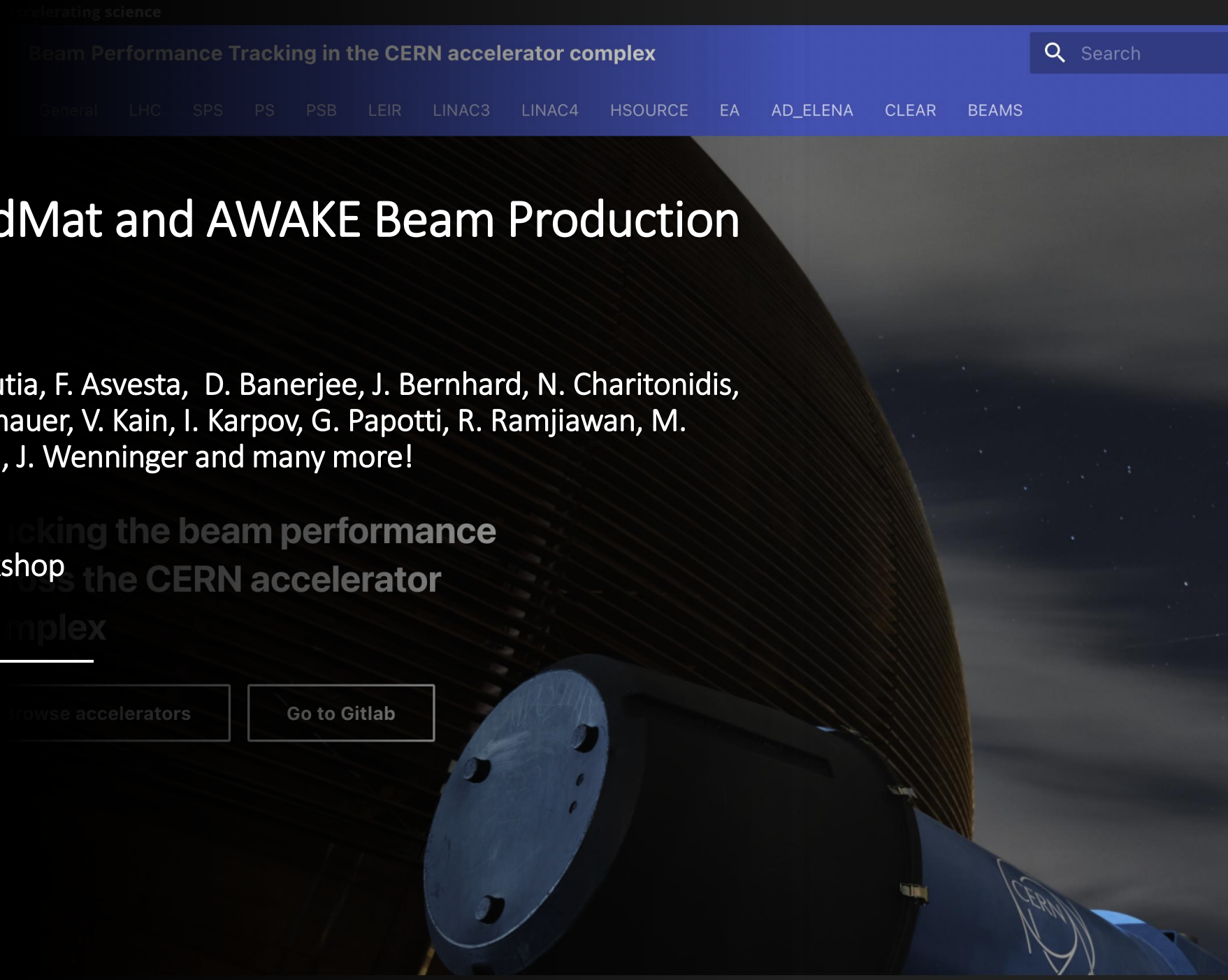
SFTPRO, SFTION, HiRadMat and AWAKE Beam Production and Delivery

K. Li with help and input from P. Arrutia, F. Asvesta, D. Banerjee, J. Bernhard, N. Charitonidis, G.-P. Di Giovanni, M. Fraser, A. Huschauer, V. Kain, I. Karpov, G. Papotti, R. Ramjiawan, M. Schenk, P. Simon, M. Vadai, F. Velotti, J. Wenninger and many more!

Joint Accelerator Performance Workshop
5th December 2022

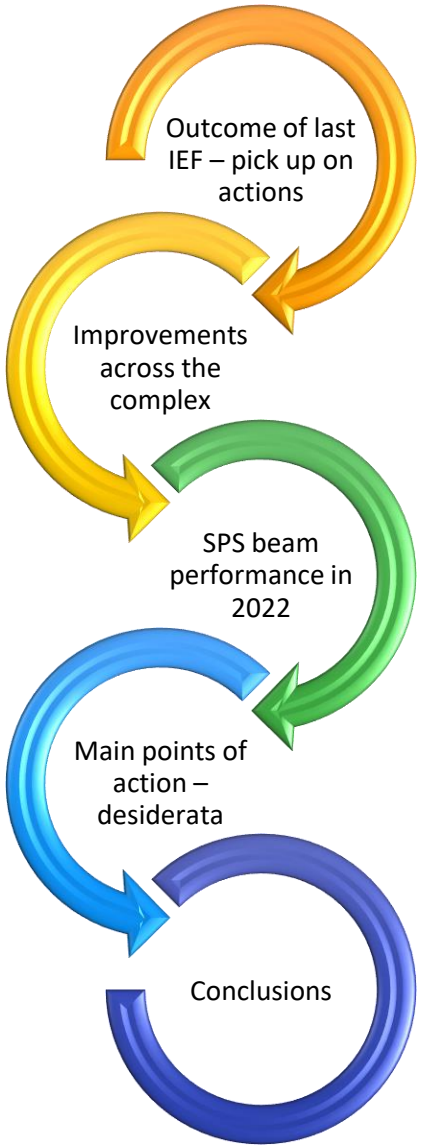


Conclusions

- Table with IEF 2021 WS actions status (https://cernbox.cern.ch/index.php/s/RJIMAIctyn4BGQU#office)

- ✓ **Barrier buckets → treated at this workshop by Mihaly**
- ✓ **Crystal channeling → treated at this workshop by Pablo; good progress in 2022 MDs in non-local channeling**
- ✓ Hysteresis correction → ongoing work, using ML techniques exploiting combinations of LSTMs and PINNs
- ✓ **Performance tracking across machines → treated at this workshop by Alex**
- ✓ **Automation and cruise control → implementation at various places (noise correction, transmission optimization using COI GeOFF components)**
- ✓ **NA beam instrumentation → mentioned again in this talk, activities started**
- ✓ **TT20 optics mismatch → treated at this workshop by Rebecca**
- ✓ **Spill noise regulation → mentioned in this talk, work ongoing**
- ✓ Experiments collaboration → done extensively in 2022, e.g., EBC, barrier buckets, RF optimization

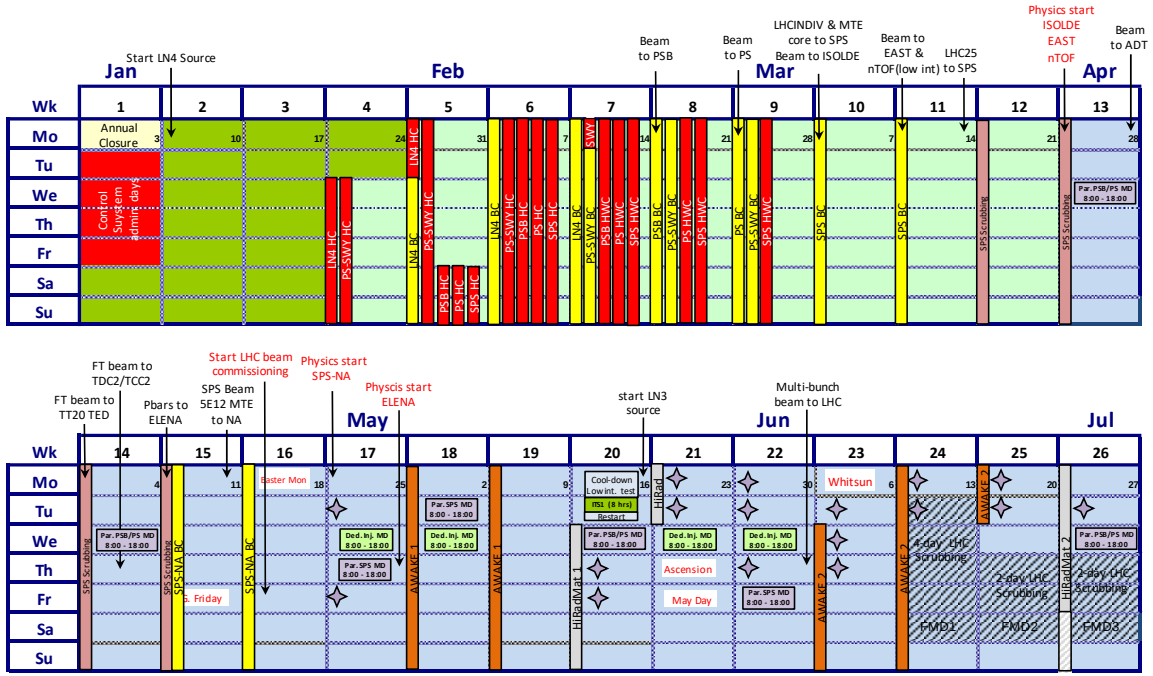
Intro and overview

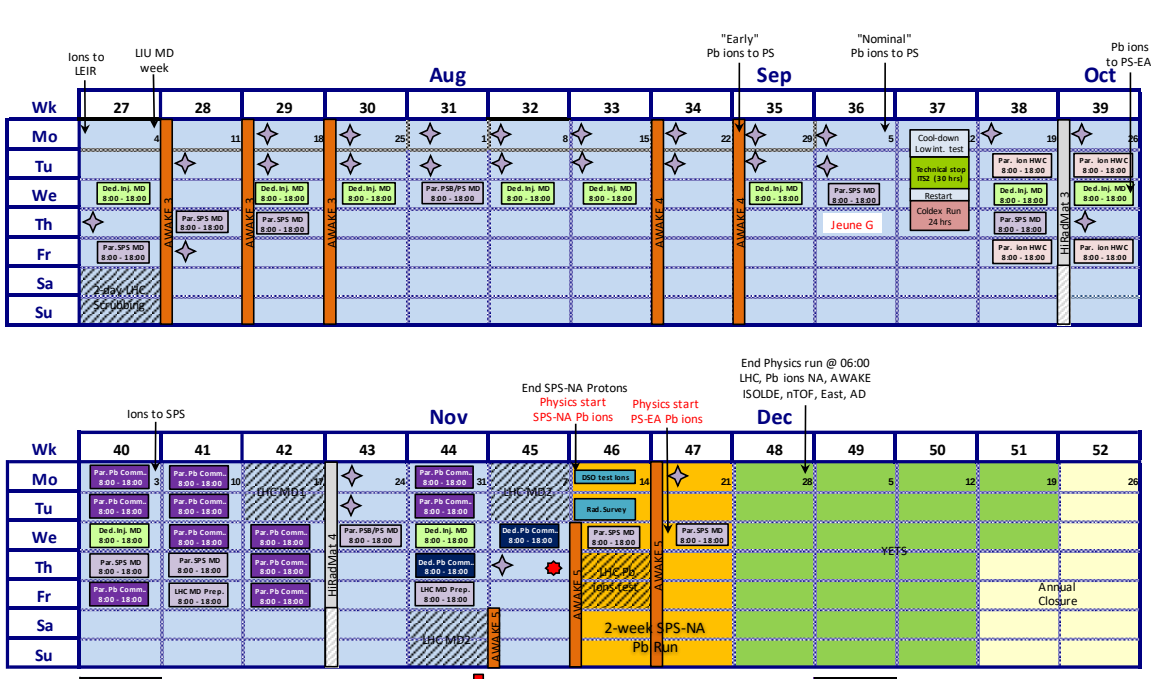


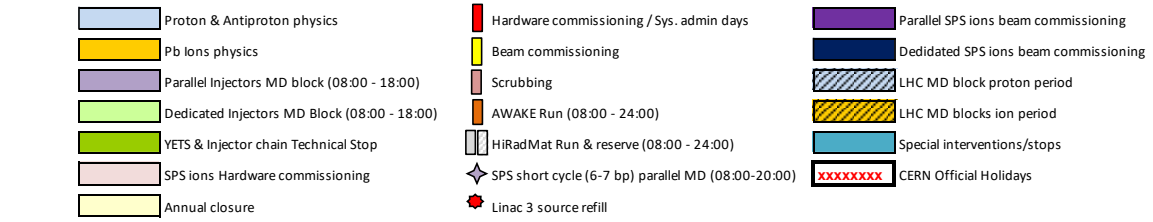
- SFTPRO + SFTION
- Secondary beamlines
- HiRadMat
- AWAKE

- SFTPRO Beam Production and Delivery (Protons + Ions) (20′ + 10′) --> **K. Li**
  Can we remove the 'ions' from this talk? (see last talk of session 6!)<–No, the discussion was that we keep it in with 1-2 slides on the very generalities of this beam. Barbara commented that what we need to mention though is the possibility of having a longer flat-top for the lower momenta (SPS) <-- A future BE-OP-SPS / BE-EA / TE-MSC action to be studied.
  - Talk by Kevin last year (add link in 2022 talk)
  - Intensity evolution along the year and mention of related radiation issues (see IEFC 7/10)
  - **Table with IEF 2021 WS actions status** (https://cernbox.cern.ch/index.php/s/RJIMA1c1yn4BGQU#office)
    - resolved / ongoing (short-/longterm) / open / will not be done
    - 6 14 Quantify any gains from longer Flat-Top length for ion and p+ spills (OP, Phys Coord, ABT) / Add planned periods to work with Experiments on spill structure in SPS (OP) — now — OP — V.Kain — Done (IEFC #304)
    - 19 SPS stability not adequate and sensitive when changing intensity, investigate as 'project' target (OP, MSC) — now — OP — V.Kain — Done (IEFC #307)
    - 66 Reinforce 'project' to use predictive hysteresis and field modeling for improving reproducibility (OP, MSC, ABP, ABT) — Q4/22?? — OP — V.Kain — In progress
    - 18 Define when PS barrier bucket is planned for production deployment (RF, OP) — Q1/22 — RF — M. Vadai — In progress
    - 20 64 Understand TT20 optics in 2022 (why Q-split is better than Q-split) (ABT, OP, EA) / Finish and report SPS MKP sectorization study (ABT, VSC, IEFC) — Q4/22 Q2/22 — ABT ABT — F.Velotti M.Barnes — In progress for end 2022 / In progress, Q3 2022
    - 17 Propose automatic surveillance and optimisation of MTE beam and extraction trajectory correction in TT2 (OP, ABT) — Q4/22 — OP — A.Huschauer — In progress with student
    - 12 Transmission to work on for ions (and other beams), make sure time available in PS and SPS schedule (OP) — now — OP — R.Alemany, OP SLs — In progress
  - **PSB improvements and issues** (remaining + new)
    - Vertical emittance adjustment (mis-steering at injection) following SPS request
    - MD version for PS with h2 at 800e10 ppr; had to reduce the Linac4 Espread
  - **PS improvements and issues** (remaining + new) for protons and ions
    - Include status of automatic island/core adjustment
    - Only mention briefly barrier bucket beam (details in session 6)
    - Transfer line trajectories vs. BLMs, BCT calibration for consistent transmission measurements, new YASP stitched model
    - Trajectory drifts (PE.SMH16) --> in YETS22/23 propose a feedback correction; affects also TOF, AD
    - KPI: MTE efficiency (from SPS BI?), losses along the complex
  - **SPS improvements and issues** (remaining + new) for protons and ions (avoid overlap with session 6!)
    - Only mention briefly empty bucket channeling beam (details in session 6)
  - Improvements and issues (remaining + new) in **secondary beam lines** (ask for input from Anna Baratto-Roldan and Maarten van Dijk on H8/H6; see e.g. last EATM talk https://indico.cern.ch/event/1209397/contributions/5085768/attachments/2526238/4345139/Electron_tests_EATM.pdf)
    - Electron beam quality in SPS H6 and H8
    - Optimization of the measurement of tiny detectors
  - What are **BE-OP plans to resolve remaining desiderata/issues and improve the beam delivery for the experiments**? How can we do better?
  - Summary slide: **top 3 desiderata** weighed by impact --> input to other session

Injectors physics delivery – schedule





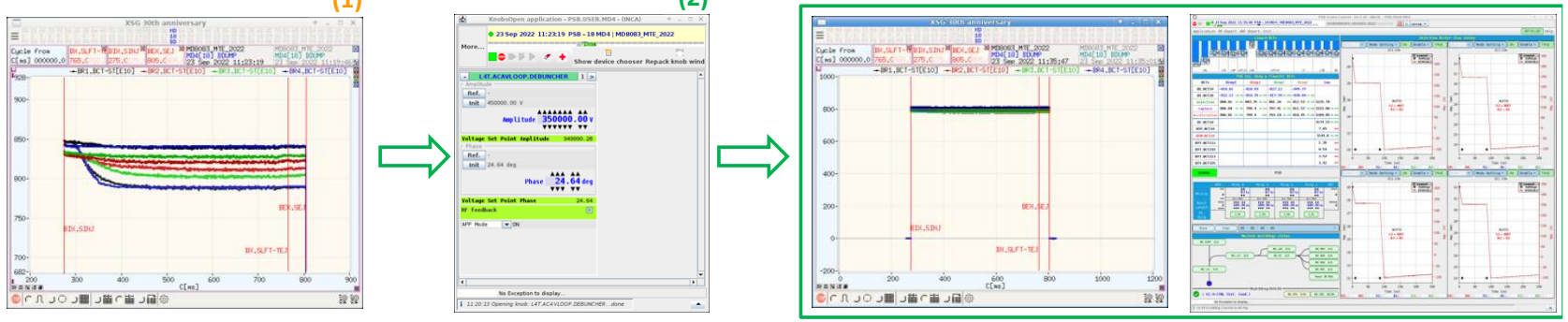


- Timely start-up of all physics programs, including ions!
- **Start of NA physics: 26.04.2022 → total of 29 weeks**
- **First HiRadMat run 18.05.2022 → total of 4 weeks**
- **First AWAKE run: 02.05.2022 → total of 11 weeks**
- **Start NA ions: 14.11.2022 → total of ~1 week**

Selected improvements along the chain – PS Booster

- Off the menu emittances – reference size for HiRadMat, variable vertical for SFTPRO
  - MTE:
    - Vertical emittance critical for machine and spitter losses in the SPS – has been optimized and can be delivered on spot by the PSB **now around 4.5 um** at ~600e10 ppr (→ 4.2e13 ppb in SPS)
    - Still to be decided whether the SPS prefers different configurations based on the intensity; at this point, does not seem to be necessary
    - High intensity variant tested up to 800e10 ppr in all 4 rings!

(1) (2) (3)



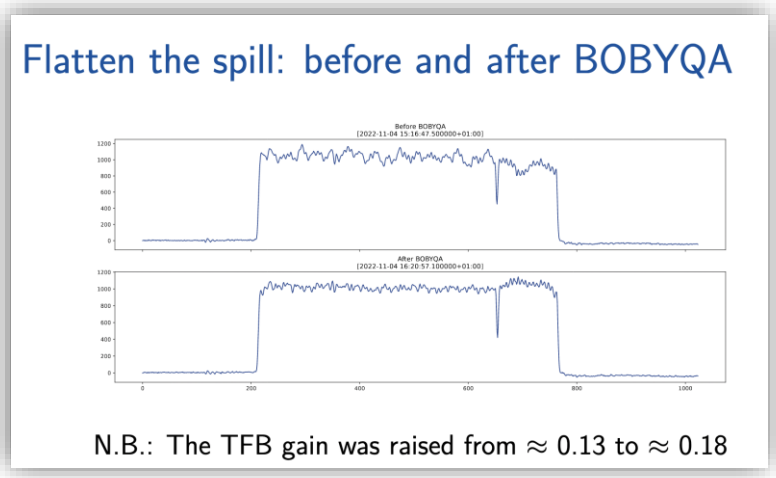
F. Asvesta

  - HiRadMat:
    - All HiRadMat optics are now matched to a **reference beam of 2.5 um emittance** at ~1.2e11 ppb
    - Beam produced in the PSB and the PS via:
      - Prolonged foil scattering (keep the painting bump on until the end – enforced in the PSB via interlock for HiRadMat!)
      - Remaining transverse BU added in the PS by approaching the tune integer – has been stable so far except for the last run → should be studied

Selected improvements along the chain – PS

- TT2 BCT calibration done on 18. August:
  - Manually adjusted the calibration factor of BCT212 to match better BCT203; after changes on the SPS side the **values are consistent with the SPS** (< 1% deviation)

- Automatic splitting ratio correction tested in MDs (beneficial impact for PS2SPS transfer and SPS transmission, especially for high intensities!)

