Transmission of proton fixed target beams in 2023 and beyond

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JAP23 Workshop

Transmission of proton fixed target beams in 2023 and beyond

How did the fixed target cycles perform in 2023?

Where do we lose protons across the complex?

What are the ongoing and future studies?

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Content

Part I

transmission of proton
fixed target beams in 2023

- Overview
- ISOLDE
- AD
- TOF
- EAST
- SFTPRO

Part II

…and beyond

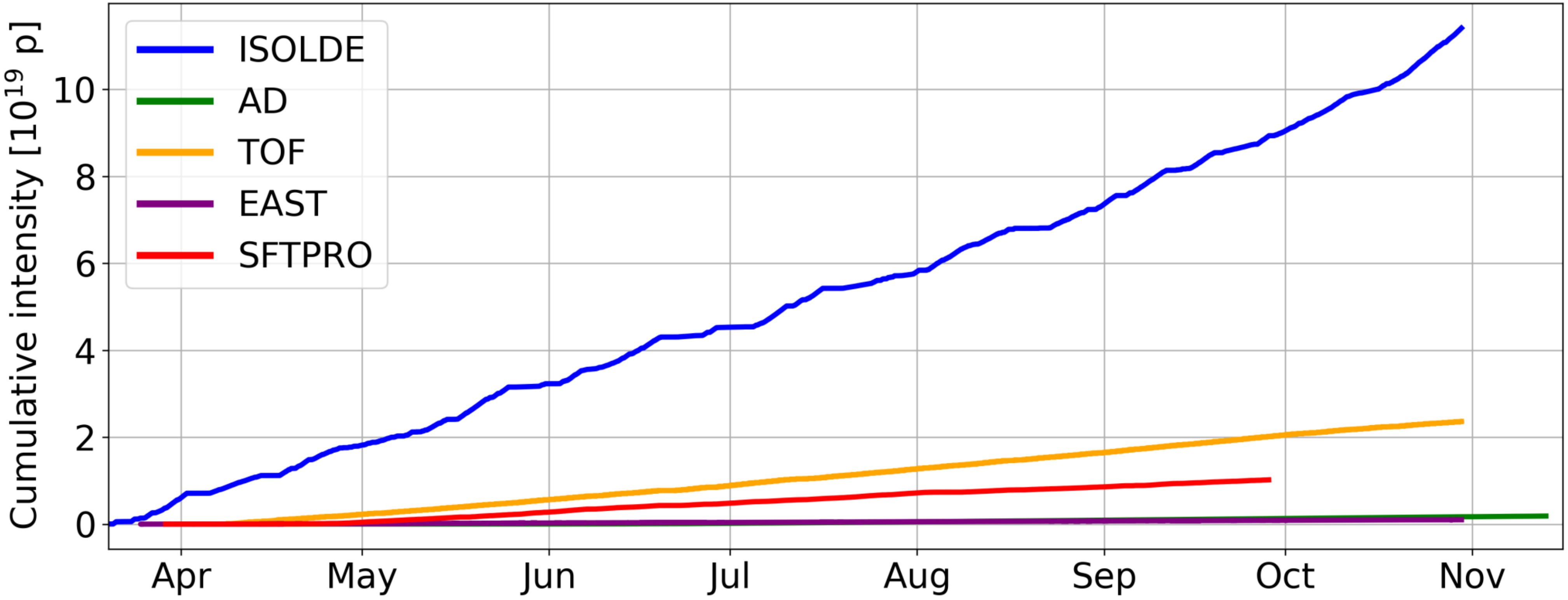
- PSB intensity reach
- PSB instability studies
- SFTPRO studies

Part I

transmission of proton fixed target beams in 2023

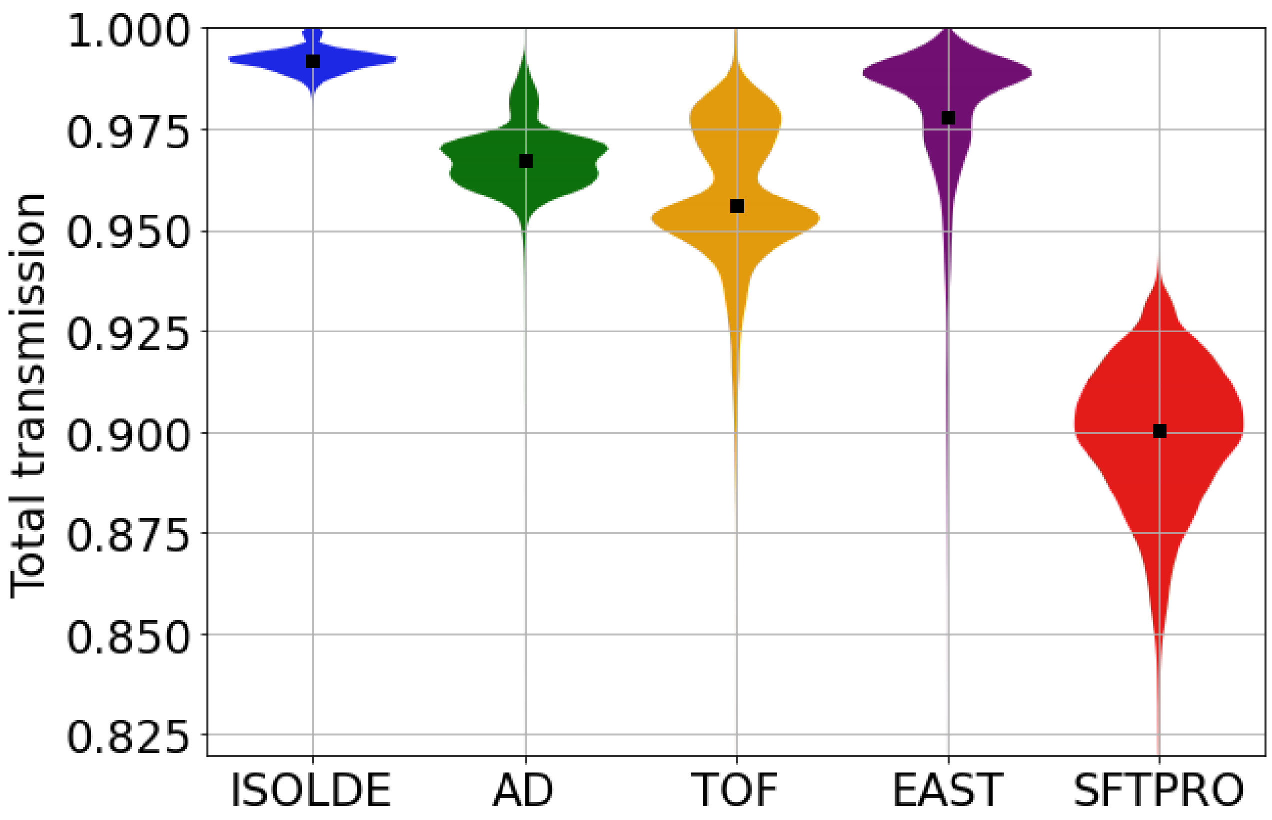
Intensity in 2023

Cumulative intensity until extraction of last synchrotron.



This talk will **not cover** transfer between last synchrotron and target: see session 6.

Transmission in 2023



$$\text{Total transmission} := \frac{Last\ synchrotron\ BCT\ @\ extraction}{PSB\ BCT\ @\ injection}$$

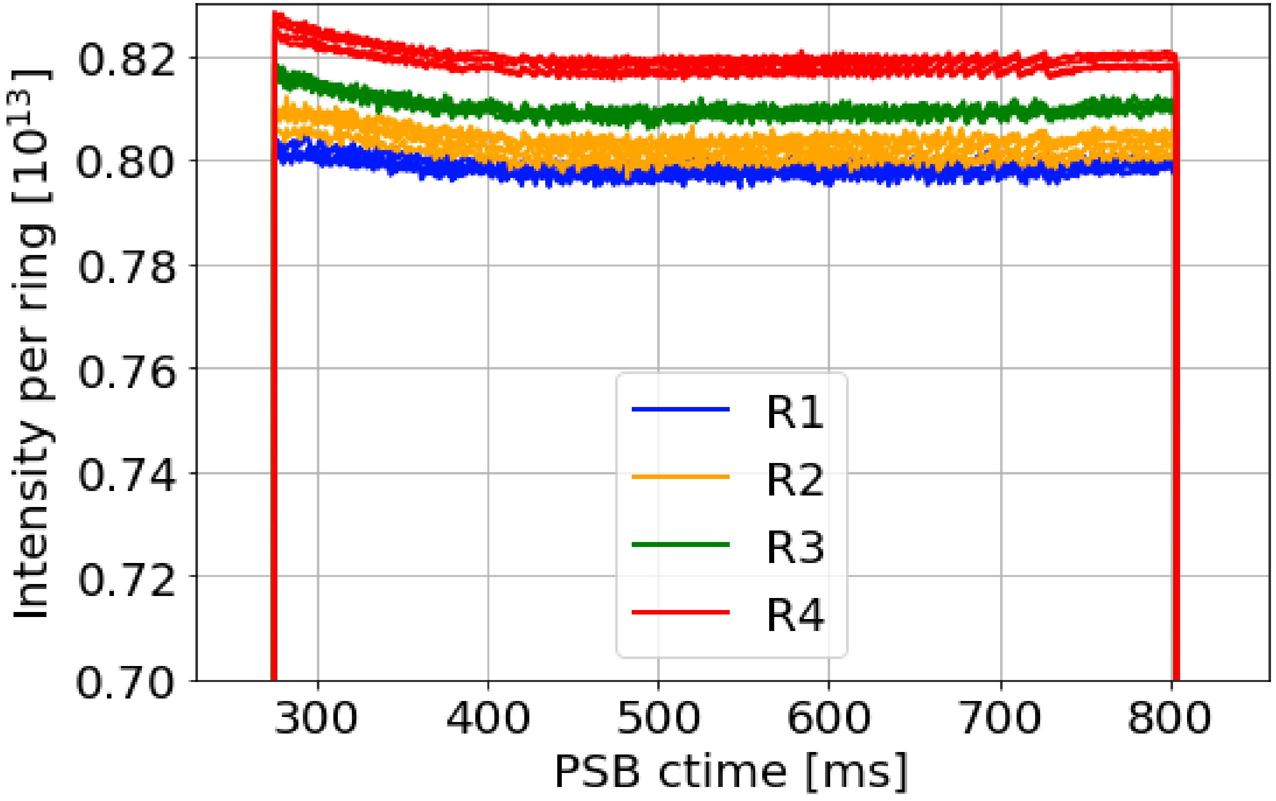
At a glance:

- **ISOLDE $> 99\%$**
- **AD $\sim 97\%$**
- **TOF $\sim 96\%$**
- **EAST $\sim 98\%$**
- **SFTPRO $\sim 90\%$**

Where do we lose protons across the complex?

ISOLDE

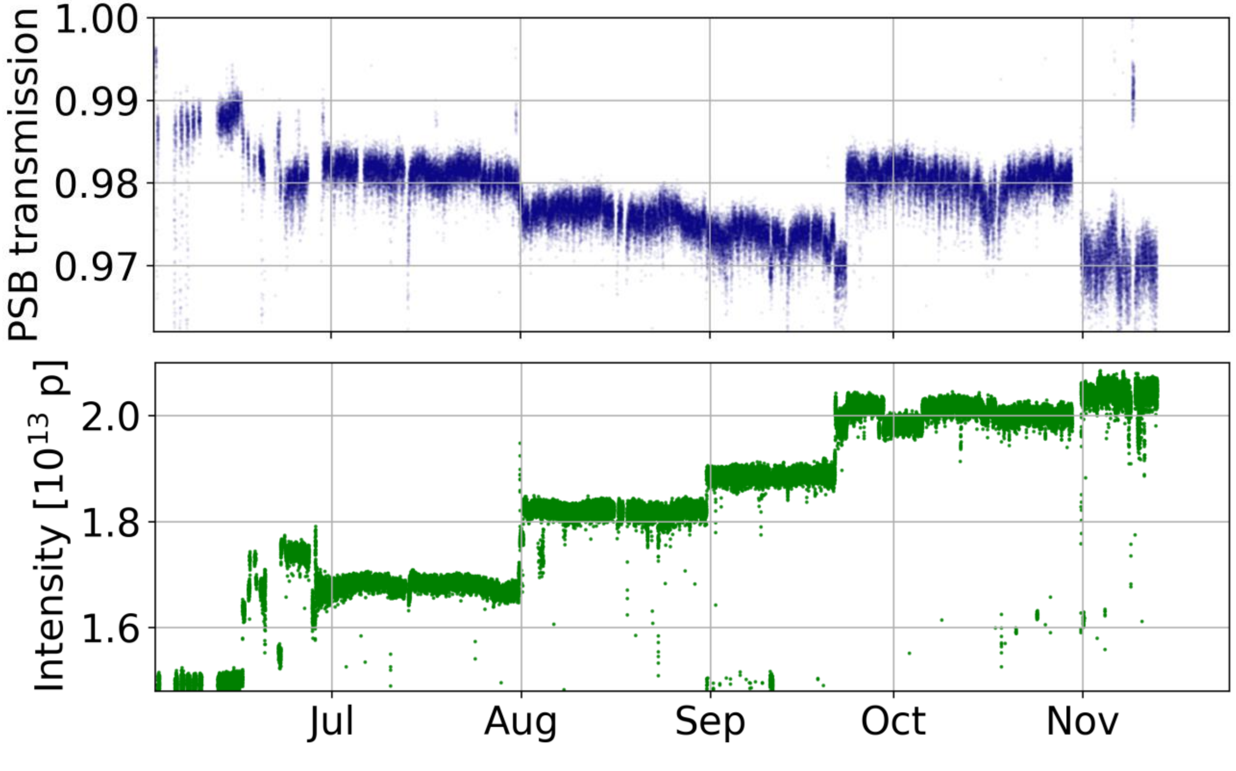
ISOLDE cycle

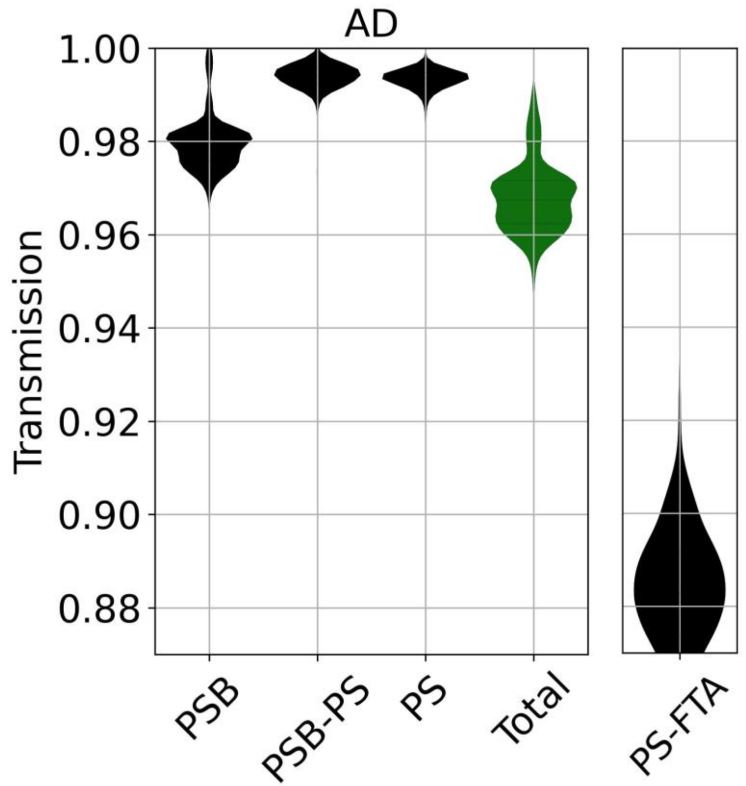


- PSB transmission $> 99\%$!
- Transverse and longitudinal optimizations in place (transverse painting, working point, resonance compensation, double harmonic, …).

