HELMHOLTZ

RESEARCH FOR
GRAND CHALLENGES

Topic

Detector Technologies and Systems

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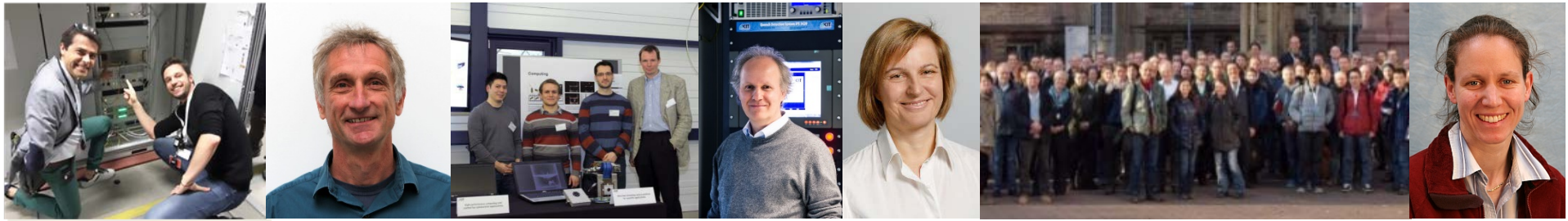
DESY. JÜLICH FORSCHUNGSZENTRUM GSI Helmholtzzentrum für Schwerionenforschung GmbH HI JENA HELMHOLTZ Helmholtz Institute Jena HZB Helmholtz Zentrum Berlin HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung KIT Karlsruhe Institute of Technology

DTS excels in detector technologies

WHO WE ARE



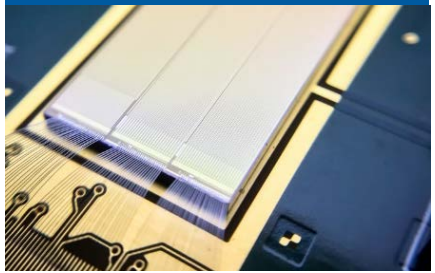
- Diverse and interdisciplinary team of staff physicists, engineers, and technicians
- Many PhD students
- Numerous collaborators
- Significant third-party funding
- Core-funded scientists: 54 FTE (2021)
- Core-financed costs: 12.5 MEUR (2021)

DTS is delivering innovative systems

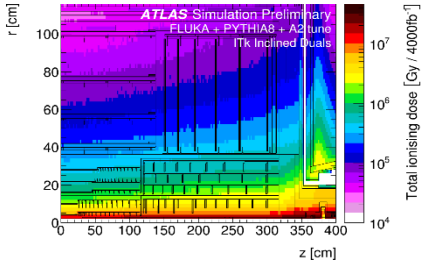
WHO WE ARE

- We are world-experts in many cutting-edge detector instrumentation technologies
- MT-DTS is a leader in systems development
- MT-DTS has a strong record in conceiving, designing, and delivering key instruments
- A key asset is our proximity to the users and science applications in MU and MML

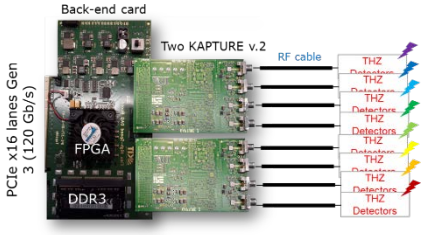
Pioneering HV-CMOS sensors



Radiation-hard sensors for LHC



Ultrafast waveform sampling for THz sensors



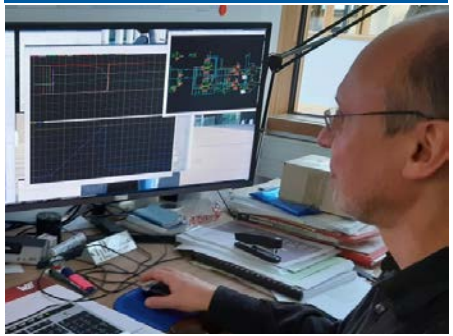
Many-pixel readout of superconducting sensors

