Beam loss and transmission along the chain

Joint Accelerator Facility Performance Workshop – 07-12-2022

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G. Papotti, R. Piandani, the Operations Team, SY-RF-FB and SY-STI-BMI

Outline

Brief overview of transmission of beams along the chain

Lower transmission for fixed target beam

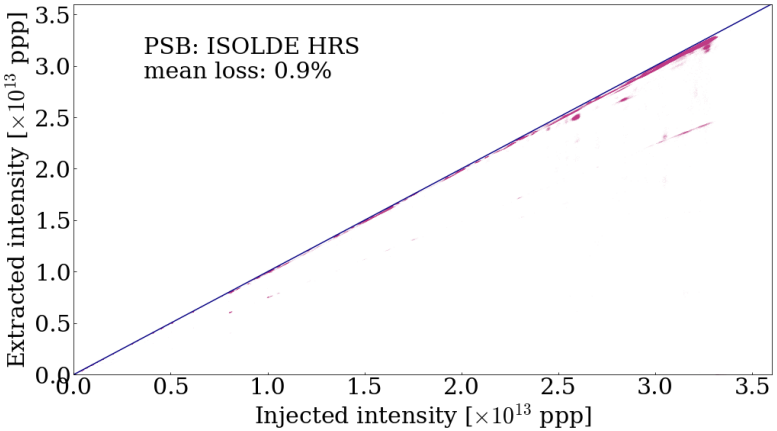
Losses with barrier buckets in the PS

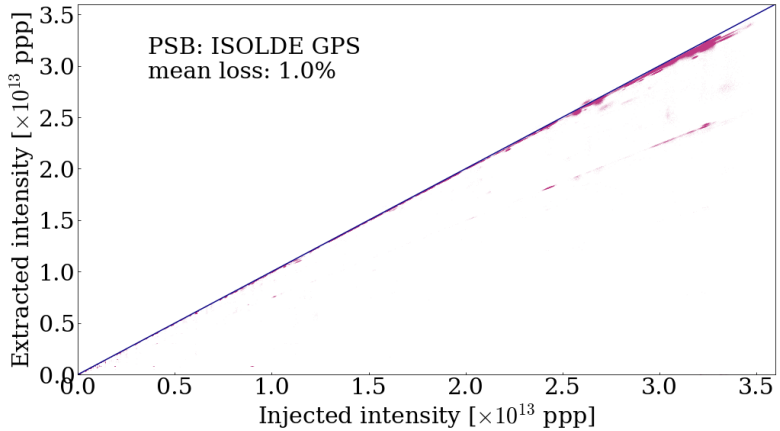
Outlook for losses further down the chain

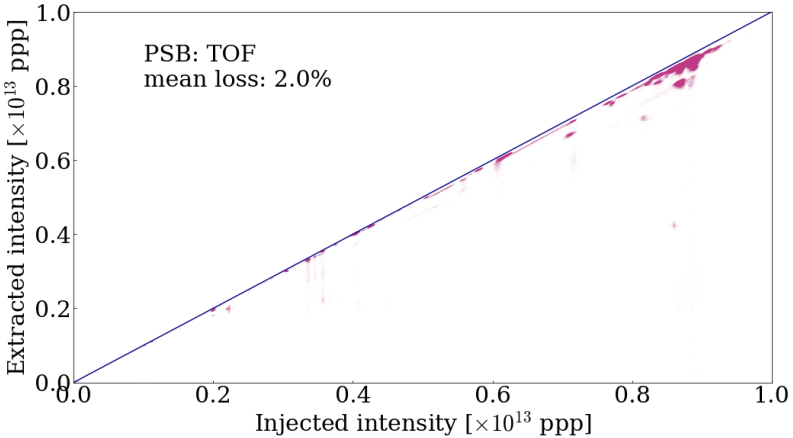
Operational aspects of barrier buckets

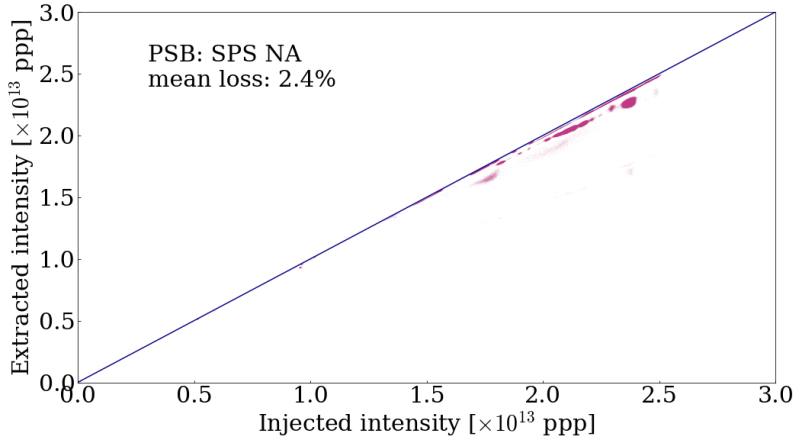
Conclusion

Extracted vs injected intensity in the PSB – all 2022







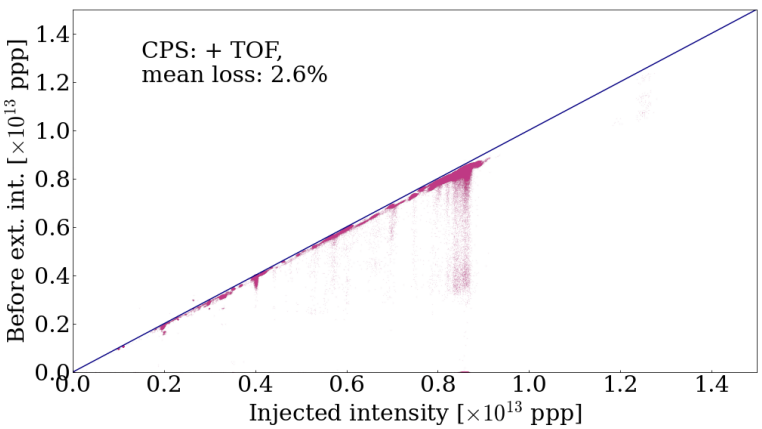


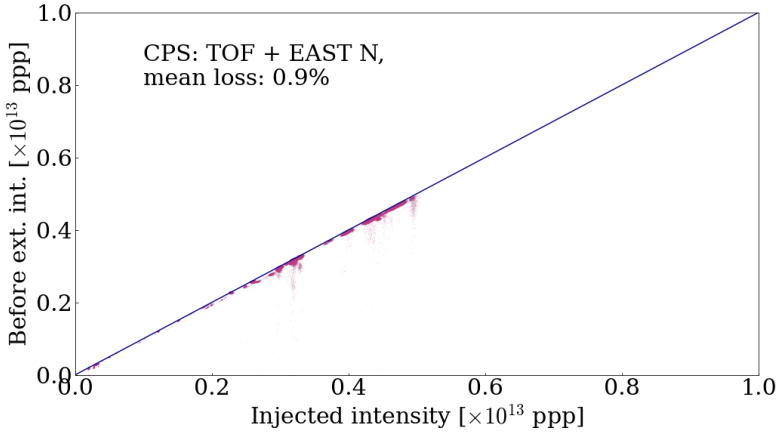
Cycle	Played
ISOLDE	3.6 M
TOF	2.5 M
SPS NA	1.1 M

