Results/Programs from IMP and THU

—— Some GEM R&D works and the CEE spectrometer

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<u>Collaborators:</u>

IMP: Limin Duan and his group, Zhiyu Sun, Guoqing Xiao

USTC: Ming Shao, Junfeng Yang, Lei Zhao

THU: Yan Huang, Yi Wang Zhi Deng…

CCNU: Nu Xu

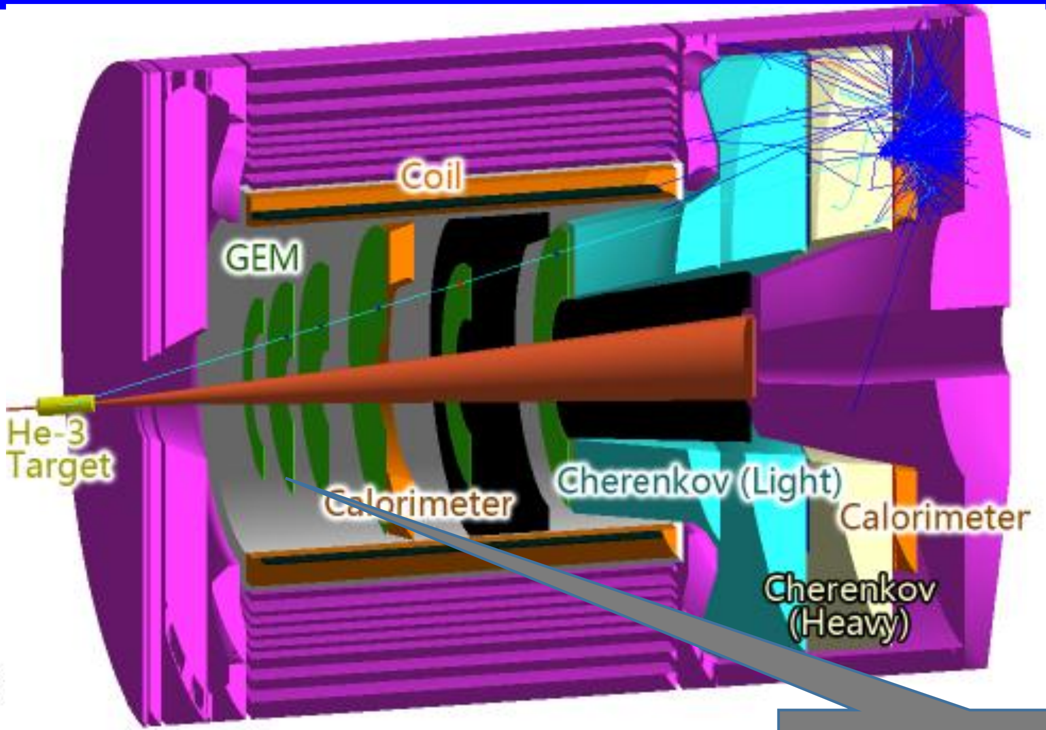
SINAP: Yugang Ma, Fei Lu

DUKE/THU: Haiyan Gao…

Contents

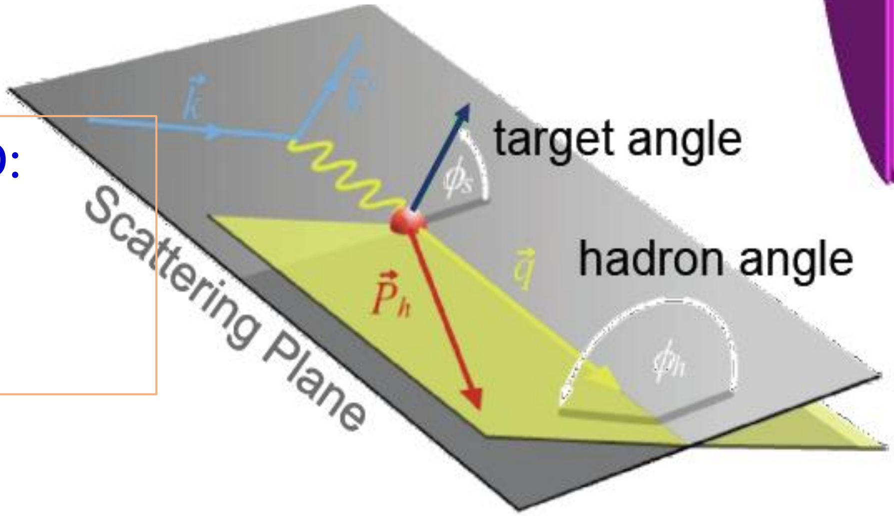
GEM detector demands from SOLID

→JLAB 12 GeV upgrade
→Nearly whole space coverage in C.M.
→Multi-subsystems including GEM, Cerenkov, MRPC
→About 1.5T central field by solenoid
→Measuring high energy electron and hadrons



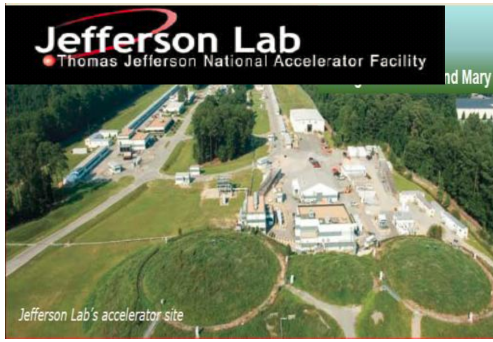
6 lays of large area GEM detector

Physical goal of SOLID:
Semi-inclusive eN process to detect the TMDs of nucleons.



- Large GEM detector is demanded in SOLID
- Possible demand in CEE for its TPC read out.

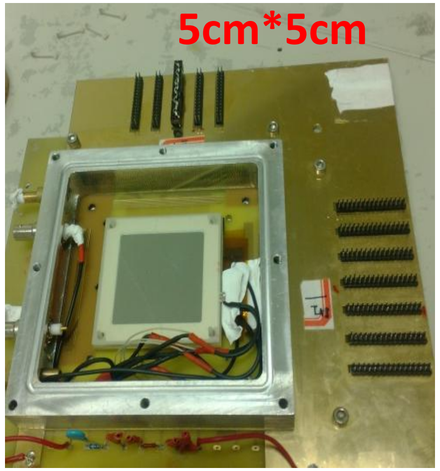
About 200 scientist from about 50 institutes from 8 countries.
From China：
USTC, CIAE, PKU, THU, LZU, IMP, HSU, SDU etc.

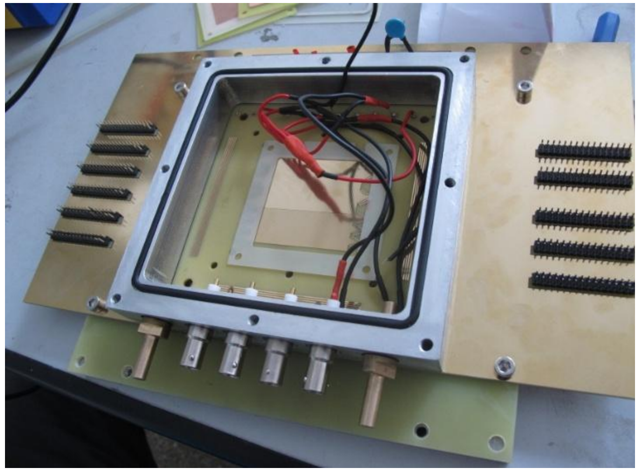


Small GEM detector test

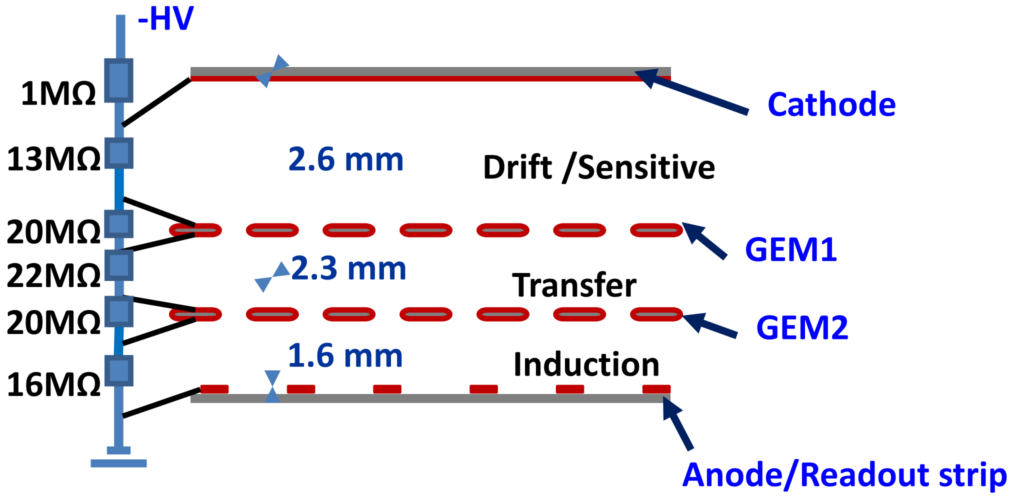
- Detector

2D GEM



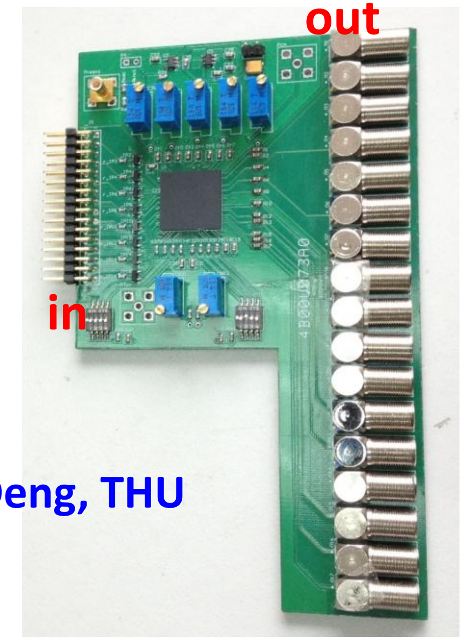


1D GEM detector



- Electronics

CASA-GEM board



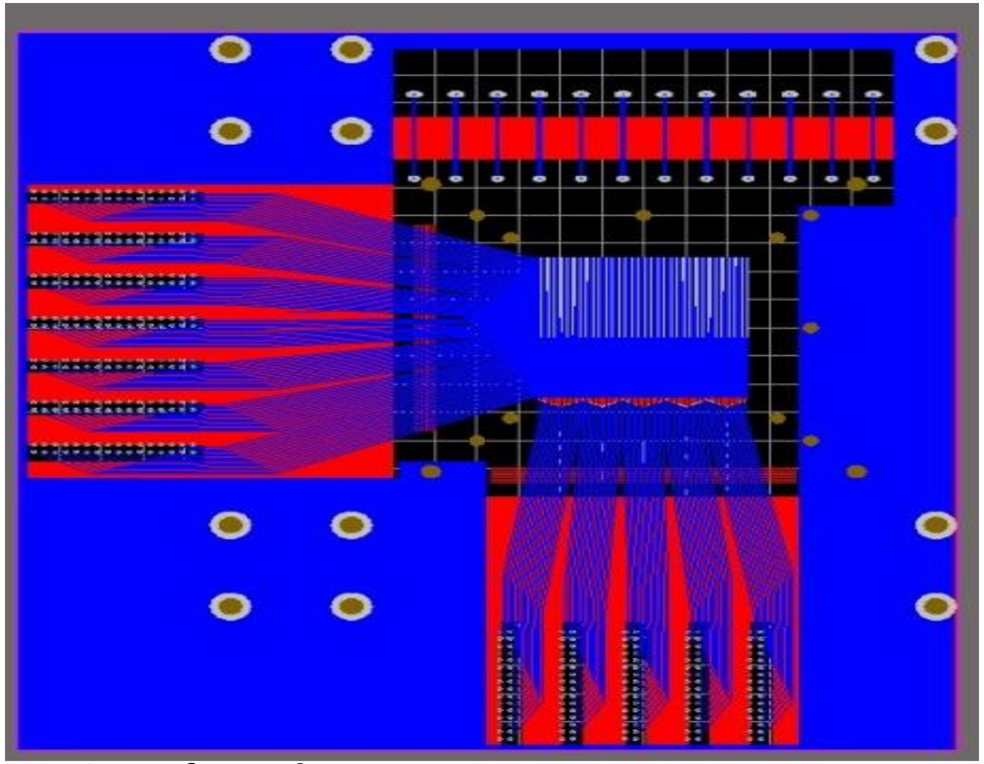
Gain	2~40mV/fC
Dynm. Rng.	0~1000fC
Shap. time	20~80ns
INL	<1%
Power	10 (11) mW/ch for Anode (Cath.) ch.
ENC	<2000e (Anode., Input Cap: 50pF), <3000e (Cathode, Input Cap: 100pF)

Developed by Z. Deng, THU

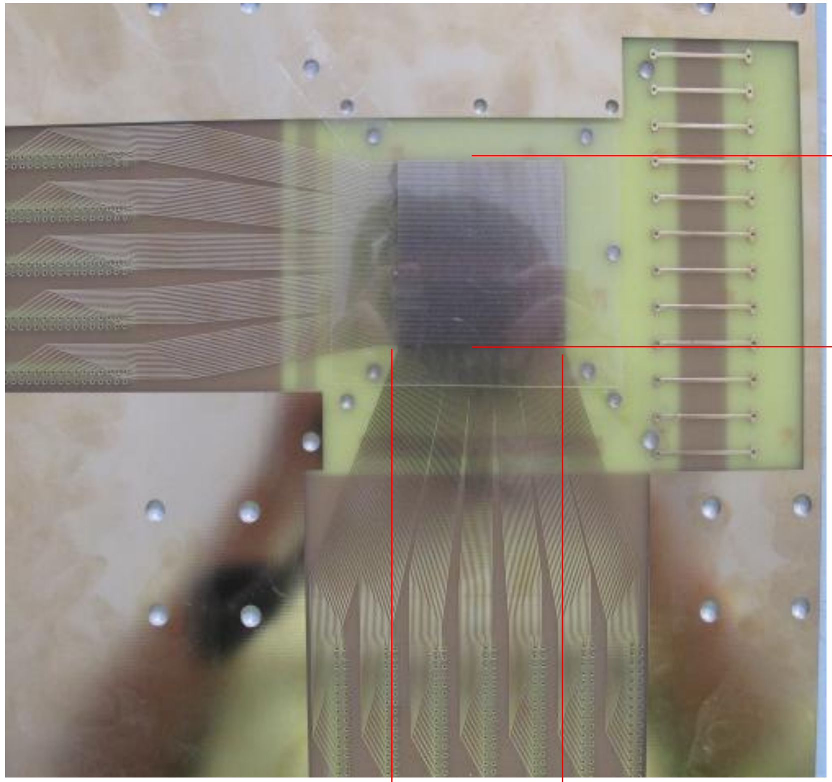
Readout Board Dimension

- 2-D read out

Extracted from the lowest foil



Design of Readout



5×16 strips in 5cm
W = 625 μm

7×16 strips in 5cm
W = 446 μm

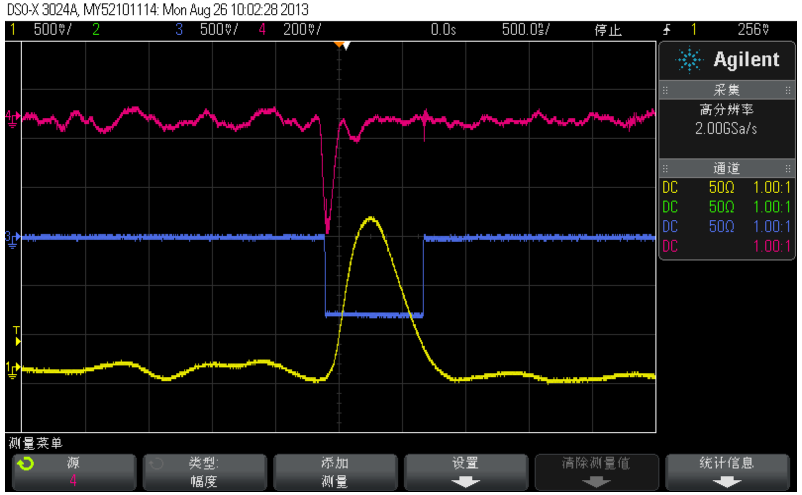
- 1-D readout

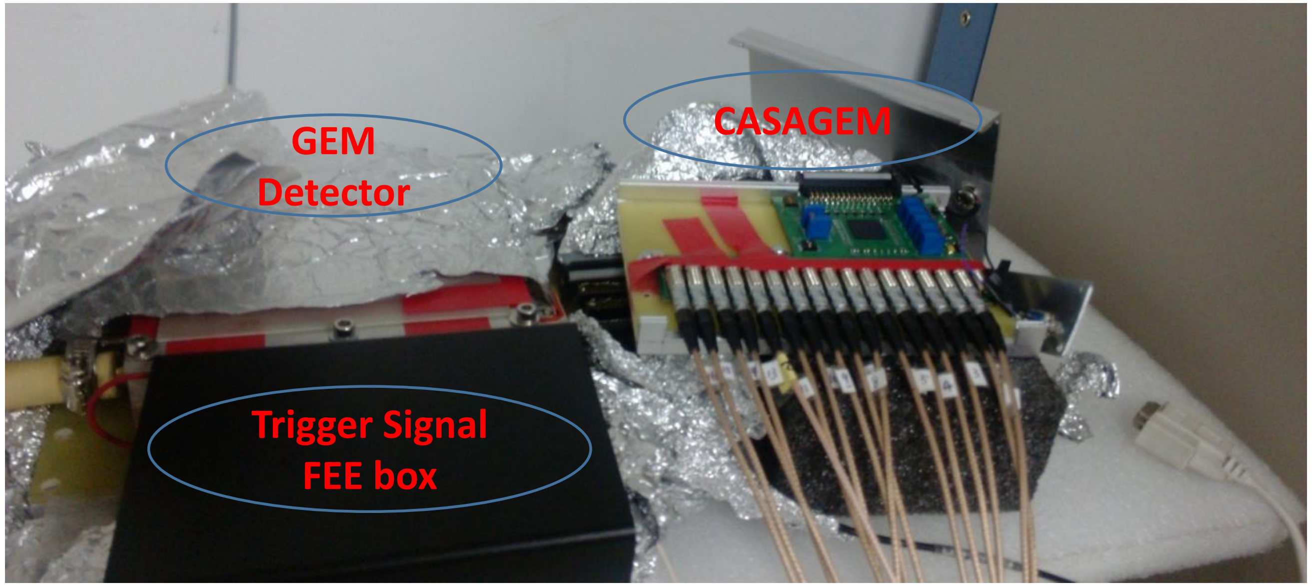
Strip: W=100+100 μm

Experimental Setup

- Trigger

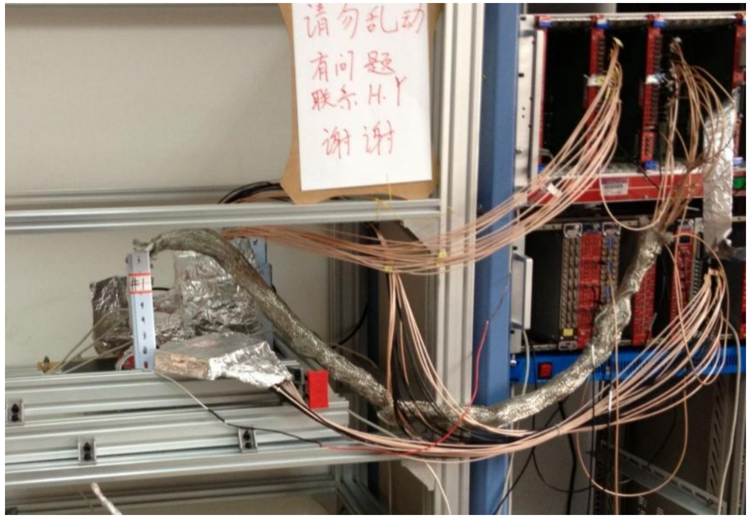
Extracted from the lowest foil



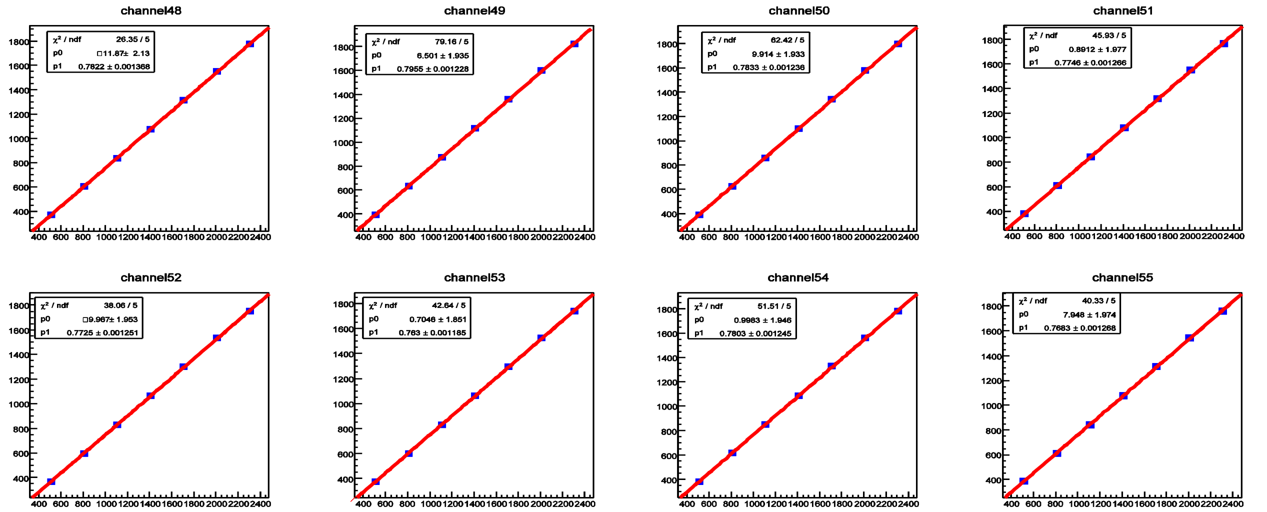


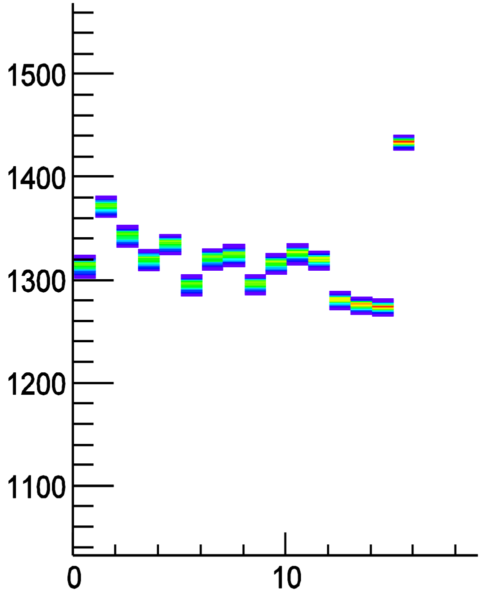
- ADC+ DAQ

VME based DAQ



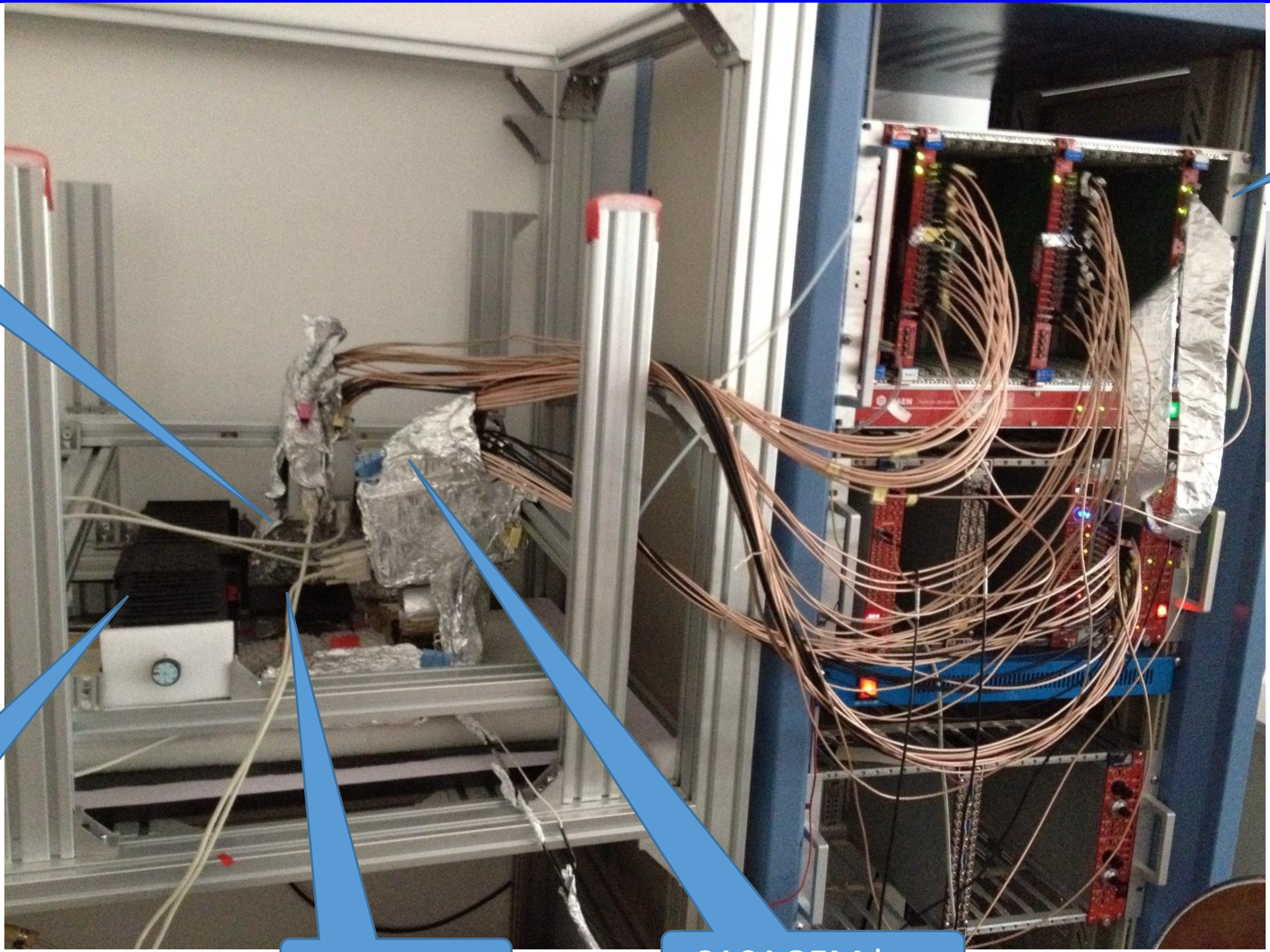
X:500 800 1100 1400 1700 2000 2300(mv)





