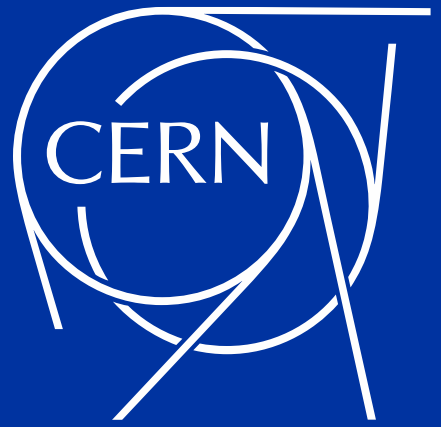


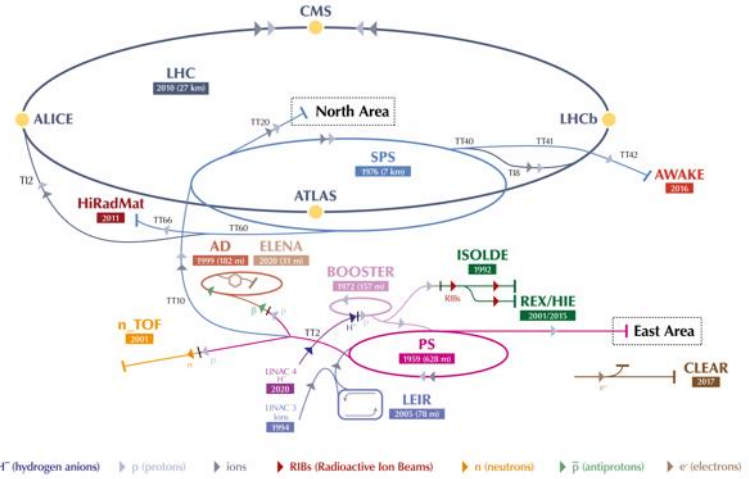
An introduction to CERN Beams Controls Software & Services

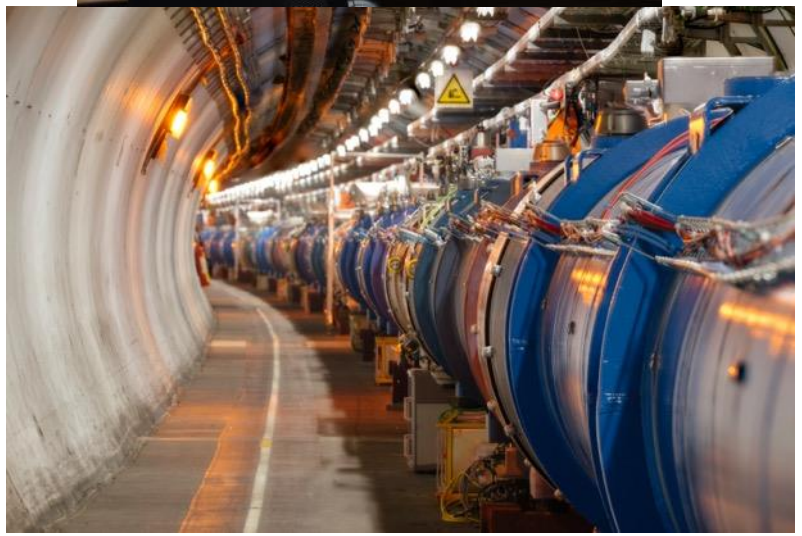
Chris Roderick

21-06-2024

CERN Beams Controls Software & Services

*"Provides **Control & Monitoring solutions** for all CERN **particle accelerators**, **transfer lines**, associated **experimental areas** & various supporting **technical infrastructure** services."*





Key aims:

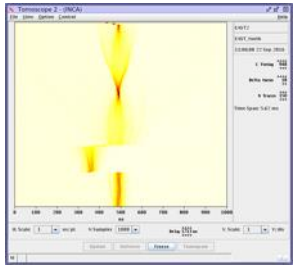
- As simple as possible
- High usability, stability, availability
- Common approach

CERN Beams Controls Software & Services

The Control System's job is to provide physicists and operators with a means to remotely:

Configure & Set states & reference values (aka *settings*) in active elements

Generate initial values, automate sequences, feedback loops, etc.



Monitor elements (instruments & actuators)

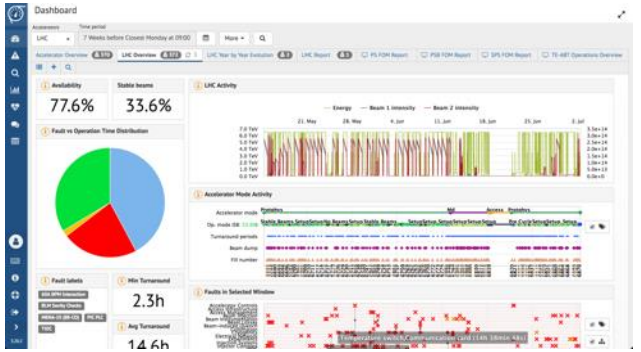
Time-tagged acquisitions with post-processing for quick detection of abnormal situations

Long-term memory of Settings & Acquisitions

Years of data with performant data extraction & analysis tools

Ensure machine protection & operational availability

High-level fast-reaction interlocks & role-based access to prevent wrong actions

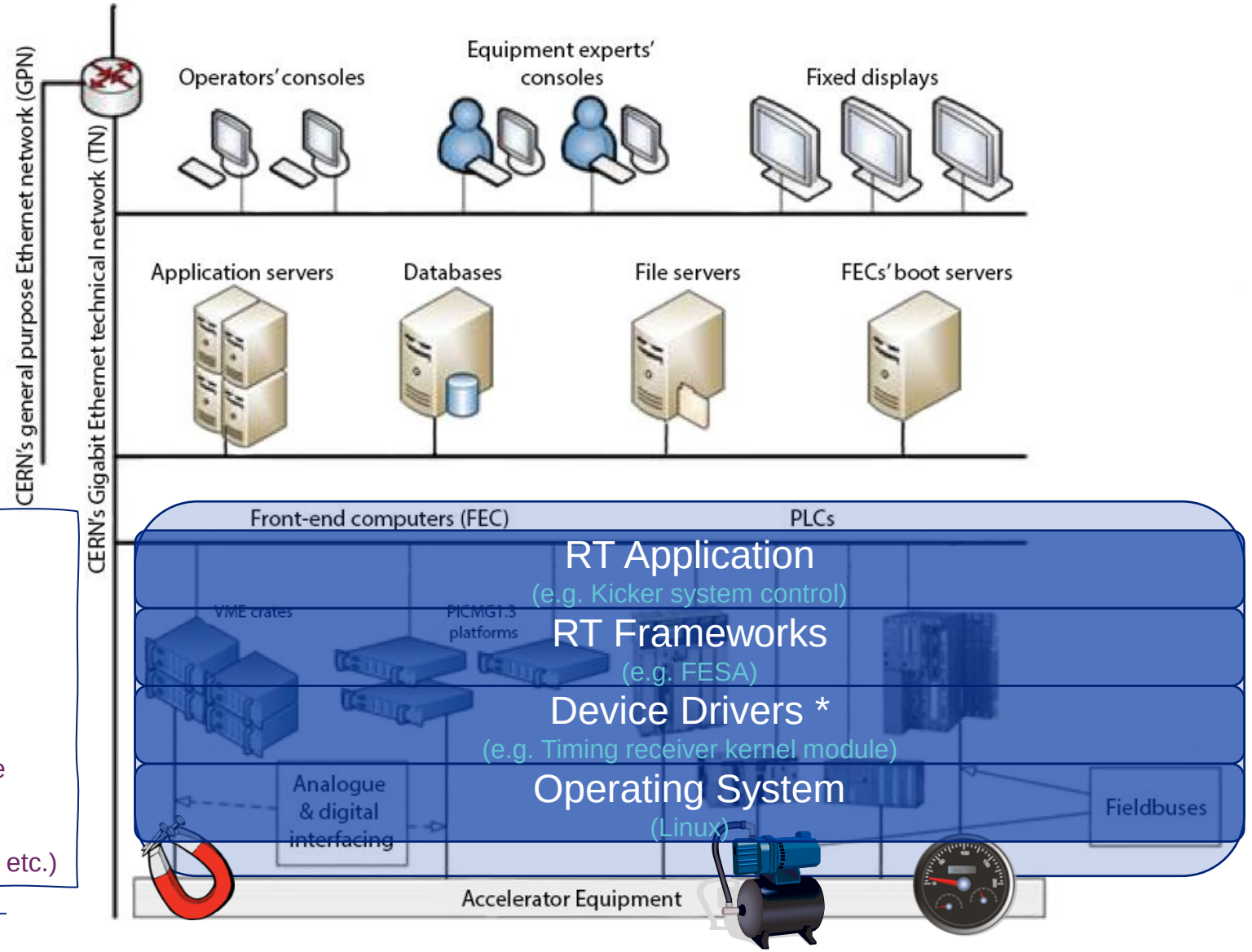


Health & Diagnostics monitoring for the multitude of sub-systems

Online failure detection, remote interventions (e.g. power cycle), failure prediction (Machine Learning) etc.