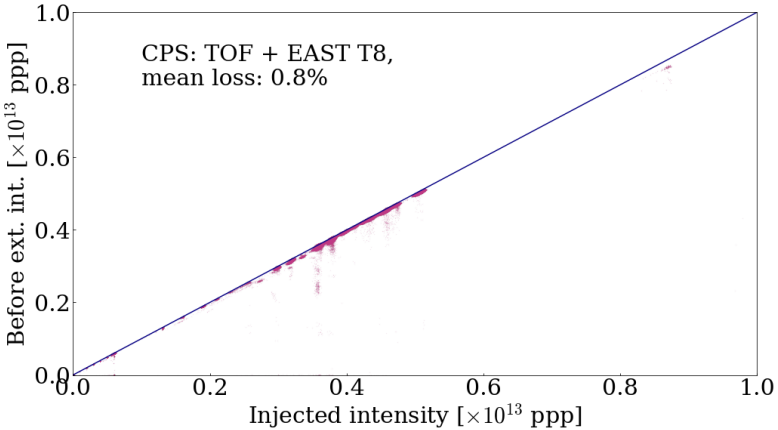
Good transmission in PSB

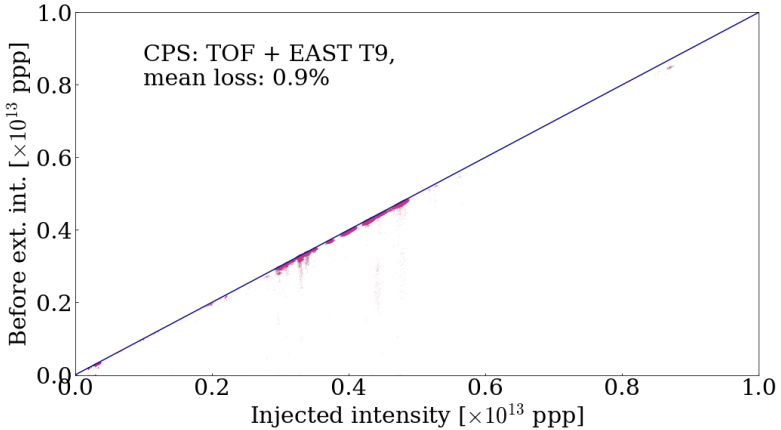
with some losses at higher intensities

Extracted vs injected intensity in the PS – all 2022





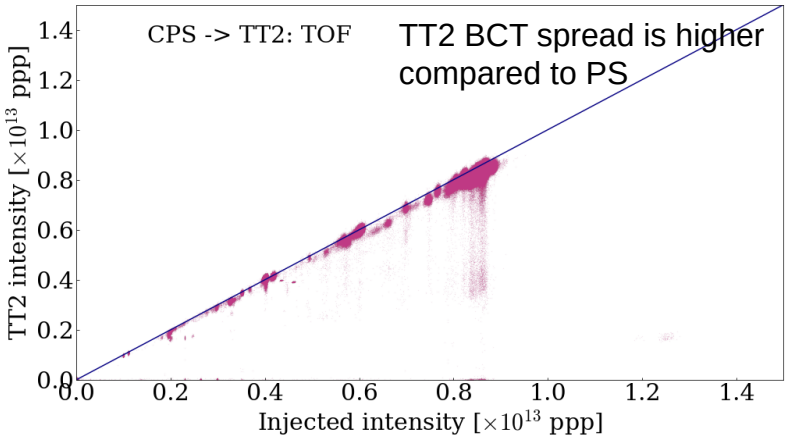


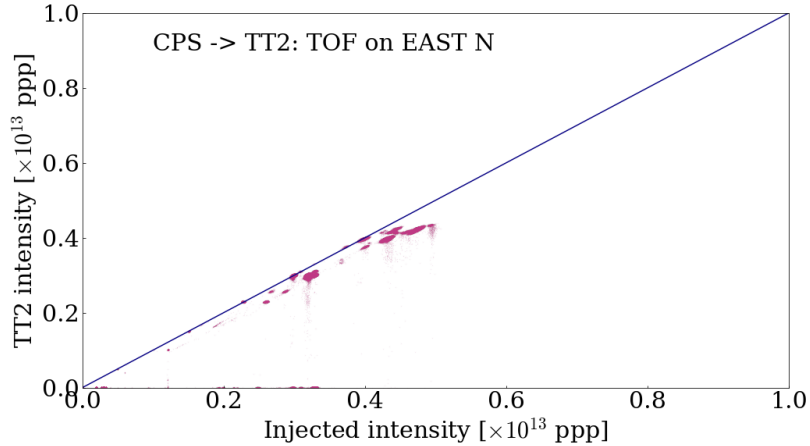


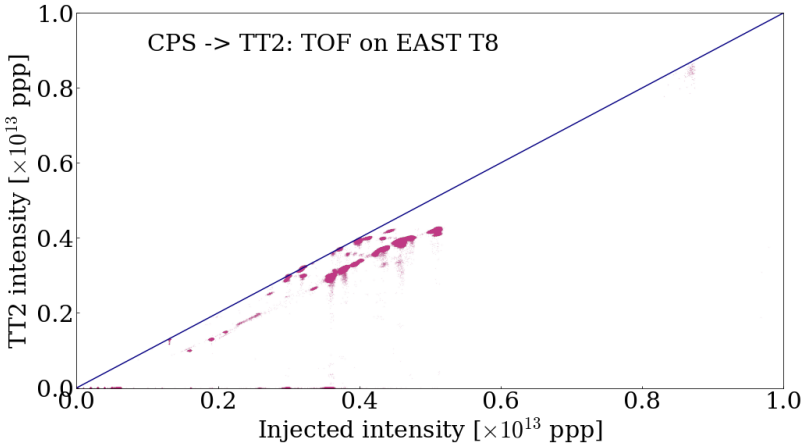
Cycle	Played
TOF	2.5 M
EAST	2.5 M
SPS NA	1.1 M

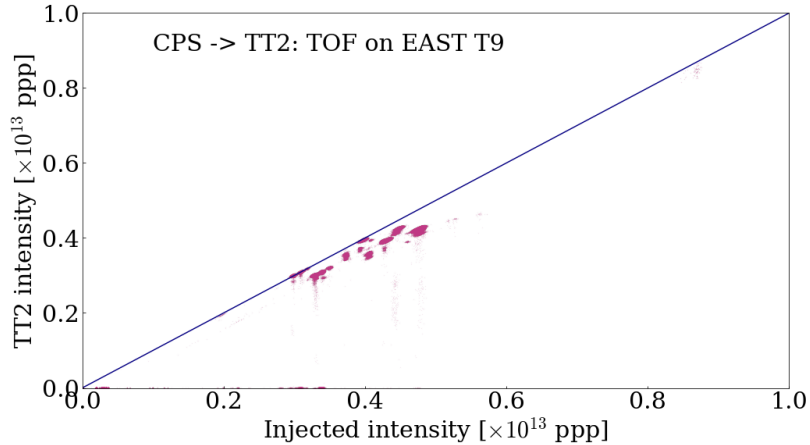
Good transmission for EAST and TOF in the PS with some losses at higher intensities for TOF.

Extracted vs injected intensity in the PS vs TT2







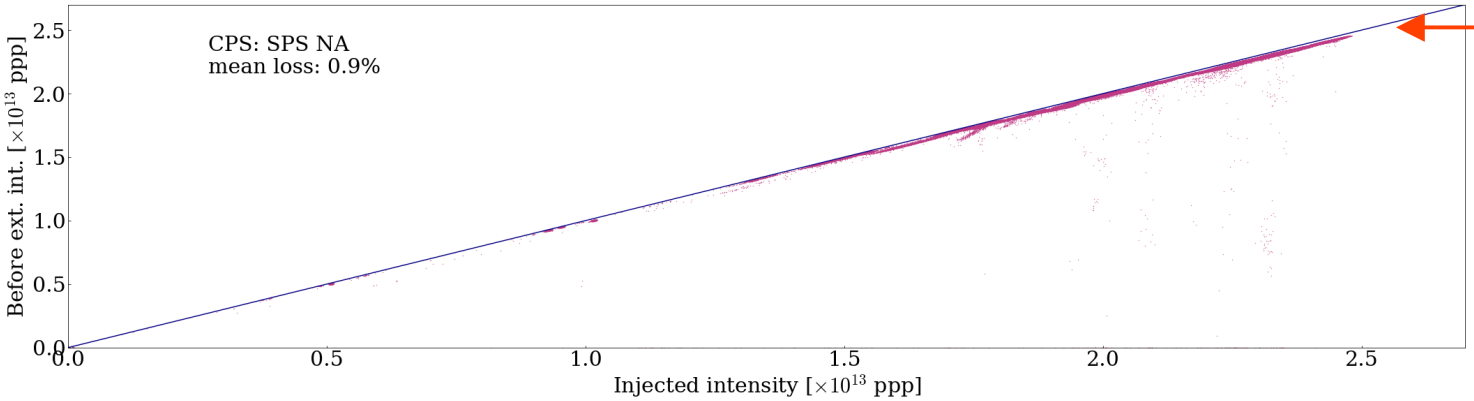


Cycle	Played
TOF	2.5 M
EAST	2.5 M
SPS NA	1.1 M

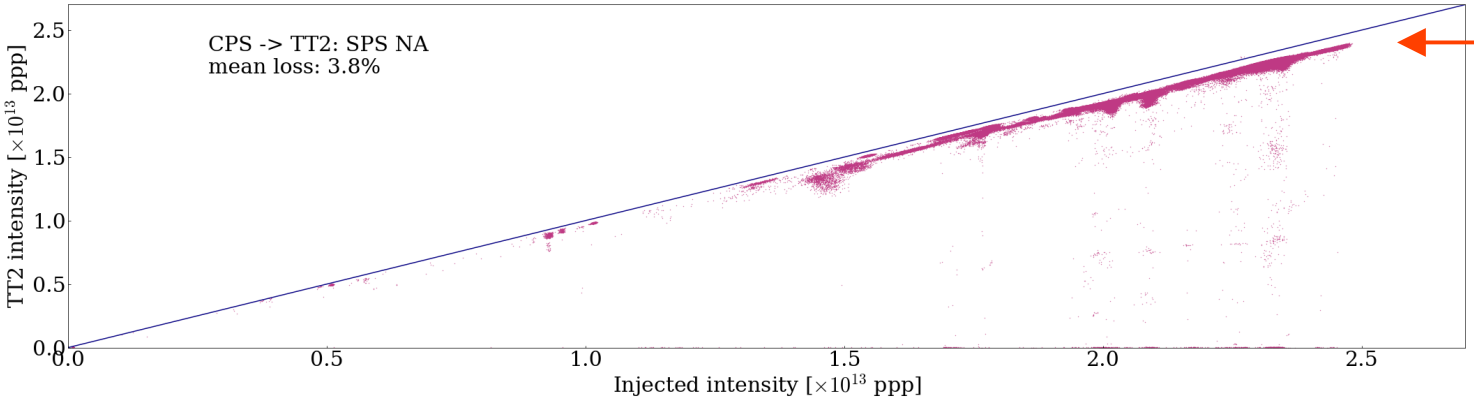
TOF extracted within an EAST cycle

Intensity in TT2 is lower, because a smaller, but not negligible intensity stays in the ring for the EAST targets

