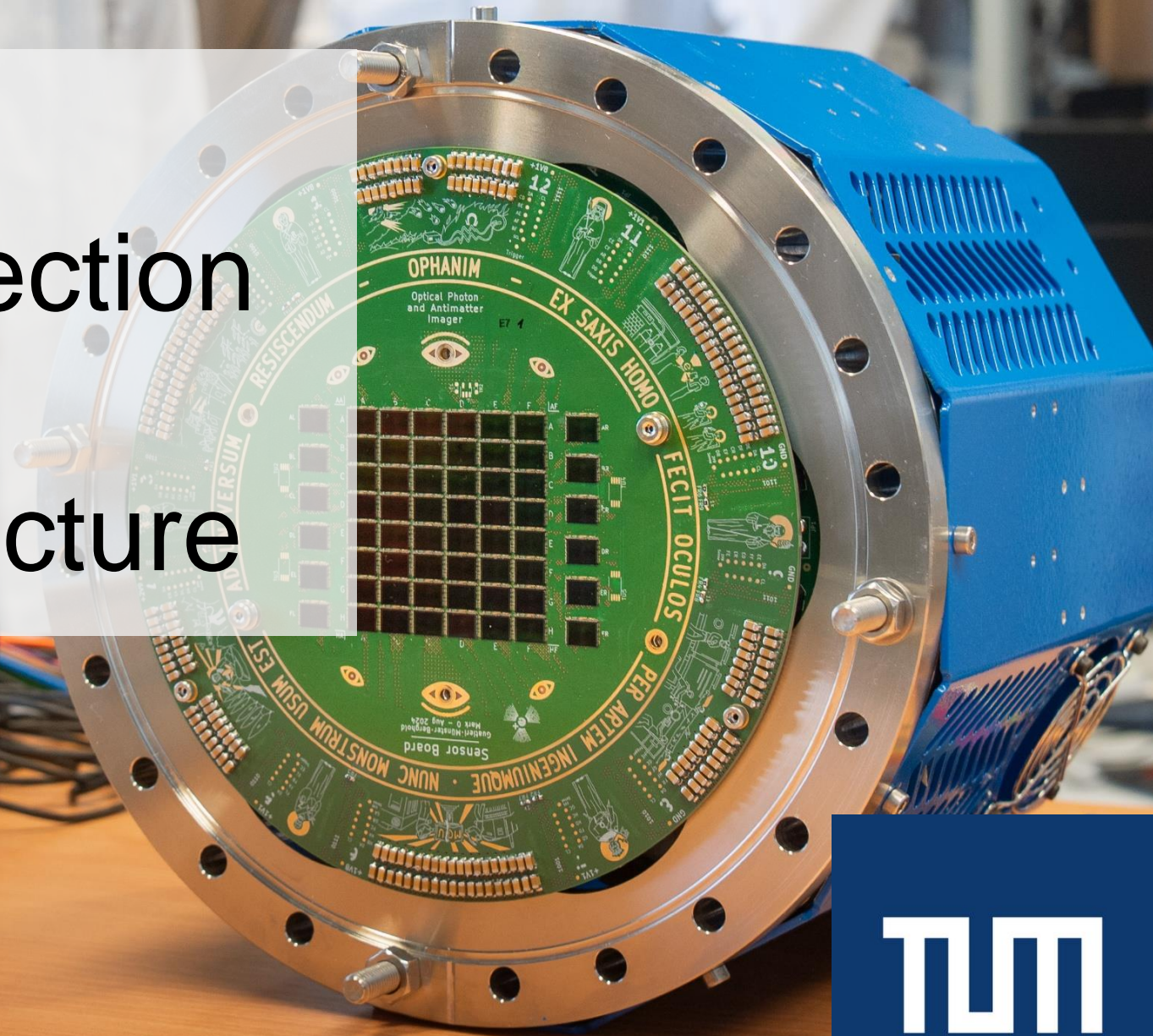


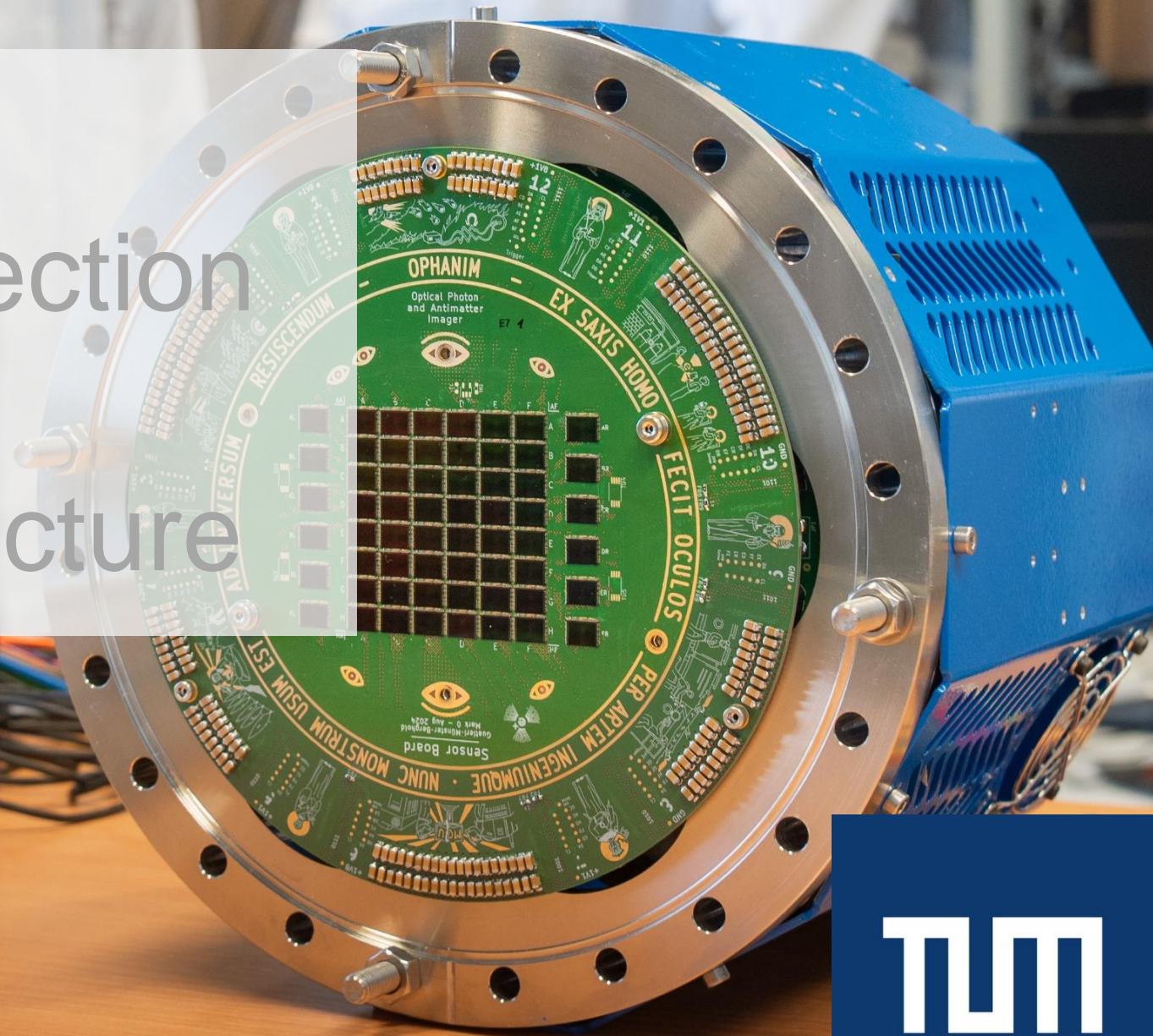
Detecting Antiprotons with Submicrometric Spatial Accuracy

