Penetrating particle ANalyzer (PAN)

Gianluigi Silvestre on behalf of the PAN consortium

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Acknowledgment:
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The Penetrating Particle Analyzer

- A compact magnetic spectrometer conceived for interplanetary and deep-space missions
- Precise measure and monitoring of flux, composition, and direction of highly penetrating particles (> 100 MeV/n)
- Consortium of three institutes:
  - Department of nuclear and particle physics, University of Geneva
  - INFN Perugia
  - Institute of Experimental and Applied Physics, Czech Technical University in Prague

PAN

Penetrating Particle Analyzer

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique nucléaire et corpusculaire

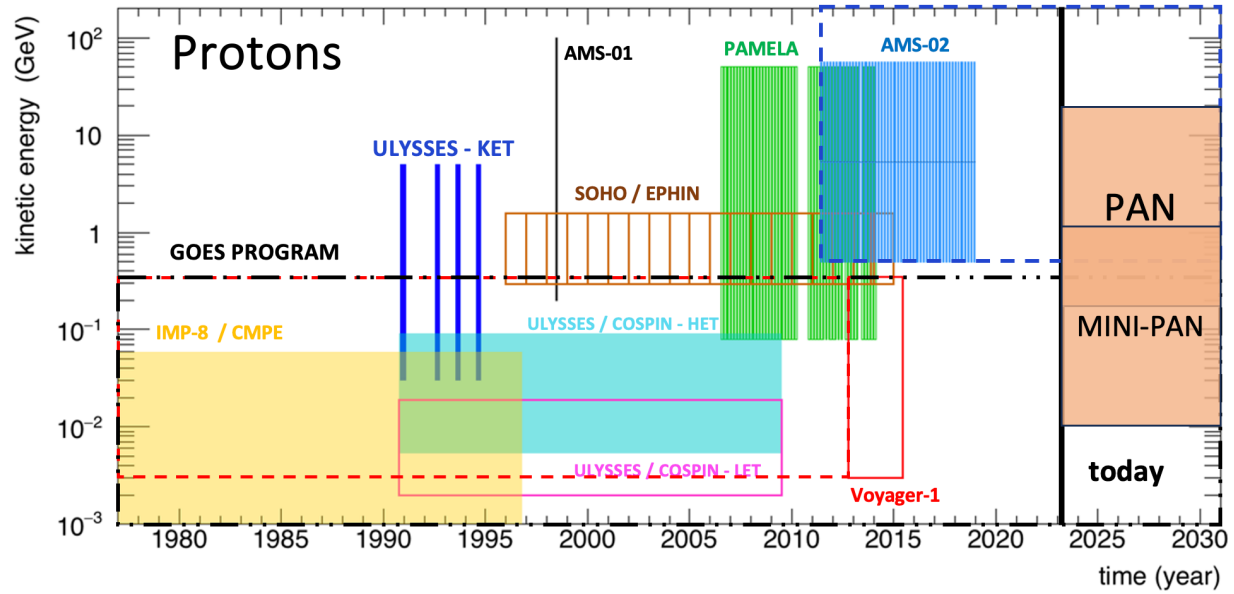
INFN PERUGIA

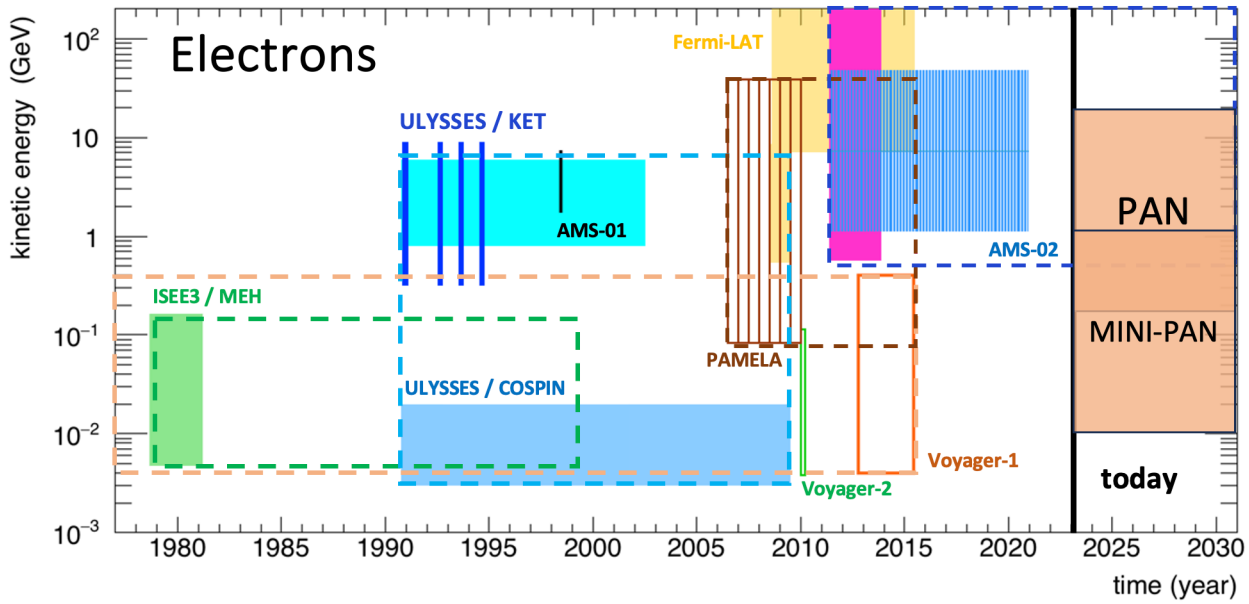
CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

Physics motivation

- Several limitations on the measurements that previous instruments could perform
  - Only possible to extrapolate LEO measurements (e.g. PAMELA, AMS-02) to deep-space
  - Measurements across and outside the heliosphere only below 100 and 500 MeV/u (ACE and Voyager)

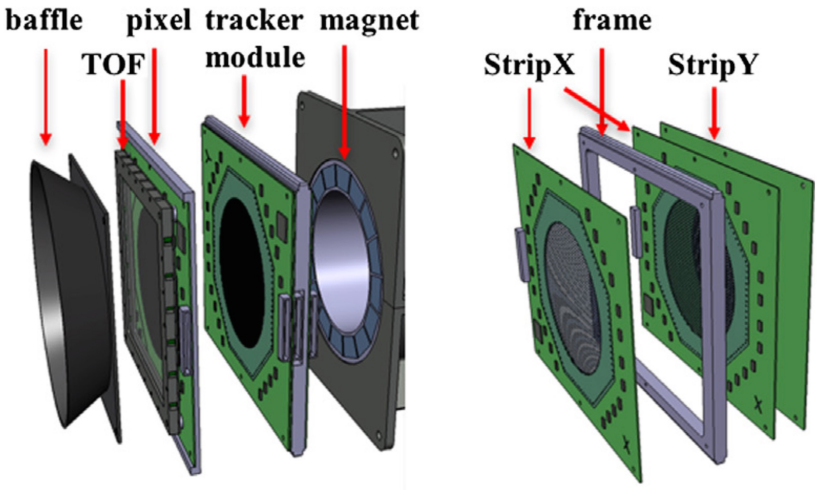
- PAN is designed to fill this gap, performing measurements over at least one solar cycle (11 years) needed for different science goals
  - Cosmic ray physics: origin of the GCRs and Antimatter searches
  - Solar physics: provide precise information on solar energetic particles
  - Space weather: Improve space weather models from the energetic particle perspective.
  - Planetary science: picture of the radiation environment of a planet/moon, in particular as a potential habitat.
  - Deep space travel: on-board instrument suitable for radiation monitoring

