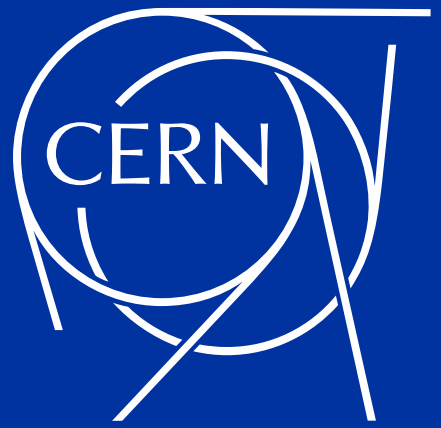

OP feedback and recommendations as we move towards automation

JAPW ’24, Montreux 10th – 12th of December 2024

Y.Le Borgne, S.Cettour Cave, L.Pereira, S.Massot, J.Dalla-Costa, D.Jacquet, D.Cotte, B.Mikulec, V.Barbet, E.Veyrunes, A.Calia, G.Trad, M.Schenk, JC Dumont, R.Maillet, GP Di Giovanni, P.Skowronski, O.Hans, G.Imesh, JL.Sanchez, R.Scrivens, T. Argyropoulos, L.Ponce, E.Piselli, M.Hostettler, B. Rodriguez Mateos, M. Schenk, V. Kain, T. Agryopoulos and many others…

OUTLINE

- **Operation Tasks and the Role of Automation**
- **How Automation Has Helped**
- **Proposed Workflow for Effective Automation**
- **Key Recommendations for Moving Forward**
- **Conclusion**

Overview of key operational tasks in 2024

Many parameters to **monitor, control and optimize** for each user in the Super Cycle !

Discussed during **Efficiency Think Tank** (ETT) process.

Role of Automation

Implementation of the ETT recommendations with the establishment of a dedicated Efficient Particle Accelerators (EPA) project until the end of LS3.

Until LS3: development and operational tests of prototypes.

Automation : increase efficiency, reproducibility, flexibility and margins for Operation

	Recommendations						
KPI	Hysteresis compensation	Dynamic Scheduling	Automated LHC Filling	Auto-pilots	Automatic fault analysis	Automatic testing and sequencing	Automatic parameter optimisation
Availability	X				X	X	
Parameter stability	X			X			X
Commissioning and set up time	X	X			X	X	X
LHC turnaround time	X	X	X	X	X		
Energy consumption	X	X	X	X	X	X	X
Integrated luminosity per time and money	X	X	X	X	X	X	X
Fixed target physics parameters (duty cycle, flux, number of shots, etc.)	X	X	X	X	X	X	X

Table 3.1: The table summarises high level KPIs for the accelerator complex and shows which of the ETT recommendations have an impact on them.

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How Automation Has Helped : « Auto-Start »

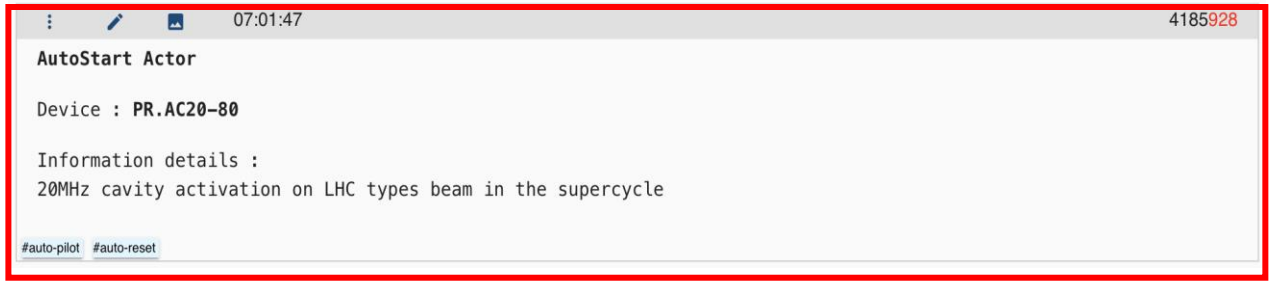
Recurrent absence of high frequency cavities for LHC beams

- Auto-start of the cavities introduced on the **30th of September 2024**

***92 automatic starts** logged in the logbook under #auto-pilot. (30/09 to 03/12)*

Implementation G.Imesh (OP)

Picture from JAP22. A.Lasheen's talk



PS Logbook Automatic entry

Some inversion issues between proton and ion cavities (currently being resolved)

How Automation Has Helped : « Auto-Reset »

