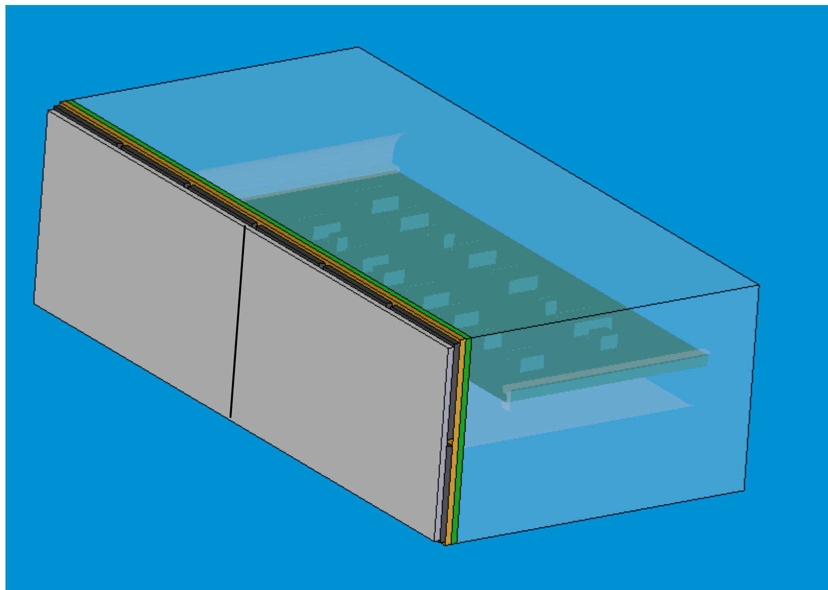
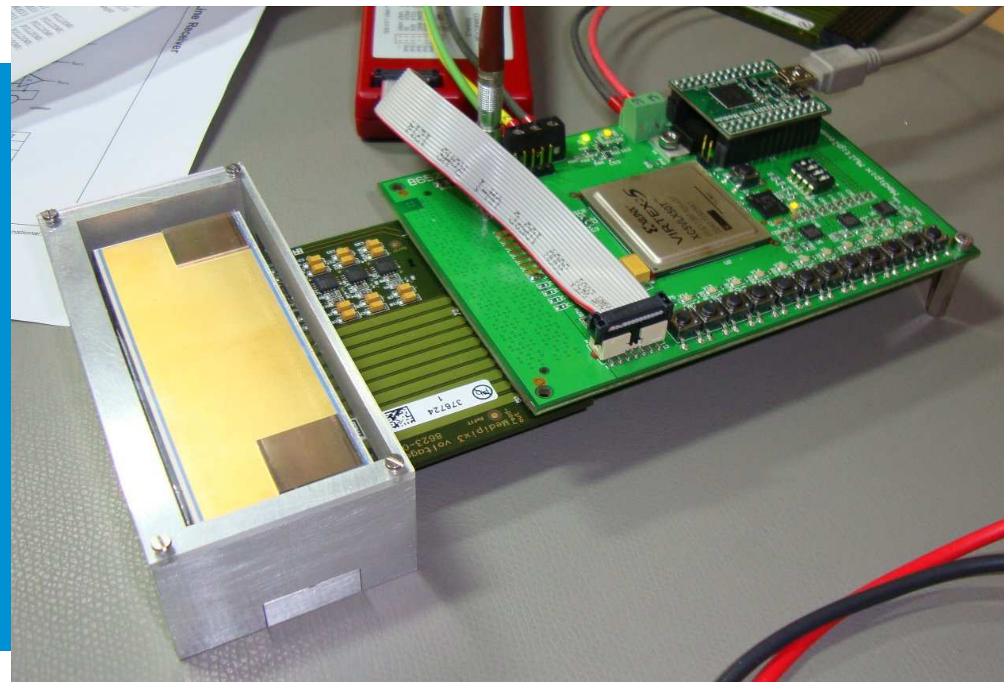
Developments in DESY FS-DS





Sergej Smoljanin
Detector Group DESY

SEI-Tagung an der GSI, 23.03.2011

HELMHOLTZ ASSOCIATION

DESY

What is our mission?

- Detector support for the experimental stations at DESY-FS:
  - Petra 3 synchrotron
  - Doris 3 synchrotron
  - FLASH free electron laser
- Support to application scientists at DESY
- Development of new detectors and detector concepts: Petra 3; E-XFEL (X-ray free electron laser); FLASH.

Who are we?

- 1 Group leader (scientist)
- 1 Project Coordinator
- 2 Detector scientists
- 2 PostDocs
- 6 Engineers (3 Microelectronic, 1 Electronic, 2 Mechanical)
- 2 Technicians (1 Electronic, 1 Mechanical)
- ½ Draftswoman

Developments

>Projects all are collaborations:

- Single crystal Diamond BPM with RF readout (ESRF; Instr. Techn.)
- Adaptive Gain Integrating Pixel Detector (AGIPD) (European XFEL)
- DEPFET Sensor with Signal Compression (DSSC) (European XFEL)
- Integrating micro-strip with analogue pipeline: Gotthard (PSI)
- Germanium pixel detectors (Canberra; IZM-Berlin)
- 2D Avalanche PhotoDiodes: XNAP (ESRF; U-Heidelberg; PKI; SPring-8)
- Large Area Medipix-Based Detector Array / Lambda

Large Area Medipix-Based Detector Array

- Development for PETRA 3 synchrotron
  - Opened in 2009, 3 out of 14 beamlines currently in user operation
- Photon-counting pixel detector array
- Applications:
  - X-ray scattering
  - X-ray imaging

Features of detector

> Medipix3 readout chip

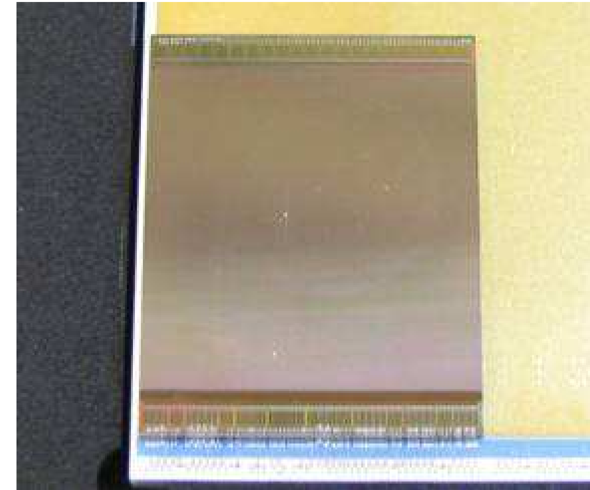
- Counts X-ray photons in each pixel
- Small pixel size (55µm, 256*256 array per chip)
- Can be used with Si, Ge, GaAs etc.

