



Development of a 3D Imaging Calorimeter for Cosmic-ray Physics

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On behalf of DAMPE collaboration

Outline

- DArk Matter Particle Explorer of China
- 3D Imaging BGO Calorimeter
- Calorimeter Design and Assembly
- Cosmic Ray Calibration
- Beam Test in CERN
- Summary

DARK MATTER PARTICLE EXPLORER

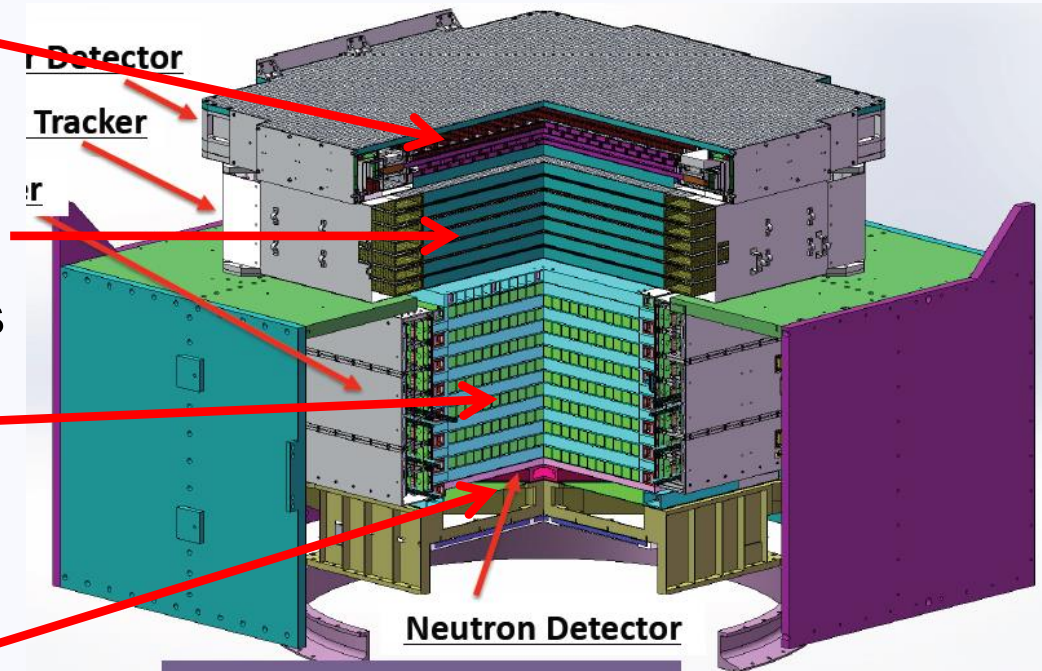
An instrument on the DAMPE Satellite

- 500km orbit
- e^{\pm} , gamma-rays
- 5GeV to 10TeV
- 1.5% @ 800GeV
- Total weight: ~1200kg



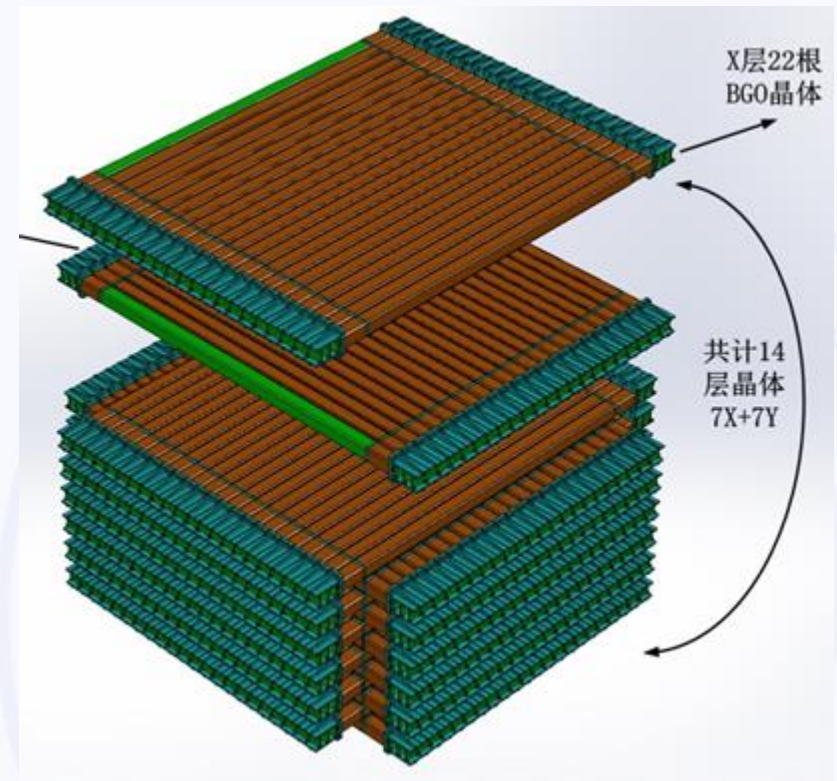
DARK MATTER PARTICLE EXPLORER

- Plastic Scintillator Array
 - Response : $Z=1\sim 20$
- Silicon Tungsten Tracker
 - 12 layers Si-strip detectors
- BGO Calorimeter
 - 14 layers BGO crystals
 - $\sim 32X_0$
- Neutron Detector
 - Plastic scintillator with Boron



3D Imaging BGO Calorimeter

- 14 layers of 22 BGO crystals
 - Dimension of BGO bar:
 $2.5 \times 2.5 \times 60 \text{cm}^3$
 - Hodoscopic stacking
alternating orthogonal layers
 - r.l: $\sim 32X_0$
 - NIL: 1.6
- Two PMTs coupled with each
BGO crystal bar in two ends
- Electronics boards attached
to each side of module

