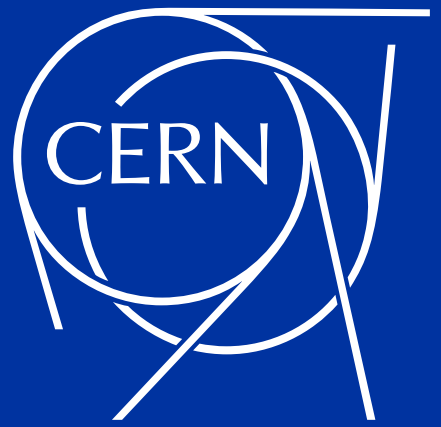


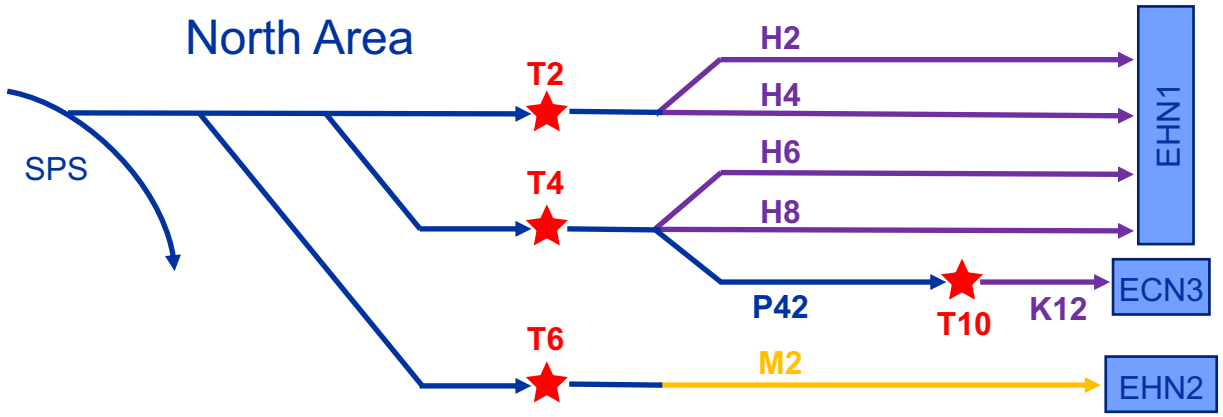
Secondary Beamline Operation 2023 and 2024 Outlook

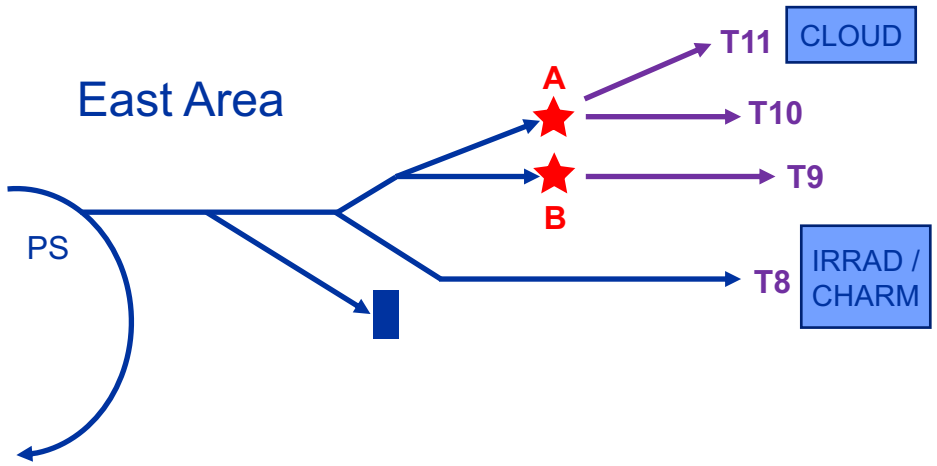
Laurie Nevay, Luke Dyks, D. Banerjee, A. Baratto Roldan, M. Brugger, J. Bernhard, N. Charitonidis, A. Ebn Rahmoun, L. Gatignon, S. Girod, A. Goillot, M. Lazzaroni, E. Parozzi, B. Rae, S. Schuh-Erhard, M. Van Dijk, C. Ahdida, M. Fraser, F. Velotti, F. Philippon, Y. Pira, F. Roncarolo, C. Vendeuvre.

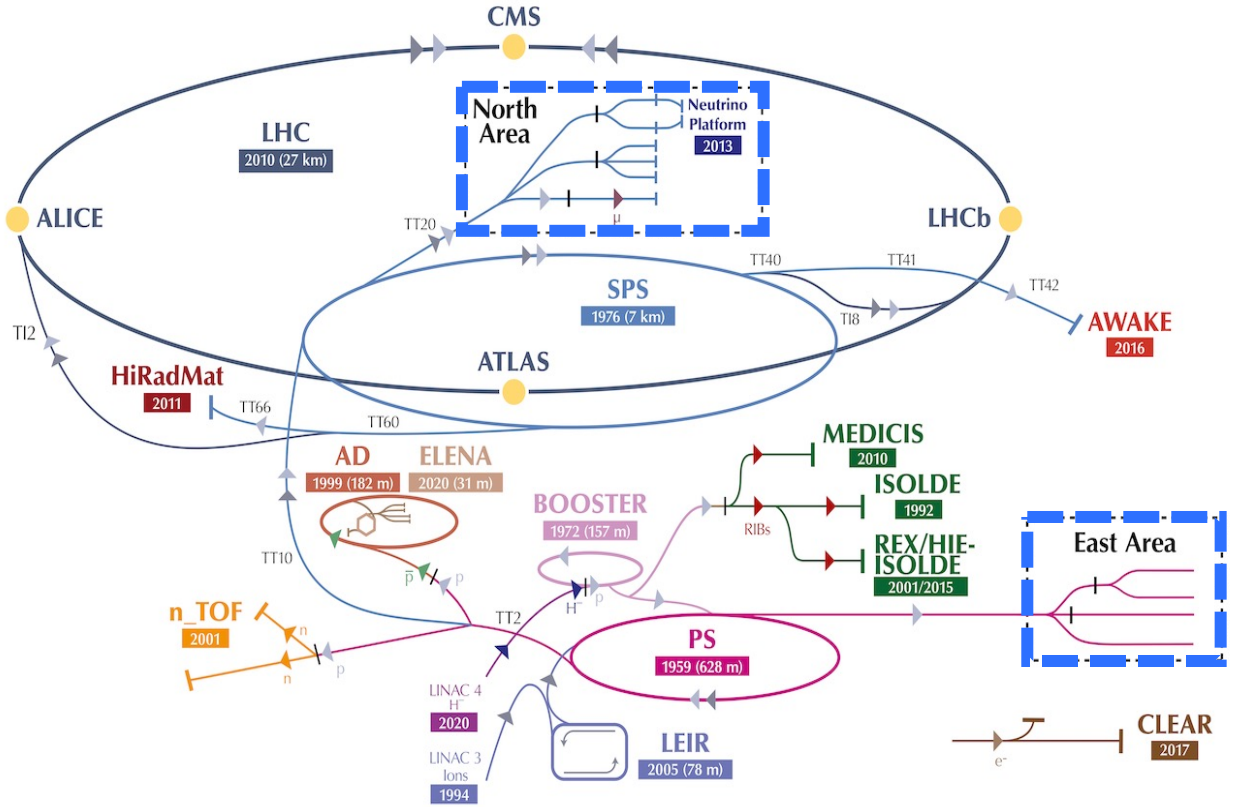
7th December 2023, JAP Workshop 2023, Montreux

