The Development of a 3D Imaging Calorimeter for DAMPE

Yunlong Zhang

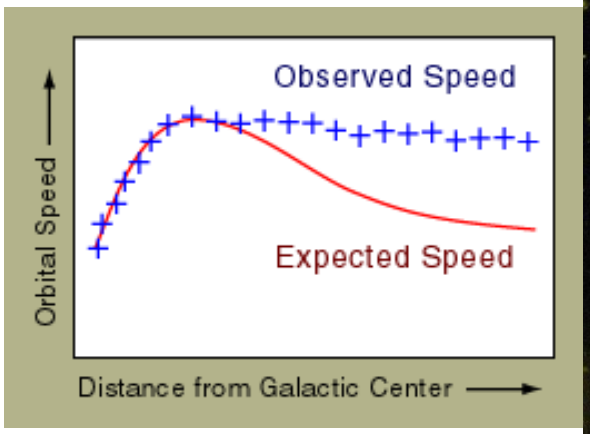
USTC

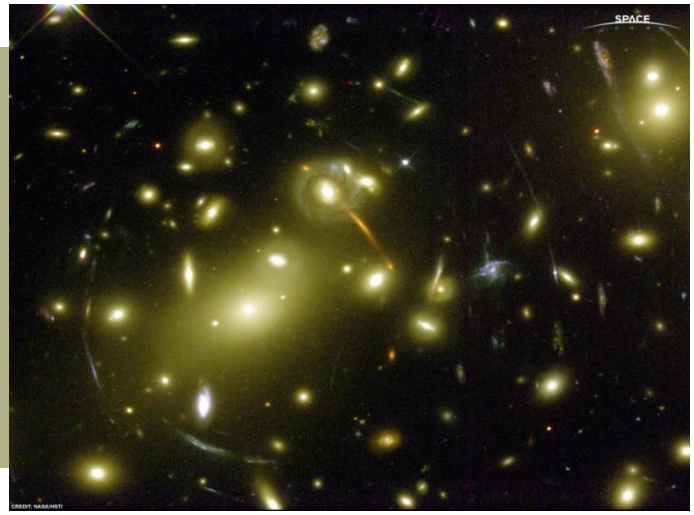
On behalf of DAMPE collaboration

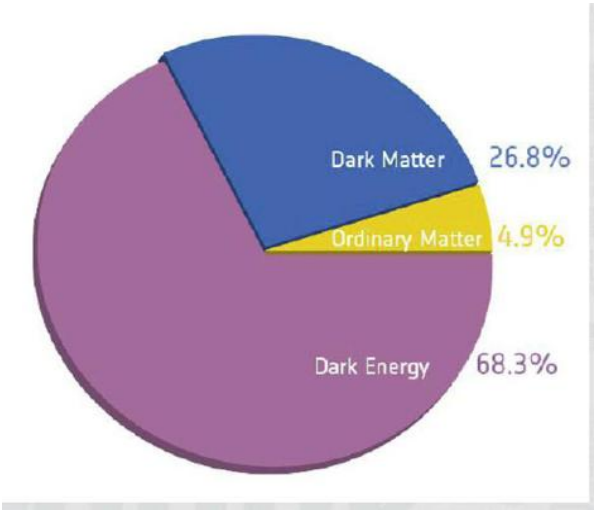
Outline

- DArk Matter Particle Explorer of China
- 3D Imaging BGO Calorimeter
- Calorimeter Design and Assembly
- Calibration
- The performance in space
- Summary

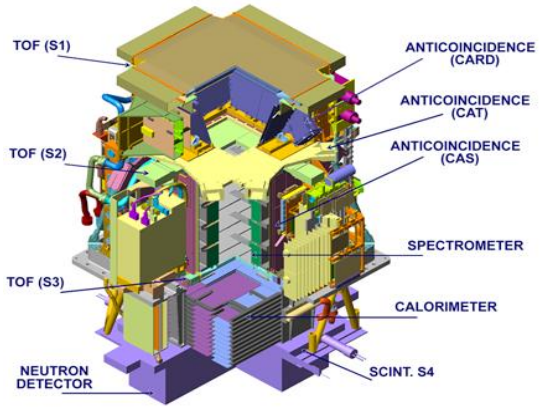
Dark Matter

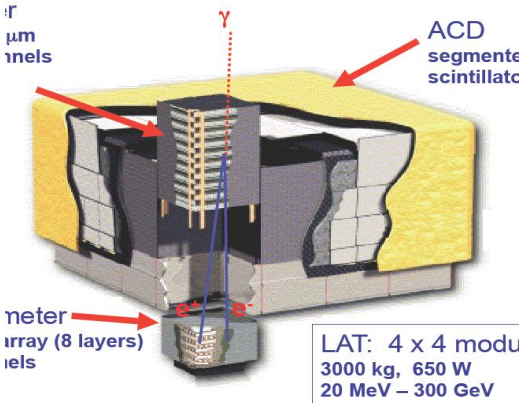

Observed Speed
Expected Speed
Orbital Speed
Distance from Galactic Center

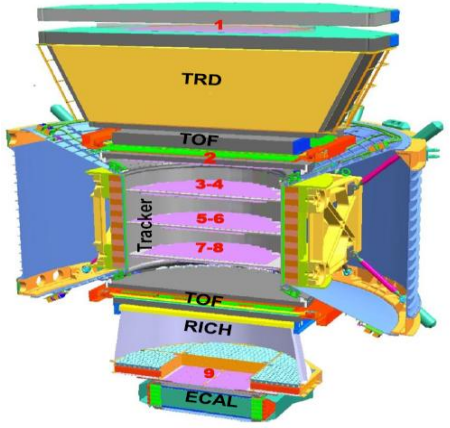


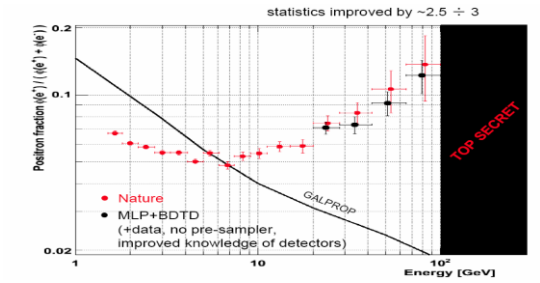

Dark Matter
26.8%
Ordinary Matter
4.9%
Dark Energy
68.3%

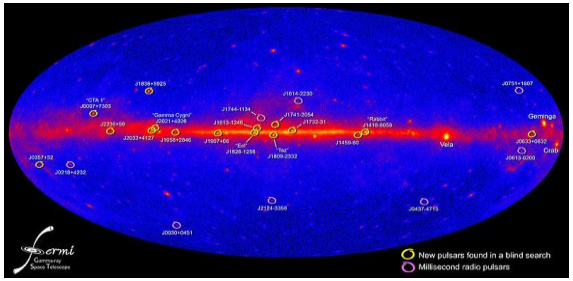
Space Particle Explorer

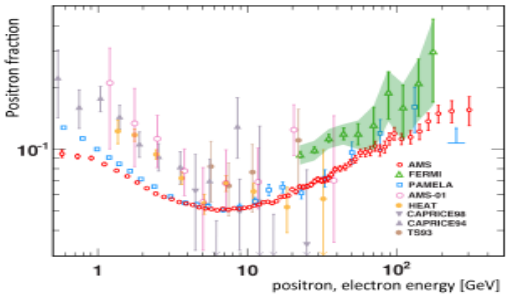












DArk Matter Particle Explorer (DAMPE)

***Science*, 20 May 2011**

NEWS & ANALYSIS

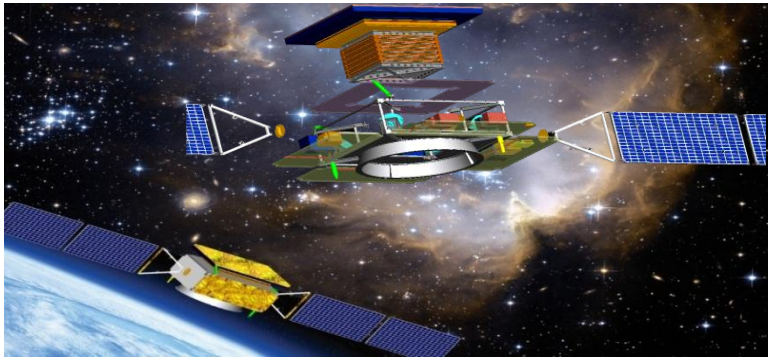
SPACE SCIENCE

Chinese Academy Takes Space Under Its Wing

LOFTY AMBITIONS

Mission	Chief scientist	Goals	Estimated launch
HXMT	Li Tipei, CAS Institute of High Energy Physics and Tsinghua University	Survey of x-ray sources; detailed observations of known objects	2014
Shijian-10	Hu Wenrui, CAS Institute of Mechanics	Study physical and biological systems in microgravity and strong radiation environment	Early 2015
KuaFu Project	William Liu, Canadian Space Agency and CAS Center for Space Science and Applied Research	Study solar influence on space weather	Mid-2015
Dark Matter Satellite	Chang Jin, CAS Purple Mountain Observatory	Search for dark matter; study cosmic ray acceleration	Late 2015
Quantum Science Satellite	Pan Jianwei, University of Science and Technology of China	Quantum key distribution for secure communication; long-distance quantum entanglement	2016

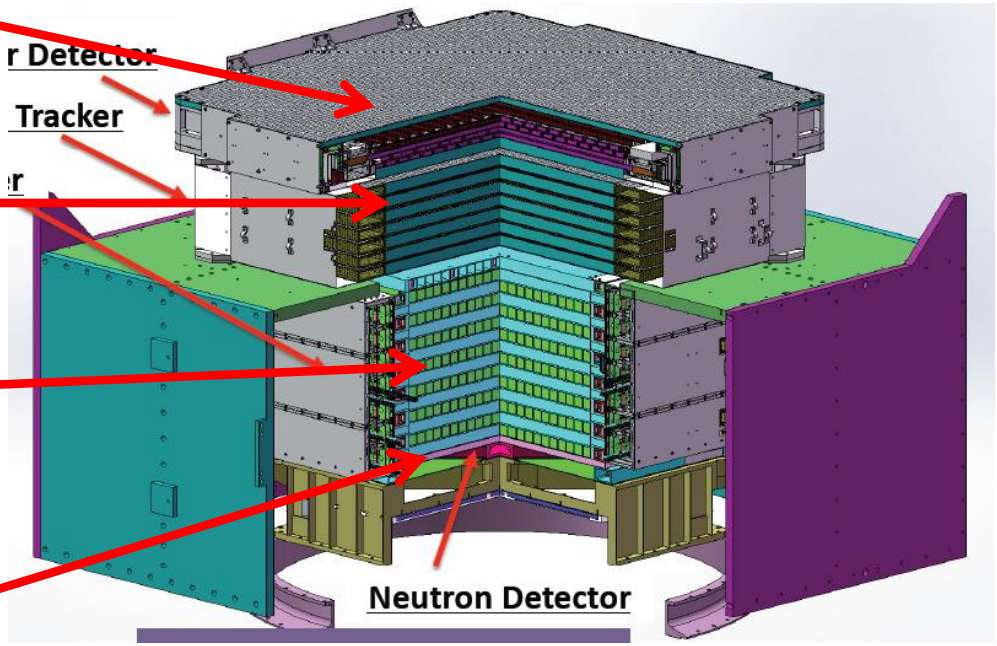
Strategic Priority Research Program in Space Science



- 500km orbit
- e+/-,gamma-rays
- 5GeV to 10TeV
- 1.5%@800GeV
- Total weight:~1400kg

