中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

AMS-02 Layer0 Tracker Upgrade

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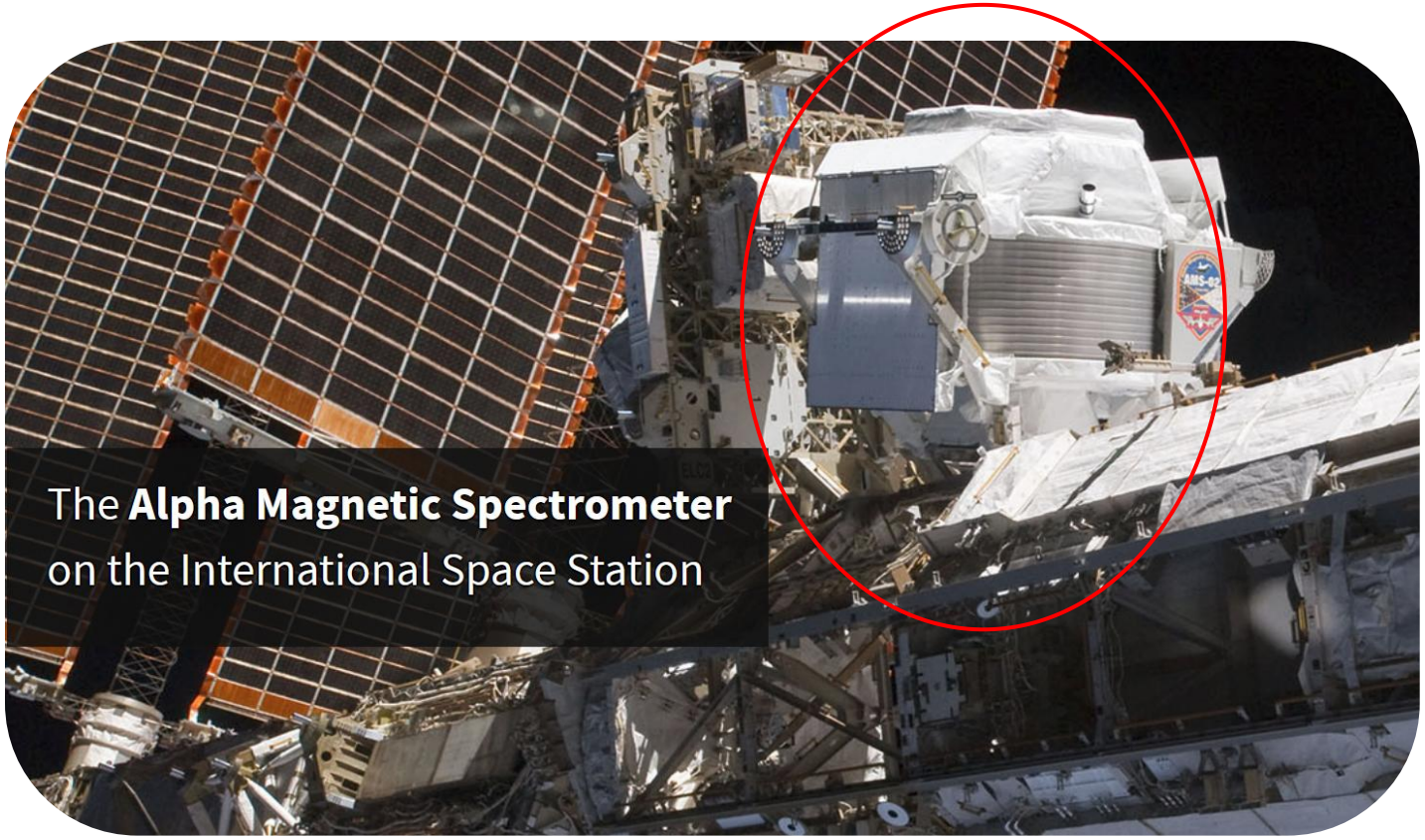
海峡兩岸尖端探測器與技術研討會

2024年6月17-19日

AMS-02

- launched to the ISS and installed on May 19, 2011
- taking data for the whole life of the ISS
- track deflection within its magnetic field => unique capability of distinguishing matter from anti-matter
- 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



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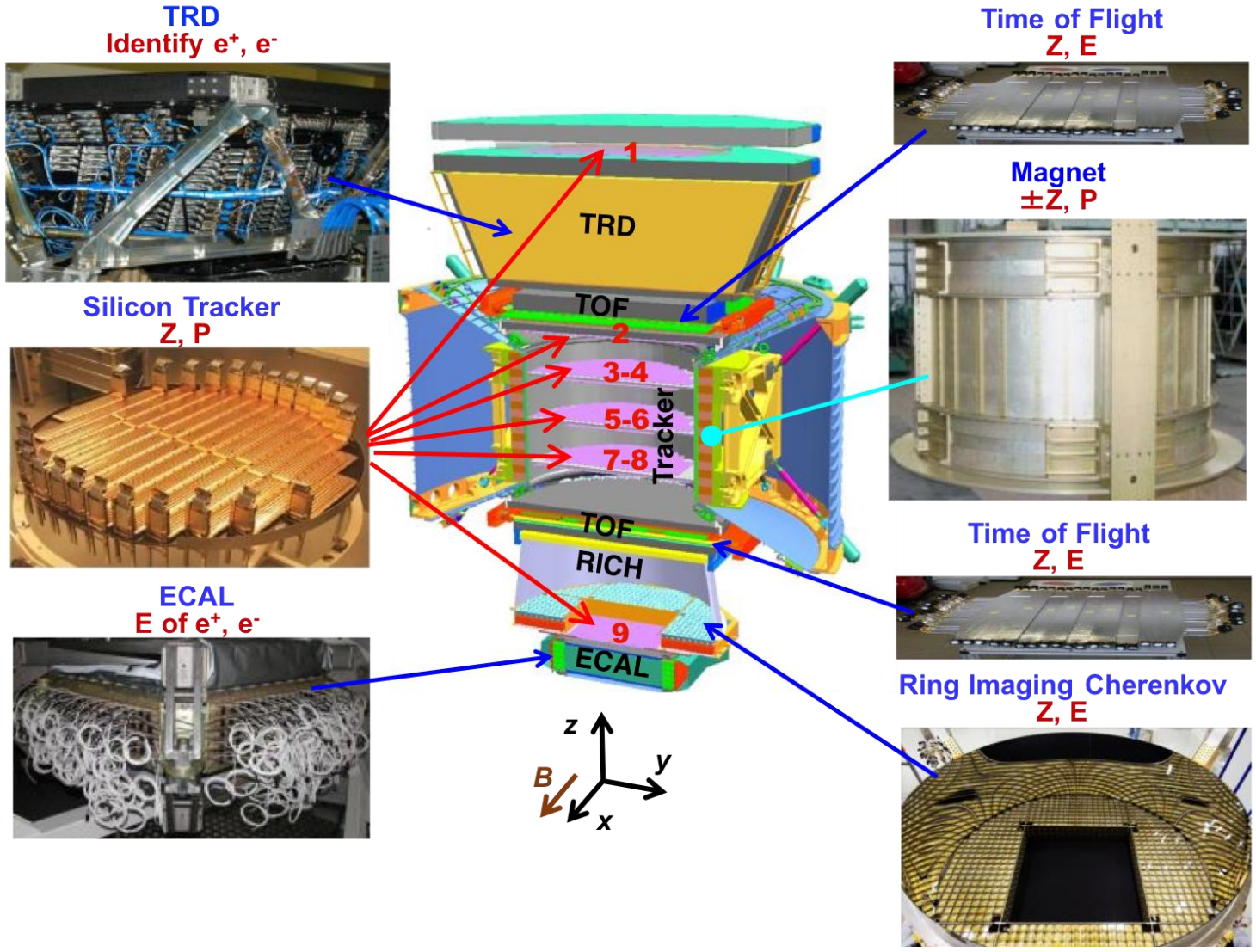
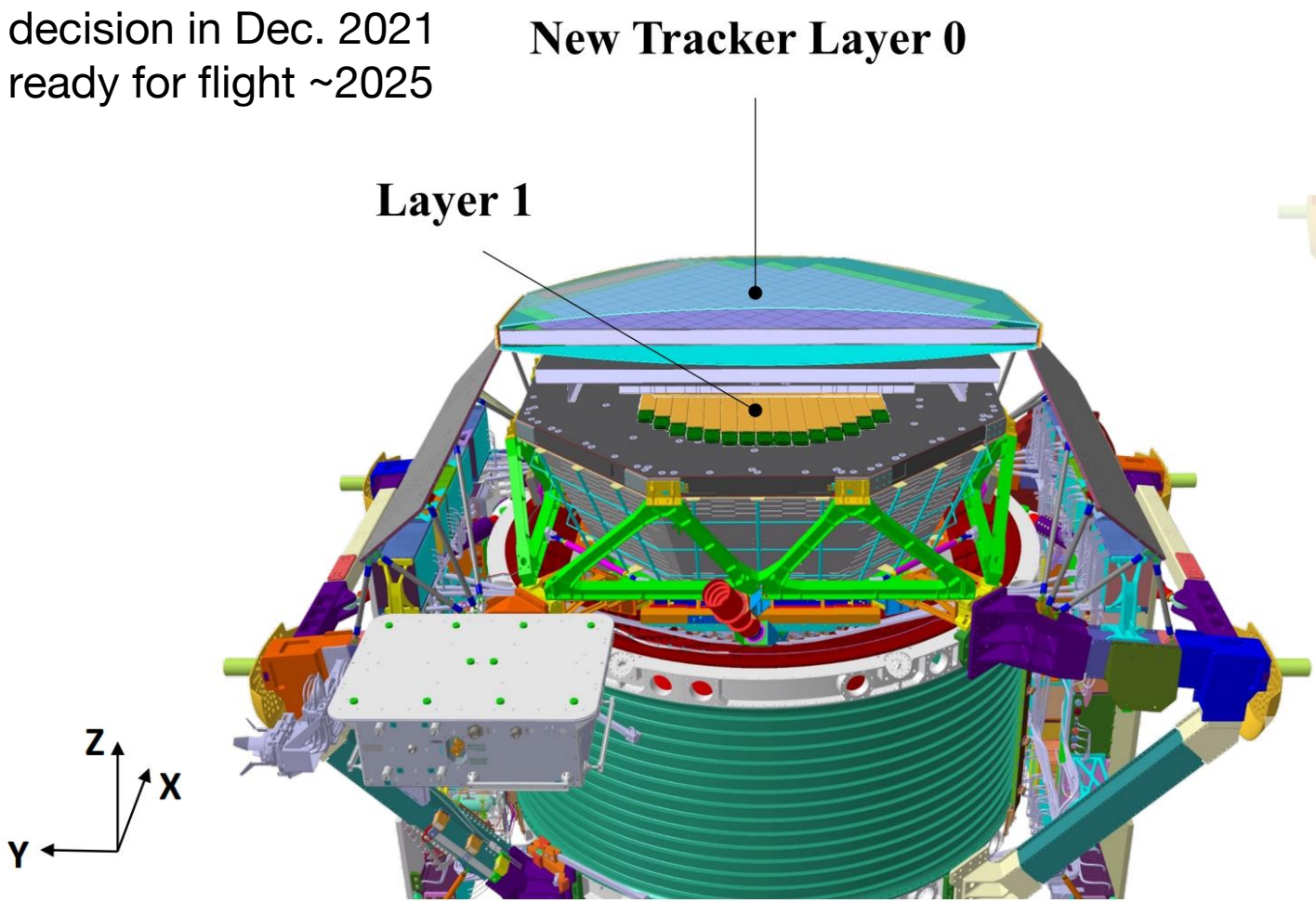
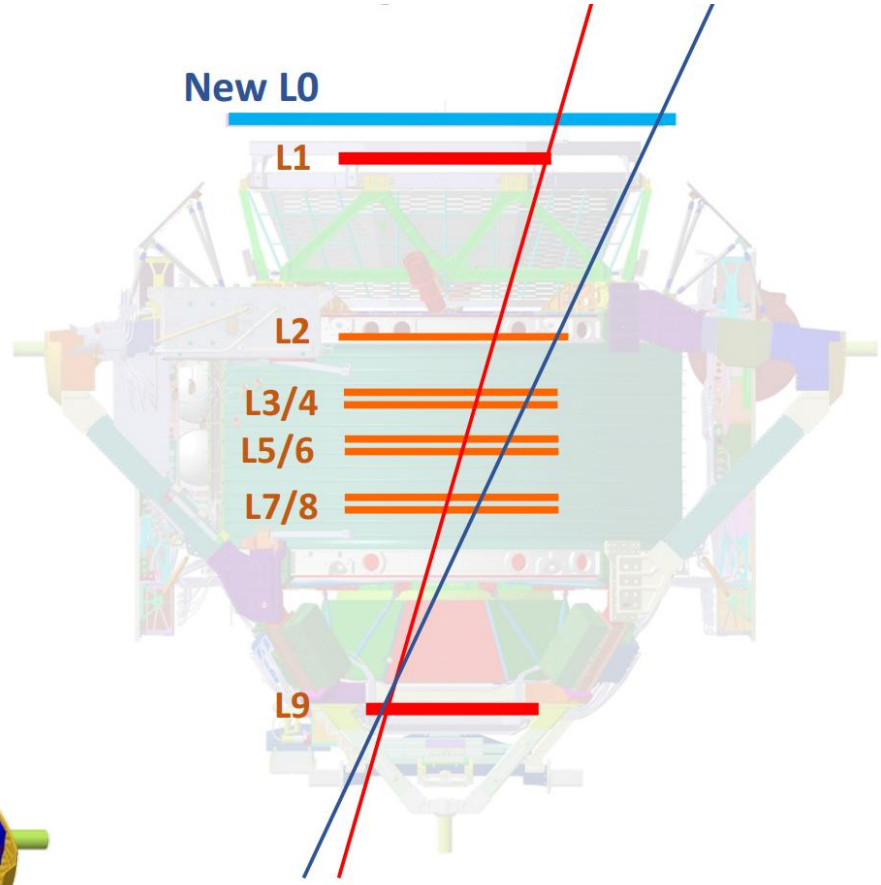


New Tracker Layer 0 Added

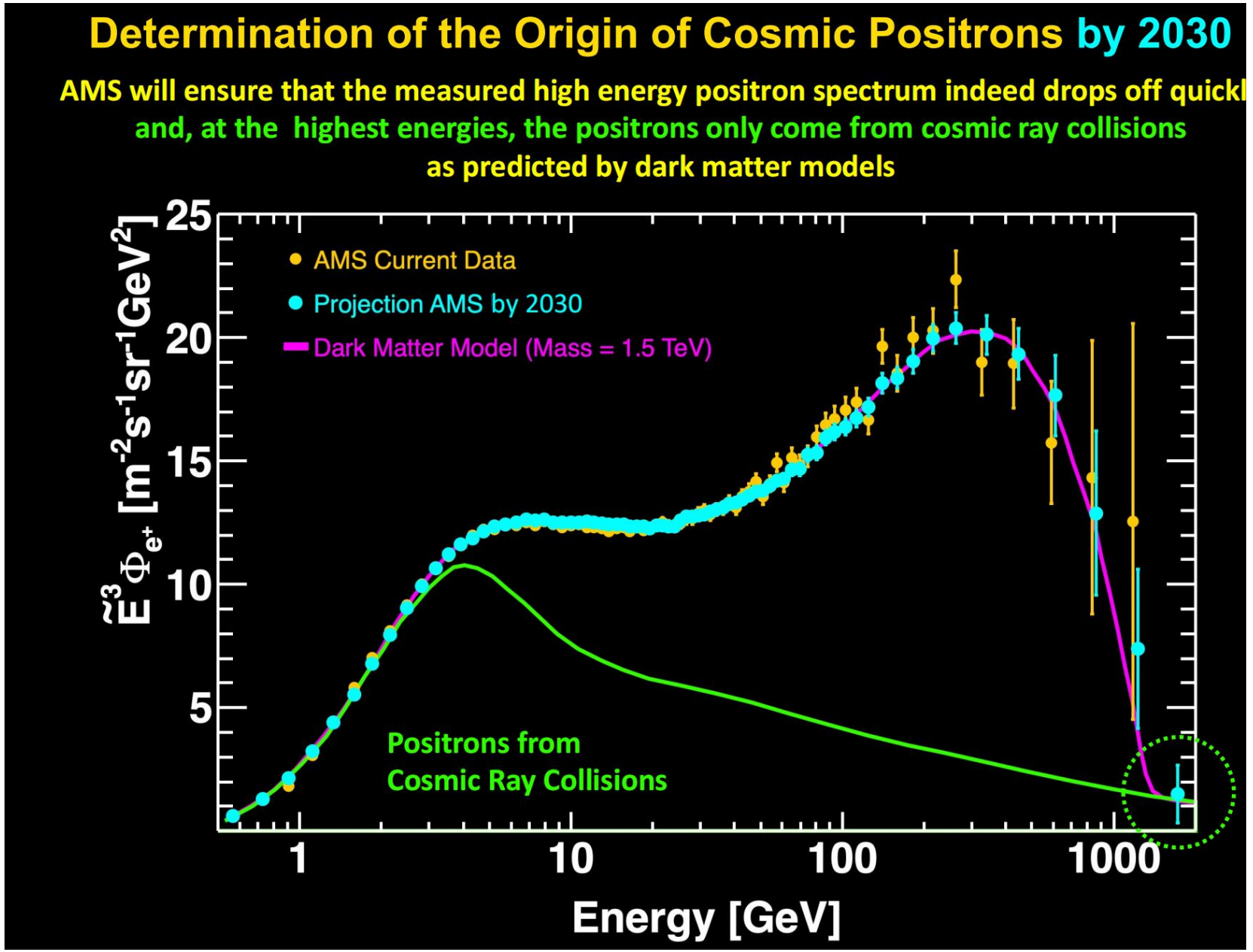
- decision in Dec. 2021
- ready for flight ~2025