World-class instrumentation for science

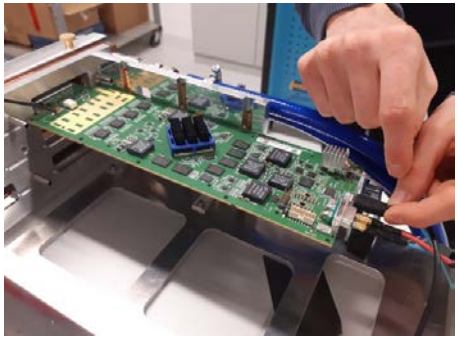
WHO WE ARE

- DTS played a leading role in developing AGIPD and DSSC pixel detectors
- 3 systems delivered to Eu.XFEL, more systems in development
- Used for pioneering science, e.g. studying antibiotic resistance mechanisms in bacteria

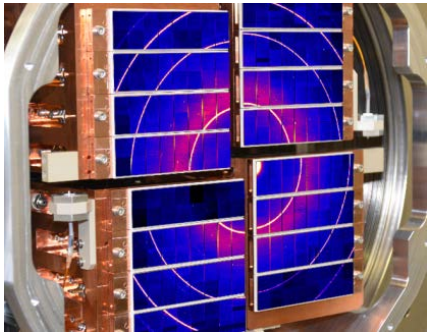
Large dynamic-gain ASICs



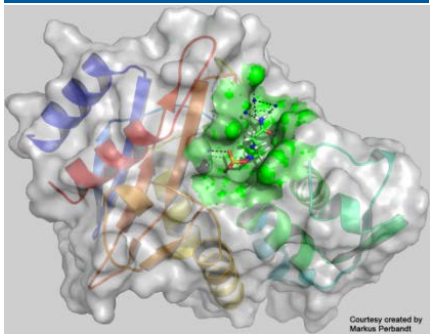
High-speed readout electronics



AGIPD system at Eu.XFEL



Avibactam drug



Reaching out to community, industry and society

WHO WE ARE

- We provide service to the community

DTS hosts TWEPP conference

Organizing Heraeus seminars

- Technology transfer is part of our mission

Spin-off X-Spectrum GmbH awarded for high-speed X-ray camera

A DTS team at a clinical study for 3D ultrasound breast cancer diagnosis

- DTS fosters public understanding of science

Town hall lectures…

… or science slam

Pushing the limits of detector physics

MISSION & STRATEGY

Mission

Conceiving and developing cutting-edge detector technologies and systems

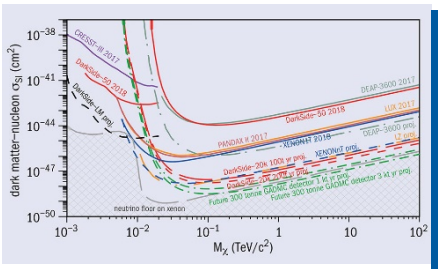
- to keep „Matter“ at the forefront of scientific discovery,
- to exploit the scientific potential of our facilities,
- and to open entirely new research directions in “Matter”

Strategy

Focusing on key challenges and areas with opportunities for revolutionary changes and maximum impact

- to realize the physical limits of space, time and energy resolution in detector systems
- to cope with the data deluge