Extracted vs injected intensity in the PS and TT2 for SFT – 2022



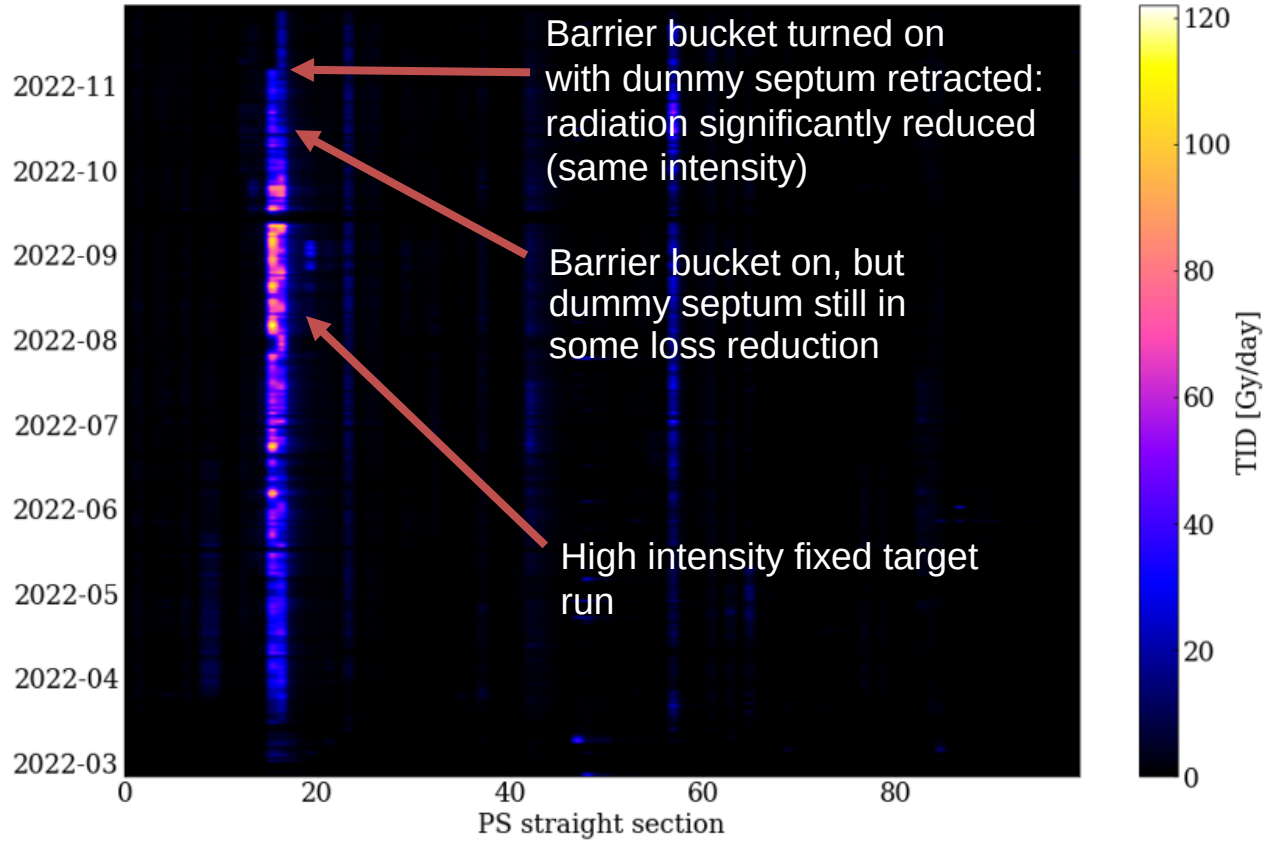
Good transmission in PS



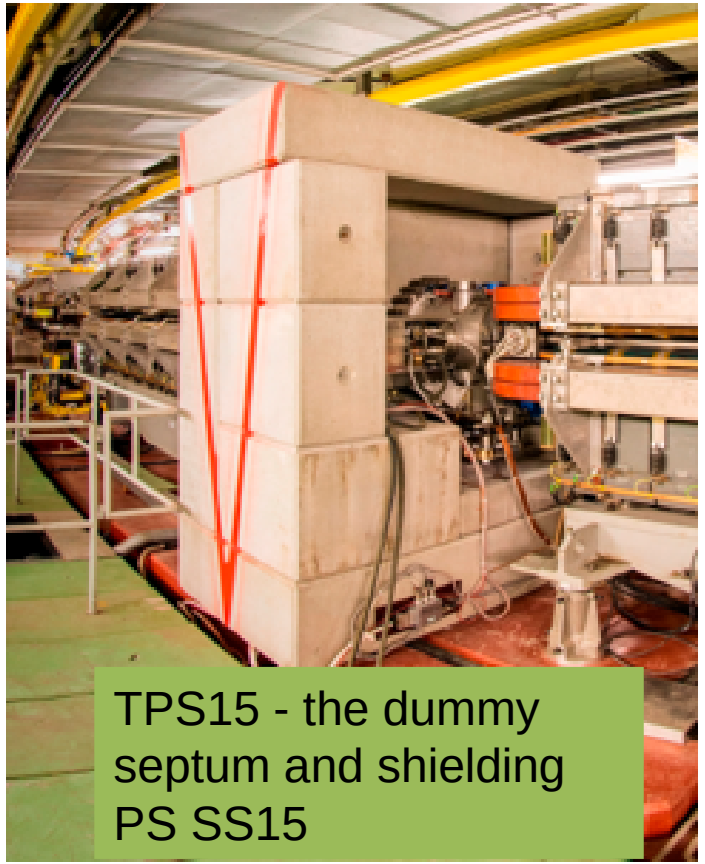
Systematically lower transmission in TT2 across all intensities

Suggesting non-intensity dependent losses

PS irradiation – mostly concentrated at extraction to TT2



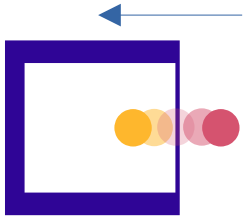
BLM data re-plotted from: https://r2e-monitoring.web.cern.ch/
Background on data taking: K. Biłko, R. García Alía, J.B. Potoine: Automated Analysis of the Prompt Radiation Levels in the CERN Accelerator Complex https://doi.org/10.18429/JACoW-IPAC2022-MOPOMS043