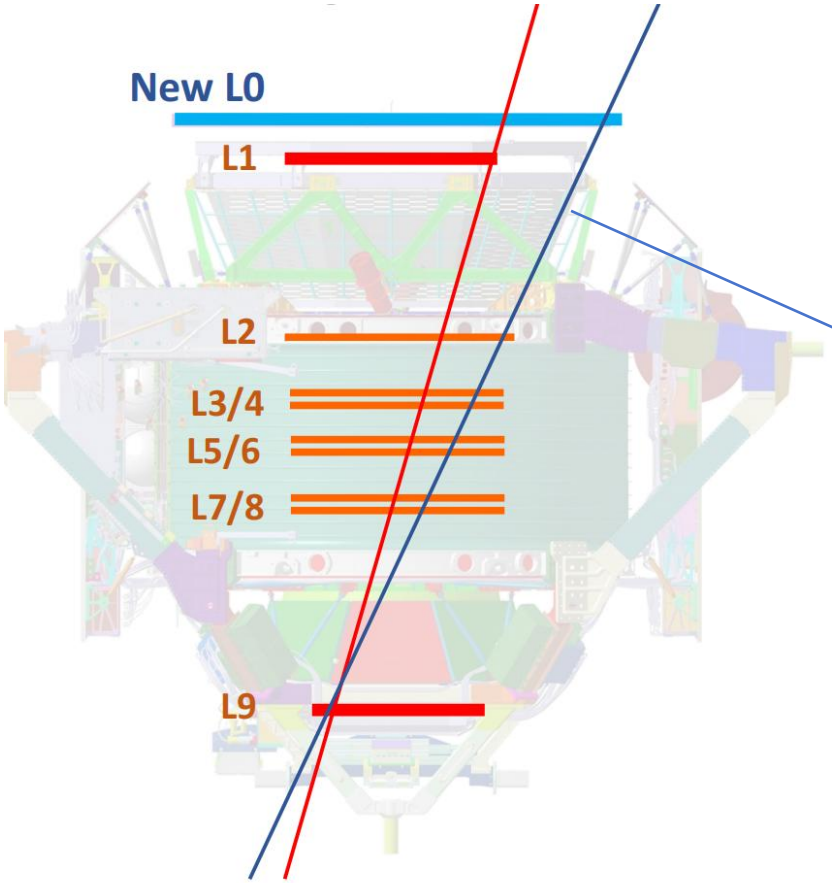


Increase of the detector acceptance by 300%

Referece：ASAPP 2023
G. Ambrosi, AMS-L0: upgrade status and prospects



Layer 0



L0: ~8 m² of silicon detector
L1+L2+...+L9: ~6 m²

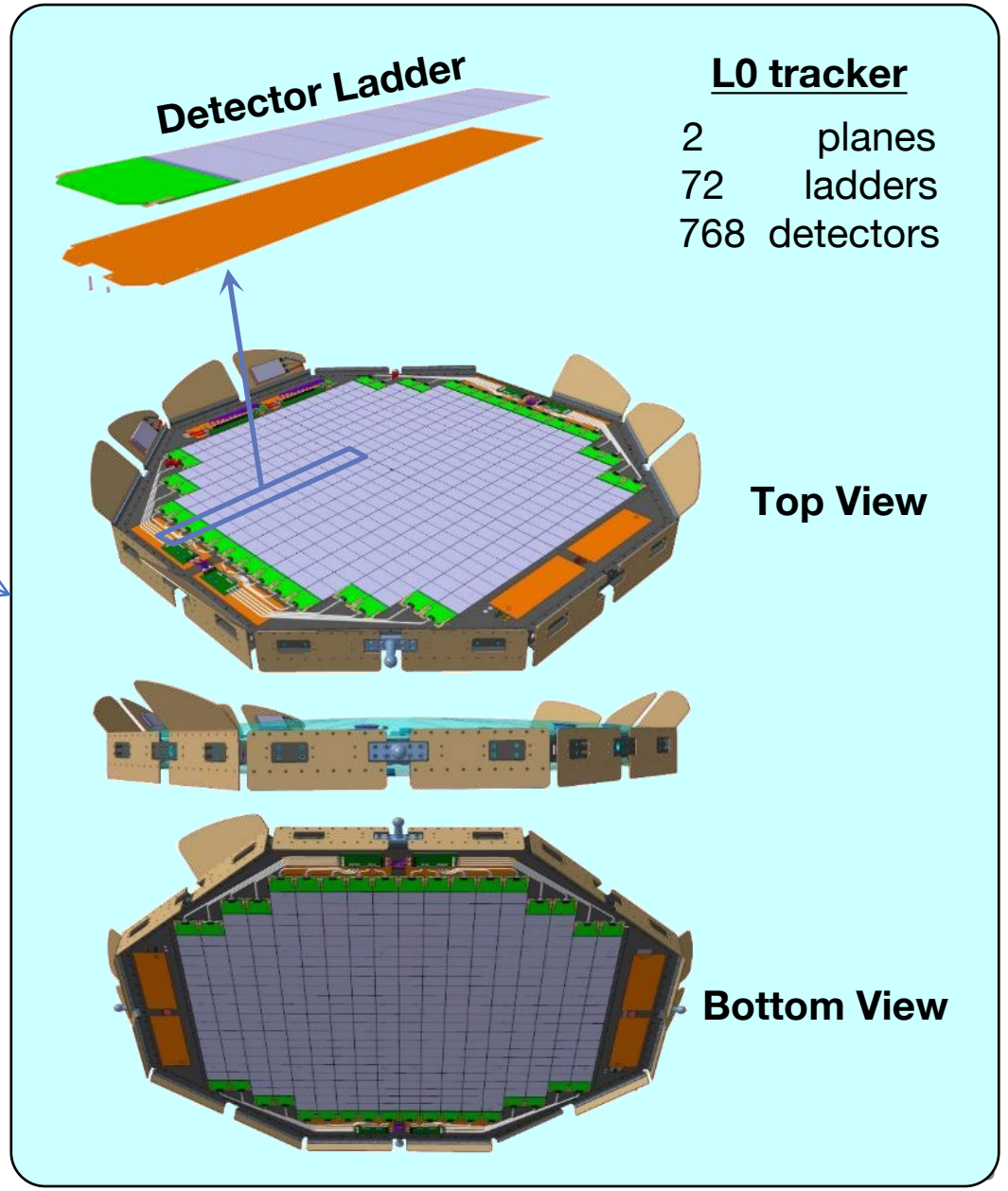
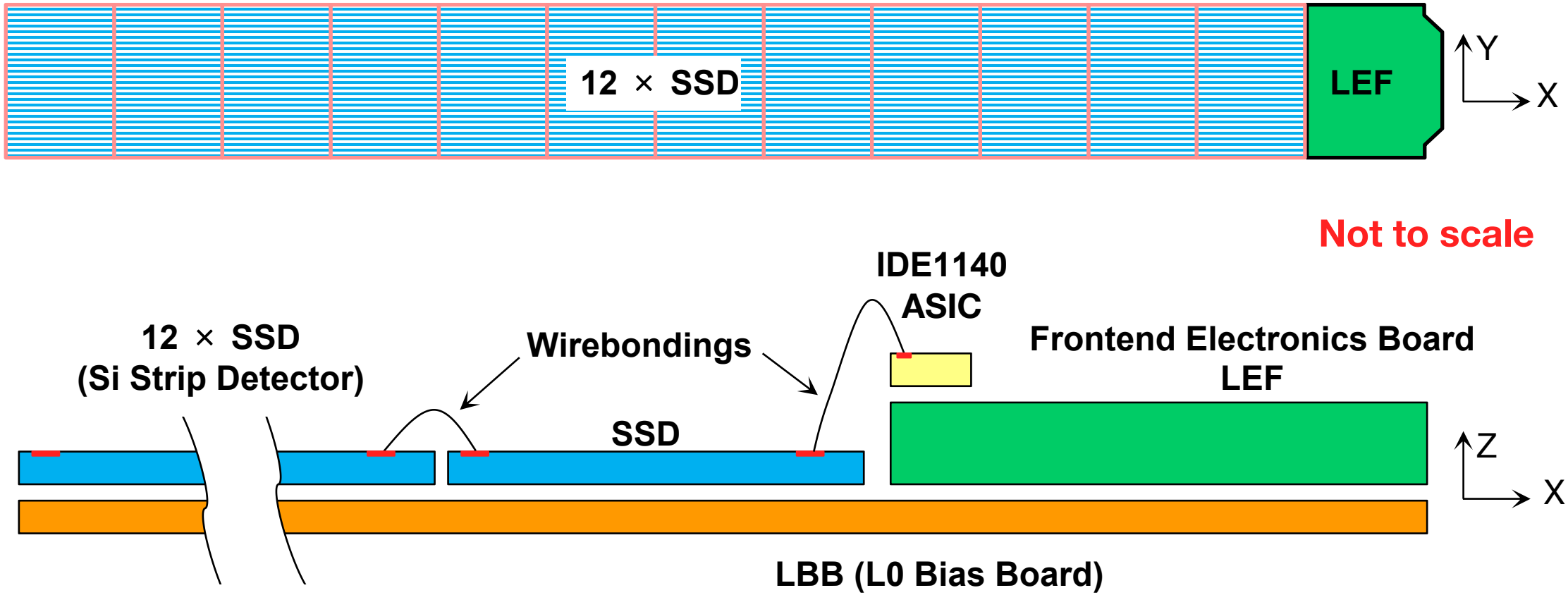


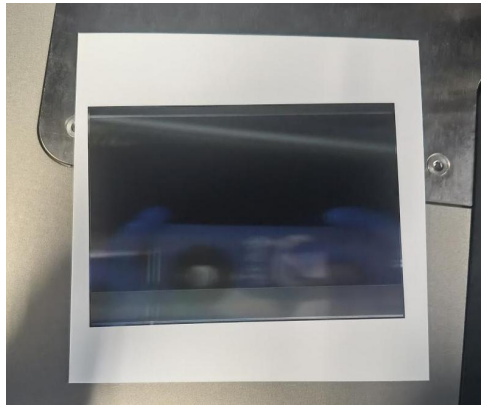
Illustration of A L0 Detector Ladder



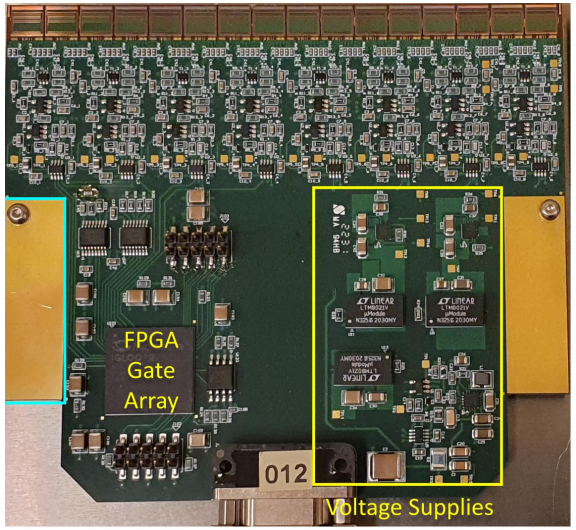
- Coupling and noise level due to long strips impose big challenges
- Precise placement of SSDs on a LBB affects the performance. We aim for < 5 μm precision
- Highly efficient and reliable wire-bonding (>12K wires per ladder)

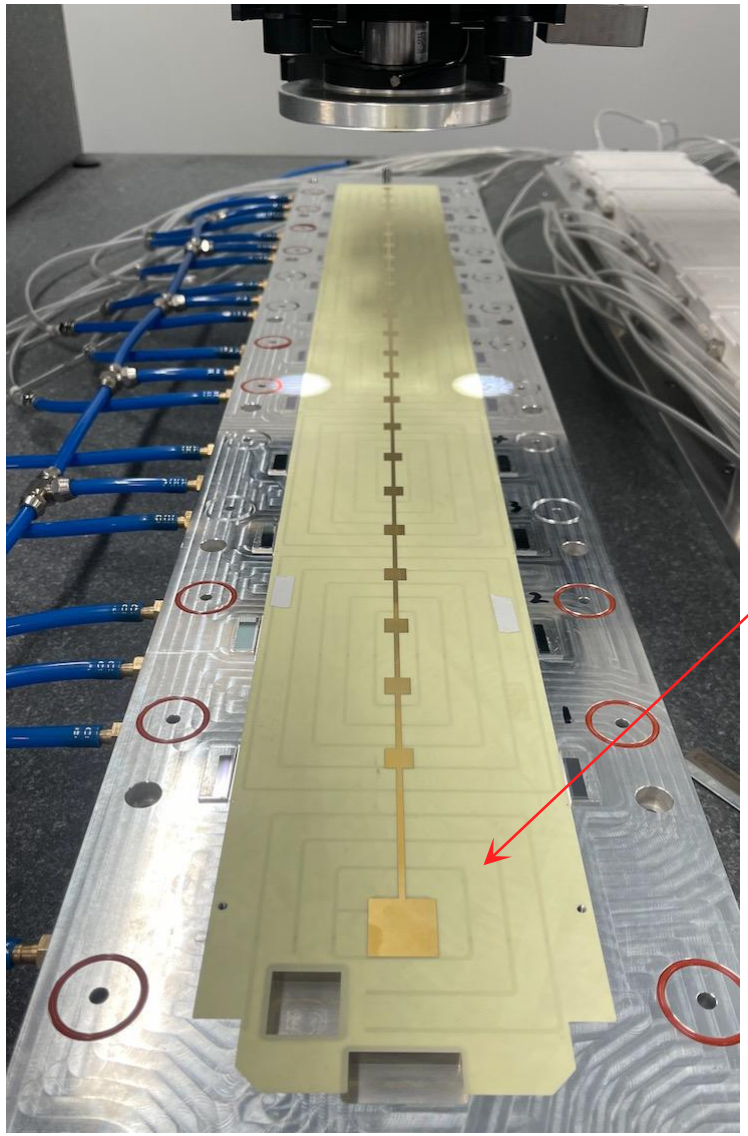
L0 Ladder Components

SSD



LEF





LBB

AMS L0 SiDet Laboratory at IHEP

Visual 3D Measuring System
(not visible from this angle)