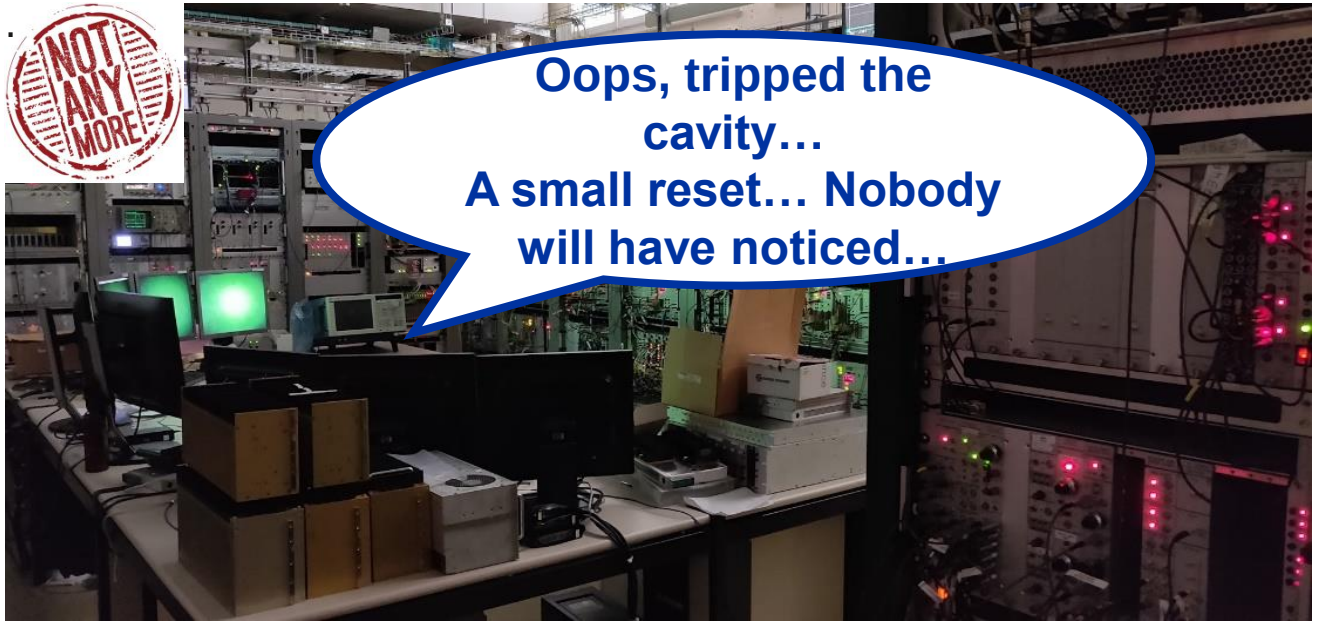
10MHz cavity frequent trips

- Auto reset introduced on the **15th of April 2024**
- Same Auto reset introduces for 20,40,80MHz on the **30th of August 2024**
- **296** automatic resets logged with #auto-reset. (not #auto-pilot)

KFA 71/79 module trips

- Also 20 automatic resets logged for KFA71 modules. (from 14/11/2024)

.



Picture from JAP22. A.Lasheen's talk

Implementation G.Imesh (OP)

09-09-2024 08:27:05 4139951

Autoreset Actor

Device : PR.AC10-91

Equipment fault details :
2024.09.09 08:26:48.340924: L2Fault; Final Ia Crowbar; LHCIND3(37)@1628[ms]; 0;Final Ia Crowbar/0;Final Crowbar Fault/5;Final HT Supply Step2/7;Final Ia Crowbar/7;Final Crowbar Fault/7;Driver

@PS

#auto-reset

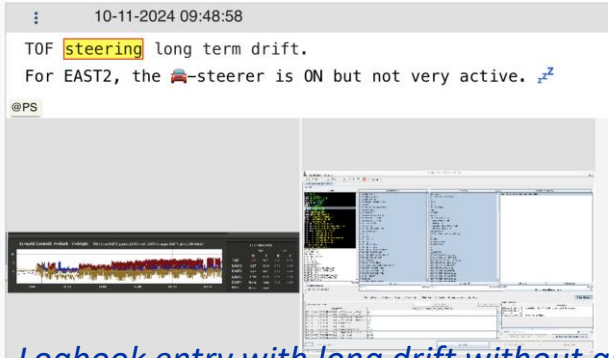
PS Logbook Automatic entry

There is a limit to the number of allowed resets, after which the on-call team has to be called.
The implementation of **auto-starts** and **auto-resets** have been elaborated in close collaboration with the equipment experts.

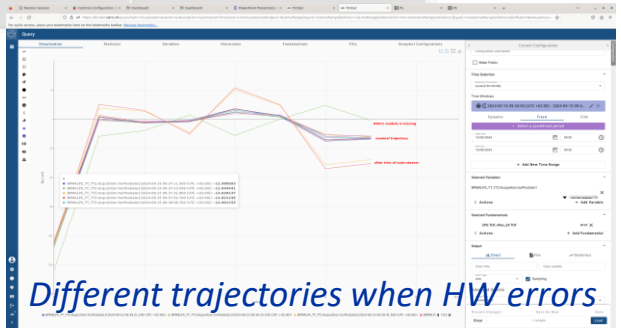
How Automation Has Helped : « Auto-Steering »

Continuous auto-steering in TT2.