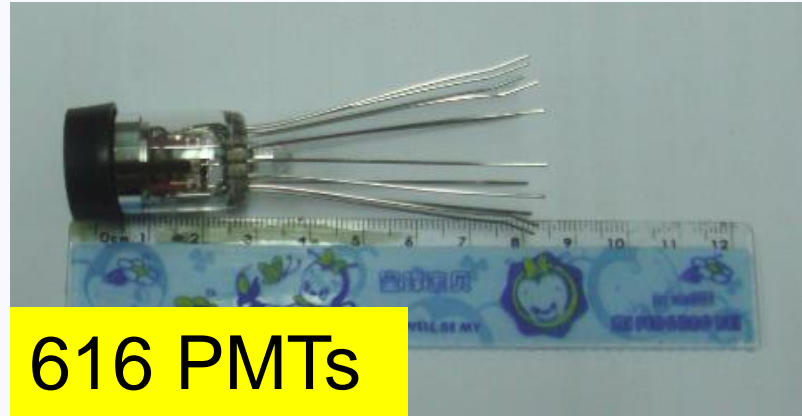


Calorimeter Elements

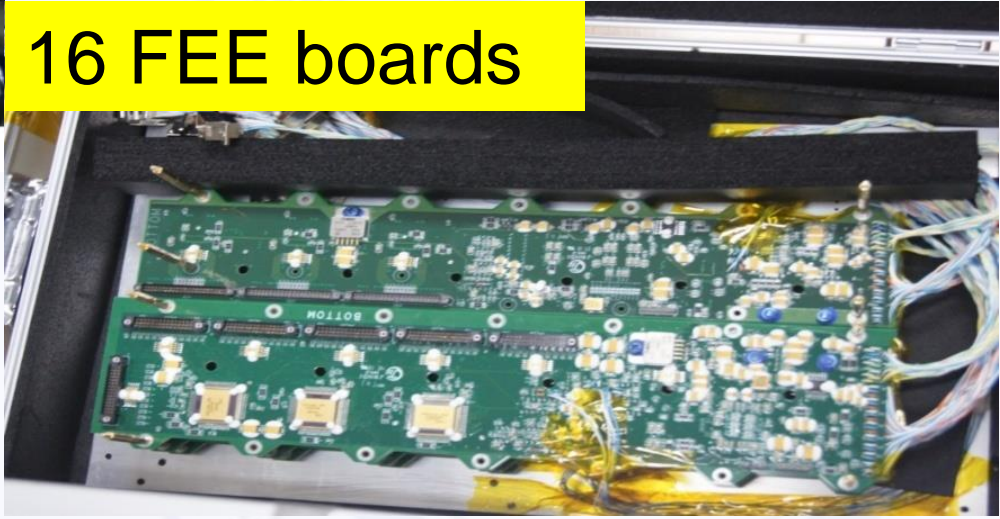
308 BGO bars



616 PMTs



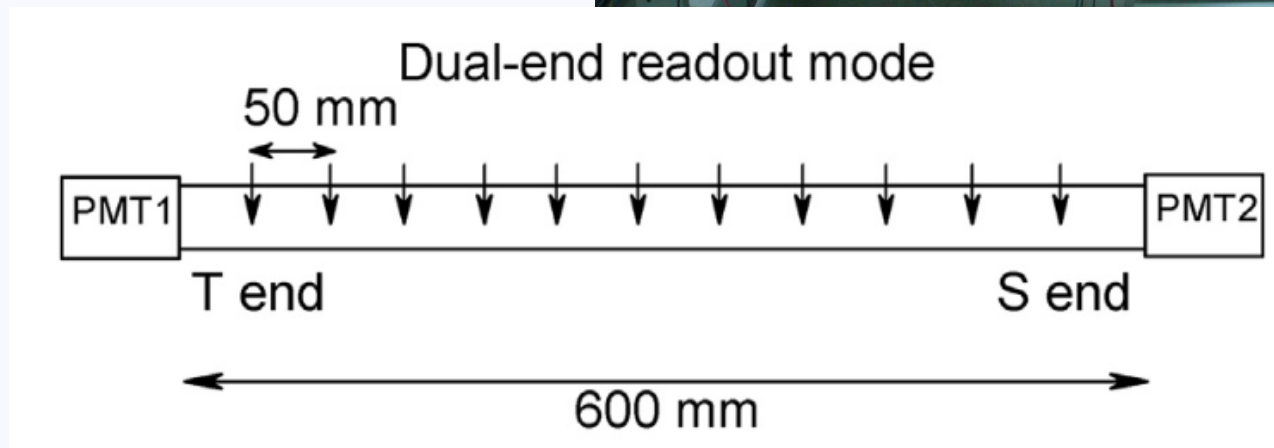
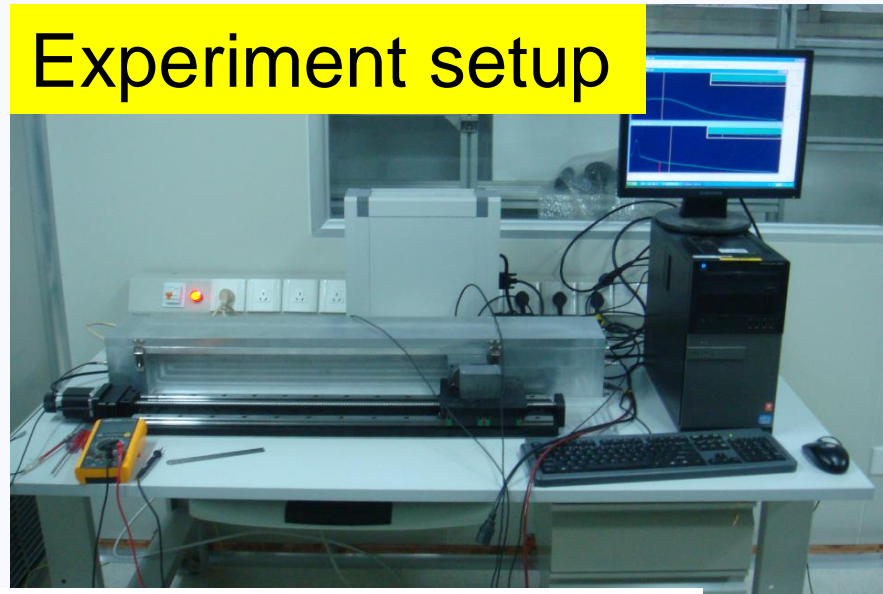
16 FEE boards



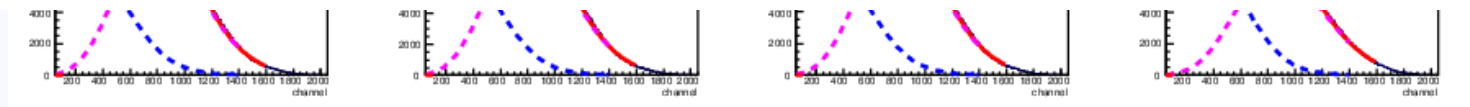
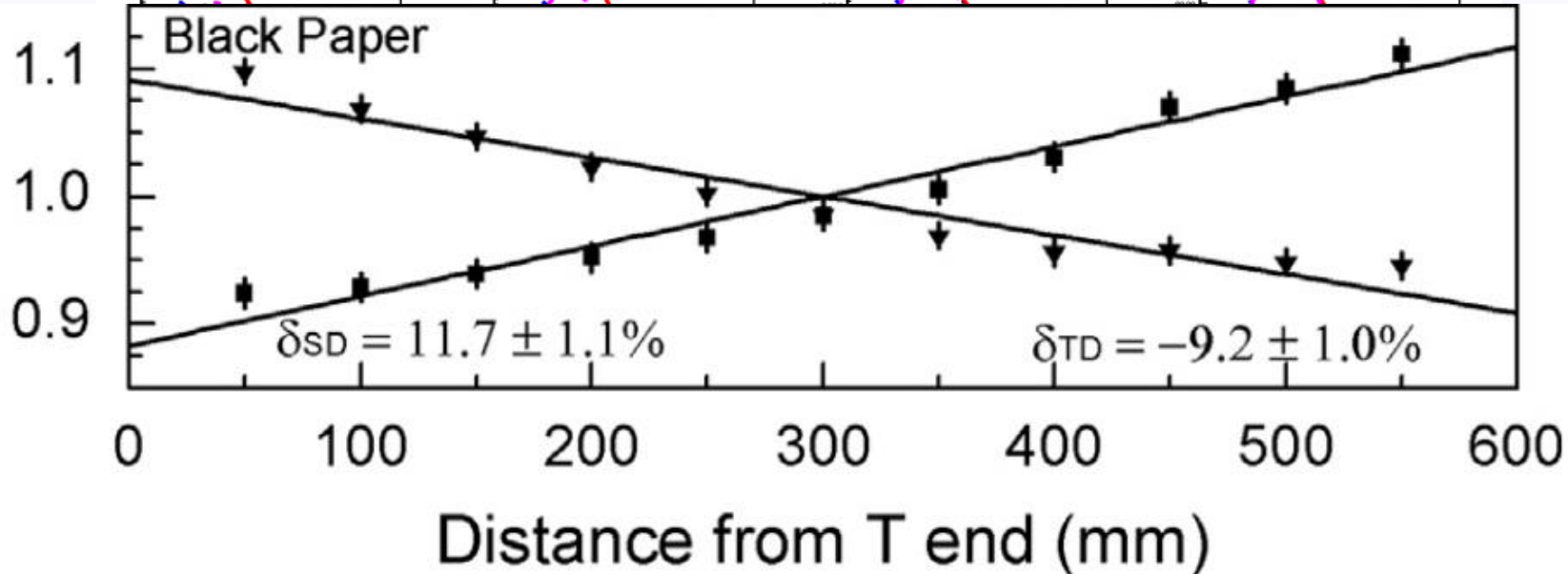
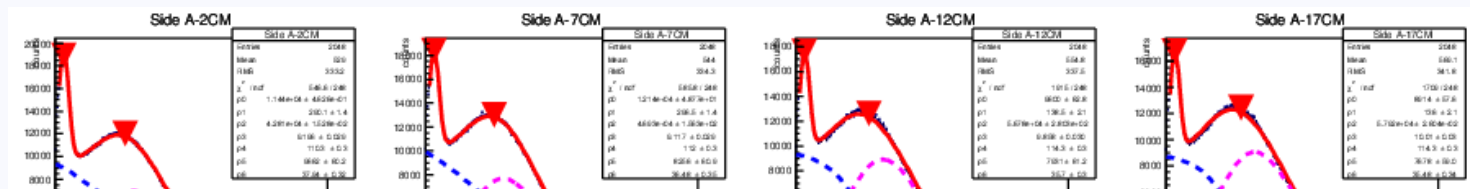
All of the elements should be tested before installed in the calorimeter

