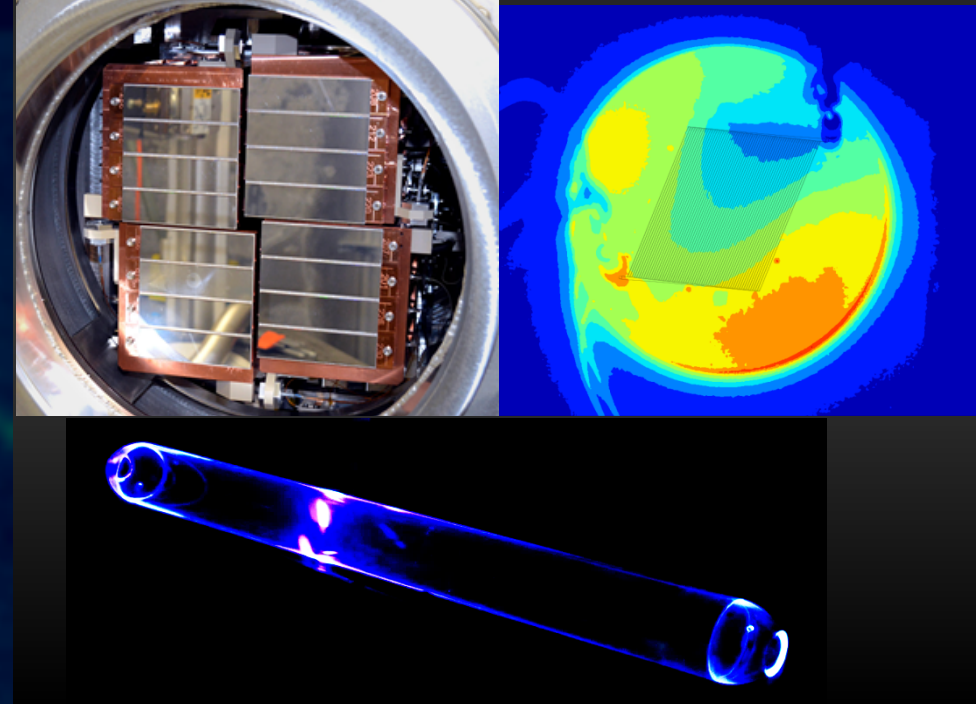


Detector Technologies and Systems

The Program at DESY



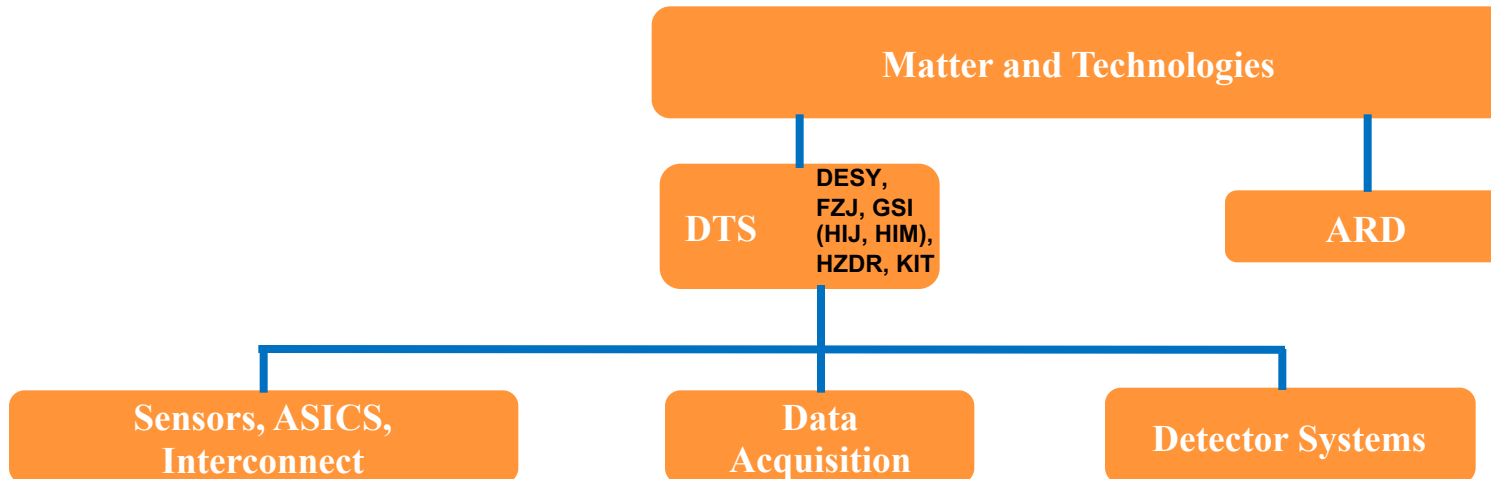
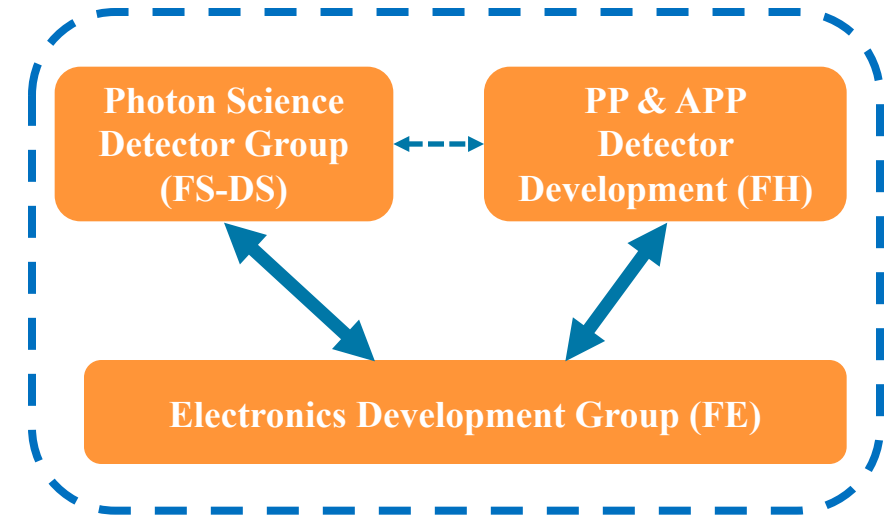
Helmholtz Program: Matter and Technologies
PoF III Topic: Detector Technologies and Systems
DESY Research Unit: Detector Developments