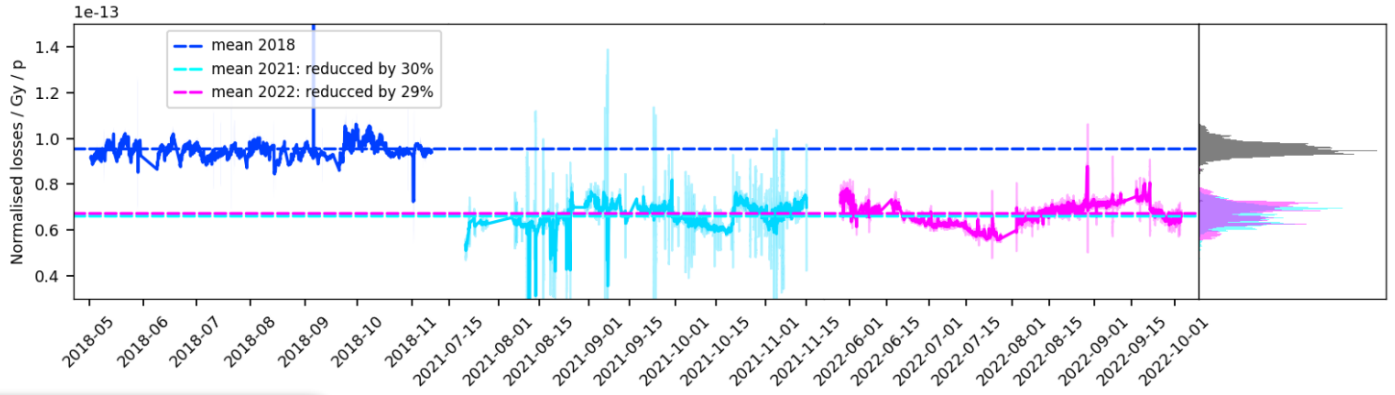


C. Uden with CSS-DSB

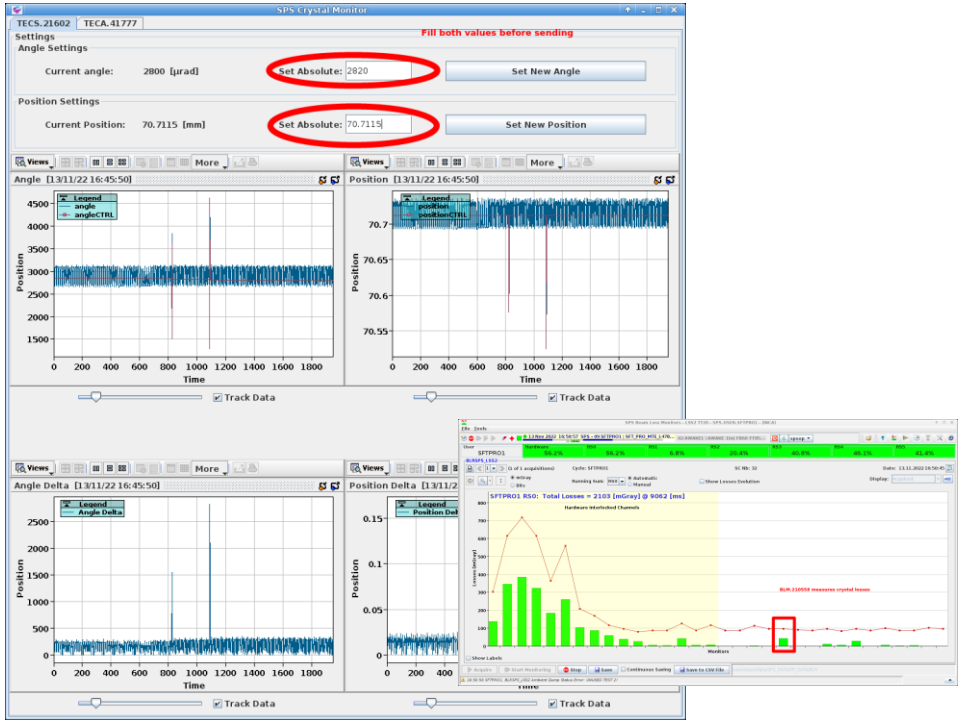
- Automatic DFAs setting up deployed during commissioning
  - DFA not pulsing every now and then, which went mostly unnoticed in the SPS
  - Not pulsing because the length of one of the LTIM trigger pulses dropped below 1us – was resolved mid-September

Selected improvements along the chain – SPS

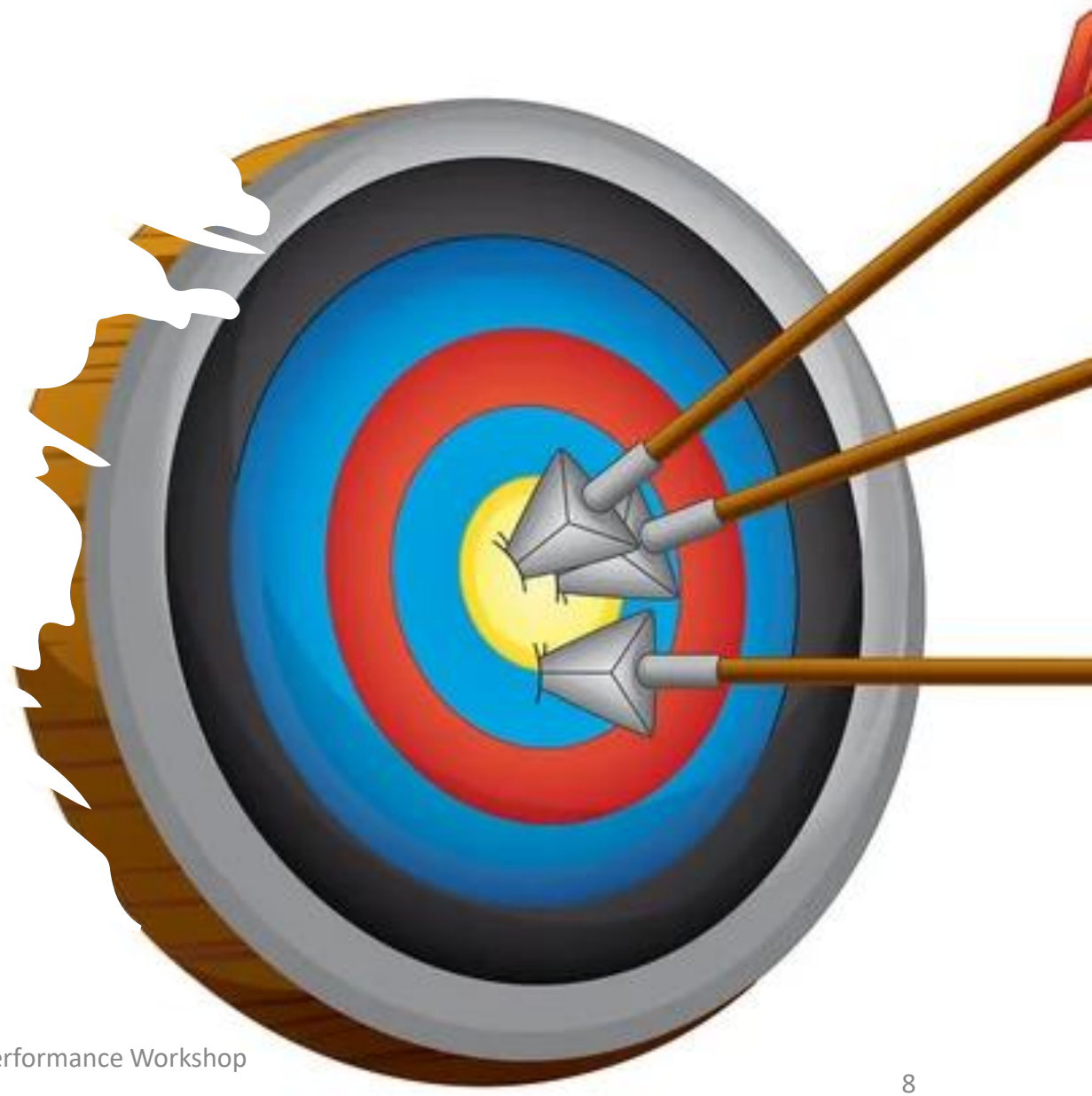
- Operational
  - Machine losses
  - Great summary at: https://indico.cern.ch/event/1164869/contributions/4891799/attachments/2480155/4257440/sx_losses_ipp_22.pdf



- Reduction of splitter losses from **larger vertical emittance** beam
- Automatic ZS and girder alignment for quick and efficient optimization of losses
- Impressive and consistent **loss reduction since LSS2 crystal** put into operation (clearly visible also in radiation survey!)
- Sudden changes during the year still occur from time to time – requires expert intervention; **operational tool ready with GUI in preparation**



SFTPROTON



SPS – SE quality control – so how did we do?

Figure	Goal	Remarks
PS2SPS transfer	95 %	Transmission at 4e13 ppb
Transmission	95 %	Transmission at 4e13 ppb
Intensity on target [arb. units]	+- 5	
Symmetry on target > 95 %	95 %	Percentage of time
Spill duty factor > 90%	90 %	Macro-structure; percentage of time
50 Hz noise < 0.1	90 %	Percentage of time
100 Hz noise < 0.15	85 %	Percentage of time

- Carry-over from 2021:

✗ • Transmission: **need more automation** for hysteresis control, orbit correction, RF gymnastics setting up

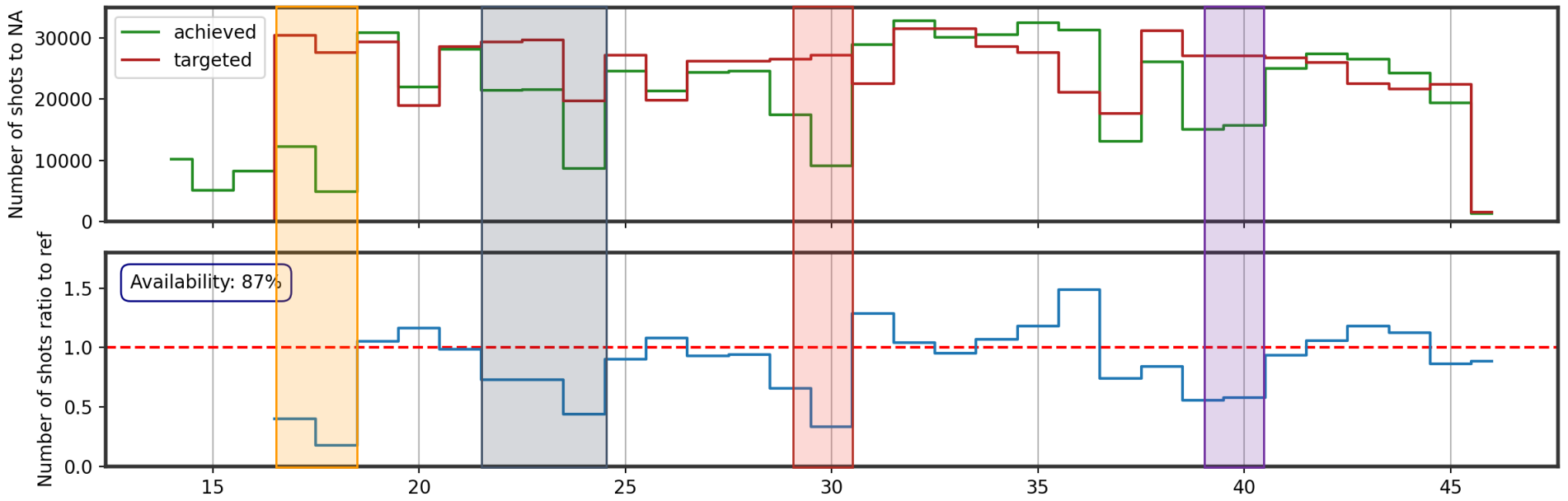
✓ • Spill quality: **need more automation for spill correction** (steering for sharing and symmetry, autospill, noise reduction)

◯ • Orbit stability at start of slow extraction for loss reduction scenarios

✓ • Spike before slow extraction start is **still present**

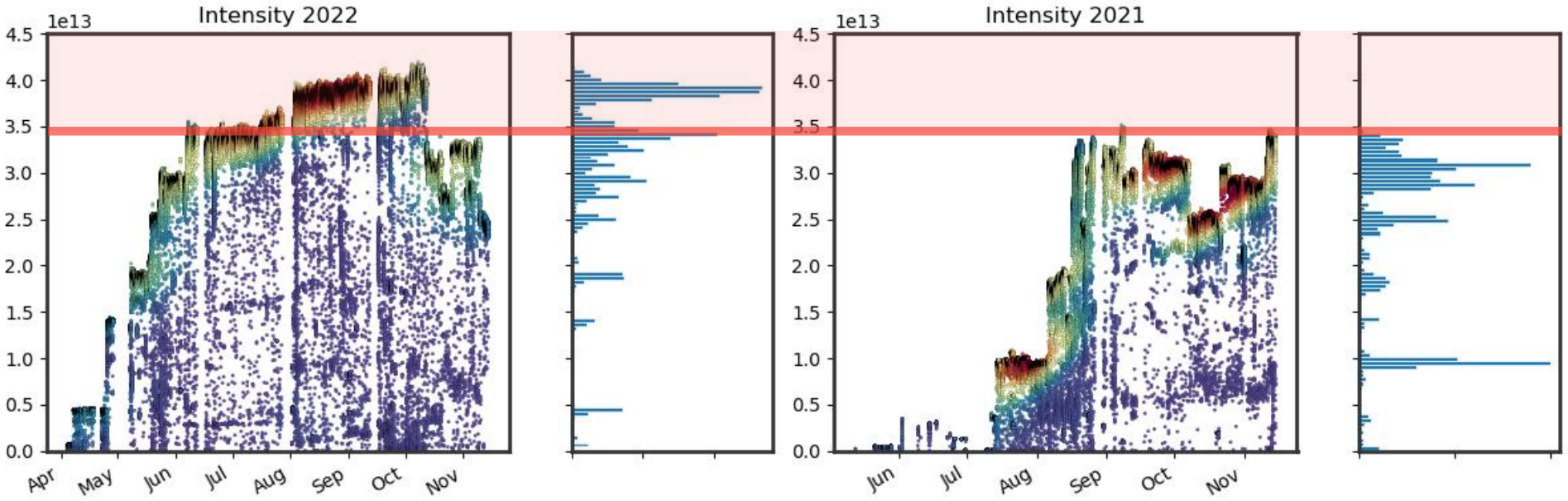
SPS NA physics delivery – "availability" overview

On average: 87% delivered shots



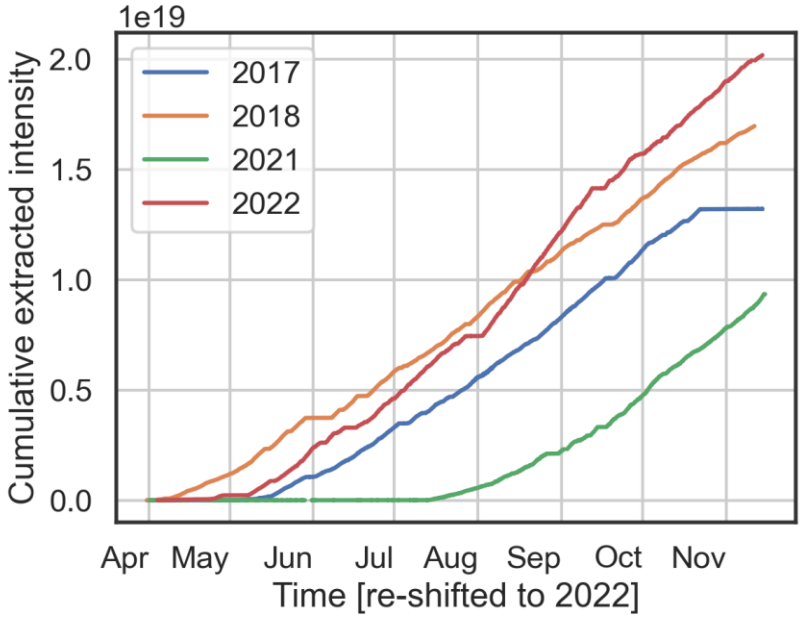
- **Weeks 17 / 18: TDC2 / TCSC water leak, intervention in BA80, fix by Friday afternoon with modified cooling circuit**
- **Week 22: ZS #1 – cables replacement ZS1 and ZS2 (4 cables – not all to specs)**
- **Week 24: ZS #2 – ion trap feedthroughs sandblasted and cable replacement (to specs)**
- Week 27: AWAKE phase loop issue found; not yet understood
- **Week 30: Wobbling magnet failure followed by TBIU event (excellent response this year from teams in BI, VSC, STI,… !)**
- Week 36: ADTH trips
- **Week 40: PS POPS**

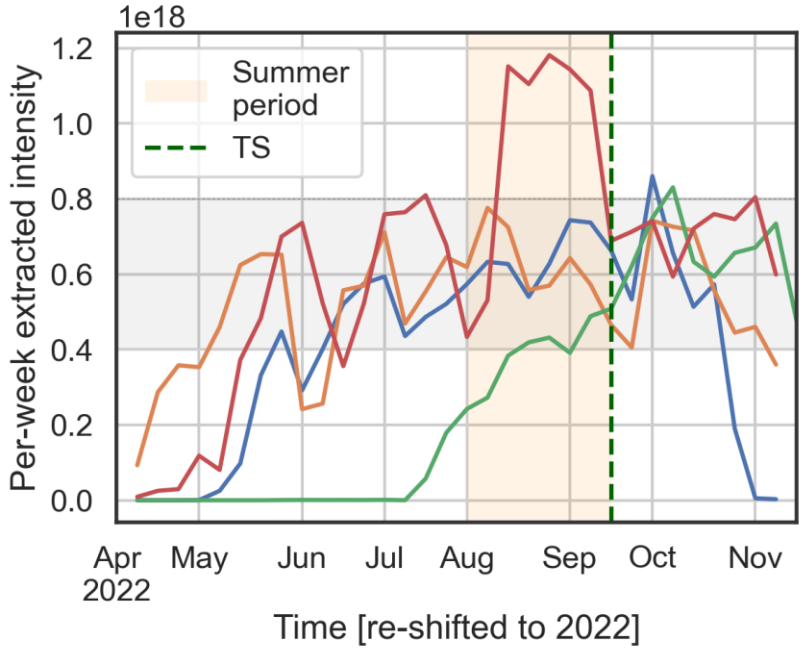
SPS NA physics delivery – intensities



- Very **high intensities requested and reached** during most part of the summer!
- Struggling with stability – running **close to the machine limits** (beam stability, losses,…)
- Still, managed to obtain mostly stable, solid and reliable beam parameters throughout the summer… up to **beyond** the generally accepted limits!

SPS NA physics delivery – intensities





- **Extracted intensities were reviewed**
- **Per-week extracted intensities still need limit to be established → 0.8e18 ppw looks like a reasonable number**
- **Cumulative extracted intensity for a typical year (29 weeks in 2022) not more than 23e18 p+**

- Very **high intensities requested and reached** during most part of the summer!
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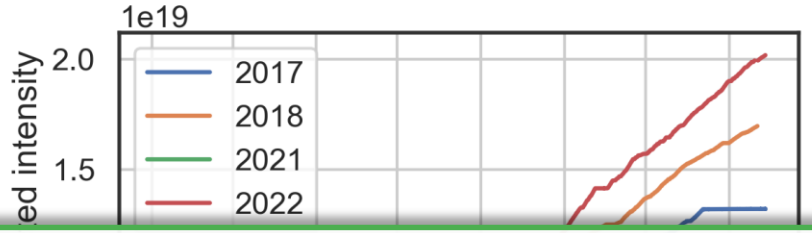
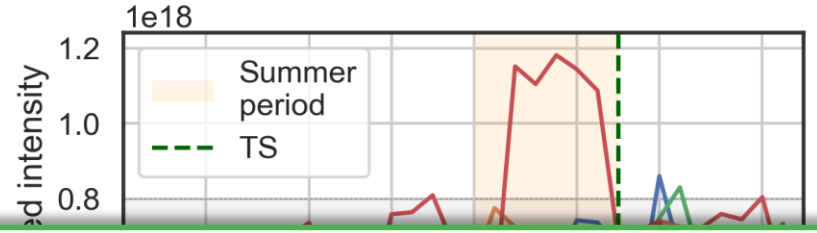
- Still, managed to obtain mostly stable, solid and reliable beam parameters throughout the summer… up to **beyond** the generally accepted limits!

→ **Unprecedented intensities and extraction rates** during summer period in 2022!

SPS NA physics delivery – intensities





- **Extracted intensities were reviewed**
- **Per-week extracted**

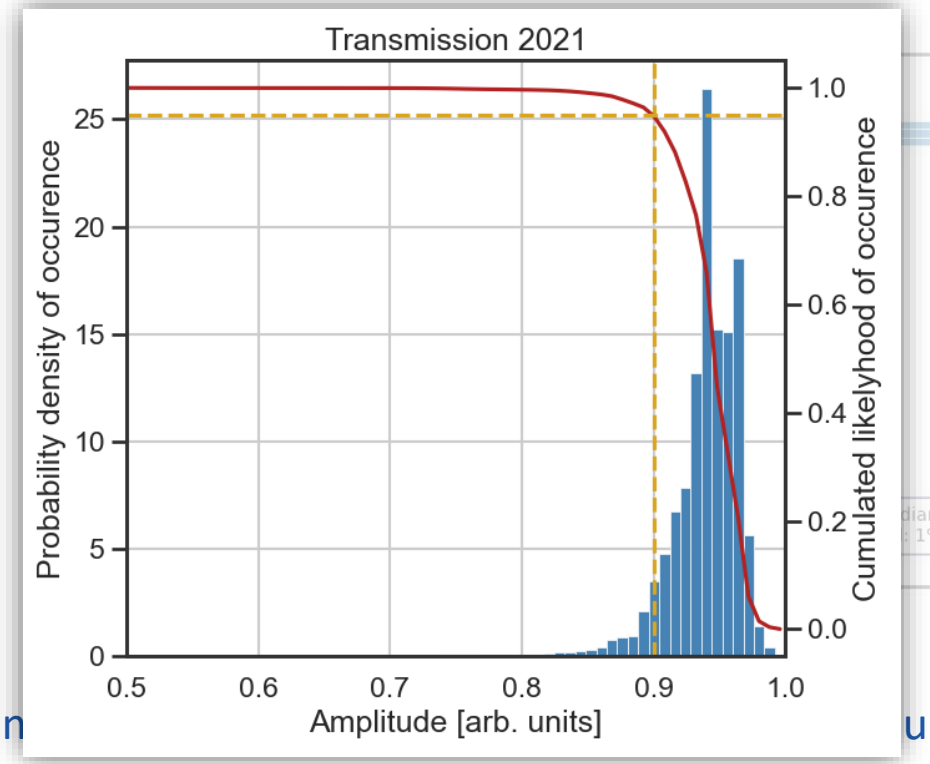
Outlook for 2023 – there is an action plan being followed up by the SLAWG:

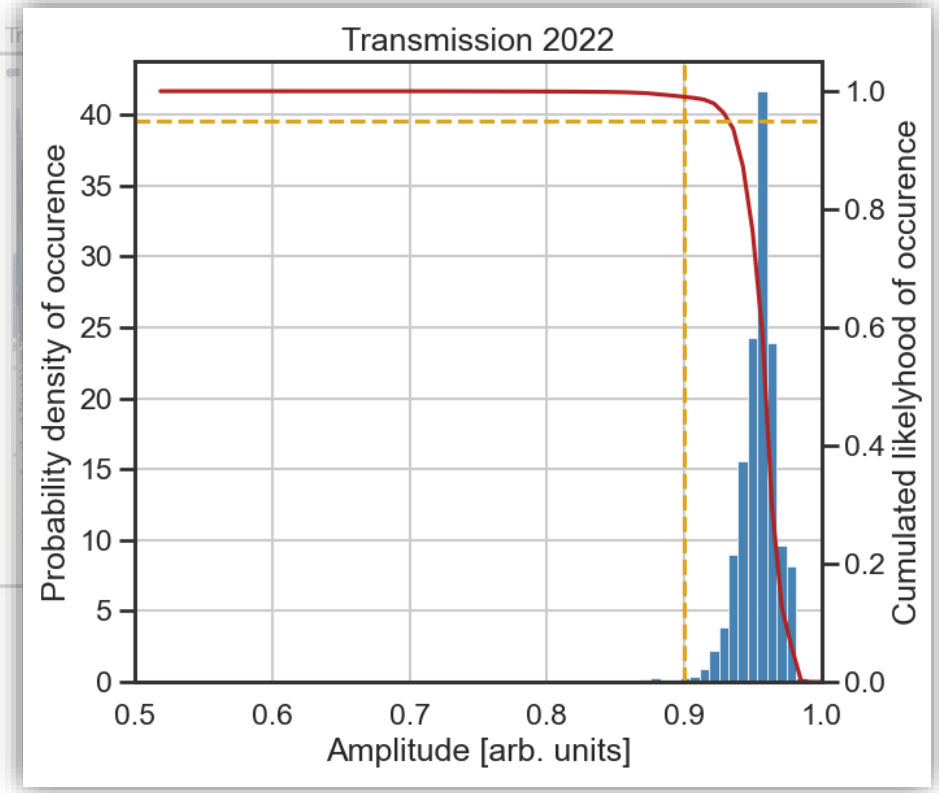
- Request for **input from BE-EA** on the required intensities for 2023 (awaiting feedback)
- With this, prepare a schedule with the 2023 NA physics requests, to be **presented to the IEFC** for approval

- SPS beam performance tracking will be prepared to monitor performance and compare with predictions
- In parallel, for failure of critical equipment (i.e., ZS or TCSC)
  - SLAWG is preparing an activation and cooldown prediction tool which will be used to analyse ZS and TCSC interventions and predict doses and cooldown times

→ **Unprecedented intensities and extraction rates** during summer period in 2022!

