Open Hardware Activities in Creotech Instruments SA and Warsaw University of Technology

by
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Creotech Instruments S.A.:

- The company, which grew out of passion
- Knowledge-based technology company
- The company gathers top-class professionals

  in electronics, physics, computer-science and mechatronics

Our mission is to create specific and individualised electronic systems for projects requiring highest standards

Who we are?

Creotech Instruments S.A.:

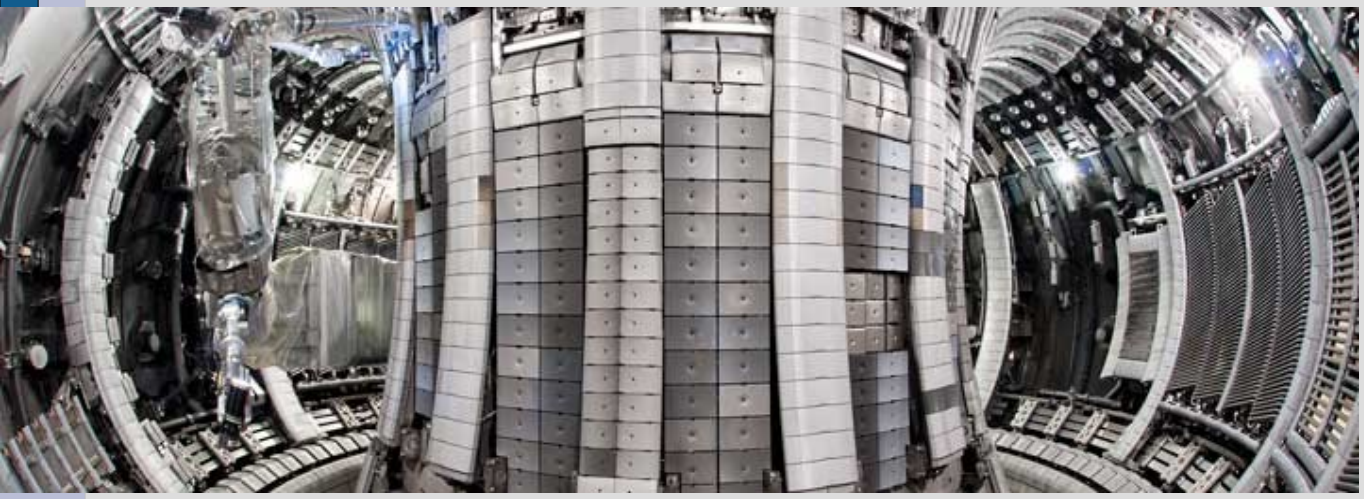
- Creotech Ltd. was founded in 2008
- 2011 – the joint-stock company Creotech Instruments S.A. was created
- 2012 – two private share emissions, work on ISO9001 started
- 2013 – an investment in a cleanroom facility carried on, start of space technologies applications' projects

  First ASIM (ISS) project completed

- 14 people employed (2 PhD, 1 MoS, 11 engineers)

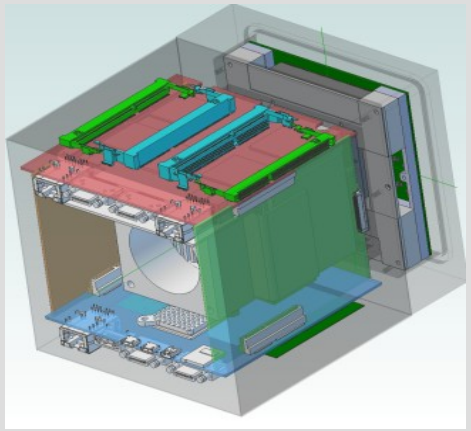
Who we are?

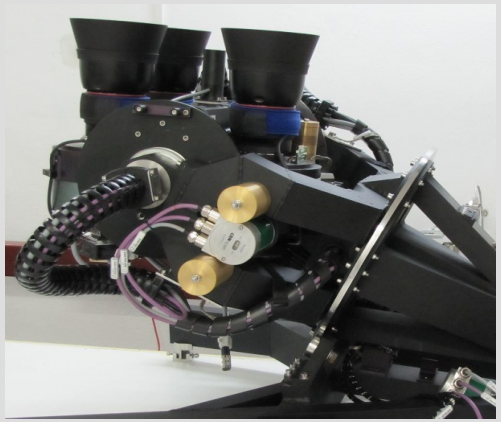
Our proprietary solutions were tested in international research projects

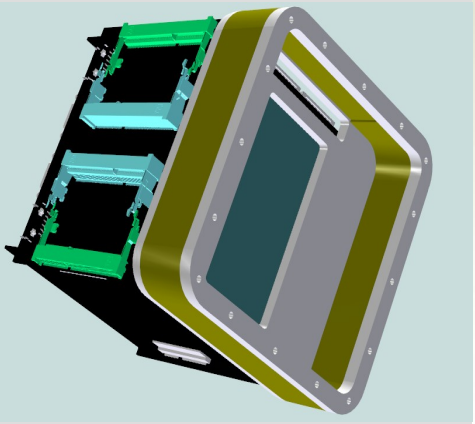


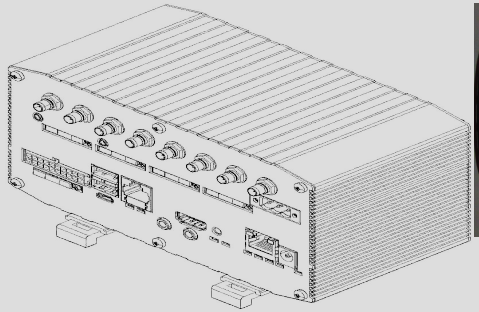
We do not only science..

But interaction with scientific projects improves our skills and know-how









Basic requirements:

- Everything needed to review and modify the design and to produce the final hardware must be published.

- The project must present an interest to the community of electronics designers for experimental physics facilities.

The result:

Open Hardware is excellent from the point of view of CERN and experimental physics community:

- it is developed for free
- it solves certain problems of the community
- community is financed from public money so there is expectation that some of scientific and technical achievements are open

Can it be also good for small companies ????

Business – is making money not giving things for free !

Why Open Hardware? :

Big Hardware Company

- we will invest 0.1% of our resources (we are big) → not a big cost for us

- we will for sure find some applications of OHW devices in our own hardware designs → sell these complex devices, and make money

- problems that we have/might have will be solved without our investments (someone else will solve it)

- we are following the trends and could react more quickly on demands from this market

OHW is good for us

Small (not only small) software companies:

- we will invest 80% of our resources → it a big cost for us

- we will understand the hardware that is given for us for free

- we will prepare software solutions for this hardware, software is our own and we have copyrights for it

- we will sell the software+hardware solution and earn money

OHW is good for us

Small hardware companies:

- we will invest 80% of our resources → it a big cost for us

- we will give for free an effect of our work

- someone else will produce it and sell under its brand

OHW – why do we want to take part in that ???

Creotech point of view...

A few words on the Creotech Instruments SA:

- Small company: ~12 engineers + technical staff
- Special equipment for tests + for production of short series of highly sophisticated solutions (i.e. ESA-certified clean-room)
- Close collaboration with WUT
- Company started by post-CERN workers and people connected with other scientific laboratories

Our business model:

- We take orders from scientific institutes and industry, we develop complete systems.
- Orders are for highly sophisticated equipment
- Sophisticated equipment consist of HW, SW and FW
- We publish HW, FW and partially SW, still keeping our experience and knowledge in system integration.
- System integration, SW and support generates most of the income. HW cost covers production, testing, warranty and support

Other institutions notice that solutions what they need are available as OH, they integrate themselves or due to sophisticated nature let us do it:

- they risk less, because in the case of lack of the support they can modify and produce the HW themselves
- they have references from other institutions where we integrated it
- they see what exactly will get

How OH gives us business opportunity

- It's great place to advertise company capabilities, skills and expertise and collect more orders
- It's place to exchange ideas, collect feedback and product improvements
- Here the company may show realized projects and get recommendations
- Sharing hardware and firmware files encourages other companies to do the same and gain part of their know-how
- Next products can be created much faster thanks to modification or re-use of existing ones, developed and tested by someone else
- Thanks to opening design files in early stage of product, other engineers may find bugs or suggest modifications which leads to better product
- By sharing own product HW and FW files, company gets vantage over competition – some clients will choose such solution which they can control, modify or repair in the future (after warranty period)

Examples of successful OH projects

hips MOUSER TME DIGIKEY MARITEX Farnell Octopart OSF.OPI Plus online SOS Esauron CTI projects CTI WEiTi (1) TMS - Users OHWR worhshop CCFE Intranet Daily Info - Your Guide... EBSCOhost Wilga

e following companies are actively using the OHR site to develop or produce open hardware, software and drivers. These companies may be paid for the open developments. Please not that companies may in fact involved in more areas than described in the table below. This table only reflects work done in the OHR site.

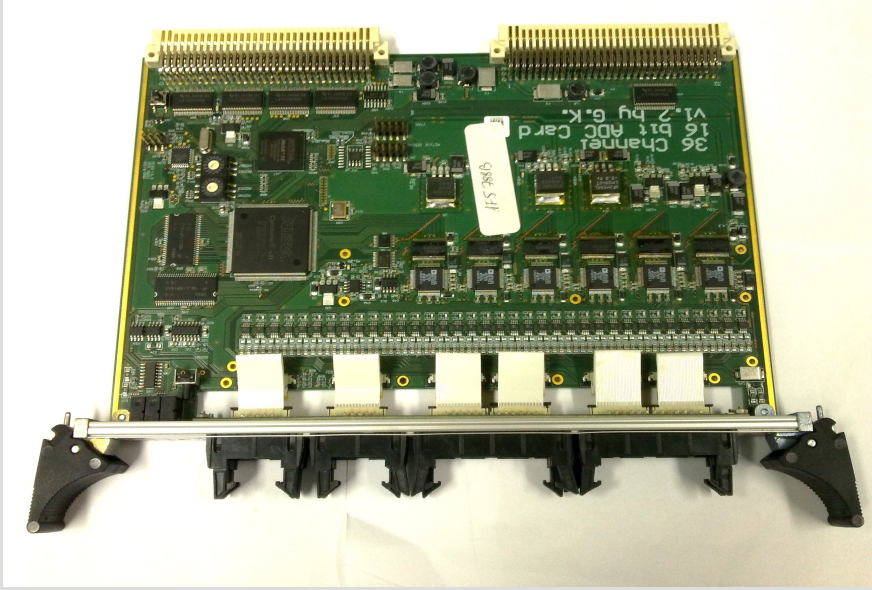
Nazwa	Opis	Country	HW development	HW commercialisation	HDL development	SW development	Projekty	Uczestnicy
Cosylab	Your trusted control system partner	Slovenia	✓		✓		2	3
Creotech	An enterprise of zeal and excellence	Poland	✓	✓			20	1
Digicom Electronics	Detail oriented, Integrated solutions, Guaranteed, Industrious, Capable, On-time, Manufacturing Excellence	USA		✓			1	0
Elproma	ELPROMA presents next generation IEEE1588 (PTPv2)	Poland					0	0
Gnudd	Helping our partners to master technologies	Italy				✓	18	2
HLP Technologies	Create Design Develop and Maintain	France	✓	✓	✓	✓	1	0
Igalia	Open source consultancy for innovative projects	Spain				✓	2	3
INCAA Computers	Your partner in automation	The Netherlands	✓	✓		✓	5	1
Integrasys	Building Success from Innovation	Spain			✓	✓	2	3
Janz Tec	Industrial Computing Architects	Germany		✓			1	0
MagentaSys	MagentaSys	Switzerland	✓				2	0
Milky Mist	Eyecandy on a Chip	France			✓		1	1
OCLogic	Hardware design and simulation	UK			✓	✓	1	0
ORSoC	FPGA, ASIC, DSP – embedded SoC design	Sweden	✓				1	0
even Solutions	Seven Solutions	Spain	✓	✓	✓	✓	12	6
Splendeo Innovación	Intuitive, easy to use web applications	Spain				✓	1	1

ossary

- HW development: Hardware development
- HW commercialisation.: Hardware commercialisation
- HDL development: Firmware development (e.g. VHDL)
- SW development: Software and driver development

VME ADC board

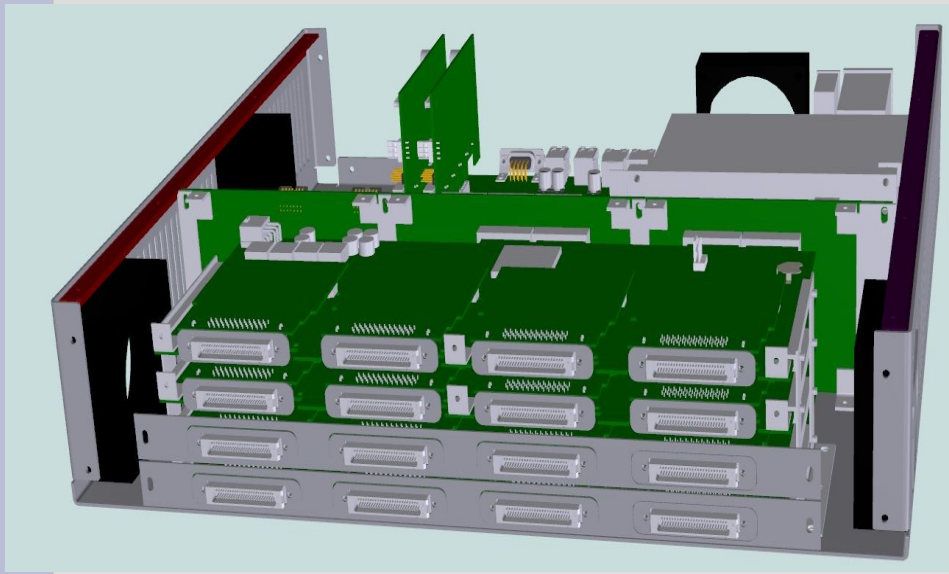
36 ADC channels, simultaneously sampling
16 bits
250kHz
64MB of RAM
Main application: SEM grids
OHWR design

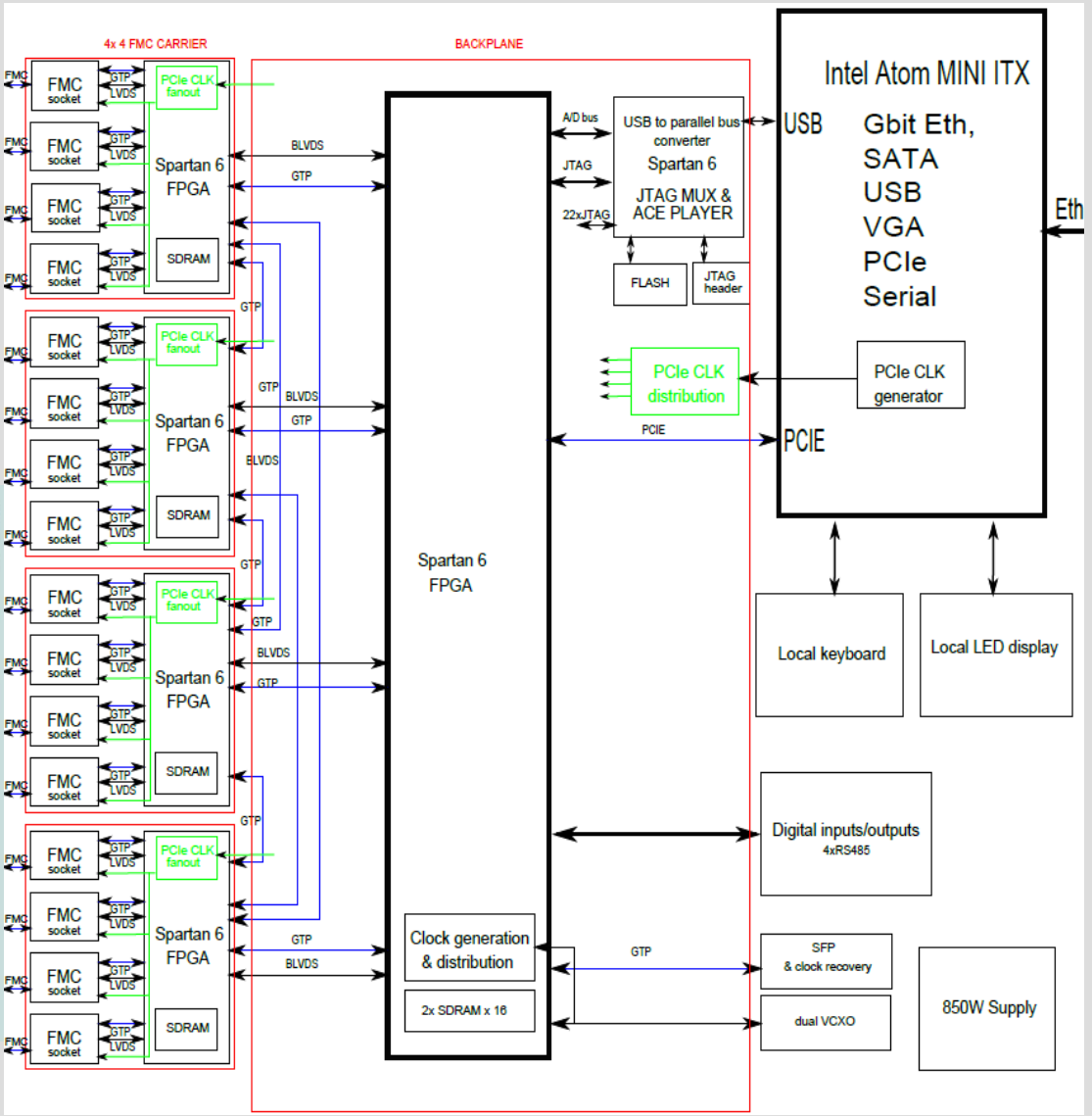


Product developed in close collaboration with CERN,
180 pieces produced
Application: Linac 4 SEM grid readout, DC transformer DAQ
CERN requested OH in call for tender

