INFN
Istituto Nazionale
di Fisica Nucleare

Results from Beam Test of the CaloCube Prototype

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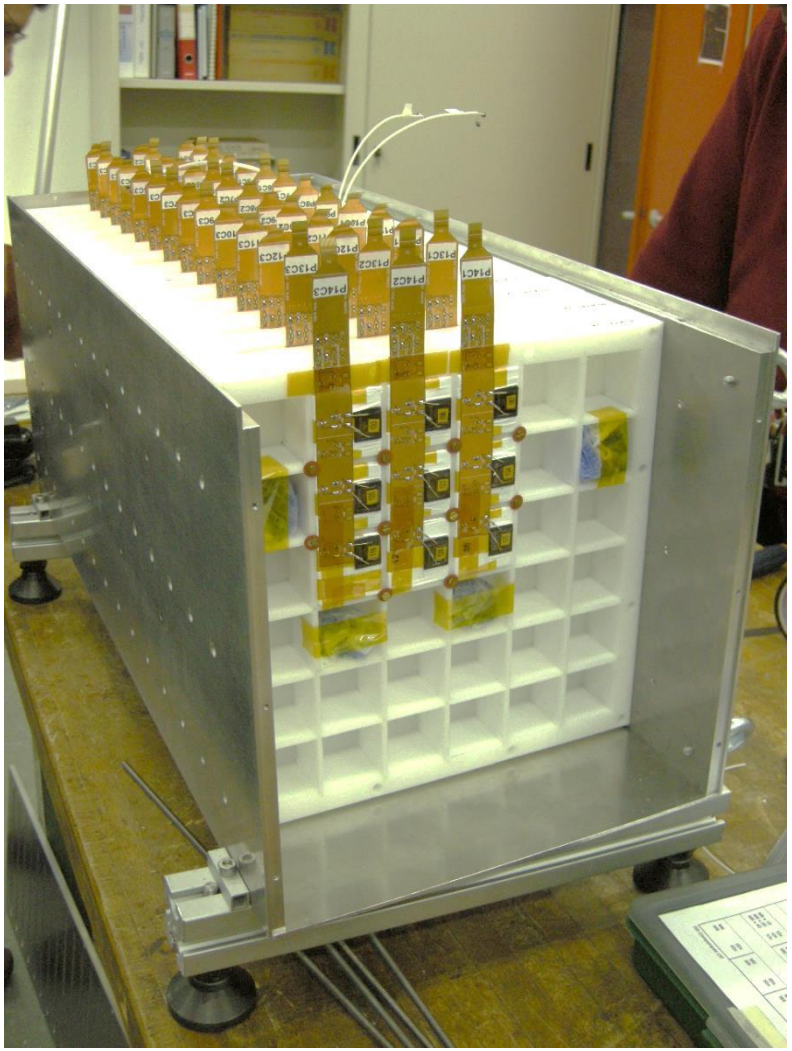
On behalf of the CaloCube collaboration

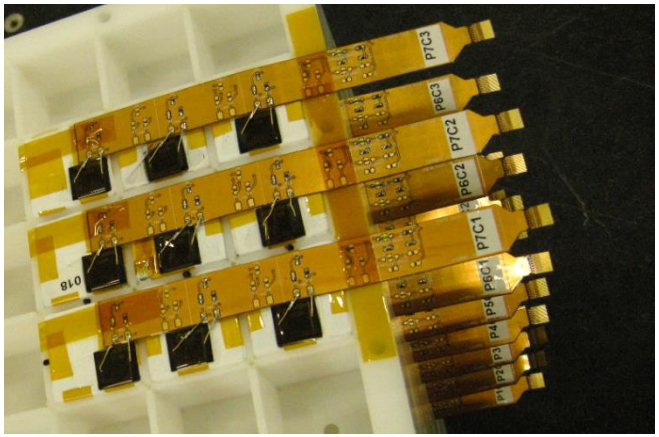
The prototype: active material

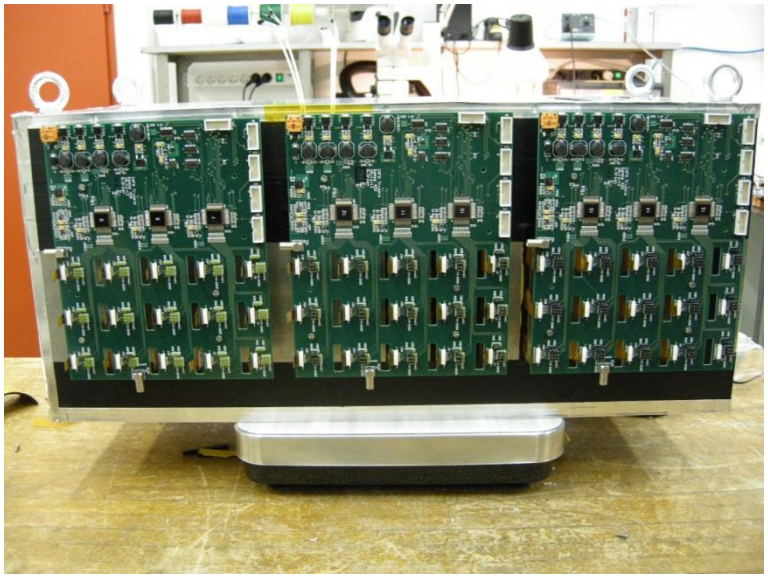
- **CsI(Tl)** scintillating crystals (produced by Amcrys)
- 3×3×14=**126** cubic elements
- **3.6 cm** side + **0.3 cm** gap
- active depth **27 X_0→1.44 λ_I**



The prototype: sensors & front-end electronics

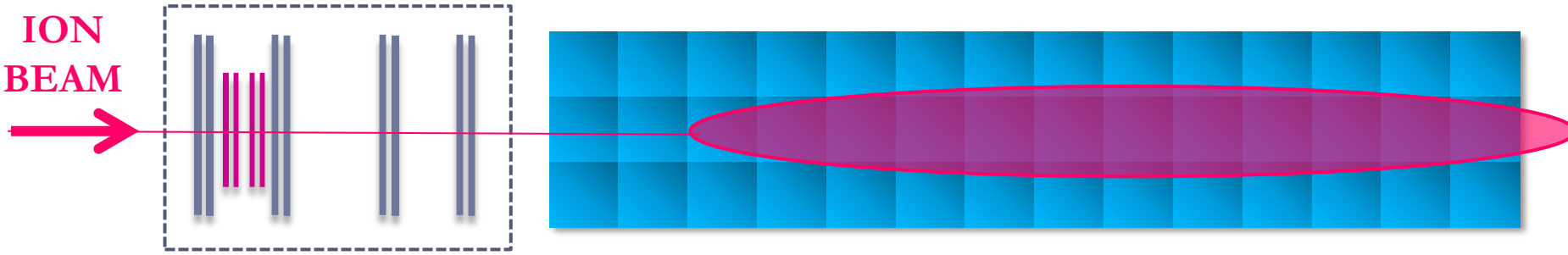
- **Excelitas VTH2090 photodiodes**
  - Large area (9.2×9.2mm^2)
- **CASIS chip** (developed by INFN-Trieste)
  - Very large dynamic range (0÷10000 MIP)
  - Automatic switching btw low and high (×20) gain mode
  - 16 channels (CSA+CDS shaper)





Setup of Feb 2013 Beam Test

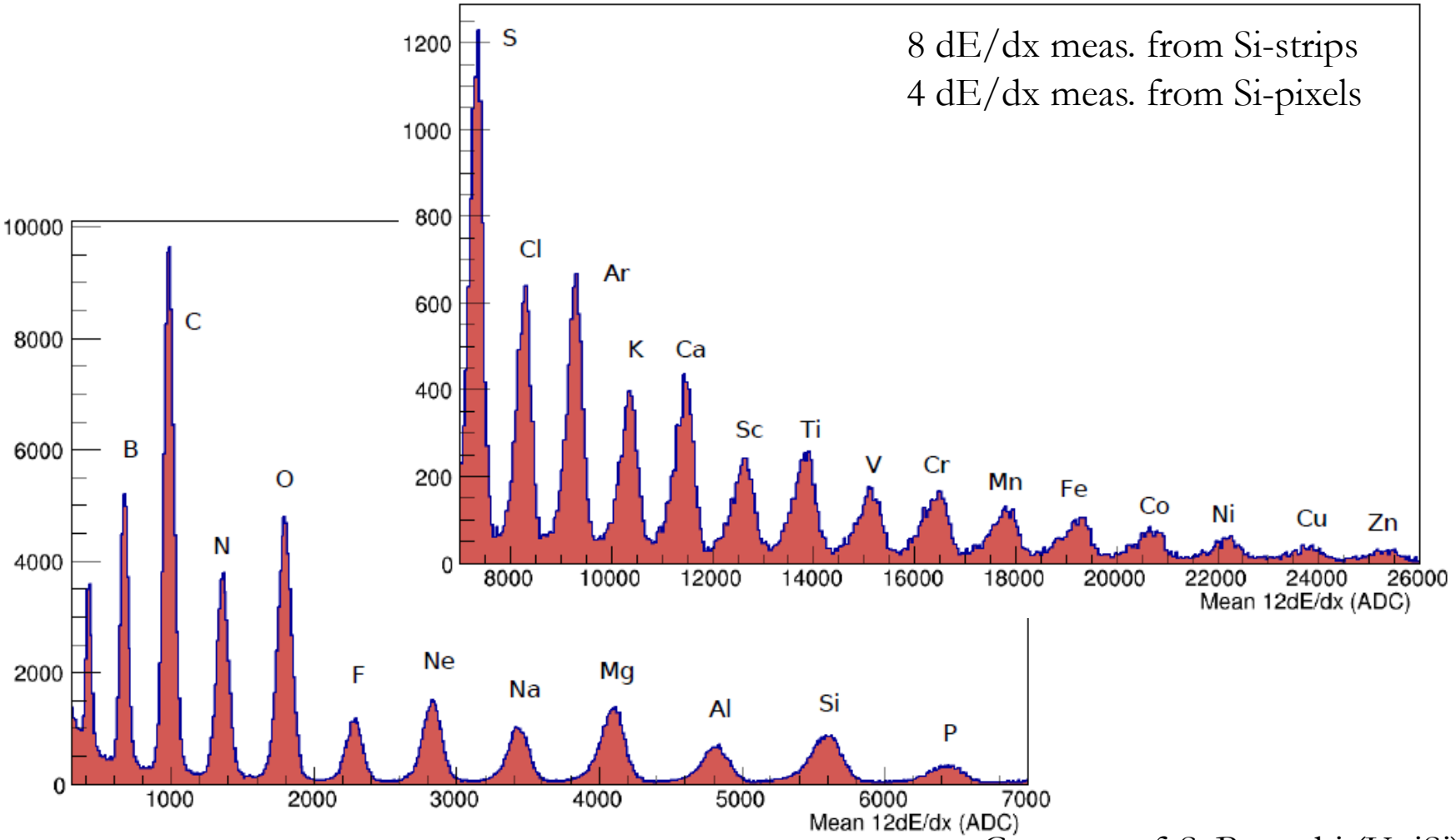
- Ion beam extracted from CERN SPS H8 line
- Primary Pb beam on Be target
- Nuclear fragments A/Z=2, from Deuterium to Iron
- Energy: **12.8** and **30.0 GeV/amu**



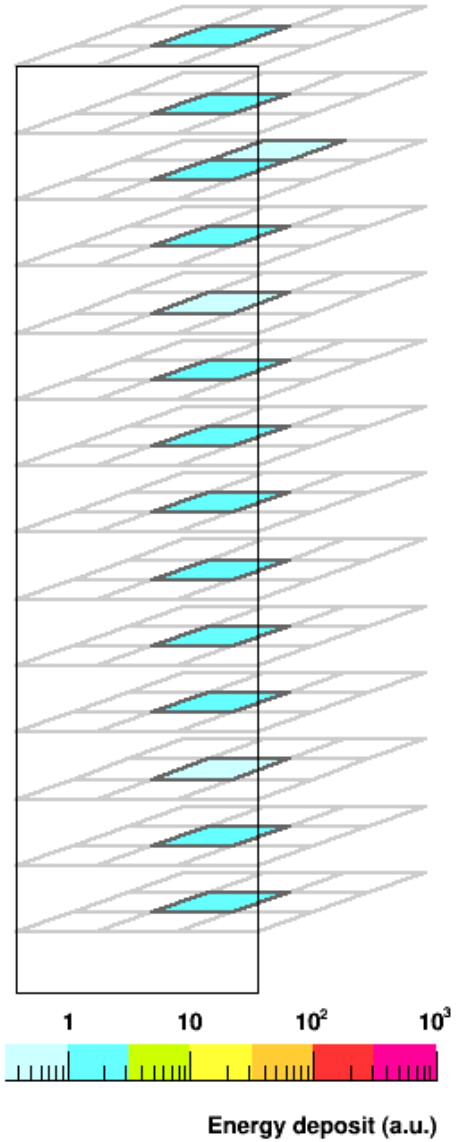
BEAM TRACKER (BT)
4 Si-pixel matrixes + 8 Si-strip layers
- Z tagging
- particle tracking (<200μm spatial resolution)

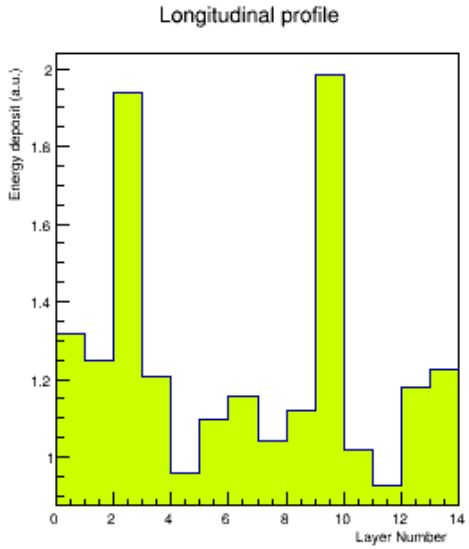
CALORIMETER
3×3×14 CsI crystals

Z-tagging with Beam Tracker (BT)

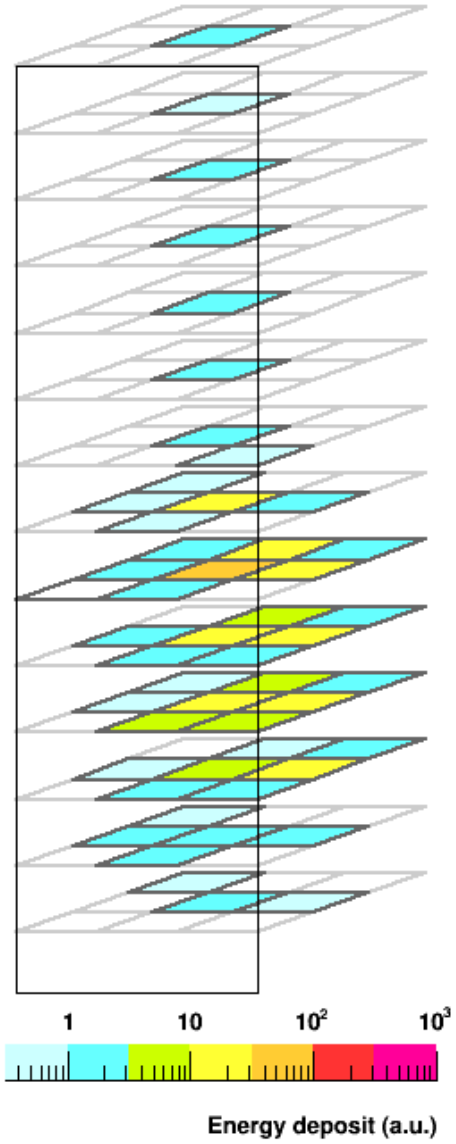


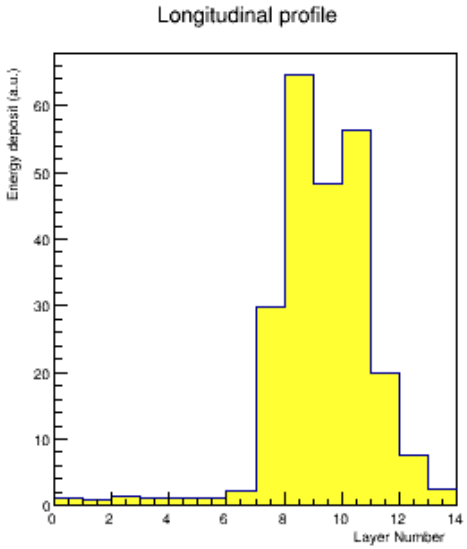
Courtesy of S. Bonechi (UniSi)



