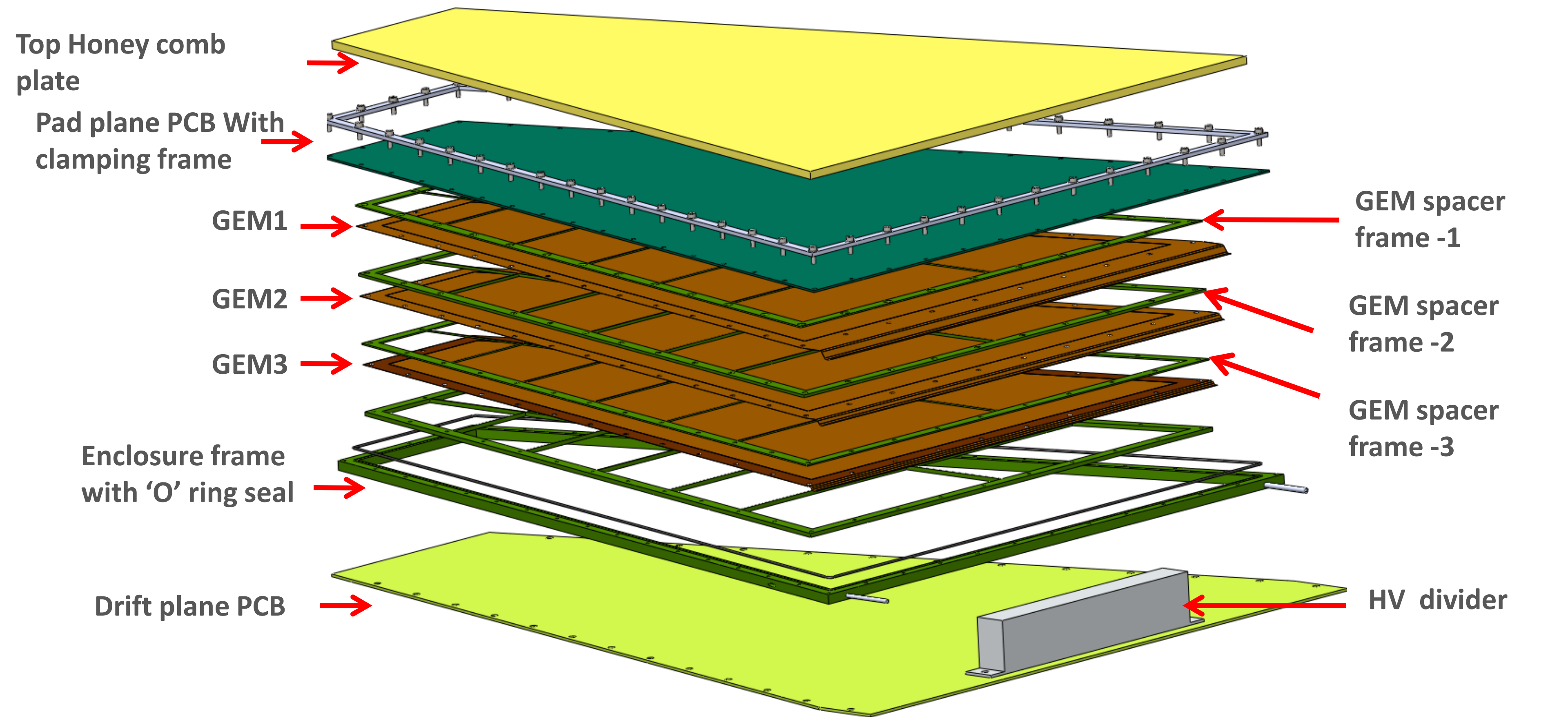
Station # for SIS100	Layer #	Total no of pads	**R1 (cm)**	Pad size (min)	**R2 (cm)**	Pad size (max)	**Area (sq.mt)**	No of 128 channel FEB/layer (round off)	No of Sector per layer
1	1	28800	**25**	4.36mm	**100.25**	17.48mm	**2.95**	240	16
	2	28800	**25**	4.36mm	**100.25**	17.48mm	**2.95**	240	16
	3	28800	**25**	4.36mm	**100.25**	17.48mm	**2.95**	240	16
2	1	30600	**34.5**	5.9mm	**146.9**	25.4mm	**6.4**	240	24
	2	30600	**34.5**	5.9mm	**146.9**	25.4mm	**6.4**	240	24
	3	30600	**34.5**	5.9mm	**146.9**	25.4mm	**6.4**	240	24

Station # for SIS300	Layer #	Total no of pads	R1 (cm)	Pad size (min)	R2 (cm)	Pad size (max)	Area (sq.mt)	No of 128 channel FEB/layer (round off)	No of Sector per layer
1	1	28800	25	4.36mm	100.25	17.48mm	2.95	240	16
	2	28800	25	4.36mm	100.25	17.48mm	2.95	240	16
	3	28800	25	4.36mm	100.25	17.48mm	2.95	240	16
2	1	30240	29.5	5mm	123.5	21.3mm	4.5	240	20
	2	30240	29.5	5mm	123.5	21.3mm	4.5	240	20
	3	30240	29.5	5mm	123.5	21.3mm	4.5	240	20

