中国科学院大学
University of Chinese Academy of Sciences

CEPC

Status of the CEPC DHCAL

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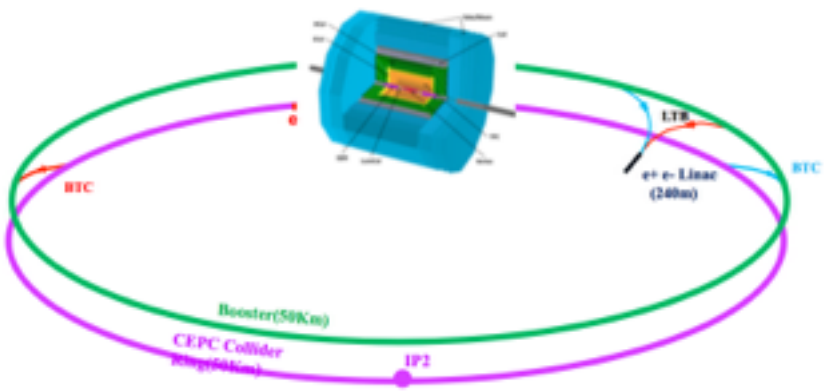
On behalf of CEPC-CALO group
University of Chinese Academy of Sciences (UCAS)

OUTLINE

- Motivation
- CEPC DHCal concepts
- Current status report:
    - Simulation
    - Detector R&D
- Conclusion & perspective

MOTIVATION



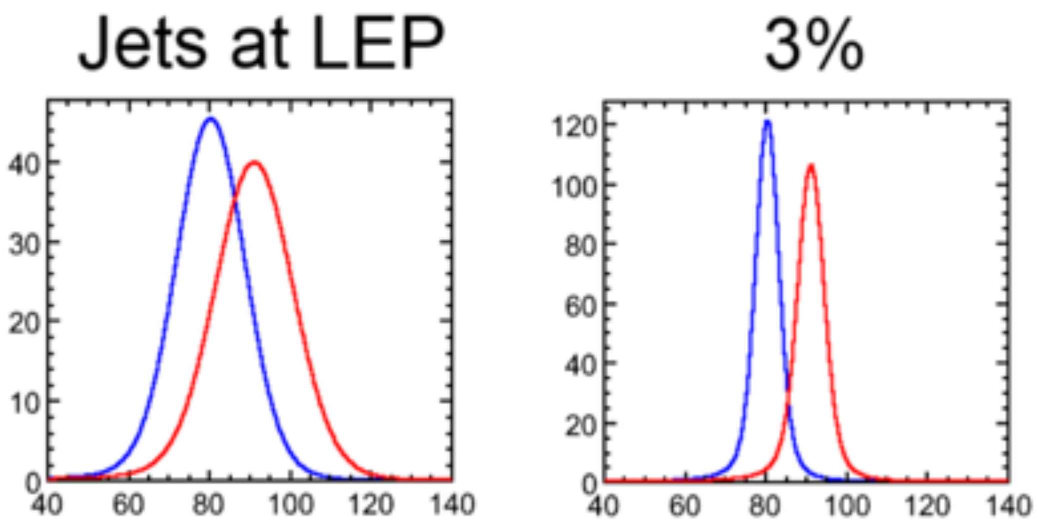
- CEPC offers unique physics possibilities:
  - precise model-independent Higgs coupling
  - precision measurements of W/Z properties
  - indirect and direct searches for BSM physics

- Jet energies resolution requirement:

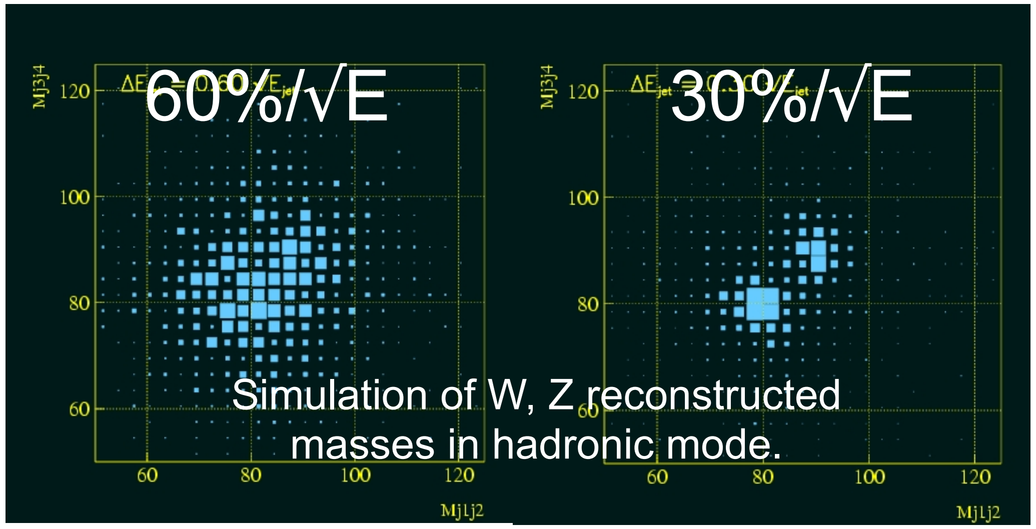
Physics Process	Measured Quantity	Critical Detector	Required Performance
$ZH \to \ell^+\ell^- X$	Higgs mass, cross section	Tracker	$\Delta(1/p_T) \sim 2 \times 10^{-5}$
$H \to \mu^+\mu^-$	$\mathrm{BR}(H \to \mu^+\mu^-)$		$\oplus 1 \times 10^{-3}/(p_T \sin\theta)$
$H \to b\bar{b},\ c\bar{c},\ gg$	$\mathrm{BR}(H \to b\bar{b},\ c\bar{c},\ gg)$	Vertex	$\sigma_{r\phi} \sim 5 \oplus 10/(p \sin^{3/2}\theta)\ \mu\mathrm{m}$
$H \to q\bar{q},\ V^+V^-$	$\mathrm{BR}(H \to q\bar{q},\ V^+V^-)$	ECAL, HCAL	$\sigma_E^{\mathrm{jet}}/E \sim 3-4\%$
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\sigma_E \sim 16\%/\sqrt{E} \oplus 1\%$ (GeV)

MOTIVATION

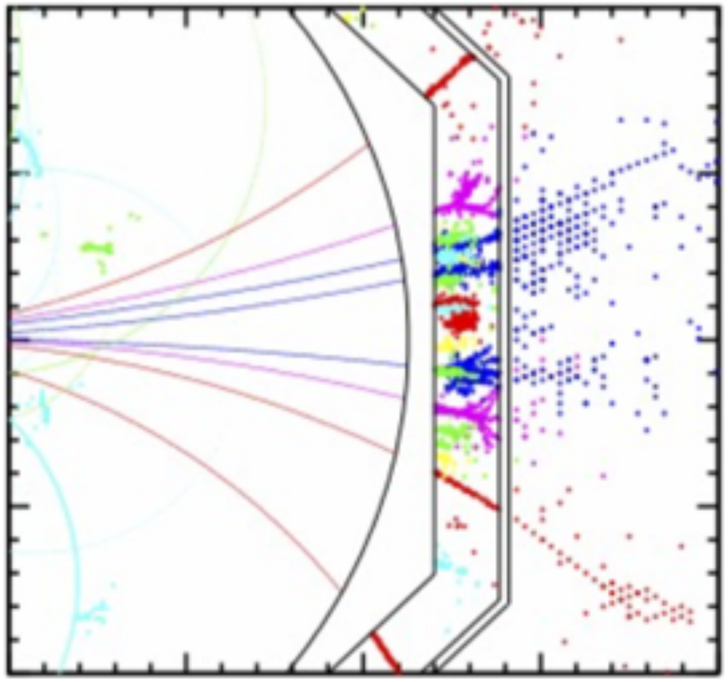
- With 3%~4% resolution, we can get:



From Katja Krüger (DESY)

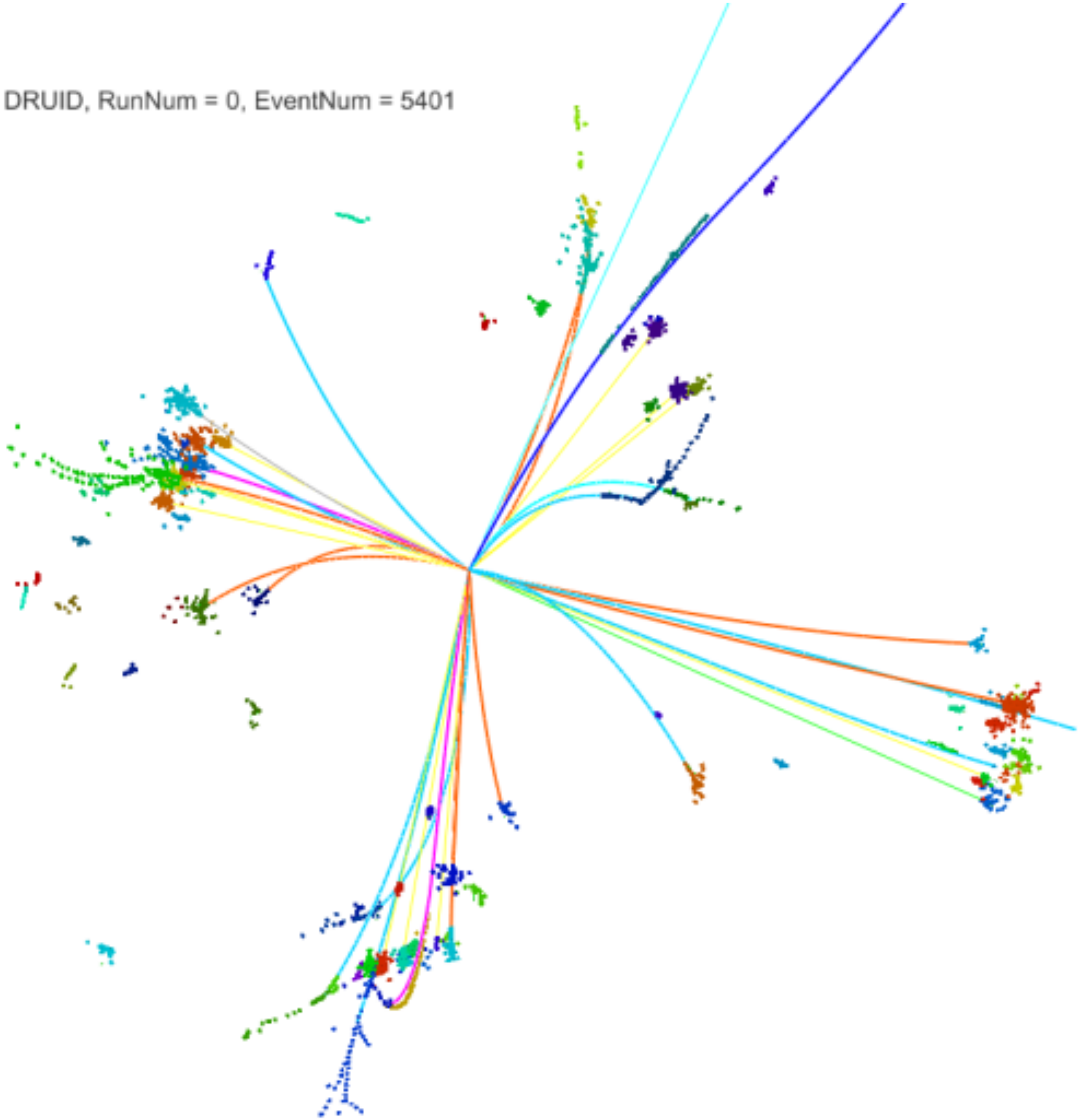


- PFA (particle flow algorithm) is needed.
    - For each individual particles in a jet, use the detector with the best energy resolution.

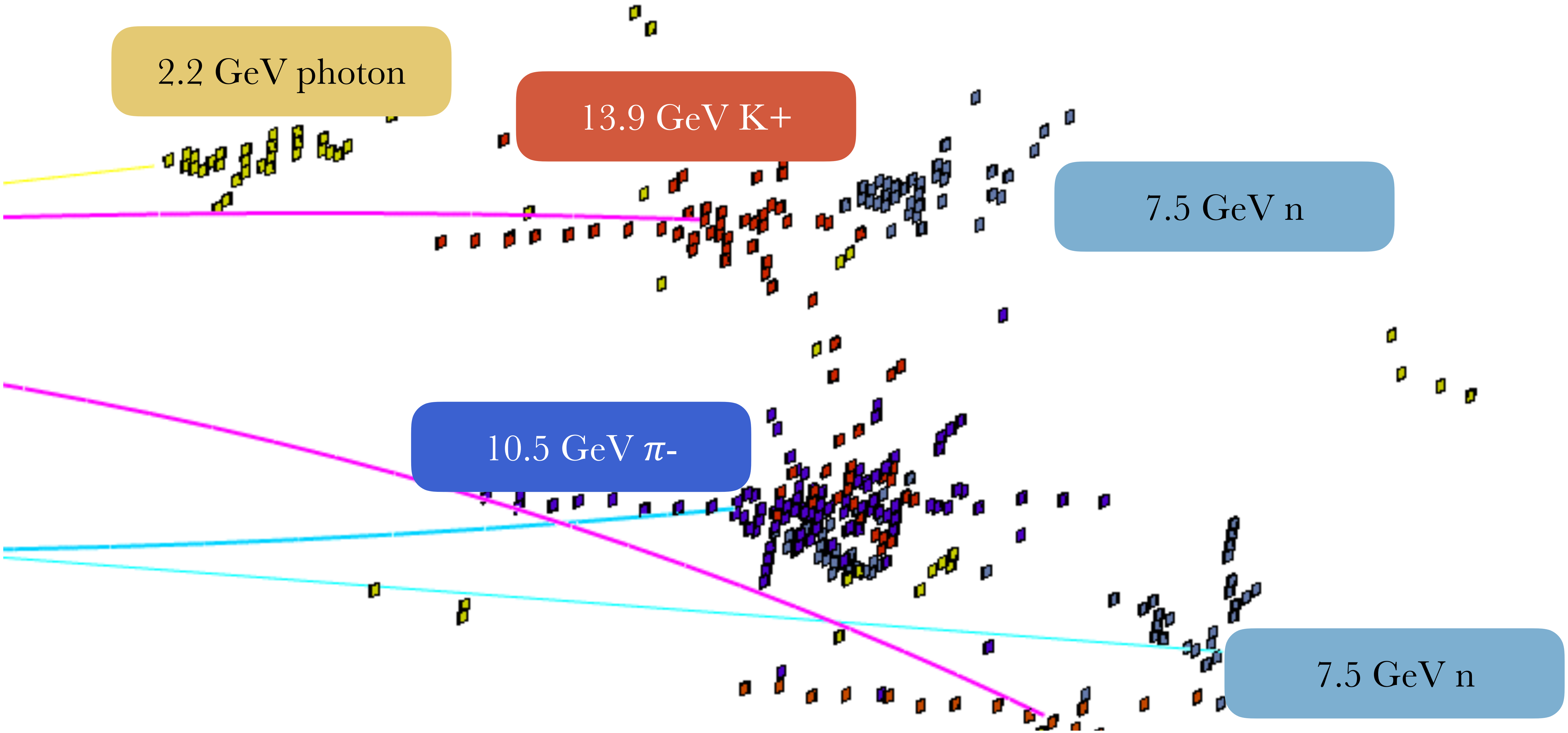


from: M.A. Thomson,
Nucl.Instrum.Meth. A611 (2009) 25

SIMULATION



By Shi CHEN (UCAS)

