Automated equipment monitoring: status and evolution

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With thanks to R. Alemany, S. Massot, M. Hostettler, P. Skowronski, E. Veyrunes

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Overview

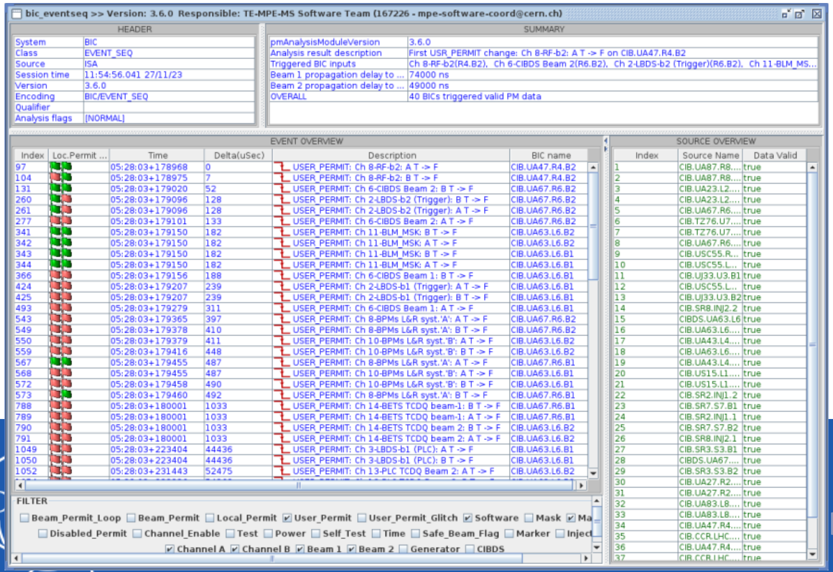
- **Introduction**
  - Purpose of monitoring
  - Systems in place across the complex
- **EPA WP8 – towards smart equipment**
  - OP monitoring
  - Status and plans for generic framework
- **Conclusions**

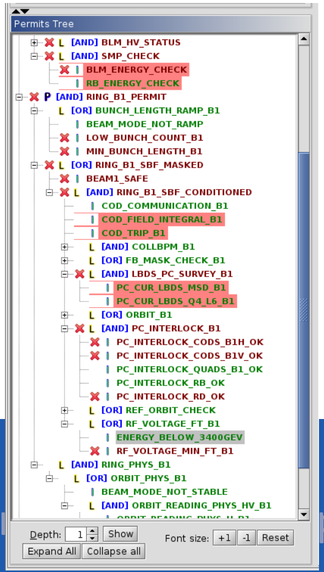
Purpose of monitoring

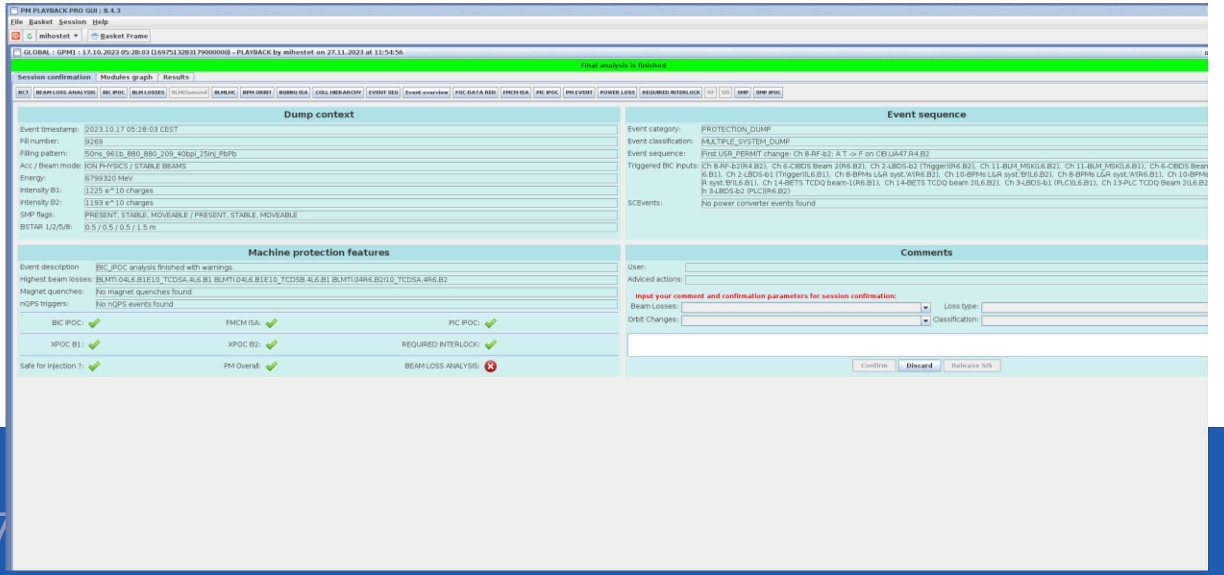
- **Avoid and reduce downtime** of our accelerators and facilities
- Provide a **snapshot** of the status of an entity, a family of equipment, an accelerator, …
- Basis for **interlocking** (BIS, SIS, external conditions, etc.)
- **Distribute** critical and non-critical **information** to various clients (OP teams, users, exchange between machines, AFT, equipment owners, etc.)
- **Trigger** manual and automatic **actions** (recovery of equipment, beam steering, etc.)
- **Predict** future equipment **behavior**

Systems in place across the complex

- **Various solutions are being used across the chain**
  - Differences are based on **criticality of interlocking**, **know-how** of available tools, **cycle length**, **number of users**, and **history**
- **LHC and SPS**
  - Operation relies on **BIS** and **SIS**, with critical hardware being direct input to the interlock system
    - machine protection: equipment failure needs to trigger beam dump asap
    - equipment monitoring used to understand the dump cause in a second stage
    - SIS (GUI and logic) tailor made for LHC and also well suitable for SPS due to cycle lengths
  - **Post-Mortem system** an additional asset for (online) fault analysis (PM-triggered UCAP AFT actor)
  - **LHCIQC** and **SPSQC** for beam quality monitoring, **BigSister** as second SIS instance to announce alarms

