

Detectors @ Zeuthen

DESY Detectors and R&D for Future Astroparticle, Particle, and Accelerator Physics Experiments

Steven Worm

Liebenberg Meeting
September 12, 2022

Silicon Sensor R&D: ULTRASAT and MAPs

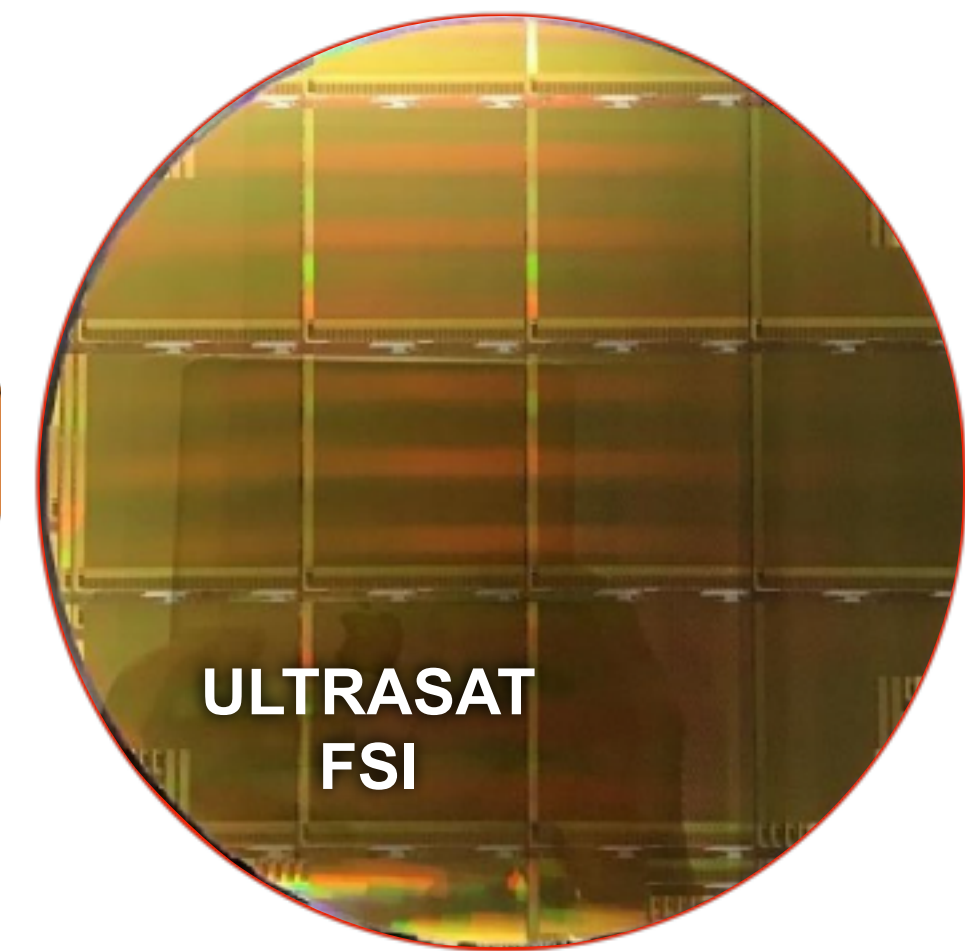
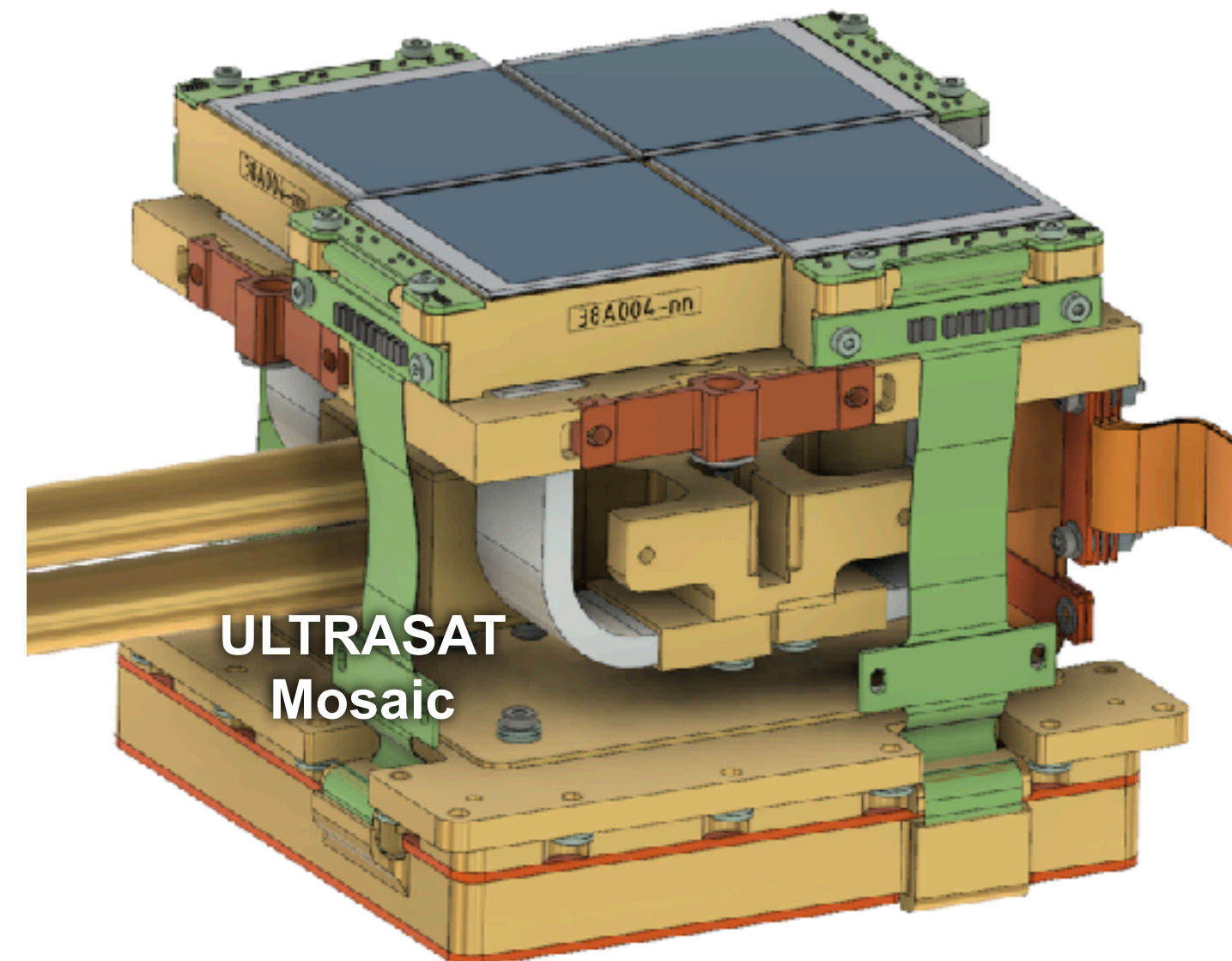
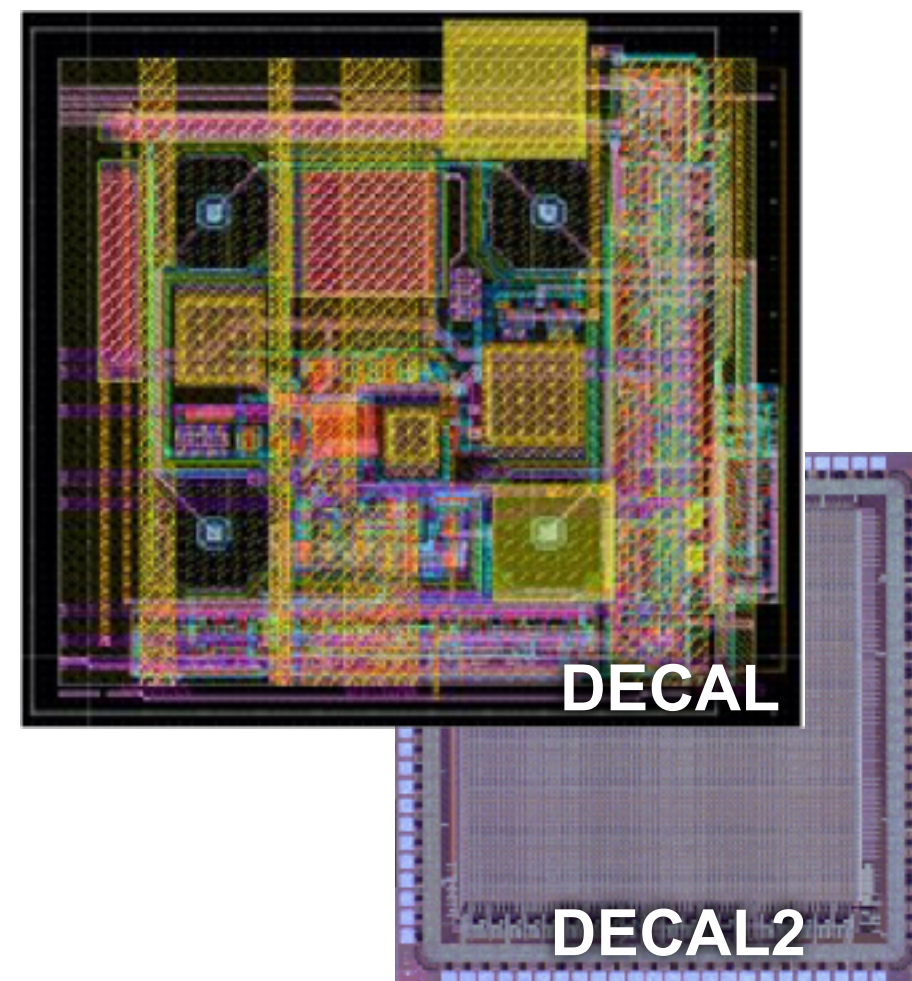
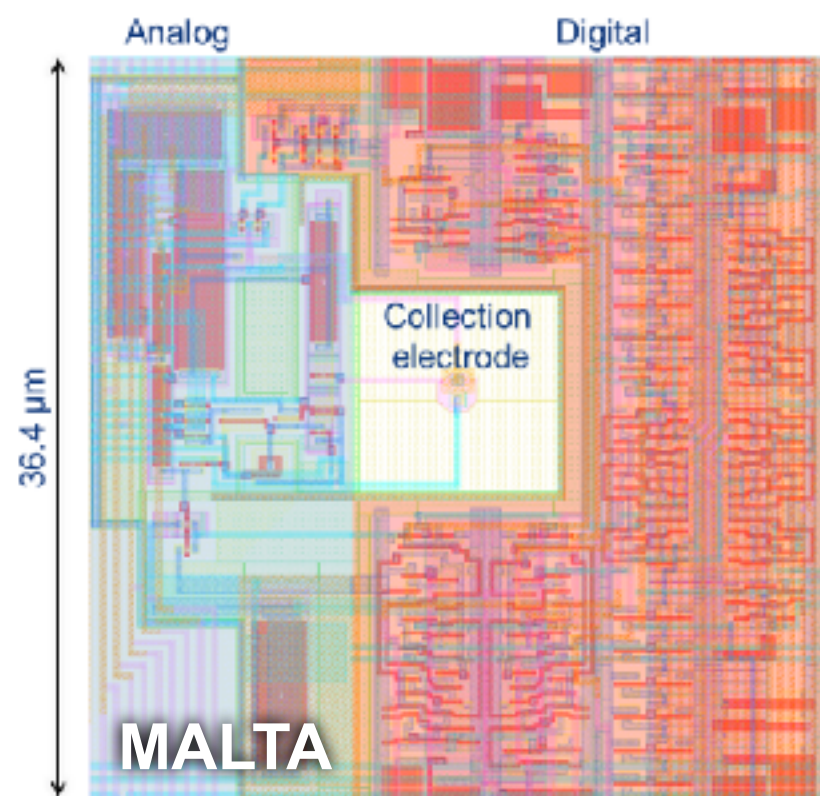
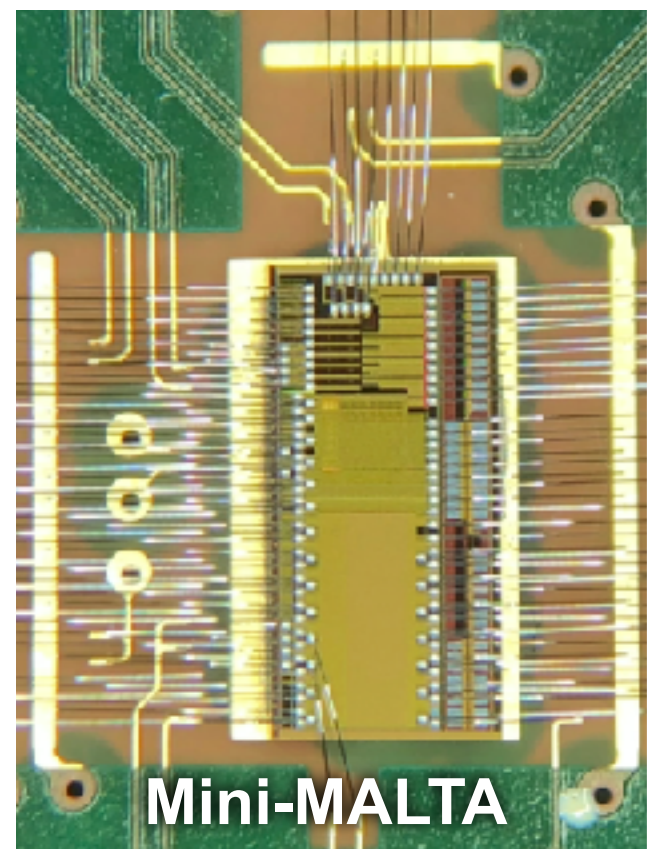


