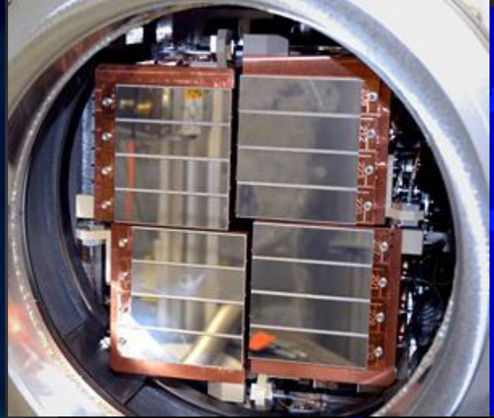
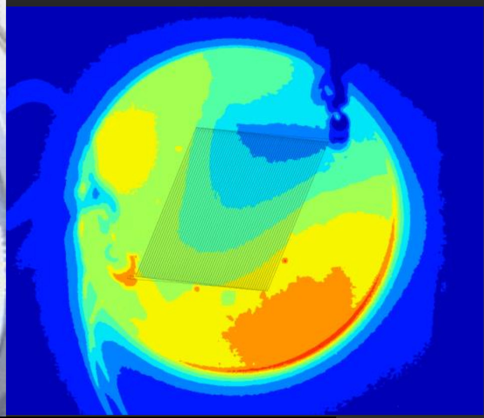
DTS ST3

Where do we stand, and where do we want to go?


Helmholtz Program: Matter and Technologies

PoF V Topic: Detector Developments and Systems

DTS contributing Centers

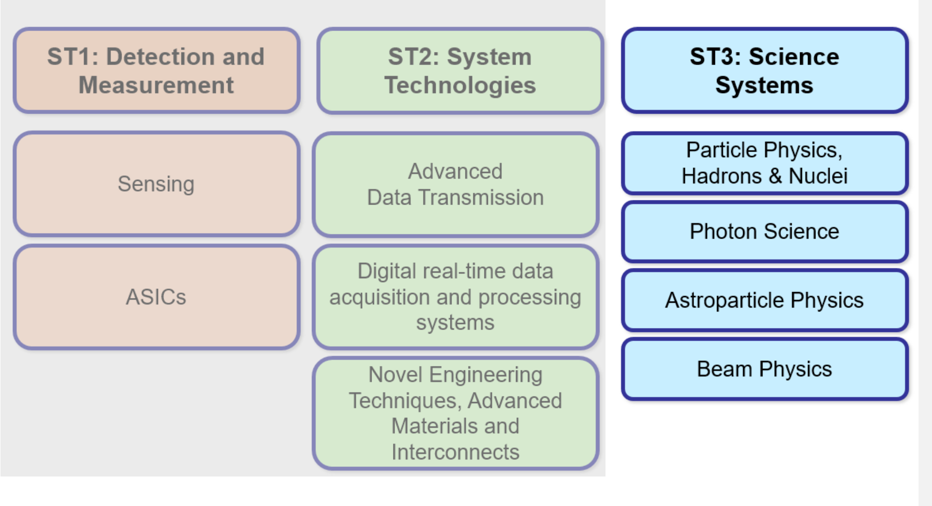
HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

MATTER AND TECHNOLOGIES

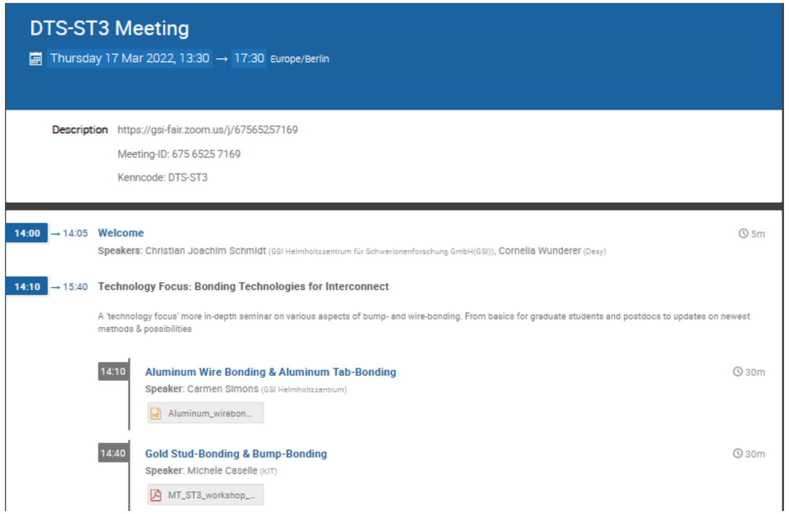
DESY

ST3 in PoF IV

- Subdivided by research area
  - WP Particle Physics, Hadrons and Nuclei *(Ch. Caesar GSI & I. Gregor DESY)*
  - WP Photon Science *(Michael Fiederle KIT & David Pennicard DESY)*
  - WP Astroparticle Physics *(Matthias Balzer KIT & Steven Worm DESY)*
  - WP Beam Physics *(Michele Caselle KIT & Markus Schwickert GSI)*
- Projects largely independent, motivated by science topic / center activities



- Communication – also for reporting etc – de facto often via (since formally established) ‘center representatives’ in addition to via WP leads
- Commenced Workshop (series) in an attempt to foster “grassroots” formation of cross-center and cross-science-topic collaborations – despite covid hurdles
  - Topical focus (2022: “Bonding”)
  - Ideas and Questions – inviting exchange at early steps
  - PoF Milestone progress talk (2022: MeV cube)


DTS-ST3 Meeting

Thursday 17 Mar 2022, 13:30 → 17:30 Europe/Berlin

Description https://gsi-fair.zoom.us/j/67565257169

Meeting-ID: 675 6525 7169

Kenncode: DTS-ST3

14:00 → 14:05 **Welcome** 5m

Speakers: Christian Joachim Schmidt (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)), Cornelia Wunderer (Desy)

14:10 → 15:40 **Technology Focus: Bonding Technologies for Interconnect**

A 'technology focus' more in-depth seminar on various aspects of bump- and wire-bonding. From basics for graduate students and postdocs to updates on newest methods & possibilities

14:10 **Aluminum Wire Bonding & Aluminum Tab-Bonding** 30m

Speaker: Carmen Simons (GSI Helmholtzzentrum)

Aluminum_wirebon...

14:40 **Gold Stud-Bonding & Bump-Bonding** 30m

Speaker: Michele Caselle (KIT)

MT_ST3_workshop_...

Some thoughts: ST3 in PoF V

- Retain subdivision by research area? Should we add Medical?
  - 4 WPs unchanged
  - 5 WPs (as before, add medical applications)
  - Other options to group projects within “Science Systems”?

- Aim should be for Projects to share/re-use e.g. subsystem components, ideally across scientific and center boundaries. ST3, and DTS, to foster this

- Ease communication –
  establish a once-a-month zoom within ST3 including WP leaders, open to more participants? Within DESY, the circle that did the core DTS work for PoF IV kept meeting, and this has fostered a better understanding and ultimately more collaboration/synergies. Try this on ST3-level?
- Continue/establish Workshop series
  (how often? Yearly, every 2nd in-person?)
  structure of 2022 workshop fits well (topical focus, questions, milestone report)

? alternative structure ?

ST3: Science Systems

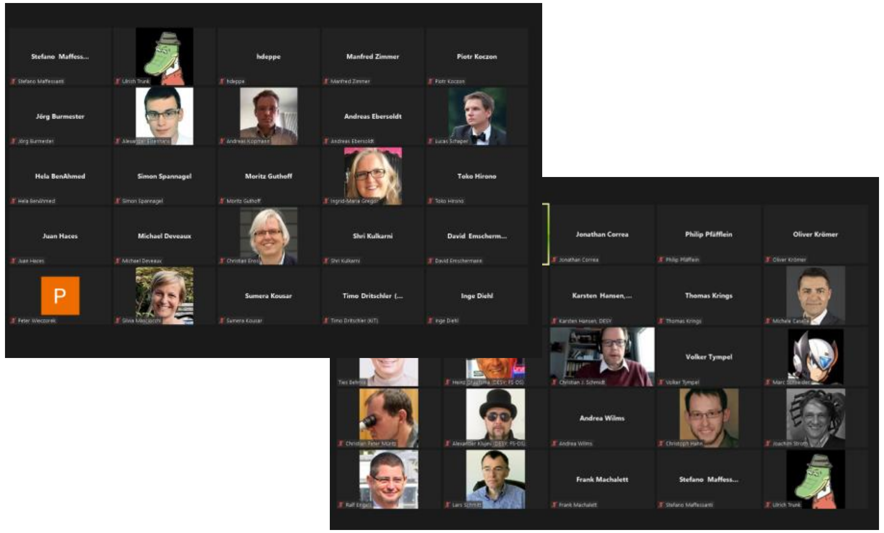
Particle Physics, Hadrons & Nuclei

Photon Science

Astroparticle Physics

Beam Physics

? Medical ?



PoF IV Milestones for ST3

	Milestone	Year	status
DTS-1	Establish and commission the DDL	2025	proposal failed
DTS-11	Evaluate the performance of a Compton detector in the high-keV to low-MeV regime	2022	done 2022 – MeV-cube talk @ ST3 workshop
DTS-12	Assemble a Si beam telescope system demonstrating at the same time ultrafast timing, high spatial resolution, and ultralow X/X0	2024	Alpide-based demonstrator by end 2024 @ DESY done: Telepix demonstrator @ KIT done: LGAD-Teleskop @ GSI
DTS-13	Operate routinely a 1k-pixel cryogenic MMC sensor array for precision QED tests at CRYRING	2025	Operated 2x64 pixels @ CRYRING in 2023
DTS-14	Provide a pixelated THz detector combining spectral, space, and time measurement for beam diagnostics	2025	KIT THESTRAL tuned 16x16 pixel prototype to be operative 2025
DTS-15	Bring into operation a highly granular 5D (position, time, energy) calorimeter prototype with SiPM readout	2026	Improved timing 2022 DESY not as much progress as hoped, for DESY work expect ~few yrs later KIT contr. DAQ (CMS track trigger)
DTS-16	Demonstrate a hybrid pixel system capable of matching CW FEL bunch rates with advanced (optical) data transmission	2027	DESY CoRDIA timeline matches. KIT working on optical transmission, first tests 2024.

