Development of compact micro-pattern gaseous detectors for application to the CEPC digital hadron calorimeter

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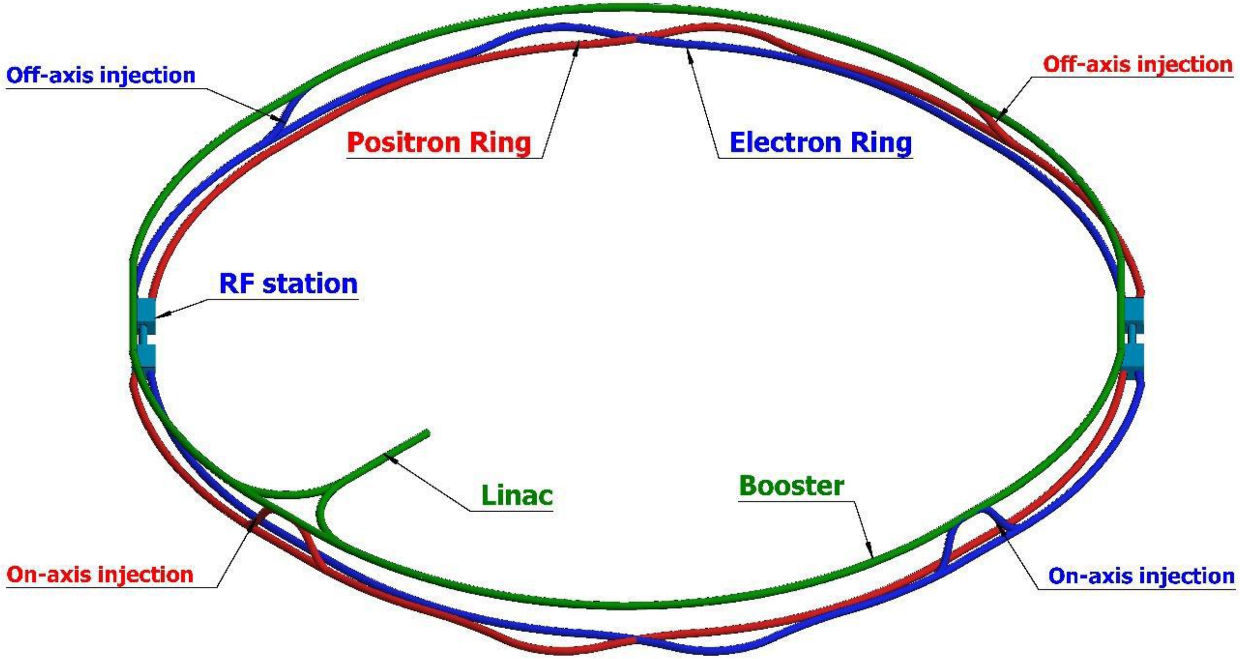
Outline

- CEPC
- CEPC baseline detector concept
- CEPC PFA HCAL Options
- MPGD for the CEPC DHCAL
  1. GEM
  2. RWELL
- Summary and plan

CEPC

- The Circular Electron Positron Collider (CEPC)



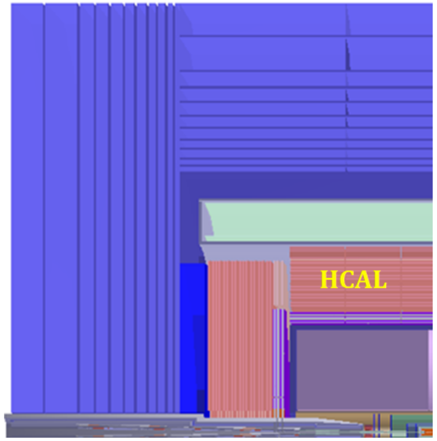
Circumference:100 km

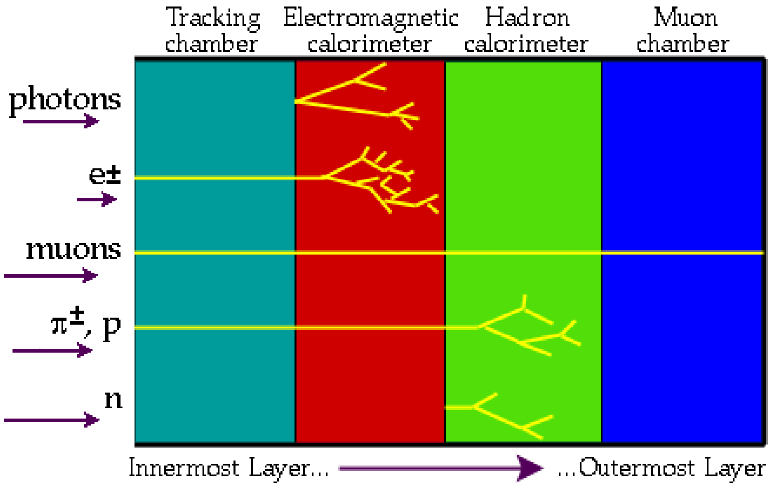
- Parameters:

Operation mode	$\sqrt{s}$ (GeV)	L per IP (10^{34} cm^{-2}s^{-1})	Years	Total $\int L$ (ab^{-1}, 2 IPs)	Event yields
H	240	3	7	5.6	1×10^6

CEPC baseline detector concept

- The CEPC baseline detector concept-guided by Particle Flow Principle





- Performance Requirements :

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E = 3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

- Characteristic of PFA calorimeter:

1. High granularity
2. Minimal dead area
3. Compact

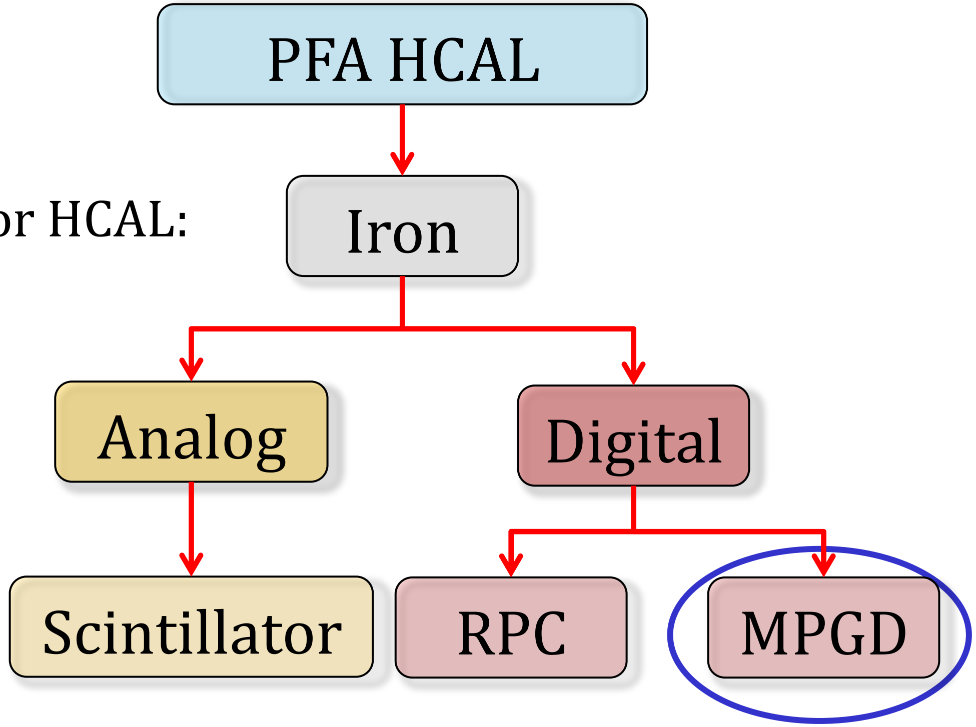
CEPC PFA HCAL Options

- HCAL options:

  1. Digital HCAL (DHCAL)
  2. Analog HCAL (AHCAL)

- Requirements of sensitive detector for HCAL:

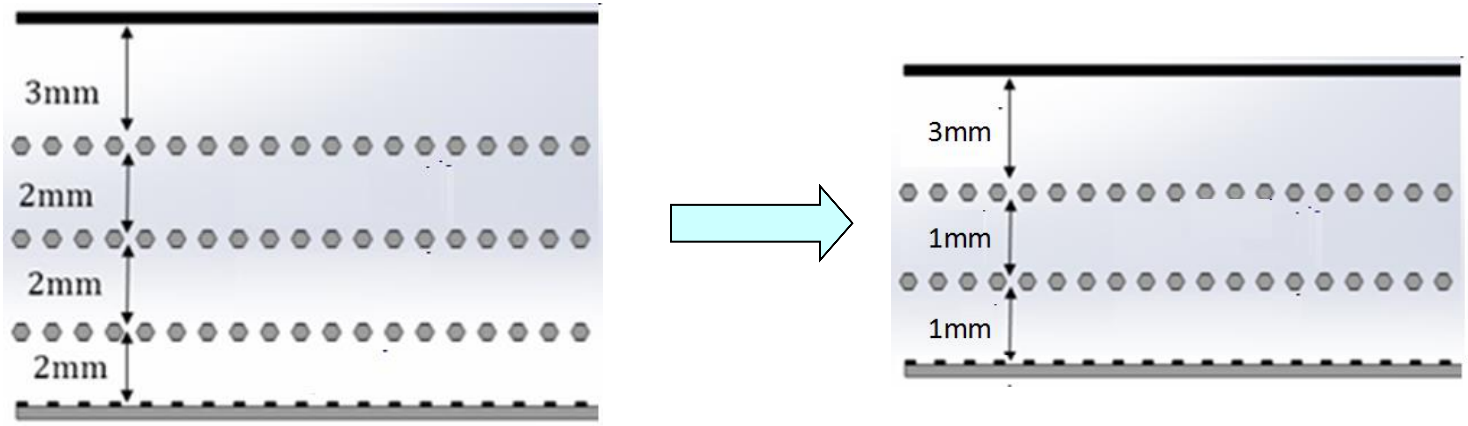
  1. Compact
  2. High detection efficiency
  3. Small readout pads
  4. Minimal dead area
  5. Large size



- MPGD could satisfy the requirements: one of candidates for CEPC HCAL

GEM for HCAL

- Typical MPGD: **GEM detector**
- To meet the requirement of compactness, a "3mm-1mm-1mm" double layer GEM detector was developed for DHCAL.



