The Layer 0 upgrade of the AMS-02 experiment on the ISS: status and perspectives

Jiang YaoZu
Università degli Studi e INFN Perugia

INFN PERUGIA
Istituto Nazionale di Fisica Nucleare
Sezione di Perugia

A.D. 1308 unipg
DIPARTIMENTO DI FISICA E GEOLOGIA
DIPARTIMENTO DI ECCELLENZA MUR 2023/2027

AMS 02: The Alpha Magnetic Spectrometer

Composed by:

• TRD (transition radiation detector): distinguish proton /antiproton from electron/ positron

• TOF (Time of Flight Counters): determine the particle time of flight and charge

• Tracker: measure the particle rigidity and charge

• RICH (Ring Imaging Cherenkov counter): measure the particle charge and velocity

• ECAL (Electromagnetic Calorimeter): distinguish between protons and electrons or positrons.

Main objectives:

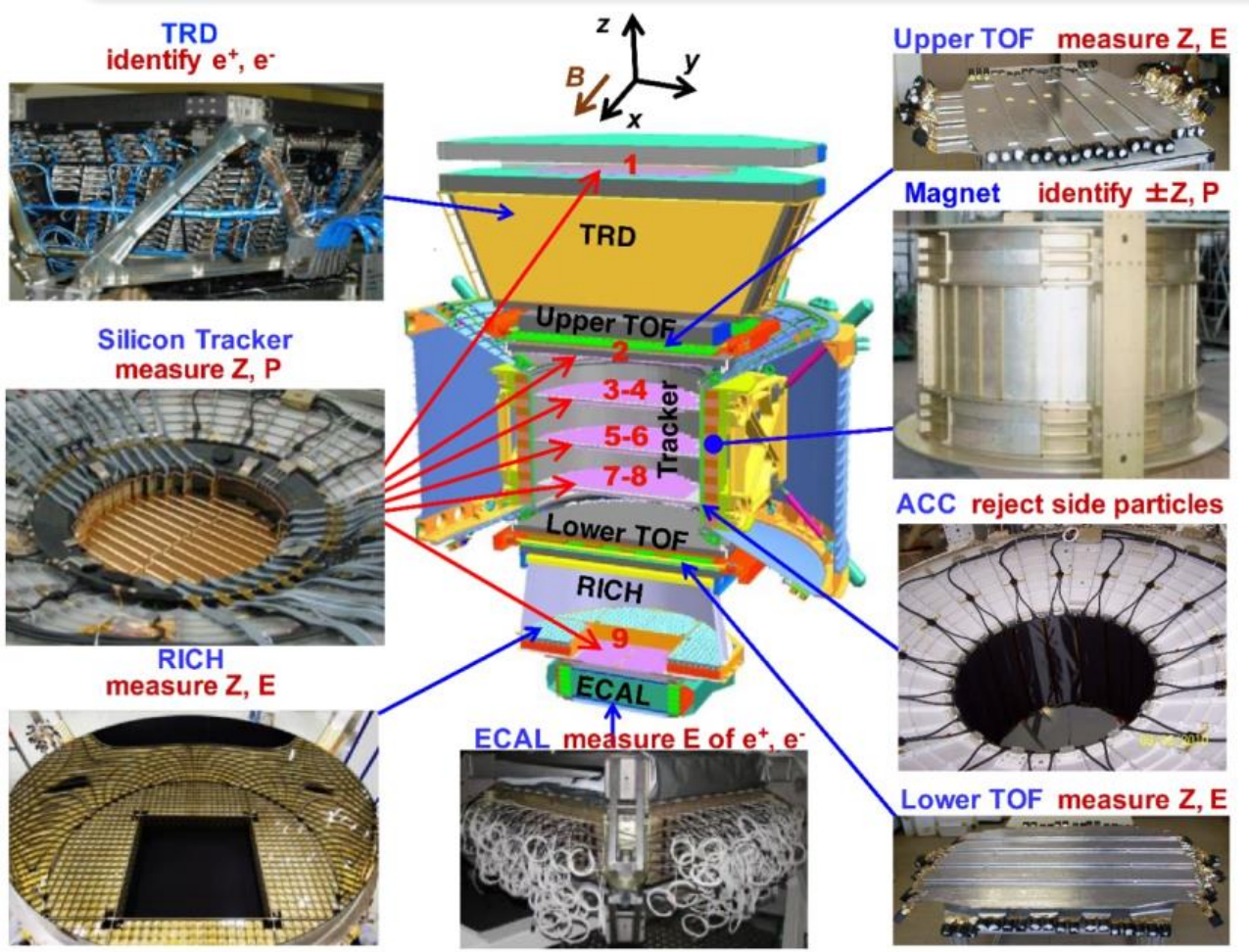
• search for Primordial Antimatter by direct detection of antinuclei

