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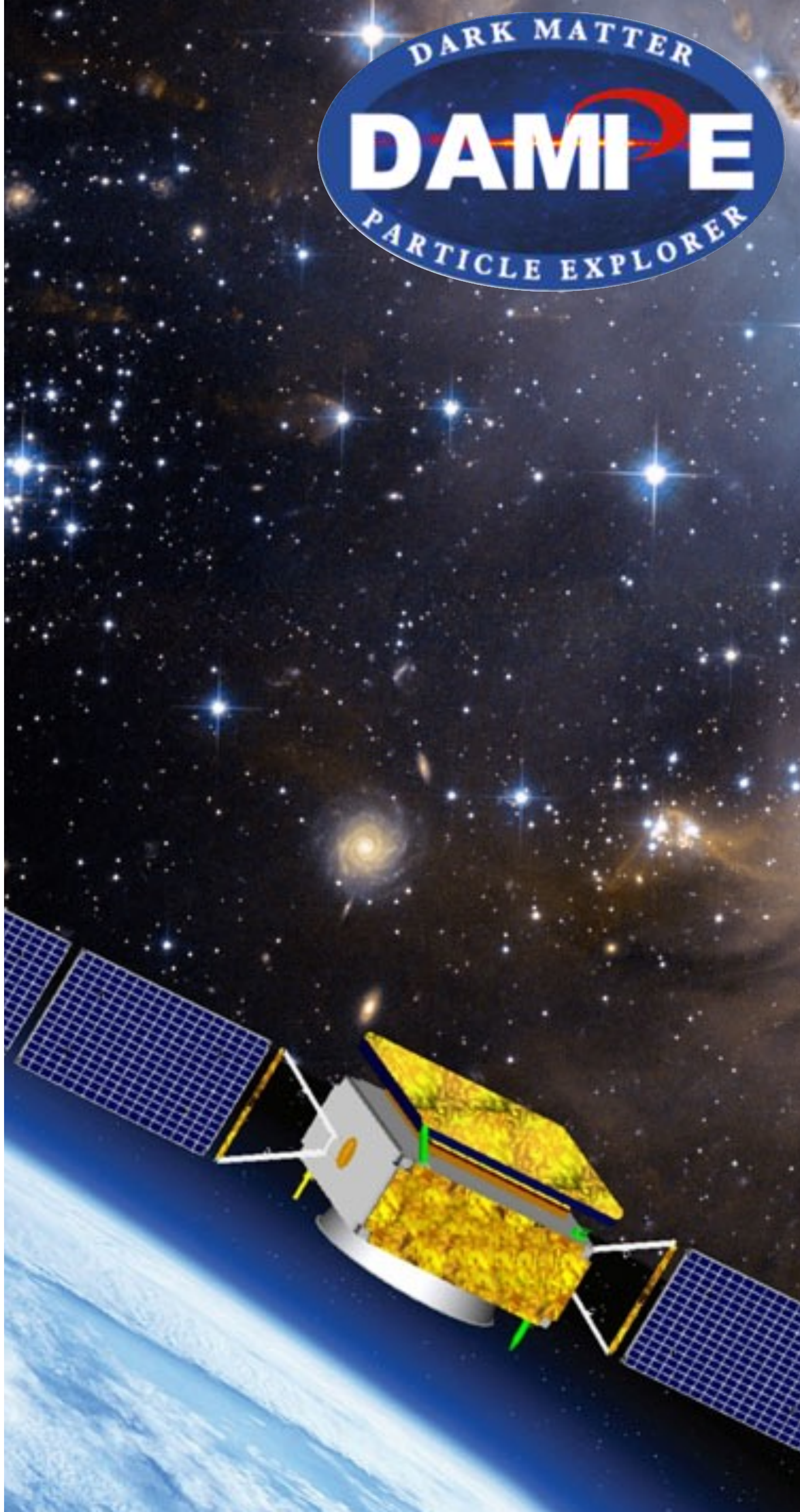
University of Science and Technology of China




# Performance of DAMPE BGO Calorimeter in Ion Beam Test

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2018/06/22

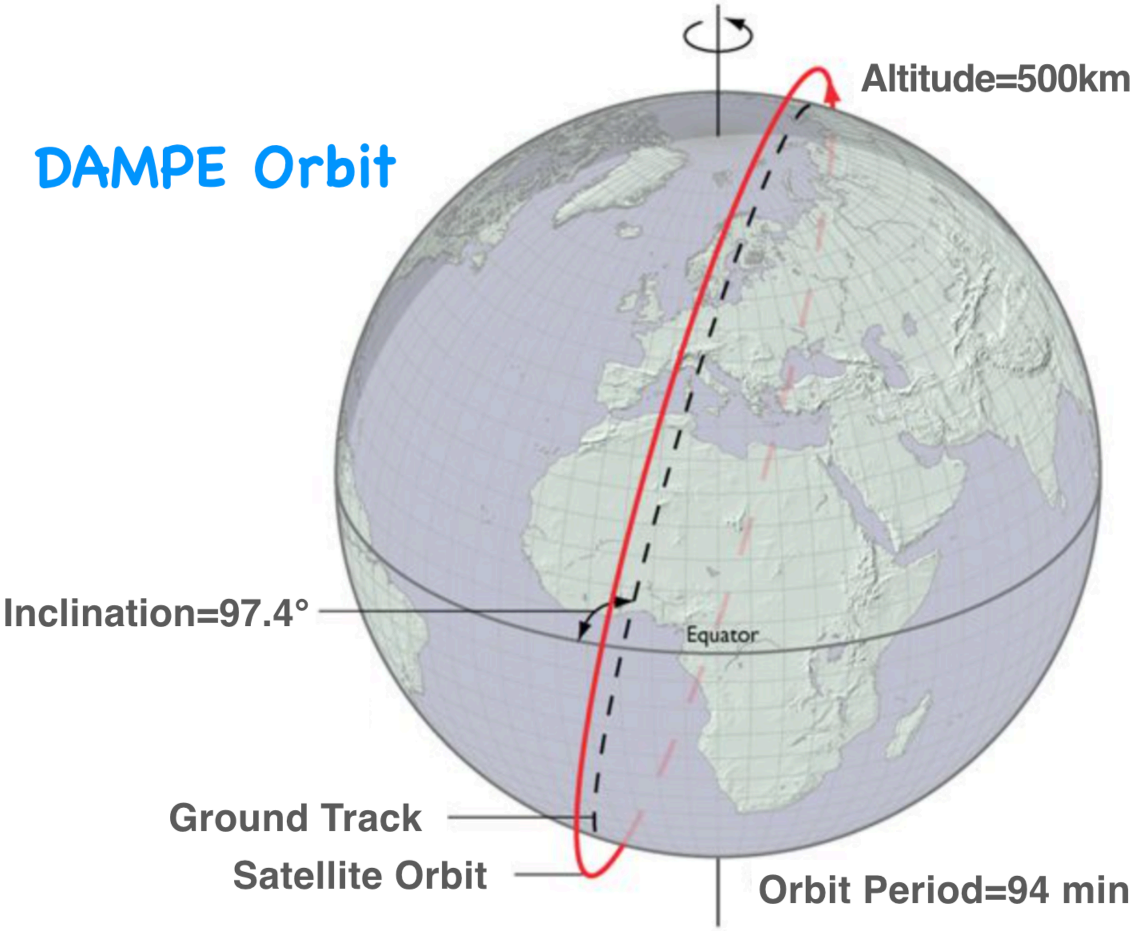
# Outline

- DAMPE experiment
- BGO calorimeter
- Ion beam test of BGO calorimeter
- Summary

# DAMPE Mission

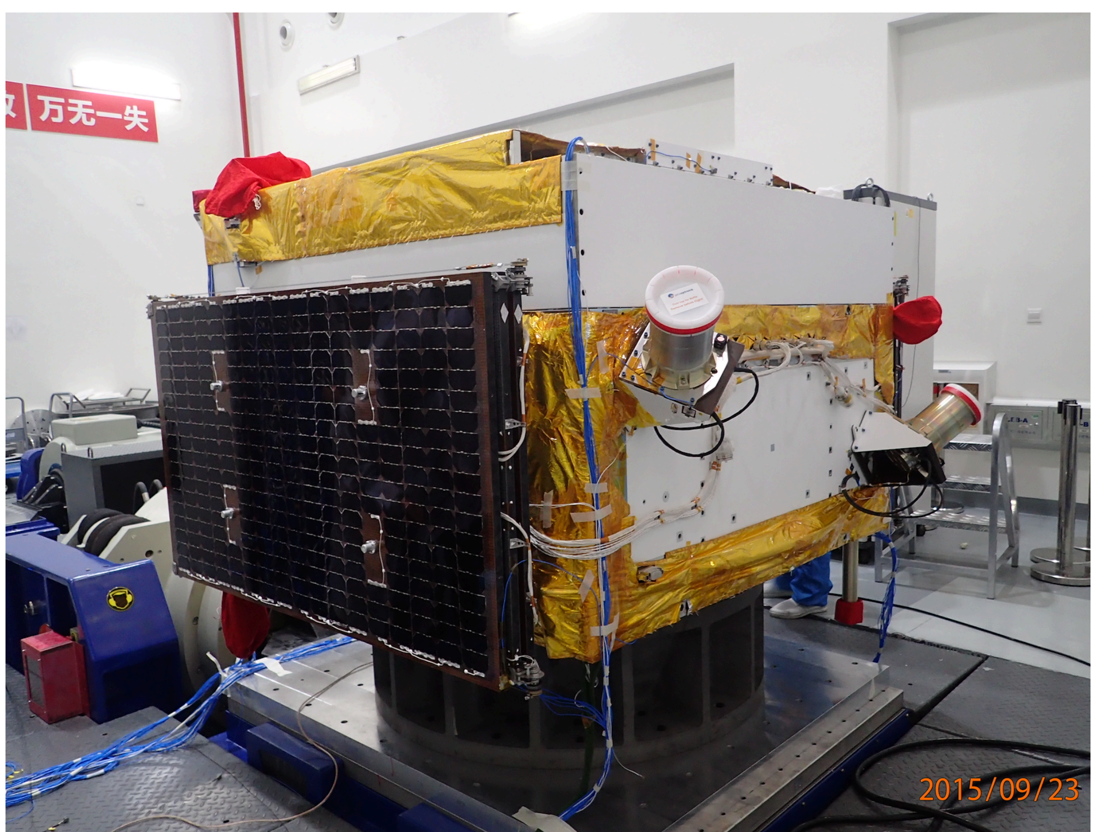
- DArk Matter Particle Explorer (DAMPE) is an orbit experiment for detecting high energy cosmic ray
- Launch: 17th Dec. 2015, CZ-2D rocket
- Life time > 3 years

- Orbit: sun-synchronous
- Altitudes: 500 km
- Period: 94 minutes
- 5 million events/day
- 16 GB/day downlink



# Scientific Objectives

| Science | Measurement |
|---|---|
| Dark Matter | GeV-10TeV electron&gamma ray spectrum and space distribution |
| Cosmic ray Origin & propagation | (1)0.1-100TeV nuclide spectrum (P-Fe)<br>(2)gamma ray spectrum and space distribution of SNR |
| Gamma ray astronomy | (1)gamma ray sources<br>(2)GRB |



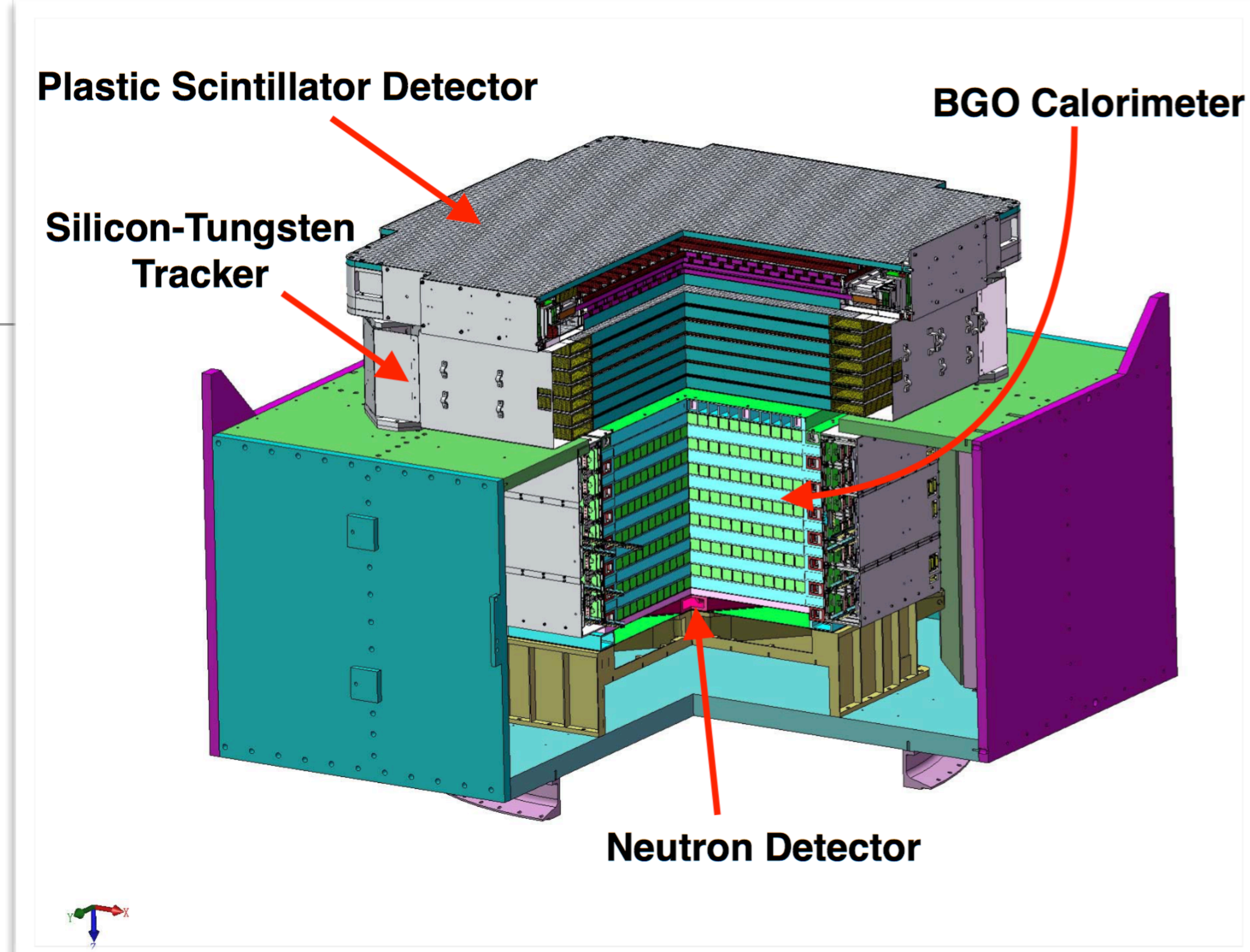

CNINA
- Purple Mountain Observatory, CAS, Nanjing
- National Space Science Center, CAS, Beijing
- University of Science and Technology of China, Hefei
- Institute of High Energy Physics, CAS, Beijing
- Institute of Modern Physics, CAS, Lanzhou

