Position Sensitive Detectors and Applications at CIAE

Xiaomei Li

Science and Technology

on Nuclear Data Laboratory

China Institute of Atomic Energy

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北京市275信箱46分箱 邮编102413 电话69357849 传真69357787

Outline

- **Developments of Advanced Gas Detectors**
- **R&D of GEM at CIAE**
- **R&D of MicroMegas at CIAE**
- **R&D of RPC at CIAE**
- **Developments of EMCal Detectors for sPHENIX**
- **ALICE Upgrade**
- **Summary and Perspective**

Developments of Advanced Gas Detectors

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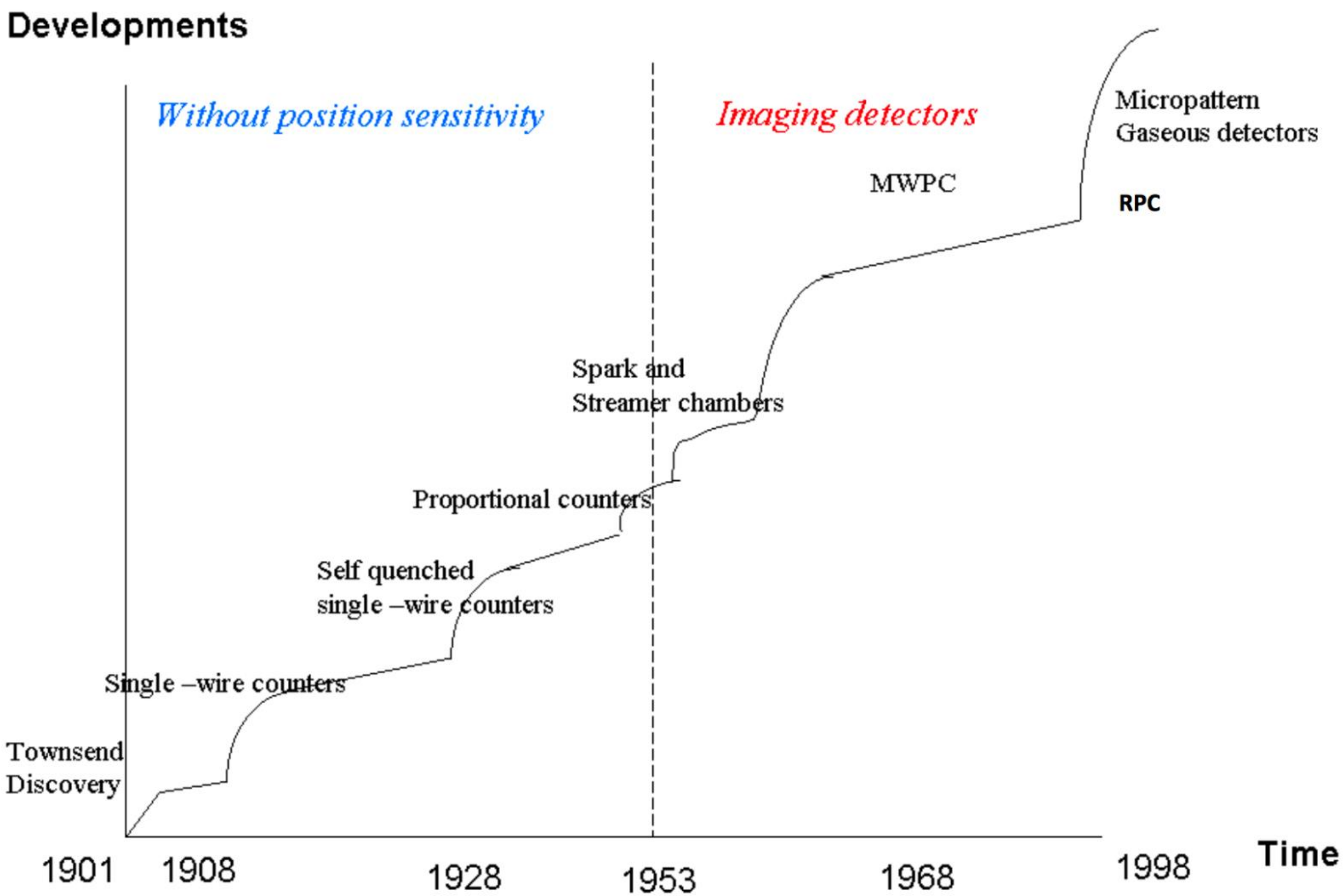
Developments of Gas Detectors



Recent High Rate and High Precision Experiments require better detectors.

Advanced Gas Detectors

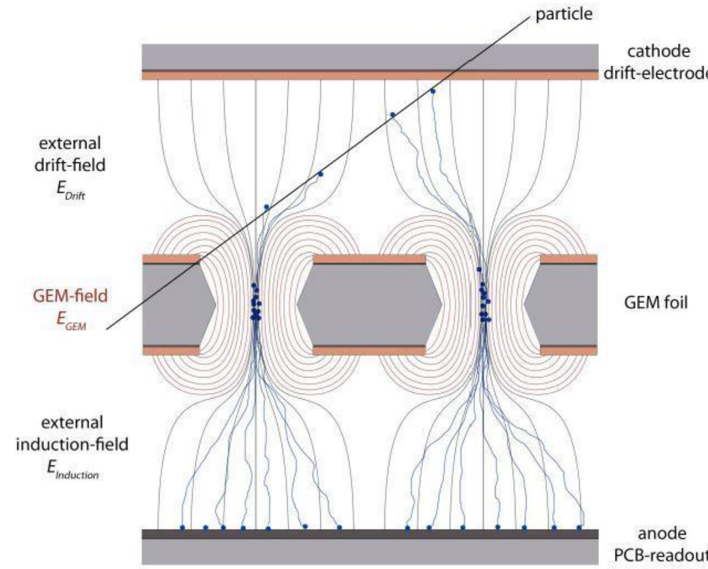
- **Micro-Pattern Gaseous Detector（MPGD）：**
  - **GEM**
  - **MicroMegas**

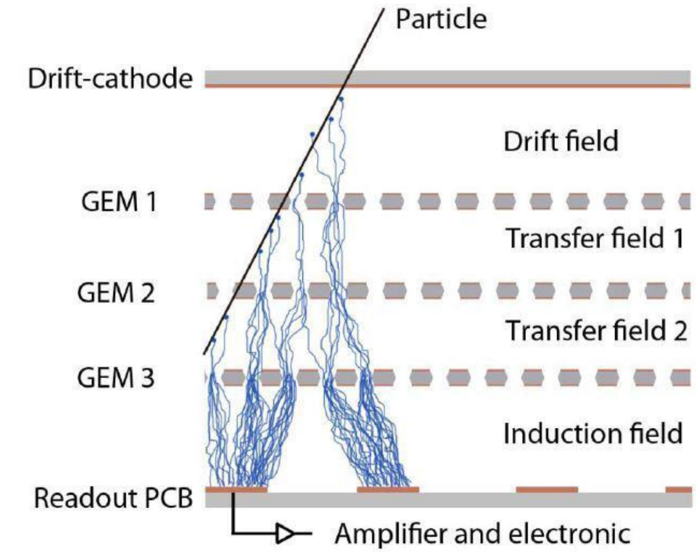
- **Resistive Plate Detector(RPC):**
  - **RPC**
  - **MRPC**

R&D of GEM at CIAE

Structure of GEM

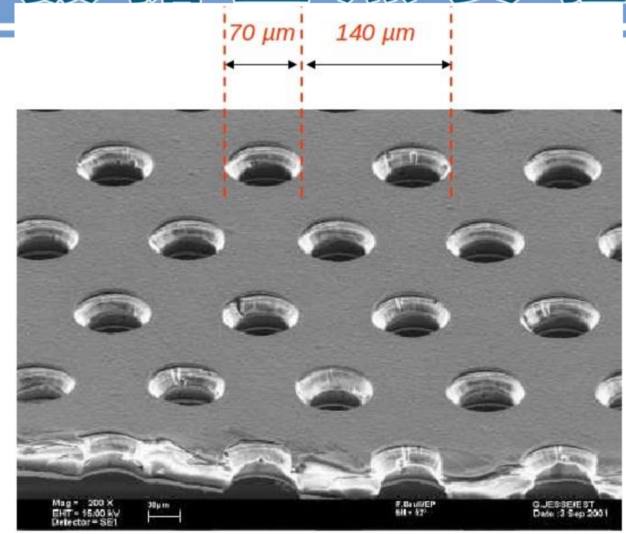
- **GEM detector:**
  - **Cathode, Drift field, GEM foil, Induction field and Readout board.**
  - **GEM foil： the most important part of GEM detector . Normally 3 GEM foils in one GEM detector.**



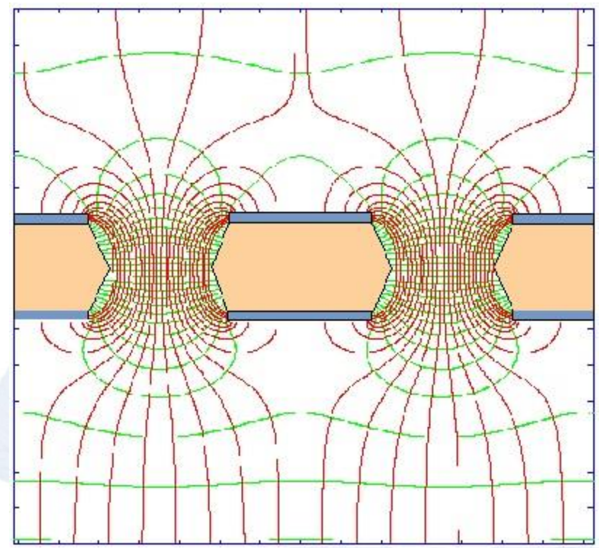


GEM Foil

1. Typical GEM Foil has 3 layers, two 5μm thick copper foils and one 50μm thick kapton foil in the middle.
2. Diameter of the hole is 70 μm , and the distance between them is 140 μm .
3. Apply electric voltages on the two copper layers.
4. Electric Field is very strong in the hole area, and weak outside the hole area.

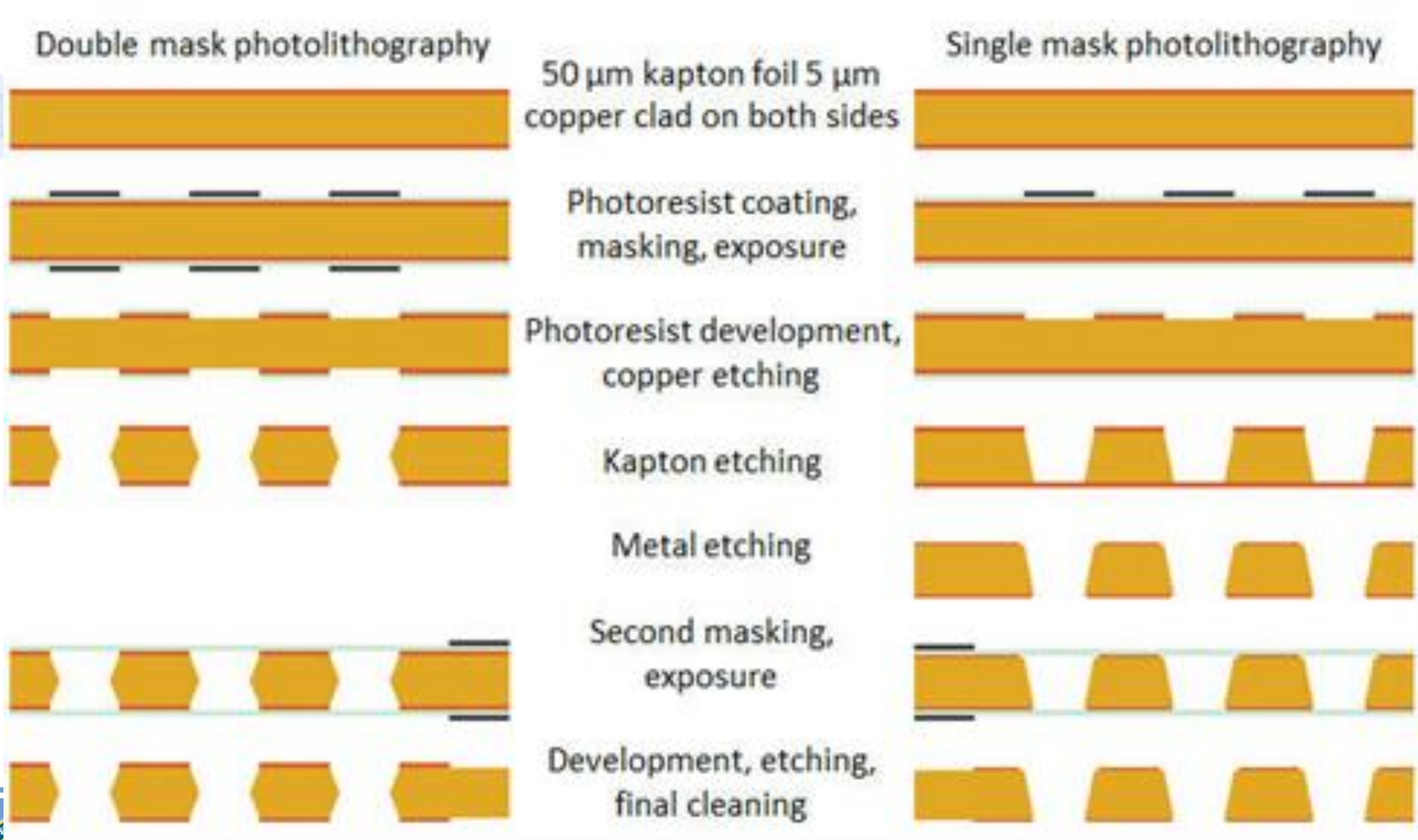


GEM Foil



GEM Field

The Procedure of GEM Foil



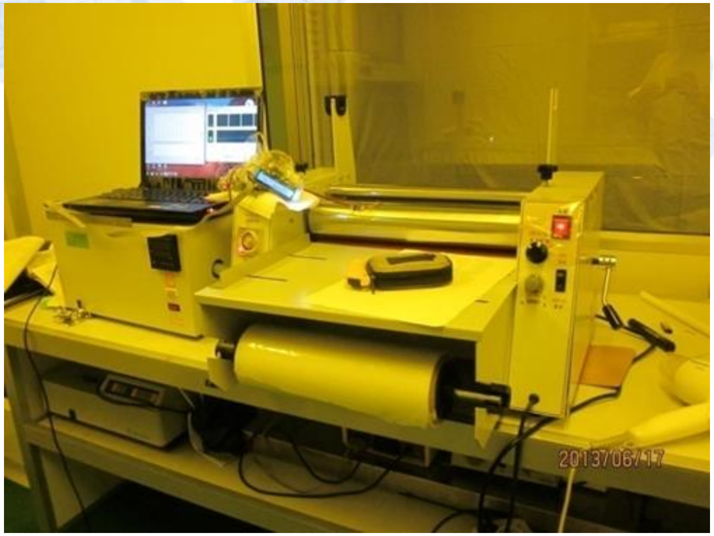
GEM License and Training

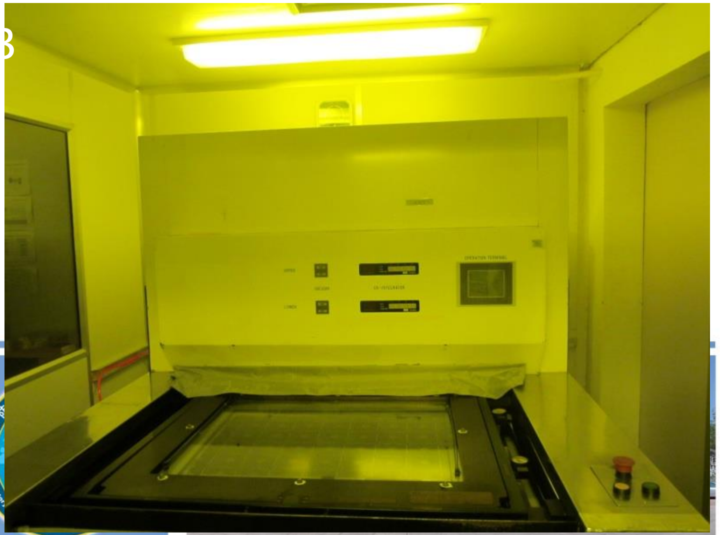
CIAE is the first chinese institution which signed officially the LICENSE AGREEMENT FOR MANUFACTURING AND COMMERCIALISATION OF GEM FOILS AND GEM-BASED PRODUCTS with CERN.

