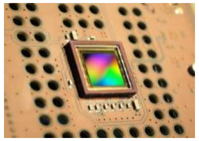
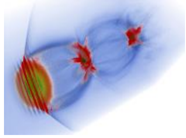
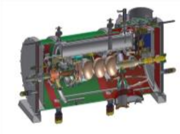
Matter and Technologies







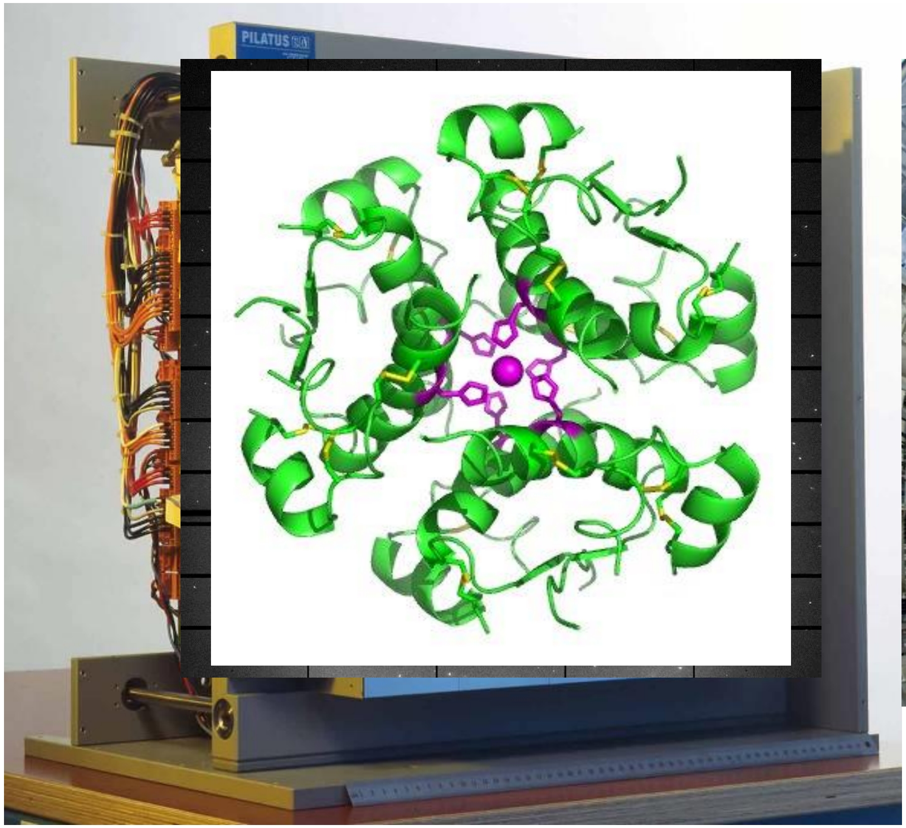
Detector technology and systems

Marc Weber

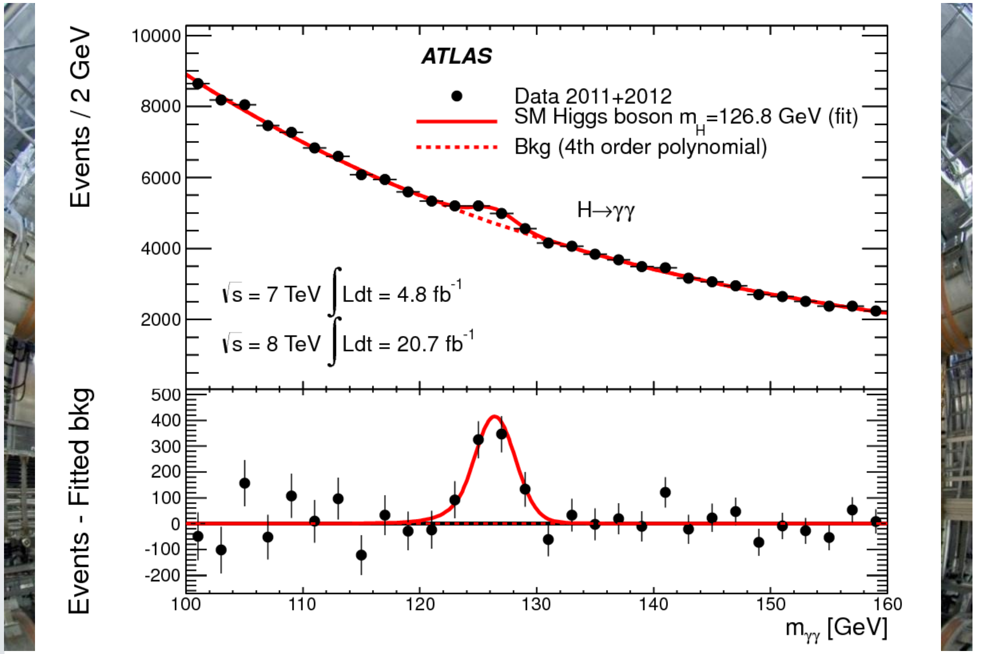
HELMHOLTZ ASSOCIATION

Detectors driven by science

Photon science



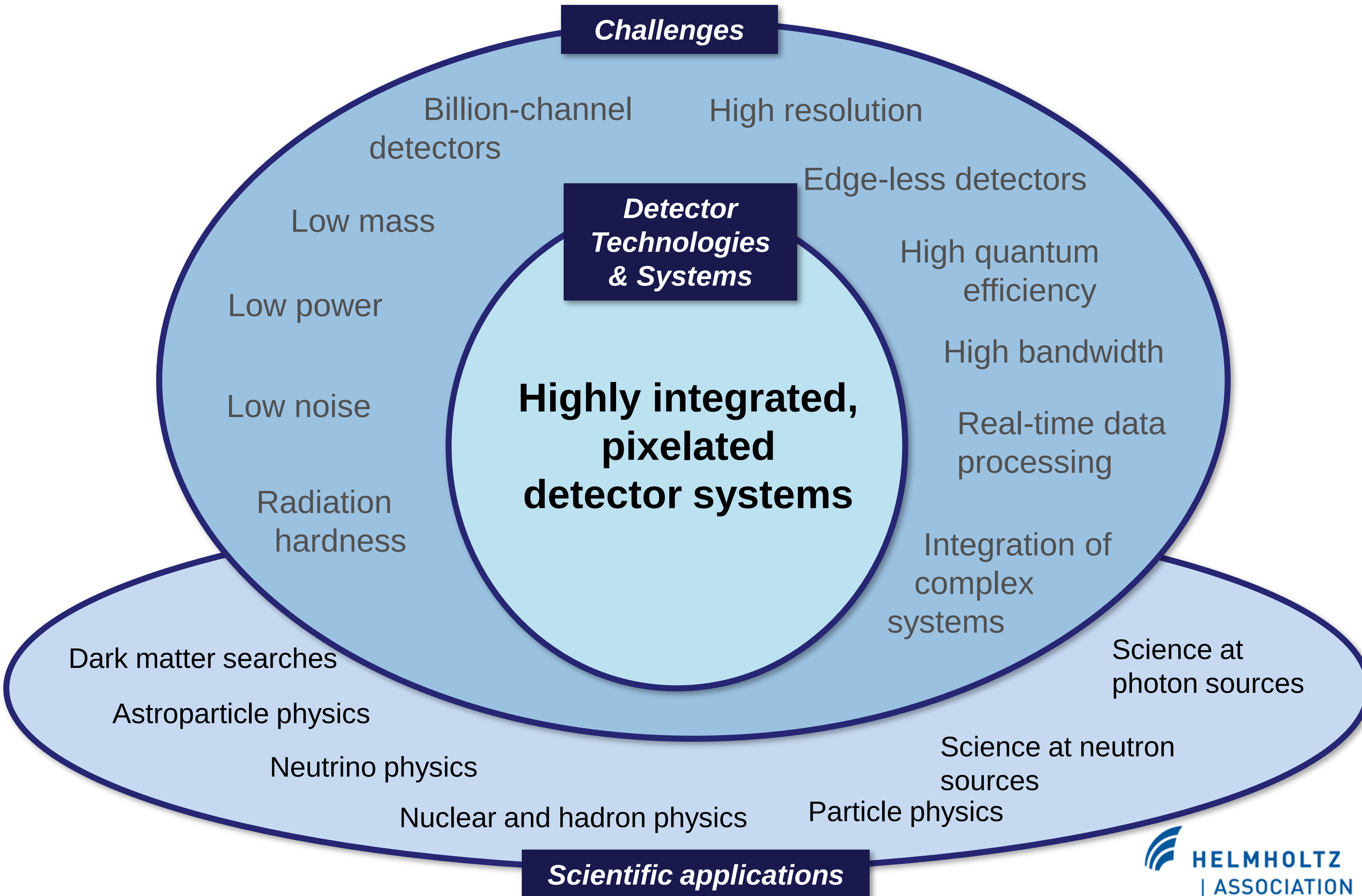
Particle physics



Science enabled by technology

HELMHOLTZ ASSOCIATION

Focus and challenges



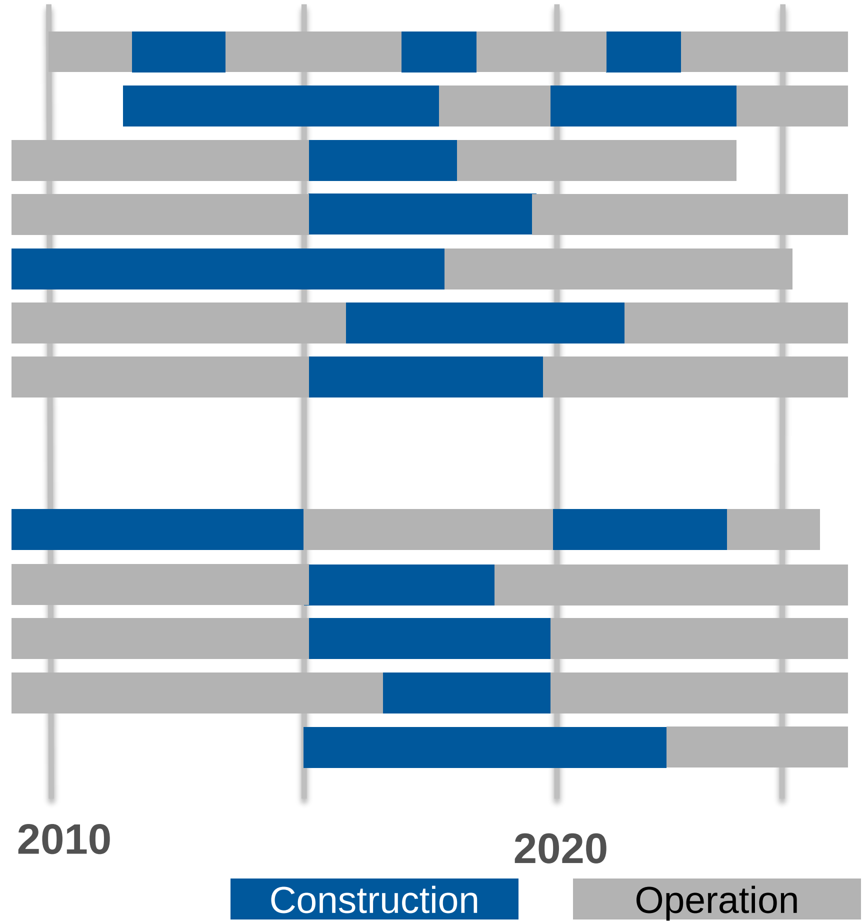
Anticipated large-scale facilities

Matter and the Universe

- LHC, HL-LHC (ATLAS, CMS, ALICE)
- FAIR (APPA, CBM/HADES, NUSTAR, PANDA)
- Pierre Auger Observatory
- IceCube, PINGU
- KATRIN
- Edelweiss, EURECA/SuperCDMS
- H.E.S.S., MAGIC, VERITAS, CTA

From Matter to Materials and Life

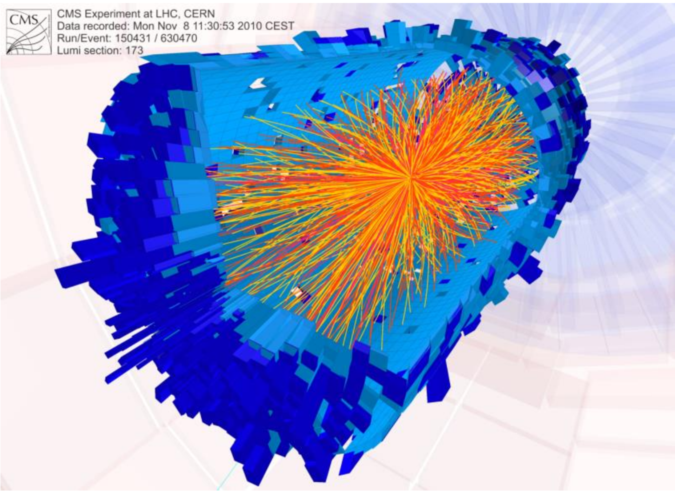
- European XFEL
- PETRA III, FLASH
- BESSY, BESSY^{VSR}
- ANKA
- ESS



Cutting-edge detectors are needed for all facilities and for all science fields in “Matter”

HELMHOLTZ ASSOCIATION

Example: LHC tracker upgrades



How to deal with ~400 billion tracks/second ?