AD

AD intensity ramp-up





- Transmission degradation in PSB correlated with intensity ramp-up: **beam setup at low intensity**; further optimizations applied later on.
- Unprecedented intensity delivered to AD!
- Significant loss **after PS extraction**: to be discussed in D. Gamba's talk.

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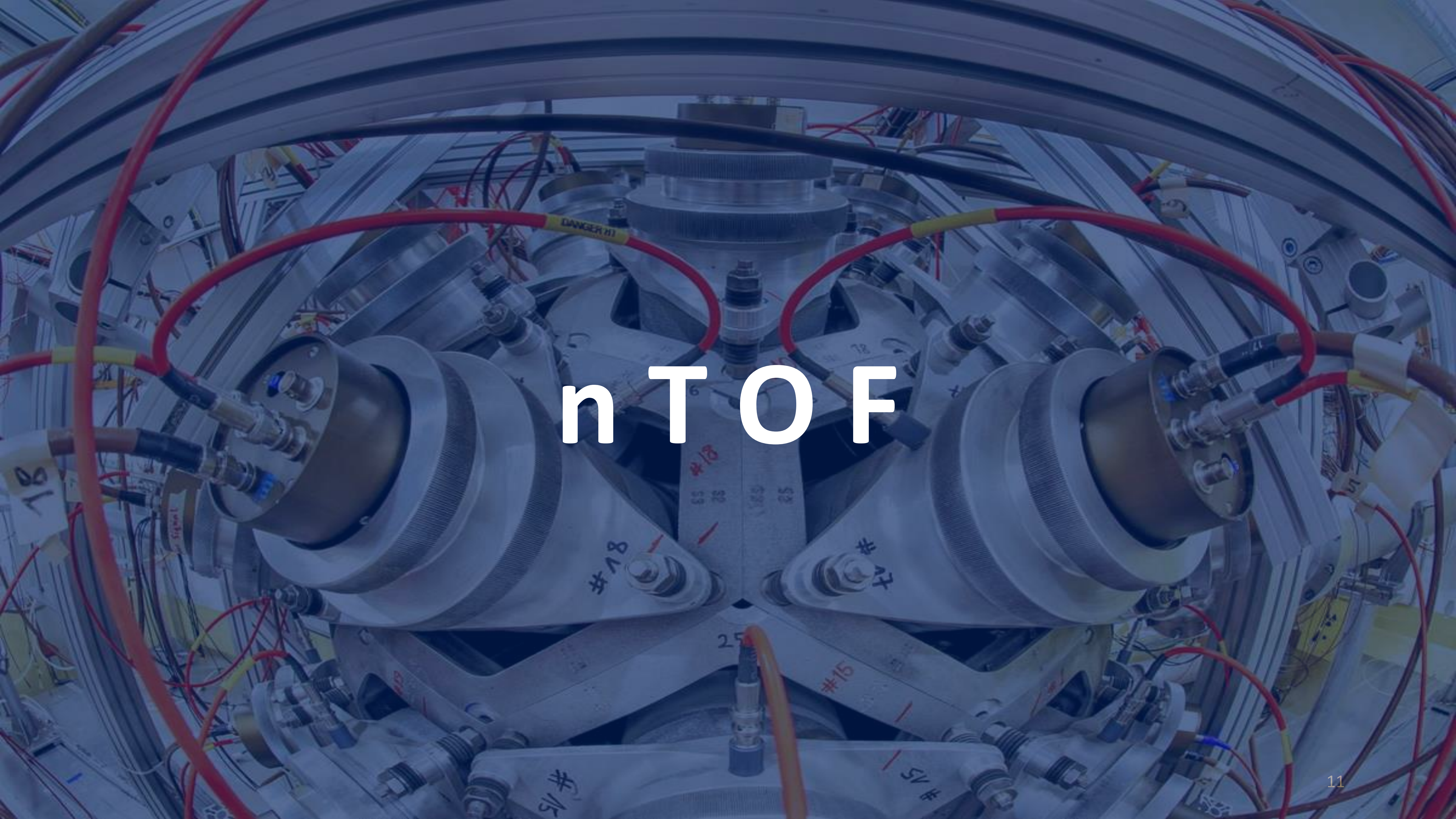
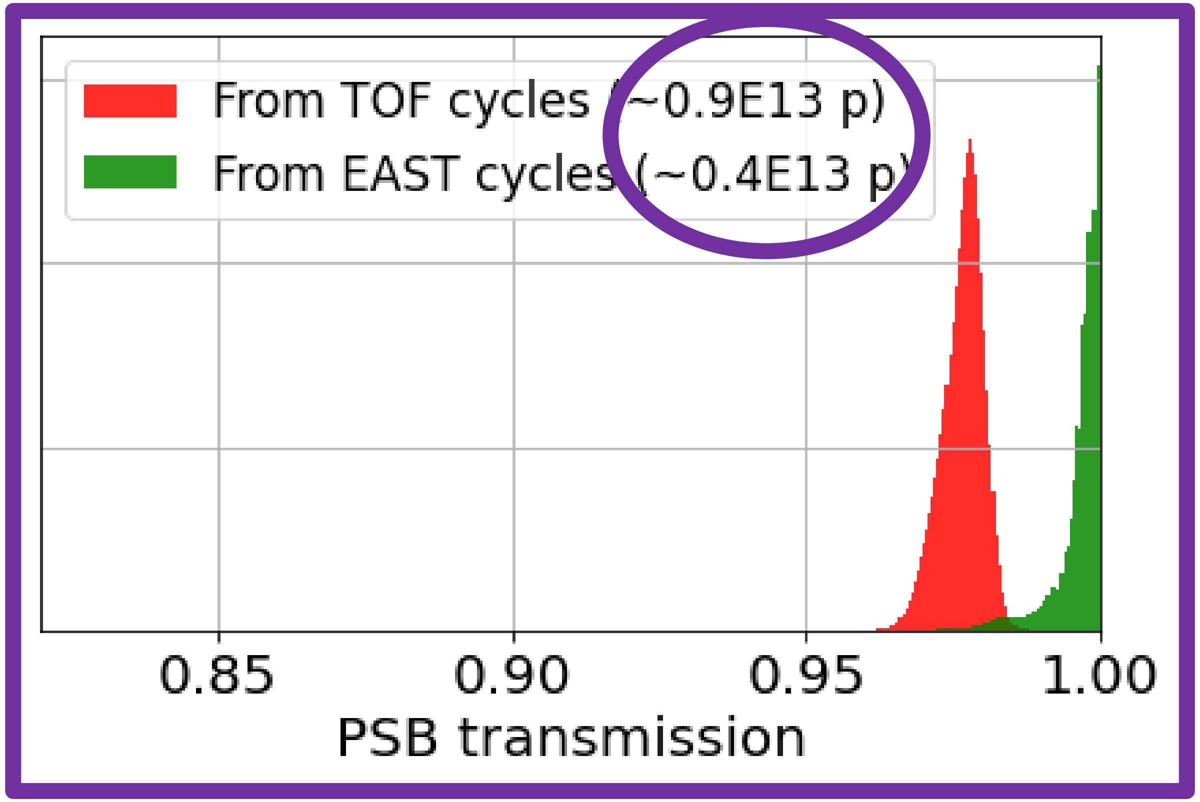
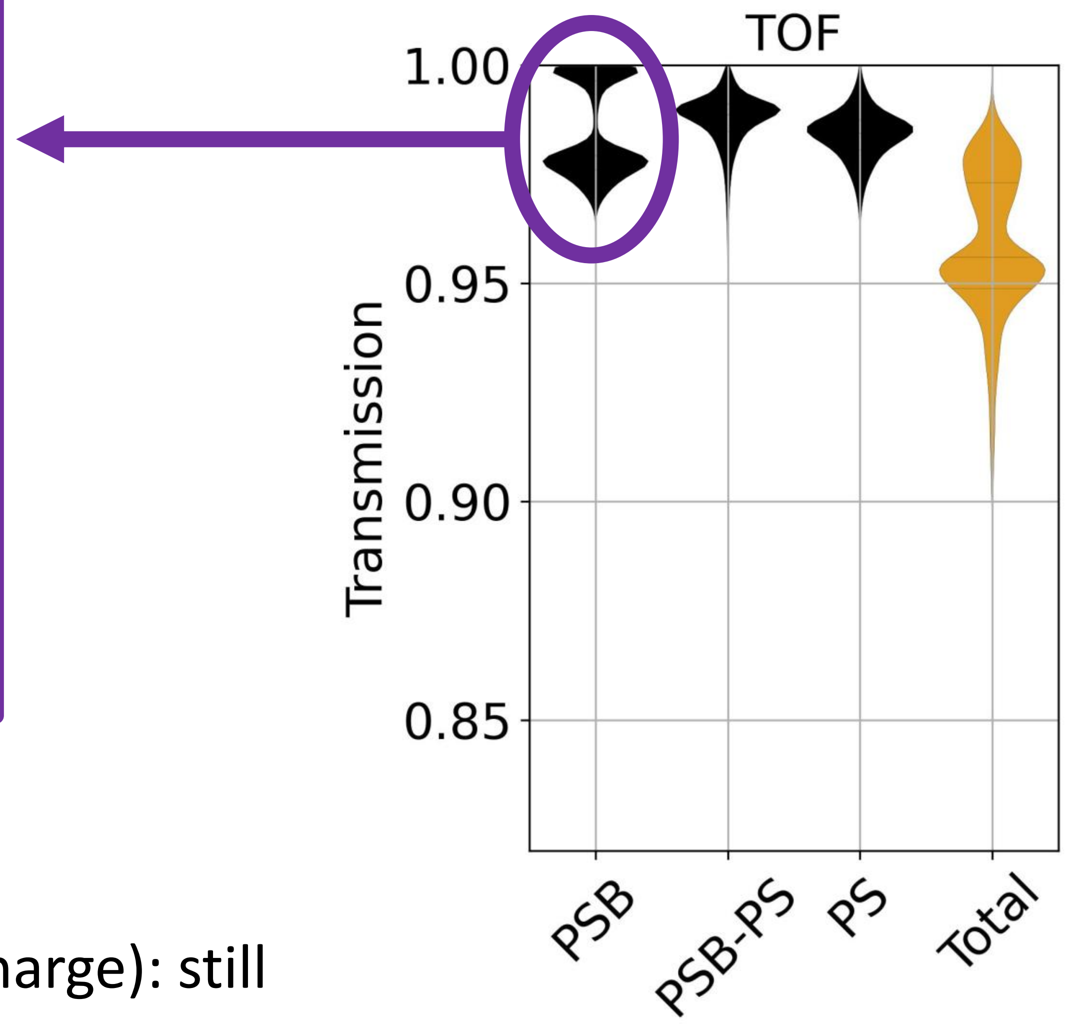


nTOF

TOF

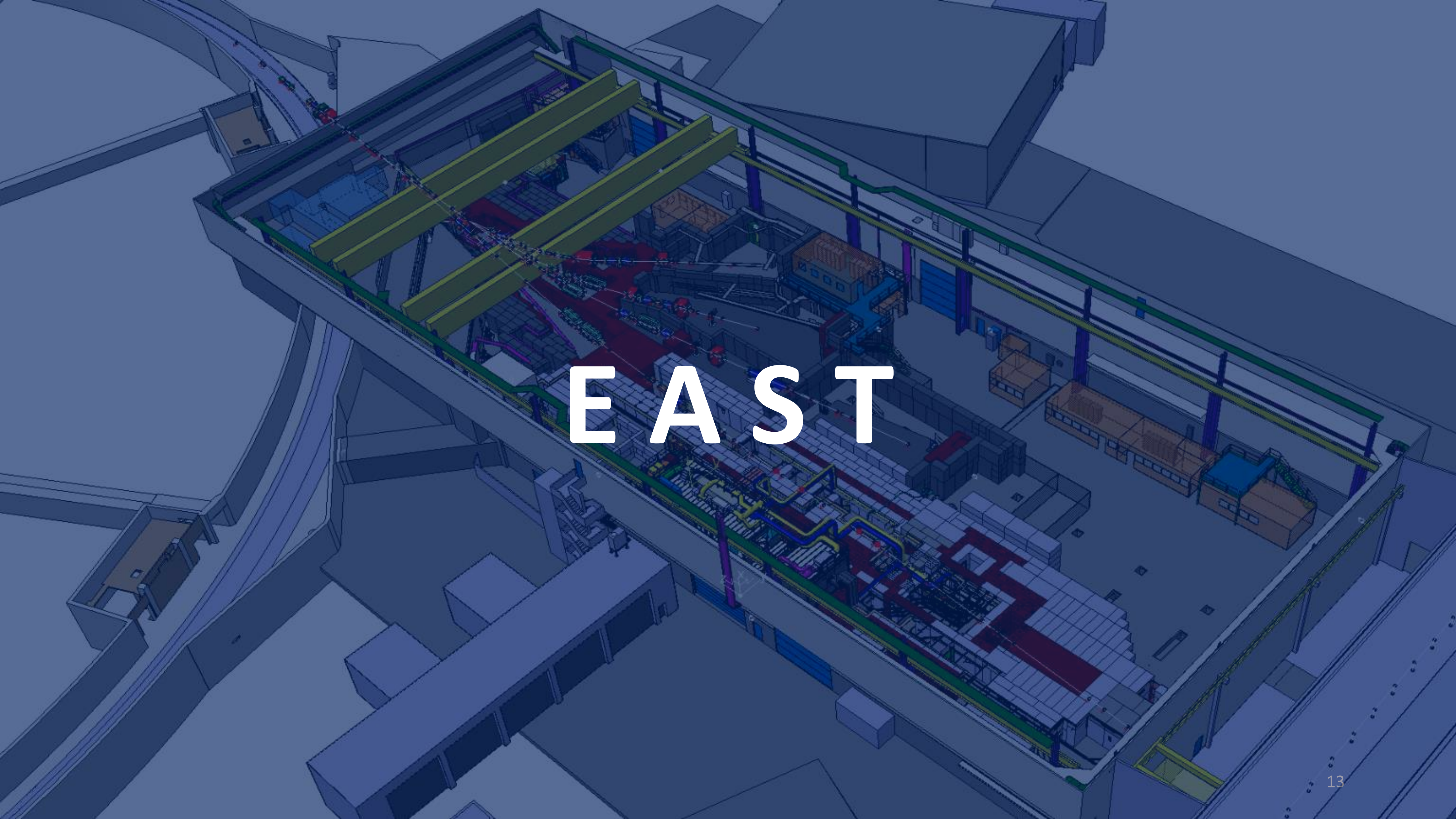




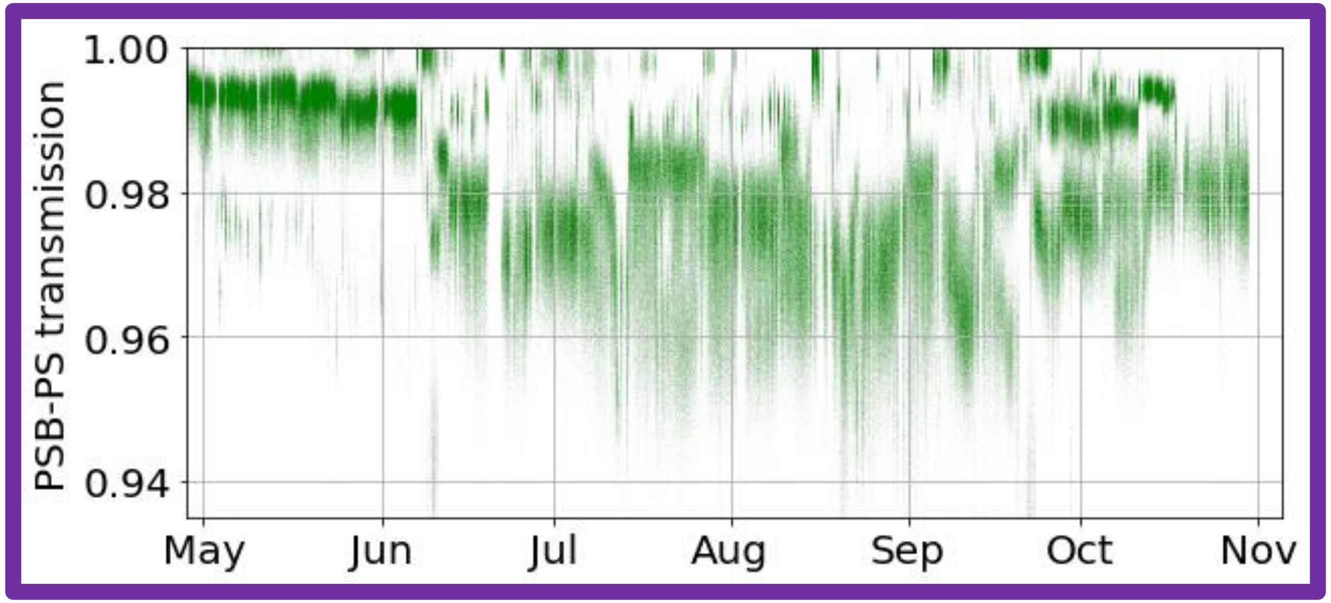
- TOF cycles: highest intensity/ring in PSB.