Regular three layer GEM detector

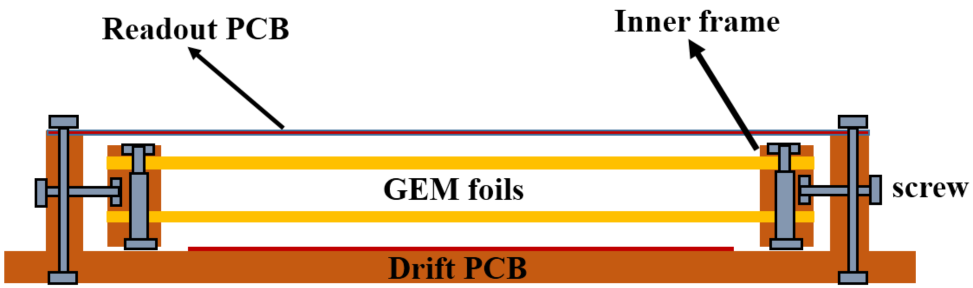
Double layer GEM detector

- Difficulties in development of the double layer GEM detector:
  1. Higher voltage added on each GEM foil
  2. Larger tension applied on GEM foils

Self-stretching technique

- Self-stretching technique was applied in production of the double layer GEM detector.

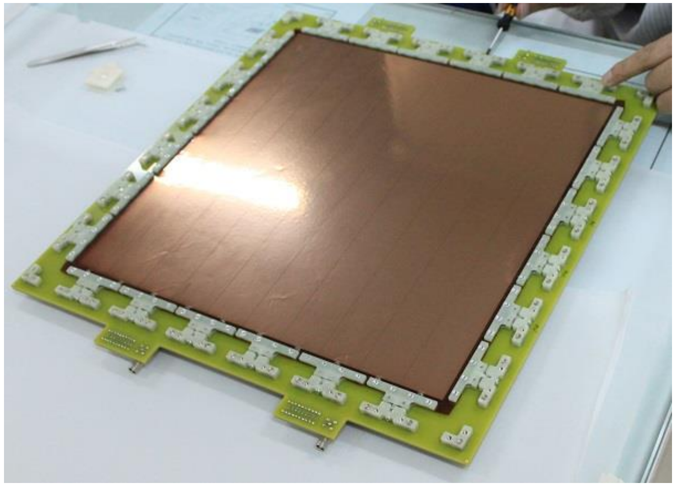
Self-stretching technique (from CERN)

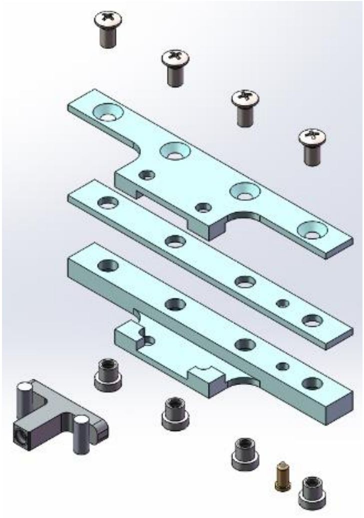


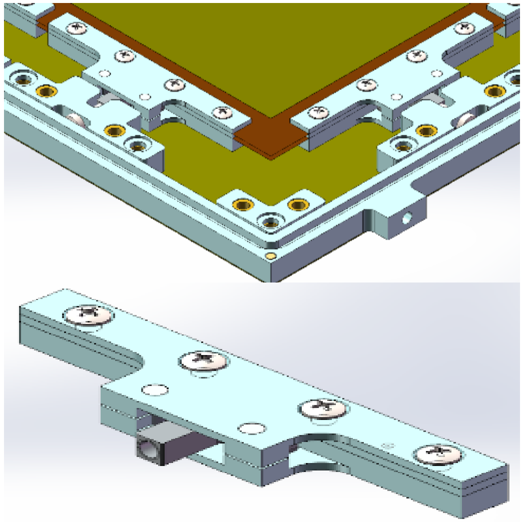
- Advantages：

1. assembling process is easy and fast
2. no dead area inside the active area
3. uniform gas flow
4. detachable

