



TOF & ISOLDE Beam Production and Delivery

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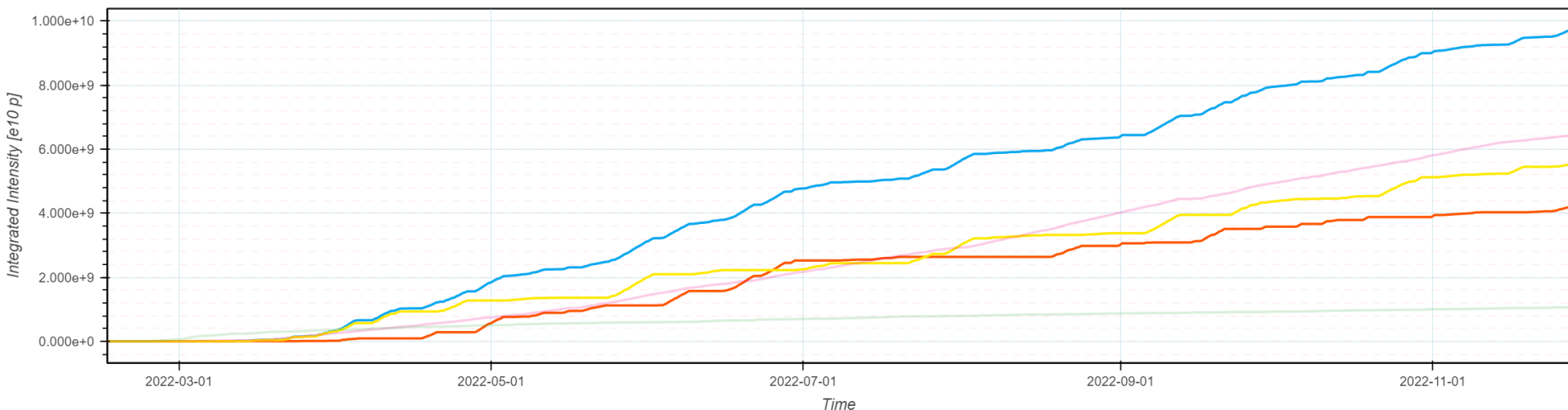
On behalf all involved and in particular BE-OP, BE-ABP, SY-RF and SY-ABT

Outline

- ISOLDE
 - Delivered intensity
 - L4 and PSB in 2022
 - Higher energy status and prospects
 - Feedback from experiments and prospect for 2023
- TOF
 - Delivered intensity
 - Intensity ramp-up
 - L4, PSB and PS in 2022
 - FTN line, hardware changes, commissioning and present reach
 - Experiment feedback and solutions
 - Prospects for 2023
- Conclusions

ISOLDE: delivered intensity

- Fast extracted beam from all PSB rings
- Largest consumer of PSB with ~ 56% of delivered protons
- Total beam delivered to ISOLDE : $9.7E19$ protons
 - 43% delivered to HRS

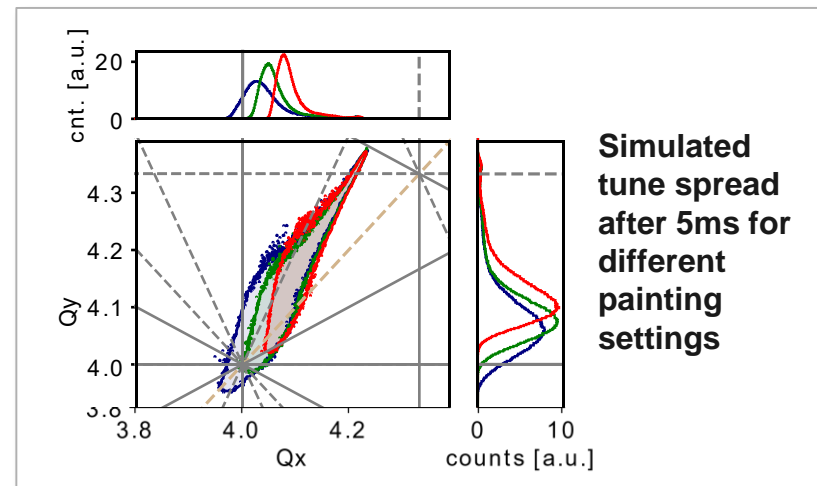
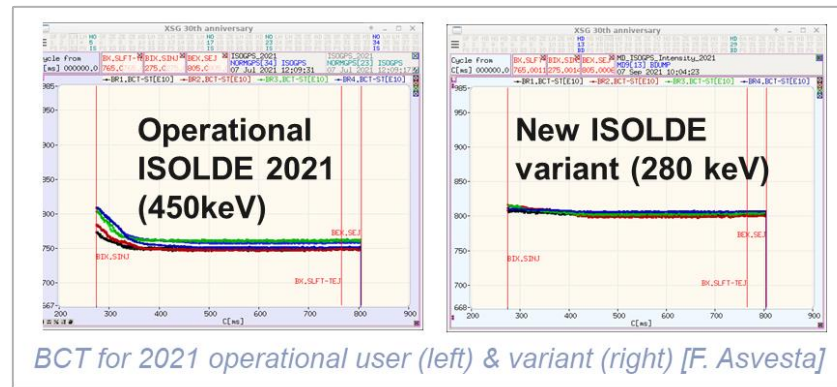