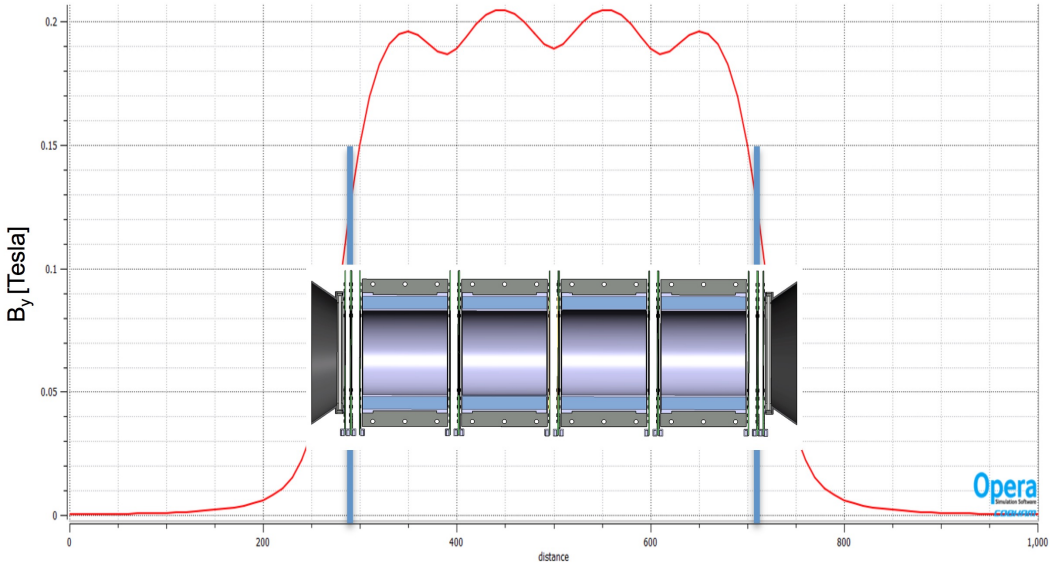




The PAN instrument

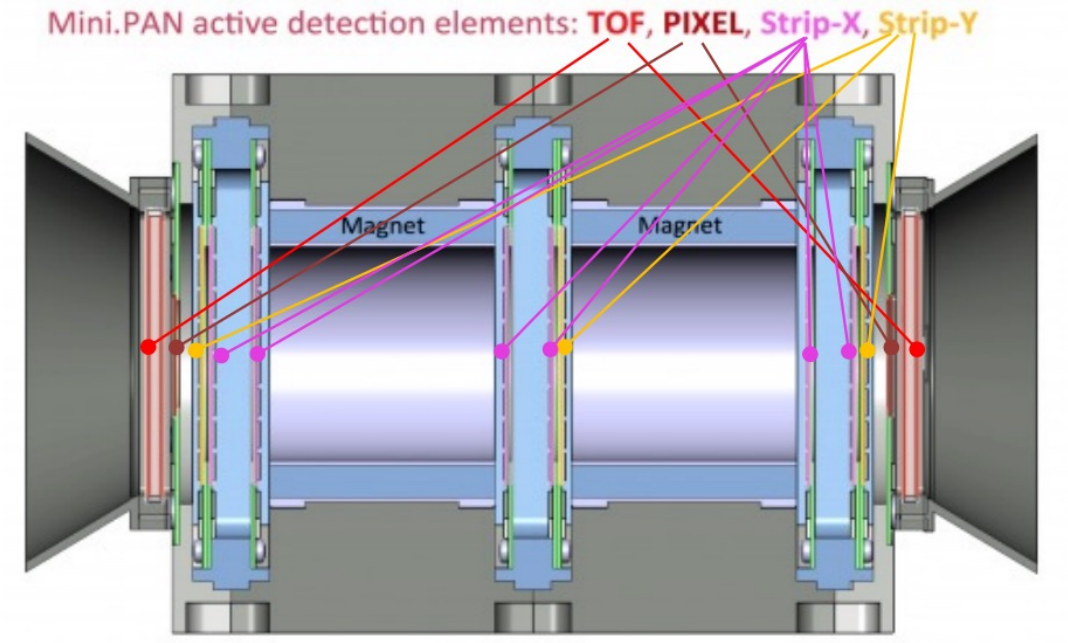
- Four Halbach permanent magnet sectors
  - Diameter and length of 10 cm
  - Dipole magnetic field of ~0.2 Tesla
- Lightweight (< 20 kg)
- Low power (< 20 W)
- Symmetric: measure particles coming in from both ends



