SOLEIL HW/SW DAQ experience and future plan

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Outline

- Hardware acquisition systems
  - MACUP project
  - PandABox and MicroTCA studies and developments
- Software acquisition systems
  - Scans
    - ScanServer
    - Flyscan
  - Detectors
    - Lima
    - MCAs
- Perspectives

SOLEIL hardware acquisition systems

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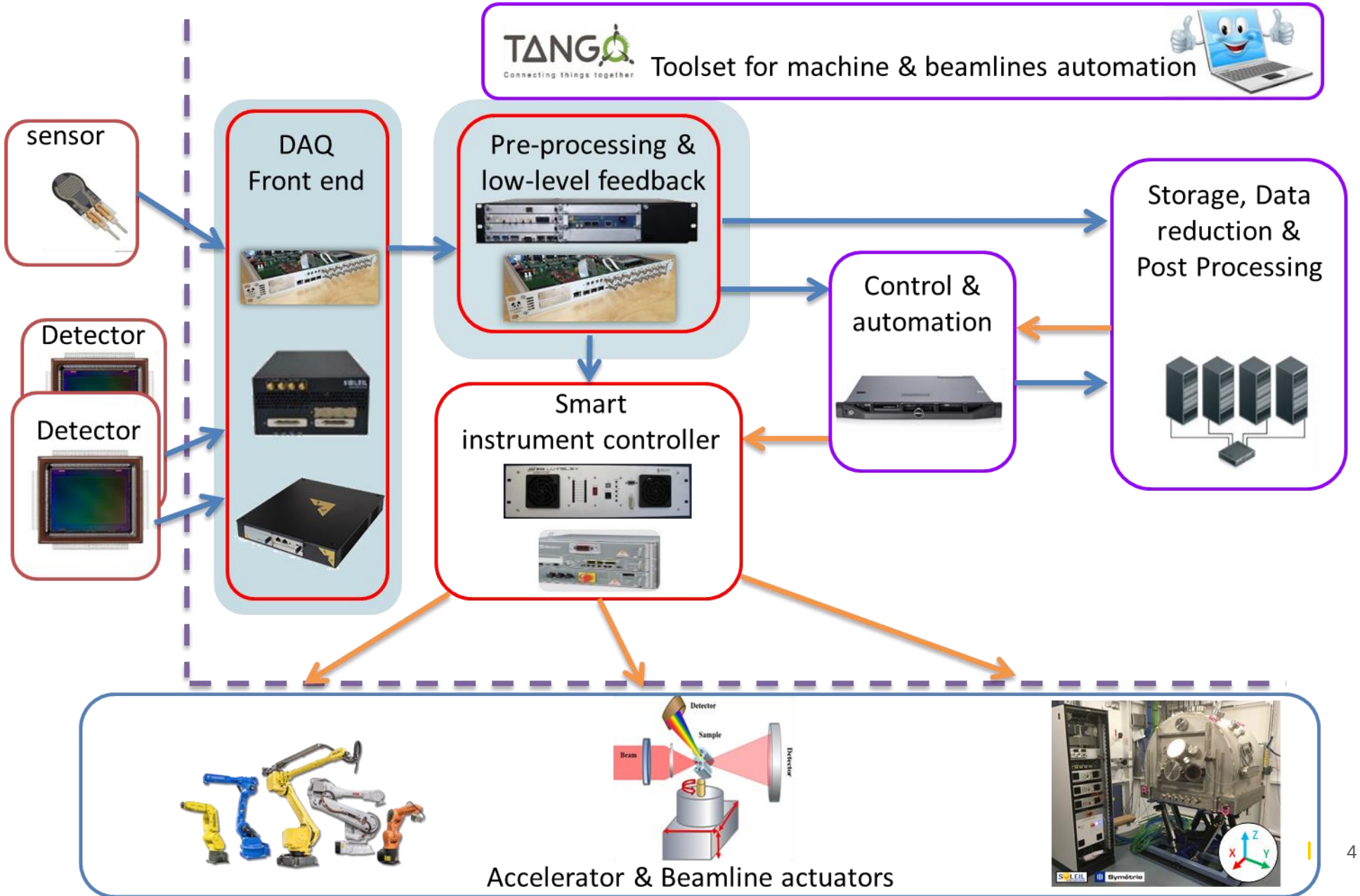
Integrated architecture for accelerators and beamlines automated processing



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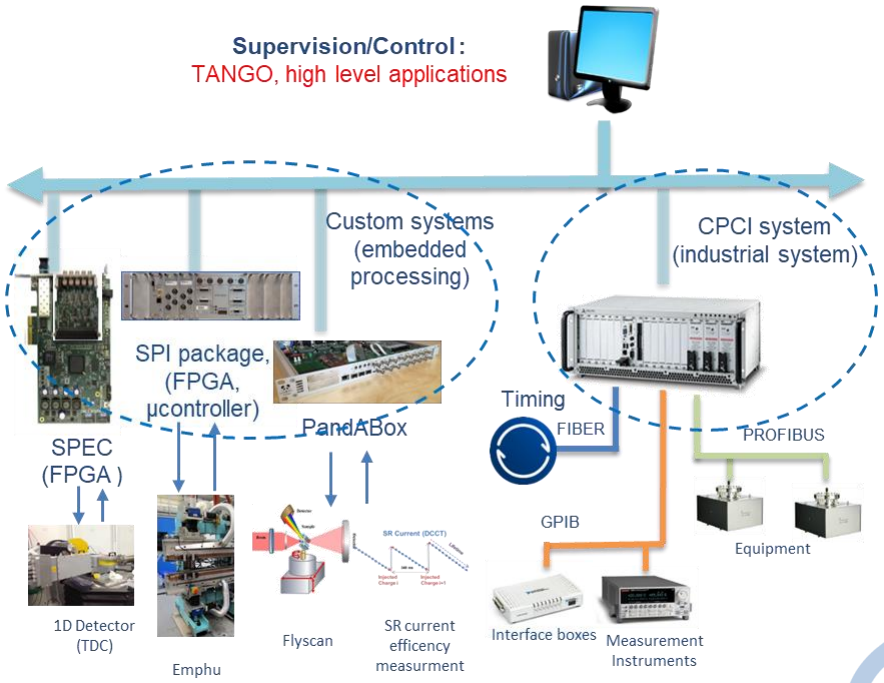
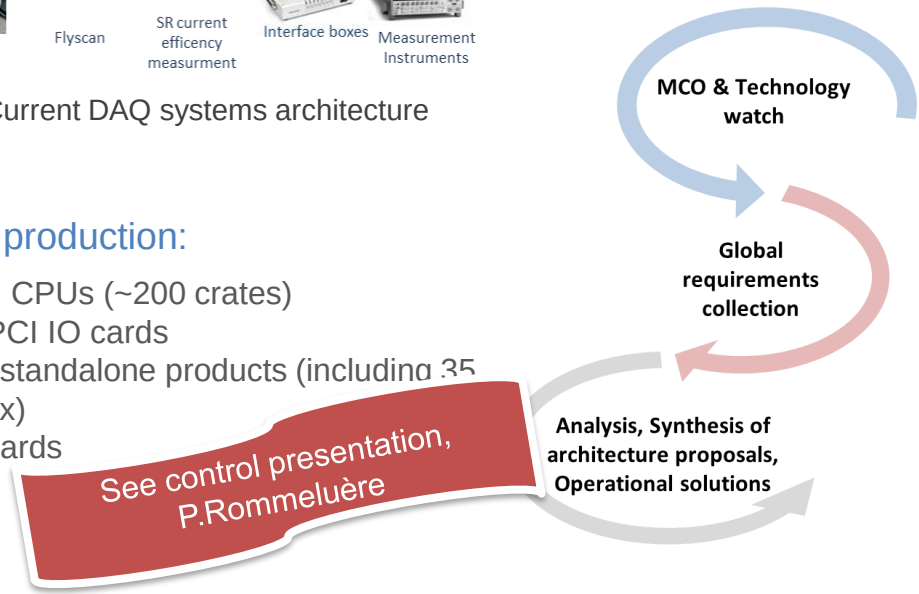
MACUP(Materials for data ACquisition UPgrade) project



Current DAQ systems architecture

Currently on production:

- 271 CPCI CPUs (~200 crates)
- ~1000 CPCI IO cards
- ~50 ETH standalone products (including 35 PandABox)
- 113 SPI cards

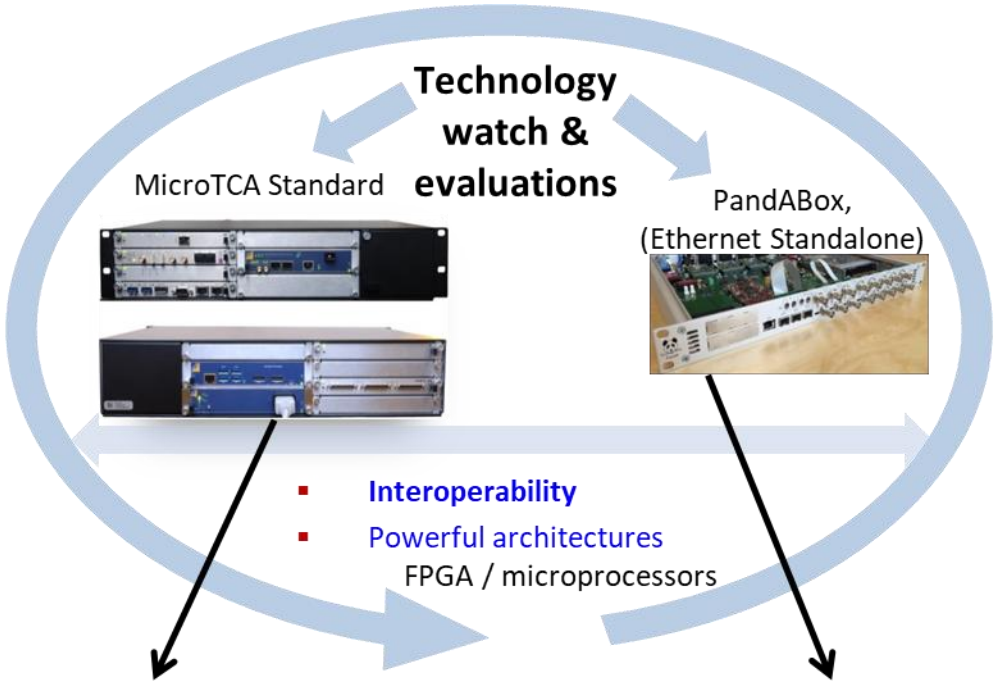


See control presentation, P.Rommeluère

- Motivations
  - Maintain installed acquisition systems at their best performance level (MOC: Maintains in Operational Conditions) and anticipate the obsolescence of the acquisition systems (e.g., sustain the systems)
  - Improve the acquisition systems by delivering higher performance and better embedded processing capacity, and answer new emerging needs
- Selected strategies
  - Deal with obsolescence of the acquisition systems
    - Industrial computer. Homogenize CPU/OS (3 CPUs/3 OS -> 1 CPU/1 OS)
    - Lighten the catalog of functions managed by the CPCI ➔PLC, Ethernet standalone products …
    - Migration obsolete FPGA based products to successors like PandABox
  - Offer new architectures, hardware and software solutions to meet emerging requirements (standardize "generic" platforms, firmware and embedded software)

MACUP project: new services catalog

Scalable FPGA/SoC technology

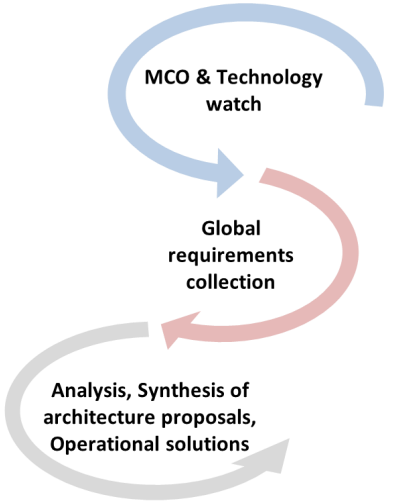


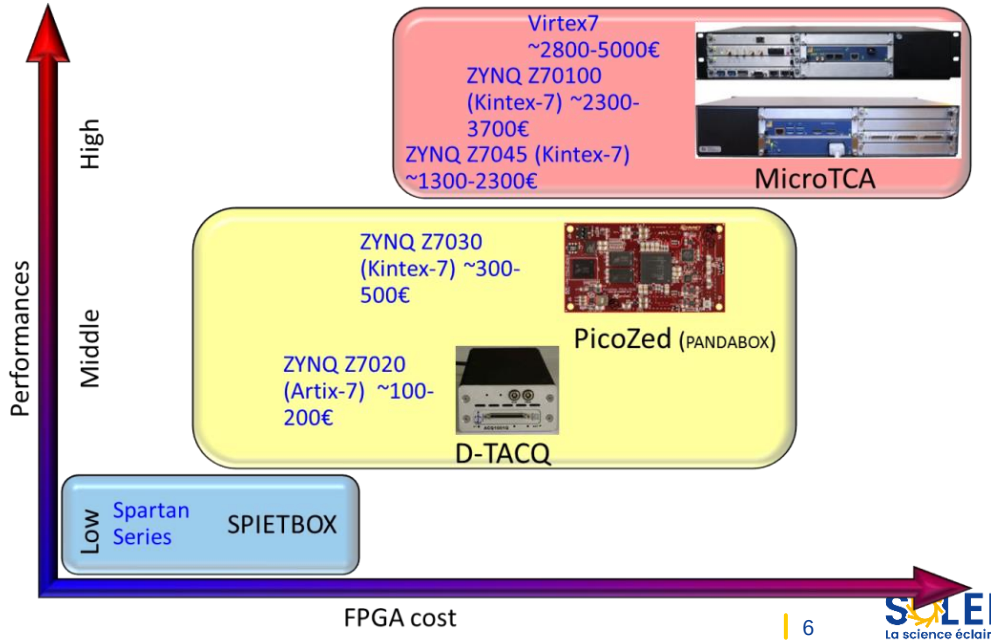
Well adapted for **demanding applications** such as LLRF, Position feedback from 2D detector, development of large detector. Technology intended for medium – long term

Under development

Well dimensioned for short term requirements such as improving scanning application, developing small detectors.