Introduction

- **Follow-up on JAP 2022 actions**
- **East Area**
- **North Area**
- **P42**







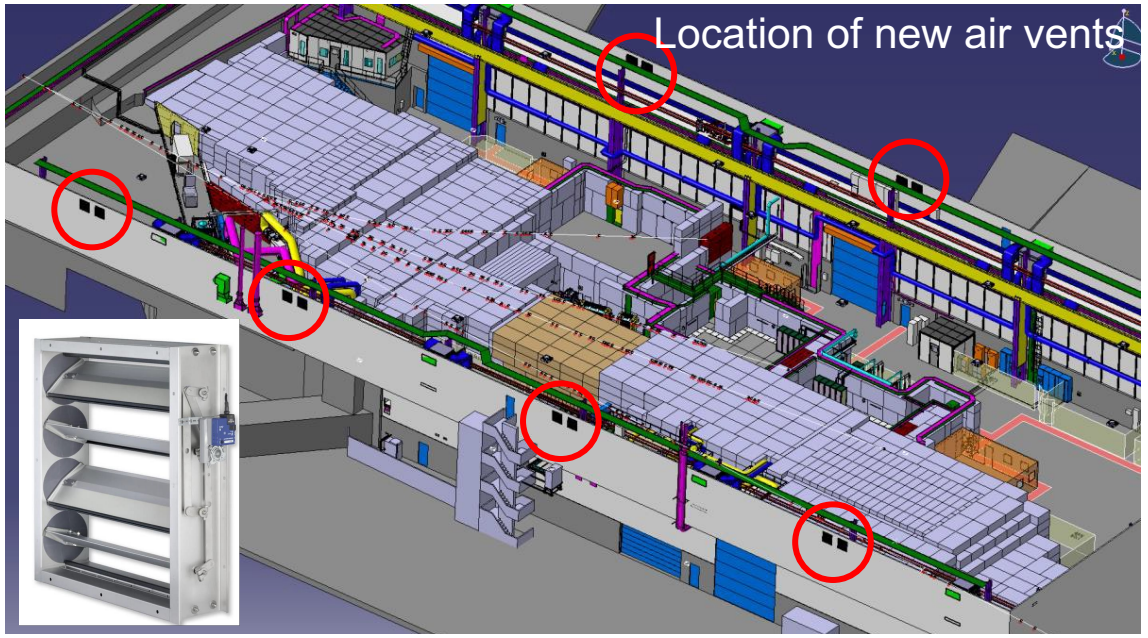
JAP 2022 Actions and Updates

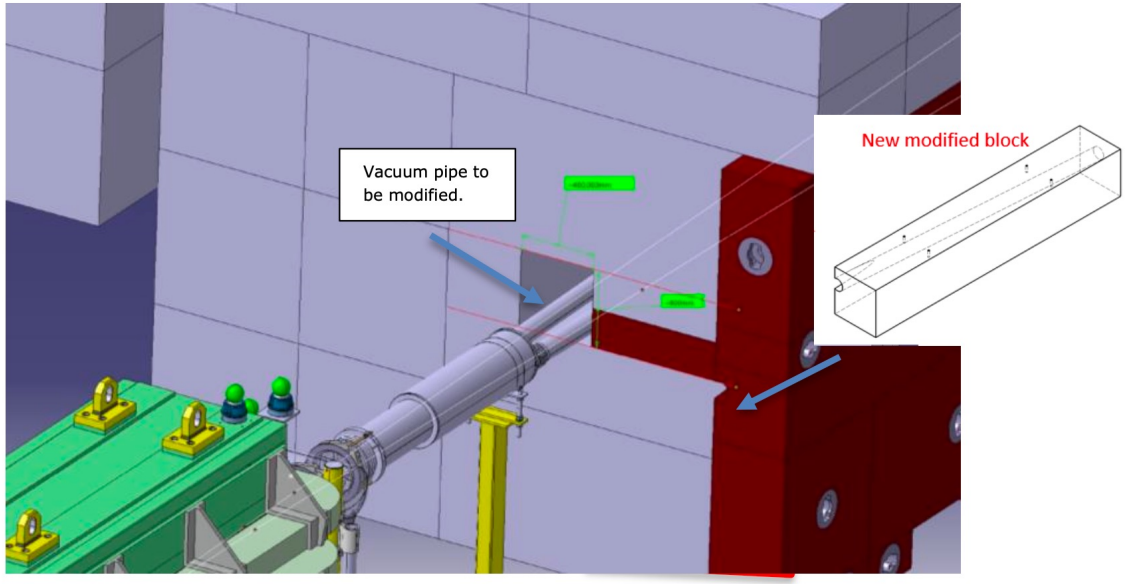
- **All follow-up actions from JAP 2022 addressed and completed:**
  - EAST dump shielding → will be installed in December (ECR: https://edms.cern.ch/document/2920070/0.2)
  - H6 / H8 electron beams → restored to previous purity / intensity
  - support the NA61 low-E beam
  - AFT active feedback
  - PBC experiment Run 4
- **H6 smaller spot-sizes and intensity improvement**
  - several strategies studied and now being discussed
  - record intensity delivered in H6 in 2023
- **Infrastructure upgrades in the East Area**
  - ventilation done; drainage solved – waiting on final safety validation
- **Introduction of a new secondary beamline stand-by service by BE-EA-LE**

East Area

East Area

- **A systematic measurement of beam composition in T09/T10 was made in tight collaboration with test beam users and BL4S**
- **East Area Dump shielding improvement studied on request of OP and additional shielding will be installed in December**
- **The water ingress due to a leak in the roof has been temporarily mitigated**
  - important to have mitigated in a general way as there is a high risk of impact on beamlines / experiments if not solved
- **New ventilation slats were installed throughout the year to mitigate high temperatures observed by CLOUD**
- **BHZ027 is close to the RMS limit of the power supply and often trips**
  - would benefit from additional energy storage unit

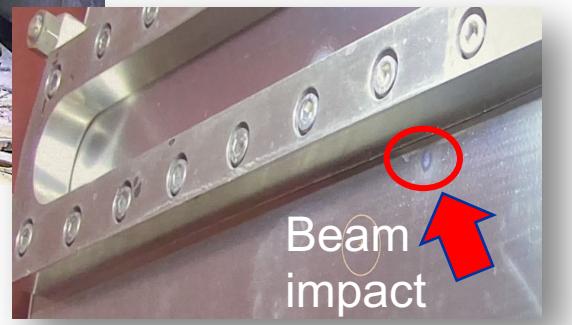




North Area

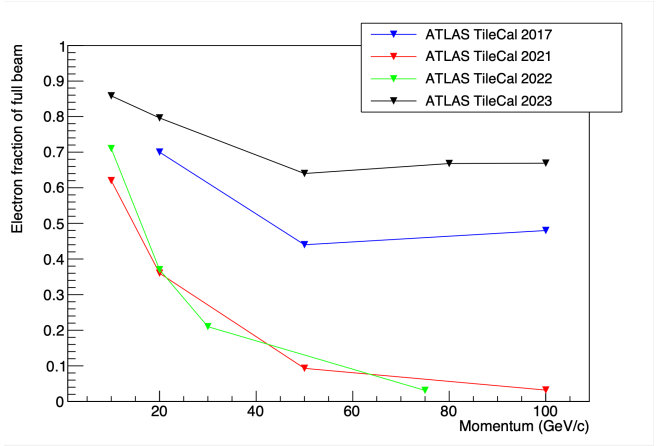
North Area Operation

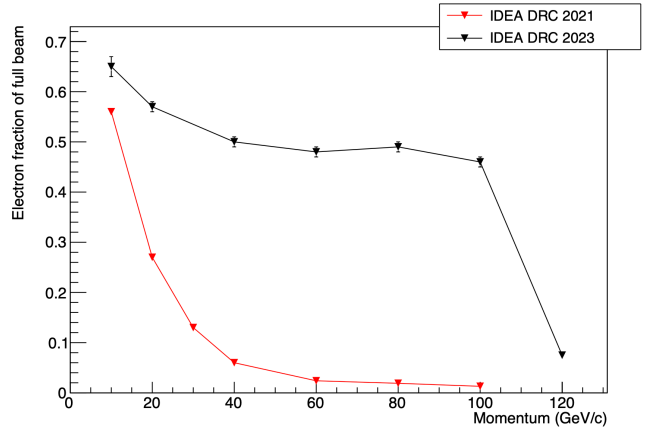
- **Significant savings of protons on target due to the optimisation of losses around the T4 target region**
  - reduced activation throughout operation
- **Significant improvement and understanding of beam losses in P42 (discussed later in detail)**
- **T4 VXSS vacuum chamber removal early in 2023**
  - T4 VXSS found displaced from geometrical scan of TCC2
  - prompt assessment and intervention to remove it entirely
  - this had a strong (positive) impact on beam losses as well as electron beams in the North Area (again, positive)
- **Development and progress towards calibration of TCC2 and TCC8 BSIs with activation foils**

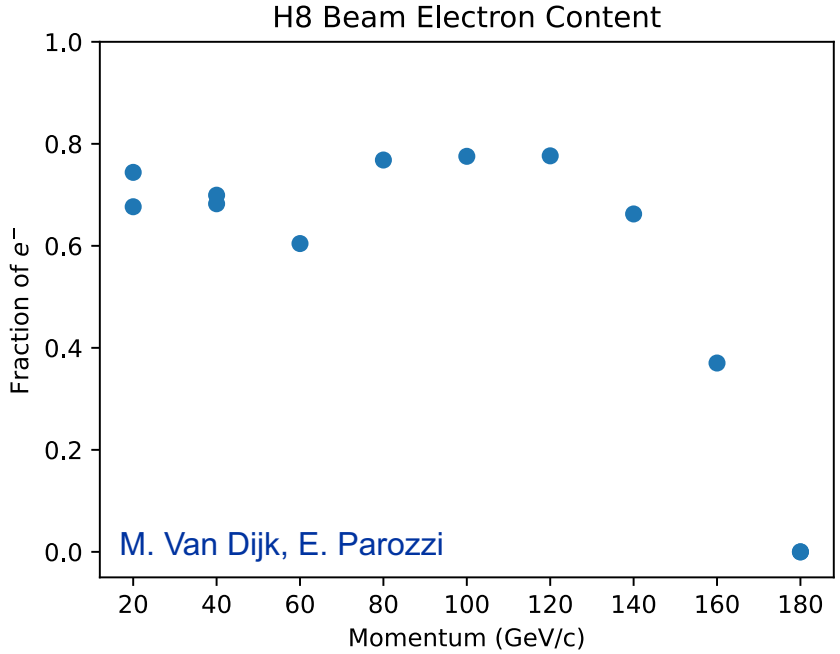


H8 & H4 Electron Beams

- **H8 users (ATLAS TileCal) reported low electron content in beam in recent years**
  - 3.2% in 2021 vs 48% in 2017 (at 100 GeV/c)
  - many investigations and confirmation in 2022
- **Removal of the VXSS had a very positive impact**
  - an XEMC calorimeter was used in H8 during beam commissioning to measure the electron content of beam
  - measured ~70 – 80% electrons up to 120 GeV/c
- **H8 tertiary beam optics re-optimised to improve transmission with local dispersion suppression at the secondary target**
- **Again possible to have electron users in H6/H8**
  - will help with the current overloading of H2/H4 beamlines
- **For NA64(e) several improvements led to records of high purity and low beam halo**
  - H4 improved vacuum, removal of instrumentation, improved optics





