The Layer 0 upgrade of the AMS-02 experiment on the ISS: Preliminary analysis of beam test

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AMS-02 (The Alpha Magnetic Spectrometer)

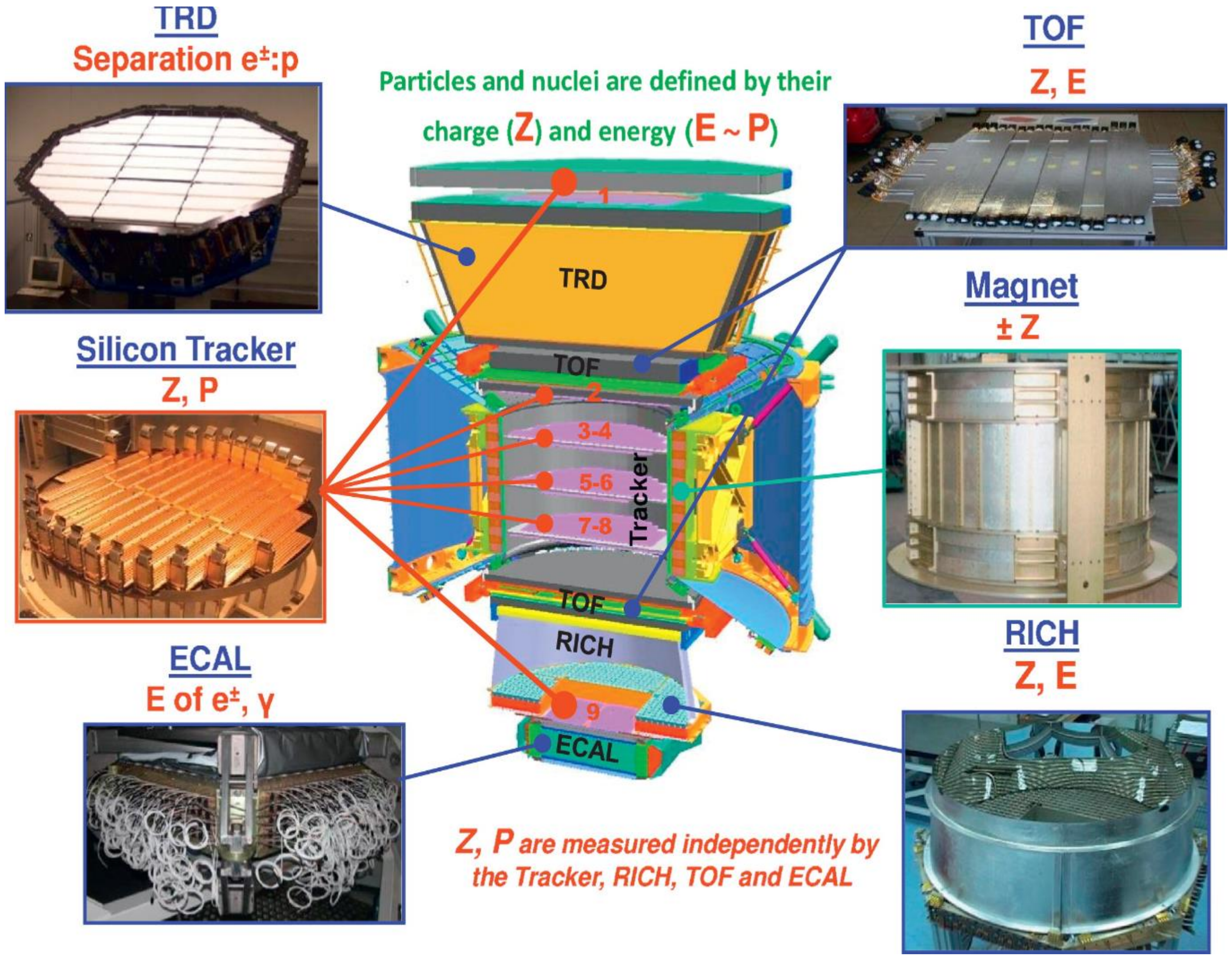
Composed by:

- TRD (Transition Radiation Detector): distinguishes heavy (e.g. proton) from light (e.g. electron or positron) particles;
- TOF (Time of Flight Counters): determines the particle time of flight and charge (Z);
- Tracker: measures the particle Rigidity (p/eZ) and charge (Z);
- RICH (Ring Imaging CHerenkov counter): measures the particle charge and velocity;
- ECAL (Electromagnetic CALorimeter): distinguishes hadronic (e.g. proton) from electromagnetic (e.g. electron, positron or gamma);

Main objectives:

- search for Primordial Antimatter by direct detection of antinuclei;
- search for indirect Dark Matter signals;
- study of production, acceleration and propagation of Cosmic-Rays;
- study of Solar Modulation effects and Solar Physics;

In orbit on the International Space Station since May 2011

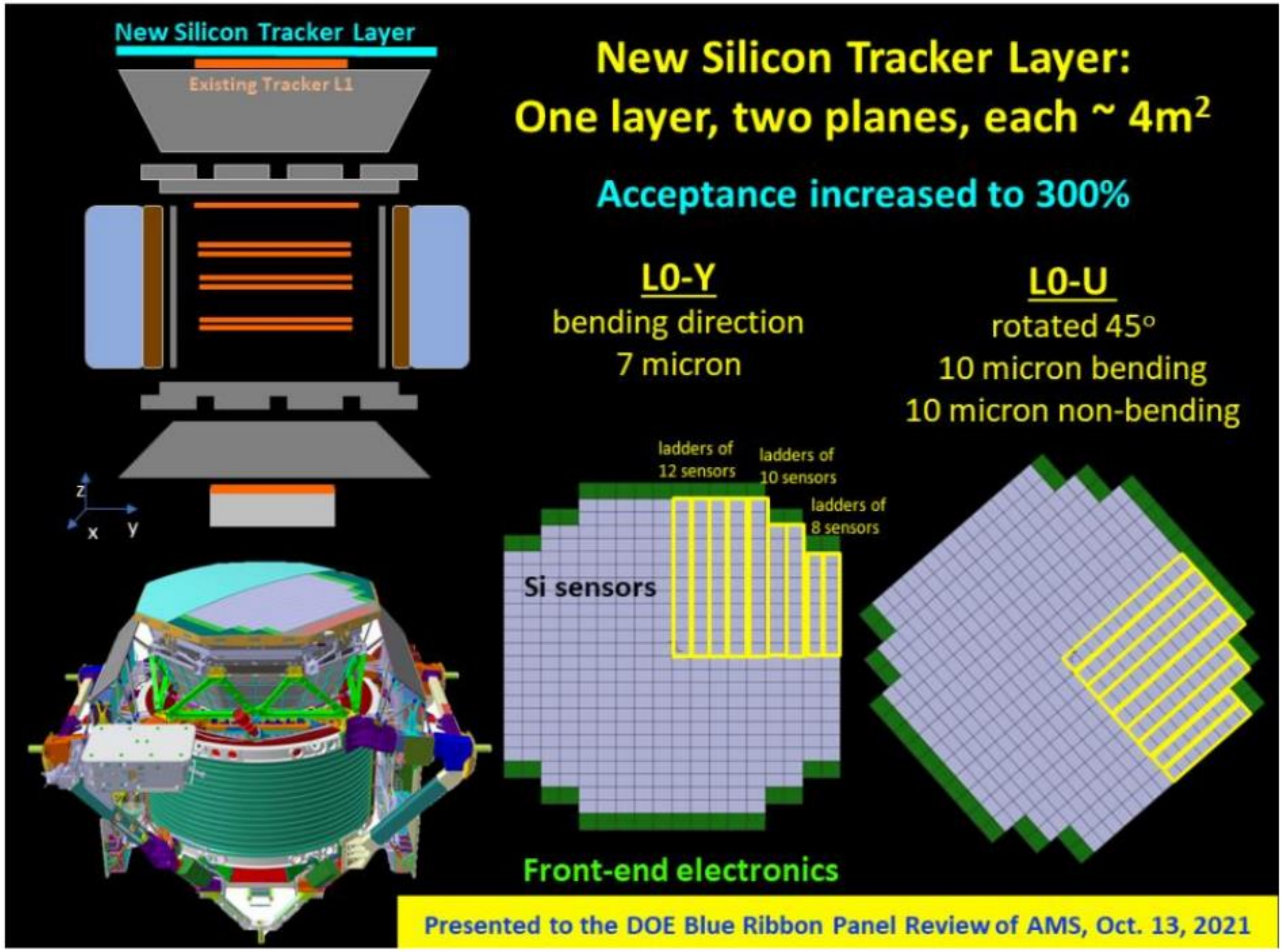


The AMS-02 Layer 0 upgrade

- AMS02-L0, an upgrade which consist in adding a new silicon detection layer, called L0, above the existing L1 layer to increase the overall acceptance area;

- Composed of two planes of silicon sensors, with one layer rotated of 45 degrees with respect to the other;

- The total area of the silicon sensors to be installed is ~ 8 m^2. will increase by 300% the acceptance of the experiment;

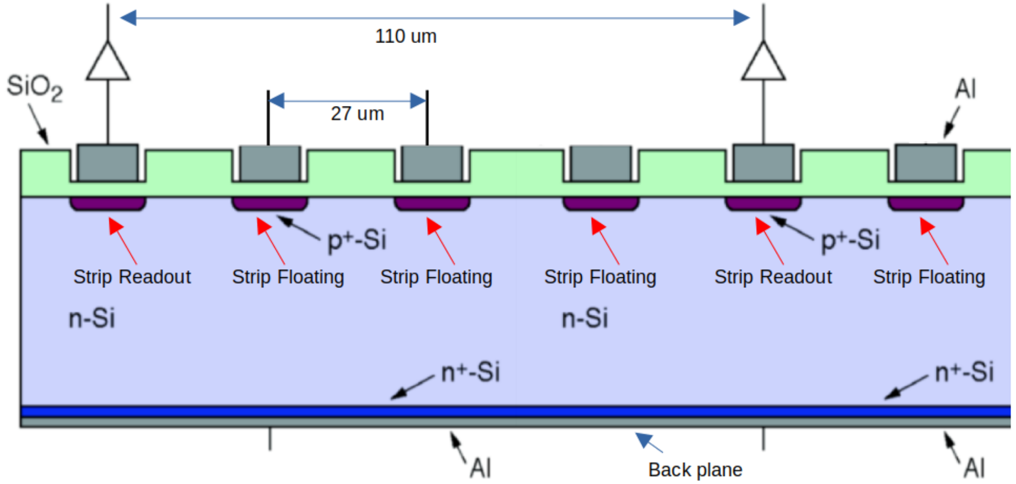


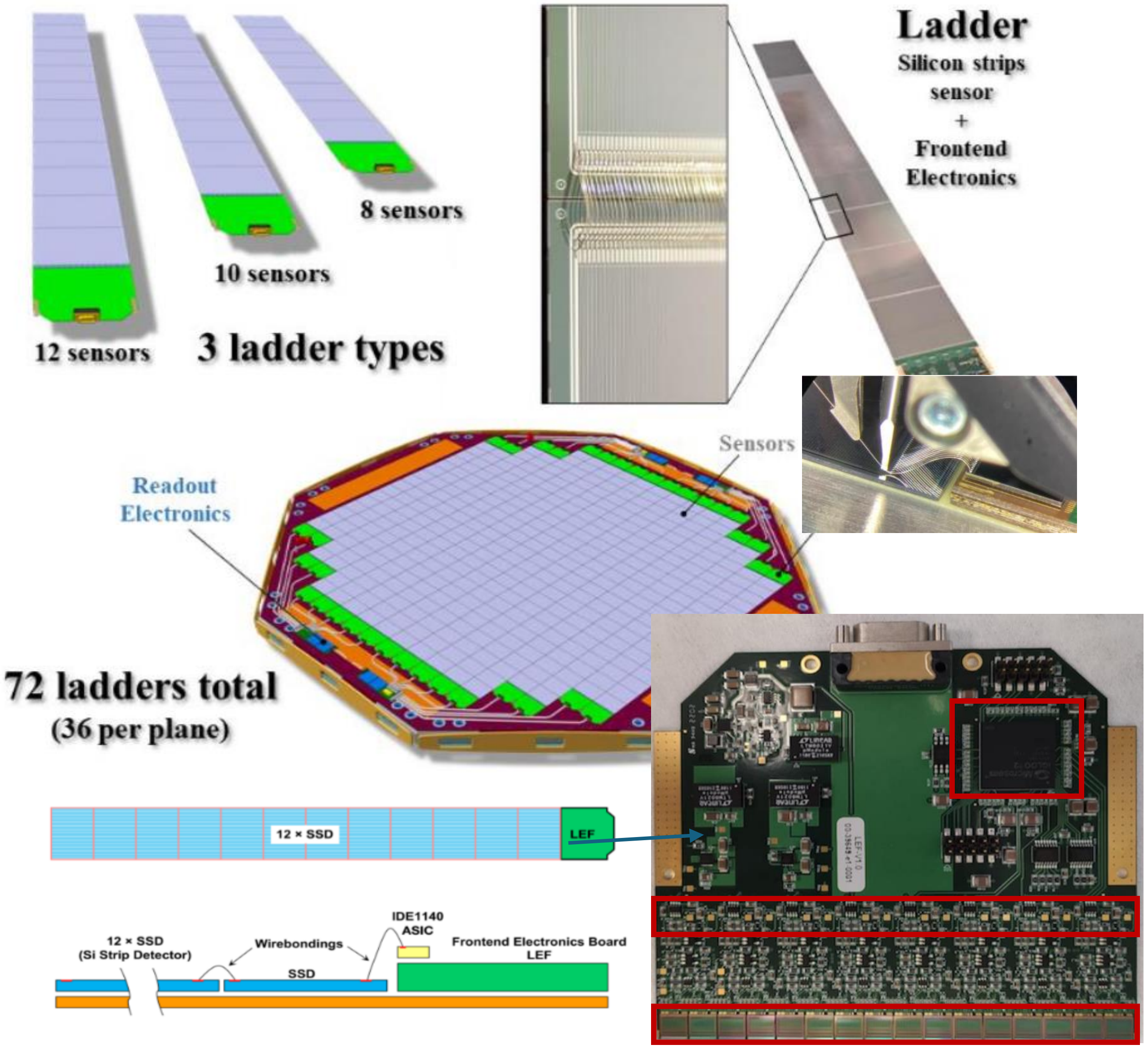
"Ladder" For AMS - L0

- Each ladder is composed of 8, 10, or 12 silicon sensors plus a frontend electronics board and a long flexible printed circuit board for mounting.