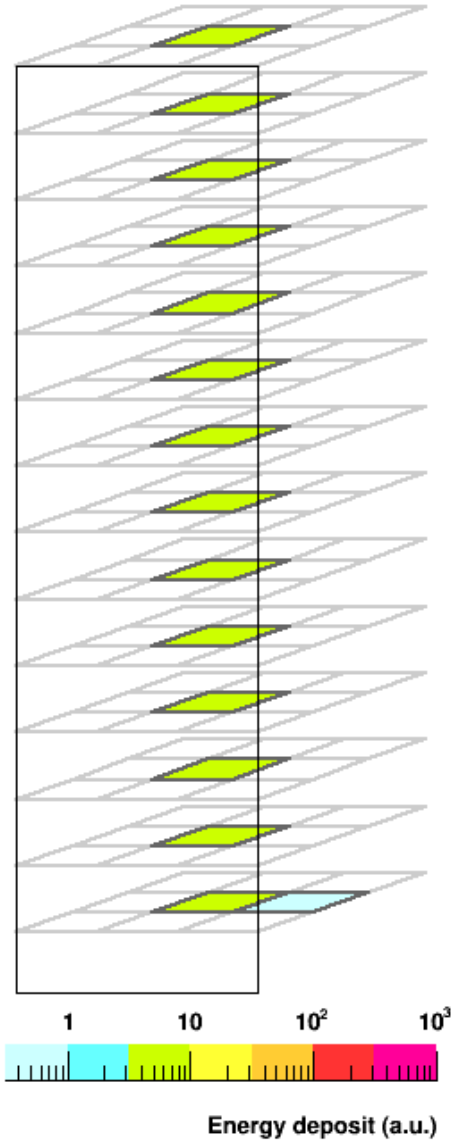


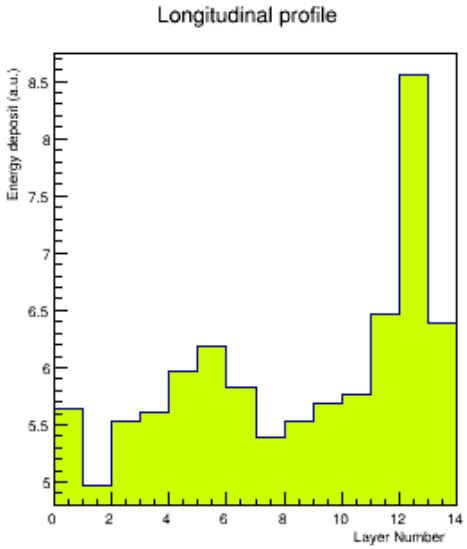
Deuterium
12.8 GeV/amu



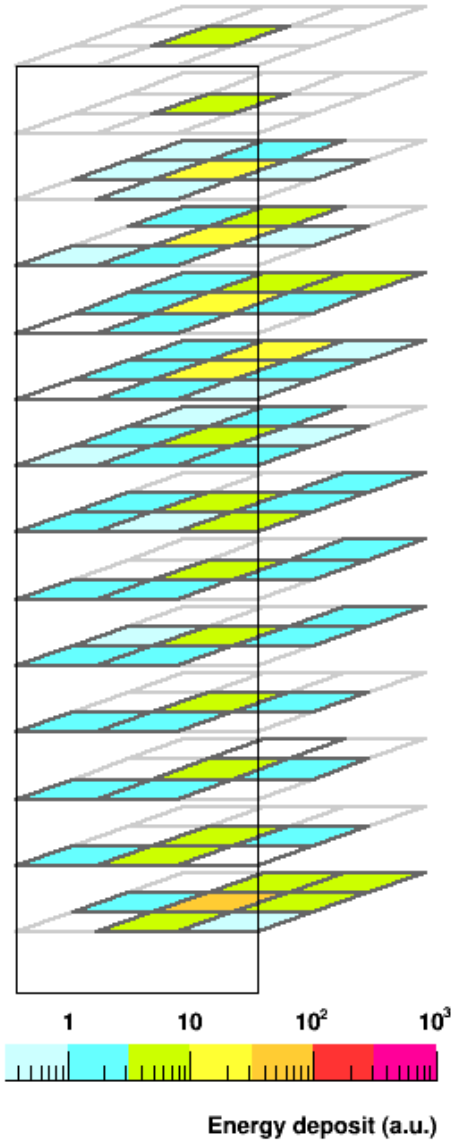


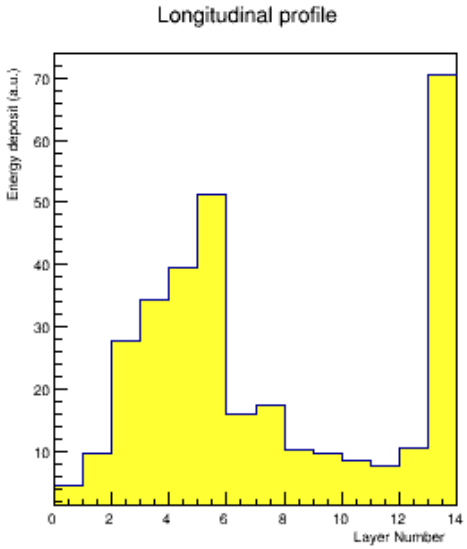
Deuterium
12.8 GeV/amu



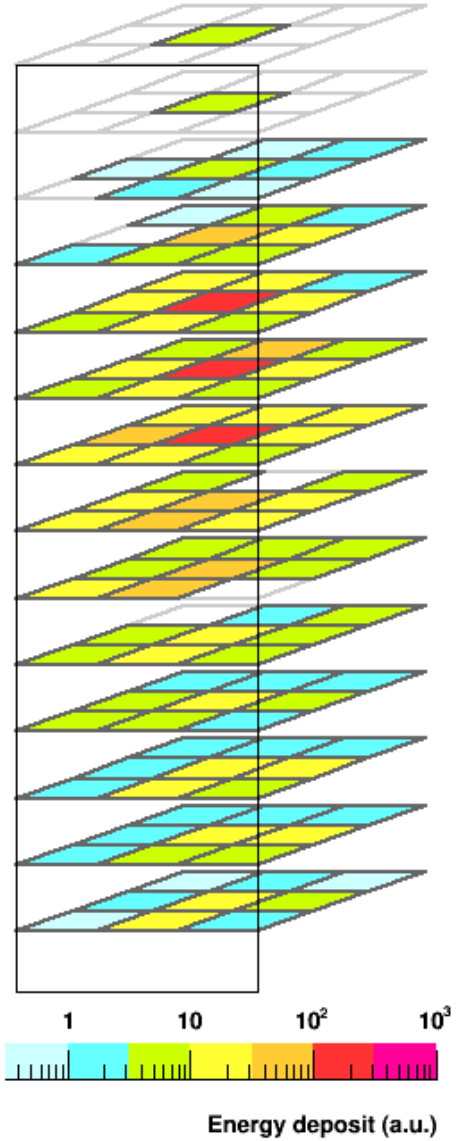


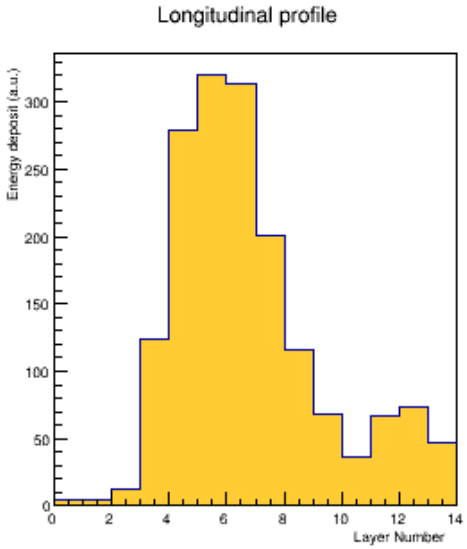
Helium
12.8 GeV/amu



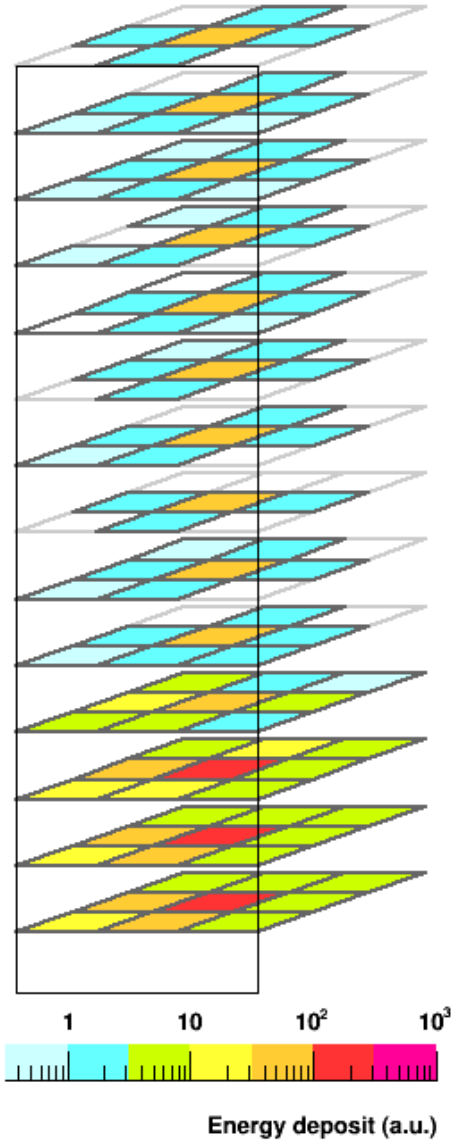


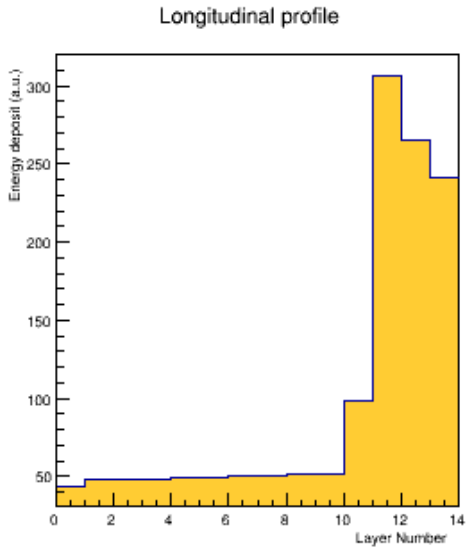
Helium
12.8 GeV/amu



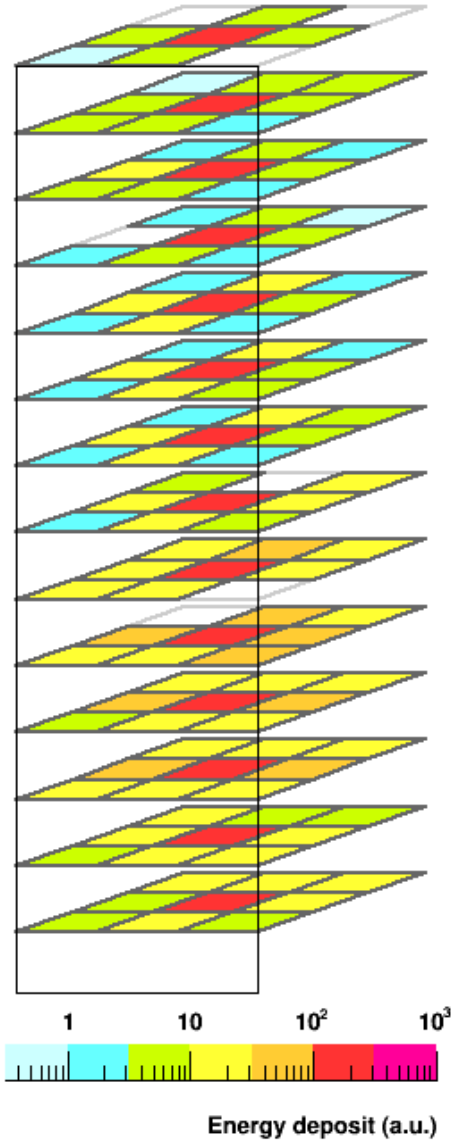


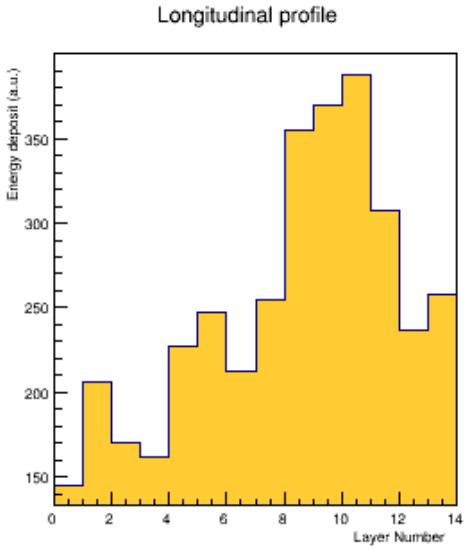
Helium
30.0 GeV/amu





Carbon
12.8 GeV/amu

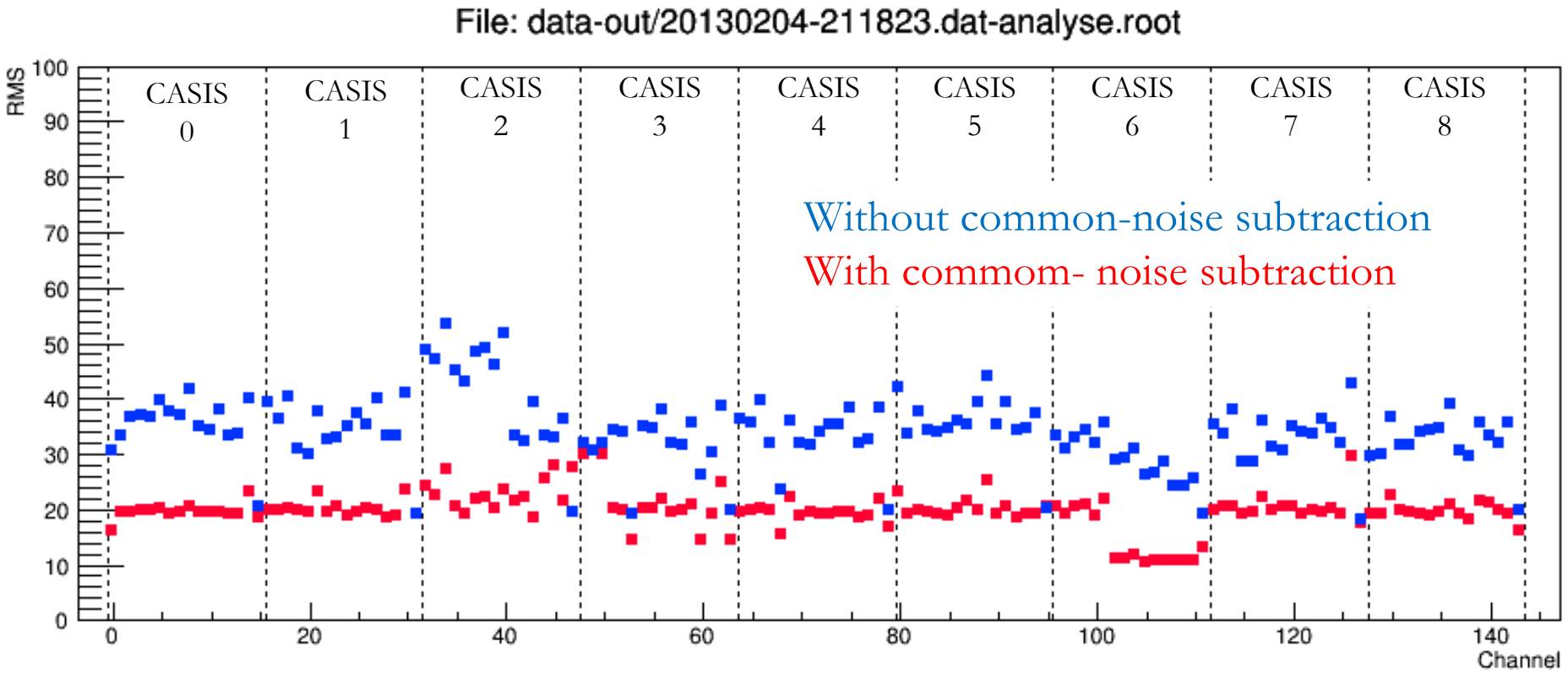




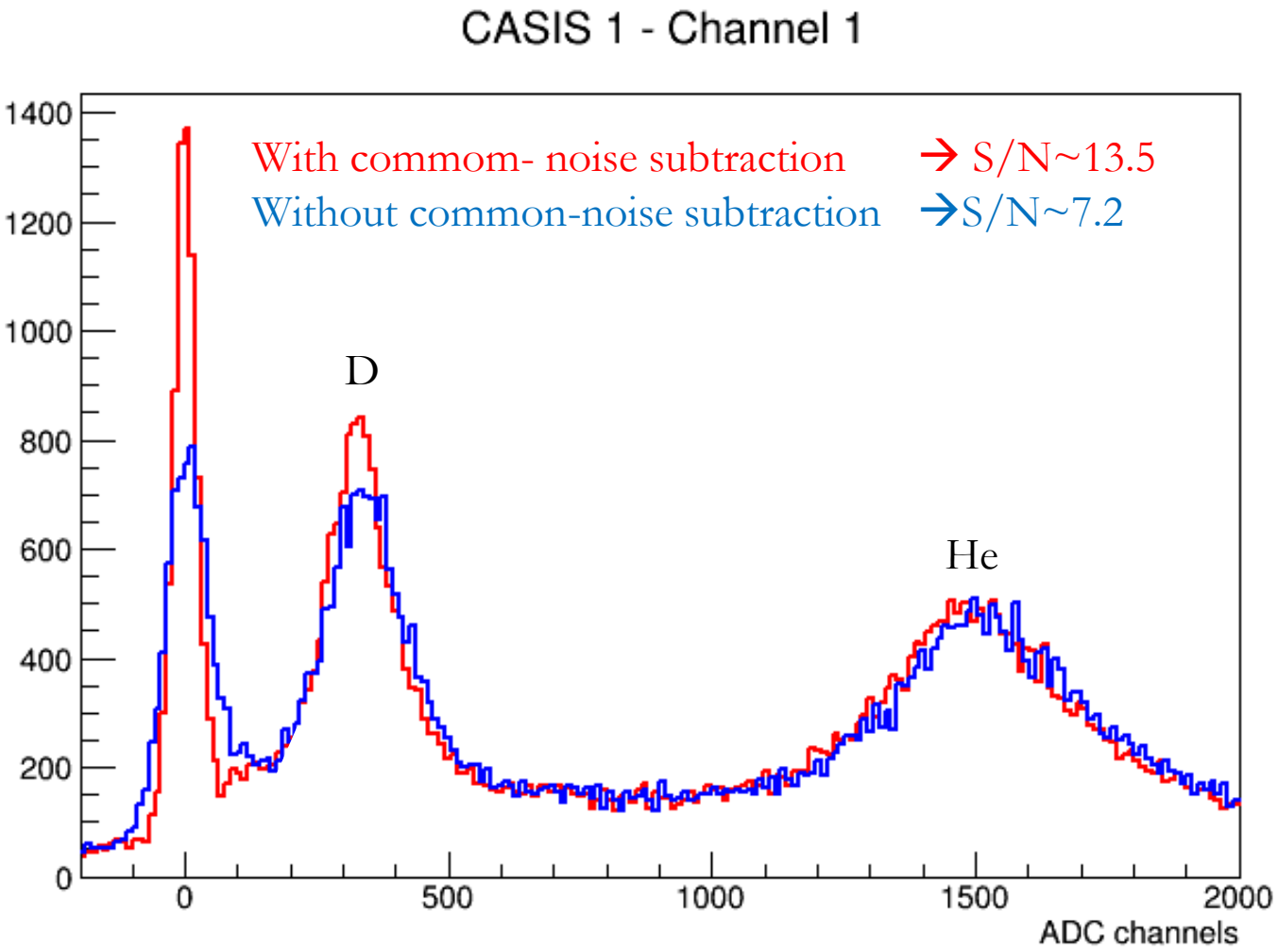
Sodium
12.8 GeV/amu