• search for indirect Dark Matter signals

• study of production, acceleration and propagation of Cosmic-Rays

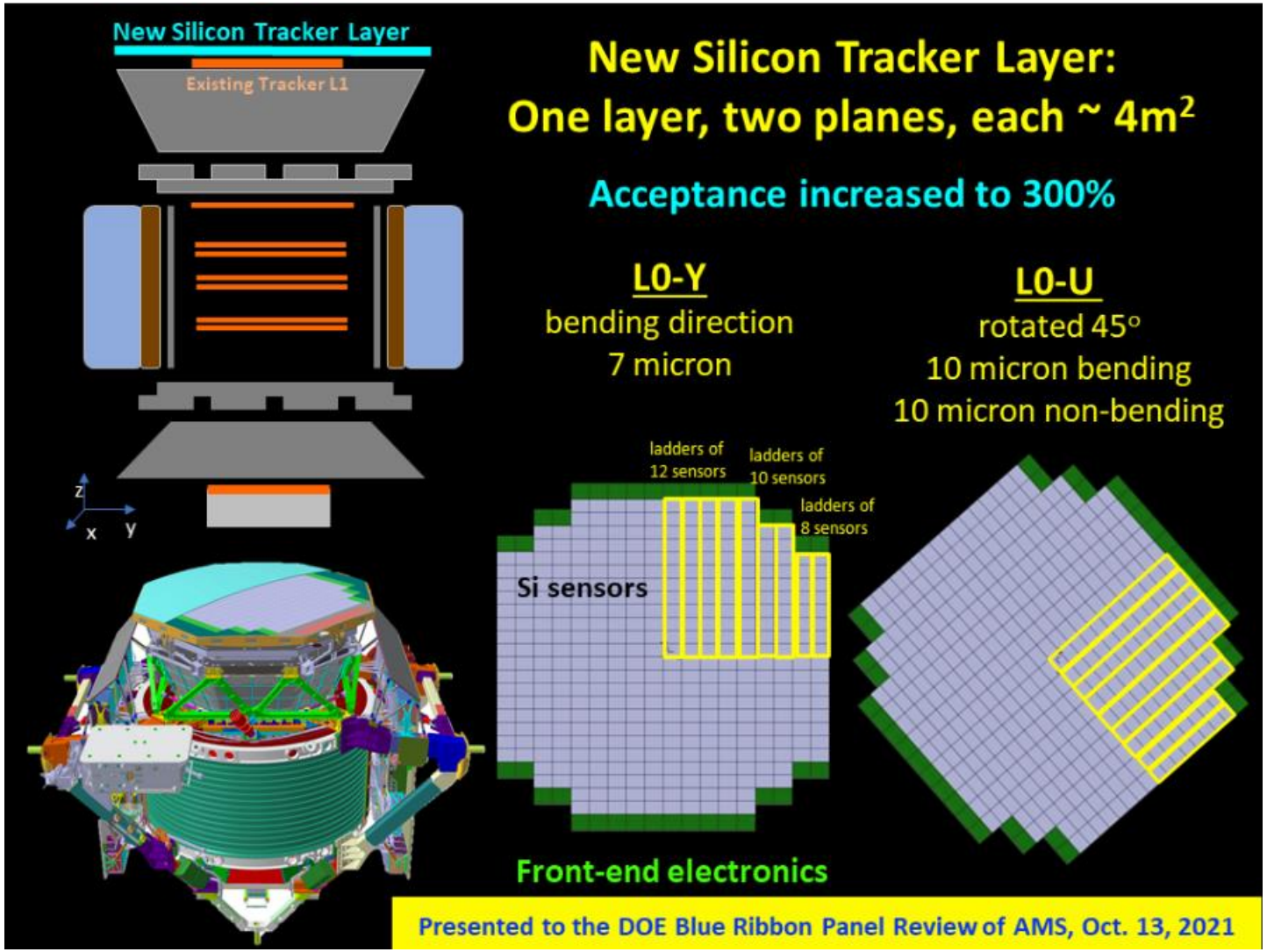
• study of Solar Modulation

In orbit on the International Space Station since May 2011



The AMS-02 Upgrade

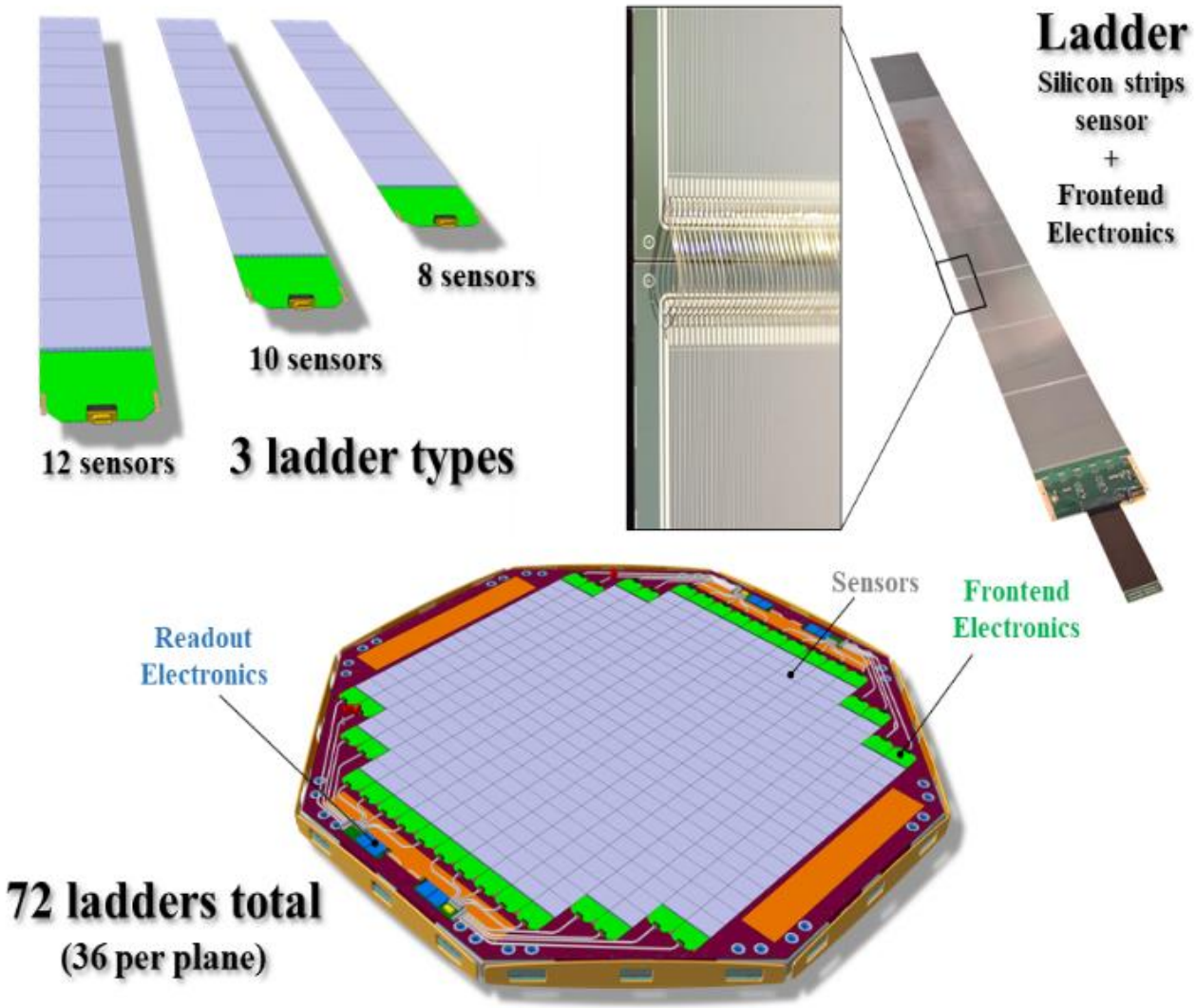
- AMS02-L0, an upgrade which consist in adding a new silicon detection layer, called L0, above the existing L1 layer to increase the overall acceptance area.
- Composed of two layers of silicon sensors, where one layer is rotated 45 degrees relative to the other.
- The total area of the silicon sensors to be installed is ~ 8 m^2. will increase by 300% the acceptance of the experiment.



To be installed in early 2026

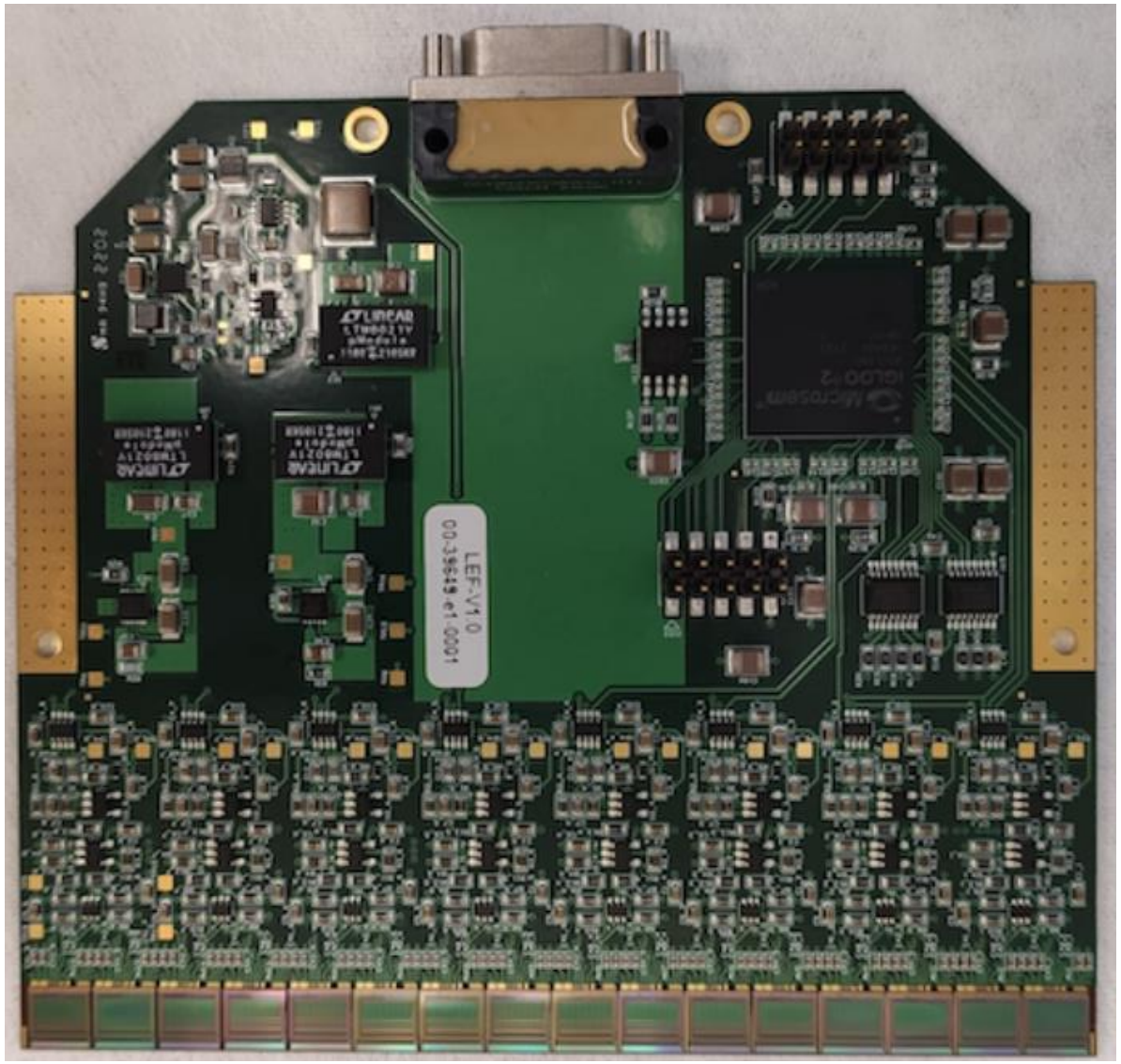
LADDER FOR AMS - L0

- To cover large areas without increasing the number of channels, the design must be based on “long” silicon sensor modules (called “ladders”).
- 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 µm.
- All channels of adjacent silicon sensors are connected in daisy chain to form a single sensor with longer strips.