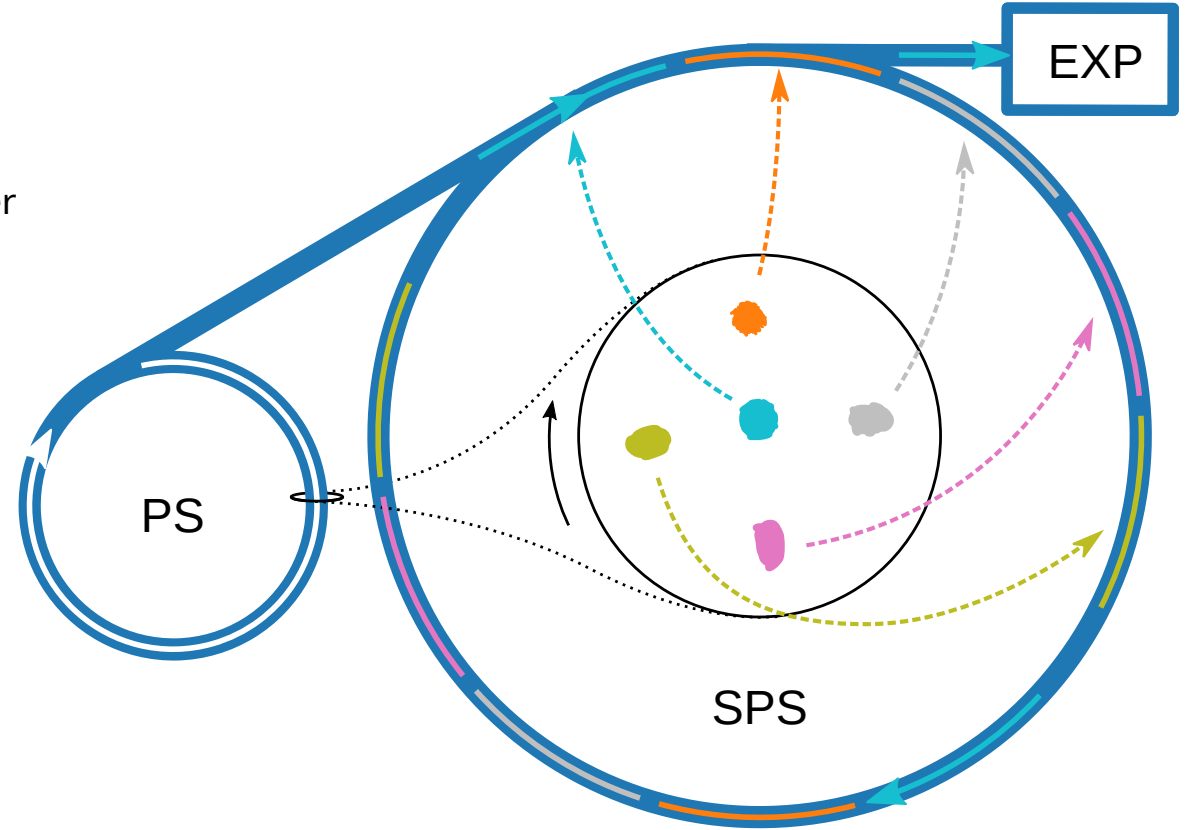
Picture: Maximilien Chefdeville & Simon Mataguez
https://psring.web.cern.ch/psring/pictures/big/ss15e-a.jpg

Extraction in the PS and loss mechanism

- Beam loss reduction at 5 turn extraction of a coasting beam
- Losses occur during the rise time of the kicker on the dummy septum



- Making a longitudinal gap in the beam during kicker rise time with a barrier bucket reduces losses:
  https://iopscience.iop.org/article/10.1209/0295-5075/128/14002
- RF needs to be synchronous with SPS



Wide-band RF needed to make a gap

RF waveform and longitudinal phase space

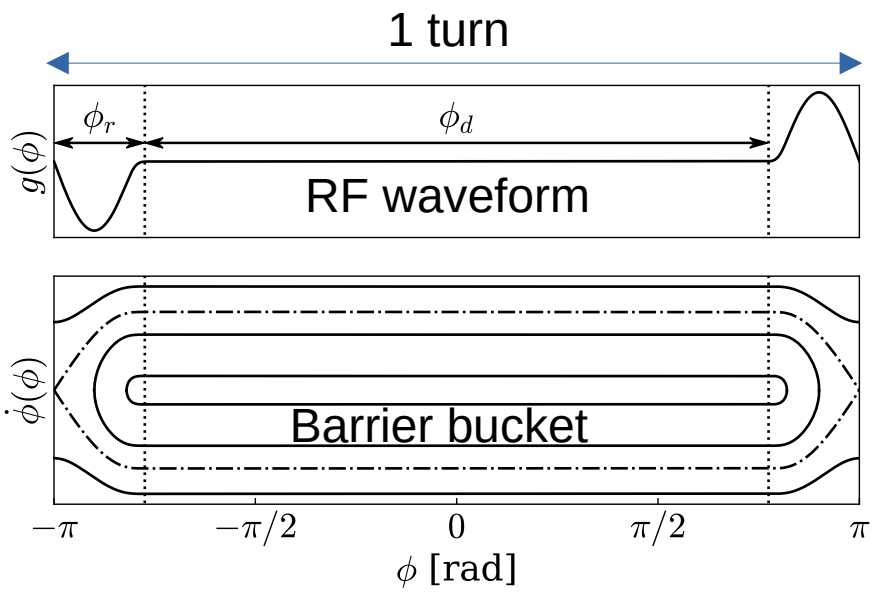


Diagram from M. Vadai et. al. Barrier bucket gymnastics and transversely split proton beams: Performance at the CERN Proton and Super Proton Synchrotrons (CC-BY 4.0)
https://link.aps.org/doi/10.1103/PhysRevAccelBeams.25.050101

Finemet wideband cavity in PS is suitable to try this scheme

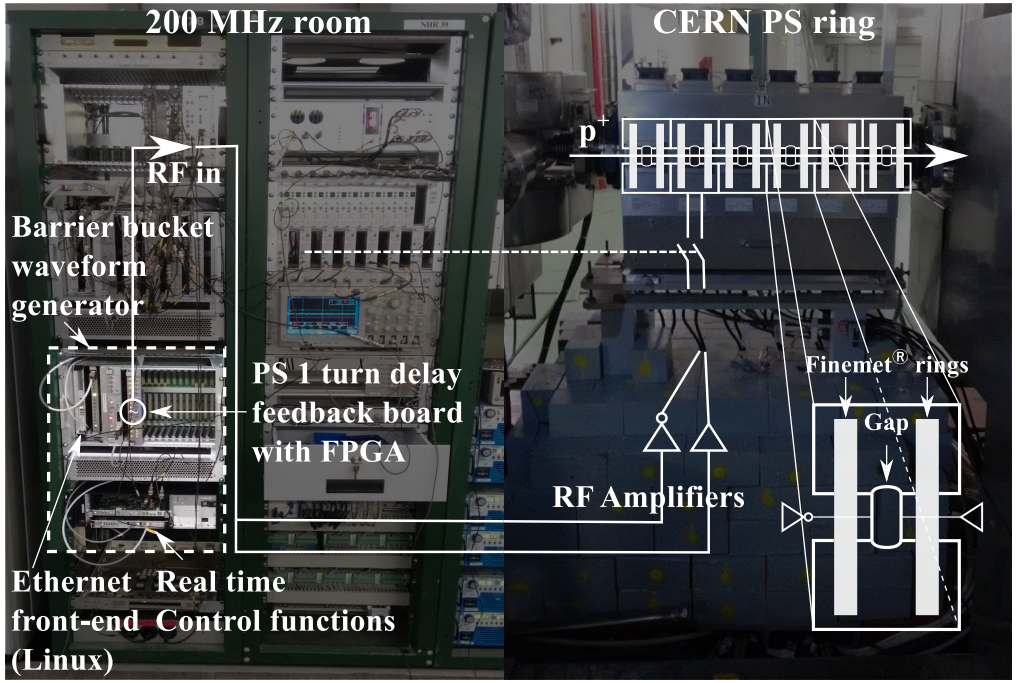


Diagram from M. Vadai, A. Alomainy, H. Damerau: Barrier Bucket Studies in the CERN PS (CC-BY 3.0)
https://doi.org/10.18429/JACoW-IPAC2019-MOPTS106

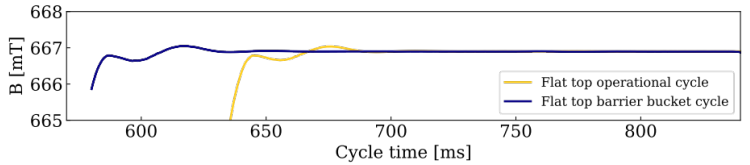
Synchronisation concept

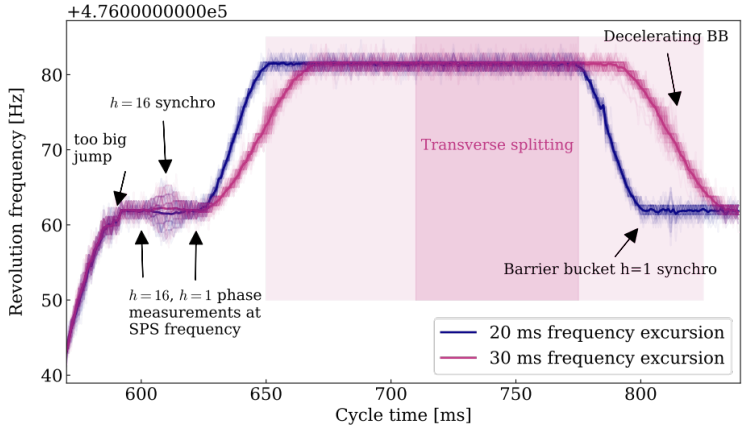
Conventional synchronisation not possible:

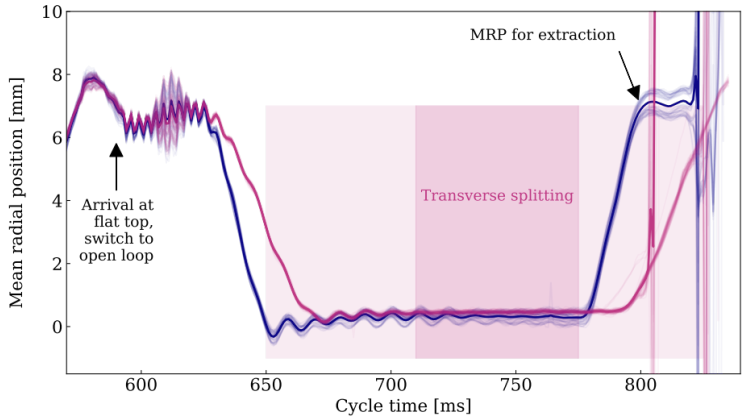
- lower RF voltage on flat top due to transverse splitting requirements

New synchro concept was designed and tested with beam – time saving in the cycle

- lower accuracy sufficient for barrier buckets
- synchronising in *h*=16 using feed-forward cogging
- setting the mean radial position for MTE and SPS extraction via phase controlled RF frequency program
- predicting the *h*=1 azimuth position







M. Vadai, H. Damerau, M. Giovannozzi, A. Huschauer, A. Lasheen: IMPLEMENTATION OF SYNCHRONISED PS-SPS TRANSFER WITH BARRIER BUCKET (CC-BY 4.0)
https://arxiv.org/abs/2210.05416

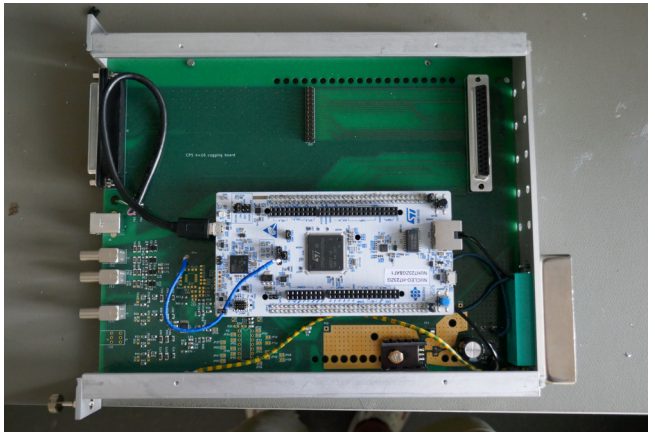
New RF hardware demonstrator boards

Modified the clock distribution of the PS beam control for synchronisation

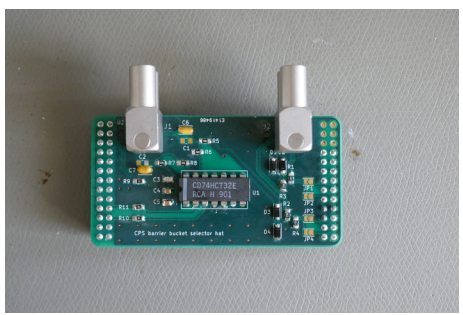
Embedded controller generates SPS synchronous RF frequency programs in real-time in the PS

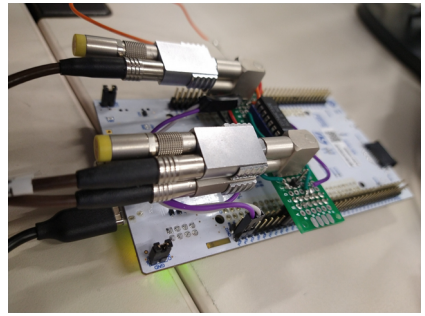
h=1 synchronisation: phase measurement and communicating phase information within a cycle to set the correct barrier position

Synchronisation related hardware consists of rapid prototypes → technical demonstrator boards only



h=16 synchro board





h=1 phase measurement hardware

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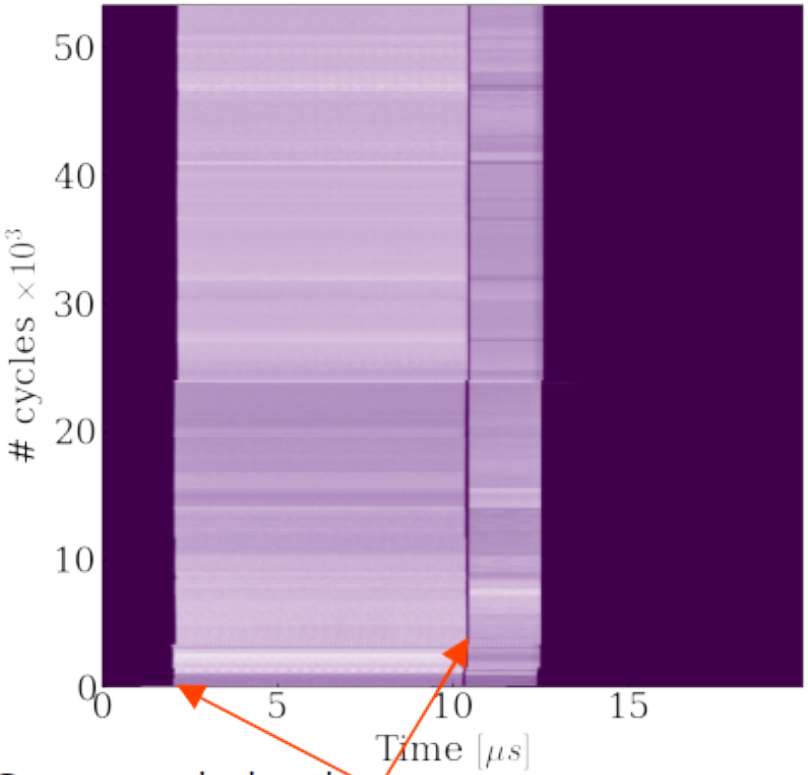
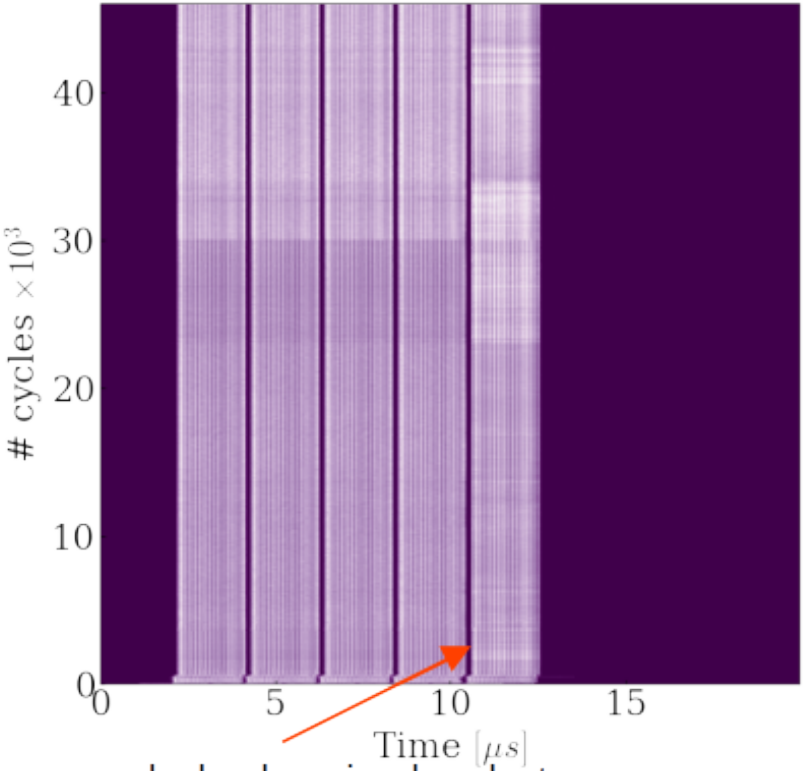
5 PS turn longitudinal profiles in TT2

