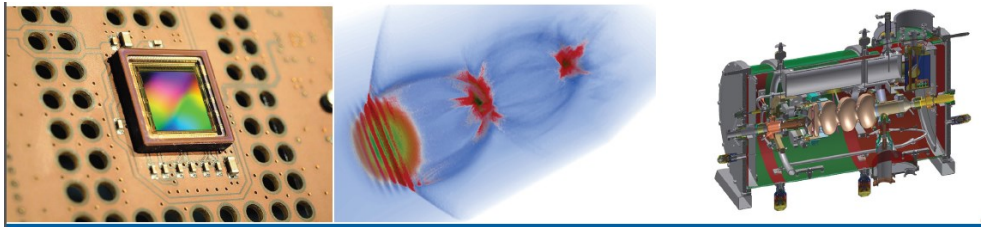


2015 – 2019

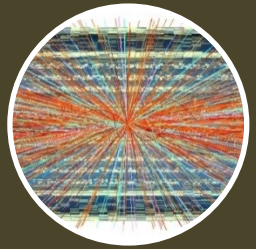
Participating Centres
Deutsches Elektronen-Synchrotron DESY
Forschungszentrum Jülich
GSI Helmholtzzentrum für Schwerionenforschung
Helmholtz-Zentrum Berlin für Materialien und Energie
Helmholtz-Zentrum Dresden-Rossendorf
Karlsruher Institut für Technologie

Matter and Technologies

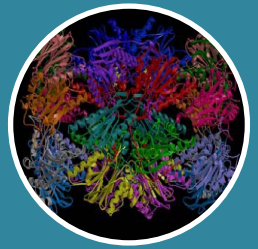
Ties Behnke
DESY

HELMHOLTZ ASSOCIATION

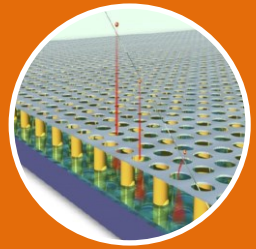
Matter and Technologies



Matter and the Universe



From Matter to Materials and Life



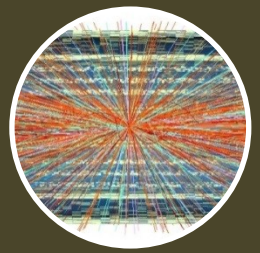
Matter and Technologies

Cross program activities within matter

Cross program activities with other research areas and outside Helmholtz

HELMHOLTZ ASSOCIATION

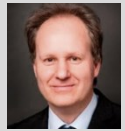
Matter and Technologies



Matter and the Universe

Accelerator (ARD)
DESY, FZJ, GSI, HZB, HZDR, KIT
Reinhard Brinkmann, DESY

Detector technologies and Systems(DTS)
DESY, FZJ, GSI, HZDR, KIT
Marc Weber, KIT

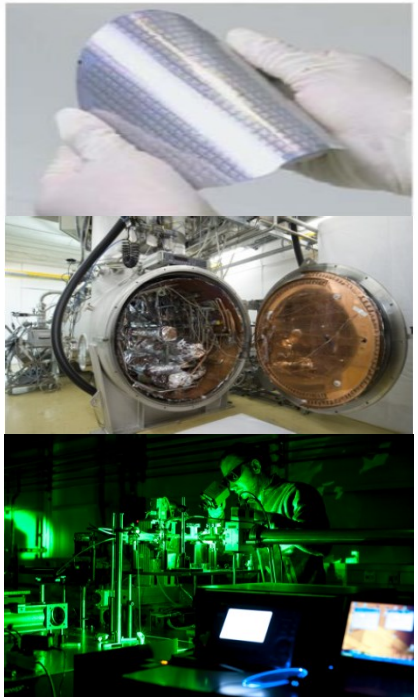


Cross program activity “Computing, Large scale data handling and processing”

Cross program activities with other research areas and outside Helmholtz

HELMHOLTZ ASSOCIATION

Matter and Technologies: A Program in Matter



Bundle competence available in matter
in accelerator and detectors science at Helmholtz:

“Matter and Technologies” will be a platform
for fundamental developments in technologies
to prepare for the future of the field.

Driven by science
Needed by the science
Important for society
Relevant for industry

Technology is the motor of innovation and excellence

Fundamental research is one of the most efficient driving forces
for new technologies

HELMHOLTZ ASSOCIATION

Matter and Technologies

Matter and the Universe

From Matter to Materials and Life

Research for accelerators and detectors

- Research fundamental problems
- Allow the researchers breathing space for novel ideas, even if they are “high risk”
- Do research with a long time line and a long term perspective

- Ensure close and active connections to the science in the fields to develop the right things for the right question at the right time.

- Come together nationally (Helmholtz and universities)
  - Seek close and intimate links with “Matter and the Universe” and with “From Materials to Matter and Life”.
- Network strongly internationally with the best players in the field.

- Attract excellent people internationally

HELMHOLTZ | ASSOCIATION

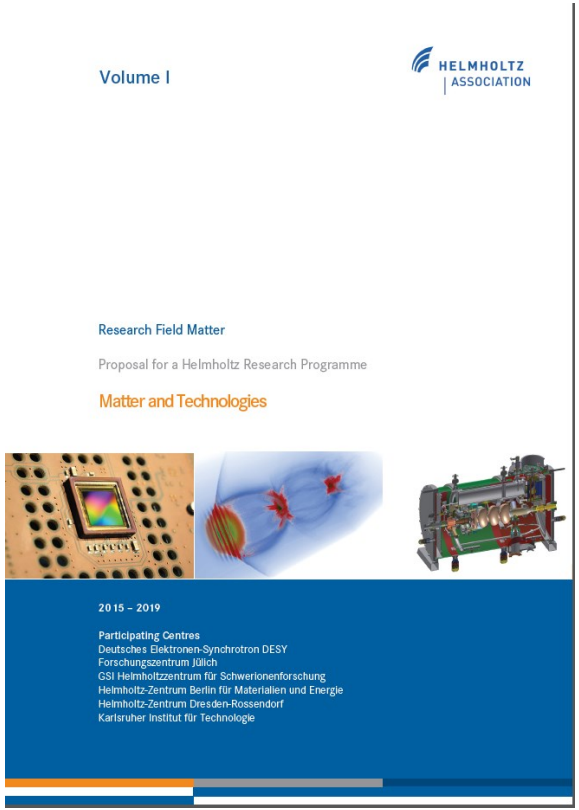
POFIII review in Dresden

Francesco Sette,
Chair of review committee

Review of the program
“Matter and Technologies”:

Dresden (HZDR), 26-28 March, 2014

Intense, very constructive discussion
of the program over two days



Large event (about 150 participants)
Extremely well organized from HZDR (many thanks to them)
Extremely solid support by all participants and members of the program.