Monolithic Active Pixel sensors @ DESY

- Tower 180nm: optical or “modified” process w/ epi
- DECAL: reconfigurable strip or pad for calorimetry
- MALTA: tracking/vertexing, rad tolerant $\geq 1e15$ n_{eq}/cm²
- Many German, international partners (ATLAS spinoff)

ULTRASAT sensors

- Tower Semiconductor 180 nm process stitched MAPs
- Back-side illuminated sensor for UV satellite telescope
- Four 22.4 Mpixel MAPs = 90 Mpixel camera mosaic
- Excellent potential for spinoffs and future R&D



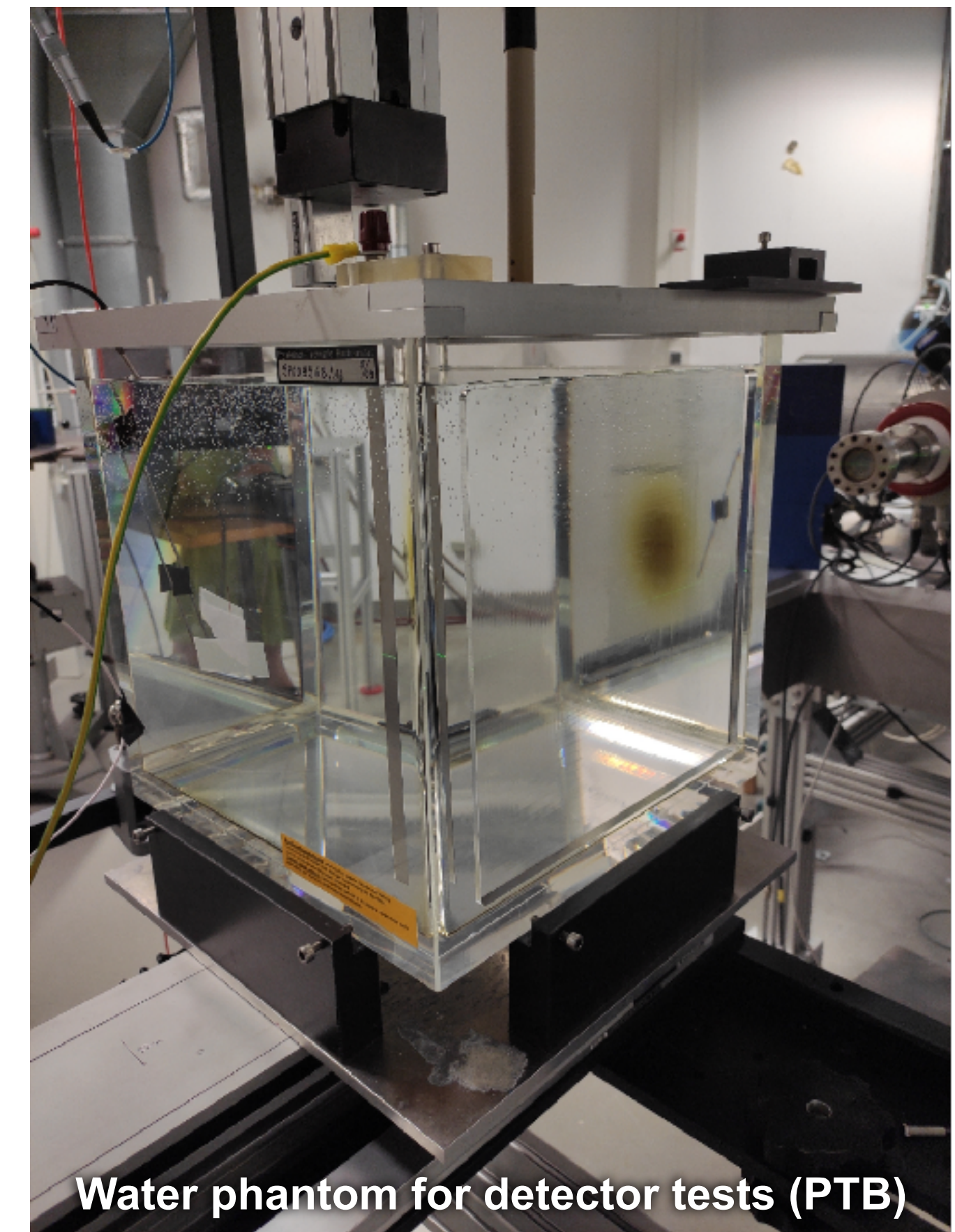
Dosimetry R&D for FLASH@PITZ

Q: How to do dosimetry for $\sim 10^{14}$ particles arriving within \sim picoseconds?