— Total to ISOLDE — ISOHRS — ISOGPS — PS — DUMP

<https://bpt.web.cern.ch/psb/YEARLY/>

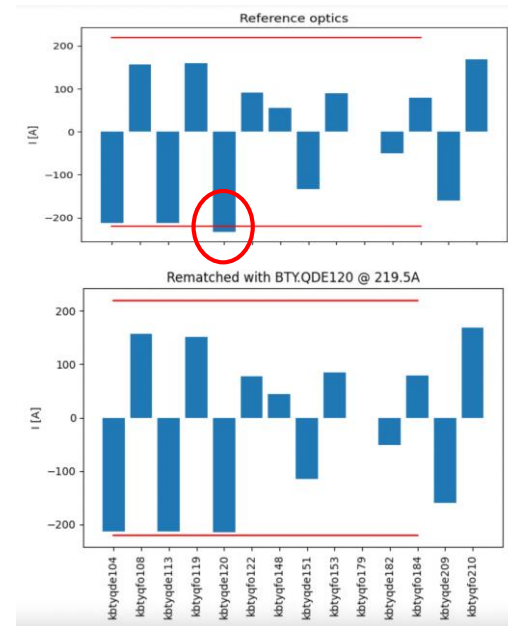
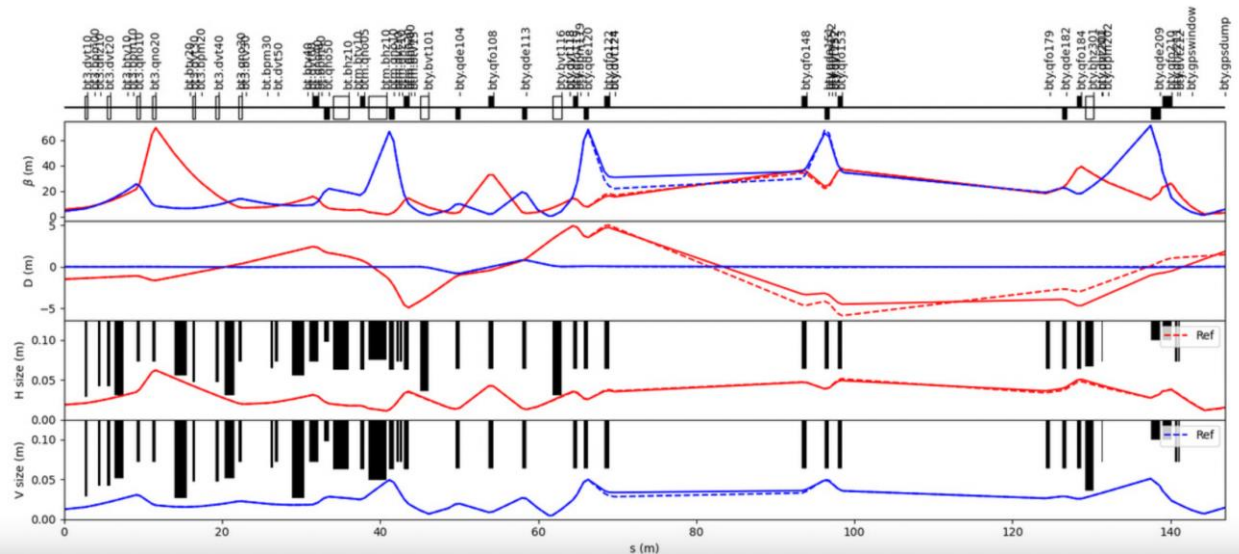
ISOLDE: L4 and PSB in 2022