ADC modules calibrated with pulse

The latest setup



Adjustable thick Slit

Precise movable platform

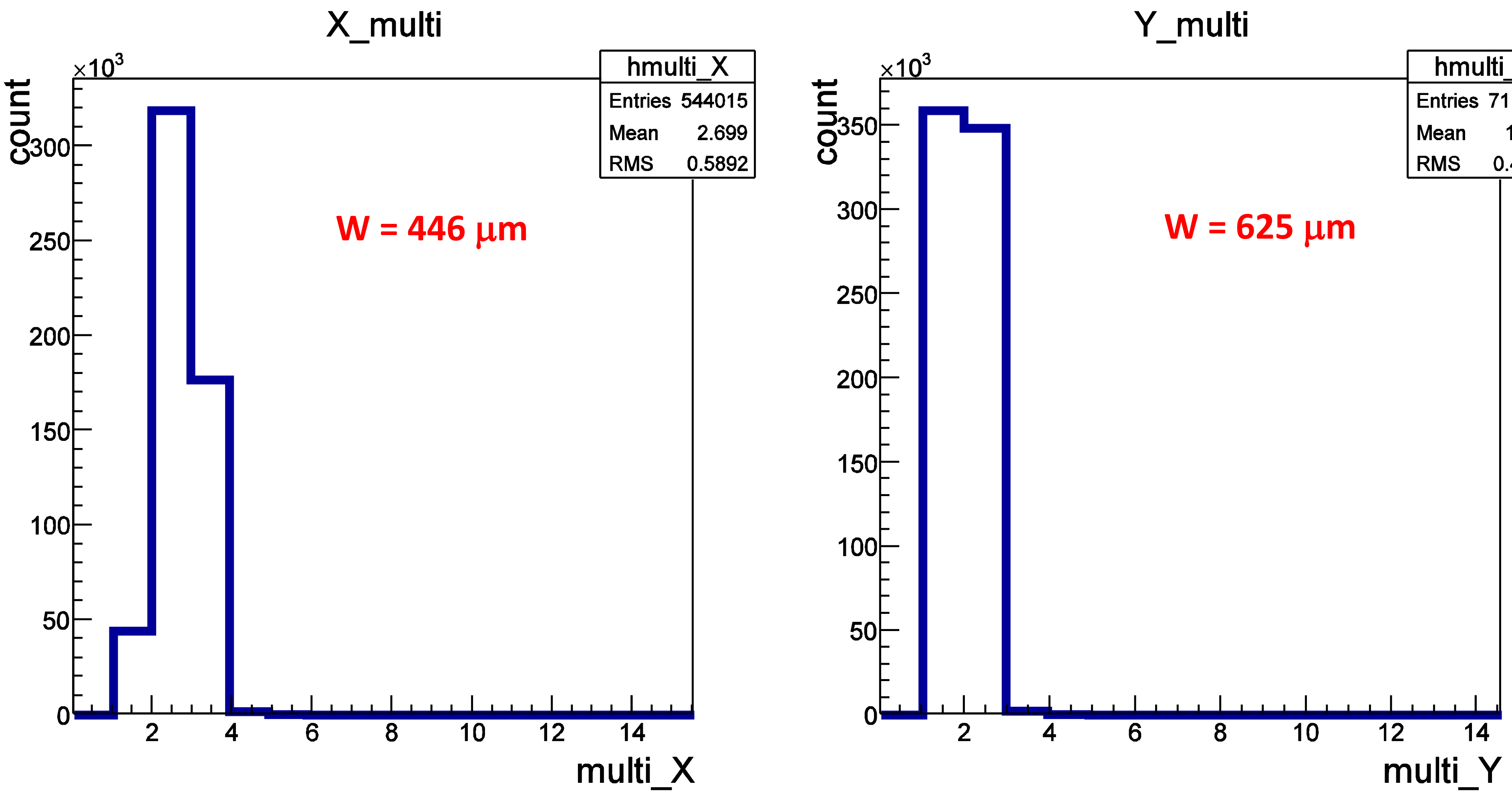
detector

CASAGEM box

VME DAQ

Acknowledgement:
96 channels peak sensitive ADC from Prof. Boqiang Ma's group (PKU)

Cluster size analysis

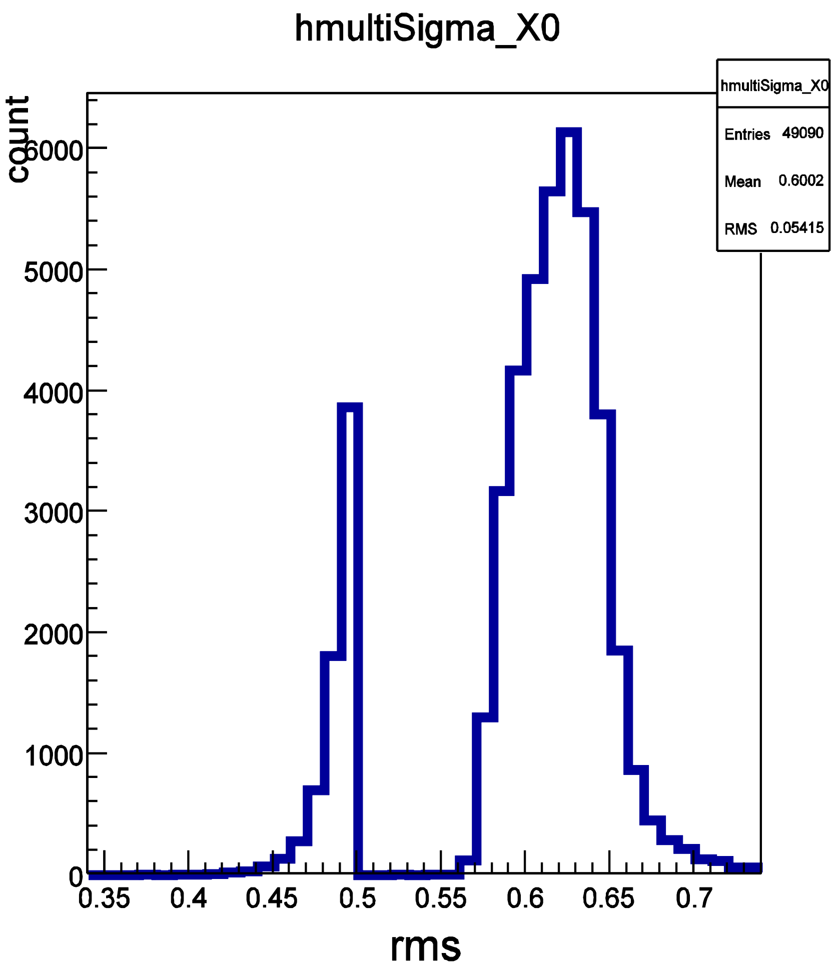


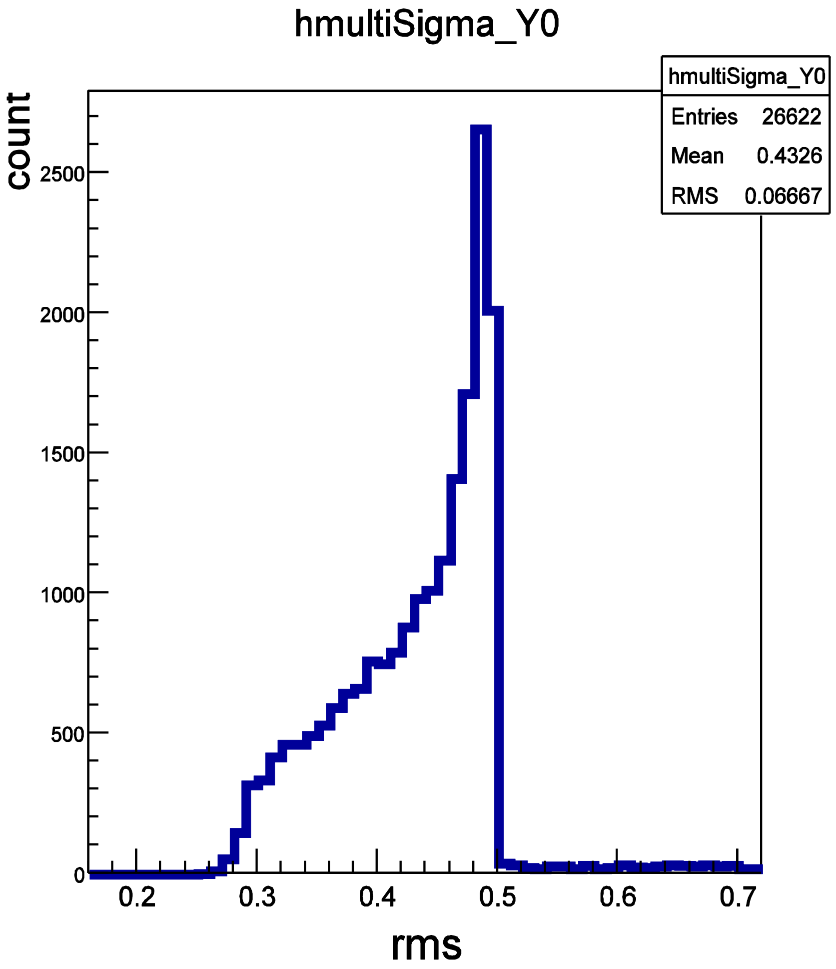
- Using larger strip distance/width to save cost, however, strip width can not go beyond a certain value.

Cluster size (2rd moment analysis)

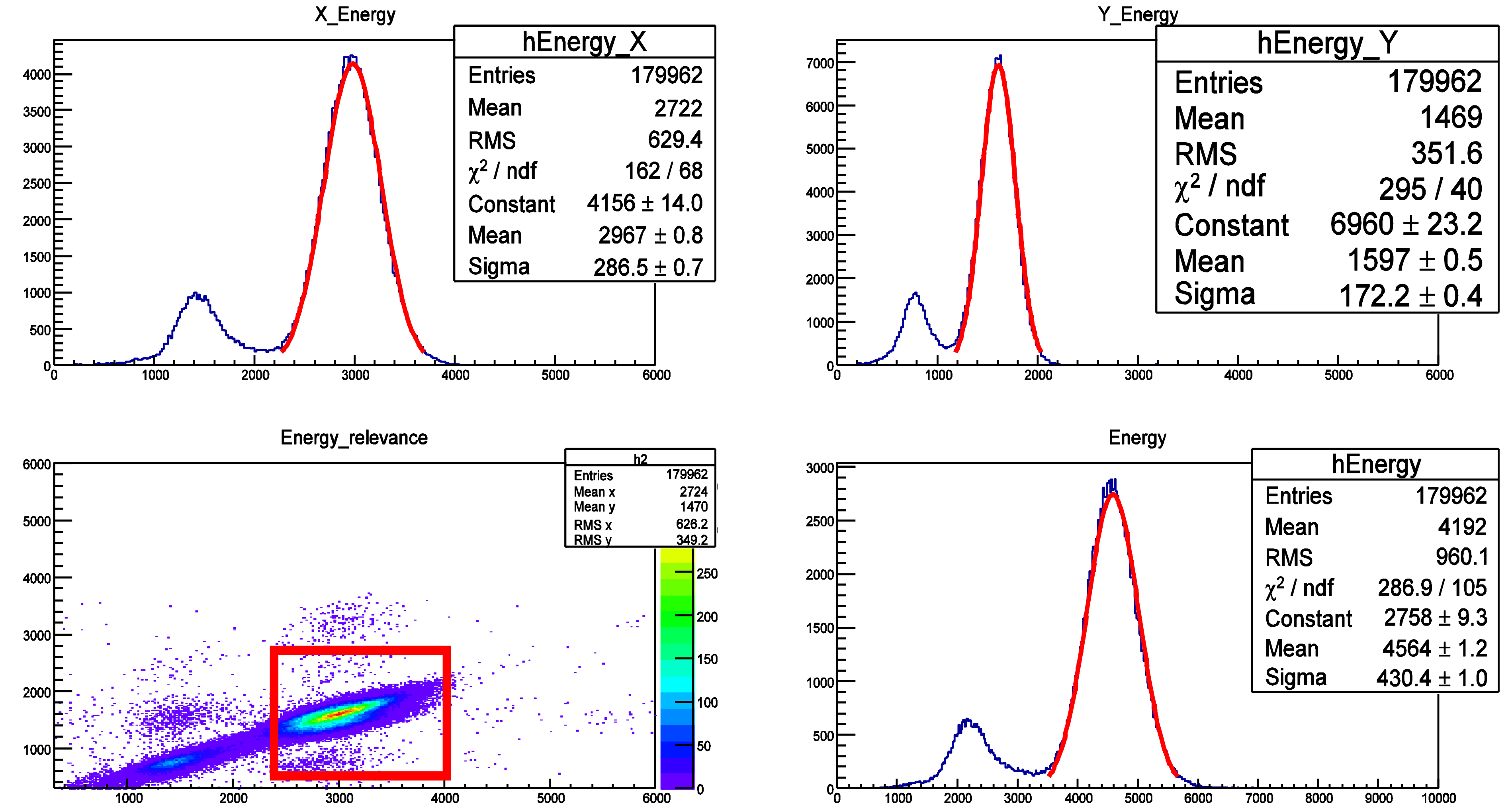
$$E[x^2] = \frac{\sum_{i=1}^{16} (x_i - \overline{x})^2 a_i}{\sum_{i=1}^{16} a_i}$$

x_i is the position of fired strip
a_i is the amplitude of signal
$\overline{x}$ is the mean position



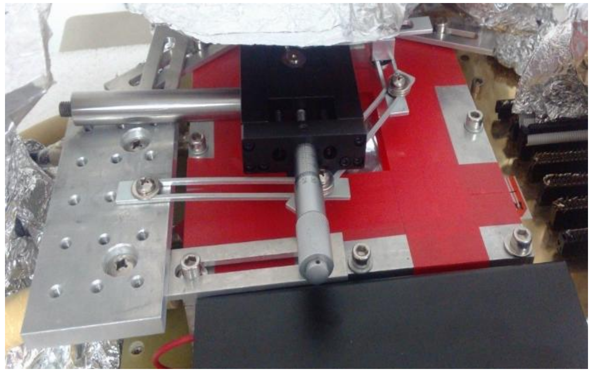


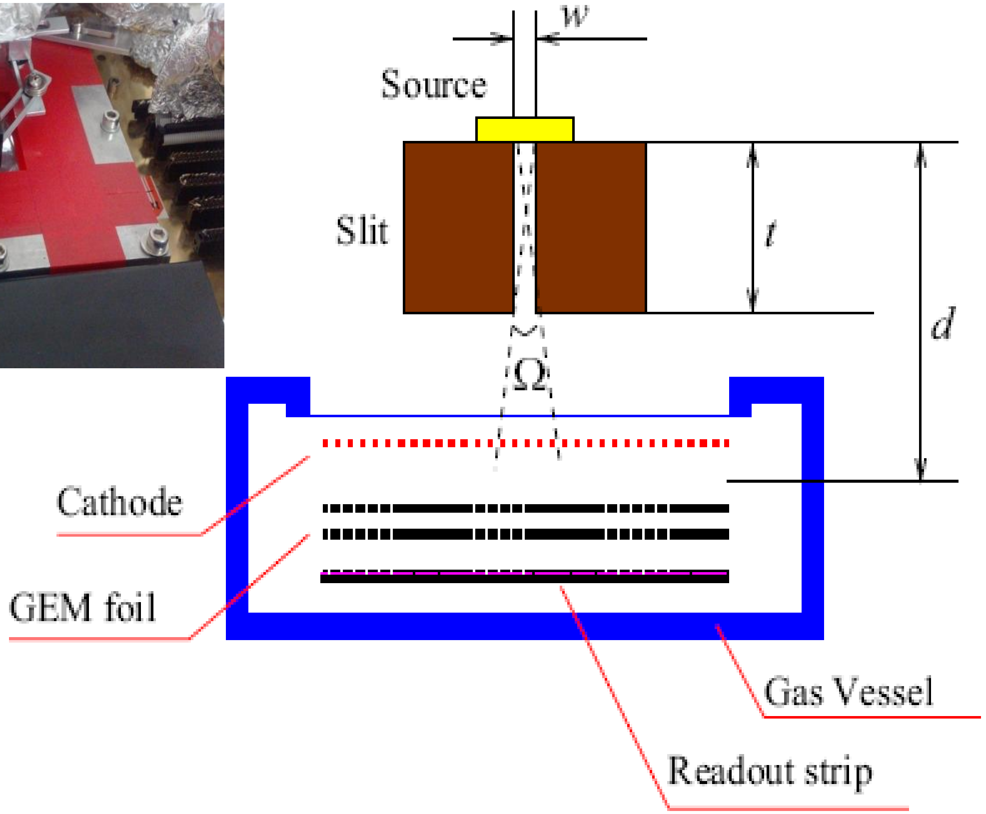
Energy Resolution with Fe-55



FWHM: X: 22% Y:25% total: 22%

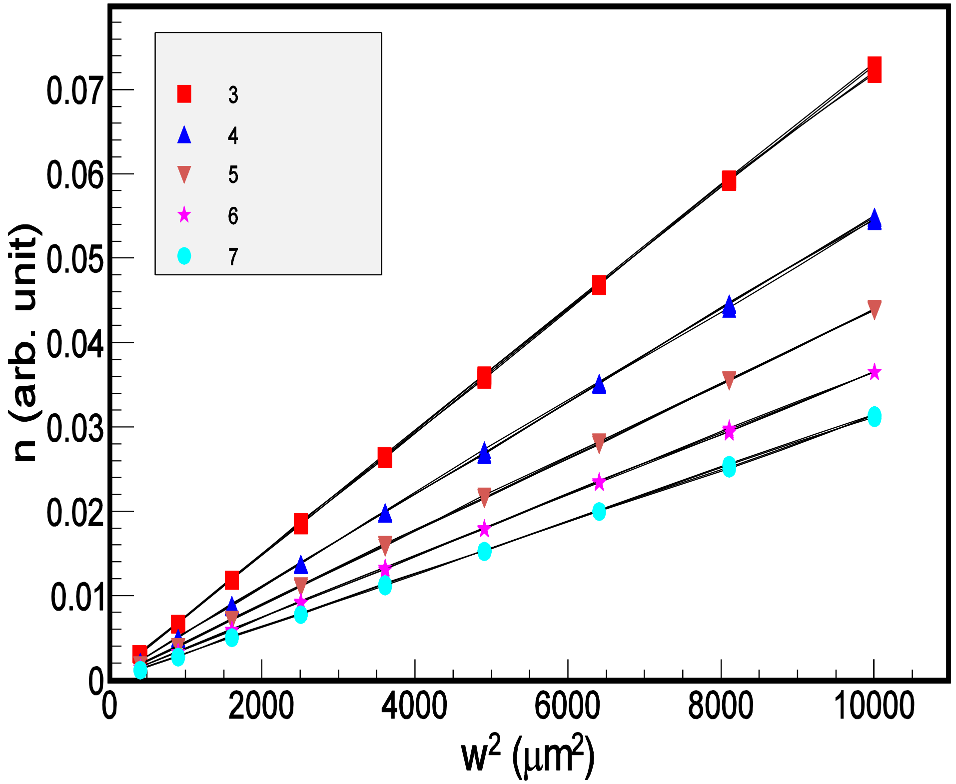
Spatial Resolution with Fe-55





$$n = \rho w \phi \Omega \eta / 4\pi \qquad n = c_2 w^2$$

$$\sigma^2_{tot} = \sigma^2_{GEM} + c_0 n$$



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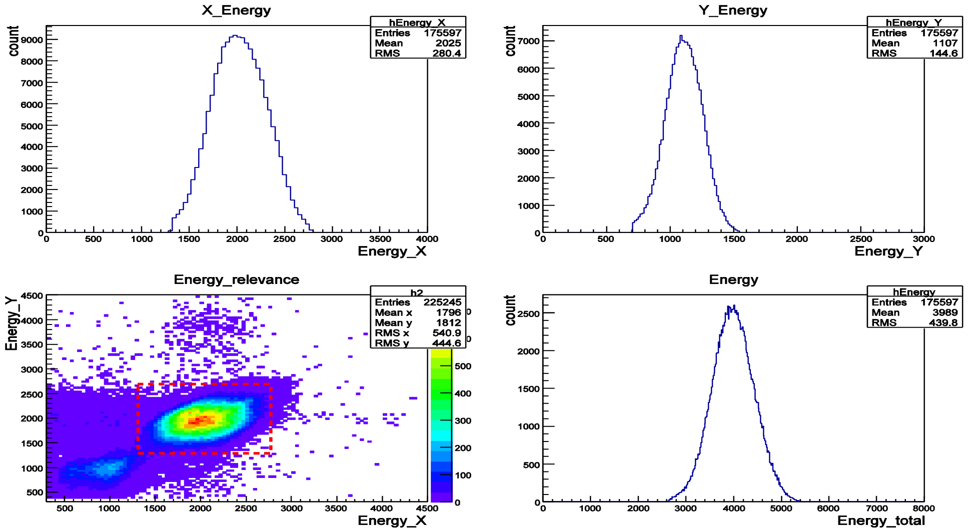
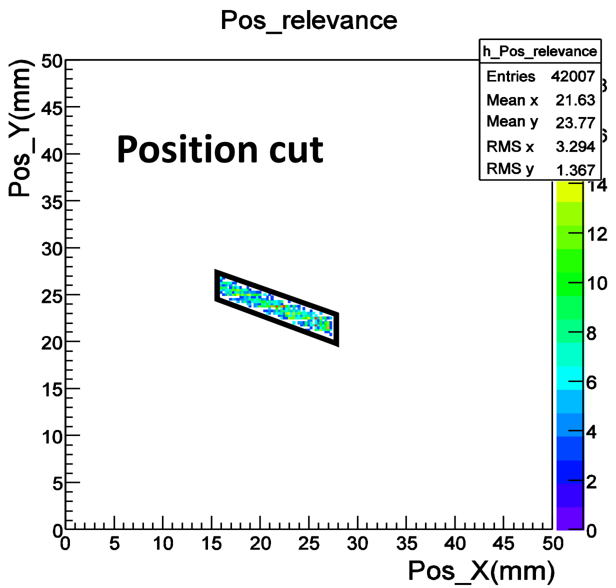
$$\sigma^2_{tot} = \sigma^2_{GEM} + c_1 \sigma^2_{Geometry}$$