I took a training for GEM foil at CERN.

Photolithography Room Construction At CIAE

The Equipments for Lamination and Exposure of Dry Film Photoresist





Lamination and exposure of dry film photoresist are the most important and difficult steps for GEM foil production.

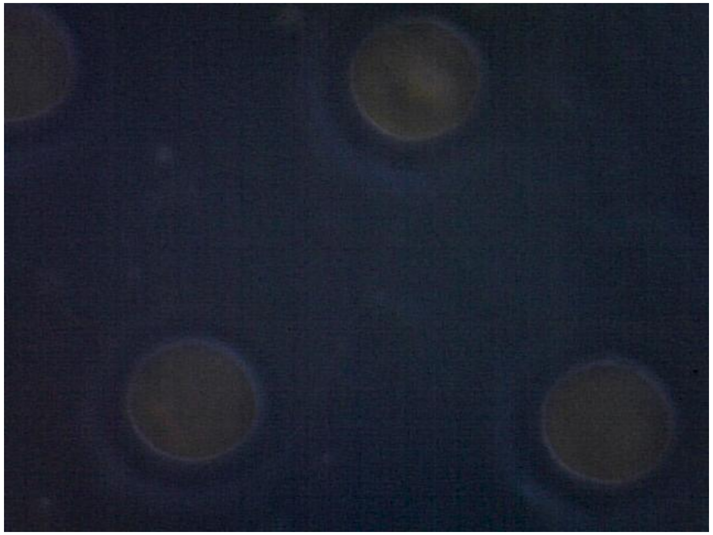
We have established a yellow light zone, Hot Roll Lamination (HRL) machine and Exposure system.

We invited a senior engineer from a famous electronic factory to CIAE and taught the PCB technology.

Exposure of Dry Film Photoresist

We use negative photoresist for GEM image transfer, unexposed areas are relatively unchanged and easily washed out during the development.

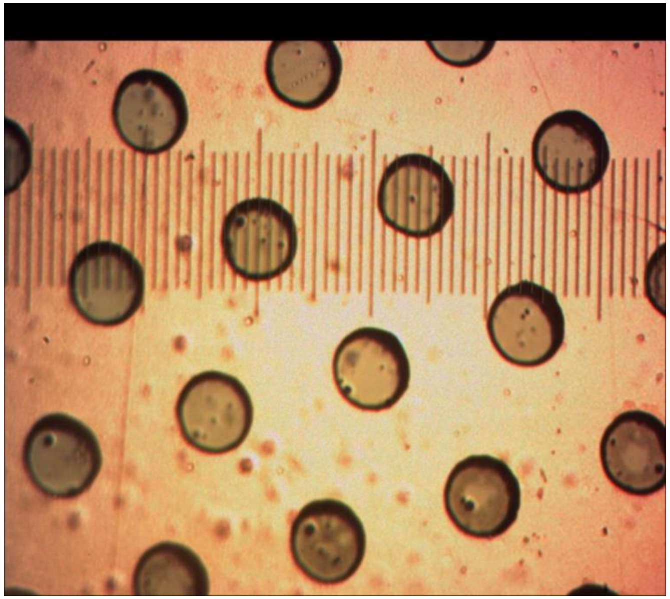
To obtain an identical copy of the photo-mask to the photoresist, vertical sidewalls in the resist are important.



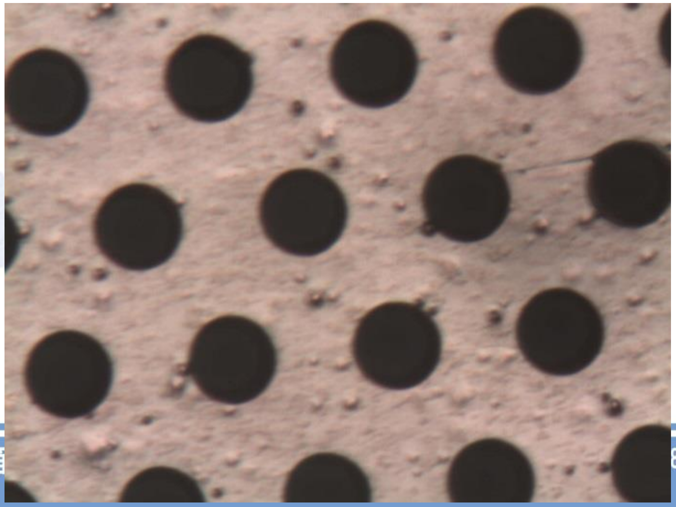
We can observe the image transfer with good accuracy.

Copper Etching and Kapton Etching

- The size of the hole is 70um as expected

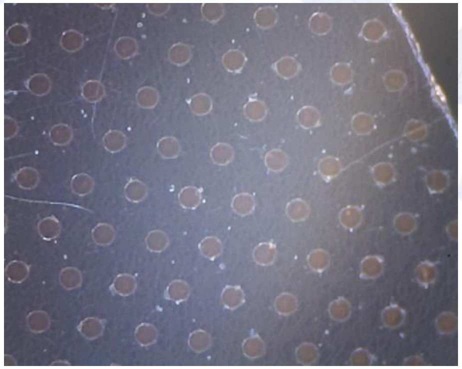


Etching Room Construction



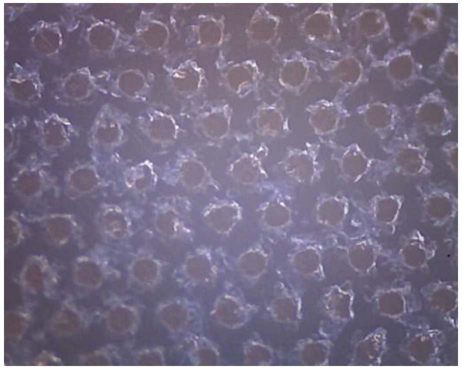
Comparison of Foils Made in Different Conditions

Insufficient development

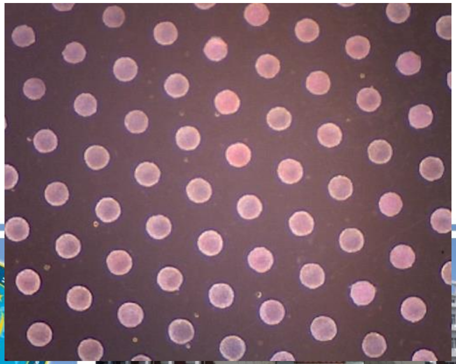


Good development

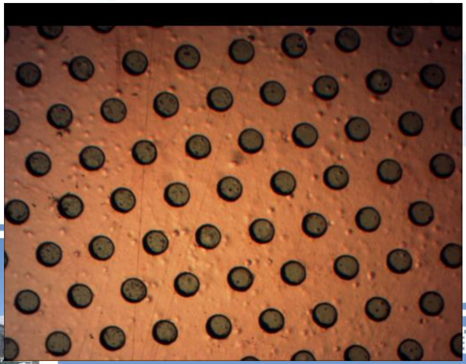
Excessive development



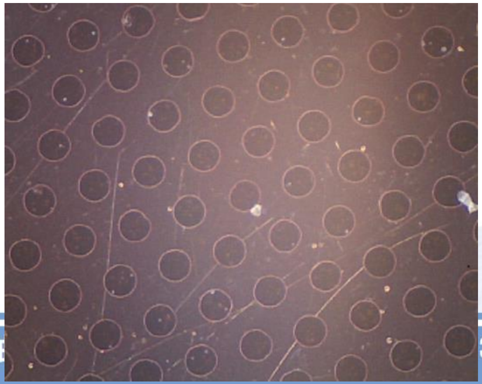
Insufficient copper etching



Good copper etching

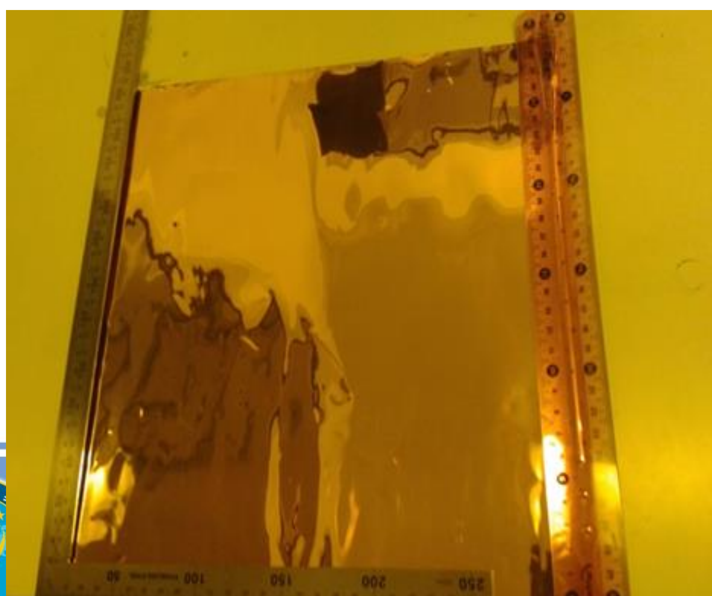


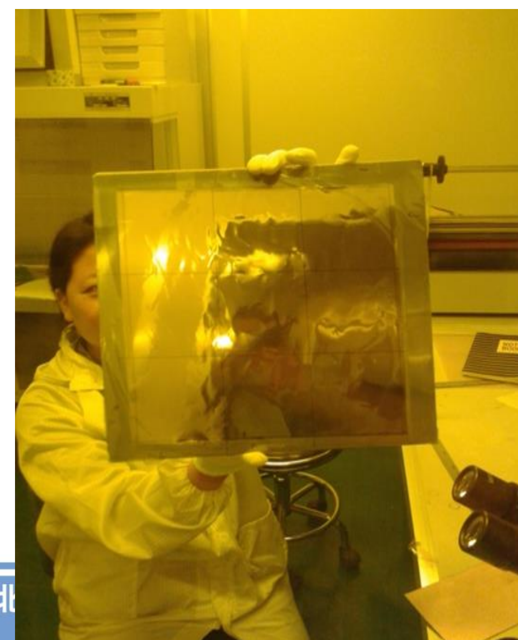
Excessive copper etching



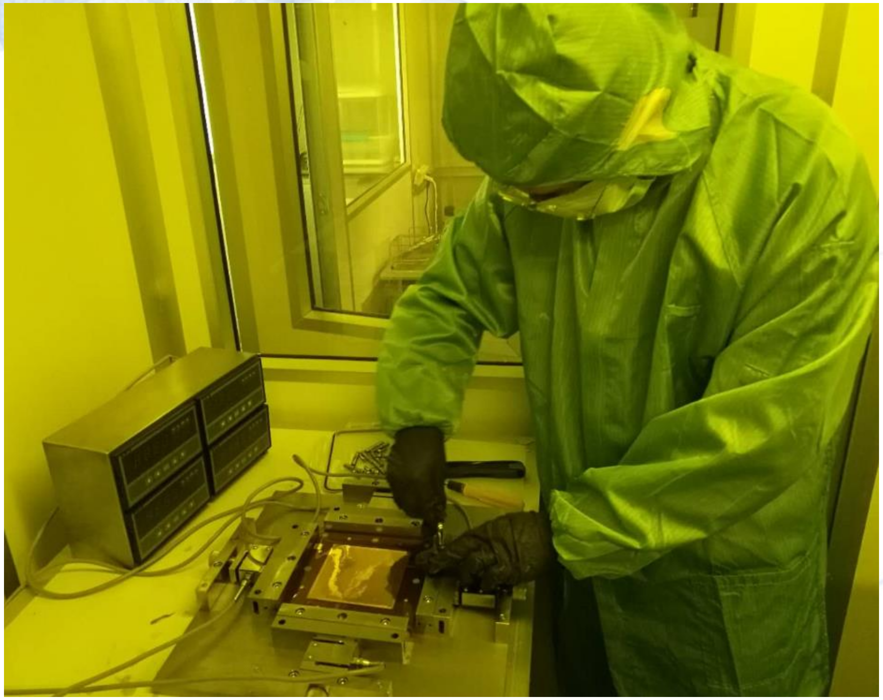
50cm*50cm GEM Foil

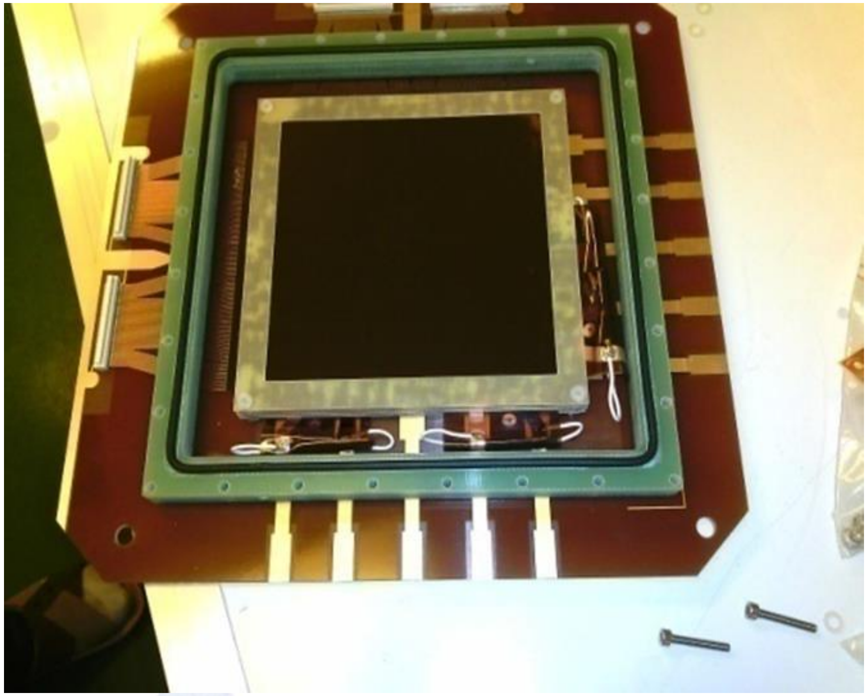
- The 50cm*50cm GEM foils were made successfully.
- Single-mask method was used.
- We did more than 200 samples before reaching this result.
- Sometimes the alignments of top and bottom masks were not perfect especially for large GEM foil. We have upgraded our alignment system.