Single crystal performance

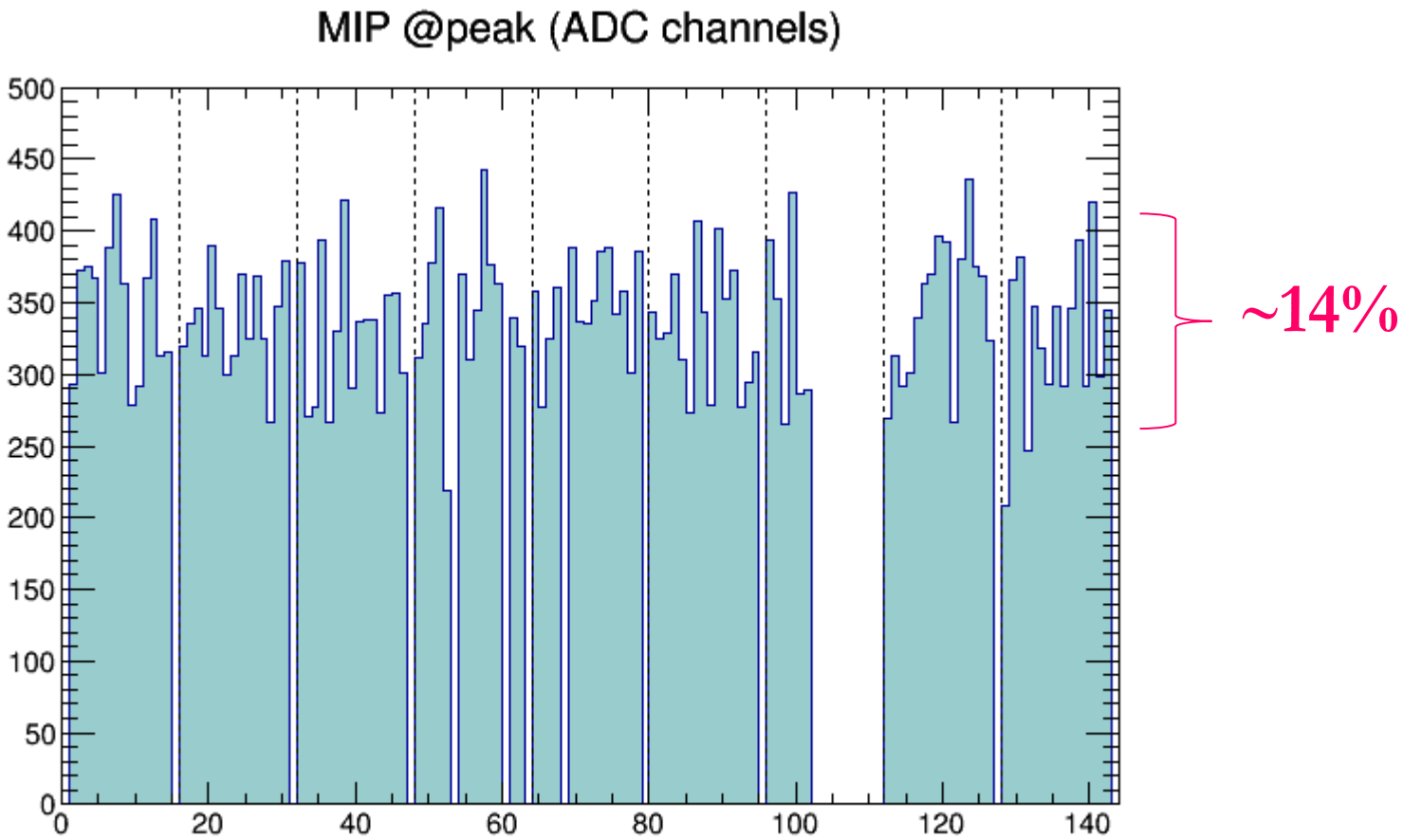
Channel Noise



MIP signal

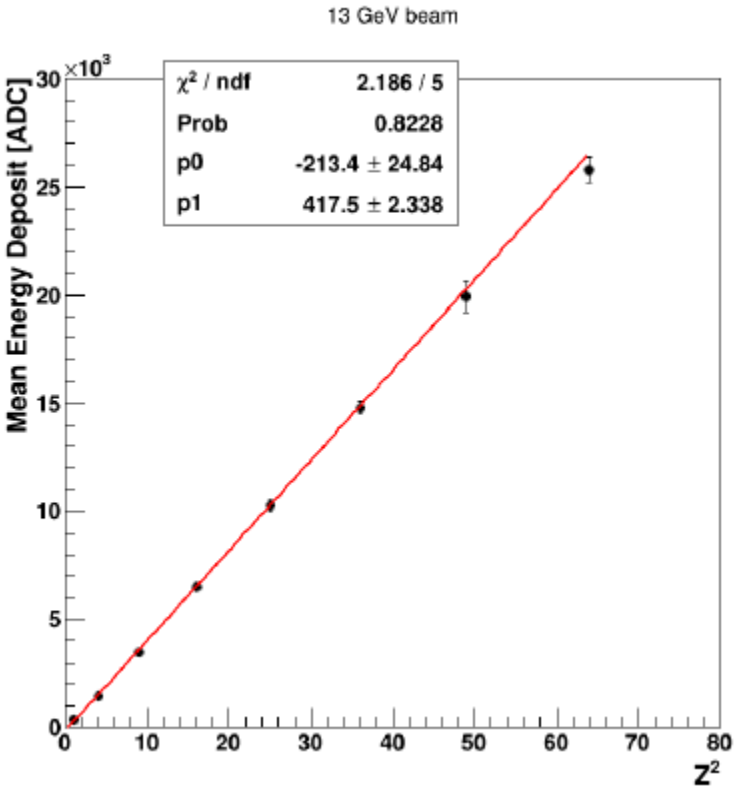

CASIS 1 - Channel 1
With commom- noise subtraction → S/N~13.5
Without common-noise subtraction →S/N~7.2
D
He
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
ADC channels

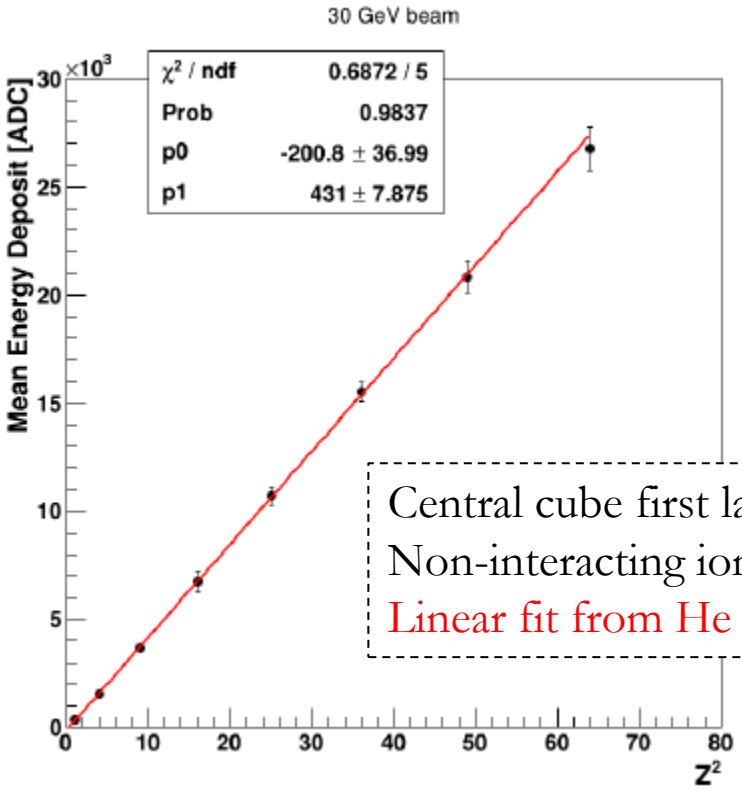
Gain dispersion



Crystal responses equalized by normalizing to 1MIP energy deposit (@peak)

Single-crystal linearity (1)



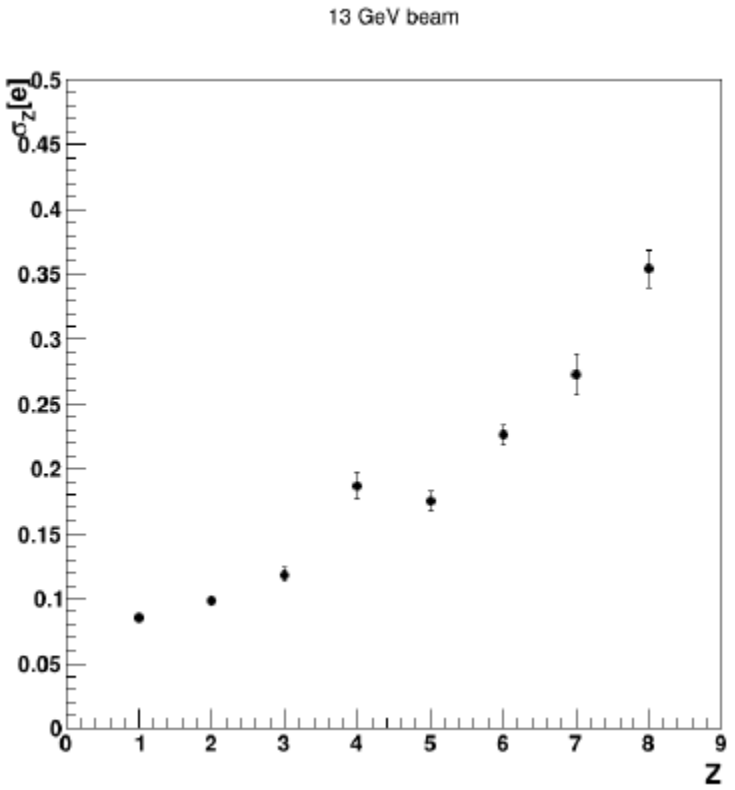


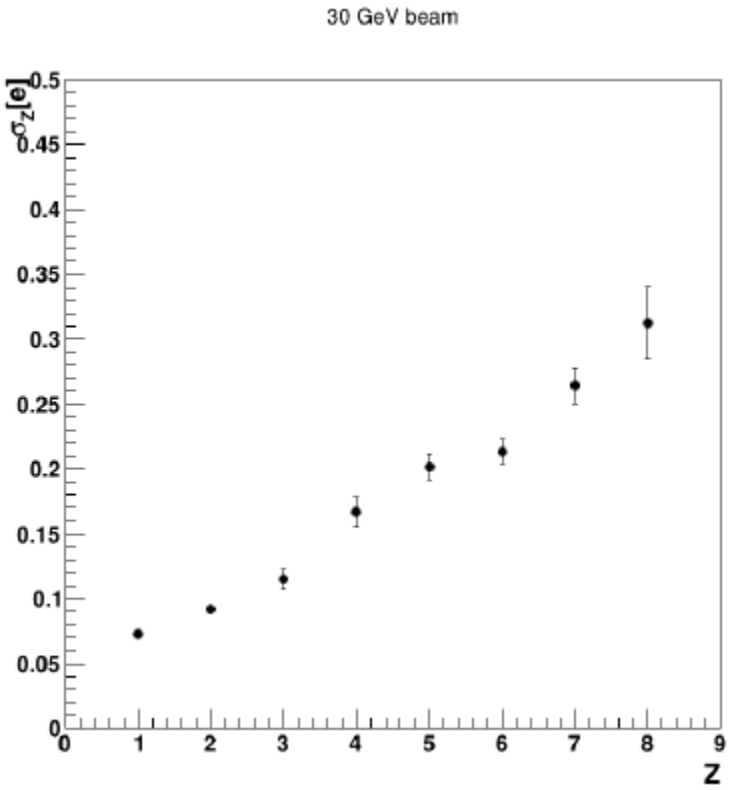
Central cube first layer
Non-interacting ions
Linear fit from He to O

Courtesy of G. Bigongiari (UniSi)

