Preliminary Result of TRD Test Beam

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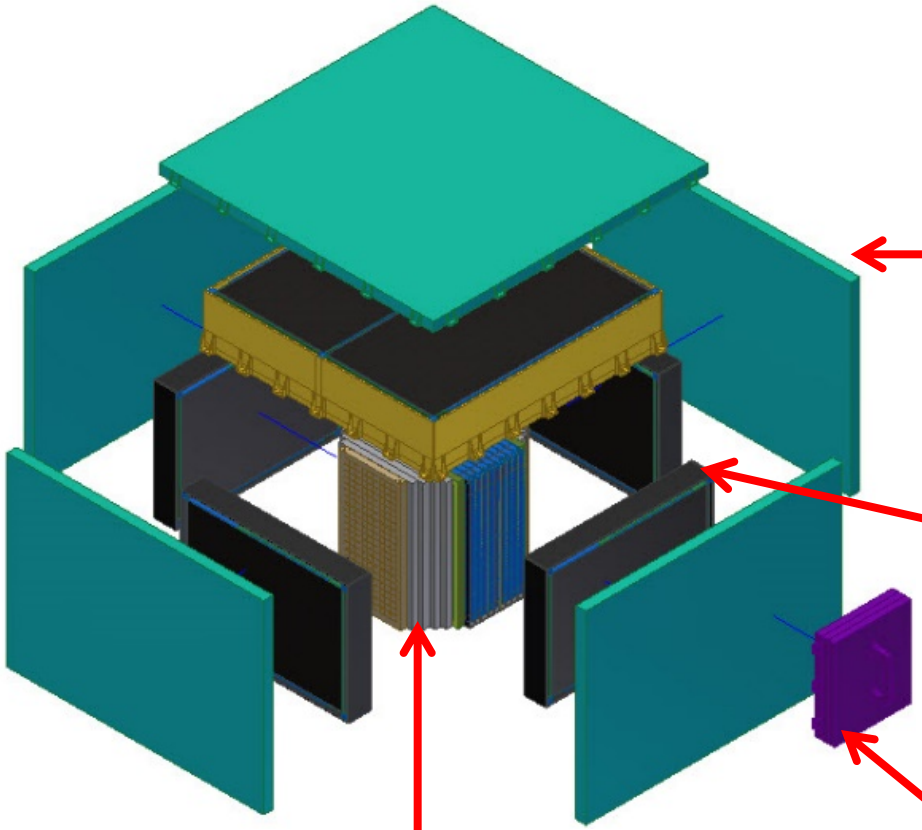
Outline

- **In-orbit Calibration of HERD-CALO**

- **TRD Design**
  - **THGEM**
  - **Radiator**
- **TRD test Beam**
  - **Layout**
  - **MIP detection efficiency**
  - **TR detection**
- **Conclusion**

HERD payload



PSD, five sides
LE Gamma identification
Charge

STK(SSD),five sides
Charge
Trajectory
Gamma tracking

TRD
TeV proton calibration

LYSO array
Trigger sub-system
ISCMOS sub-system

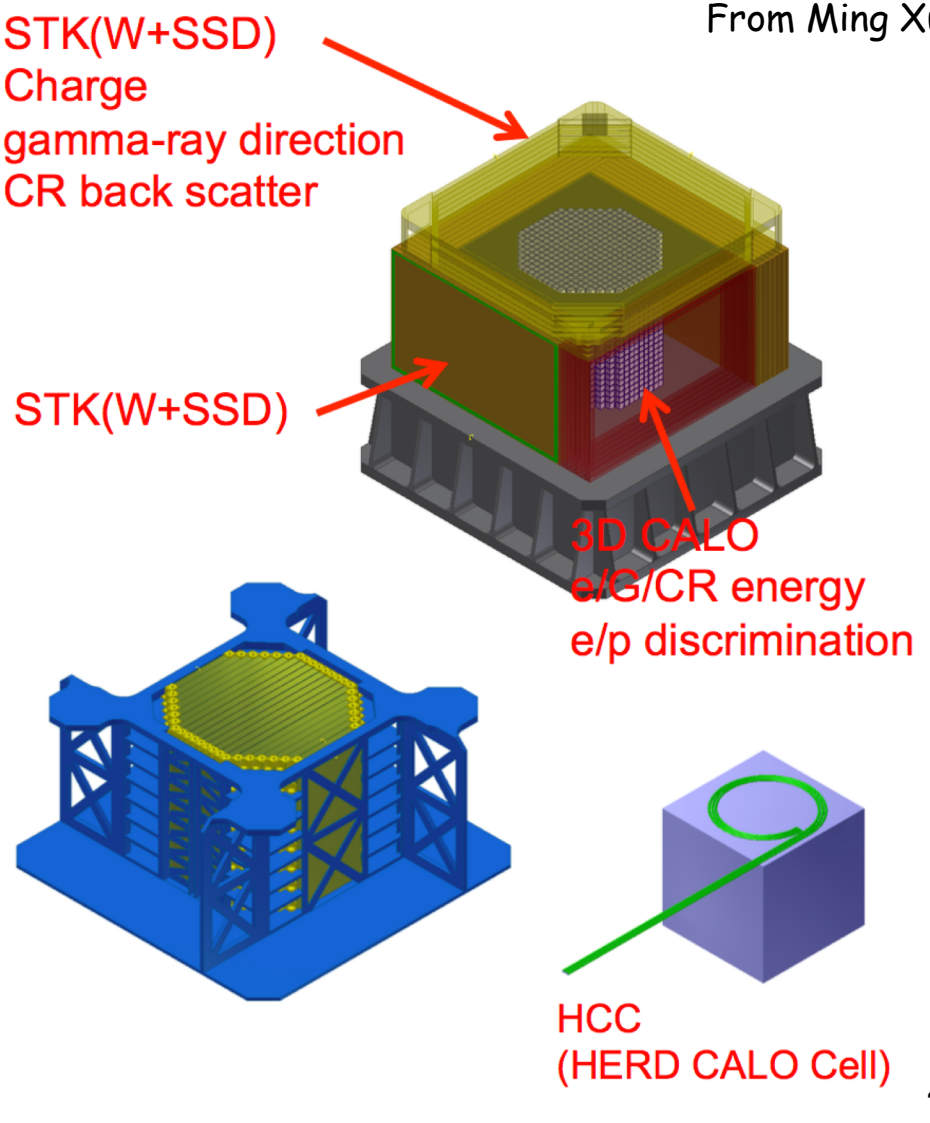
CALO, 3-d
e/G/CR energy
e/p discrimination

HERD CALOrimeter

- HERD's science goals (DM search, PeV CR physics) are strongly depend on the performance of calorimeter. Calibration of CALO is essential to the understanding the behavior of the instrument and interpret its science results

electron / photon energy range	10 (0.5)GeV—10 TeV
proton range	30 GeV—PeV
num. of crystals	~7500 LYSO
LYSO crystal	3cm*3cm*3cm
WLFs readout	3 ch./ crystal
D.R.	~10^7 （30-10^8p.e.）
trigger rate	< 500 cps
working type	calibration; low E. photon; high E. charged CR

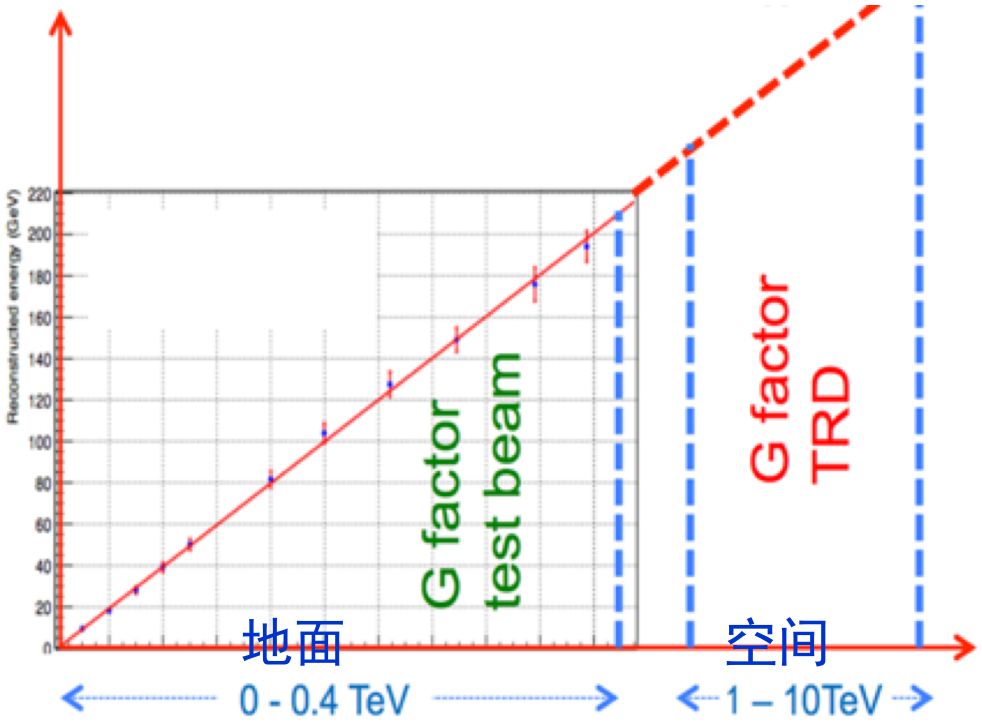
From Ming Xu



Calibration strategy

- Before launch
  - Ground calibration using MIPs signal of the cosmic muon tracker(mass production)
  - calibration with test beam (High/low gain, energy scale, energy resolution…)
- After launch
  - On-orbit calibration with cosmic rays (the geomagnetic cutoff)
  - LED monitor
  - Calibration with Transition Radiation Detector (TRD) , absolute energy scale from 1 TeV ~ 10 TeV (proton)