ITALY
- INFN Perugia and University of Perugia
- INFN Bari and University of Bari
- INFN Lecce and University of Salento

SWITZERLAND
- University of Geneva

# DAMPE Detector

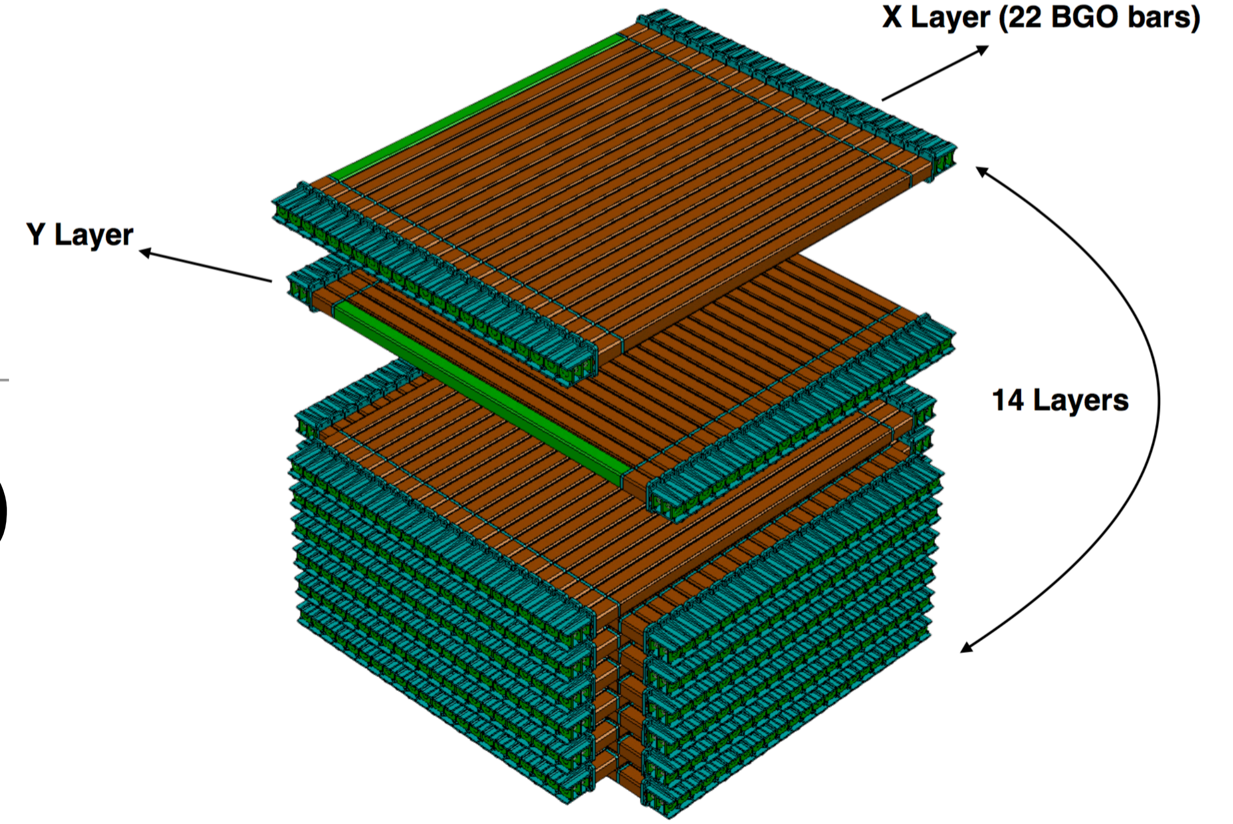
- Charge measurement (dE/dx in PSD, STK)
- Precise tracking (STK + BGO)
- Precise energy measurement (BGO)
- Particle identification (BGO + NUD)




| | DAMPE | Fermi | AMS02 | CALET |
|---|---|---|---|---|
| Radiation length | 32 | 8.6 | 17 | 28 |
| Energy resolution | 1.5%@ 100 GeV | >8.5%@ 100 GeV | 2%@ 100 GeV | 2%@ 100 GeV |
| Acceptance ($m^2Sr$) | >0.3 | >2 | 0.055 | 0.12 |
| Background suppression | $10^5$ | $10^3$~$10^4$ | $10^5$ | $10^5$ |

# BGO Calorimeter

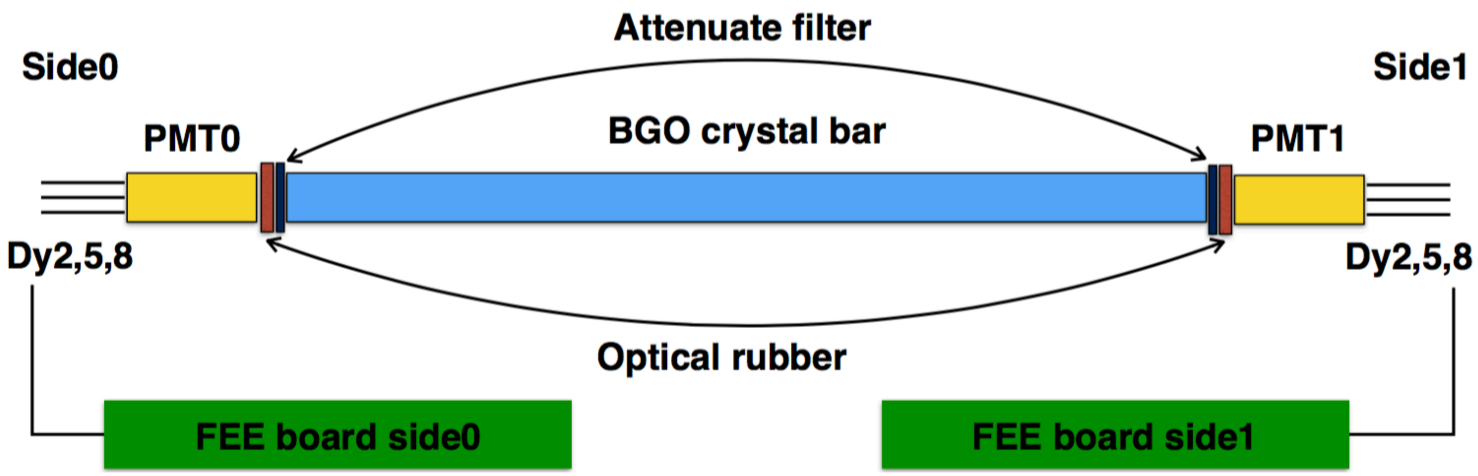
- 308 BGO bars (25*25*600 mm$^3$)
- 14 layers, 22 bars per layer
- 32 radiation lengths
- 1.6 nuclear interaction lengths
- Energy range: 5GeV-10TeV(e/γ)
- Energy resolution: 1.5%@800GeV (e/γ)
- Energy range of proton/nuclide: 50GeV-100TeV
- Energy resolution of proton: <40%@800GeV