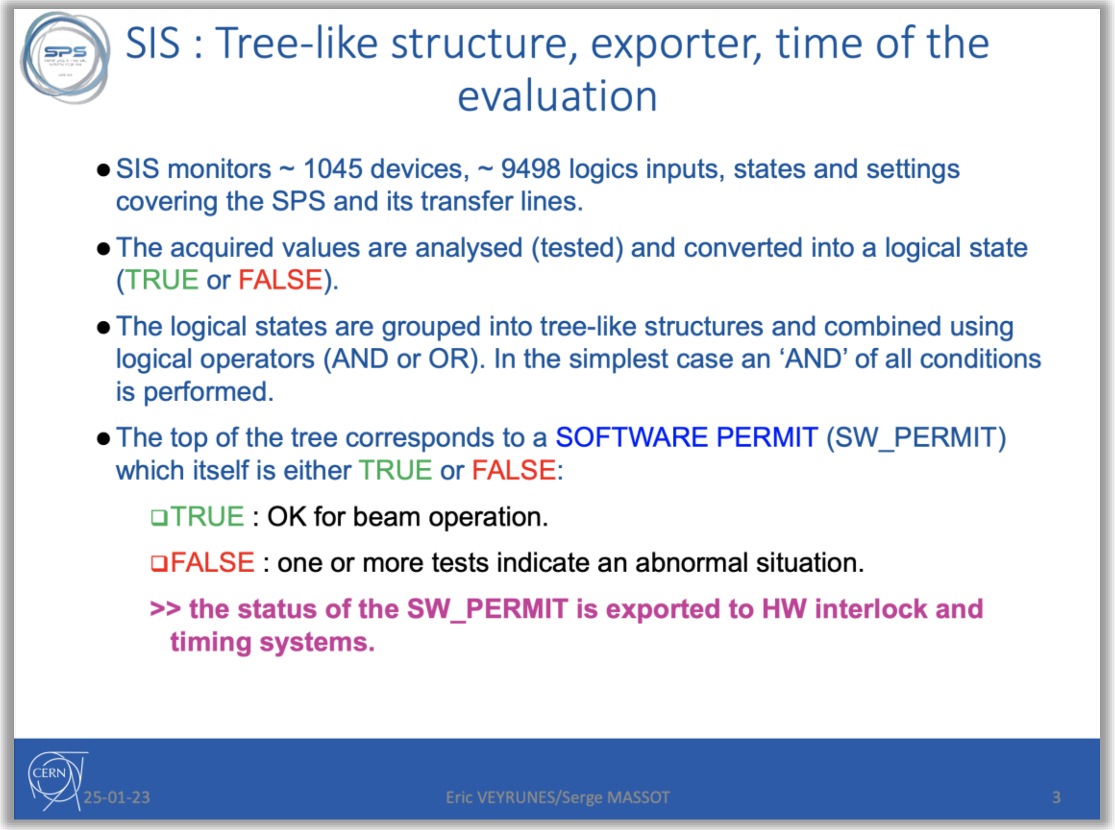


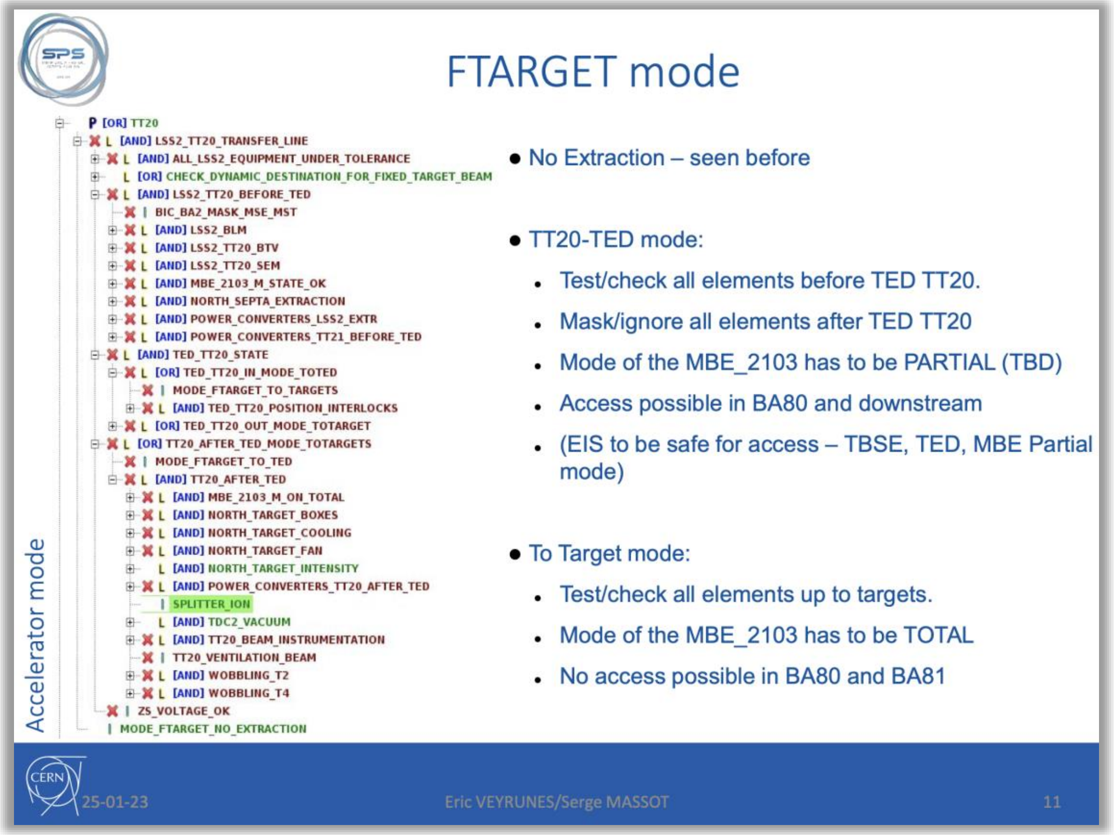




Systems in place across the complex

- **SPS**

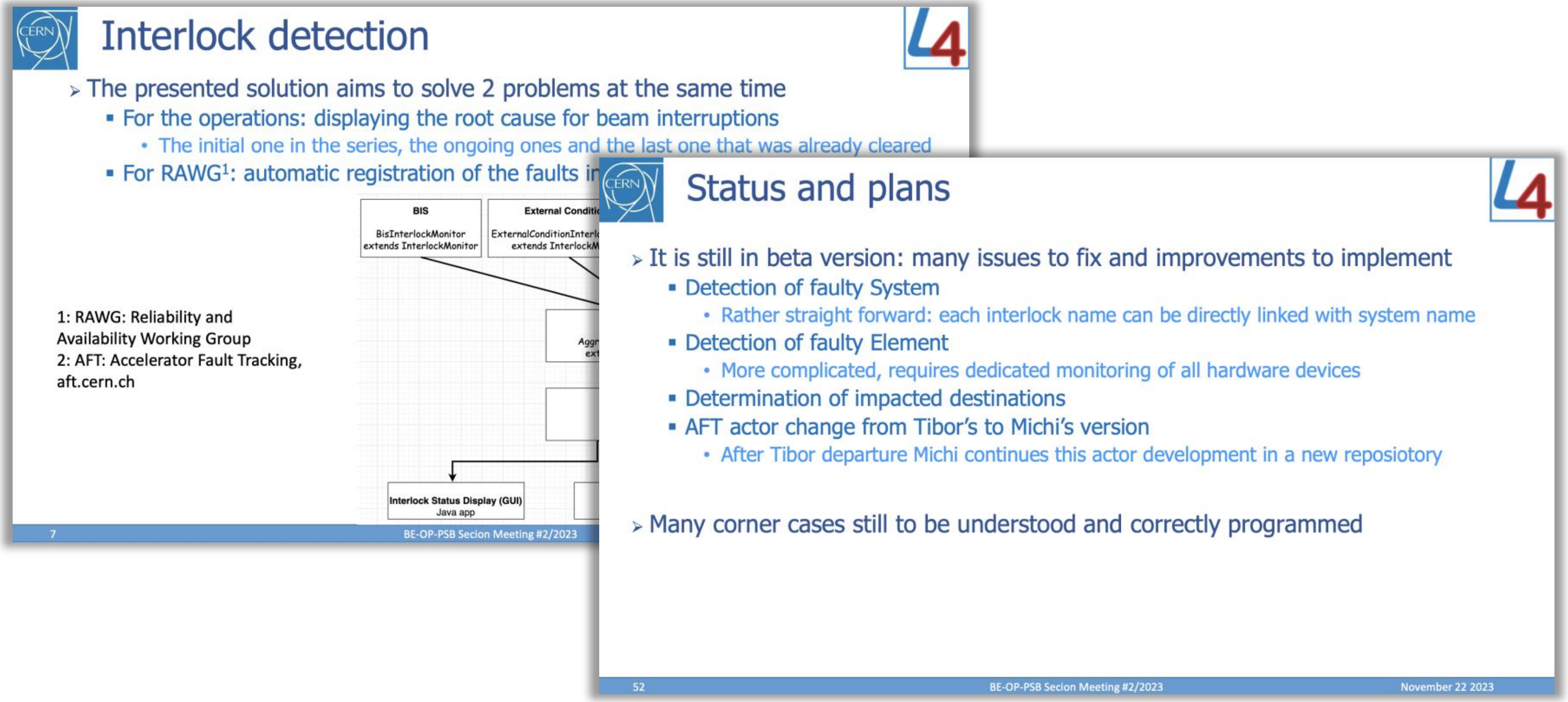




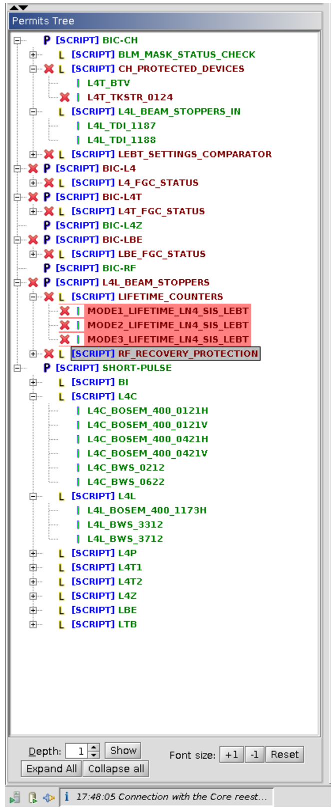
S. Massot, E. Veyrunes, Interlocks SPS, OP shutdown lecture, 2023

Systems in place across the complex

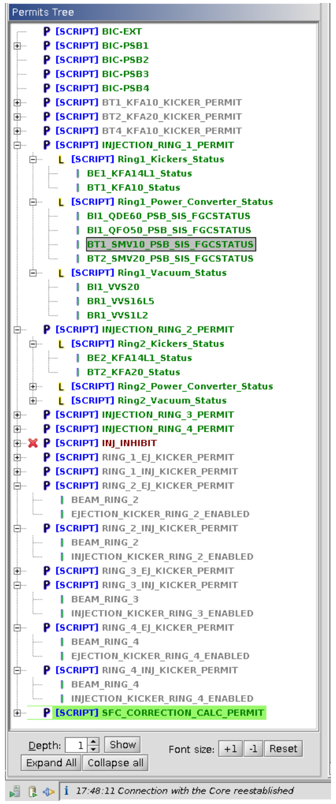
- **Linac4 and PSB**
  - SIS limitations for fast cycling machines → **UCAP developments**



