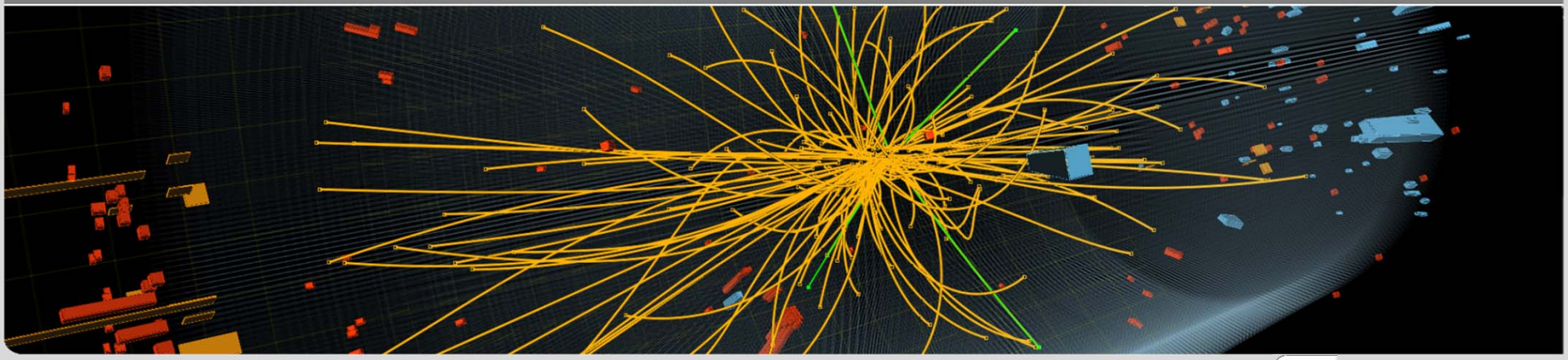
Karlsruher Institut für Technologie

Section Embedded Parallel Systems EPS

Matthias Balzer

INSTITUTE FOR DATA PROCESSING AND ELECTRONICS (IPE)

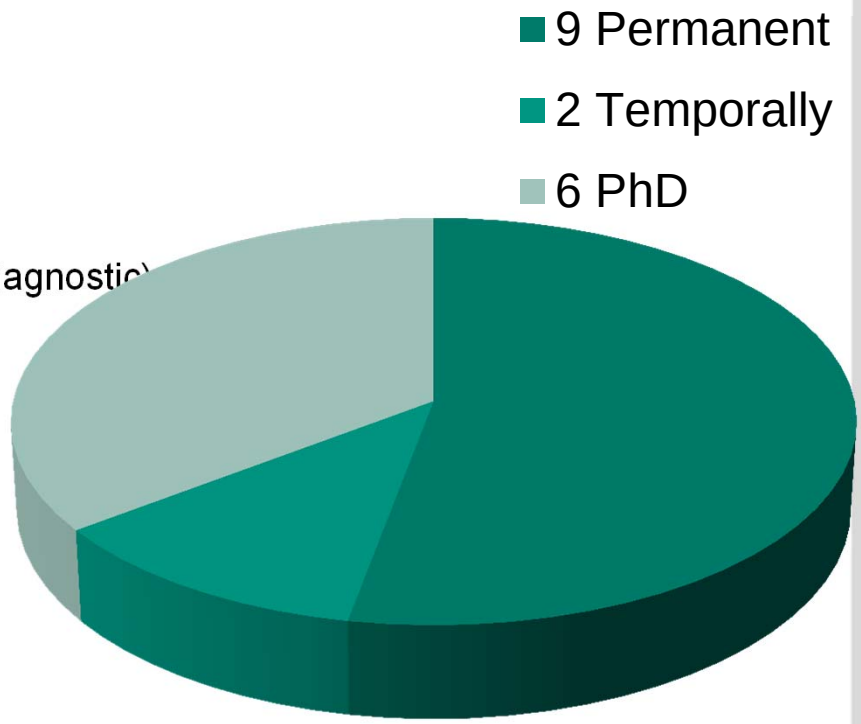


EPS Competences

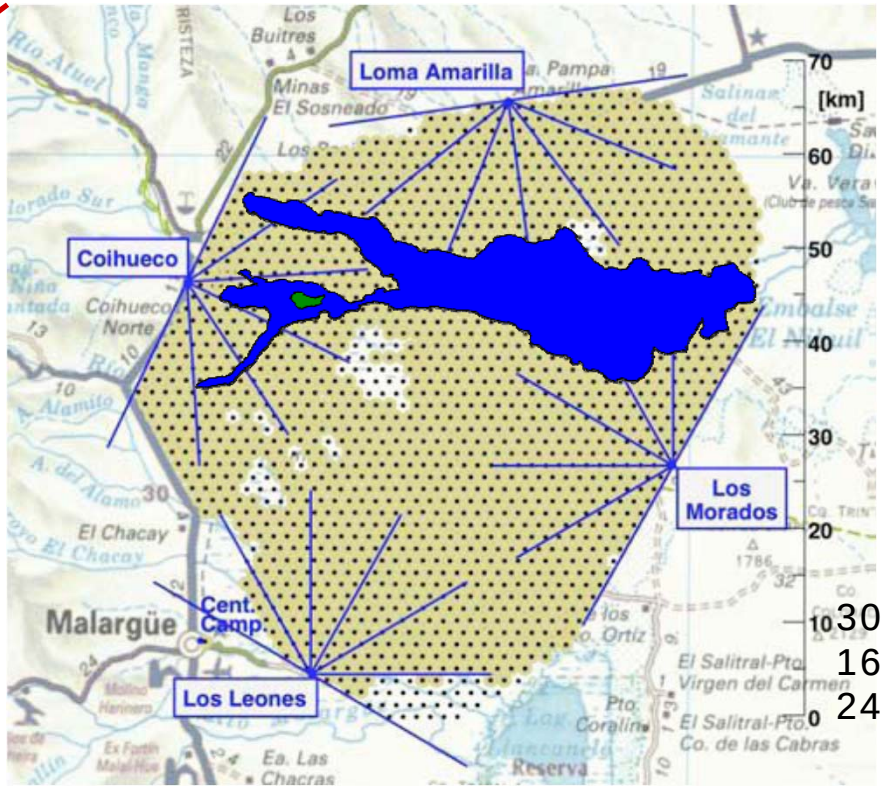
- Development of embedded systems
  Hardware, firmware and software for fast parallel data acquisition and processing
- High speed data transmission
  Copper and optical links with commercial components
- PCB design
  Layout
  Simulations for signal integrity, electromagnetic compatibility and thermal analysis
- Production and tests of hardware

EPS Projects and Resources

- Pierre Auger Observatory (Astro Particle Research)
- KATRIN (Neutrino)
- Ultra Sound Technology Transfer Projects
  - Ultra Sound CT (USCT)
  - Pipeline Inspection
- Camera Systems for Beam Line Imaging
- KAPTURE and KALYPSO (THz Detectors for Beam Diagnostic)
- DAQ for microwave SQUID multiplexing (MMCs)
- Quantum Sensing and Control (Qubit)
- CMS Track Trigger (CERN LHC-upgrade)
- TRISTAN (Sterile Neutrino)
- DARWIN (Dark Matter)