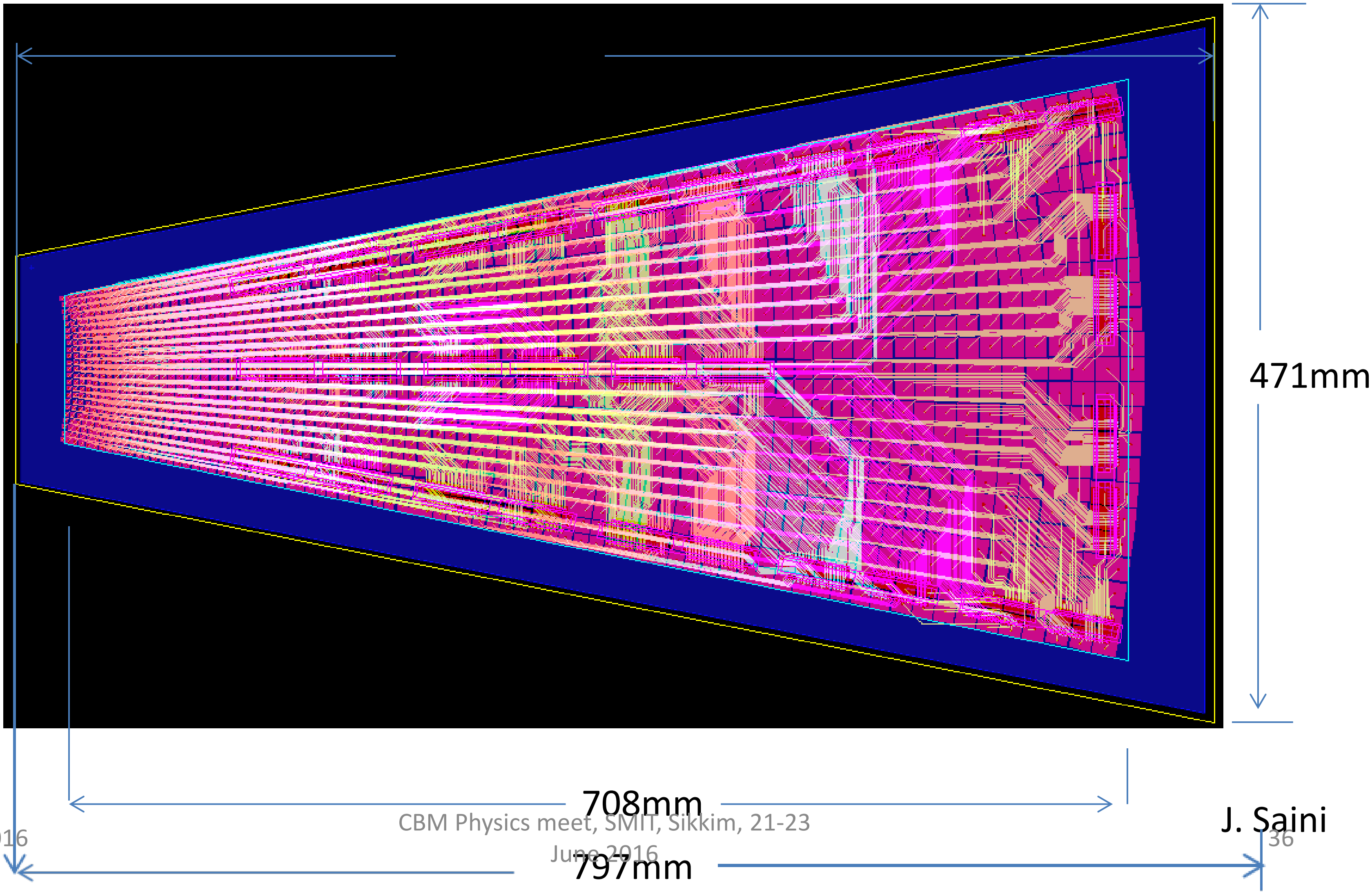

844.189mm
797.189mm


22.5°
492
470
382
52
813
808
722
708
797
844
100.25
153

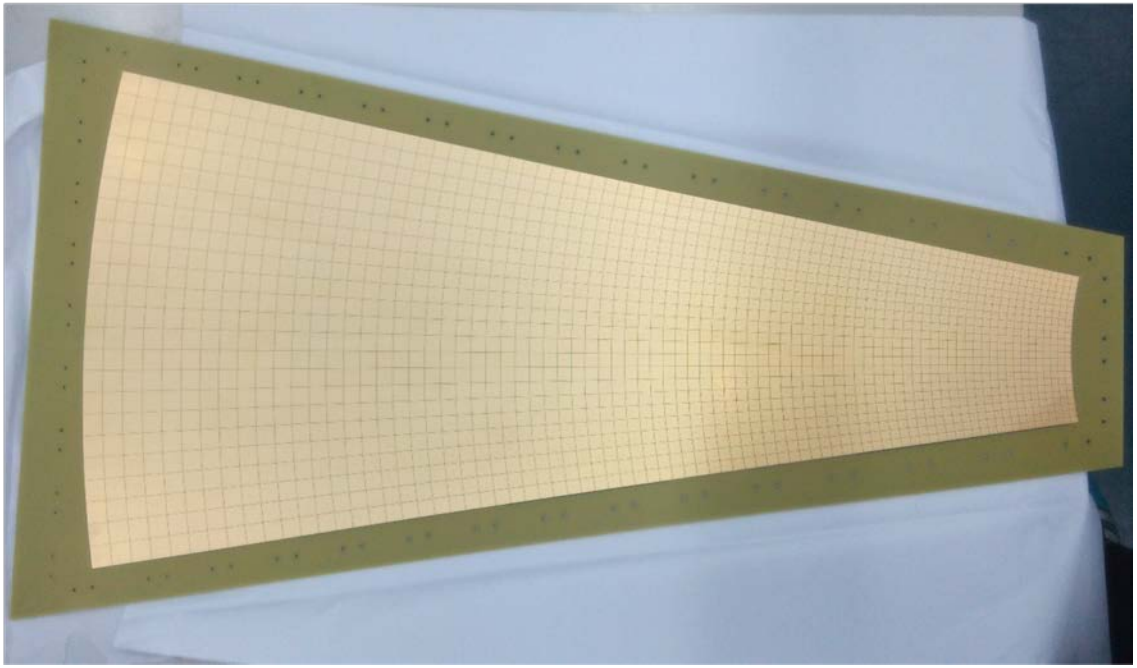
Sector Chamber elements – (old design)



Real size readout PCB designed at VECC



J. Saini



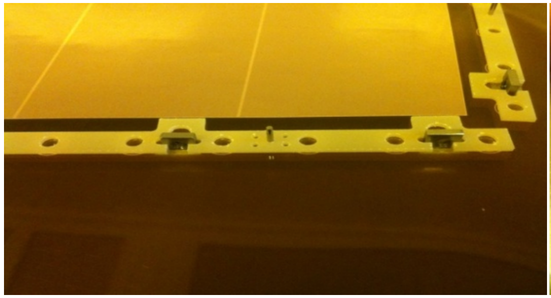
Readout PCB inner side

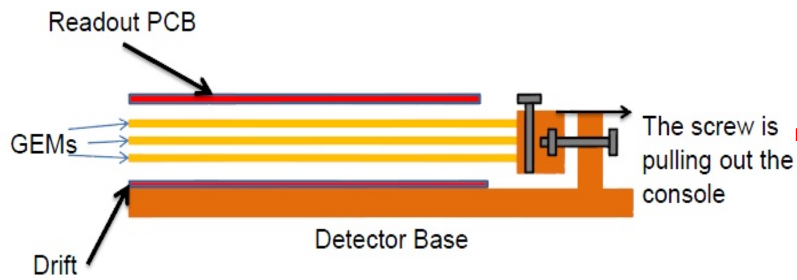
Readout PCB outer side with FEB connectors

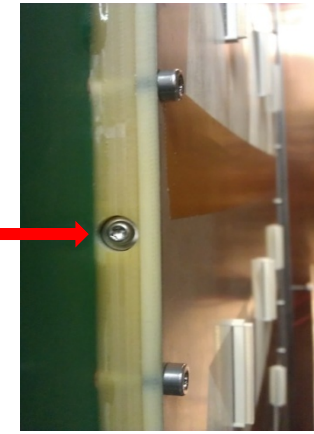
Real size GEM foil

For CBM MUCH -- GEM foils having 24 HV Segmentation.

Stretching of GEM foils – glue-less approach – “ns2”







•Now all the three layers of each clamp segment are fastened together with screws at select places. While designing the layout of the GEM foil some circular copper patterns are generated at the edges to enhance the grip of the edge clamp segments.

•The clamp segments are provided with an internal groove to accommodate a stainless steel nut. Thus after assembly of the segment a screw can be inserted sideways through the segment which mates with the embedded nut Fig.xx

•The outer chamber frame has provision to insert screws from side walls through a small gas tight O-ring seal and the screw can be coupled to the embedded nut in the corresponding clamp segment.