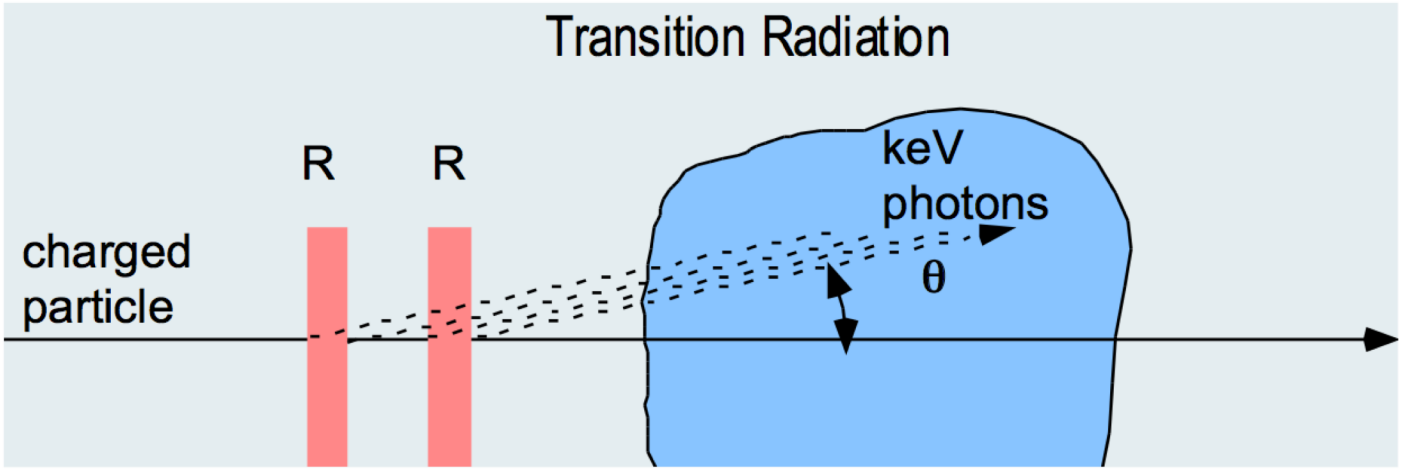
Calibration with TRD



- The CALO energy scales could be obtained by test beam up to 400 GeV
- TRD provides a feasible calibration for proton between 1- 10 TeV

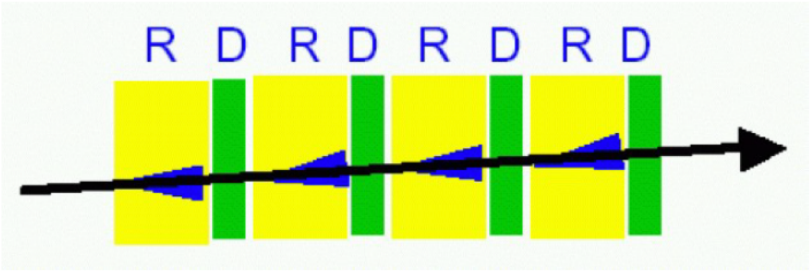
Transition Radiation

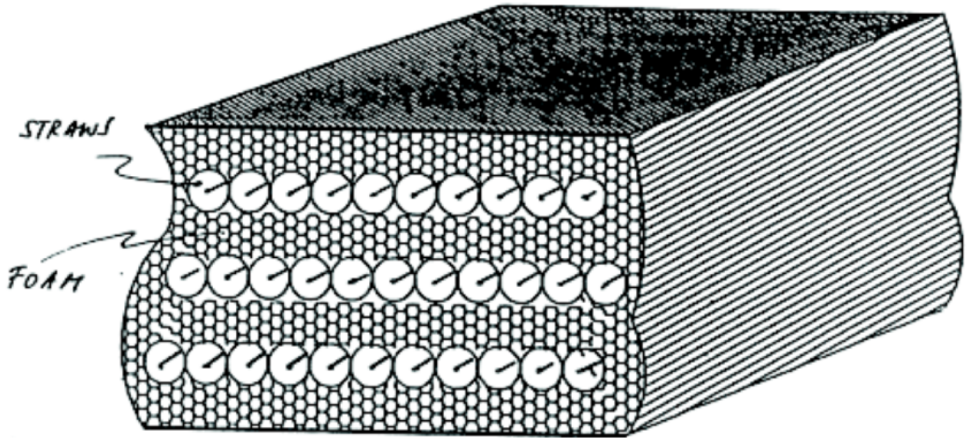
- The sudden change in electric field as an ultra-relativistic charged particle passes from one medium to another results in ~ keV photons
- Ultra-relativistic: $\gamma > 1000$ ($\gamma = (1-\beta^2)^{-1/2} = E(k) / m0$)
  - usually γ(threshold) =1000; γ(saturation) = 10000;
- Light is emitted at the angle $\theta \sim 1/\gamma$ ($\gamma \sim 10^3$, $\theta \sim 1$mrad)



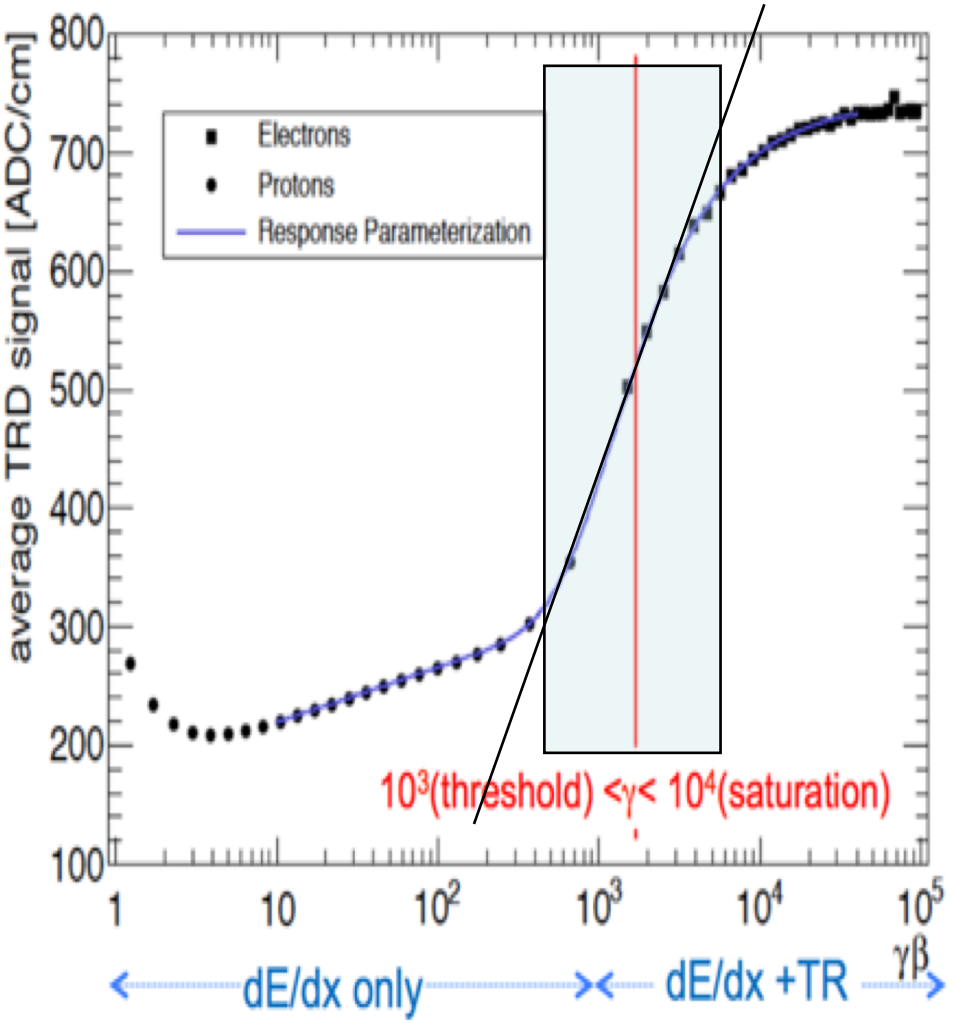
How TRD works

- TRD: radiator-detector sandwich
  - radiator: pile of foils, foam (small **Z**), need many transitions for significant TR photons
  - photon detector, detect keV photons (photo-elect absorption $\propto$ $\mathbf{Z}^5$)
- normally, TR can NOT be measured alone, signal from ionization is overlying
  - dE/dx + TR





TRD for Calibration



Lorentz factor: $10^3 < \gamma < 10^4$

Electron: 0.5 < E(k) < 5 GeV

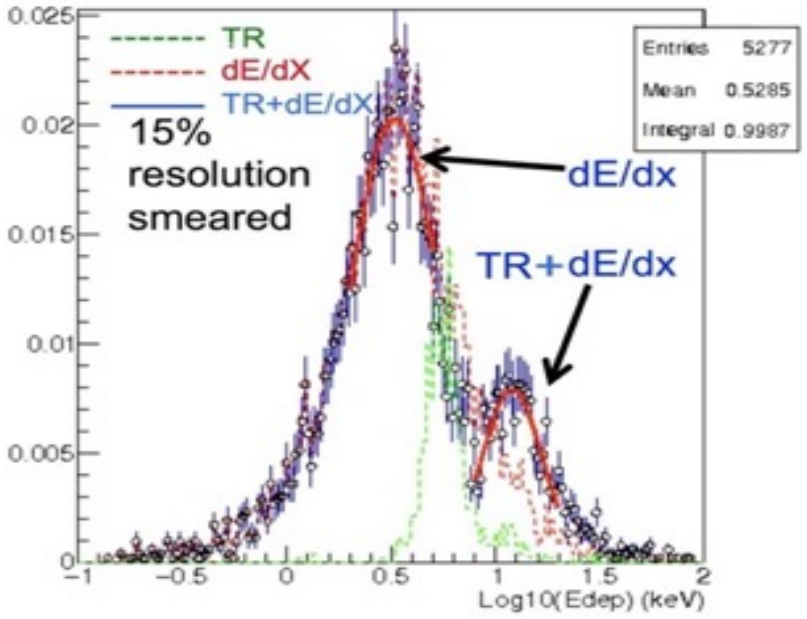
Proton: 1 < E(k) < 10 TeV

TRD-calibrate procedure:

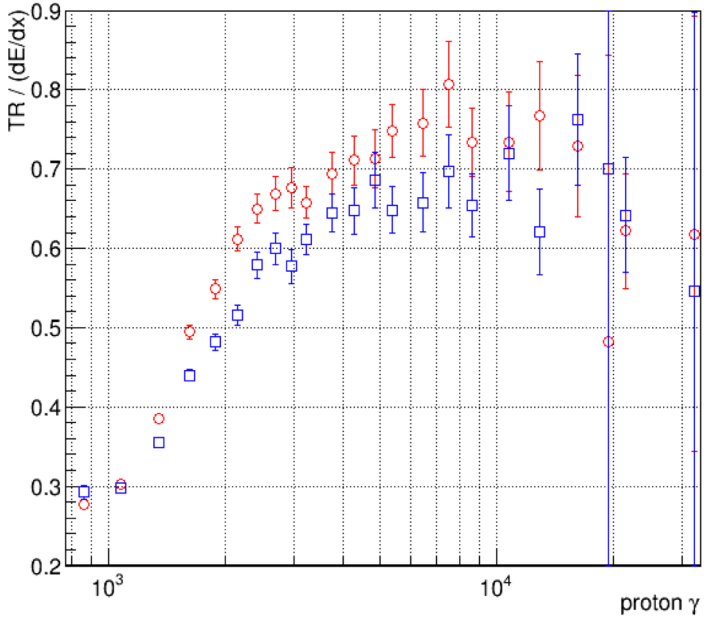
1. TRD calibrate by electron (test beam / in space)
2. 10 TeV proton & 5 GeV electron, same response in TRD
3. Calibrate 1 - 10 TeV proton CALO by TRD in space

TRD for Calibration

- A complete calibration in 2-3 months in-orbit operation with MWPC.