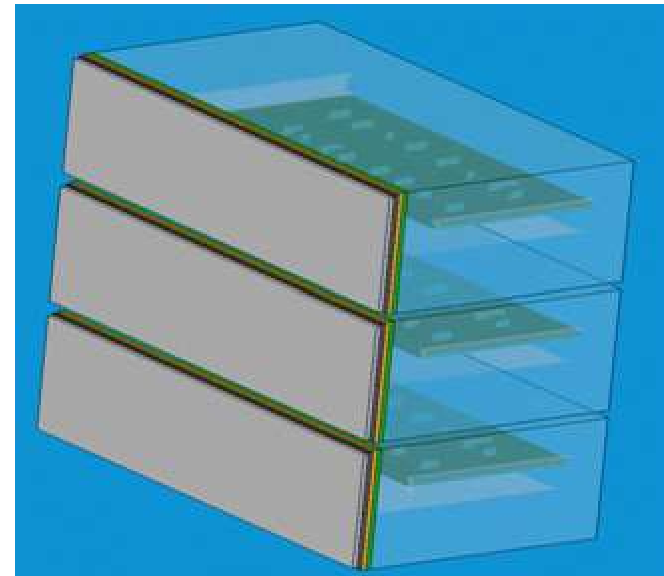
> Tilable detector array

- 12-chip module (85mm by 35mm)
- Small edge area for tiling

> High speed readout

- 2000 fps (12-bit counter depth)
- No dead time





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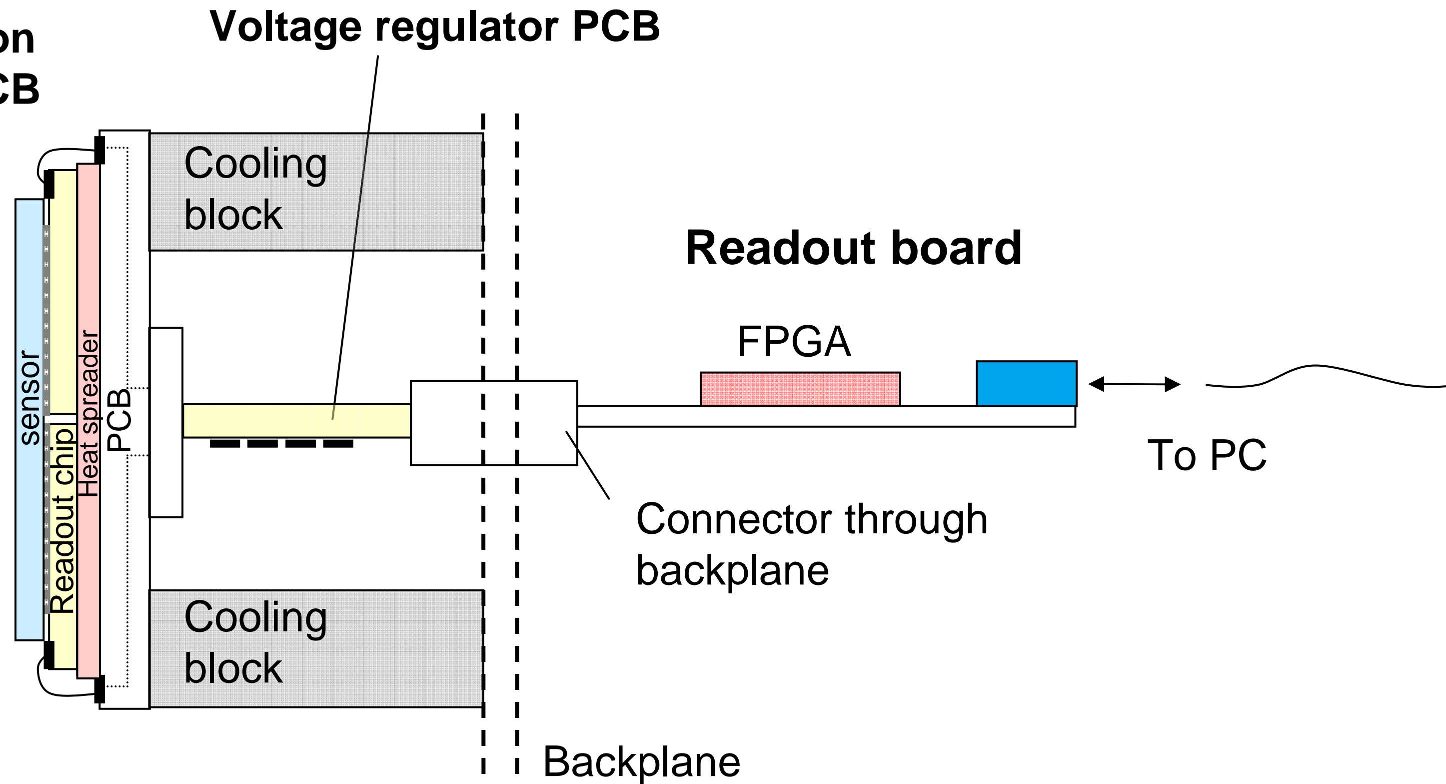
System design



