MALTA- Radiation Hard Monolithic Active Pixel Sensor (MAPS) for tracking applications

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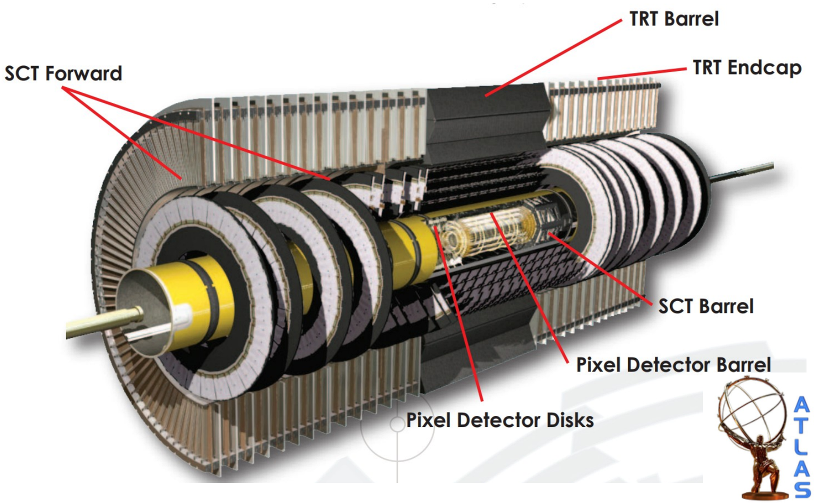
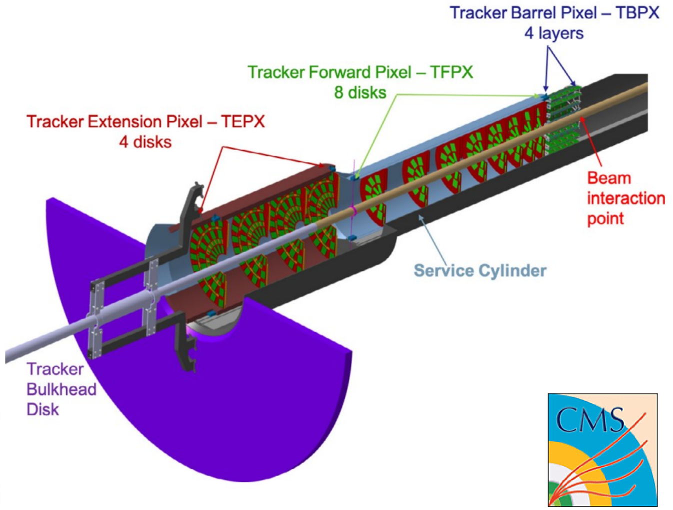
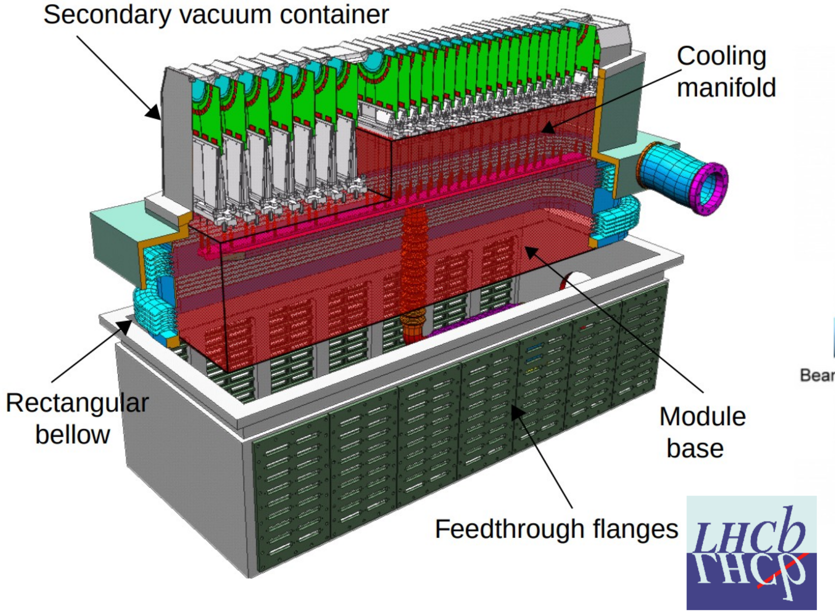
Inner tracking detectors

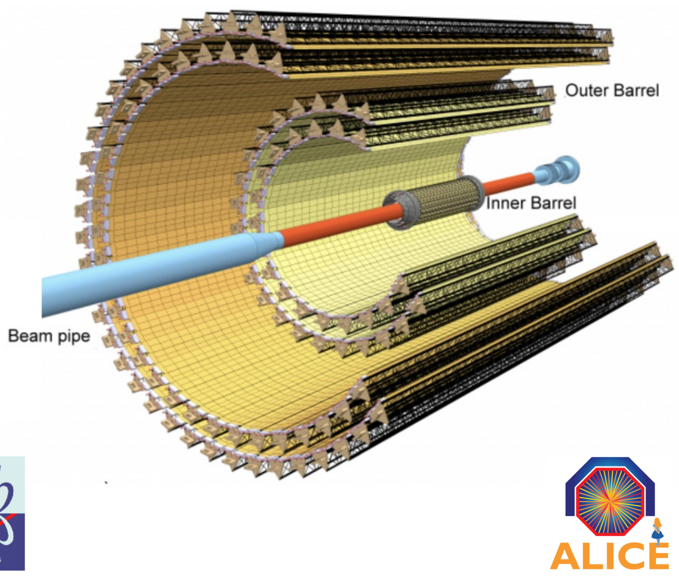
Tracker properties wishlist:

- “Transparent” detectors → thin sensors/ reduced tracking volume
- Very high granularity → very small pitches
- Radiation hardness up to 1-2 E15 NIEL and 80Mrad TID
- Very high efficiency (track reconstruction) >95%
- Low noise <40Hz
- Good timing response (timing resolution <25 ns)
- Good hermeticity → module assembly

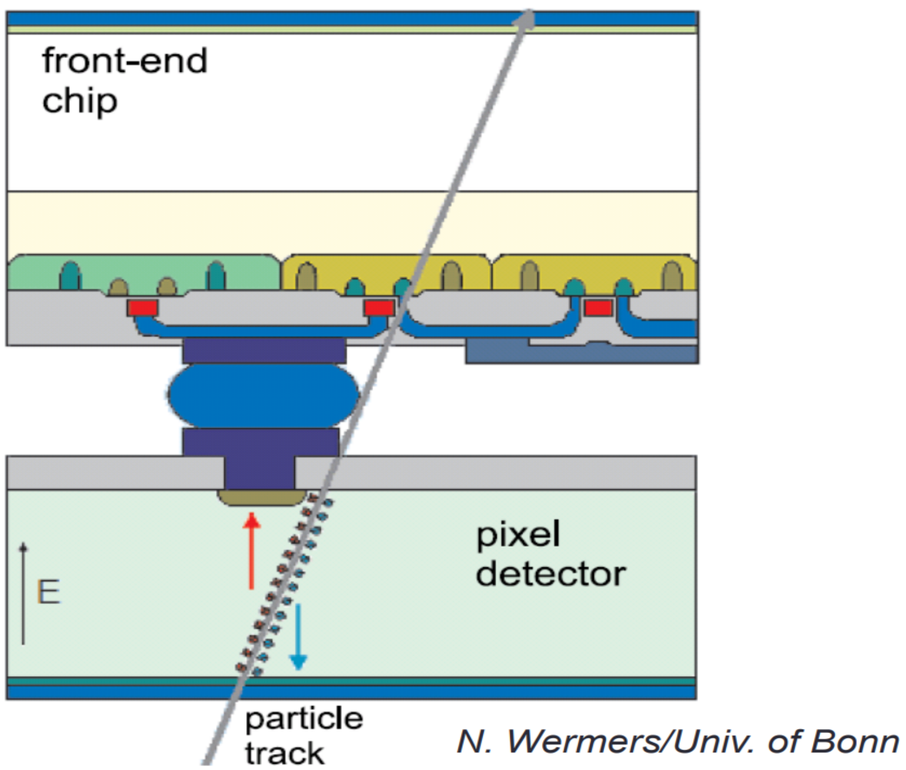


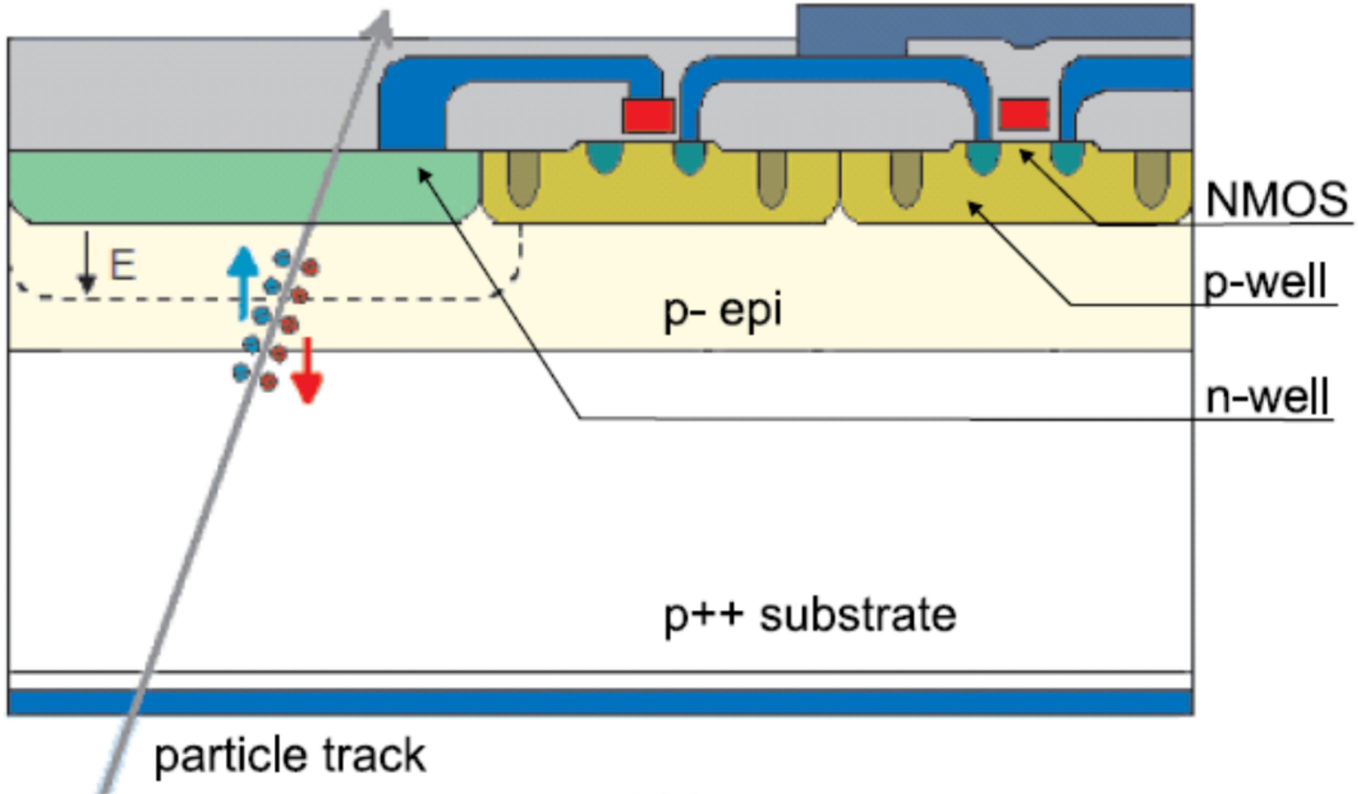






Hybrid vs MAPS





Hybrid sensors

- Sensing chip + Read out chip (ROC)
- Expensive bump bonding procedure + large material budget
- Limited to larger pixel pitches
- Complex signal processing in the ASIC