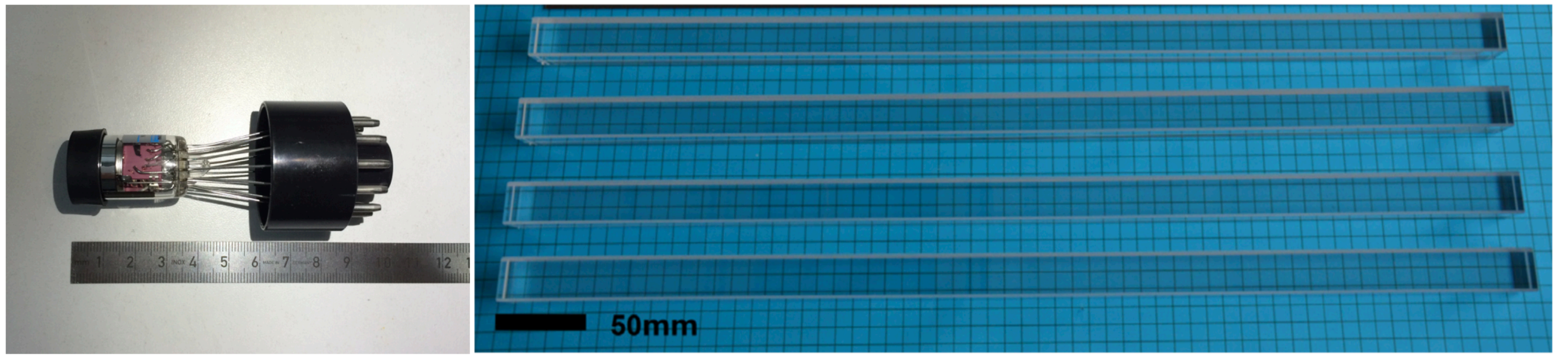


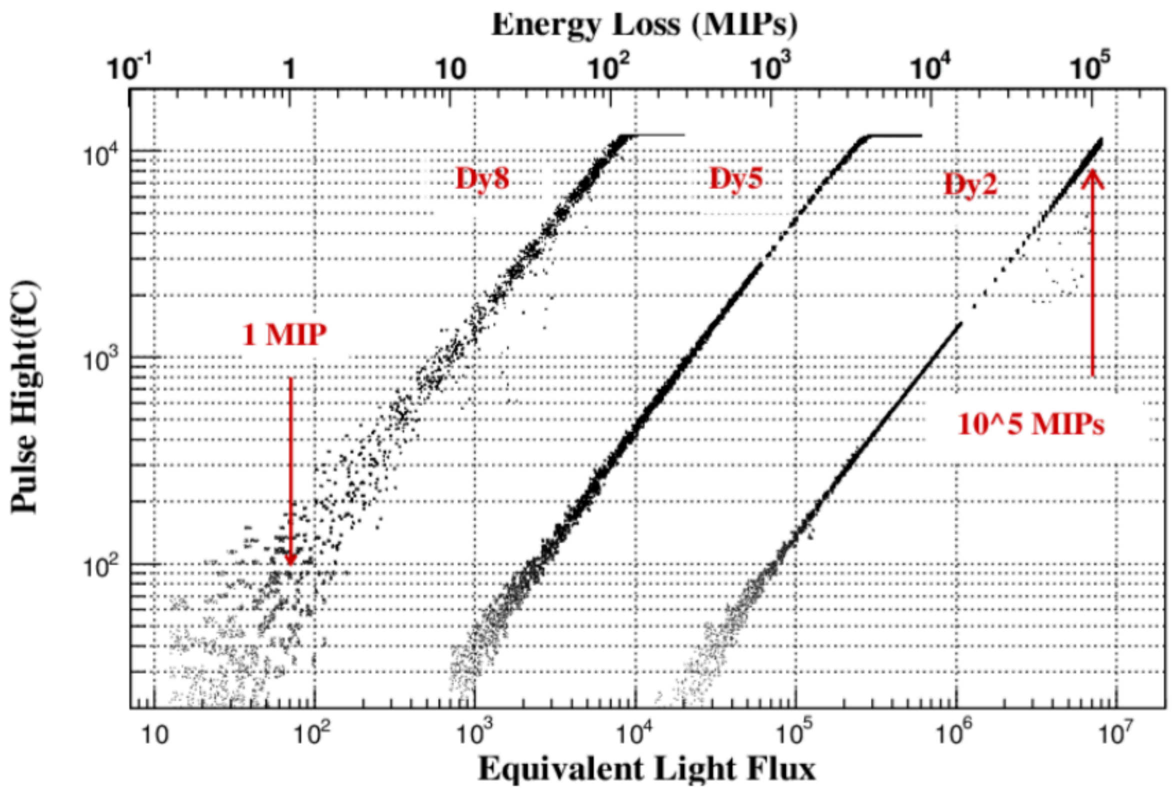

- ✦ Provide trigger
- ✦ Energy measurement
- ✦ e/p seperation
- ✦ Track seed

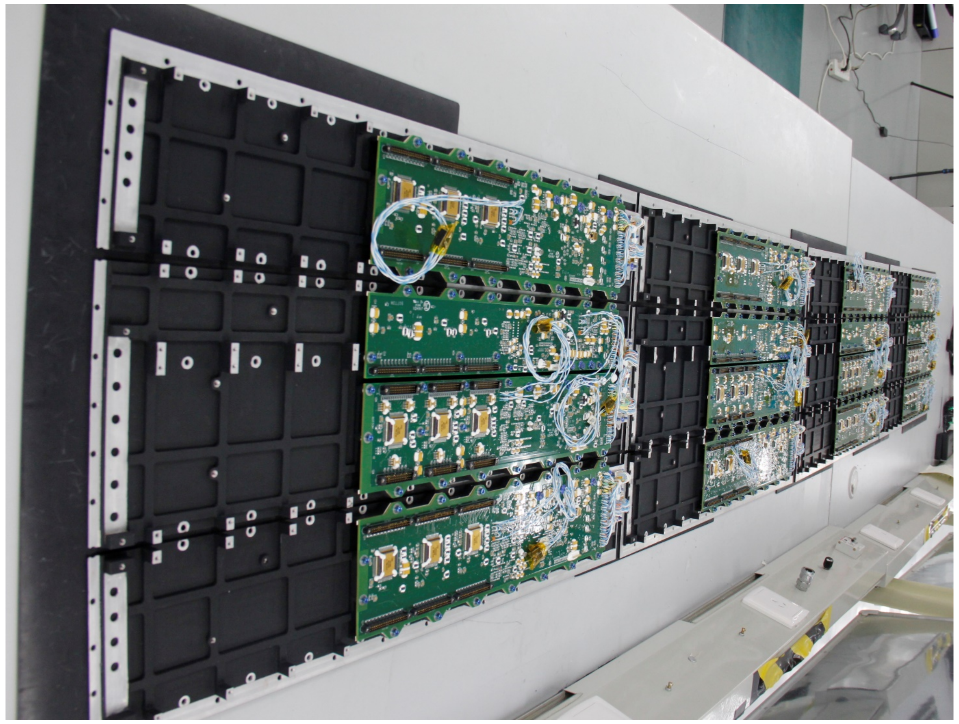
# Detection Unit of the BGO ECAL

- Energy response of one BGO bar is from 10MeV (0.5MIPs) to 2TeV ($10^5$MIPs)
- Two-end measurement of one BGO bar
- Multi-dynode readout of one PMT