Linac4 SIS



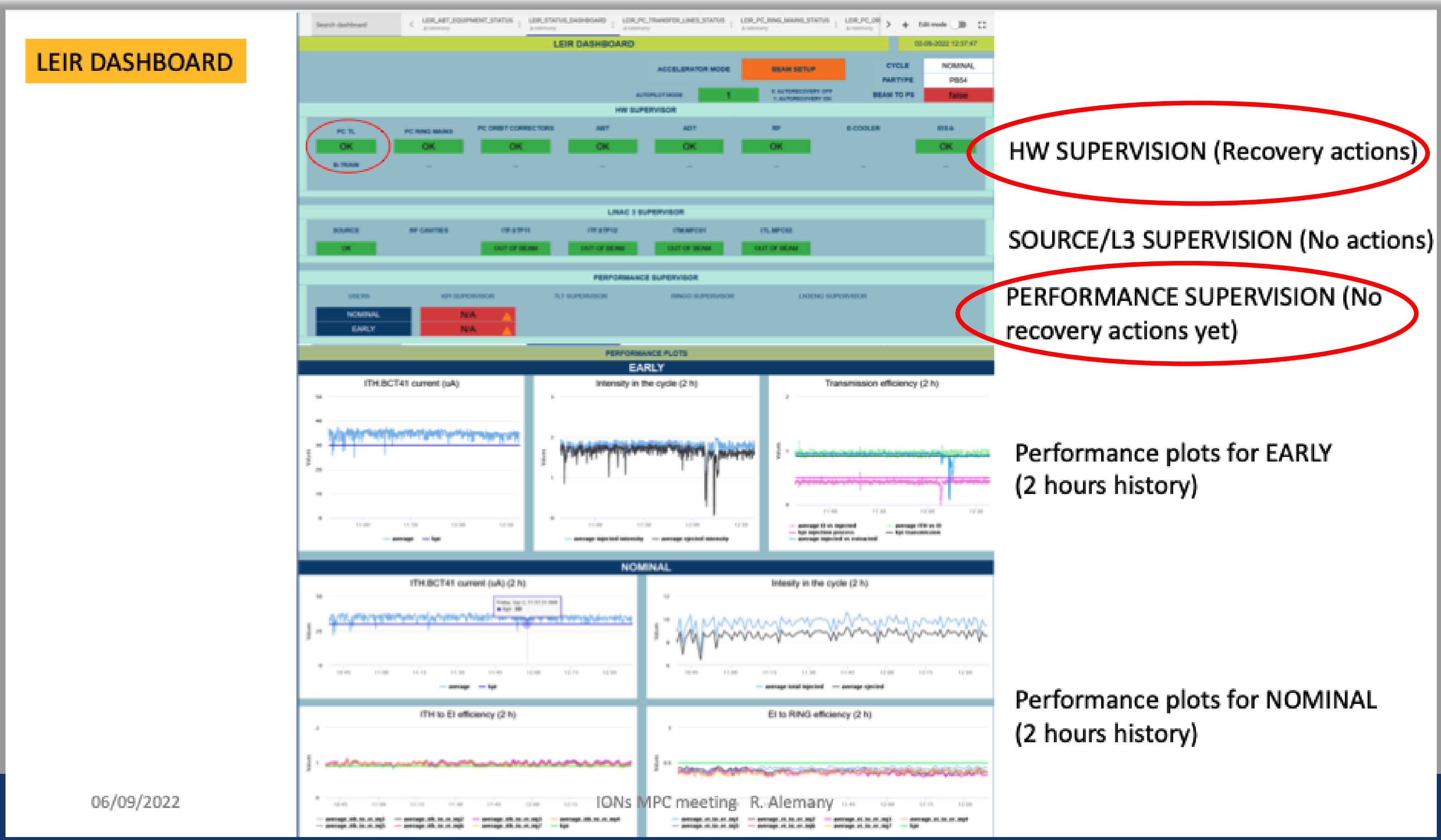
PSB SIS



P. Skowronski, Linac4 Interlocking and AFT

Systems in place across the complex

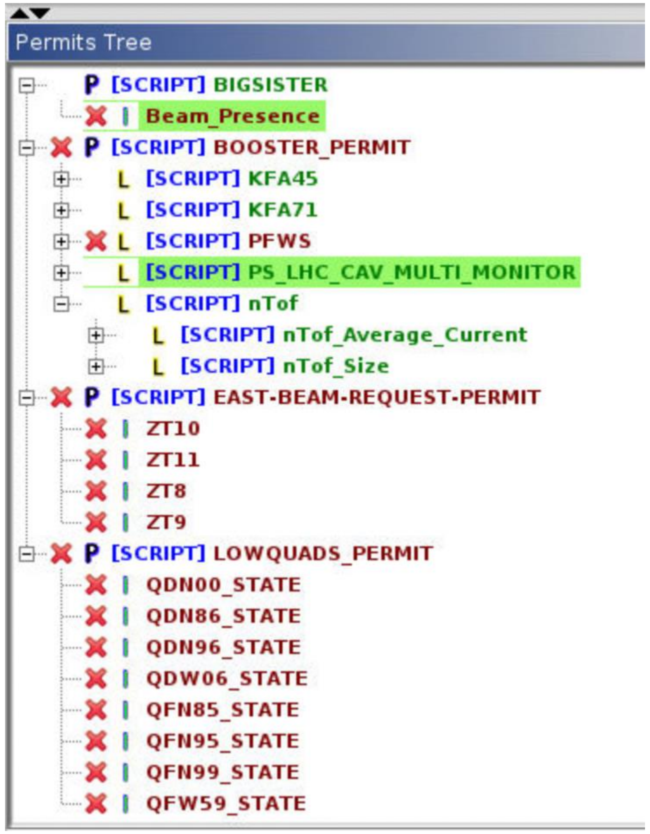
- **LEIR autopilot (UCAP-based, WRAP display)**



R. Alemany, [LEIR Autopilot]

Systems in place across the complex

- **PS**
  - **SIS** in PS far **less developed** than in other machines
    - **Interlocking PSB beam production** in case of failure of major equipment (after first bad shot)
    - **Beam quality monitoring** for nTOF via SIS (flux and beam size checks)
  - **BigSister** as AFT actor
    - Based on BCT reading, **requiring manual completion** of AFT entry (*Downtime to be updated)*



Towards smart equipment

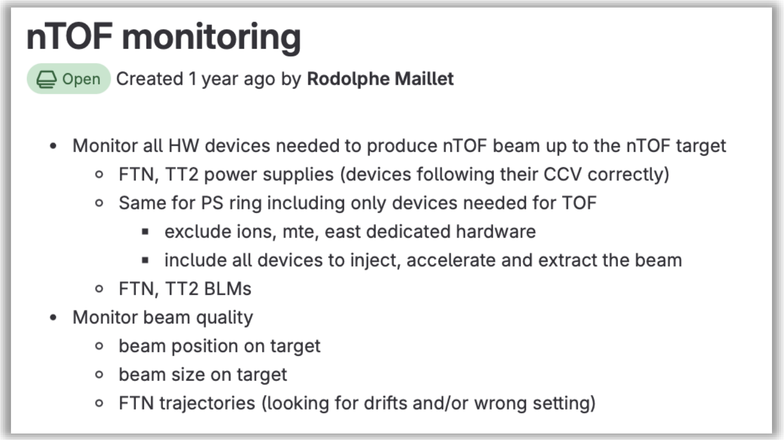
- **Large fraction of downtime in our accelerators due to resetable equipment faults**
  - Significant amount of time spent to understand situation and, eventually, reset
- **Equipment issues can very often be predicted and planned stops can be targeted for maintenance to avoid unforseen stops**
- **Beam characteristics can be important input to proper equipment functioning**
- **EPA project includes *WP8 – Automate Equipment* to streamline the management of equipment**
  - Equipment **configuration**, **monitoring**, **fault analysis** and **recovery**
  - Automating equipment must become a **common effort**
  - **Common vision and strategy** being defined together with equipment groups