Barrier off



Gaps made by the extraction kickers → beam loss

Synchronous barrier

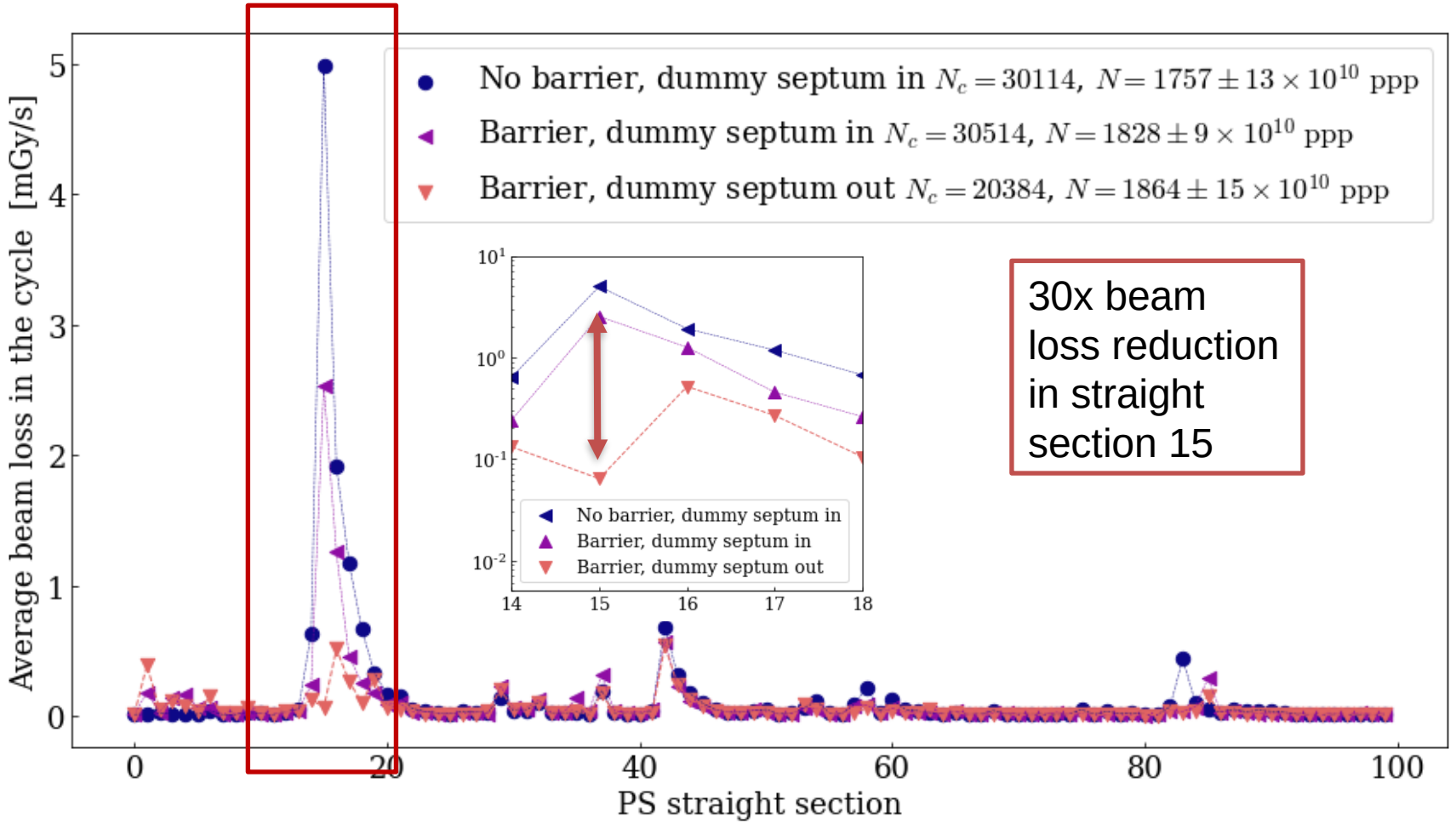


Gaps made by barrier buckets → beam loss significantly reduced

Beam loss reduction by barrier buckets during the pilot run

80k cycles in total

1.8 x 10^{13} ppp intensity



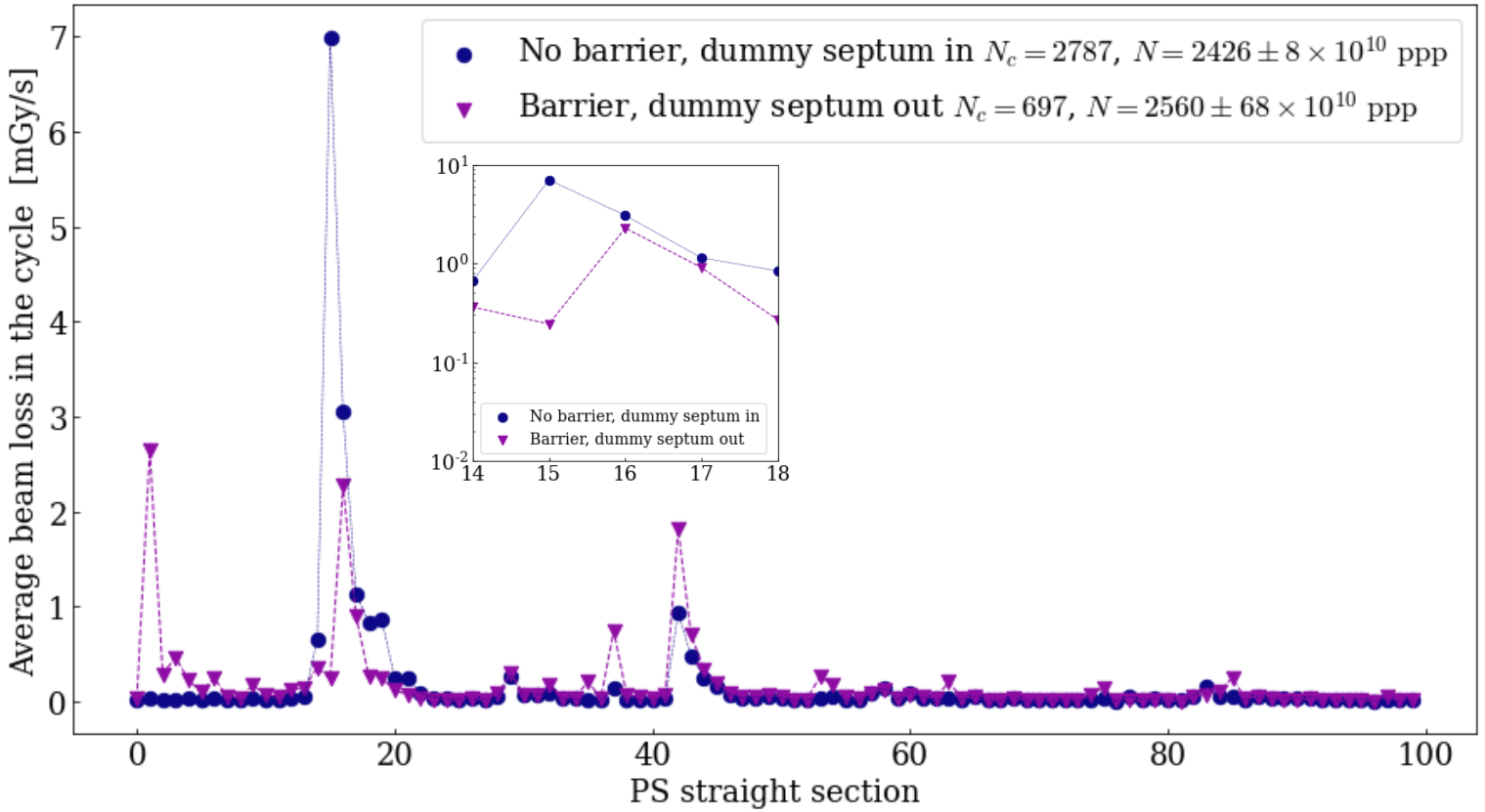
Barrier bucket at highest intensities (MD)

Barrier bucket MD at 2.5-2.6 x 10^{13} ppp

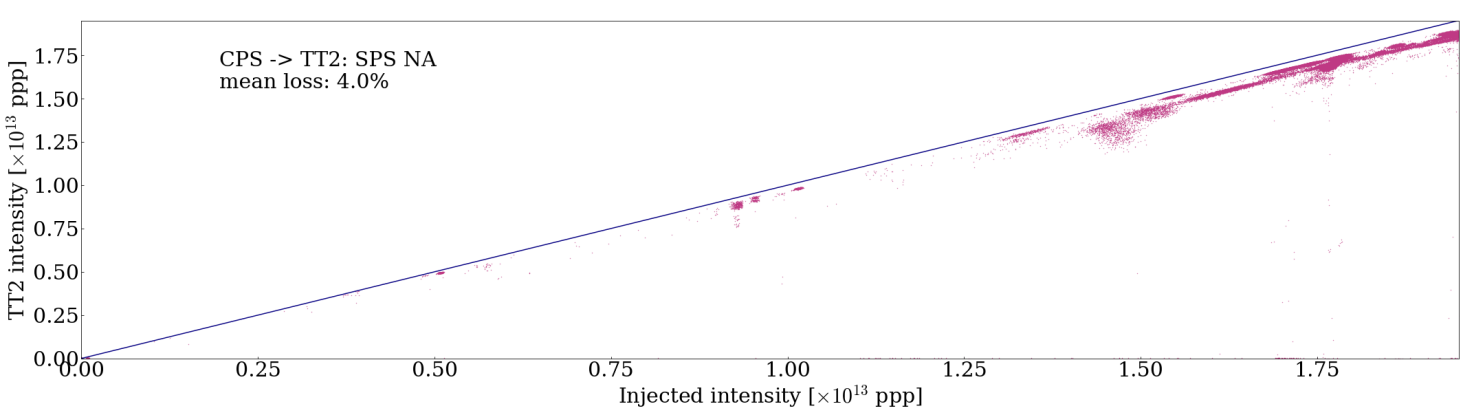
Highest intensity SFTPRO operational beams in 2022 at 2.4-2.5 x 10^{13} ppp