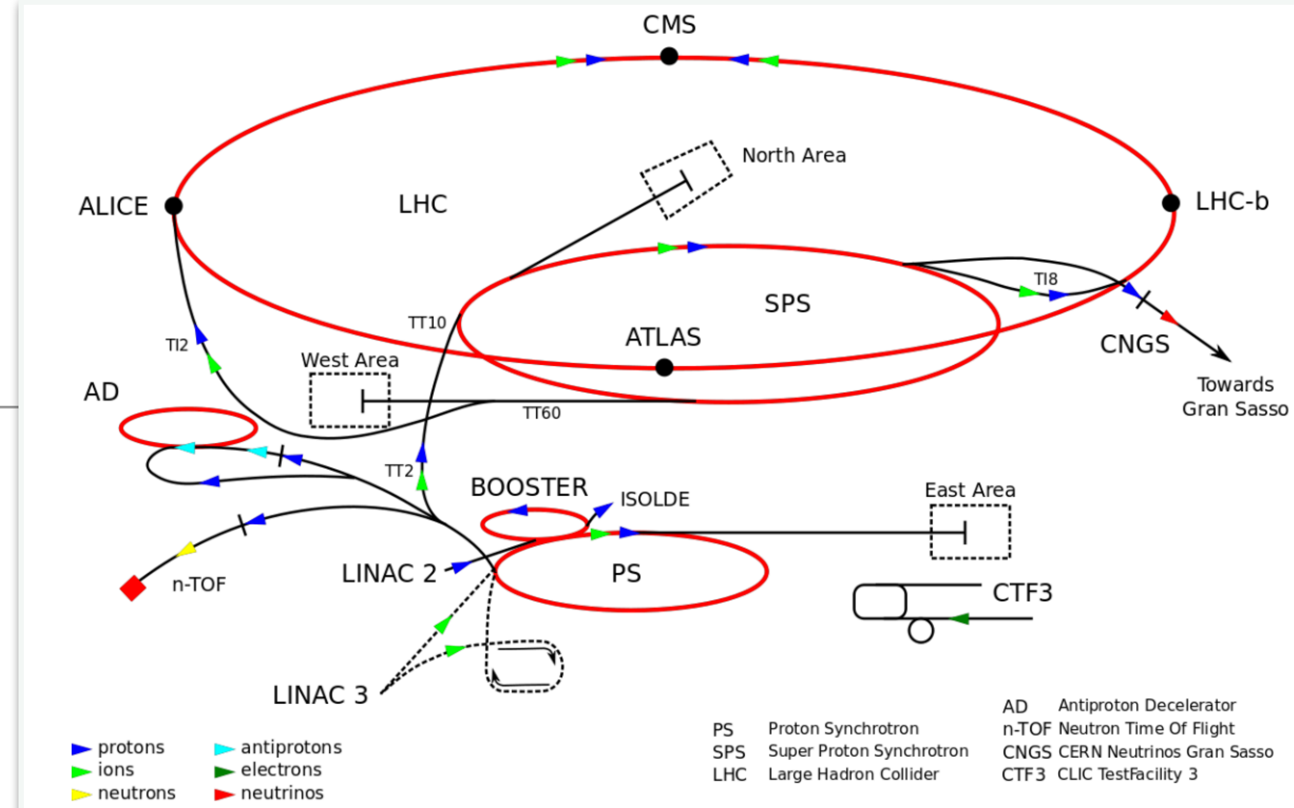



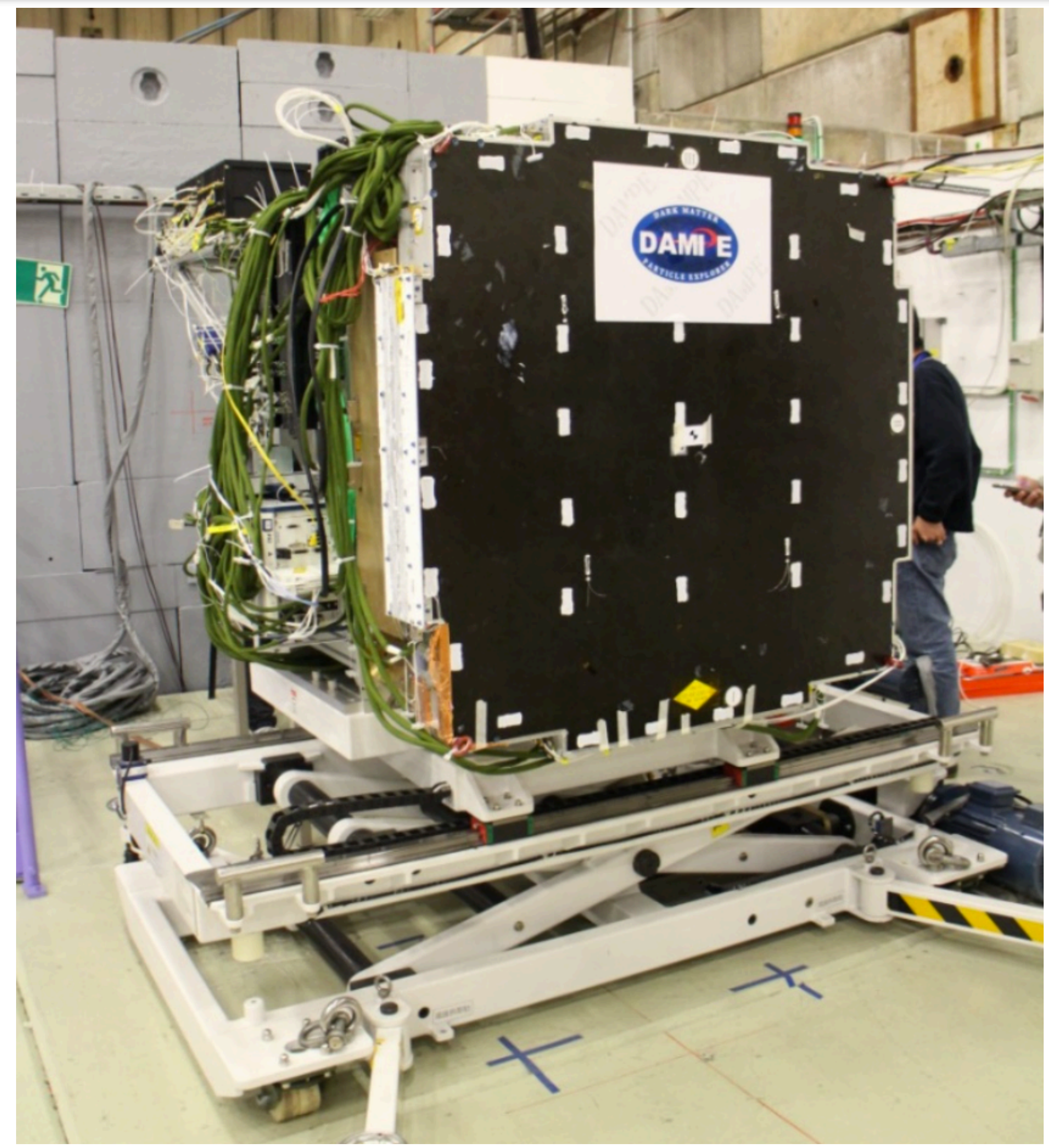



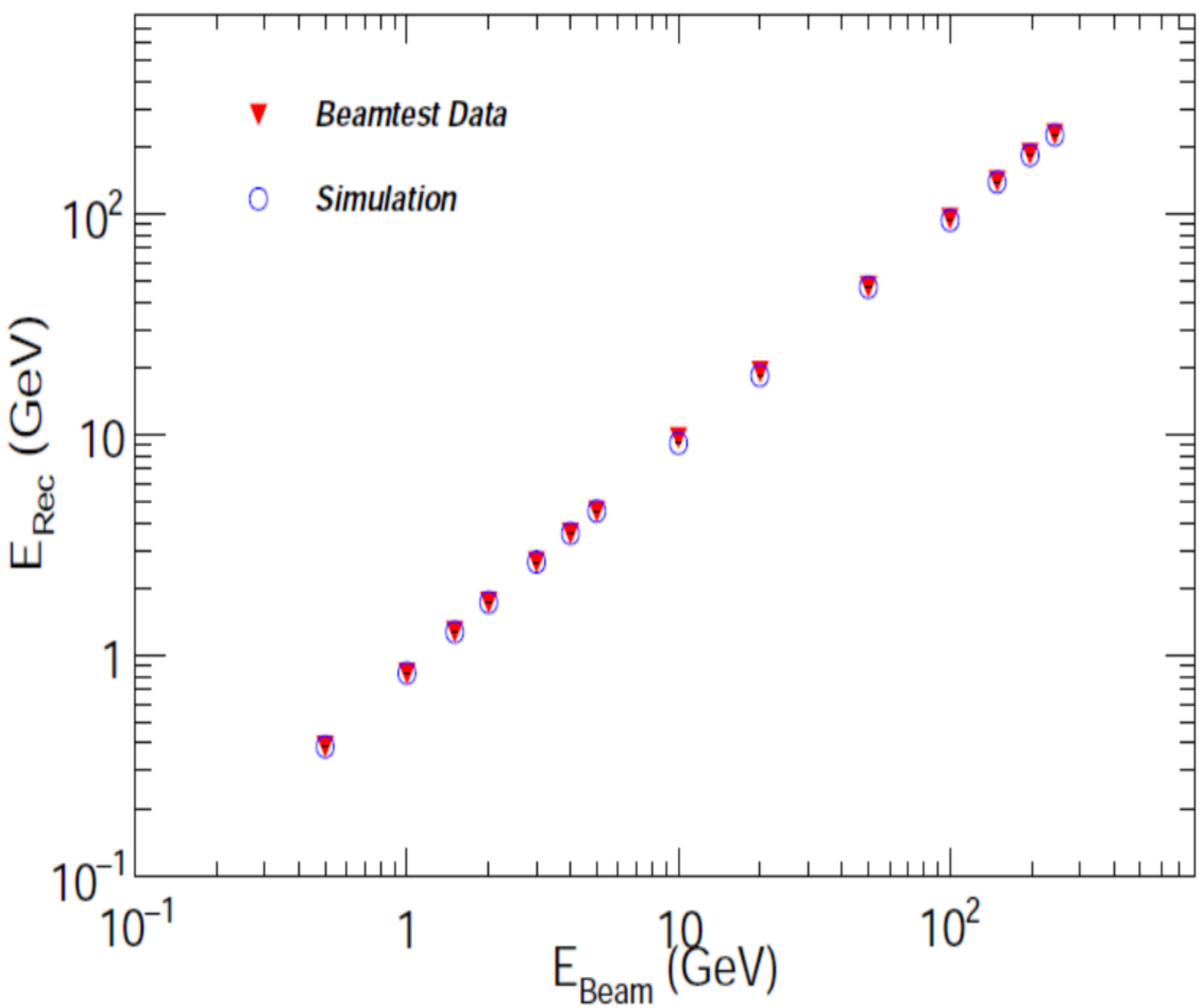
# Beam Test @ CERN

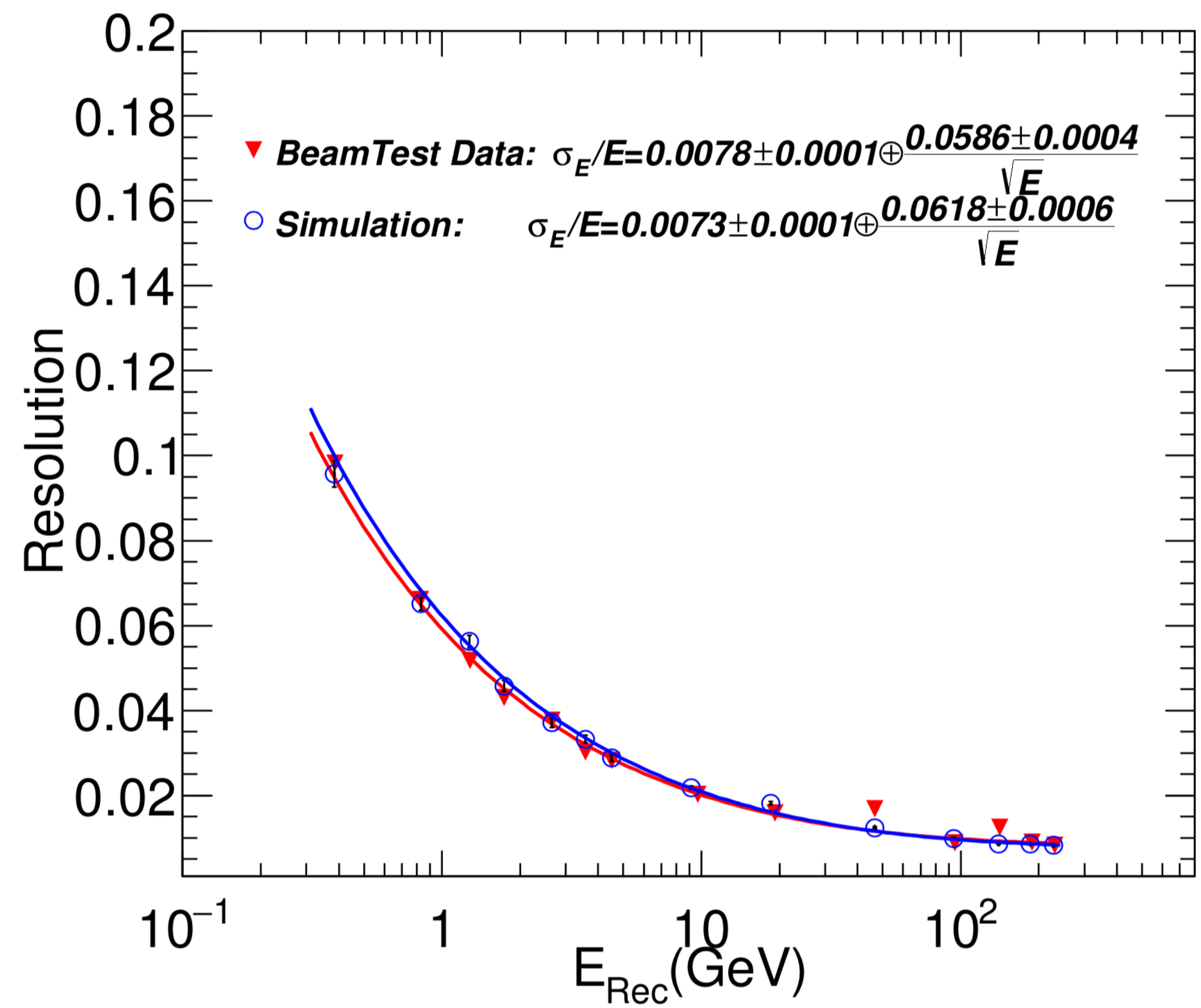
- 22 days, PS & SPS
  - electron: 0.5 - 243 GeV
  - Proton: 3.5 - 10 GeV
  - gamma: 0.5 - 20 GeV
  - muon: 150 GeV
- 17 days, SPS
  - Argon: 30, 40, 75 GeV/n
  - Proton: 30, 40 GeV
- 21 days, SPS
  - Proton: 400 GeV
  - electron: 20 - 150 GeV



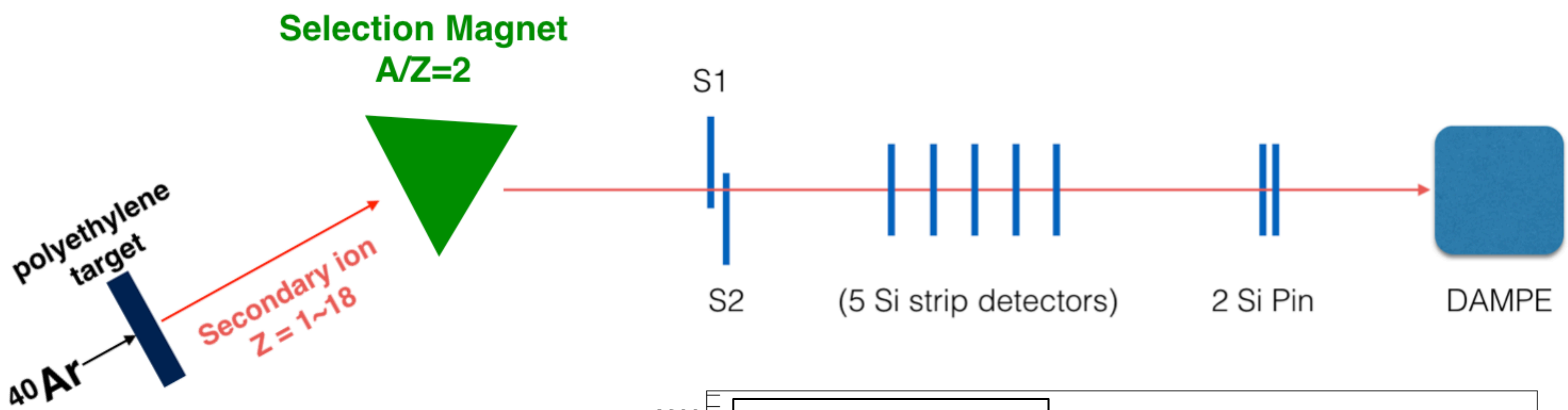
# Electron Response in the BGO Calorimeter (Beam Test)



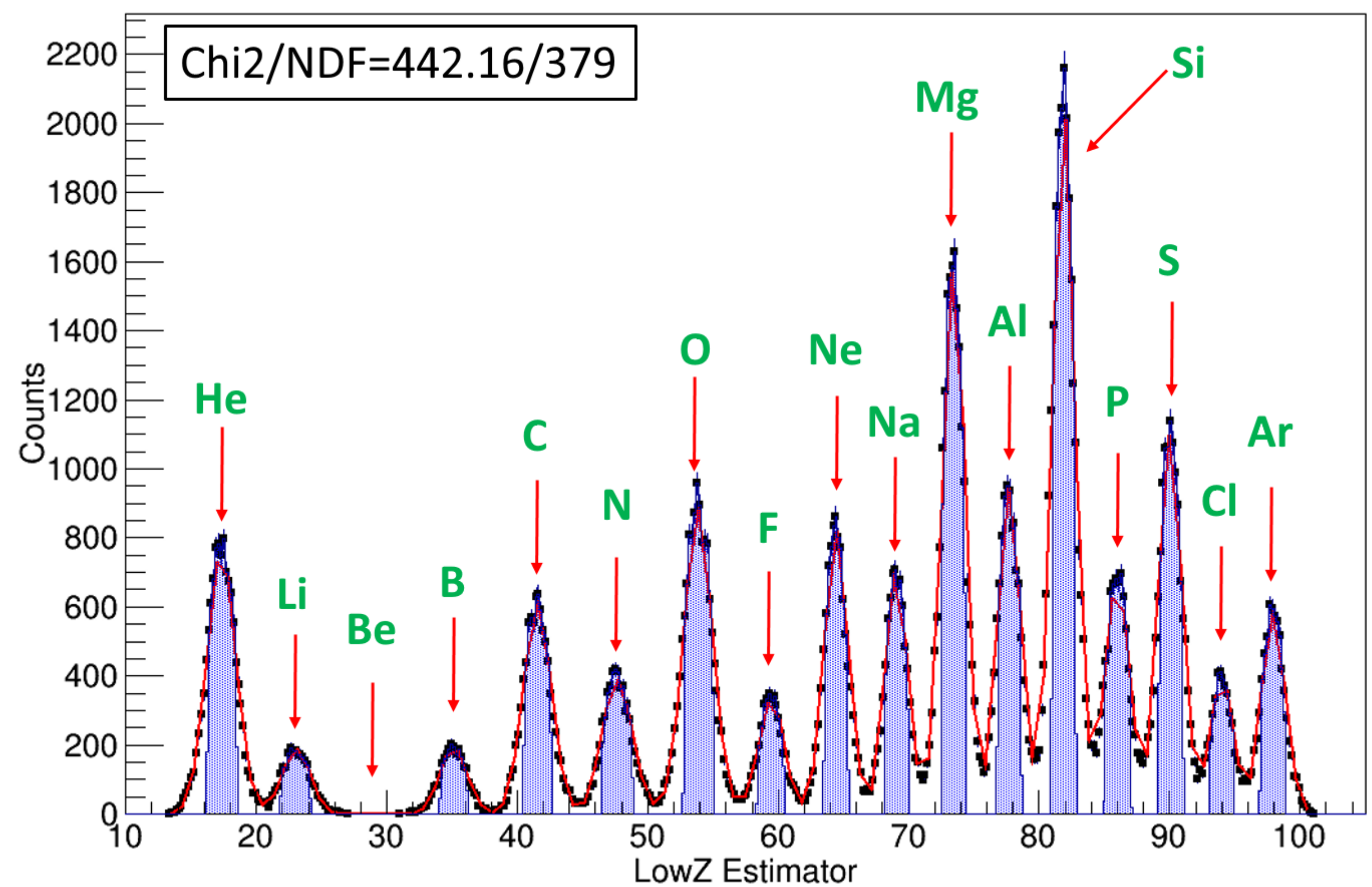

Jin Chang, et al., Astroparticle Physics, 95 (2017): 6-24.
Zhiyong Zhang, et al., NIM A, 836 (2016): 98-104.

# Ion Beam Test Set up & Charge Measurement




Momenta: 40 & 75 GeV/n

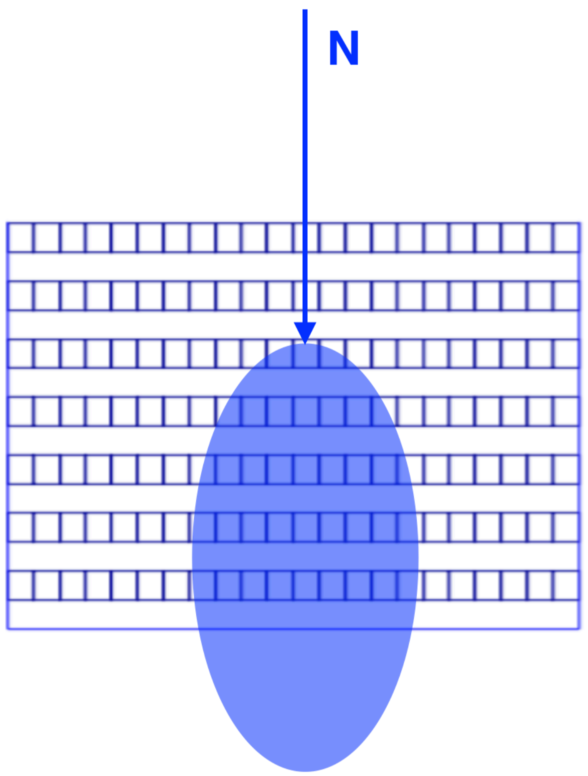
Charge identification with dE/dx detectors before the BGO Calorimeter