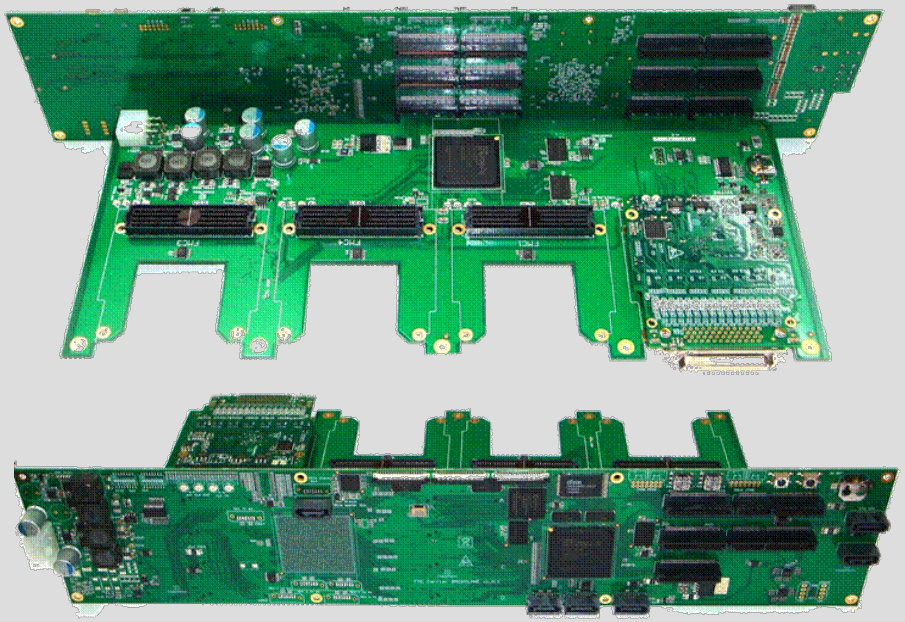
Custom FMC Carrier

- Up to 36 FMC
- PCIe Gen2 (5gbit/s)
- Global CLK distribution
- White Rabbit/ IEEE1588
- Max 46 FPGAs





Custom FMC Carrier



High speed 18xFMC carrier
WR enabled
max 22 FPGA
Dual Core or I7 CPU
1kW PSU

Backplane + carrier

Possible applications of single 4U carrier

- 512 channels, 10bit, 100MS/s acquisition for photonic detectors (visible, X, Gamma) – spectrometers, 2D imaging.
- 128 channel Software Defined Radio, 0.4-4GHz for passive radar
- 1024 channels, 16bit, 1MS/s acquisition for process control
- Fast feedback multi-dimensional cavity controller for accelerators beam control (i.e. free electron lasers)
- Data concentrator for 64 fibre channels
- Supercomputer, up to 1Tera Instructions Per Second (512 ARM cores)
- DSP computing platform, up to 256 cores at 1.5GHz
- Country or region - scale positioning system (with WR support)
- Automatic test equipment

Great isn't it ?!

But....

- The costs of the development are high
  (at the moment several Polish institutes are being involved, but it is still not enough)
- The costs of the tests are much higher
- There is a high probability that the scientific community will “not buy it”
  - risk of a new not-proven standard !
- There is a high probability that a large company will quickly propose something similar (with copy-rights and patents)
- There is a high probability that no-one will hear about this (another forgotten brilliant :o) idea)...

The solution is Open Hardware!

By giving the core of the system to open hardware directory we will:

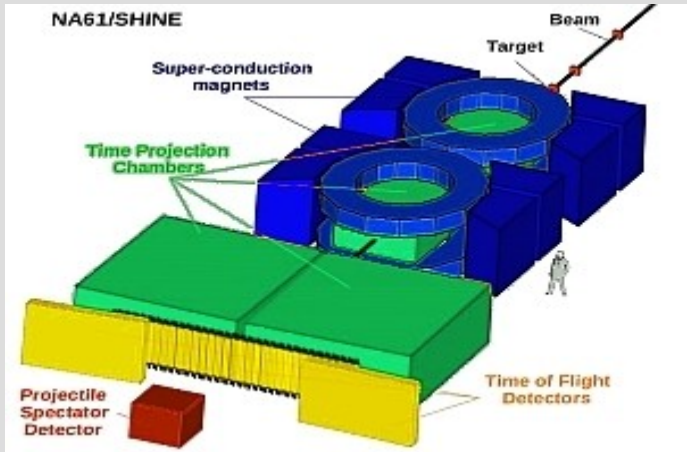
- **Let people know that it is existing and is great !**
- **Convince people to develop it, check and provide their improvements**
- **Lower significantly the costs of development**
- **Make it cheap (cheaper than other standards)**

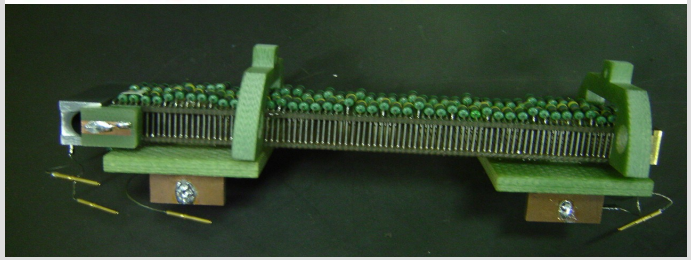
A piece of cake for Creotech:

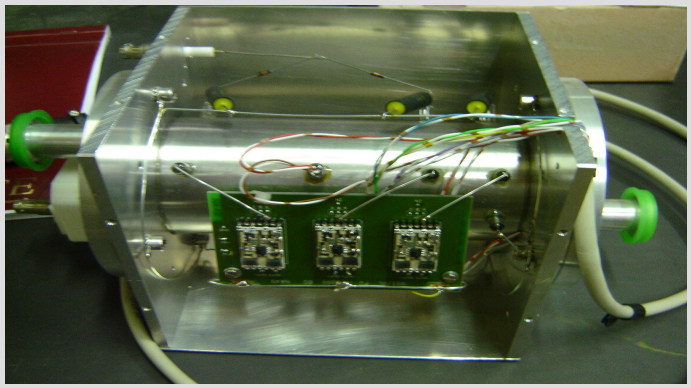
- **We are a proponent of this standard and we plan to make a production**
- **As a proponent we believe that we obtain several contracts for production of the system that we know the best**
- **As a proponent we believe that we will support the institutes that are implementing the system**
- **As a proponent we plan to develop different extensions to the core of the system, the extensions will be sold as our own products**

CER NSPS NA61 ion velocity monitor

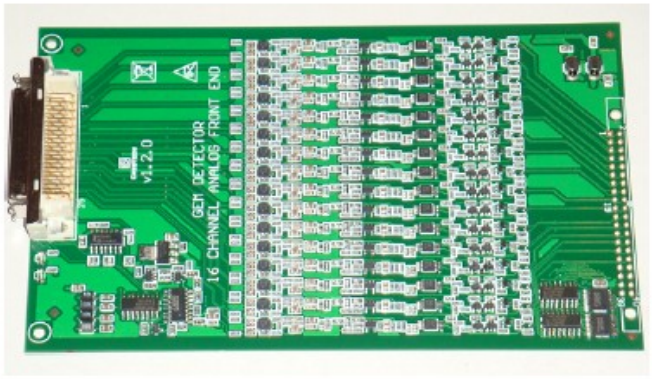
- NA61/SHINE studies hadron production in hadron-nucleus and nucleus-nucleus collisions at the CERN SPS.
- Large acceptance hadron spectometer
- Excellent capabilities for momentum, charge and mass measurements.
- Time Projection Chambers, Time of Flight and Projectile Spectator Detectors
- Reference ion-velocity (in delivered gas) monitoring system is needed
- Measurement of ToF, temperature, pressure, voltage
- Supply of 3 HV electrodes
- Online processing and calculations
- Single GbEth interface