Done





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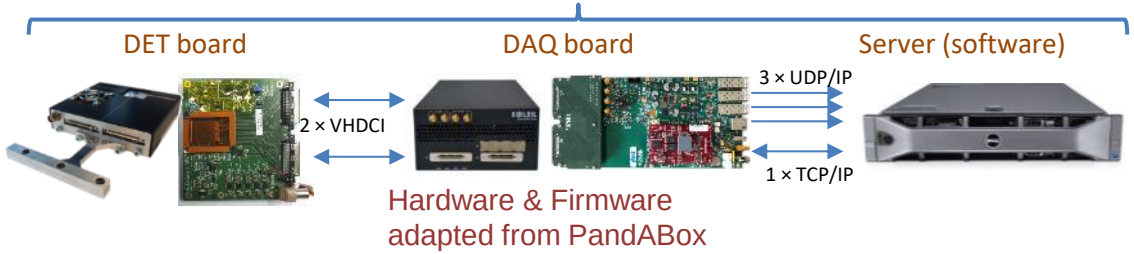
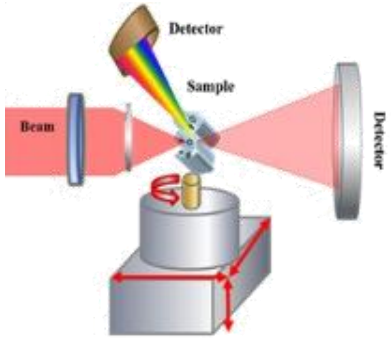
Developments around PandABox

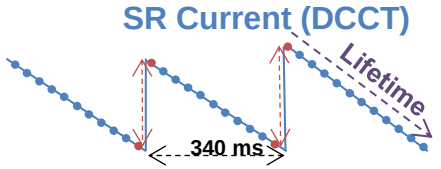
- UFX detector DAQ interface



- Continuous scan applications (Flyscan)



- **CIEL (Current Injection Efficiency and Lifetime) :**
  - New acquisition system for the DCCT

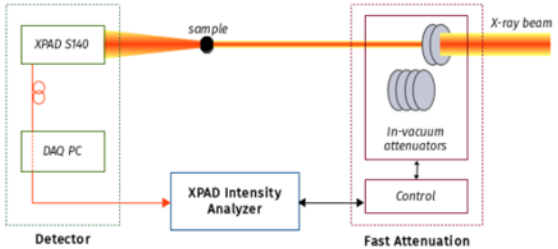


DMM NI PXI 4071

FMC 24 bits ADC

- FastATT XPAD: Upgrade of the real-time control system for the Fast beam-ATTenuation with an XPAD detector

Global architecture of the XPAD controlled beam-attenuation system



cyclic estimation of photon flux

continuously adapts beam attenuation

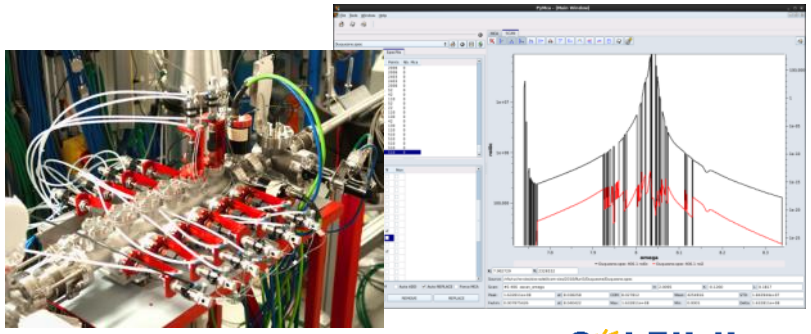


Fig.: attenuation system installed on the SixS beamline at SOLEIL

- Beamline DAQ systems upgrade:
  - QEXAFS monochromator position and ionization chamber captures → On going project
  - Strain gauge measurement for the fatigue test machine
  - Nanoprobe interferometers position captures
  - …

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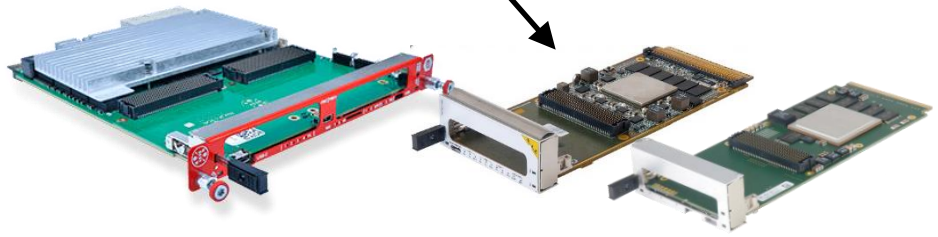
MicroTCA standardization - Selected hardware for evaluations

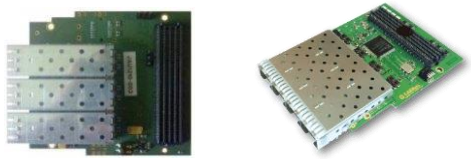
NAT-MCH-PHYS80 MTCA Carrier Hub for MTCA.4 and MTCA.4.1 applications
supports GbE and PCIe Gen 3 switching and optical & copper PCIe x8/x16 uplinks

NAT NATIVE-mini
Smallest (1U) MicroTCA-chassis for industrial applications, with integrated MCH

NAT-JSM
JTAG Switch Module



AMC for DAQ & signal processing applications and computing nodes based
- NAT NAMC-ZYNQ-FMC: FMC Carrier AMC with Xilinx Zynq-7000 FPGA SoC (EOL)
- NAT NAMC-ZYNQUP -FMC: FMC Carrier AMC with Xilinx Zynq UltraScales+ FPGA MPSoC
- CAENels DAMC-FMC2ZUP: FMC HPC& FMC+ Carrier AMC with Xilinx Zynq UltraScale+ MPSoc



FMC SFP+ & 4SFP+
High throughput Interface

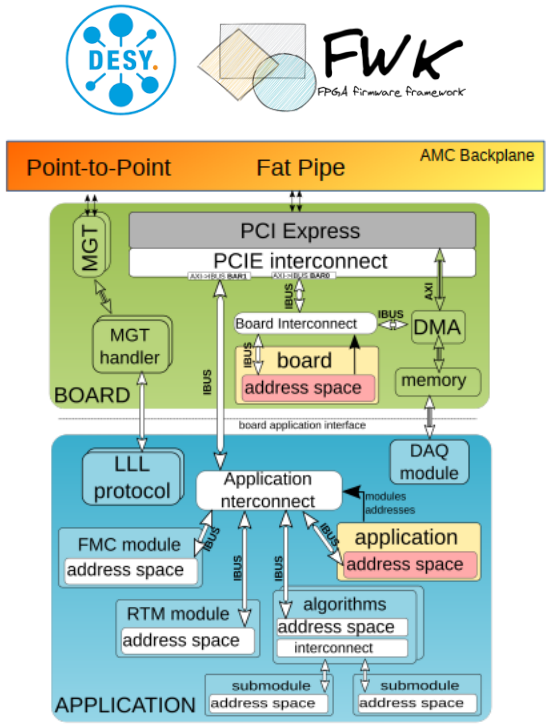
+

FMC Firefly module (14Gbps x 10)