  - Details and timeline can be found here

Towards smart equipment

- **WP8 aims at**
  - the development of a **unified way of reporting equipment status**
  - providing **intervention assistance** with suggestions, leads, and analytics
  - equipment that **self-analyses the source of an issue** and communicates it clearly
  - **early identification** of upcoming **failures** to allow for scheduled maintenance
  - development of **self-configuring equipment** given the operational conditions
- **Activities being carried out in parallel**
  - Implementation of **general equipment monitoring**, **automatic fault recording** and **auto-resets** by OP
  - WP8 implementation of **automatic fault monitoring, recovery and prevention,** and **beam-based configuration** on the **equipment side**
    - Definition of **pilot projects** in different equipment groups (see Kostas' talk)
    - Definition of **interface and architecture for data analysis** and **automatic recovery frameworks**

UCAP-based PS performance monitoring system

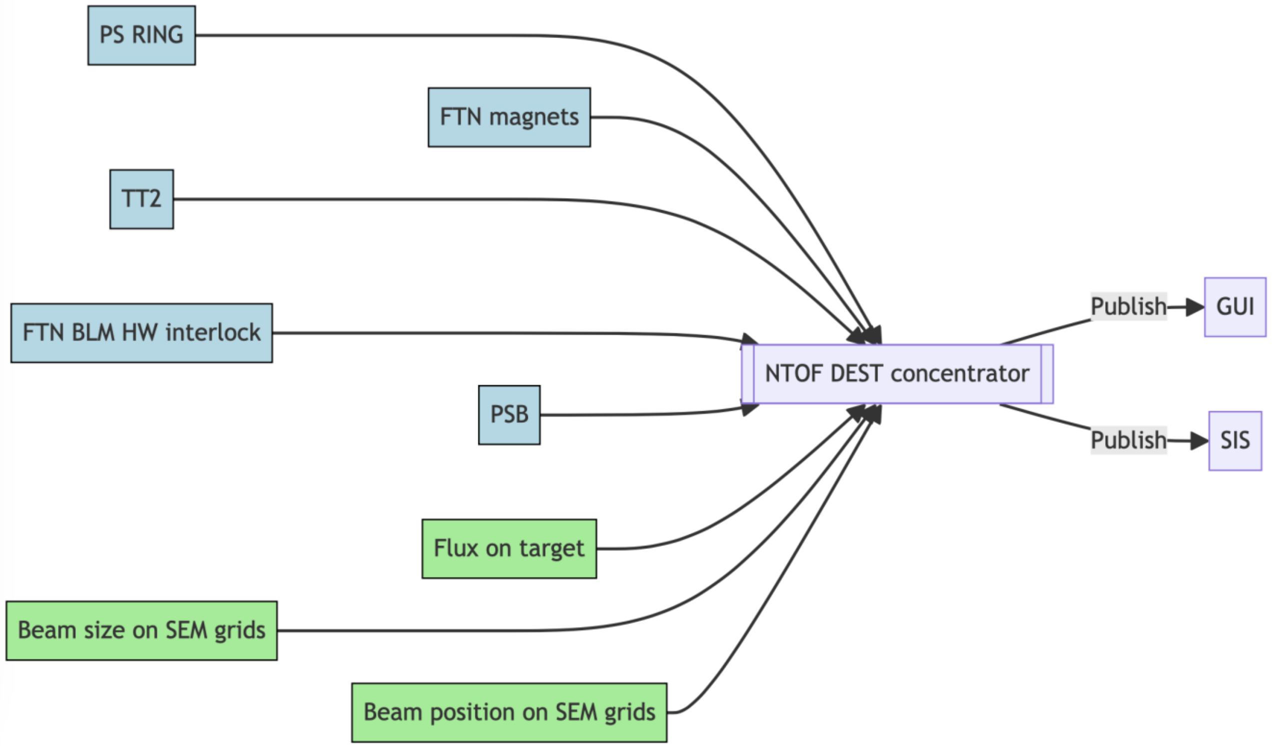
- **Performance monitoring == equipment and beam quality monitoring**
  - Crucial in the **PS as multi-user facility** with many different requirements in terms of beam characteristics
  - Java on UCAP: equipment monitoring
  - Python on UCAP: beam quality monitoring
- **Monitoring the health of the different *destinations***