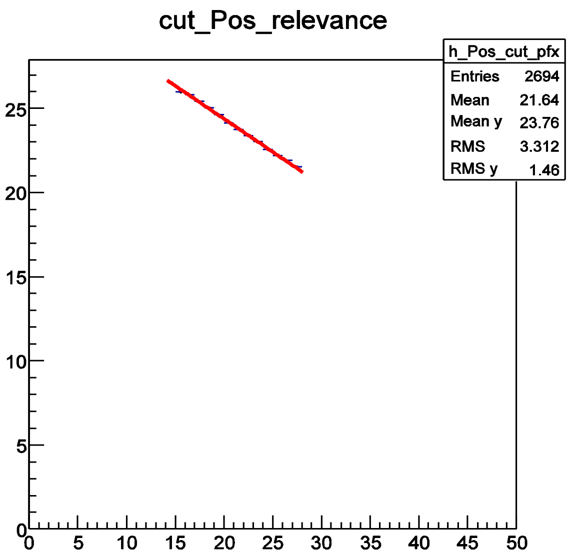
$$\sigma_{Geometry} = c_2 w$$

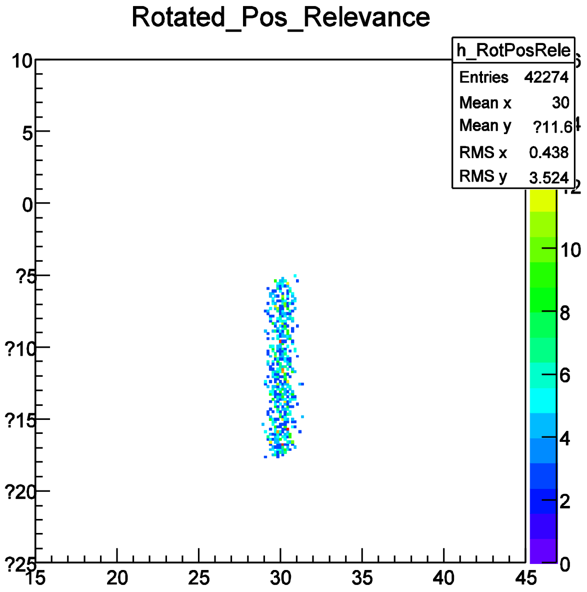
$$\sigma^2_{tot} = \sigma^2_{GEM} + c_0 w^2$$

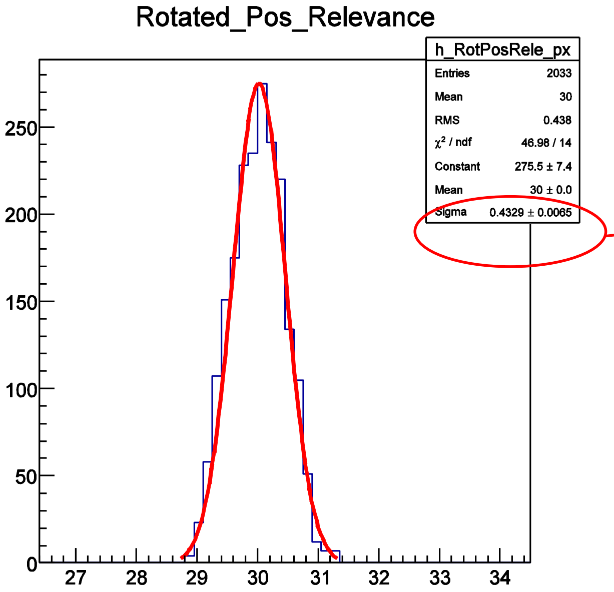
Spatial Resolution with Fe-55





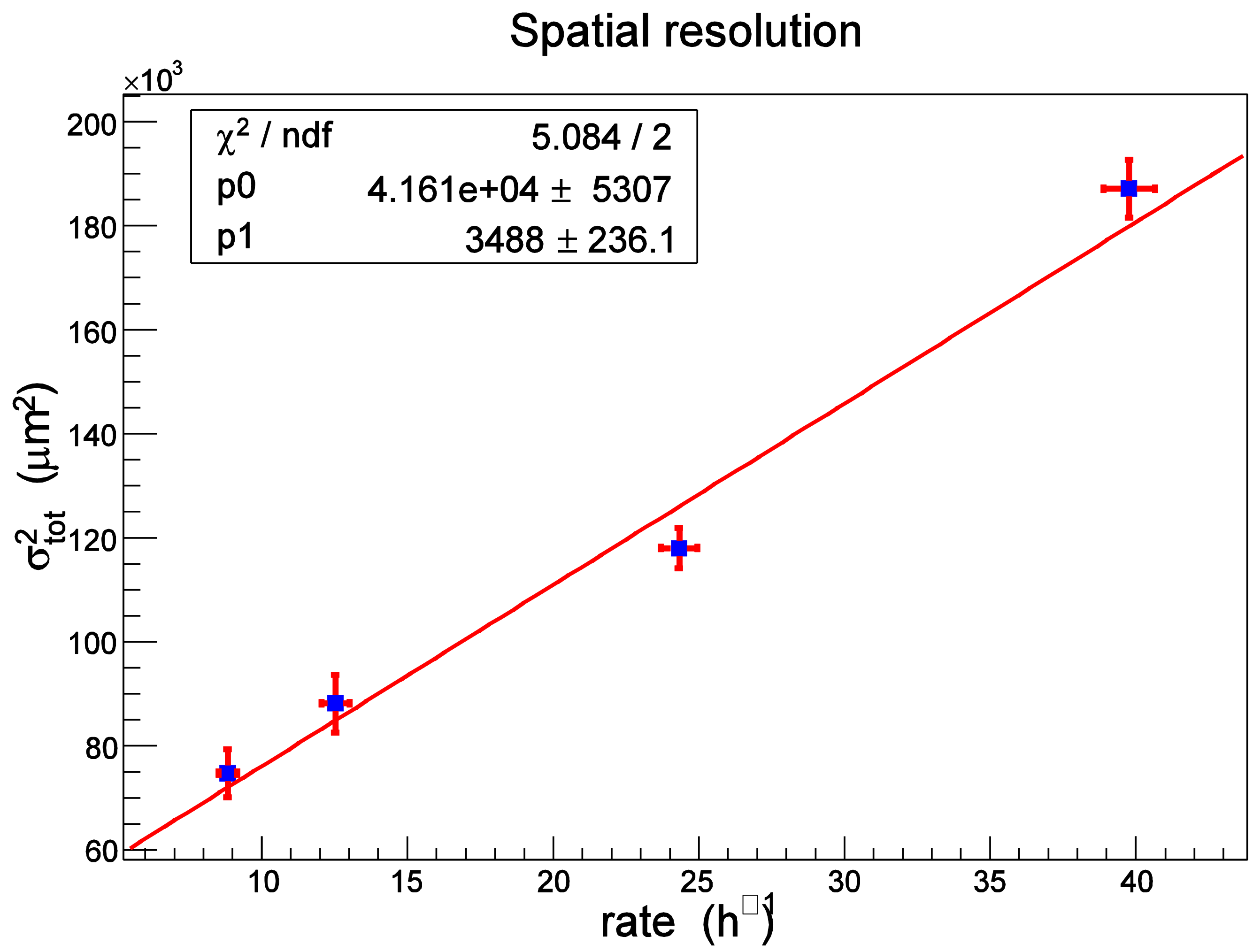






σ_{tot}=432 μm

Spatial resolution



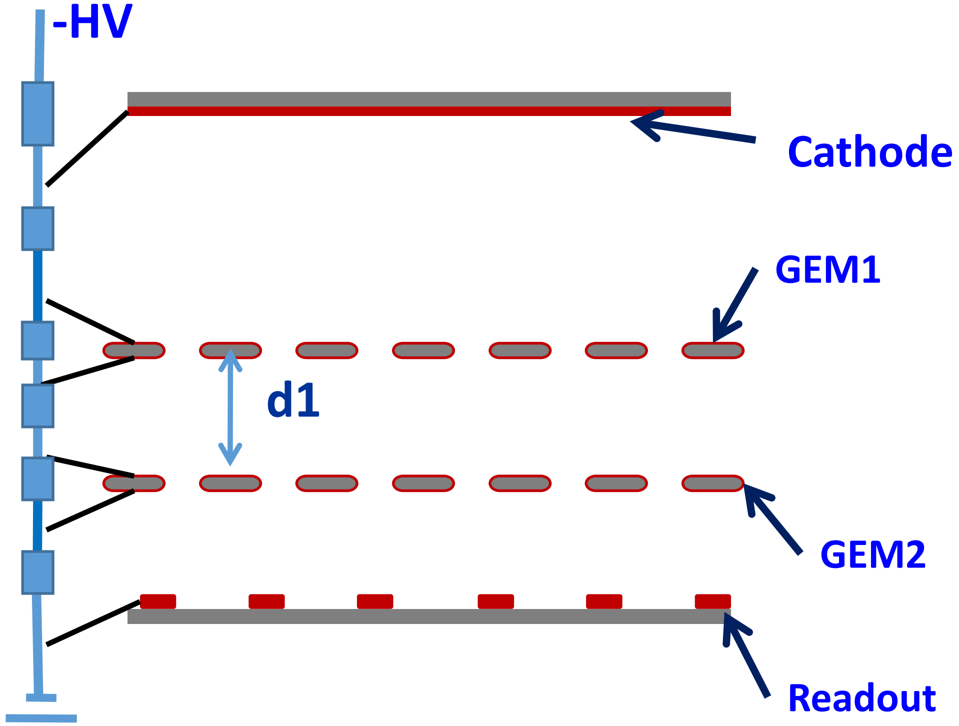
strip width(μm)	δ_{exp}(μm)	δ_{theo}(μm)
200	56±15	58
X:446 Y:625	204±13	221
446	159±22	129

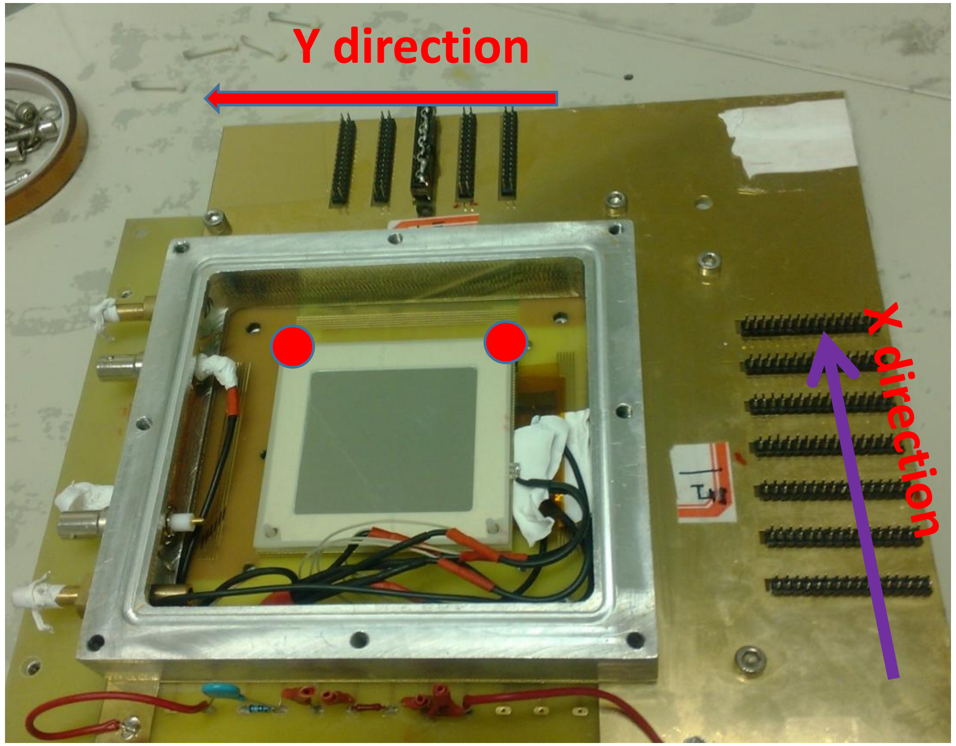
$$\delta_{theo} = \frac{w}{\sqrt{12}}$$

- $\sigma_{GEM} = 204 \pm 13(\mu m)$

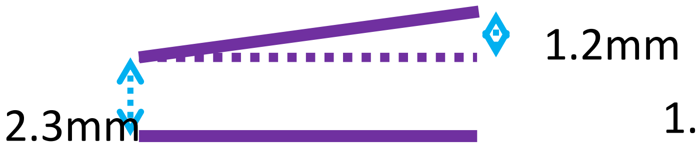
Non-uniformity effects of the inter-foil distance

- **Why this study?**

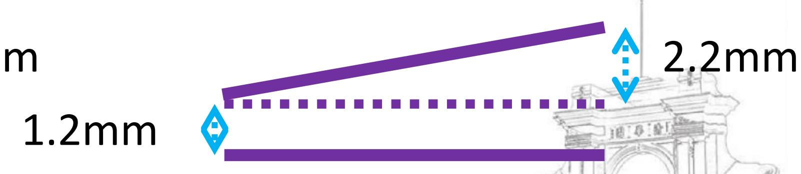




Extra spacer to extend the gap at one side

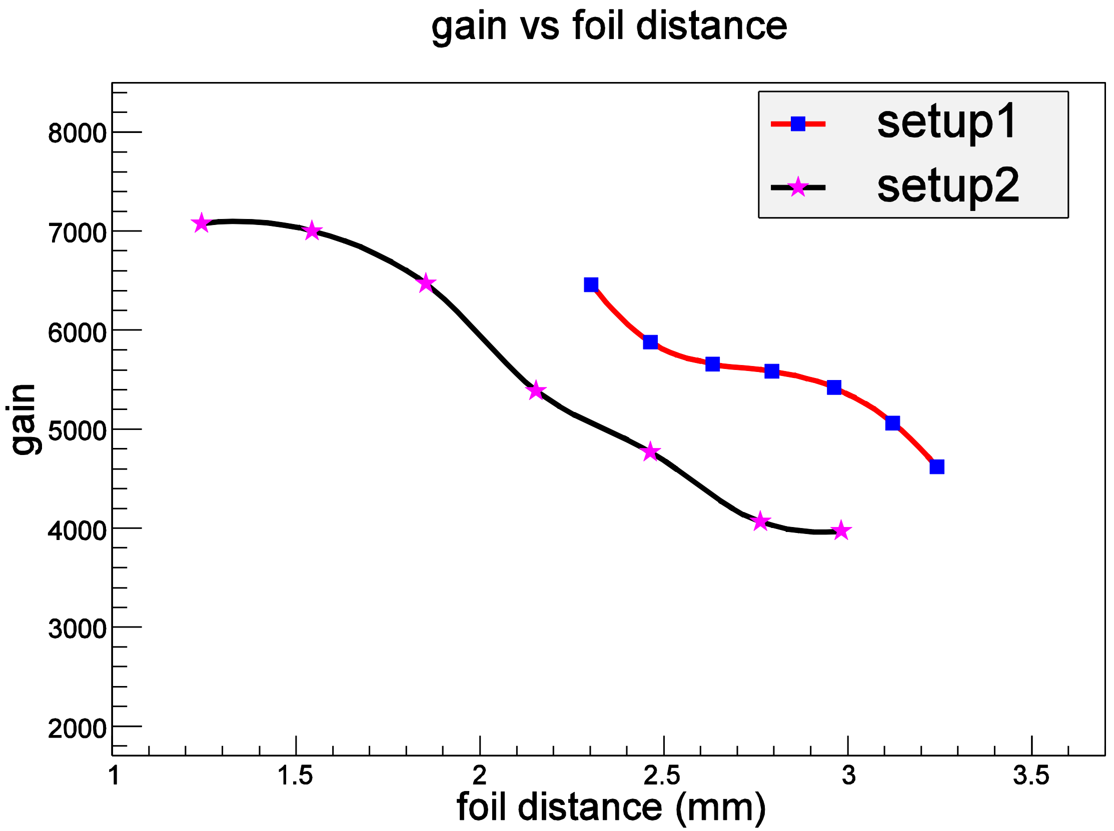


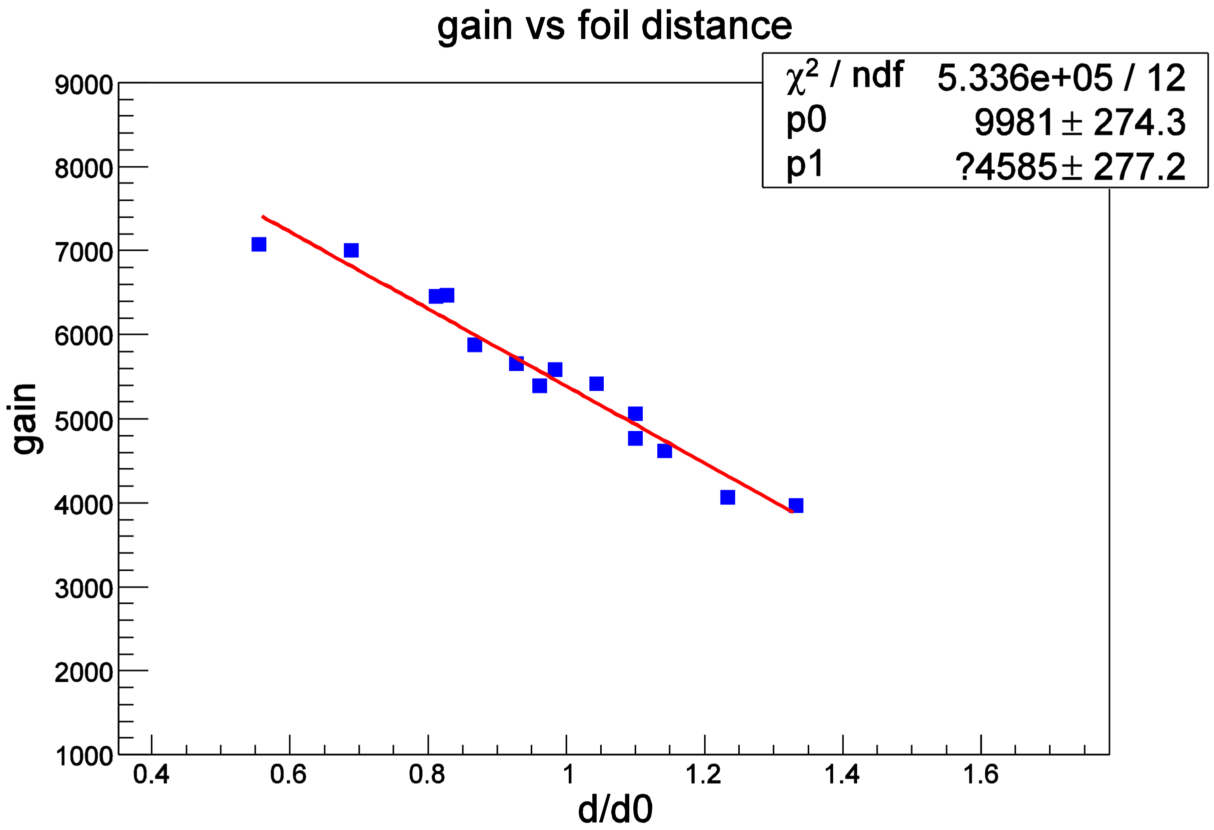
Scheme of setup1



Scheme of setup2

Gain variation vs. distance change

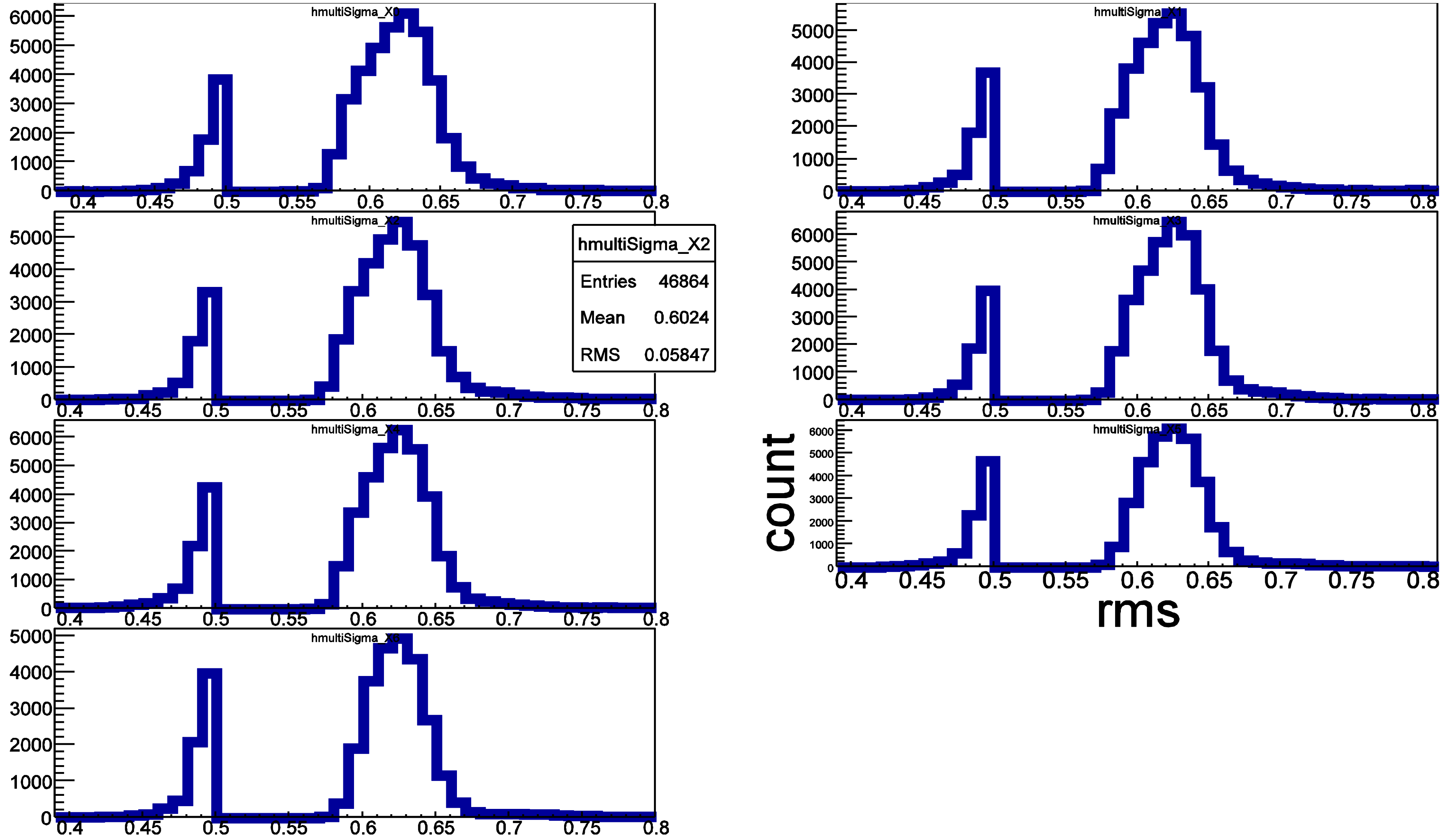




- **The gain exhibits a linear dependence on the relative change of the distance.**

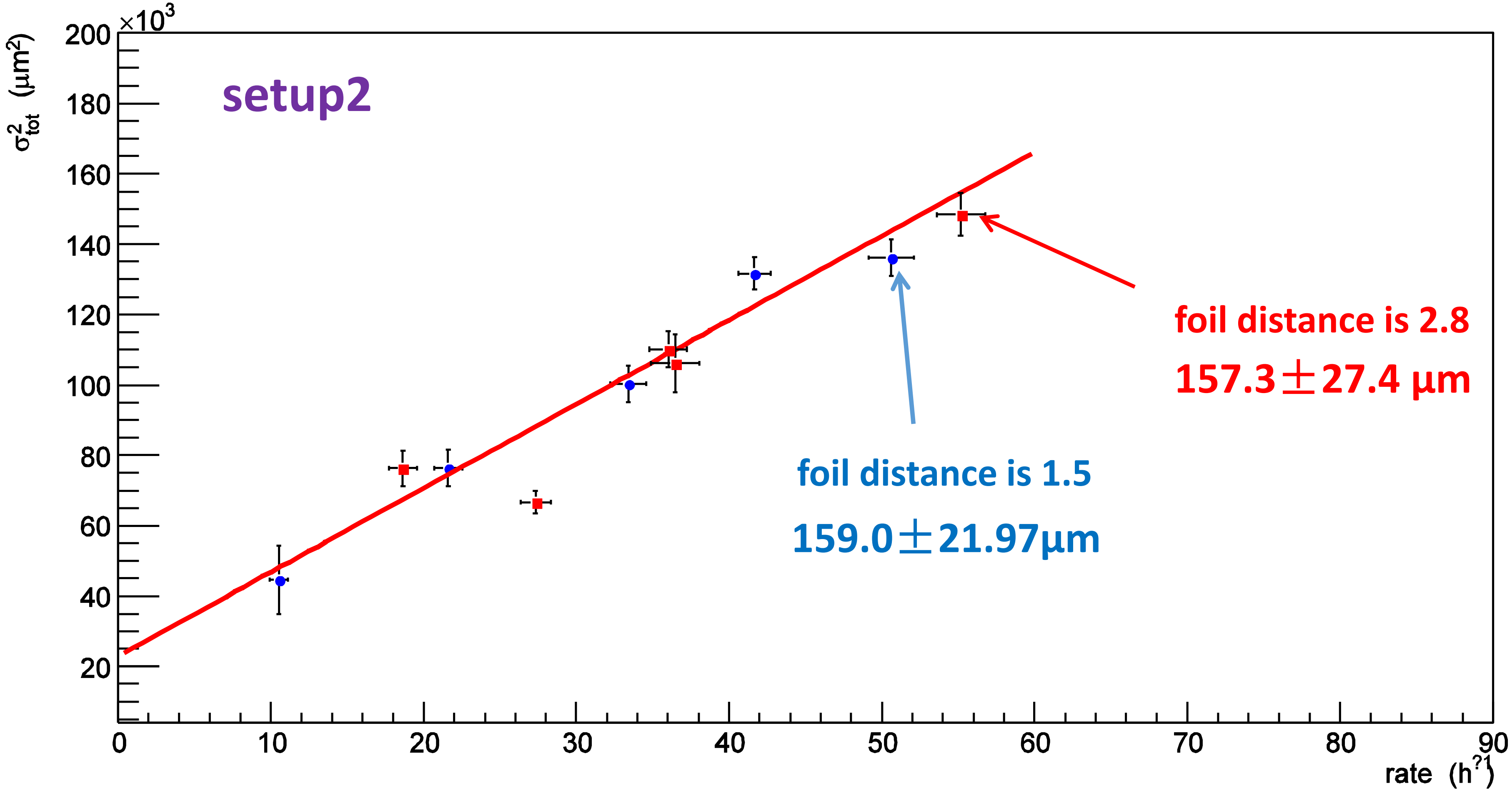
1% distance variation causes approximately 1.2% variation in gain.

