

Design and characterisation of the HEPD-02 MAPS-based tracker for operations in space

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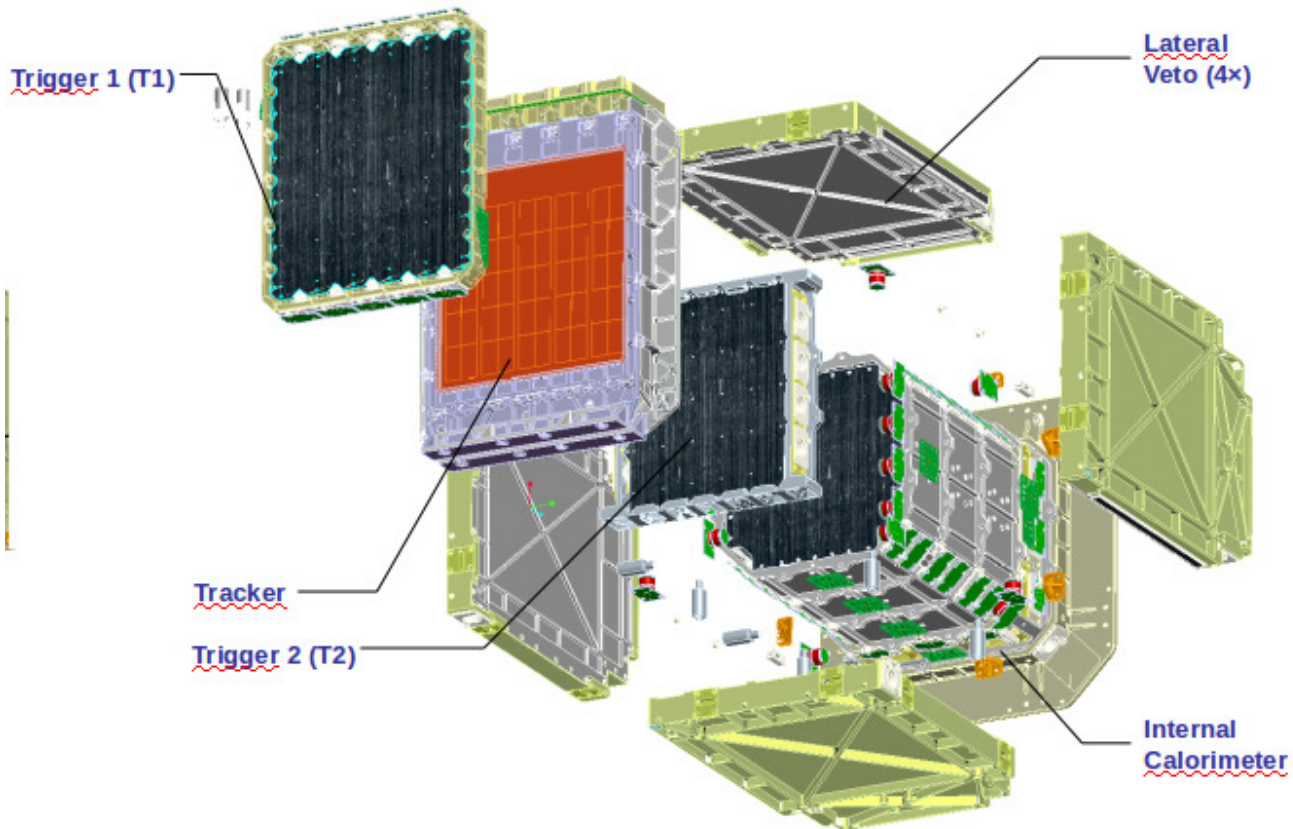
INFN – TIFPA

IPRD2023, September 25, 2023



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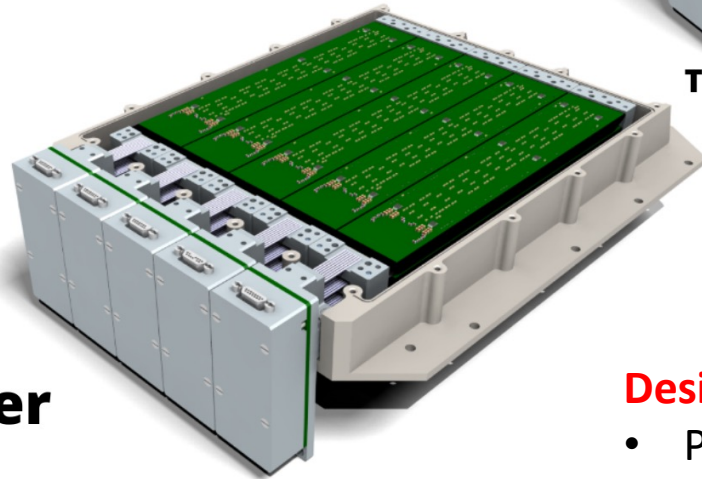
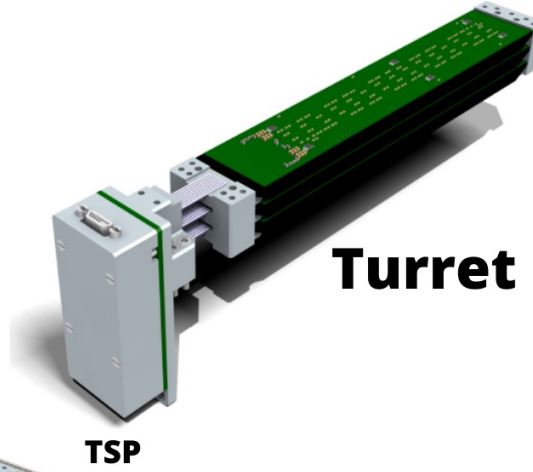
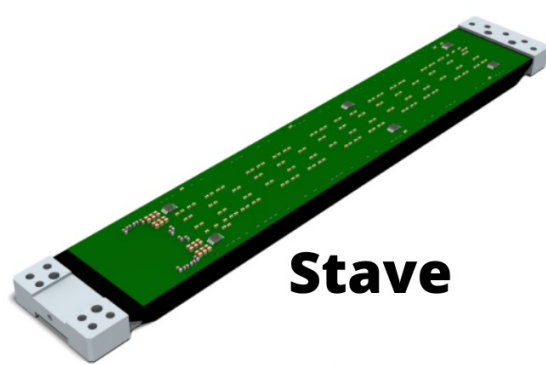
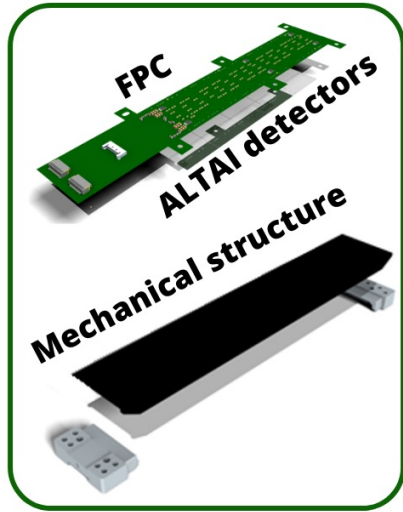
The HEPD-02 detector