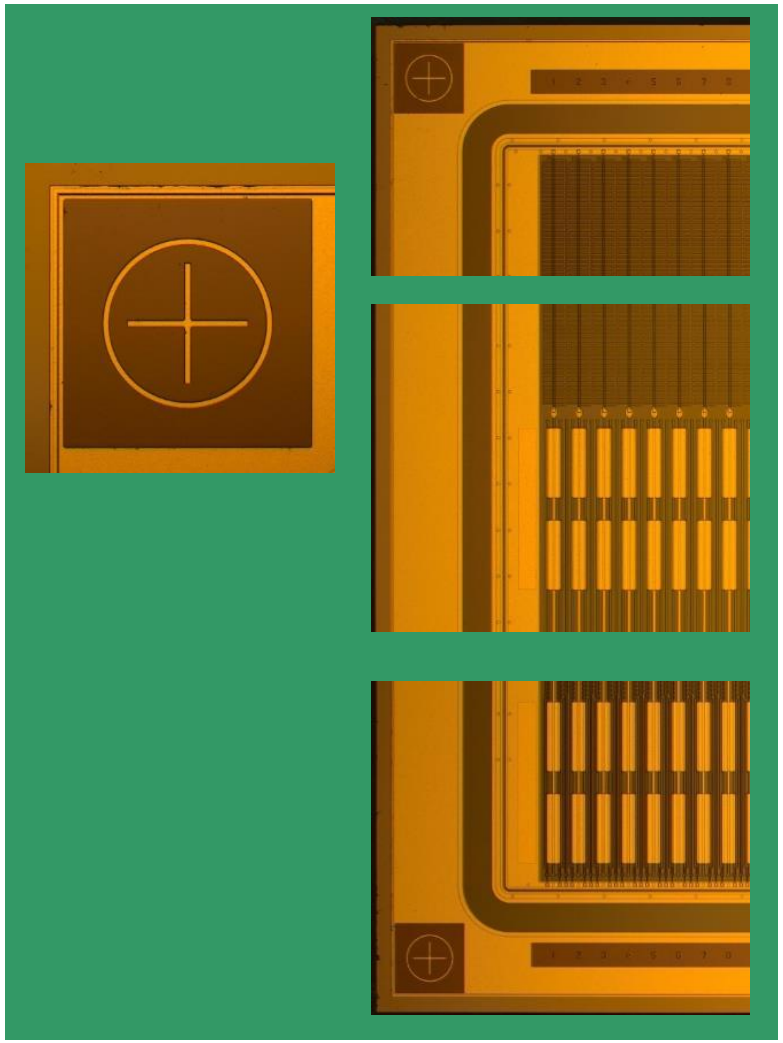
Wire Bonding Machine

Pull Tester
for Q/A of wire-bonding

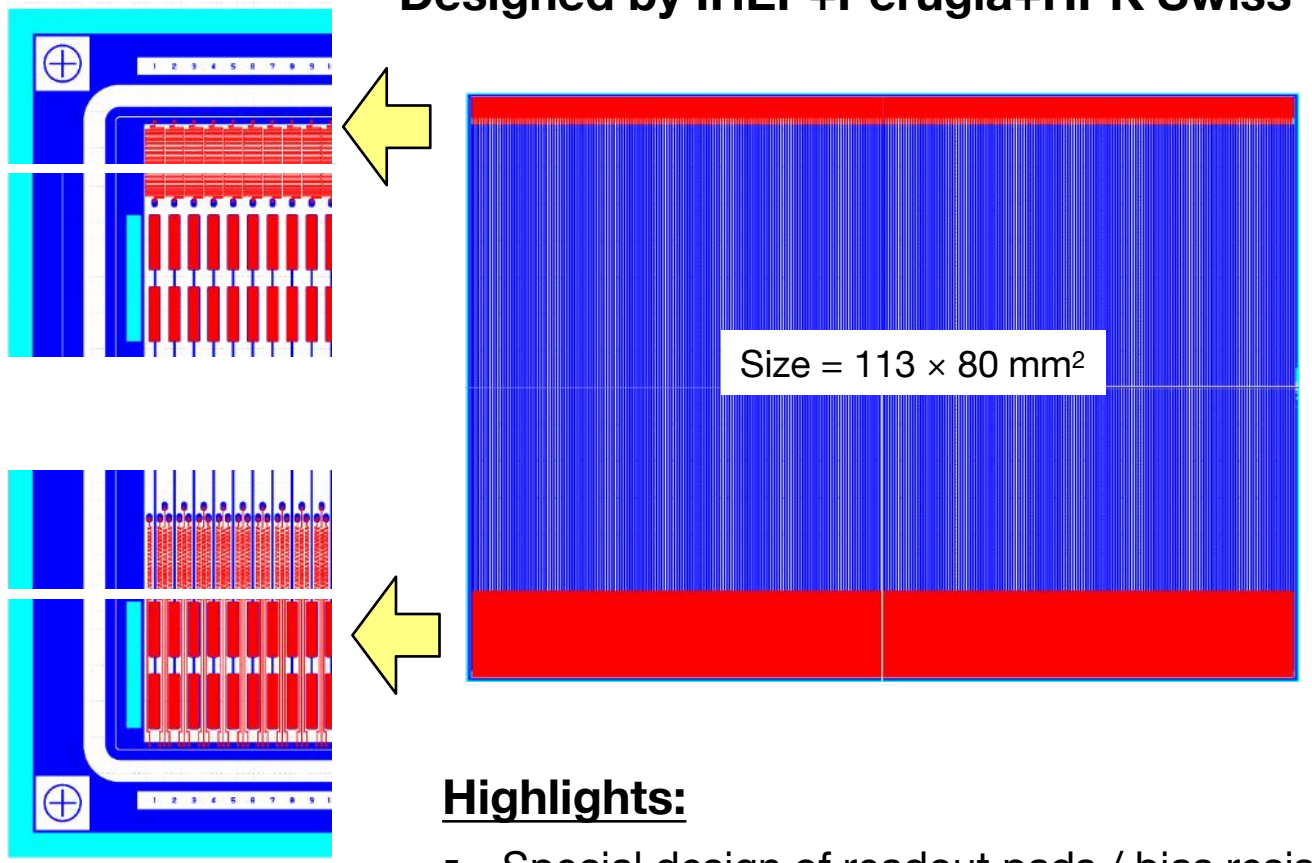
Gantry
for ladder assembling

Probe Station
for Silicon Strip Detector Q/A

The Silicon Strip Detector



Designed by IHEP+Perugia+HPK Swiss

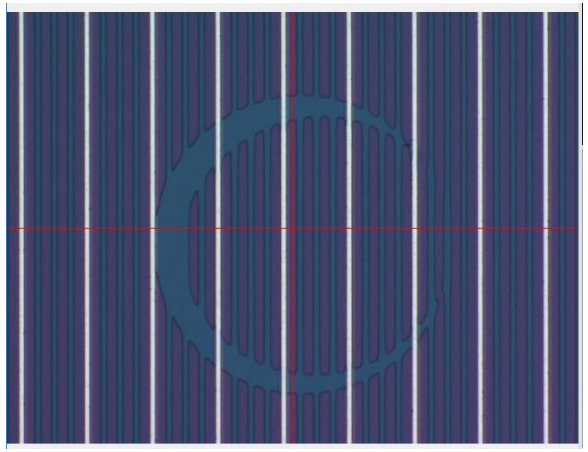


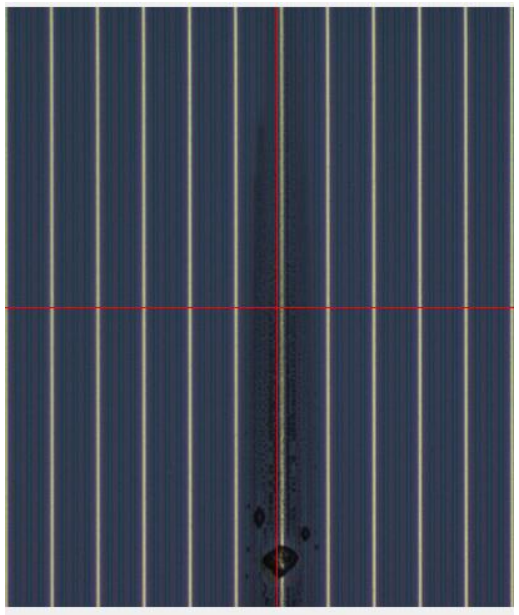
Highlights:

- Special design of readout pads / bias resistors
- Alignment marks for precise placement
- strip pitch 27.25 μm, readout pitch 109 μm

SSD Visual Inspection

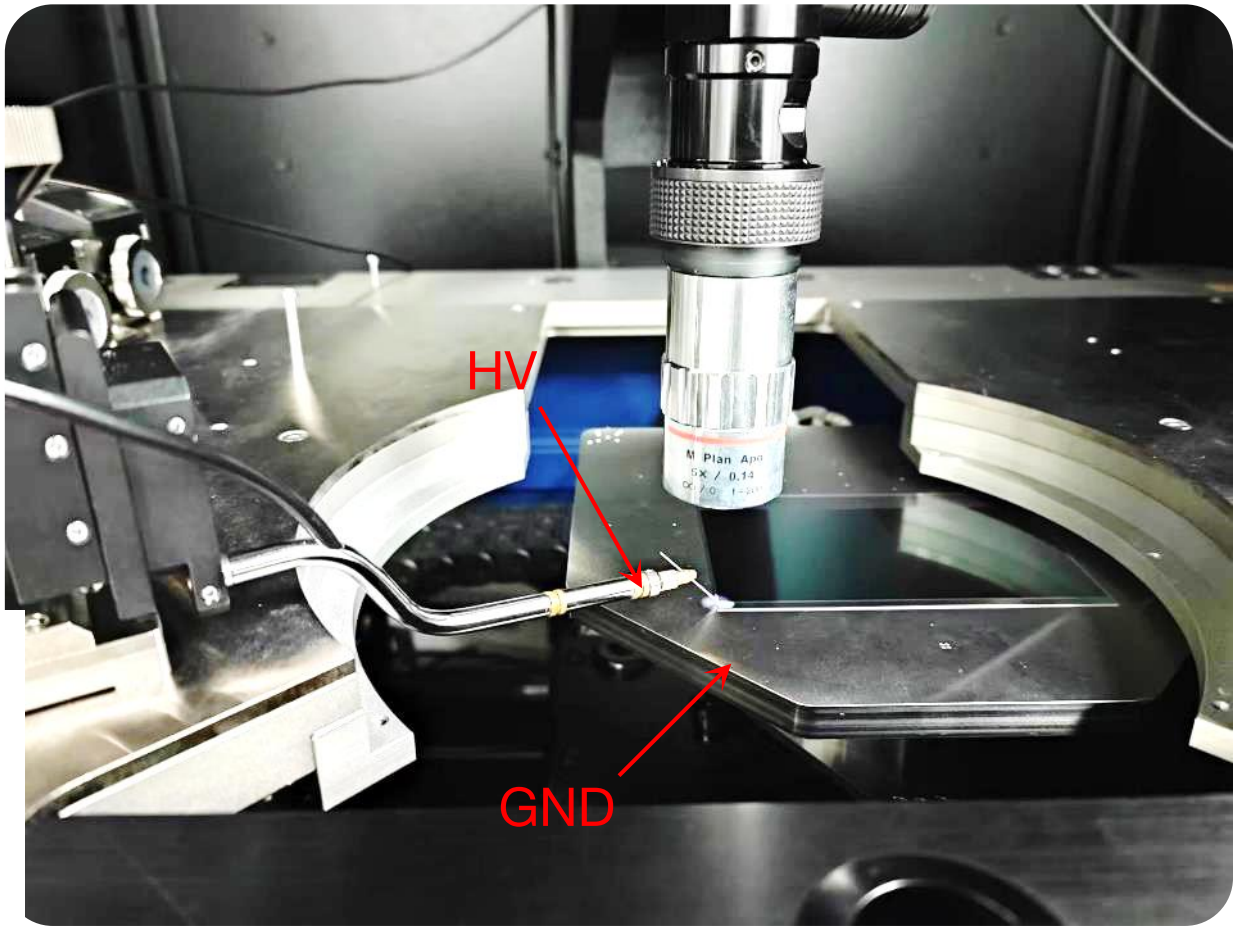
- Identify debris, scratch or any other defect
- Generally there is no surprise

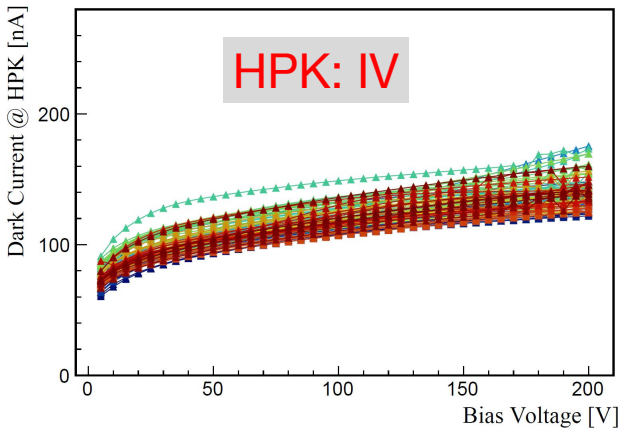


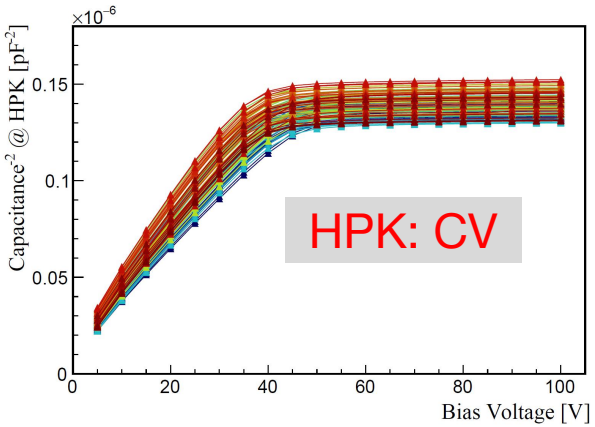


SSD IV & CV Scan

- All SSDs were characterized by HPK before the deliveries
- ~10% of all SSDs were re-tested at IHEP
  - consistent results between IHEP and HPK