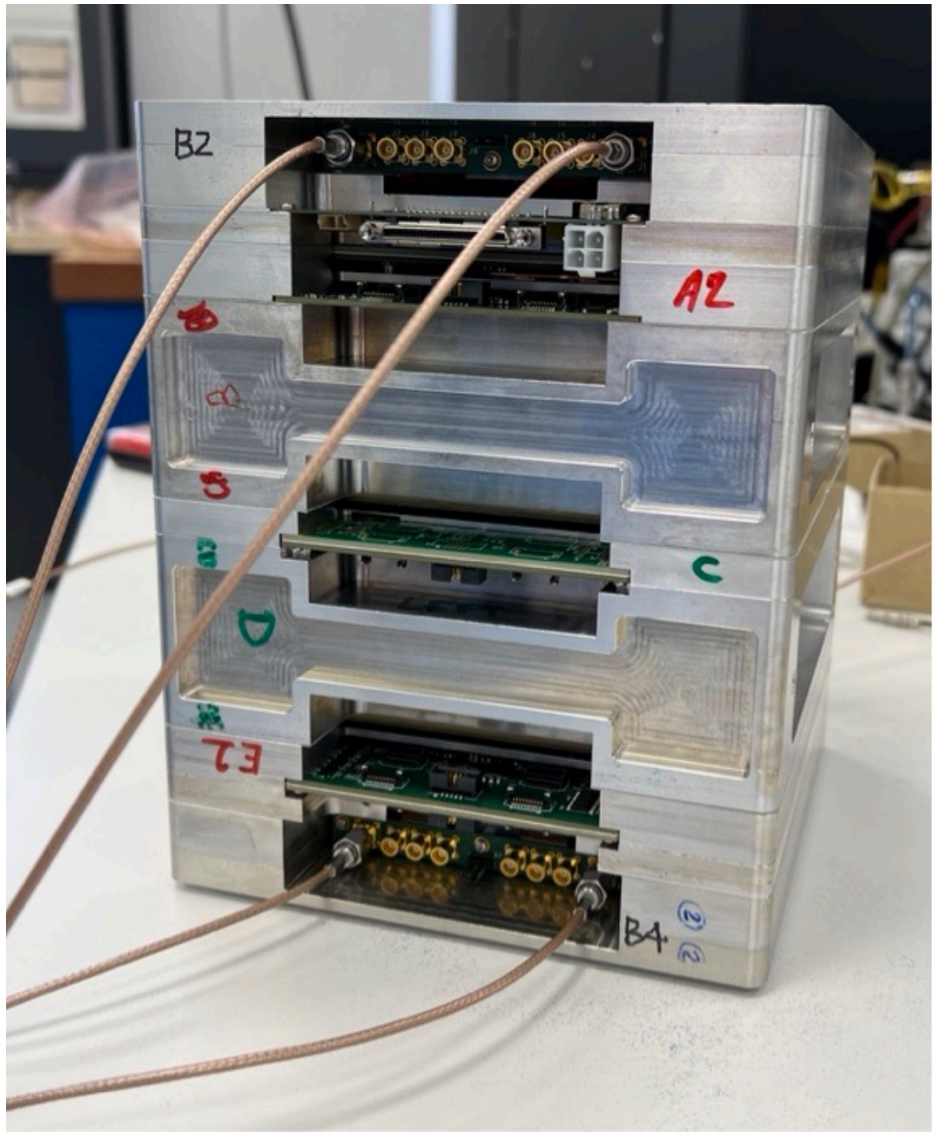


The mini.PAN demonstrator

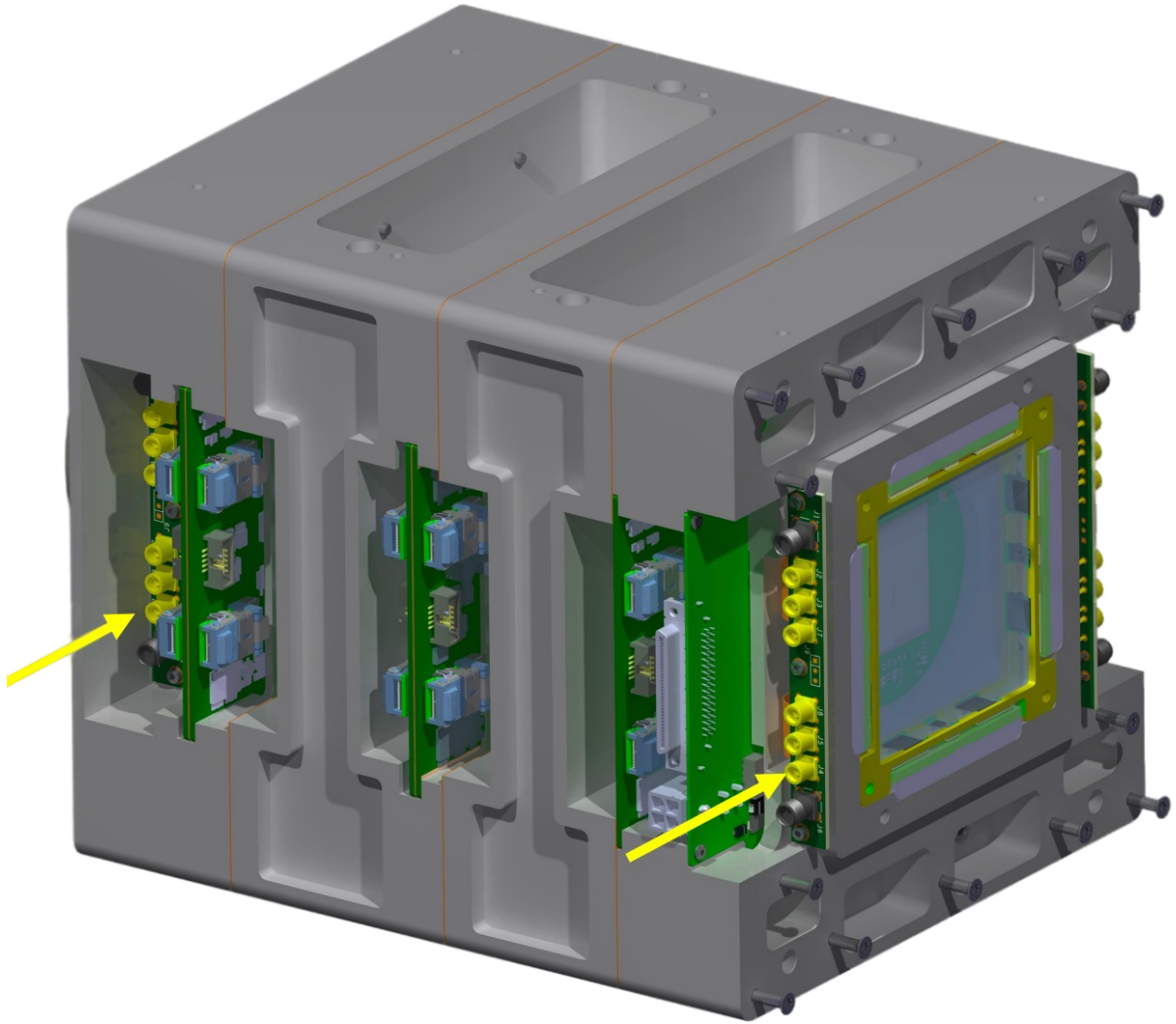
- Funded by the EU H2020 FETOPEN program for 3+1 years (2020-2023)
- Smaller scale demonstrator for PAN technology
- Two sectors with smaller dimensions with the same instrumentation
- Shorter sector length (5 cm) compensated by a stronger magnetic field.



Horizon 2020
European Union Funding
for Research & Innovation

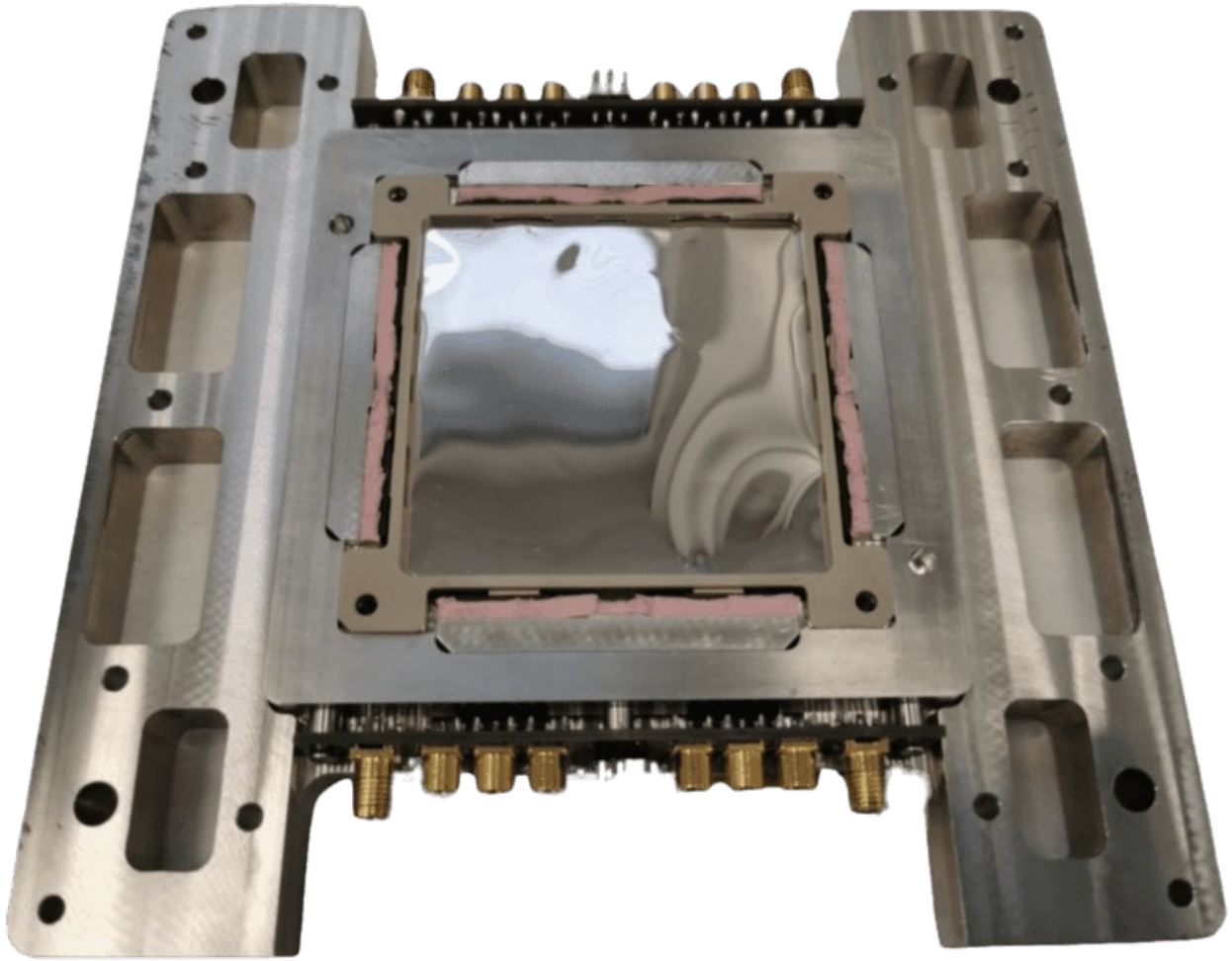


mini.PAN demonstrator TOF



- Two Time Of Flight modules
  - Positioned at the ends of mini.PAN
  - Fast response scintillator
  - SiPM readout around perimeter
- Readout performed with two ASICs
  - Triroc: used for time measurements, charge ID and trigger
  - Citiroc: used for redundant charge ID and trigger

