



Calorimetry for the
High Energy Frontier

Lyon, France
2 - 6 October 2017

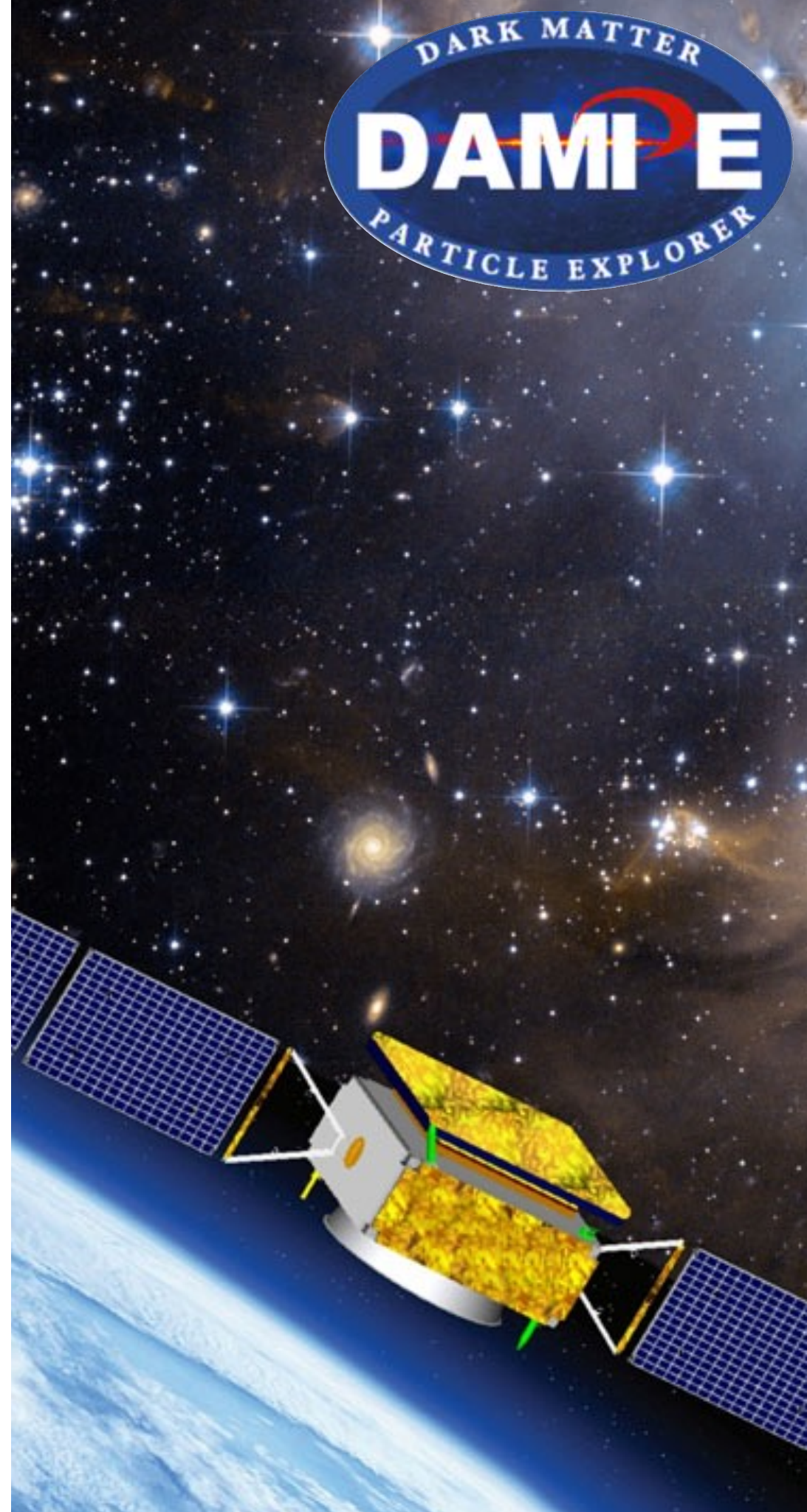


Response of the DAMPE BGO Calorimeter to Nuclide

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(On behalf of the DAMPE
collaboration)

State Key Laboratory of Particle Detection
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University of Science and Technology of China
02/10/2017



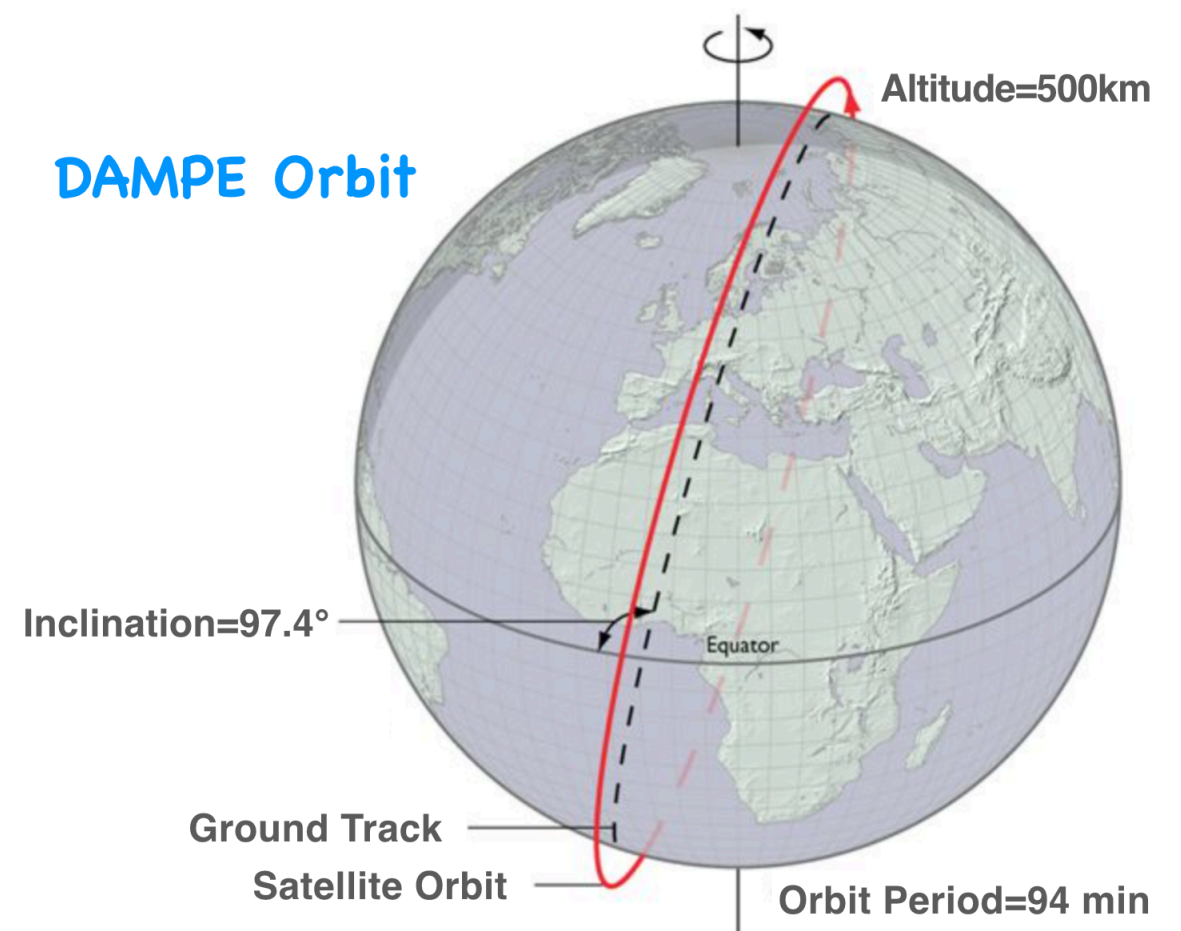
Outline

- DAMPE experiment
- BGO calorimeter
- Beam test of BGO calorimeter
- Orbit performance
- Summary

DAMPE Mission

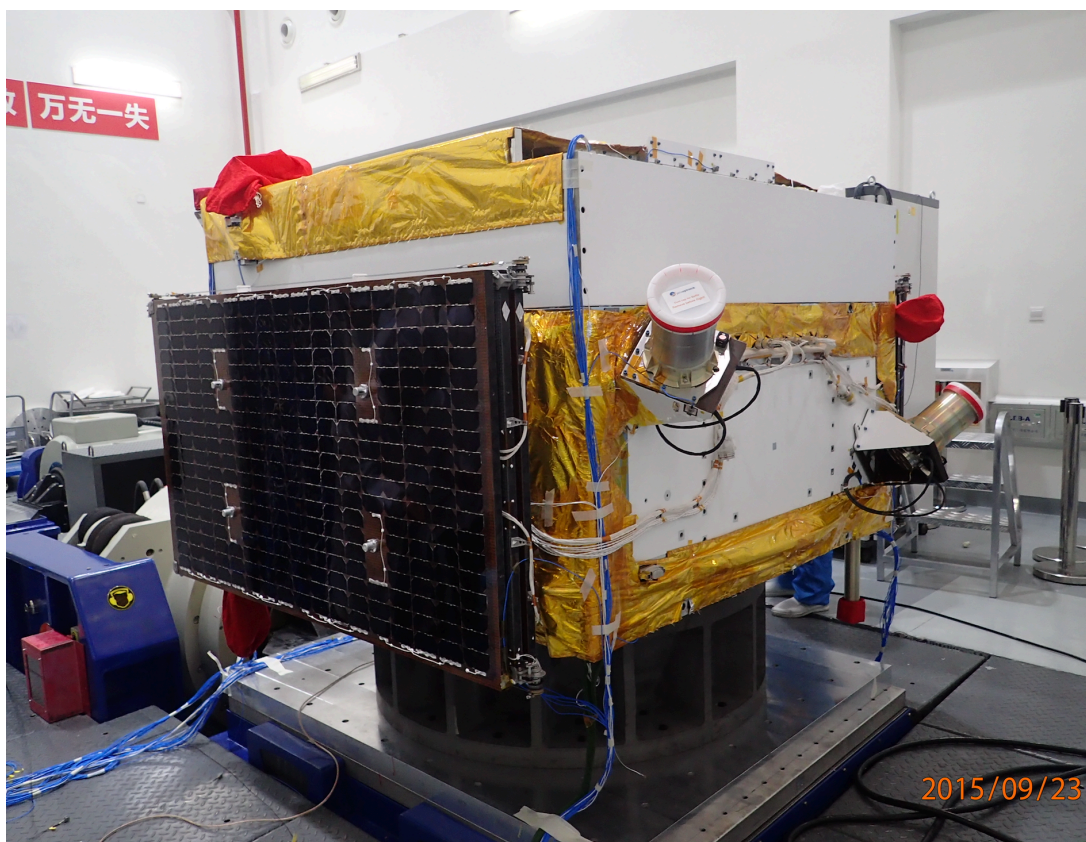
- **D**Ark **M**atter **P**article **E**xplorer (DAMPE) is an orbit experiment for detecting high energy cosmic ray
- Launch: 17th Dec. 2015, CZ-2D rocket
- Life time > 3 years

- 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) (2)gamma ray spectrum and space distribution of SNR
Gamma ray astronomy	(1)gamma ray sources (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



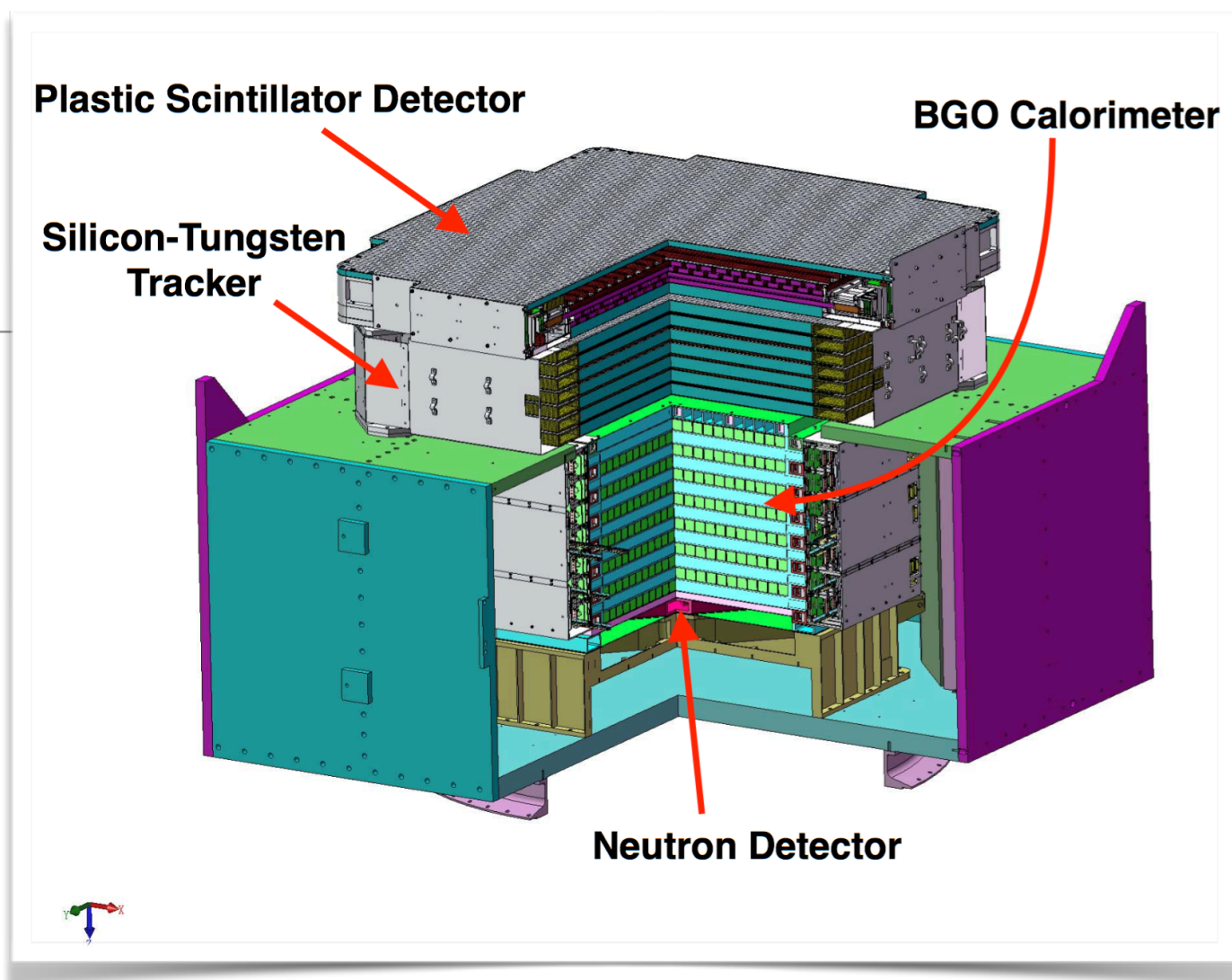
SWITZERLAND

- University of Geneva



DAMPE Detector

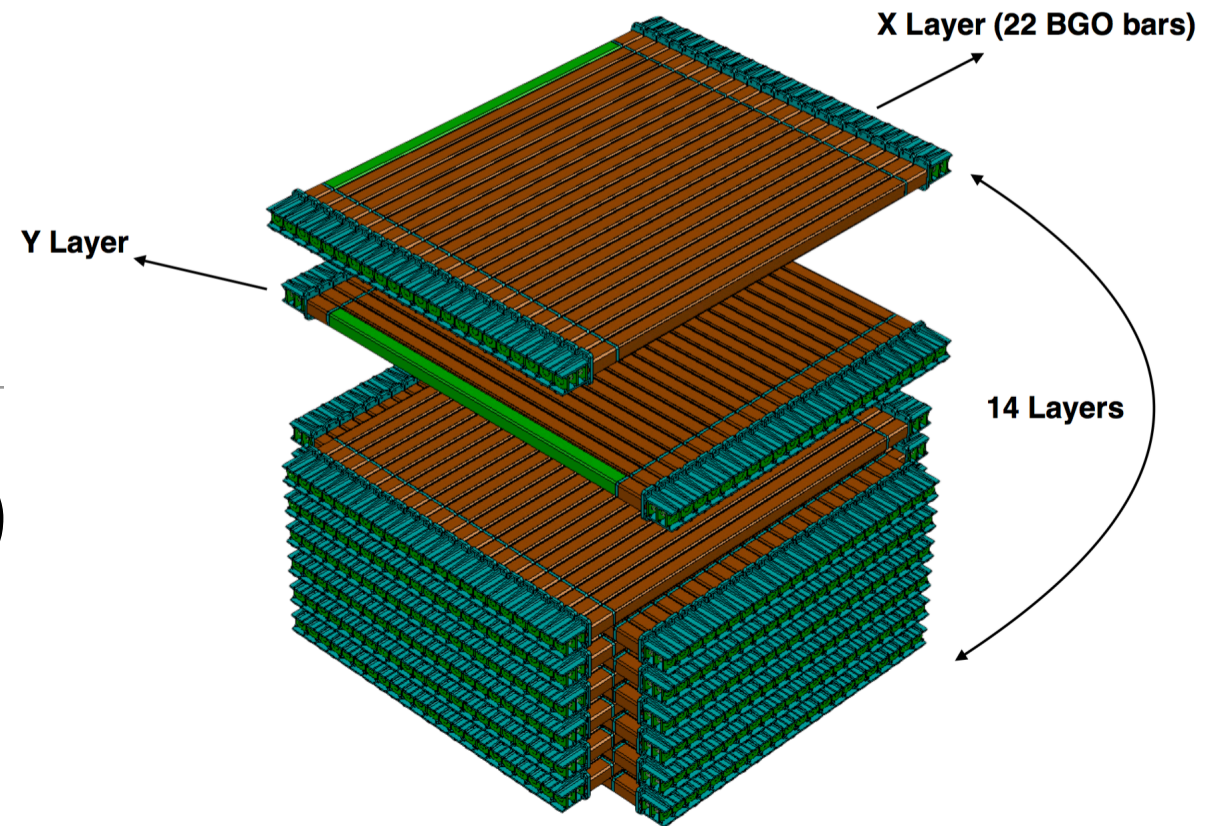
- Charge measurement (dE/dx in PSD, STK)
- Precise tracking (STK + BGO)
- Precise energy measurement (BGO)
- Particle identification (BGO + NUD)



	DAMPE	Fermi	AMS02	CALET
Calorimeter thickness (X0)	32	8.6	17	28
Energy resolution	1.5%@800 GeV	>8.5%@100 GeV	2%@100 GeV	2%@100 GeV
Angle resolution	0.1°@100 GeV	0.1°	0.1°	
Acceptance (m ² Sr)	>0.3	>2	0.055	0.12
e/p discrimination	10 ⁵	10 ⁴ ~10 ⁵	10 ⁵	10 ⁵ ₅

BGO Calorimeter

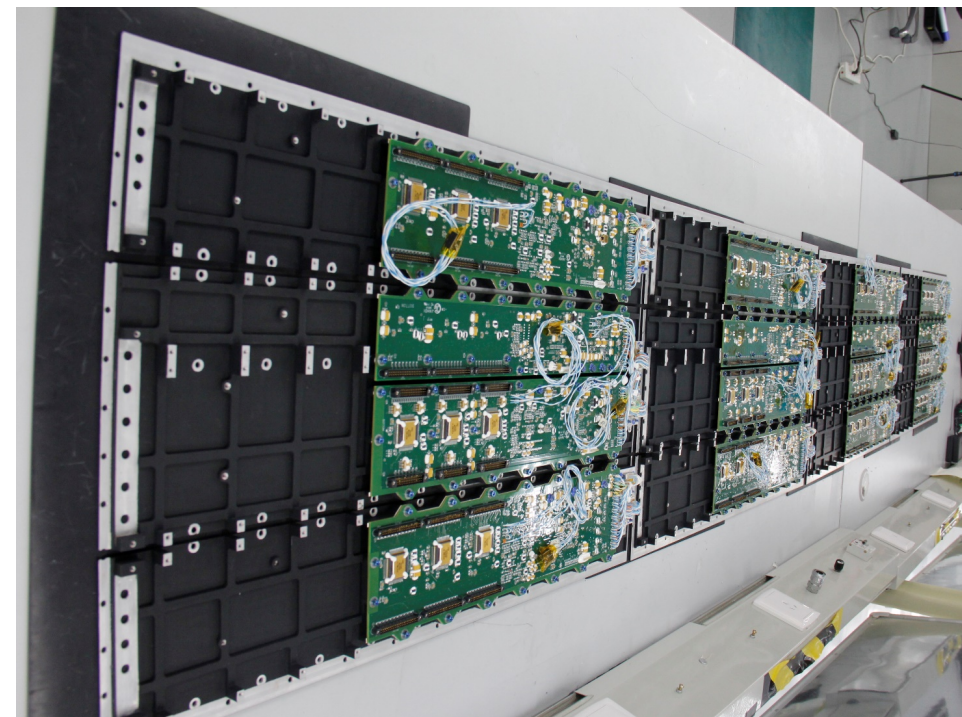
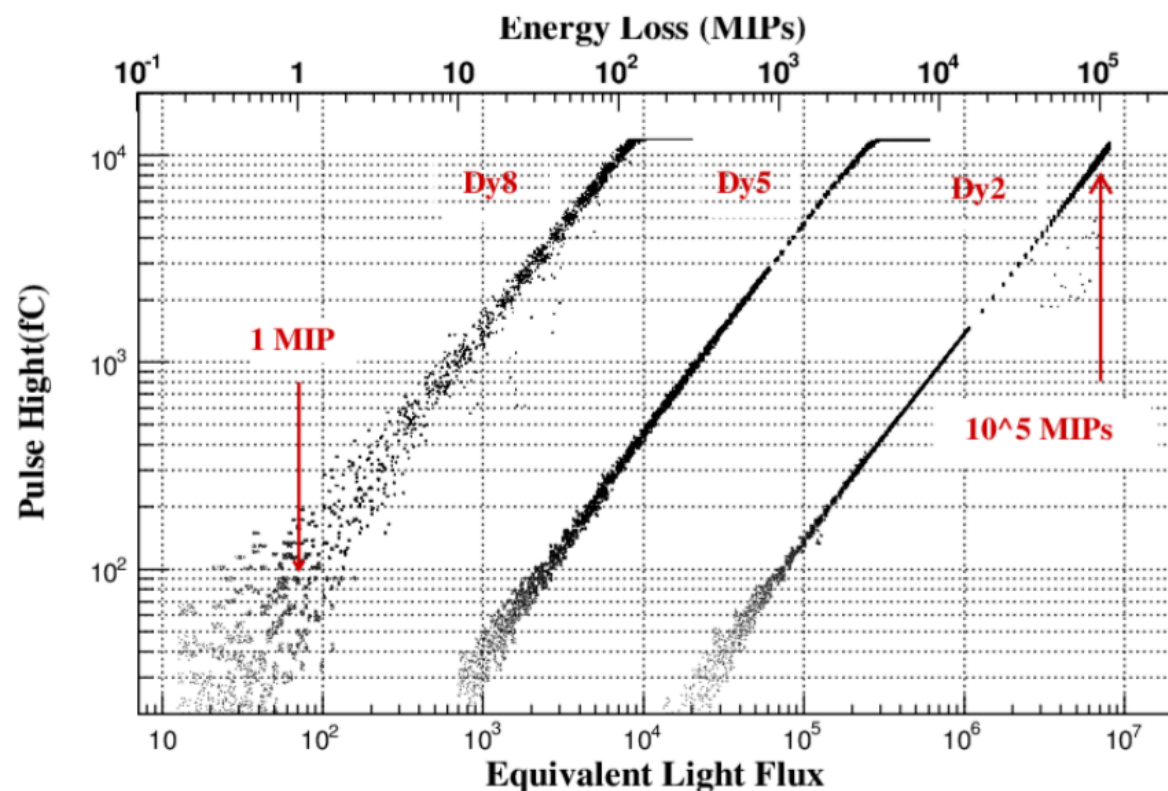
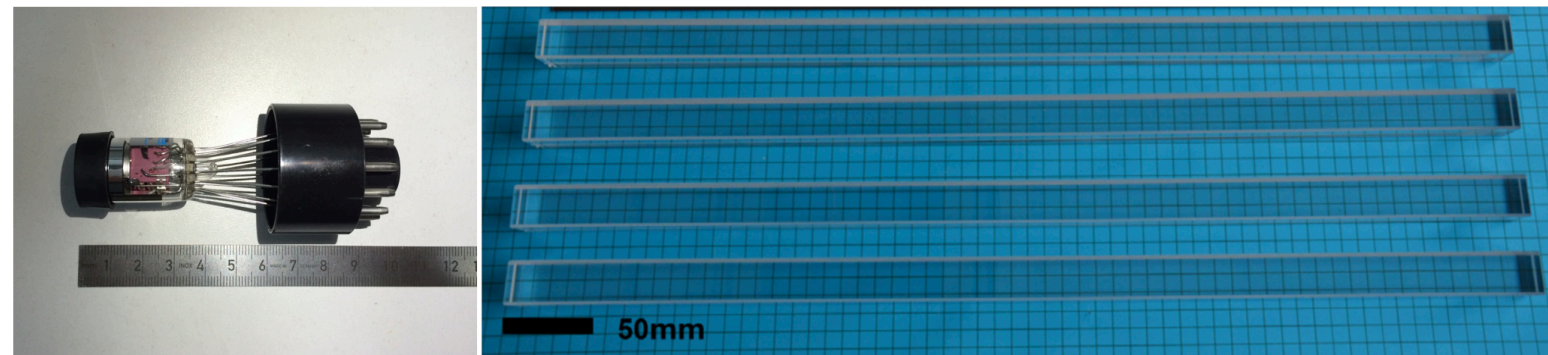
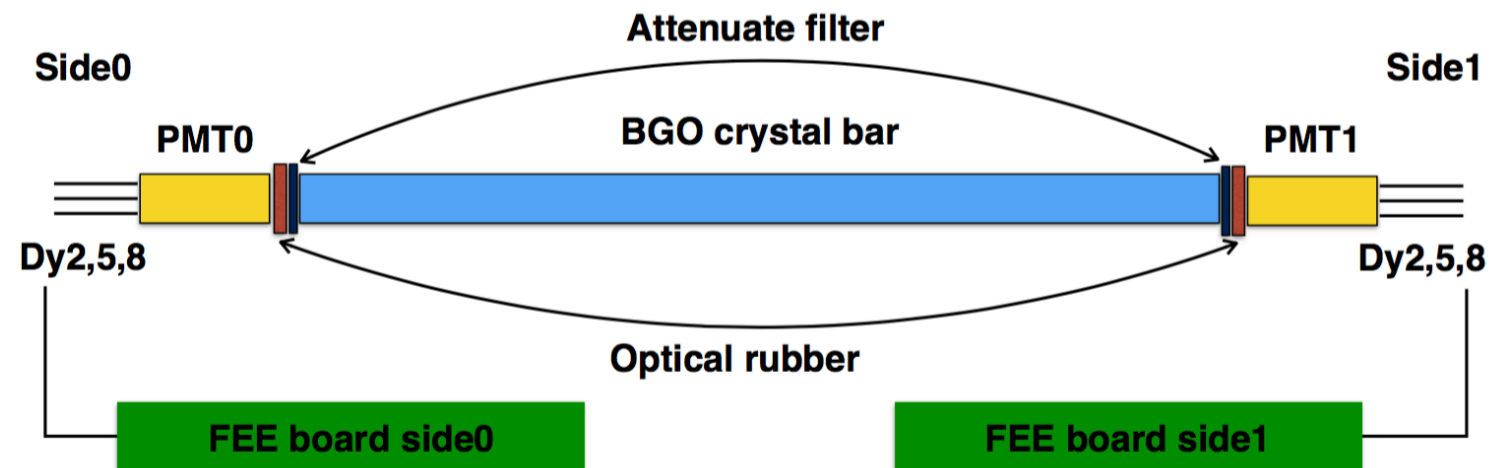
- 308 BGO bars ($25 \times 25 \times 600 \text{ mm}^3$)
- 14 layers, 22 bars per layer
- 32 radiation lengths
- 1.6 nuclear interaction lengths
- Energy range: $5\text{GeV}-10\text{TeV}(e/\gamma)$
- Energy resolution: $1.5\% @ 800\text{GeV}(e/\gamma)$
- Energy range of proton/nuclide: $50\text{GeV}-100\text{TeV}$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