Z resolution

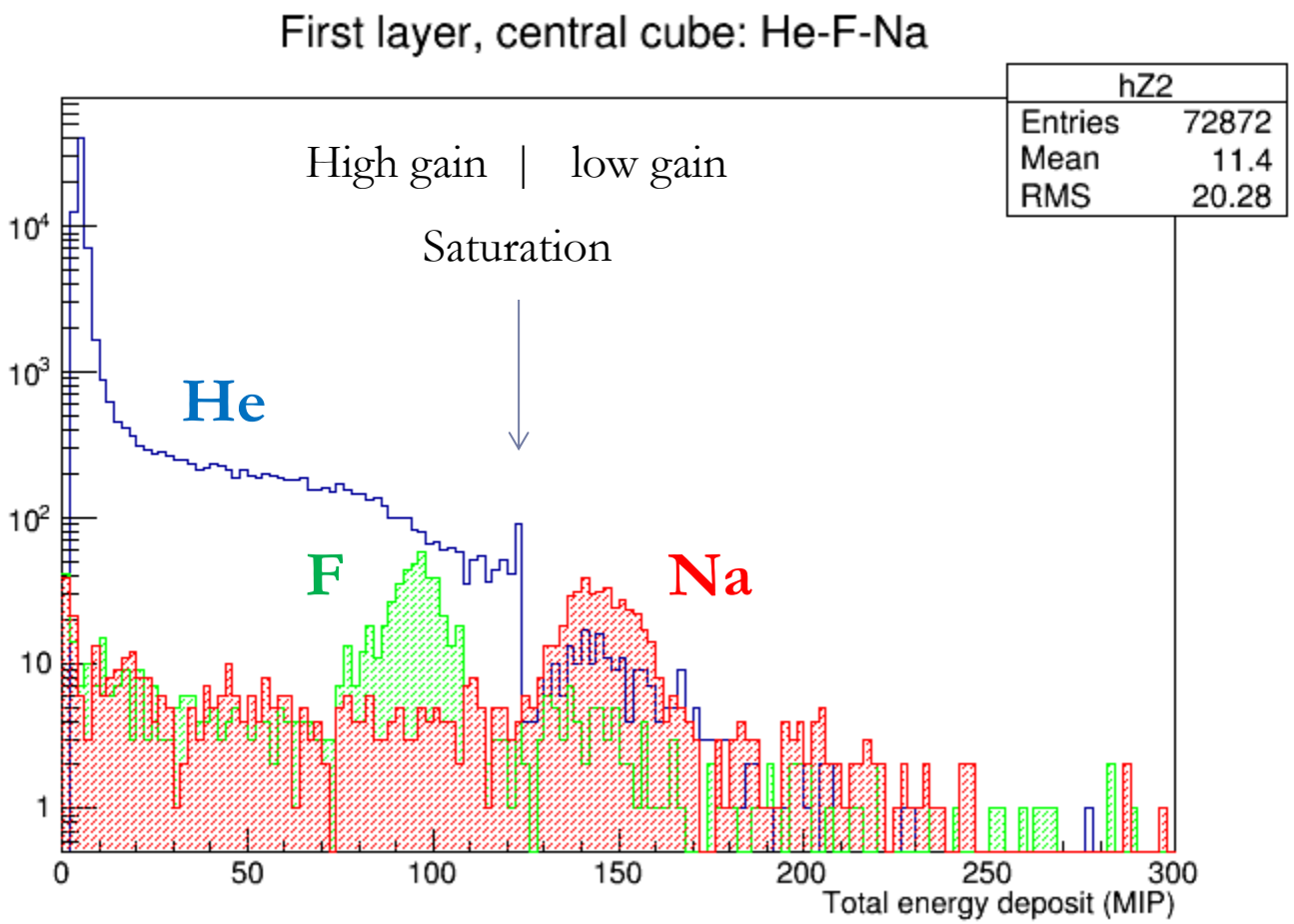
$$\sigma_z = \frac{RMS[Z]}{Mean[Z+1] - Mean[Z]}$$



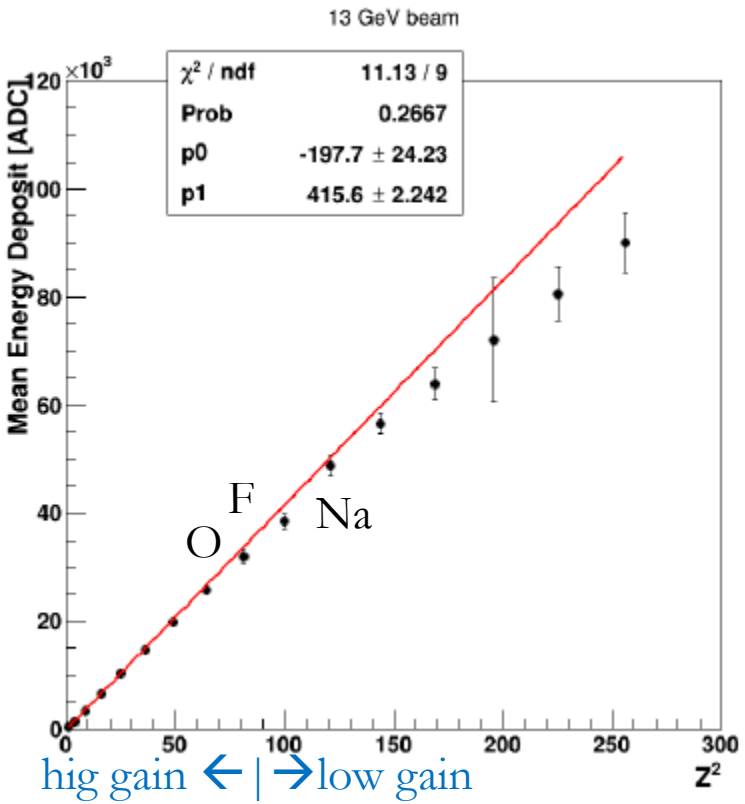


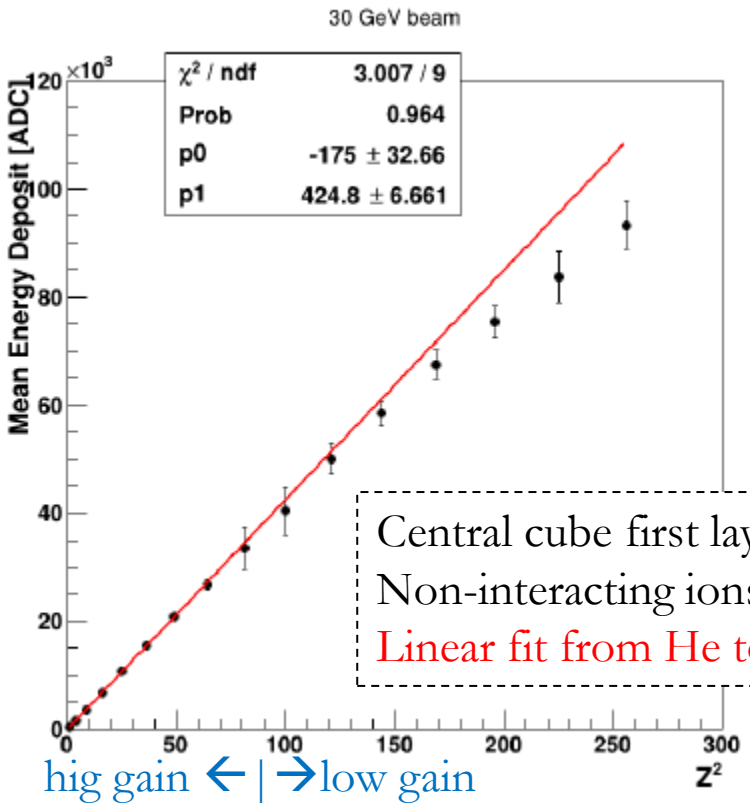
Courtesy of G. Bigongiari (UniSi)

Switching from high to low gain



Single-crystal linearity (2)



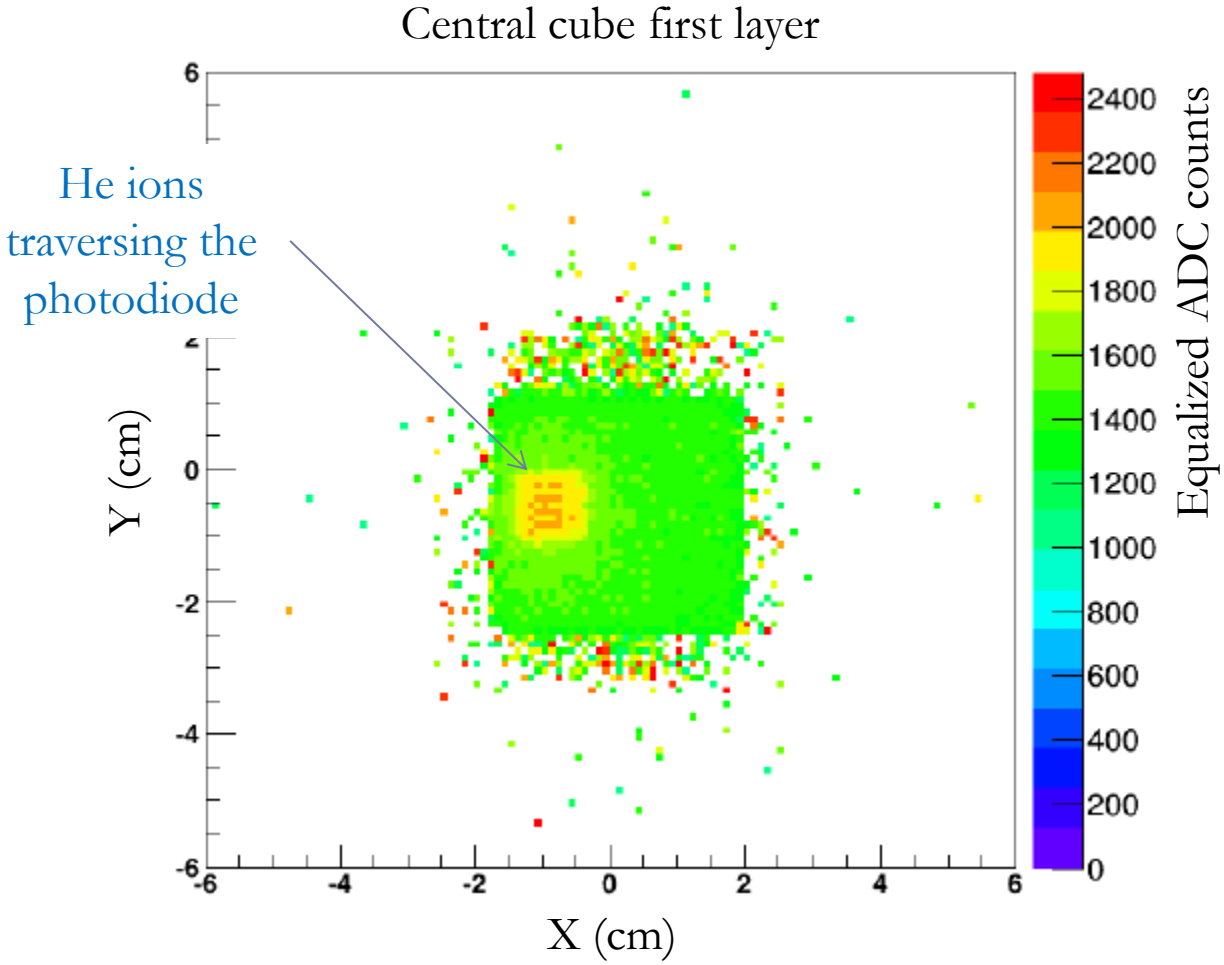


Central cube first layer
Non-interacting ions
Linear fit from He to Mg

Ratio between low and high gain different from nominal one (1/20) ?

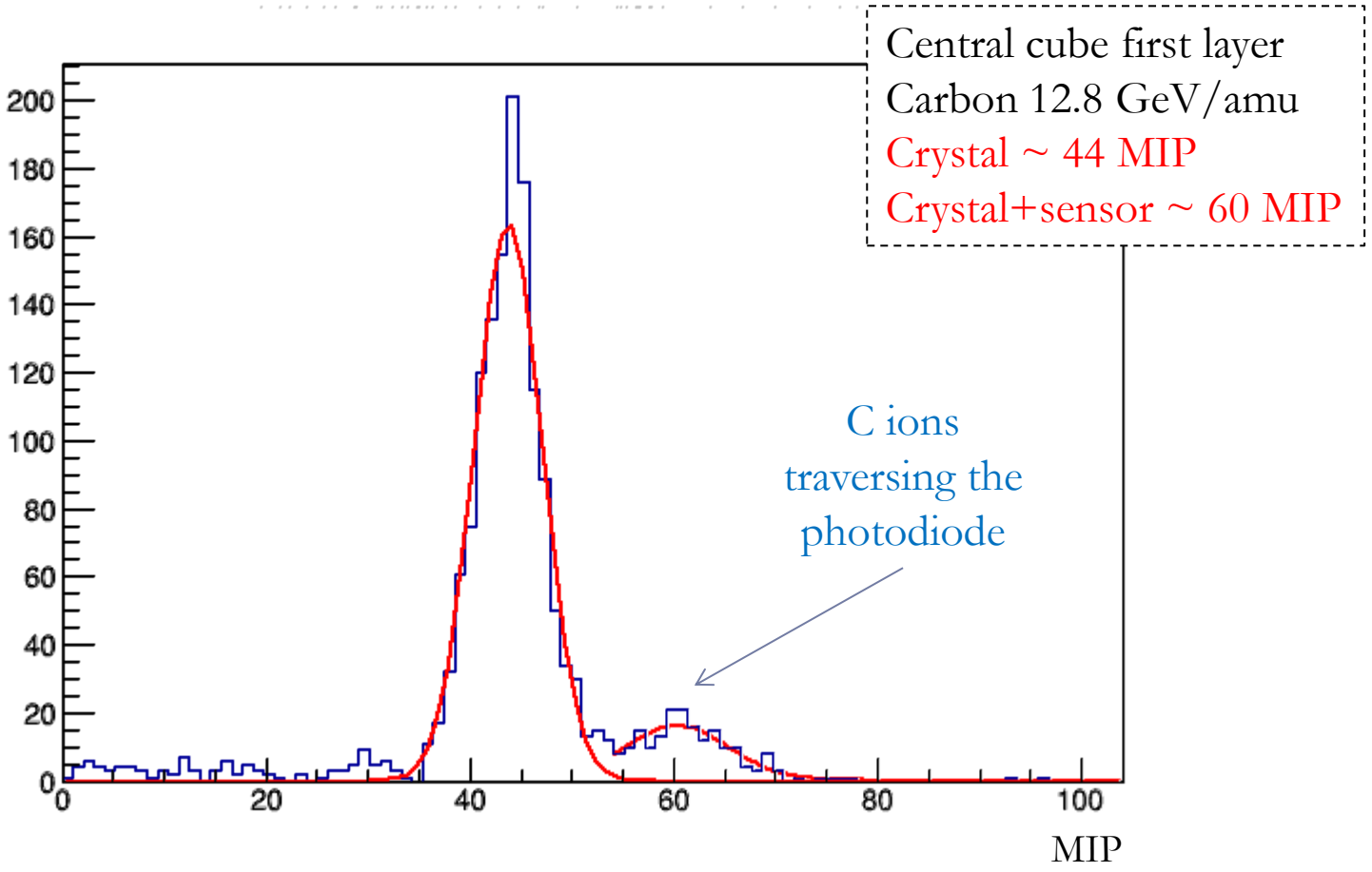
Courtesy of G. Bigongiari (UniSi)

Direct energy deposit on photodiode



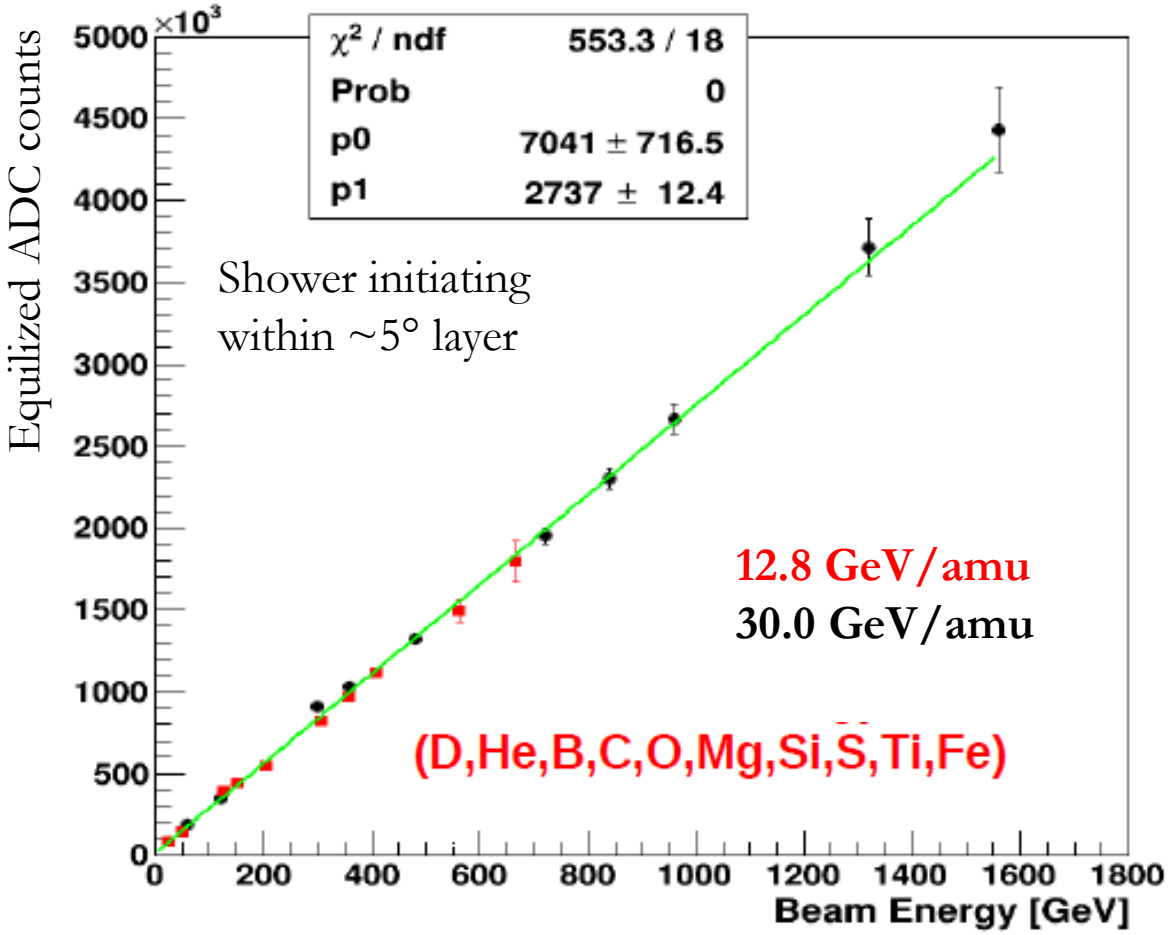
Courtesy of G. Bigongiari (UniSi)