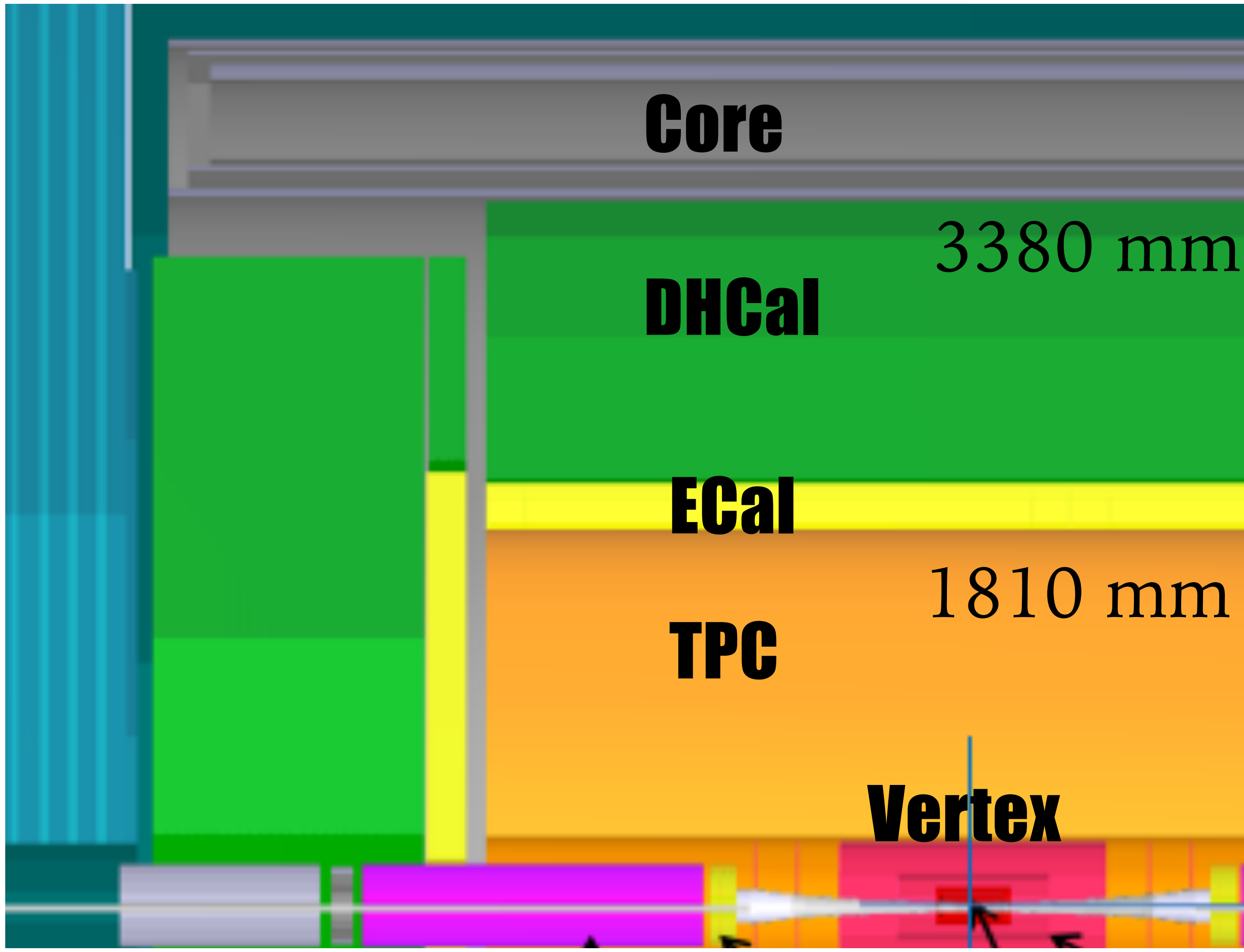


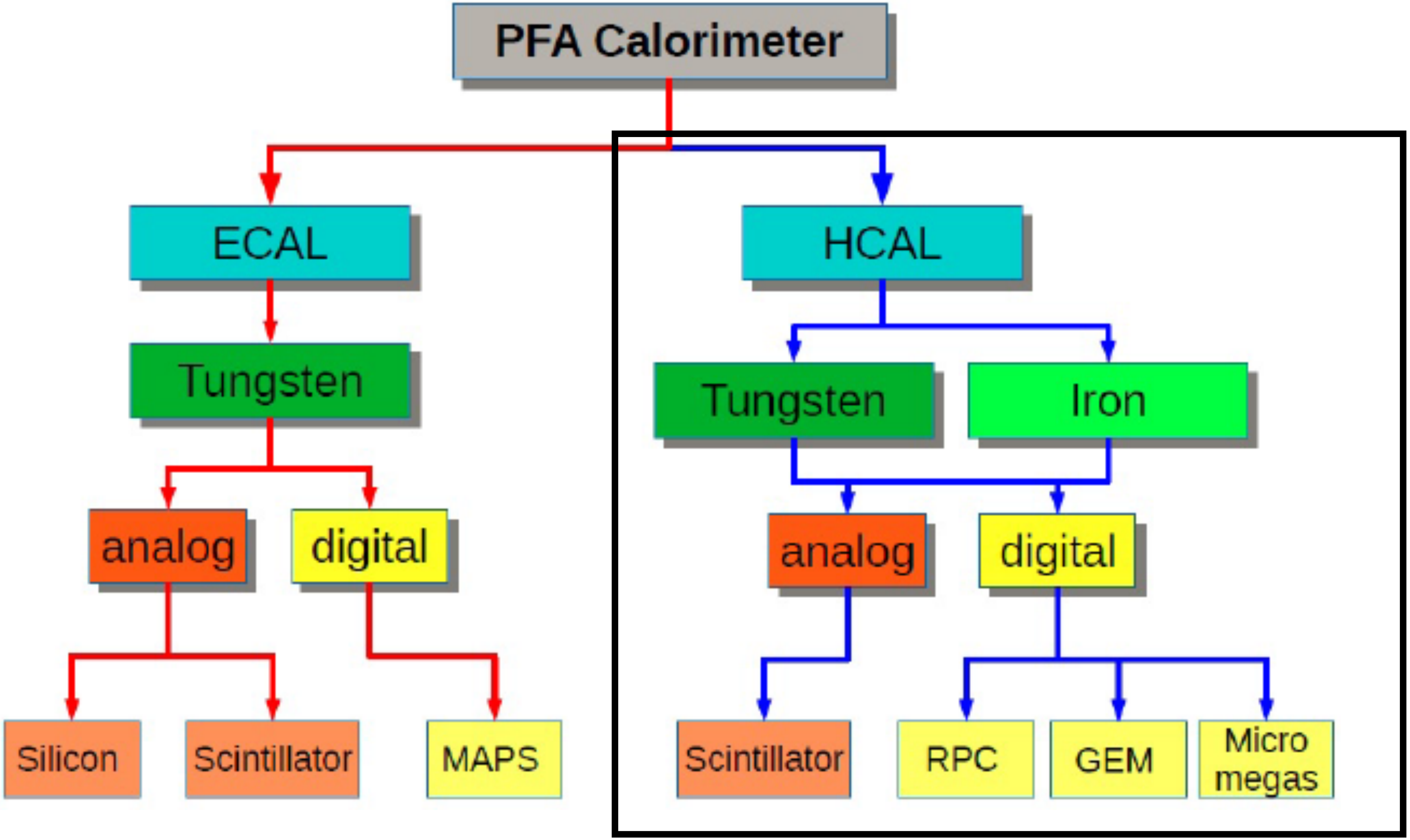
„typical" jet:

		$(\sigma_{jet})^2$
~ 60% charged particles	tracking	$= (\sigma_{tracks})^2$
~ 30% photons	EM calorimeter	$+ (\sigma_{EMCalo})^2$
~ 10% neutral hadrons	HAD calorimeter	$+ (\sigma_{HADCalo})^2$
~~ 1% neutrinos~~		$+ (\sigma_{loss})^2 + (\sigma_{confusion})^2$

CEPC DHCAL CONCEPT - PFA DETECTOR

- Good separation of particles entering the calorimeter
  - Large radius & length
  - Large magnetic field (chg. neu.)
- Minimal amount of dead material between tracker & calorimeter
  - DHCal/ECal inside core
- Compact shower to minimize the overlap
  - Small Molière radius
- Detailed information of shower position & shape
  - High granularity calorimeter



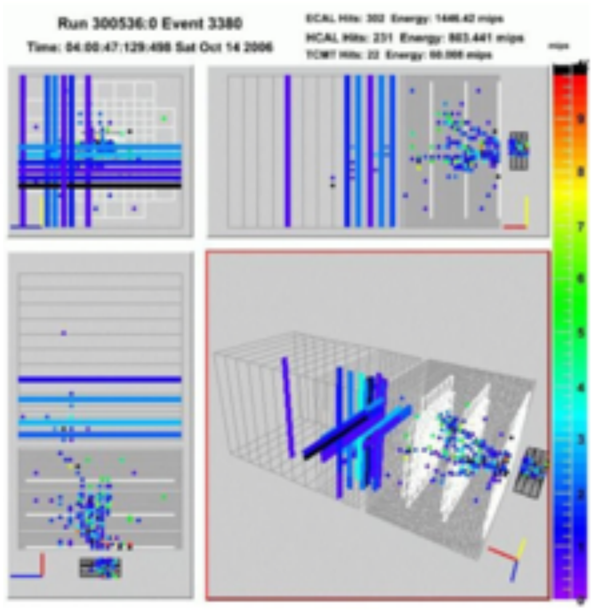

PFA Calorimeter
ECAL
HCAL
Tungsten
Tungsten
Iron
analog
digital
analog
digital
Silicon
Scintillator
MAPS
Scintillator
RPC
GEM
Micro megas

CALICE DHCAL

From Katja Krüger (DESY)

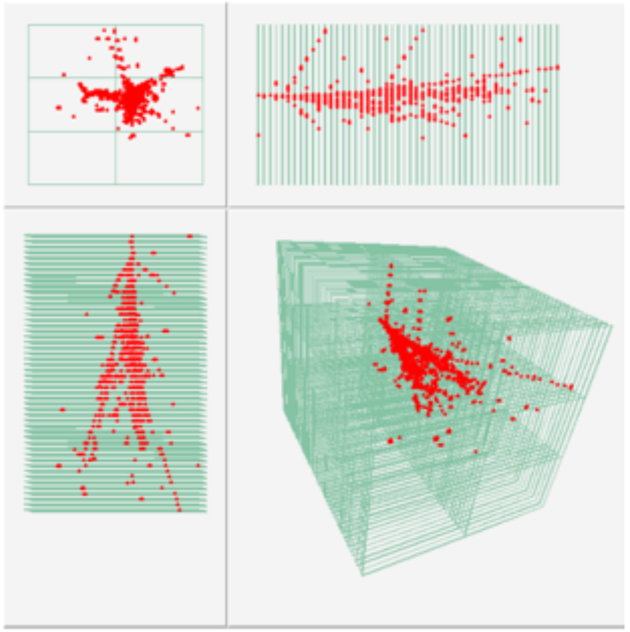
Analog DHCal

- Scintillator tiles with wave length shifting fibers, read out by SiPMs
- 3*3 cm^2 - 12*12 cm^2 tiles
- readout: 12 bit (analog)
- **ILD option, SiD baseline, CLIC**



Digital DHCal

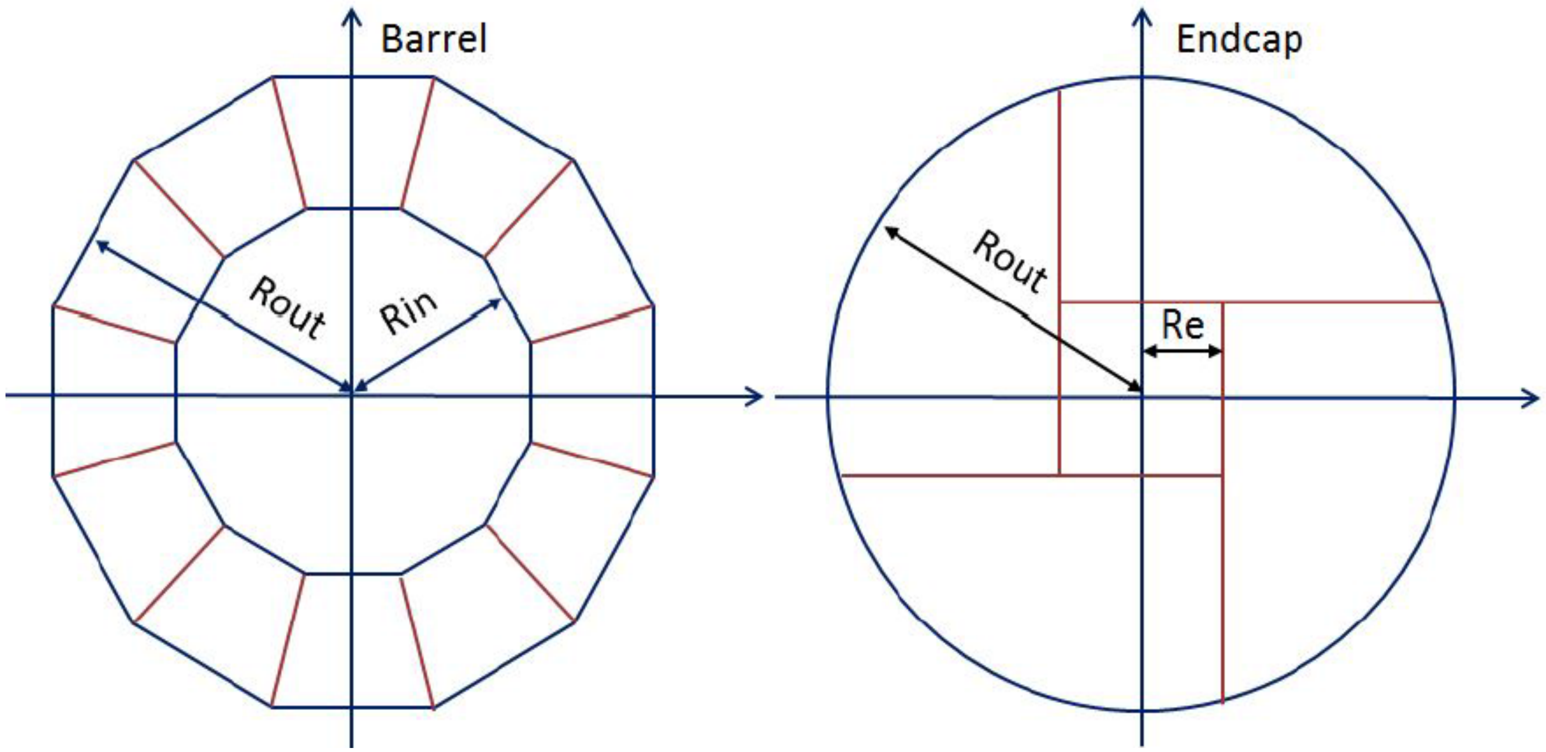
- Resistive Plate Chamber: local gas amplification between 2 glass plates with high voltage
- 1*1 cm^2 readout pads
- readout: 1 bit (digital)
- **SiD alternative**



CEPC DHCAL OPTIMIZATION

- To full fill the requirements of CEPC PFA, the DHCal is optimized by the following:
  - layers of DHCal, scanned from 20 layers to 48 layers.
  - size of each cell, scanned from 10 mm to 80 mm.
  - digitization (Q spectrum, spatial resolution, semi-Digi, etc..)

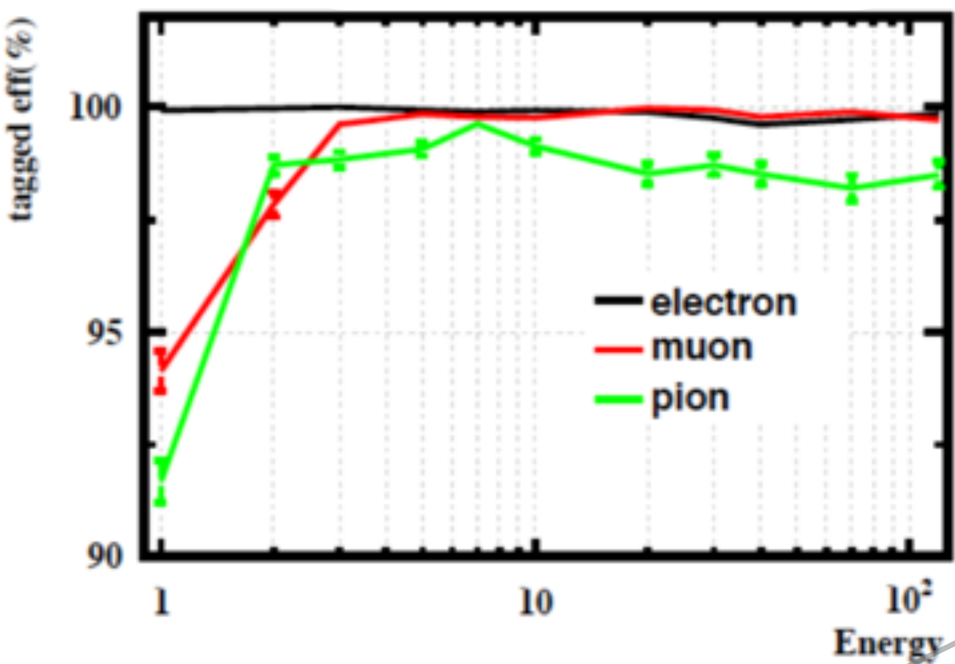
- The HCAL consists of
  - a cylindrical barrel system: 12 modules
  - two endcaps: 4 quarters
- Absorber: Stainless steel



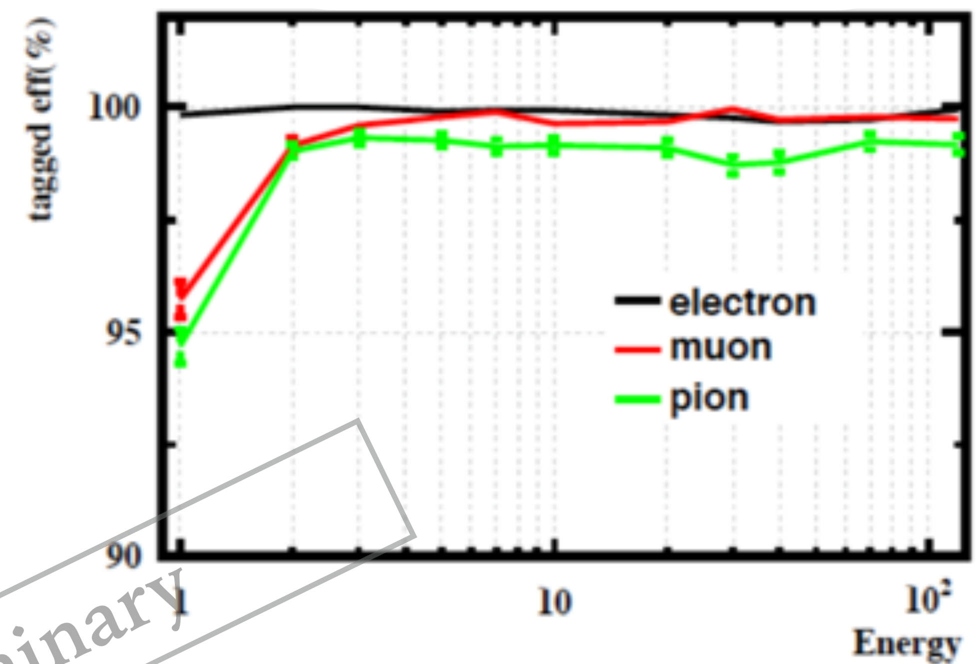
DHCAL LAYER NUMBER

Preliminary result From **Manqi** and **Dan Yu**'s report (IHEP)