LADDER Electronics Front End Board

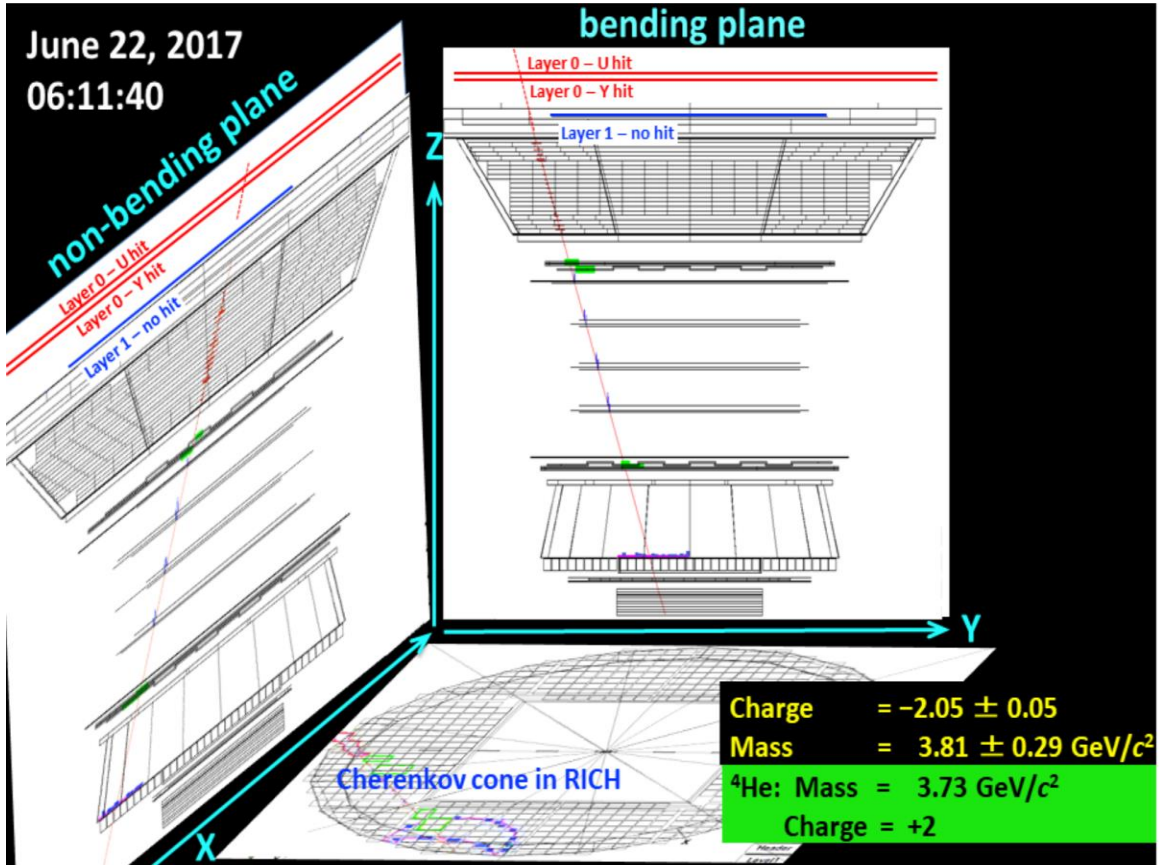
- The board is equipped with 16 VA chips (IDE1140).
- Each two VA chips are connected to the same ADC.
- Only one digital interface
- The data compression (zero suppression) will be implemented in the FPGA itself



Physics Justification For The Upgrade

- **Provides additional measurement points and constraints**

- Extend the energy range of the positron flux measurement to ~ 2 TeV from the current ~ 1.5 TeV (1 TeV published in 2019) and reduce the uncertainties at least by a factor of two
- Extend the energy range of the electron flux measurement up to 3 TeV from the current ~ 2 TeV (1.4 TeV published in 2019) and reduce the uncertainties at least by a factor of about two
- Enable to provide a complete and accurate spectrum for all the 29 elements



Event display of an anti-^{4}He data event. Y-Z is the bending plane. X-Z is the non-bending plane

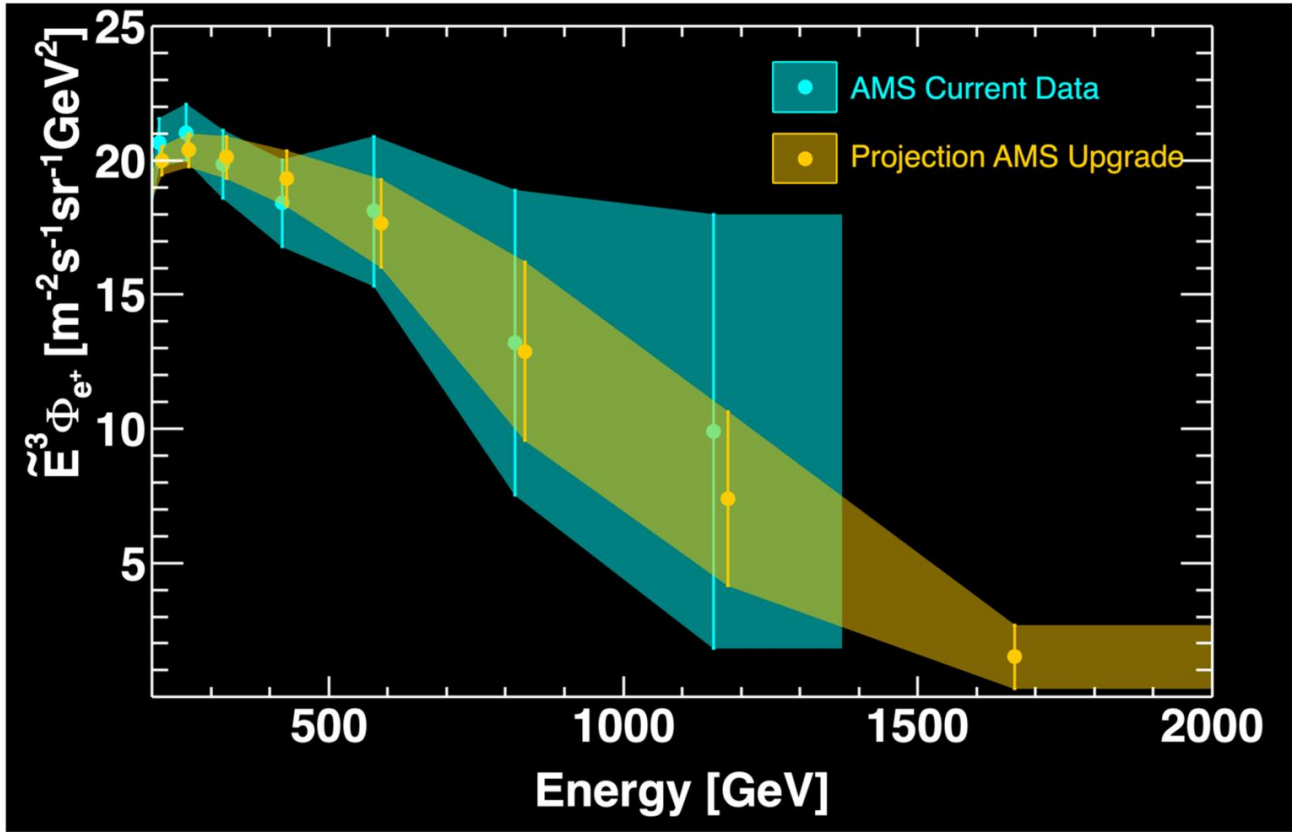
Physics Justification For The Upgrade

- Provides additional measurement points and constraints

- **Extend the energy range of the positron flux measurement to ~ 2 TeV from the current ~ 1.5 TeV (1 TeV published in 2019) and reduce the uncertainties at least by a factor of two**

- Extend the energy range of the electron flux measurement up to 3 TeV from the current ~ 2 TeV (1.4 TeV published in 2019) and reduce the uncertainties at least by a factor of about two

- Enable to provide a complete and accurate spectrum for all the 29 elements



Positron spectrum at highest energies for the current data (blue shading) and with the upgrade through 2030 (gold shading).