Direct energy deposit on photodiode



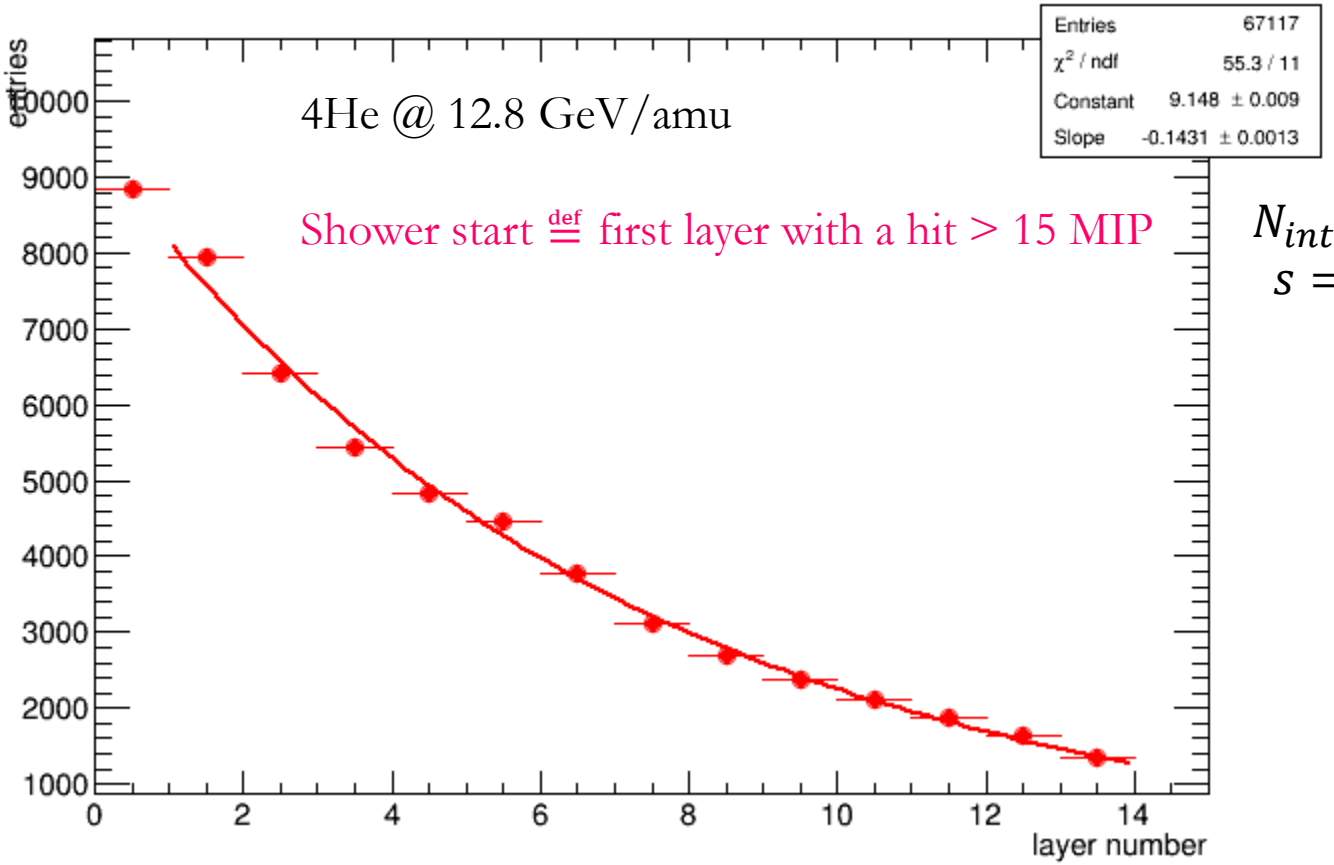
Shower study

Calorimeter linearity



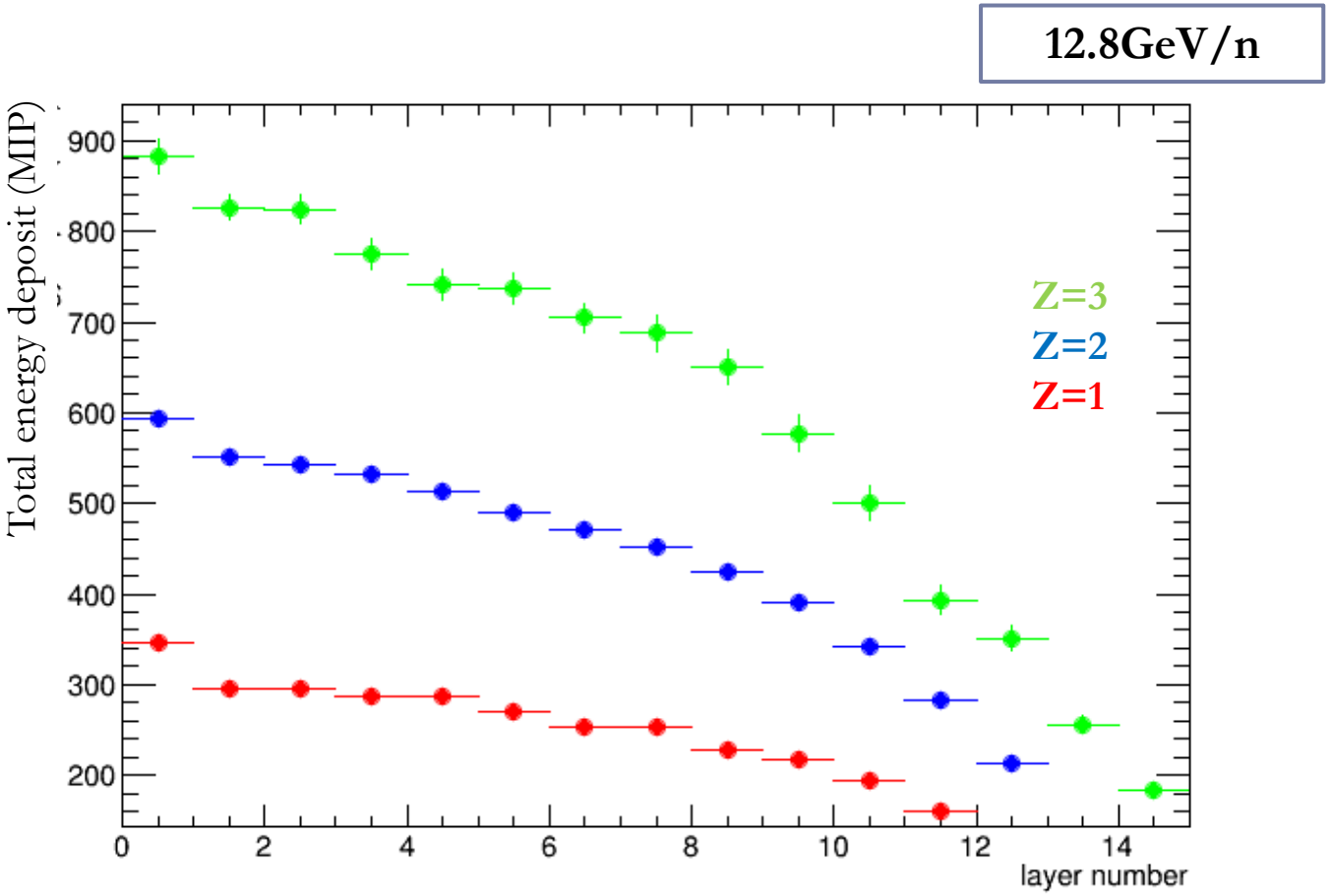
Courtesy of G. Bigongiari (UniSi)

Shower starting-point distribution



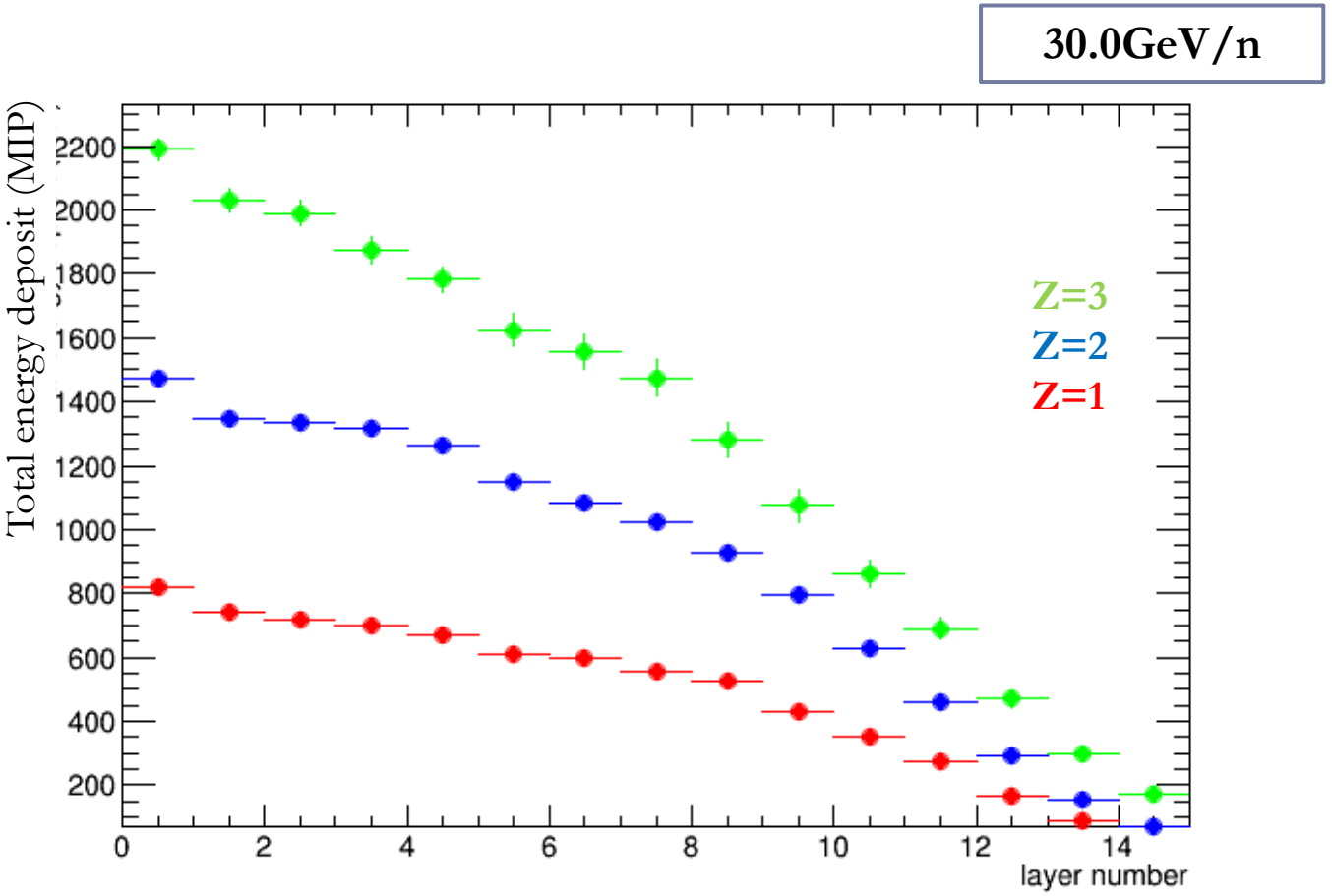
$$N_{int}(i) \propto e^{-i \cdot s}$$
$$s = \Delta x \cdot \sigma_{int}$$

Total energy deposit vs shower start



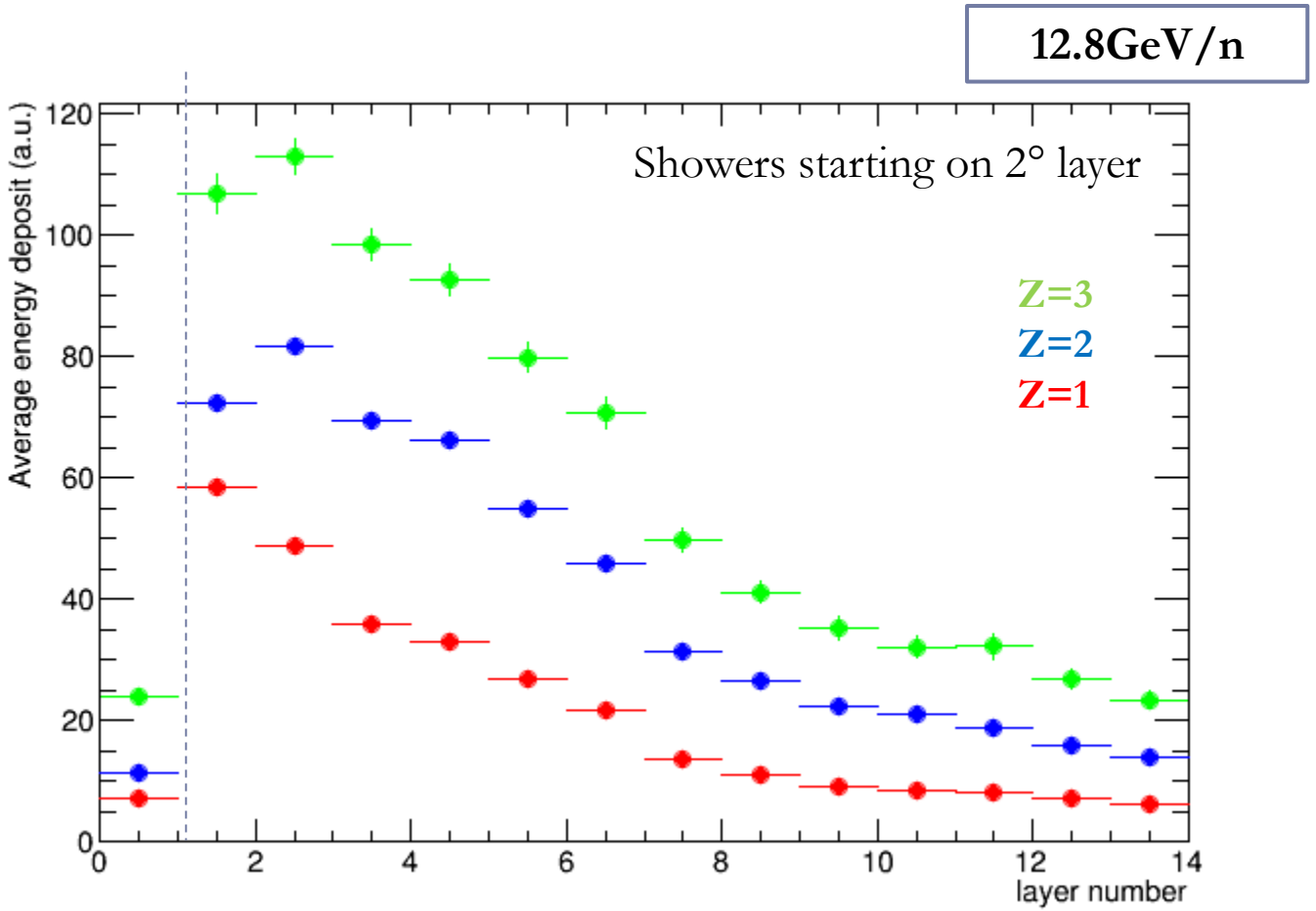
Shower start→ First layer with a hit > **15 MIP** (D and He) or **30 MIP** (Li)