mini.PAN demonstrator TOF



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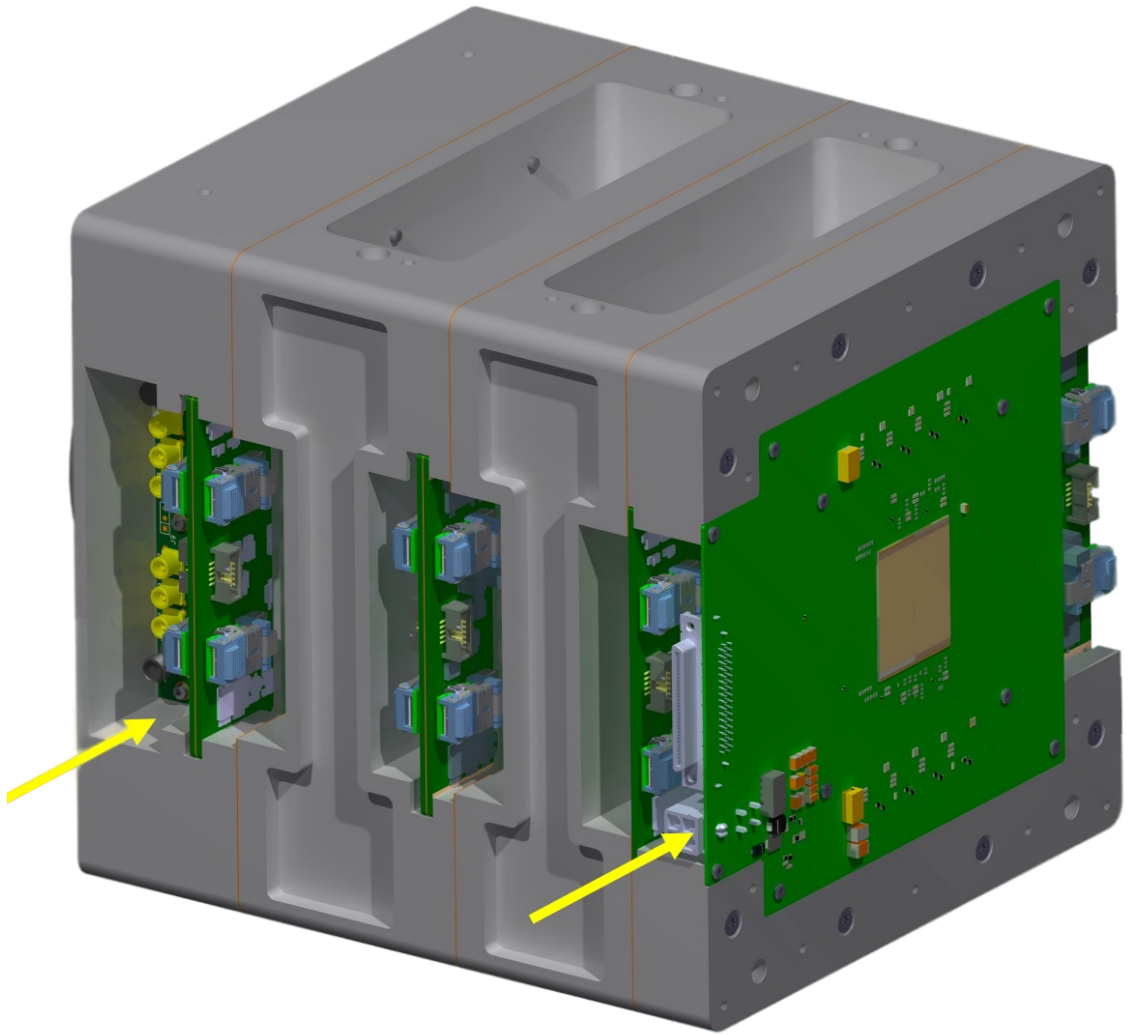
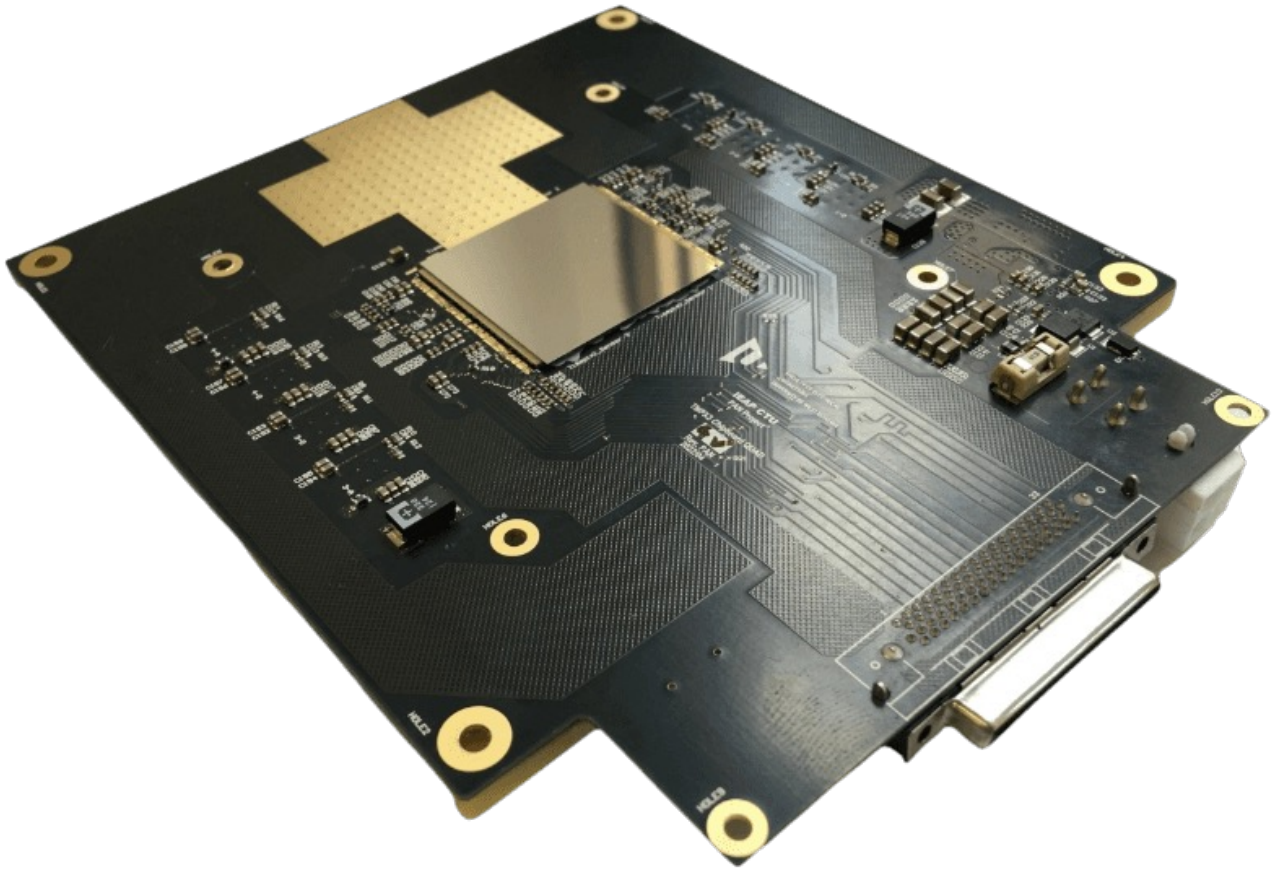
mini.PAN demonstrator PIXEL