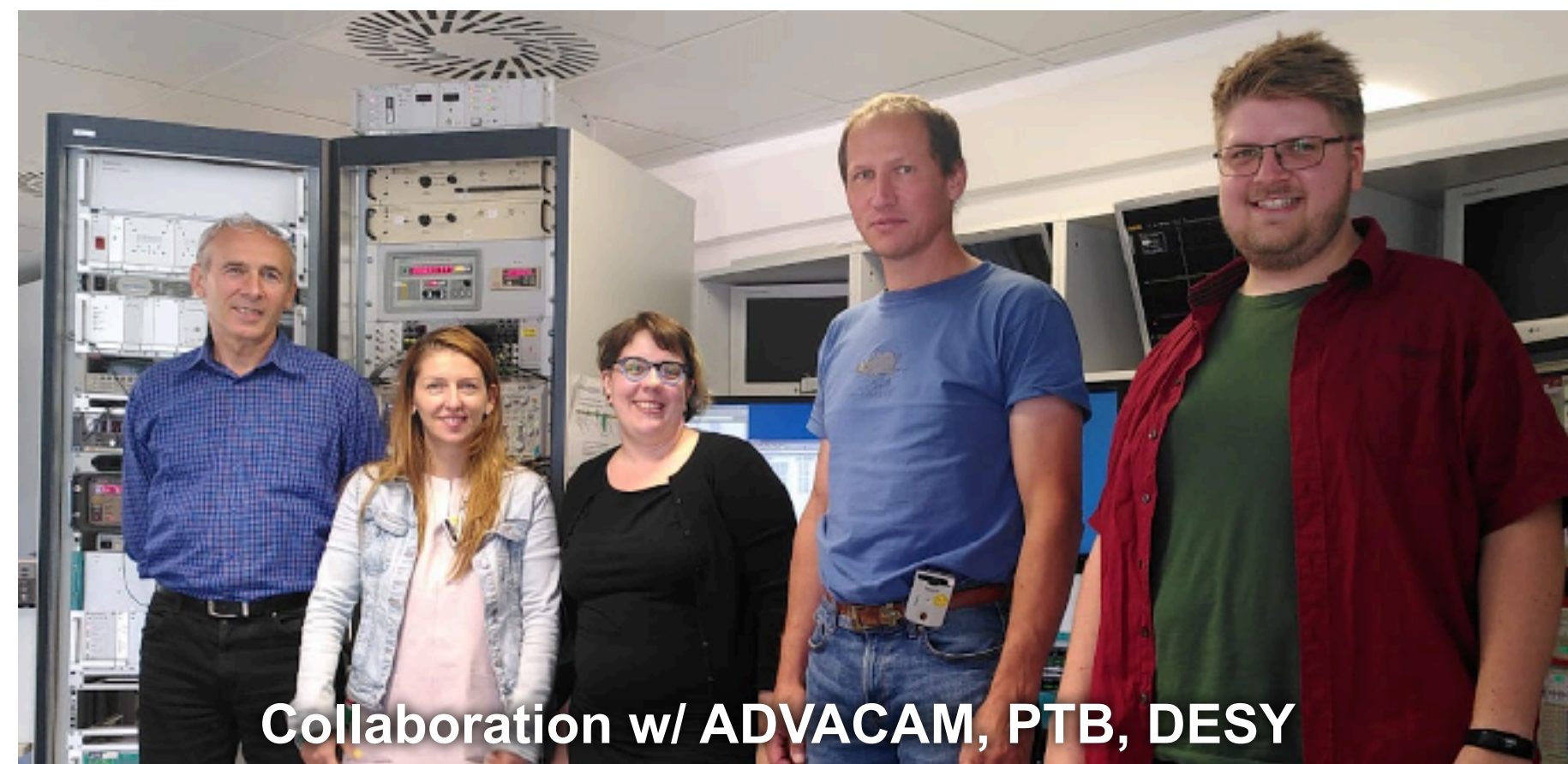


- **Photo Injector Test facility at DESY Zeuthen**

- Unique test facility for FLASH radiotherapy: parameter space studies for Bio/RT
- Studying existing dosimetry techniques, applicability of FH+AP sensors (eg MAPs)
- Excellent potential for science impact, societal impact, commercial connections...



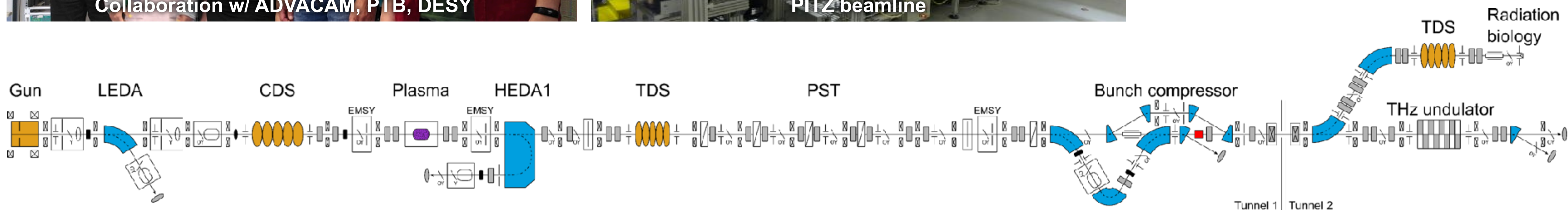
Water phantom for detector tests (PTB)



Collaboration w/ ADVACAM, PTB, DESY

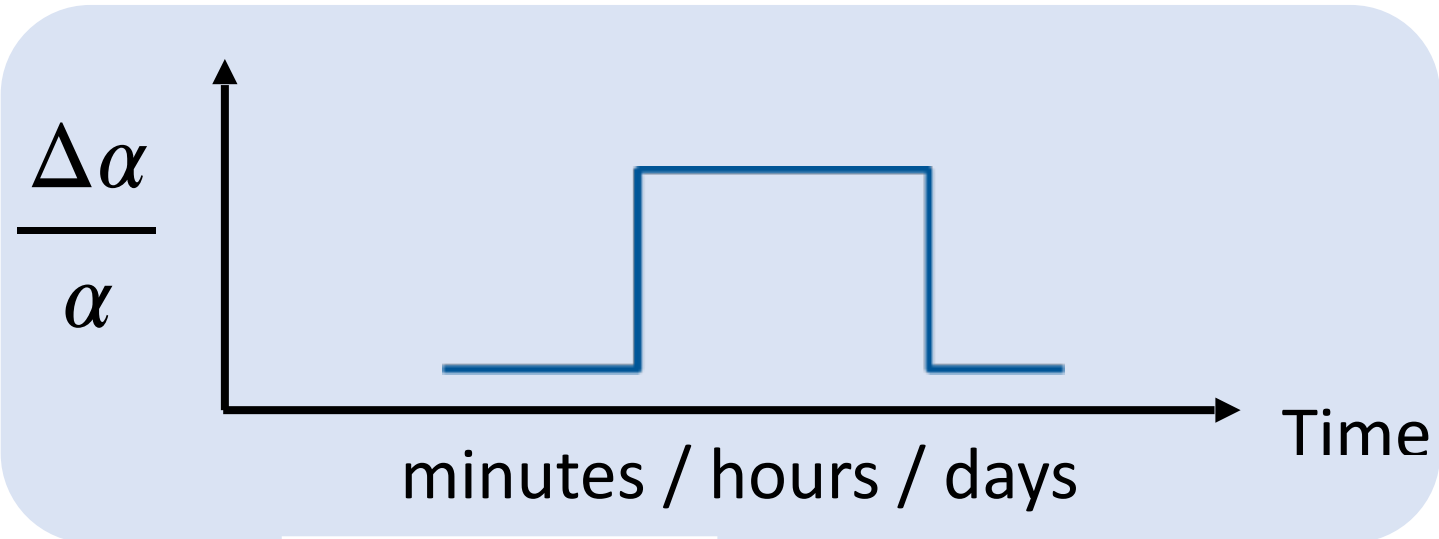
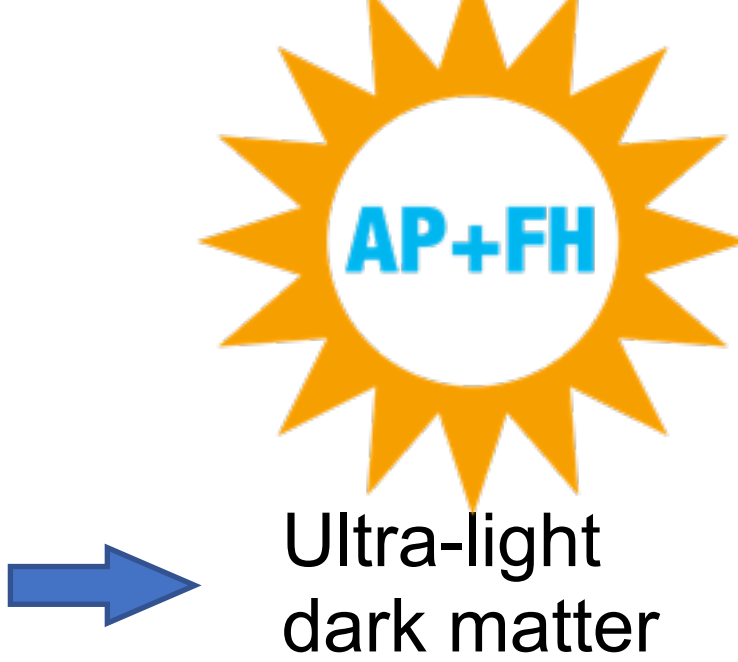
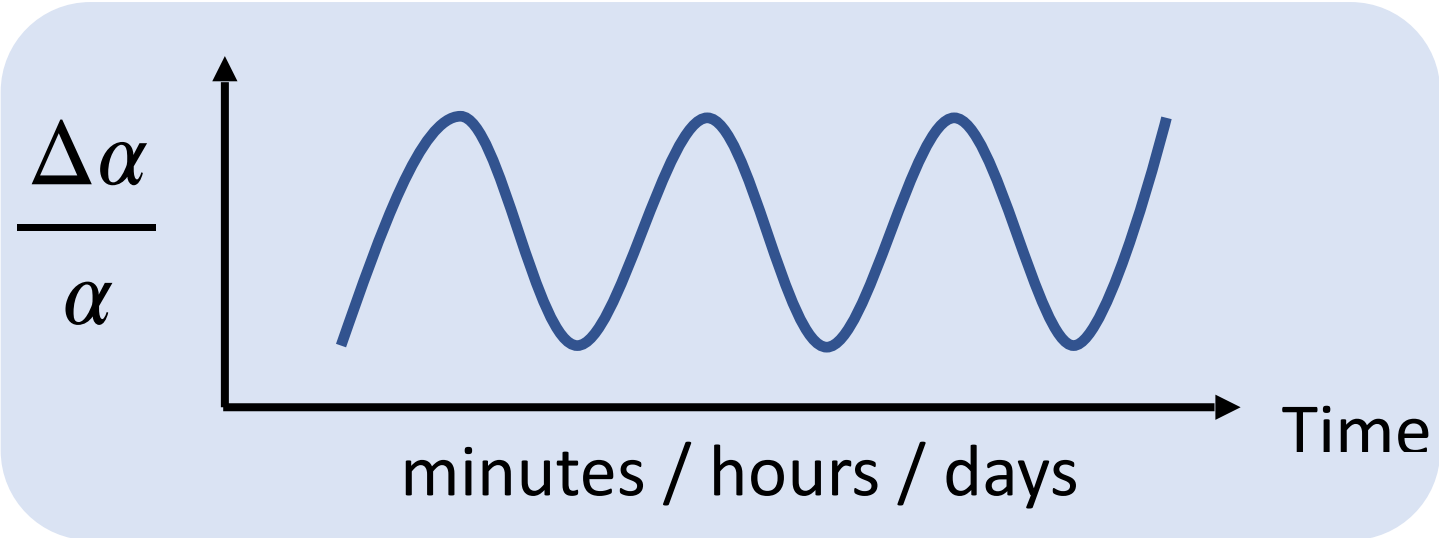