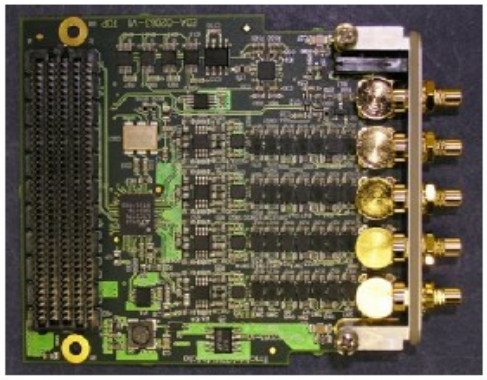


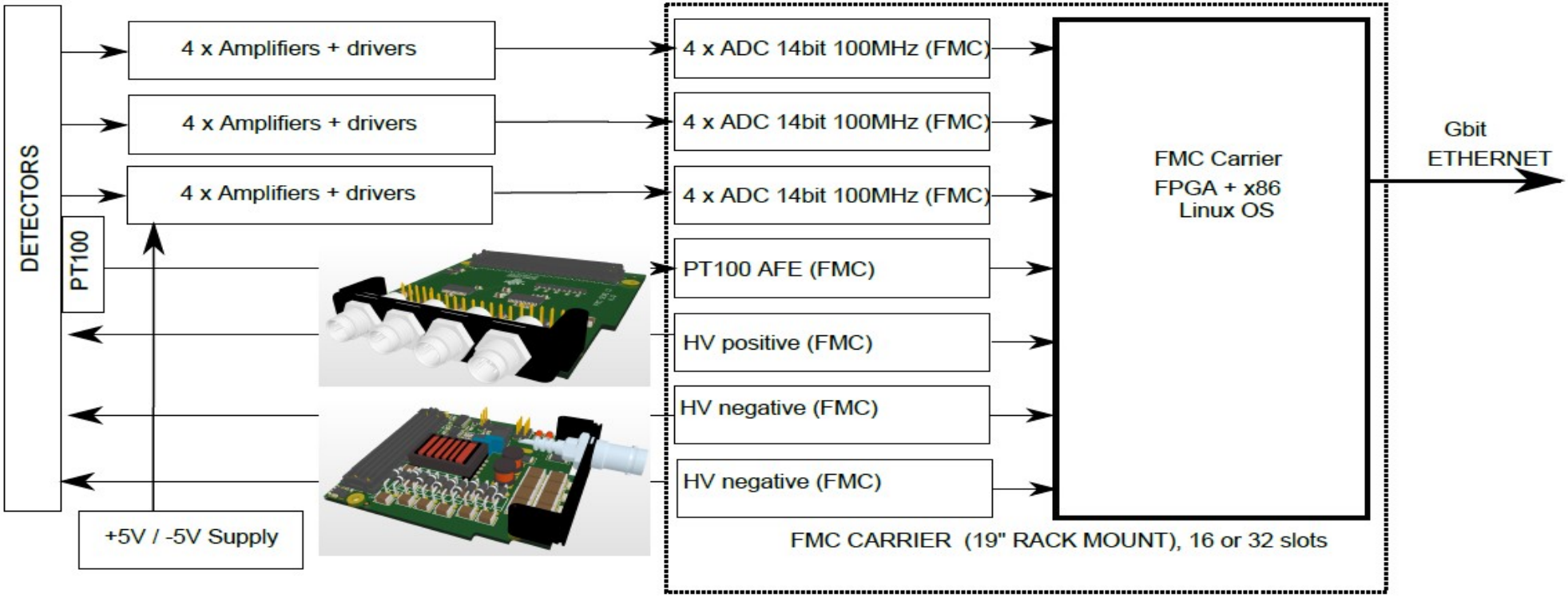




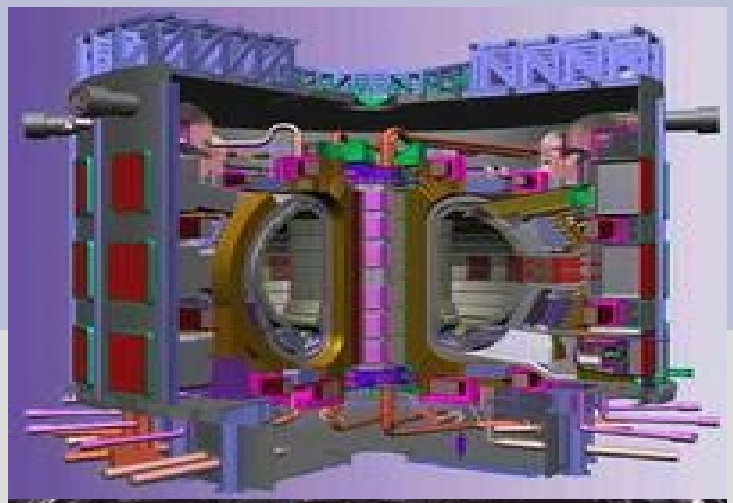
CERN NA61 ion velocity monitor

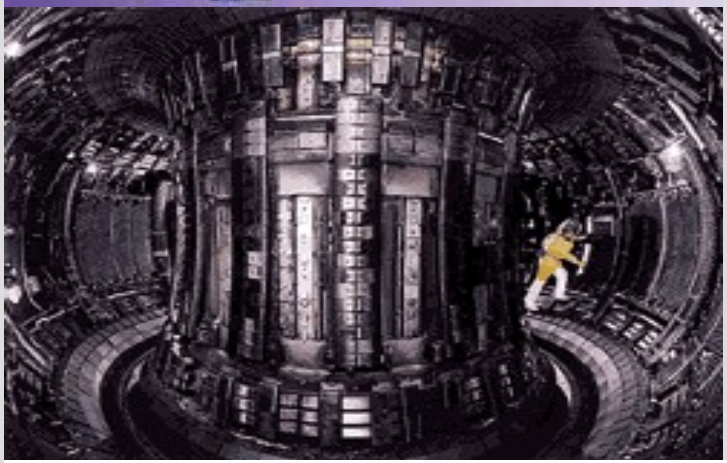


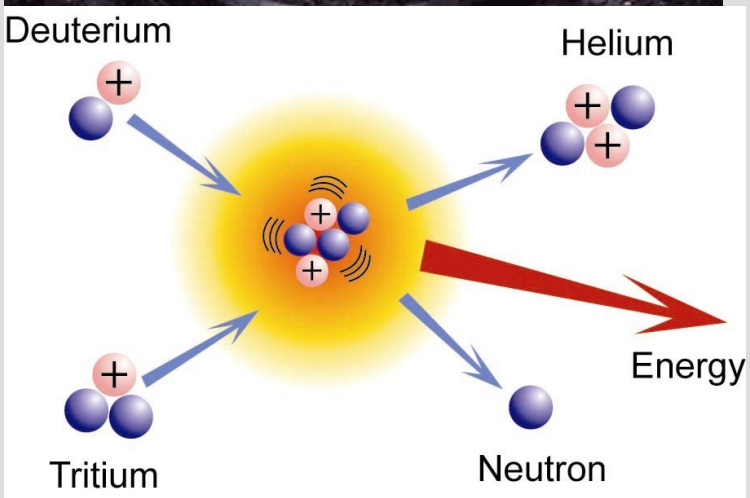




Joint European Torus

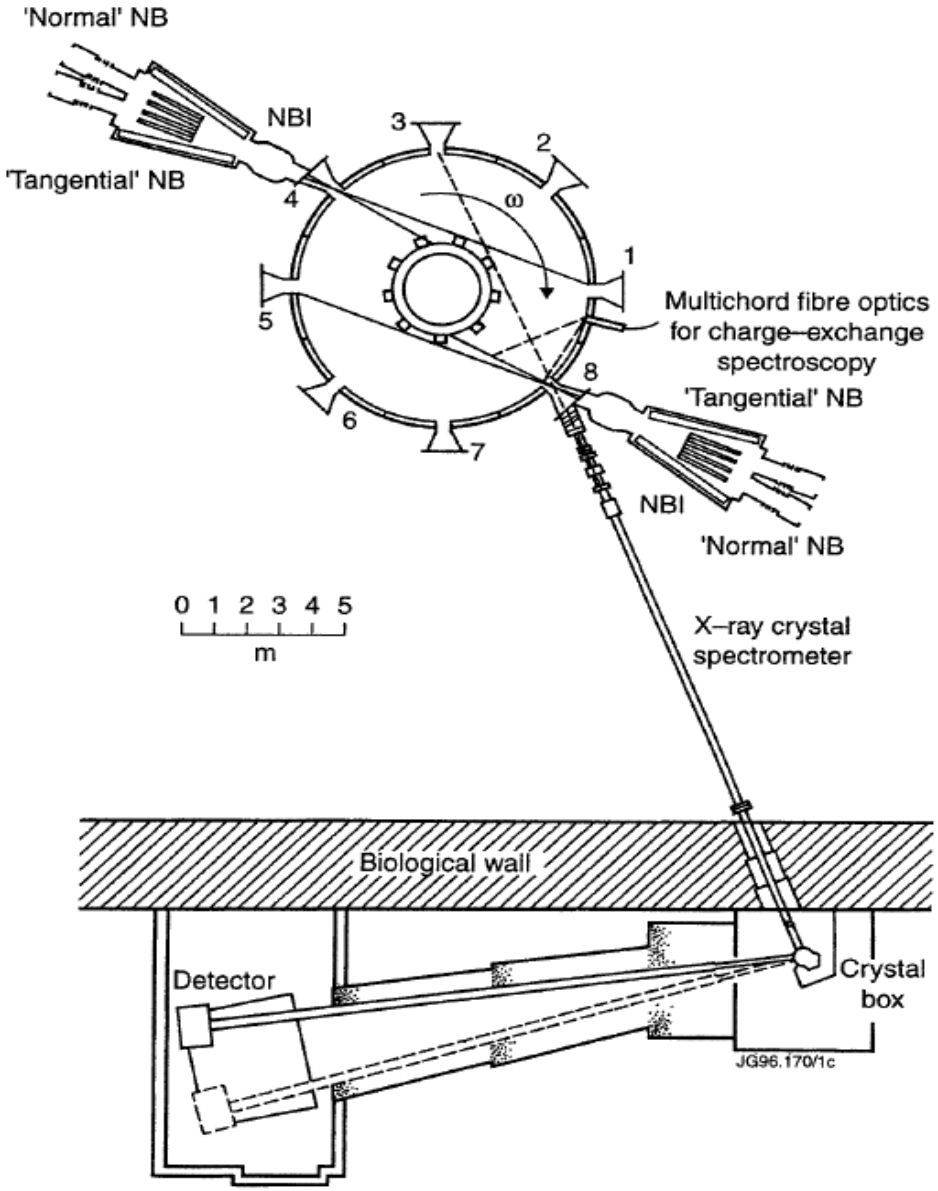




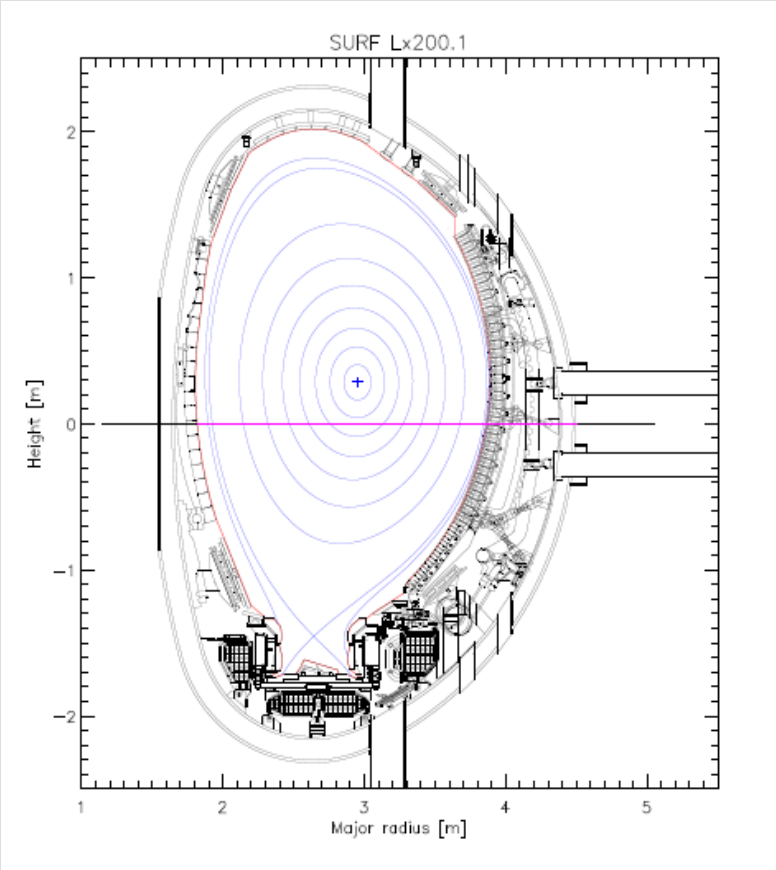


- Nuclear fusion: Deuterium (sea water) + Tritium (Lithium)
- ITER prototype
- Safe operation - reaction requires very specific conditions. Immediate machine stop possible.
- 100mln K - ohmic & microwave heating,
- 1g of fuel = 11T of coal, no emission of wastes or CO2
- 1m^3 of H2O contains 10g of Deuterium – fuel for milions of years
- Difficult to keep the reaction for more than a few second
- Plasma contamination → new wall material research
- Plasma spectrum monitoring required