Markus Münster
TIPP2026

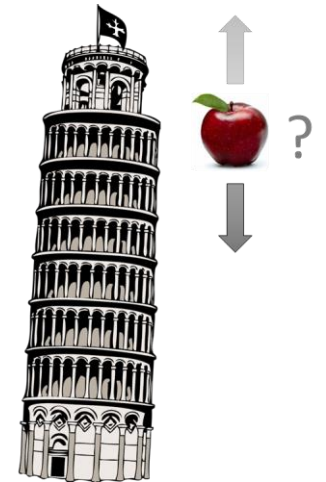
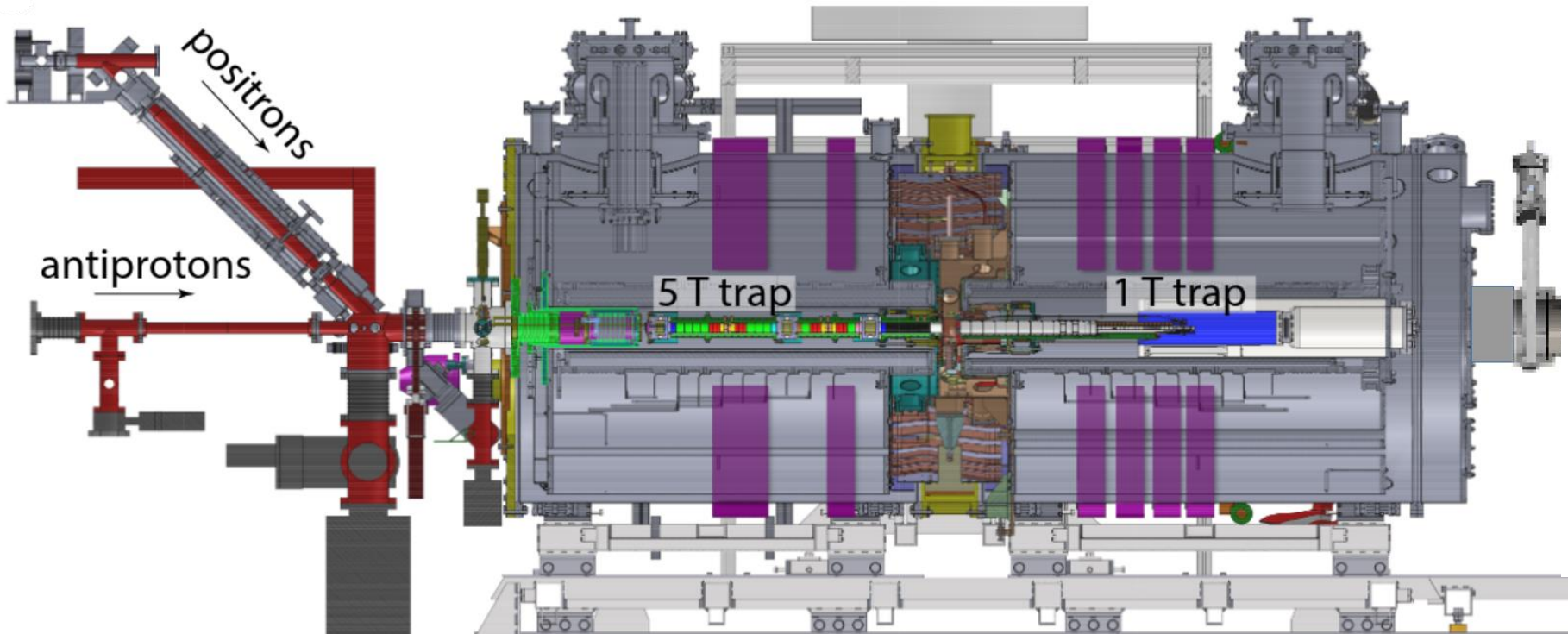
1. Motivation
2. Antiproton Detection
3. Resolution
4. System Architecture



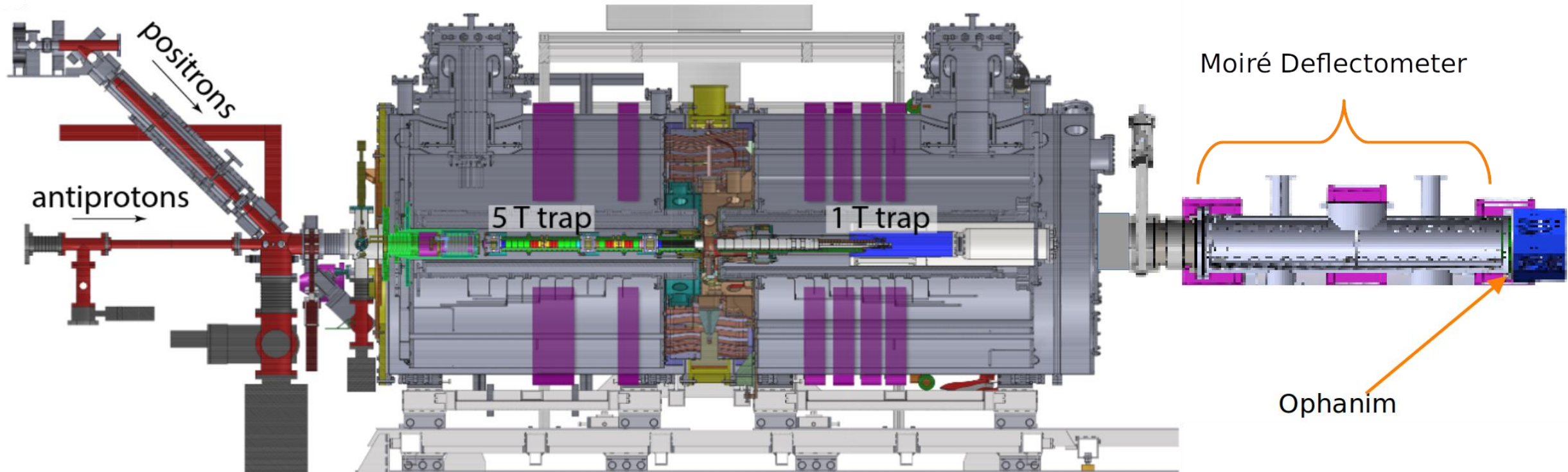
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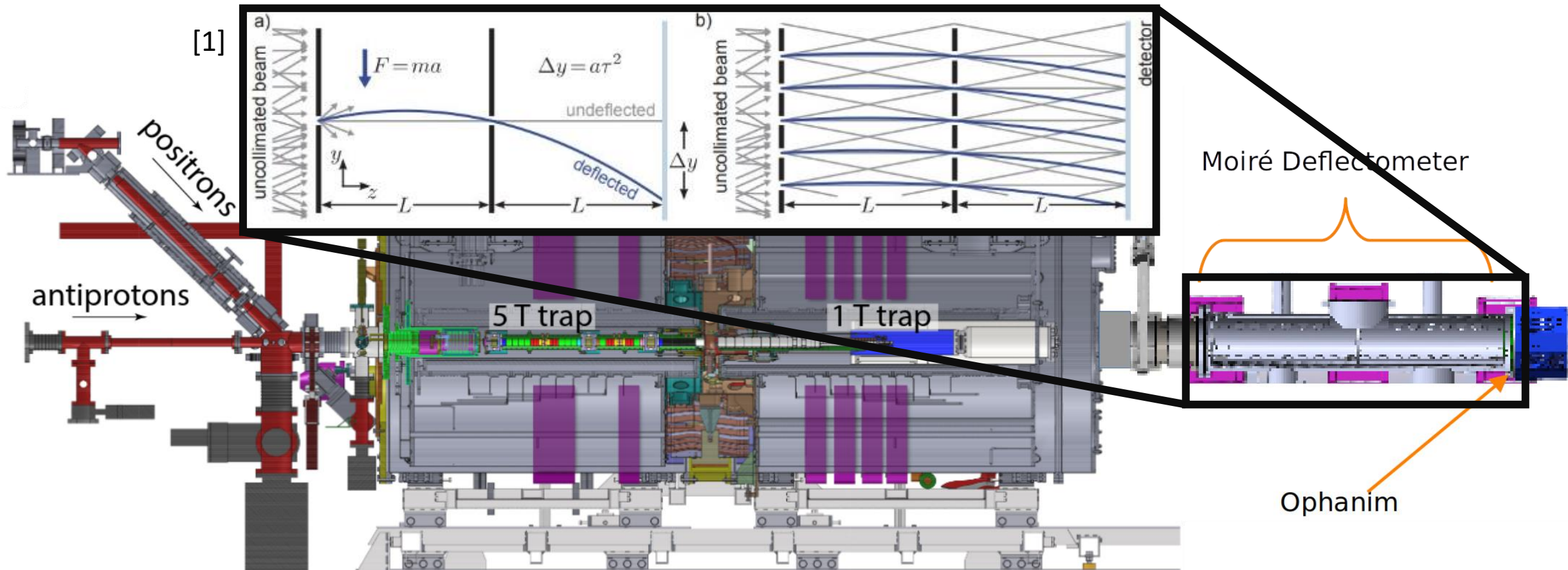
Motivation: Experimental Setup of AEgIS



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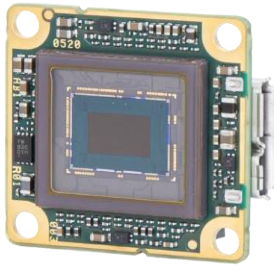
Motivation: Experimental Setup of AEgIS



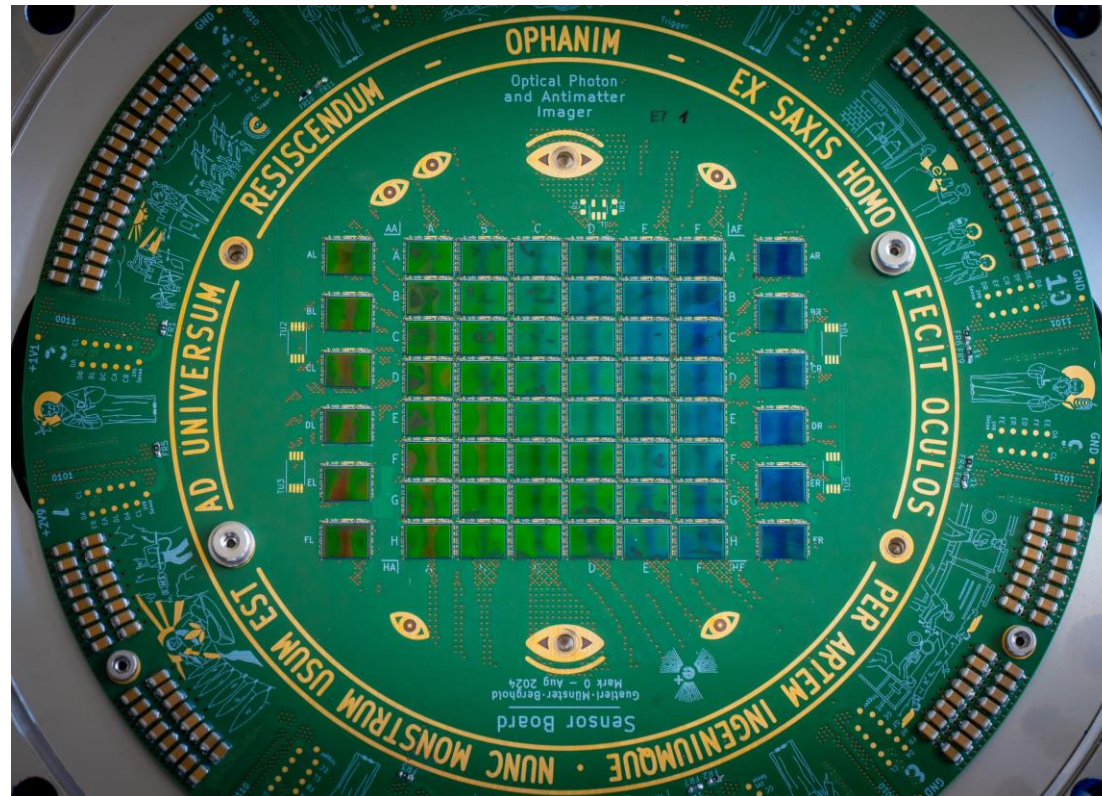
[1] Aghion, S., Ahlén, O., Amsler, C. *et al.* A moiré deflectometer for antimatter. *Nat Commun* 5, 4538 (2014).