Effects on Cluster size and spatial resolution



- Cluster size shows insignificant effect.

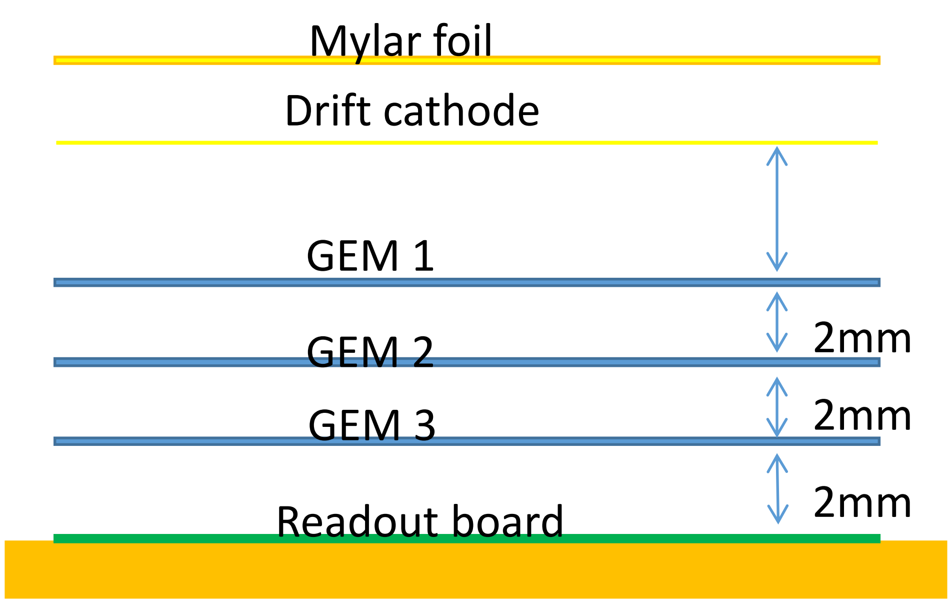
Neither does the spatial resolution

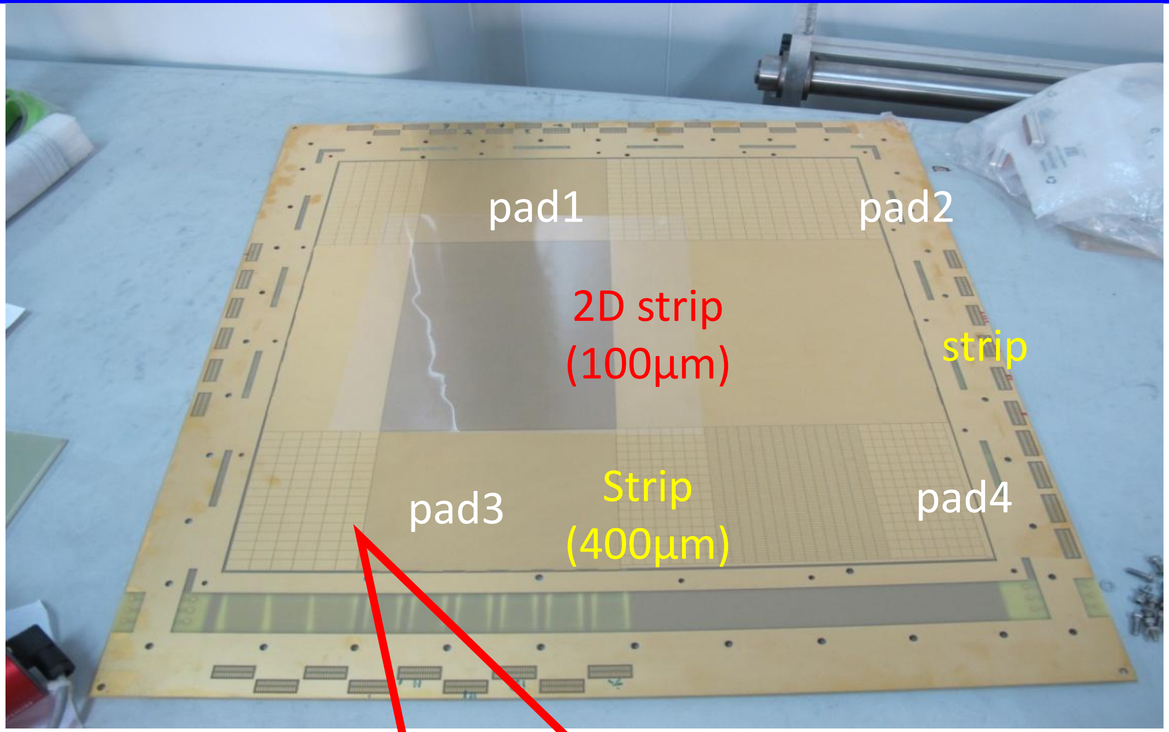


- Spatial resolution shows neither dependence on the distance changing

Larger area GEM detector assembling

Scheme of the triple GEM 45cm*45cm

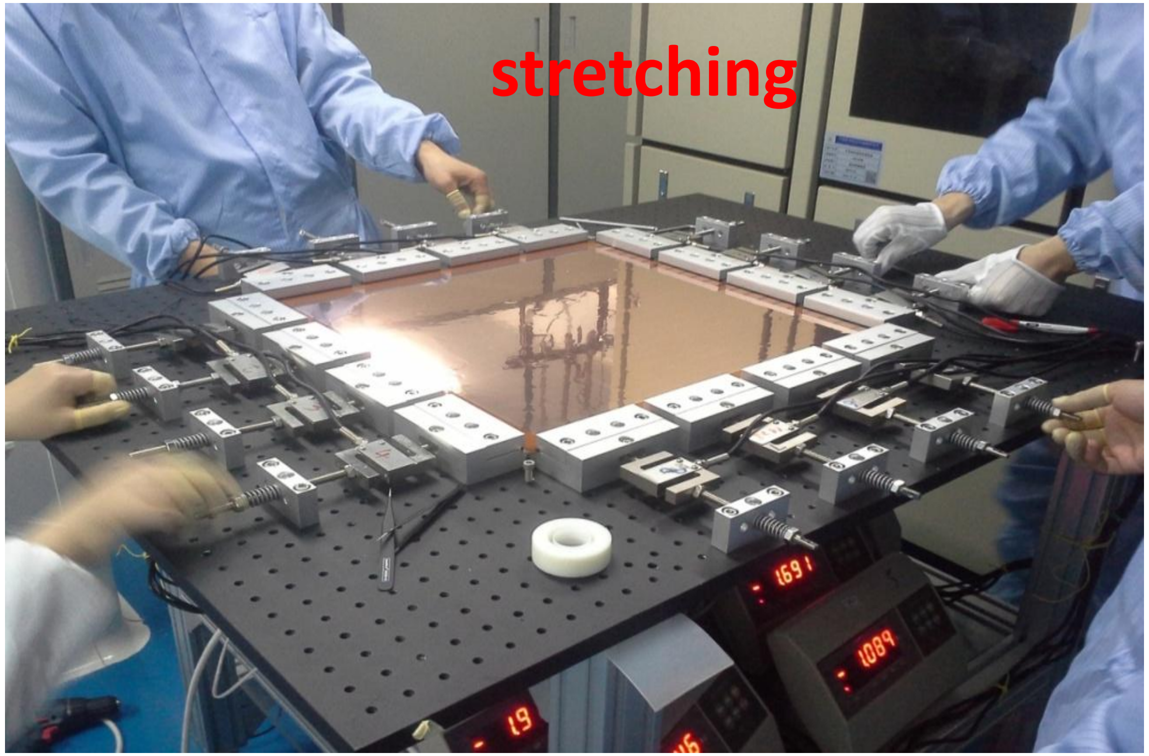


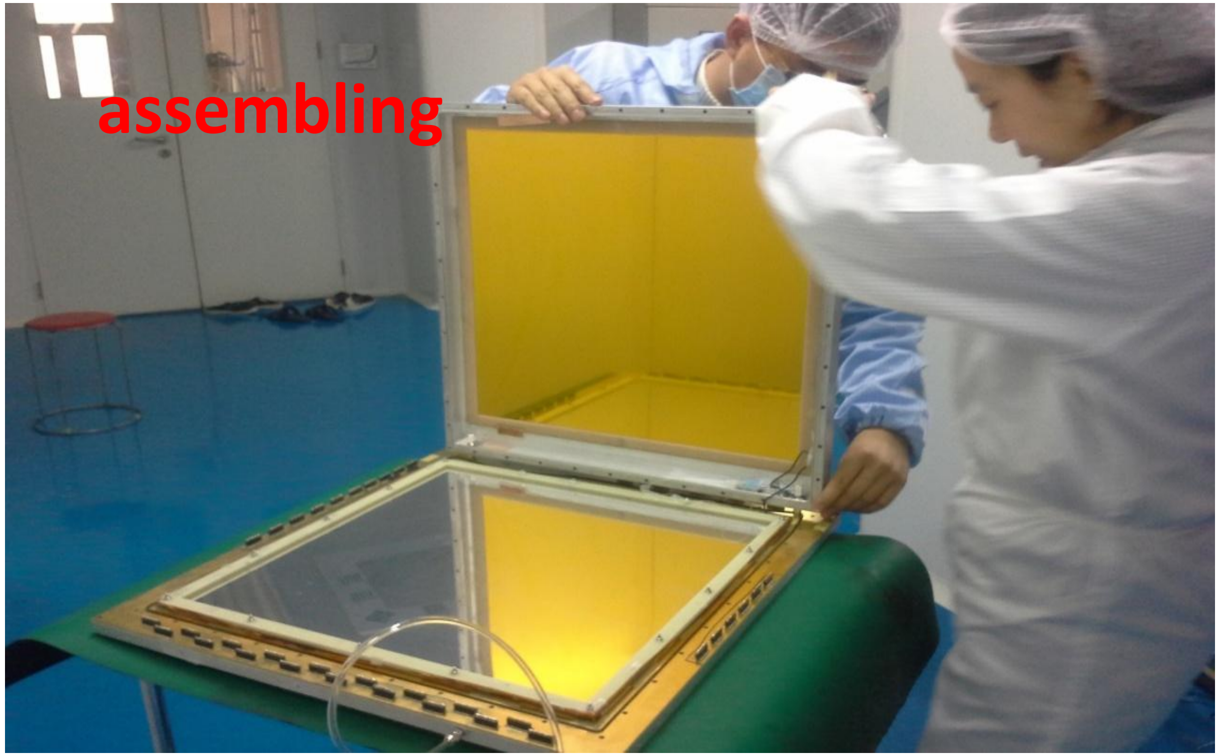


Pad:
2mm*7mm
7mm*7mm
7.5mm*12.5mm

- Larger area GEM detector being assembled and debugged.

Larger area GEM detector assembling





- Clean room of Prof. Limin Duan’s group in IMP.
- Debug going on.

The CEE experiment

1 GEM activities at THU and IMP

Introduction and Experimental Setup

Non-uniformity effects of the inter-foil distance of GEM detector

Assembly of Large area GEM detector

2 The CEE experiment

Introduction

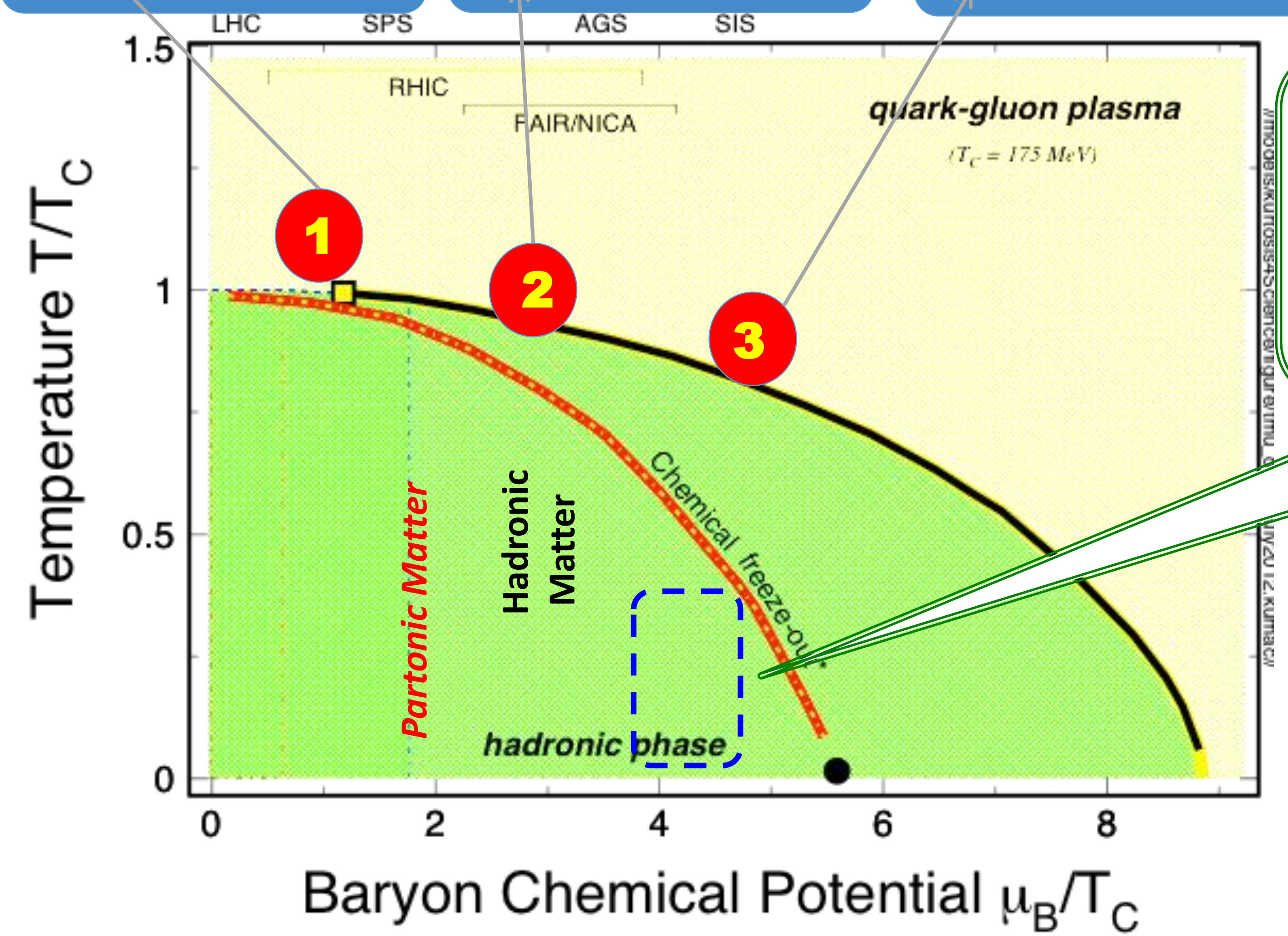
Conceptual design

Progress of the R&D studies

3 Summary

To understand the nuclear equation of state

1. T_{ini}, T_C — ***LHC, RHIC***
2. T_E — ***RHIC, SPS***
3. Large μ_B — ***FAIR, CSR***



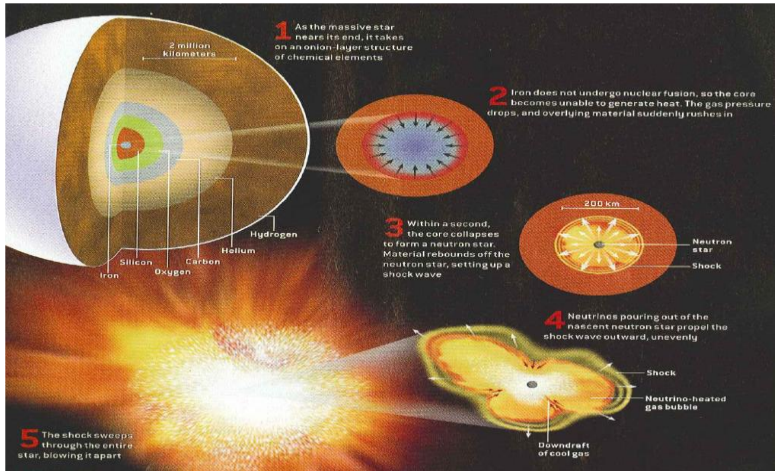
CEE:
A spectrometer for cool dense nuclear matter studies

1) Low temperature, high baryon density
2) quarkyonic matter ?
3) Particularly, symmetry energy $\mathbf{E_{sym}}(\rho)$

Symmetry energy at supra-saturation density

- In the hadron phase, the iso-vector part of the nuclear potential, namely the symmetry energy, is a key point.

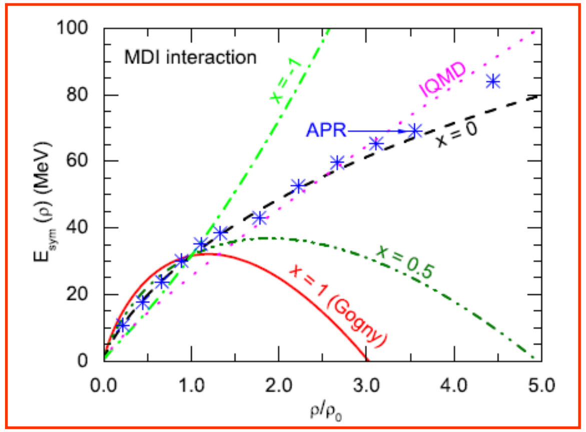
→ Nuclear and astrophysics input

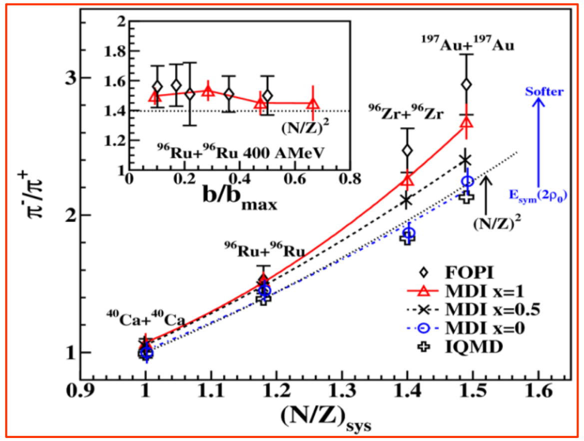


Neutron Star——a remote cool dense nuclear object

Proton fraction in neutron star
M-R relation
D-Urca process
Core-crust transition density
etc…

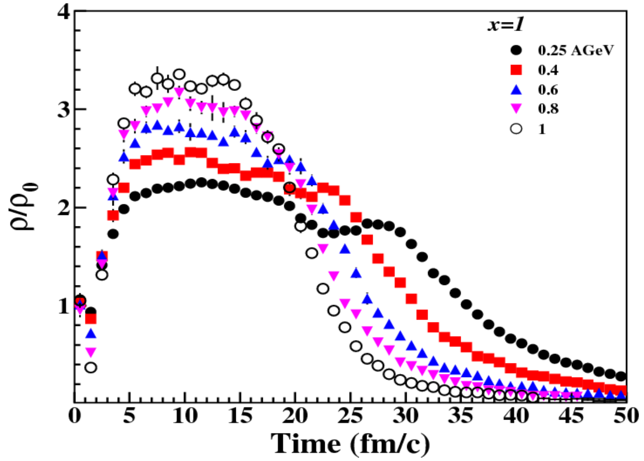
→ Density dependence not fixed



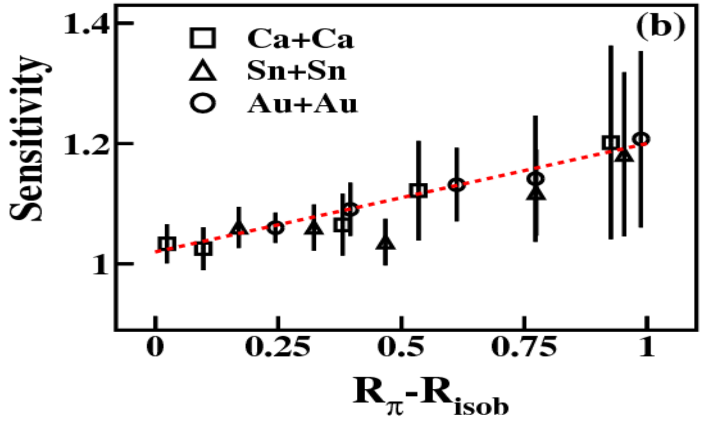


→ HIRFL-CSR energy is preferential $E_{sym}(\rho)$ studies

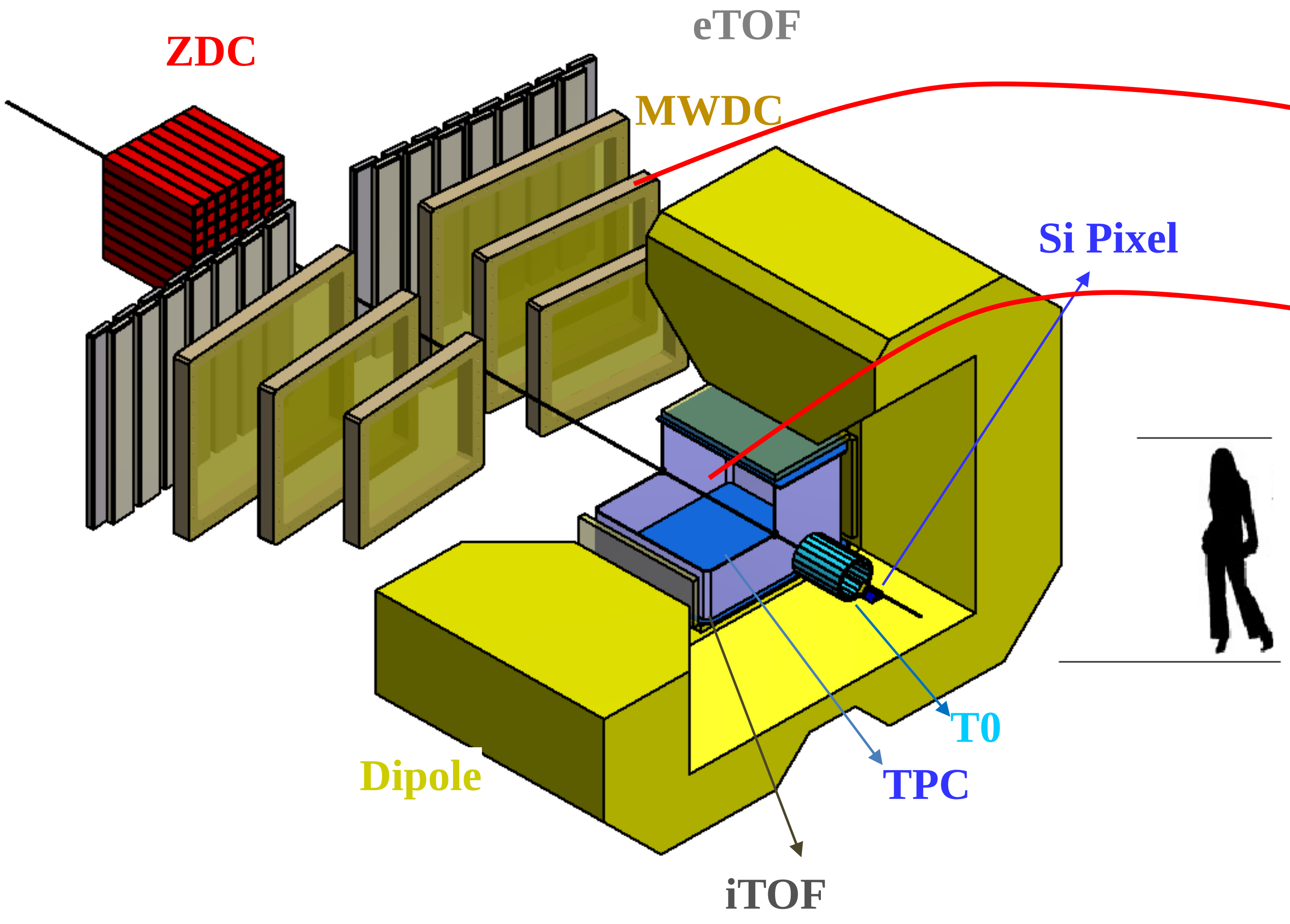
•Because $\rho \sim 2\rho_0$ density achievable