HELMHOLTZ ASSOCIATION

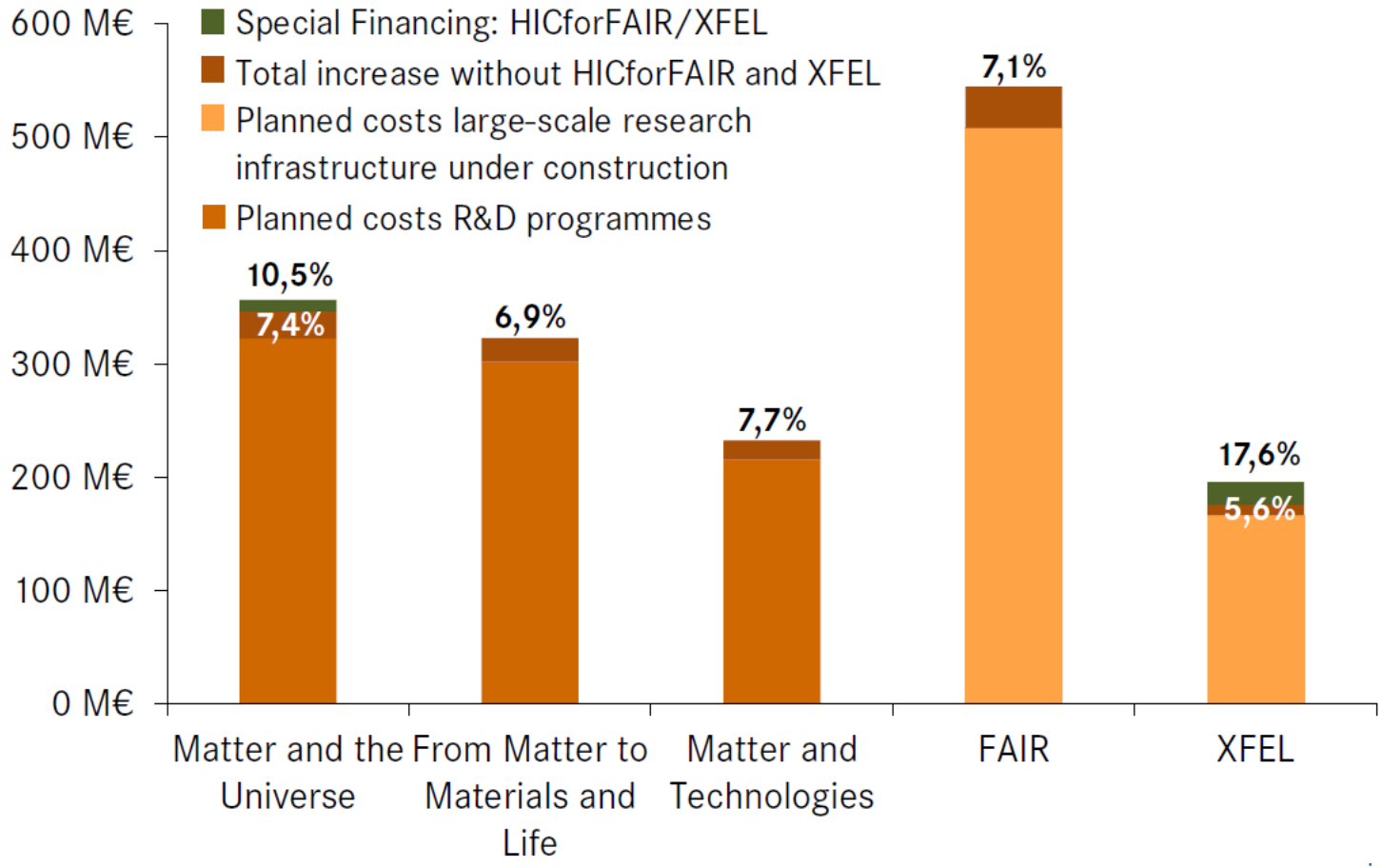
Matter and Technologies: Recommendations

Strategic recommendations:

- The development of CW RF to FLASH and XFEL should be viewed as the highest priority objective of topic Accelerator R&D (ARD).
- The development of laser plasma acceleration should be pursued with high priority
- During the mid-term reviews, it should be examined to what extent the planned objectives of the programme have been achieved, and if necessary new plan objectives have to be formulated. In addition, functionality and success of the management and coordination structures of the topic should be checked.
- A long-term perspective for the programme topic Detectors Technologies and Systems (DTS) should be developed.
- For DTS the development of shared research infrastructures is highly recommended. These infrastructures should be also accessible for university partners.
- The transfer of technology in both programme topics should be further advanced considering probable developments which take place at the periphery of the programme topics.

HELMHOLTZ | ASSOCIATION

Development of the Costs within Matter



Accelerators: Engines of Discovery

Accelerators are the engines of the research field “Matter”, they are engines of discovery

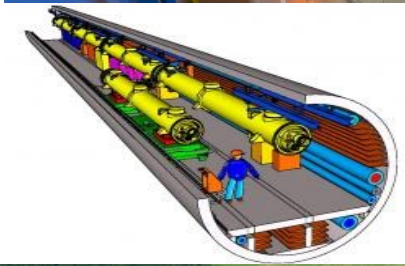
Helmholtz looks back at many decades of cutting edge accelerator research and facilities.

We design, we build, we participate in some of the worlds most advanced accelerator based facilities.

Challenges:

- Highest beam intensities
- Highest beam energies
- Highest brilliance
- Reliable, efficient operation

LHC



XFEL

FAIR

Superconducting RF technology

Concepts & tech. hadron acc.