- Cycle optimizations tested in 2021 and implemented since the start of 2022
 - Reduced L4 momentum spread from 450 keV RMS to 280 keV RMS
 - Optimized working point
- No major gain obtained from transverse painting optimisation
- Now typical losses ~1-2%



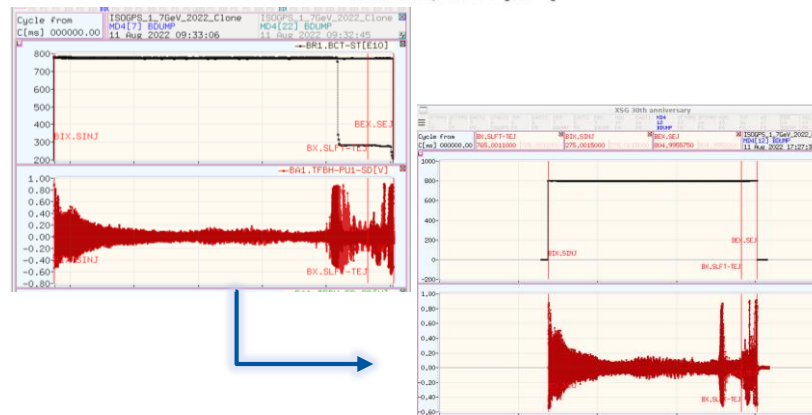
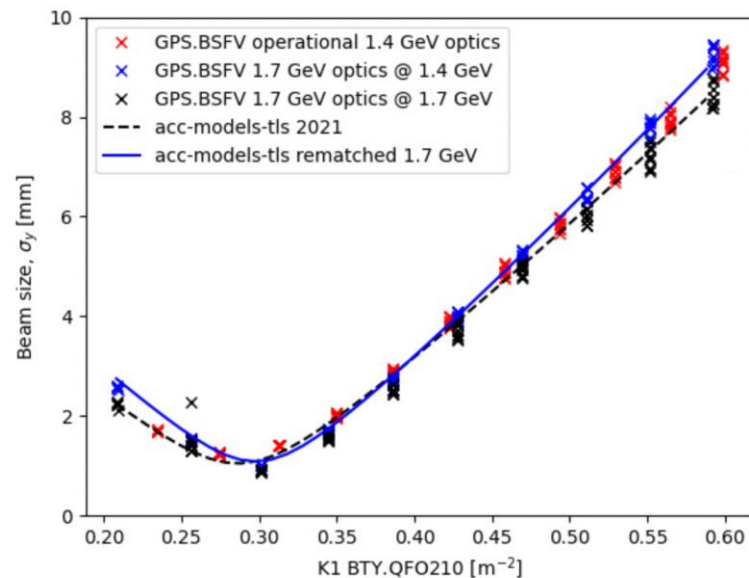
ISOLDE: higher energy

- PSB upgrade opened the path to ISOLDE beam beyond the pre-LS2 1.4GeV limit
- Limited to 1.7 GeV by power converter current in BTY vertical dipoles
- Optics rematched to keep all quadrupole settings within power converter limits for 1.7 GeV



ISOLDE: 1.7GeV operation

- Beam size upstream of GPS target measured as a function of the last gradient of the last quadrupole using a SEM grid
 - Very good agreement with the model
- Instability above 1.4GeV observed for the first time cured using linear coupling
- Operation considerations
 - Acceleration cycle adjusted similarly to TOF to overcome the high energy instability
 - Switch between 1.4 GeV and 1.7 GeV requires manual settings swaps and checks, but acceptable
- First (ever) ISOLDE run at 1.7 GeV done in August (week 32), and second run in week 41
- Operation up to 2GeV is technically possible but requires hardware changes



Mini-workshop on ISOLDE consolidation and improvement <https://indico.cern.ch/event/1208149>
L4/PSB MPC #81 <https://indico.cern.ch/event/1179484/#5-psb-status>
CERN-PBC-Notes-2022-008 <https://cds.cern.ch/record/2838061>
Status of the PSB instabilities studies, <https://indico.cern.ch/event/1179487>

