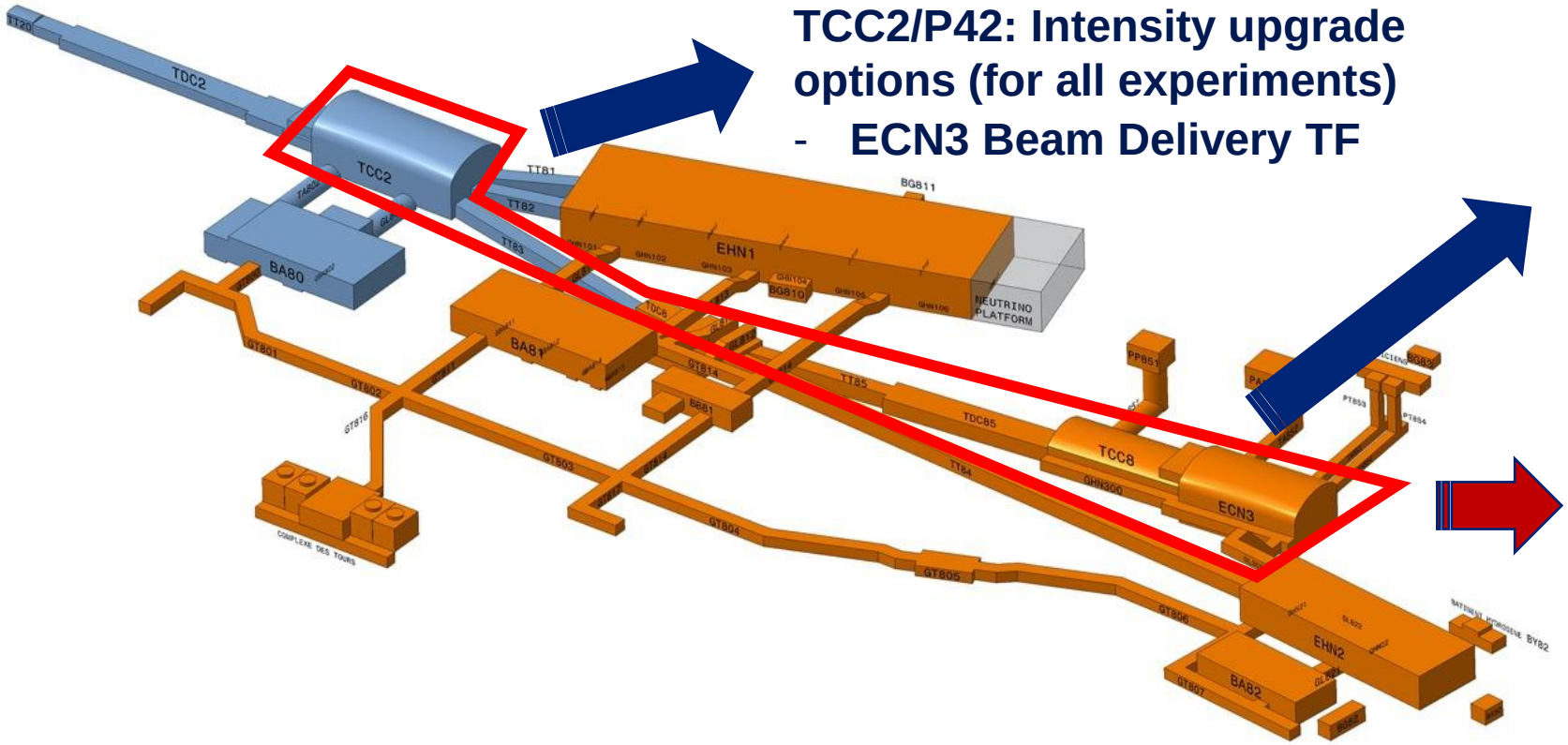
Physics Beyond Colliders Annual Workshop

7 - 9th November 2022

M. Brugger, M.A. Fraser on behalf of the PBC ECN3 Task Force team

NA-CONS -> ECN3 Intensity Upgrade

Consolidation Phase 1 (funded):
2019 – 2027: primary areas, BA80 & beamlines towards EHN1 & TDC8



TCC2/P42: Intensity upgrade options (for all experiments)
- **ECN3 Beam Delivery TF**

TCC8/ECN3: Experiment specific:
- **BDF/SHiP WG**
- **CBWG**

Beam Areas concerned with the upgrade of ECN3 to a high intensity facility

Consolidation Phase 2 (not yet funded):
2028 – 2033: BA81, BA82, EHN1, EHN2 & associated beamlines

See Y. Kadi's talk on for implications for NACONS

Who are we ?