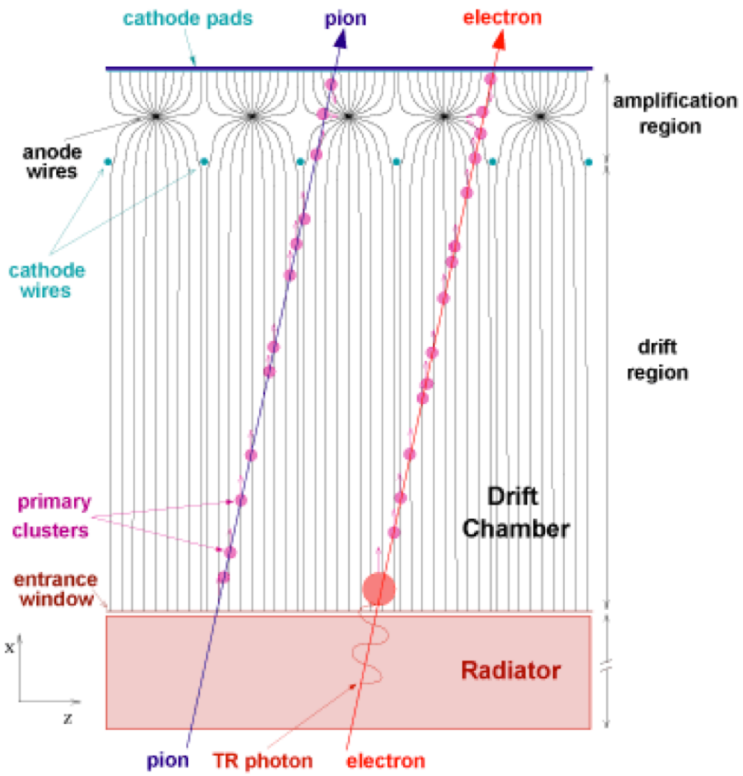


TRD E spectrum of TeV protons

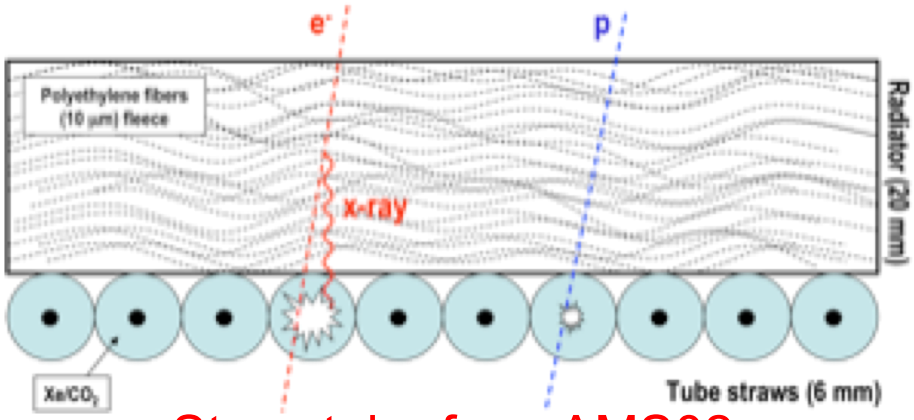


3 months simulated observation, (TRD~0.75 m^2)

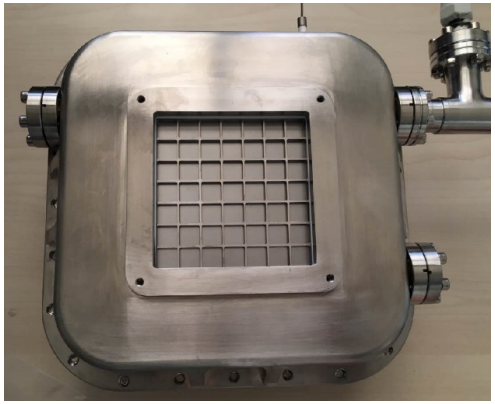
TRD



Drift Chamber from Alice



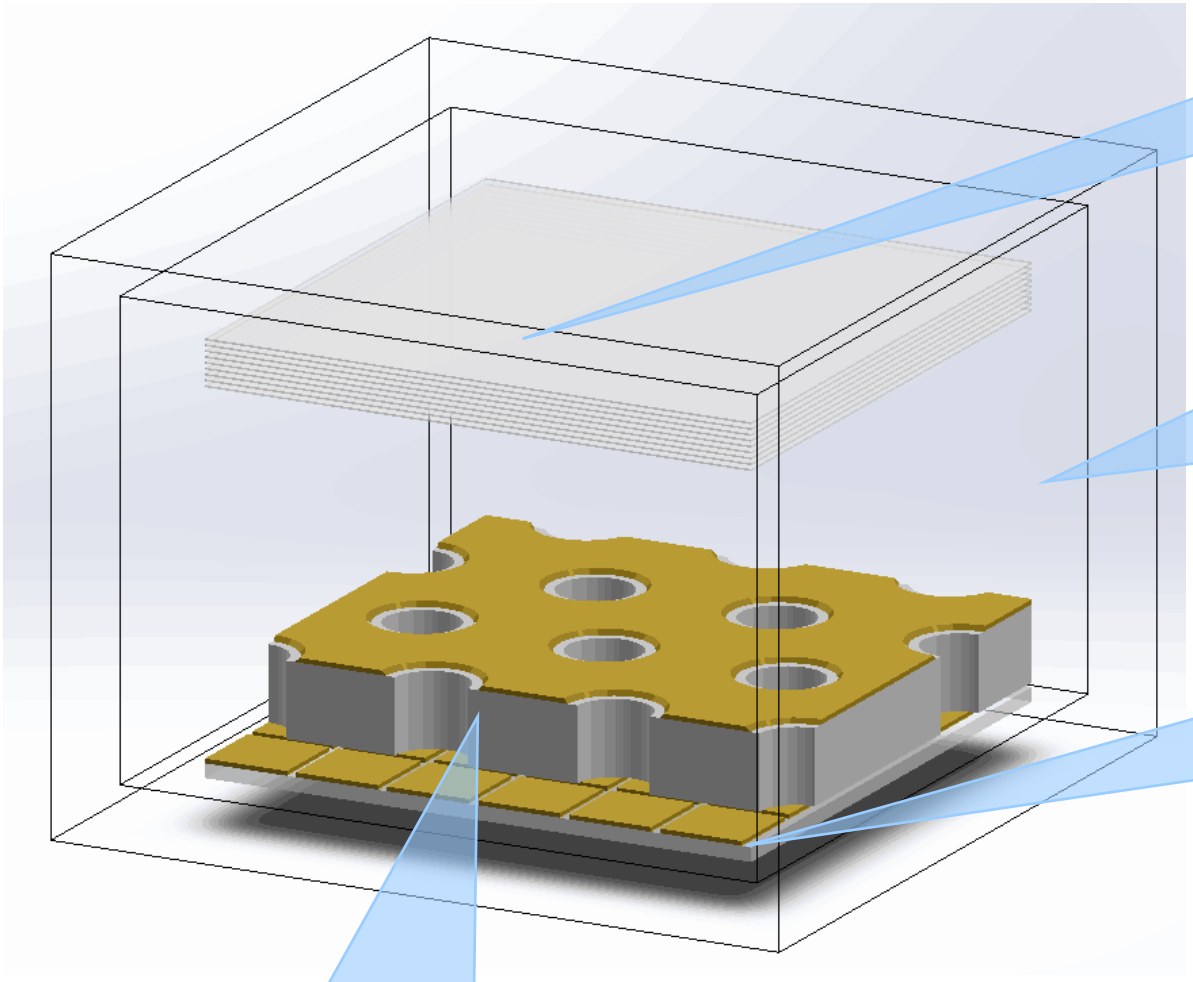
Straw tube from AMS02



MWPC

（from h. Feng）

THGEM-TRD Preliminary Design



Radiator:
pile of foils,
foam,fiber(small Z)

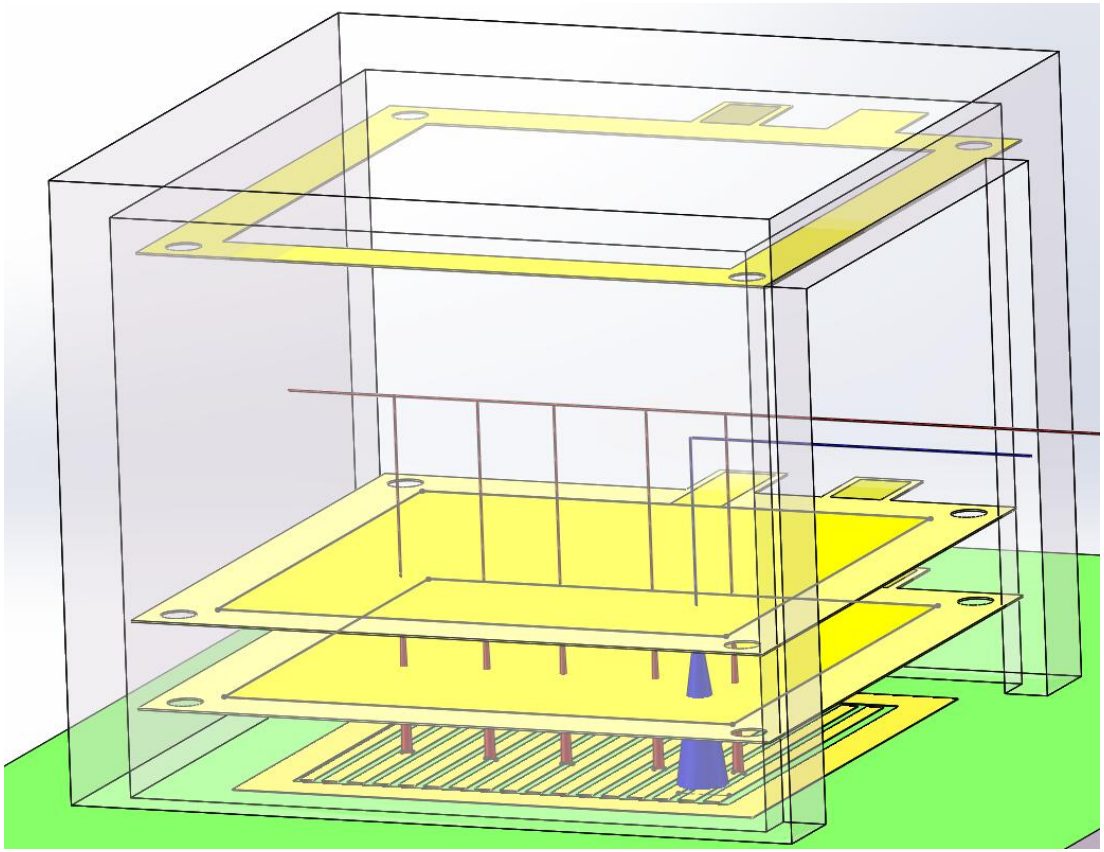
Gas:
Xe+CO2 (85+15)