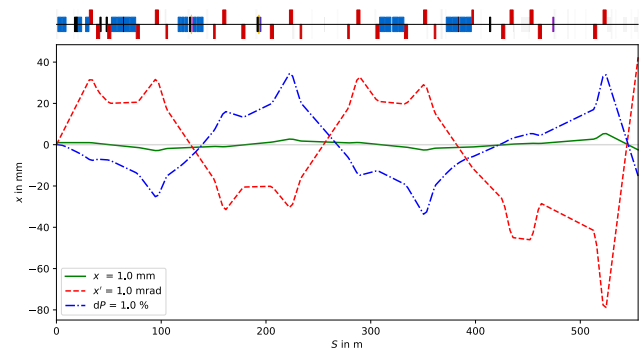


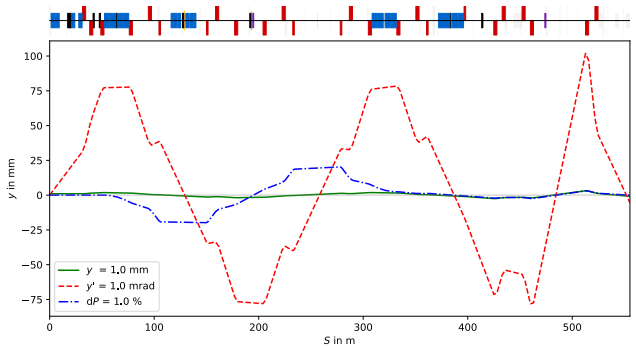
XEMC calorimeter data showing fraction of electrons See: https://indico.cern.ch/event/1314360/#71-h8-electron-beam-update

H6 Spot Size and Intensity

- **Silicon pixel tests in H6 test out very small sensors**
  - require small and higher intensity beam to get enough hits
- **Request to study smaller spot sizes in H6**
- **In 2023, with the removal of the T4 VXSS we were able to reach up to 6 x 10^6 particles / spill**
  - improved transmission for same RP monitor limit
- **Studies show smaller spot sizes can be achieved upstream if experiment moves setup**
  - do-able now with minimal cost
- **An alternative is the addition of 2x quads at the end**
  - infrastructure being assessed and cost estimated

PPE156 at the end of H6





optics with new final doublet

M2 Beamline

- **Several challenging changeovers between big setups successfully completed (AMBER, NA64μ, MUonE) in a short time, minimising the downtime**
- **The MUonE tent and infrastructure worked well to isolate the environment of the precise experiment**
- **During a high intensity hadron test in September, losses were identified in a vertical momentum-defining bend**
  - double-peaked beam profiles due to losses understood
  - a re-alignment of the section is scheduled for the EYETS
- **For a higher intensity hadron beam, new studies show making the vacuum more continuous will be beneficial**
  - reduced angular spread from multiple-scattering will improve the CEDAR efficiency for tagging particles
  - timeline → 2023: integration model; 2024: detailed study and budget request; 2025: procurement; LS3: installation
  - still requires approval of resources

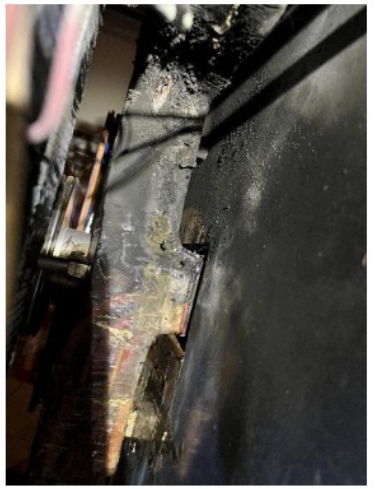

CEDAR-N for AMBER $\bar{p}$


AMBER PRM TPC


NA64mu

Ion Operation

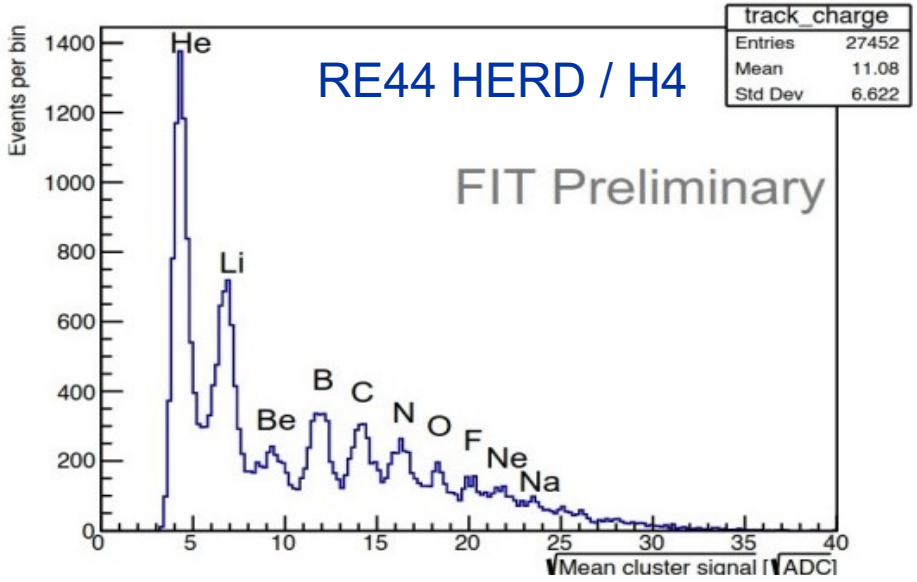
- **MSN Magnet Fire in H4 (MSN.X0220031)**
  - the fire was most probably caused by an electrical arc due to an inter-turn short or short to ground
  - 3 days downtime for all North Area users and H4 users (AMS) were successfully moved to H8
  - the incident was relatively close to the end of the physics run so continued operation in other lines was prioritised



Connection side coil

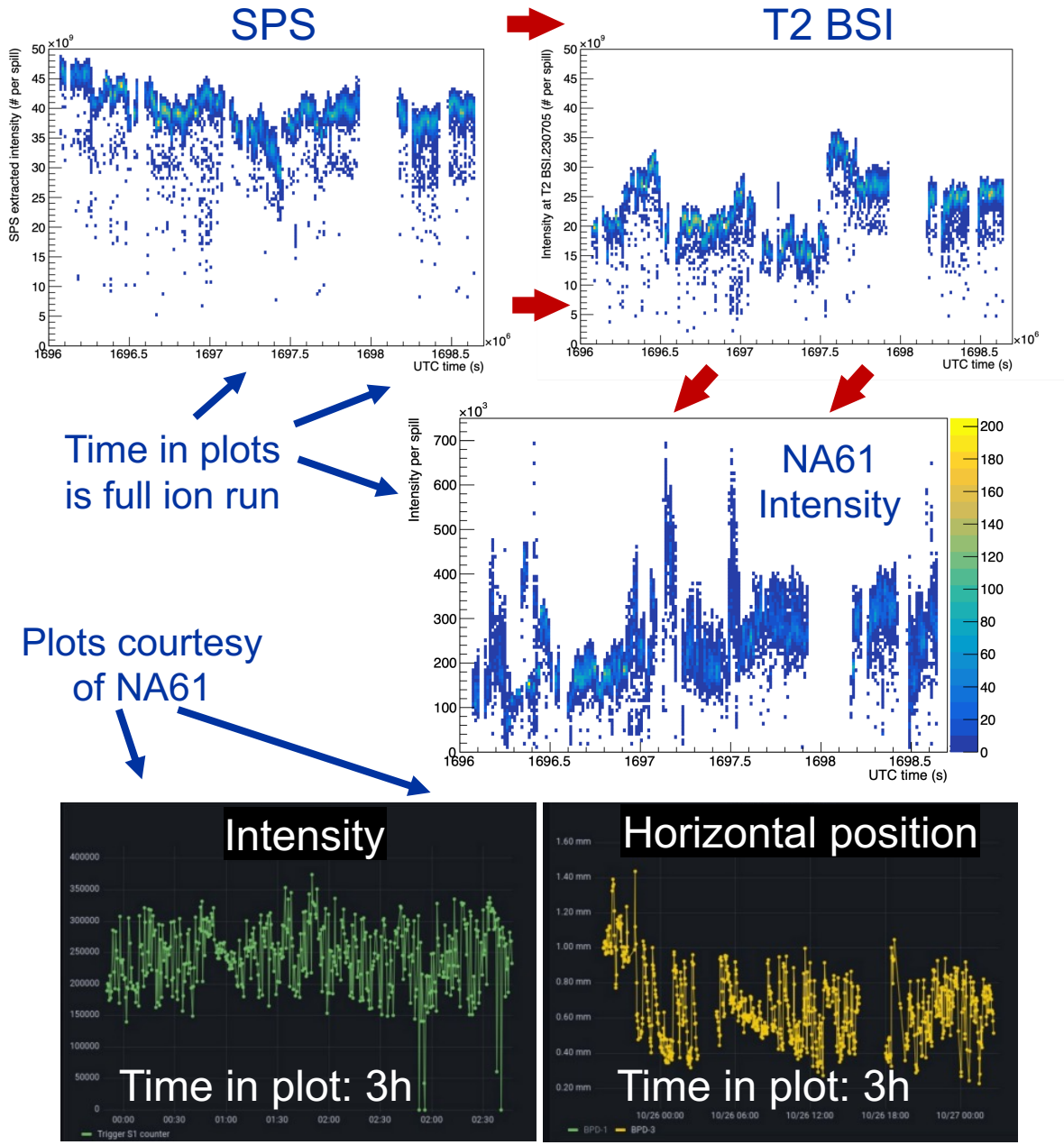
Connection side top

- **A very near-miss and it could have been much worse and highlights the importance of NA-CONS**
  - a similar fire happened in the same design of magnet in P42 (2021)
- **Besides this, all ion beams were delivered as requested including fragmented ion beams**
  - new secondary target installed in H8 for enriched low-Z fragments
  - improved beam for NA60+ in H8 from improved optics and the T4 VXSS removal