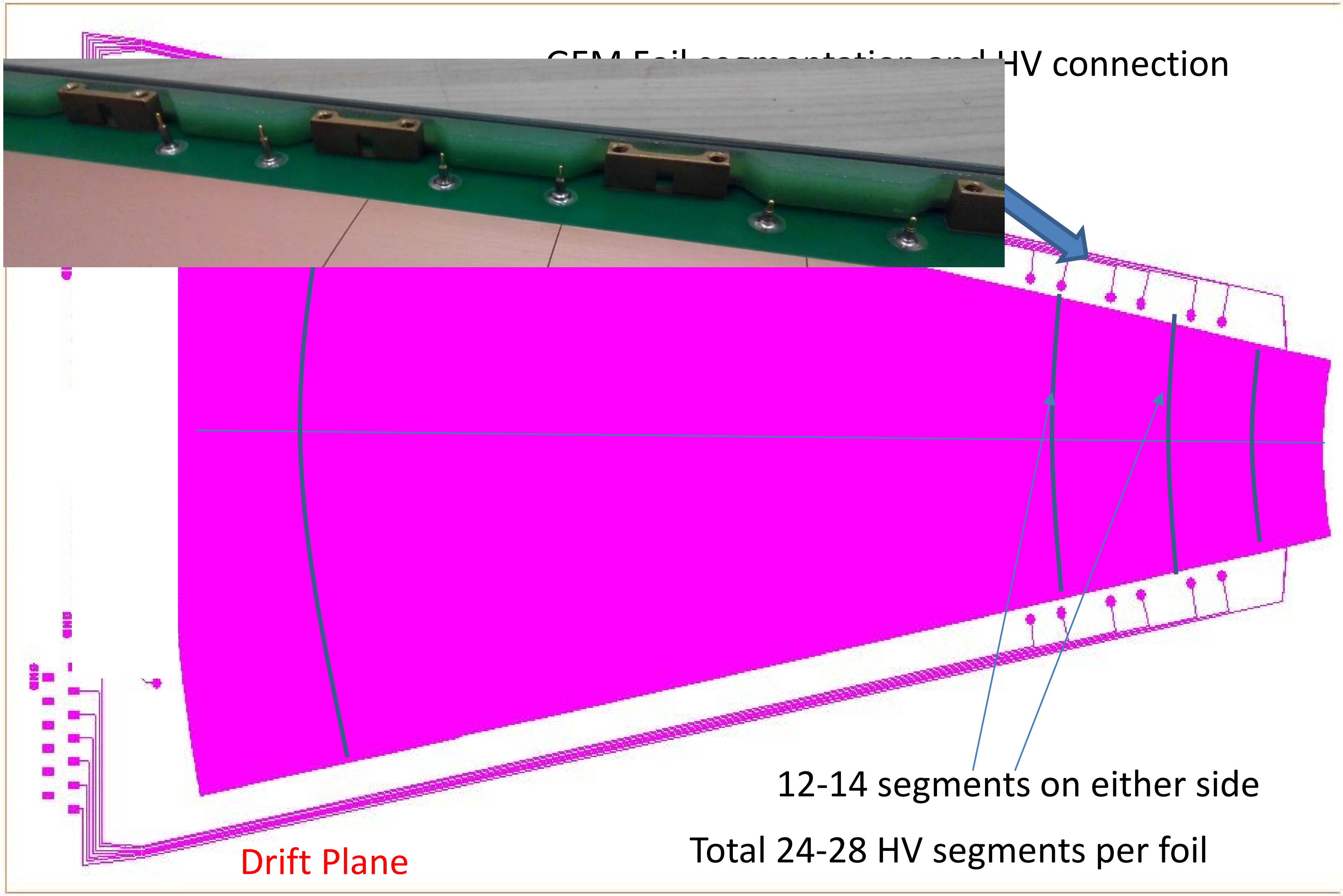
•After clamping all the foils the screws on the sides of the chamber frame can be tightened to stretch the foils in-situ .The screws are tightened until optimum tension is reached in all the three GEM foils.

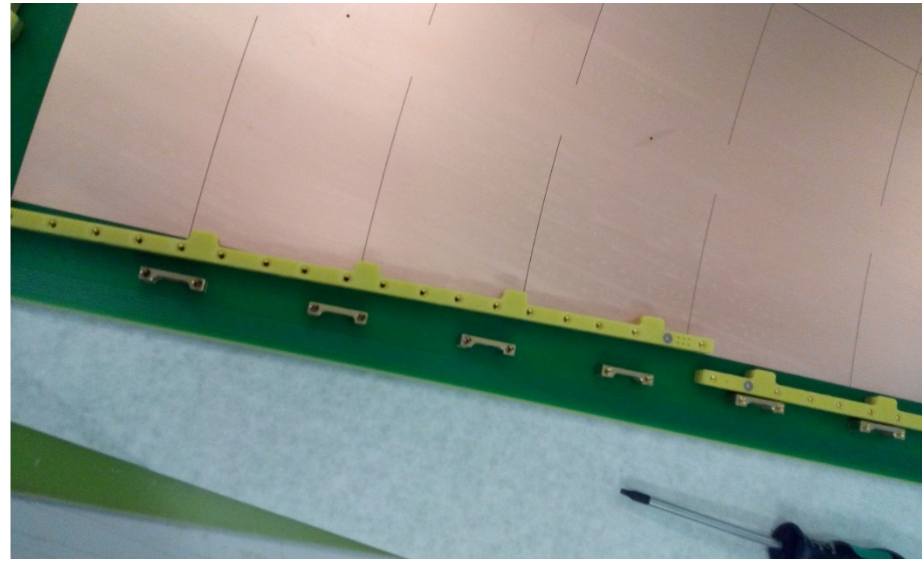
•HV contacts are brought out of the foils through spring contacts. This needs further improvement.

•For large scale production it may be possible to mould the clamp segments with some engineering plastic like PEEK.

This method completely eliminates the slow gluing procedure and suitable for large volume production of chambers. Also since the grid-spacers are absent in the active zone, sparking probability due to glass filaments on the grid edges is eliminated. The chamber is opened for GEM replacement.