6 months in, excellent progress and no showstoppers identified!

https://indico.cern.ch/category/15293

We are a small team, solution focused, trusting expert opinion:

Co-Chairs: M. Brugger (PBC-CB WG, BE/EA), M. Fraser (PBC-BDF WG, SLAWG, SY/

Scientific Secretary: Rebecca Ramjiawan (PBC Fellow, SY/ABT)

Core-team representatives:

- **NA-CONS:** Y. Kadi (PL), R. Folch (Engineering), T. Zickler (Powering)
- **TT20/P42 beam studies:** Y. Dutheil, F. Velotti (SY/ABT, BE/OP)
- **TCC2/P42 and impact on secondary beam studies:** J. Bernhard, M. van Dijk (BE/EA)
- **Target stations, TAXs design:** M. Calviani, F. Sanchez-Galan, L. Salvatore Esposito, J-L. Grenar
- **Radiation Protection:** C. Ahdida, E. Nowak, H. Vincke (HSE/RP)

Informed in all communications, as well as required for specific subjects:

- G. Arduini (PBC), V. Kain (BE/OP), P. Schwarz (TE/MSC), F. Roncarolo (EABIWG, SY/BI), H. Bart BE/OP, SY/ABT),), I. Josifovic (SY/EPC), C. Pasquino, L. Krzempek (TE/VSC, BE/EA), P. Bestma Lafarge (EN/HE), F. Galleazzi + M. Lazzaroni (EN/ACE), Y. Body, S. Deleval (EN/CV), K. Balazs (S

Mandate: https://edms.cern.ch/document/2790130/1

Technical highlights/activities

- **Intensity scenarios and proton sharing**

- **Beam delivery studies:**
  - TT20 optics discrepancy (first pointed out during start-up post-LS2)
  - **Proof-of-principle tests planned for early 2023: sending high intensity beams through TCC2**
    - T6 bypass option discarded, removal of P6 magnets planned for YETS22/23
    - Vertical T4 bypass (i) magnetic bump and (ii) target mechanical actuation
  - Understanding present radioprotection limitations in beam transfer from TCC2 to TCC8 in P42
  - Understanding measurement calibration of primary proton beam intensity

- **Understanding hardware limits:**
  - FLUKA / thermomechanical studies of Beam Intercepting Devices
  - Check NACONS compatibility with PBC (scope and schedule), assess needs for upgrade and costing

- **Assessing technical requirements for experiment infrastructure needs (via NACONS)**
  - Input received from BDF/SHiP and CB WG for impact on services and costing Civil Engineering studies

Intensity scenarios and proton sharing (i)

- **Agreed a baseline set of scenarios for all experiments:**
  - **Shared:** similar to NA operation today (splitting of primary beam) with increased intensity to ECN3
  - **Dedicated:** additional NA user, no splitting and transfer direct to ECN3 via T4 bypass

Scenario	Cycle/Spill Length (frequ.) [s]	Shared NA or Dedicated spill	Long-term SPS Extracted Intensity SPS-TT20 [p/spill]	Intensity T4/TCC8 Targets [p.o.t./spill]	Annual Intensity T4/TCC8 p.o.t./year	Comments
Today achievable -> Commissioning Run (1-2y depending on Exp.?)	10.8 / 4.8 (3000Spill/d)	S	3-3.5x10^{13}	1.3-1.5x10^{13}	0.8-0.9x10^{19}	Limited by splitter losses and T4 target/TAX
Run 4 scenario after commissioning	10.8 / 4.8 (3000Spill/d)	S	up to 4x10^{13}	~2 x10^{13}	~1.2x10^{19}	Requires reduction of the splitter losses by a factor 2-3 and possible upgrade of the T4 target/TAX station
	7.2 / 1.2 (3-6000Spill/d)	D	~2.x x10^{13}	~2x10^{13}	~1-2x10^{19}	acceptable with limited modifications, then staged for the final intensity upgrade
Run 5 scenario	10.8 / 4.8 (3000Spill/d)	S	up to 4x10^{13}	~2 x10^{13}	~1.2x10^{19}	
	7.2 / 1.2 (6000Spill/d)	D	~4 x10^{13} (5x10^{13})	~4x10^{13}	~4x10^{19}	