nTOF monitoring

Open Created 1 year ago by **Rodolphe Maillet**

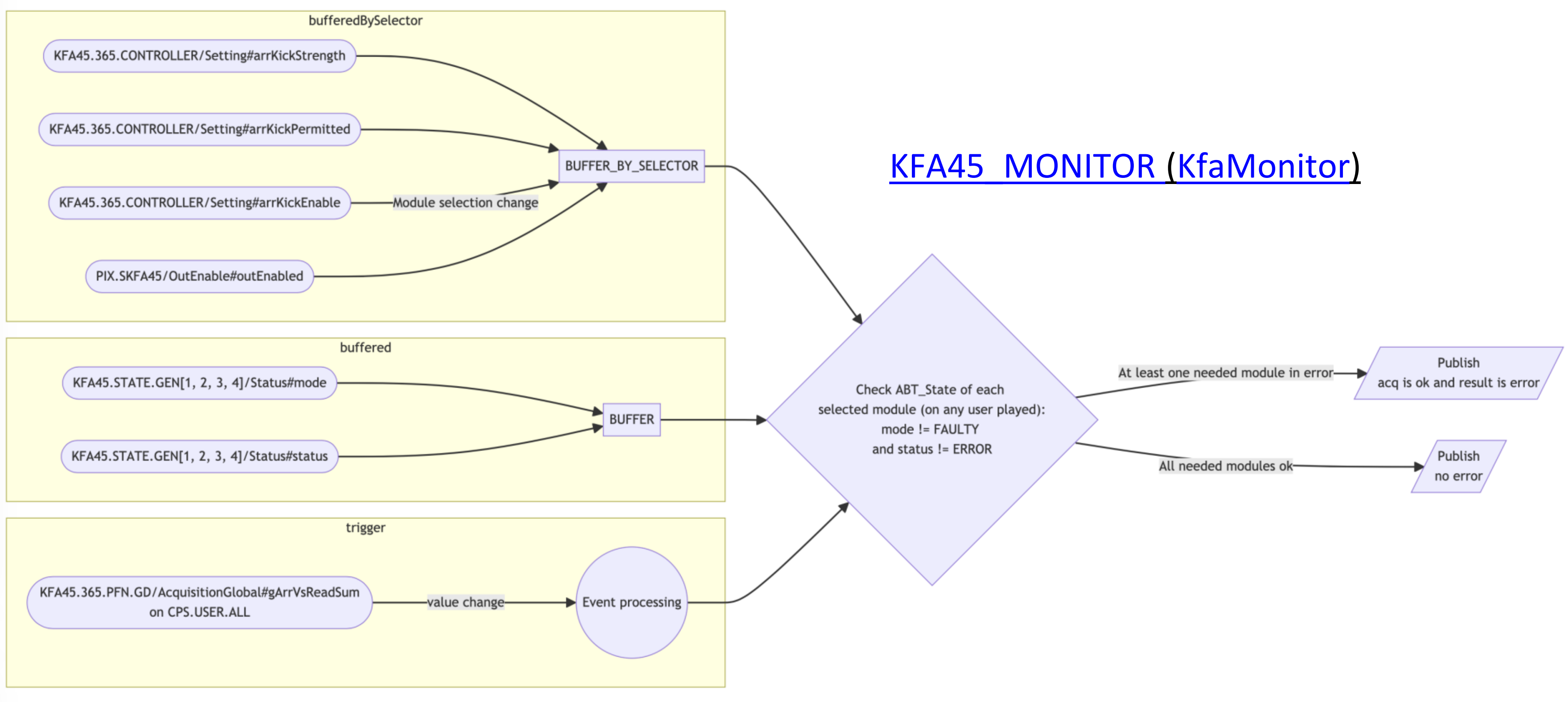
- Monitor all HW devices needed to produce nTOF beam up to the nTOF target
  - FTN, TT2 power supplies (devices following their CCV correctly)
  - Same for PS ring including only devices needed for TOF
    - exclude ions, mte, east dedicated hardware
    - include all devices to inject, accelerate and extract the beam
  - FTN, TT2 BLMs
- Monitor beam quality
  - beam position on target
  - beam size on target
  - FTN trajectories (looking for drifts and/or wrong setting)