GEM Foil segmentation and HV connection





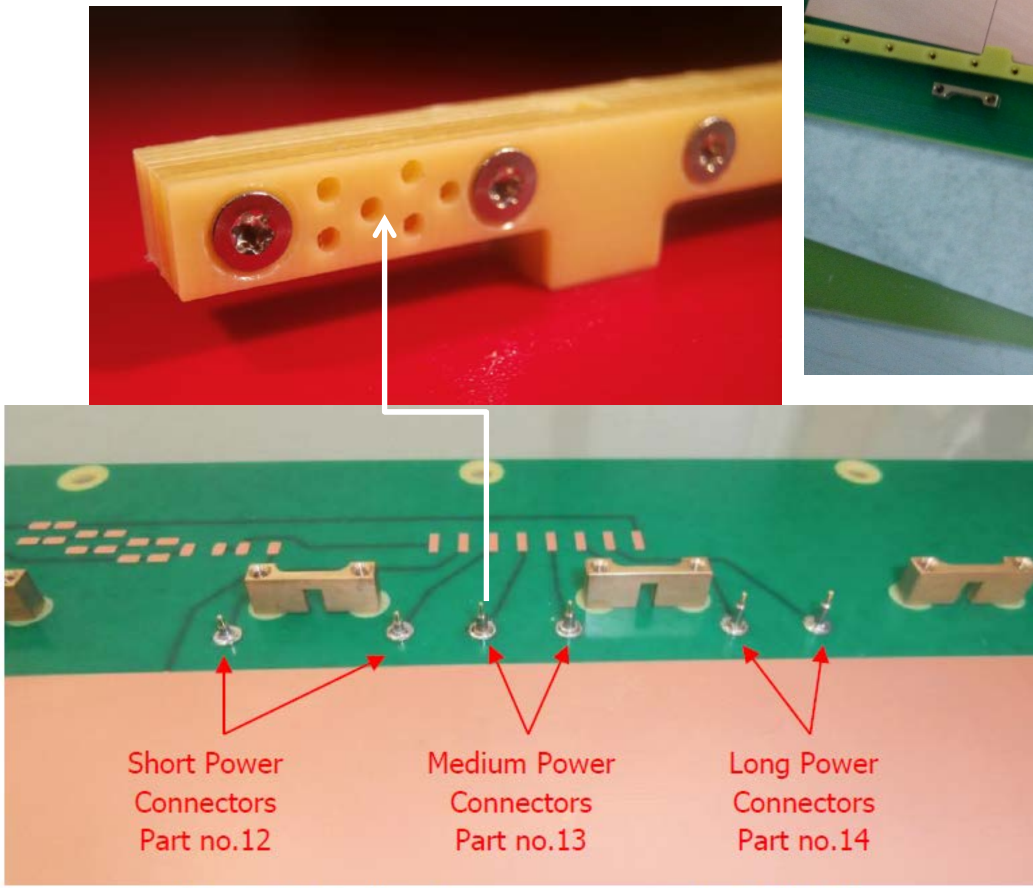
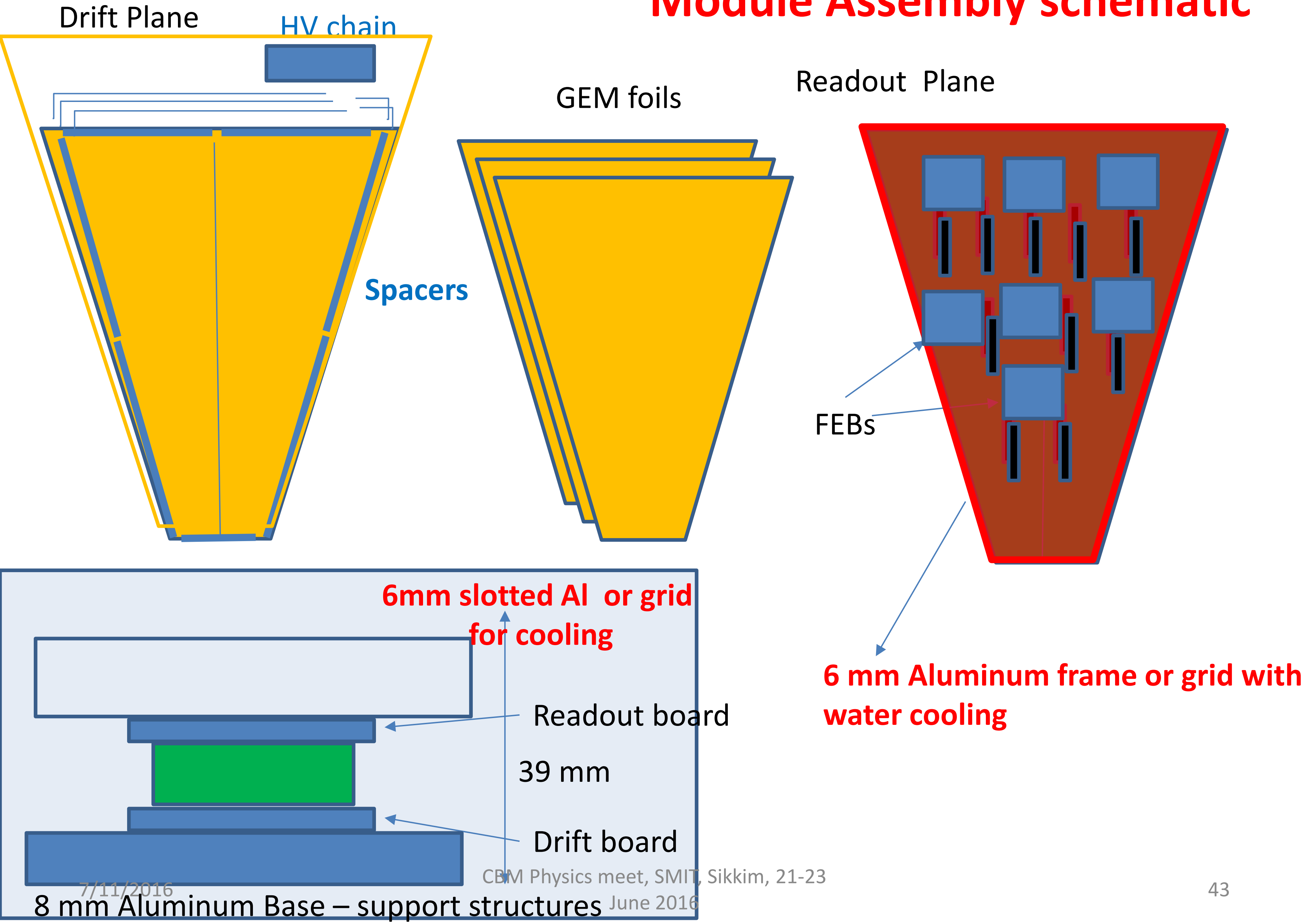


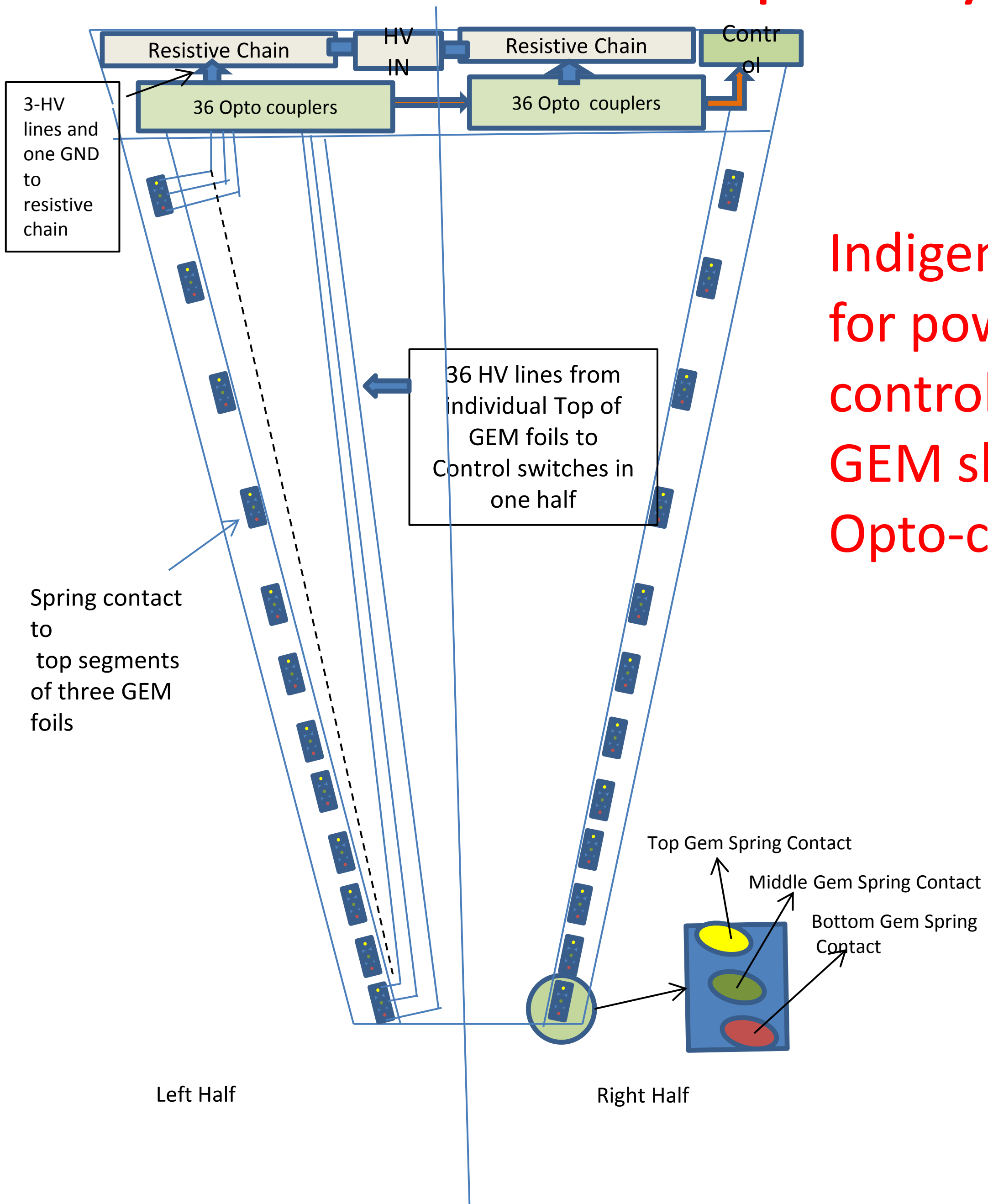
Figure 8: Position of power connectors for GEM foils.