Monolithic sensors

- One chip = Sensor + ROC
- Commercial available CMOS processing
- Low material budget
- Challenges in implementing in-pixel logic

Tracker properties wishlist

- “Transparent” detectors → thin sensors/ reduced tracking volume
- Very high granularity → very small pitches
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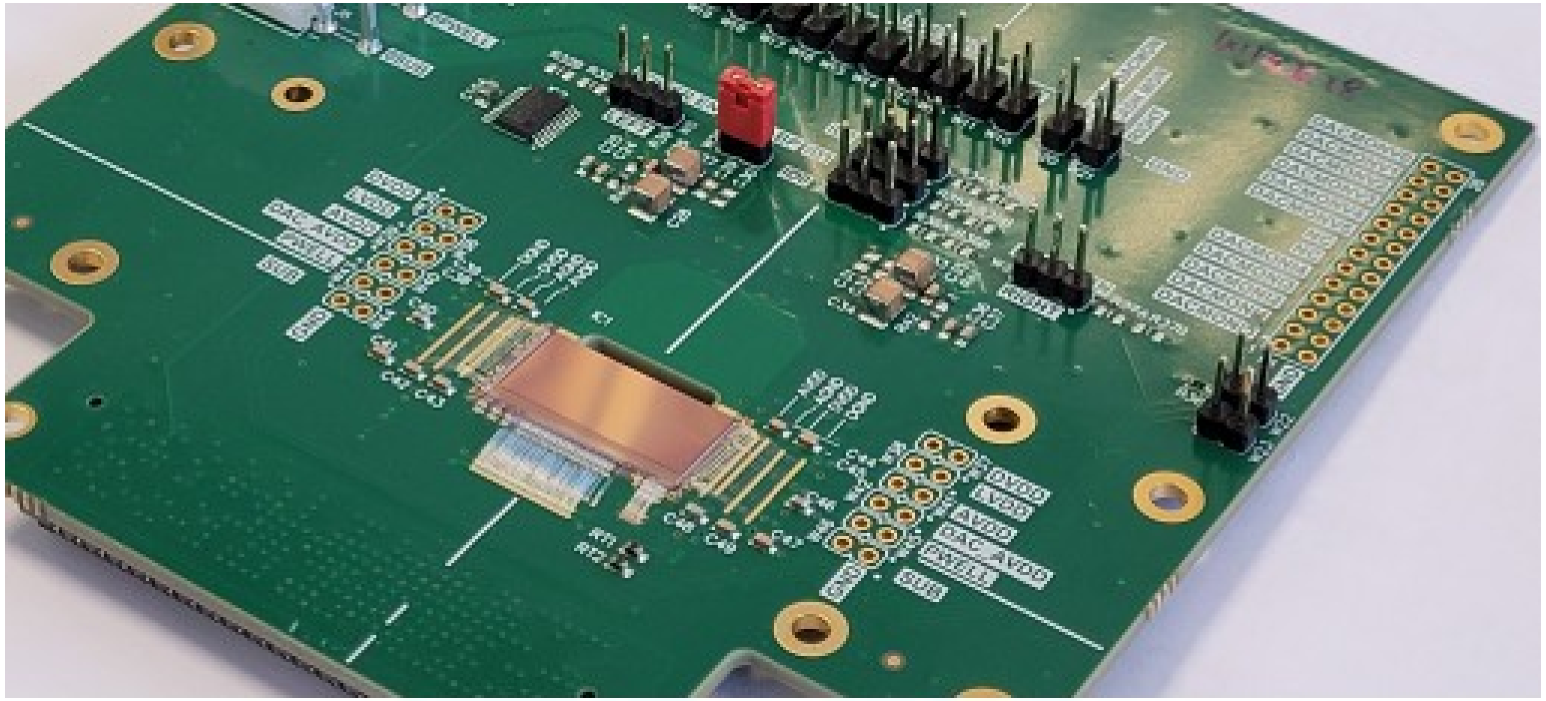
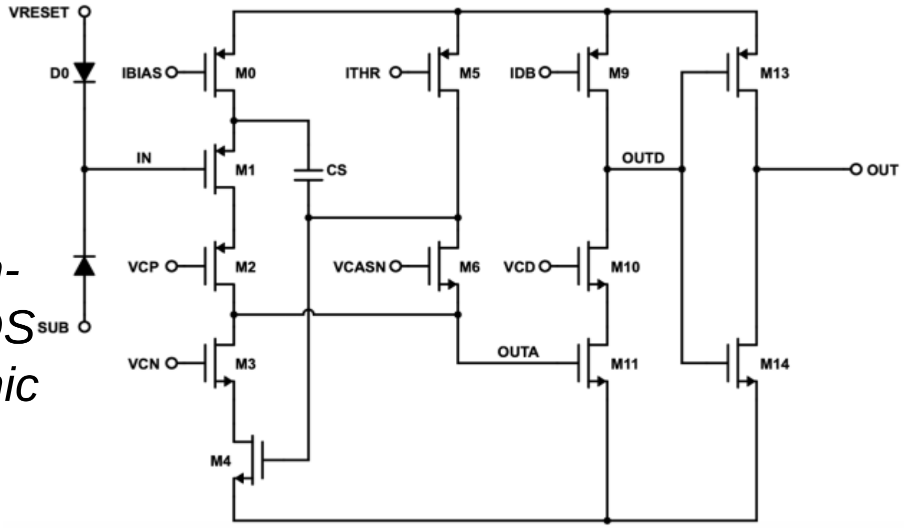
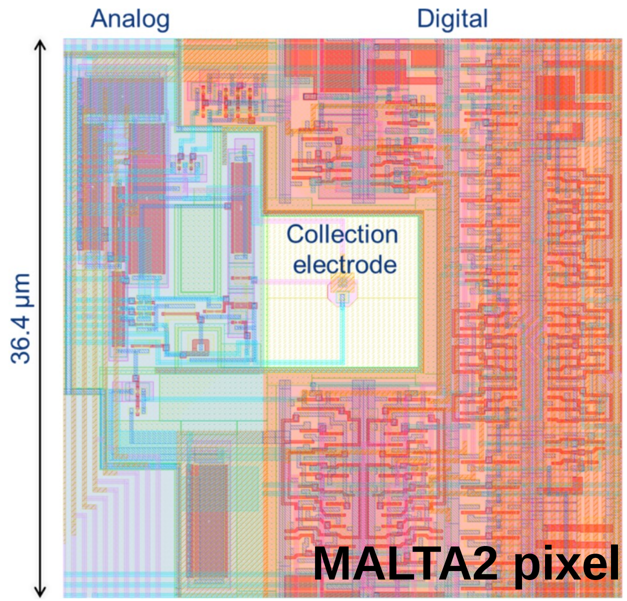
Tower MALTA2