- Positioned between TOF and TRACKER modules at the ends of mini.PAN
- Equipped with a Timepix3 quad detectors
  - 262’144 pixels with pixel pitch 55 µm (2.8 x 2.8 cm)
  - Simultaneous time of arrival (ToA) and time over threshold (ToT) measurement in each pixel.
  - Sensor thickness 300 µm
  - ToA binning: down to 1.56 ns
- Used in low power mode (4W instead of 6W) with no significant performance loss
- Even lower power mode (2.4W) under study

mini.PAN demonstrator PIXEL



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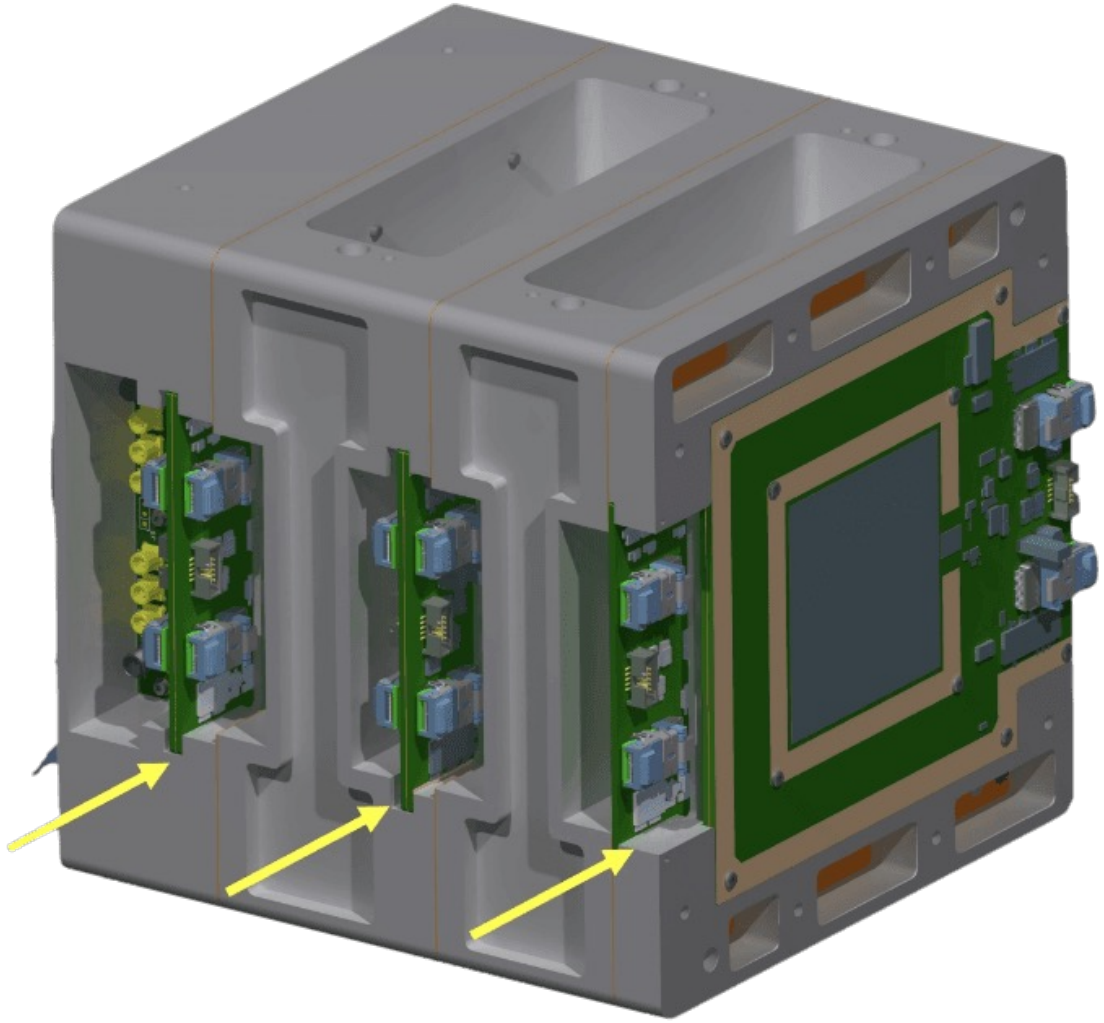
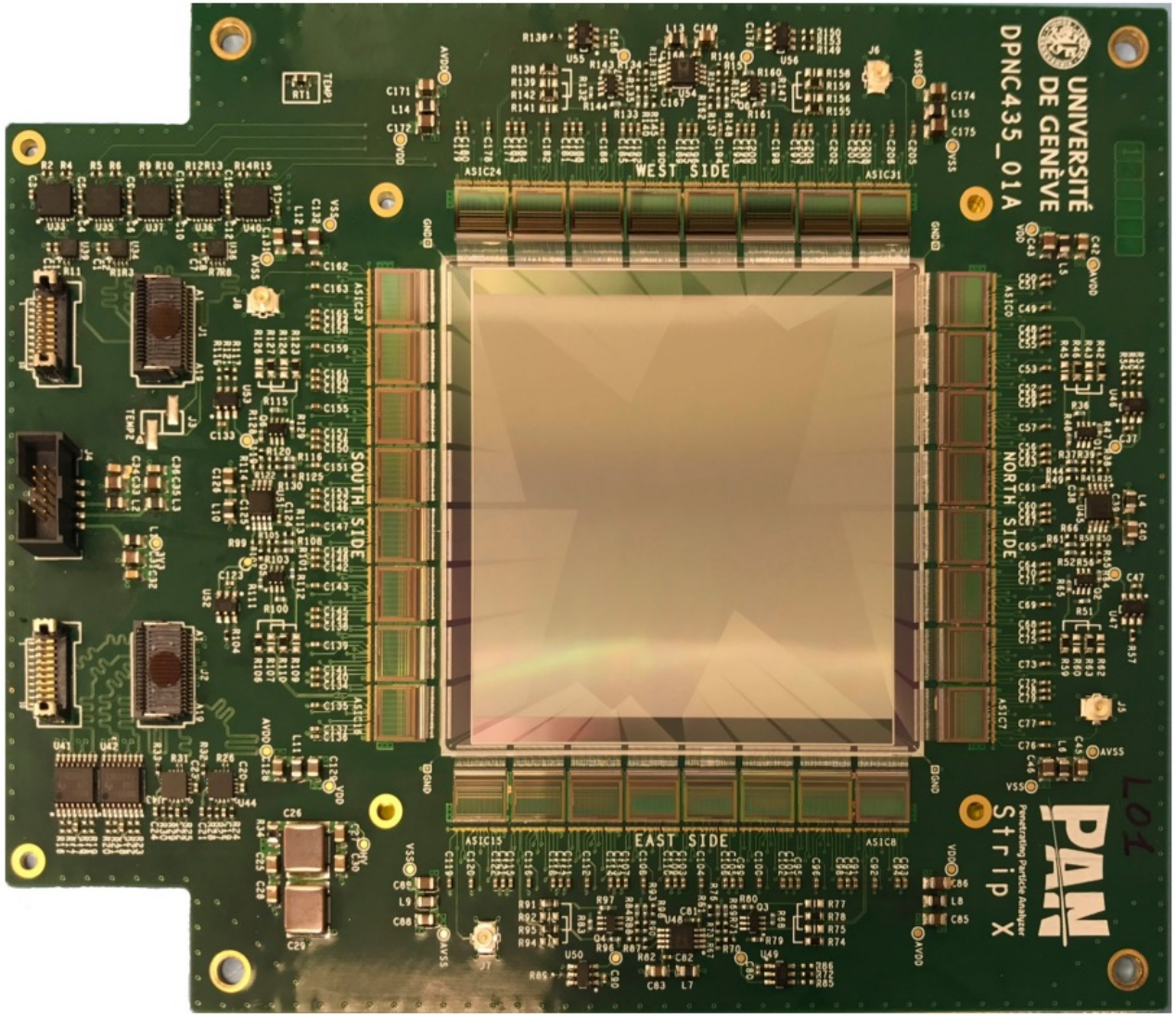
mini.PAN demonstrator TRACKER