Kin. energy range (electron)	3 MeV to 100 MeV
Kin. energy range (proton)	30 MeV to 200 MeV
Angular resolution	$\leq 10^\circ$ for $E_{kin} > 3$ MeV electrons
Energy resolution	$\leq 10\%$ for $E_{kin} > 5$ MeV electrons
Particle selection efficiency	$> 90\%$
Detectable flux	up to $10^7 \text{ m}^{-2}\text{s}^{-1}\text{sr}^{-1}$
Operating temperature	-10 °C to +35 °C
Operating pressure	$\leq 6.65 \cdot 10^{-3} \text{ Pa}$ ("vacuum")
Mass budget	50 kg
Power Budget	45 W
Data budget	$\leq 100 \text{ Gb/day}$

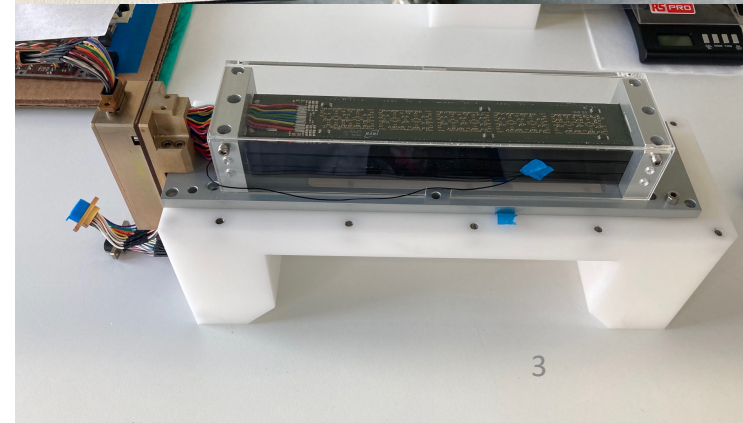
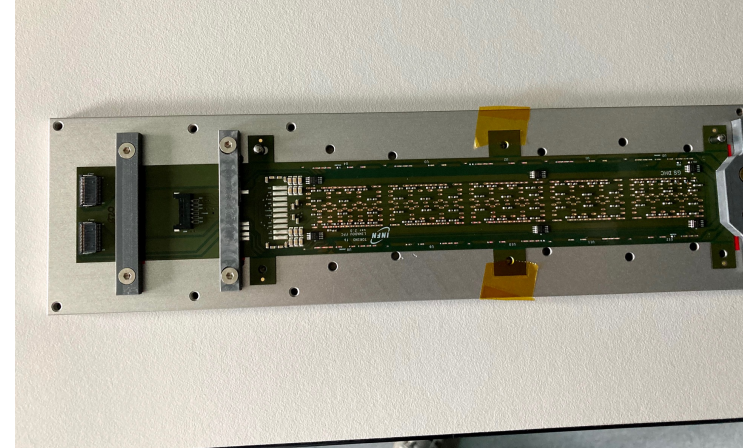
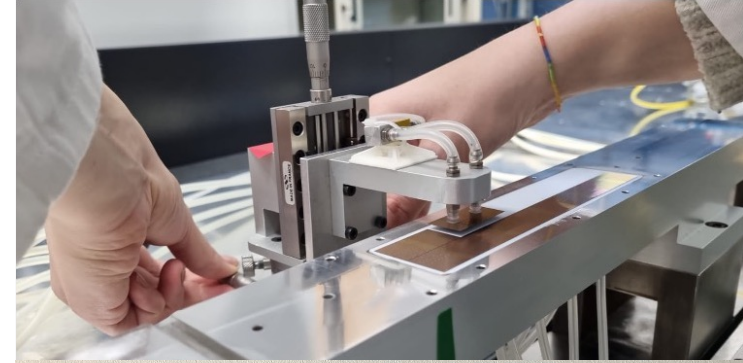
For more information on HEPD and CSES:
C. DeSantis, The High Energy Particle Detector (HEPD-02) for the second China Seismo-Electromagnetic Satellite (CSES-02), **Tomorrow, 14:20**
V. Scotti, The DAQ and trigger of the High Energy Particle Detector (HEPD-02) for the CSES-02 space satellite, **Tomorrow, 18:00**
F. M. Follega The CSES mission: a sophisticated multi-point space observatory, **Wednesday, 11:50**