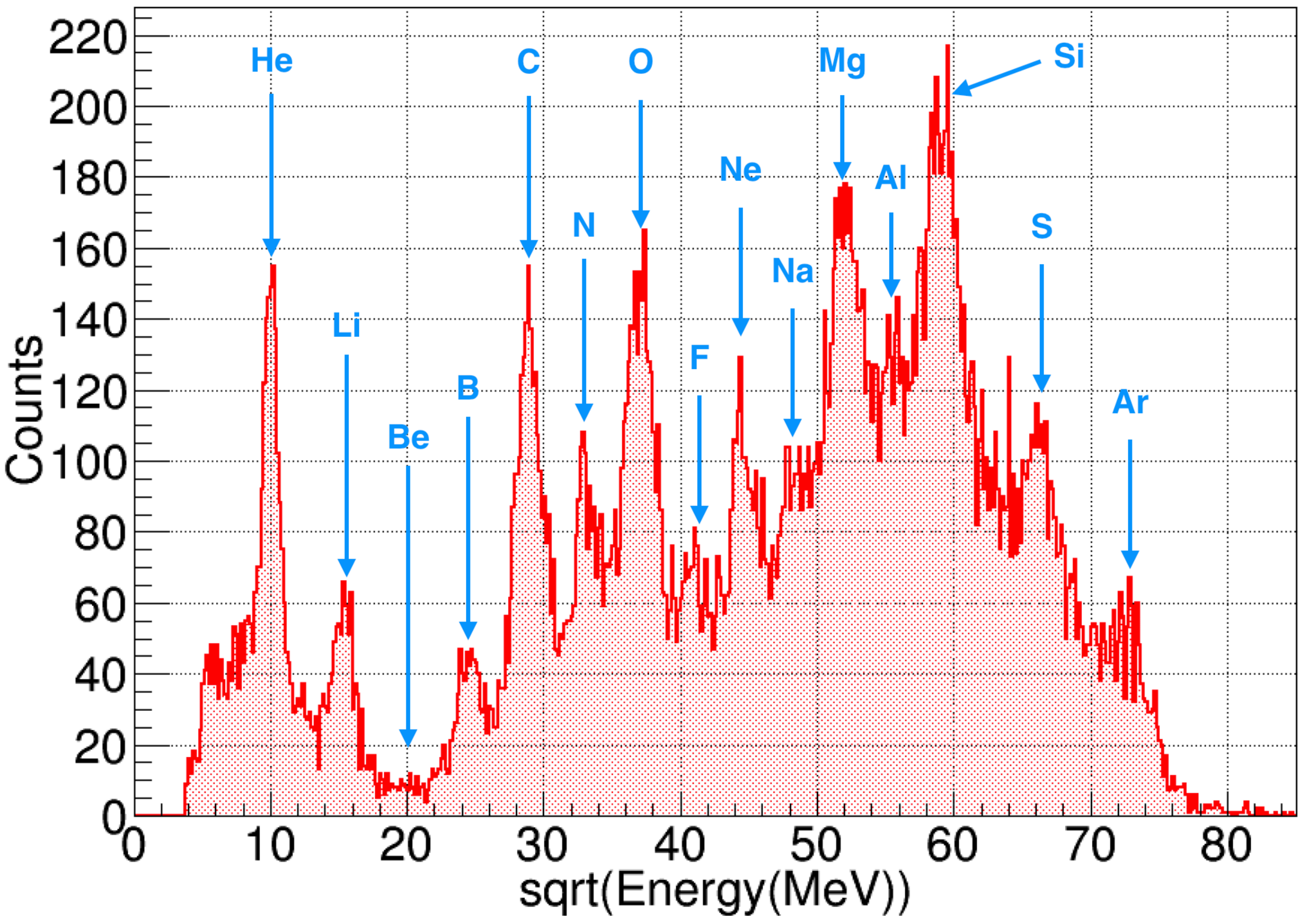



Charge Estimator

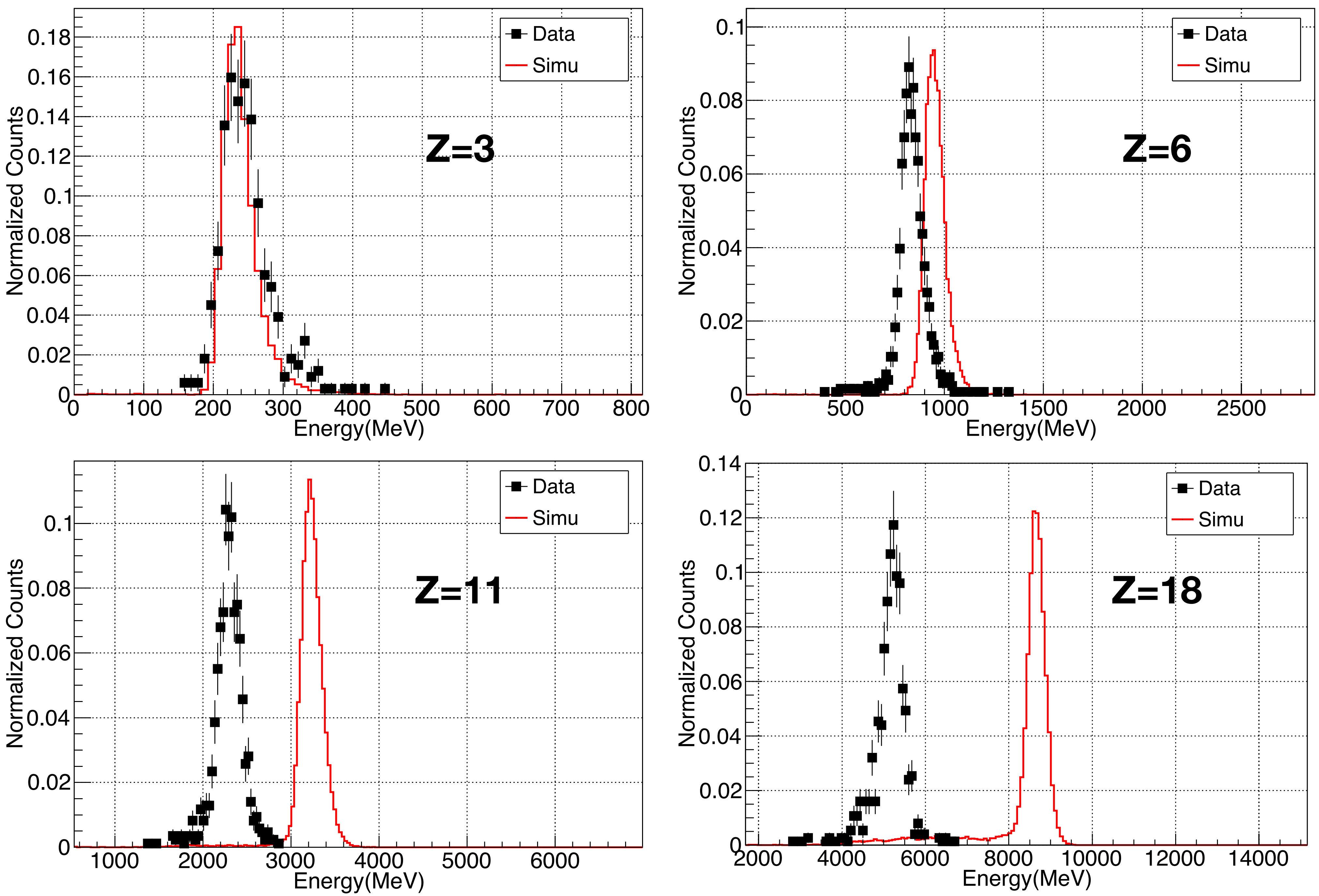
# Charge Identification with the BGO Calorimeter