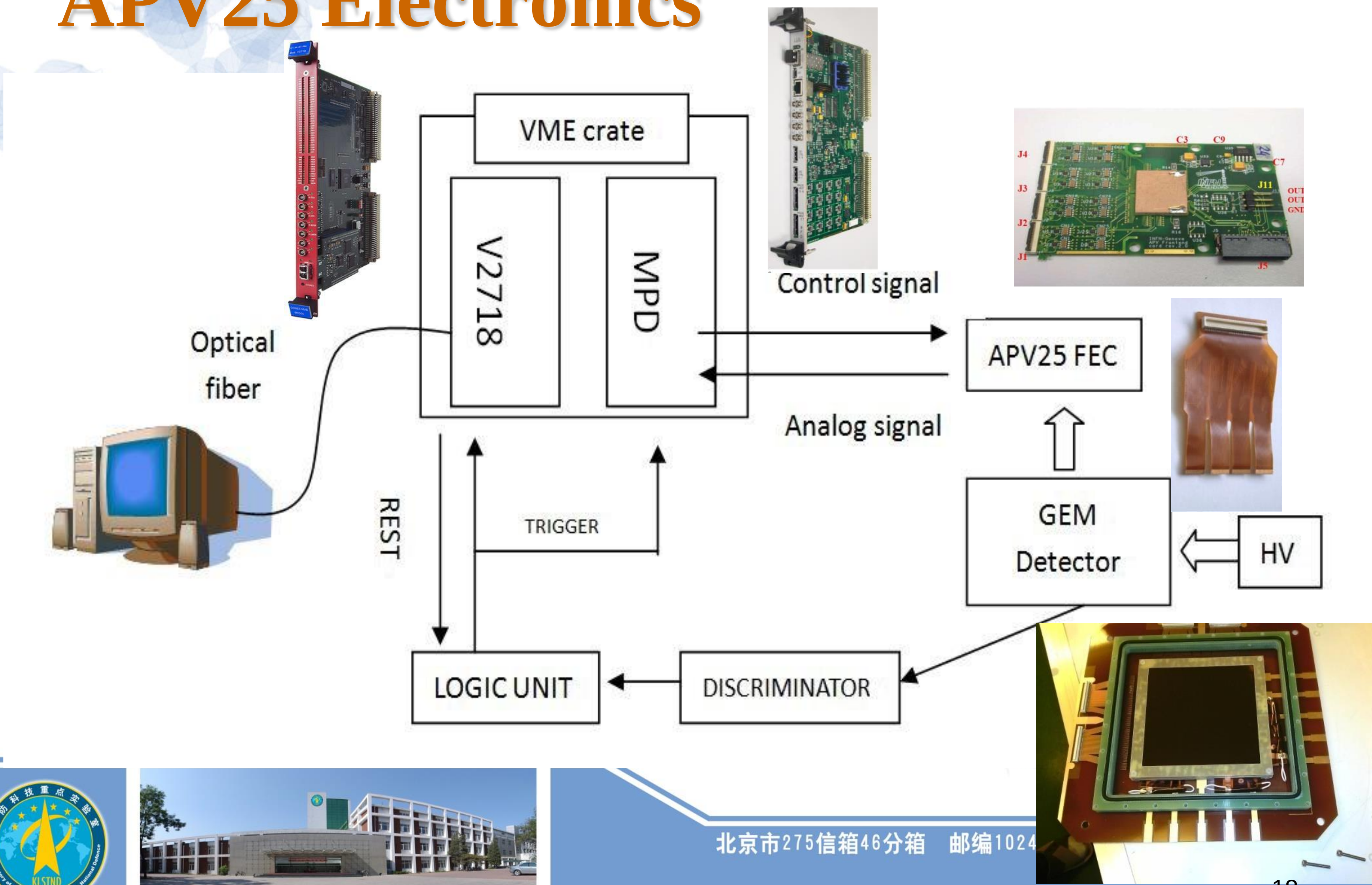
GEM Detector Assembly at CIAE





active area 10*10cm

GEM Test system with APV25 Electronics



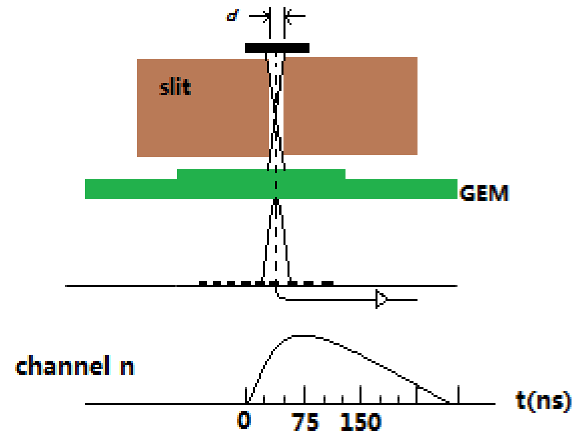
Spatial resolution

$$\sigma_{tot}^2 = \sigma_{GEM}^2 + c_1\sigma_{geometry}^2$$

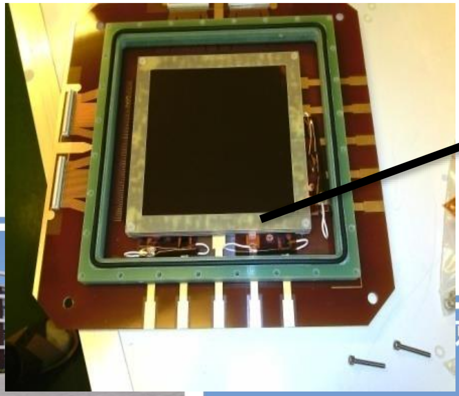
When: $\sigma_{geometry} \ll \sigma_{GEM}$

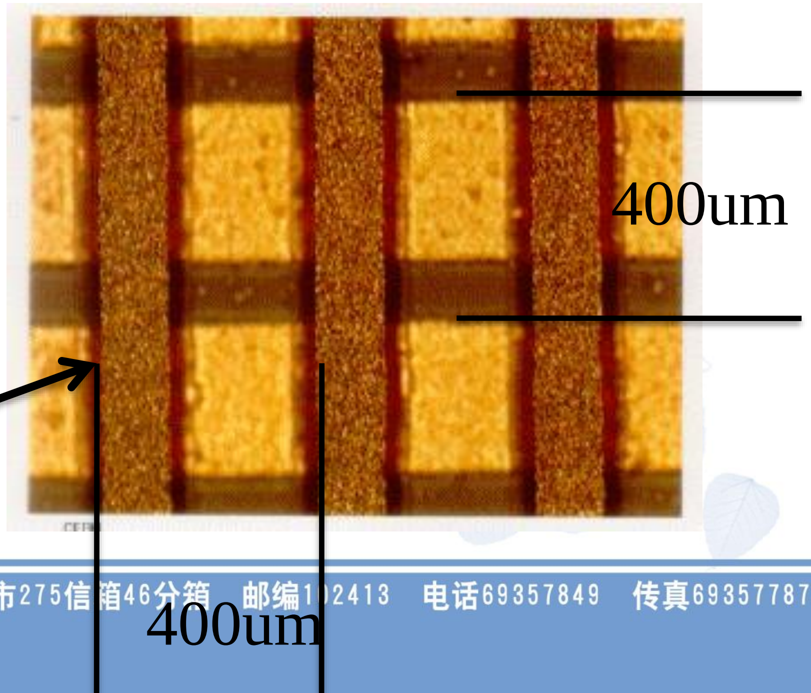
$$\sigma_{tot}^2 \cong \sigma_{GEM}^2$$

Spatial resolution≈76um

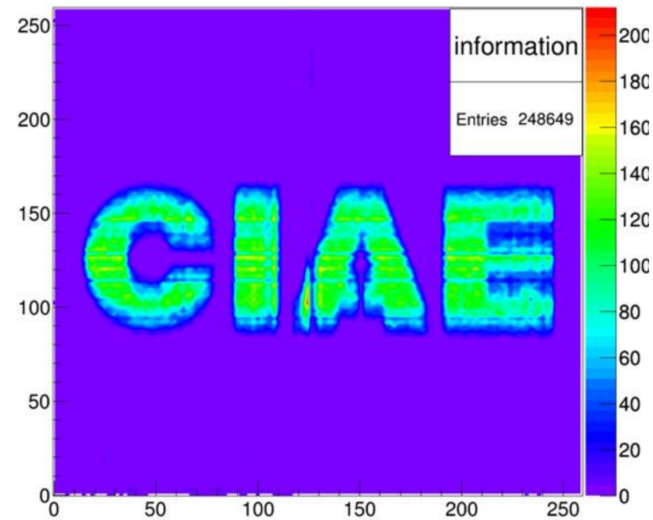


- **Slit(um): 20;**
- **Ar: CO_2=70% : 30%;**
- **HV: 3600V;**
- **The distance between strips: 400um.**

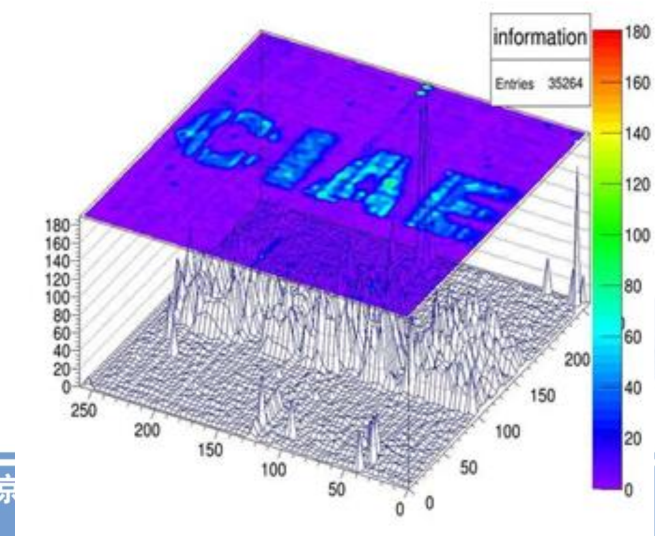




X-ray imaging @ CIAE

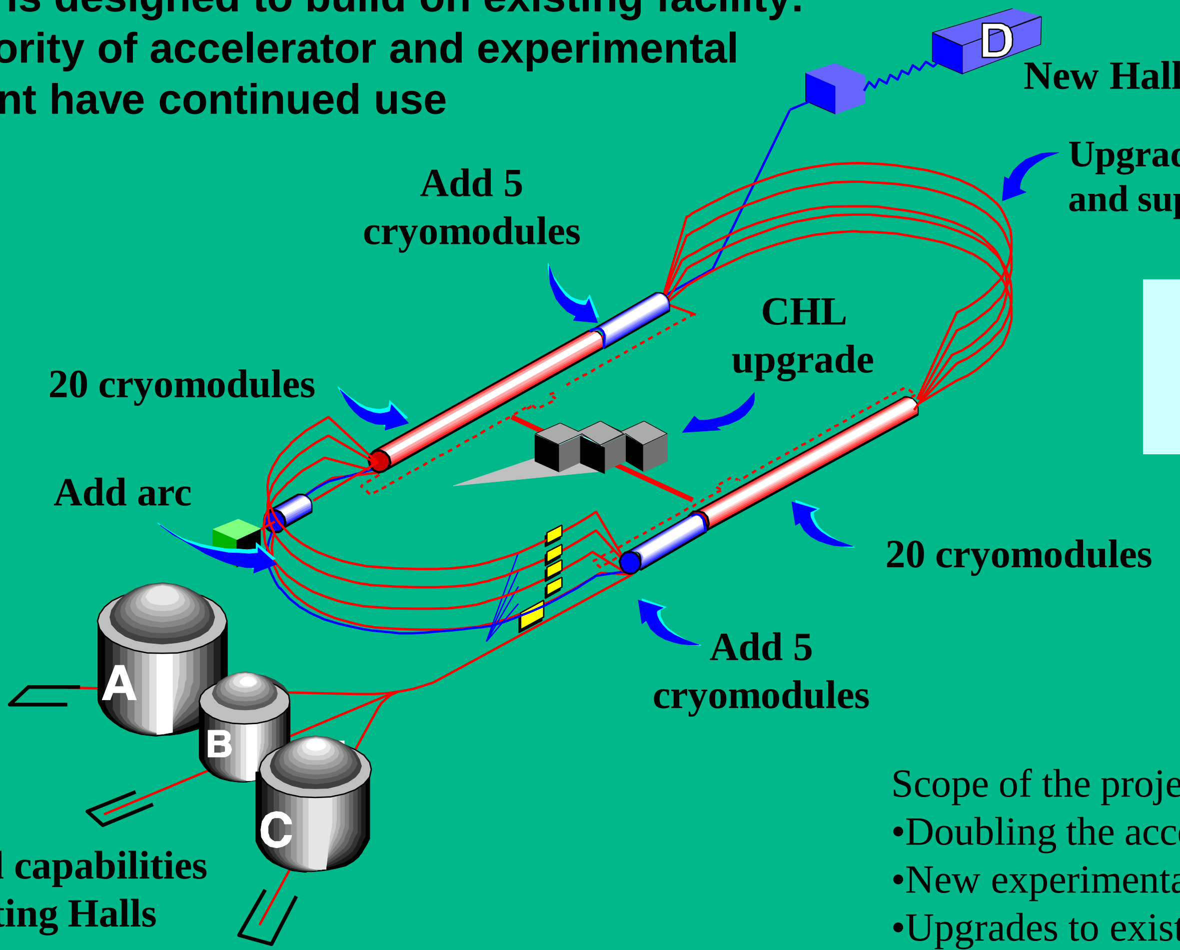


- X ray Energy: 8.9keV;
- about 1k sample rate
- 256 channels for each dimension(512 channel in total);
- 4 APV FECs were used (2 for each dimension)



JLab 12 GeV Upgrade

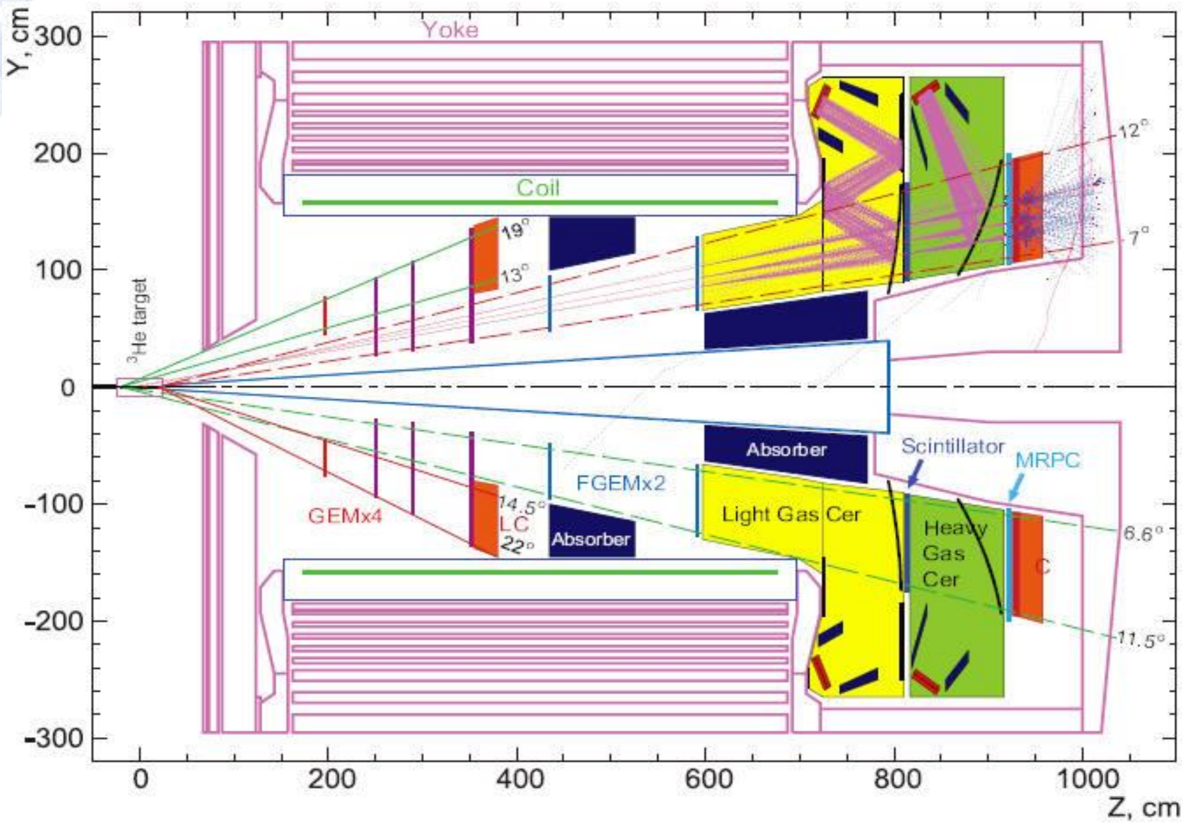
Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use



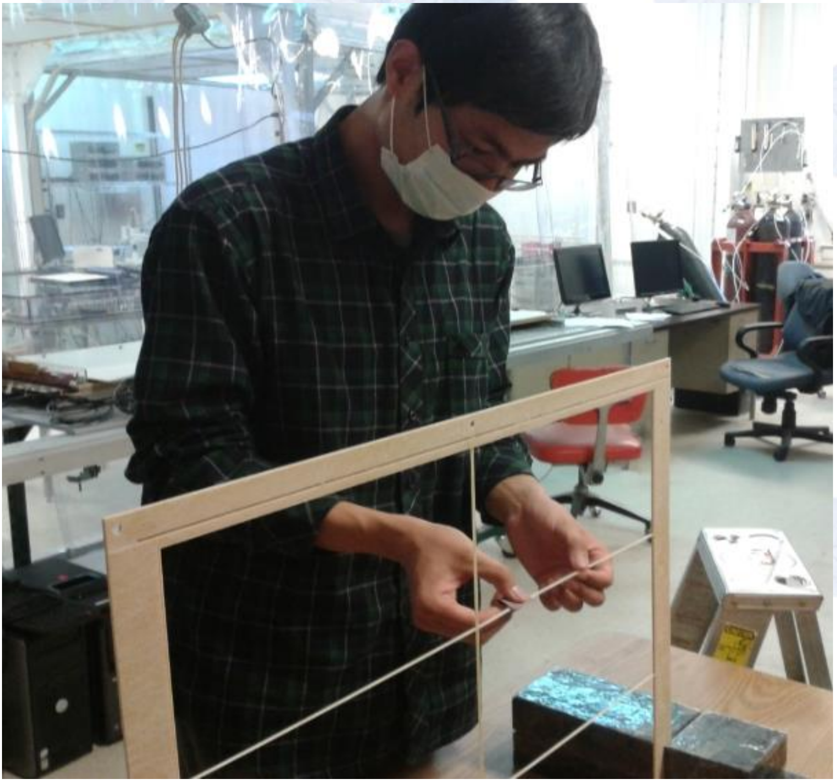
Maintain capability to deliver lower pass beam energies: 2.2, 4.4, 6.6….