H2 Ion Beam Fluctuations

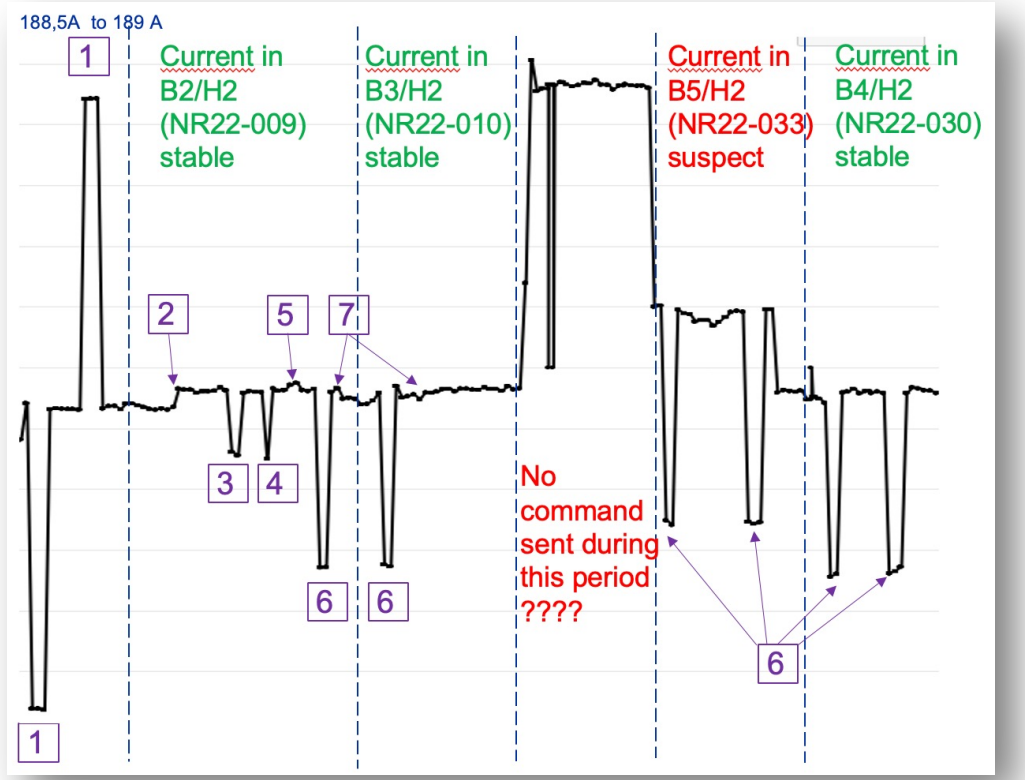
- **NA61 saw frequent beam movements in the 2023 ion run**
  - movement was in the horizontal plane on a short timescale
  - large fluctuations in intensity seen (factor ~2) at times
- **SPS extracted intensity and T2 BSI also show fluctuations but not as much as what NA61 sees (also in T4/H8)**
  - beam instrumentation not ideal for ions – a known issue
- **Most likely this is a combination of several factors**
  - upstream position / angle fluctuation in extraction → T2
  - movement of beam at target position → narrow acceptance in H2 with necessary collimation
- **Needs further study of intensity fluctuations and beam movement (OP / ABT with input from BI)**



North Area Operation Continued

- **CEDAR detectors have experienced many issues**
  - faults have been collected and actively tracked (see Maarten's talk)
- **NA61 vertex magnet experienced cryogenic cooling problems but these were solved**
- **Some issues encountered with ECN3 access system**
- **H2 moving beam issue – BA81 power converter cross-talk**
  - it was found that the beam in H2 moves sporadically
  - correlated with changes in other beamlines
  - a very small change in current below measurement resolution
  - unfortunately requires beam time in the whole of EHN1 to understand (see https://edms.cern.ch/document/2932122/1)
  - few tests show correlations but needs further study
  - require some beam time in 2024 to study this

Y. Gaillard, X. Genillon



H2 beam position for turning on / off H4, H6, H8 for power converters grouped by BA80 / BA81

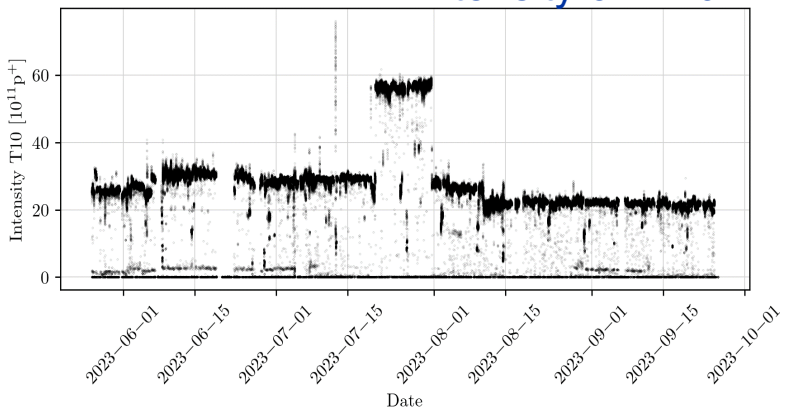

P42

P42 Operation in 2023

- **2023 operation on P42 successful**
  - Record availability at T10
  - Successful beam dump run
- **Radiation levels and losses significantly reduced**
  - VXSS chamber removed
- **New beam instrumentation installed**
  - SEM grid profile monitors **(Federico Roncarolo SY-BI)**
  - Beam loss monitors **(Christos Zamantzas SY-BI)**
- **Beamline improvements**
  - Done in collaboration with NA-Cons
  - P6 bends removed
  - Beamline smoothing campaign **(Camille Vendeuvre)**
  - SEM devices with faulty IN/OUT motors moved
- **Optics studies and further consolidation**
  - BDSIM and FLUKA models developed
  - For present operation for NA62
  - For future **H**igh-**I**ntensity ECN3 Project
    - Dedicated and Shared optics
- **Big thanks to all involved!**

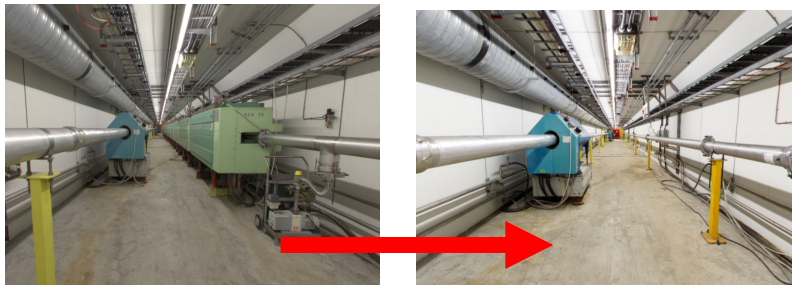
VXSS Chamber

Intensity on T10

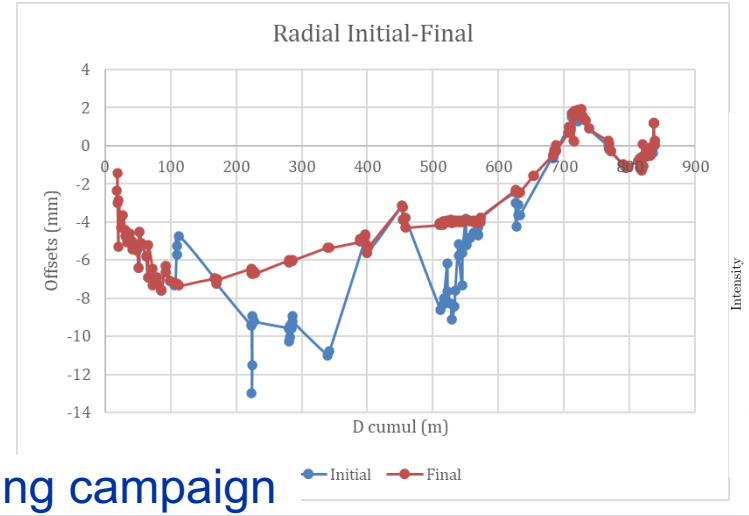


P6 bends before

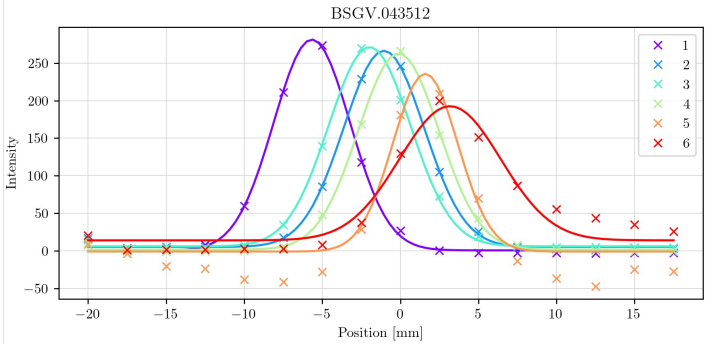
After



BSG profile monitor



Smoothing campaign

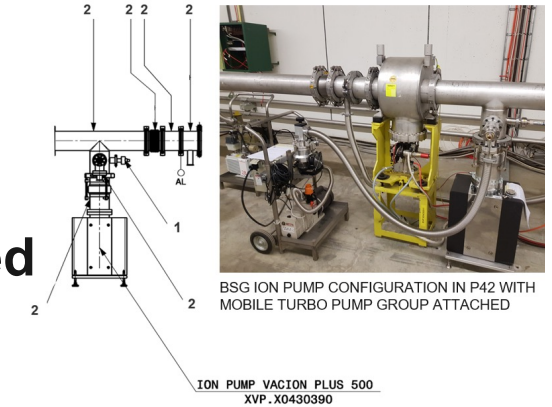


Grid during kick response study

Instrumentation Improvements

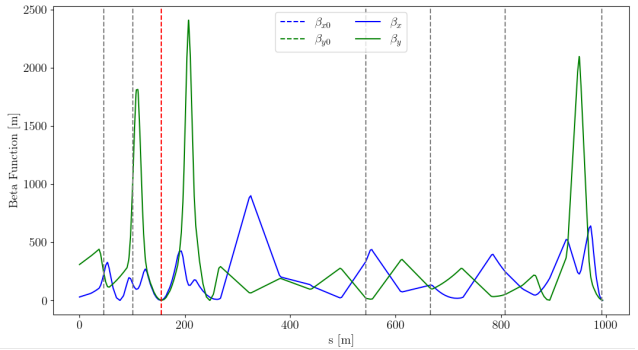
SEM Grids Installed

- **Previous optics studies performed on TT20**
  - Mini-scanner on P42 would have taken too long
- **3 new BSG grids installed + existing one moved**
  - S = 389, 512, 653, 836 m (EDMS 2777725)
  - BSG 653 not in dedicated vacuum
  - **6 in total** on TT24 + P42
- **Allowed kick response study and quad scan**