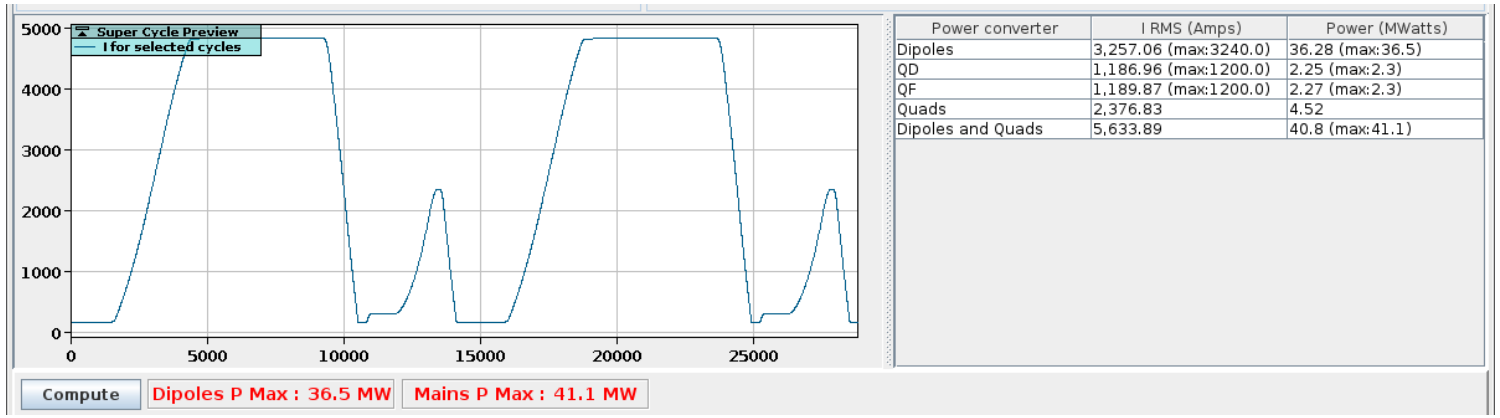
***Limitations:**

- todays intensity limit the T4/TAX (~1.5E13, tbc and hole deformation to be considered)
- splitting losses and respective RP limits, also downstream TCC2
- incident/accident losses/scenarios (bypass of target/TAX/RP)

*200 days/yr, assumed 80% availability, transmission and intensity under study (splitting, transmission TCC2 to TCC8)

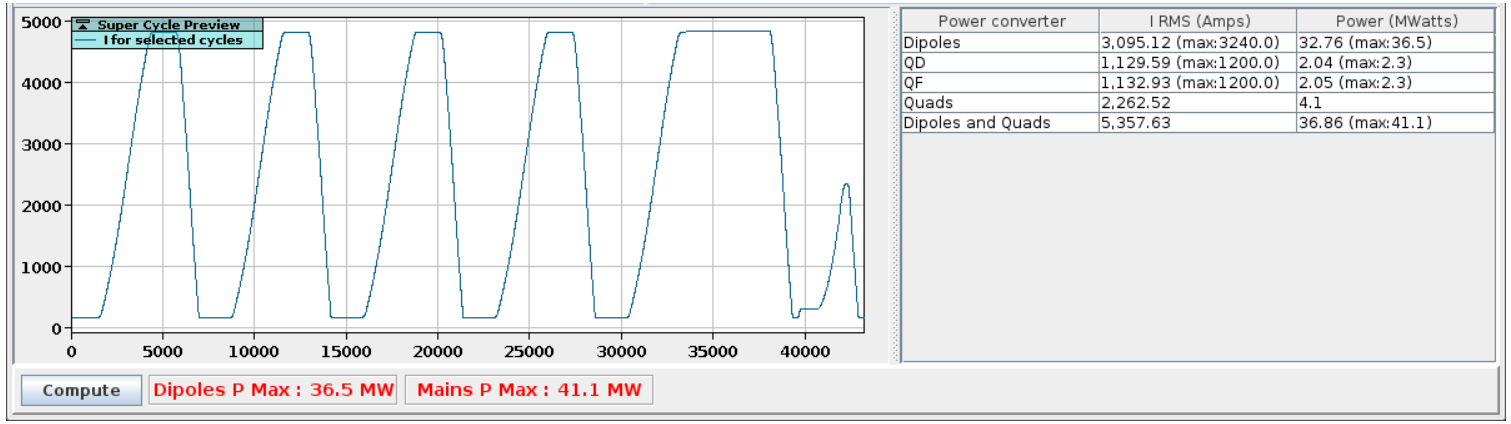
Intensity scenarios and proton sharing (ii)