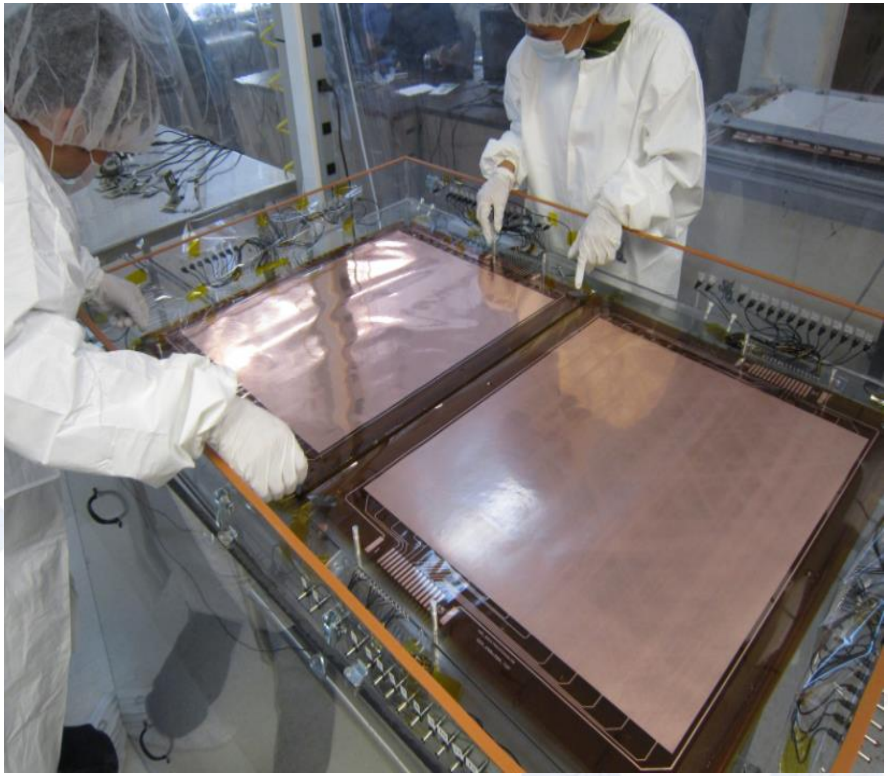
Scope of the project includes:
- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

GEM: SoLID Spectrometer at JLab

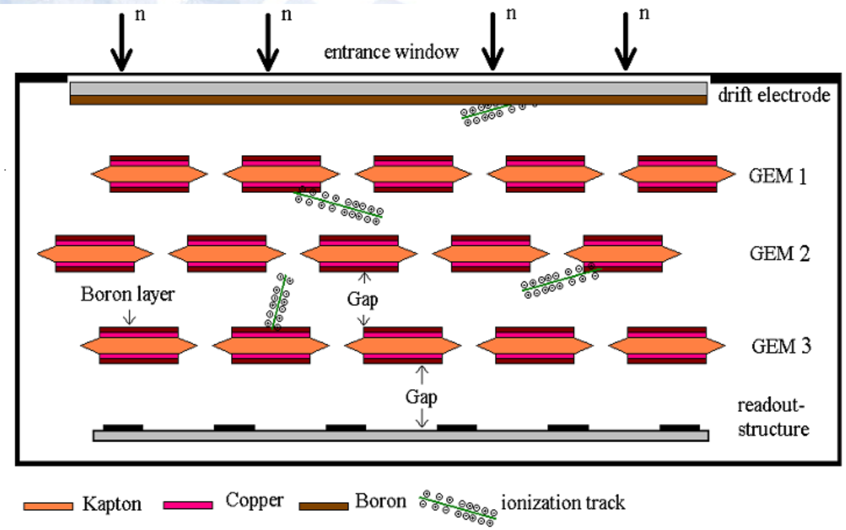


Students working at JLAB and UVA

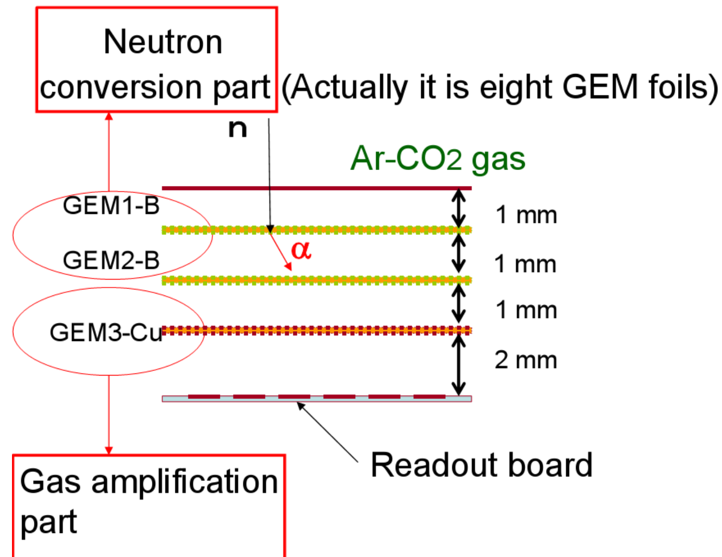


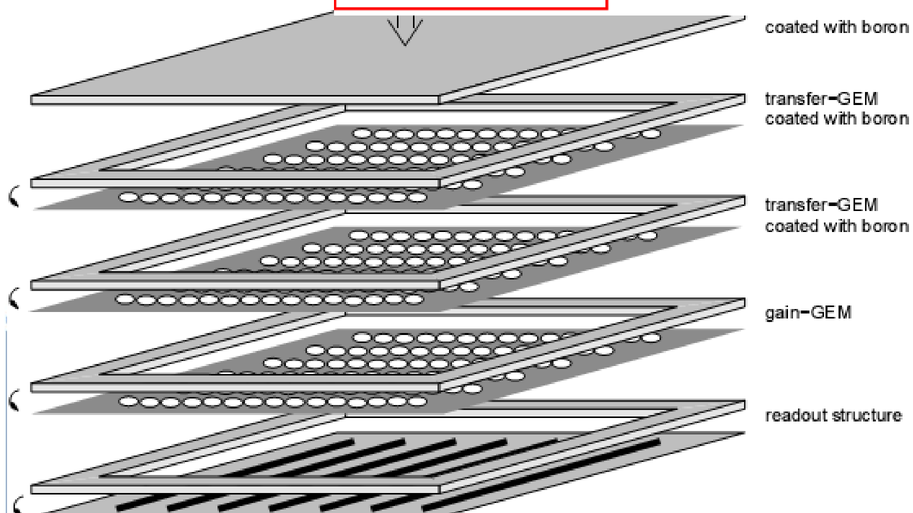


GEM: Neutron Detection



KEK

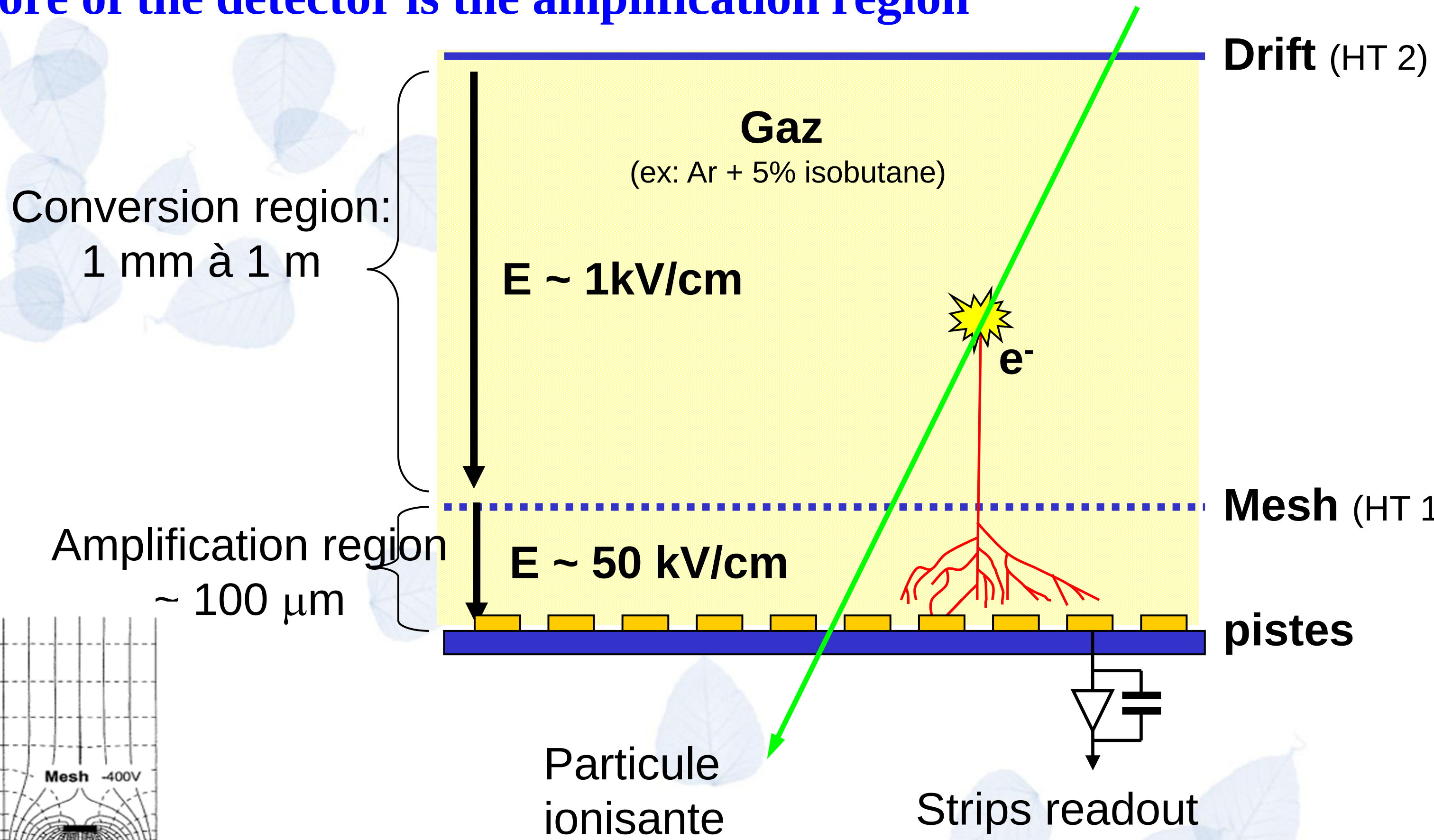


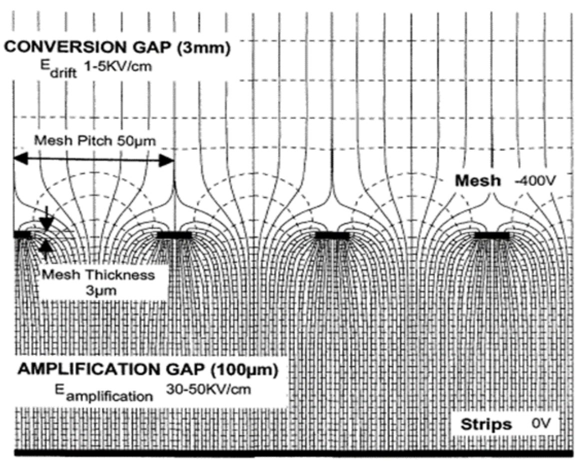


R&D of MicroMegas at CIAE

Structure of MicroMegas

- The core of the detector is the amplification region





Micromegas Classifications

– Classic Micromegas
  - Mesh on a frame
– Bulk Micromegas
  - photolithography process is used to attach the mesh on the PCB.
– Microbulk Micromegas
  - Mesh and PCB made on a unique kapton foil, the mesh layer is thinner.

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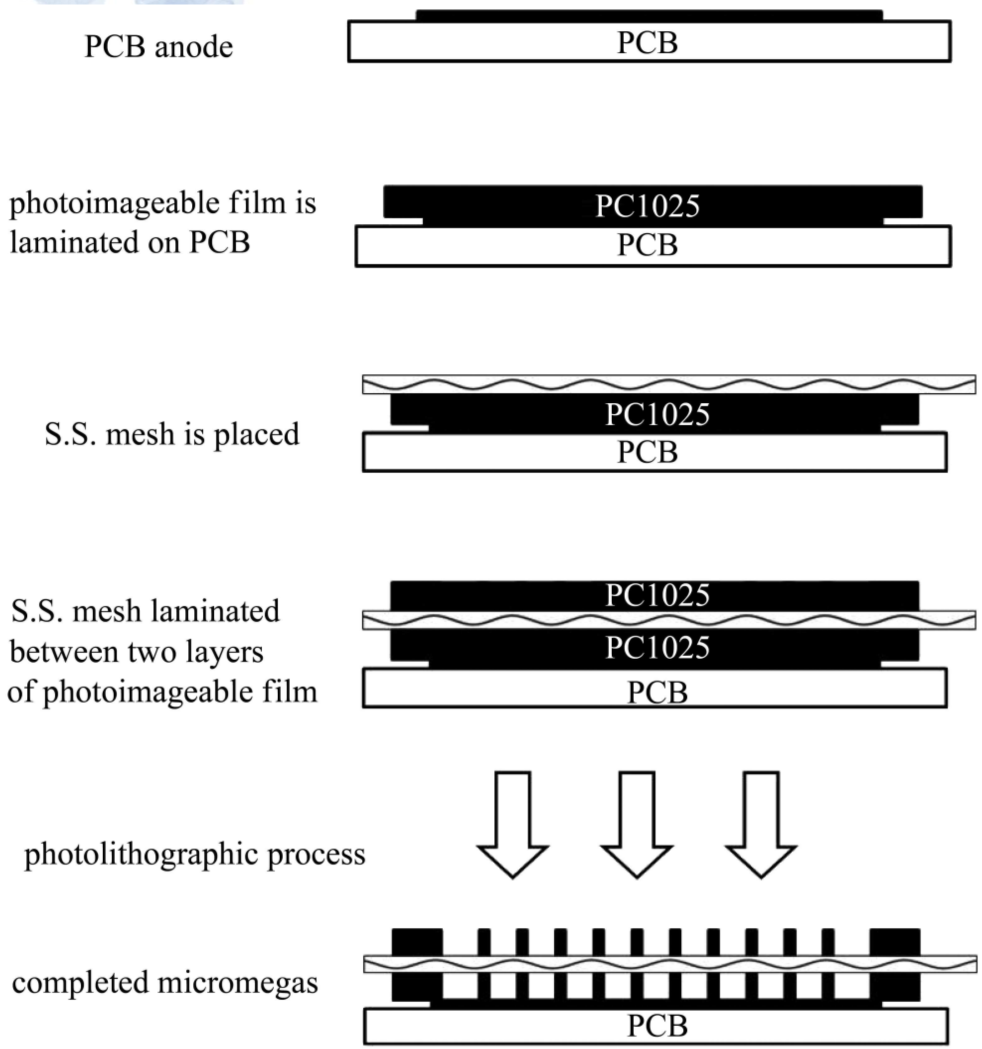
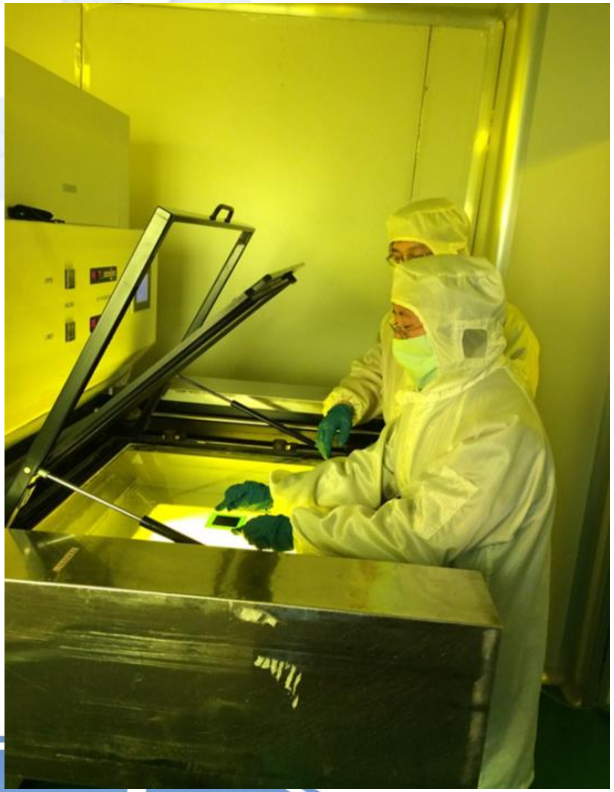
Stucture of Bulk MicroMegas