Pierre Auger Observatory



3000 km^2
1600 Surface Detector
24 Telescope

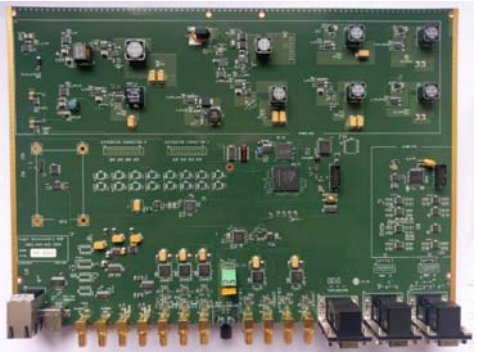
Pierre Auger Observatory

- 24 Fluorescence Telescopes

- 1660 Surface Detectors
  Cherenkov Detectors
  Now electronic upgrade

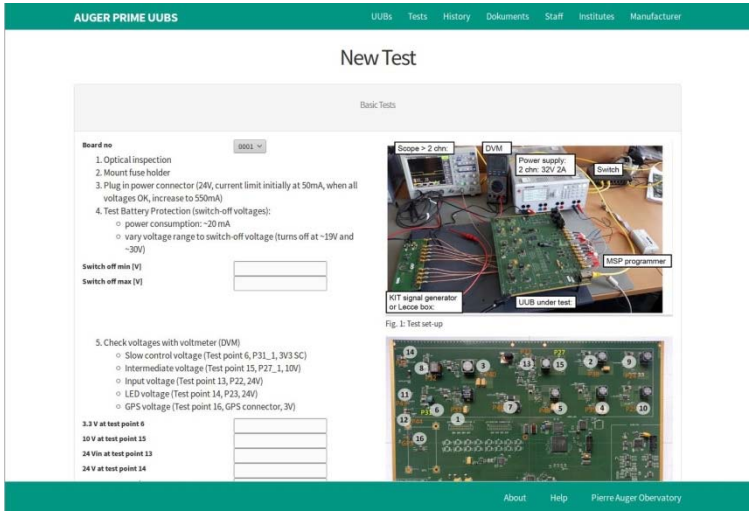
New Electronic for Auger Prime Upgrade

- Task is the development of production test and production management tool (MSA)



- 2000 boards will be assembled by an company
- Production test has to be simple and fast

- Production management system guides through the test and provides all documents

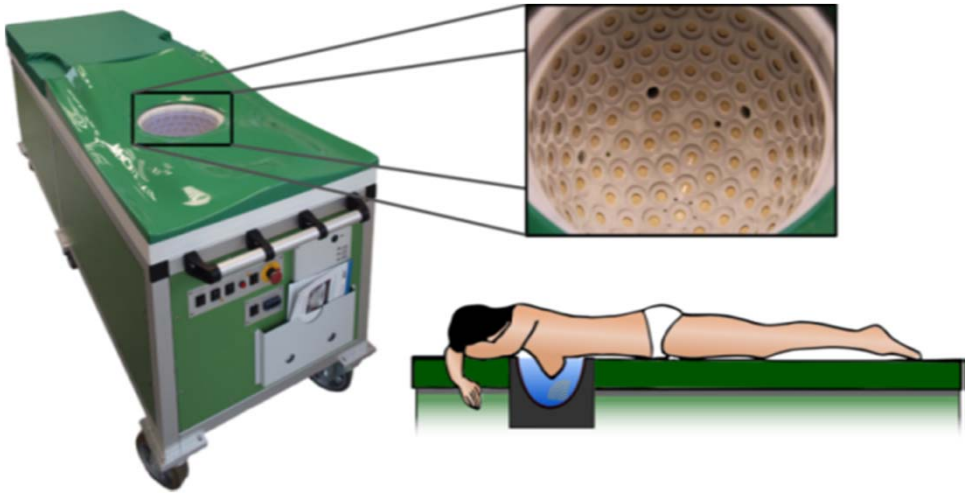


Ultra Sound Computer Tomograph (USCT)

Early Breast Cancer Detection

- Actual System for Clinical Study

US-Sensor Aperture



IPE DAQ V4

- Multi purpose DAQ
- VME like system

- FPGA based read out
- Digitization in crate

Next Generation of USCT DAQ

- MTCA.4 based DAQ System

32 ADC-RTM

4 x 8 ADCs
20 MSPS/12b

HGF-AMC

- Kintex7
- 8 GB SODIMM DRAM
- 4 x SFP+
- PCIe Gen2

MTCA.4 Crate with 12 Slots

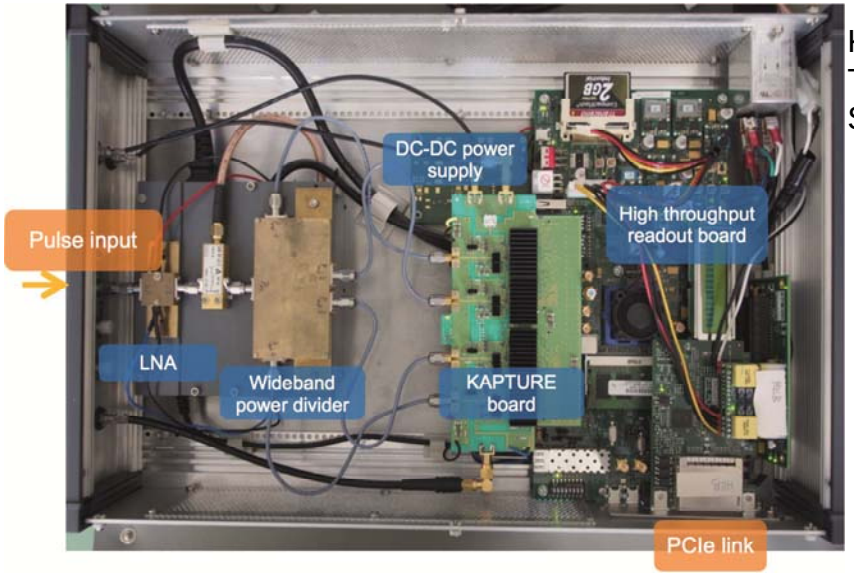
Camera Systems for Beam Line Imaging (UFO)

- FPGA based readout system of image sensors
- Support of several CMOS image sensors
- Online data processing and data reduction
- High speed data transfer to GPU host
  with Direct FPGA/GPU DMA via PCIe

High-performance DAQ framework for high speed cameras
in cooperation with Helmholtz Zentrum Geesthacht

- HiFlex1
  Virtex7, 4 GB DDR3, 2 HPC FMC, PCIe Gen3 x8

KAPTURE Beam Monitoring

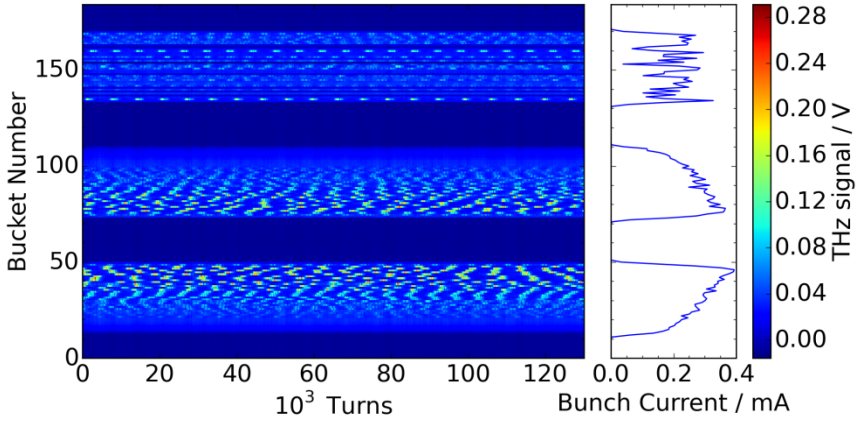


KAPTURE is an ultra-wideband readout electronics for ultra-fast Terahertz detectors: YBCO, hot-electron bolometer, quasi-optical Schottky diodes, etc.