Current Status
Project collection

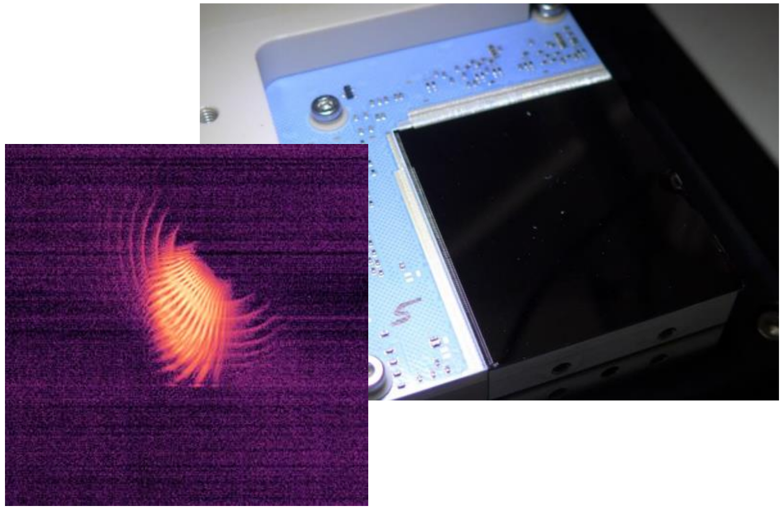
Part I: “done by 2028”

Percival 2-Megapixel soft X-ray CMOS imager

Single photon to 50000 photons, 250-1000 eV, up to 300 Hz frame rate, 4x4cm2 imaging area

Photon Science
end before 2028

- Large-area BSI-processed soft X-ray imager for FELs and synchrotrons
- Meets key challenges simultaneously:
  multi-Megapixel, fast (300kHz, more in ROI), low noise (15e-) & high dyn. range
- Successful pilot user experiments with prototype sensor 2020-2023
- Respin sensor (crosstalk & ‘bathtub’ problems removed) in hand Jan 2024,
  BSI-processed respin system expected ready for commissioning mid-2024
  System upgrade for full 300Hz+ speed by early 2025



- **Why is this cool?**
- The unique COMBINATION of features
- System developed in international collaboration of institutes, lead at Helmholtz (DESY)
- Combination of dynamic range, speed, and size remains competitive (despite project delays incurred)
- Could become testbed for edge data reduction

Contact: cornelia.wunderer@desy.de

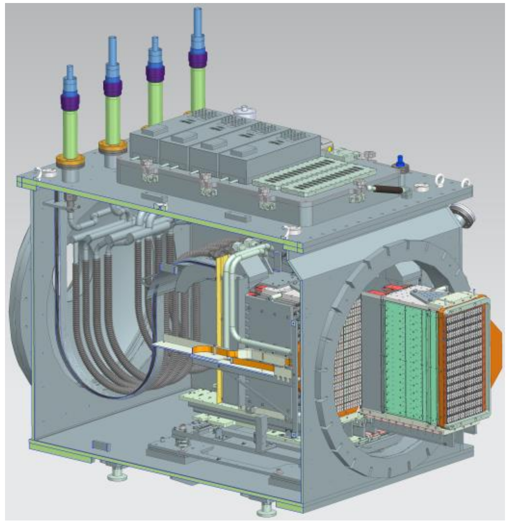
- **Links to others?**
- D MA: 20 Gbit/s raw data stream (+ overhead, metadata)
- ST2: communicate from vacuum over few optical lines, cooling approaches
- Other soft X-ray applications, low-energy electrons

- RutherfordAppletonLaboratory (UKRI/STFC, UK), Elettra Synch. Trieste (Italy), Diamond Light Source (UK), Pohang Accelerator Lab (Korea), Soleil (France)

2nd Generation AGIPD Systems for EuXFEL

Photon Science end before 2028

- Development of new AGIPD systems for EuXFEL user consortia based on new readout electronics
- 4MPix AGIPD system for SFX user consortium
- 1MPix AGIPD system for HIBEF user consortium
    - Initially equipped with Silicon sensor Front-End Modules (FEM)
    - High-Z FEMs (electron-collecting ASIC and sensor) under development
- Systems planned to be installed end of 2024



- **Why is this cool?**
- Improved performance compared to 1st generation systems due further optimised cooling system
- Modular readout electronics simplifies integration, operation and building of systems in other sizes, such as a single module system.
- Development of High-Z FEMs enables science at higher photon energies

- **Links to others?**
- High data rates (>0.5 Tbit/s for 4Mpix system) leads to links to DMA: data processing and reduction
- Collaboration with EuXFEL

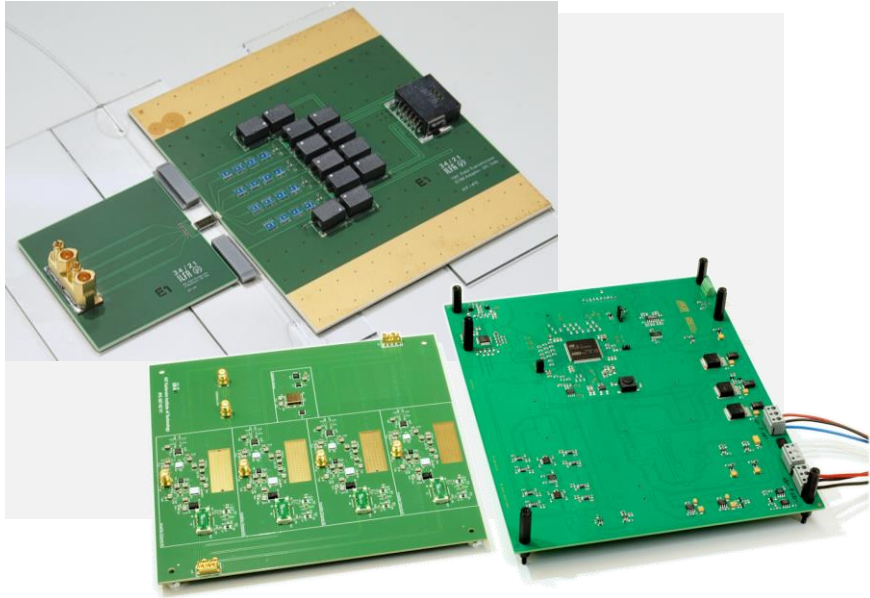
Contact: torsten.Laurus@desy.de

Silicon photonic demonstrator

Silicon photonic, wavelength division multiplexed data transmission

?? ST3 or better ST2 ??
end before 2028

- Optical data transmission between silicon photonic transmitter chip and COTS receivers using wavelength division multiplexing
- Transmitter chip includes silicon photonic Mach-Zehnder modulators and optical (de-)multiplexers for 4 wavelength channels around 1550nm
- Transmitter core ready with electrical connection boards and optical fiber-chip-coupling set up; electronic driver and slow control under test; single channel receiver ready, multi channel receiver in progress
- First tests expected in Q1/2024, system running in Q3/2024



- High bandwidth data transmission from detector to counting room (40 – 128 Gb/s/fiber)
- Scalable to many more wavelength channels
- Silicon photonic devices can be made extremely radiation hard (1.2 Grad(SiO_2) TID demonstrated)

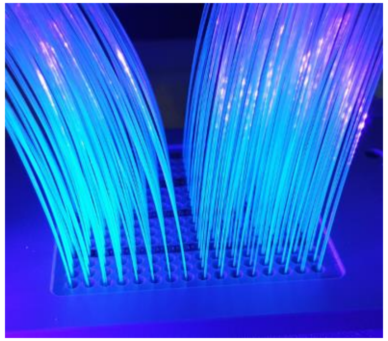
- **Links to others?**
- DTS-ST1 and ST2
- CERN DRD7
- Desy???

Contact:
Marc Schneider, KIT, marc.schneider@kit.edu

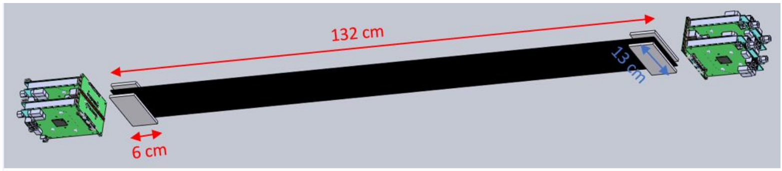
SciFi Tracker

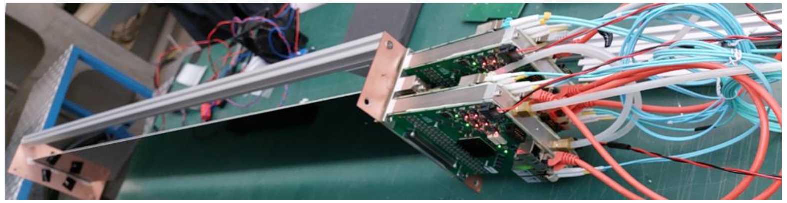
Ions
end before 2028

Scintillating Fiber based 4d Tracker @ High Rates and with Large Dynamic Range



- Large-area 4d Tracking detectors build from Scint. Fibers + MAPMT or SiPM
- designed for tracking of ions (in NUSTAR)
- Meets key challenges simultaneously :
  - large area(up to approx. 200 x 100 cm2)
  - large dynamic range (p to U)
  - low material budget
  - Fast, readout electronic designed @ GSI-EE (PADI ASIC + FPGA TDC) 128 ch module with 200ps time resolution, includes ToT measurement
- First detectors used in beam times (2018@KVI / development ongoing).
- to come in near future :
  - Proton Arm Spectrometer (PAS): multi layer ribbons for detection of protons
  - optimization of ‚form factor‘ and cooling for usage @ SuperFRS for beam tracking





Why is this cool?

- One huge advantage of using fiber ribbons as active volume is the geometrical flexibility.
- The low material budget and, last but not least, cost are additional positive factors.
- evolution of the 3D-printing technique might pave new roads.
  - inspired by e.g. photonic wire bonding one could think of printing scintillating fibers

Links to others?

• so far developed at GSI in collaboration with TU Darmstadt and Uni Frankfurt
• Besides the ’classical’ tracking detectors (e.g. LHCb upgrade) also beam monitors for e.g. therapy applications have currently been developed based on scintillating fiber ribbons.