HEPD-02 tracker design



Design requirements:

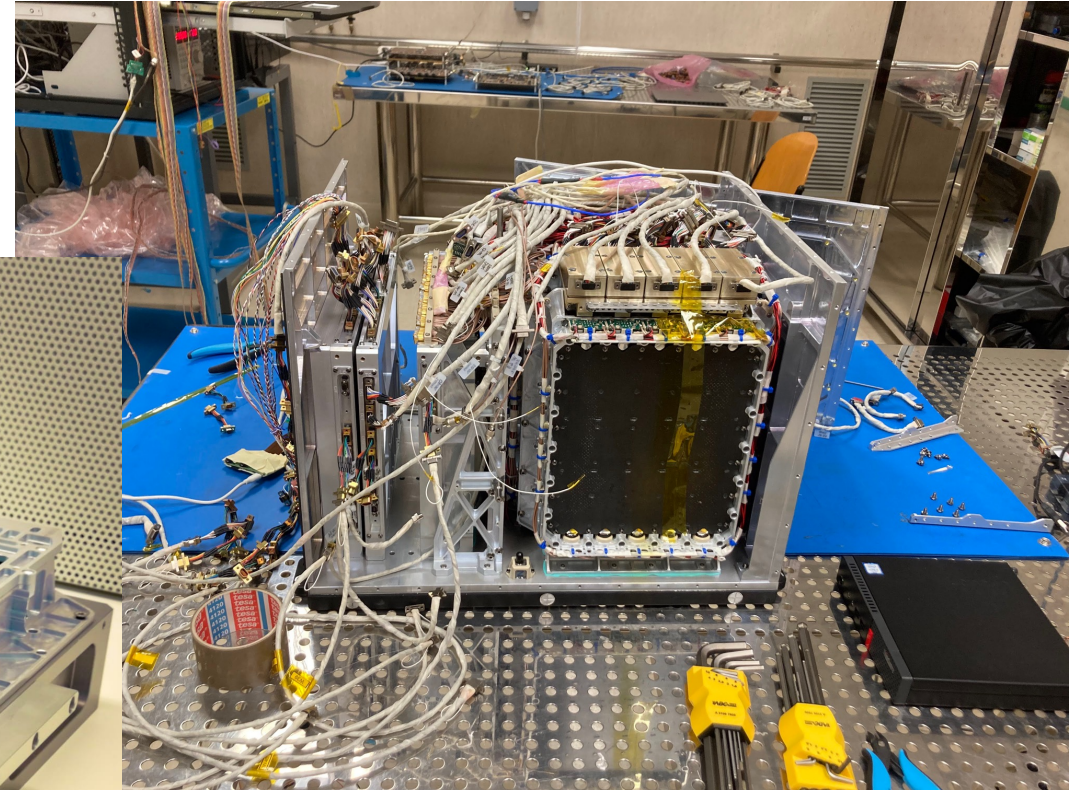
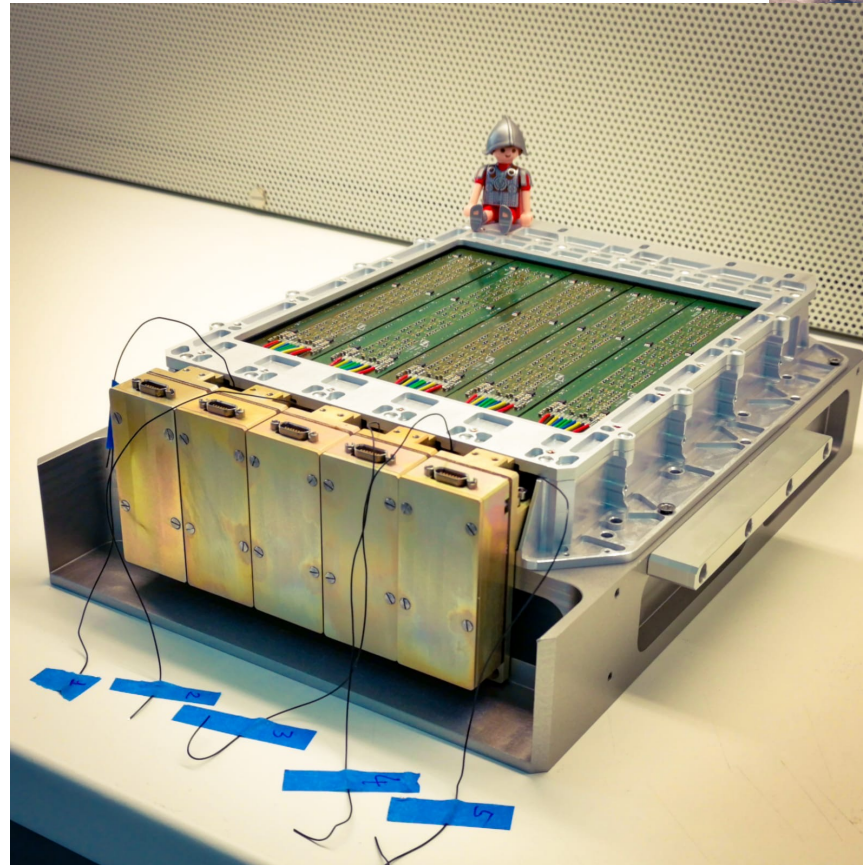
- Power consumption reduction
- Temperature control
- Mechanical stability
- Material budget minimisation



Tracker construction and integration

A team effort:

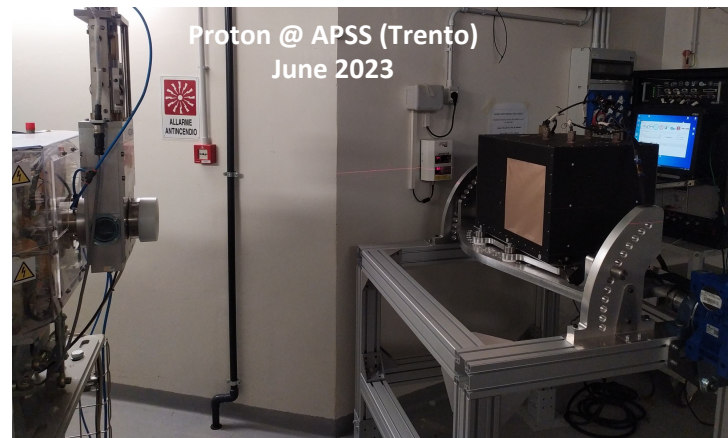
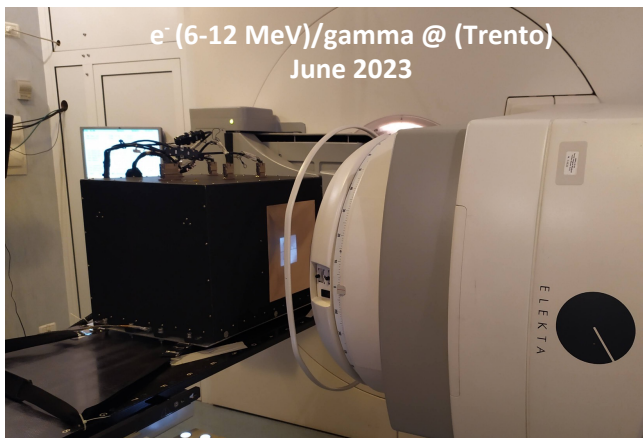
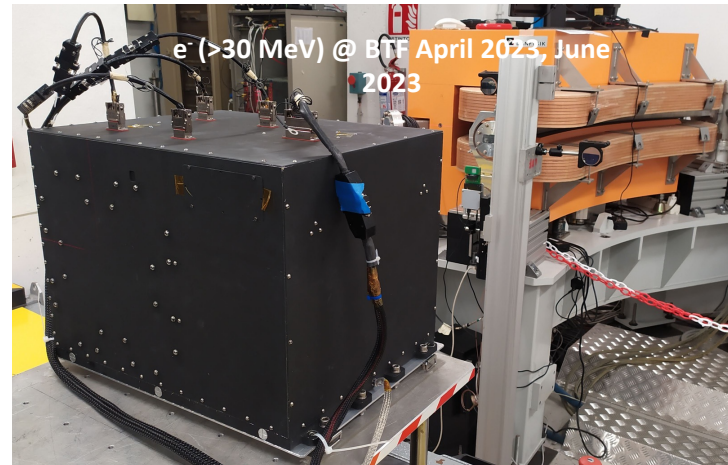
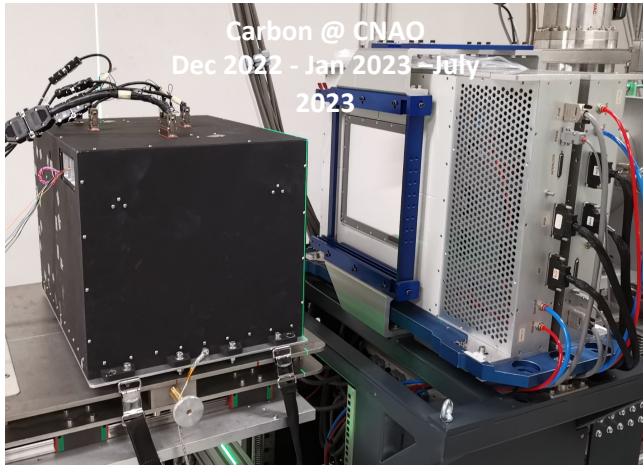
- HIC assembly in **Torino**
- Wire bonding in **Bari**
- Stave assembly in **Torino**
- Turret assembly in **Trento**
- Turret characterisation in **Trento**
- Tracker assembly in **Roma Tor Vergata**
- Integration on HEPD-02 in **Roma Tor Vergata**



Production summary:

- 84 HIC assembled
- 48 STAVE assembled
- 11 turrets assembled (1 EM level, 10 QM/FM level)
- 2 trackers

HEPD-02 characterisation campaign



Calibration tests:

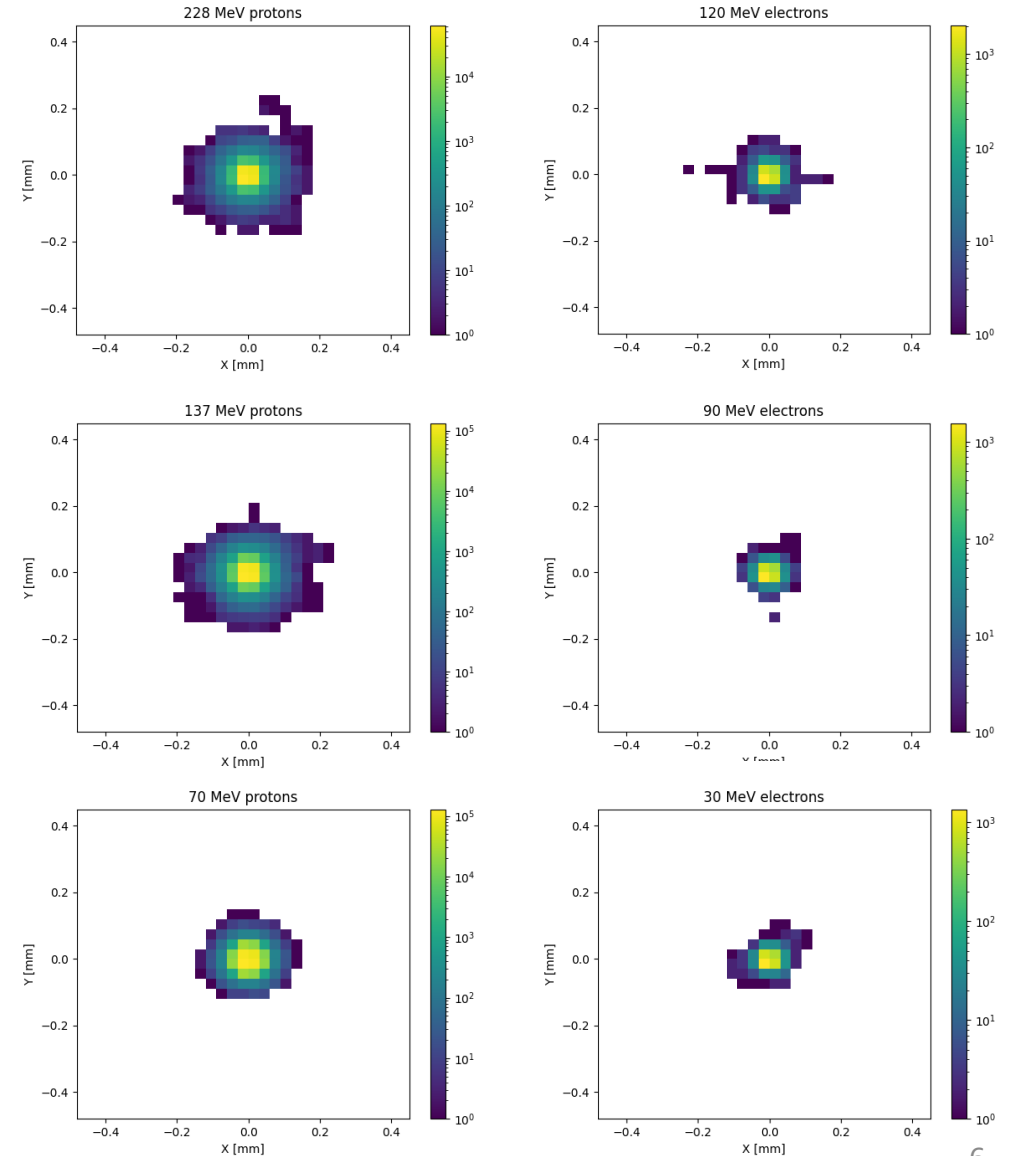
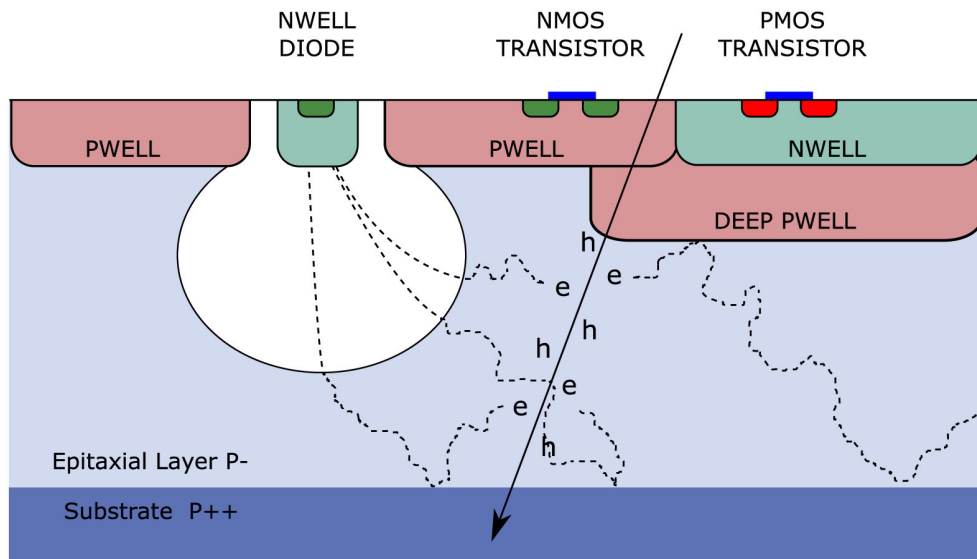
- **Carbon @ CNAO** (Pavia, Italy) in December 2022 and January 2023
- **Electrons (30-450 MeV) @ BTF** (Frascati, Italy) April 2023

Full characterisation:

- **Protons @ Proton Therapy Center** (Trento, Italy) June 2023
- **Electrons (6-12 MeV) @ S. Chiara Hospital** (Trento, Italy) June 2023
- **Electrons (30-450 MeV) @ BTF** (Frascati, Italy) June 2023
- **Carbon @ CNAO** (Pavia, Italy) July 2023