GEM foils for Real-size prototype

Module Assembly schematic

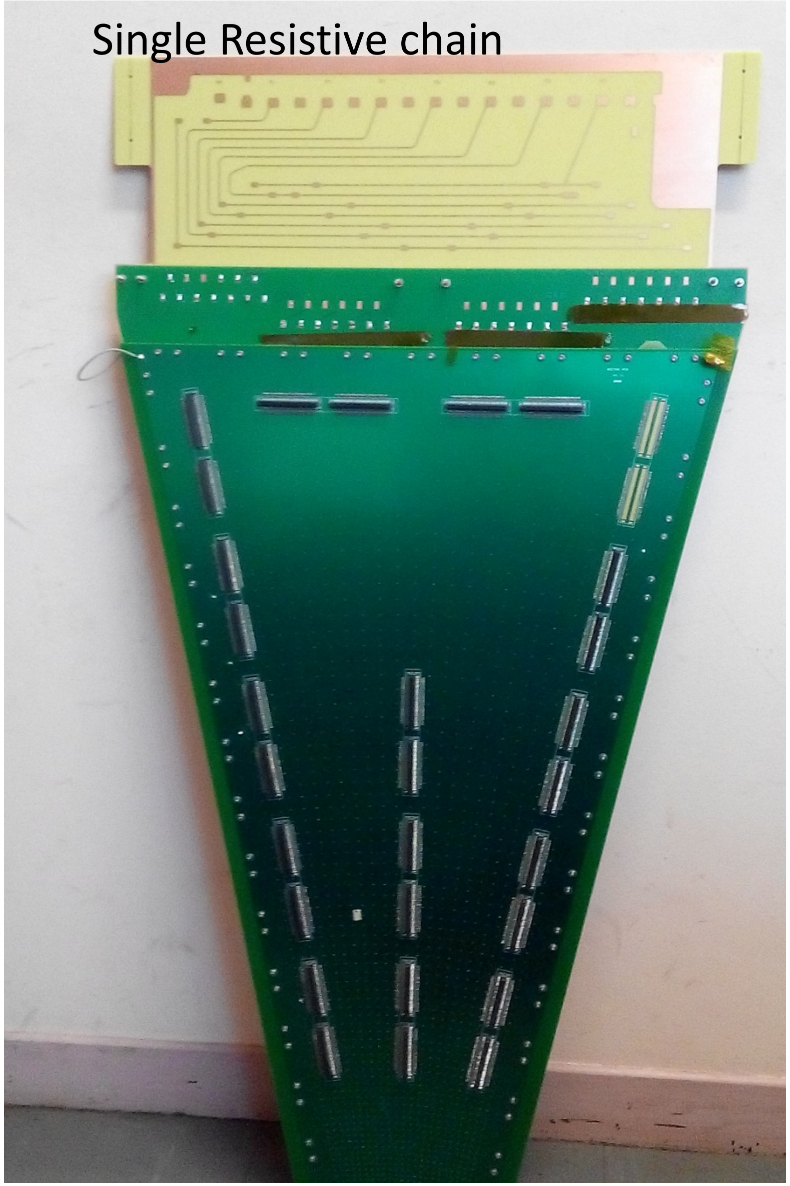


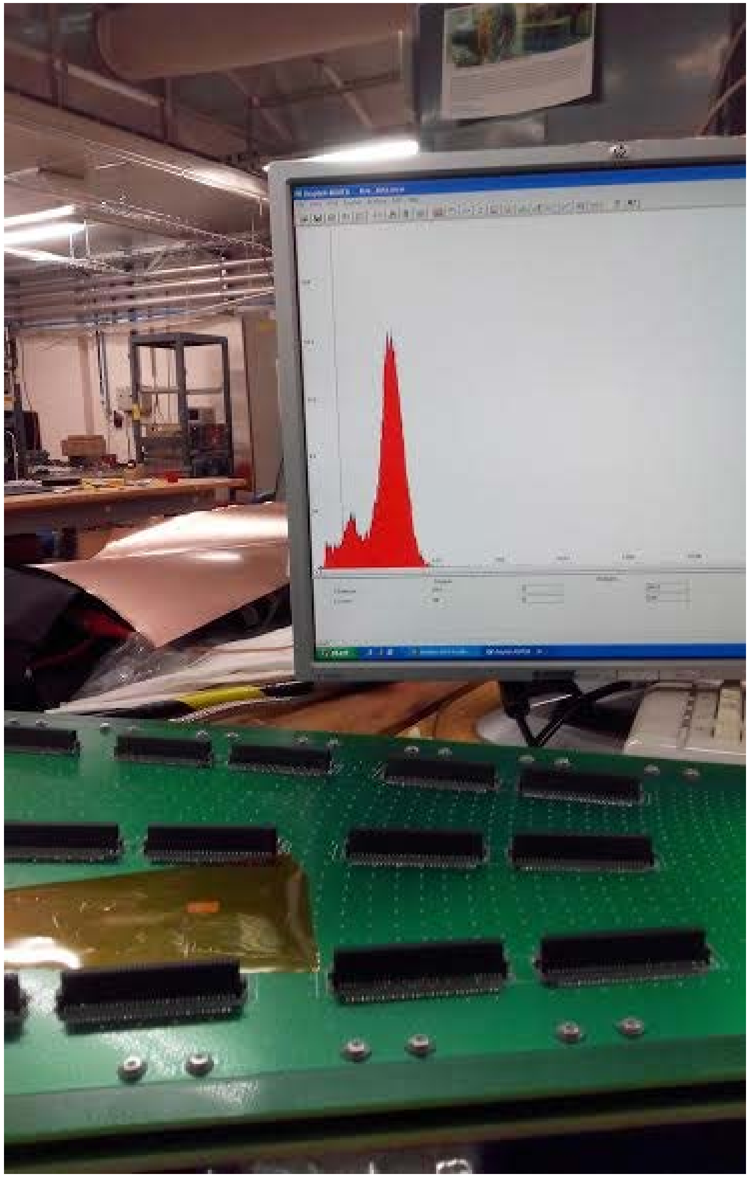
Bottom of Drift PCB for future prototypes