- five- to tenfold increase in track density and thus channels number
- massive power distribution and cooling challenge
- tenfold increase in radiation levels
- Need a first level trigger decision within ~6 µs to do the science.

We are close to the experiments and the science.
Detectors and technologies are **not** available
off-the-shelf.

HELMHOLTZ
ASSOCIATION

How to cope with these challenges?

Successful detector instrumentation demands:

- Deep understanding of underlying physics principles
- Broad technological expertise and multidisciplinary approaches
- Access to sophisticated and expensive technological processes
- Experience to combine technological building blocks into complex systems

- Understanding of the science detectors will deliver
- Creativity and originality

HELMHOLTZ
| ASSOCIATION

Detector technology and systems (DTS)

- 5 Helmholtz centers/institutes

- Demonstrated history in detector conception, design and delivery
- Multi-disciplinary teams of scientists, engineers and technicians
- Access to major technical facilities and infrastructures

- Well-embedded in international instrumentation community and experimental collaborations
- Numerous national and international leadership positions

DTS is an ambitious attempt to exploit synergies between centers *and* disciplines.

Philosophy and choices

For "best value for money", we were guided by:

- Which are the key technologies to enable the science?
- Which detector types offers the highest science return?
- Where are synergies largest and where is collaboration most rewarding?
- Where is DTS world-leading and where should its technical portfolio be enhanced?

HELMHOLTZ | ASSOCIATION

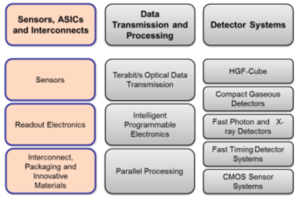
Topic structure

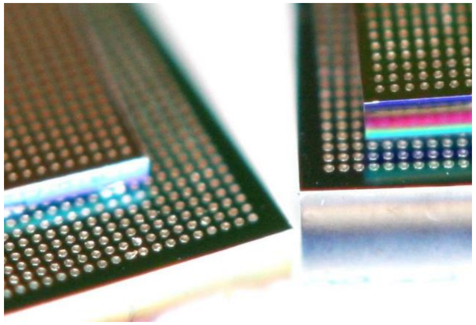
Sensors, ASICs and Interconnects	Data Transmission and Processing	Detector Systems
Sensors	Terabit/s Optical Data Transmission	HGF-Cube Compact Gaseous Detectors
Readout Electronics	Intelligent Programmable Electronics	Fast Photon and X-ray Detectors Fast Timing Detector Systems
Interconnect, Packaging and Innovative Materials	Parallel Processing	CMOS Sensor Systems

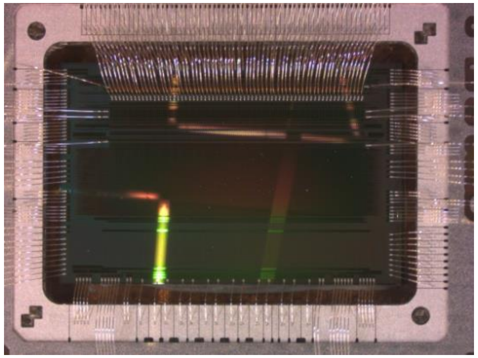
Networking, Outreach and Applications beyond "Matter"