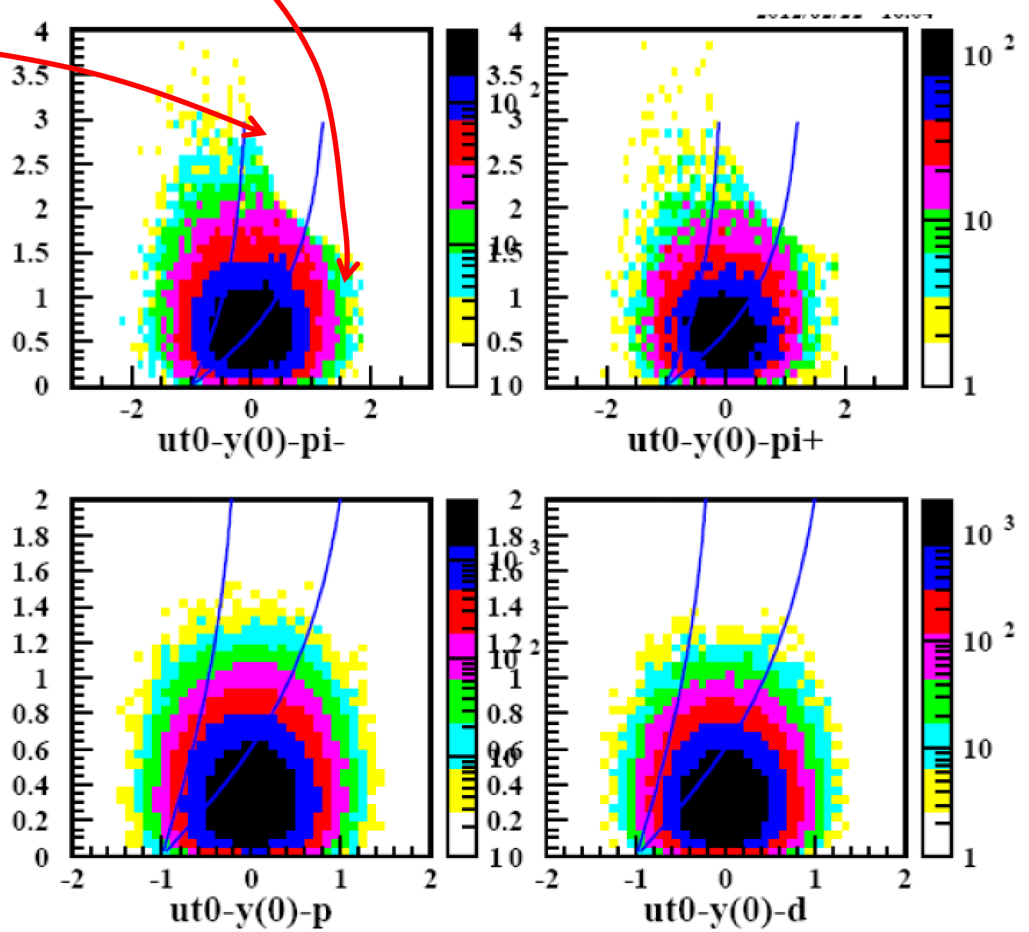
•Observable sensitively depend on $E_{sym}(\rho)$



Esym(ρ) at supra-saturation studies at HIRFL-CSR

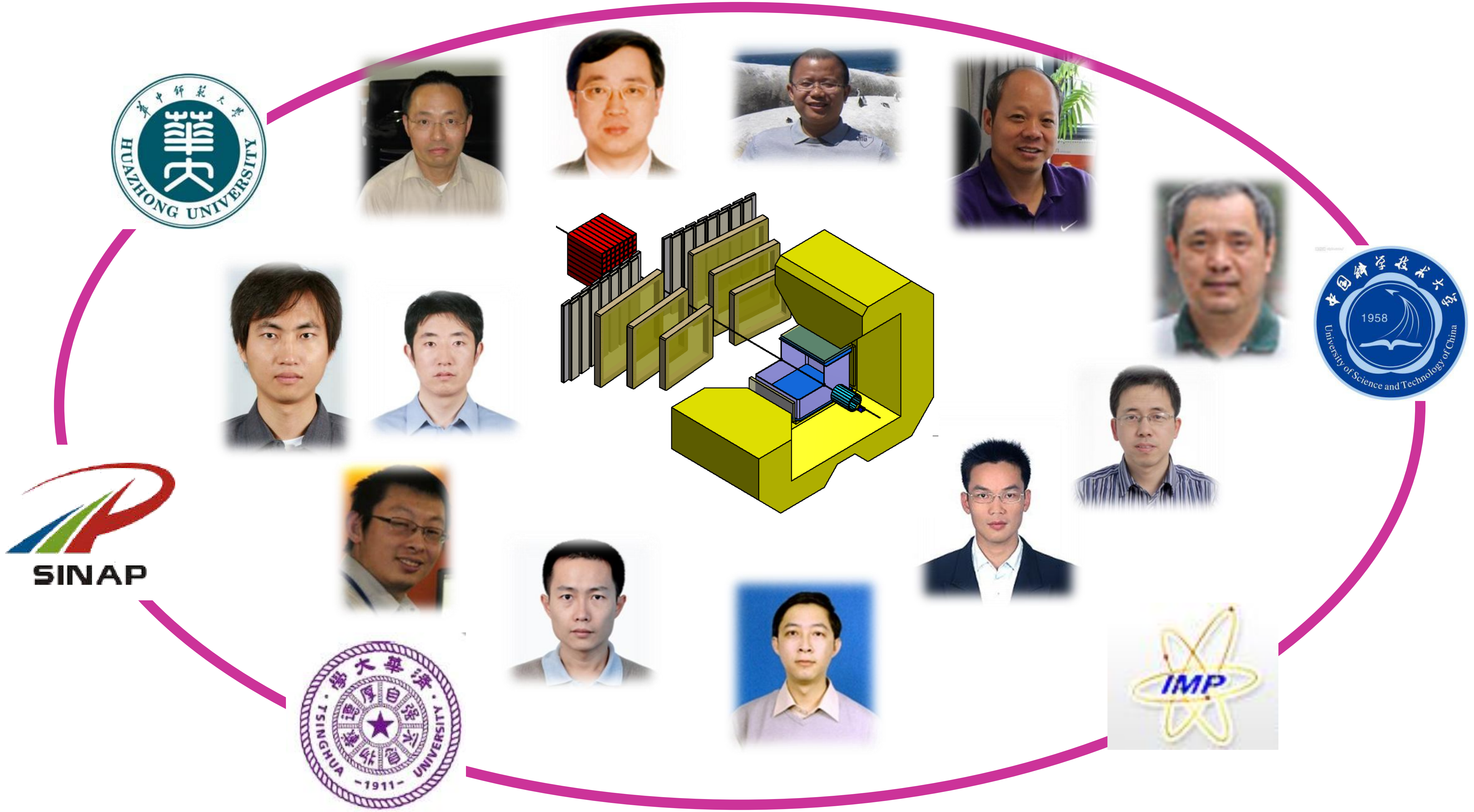


$$E\frac{d^3\sigma}{dp^3}=\frac{1}{p_t}\frac{d^3\sigma}{dy\,dp_t\,d\varphi}$$

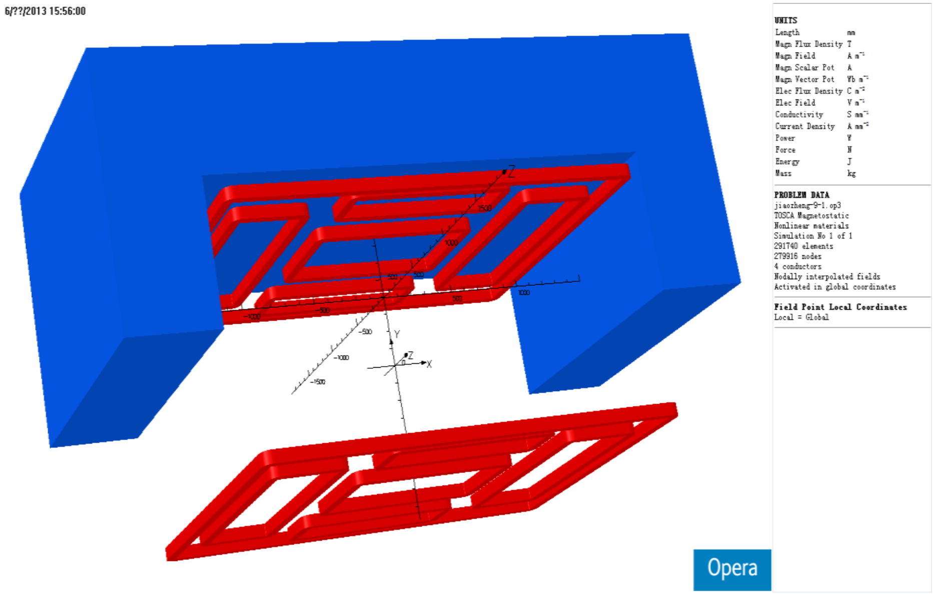


CEE

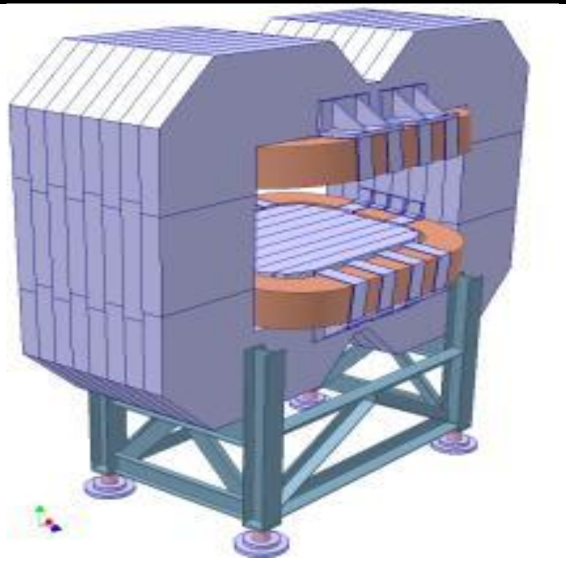
Pre-CEE collaboration

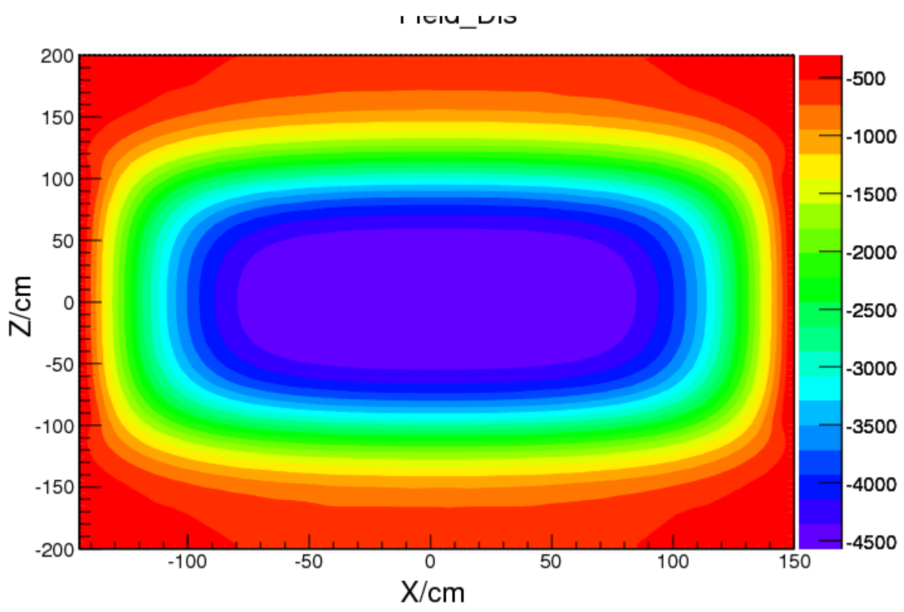


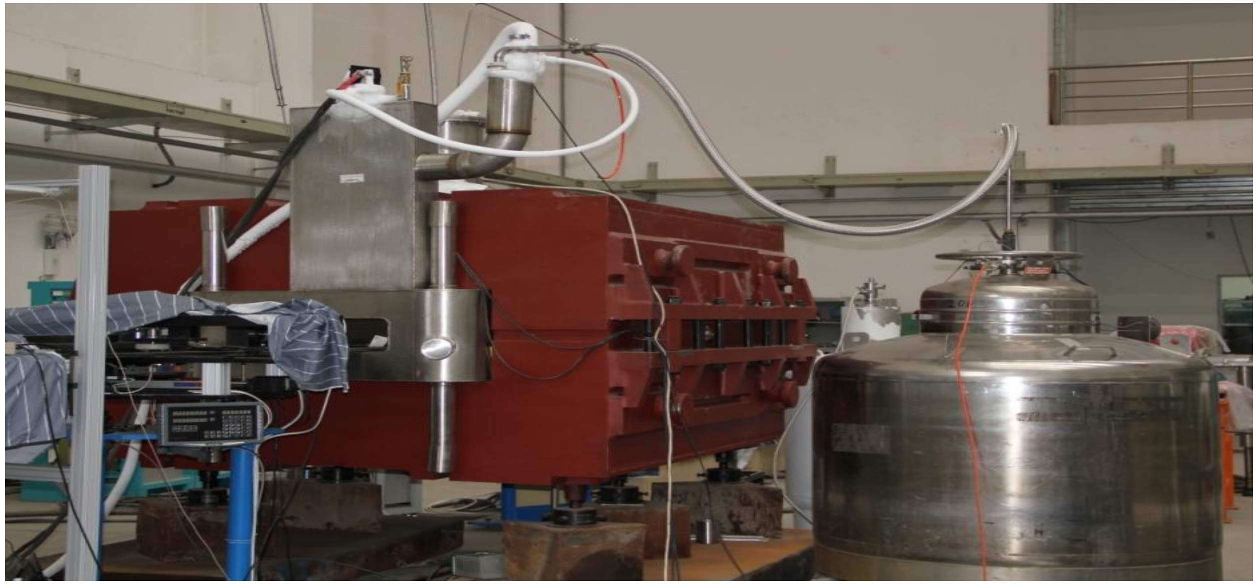
Design of the Dipole



Central Field	0.5 T
Hom. Region	~1 m×0.9 m×1.2 m^3
Uniformity	1%
Total Size	～2.5×3×4 m^3
Total Weight	~200 Ton

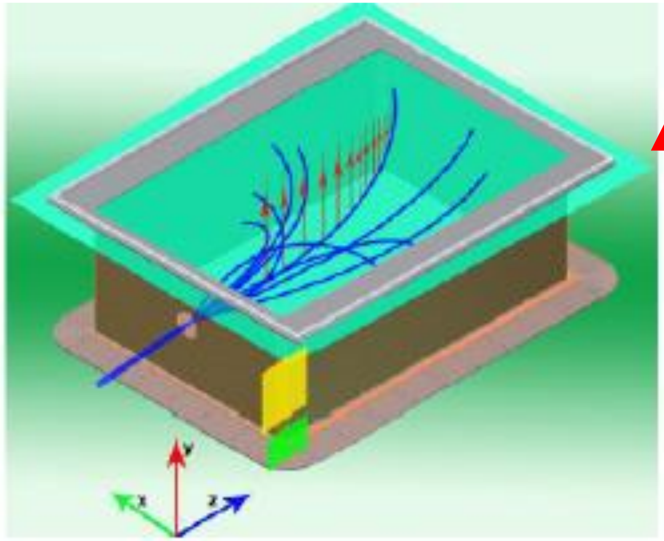






Prototype of a superconductive magnet (Made in IMP, for FAIR)

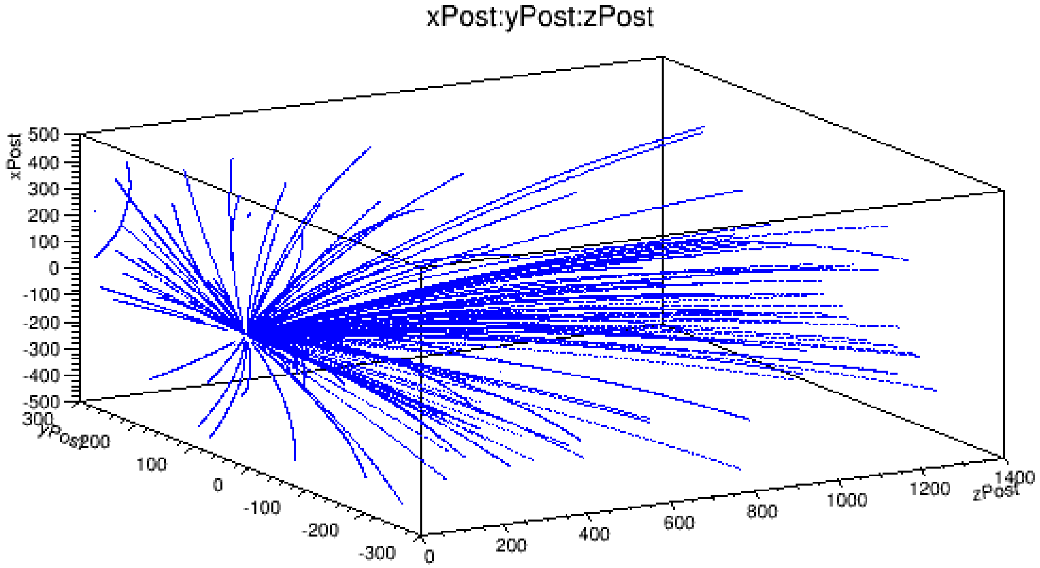
TPC: Conceptual Design

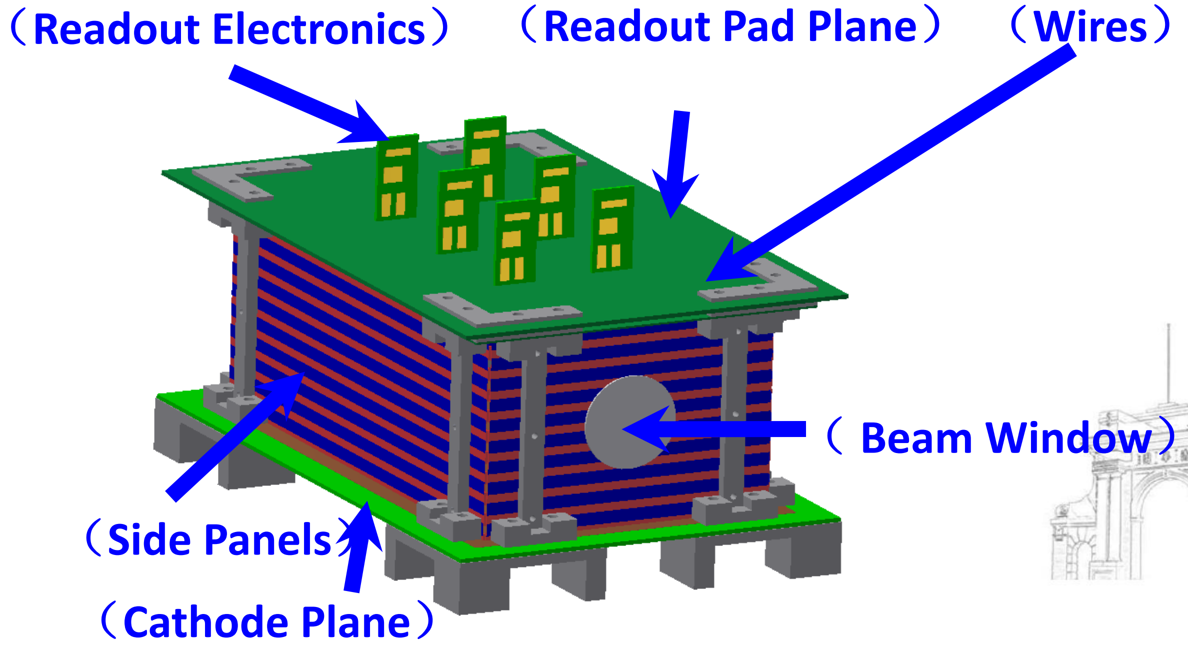


B, E

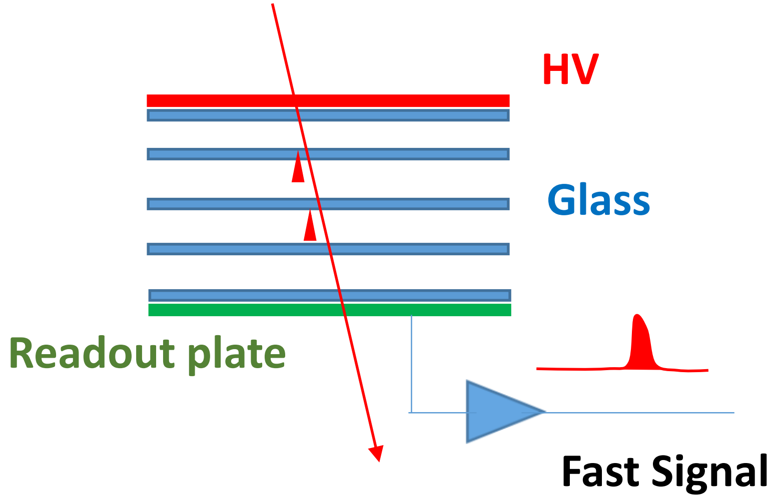
TPC:
- **B//E**
- **Particle bending due to B**
- **Ionized electrons drift due to E**
- **Collect signal when e arrive**

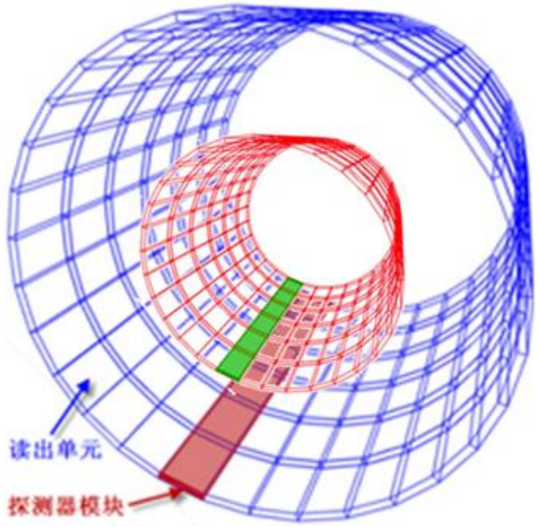
Read out area	**~1.1 m× 0.9 m**
Pad. number	~10000
Pad size	~9 mm × 1.1 mm
Max. drift leng.	~ 50 cm
Working gas	90% Ar + 10% CH_4
E Field	150V/cm
dE/dx range	Z<=6, π,p,d,t,He-C
Double track res.	2.5 cm
Max. Multi.	200