Heinz Graafsma
Center Evaluation DESY, 5 – 9 February 2018

Research Unit: Detector Development

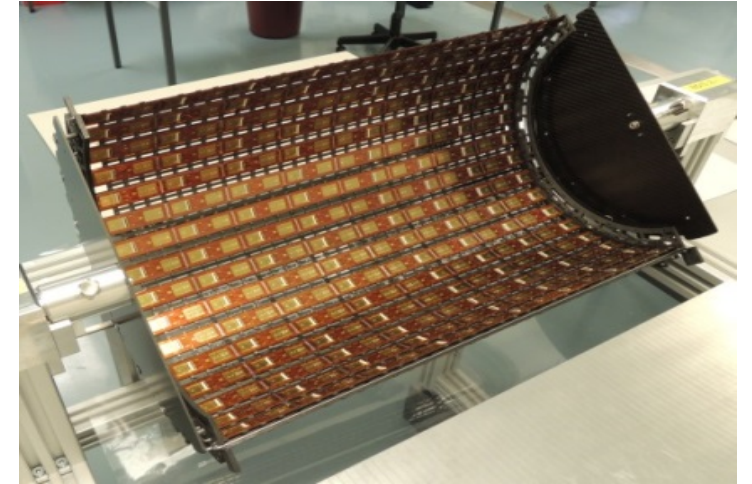
Structure

- Research Unit **Detector Development** consists of 3 groups
 - Photon-Science Detector Group (FS-division)
 - Particle and Astroparticle Physics Detector Development (FH-division)
 - Central Electronics Development Group
- Develops detector technologies for science applications (MML and MU)
- Builds detector systems for experiments at DESY or with DESY involvement
- RU **Detector Development** maps on to the Research Topic: **Detector Technologies and Systems (DTS)**

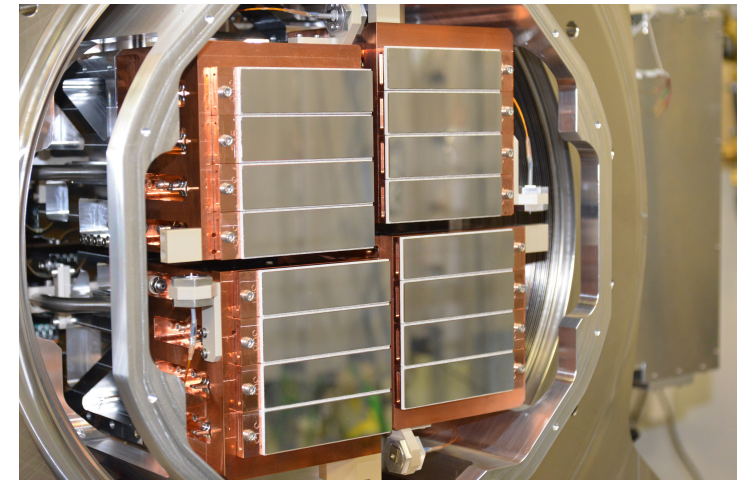


Science driven Detector Development

- We are closely linked to and partly integrated into the application fields MML and MU → system developments are driven by science requirements.
- Examples of systems build for science are:
 - Module construction for CMS barrel
 - SiPM development for FLC
 - End-cap construction for ATLAS and CMS
 - AGIPD and DSSC for European XFEL
 - LAMBDA for PETRA III and PERCIVAL for FLASH
 - Digital Optical Modules (DOMs) for iceCube
 - Cameras for H.E.S.S.
- R&D on new materials, innovative concepts and novel detectors systems are addressing upcoming challenges: increased radiation levels, increased granularity, increased data rates, reduced materials budgets, etc.
- Laboratory wide there is a main focus on solid state detectors. We are developing a coherent strategy towards their development.



1/2 barrel for CMS



AGIPD at the European XFEL

Detector Development is (Inter-)national

Developments are done both in competition, and in collaboration

Particle Physics

DESY has decades of experience in assembling and commissioning complex systems and leading large international collaborations.