& much more…

High-Level Software Architecture



Front-end Tier

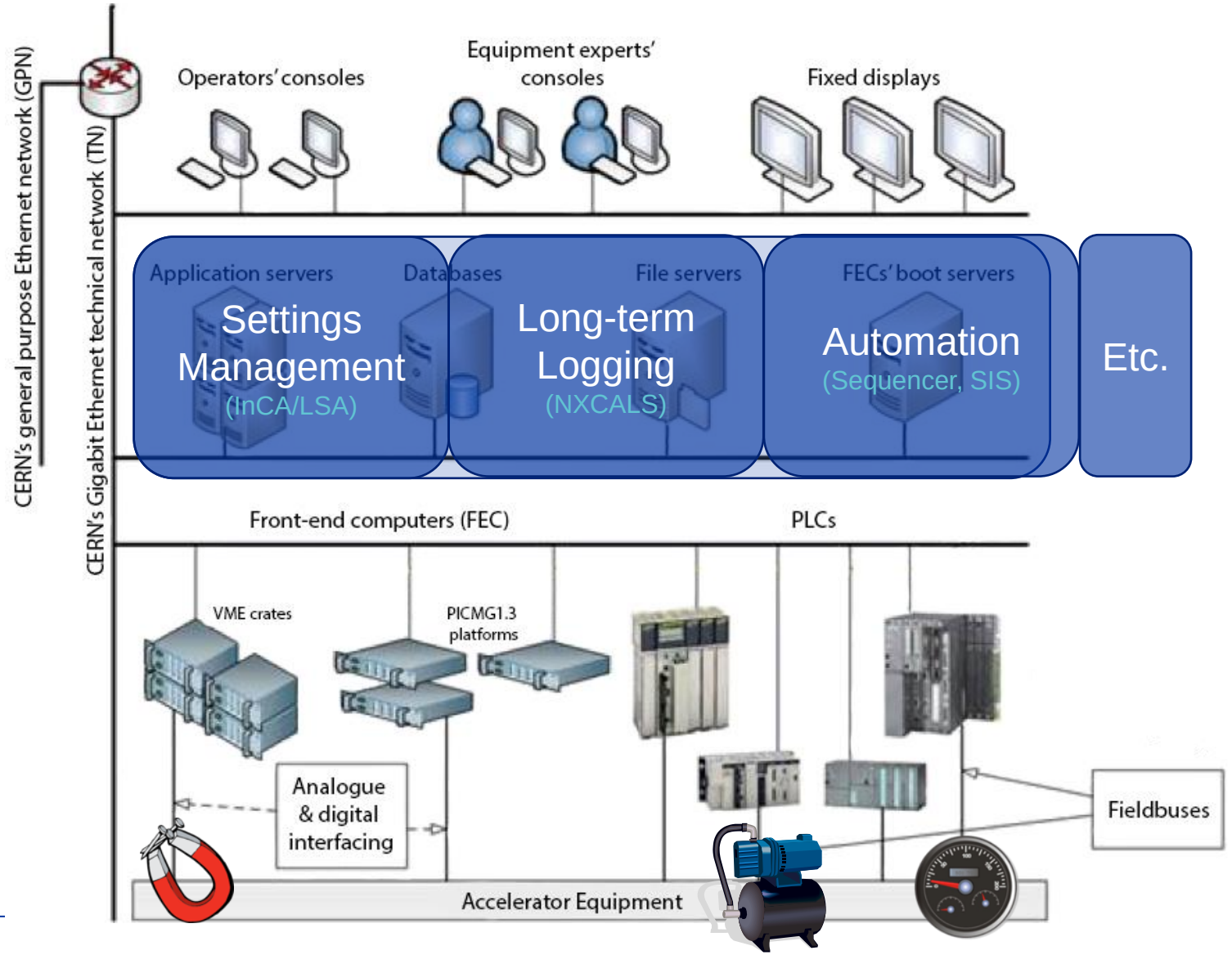
Real-time control and acquisition

- Limited, local scope
- Fast reaction possible (interrupts)
- Limited computing power (compared to other tiers)
- Equipment processing to provide a high-level view of hardware
- Real-time (RT) applications rely on frameworks, which capture recurring aspects (react to events, publish new data, etc.)
- Based on technologies close to HW (C for drivers, C++ for RT, etc.)

High-Level Software Architecture

Server Tier
General purpose services
& Specific business logic

- Broader scope; able to coordinate across entire accelerator
- Powerful computers
- Less reactive (network) and at a higher-level of abstraction
- Based on technologies suited for higher-level logic (e.g. Java)



High-Level Software Architecture

Client Tier

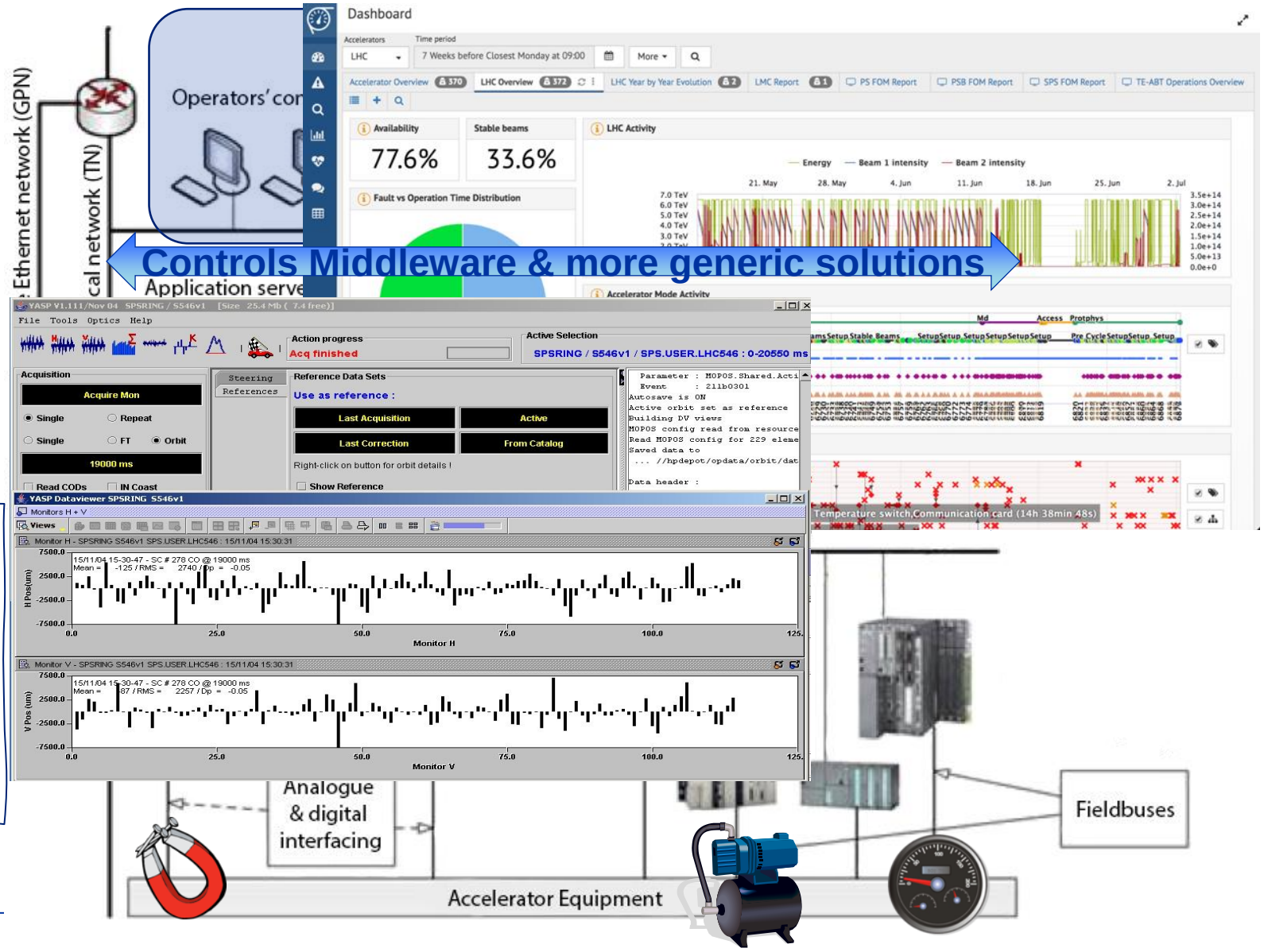
Graphical applications

Different technologies in use

- Java Swing, Java FX
- PyQt
- Web ecosystem (Angular)