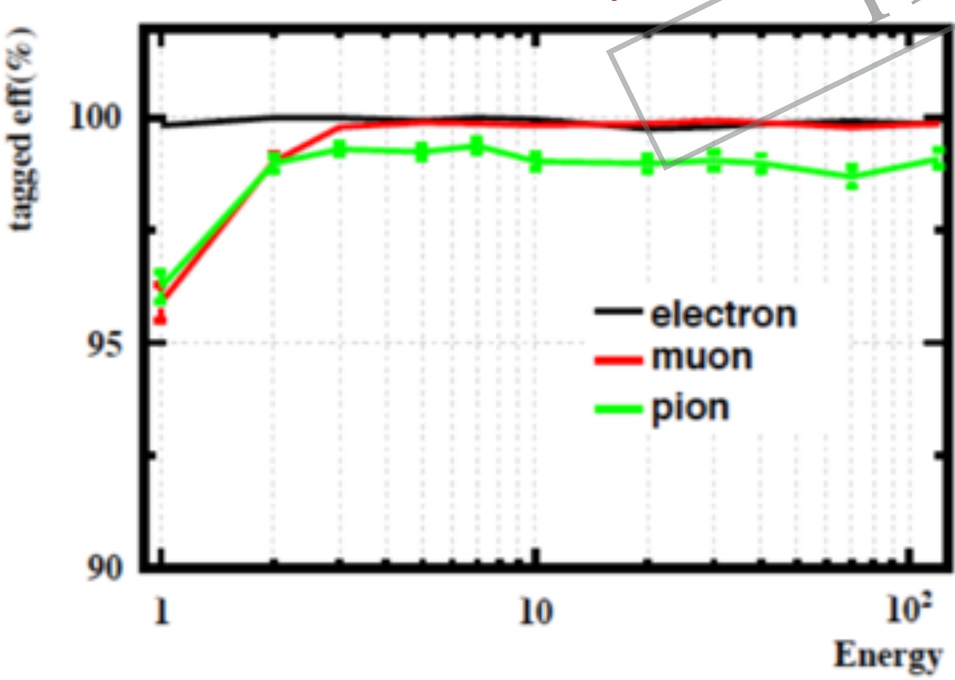
20 layers



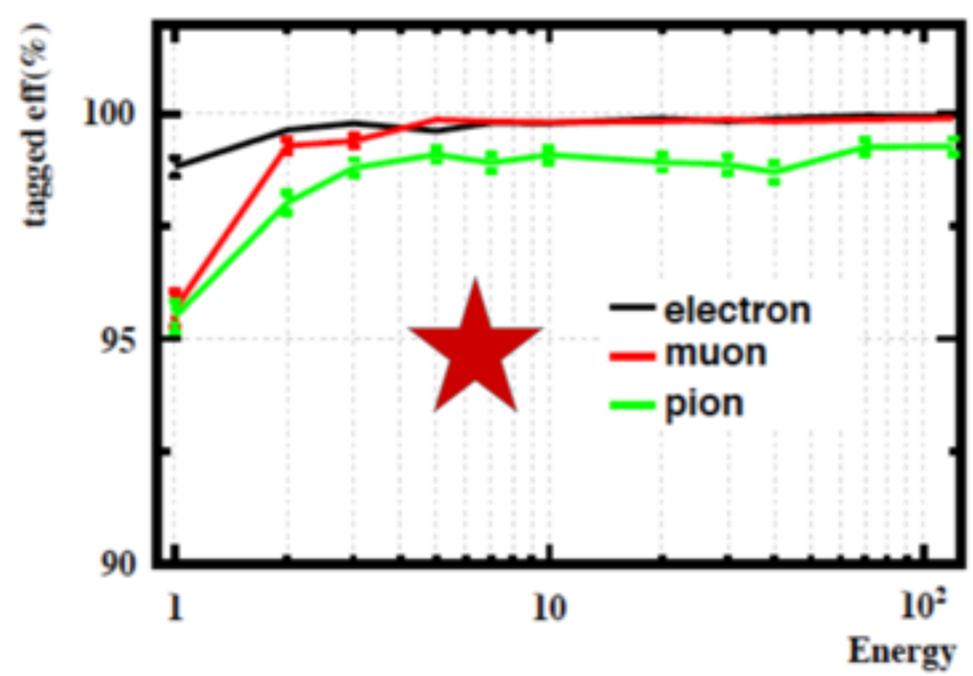
30 layers



40 layers

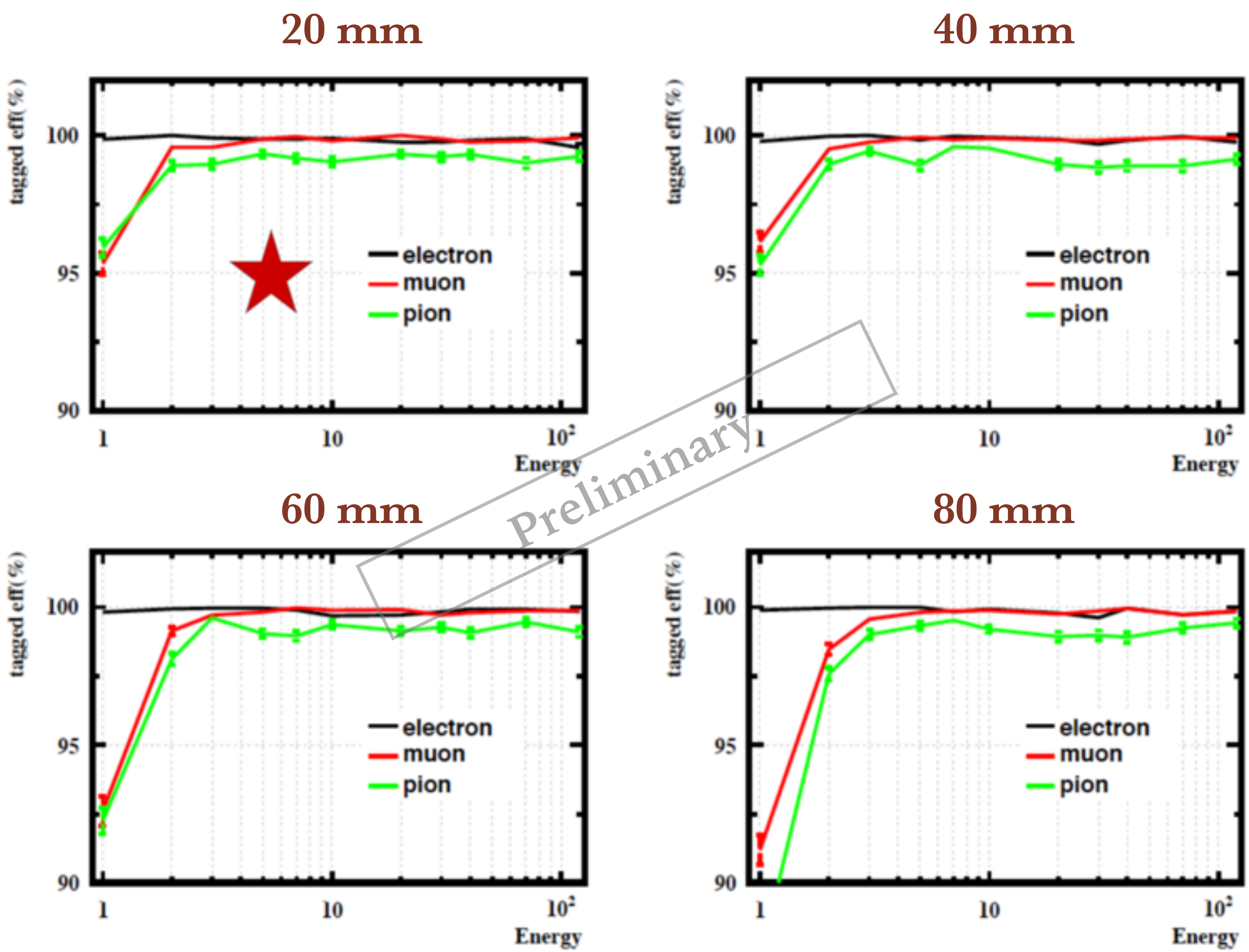


48 layers



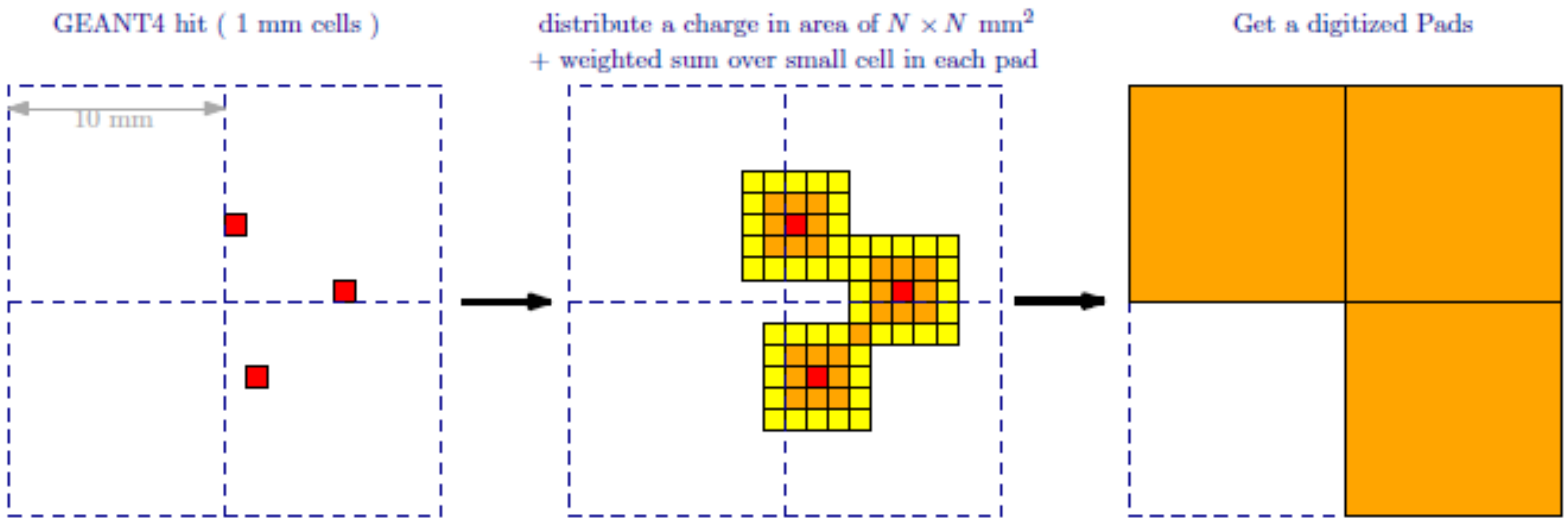
DHCAL CELL SIZE

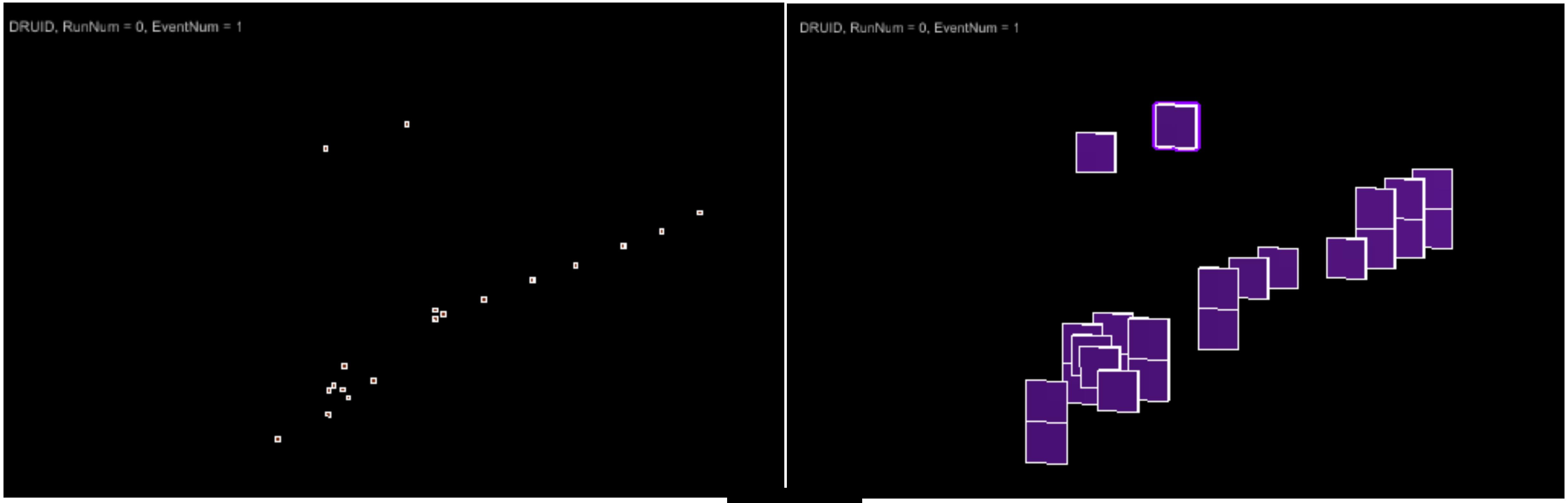
Preliminary result From **Manqi** and **Dan Yu**'s report (IHEP)

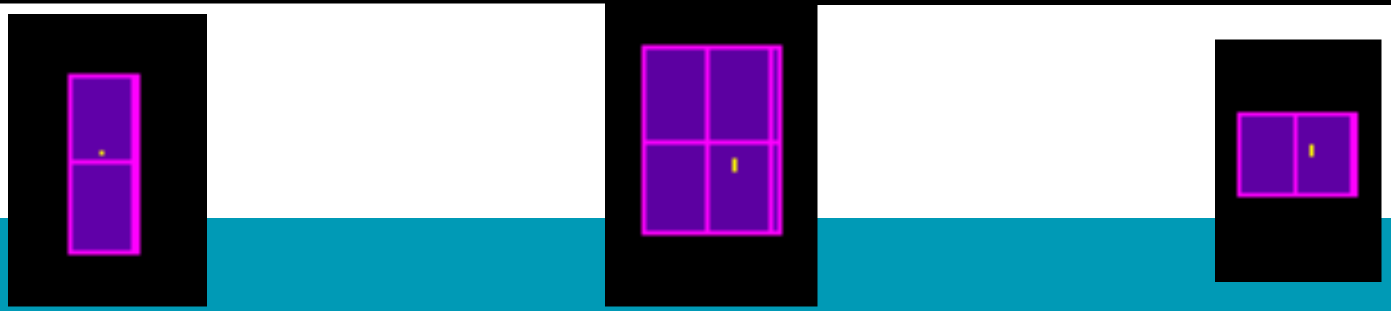


The smallest size gives the best result.