- ♦ Provide trigger
- ♦ Energy measurement
- ♦ e/p separation
- ♦ Track seed

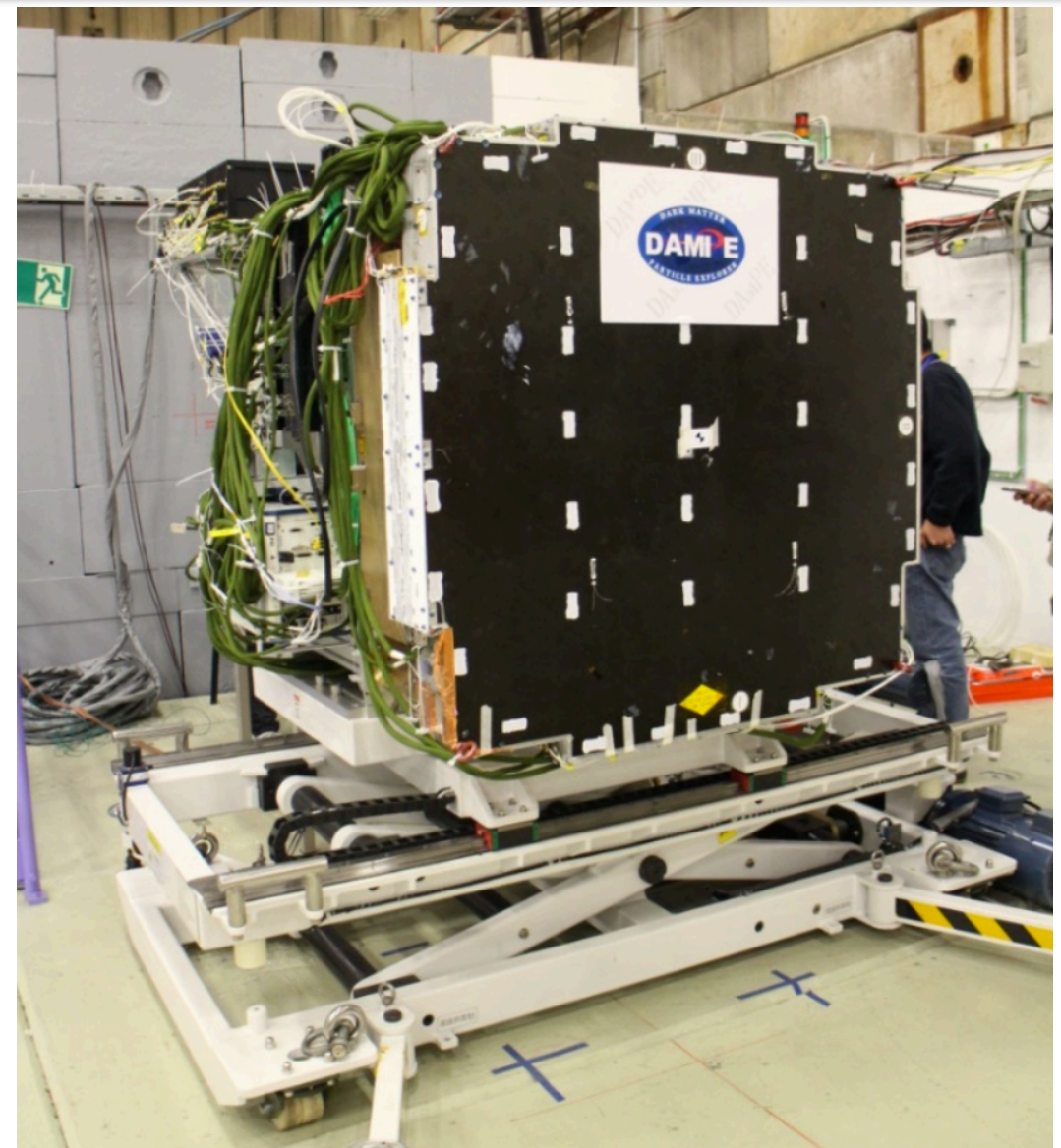
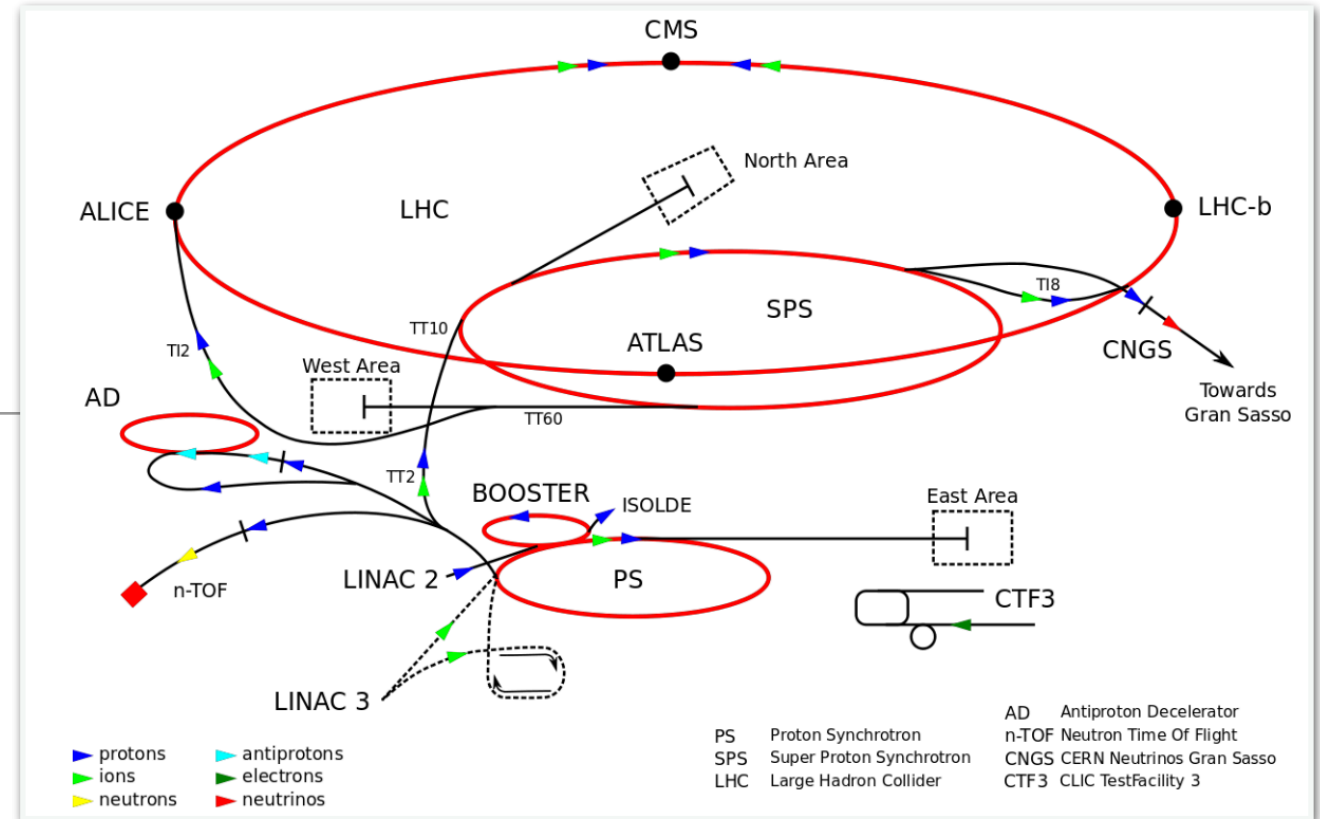
Detection Unit of the BGO ECAL

- 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

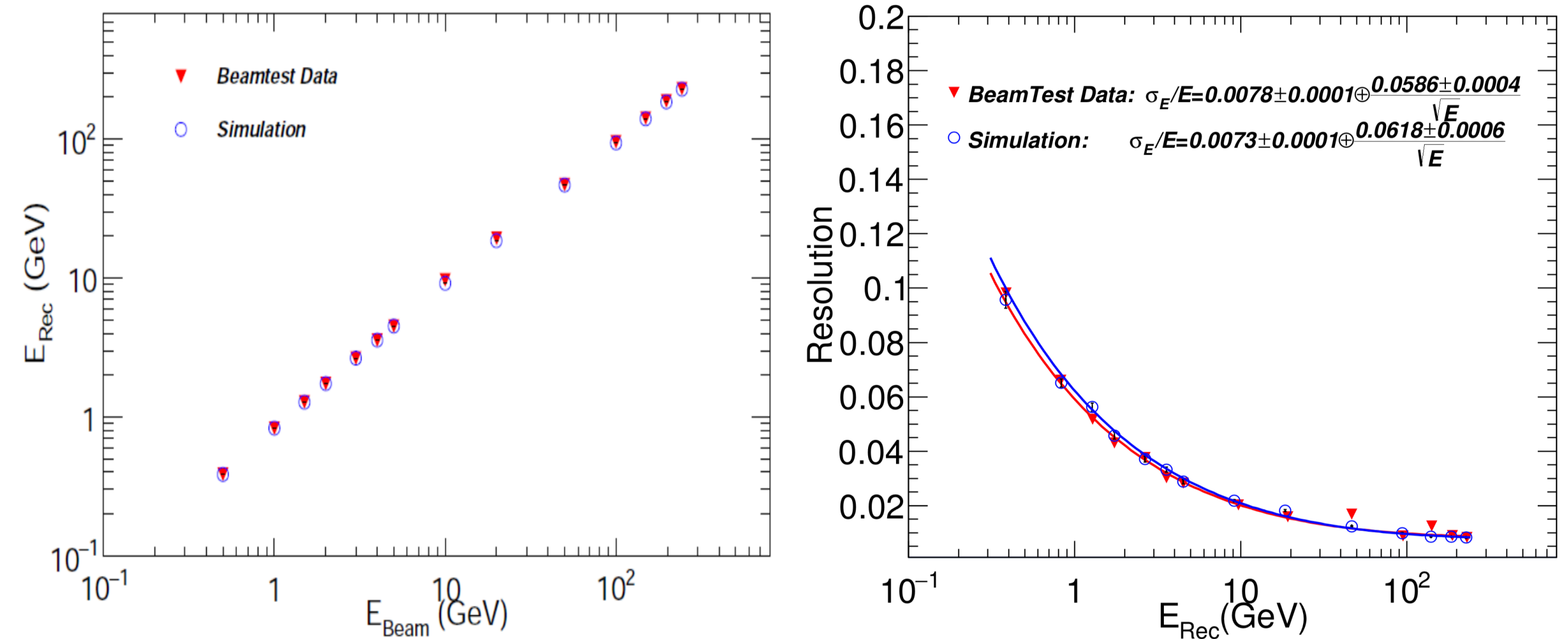


Beam Test @ CERN

- 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



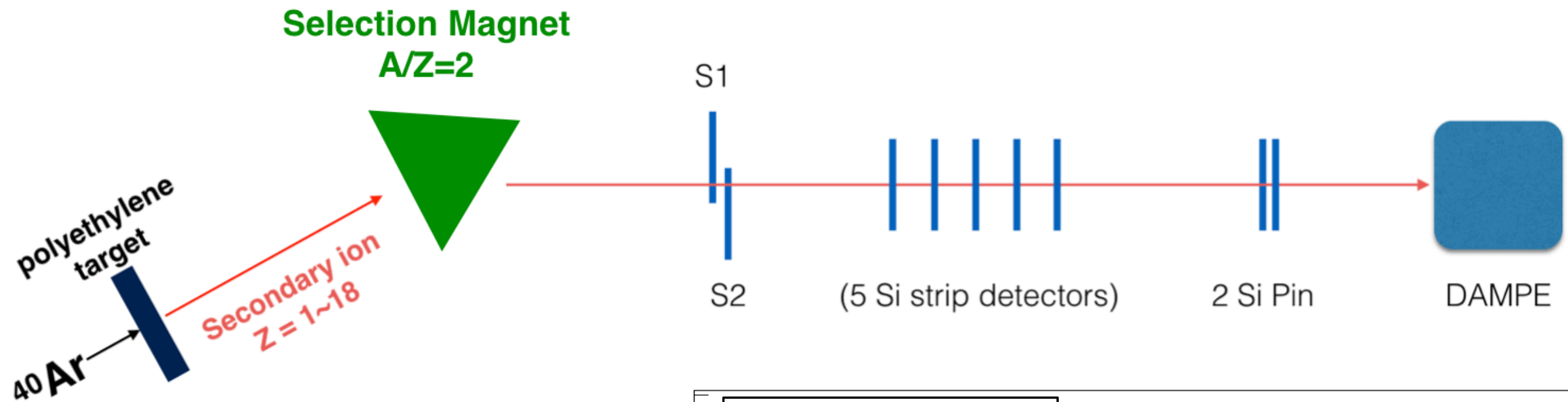
Electron Response in the BGO Calorimeter (Beam Test)



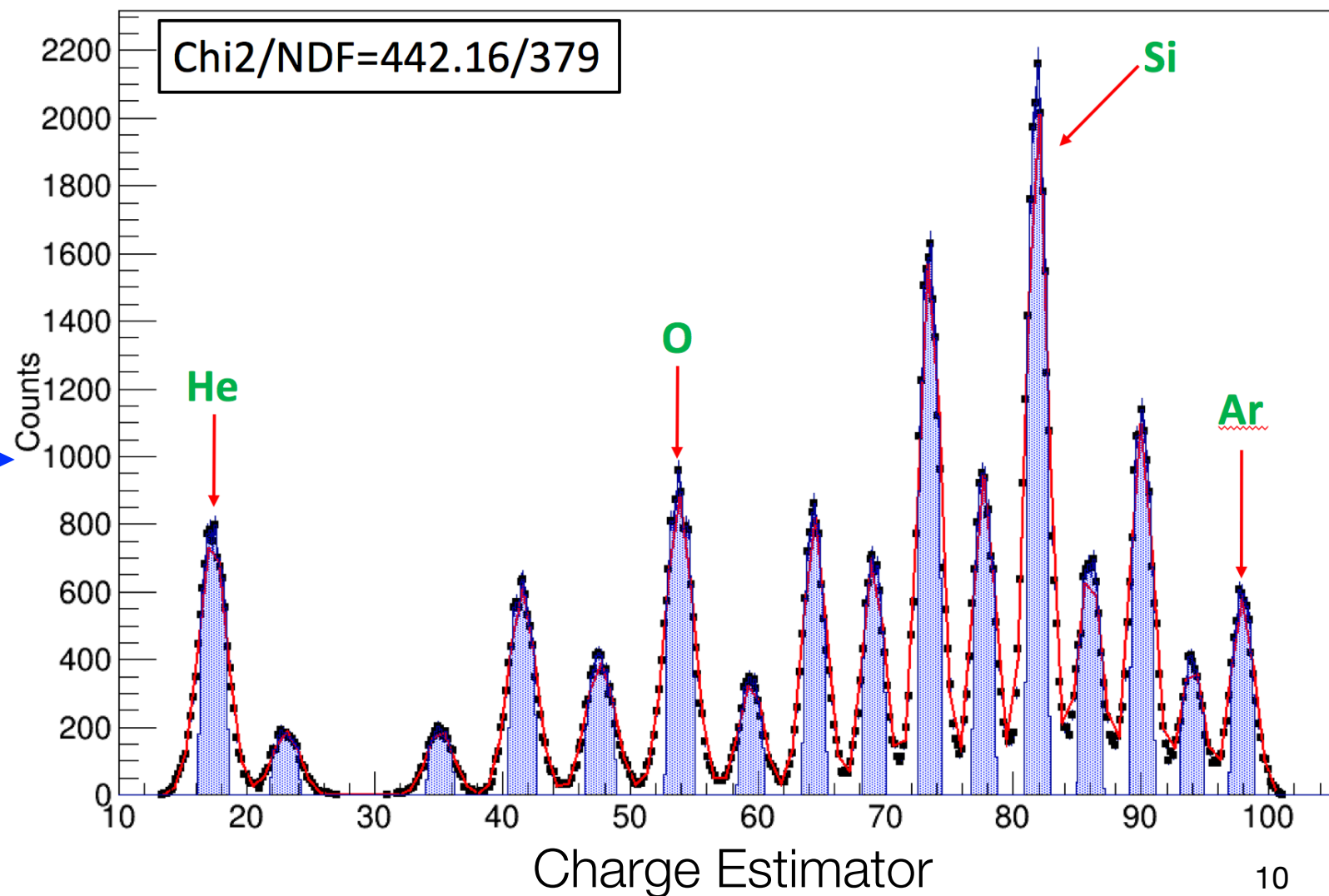
Jin Chang, et al., *Astroparticle Physics*, 95 (2017): 6-24.

Zhiyong Zhang, et al., *NIM A*, 836 (2016): 98-104.

Ion Beam Test Set up & Charge Measurement

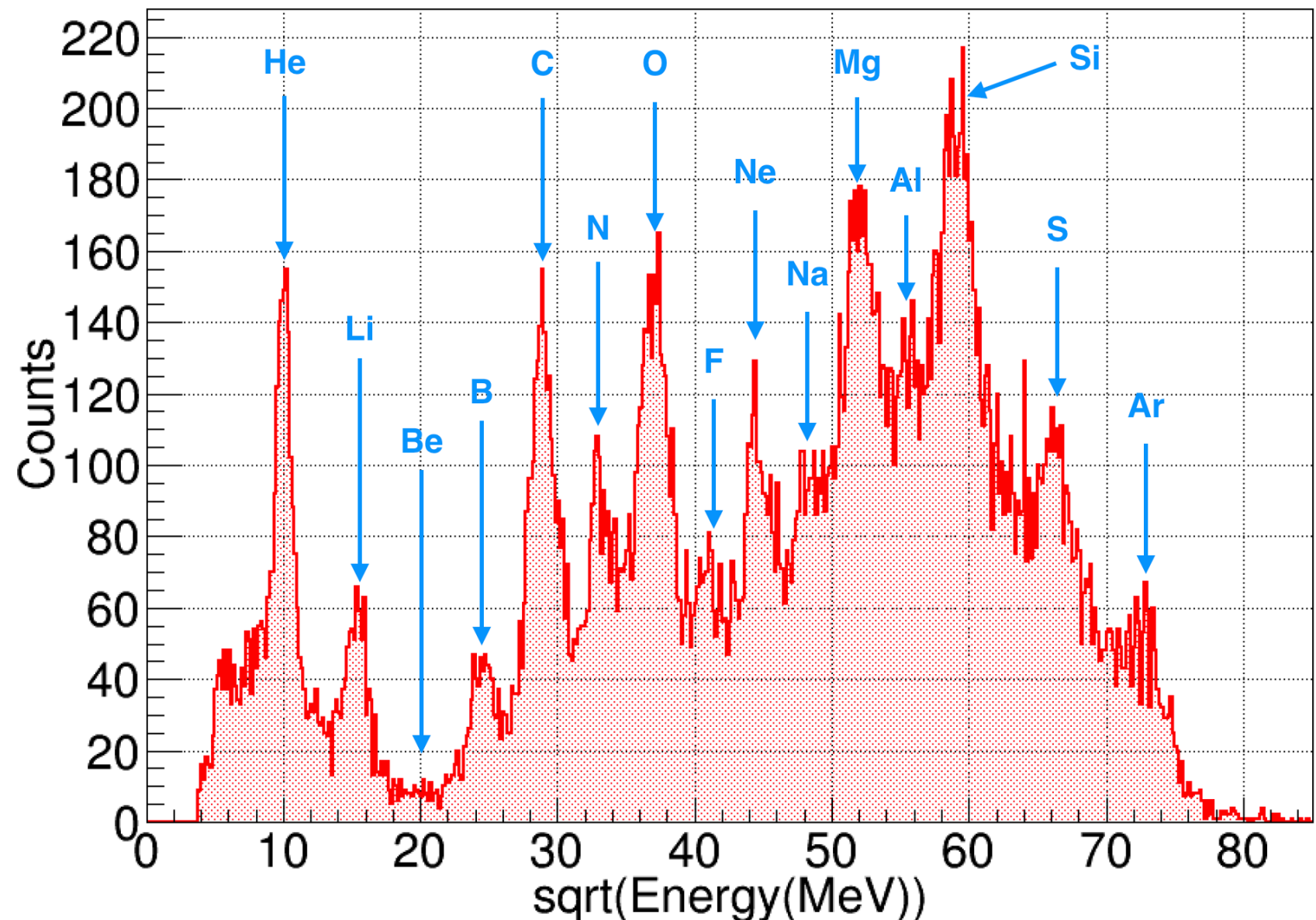
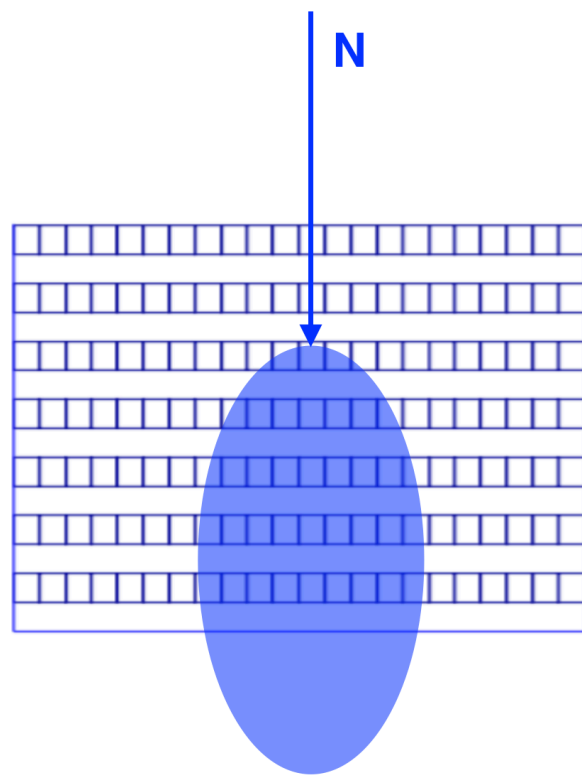