PITZ beamline

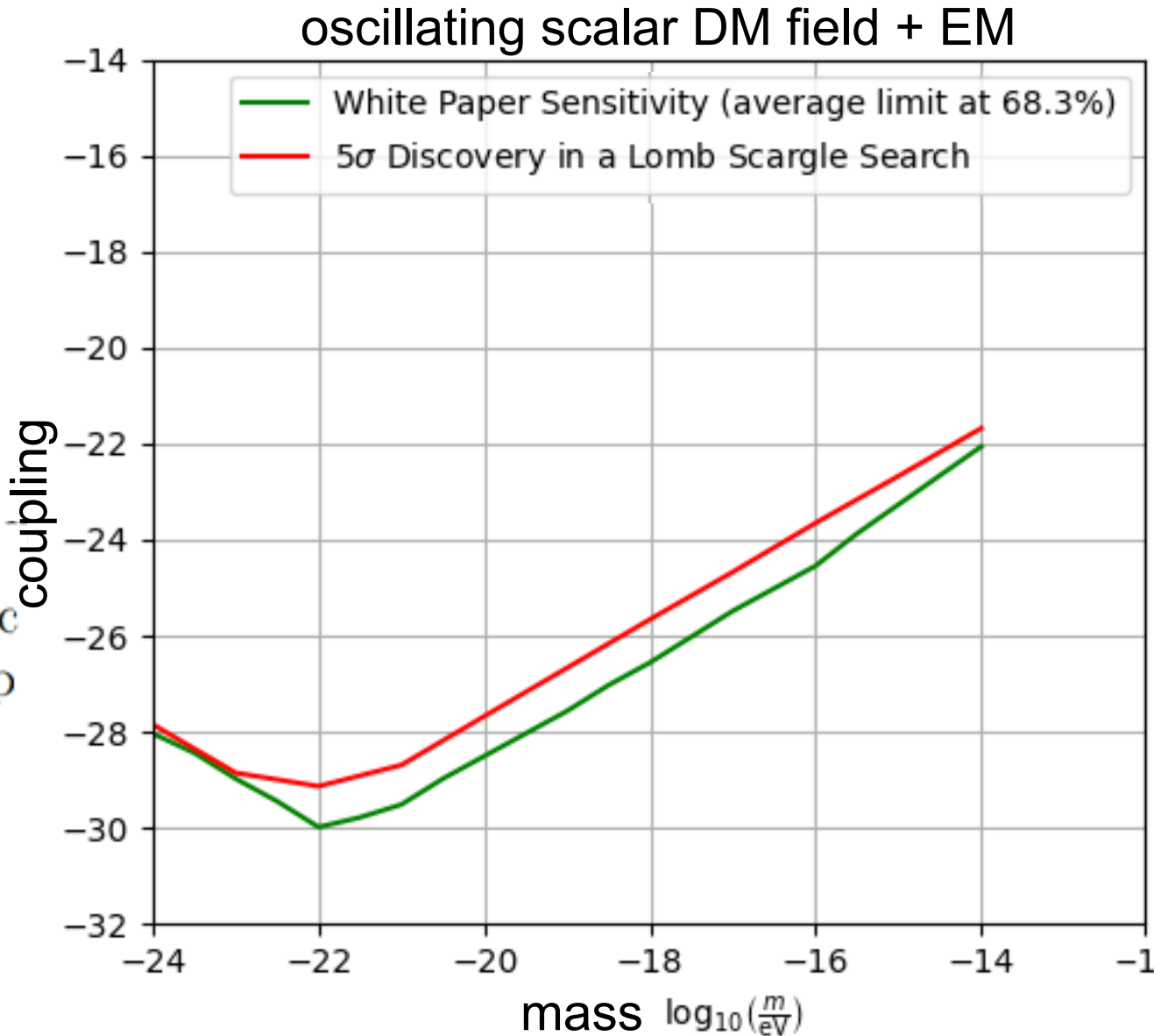
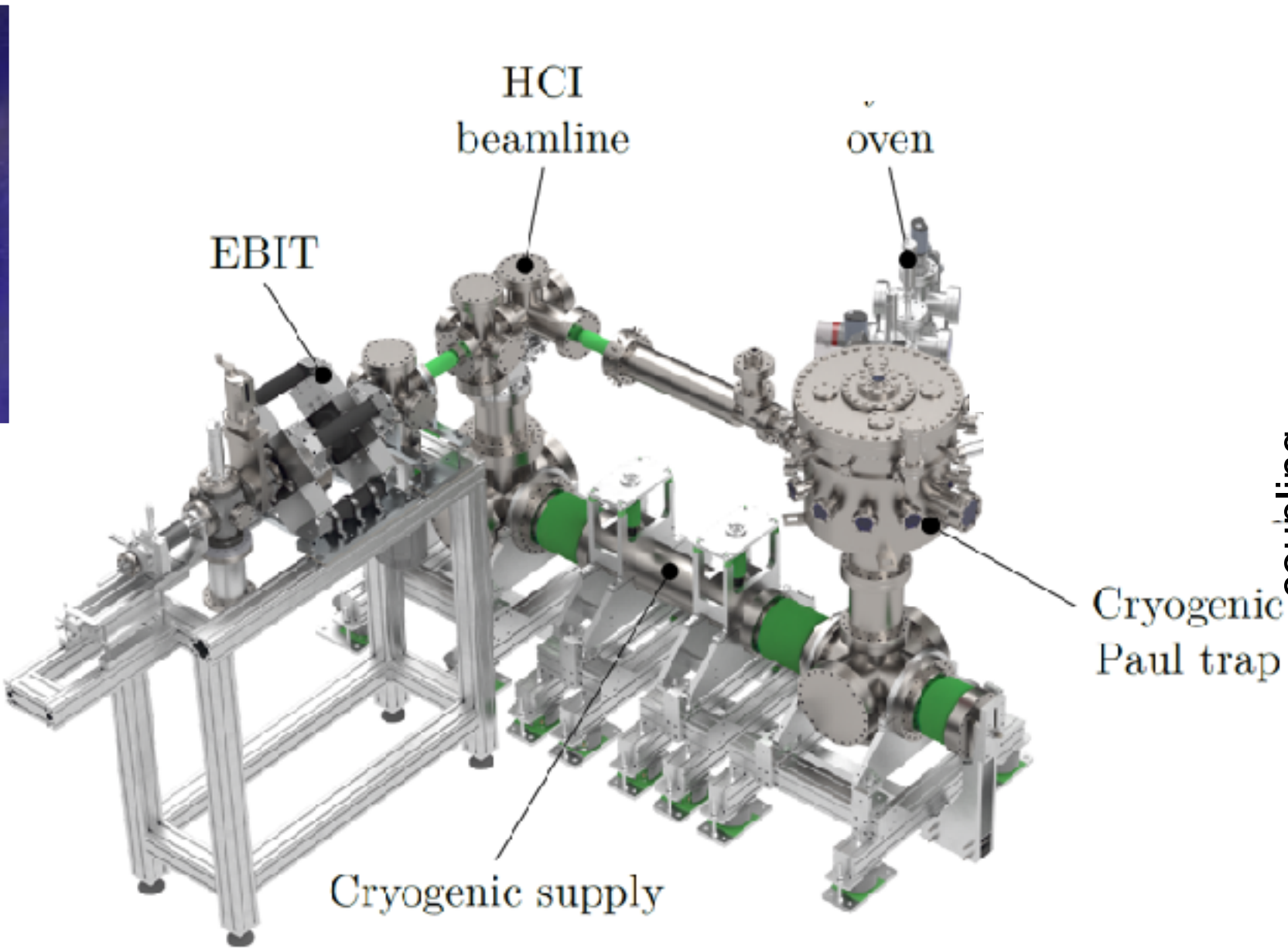
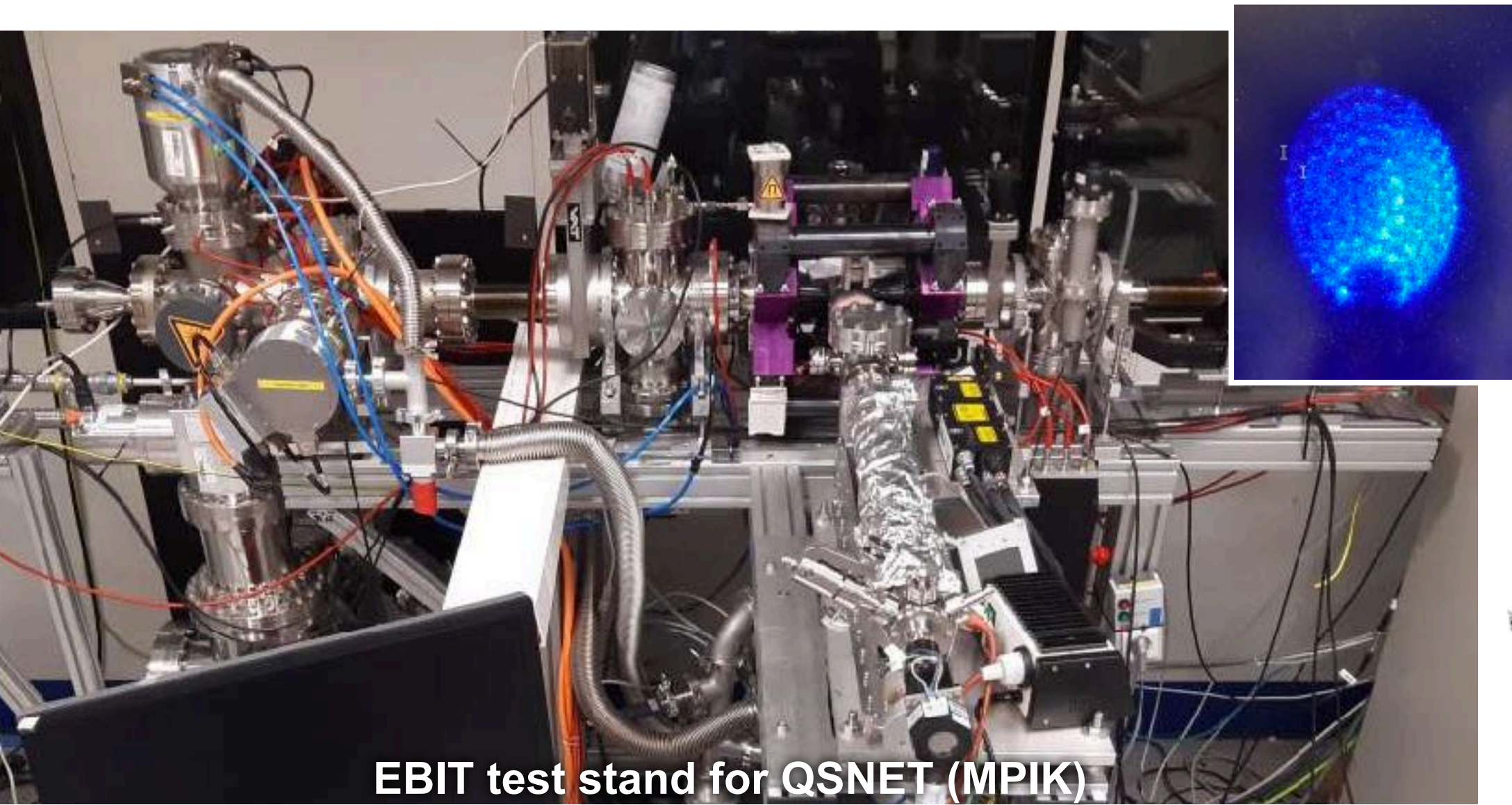