ISOLDE: feedback and prospects

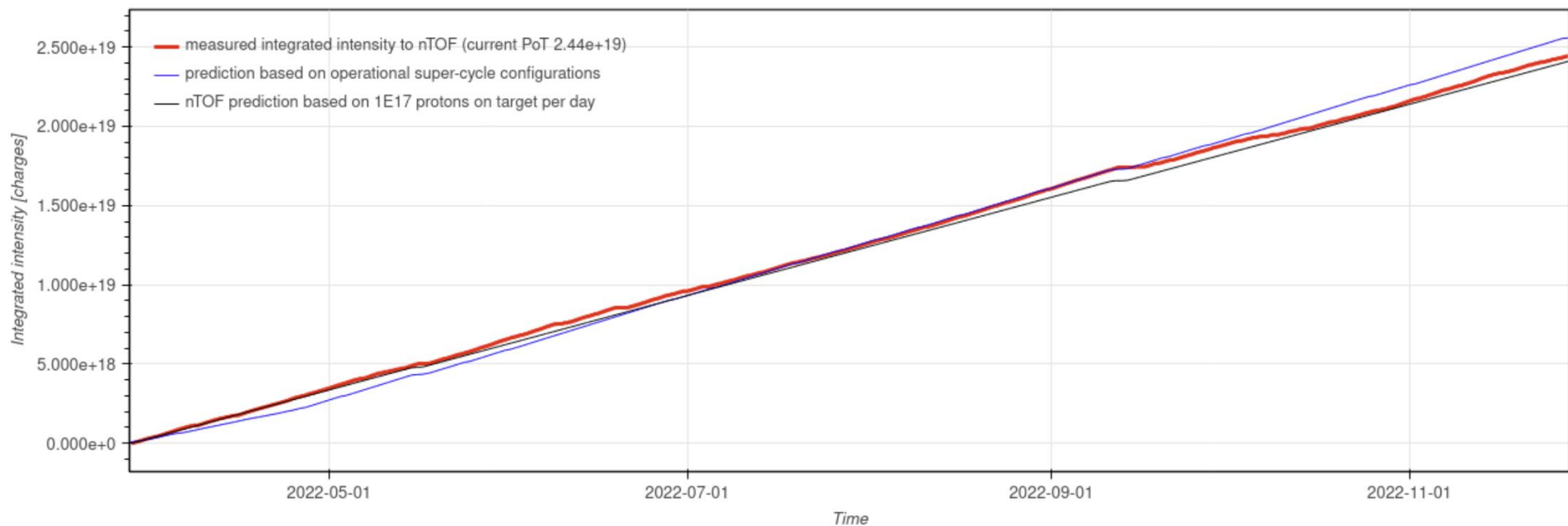
- Experiments very satisfied of the protons availability
 - Several feedback regarding hardware in the ISOLDE area itself

- Request to have occasional 1.7GeV runs

- Prospects for 2023
 - Resuming of high intensity MDs, stopped since late October due sparking and vacuum issues
 - Higher intensity with longitudinal painting
 - Occasional 1.7GeV, as requested by experiments