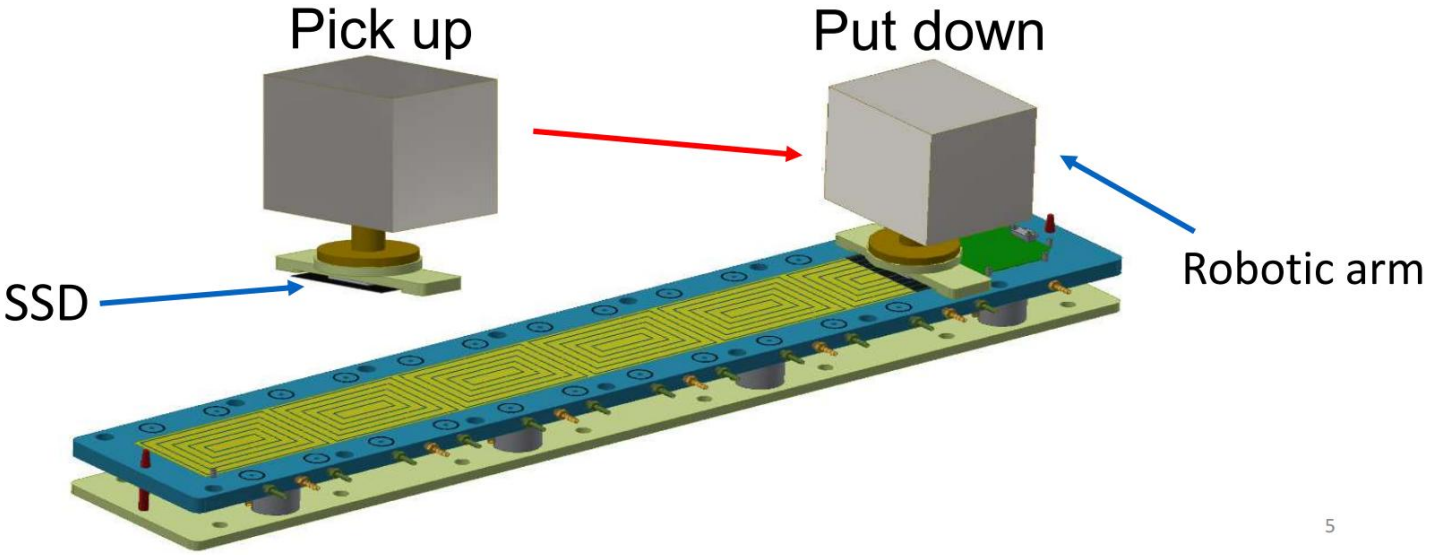


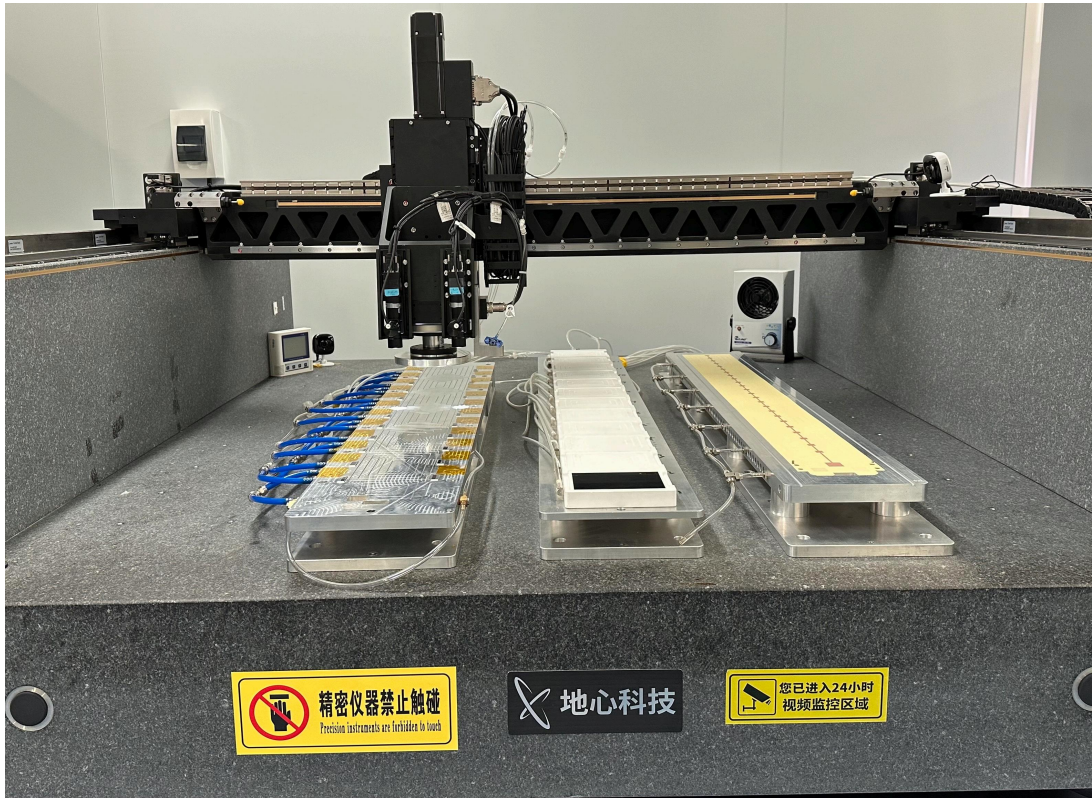




Ladder Production Procedure

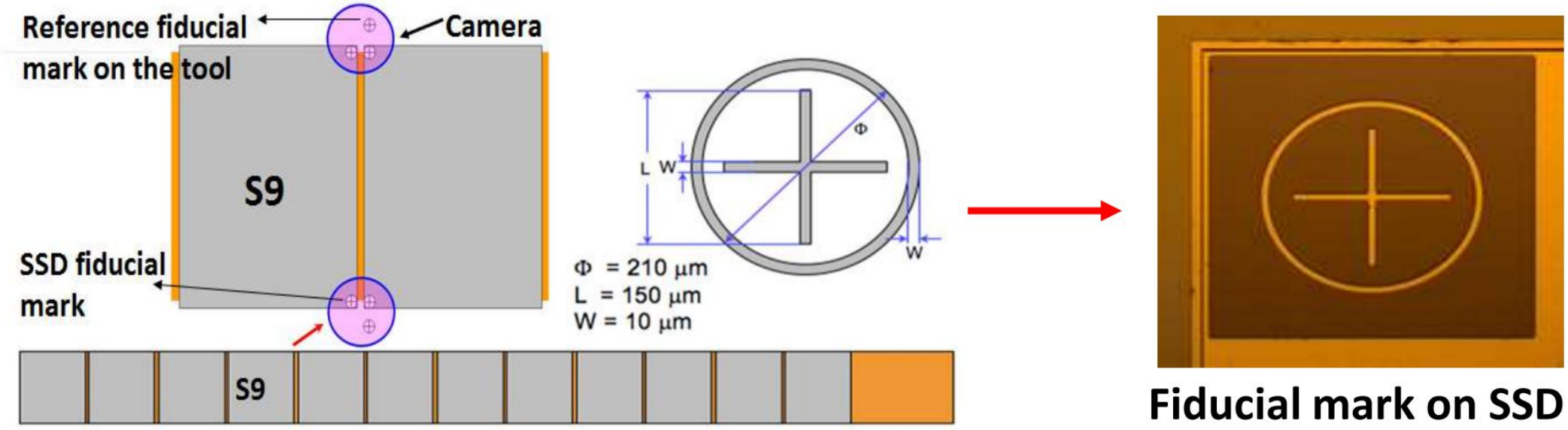
- high-precision (~1um) gantry system for assembly





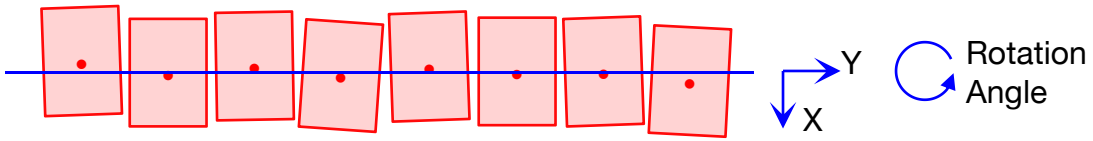
Ladder Production Procedure

- in-situ align the fiducial marks on SSDs during assembly

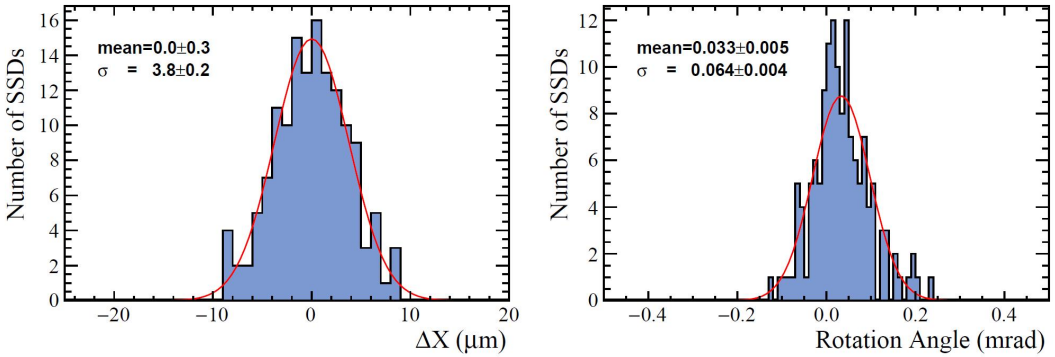


Metrology Using A Visual 3D Measuring System

Relative positions of all SSDs are precisely measured



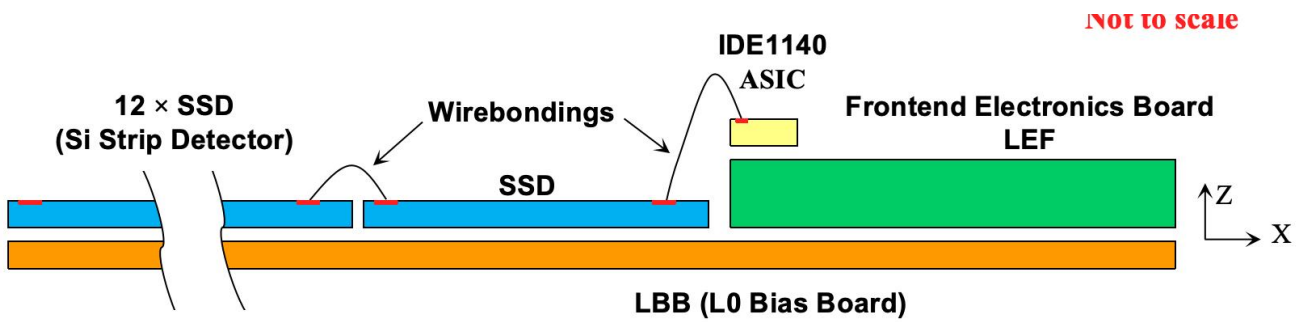
8 dummy ladders & 7 QM ladders

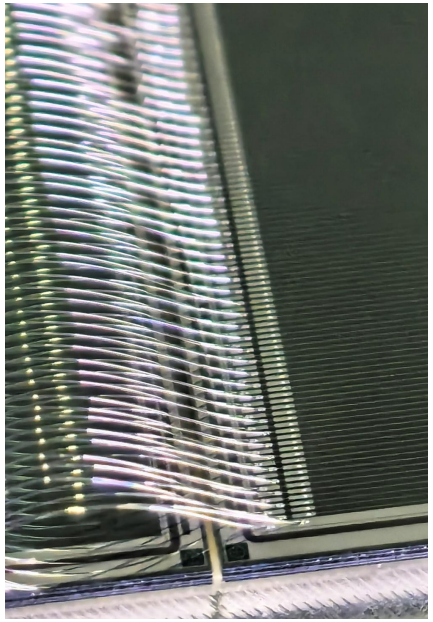


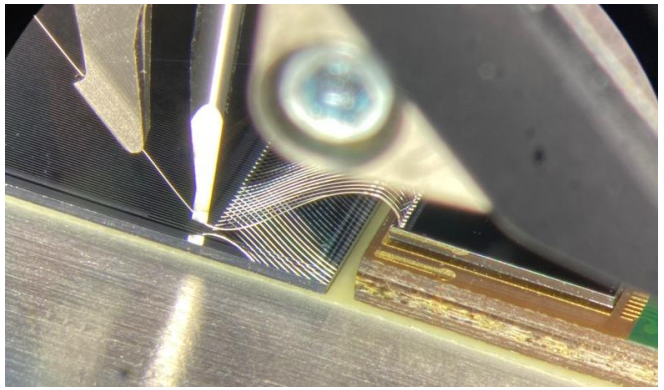
The 5 μm precision goal has been achieved

Wire Bonding Process

- Highly efficient and reliable wire-bonding (>12K wires per ladder)

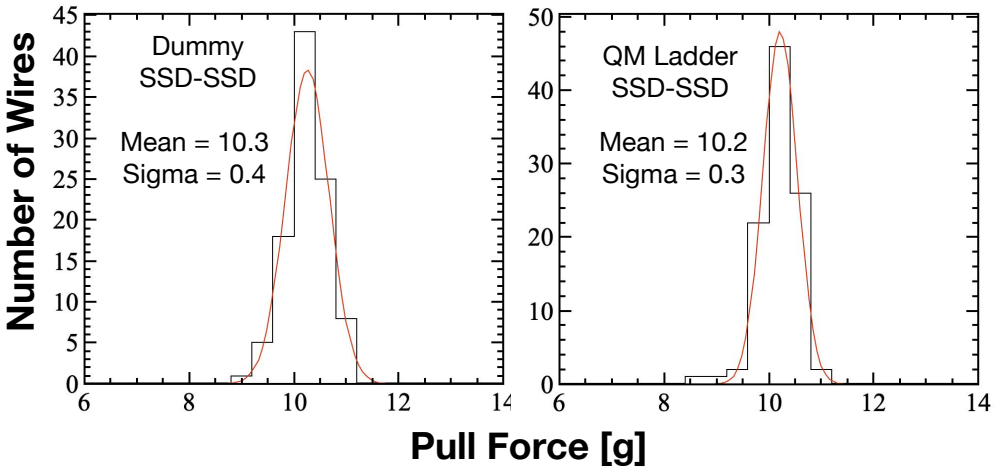


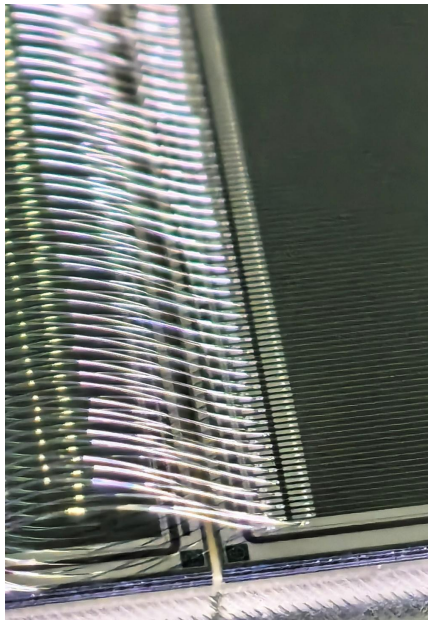


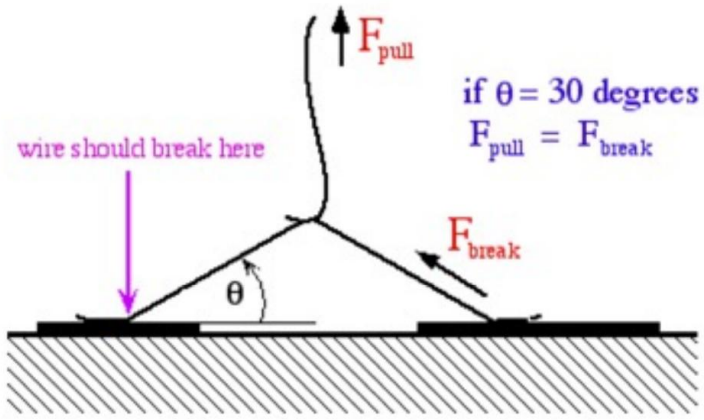


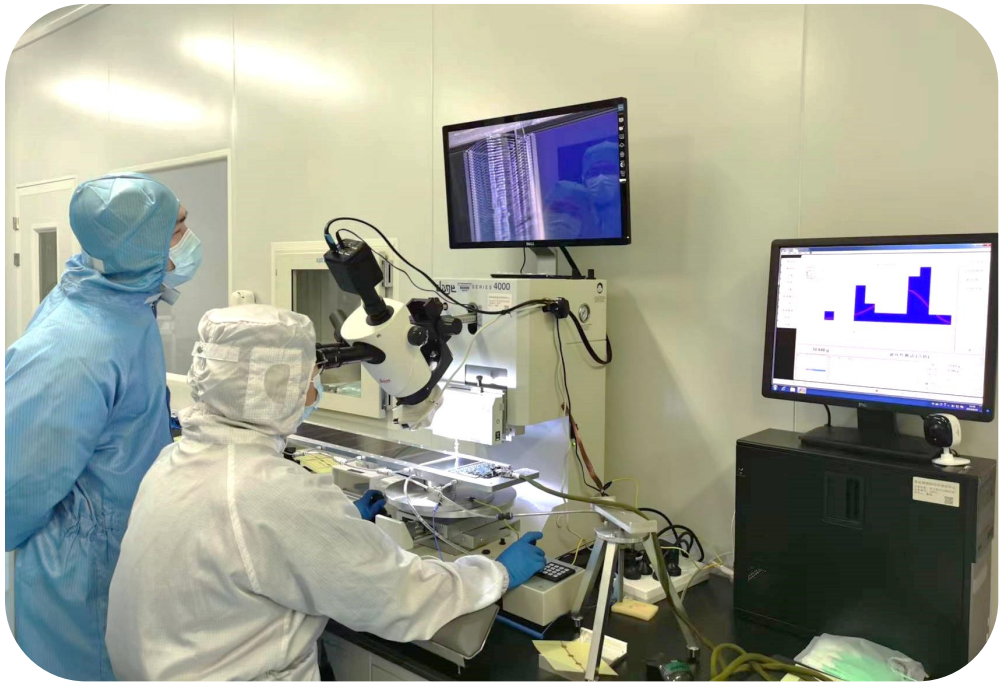
Pull Test

- High F_{break} means strong and reliable
- Regulate the bond force & ultrasonic power to optimize the F_{pull} (F_{break})