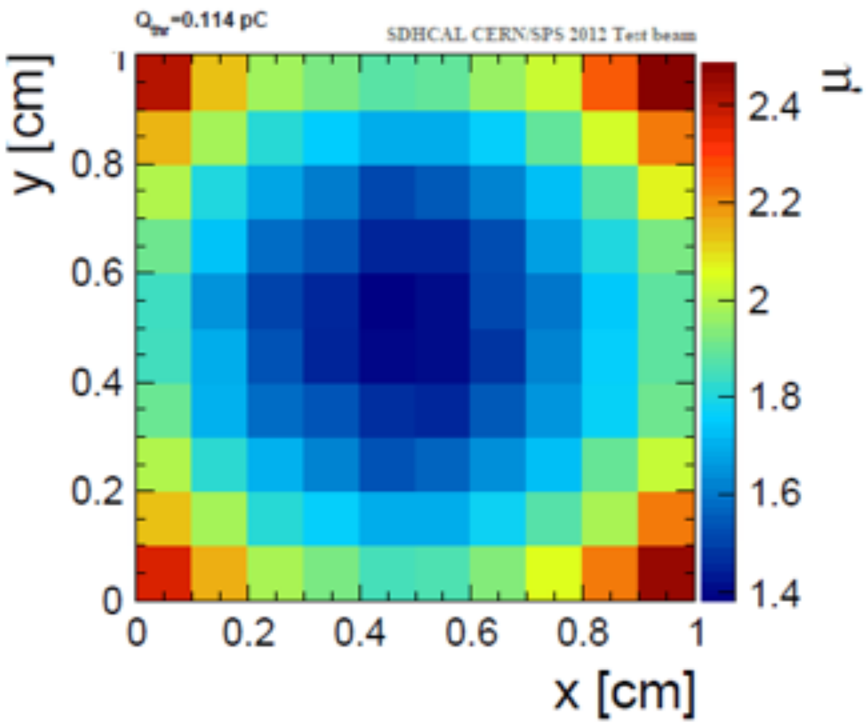
DIGITIZATION CONCEPT





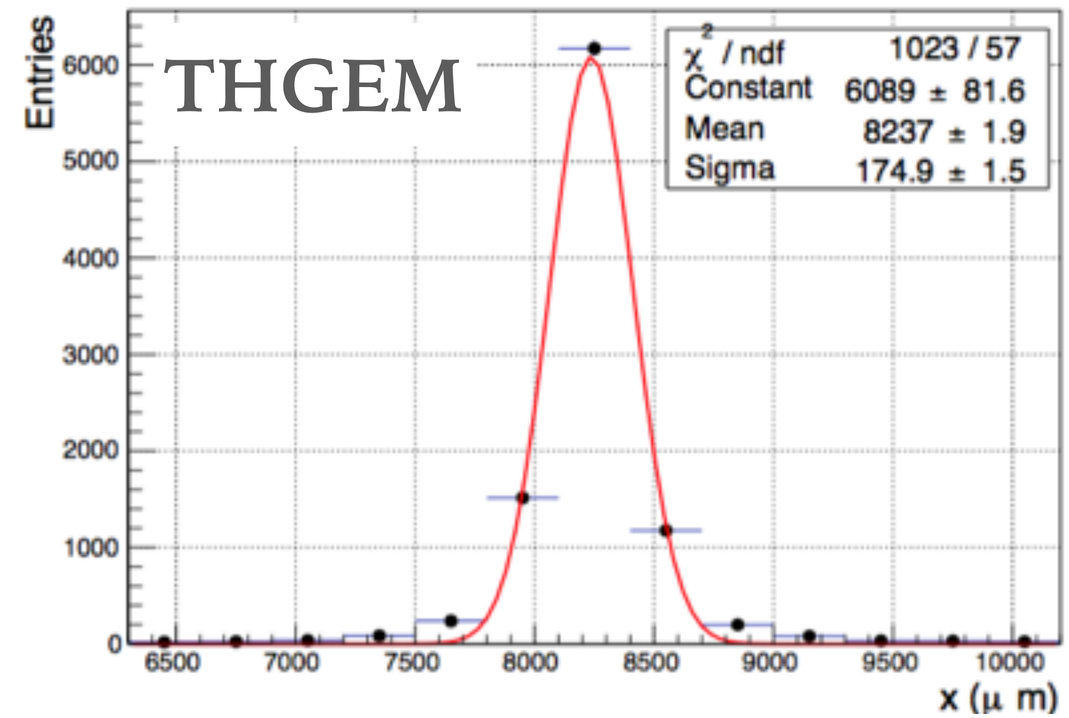


DIGITIZATION INPUT

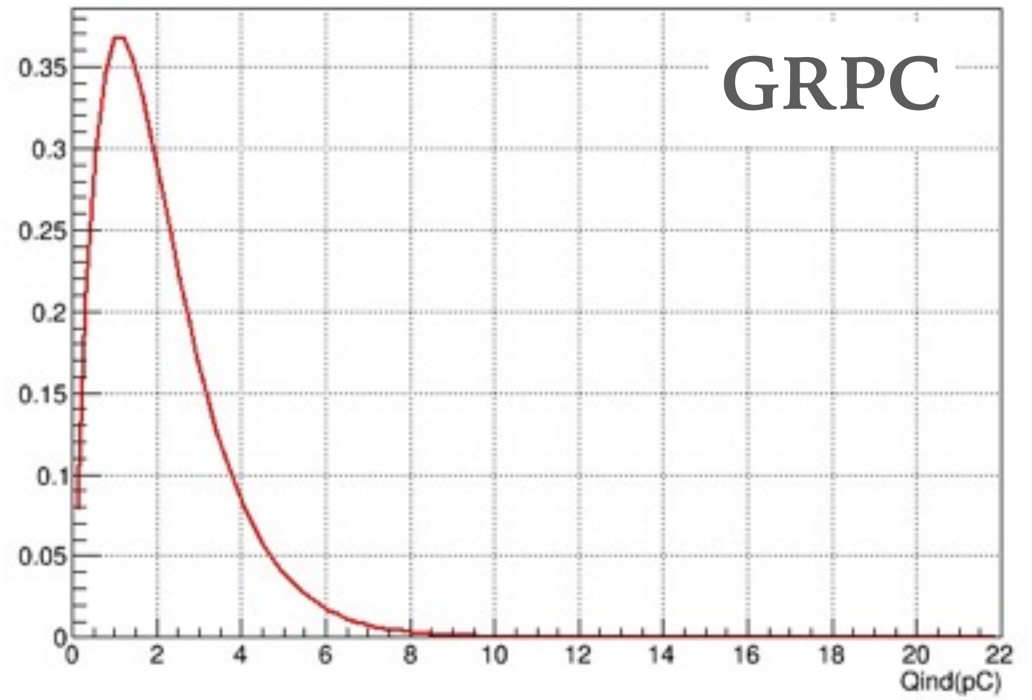


Multiplicity *~ 2mm spa. res.*

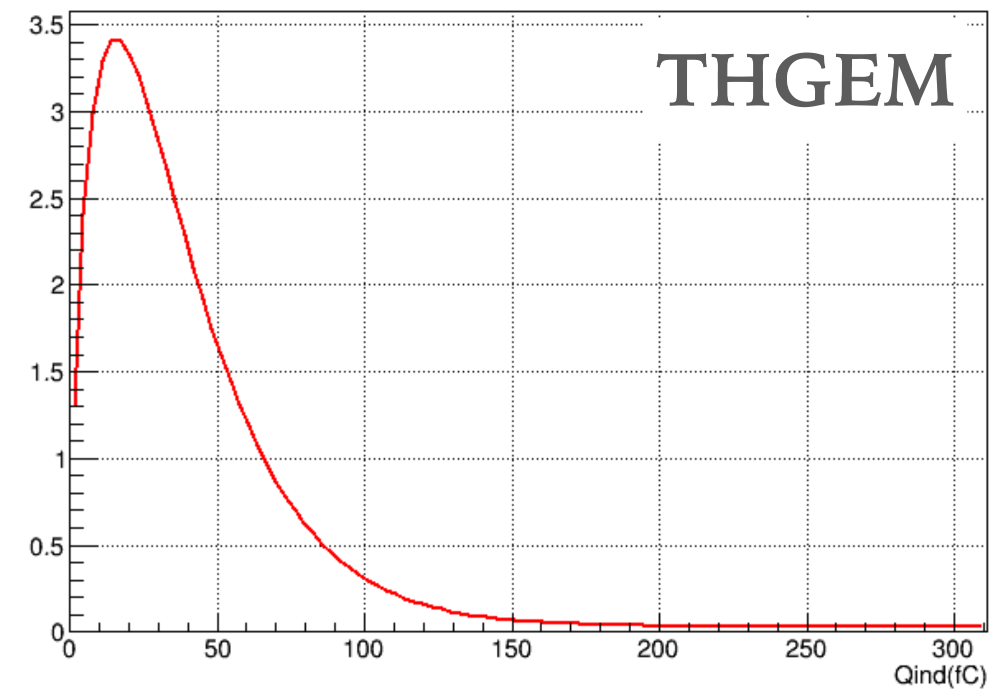
~ 0.5mm was used



Spatial res. obtained from binary readout



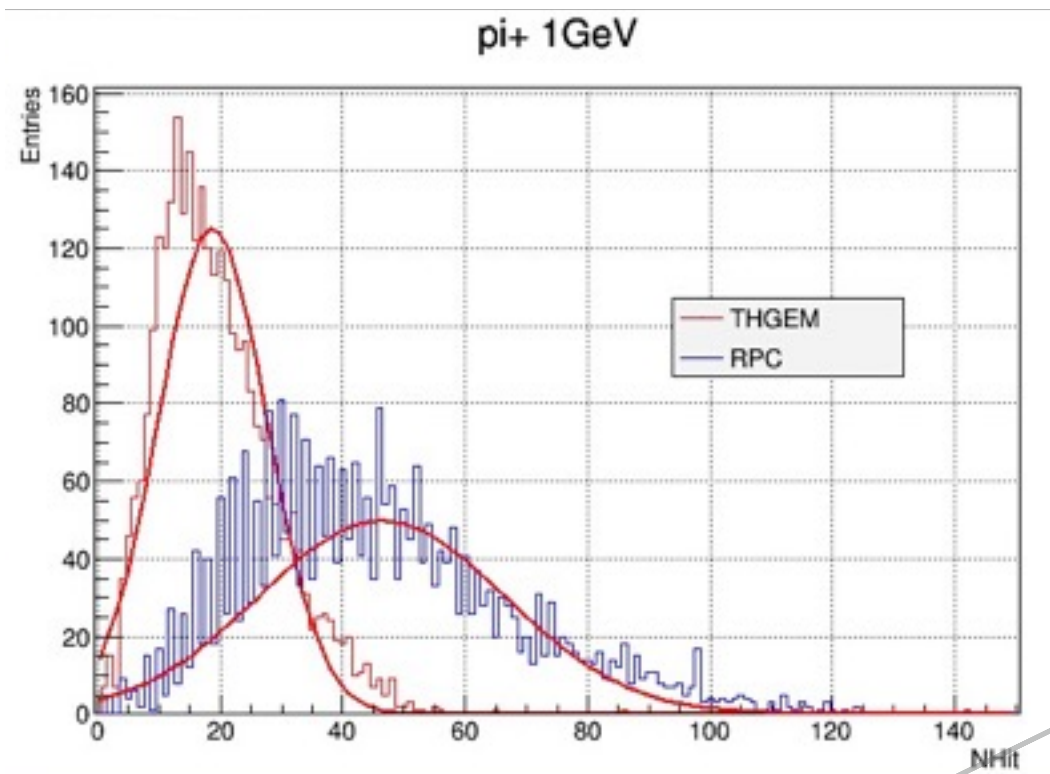
Q spectrum

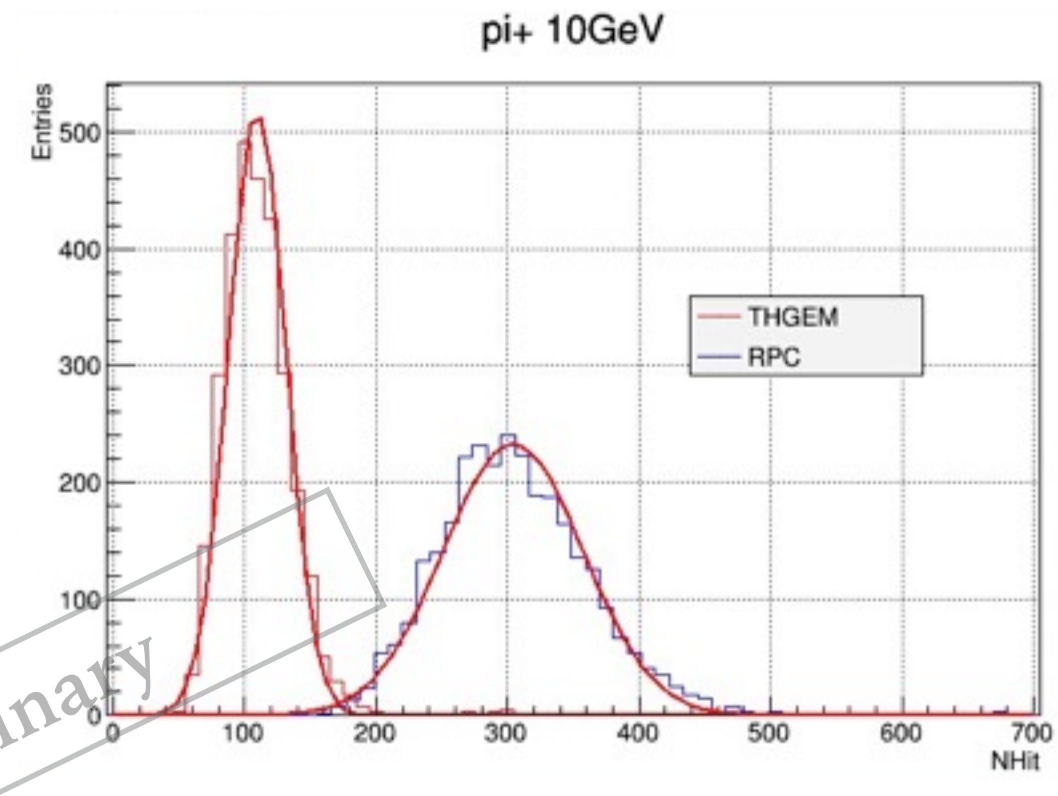


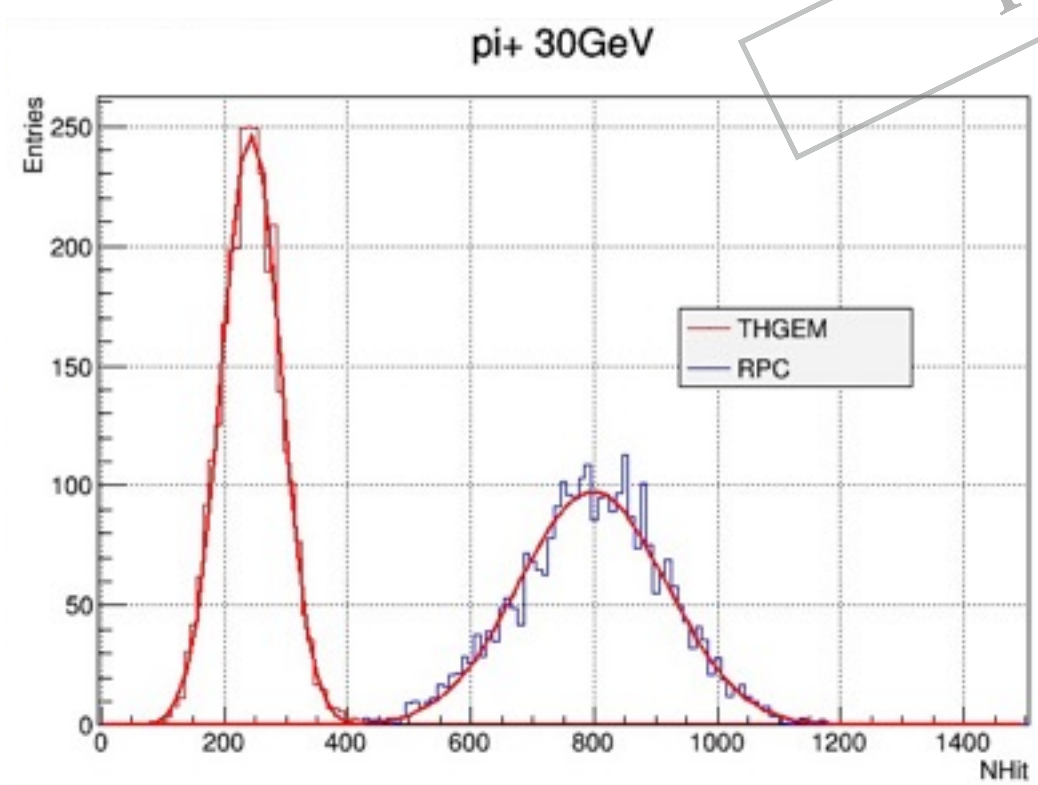
Q spectrum

DIGITIZATION

Preliminary result From **Shi CHEN**'s report (UCAS)







- 10mm x 10mm cell size and 200 layers of DHCal (only) were using to study the digitization response.
- The non-gaussian like shape of 1 GeV is caused by the decay of pion before reaching DHCal.

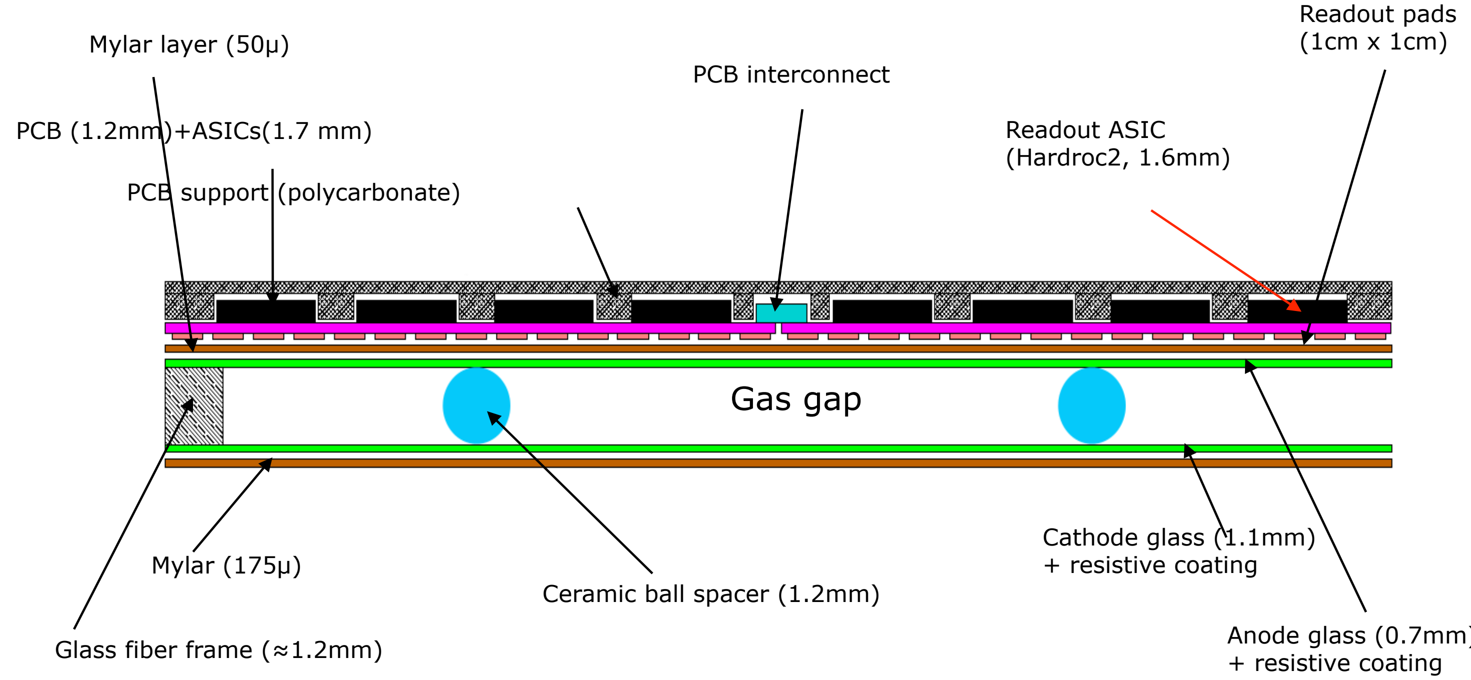
DETECTOR R&D

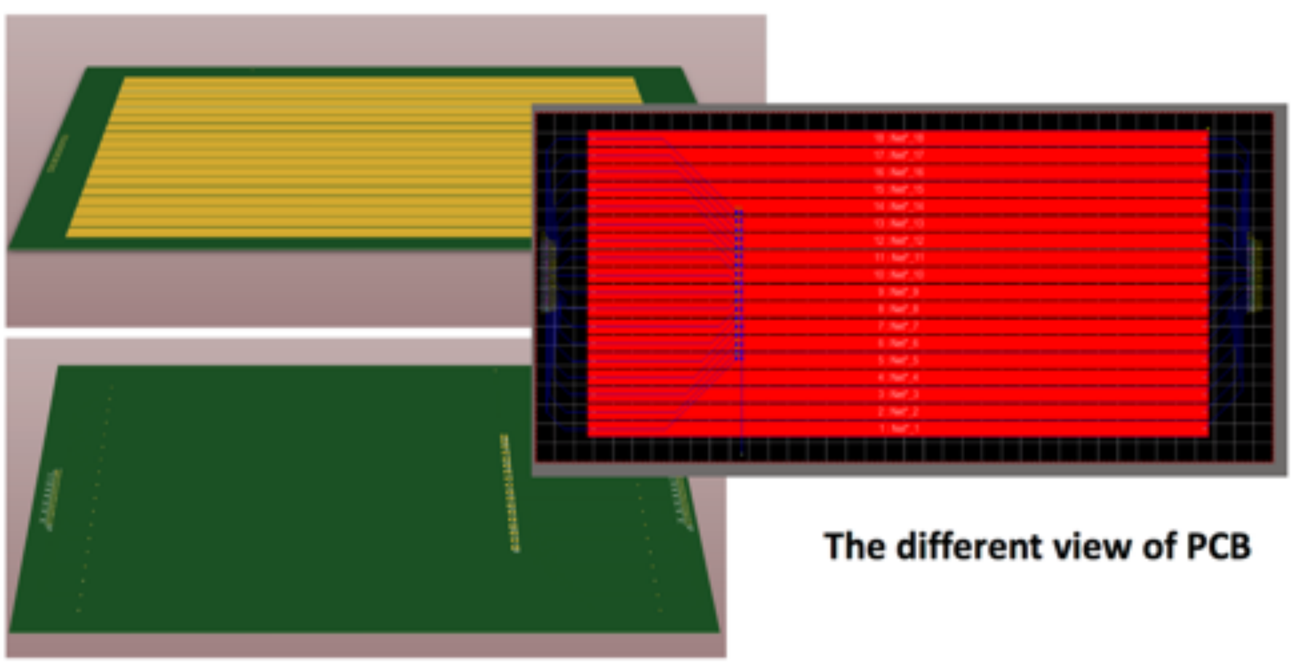
- Different type of sensitive detectors
  - RPC → Large Glass RPC
  - GEM → Double-layer, self-stretching
  - THGEM → Well-THGEM, Larger size

RPC R&D

From **Haijun Yang** (SJTU)

- ➤Large Glass RPC R&D
  - ➤Negligible dead zone
  - ➤Large size: 1x1 m^2
  - ➤Cost effective
  - ➤Efficient gas distribution system
  - ➤Homogenous resistive coating