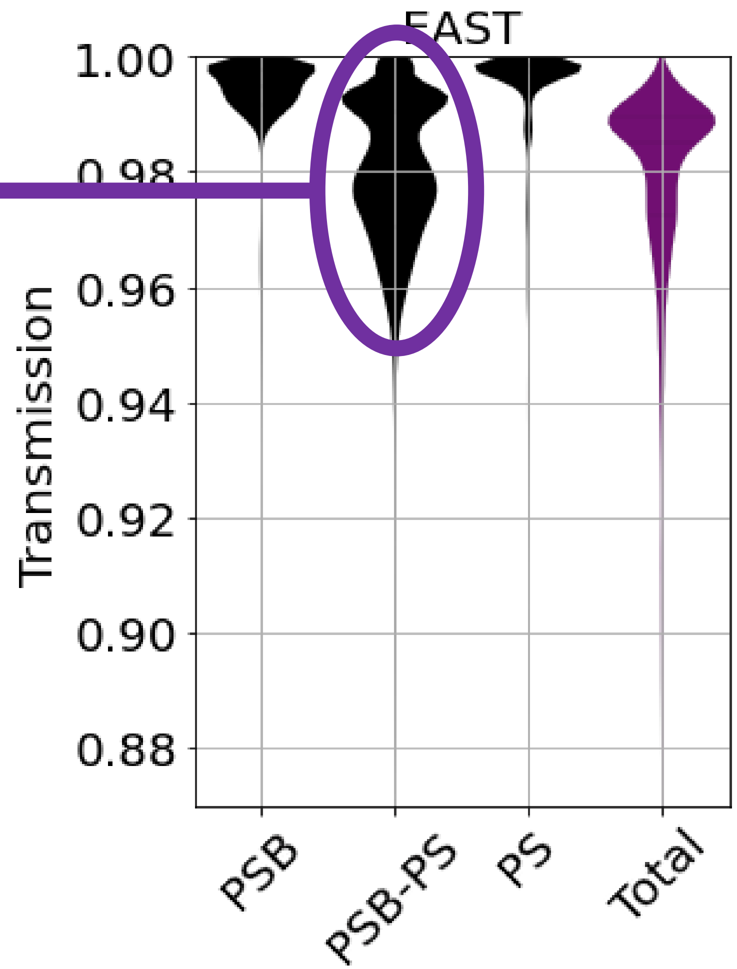
- Loss mostly at beginning of cycle (high space charge): still **~98% transmission** in PSB.

EAST



EAST





- $> \mathbf{98\%}$ overall transmission!
- Some spread in transmission between PSB-PS: to be understood.

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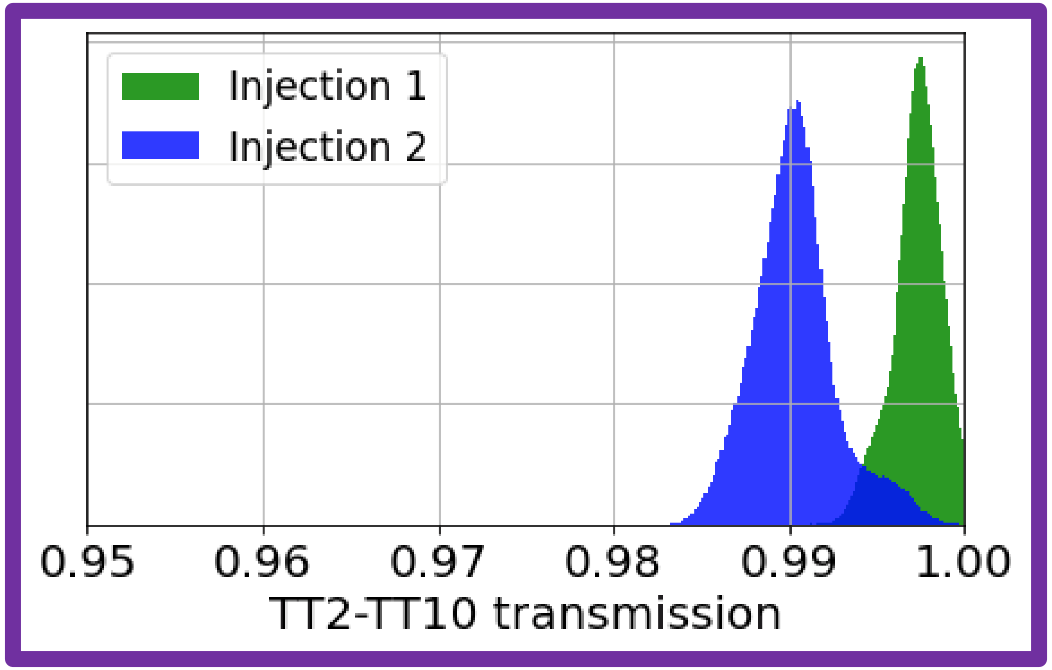
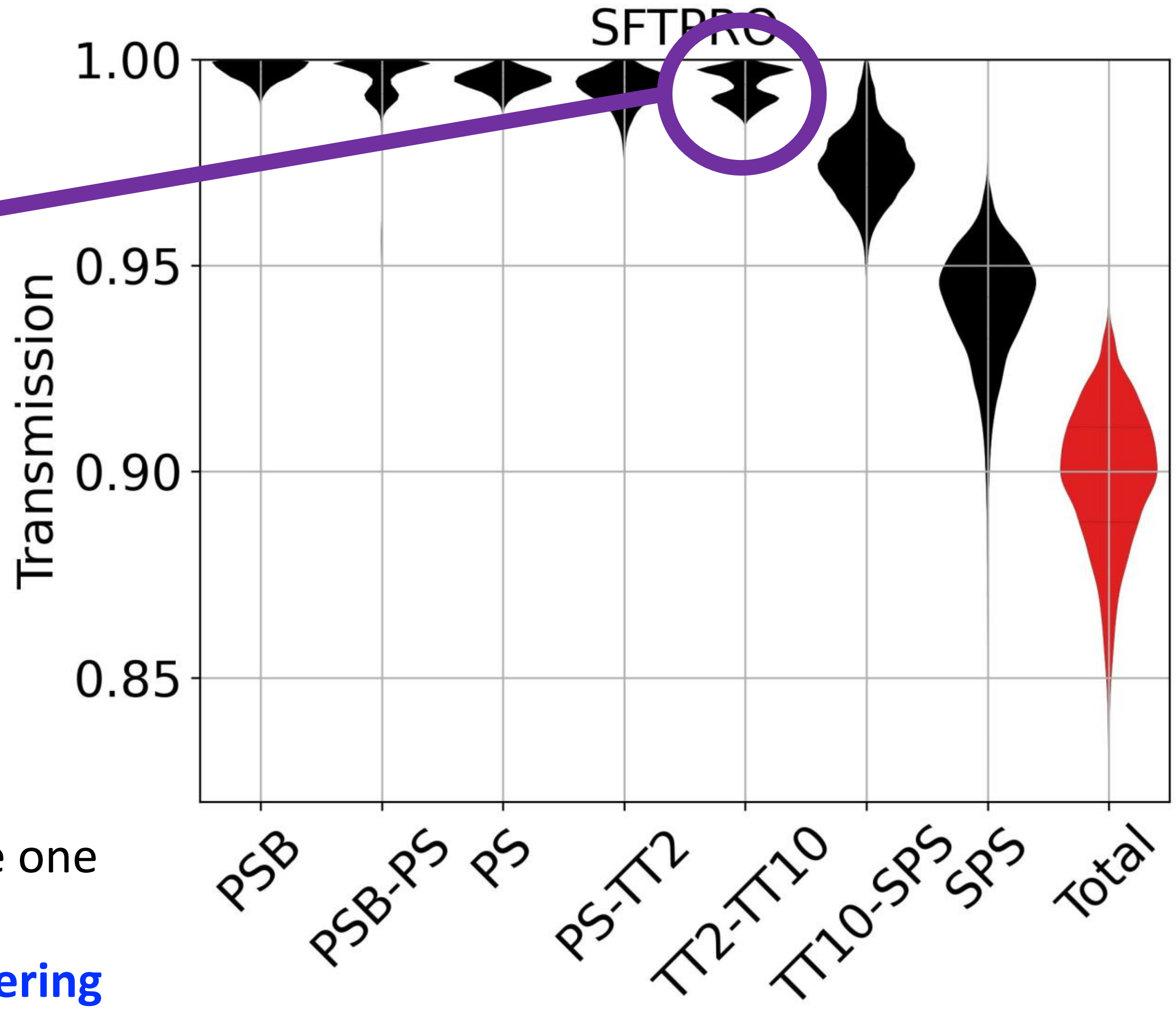
SFTPRO


T10 target
ECN3
EHN2
K12
M2
EHN1 Neutrino Platform
P42
EHN1
T2, T4, T6 targets
TT20 transfer line

SFTPRO transmission breakdown





- Reason for difference in transmission not completely understood.
- Difference in extraction/steering of two injections can be one of the causes (steering is optimized for 1st injection).
- Plans for: fine **calibration** of extraction, **independent steering** correction, **automatic steering framework**.

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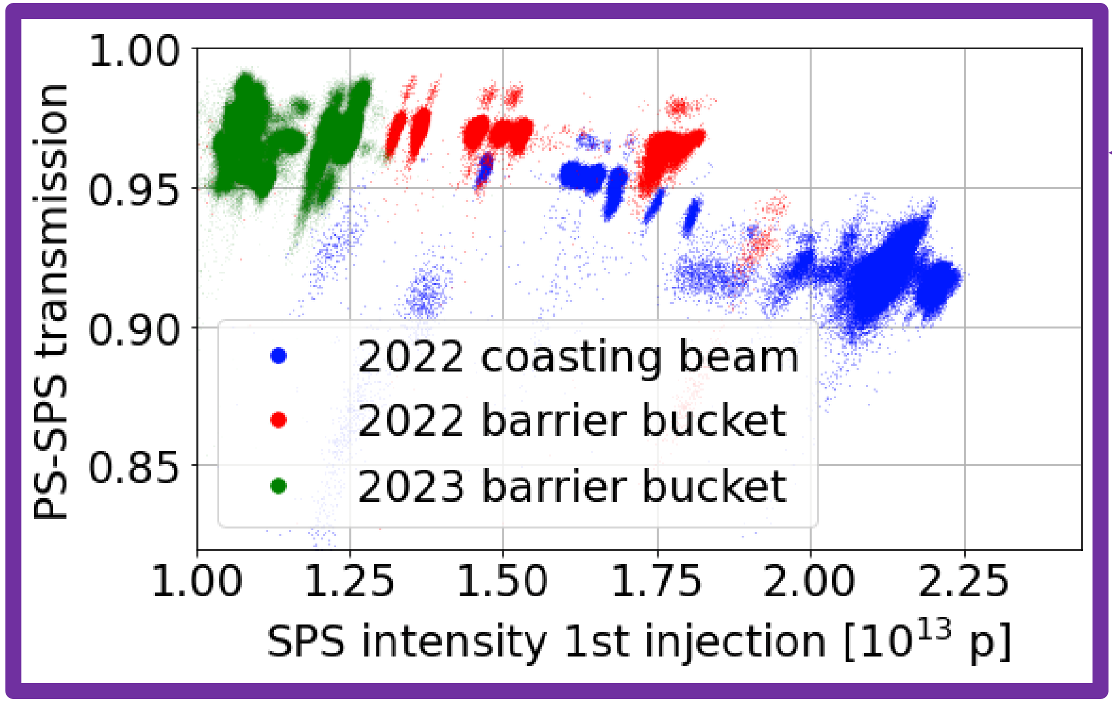
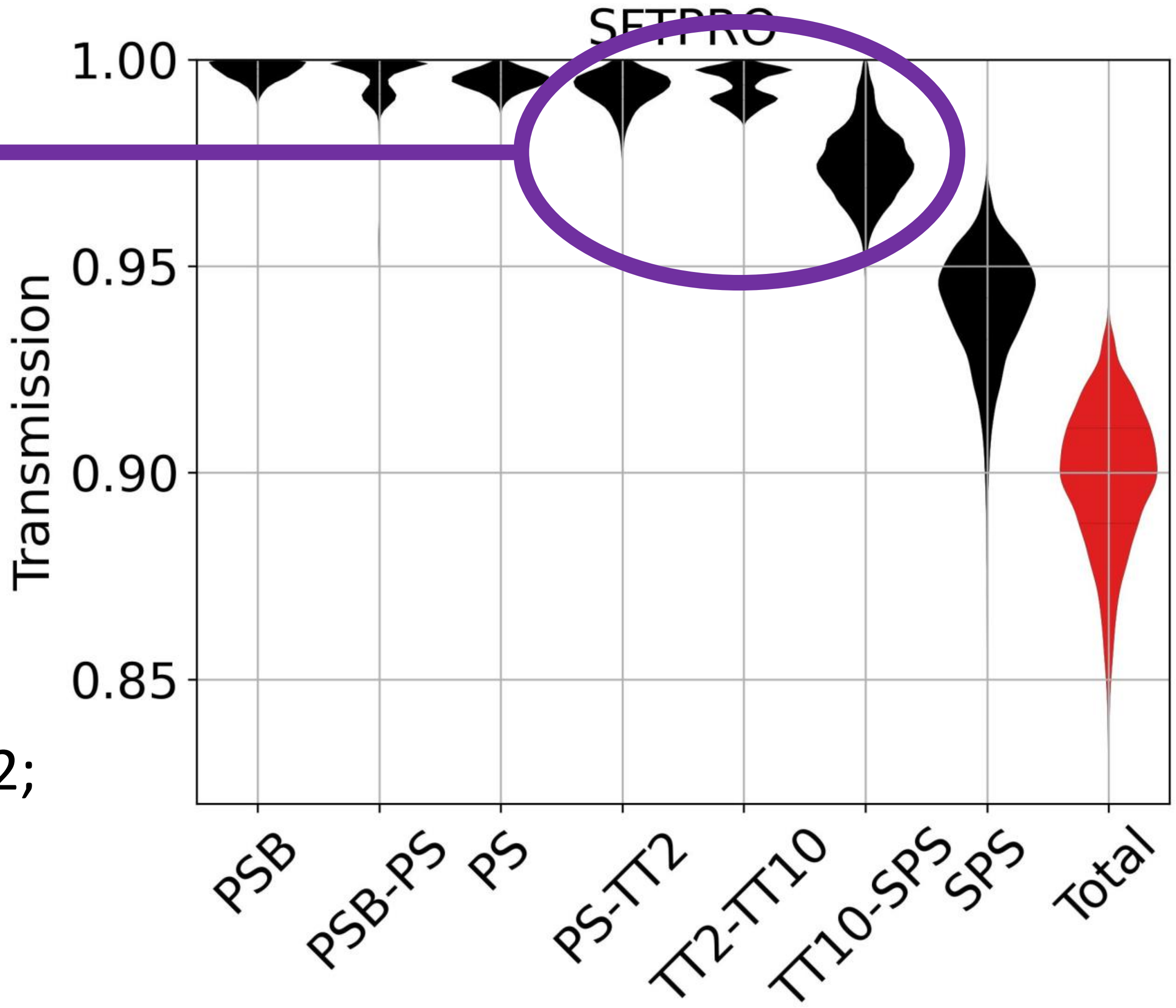
SFTPRO transmission breakdown





- Barrier bucket used since mid-October of 2022; operational in 2023.
- Barrier bucket creates longitudinal gap during rise time of extraction kicker: gain in PS-SPS transmission of $\sim 1 - 1.5\%$.