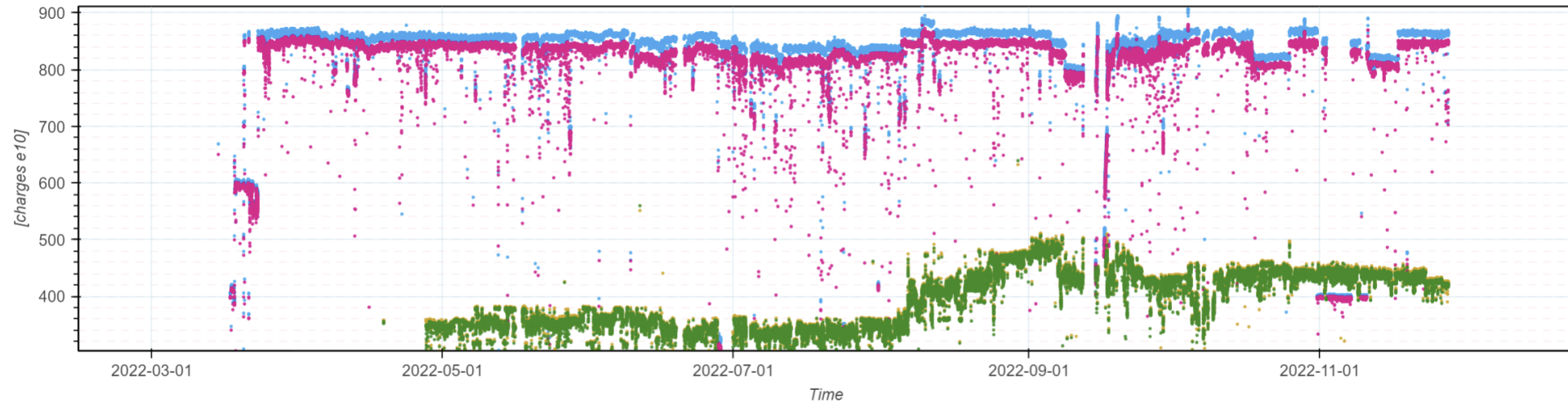
TOF: delivered intensity

- Single bunch 20 GeV/c beam fast extracted from the PS
- Total delivery of $2.44E19$ protons and $\sim 1E17$ protons per day



TOF: intensity ramp-up

- Swift ramp-up and stable operation since March



● After injection - Nominal ● After injection - Parasitic ● Before extraction - Nominal ● Before extraction - Parasitic

TOF: L4, PSB and PS in 2022

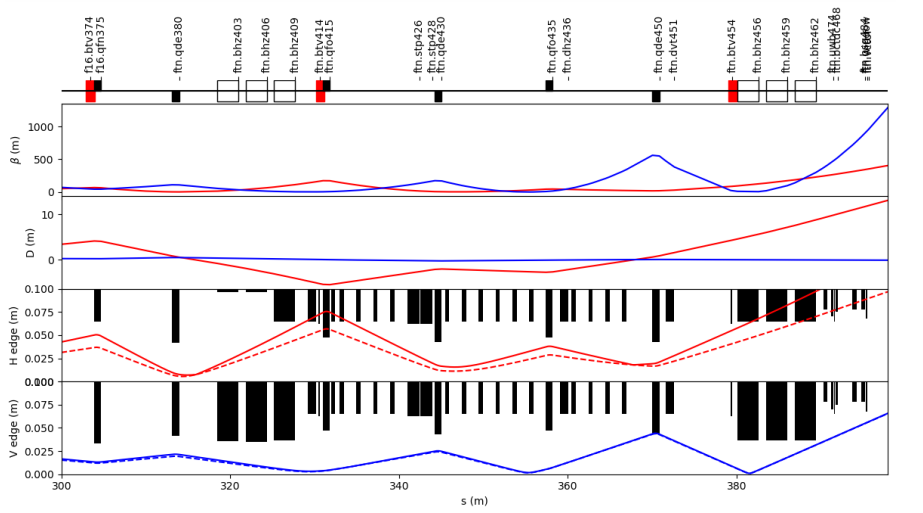
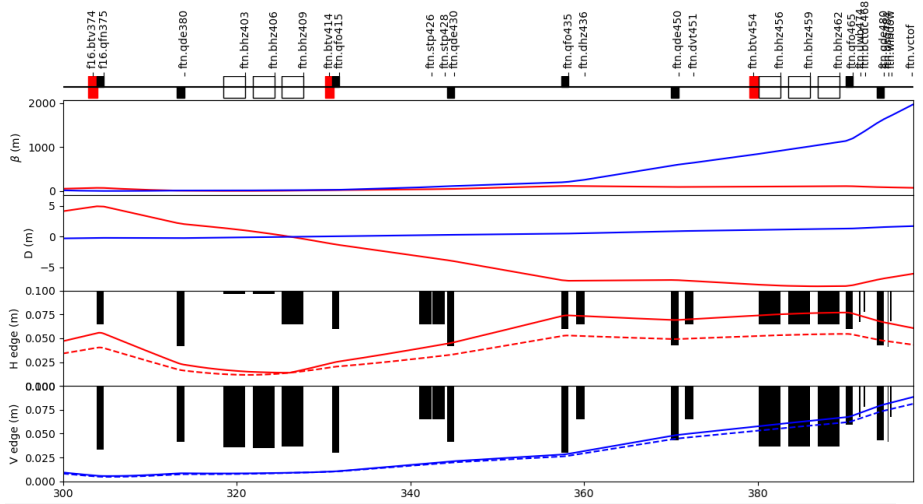
- Beam produced only in R2
 - R3 setup can be used as back-up

- Acceleration in the PS
 - Intensity limited by stability at transition

- EAST parasitic bunch
 - Bunch with lower intensity accelerated on EAST cycle and extracted