- Three tracker modules each with three sensors
  - Two to measure the X-coordinate (“Strip-X”)
    - 150 µm thickness, 25 µm pitch, 2048 strips, all read out
    - 32 IDEAS IDE1140 ASICs to read out one sensor
    - Double metal layer to route the signals all around the sensor
    - Active area: 5 cm x 5 cm
  - One to measure the Y-coordinate (“Strip-Y”)
    - 150 µm thickness, 400 µm pitch, 128 strips, all read out
    - 1 IDEAS VATA GP 7.2 ASIC to read out one sensor
      - Trigger signal generation capabilities
    - Active area: disk of 5 cm diameter
  - All sensors produced by Hamamatsu

mini.PAN demonstrator TRACKER



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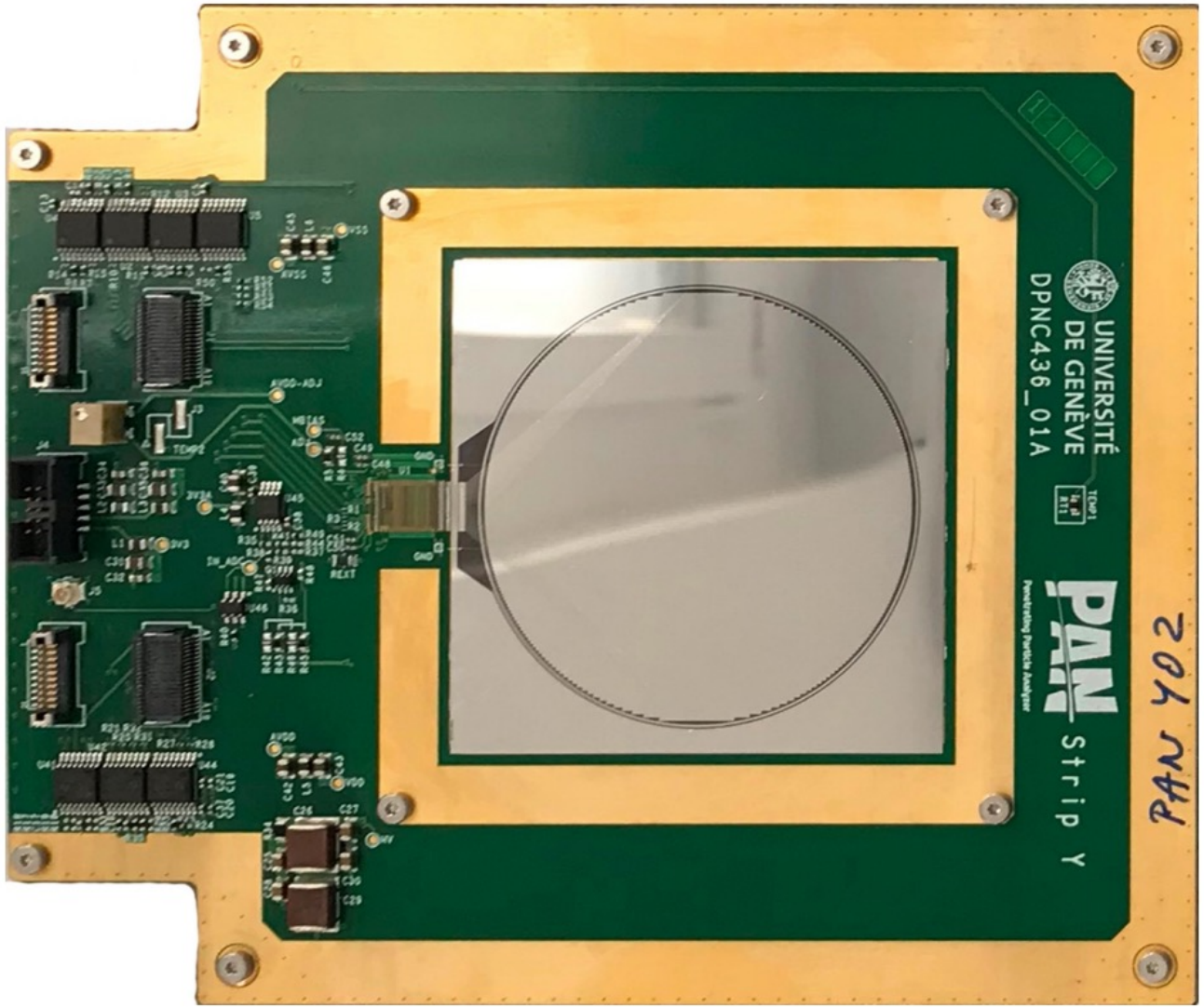