- Each silicon sensors with an area of 8x11 cm^2, containing 1024 readout channels with a pitch of 110 um (the implant pitch is 27.5 um with 3 floating strips). All channels of adjacent silicon sensors are connected in daisy chain to form a single sensor with longer strips.

- The frontend electronics board is equipped with 16 VA chips (IDE1140), and 8 ADCs (14 bit). Thanks to the onboard FPGA the board has only a digital interface, and the data compression will be implemented in the FPGA itself.





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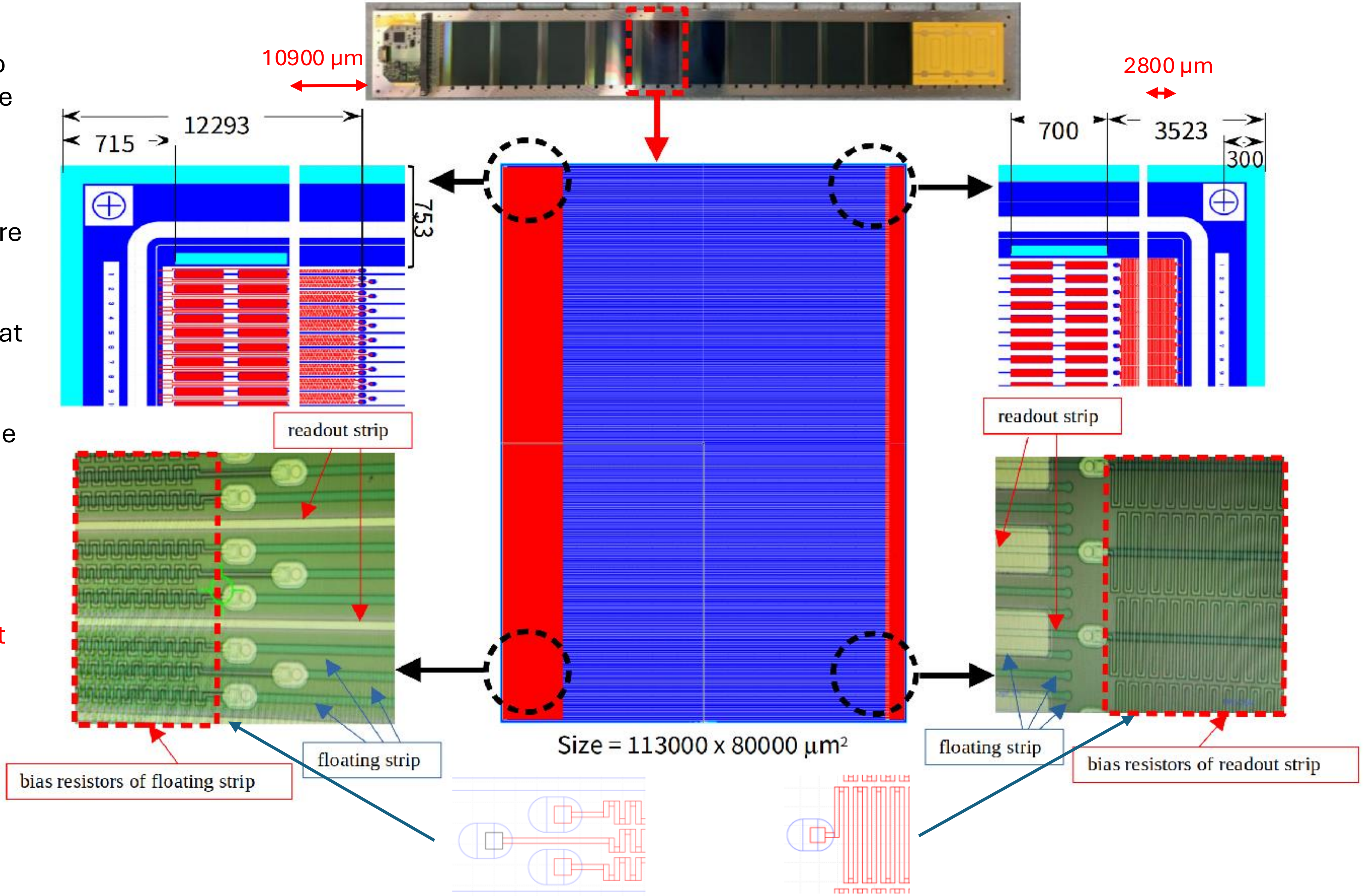
Bias resistor regions

- Bias resistors, made of polysilicon in a serpentine shape connect the bias ring to each of the strips, providing them with the voltage that allows the depletion of the junction.

- The bias resistors for the readout strips are located at the right end of the detector, while the bias resistors for the intermediate (floating) strips are located at the left end.

- The sizes of the bias resistor regions at the left and right ends are not identical. And the structure of the bias resistor regions are different:
  - floating strips are continuing under their bias resistor
  - floating strips finish before the start of the readout strip bias resistors

- The structural differences between the bias resistor regions at the two ends result in differing detection efficiencies and spatial resolutions when measuring particles.



Beam test

The most recent beam tests conducted at CERN are as follows :

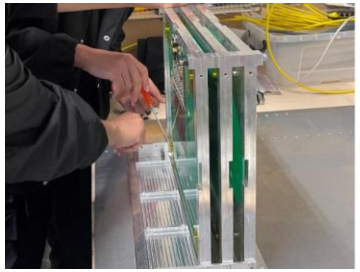
- In October 2023, we performed a heavy ion beam test on the AMSL0 ladder, primarily to study its charge identification capability, especially for high-charge particles. Unfortunately, we had only one full night of data;

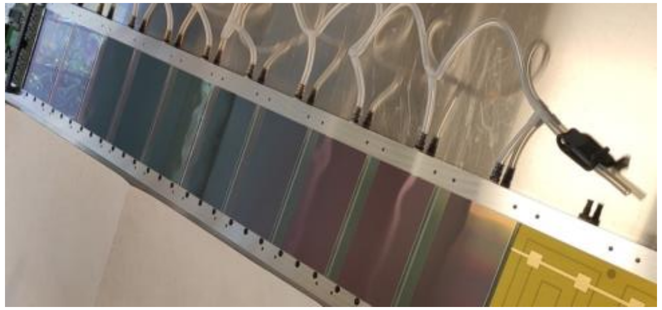
- In May 2024, we conducted a muon beam test on the AMS-L0 ladder, mainly to investigate its spatial resolution and the detector efficiency of the bias resistor region on the silicon microstrip sensors that make up the ladder;

- In November 2024 (a week ago), we carried out another test with heavy ions. This time, in addition to continuing to study its charge identification ability, we also examined the interaction between the L0 support structures (carbon fiber) and the passing heavy ions.

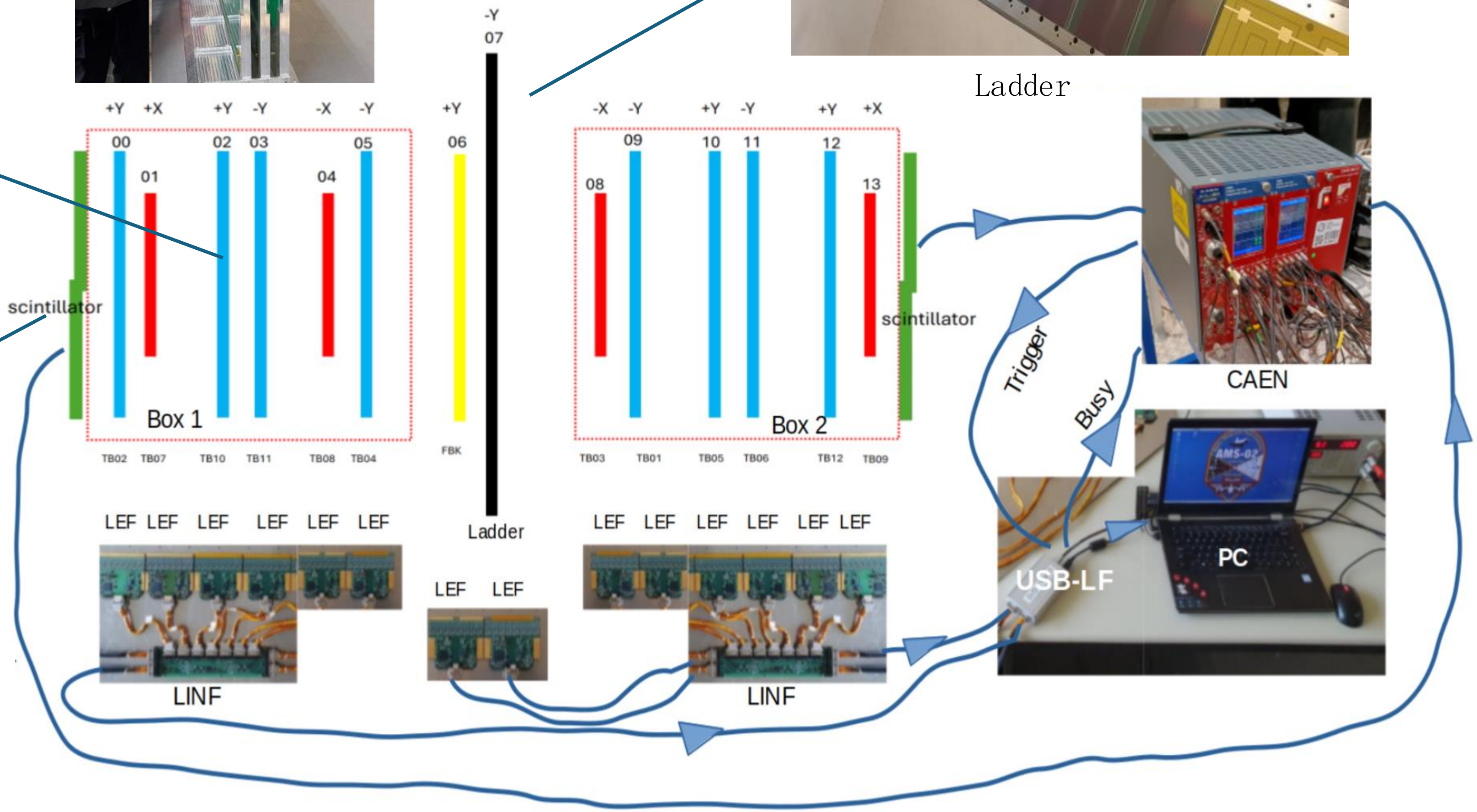
AMS-L0 muon beam test (May 2024): setup

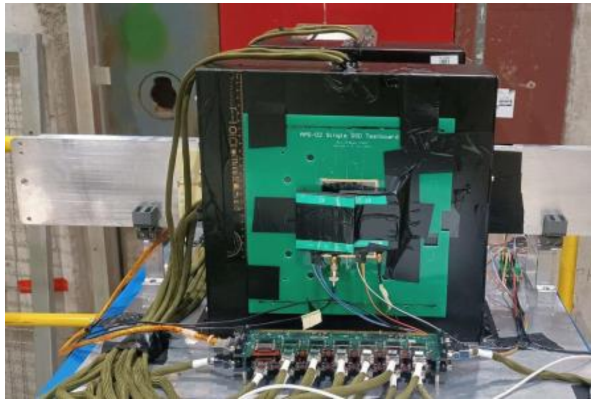
short detector





Ladder





scintillator

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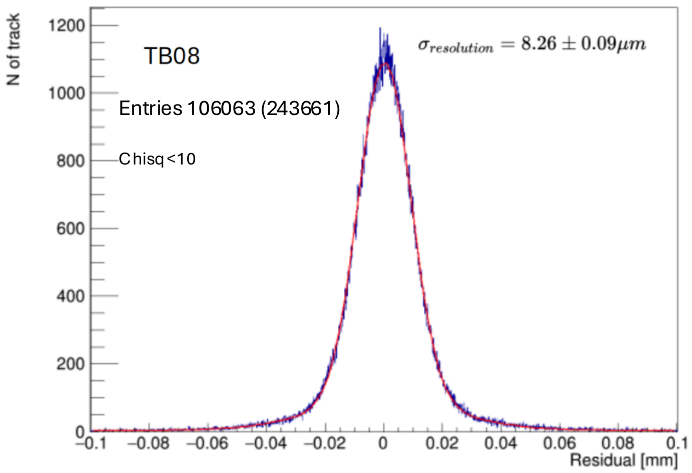
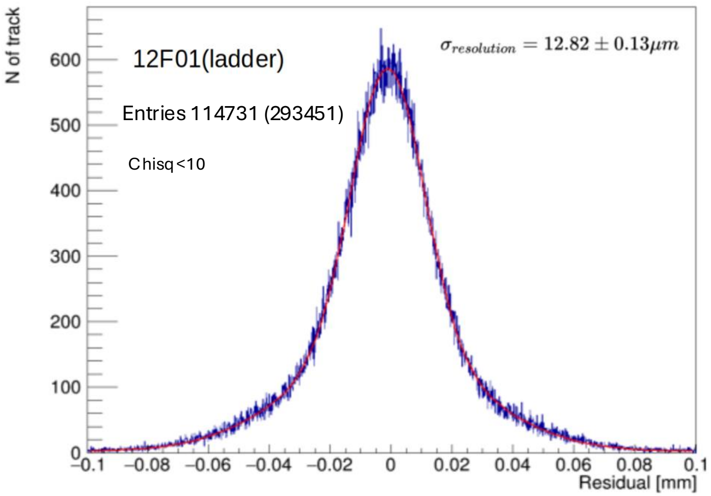
AMS-L0 muon beam test (May 2024): spatial resolution of the region without bias resistor