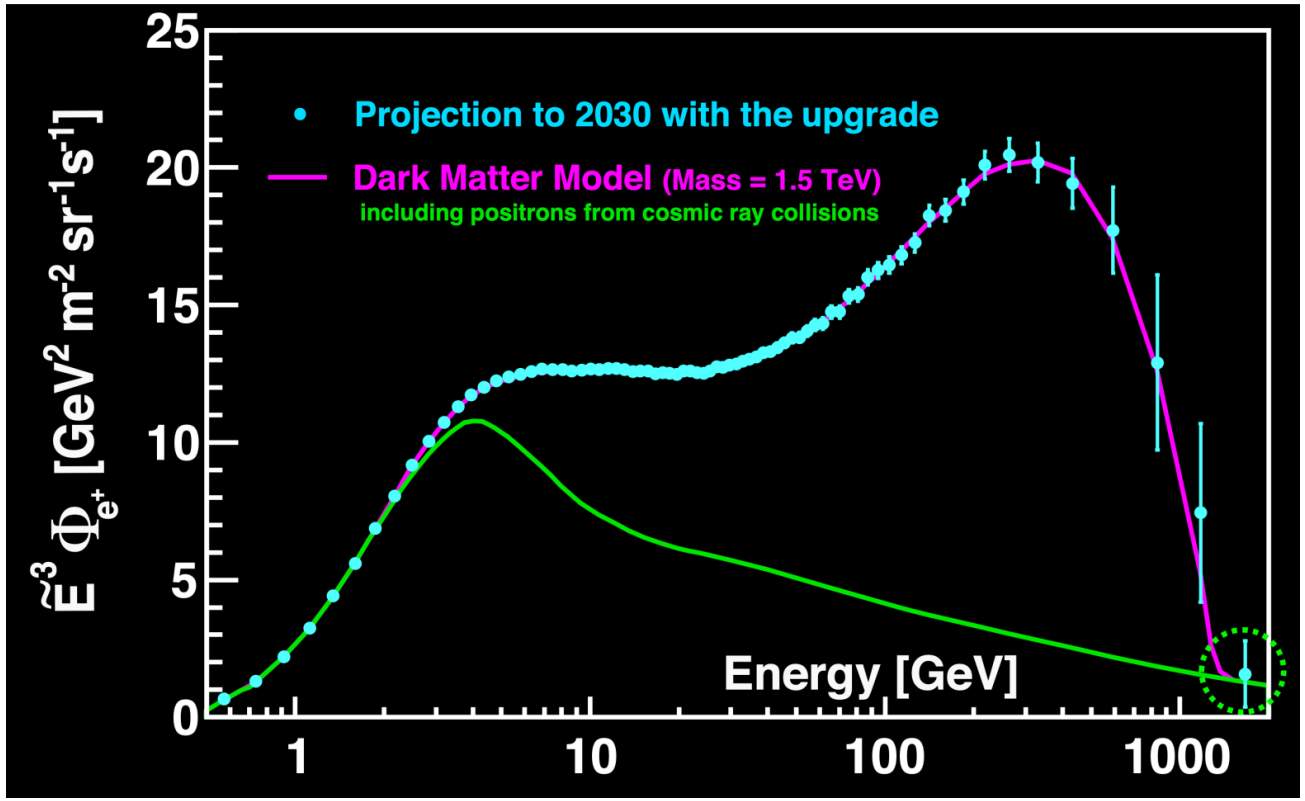
Physics Justification For The Upgrade

- Provides additional measurement points and constraints

- **Extend the energy range of the positron flux measurement to ~ 2 TeV from the current ~ 1.5 TeV (1 TeV published in 2019) and reduce the uncertainties at least by a factor of two**

- Extend the energy range of the electron flux measurement up to 3 TeV from the current ~ 2 TeV (1.4 TeV published in 2019) and reduce the uncertainties at least by a factor of about two

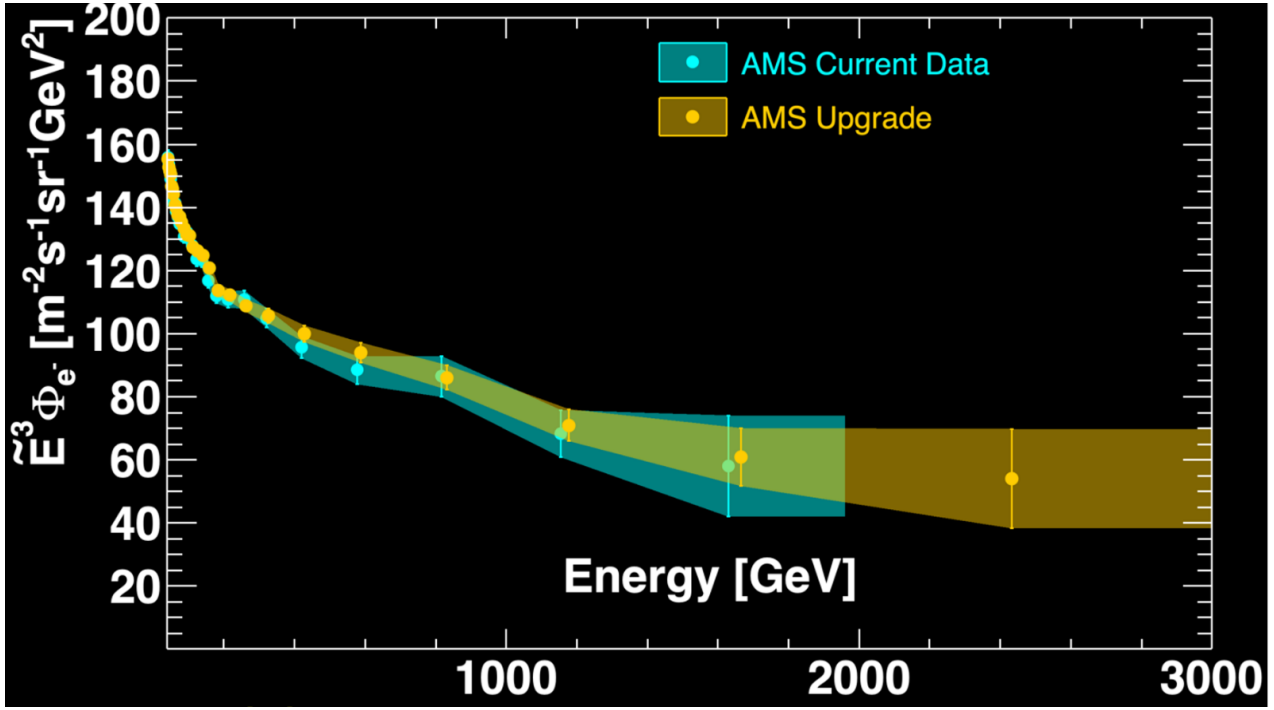
- Enable to provide a complete and accurate spectrum for all the 29 elements



Positron spectrum with the upgrade through 2030 (cyan points) together with a dark matter prediction (magenta curve) which includes cosmic ray collisions (green curve).