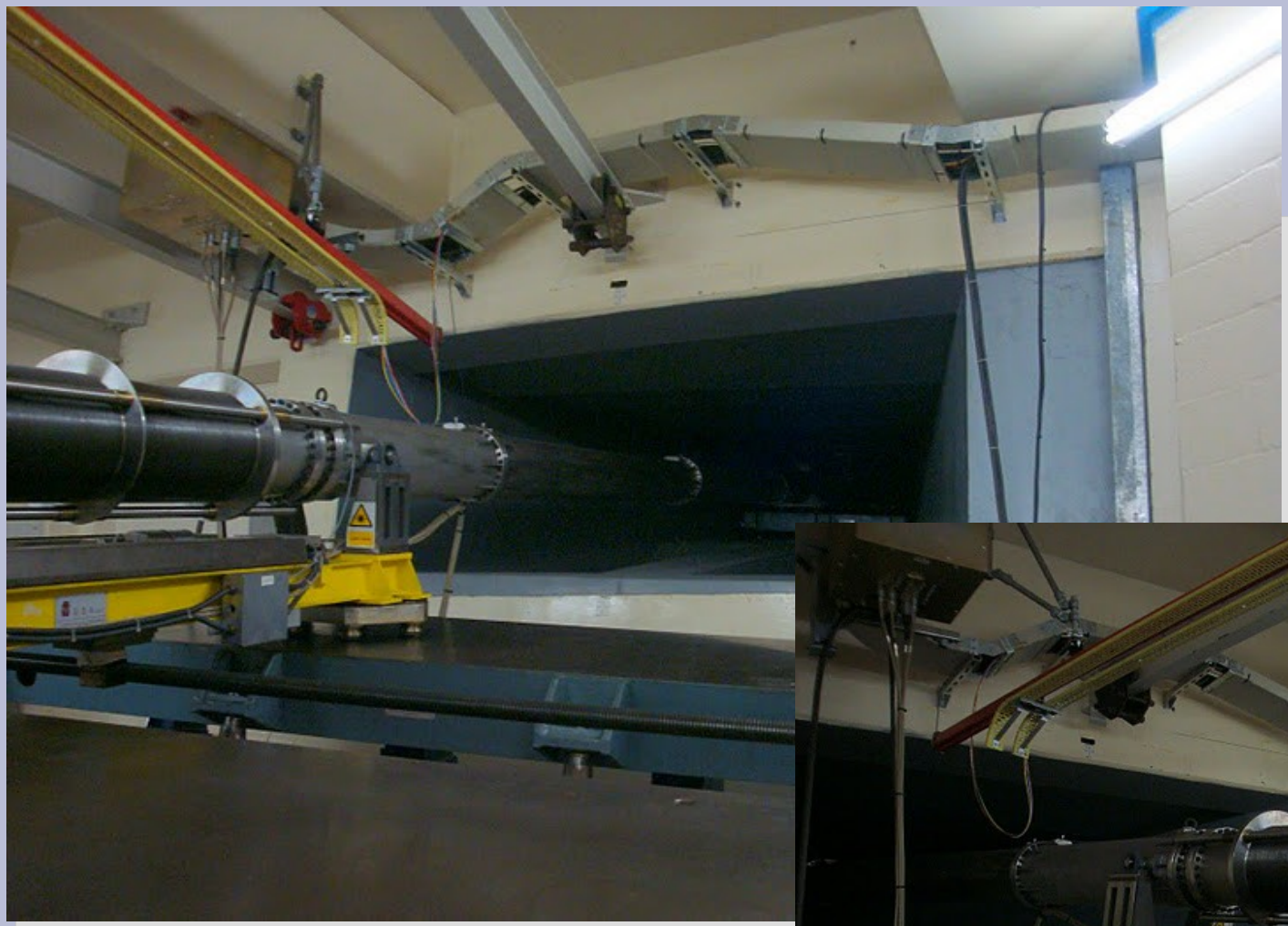
X-ray spectrometer



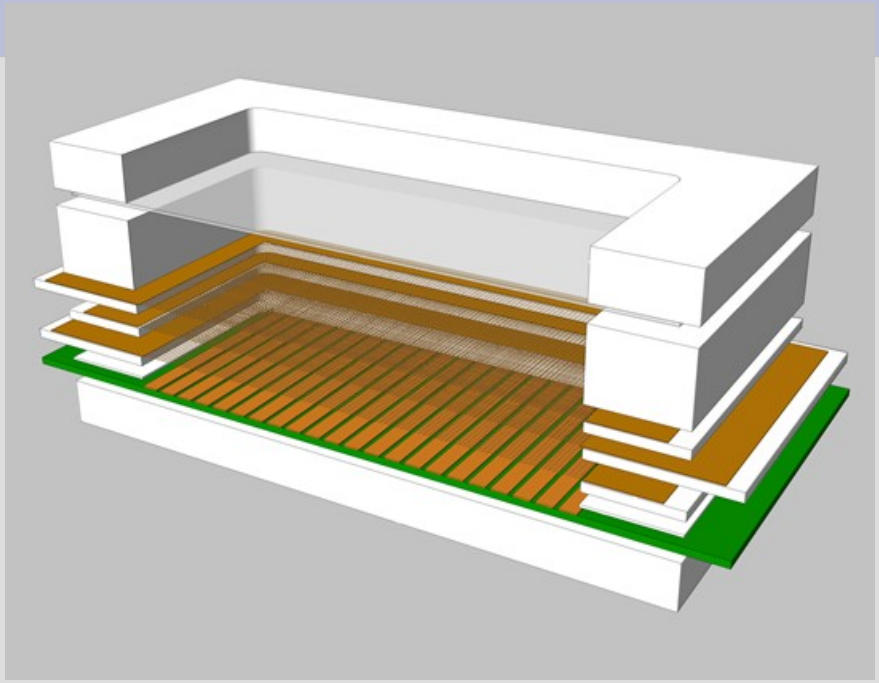
Spectrometer =
crystal + detector

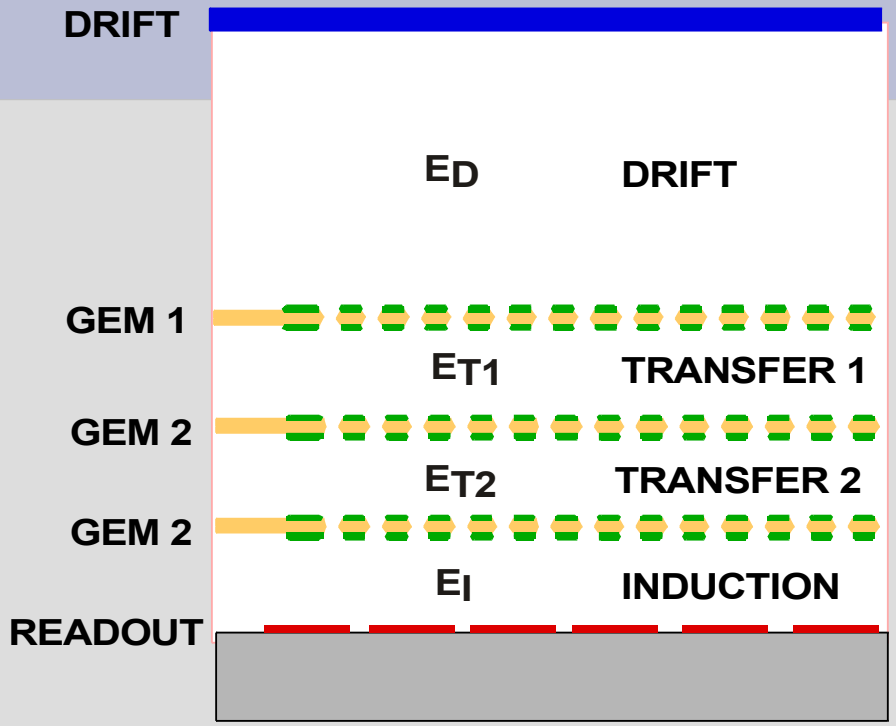


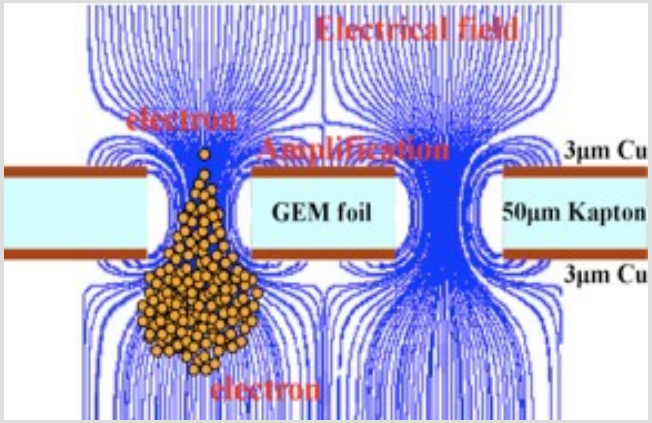
Spectrometer tube

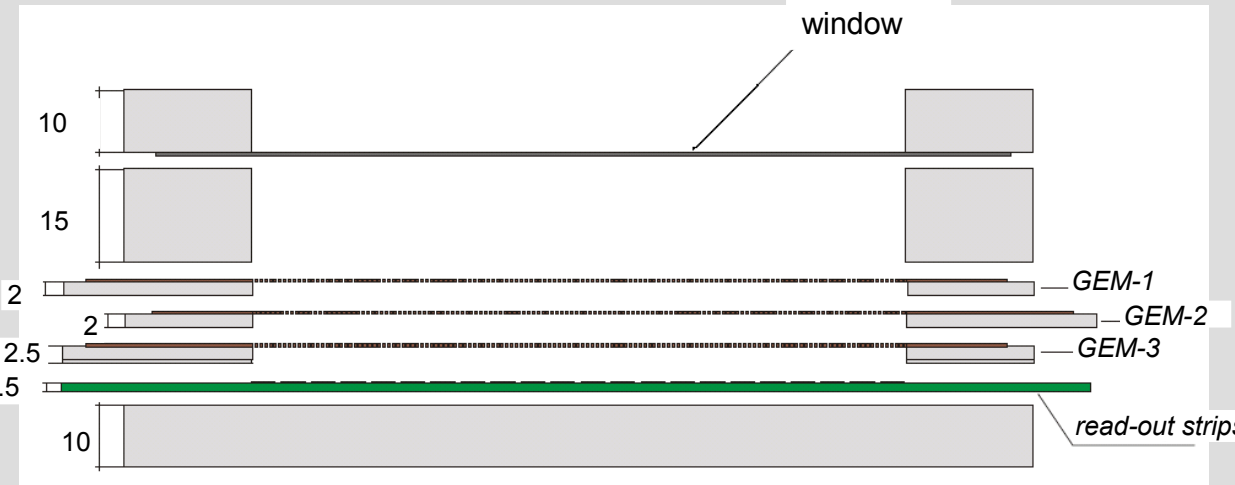


GEM Detector – photon to electron conversion

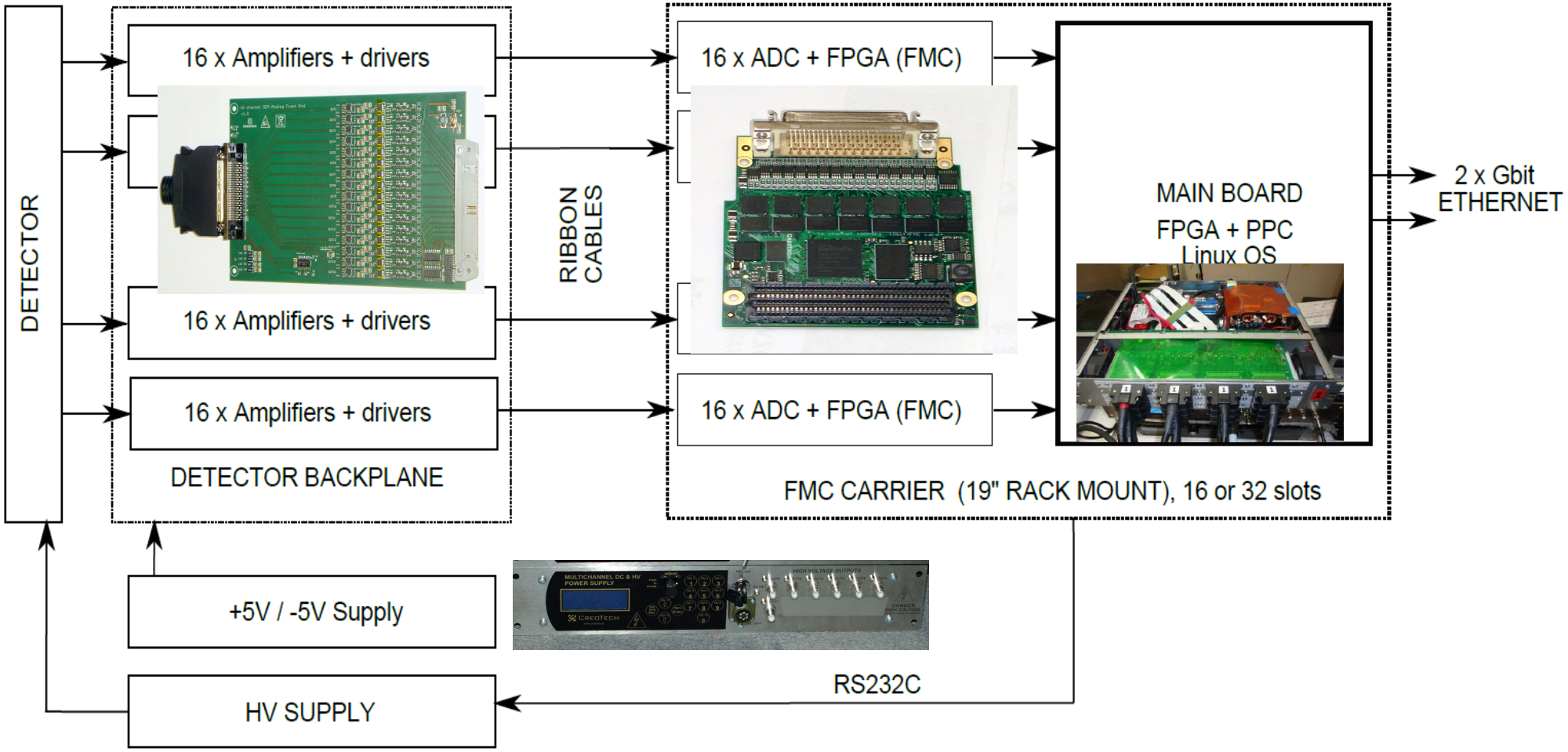






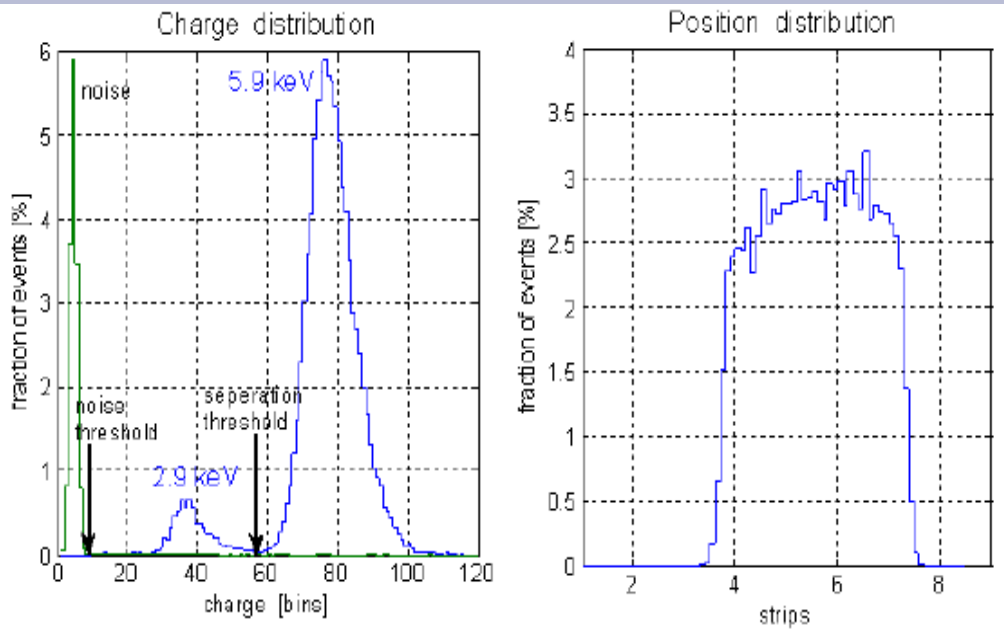


Processing electronics



256 strips, charge: 100fC (10uA/10ns)
256 charge amplifiers
256 ADCs, 10bit, 100MS/s
22 FPGA chips

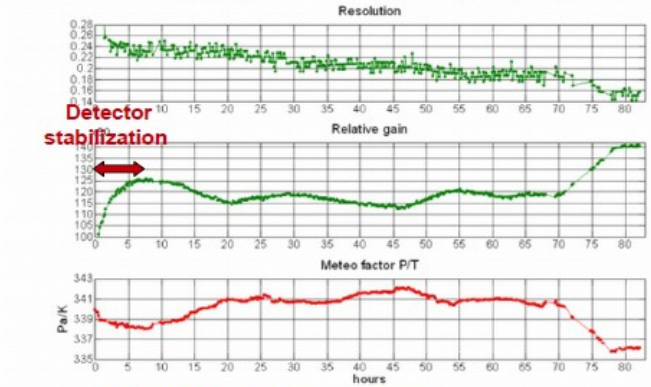
Results



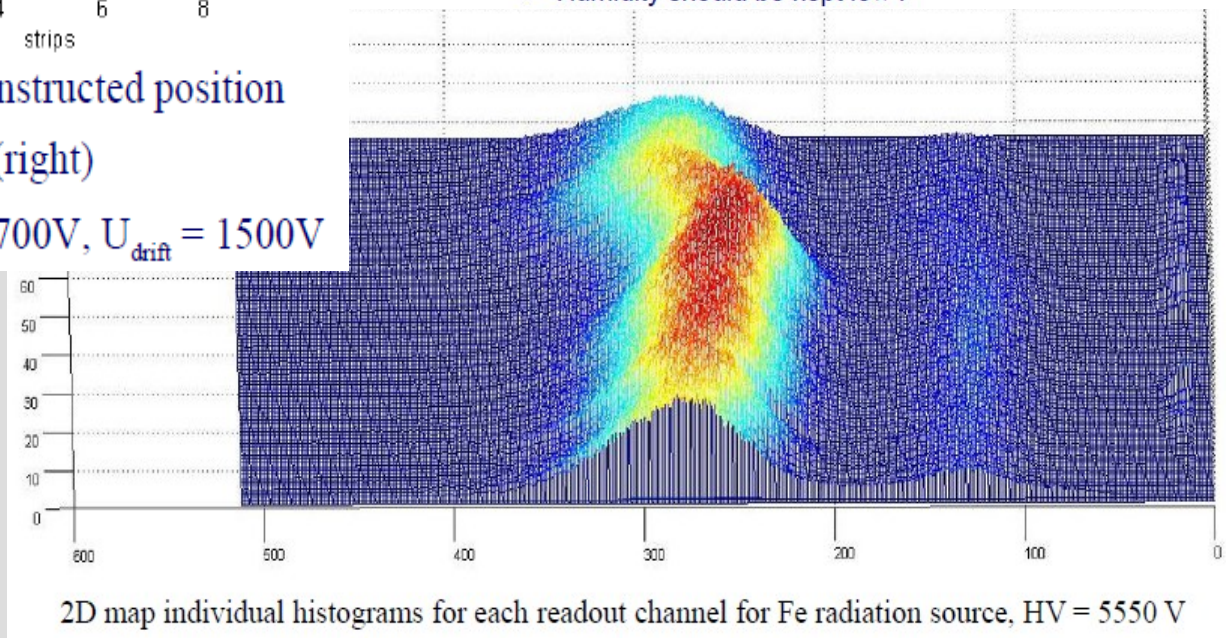
Collected charge distribution (left) and reconstructed position distribution within anode strips (right)

U_{ind} = 1250V, U_{GEMs}= 350, 370, 390V, U_{trans} = 700V, U_{drift} = 1500V

Detector characteristics & Meteo factor P/T vs time
First 83 hours after applying final HV = [1000,360,700,360,700, 360,1000]

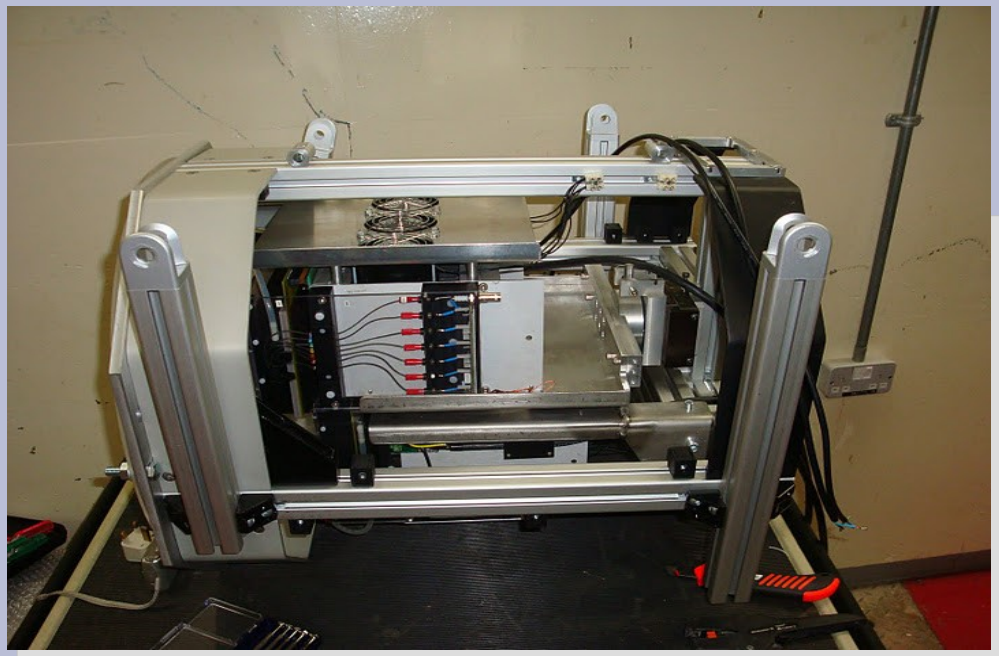


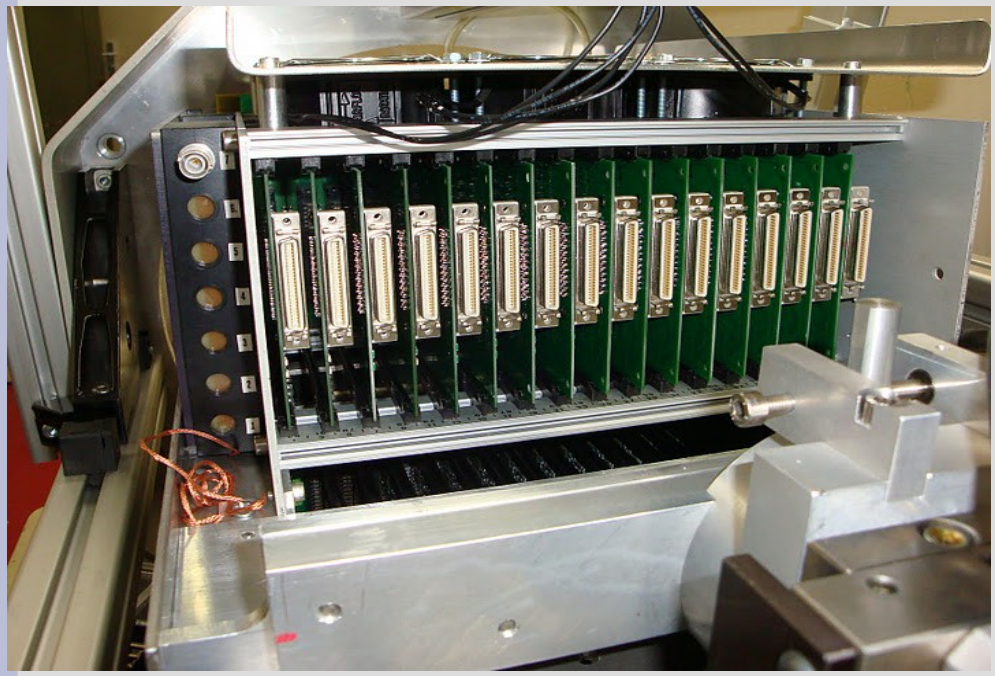
- Gain stabilization: ~8 hours
- Optimal resolution needs longer time
- Detector control using temperature and pressure
- Humidity should be kept low !



2D map individual histograms for each readout channel for Fe radiation source, HV = 5550 V

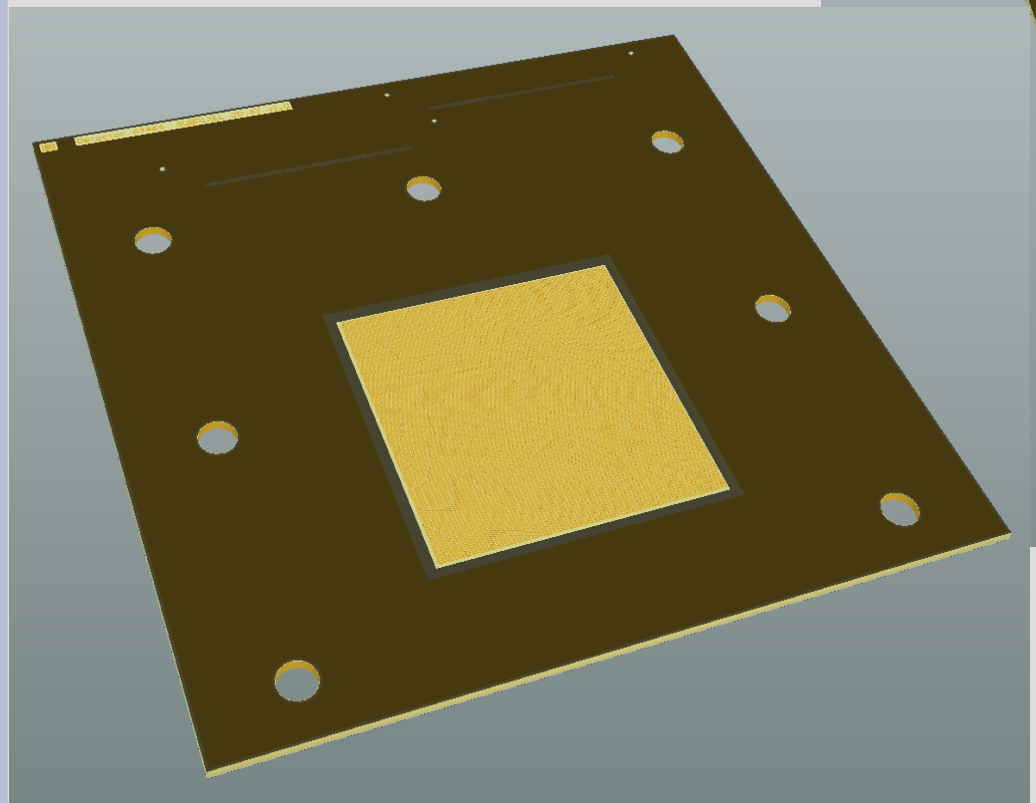
Final detector system

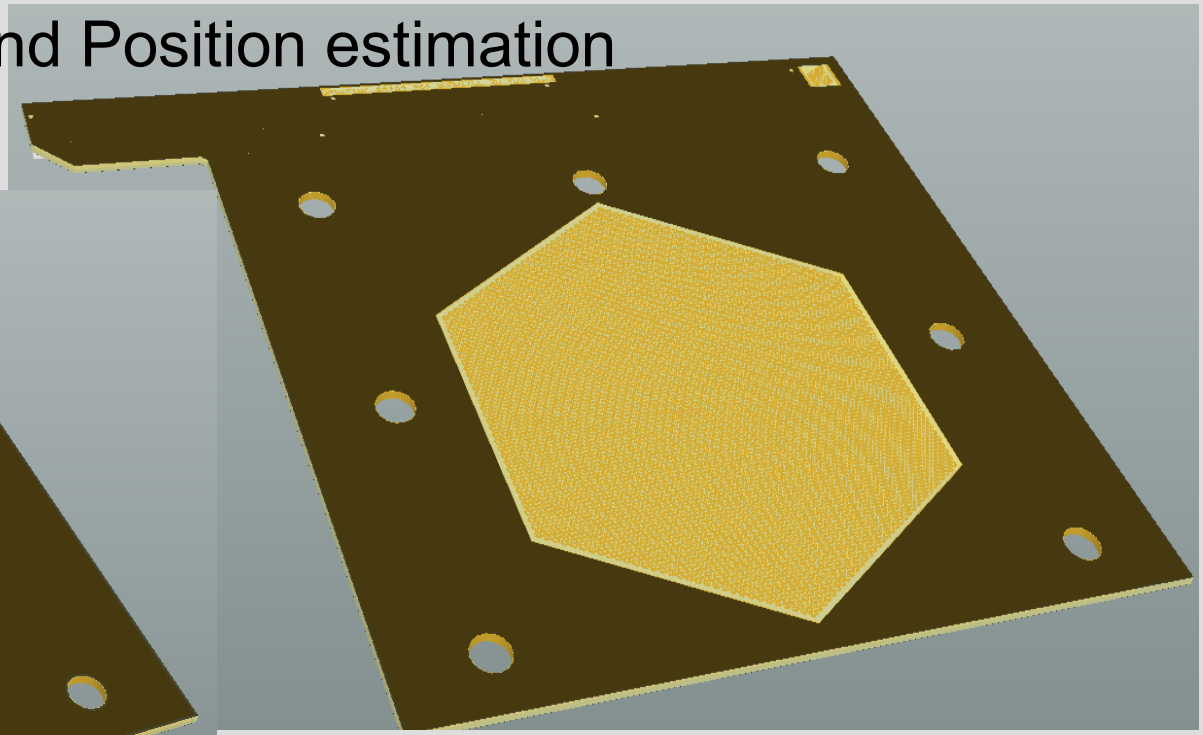




GEM-based large format X-ray camera

- High resolution, 640x640
- 128x128 analogue channels
- 10x10cm imaging area
- Low cost GEM detector
- Single photon Energy and Position estimation