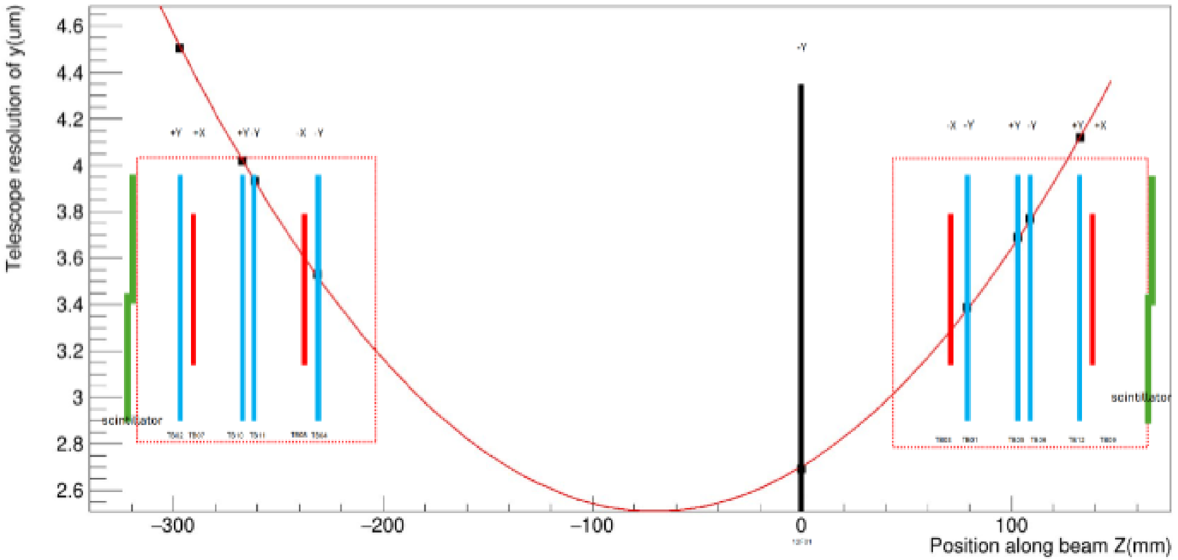
Residual unbiased:

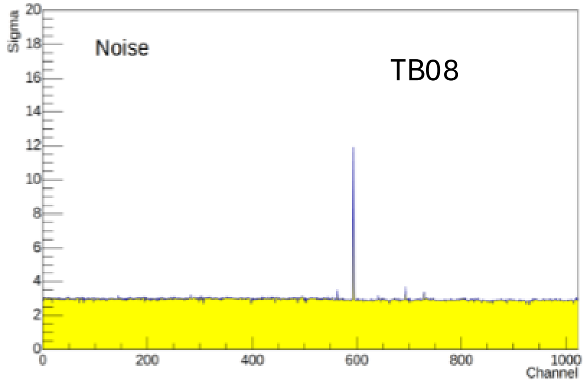
$$UR_i = X_{impact,i} - X_{predicted,i}$$

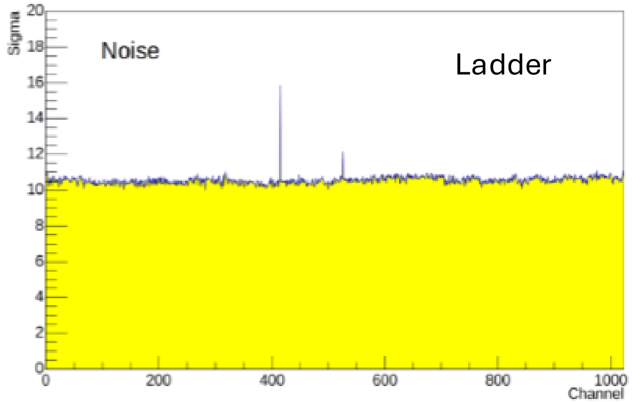
Standard deviation :

$$\sigma_{UR,i} = \sqrt{\sigma^2_{fit,i} + \sigma^2_{resolution,i}}$$

$$\sigma_{fit,i} = \sqrt{\left(\sigma_s^2 \sum_j^n z_j^2/n + \sigma_s^2 \cdot z_i^2 - 2z_i\sigma_s^2 \cdot \sum_j^n z_j^2/n\right) \Big/ \left(\sum_j^n z_j^2 - \sum_j^n z_j \sum_k^n z_k\right)}$$



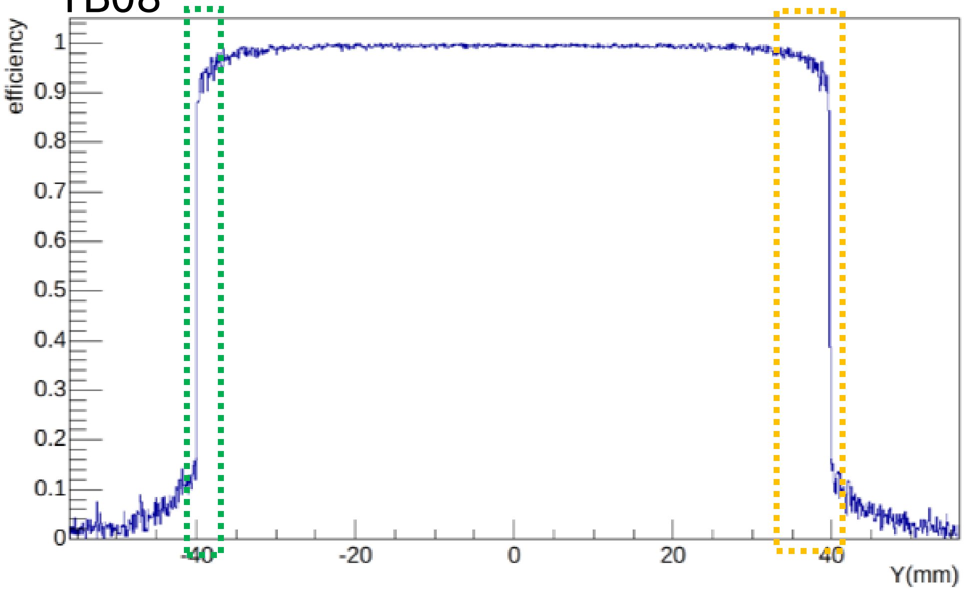


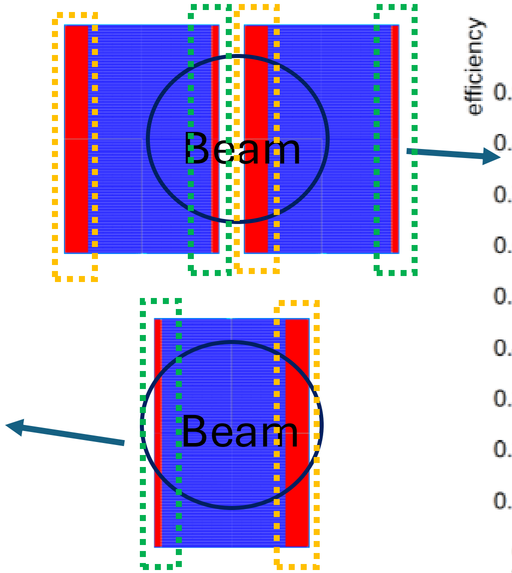


The accuracy of the trajectory reconstructed by the beam monitors varies with the Z coordinate.

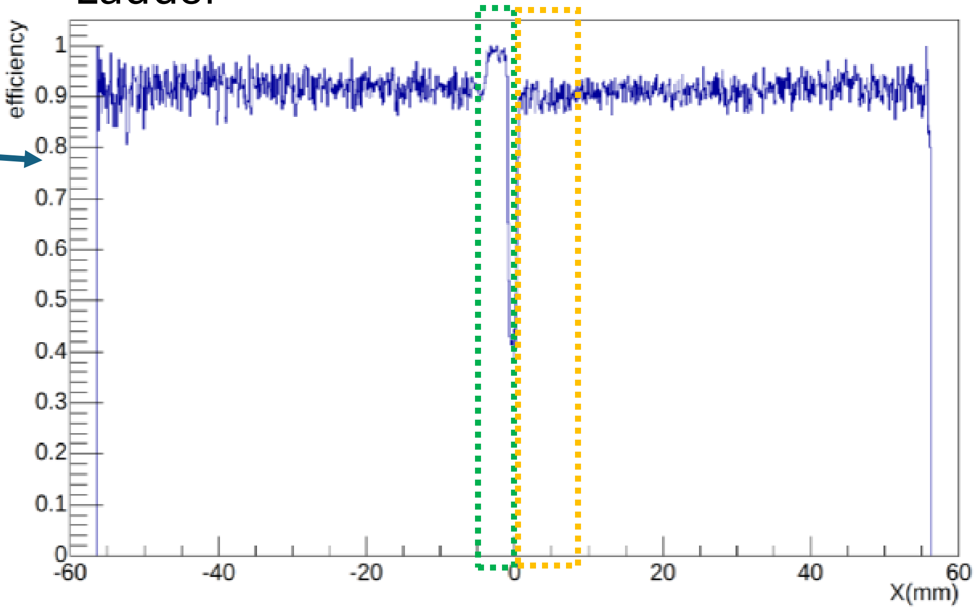
AMS-L0 muon beam test (May 2024): the detection efficiency of resistor regions

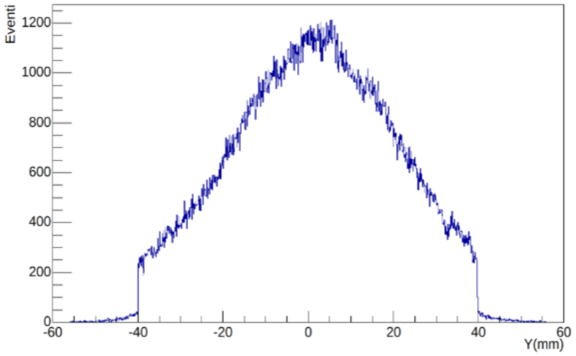
TB08



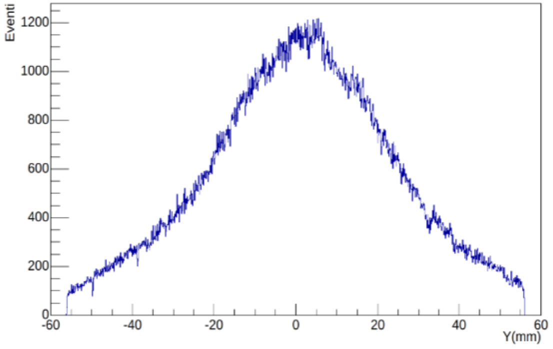


Ladder

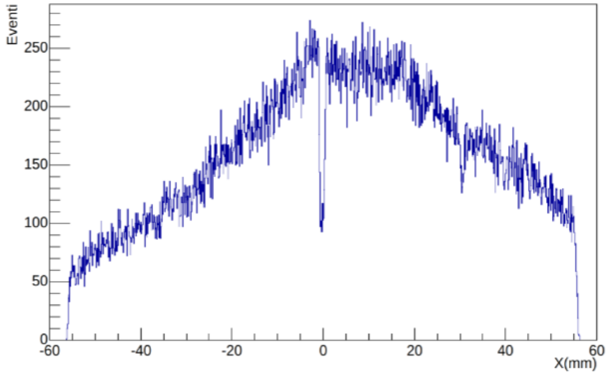




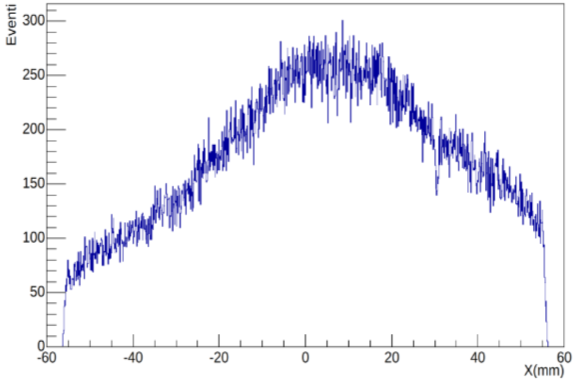
Particles detected by the DUT (TB08), at DUT location



