EUROPEAN
SPALLATION
SOURCE

MTCA systems at ESS

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Agenda

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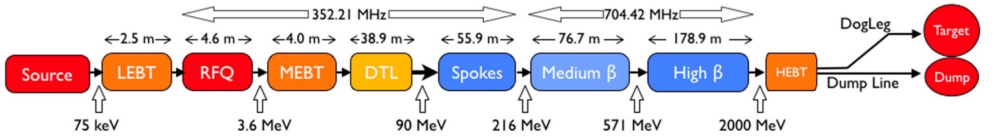
Introduction

Introduction

European Spallation Source (ESS) Status

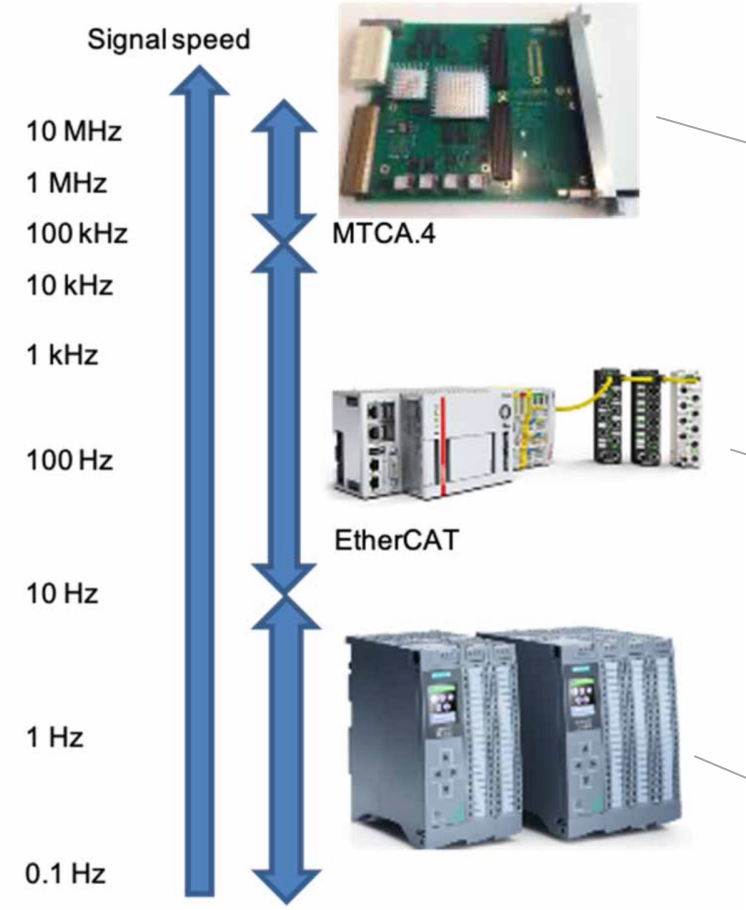
- ESS in a nutshell:
  - Linear Proton Accelerator designed for a beam average power of 5MW;
  - Rotating tungsten target station to produce neutrons;
  - (up to) 22 neutron instruments (beamlines);
- Current Status:
  - Installation and conditioning of the latest cryomodules;
  - Beam on dump scheduled to January/25;
  - Beam on target in September/25;
  - User program to start in 2027;



Parameter	Value
Ave power (design) [MW]	5
Max energy (design) [MeV]	2000
Peak current [mA]	62.5
Pulse length [ms]	2.86
Rep rate [Hz]	14
Duty factor [%]	4
RF freq [MHz]	352.21/704.42

Introduction

Control System Hardware Strategy defined by ICS



MTCA.4 for applications with data acquisition exceeding few kHz;
These applications require a FPGA and custom, high-speed signal processing in system;

For slower signals, EtherCAT will be used as a real-time fieldbus with good price/performance ratio;
Synchronization and event information are key for applications where a full custom platform solution would be too costly;

Low speed signals are handled with commercially available PLC systems;
This is a cost-effective solution that addresses ESS reliability and maintainability requirements;
The PLCs are connected to EPICS for further integration into the control system;

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MTCA Systems at ESS

MTCA Systems at ESS

Overview of the MTCA applications (as accurate as possible)