Charge identification
with dE/dx
detectors before
the BGO Calorimeter



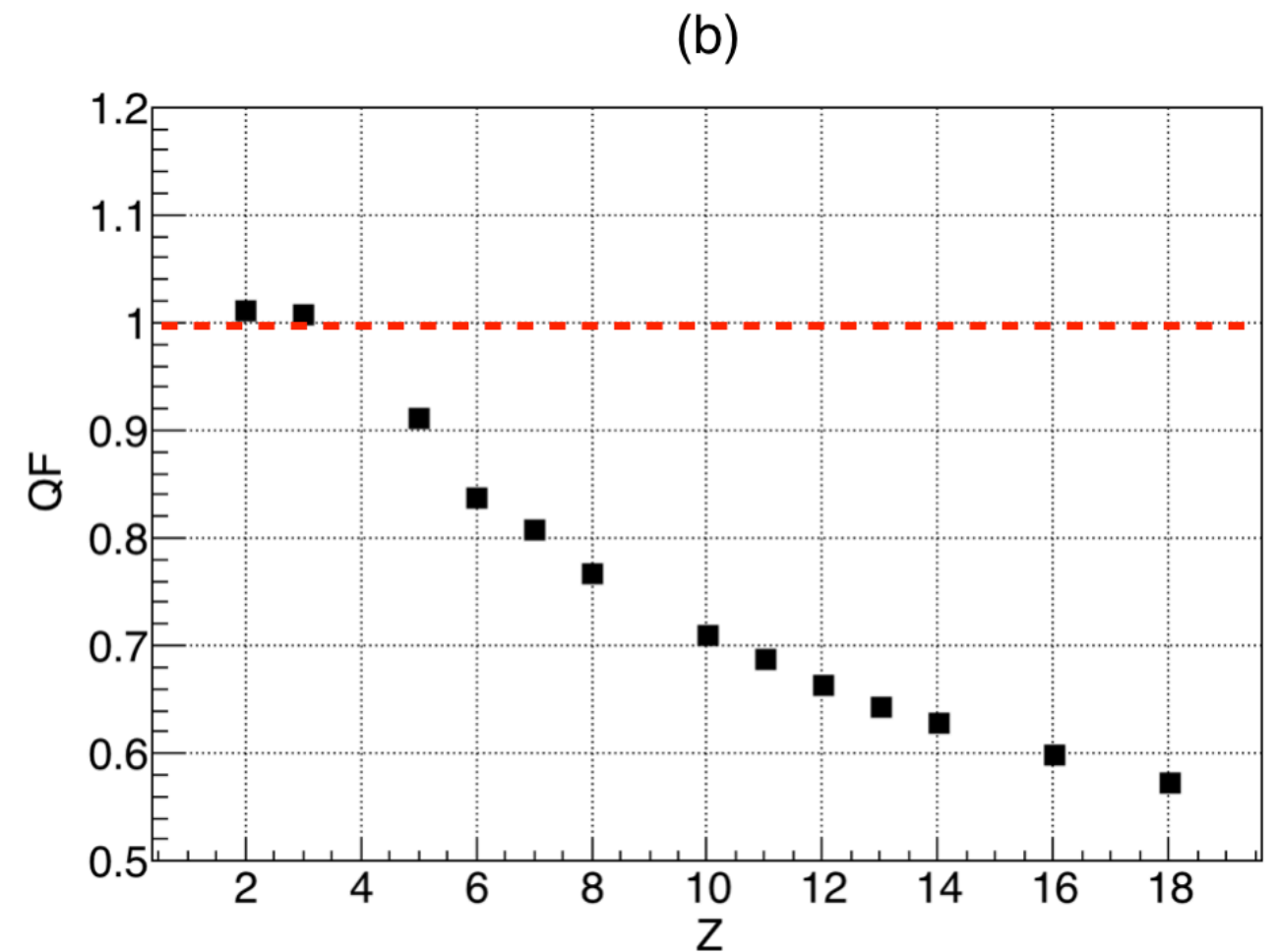
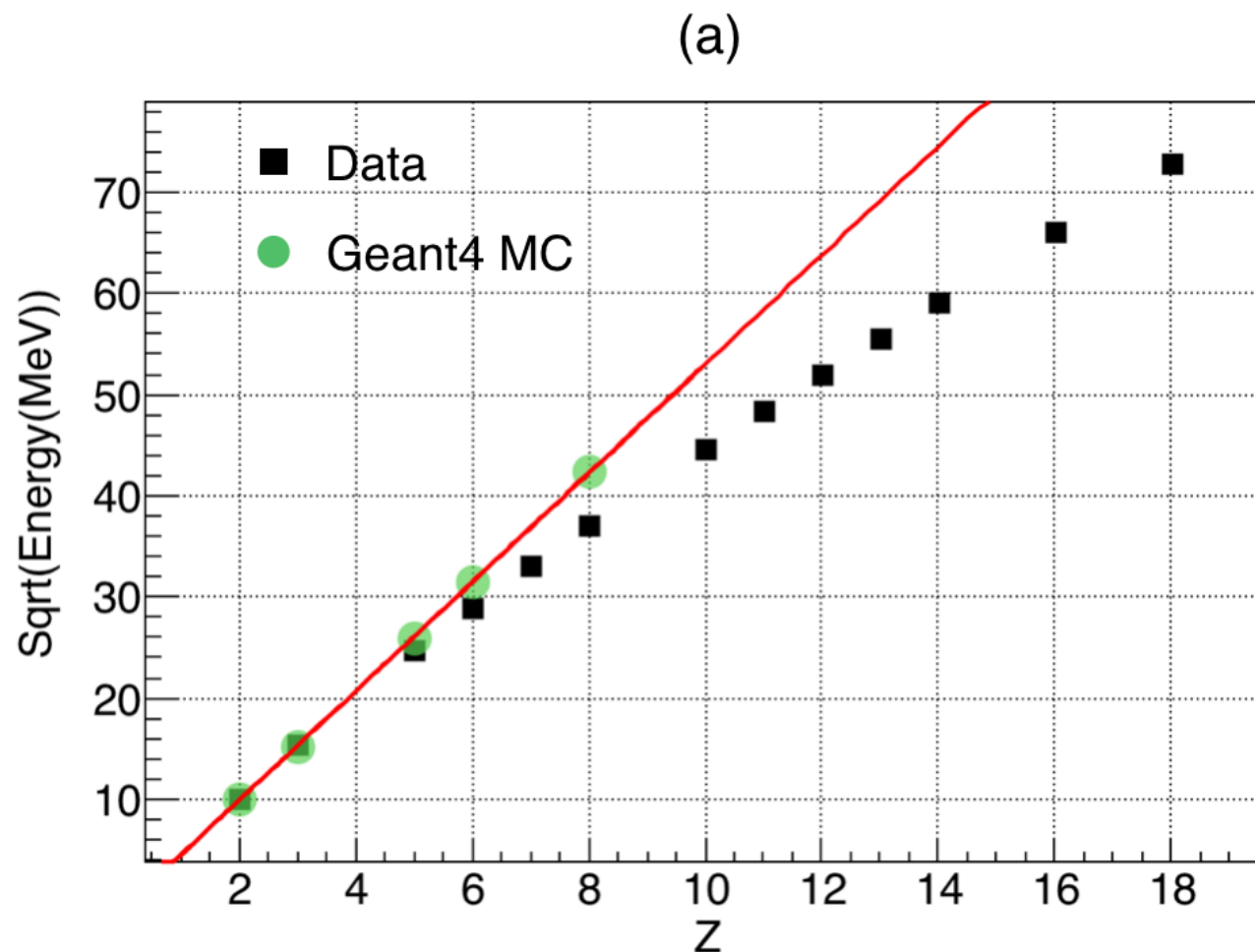
Charge Identification with the BGO Calorimeter

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



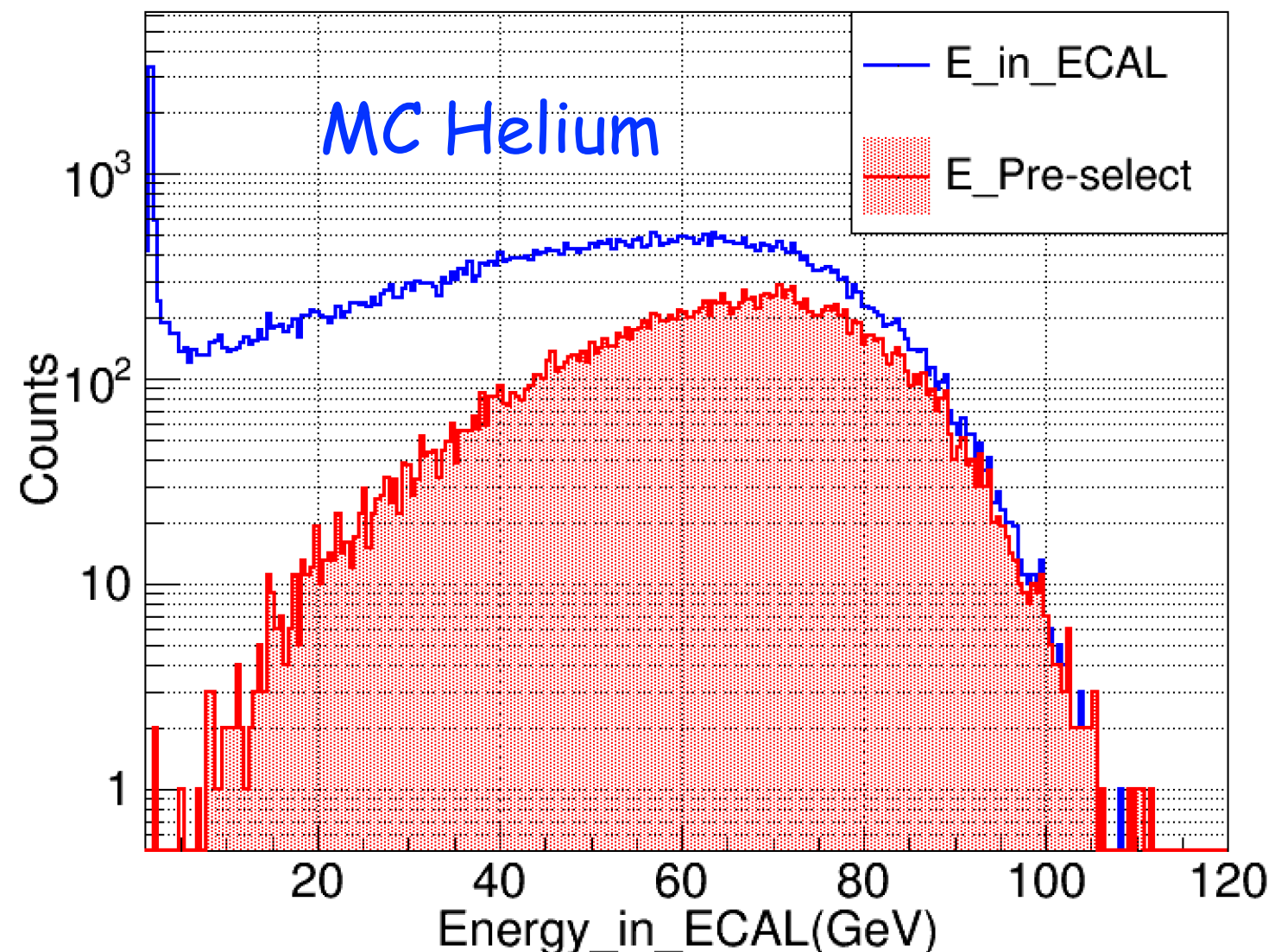
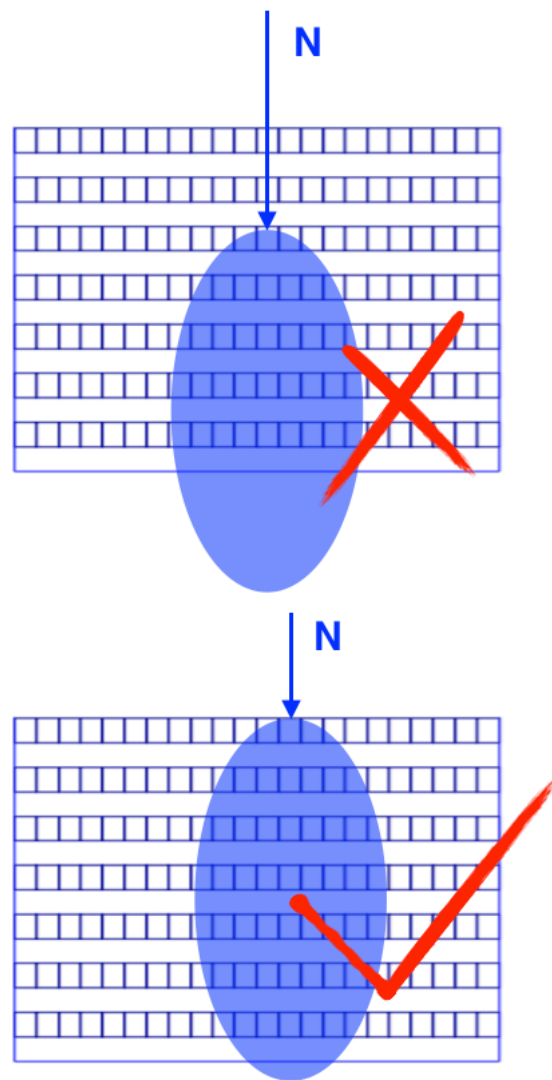
Quenching Effect of the BGO Crystal

- Quenching effect was observed in the case of $Z > 5$
- $QF = \text{Peak}_{\text{Data}} / \text{Peak}_{\text{simu}}$



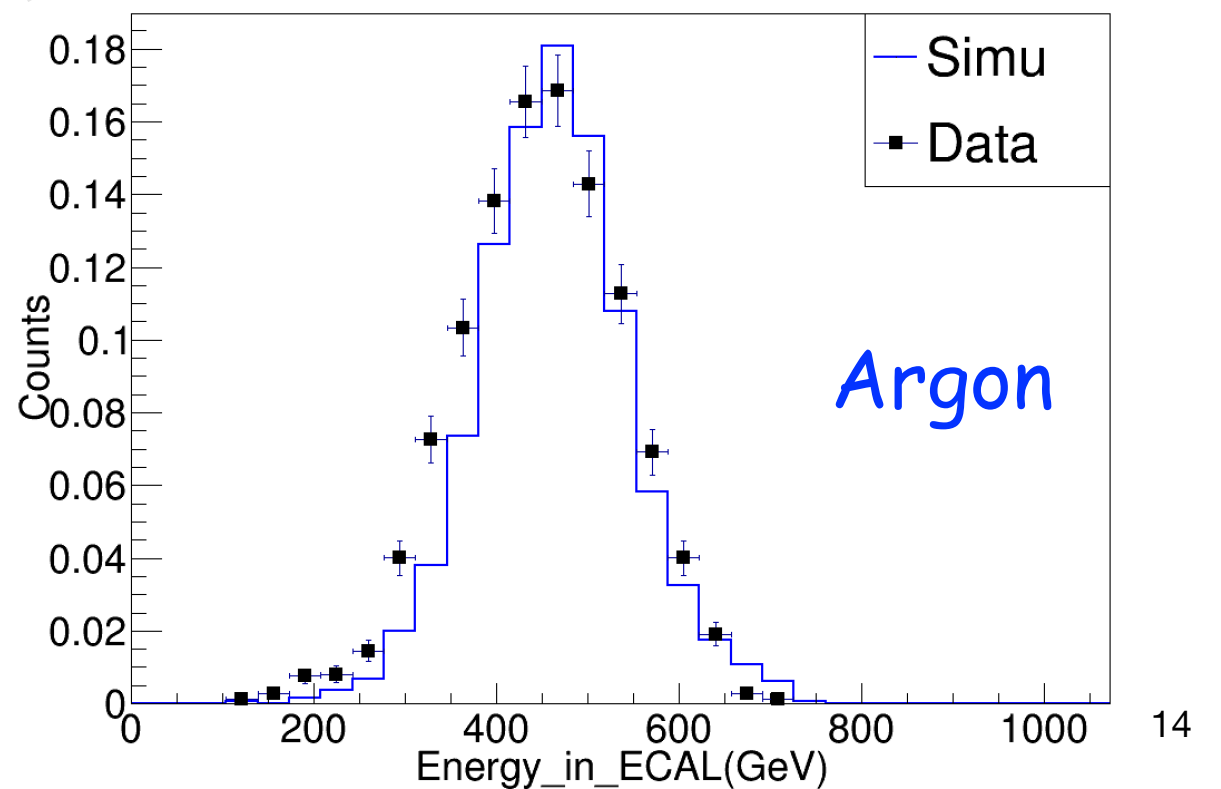
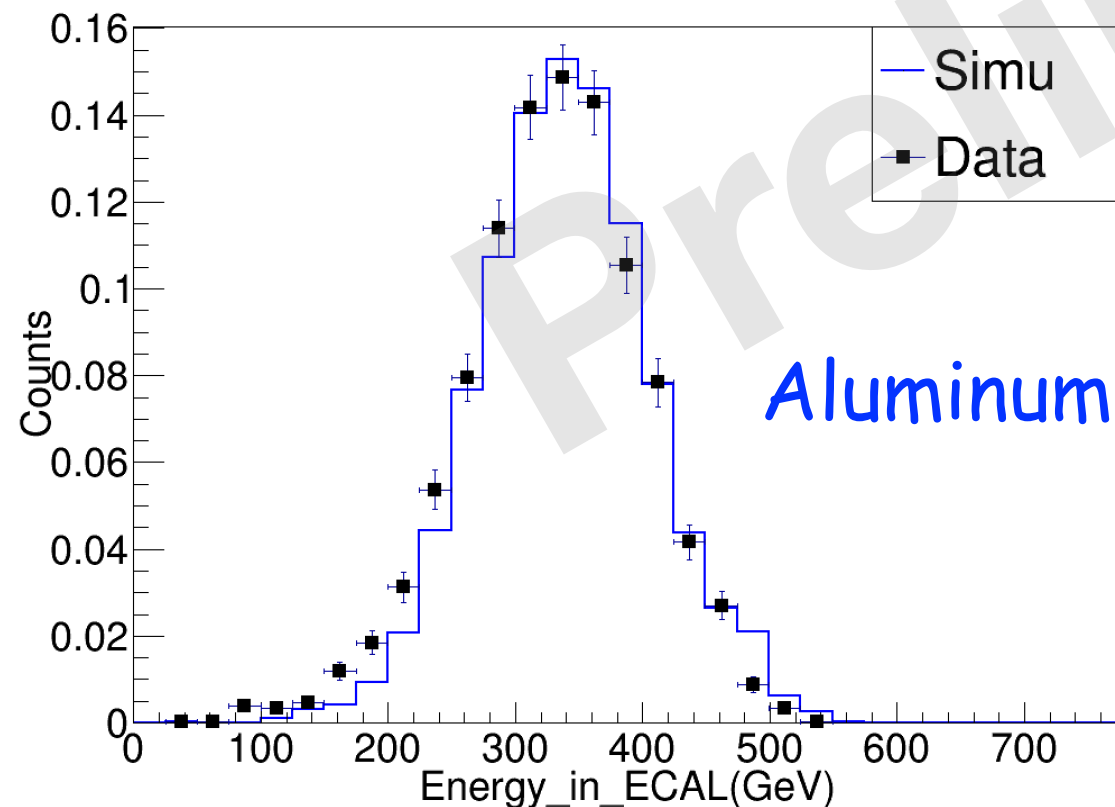
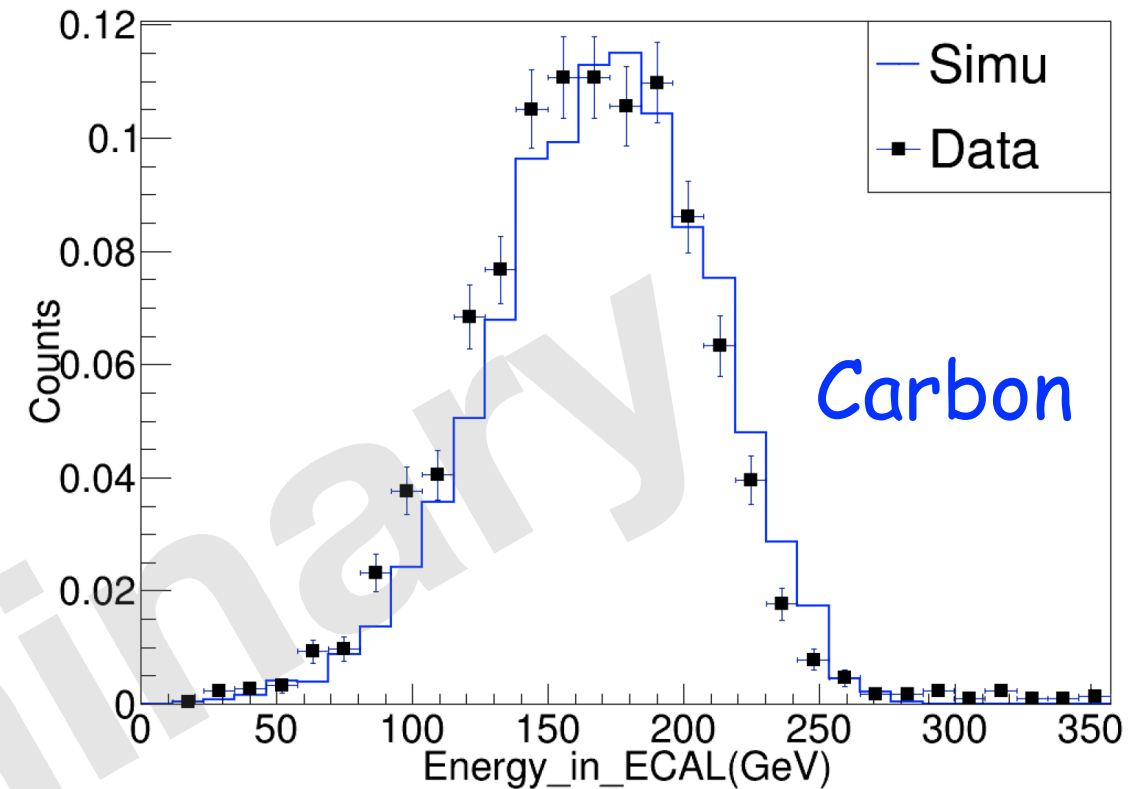
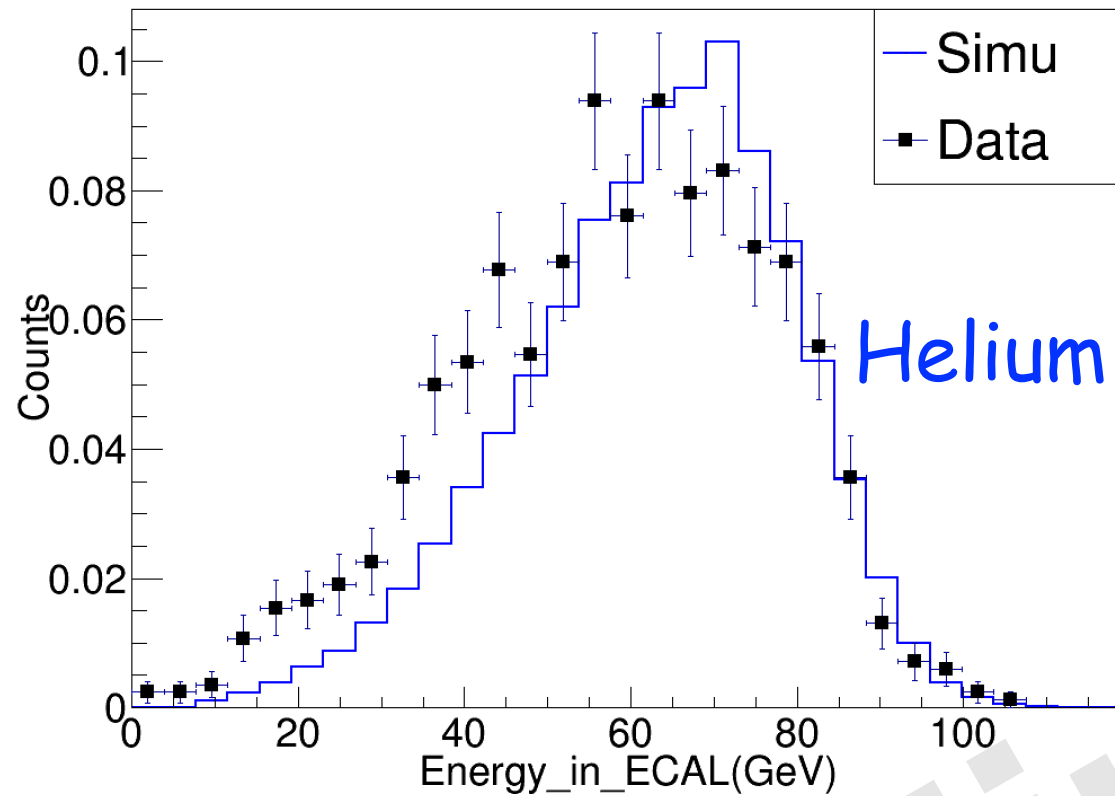
Energy Response to Nuclide