ps & fs el. and photon beams

Novel acceler. concepts

HELMHOLTZ ASSOCIATION

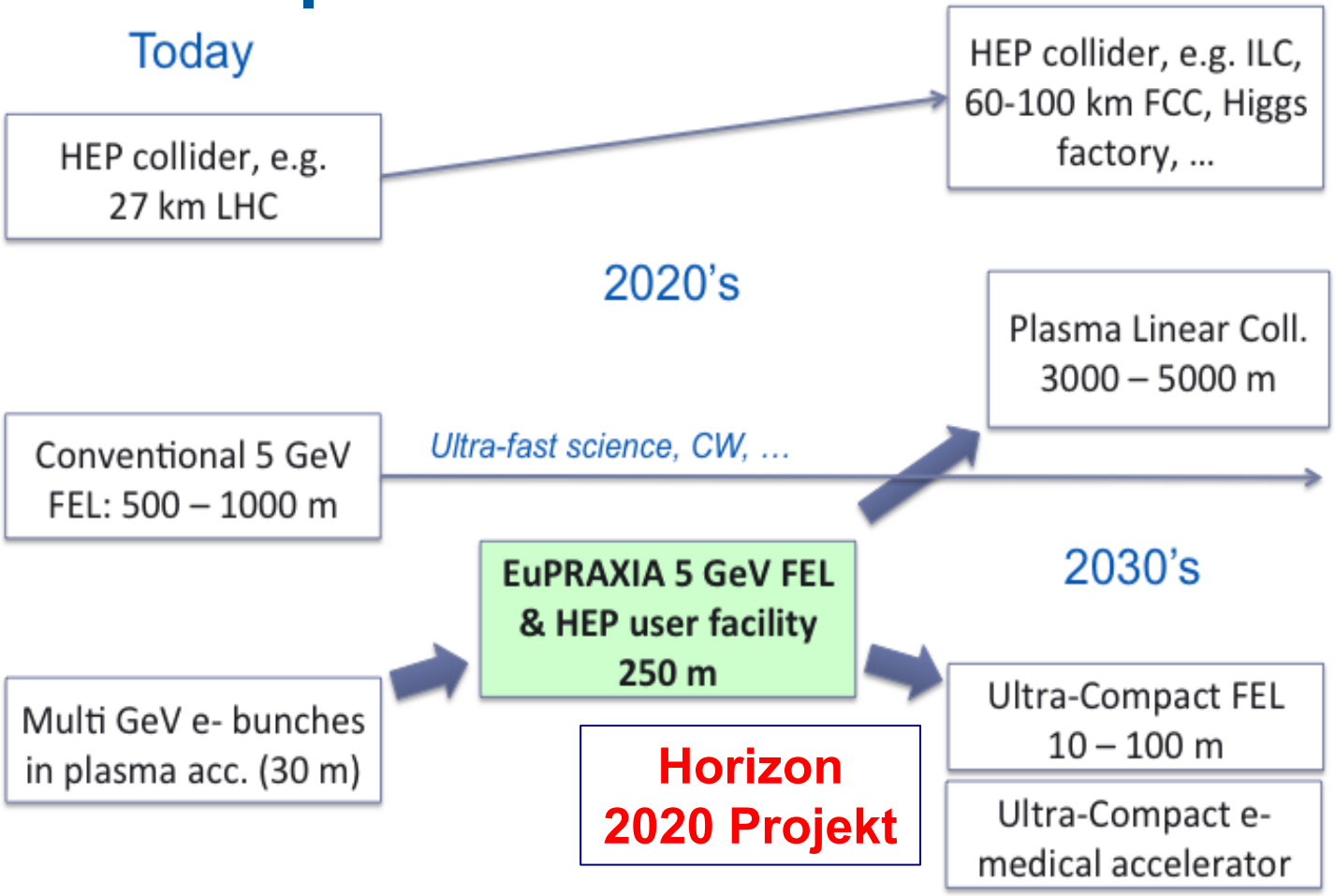
= Laser Puls

= Elektron Puls

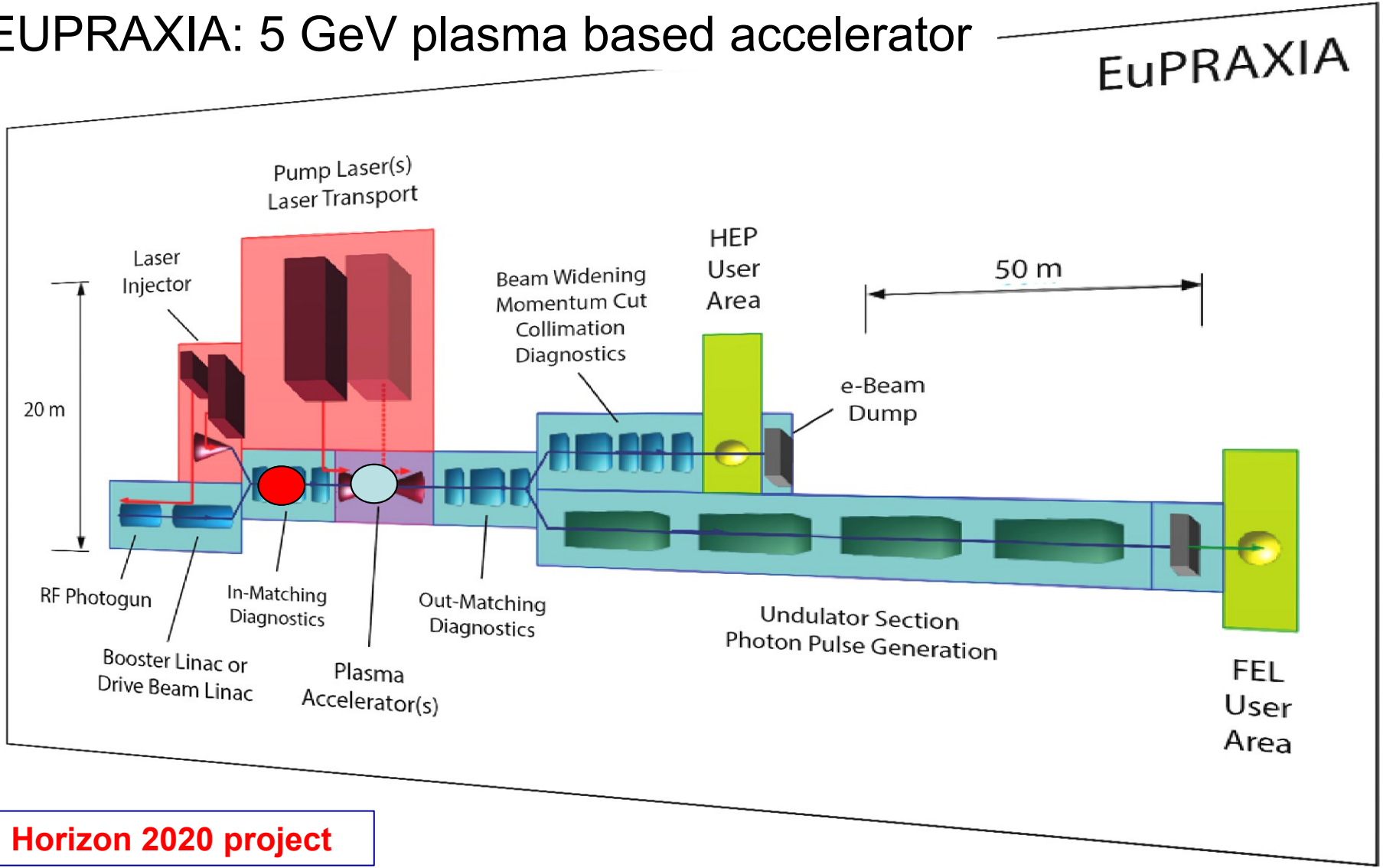
Plasma channel

The 100 billion volt machine

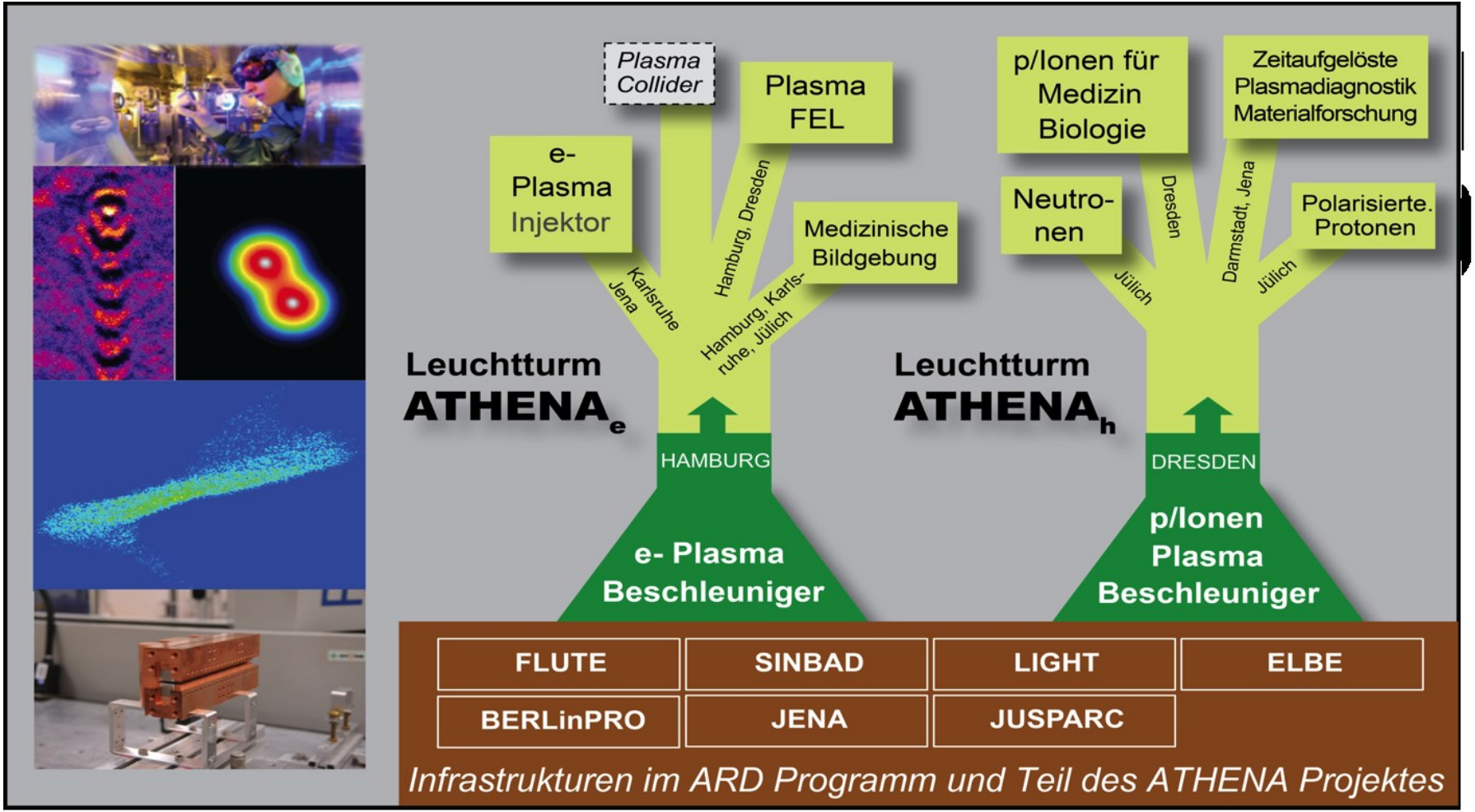
The Roadmap


Today
HEP collider, e.g. 27 km LHC
HEP collider, e.g. ILC, 60-100 km FCC, Higgs factory, …
2020's
Plasma Linear Coll. 3000 – 5000 m
Conventional 5 GeV FEL: 500 – 1000 m
Ultra-fast science, CW, …
EuPRAXIA 5 GeV FEL & HEP user facility 250 m
2030's
Multi GeV e- bunches in plasma acc. (30 m)
Ultra-Compact FEL 10 – 100 m
Ultra-Compact e- medical accelerator
Horizon 2020 Projekt

EUPRAXIA: 5 GeV plasma based accelerator



Horizon 2020 project



ATHENA: 2018 – 2021, strategic investement, 6 centres, 1 MPG, universities, international partners,

Shared usage of infrastructures for plasma acceleration with 2 topical centers (DESY, HZDR)

Detectors: Eyes of Discovery

Detectors are key to new discoveries