MIP events in first layer of the BGO ECAL were utilized to identify charge

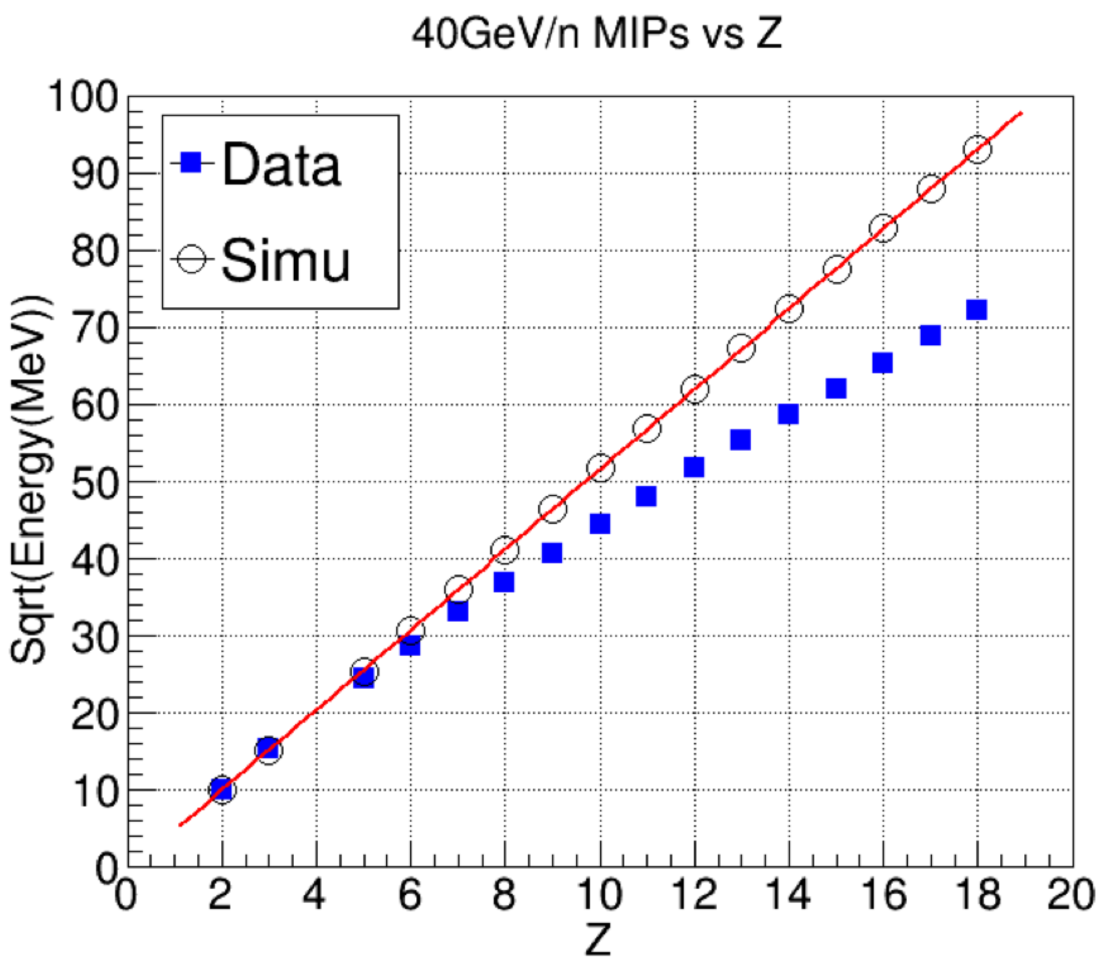


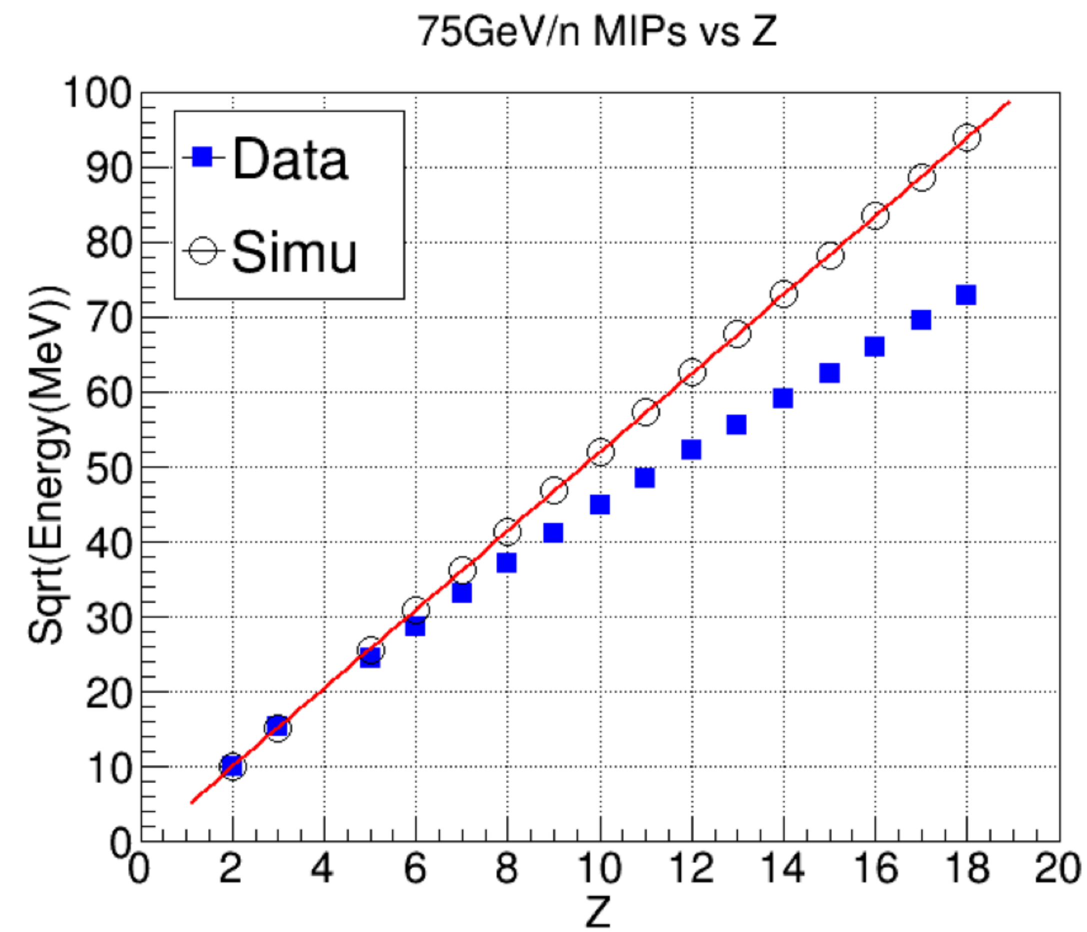



# Charge Identification with the BGO Calorimeter

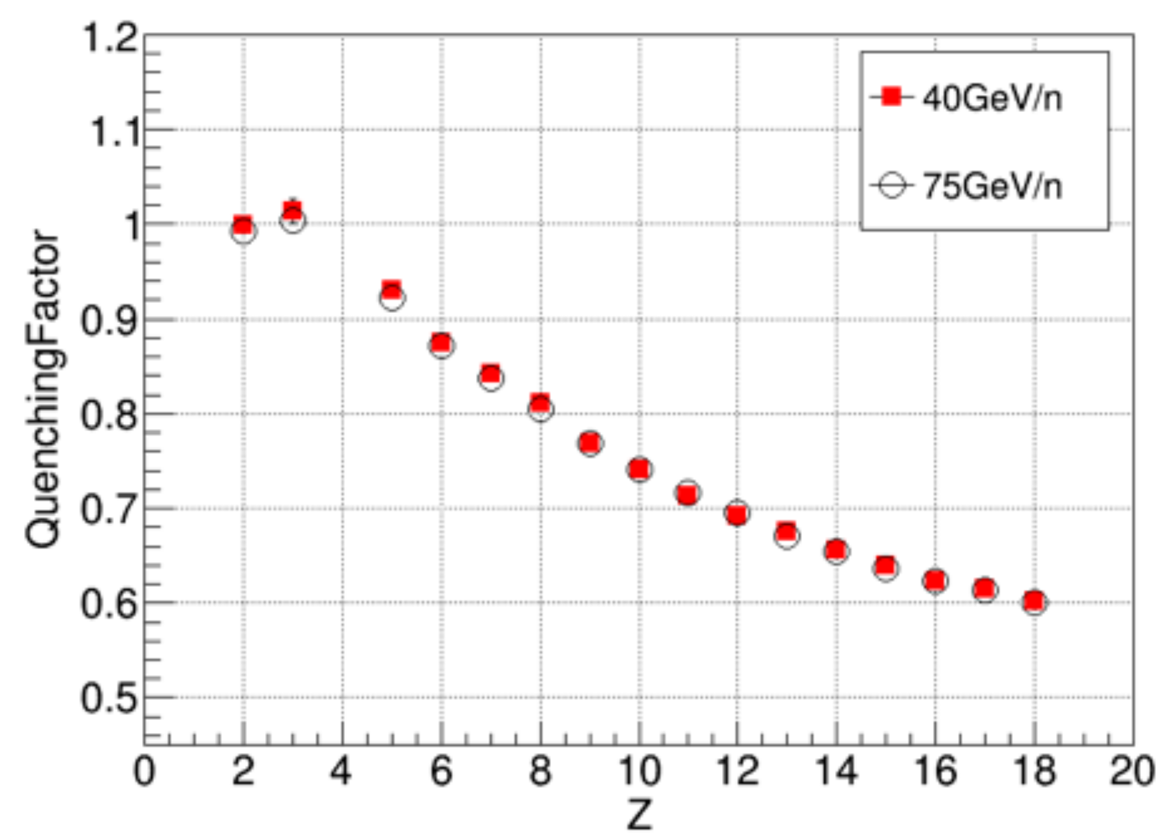


# Quenching Effect of the BGO Crystal



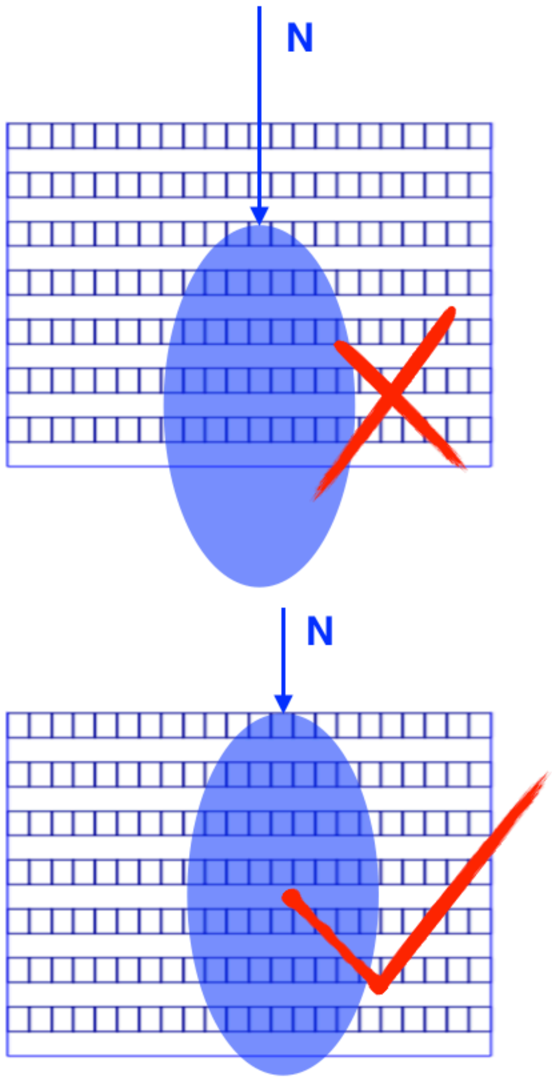



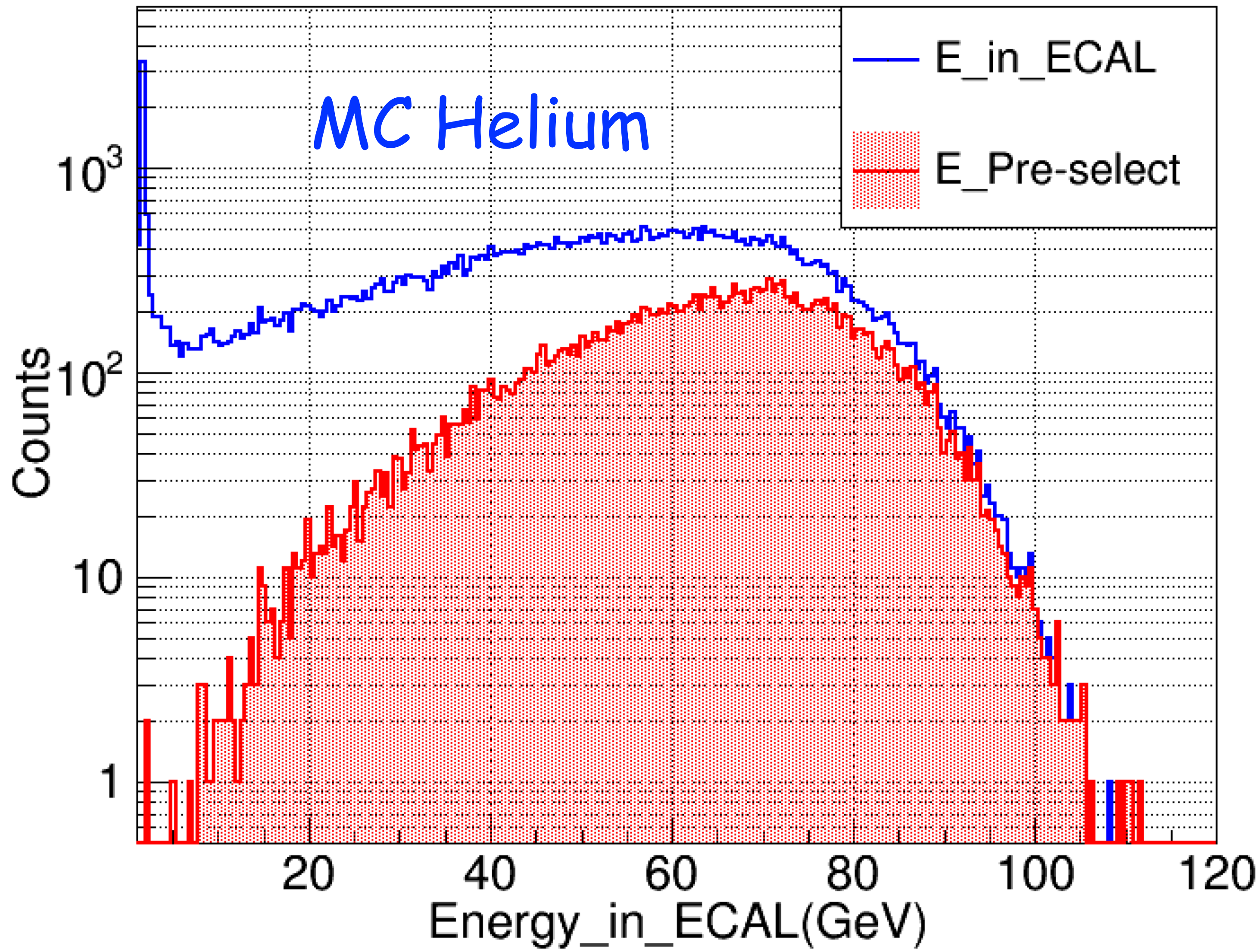

- Quenching effect was observed in the case of Z>5
- $QF = Peak_{Data}/Peak_{Simu}$



# Energy Response to Ions

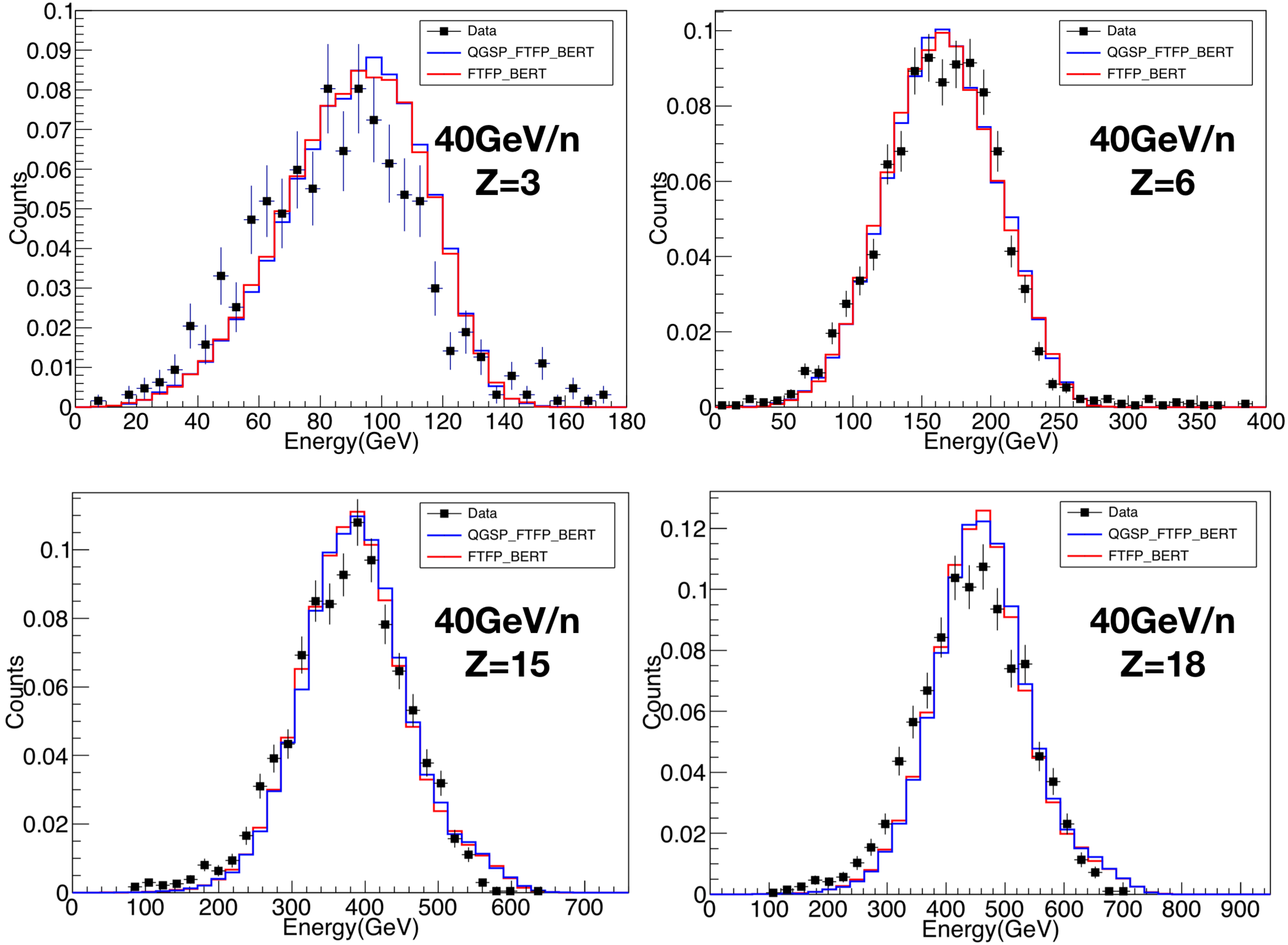
- A pre-selection is applied to ion data
  - Pass high energy trigger
  - Shower starts at the top of the BGO calorimeter