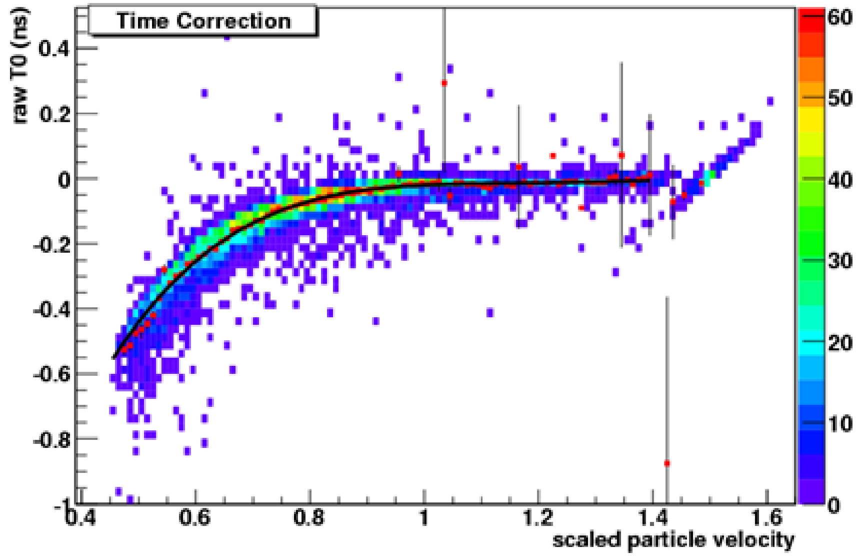




TOF (time of flight): Conceptual Design





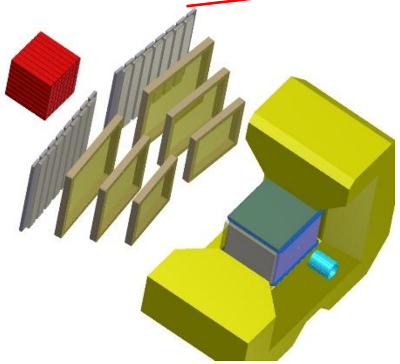


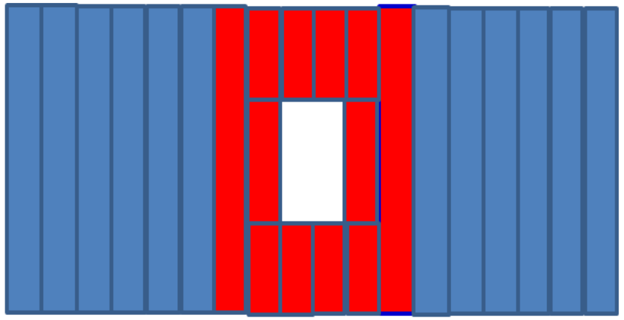
MRPC:

→Very high V over gaps between glasses in stack;

→ Ionization and avalanche occurs

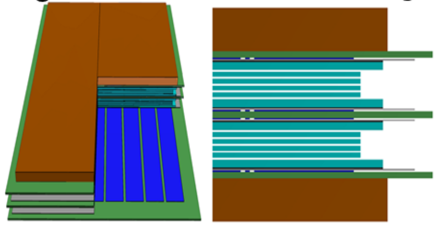
→Collect the induced signal from pad





Normal
High Gra.
High Reso. MRPC

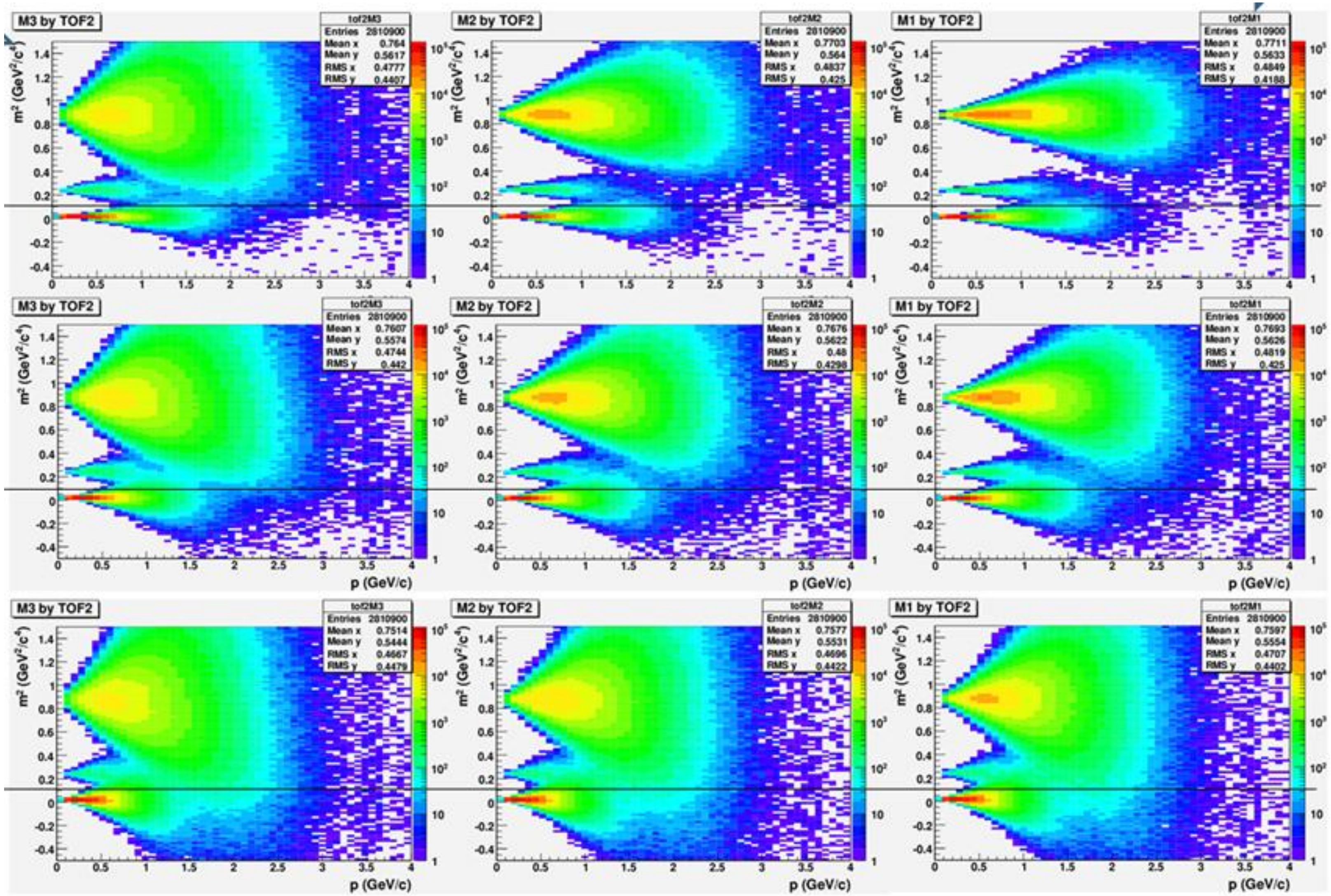
High Count、
High Gra. High Reso.



T0+TOF	
Time resolution	<80 ps
Occupancy	<10%
Total Area	$12m^2$
# channels	3000

PID for TPC+iTOF

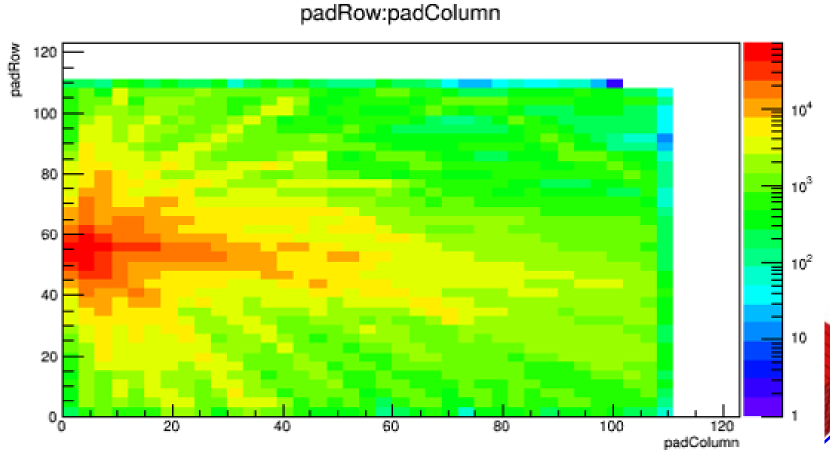
	δp=10%	δp=5%	δp=2%
δt=50ps			
δt=100ps			
δt=200ps			

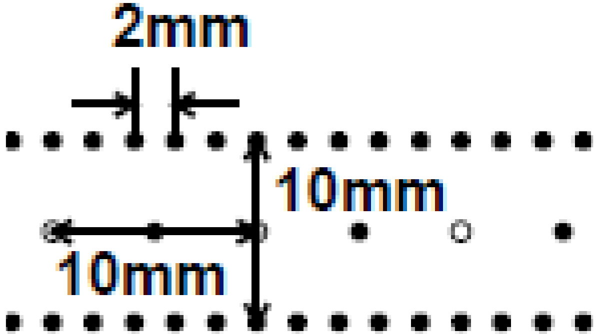


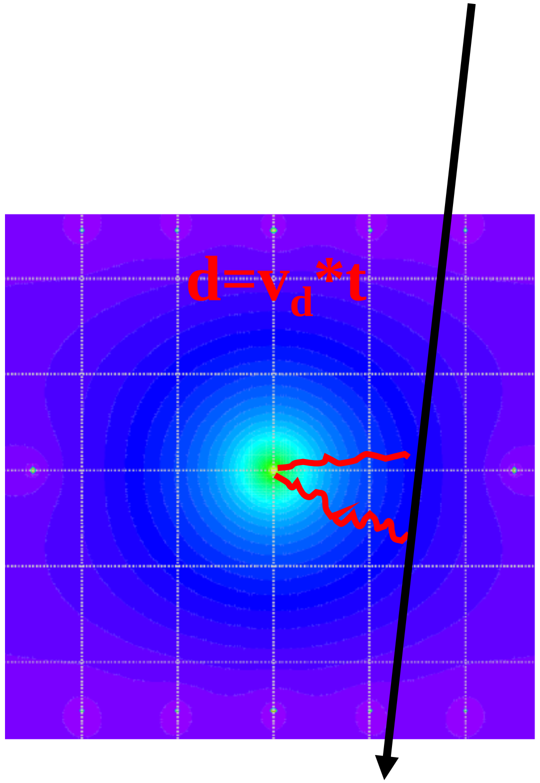
Forward MWDC conceptual design

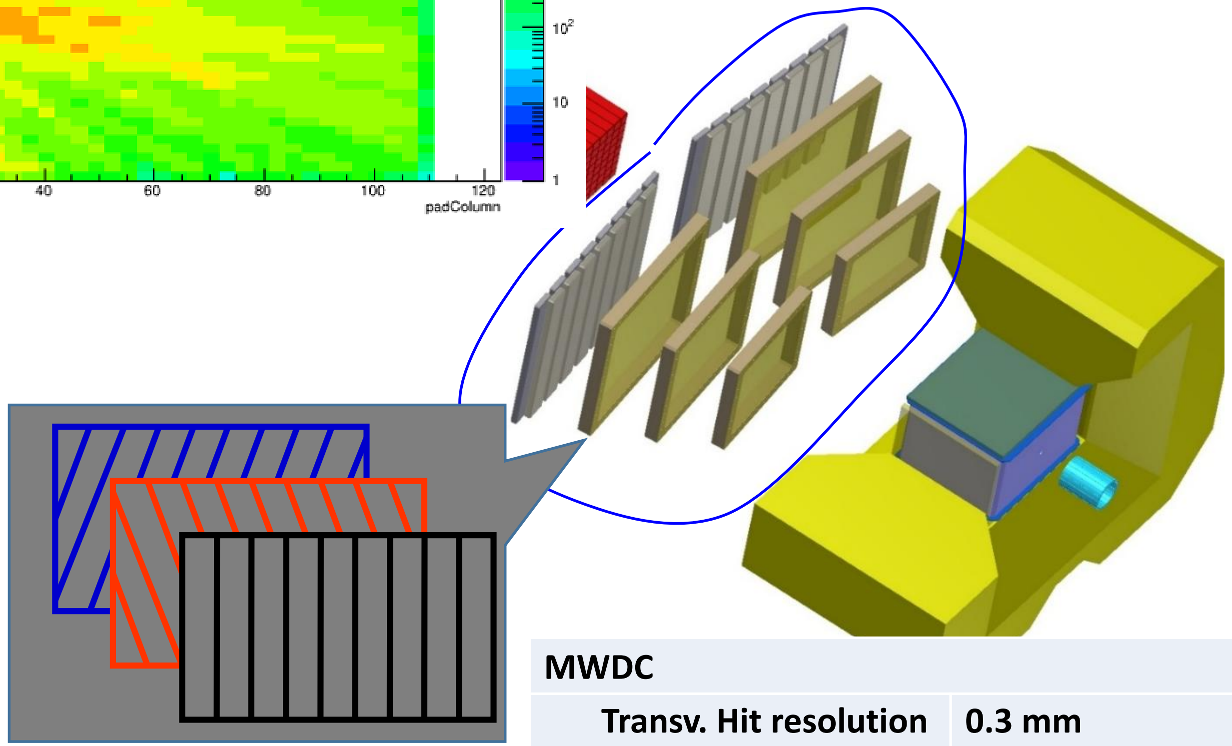
- High track density at small angle
- Many heavy fragments
- High rate at small angle

Forward tracking needed









MWDC:

E field is formed in cell

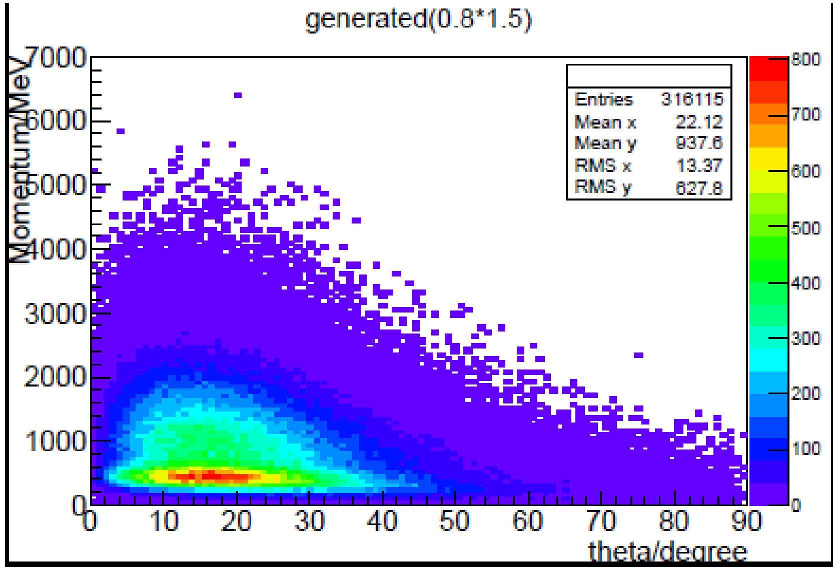
Track leaves ionizations

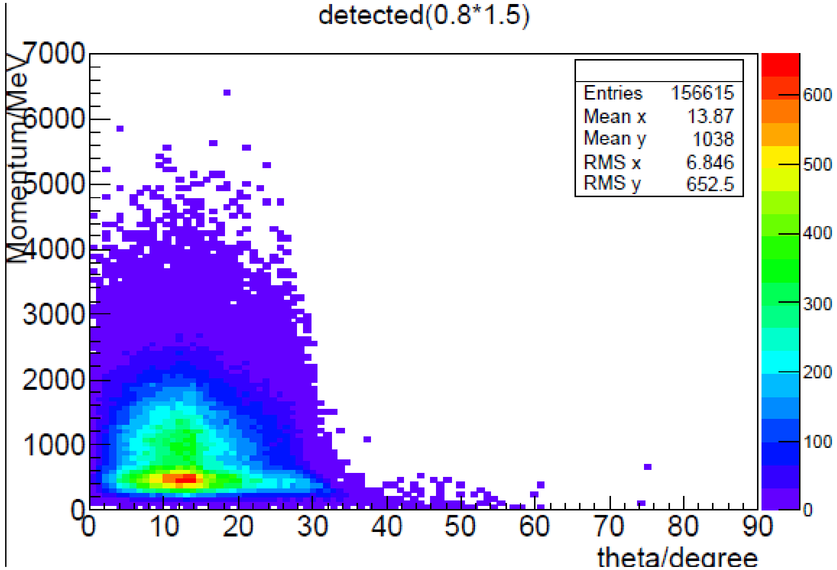
Deduce drift length from t_d

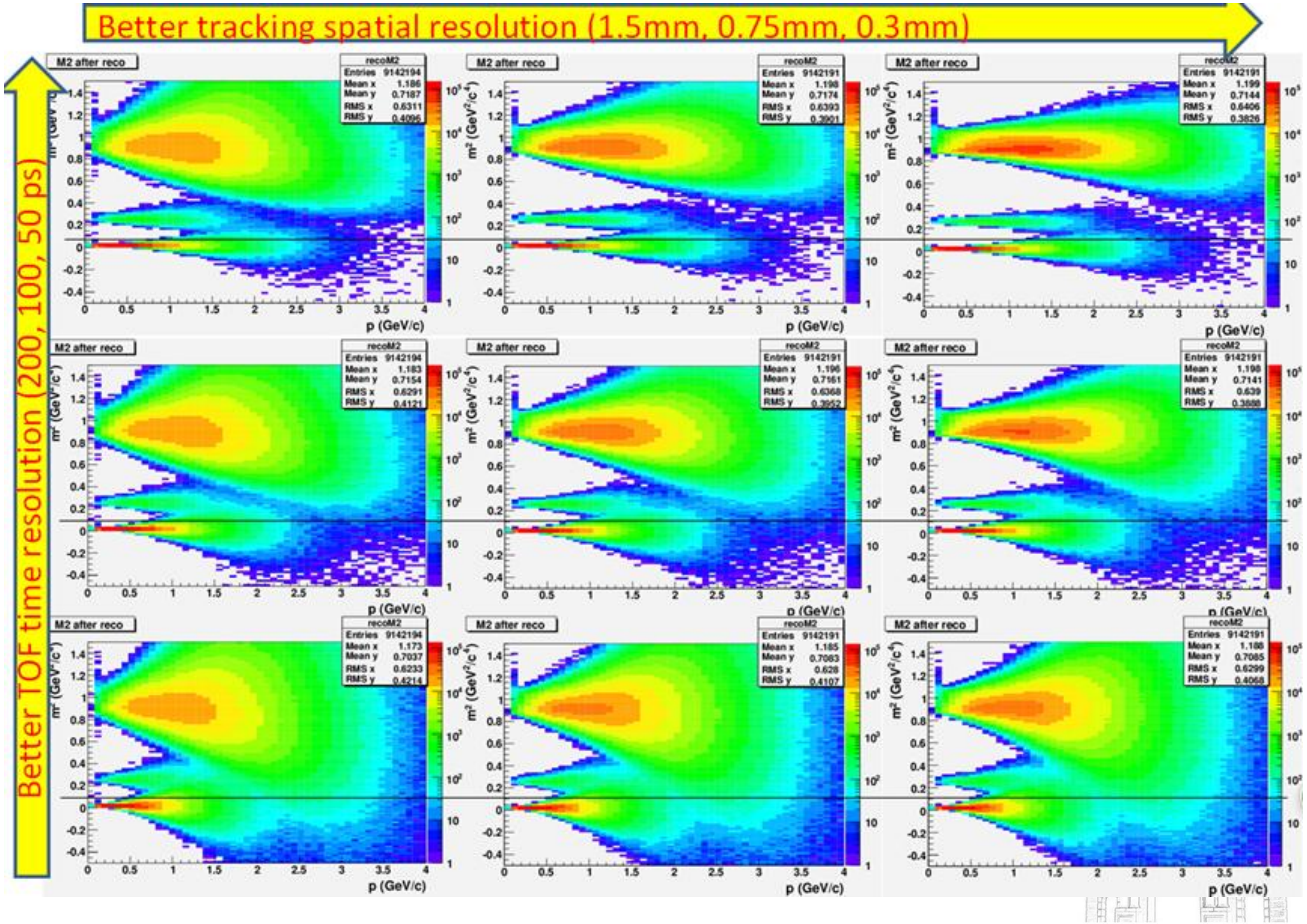
Construct track from multi cells

MWDC	
Transv. Hit resolution	0.3 mm
# of layers	3*3
# of channels	3000
Total area	8 m^2
Momentum Resolution	5%