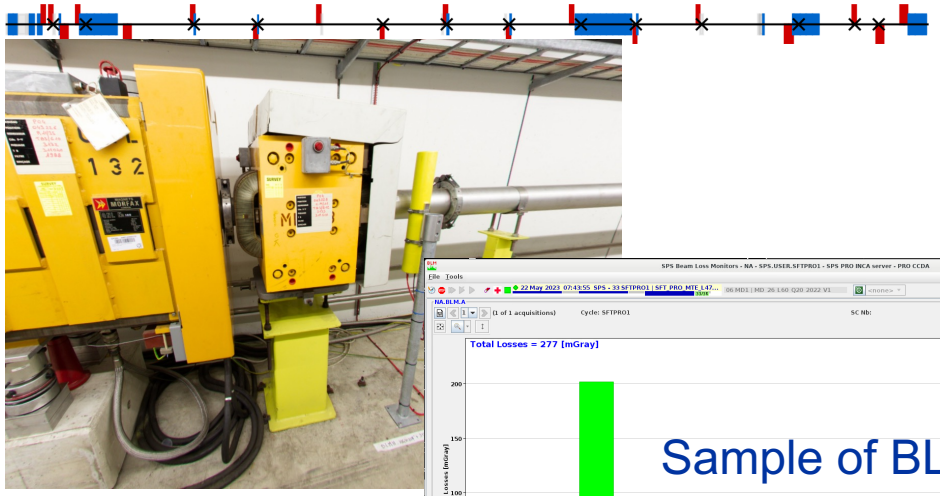
BSG ION PUMP CONFIGURATION IN P42 WITH MOBILE TURBO PUMP GROUP ATTACHED

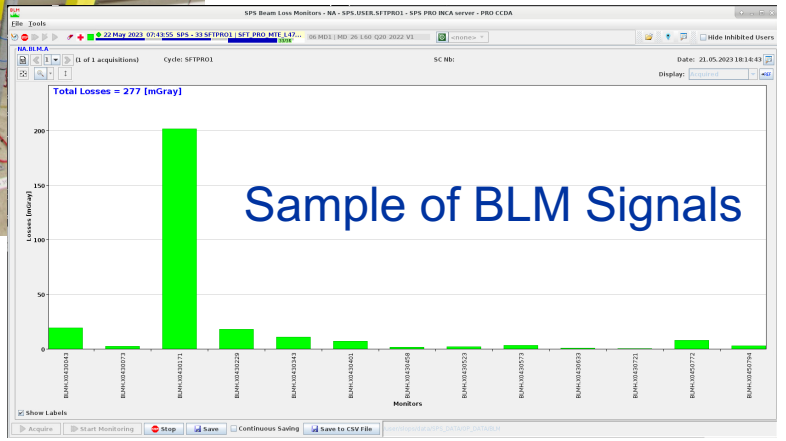
TT24 – P42 Optics and BSG Locations



BLMs Installed

- **Loss sources or location not well understood**
- **13 BLMs installed (EDMS 2777729)**
- **Have helped in finding loss sources**
  - Large peak at ~170 m is β_x max and D_x max
- **Have helped with intensity and vacuum RP studies**
- **Have prevented RP issues during optics MDs**

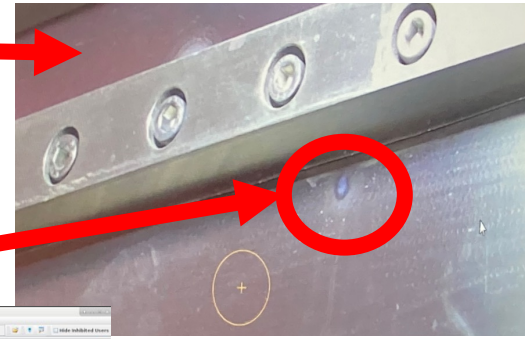


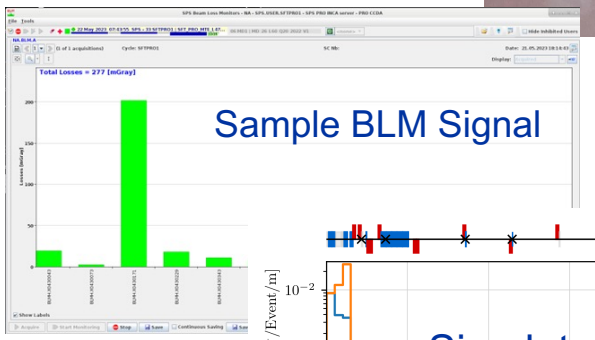


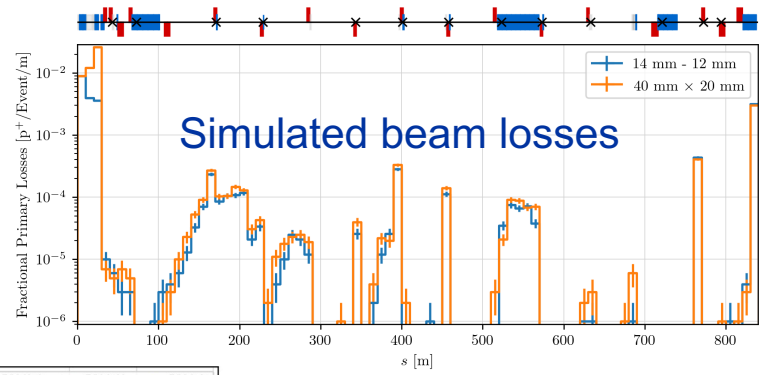
Sample of BLM Signals

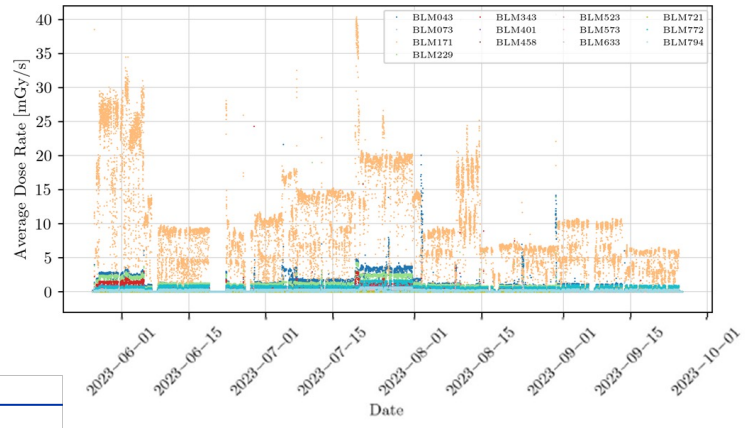
Beam Losses in P42

- **In recent years beam losses were very high in key areas**
  - EHN1 Saleve ramp
  - TCC8/ECN3 bridge
  - Problem for ongoing operation
- **Major source identified in YETS → VXSS chamber**
  - Beam was passing through 22 mm stainless steel
  - Chamber removed completely
  - Extra ~7 m of air → potential air activation assessed by RP, found acceptable
- **Losses much lower → Significant Radiation reduction**
- **Beam losses still present**
- **Using model in BDSIM to identify source**
  - Appears to be driven by beam matter interactions
- **Dominant source is likely interactions with air in TAX region**
- **Large variation seen during run**
  - Despite stability in P42
  - Study of correlations and conditions ongoing
  - Transmission during dedicated optics lower
- **New optical fibre dosimeters to be installed**
  - Both active and passive
  - Will provide higher resolution loss positions









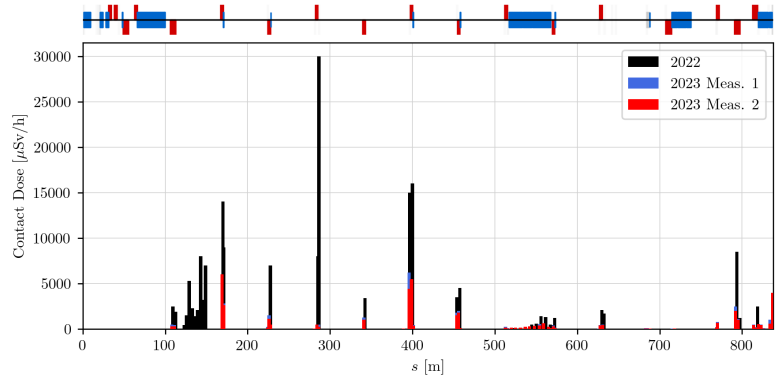
BLMs throughout 2023

Radiation Studies

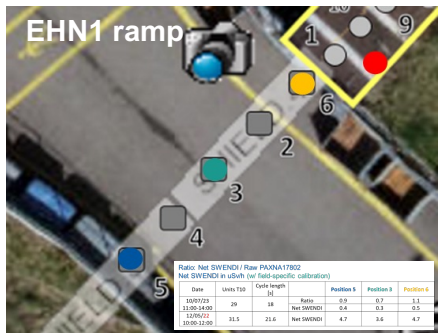
- **Post-LS2 radiation levels too high**
- **Activation survey of beamline equipment**
- **RP studies focussing on EHN1 ramp and ECN3 Bridge**
- **Factor 8 reduction in dose rate since 2022 on EHN1 ramp**
  - Within area classification
  - VXSS removal
  - ~100 hours of beamline commissioning
  - Shielding improvements
  - SEM devices with faulty IN/OUT motors moved away from beam
  - Removal of P6 dipoles
  - Beamline smoothing → Particularly collimators (EDMS 2927202)
- **Radiation levels on bridge within present area classification**
  - Radiation levels are close to limit
  - Installation of RP monitor with interlock ongoing
- **Dedicated FLUKA studies of future shielding scenarios**
  - Iron
  - Iron + concrete
  - Movement of aperture restrictions
  - Strategy depends on loss reduction
- **Successful Beam dump run**
  - 60 units on T10
  - Dose rates on ramp average 1.1 uSv/hr