FMC ADC/DAC/DIO modules

MicroTCA standardization - Expected generic Framework

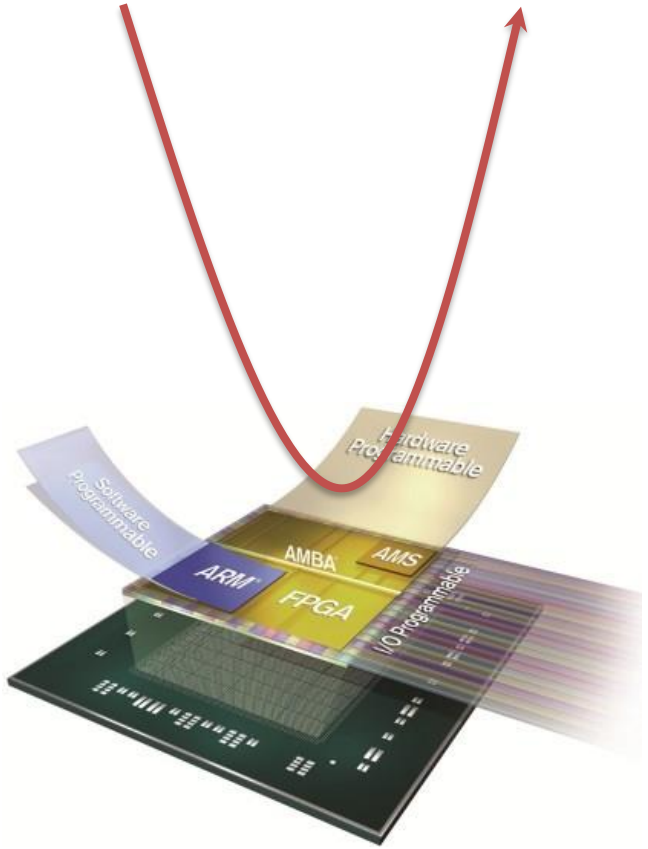
Modular Interfacing & Processing



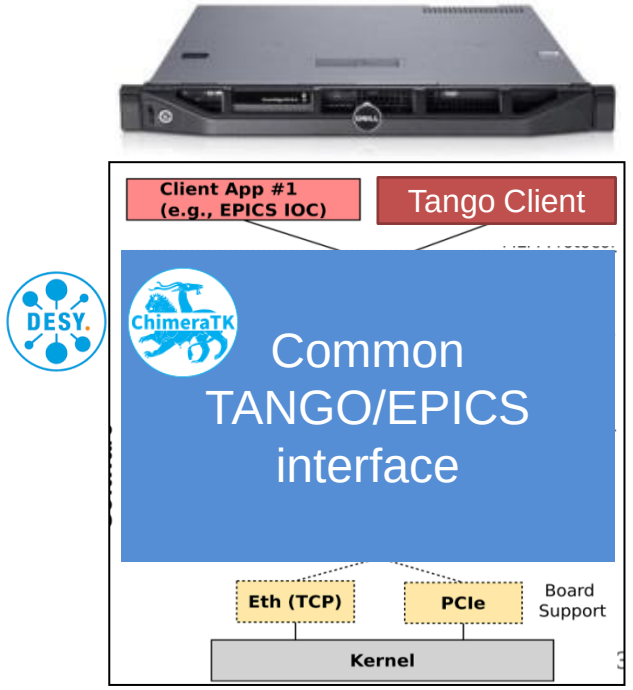
Gateware*

* Schema not up to date

Data flow



Control Framework Ready



Software

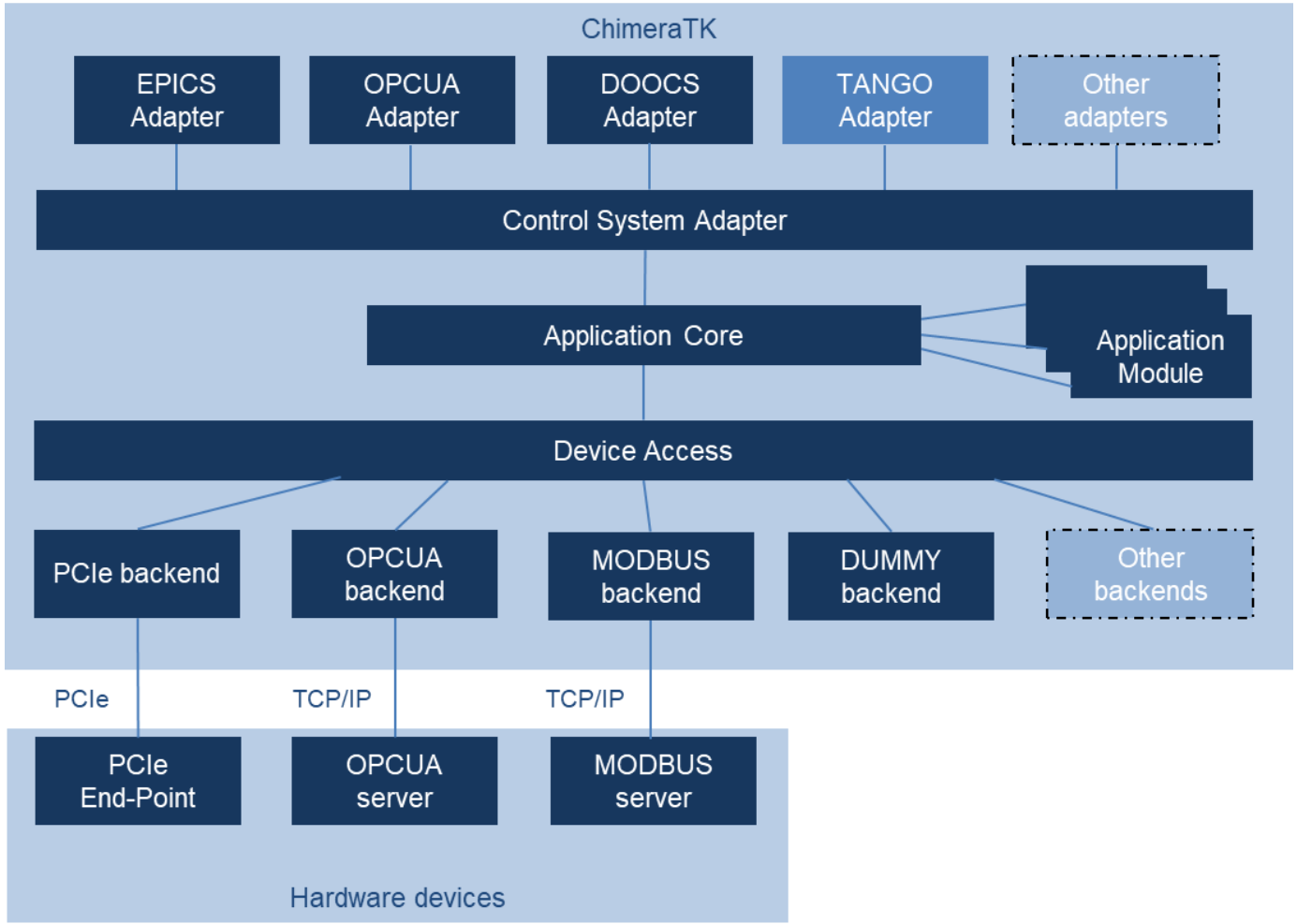
Modular Powerful Connectable

Flexible Framework architecture

for embedded processing and connectivity for Control and DAQ

MicroTCA standardization - ChimeraTK software toolkit

- Control system and Hardware Interface with Mapped and Extensible Register-based device Abstraction Tool Kit
- Developed by DESY
- ChimeraTK “Tango Adapter” is under development at SOLEIL

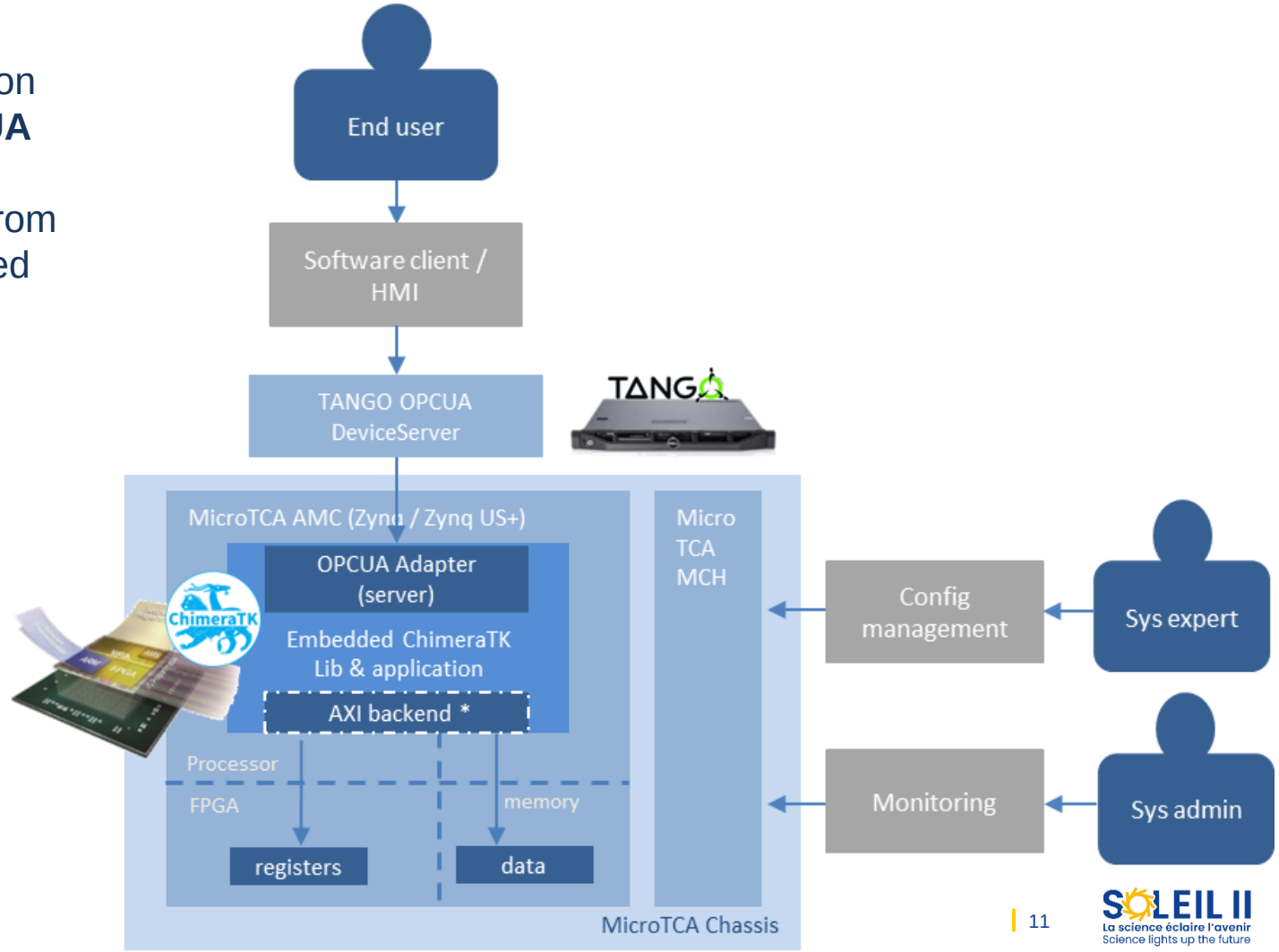


MicroTCA standardization - Integration to the control system

2 selected complementory architectures:

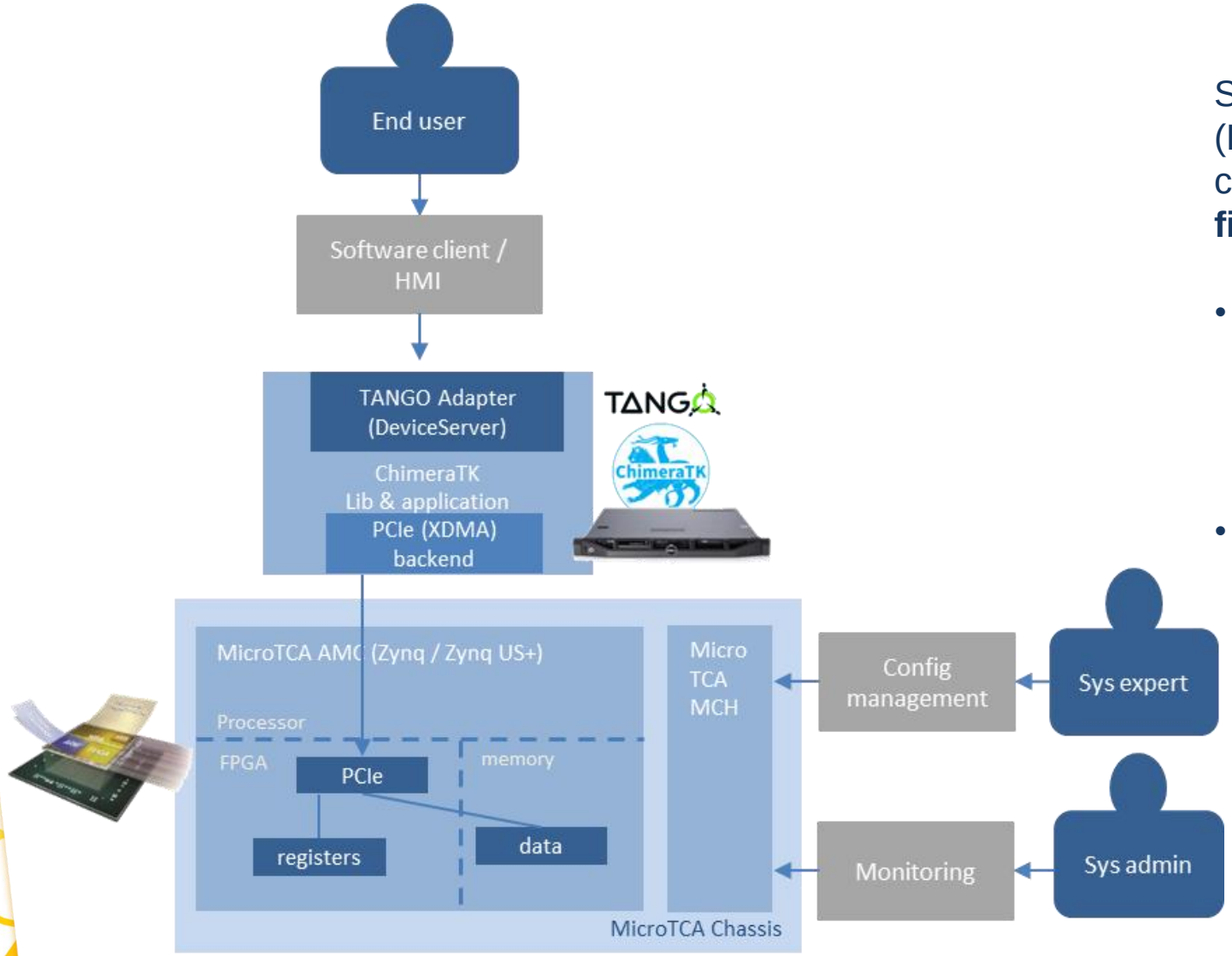
Solution 1: remote TANGO DeviceServer communicates with **ChimeraTK embedded** on the MTCA Zynq PS over Ethernet and **OPCUA** protocol

- Embedded ChimeraTK takes FPGA data from AXI bus to the custom process implemented on its Application level, and expose processed data to the OPCUA Adapter (server)
- * ChimeraTK “AXI (UIO) backend” development just released by DESY



MicroTCA standardization - Integration to the control system

2 selected complementory architectures:



Solution 2: ChimeraTK with “TANGO Adapter (DeviceServer)” on the control server, communicates with MTCA FPGA over **PCIe-over-fiber** link

- ChimeraTK takes FPGA data from PCIe link to the custom process implemented on its Application level, and expose processed data to the TANGO Adapter (DeviceServer)
- PCIe-over-fiber’s hot-swapping feature needs to be studied→ Evaluated but not stable

MicroTCA applications

- Applications
  - FOFB upgrade (Diags group collab)
  - DLLRF upgrade (RF group)
  - Fast acquisition: e.g. ADC for QuickExafs, digitizer for filling pattern measurement etc.