Total energy deposit vs shower start

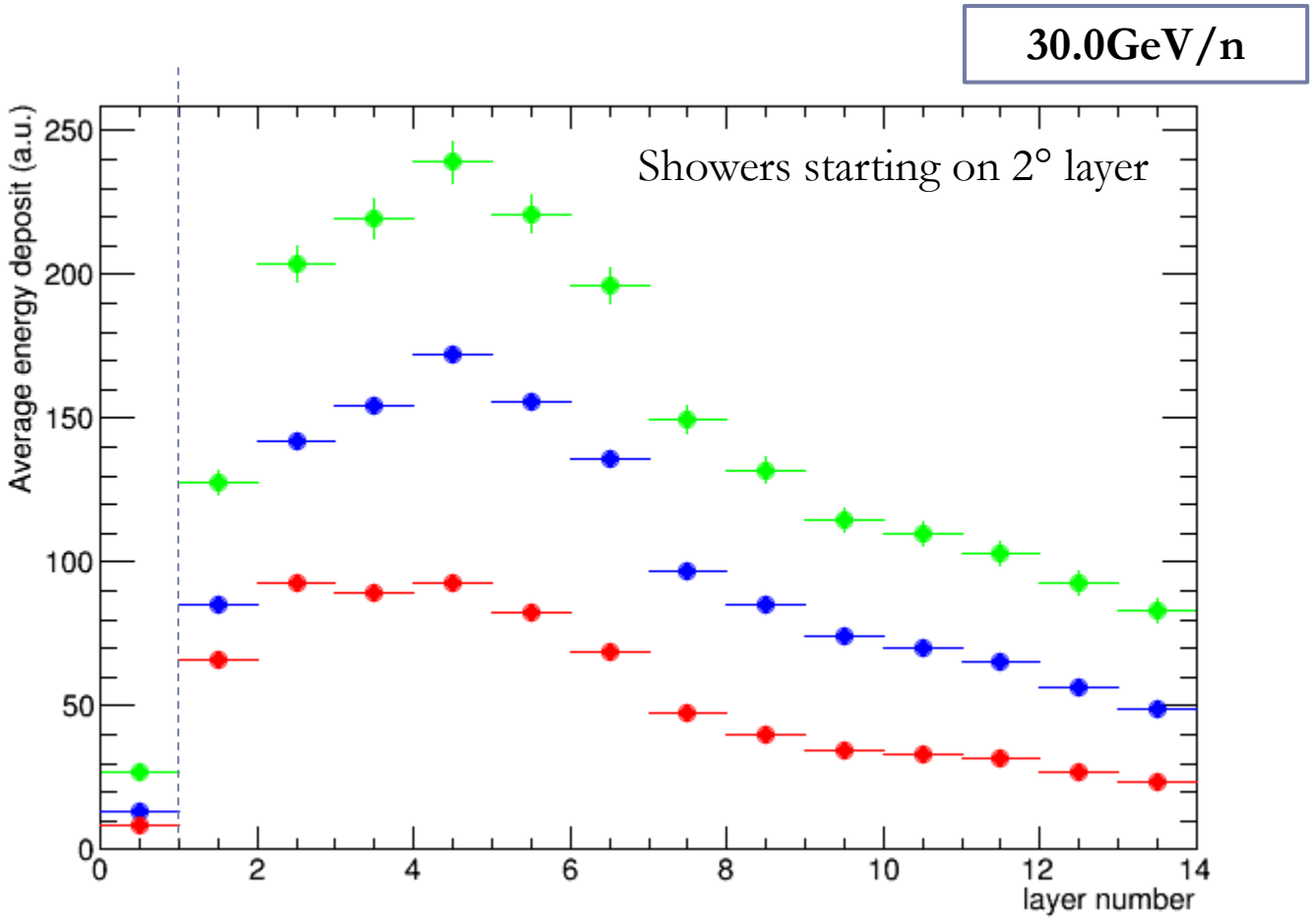


Shower start→ First layer with a hit > **15 MIP** (D and He) or **30 MIP** (Li)