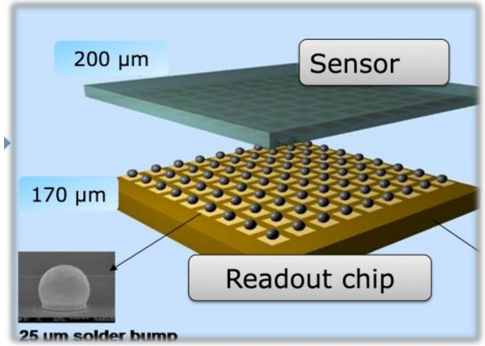
HELMHOLTZ ASSOCIATION

Sensors, ASICs and Interconnects









Objectives:

- technologies for unprecedented efficiency, resolution and fluences
- mass- and edge-less detectors
- transition from millions to billions of pixels

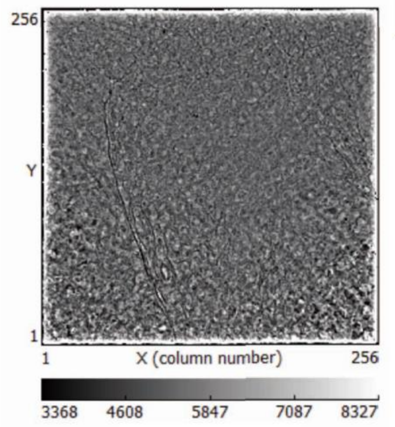
Challenges:

- extreme environmental requirements
- extreme integration density and functionality
- analog design for shrinking transistor size
- transition from hybrid pixels to 3D and monolithic technologies

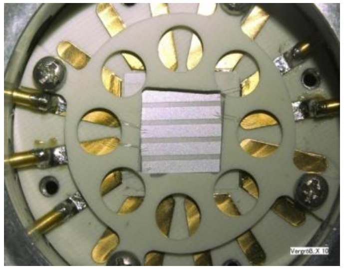
HELMHOLTZ ASSOCIATION

Competence and breadth in sensors

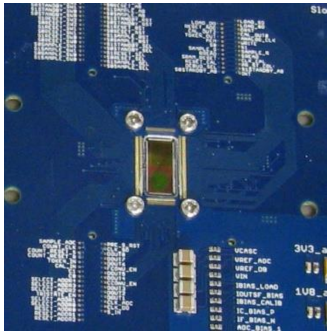
- Our sensor portfolio ranges from CdZnTe, diamond, GaAs, Ge, Si to cryogenic YBCO sensors.
- We host and have access to unique irradiation facilities at DESY, GSI, KIT.
- Our sensor specialists are driving the field and hold key positions in various experiments.

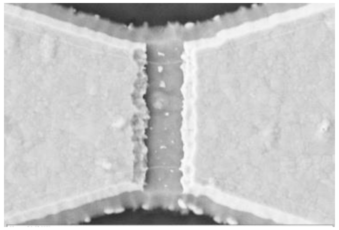


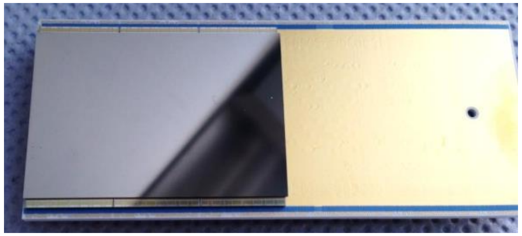
GaAs 500 µm


Diamond on Iridium 962


GEM-TPC

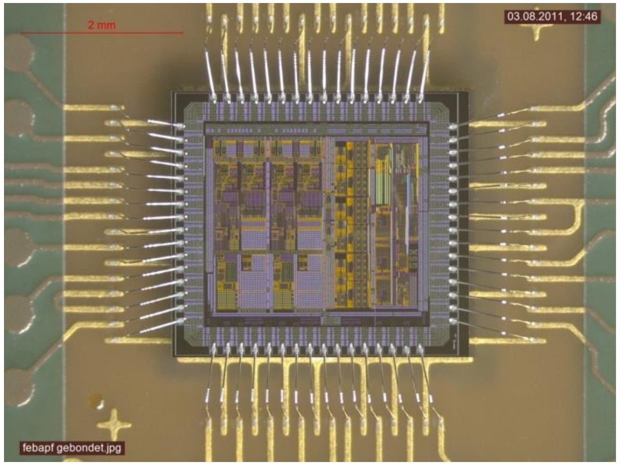

Percival CMOS


Cryogenic YBCO


Helmholtz cube with CdTe and GaAs

HELMHOLTZ | ASSOCIATION

Sharing of expensive technologies

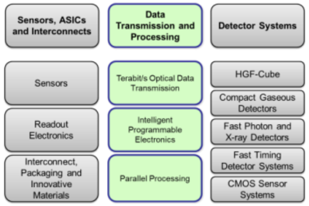


- Advances in microelectronics will enable detectors of unprecedented functionality.
- Custom microchips (ASICs) are a must.
- *However* costs for modern IC technology (< 65 nm CMOS, 3D, etc.) become prohibitive. Design process is getting involved and lengthy.

=> We combine forces, share designs and submissions, develop common building blocks between DESY, FZJ, GSI and KIT.