Current design – USB readout for testing and firmware development

Final design - High-speed readout with 10 Gigabit Ethernet

Detector head

Silicon sensor

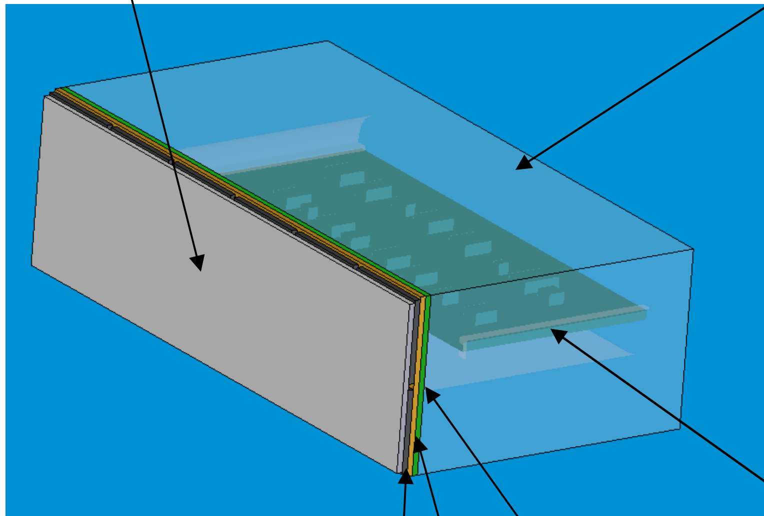
84 mm * 28 mm

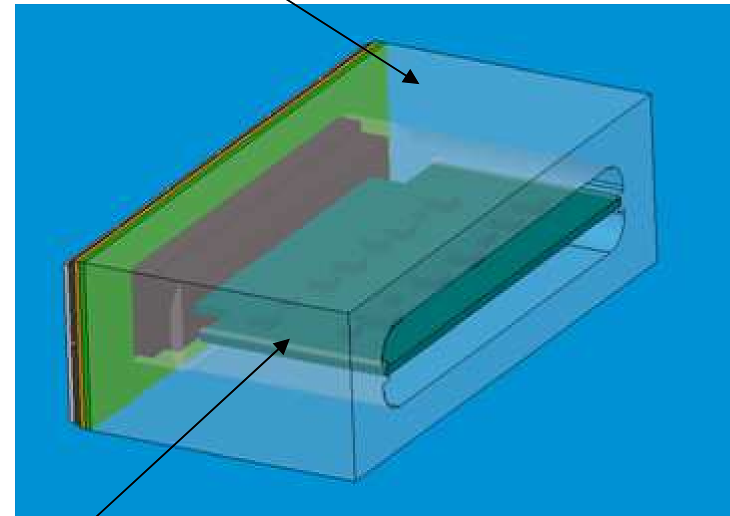
or

High-Z sensors

Each 42 mm * 28 mm

Cooling block





Module ceramic

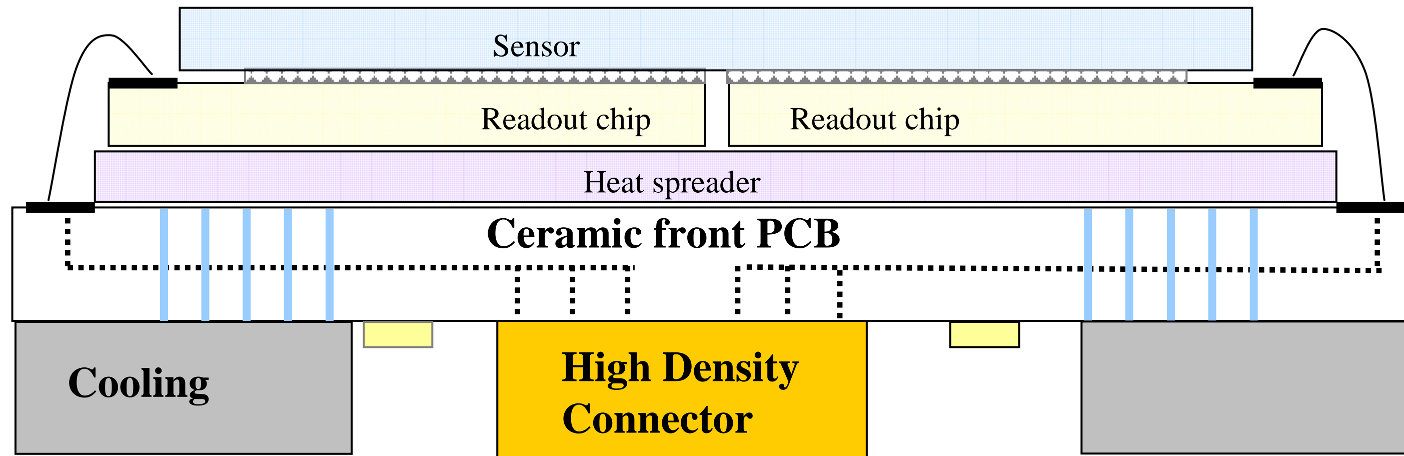
Voltage regulator board

Heat spreader

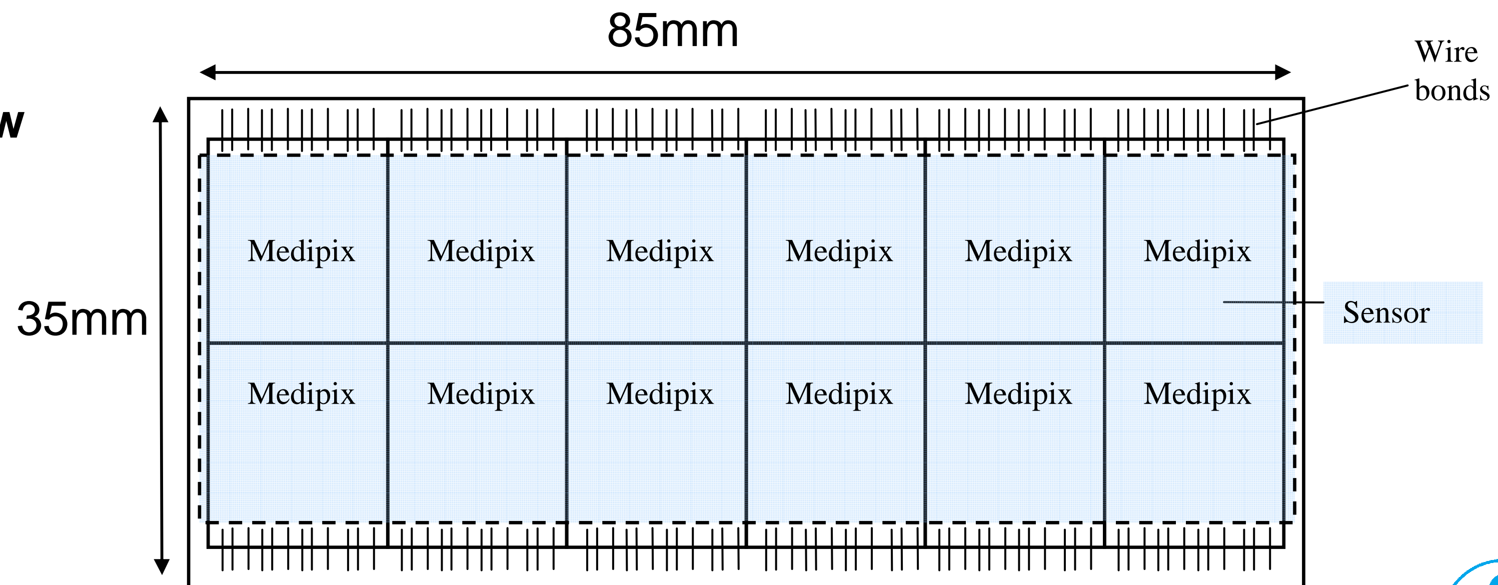
12 Medipix 3 chips under each sensor

Detector assembly on ceramic PCB

Side view



Top view



Design of front PCB

Requirements for Front PCB

- 150 LVDS pairs needed (for full speed readout)
- Total current around: 12A
- High Density Connector
- Thermal coupling to each chip
- Low operating temperature for Germanium Sensor: -50℃