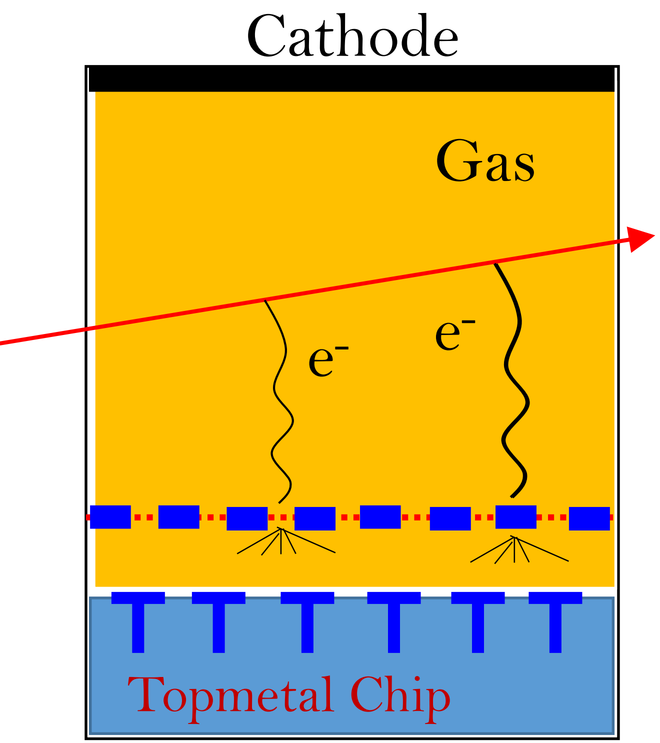
Coverage and PID with MWDC+eTOF

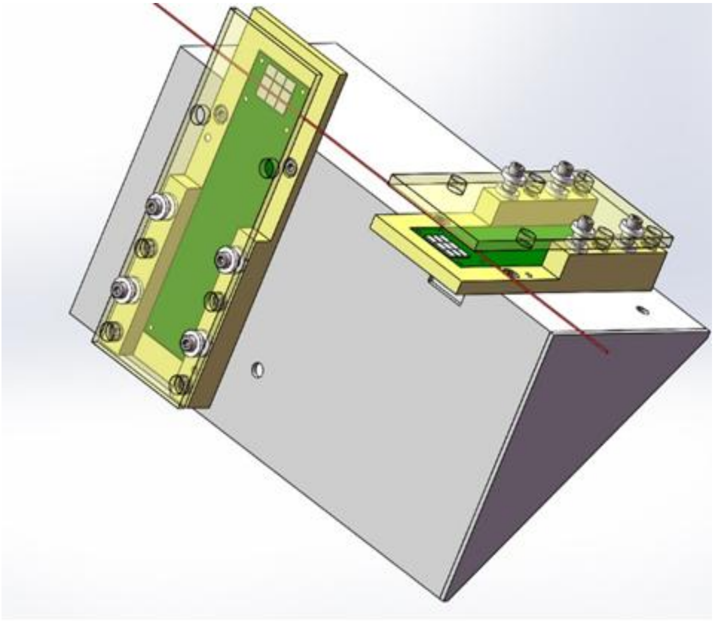


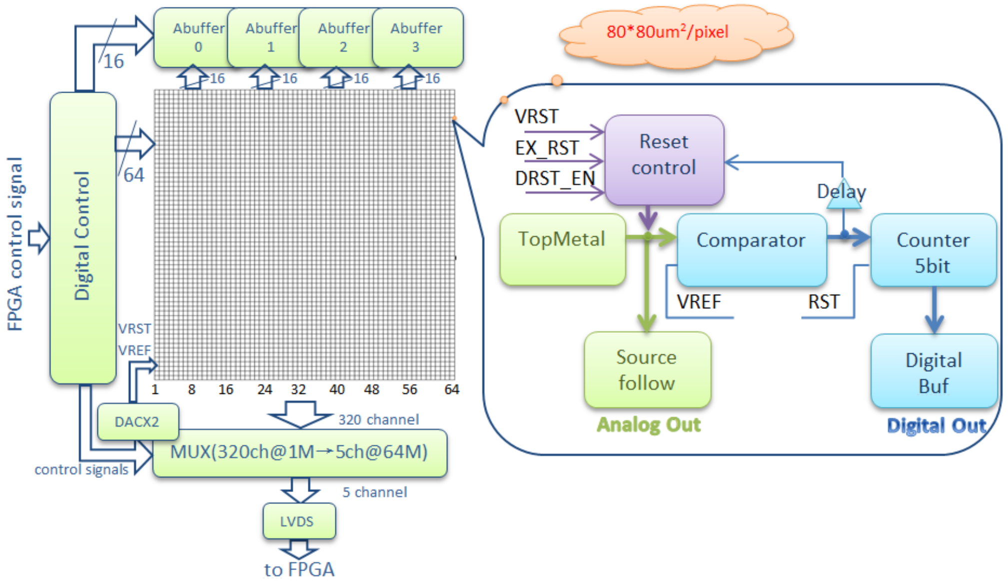


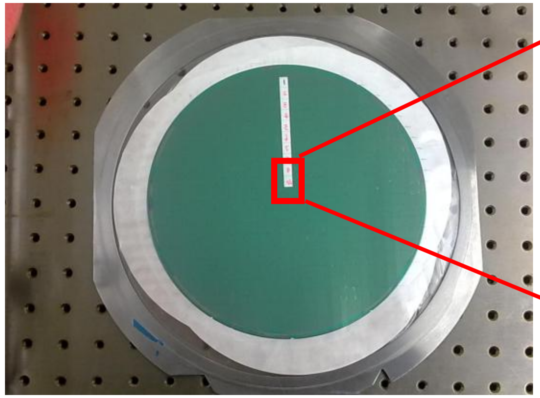


Silicon Pixel conceptual design

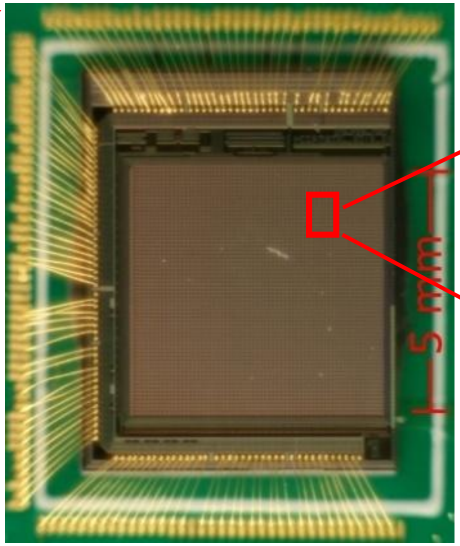




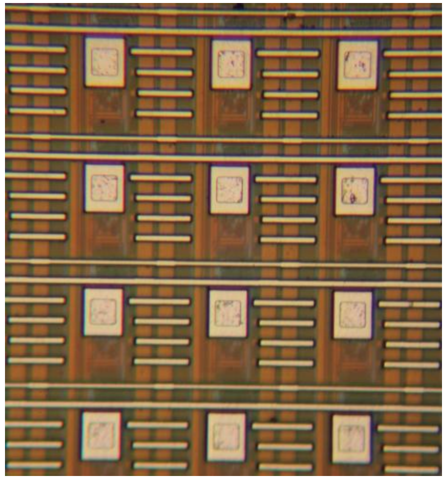




Silicon wefal



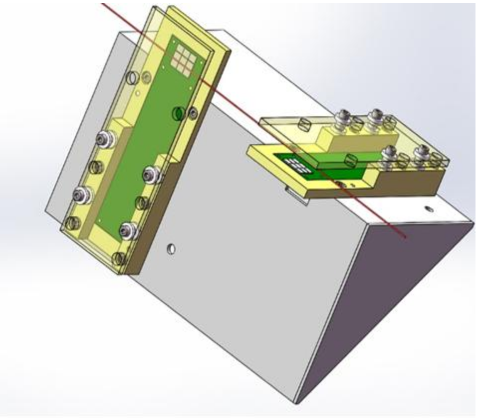
Topmetal chip

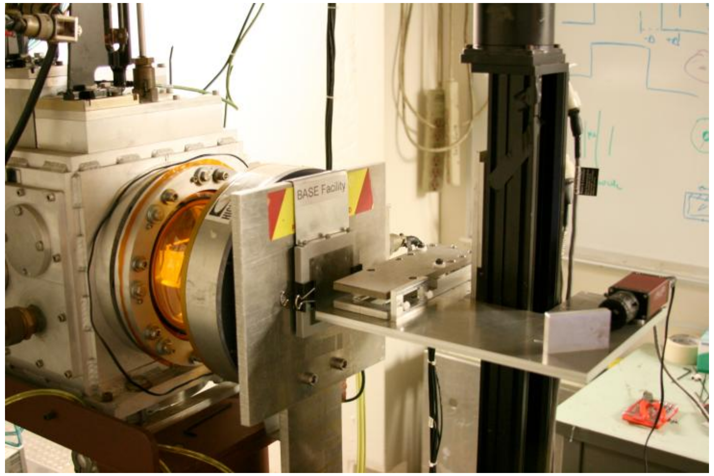


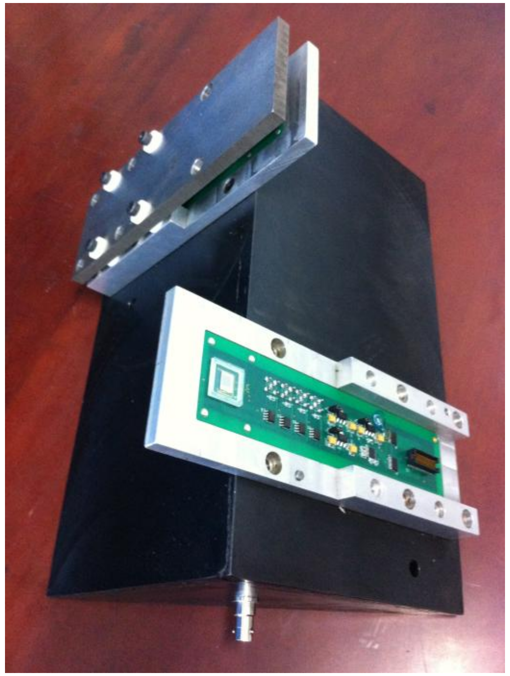
Pixel Size:

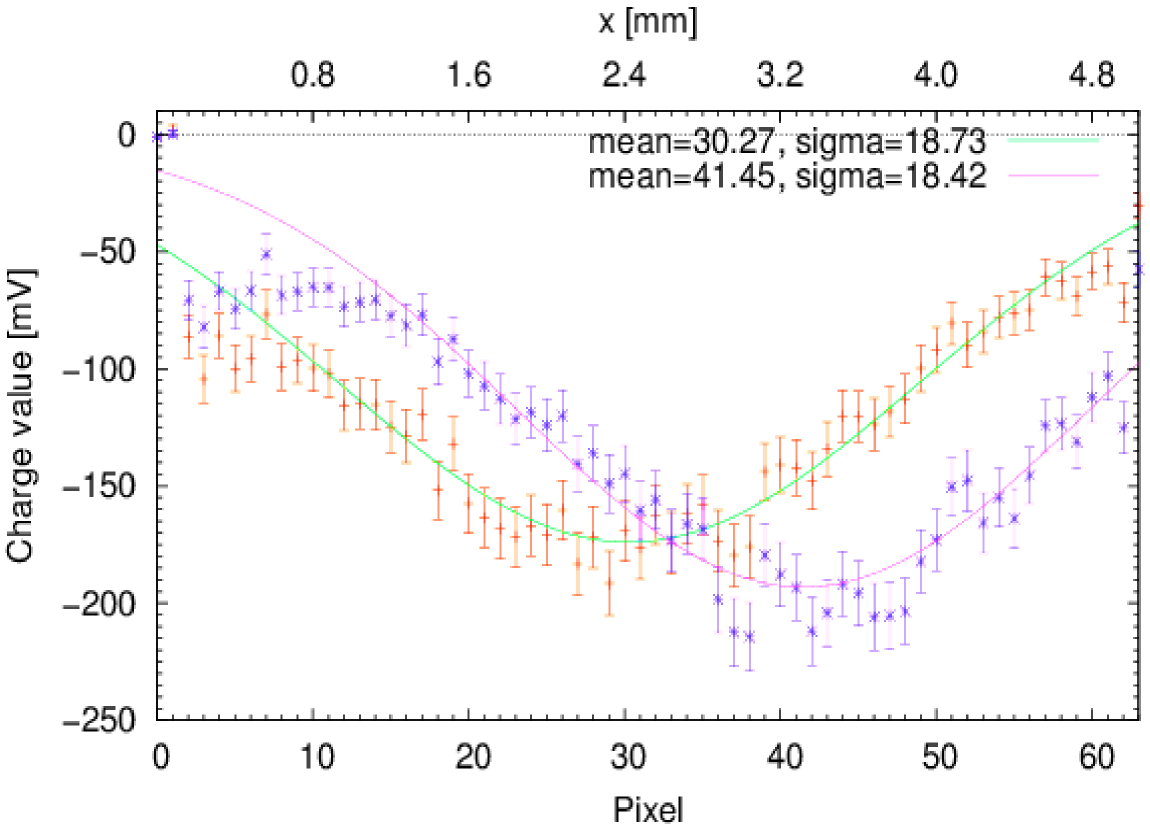
80 μm*80 μm

R&D the Si pixel detector



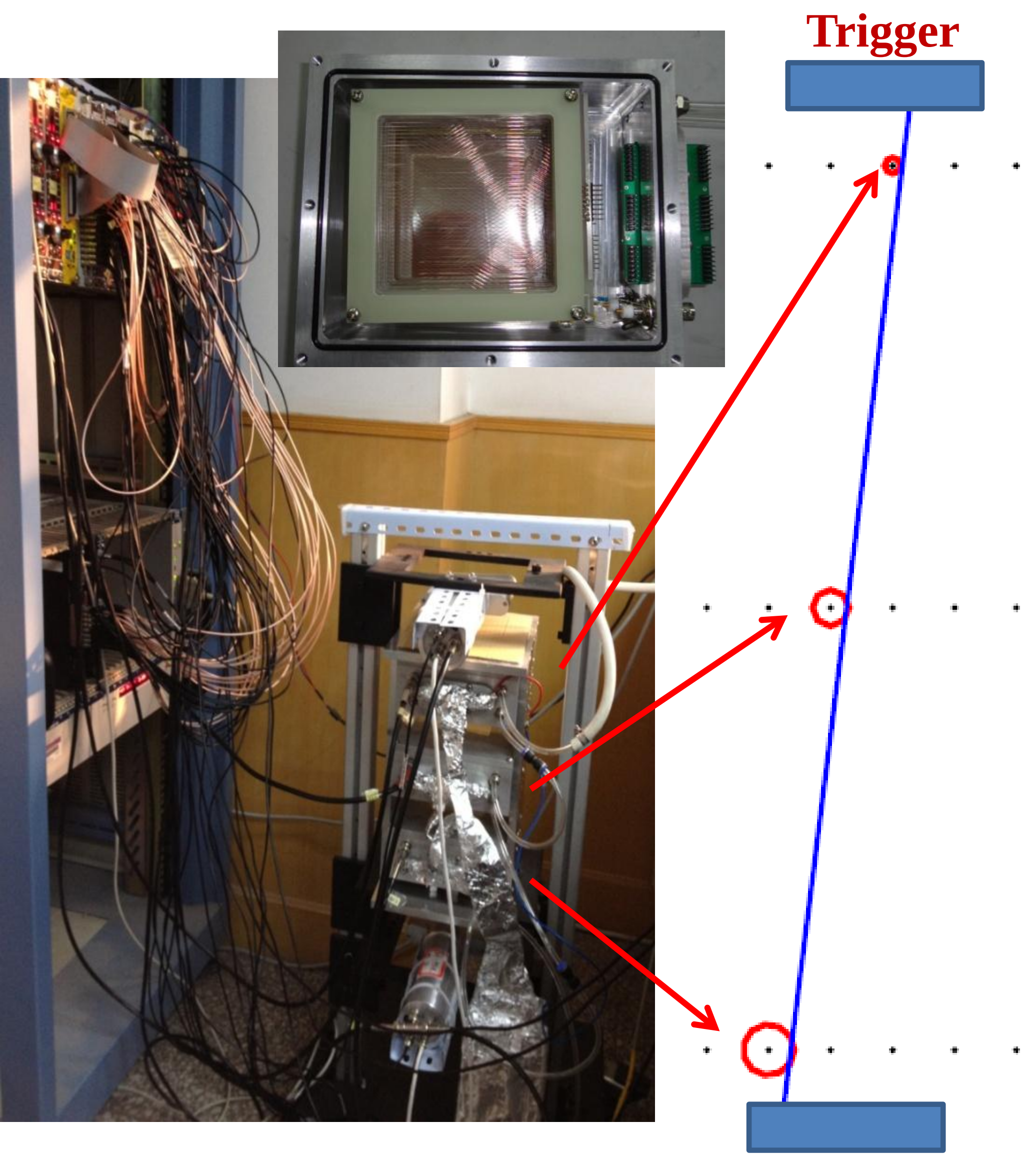




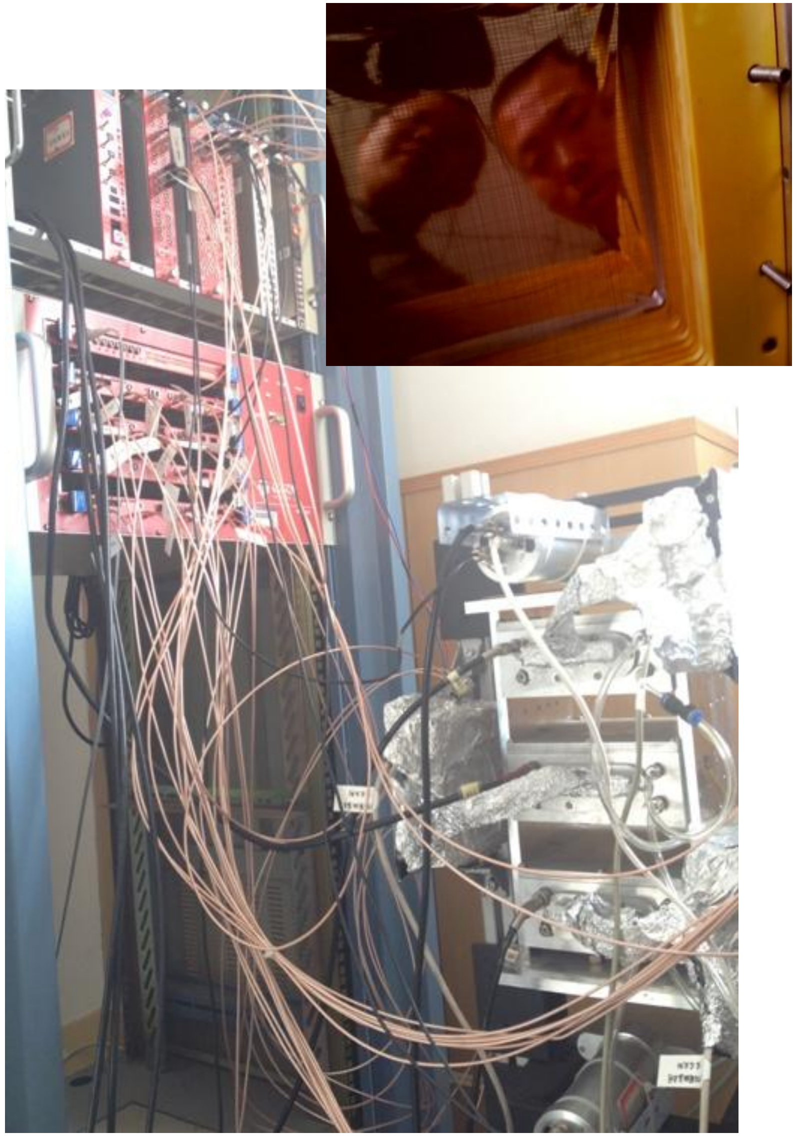


1) Online test done at Berkeley , May, 2014
2) Spatial Resolution < 0.5mm !
3) Further test at IMP planned in Sept. 2014

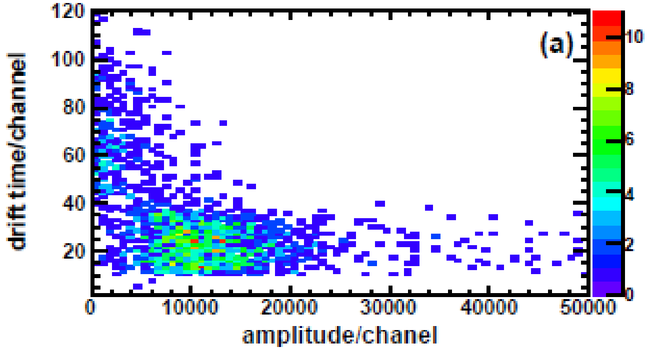
R&D of MWDC array

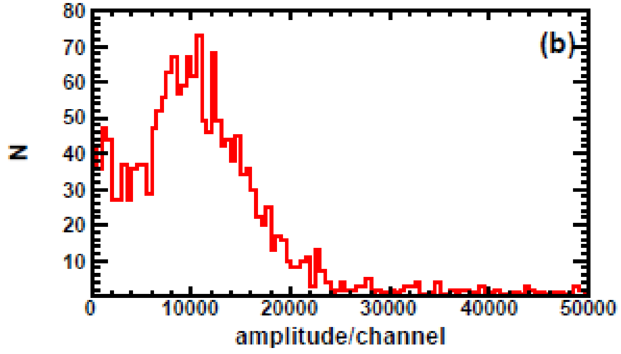


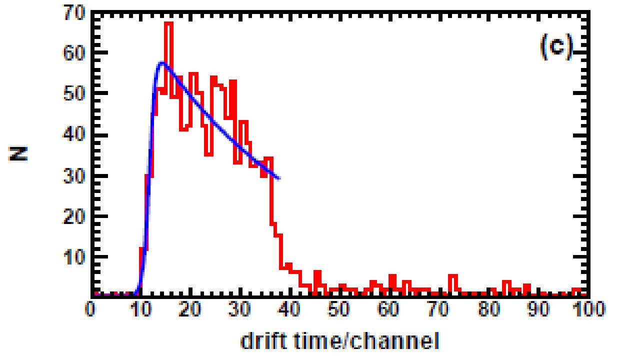
Conventional electronics



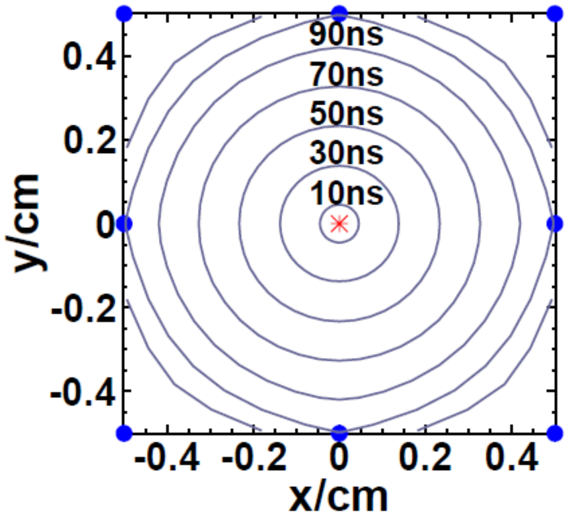
FLADC for timing measurement

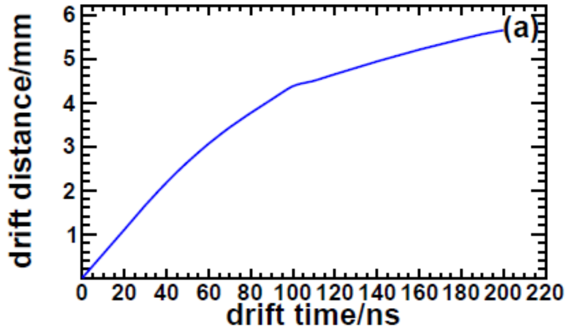


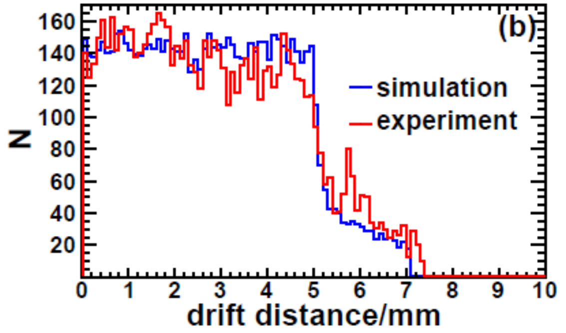




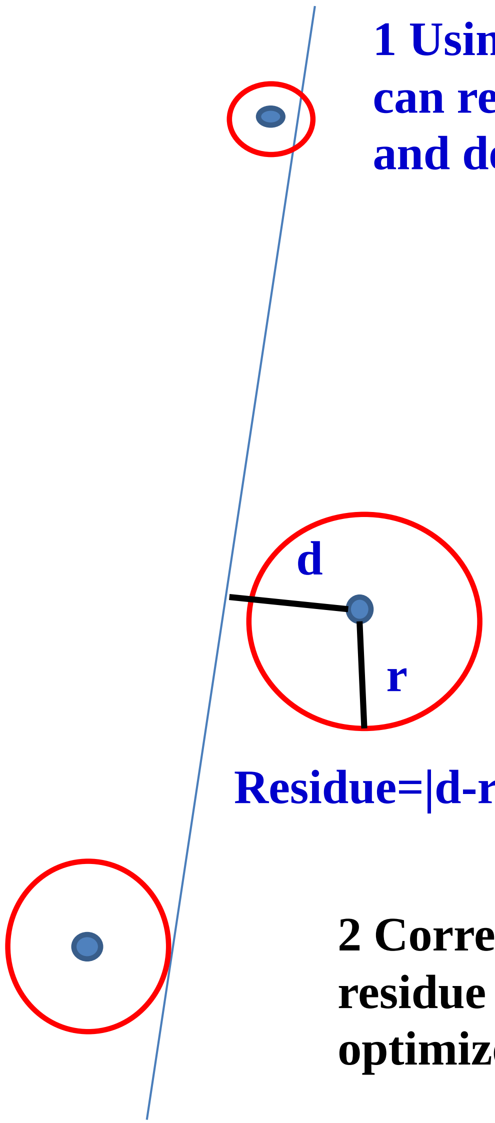
Spatial Timing Relation Calibration



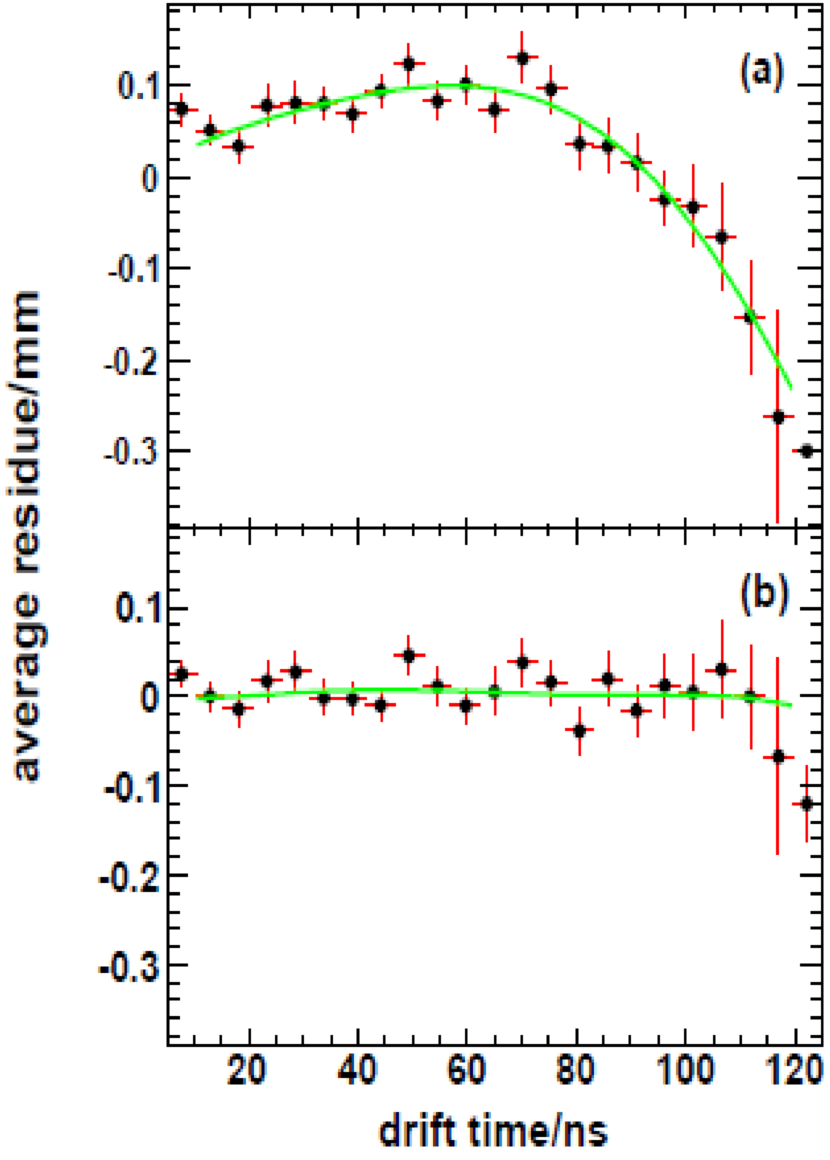




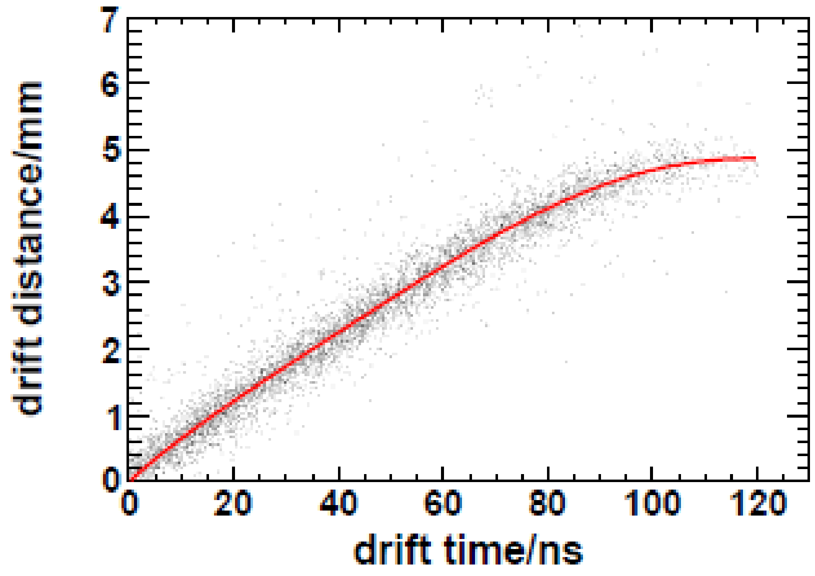
1 Using R-T relation, one can reconstruct the track and deduce the residue.