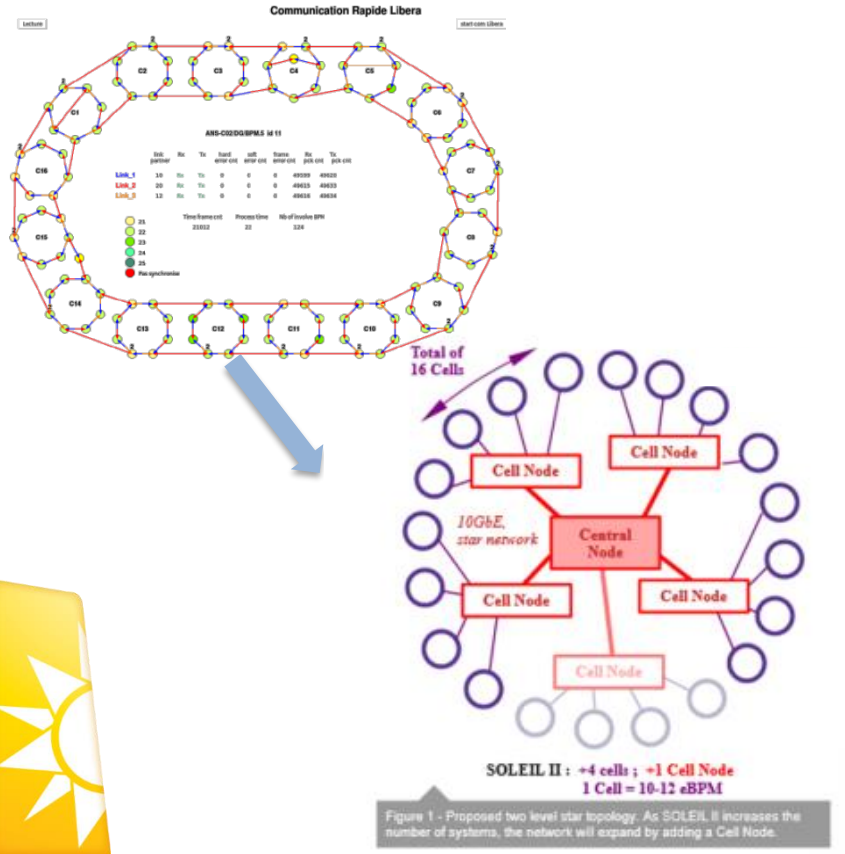
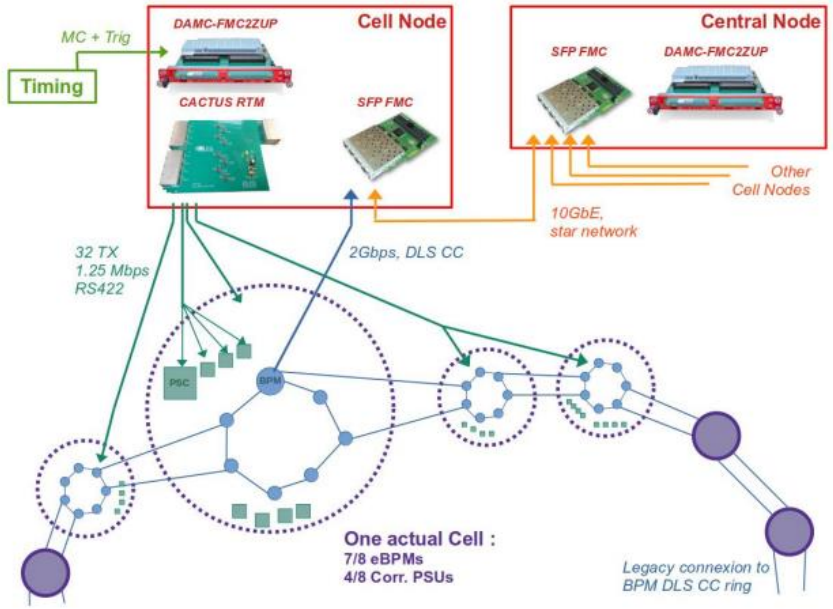
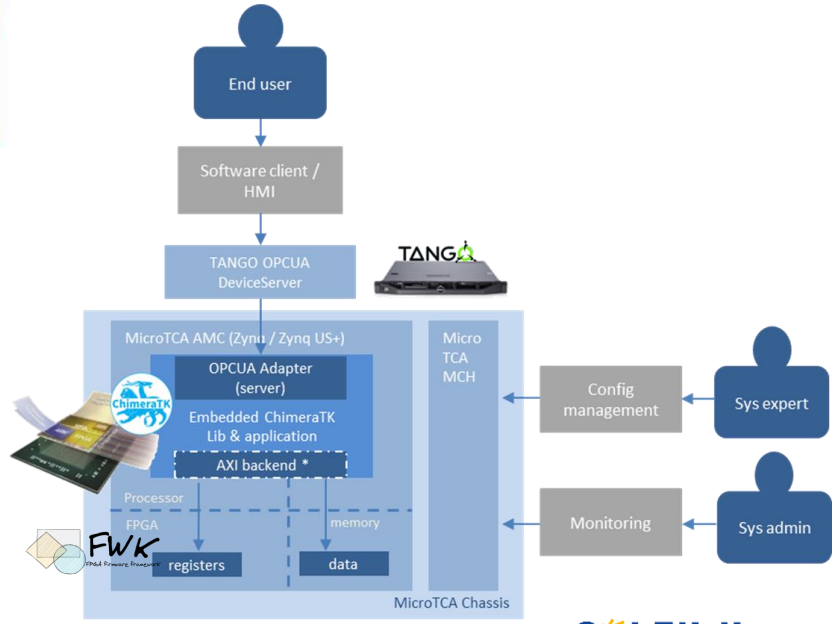


Figure 1 - Proposed two level star topology. As SOLEIL II increases the number of systems, the network will expand by adding a Cell Node.



System integration. One Cell node is connected to 4 cells.



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SOLEIL software acquisition systems

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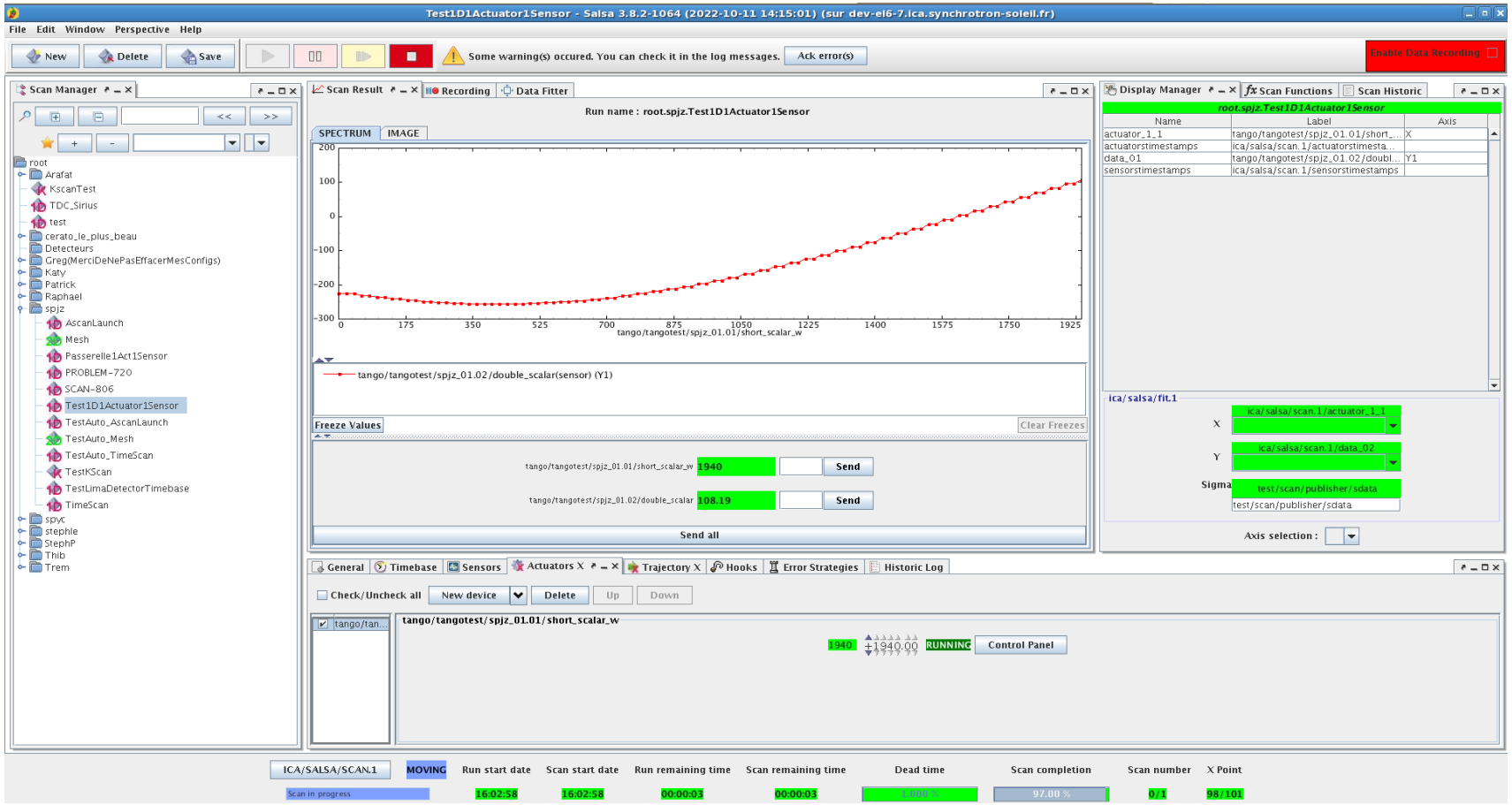
ScanServer

- Generic Tango DeviceServer (C++)
- 1D / 2D step scans
- Plugins system (68)
- Easily configurable by users
- ISAC Clients integration
- Legacy system
- Does the job since 2005 on ~85 % of Beamlines !!!



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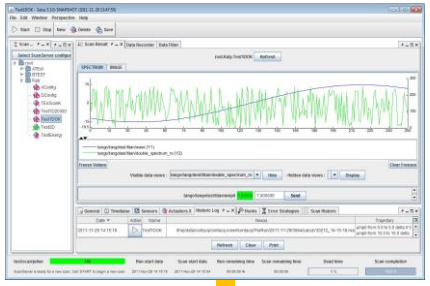
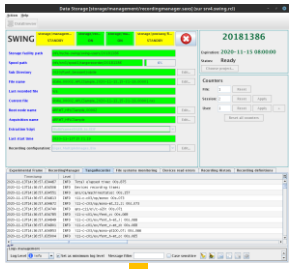
ScanServer – Data flow



SALSA



DataStorage

Tango bus

FileTransfer

Sensor(s)

ScanServer

RecordingManager

Scan data

Move files
asynchronous

Scan data

Metadata

projects & users info

Metadata configuration

Storage facility

NeXus

Spool (local storage) (NFS)

Tango controls

Tango data

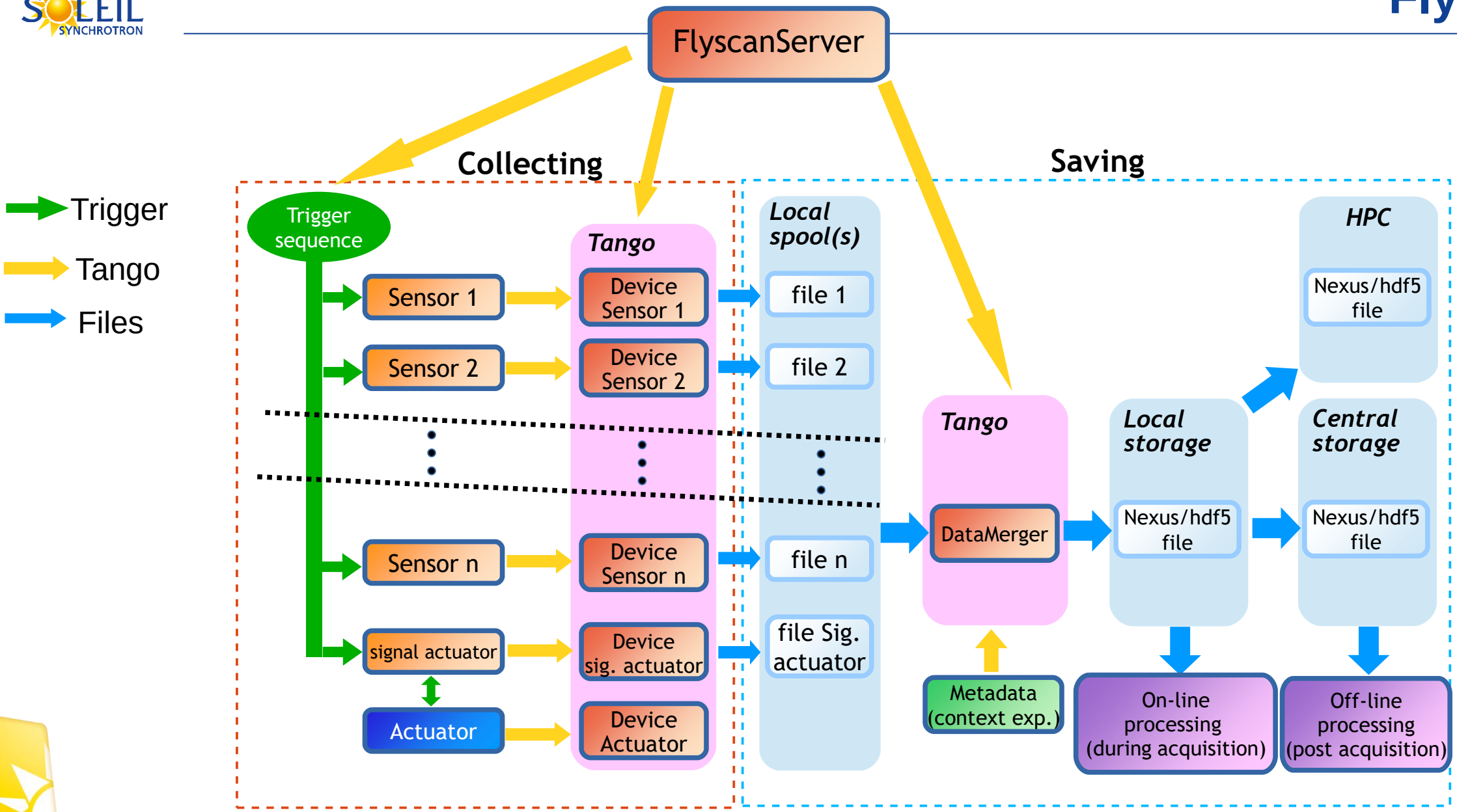
Files

Flyscan

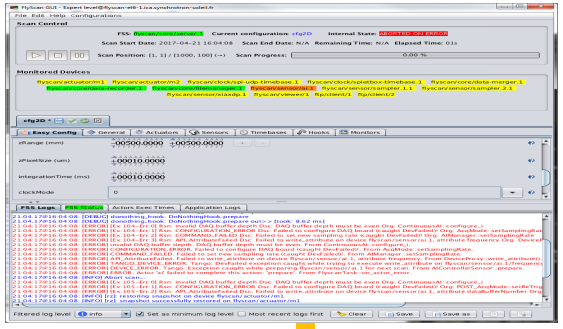
- Tango DeviceServer (C++)
- With plugins (52 in C++ / python)
- Continuous and step scans in N dimensions