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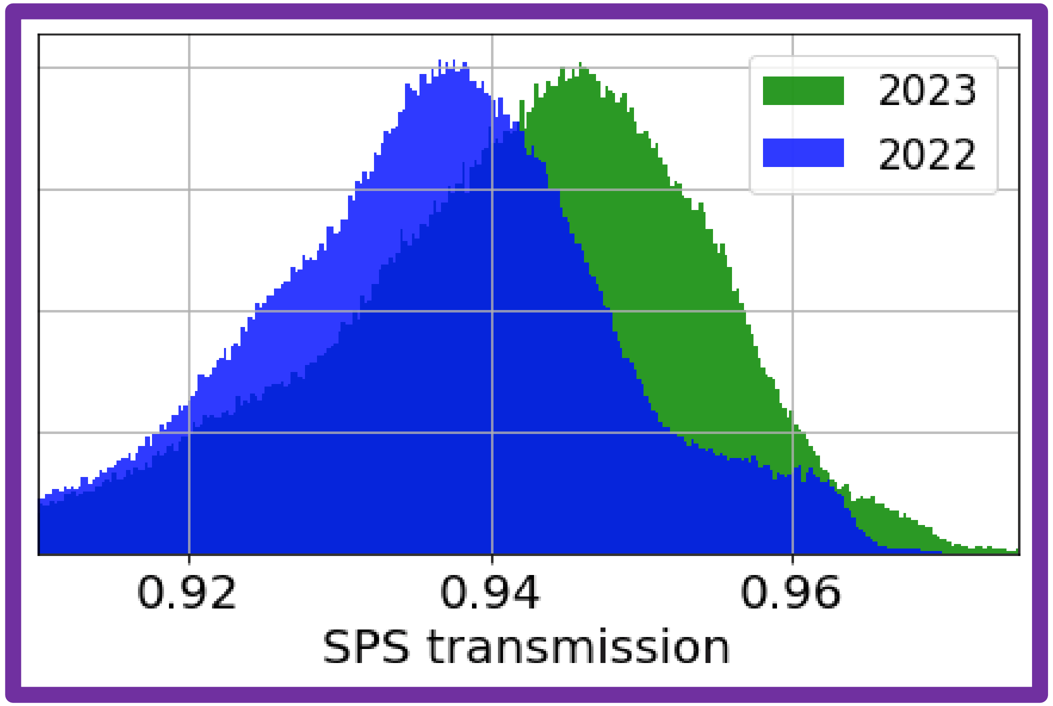
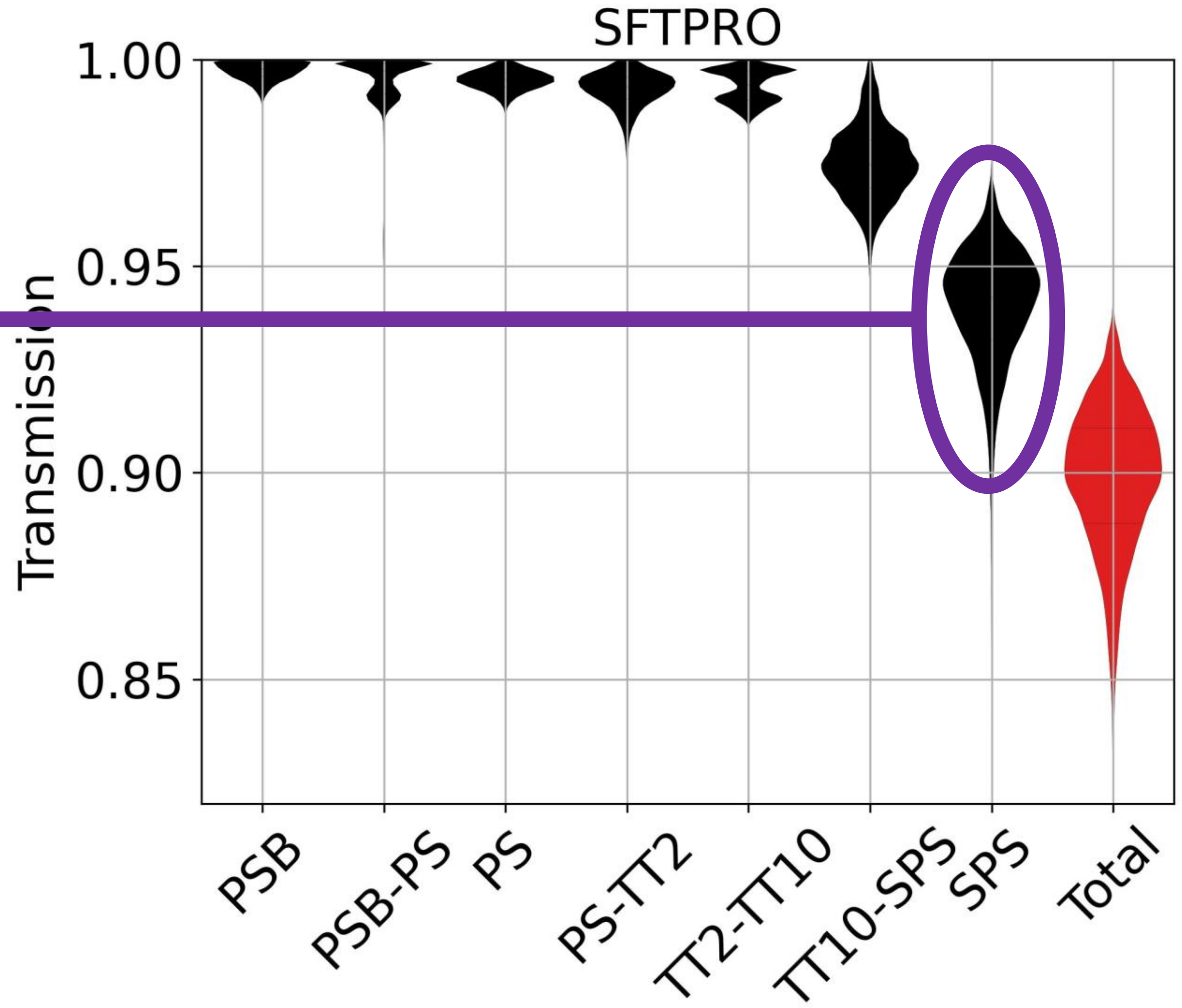
SFTPRO transmission breakdown





- Better overall SPS transmission (in-ring) compared to 2022.
- Compromise between **SPS transmission** and **splitter losses** (see IPP 14/07/2022).

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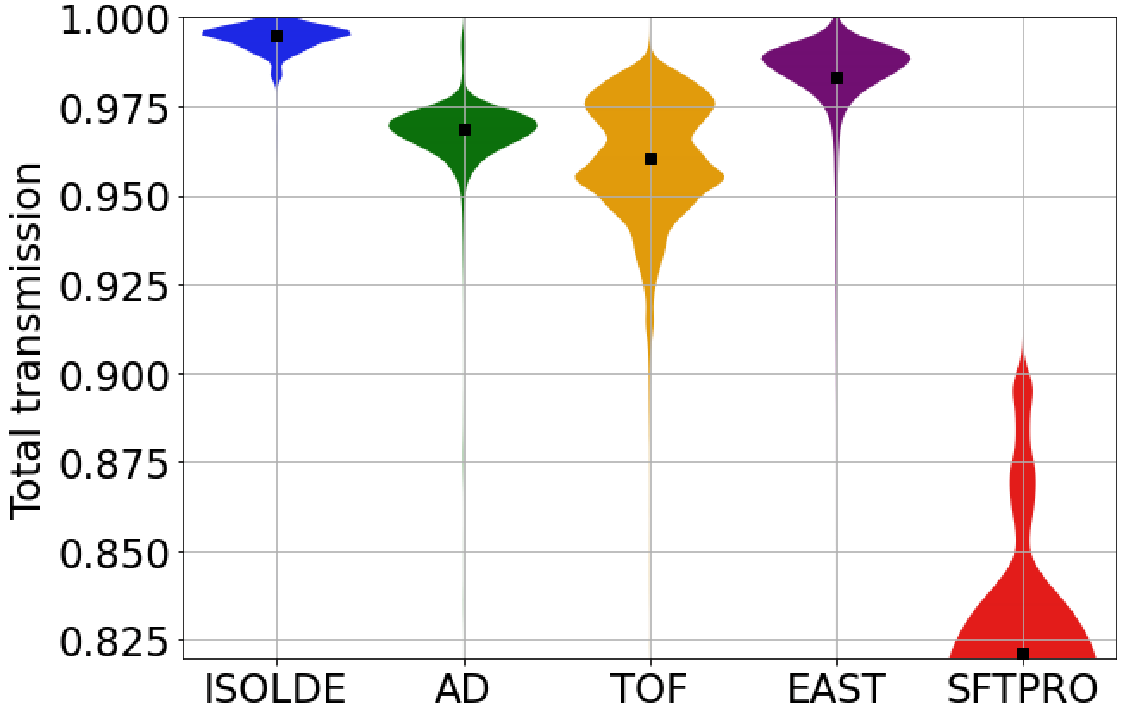
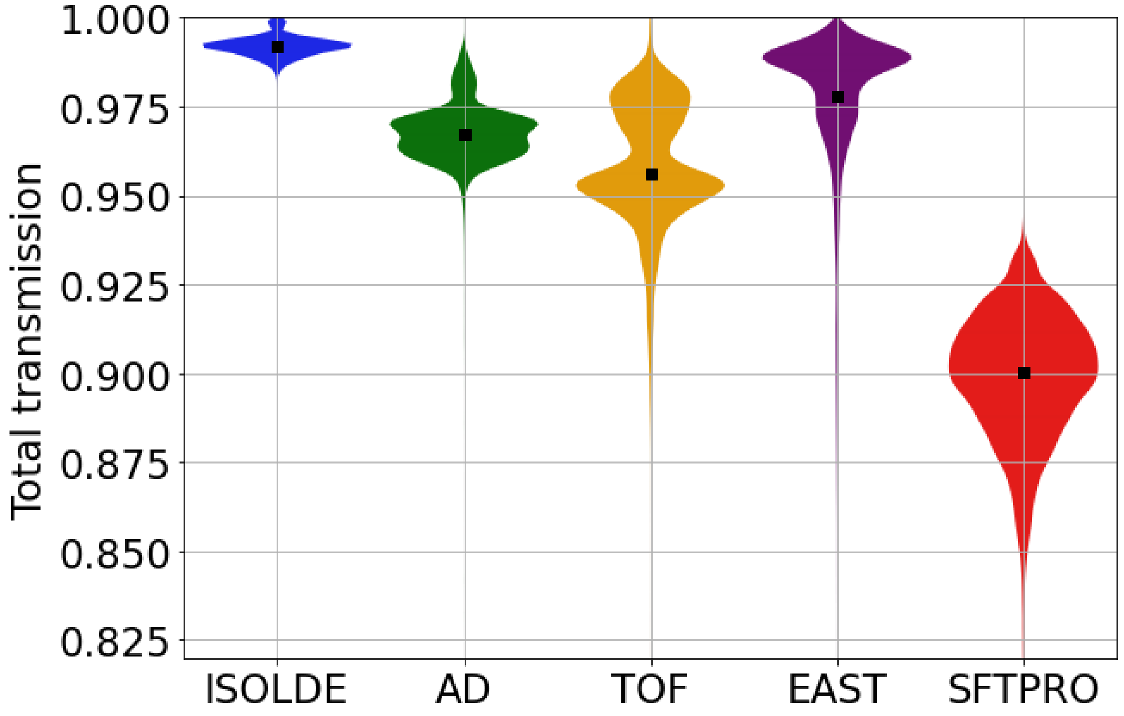
2022



2023



(Lower intensity than 2022)

In 2023, we matched or even surpassed transmission performance of 2022.

What can we expect for the next years?

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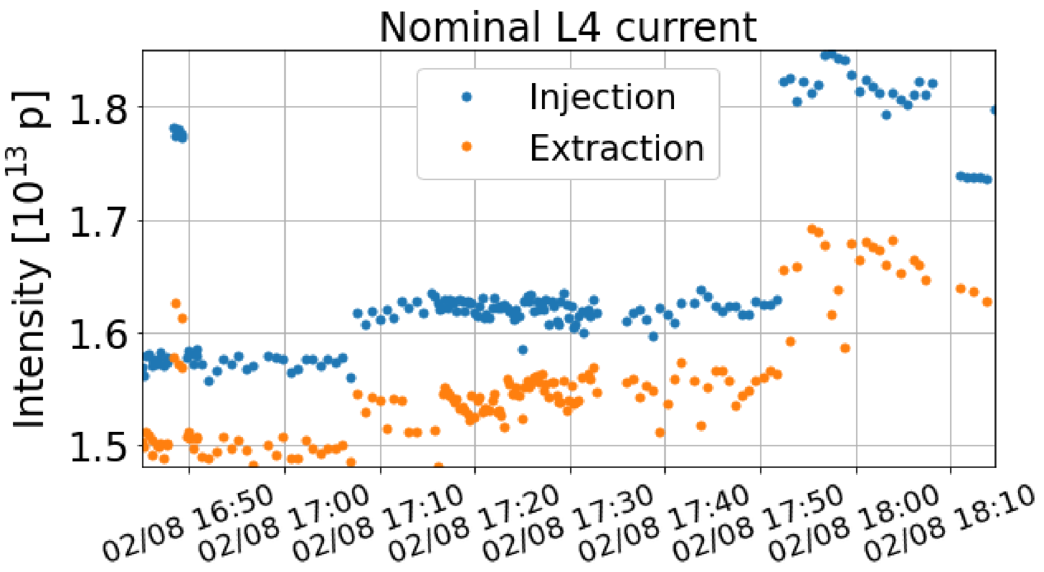
Part II

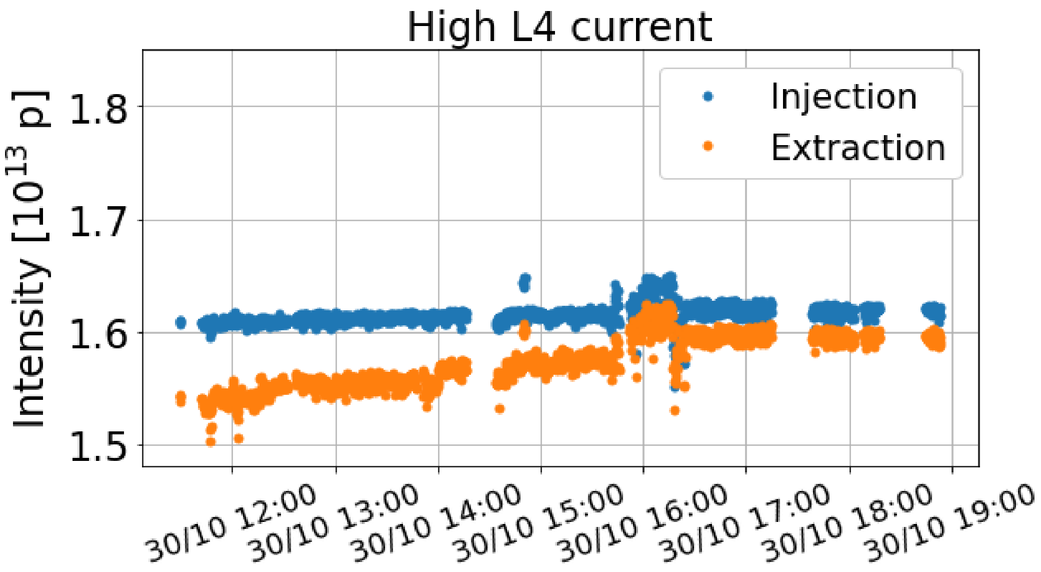
…and beyond

Can we push PSB intensity?