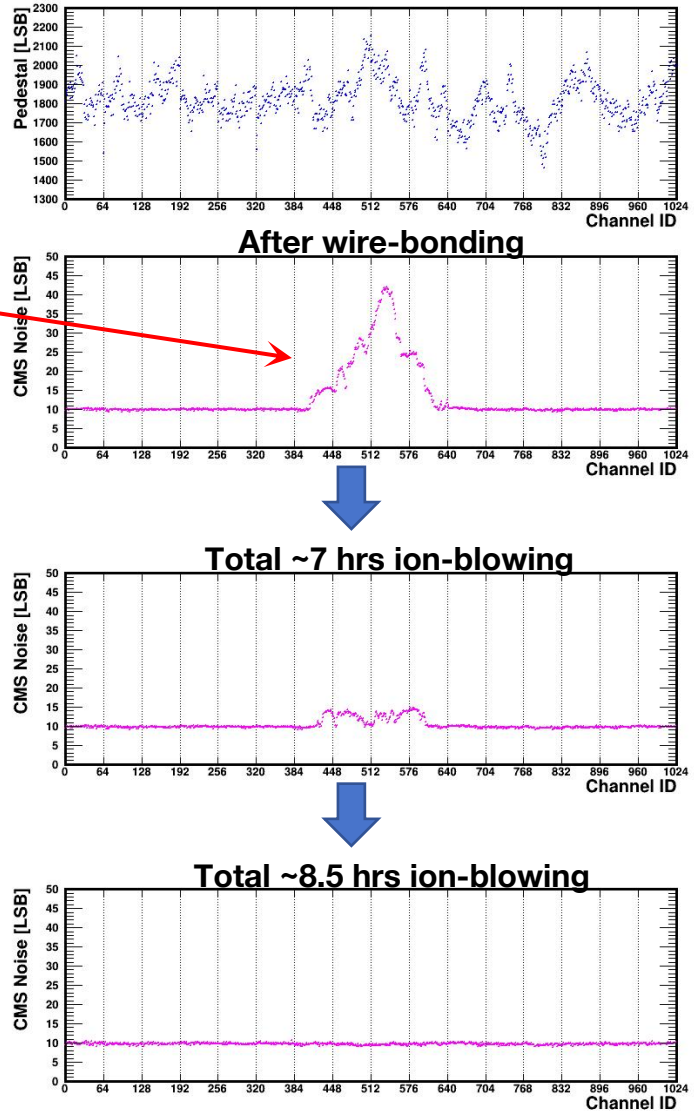


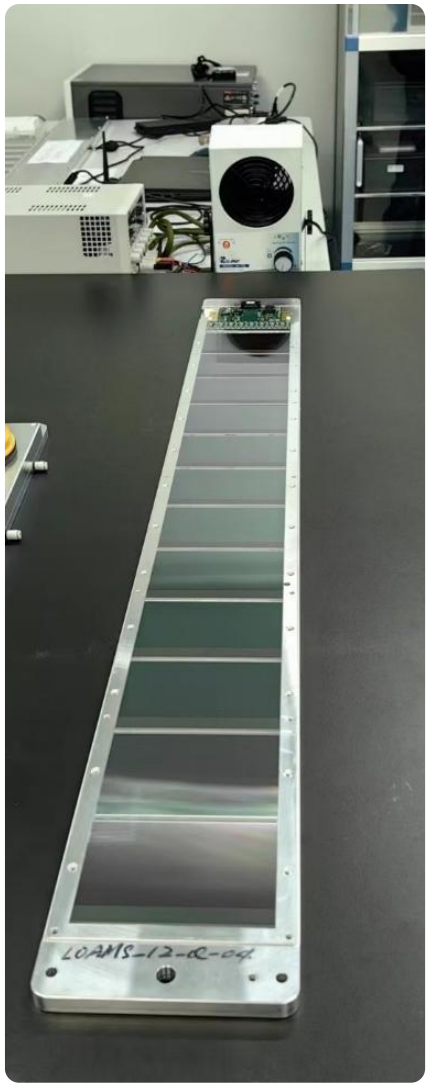




Ladder Electronics-Test: noise

- Large abnormal noise happend around the central region of the sensors
- Recovering after very long time ionizing-air blowing
- static charge from the vaccum pen when moving sensor:
  “cleaning” the vaccum pen can avoid this issue