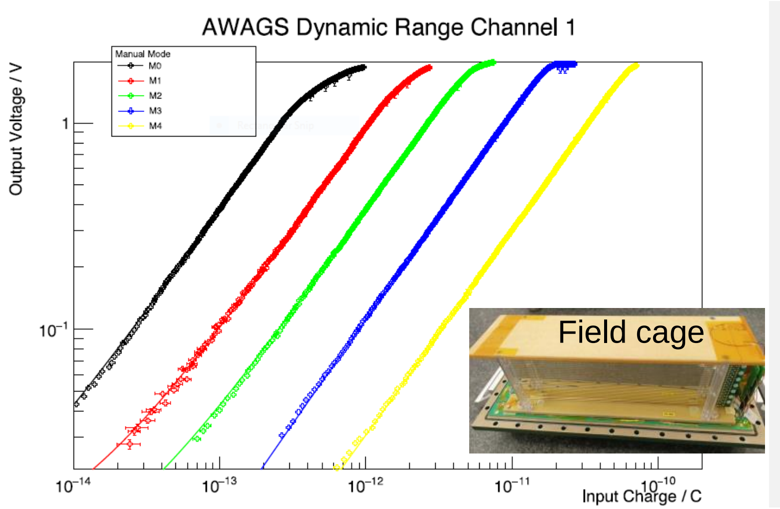
project proposer: Christoph Caesar C.Caesar@gsi.de
Deniz Savran D.Savran@gsi.de
Michael Heil M.Heil@gsi.de

Tracking detector for heavy ions

Particle / Ions
End before 2028

TPC at atmospheric and low pressure with huge dynamic range: from proton to uranium ions detection.

- The Time Projection Chamber is successfully used as tracking detector for beam diagnostic in heavy ion beams facility (FRS and planned at Super-FRS and beyond)
- Readout in strips of 0,25 mm with a 0,4 mm pitch
- 400 mm x 100 mm beam acceptance
- Ar/CH_4 (90/10) starting gas mixture, but targeting no flammable gases with low transverse diffusion coefficient
- Rate capability of double detector with opposite drift fields up to 2 kHz/mm^2
- 5 gain amplification in manual or automatic mode and signal digitisation on chip and optical output



- **Why is this cool?**
- Position determination (x,y coordinates)
- Very low material budget
- Uniform drift field
- The CTR16* is a compact FEE (analog and digital part in one ASIC)
- The CTR16 is based on the AWAGS** input stage charcterised by the huge dynamic range
- Radiation tollerant ASIC

*H. Flemming, et al., JINST 17 (2022) C07002
**P. Wieczorek, et al., JINST 17 (2022) C06010

- **Links to others?**
- The FEE has been designed and developed by the EE department at the GSI
- Field cage concept, design and production by B. Voss (GSI)
- Initiating collaboration with TU Darmstadt (Obertelli) and INFN Frascati (Bencivenni)
- At GSI: H. Flemming, S. Löchner, C. Nociforo, E. Rocco, P. Wieczorek

Contact: c.nociforo@gsi.de

UHV particle detectors

Beam Monitoring
AstroParticle
Presume end before 2028?

Low-energy heavy ion detection under extreme conditions

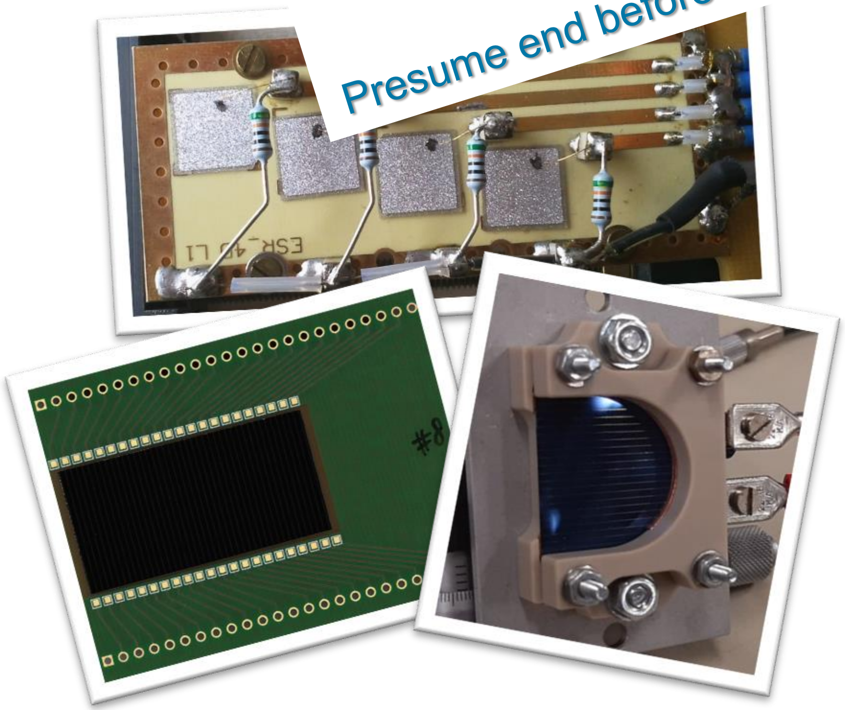
- **high performance ion detection** in ultra-high vacuum (UHV) is the basis for advanced storage ring experiments in atomic & nuclear physics

  minimum requirements: *- energy, time and/or position resolution*

  - low outgassing rate and in-situ bakeout

  project goal: ***- detectors with improved radiation hardness***

- separate approaches are persued for different experimental demands
  - diamond detectors [first prototype accomplished]
  - solar cells [two prototypes tested, updated versions planned for 2024]



Why is this cool?

- radiation hard detectors suffer less damage by implanted ions
  - ➢ long-term usage & less frequent replacements
  - ➢ reduced downtime and vacuum breaking of the storage ring
- performance comparable to systems in standard environments
- the new detection systems will facilitate in-ring reaction studies with low-energy ions as envisioned at CRYRING@ESR

Links to others

- DTS-ST3: Astro particle physics
- ARD: the easy handling and robustness of solar cells makes them a good choice for beam monitoring in heavy ion accelerators (e.g. UNILAC)

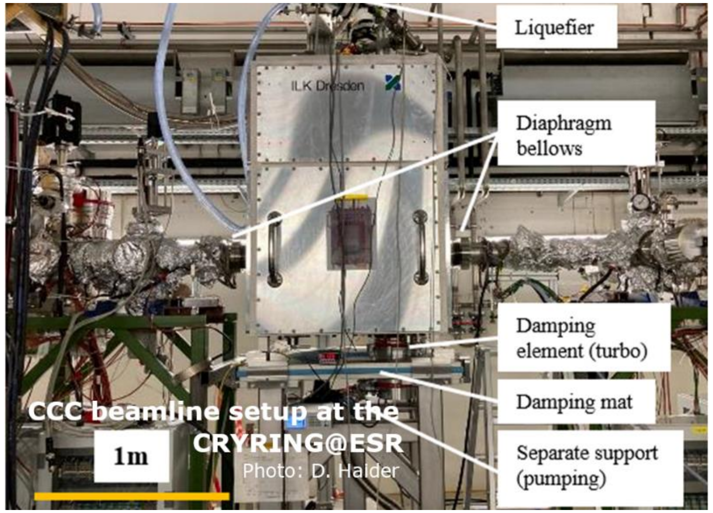
Participating centers/institutes: GSI & HI-Jena
PI/Proposer: J. Glorius, A. Gumberidze
Partners: FH Aachen, LP2iB Bordeaux

Cryogenic Current Comparator Detectors

Particle/Ion
Beam Diagnostics
?? End before 2028 ??

Development and optimization for ultra sensitive beam intensity measurements in storage rings/ transfer sections

- Development and optimization of a SQUID based sensor setups for measurement of beam currents on nano-ampere scale in storage rings and transfer sections
- Superconducting pickup coils and sc magnetic shield for high resolution detection of the beam's magnetic field
- Effective suppression of electromagnetic noise by superconducting magnetic shield
- Dedicated CCC system installations at FAIR and CERN in transport sections



- **Why is this cool?**
- CCCs are the only non intercepting devices for beam current measurement in nano-ampere range, means for precise intensity calibration for physics experiments
- Present studies reveal possibility to improve detection threshold using dual-core sensors
- Expansion of the dynamic range through the use of multi-SQUIDs

- **Links to others?**
- DTS ST3: Tunneling Magneto Resistance Beam Current Transformer
- ARD ST3: Novel beam instrumentation for high precision beam diagnostics

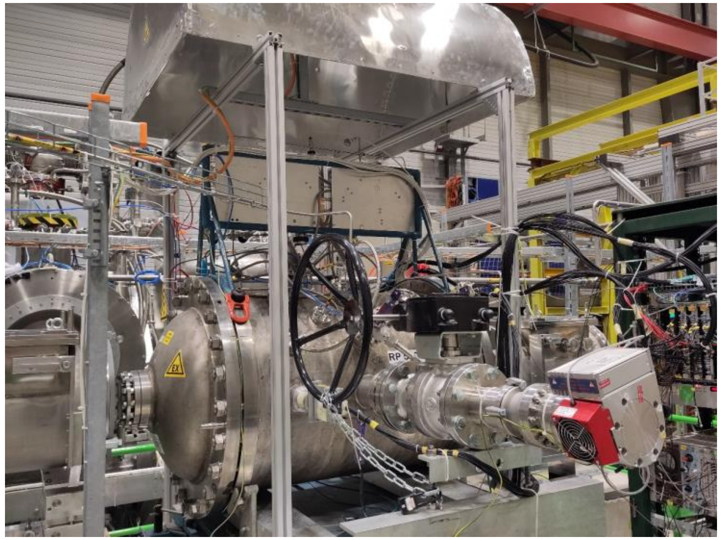
Participating centers institutes : GSI, HI Jena, CERN
PI/ Proposer : T. Sieber, V. Tympel, M. Schwickert
m.schwickert@gsi.de
Partners: Uni Jena, TU Darmstadt, IPHT Jena, Supracon AG

Multipurpose active targets

Ultra-clean high-pressure TPCs as active targets for nuclear and high-energy physics