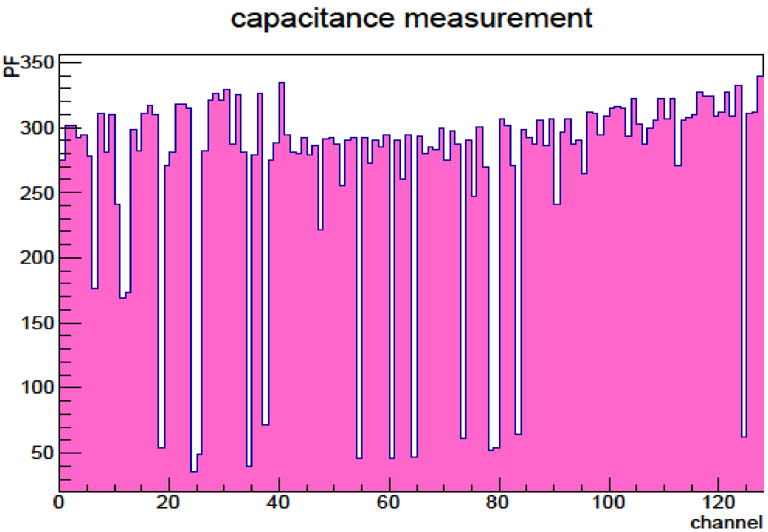


Reference:Study of bulk micromegas detector
Chinese Physics C Vol. 34, No. 10, Oct., 2010

Manufacture of Bulk MicroMegas at CIAE



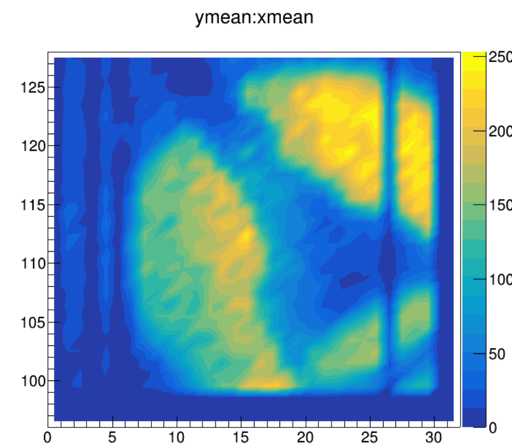
Capacitance and Resistance Automatic Testing System Invented by CIAE

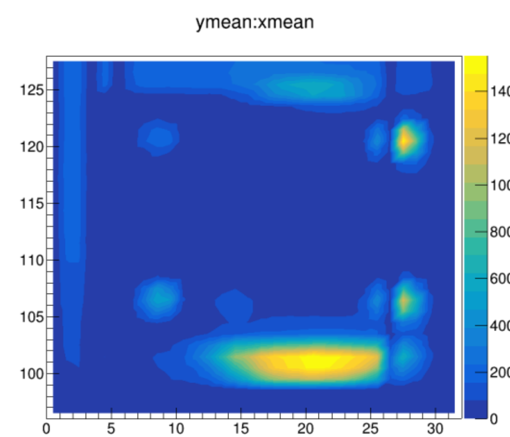


不同通道电容值分布图

Bulk Micromegas X-Ray Imaging

- Bulk Micromegas
- Argon + 30%CO_2
- Mesh: -550V(max -620V)
- Drift: -2500V
- 50kV X-Ray tube





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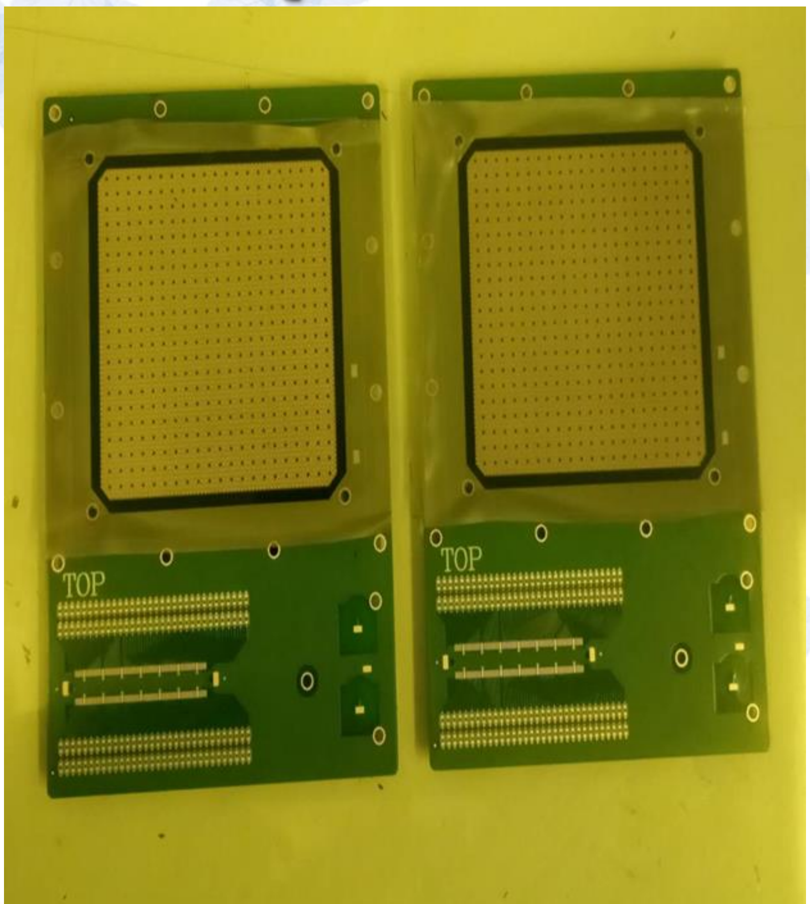
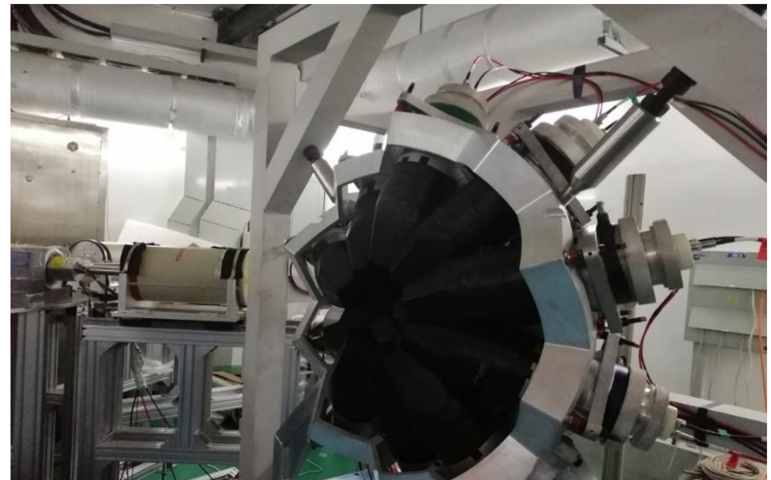
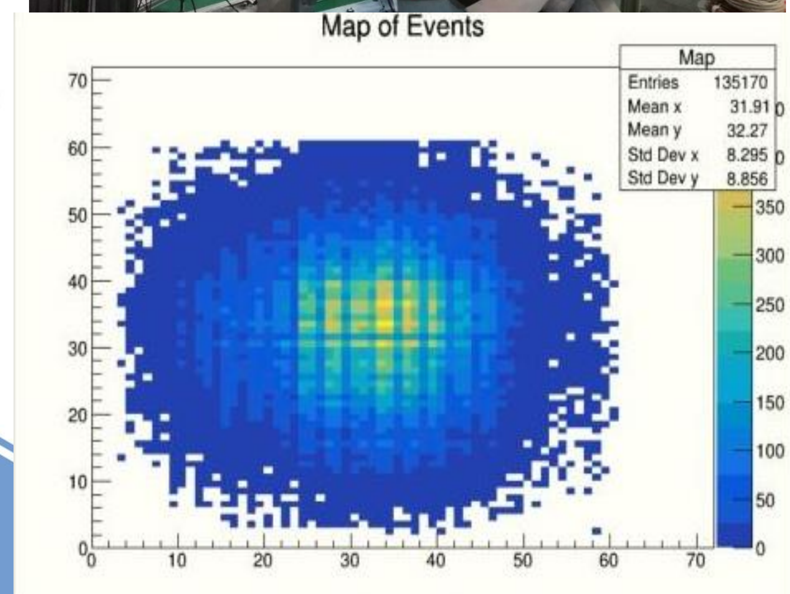
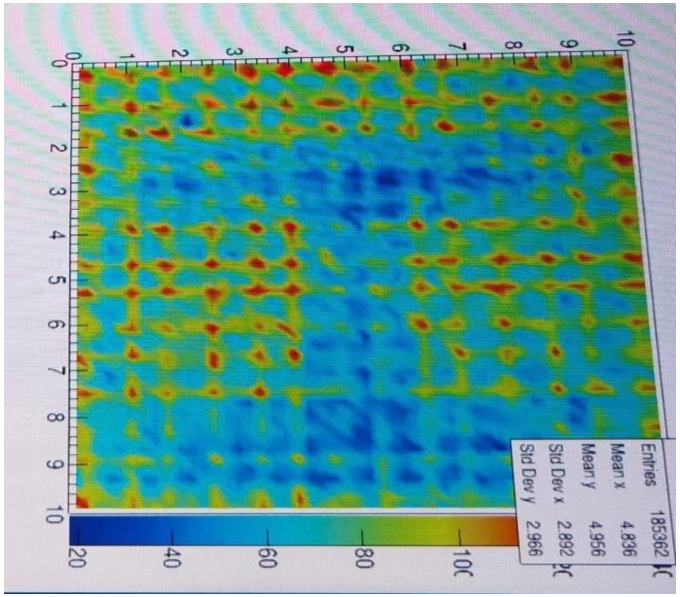
Neutron imaging at China Spallation Neutron Source



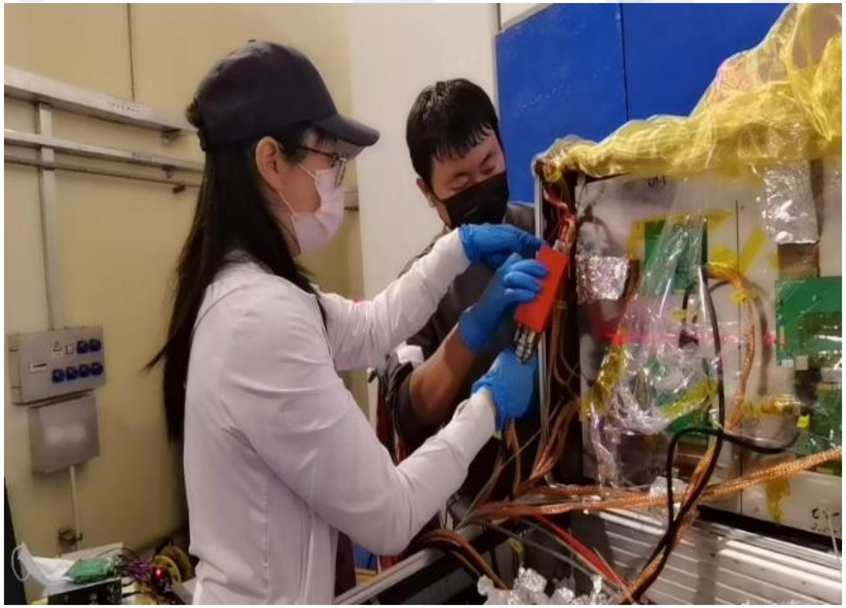


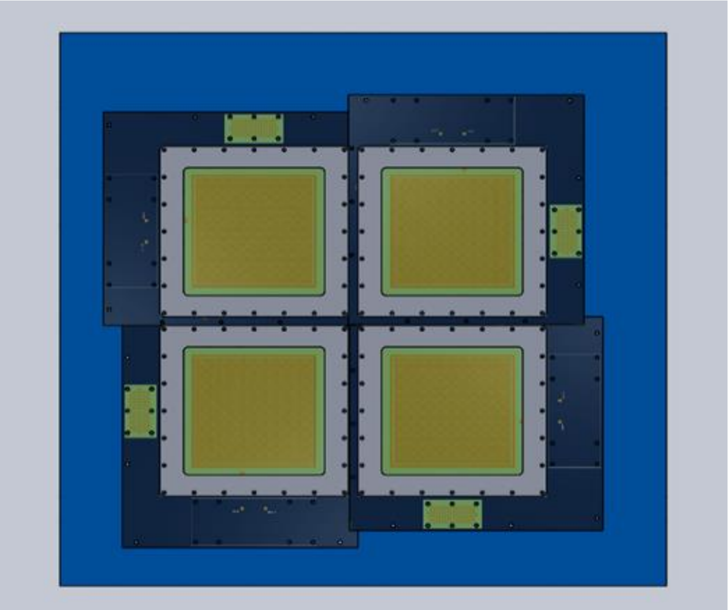


Neutron Imaging at CIAE

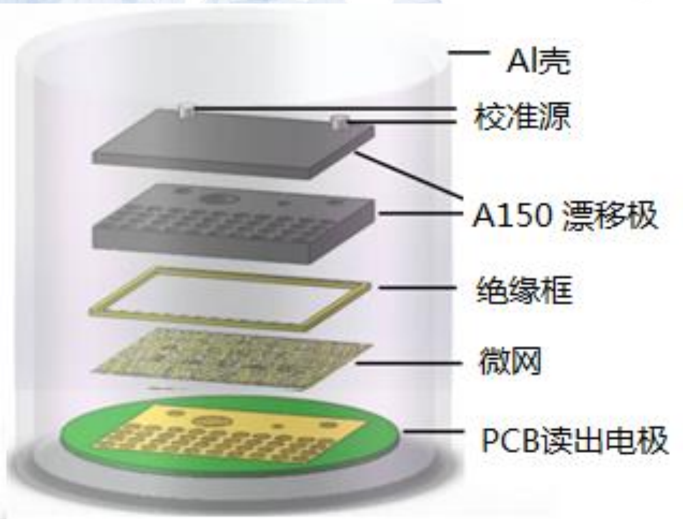


Neutron Imaging at CIAE 100MeV Cyclotron



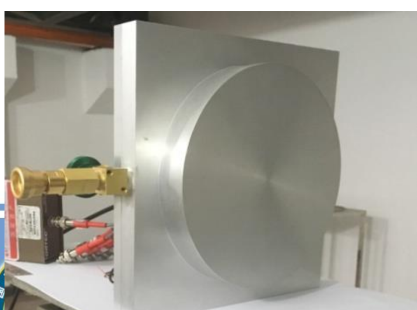


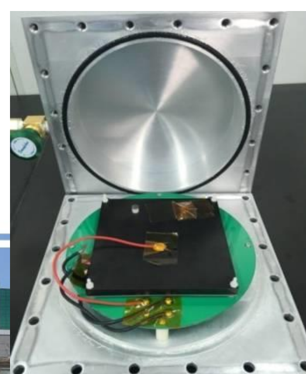
Bulk MicroMegas: TEPC at CIAE



TEPC is widely used in microdosimetry.