- The International main players and **partners**:
 - CERN, Fermilab, KEK, SLAC, BNL, ANL, STFC/RAL, CES&CNRS, IFIC, PSI, Uni-Hamburg, Helmholtz Alliance Physics at the Terascale

Photon-Science

DESY has developed a number of cutting-edge detector systems for Storage Rings and FELs.

- The International main players and **partners**:
 - CERN (R&D), Fermilab (R&D), HLL/MPG, KIT, PSI/SLS, SACLA/Spring-8, SLAC/LCLS, STFC/RAL

Astroparticle Physics

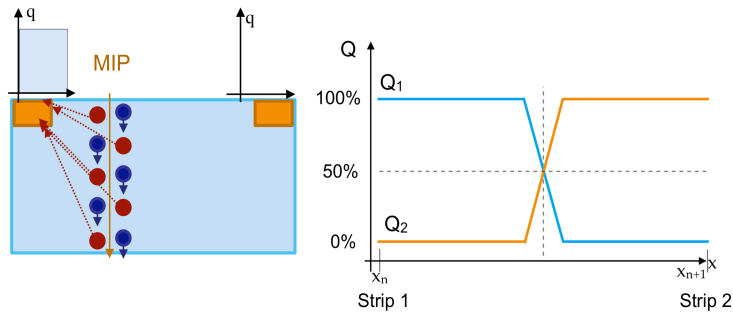
DESY has long lasting experience in building detector systems located in remote and harsh environments.

- The International main players and **partners**:
 - Caltech, CEA Saclay, CNRS, CPPM, INAF, KIT, Max Planck (Heidelberg, Munich), Nikhef, UW Madison

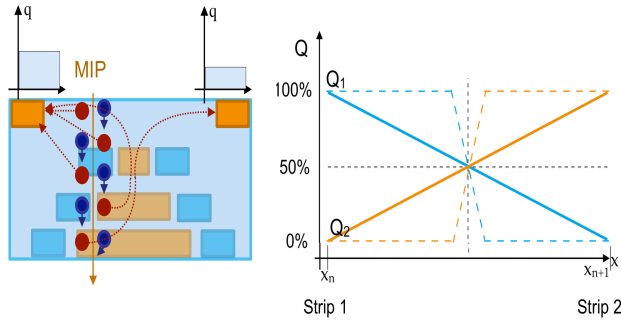
Some major achievements

Technology

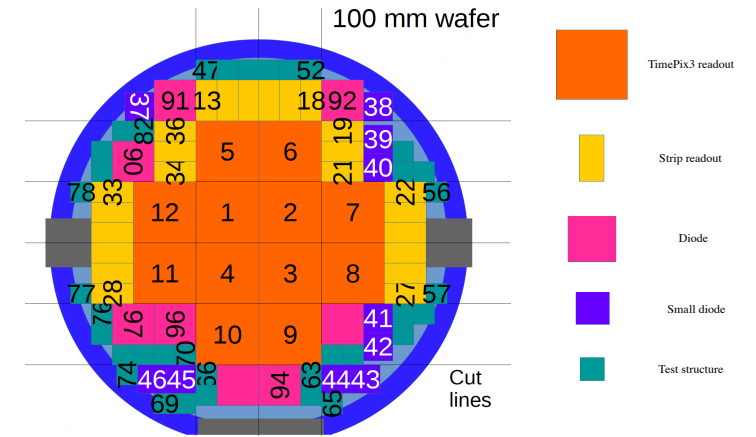
- Enhanced Lateral Drift Sensors (details on poster #27 by A. Velyka and H. Jansen)



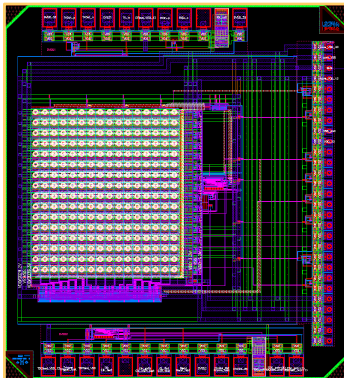
standard planar sensor



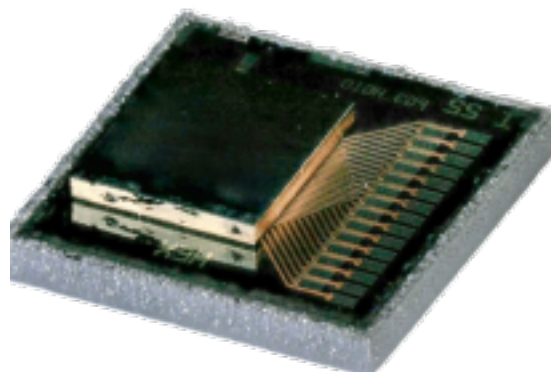
Enhanced lateral drift sensor



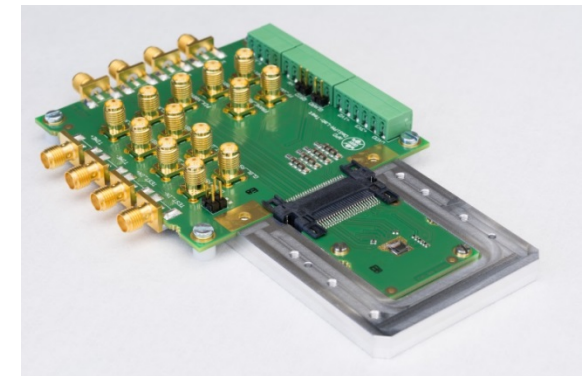
- Fast digital Si-Photomultiplier (details in poster #24 by P. Kalavakuru & I. Diehl)