High-intensity parallel and dedicated MDs in PSB during 2023:

- **Achieved**: $\mathbf{1.7 \times 10^{13}}$ (nominal L4 current; transmission fluctuations) and $\mathbf{1.6 \times 10^{13}}$ (high L4 current; $\mathbf{> 98\%}$ transmission) extracted protons.
- **Key optimizations**: painting, working point, resonance compensation, field correction, RF voltage increase + tripleH.
- **2024 plan**: keep high-intensity cycle in supercycle and/or have semi-dedicated days with high L4 current (produce operational beams with high current).





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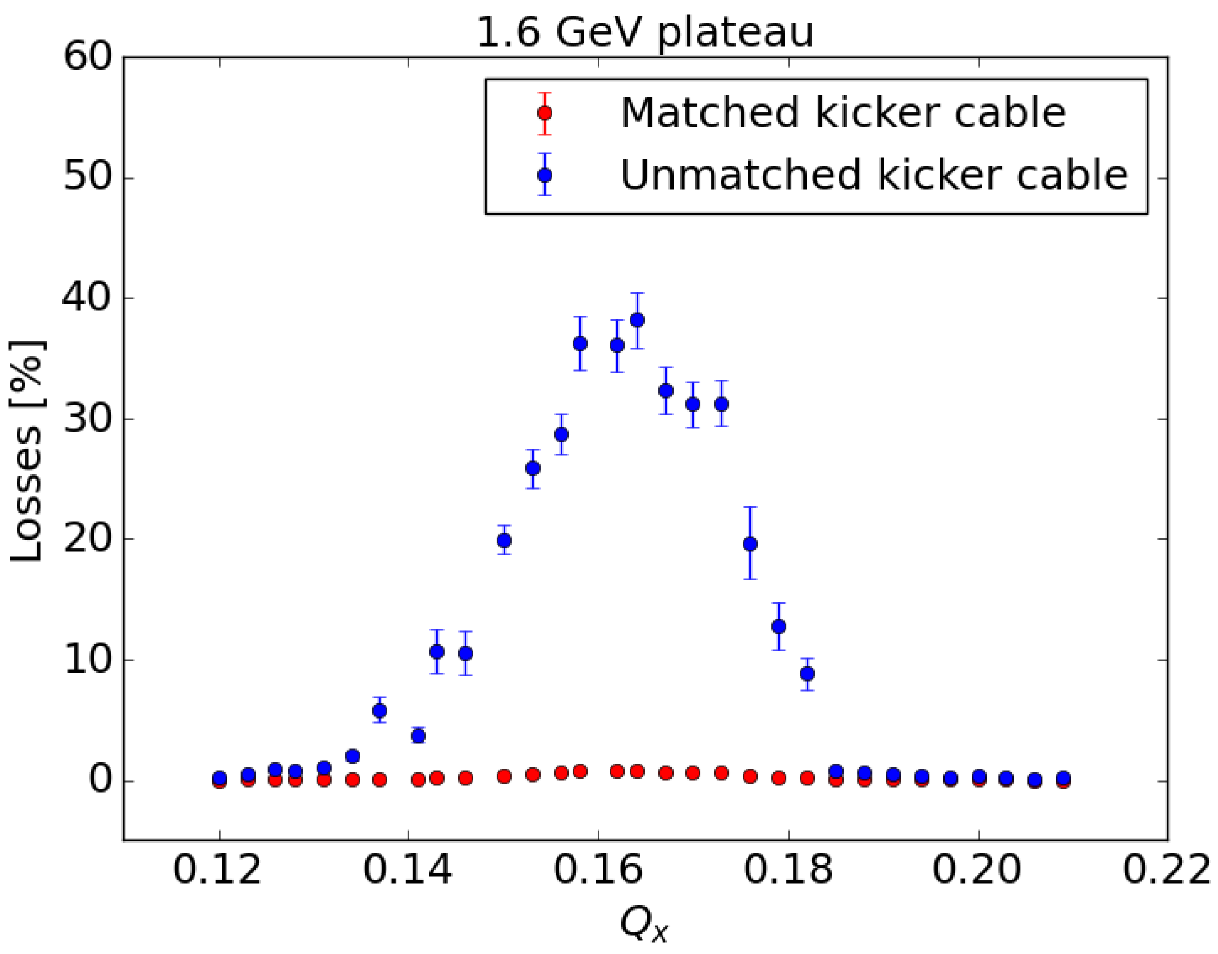
PSB instabilities at high intensities

- New instability observed at ~1.6 GeV and high intensities.
- Current mitigation strategy is **coupling resonance**: can lead to higher emittances and losses.
- Dedicated MD showed that instability is coming from extraction **kicker termination**.
- Kicker cannot pulse with matched cable: **working point adjustments** may help in the short term. Hardware modification options are considered.



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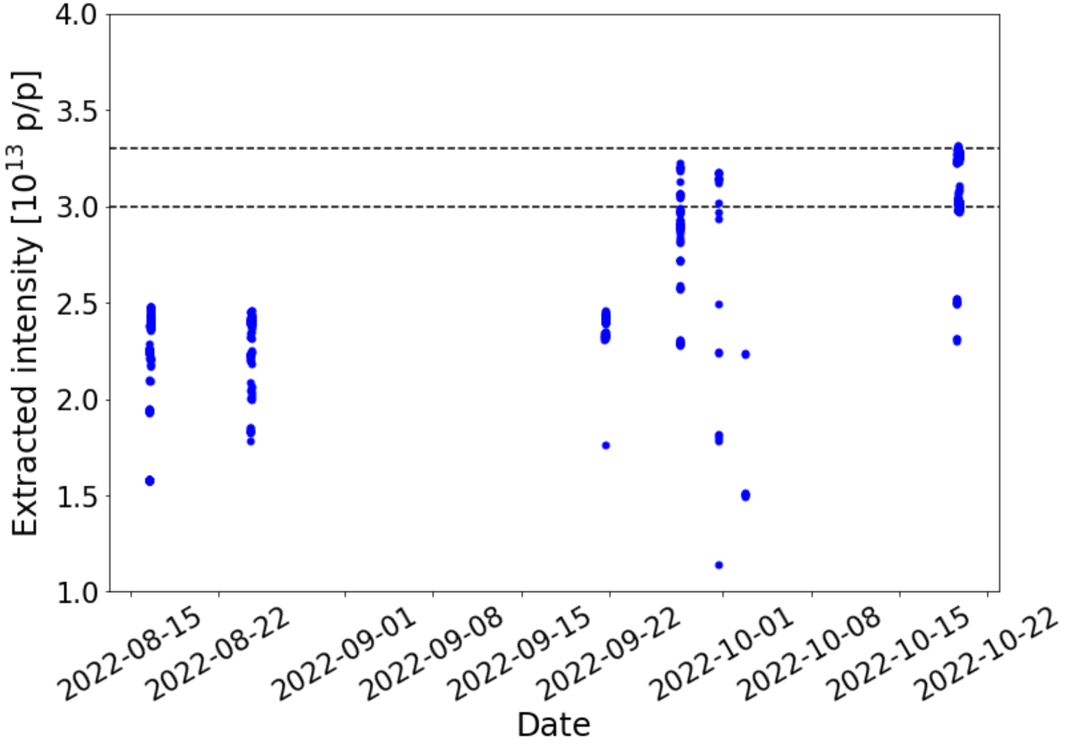
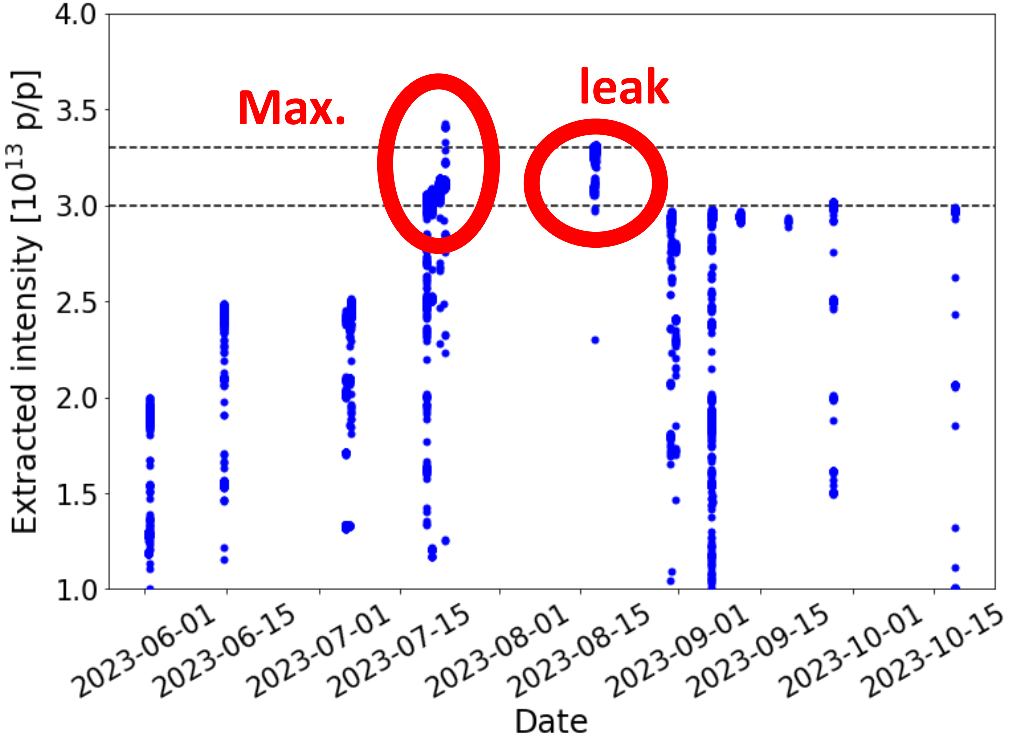
Pushing MTE intensity in the PS

High-intensity tests in the PS:

2022: no barrier bucket



2023: with barrier bucket



- Non-conformity with RF bypass: decided not to exceed 3×10^{13} protons during ion run.
- Explore **intensity reach** of barrier-bucket MTE up to maximum digestible intensity in SPS.

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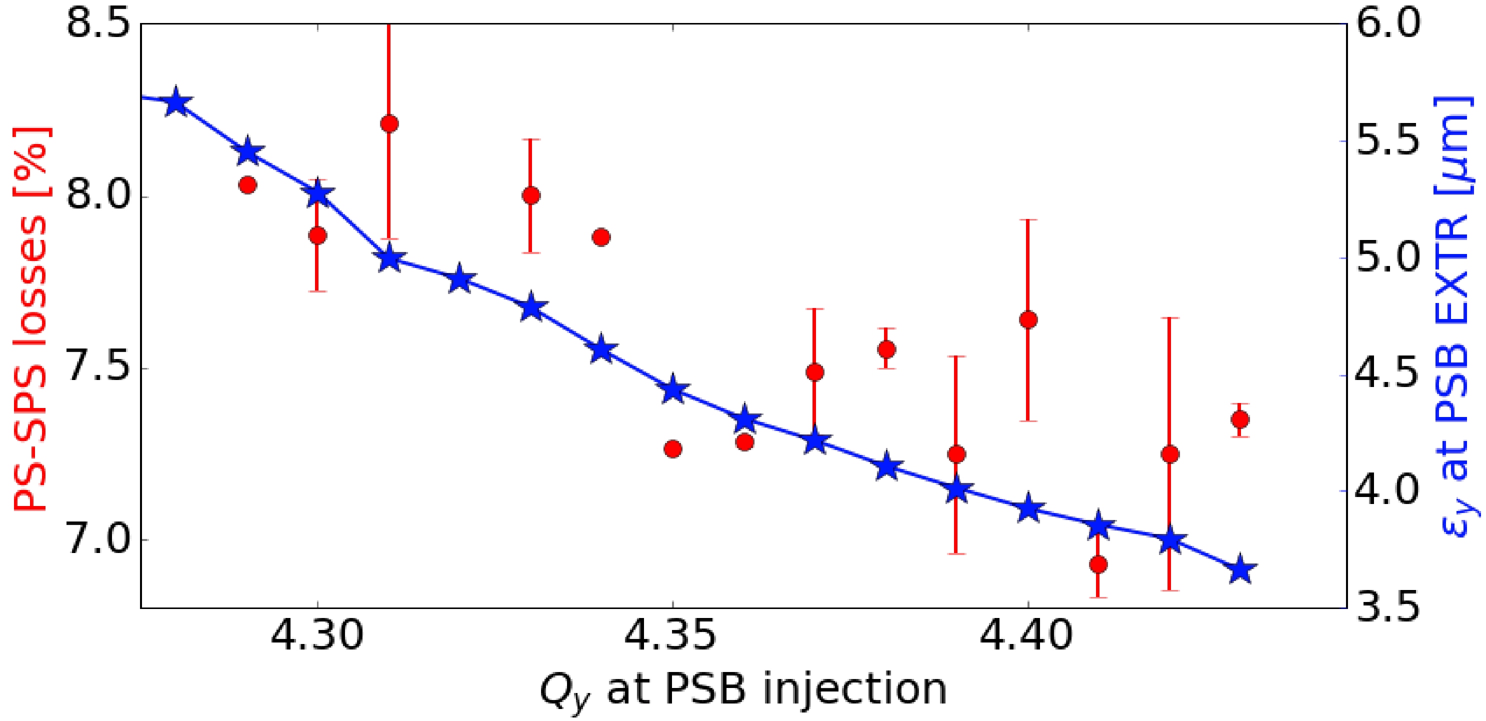
SFTPRO transmission along the chain

- Short parallel MD ongoing to **understand** behavior of **SFTPRO transmission**.
- Tailoring **emittances in PSB** to determine impact of beam size and shape.
- Optimizing TFB frequency and tune to **reduce TFB gain** in the PS.