TOF: FTN line

- Aperture limitations
 - Performance limited by strong activation in 2021
 - Issues and possible mitigations following in the FTN WG
- Mitigation proposed in December 2021
 - Replacement of vacuum window for increased aperture
 - Removal of 2 quadrupoles after the last dipoles
 - Change of optics for stronger focusing
- ECR validated in December 2021

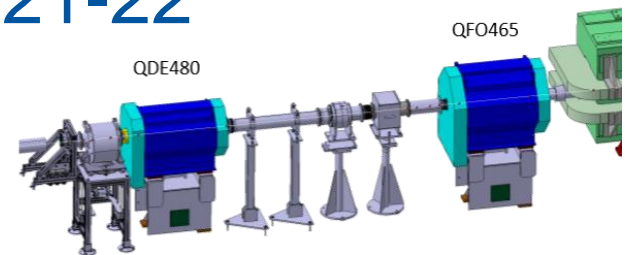


B. Mikulec, FTN WG, <https://indico.cern.ch/category/14390/>
 ECR PS-LJ-EC-0013, <https://edms.cern.ch/document/2669033>

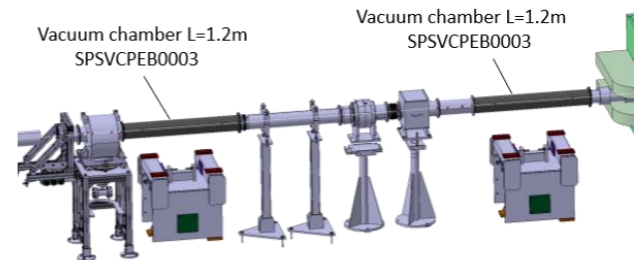
TOF: FTN line hardware during YETS 21-22

- Removal of 2 quadrupoles
 - Removal and transport of 2 quadrupoles
 - Installation of 2 replacement vacuum chambers
 - Changes to cabling and interlocks
 - Retuning of the quadrupole string power supplies
- Replacement of vacuum window
 - Procurement and fabrication of the vacuum window
 - Installation of the vacuum window shortly before the restart in 2022
- Tight schedule and many groups involved but successful completion before the 2022 restart

FTN LINE
CURRENT SITUATION

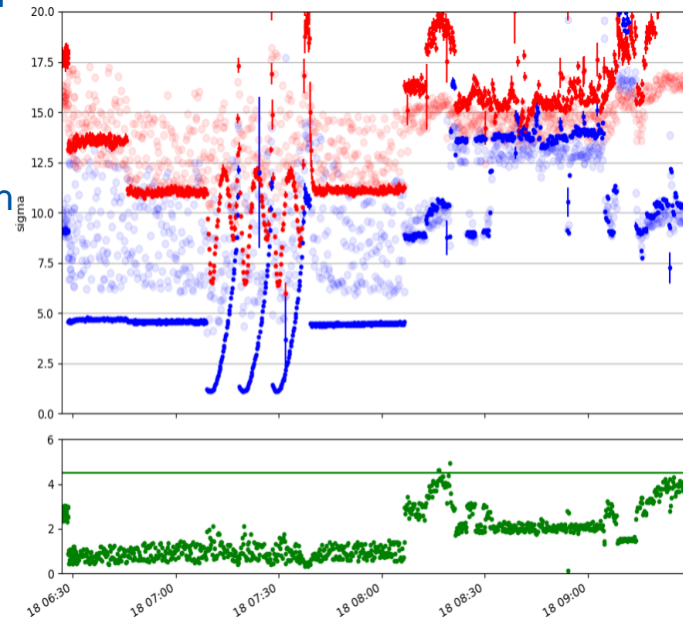
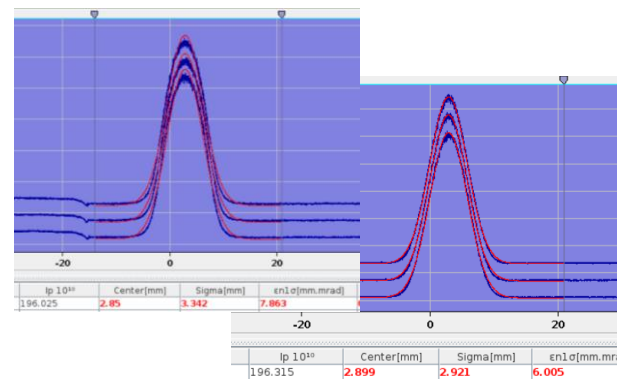