System	*Crates (BOD)*	*Crates (BOT)*
Timing Distribution System (TD)	25	**30**
Machine Protection System (MPS)	8	**8**
RF Distribution System (LLRF and LPS)	91	**155***
LEBT and MEBT Choppers	2	**2**
Diagnostics – Beam Position Monitor (BPM)	19	**19**
Diagnostics – Beam Current Monitor (BCM)	9	**9**
Diagnostics – Faraday Cup (FC)	1	**1**
Diagnostics – Emittance Meter Unit (EMU)	2	**2**
Diagnostics – Wire Scanner (WS)	6	**6**
Diagnostics – Beam Loss Monitor (icBLM)	13	**18**
Diagnostics – Beam Loss Monitor (nBLM)	5	**10**
Diagnostics – Aperture Monitor and Grid (APTM/Grid)	5	**5**
Diagnostics – Imaging Systems	2	**4**
Others (Raster Magnets, test stands)	3	**3**
Total	**191**	**272**

MTCA Systems at ESS

Overview of the MTCA applications

- MTCA is the standard for any high performance application for the linac;
  - No plans for using MTCA systems for target and instruments (except for the timing system);
- ICS Hardware and Integration Group is responsible for:
  - Purchasing/receiving the MTCA components – sometimes from an in-kind contribution;
  - Assembly and preparation of a “basic” crate: Chassis/PM/CU + MCH + CPU + EVR;
  - Development and support of the EPICS IOCs for MTCA applications;
  - Deployment and monitoring of IPMI IOCs;
  - Firmware development for the FPGAs – shared effort with RF/PBI groups;
  - Inventory management – shared effort with RF/PBI groups;
  - End-to-end management of the FBIS and Timing Distribution systems;
- Non-ICS stakeholders (RF/PBI) participate a lot!
  - Testing of the complete system before and after deployment on site;
  - Tracking down and solving configuration, hardware and software issues;
  - Firmware and low-level software development;

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Hardware Components

Hardware Components

Basic components: chassis, power module, MCH

MTCA Chassis – nVent/Schroff

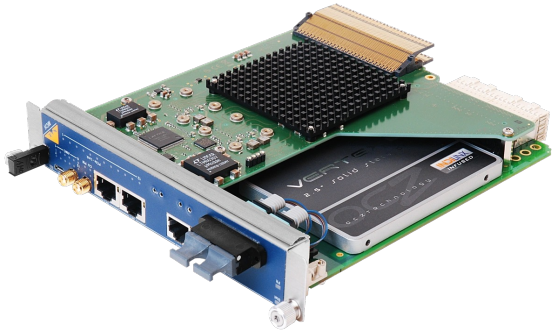
- 9U – full redundancy, 12 slots for AMCs with RTMs;
- 3U – single MCH, 6 slots for AMCs – 4 with RTMs;

Power Modules

- Wiener 1000W – used for systems more sensitive to noise;
- N.A.T 600W – used for redundancy in the 3U crates;

MCH: NAT-MCH-PHYS

- PCIe Gen3 x4 links to each AMC;
- Standard configuration for 9U or 3U crates;



Hardware Components

Timing Distribution System AMCs

Event Generator and Fanout – MRF MTCA-EVM-300

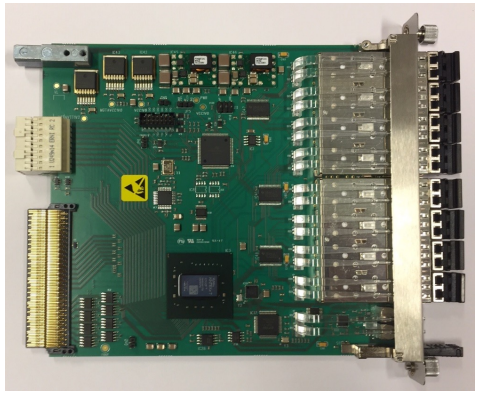
- One unit to act as the Event Master (EVM) of the timing system;
- Input for RF and PPS signal for clock and timestamp distribution;
- 7-Way Fanout for distribution (dual functionality);
- Community supported drivers: mrf (Linux) and mrfioc2 (EPICS);