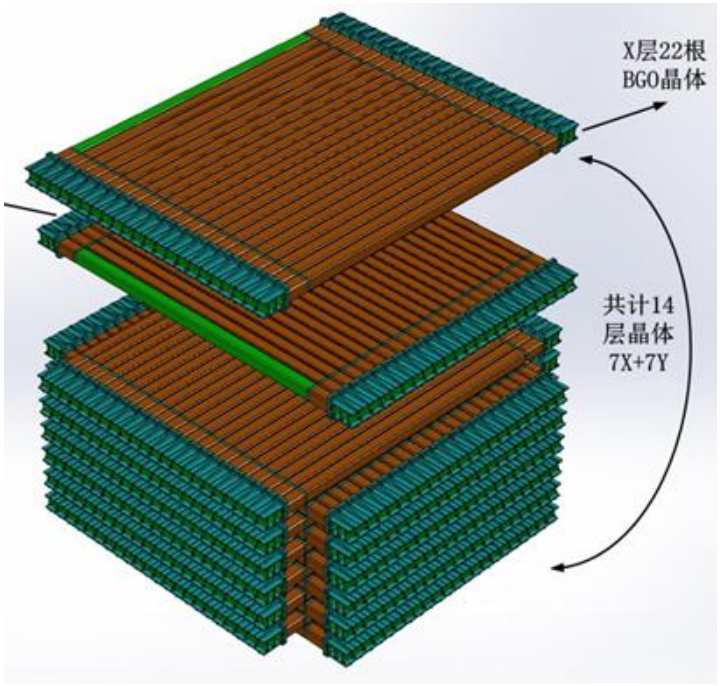
DArk Matter Particle Explorer (DAMPE)