- Long commissioning phase to make it efficient.
  - Still in the process of finding the **best trigger thresholds**.
    - Overly sensitive settings lead to **excessive small trims** (tens of mA).
    - Insufficient sensitivity results in **no trims at all**.
  - PS-specific constraints : Avoid trimming on **LSA corrections** !
    - Seen thanks to LSA sanity check -> **cockpit online checks !**
  - Also **helped to diagnose problems** with new TT2 ALPS Pick-Ups.
  - Attention, the system is trying to **compensate for sporadic hardware errors**.
    - include a correct treatment of equipment faults or supercycle composition.
- Limitations for AD
  - Limited by only three Pick-Ups in TT2 before the bend to FTA. (no Pick-Ups in FTA)



Logbook entry with long drift without any trim



Different trajectories when HW errors

How Automation Has Helped : « PS-Booster »

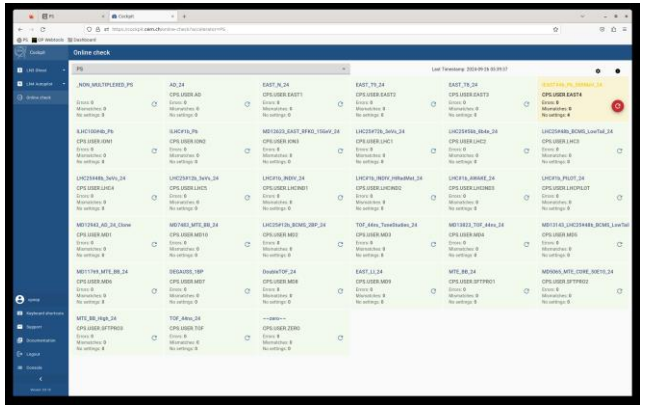
Optimizer for **Extraction and Transfer Line** improving losses in the extraction and recombination regions.

- Based on optimization framework «Generic Optimization Frontend and Framework» (GeOFF)
- Very nice and complete documentation. https://recomb.docs.cern.ch/userguide.html
- Improvements in the losses every year.

FGC logger : **FGC automatic notification in logbook** (*Power Converter Fault, LSA re-drive failed,* …)
Logbook entries are a bit lengthy when there are too many elements in fault.

LSA sanity checks and notifications (*too many trims, online checks incoherences*, …)

PSB Logbook Automatic entry from FGC



LSA Online checks in cockpit

How Automation Has Helped (or not) : « SPS »

Continuous **noise compensation** (50Hz/100Hz) on SPS QF (based on SX spill):

- Far from being an optimal experience for SPS operation team
- Sometimes takes a very long time to converge
- Loss of control: cannot be **stopped** or **restarted** or **rolled back** easily.
- Frequently **requires expert intervention.**
- **Major Bug Fix on 07.10.24 – Impacted 50Hz**

50Hz and 100Hz compensation

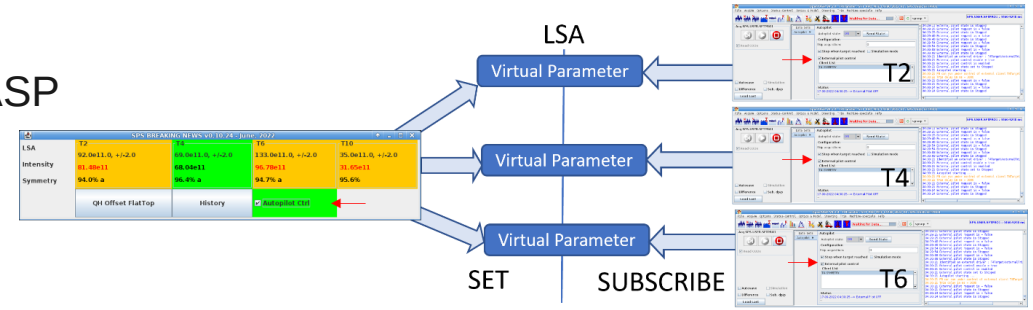
SHIFT SUMMARY:

_ 50Hz noise very high...for all the night
_ NA62 complains about 50 Hz but we said that we can't do anything...
_ It seems that the 50 Hz algorithm is not working well because we saw that the amplitude and the gain of the 50 Hz doesn't change (flat function) even if the noise is very high.