Compare with MWPC:
Easy Assembly,
More Sensitive

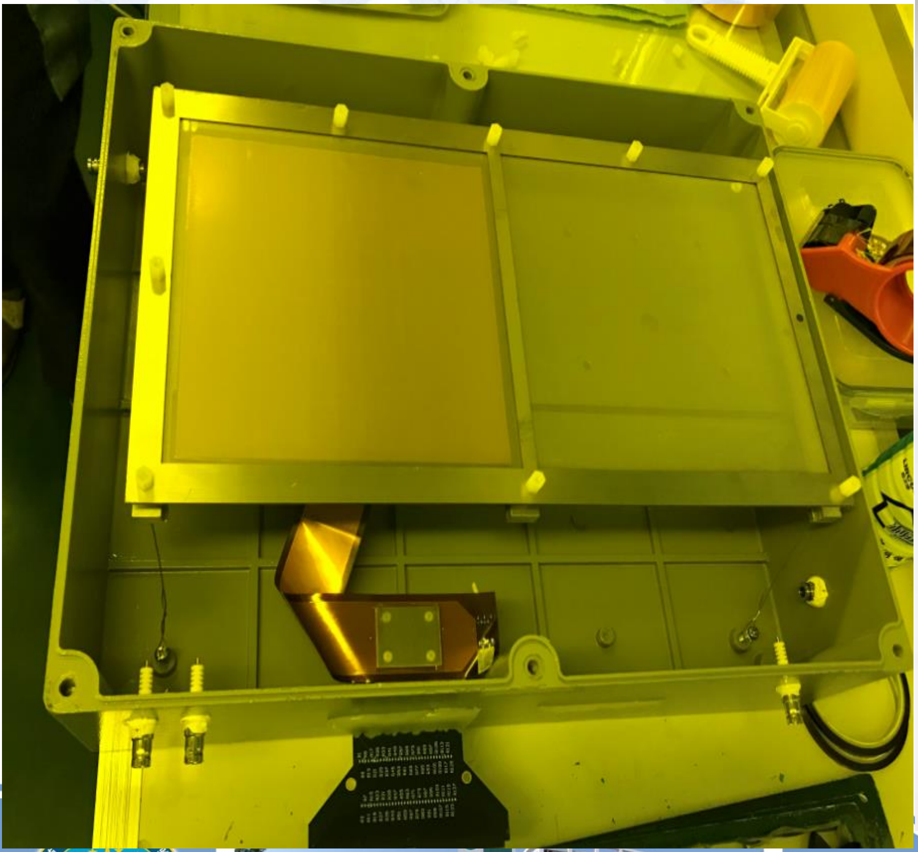




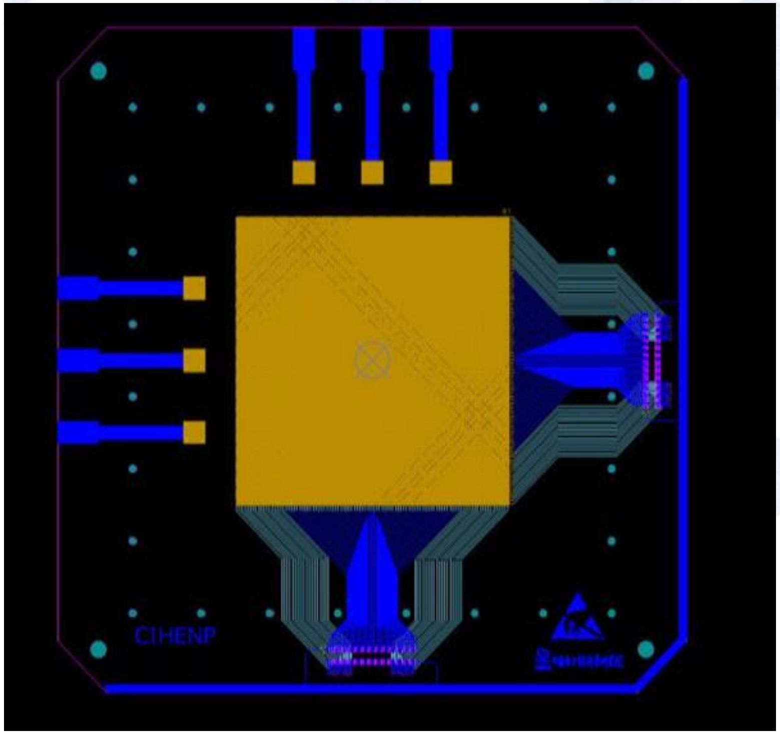
Compare with GEM:
More stable

Tissue Equivalent Proportional Counter

PandaX-III MM Test Platform at CIAE

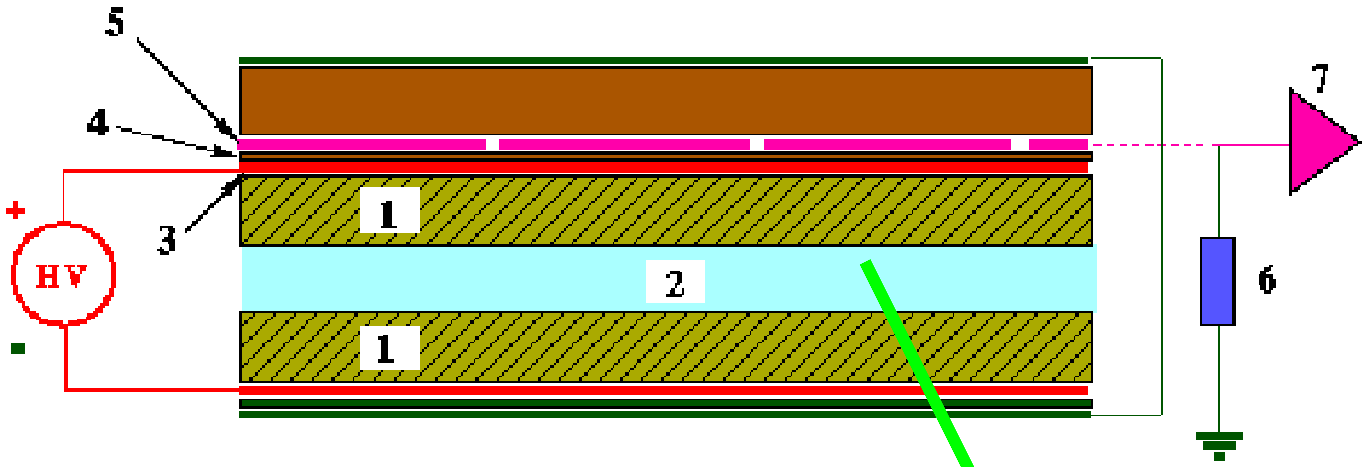


Bulk MicroMegas for the R&D of CEPC TPC

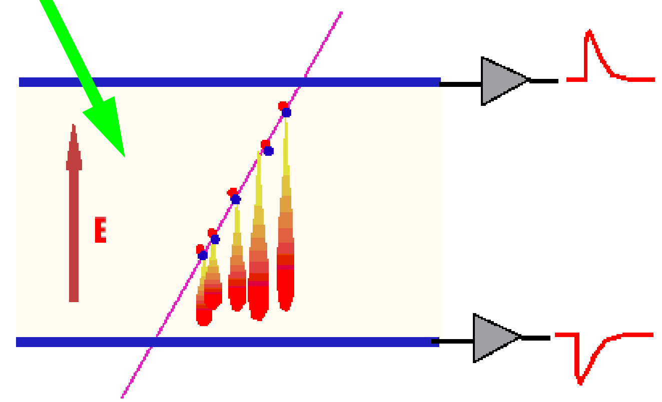


R&D of PRC at CIAE

Structure of RPC



- Bakelite resistivity 10^{10}- 10^{12} Ωcm
- Gas Gap: 2 mm
  Gas pressure : ~ 1 Atm
  Gas mixture: F134a, Isobutane, SF_6
- HV electrodes : 100 μm graphite
- Read-out strips



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RPC Prototypes

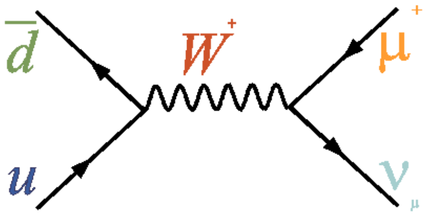
The upstream of Prototype No.2 is separated into two parts and the readout strips are jointed with ground by matched resistances.

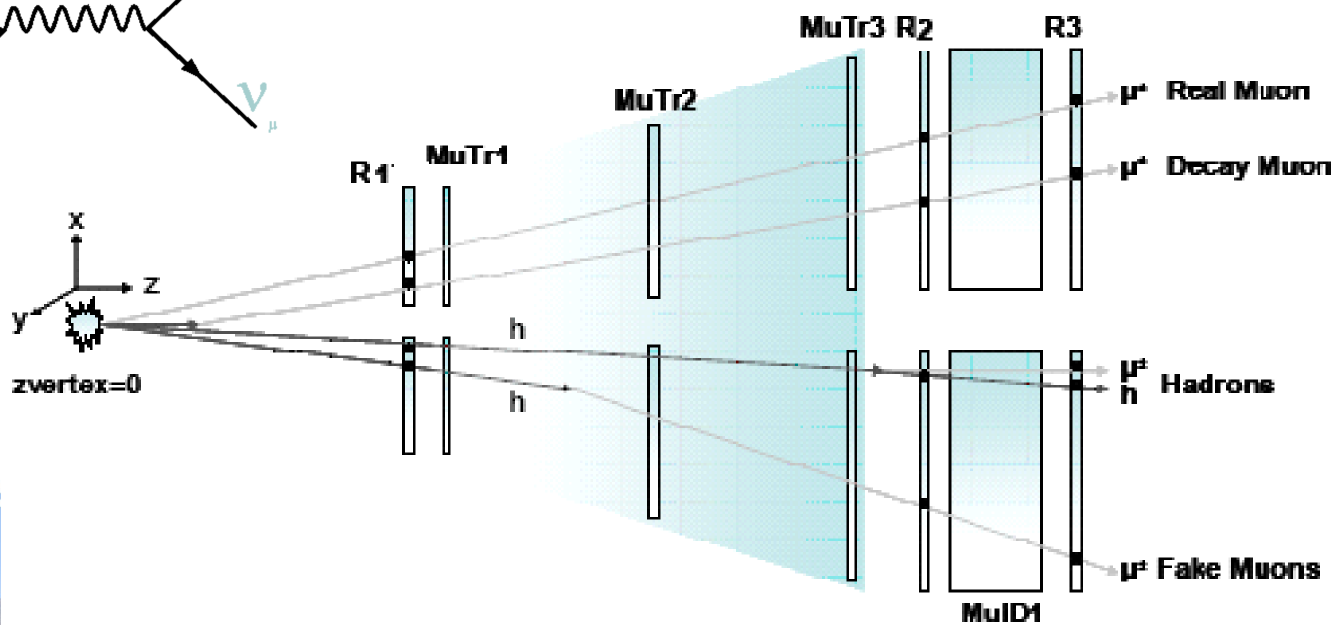
PHENIX @ BNL

北京市275信箱46分箱 邮编102413 电话69357849 传真69357787

Motivation of the PHENIX Forward Upgrade

Add RPC (Resistive Plate Chamber) as a fast muon trigger to study the quark-gluon structure of the proton by observing W-bosons from colliding polarized proton beams at RHIC.

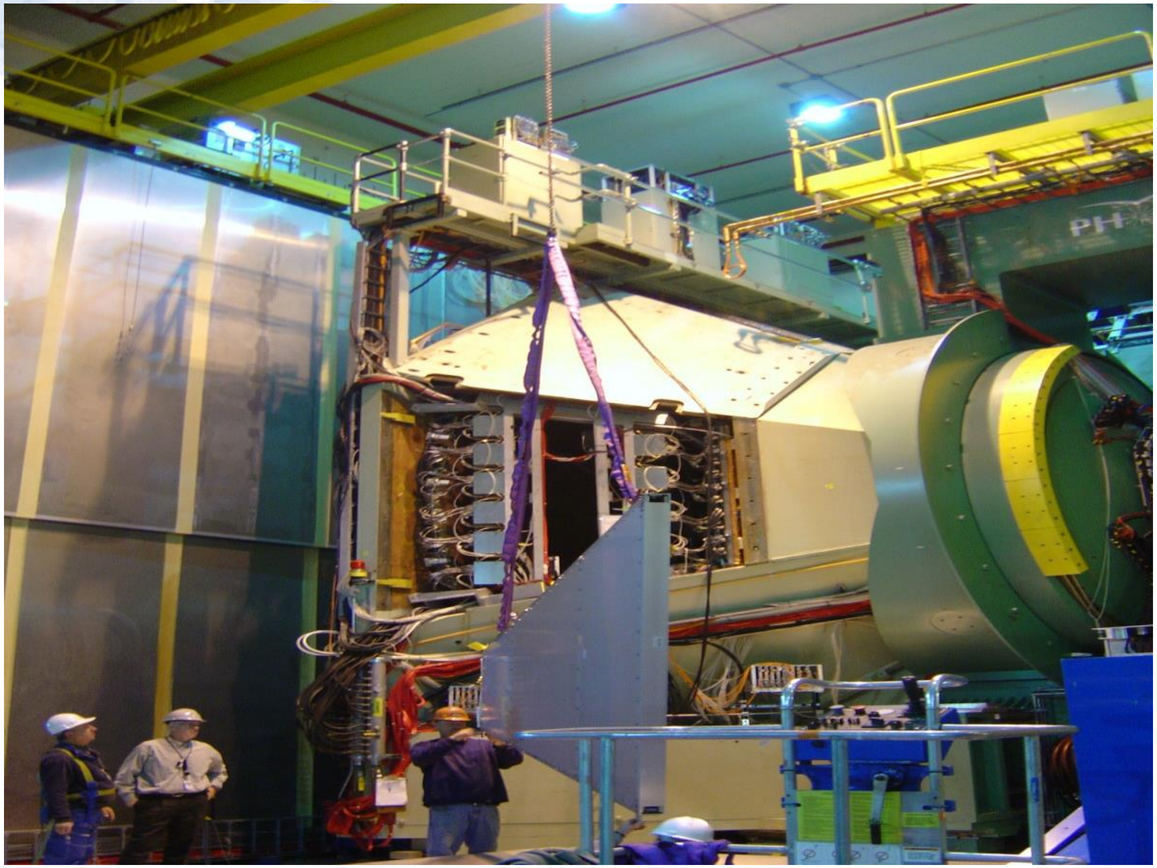




RPC installation at PHENIX

CIAE Carried out the design and production of the module parts of RPC detectors for PHENIX forward upgrade,

RPC installation at PHENIX



This work was awarded the Beijing Science and Technology Prize.