ASIC



Bare Module

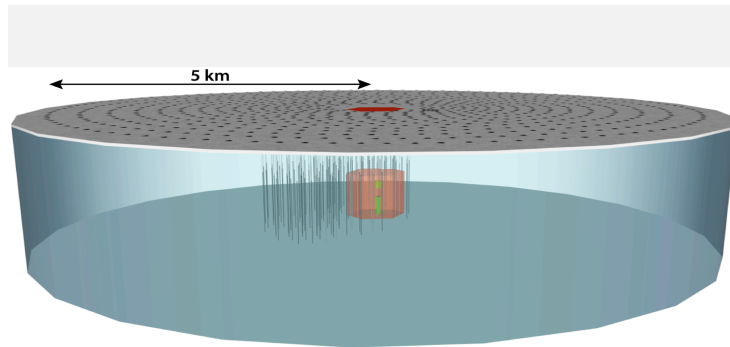


Test Carrier

Some major achievements

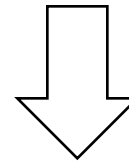
Technology

- multi-PMT DOM (mDOM) for IceCube-GEN2 (details in talk by T. Karg in parallel session)

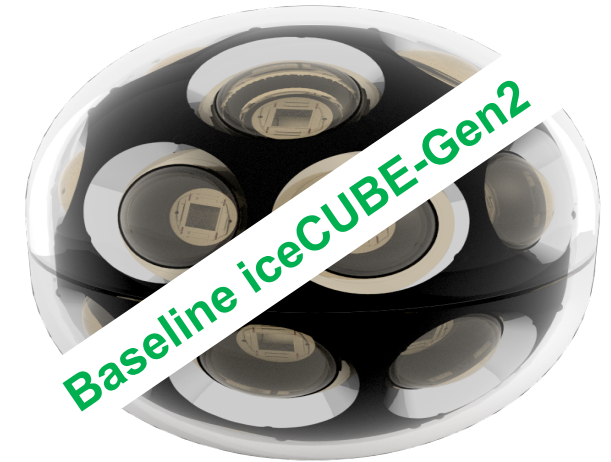


iceCUBE and iceCUBE-Gen2

single 10-inch PMT in 13-inch vessel

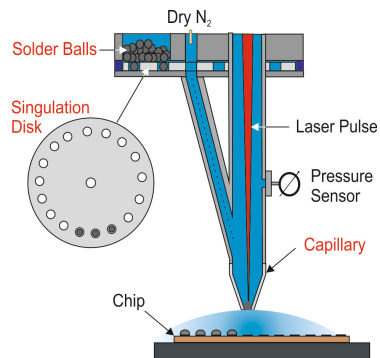


24 x 3-inch PMTs in 14-inch vessel

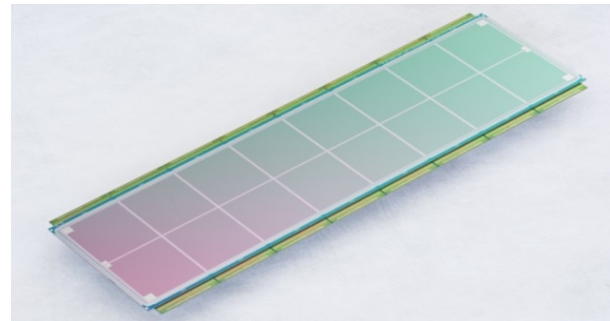
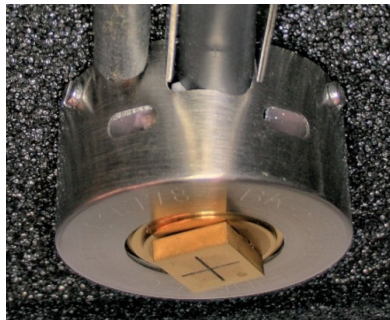


multi-PMT DOM

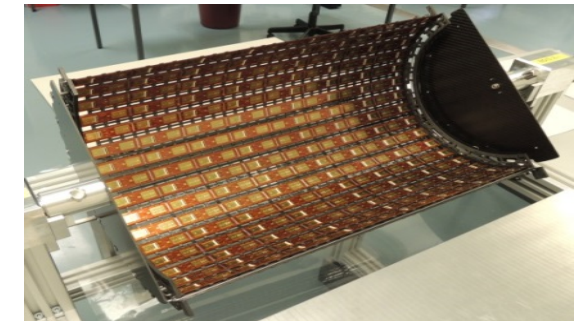
- In-house Bump-Bonding for CMS Pixel Detector Phase I (details in talk by K. Hansen in parallel session)