Physics Justification For The Upgrade

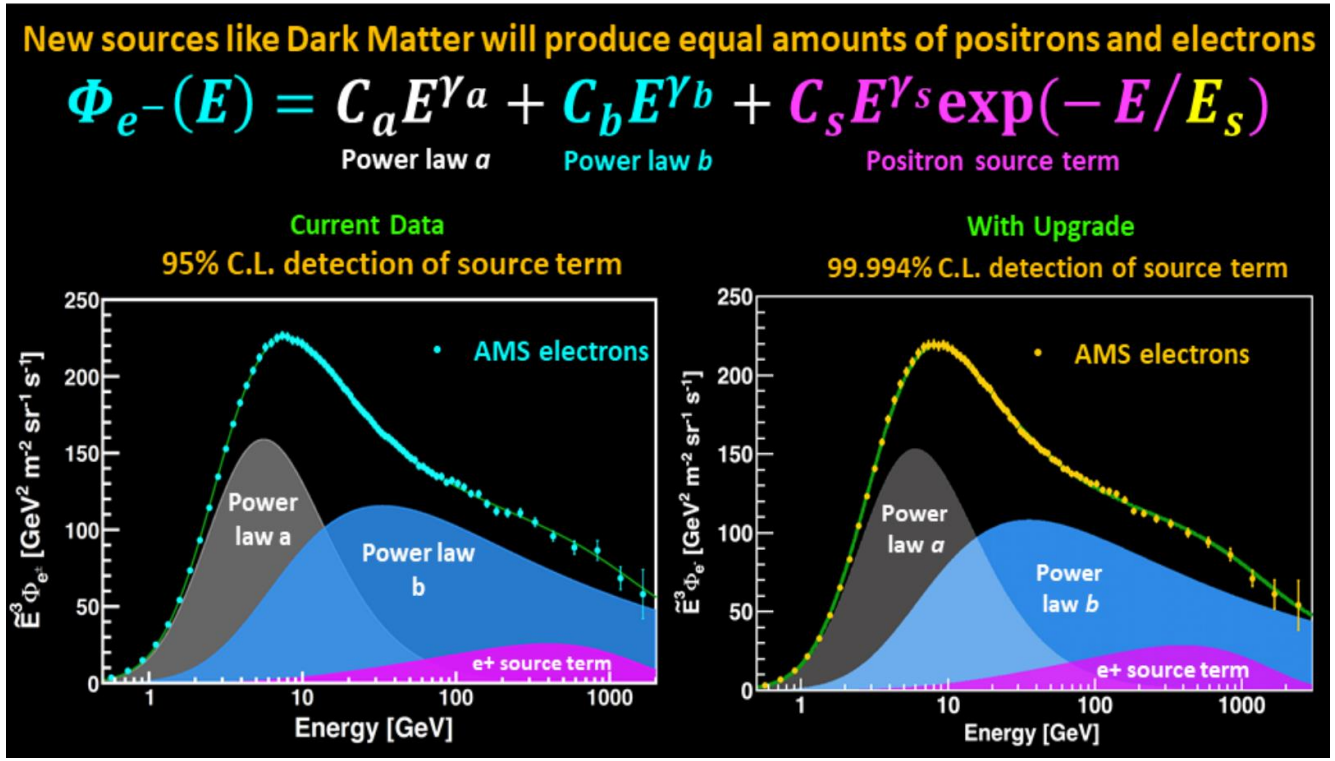
- Provides additional measurement points and constraints
- Extend the energy range of the positron flux measurement to ~ 2 TeV from the current ~ 1.5 TeV (1 TeV published in 2019) and reduce the uncertainties at least by a factor of two
- **Extend the energy range of the electron flux measurement up to 3 TeV from the current ~ 2 TeV (1.4 TeV published in 2019) and reduce the uncertainties at least by a factor of about two**
- Enable to provide a complete and accurate spectrum for all the 29 elements



Electron spectrum at high energies for current data (blue shading) and with the upgrade (gold shading).

Physics Justification For The Upgrade

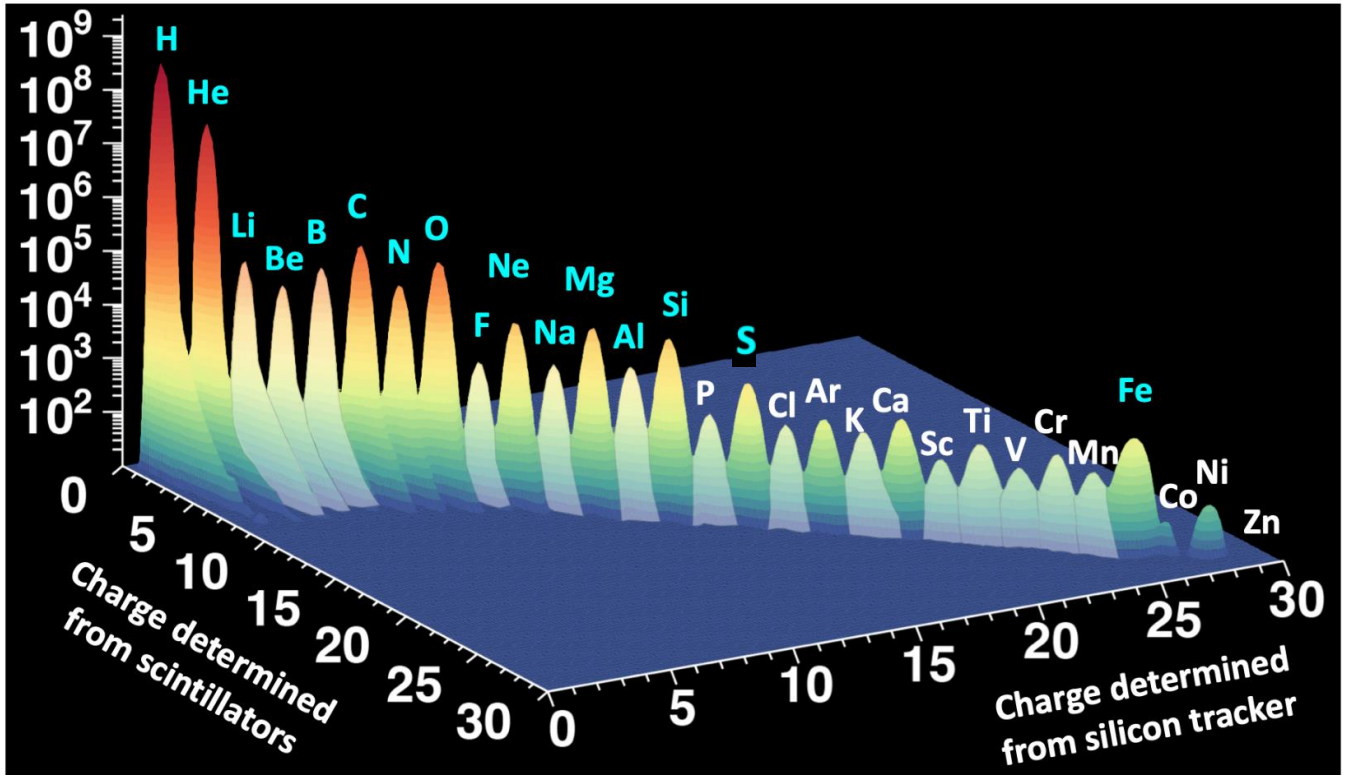
- Provides additional measurement points and constraints
- Extend the energy range of the positron flux measurement to ~ 2 TeV from the current ~ 1.5 TeV (1 TeV published in 2019) and reduce the uncertainties at least by a factor of two
- **Extend the energy range of the electron flux measurement up to 3 TeV from the current ~ 2 TeV (1.4 TeV published in 2019) and reduce the uncertainties at least by a factor of about two**
- Enable to provide a complete and accurate spectrum for all the 29 elements



Origin of high energy electrons. the electron spectrum can be described by the sum of two power law components and a charge symmetric positron source term.