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



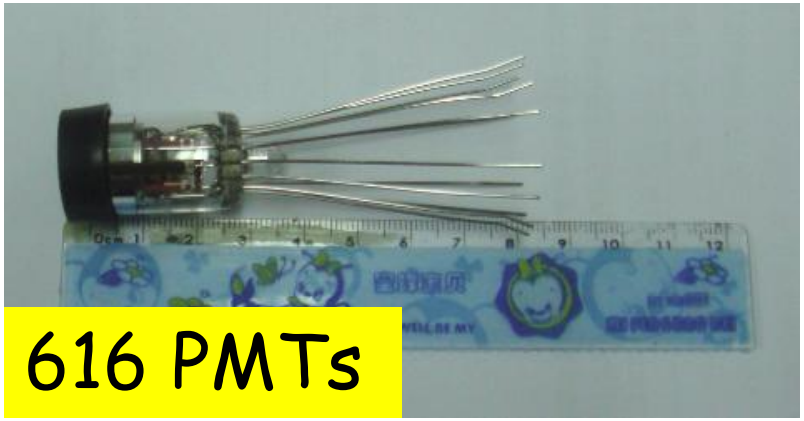
3D Imaging BGO Calorimeter

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



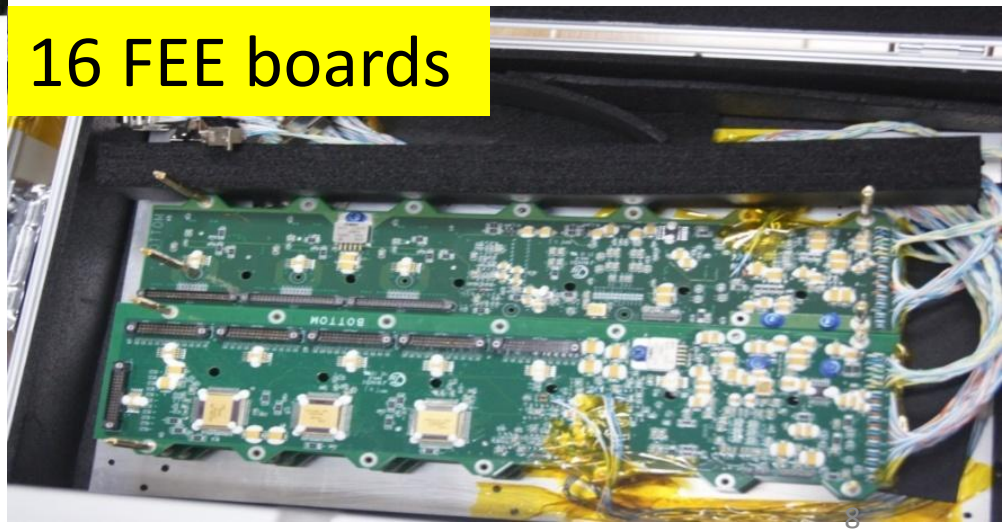
Calorimeter Elements

308 BGO bars



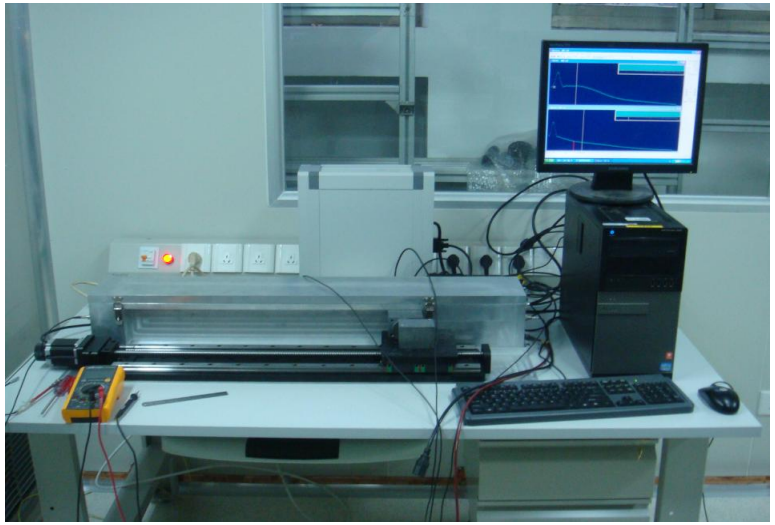
616 PMTs

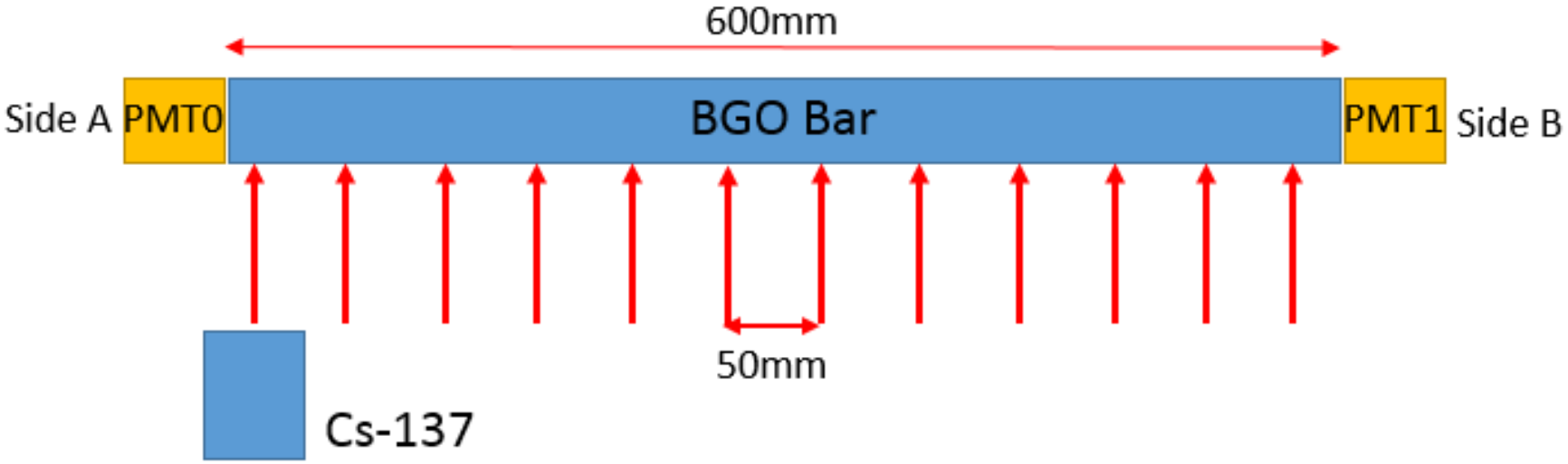
16 FEE boards



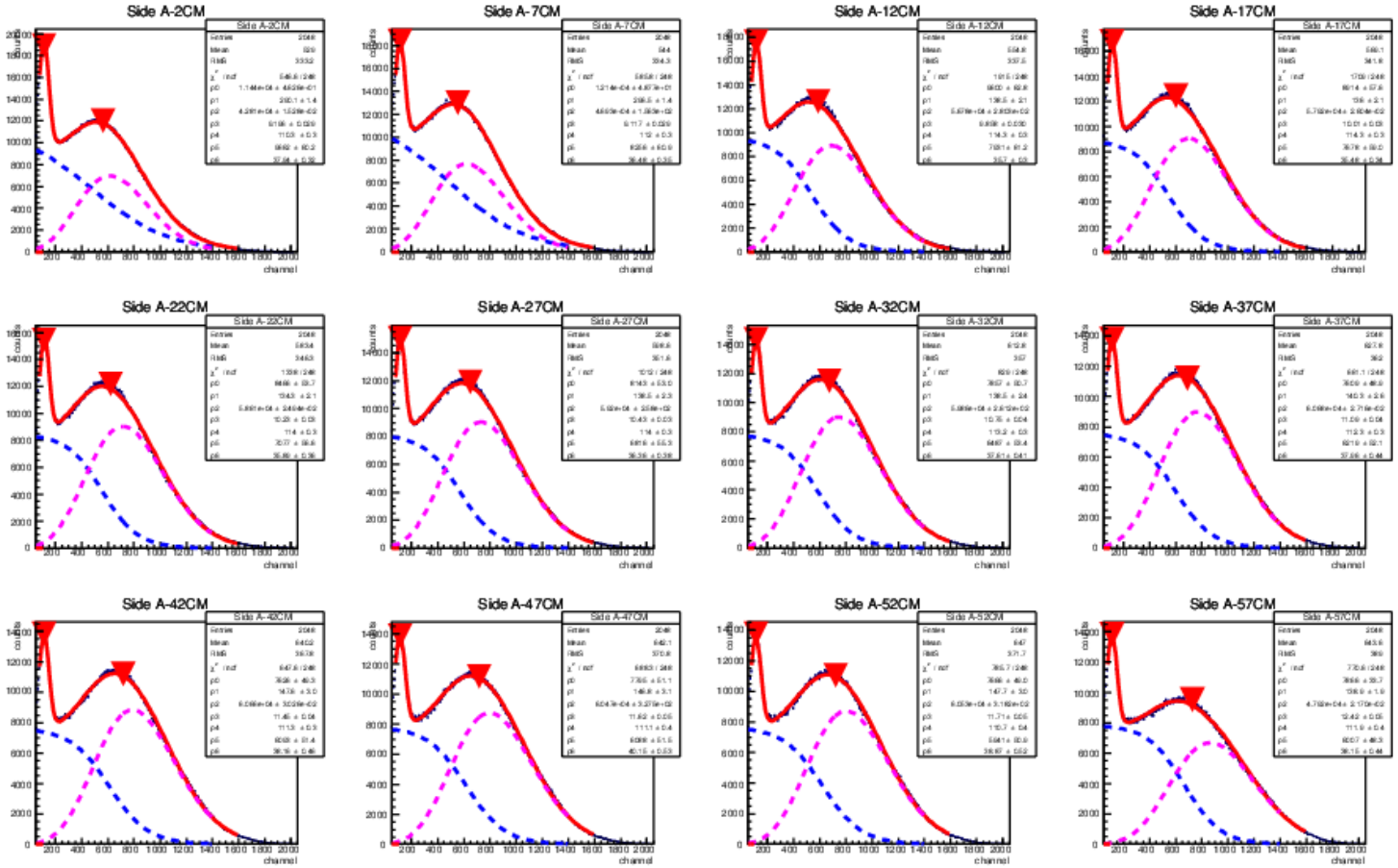
Asymmetry of BGO Bar

- The light yield
- The Asymmetry



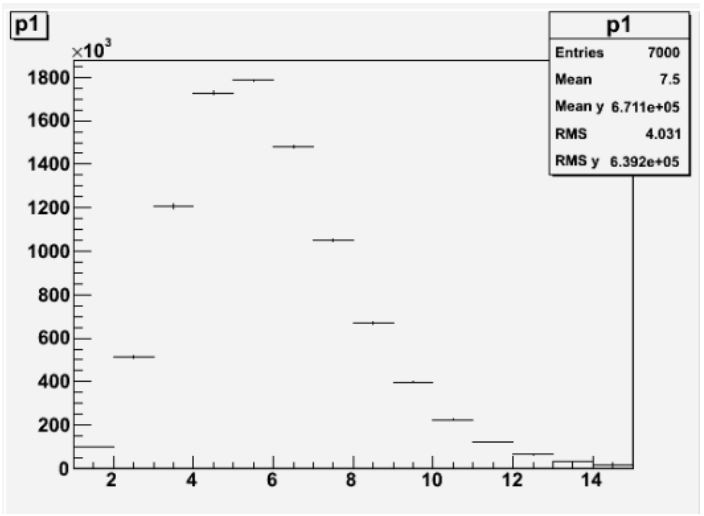


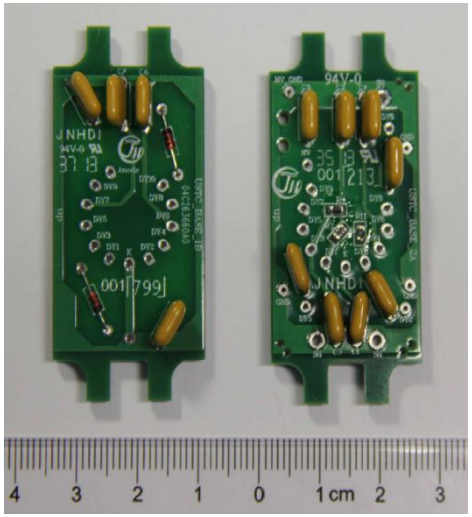
The BGO Crystal Bars

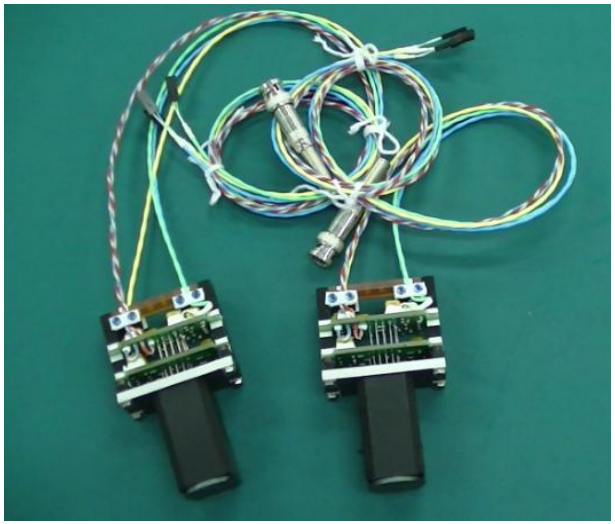