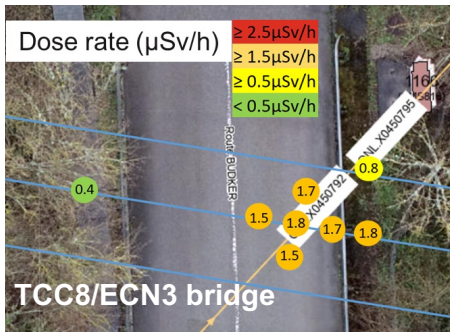
Big contribution from RP and BMI

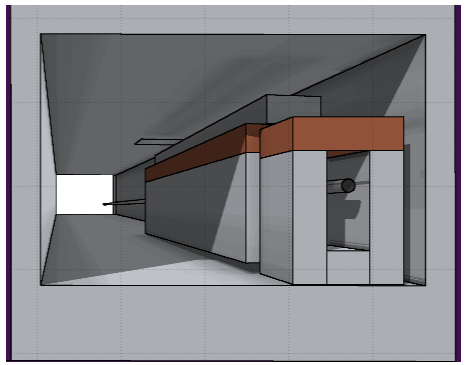
Contact dose 2022 vs 2023



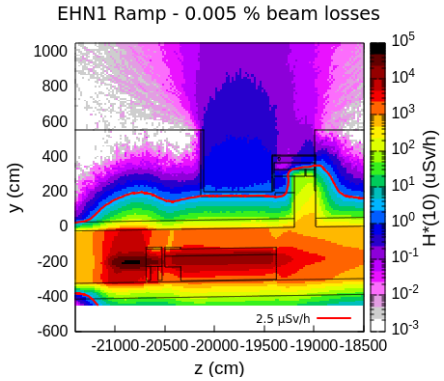
Several RP surveys at the EHN1 ramp and TCC8/ECN3 bridge





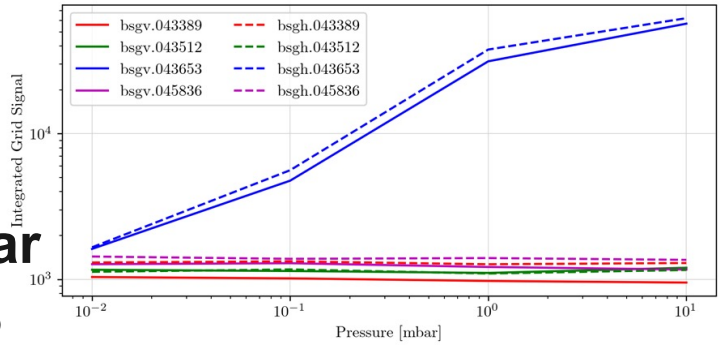


Detailed P42 FLUKA model

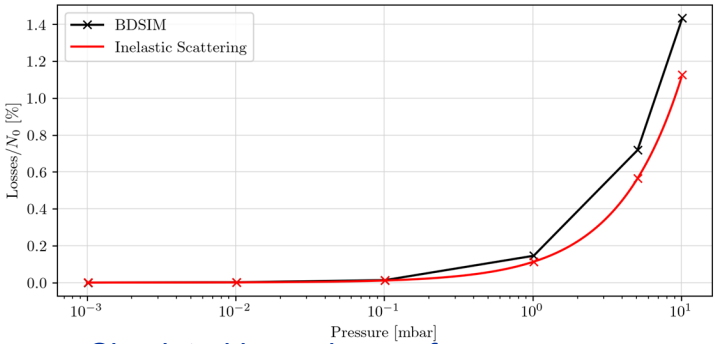


Vacuum Level Study

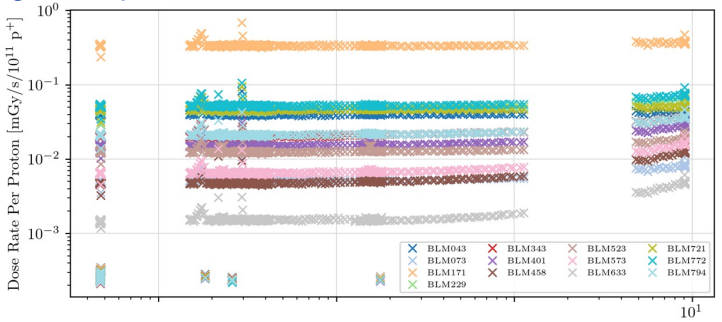
- **Nominal Vacuum level in P42 ~ 10^{-3} mbar**
  - Collaboration between NA-Cons and HI-ECN3
  - What vacuum level is required for HI-ECN3?
  - Impact on losses, RP, and BSG grids
- **Test performed from 10 mbar – 0.01 mbar**
  - Measure BSG 653 vs BSG in dedicated vacuum
  - Record BLM data and RP monitors
- **BSG performance improves with lower pressure**
  - Operation at nominal pressure comparable to high vacuum
- **Beam losses reduce with lower pressure**
  - Very small difference from baseline losses below 0.1 mbar
- **Radiation levels reduce with lower pressure**
  - Very small change in measured dose below 0.1 mbar
- **Nominal vacuum should be okay for HI-ECN3**
  - To be verified
- **Functional specification being drafted for consolidation**



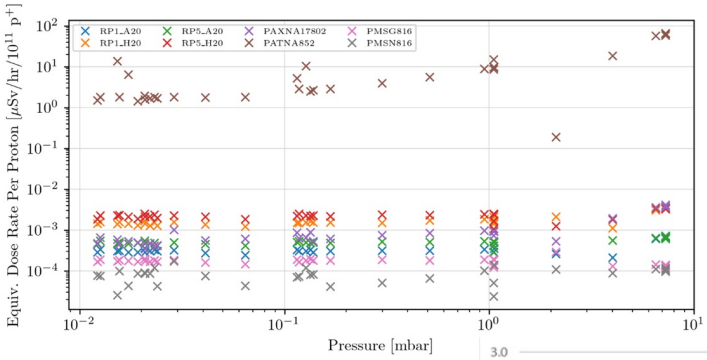
Integrated BSG Signal vs pressure



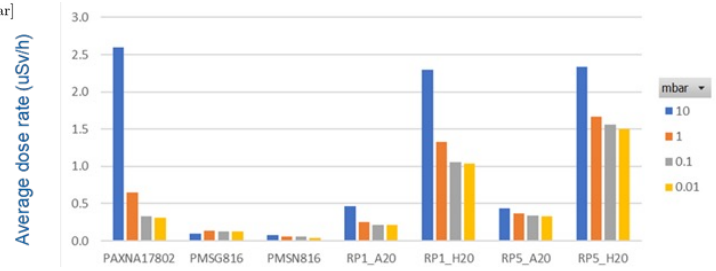
Simulated beam losses from vacuum



Dose rates measured by BLMs vs pressure



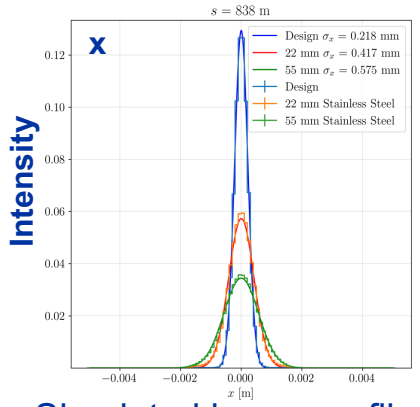
RP Dose rates vs pressure



Average RP doses over each pressure interval

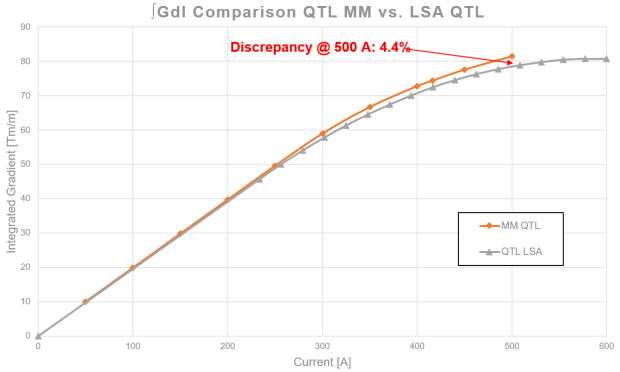
Optics studies

- **Since 2018 T10 Beam spot has been too large**
  - Entirely due to **VXSS** → consistent with BDSIM simulations
  - Reduction from 0.5 x 0.75 mm² → 0.26 x 0.28 mm²
- **Longstanding issue of TT20 and P42 mismatch**
  - Collaboration between ABT, OP and EA to match entire beamline
- **Magnet measurements**
  - Transfer function in LSA and YASP is from unknown source
  - QNL and QTL magnets have been remeasured
  - Up to 5 % discrepancy
  - Some magnets are very sensitive → final focus
- **YASP test planned for 2024**
- **New instrumentation has enabled new optics studies**
  - MDs dedicated to optics studies
- **Kick response study**
  - Scan of horizontal and vertical correctors
  - Optics changed between correctors and BSGs
  - Some agreement but not total → Analysis ongoing
- **Quad scan**
  - Scanned quads along entire TT24-P42 line
  - Use MADX model from KR study to fit initial conditions