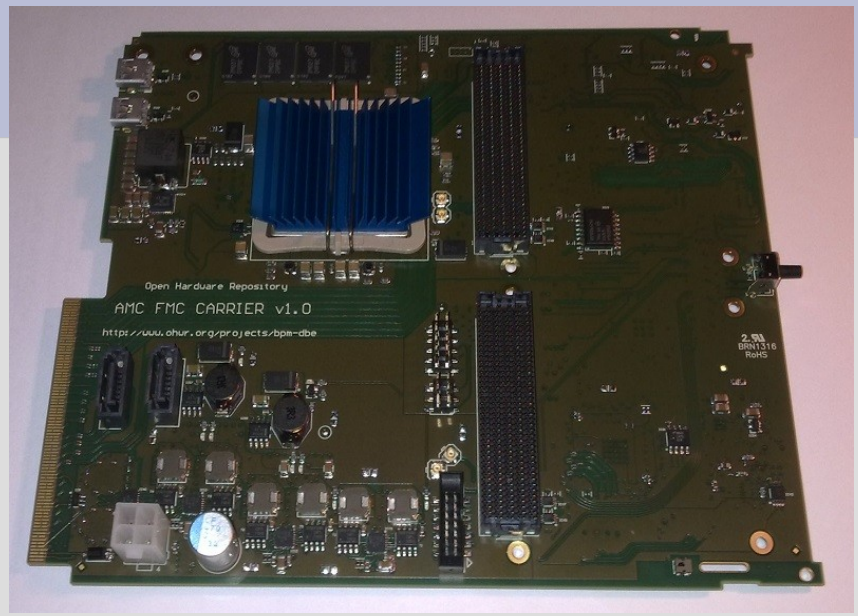


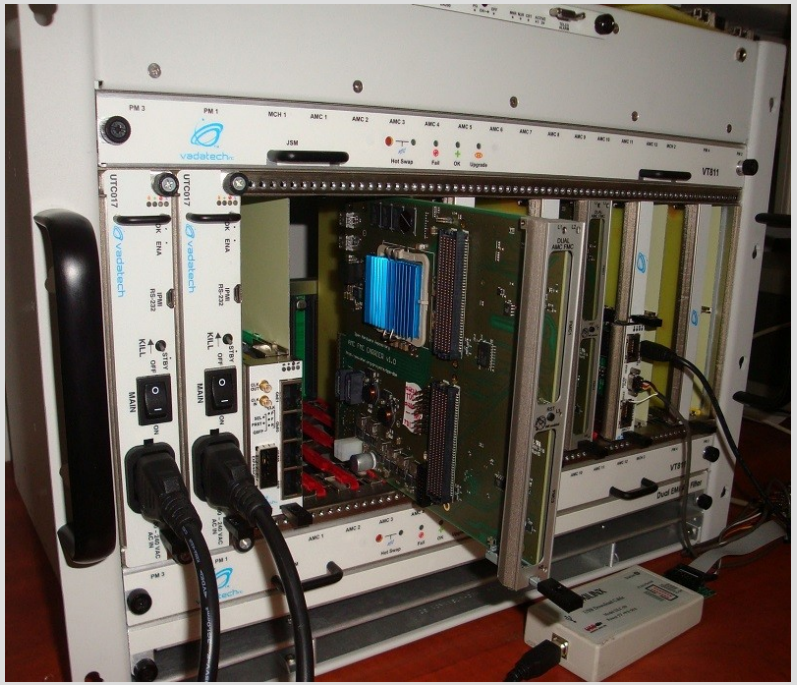


AMC FMC board

- 7-series FPGA, Artix 200T
- PSU capable of Kintex
- Same bank structure as Kintex
- Dual HPC FMC
- Clock crossbar
- 4Gbit SDRAM
- 2x 256Mbit FLASH
- Custom NXP MCMC
- SCANSTA JTAG switch

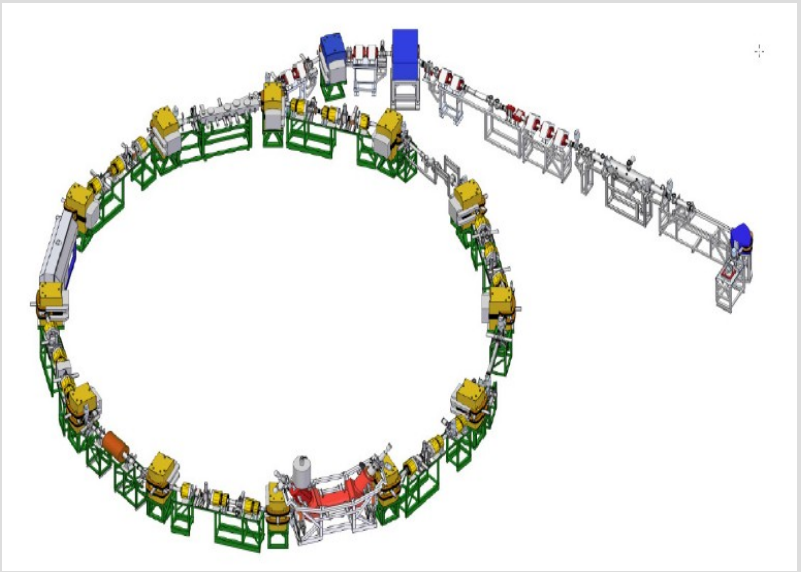
- Fully debugged HW – no corrections needed
- Used for GSI TMS, Sirius and others
- SDRAM, PCIe with DMA working
- Custom MCMC working with Vadatech MCH

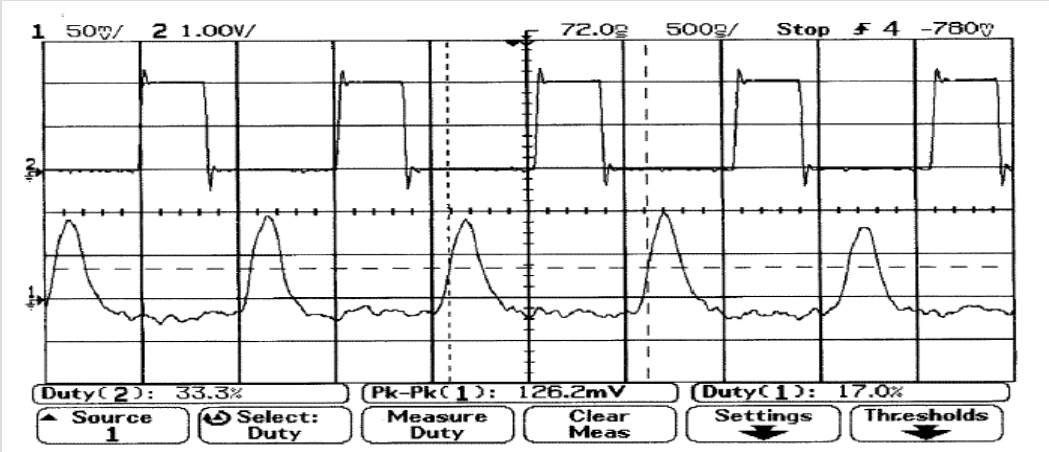


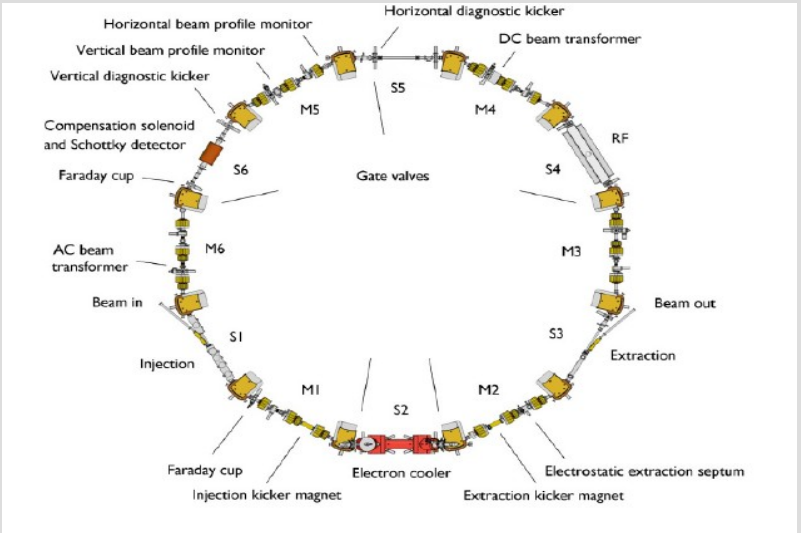


BPM system for Cryring GSI

- 8 PU units
- Trajectory and orbit measurement
- Adaptive PLL algorithm in FPGA
- uTCA system with custom AMC and ADC
- 5 AMC FMC carriers
- 8 quad channel, 250MHz, 16bit FMC cards
- Sub-ns synchronisation, WR-enabled

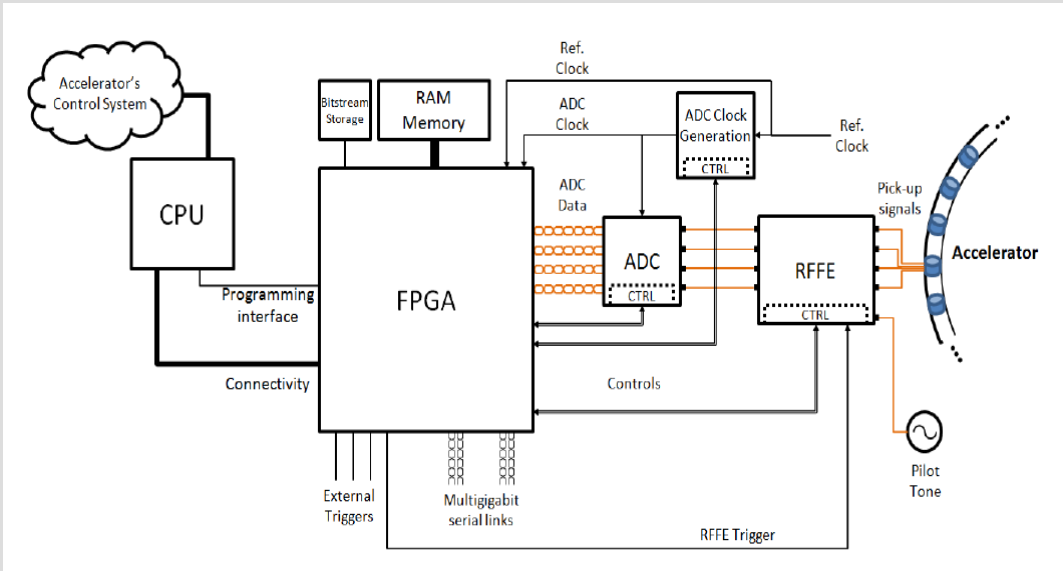


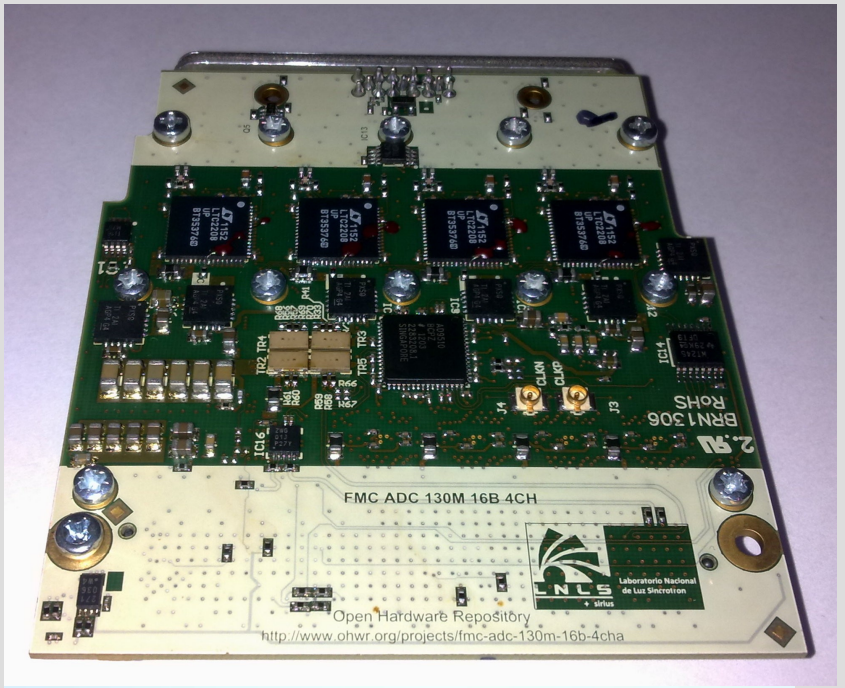


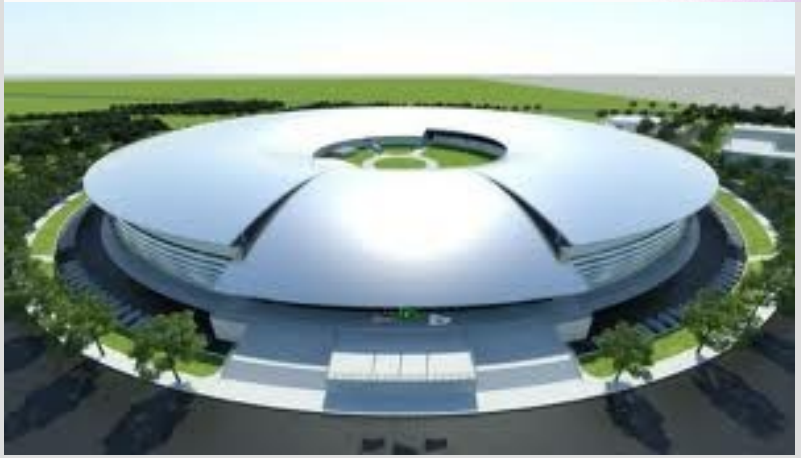


BPM system for Sirius (LNLS)

- 3Gev 3-rd gen light source
- 160 BPM units (640 ADC channels)
- Custom, quad channel 130Mhz, 16bit FMC cards
- Sub-sampling of 480 MHz RF
- On-line processing