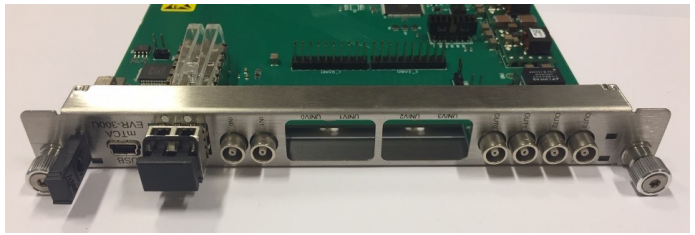
Event Receiver – MRF MTCA-EVR-300

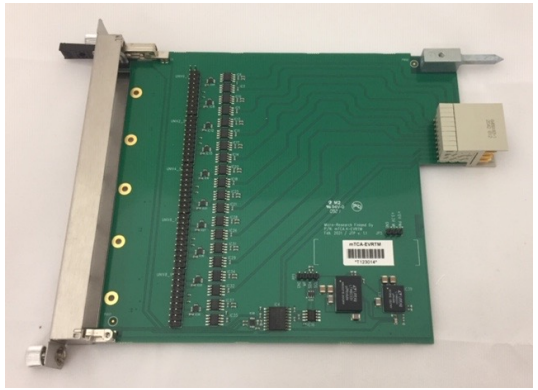
- Present in any MTCA crate at ESS;
- Clocks from/to TCLKA/TCLKB;
- Driving/receiving differential triggers AMC RX/TX ports 17 to 20 (MLVDS);
- Front panel 4 x TTL outputs, 2 x TTL inputs;
- Delay compensation with feedback;
- Front panel 2 Universal I/O modules;

Event Receiver RTM – MRF MTCA-EVM-300

- I/O expansion – up to 5 UnivIO/Delay modules







Hardware Components

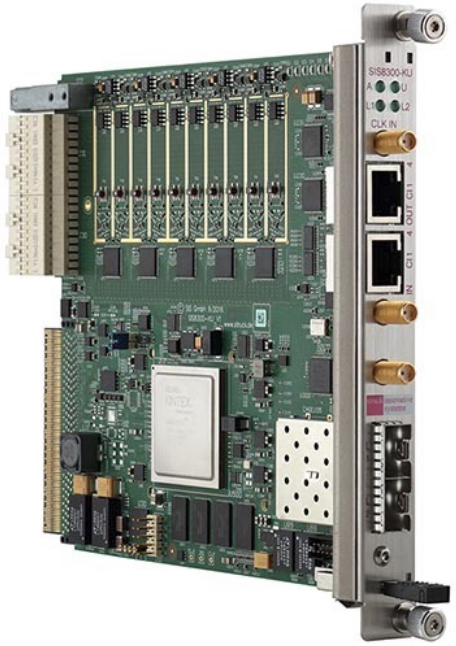
AMCs and RTMs

Concurrent Tech. AM G6x

- Widely used to host EPICS IOCs
- Intel Xeon Family – x86_64
- Up to 16GB of RAM
- Discuntined model AM900 still used;

Struck SIS8300KU

- 10 channels ADC at 125 MSPS
- Xilinx Kintex Ultrascale FPGA
- SFP+ for high speed interconnect
- Analog RTM interface class A1
- Used for BPM, BCM, LLRF



Struck RTMs

- SIS8900 – Standard Analog IO
- Down-convterter RTMs

Hardware Components

IOxOS AMCs

IOxOS IFC1410

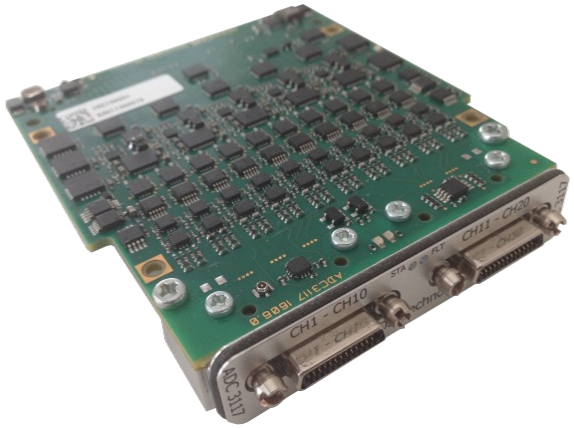
- FMC carrier with FPGA and CPU
- Xilinx Kintex Ultrascale MODEL with PCIe endpoints to local CPU and AMC backplane; 1 Gbit DDR3
- Freescale Qoriq MODEL – 8 cores / 2GB RAM
- Diskless setup; Boot is controlled by local CPU and downloads FPGA firmware via TFTP from a boot server;
- Used for RFLPS, FBIS, icBLM, nBLM, EMUs;
- Digital RTM interface;