Electric:
Analog readout/
Waveform readout

Detecor: Well-THGEM

2D/3D FADC readout to increase the separation of dE/dx and TR signal

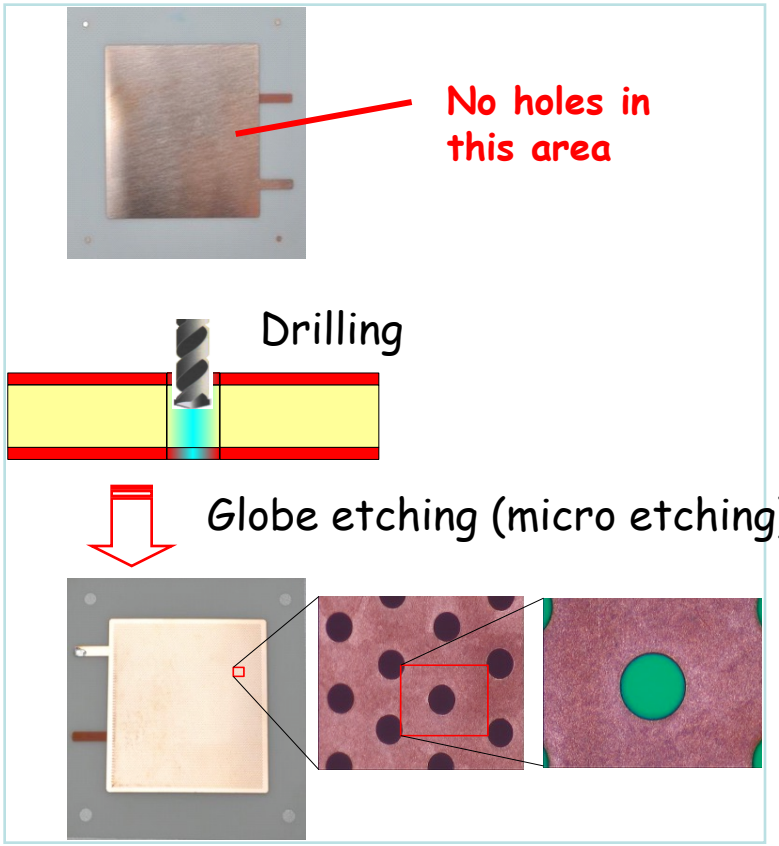
Side-on TRD



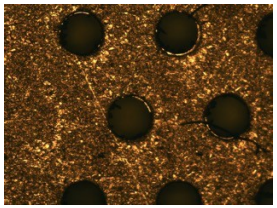
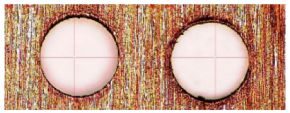
- The signals of TR are coupled with dE/dx in detector
- Side-on TRD have the ability to separate the TR signal form dE/dx EVENT by EVENT

- TR：10 keV @ γ～10^3
- dE/dx：8.7keV/cm @1atm Xe

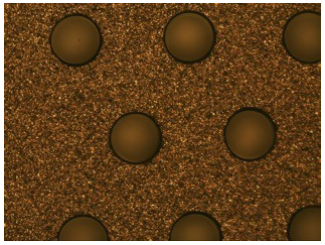
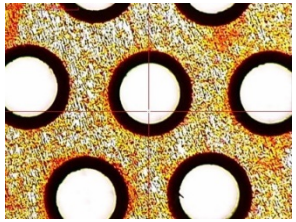
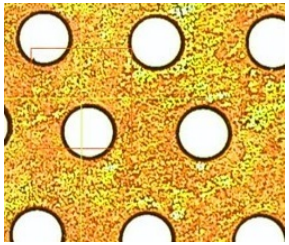
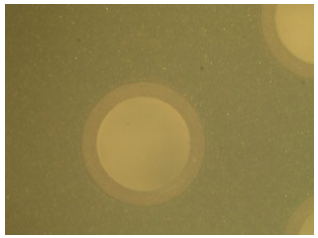
THGEM production



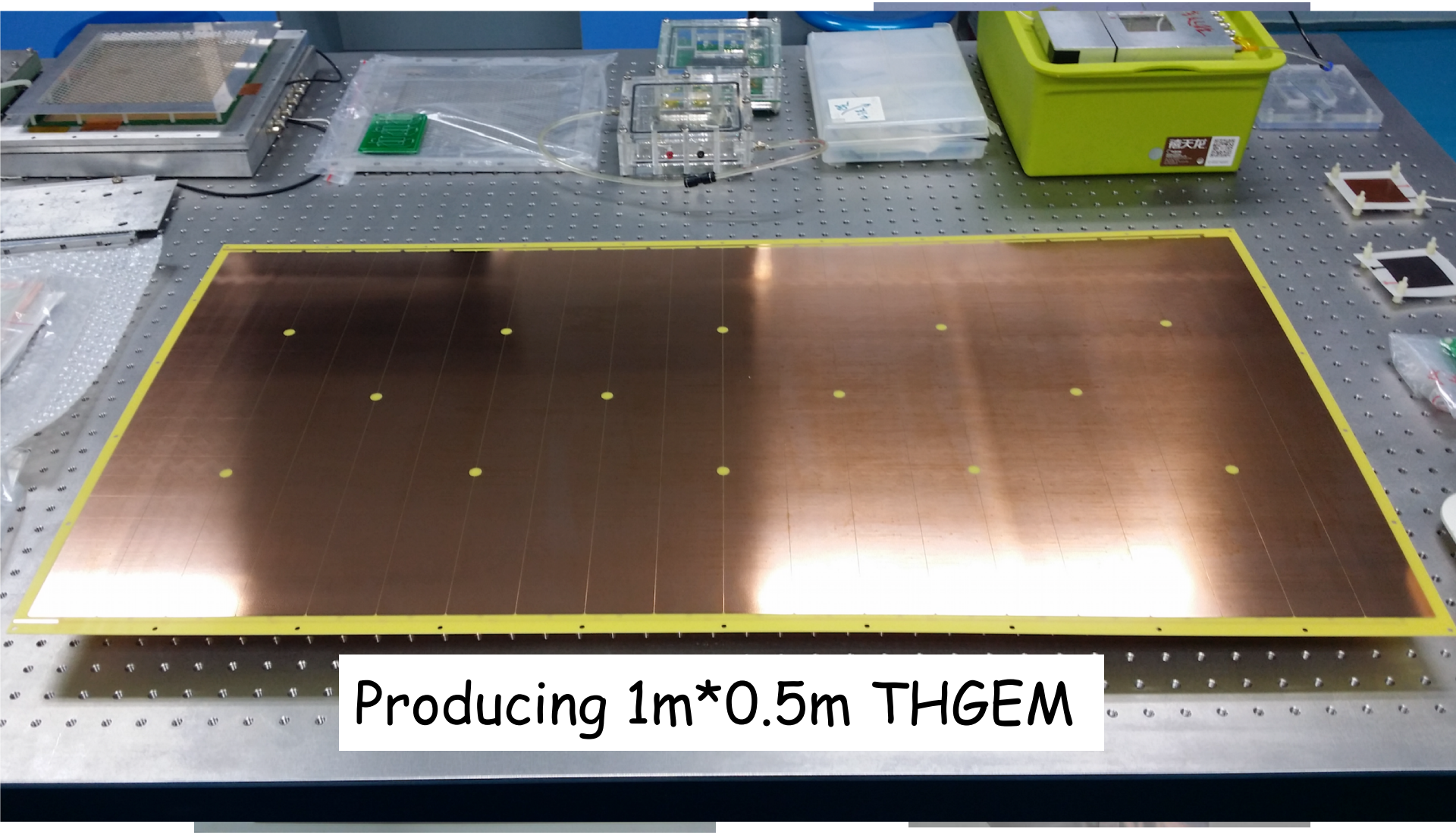
1. Mechanical drilling or laser drilling

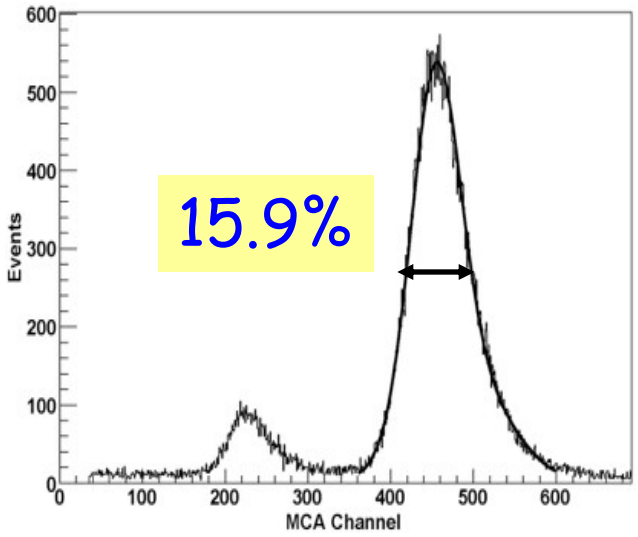
2. Etching：
   globe etching,
   mask etching,
   electrical chemical etching