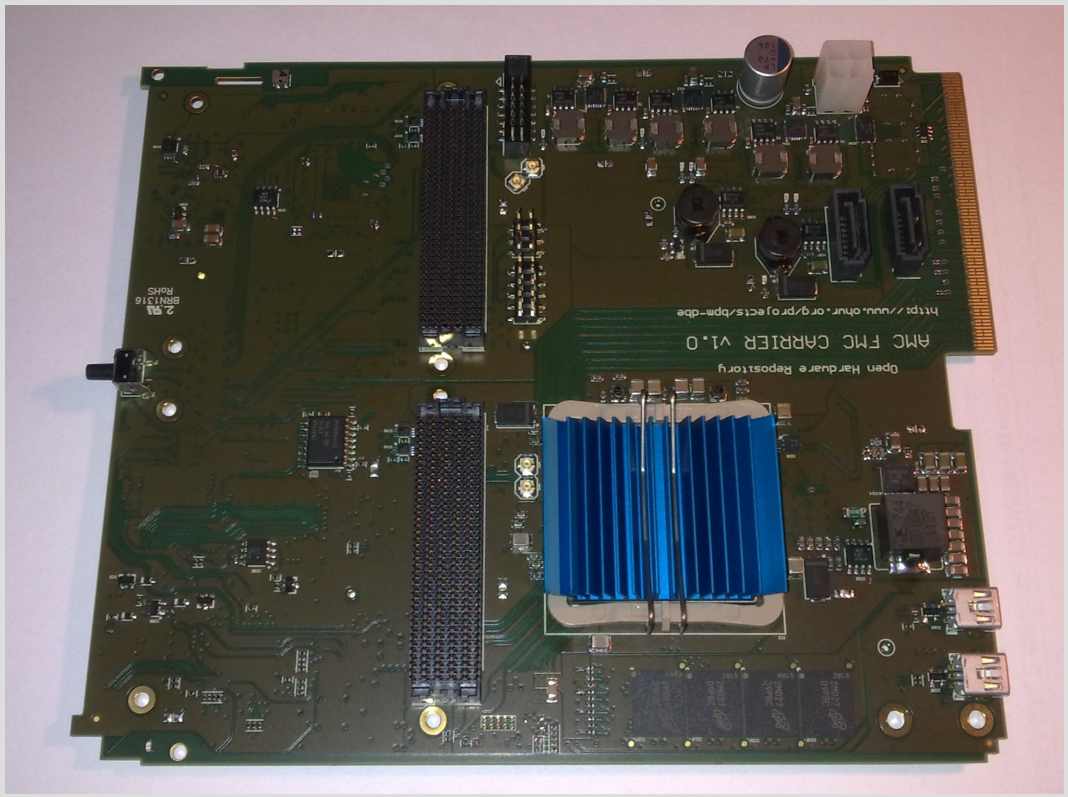


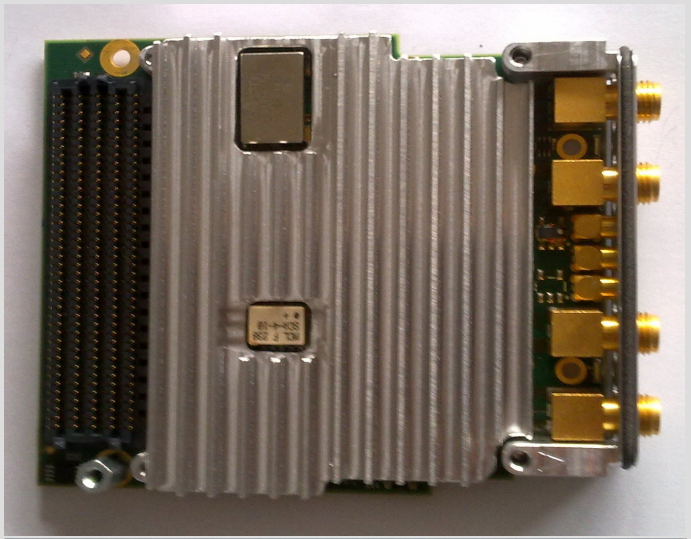


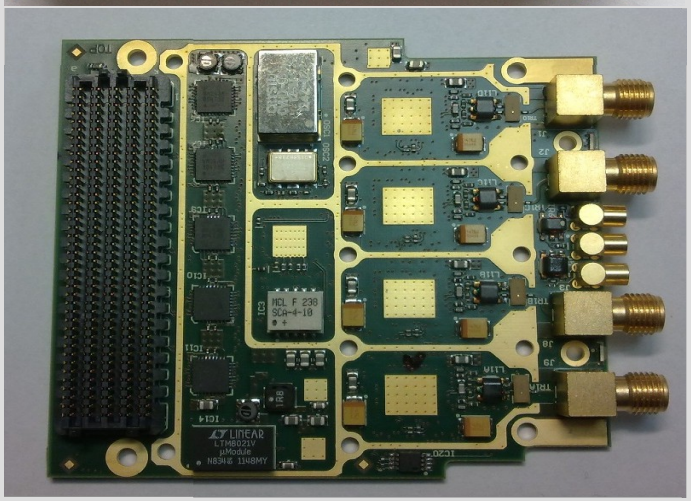


Custom AMC and FMC boards for BPM applications

- 2 FMC ADC (130 and 250MHz, 16bit)
- Custom 7-series FPGA AMC FMC HPC carrier

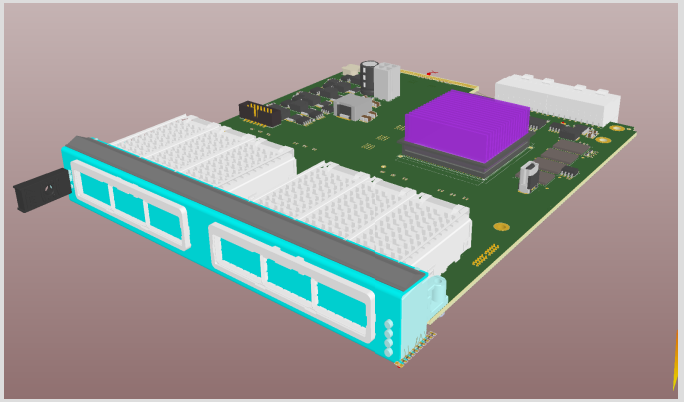




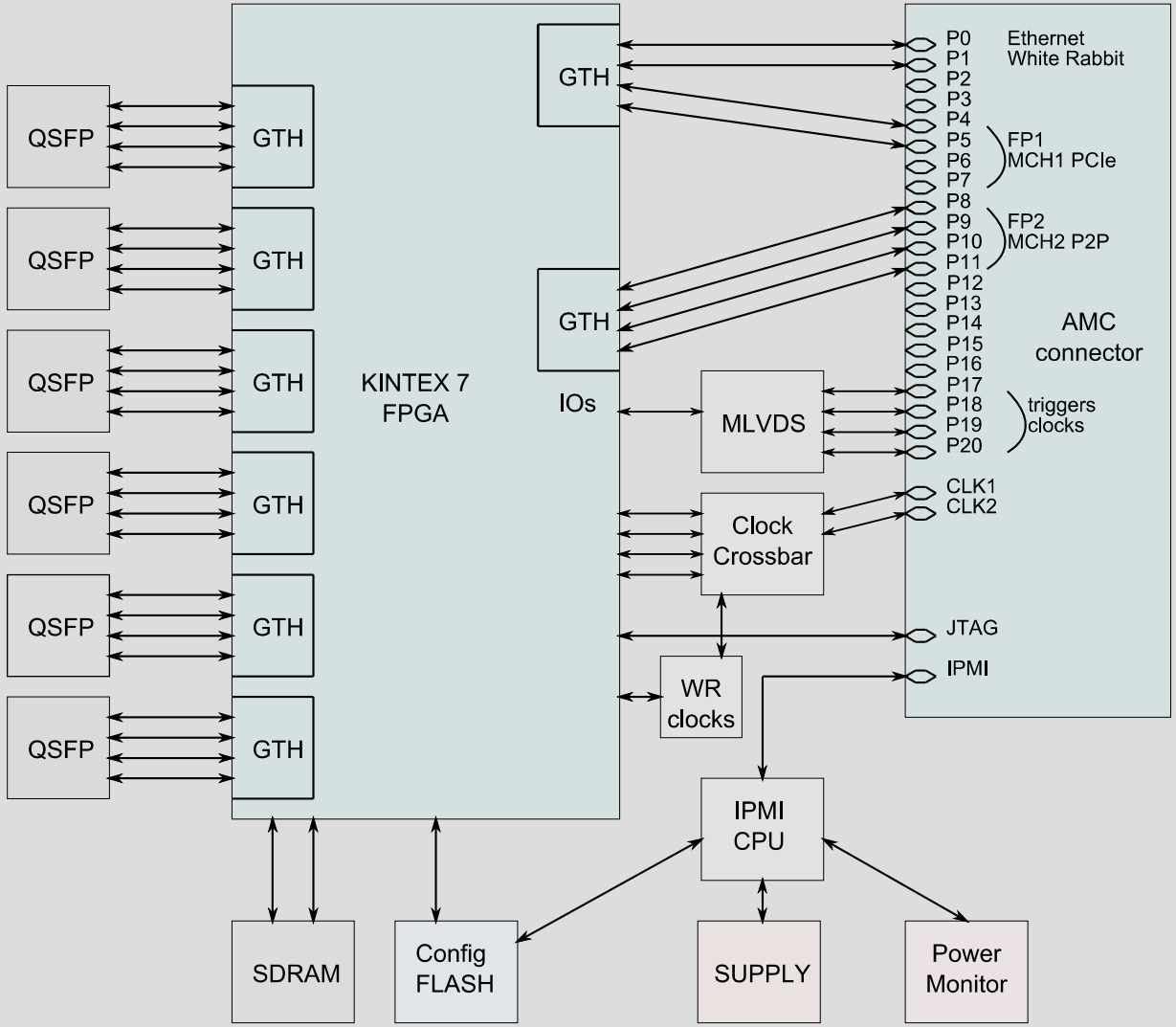


AMC FPGA board

- Kintex 7 FPGA (XC7K420T or XC7K480T), 32 GTX, 760 LC, 34,380 Kb RAM, PCIe Gen 2 core,
- 6 **QSFP**, 24 x10Gbit/s optical links per board
- clock distribution circuit with crosspoint switch, VCXO, WR clock recovery
- IPMI processor
- DDR3 SDRAM, 800MHz, 3 individual SDRAM controllers
- configuration FLASH. Update via JTAG from MCH2
- 1x GTX (Port0) for Ethernet (MCH1)
- 1x GTX (Port1) for WR (MCH2)
- 4xGTX (FP1) PCIe from MCH1
- 4xGTX (FP2) crossbar from MCH2
- 24xGTX 6xQSFP
- Stand-alone operation possible



AMC board


QSFP
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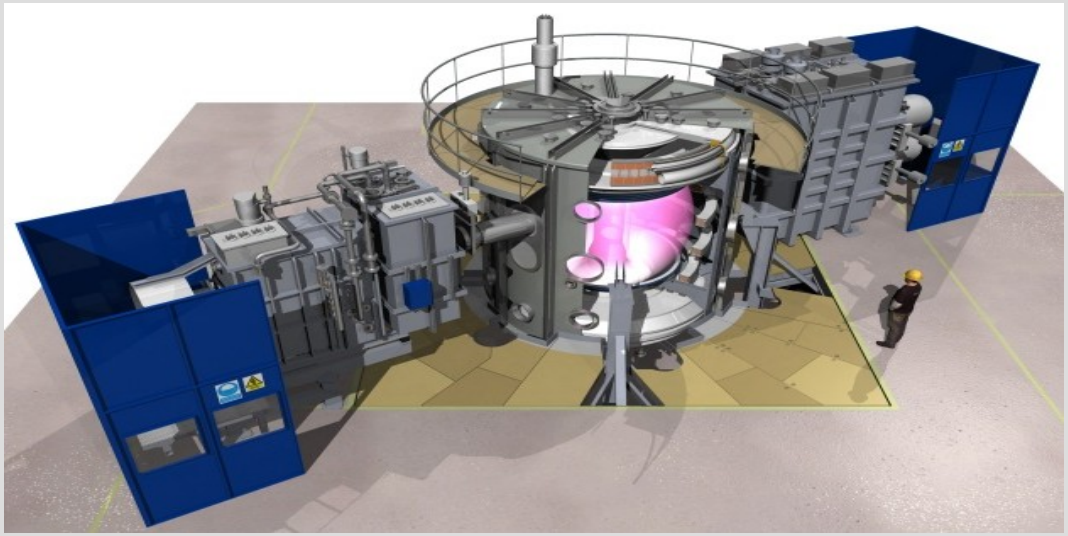
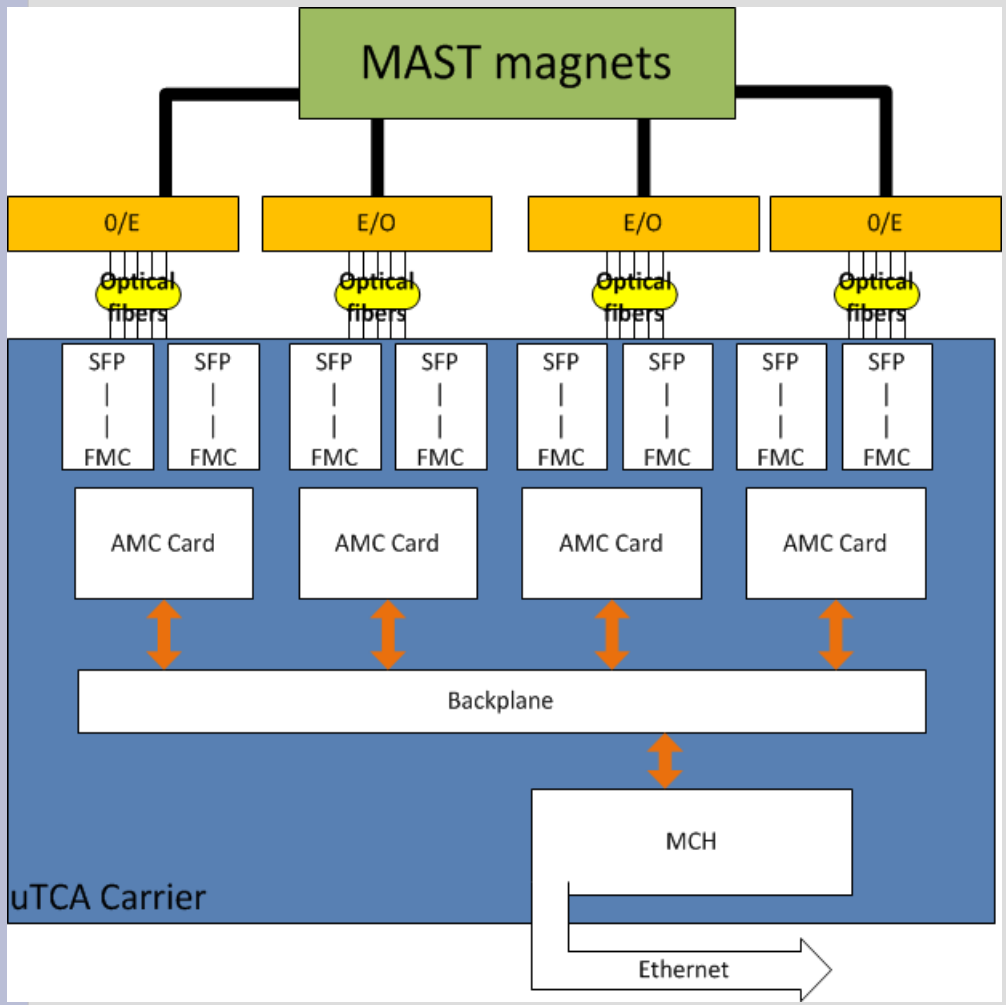
KINTEX 7
FPGA
IOs
MLVDS
Clock
Crossbar
WR
clocks
P0
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15
P16
P17
P18
P19
P20
Ethernet
White Rabbit
FP1
MCH1 PCIe
FP2
MCH2 P2P
triggers
clocks
AMC
connector
CLK1
CLK2
JTAG
IPMI
IPMI
CPU
SDRAM
Config
FLASH
SUPPLY
Power
Monitor

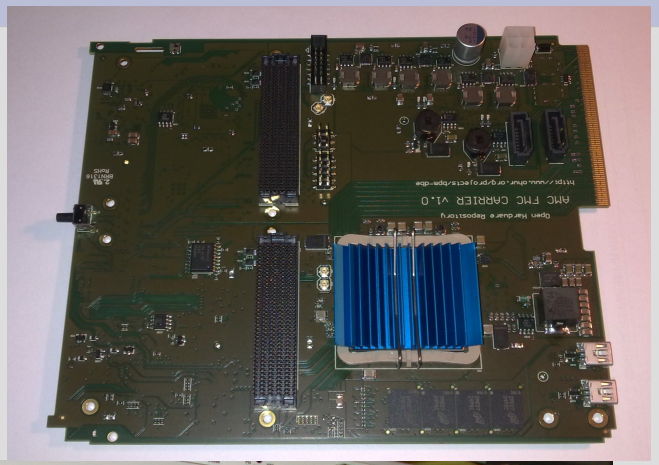
Diagnostic and control system for MAST superconducting divertor magnets

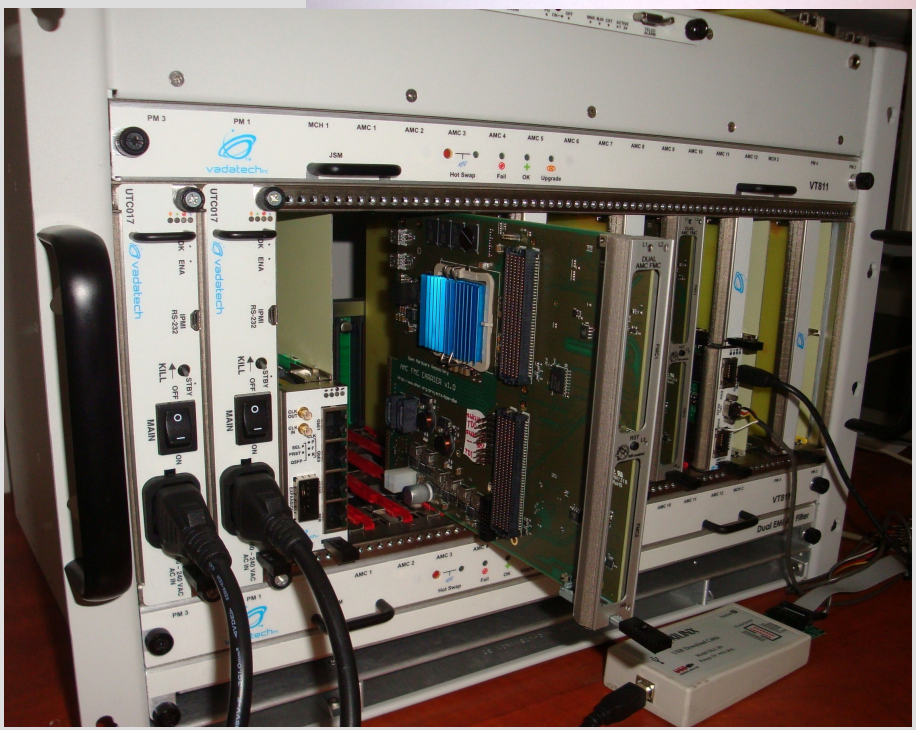
- Control and protection of superconducting magnets
- Isolated voltage and current measurement
- Low reaction time (us)
- Quench detection and brake choppers control
- Recent FPGA technology
- UTCA platform
- SFP fibre isolation
- Remote ADC and DAC