Particles detected by the full telescope, at DUT location

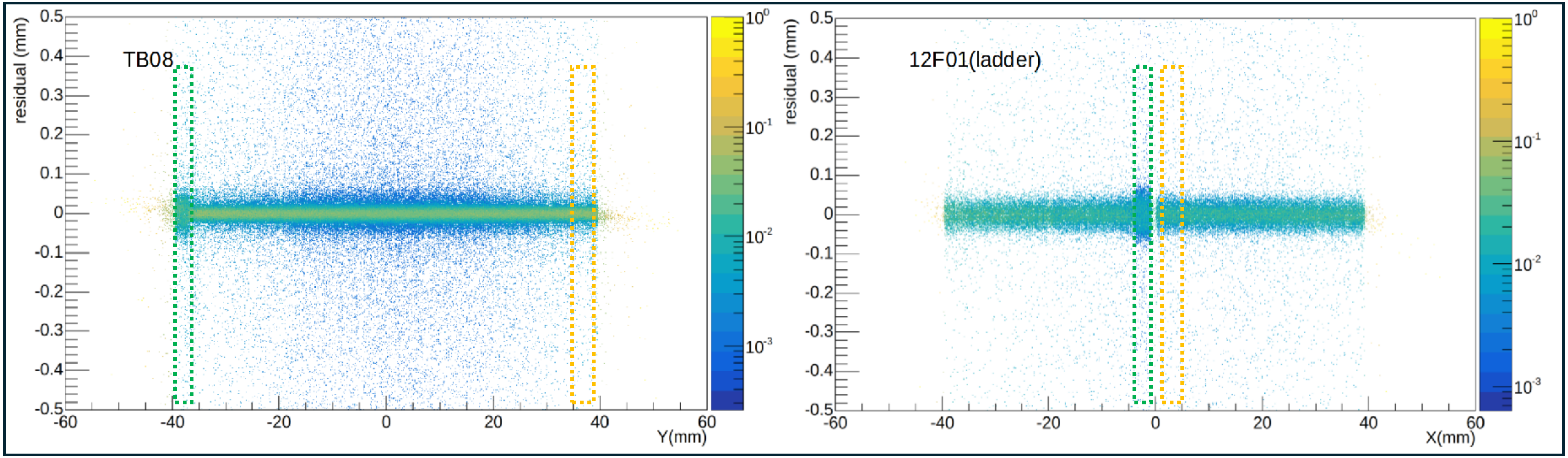


Particles detected by the DUT (ladder), at DUT location



Particles detected by the full telescope, at DUT location

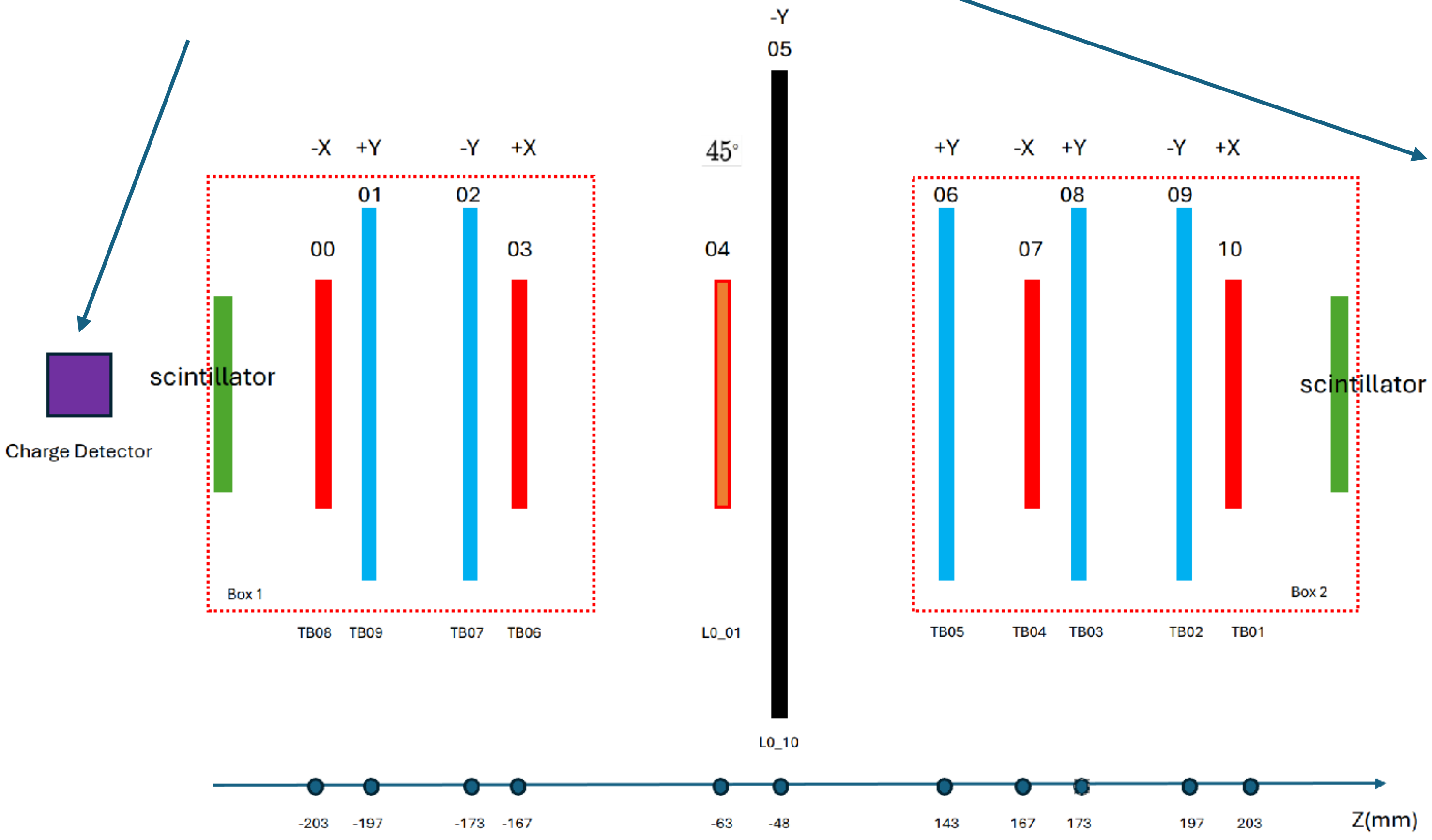
AMS-L0 muon beam test (May 2024): the spatial resolutions of resistor regions

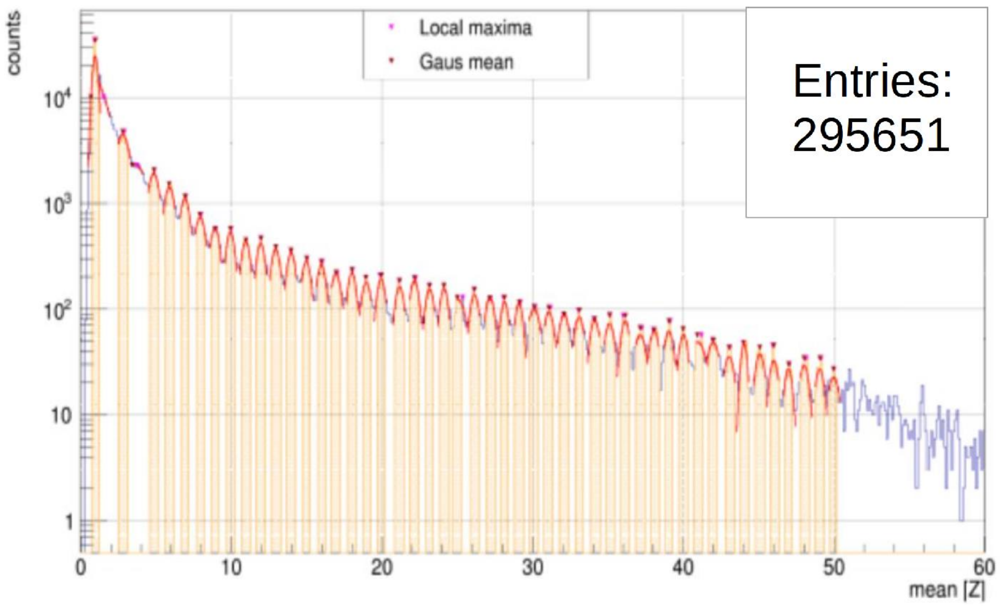


- The distribution of unbiased residuals is wider in the readout strip bias resistor region: this indicates that the spatial resolution in this region is relatively poor.
- For the intermediate strip bias resistor region, there is no significant change in spatial resolution compared to the non-biased resistor region.

AMS-L0 heavy ions beam test (October 2023): setup

Charge Tagger (INFN-Fi), **CT**: 6 "naked" and "blind" photodiodes

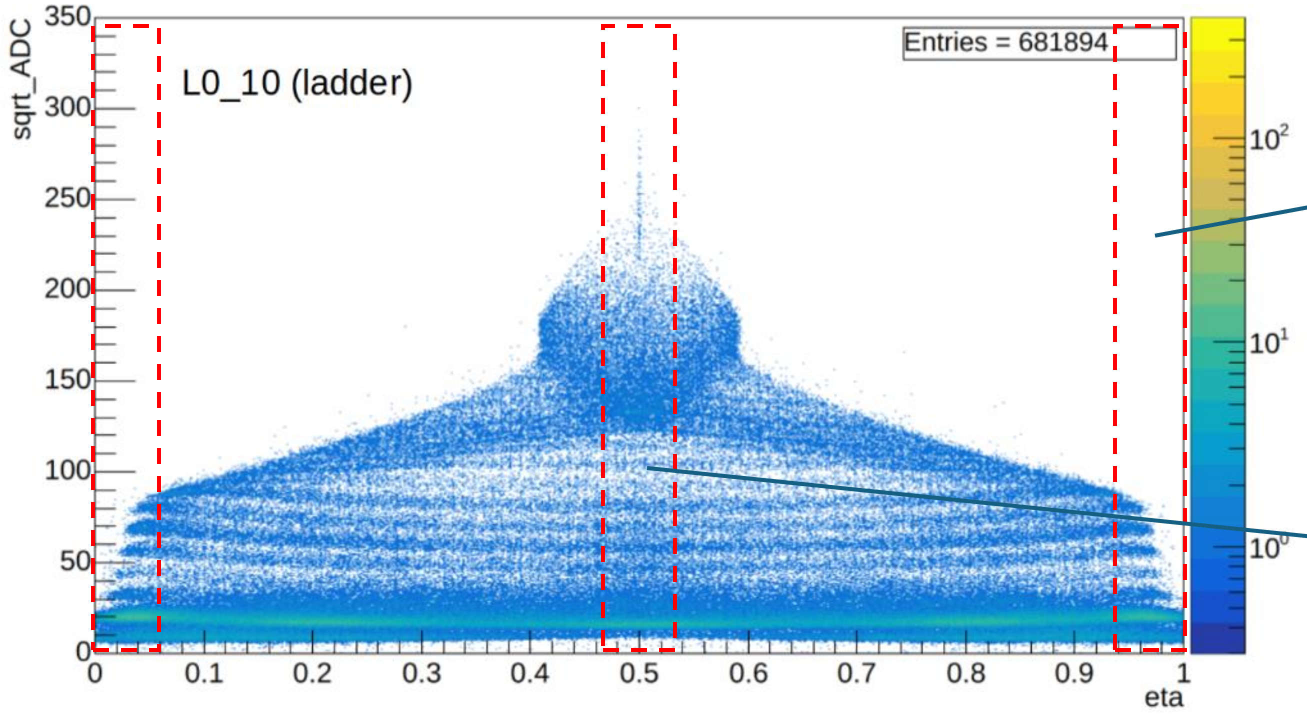


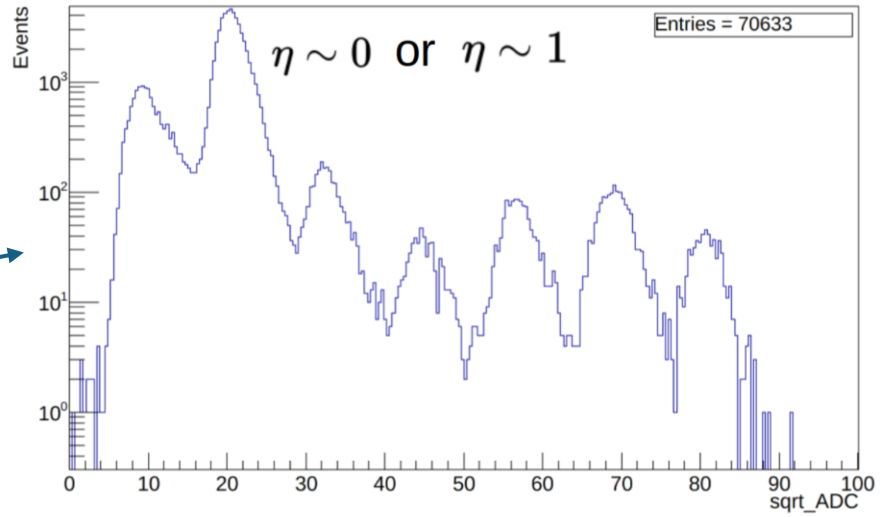


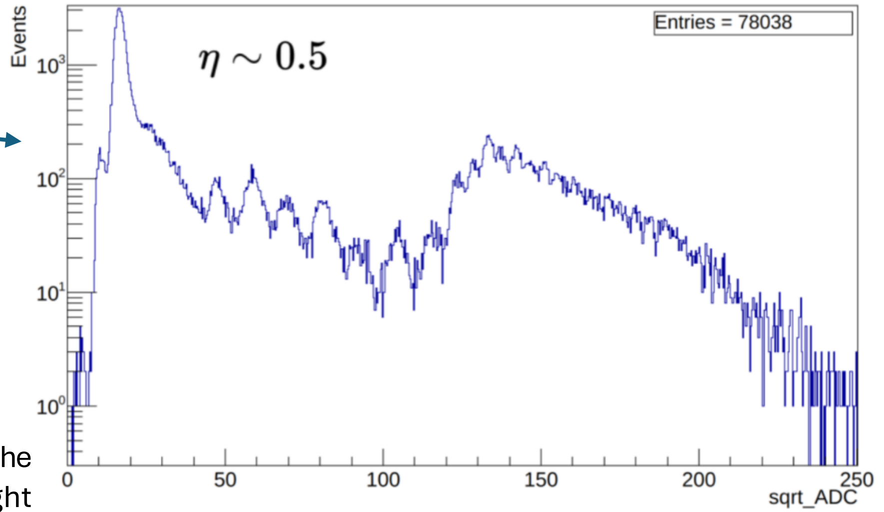
The configuration for studying the charge measurement capabilities of the ladder.