Equipment



Bare Module

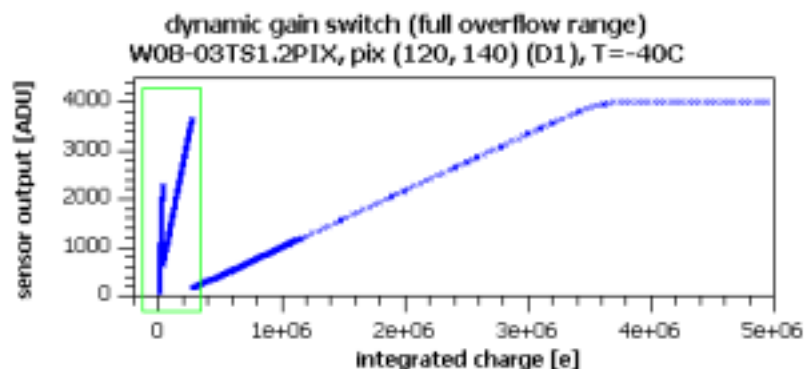


1/2 Barrel (L4) 256 Modules

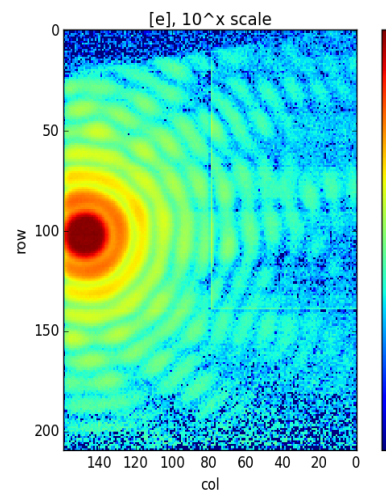
Some major achievements

CMOS Imagers: Percival (details on poster #25 by J. Correa & B. Boitrelle)

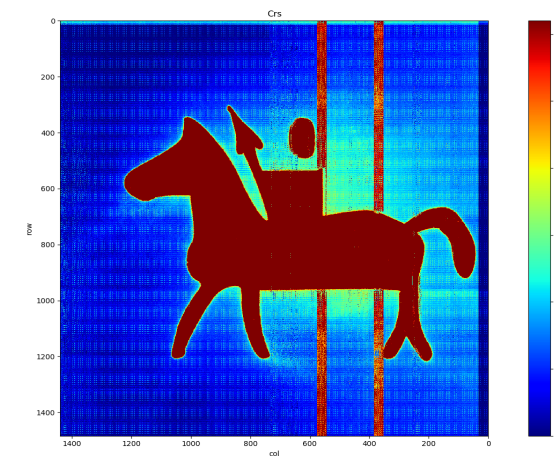
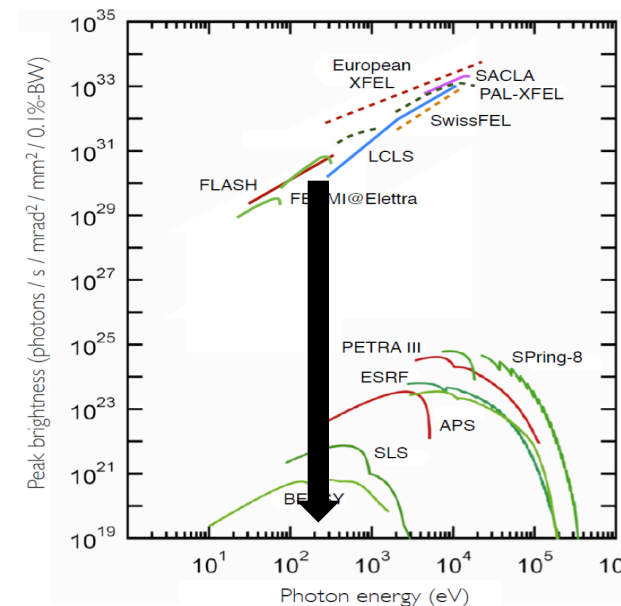
- For FLASH an imager for low energies is needed with
 - multi-mega pixels of few tens of microns
 - single photon sensitivity & large dynamic range
- ➔ Back-illuminated CMOS imager was most appropriate technique
- ➔ STFC/RAL contracted to design the sensor
- ➔ Elettra, Diamond Light Source & PAL joined the project (Soleil observer)