Quantum Sensing & QSNET

- Clock-based search for variations in alpha — optical atomic clock based on trapped, highly charged ion
- QS essential for ultra-light Dark Matter (eg axion/ALPs)
- Physics beyond colliders: fantastic new tools lead to new, innovative table-top experiments (QSNET)
- Strong links to quantum computing, AP, FS...



Dark matter, topological defects



DESY R&D Research Infrastructure

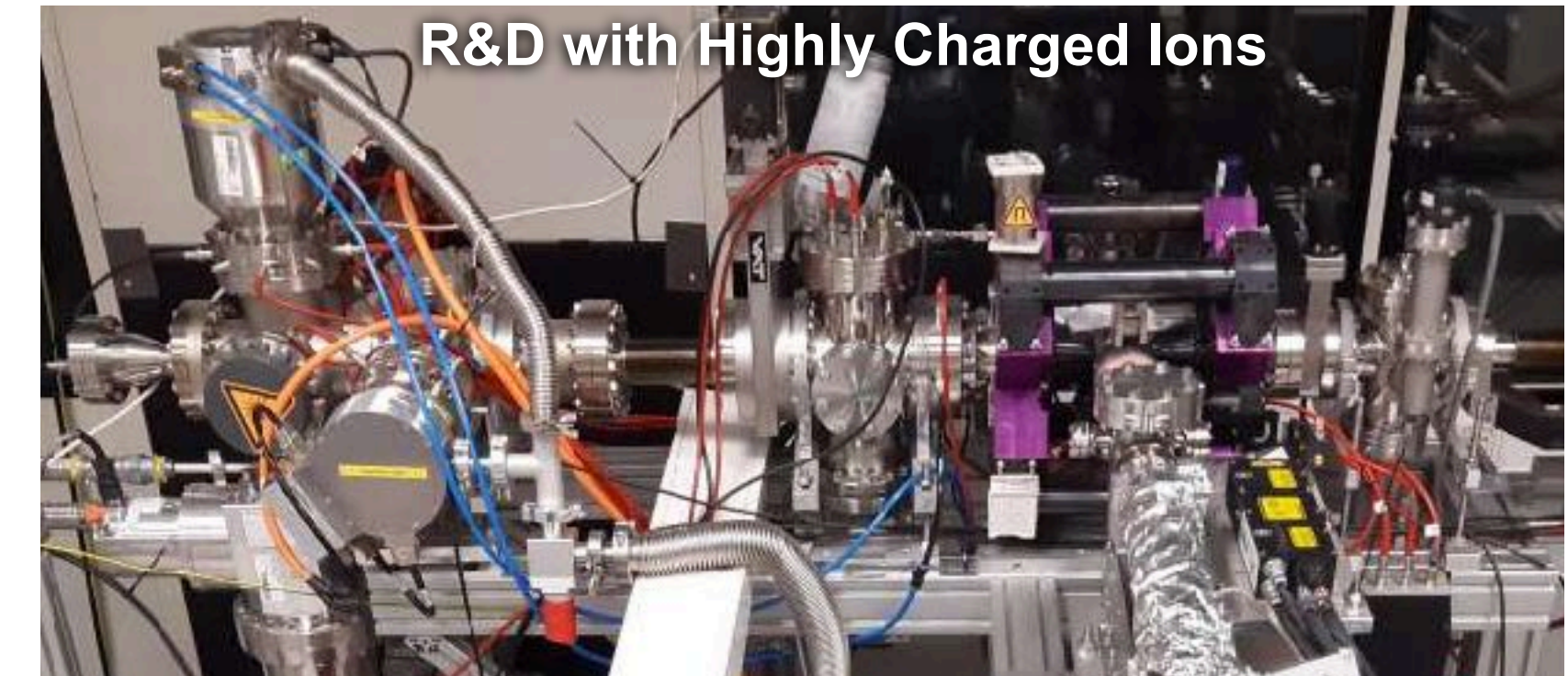
Project-Funded Infrastructure

- ATLAS cleanroom, Bohnsdorf facility, Spectroradiometric Calibration Facility, ULTRASAT TVAC, IceCube R&D facilities, PITZ test facilities, electronics & mechanical (3D printing)



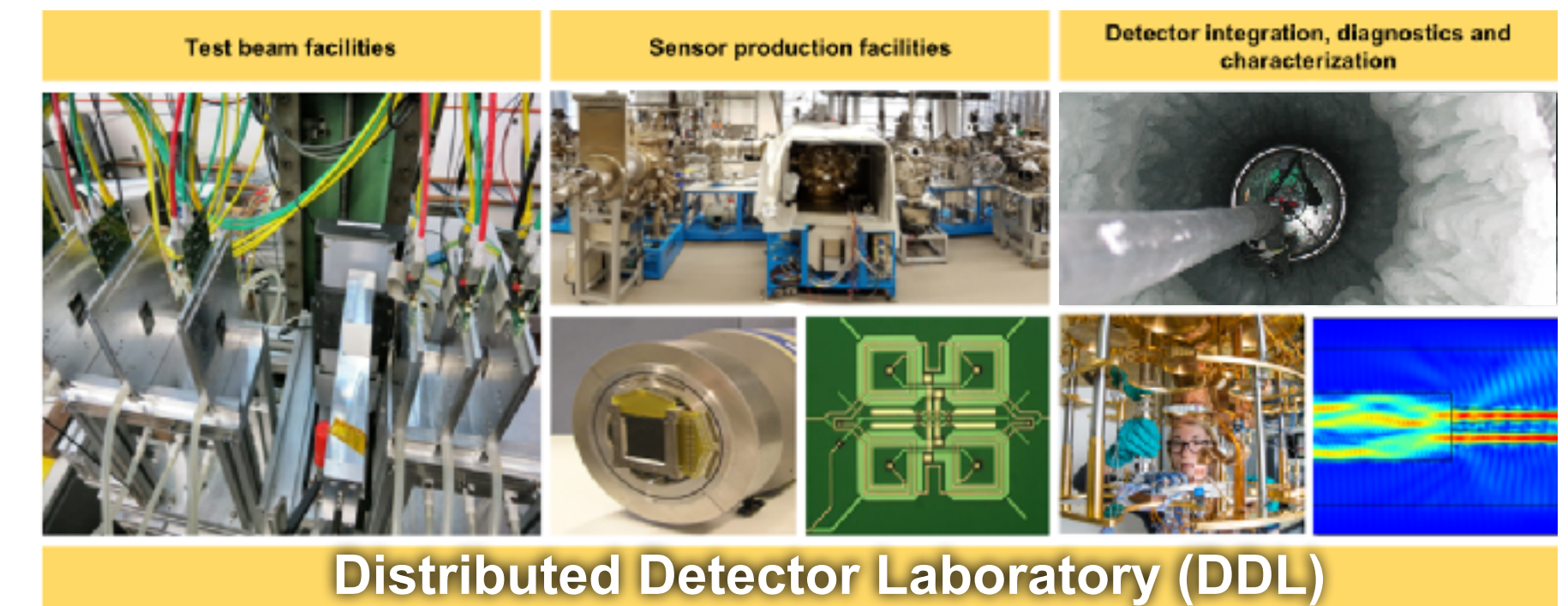
Center for Quantum Technologies and Applications (CQTA)

- Brandenburg funding for quantum computing & applications, sensing (€15M)
- Quantum Computing: Algorithms and Applications
- Quantum Sensing for fundamental physics, ultra-light Dark Matter