Helmholtz has been a key player in major experiments in the past and present, for a wide range of applications.

Challenges:

- Unprecedented photon and particle fluxes
- Highest spatial, temporal and energy resolution
- Highest sensitivity
- Dramatic increase in data rates and volumes

Enable technologies, develop novel concepts, design complex systems.
Make cutting-edge detectors affordable and exploit synergies.

Sensors, ASICs, Interconnects

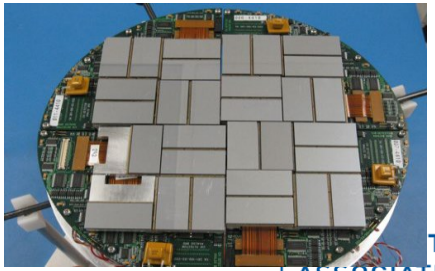
Data Transmission and Processing

Detector Systems

Experiments at collider and hadron facilities

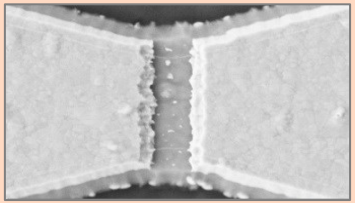
CMS detector

Experiments at Photon and Neutron Sources

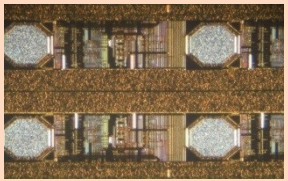


XCLS detector

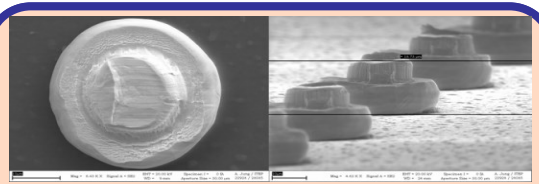
Sensors, ASICs and Interconnects



Sensors

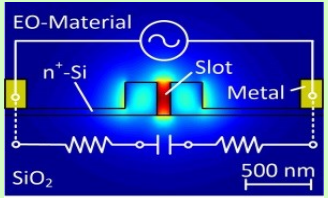


Readout Electronics



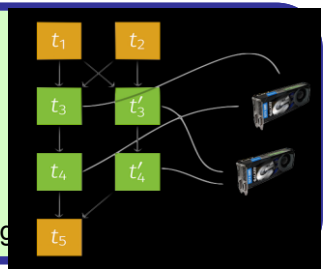
Interconnect, Packaging and Innovative Materials