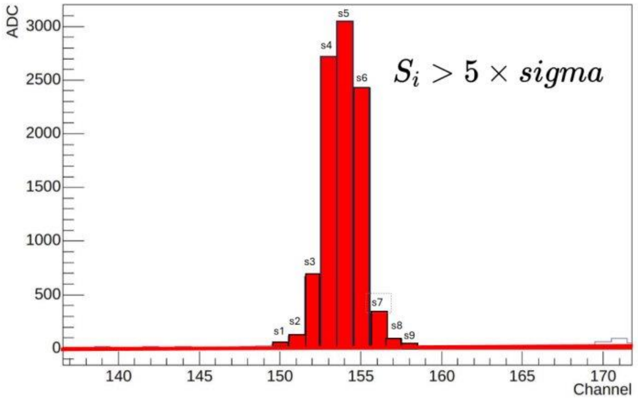
Minimum Ionizing Particles peaks measured by Charge Detector.

AMS-L0 heavy ions beam test (October 2023)**: setup**

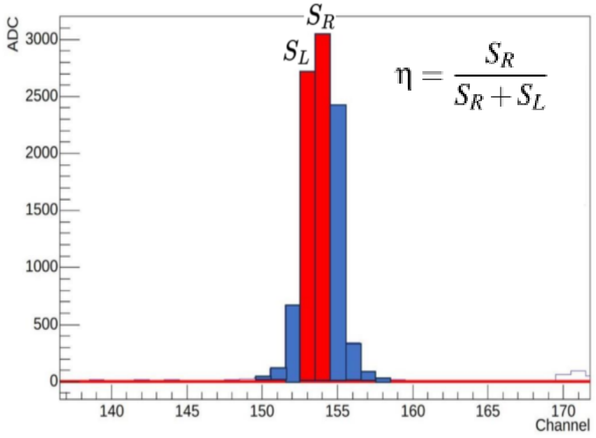






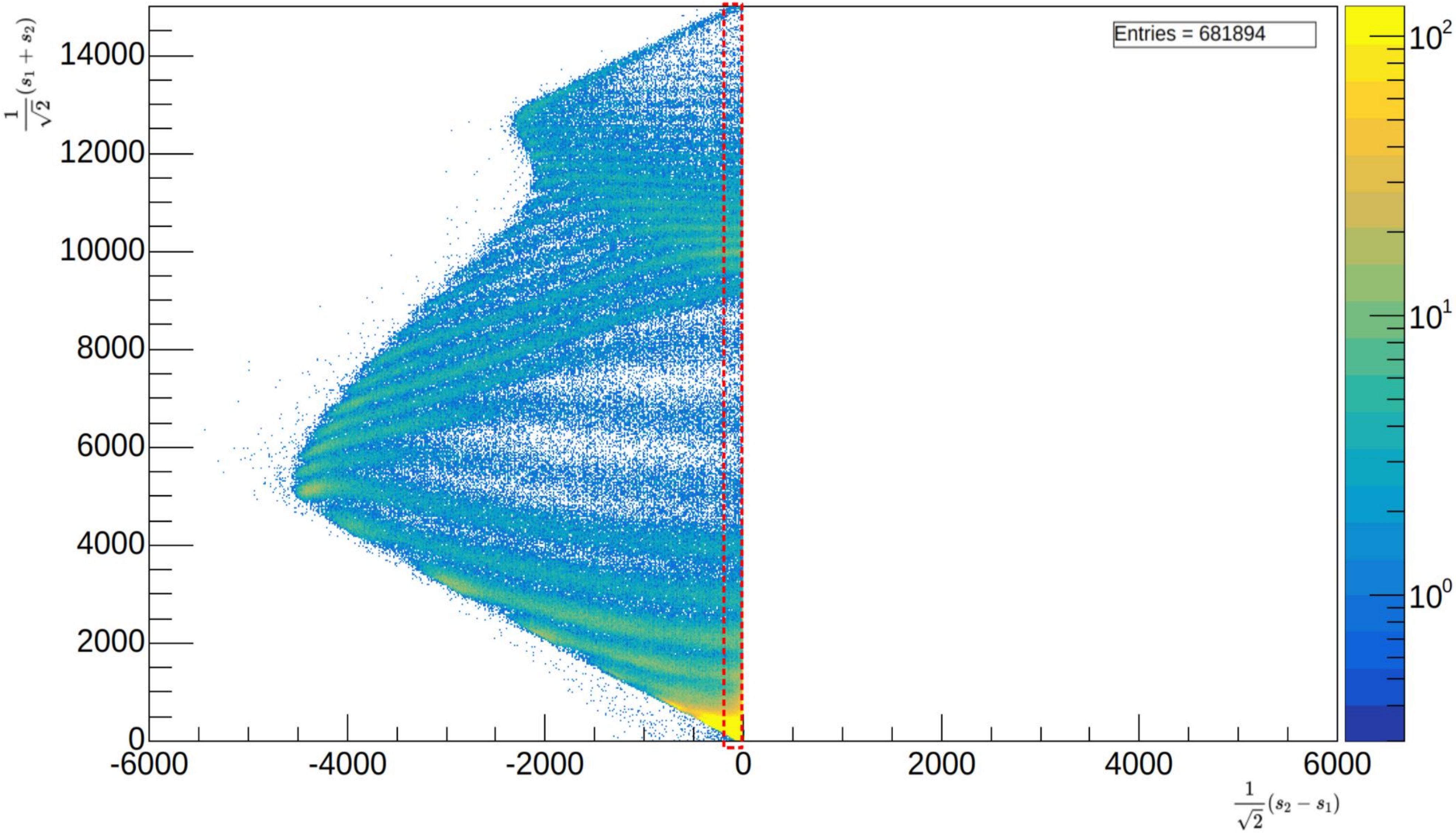


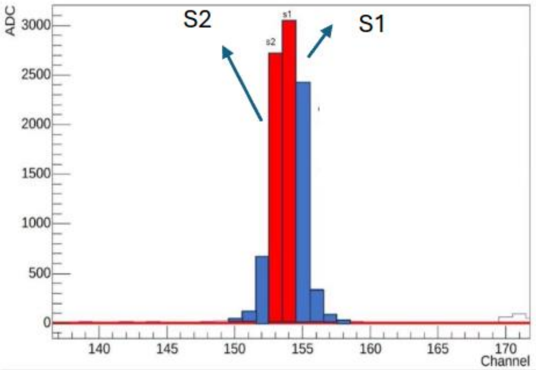
The cluster is a collection of strips with signal magnitudes exceeding a certain threshold near the particle hit position.



$\mathbf{S_L}$ and $\mathbf{S_R}$ represent the signal values of the left and right readout strips, respectively, which have the strongest signals in the cluster and are closest to the particle impact point.

AMS-L0 heavy ions beam test (October 2023): charge resolution





- **S1** is the strip with the maximum signal in a cluster, typically the one closest to the particle impact position
- **S2** is the strip with second largest signal in a cluster.

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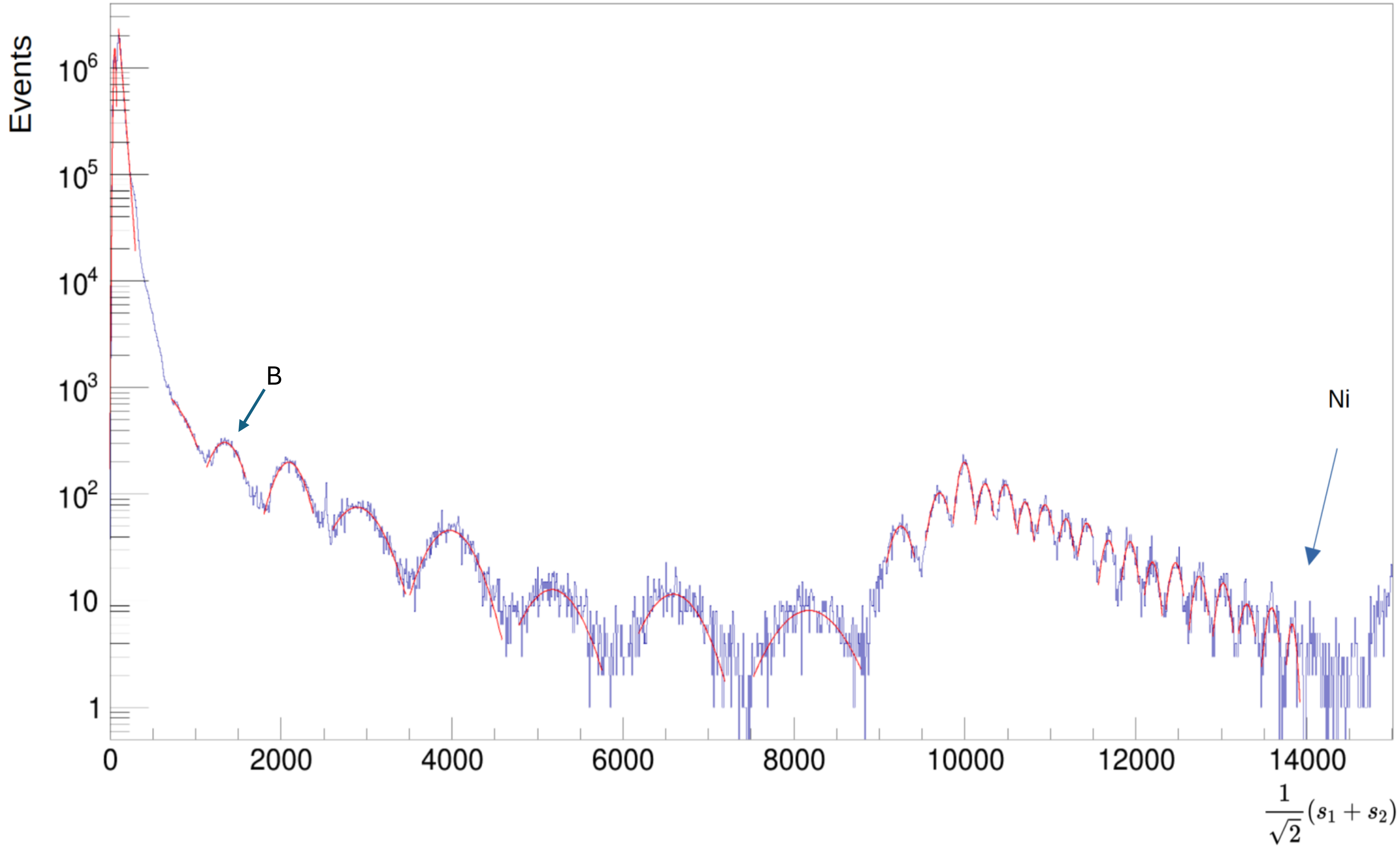
AMS-L0 heavy ions beam test (October 2023): charge resolution



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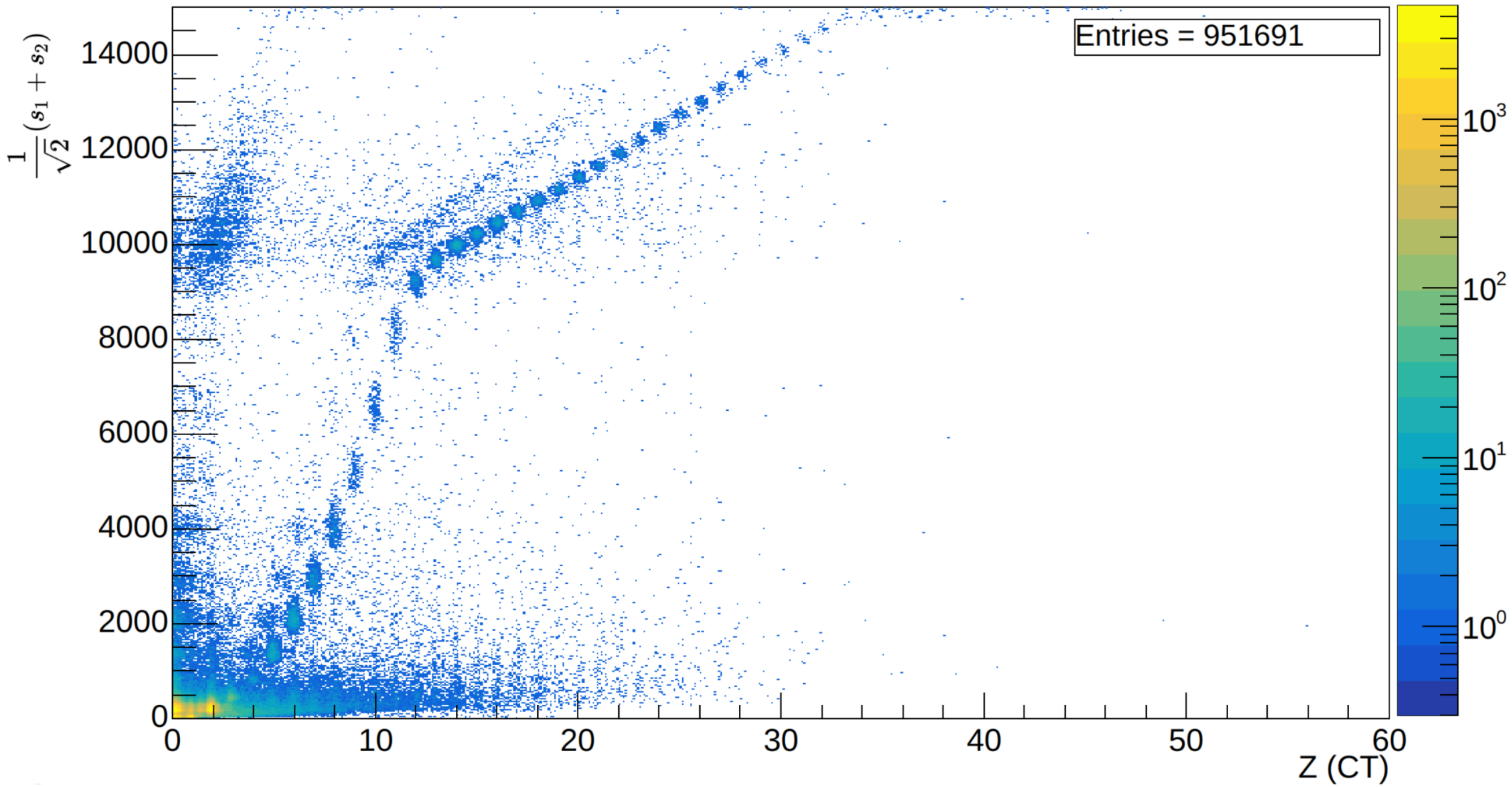
AMS-L0 heavy ions beam test (October 2023**):** The Synchronization between the CT and adder.