Det. Lab. for Extreme Environmental and Operational Conditions

- Part of Helmholtz €31M Distributed Detector Laboratory (DDL)
- Positive review by Helmholtz, funding decided in October?
- **Harsh, remote environments:** desert, polar regions, deep sea, outer space
- **High-spec:** detectors with low power, remote ops, high reliability, scalability
- **Precise:** low noise, sub-nanosecond timing/triggering over large distances



Group, Funding & Commitments

- **Group:** S. Worm + **PhD:** V. Berlea, L. Kozhiparambil-Sajith, F. Riemer **MS:** S. Kreienbaum, L. Fasselt
- **Pending hires:** staff position (QS), new postdoc (QS), new student (silicon), tech (2023+)
- **Funding:**
 - W3 Professorship Funds (Helmholtz) 360 k€ — startup, support of group budget
 - Lab Infrastructure (Brandenburg) 307k€ — equipment for electronics+mechanical shops, detector group
 - CQTA (Brandenburg) 15 M€ (~1/3 for QS) — quantum sensing, QSNET, connection to quantum computing
 - QSNET (UK) 3.7 M£ (no direct funding) — international collaboration building EBIT + trap demonstrator
 - DDL (Helmholtz) ~1.3 M€ (pending) — Hall refurbish, cleanroom and group lab space, ITT support
 - CISLAC (DLR) ~1.6 M€ (pending) — EBIT + trap for highly charged ion clock, fibre infrastructure, networking demonstrator, postdoc, students

Seven Questions: Silicon MAPS

- 1. Where are our scientific and technological gold mines?
 - large-area custom MAPS for science
 - essential tech for almost any new FH or gamma AP experiment
- 2. What are our future applications fields ?
 - custom imaging for science a huge growth area for all of DESY; FH, FS, AS, M, ...
- 3. What are our mission-critical research infrastructures? (local/current)
 - testbeams (PITZ, DESY-HH)
 - cleanrooms
 - we are one of only a few places with critical (engineering) mass to develop new technologies
- 4. What are further RIS with high discovery potential? (global/future)
 - satellite/space applications, new collider experiments
- 5. What are DESY obligations in international collaborations?
 - part of active international R&D efforts (eg with CERN)
 - well placed in international organisation of R&D (eg CPAD)
- 6. How can we increase the societal impact of the lab? (global challenges, mitigation of global warming)
 - huge range of scientific and industrial applications: need better coordination with ITT, e.g. via Distributed Detector Lab (DDL)
- 7. How do we set up our service groups, deal with lab space?
 - small footprint, but existing efforts need improved coordination and facilities (DDL)
 - Support is currently project-driven: expand internal R&D funding?

Seven Questions: FLASH@PITZ Dosimetry

- 1. Where are our scientific and technological gold mines?
 - global impact on cancer treatment
- 2. What are our future applications fields ?
 - technologies underpin all medical treatment
- 3. What are our mission-critical research infrastructures? (local/current)
 - PITZ accelerator - unique facility to test beam parameters
 - particle testbeams (PITZ, DESY-HH)
 - cleanrooms
- 4. What are further RIS with high discovery potential? (global/future)
 - good position globally to contribute to next-gen RIS
- 5. What are DESY obligations in international collaborations?
 - part of active national R&D efforts
- 6. How can we increase the societal impact of the lab? (global challenges, mitigation of global warming)
 - project is all about societal impact
- 7. How do we set up our service groups, deal with lab space?
 - benefits from consolidation and improvements from DDL
 - service support: needs investment seeded by external funding

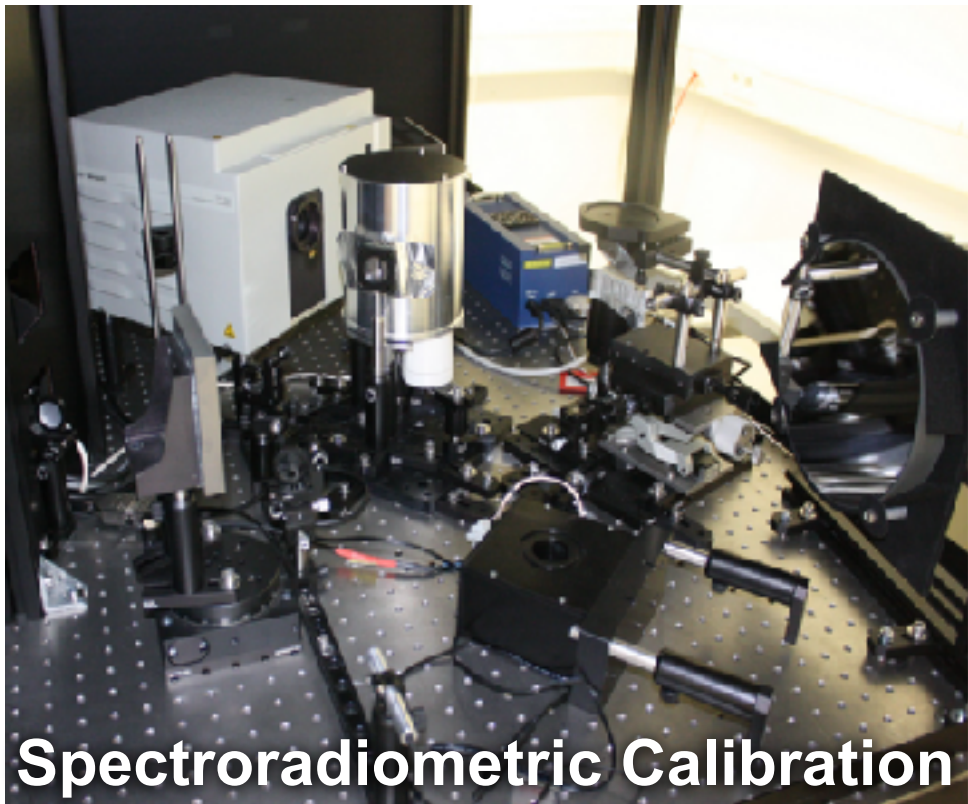
Seven Questions: Quantum Sensing + QSNET

- 1. Where are our scientific and technological gold mines?
 - Discover ultra-light Dark Matter!
 - incorporation of Quantum Sensing at DESY: essential for light particle searches; future path for FH and AP sensing
 - supports and builds CQTA
- 2. What are our future applications fields ?
 - novel techniques enabling a range of science: FH, AP, also FS
- 3. What are our mission-critical research infrastructures? (local/current)
 - vacuum, laser, cryo, cleanrooms... excellent support at DESY
 - expertise with data handling, analysis, statistics, algorithms
 - fibre link (and scientific link) to HU; Sr lattice clock reference
- 4. What are further RIS with high discovery potential? (global/future)
 - link to global activities building up at CERN, in US and UK, etc
 - space-based experiments
 - highly charged ions for FS, AP, etc...
- 5. What are DESY obligations in international collaborations?
 - building and operating QSNET w/ international partners
 - well placed in international organisation of R&D (eg CPAD, ECFA, CERN)
- 6. How can we increase the societal impact of the lab? (global challenges, mitigation of global warming)
 - informs our understanding of quantum computing (CQTA)
- 7. How do we set up our service groups, deal with lab space?
 - requires diverse support from service groups (see 3.)
 - DESY support currently minimal → 3rd party funding