Data Transmission and Processing



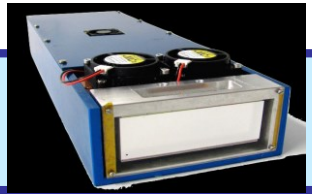
Terabit/s Optical Data Transmission

Intelligent Programmable Electronics

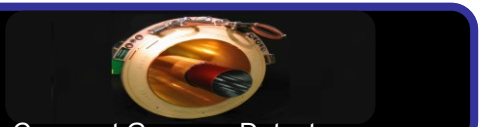


Parallel Processing

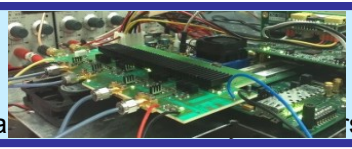
Detector Systems



HGF-Cube

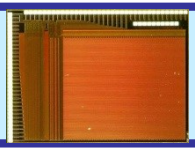


Compact Gaseous Detectors



Fa s

Fast Timing Detector Systems

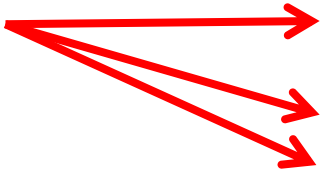


CMOS Sensor Systems

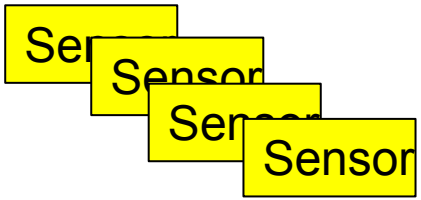
ASSOCIATION

Global trends

Highly pixelated systems (“Giga pixel”)



Silicon tracker
gaseous chamber readouts
granular calorimetry
Photon sensing



Sensor is very application specific

Interconnect

Readout / processing

Control/ Management

Data Flow and handling

Data compressing and storage

Data mining/ analysis

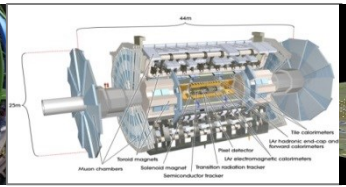
System behind the sensor is
(very) similar for all applications

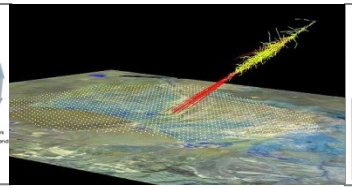
ASIC competence

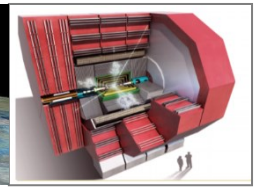

ANKA KIT

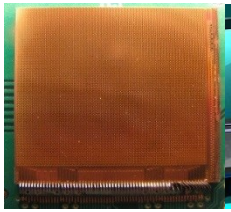

PET Scanner

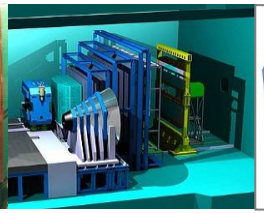

CMS

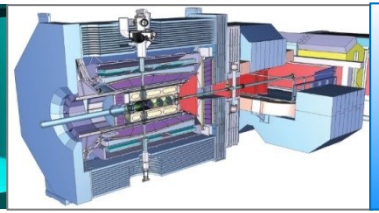

ATLAS

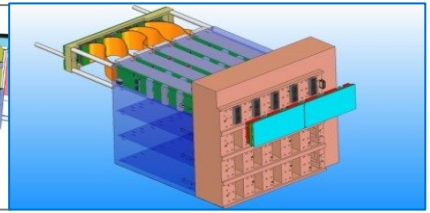

Pierre Auger


CLIC


@XFEL.EU

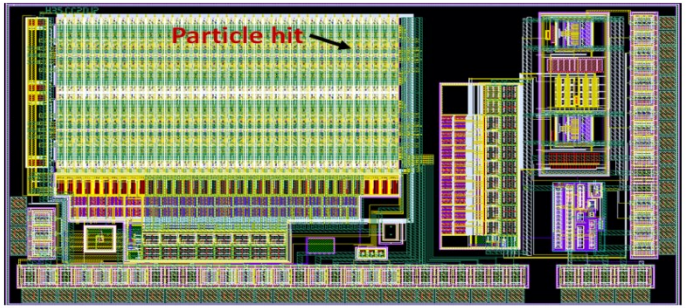

CBM @FAIR


Panda @FAIR


DSSC @XFEL.EU

Large expertise in many places
Distributed
Both Universities and Helmholtz centres

Particle physics →



Test chip example – Feb 15' – AMS H350nm

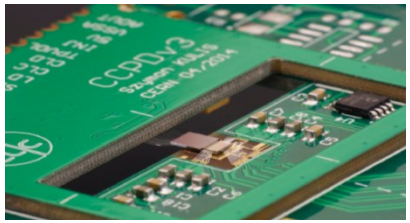
← Ultrasound receiver signal amplifier (~ 1 mV)

← Ultrasound driver signal amplifier (~ ± 50 V)

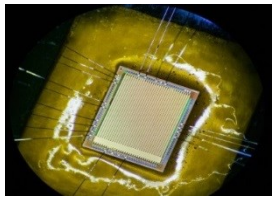
ASIC activities in MT

Many processes, e.g.

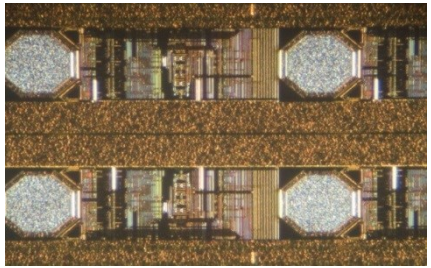
- AMS 350nm CMOS
- AMS 350nm HV-CMOS
- AMS 180nm HV-CMOS
- XFab 180nm HV-SOI
- LFoundry 150nm HR-CMOS
- UMC 180nm
- IBM 130nm
- GF-Tezzaron 130nm 3D-CMOS
- UMC 65nm
- TSMC 65nm



CCPD Sensor



HVCMOS Sensor



Flip-Chip Technology

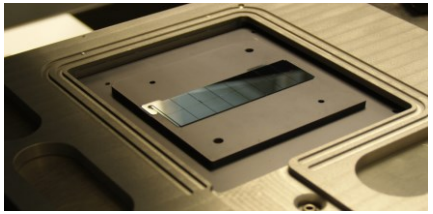
Flip-Chip Bonding

Flip Chip (CMS-ROC)