SPS logbook summary

SPS Target autopilot application is monitoring LSA References, Target intensities and symmetries

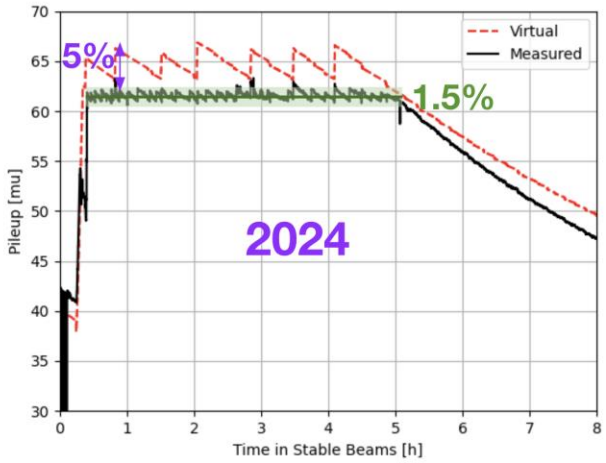
- Good experience already since 2023.
- Auto-pilot triggered when target symmetry **drops below 90%** using YASP
- **No correction if no beam**
- Already mentioned as good use case during :
- **IPP on Efficiency and Automation from E.Veyrunes**

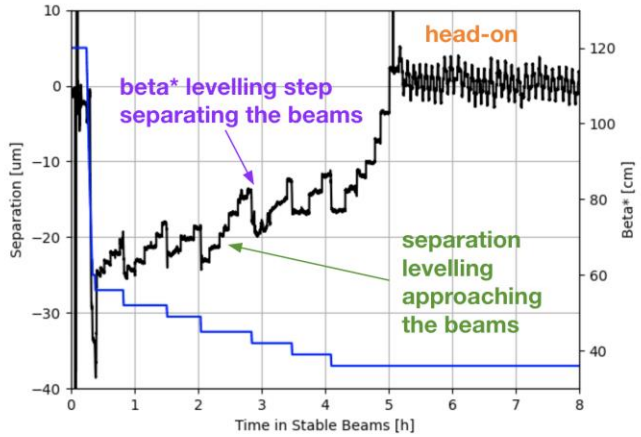


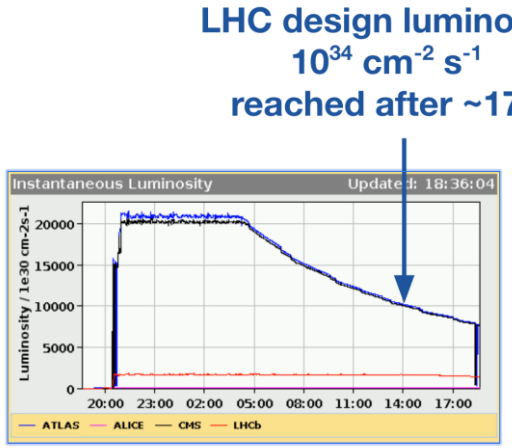
How Automation Has Helped : « LHC »

When LHC is in stable beam, keep a constant luminosity with **Luminosity levelling** : beta* and separation

This automation makes the life of LHC-OP easier in stable beam, around **20 clicks needed in 12 hours** (if everything goes well)

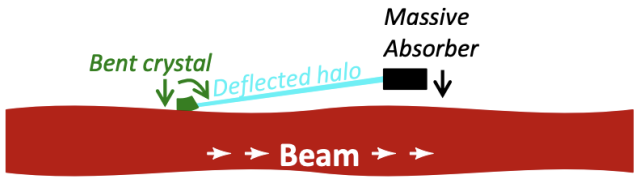






Crystal collimation during ion run.

- **Automatic optimization of channeling** orientation.
- Implemented periodic automatic optimizations at intervals tuned to avoid channeling loss
- Full cycle covered; real-time trims in the ramp



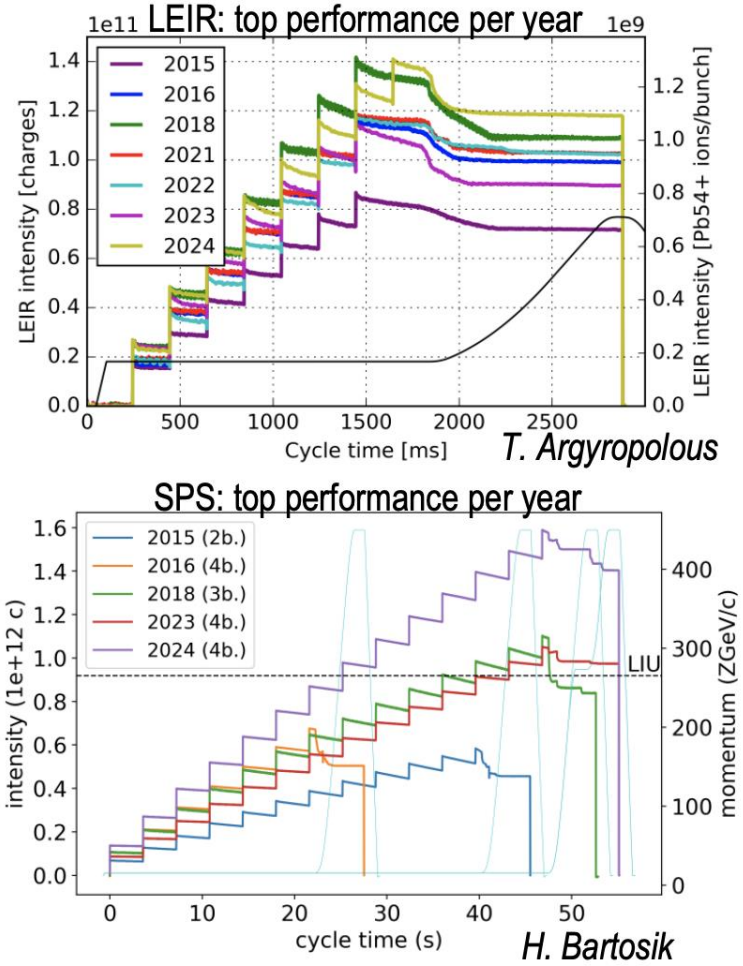
How Automation Has Helped : « LN3 / LEIR »