Dynamic gain-switching covering single photons to 5×10^4 photons/pixel/shot



92 eV diffraction image of a pin hole



Visible light image of front-side illuminated sensor

Some major achievements

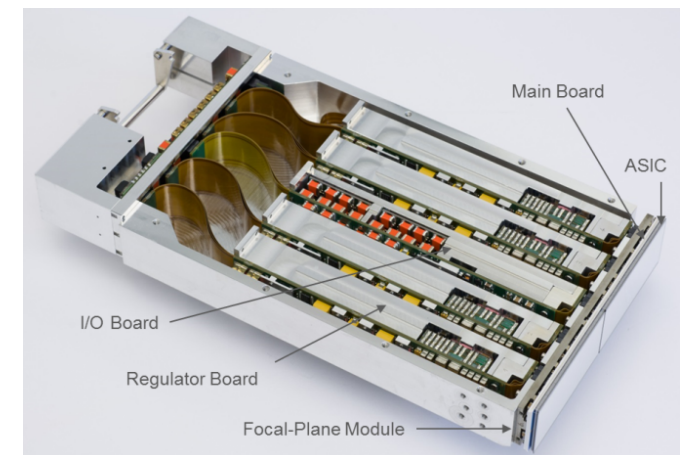
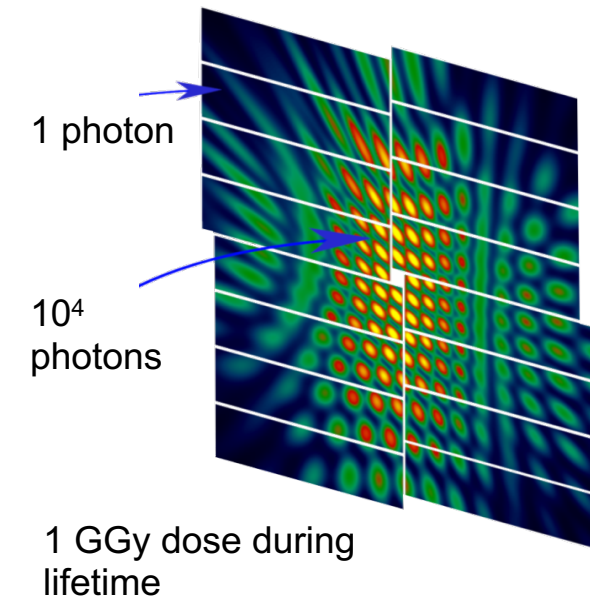
Large area detectors for the European XFEL

The European XFEL needs conceptually new detectors:

- Single shot → integrating detectors (not photon counting)
- Large DR → non-linear gain or adaptive gain (per pixel, per shot);
- 4.5 MHz imaging → in-pixel frame storage
- Large accumulated X-ray dose → radiation tolerant design

→ Three major development projects in Europe:

- **L**arge **P**ixel **D**etector (LPD) (UK based)
 - three parallel gains; analogue image storage
- **D**EPFET **S**ensor with **S**ignal **C**ompression (DSSC) (German/Italian)
 - non-linear gain; digital image storage
- **A**daptive **G**ain **I**ntegration **P**ixel **D**etector (AGIPD) (German/Swiss)
 - adaptive gain; analogue image storage



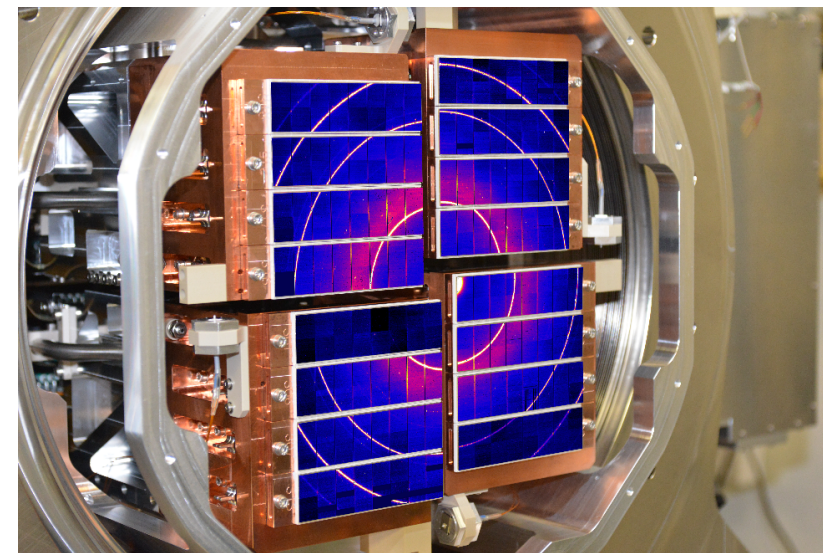
DEPFET Ladder

Some major achievements

AGIPD for European XFEL (details on poster #26 by A. Allahgholi and T. Laurus)

Adaptive Gain Integrating Pixel Detector (AGIPD)

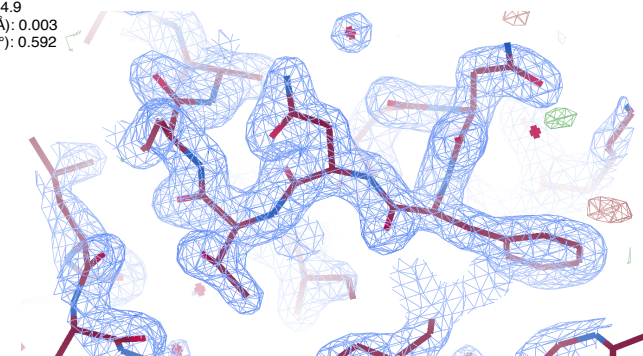
- Uses an innovative adaptive-gain concept, and analogue in-pixel storage of images.
- DESY leadership and involvement in all aspects
- First 1M-pixel system installed at SPB/SFX station and successfully used in first user experiments
- First structures are solved using AGIPD, and users expressed extreme appreciation of system; especially large DR.
- Second 1M-pixel system ready for installation at MID station
- 4M-pixel system under development for SFX station; with completely new interface electronics based on fiberoptics-data transmission.
- 1M-pixel for high-energies under development for HiBEF station; deploying new sensor materials: GaAs / CdTe



First round of reflection intensities from XFEL2012 data are accurate enough to produce a structure

Results from XFEL2012, initial refinement:

$R_{\text{work}}/R_{\text{free}}$: 0.168 / 0.193
Average Biso: 34.9
RMSD bonds (Å): 0.003
RMSD angles (°): 0.592