Bonding

16 x

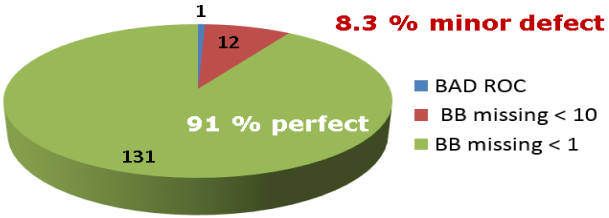
Reflow of Bare Module



16 ROCs on sensor module

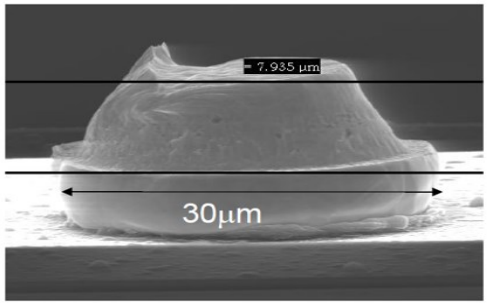
30 µm SnPb bumps

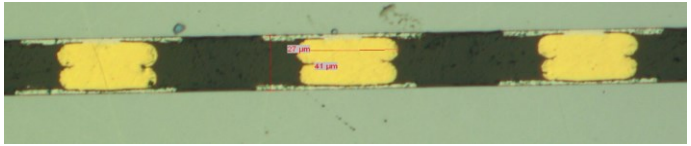
Preliminary 144 ROCs yield



Au stud bumping

Bumping Process

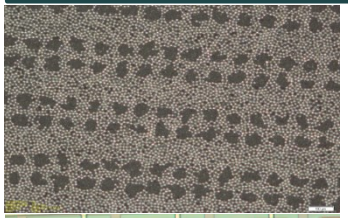




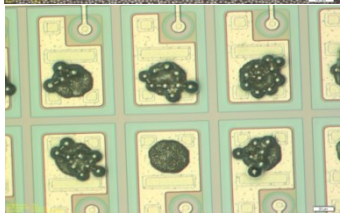
cross section: excellent bonding results

- Bump diameter: ~ 30 µm
- Bump height: ~ 15 µm
- Fast: 18 bumps/s
- High process stability
  → 4000 bumps without one missing

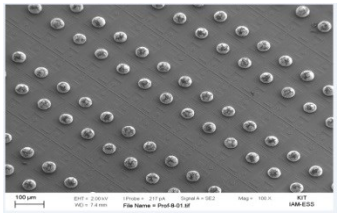
Precoat by powder sheet



PPS sheet after processing



Single sensor with transferred balls

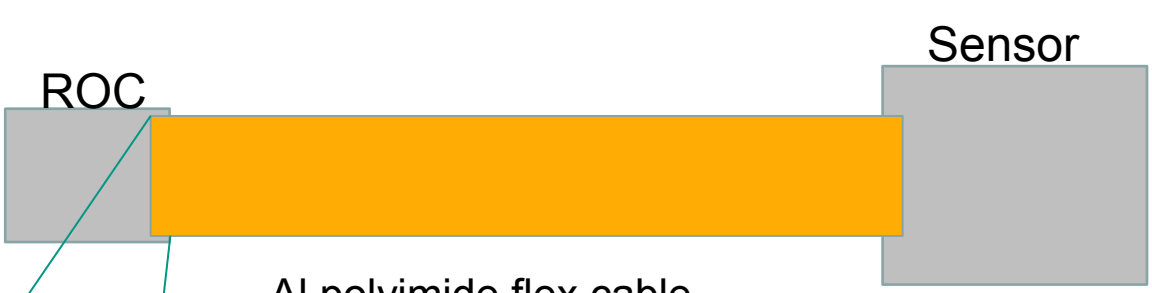


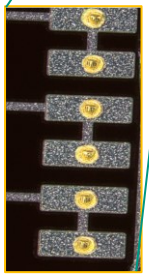
Sensor after reflow

- SAC Bumps with reproducible diameter
- Easy process
- Homogeneous temperature required

Substrate Technology

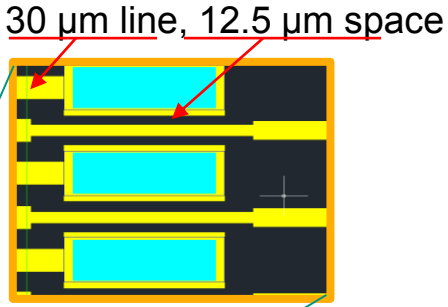
Interconnects on flexible, ultra-thin fine-pitch flex cables for very low-mass connections