SPS NA physics delivery – transmission





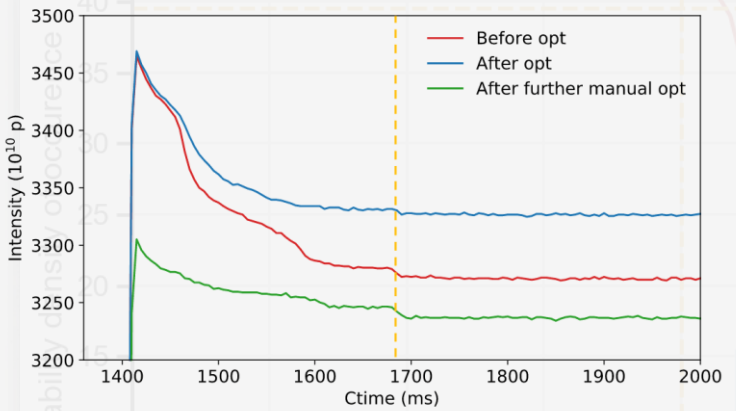
- Tran…und 95%!
- Generally good quality beams from the PS for most of the time!
- Transmission correlated with intensity – large intensities slightly penalized with poorer transmission

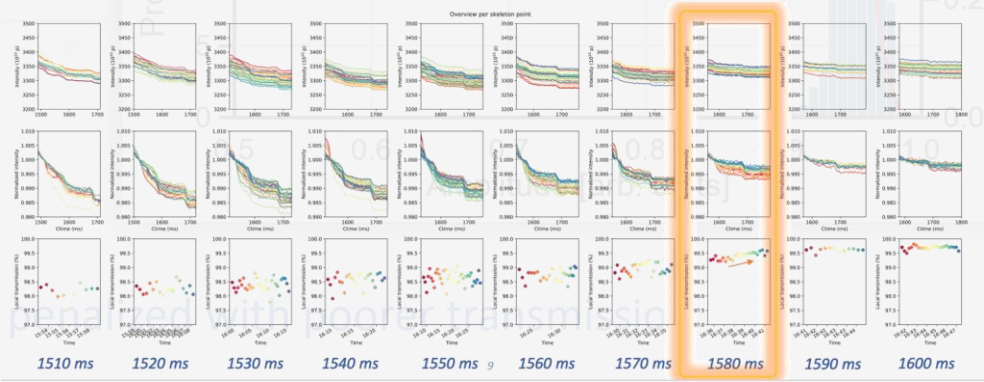
- Remained clearly **above 95% transmission for more than 90% of the time** – despite borderline intensities

SPS NA physics delivery – transmission

Work for the future:

- **Continuous optimization still done mostly by hand… but done well!**
- **Automation – potentially running in the background, under investigation in collaboration with CSS-DSB**

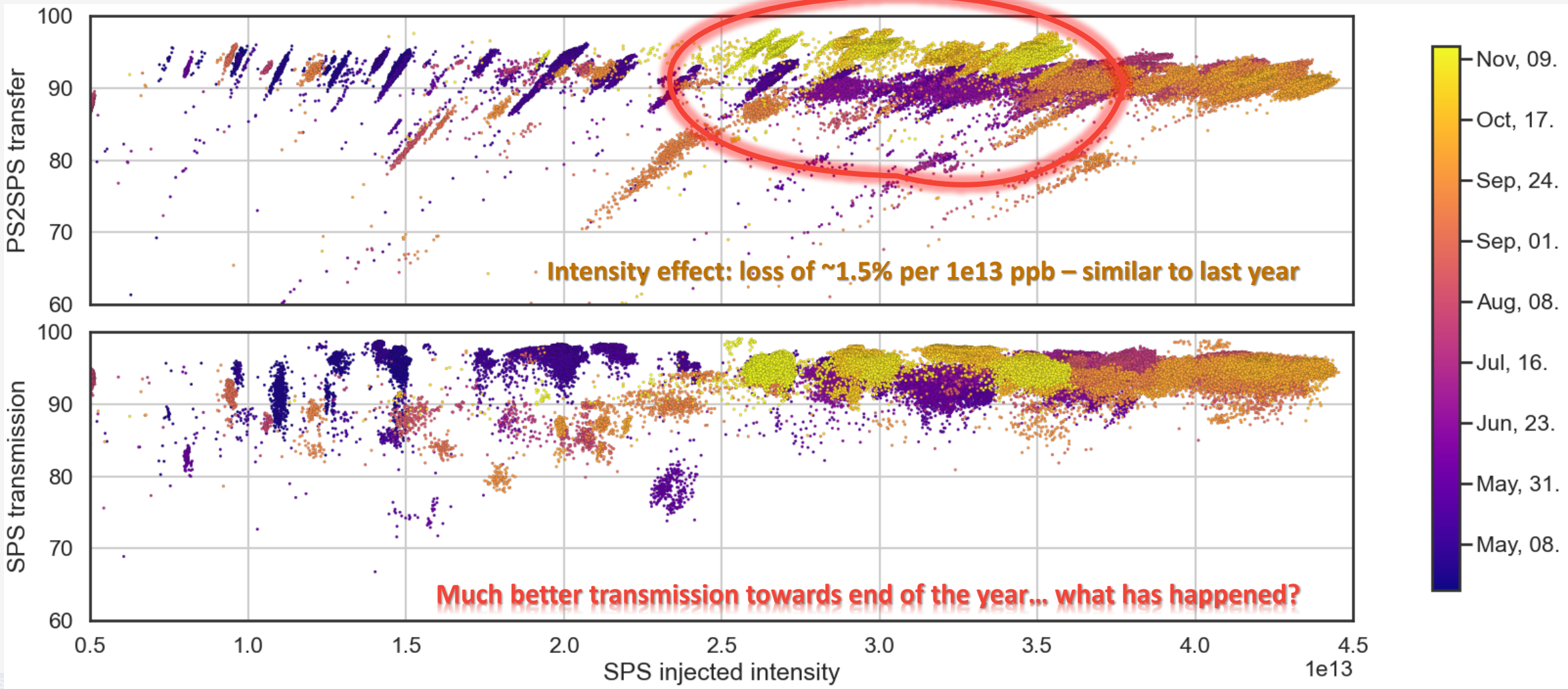




- Remained clearly **above 95% transmission for more than 90% of the time** – despite borderline intensities

PS2SPS transfer in 2022

- Intensity dependence **very similar** to last year – though **higher intensities** reached overall!



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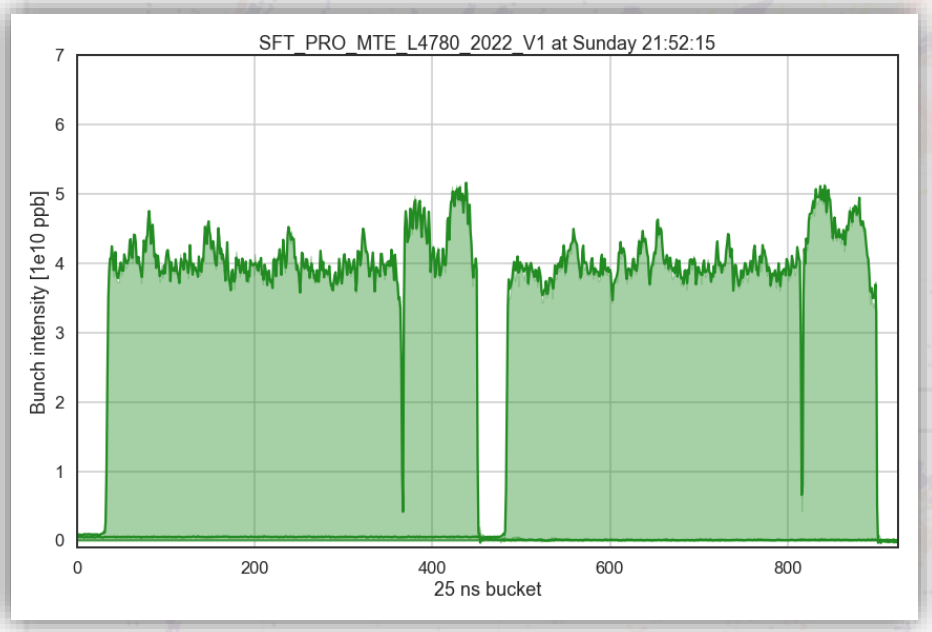
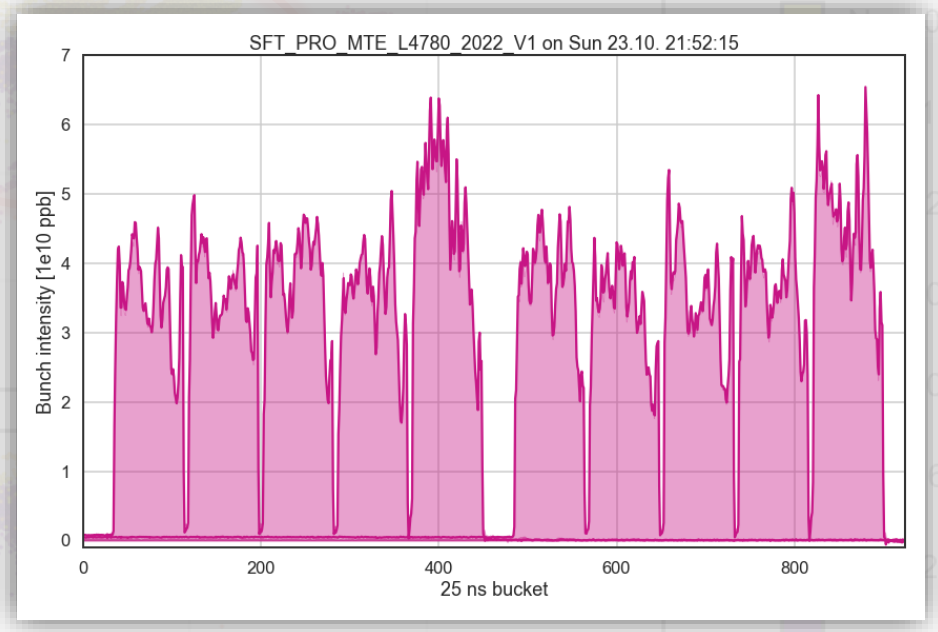




- Operational deployment of **barrier buckets** in the SPS
- Barrier buckets taken routinely **as of mid-October 2022**

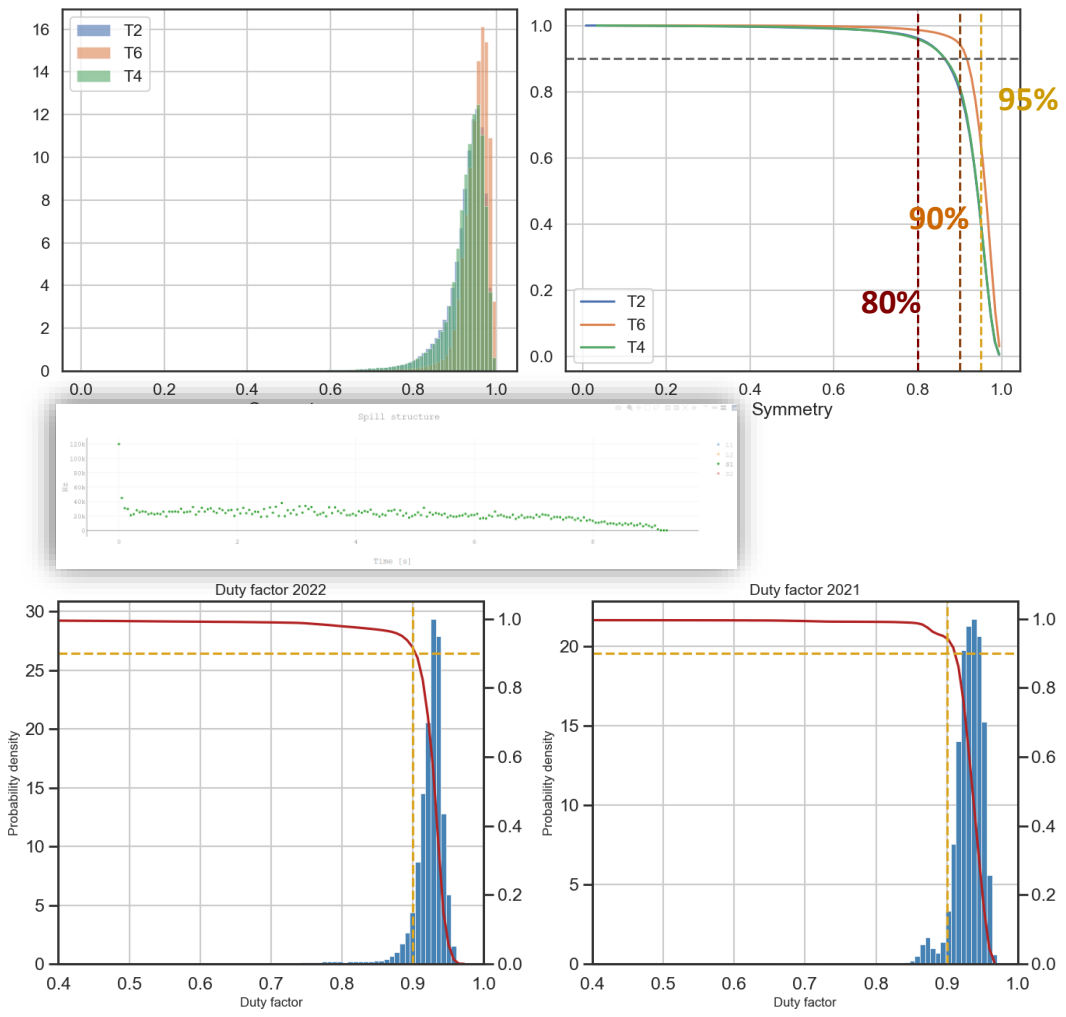
- More infos on barrier buckets in Mihaly's talk

SPS – quality control – other KPIs

- Intensity on target
  - Around 85% on average – similar to last year
  - Could be further improved in the future via **auto-pilot approach** as used for symmetry-on-target

- Symmetry
  - Clear **improvement over last year**
  - Thanks to **auto-pilot mostly active**, less drifts go unnoticed
  - Polarity change during steering disruptive – need to **find better operational integration**

- Spill duty factor – effective spill length / actual spill length:
  - Based on BSI measurement
  - Not sensitive to spikes at start of spill – need NA feedback for this
  - Spikes have **calmed down significantly during 2022** thanks to RF improvements (see later)



Symmetry	Time of run
> 95 %	65 %
> 90 %	80 %
> 80 %	95 %

- Did not meet our goals, again (goal > 95% for 95% of the time)
- Try new ideas and methods (ABO?)
- Ultimate goal – **BSGs around targets** (beam instrumentation)

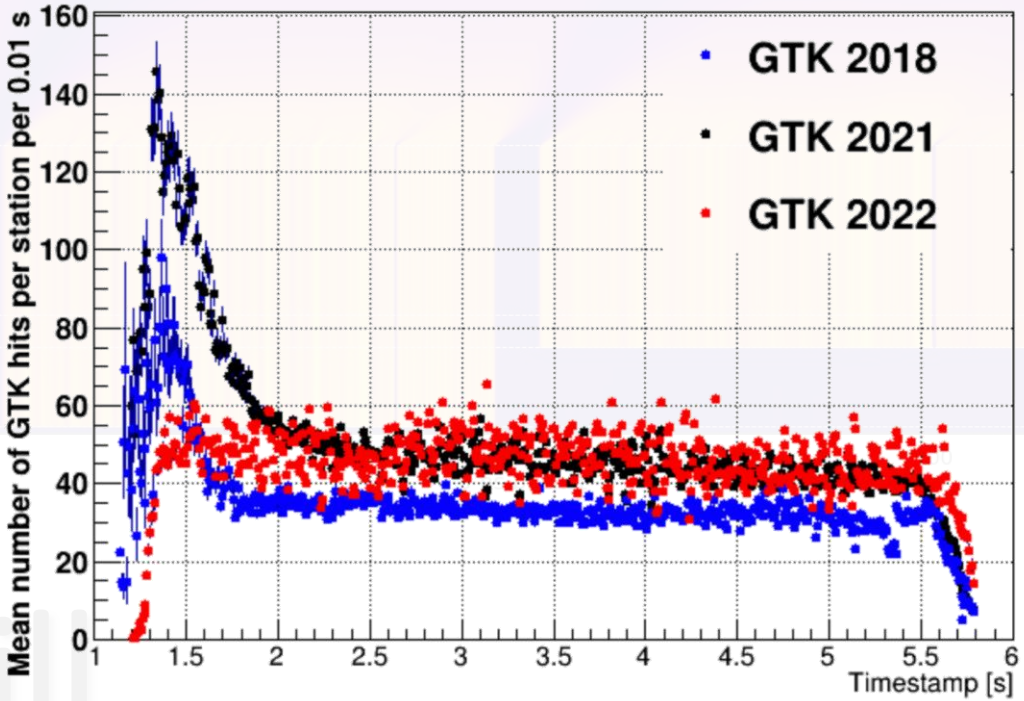
- Spill duty factor **> 90% for more than 90% of the time**
- Very similar to previous year
- Spike at start of spill not visible in BSI

2021

2022

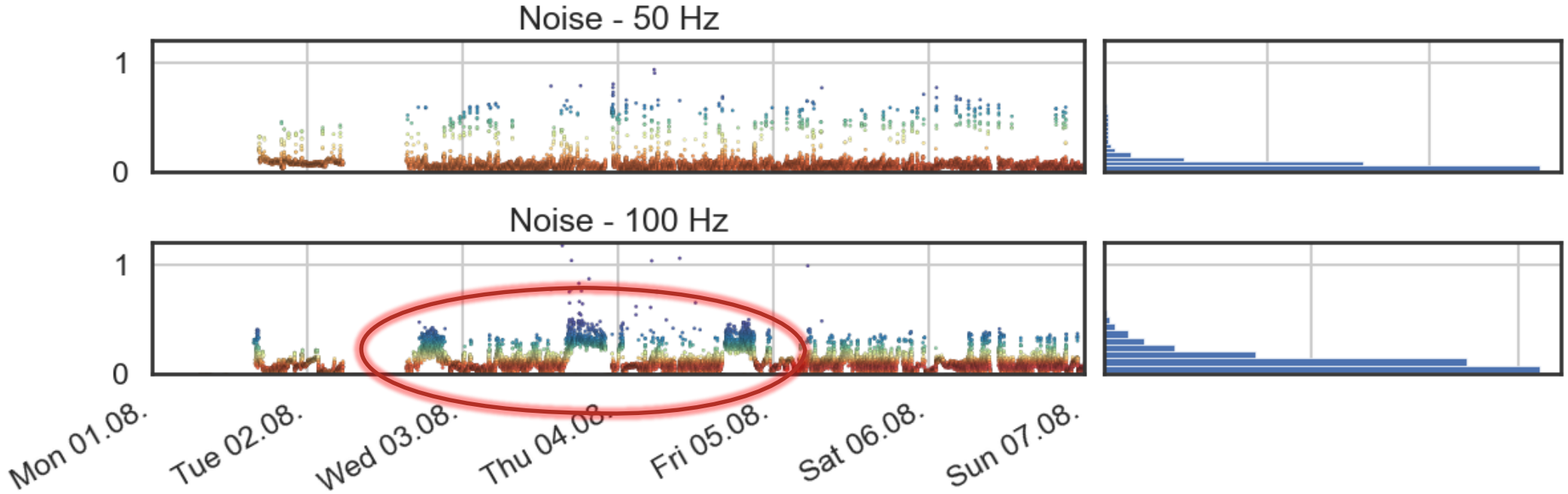
- Spill quality issues observed in 2021 solved
  - Also thanks to very fruitful collaboration with NA62
  - 200 MHz structure gone & “bump” gone
- SFTPRO improvements in 2022 based on
  1. VRF = 0 by counter-phasing, voltage errors pre-corrections, delayed RF off (400 ms after start flat top)
  2. Use of 800 MHz RF system and controlled longitudinal blow up for beam stability and improved Dp/p
  - Prepared during beam commissioning and machine developments
    - Some fine tuning in parallel to physics

More details in 307th IEFC and Mini IPP on slow extraction



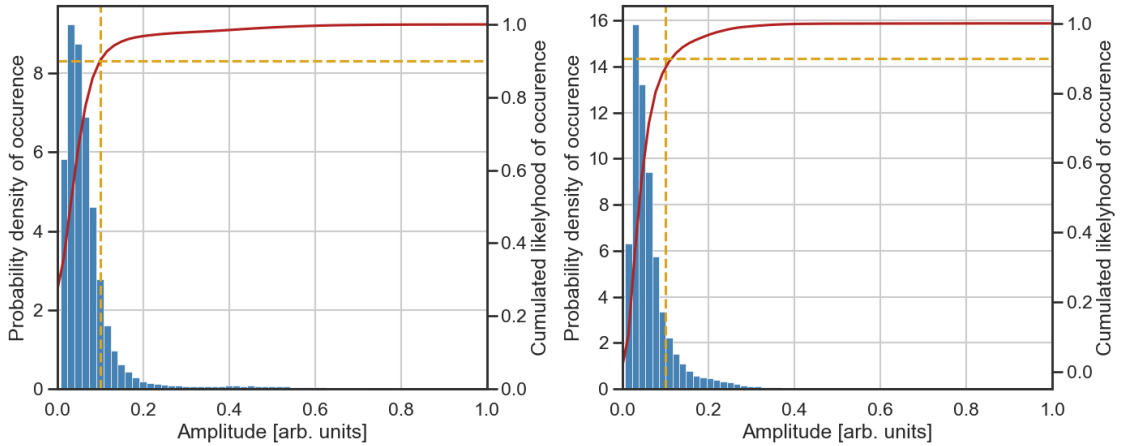
R. Piandani

SPS NA – what about the “classical” spill noise?



- Noise evolution over the year – often under control, but…
- Periodically occurring runaway phases encountered, for which **automatic correction has difficulties** to cope with!