Very good performances up to LHC in 2024.

- Thanks to the performance of the **optimizers implemented** at LN3 and LEIR, the ion beam intensity was optimal in 2024.

- A key strategy for improvement has been the **use of optimizers on MD cycles first**, followed by **copying the best settings** to the operational cycle.
  - This approach is only possible thanks to the ability to easily clone cycles, a method that is also widely used in PSB and PS.

- This approach allows for **gradual improvement** of operational beams as the **optimizers progress** and demonstrate their **effectiveness**.



LEIR and SPS BCTs

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Proposed Workflow for Effective Automation

Adaptation Period is Essential

- Operators emphasize the need for time to adapt to a new system.
- **Automation documentation and knowledge transfer is important !**
- A gradual transition is preferred to ensure confidence and efficiency.

Preference for "Automation on Demand"

- Initial preference for automation triggered and validated during **Machine Development** (MD) sessions.
- Allows operators **to build trust in the system** and **maintain control** during critical phases. (ex : PS LHC splittings)

Long-Term Goal: Full Automation

- The primary challenge is achieving reliable full automation with minimal human intervention.
    - Always maintain control and the ability **to stop or restart an automation**. (SPS Main noise 50Hz-100Hz)
- Focus is on optimizing the system to ensure stability, efficiency, and safety during continuous operation.

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Enhanced Monitoring of automation and auto-pilots

Visibility: Ability to see, at a glance, the **current status**:

- Enabled, disabled, or paused (on a PPM basis).

Problem Detection:

- Identify issues such as **no trims** for an extended period, **excessive trims**, incorrect inputs, or system **exceptions**.

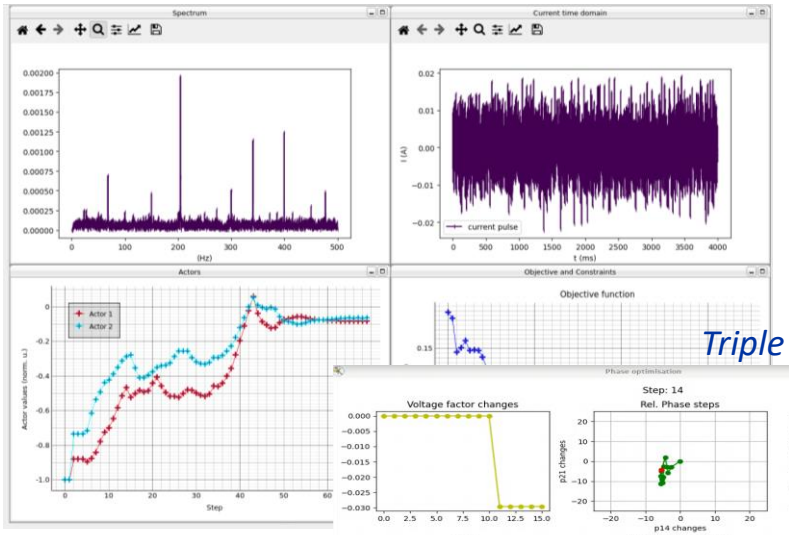
Limitation Awareness:

- Detect when a corrector/actor **approaches its limits** (e.g., outside safety margins or nearing maximum current).