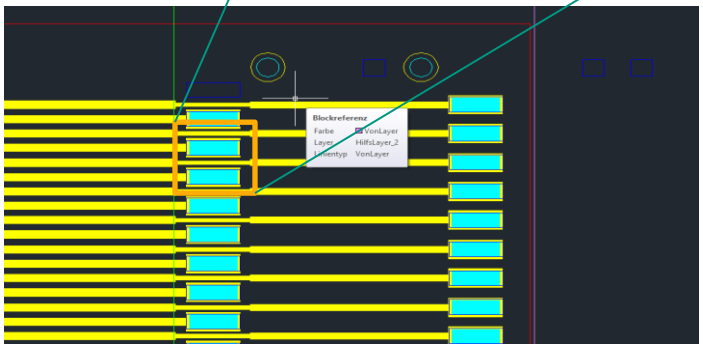




Al polyimide flex cable

- height: 20 µm single layer
- 30 µm width, 12.5 µm gap
- 30 cm cable length



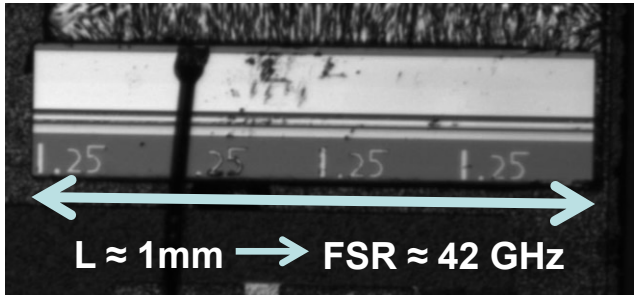


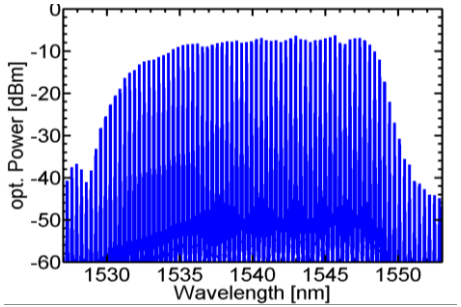
Evaluation of gold stud bumps + PPS

Courtesy SE SRTIIE, Kharkov, Ukraine

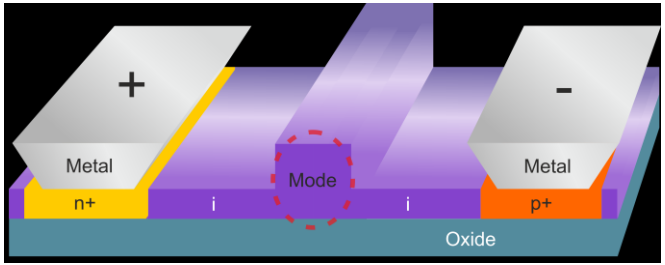
HELMHOLTZ ASSOCIATION

System elements for Tb/s data transmission

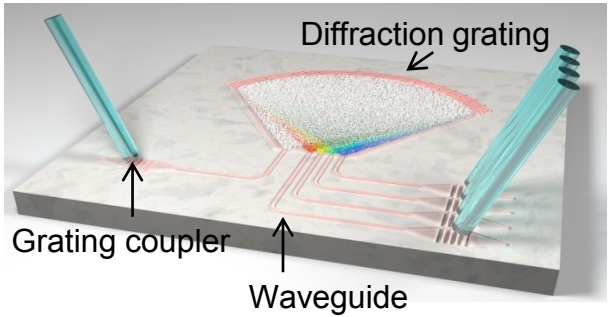


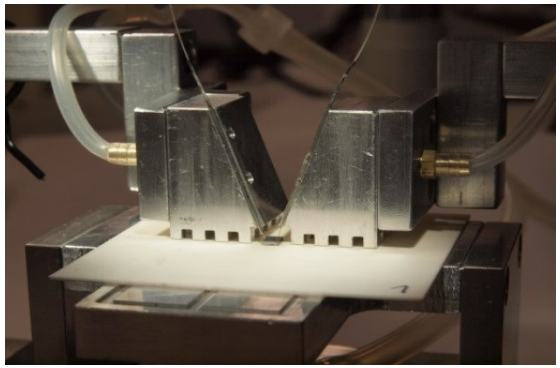


Quantum dash mode-locked laser diode

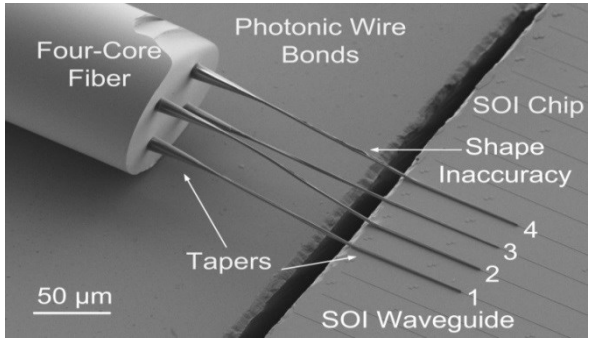


PIN electro-optical modulator

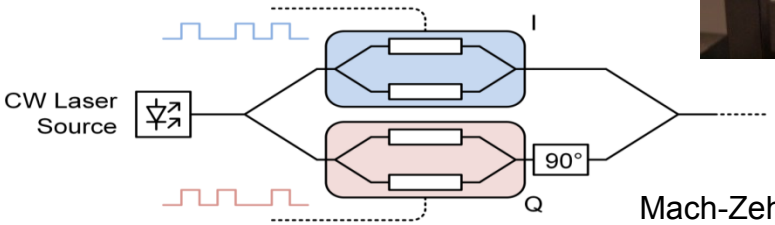




Fibre coupling



Photonic wire-bonds

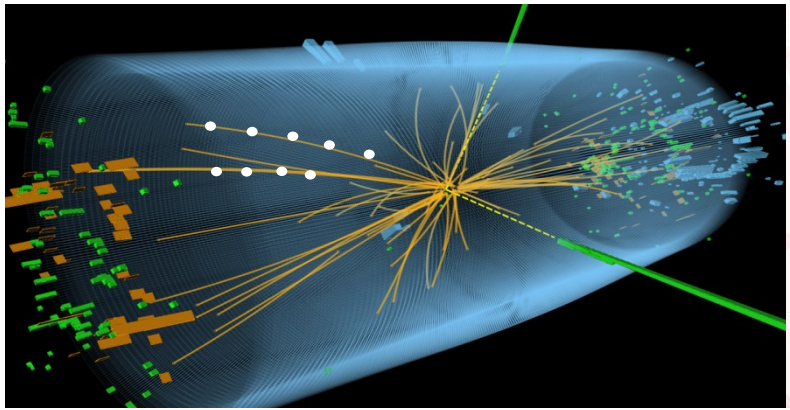


Mach-Zehnder interferometer

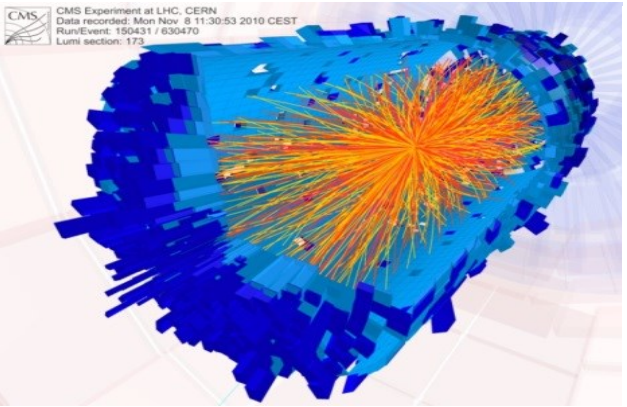
HELMHOLTZ ASSOCIATION

Fast Data Handling

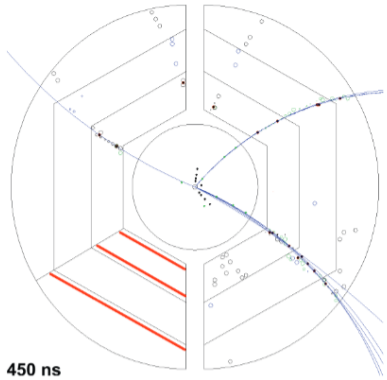
LHC today



HL-LHC ≈ 2023

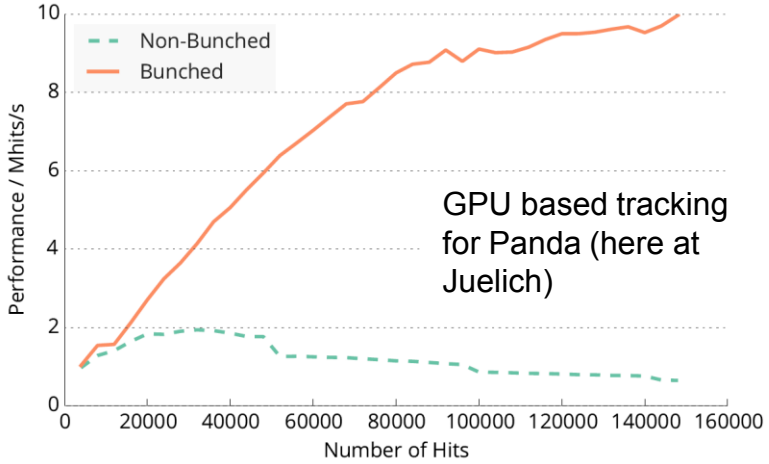


PANDA simulation

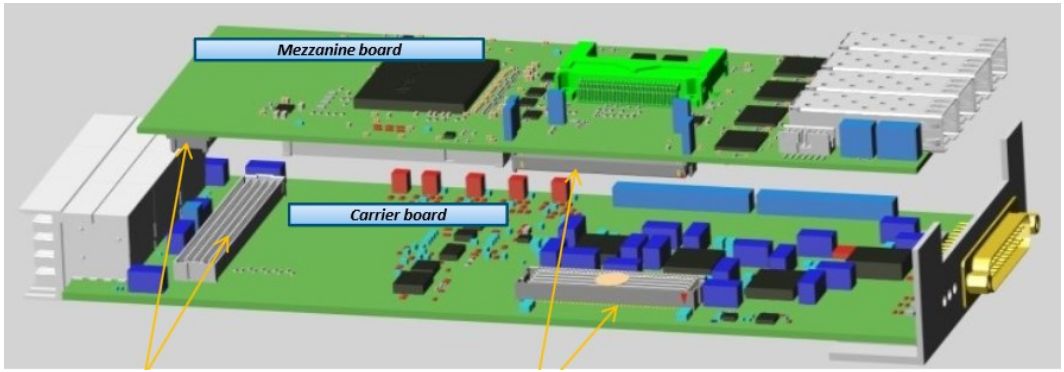


Modern experiments produce huge amounts of data.
Both hardware and software is needed to deal with this.