Communication

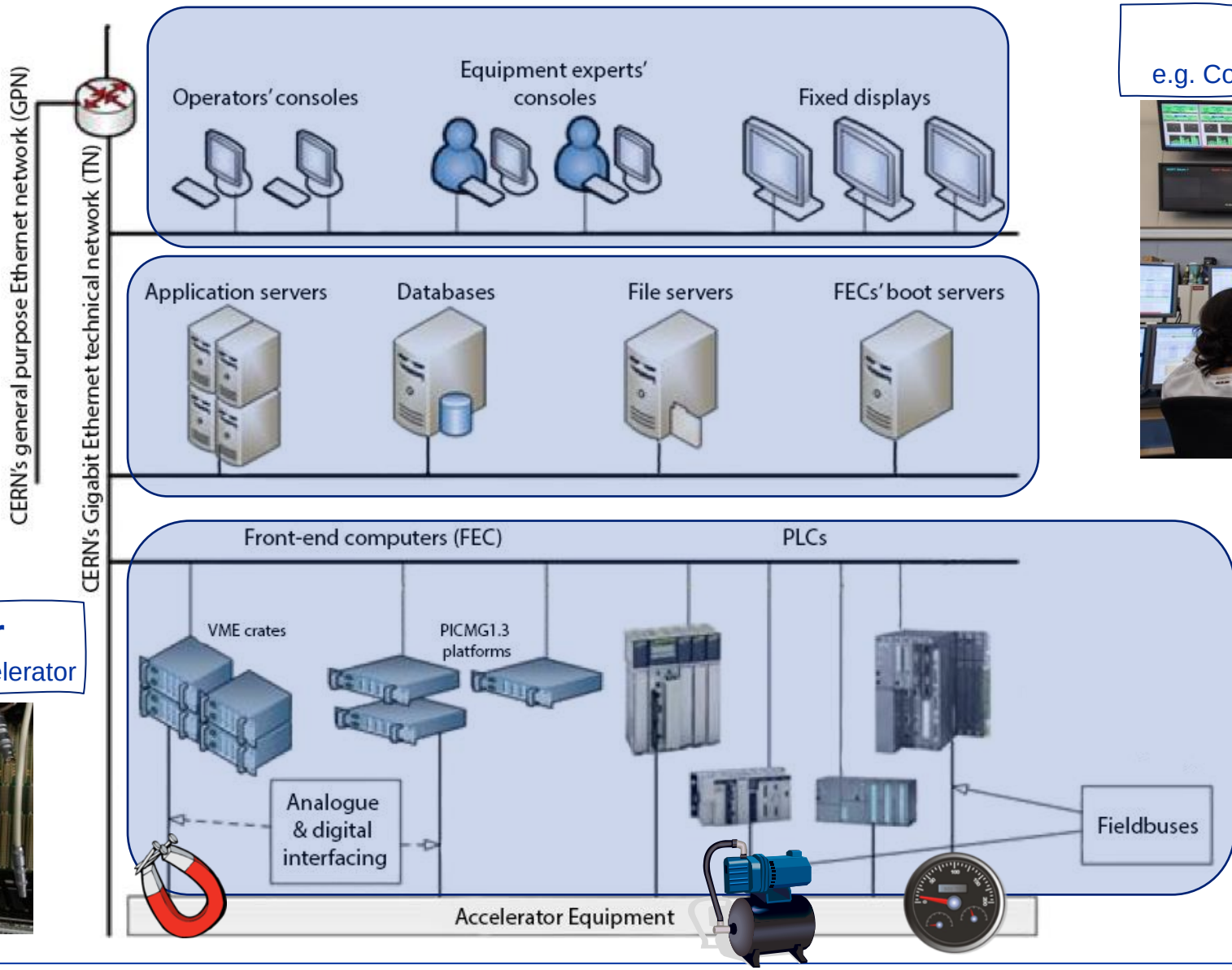
- Accelerator-specific protocols for the lower layers
  - Controls Middleware (CMW)
- More generic technologies for the higher layers
  - RMI/JMS
  - REST
  - gRPC
  - …



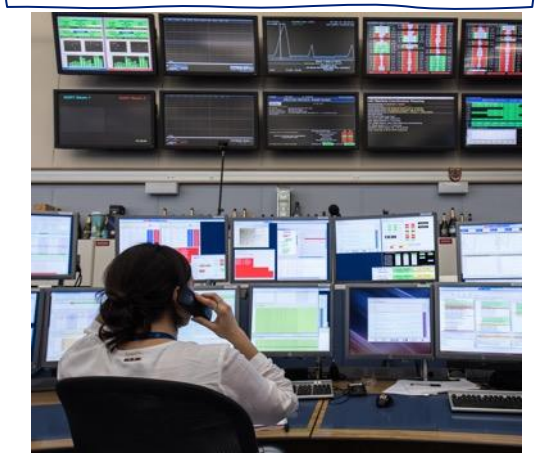
High-Level Hardware Architecture

Server Tier
Central computing infrastructure

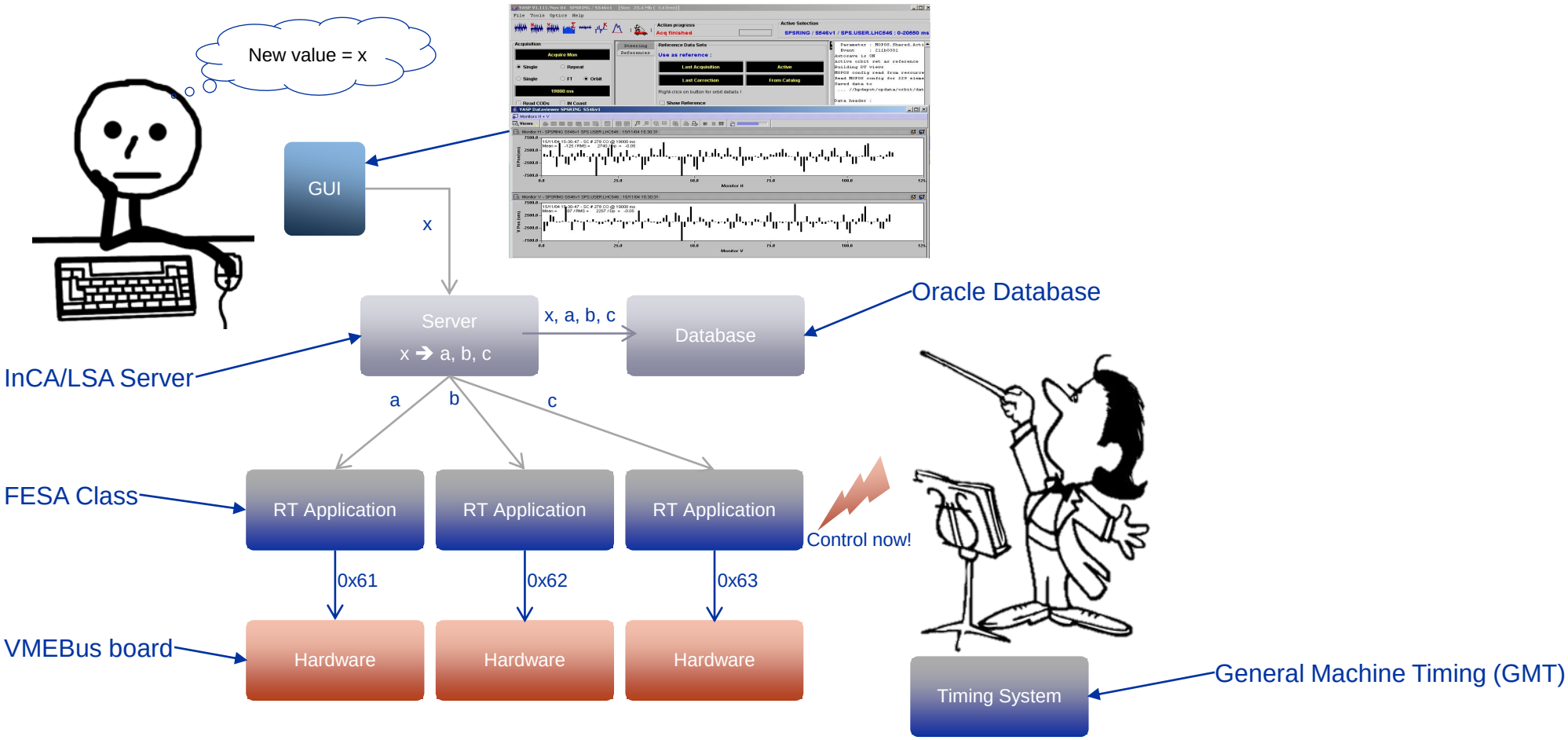
Resource Tier
Electronics close to the accelerator