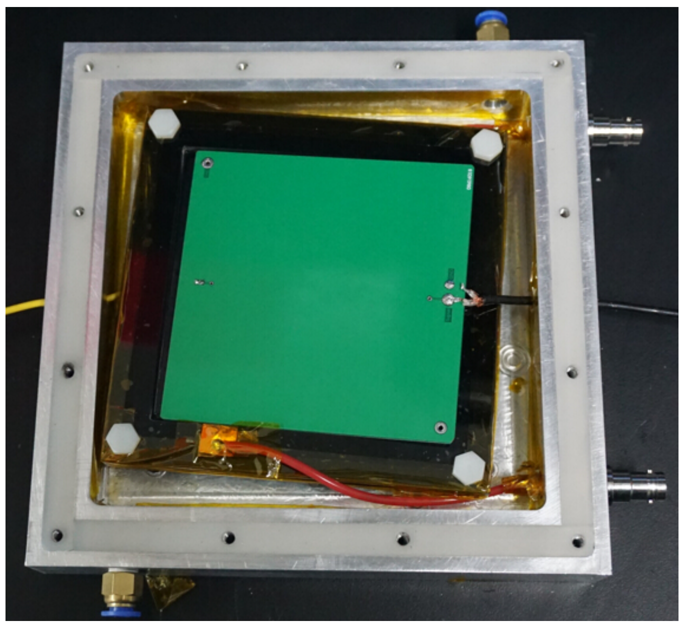


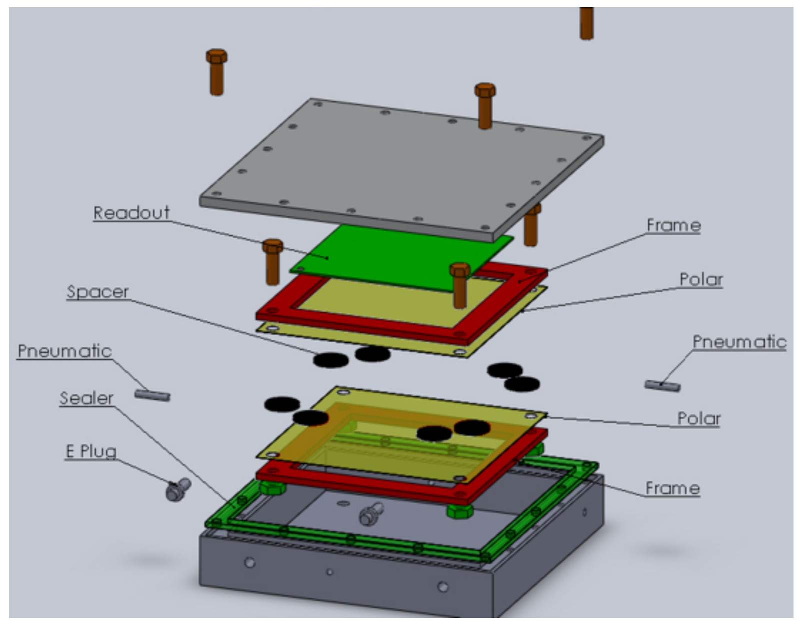
The different view of PCB

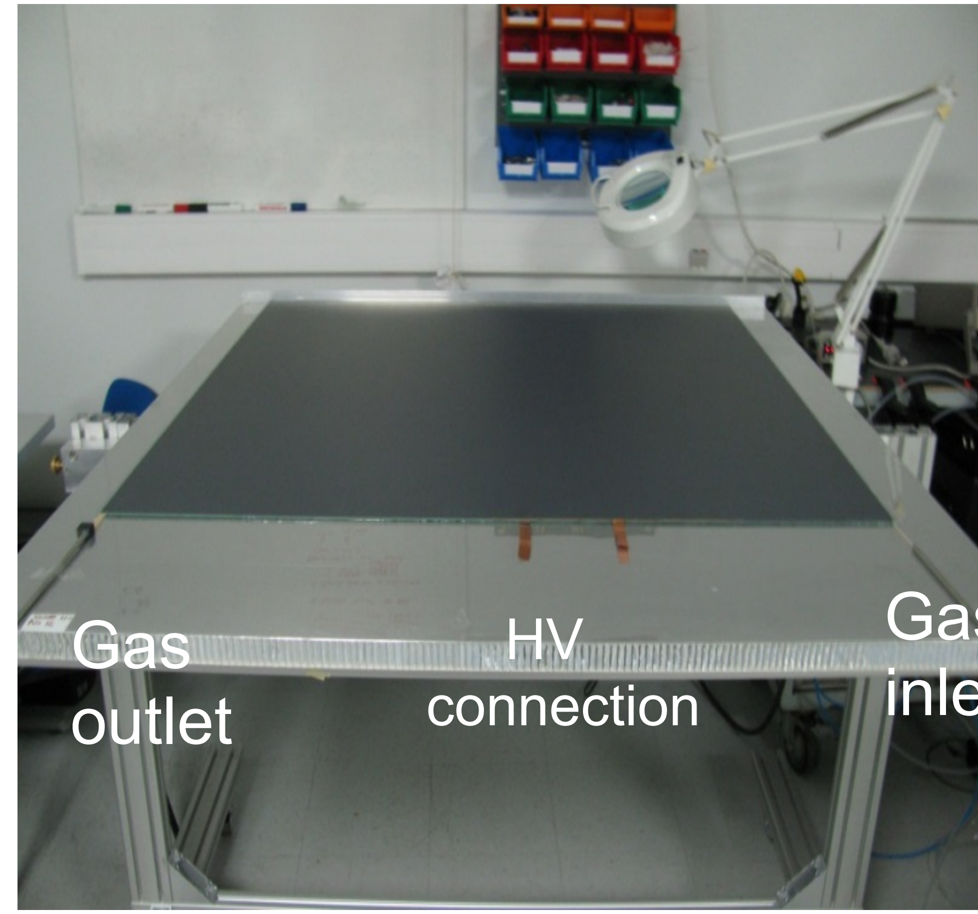
RPC R&D

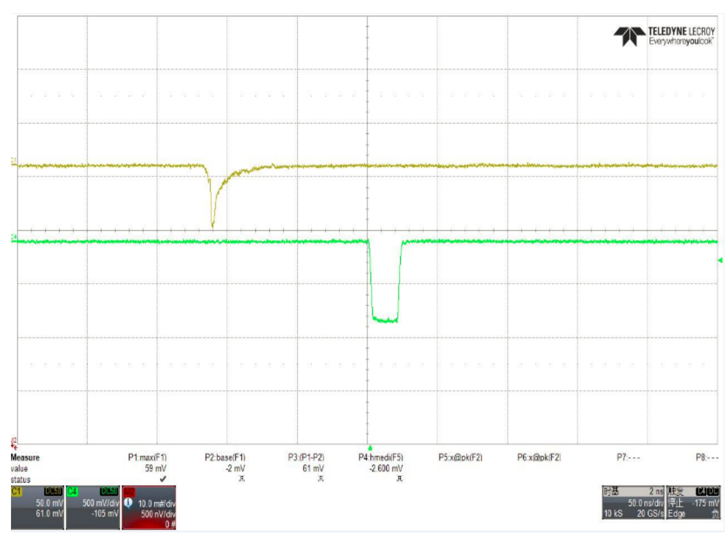
From **Ran HAN** (BISEE)

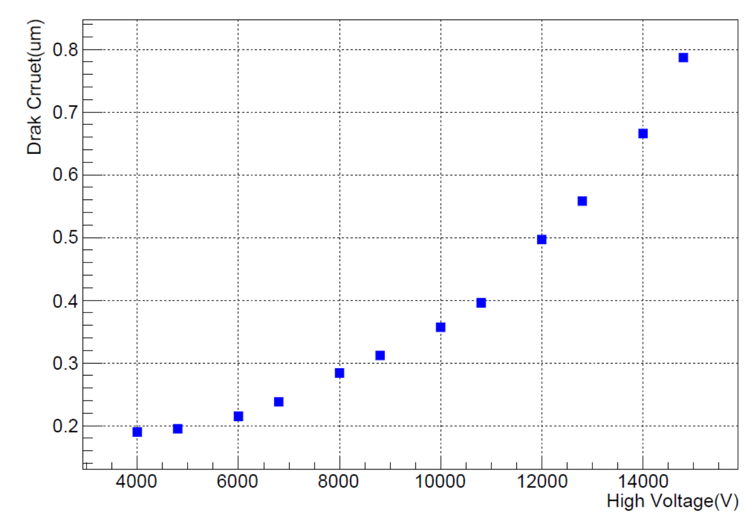
- A new concept of RPC: Carbon-dopped low-resistive polyimide foil





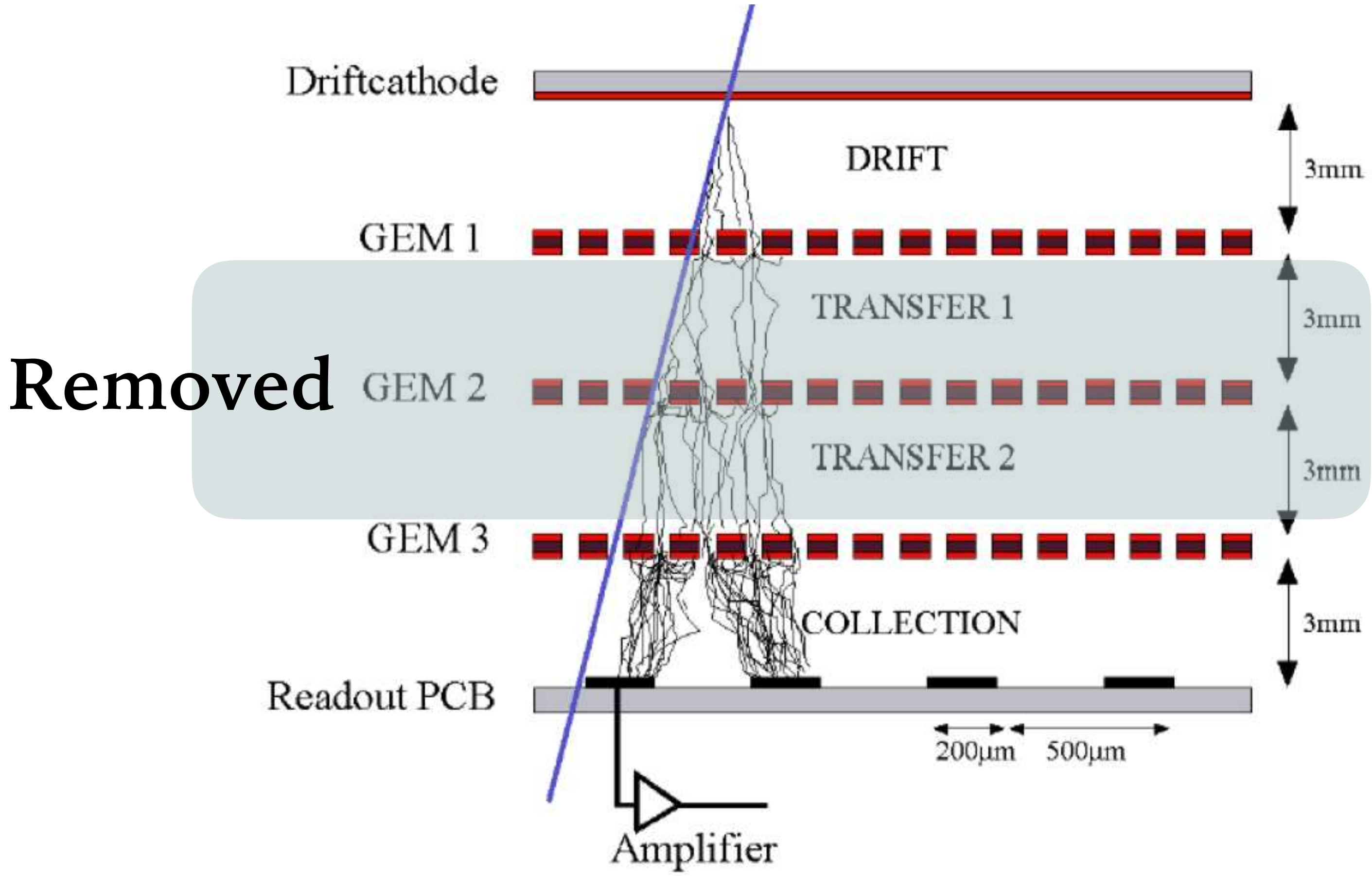


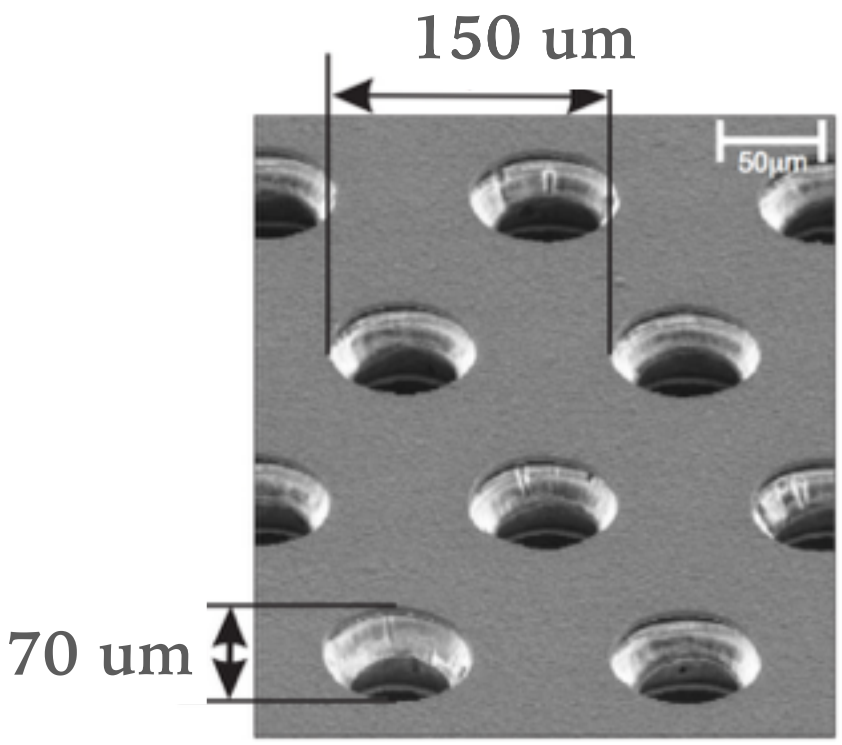




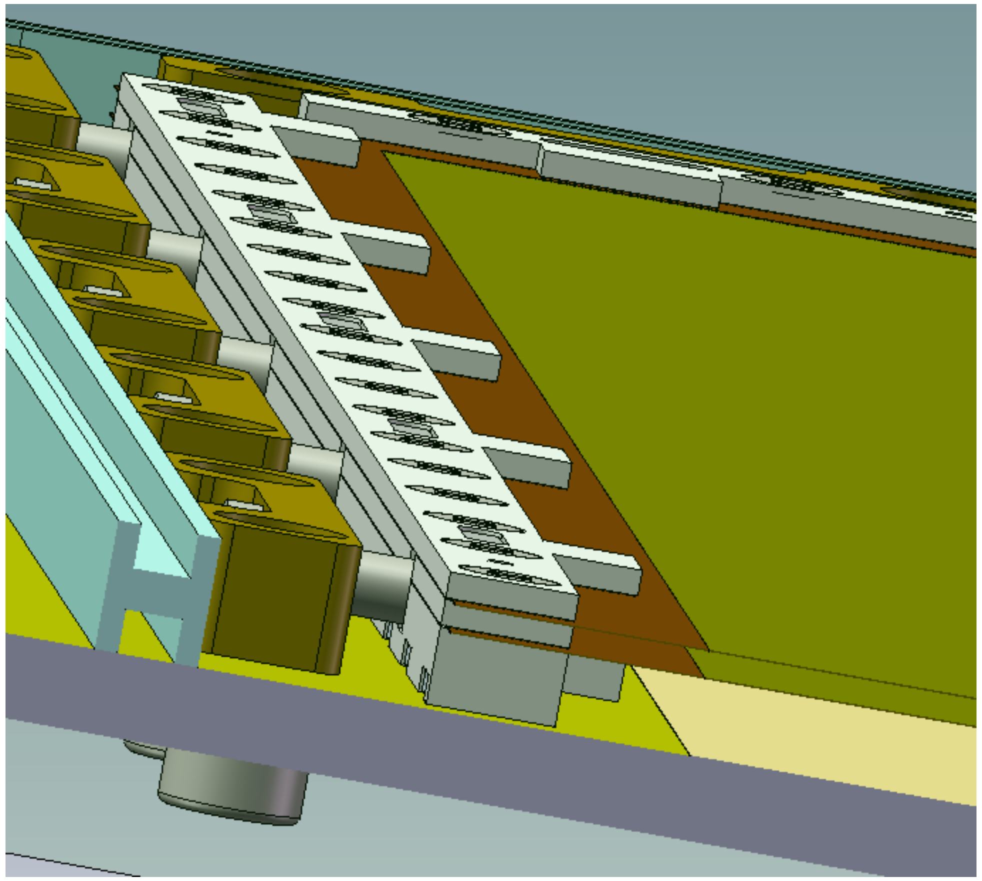
GEM R&D

From **Jianbei LIU** (USTC)