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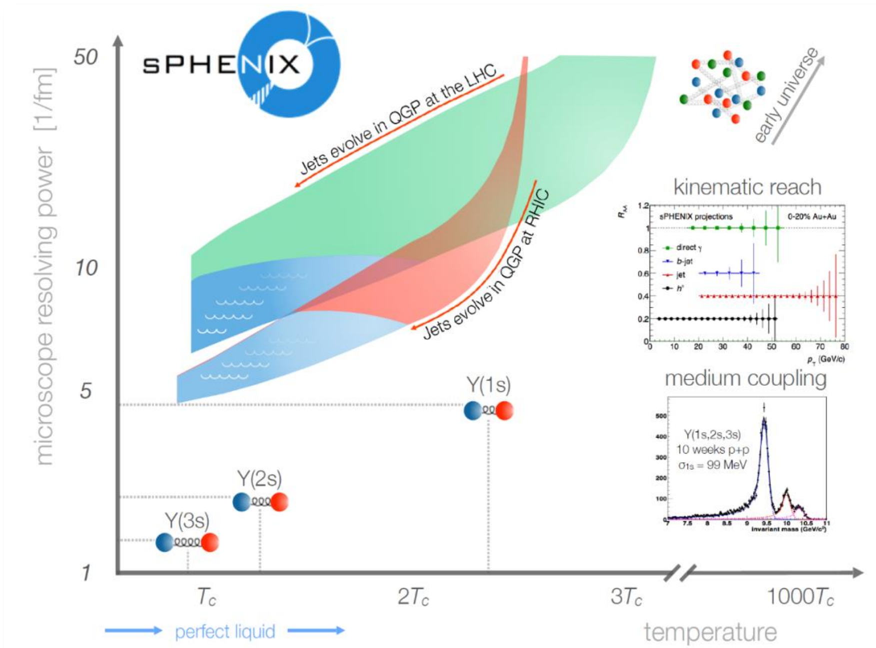
Developments of EMCal Detectors

for sPHENIX

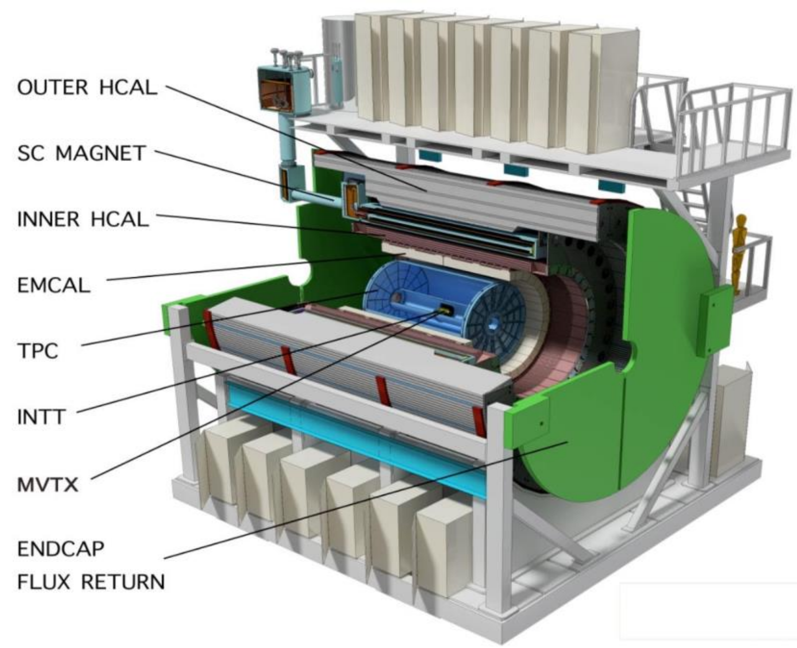
北京市275信箱46分箱 邮编102413 电话69357849 传真69357787

Objectives of sPHENIX

The scientific objective of the sPHENIX experiment is to gain an understanding of the evolution of the system and its coupling strength at RHIC from the initial high temperatures. It will address fundamental questions about the nature of the strongly coupled quark-gluon plasma (QGP). This will be accomplished by using hard-scattered partons that traverse the medium and the Upsilon states to investigate the medium at the different length scales.



Ref:arXiv:1207.6378v2 [nucl-ex] 27 Jul 2012

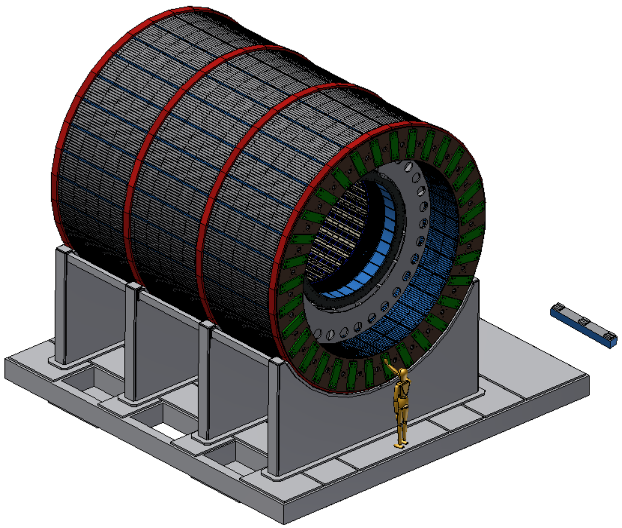


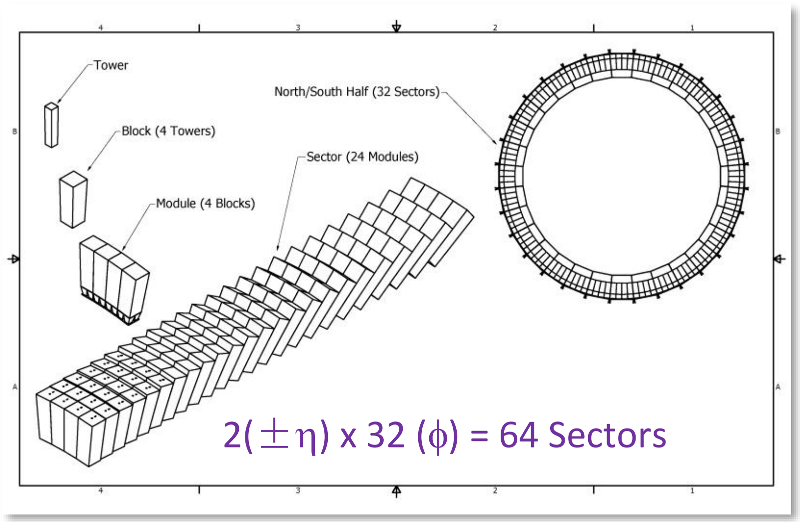
sPHENIX Detector

EMCal Design Performance

The EMCal (Electromagnetic Calorimeter) is an essential sub-detector for sPHENIX to measure the QGP near the critical temperature.

EMCal covering $\pm$ 1.1 in η and 2π in ϕ. $\Delta\phi \times \Delta\eta \sim 0.025 \times 0.025$

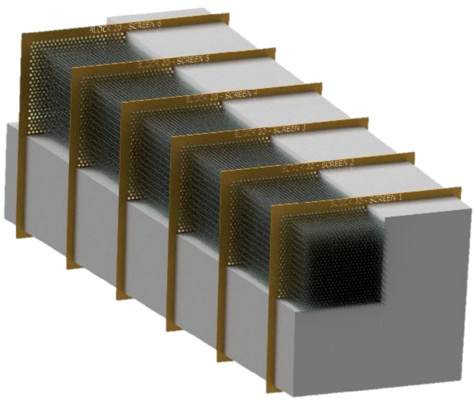


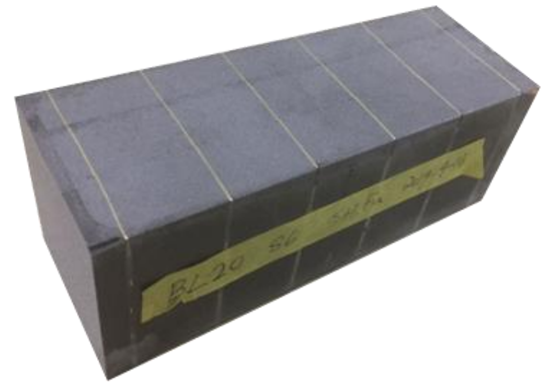


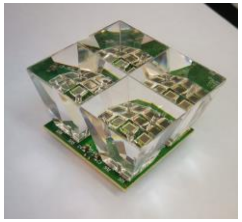
The EMCal performance is central to the direct photon and Upsilon measurements and it is also a key component, along with the HCal, of the jet reconstruction.

EMCal Block Design

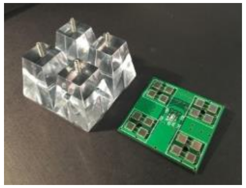
The EMCal block design consists of scintillating fibers embedded in the absorber material, which is a matrix of tungsten powder infused with epoxy (W/SciFi).

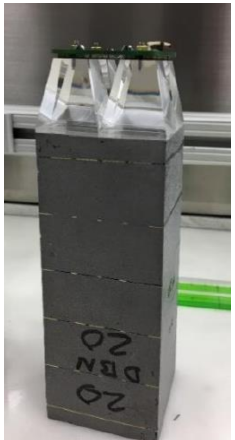






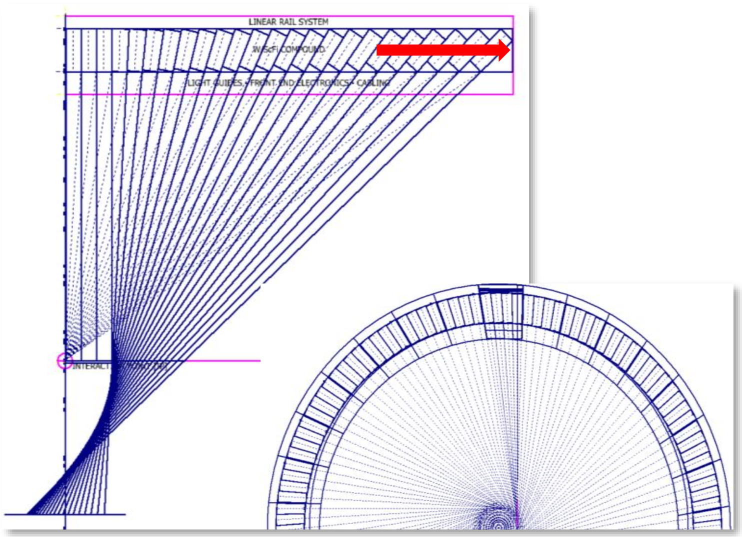
- ➢ High density (9-10 g/cm^3), low radiation length (~7 mm), small Molière radius (~ 2 cm), compact structure and low cost.
- ➢ The readout system adopts light guide combined with SiPM.





W/SciFi Block

The Contribution from China



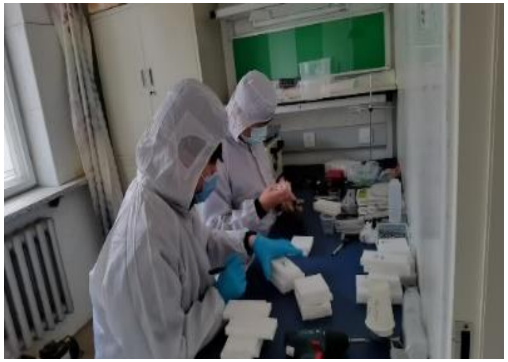
- Total 6144 blocks for EMCal
- 1248 blocks ($0.8<|\eta|<1.1$) will be made in China.

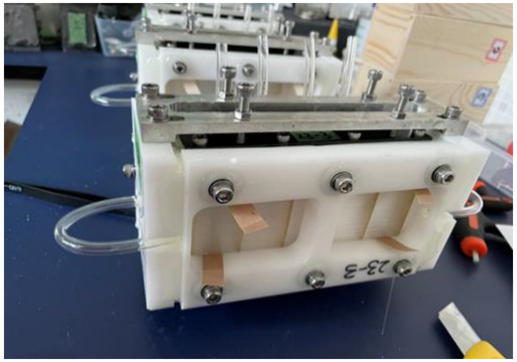
The pseudo-rapidity coverage of $0.8<|\eta|<1.1$ can greatly enhance the physics capability for jets and Upsilon measurements.

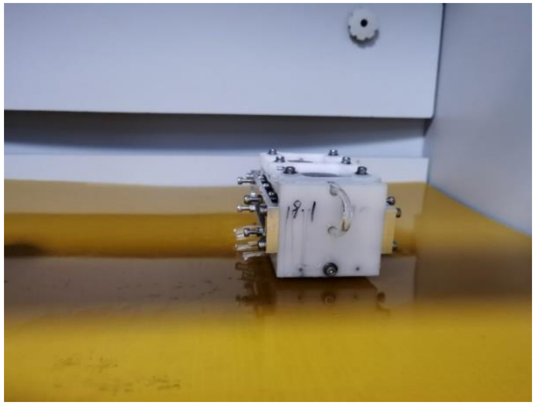
- Fudan, CIAE, and PKU are the main cooperative sites in EMCal construction and make an important contribution to the sPHENIX experiment.

sPHENIX EMCal R&D Center at CIAE

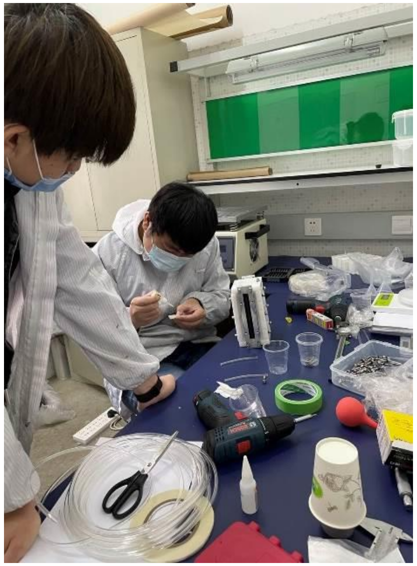
- 2668 fibres in one block
- 1600 kg in total
- 97% finished product ratio







Block Mass Production

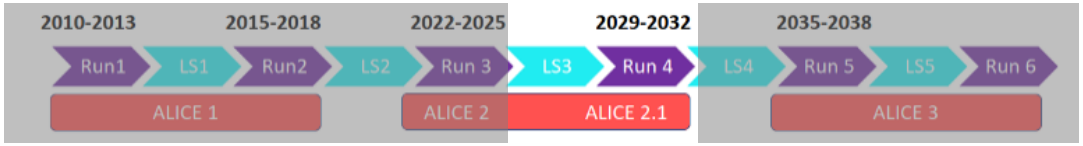




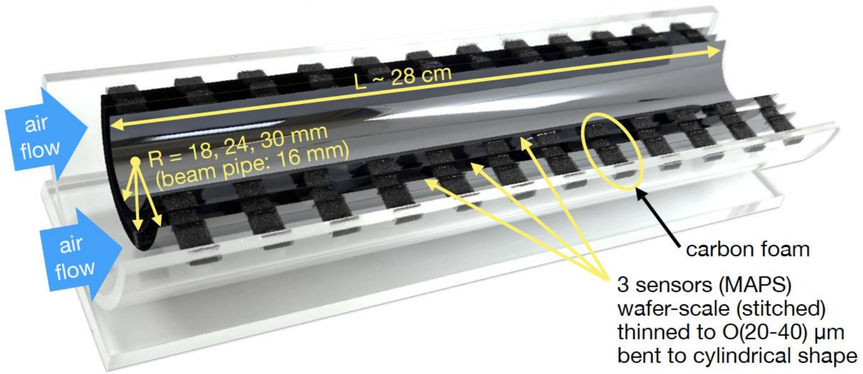

Block Mass Production

ALICE Upgrade

The ALICE 2.1

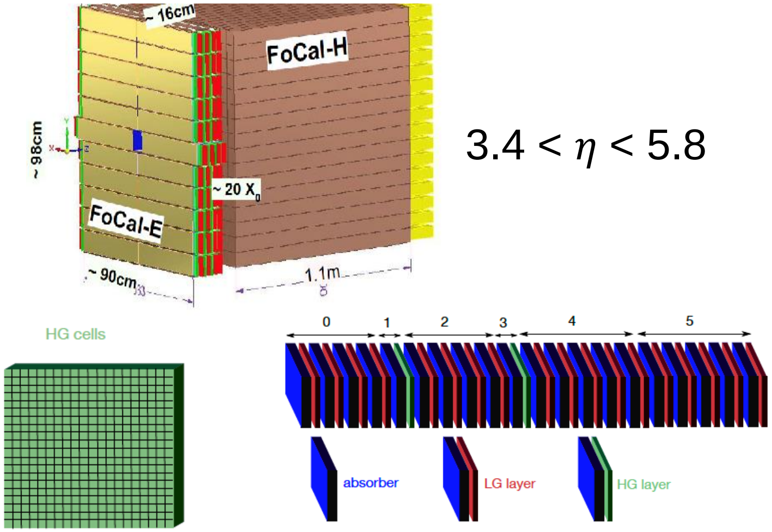


Stiching MAPS-based ITS3



- Replacement of 3 innermost layers of ITS2
- Curved wafer-scale ultra-thin silicon sensors: cylindrical layers (1 sensor per half layer)
- Low power → air cooling → low material budget
- Improved tracking precision and efficiency at low p_T

Silicon-based FoCal

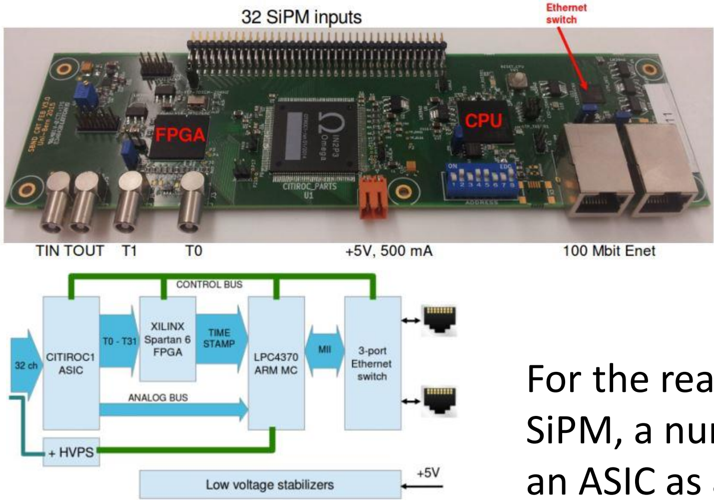


$3.4 < \eta < 5.8$

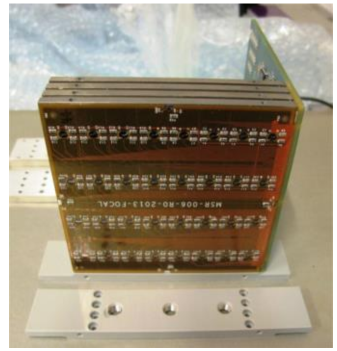
✓ Pad (1x1 cm^2): shower profile and total energy
✓ Pixel (30x30 µm^2): position resolution to resolve overlapping showers