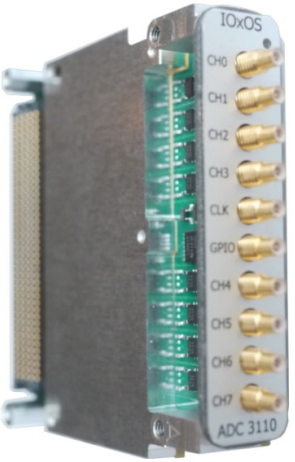
IOxOS IFC1420

- Similar design with FPGA and CPU in the same AMC;
- One HPC FMC slot;
- Custom mezzanine connected to FMC2 providing 8x 16-bit ADC channels @ 250 MSPS;
- Analog RTM interface;

Hardware Components

FMCs and RTMs





IOxOS ADC3117 – Analog Inputs FMC

- 20x 16-bit ADC channels @ 5 MSPS;
- 2x DAC 16-bit @ 1 MSPS;
- 3M SDR (Camera Link) connectors to fit all 20 channels;

IOxOS DIO3118 – Digital IO FMC

- 20x LVTTL inputs + 1 LVDS input;
- 20x LVTTL outputs + 1 LVDS output;

IOxOS ADC311x – Analog Inputs FMC

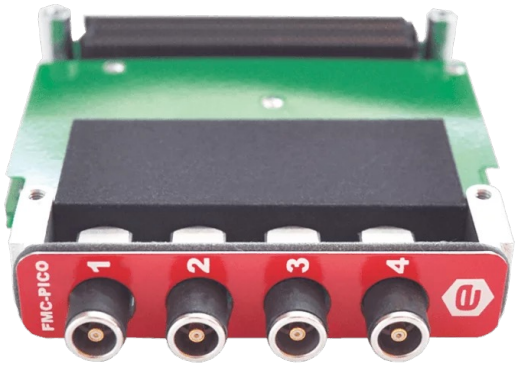
- 8x 16-bit ADC channels @ 250 MSPS;
- AC coupled and DC coupled version;

CAENels FMC-Pico – Current Input FMC

- 4x 20-bit 1MSPS current input with selectable range 1uA/1mA;

IOxOS Digital RTM – RSP_1461

- Digital IO extension for IFC1410 – SFP Ethernet 10G / Custom I/O mez.



Hardware Components

Other applications

- The idea is to keep a short list of MTCA hardware that would cover all main applications at the facility – we still adhere to this strategy;
- Projects with very specific requirements led to the development of other solutions, either led by an in-kind partner or other groups inside the ESS organization;
  - RTM carrier and specialized RTMs for LLRF piezo controller and local oscillators;
  - CAENels DAMC FMC carrier for the proton beam grid monitoring;

- After a long period of design, fabrication, development, validation an tests we now hope to start looking at the next generation. Or at least as soon as we have beam on target…

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Software Components

Software Components

FPGA Firmware and Hardware Abstraction Layers

- TOSCA Framework from IOxOS was used as the base for the specific applications on the IFC14x0 family:
  - Based on PCIexpress, implements a Network-on-Chip technology;
  - Linux kernel module provided by vendor;
- ESS FPGA Framework was designed initially as a standardization effort between LLRF, BPM and BCM projects;
  - Based on Xilinx IP blocks and AXI4 interconnections;
  - Version “1” uses Struck PCIe block and therefore Struck “sis8300” Linux driver;
  - Version “2” uses Xilinx PCIe IP and therefore Xilinx XDMA Linux driver;
  - Microblaze CPU to perform all the peripheral configuration of the AMC and FMCs;
  - Modular register bank that “describes” the functional blocks of the firmware;
- We are slowly moving towards the standardization of all firmwares to the ESS FPGA Framework (XDMA);
  - Will be hard to achieve when we have well estabilished systems running in production, but certainly worthy when we look at the long term operation of the facility;