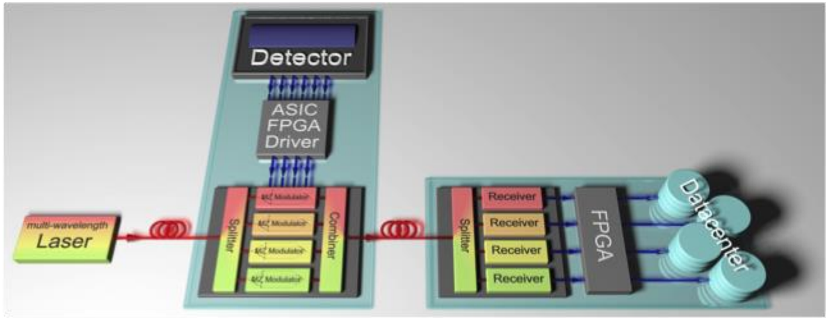
=> We strengthen overall expertise by creating a new ASIC design group at FZJ and a new ASIC professorship at KIT.

Data Transmission and Processing



Objectives:

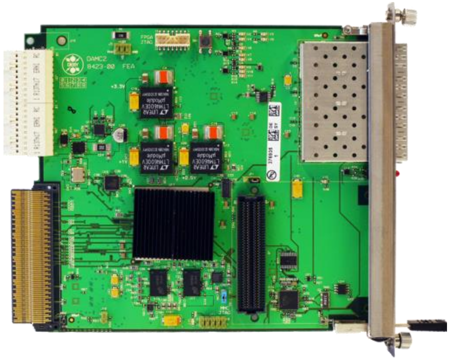
- Coping with unprecedented detector data rates and volumes



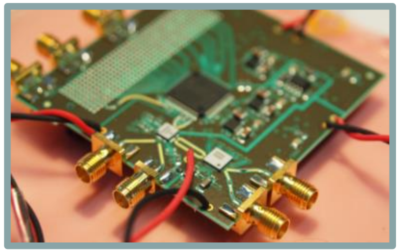
Optical data transmission for detectors

Challenges:

- Moving electronic intelligence (FPGAs) closer to detector despite radiation and power constraints
- Tb/s optical links for data transmission out of detector volume
- Innovative DAQ and trigger architectures.
- Detector-related advanced algorithms and computing.



Helmholtz MTCA.4 AMC

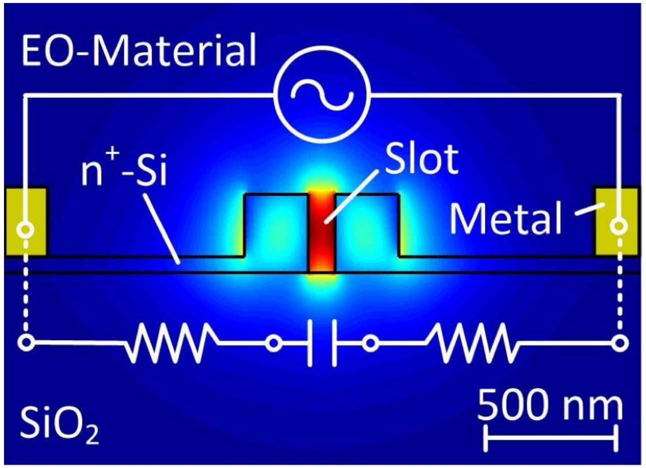


Picosecond sampling

HELMHOLTZ ASSOCIATION

Original and high-gain research

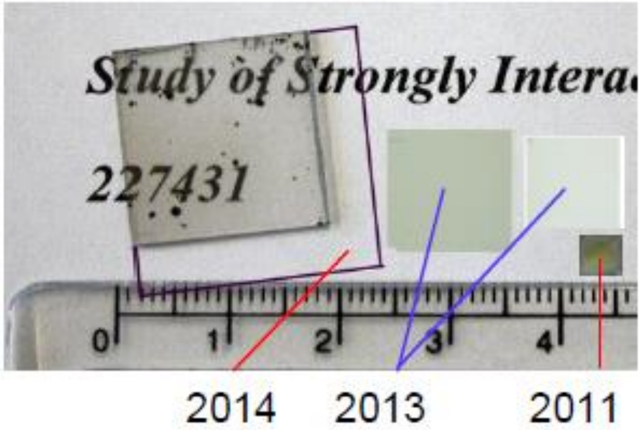
- Our portfolio includes selected high-risk/high gain elements
- We adapt technologies from elsewhere (e.g. telecommunication) to detectors
- We support others moving from prove-of-concept to production systems



Principle: Electro-Optical-Modulation

Example 1: Electro-Optical-Modulation

(see talk of C. Koos)



DOI samples produced in Augsburg

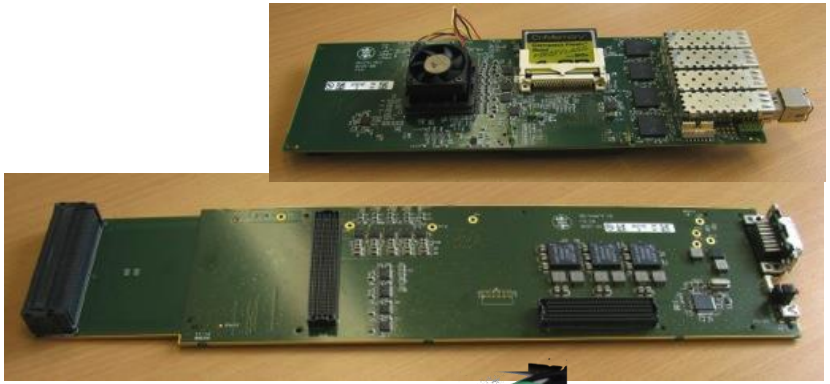
Example 2: Large-area diamond detectors

(University Augsburg: Diamond-on-Irridium)