M. Caselle et al., JINST 12 C01040 (2017)

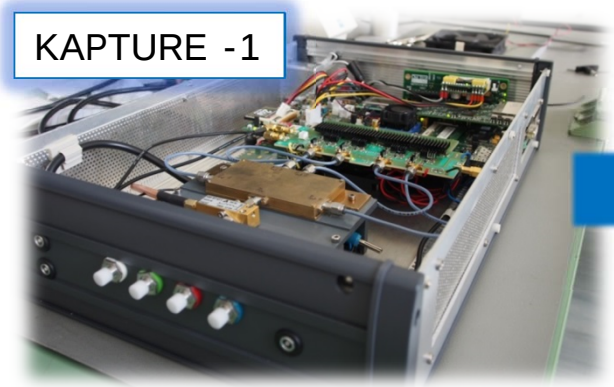
- Memory-efficient approach
- Up to 500 MHz pulse repetition rate
- Pulse amplitude (mV) and arrival time (ps) accuracy
- Fundamental for futures accelerator research

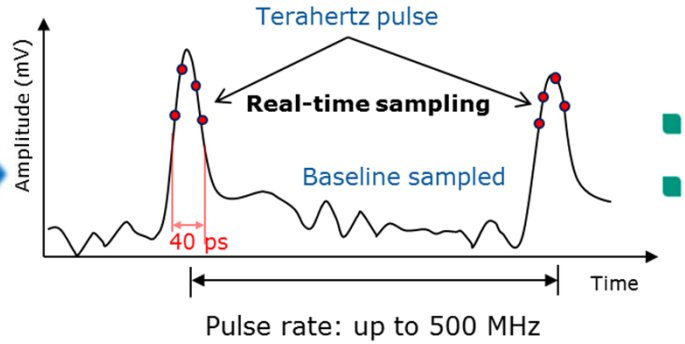
Coherent terahertz radiation measured by KAPTURE at KARA



KAPTURE -2

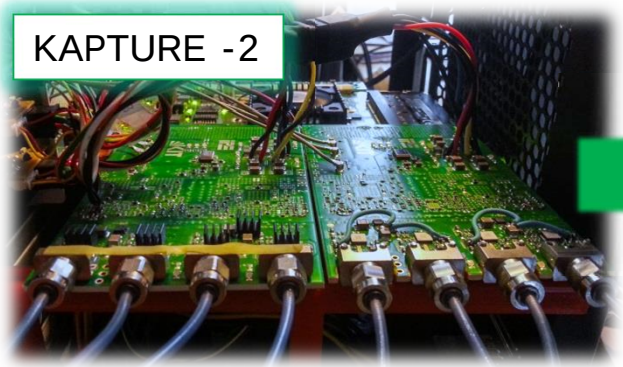
KAPTURE -1

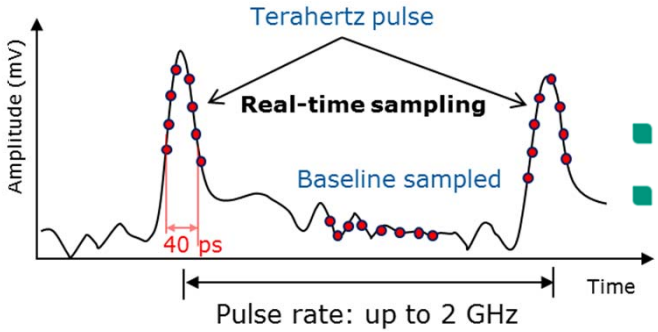




- 4 sampling points
- Max pulse rate of 500 MHz

KAPTURE -2





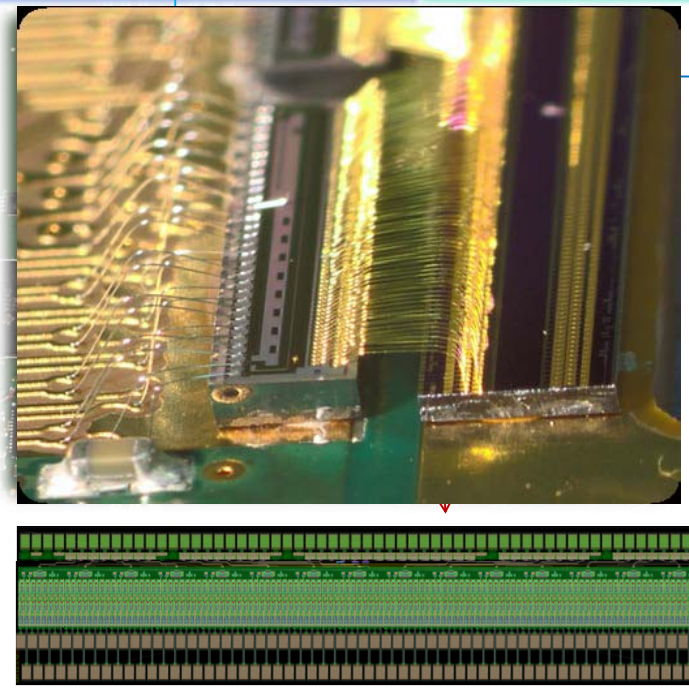
- 8 sampling points
- Max pulse rate of 2 GHz

8 sampling points setup (last beam test @ KARA)

KALYPSO –2

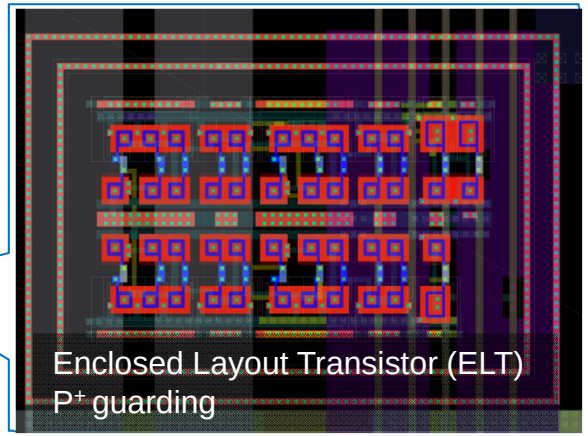
Line array sensor: 1024 channels

Up to 8 parallel front-end readout ASICs



New front-end ASIC (Gotthard-HR)

- Line array sensor up to 2048 channels (near-UV, VIS, near-IR)
- Up to 8 parallel low-noise front-end Gotthard-HR (KIT, PSI)
- Frame rate up to 10 Mfps, continuous acquisition for long time (sec, hours,.)