R. Maillet, nTOF monitoring on Gitlab

UCAP-based PS performance monitoring system

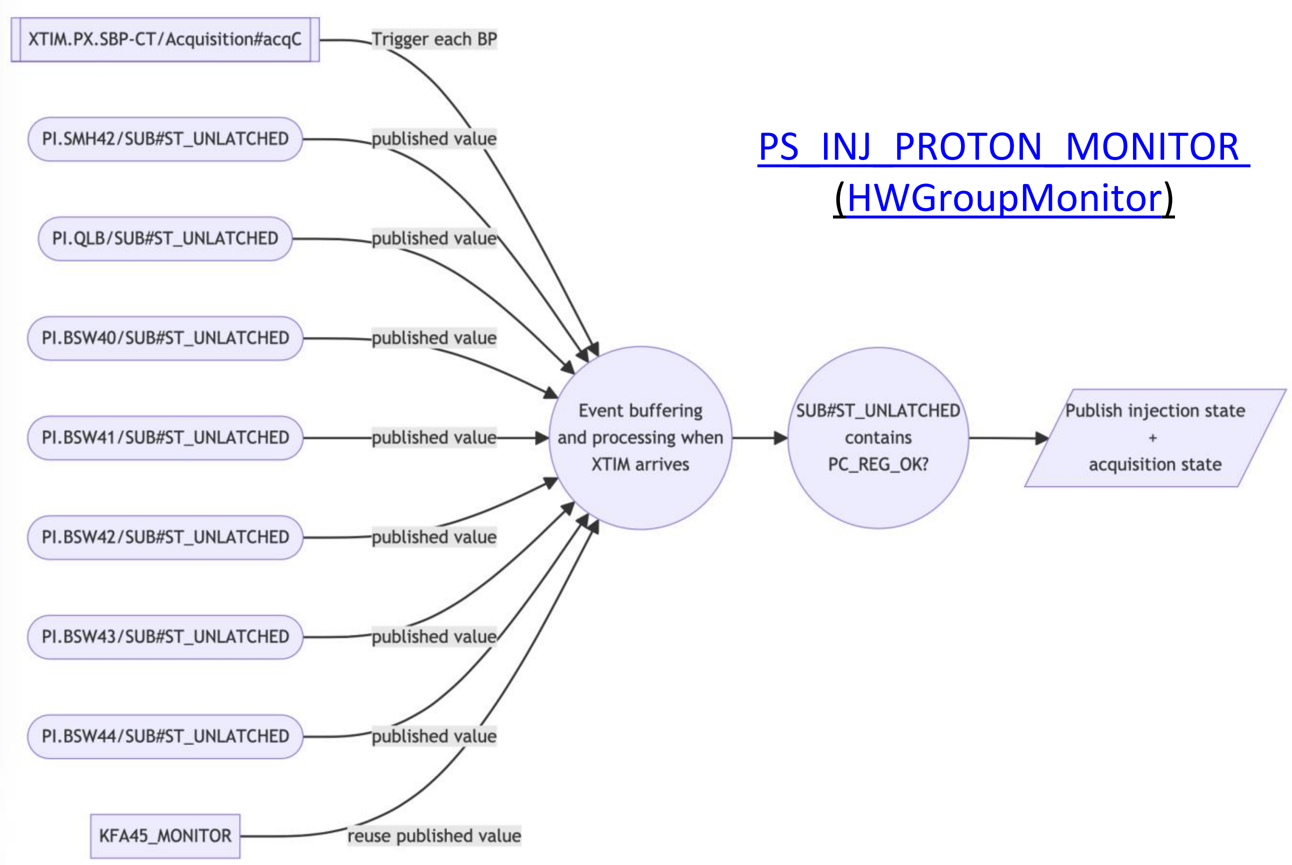
- **Status of monitoring**
  - **reusing infrastructure** from PSB for FGCs (covering ~80% of the equipment)
  - **PS-specific developments** for kickers and RF cavities
    - publication of generic simple Boolean flags
    - collaboration with equipment experts to define logic
- **Developments eventually to be taken over by equipment experts**



KFA45_MONITOR (KfaMonitor)

UCAP-based PS performance monitoring system

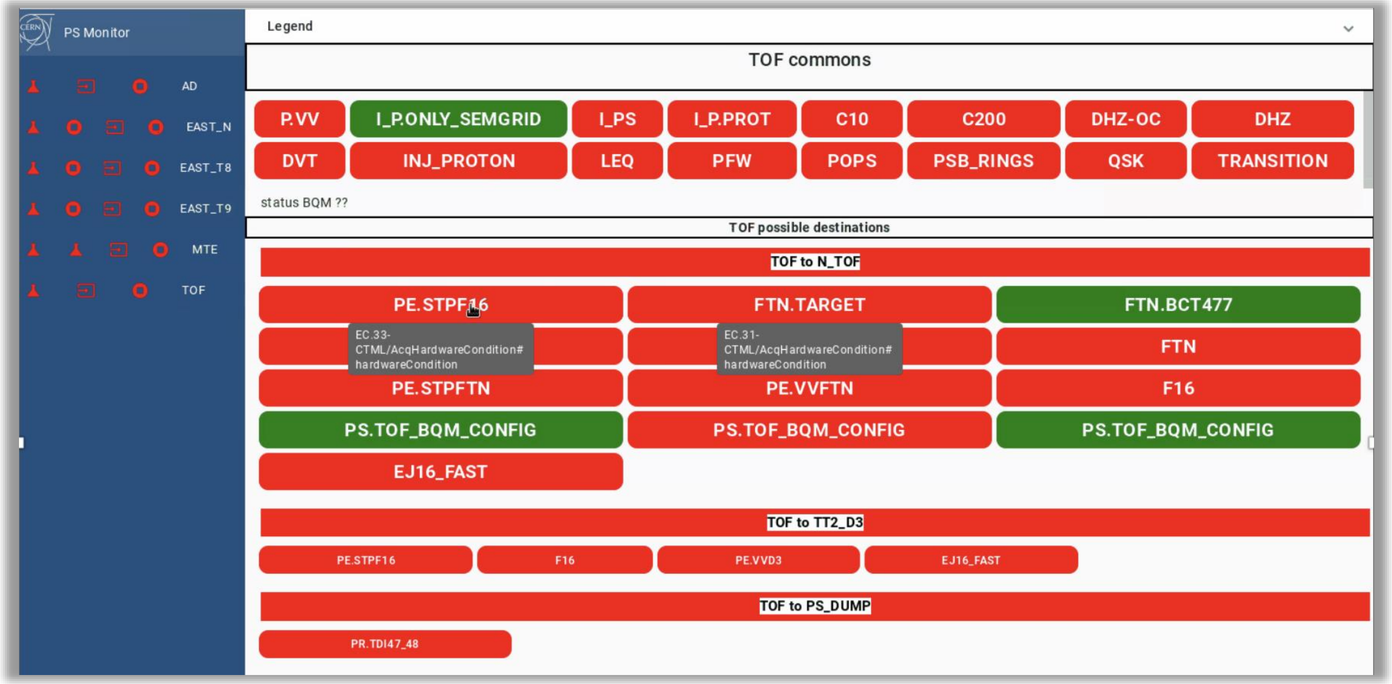
- **Concentrating similar equipment as *hardware groups***
  - Avoids the creation of 100s of additional virtual devices
  - Generic class implementation (HWGroupMonitor) for various applications
  - To be used as input for destination concentrator
- **Destination concentrator**
  - "Can beam be sent to **<DEST>**?"
  - Publishing PSB user and **number of turns** in a given ring to be set to **zero** (action on BIX.NT0)
    - **health of destination checked every cycle (in contrast to SIS)**
  - Virtual UCAP device per PS destination



PS_INJ_PROTON_MONITOR (HWGroupMonitor)

UCAP-based PS performance monitoring system

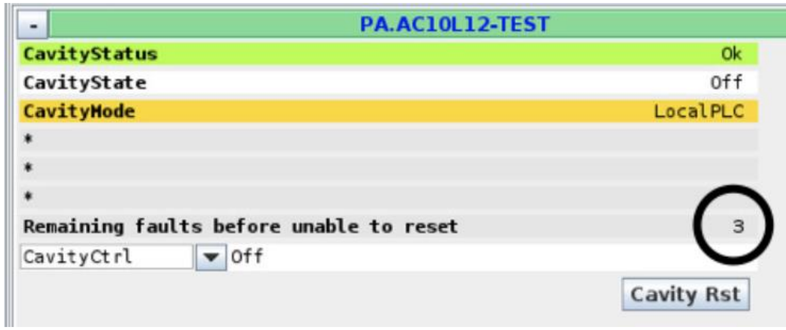
- **Development of a monitoring GUI**
  - Choice of **web-based solution** for convenient access to global machine status parameters
  - **Prototype GUI** based on accsoft-web-seed
    - supported by BE-CSS
    - intially tested with WRAP,
      but functionality not mature enough
  - Planning to **add** important **beam quality information**
    - TOF bunch length, steering and beam size on target
    - LHC bunch-by-bunch variation of intensity, length
    - MTE splitting efficiency
    - …