The Test of BGO Crystal Bars

- The light yield
- The uniformity of light collection

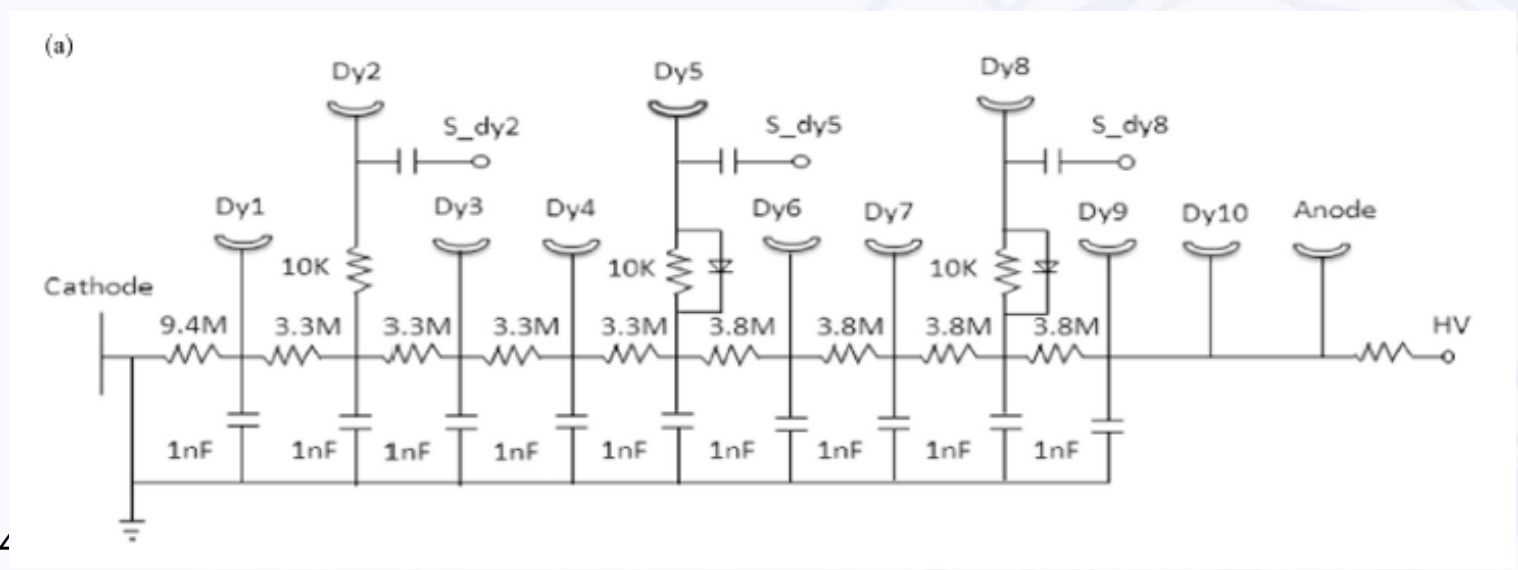


The Uniformity of BGO Crystal Bars

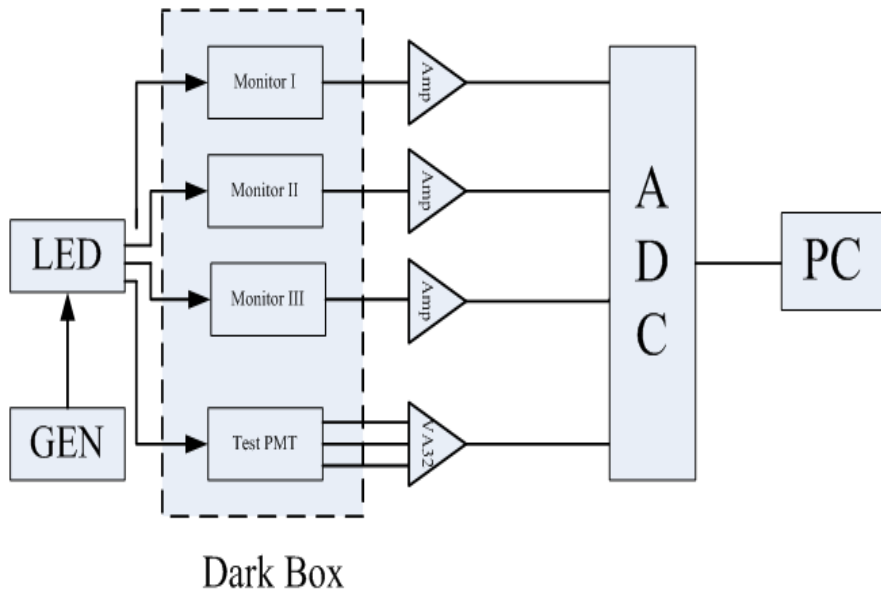


PMT Test

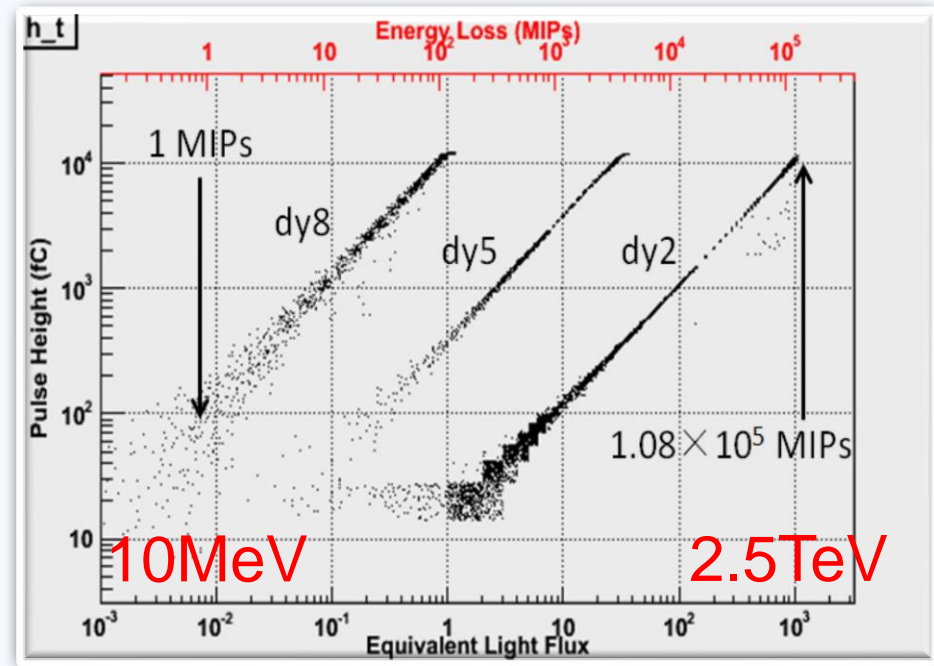
- In order to measure 5GeV to 10TeV e, γ -ray
- Each BGO element readout should cover the dynamic range from 10MeV to 2TeV
- One PMT with 3 dynodes output method has been developed



PMT Test



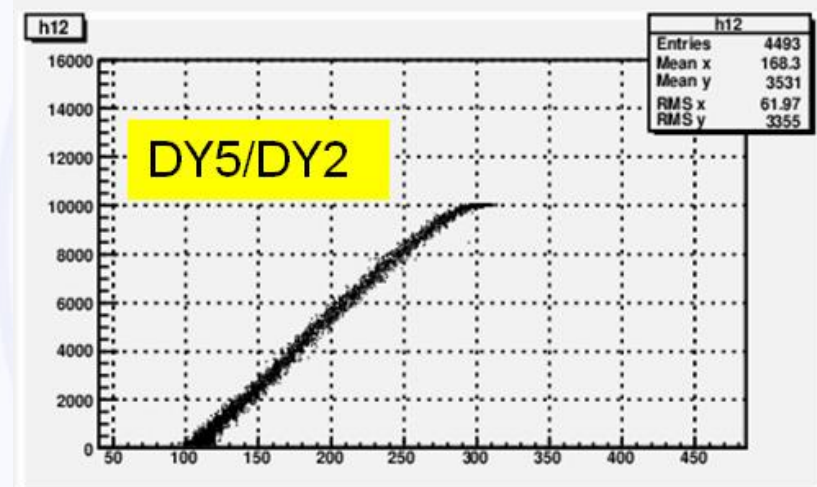
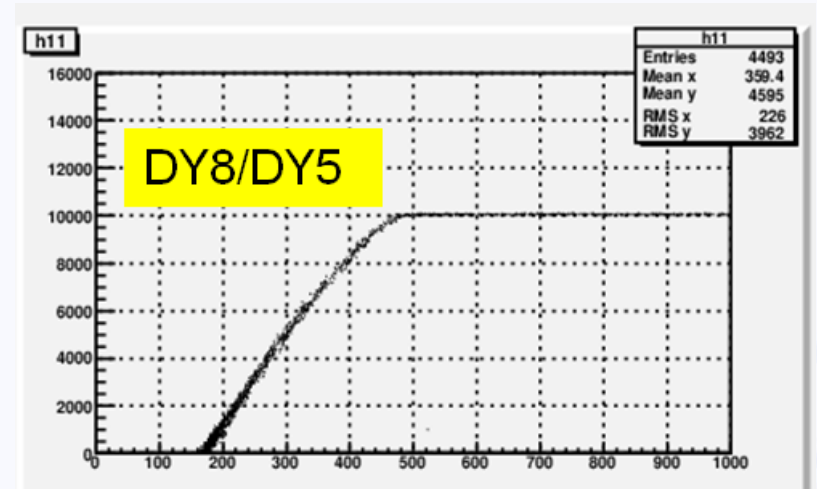
LED Calibration Schematically



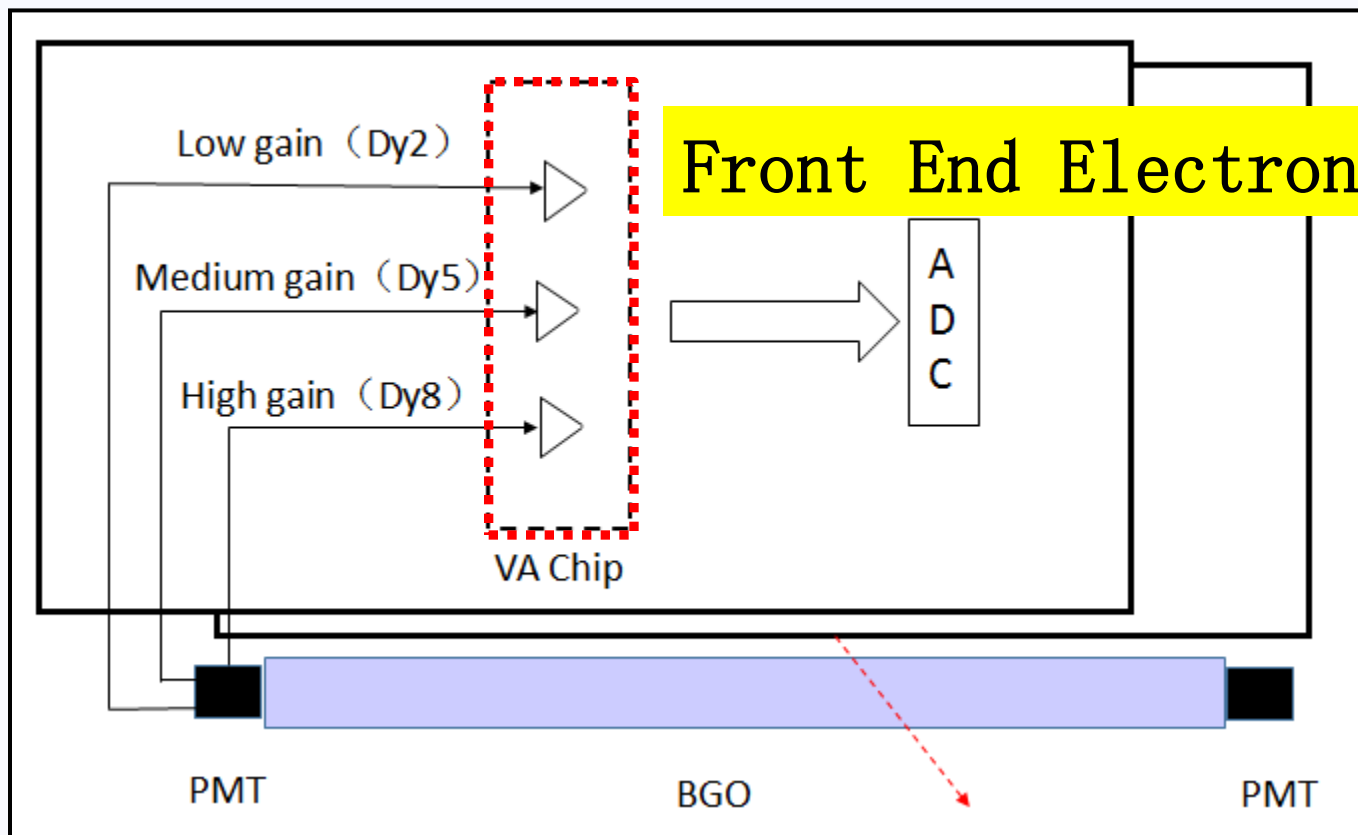
The dynamic range

PMT Test

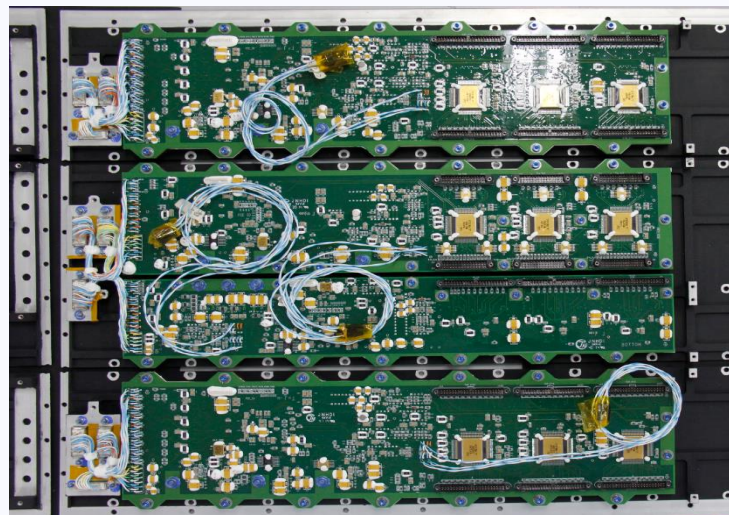
- Each PMT should be tested before installed