- **30 cm×30 cm** double layer GEM detector

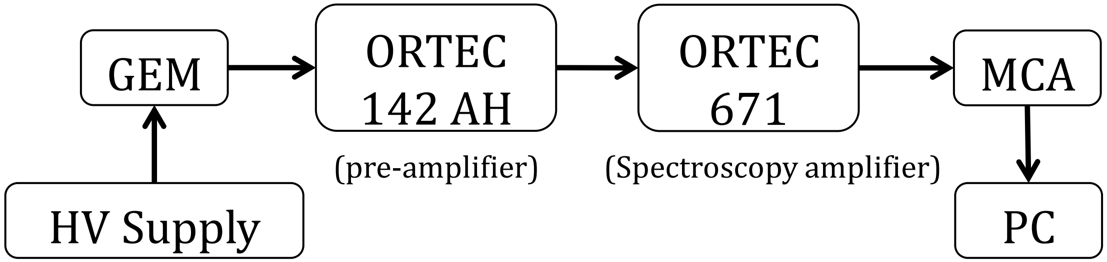




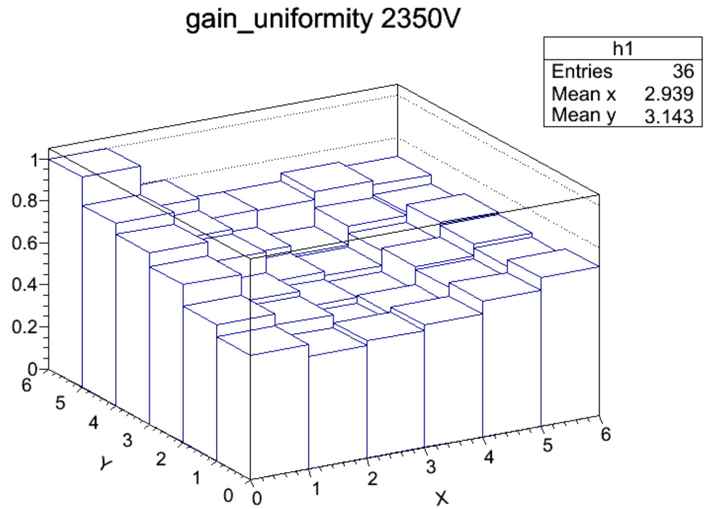


Gain

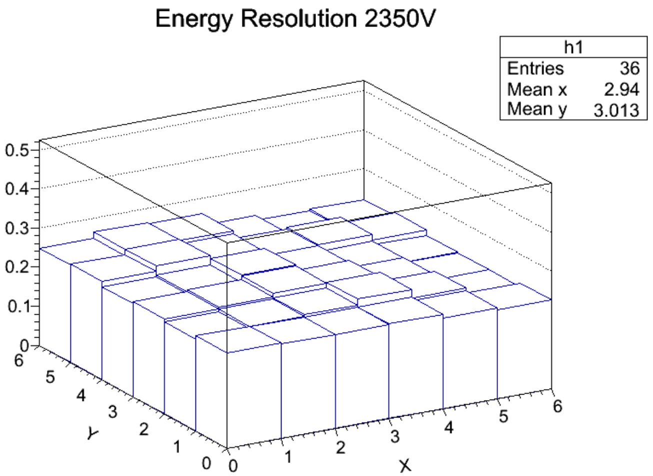
- Test setup：



- 70%Ar+30%CO_2:



Gain uniformity： ~16%

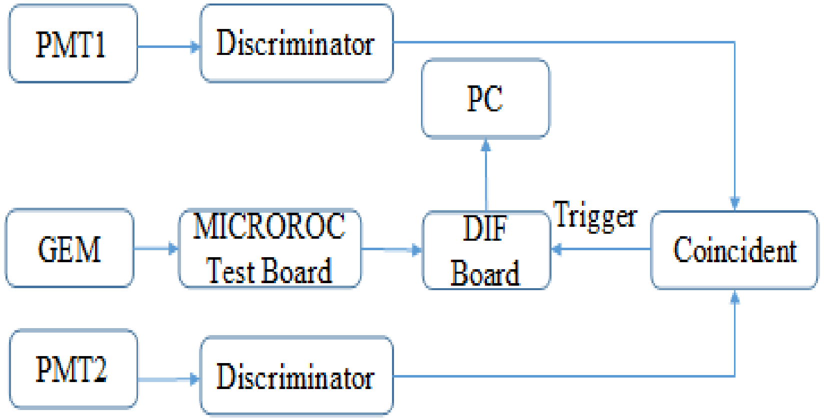


Energy resolution： ~24%

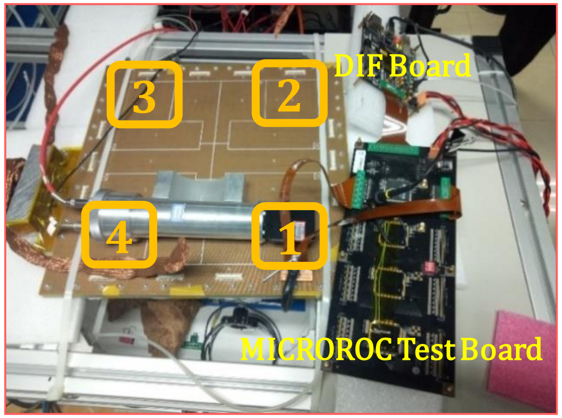
- Maximum gain: ~3200

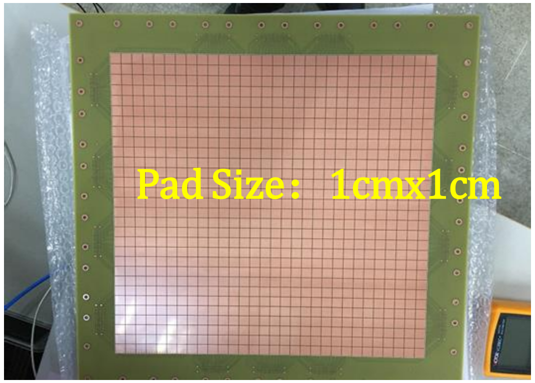
Cosmic ray test

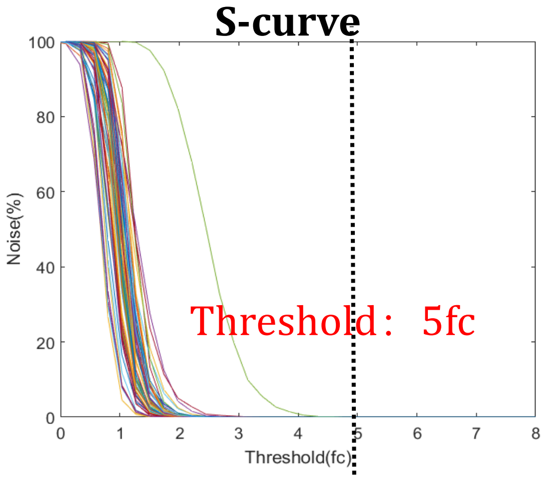
- MICROROC is a digital readout chip developed for DHCAL.
- Detection efficiency and hit multiplicity have influence on energy reconstruction for DHCAL.
- Cosmic ray experimental setup：
  1. Digital ASIC chip: **MICROROC**
  2. Readout pad size: **1cm×1cm**
  3. Threshold： **5fc**
  4. Scintillator(trigger)： 5cm×5cm



- Four 8cm×8cm corner areas were measured.



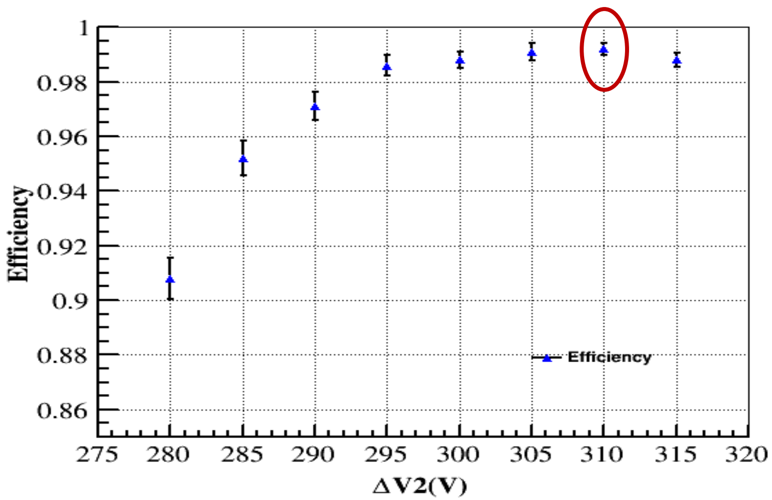




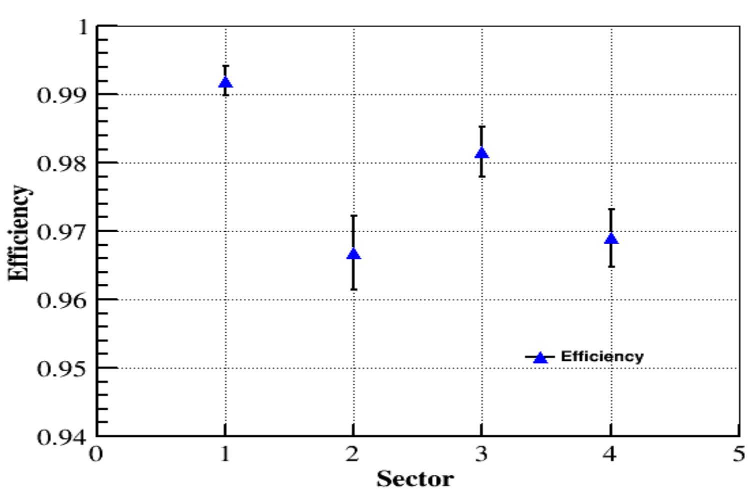
Detection efficiency

- 70%Ar+30%CO_2: 10981/13000~**84.5%** **@3200 (Maximum gain)**
- 95%Ar+5%iC_4H_{10}:

Detection efficiencies vary with voltage



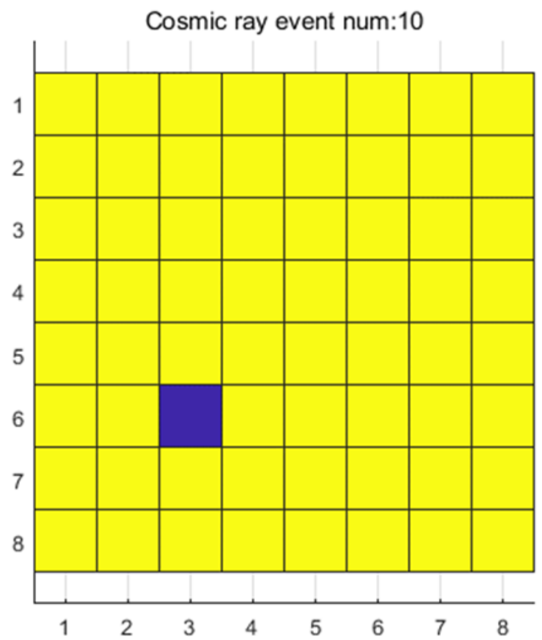
Detection efficiencies in different area



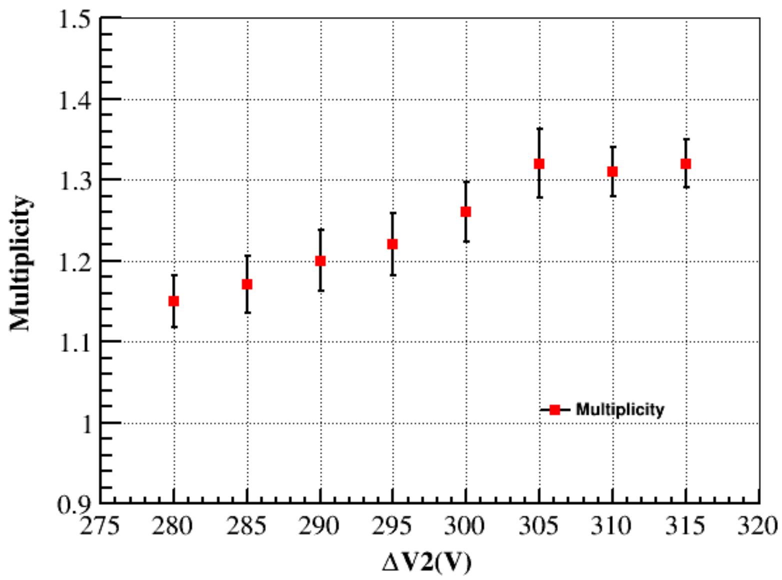
- Detection efficiency: ~**95%** @5500 gain
- Detection efficiency in the four areas： >95%
- Working gas in the following studies: 95%Ar+5%iC_4H_{10}.

Hit Multiplicity

Hit Multiplicity： Average hit number per MIP event



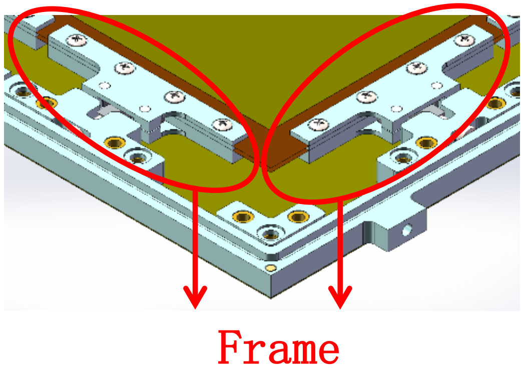
Multiplicity vary with voltage



- Combined with the detection efficiency, multiplicity is about **1.2 @95%** detection efficiency.
- Multiplicity is related to gain of the detector with a 5fc threshold.

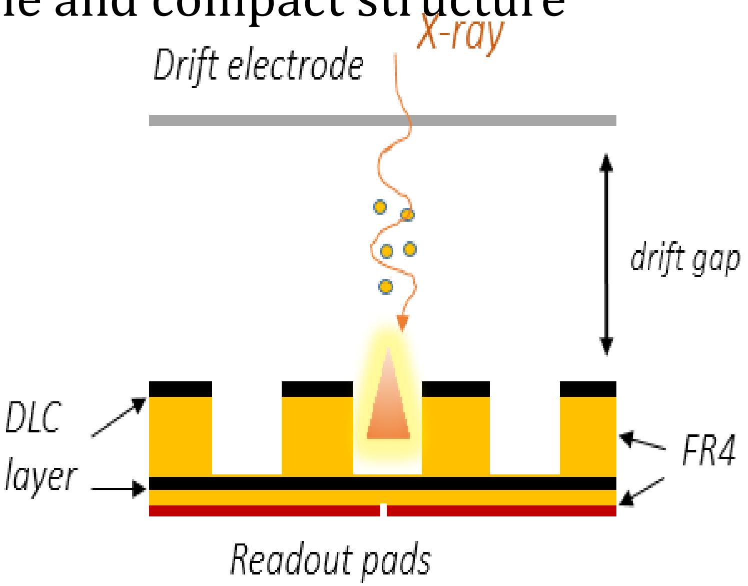
Another MPGD for DHCAL

- Problems with the GEM detector for application to the DHCAL:



1. Hard to reduce dead area(~10%) caused by the frame.
2. Complex mechanical structure

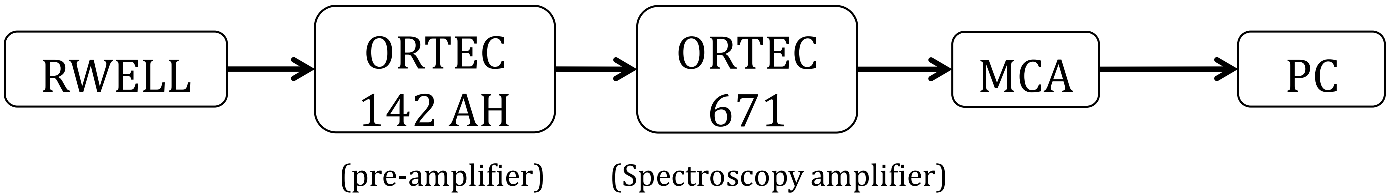
- Resistive WELL detector (RWELL): a simple and compact structure
  1. Only a drift gap
  2. One stage gas amplification
  3. Resistive layer

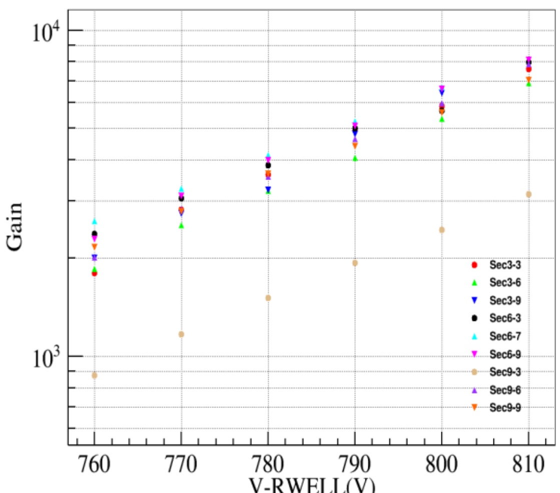


- Compare to GEM detector, it has advantages:
  1. No tension, no inner frame
  2. No transfer and induction gap

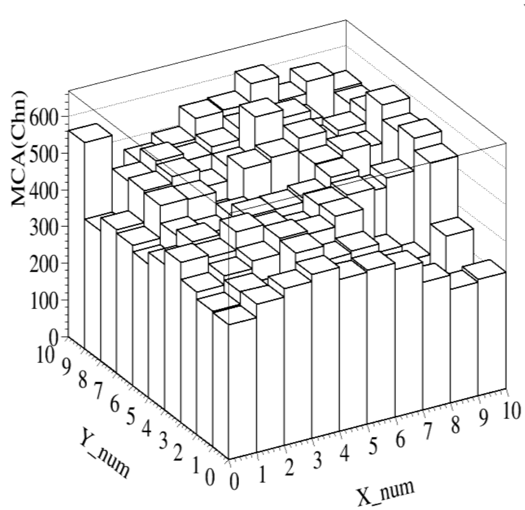
Gain

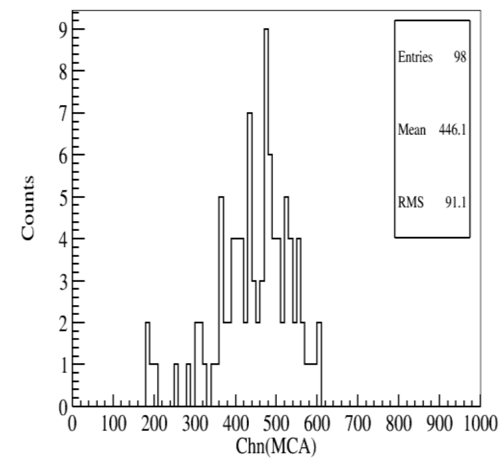
- Test setup :