No blocking longitudinal instability at flat-top → losses at injection and at transition

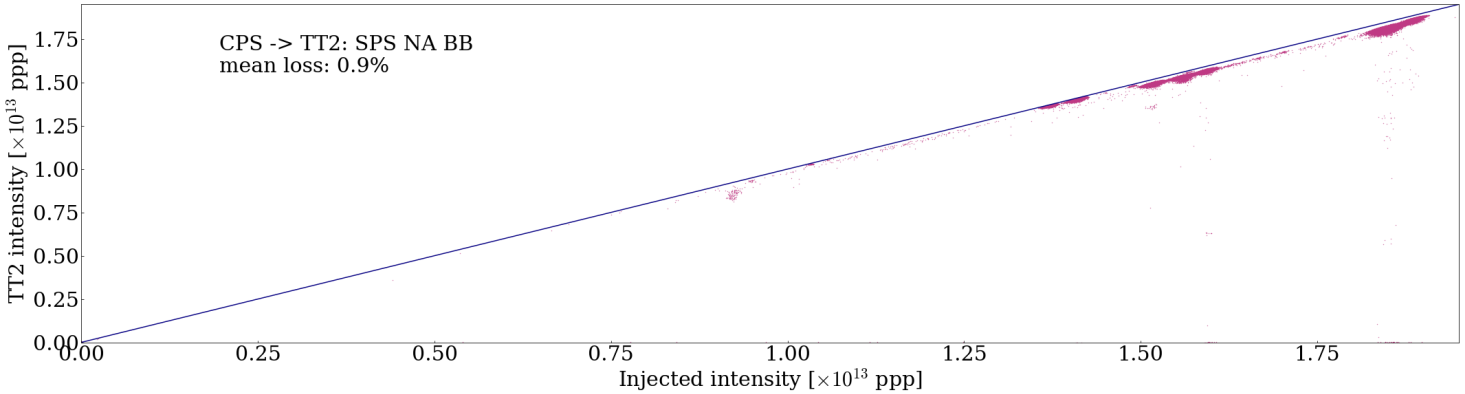
High intensity cycle needs work, but there is no showstopper



Extracted vs injected intensity in the PS and TT2 for standard SFTPRO and barrier bucket pilot

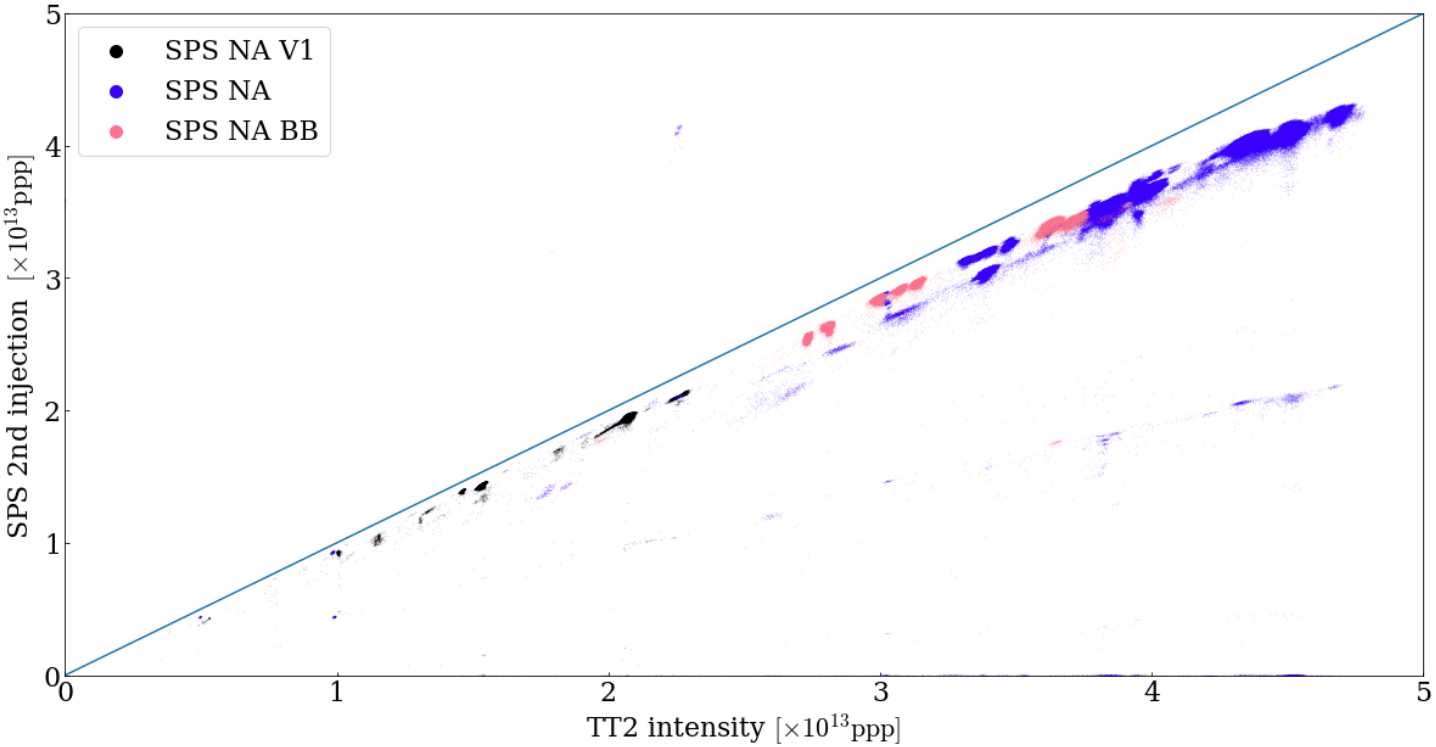


Transmission without barrier bucket (all year)



Improved transmission with barrier bucket with dummy septum out

What about TT2 to SPS?



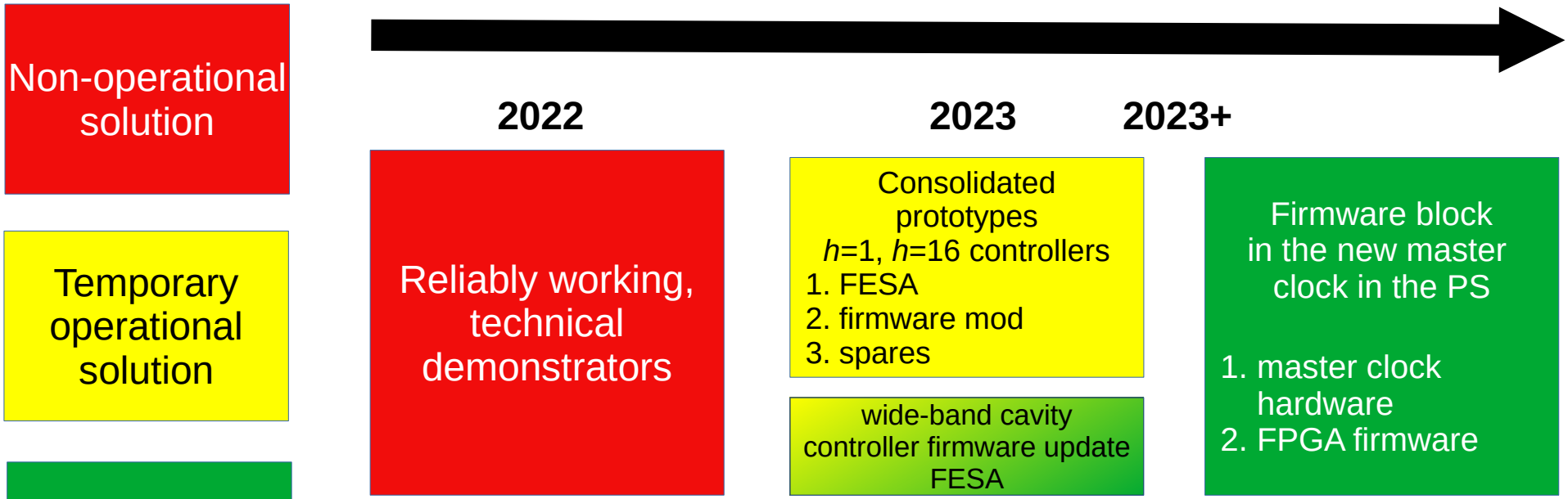
- 1.1M PS cycles without BB
- 200k PS cycles with BB

- Bad news: losses seem to exist from TT2 to SPS injection 5-10% intensity dependent

- Good news:
  - barrier bucket has similar losses as nominal
  - **gains in PS are passed on** as TT2 is now the reference

- SPS injected intensity is taken from the BCT after 2nd injection.
- The intensity that is accelerated in the SPS
- Weights 1st and 2nd injection differently