HELMHOLTZ ASSOCIATION

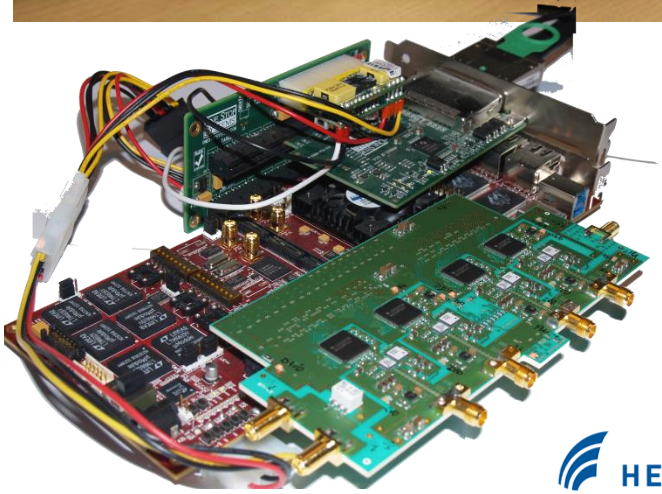
High-tech systems at fast R&D cycles

- Long lead times are a nuisance and costly
- Our approach is: modular frameworks, common platforms and synergetic collaboration



Example 1: Readout for HGF cube

Readout, ADC, 10GbE links

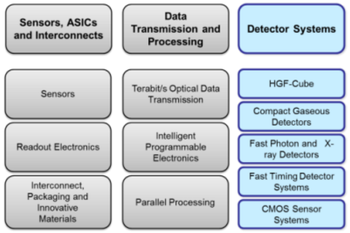


Example 2: UFO High-throughput DAQ framework

High speed detectors, FPGA, PCIe links, GPUs

HELMHOLTZ ASSOCIATION

Detector Systems

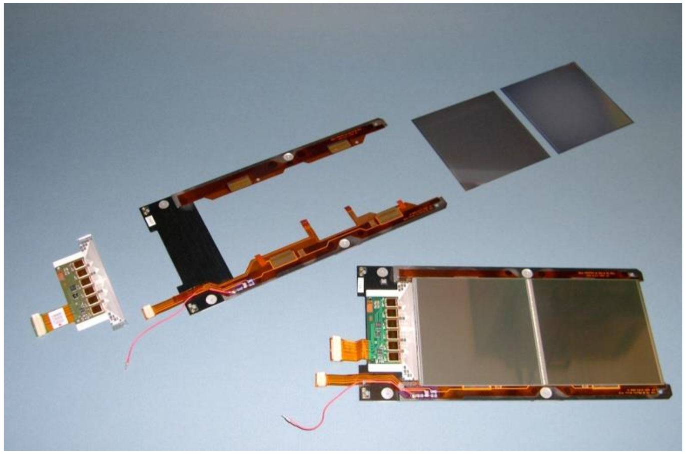


Objectives:

- Demonstrate cutting-edge technologies in complex, functional and scalable systems

Challenges:

- Need to be selective
- Find balance between systems ready for use and prototypes
- Be ambitious while avoiding blue sky research



CMS Tracker Inner Barrel

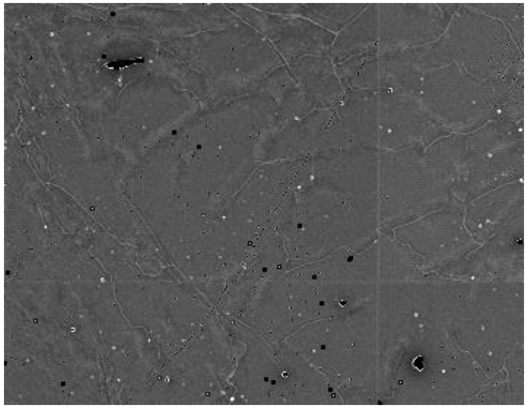
Smart tomography camera

HELMHOLTZ ASSOCIATION

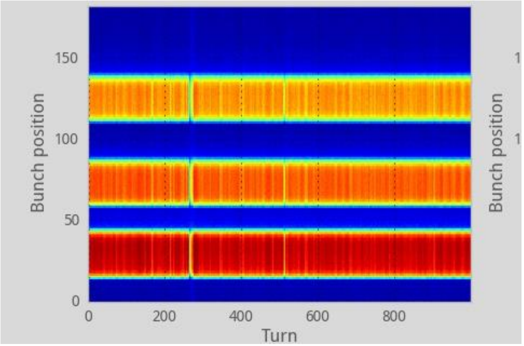
Demonstrators for science

- We aim to develop modular demonstrator systems ready for use at beam line or test beam.