- 2022 just on target; an improvement over last year
- Auto-launch of optimizer kept active most of the times; algorithms **not yet able to reliable follow** the noise evolution (BOBYQA, EIS,…)
- In the future, may try adaptive algorithms, or ABO, amongst others



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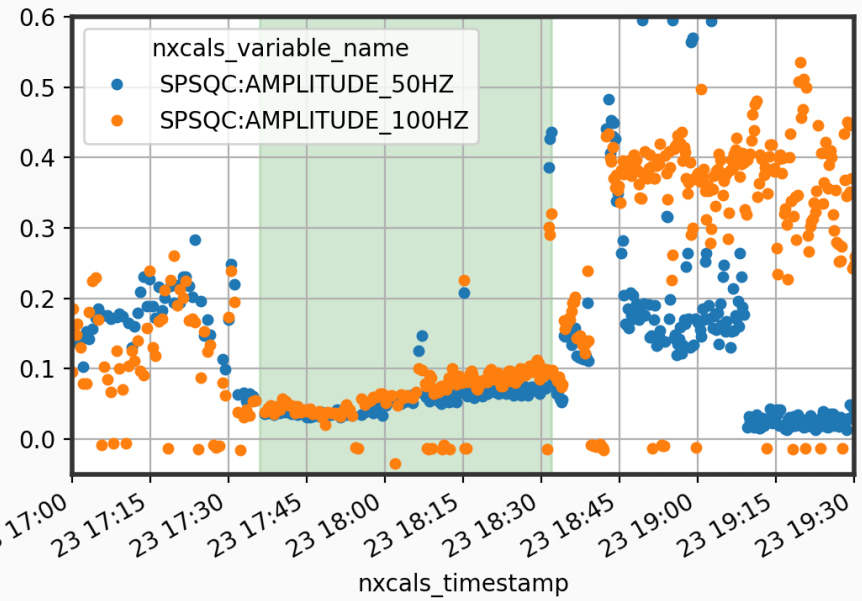
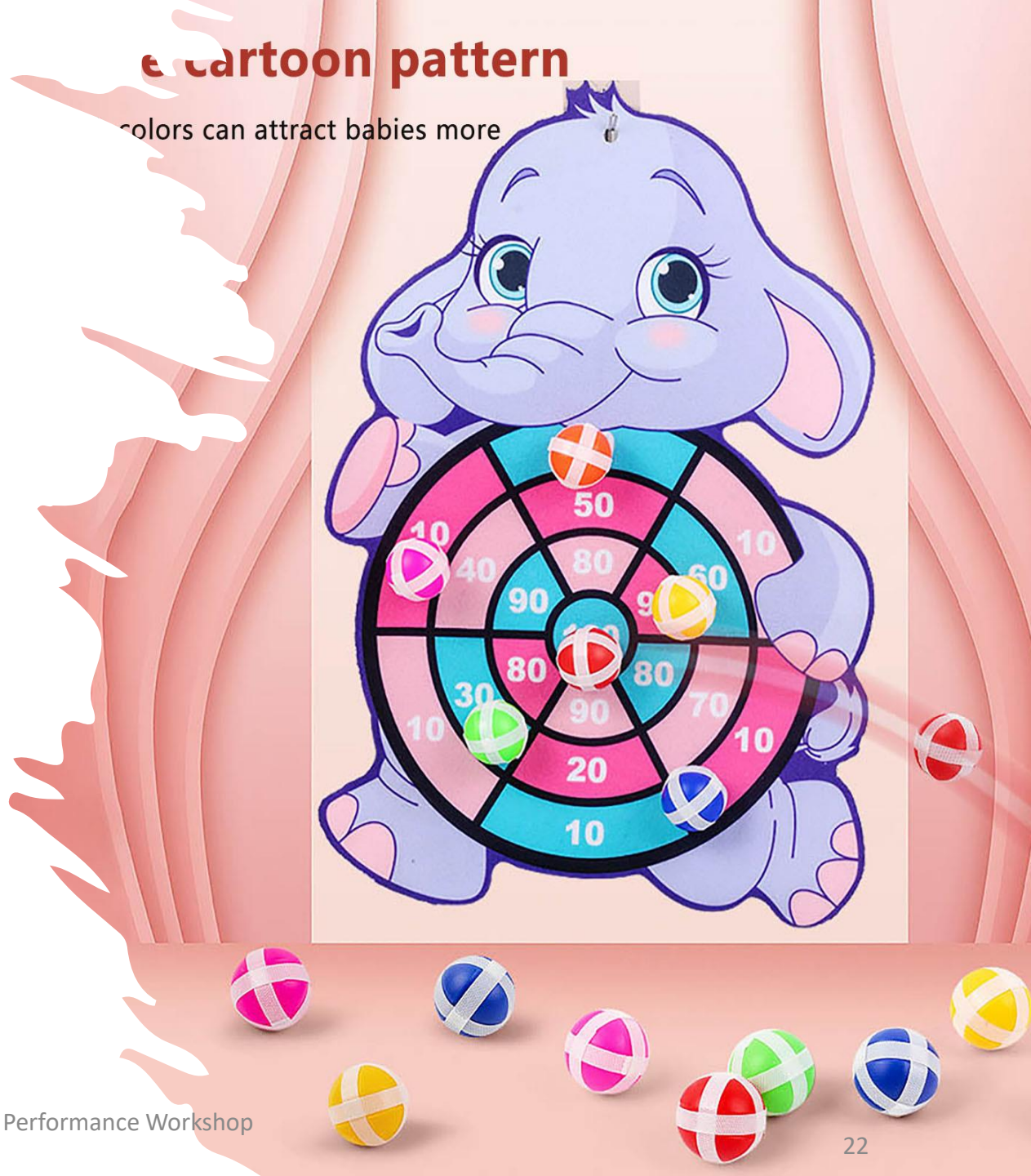


More details and analysis to be found in Pablo’s talk

Work for 2023:

- Need to **invest more in regulation on the HW side (EPC)** and **SW optimization (CSS)** + alternative techniques, i.e., empty bucket channeling
- Get common set of KPIs from experiments – connected to this, also **review machine KPIs** (i.e., quantifying spill quality across all timescales; instrumentation needed)

SFTION


cartoon pattern
colors can attract babies more
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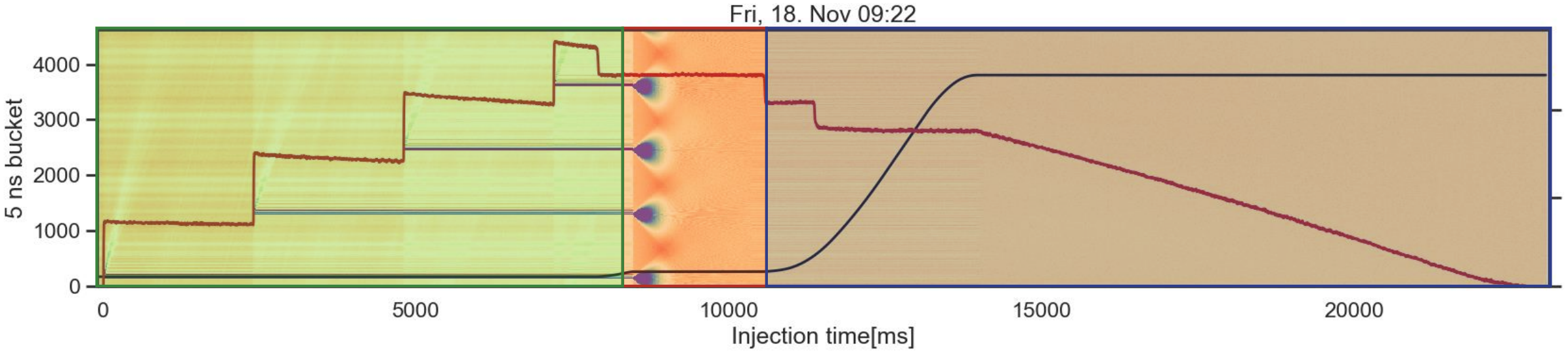
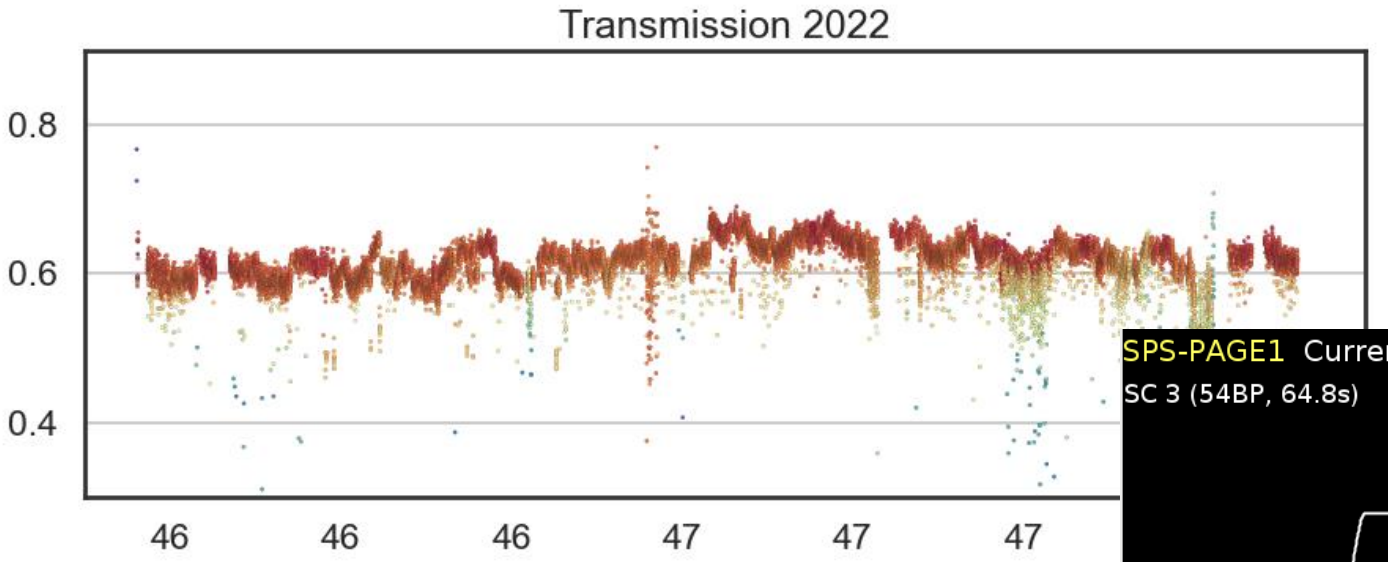
SPS 2022 FT Ions – cycle

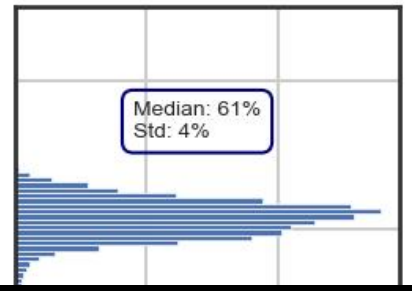


Work for 2023:

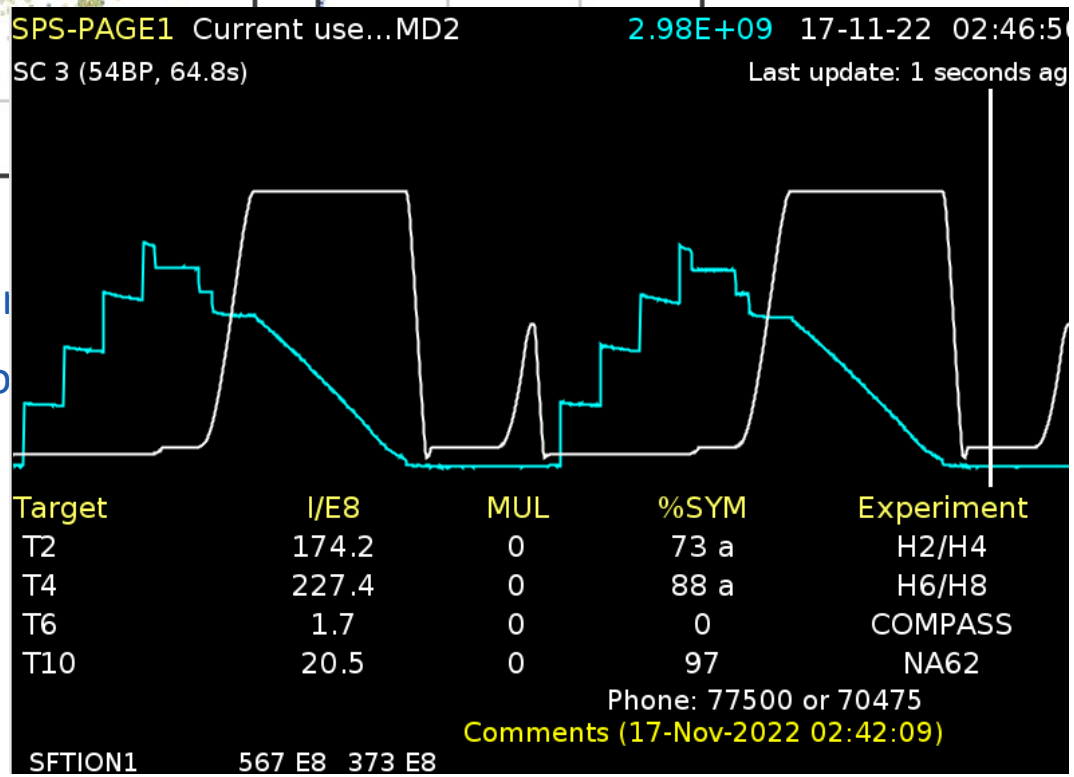
- Quite a few settings and sequences to juggle on RF side → after first commissioning **will need consolidation** in terms of operational integration (HL knobs, value generators)
- Study possibility of prolonged spill length at lower rate for low energy ions
- ABT interested in studying alternative SE techniques for ions where radioactivation from beam loss is not critical

SPS 2022 FT Ions – intensity & transmission

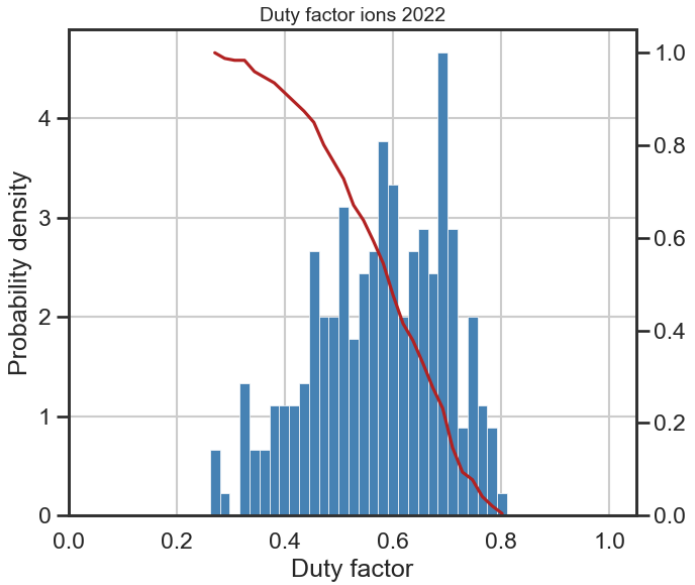


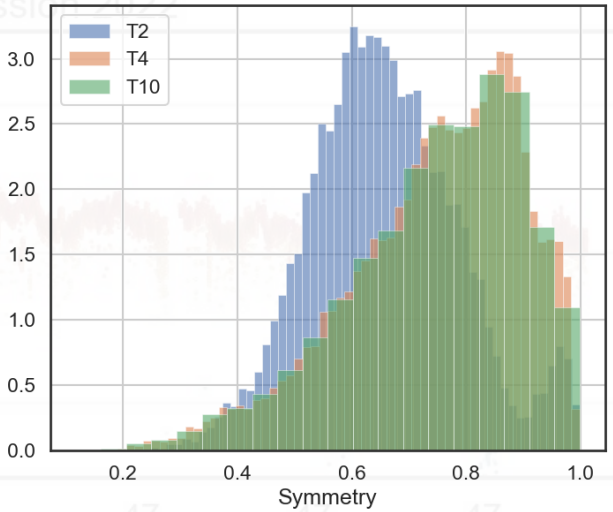


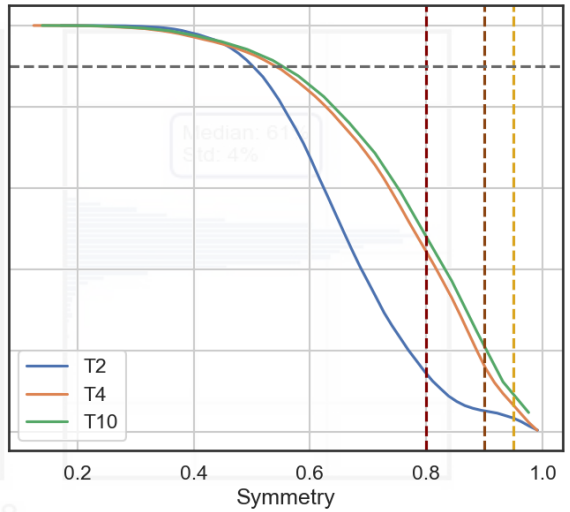
- Overall intensity less of an issue as we are providing more ions thar
- Transmission not much of an issue either – also due to low radiatio



SPS 2022 FT Ions – spill quality "monitoring"



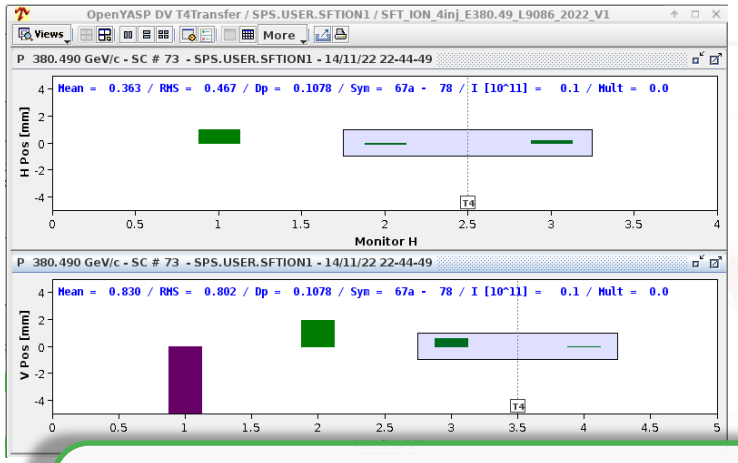


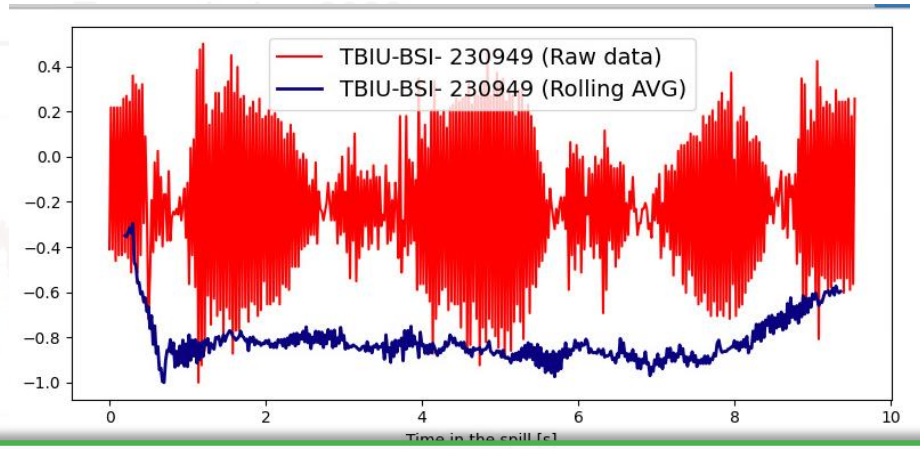


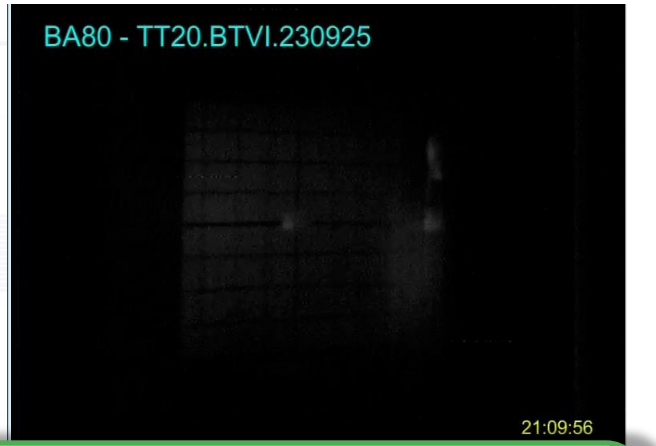
- Overall intensity less of an issue as we are providing more ions than actually used by the experiments
- Transmission not much of an issue either – also due to low radiation doses from ion beams

- Spill quality assessment difficult due to **beam instrumentation which is not perfectly well adapted** to the very low intensity ion beams → e.g., BSIs highly infiltrated by noise
- No good measurements of symmetry or noise content

SPS 2022 FT Ions – spill quality "monitoring"





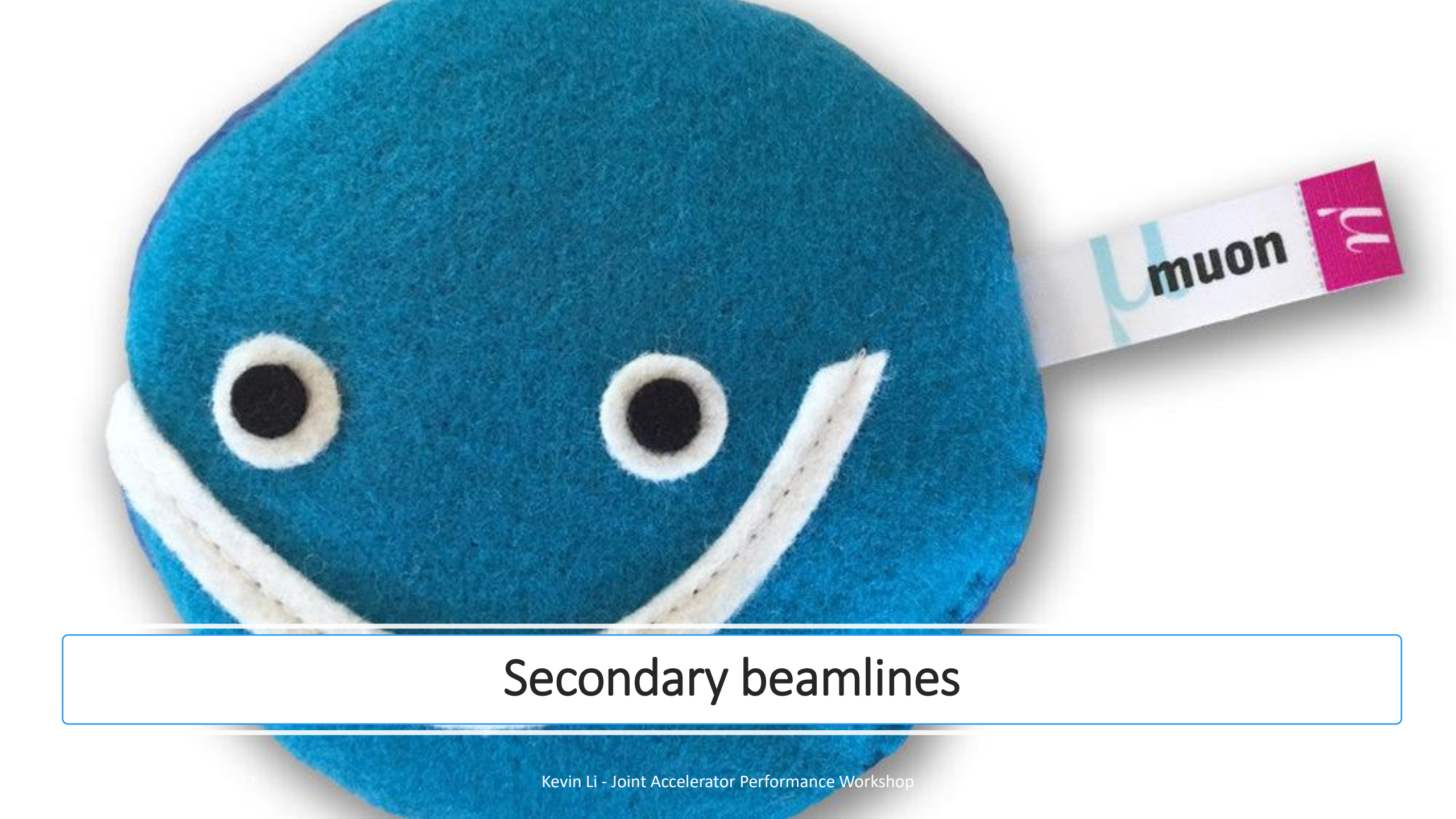


Wish list for the future:

Beam instrumentation in the target lines is **a general difficulty for slow extraction setting up** – it is hard for protons and it is yet more challenging for ions – every year we face the risk of losing lots of time for steering to targets:

- **Re-aligning beam – target – TBIU after wobbling magnet failure**
- **Steering-to-targets of ions beams at start of ion run**

Is highly important and is currently being addressed in the framework of revision NA target station consolidation
→ need to produce a **clear functional specification** especially for the beam instrumentation to be defined by BE-EA in collaboration with BE-OP and SY-ABT as input for SY-BI



Secondary beamlines

Smaller beam spots in H6 and H8

Options - machines:

Scheme	Advantage	Disadvantage
H8 microbeam optics	1.5 mm primary beams upstream zone of H8	Dedicated running implying stop of P42 and thus NA62

Work for the future:

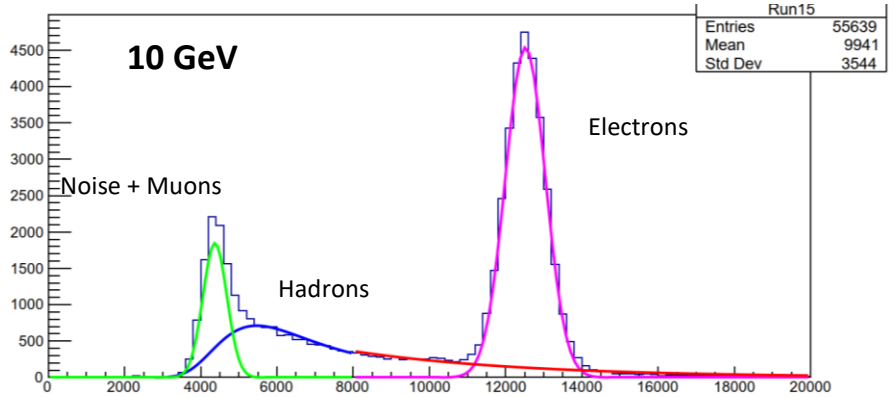
- Study **dedicated optics for one user location** (e.g. H6A) and possible addition of new quadrupoles to allow best focus (BE-EA)
- Check **feasibility and cost of additional quadrupoles** between user set-ups to see whether a second user location could be provided (BE-EA)