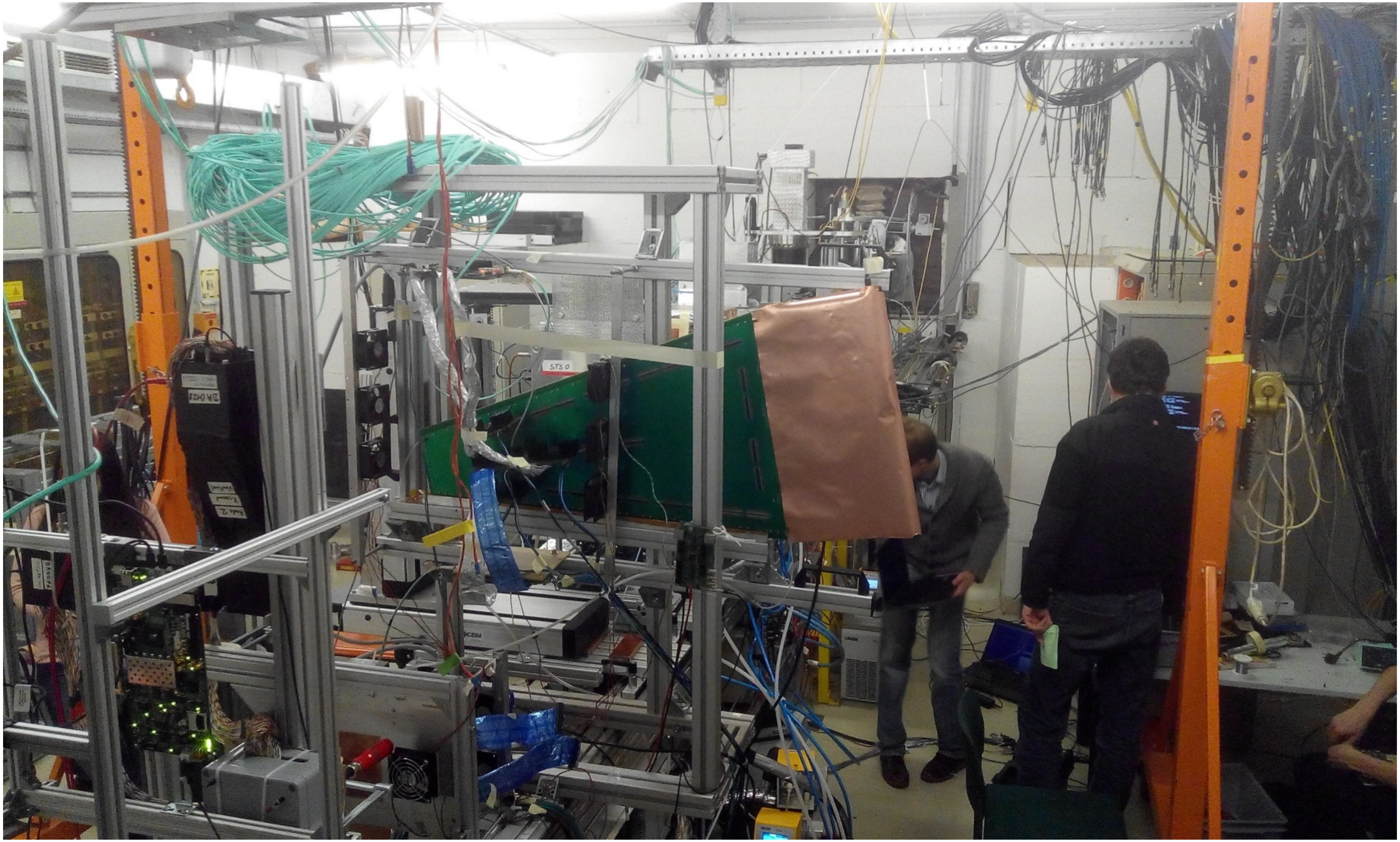
Indigenous design for powering and controlling the GEM shorts using Opto-couplers.

The Real size prototype, response to Fe55 X-rays

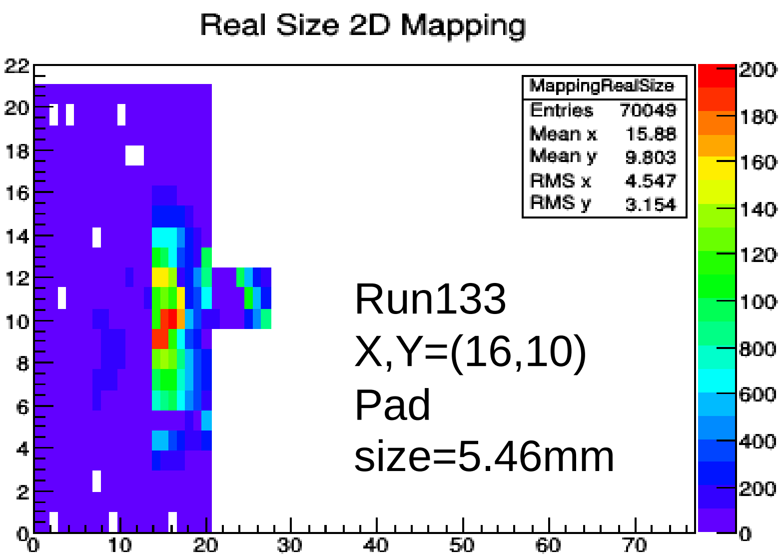


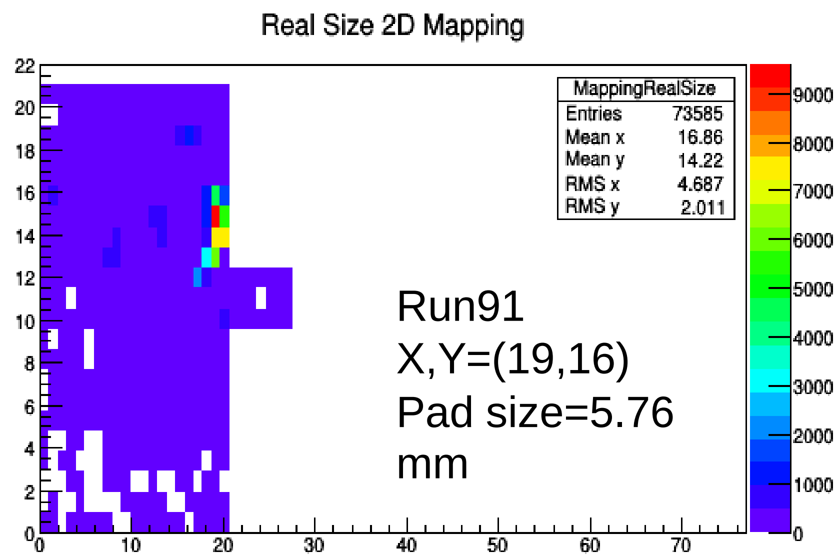


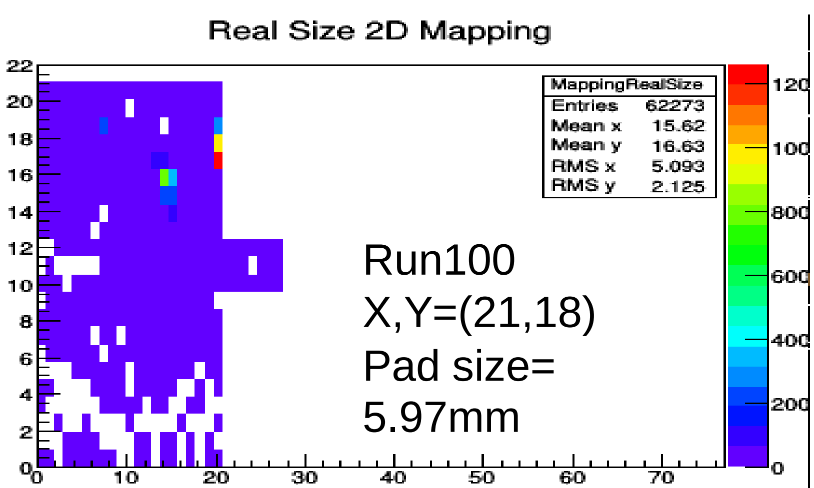
Beamtest of real size prototype at JESSICA@COSY, Juelich