What is the OPHANIM Detector?

O_{ptical} P_Hoton and A_Ntimatter I_Mager



X 60 =

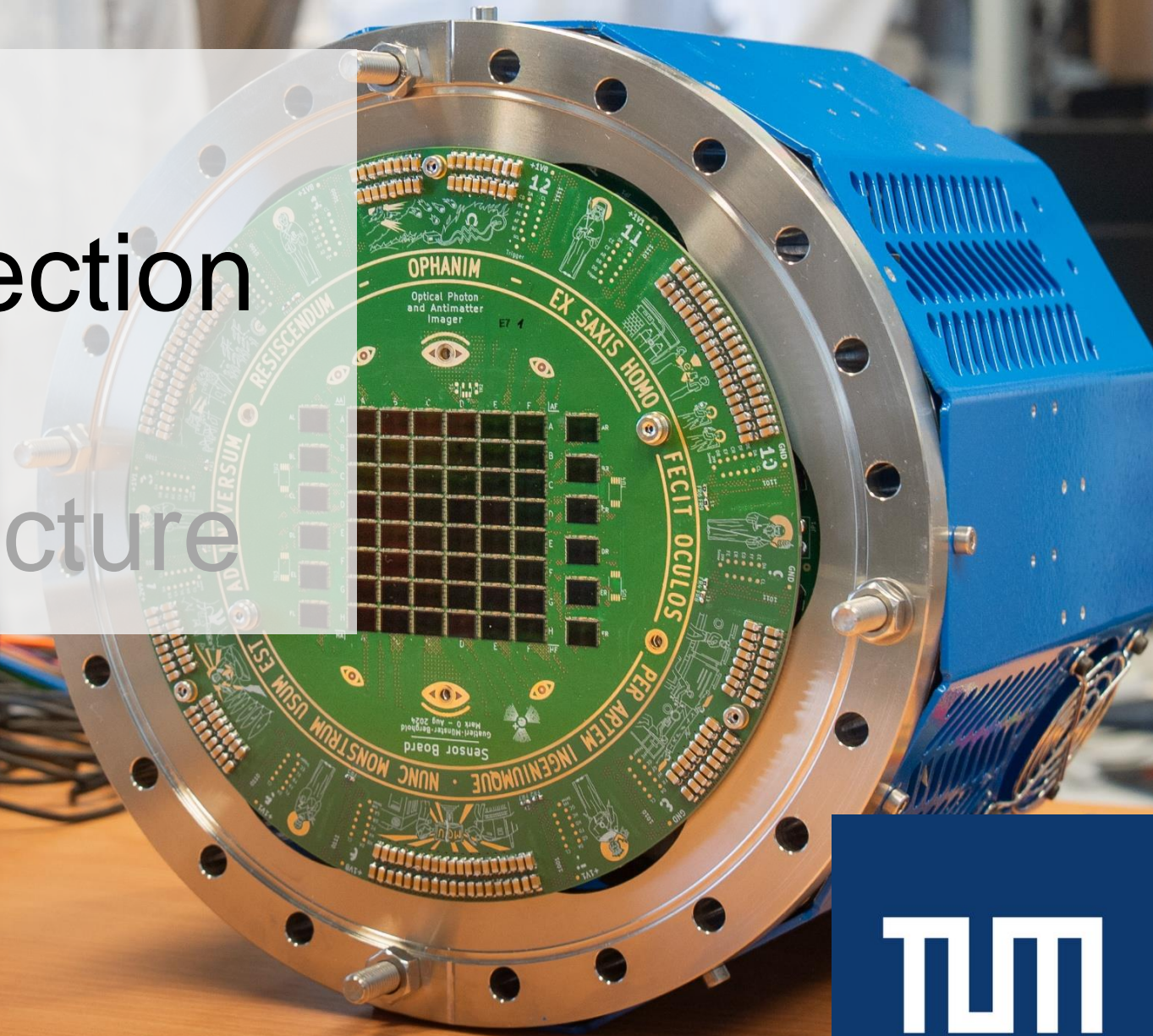


OPHANIM Detector

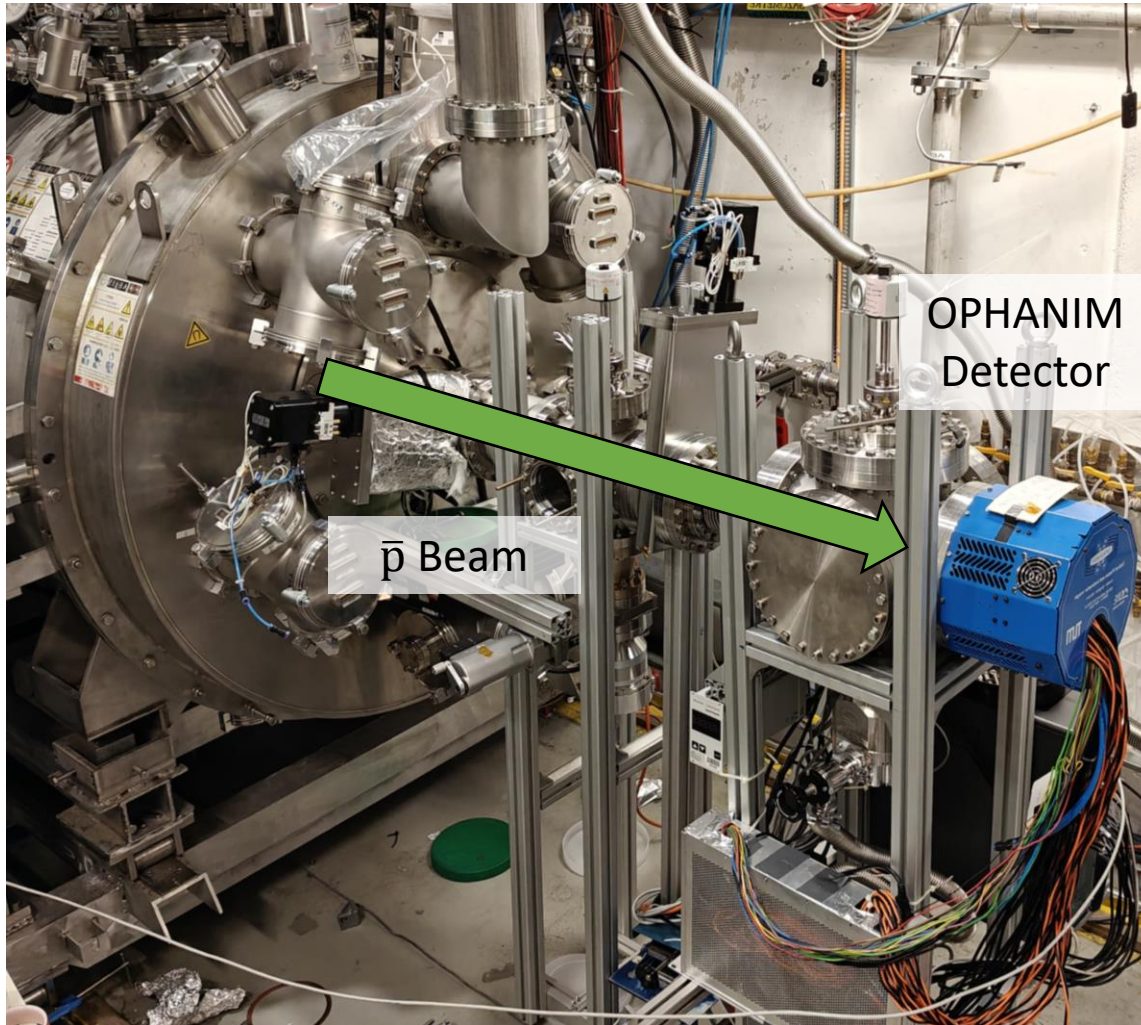
- 3852 MP
- Pixel Size: $0.8 \times 0.8 \mu\text{m}^2$
- $55.32 \times 55.96 \text{ mm}^2$
- 66% active area