Software Components

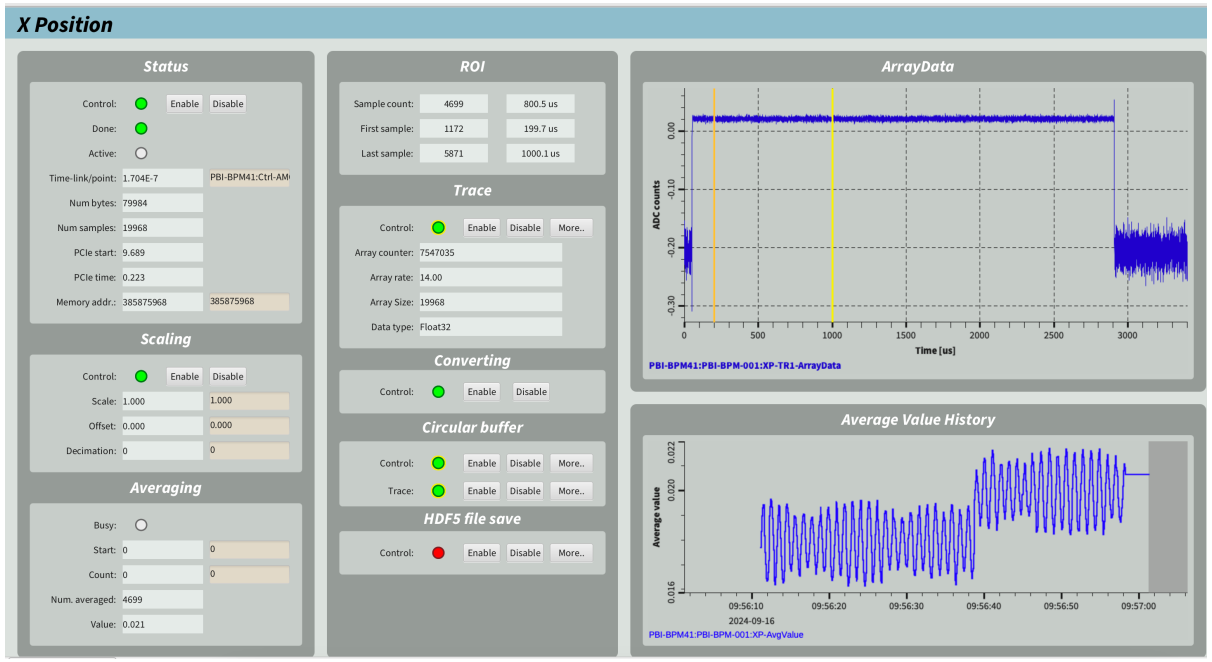
Linux and EPICS

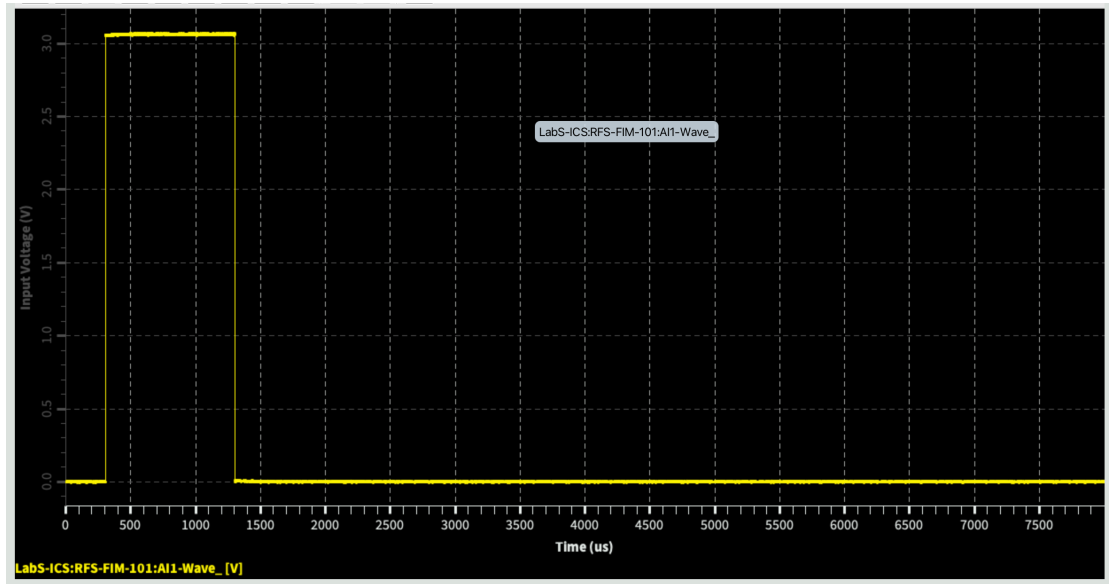
- Two (2) different architectures for CPUs: **`x86_64`** and **`powerpc64`** (IFC1410);
  - The IFC14x0 systems run an Yocto-based distribution with kernel 4.14;
  - Concurrent Tech. CPUs run CentOS 7 (with PREEMPT_RT) and also Yocto (kernel 4.14);
- New release of our Yocto based OS (ESS Linux) is ready to be used in production;
  - Yocto release “kirkstone” with Linux kernel 5.85 - with and without RT versions;
  - Fully copatible with both hardware architectures;
  - Fully integrated to ESS INFRA services (remote OS installation, node_exporter, Ansible playbooks, etc..);
- ESS is moving from CentOS7 to Ubuntu (and ESS Linux for MTCA CPUs);