Nobel price – realizing what matters

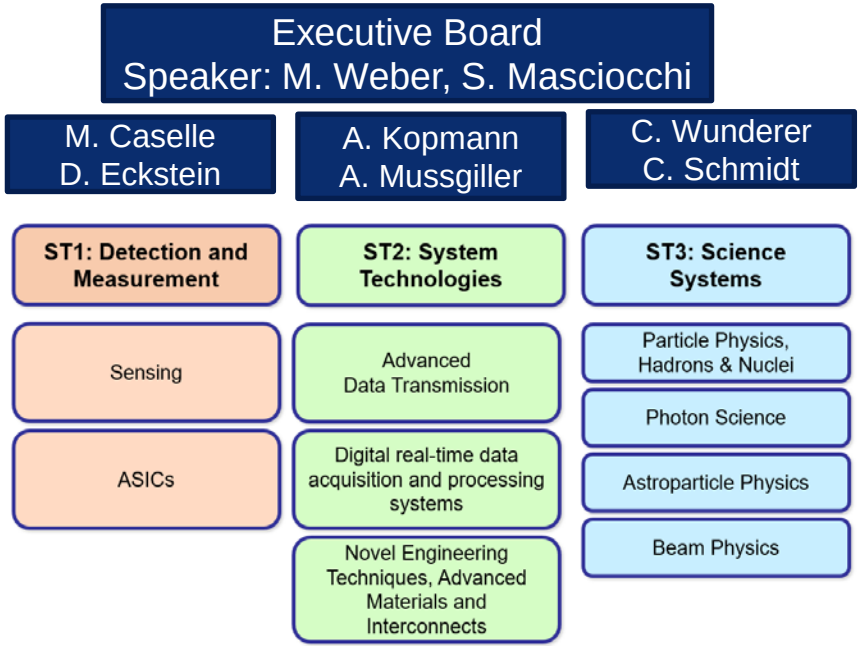


Shifting limits in Dark Matter searches

Enabling excellent science through unique detectors

TOPIC STRUCTURE

- Subtopics directly reflect strategy:
  - realizing the physical limits resolution in detector systems
  - coping with the data deluge
- DTS demonstrator projects form an effective link across Matter
- Organizational structure is light-weight but effective

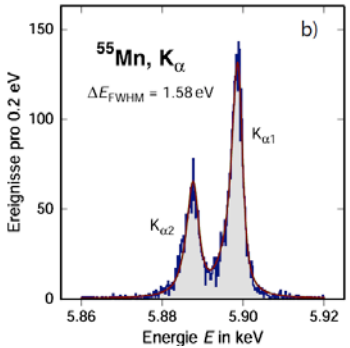


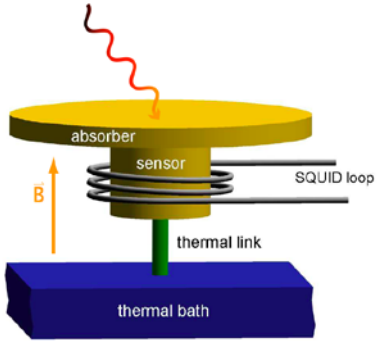
ST1 highlight: high-resolution superconducting sensors

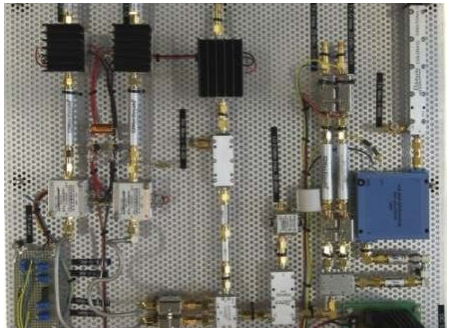
SCIENTIFIC FOCUS

- Pushing cryogenic superconducting sensors requires high-tech infrastructure
- We hope to establish unique competences in Europe
- Substantial addition to technology portfolio of Matter
- Very strong support by community and world-leading associated partners

Supreme energy resolution	Metallic magnetic calorimeters (MMC)	RF electronics	Hot-electron bolometers







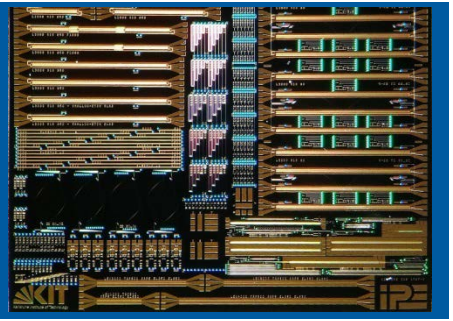
System technologies (ST2)

SCIENTIFIC FOCUS

We have identified technologies that are essential for future detector systems and where we are aiming for technological leadership