Electron tests in H8

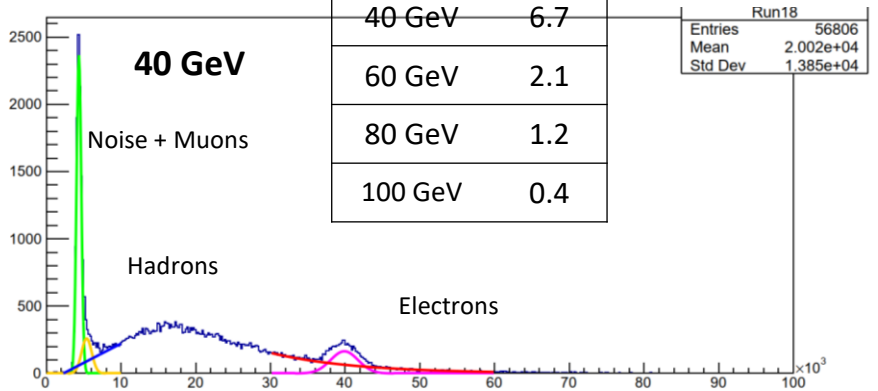
- Before LS2, deterioration of electron intensity and purity in tertiary electron beams in H6 and H8 has been observed

- Investigations have not yet been conclusive:
  - H8 beam line opened, no obstruction found (TCC2 could not be checked due to radiation conditions)
  - Electron composition measurements were performed in H8 with tertiary beams up to 300 GeV/c with a XEMC (electromagnetic calorimeter in W35/36) – measurements confirm pre-LS2 observation, especially from 40 GeV/c upwards, but did not show any further degradation since 2021

- Proposition:
  - Check the **P42 electron beam during the upcoming commissioning** to check the common part of the H6, H8 and P42 beam lines in TCC2
  - Meanwhile, do not use H6 and H8 for high-energy electron beams and users that require high electron purities



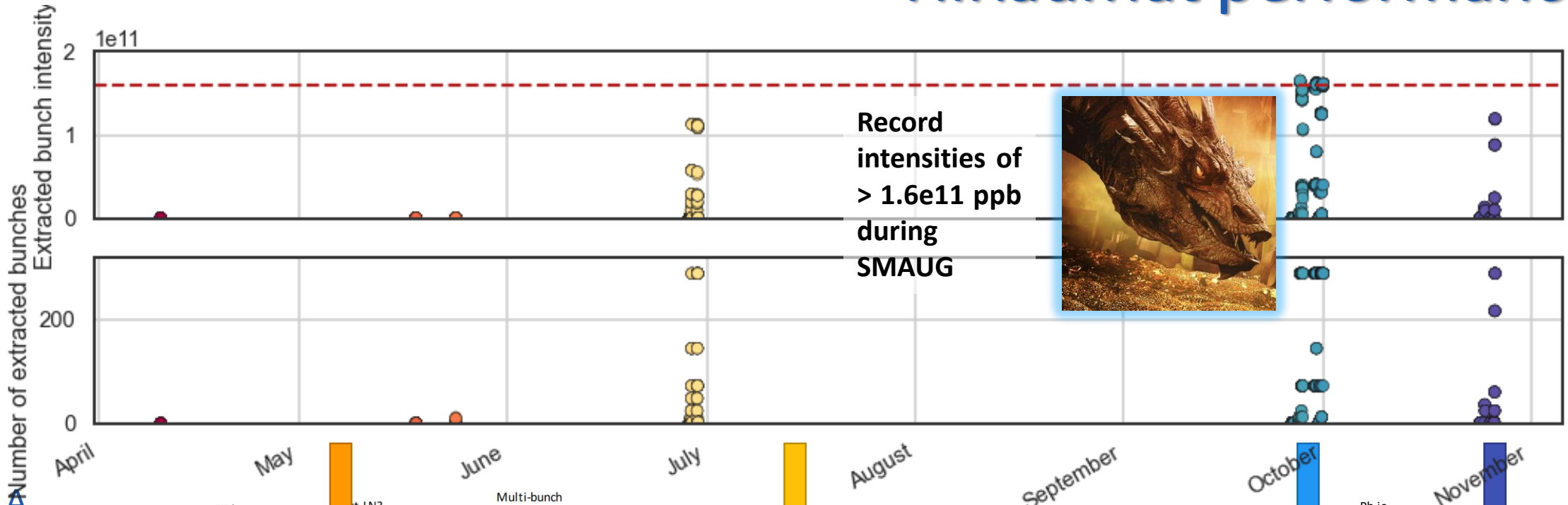
Momentum	Purity %
10 GeV	53.7
20 GeV	27.1
40 GeV	6.7
60 GeV	2.1
80 GeV	1.2
100 GeV	0.4



HiRadMat

HiRadMat performance

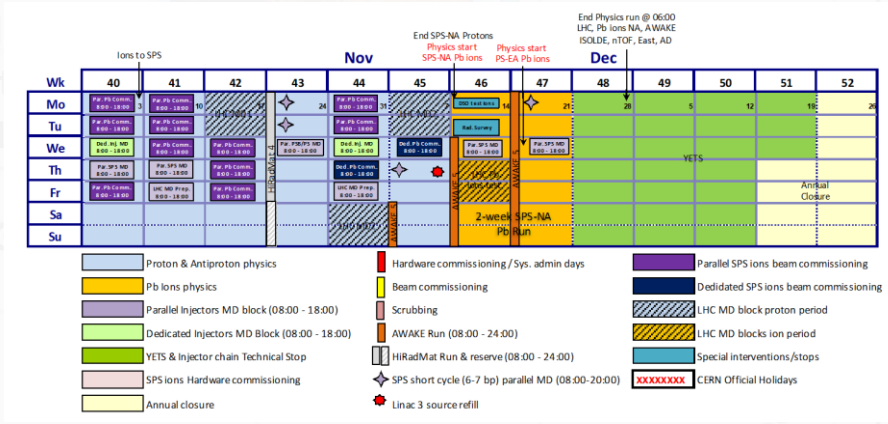
- A



HiRadMat performance

HiRadMat key improvements over 2021:

- Removal of frail MKDV!
  - Eliminated the need for pre-scrubbing
  - Running **288 bunches at high intensities effectively**
  - Ability to adjust bunch length and batch spacing to dodge remaining kicker vacuum limitations
- Careful scheduling avoiding any parallel ongoing activities (4 weeks + 1 spare)
  - HiRadMat is **non-routine operation** and requires close attention and frequent interaction between machine and experiment
- Running with canonical 2.5 um emittance beams; using optics to match spot size onto experiments
- Adapted optics for windows protection
- HiRadMat Upgrade Study WG ongoing for yet more improvements!



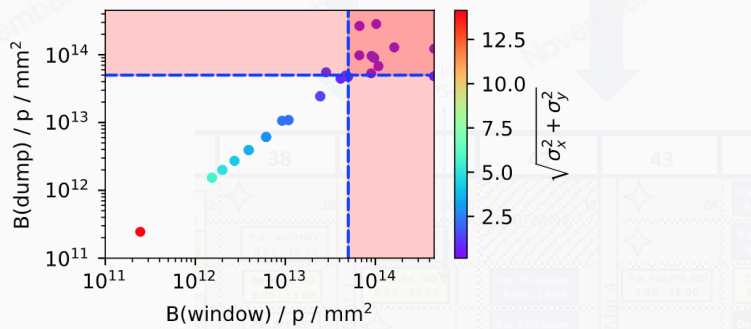


Figure 3.7 – Overview of the previous HiRadMat optics available in operation and compared with the brightness limitations obtained.

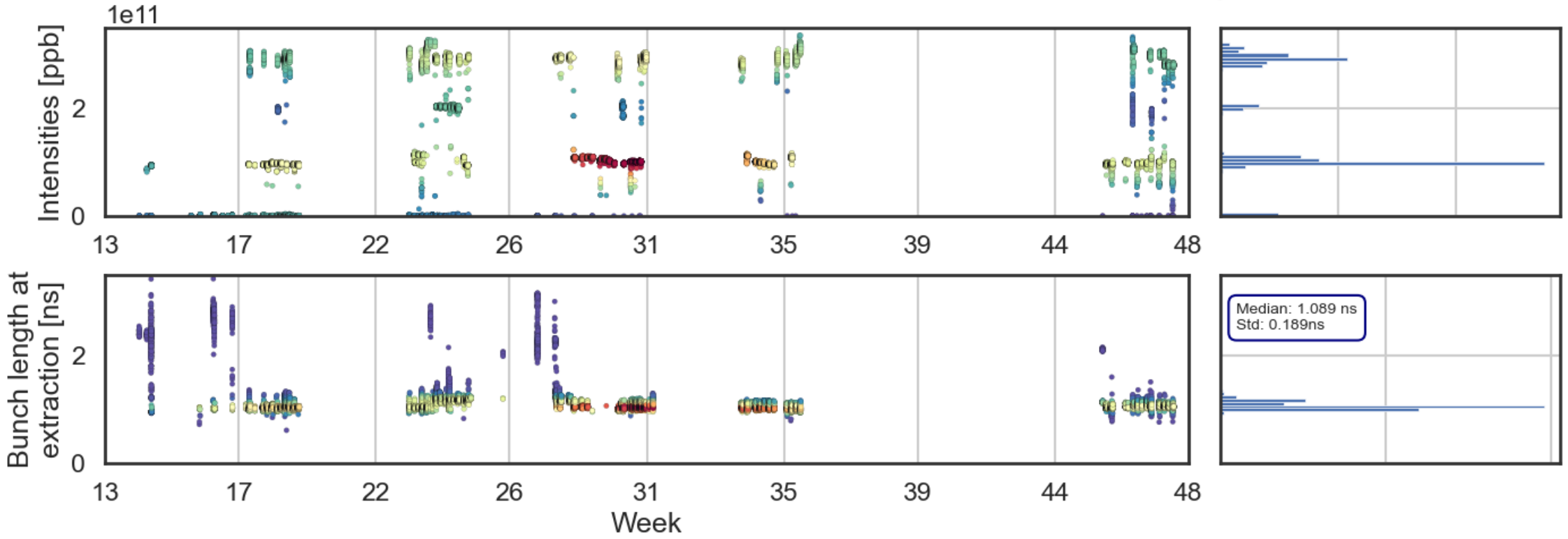
HiRadMat performance

Wish list for 2022:

- Keep good **scheduling practice and disentangling** the various parallel activities
- On-the-fly optics generation tool
- Establish sort of **mini-commissioning before each run** to do basic checks and verification together with HiRadMat team (emittances, optics, BTV,…)

AWAKE

AWAKE performance

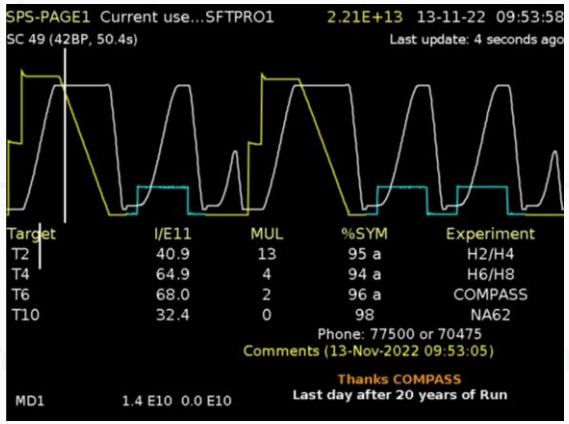


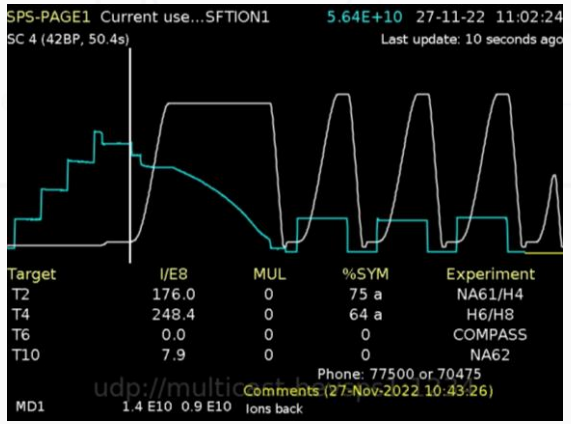
- Generally good performance and beam delivery up to specs throughout the year
  - Main “issues” are essentially **availability and duty cycle**
  - Issue with phase loop instability for high intensity bunches **has been mitigated** (understanding still to be established!)

AWAKE performance

Work for 2023:

- Availability – try to be as available as possible…!
- Duty cycle: AWAKE prefers **shorter period at high duty cycle** – needs to be discussed and folded into the planning (could they maybe always fit between LHC fillings?)





- Semi-remote scans:
  - How can we improve the effectiveness of the AWAKE – CCC interaction?
  - How can we make the FEI more transparent?

Take-away

Desiderata digest

Wish list for 2023:

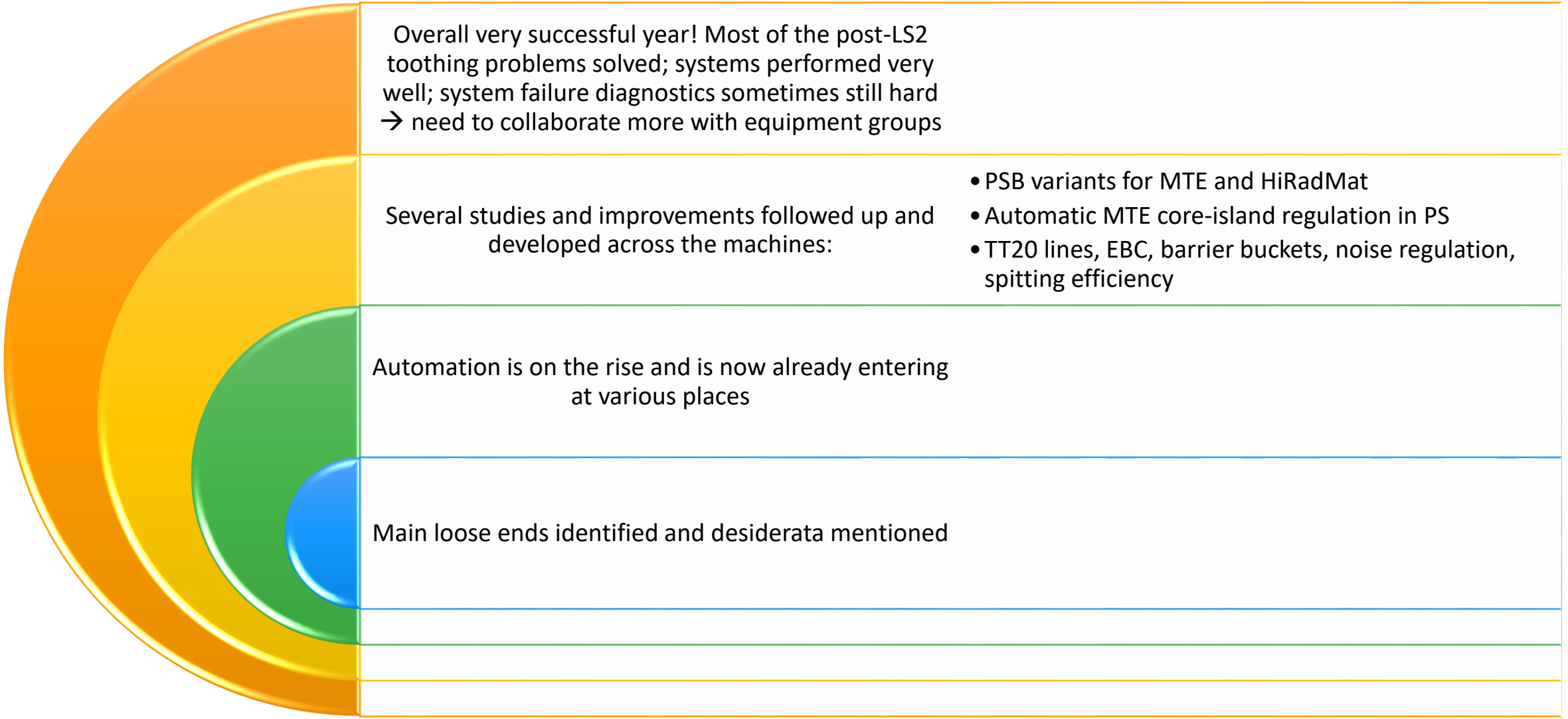
1. Plan for slow extraction line beam instrumentation to make setting up of slow extraction more efficient (big uncertainty and stressful situations every year; high radiation zone, so you want to know what is going on!)

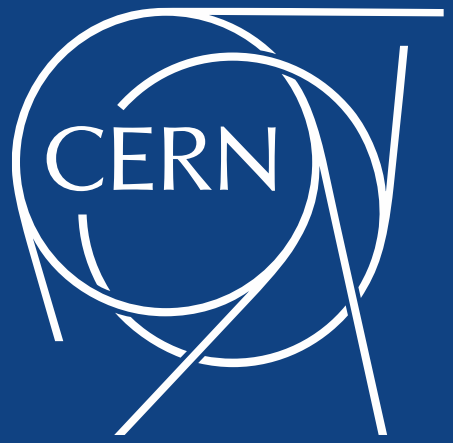
2. Progress and understanding of 100 Hz noise issue; why is it still so much worse that in 2018? Strategy for 2023?

3. Spike at start of spill still a problem sometimes – invisible on CCC side; how can we improve this?

- Get **common set of KPIs** from experiments
- Get feedback from experiments if **our perception of beam quality is correct and our KPIs are well dimensioned** – where should we concentrate our efforts for maximum efficiency (do we need additional BI)?

Conclusions

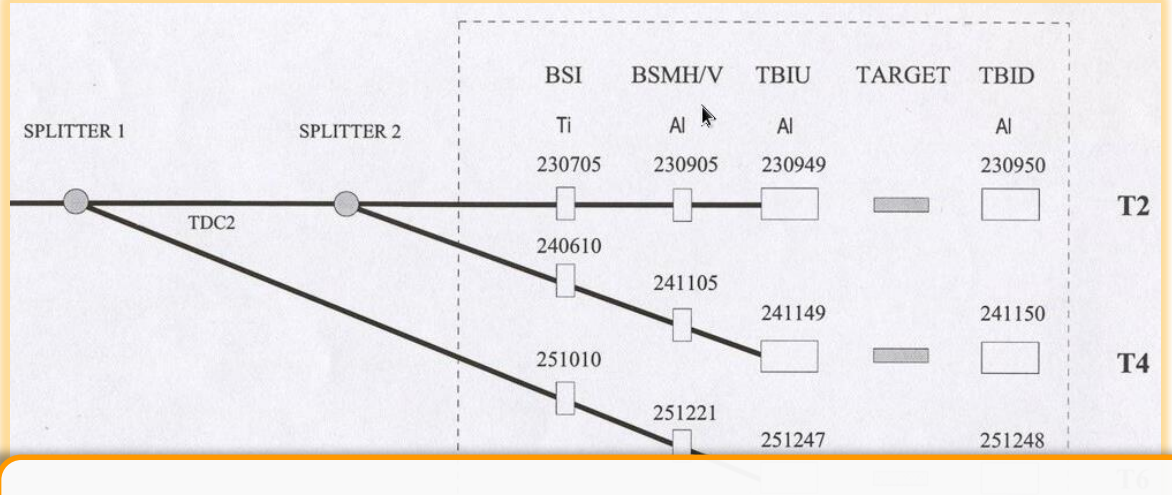



CERN

SPS – loose ends – target area BI, diagnostics

- Target area instrumentation
  - Steering to target relies heavily on intensity and position measurements in target region
  - Instrumentation consists mainly of **secondary emission devices** (beam turns into a continuous spill during slow extraction)

  - Beam instrumentation in target lines is **very inadequate (BSPs) in general** → full functionality is essential for target steering
  - NA instrumentation must, in addition, be **fully integrated into ISTs** – clarification of **responsibilities for target area ISTs**; self-checks to ensure full systems standalone functionality (alignment and positioning, motors movements, bias voltages, calibrations settings, standby currents, vacuum,…) before entering HWC period

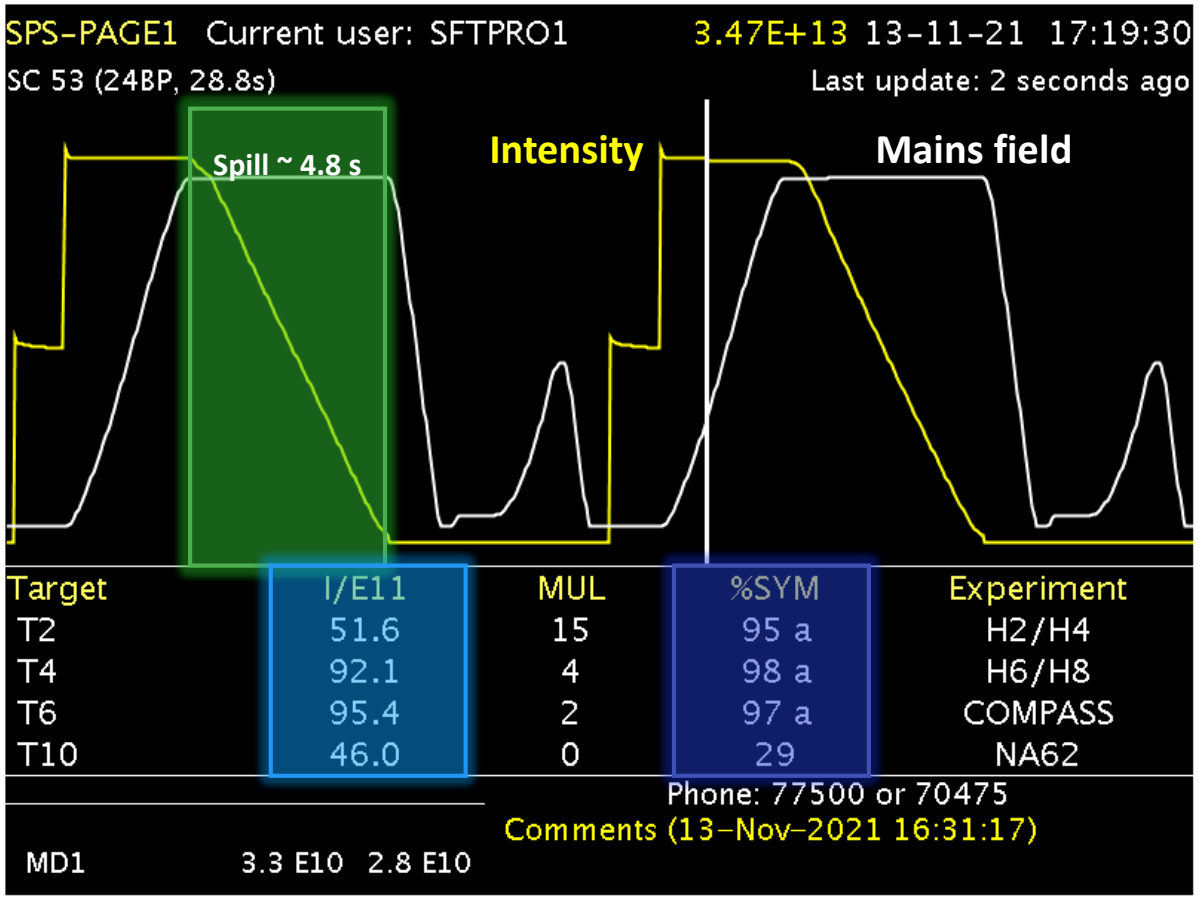


Problem has been picked up and is being addressed across the sector together with groups from BE, SY, TE.