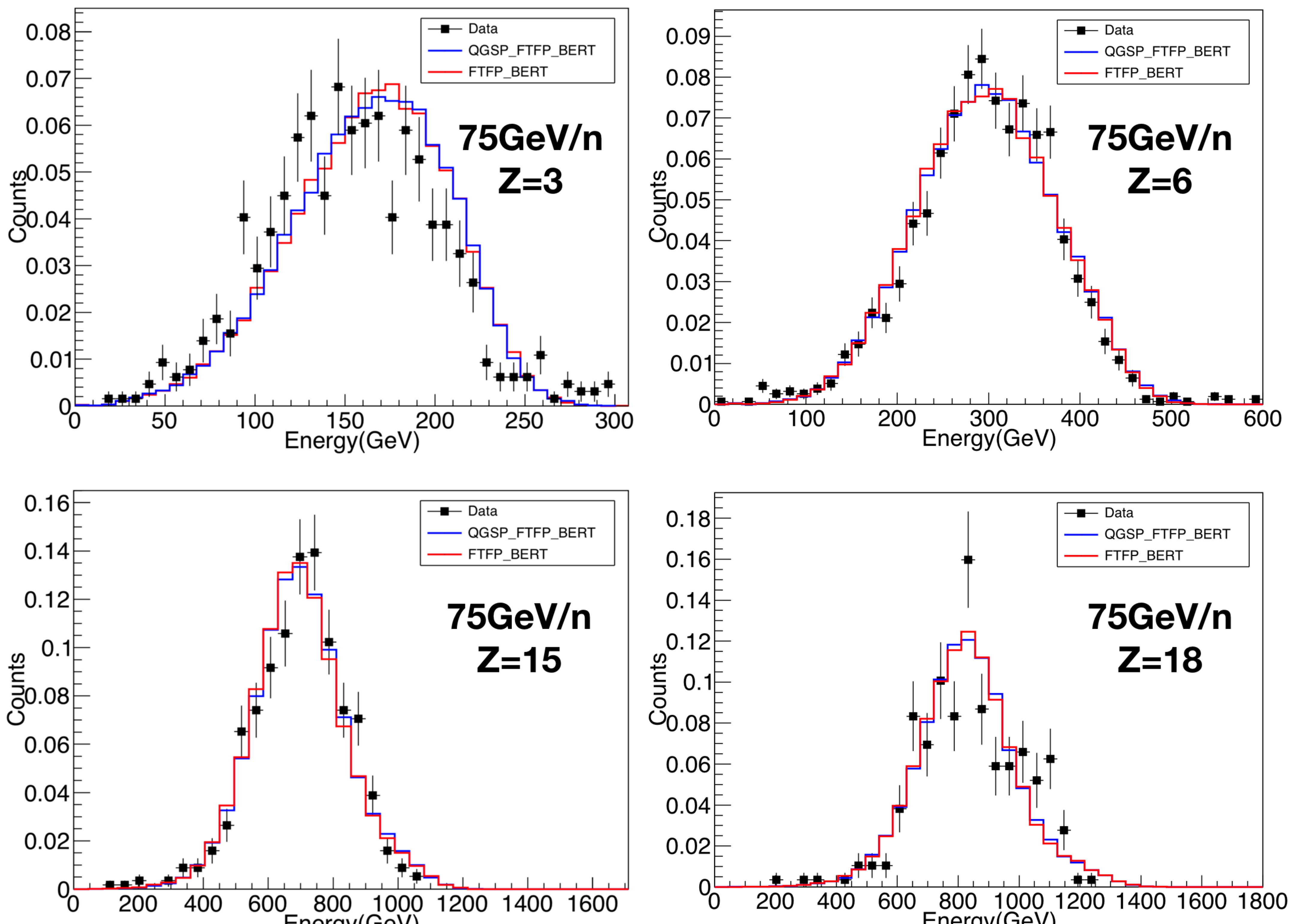



# Energy Response to Ions (40 GeV/n)

## MC: Geant4.10.1 QGSP_FTFP_BERT & FTFP_BERT



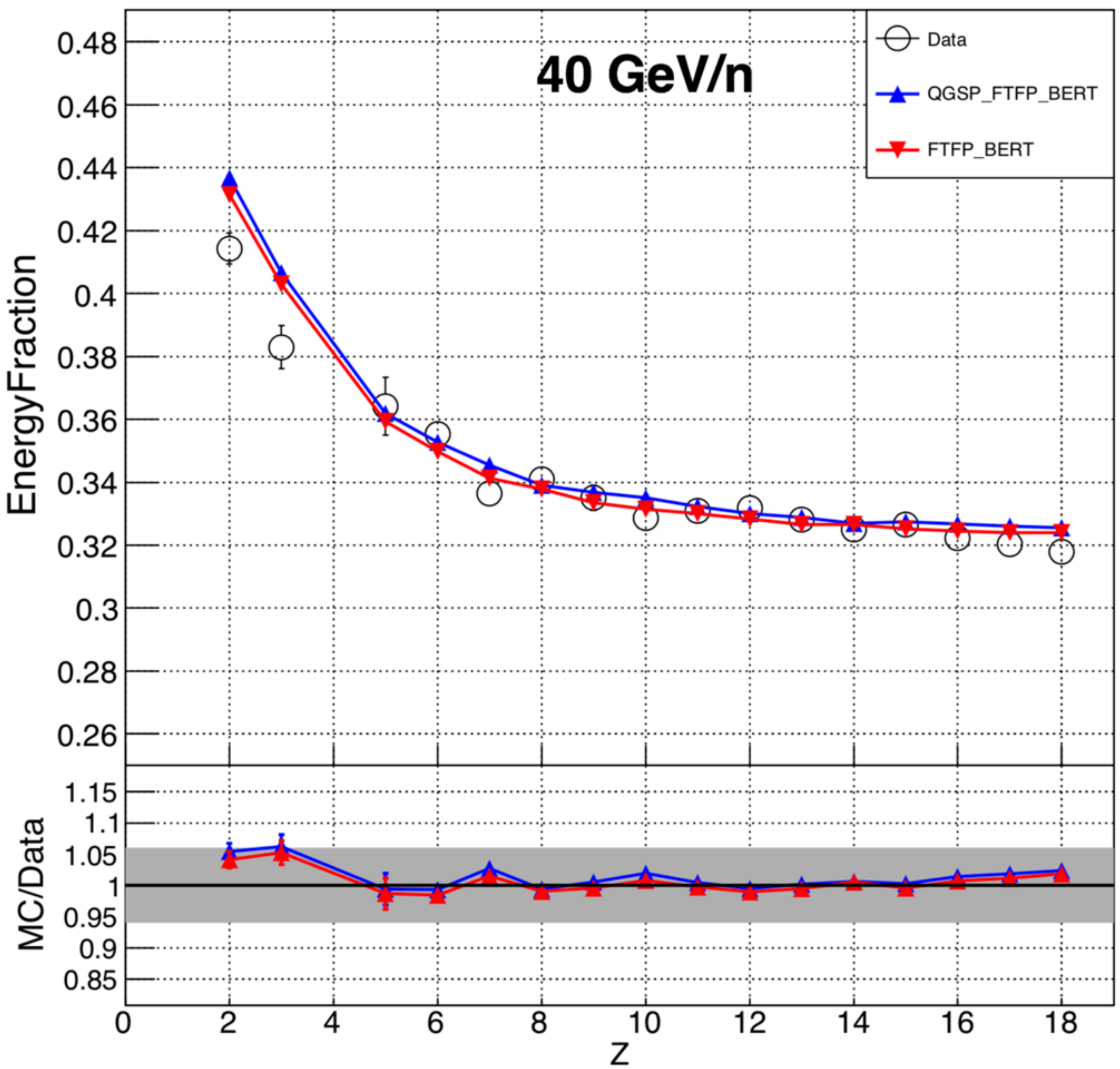
# Energy Response to Ions (75 GeV/n)

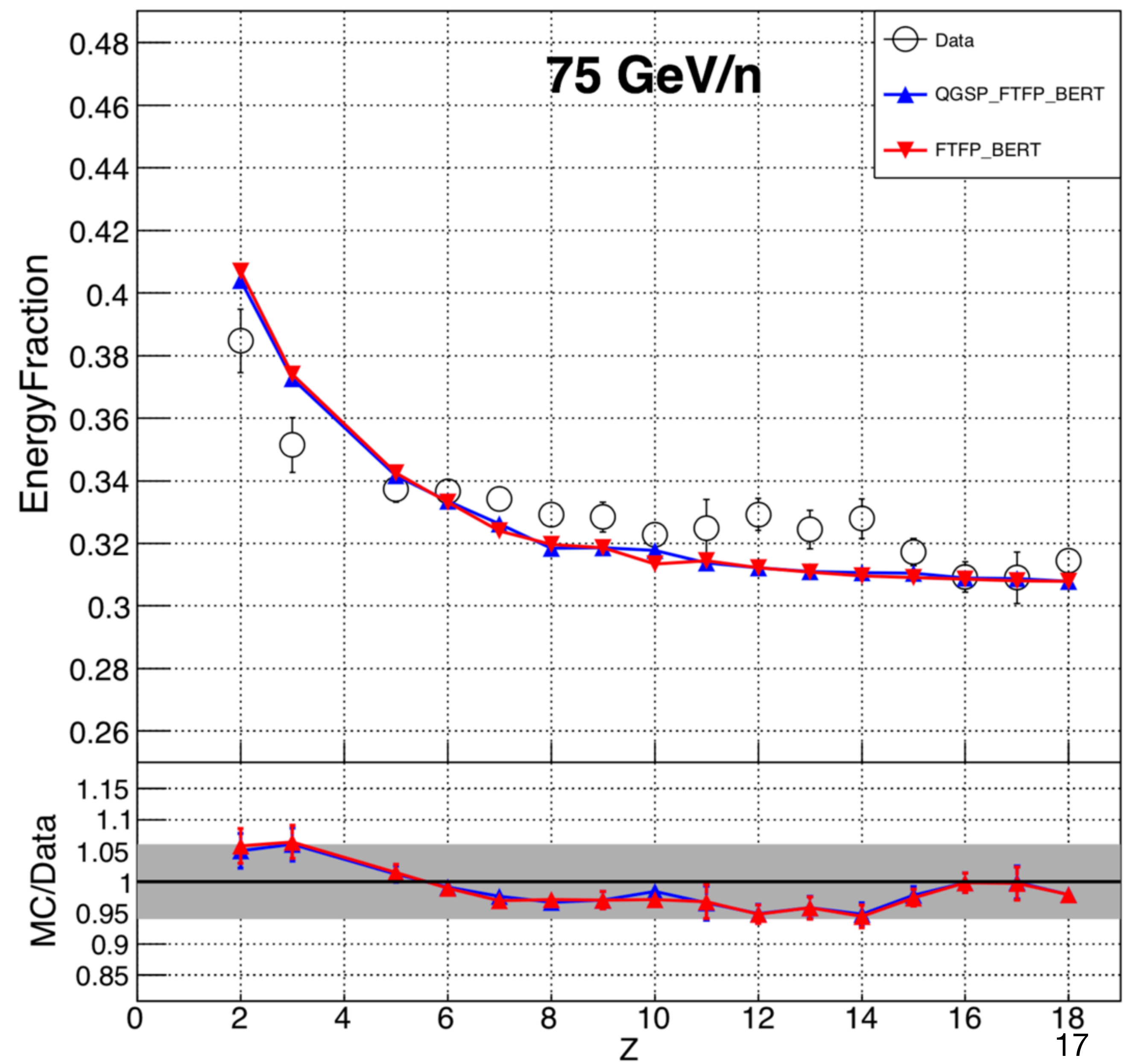


# Energy Fraction to Ions

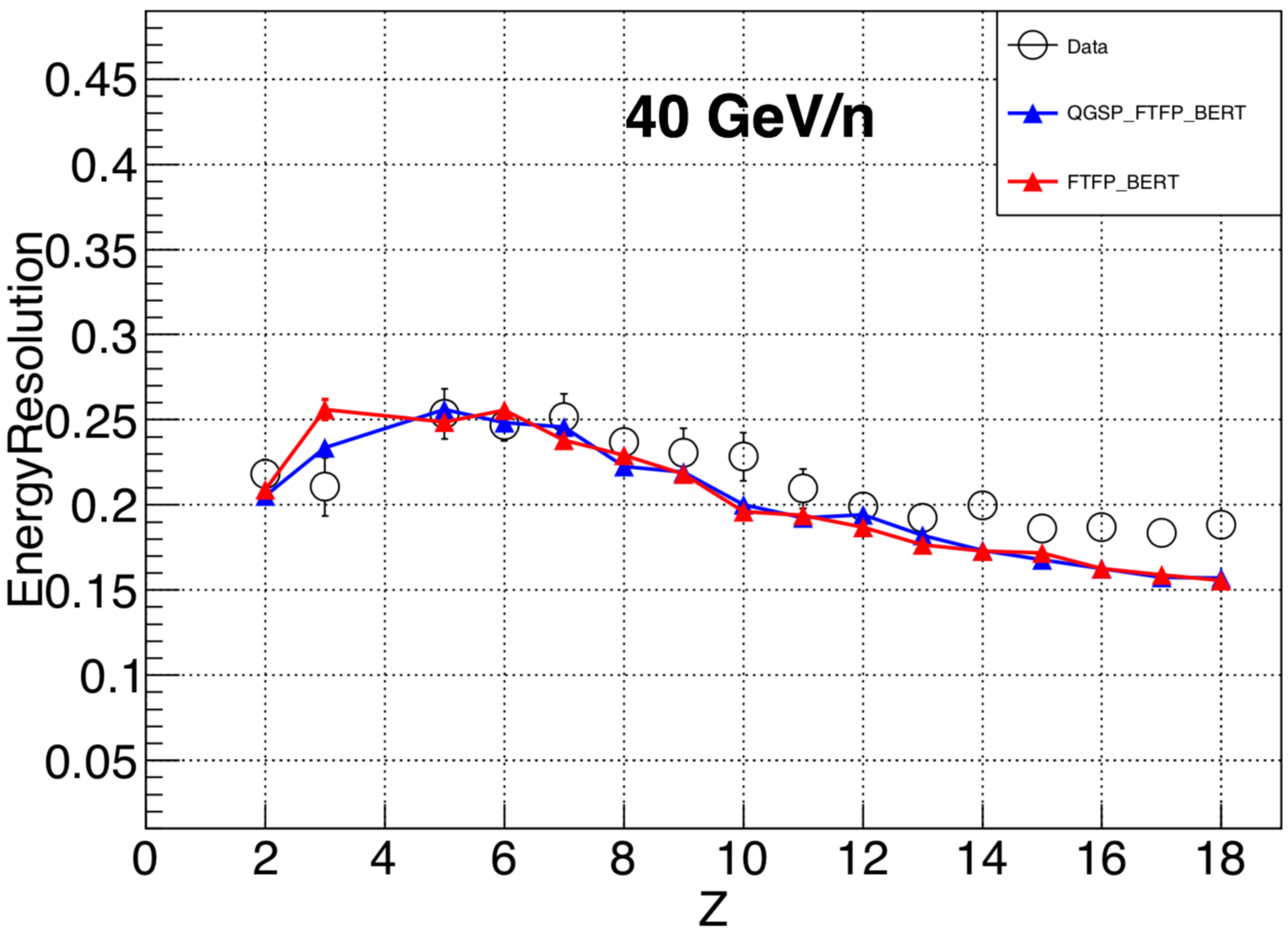
Energy Fraction = Energy Deposition/Incident Energy