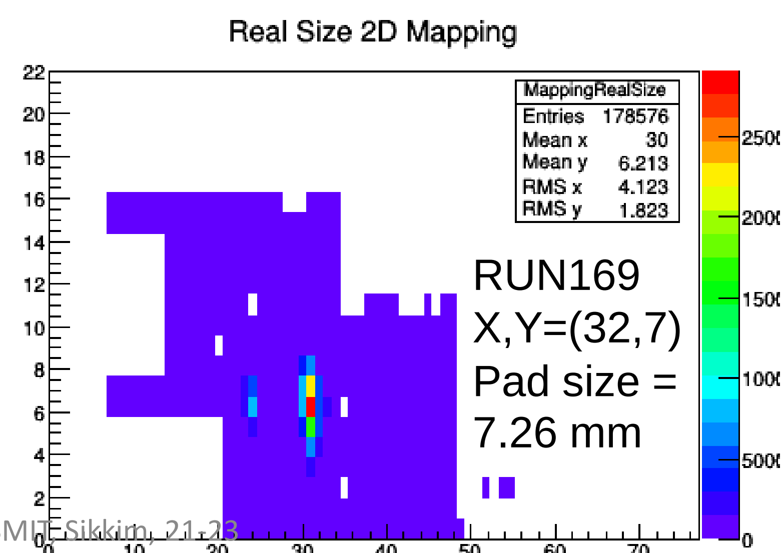


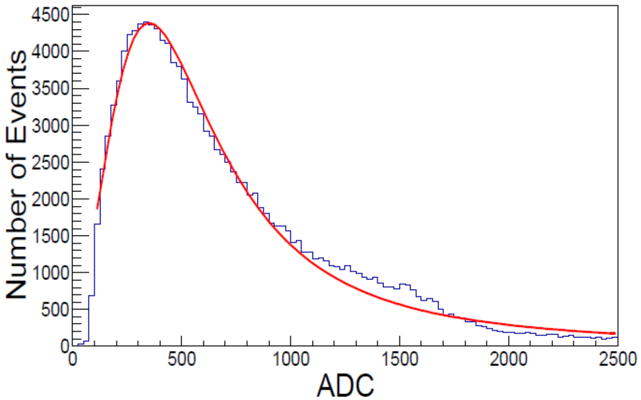
Beam spots at different positions of the prototype