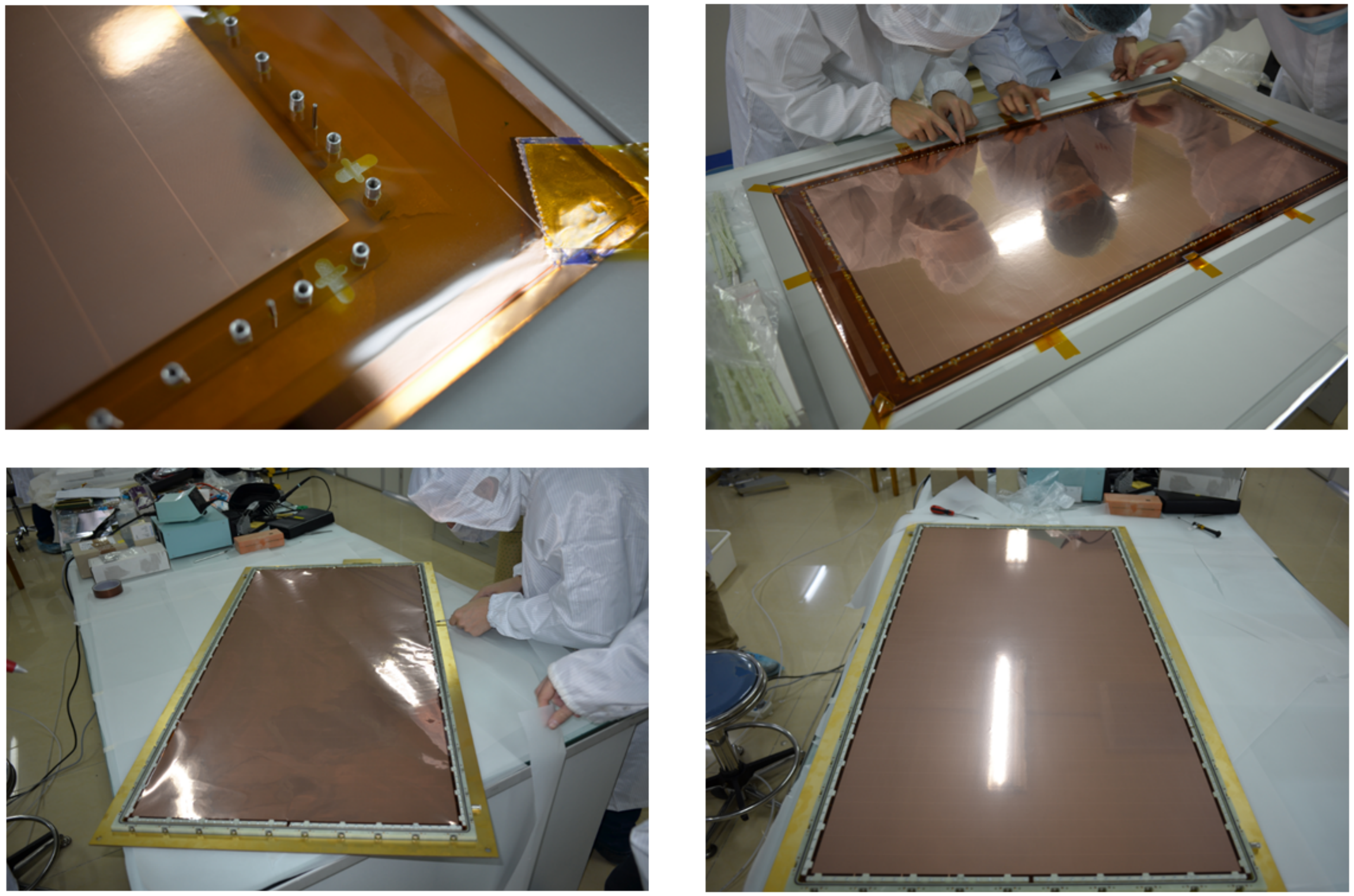
- Detector size: 1m*0.5m, limited by GEM foil size
- Double-GEM structure (3mm-1mm-1mm) adopted to minimize the thickness of detectors to accommodate the compactness requirement of DHCAL
- Double-GEM can still produce reasonable gain under safe operation condition according to our measurements and experience



GEM R&D

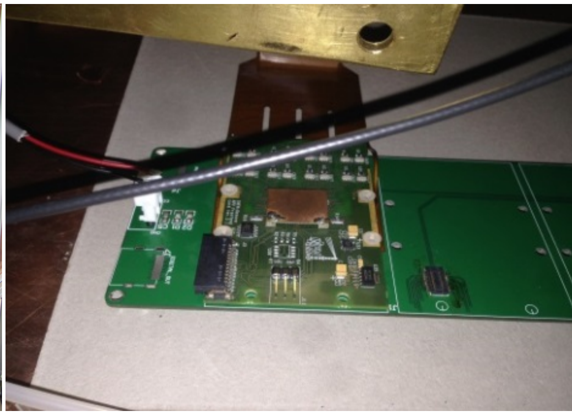
From **Jianbei LIU** (USTC)

GEM assembly using a novel self-stretching technique

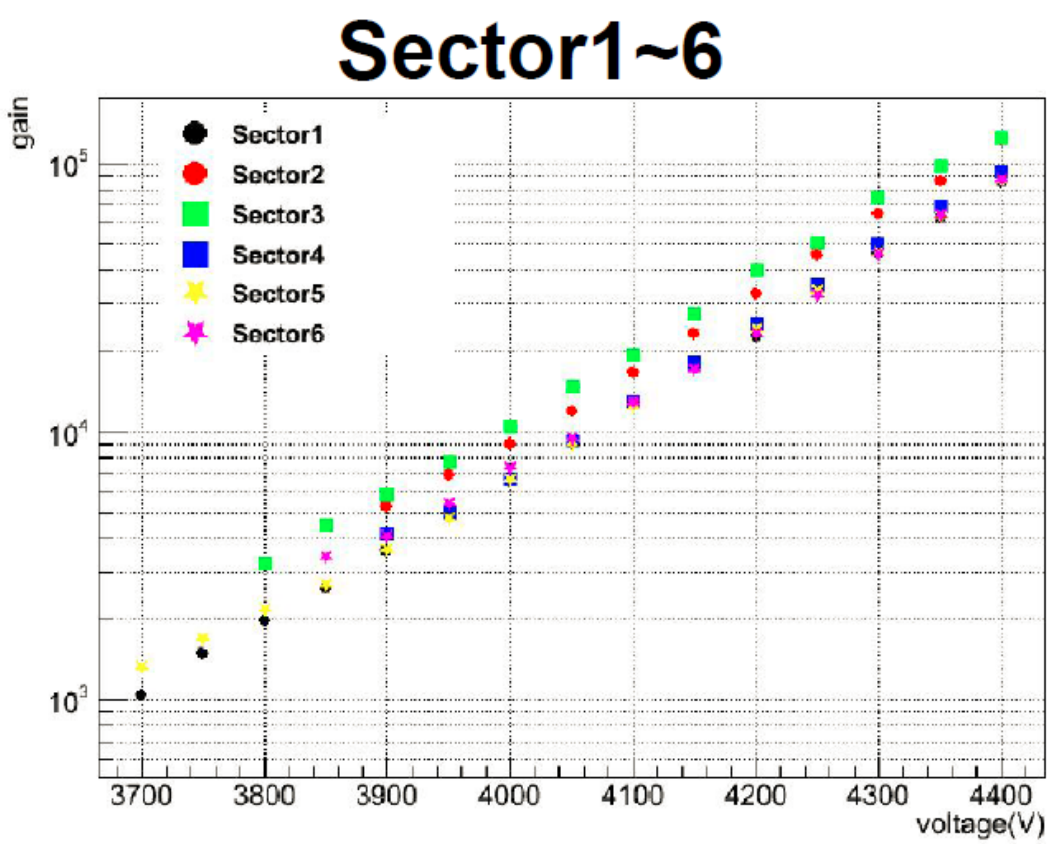


APV25 GEM readout

INFN APV25 chip



- Large-area GEM ($0.5x1m^2$) is one of main detector R&D focuses at USTC recently.



➔ **Resolution uniformity ~11%**

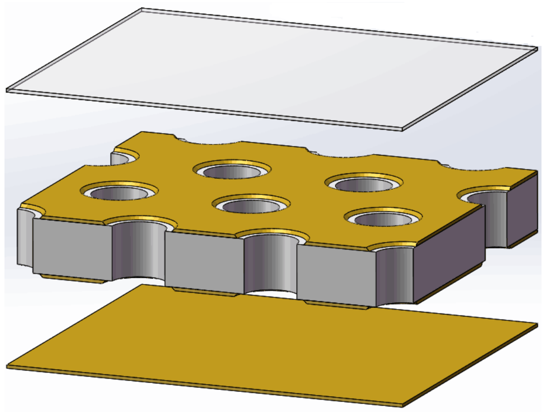
➔ **Gain uniformity ~16%**

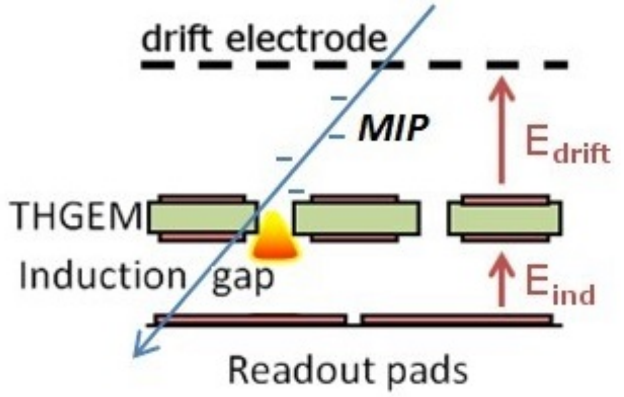
➔ **Can reach gain of 10^4 at 4000V**

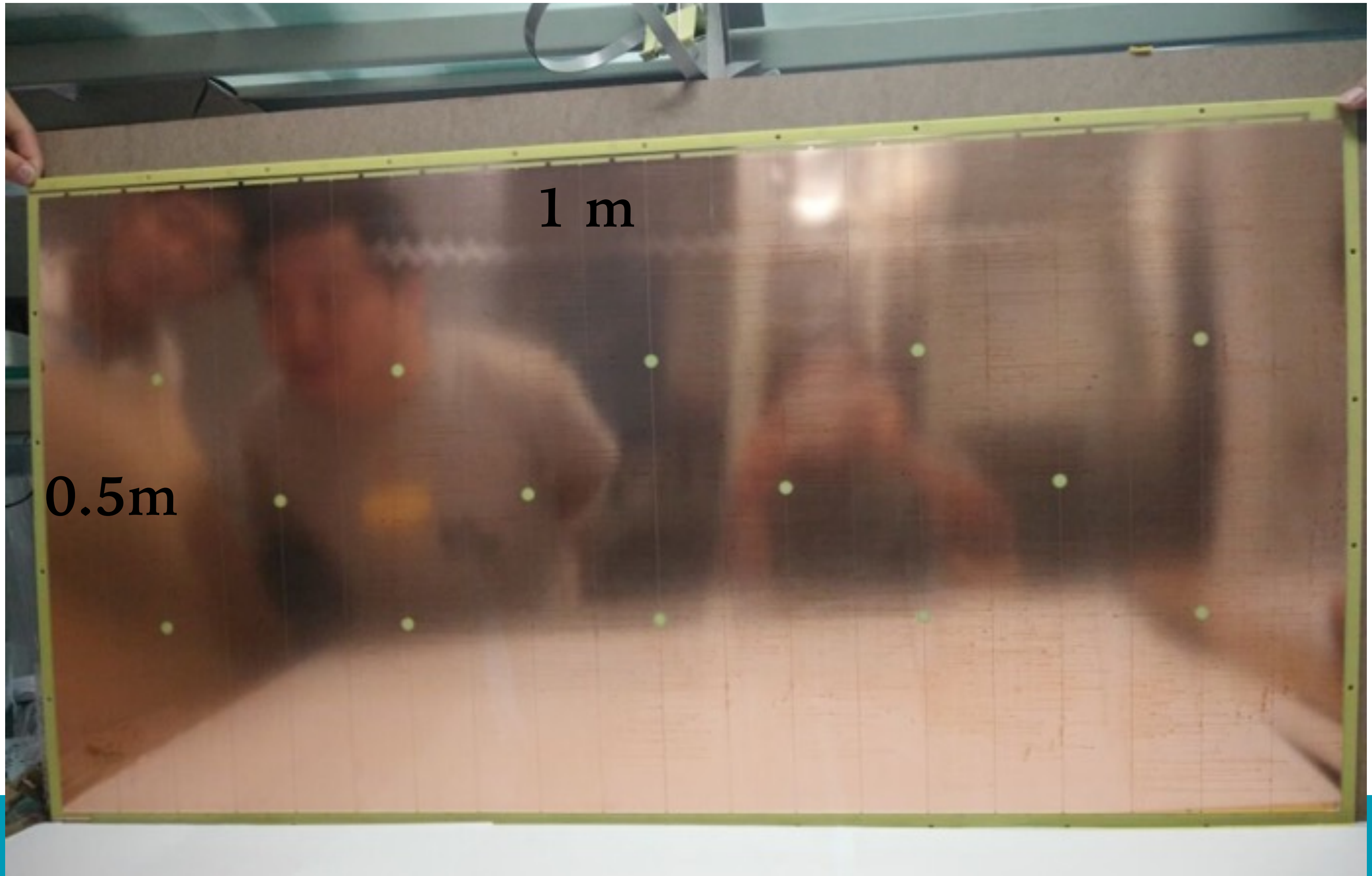
THGEM R&D

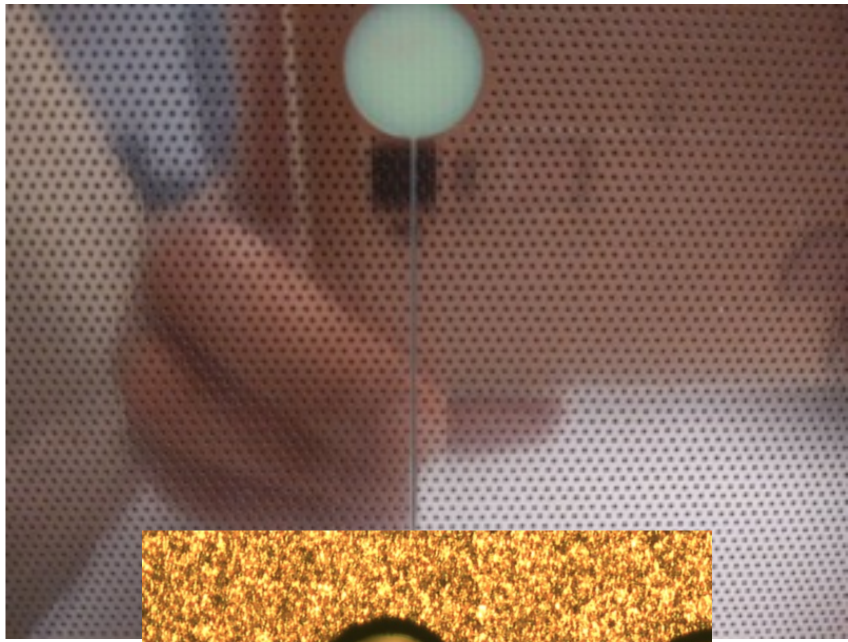
From **Qian LIU/Hongbang LIU** (UCAS / GXU)

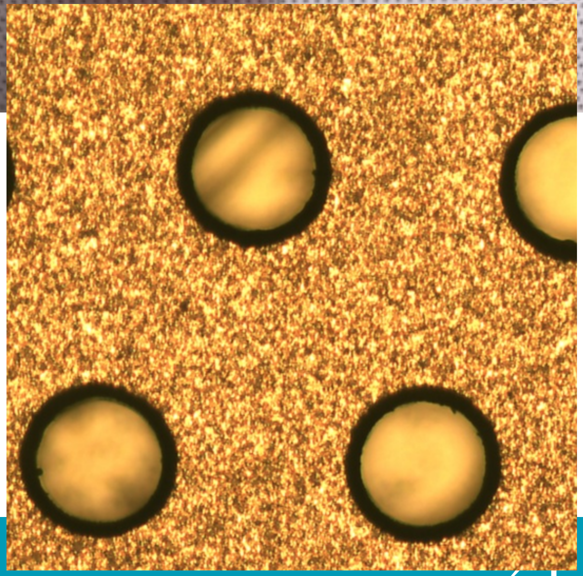
- Derived from GEM, but larger hole/pitch.The size can vary from 150 um to 1 mm accordingly.
- Self support, larger gain, good spatial resolution.
- Domestic manufactured, large area: 1m*0.5m has been made successfully.







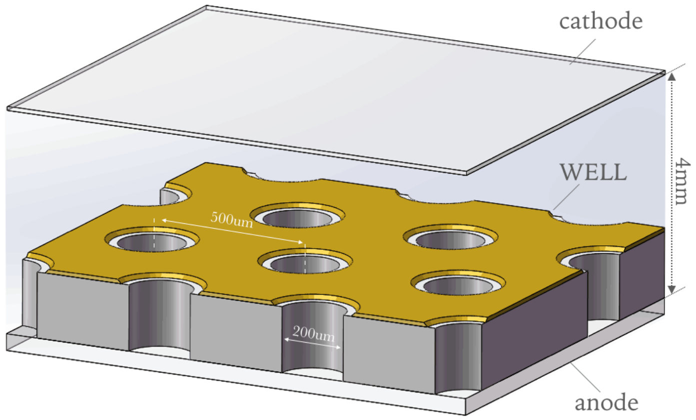


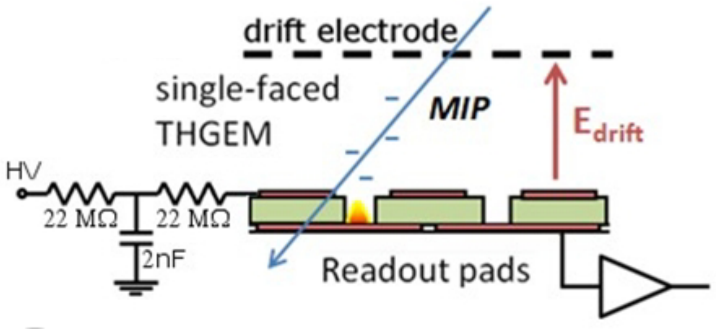


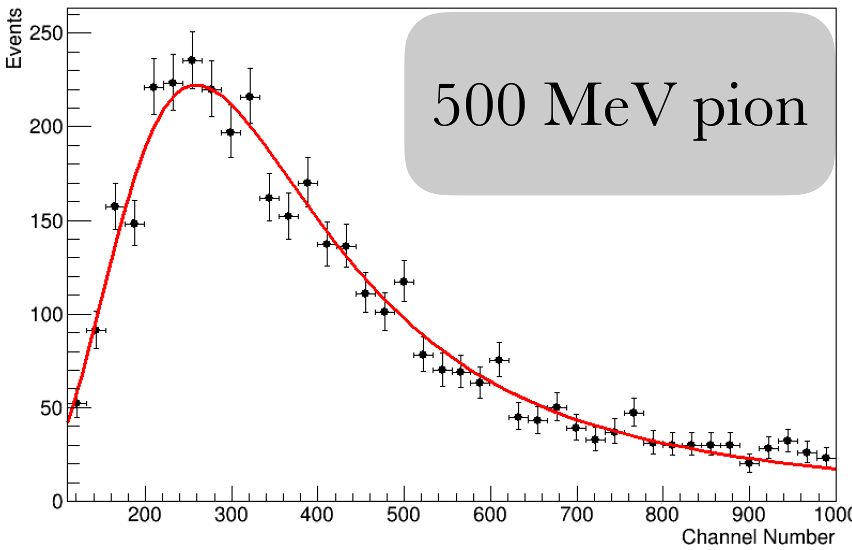
WELL-THGEM

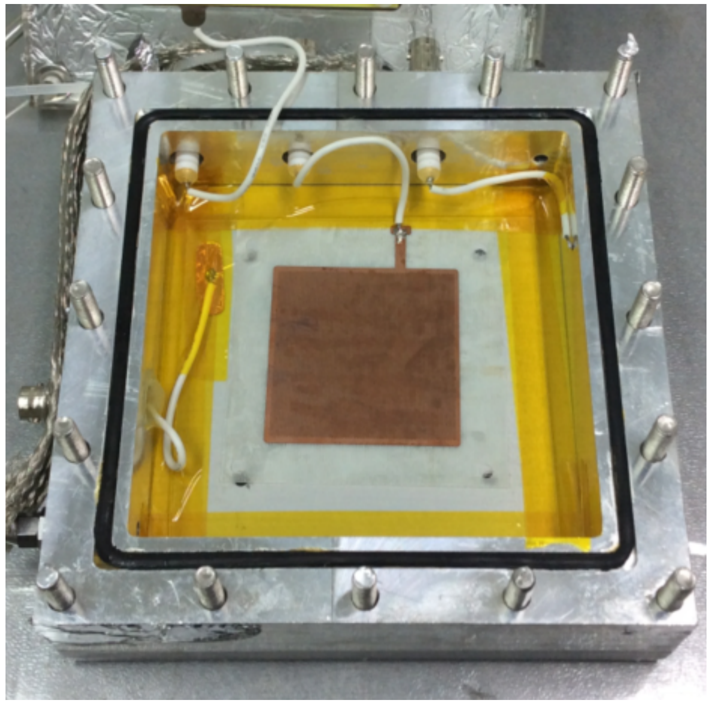
From **Qian LIU/Hongbang LIU** (UCAS / GXU)