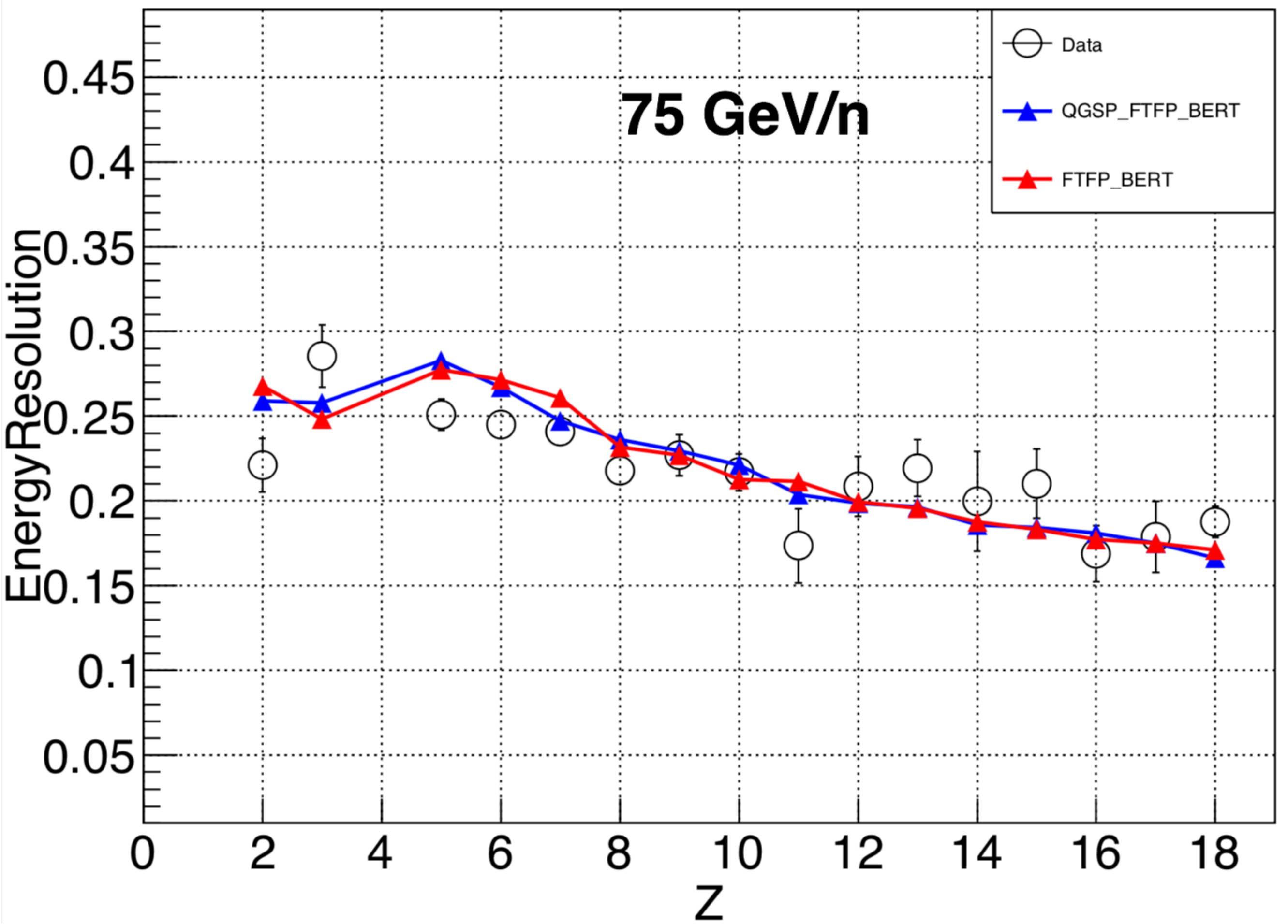
Within max difference ~ 6%



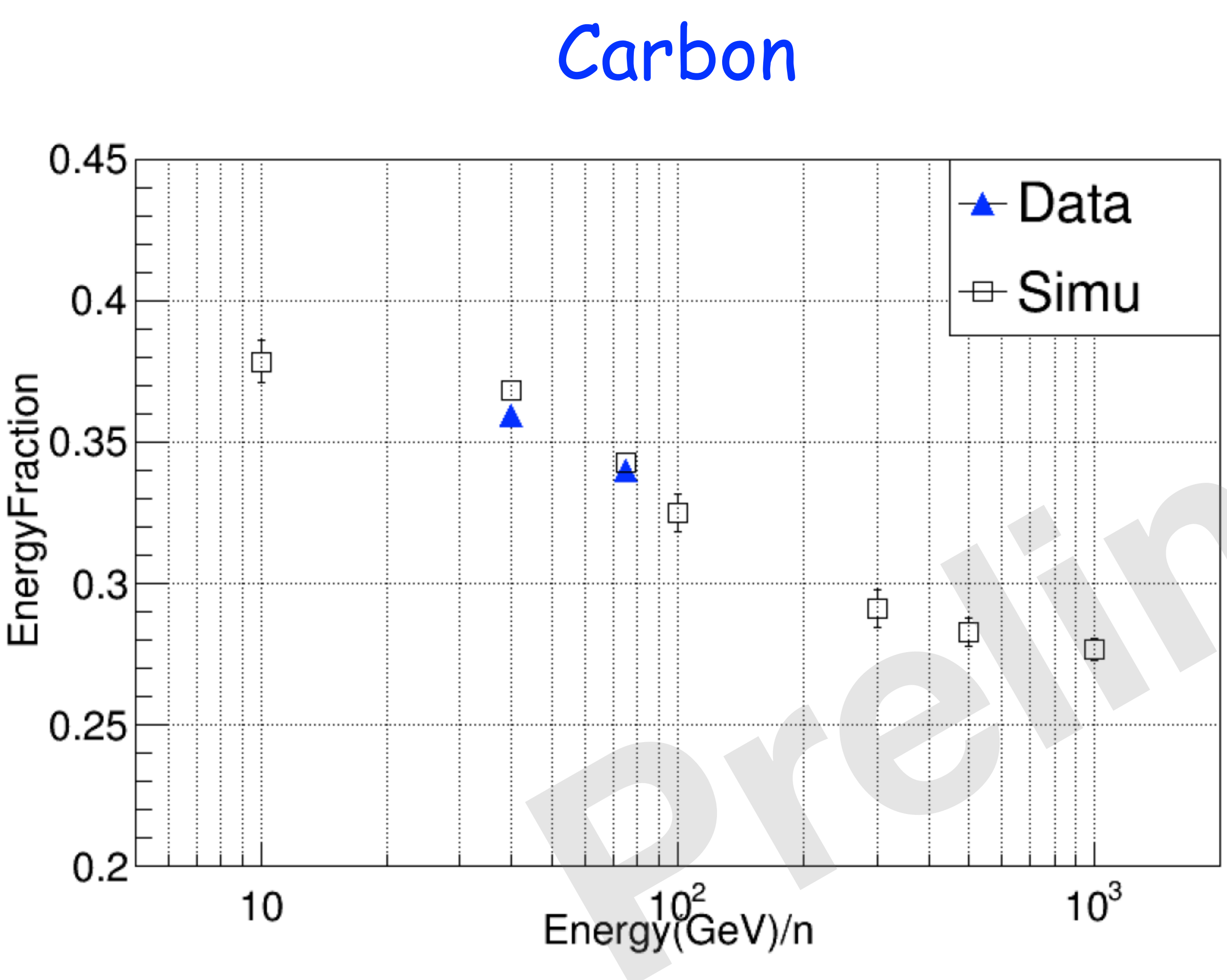



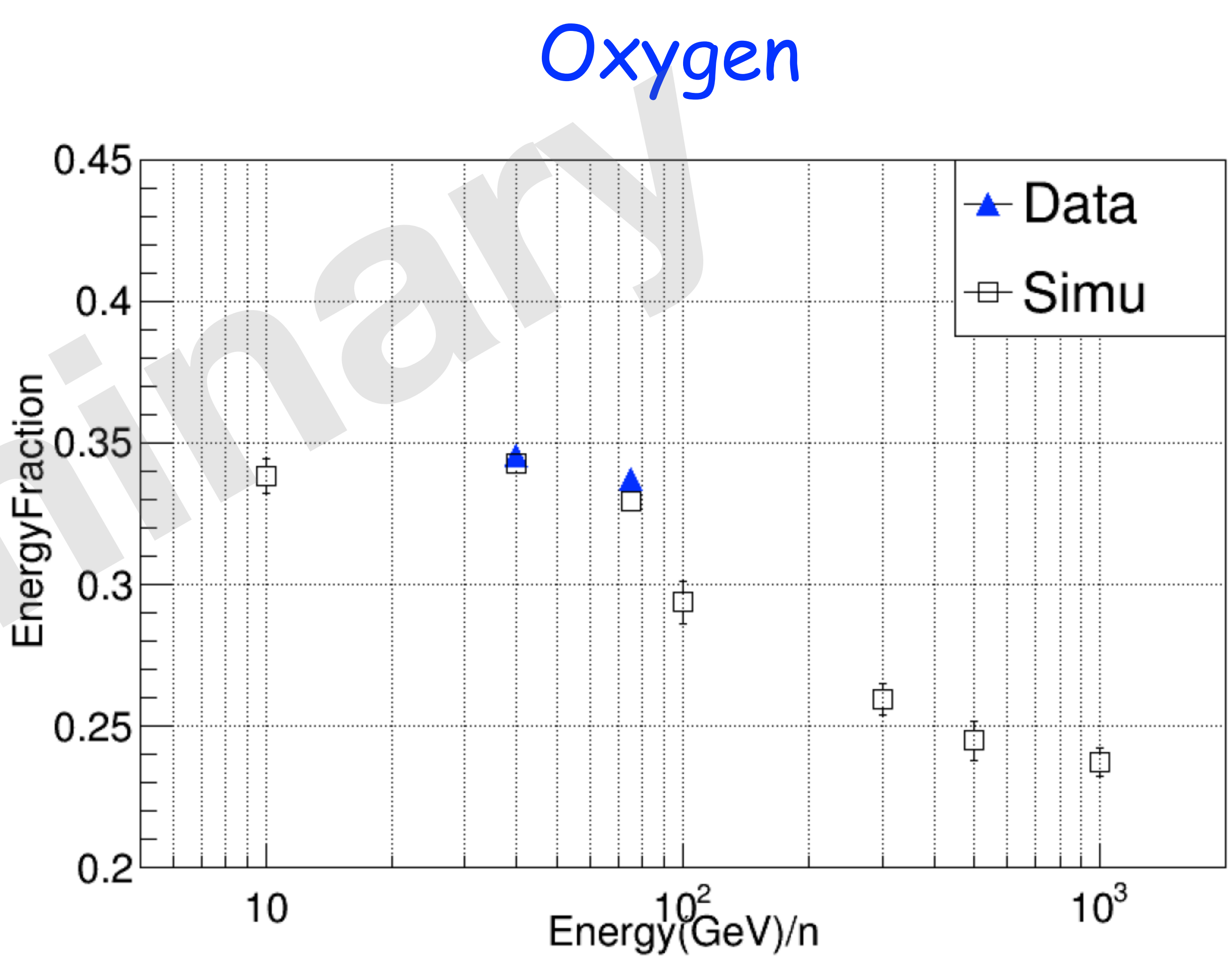
# Energy Resolution to Ions



# Energy Fraction vs Incident Energy



# Summary

- An ion beam test was performed for the DAMPE BGO ECAL
- Quenching effect of BGO crystal is observed in high energy ion beam
- More than 30% energy deposited in the BGO ECAL for each kind of ion
- The max difference for energy fractions between MC and data is about ~ 6%
- Energy resolution is better than 30%

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- The max difference for energy fractions between MC and data is about ~ 6%
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Thank you!

# Backup

# Different MC Model (40 GeV/n)