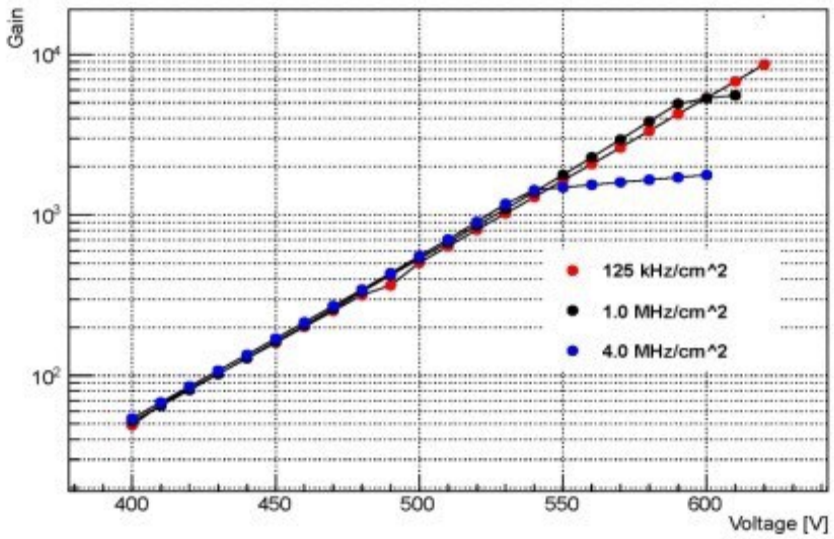





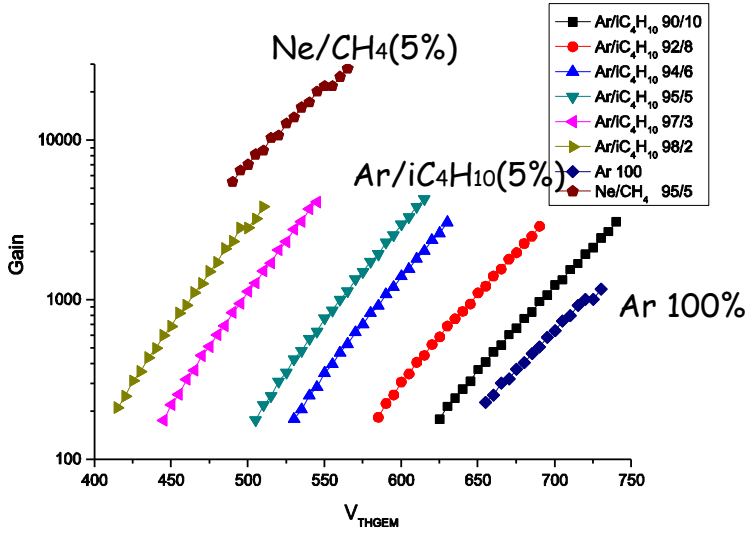
THGEM production（cont.）

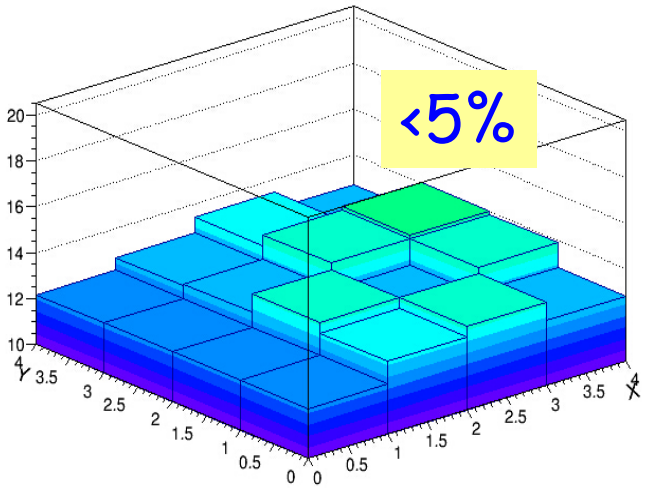


Performance of THGEM

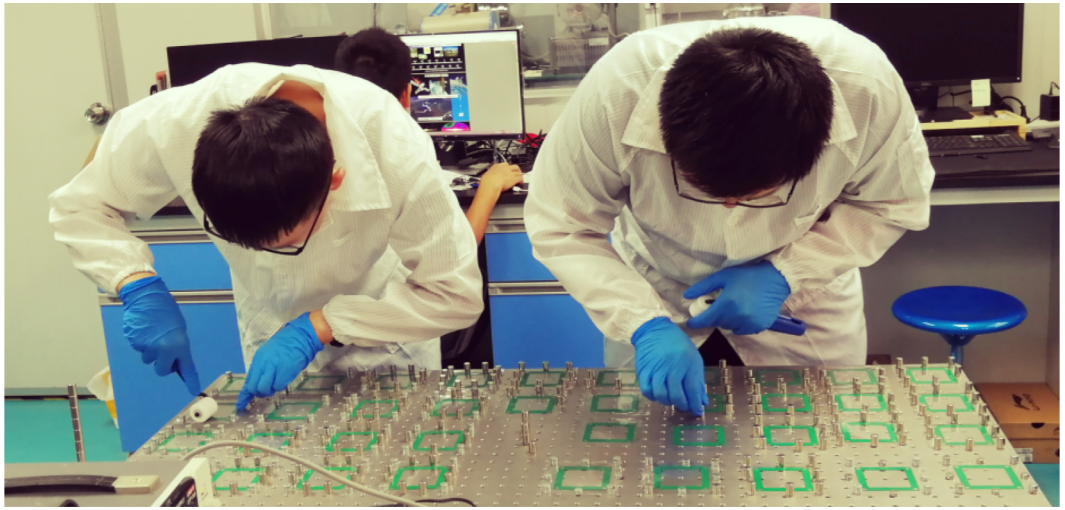


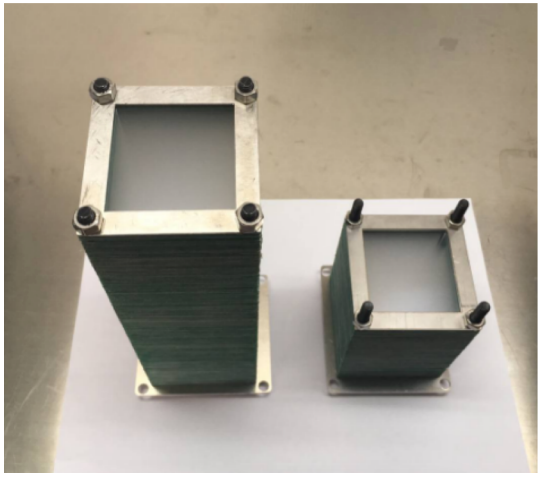


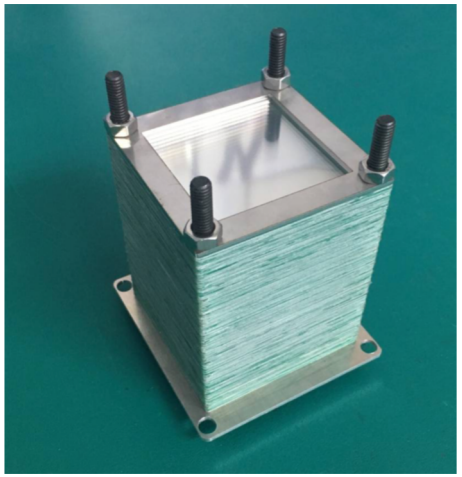




Radiator

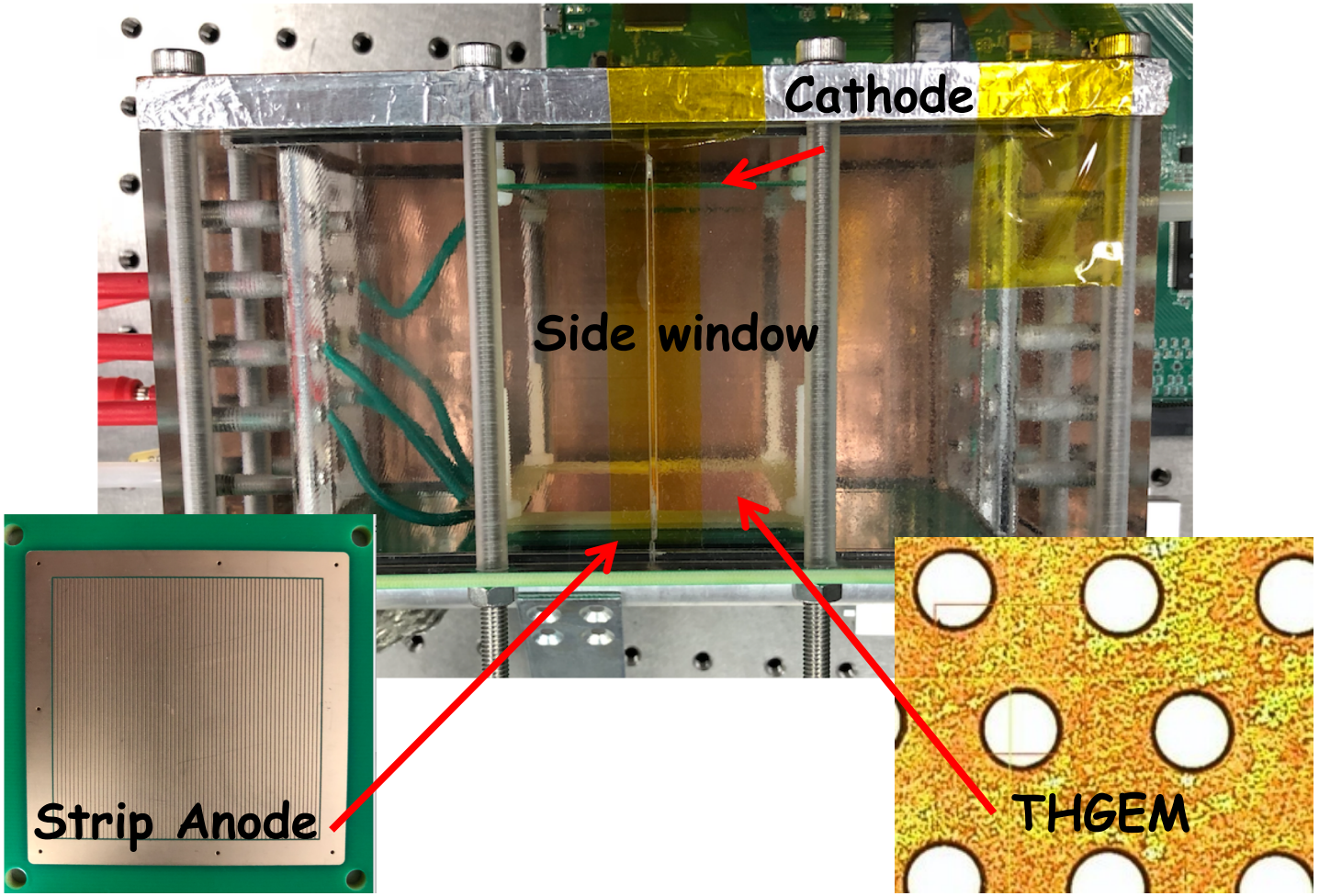




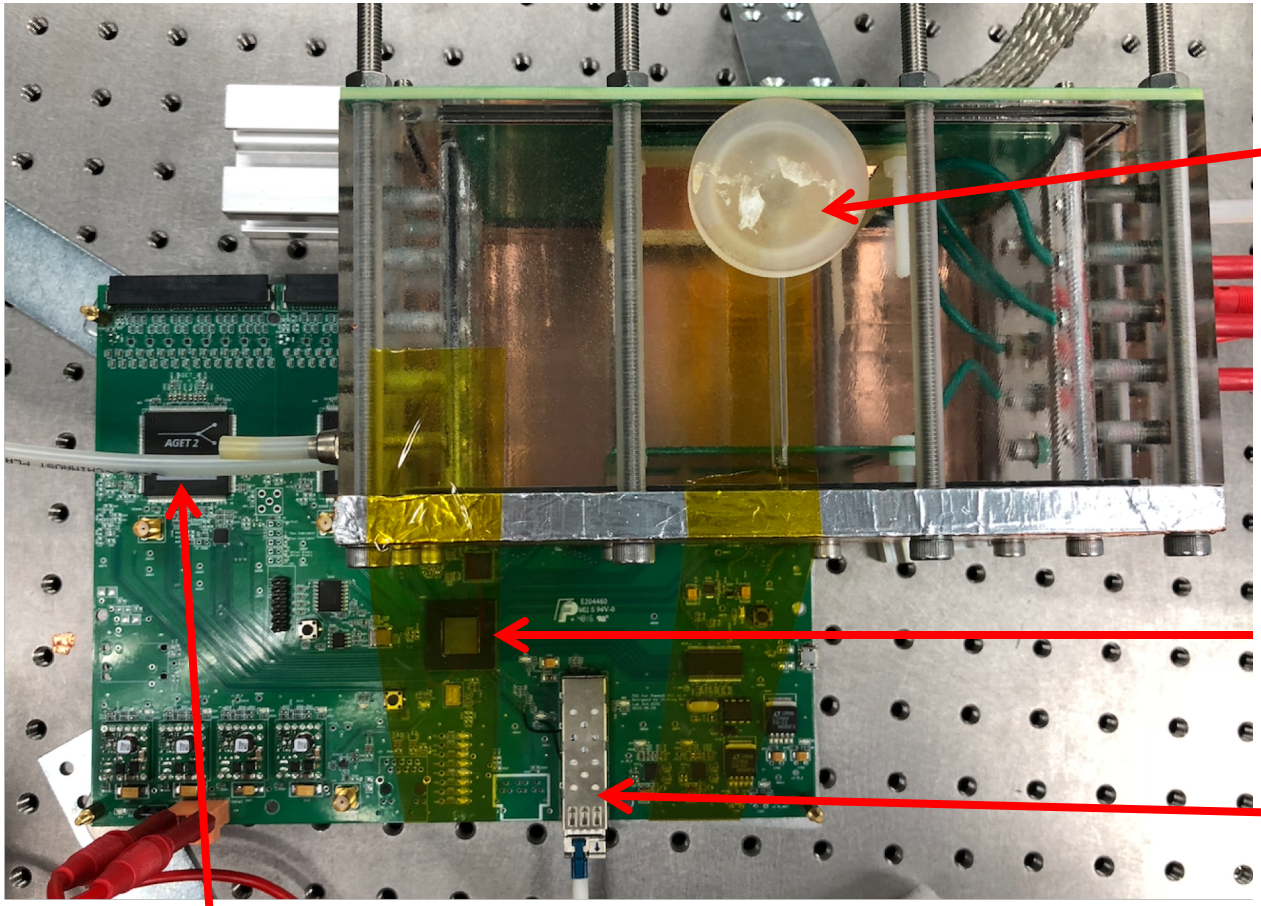


- 300 foils of radiator PP(0.02mm)+Air(0.5 mm)
- 150 foils of radiator PP(0.02mm)+Air(0.5 mm)
- 225 foils of radiator PP(0.02mm)+Air(0.8 mm)