Detector response: cluster size

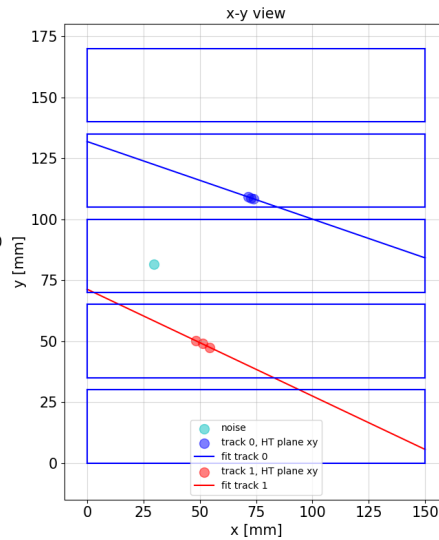
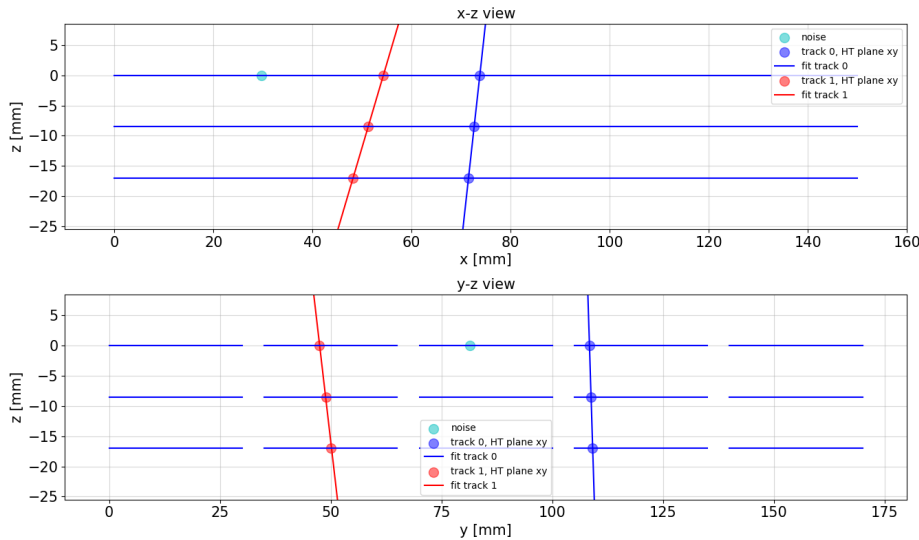
- ALTAI is a **digital detector**. The only information obtained is the position of the pixels over the given threshold
- It is also designed to work **undepleted**, with the diffusion as the main process driving the charge motion
- Because of diffusion, the number of contiguous pixels over threshold is related to the amount of energy deposited inside the active layer of ALTAI
- It is possible to use the cluster size to get information on the incoming particle.



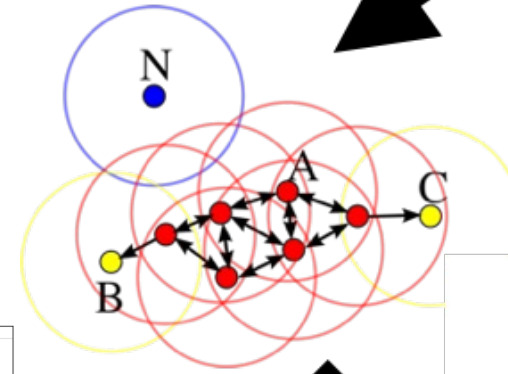
Data reconstruction

The data collected from the tracker are processed as follow:

- Check for **noisy pixels** not identified by the onboard procedure and masking
- **Clustering** of closed-by pixels (DBscan algorithm)
- Reconstruction of the variable number of **tracklet** using a Hough Transform
- **Fit of points** associated to a tracklet with a 3D line