- **Proton sharing studies to be updated [**CERN-ACC-NOTE-2018-0082**] with latest information:**
  - **Shared:** similar to NA operation today (splitting of primary beam) with increased intensity to ECN3



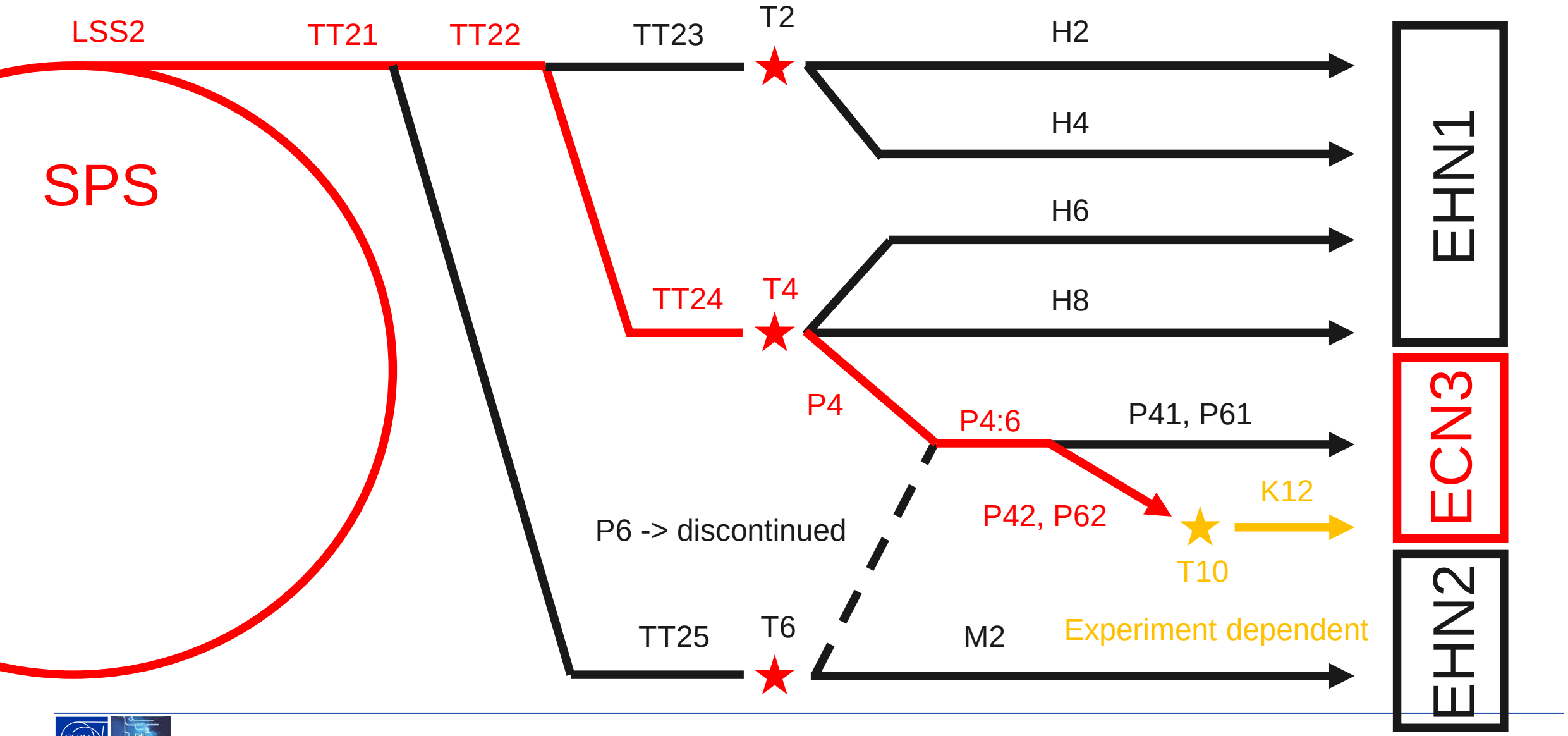
Power converter	I RMS (Amps)	Power (MWatts)
Dipoles	3,257.06 (max:3240.0)	36.28 (max:36.5)
QD	1,186.96 (max:1200.0)	2.25 (max:2.3)
QF	1,189.87 (max:1200.0)	2.27 (max:2.3)
Quads	2,376.83	4.52
Dipoles and Quads	5,633.89	40.8 (max:41.1)

  - **Dedicated:** additional NA user, no splitting and transfer direct to ECN3 via T4 bypass