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



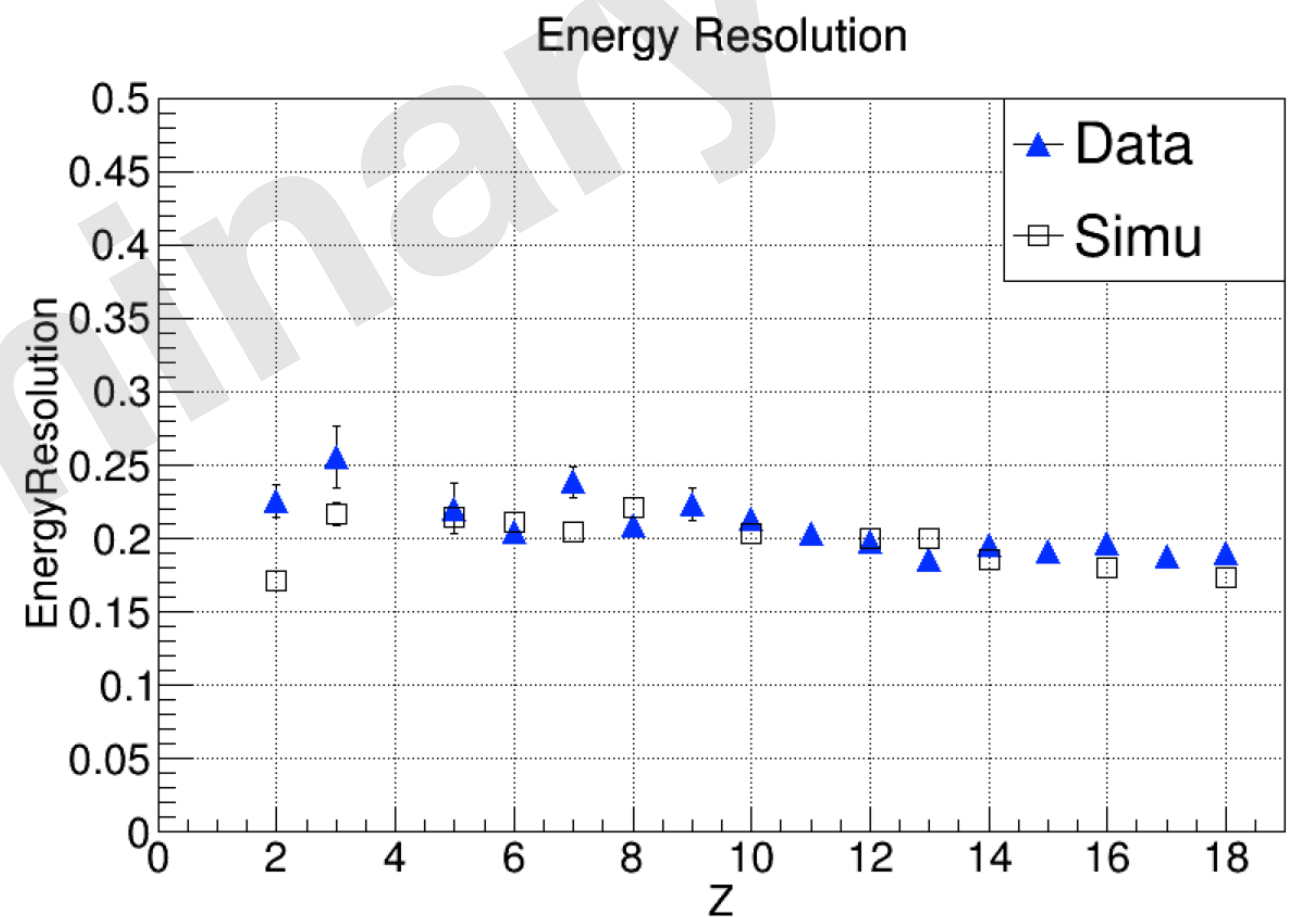
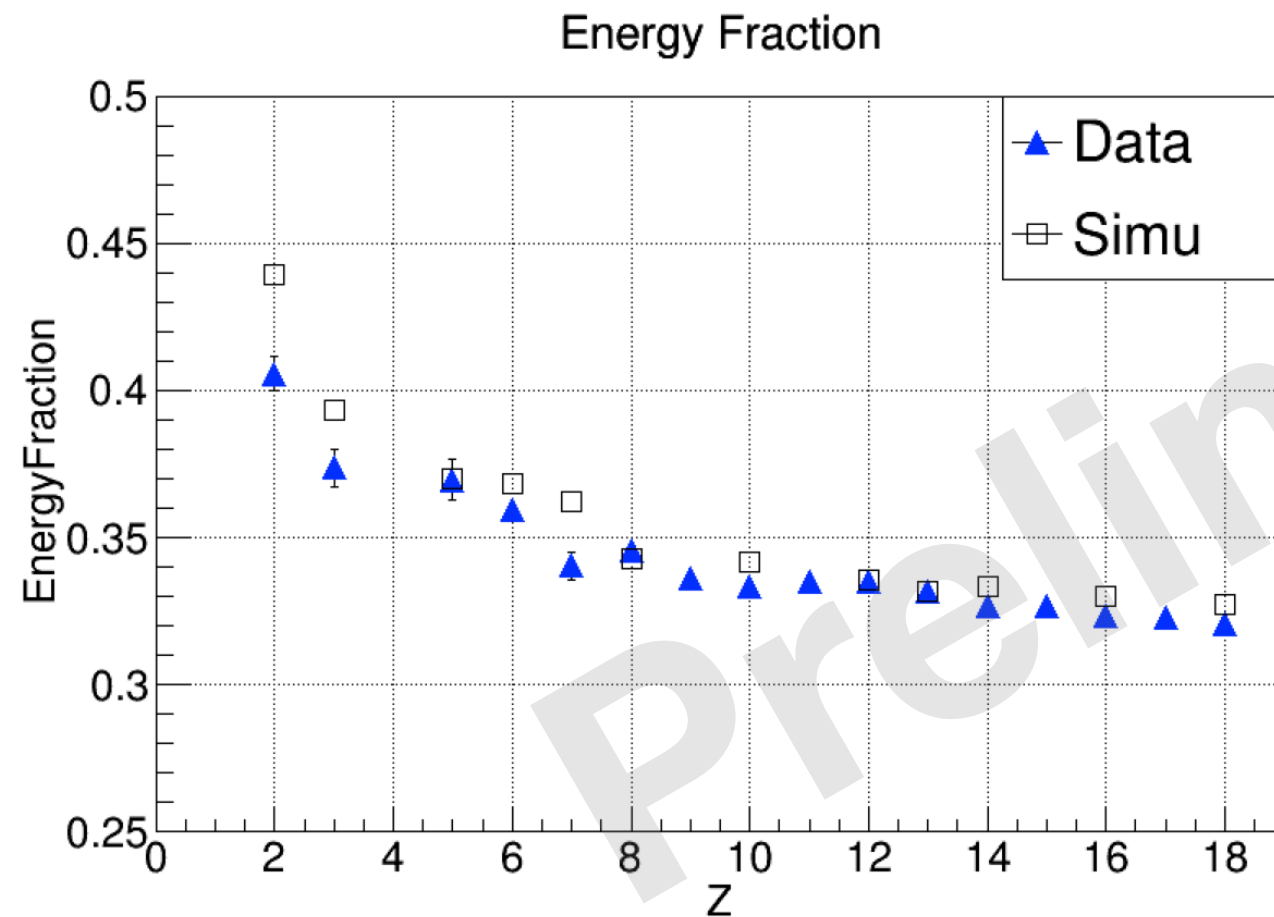
Energy Response to Nuclide (40 GeV/n)

MC: Geant4.10.1 QGSP_FTFP_BERT

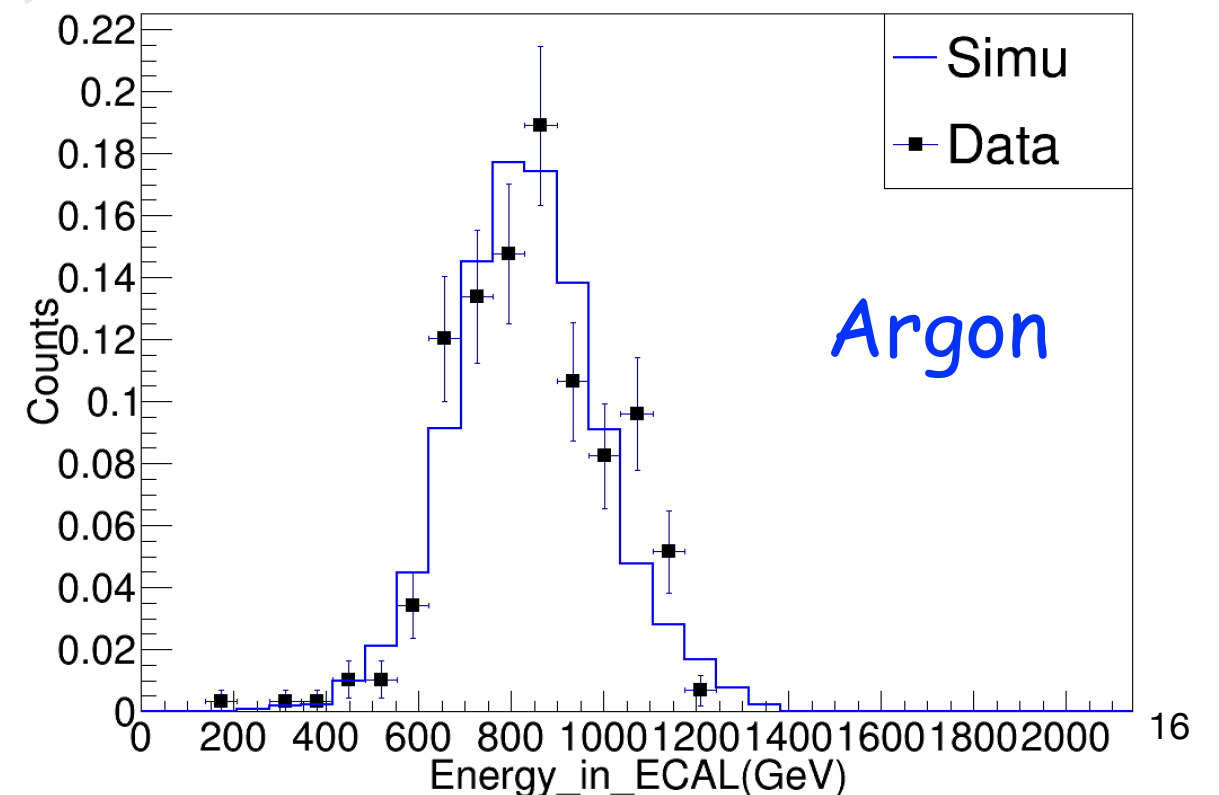
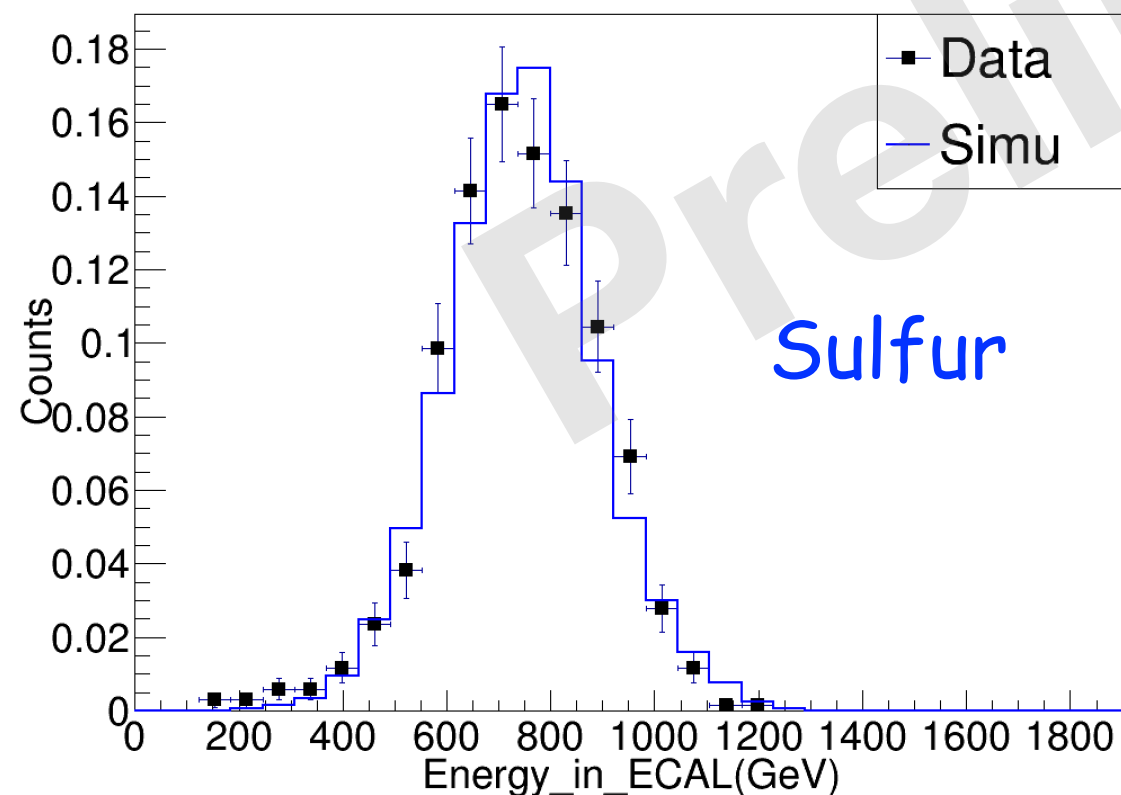
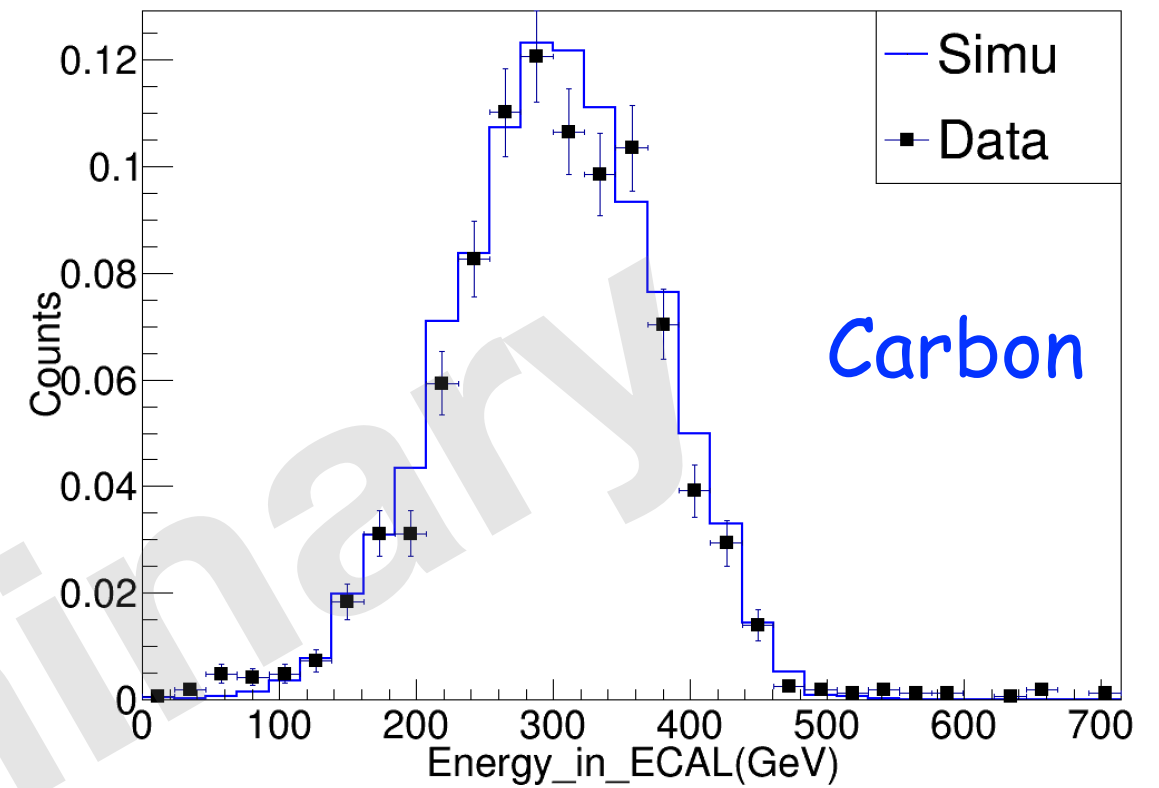
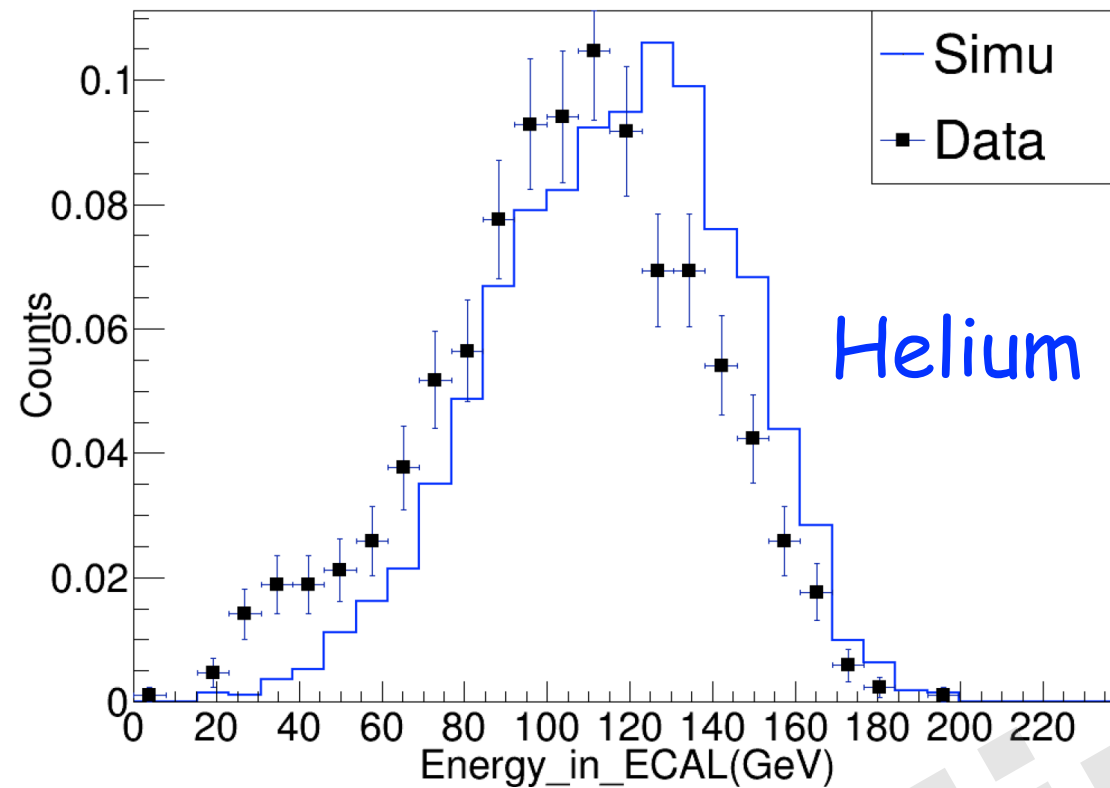


Energy Response to Nuclide (40 GeV/n)

Energy Fraction = Energy Deposition/Incident Energy

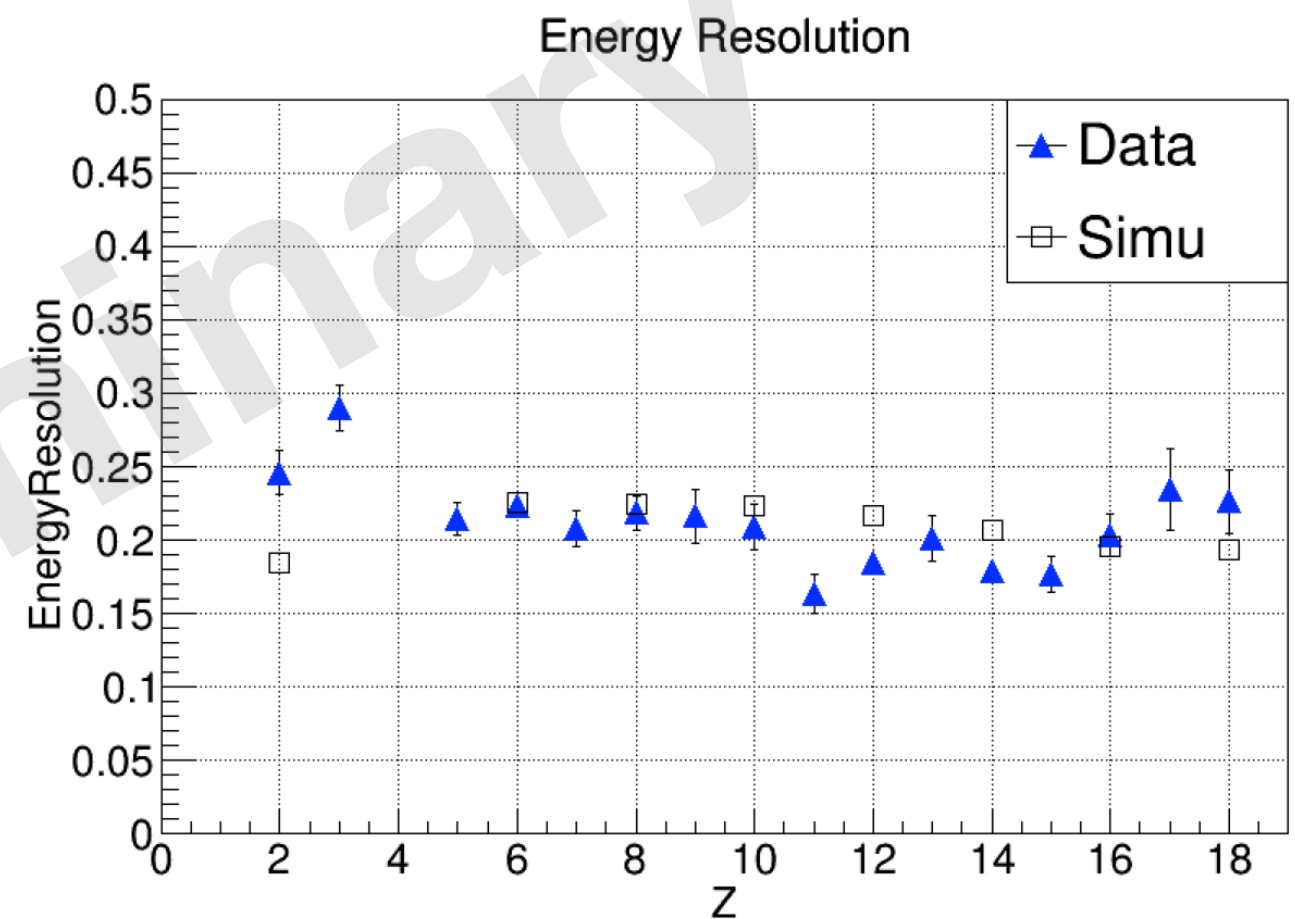
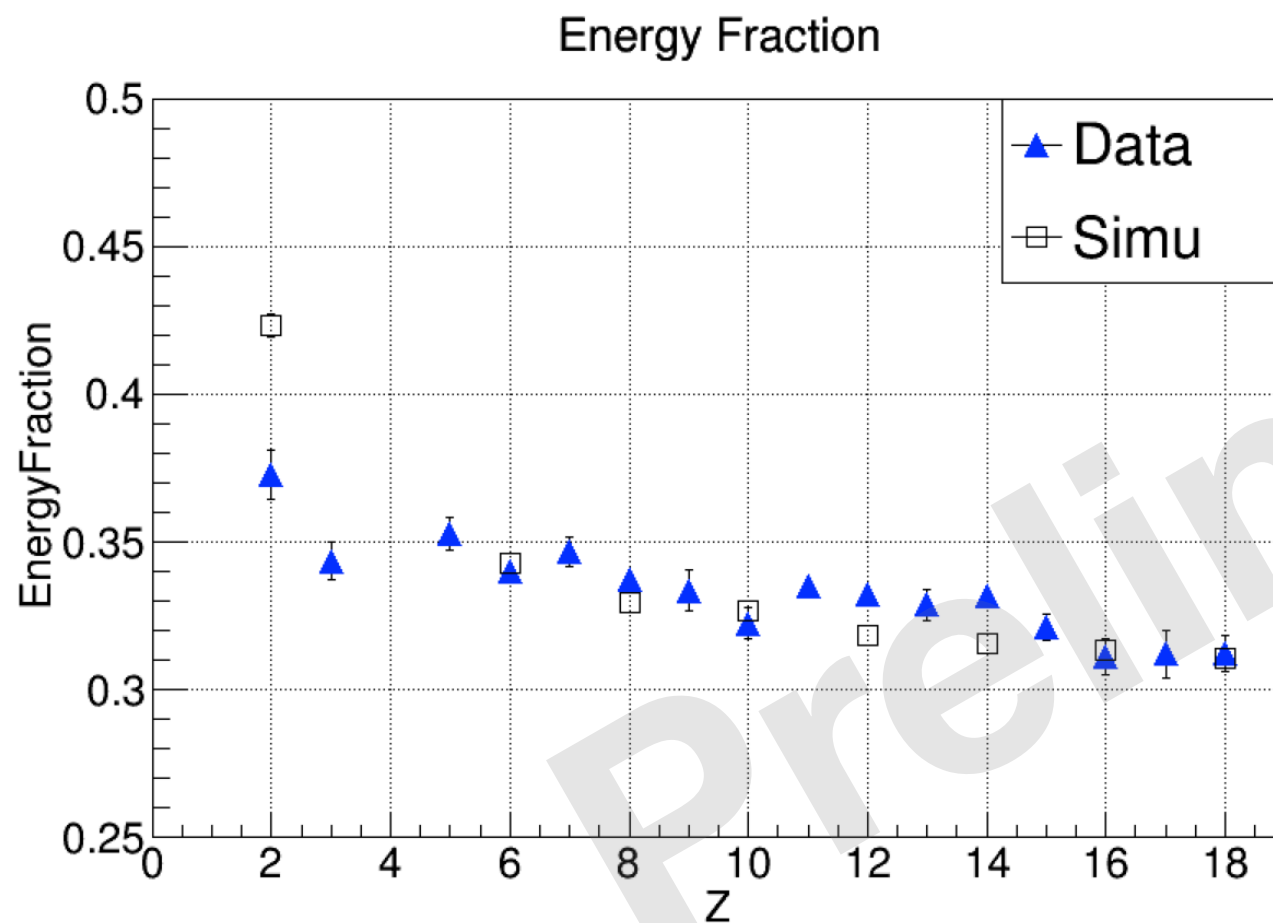