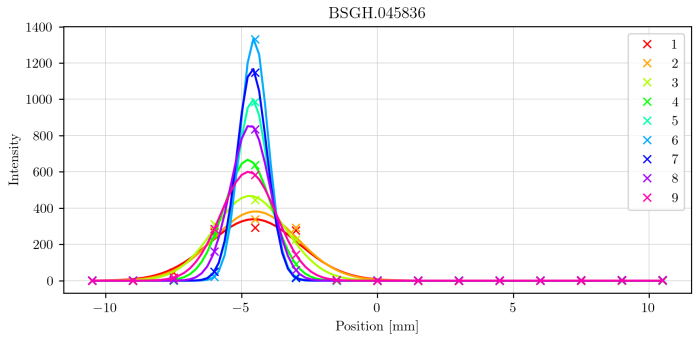


Simulated beam profile T10

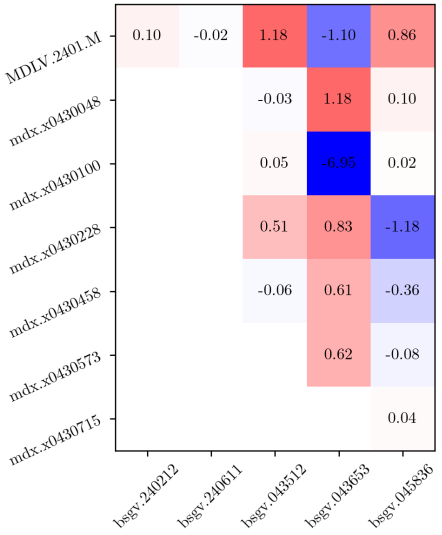

Broken Vacuum window



QTL Magnetic field measurements



BSGH.043836 During Quad scan



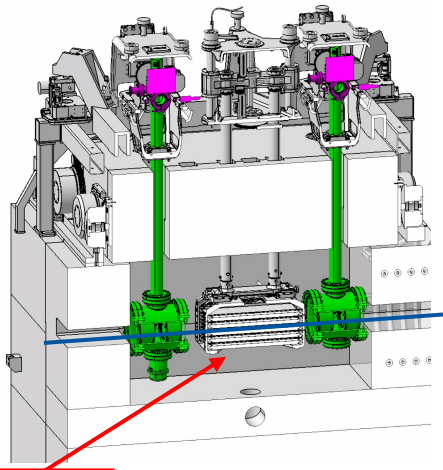
Error on KR R12

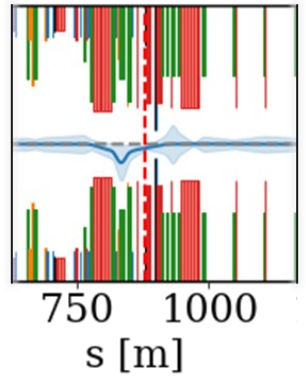
T4 Vertical Bypass

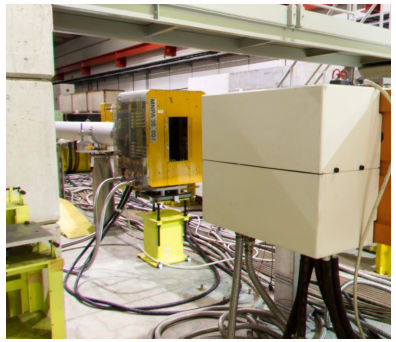
- **Vertical bump around T4 target for HI-ECN3**
  - Protect T4 target
  - Improve transmission through T4 region
  - Reduce losses downstream
- **New dipole kicker installed in YETS**
  - Temporary cabling and cooling
  - Installed in air → connect to vacuum in LS3
  - EDMS 2797504
- **Tested in MDs in 2023**
  - 300 mm Be Target (λ_I = 421 mm) → ~48 % survival
- **Results suggest a possible working point**
  - Successfully bumped beam → - 4 mm – + 3 mm
  - Bump not fully closed → could be due to optics issues
  - Intensity changed on T10
    - Interactions in target
    - Issues with BSI readings (see Maarten Van Dijk)
  - Beam loss is asymmetric at BLM 043

- 3 mm is possible operating point

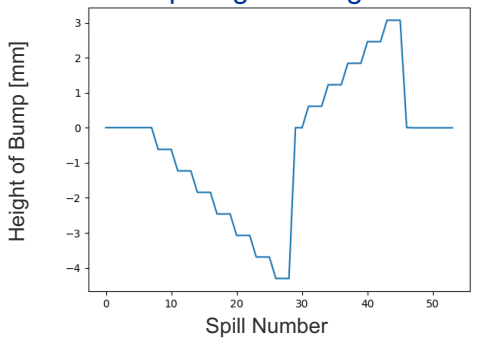
T4 target assembly



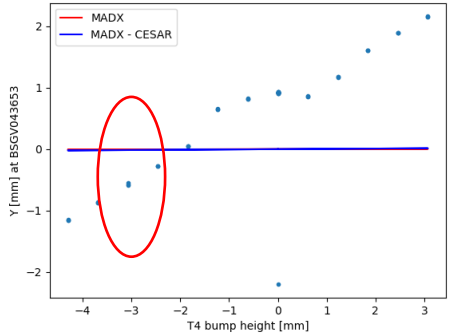




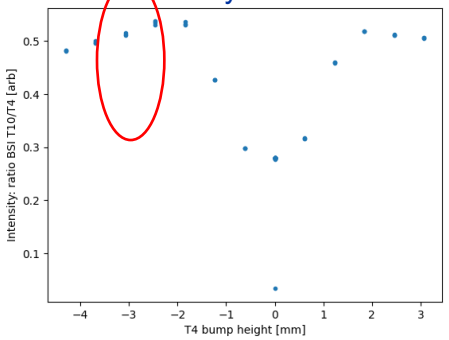
Bump height during test



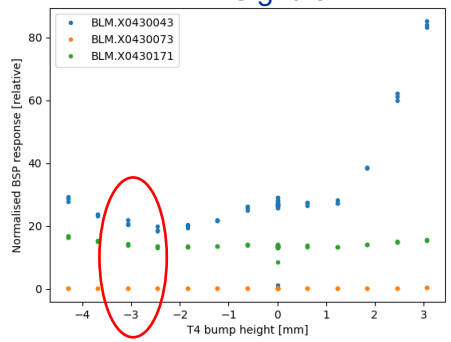
Displacement on BSG043653



Intensity T10 / T4



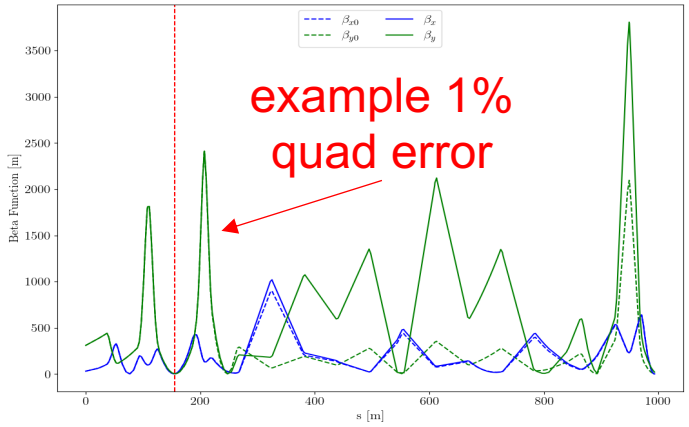
BLM Signals

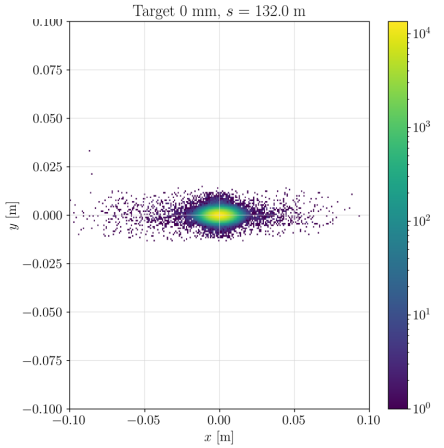


Future Optics Studies

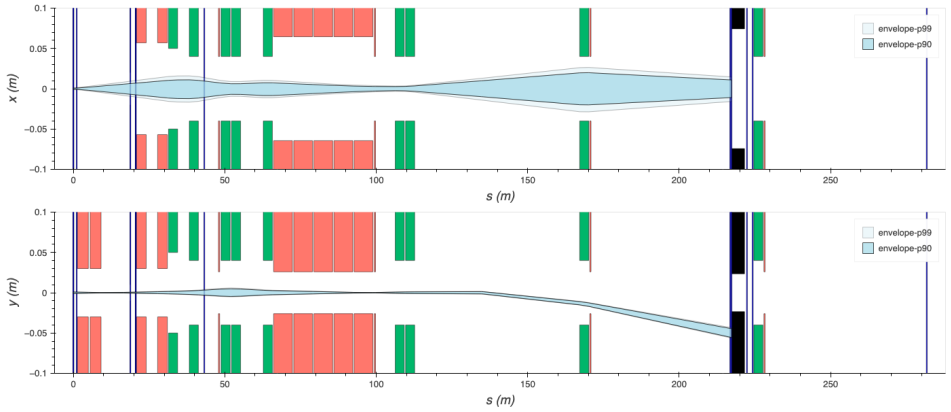
- **Implement new QNL and QTL transfer function in LSA**
  - Initial check during commissioning
- **Re-analyse optics with new TF**
  - Transfer lines may require re-tuning
  - Repeat KR study and quad scan
  - May require MD time
- **Design new TT24-P42 optics for new constraints**
  - Reduce sensitivity
  - Reduce impact of beam scattering
  - Beam collimation
- **Dedicated beam dump optics**
  - Location and performance to be evaluated
- **Implement optics in MDs**
- **Vital for success of HI-ECN3**
  - Match optics
  - Reducing beam losses