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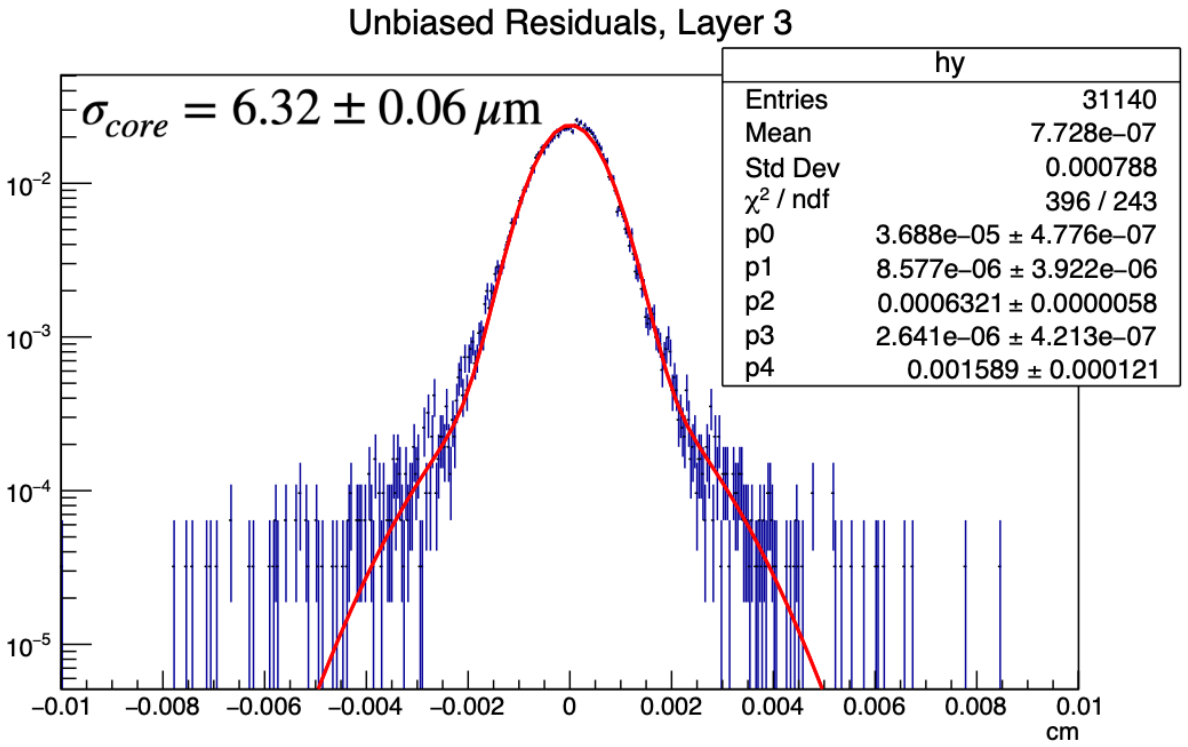
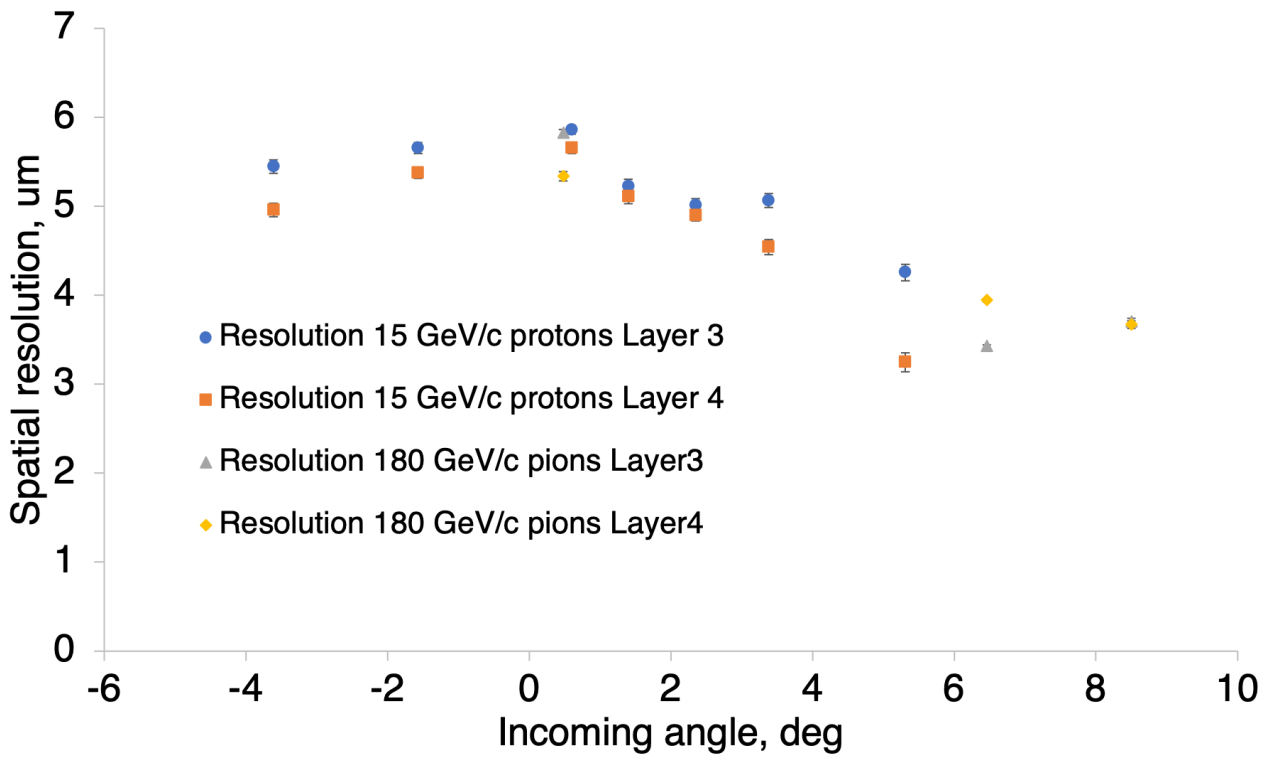
mini.PAN demonstrator PERFORMANCE

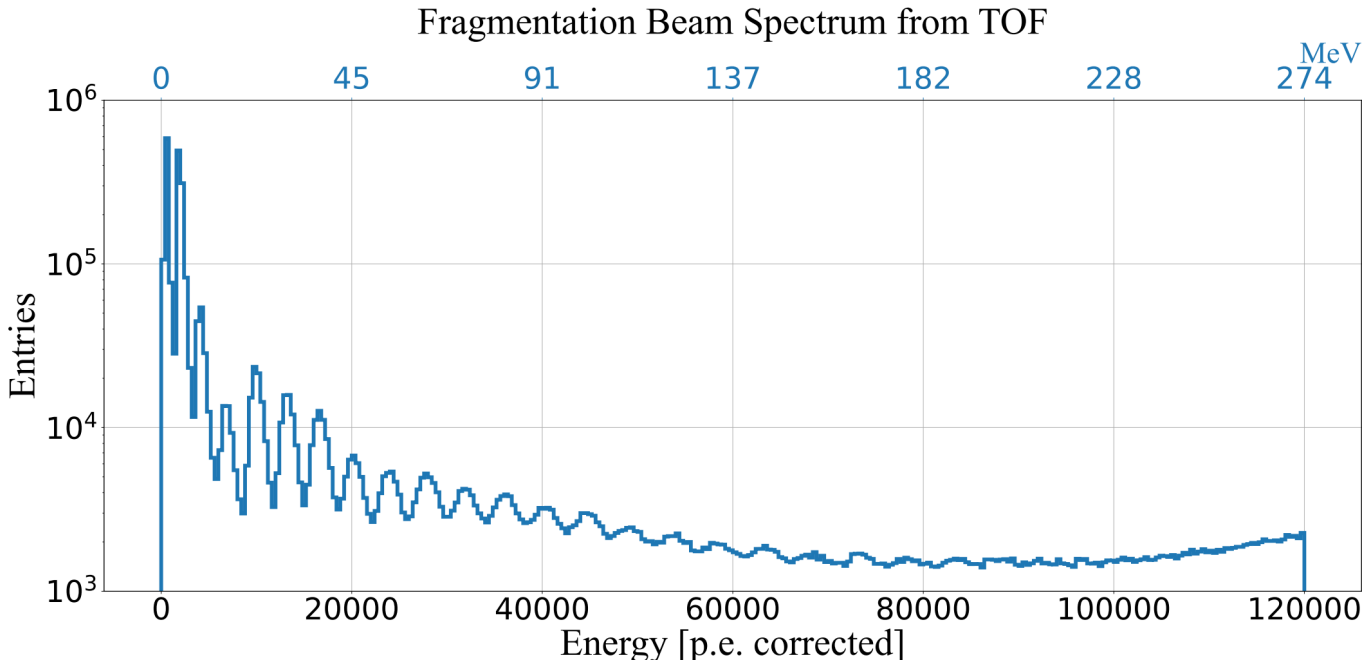
- mini.PAN has been tested at several beam tests at CERN in 2022 and 2023
- Position resolution measurements done with runs w/o magnets, 15 GeV/c positive hadrons
- Tracks reconstructed with Strip-X and Pixels
- Spatial resolution after Multiple Coulomb Scattering and track error extrapolation computed for different incident particle angles
- Momentum resolution currently under study