Sony IMX686:
64.2 MP CMOS
Smartphone Camera Sensor

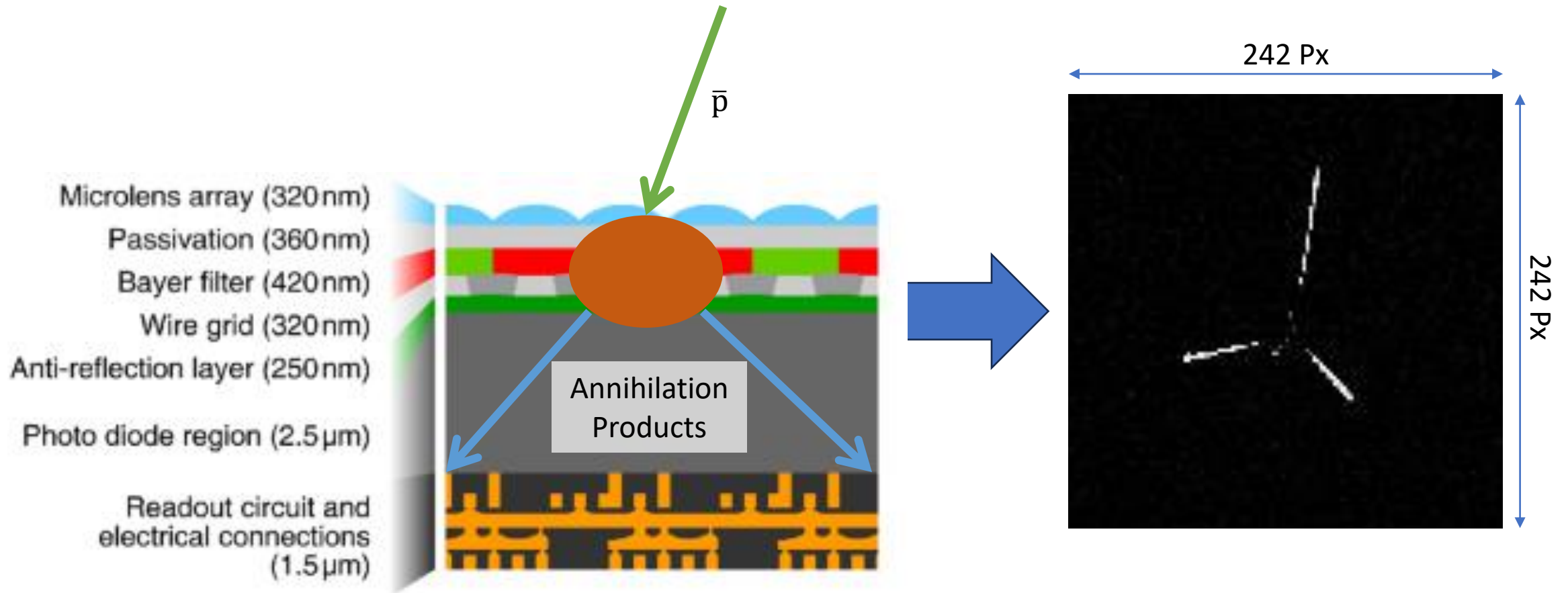
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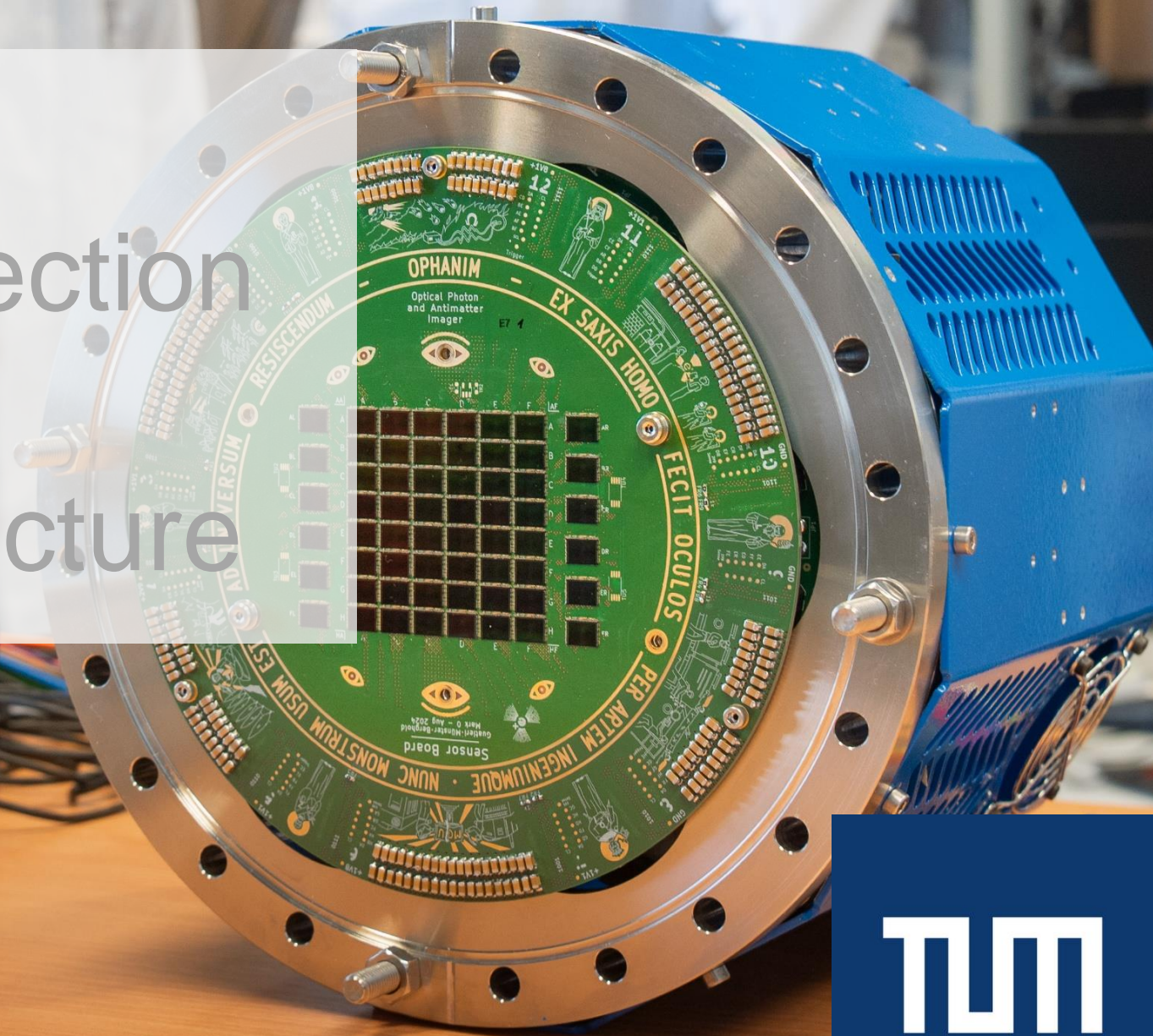
Antiproton Detection



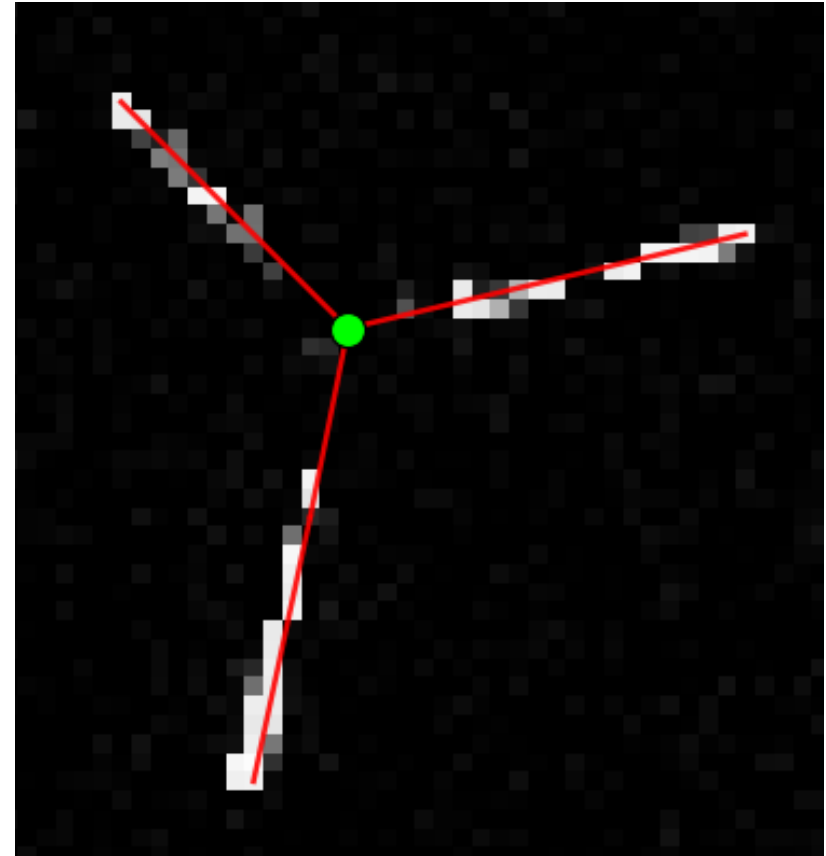
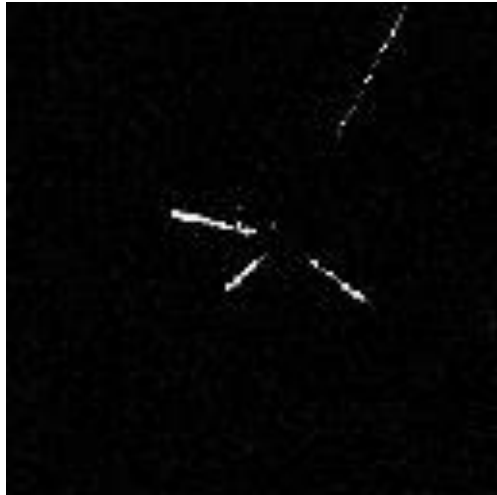
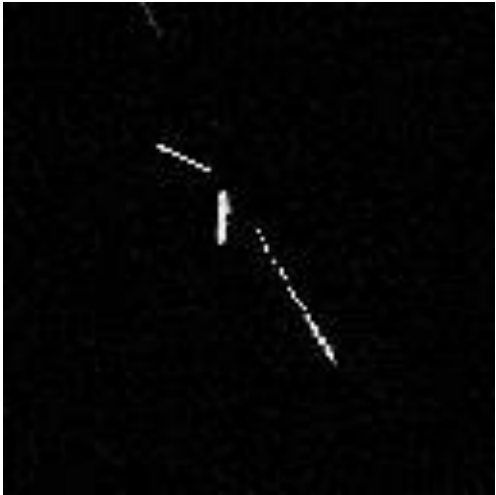
Antiproton Detection