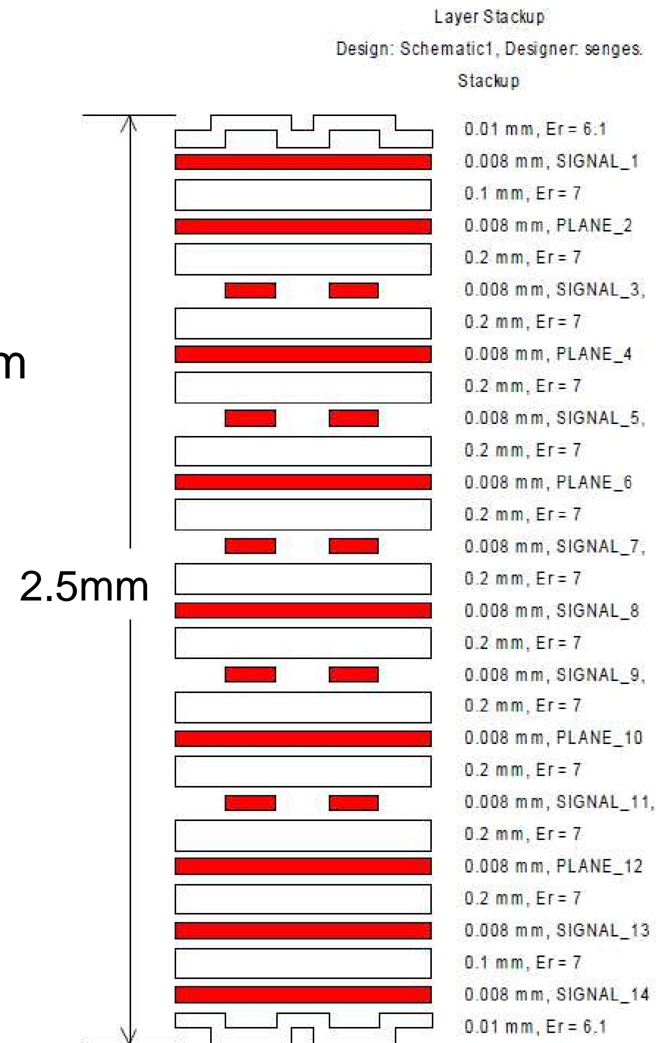
Material of PCB

- Low Temperature co-fired Ceramics (LTCC)

Coefficient of Thermal Expansion (ppm/K)	
GaAs	5.7
Ge	5.9
Si	3.3
LTCC	5.5
FR4	15

Multilayer PCB in LTCC Technology (KOA, Japan)

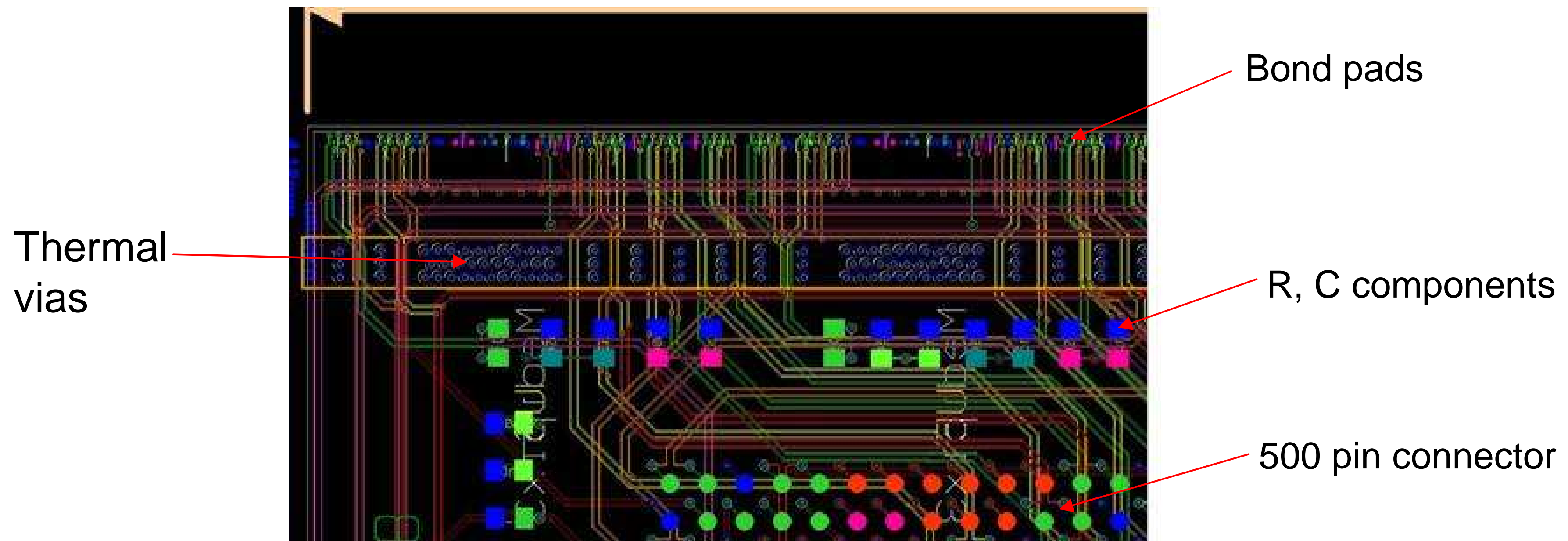
- > 14 Layer
  - Maximum Number of Layers: 20
- > Thickness of Signal Layer 200µm
  - Standard thickness: 80µm, 100µm, 125µm
- > Trace Width 70 µm, 170µm Diff Pair Spacing (100Ω impedance)
  - Minimum Trace Width: 60 µm
  - Minimum Trace to Trace spacing: 60µm
- > Via diameter 100µm
  - Available via diameter: 100µm, 150µm, 200µm