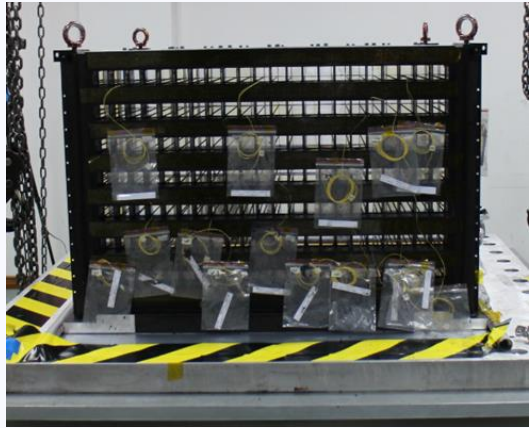
Front End Electronics



Front End Electronic Boards



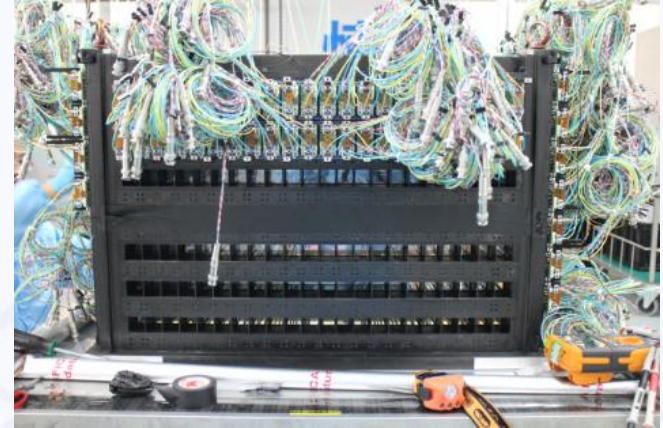
Calorimeter Assembly



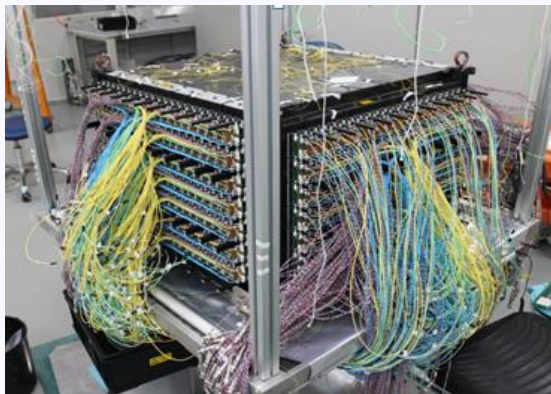
Carbon Fiber Structure



BGO crystal install

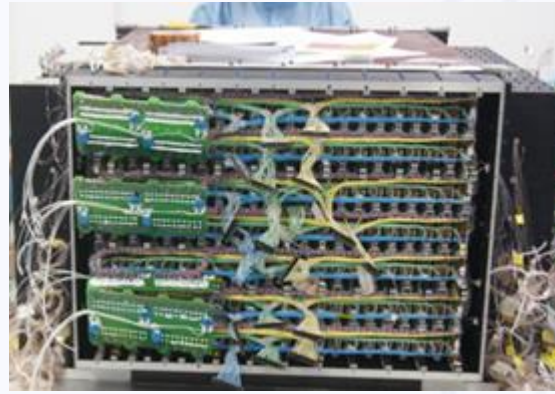


PMT install



Cable arrange

2015/4/13



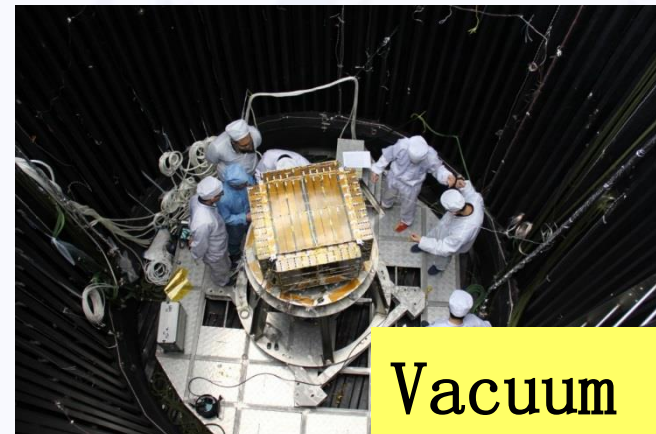
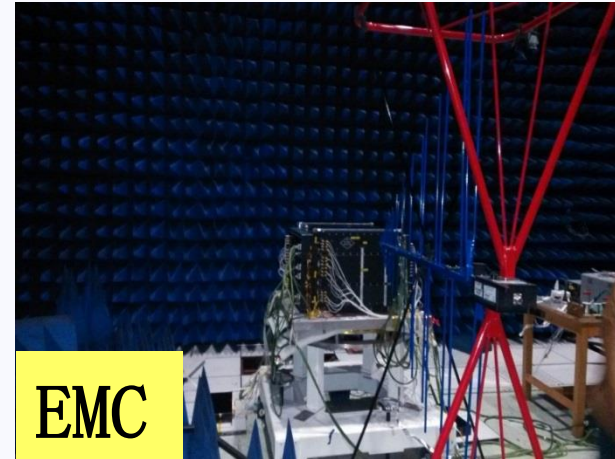
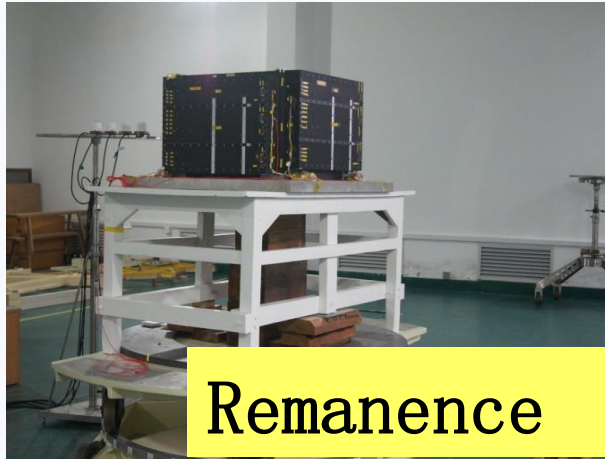
Cable connector

USTC



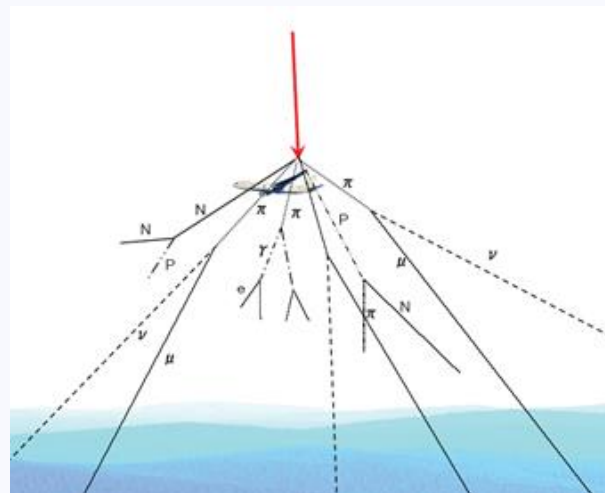
BGO Cal

Environmental Testing

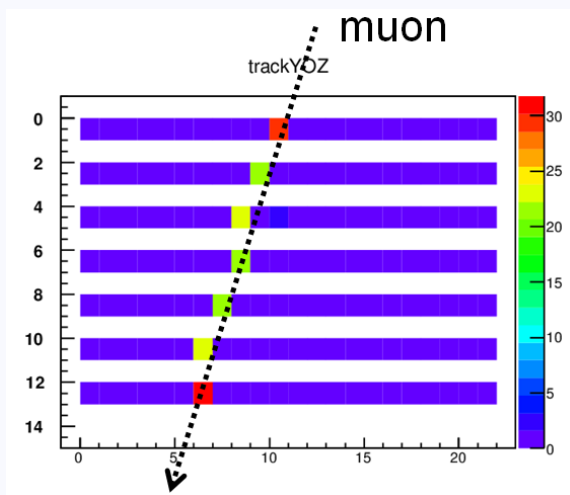


Cosmic-ray Calibration

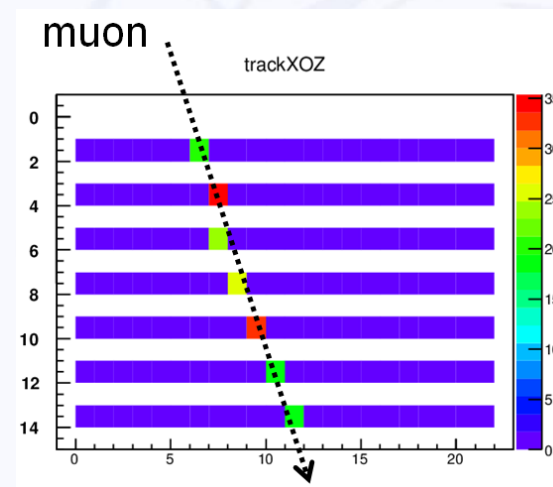
Use Cosmic-ray (muons) in lab to calibrate BGO Calorimeter