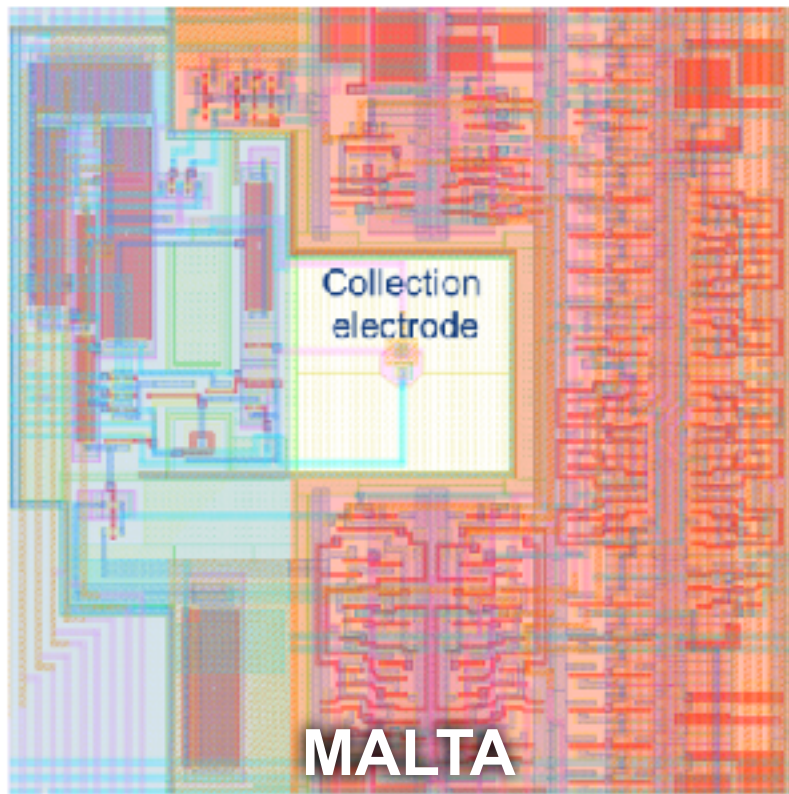
Detectors @ DESY Zeuthen



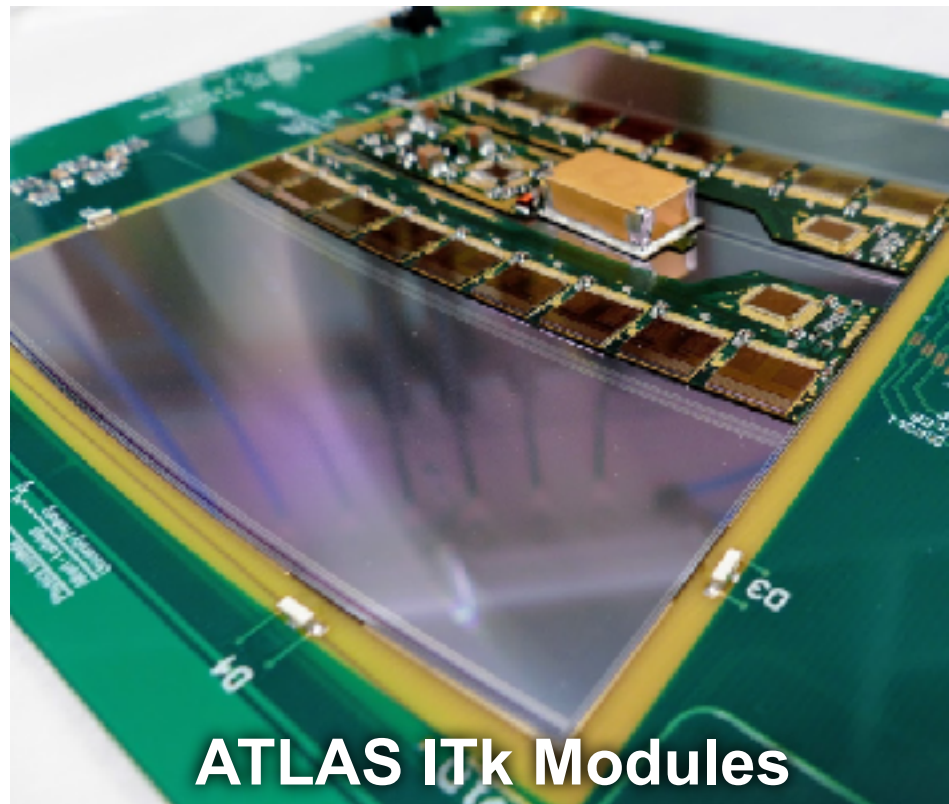
IceCube-Gen2 prototypes



Spectroradiometric Calibration



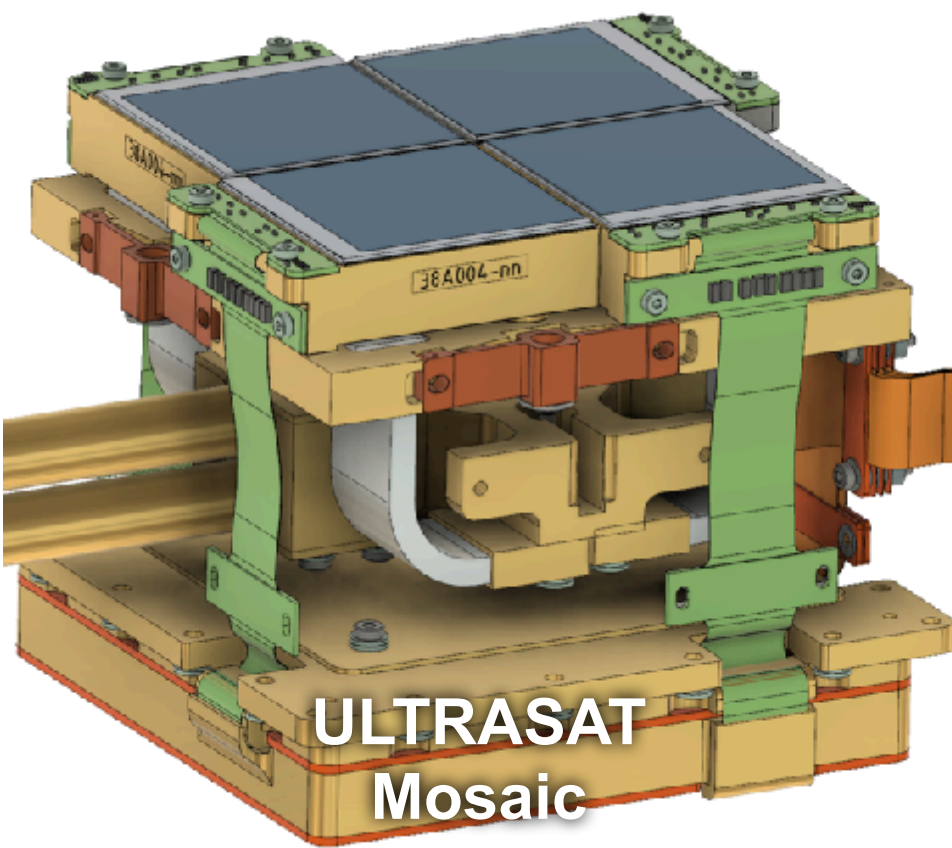
MALTA



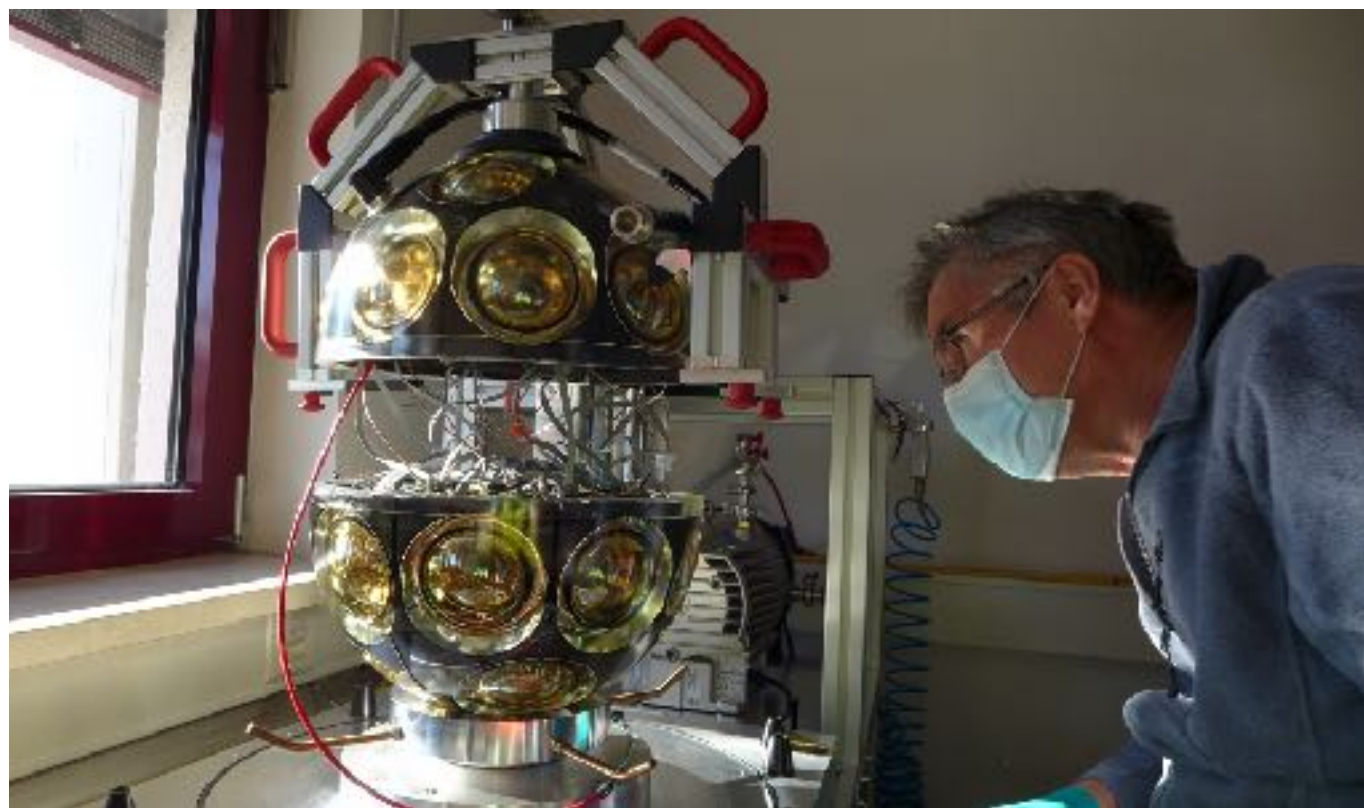
ATLAS ITk Modules



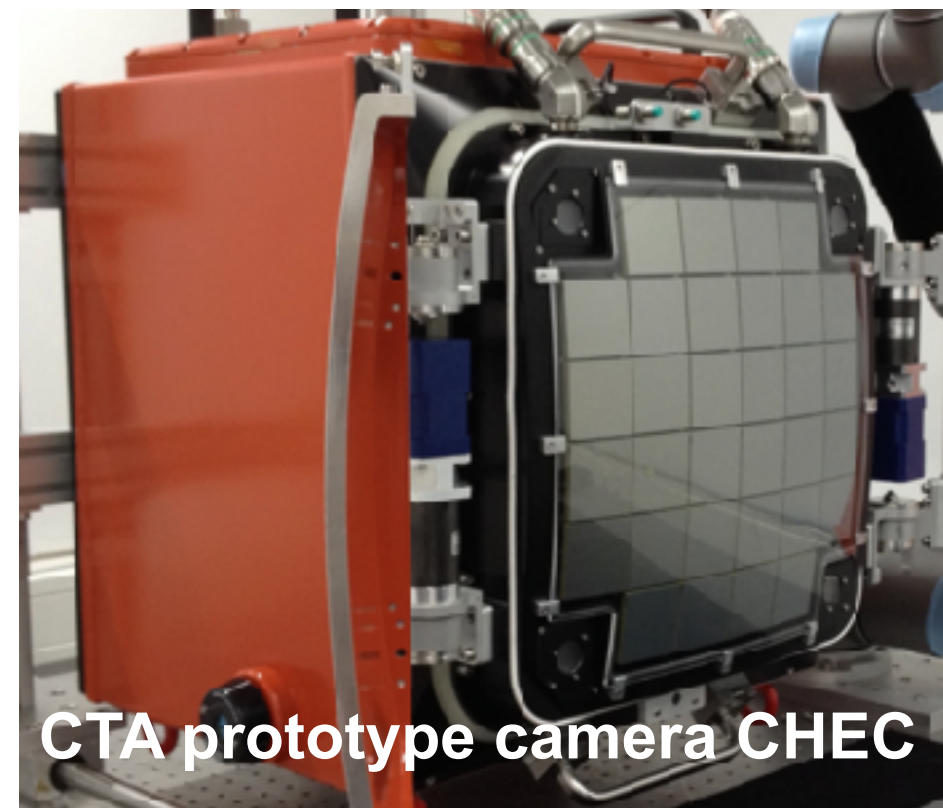
ATLAS ITk DAQ



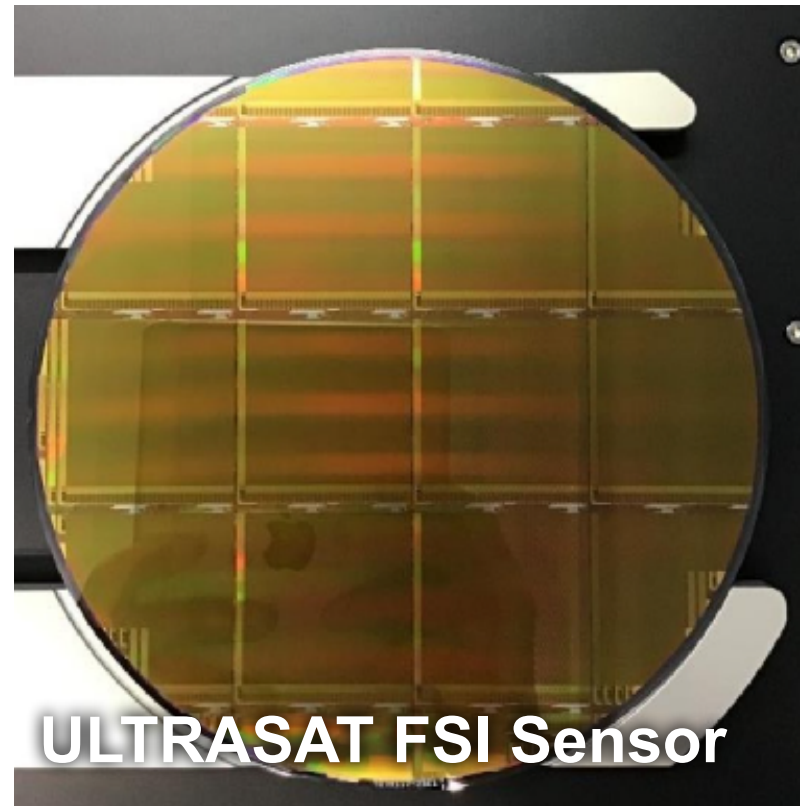
ULTRASAT Mosaic