- Project started in 2010
- In production since 2014
- On 14 BL (out of 29)
- Number of configs: ~ 30 (one config = one acquisition, e.g. mesh, Tomo …)
- Complex configs : by ctrl people

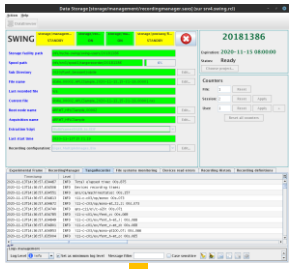
Flyscan


FlyscanServer
Collecting
Saving
Trigger
Tango
Files
Trigger sequence
Sensor 1
Sensor 2
Sensor n
signal actuator
Actuator
Tango
Device Sensor 1
Device Sensor 2
Device Sensor n
Device sig. actuator
Device Actuator
Local spool(s)
file 1
file 2
file n
file Sig. actuator
Tango
DataMerger
Metadata (context exp.)
Local storage
Nexus/hdf5 file
On-line processing (during acquisition)
HPC
Nexus/hdf5 file
Central storage
Nexus/hdf5 file
Off-line processing (post acquisition)

Flyscan – Data flow



FlyscanGUI



DataStorage

Tango bus

FileTransfer

Sensor(s)

FlyscanServer

config.txt

RecordingManager

projects &
users info

Metadata
configuration

Move
files
asynchronous

Scan data

Metadata

NeXus

Spool

Storage facility

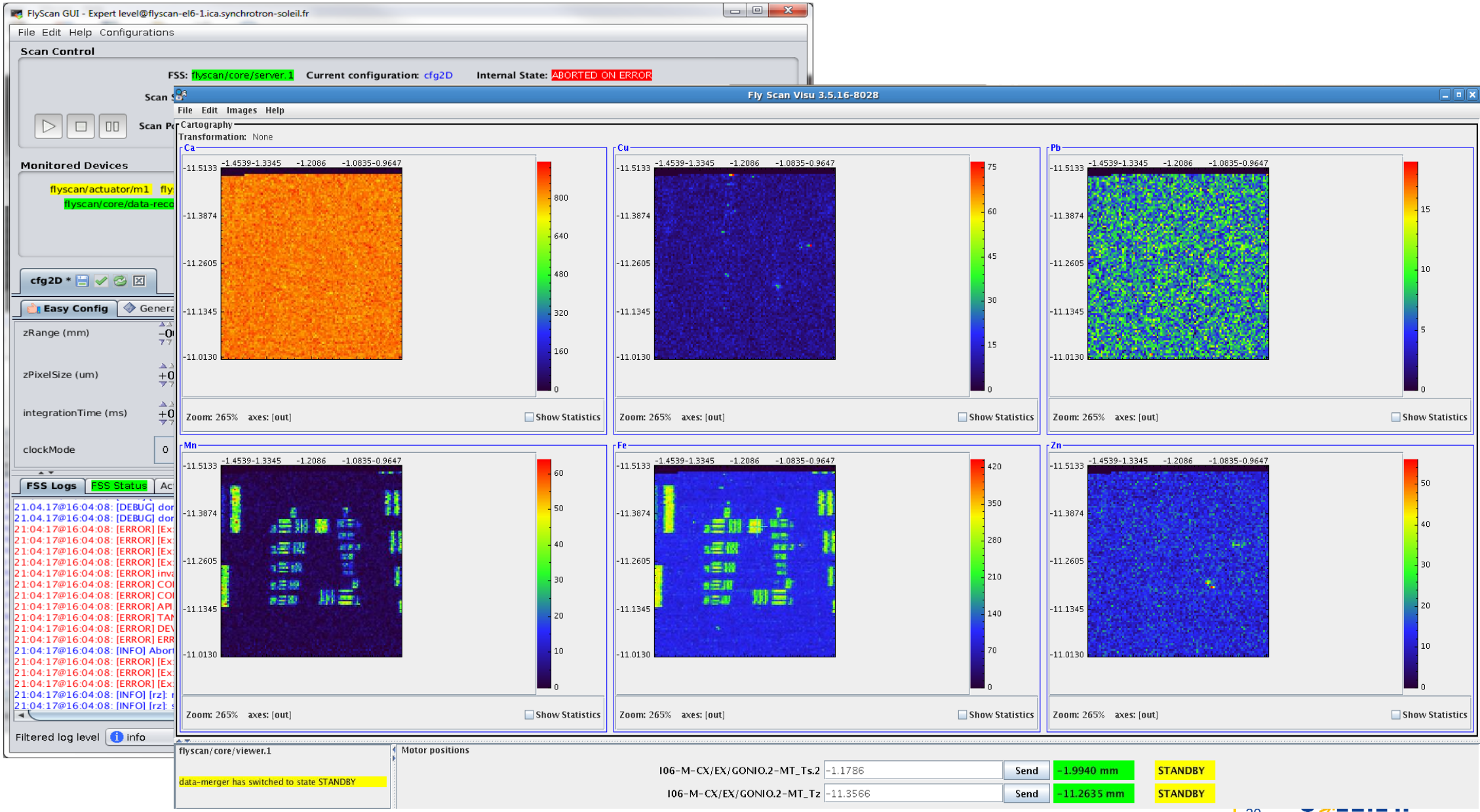
DataMerger

Up to
700 MB/s

Tango controls

Files

Flyscan



Flyscan

- **Python** interface & **ipython** profile

```
In [9]: fss.cfgs.cfg2D.easy_config.parameters
Out[9]:
EasyConfigProp()
 +- clockMode ......... 0
 +- integrationTime ... 10.0
 +- split ............. 1
 +- xPixelSize ........ 100.0
 +- xRange ............ [-10000.0, 10000.0]
 +- xrf_config ........ {"P": [400, 430], "K": [652, 689], "S": [452, 485], "Cl": [516, 552]}
 +- zPixelSize ........ 200.0
 +- zRange ............ [-500.0, 500.0]
```

- **SPYC** (SOLEIL's Python Command line interface) integration

- **FlyscanViewer** Tango device
  - Display data during acquisition as Tango attributes from final Nexus file
  - Plugin system to do some data reduction

Detectors - Lima

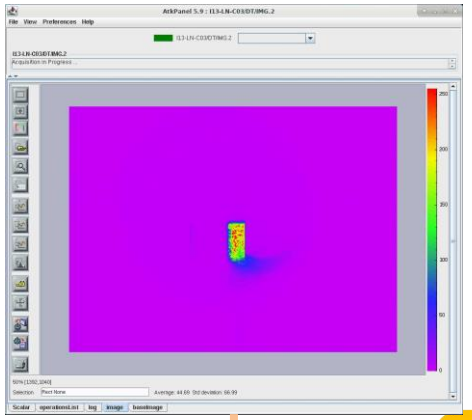
- **L**ibrary for **IM**age **A**cquisition
- C++ with Python interface
- **Generic** part with standard interface
- **Plugin** system to handle camera **specific** stuff
- Collaboration with ESRF, ALBA, MAX4, DESY
- **21** Camera type supported at SOLEIL (45 in total)
- Basler (Beam Monitoring), Hamamatsu, Eiger, Pco …
- **301** instances (200 Basler)

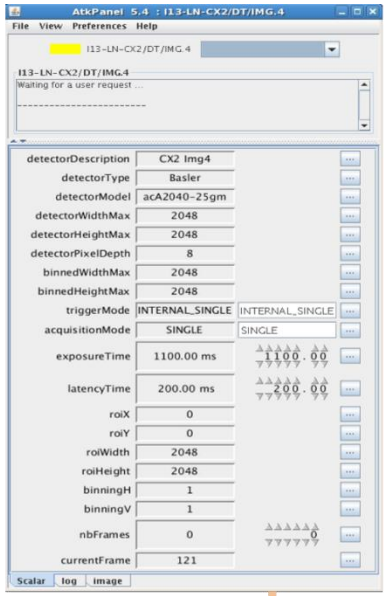
#	Detector	NB instance
1	Andor	1
2	Basler	200
3	Dhyana	8
4	Eiger	3
5	Hamamatsu	15
6	ImXpad	8
7	Lambda	3
8	Marccd	1
9	Maxipix	1
10	Merlin	10
11	Pco	9
12	PerkinElmer	1
13	Pilatus	4
14	Princeton (Teledyne)	1

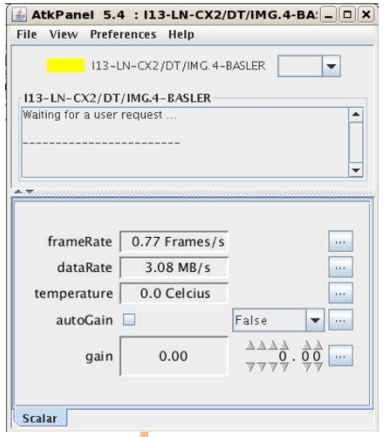
#	Detector	NB instance
15	RoperScientific	3
16	SLSEiger	1
17	SLSJungFrau	1
18	SpectralInstrument	1
19	SpectrumOne	1
20	UFXC	2
21	Uview	1

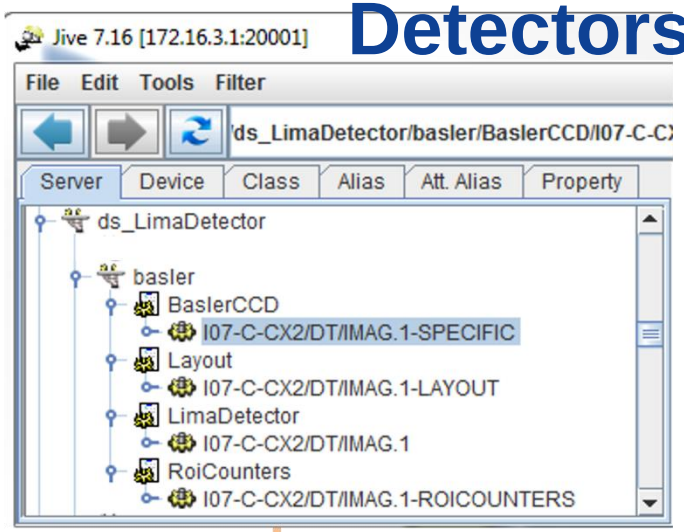
https://lima1.readthedocs.io/en/latest/
https://lima-tango-cpp.readthedocs.io/en/master/

Detectors - Lima









TANGO Software bus

ds_LimaDetector

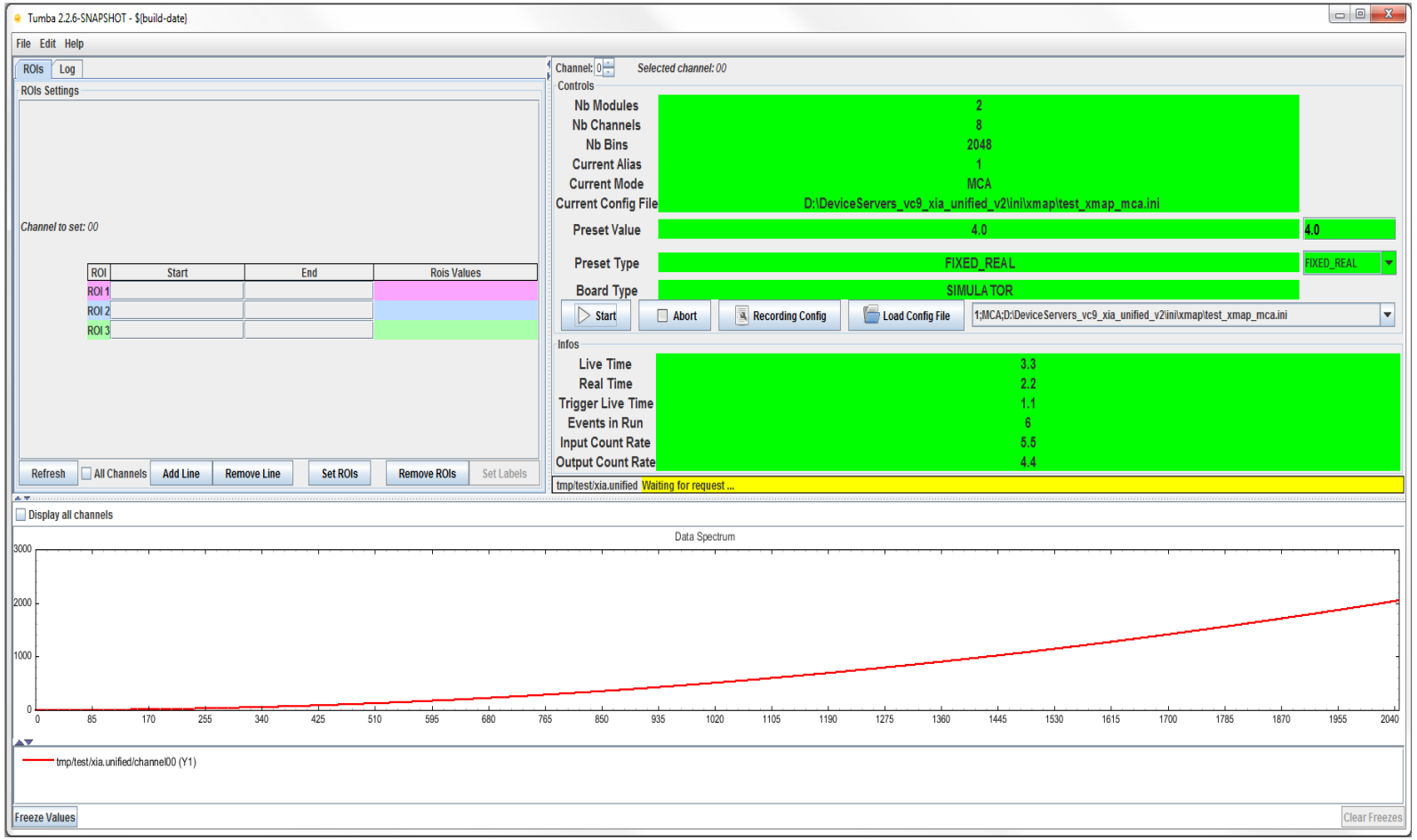
Optional

LimaDetector	BaslerCCD	Layout	RoiCounters
▪ Start ▪ ExpoTime ▪ NbFrames ▪ ...	▪ IPAddress ▪ PacketSize ▪ Gain ▪ ...	▪ Flip ▪ Rotate ▪ ...	▪ Rois ▪ Sum ▪ Std ▪ ...