Side-on TRD Chamber



Side-on TRD first Prototype



Fe Xray source

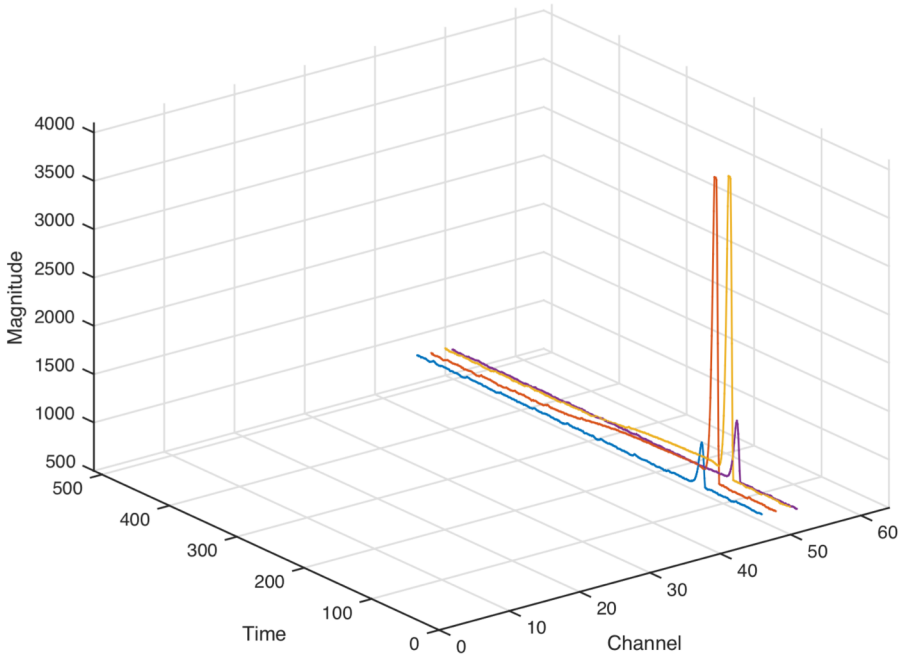
FPGA

Fiber
Connector

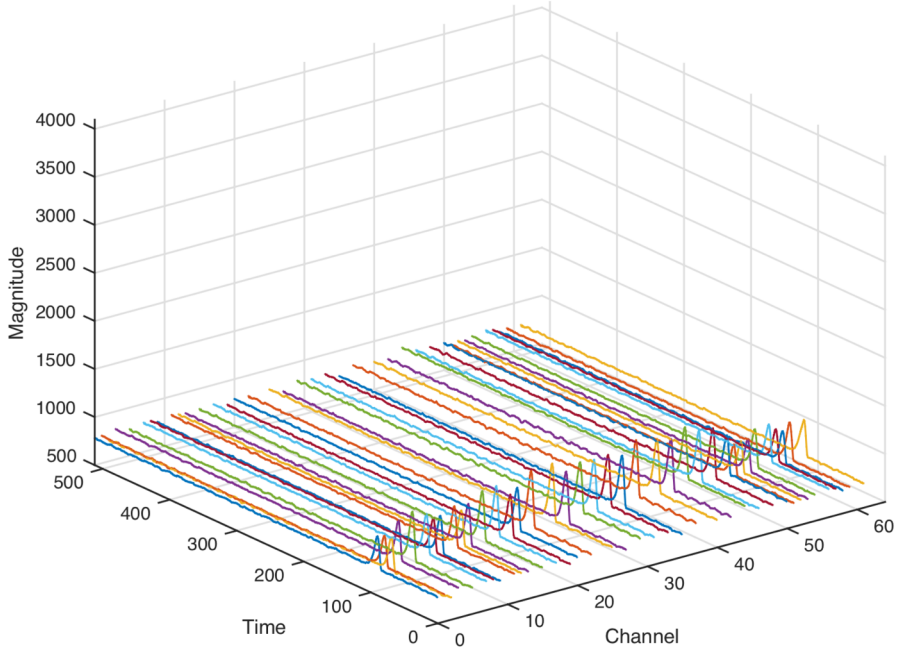
AGET ASIC

Side-on TRD Preliminary Result

5.9 keV X-Ray

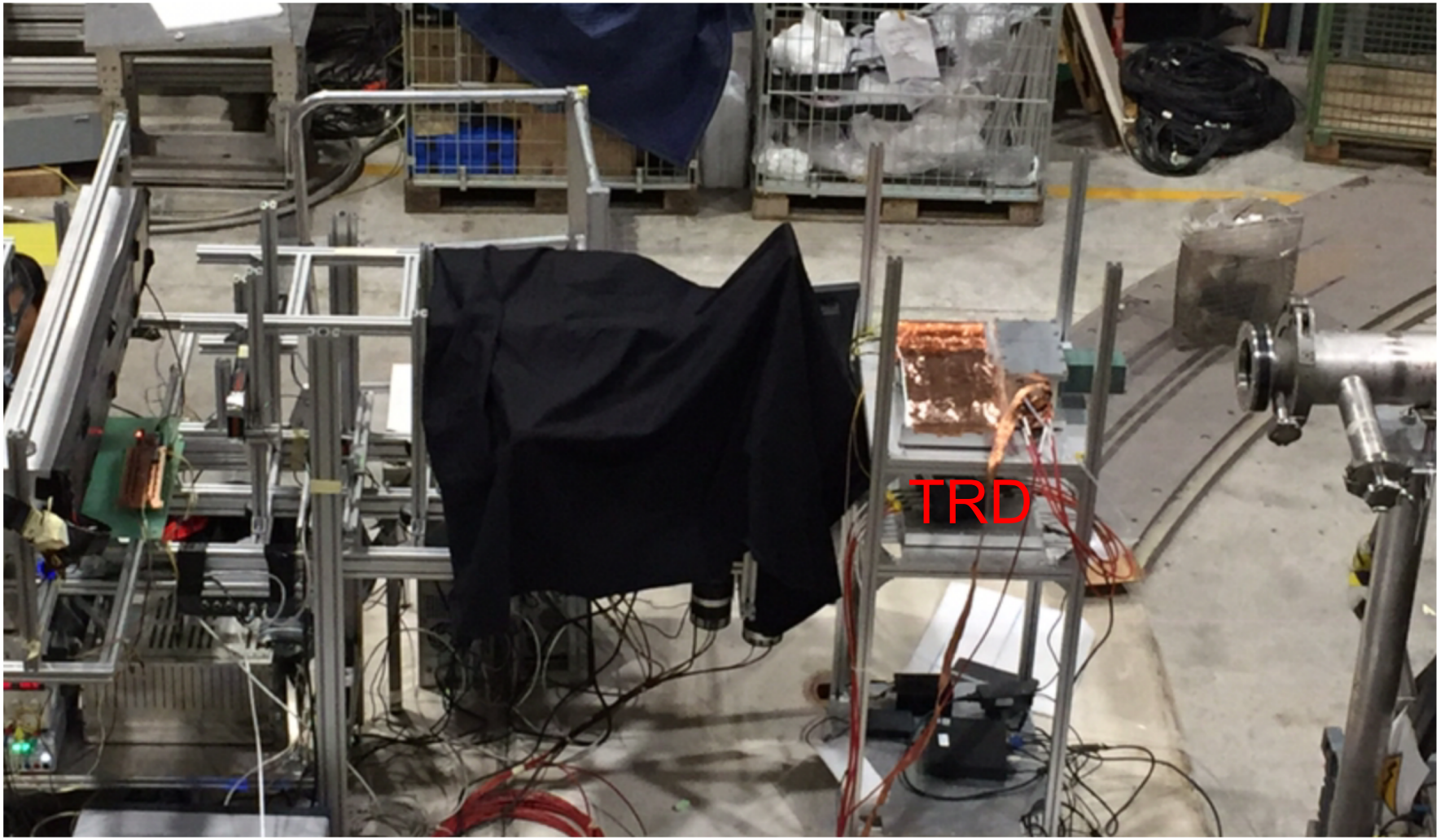


Cosmic ray

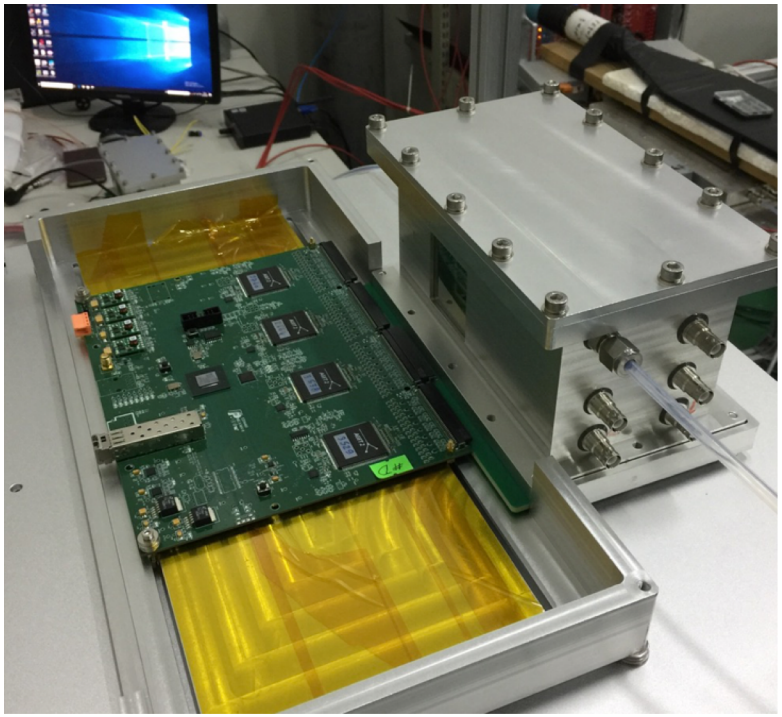


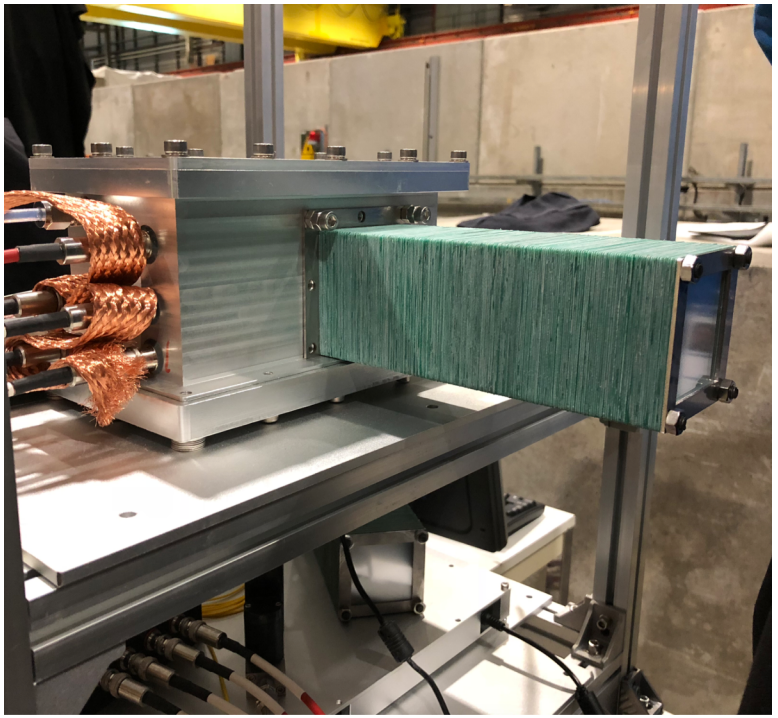
- X-Ray signals and MIP signals was tested in lab