Gain： ~8000





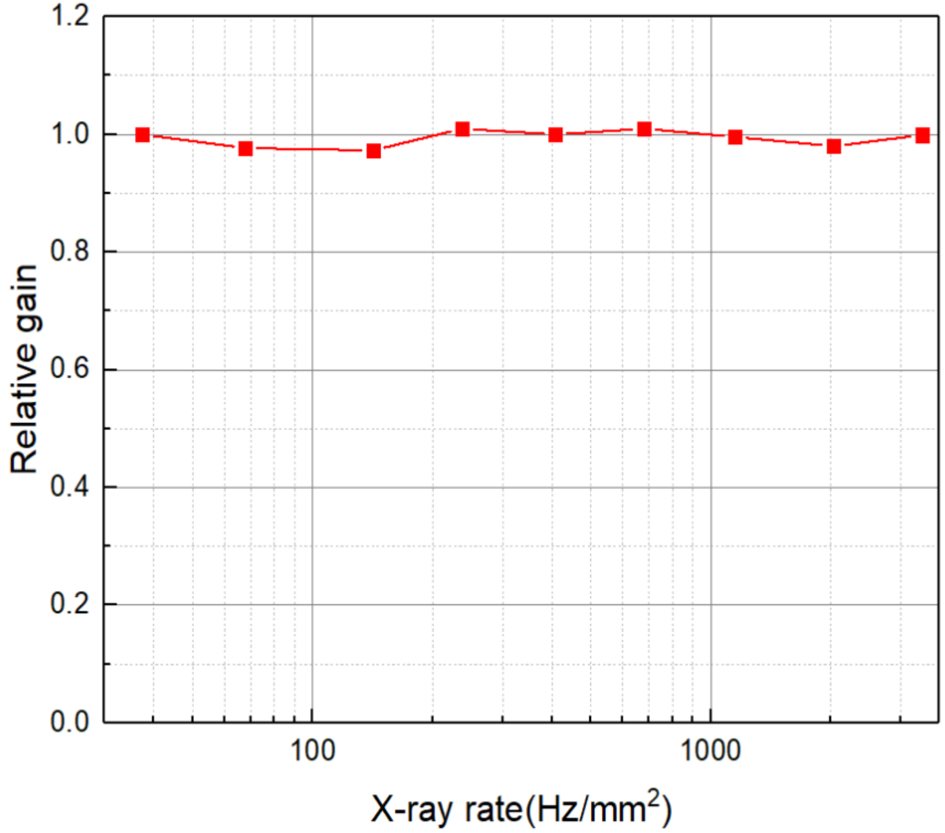
Gain uniformity :RMS/Mean ～20.4%

- Gain uniformity is not good. Possible reason:

  1. Gas flow
  2. Uniformity due to the thermal boding procedure

Rate Capability

- RWELL is irradiated with 8 keV X-ray, and gain of the detector is almost no reduction@300kHz/cm^2 (Initial gain G0:～5500).



- Detector discharge while irradiated at a higher rate

Summary and plan

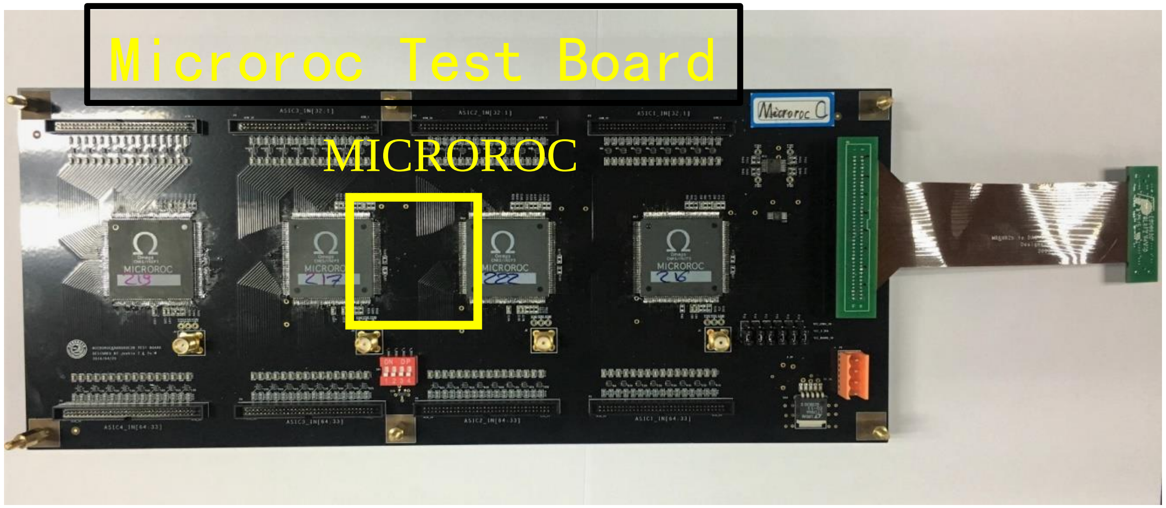
- Detection efficiency of the double GEM detector to MIP could reach 95% where the hit multiplicity is about 1.2 .
- Dead area of GEM detector using self-stretching technique is hard to reduce, then RWELL detector is developed as one of the candidates.
- A 25cm×25cm DLC-coating RWELL detector with thermal bonding technique has been preliminarily studied. Results show gain of the detector could reach 8000 with a 20% uniformity and rate capability could reach 300kHz/cm^2.
- Based on the results, RWELL detector is considered as a promising candidate. A 50cm×100cm RWELL detector is in preparation.

Thank you !

- Backup

Readout ASIC

Readout ASIC	Channels	Dynamic Range	Threshold	Consumption
GASTONE	64	200fC	Single	2.4mW/ch
VFAT2	128	18.5fC	Single	1.5mW/ch
DIRAC	64	200fC for MPGD	Multiple	1mW/ch, 10μW/ch(ILC)
DCAL	64	20fC~200fC	Single	——
HARDROC2	64	10fC~10pC	Multiple	1.42mW/ch,10μW/ch(ILC)
MICROROC	64	1fC~500fC	Multiple	335μW/ch



MICROROC Parameters:

1. 64 Channels
2. 3 threshold per channel
3. Thickness: 1.4mm
4. 128 hit storage depth
5. Minimum distinguishable charge:2fC