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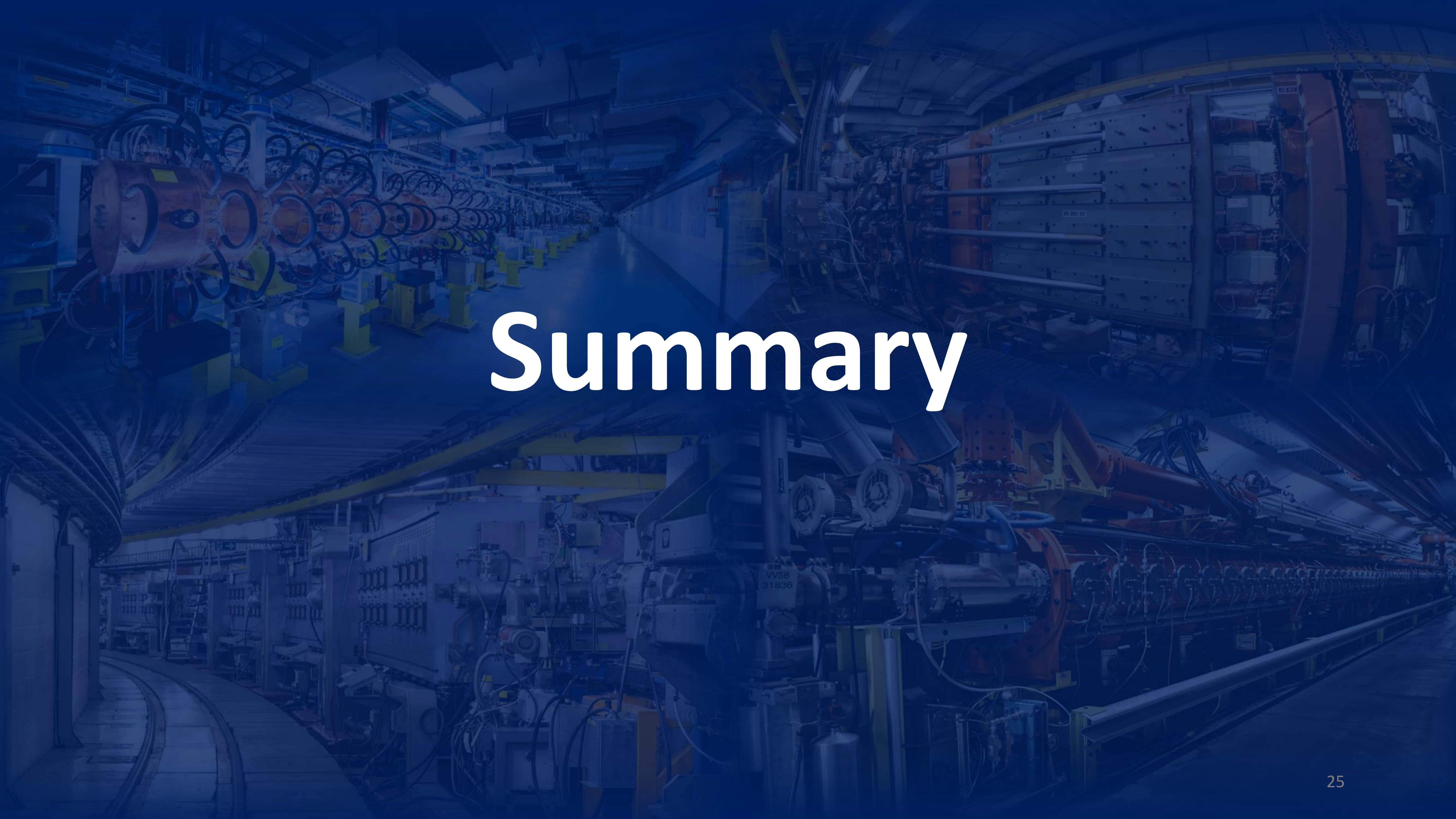

Summary

Summary

How did the fixed target cycles perform in 2023?

- Excellent transmission throughout the complex: $> 96\ \%$ for all beams but SFTPRO ($90\ \%$).

Where do we lose protons across the complex?

- Different processes lead to losses in different locations (rings and transfer lines):
  - Example of space charge related loss of TOF early in the PSB cycle.
  - Example of barrier-bucket transmission gain.
- Need of better **monitoring along the year** to tackle issues as they arise:
  - Example of transmission degradation with intensity ramp-up in AD.
  - Example of transmission discrepancy of SFTPRO injections: independent steering correction for injection #1 and #2, automatic steering framework.

What are the ongoing and future studies?

- Intensity reach in PSB: $> 1.6 \times 10^{13}$ **p/ring** (nominal or high L4 current)!
  - Stability and reproducibility to be tackled in 2024.
- Intensity reach in PS for MTE: $> 3 \times 10^{13}$ **protons/pulse**!
  - RF bypasses will be checked electrically & visually to exclude further non-conformity: validate barrier-bucket MTE up to maximum intensity for SPS.
- SFTPRO: lower transmission and most complicated beam along the chain.
  - More critical beam for **well defined characteristics and margins**.
  - MDs ongoing for **coordinating parameters along PSB-PS-SPS**.

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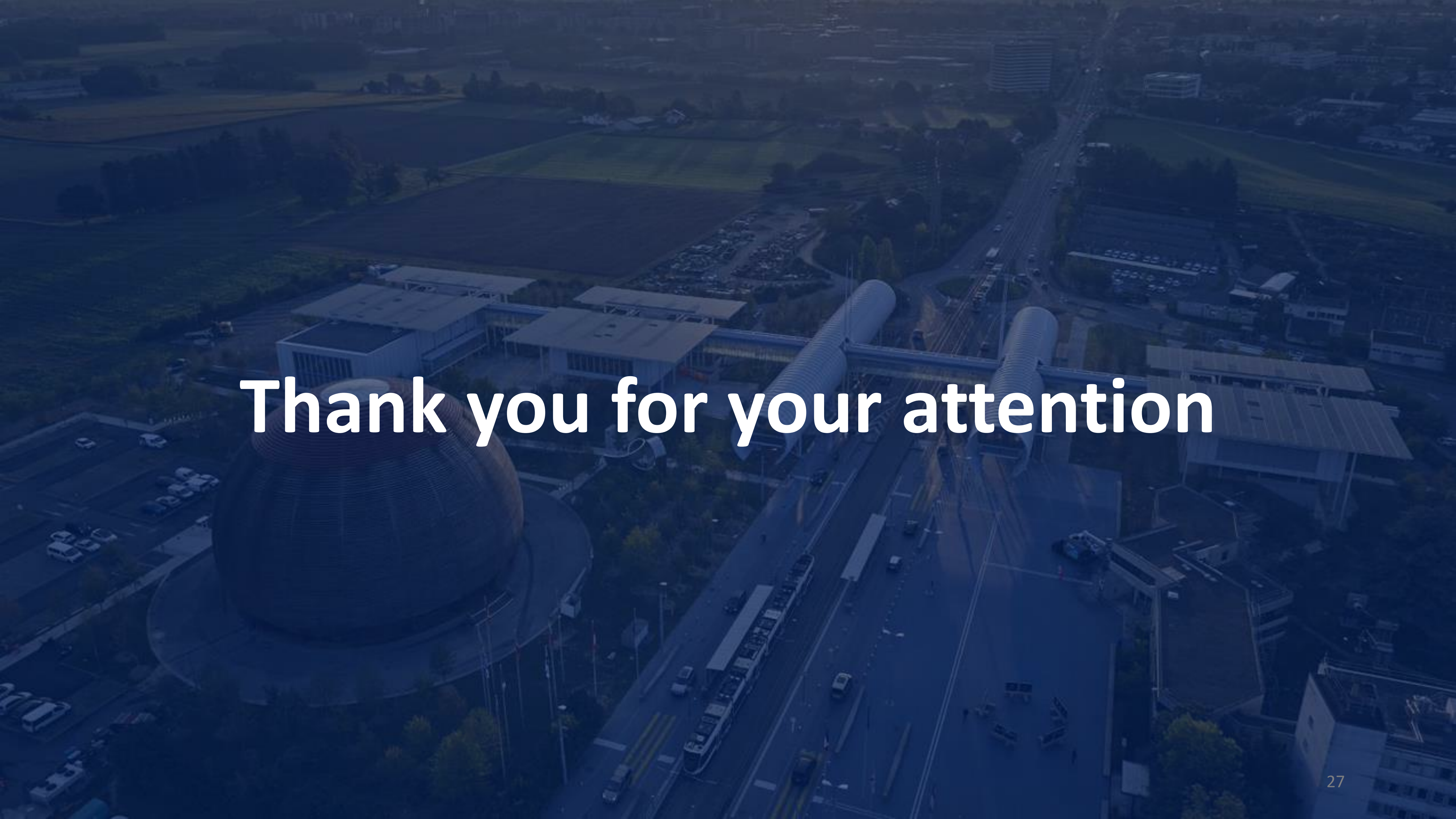
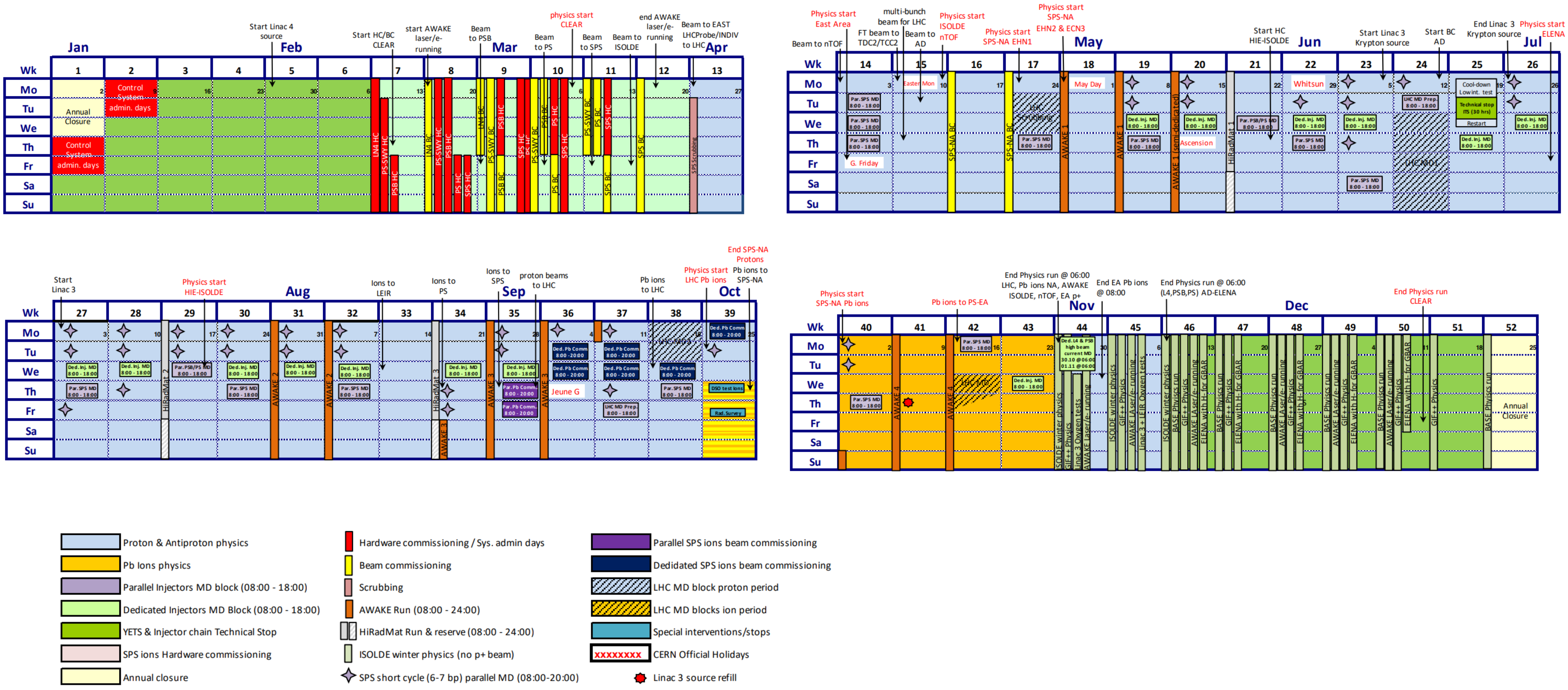