- **224 x 512** pixels (36.4 μm² pitch)
- **Small** collection electrode (2-3 μm²)
- **Low** power consumption
- **Thin** detecting material (30 μm EPI & 100 μm Cz)
- **Asynchronous readout** (No distributed clock across matrix)
- New Front End (FE) and slow control
  - *[1] Piro, F et all."A 1 μW radiation-hard front-end in a 0.18 μm CMOS process for the MALTA2 monolithic sensor - 2022*





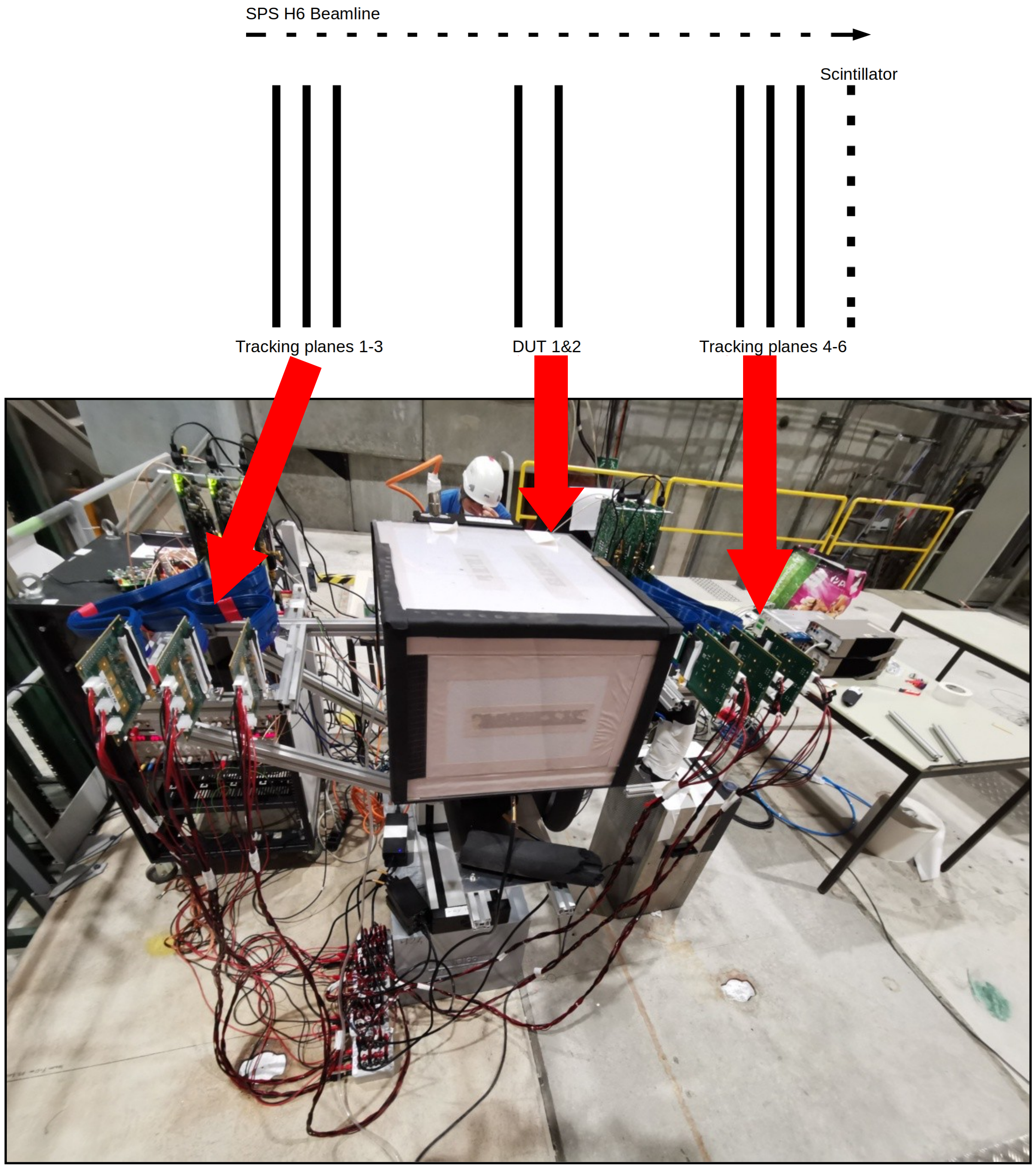
MALTA2 cascoded FE



MALTA2 pixel

MALTA SPS Telescope

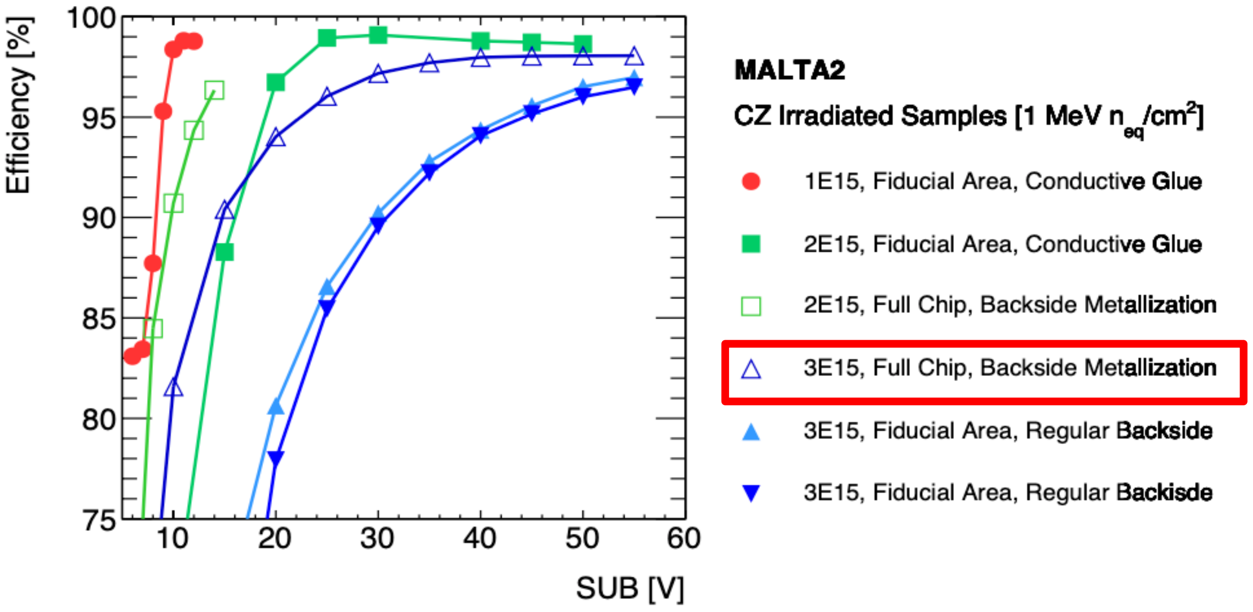
- **Malta Telescope** operated the whole of 2021 and 2022 at CERN SPS H6 beamline. New measurements already on the way for 2023