FTN LINE
MODIFICATION 2022



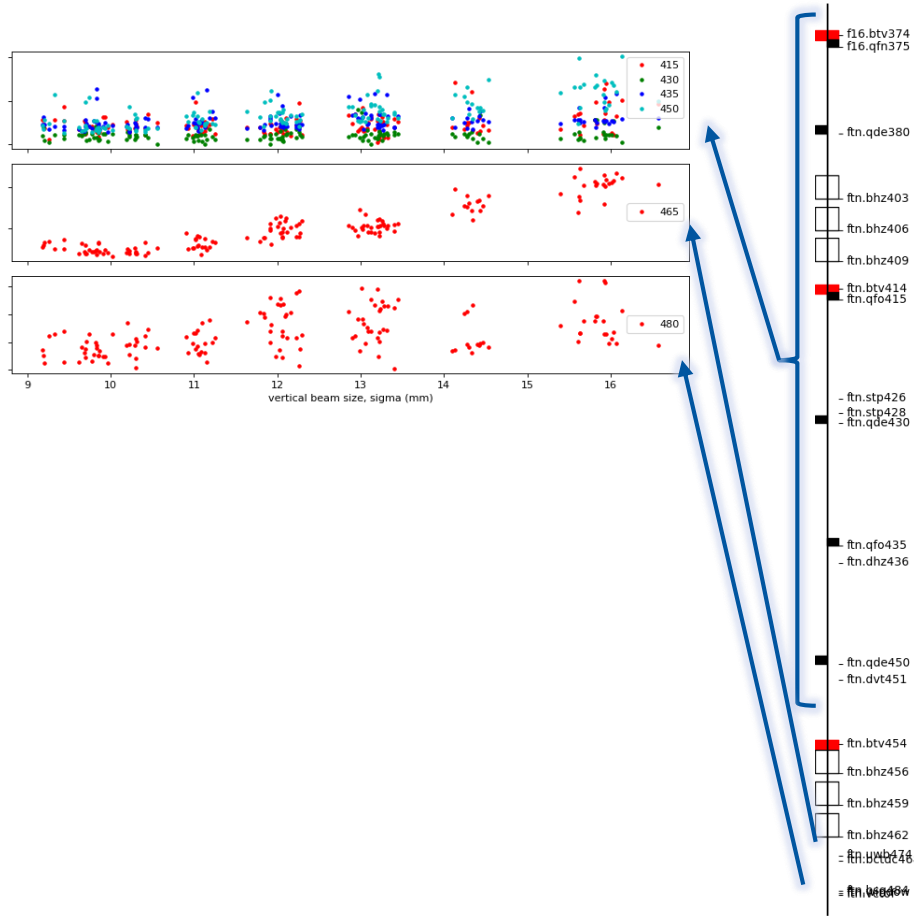
TOF: FTN restart and commissioning

- Started 12/03/22 with low intensity setup
 - Interleaved FTN optics commissioning with beam for physics nTOF
 - Special PSB variant with low intensity and high vertical emittance to mirror the high intensity beam characteristics. Achieved by adjusting the painting at injection, working point manipulations and the use of the linear coupling resonance in combination with skew quadrupoles
- Iterative process
 - Beam optics characterisation and optics steps to identify and reach the aperture limits of the line
 - Beam steering along FTN, using BTVs and loss signal
 - Intensity increased until nominal reached
 - Important input from SY-STI with a figure of merit and associated damage threshold to guide the commissioning (in green)
- Completed on 23/03/22
 - Full characterisation of the optics and aperture limits



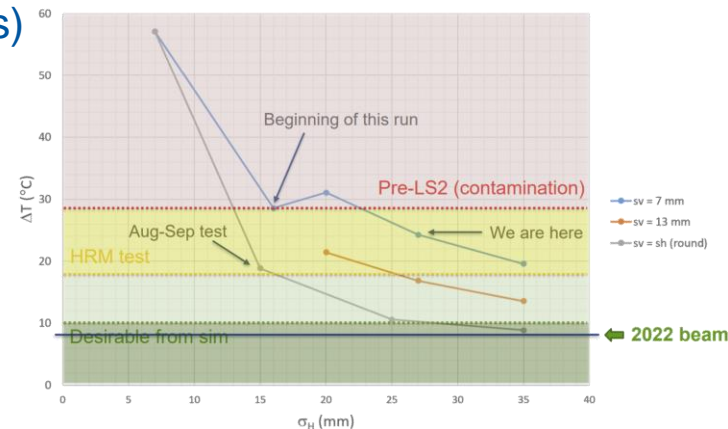
TOF: FTN line 2022 reach

- Experimental demonstration of a vertical aperture after the last dipoles, coherent with the model
 - Linear increase of losses measured at 465 as a function of vertical beam size above ~11mm
- Consensus with STI and OP to operate with 30mm horizontal and 13mm vertical beam size