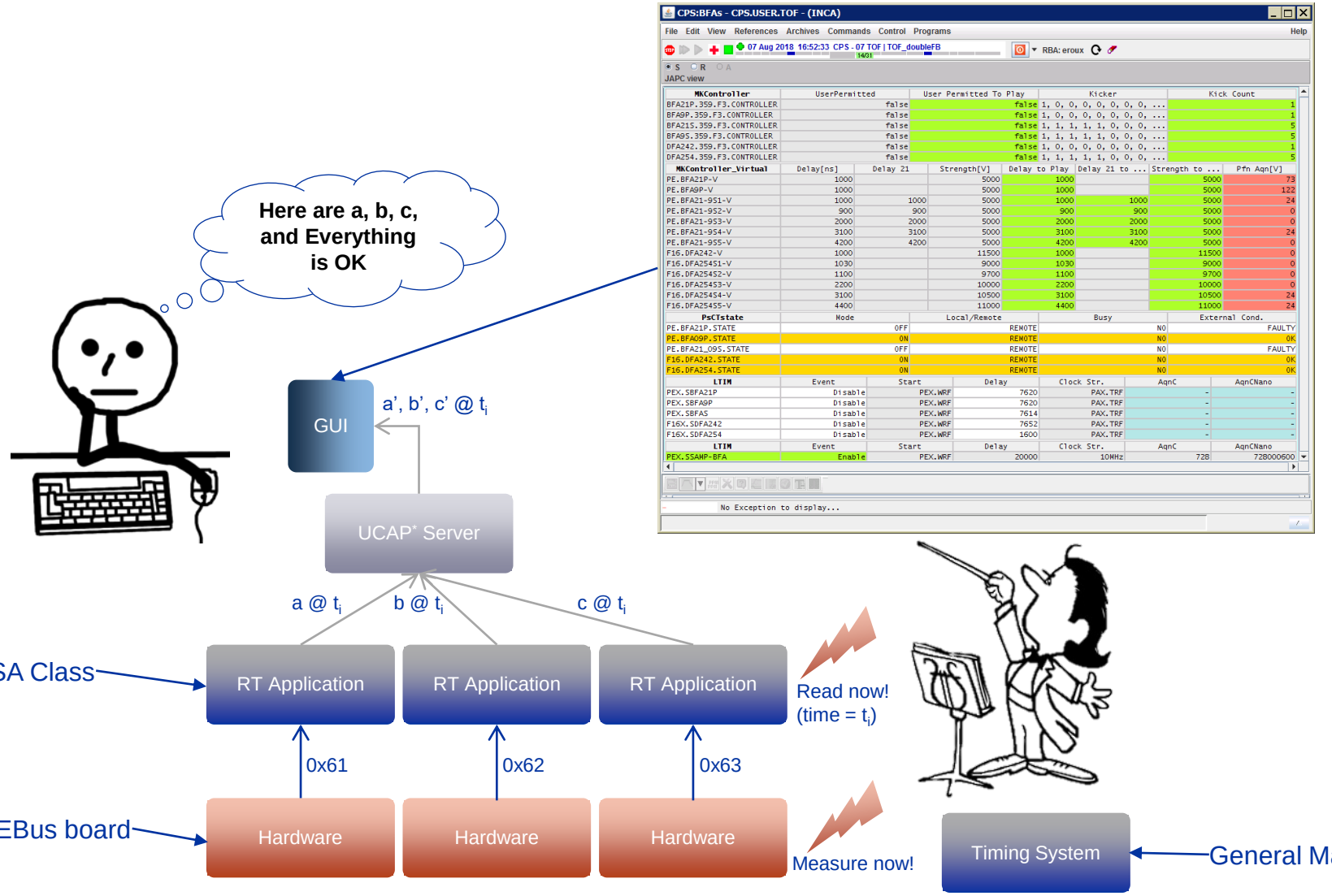
Client Tier
e.g. Control Room infrastructure