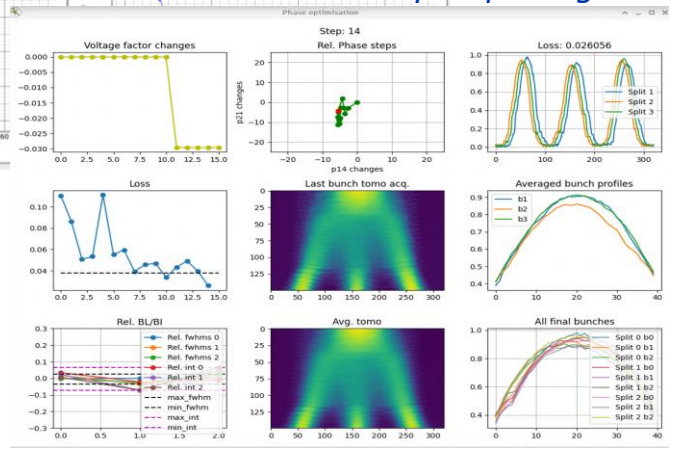
Integration of a Monitoring Dashboard

- Implement a dedicated dashboard or Vistar.
- **Centralized overview**, quick status checks, and early detection of anomalies.
- Develop a generic monitoring tool to quickly check beam quality in each machine.

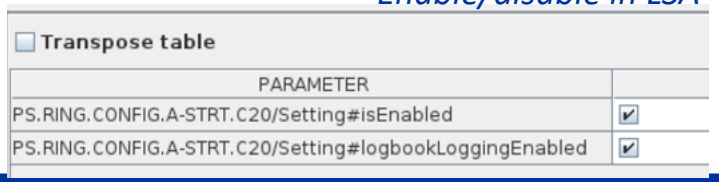
SPS main noise - LHC ion beam



Triple Splitting PS



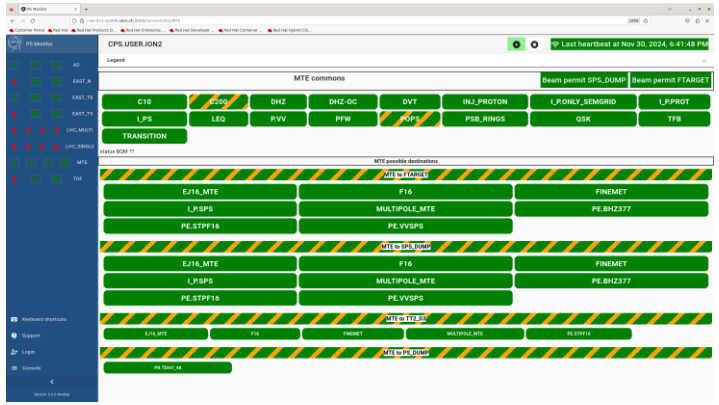
Enable/disable in LSA



Challenges in Diagnosing Issues

Automation and Optimizers

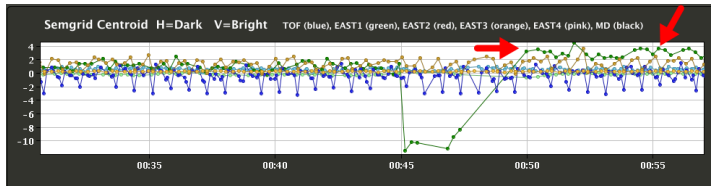
- These systems often **operate well autonomously.**
- An optimizer can work on one user but not on another
- Running multiple layers simultaneously **can obscure the root cause** of a problem.



Equipment monitoring system

Post-Mortem Analysis

- Perform detailed **detective work** to:
  - Trace the sequence of actions taken by AI and optimizers.
  - **Understand the triggers** and **determine why** these actions occurred.
    - **Hard to find when not documented.**



Position on nTOF Target

- Ensuring clear diagnostics and transparency is critical for maintaining reliable operations.

Challenges in Diagnosing Issues

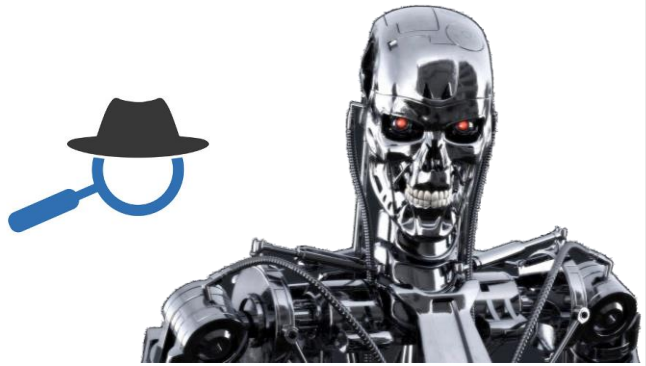
Example of logbook entry following a beam cut to nTOF.

- Illustrate the detective work needed in case of equipment failure.

07-09-2024 16:07:55 4139104

Trip of C91 and KFA71 mod6 and 9, then skynet took command :
- SIS cut TOF
- I_P.SOFT.EAST_T8 cut T8 (why are the new ECs only used on T8 ?)
- autoreset restarted C91 that tripped again (we think, since we also did -afterwards- a manual reset)
- in the meantime autosteerer had corrected TT2
- after we reset the cavity and the kicker modules, TOF, EAST1 and EAST2 h position was > 5mm
- SIS kept cutting TOF
- we rolled back the settings from 14:15 when, like now, everything was pulsing fine

@PS



- Often, the automation does not restore the initial conditions once the equipment is back.
- A manual action is required to find and restore initial settings.