1. Motivation
2. Antiproton Detection
- 3. Resolution**
4. System Architecture

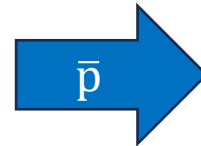
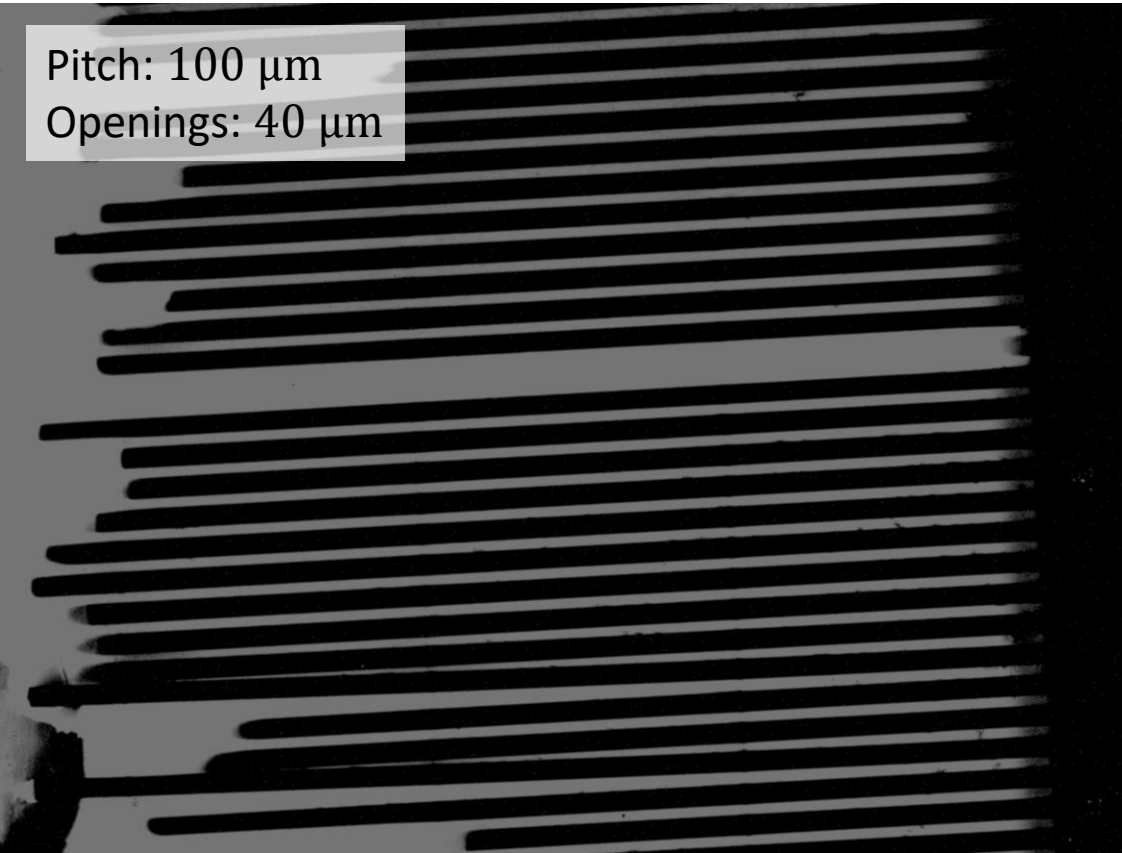