Thank you for your attention

Backup

2023 schedule



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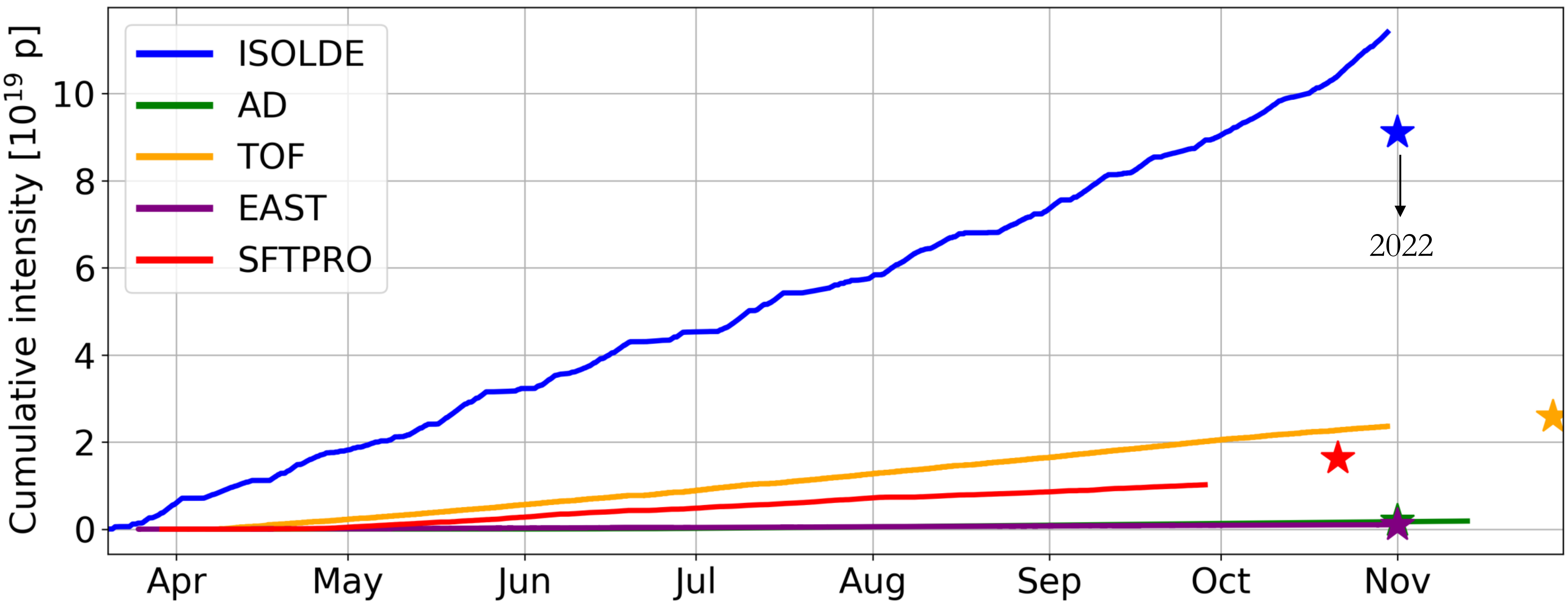
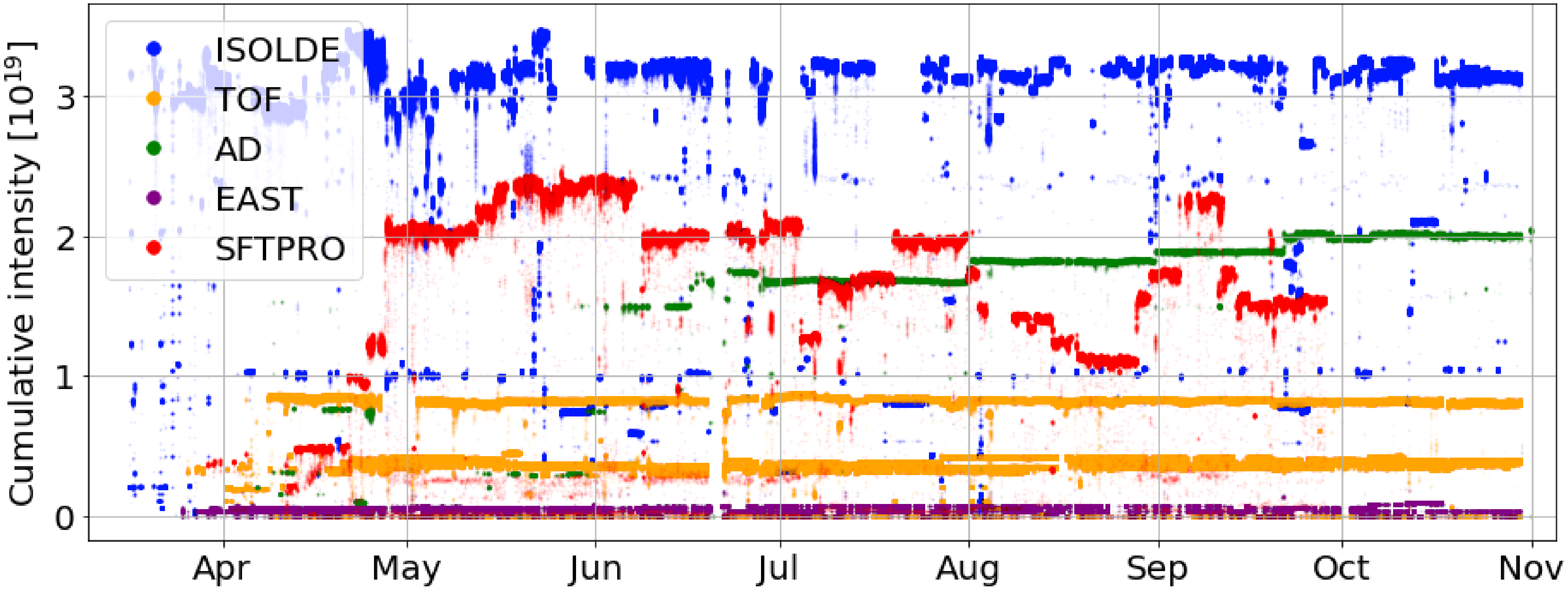
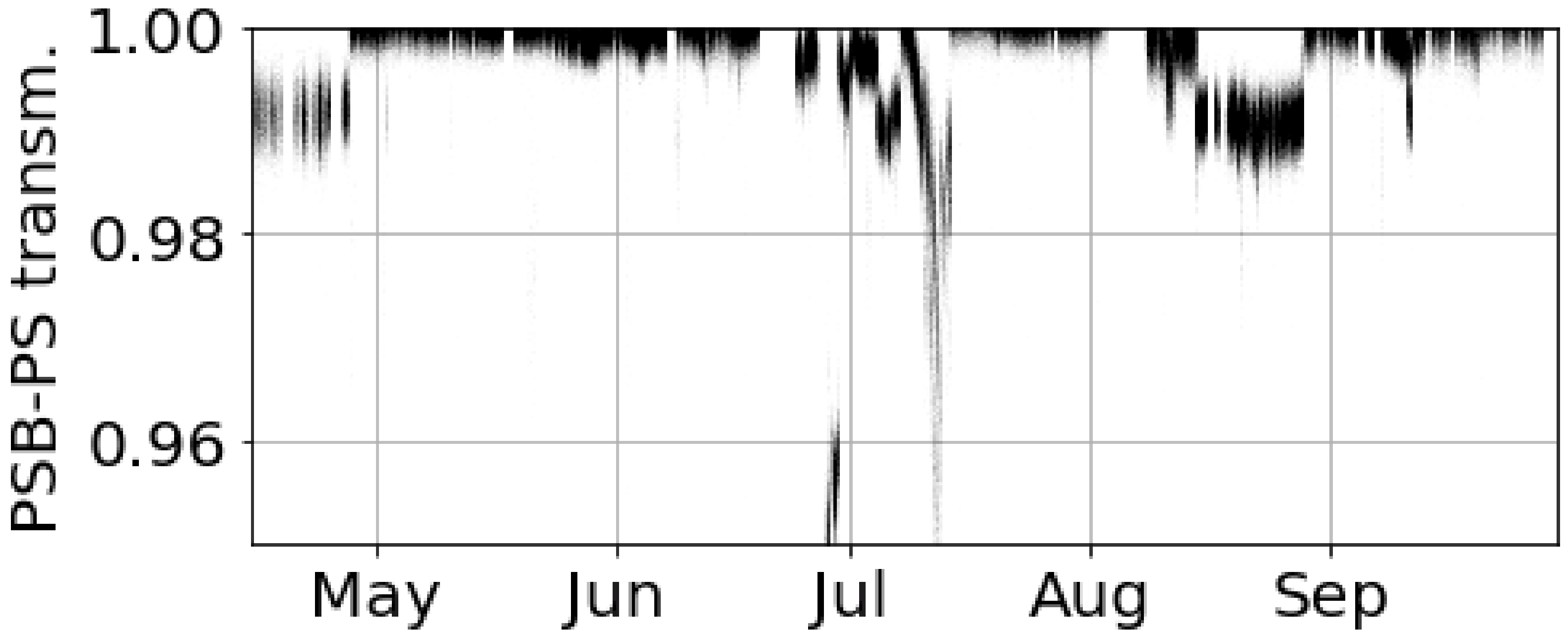
Intensity in 2023 and 2022



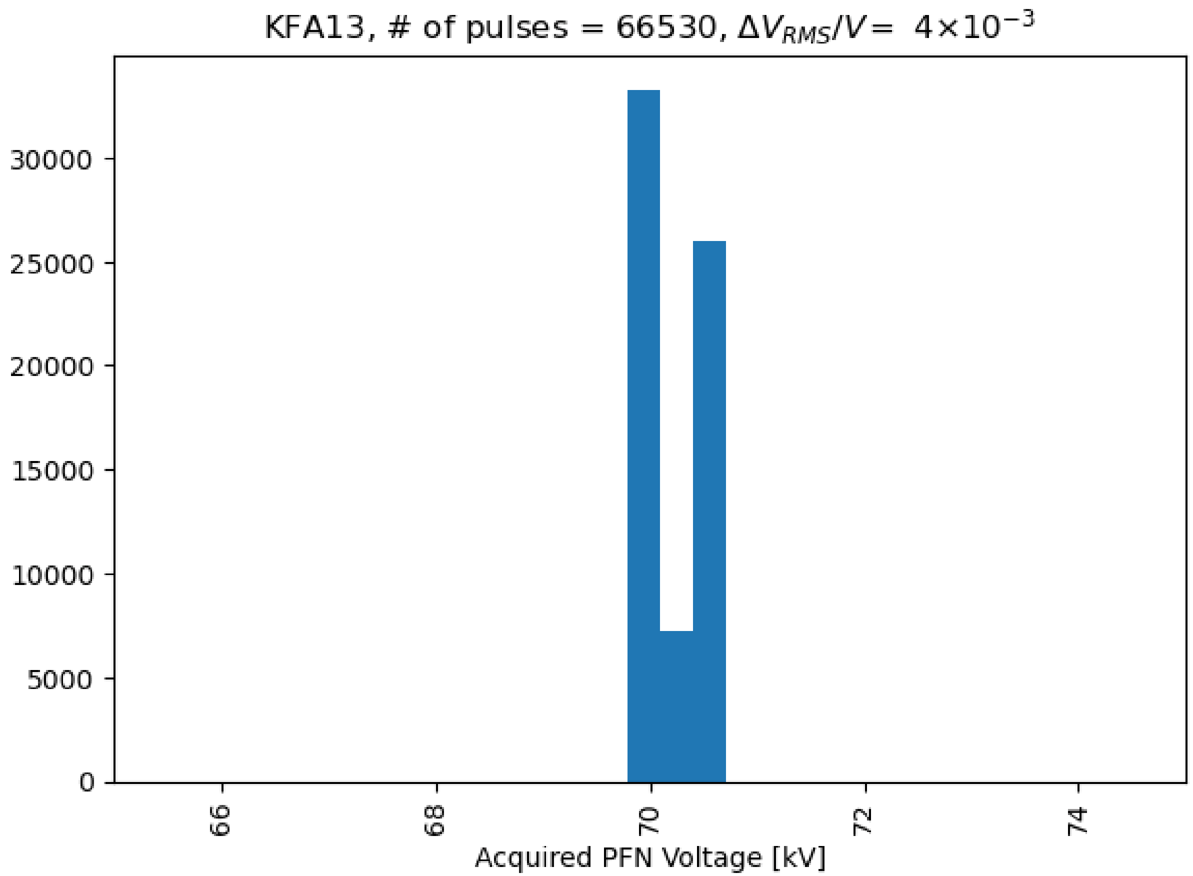
2023 intensity per day

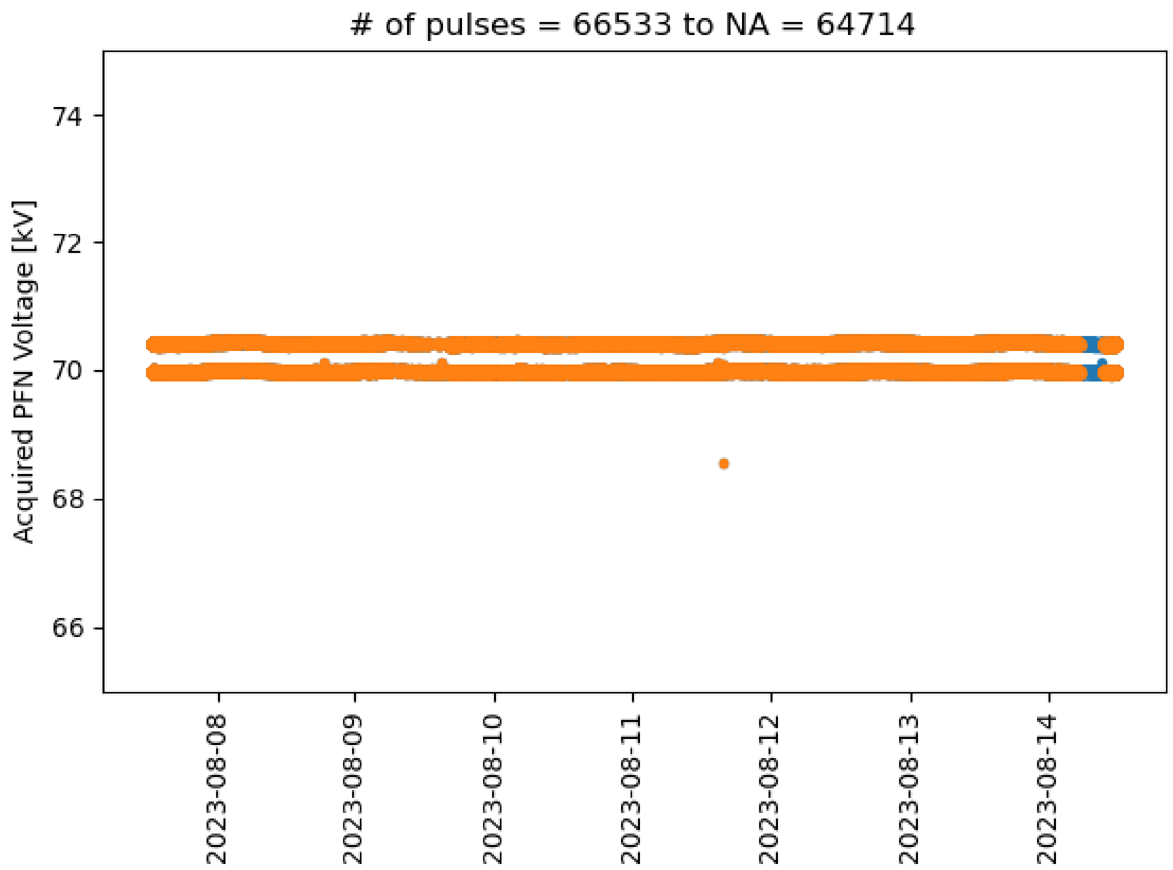


SFTPRO PSB-PS over the year



Voltage acquisition of KFA13



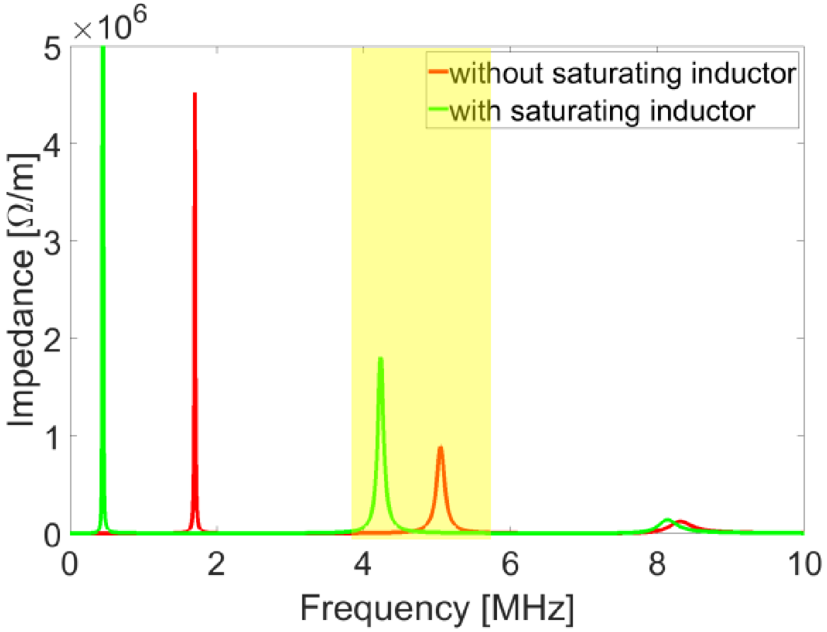


- Two data series correspond to first and second extractions from the PS
- Caused by the two different capacitor banks charging the same PFL.

PSB instability at 1.6 GeV

Expectations from the model: could we cure the instability?