Proposal : introduce a kind of “Hardware sanity check” would be nice to have on top of all automation system as a prerequisite to keep it running. Checking at least if the destination ok.

Sequencer and orchestration

Task Automation:

- Facilitates the **sequential execution of repetitive tasks** (e.g., switching zones to access mode or beam mode).
- Error Prevention: Ensures **no critical step is missed** during complex procedures
- Acts as a reference in case of mistakes or omissions, improving operational consistency
- Feature Proposal: **Enable the launch of LSA TAGs** directly from the sequencer.
- LHC Filling orchestration still to be defined (what to do and when ?)

Announcer and Communication

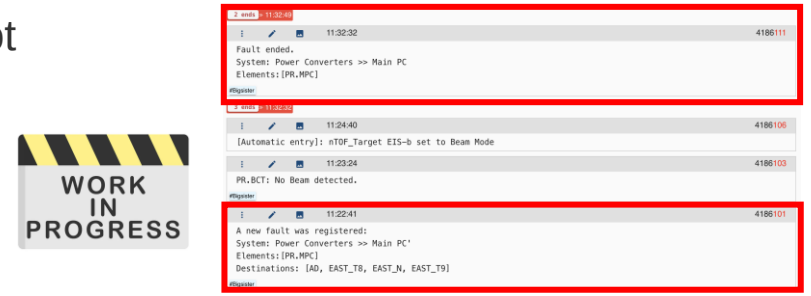
- Operators express concerns about **excessive vocal messages** from automation systems. (1 announcer per CCC island)
- A **better** use of **filtering system** is suggested to prioritize important notifications.
- **Adjust the volume** settings to minimize interference with other islands, ensuring clear and efficient communication.
- Investigate other announcer ?

Automatic Fault analysis and AFT reporting

Varied Implementations with **Positive Feedback from OP**

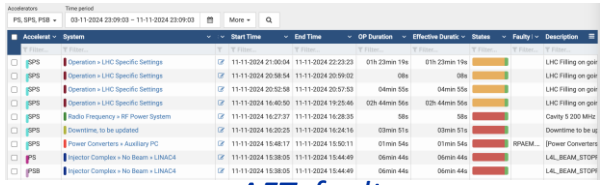
- Different approaches for fault generation across CERN machines.
- **Manual Fault Creation:**
  - LN3/LEIR: AFT faults still require manual intervention.
  - AD : Suggestion for automatic AFT creation for AD/ELENA based on BCT7049
- **Automatic Fault Creation**:
  - LN4/PSB: Faults generated via Piotr's Interlock application, establishing the root cause of "no beam" while SIS is used in PSB.
  - PS/SPS: Highly effective automatic fault creation using SIS and/or UCAP.
    - The system can deduce the source "AFT system" responsible for the fault
  - LHC :
    - Post-Mortem analysis: Faults are manually categorized.
    - Automatic creation triggered when faults occur around or just before injection.

LN4 Interlock status display



Automatic Fault entry in logbook

- **Ongoing Developments** : Enhancing the automatic linking of machine faults using UCAP devices.