Reconstructing the data requires new technologies:
- Algorithmus development
- Computing: for example GPU computing



System: Helmholtz Cube



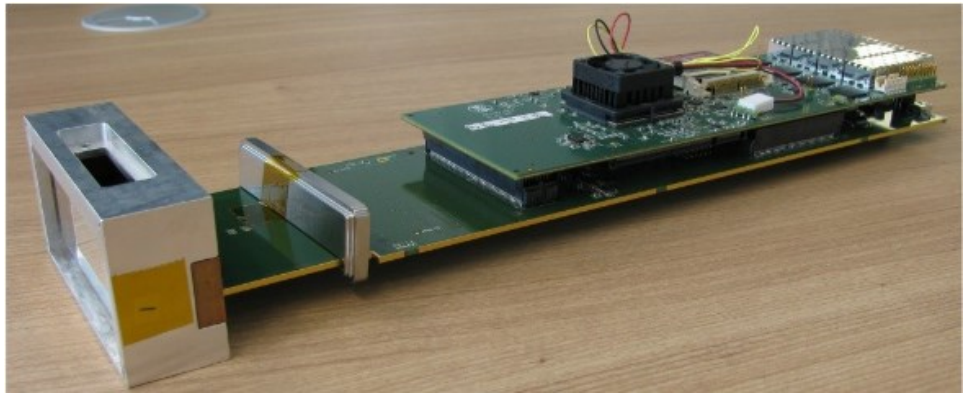
Versatile, flexible basis for sensor test and (small scale) use.

Up to 2kHz frame rate
Simple to use, fast to setup.

Realised for several technologies:

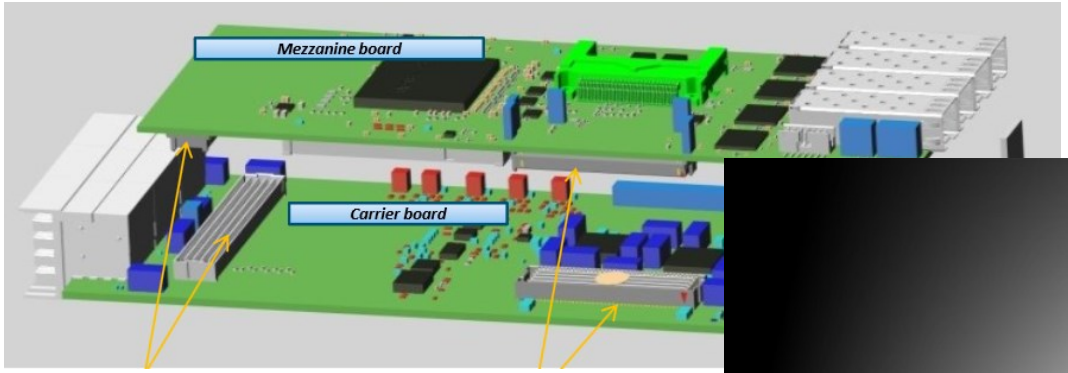
- Silicon
- GaAs

Basis for commercial spin-off (x-spectrum)



HELMHOLTZ ASSOCIATION

System: Helmholtz Cube



Versatile, flexible basis for sensor test and (small scale) use

Realised for several technologies:

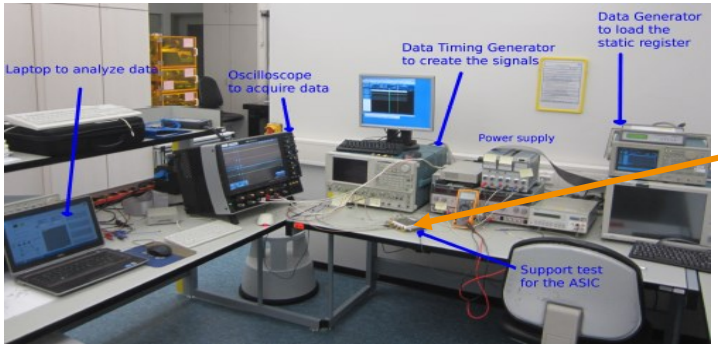
- Silicon
- GaAs

Basis for commercial spin-off (x-spectrum)

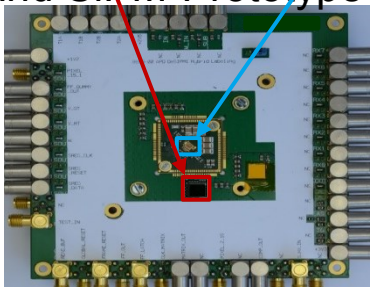
ASSOCIATION

Fast digital imaging systems with SiPMs

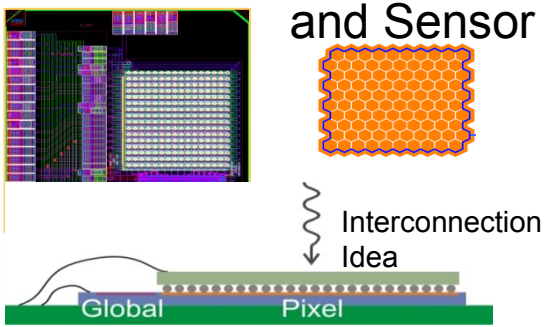
Test Environment



Test Board with ASIC- and SiPM-Prototype



Layout of ASIC and Sensor



- 1st ASIC successfully tested with SiPM prototype
- Few 10 ps intrinsic time resolution
- 30 µm SAC solder balls on ASIC
- Fast sensor for digital SiPM test setup in production at MPI-HLL
- HGF-AMC based DAQ-system in preparation

Digital SiPM imaging system in 2016

Summary

Matter and Technologies is picking up speed

Accelerator Science is developing rapidly within Helmholtz

Large scale invest proposal has been submitted

Detector Development serves a broad community of people from particle physics to applied sciences

Dates:

Second MT plenary meeting: March 8/9 at the KIT

HELMHOLTZ ASSOCIATION