  - *[2] Milou van Rijnbach, et. all “Performance of the MALTA Telescope” - 2023*
- **2022/23 SPS Test beam** Goals for MALTA2:
  - Radiation tolerance
  - Timing performance
  - Grazing angle studies
  - Telescope service for external users
- **Six MALTA tracking planes** (2x Cz, 4 Epi), Scintillator and Cold Box with capacity for up to 2 DUTs

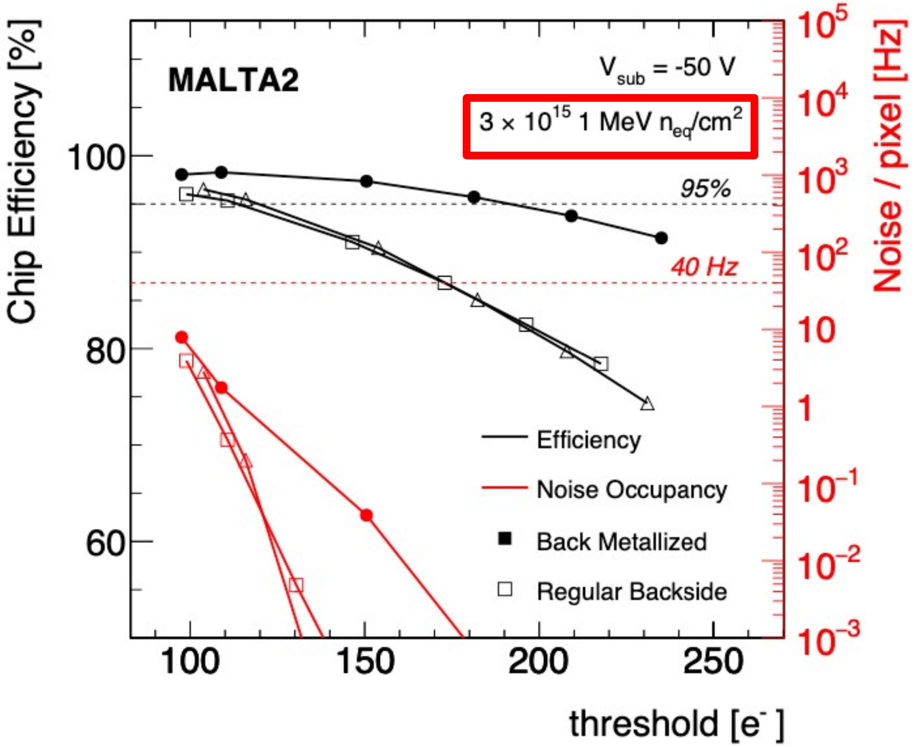


Tracker properties wishlist

- Radiation hardness up to 1-2 E15 NIEL and 80Mrad TID
- Very high efficiency (track reconstruction) >95%
- Low noise <40Hz