Silicon photonics

A game-changing technology enabling trigger-less detectors



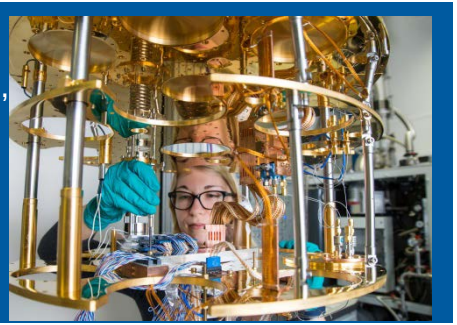
Real-time data acquisition

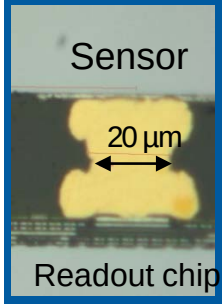
Scaling-up to Terabit/s, advanced algorithms, detector intelligence

Cryogenic readout

Enabling 1k-pixel cameras, superconducting electronics

Spin-off: Quantum Computing





Novel engineering techniques

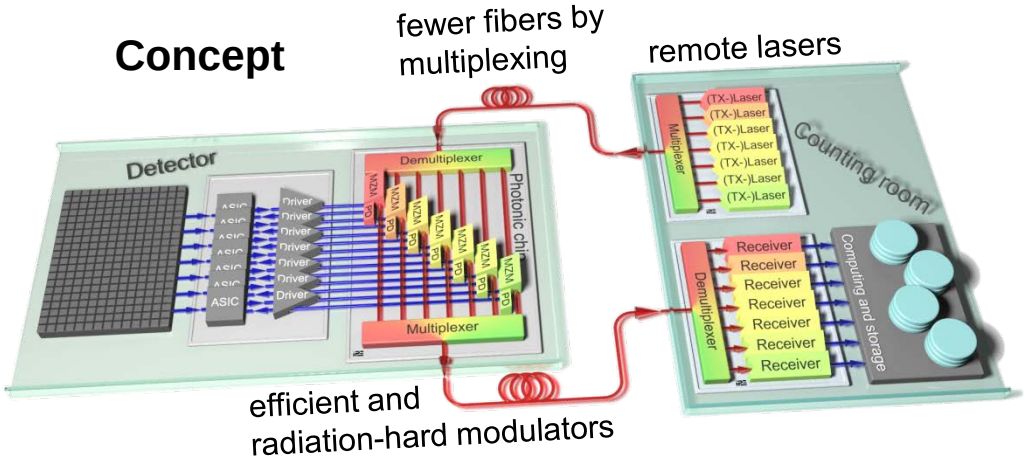
High-density electronic integration, microfabrication

ST2: Realizing the potential of silicon photonics

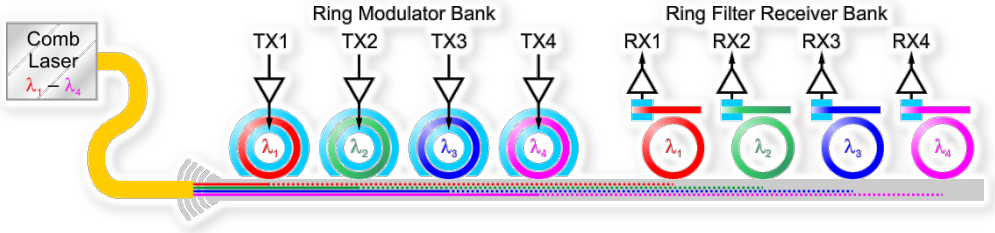
SCIENTIFIC FOCUS

- Pioneering silicon photonics for detector instrumentation
- **Goal:** record data transmission bandwidth of ~ 8 Tbit/s per fiber with wavelength division multiplexing
- Joint ST1 and ST2 **milestone**: Establish silicon photonics components for data transmission by 2025

Concept



Vision – compact optics by ring modulators



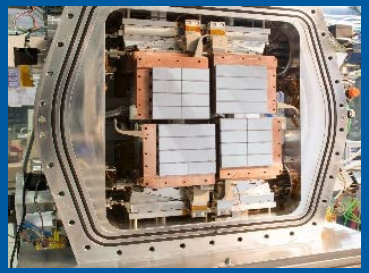
Partners:

Science systems (ST3)