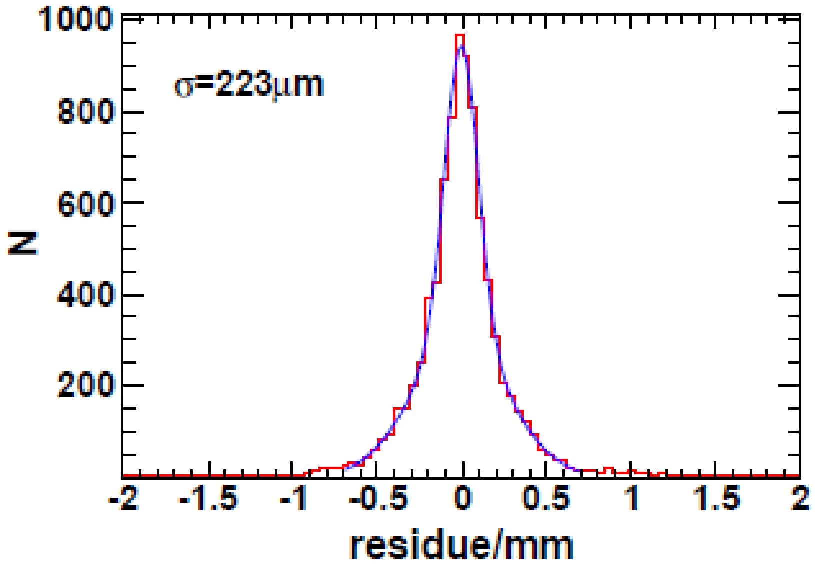


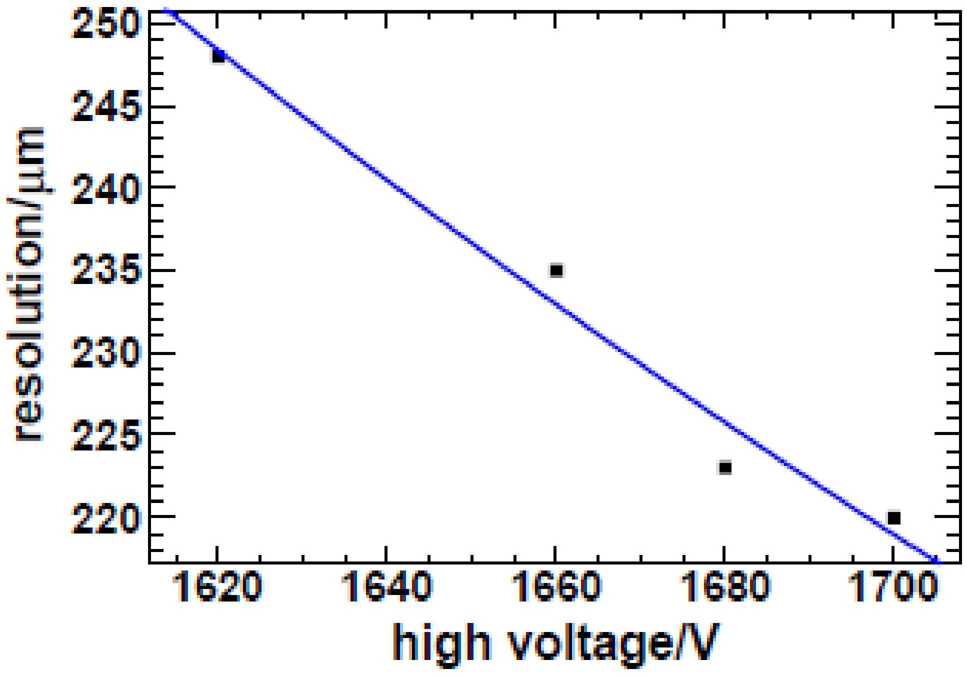
2 Correct the STR till the residue distribution is optimized.



MWDC array performance







σ=220 μm

Yi Han, XZG et al, Chin. Phys. C, to be published.

100cm*100cm MWDC array constructed.

40cm *40cm MWDC array in construction.

Day one beam test, ~May 2015.

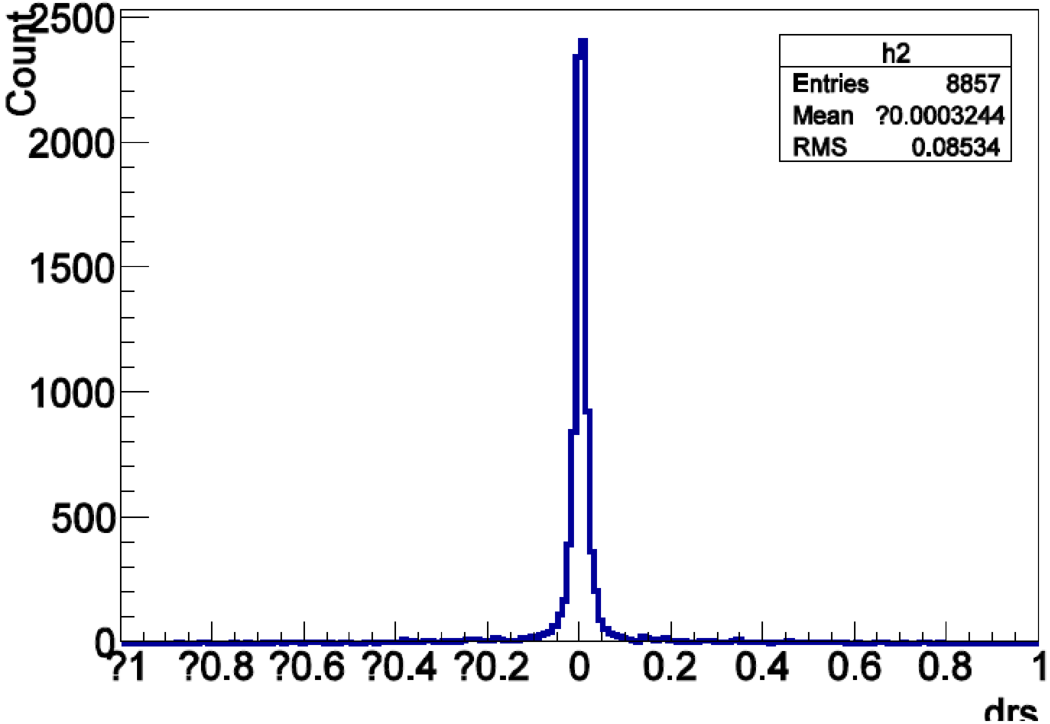
3-D track finding and reconstruction in MWDC

1 To fit the drift length measured by X, U and V wires by minimizing the χ2

$$\chi^2 = \sum_i \frac{[x_i - (a'\cos\alpha_i + c'\sin\alpha_i)z_i - (b'\cos\alpha_i + d'\sin\alpha_i)]^2}{[1 + (a'\cos\alpha_i + c'\sin\alpha_i)^2](\delta d_i)^2}$$

2 Analytically a set of equations can be derived and solved:

$$\begin{cases} \sum_i (z_i^2(\cos\alpha_i)^2 a' + z_i(\cos\alpha_i)^2 b' + z_i^2\sin\alpha_i\cos\alpha_i c' + z_i\sin\alpha_i\cos\alpha_i d' - x_i z_i\cos\alpha_i) = 0 \\ \sum_i (z_i(\cos\alpha_i)^2 a' + (\cos\alpha_i)^2 b' + z_i\sin\alpha_i\cos\alpha_i c' + \sin\alpha_i\cos\alpha_i d' - x_i\cos\alpha_i) = 0 \\ \sum_i (z_i^2\sin\alpha_i\cos\alpha_i a' + z_i\sin\alpha_i\cos\alpha_i b' + z_i^2(\sin\alpha_i)^2 c' + z_i(\sin\alpha_i)^2 d' - x_i z_i\sin\alpha_i) = 0 \\ \sum_i (z_i\sin\alpha_i\cos\alpha_i a' + \sin\alpha_i\cos\alpha_i b' + z_i(\sin\alpha_i)^2 c' + (\sin\alpha_i)^2 d' - x_i\sin\alpha_i) = 0 \end{cases}$$



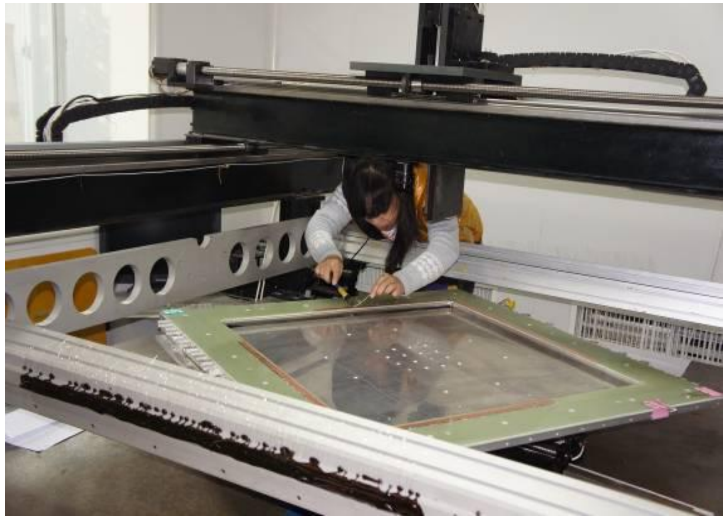
3 Then the parameters of the straight track can be derived.

**3D residue distribution from Geant 4 simulation.
(include track finding)**

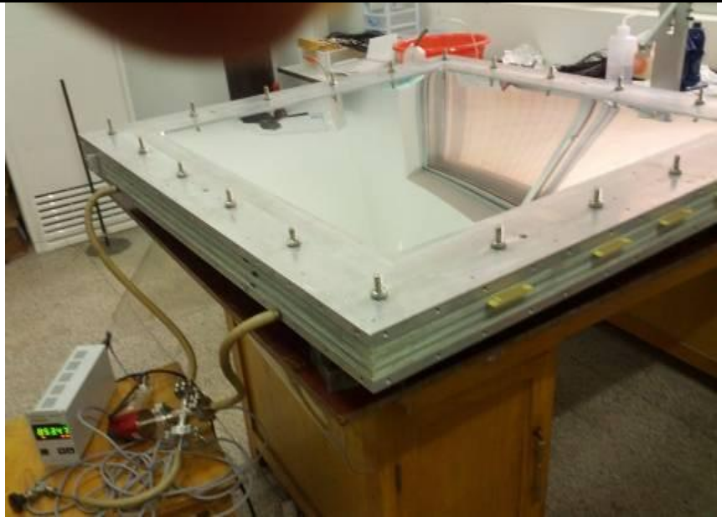
CEE

Manufactory of large MWDC

Wiring:
Frame=1.6m×1.6m。

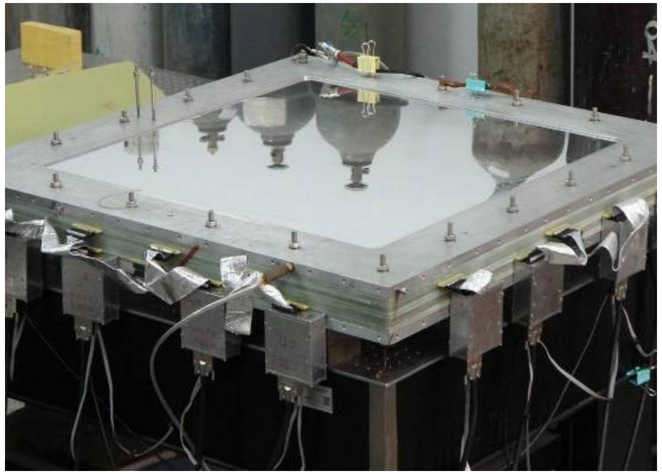


Soldering Wire and Frame

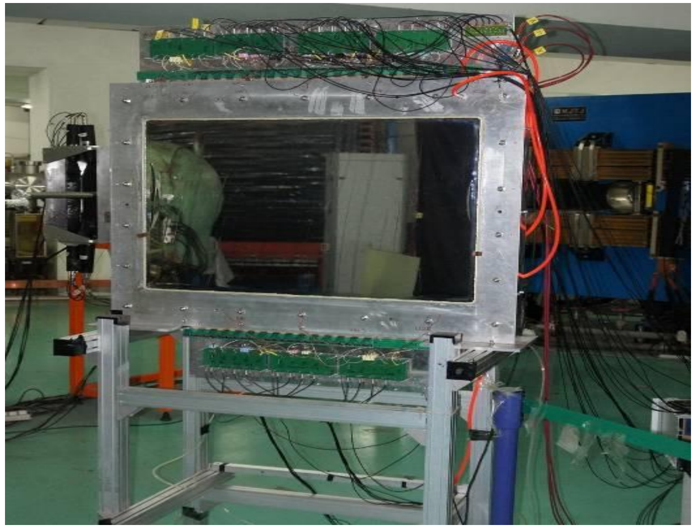


Leak rate Test

Wire Frame/Tension Preset

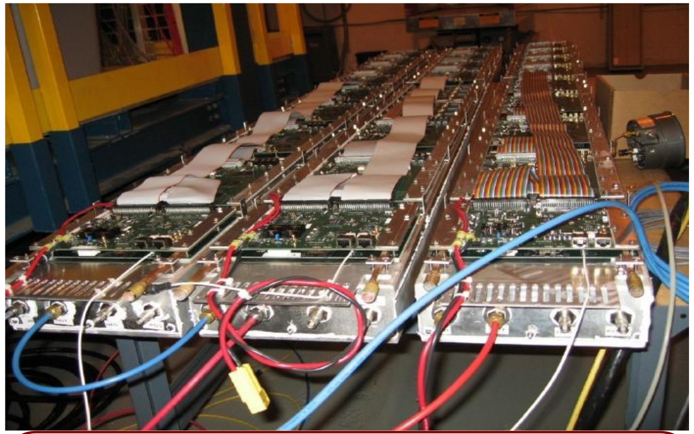


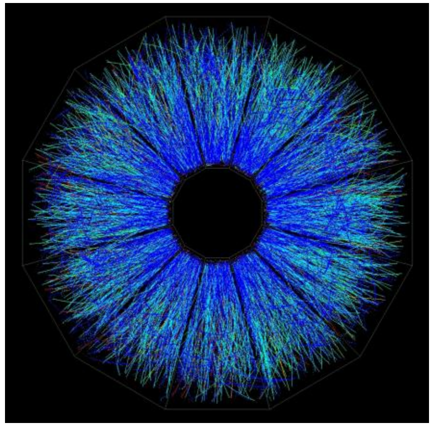
A Large MWDC to be completed



Installed for Beam Test

R&D-MRPC



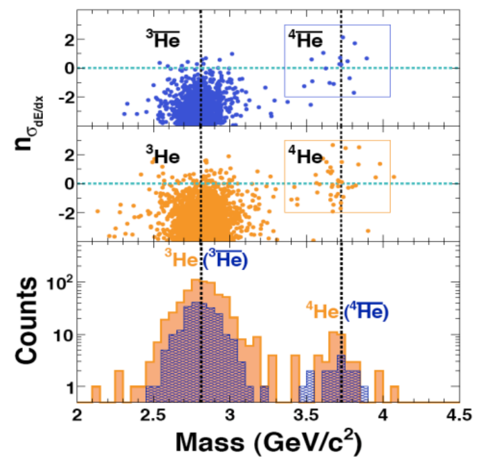


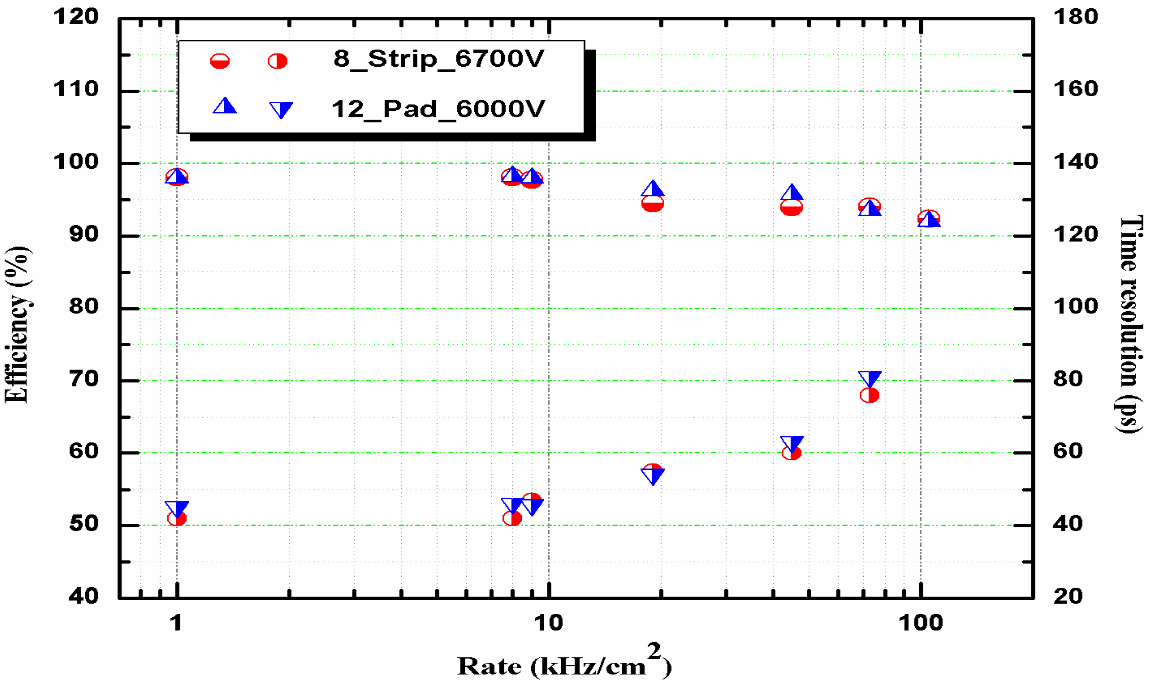
nature April, 2011

"Observation of the Antimatter Helium-4 Nucleus"

*by **STAR Collaboration***

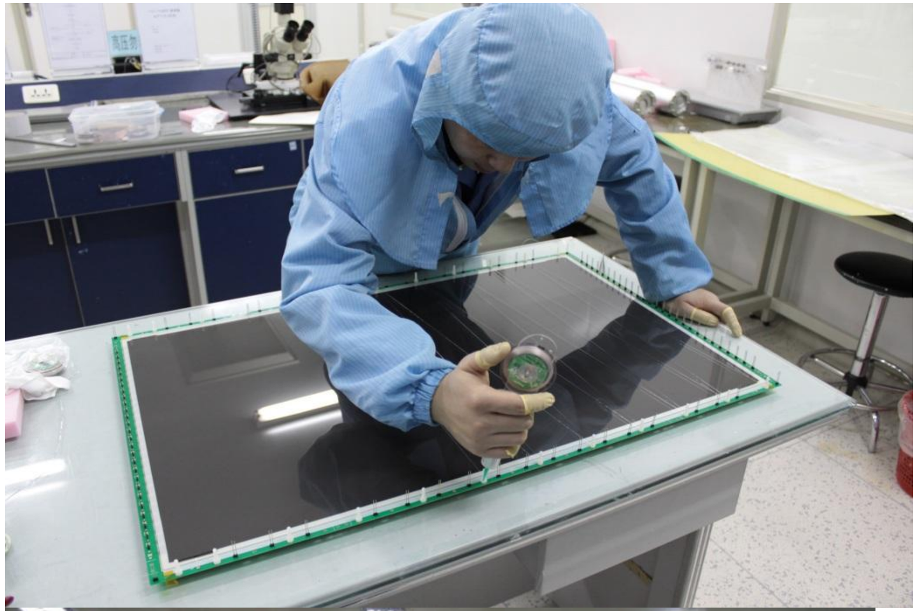
***Nature**, 473, 353(2011).*

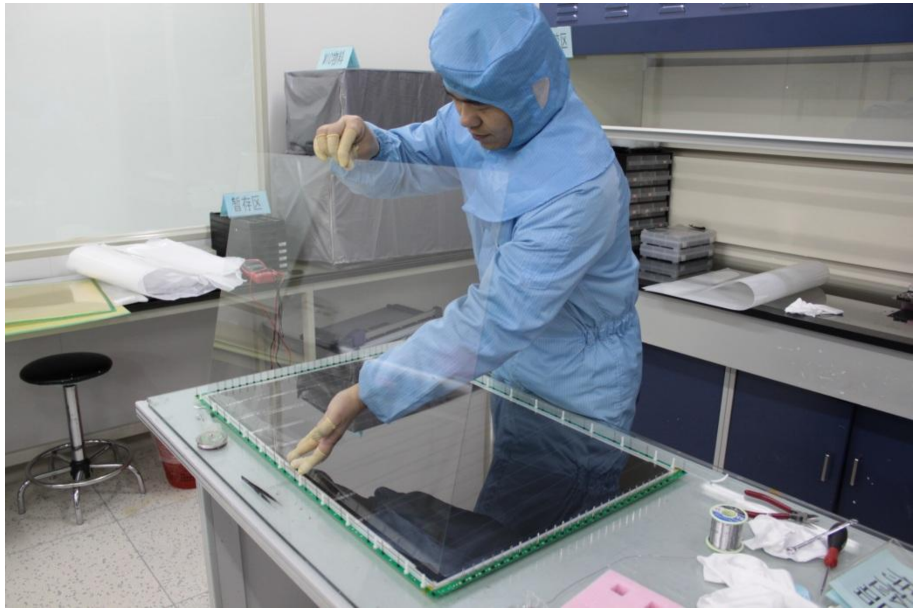




Momentum		500MeV	600MeV	800MeV
Pion sample	#1	56	47	45
	#2	51	48	40
	#3	46	48	45
Proton sample	#1	29	32	36
	#2	28	30	35
	#3	31	31	35

Production and QC of large MRPC by THU





Summary and acknowledgement

→ GEM R&D for SOLID:

1 GEM R&D has been started in THU in collaboration with Prof. Duan from IMP. The performance of the small GEM prototype is demonstrated good. Using a novel method, the non-uniformity effects of the inter-foil distance is studied. Large area GEM detector assembly is ongoing.

→ CEE at HIRFL-CSR:

2 The conceptual design of the CEE is presented. R&D work for most of the sub-systems have been well started. Performance of MWDC and MRPC have been tested and meet the requirement of CEE.

Acknowledgement:

Funding: 1. NSFC, 2.Tsinghua University Initiative Scientific Research Program.

Thank You for your attention!