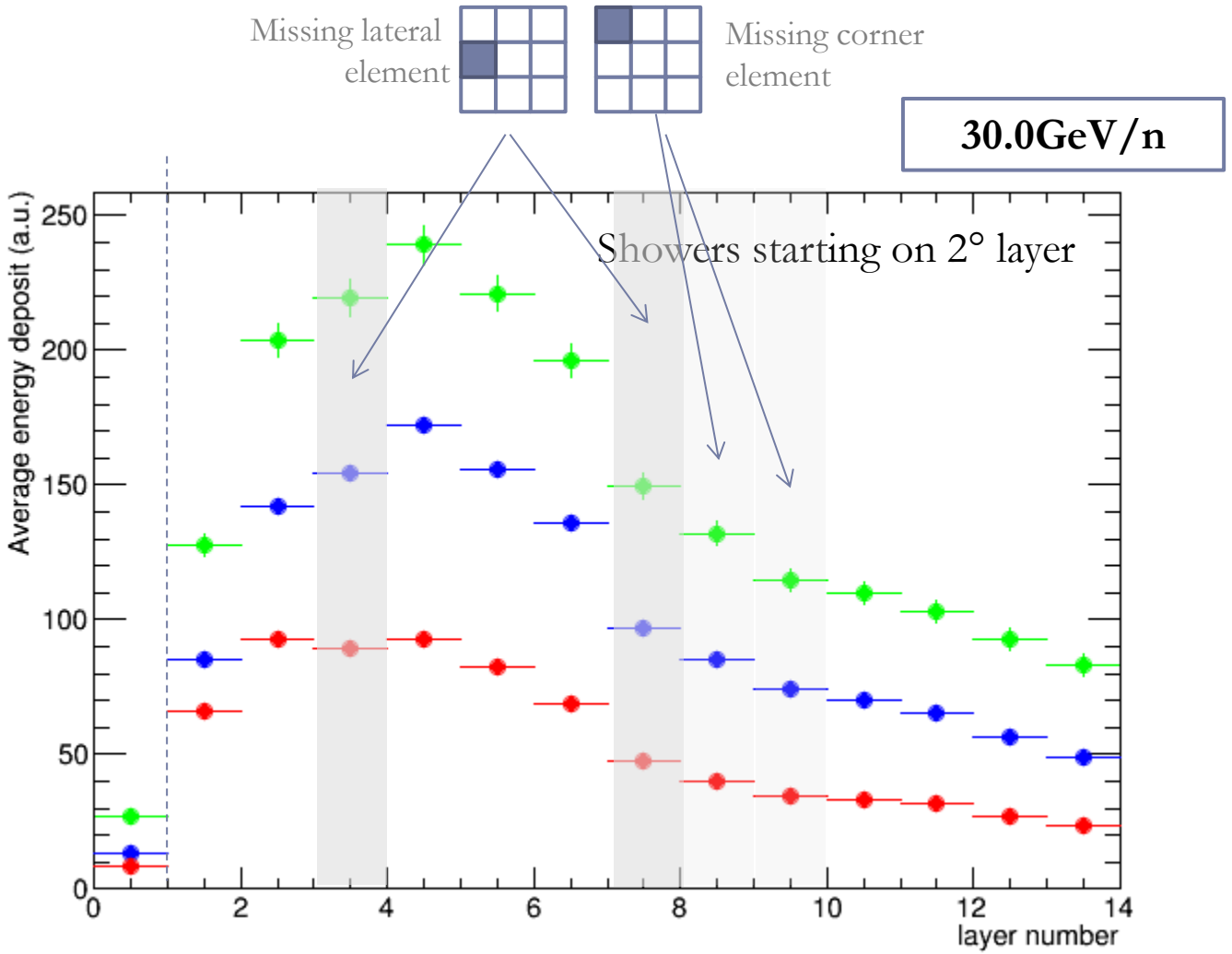
Average shower profile



Average shower profile

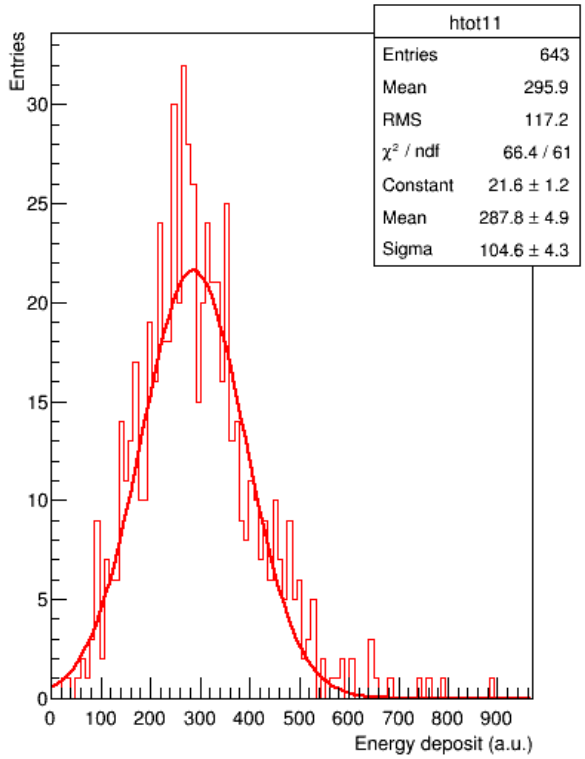


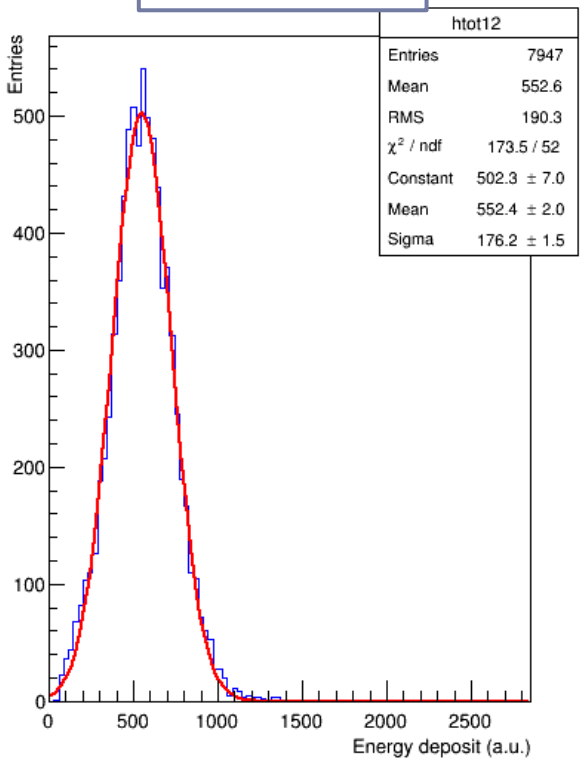
Average shower profile

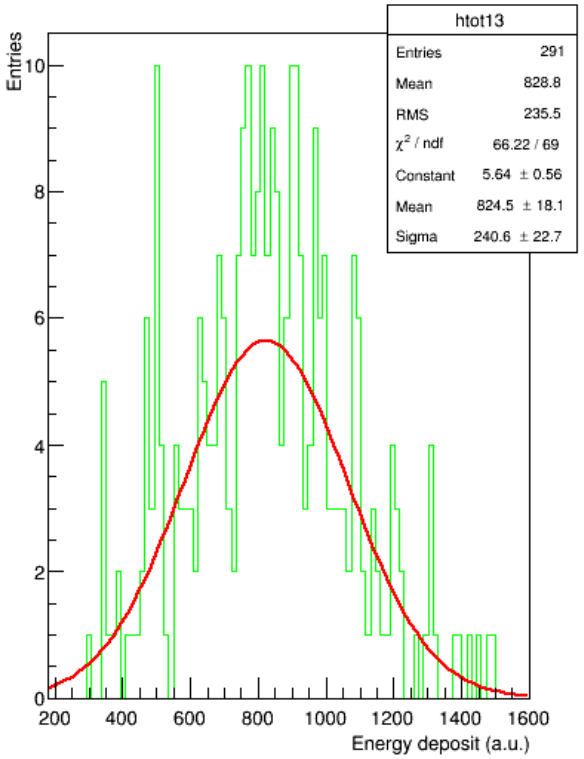


Total energy distribution

12.8 GeV/n



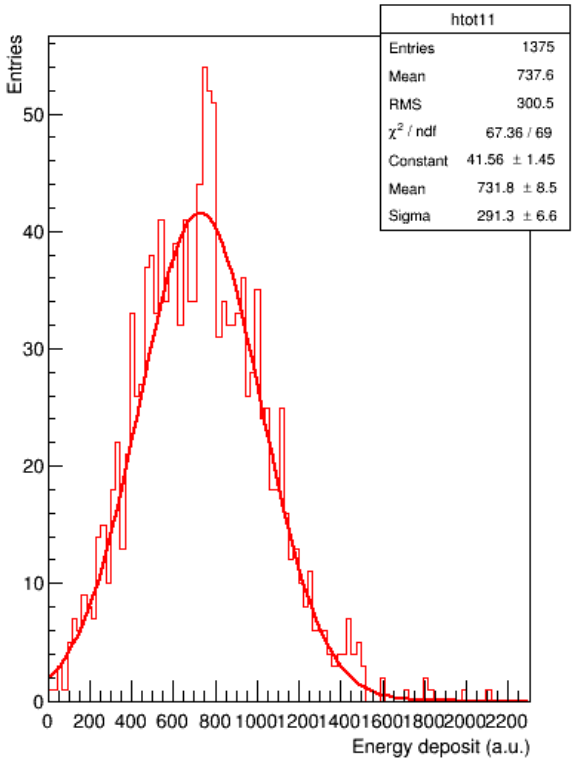


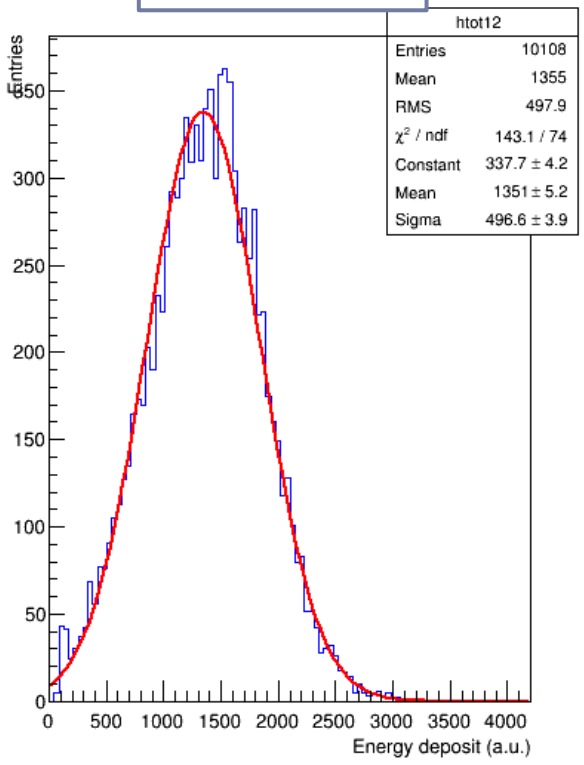


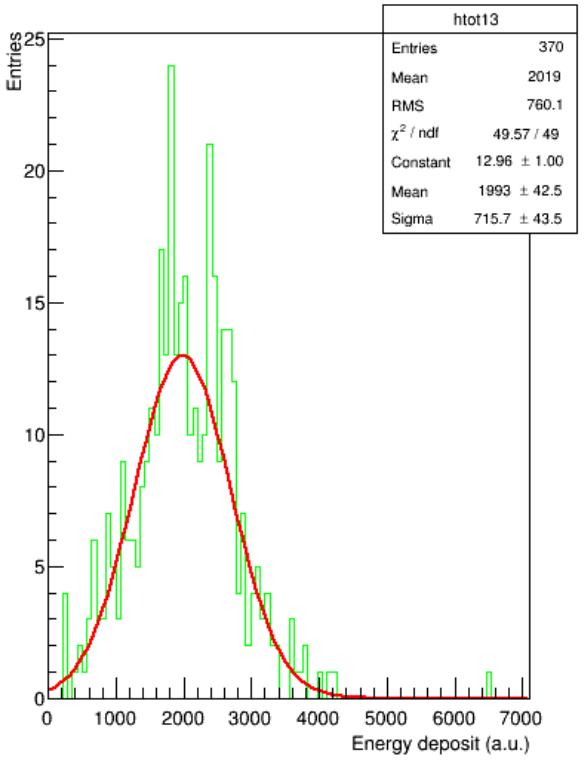
Showers starting on 2° layer

Total energy distribution

30.0 GeV/n

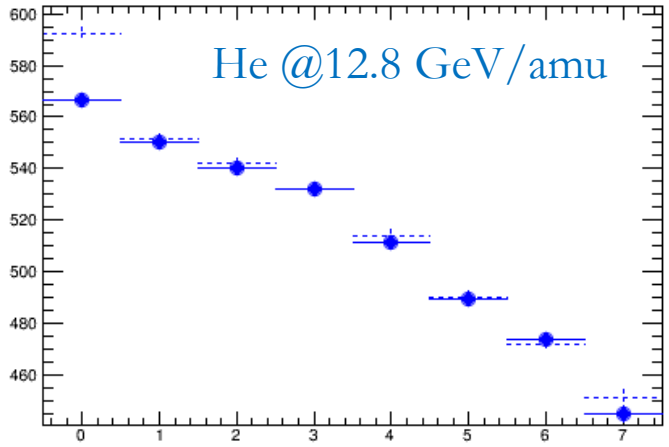


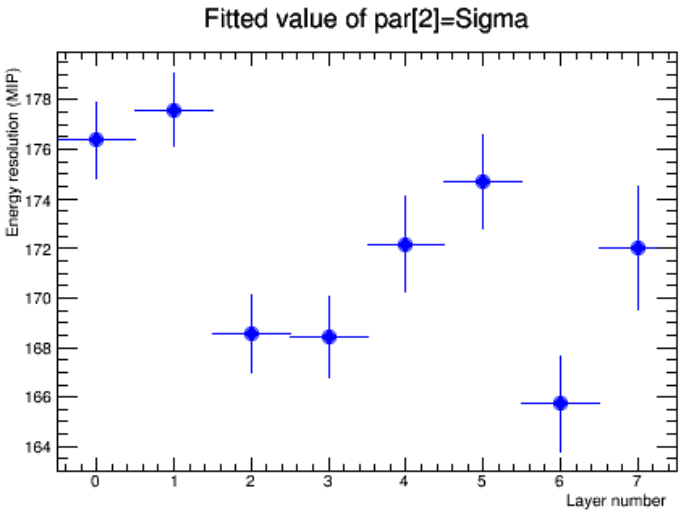


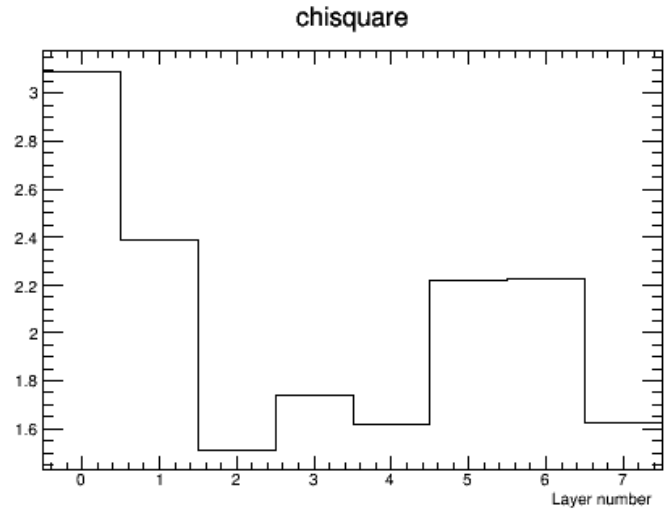


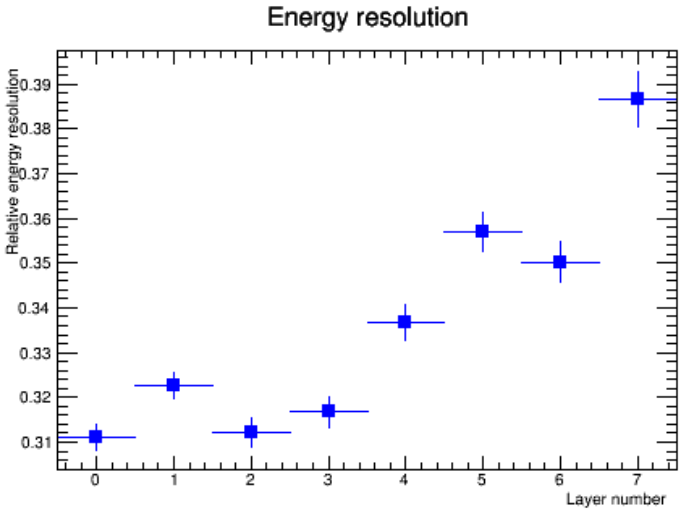
Showers starting on 2° layer

Energy resolution

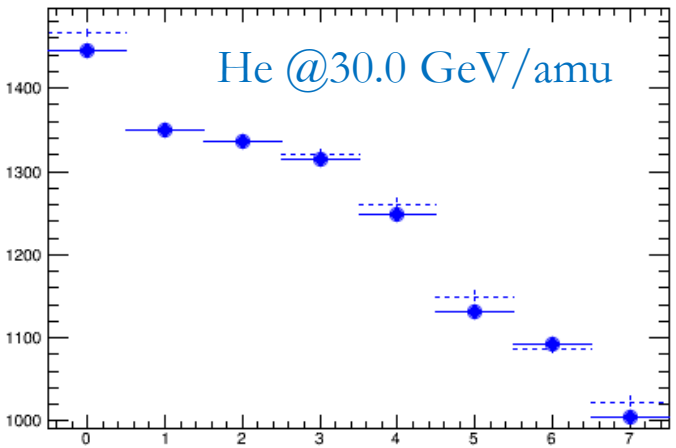


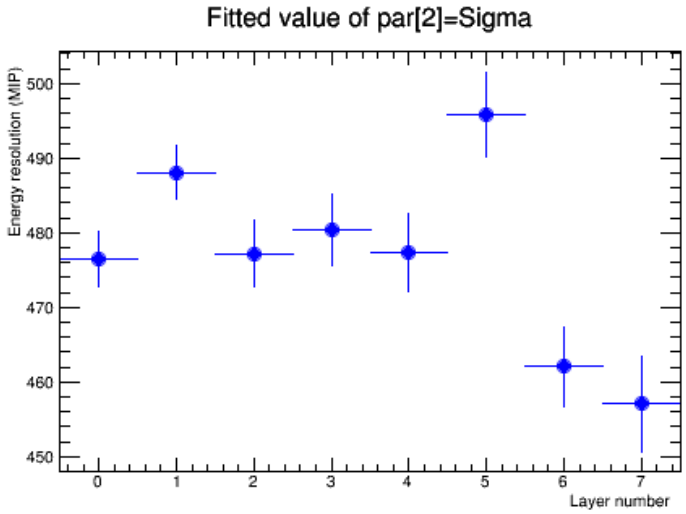


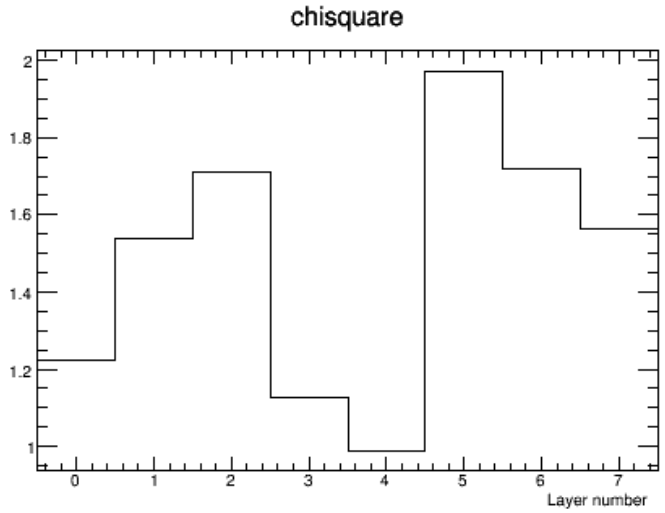


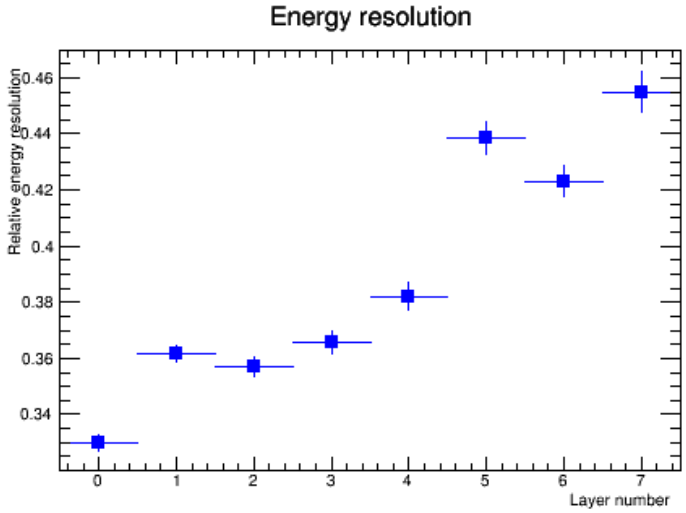


Energy resolution

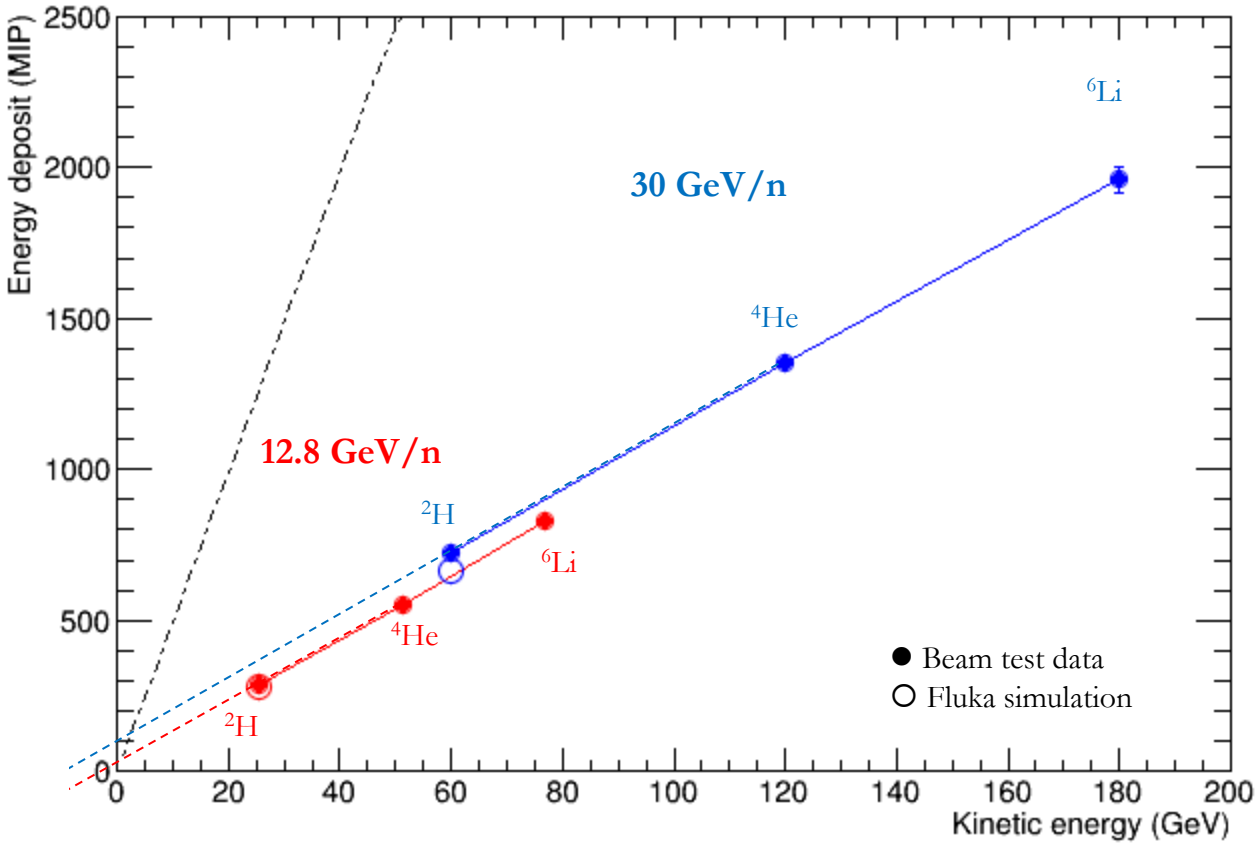




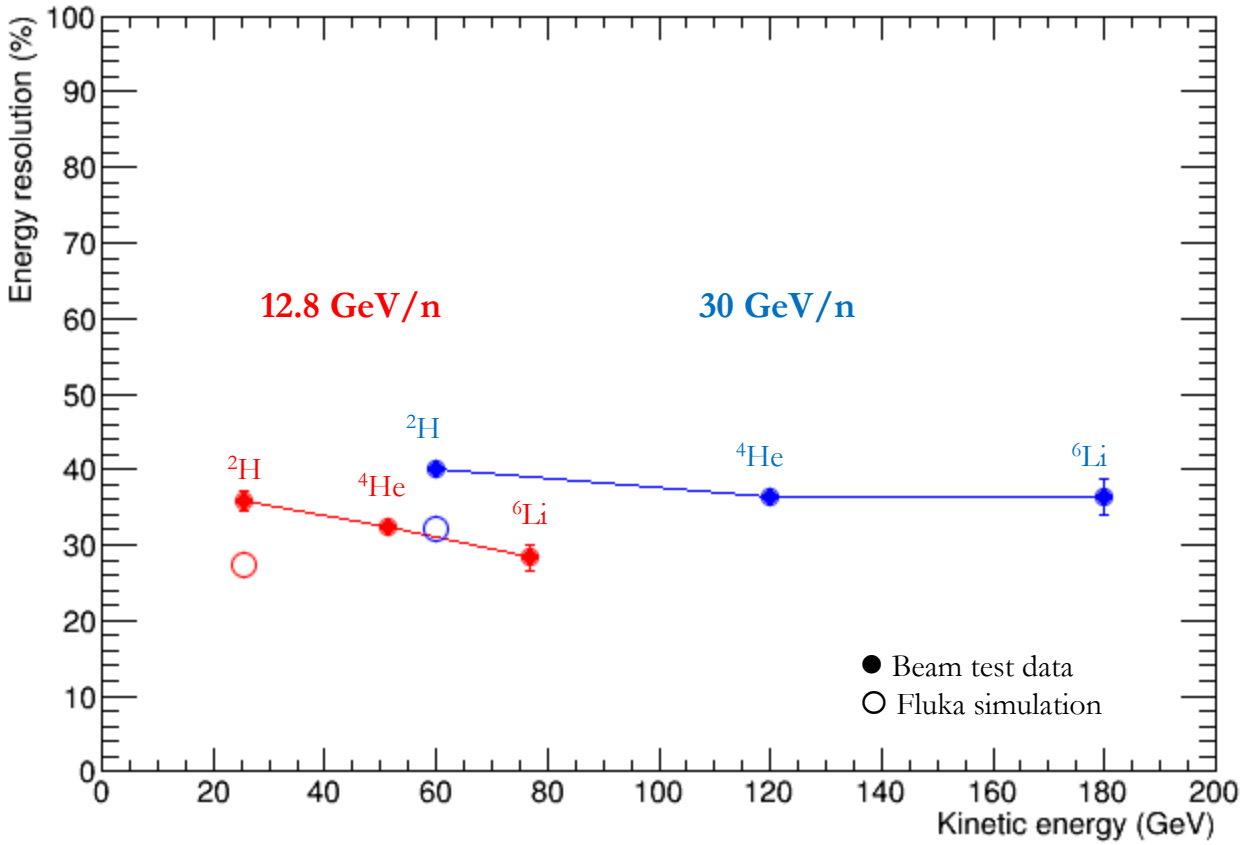




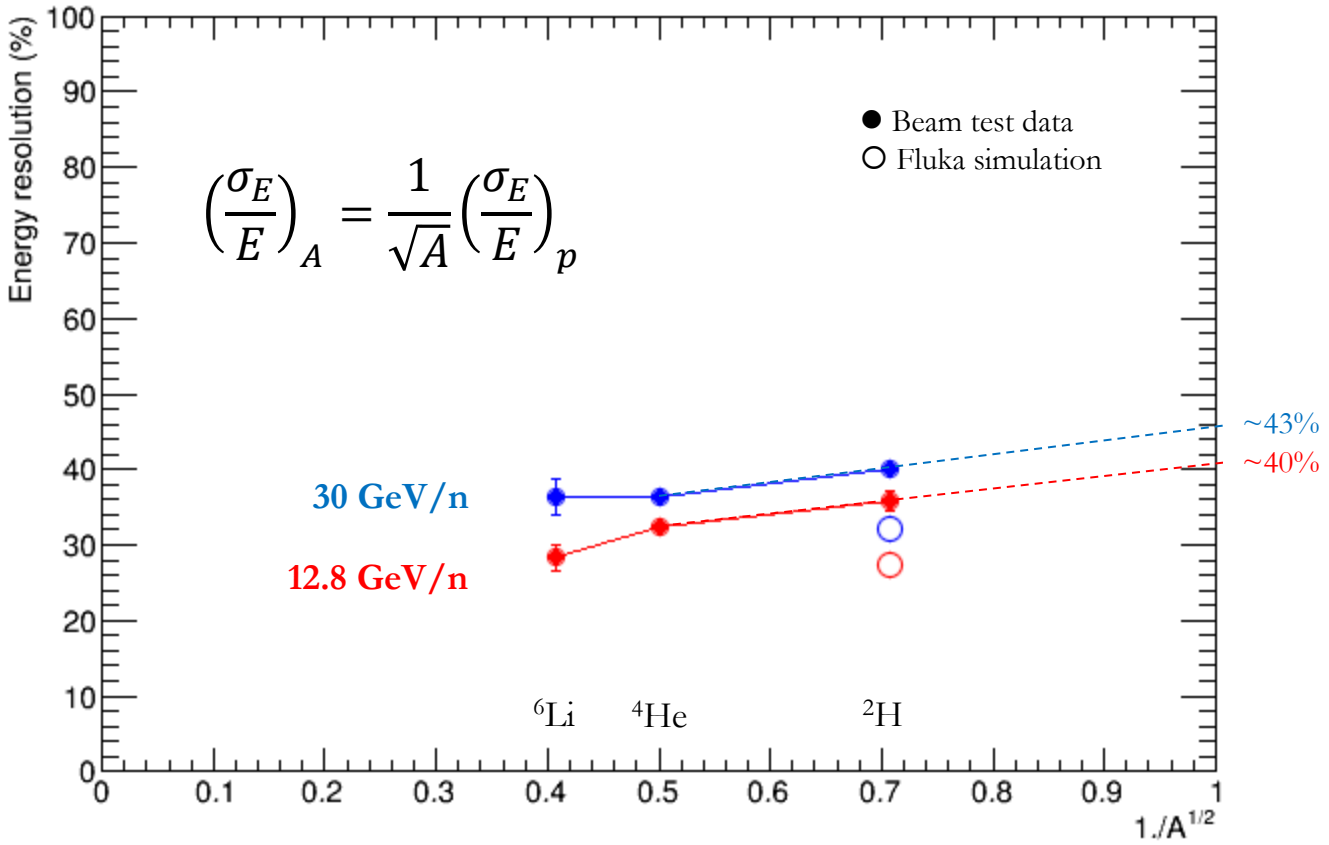
Total energy deposit vs energy



Energy resolution



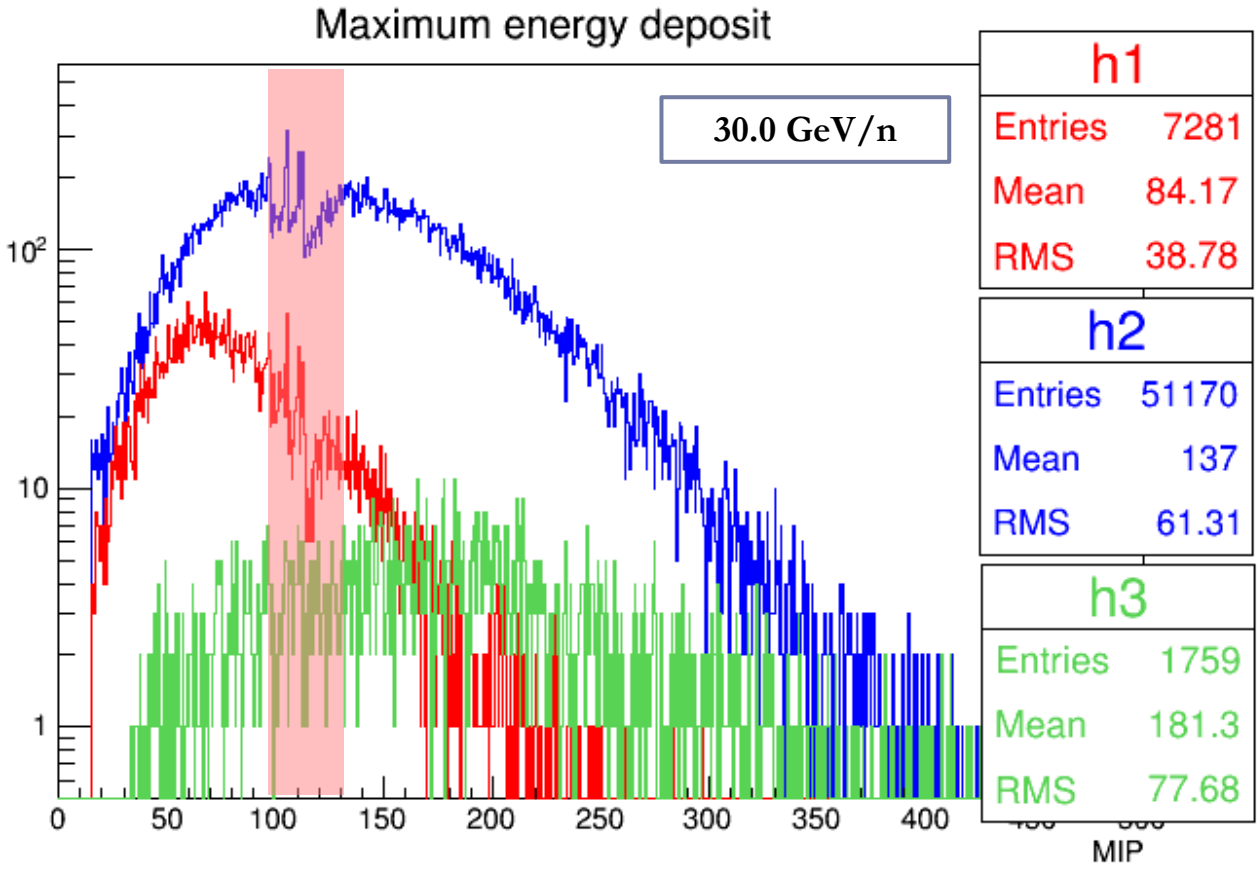
Energy resolution