Cooling and front PCB design

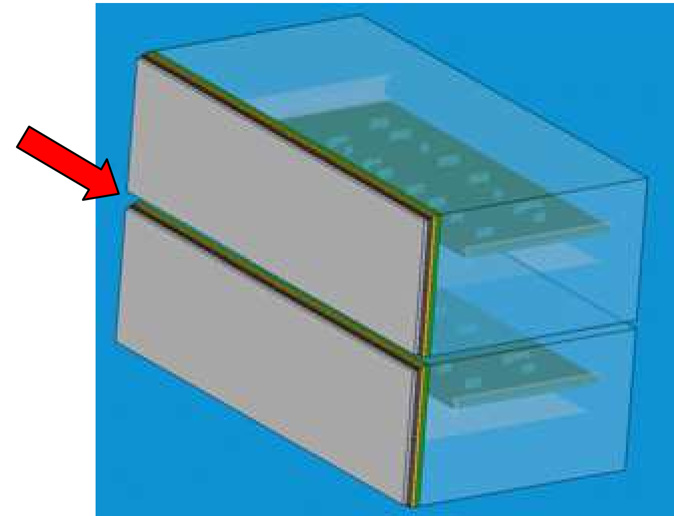
Design issues

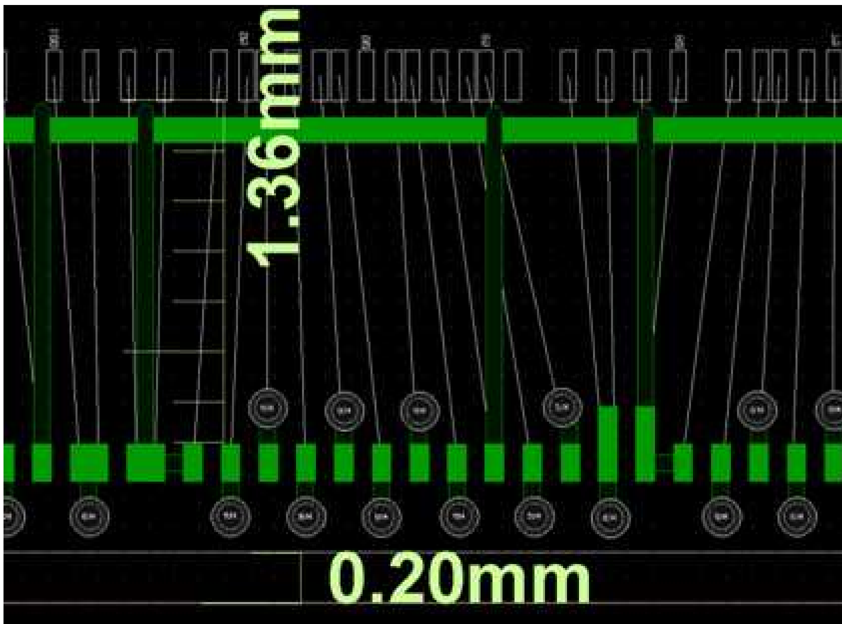
- Cooling frame occupies space on the back underneath each PCB
- Space available for connector and other components reduced
- Thermal vias make routing more difficult

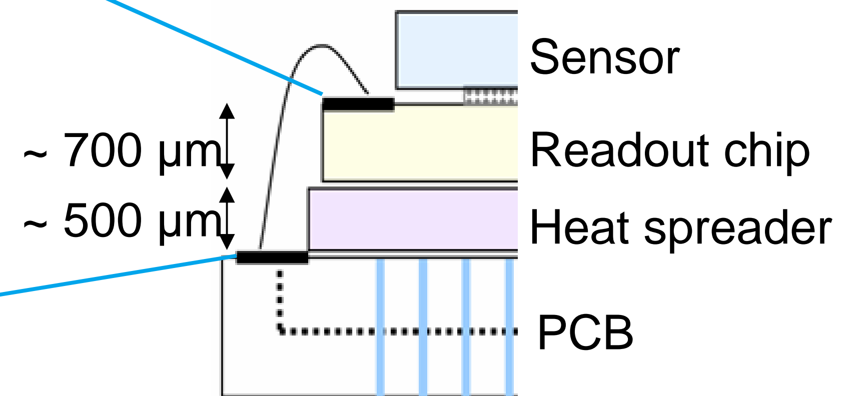


Wire bonding

- Wire-bonding done in-house at DESY
  - 75µm minimum pad width, 75µm gap
  - 1.36 mm from readout chip pads to PCB
- Future design should reduce bond distance