SCIENTIFIC FOCUS

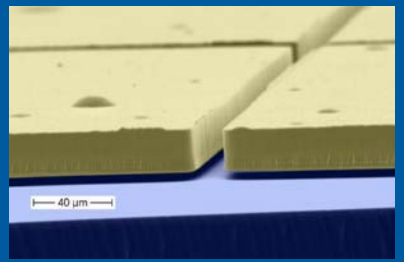
Enabling 4D detector systems with unprecedented time, energy, and position resolution

High-energy physics
Ultra-low material silicon detectors with excellent time and spatial resolution



Photon science
Megapixel detector for soft X-rays,
high-Z detectors,
MHz- frame rates

Astroparticle physics
Cryogenic detectors of unique energy resolution for dark matter searches and neutrino physics

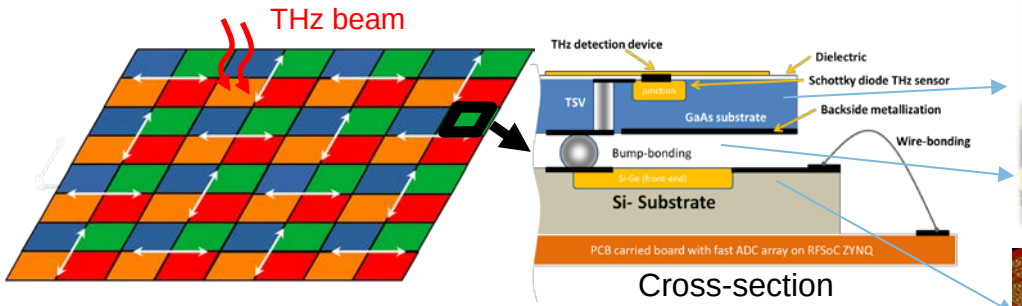


Beam physics
Multi-spectral THz detectors for beam diagnostics

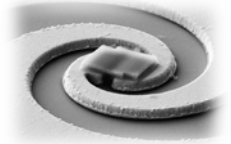
ST3: TeraHErtz pixelated SpecTRAL detector (THESTRAL)

SCIENTIFIC FOCUS

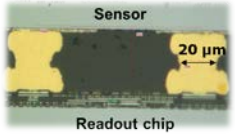
Large-area pixelated THz detectors - combining spatial, spectral, timing and polarization measurement



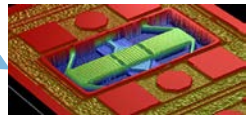
Cross-section



Custom pixelated room-temperature or cryogenic THz sensors (ST1)



High-density gold stud bump-bonding technology (ST2)



Front-end ASICs developed in SiGe BiCMOS technology (ST1)

Continuous data acquisition up to 500 Mfps, data rates of ~400 Gb/s (ST2)

- Applications: THz imaging; medical, pharmaceutical, material science; spectroscopy; THz wireless communications
- Milestone: Readout ASIC in SiGe technology by 2024
- Milestone: THz detector system by 2025

Teaming up with leading institutions

COOPERATION

in Helmholtz:

- Collaboration between the centers in DTS is traditionally strong
- Many DTS staff members work part-time on experiments or projects within MU and MML
- Close collaboration with ARD (especially in beam diagnostics)
- Innovation pool projects with DMA scientists

World-wide:

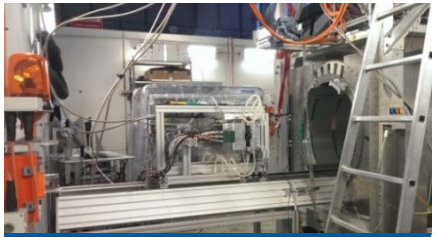
- Close collaboration with excellent German universities
  - Humboldt-Universität zu Berlin
  - Universität Hamburg
  - Universität Heidelberg
- Numerous cooperations with leading international institutions in our field

Unique facilities for cutting-edge detectors assemblies

INFRASTRUCTURES

Cutting-edge infrastructures operated by professional and permanent staff are a distinct asset of MT-DTS