Energy Response to Nuclide (75 GeV/n)



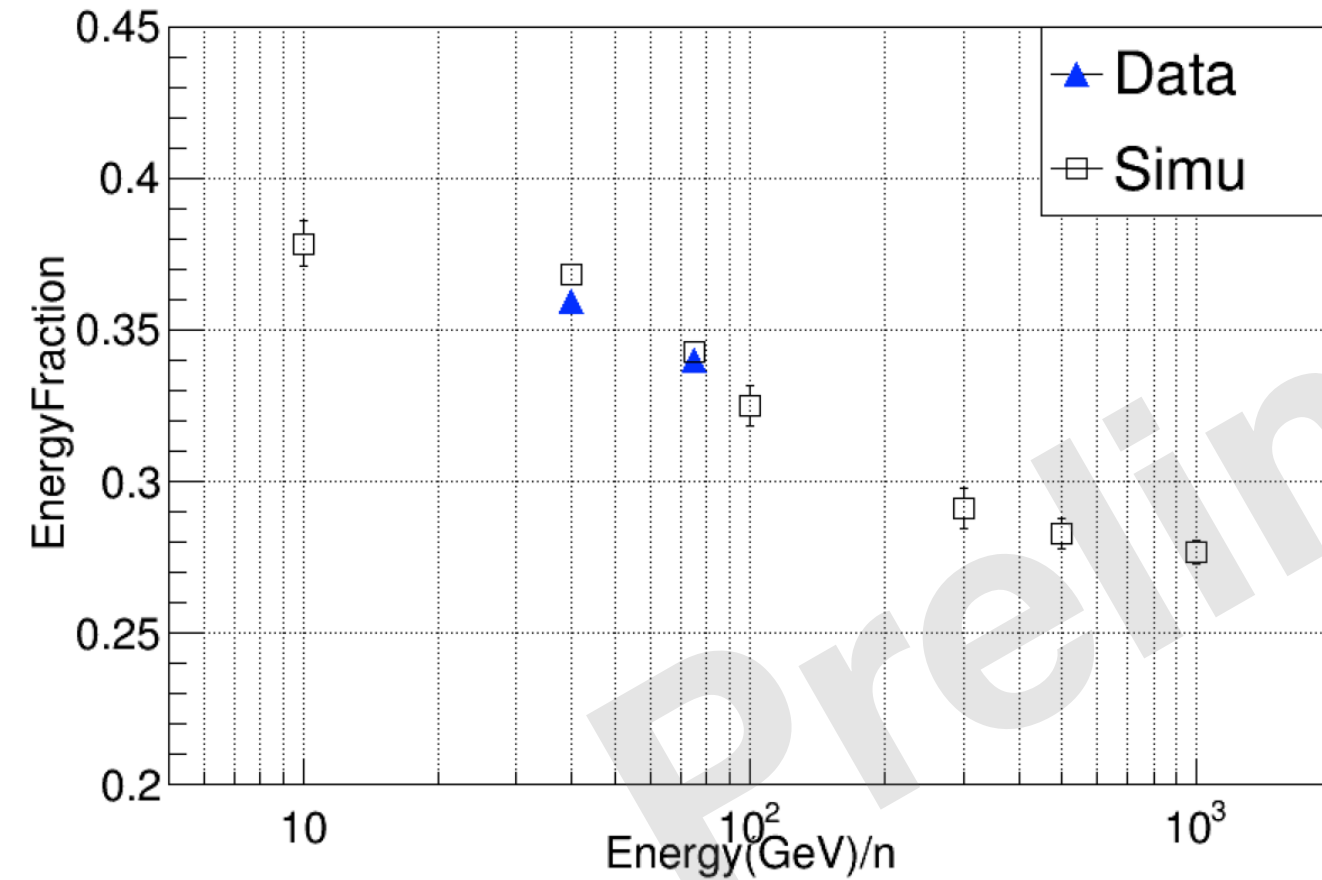
Energy Response to Nuclide (75 GeV/n)

Energy Fraction = Energy Deposition/Incident Energy

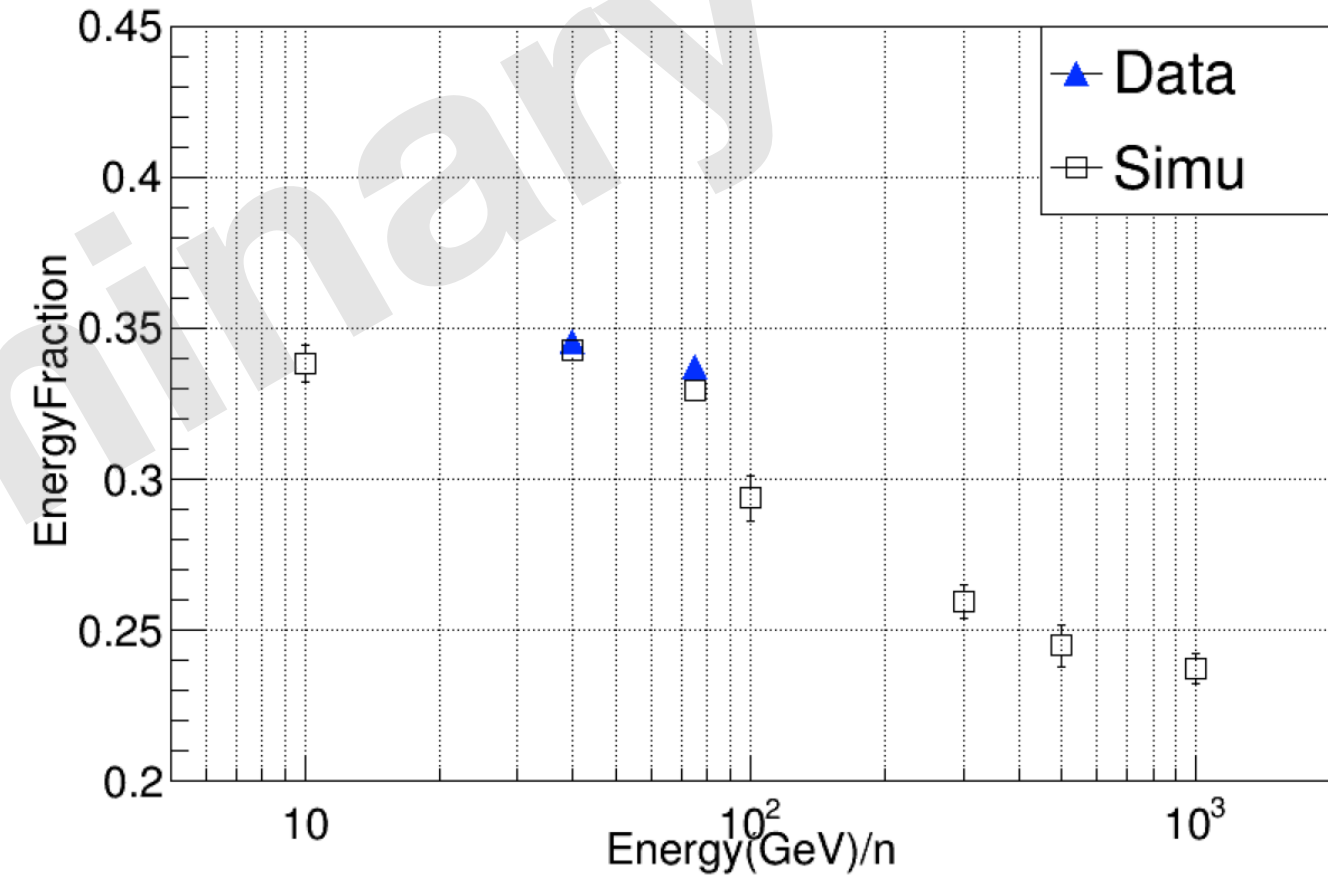


Energy Fraction vs Incident Energy

Carbon



Oxygen

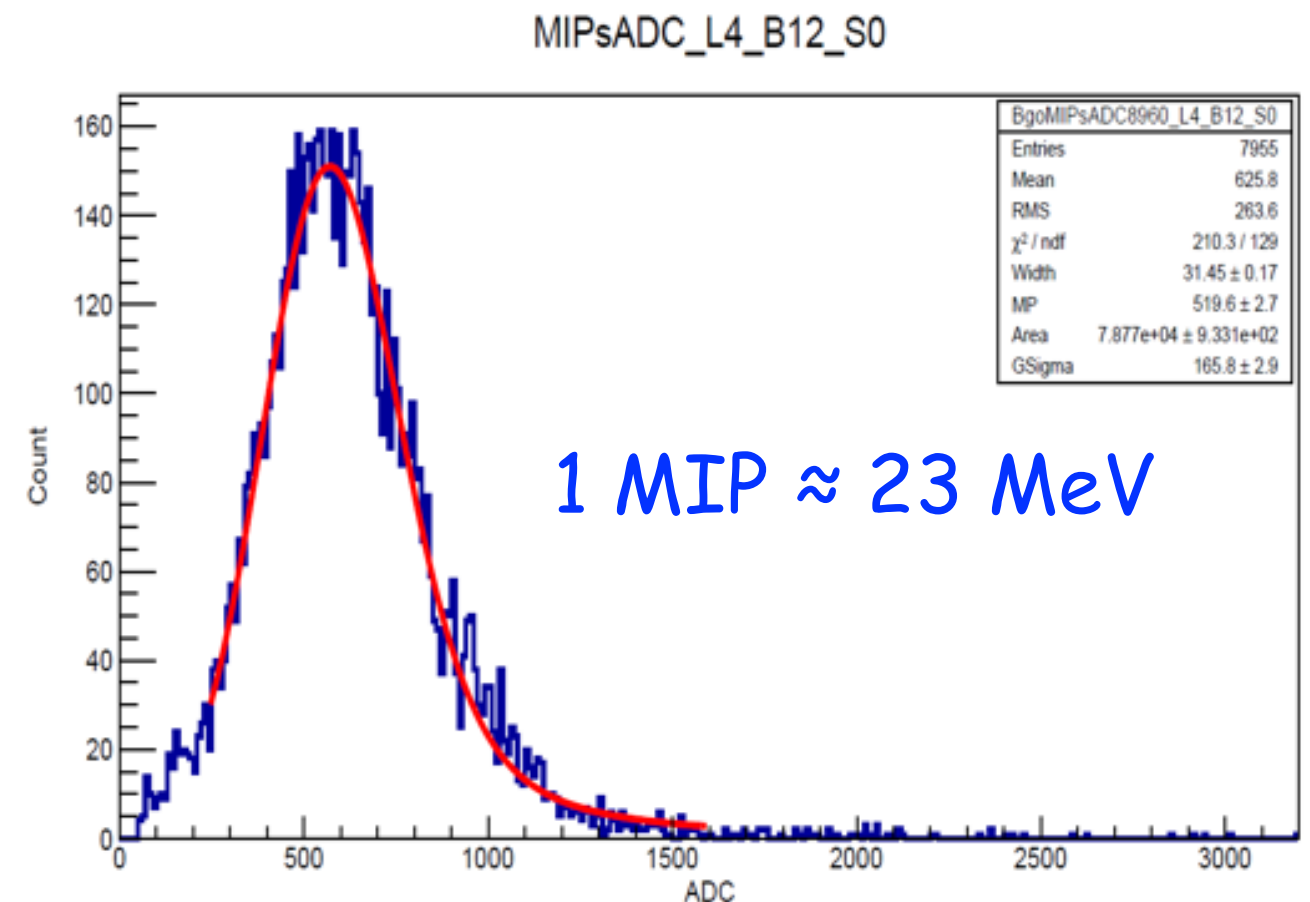
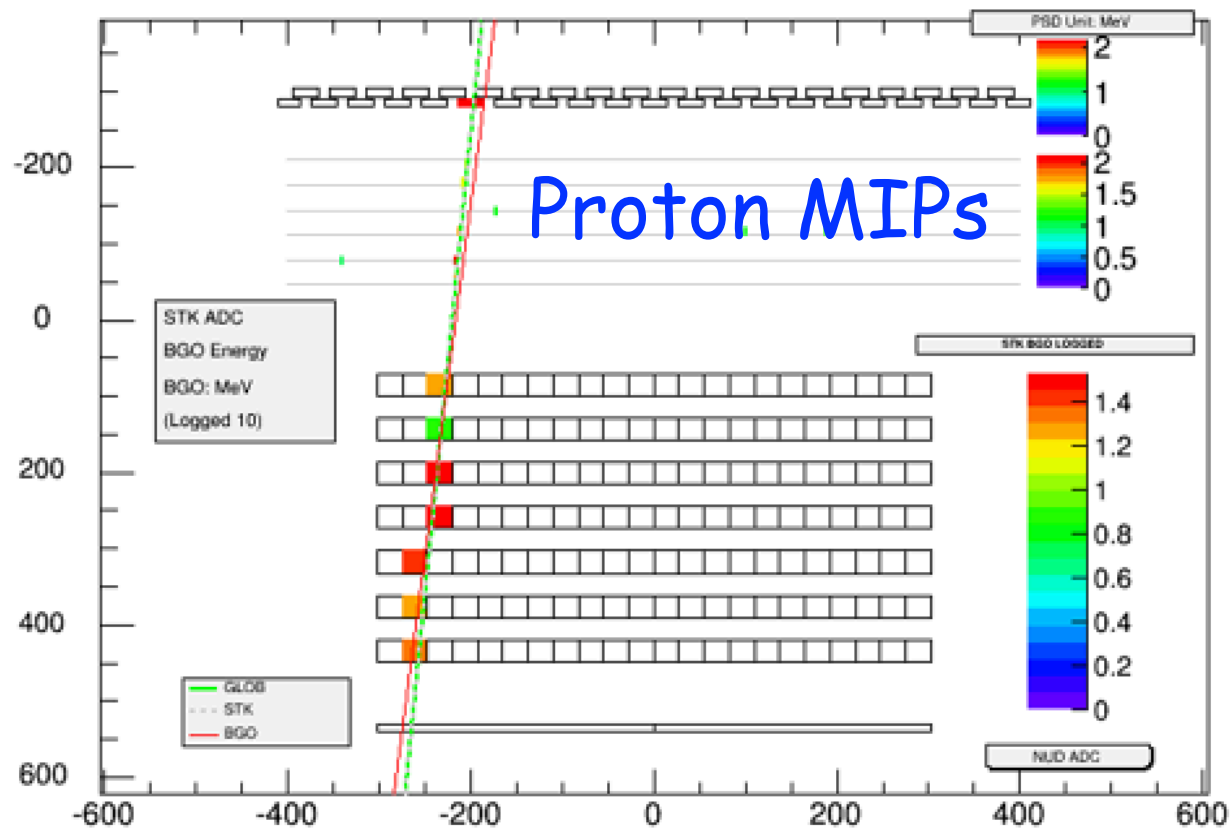


Orbit Performance

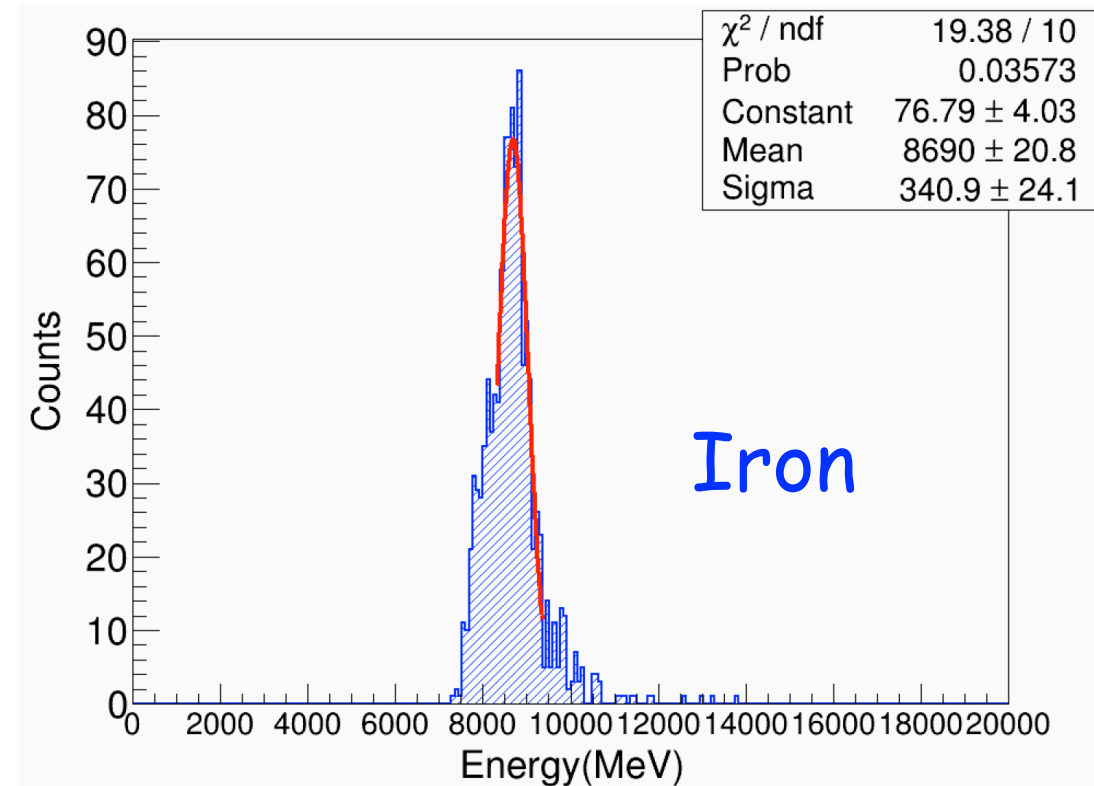
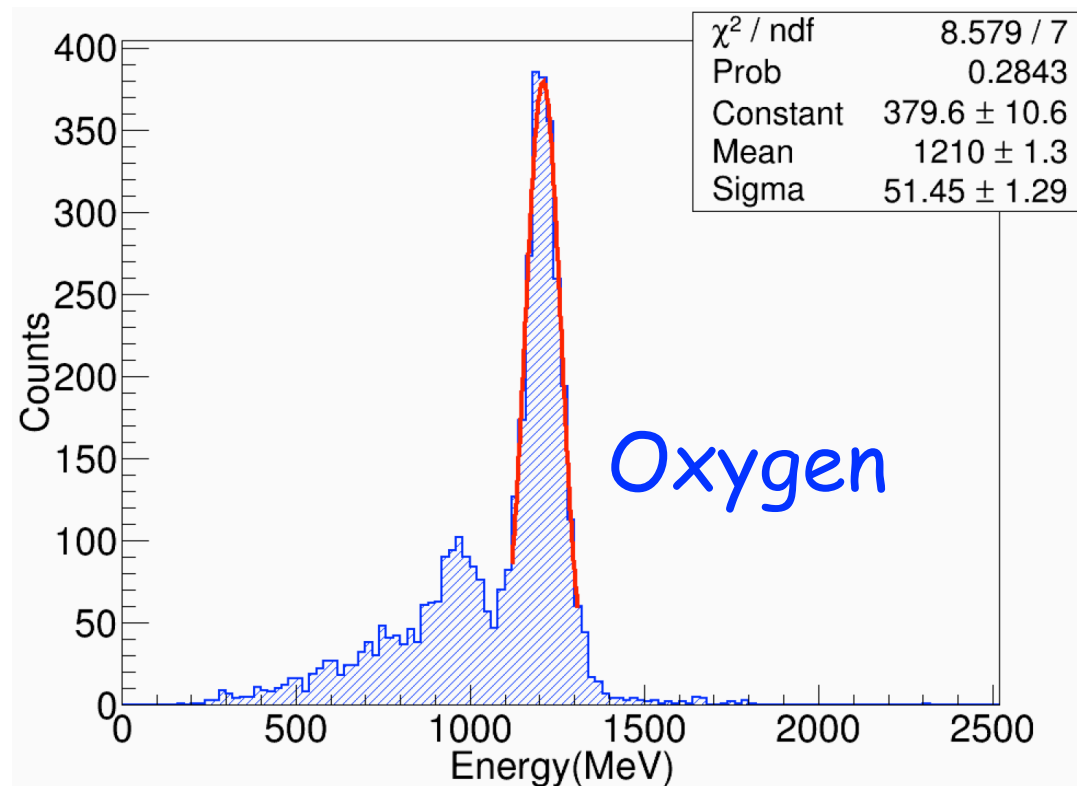
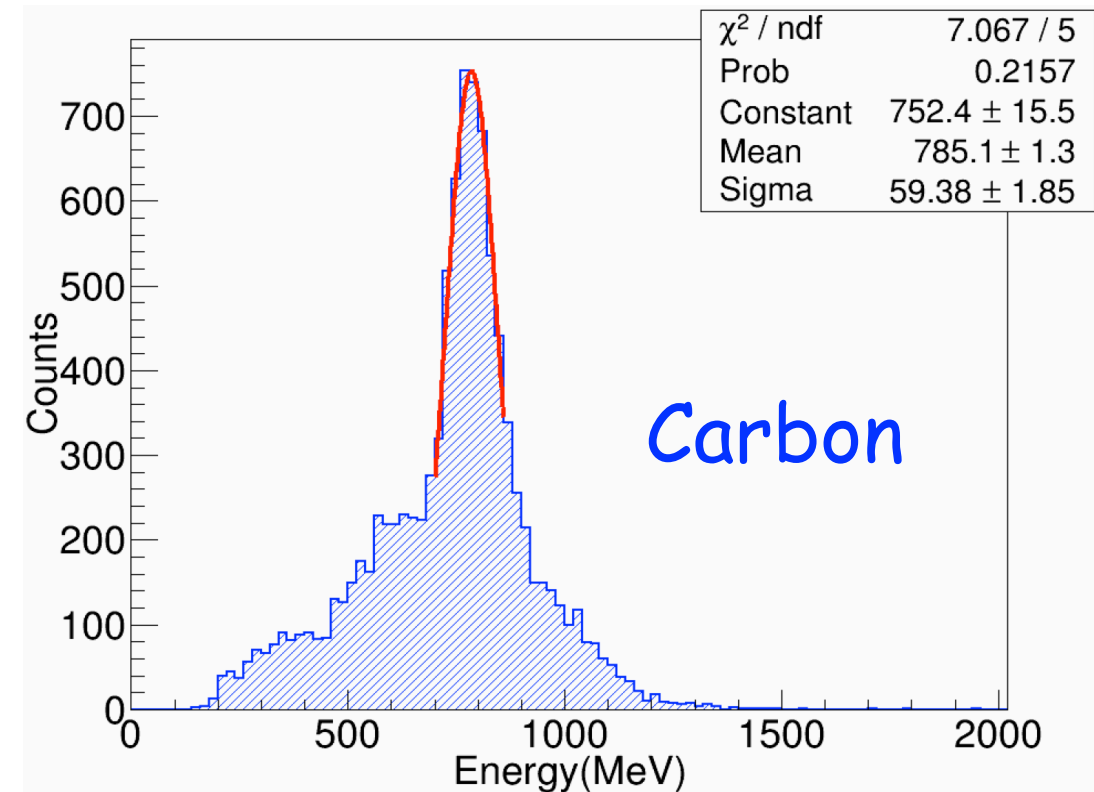
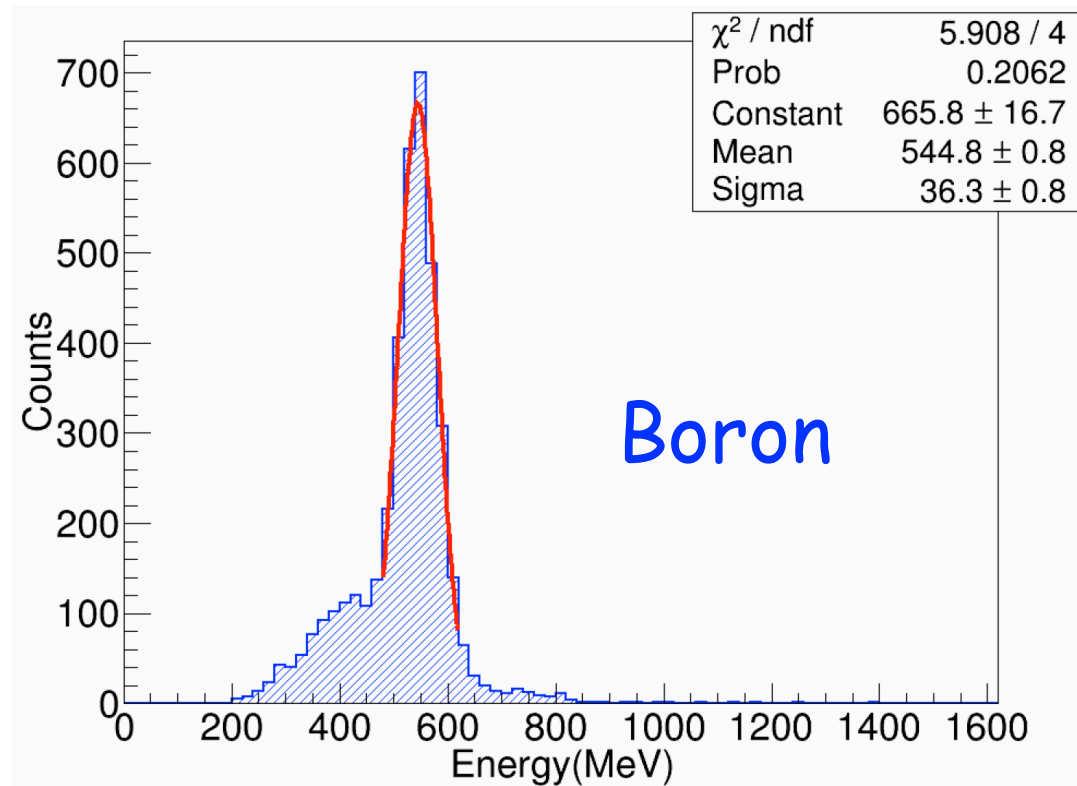
Launched on 17th Dec. 2015
Jiuquan Satellite Launch Center, Gobi desert