Present TT24-P42 optics





Simulated beam profile



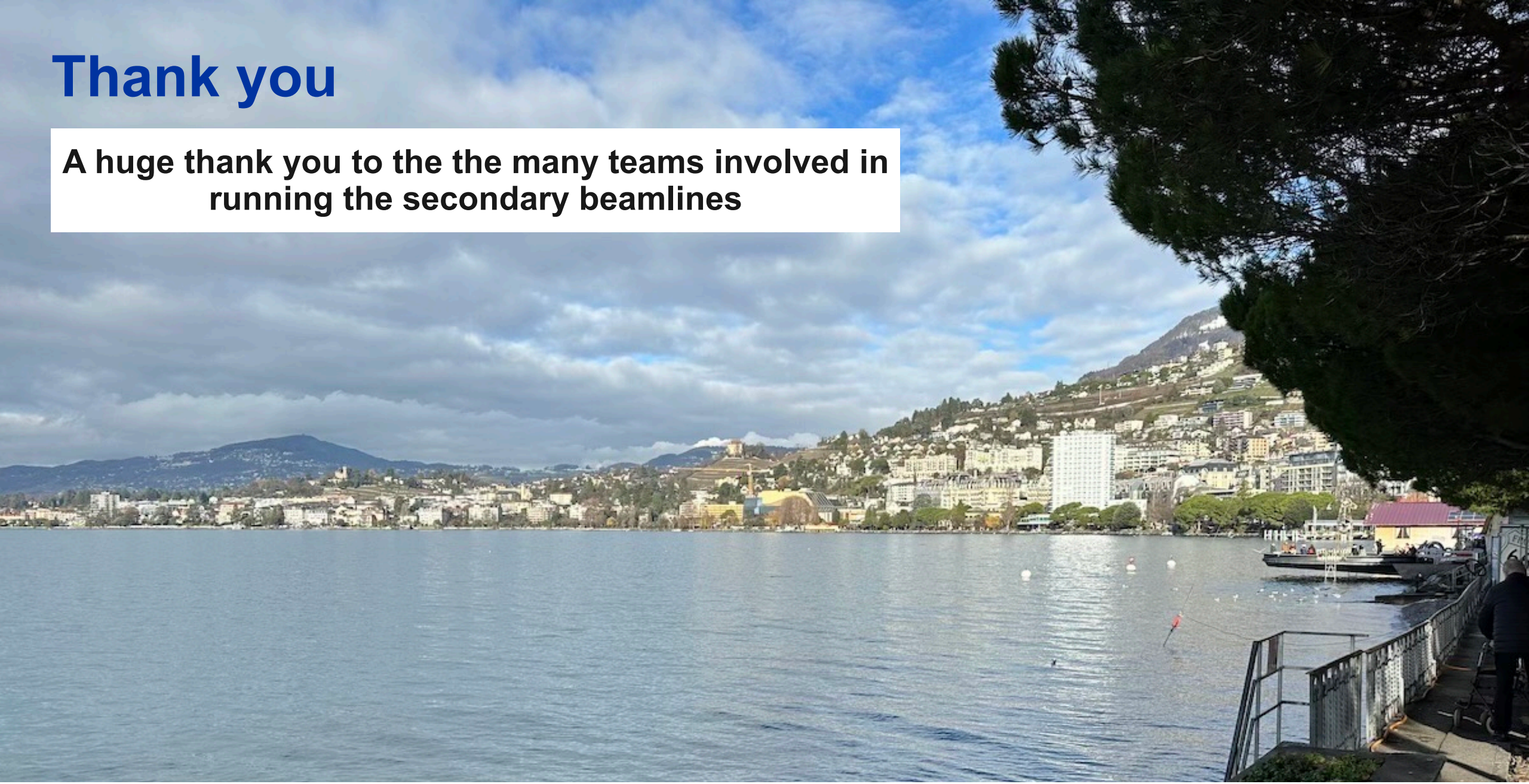
Beam dump optics

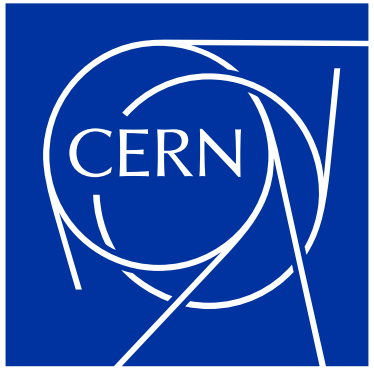
Summary

- **East Area**
  - roof water ingress needs to be properly mitigated
  - BHZ027 magnet would benefit from an additional energy storage unit
- **M2 vacuum request for future Drell-Yan resources need to be approved following the budget estimation in 2024**
- **Ion beam fluctuations (intensity and trajectory) need further investigation**
- **H2/H4 moving beam issue needs time during commissioning to be understood**
- **Electron beams are back in H8/H6 !**
  - realignment of H6 / H8 in YETS → commissioning will be thorough and also re-confirm H6 electron beams
- **P42**
  - radiation levels significantly reduced
  - optics being studied
  - MD time important in realising HI-ECN3

Thank you

A huge thank you to the the many teams involved in running the secondary beamlines





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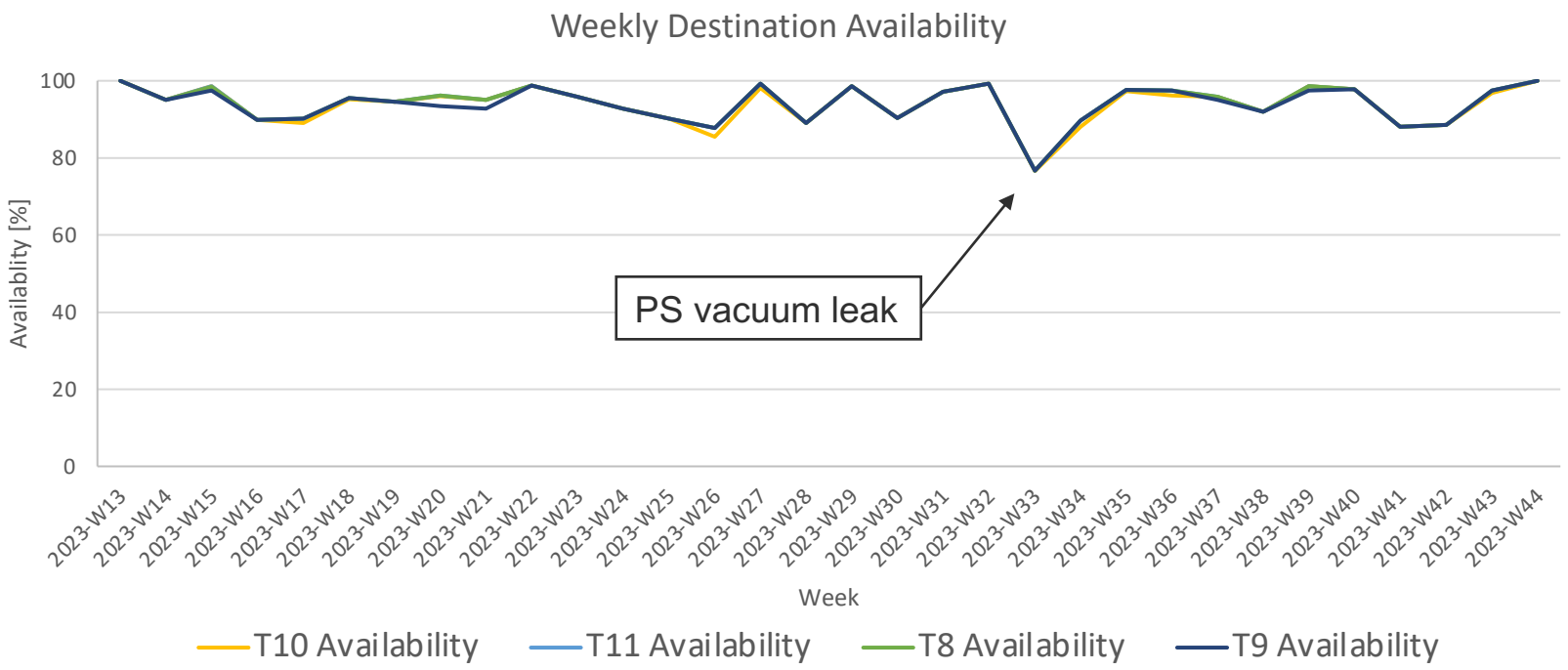
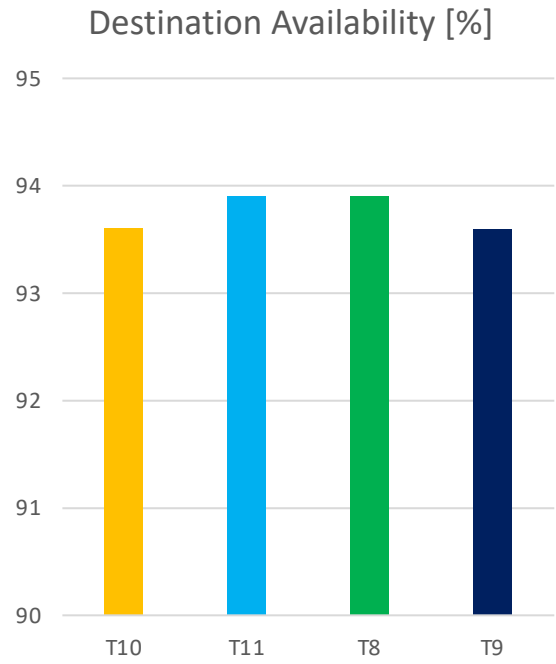
Backup

East Area Availabilities

- **Very good availability** for all beam lines of the East Area, also thanks to the very good PS availability.
- **No major issues** in the secondary beam lines and experimental area infrastructure.





North Area Availabilities

- **Overall, there was good availability for all beam lines of the North Area, and also thanks to the good SPS availability.**
- **A few major issues in the secondary beam lines and the experimental area infrastructure led to less availability in certain weeks**
  - top 3 issues: CEDAR issues during the AMBER p-bar run; cryogenics issues with the NA61 spectrometer magnets; and the MSN fire, affecting the overall NA availability during the ion run.