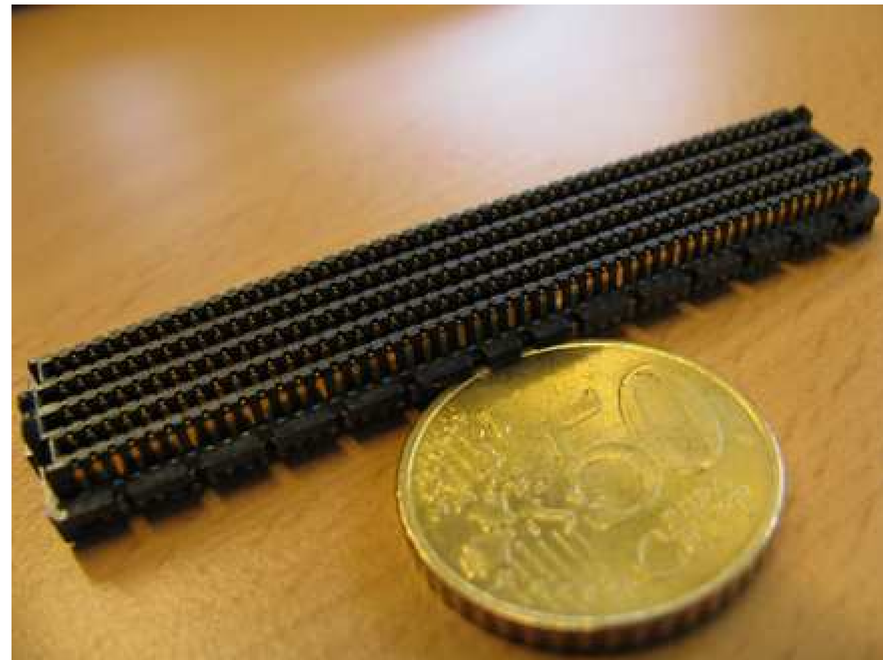




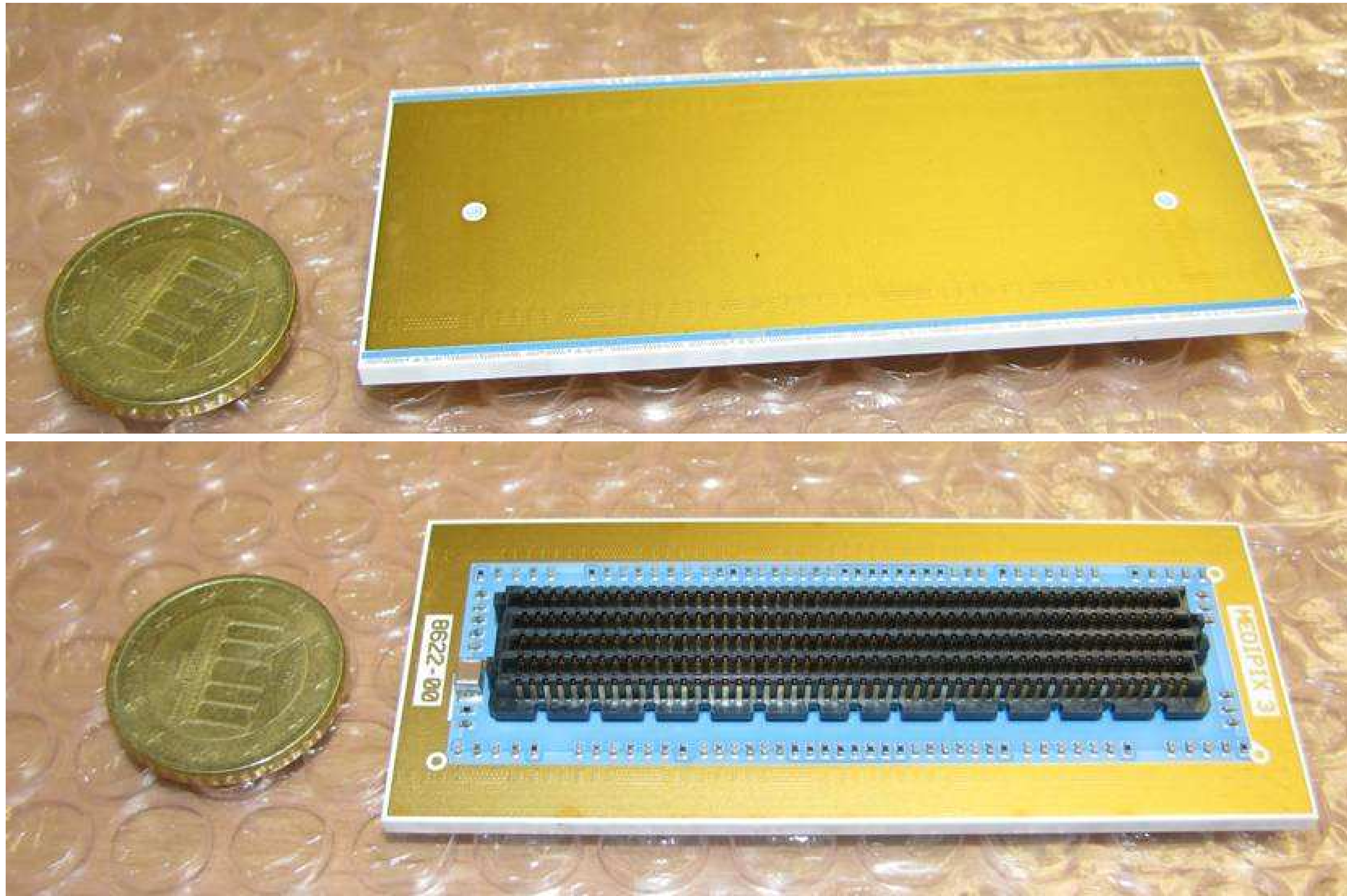
High-density connector for front PCB

- 500 pins including voltage supplies
- Samtec High Speed/High Density Open Pin Field Array, SEAM Series
  - Number of rows: 10
  - Number of pins per row: 50
  - pitch: 1,27 mm
  - Operating Temperature Range:

    -55℃ to 125℃
  - Maximum Current per pin: 2A



Completed module ceramic PCB



Voltage regulator PCB

> Transfer of the data

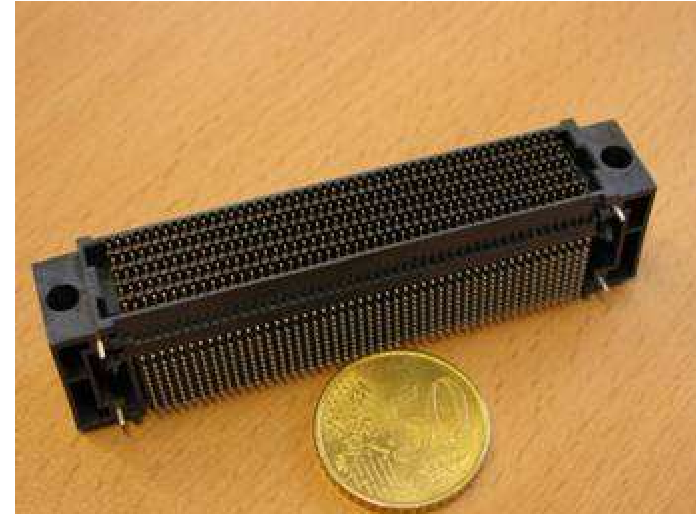
- 150 LVDS through the board

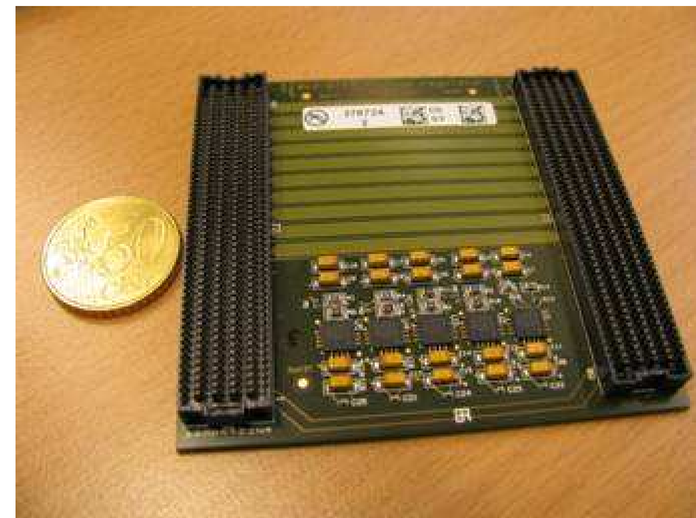
> Power supply

- 5 low-dropout linear regulators
- 4A current per each regulator

> Hi-Density right angle connector, SEAF-Series

> Currently, Samtec are having problems!