The High Dynamic Readout Design

- 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

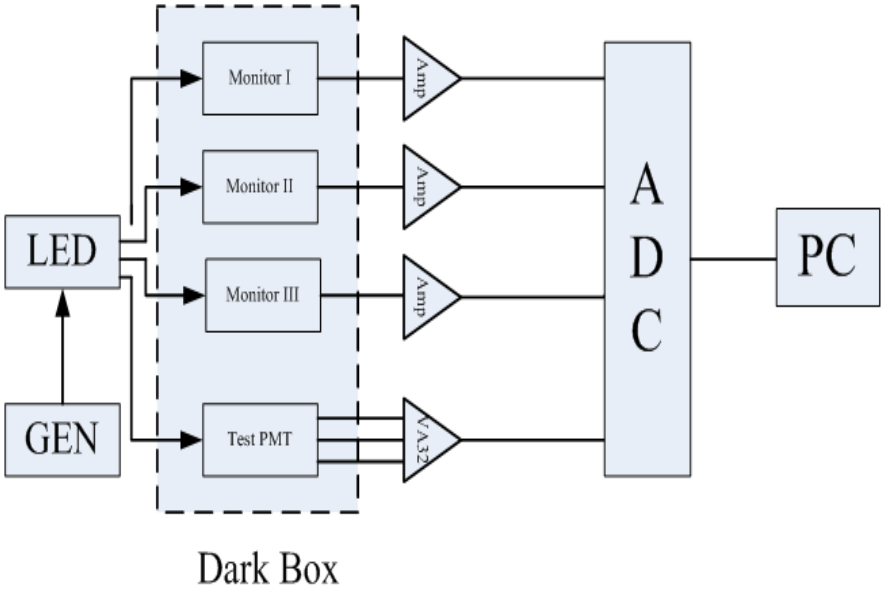




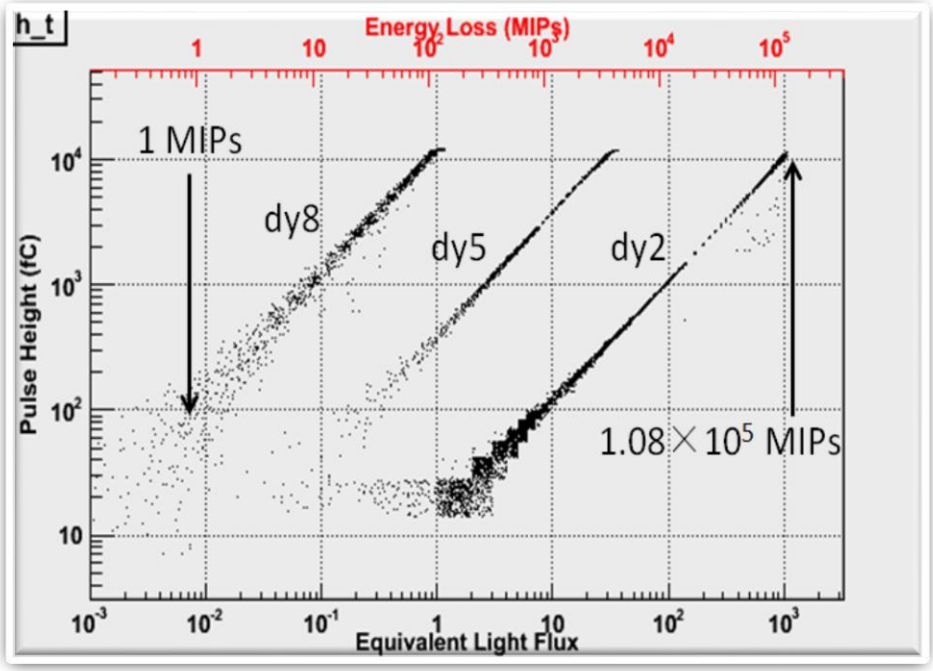


~20% of energy deposition in ONE BGO crystal

The High Dynamic Readout Design

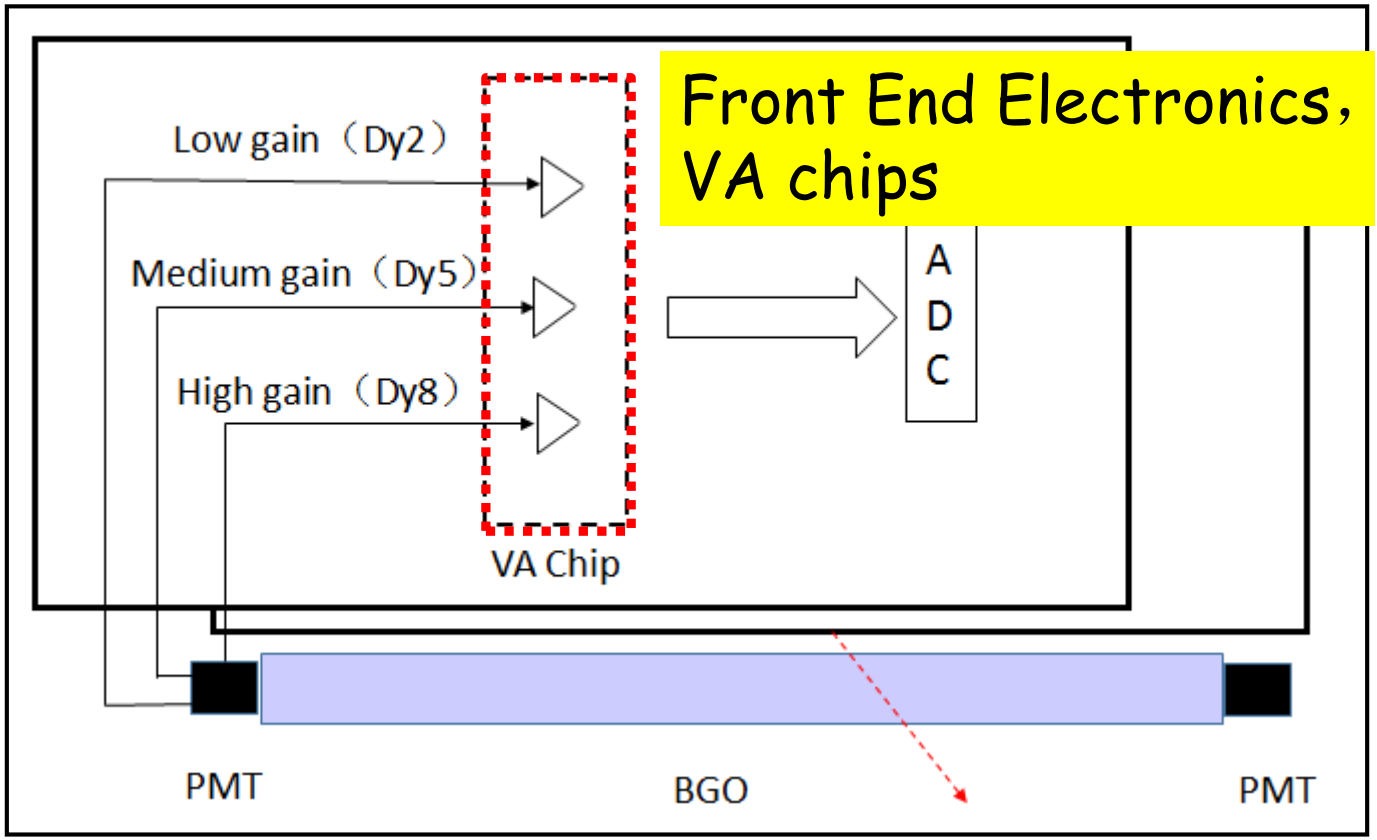


LED Calibration Schematically

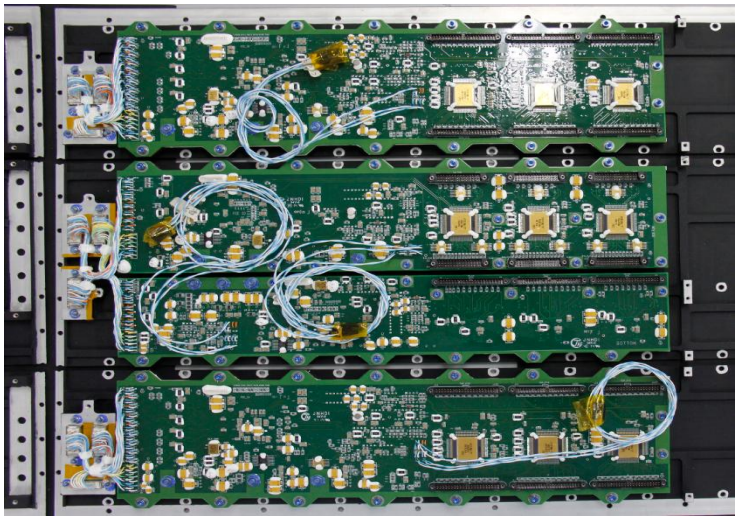


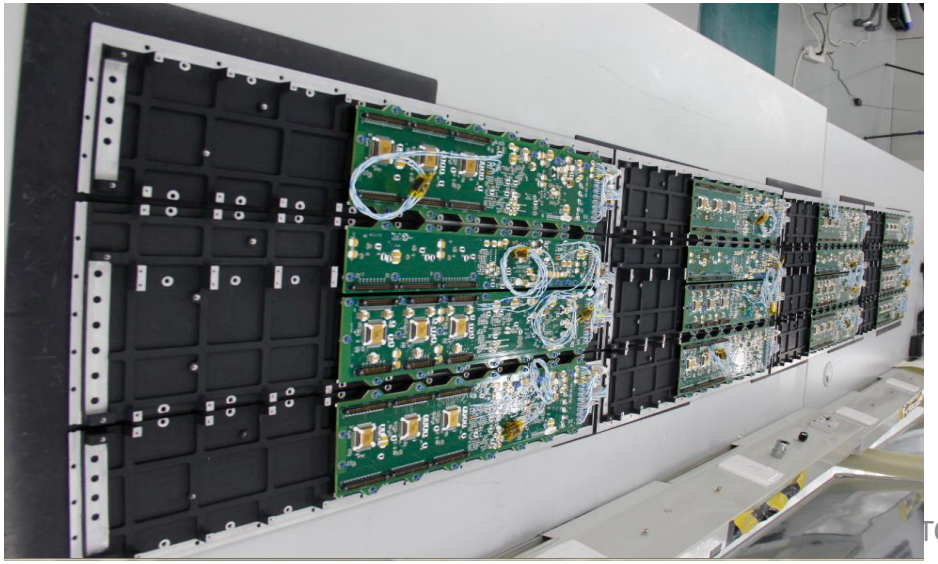
The dynamic range

Front End Electronics

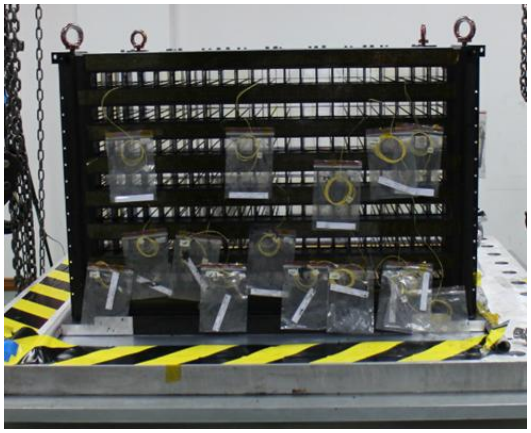


Front End Electronic Boards



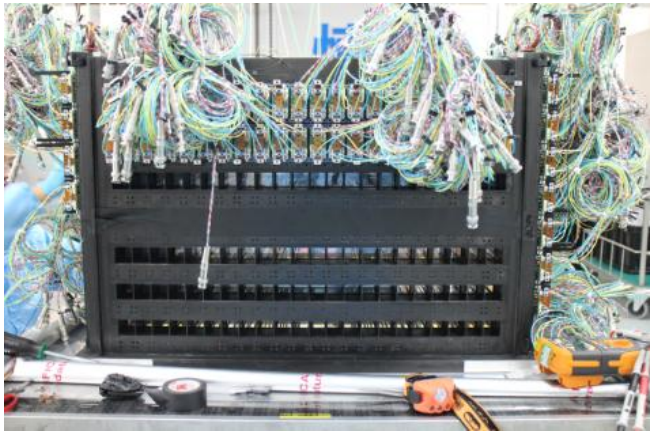


Calorimeter Assembly

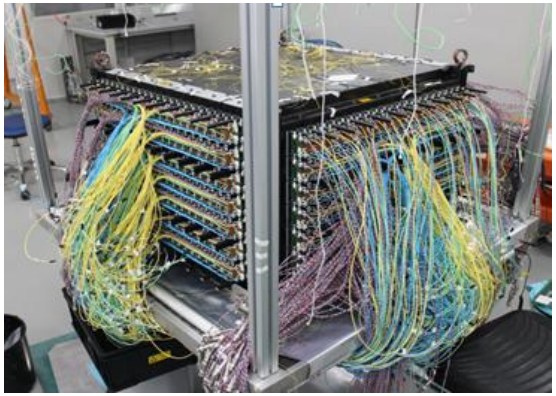