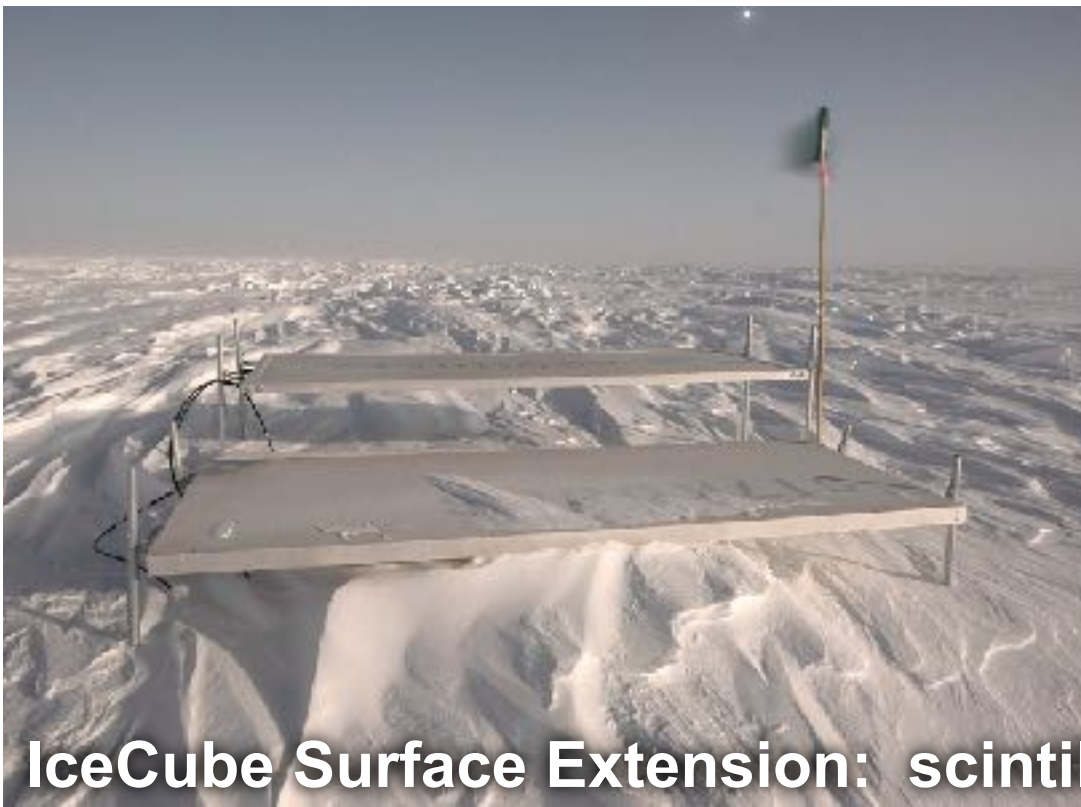
CTA prototype camera CHEC



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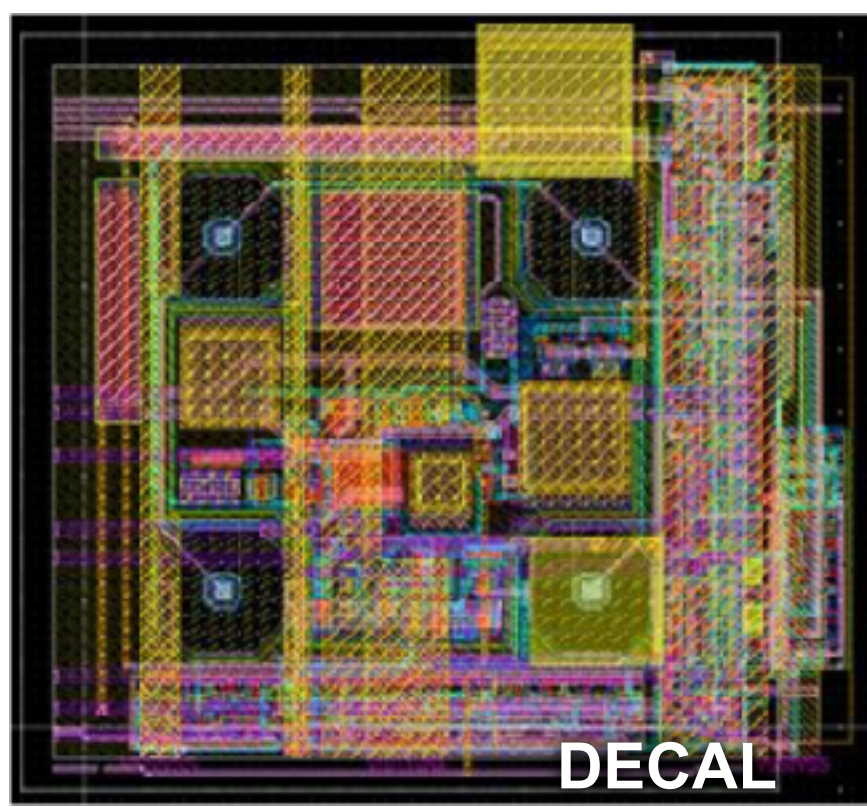
ULTRASAT FSI Sensor



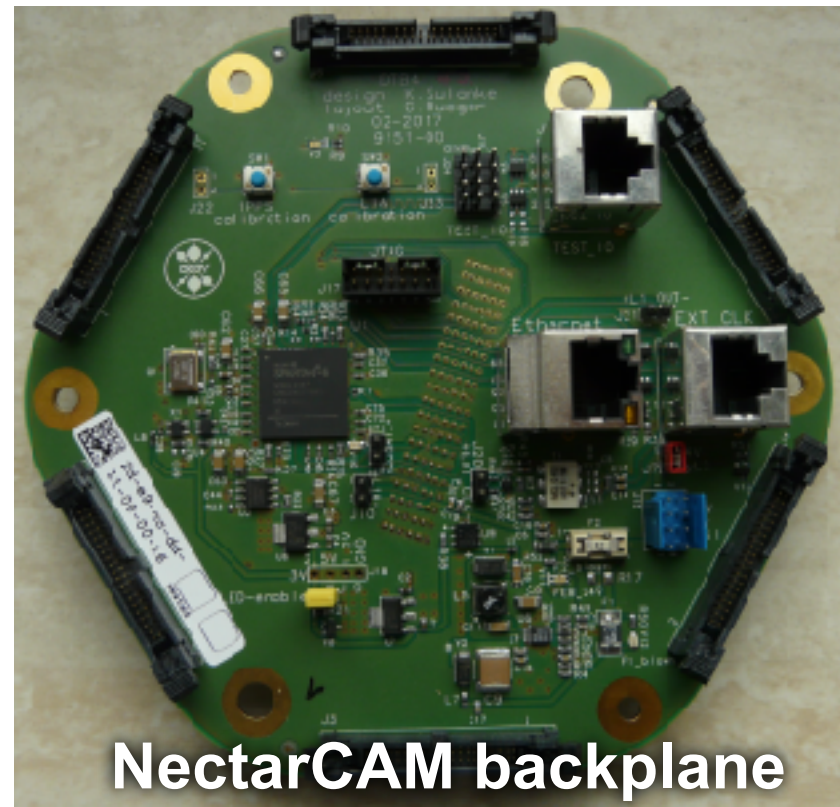
IceCube Surface Extension: scintillator + radio air shower array



IceCube Surface Extension: scintillator + radio air shower array



DECAL



NectarCAM backplane



CTA 12 m MST prototype