Software Components

Linux and EPICS

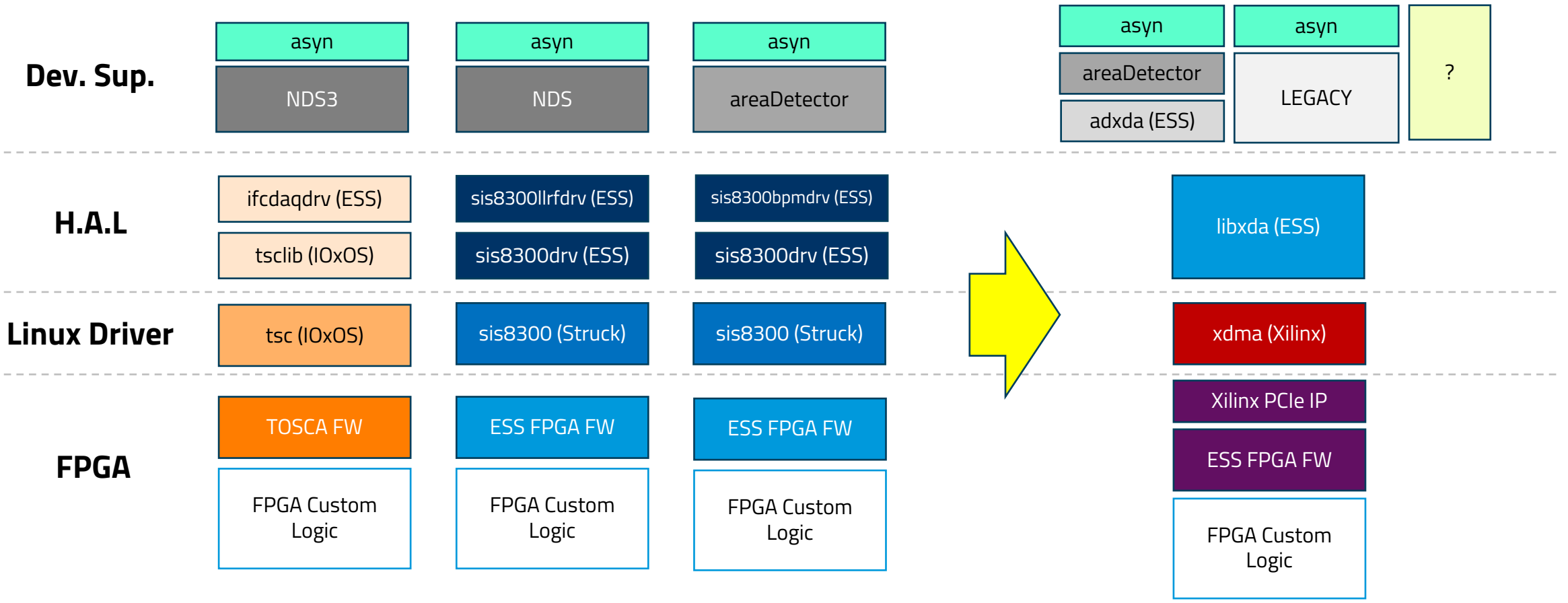
- For EPICS device support, we have a small fauna of modules:
  - LLRF IOC is still based in NDS/asyn;
  - All systems based on IFC1410 uses NDS3/asyn device support;
  - Diagnostics systems are all built on top of areaDetector (mostly 1D NDArrays);