X-D

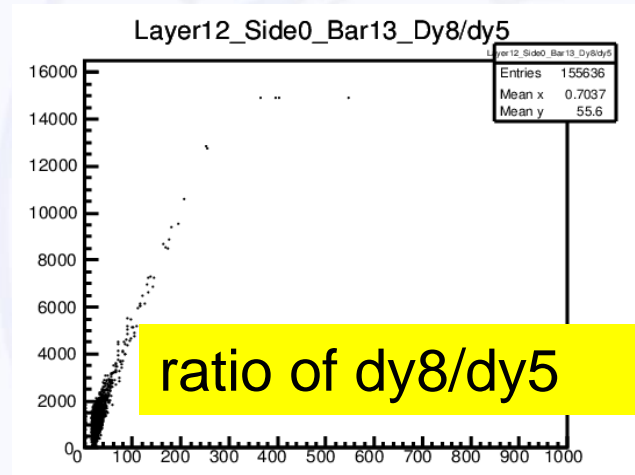
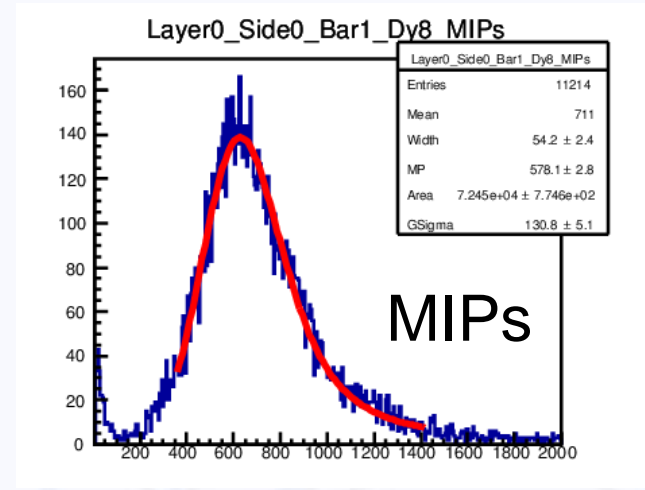
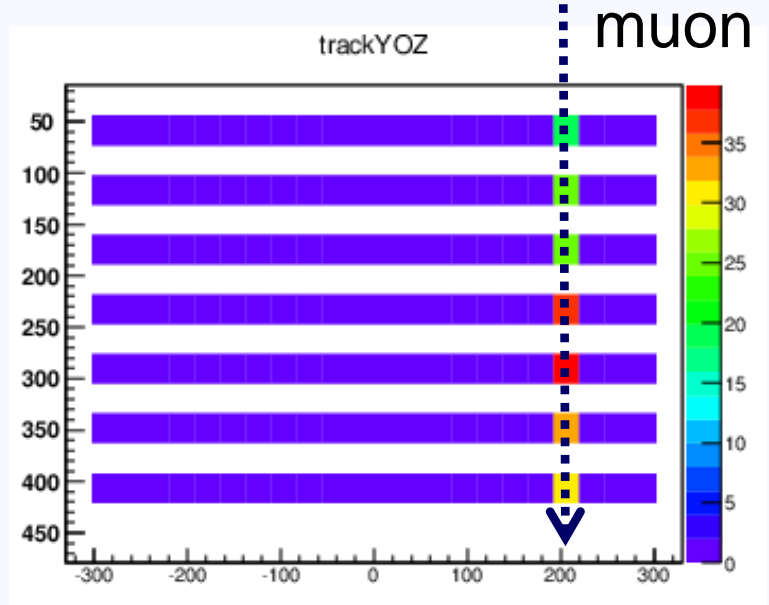


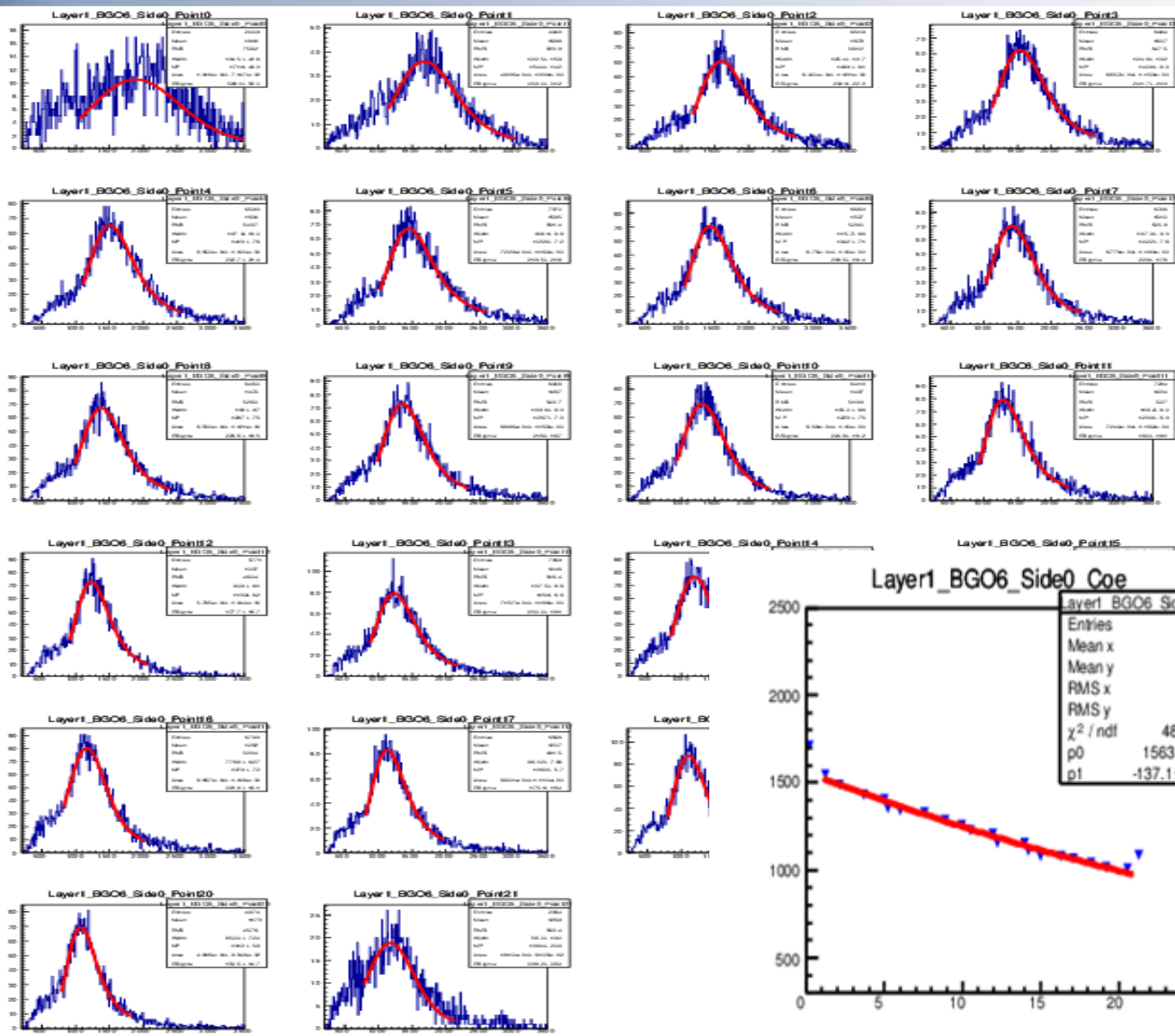
Y-D



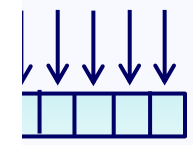
MIPs and Dynode Ratio

Select the vertical incident muon events



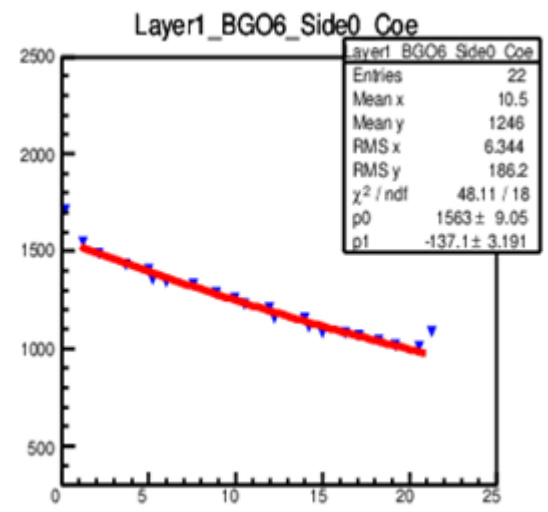


Bar



22 parts.
of BGO

d.