SPS – supercycle

- Several parameters and **performance indicators** are closely monitored to ensure **optimal spill quality**

NA production supercycle



Main culprits:

- Eddy currents & hysteresis effects
- Noise on mains

Correction knobs:

- Horizontal tune + auto-spill application – trims on tune and momentum (COSE)
- Noise injection into QF based on measurements of BSI

- Sharing → vertical (orthogonal) steering in YASP
- Steering → (orthogonal) steering YASP

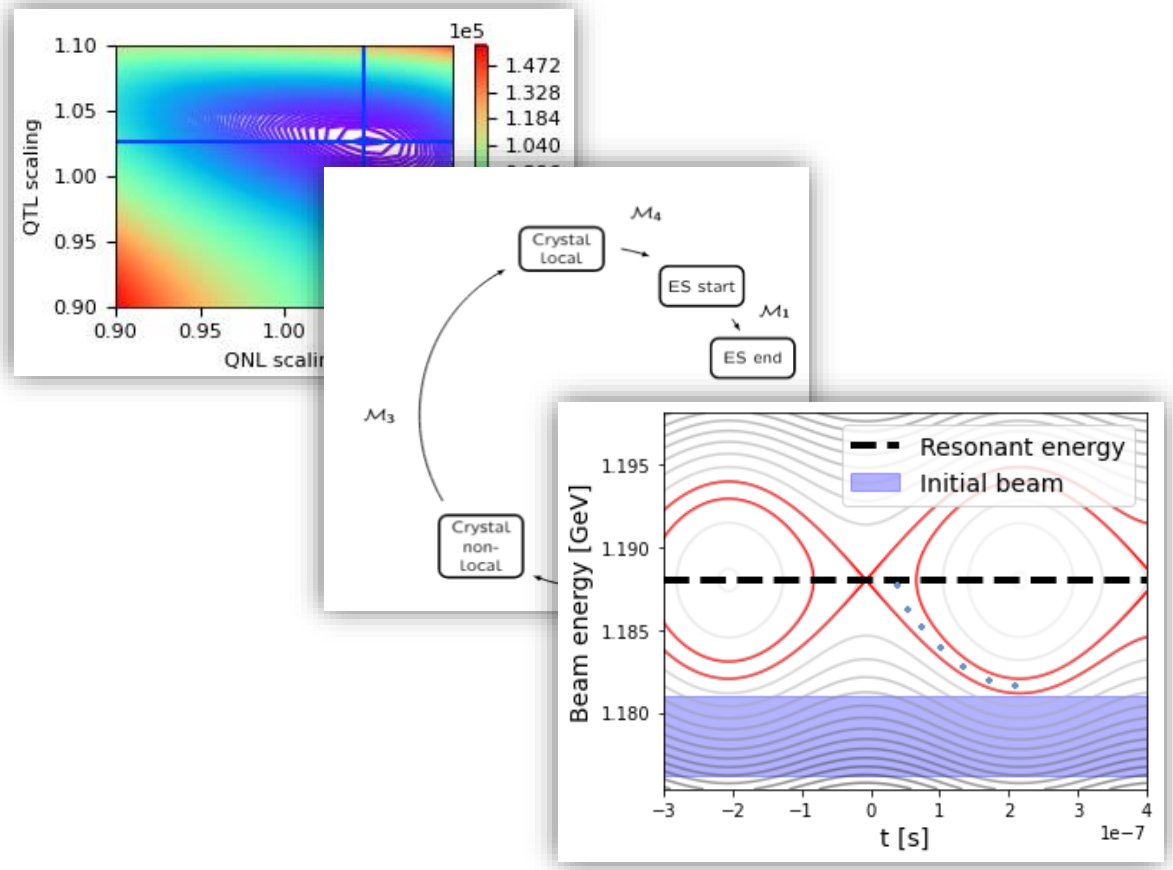
Beam quality:

- Constant and homogeneous spill (max. effective spill length, low harmonics content)

- Constant & correct intensity on target
- Constant & correct steering on target (symmetry = 100%)

Selected improvements along the chain – SPS

- Operational
  - New stitched models for TT2-TT10
  - Machine losses
  - Splitting efficiency
  - Advanced algorithms for noise suppression



- Studies:
  - TT20 optics studies → treated in Rebecca's talk
  - Non-local crystal channeling → treated in Pablo's talk
  - Empty bucket channeling → noise reduction; will say a word on this; will be treated in much more detail in Pablo's talk

Selected improvements along the chain – SPS

- Operational
  - New stitched models for TT2-TT10
  - Machine losses
  - Splitting efficiency
  - Advanced algorithms for noise suppression

- New **advanced algorithms put in place and integrated** into optimization framework (implementation uses COI GeOFF components) for improved spill noise regulation

- Despite first promising results, the problem remains sophisticated and **algorithm tuning is delicate** → holy grail not yet found (see later)

Extremum seeking for stabilisation: modelfree; deploys periodic perturbations

Bounded, self-turning off

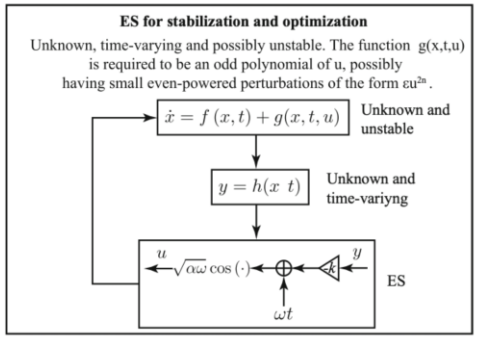
$$u_i(n+1) = u_i(n) + \Delta\sqrt{\alpha\omega_i}\cos(\omega_i n\Delta + ky(u(n)))$$

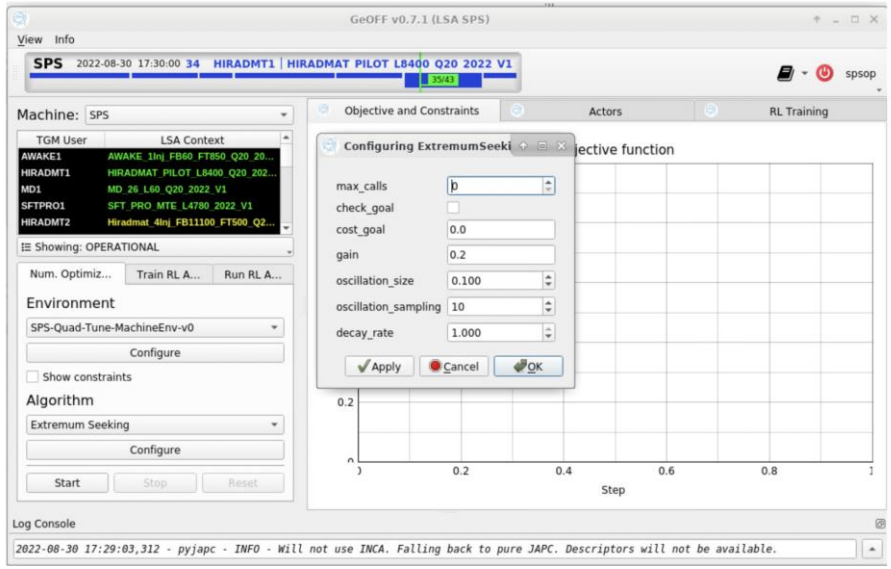
Different degrees of freedom u_i with different frequencies ω_i

Provide:

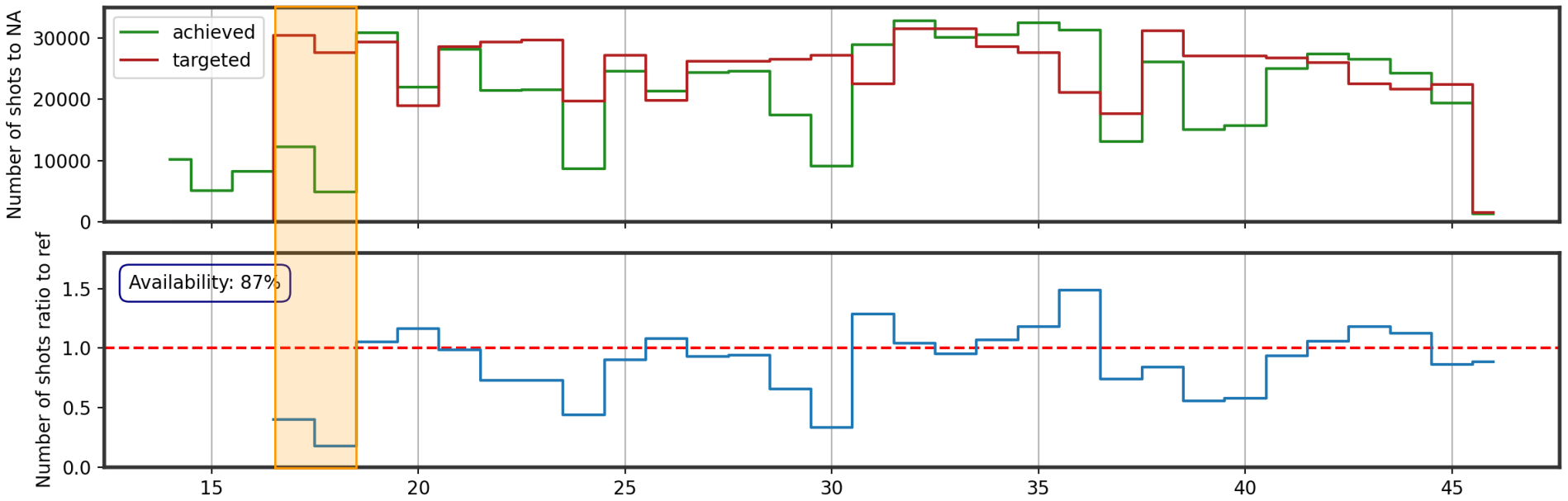
norm. oscillation amplitude

gain

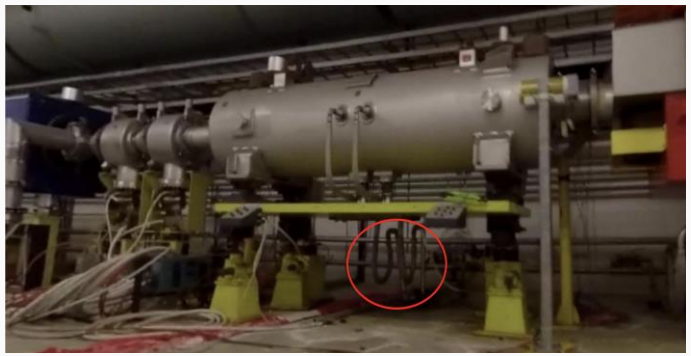




SPS NA physics delivery – “availability” overview

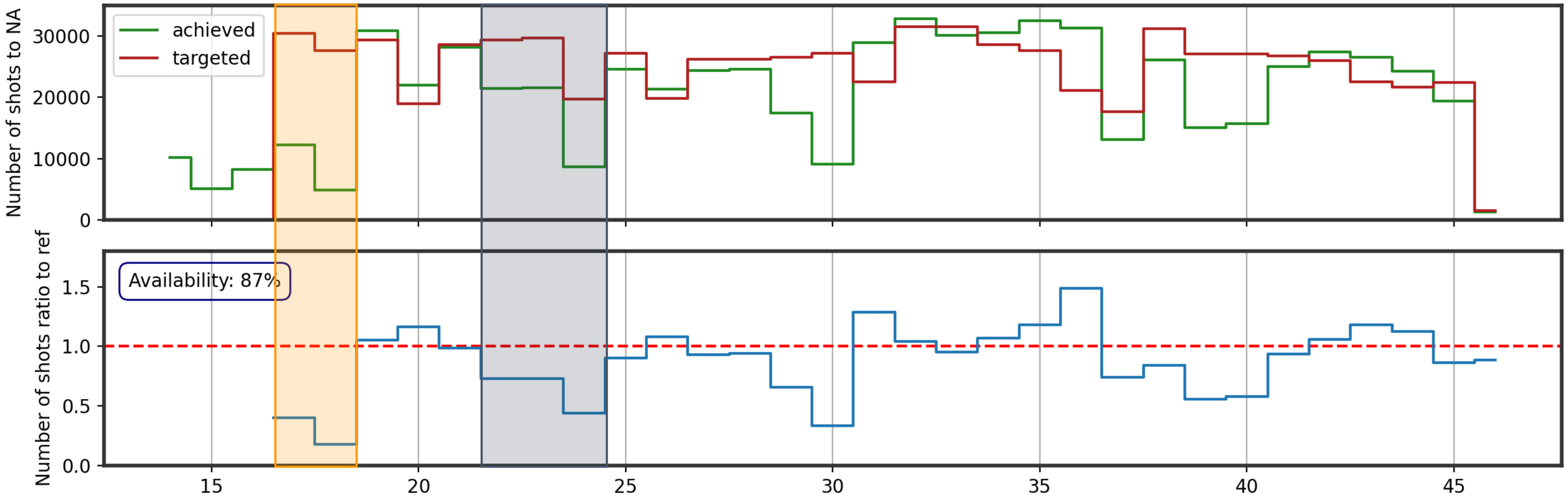


- **Weeks 17 / 18: TDC2 / TCSC water leak, intervention in BA80, fix by Friday afternoon with modified cooling circuit**



- Difficult intervention due to high radiation zone → cool down needed
- Fixed: mid-term fix, conform to operational needs
- Follow-up: consolidation planned in the framework of NA-CONS

SPS NA physics delivery – “availability” overview



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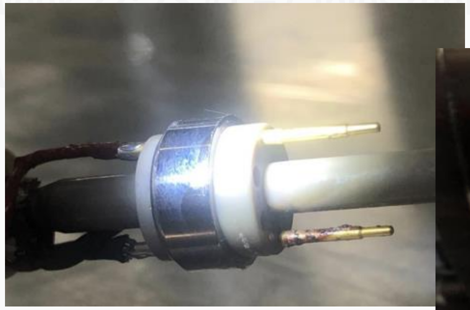
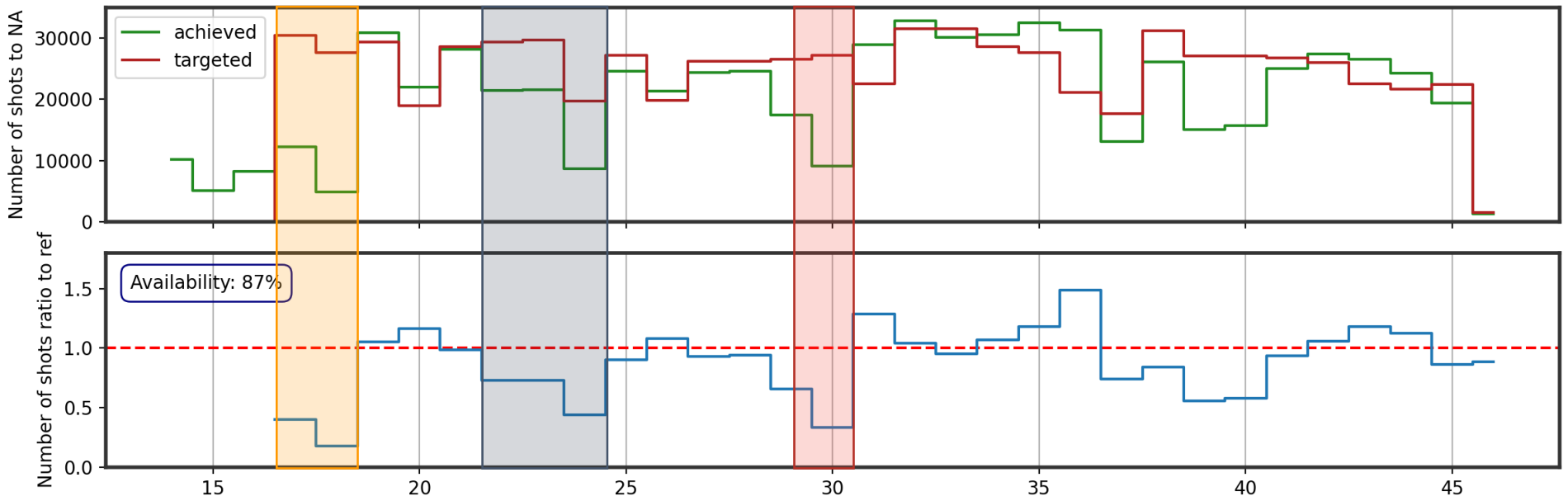


- Difficult intervention due to high radiation zone → cool down needed
- Fix: sandblasted and installed new cables
- Follow-up: pending

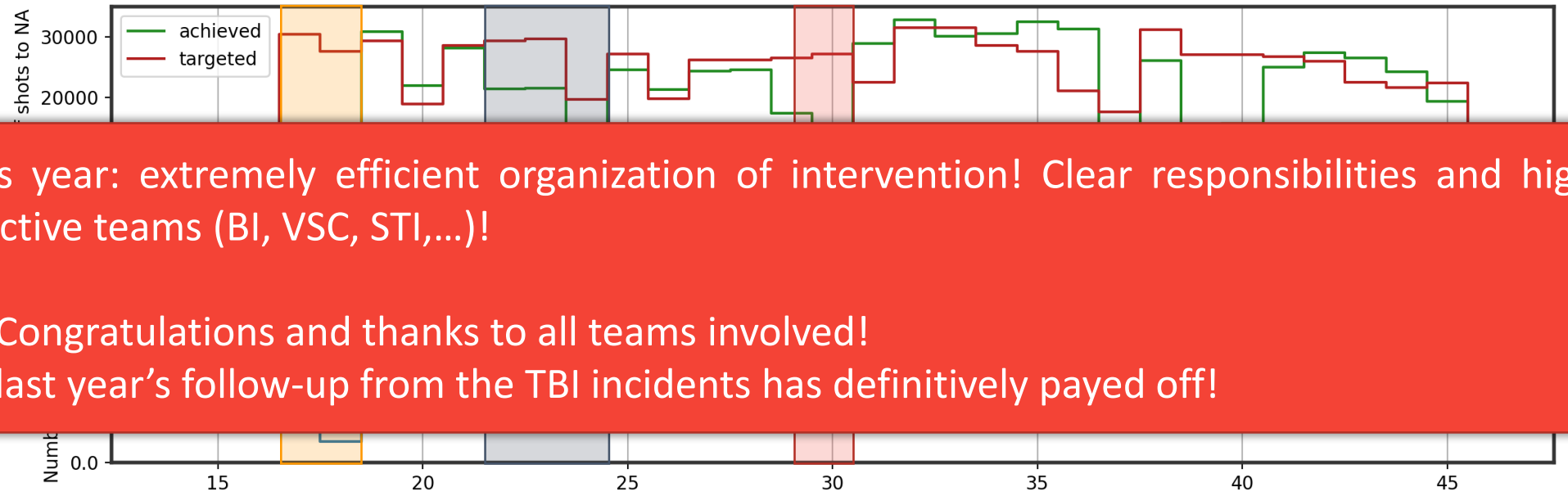
SPS NA physics delivery – "availability" overview



- **Weeks 17 / 18: TDC2 / TCSC water leak, intervention in BA80, fix by Friday afternoon with modified cooling circuit**
- Week … ent 2S1 and 2S2 (4 cables – not all to specs)
- Week … ugs … …
- Week … found, not yet understood
- Week … followed by TBIU swap

- Difficult intervention due to high radiation zone → cool down needed
- Fix: installation of spare TBIU (several problems identified), improved monitoring and protection of PCs
- Follow-up: NA-CONS TCC meeting organized with follow-up action for the different stakeholders (https://indico.cern.ch/event/1188410/)

SPS NA physics delivery – "availability" overview



This year: extremely efficient organization of intervention! Clear responsibilities and highly reactive teams (BI, VSC, STI,…)!

→ Congratulations and thanks to all teams involved!
→ last year's follow-up from the TBI incidents has definitively payed off!

- **Weeks 17 / 18: TDC2 / TCSC water leak, intervention in BA80, fix by Friday afternoon with modified cooling circuit**
- Week [illegible] ent 2S1 and 2S2 (4 cables – not all to specs)
- Week [illegible] ugns [illegible]
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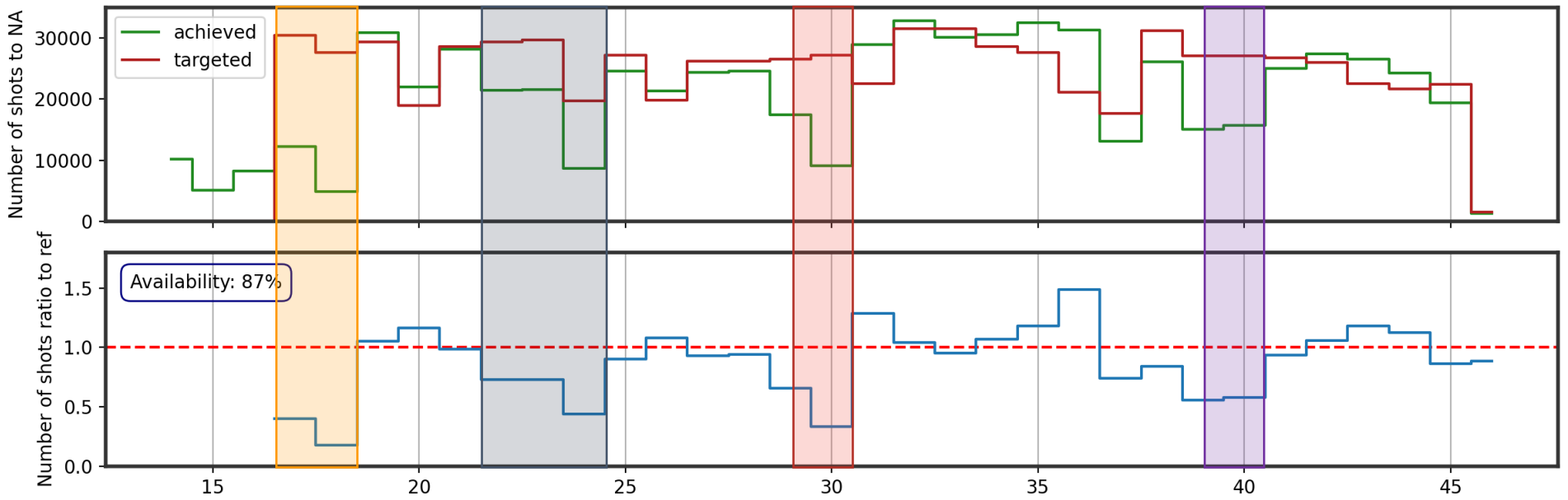
- Follow-up: NA-CONS TCC meeting organized with follow-up action for the different stakeholders (https://indico.cern.ch/event/1188410/)

SPS NA physics delivery – "availability" overview

On average: 87% delivered shots



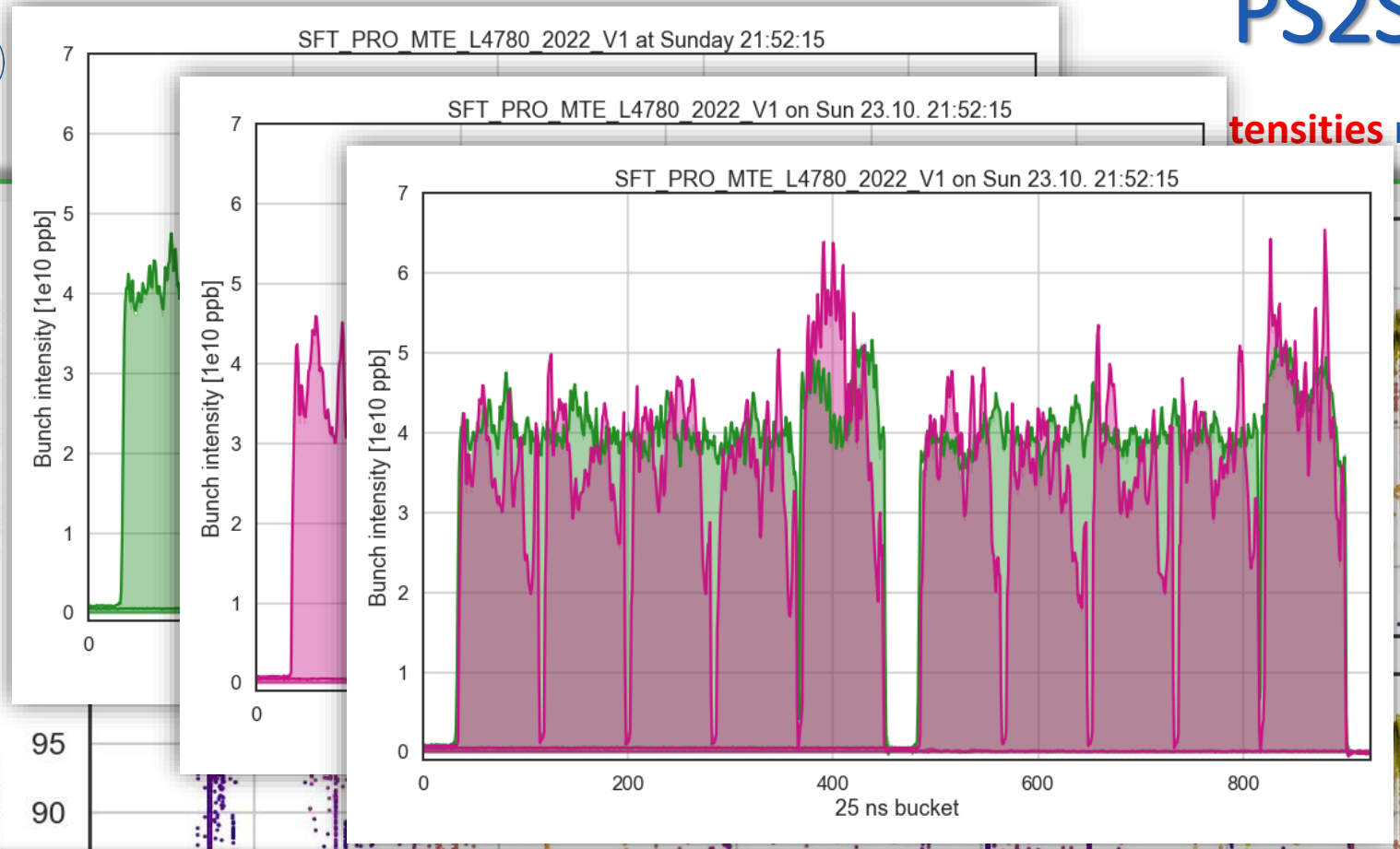
- **Weeks 17 / 18: TDC2 / TCSC water leak, intervention in BA80, fix by Friday afternoon with modified cooling circuit**
- **Week 22: ZS #1 – cables replacement ZS1 and ZS2 (4 cables – not all to specs)**
- **Week 27: SWAN phase loop issue found; not yet understood**
- **Week 30: Wobbling magnet failure followed by TBIU event**
- **Week 40: PS POPS**

This year: extremely efficient organization of intervention! Clear responsibilities and highly reactive teams (BI, VSC, STI,…)!