Software Components

FPGA Firmware and Hardware Abstraction Layers



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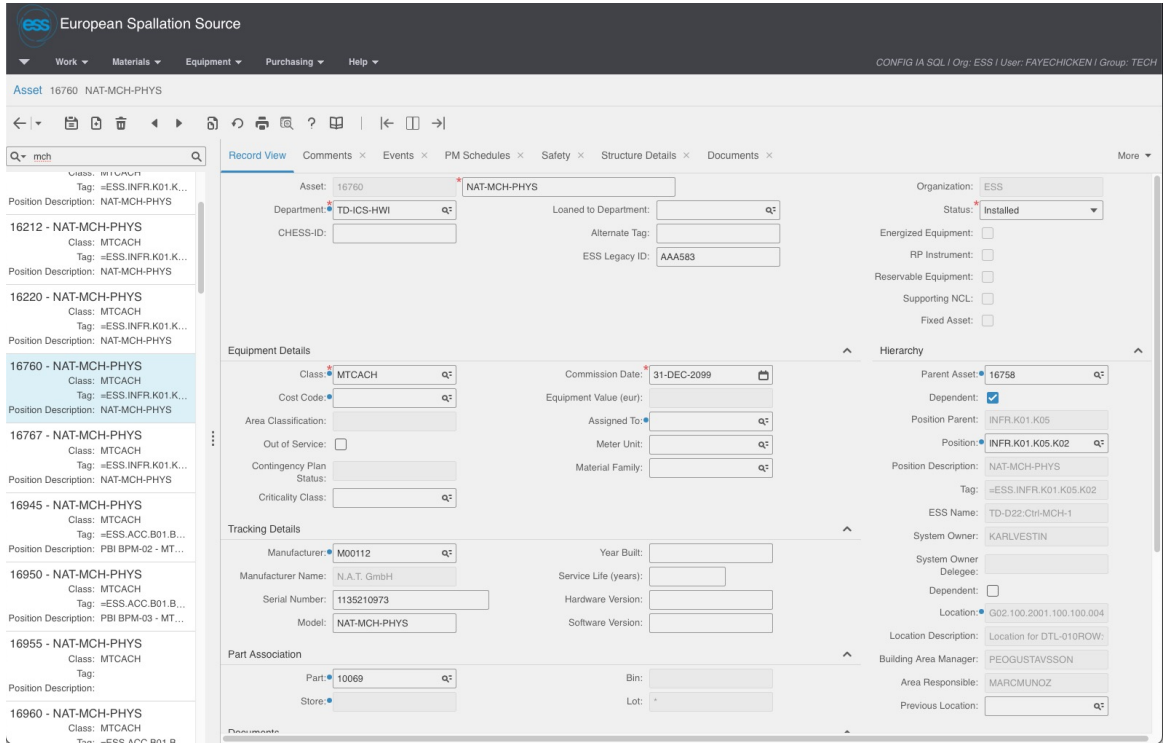
Management

Management

Documentation and Inventory

- Inventory management is done through the ESS official tool;
  - EAM – Enterprise Asset Management;
  - Resposability of registering MTCA devices is scattered across different groups and stakeholders;
- Issues are (usually) tracked via JIRA;