Radiation hardness



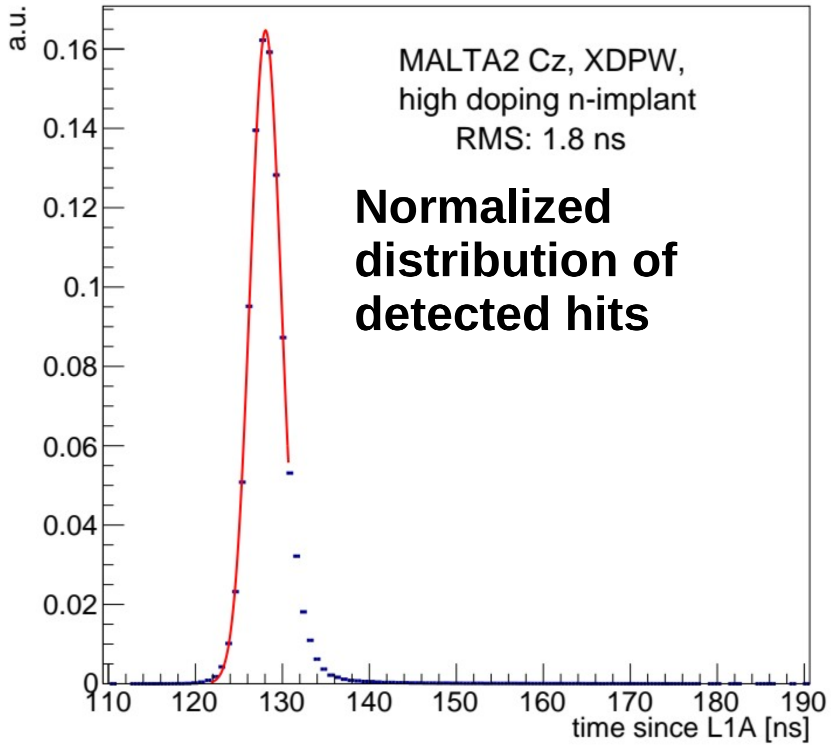


- Increase in chip efficiency with higher substrate voltage (SUB) and lower discriminator threshold
- Large chip efficiency (>95%) recovered for radiation fluences up to 3E15 NIEL (1.5 times the expected life time dose of the ITK outer layer)
- Especially good performance for new backside metallization procedure >97% for highest irradiation dose
- Many chip configurations satisfy an operating window of >95% eff and < 40Hz noise (ITK specifications)
  - *[3] D.V. Berlea, et all. "Radiation hardness of MALTA2, a monolithic active pixel sensor for tracking applications" - 2023*

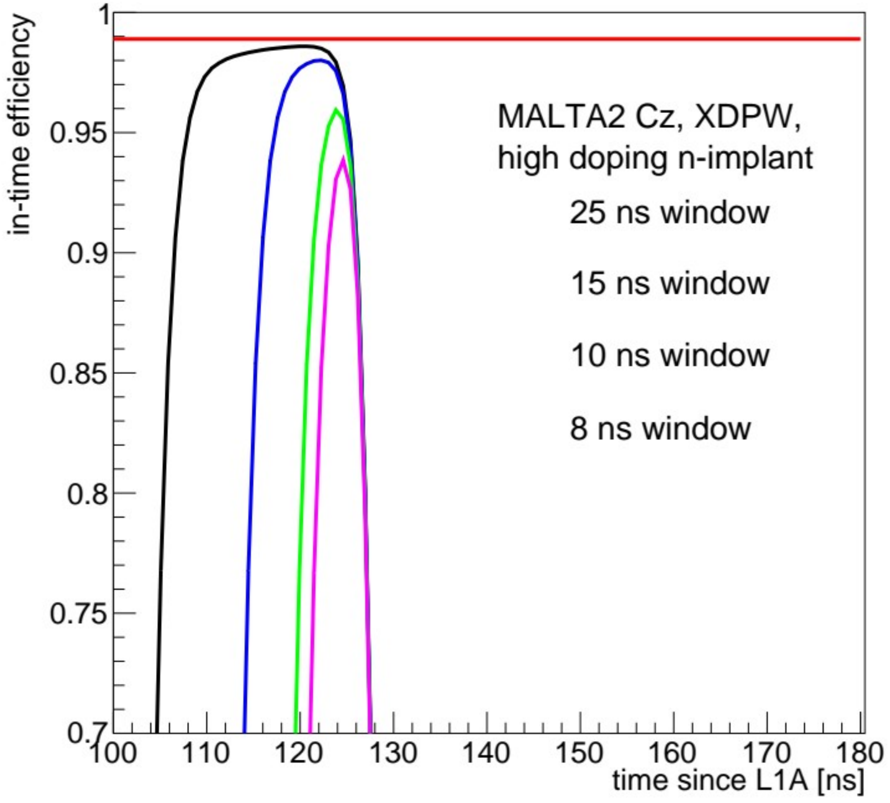
Tracker properties wishlist

- Good timing response (timing resolution <25 ns)