Vertexing

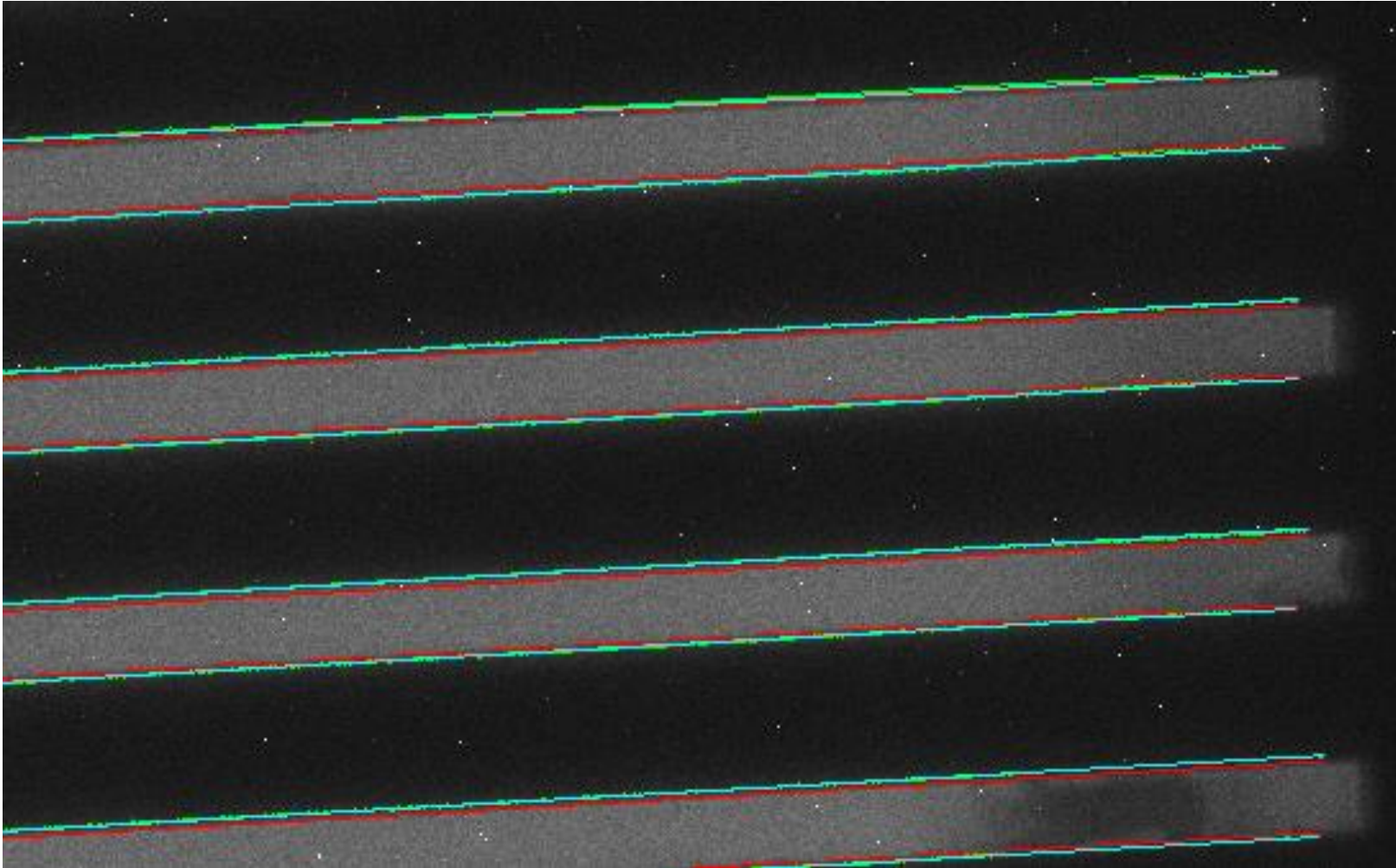


Quantifying the Resolution

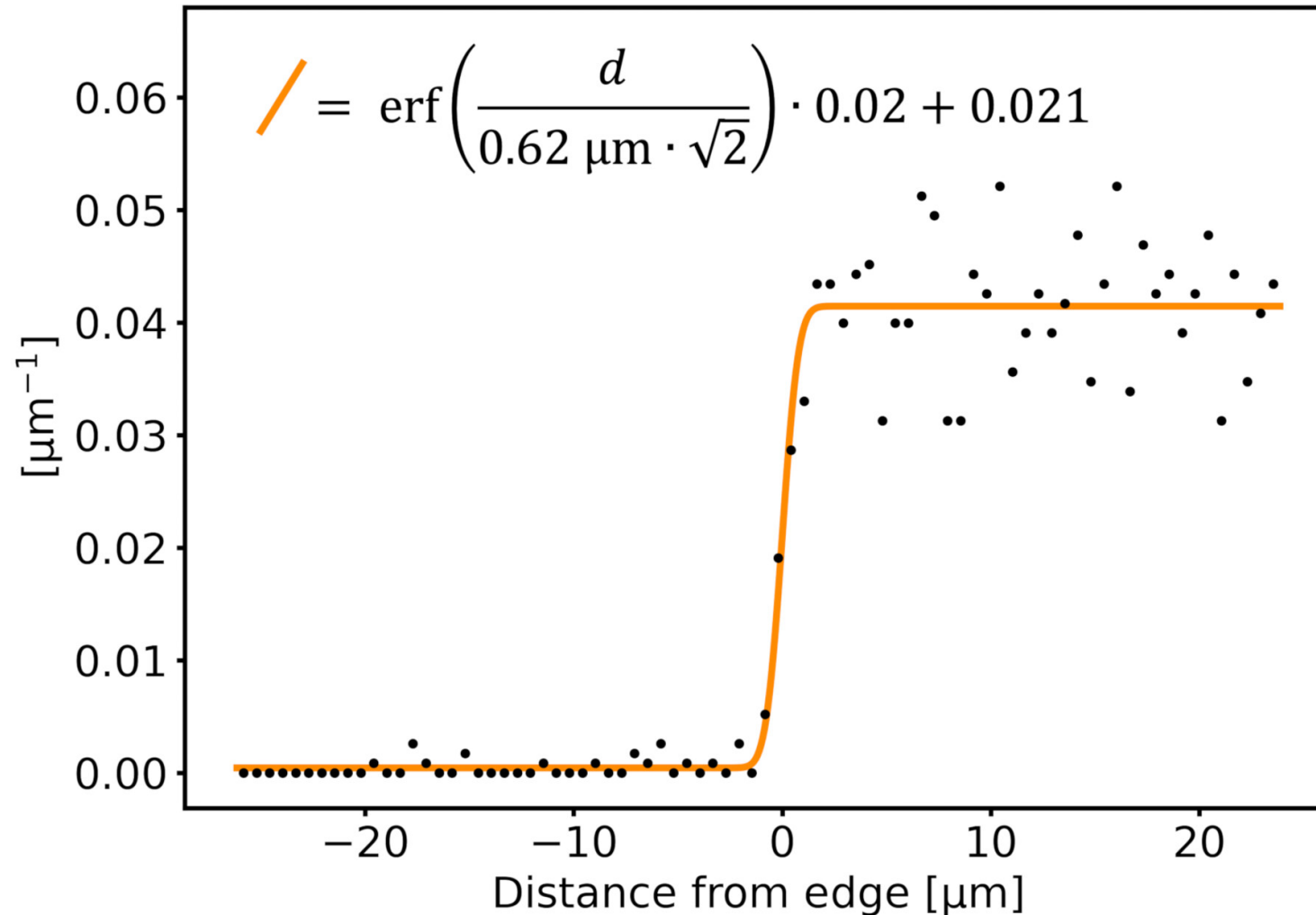
Pitch: 100 μm
Openings: 40 μm



Quantifying the Resolution



Quantifying the Resolution



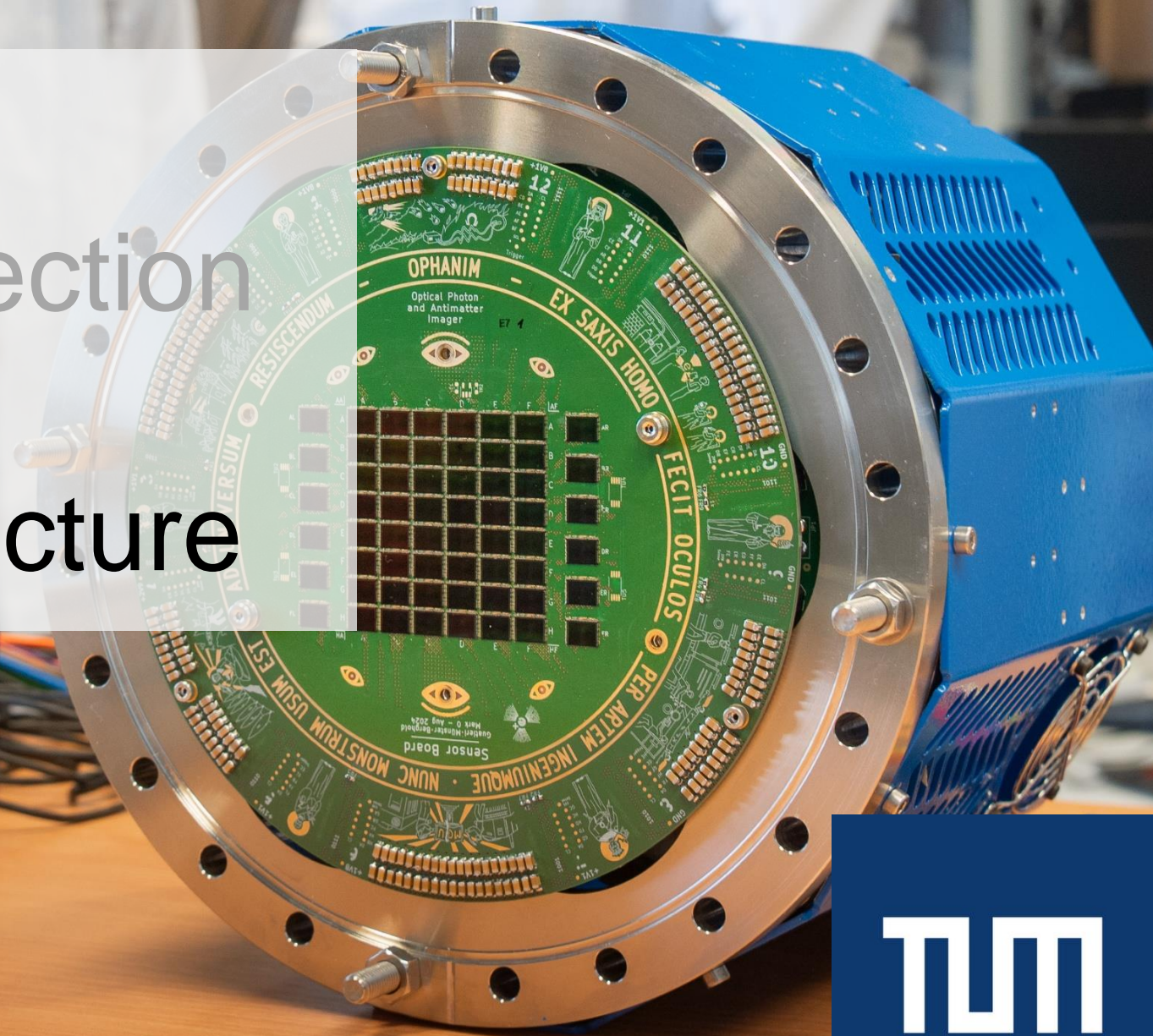
Previously with Timepix3:

22 μm [2]

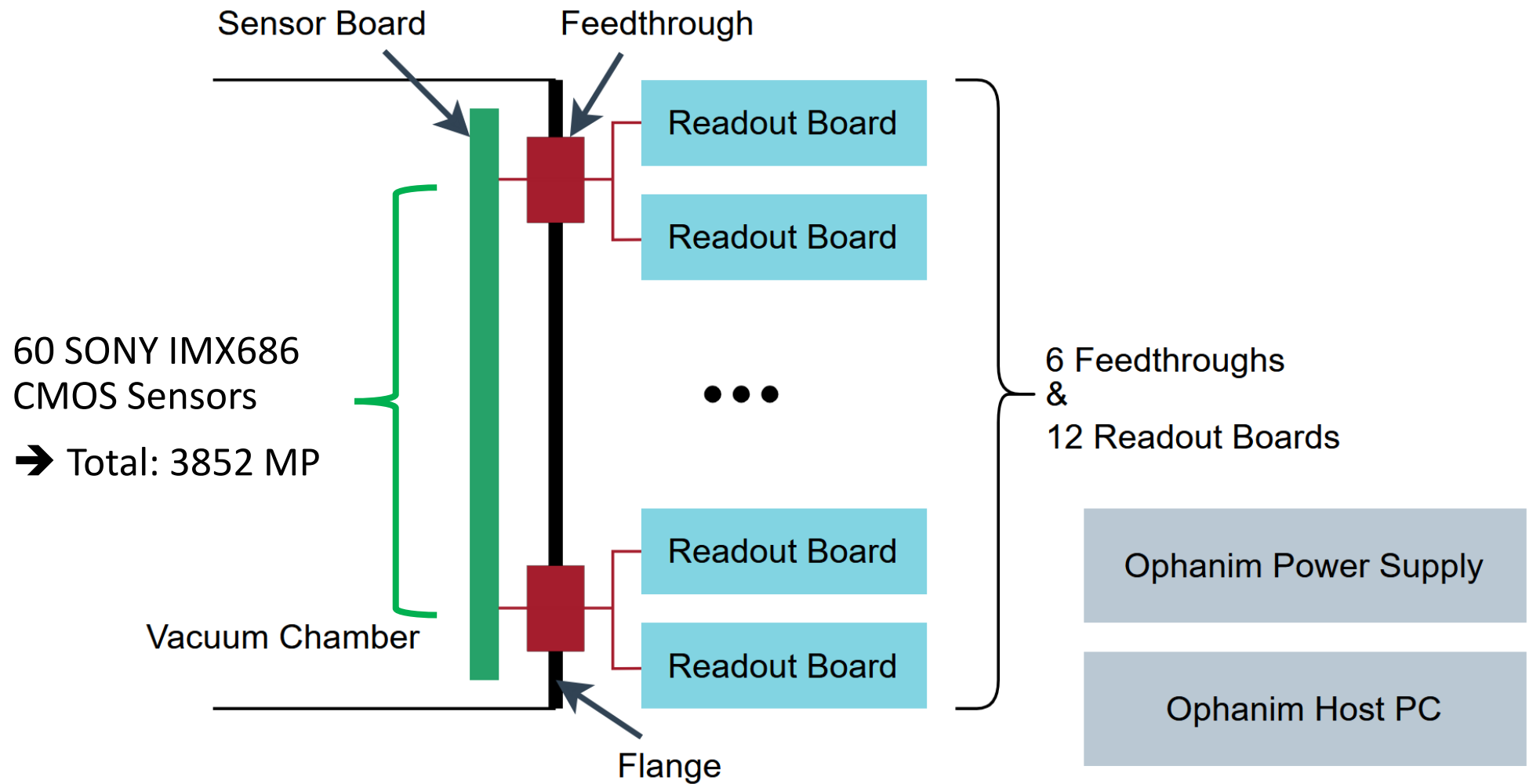
Resolution:
 $0.62^{+0.40}_{-0.22} \mu\text{m}$

[2] H. Holmestad, Data analysis, simulations, and reconstruction of antiproton annihilations in a silicon pixel detector. Phd thesis, University of Oslo, department of Physics 2018.