Examples – Accelerator Control

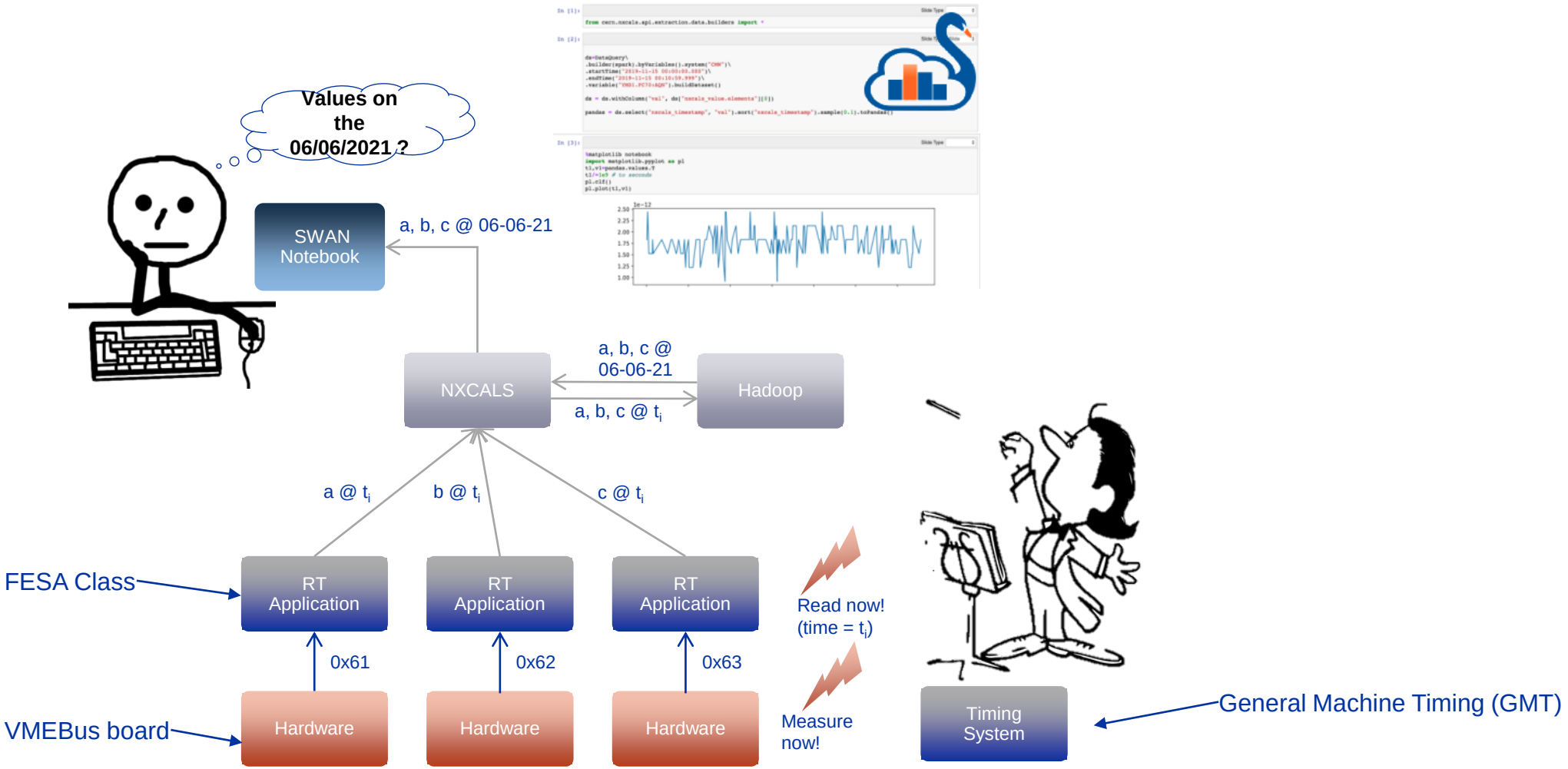


Examples – Equipment Monitoring



*UCAP: Unified Controls Acquisition & Processing framework

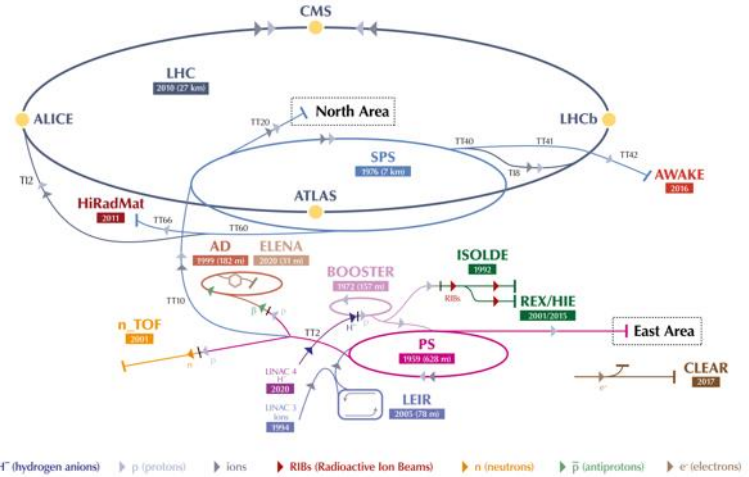
Examples – Timeseries Data Logging

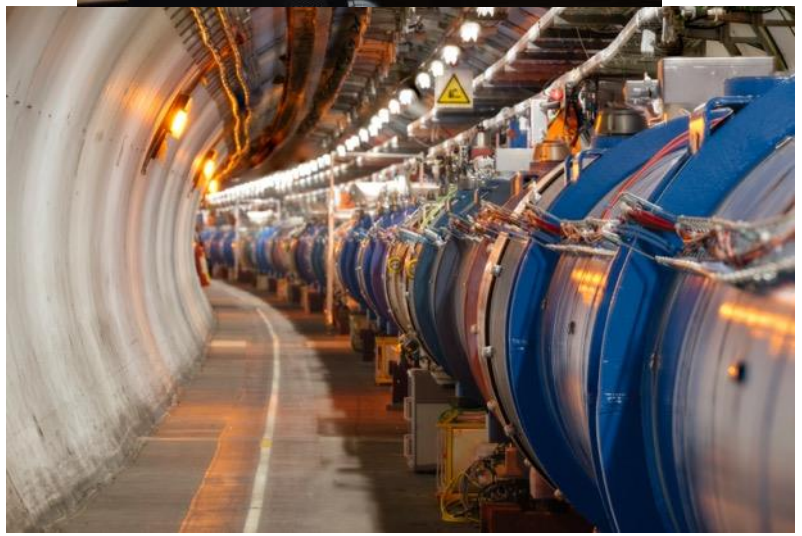


*SWAN: Service for Web based ANalysis

Questions?

*"Provides **Control & Monitoring solutions** for all CERN **particle accelerators**, **transfer lines**, associated **experimental areas** & various supporting **technical infrastructure** services."*



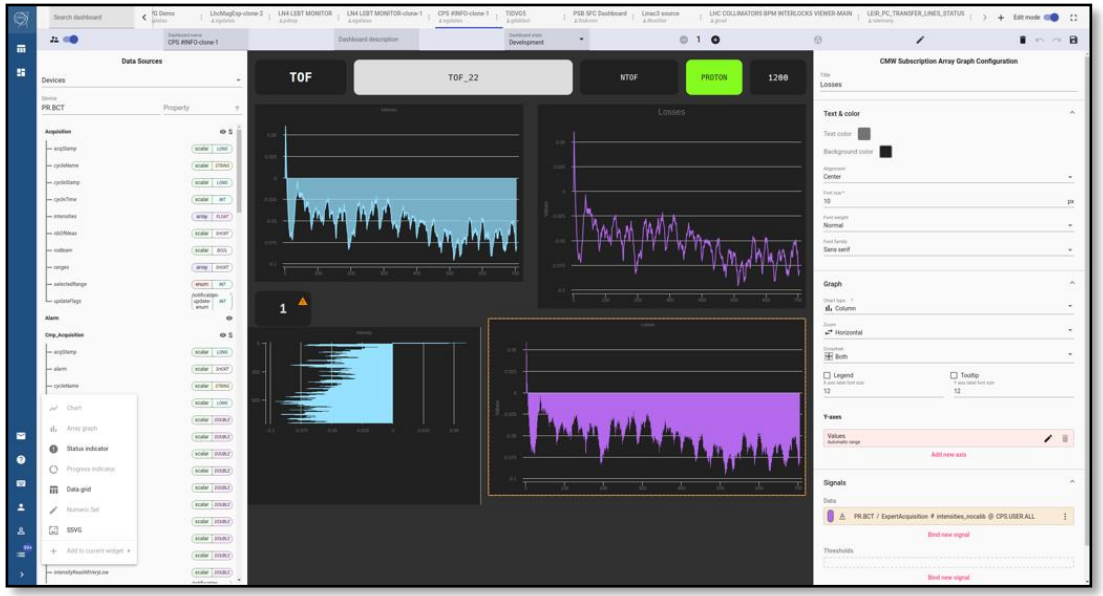


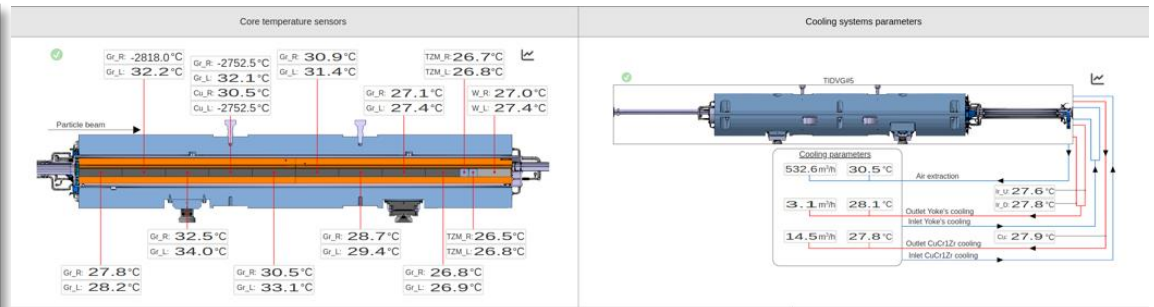
Key aims:

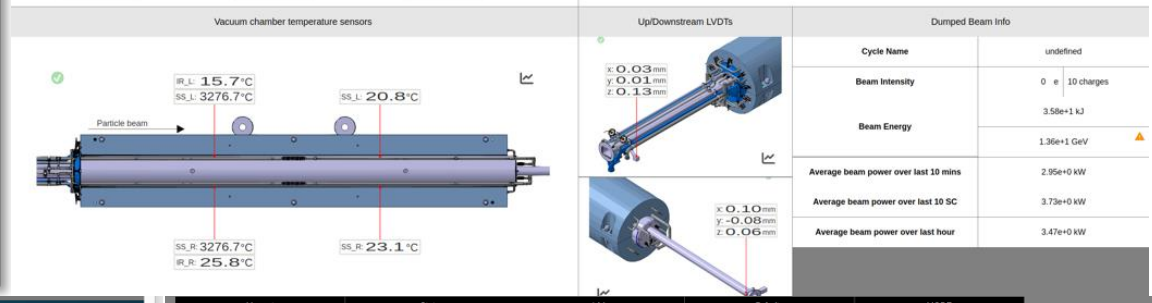
- As simple as possible
- High usability, stability, availability
- Common approach