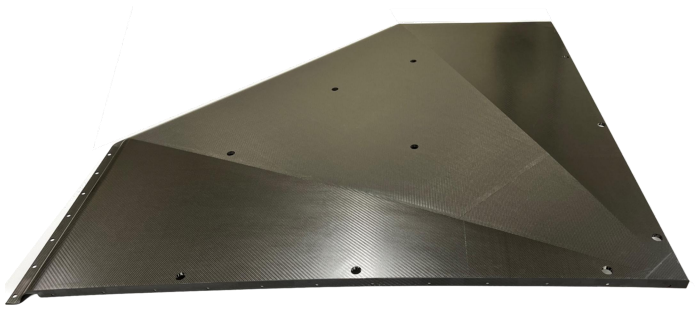


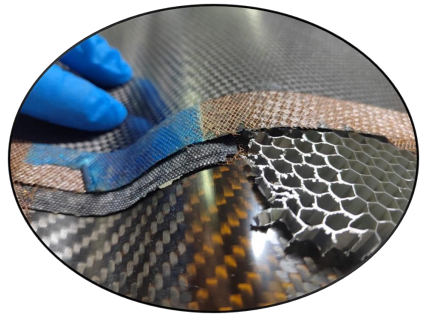


L0 Ladder Production

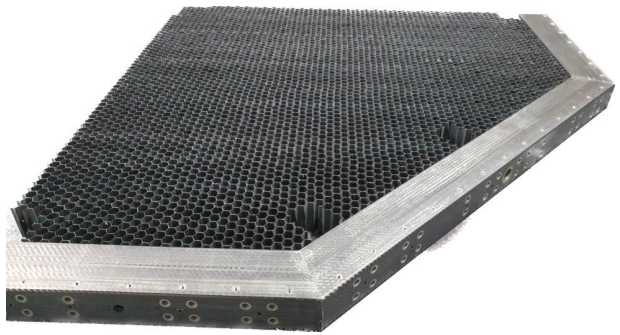
Layer0 Mechanics

- Cupola Top & Bottom
  - EMI Shielding, Thermal radiator, Light shielding





- Carbon-plane and carbon-frame realize a thick stiff plane

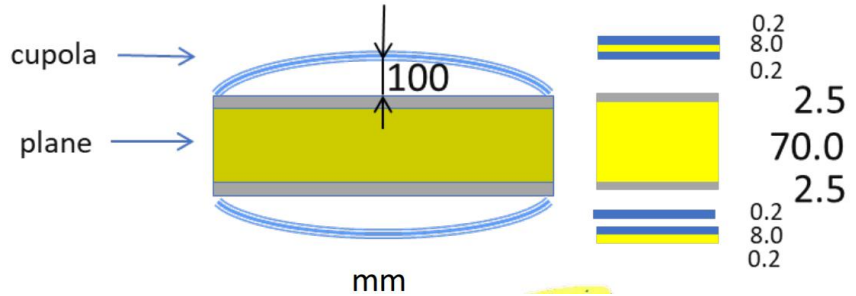


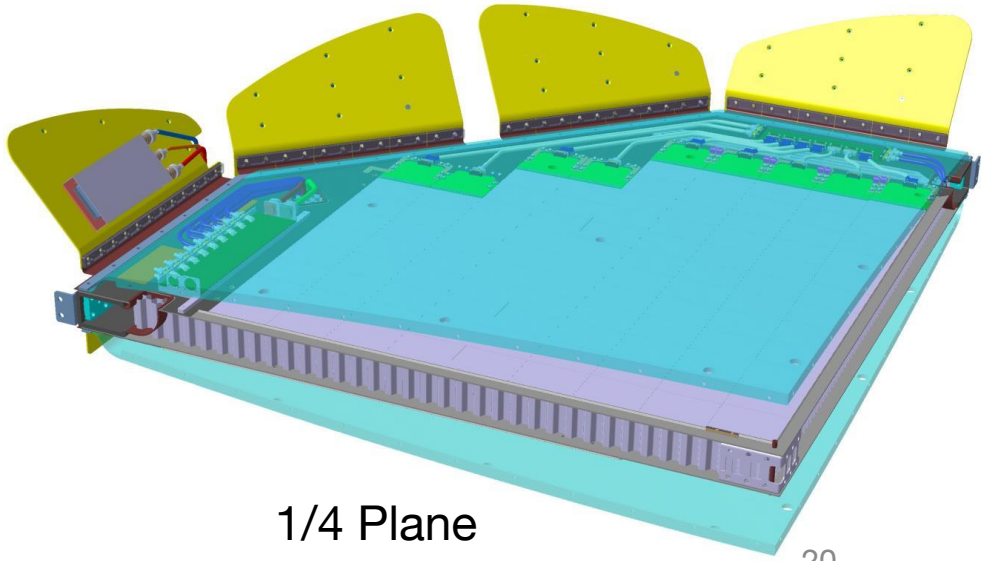
Dimensions

~2.6m diameter

~ 30 cm thick

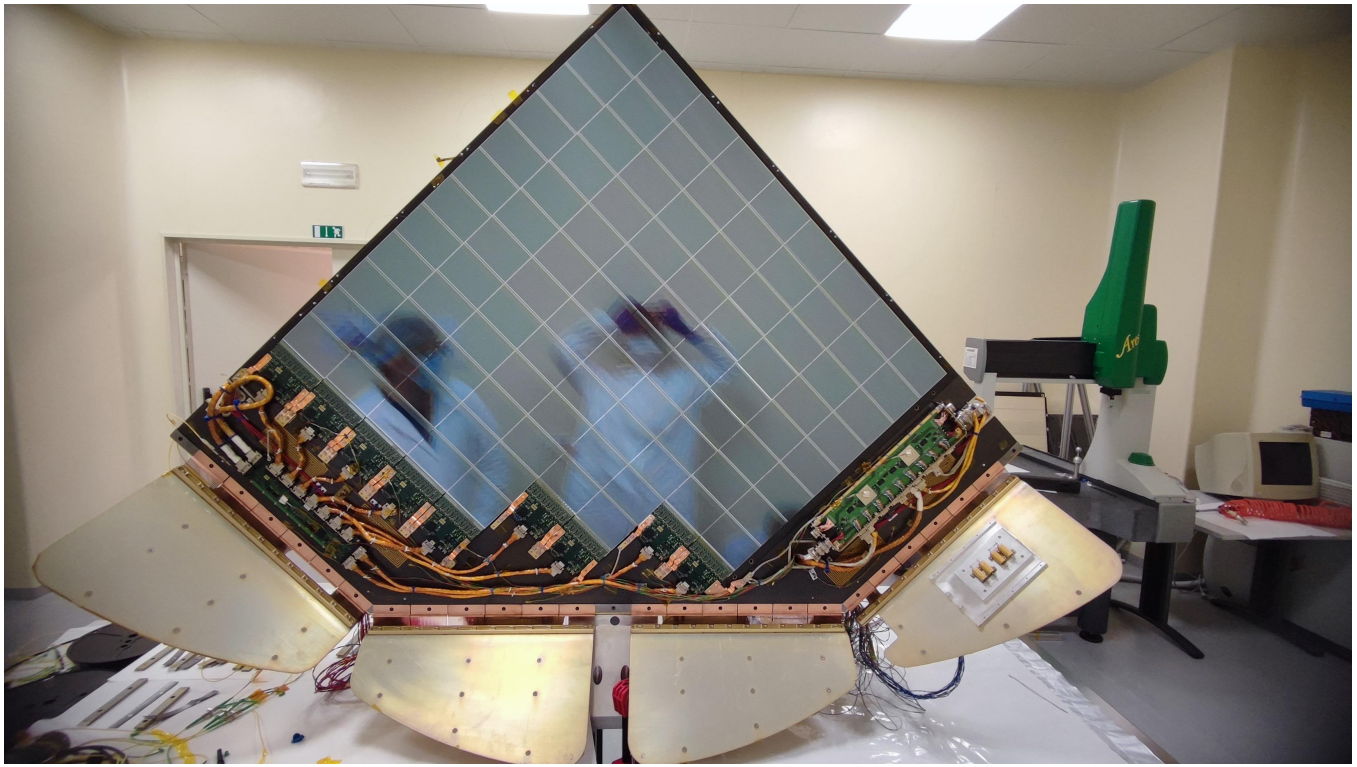
~ 250 kg





1/4 Plane

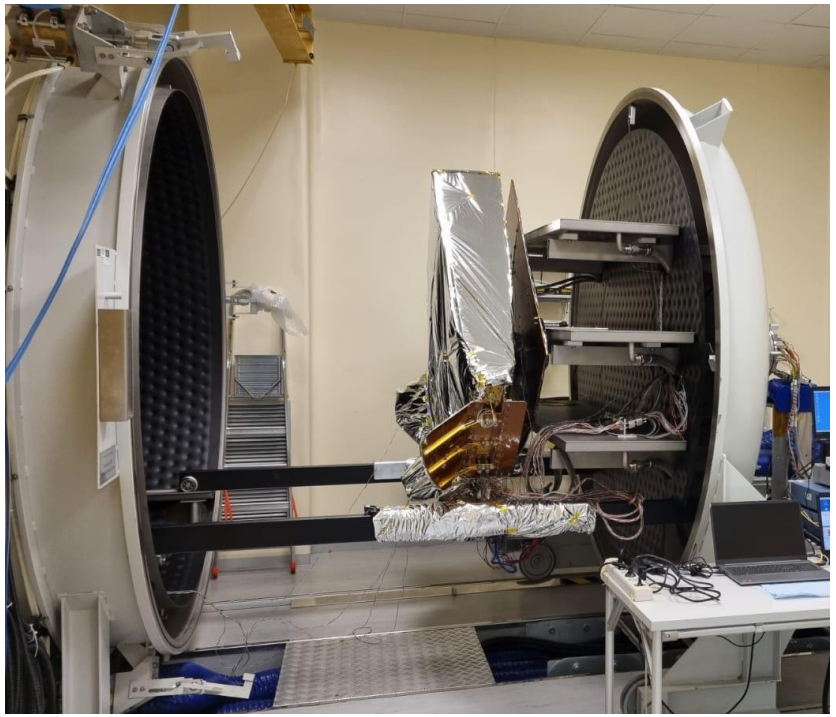
1/4 Plane Integration



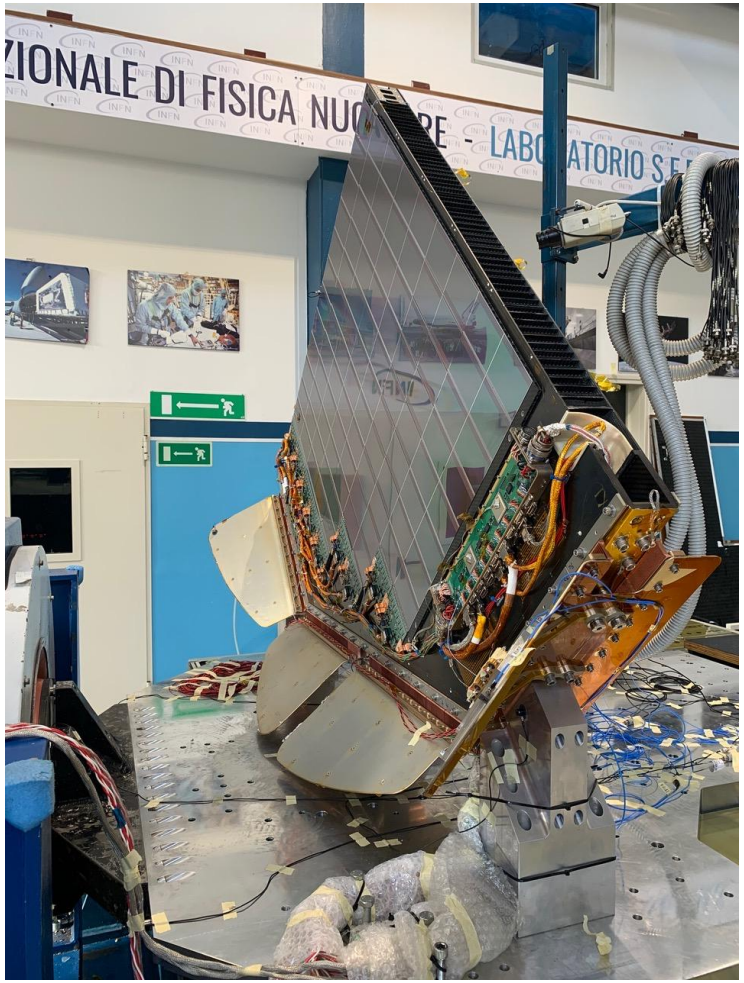
1/4 Plane with ladders and electronics

1/4 Plane with Cupola

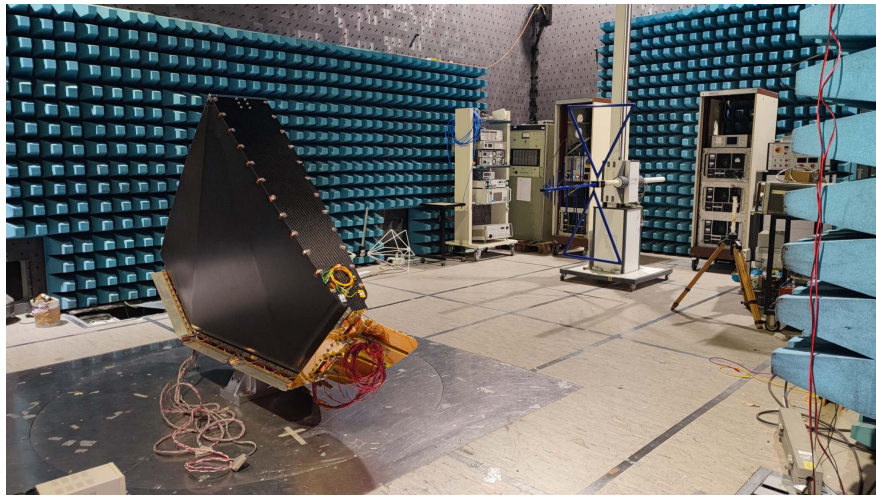
1/4 Plane Testing



Thermal Vacuum test

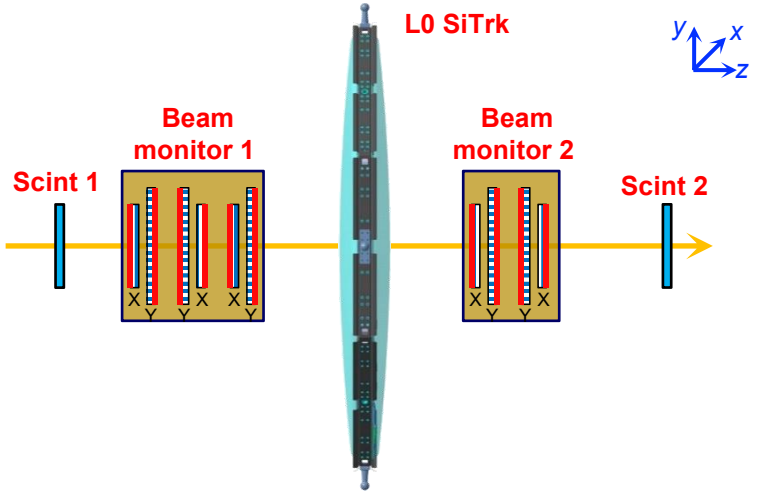


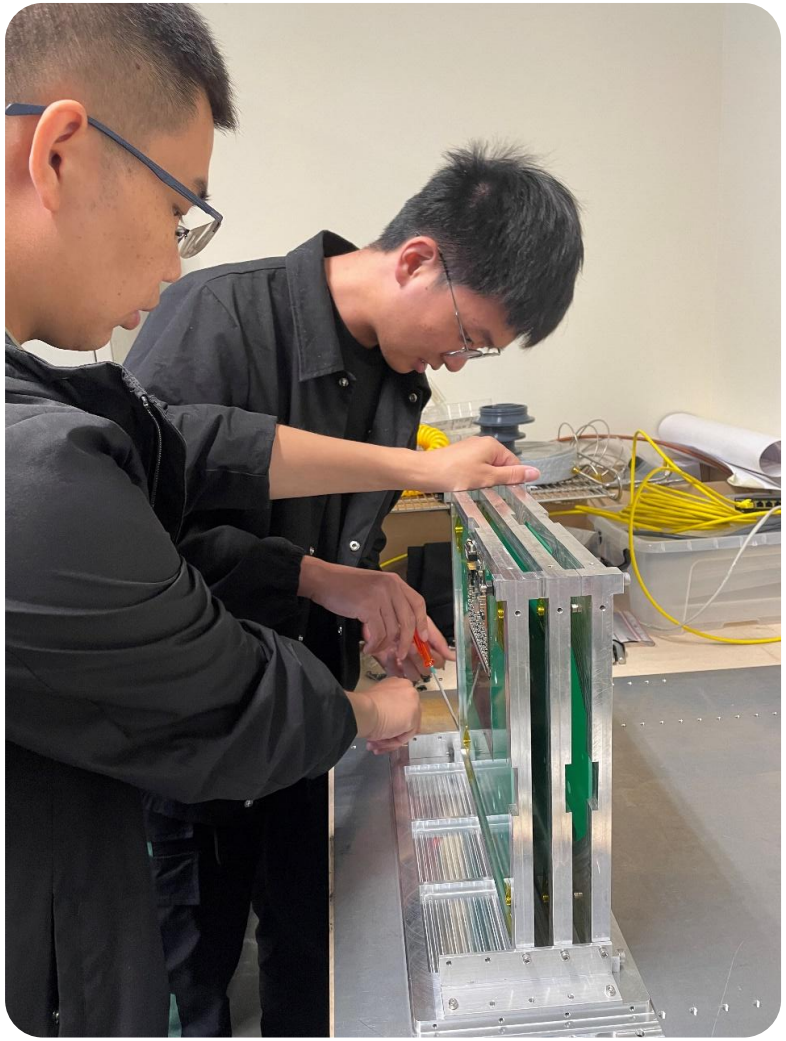
vibration test: no bonding-wire failure



EMI test

Beam Monitors

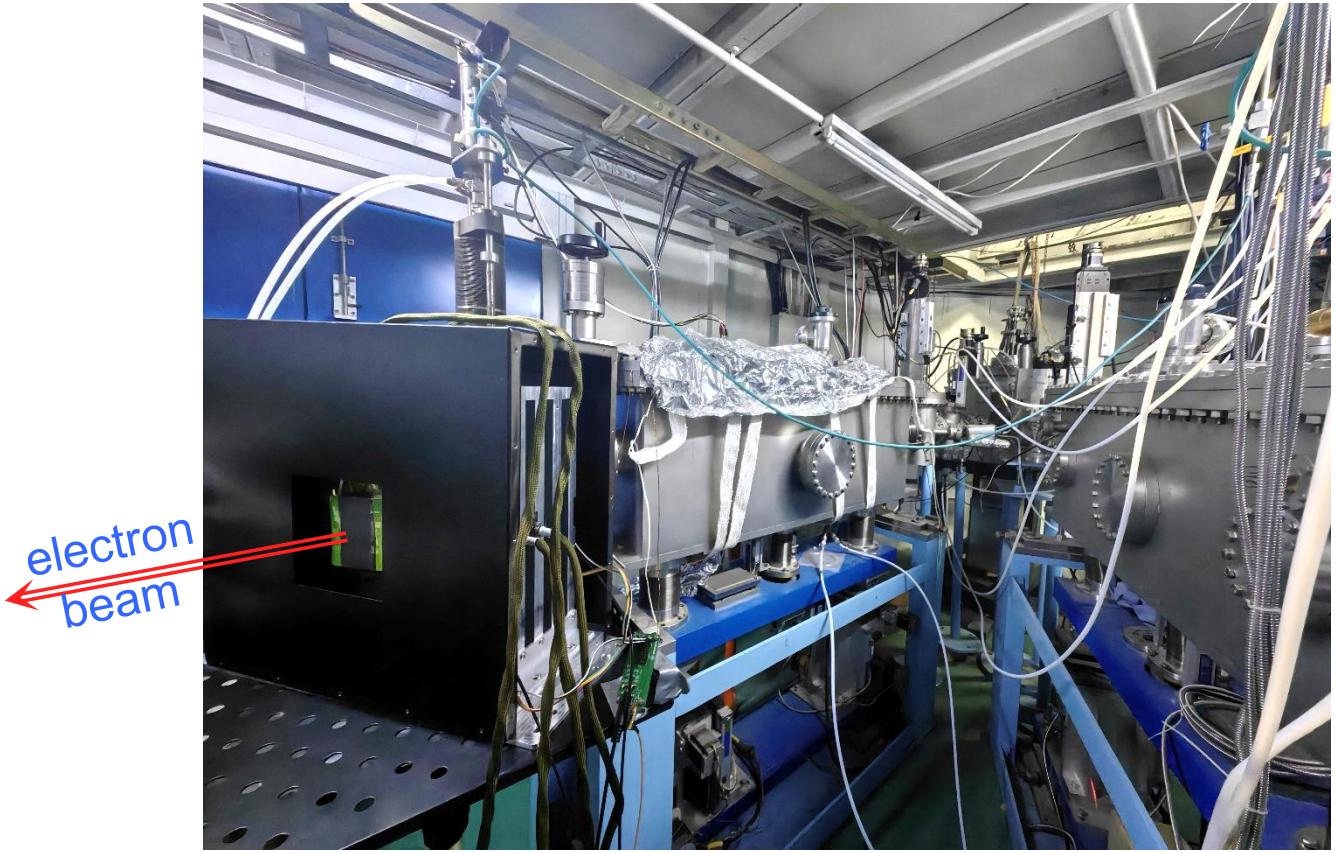


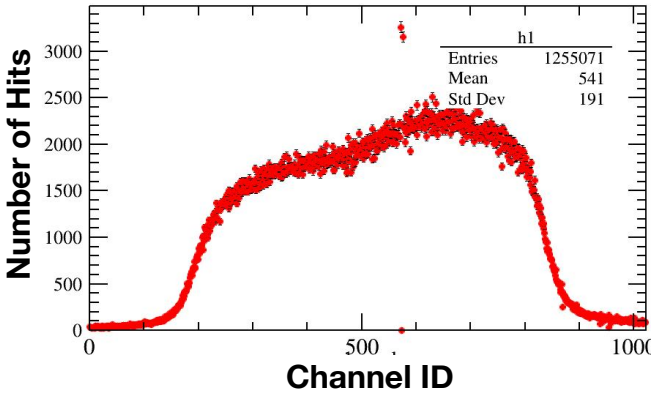


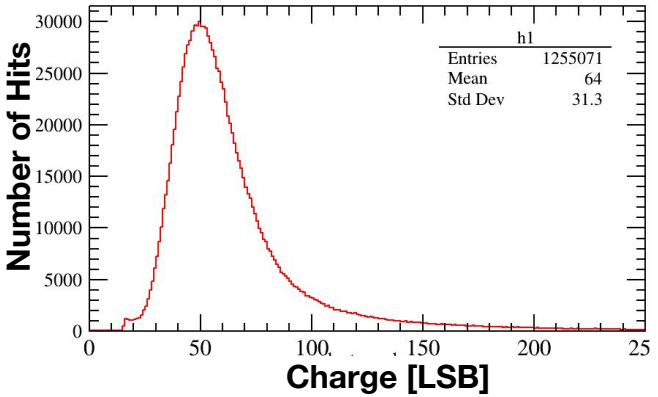
- high energy beam for charactizing the SSD/Ladder/Layer0 performance
- same SSD and LEF used for beam monitor

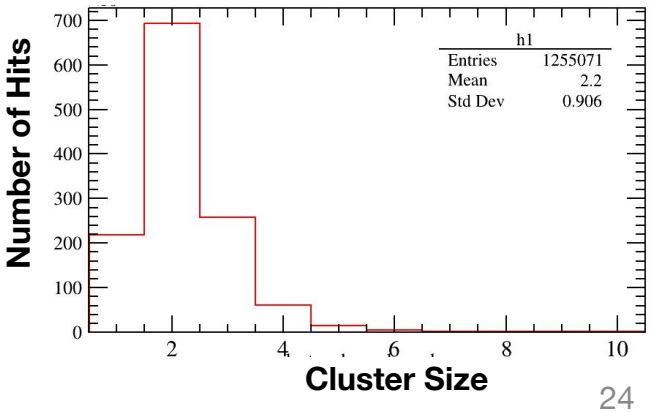
Testbeam at IHEP

- Beam monitors were tested in an electron beam at IHEP
- To validate the data acquisition system, and reveal issues



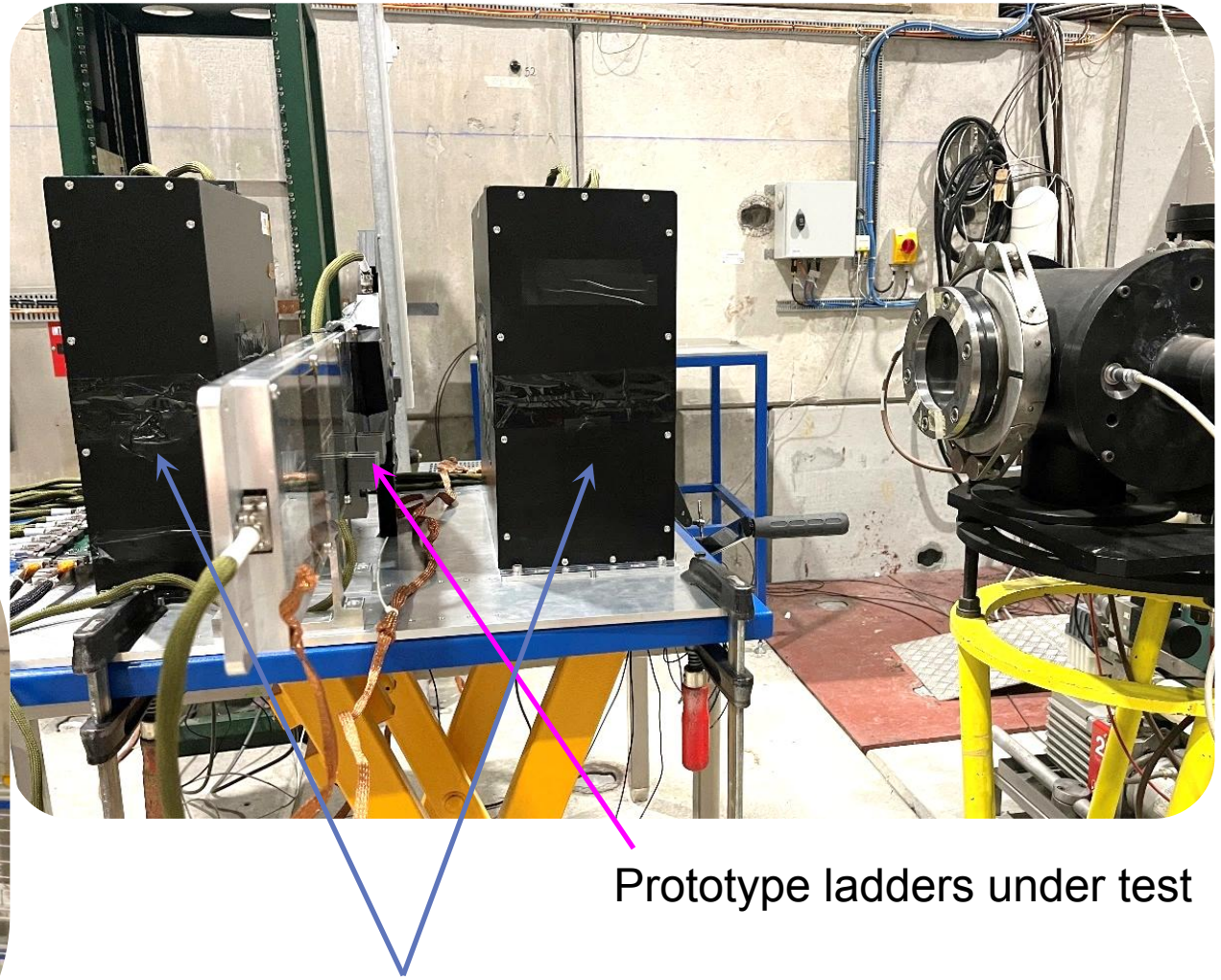






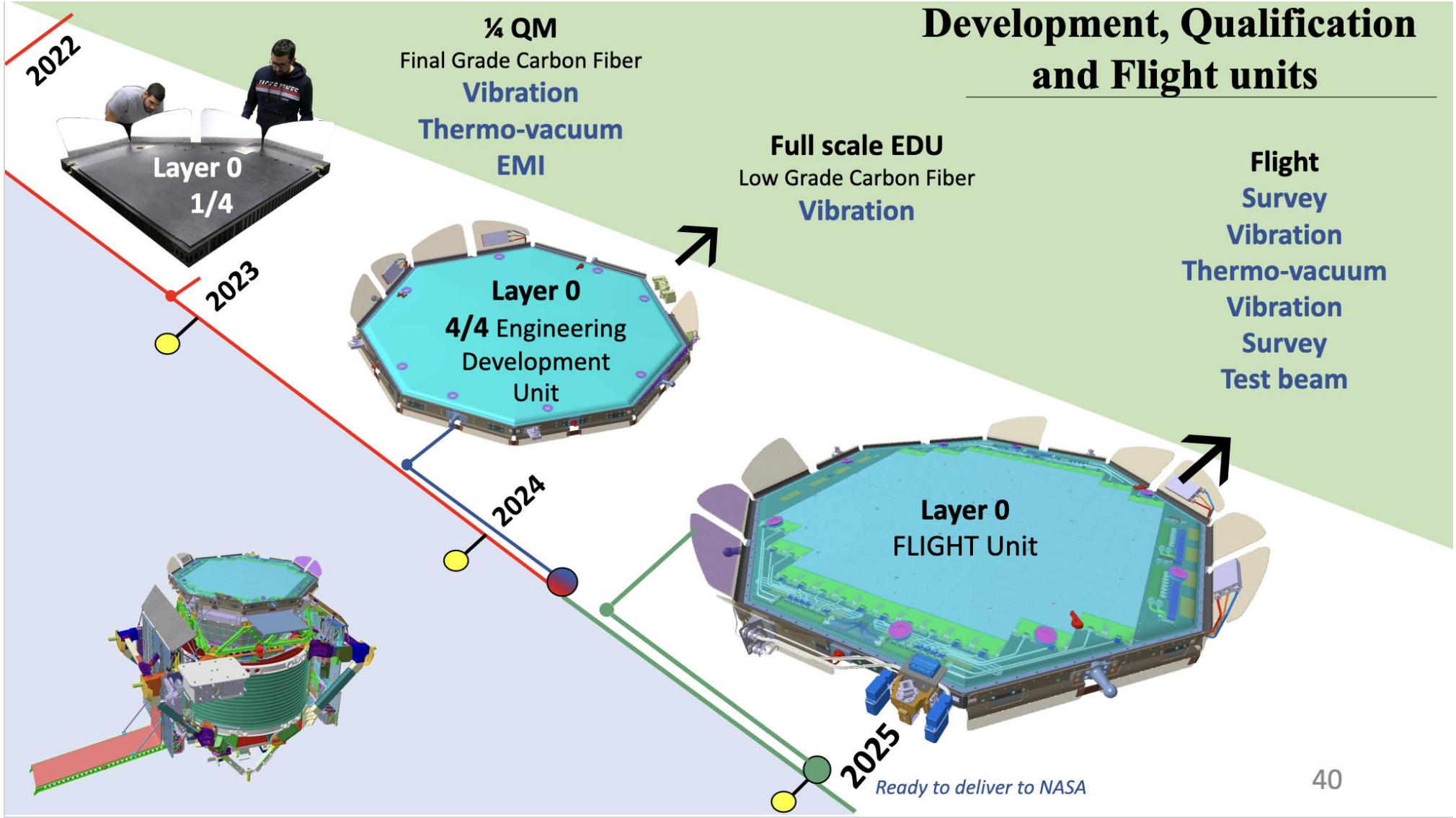
Testbeam at CERN: 2023, 2024

- Prototype detector ladders were tested in muon,proton, and ion beams at CERN
- Beam monitors were used as tracking
- Data are being analyzed
- test-beam planed in 2024