Emerging applications for direct X-ray spectroscopy

front-end designed according to radiation hardness layout techniques

PCIe Readout System HiFlex 2 for Photon Science, MMC and …

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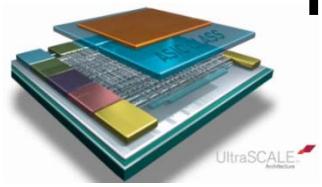
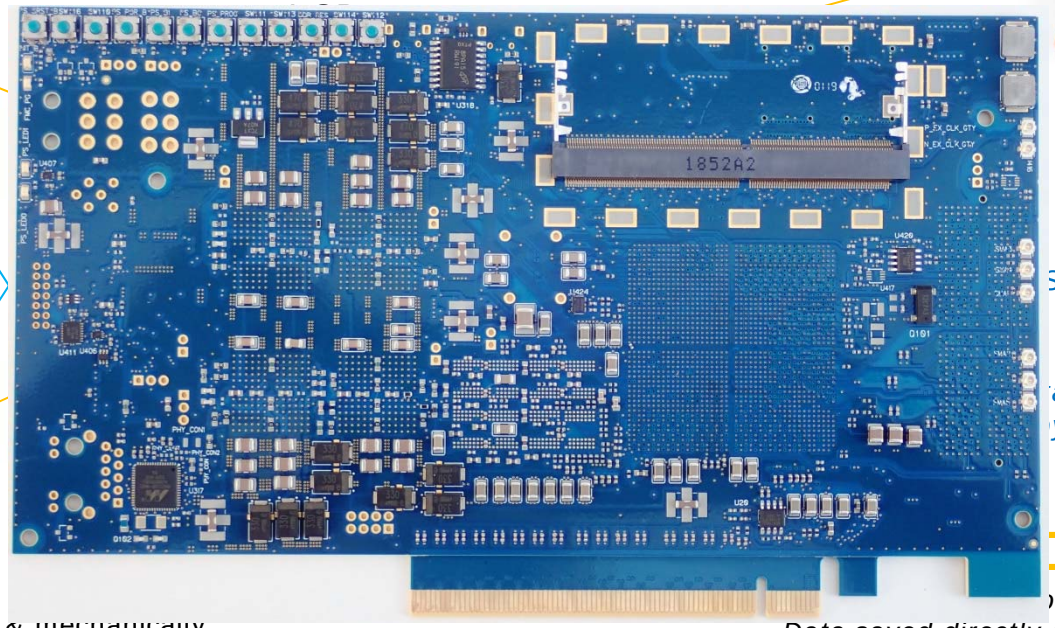
Quad-core ARM



FPGA

\+

Processor



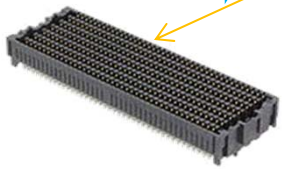
FireFly optical/electrical

4/12 lanes (full-duplex)
112 – 192 Gb/s

SB 2.0 (by processor)

andard TCP/IP Ethernet
y processor)

Front-End:
CAMERAs
Beam Dia



New FMC+: electrically & mechanically
compatible with standard FMC

ns:
Data saved directly on solid Disks

DAQ for Microwave SQUID Multiplexing

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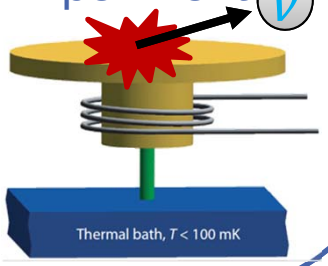
Experiment



Signal Processing

Board Support Package

ECHo

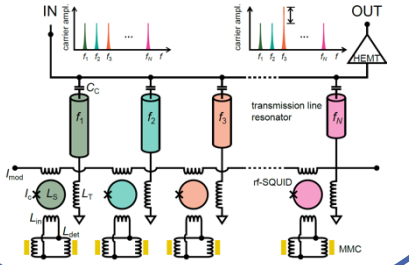
Neutrino mass determination

FMC+

ZYNQ UltraSCALE+

HiFlex 2

Multiplexing



RF Mixer Board

DAC

ADC

Converter Board

Quantum Sensing and Control

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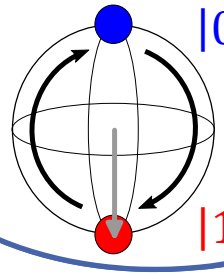
Quantum exp.

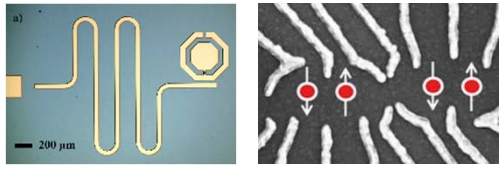


Pulse Control & Processing

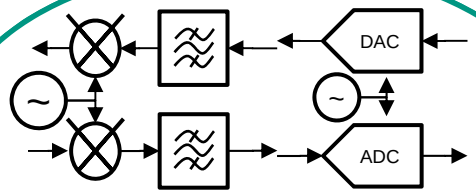
Board Support Package & Qkit integration