Carbon Fiber Structure

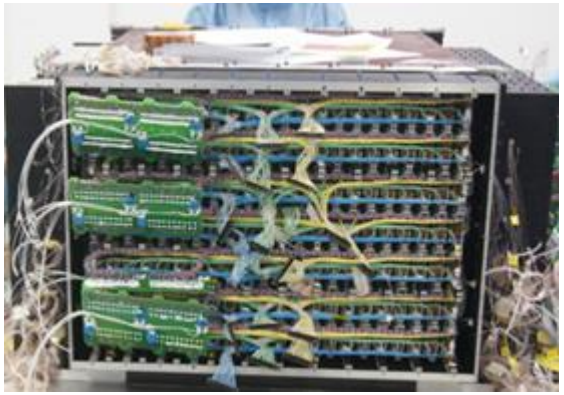
BGO crystal install



PMT install



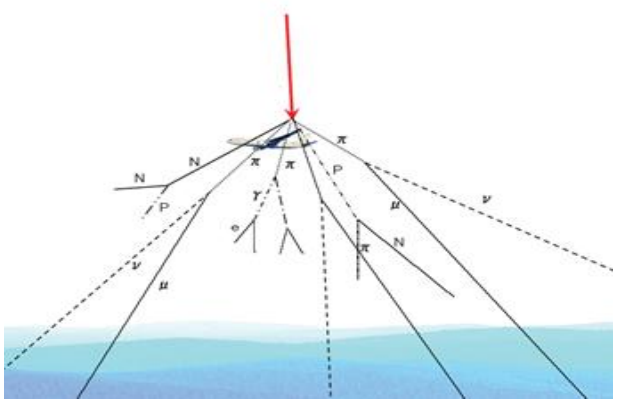
Cable arrange

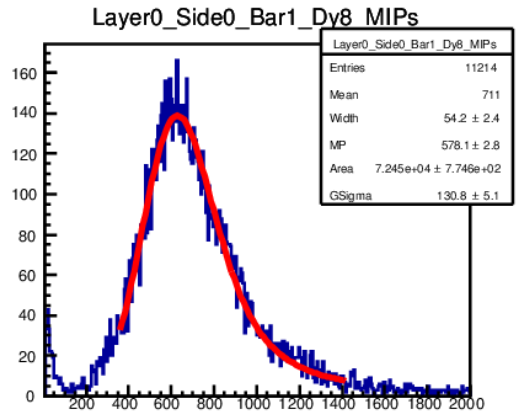


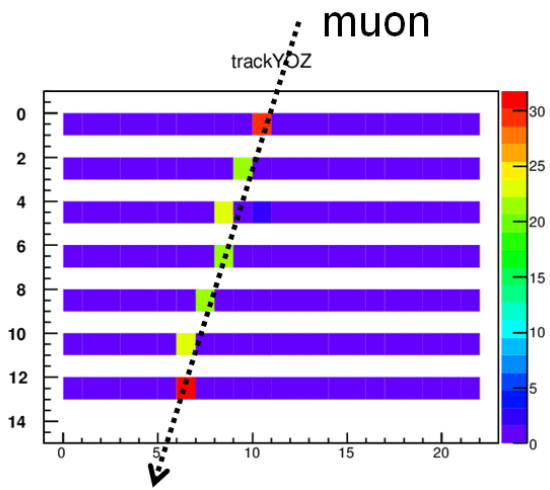
Cable connector

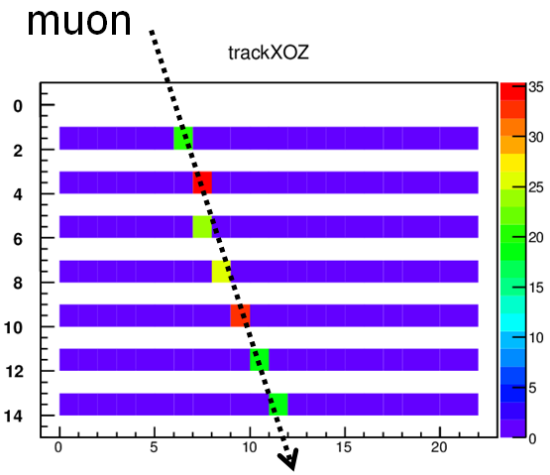
BGO Cal

The Energy Calibration



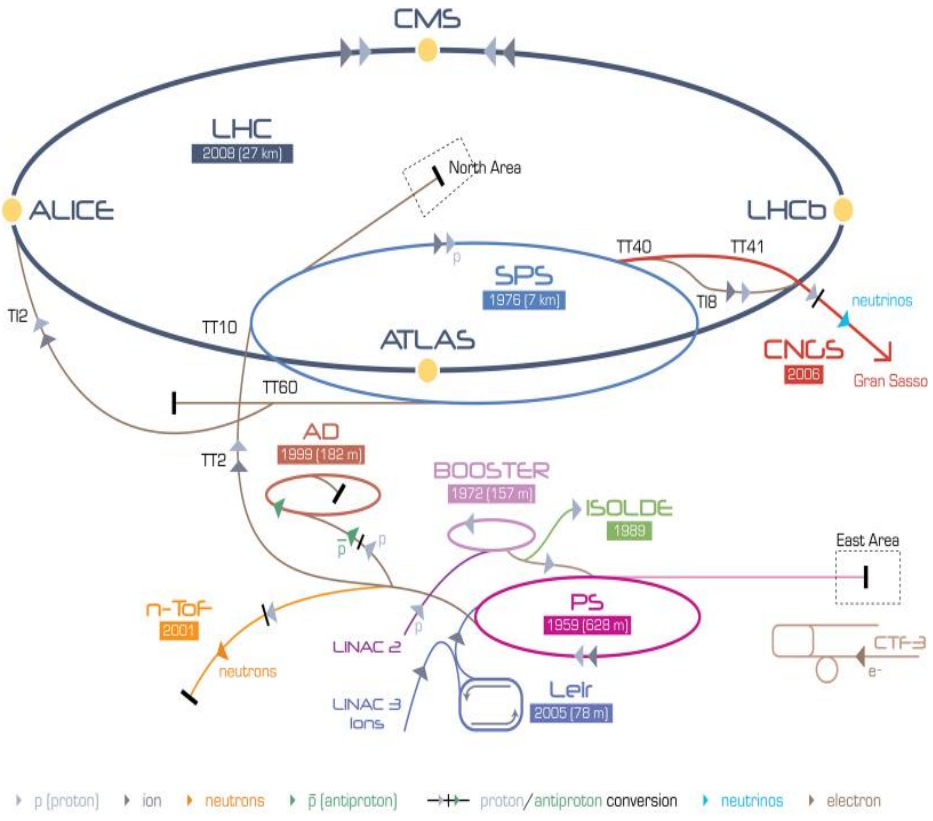




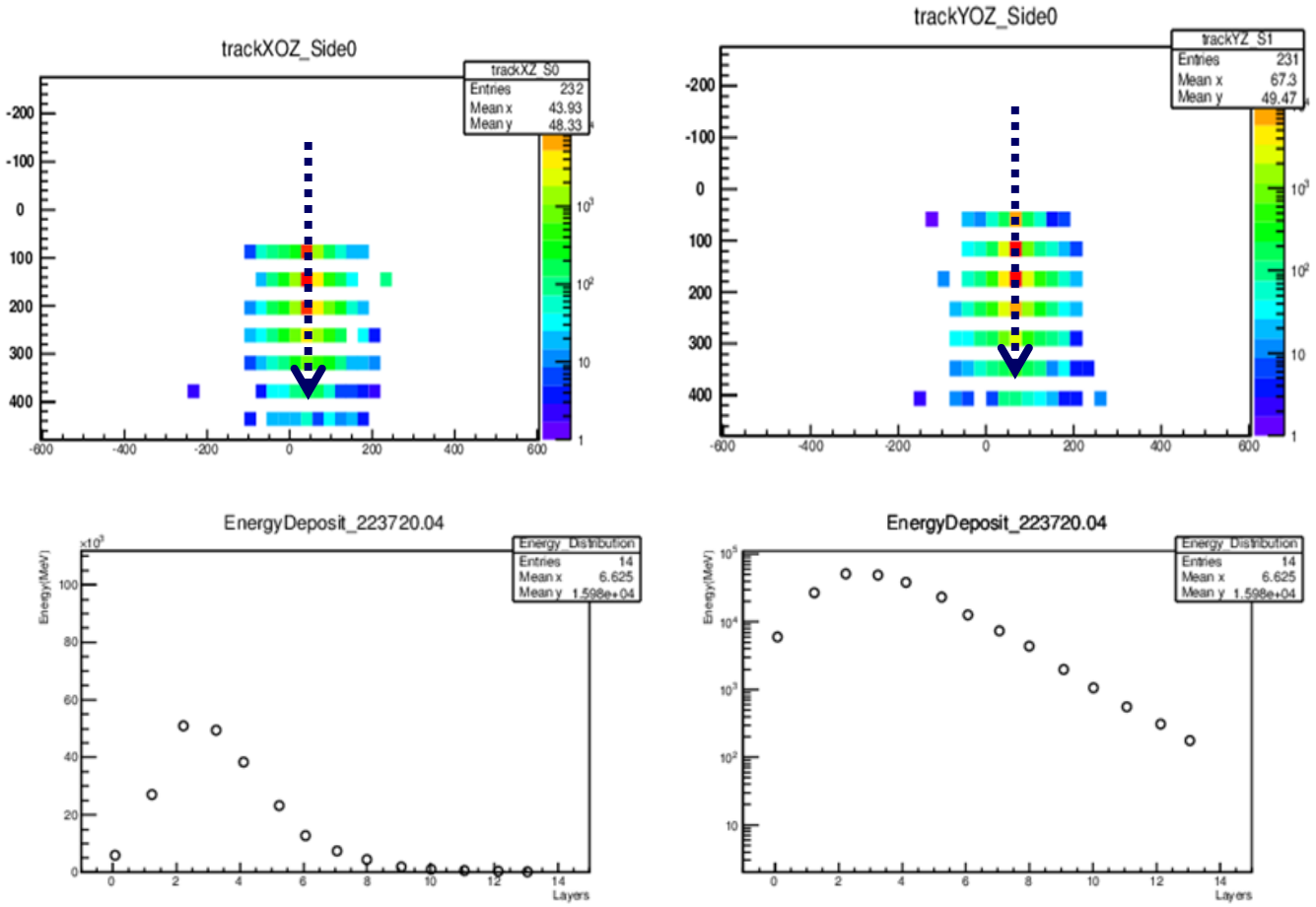


Beam Test in CERN

- PS：protons Momentum 24 GeV/c， Secondary hadrons and electrons
- SPS: protons Momentum 400GeV/c, Secondary hadrons and electrons，Pure electrons from 5GeV to 300GeV