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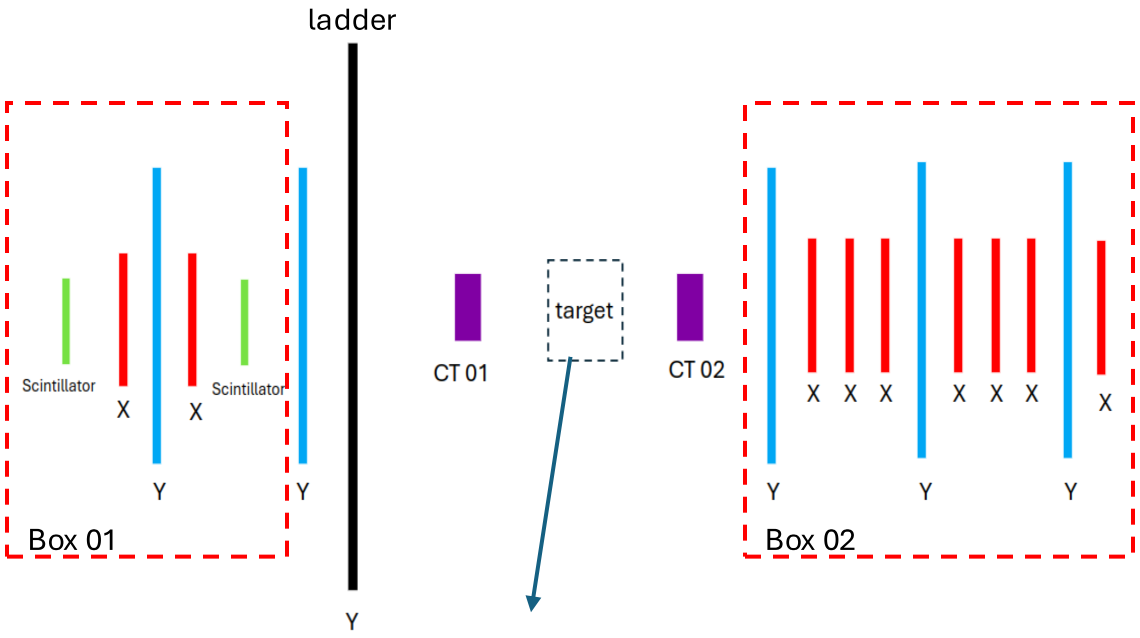
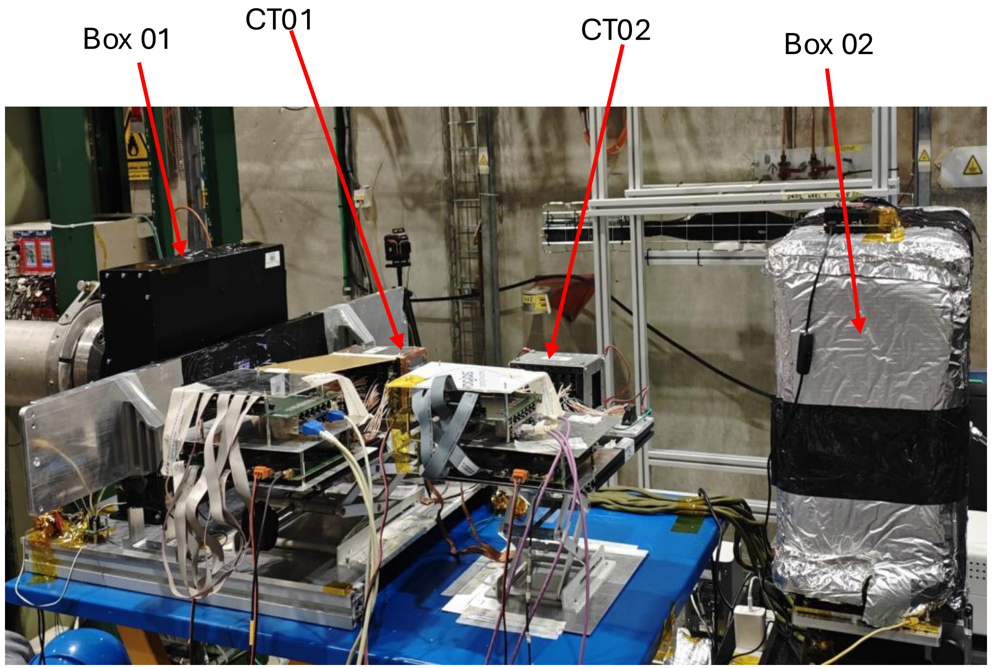
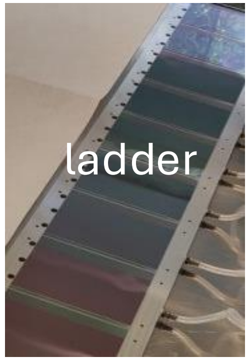
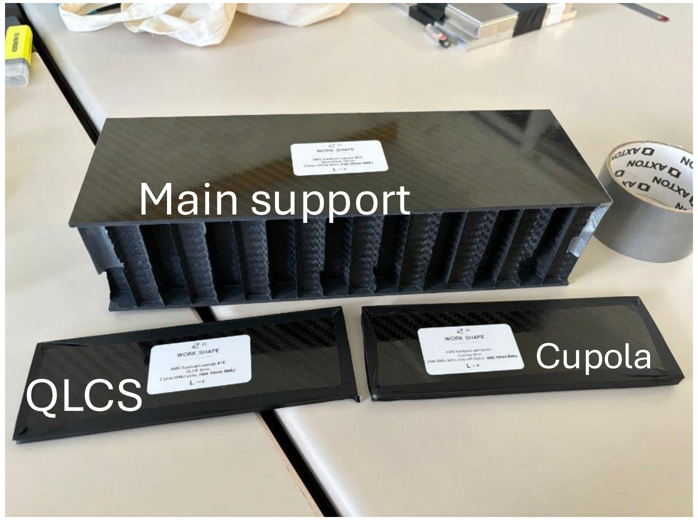
AMS-L0 heavy ions beam test (November 2024): SETUP