Orbit Calibration with Nuclide

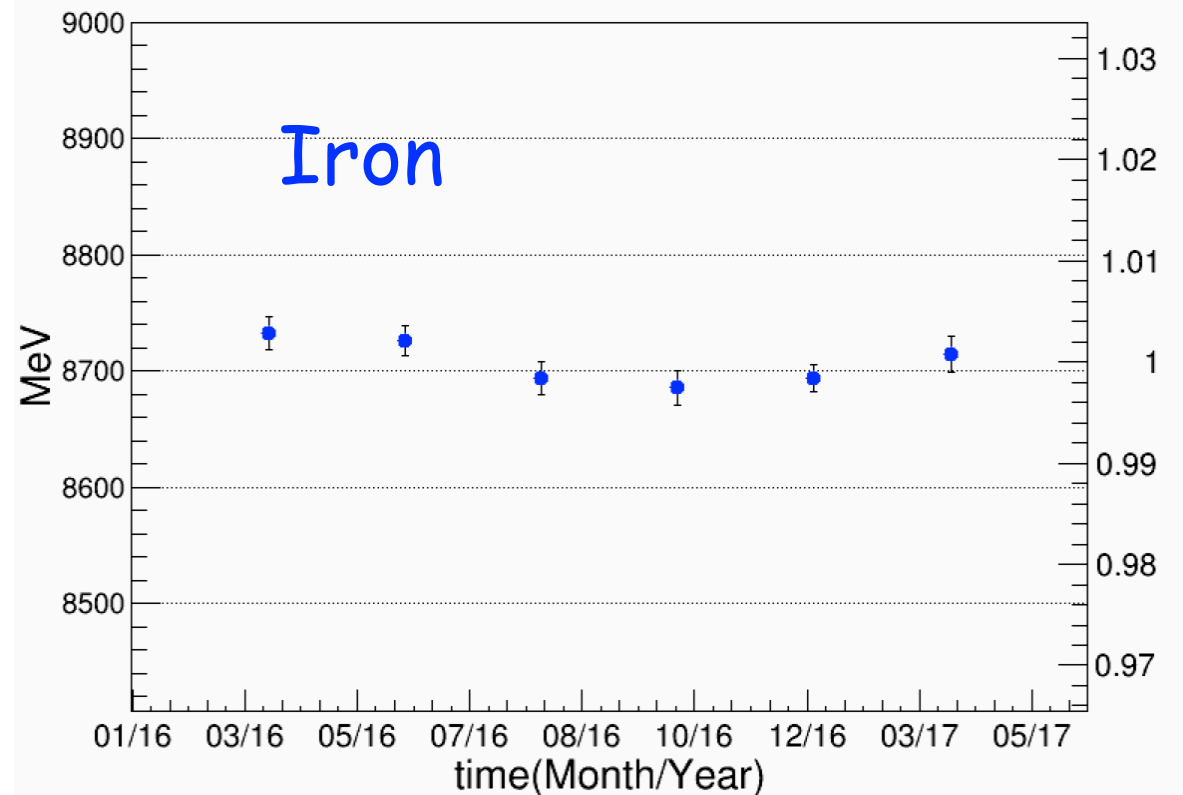
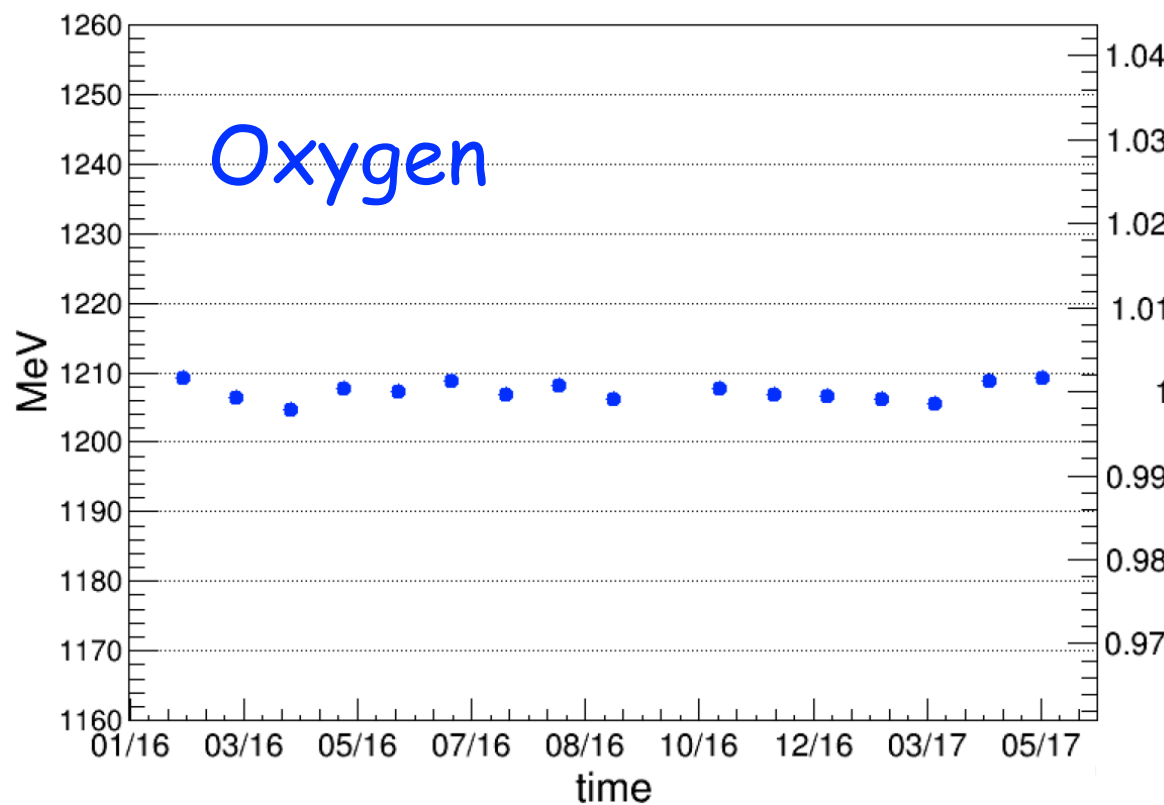
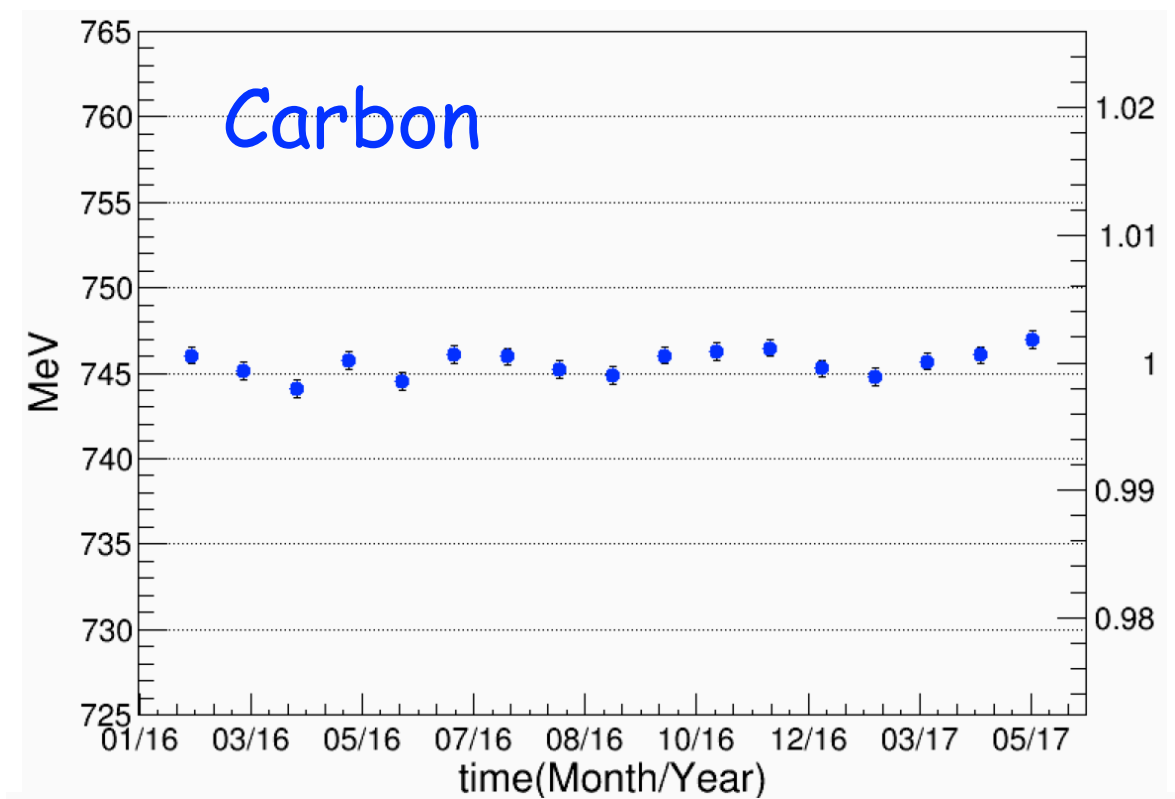
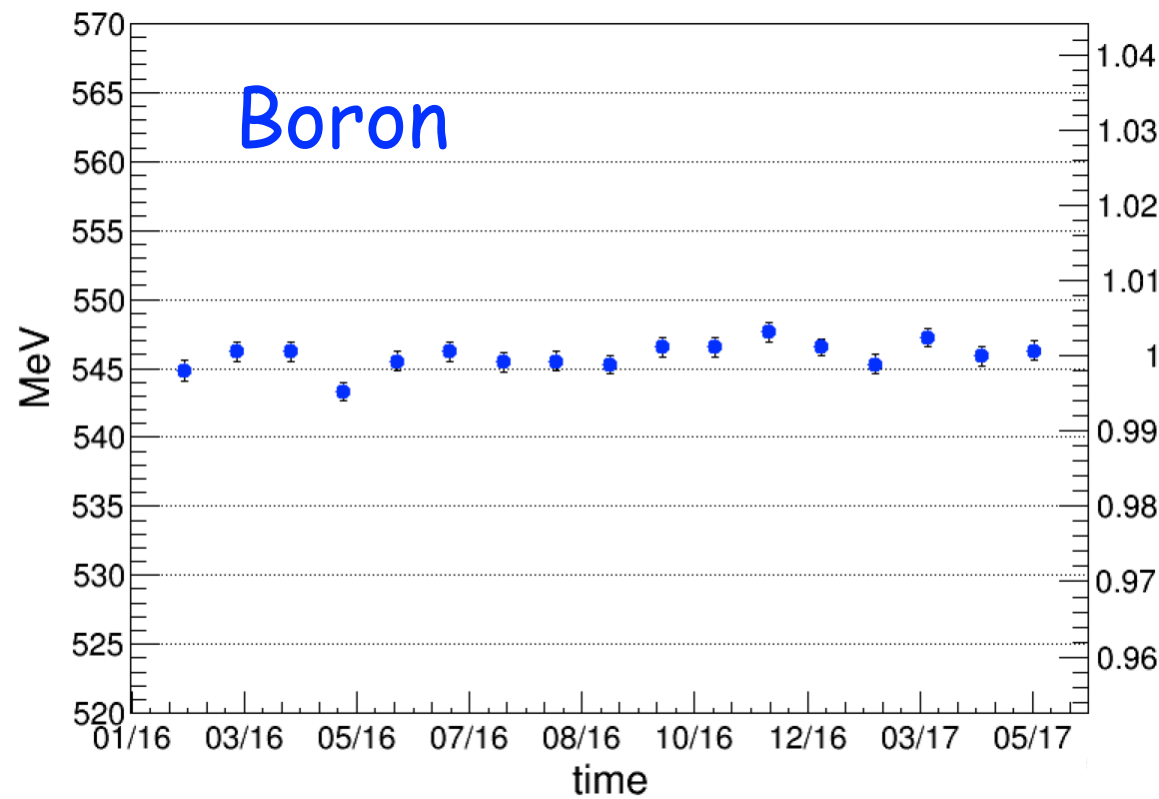
- No mono energy source in space
- Proton/Nuclide MIP events are utilized to do energy calibration



MIP Events of Nuclide



Long Time Stability



Summary

- A BGO calorimeter was built for DAMPE mission
- Ion beam test was performed for the BGO ECAL
- Quenching effect of BGO crystal was observed
- More than 30% energy deposited in the BGO ECAL
- Energy resolution is better than 30%
- Nuclide MIP is good reference for energy measurement on orbit