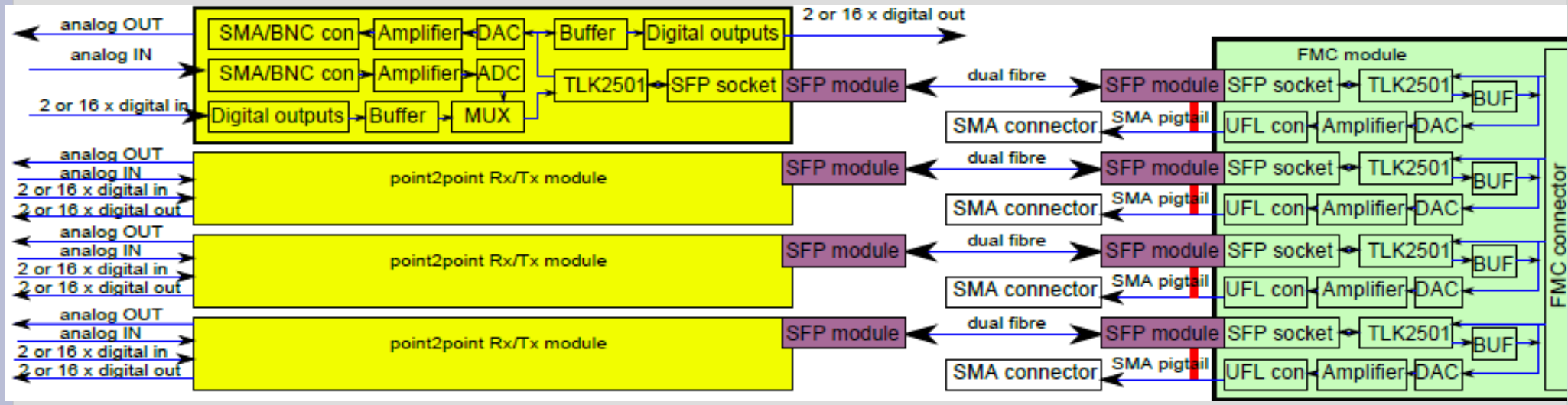
System block diagram

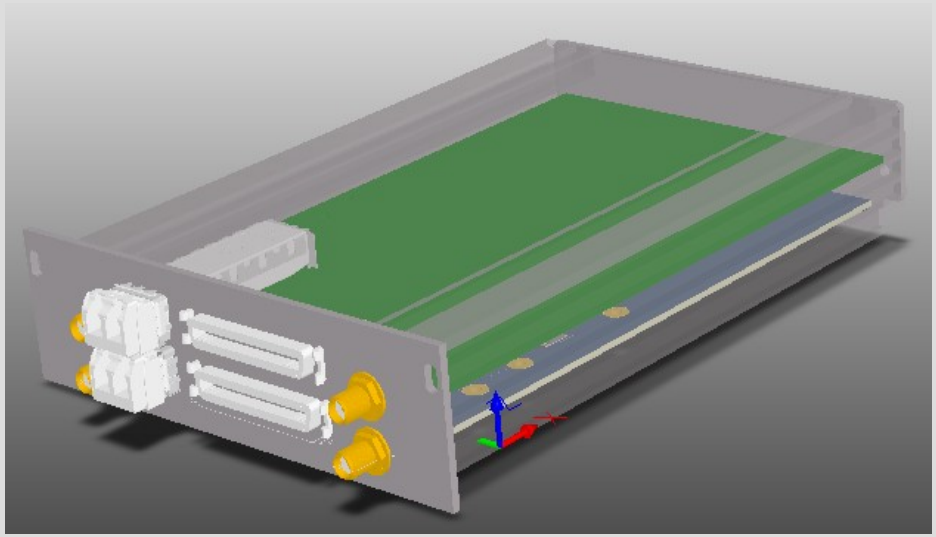


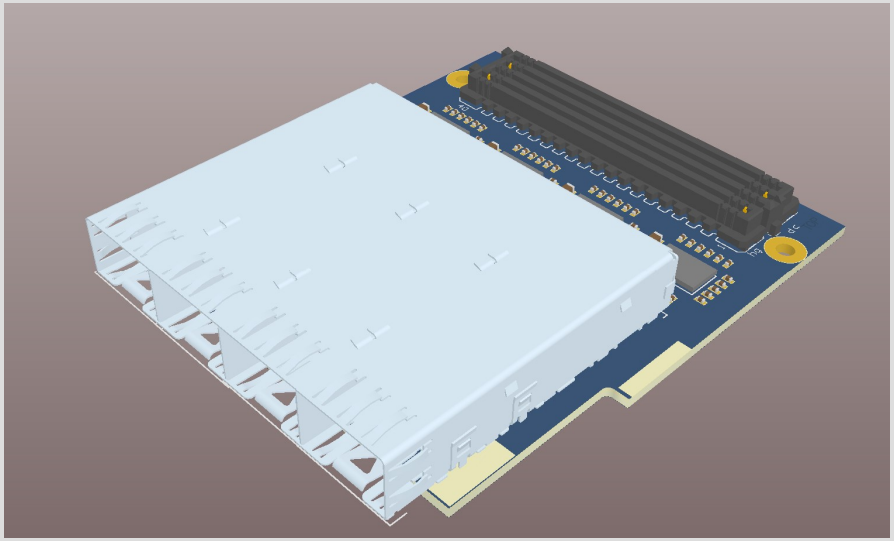




Optical ADC/ DAC/ DIO – custom design

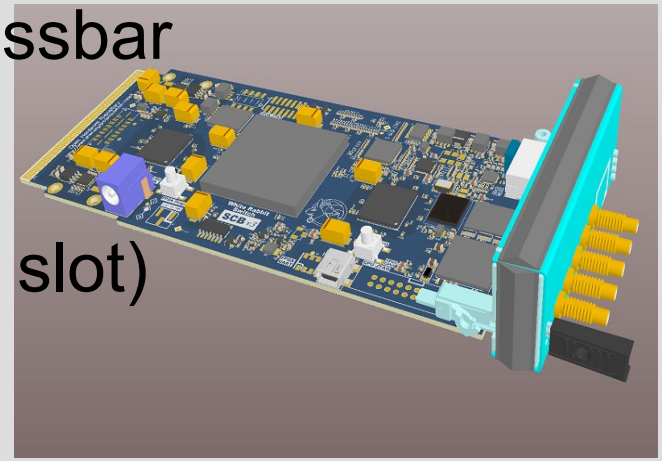




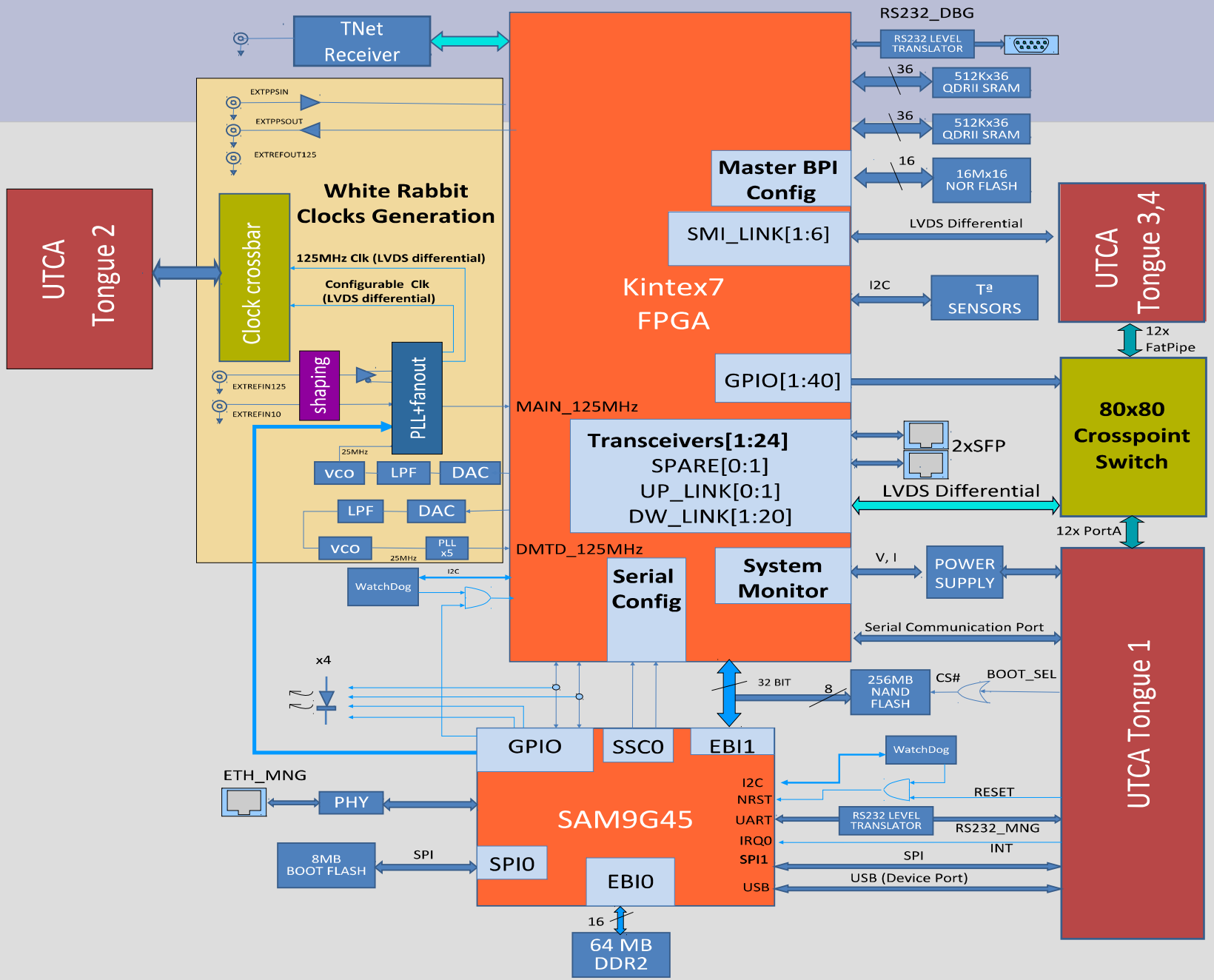


MCH WR timing receiver/switch

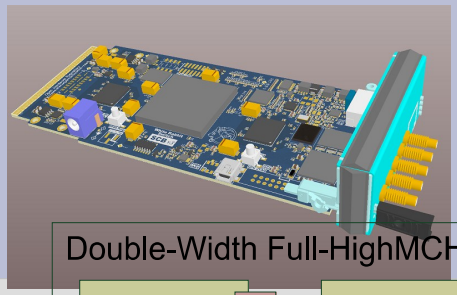
- Modified standard 18 port WR switch from OHWR
- Bigger FPGA, Kintex7 with 24GTX
- Additional 80x80 4.25Gbit Crosspoint Switch (crossbar)
- All 12 AMC Port1 routed to crossbar
- 24GTX routed to crossbar
- All FP2 routed to crossbar
- The crossbar used to setup p2p and 1-to-all links between all AMCs, up to 5x4.7Gbit/s per link
- Low jitter clock distribution based on crossbar
- Dedicated Tnet receiver
- IPMI
- Optional RTM for CPU (saves one AMC slot)
- GenIII PCIe or crossbar switch options