Example 1:
Helmholtz cube
Image with CdTe sensor

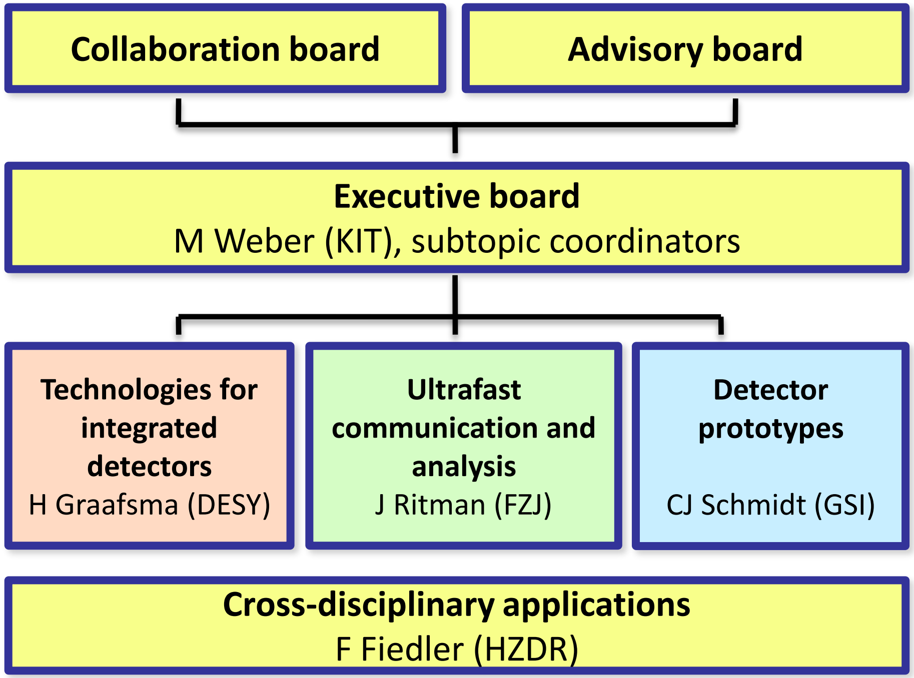


Example 2:
Beam diagnostics with superconducting THz sensor



Organisation

- Precursor of DTS was established in 2012.
- Since then, we have a lean but proven organisational structure.
- Experienced subtopic coordinators are assigned and have been active since 2012.
- Goals, milestones and responsibilities are well-defined.



- We are, however, prepared to accommodate the unexpected and to react to opportunities not obvious today.

HELMHOLTZ ASSOCIATION

From Helmholtz to Universities and Society

- Close collaboration with many major research centers and universities
  - within experiments
  - through Helmholtz Alliances (HAP, Terascale) and “MUTLink”

Compact Muon Solenoid experiment at CERN’s LHC

CMS

panda

European XFEL

HELMHOLTZ ASSOCIATION

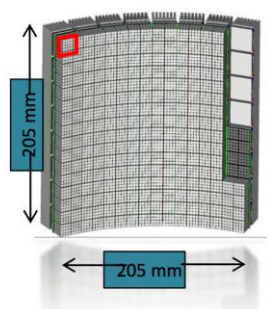
Alliance for Astroparticle Physics

PHYSICS AT THE TERA SCALE

Helmholtz Alliance

- Topical workshops
- WE Heraeus seminar
- Applications in other field
- Support of spin-offs / industry

Wilhelm und Else Heraeus Stiftung



HELMHOLTZ ASSOCIATION

Summary

- “Detector technology and systems” is fully aligned with the strategy of “Matter”
- DTS raises the level of cooperation between the HGF center and partners to a new level

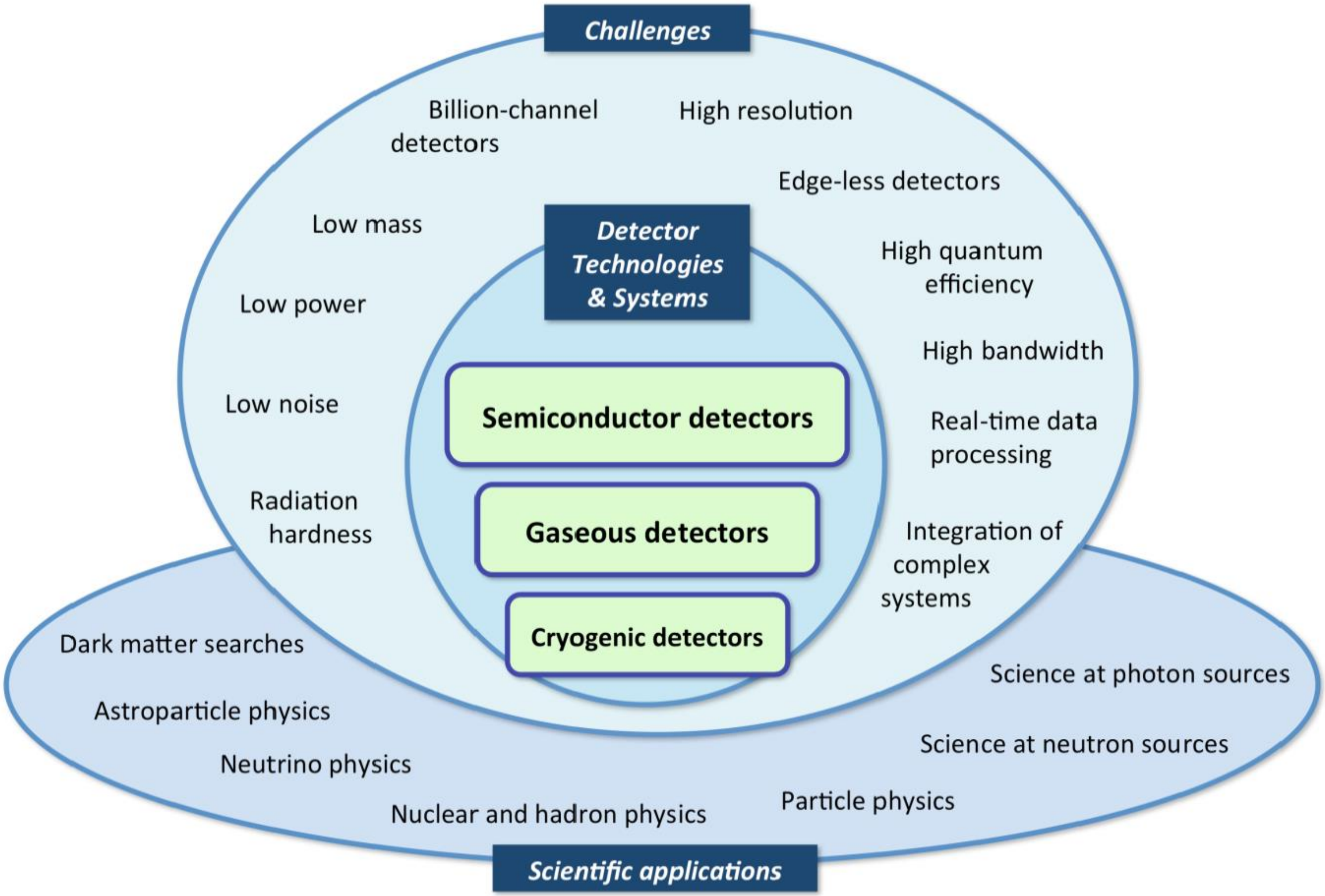
We believe:

- to have compiled a coherent research portfolio that fits our competences and scientific needs
- that DTS will be a major player in the international community
- that DTS will be a leader in shaping detector systems of unprecedented performance and complexity for the large-scale facilities of tomorrow.

HELMHOLTZ ASSOCIATION

Appendix

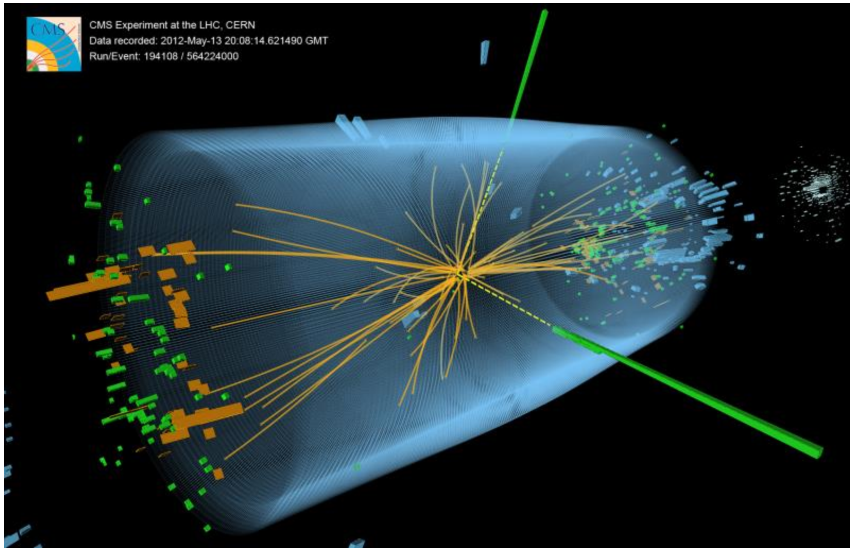
Detector challenges in “Matter” are extreme



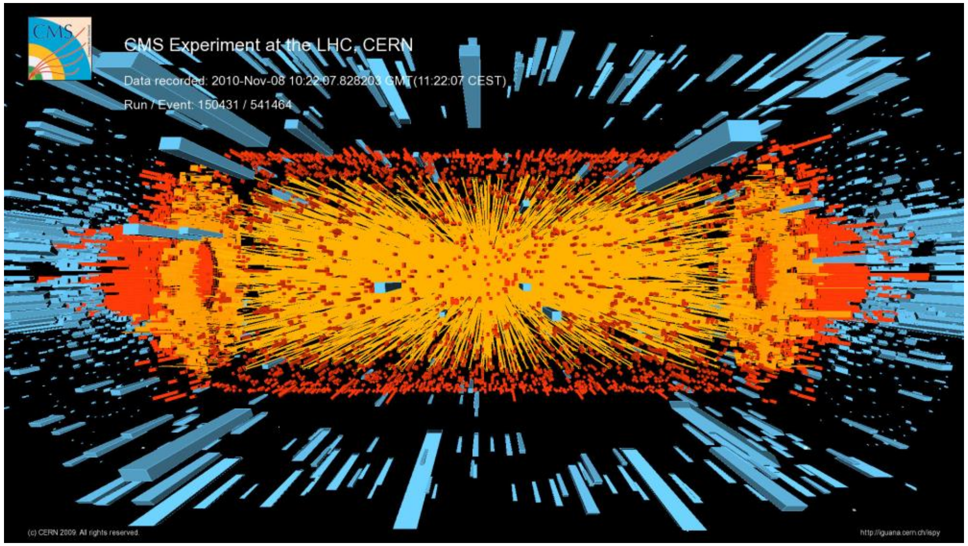
Our detectors and technologies are not available off-the-shelf.

HELMHOLTZ | ASSOCIATION

Vom LHC zum High-Luminosity-LHC



p-p-Kollisionen: ~ 1000 Spuren/Ereignis



Pb-Pb –Kollisionen: ~ 10000 Spuren/Ereignis
≙ HL-LHC

- LHC sollte > 20 Jahre Daten liefern
- statistische Messfehler sinkt nur mit $1/\sqrt{N}$
- daher Umbau des LHC in verschiedenen Phasen

HELMHOLTZ | ASSOCIATION