Lima (LimaCore + LimaBasler + Processlib)

Detectors - MCA

- XIAs
  - Xmap
  - Falcon
- Xspress3
- DanteDpp
- Not a standardized lib as Lima
- But trying to get a standardized Tango interface



Acquisition system perspectives

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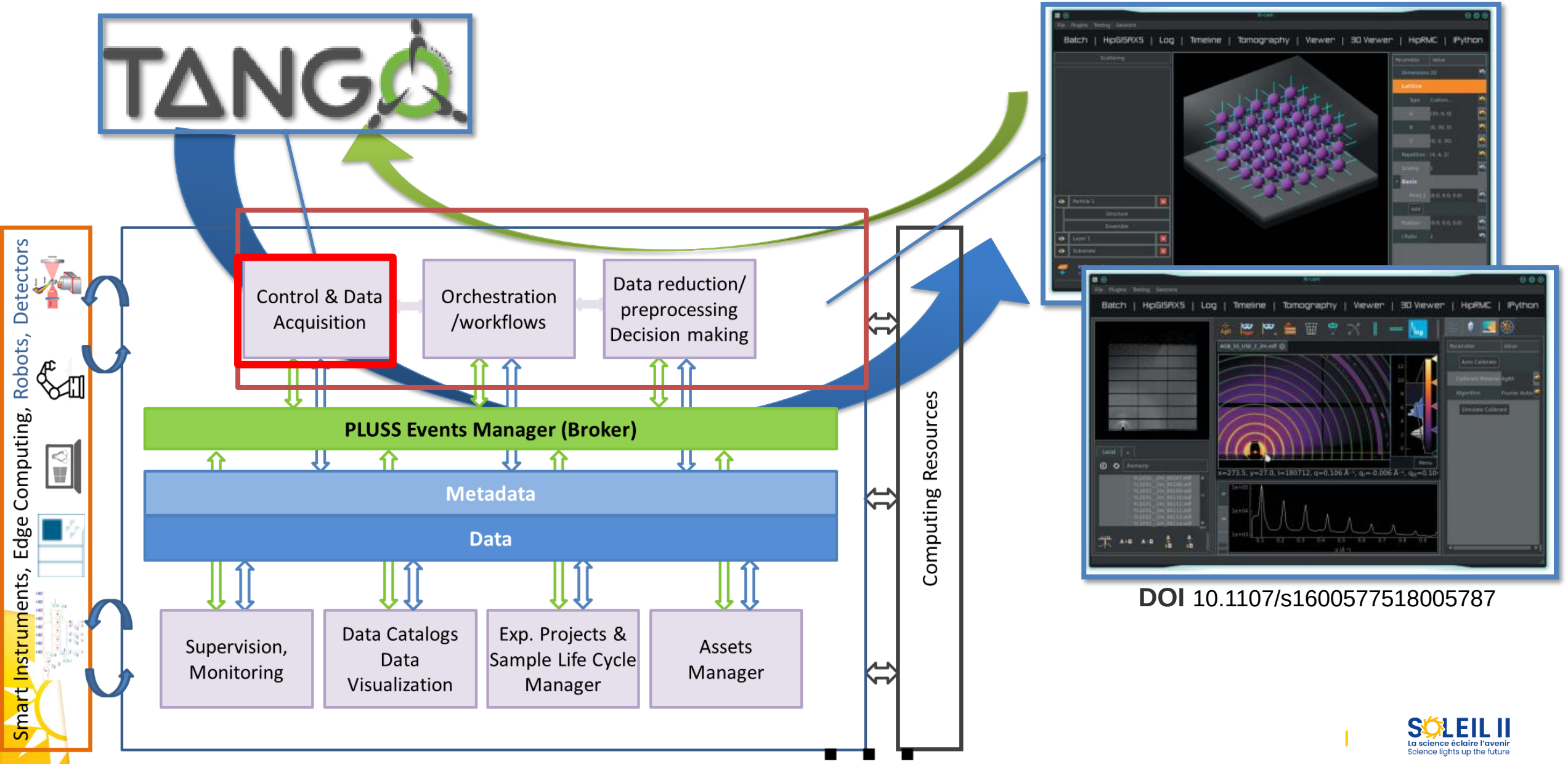
Process with DAQ, Data Reduction and AI



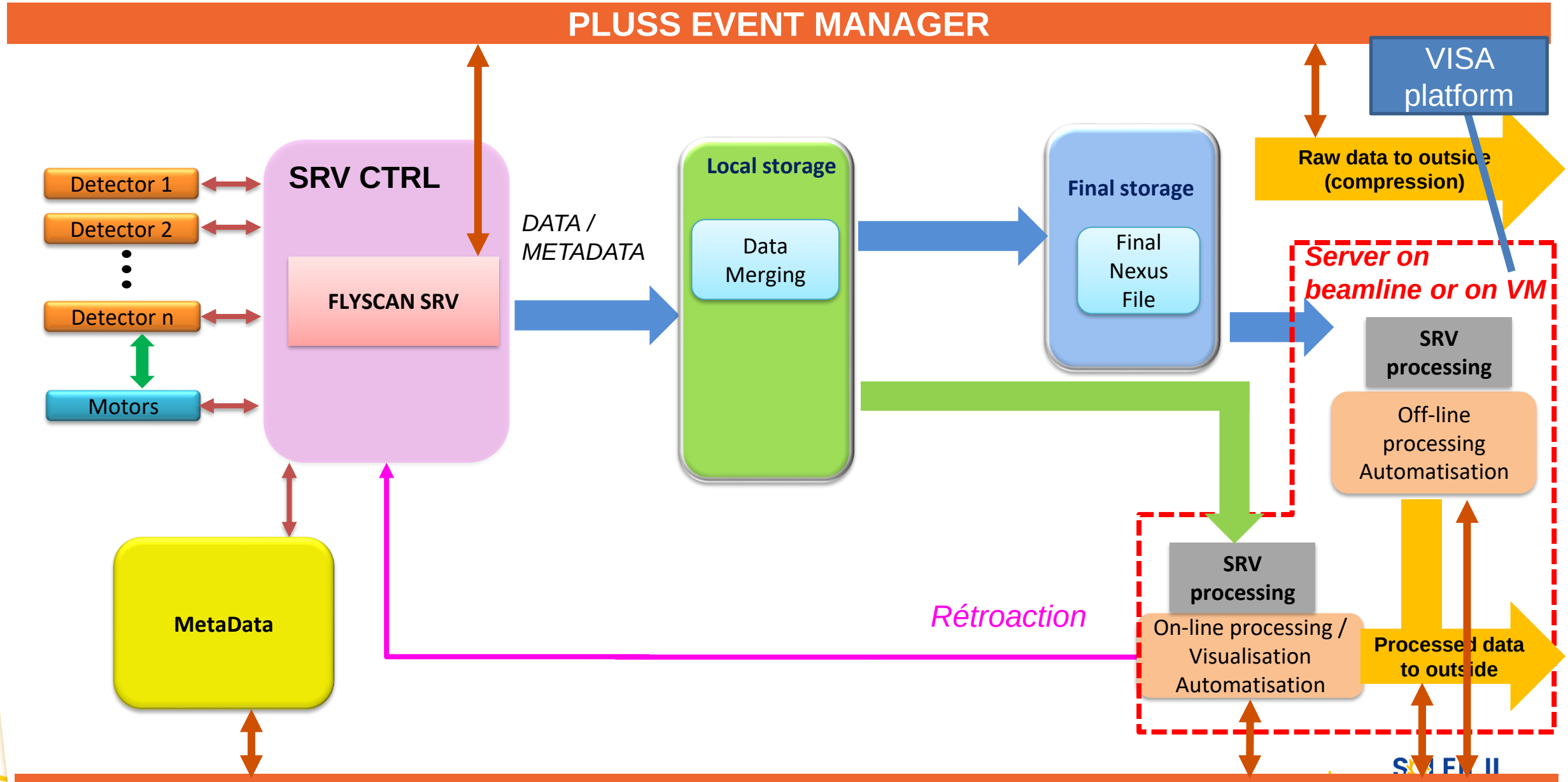
DOI 10.1107/s1600577518005787

Perspectives

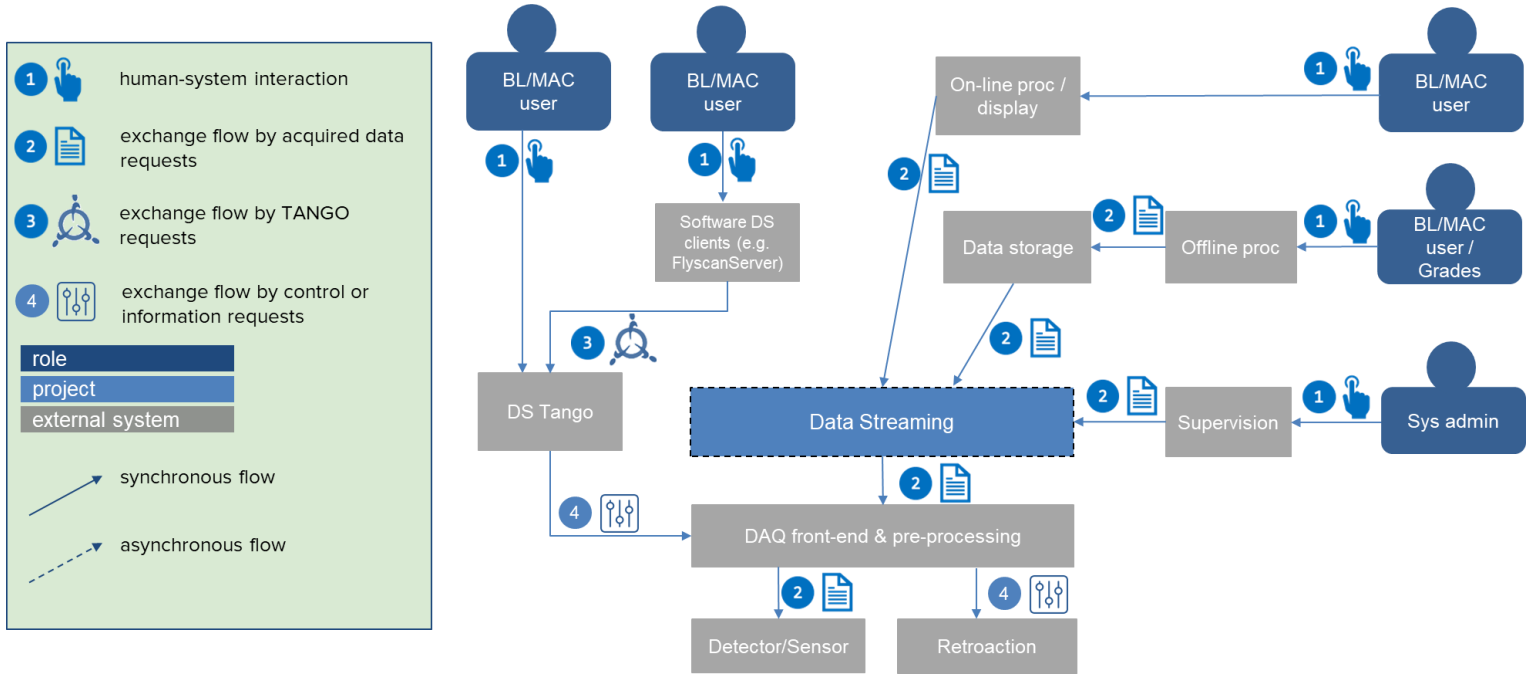
- Hardware systems
  - Put MTCA systems on production for SOLEIL
    - HW, FW, SW standardization and development
    - MicroTCA systems monitoring (Zabbix under evaluation)
  - PandABox Gen 2
  - Migrate legacy/obsolete systems to new products

- Software systems
  - Decommissioning of the ScanServer: towards Flyscan
  - Flyscan upgrade
    - With automatic retroaction
    - Visualisation improvement
    - Connected to PLUSS* (event & api manager)
      - * see Gwenaelle's DataManagement slides

Flyscan V2 Architecture



- Data Streaming
  - New solution for future requirements
  - Lima2, ASAPO, Hidra, Odin, DataStaMP …
  - Interaction with PLUSS



Open Questions

- Questions
  - MicroTCA generic framework ?
  - MicroTCA monitoring / supervision ?
  - Embedded SW: CI/CD ?
  - Which GUI for detectors ?
  - Data / Metadata streaming ?
    - which ?
    - Lessons learn on selection ?
  - Data reduction at edge computing (GPU, FPGA) ?
  - Post processing automation

Thank you!