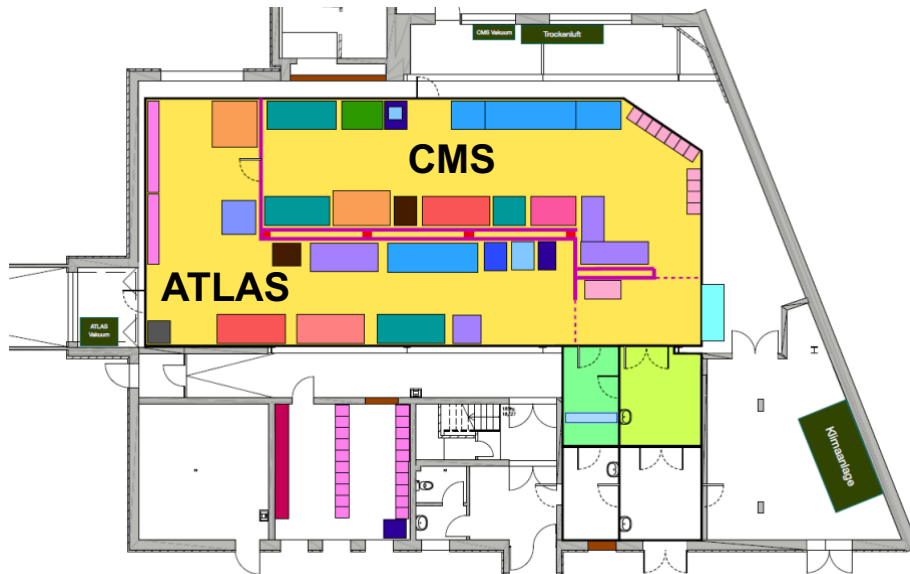


Dominik Oberthur: Structure refinement
17 Nov 2017

Organizational and structural progress

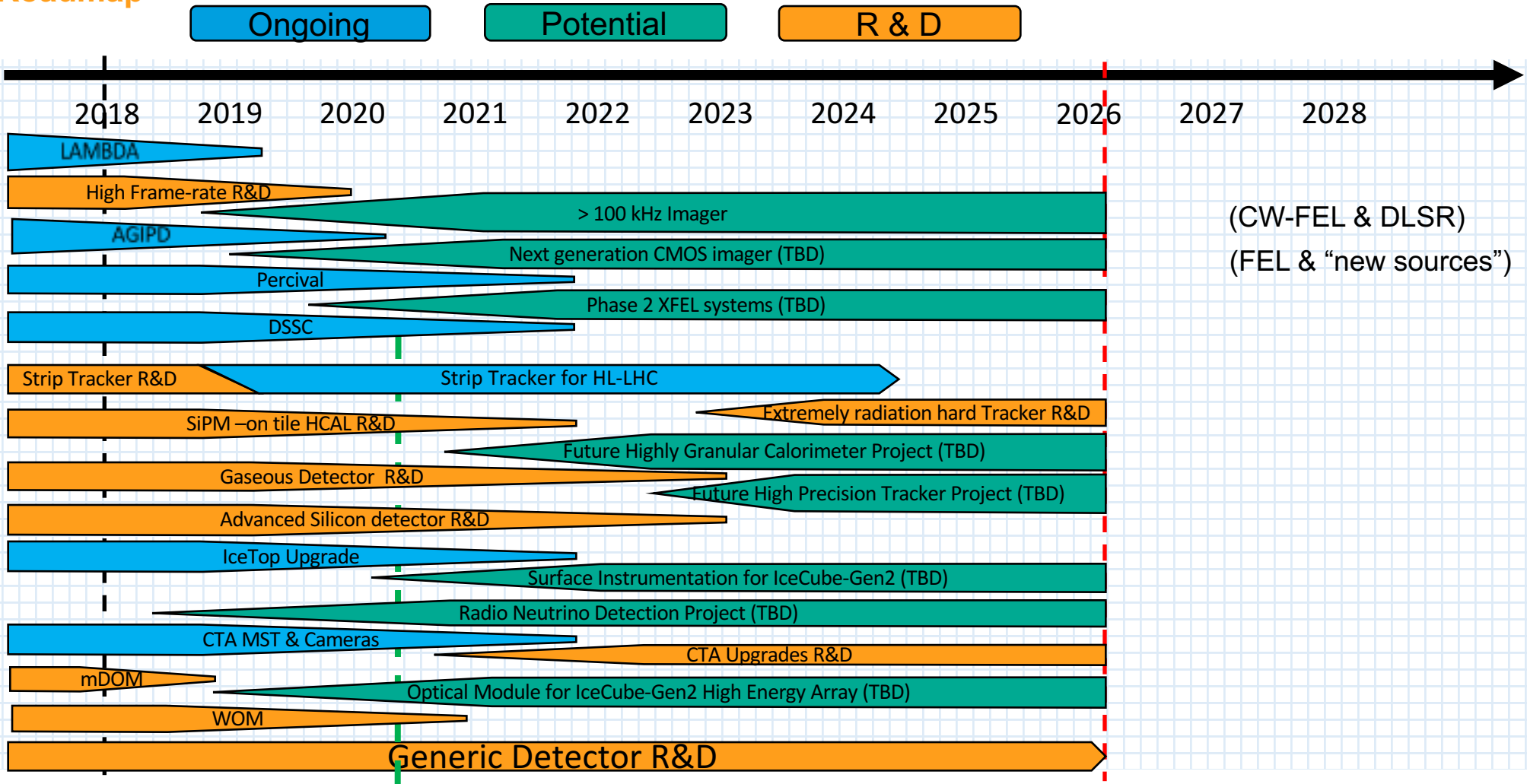
Towards a lab-wide detector activity

- Dedicated detector group for photon-science
- Establishment of a joint-detector lab in CFEL (DESY, Max Planck, Uni-HH)
- Construction of a Detector Assembly Facility (DAF) for LHC-upgrades
- Common detector strategy document between FS, FH and FE
- Weekly meetings between core detector people in FS, FH and FE
- Creation of a successful spinoff company, X-Spectrum, selling detectors developed by DESY



What is next?

Detector Roadmap



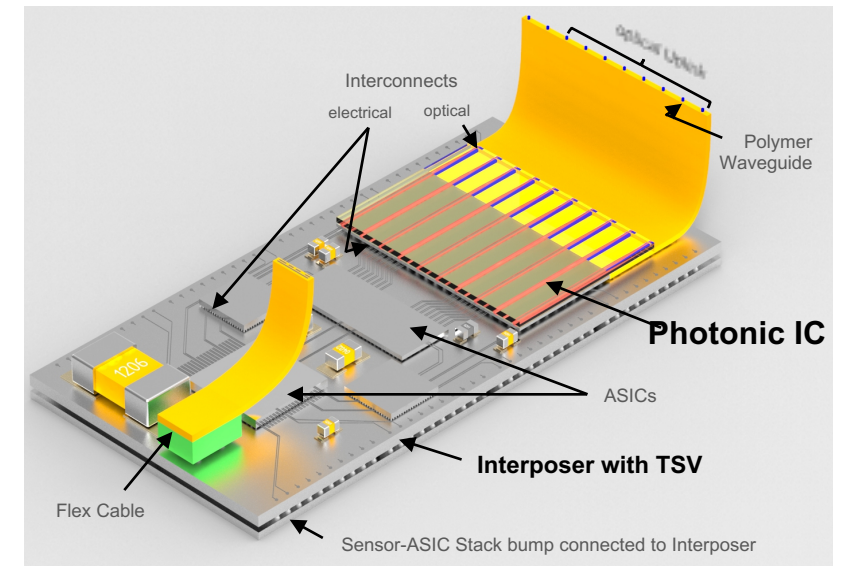
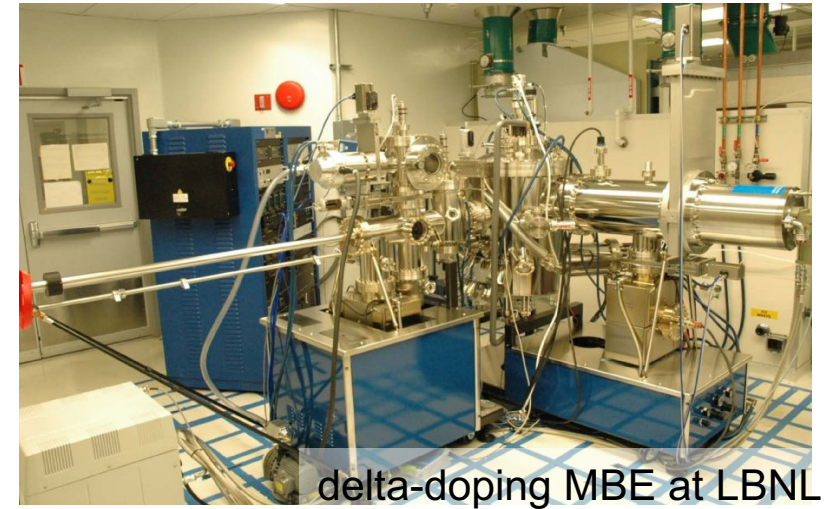
European Strategy for
Particle Physics

End of POF IV

What is next?

Technology Roadmap

- Active pixel sensors: DEPFETs, SiPMs, Low-Gain Avalanche Detector (LGADs)
- Post-processing of sensors and CMOS-imagers
- CMOS-imagers (DESY internal design)
- ASICs with smaller CMOS feature size: 65 nm as HGF “standard”
- 3D integration including CMOS-imagers and ASICs
- High density interconnect technologies, including TSV’s
- High speed optical links > 100 GigaBit
- FPGA & Firmware for data handling
- Novel materials and production techniques
- Cryogenic detectors



What is next?

Organizational

- Continue actions towards lab-wide detector program
 - Finalize DESY Detector Strategy
 - Establish Detector Competence Team as permanent body
 - Yearly Detector Developers retreat
 - Mutual internal project reviews
 - Increasing interaction between Hamburg and Zeuthen
 - Build strong link with Data Management and Analysis (DMA) Program
- Continue growing international visibility and importance in all fields
 - Secure project leads for future source upgrades
 - Strengthen links with our (inter-)national partners
 - Strong involvement in a Helmholtz Distributed Detector Laboratory
- Continue outreach and spin-out activities
 - Strong involvement in (inter-)national schools
 - Strong involvement in DESY's Innovation Center