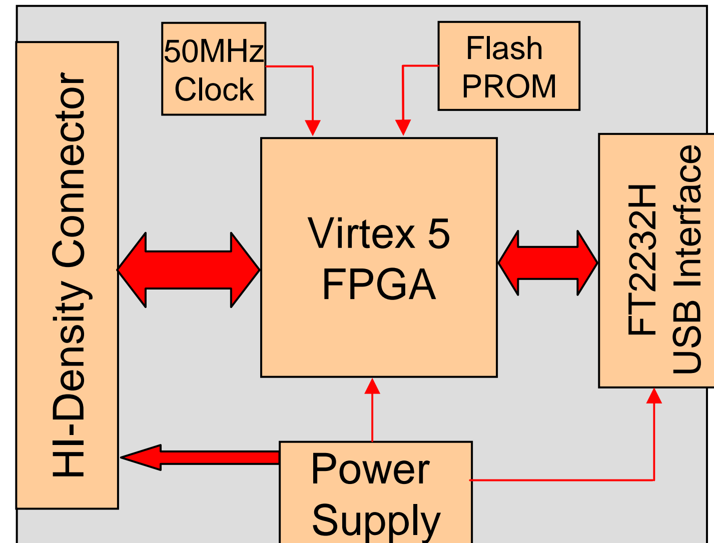




DESY

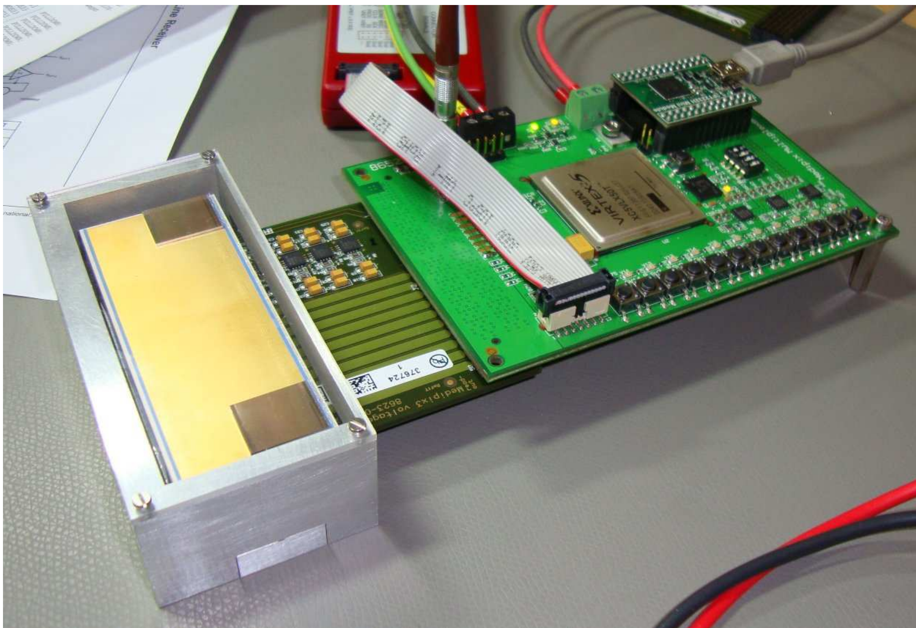
Readout board

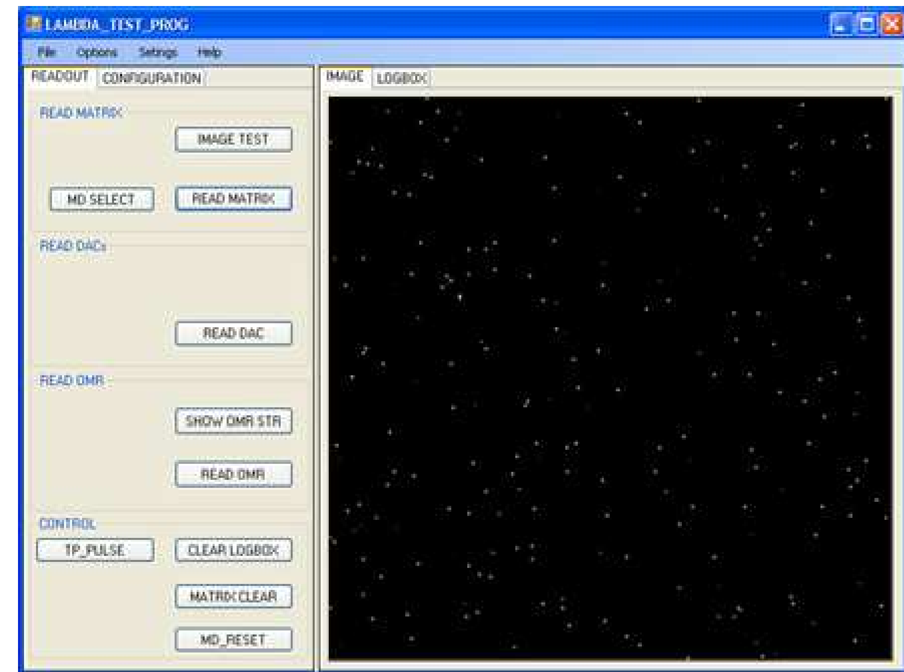
- Used for testing of firmware and detector components
- Central element
  - Virtex 5 XC5VLX50T
- USB 2.0 Interface for communication with PC
  - FT2232H USB Controller
  - Data throughput around 25 Mb/s



Progress to date

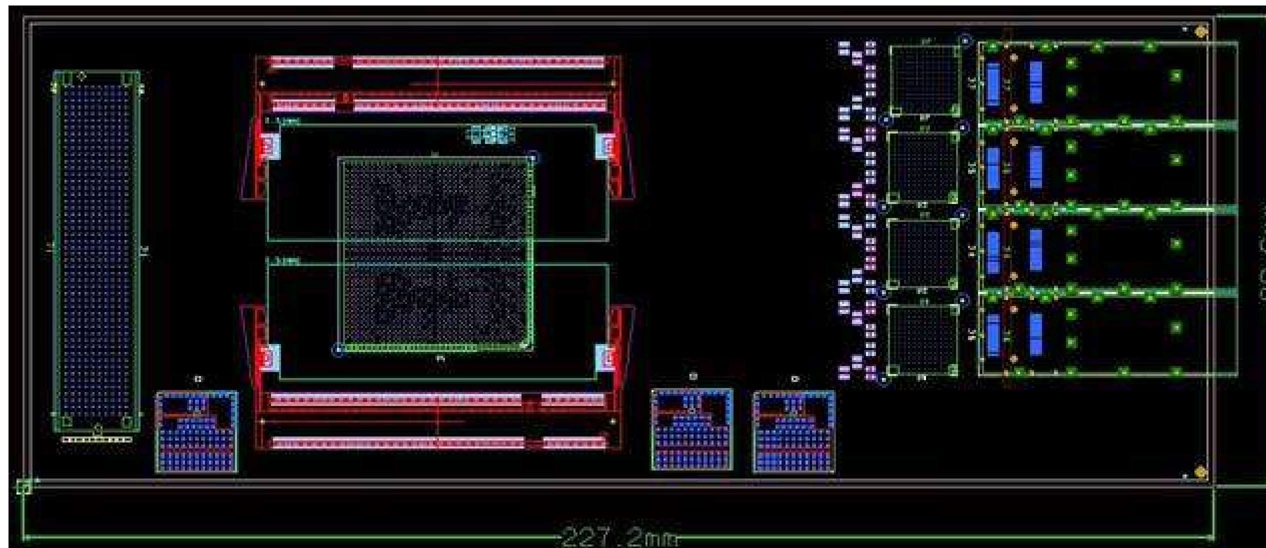
- Prototype system working with 2 bare Medipix3 chips
  - No sensor attached, but can set threshold low and measure hot pixels
- Preparing to work with 2*2 chip „quad“ sensor
  - Currently wire-bonding quad sensor
  - Developing firmware for multi-chip readout and pixel fine tuning





Planned High-speed readout board

- Modified version of XFEL readout board
- 4 * 10 GBE links to allow continuous readout at full speed (2000 fps)
- SODIMM memory to allow temporary storage
  - Will allow re-arranging of data, burst operation, processing…
- Control by USB interface
- Inputs from beamline control