DBscan clustering



Hough Transform track seeding

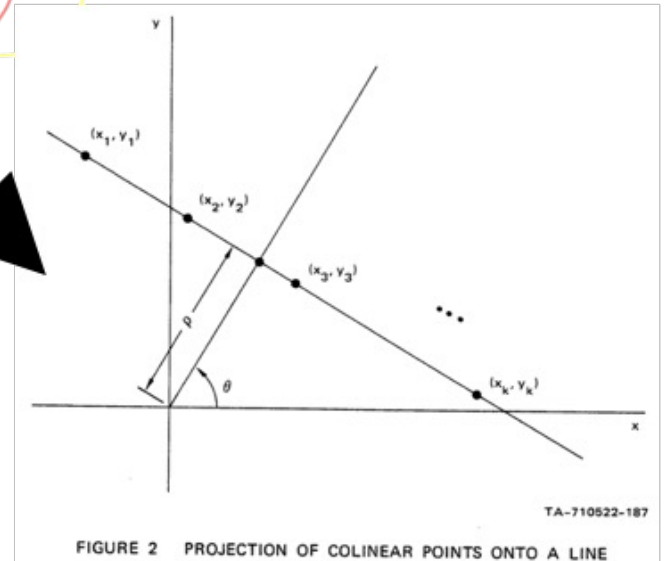
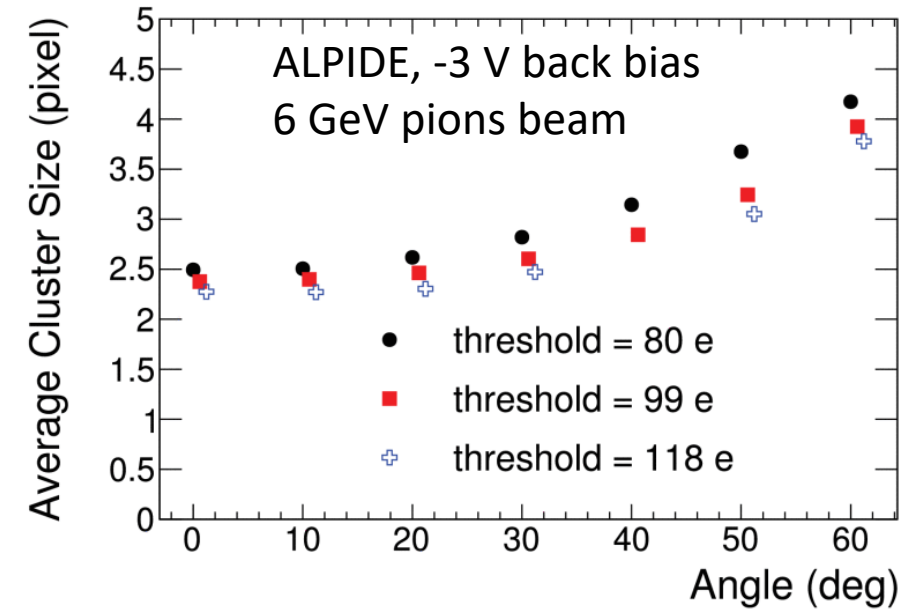
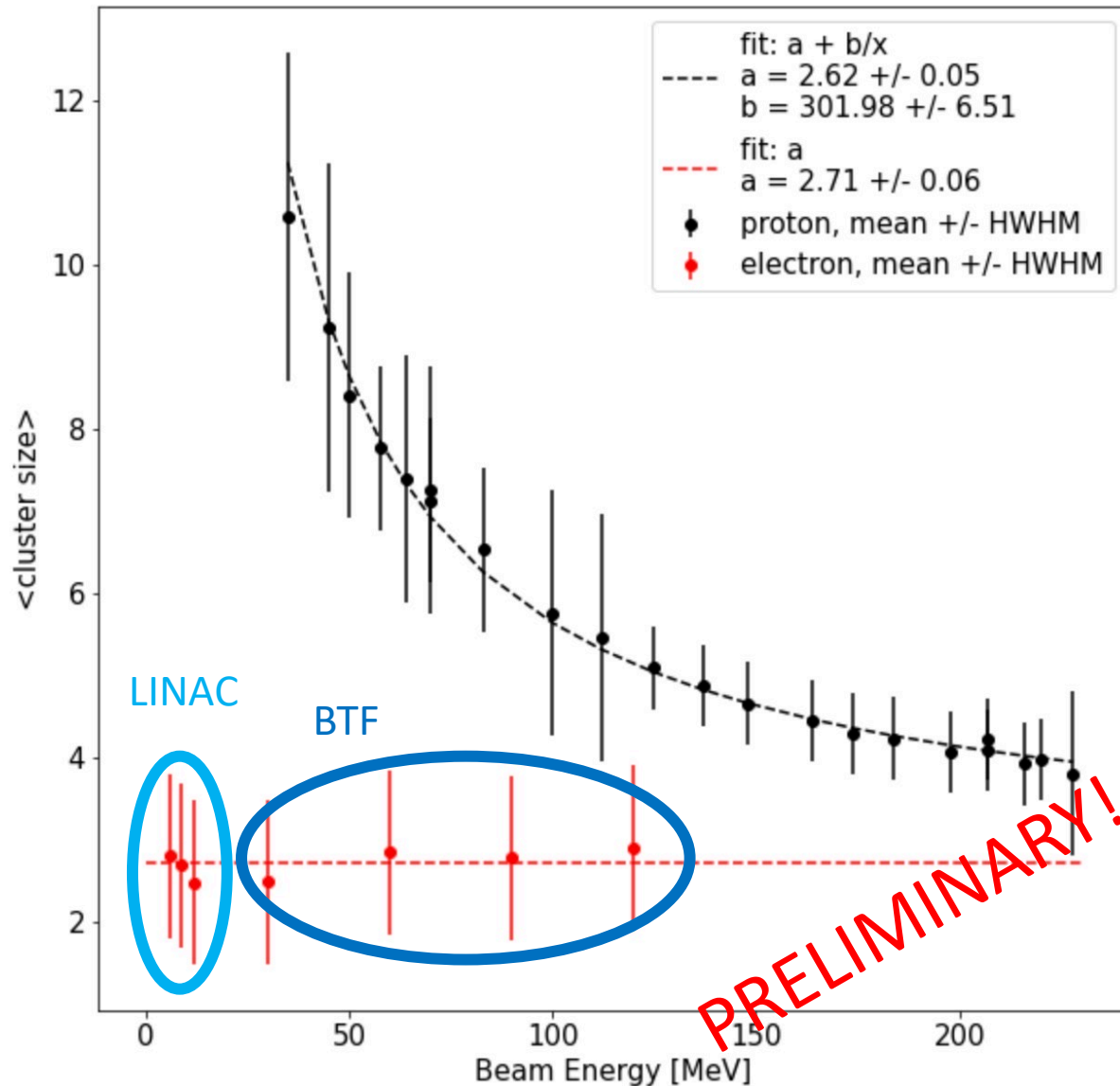