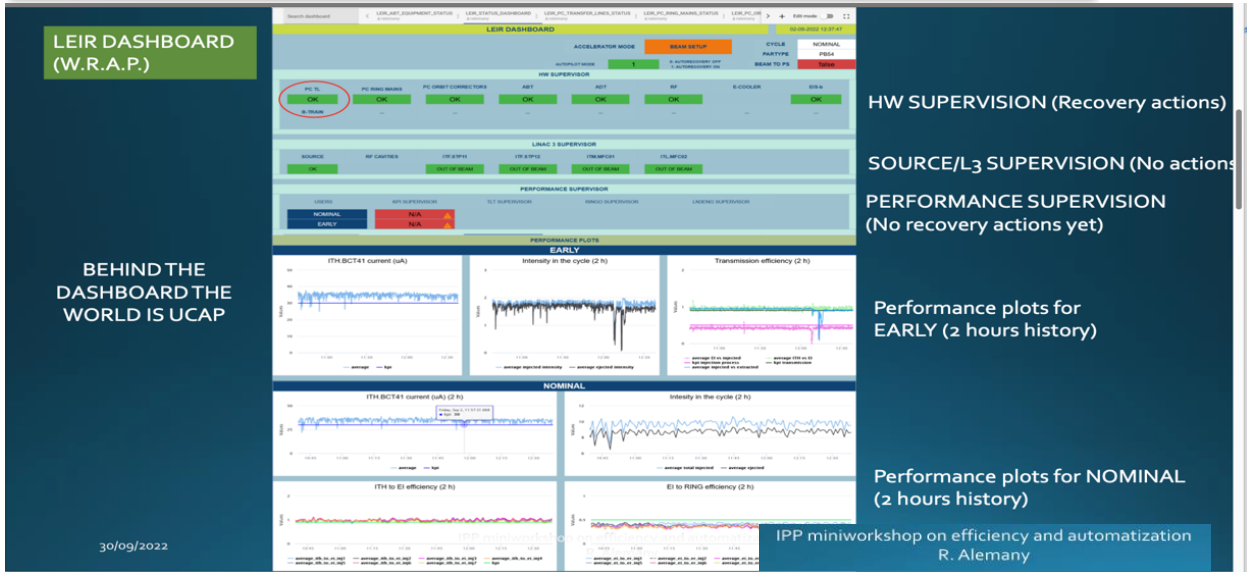
Additional Slides

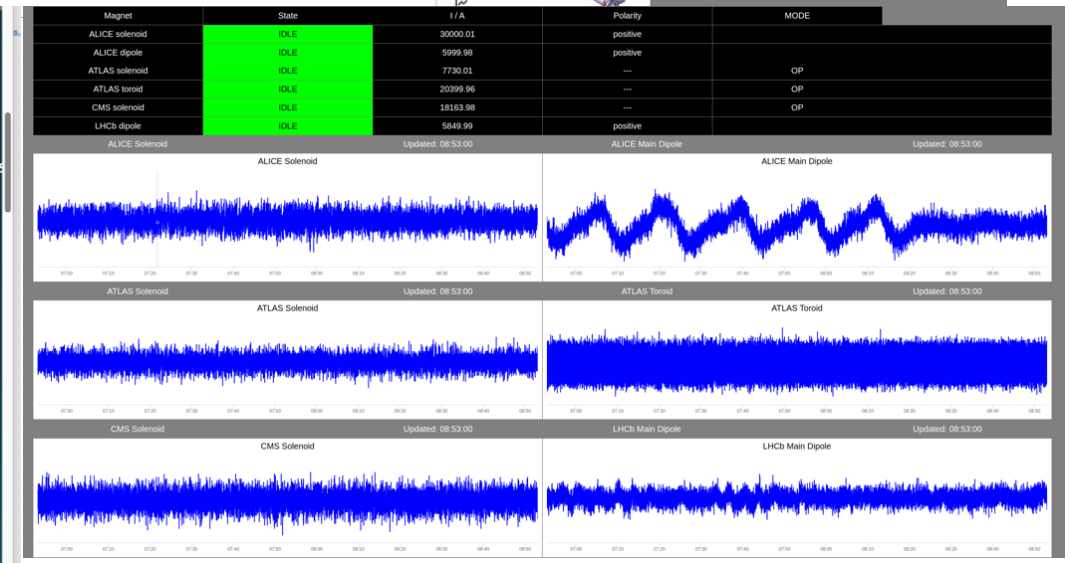
WRAP


TOF
TOF_22
NTOF
PROTON
1200
Losses

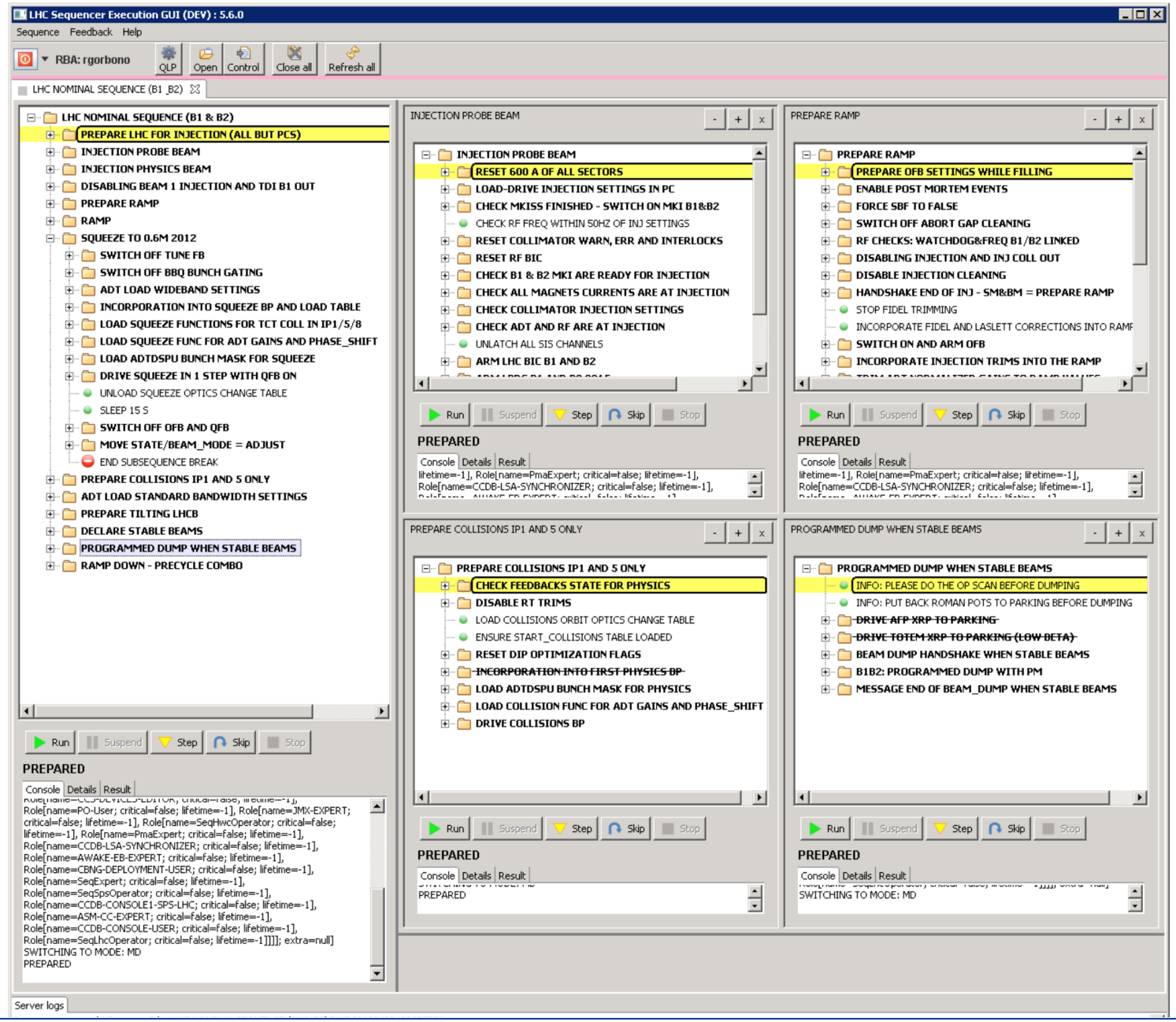

Core temperature sensors
Particle beam
Cooling systems parameters
Cooling parameters
Air extraction
Outlet Yoke's cooling
Inlet Yoke's cooling
Outlet CuCr1Zr cooling
Inlet CuCr1Zr cooling


Vacuum chamber temperature sensors
Particle beam
Up/Downstream LVDTs
Dumped Beam Info
Cycle Name
undefined
Beam Intensity
Beam Energy
Average beam power over last 10 mins
Average beam power over last 10 SC
Average beam power over last hour


LEIR DASHBOARD (W.R.A.P.)
BEHIND THE DASHBOARD THE WORLD IS UCAP
30/09/2022
HW SUPERVISION (Recovery actions)
SOURCE/L3 SUPERVISION (No actions
PERFORMANCE SUPERVISION (No recovery actions yet)
Performance plots for EARLY (2 hours history)
Performance plots for NOMINAL (2 hours history)
IPP miniworkshop on efficiency and automatization
R. Alemany