Test beam layout

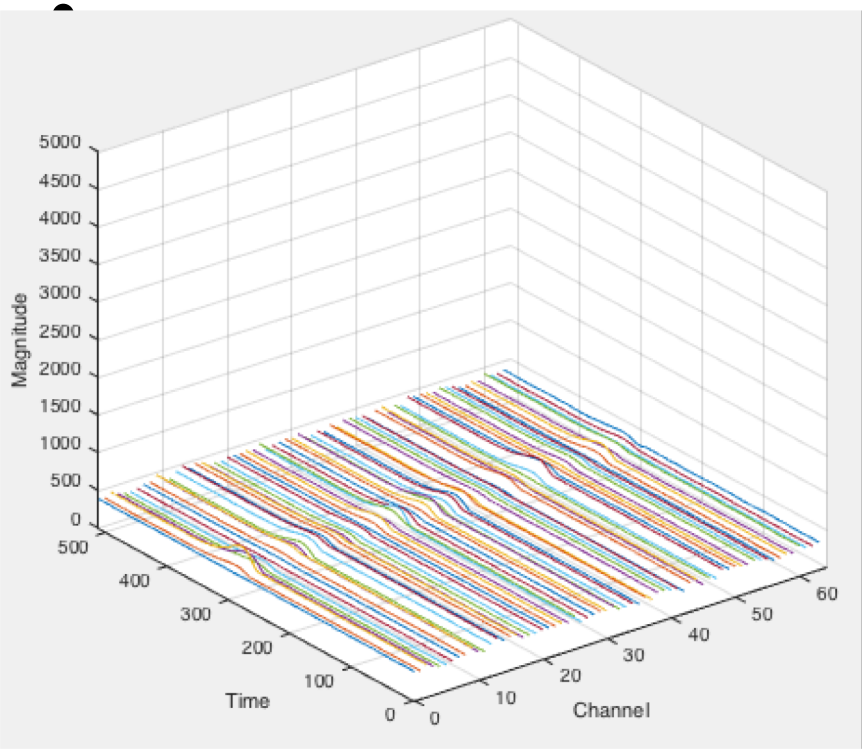


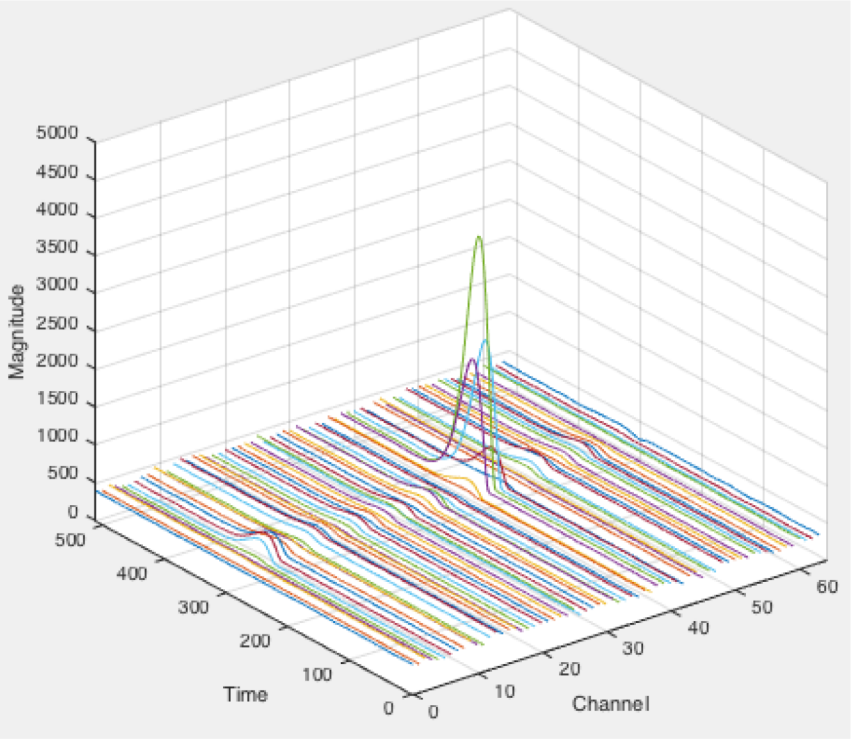
The Third Prototype of TRD





TRD Beam test

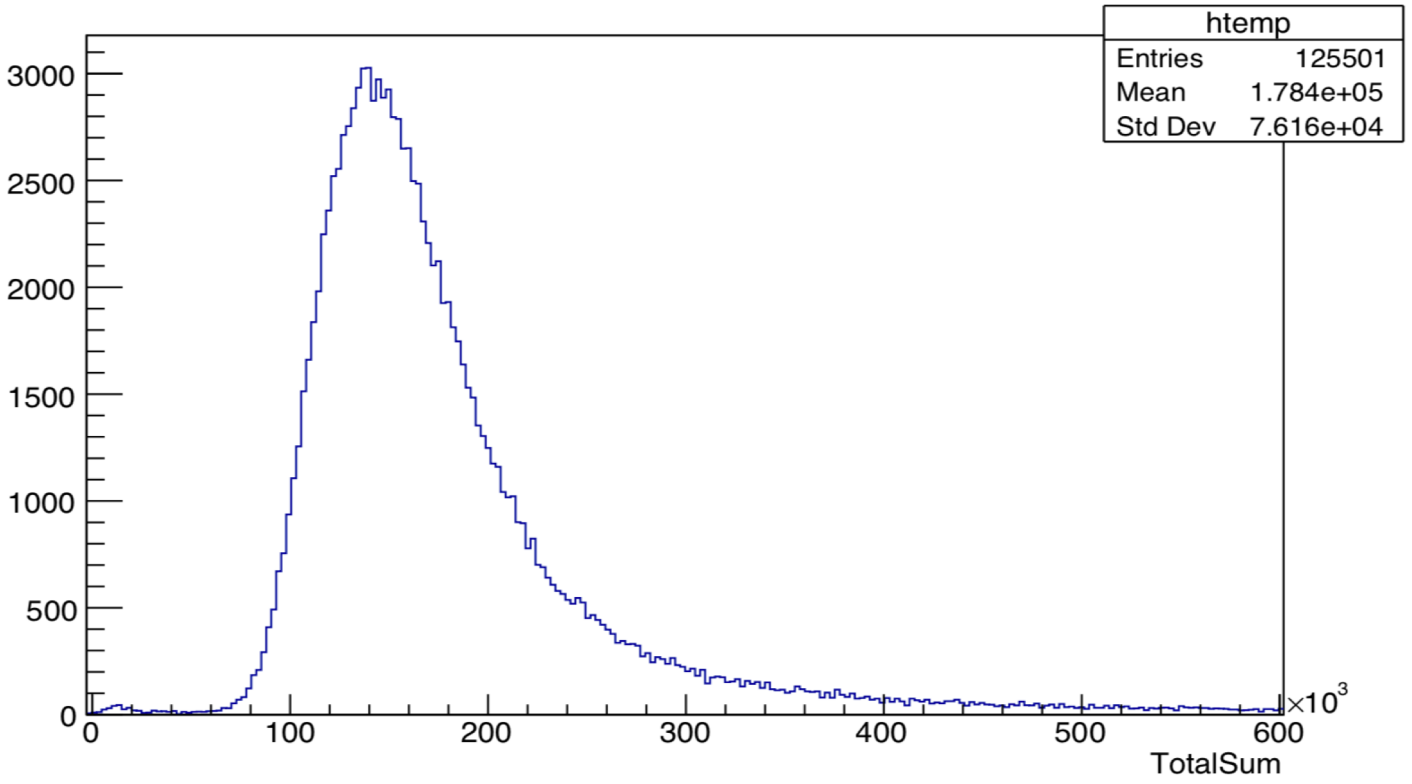




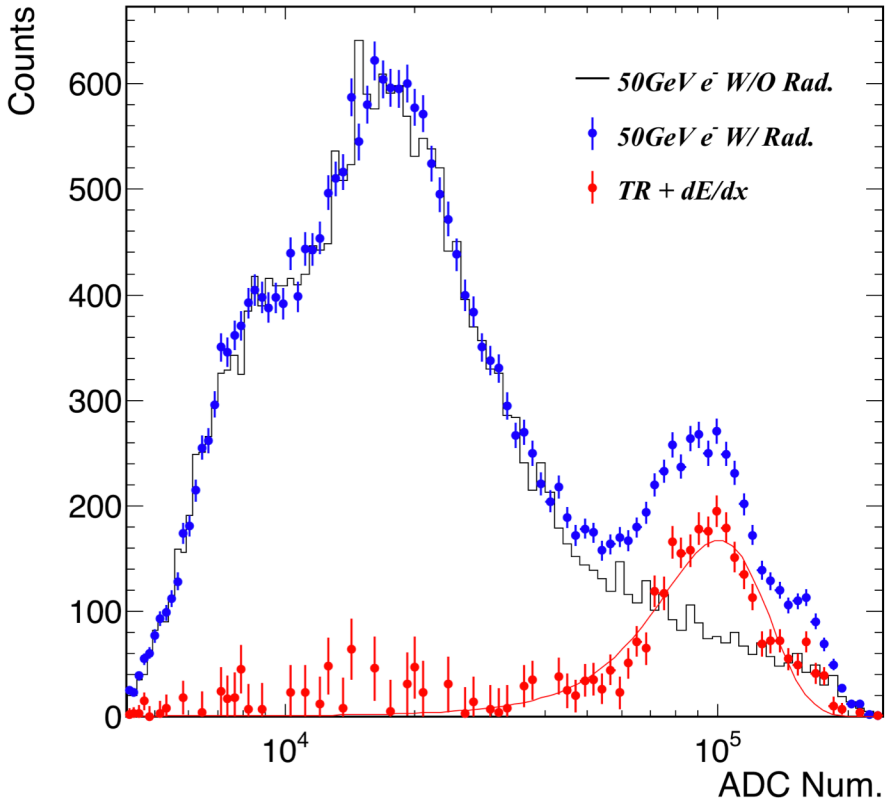
This peak is a TR-Xray or a delta electron?

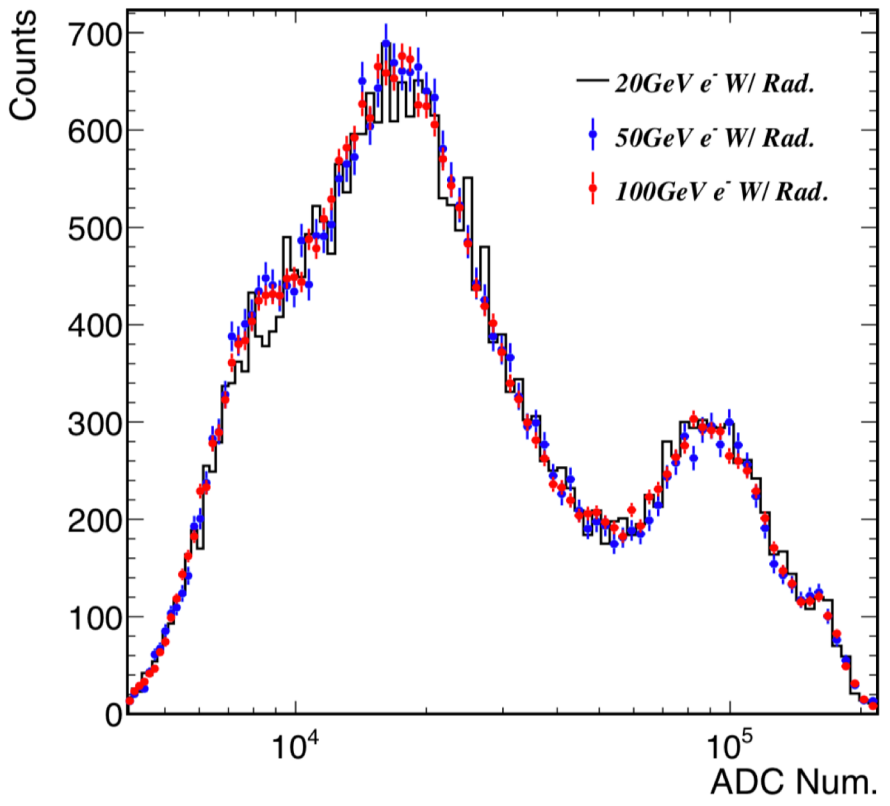
TRD detection efficiency

- 400GeV Proton beam
- 99.8% MIP detection efficiency



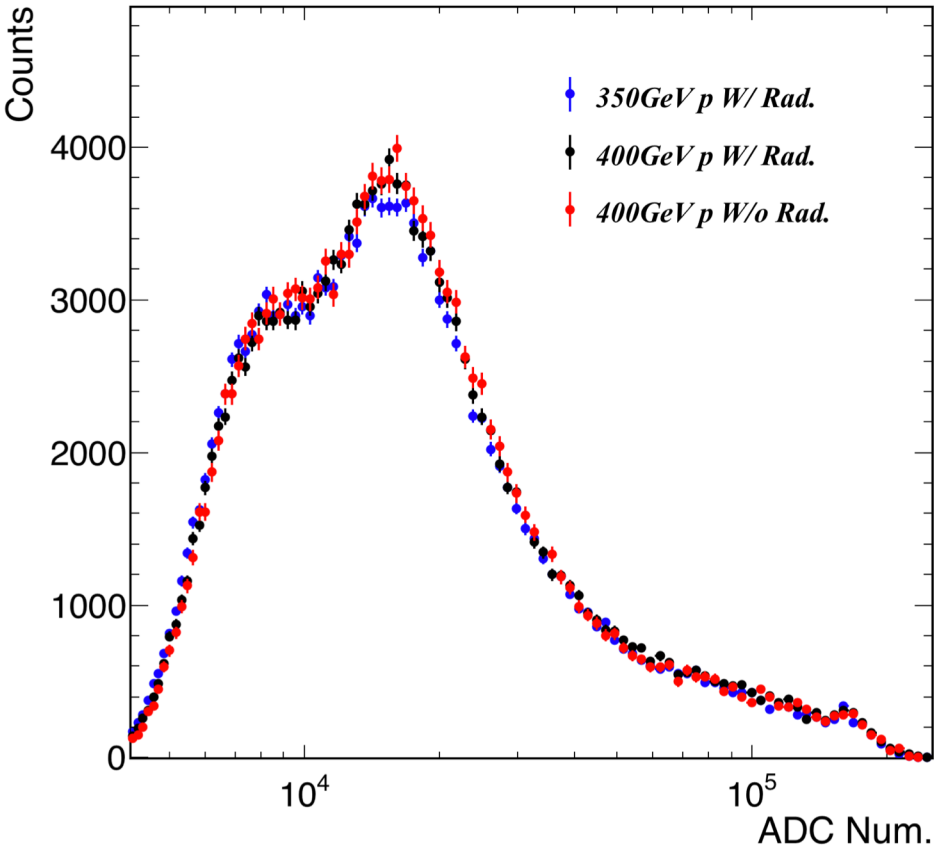
TR detection

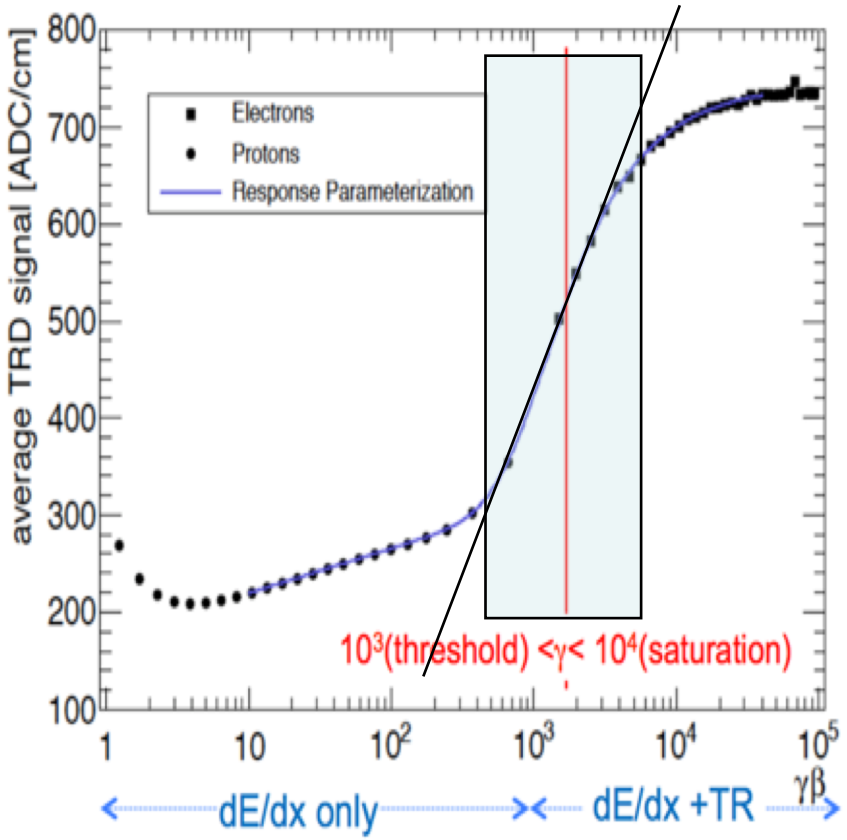




20GeV, 50GeV,100GeV electron beam

Significant TR signal





- TRD had been tested with proton beam(below the threshold) and electron beam(saturation).
- 1-5 GeV electron beams are needed

Summary

- Side-on TRD with high detection efficiency will shorten the calibration time on-orbit.
- Significant TR signal have been measured.
- TRD had been tested with beams below the threshold and above the saturation.
- We need 1-5 GeV electron beams to calibrate the linear region.

THANK YOU !