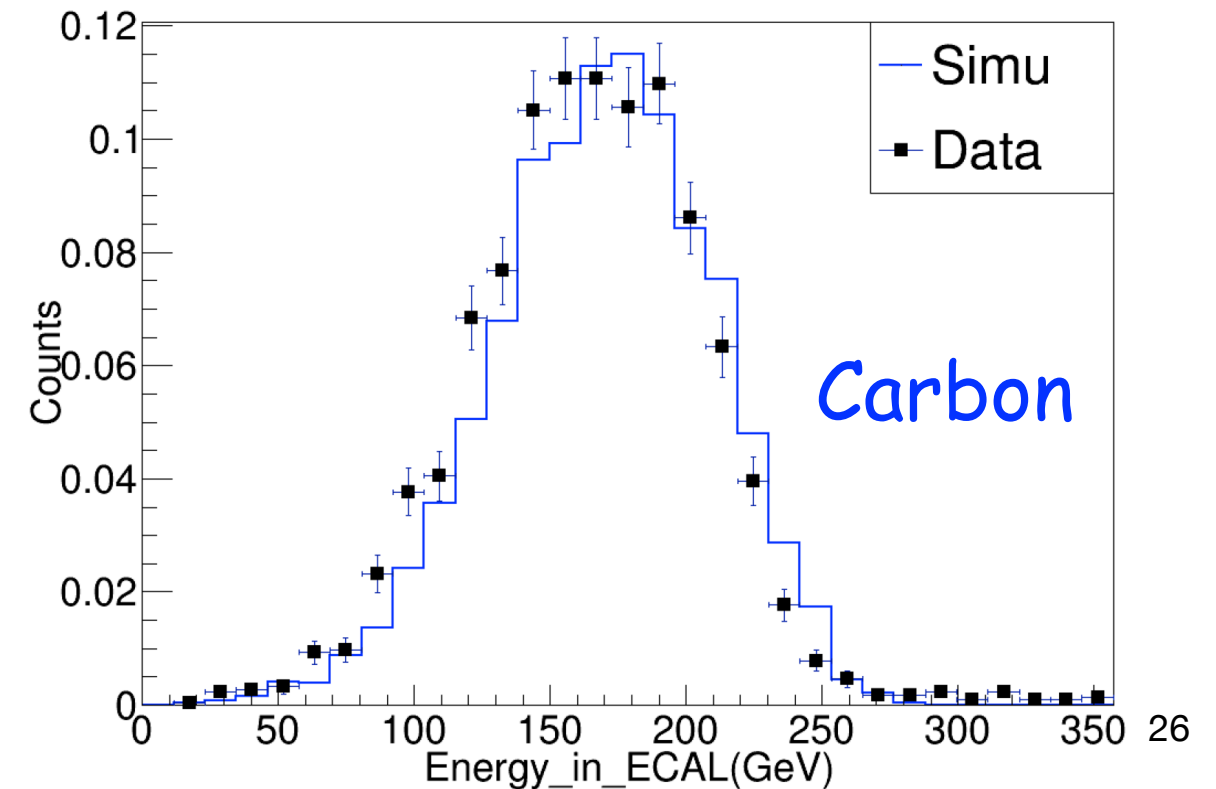
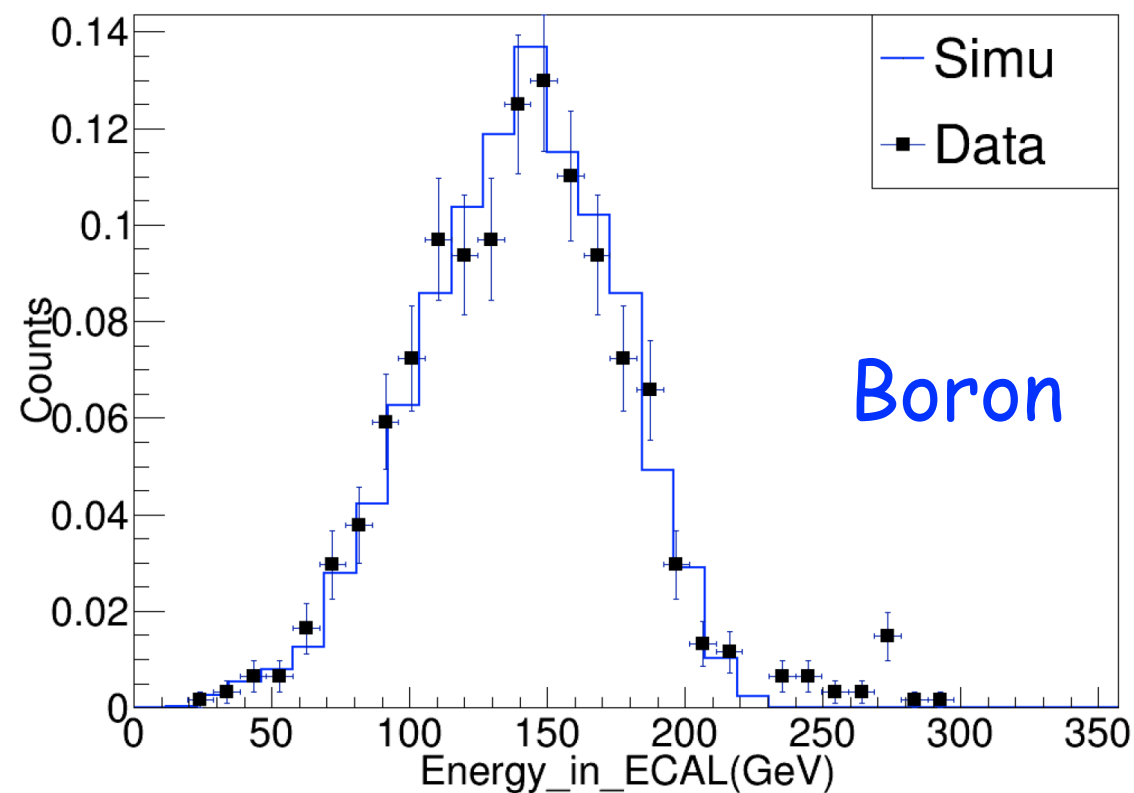
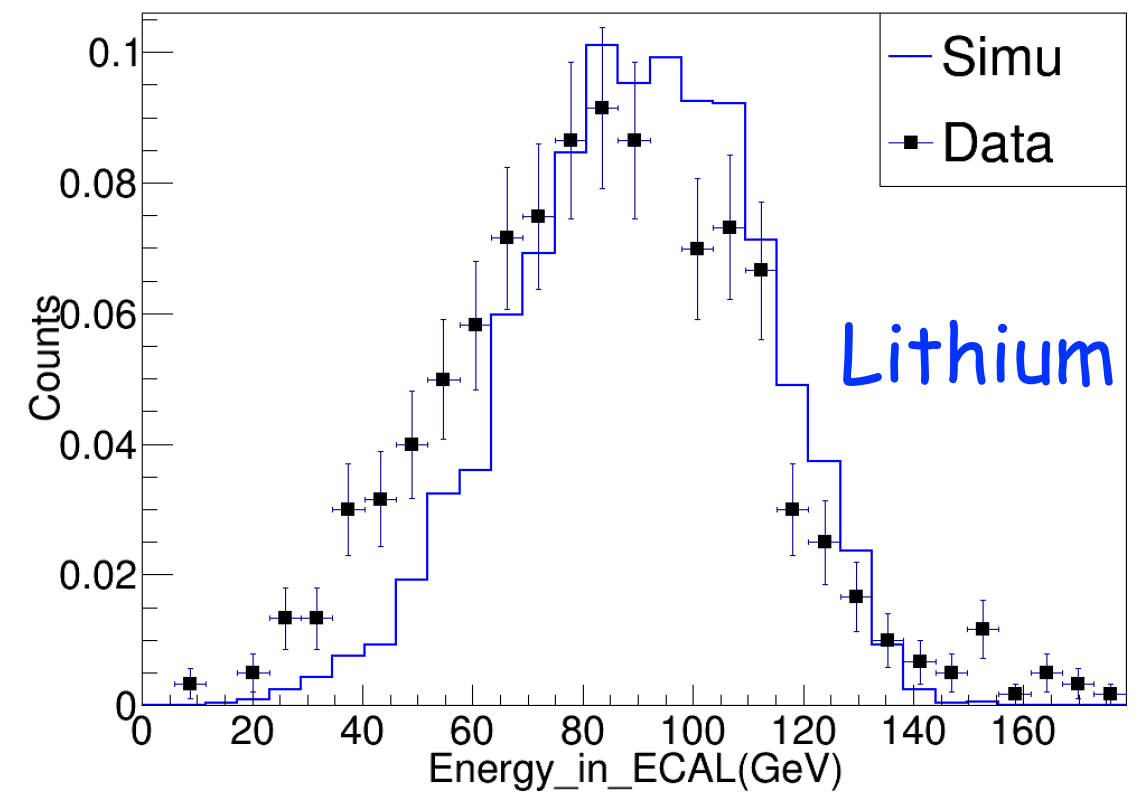
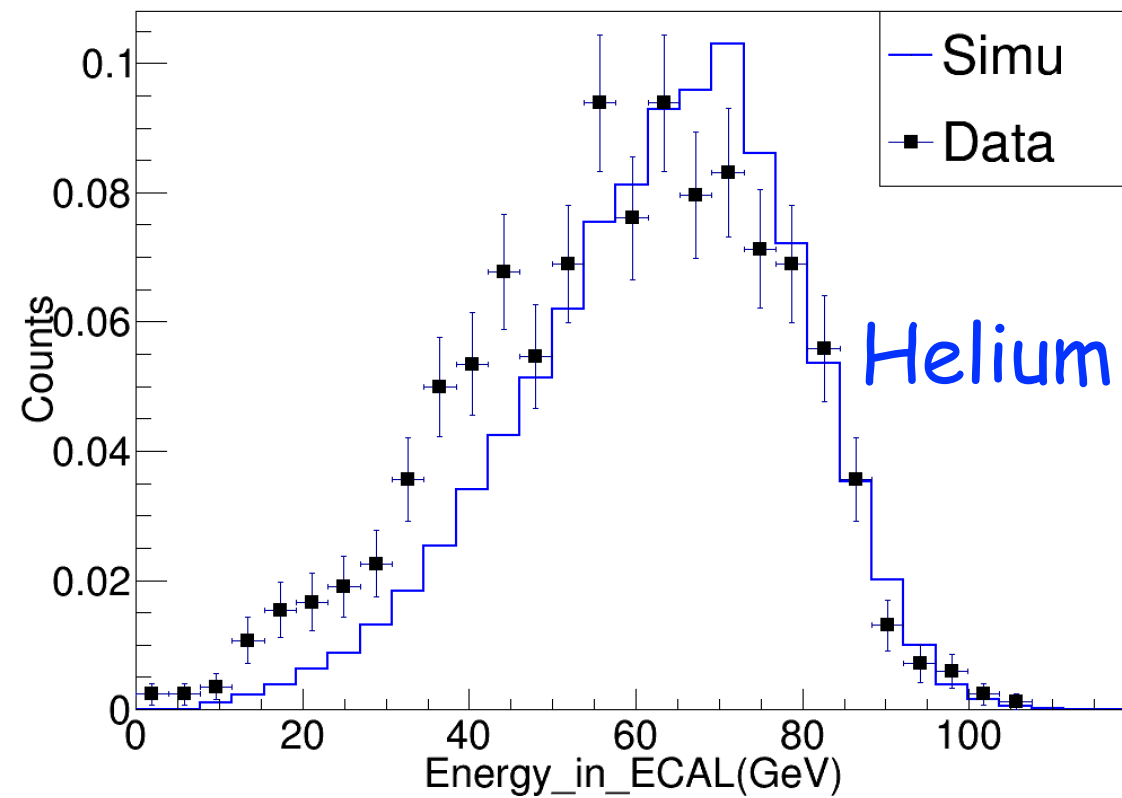
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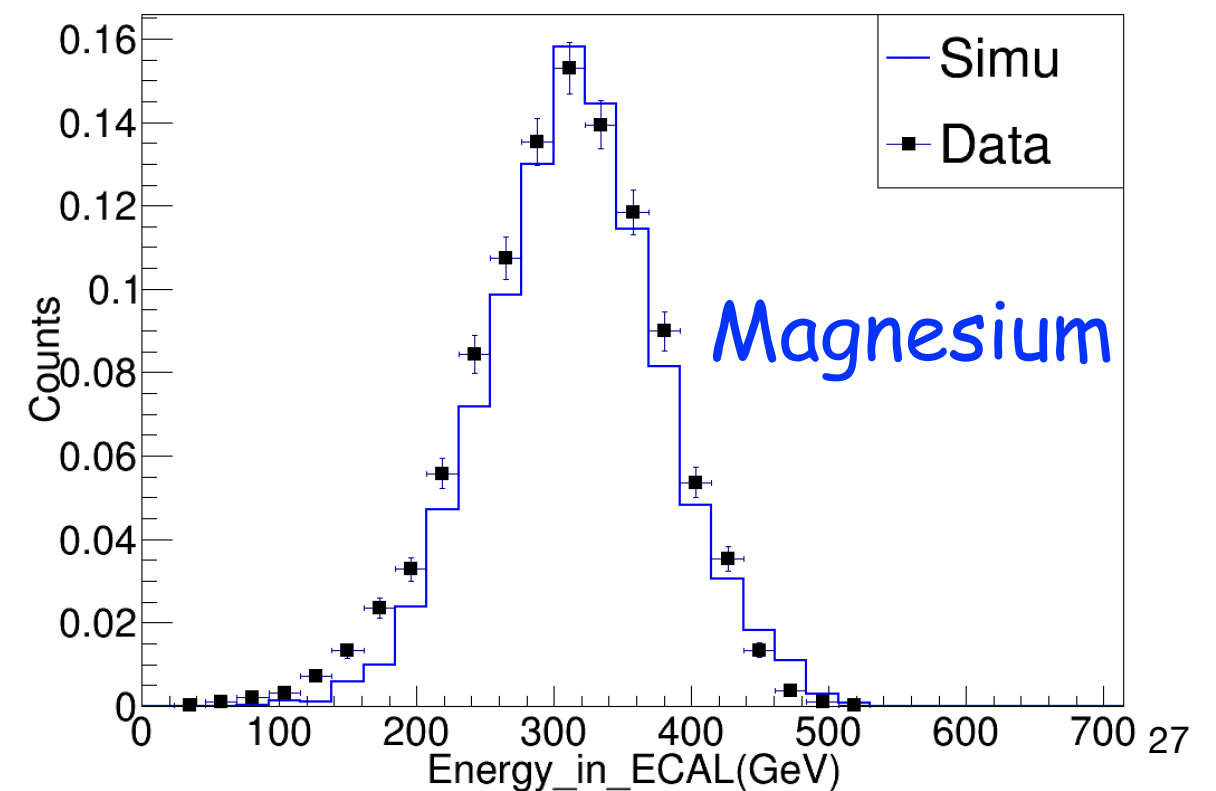
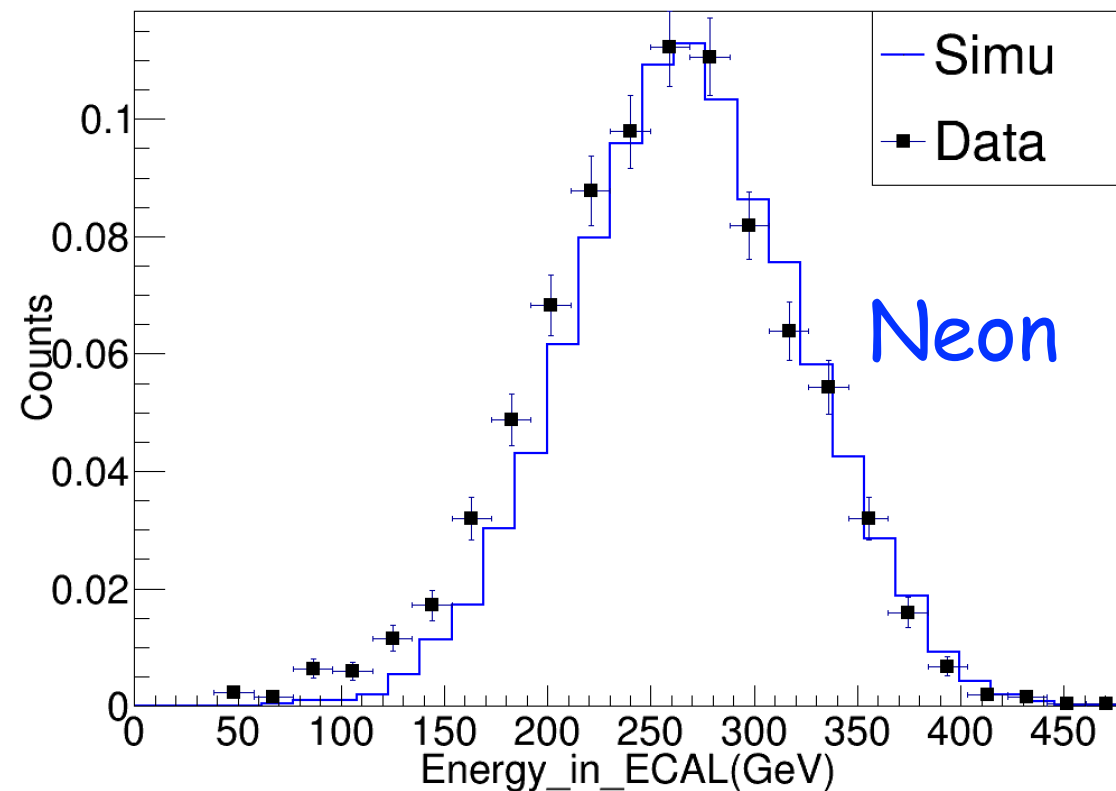
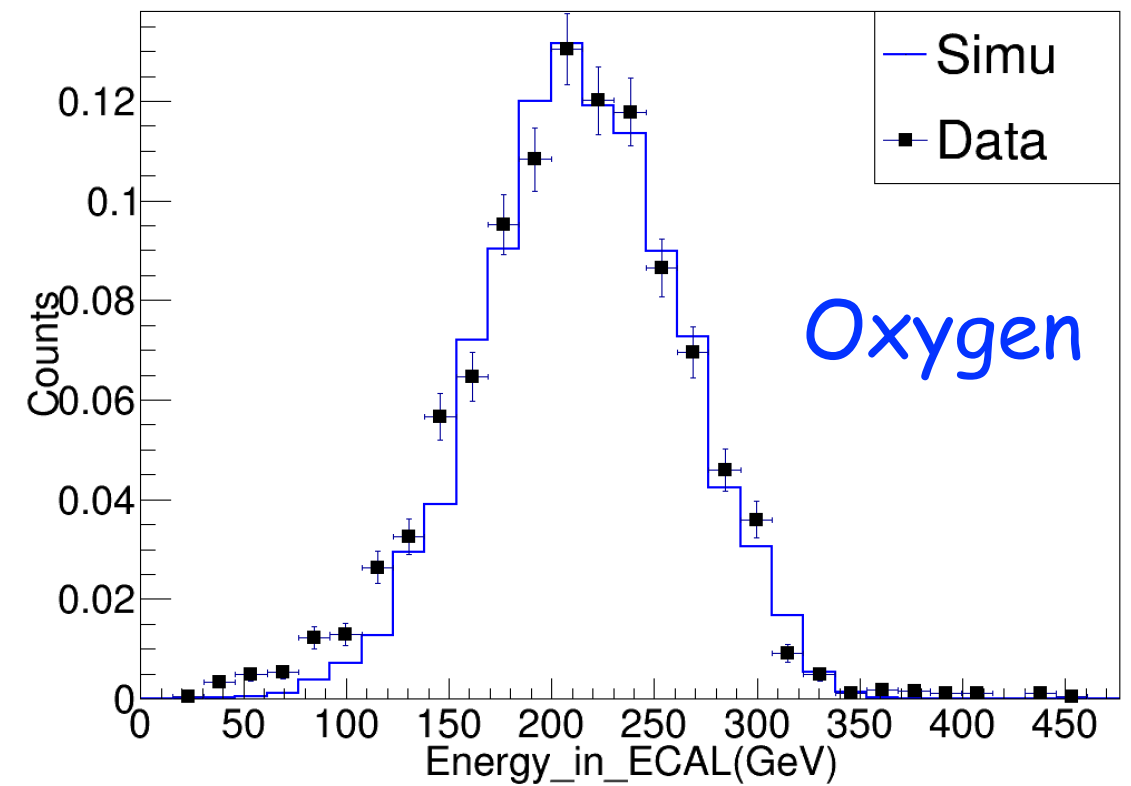
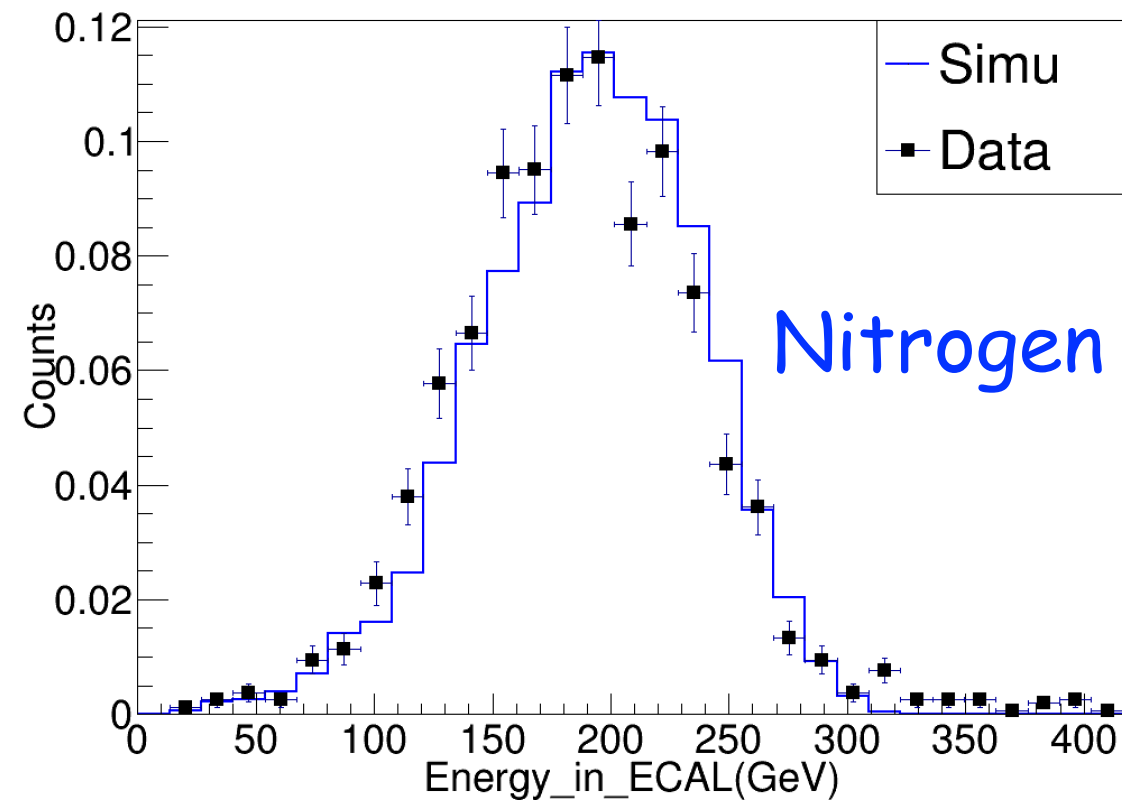
Thank you

Backup

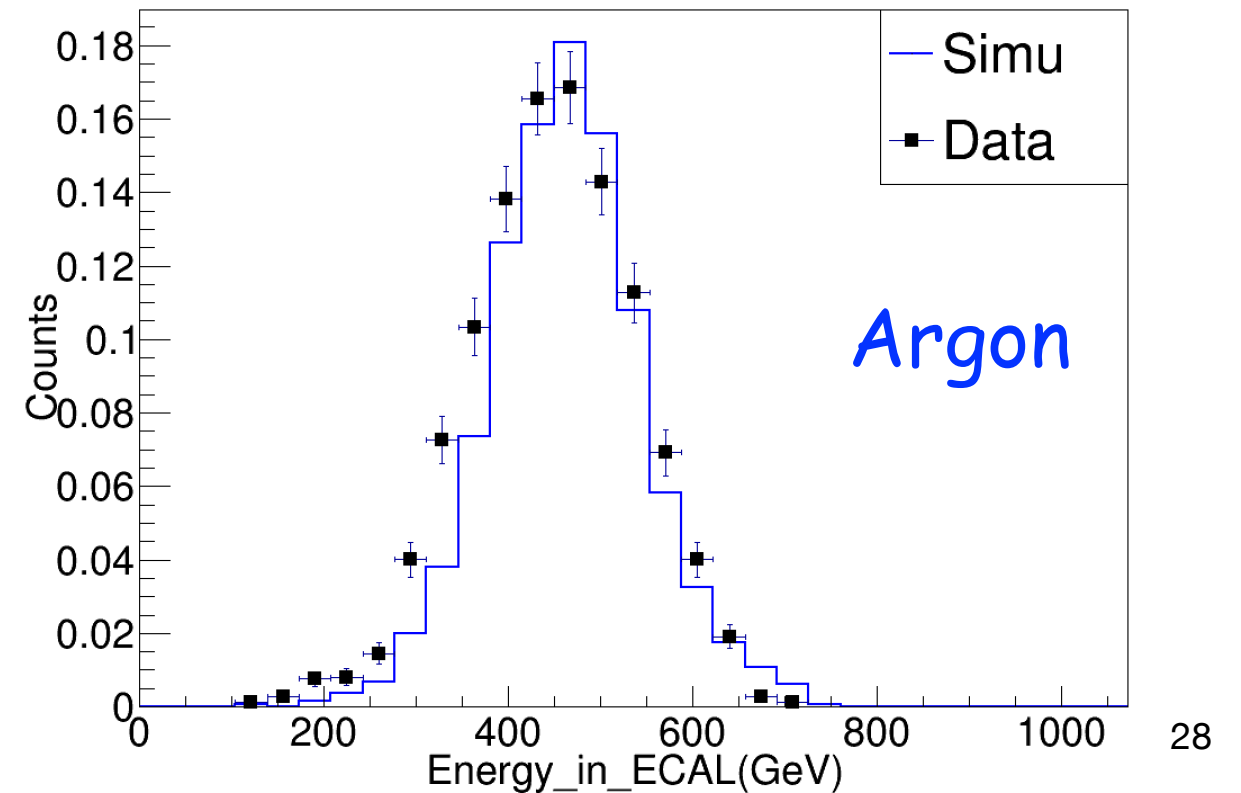
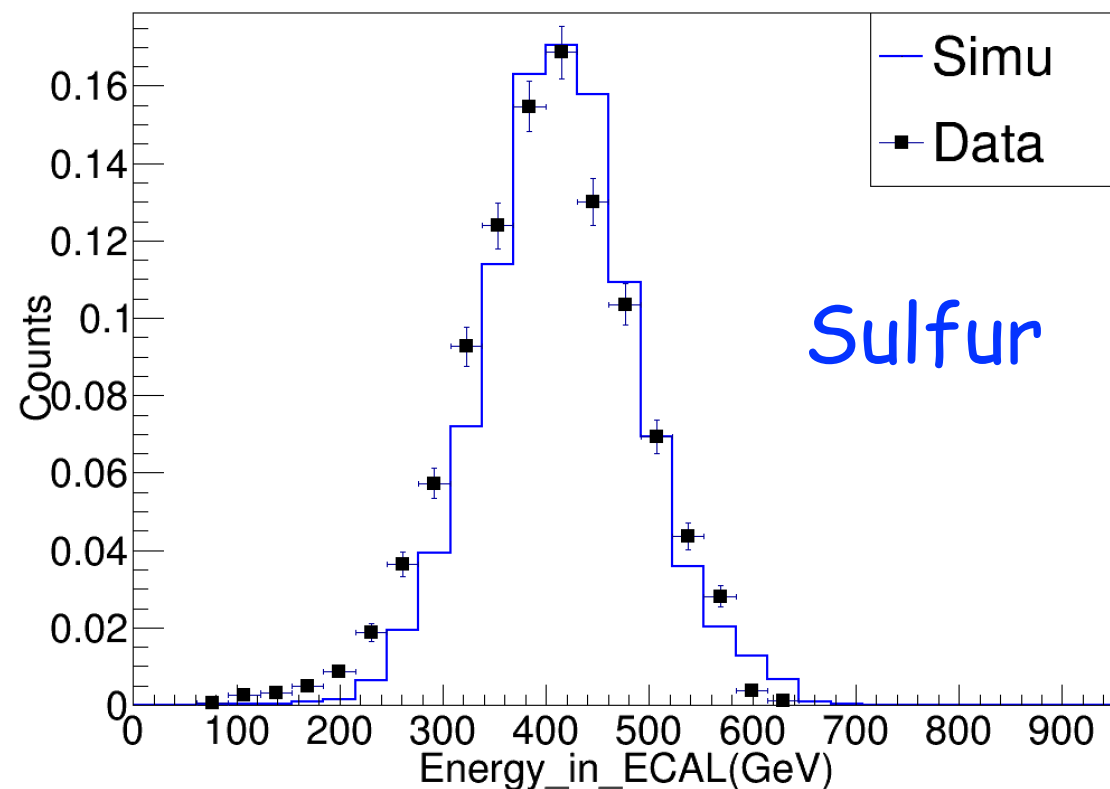
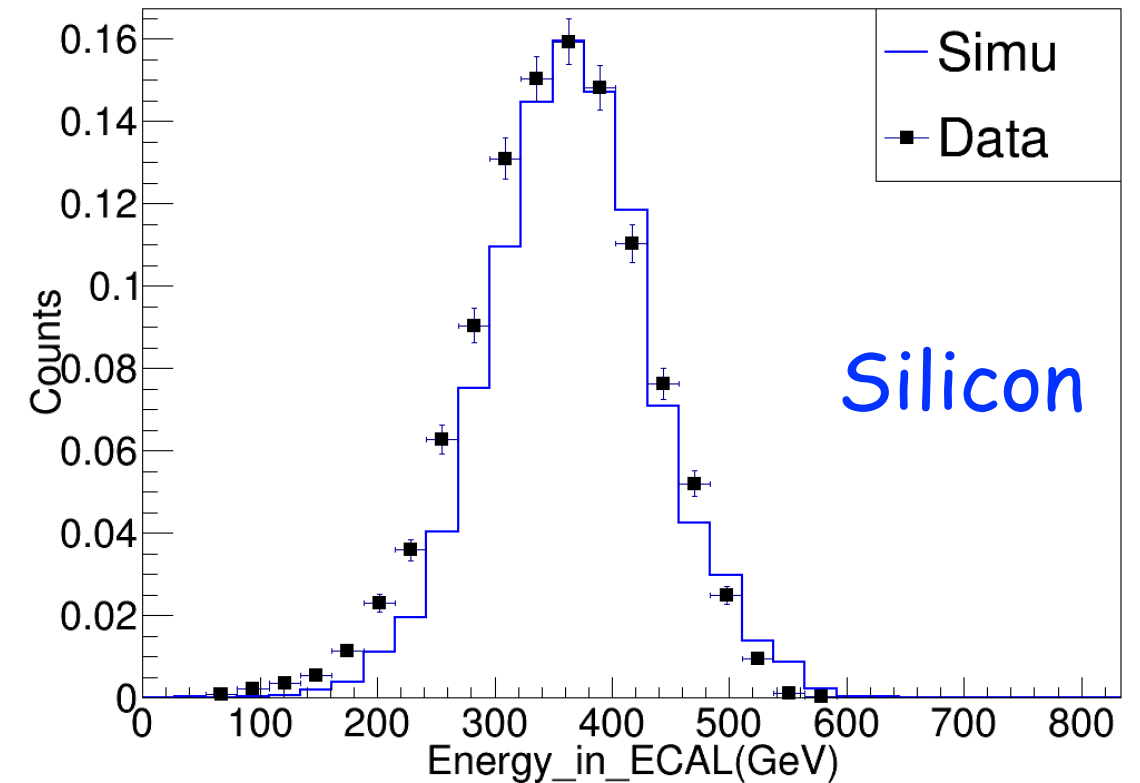
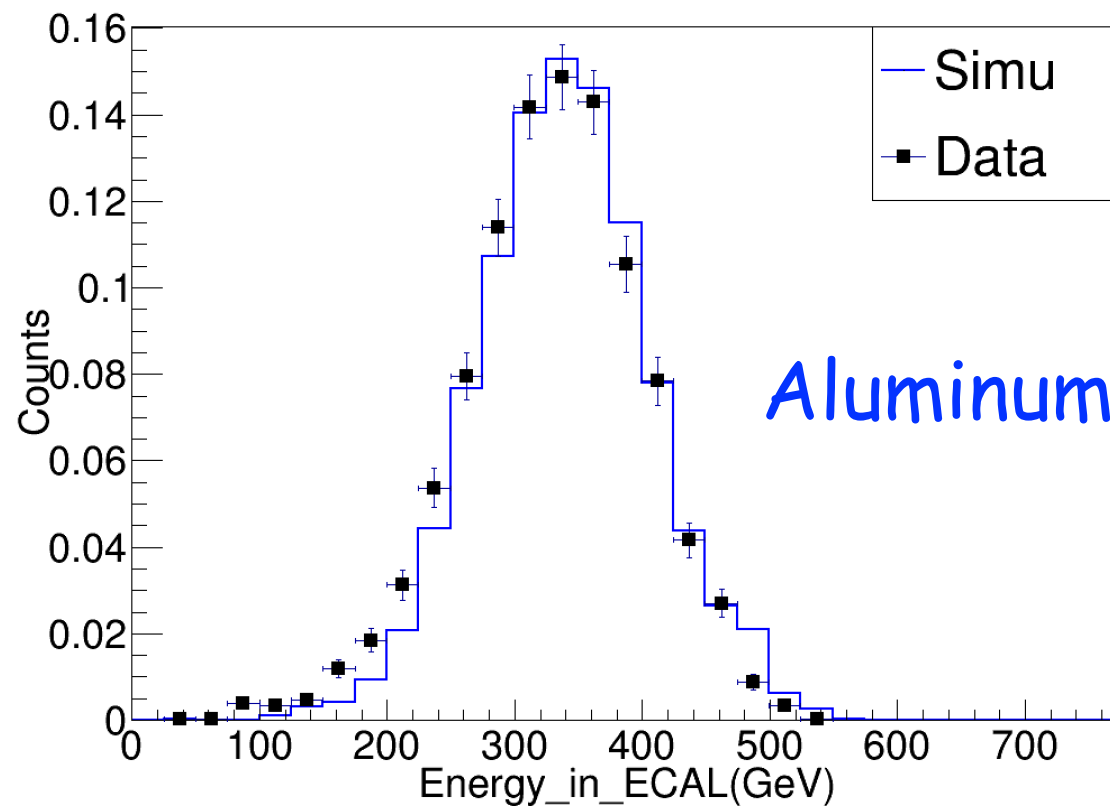
Energy Response to Nuclide (40 GeV/n)