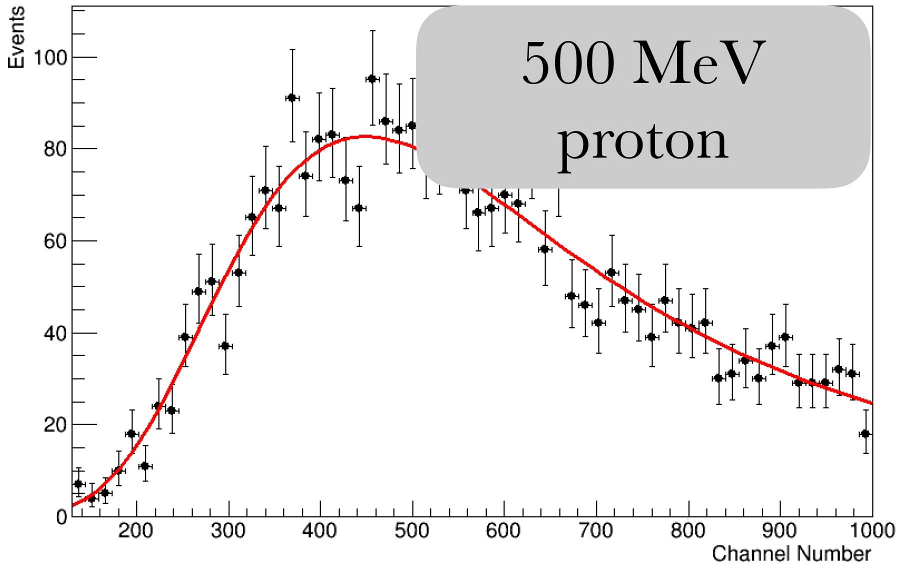
- The detection efficiency of well-THGEM was measured with the BEPC pion and proton beams.
- Ne/CH4 (95/5) ,Gain ~ 9000
- Eff (proton) > 99%; Eff(Pion) > 94%







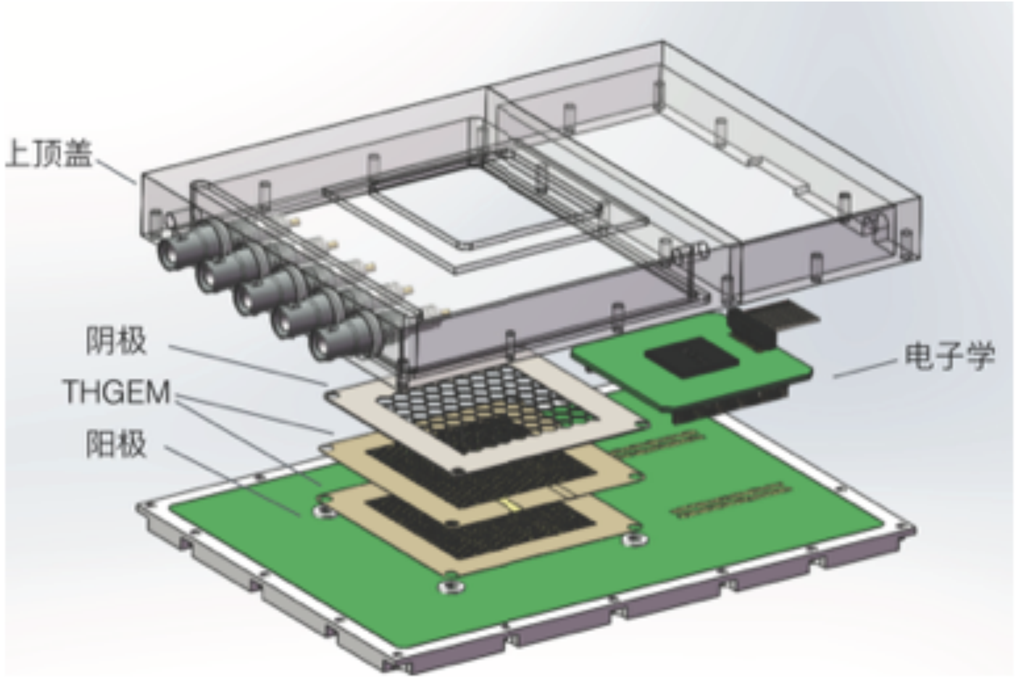


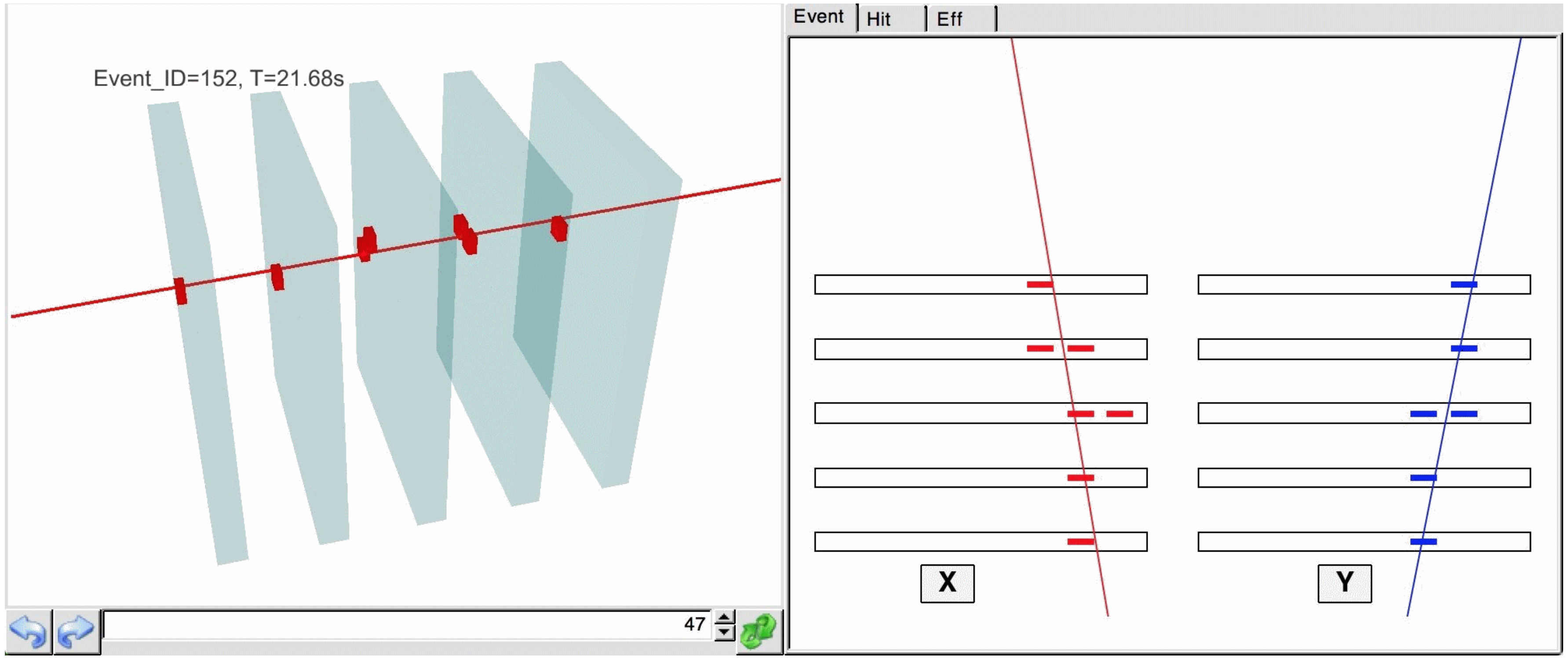


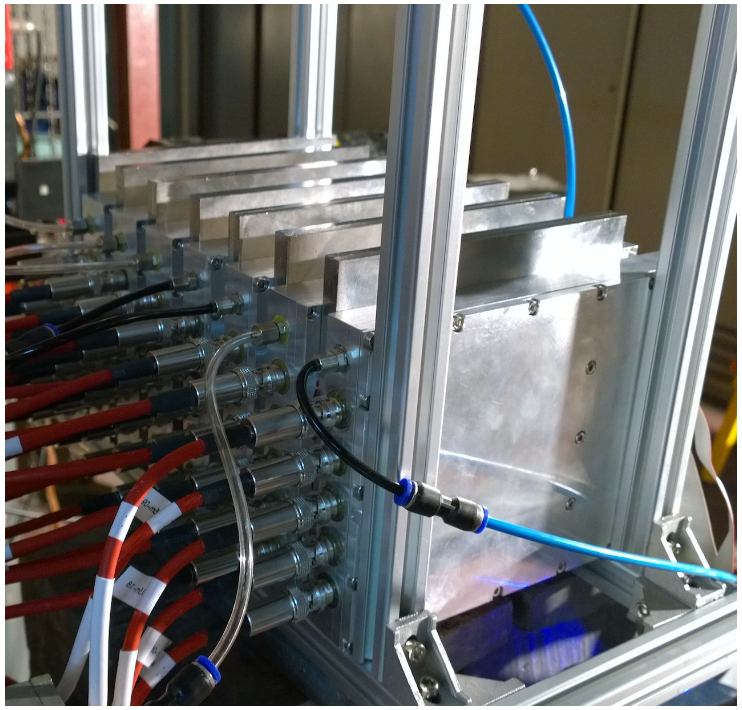
WELL-THGEM BEAM TEST

From **Qian LIU/Hongbang LIU**
(UCAS / GXU)

- 7 THGEMs ware installed, and 5 of them were used, and flushed with Ar/iso-butane = 97:3.
- 1 threshold, binary readout
- 900 MeV proton beam was used
- 5cm x 5cm sensitive region
- ASIC: Gastone (From INFN)



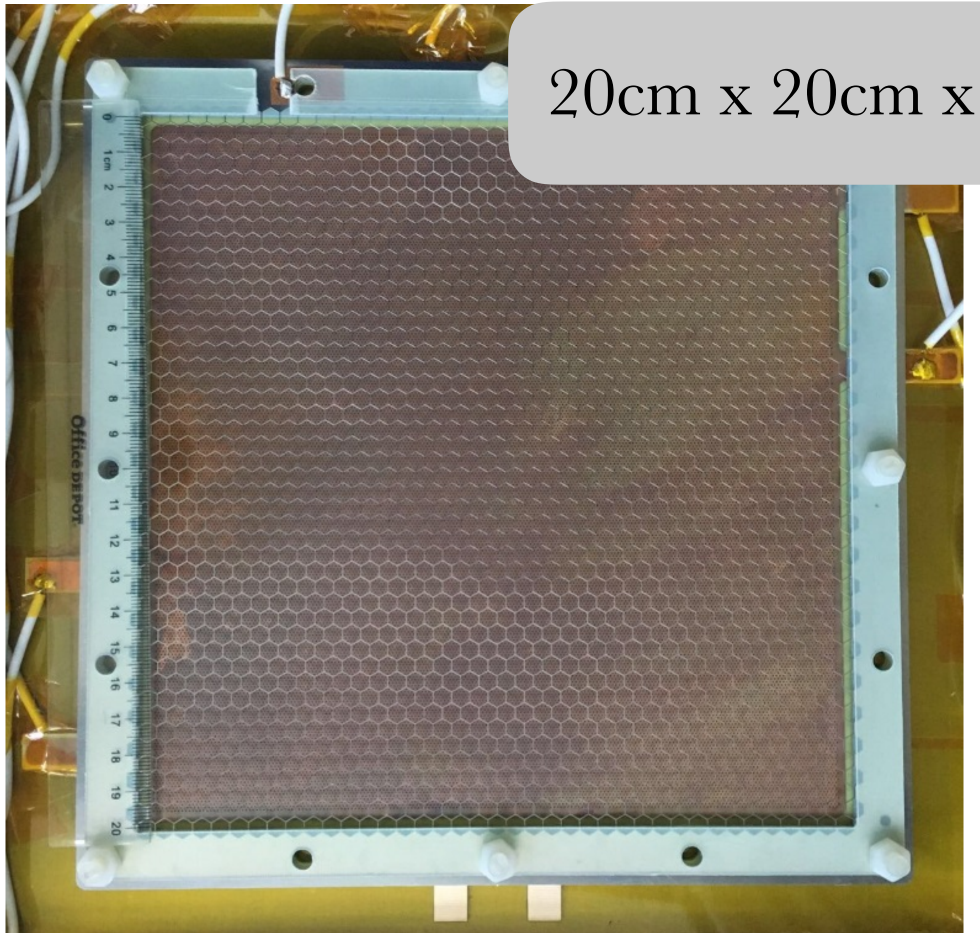




THGEM R&D

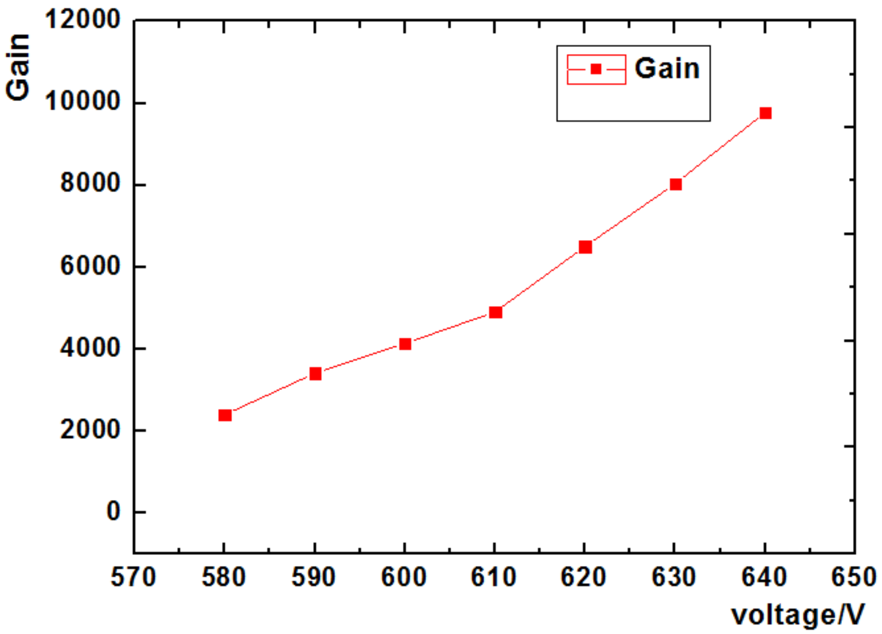
From **Boxiang YU** (IHEP)

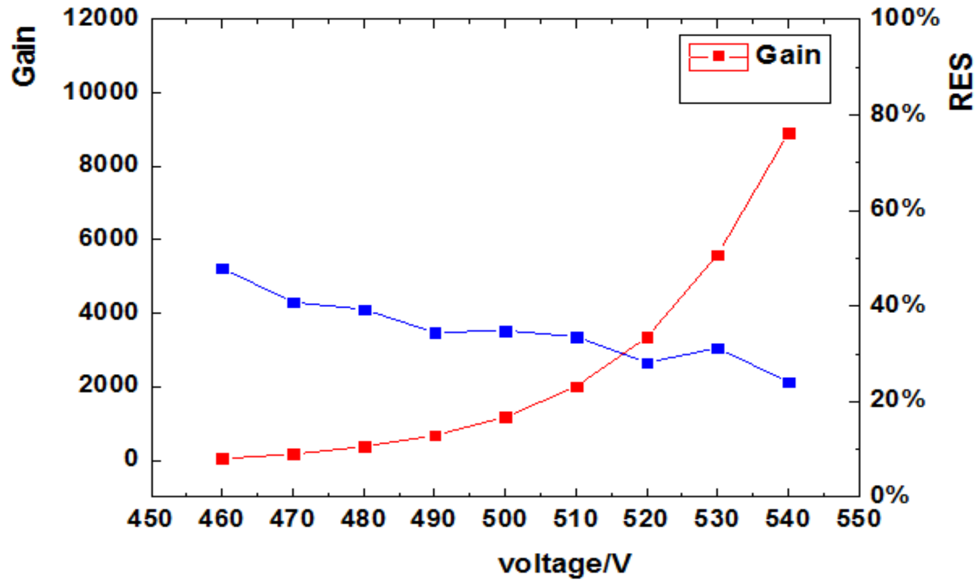
- Double layer of THGEM
- Gas: Ar/isobutane (97:3)