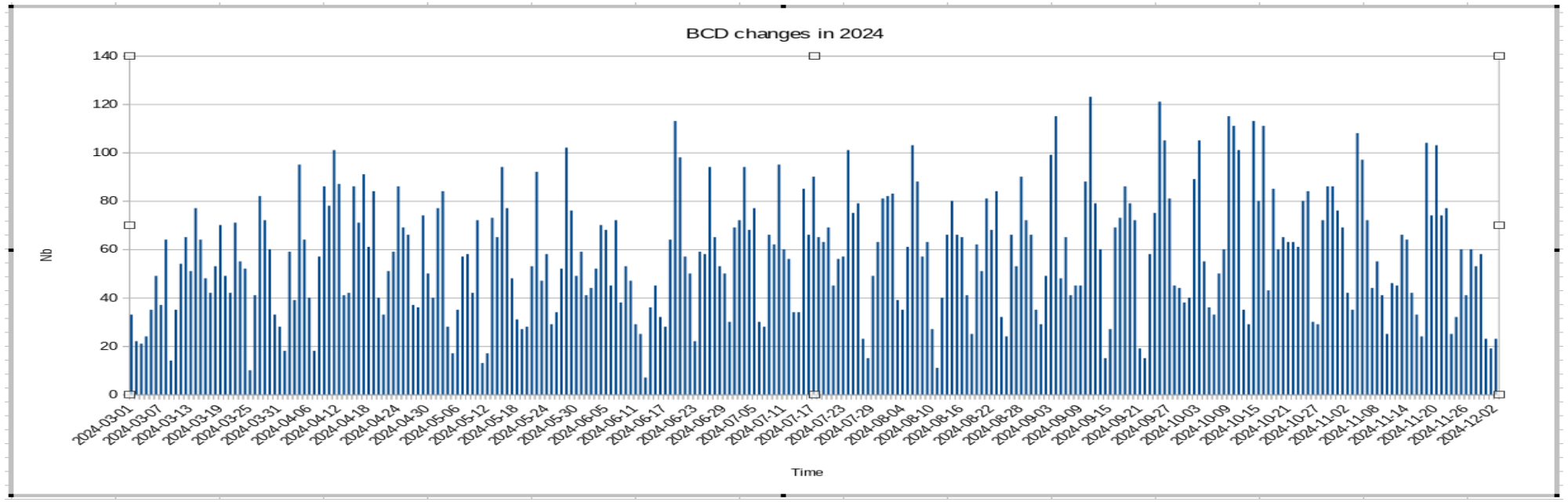


AFT faults

What is the next priority ?

- One important and recurrent point is the **Dynamic Beam Scheduling**.
  - Automatically and dynamically schedule beams

Today, the manual edition task is highly **time-consuming**, requiring significant effort to program the sequence.



Daily Super Cycle Changes in 2024

In 2024, we modified the super cycle composition **16700** times.

Involve AD team in the discussion in case of issues with AD beam.

Statistics

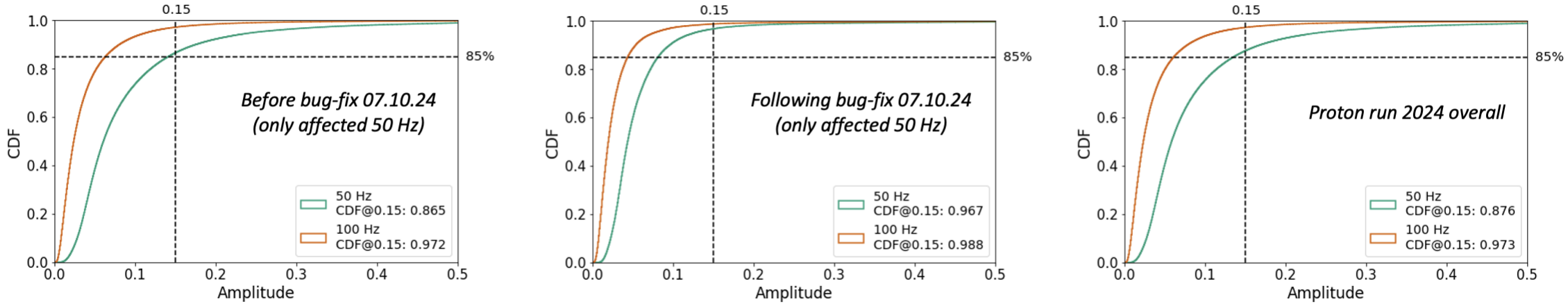
	2021	2022	2024
Average	42	51	58
Maximum	102	108	123

Conclusions / Summary

- **Improve knowledge transfer, how the optimizer work and how to react in case of issue and document it !**
  - Automation is not about replacing human operators but enhancing their ability to focus on higher-value tasks.
  - When automation fails, keep the possibility to take alternative action manually. (keep control)
- **Monitoring optimizer, autopilot, automation in general is very important !**
  - Let’s improve the monitoring in all machines.
  - Transparent structure for the organisation of optimisers across machines, to reinforce synergies.
- **Next subject where we would like to see automation is the beam scheduling.**
  - Common problem in several machines.
  - LHC filling with an Orchestrator.

50 Hz compensation in SPS

If we look purely at the spill noise performance for the proton run 2024 overall, the requirements from North Area experiments (NA62 in particular) are fulfilled. The goal is to be below 0.15 in 50 Hz (and 100 Hz) noise amplitude for at least 85% of the extracted spills :



Left: performance since start of proton run 2024, and until the bugfix,
even with the bug, and the associated phone calls, we were fulfilling the requirements from the user perspective.

Middle: performance after bug-fix and for the remainder of the proton run (only 3 weeks);
much more margin and no more phone calls during that period ;)

Right: proton run overall. Based purely on that data, you might think everyone was happy since the requirements are fulfilled ...

Centralized Overview in Automation

- Proposed Solution:
  - Develop a generic framework to unify automation processes across machines.
  - Create **dedicated folders** for optimizers to provide a global view and facilitate reuse.
  - Develop a generic monitoring tool to quickly check beam quality in each machine.
- Benefits:
  - **Avoid duplication development**, ensure reusability, **conflicting objectives** between optimizers.
- Considerations:
  - Account for the **different time constants** of optimizers (e.g., shot-by-shot in TT2 vs. averaging 3 shots in FTA).