Qubits

Qubit HW



ZYNQ RFSoC

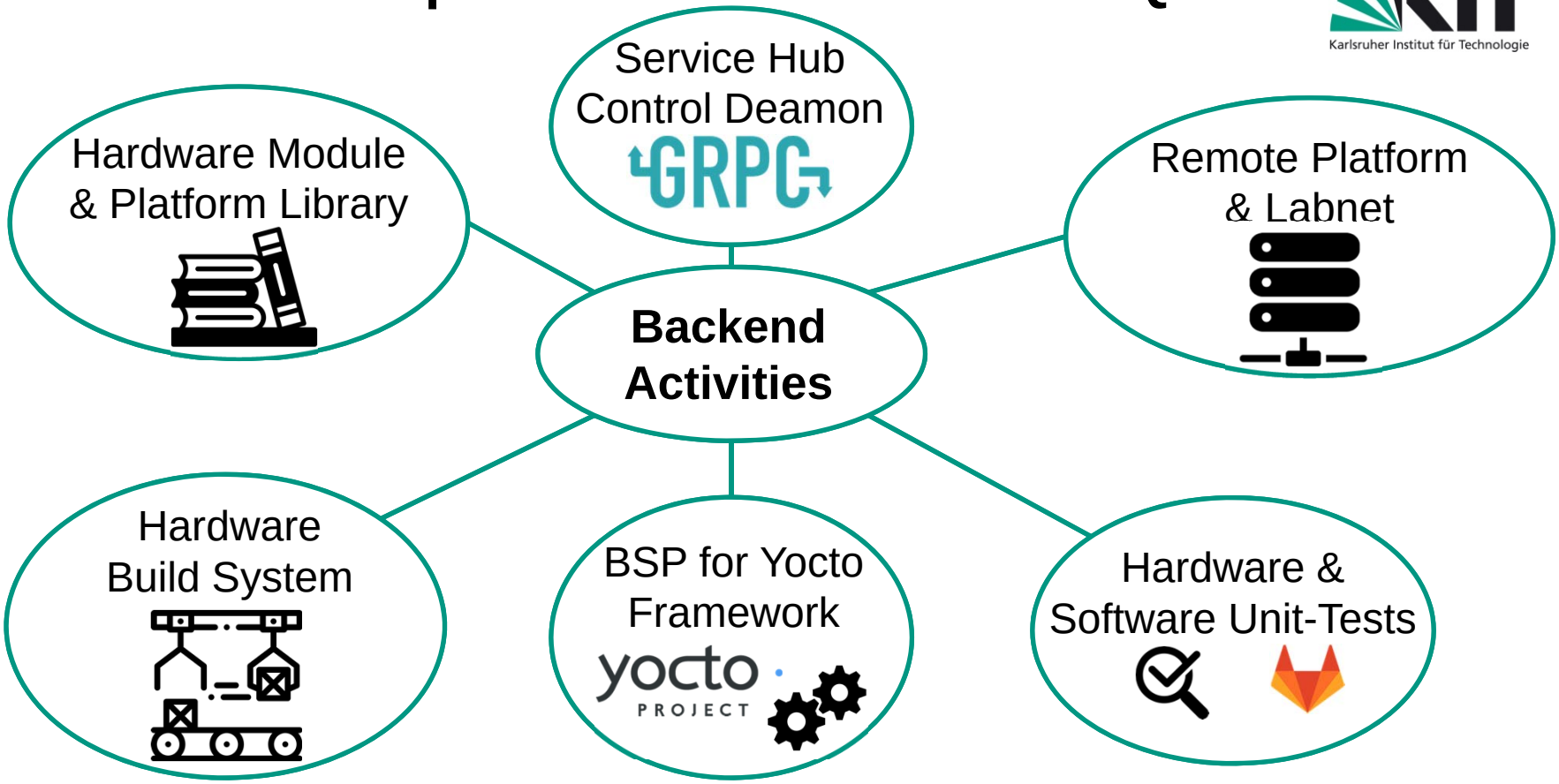


ECHo Readout

FMC+ ZYNQ UltraSCALE+

HiFlex 2

Common Development Platform for MMCs/Qubits

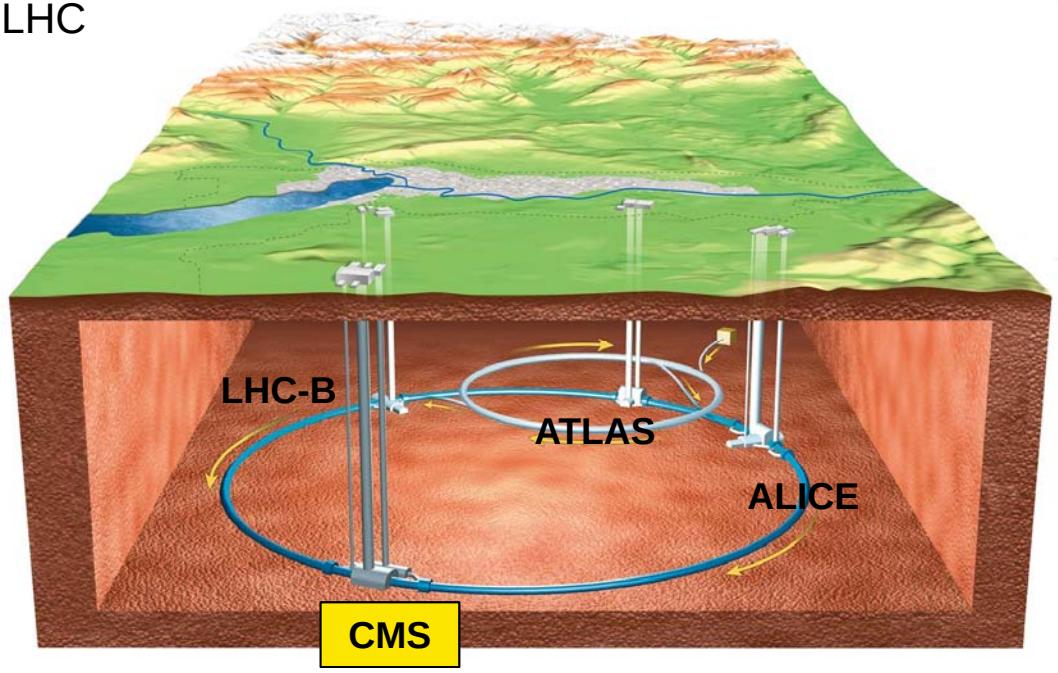


CMS at Large Hardon Collider (LHC)

- CMS: One of 4 large experiments at LHC
- Length of accelerator 27 km
- Proton-Proton collision every 25 ns

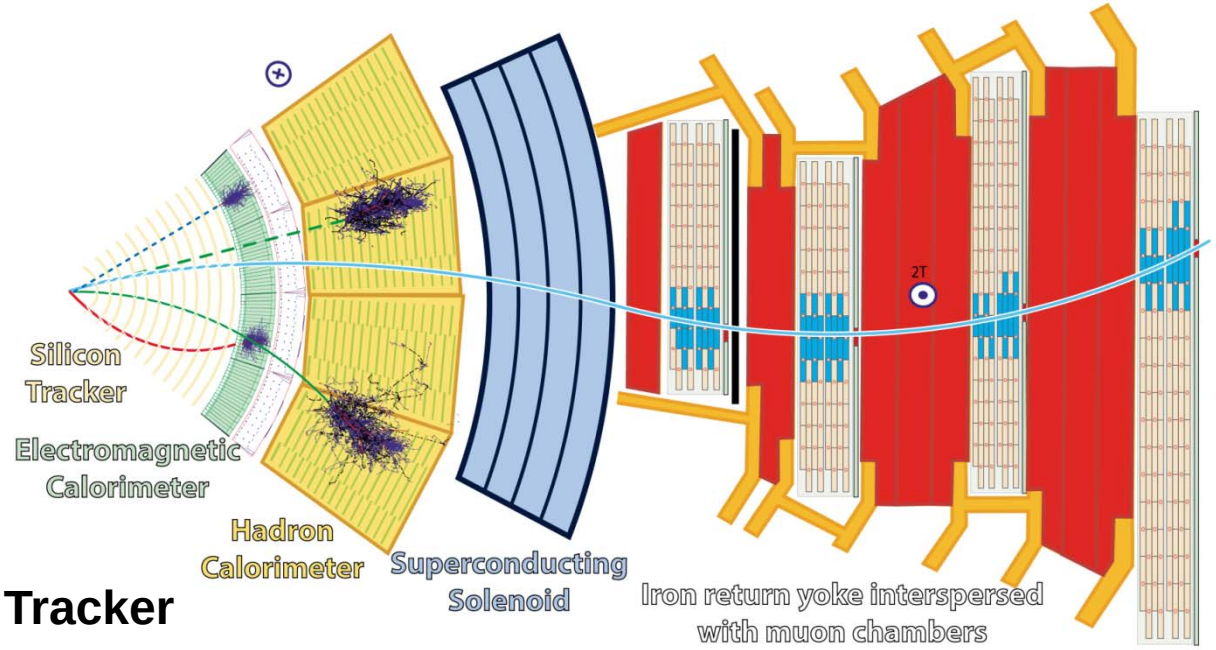
High Luminosity-LHC

- Factor 5 more events
- New detector modules
- New „Online Track Trigger“
- Extended L1 Trigger