Particle & beyond end before 2028

- High-pressure (up to 20 bar) TPC system as active target (target gas used as detection media by a particle detector)
- Ultra-clean device (gas impurities ≤1 ppm, with gas purification and circulation)
- No gas amplification → best achievable energy resolution
- Waveform collection → full information about recoil particles, 3D track reconstruction
- Smaller prototypes used for different experiments at GSI and CERN
- Full-size system planned in 2024/2025



- **Why is this cool?**
- enable performing top-level measurements not doable otherwise
- the unique COMBINATION of features – ultra-high-vacuum grade high-pressure device
- synergy - system applicable for nuclear and high-energy physics experiments
- development within an international collaboration of institutes and universities

- **Links to others?**
- DMA: up to 10 Gbit/s waveform data rate; data processing and reduction in an online CPU/GPU farm are crucial
- DTS-ST2: DAQ for large-size events; clean materials, cables, interconnects
- Knowledge transfer to medicine, chemistry, biology, material science (surface treatment, cleaning, high-pressure technique)
- Technical University Munich, University of Bonn, CERN, PNPI of NRC «Kurchatov Institute» (Russia)

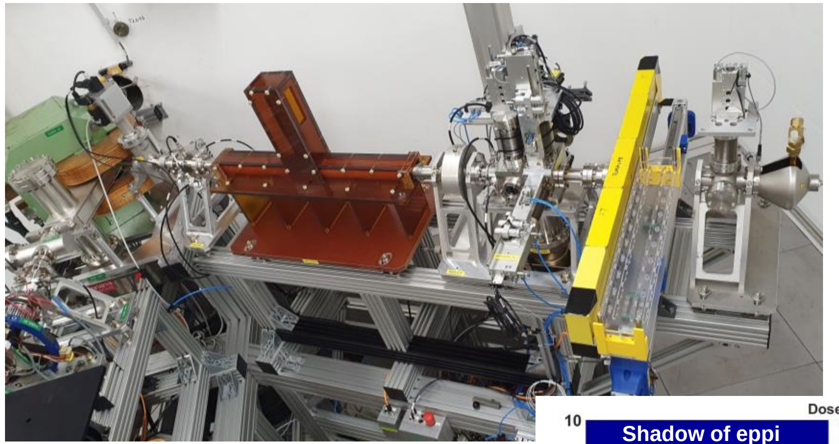
Contact: Oleg Kiselev GSI

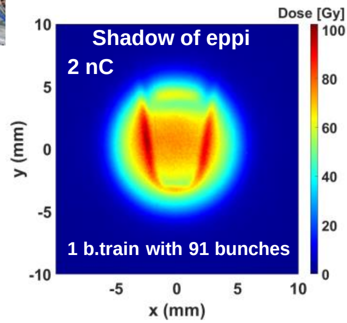
Dosimetry at FLASH*lab*@PITZ

Detector tests for medical applications such as radiation therapy at ultra-high dose rates

Beam diagnostics, Medical
? End before 2028 ?

- All existing active detectors suffer from saturation at ultra-high dose rates
- New beamline and a setup for in air & in water measurements was built in 2022
- Characterization of existing and development of new detectors
- Gafchromic films were established for reference dosimetry (BUT: readout 24h after irradiation)
- NitroFLASH project started in Sept. 2023 (for 3 years)
  → Modification of an existing florescence detector for ultra-high dose rates
- Extension of beamline is planned for 2024 (pre-assembling in progress)





- **Why is this cool?**
- Interdisciplinary project and a possible breakthrough in cancer research
- Worldwide uniquely wide parameter range available (16 orders of magnitude)
- Extremely flexible pulse structure for radiation (ps → µs → ms → s, min)
- Tight control and high stability of radiation

- **Links to others?**
  Dosimetry
- PTB (Alanine dosimetry)
- NPL (Transmission calorimeter)
- Charité (calibration with medical beam)
- Timepix 3&4

Biology
- TH Wildau, HZDR, dkfz, Charité, CHUV, Uni Hamburg, Uni Manchester

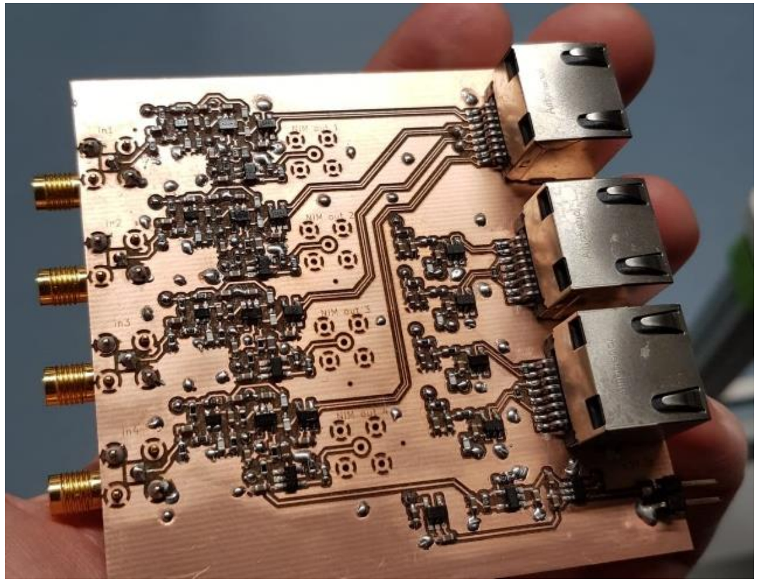
Contacts steven.worm@desy.de, frank.Stephan@desy.de

ToF detectors for heavy ion detection

Particle / Ion
end by 2028

Homogenious transmission detectors for fast timing/triggering and energy

- Fast homogeneous ToF detector for particle identification (σ_t = 20 ps for U ions) between focal planes at second-generation in-flight fragment separators
- Scintillator, SiC, diamond detectors
- Pulse-processing electronics architecture for photomultipliers coupled to fast scintillators (e.g. Twin_peaks_CFD1) under development at GSI-EE
- Multi-channel analogue FEE with discriminator (LED/CFD) and amplification stage for fast signals
- 4-ch FEE prototype (LED+TAMEX4) tested in December 2023 (see Figure)
- Test of radiation-hard sensors planned in March 2024



- **Why is this cool?**
- Precise timing at 1 MHz rate
- Radiation hardness (1 kGy/year)
- In-flight separation
- Precise momentum measurements
- Solid active target

- **Links to others**
- DMA: fast FPGA readout, trigger logic
- DTS-ST1: radiation-hard sensors
- Field: Nuclear Physics, Astrophysics, Medicine
- Involved partners: University of Catania, University of Milano, INFN Sez. Catania, INFN Sez. Milano, GSI, TU Darmstadt, INFN-LNS

Contacts c.nociforo@gsi.de

Current Status
Project collection

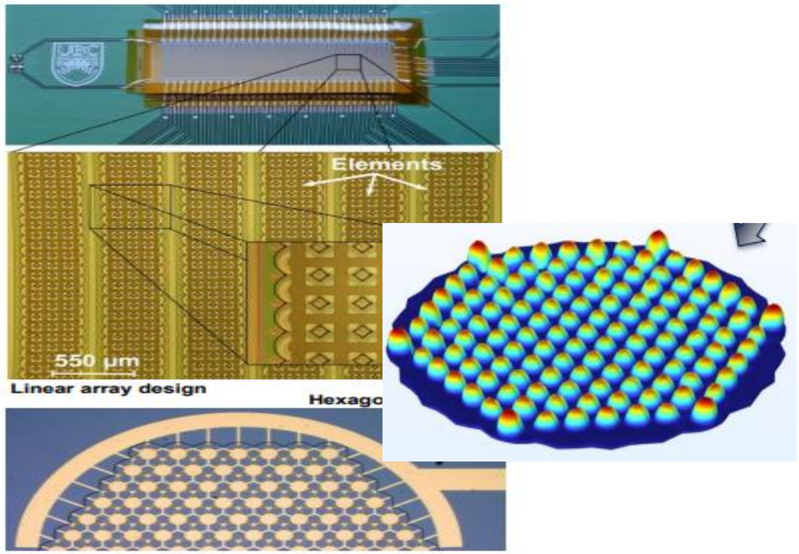
? Timeline unclear ?

CMUT based ultrasound transducer arrays (CMUTArrays)

medical
Timeline?
(?MT-DTS?)

Integration of groundbreaking transducer technology for ultrasound imaging and inspection systems

- CMUT-based ultrasonic transducers are a novel technology that offers many advantages over current piezo-based transducers, including wider bandwidth, better impedance matching, easier and cheaper production, and more integrated transducers.
- Combined with customized USCT ASICs and front end boards, more cost-effective and better transducer arrays could be developed for use in USCT, US sonography and materials testing. UBC's dedicated polyCMUTs have already shown great potential for use in USCT applications.



- **Why is this cool?**
- CMUTs are a disruptive technology for ultrasound transducers
- CMUTs can be manufactured directly in combination with dedicated ASICs, which can lead to much denser arrays
- The technology promises much cheaper and better ultrasound transducers
- Applications: USCT, sonography, material testing

- **Links to others?**
- MT-ST1 and MT-ST2
- Medical technology in MT (ultrasound imaging, wearable applications,...)
- UBC Vancouver (CA)

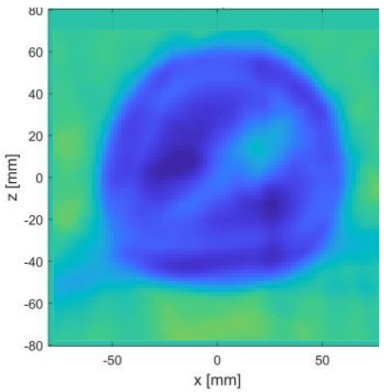
Nicole Ruiter / nicole.ruiter@kit.edu, KIT

3D USCT for FWI and Paraxial (paraxUSCT)

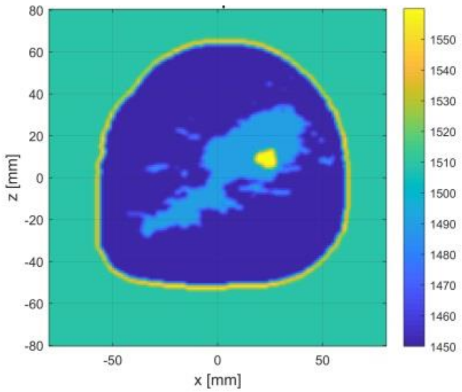
medical
Timeline?
(MT-DTS?)