→ Congratulations and thanks to all teams involved!
→ last year's follow-up from the TBI incidents has definitively payed off!

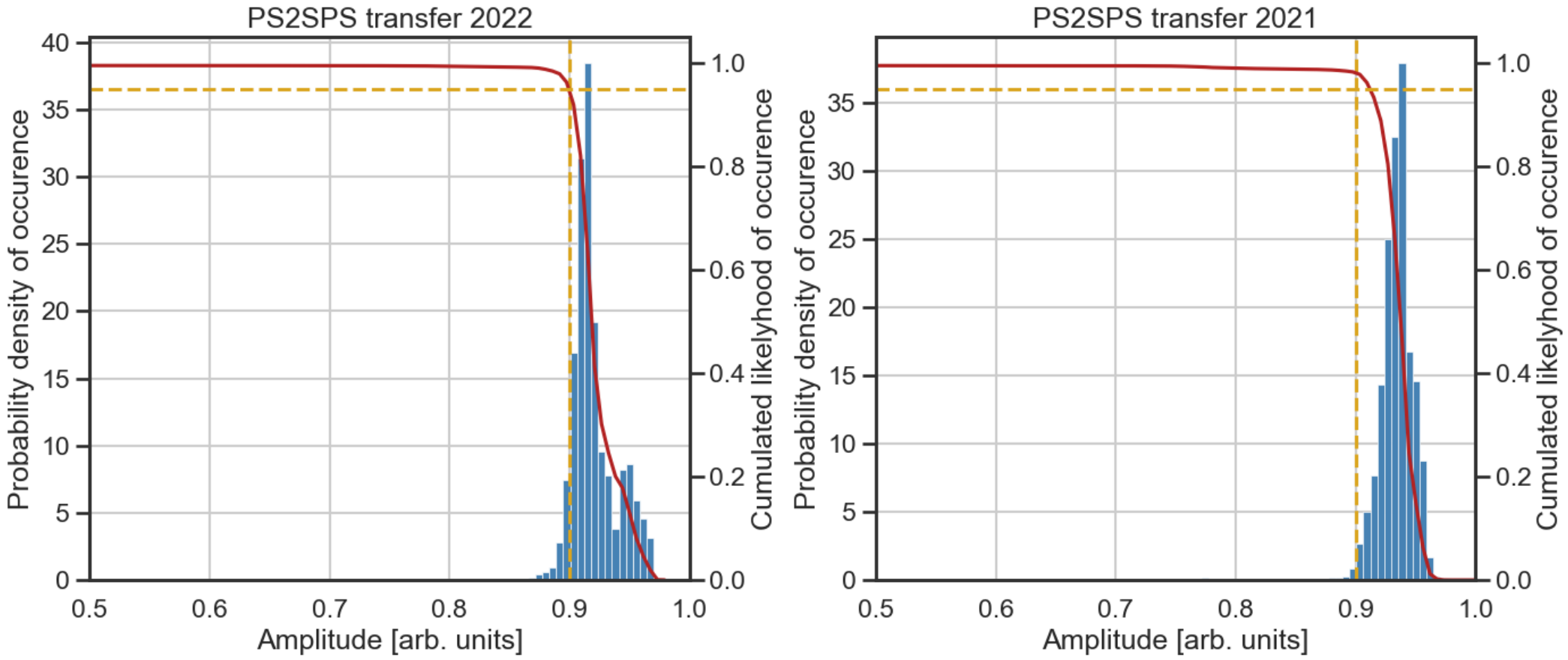
PS2SPS transfer in 2022

tensities reached overall!

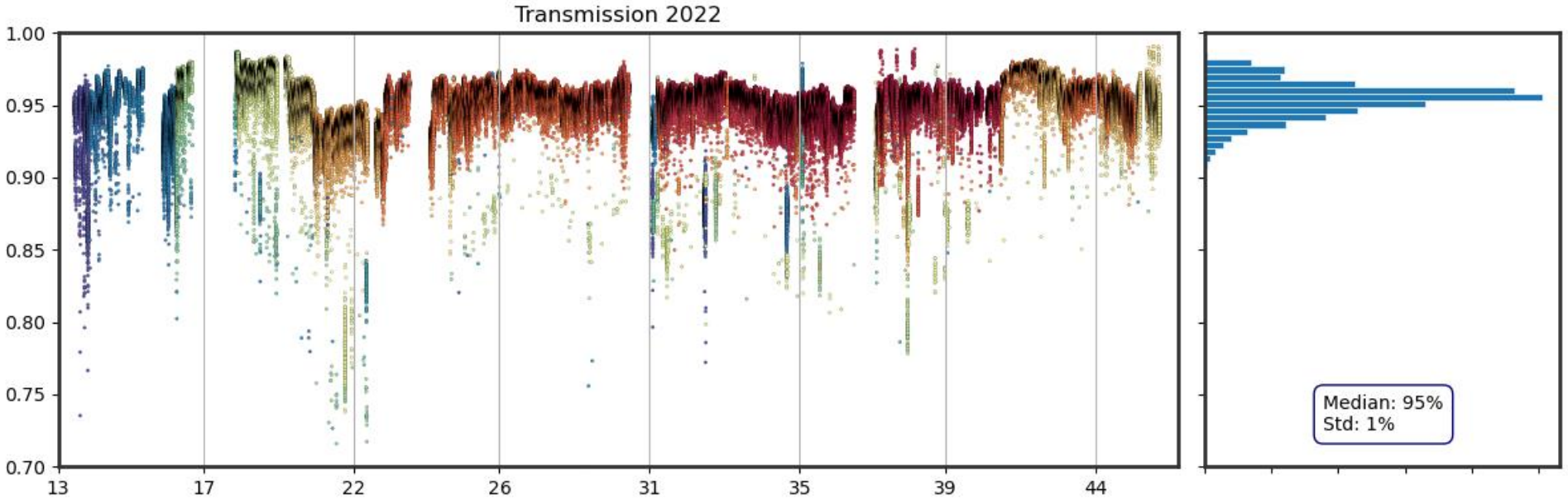


- Operational deployment of barrier buckets in the SPS
- Barrier buckets taken routinely as of mid-October 2022

- More infos on barrier buckets in Mihaly's talk


PS2SPS transfer 2022
Probability density of occurence
Cumulated likelyhood of occurence
Amplitude [arb. units]
PS2SPS transfer 2021
Probability density of occurence
Cumulated likelyhood of occurence
Amplitude [arb. units]

SPS NA physics delivery – transmission

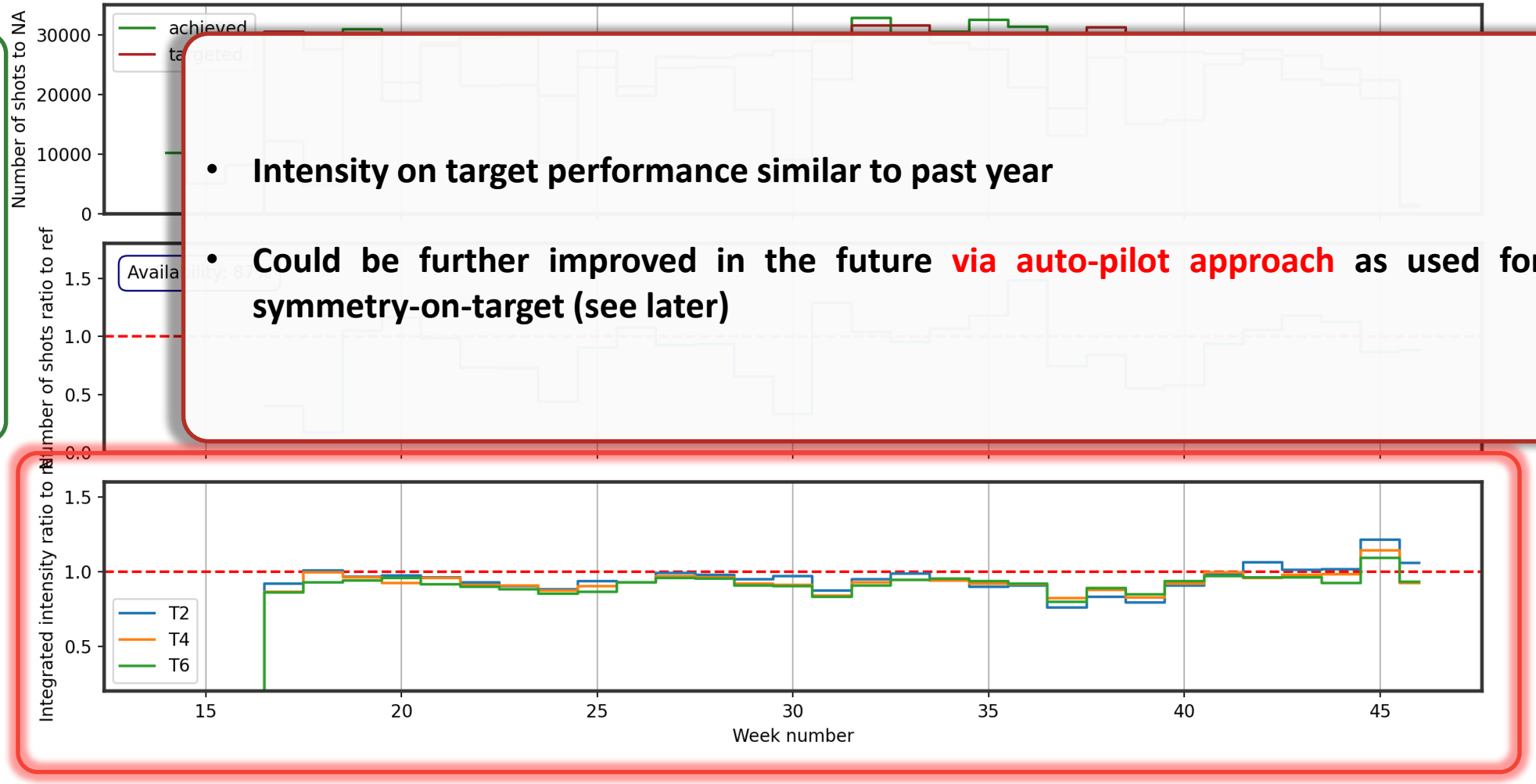


- Transmission overall pretty good with a mean around 95%!
- Generally good quality beams from the PS for most of the time!
- Transmission correlated with intensity – large intensities slightly penalized with poorer transmission

SPS NA physics delivery – "availability" overview

KPI experiments:

Intensity on target ~ 85% on average



- **Intensity on target performance similar to past year**
- **Could be further improved in the future via auto-pilot approach as used for symmetry-on-target (see later)**

SPS NA – what about the “classical” spill noise?

2022

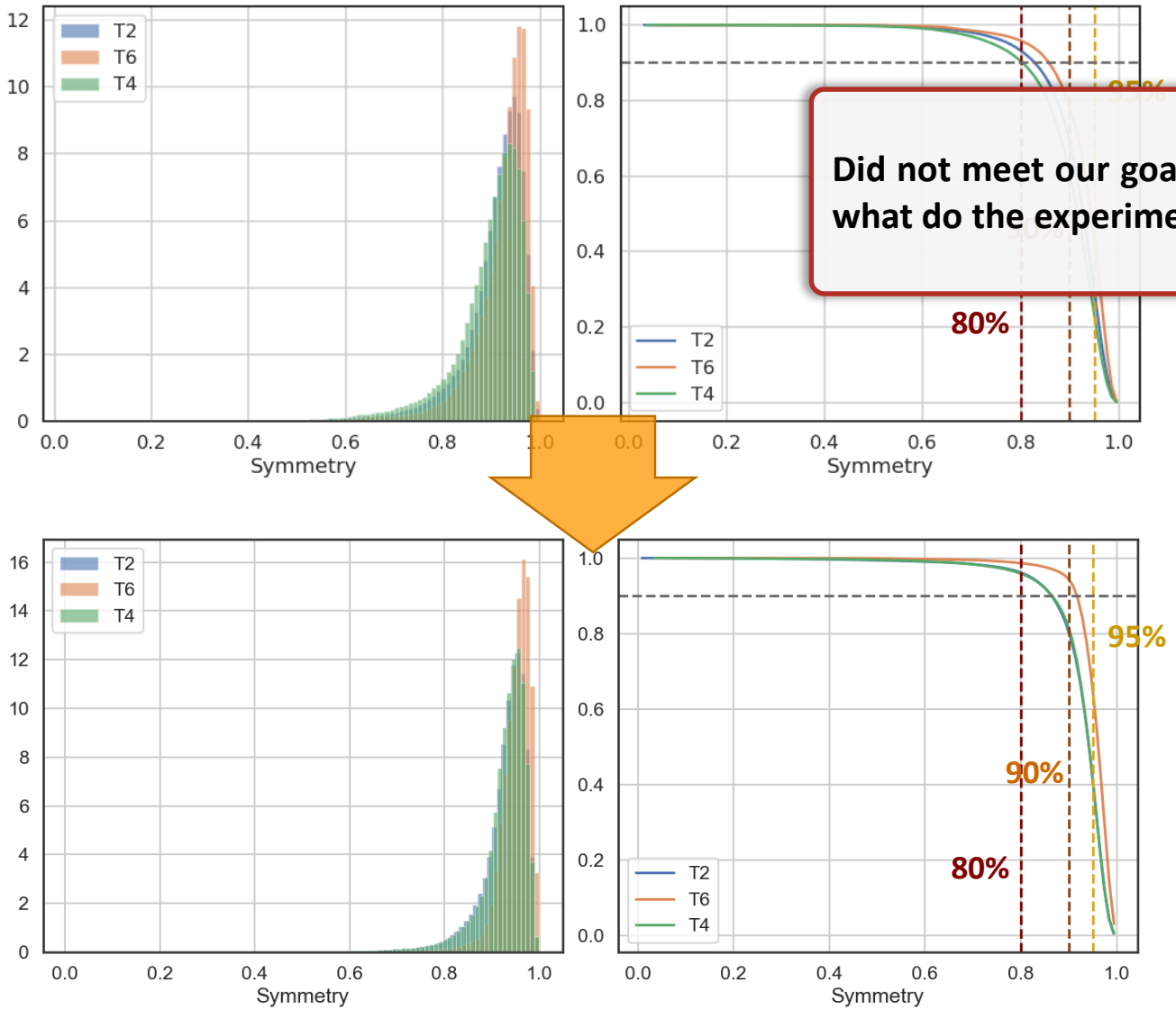
COMPASS (thanks to Jan Matoušek):

- Prefer a flat top and **high and stable intensity**, smaller spread is better.
- The EBC test has the smallest spread, on the other hand it lasted only about 50 minutes.
- 100 Hz peak; in 2021 these components were relatively stronger than in 2022 and the EBC seems to be reducing them a little bit more.
- In 2021 we were observing a peak in this dead time that was much larger than the one in the average intensity in spill plot. Now **we do not observe this feature**.

NA62 (thanks to Roberto Piandani):

- This year **the beam quality is improved a lot**, especially at the beginning of the extraction.
- What is fundamental for us is the **intensity stability along the spill**, our data taking is suffering a lot the 50 and 100 Hz components, probably better this year (at least the 50 Hz), this the reason why we pushed a lot to have the EBC extraction.
- What is dangerous for us is also **the spike at the beginning** (less dangerous at the end) because it's causing failures in the DAQ of some detectors preventing the acquisition of the full spill.

SPS – quality control – symmetry 2022



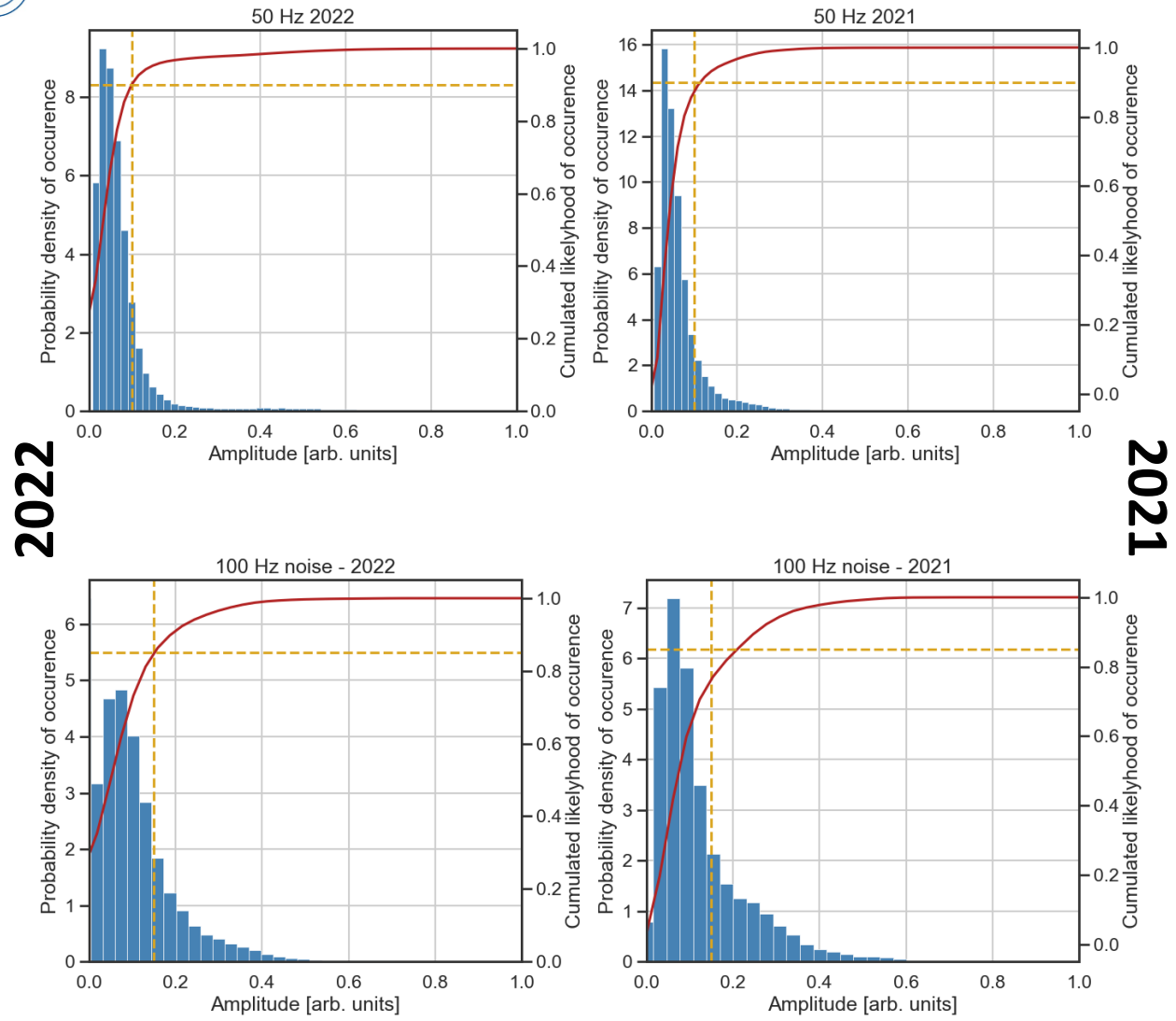
Did not meet our goals, again – but what do the experiments say??

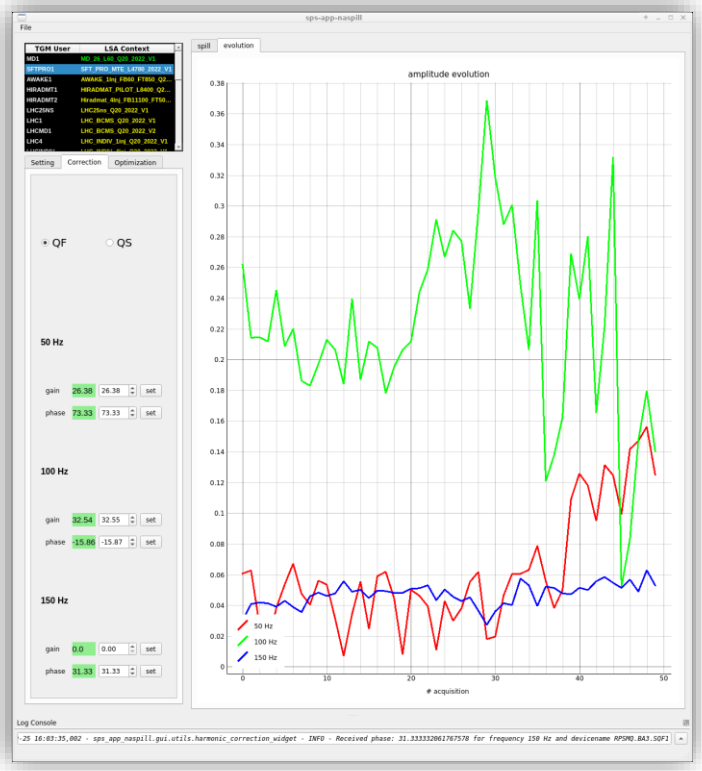
Symmetry	Time of run
> 95 %	25 %
> 90 %	70 %
> 80 %	90 %

→ Thanks to auto-pilot mostly active, less drifts go unnoticed
→ Clear improvement over last year
→ Stability particularly challenging due to the very high intensities challenging stability in general

Symmetry	Time of run
> 95 %	65 %
> 90 %	80 %
> 80 %	95 %

SPS NA – what about the “classical” spill noise?