Compact Muon Solenoid

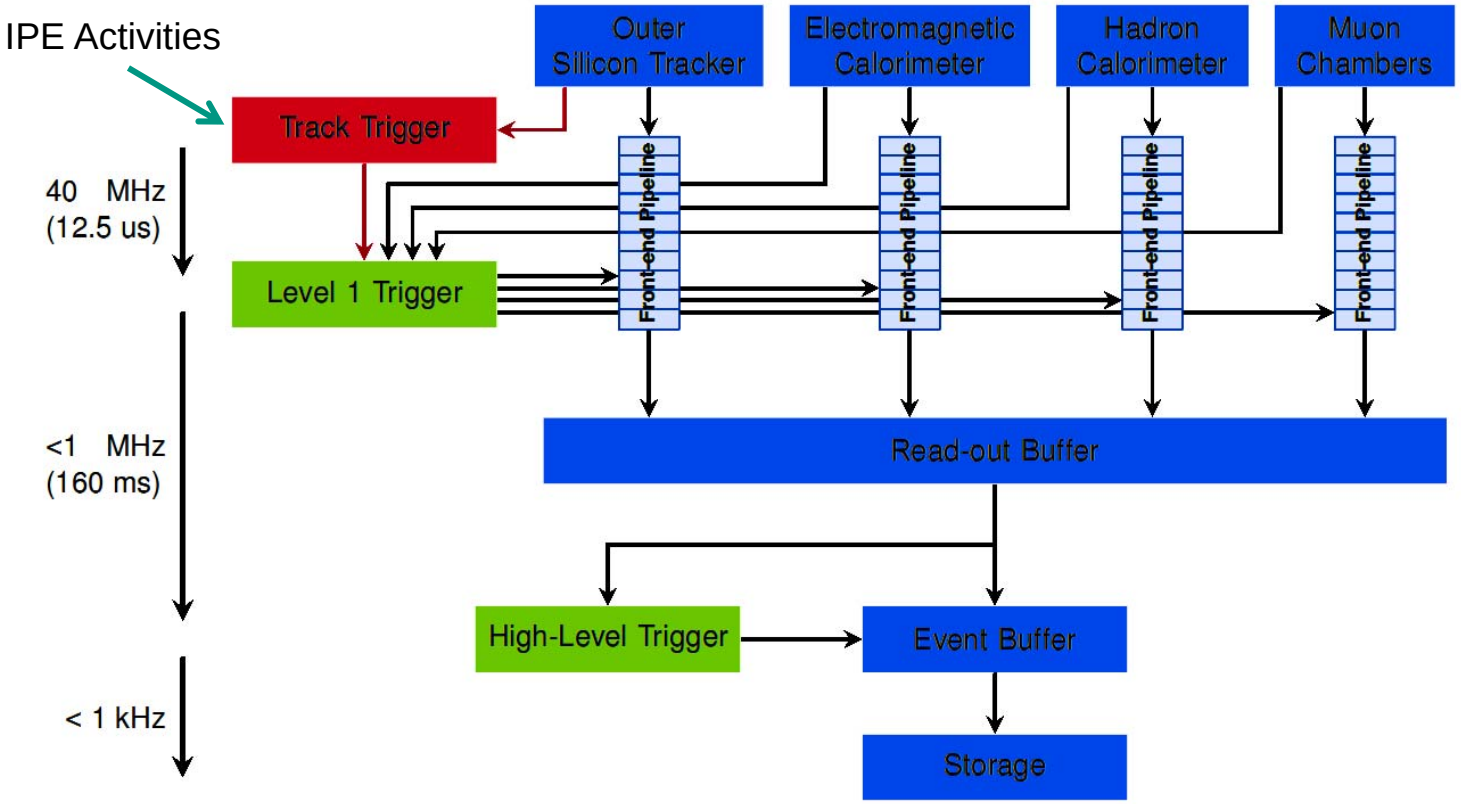
CMS Detector



Silicon Tracker

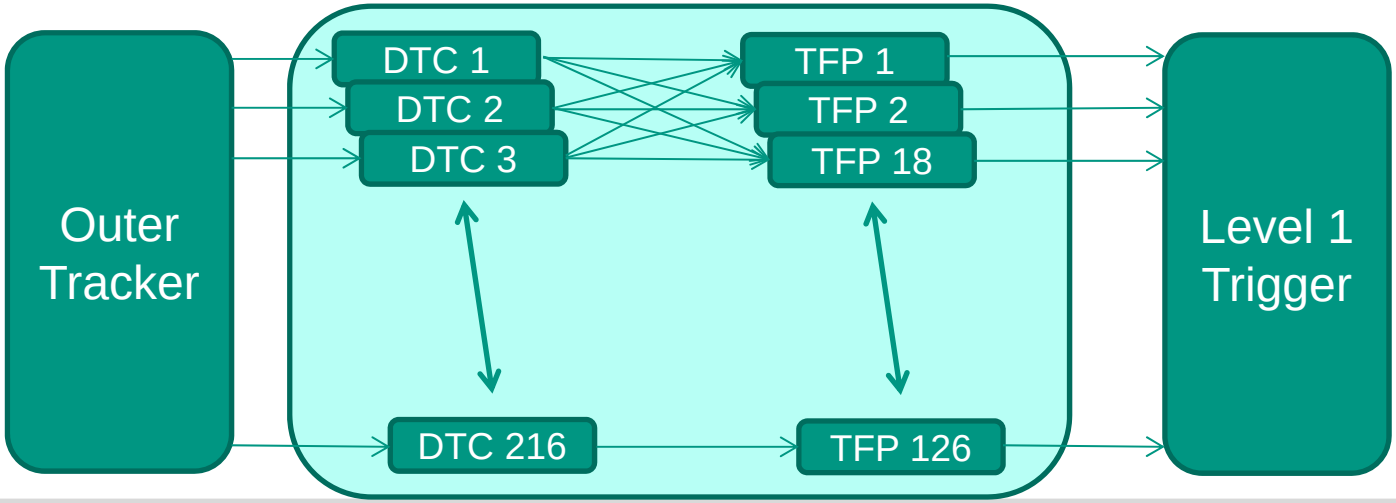
- Inner Tracker → 6 layers pixel modules
- **Outer Tracker** → 6 layers “pixel & stripe” and “2 stripe” modules (ps, 2s)