Each E
parts k
layers

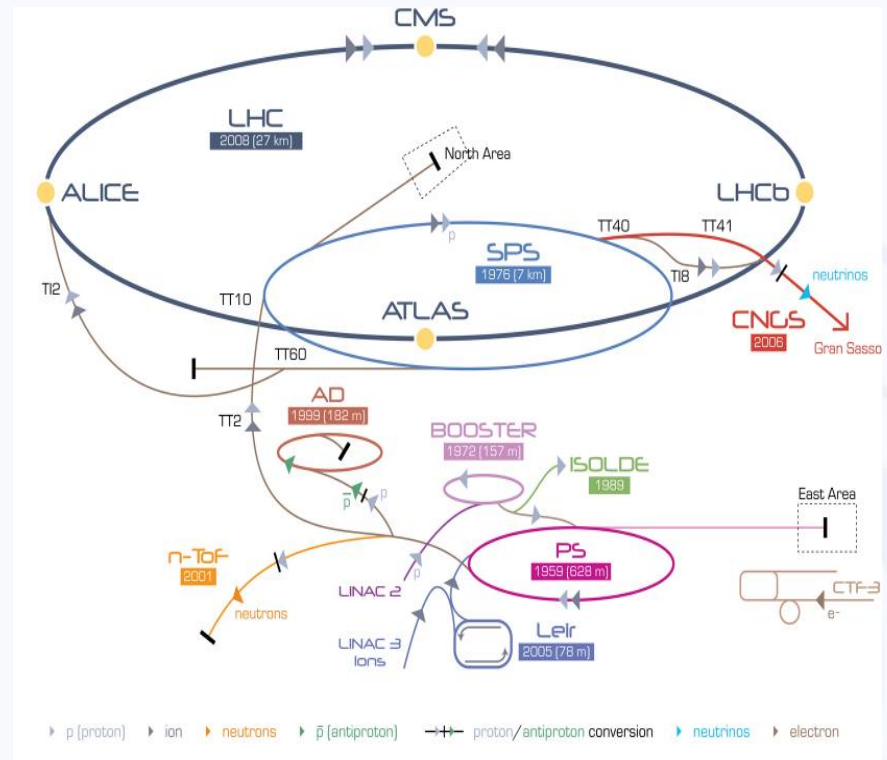
Beam Test in CERN

e^+ : 0.5GeV–250GeV

Pion: 10GeV

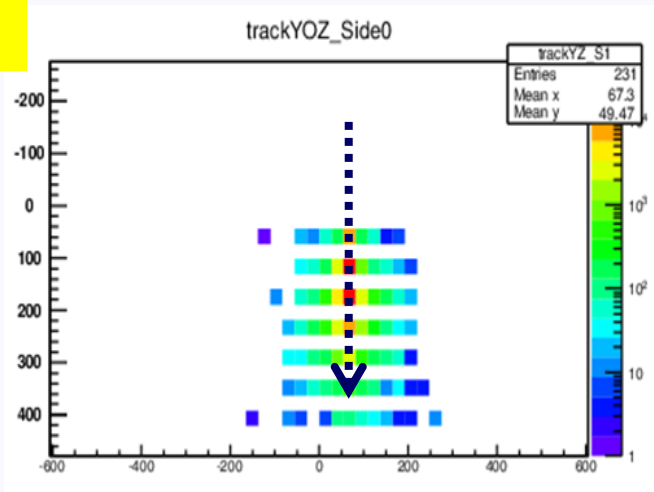
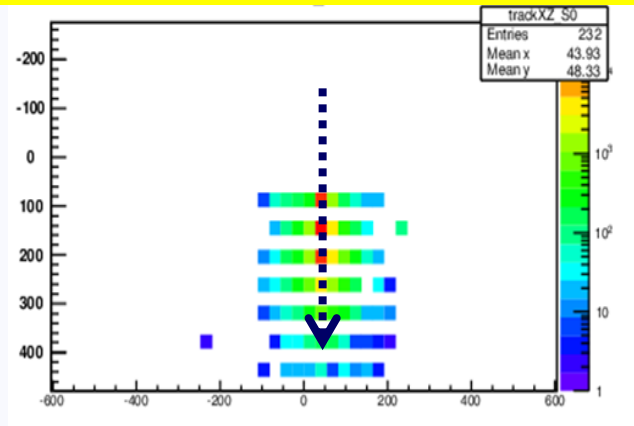
proton: 400GeV

Muon: 150GeV

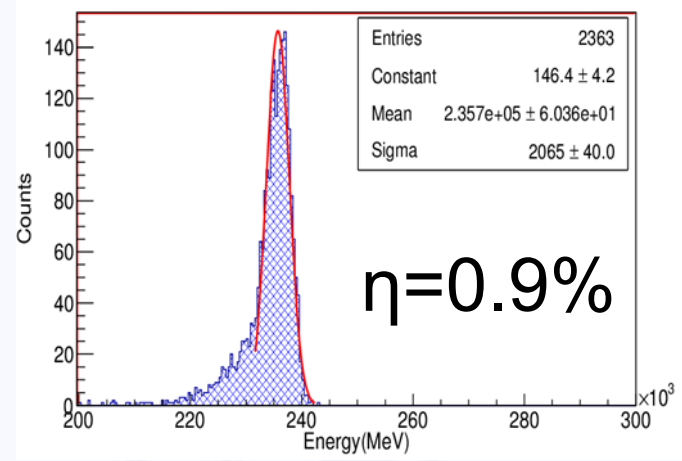


BGO CAL Response to High Energy e⁺

250GeV e⁺ shower profile

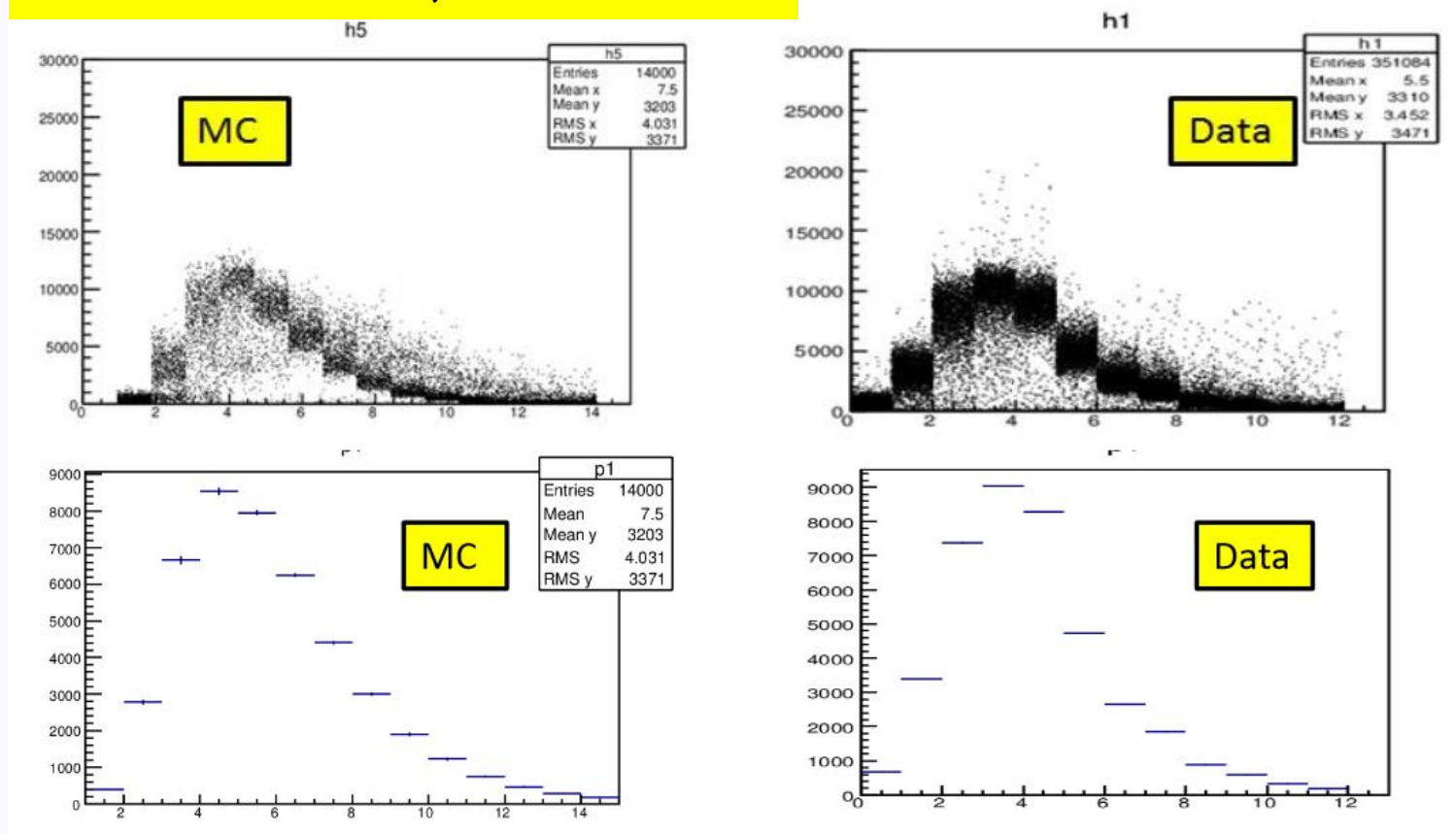


The mean value of energy deposition distribution of 250GeV positron in BGO calorimeter is 235 GeV. The resolution is 0.9%.

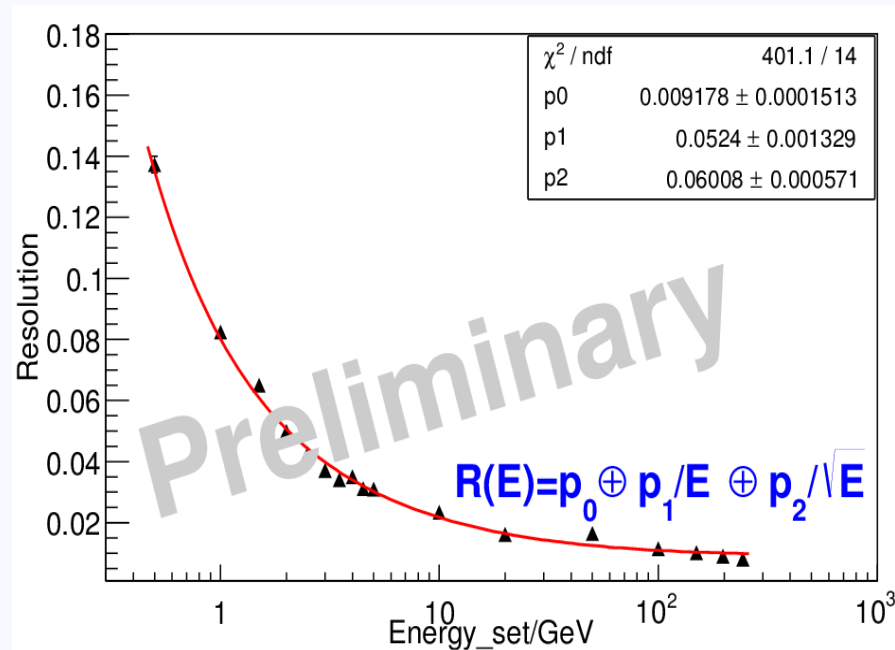
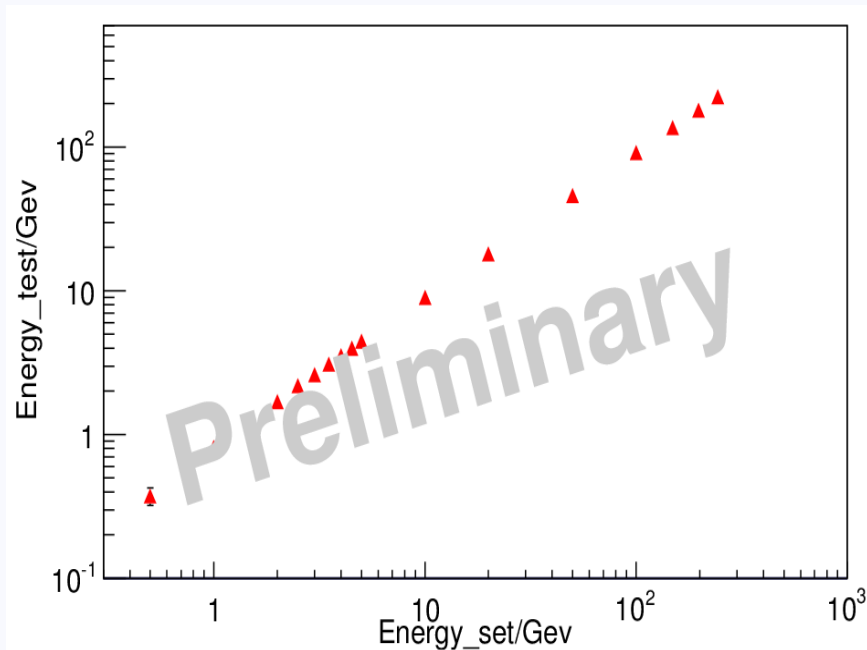