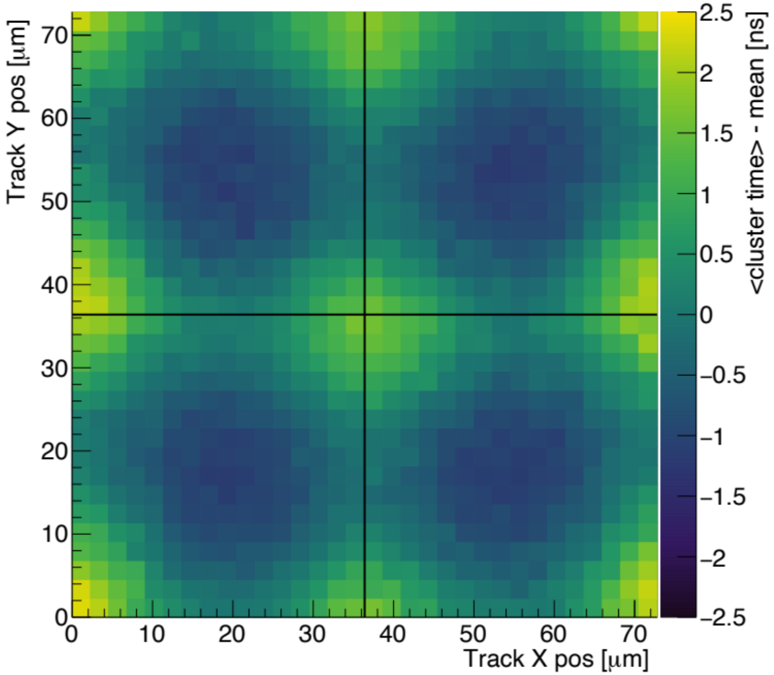
Timing



Normalized distribution of detected hits



In time efficiency of detected hits



4x4 in pixel timing projection

- Timing information related to a scintillator trigger (L1A)
- 1.8 ns timing resolution reconstructed for a MALTA2 sample
- Pixel corners generate late-arriving signals; <2 ns timing resolution
- > 98% of signals arrive in a 25 ns window
  - *[4] G. Gustavino, et all. “Timing performance of radiation hard {MALTA} monolithic pixel sensors” -2022*

Tracker properties wishlist

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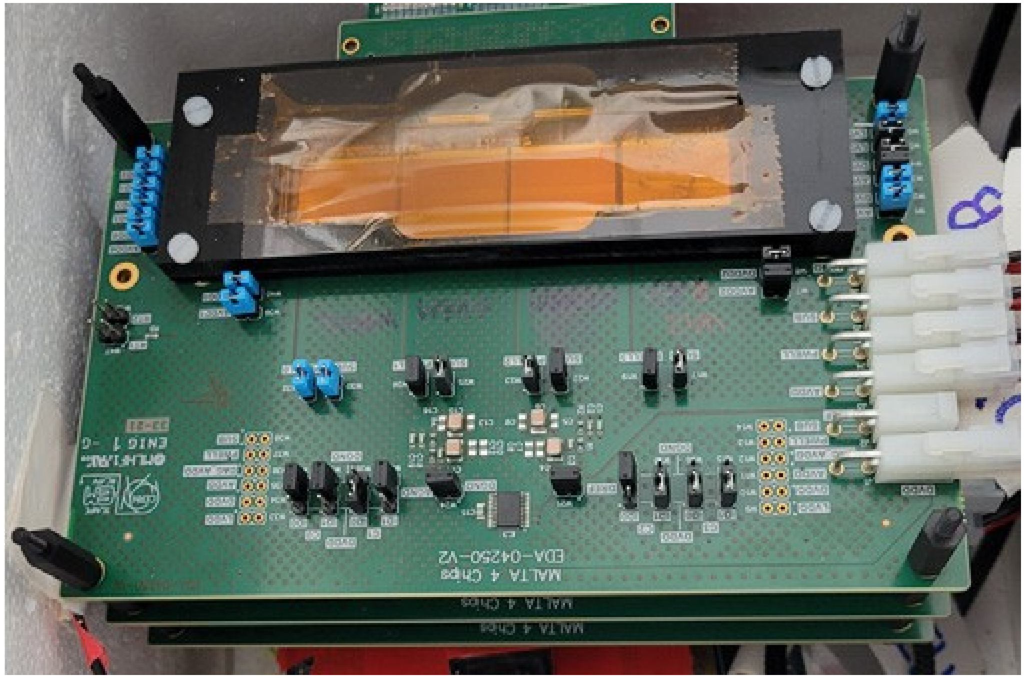
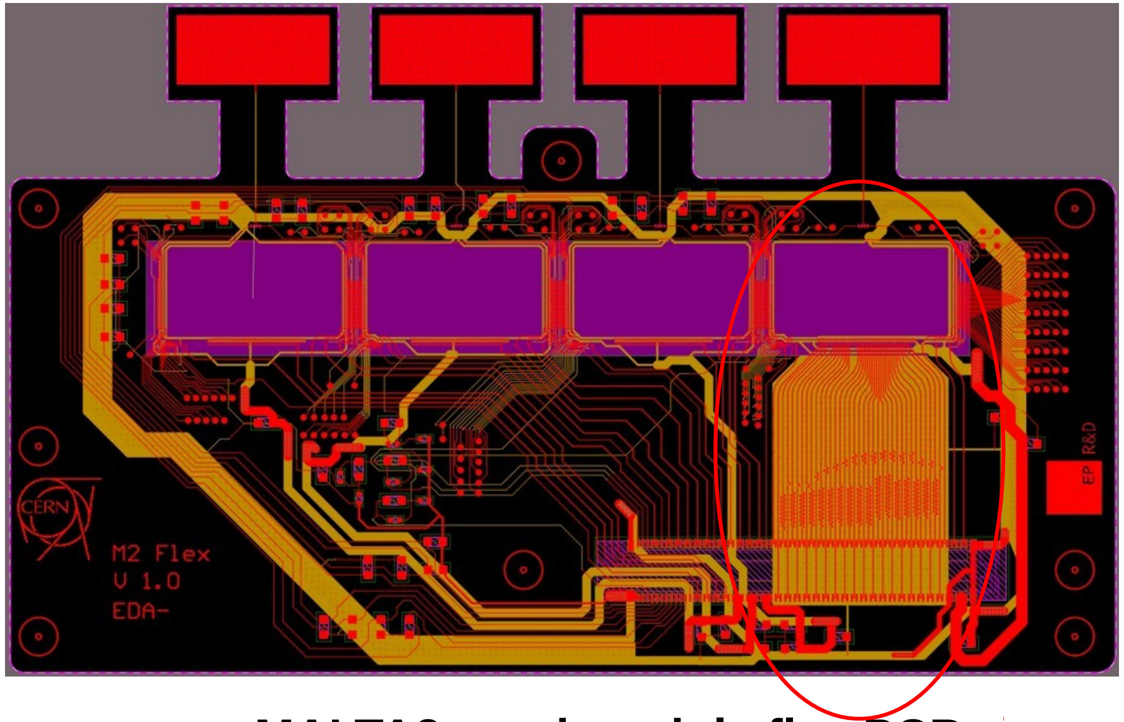
- Module assembly