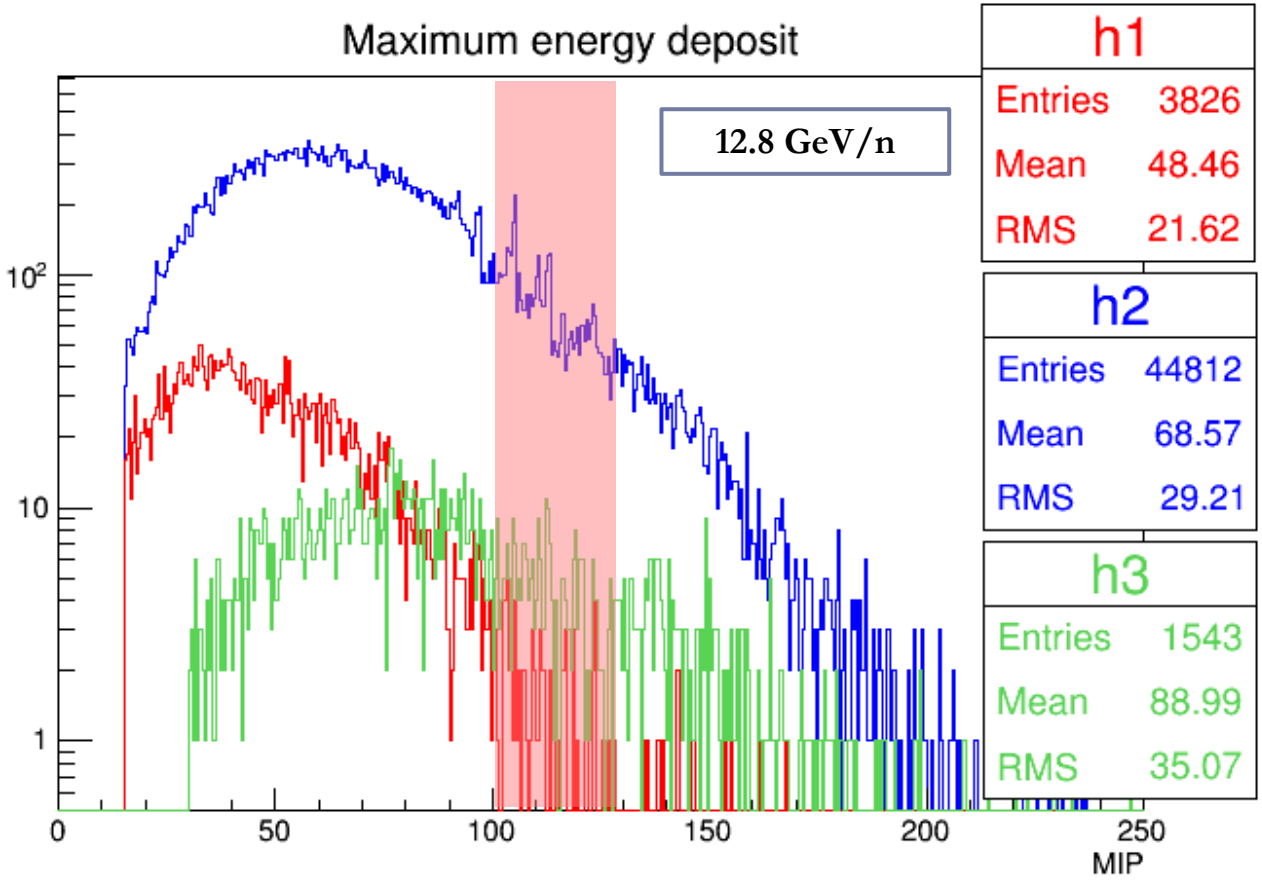
Data vs Simulation

- Possible causes of observed discrepancies:
  - Saturation / low-to-high gain ratio
  - Uncertainties associated with crystal calibration (ADC-to-MIP conversion, gain equalization)
  - Fluctuation on photon collection efficiency → see Starodubtsev presentation
  - Fluctiations on shower development , not well described by Fluka hadronic model ? → see Papini/Bottai presentation

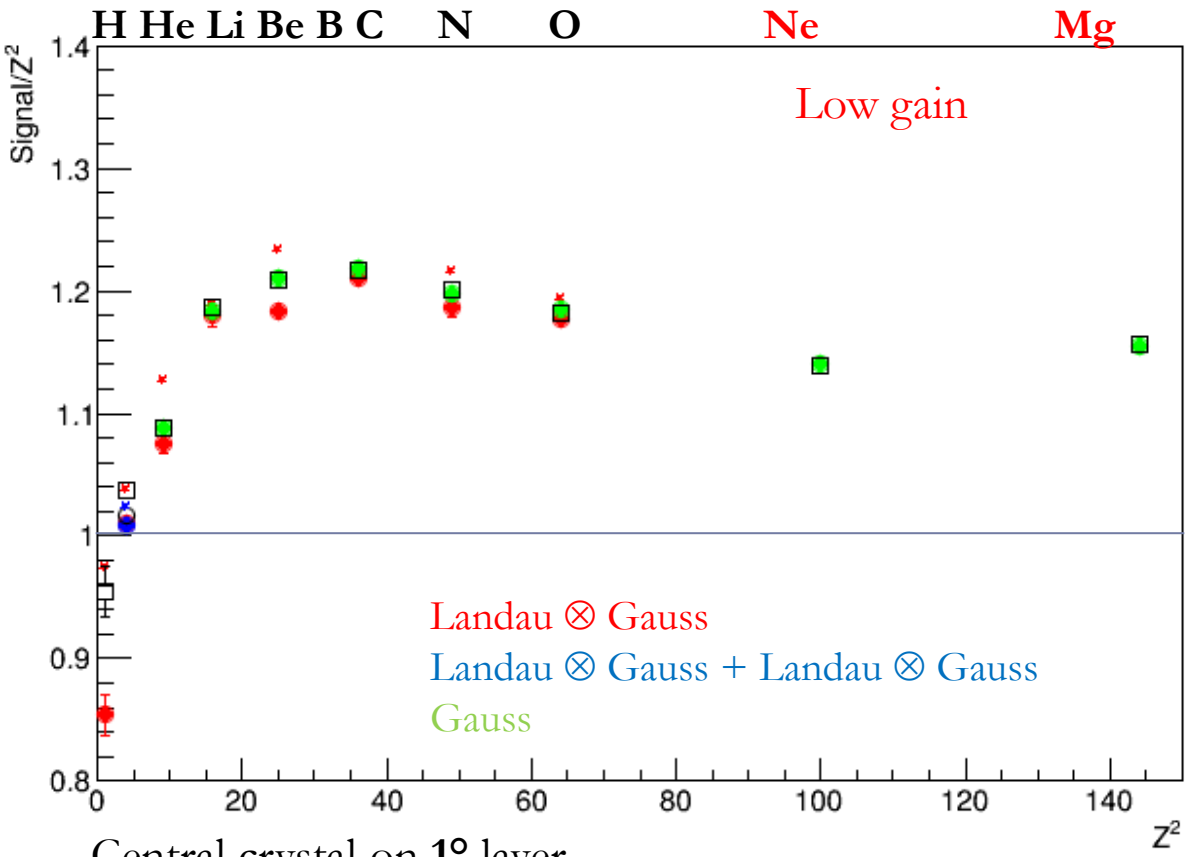
Saturation


Maximum energy deposit
30.0 GeV/n
h1
Entries 7281
Mean 84.17
RMS 38.78
h2
Entries 51170
Mean 137
RMS 61.31
h3
Entries 1759
Mean 181.3
RMS 77.68
10^2
10
1
0
50
100
150
200
250
300
350
400
MIP

Saturation

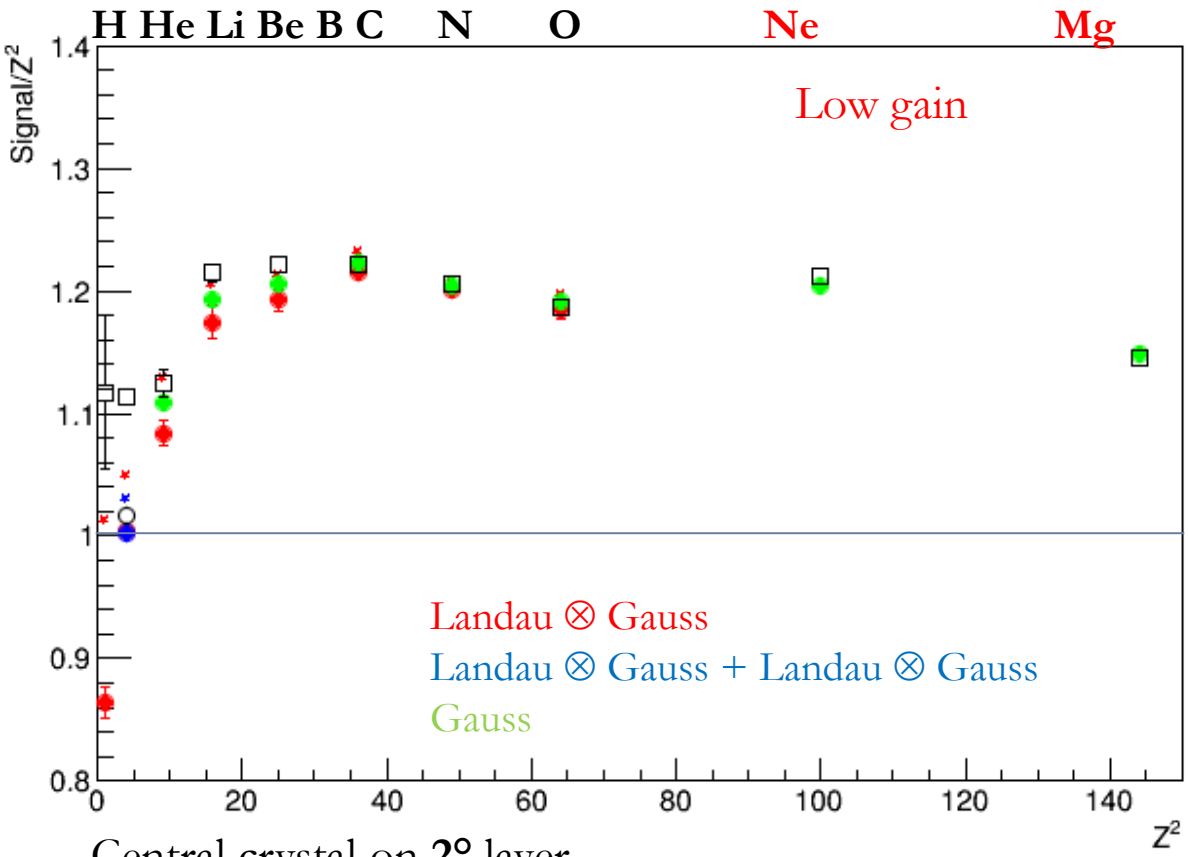

Maximum energy deposit
12.8 GeV/n
h1
Entries 3826
Mean 48.46
RMS 21.62
h2
Entries 44812
Mean 68.57
RMS 29.21
h3
Entries 1543
Mean 88.99
RMS 35.07
10^2
10
1
0
50
100
150
200
250
MIP

Signal vs Z^2



Central crystal on **1°** layer
Non-interacting ions12.8 GeV/n
Sensor excluded

Signal vs Z^2



Central crystal on **2°** layer

Non-interacting ions12.8 GeV/n

Sensor excluded