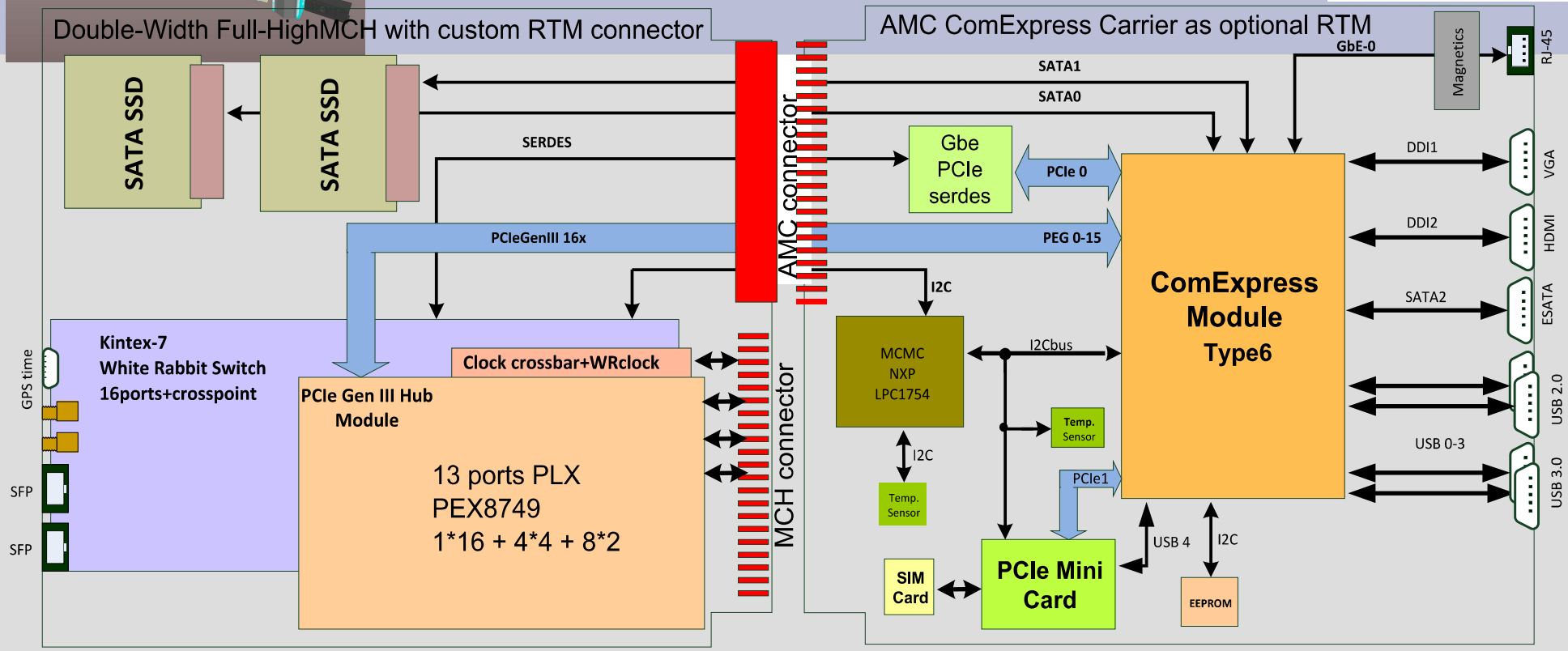


MCH WR timing receiver/switch



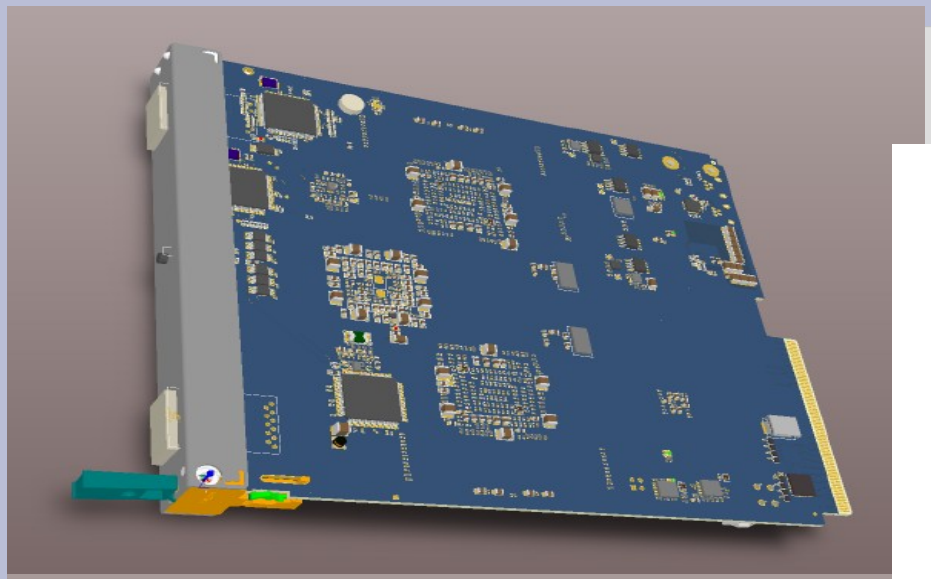
MCH WR with slot-saving AMC/RTM CPU

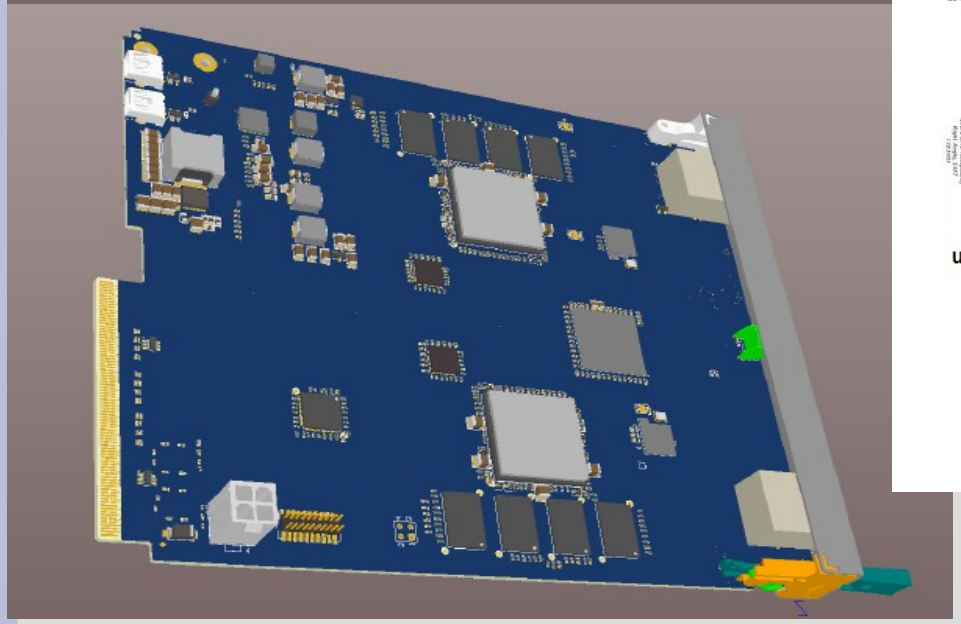


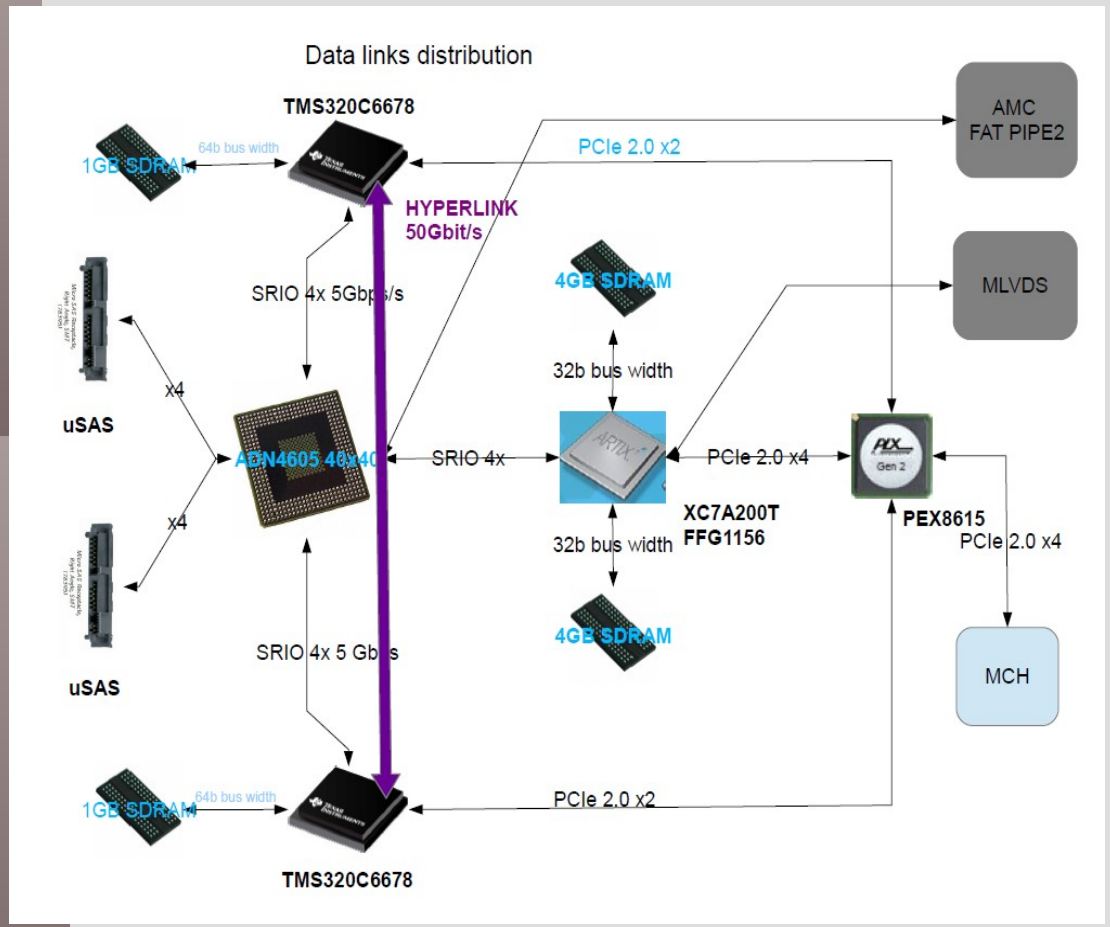


- Saves one AMC slot. 12 AMC slots available!
- Low cost (<1.5k EUR) OH solution. Recent x86 I7 CPU
- Works as main or redundant MCH
- No more troubles with IPMI caused by MCMC!

DSP accelerator – 16 cores with flexible crosspoint switch

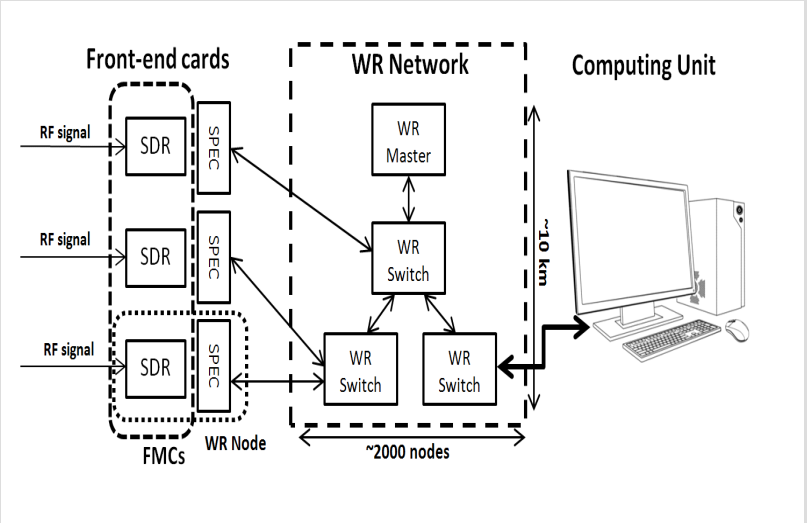


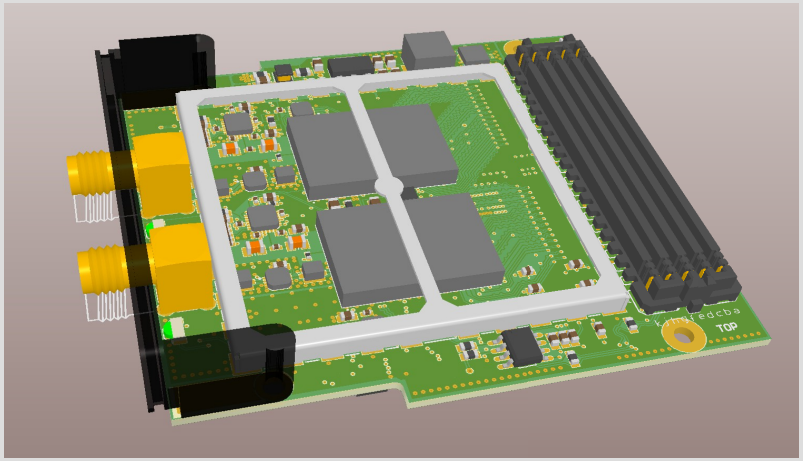




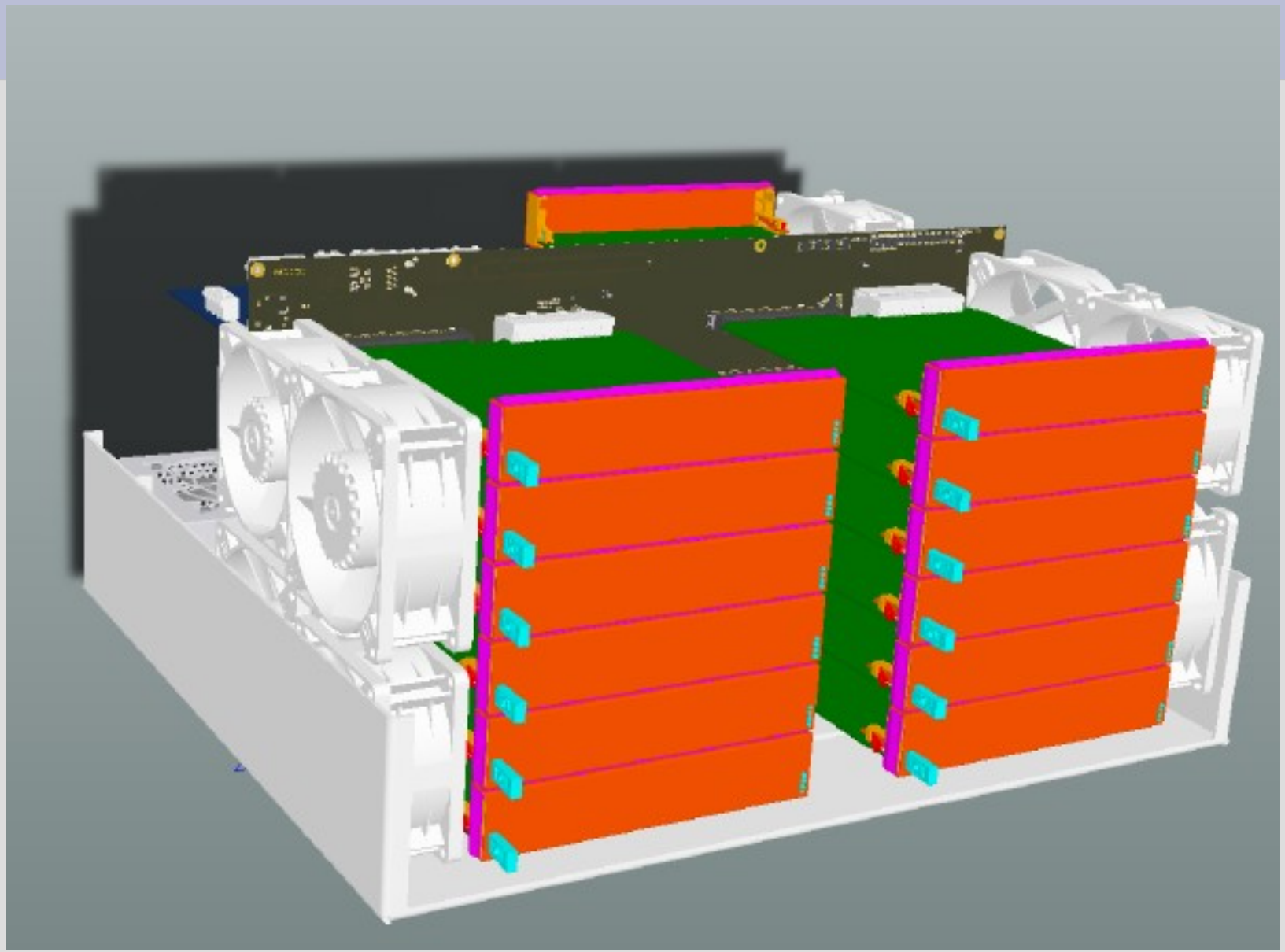
Local positioning system

- Positioning of any RF transmitter (1-way communication) like cell phone or active RFID tag
- Inside buildings or cities
- Jamming-resistant
- Multilateration technique + Time of Flight
- Software Defined Radio FMC

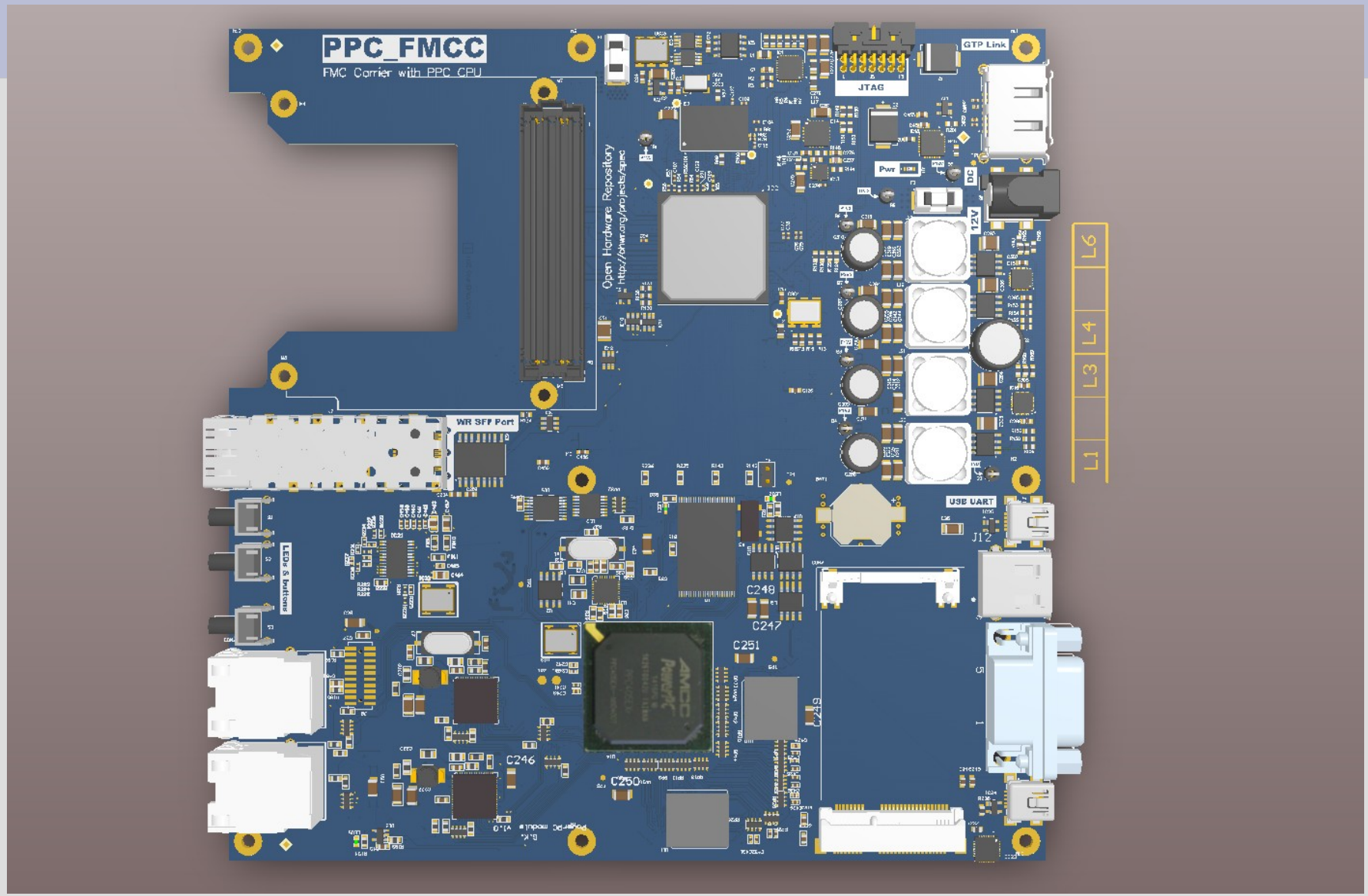




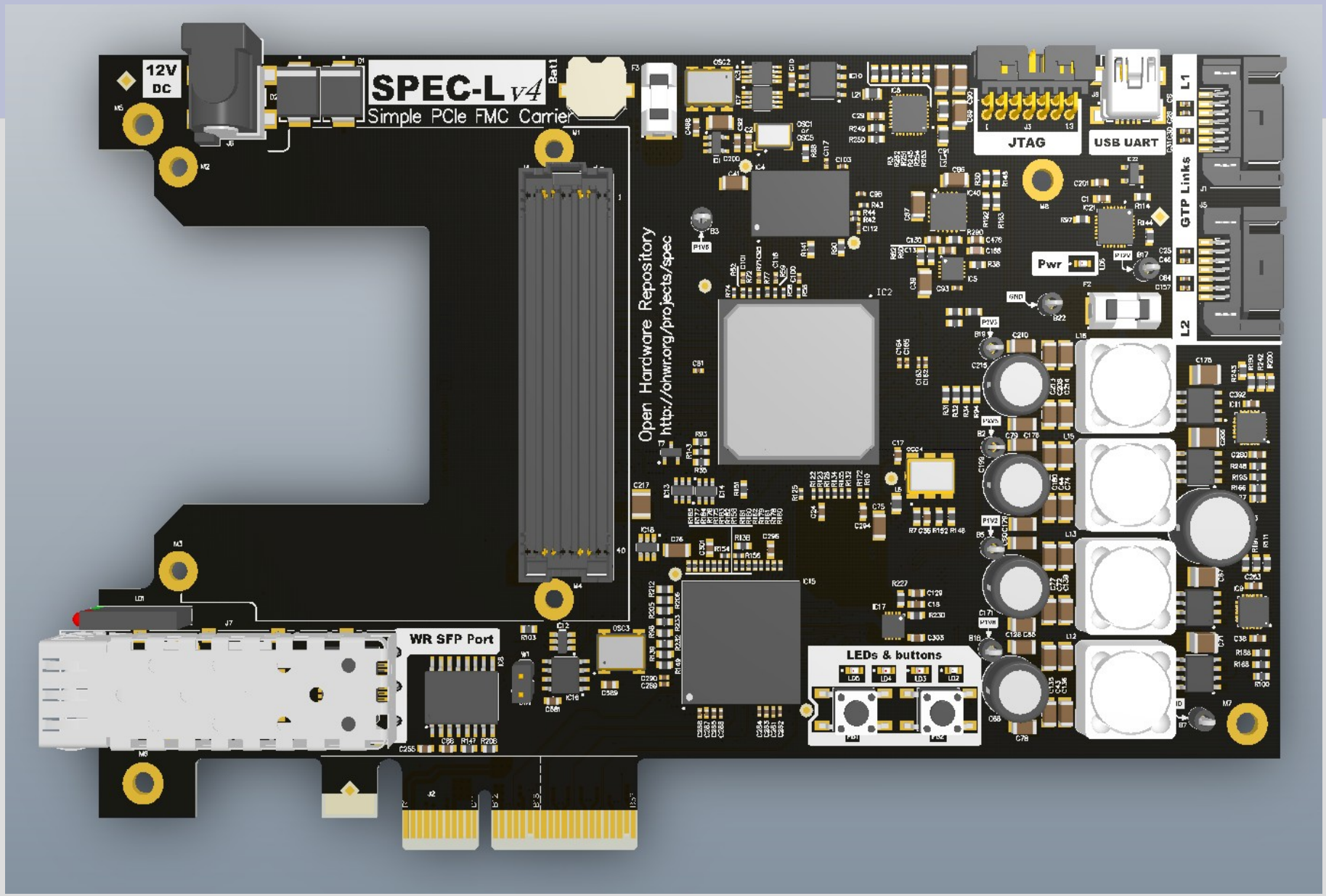
WR-based uTCA platform for HEP applications



Stand-alone FMC carrier, based on SPEC, with Power PC processor and Linux



SPEC-L with large, Spartan6-150 FPGA and bit-stream encryption



THANK YOU