Next steps for operational barrier buckets



- Temporary solution can not be maintained permanently
- Requires resources for final implementation

Conclusion

Transmission:

- Transmission per accelerator is good slightly decreasing with intensity
- Losses seem to occur between accelerators e.g. between PS and SPS

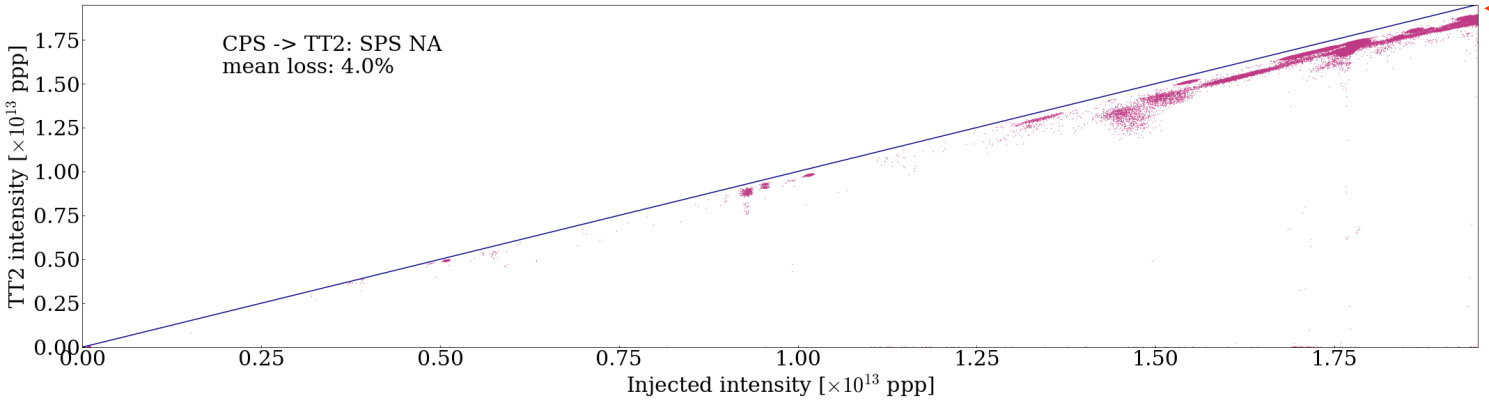
Barrier bucket beam loss mitigation technical demonstration successful:

- Beam reliably delivered to NA experiments during pilot run
- Barrier buckets can cover entire intensity range of present SFTPRO beam
- Important radiation at hot spot (SS15) significantly reduced in the PS
  → dummy septum becomes redundant

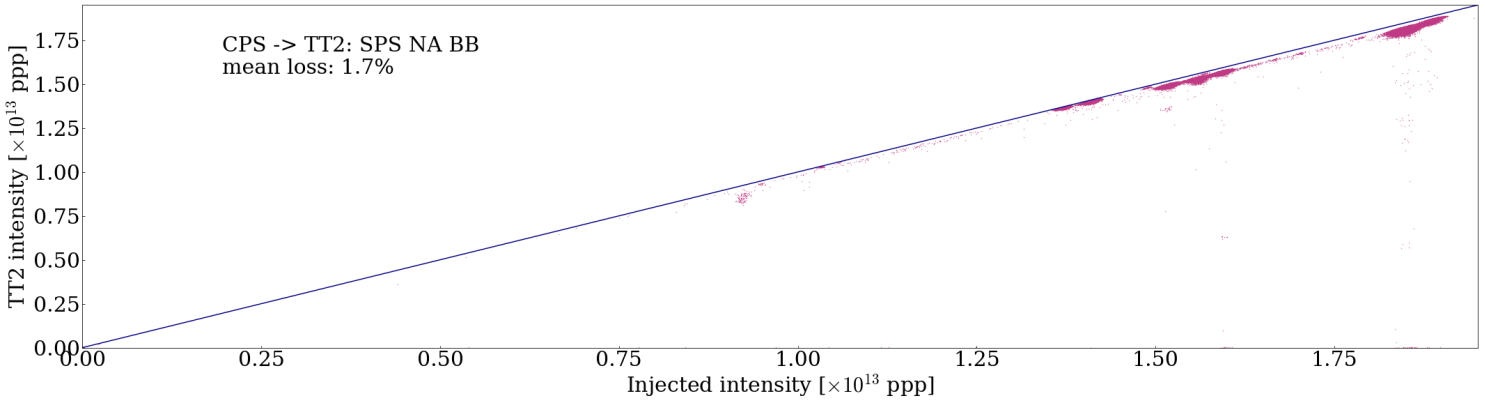
Investigate important losses between TT2 and SPS → PS2SPS

Spares

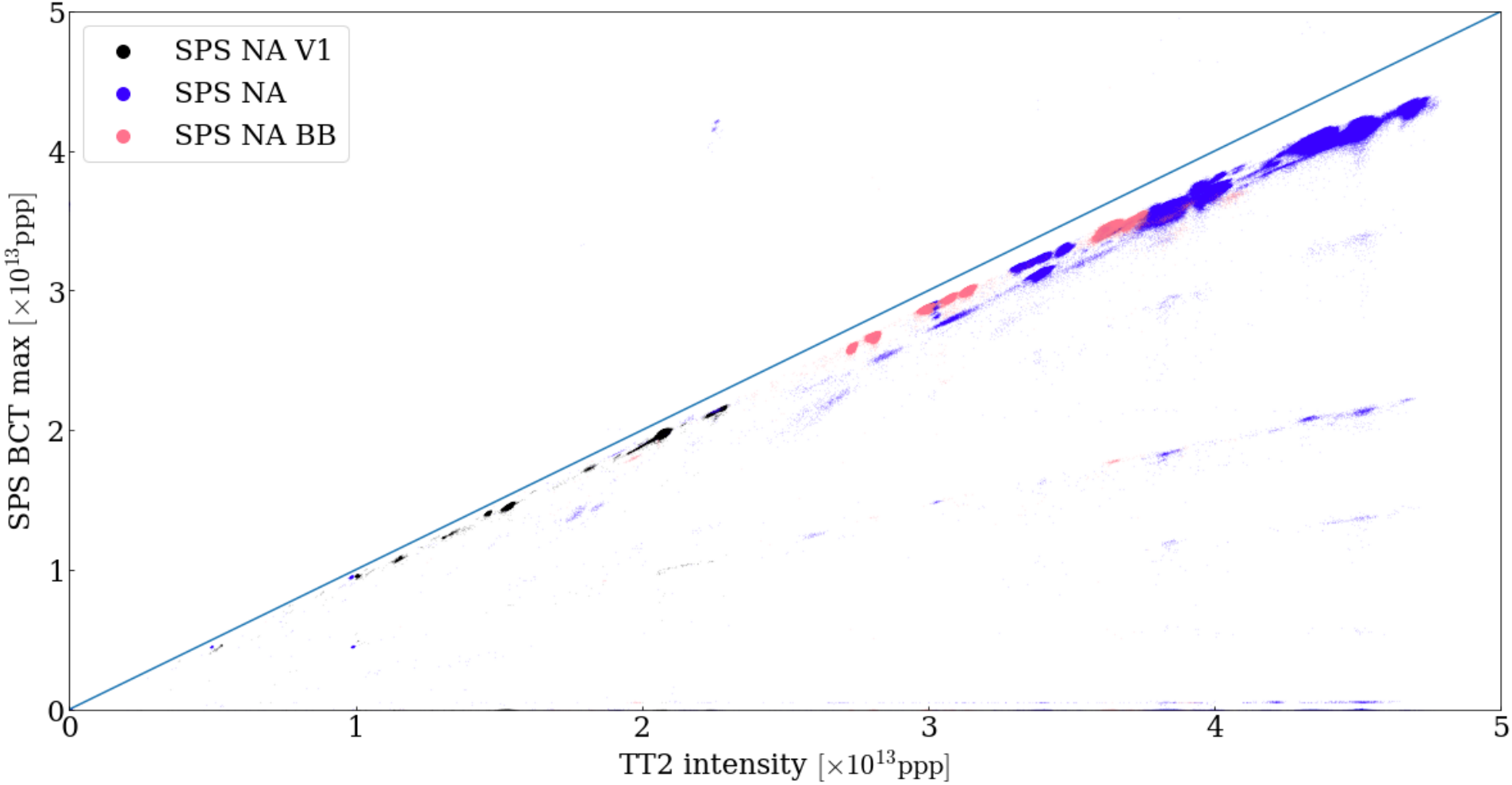
Extracted vs injected intensity in the PS and TT2 for standard SFTPRO and barrier bucket pilot dummy septum in and out



Transmission without barrier bucket



Improved transmission with barrier bucket


SPS NA V1
SPS NA
SPS NA BB
SPS BCT max [$\times 10^{13}$ppp]
TT2 intensity [$\times 10^{13}$ppp]
0
1
2
3
4
5