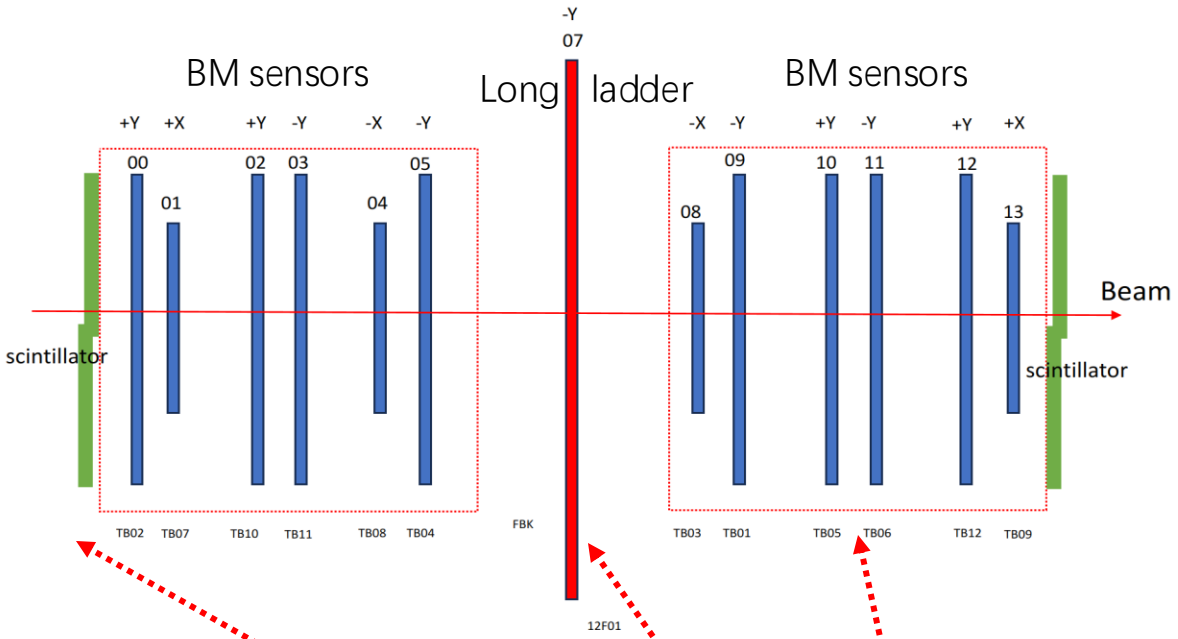
Physics Justification For The Upgrade

- Provides additional measurement points and constraints .
- Extend the energy range of the positron flux measurement to ~ 2 TeV from the current ~ 1.5 TeV (1 TeV published in 2019) and reduce the uncertainties at least by a factor of two
- Extend the energy range of the electron flux measurement up to 3 TeV from the current ~ 2 TeV (1.4 TeV published in 2019) and reduce the uncertainties at least by a factor of about two
- **Enable to provide a complete and accurate spectrum for all the 29 elements**



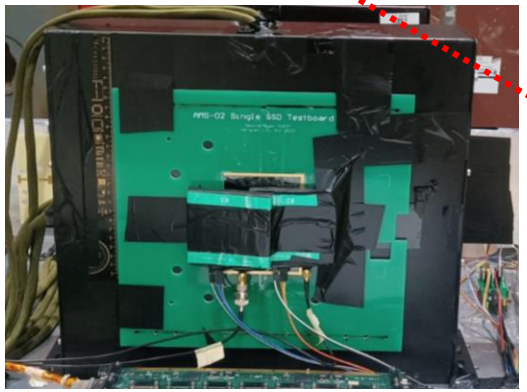
The 16 elements that AMS has published are marked in cyan. The 13 elements marked in white currently have limited statistics.