Low frequency 3D ultrasound tomography device for highly advanced imaging algorithms

- More advanced image reconstruction methods require ultrasound signals with significantly lower frequencies.
- This is technically very demanding - suitable ultrasound transducers and electronics are not available.
- Speed of sound and attenuation images in submillimeter resolution with MRI-like quality are possible
- Enables extending the range of applications of ultrasound tomography systems: due to the lower absorption of frequencies below 1 MHz, structures containing bone can also be imaged, e.g. brain, joints, abdominal cavity



Ray-based reconstruction



Paraxial approximation reconstruction

- **Why is this cool?**
- Low frequency ultrasound enables imaging of the brain, joints and abdomen with ultrasound in MRI image quality
- Technology for low frequencies needs new developments, but will ultimately enable simpler and cheaper devices
- AI driven reconstruction currently under development will enable advanced 3D image reconstruction in seconds

- **Links to others?**
- Medical technology in MT (dedicated ASICs, therapy planning,...)
- Univ. Heidelberg / Mannheim (DE)
- Barcelona Supercomputing center (ES), Imperial College (UK), Fraunhofer Dresden (DE)
- Companies: Frontwave (ES), ARCTUR (SI)

Nicole Ruiter / nicole.ruiter@kit.edu, KIT

Schottky detectors for storage rings

Highly sensitive non-destructive particle analysis

- Novel non-destructive resonant and non-resonant Schottky detector systems for fast and highly sensitive measurements in storage rings experiments
- Cavity based pick-ups for high energy, and slow-wave pick-ups for low energy storage rings
- Improved accuracies in combination with isochronous ion optical settings of the storage ring
- Currently working on prototypes with transversal sensitivity for R3, RIKEN and SRing, HIAF
- Future data acquisition framework takes based on Software Defined Radio (SDR), sharing common components with future FAIR control system → increased compatibility + scalability.
- Use of High Performance Computing (HPC) facilities and machine learning for large scale data analysis.

- **Why is this cool?**
- Beams of down to single stored ions can be continuously monitored.
- Among many other measurable parameters, they can provide time-resolved information on the frequency and the intensity of the beam.
- Precision determination of mass and lifetime of different fragments / species is possible.
- For intensity measurements, resonant Schottky pickups can compete with Cryogenic Current Comparators (CCC) for beam specific setups.

- **Links to others?**
- DTS-ST3: Astro particle physics.
- DMA: Analysis and (long term) storage of high volumes of data, machine learning, Open Science
- ARD: Application of these detectors for the commissioning of the accelerator machines in FAIR

Participating centers/institutes: GSI
PI/Proposer: S. Sanjari
Partners: MPIK Heidelberg, RIKEN, IMP Lanzhou

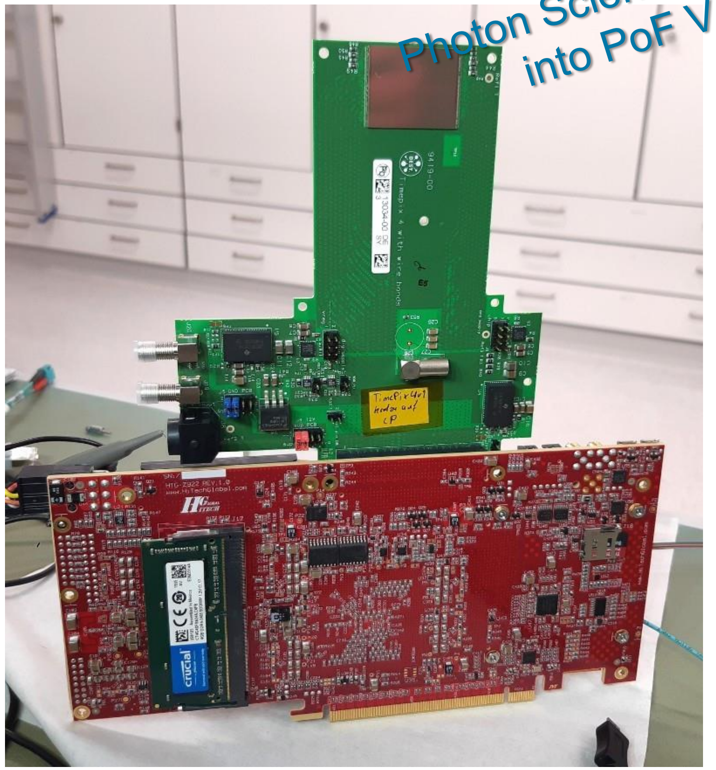
Current Status Project collection

Part II: (extending into) PoF V

TEMPUS

Photon Science into PoF V

- **A versatile detector with event-by-event readout of time and energy information**



- Hybrid pixel detector
- ASIC developed by Timepix4 collaboration
- Key features:
  - Event-by-event readout with ~200 ps timestamping, time-over-threshold
  - energy measurement, and 55 μm pixel size
  - High data bandwidth (up to 80 Gbit/chip): ~1x10^9 events / s
  - Additional photon-counting mode with improved count rate w.r.t. Medipix3
- Timeline: single-chip system development/commissioning through 2027
  multi-chip systems commissioning & deployment from 2028

- **Why is this cool?**

Very wide range of applications:

- Synchrotrons: good conventional X-ray imaging plus special applications to time-resolved experiments
- Ion / electron detection e.g. mass spectroscopy (tie in with laser / accelerator research)
- Particle physics R&D (e.g. time projection chambers)

- **Links to others?**
- High data rate and diverse applications naturally lead to links to DTS-ST2 (heterogeneous DAQ systems) and DMA
- Potentially a good detector for use with novel accelerators (zero suppression of data, time of flight capability…)
- Potential applications in other fields, e.g. particle detection in hadron therapy
- Part of the Medipix4 collaboration – CERN and 20+ other
- Collaboration with University Jena

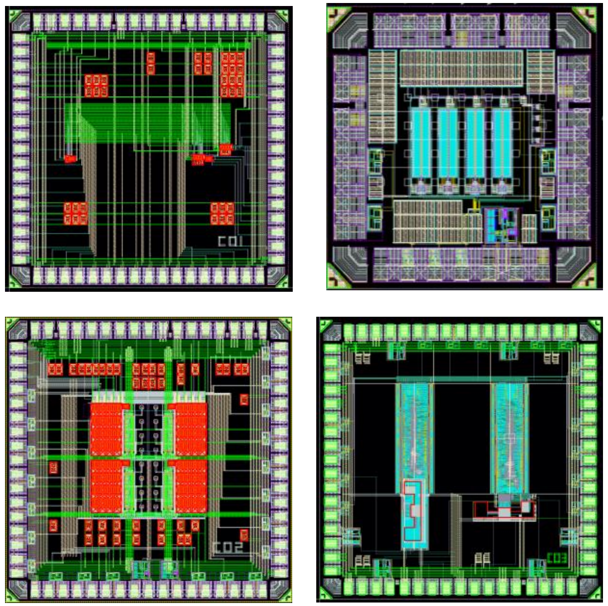
Contact: jonathan.correa@desy.de

Continuous Readout Digitising Imager Array (CoRDIA)

Photon Science into PoF V

150-kHz pixel detector for future light sources

- Hybrid pixel integrating detector
- Designed for 4th-generation synchrotrons and CW-FEL sources:
  - Continuous operation at 150 kHz frame rate
    Adaptive Gain Front-end, on-chip ADCs, GWT high-speed data streamout
  - Multi-megapixel tileable system with 110um pixel size
  - Compatible with Silicon (for ~10keV ph) and High-Z sensors (for hard X-rays)
- Prototypes designed, produced (MPW) & tested from 2021 to today
  1 generation detector to be ready for first photons at Petra-IV (2029)



- **Why is this cool?**
- Crucial to efficient use of and diffraction-limited synchrotrons (PETRA-IV)
- Could be an interim solution to the needs of the Eu.XFEL transition to CW regime
- Single system can be a workhorse for many different experiments and sources

Contacts: alessandro.marras@desy.de
cornelia.wunderer@desy.de

- **Links to others?**
- DMA: > 1 Tbit data rate means data processing and reduction are crucial to make data volume manageable
- DTS-ST2: Data rate requires high-bandwidth optical links. Heterogeneous computing hardware likely to be most efficient as first layer of data processing
- Possible application to compact FEL experiments

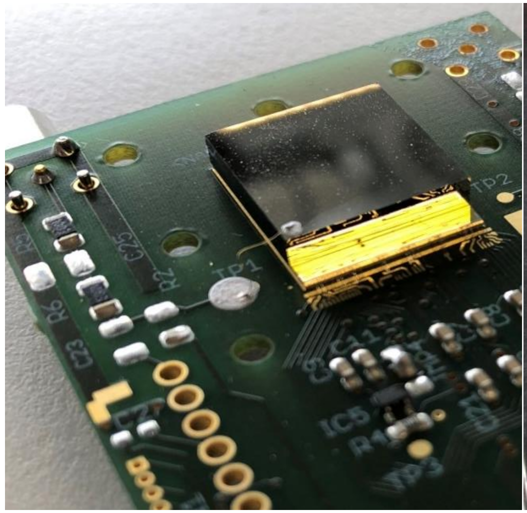
- Collaboration between DESY and Bonn University
- Under test using the Caribou system (DESY-FE)

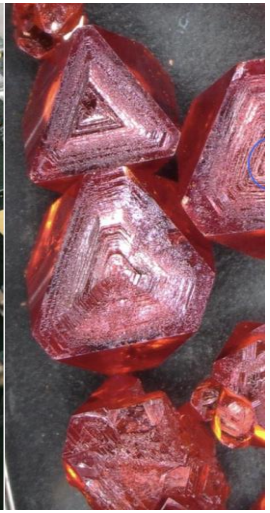
High-Z Detectors Materials - Applications

Photon Science
PoF V

High-Z sensors for x-ray detector applications

- Development of two materials **CdZnTe and Pervoskites** for efficient detection of high energy photons
- Setting up material and technology supply chain:
  - Crystal growth / Interconnection technology / Processing
- National source of high efficient sensors
- Timeline / Milestones:
  CdZnTe source (2028), Perovskite detectors (2029), Large area detectors by direct deposition on electronics (2030)