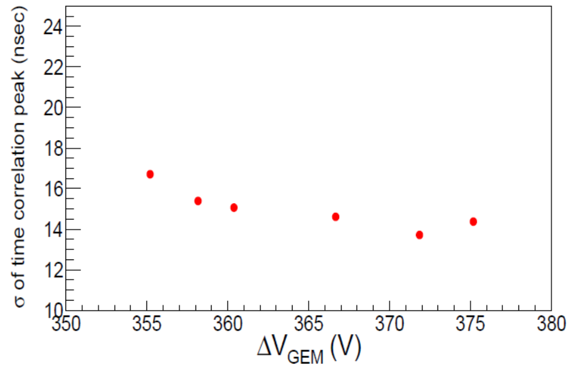




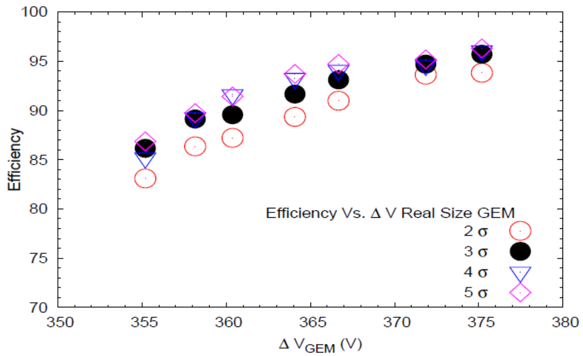


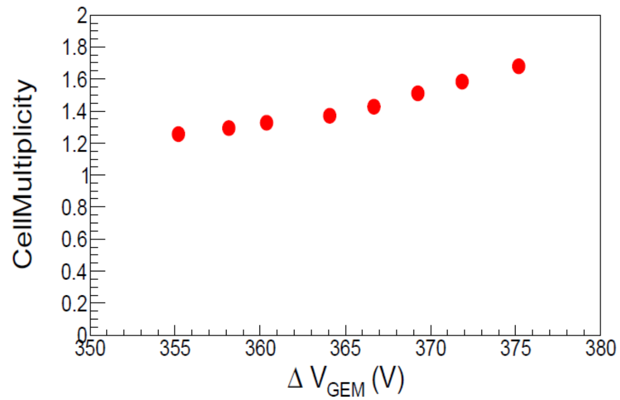




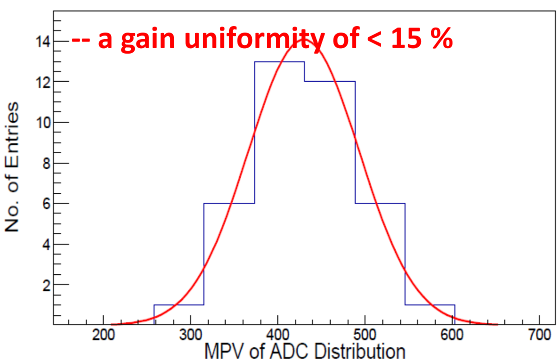


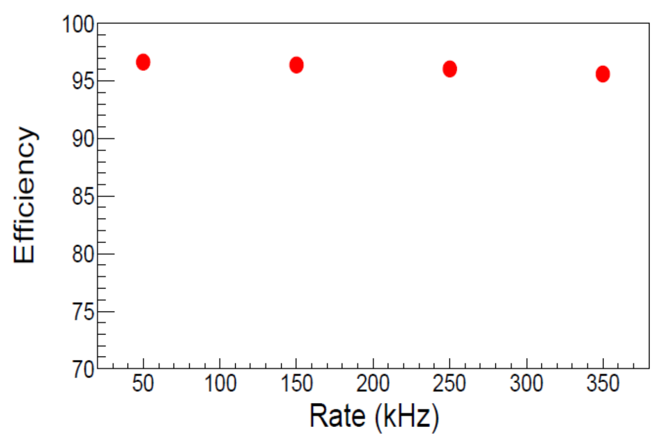
Test Results of Real Size Prototype

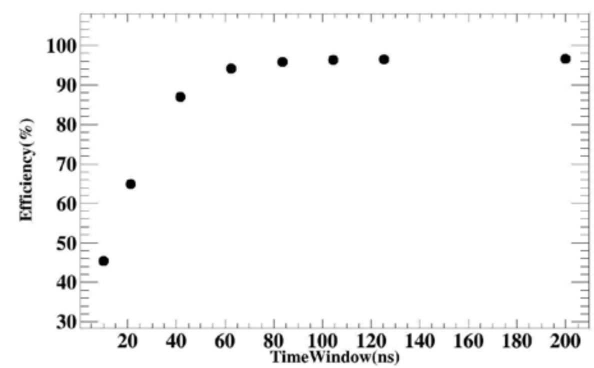




Analysis by:
R. Adak, S. Samanta, BI
& A. Kumar, VECC





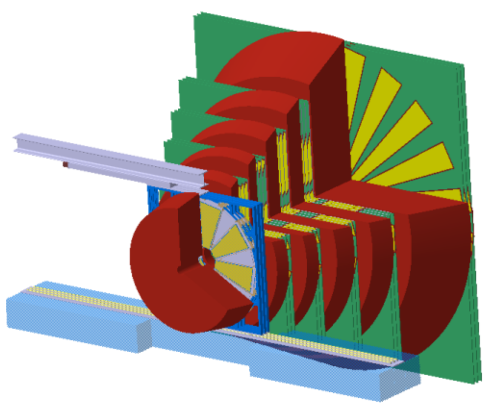


Compressed Baryonic Matter Experiment

Technical Design Report for the CBM

Muon Chamber (MUCH)

The CBM Collaboration



December 2013

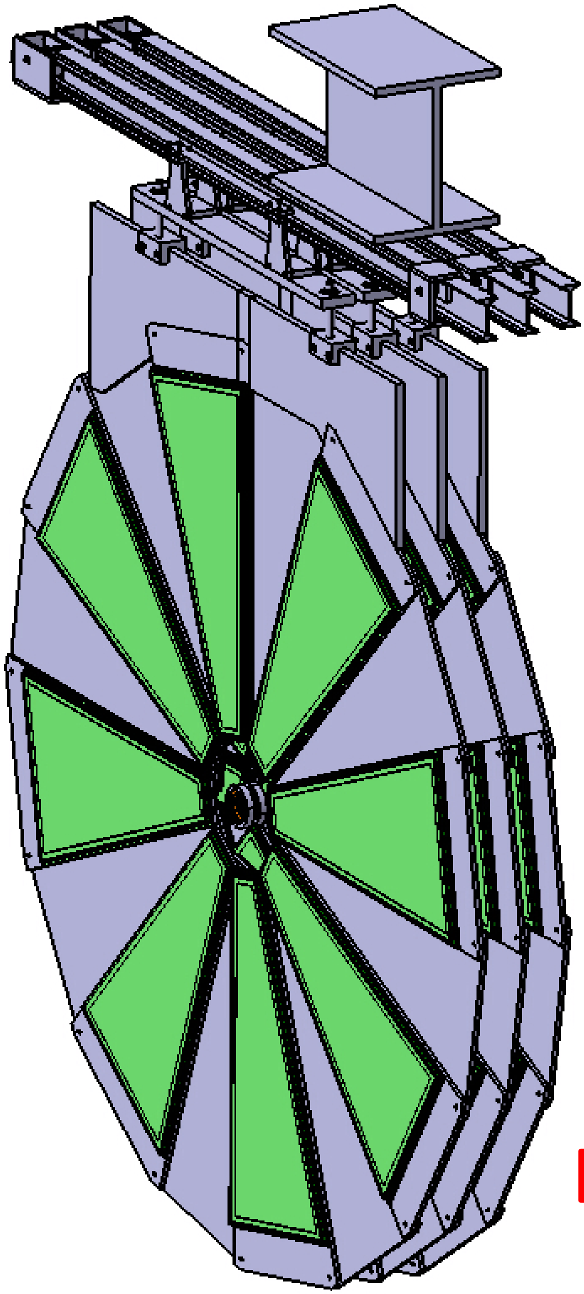
Technical Design Report
Submission for internal review: 21/10/13
Review: 7-8 Nov 2013

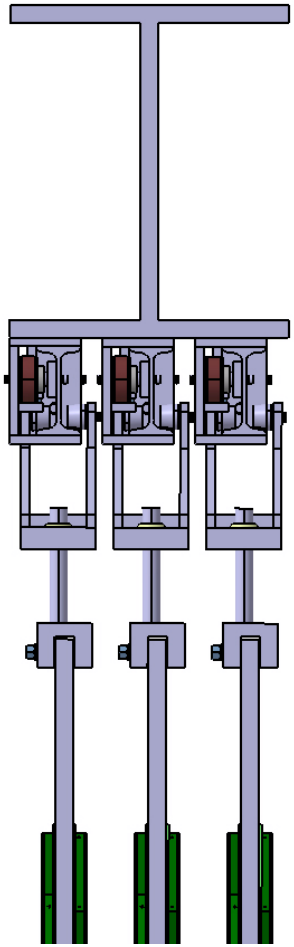
Submitted to FAIR: December 2013

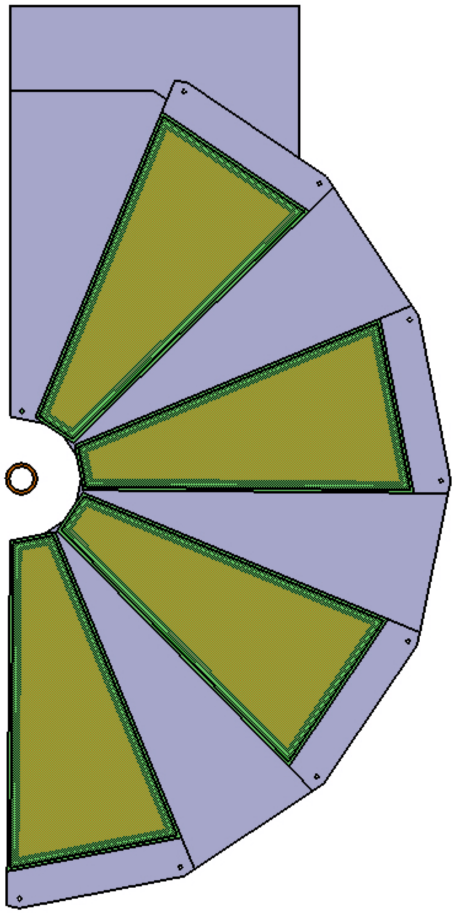
Approved – December 2014

(VECC + 12 Indian Institutes, PNPI Gatchina, JINR Dubna)

New Mounting Scheme







Being developed by MEG Group VECC

Summary

- Dimuon measurement is at the core of the CBM physics program
- Feasibility studies performed for a layout with segmented absorber and detector triplets.
- Different detector technologies will be implemented at different stations
- SIS100 layout R&D completed, can be extended to SIS300 chambers
- First Real size Prototype using "ns2" stretching assembled and tested successfully with proton beams and using self triggered nXYTER electronics.
- Detector design criteria of >90% efficiency and rate capability validated.
- Mechanical design underway for superstructure and detector chambers.
- Instrumented absorbers by the Russian Colleagues.
- GEM foil production for the first station will start in August at CERN,
- PCB and other components will be made by Indian Industry.
- <u>Efforts are ALSO on to produce Indigenous GEM foils at ECIL Hyderabad.</u>
- Module Production to begin next year.

Thank You