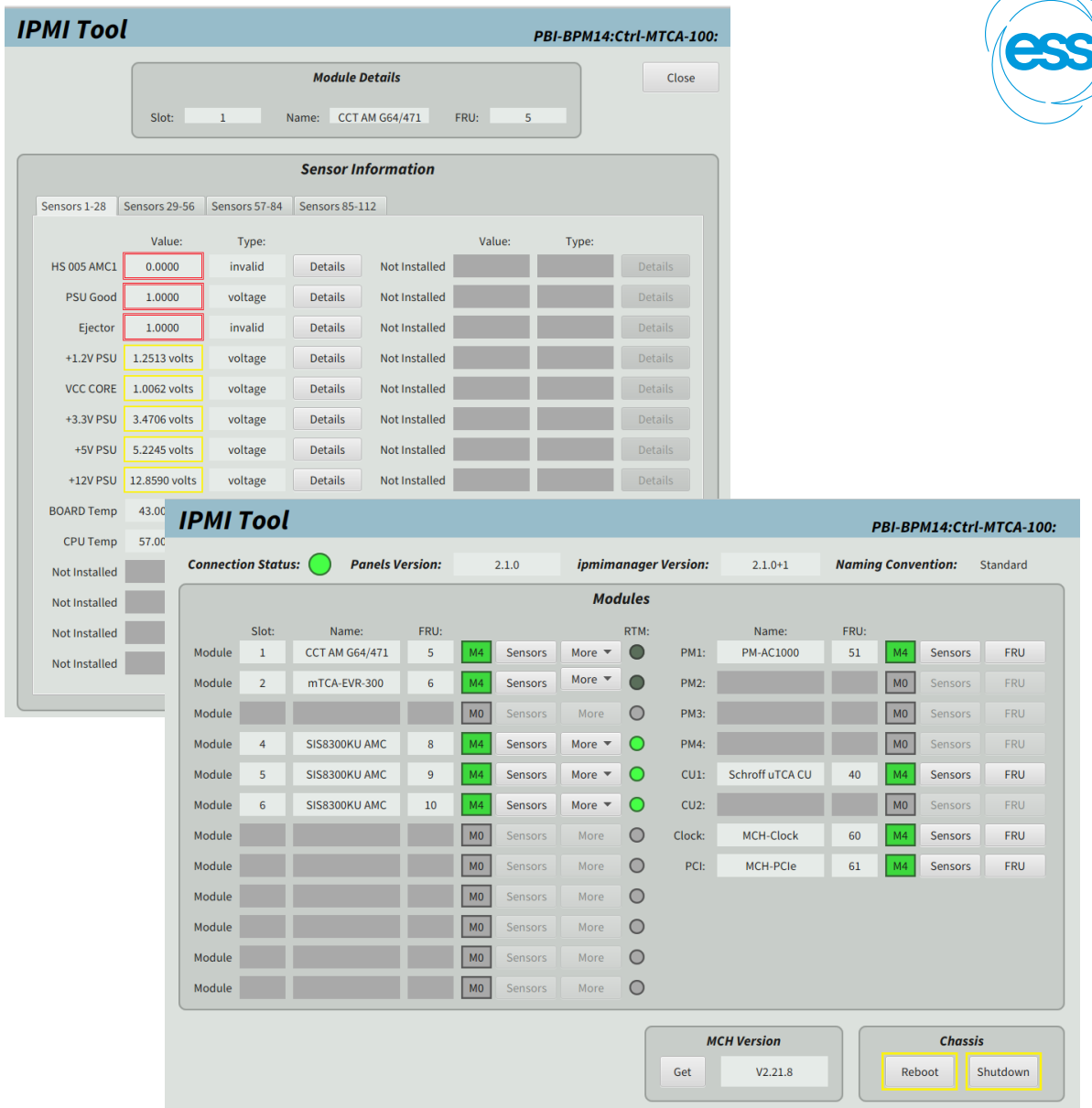
- We have two documents released* in the Systems Engineering platform (CHESS) for MTCA systems:
  - Supported hardware;
  - Rules for high-performance systems;



Management

IPMI Monitoring

- A lot yet to be done;
- IPMI EPICS monitoring is part of an in-kind contribution from Poland;
- First version (ipmiManager) was delivered and we have some IOCs running (BPM and LLRF)
  - Based on openIPMI library;
  - Asyn and StreamDevice device support;
- Dynamic generation of DB files and even OPIs;
- We need to put more effort on the deployment of all instances and the setup of an alarm dashboard for our systems;



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Conclusion

Conclusion

- ESS is fully commited to use MTCA as the standard hardware platform for fast acquisition systems;
- The entire timing distribution system is based on MTCA;
- We aim to provide a standard set of hardware that would cover all needs;
- We work in collaboration with our stakeholders in order to maintain the MTCA systems;
- Many different software/firmware families running on MTCA at ESS, the next goal is to push the standardization on these layers;
- A lot of work still to be done on IPMI monitoring and management of crates;

Thank you / Obrigado / Tack