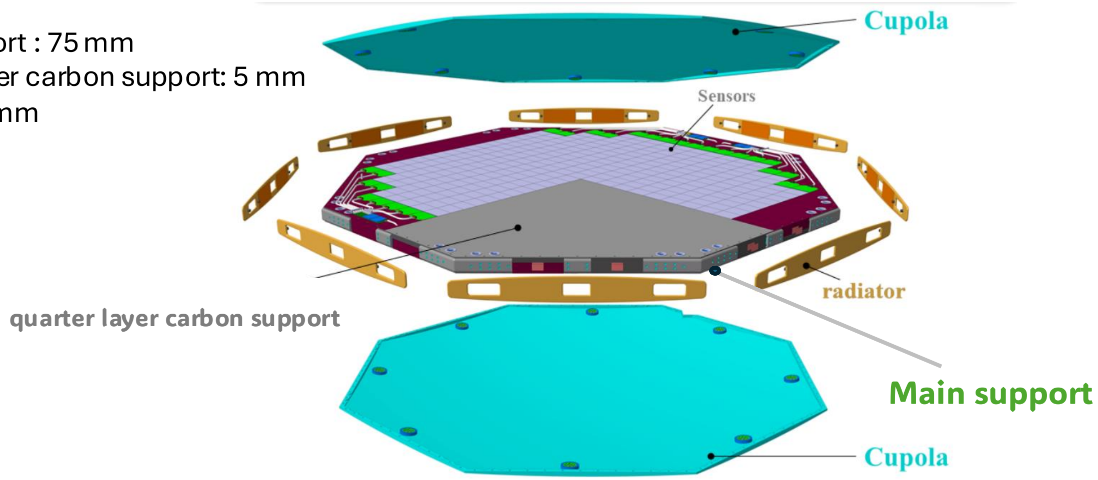




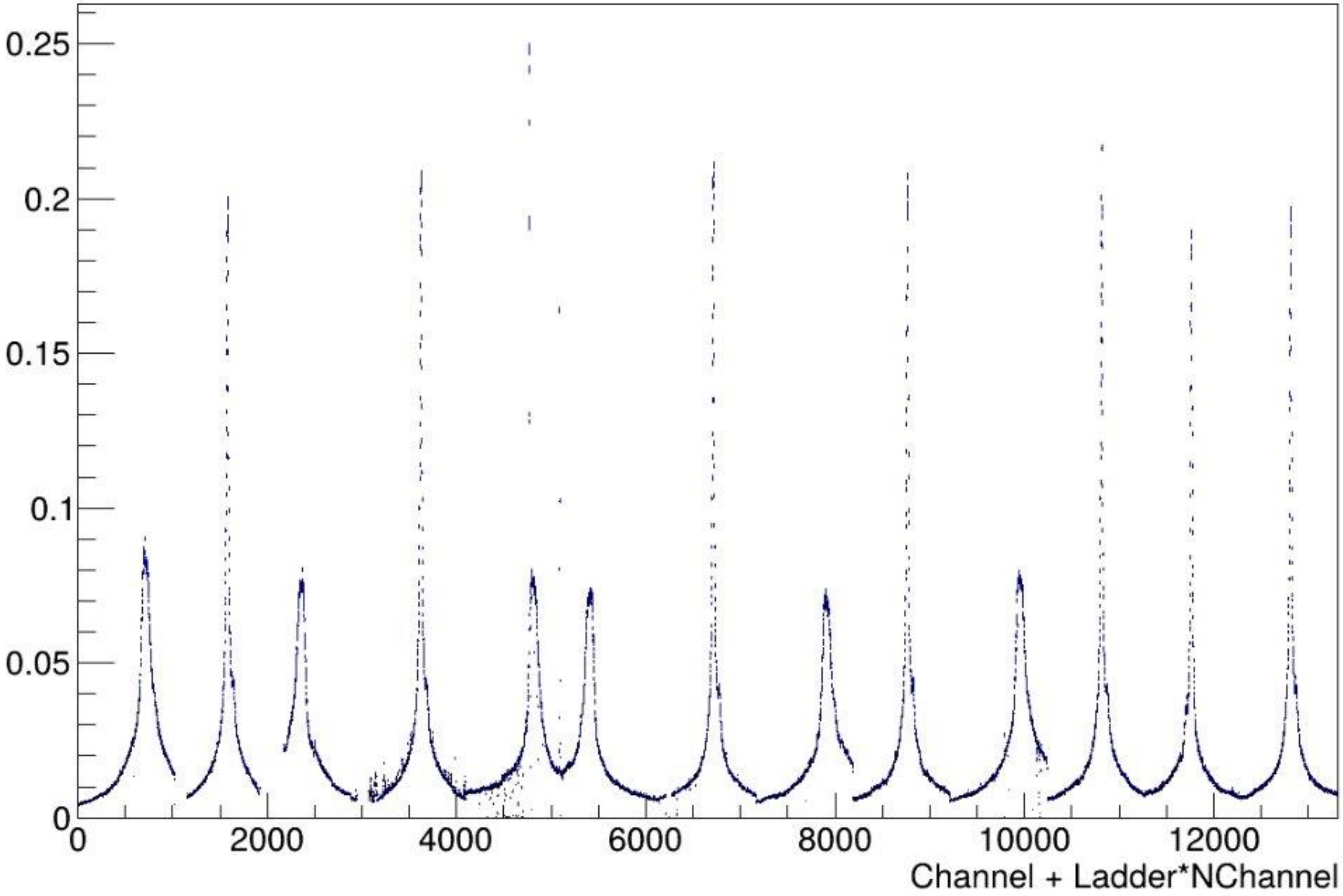




- Main support : 75 mm
- quarter layer carbon support: 5 mm
- Cupola: 8 mm



AMS-L0 heavy ions beam test (November 2024**): SETUP**



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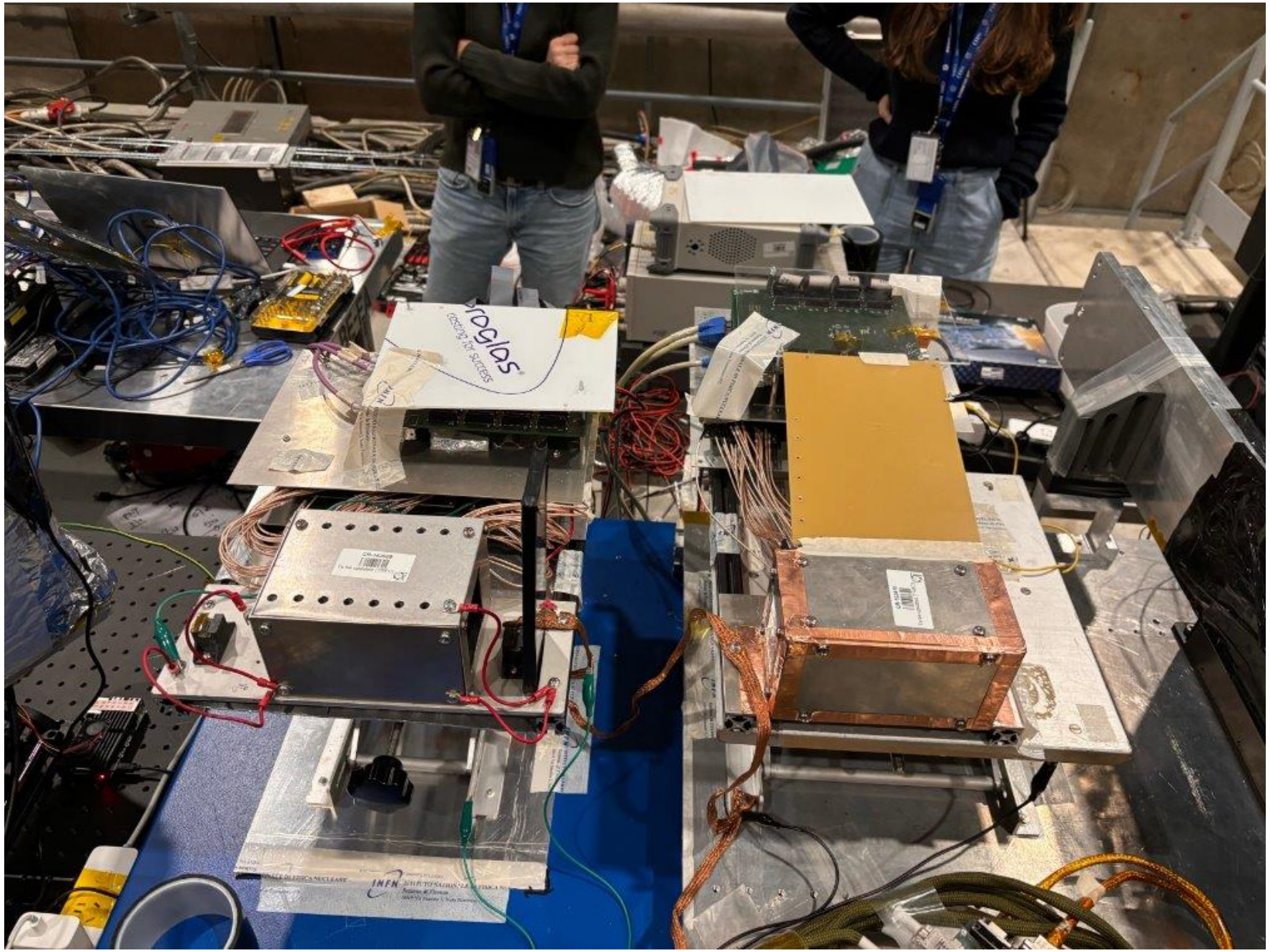
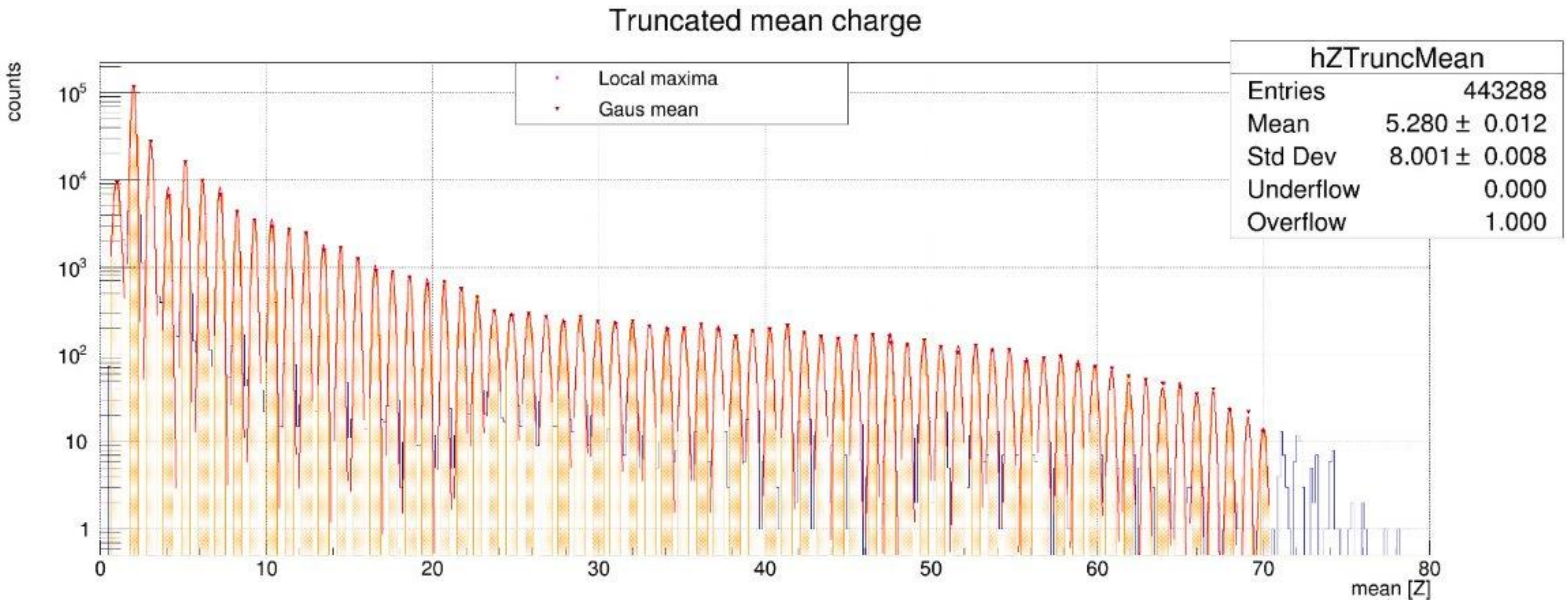
AMS-L0 heavy ions beam test (November 2024**): SETUP**

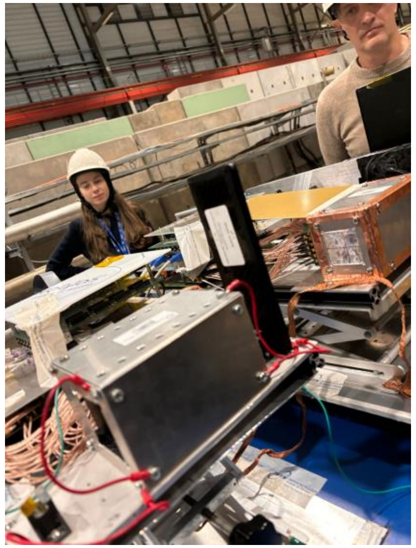


2 CTs

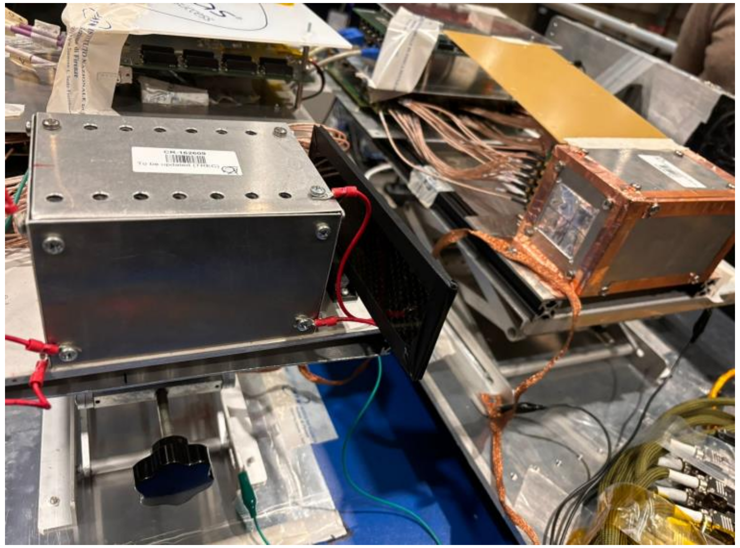
AMS-L0 heavy ions beam test (November 2024**): SETUP**



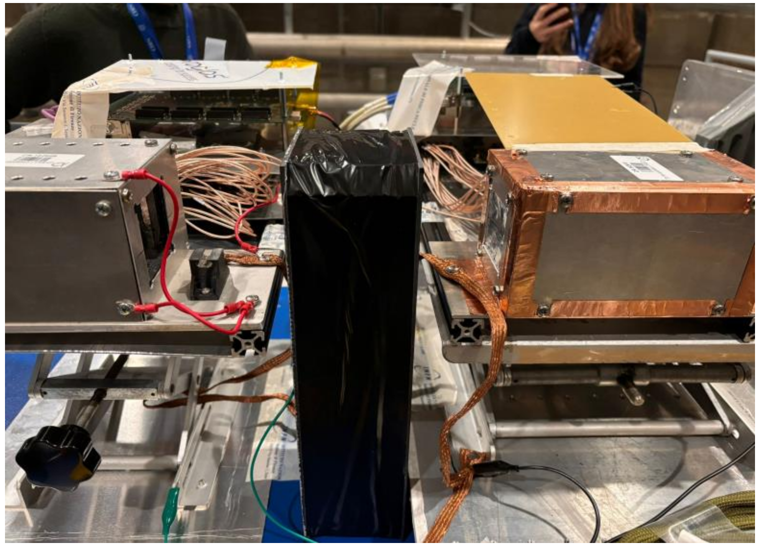
AMS-L0 heavy ions beam test (November 2024): SETUP