Referece：ASAPP 2023
G. Ambrosi, AMS-L0: upgrade status and prospects

Roadmap



Backup

L0 Electronic Front End (LEF)

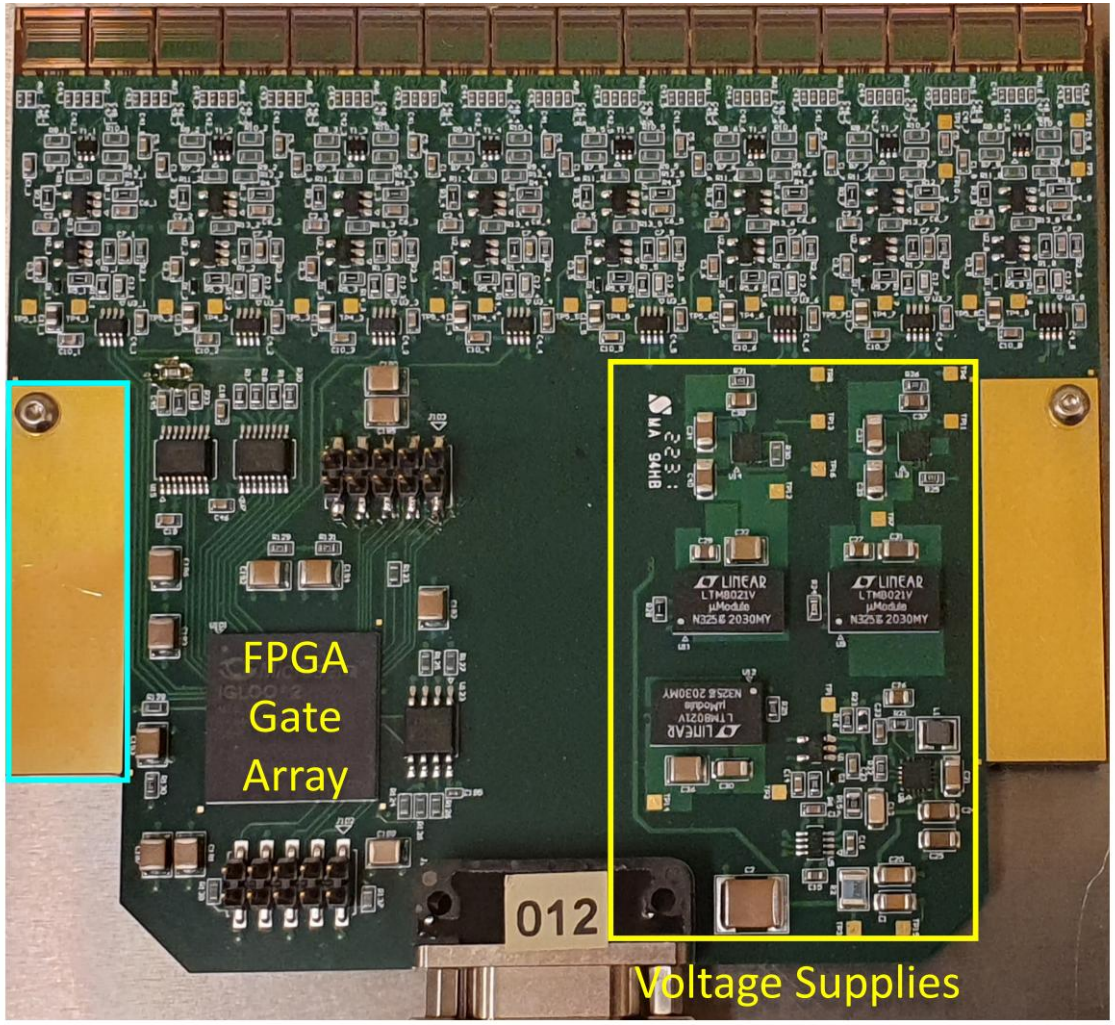
8 Amplifiers

8 14-Bit, 2.5Msps, Serial Sampling ADCs, 4096mV

Thermal Strips

1. Heat path to radiators.

2. Ground path to chassis



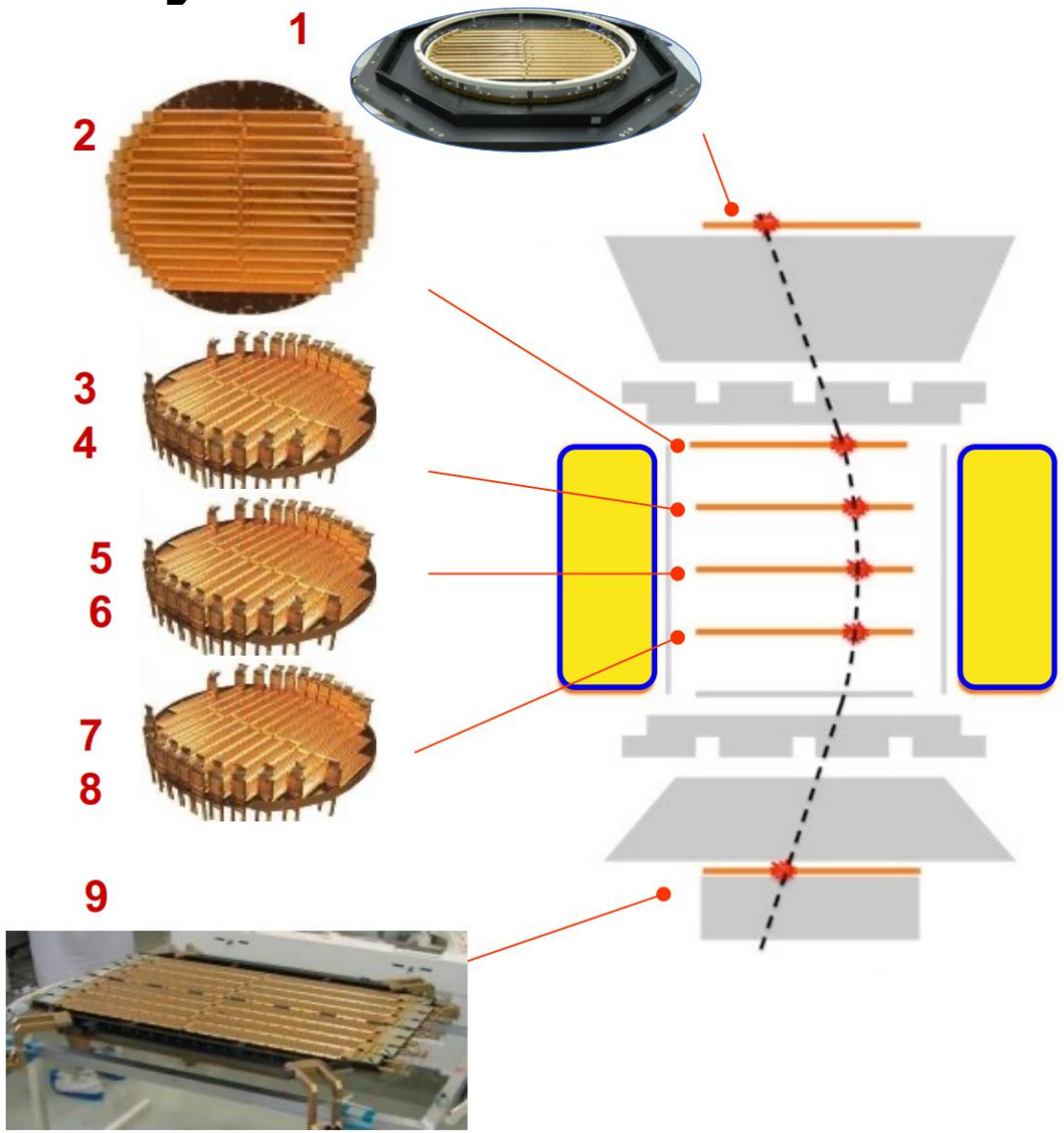
16 IDE1140, 1024 strips

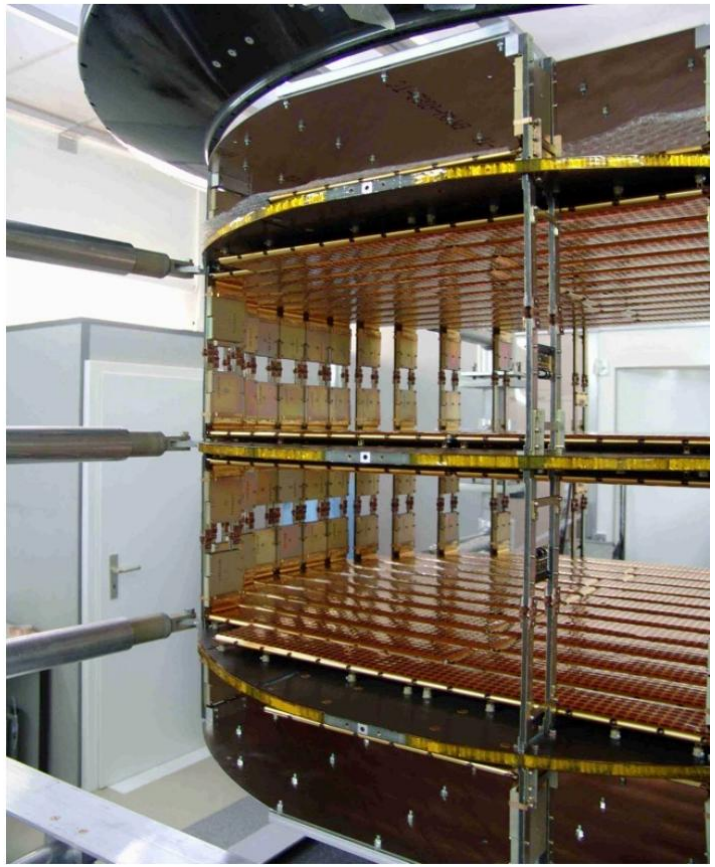
Each IDE1140 (“VA”)

- 64 channels charge amplifier/ shaper.
- Sample and hold.
- 64 channels analog multiplexor.
- 2.6 uA per 1 fC differential current output

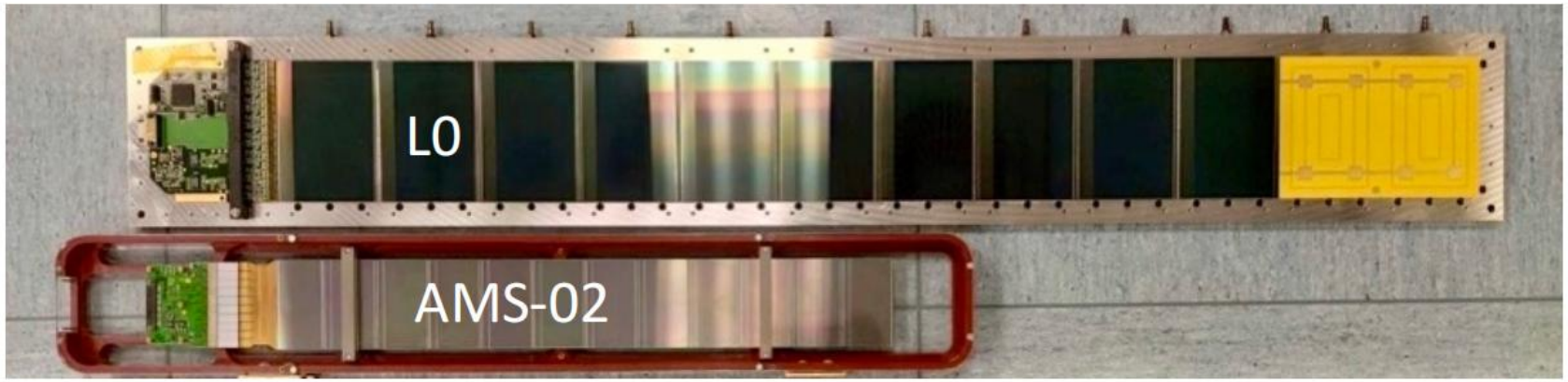
https://indico.cern.ch/event/1208314/contributions/5283387/