FIGURE 2 PROJECTION OF COLINEAR POINTS ONTO A LINE

Cluster size: results

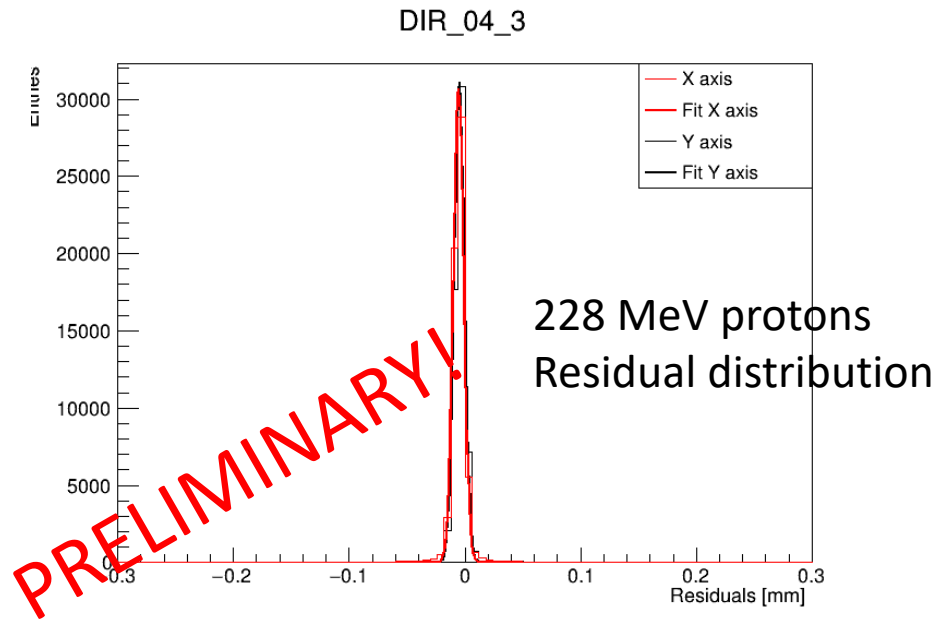
[DOI: 10.1109/NSSMIC.2017.8532940](https://doi.org/10.1109/NSSMIC.2017.8532940)



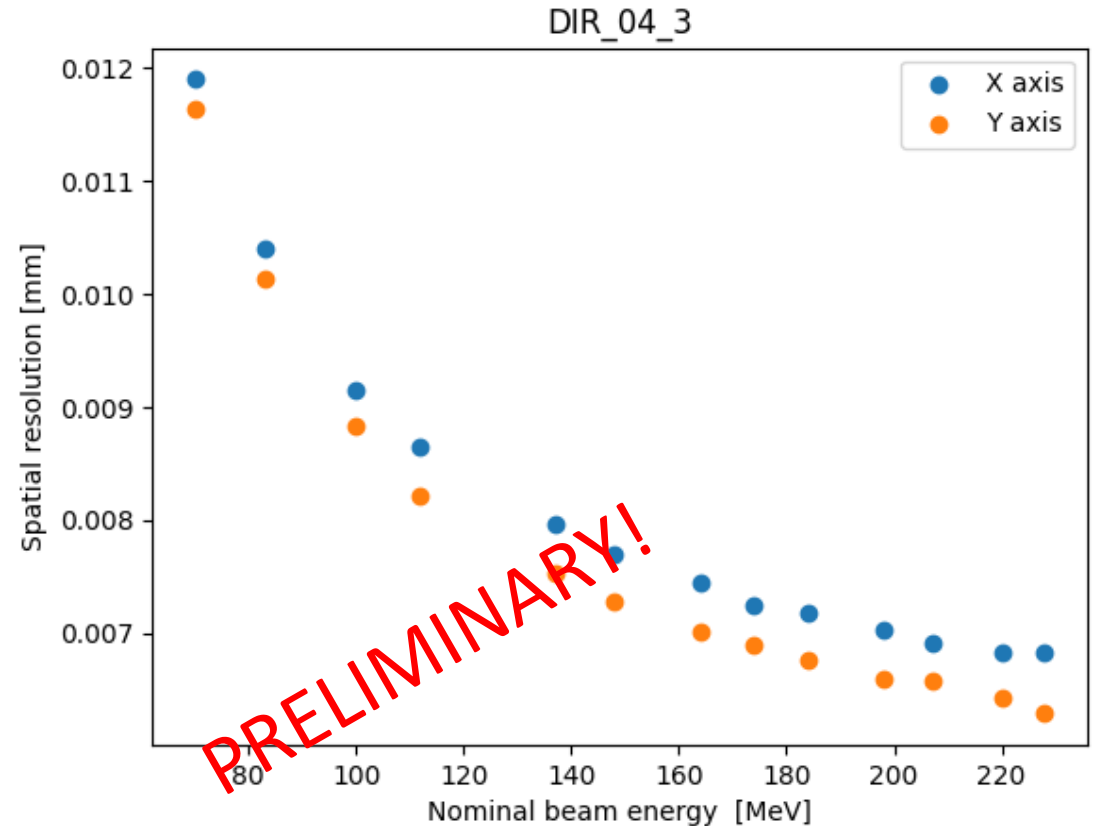
ALI-PERF-140425

- **Cluster size** for MIP is **2.7 pixels** for ALTAI (unbiased), compatible with the **2.5 pixel** value for ALPIDE at -3 V of back bias
- The cluster size for protons depends on the energy of the beam,
- It can be used as input for **PID algorithms**

Tracking performance



- **Residuals** after tracking are fit with a gaussian
- **Mean** and sigma are used to study the quality of the alignment
- First results, with no software correction, are **quite good**
- **Spatial resolution** obtained from the squared sum of mean and sigma obtained from the fit of residuals
- Discrepancies are to be attributed to the mean value of distributon (it can be corrected!)



- Spatial resolution quoted by ALICE for **ALPIDE** is **4 μm** for MIPs
- Without any kind of software correction we have **7 μm**
- **Software corrections** under development

Conclusions

The **HEPD-02** is **qualified, characterised** and **ready for the integration** on the CSES-02 satellite.
The **launch** is scheduled for **2024**.

The **tracker** has been fully **assembled, qualified** and **characterised**.

Preliminary results from the test beam have been shown

The **cluster size** evolves as expected, with results overlapping the ALPIDE ones in literature

The **spatial resolution** is good and can be further improved by applying correction factors for the alignment

The **analysis is ongoing** and a complete paper with all the tracker details is in preparation