- **Could imagine simplified GUI for the users**

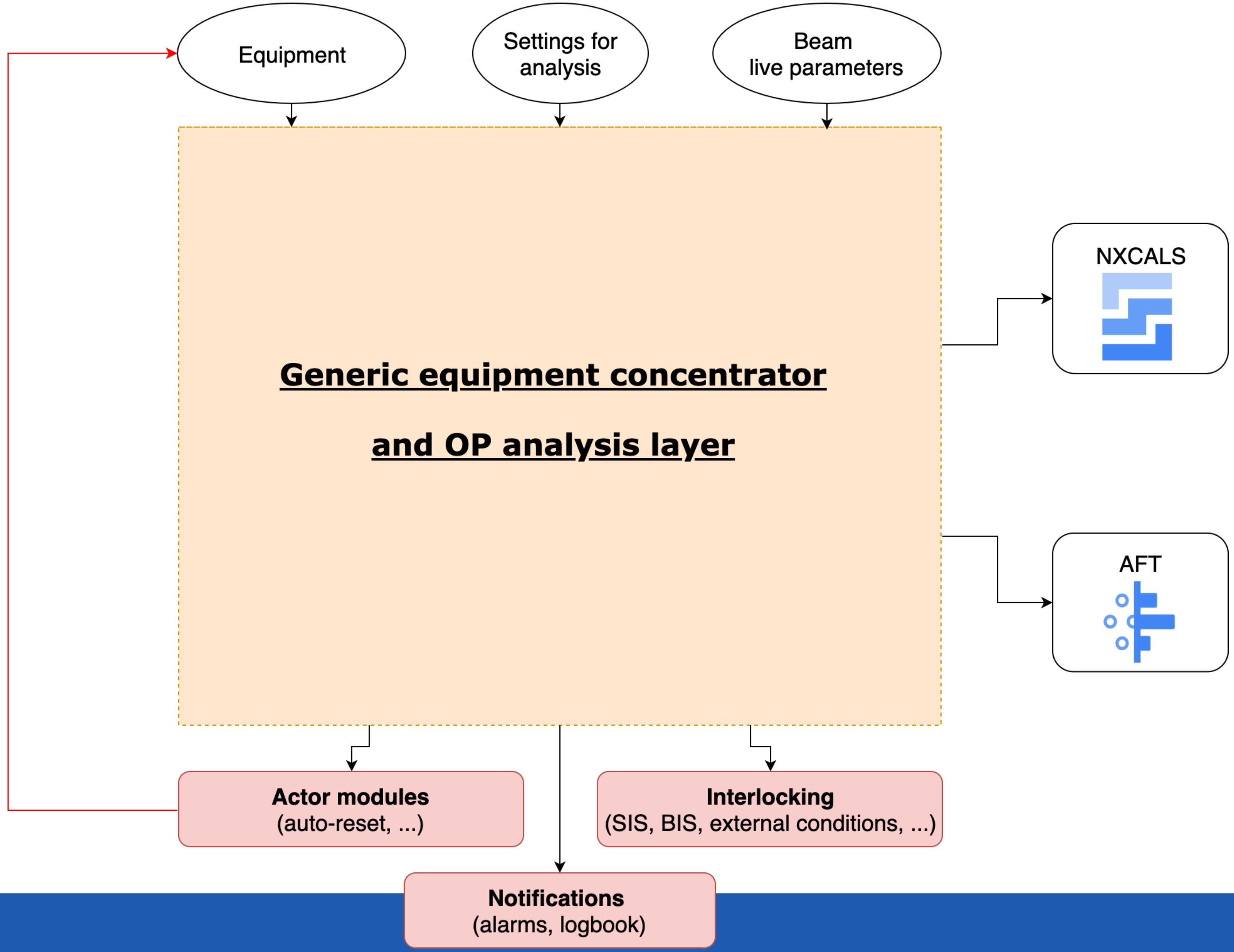
UCAP-based PS performance monitoring system

- **Auto-reset**
  - **Protoype development** started on PS 10 MHz cavities
  - Discussed and agreed with SY-RF group
    - cavity **PLC counts the number of resets** in a given time window
    - **Maximum number of resets** after which cavity becomes **unresetable** and expert/piquet needs to be called
  - **Benefits**:
    - Potential to **avoid radiation alarms** due to early resets
    - **Avoiding too many** (manual) **resets** with negative implications on the hardware
    - **Automatic AFT** of single cavity faults
  - **To be extended** to other equipment **in agreement with experts**