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Backup slides

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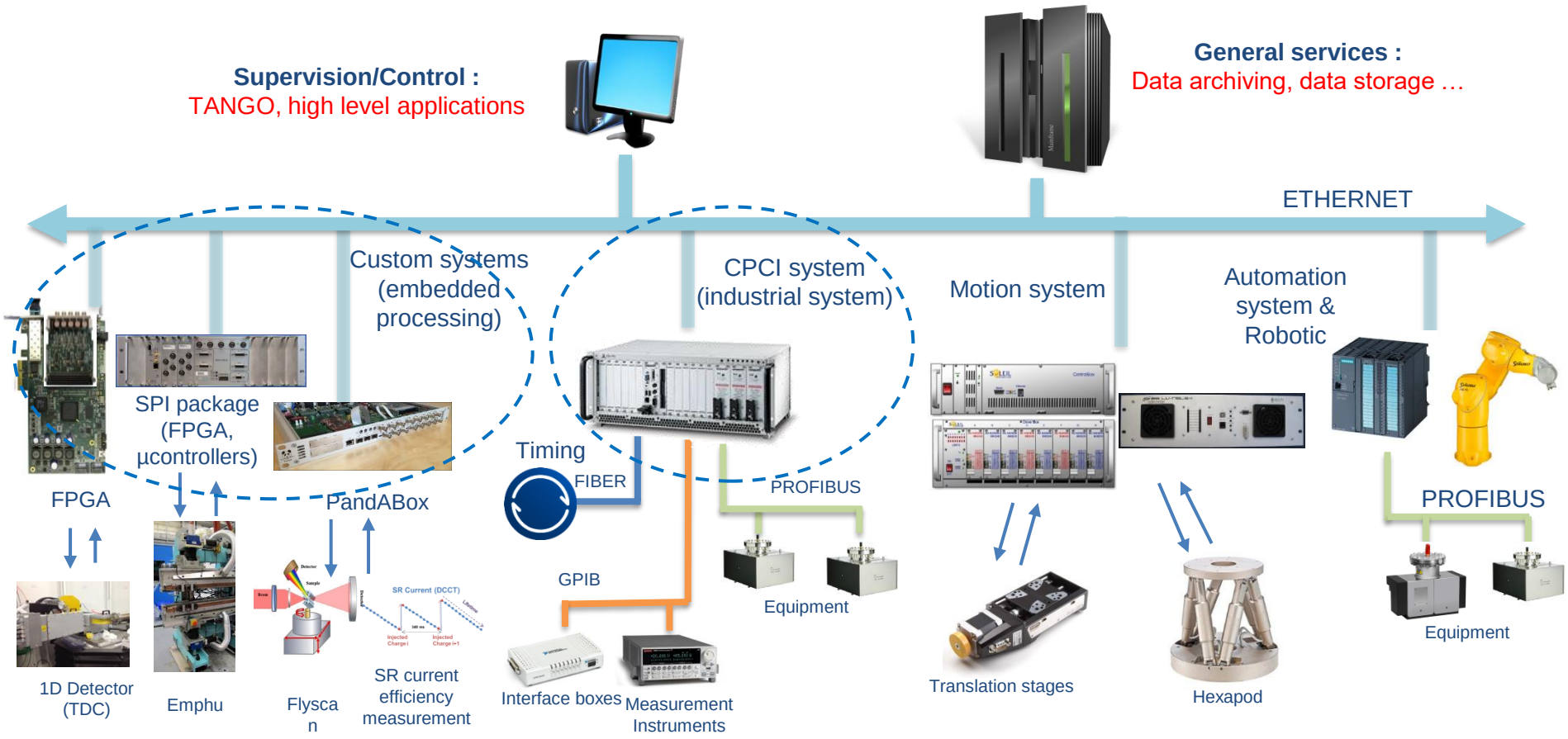
Control command and acquisition architecture at SOLEIL

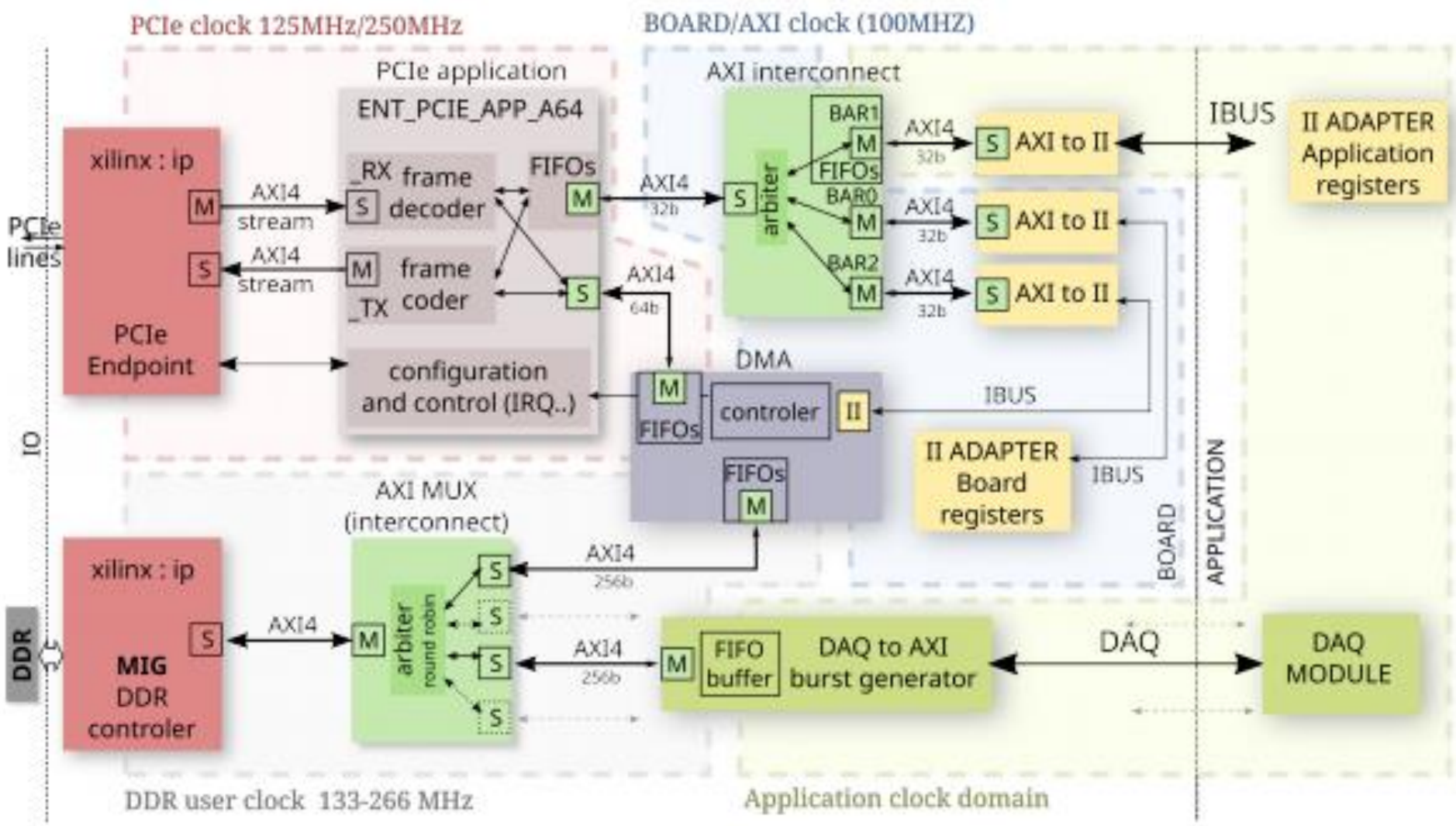


Acquisition and onboard processing

Motion control systems

Automation & Robotics

FWK framework



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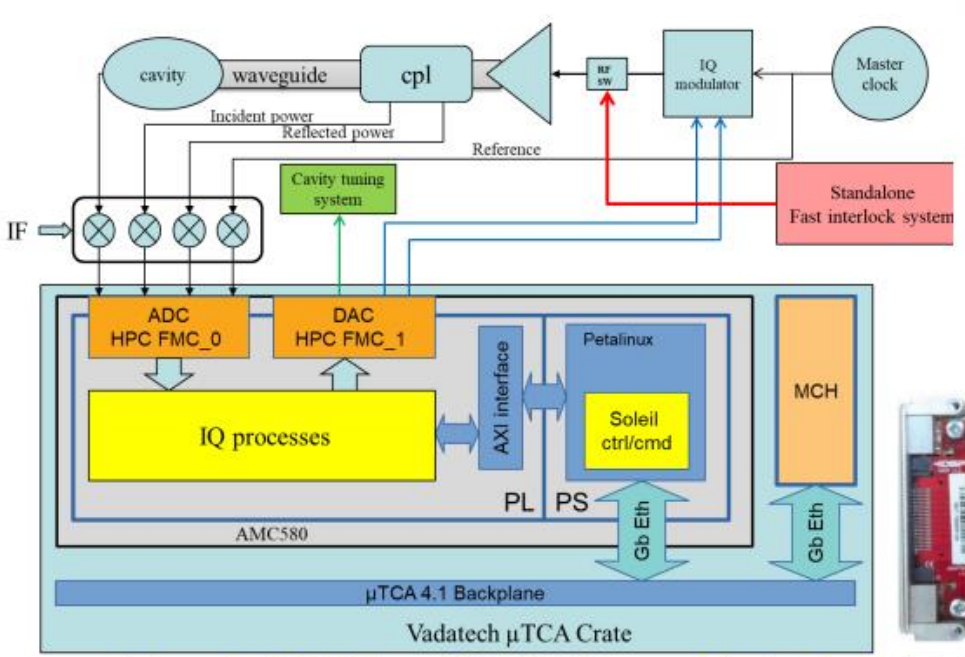
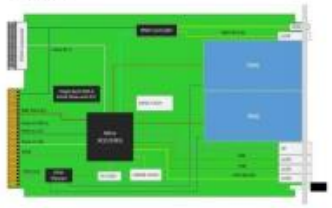
The progress of the DLLRF on MicroTCA





- 4 channels ADC FMC board (TECHWAY) successfully interfaced into the Zynq of the ZC706 evaluation board, IQ process tested and validated
- Configuration and setup of Vadatech MicroTCA: done
- Migration of the previous development to the AMC580 (Vadatech) board is successful
- Development of python socket server on PS side for communication is done
- Interfacing of DAC FMC board (FMC224) is ongoing
- Interoperability difficulties during development: Vadatech AMC580 seems not working on NAT MicroTCA rack
- After repairing of the power supply of AMC580, we never tried it again and AMC580 is working fine on Vadatech rack

Today status: The main deal is to interface the DAC FMC.
Then all IQ process are ready to be implemented.

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PandABox project
(Position and Acquisition)

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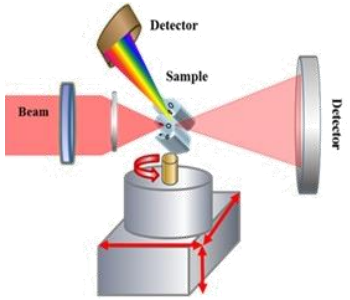
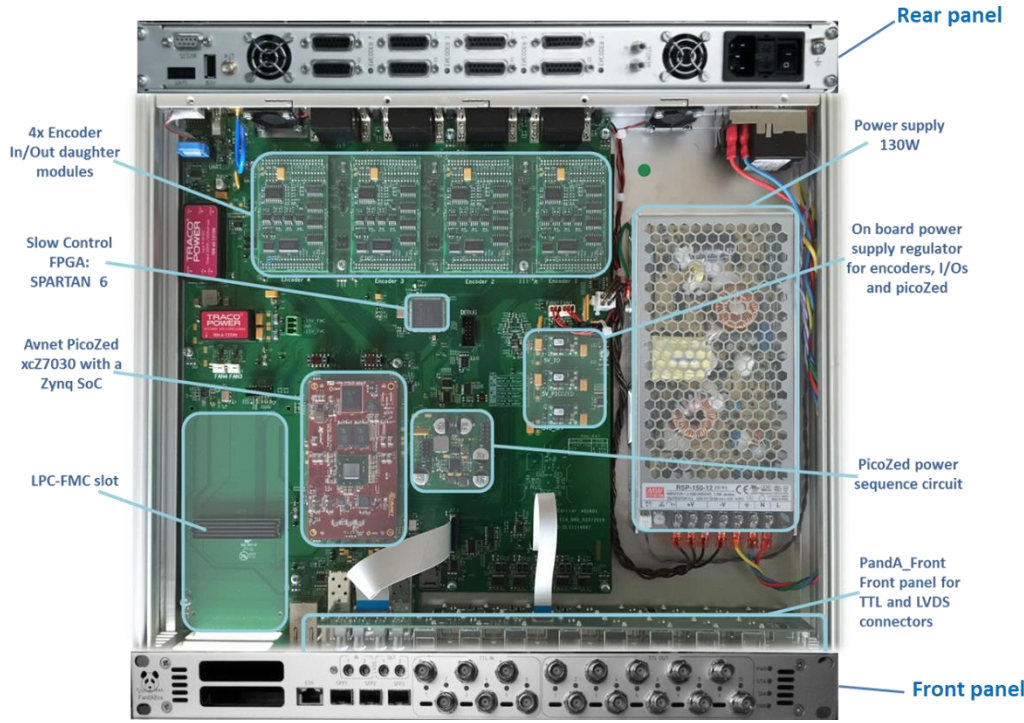
PandABox project context