- **Why is this cool?**
- Source for detector material is crucial limitation for the development and application with high x-ray energy photons
- The available technology opens the door to further fields of application e.g. Medical and industrial applications (e.g. Computer Tomography)
- Perovskite crystals are new class of semiconductors with the potential for production of large detector arrays

- **Links to others?**
- DTS-ST1: High-Z sensor development and production
- DTS-ST2: DAQ system

- Common activity with MML
- Possible application beyond MT: Medical, NDT, Security
- DESY, University Freiburg, Fraunhofer ISE, PSI

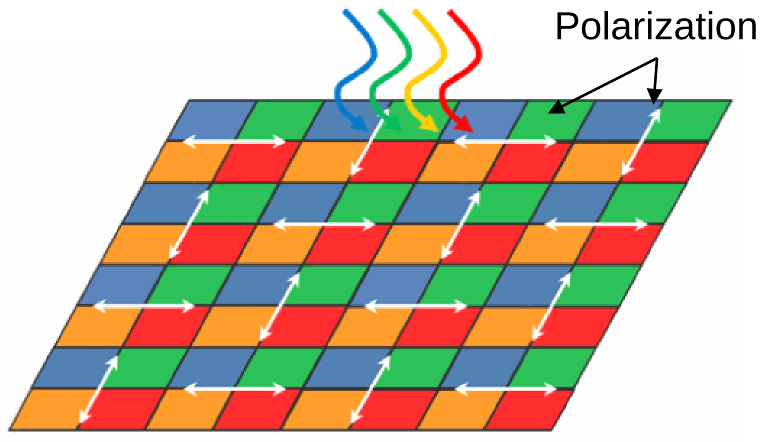
Contact: Michael Fiederle (KIT)

TeraHErtz pixelated SpecTRAL - Applications

Beam Diagnostics
?Medical?
end ~ 2028 (?)

Large-area pixelated THz detector

- Cutting-edge THz detector that combines: spatial, spectral, timing and polarization measurement
- Development of a monolithic-THz with antenna, detector and electronics integrated in a single substrate
- Integrated THz antennae in SiGe technologies
- 2025 demonstrator: full prototype 16x16 pixel, tuned
- 2028, THz detector system ready to be deployed for applications



THESTRAL
(TeraHErtz pixelated SpecTRAL detector)

- **Why is this cool?**
- High-speed beam diagnostics of micro-bunching instabilities
- Unique THz large-area detector for medical THz imaging and material sciences
- High-throughput ***pump-probe*** experiments
- THz imaging and spectroscopy
- THz wireless communication

- **Links to others?**
- MT-ARD: sophisticated beam diagnostic instrumentation
- DTS-ST1: developing of ASIC in SiGe technology
- DTS-ST2: DAQ system

- Medical: Potential applications in THz medical imaging
- MML: advanced pump-probe experiments

- **Synergy: KARA, IHE and IPE centered at KIT**

Contact: Michele Caselle and Cagri Ulusoy (KIT)

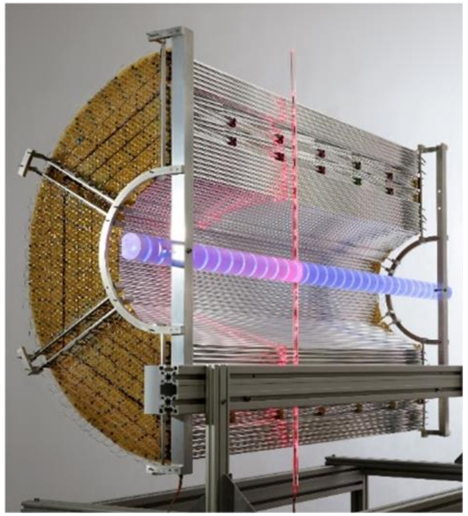
Straw Technology

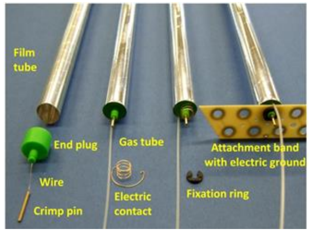
Straw Tracker for Application in Hadron Physics

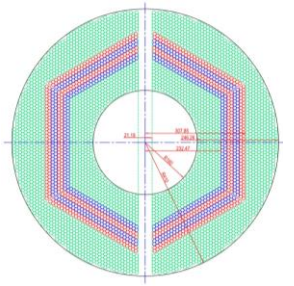
Particle / Hadron into PoF V

Technology

- Gas-filled drift tubes (straws) with 27µm thin film walls (<0.04% X_0/straw)
- Modules of close-packed, self-supporting straw layers at over-pressure (1 bar)
- (4D+PID) Straw tracker with low material budget (<1.3% X_0 and 27 straw layers)
  - Drift time readout for 3D-space and t0-extraction (4D)
  - Charge readout (dE/dx) for PID in lower momentum region (<1GeV/c)
  - Particle rates up to 1 MHz/straw, spatial resolution <150µm (σ)
- Status: straw assemblies completed, electronic readout (ASIC) developed and existing
- Next: set up one complete sector of a central barrel (4D+PID) straw tracker system







Why is this cool

- Low material budget, but robust mechanics at 1bar over-pressure
- Variety of detector geometries from planar to barrel shape
- Next generation straw trackers have to fulfill 3D-space, t0 time and particle dE/dx measurement
- Exciting straw R&D projects for new application
  - ultra-thin (<15µm) straws for radiation length <0.02% X_0/straw
  - ultra-long (5m) straws for large-area (50m^2) tracker in vacuum

Links to others

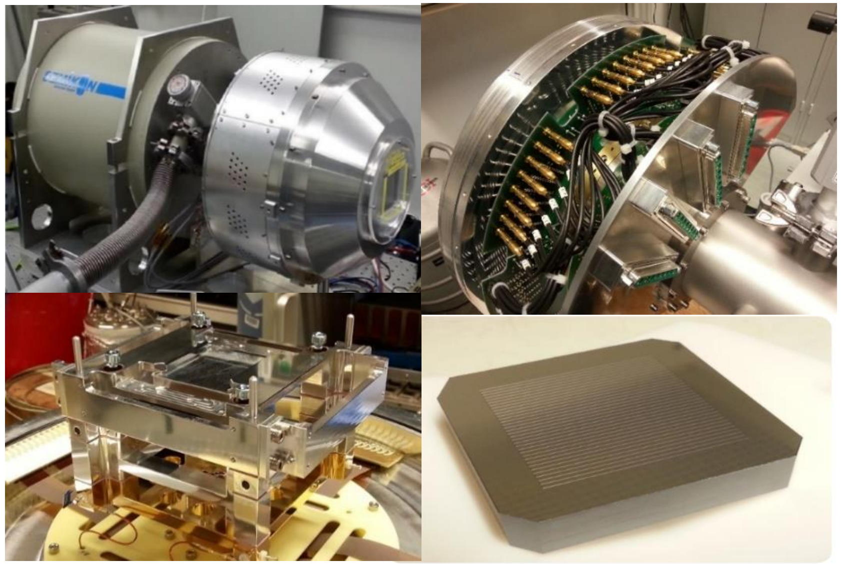
- Straw systems for HADES and PANDA at FAIR
  - Partners: JU Krakow, AGH Krakow, IFIN-HH Bucharest, GSI
- (4D+PID) Straw Tracker R&D project within DRD1@CERN
- Broad field of straw application R&D within DRD1 beyond 2027
  - High-energy physics at future colliders, Hadron physics
  - Dark sector, Rare event searches, Neutrino physics

Contact: Peter Wintz, FZ Juelich, p.wintz@fz-juelich.de

Imaging Detectors for Hard X-Rays and γ-Rays

AtomicPhysics, Astro, medical
Into PoF V

Polarimetry, Imaging, Spectroscopy for medium to high energies



Planar 2D micro-strip semiconductor detectors with 4D readout

- Thick Si(Li)-DSSD and Ge(i)-DSSD sensors dedicated for hard x-rays and γ-rays
- Strip pitch between 0.1 mm and 2 mm; typically 1000 to 5000 quasi-pixels; depth resolution 1 mm@10mm crystal thickness; sensor stacking option
- Large active areas: up to about 4096 mm^2 per sensor
- Energy resolution below the 1% regime
- Timing(nsec) and multi-hit capability
- Multi-kHz readout frequency

Why is it cool?

- Collimator-Free Compton Camera use several interaction points to reconstruct incident angle without use of a collimator
- 3D tomography with a single detector
- Precise Polarimetry for hard photon energies (40keV-2MeV)
- Wide range of applications; e.g. atomic physics, medical imaging, space missions

Links to others?
Programs: MU and MML

DTS: DMA: High volume of data are acquired; simultaneous acquisitions and real time analysis; high performance computation and long term storage.

Participating centers/institutes: GSI, HI-Jena, FZJ

PI/Proposer: U. Spillmann, T. Krings, G. Weber, Th. Stöhlker
U.Spillmann@gsi.de

Partners: Univ. Jena

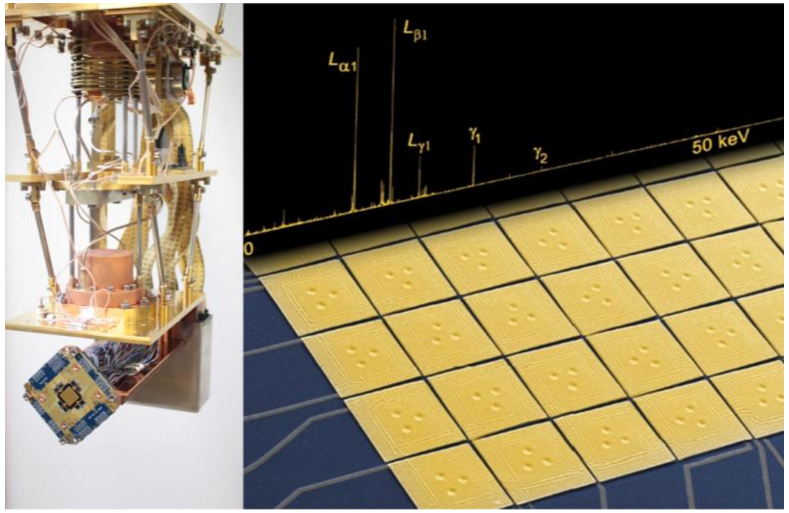
Large-Array Micro-Calorimeter

Realization of a detector system with > 1000 pixels

Photon Science
Particle / Ion
Beyond 2028 ?