Trigger System of CMS HL-LHC

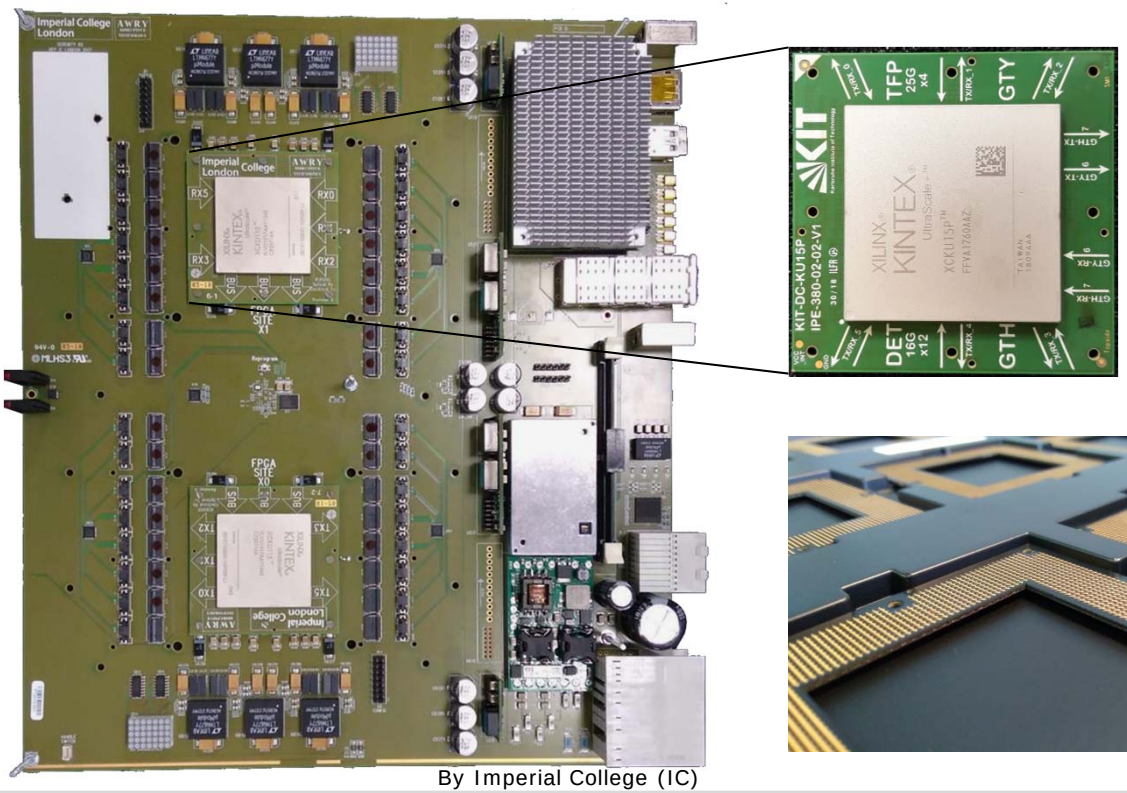


Data Flow for Track Trigger

- Data, Trigger and Control (DTC) receives data subsets from Outer Tracker
- DTC shares data to “Track Finding Processor” (TFP) (Space, Time)
- TFP searches for tracks and submits track info to L1 Trigger
- One DTC is connected to minimum 24 TFPs



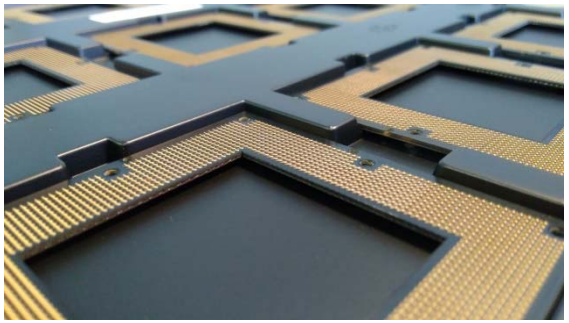
ATCA Board for CMS Track Finder



By Imperial College (IC)

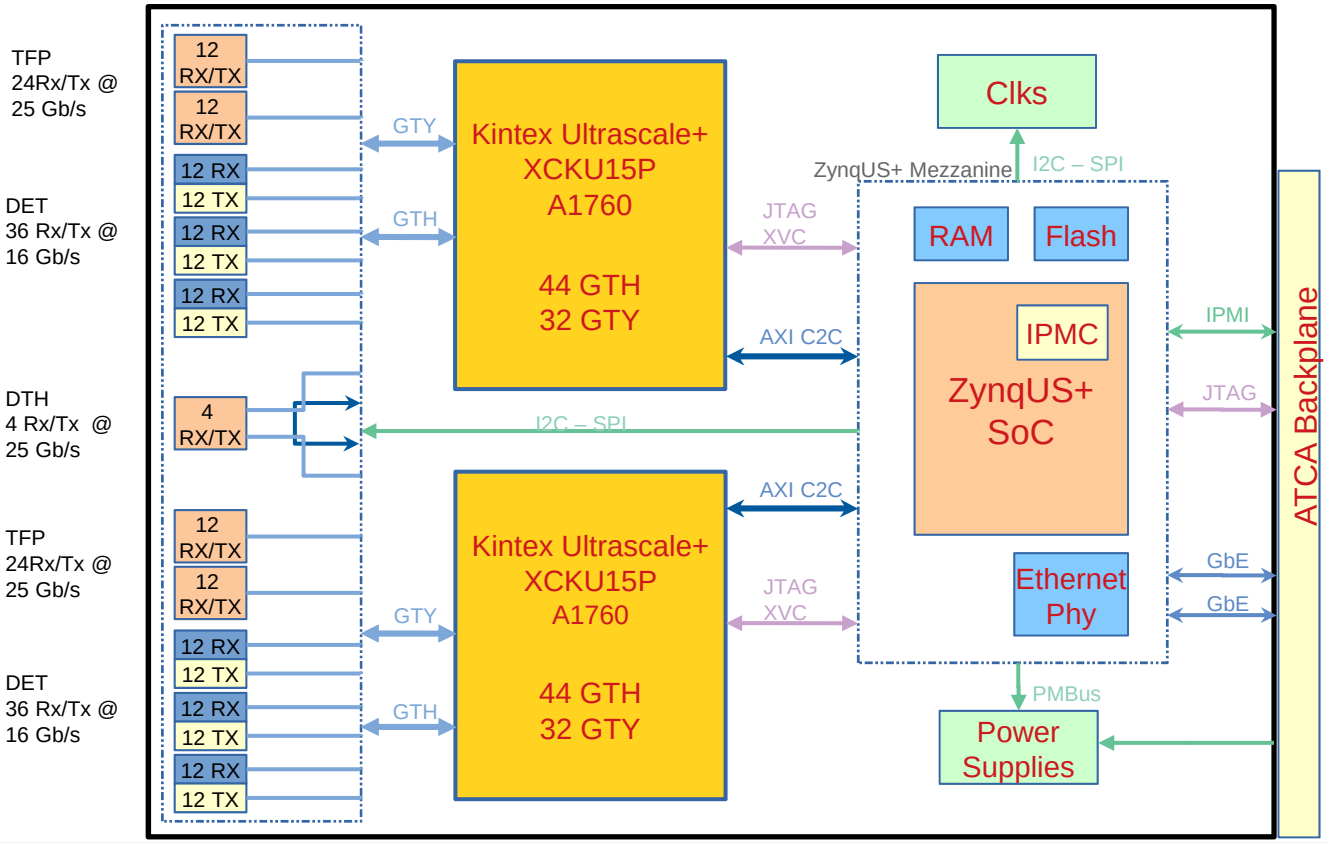
Different Daughter Cards

IC:	KU115
KIT:	KU15P
TIFR:	VU7P



Interposer: Connector between Boards

IPE Architecture of CMS ATCA FPGA Board



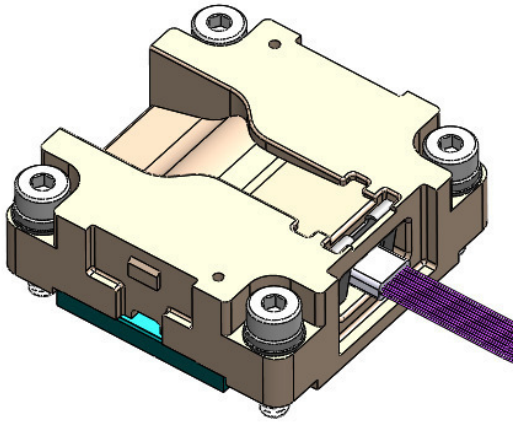
Firefly Samtec Optics
BOA Finisar Optics
16/25 Gb links