BGO CAL Response to High Energy e^+

MC vs. Data, 50GeV e^+



BGO CAL Response to High Energy e^+



Energy deposition vs. incident energy

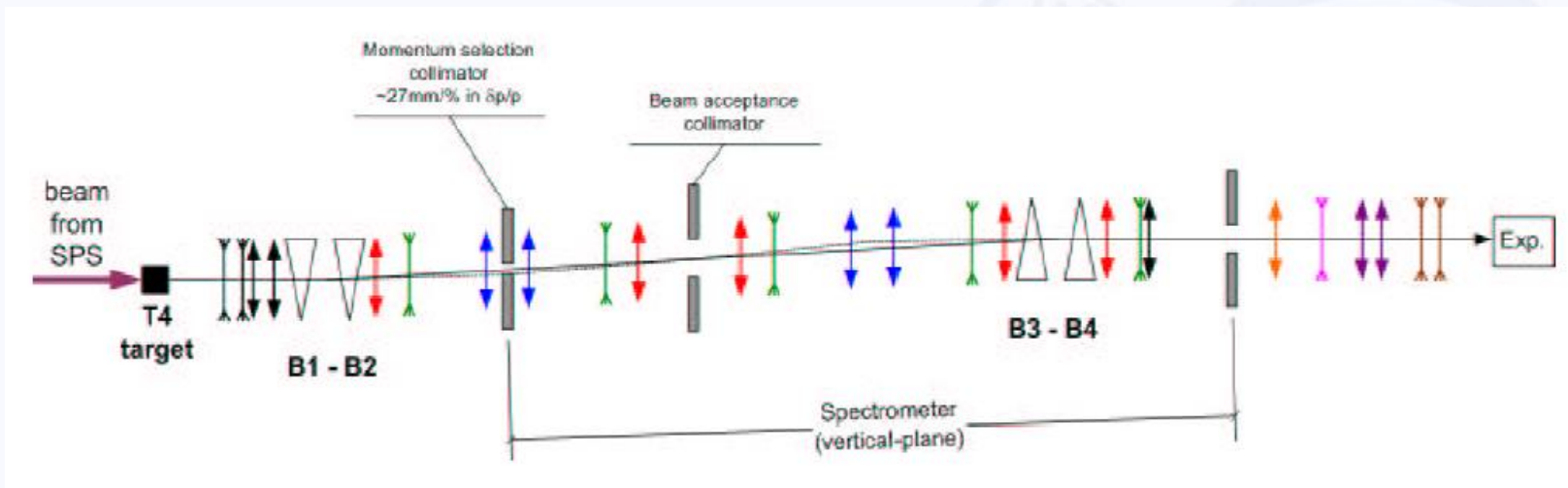
Energy resolution vs. incident energy

Ions Beam Test

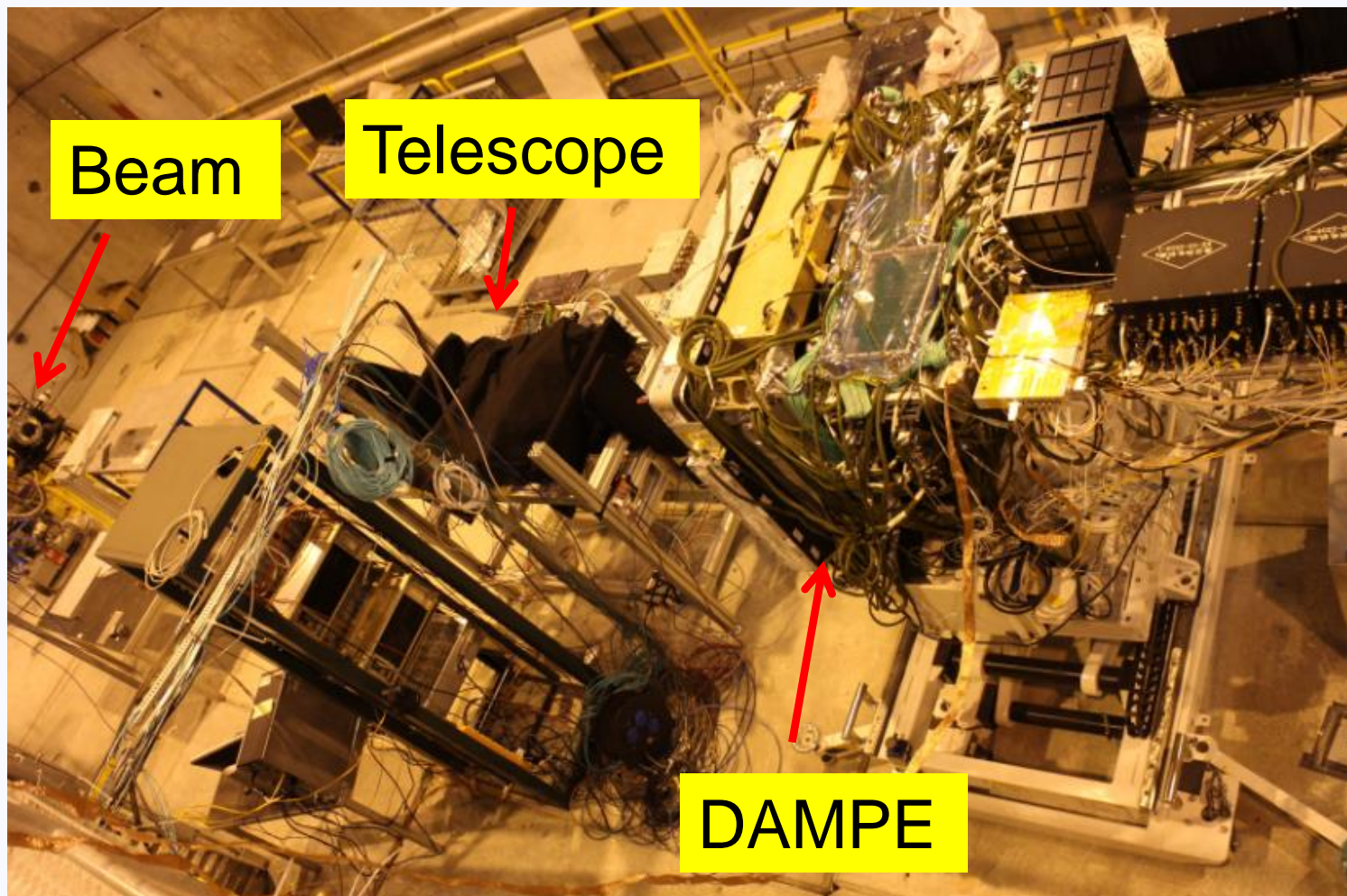
The Primary Beam: ^{40}Ar with 40,75 GeV/c/n

Target: Polyethylene

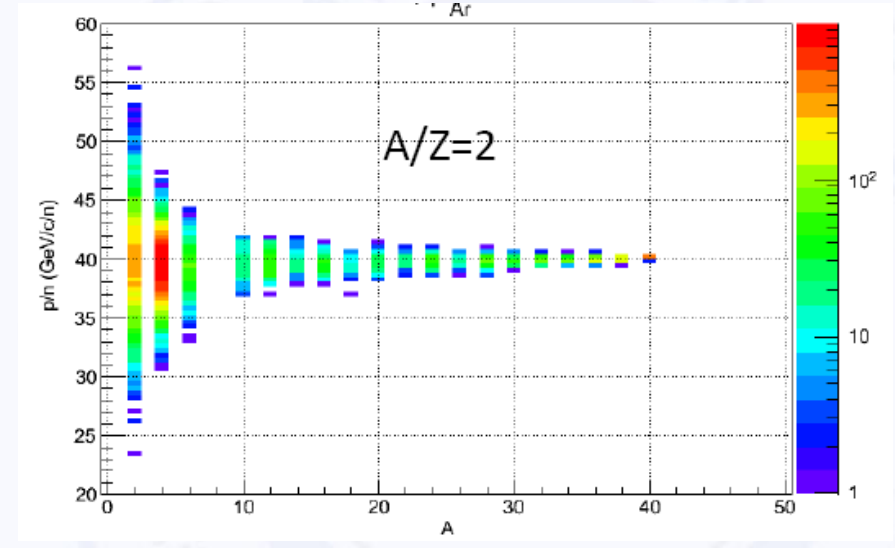
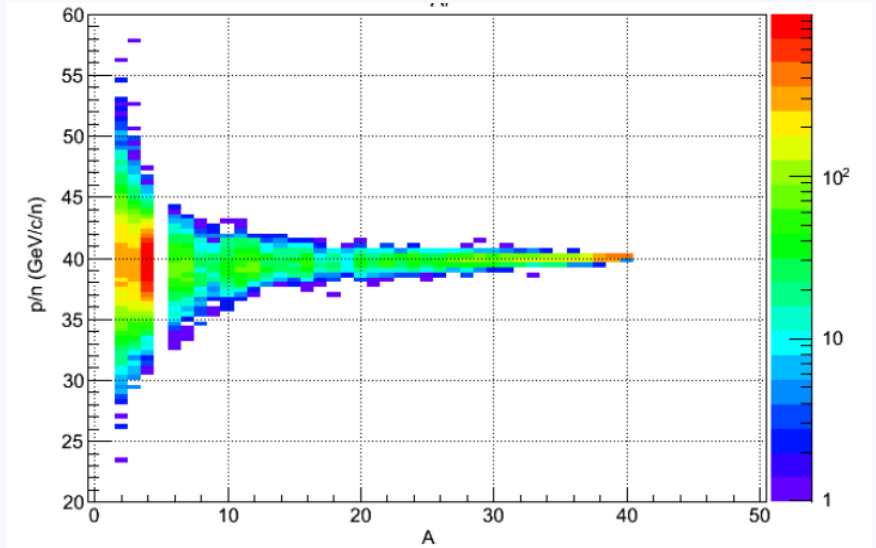
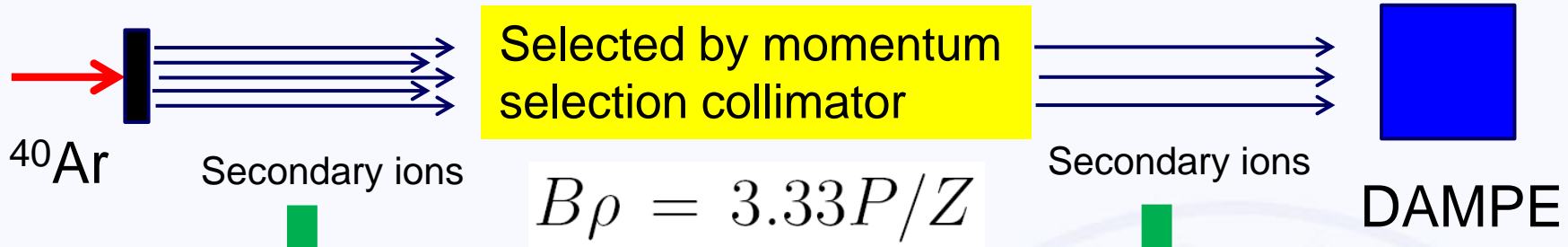
Secondary ions: ^2H , ^4H , ^6Li ... with 40,75 GeV/c/n