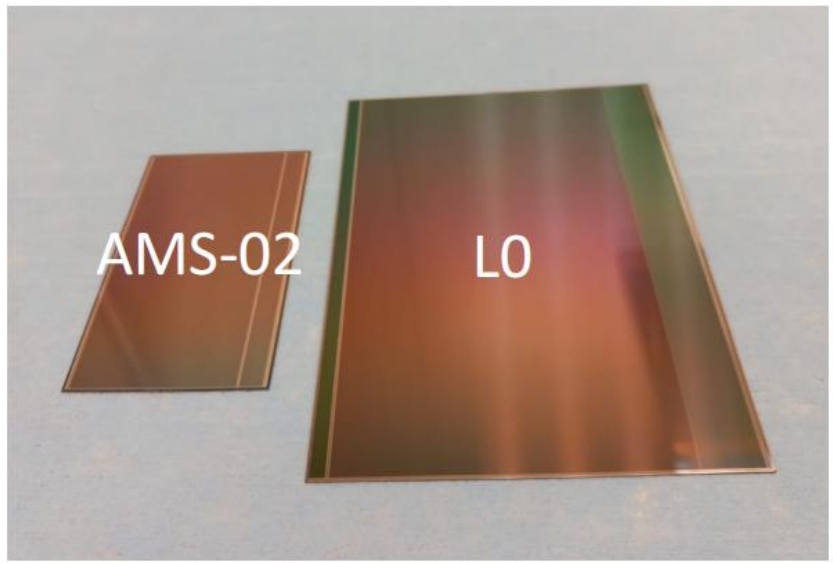
The layout of the AMS-02 Tracker



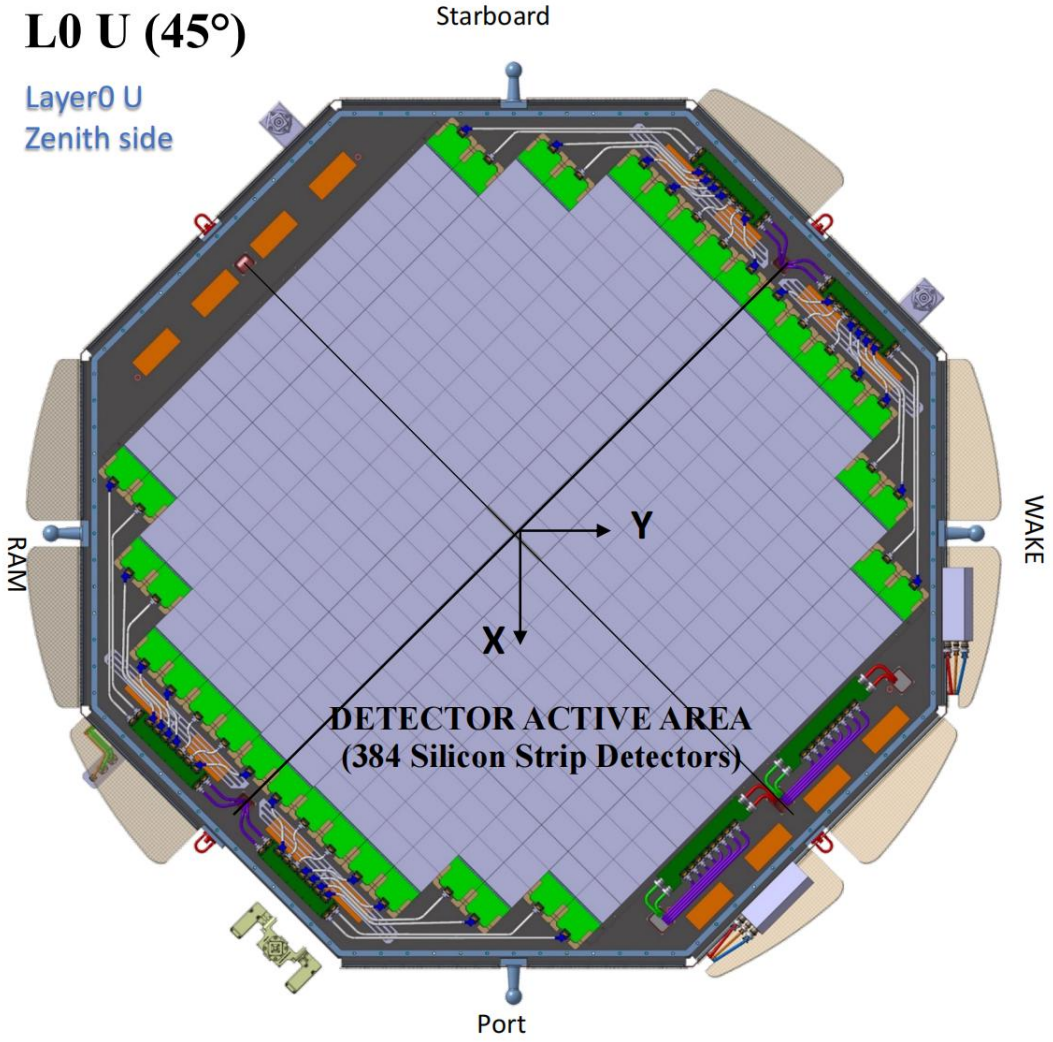


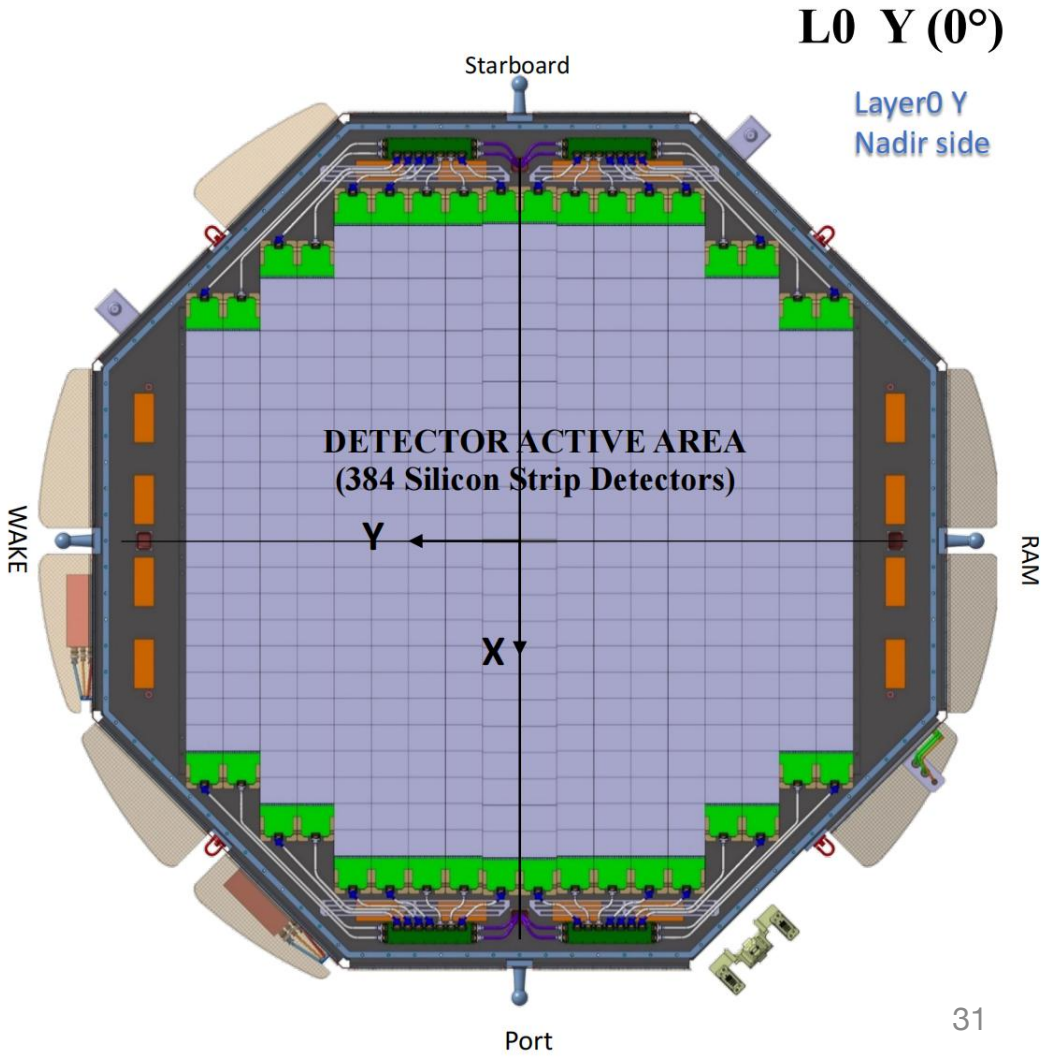
AMS-02 vs L0 ladders





Plane layout





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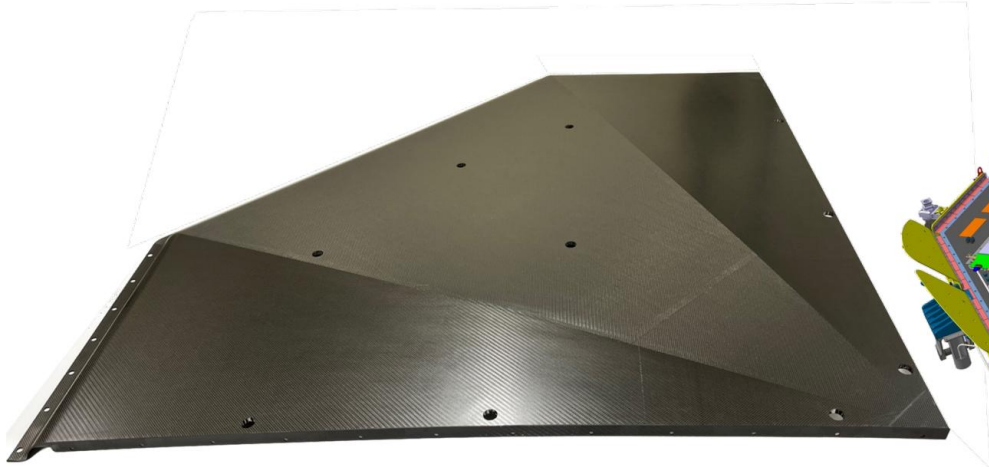
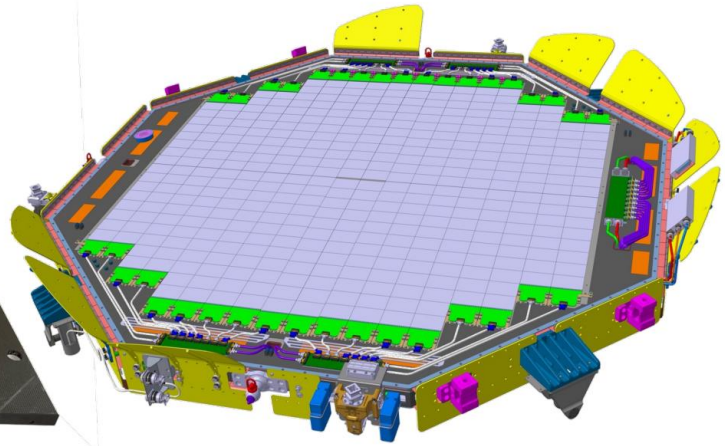
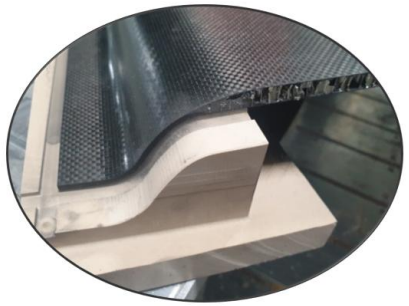
Mechanics

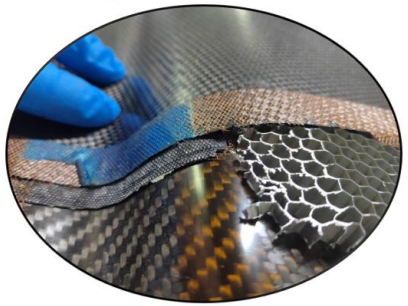
Light carbon cupola





Transition from sandwich to bolted interface





Aluminum honeycomb
Carbon skin
Copper net for EMI

C. Gargiulo

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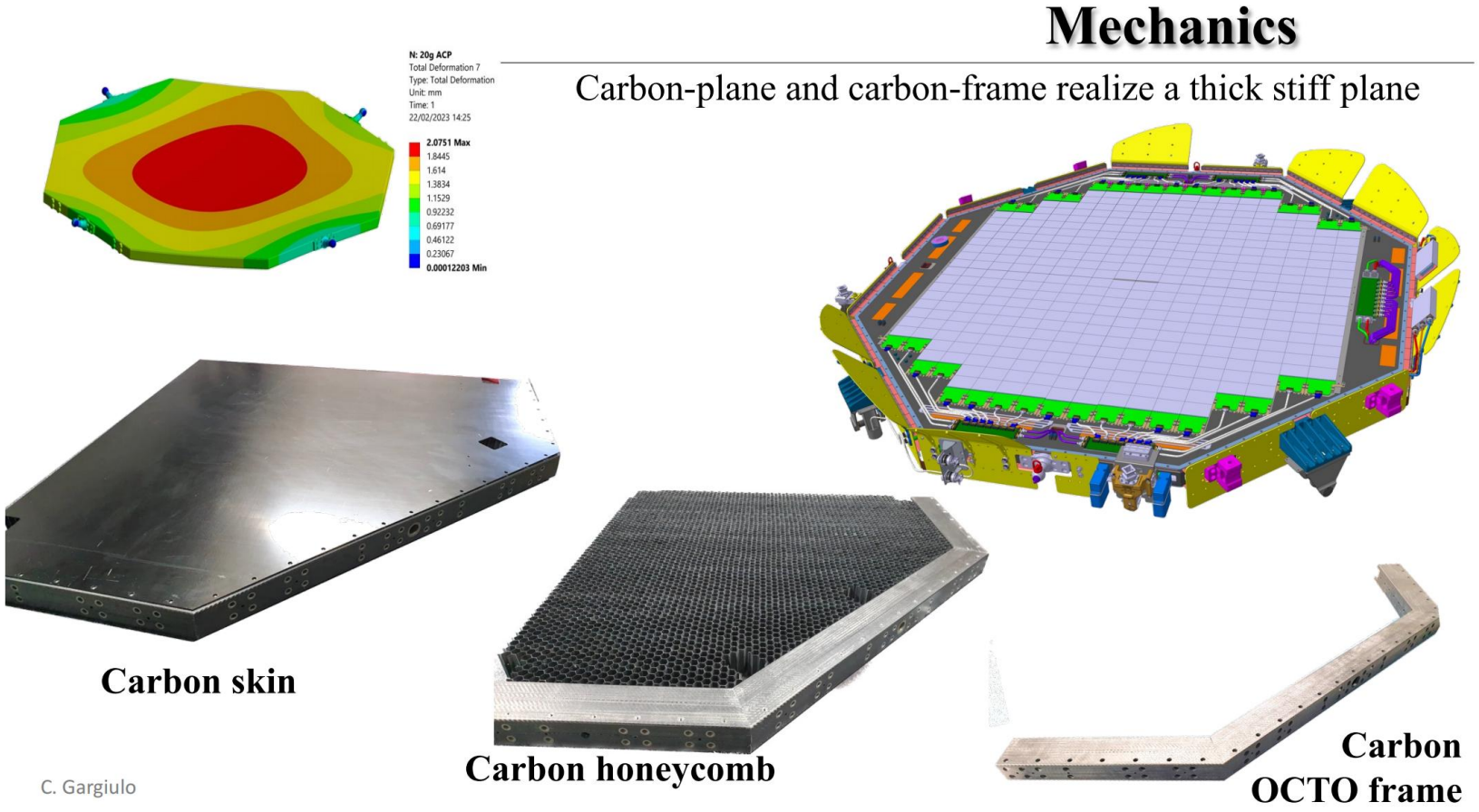
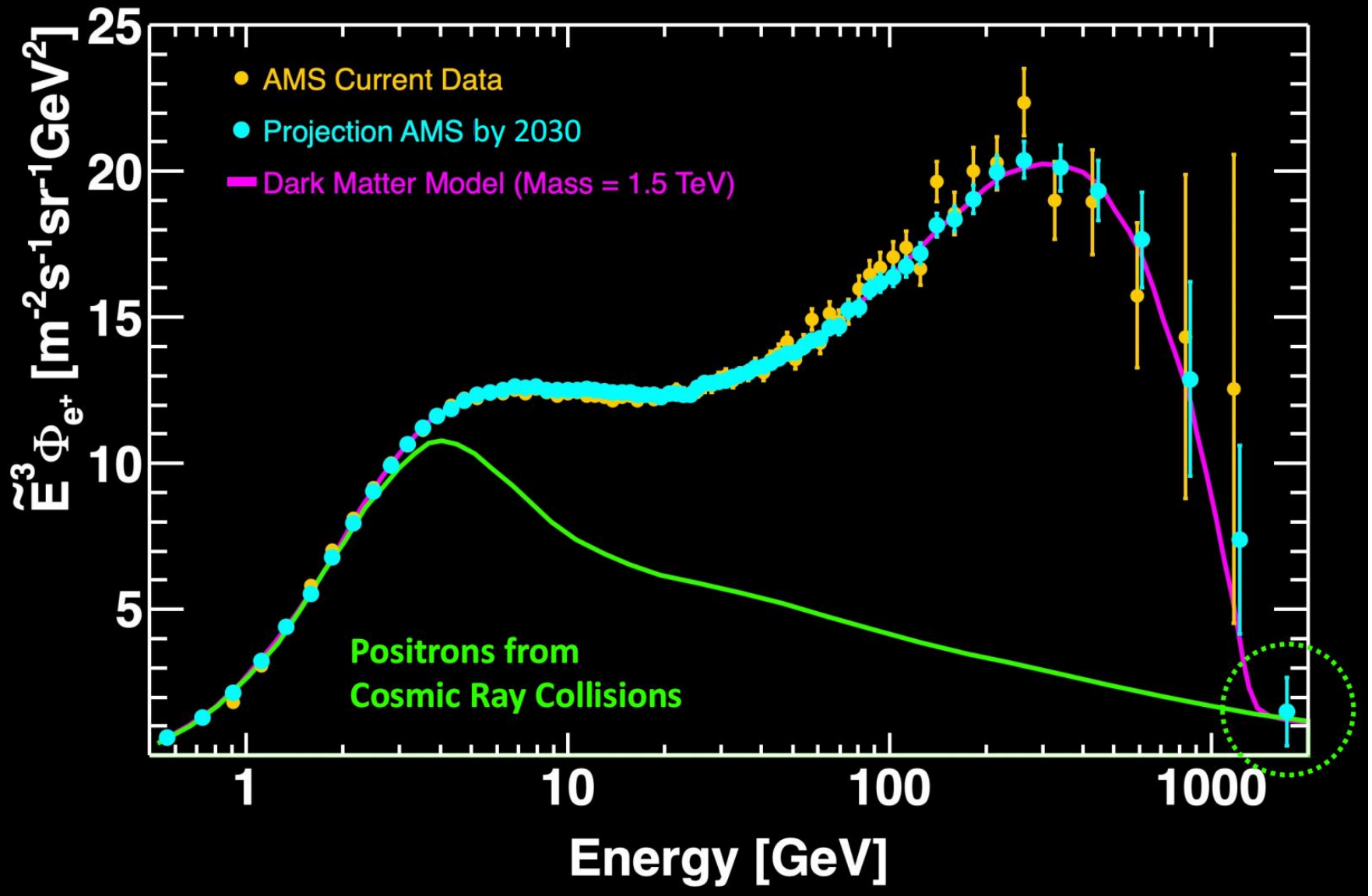


Determination of the Origin of Cosmic Positrons by 2030

AMS will ensure that the measured high energy positron spectrum indeed drops off quickl
and, at the highest energies, the positrons only come from cosmic ray collisions
as predicted by dark matter models



By 2030, AMS will extend the energy range of the positron flux measurement from 1.4 to 2 TeV and reduce the error by a factor of two compared to current data