Strategic Goal of the Topic

Precision x-ray spectroscopy is an indispensable tool to study atomic structure of matter and to push the limits of our understanding of quantum electrodynamics as well as relativistic effects. The ongoing development of metallic magnetic micro-calorimeters (MMC), which combine the superior energy resolution of crystal spectrometers with the broad spectral bandwidth of conventional solid-state detectors, is already providing new experimental possibilities. It is crucial that HGF takes a leading role in harnessing the full potential of this new detector technology, in particular at large-scale research facilities as for example FAIR.



Why is this cool?

- 1 – 2 orders of magnitude improvment in spectral resolution compared to semiconductor x-ray detectors
- Innovative microwave multiplexing will enable large-arrays with >1000 pixels
- Combination of high sprectral resolution, broad bandwith acceptance and imaging capabilities provides unique experimental possibilities.

Lead center/institute:
GSI, HI Jena

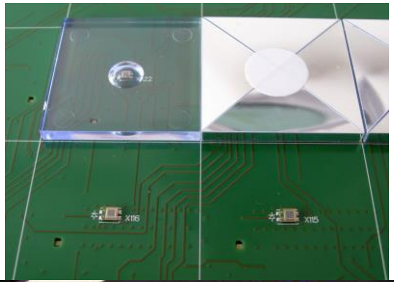
Proposed by:
G. Weber, Th. Stöhlker, M. O. Herdrich

Partners:
- Kirchhoff-Institute for Physics, Heidelberg University
- Institut für Mikro- und Nanoelektronische Systeme, KIT

Publications:
- D. Hengstler et al., Phys. Scr. 2015, 014054 (2015)
- S. Kraft-Bermuth et al., Atoms 6, 59 (2018)
- Ph. Pfäfflein et al., Phys. Scr. 97, 114005 (2022)

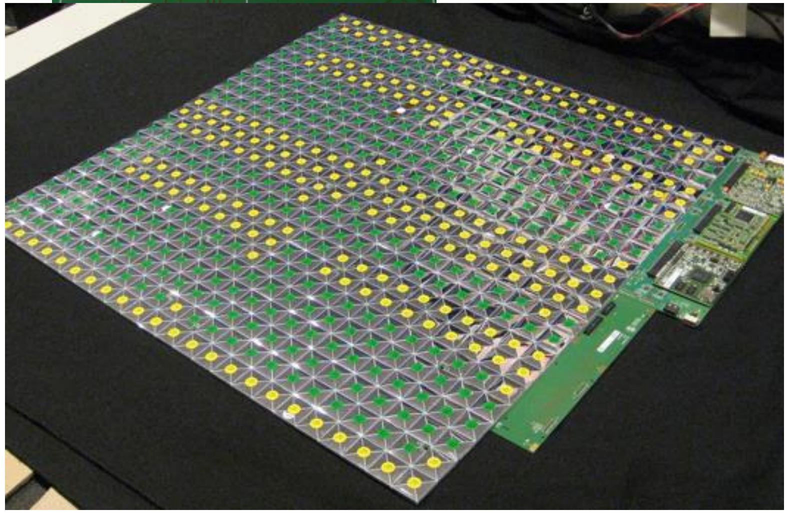
Highly Granular SiPM-on-Tile Calorimeter

Imaging Calorimetry for future Higgs Factories



Particle Physics
PoF V

- Highly granular hadron calorimeter based on SiPMs directly coupled to small scintillator tiles with electronics integrated into active layers
- Prototype has been built with electronics suitable for linear electron-positron colliders
- Currently the SiPM-on-Tile technology is being put into use for the HGCAL upgrade of the CMS detector for HL-LHC
- Plan for POFV: adapt system (readout electronics, DAQ, power distribution, cooling) for circular colliders



- **Why is this cool?**
- Cost-effective scalable solution for highly granular hadron calorimeter
  - Necessary to reach jet energy resolution goal at Higgs factories
  - Attractive option for many future particle physics experiments

- **Links to others?**
- Developments previously within the CALICE Collaboration, now within ECFA DRD6
- Strong collaboration with German partners:
  - Uni Göttingen, Uni Hamburg, Uni Heidelberg, Uni Mainz
  - Helmholtz Centers: DESY and KIT

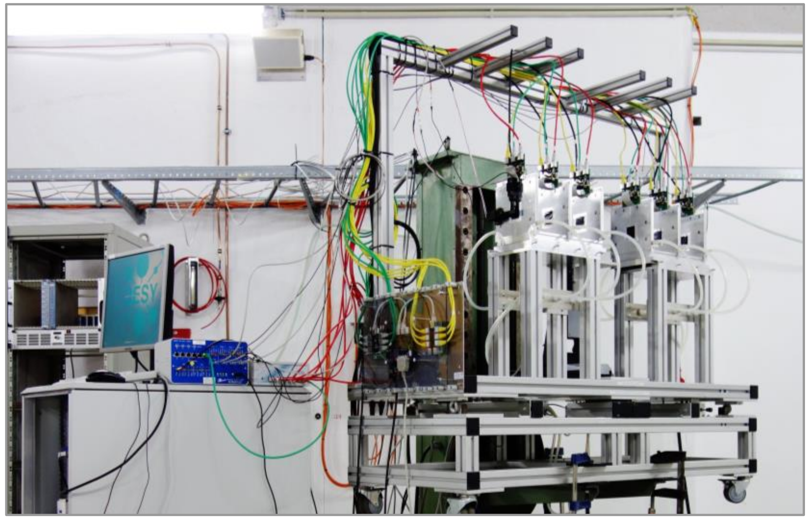
Contact: felix.sefkow@desy.de katja.krueger@desy.de frank.simon@kit.edu

Beam telescope for precision timing and space resolution

Beam Monitoring
PoF V

•Next generation of work horses at the test beam

- Upgrading the telescopes to state-of-the art Monolithic Active Pixel Sensors
- Adding timing capability to time-tag particles
  - HV CMOS Layer providing nano-second timing on region-of-interest triggers
  - Exploring LGAD technology do provide below 100 pico-second resolution
- Architecture allows to easily incoporate new sensors as they become available
- First Stage 2024, based on Alpide (matching PoF IV milestone)
- 2nd Stage within / 2nd half of of PoF V



- **Serves a Demonstrator for a paradigm changing technology in particle and heavy-ion physics**
- **A most useful device for beam tests**
- **Nice collaboration across all centers and several key technologies**

- **Links to others?**
- MT-ARD or DMA? No
- DTS-ST1/2/3 or DDL? all
- Other science application fields? MU activties
- DESY, GSI, KIT

Contact: marcel.stanitzki@desy.de

Extreme dynamic range timing and tracking detector system for heavy ions

Si strip detectors for fast timing/triggering

Particle / Ion
Into PoF V ?

- Radiation-hard large area and homogeneous ToF detector for heavy ions detection:
  - total channels (strips) > 1500 chs
  - timing resolution (full): $\sigma_t < 35$ ps, $\sigma_t = 20$ ps for U
  - rate capability: 15 kHz/strip
  - radiation dose: 1 kGy/year
- First silicon-strip prototype 64x64x0.3 mm^3 in-beam tested ($\sigma_t = 18$ ps for Au)
- Technology/producer for mass production needs to be found

- **Why is this cool?**
- Si for fast timing/triggering
- position sensitivity (strips)
- in-flight isotope separation
- low material budget
- radiation hardness

- **Links to others?**
- DMA: fast FPGA preprocessing, trigger logic
- DTS-ST1: radiation-hard sensors
- DTS-ST2: data transfer from vacuum over optical lines, cooling in vacuum, high-density interconnects
- Astrophysics, medicine

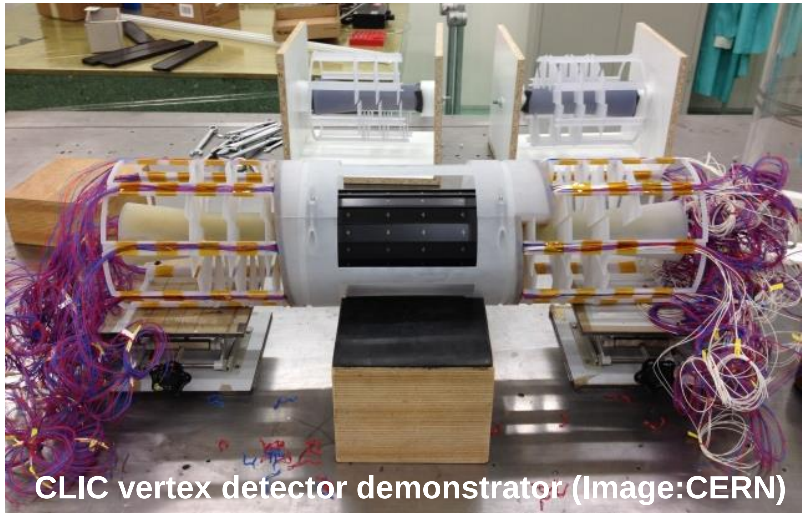
Chiara Nociforo, Oleg Kiselev GSI

A Tracker for the Future

Second line with sub title, application field

Particle physics
PoF V

- Development of a technology demonstrator for a tracking system for a future Higgs factory experiment.
- Incorporation of ongoing technology developments.
  - 65 nm MAPS, advanced interconnects, Si-photonic readout, ultra light weight mechanics, air cooling.
- Large scale prototype performance evaluation in beam test.



CLIC vertex detector demonstrator (Image:CERN)

- **Why is this cool?**
- Design goals driven by cutting edge technology development.
- Tool to provide realistic design goals for the front end system, readout and mechanics.
- Application driven mechanics and cooling R&D.