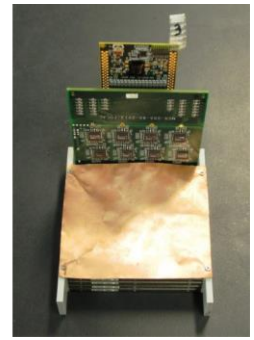
ALICE 2.1-Focal Readout Electronics

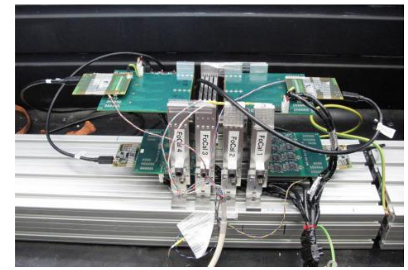
M. Auger et al 2016 JINST 11 P10005



FoCal-H 2021 prototype readout electronics

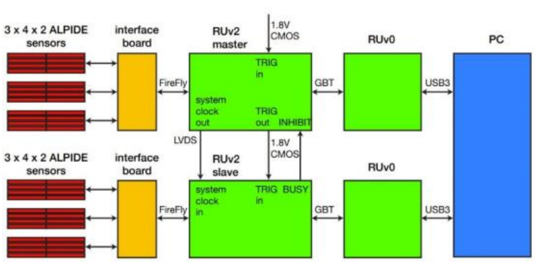






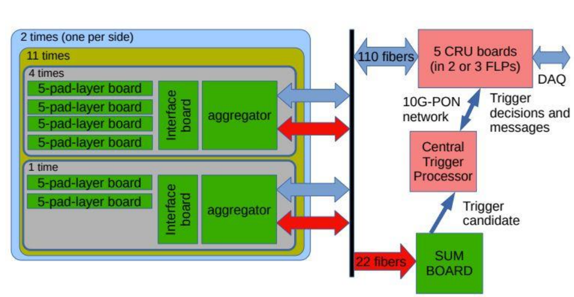
arXiv:1912.11115

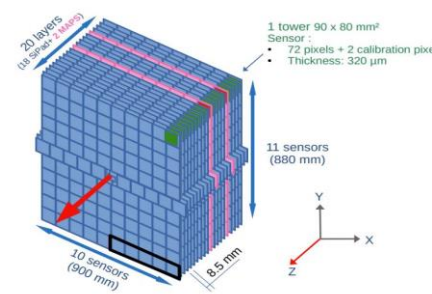
For the readout electronics of Focal-H, with a focus on the readout of the SiPM, a number of prototype electronics have been developed that use an ASIC as an analog front-end and an FPGA as a digital back-end. In the case of Focal-E, the electronics scheme chosen is also different due to the different granularity of the pad layer and the pixel layer.



arXiv:2209.02511

FoCal-E pixel layer prototype EPICAL-2 readout electronics

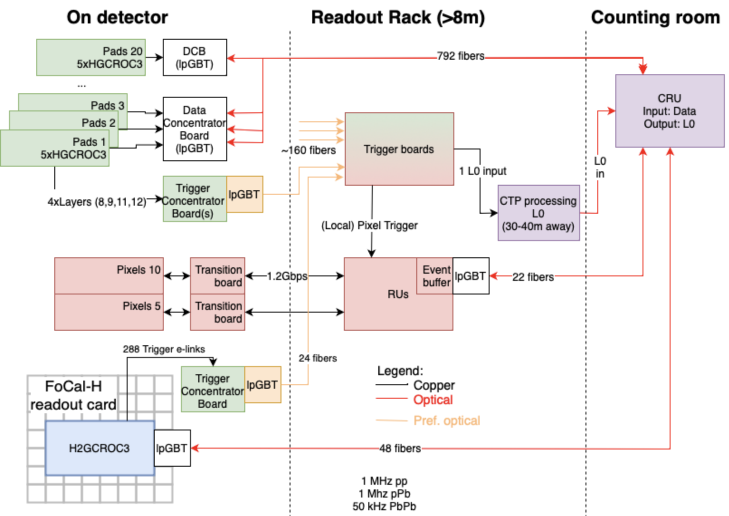




arXiv:2302.13912

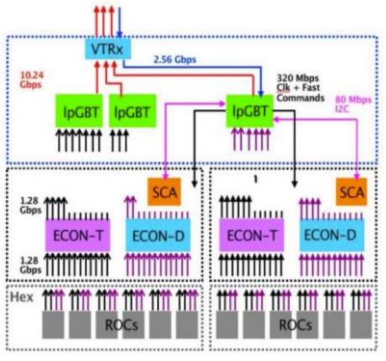
FoCal-E pad layer prototype readout electronics

ALICE 2.1-Focal Readout System

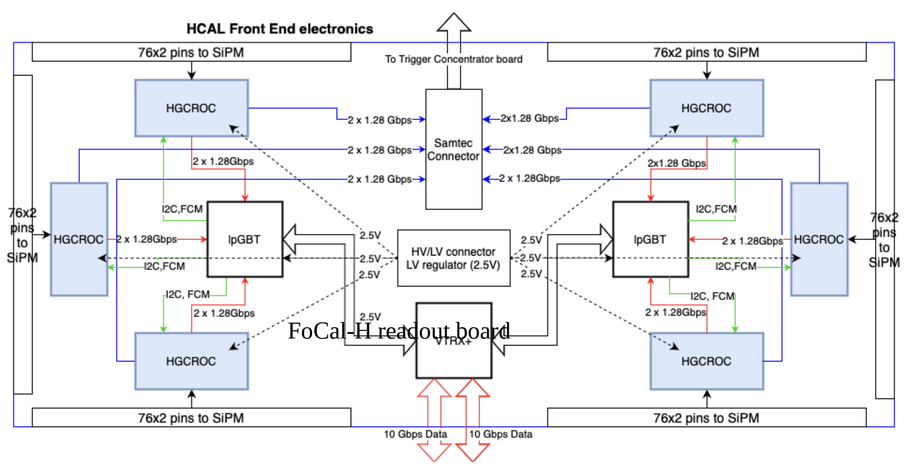


FoCal readout system

Focal Electronics' research borrowed part of the CMS design, and it is planned to use HGCROC as the front-end chip, ECON chip for data compression, lpGBT chip for data transmission, and FPGA for control.



CMS CR -2021/228



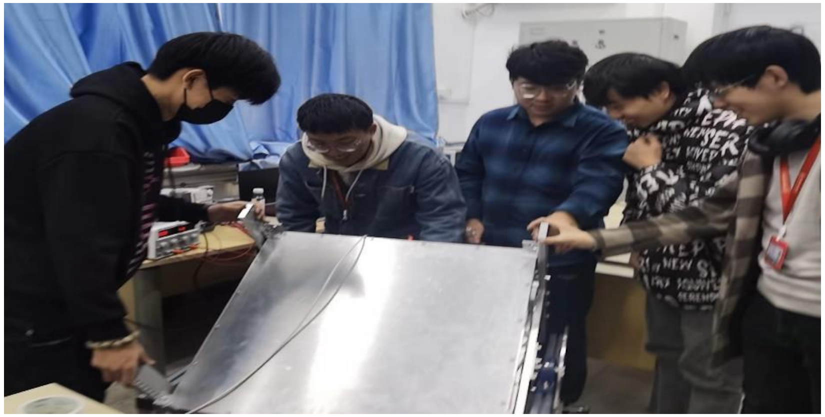
FoCal-H readout board

- Protect FPGAs with Long Readout Rack
- Use ECON-D and lpGBT readout pixel data
- ALPIDE pixels use continuous trigger mode, or through signals provided by the Pad layer

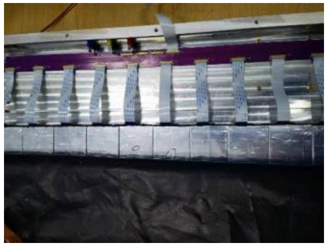
- 6 HGCROC, 2 LpGBT, 1 VTRX+
- 6x72 = 432 channels
- Use ECON-D / ECON-T ASIC compress data

we have to make some improvements.

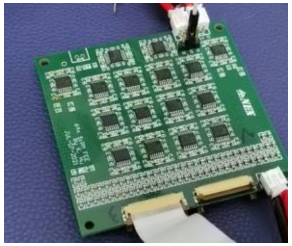
Scintillation Detector Array



Cosmic ray test

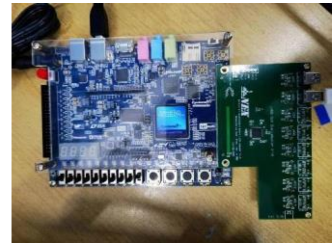


Detector

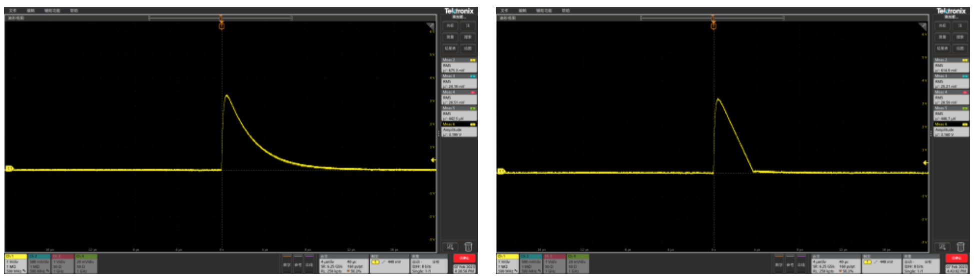


Analog Front End

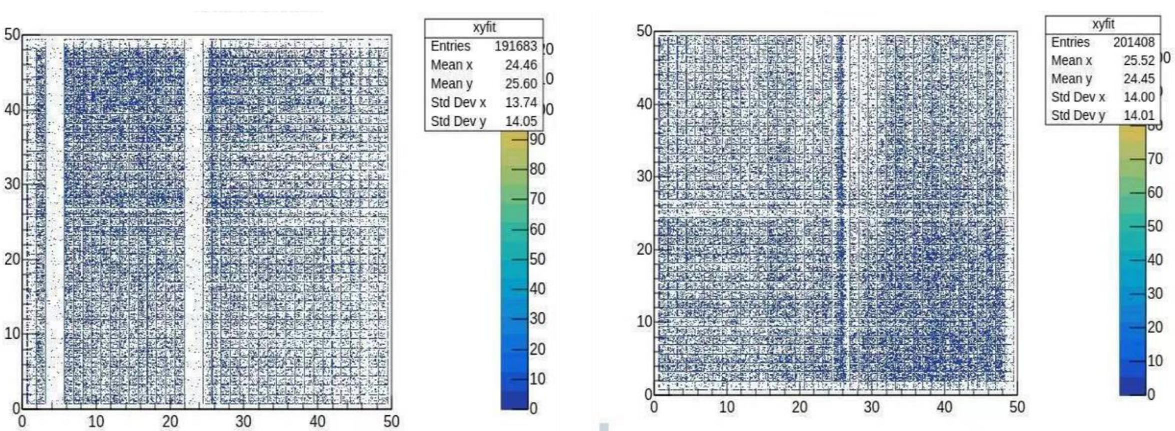
Digitalizer



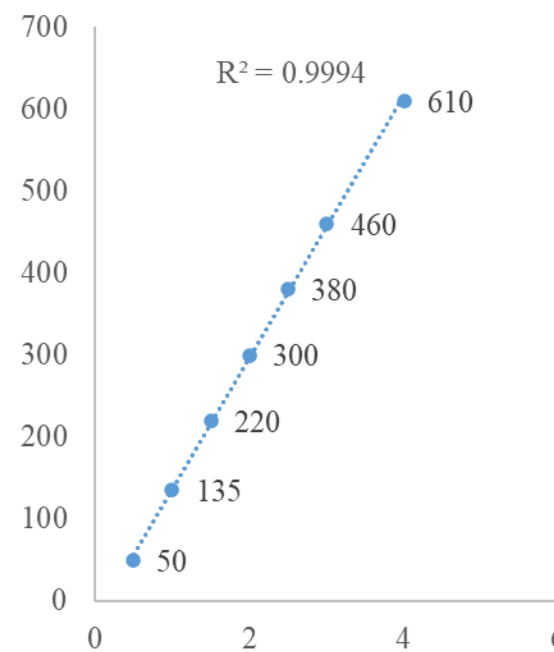
DA
Q



Linear discharge test



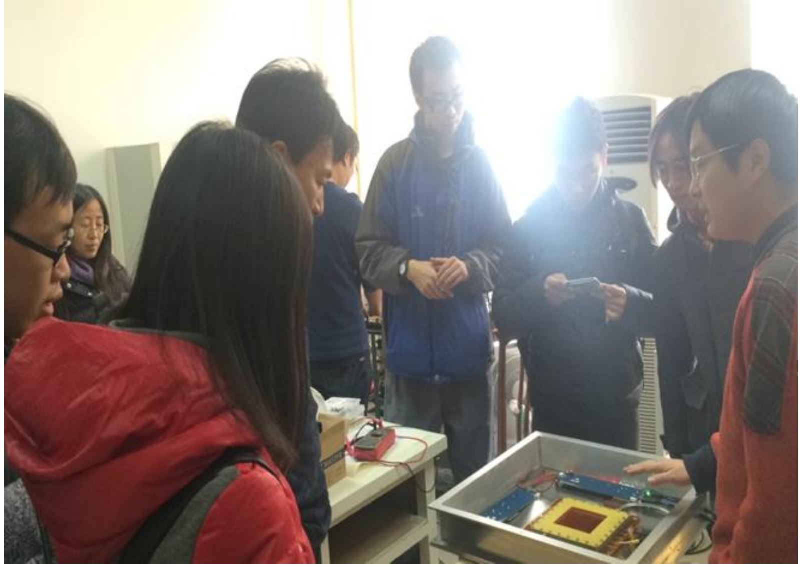
cosmic ray event



Linearity

Team Members

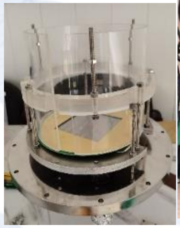
Visitors

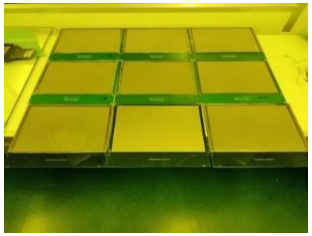
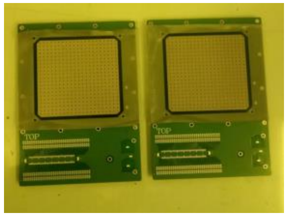
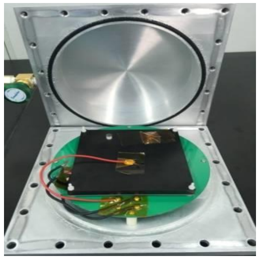


Summary and Perspective

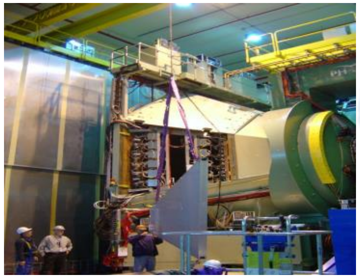
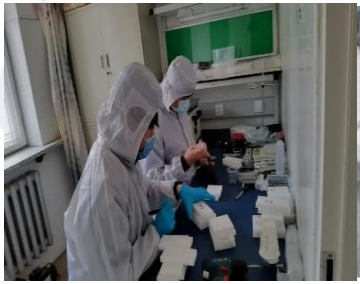
Current Applications and Collaborations








Thanks for your attention!

北京市275信箱46分箱　邮编102413　电话69357849　传真69357787