Beam Test 2024 With Muons at CERN SPS

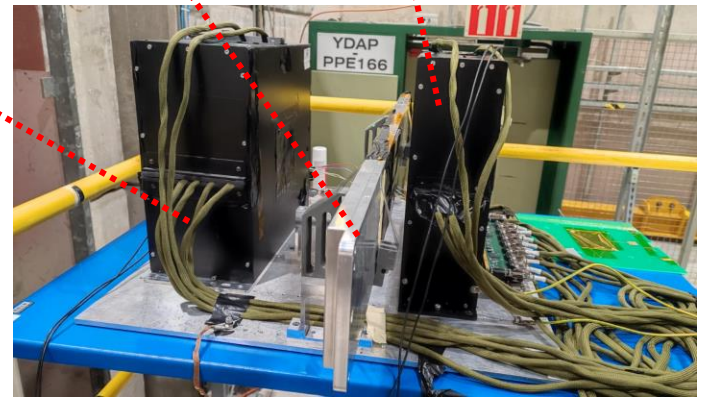


Assembling the BM sensors

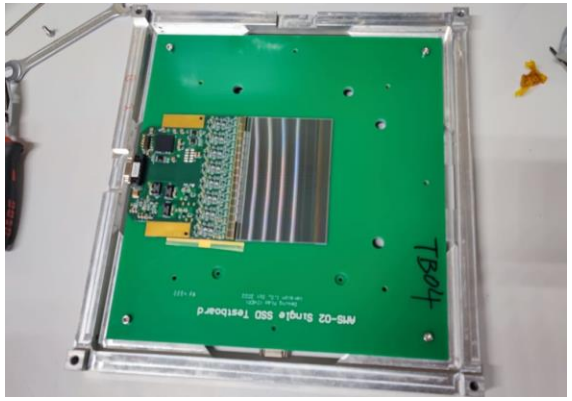
long ladder



scintillator



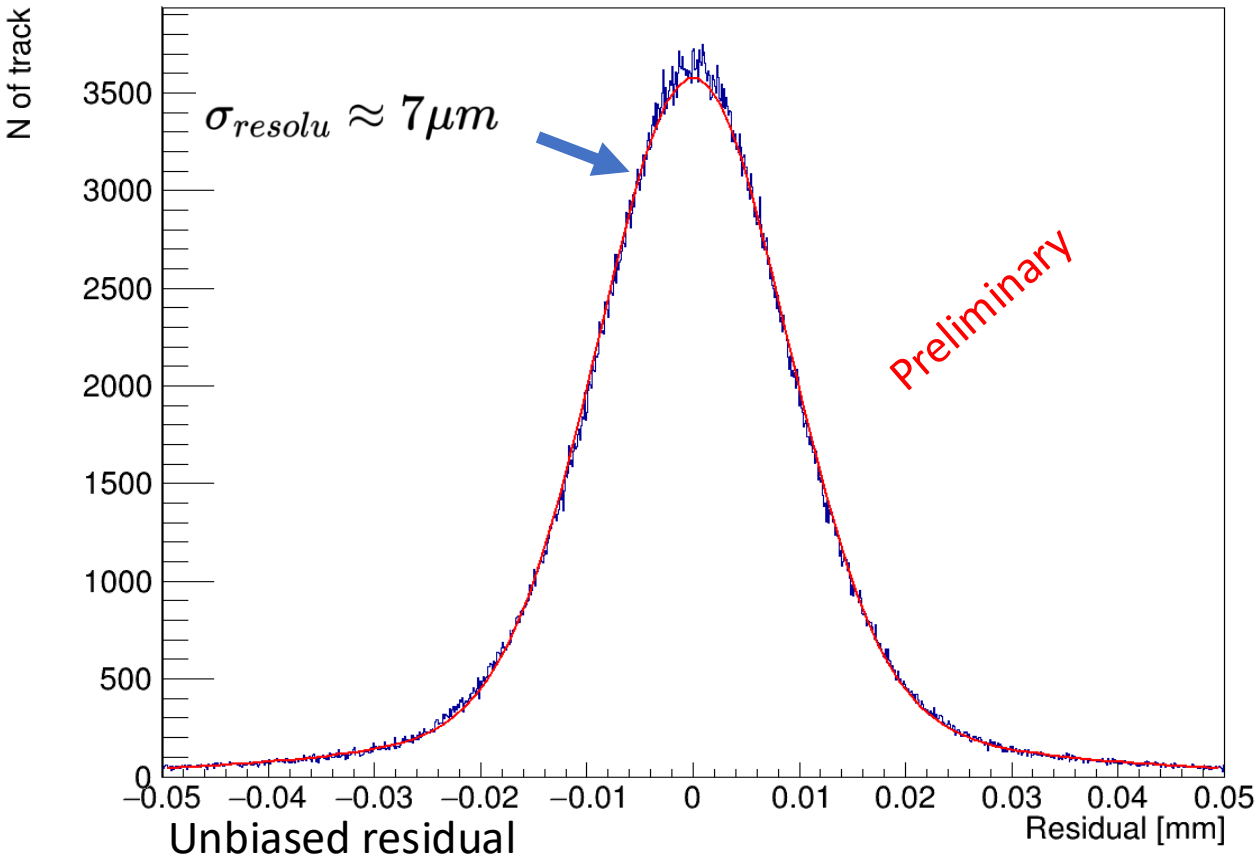
Setup

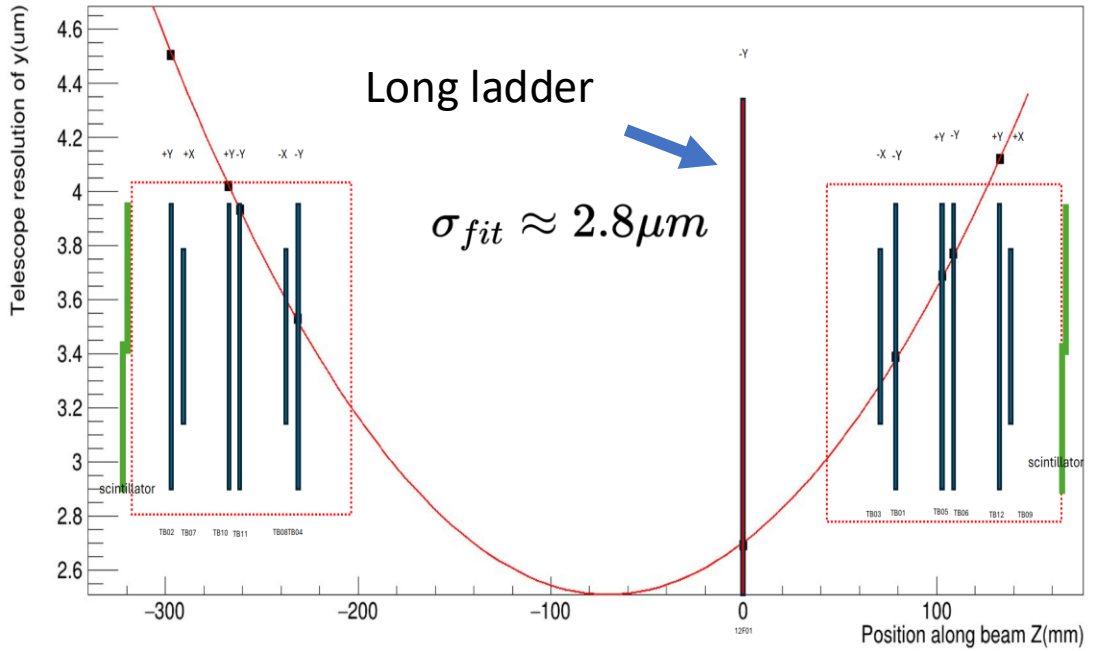


single BM sensor

Spatial Resolution

L0 Beam monitor (BM)

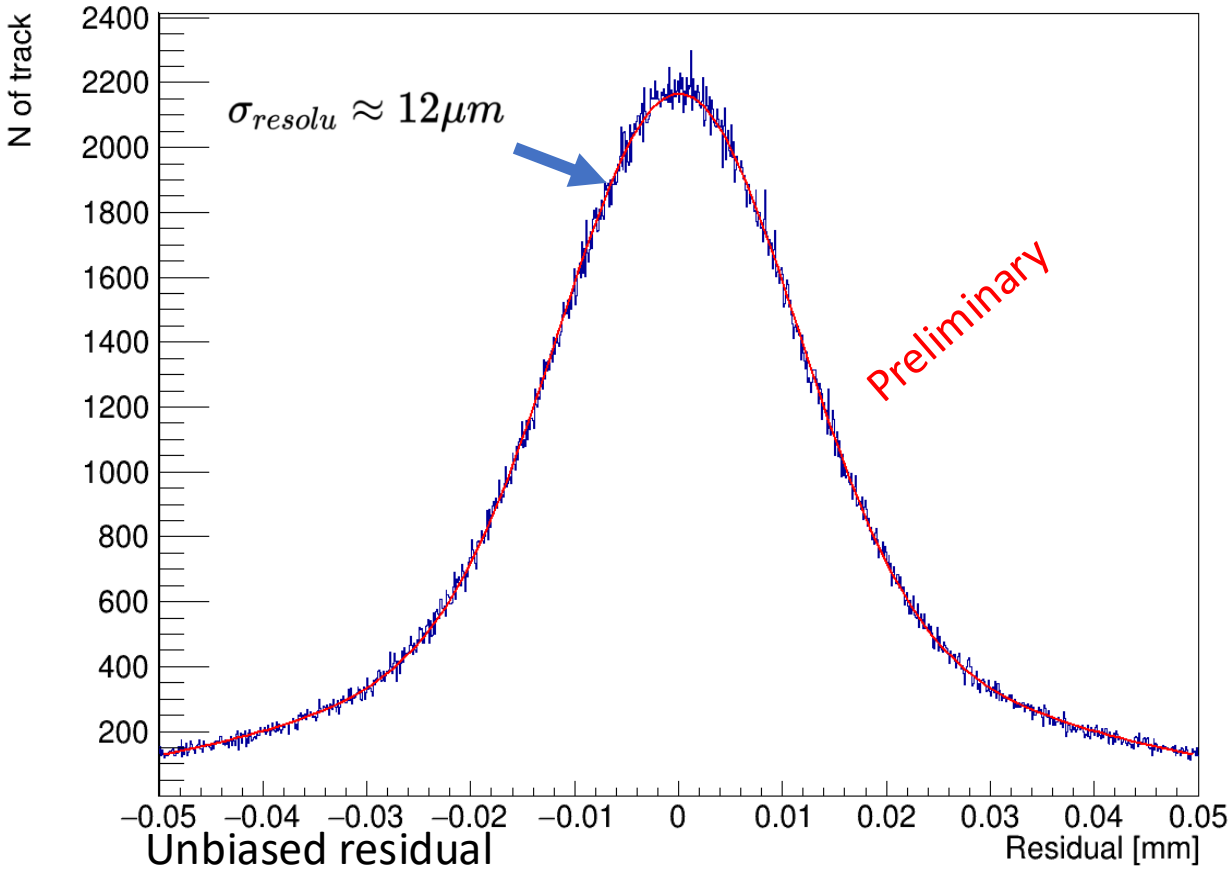


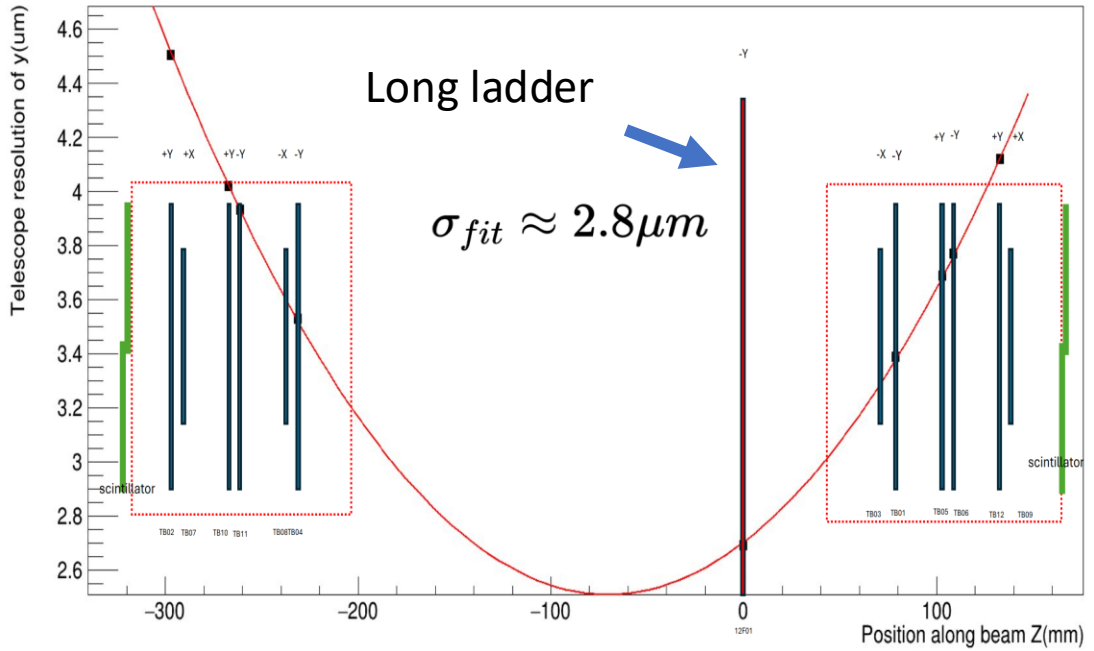


- The width (sigma) of the residual distribution can be expressed as the sum of two contributions, the intrinsic resolution of the sensor and the error in the fit prediction.
- $\sigma_{RES,i} = \sqrt{\sigma_{fit,i}^2 + \sigma_{resolu,i}^2}$.