- **Links to others?**
- Combined effort with DTS-ST1 & DTS-ST2.
- Link to MU for physics design goals
- Collaboration with DRD3, DRD7 & DRD8

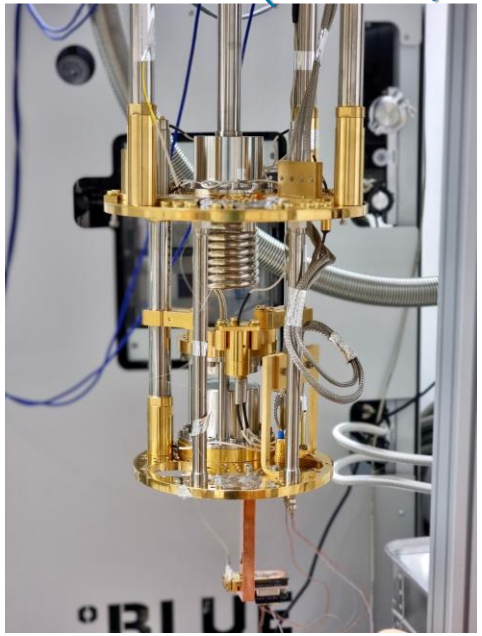
Contact:
Moritz Guthoff, DESY, moritz.guthoff@desy.de
Andreas Mussgiller, DESY, andreas.mussgiller@desy.de
Simon Spannagel, DESY, simon.spannagel@desy.de

Low-background cryogenic detector systems

(Astro) Particle physics
PoF V

Transition Edge Sensors et al for axion/dark matter searches

- Develop systems for axion/dark matter detection ➔ detection of extremely low signal rates
- Currently: Transition Edge Sensor setup for ALPS II and a direct dark matter search
  - Aims: Low dark count rate for 1064 nm photons ($< 7.7 \cdot 10^{-6}$ Hz) with high (>90%) efficiency and good (<10%) energy resolution ➔ in reach
- First system still within PoF IV, optimized systems including for other applications like possibly other axion experiments, GW planned for PoF V



- **Why is this cool? – it's very cool: below 100 mK**
- Enables axion searches
- Can even be used for direct dark matter detection
- Detailed understanding of the system including simulation
- Applications to other fields like metrology, Quantum computing
- **Contact**: Friederike Januschek friederike.januschek@desy.de; Axel Lindner axel.lindner@desy.de

- **Links to others?**
- DTS-ST1 (cryogenic sensors)
- Cryogenic Sensor Production Facilities
- Photonics
- Quantum Computing

Involved groups: DESY, UHH, SDU, Glasgow
Involved Partners: PTB+TU Berlin, NIST

MATTER AND TECHNOLOGIES DETECTOR TECHNOLOGIES AND SYSTEMS

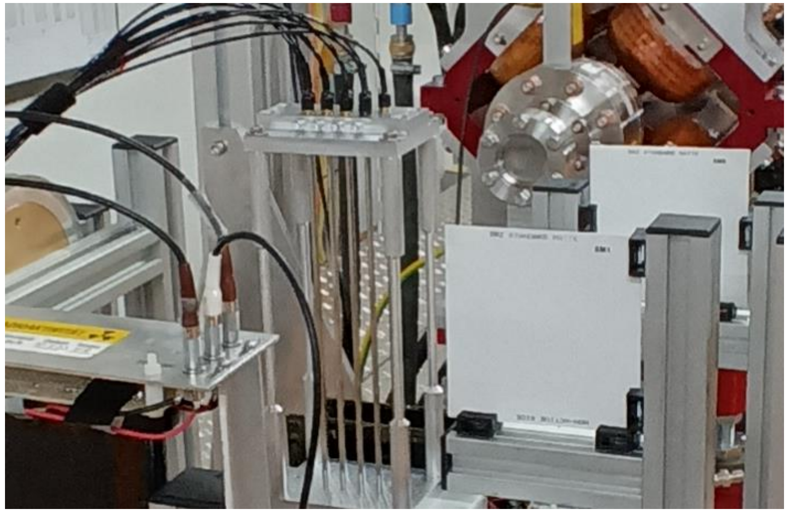
MATTER AND THE UNIVERSE

High-rate Electron Detection Systems

Beam Diagnostics
PoF V

Gas Cherenkov Systems for high-rate applications in high-density experiments and beam diagnostics

- Develop robust and versatile detection system for measuring rate and position distribution of up to 10^{10} electrons based on gas Cherenkov tubes and SiPMs.
- Status: Prototype built and tested at ARES in 2023 (8 channels, picture)
- 2024: prototype for and measurements at FACET / E320 planned (16 channels)
- Coming years / POF V:
  - Full detector for E320 and possibly other strong-field QED experiments
  - Including in particular LUXE (2x 100 channels)
  - Application in electron beam polarimetry (ELSA, EIC, Higgs Factory, …)



- **Why is this cool?**
  - **Versatile, data-sparse and robust (background-tolerant, radiation-hard) detection system for high-rate environments**
  - **Percent-level precision on rates and position distribution of up to 10^{10} electrons, independently of their energy above a tunable threshold of few to 20 MeV**
  - **Many cross-disciplinary applications in particle physics, high-density physics and accelerator diagnostic**

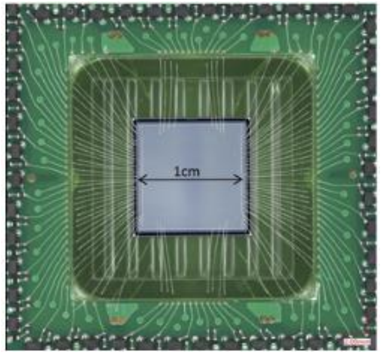
- **Links to others?**
- MT-ARD – yes, beam diagnostics
- Strong-field QED, Spin Physics, Plasma Experiments, Accelerator Diagnostics
- DESY, SLAC (FACET / E320), HI Jena and KIT (LUXE)

Contacts jenny.list@desy.de

Milestone slides (not nearly all)

Low Mass Tracking System Based on LGAD Sensors.

- Low-mass Si beam telescope with ultra-fast timing and high spatial resolution
  - 4 LGAD strip detectors with 200µm thickness, 100µm pitch and 86 channels
  - Fast readout electronics including FPGA-based TDCs
  - Excellent intrinsic time resolution for MIPs (<68ps)
- Investigation of large area system is currently ongoing
  - Dedicated low-mass module design
  - Low power ASIC development – feasibility study



- **Why is this cool?**
- Wide range of applications
  - Beam monitoring system for nuclear physics (e.g. CBM, HADES, S-DALINAC) or medical physics (ion beam therapy at MedAustron)
  - PiD by T0F in HADES, CBM
  - Ion imaging system to improve treatment planning in ion beam therapy (*Ulrich-Pur et al. 2023*)

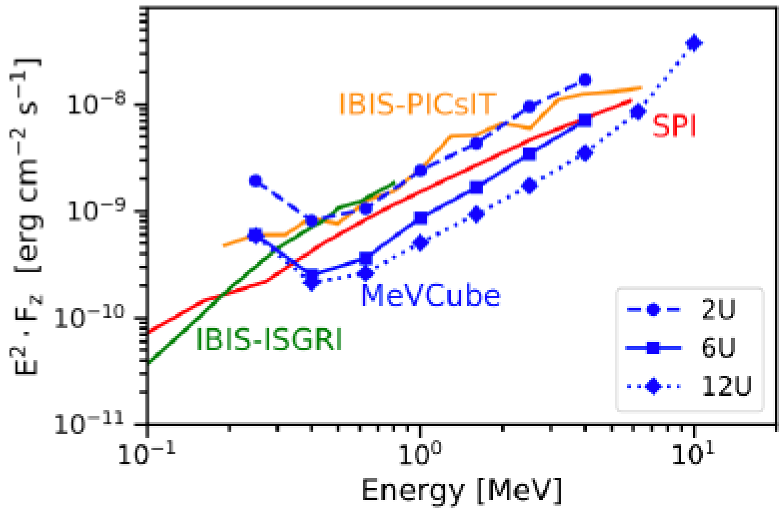
- **Links to others?**
- MT-ARD or DMA?
- DTS-ST1/2/3 or DDL?
- Other science application fields?
- List all involved partners, in particular all Helmholtz Centers

Contact: j.pietraszko@gsi.de

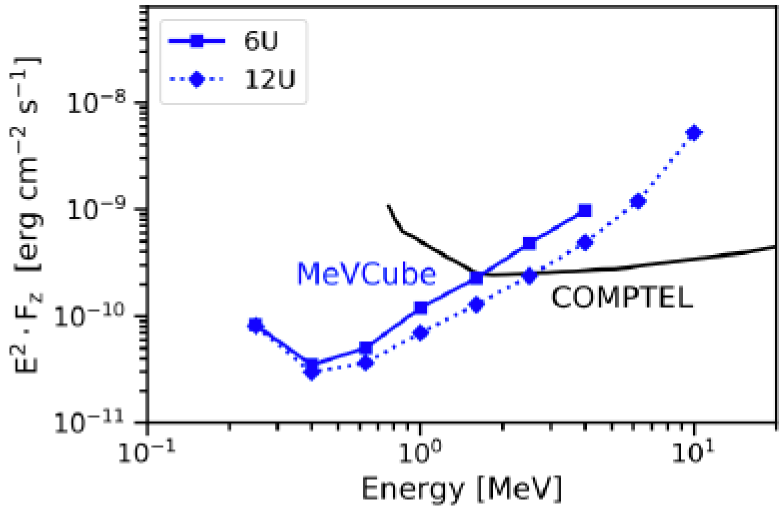
MeV cube – Summary slide from 2022 ‘Milestone Report’ presentation at ST3 Workshop

Summary

- We have evaluated the performance of CdZnTe detectors in a laboratory test setup.
- Energy resolution and depth-of-interaction resolution have been measured and are meeting / exceeding the requirements.
- Sensitivities for various CubeSat configurations have been calculated using simulations with input from the measurements.
- The improvements in efficiency from a steering grid are not high enough to justify the added complexity.
- Two papers are (almost) ready for submission.
- Next phase of project has started.



1U = 10 x 10 x 10 cm (CubeSat size)



DESY.

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Summary

- Portfolio of Projects, still working on how to best “extract common themes” from the breadth DTS offers
- Milestones from PoF IV:
  - We need one slide from each Project addressing or partially addressing one of the PoF IV DTS (ST3) milestones
  - Please help us to thus “fill the overview table with life” within the next ~ week or so (in time for 25 Jan)
- Our biggest challenge remains improving and facilitating communication across science fields and centers – collaboration and exploration of synergies throughout all of DTS should be(come) a natural first thought
- Looking forward to PoF V