Cupola

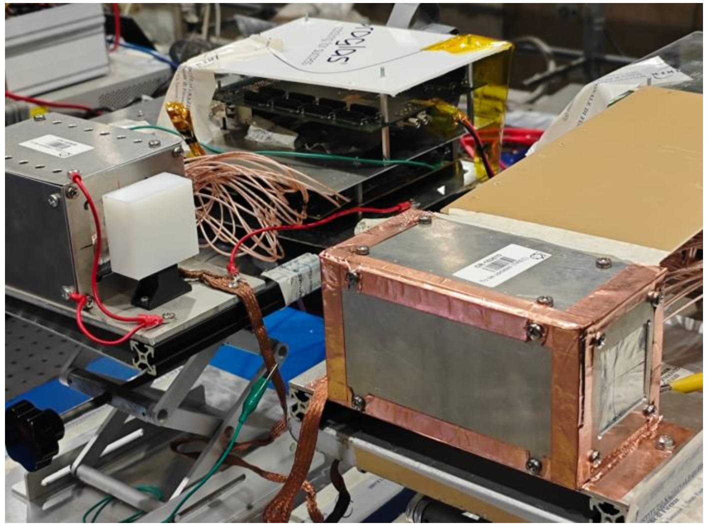


QLCS

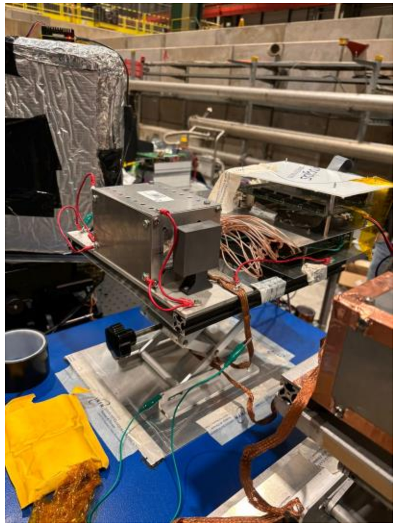


Main support

Ladder



Polyethylene



Graphite

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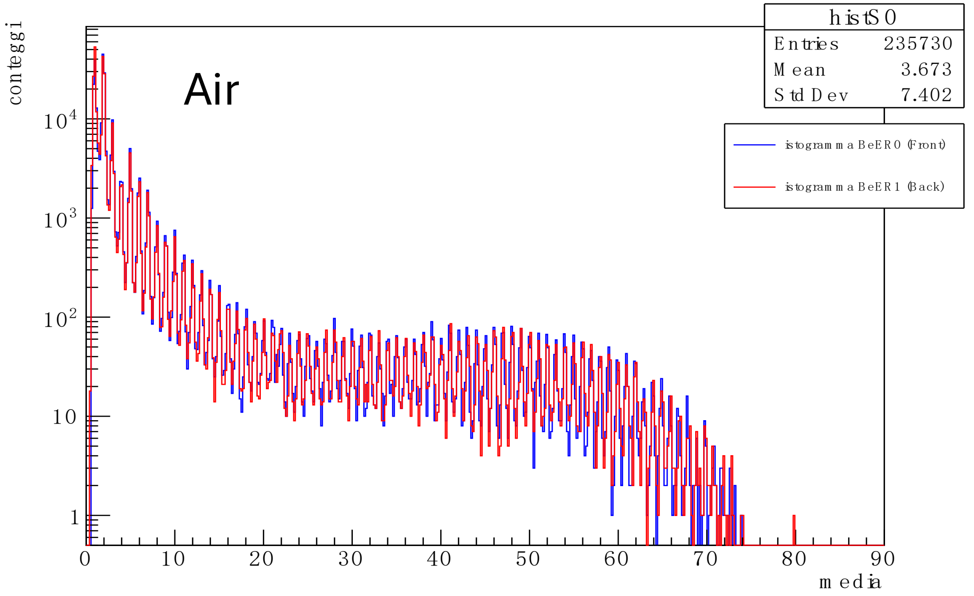
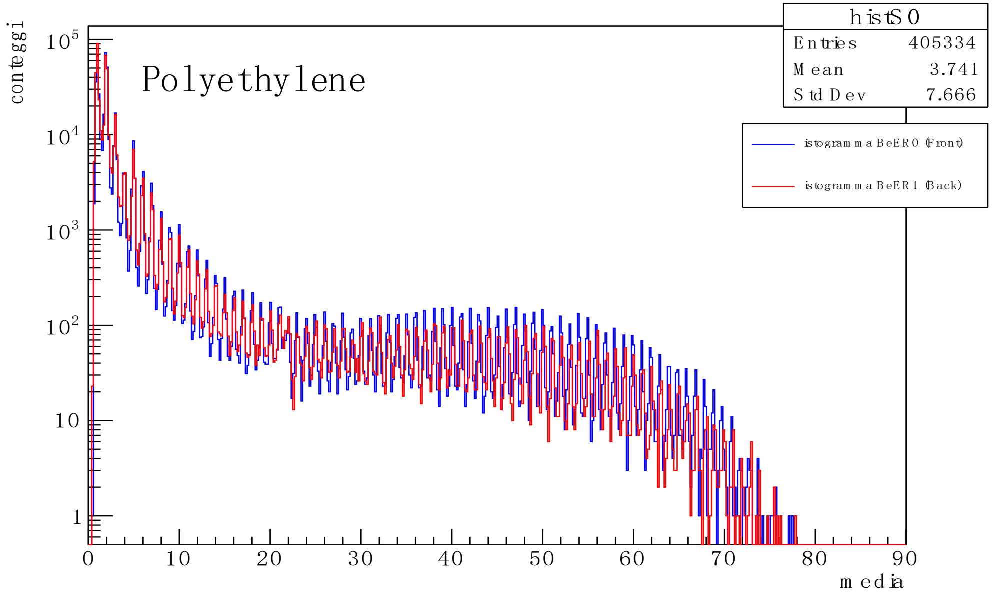
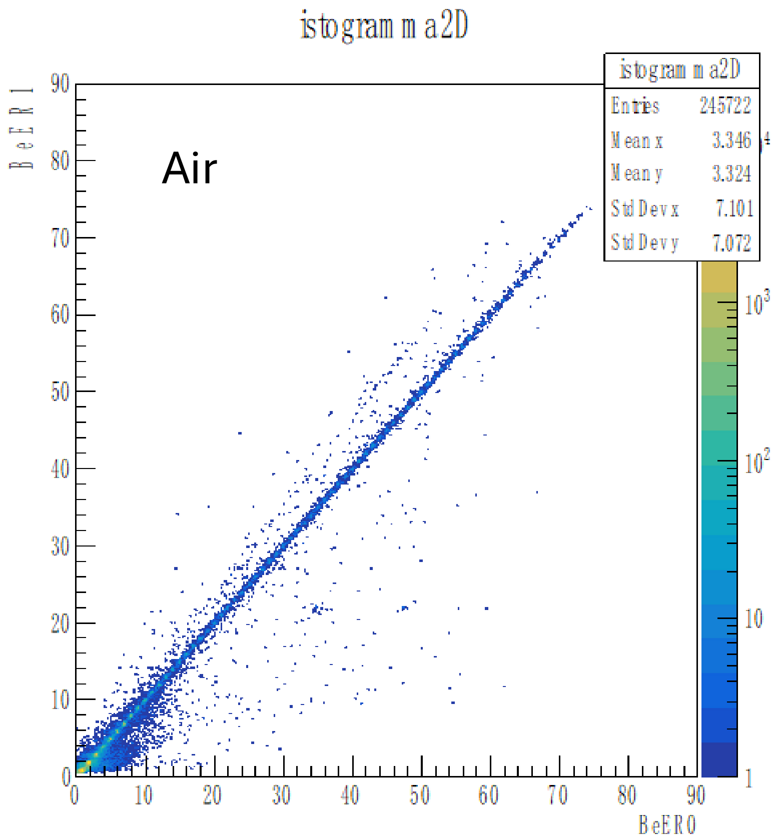

Air
histS0
Entries 235730
Mean 3.673
Std Dev 7.402
istogramma BeER0 (Front)
istogramma BeER1 (Back)
conteggi
media


Polyethylene
histS0
Entries 405334
Mean 3.741
Std Dev 7.666
istogramma BeER0 (Front)
istogramma BeER1 (Back)
conteggi
media


istogramma2D
Air
istogramma2D
Entries 245722
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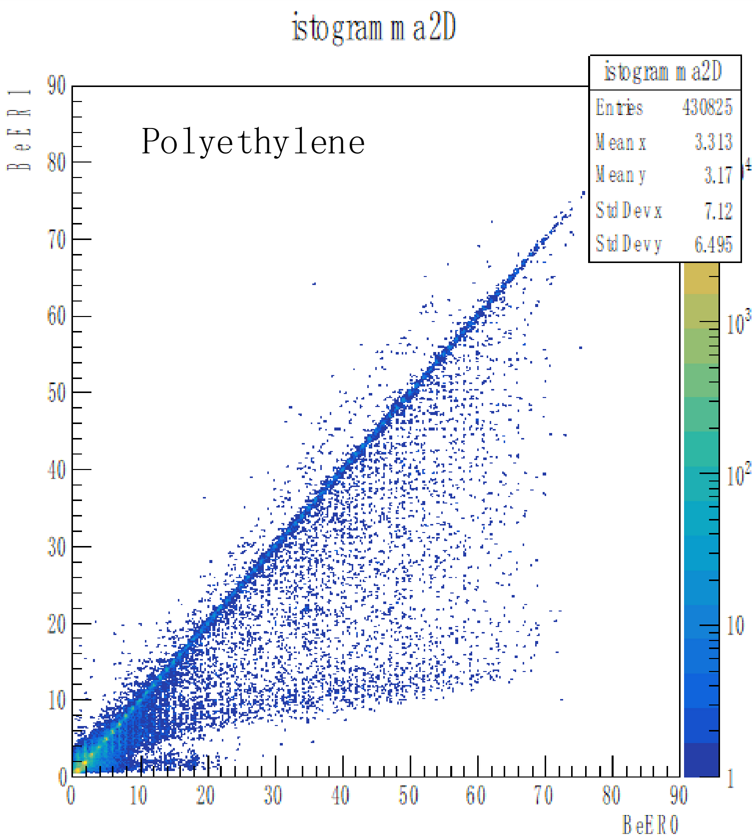
Mean y 3.324
Std Dev x 7.101
Std Dev y 7.072
BeER1
BeER0


istogramma2D
Polyethylene
istogramma2D
Entries 430825
Mean x 3.313
Mean y 3.17
Std Dev x 7.12
Std Dev y 6.495
BeER1
BeER0

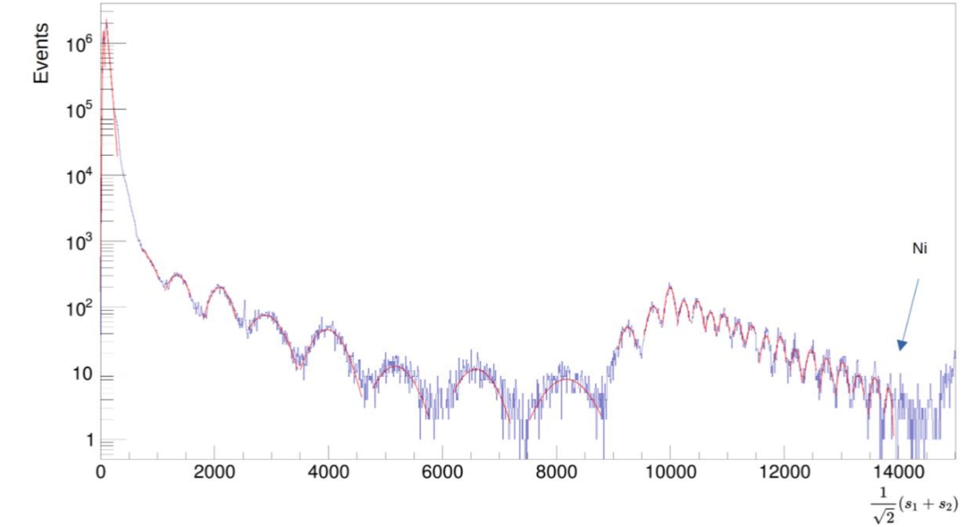
Summary

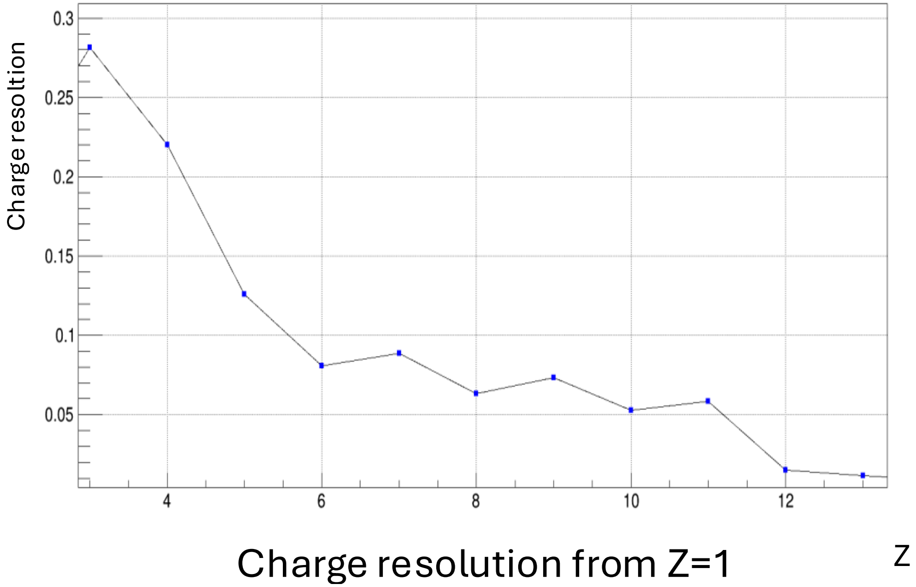
- The spatial resolution of the long ladder is around 12 micrometers
- The long ladder can identify charge up to nickel

Thank you for your attention.

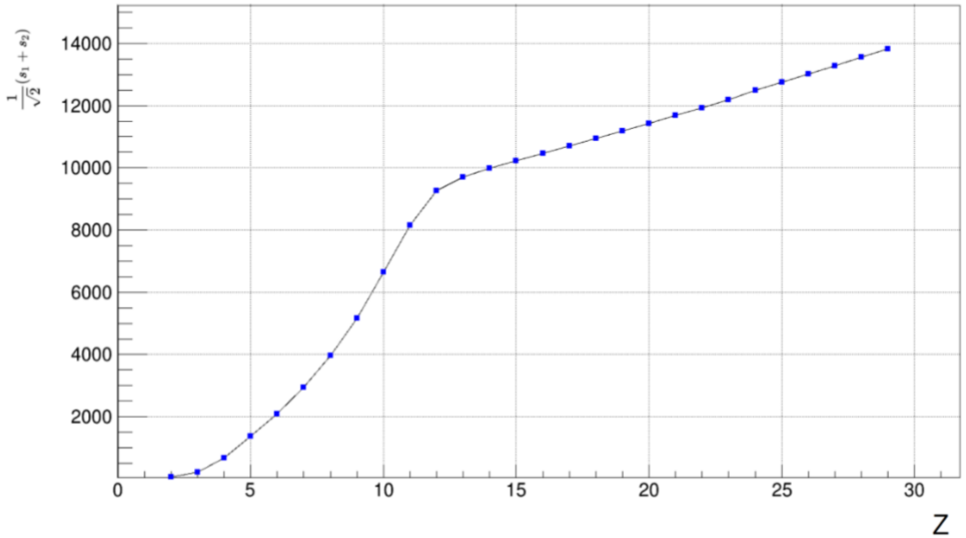
fine

Backup

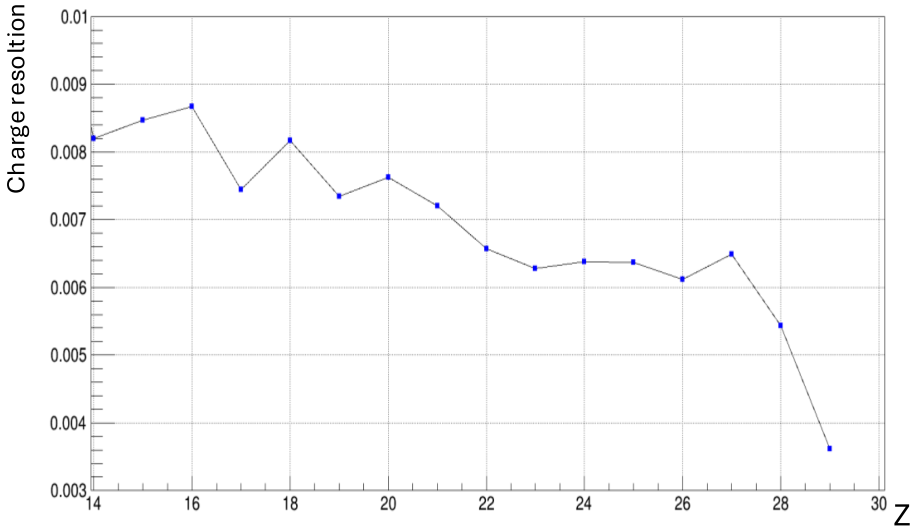




Charge resolution from Z=1



Peak value vs Z



Charge resolution above Z=13