- Initial objectives
  - Connecting **Motion Control** Systems and **Data Acquisition** Systems for simultaneous and multi-technique scanning applications
  - Providing Encoder Processing, Common Synchronous Triggering and Data Captures
- Motivations
  - Managing obsolescence and limitations
  - Maintaining modularity
  - Improving performance
- Organisation
  - Development collaboration between SOLEIL and Diamond
  - Task sharing
    - SOLEIL: Electronics and Mechanics
    - Diamond: Firmware, Software and Web GUI
- Resulting system
  - **Flexible** design solution, **open** and **extensible** platform
    - Modular hardware with removable modules
    - Firmware and software easily configurable and adaptable



Hardware architecture

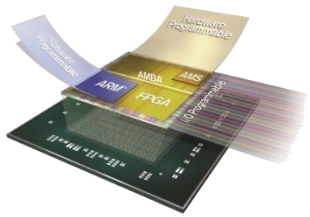
- Packaged in a 19” 1U rack
- Platform developed around an off–the-shelf product:
  - Avnet PicoZed Z7030 module based on a Xilinx Zynq 7030 SoC (System On Chip)
- HW architecture around PicoZed and I/O interfaces
  - 4-Channel Encoders I/Os (Quadrature, SSI, BiSS-C, EnDat)
  - TTL and LVDS I/Os
  - 1 Gigabit Ethernet for Control and DAQ
  - 3 SFP ports
  - FMC LPC slot
  - On board clock tree & power supplies
  - Slow control via a Xilinx SPARTAN-6 FPGA:
    - Temperature monitoring
    - On-board power supplies voltage monitoring
    - Fan-speed monitoring
    - Configurations of the I/O encoder signals
    - Front panel configurations
  - JTAG for SoC and FPGA debugging
  - RS-232 serial console terminal
  - USB host for firmware upgrades

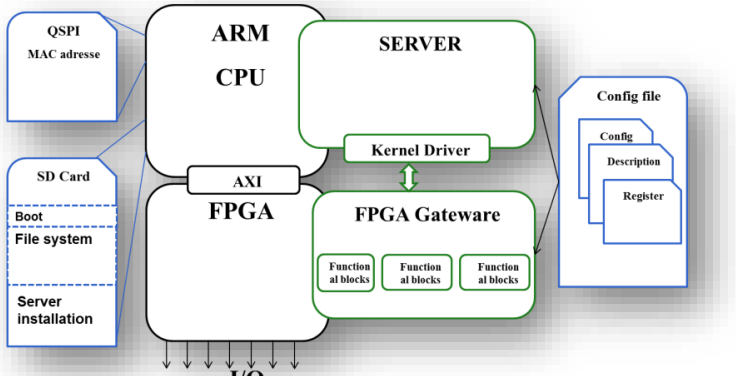


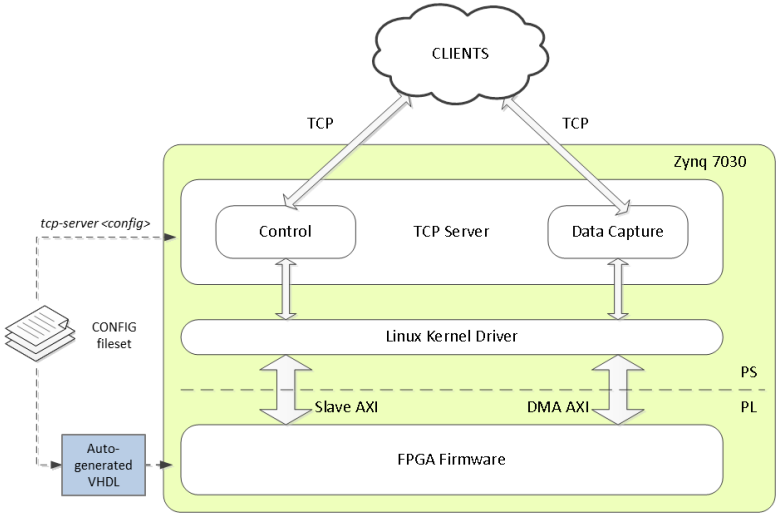
https://www.ohwr.org/project/pandabox-hw/blob/master/PandABox_User_Guide.pdf

Firmware architecture

- Flexible and configurable architecture







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ICALEPCS2017, Barcelona, Spain JACoW Publishing
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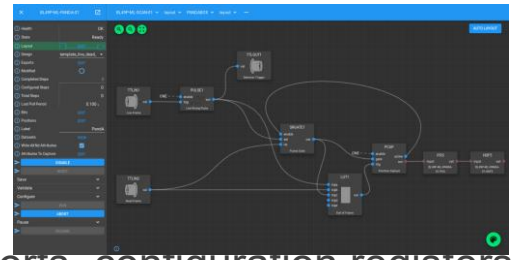
– **FPGA firmware layer (PL)**
  - Structured into numerous Functional Blocks (FBs)

– **TCP-Server layer (PS)**
  - **Two** socket **endpoints** to connect to clients (EPICS, TANGO, etc.)
    – configuration **control** (control & status register)
    – streamed data **capture** (interface with DMA engines for synchronous R/W)

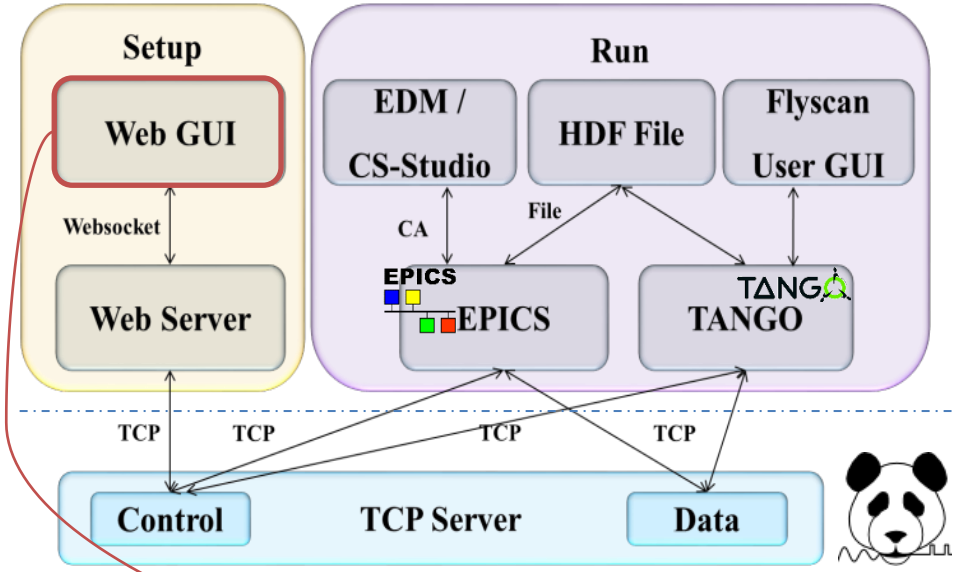


⇨ 2 layers **tightly coupled** through **a common set of configuration files** (FB's I/O ports, configuration registers, and descriptions)

⇨ Allowing to **design and compile** a custom set of **FBs** into the **firmware** with **access from the TCP Server**

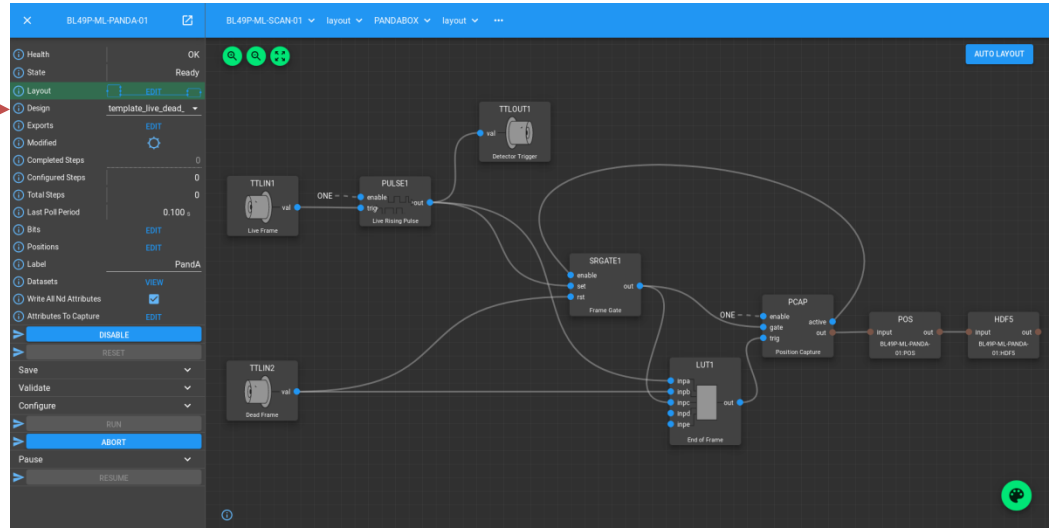
- Fully **re-wirable** (at run-time) architecture

Software architecture



- **TCP Server**
  - To **interface** with either **TANGO** Device Server, **EPICS** IOC, or web-server

- **Web GUI**
  - **Visualizing** and **wiring** the functional blocks
  - **Setting** the functional blocks' **parameters**
  - Help to **build** customized **applications**



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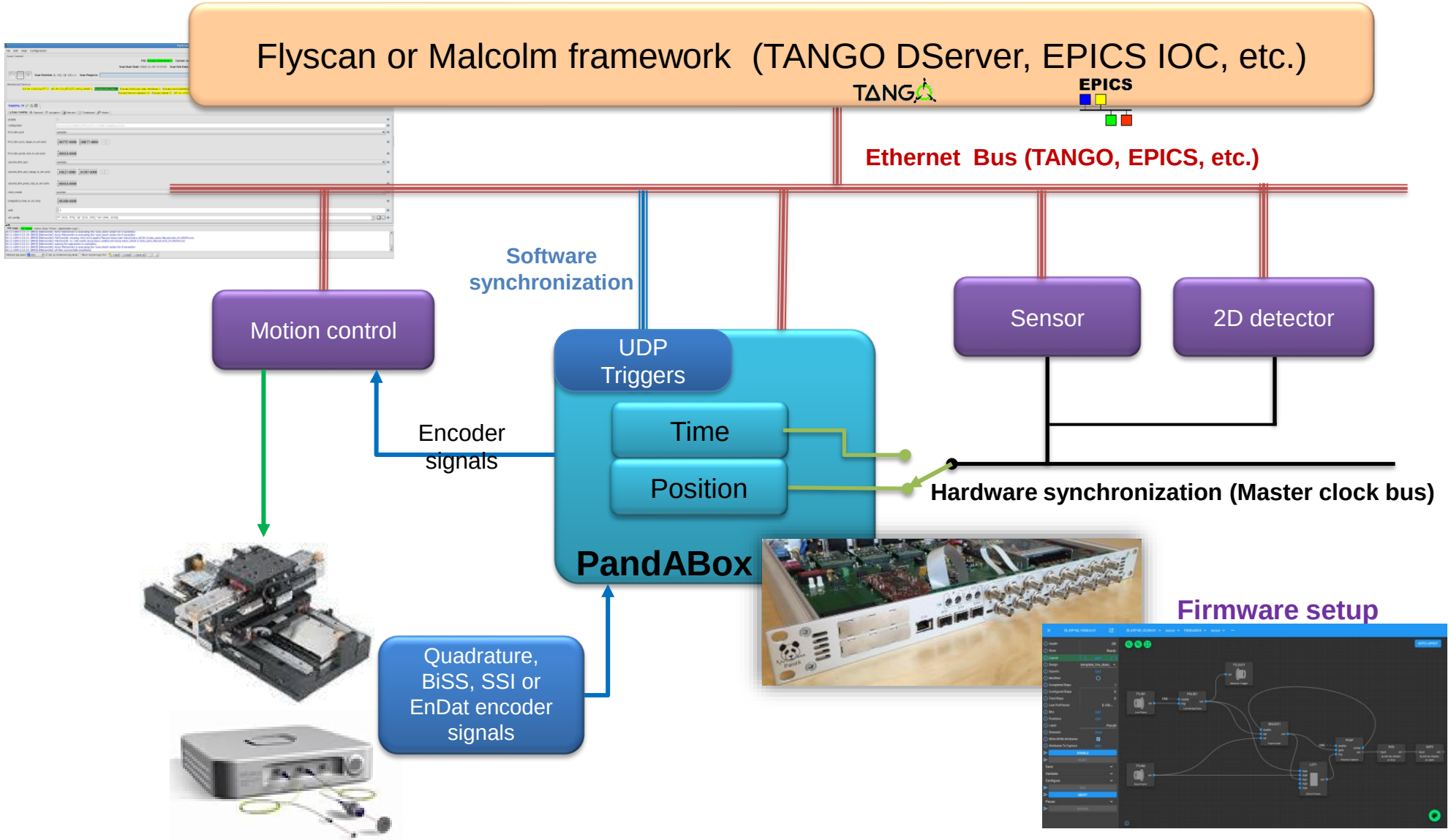
Continuous scanning application



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