TOF: FTN line WG

- Present line performances
 - Reasonable levels of activation measured during TSs at the end of FTN line. Estimated that a large part of the measured activation is unavoidable (window & grid wires)
 - Beam density on-target at acceptable levels
- FTN WG outcome and conclusions
 - The present performance of the line is sufficient both for the target and for the operation
 - The grid at the end of the line is required for operation and a spare should be available soon
- Present performance opens the path to higher flux operation



R. Esposito, Update on target simulations, <https://indico.cern.ch/event/1176384>
Post-mortem of high intensity tests in n_TOF, <https://indico.cern.ch/event/1223498/>

TOF: Feedback from experiments and solutions

- Pre-pulses observed by the experiment at the start of 2022
 - Caused by satellite bunches on the bucket in front of the main bunch
 - Careful observation with the BSM (very small satellite bunch) and adjustment of the bunch rotation solved the issue
- Bunch length of 28ns is needed for some experiments next year and favored for the whole year if the nominal intensity can be maintained
 - Present setup at 42ns with larger longitudinal emittance provides reduced losses at extraction and easier transition crossing
 - Lower longitudinal emittance and careful adjustment of transition crossing can provide a 28ns with reasonable losses
 - Extraction losses benefit strongly from the removal of the dummy septum (needed for MTE without barrier bucket)
 - 28ns compared to 42ns in November 2022, shows ~50% larger losses at extraction but stable transition crossing
 - For next year: recommissioning with only 28ns configuration with adjustment of ring and FTN optics but fall back to 42ns for nominal intensity if losses are too high

TOF: Feedback from experiments and solutions

- Neutron flux in EAR2 dependence with vertical position on target
 - PS SIS interlock on beam position established to $\pm 5\text{mm}$ in horizontal and $\pm 3\text{mm}$ in vertical
 - Plans to establish golden trajectories in F16 for TOF cycles and investigate the possibility and need for automatic correction
- Incorrect proton counting for a few days after TS2
 - Timing changes during TS2 impacted the BCT windows and biased the measurement of all BCTs in TL out of the PS
 - Issue was identified and solved after a few days, but is not expected to occur again

TOF: Prospects for 2023

- Double batch TOF beam
 - Single PS cycle with 2 bunches extracted 1.2s apart to allow for increased flux
 - BI equipment needs to become compatible with two extractions per cycle
- Flexible adaptation of the SC to exploit maximum flux reach → automatic beam scheduling needed for very efficient operation (work ongoing, first steps this YETS, full implementation LS3)
- Maximum intensity per bunch of TOF beam can be explored in the PS
- Maximum intensity of parasitic TOF on EAST cycles can be explored in the PS
- Impact of stray field of SMH16 CONS eddy current septum on second bunch (remaining circulating) is being studied
 - Transient magnet simulations in progress
 - Stray field measurements added to CONS programme

Conclusion

- ISOLDE

- Cycles improvements developed in 2021 and implemented on the operational cycle since the start of the 2022 run for improved injection and acceleration efficiency
- Successful commissioning of a 1.7GeV cycle and optics, with minor adjustment to the acceleration cycle and transfer line optics
- Very good availability throughout the year
- Longitudinal painting and resuming of the high intensity MDs for 2023

- TOF

- Swift commissioning and continuous delivery of $\sim 1E17/day$
- Successful FTN modifications and optics commissioning to provide acceptable beam characteristics to the target
- A few issues during the year were addressed during the year thanks to a close communication between the experiment, machine experts and OP
- Exploration of double batch, parasitic and single bunch intensity limits for 2023
- Study of the SMH16 septum effect on the circulating bunch in 2023
- Commissioning of ring and transfer line with 28ns at the start of 2023

- General

- Optics and beam transport modelling should be part of any upgrade or consolidation

Thank you