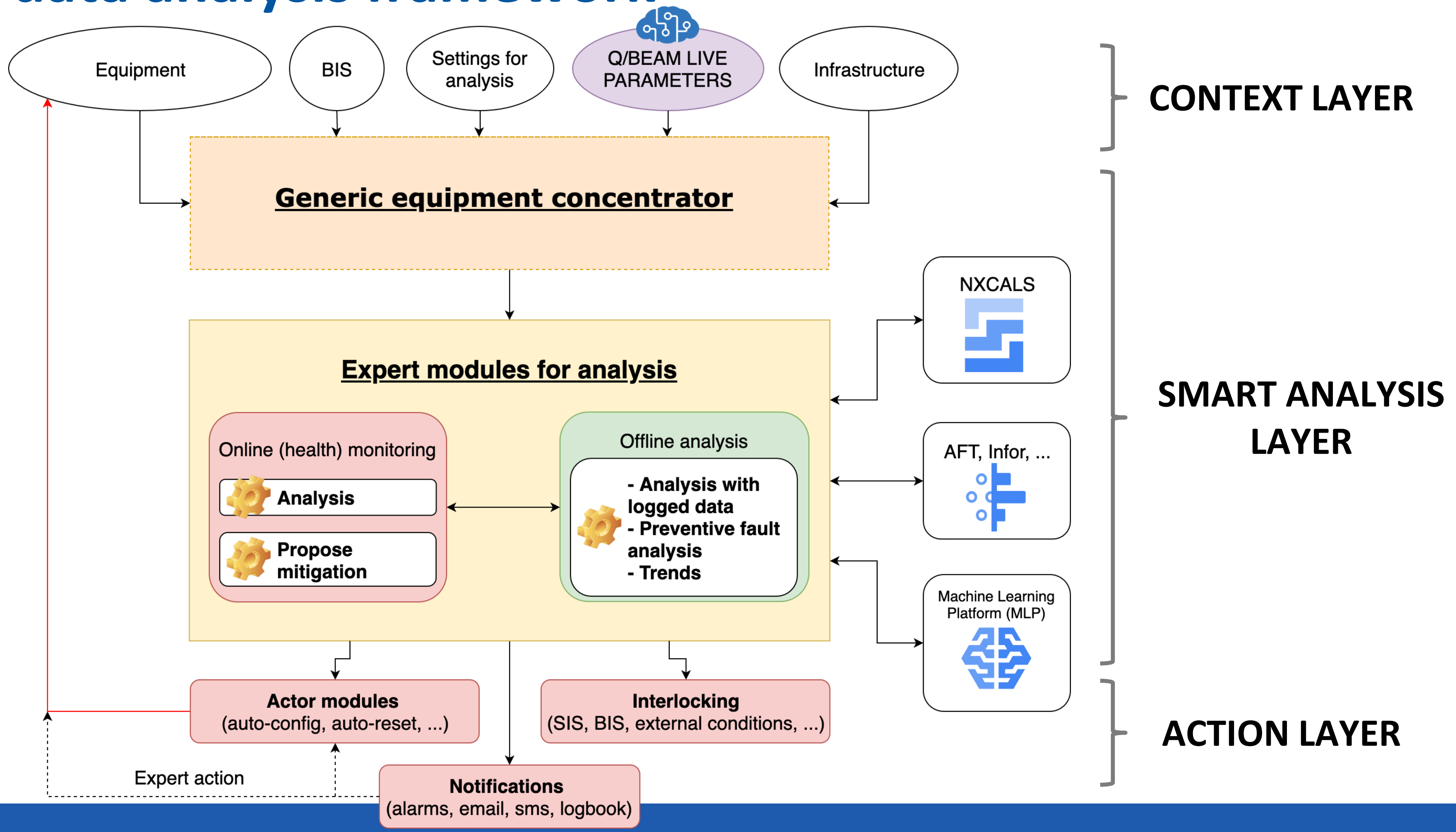


- **Other related developments**
  - Defining a **clear and generic naming convention** for OP-UCAP developments (large number of new developments with an increasing trend)
  - Developing a **reference GUI** to acquire and average data, and save references in virtual devices
  - Implementation of the **AFT actor** on the hardware group monitor niveau
  - Use the **announcer** to inform about performance issues

From the UCAP-based PS performance monitoring system …



… to the WP8 data analysis framework



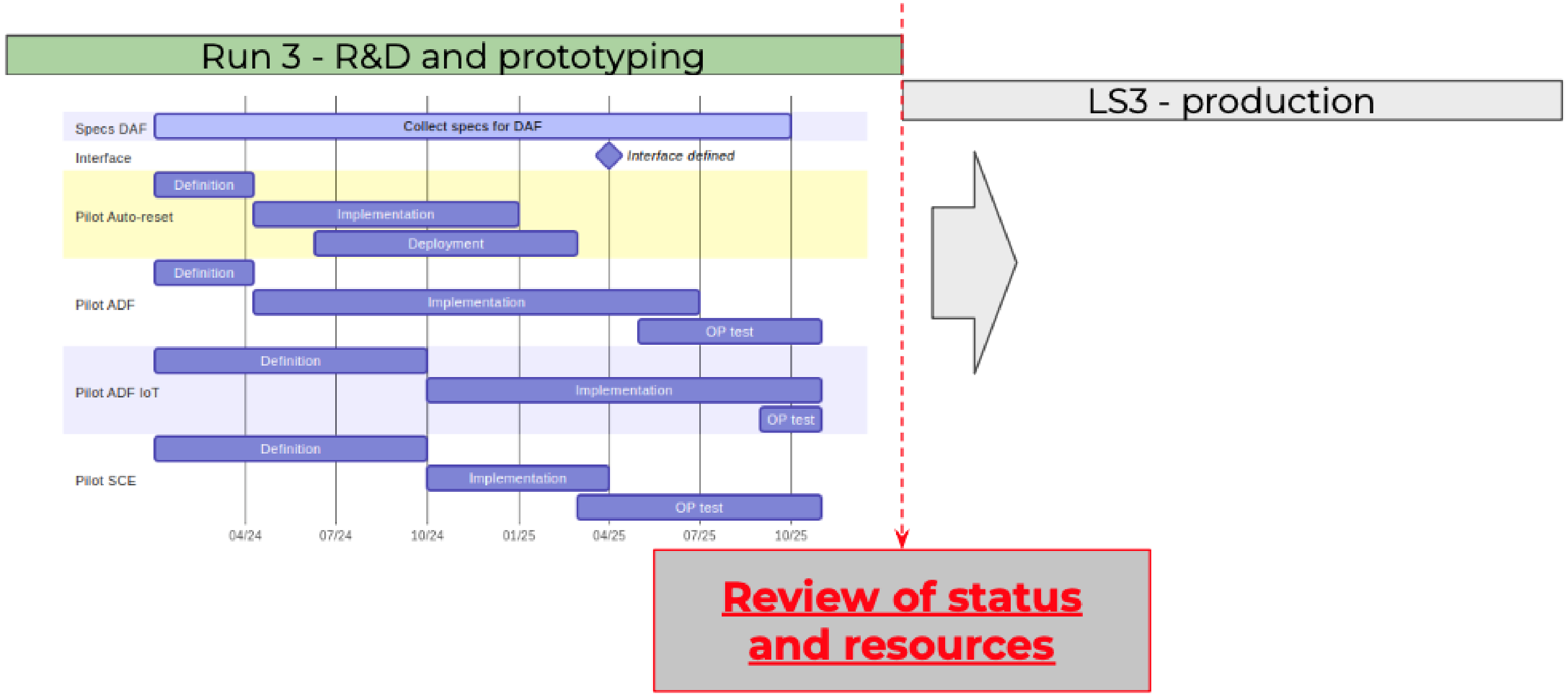
Conclusions

- **Large effort ongoing to bring performance monitoring to a next level in the PS**
  - **Concentrating** equipment and beam **information** to alert, act and interlock
- **EPA WP8 paving the way for future autonomous equipment management**
  - **Preparing pilot projects** as presented by Kostas
  - PS performance monitoring system as **additional pilot project**
    - **Testing** of monitoring **GUI** solutions, destination-based **interlocking**, **alerting** and **announcing**, **automatic fault tracking**, etc.
  - Defining (and eventually implementing) a **generic data analysis framework** based on the various existing solutions and collecting all requirements
    - to ease maintainability and development, and to share knowledge
    - framework allows to implement monitoring, recovery, alerting and fault tracking **directly by the equipment owners**, who know their systems best
- **Common effort between equipment groups, controls groups and OP needed to make this happen**

Backup

Proposed timeline

- ➔ Initial phase of definition of pilot projects, interface for equipment and tools to use for pilots
  - Approval via CTTB for interfaces
- ➔ Work on all pilots in parallel and feedback to specs for DA framework and specs for future interface of equipment and the upper layers
- ➔ All this deliverable by end of Run3 (if extended to 2026) ⇒ LS3 dedicated to deployment to all equipment



Main deliverables - **only to end of 2026**

- ➔ Define scope and requirements with all equipment groups Q4 23
- ➔ Define KPIs to quantify performance gain during the execution of the WP: Q1 2024
- ➔ Define interface for clear equipment status labelling: Q2 2024
- ➔ Pilots projects (with graduate resources attached)
  - Self-recovery from faults (automate what is now done manually)
  - Auto-recovery based on advanced algorithms and failure prediction
  - Multi-sensor Internet-of-Things (IoT) devices applications:
    - Automatic commissioning sequences
    - Diagnostics and failure prediction
  - Pilot project on self-configuring equipment
    - Define, develop and deploy pilot project: Q3 2026
- ➔ Define automatic recovery tool interface and architecture: Q4 2026 (throughout)
- ➔ Define requirements for data analysis tool: Q4 2024 and Q4 2025