The impedance can be significantly modified inserting a saturating inductor in the kicker circuit (between the kicker and the transmission lines) as proposed by M. Barnes



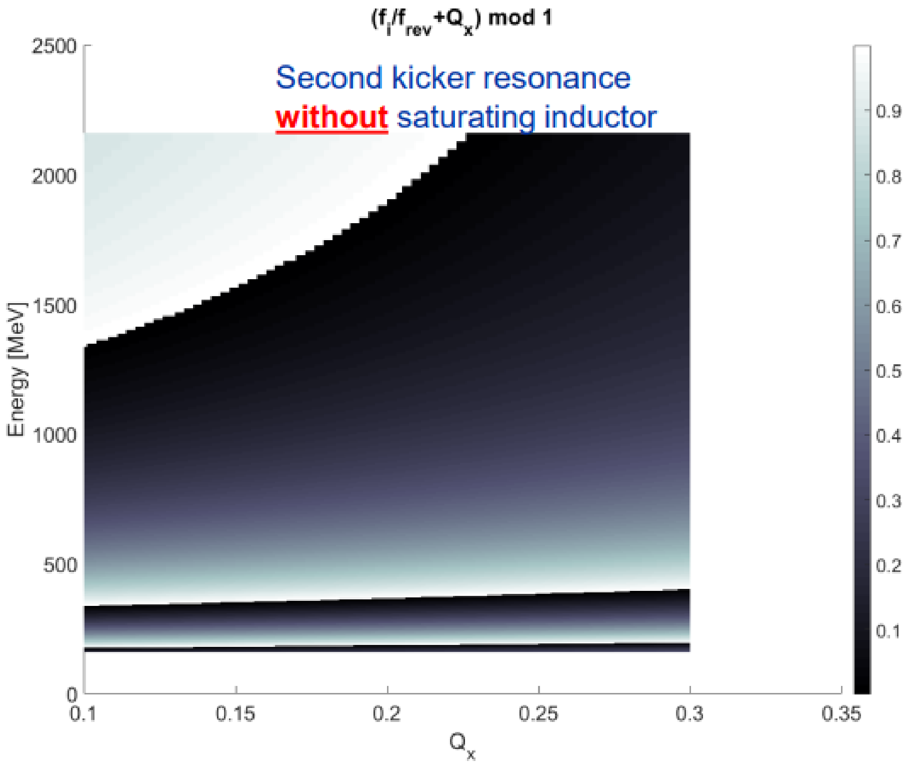
Case study investigated for the suppression of the 160 MeV instability

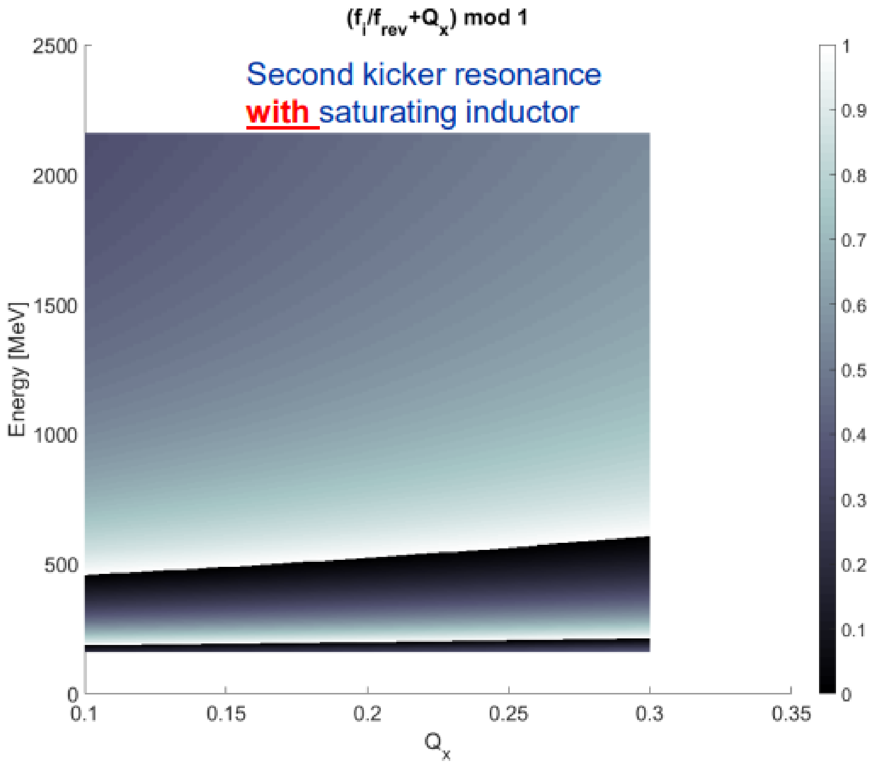
CEI section meeting 11/16/2023 21

[C. Antuono et al., CEI section meeting 16/11/23]

PSB instability at 1.6 GeV

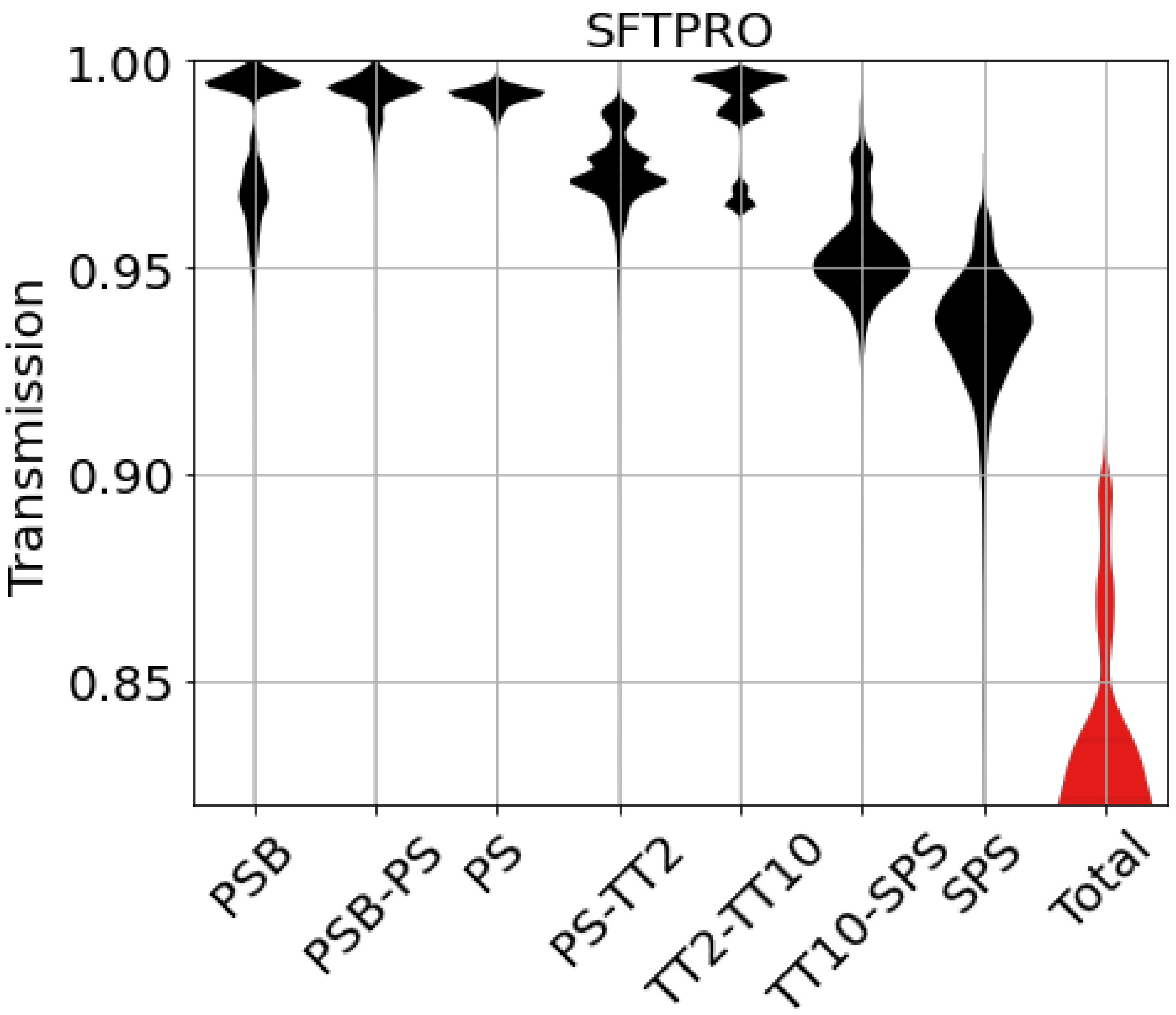
- The instability at 1.6 GeV disappears with the saturating inductor



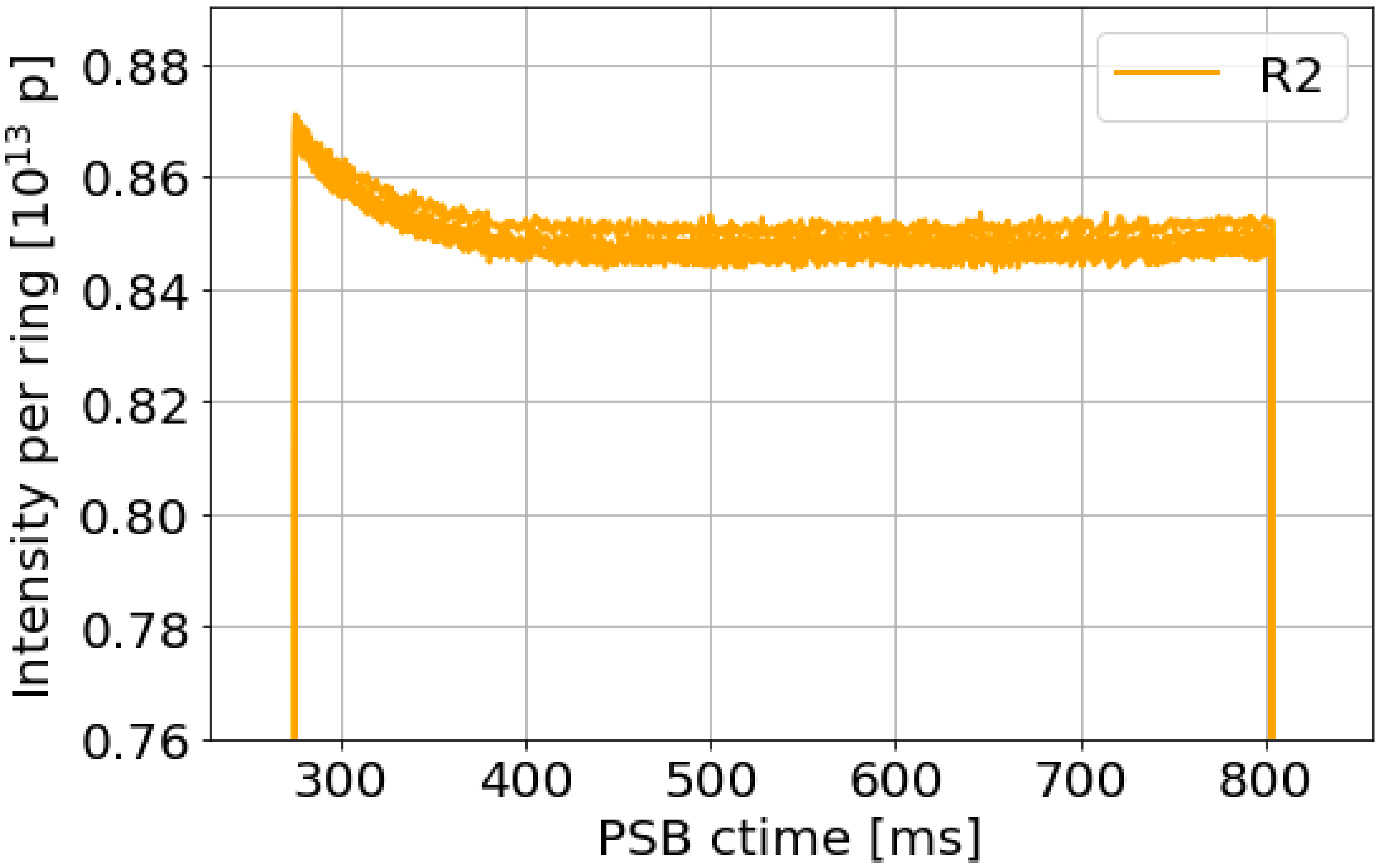


C. Antuono et al., CEI section meeting 16/11/23

SFTPRO transmission in 2022

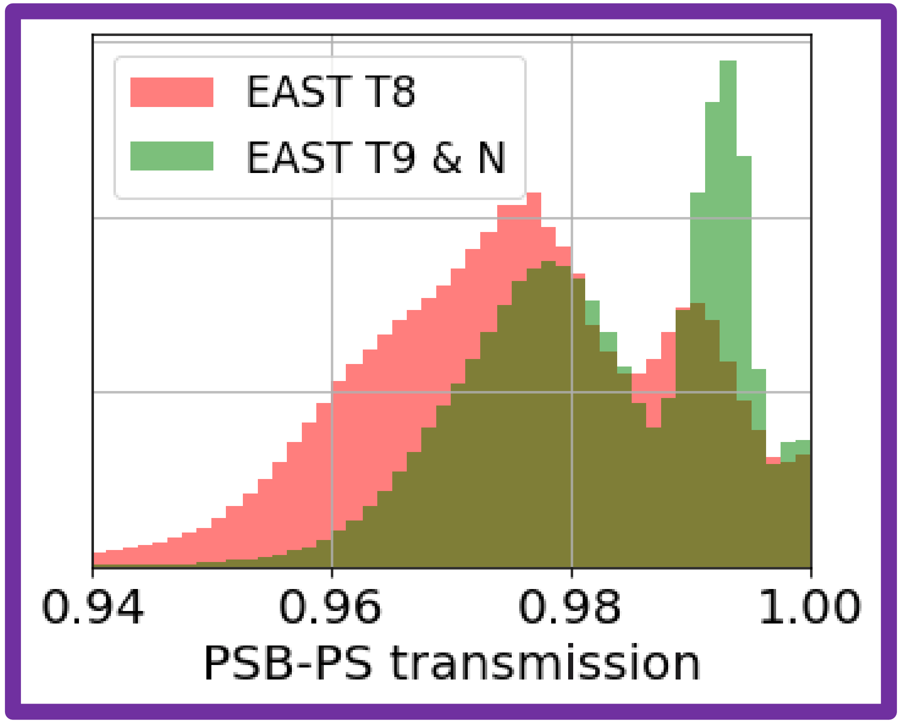


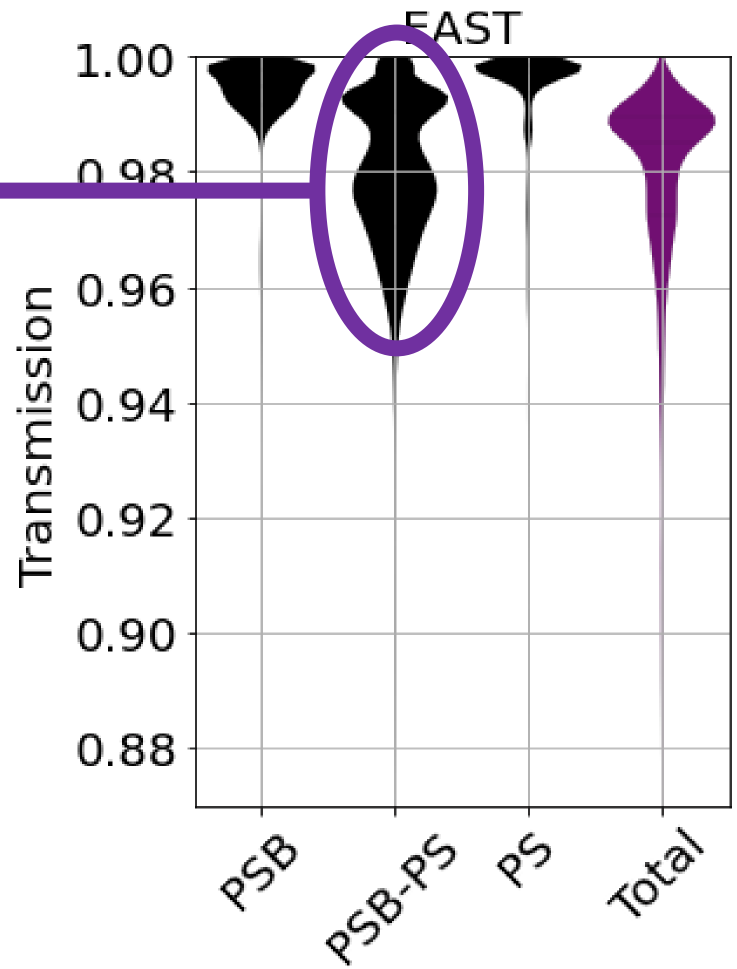
TOF



- Loss mostly at the beginning of cycle (high space charge).
- Still **~98% transmission** in PSB.
- New instability observed at ~1.7GeV that TFB cannot cure.
- Instability currently mitigated by **approaching coupling resonance**.

EAST





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