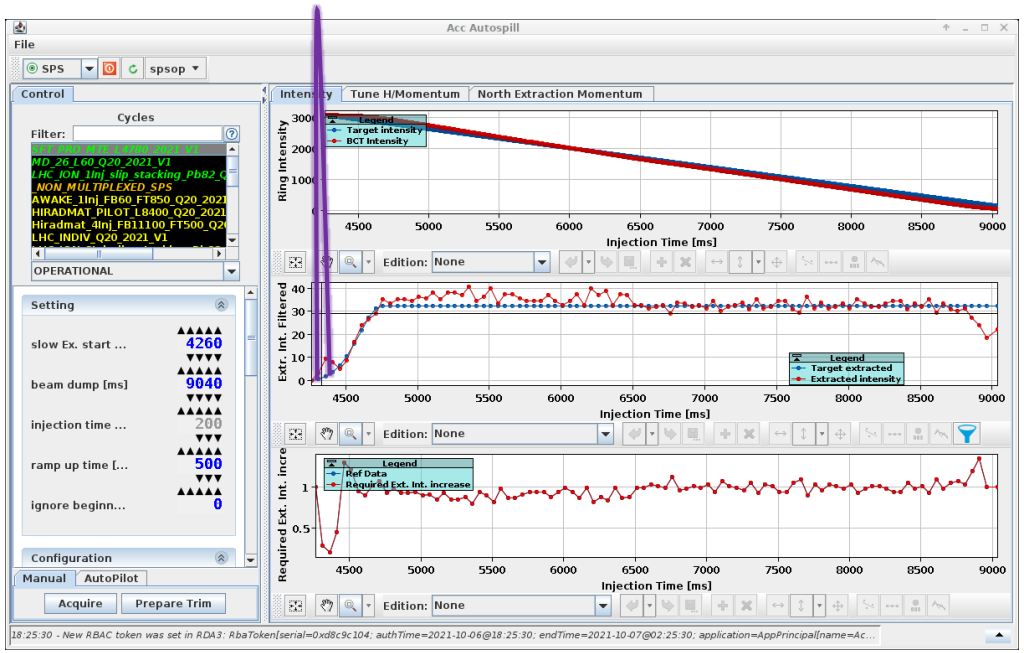


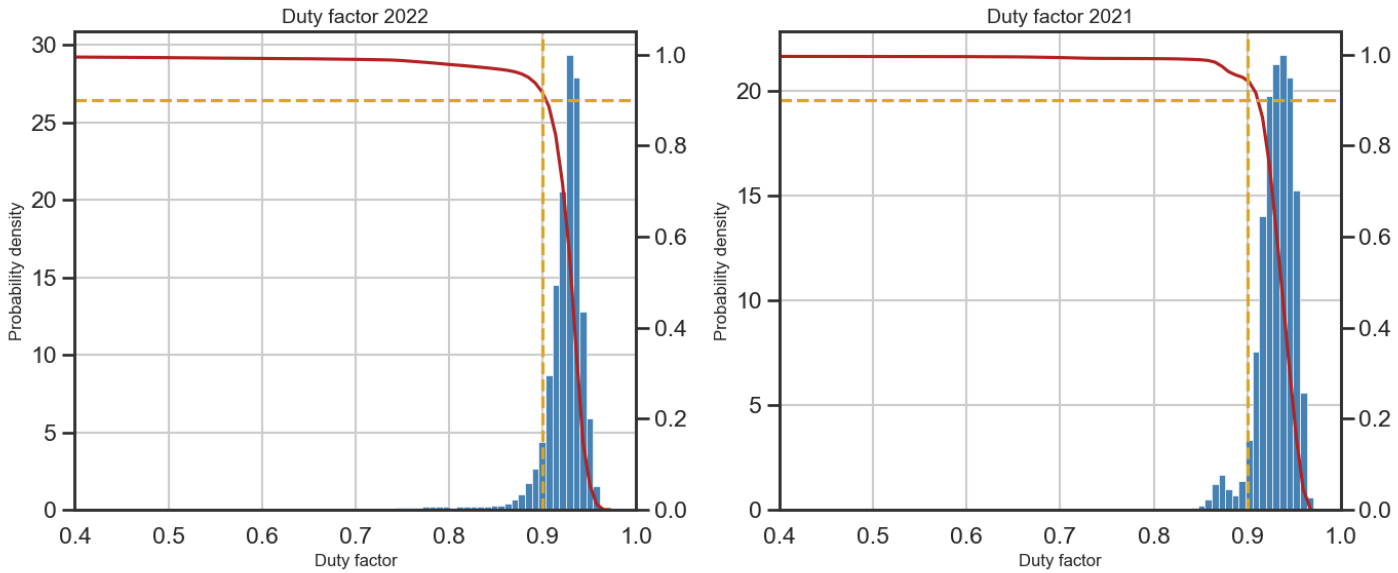
- 2022 just on target; an improvement over last year
- Auto-launch of optimizer kept active most of the times; algorithms **not yet able to reliable follow** the noise evolution (BOBYQA, EIS,…)
- In the future, may try adaptive algorithms, or ABO, amongst others

SPS – quality control – duty factor 2022

- Spill duty factor – effective spill length / actual spill length:
  - Based on BSI measurement
    - Need NA feedback for this
    - Not sensitive to spikes at start of spill
  - Spikes **have calmed down significantly** during 2022 thanks to RF improvements (see later)

- Spill duty factor **> 90% for more than 90% of the time**
- Very similar to previous year
- Spike at start of spill not visible in BSI



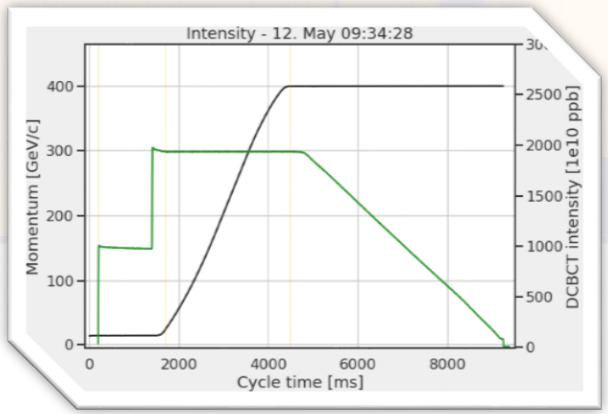


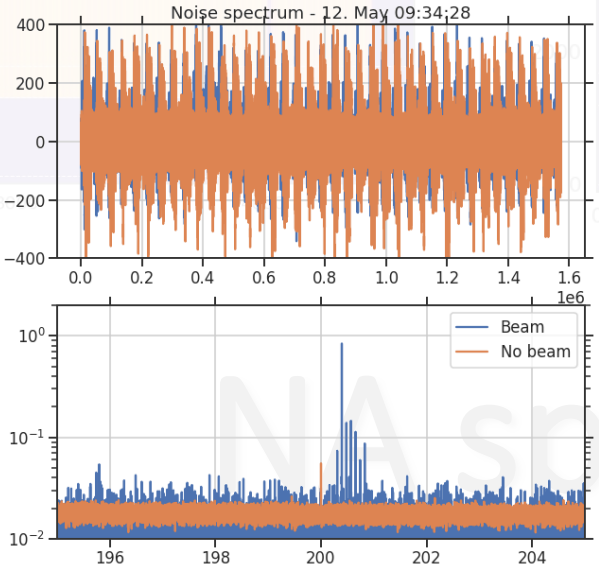
2021

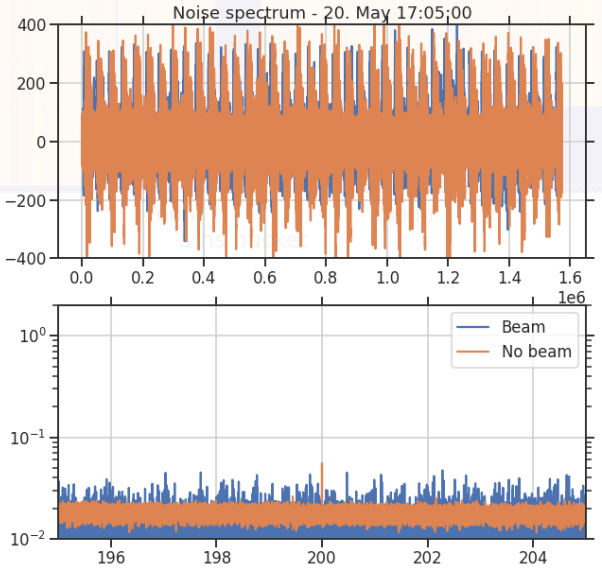
2022

- Suppression of spill microstructure achieved thanks to active control of total RF voltage via cavity counter-phasing

- Suppression of 200 MHz structure by optimizing RF off timing shortly after start of slow extraction





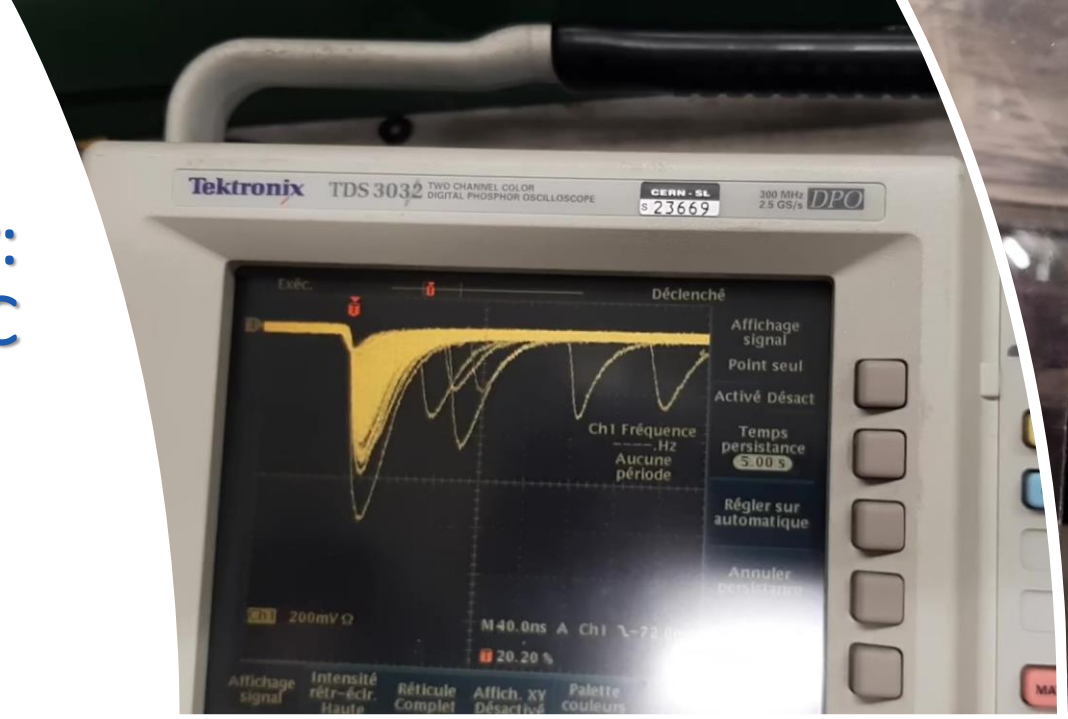


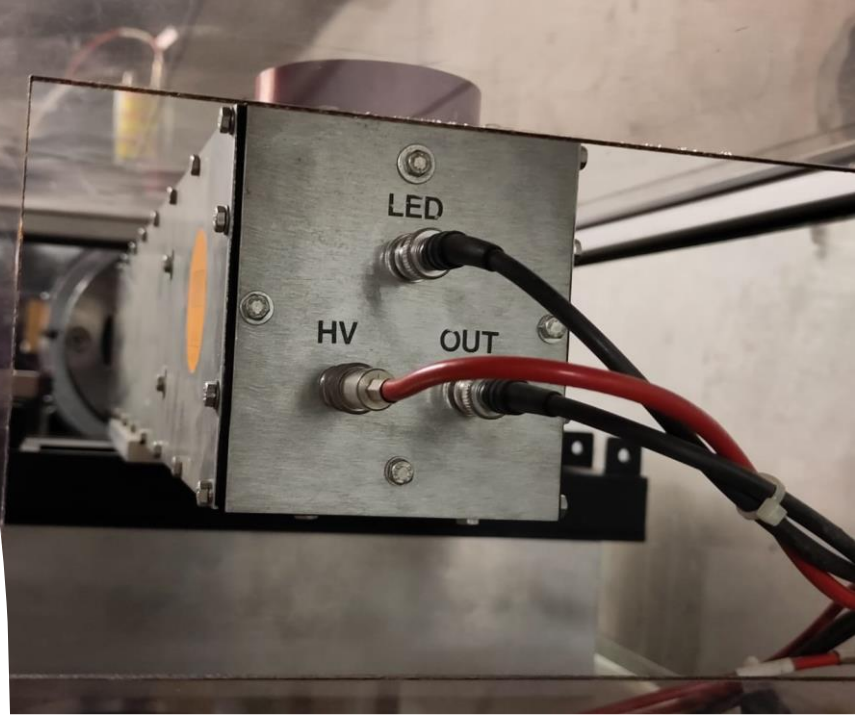
Electron Purity: XEMC

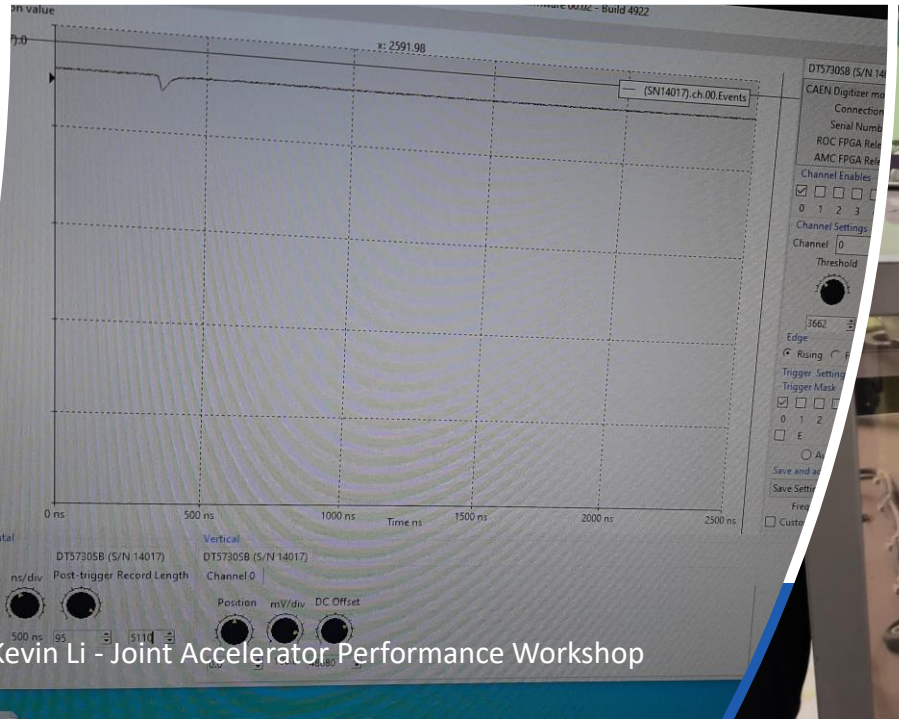
- The XEMC was installed about 420m from the T4 target.
- XEMC → lowest priority in the migration from FESA2 to FESA3

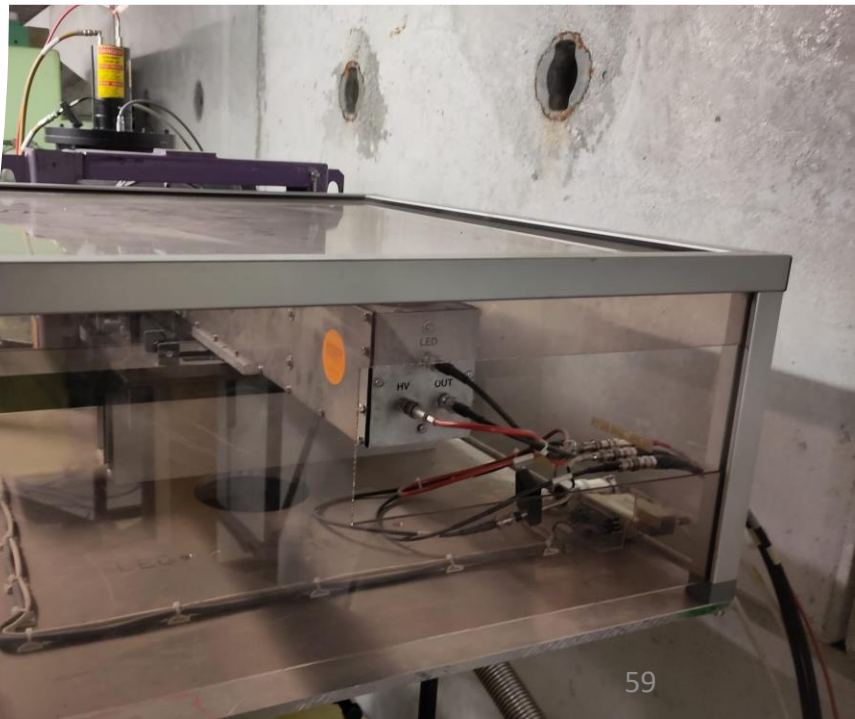
→ Not possible to control the device from CESAR.

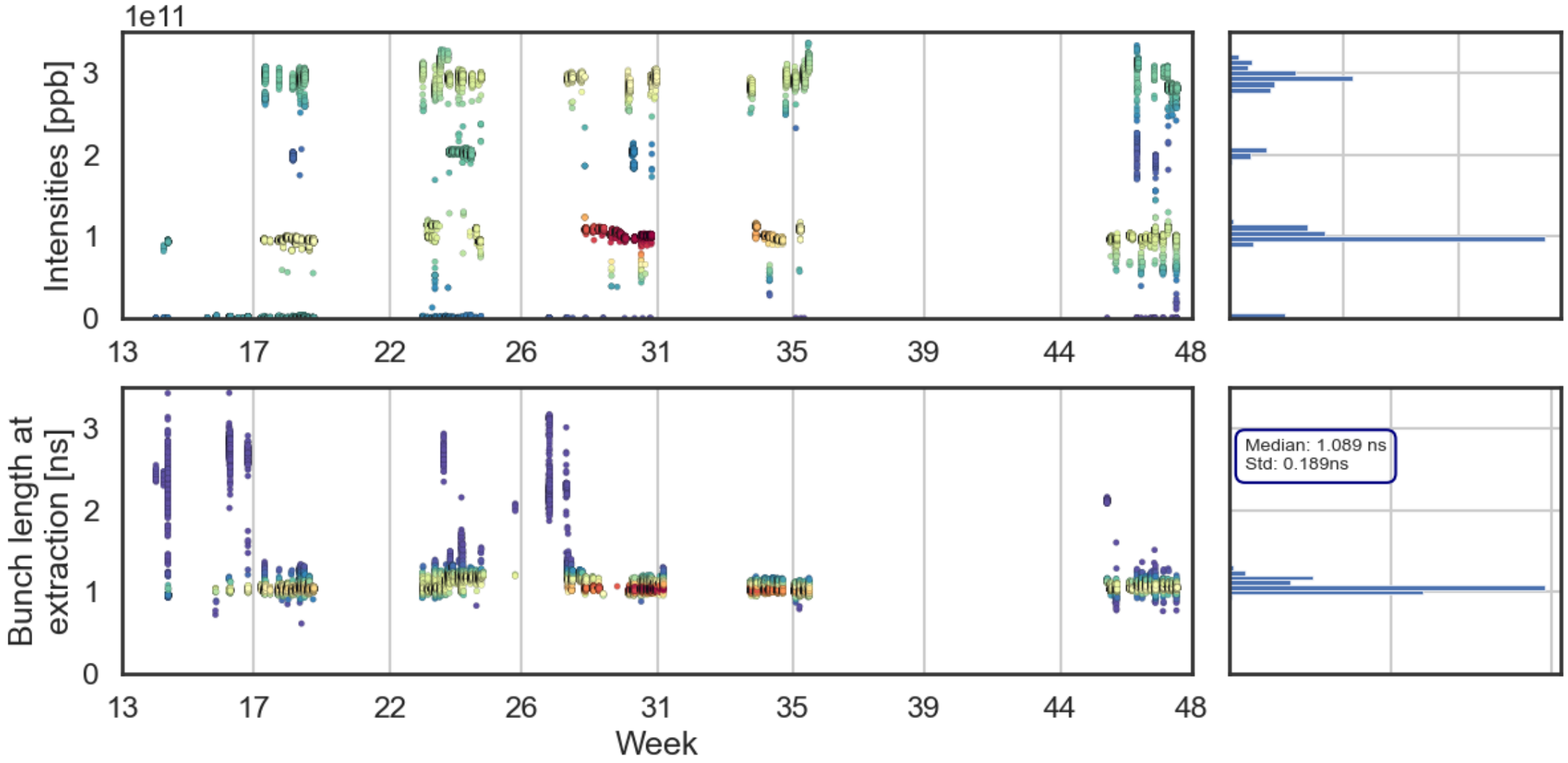
- **Temporary solution**: CAEN Digitizer to read signals from XEMC, model DT5730SB, 8 ch 14 bit, 500.0 MS/s (**thanks to SY-BI**).
- Motor of the XEMC disconnected and XEMC roughly aligned with the beam.



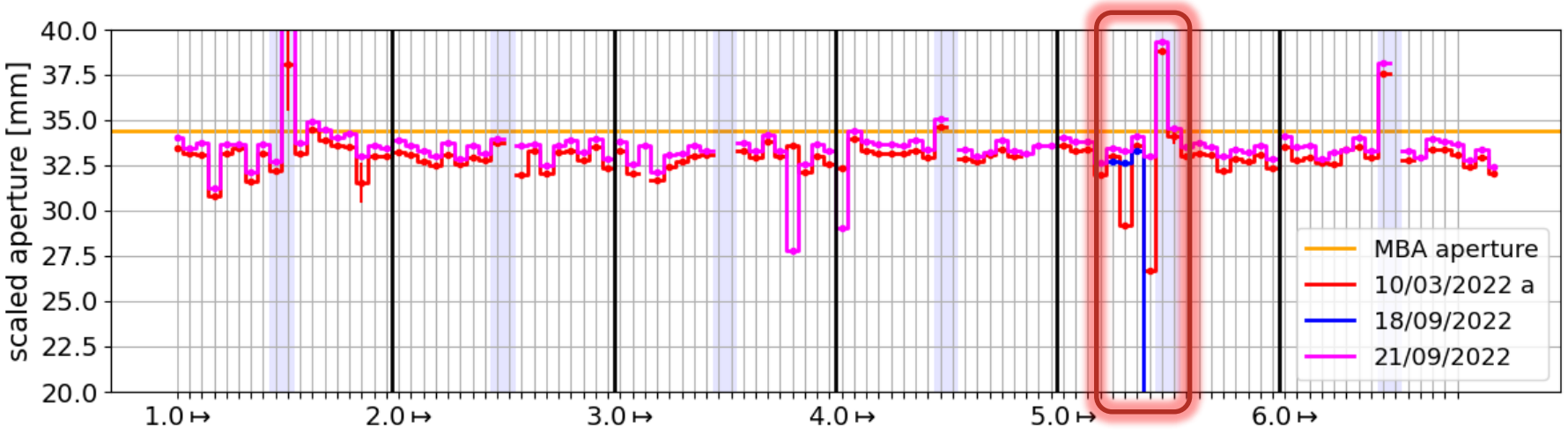







1e11
Intensities [ppb]
0
1
2
3
13
17
22
26
31
35
39
44
48
Bunch length at extraction [ns]
0
1
2
3
13
17
22
26
31
35
39
44
48
Week
Median: 1.089 ns
Std: 0.189ns

What about the aperture evolution?



- Open action:

66	Define the optimal dates for systematic aperture measurements in the SPS, to look for potential aperture restrictions	304	25/03/2022	SPS-OP		Open

  - Carried out this year – a little earlier than planned, right after the TS, due to measured hotspots and increased radiation levels
  - New **aperture restrictions were identified**, which have not been present at start of the year

Indeed, very important action → can now serve as important input for YETS activities!