MALTA modules



MALTA Quad board



MALTA2 quad module flex PCB

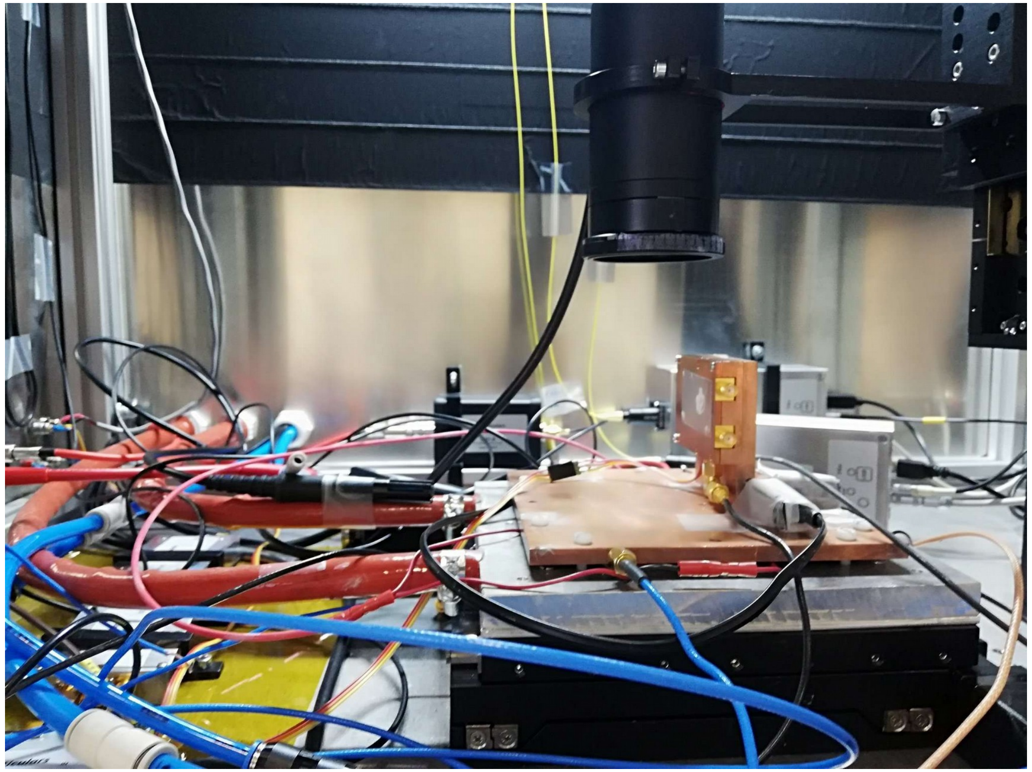
- 4 module boards daisy linked. Data output from a primary chip
  - *[5] F. Dachs, et all. "Development of a large-area, light-weight module using the MALTA monolithic pixel detector" -2022*
  - *[6] J Weick, et all. "Development of novel low-mass module concepts based on MALTA monolithic pixel sensors"*

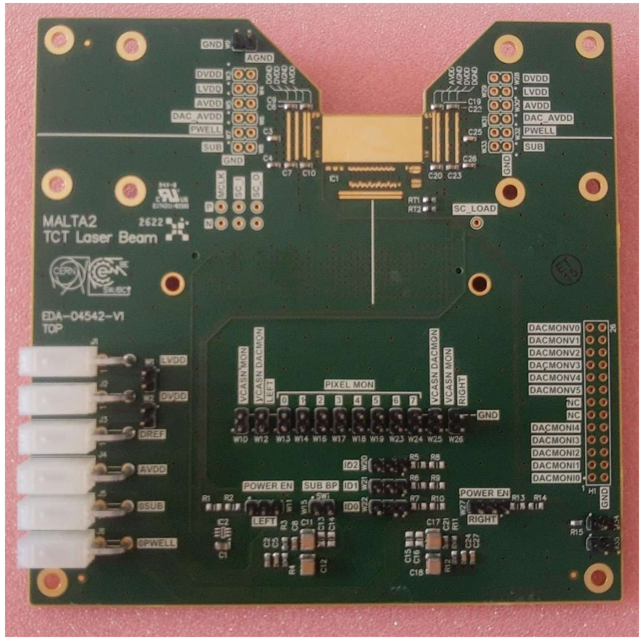
Conclusions

- MALTA2 shows radiation hardness up to 3E15 NIEL
- Timing resolution of 1.8 ns
- Module assembly of up to 4 chips is underway

At DESY…

- E-TCT studies being set-up
- Complimentary study of the depletion depth to the grazing angle studies at SPS CERN
- Custom made board for MALTA2 sensors





Backup

Recent papers

- [1] https://cds.cern.ch/record/2824515?ln=en#
- [2] https://arxiv.org/abs/2304.01104
- [3] awaiting publication
- [4] arXiv:2209.14676
- [5] https://cds.cern.ch/record/2846297?ln=enhttps://cds.cern.ch/record/2846297?ln=en
- [6] https://dx.doi.org/10.1088/1748-0221/18/04/C04003
- Many many more:
- Heinz Pergnegger, et. all "MALTA-Cz: A radiation hard full-size monolithic CMOS sensor with small electrodes on high-resistivity Czochralski substrate" https://arxiv.org/abs/2301.03912
- ….

Thank you

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