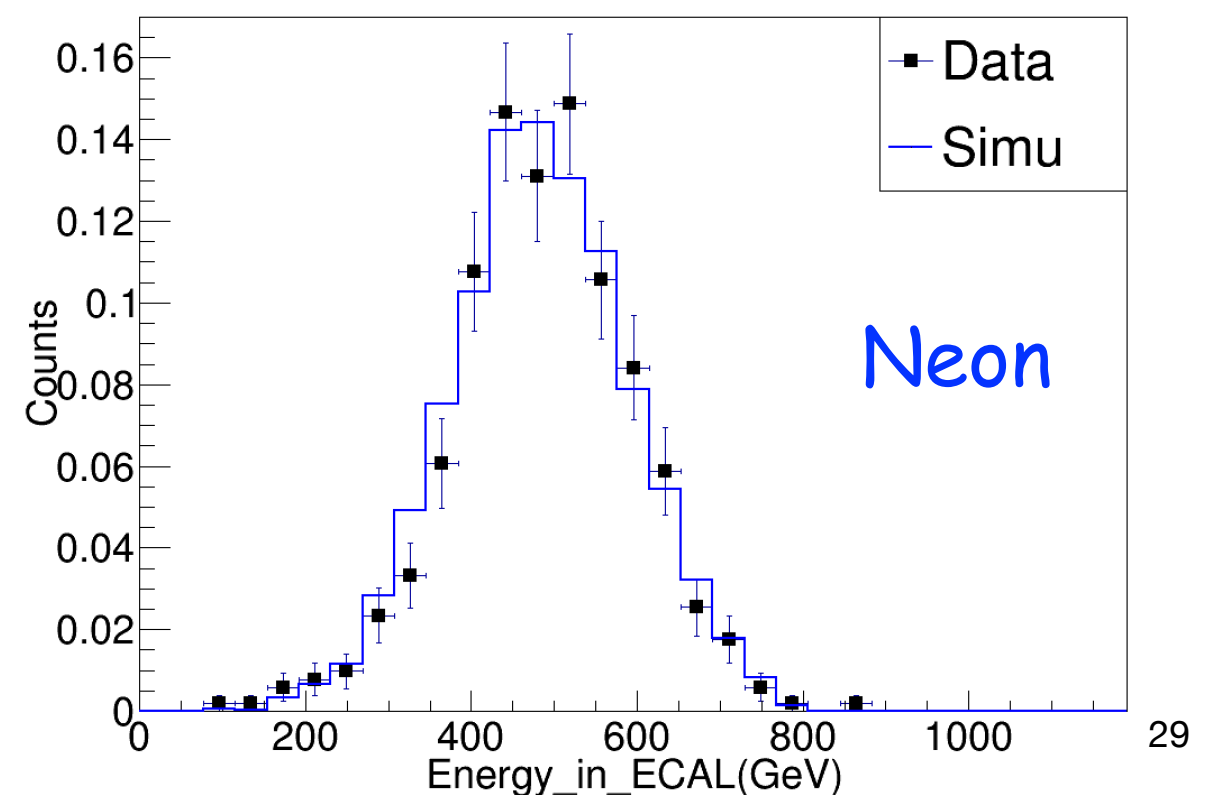
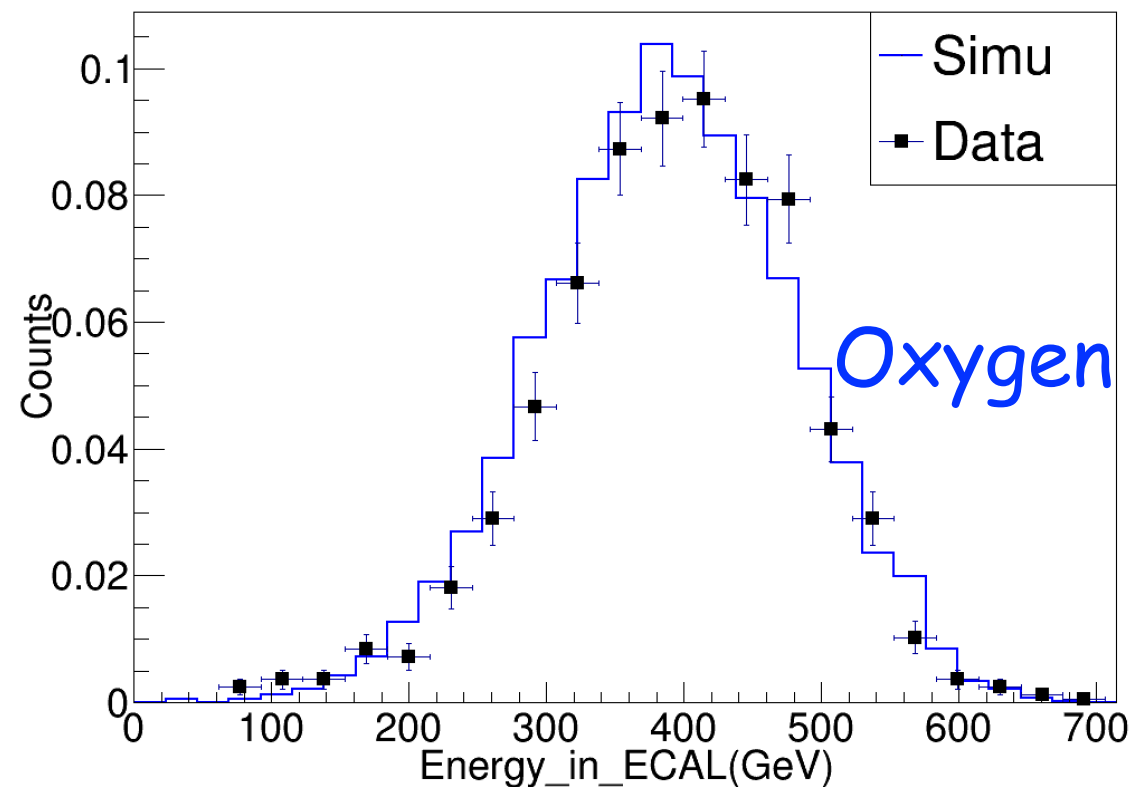
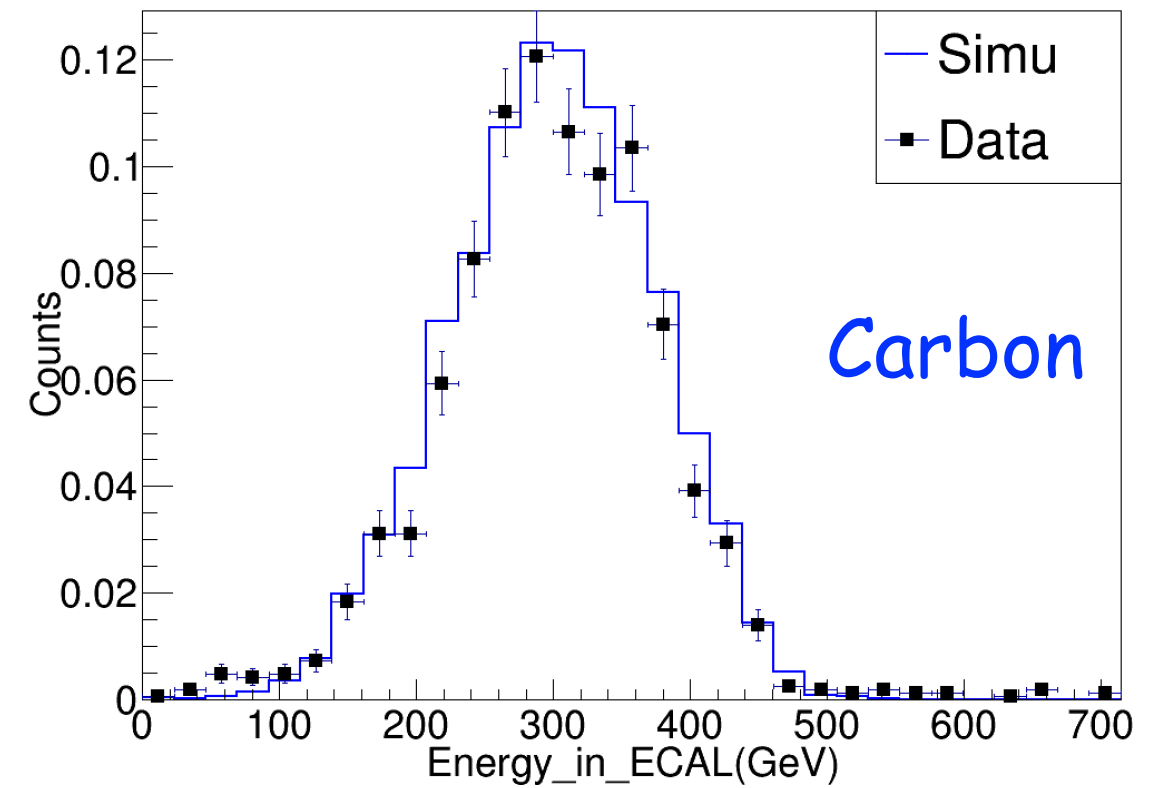
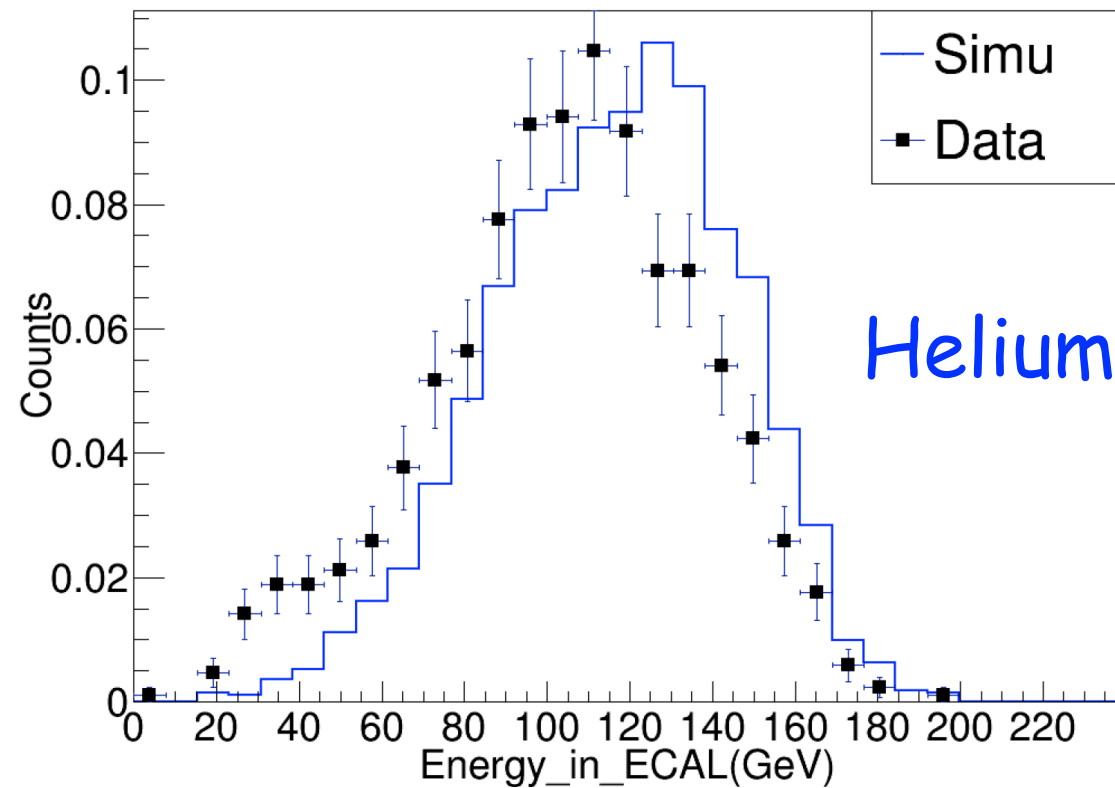
Energy Response to Nuclide (40 GeV/n)



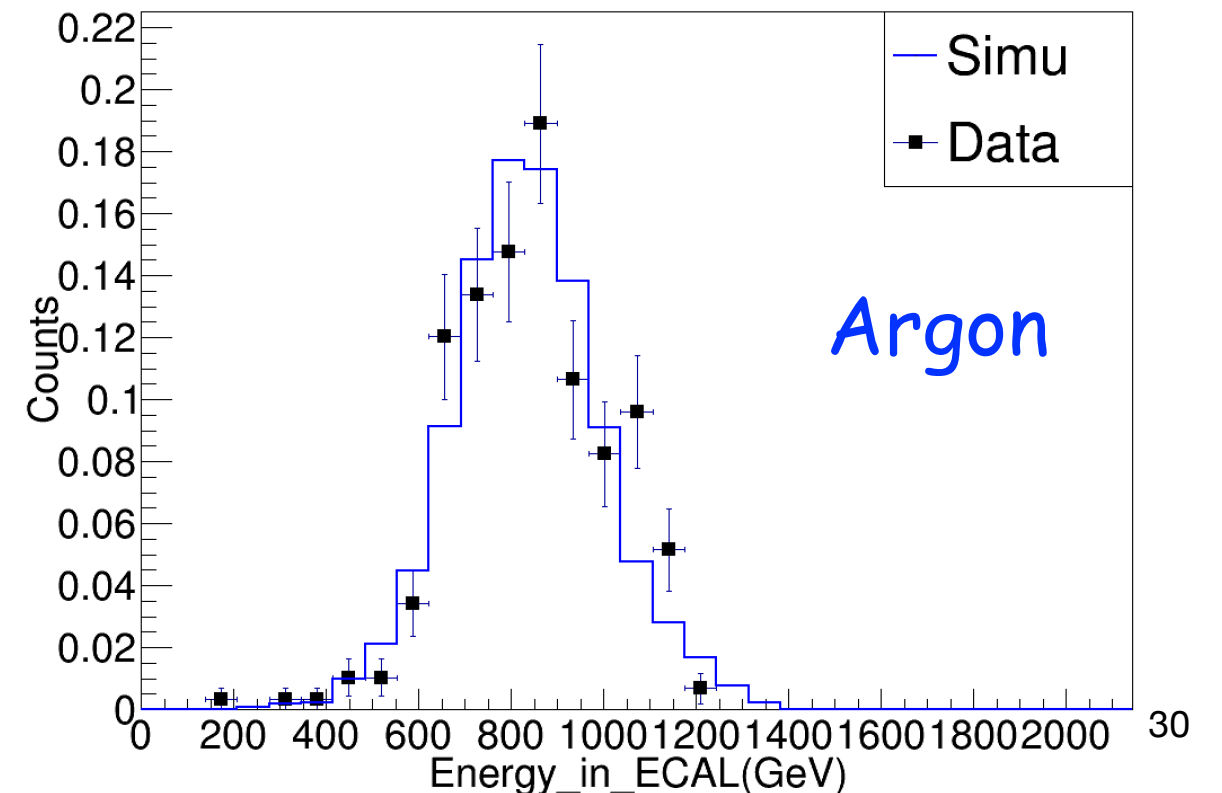
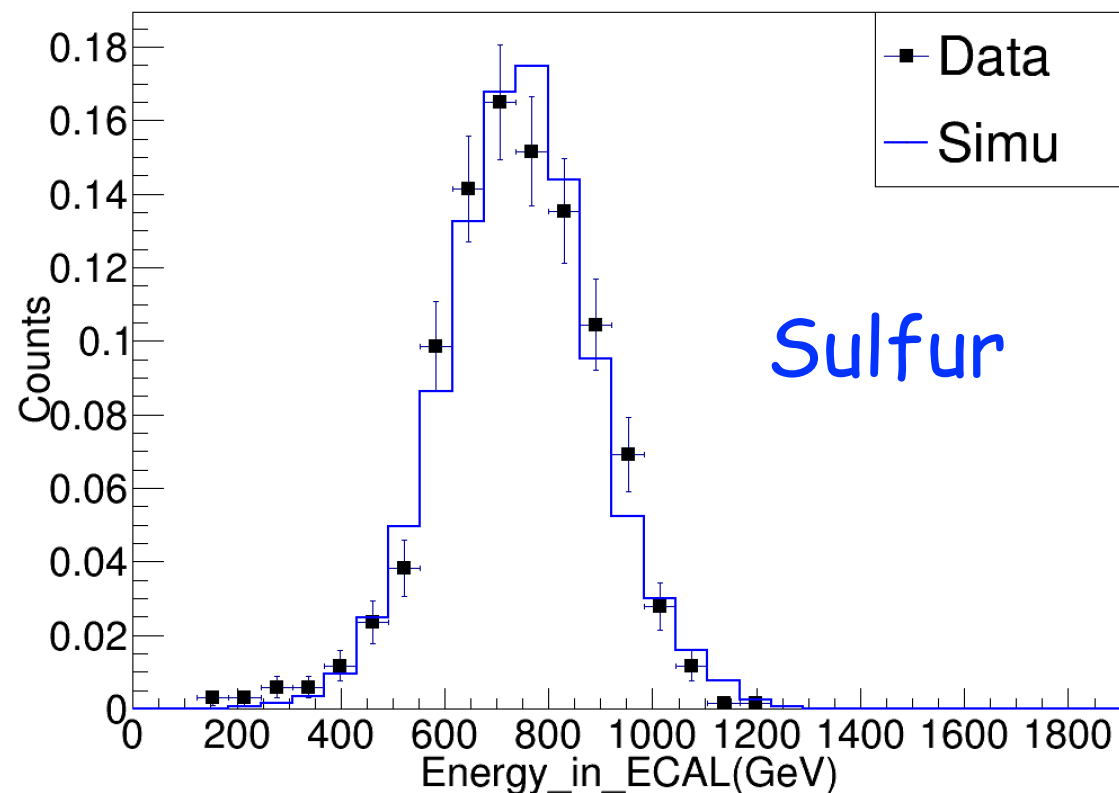
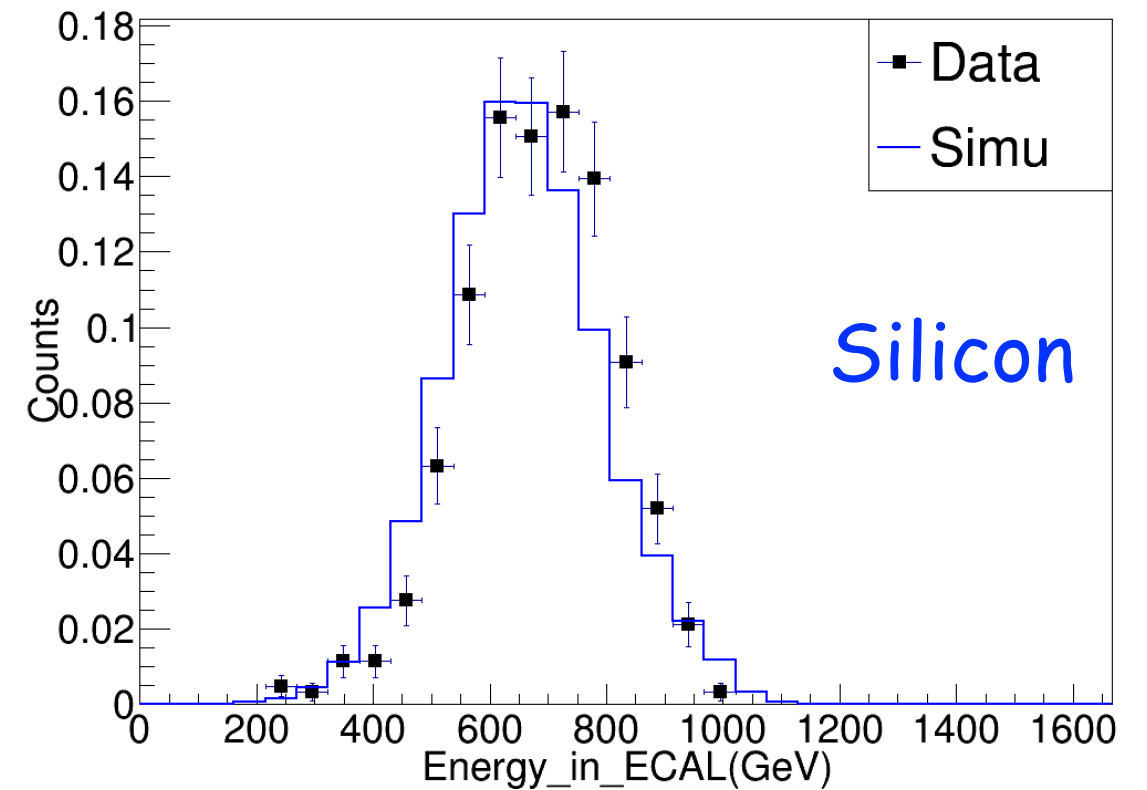
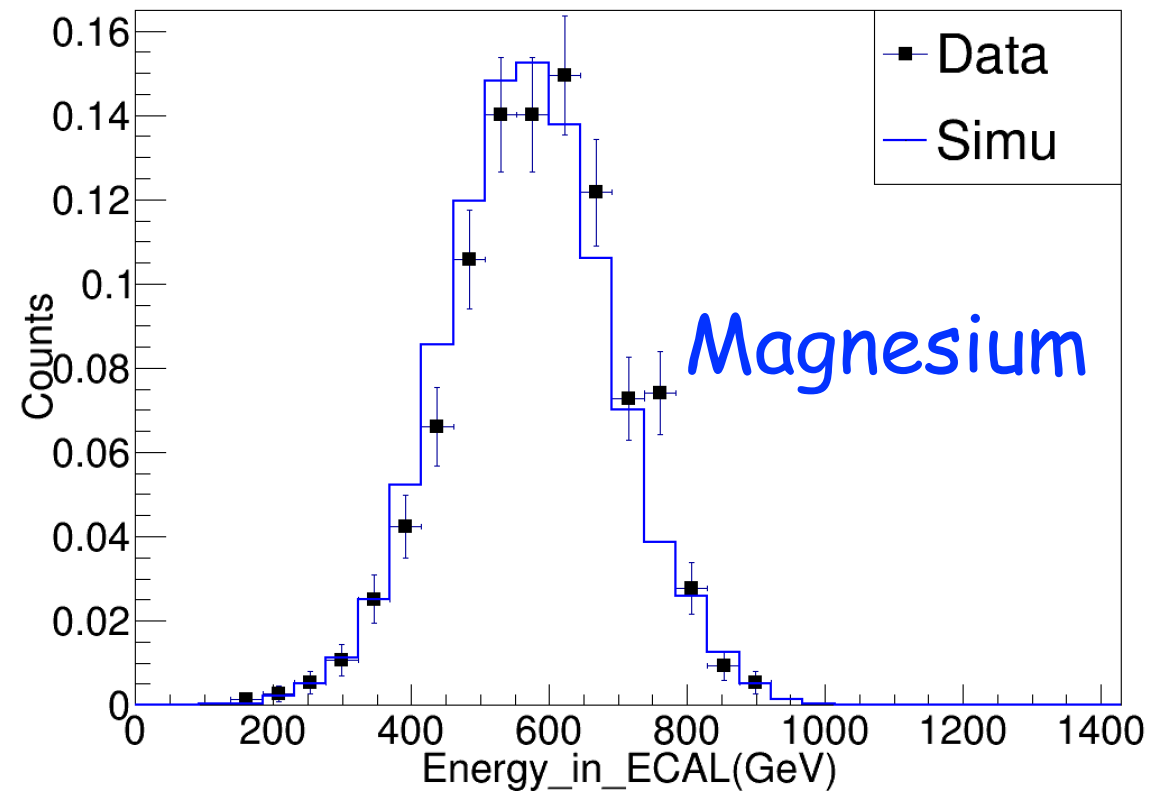
Energy Response to Nuclide (40 GeV/n)



Energy Response to Nuclide (75 GeV/n)



Energy Response to Nuclide (75 GeV/n)



Different MC Model (40 GeV/n)