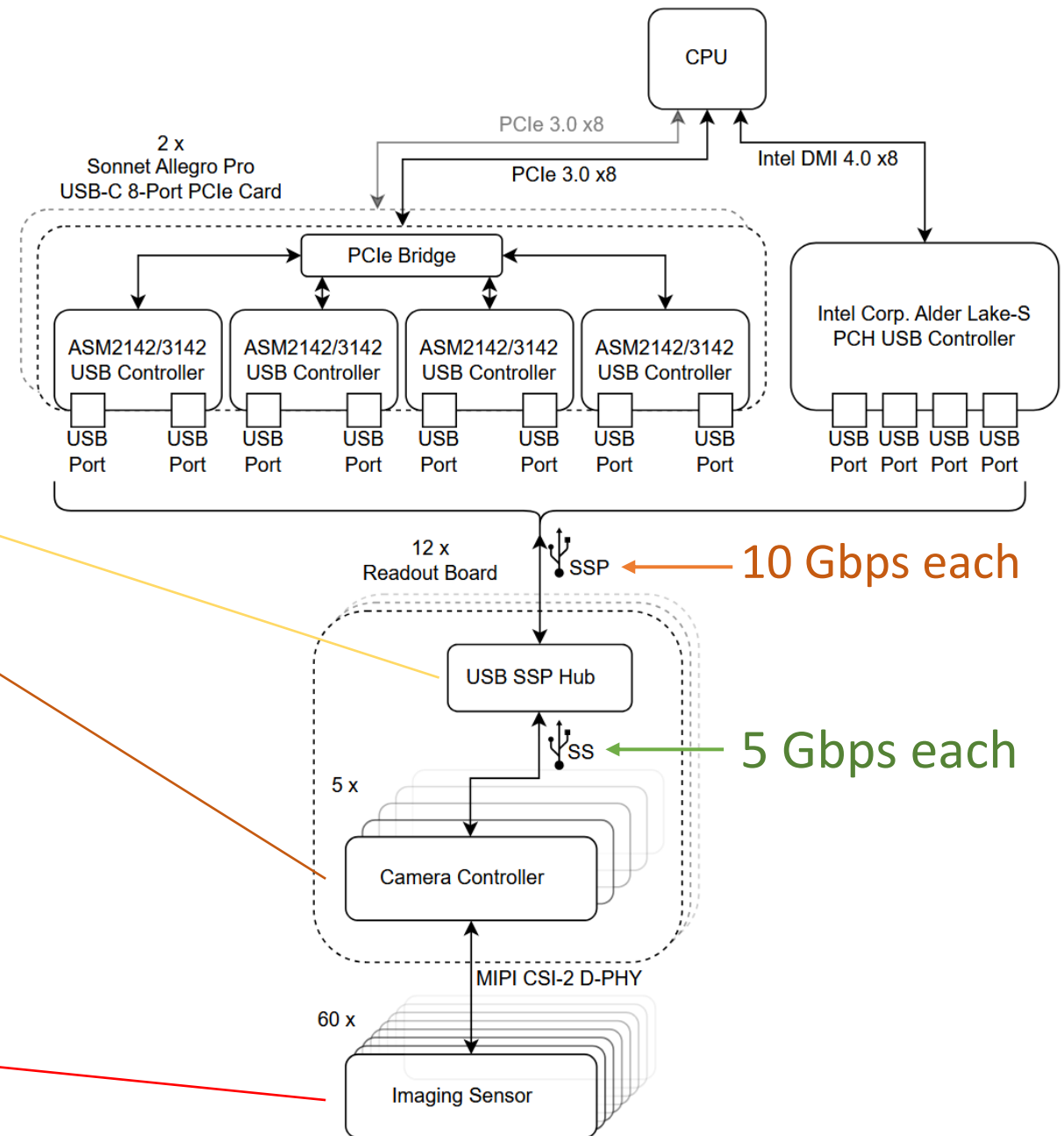
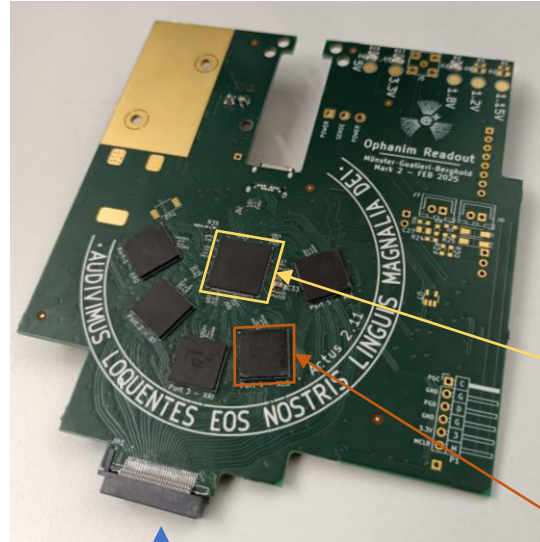
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Hardware Overview

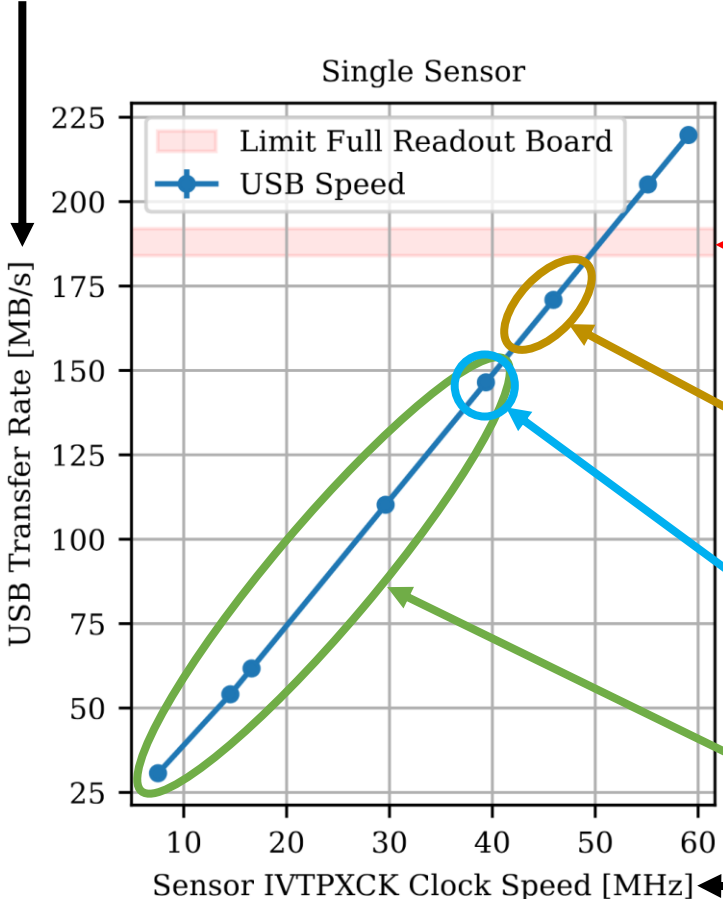


OPHANIM Data Bus



Data Streaming

actual Payload



10 Gbps
 ⇔
 920 to 960 MB/s → Shared by 5 Devices → 184 to 192 MB/s per device of usable Payload

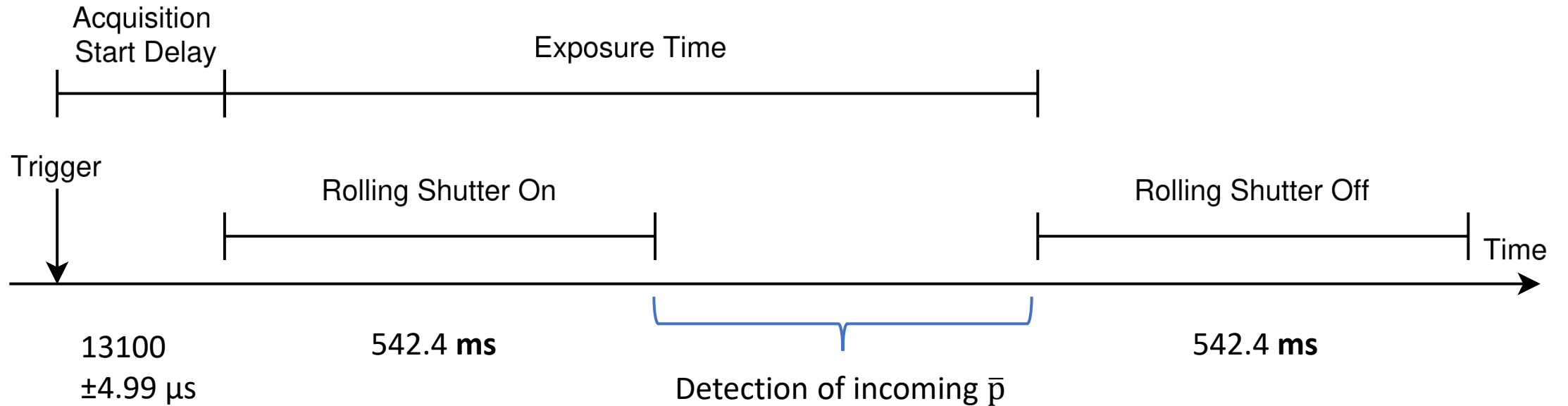
Possible with improved USB-PCIe Interface