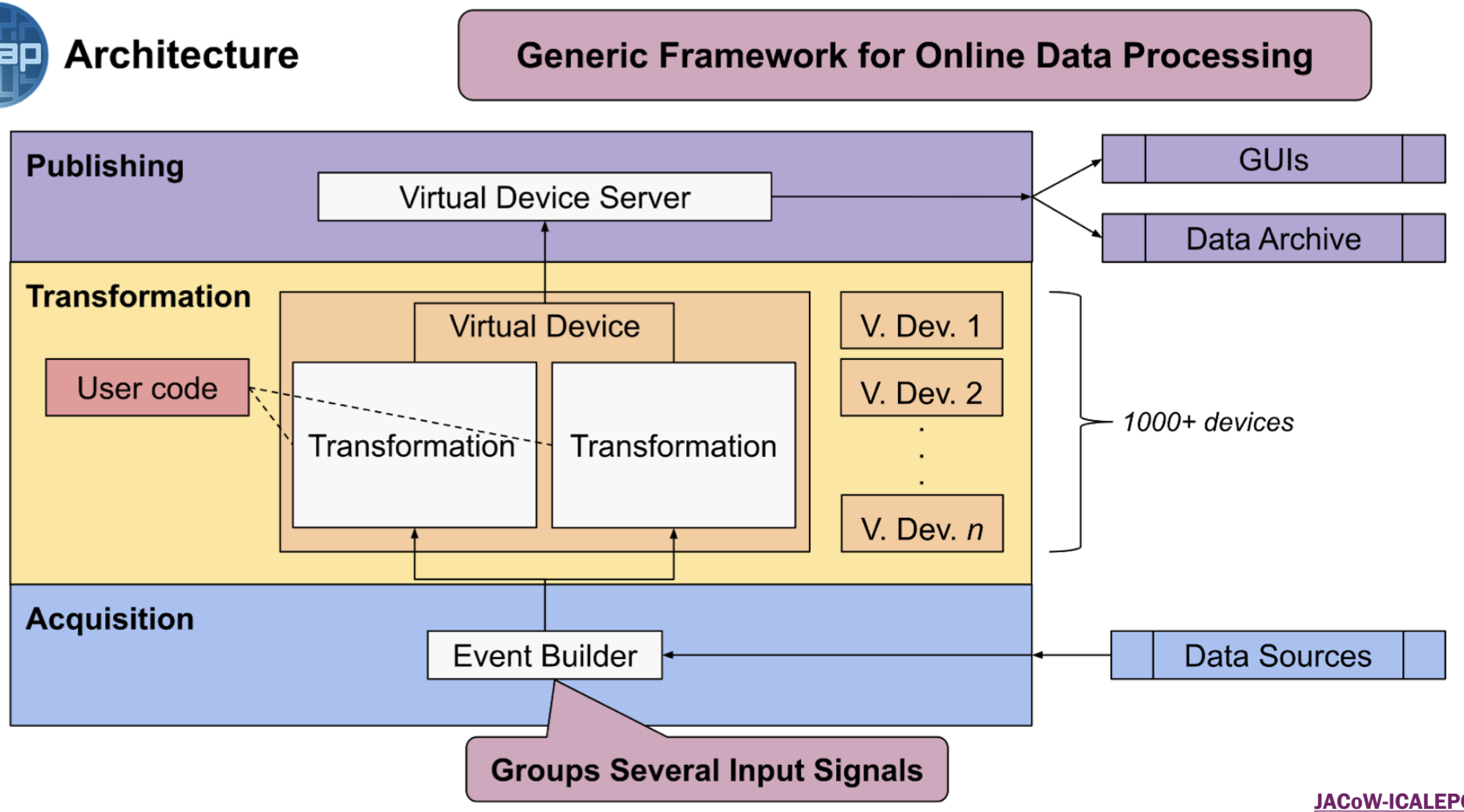

Magnet
State
I / A
Polarity
MODE
ALICE solenoid
ALICE dipole
ATLAS solenoid
ATLAS toroid
CMS solenoid
LHCb dipole
ALICE Solenoid
ALICE Main Dipole
ATLAS Solenoid
ATLAS Toroid
CMS Solenoid
LHCb Main Dipole

Sequencer


LHC Sequencer Execution GUI (DEV) : 5.6.0
Sequence Feedback Help
RBA: rgorbono
QLP Open Control Close all Refresh all
LHC NOMINAL SEQUENCE (B1 _B2)
LHC NOMINAL SEQUENCE (B1 & B2)
PREPARE LHC FOR INJECTION (ALL BUT PCS)
INJECTION PROBE BEAM
INJECTION PHYSICS BEAM
DISABLING BEAM 1 INJECTION AND TDI B1 OUT
PREPARE RAMP
RAMP
SQUEEZE TO 0.6M 2012
SWITCH OFF TUNE FB
SWITCH OFF BBQ BUNCH GATING
ADT LOAD WIDEBAND SETTINGS
INCORPORATION INTO SQUEEZE BP AND LOAD TABLE
LOAD SQUEEZE FUNCTIONS FOR TCT COLL IN IP1/5/8
LOAD SQUEEZE FUNC FOR ADT GAINS AND PHASE_SHIFT
LOAD ADTDSPU BUNCH MASK FOR SQUEEZE
DRIVE SQUEEZE IN 1 STEP WITH QFB ON
UNLOAD SQUEEZE OPTICS CHANGE TABLE
SLEEP 15 S
SWITCH OFF OFB AND QFB
MOVE STATE/BEAM_MODE = ADJUST
END SUBSEQUENCE BREAK
PREPARE COLLISIONS IP1 AND 5 ONLY
ADT LOAD STANDARD BANDWIDTH SETTINGS
PREPARE TILTING LHCB
DECLARE STABLE BEAMS
PROGRAMMED DUMP WHEN STABLE BEAMS
RAMP DOWN - PRECYCLE COMBO
Run Suspend Step Skip Stop
PREPARED
Console Details Result
Role[name=PO-User; critical=false; lifetime=-1], Role[name=JMX-EXPERT; critical=false; lifetime=-1], Role[name=SeqHwcOperator; critical=false; lifetime=-1], Role[name=PmaExpert; critical=false; lifetime=-1], Role[name=CCDB-LSA-SYNCHRONIZER; critical=false; lifetime=-1], Role[name=AWAKE-EB-EXPERT; critical=false; lifetime=-1], Role[name=CBNG-DEPLOYMENT-USER; critical=false; lifetime=-1], Role[name=SeqExpert; critical=false; lifetime=-1], Role[name=SeqSpsOperator; critical=false; lifetime=-1], Role[name=CCDB-CONSOLE1-SPS-LHC; critical=false; lifetime=-1], Role[name=ASM-CC-EXPERT; critical=false; lifetime=-1], Role[name=CCDB-CONSOLE-USER; critical=false; lifetime=-1], Role[name=SeqLhcOperator; critical=false; lifetime=-1]]]]; extra=null]
SWITCHING TO MODE: MD
PREPARED
INJECTION PROBE BEAM
INJECTION PROBE BEAM
RESET 600 A OF ALL SECTORS
LOAD-DRIVE INJECTION SETTINGS IN PC
CHECK MKISS FINISHED - SWITCH ON MKI B1&B2
CHECK RF FREQ WITHIN 50HZ OF INJ SETTINGS
RESET COLLIMATOR WARN, ERR AND INTERLOCKS
RESET RF BIC
CHECK B1 & B2 MKI ARE READY FOR INJECTION
CHECK ALL MAGNETS CURRENTS ARE AT INJECTION
CHECK COLLIMATOR INJECTION SETTINGS
CHECK ADT AND RF ARE AT INJECTION
UNLATCH ALL SIS CHANNELS
ARM LHC BIC B1 AND B2
Run Suspend Step Skip Stop
PREPARED
Console Details Result
lifetime=-1], Role[name=PmaExpert; critical=false; lifetime=-1], Role[name=CCDB-LSA-SYNCHRONIZER; critical=false; lifetime=-1],
PREPARE RAMP
PREPARE RAMP
PREPARE OFB SETTINGS WHILE FILLING
ENABLE POST MORTEM EVENTS
FORCE SBF TO FALSE
SWITCH OFF ABORT GAP CLEANING
RF CHECKS: WATCHDOG&FREQ B1/B2 LINKED
DISABLING INJECTION AND INJ COLL OUT
DISABLE INJECTION CLEANING
HANDSHAKE END OF INJ - SM&BM = PREPARE RAMP
STOP FIDEL TRIMMING
INCORPORATE FIDEL AND LASLETT CORRECTIONS INTO RAMP
SWITCH ON AND ARM OFB
INCORPORATE INJECTION TRIMS INTO THE RAMP
Run Suspend Step Skip Stop
PREPARED
Console Details Result
lifetime=-1], Role[name=PmaExpert; critical=false; lifetime=-1], Role[name=CCDB-LSA-SYNCHRONIZER; critical=false; lifetime=-1],
PREPARE COLLISIONS IP1 AND 5 ONLY
PREPARE COLLISIONS IP1 AND 5 ONLY
CHECK FEEDBACKS STATE FOR PHYSICS
DISABLE RT TRIMS
LOAD COLLISIONS ORBIT OPTICS CHANGE TABLE
ENSURE START_COLLISIONS TABLE LOADED
RESET DIP OPTIMIZATION FLAGS
INCORPORATION INTO FIRST PHYSICS BP
LOAD ADTDSPU BUNCH MASK FOR PHYSICS
LOAD COLLISION FUNC FOR ADT GAINS AND PHASE_SHIFT
DRIVE COLLISIONS BP
Run Suspend Step Skip Stop
PREPARED
Console Details Result
PREPARED
PROGRAMMED DUMP WHEN STABLE BEAMS
PROGRAMMED DUMP WHEN STABLE BEAMS
INFO: PLEASE DO THE OP SCAN BEFORE DUMPING
INFO: PUT BACK ROMAN POTS TO PARKING BEFORE DUMPING
DRIVE AFP XRP TO PARKING
DRIVE TOTEM XRP TO PARKING (LOW BETA)
BEAM DUMP HANDSHAKE WHEN STABLE BEAMS
B1B2: PROGRAMMED DUMP WITH PM
MESSAGE END OF BEAM_DUMP WHEN STABLE BEAMS
Run Suspend Step Skip Stop
PREPARED
Console Details Result
SWITCHING TO MODE: MD
Server logs