Spatial Resolution

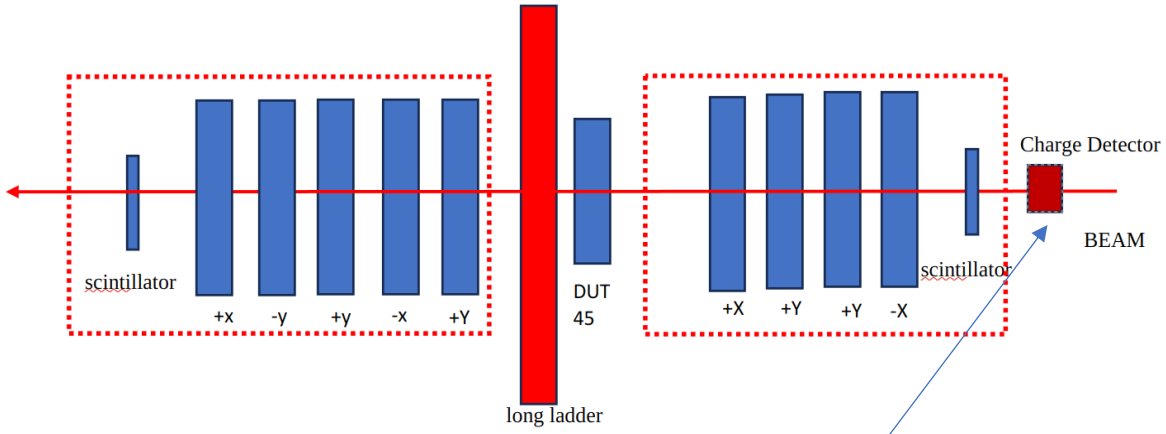
Long ladder

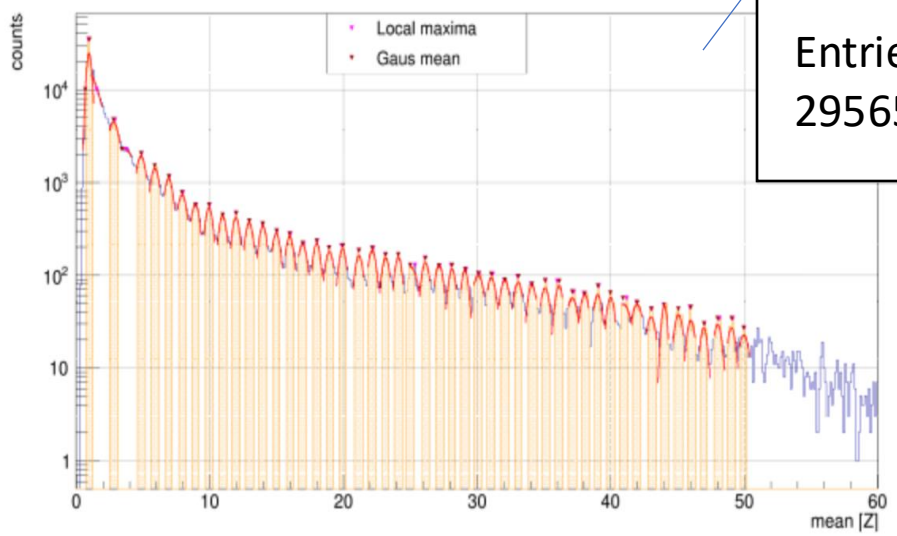




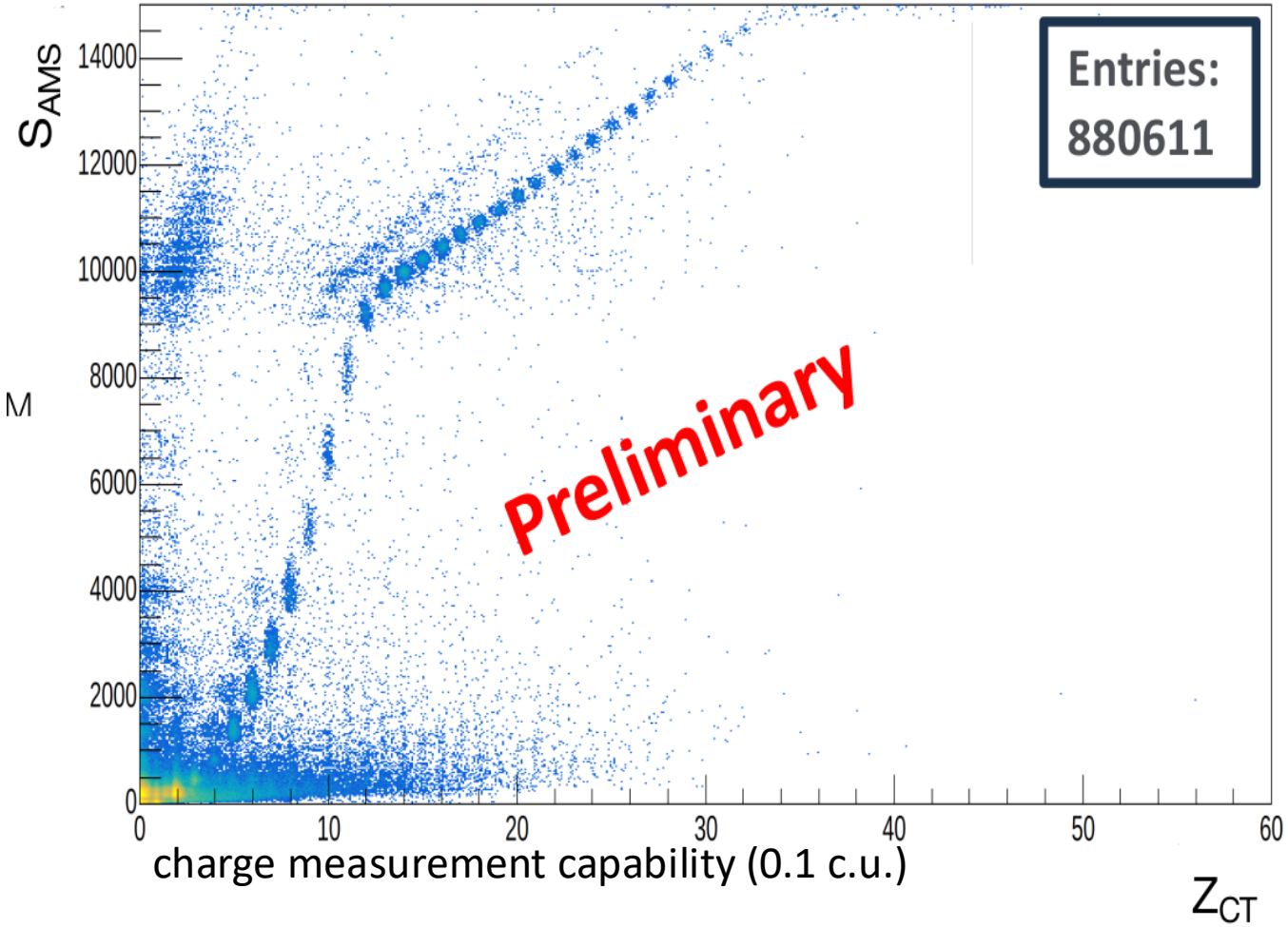
- The width (sigma) of the residual distribution can be expressed as the sum of two contributions, the intrinsic resolution of the sensor and the error in the fit prediction.
- $\sigma_{RES,i} = \sqrt{\sigma_{fit,i}^2 + \sigma_{resolu,i}^2}$.

Beam Test 2023 with ions at CERN SPS





Entries: 295651



Mimimum Ionizing Particles peaks measured by Charge Detector (**thanks to the INFN Florence HERD group**)

CONCLUSION

- The upgrade would provide improvement of a factor 3 of the AMS-02 acceptance
- The improved acceptance offers the possibility to reach enhanced accuracy in the cosmic rays measurements and possibly observe signals of new physics
- The production of the modules(ladders) is on-going and in few weeks all the modules will be ready for the final integration
- The modules are showing performances coherent to design and expectations:
  - the spatial resolution is around 12 micrometers
  - the charge identification allow to identify nuclei up to nickel

Thank you for your attention.

Backup

Quarter Plane Qualification Model:

- Vibration (Sine Sweep)
- Pyroshock
- ElectroMagnetic Interference, EMI
- ThermoVacuum Test, TVT