Electronic interconnect and packaging centers



Test beam facilities

Heavy-ion microbeam

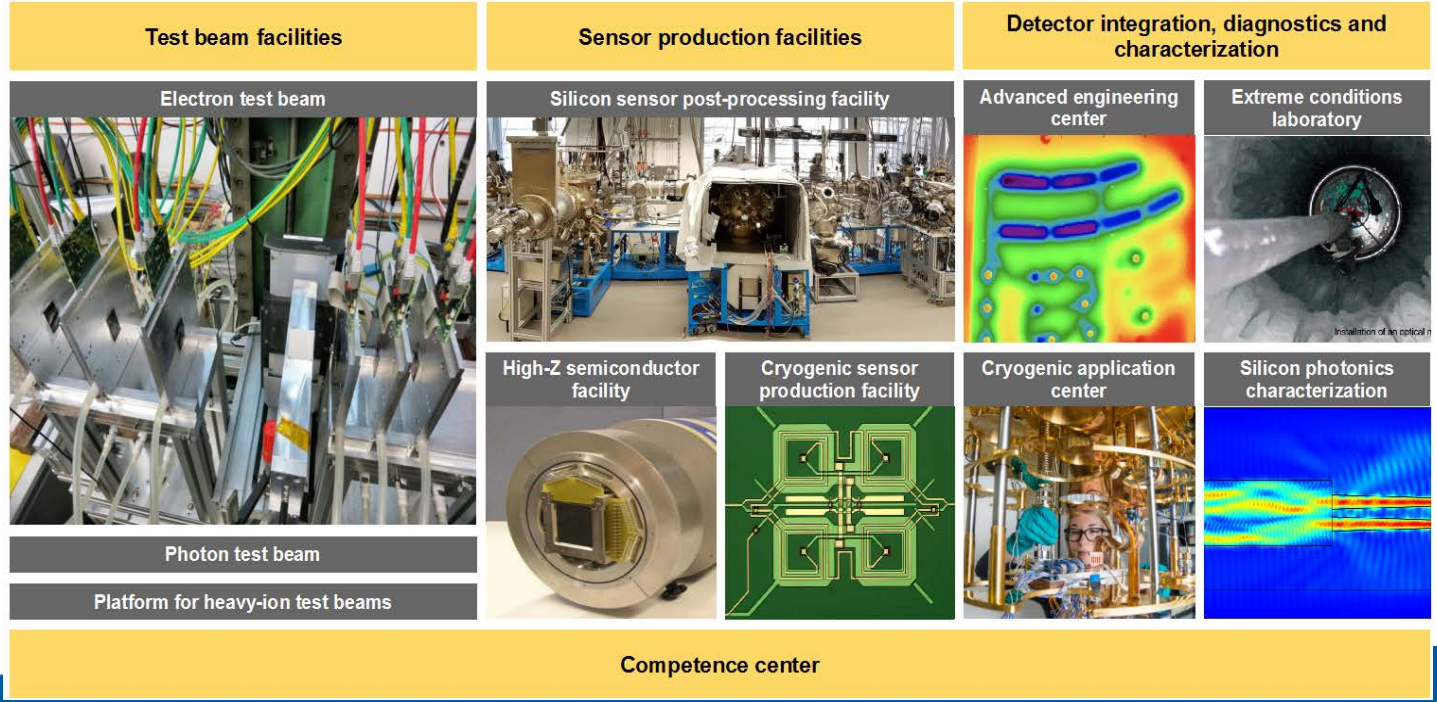
Micro- and radiowave characterization labs

Detector assembly lab

Helmholtz Distributed Detector Lab (DDL)

INFRASTRUCTURES

- Huge leap forward for Matter high-tech infrastructure
- Purpose: conceive, design, produce and characterize sensors of unprecedented resolution and efficiency



DTS – the international hub for detector technology

VISION 2027

- Establishing and operating world-wide unique laboratory infrastructure
- Pioneering ground-breaking technologies:
  - pixelated cryogenic sensors for Dark Matter searches, metrology, …
  - silicon photonics for detector readout
  - hybrid sensor design for optimized performance
- Pushing limits in data rate by orders of magnitude
- Delivering critical contributions to Helmholtz facilities: PETRA 4, CW-XFEL, …
- Actively scouting and identifying emerging technologies for the next decade
- Training young scientists, technology experts and future leaders for academia and the high-tech industry

Back-up