Conclusions

- We are developing detectors for Petra 3, E-XFEL and FLASH
- Example: Large Area Medipix Based Detector Array
- Developed LTCC board with large number of signal lines
- Prototype system works with single chips
- Longer-term developments will allow high-speed readout of sensor array

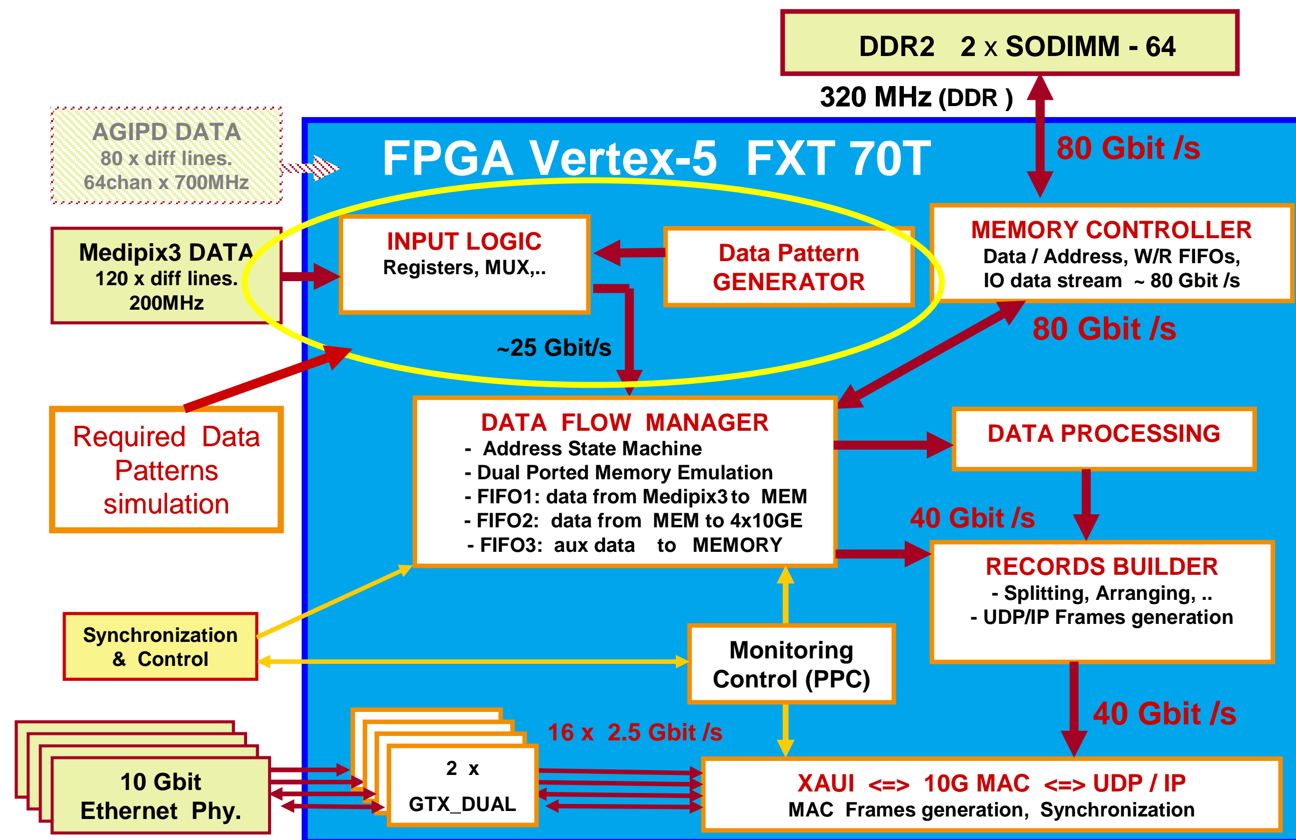
Large-area Medipix3 project

Thanks for listening

Planned high-speed FPGA Firmware

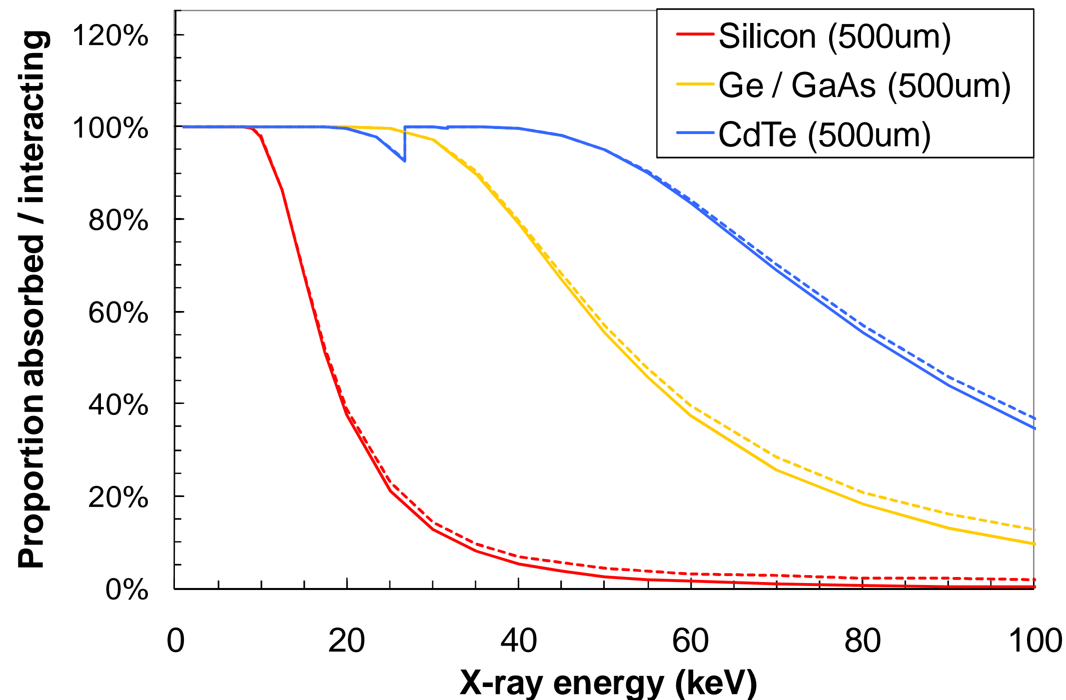
> High data throughput and 10 GBE control being developed by DESY for XFEL

- Mannfred Zimmer, Igor Sheviakov (FEA, DESY)



High-Z materials

- Many Petra-III (DESY synchrotron) experiments up to 100 keV x-ray
  - Replace silicon with another semiconductor



- Germanium:
  - Germanium (Canberra),

    Still tests: How sensitive are diodes to high temperatures
  - Indium bump bonding (IZM)

    Relatively cold bonding (<100℃)

Ceramic PCB