20cm x 20cm x 5 mm

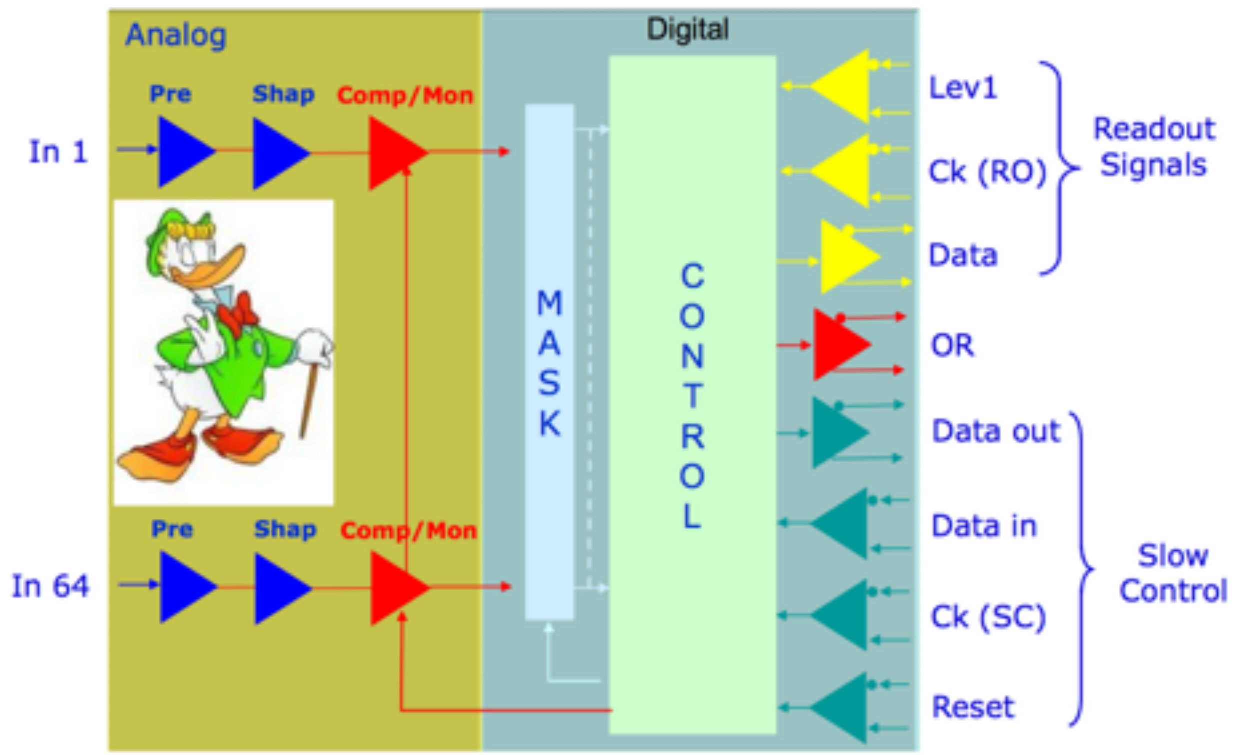
6cm x 6cm x 6 mm





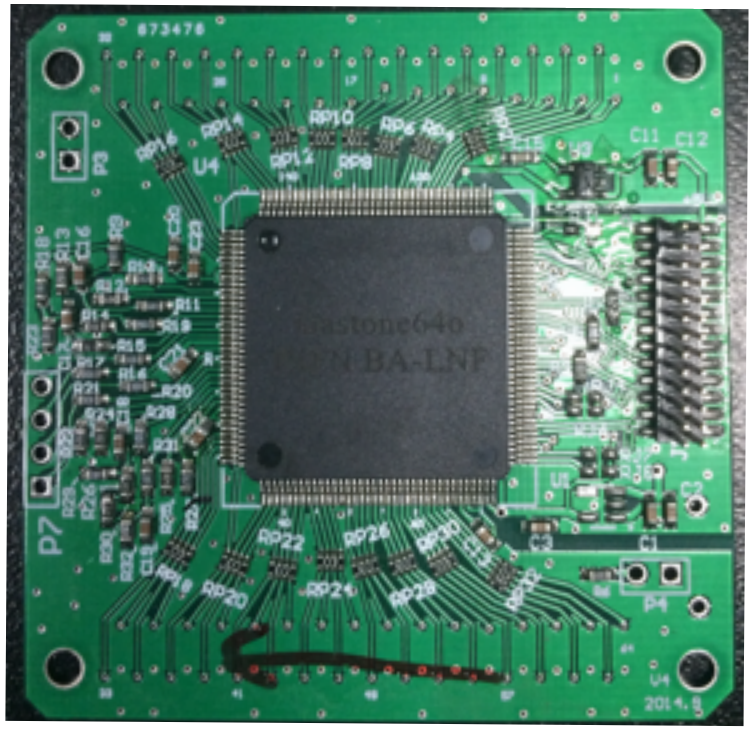
DAQ SYSTEM: GASTONE

From **Qian LIU/Hongbang LIU** (UCAS / GXU)



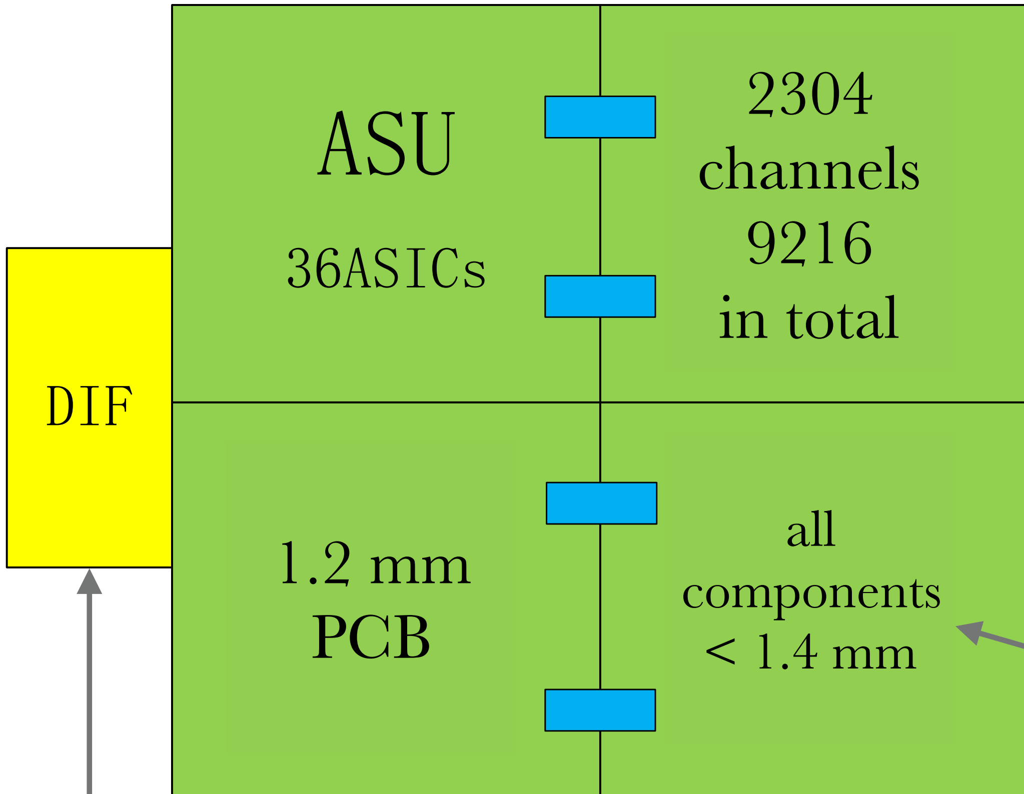
GASTONE (Gem Amplifier Shaper Tracking ON Events)

N channels	64
Chip dimensions	4.5 × 4.5 mm^2
Input impedance	120 Ω
Charge sensitivity	16 mV/fC (C_{det} = 100 pF)
Peaking time	90 ns (C_{det} = 100 pF)
Crosstalk	< 3%
ENC	800 e^- + 40 e^-/pF
Power consumption	~6 mW/ch
Readout	Serial LVDS (100 Mbps)



HARDROC/MICROROC

From **Jianbei LIU** (USTC)

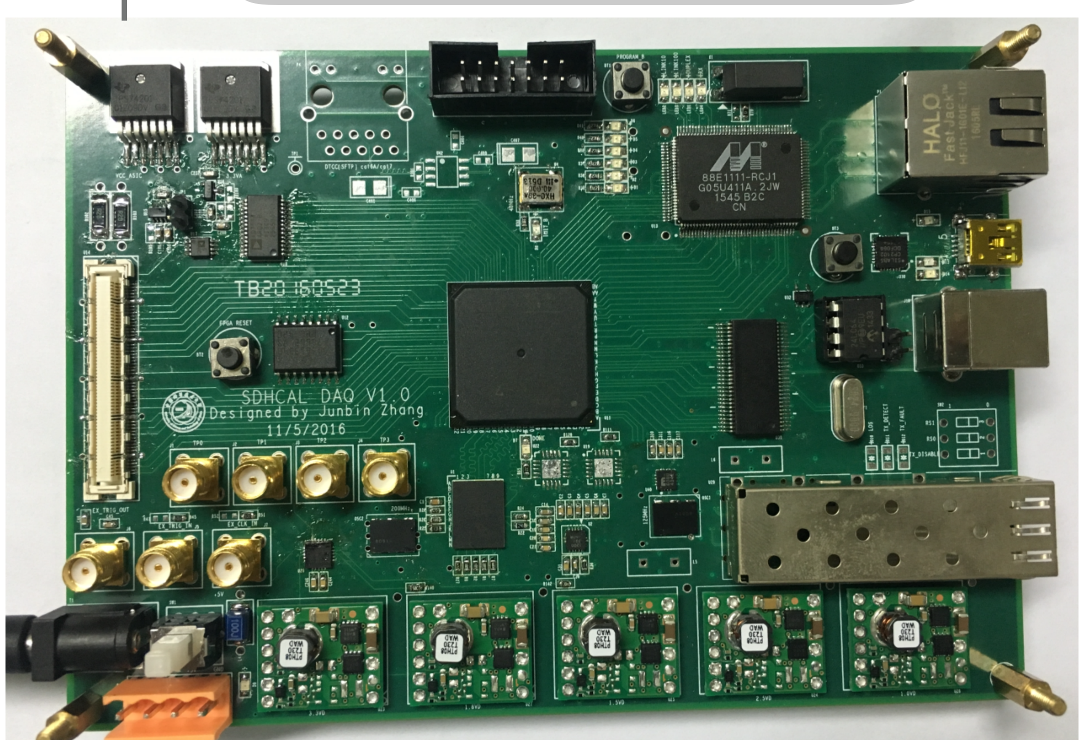


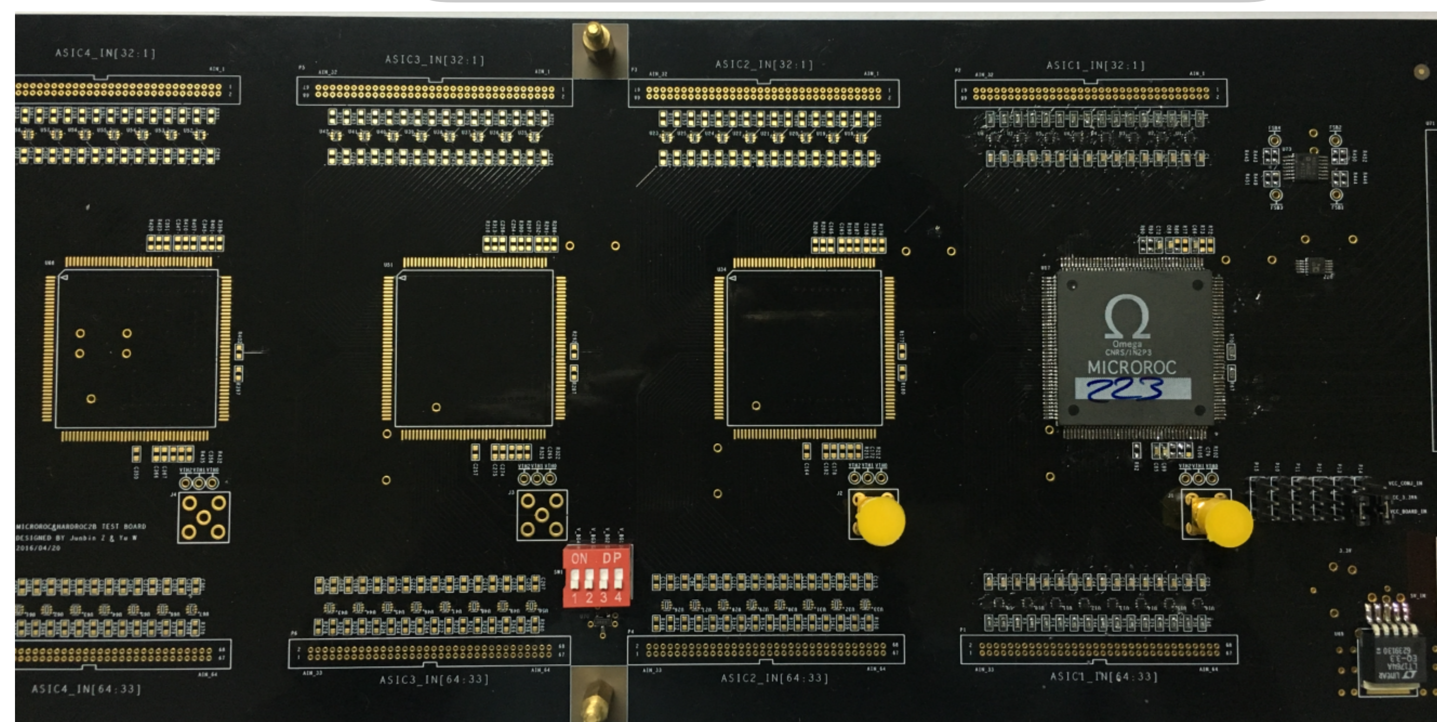
Multi-thresholds	channels	Dynamic range
Hardroc2	64	10fC~10pC
Hardroc3	64	10fC~50pC
Microroc	64	1fC~500fC

MICROROC is dedicated chip for GEM/MICROMEGAS. MICROROC (pin pin compatible with HR2b) is based on HR2b same back-end, same readout format, same pinout, only the preamplifier is changing.

Detector InterFace (**DIF**)

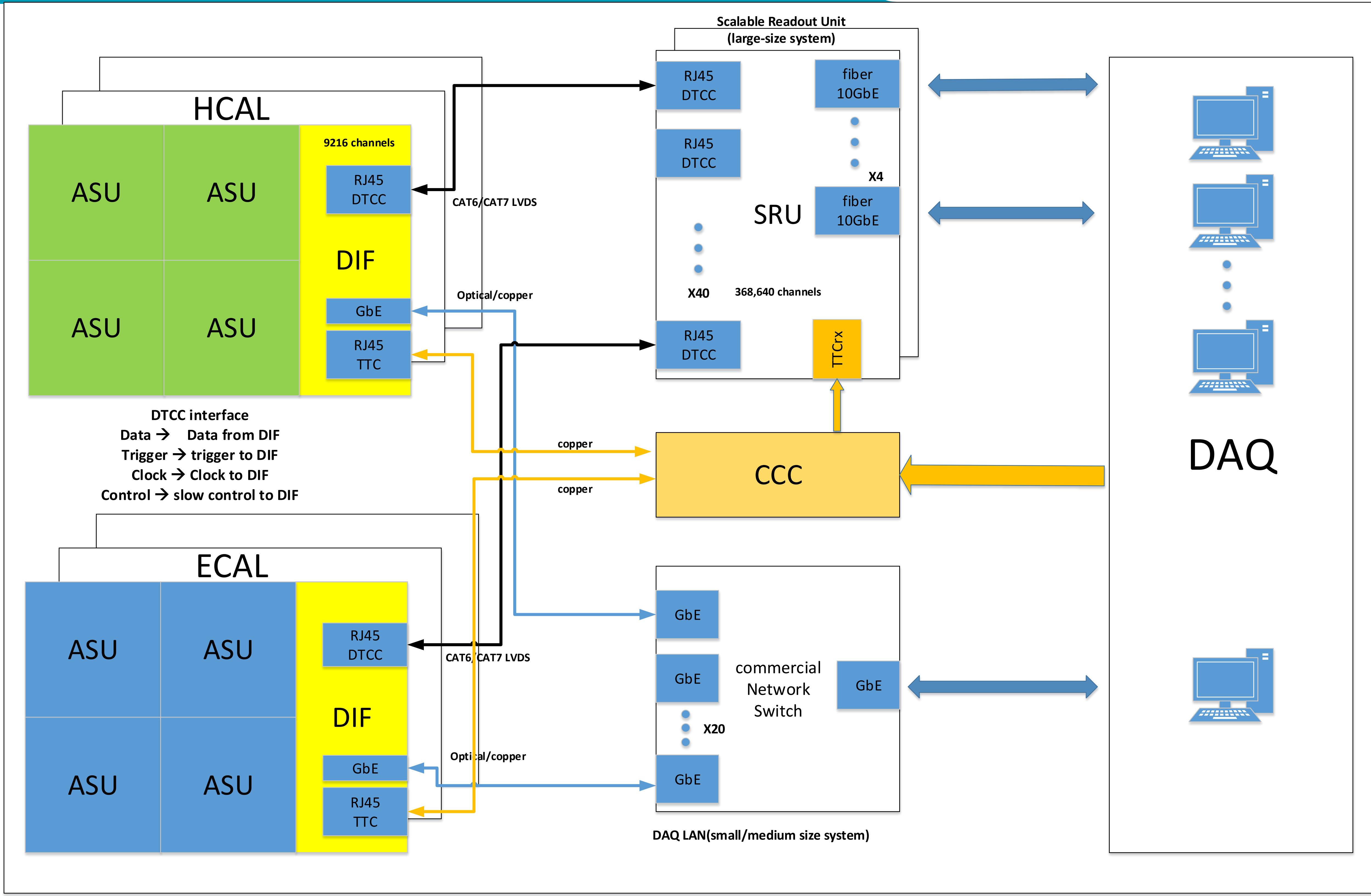
Active Sensor Unit (**ASU**) Test boards





DAQ SYSTEM DESIGN

From **Jianbei LIU** (USTC)



CONCLUSION

- Detector simulation:
  - Granularity of calorimeters optimization
  - Number of layers of calorimeters optimization
  - Digitization (RPC/GEM/THGEM)

- Detector R&D
  - RPC (Glass RPC, Polyamide RPC)
  - GEM (double GEM structure, self-stretching)
  - THGEM (Well-THGEM, double THGEM structure)

NEXT TO DO

- Larger detector (RPC/GEM/THGEM) design & build up.
- Study the performance of large detector: gain, efficiency, energy resolution, uniformity, etc.
- Electronics readout
  - Low-power consumption, highly integrated, etc.
  - ASIC: Gastone, Hardroc, Microroc, etc.
- Cosmic ray test / beam test.
  - compare with MC simulation.

- Time information?

Many thanks to all members of the CEPC Calorimeter working group!

BACKUP

BEAMTEST BY GASTONE

From **Qian LIU/Hongbang LIU**
(UCAS / GXU)