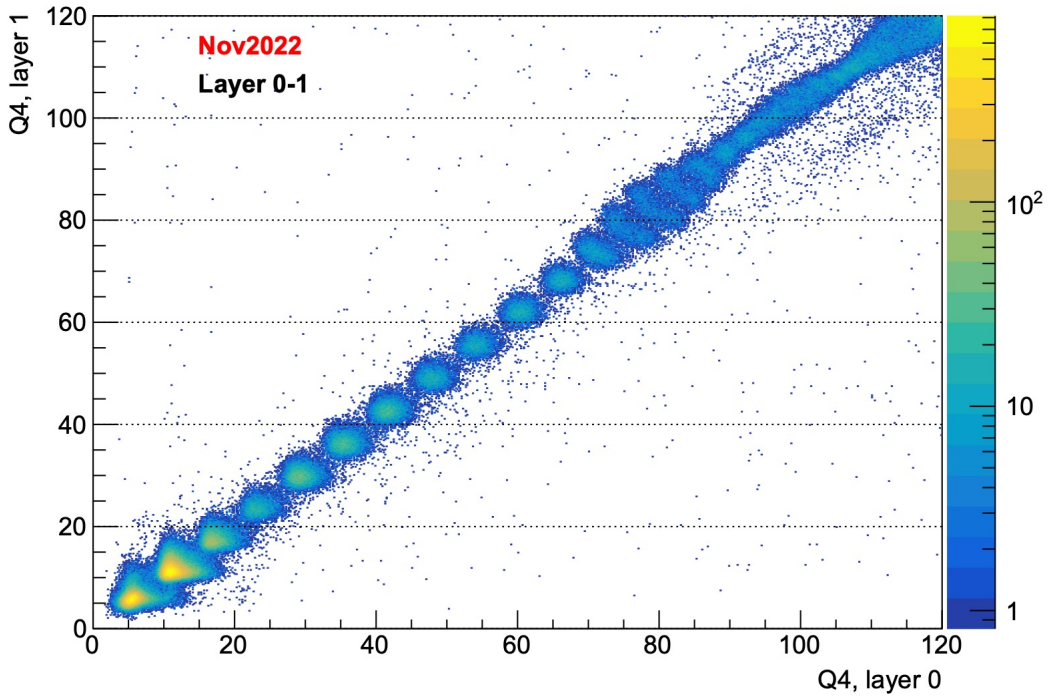




mini.PAN demonstrator PERFORMANCE

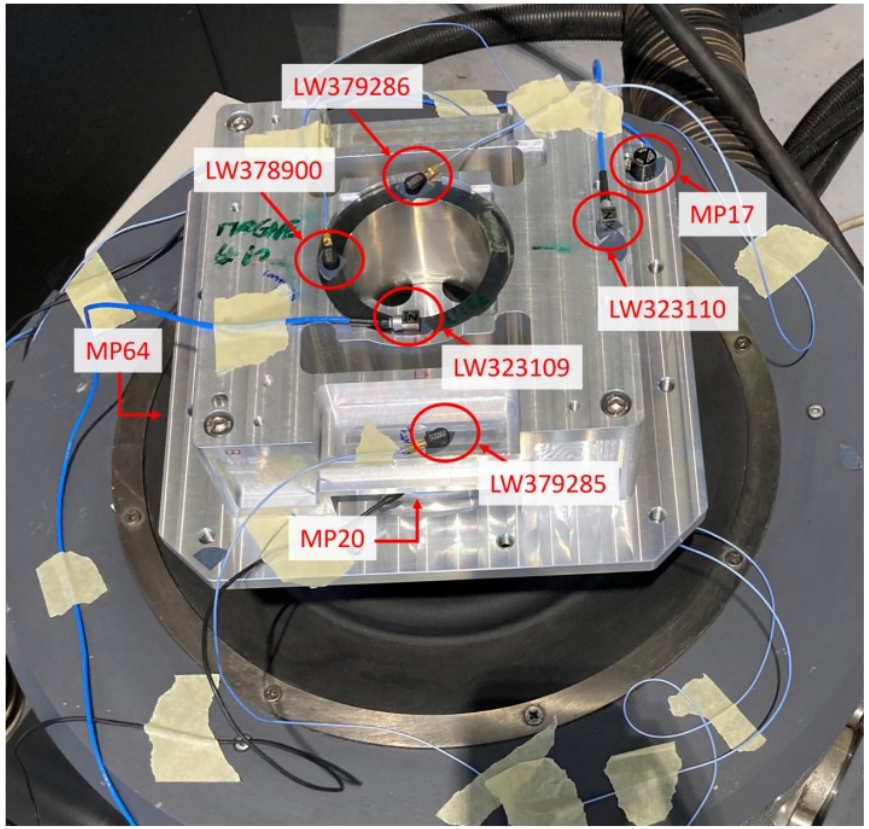
- Charge identification capabilities tested with fragmented ion beam at CERN SPS in 2022 and 2023
  - Charge separation for Time Of Flight detector up to Z = 21
  - Redundant charge measurement performed by Tracker module up to Z = 17



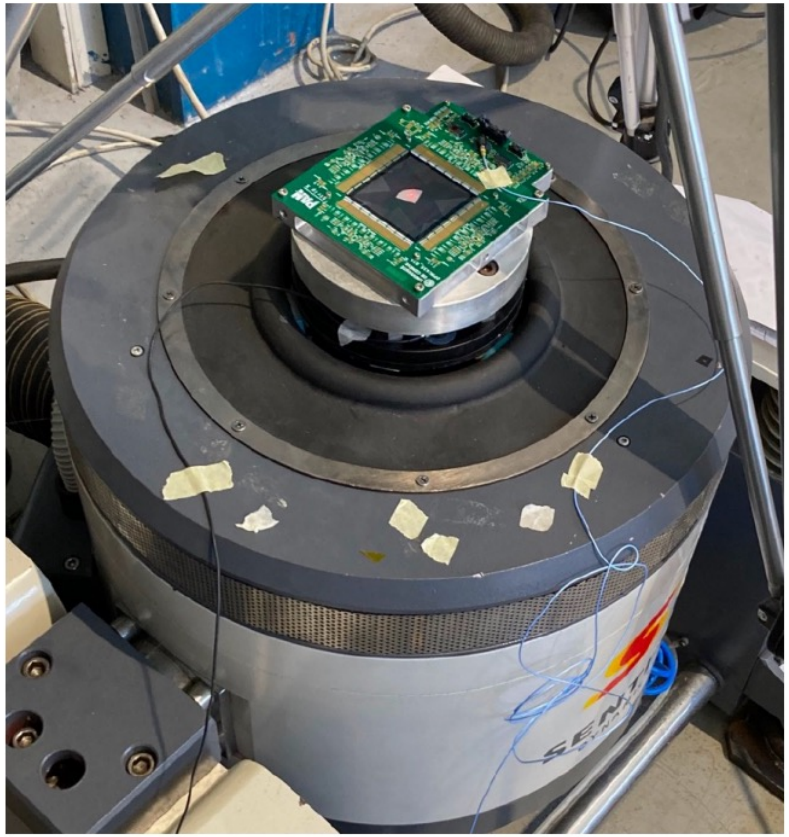


mini.PAN demonstrator SPACE QUALIFICATION

- Activity conducted by the University of Perugia at SERMS laboratories in Terni
- Vibration and shock tests of mechanical grade versions of the detectors
- Magnet vibration test revealed a need for improvement in magnet fixation
- Thermal tests of detector modules will be done in November 2023
- Possibly a thermal vacuum test will be done later in 2023.



Magnet: vibration



Tracker: vibration

Tracker: shock

Conclusions

- Demonstrator construction has reached completion
- Extensive testing over the past two years that has demonstrated its excellent performance,
  - Position resolution reaching 3.43 ±0.02 μm using pixel and silicon strip tracker
  - Ion identification up to Z = 21 by ToF and Z = 17 for StripX
- The work on momentum resolution estimation is ongoing.
- Additional beam tests being planned at CERN, and potentially TIFPA.
- Vibration and thermal tests performed /scheduled for the second half of 2023
- The mini.PAN concept was adopted in several mission proposals like *REMEC*, *Pix.PAN*, and *LOP-G (Lunar Orbital Platform-Gateway)*

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Thanks for your attention

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