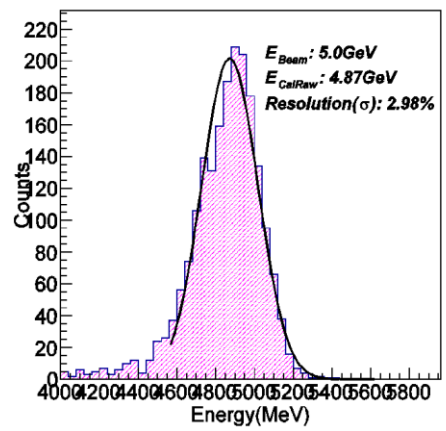


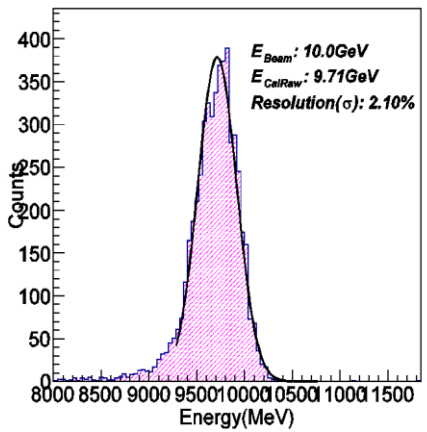
BGO CAL Response to High Energy e

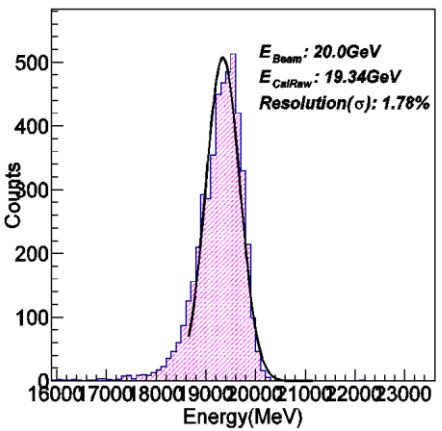


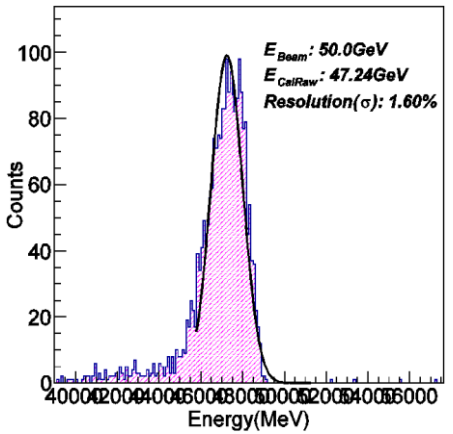
250GeV e shower profile

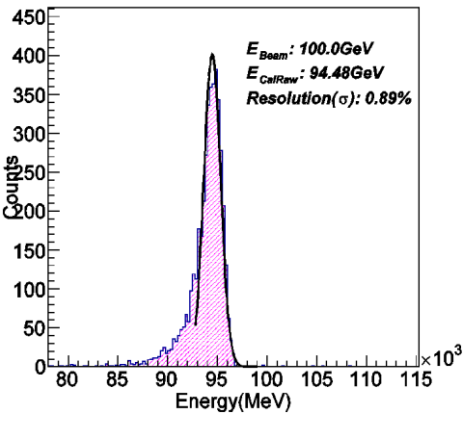
Electron Energy Rec（SPS）

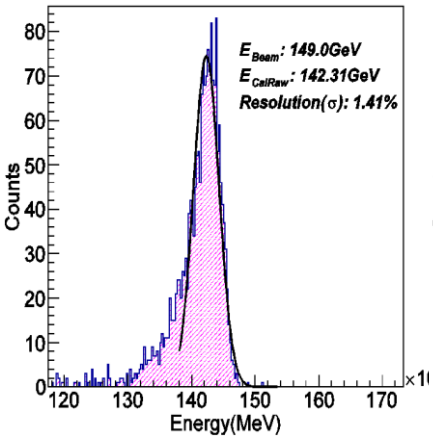


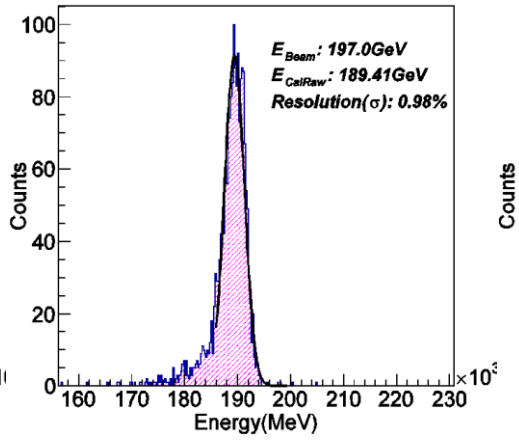


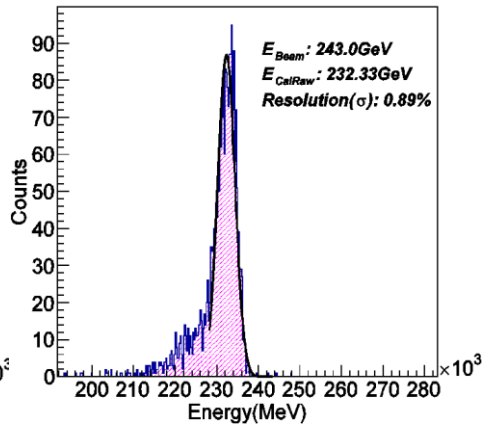






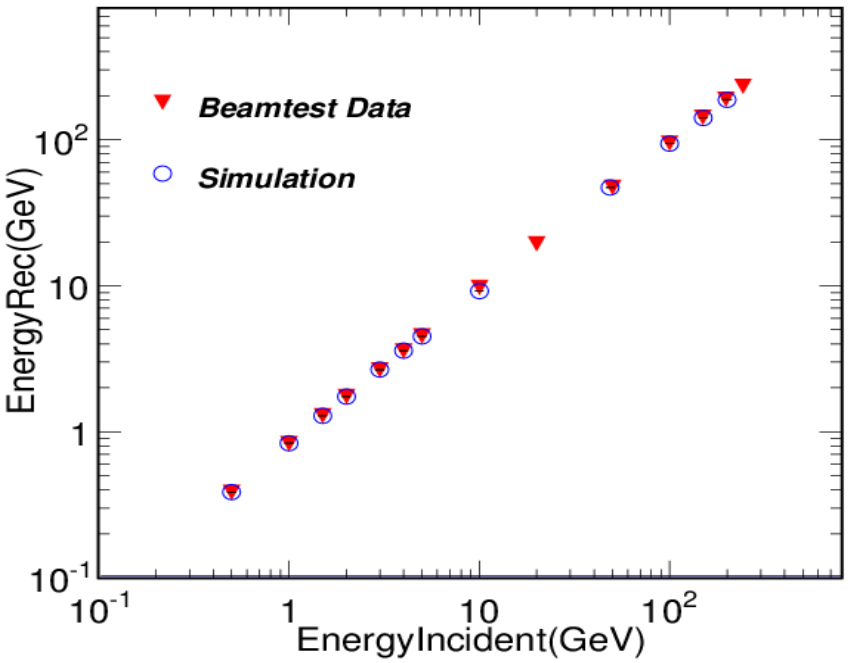


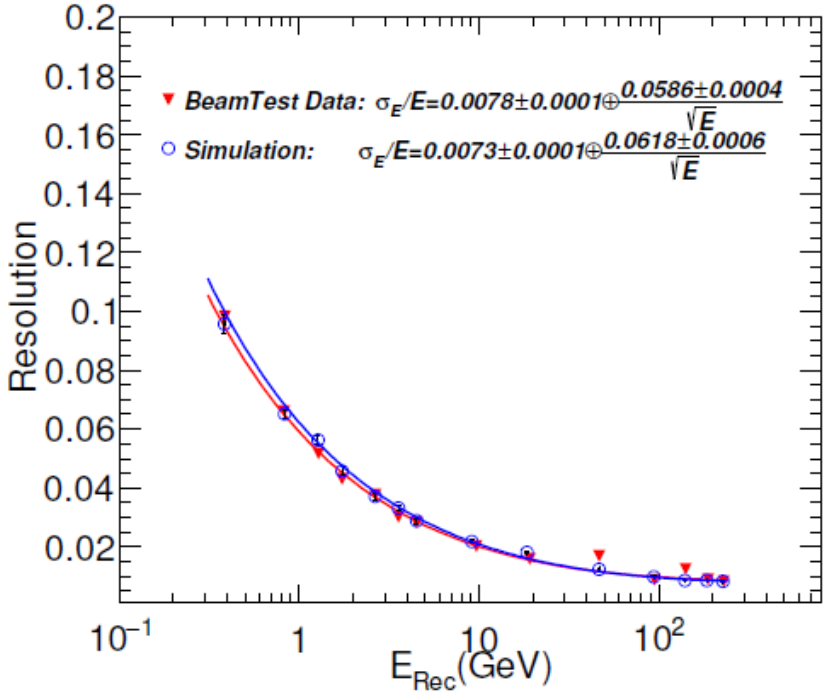




5, 10, 20, 50, 100, 149, 197, 243 GeV electrons

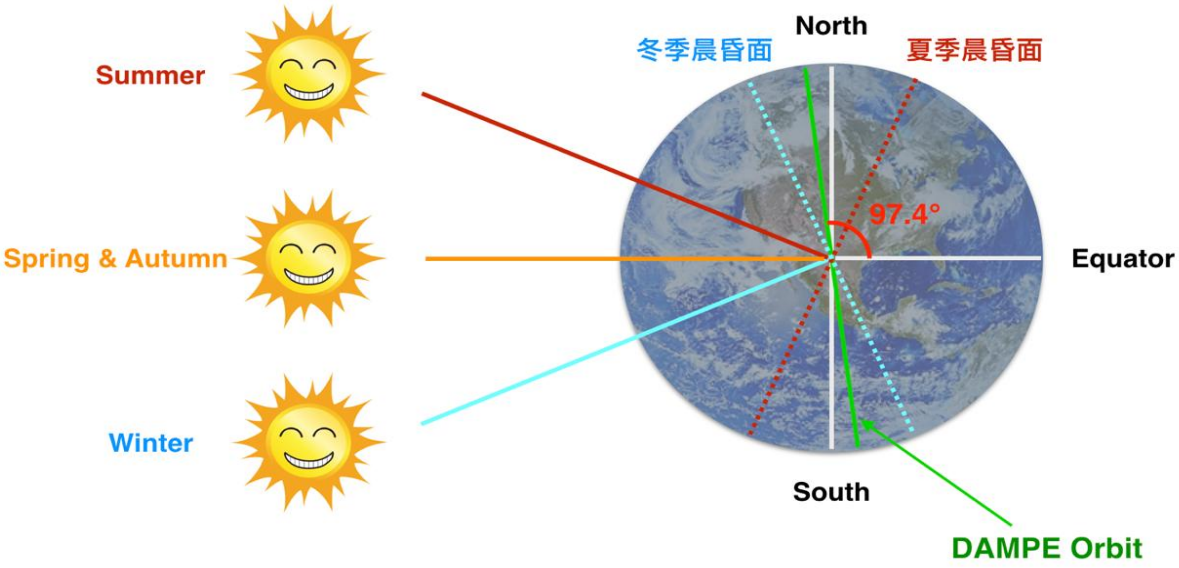
Energy linear Response