Ions Beam Test

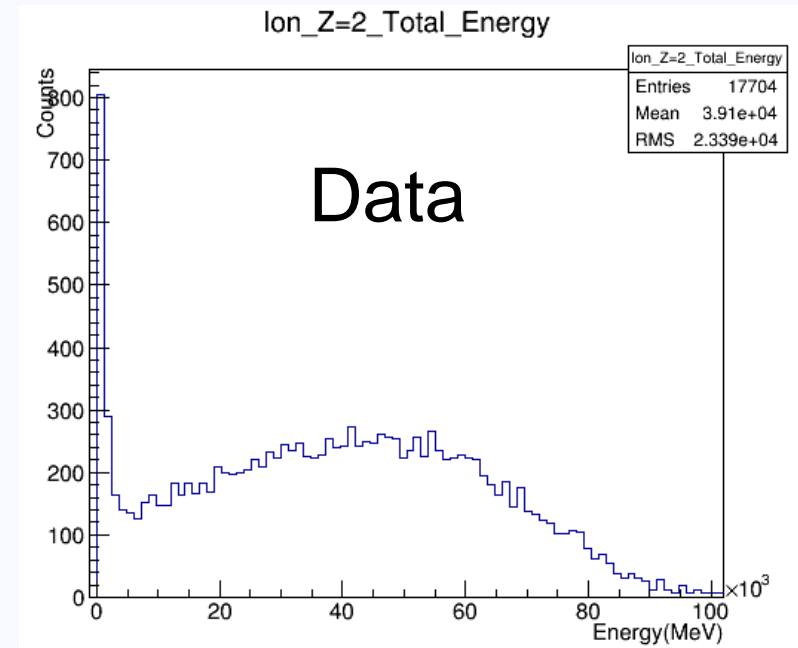
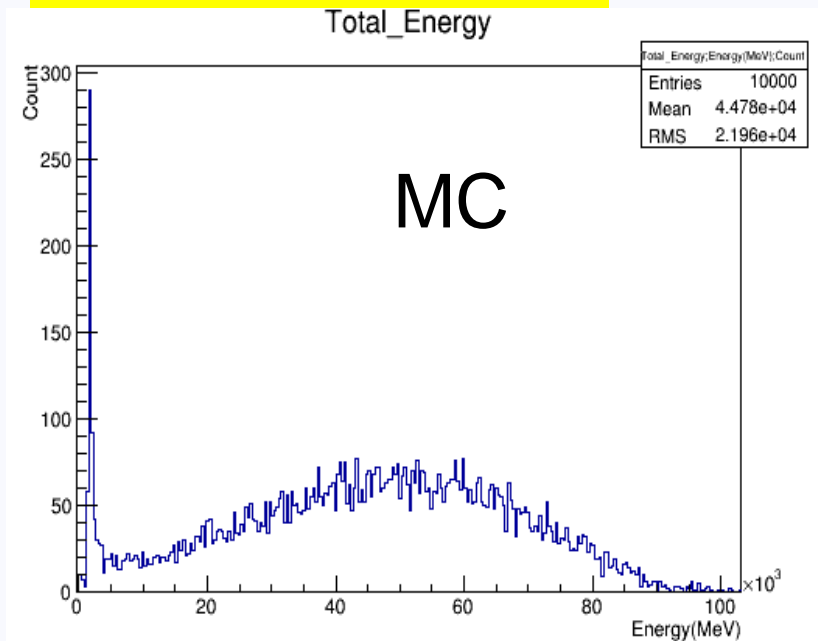


Ions Beam Test



BGO CAL Response to High Energy Ions

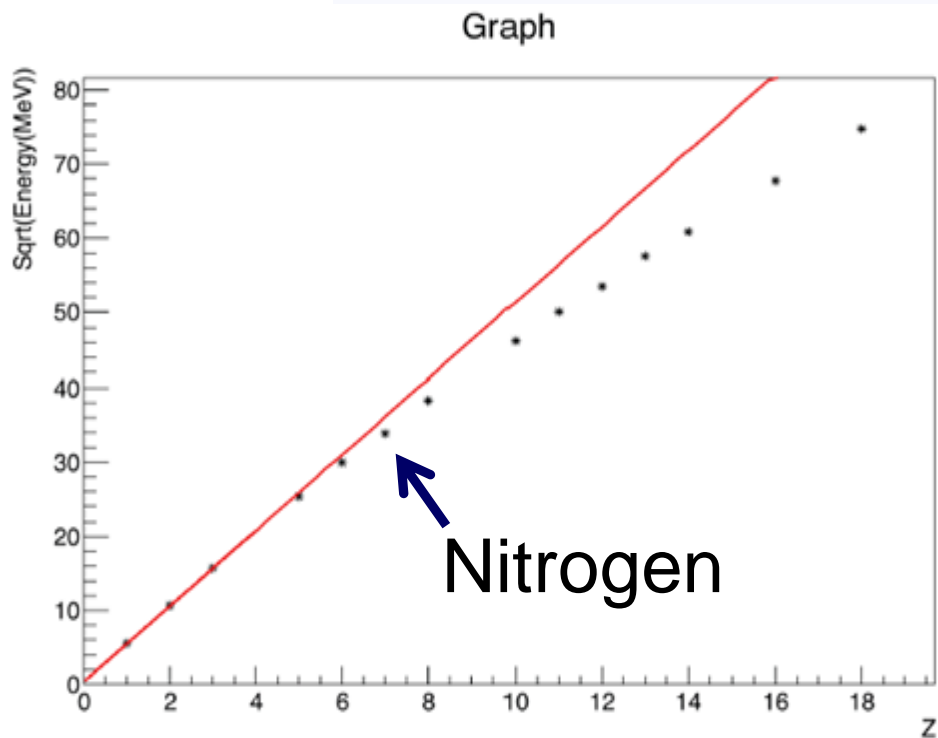
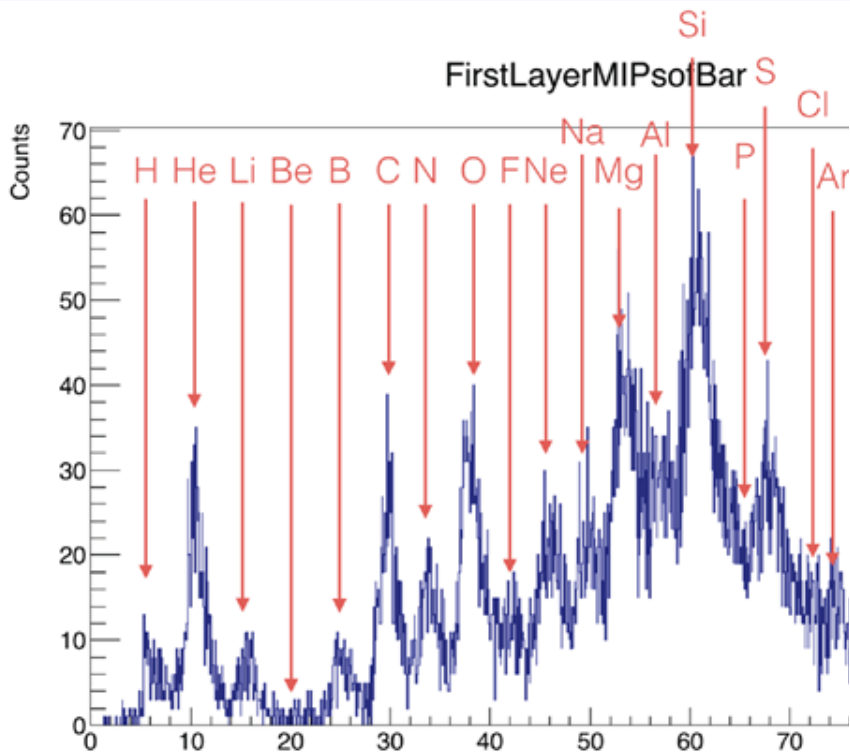
^4He 40GeV/c/n



The mean value of energy deposition in calorimeter is about 40% of incident energy.

BGO CAL Response to High Energy Ions

The quenching effect of BGO crystal to heavy ions



Summary

- A 3D imaging BGO calorimeter has been built for DAMPE experiment
- The Calibration results show the calorimeter works well
 - Cosmic ray test
 - Beam test
- Some data analysis work is still in progress



THANKS