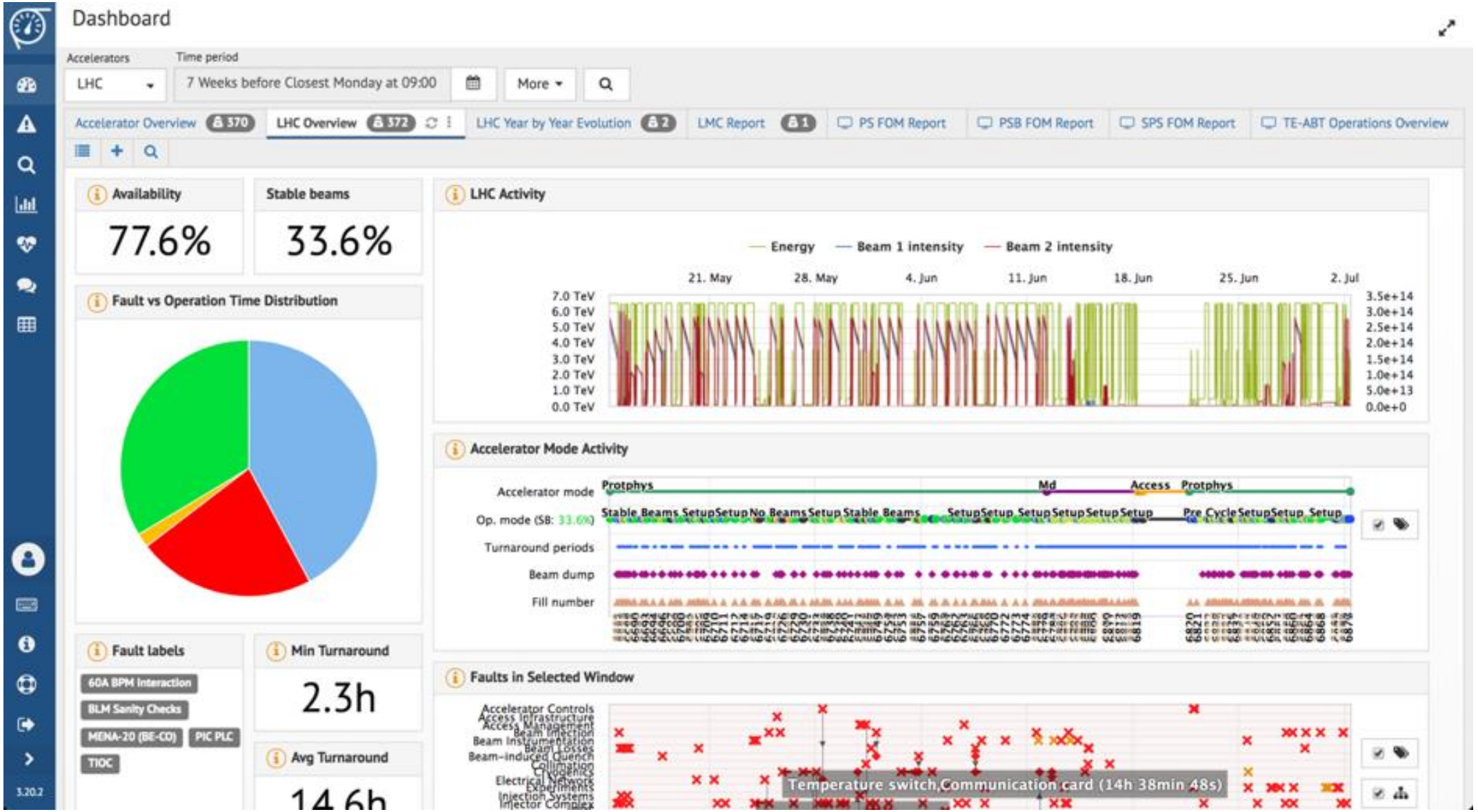
UCAP

Architecture



Find more at:
JACoW-ICALEPCS2021-MOPV039_Poster
JACoW-ICALEPCS2021-MOPV039_Paper

Fault Tracking & Availability



NXCALS – Data Logging System

Data Sources

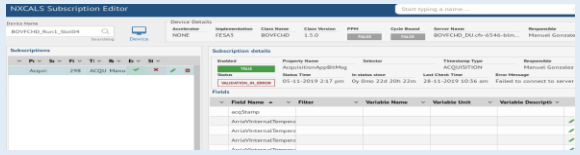
TIM & REMUS Datasources

WinCC OA Datasources

CMW Datasources

Settings, PM, etc

Configuration via CCDE



Data Storage

kafka cluster

ETL

ETL

ETL

ETL

APACHE HBASE

hadoop HDFS

ORACLE

Heterogenous Inputs

Spark API

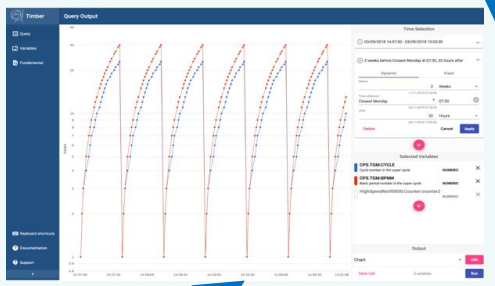
NXCALS Data Access API

MetaData API

Data Extraction

SWAN (Jupyter)

TIMBER - GUI



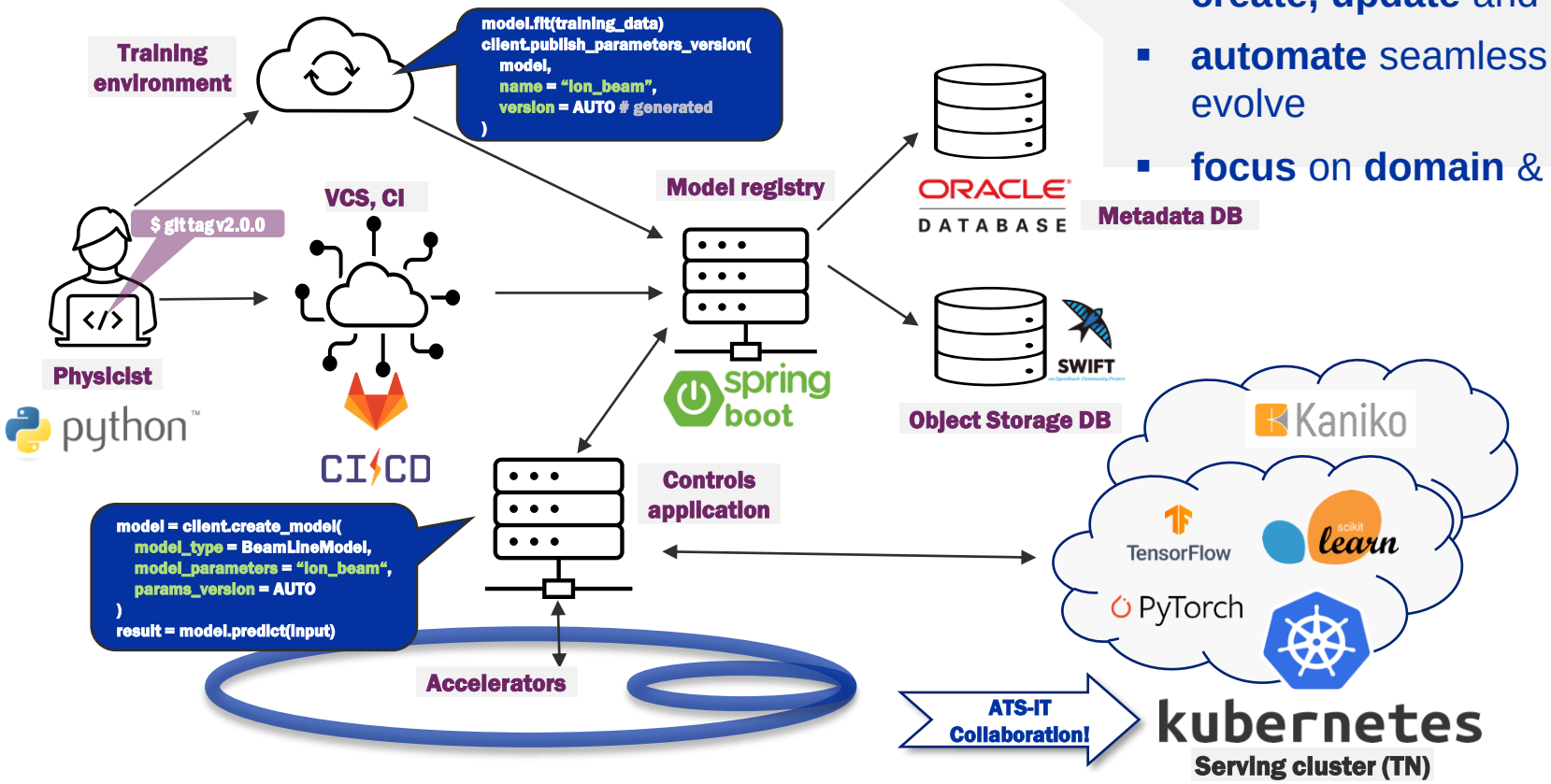
CERN Specific API

Spark Bundle "pip install nxcals"

Extensive Set of APIs & Tools

Machine Learning Platform (MLP)

Machine Learning Platform (MLP) is the **new central platform** for **storing**, **versioning** and **deploying** ML **models** in the CERN **Control Centre**



- **create, update** and **deploy** models with **minimal effort**
- **automate** seamless model updates as machines characteristics evolve
- **focus** on **domain** & **ML** by abstracting the infrastructure

Find more at:
JACoW-ICALEPCS2021-MOBL03
https://indico.cern.ch/event/1175862/