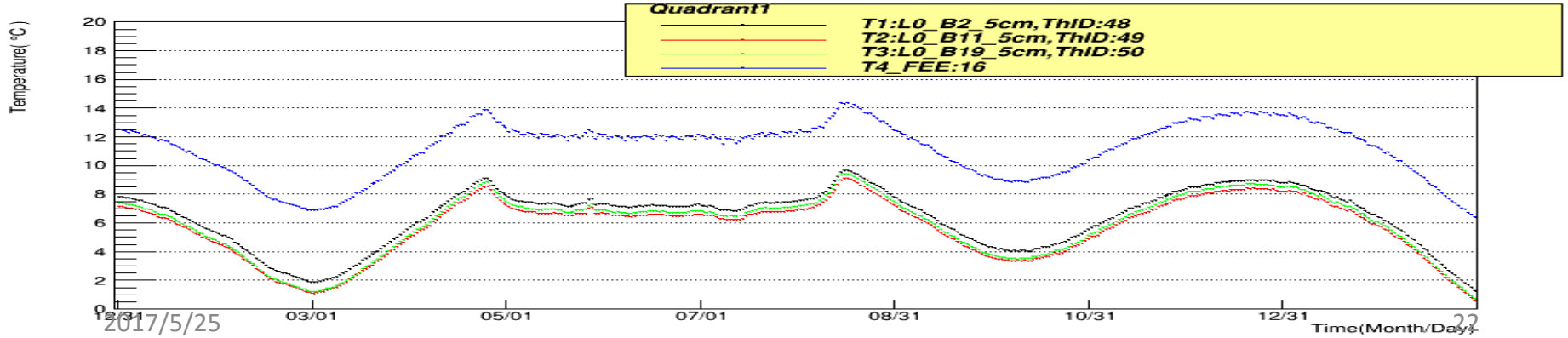




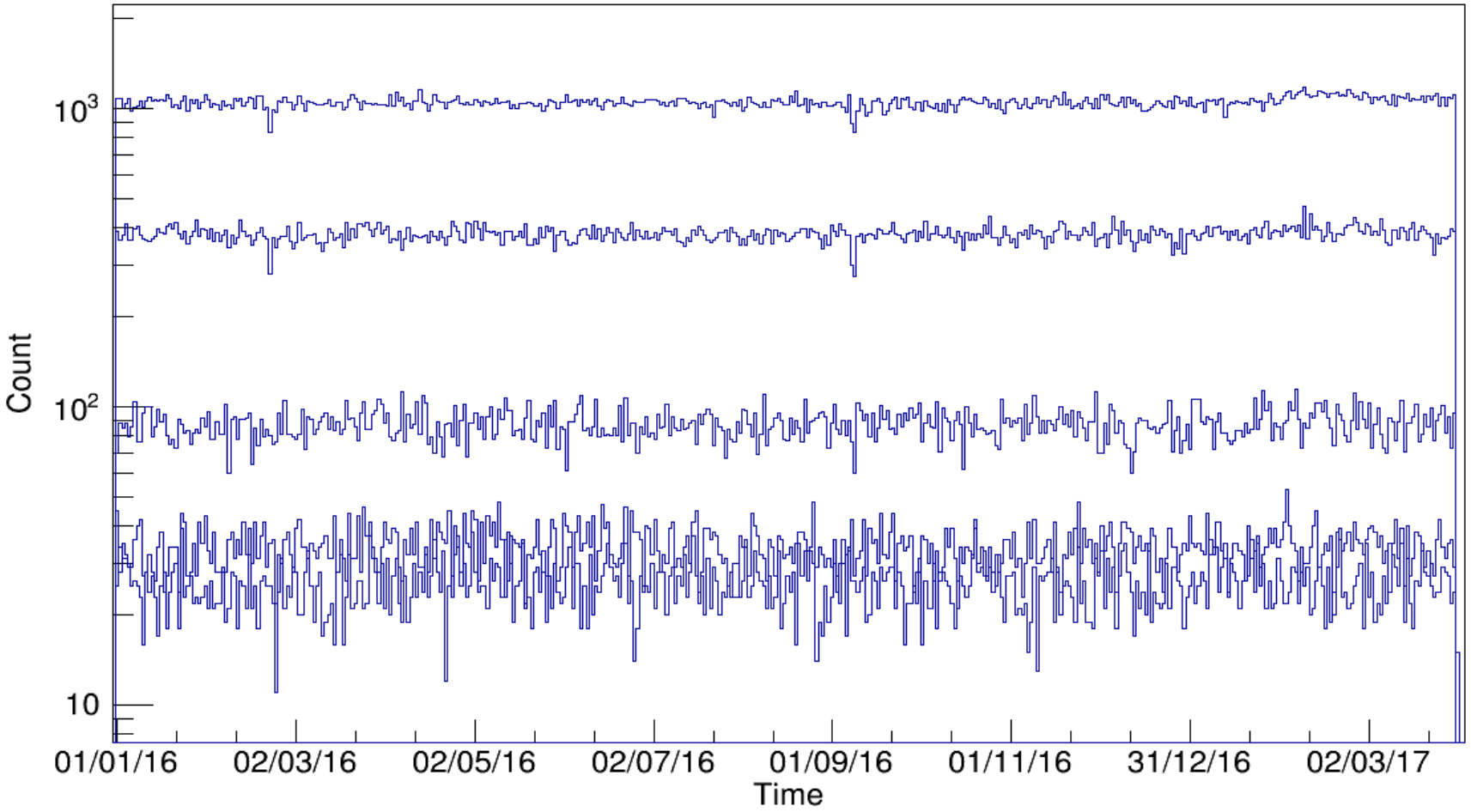
Lunched in 12.17.2015

DAMPE in Space

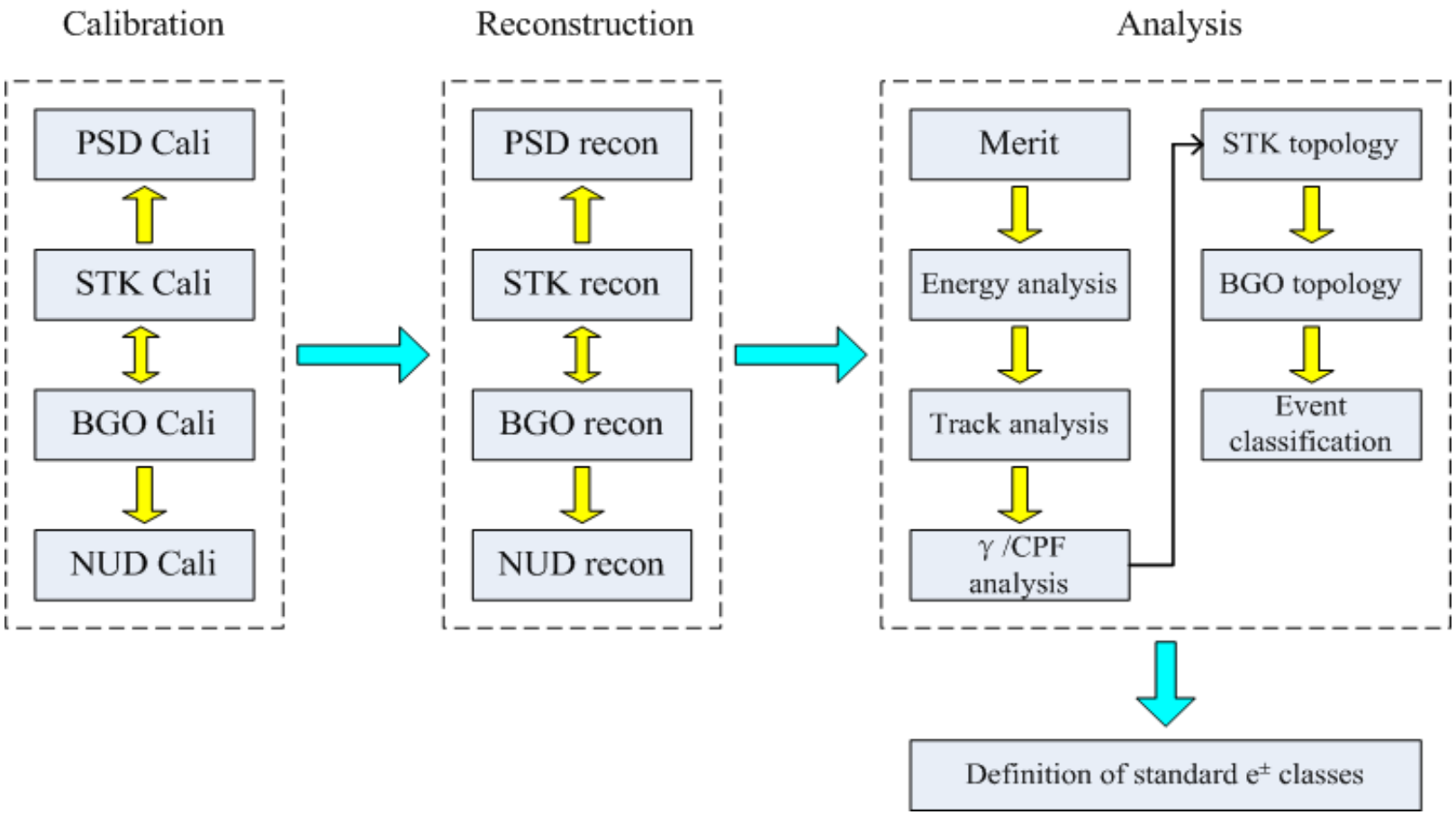




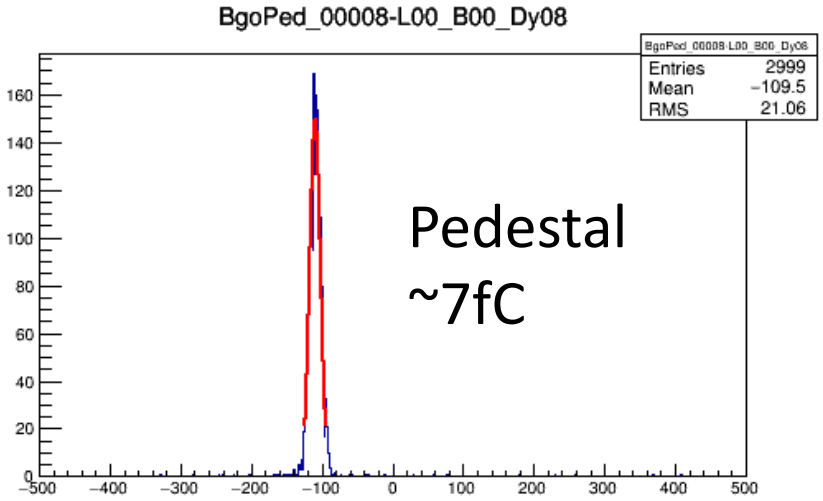
Event Trigger Rate

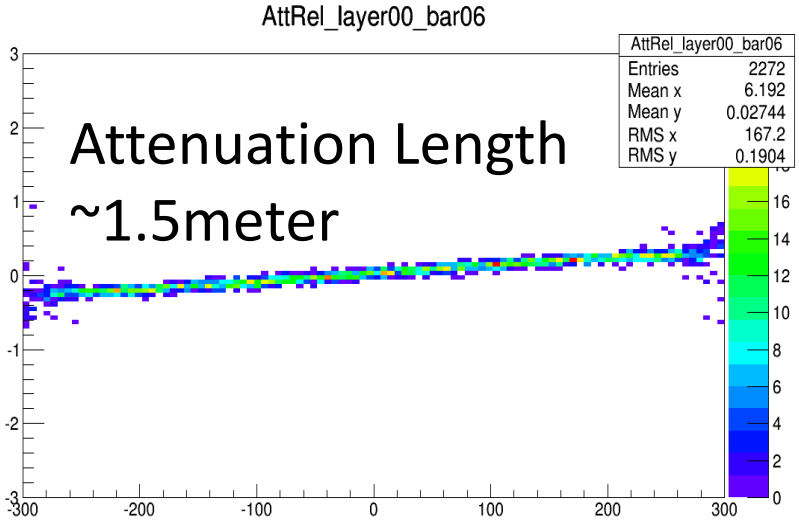


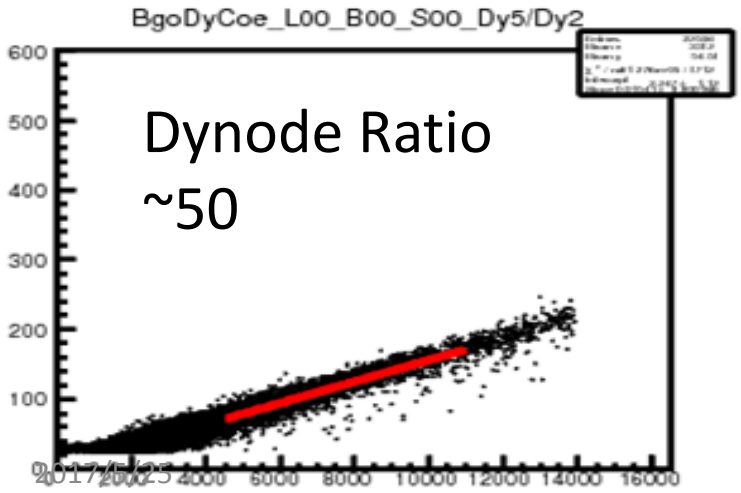
The Data Analysis Flow

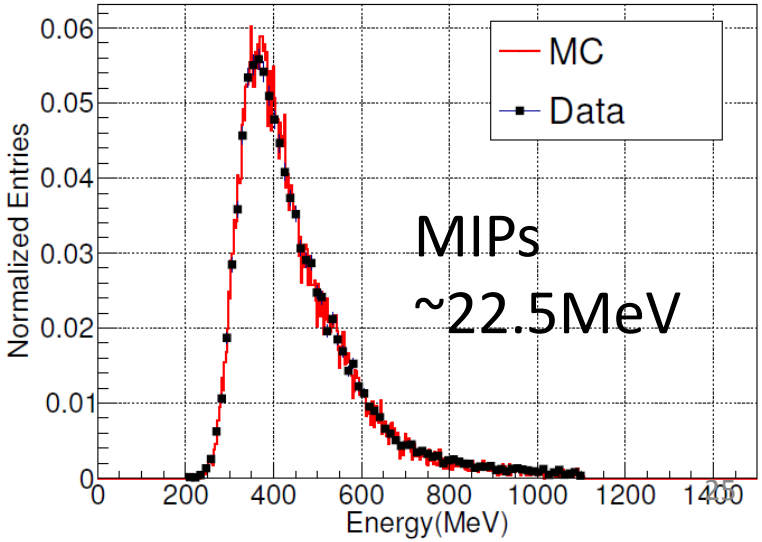


calibration



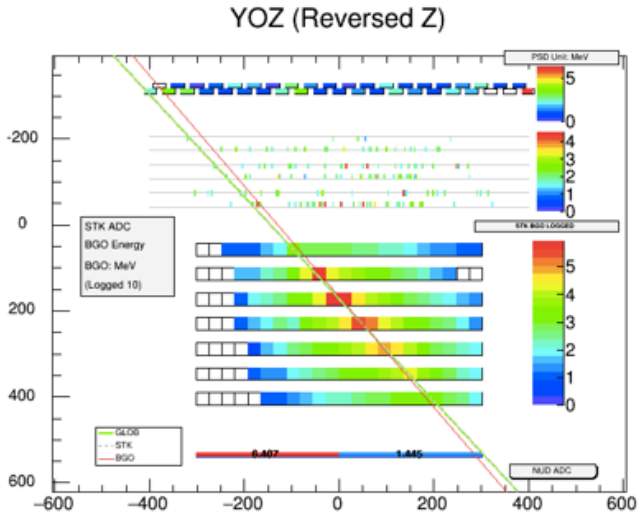


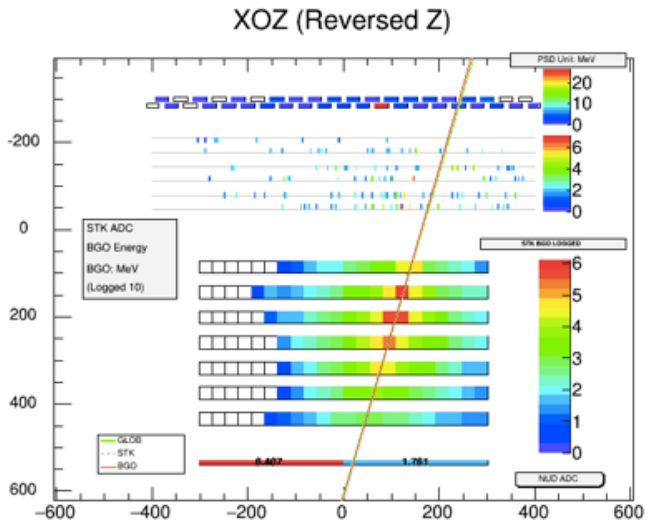




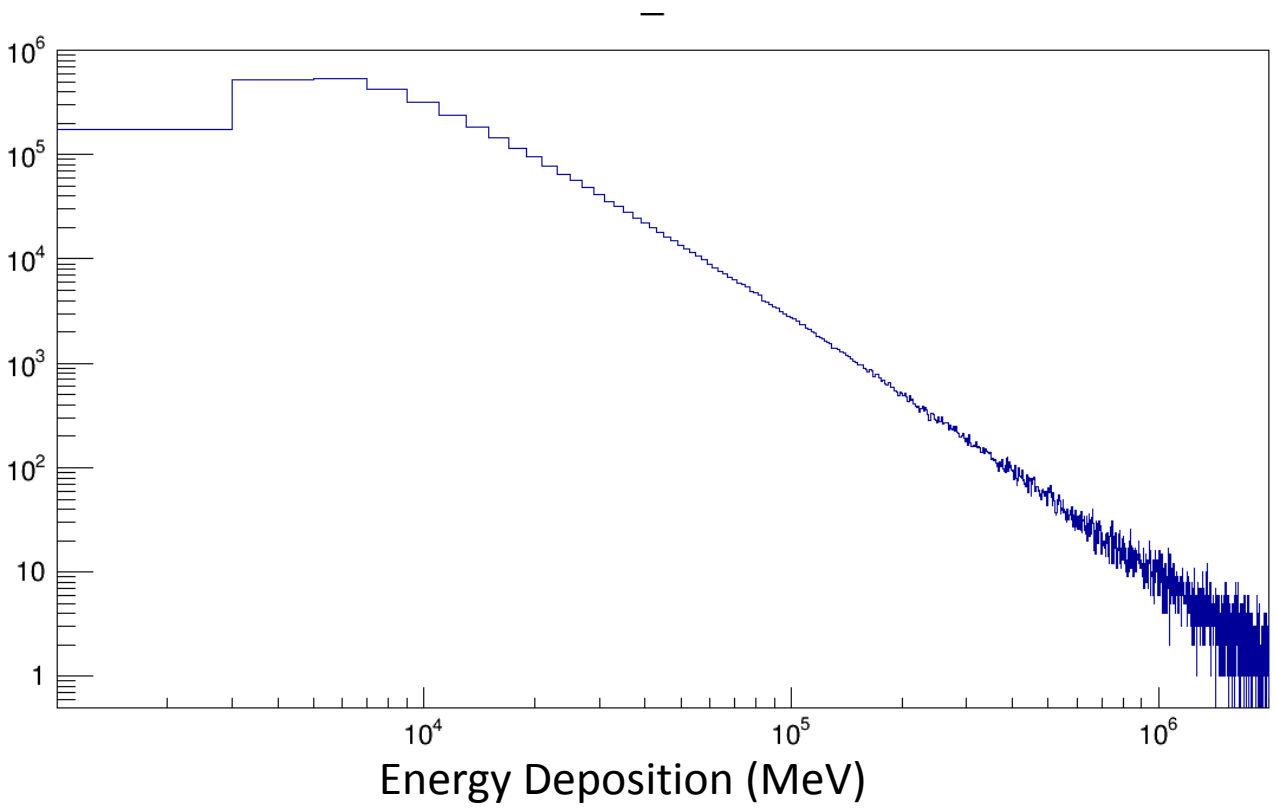
Event Selection

- High Energy Trigger
- Hits number in ECAL
- Forward of View events
- Shower axis within fiducial volume