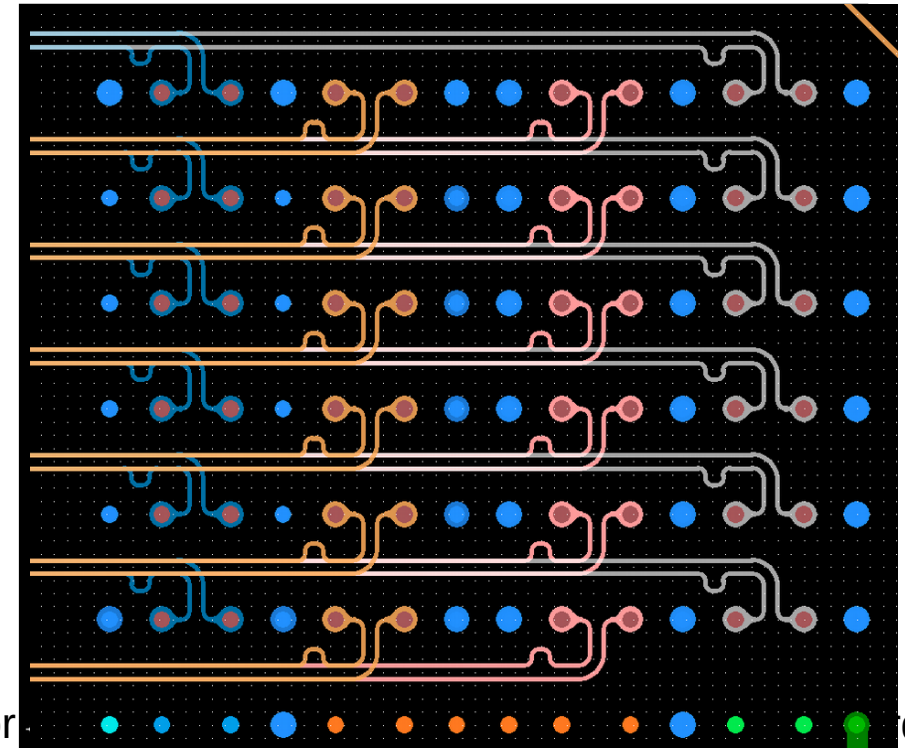
Integration in ZynqUS+
IPMC
Slow Control
Calibration of FE-Detectors

Complex FPGAs

Evaluation of 25 Gb/s FINISAR Optics

BOA Component

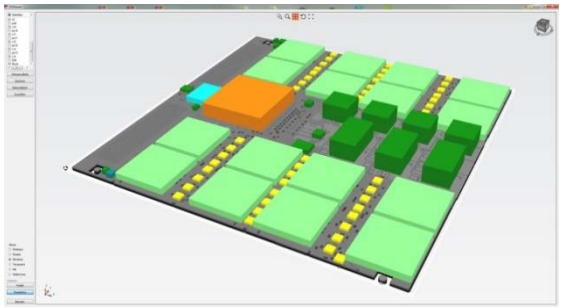


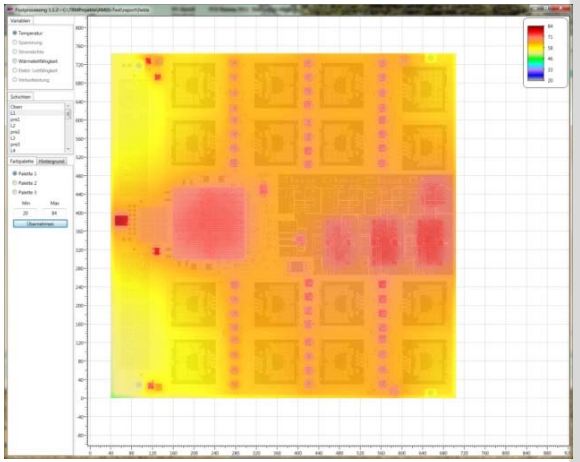


- 1.06 – 28.1 Gb/s
- 12(Tx) + 12(Rx), full-duplex transceiver
- 24x24x10mm, Flat-top housing form factor

PCB Design at IPE

- Many hardware developements
- Different groups use different PCB-Tools
  Altium™, Eagle™, Target™, …
- **PADS™** with DxDesigner is the favorite PCB tool
- **Expedition™** for very complex and challenging designs
- EMV, thermal, signal and power integrity simulation
- Provision of component library
- Approved interface to assembly workshop





Conclusion

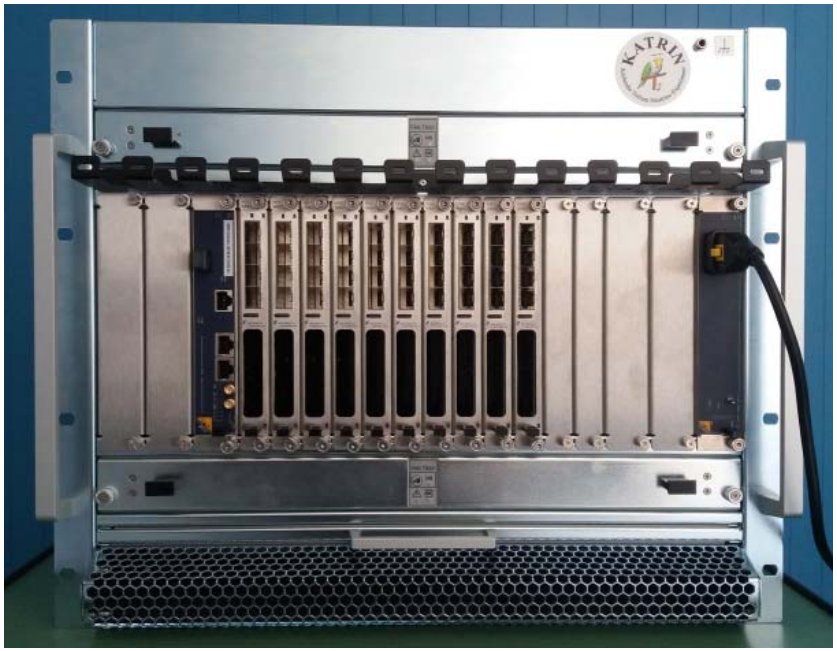
- Development, commissioning and maintenance of DAQ Systems

- FPGA is the important component for parallel and real time online processing
- SOC-FPGAs are used in systems
- High speed data transfer established (PCIe, SFP+)
  or in evalutation phase (i.e. BOA 25Gb/s)

- MTCA.4 and ATCA are the standardized systems
- Custom solutions are developed for experiments

- Know How for development of challenging PCBs

- Succesful cooperations with all IPE-sections



MTCA.4 DAQ for KATRIN Remote ADCs Test

Many thanks to my colleagues for the slides !