146 MB/s per device
 → ca. 730 MB/s on Hub ⇔ USB Controller Connection
 → ca. 8.76 GB/s in total

Can be achieved with entire detector with given hardware

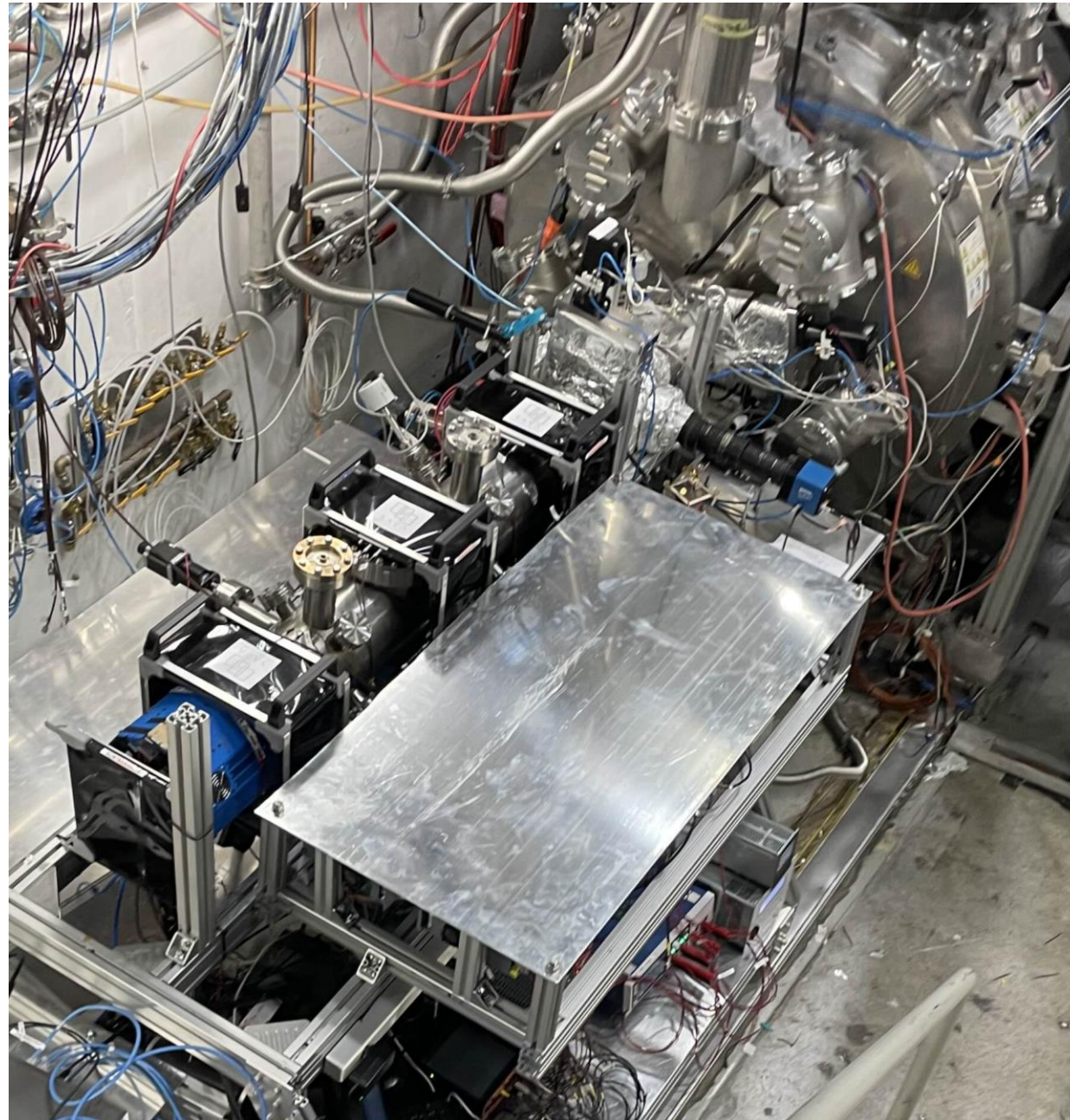
← Internal Sensor Clock determines the Pixel-Readout Frequency

Acquisition Procedure



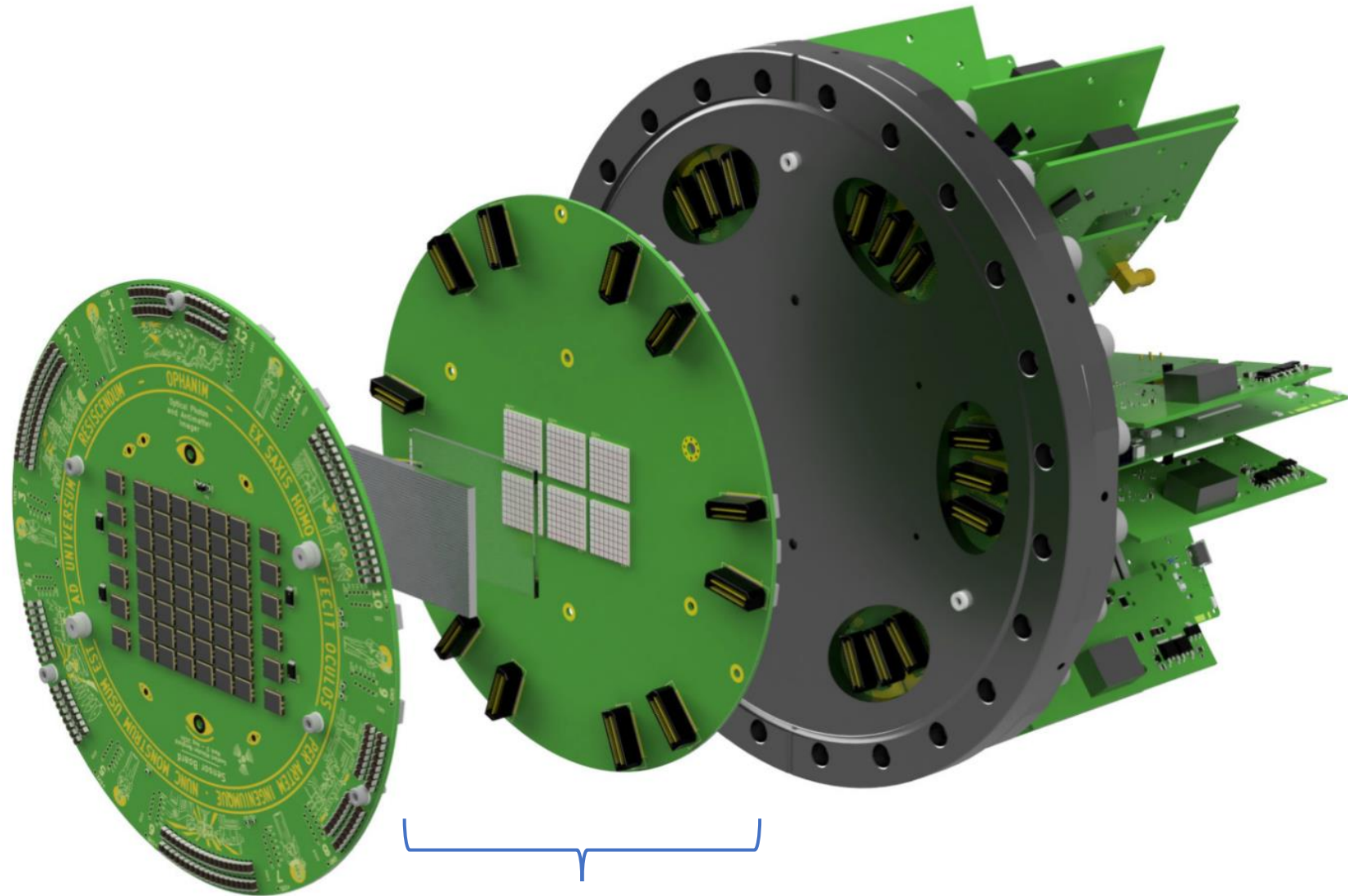
- Image Streaming with up to ca. 1.8 FPS possible with current Hardware
- At AEGIS: Single images with long exposure times (order of 10^1s)

Outlook



Outlook

- Time Sensitivity
- Particle Tracker



Additional MPPCs

Acknowledgement

Dr. Francesco Guatieri
Michael Berghold
Dr. Ruggero Caravita
Prof. Dr. Christoph Hugenschmidt



Paper: Real-time antiproton annihilation vertexing with submicrometer resolution