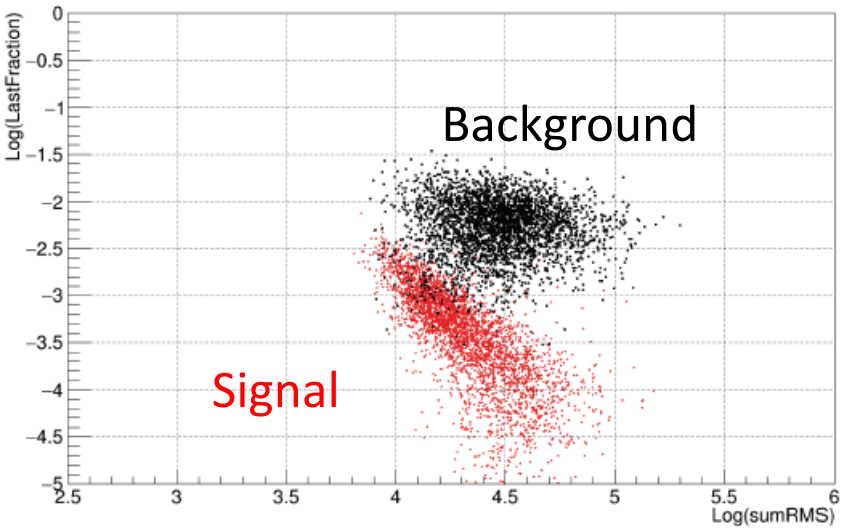


Energy Deposition in BGO calorimeter

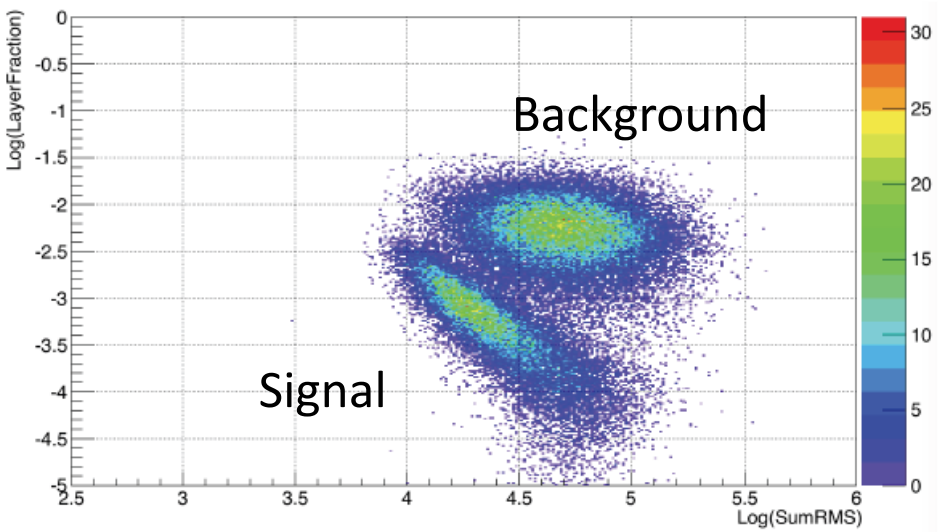


e/p separation with ECAL

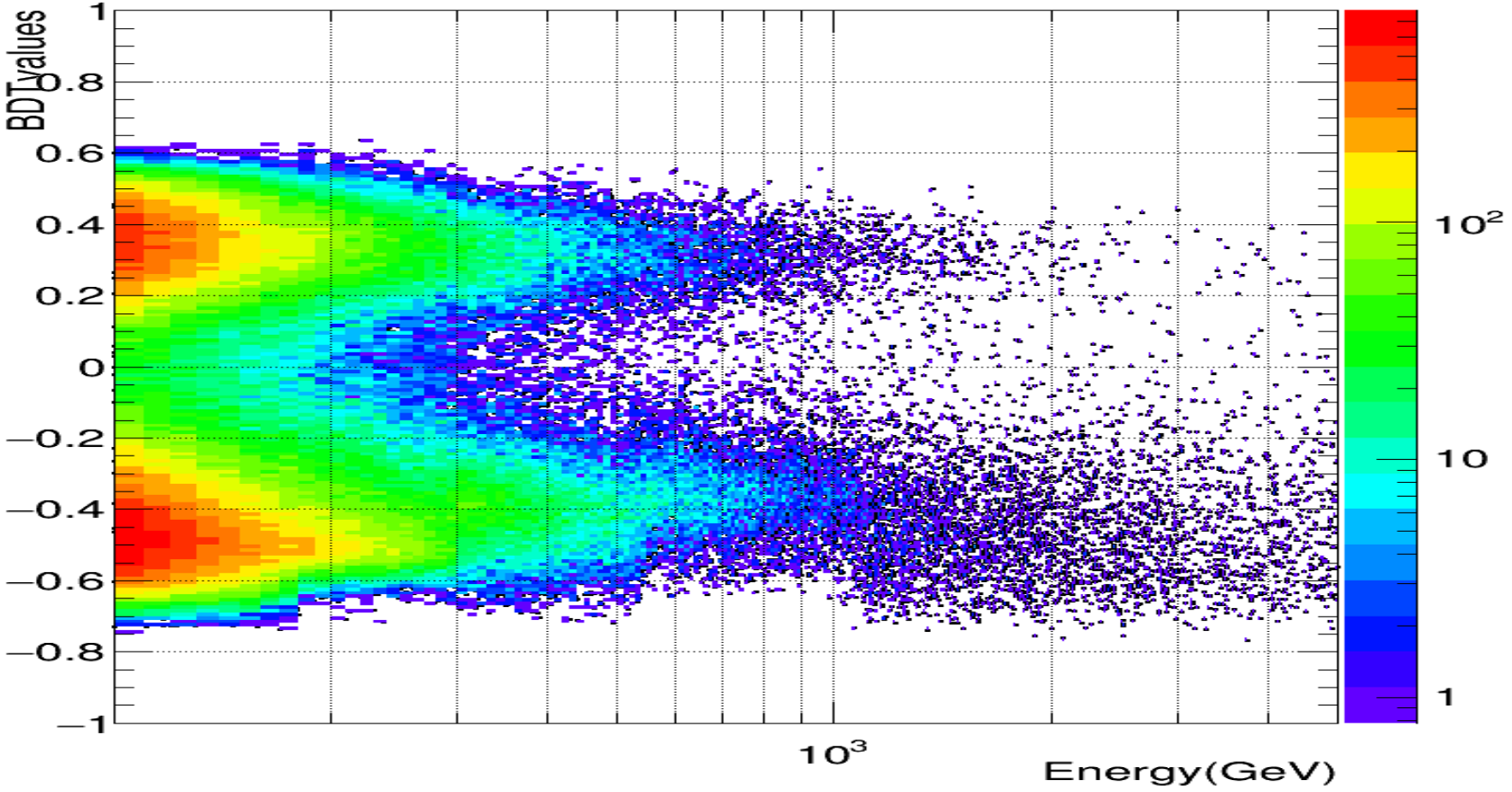
Simulation 100 ~ 150 GeV



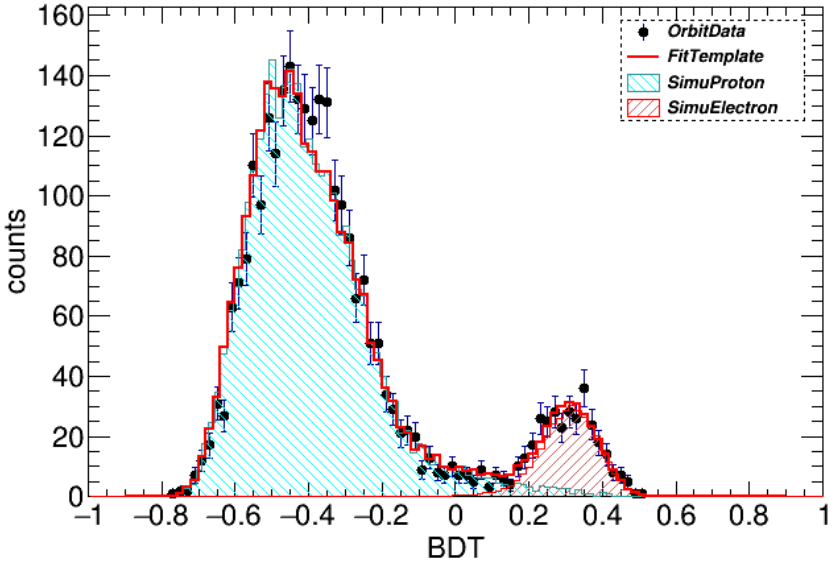
Data 100 ~ 150 GeV

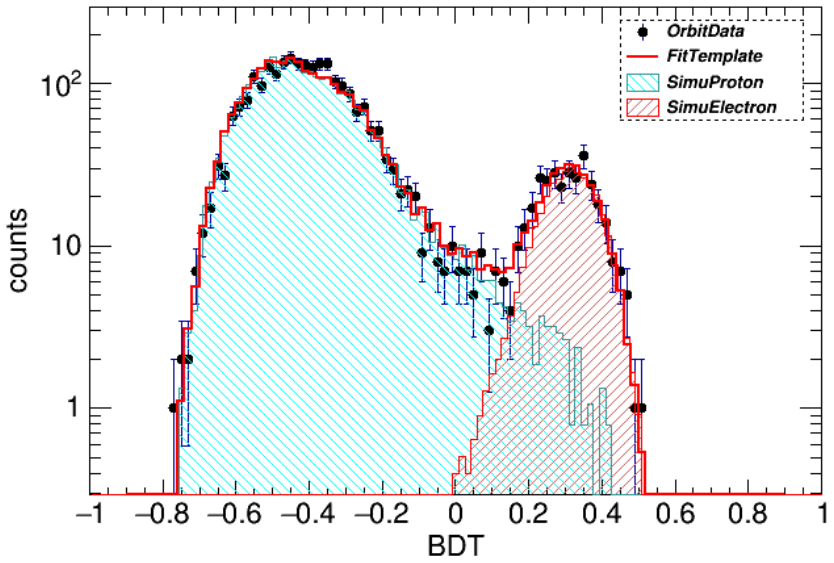


e/p separation with ECAL



Template fit (TeVs)



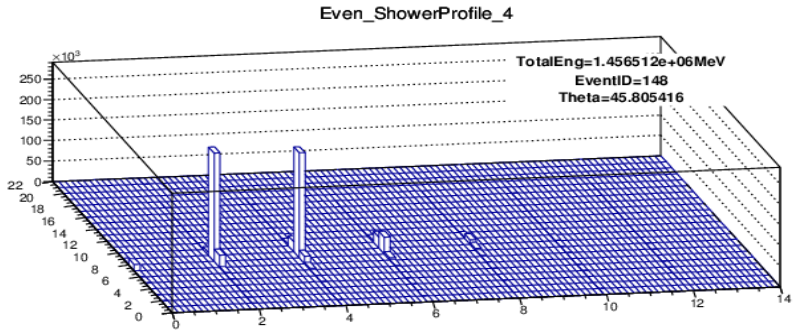


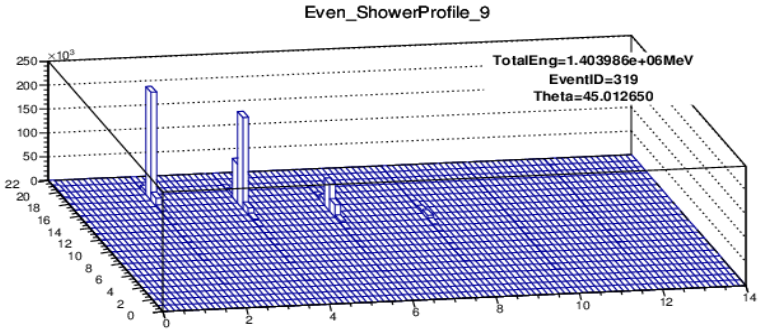
6.9% proton contamination at ~90% electron efficiency

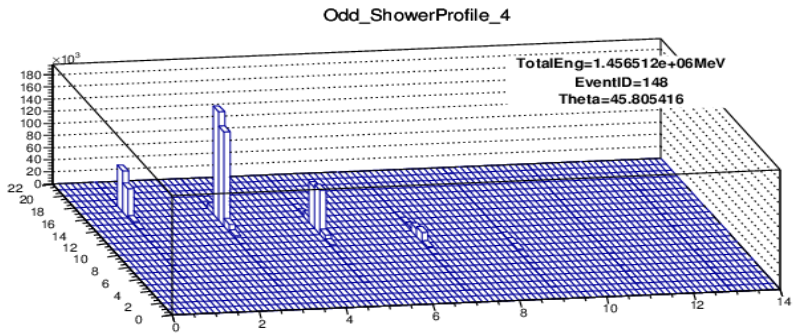
Signal /background = 299/2443

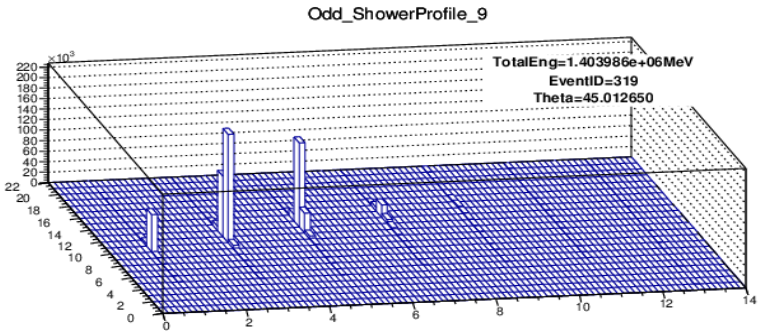
Chi^2/ndf: 89.8/61

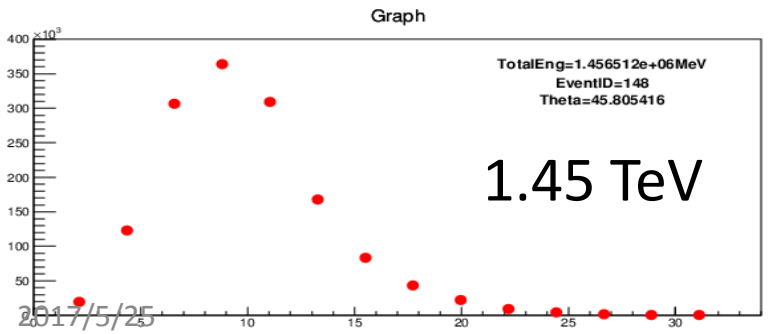
e+/- candidates

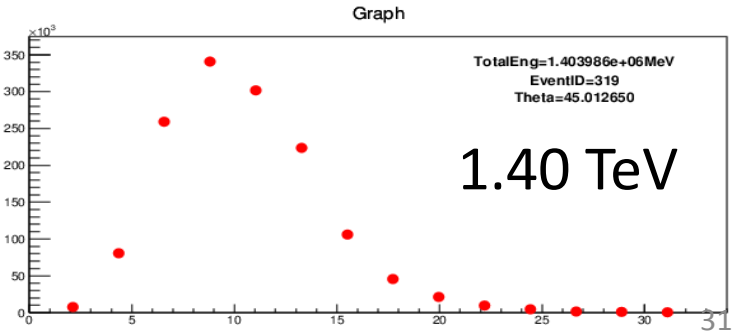












Summary

- An Imaging 3D BGO Calorimeter was built for DAMPE in the past several years
- The performance of the calorimeter is very good
- The instrumentation works very well in space
- The DAMPE opens a new window to the TeV energy range

THANKS