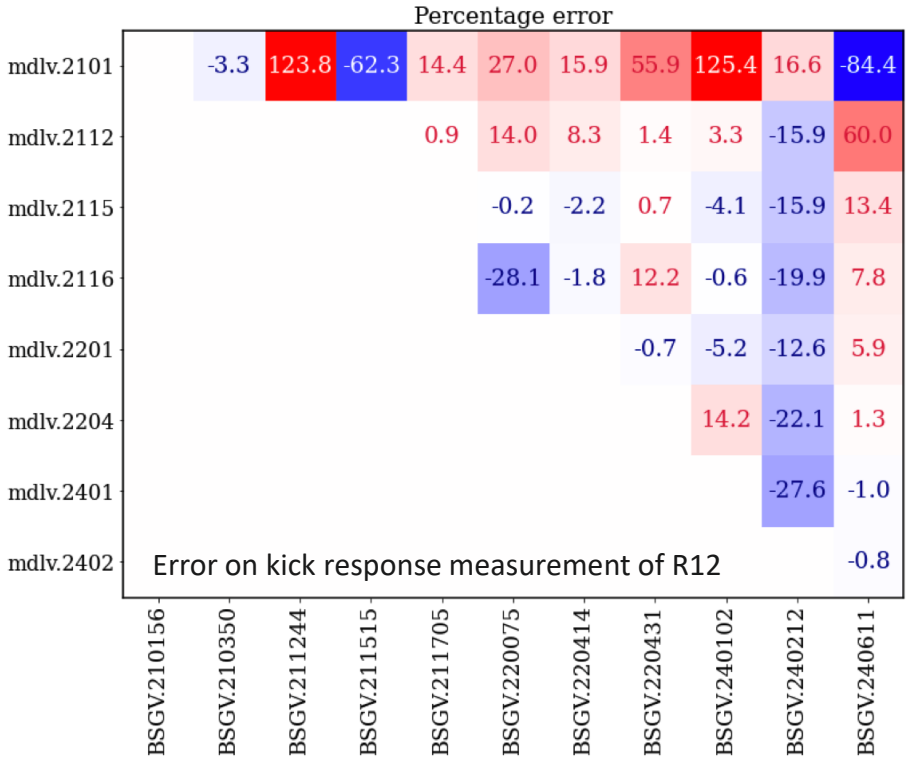
Power converter	I RMS (Amps)	Power (MWatts)
Dipoles	3,095.12 (max:3240.0)	32.76 (max:36.5)
QD	1,129.59 (max:1200.0)	2.04 (max:2.3)
QF	1,132.93 (max:1200.0)	2.05 (max:2.3)
Quads	2,262.52	4.1
Dipoles and Quads	5,357.63	36.86 (max:41.1)

Dedicated ECN3 cycle



TT20 optics studies

- **Discrepancy between TT20 optics model and measurement still not understood:**
  - A long standing issue (probably) dating back for decades
  - Disassembled and checked suspect magnet chain upstream in TT20 during ITS2: **no problem found**
  - Consistent with systematic errors on quad strength of a few % (possibly from transfer function)



- **Investigations ongoing:**
  - Limited beam instrumentation available
  - **Magnetic measurements planned with NACONS**
  - Try an iterative empirical approach and adapt model to measurements: to be seen if this is good enough.

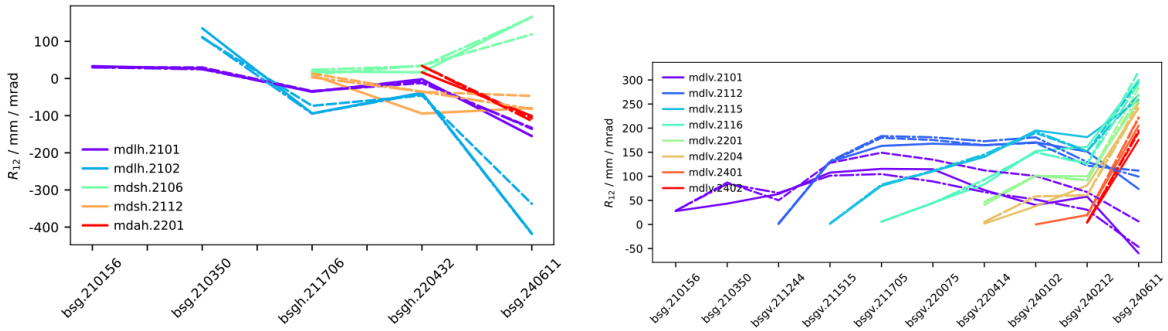
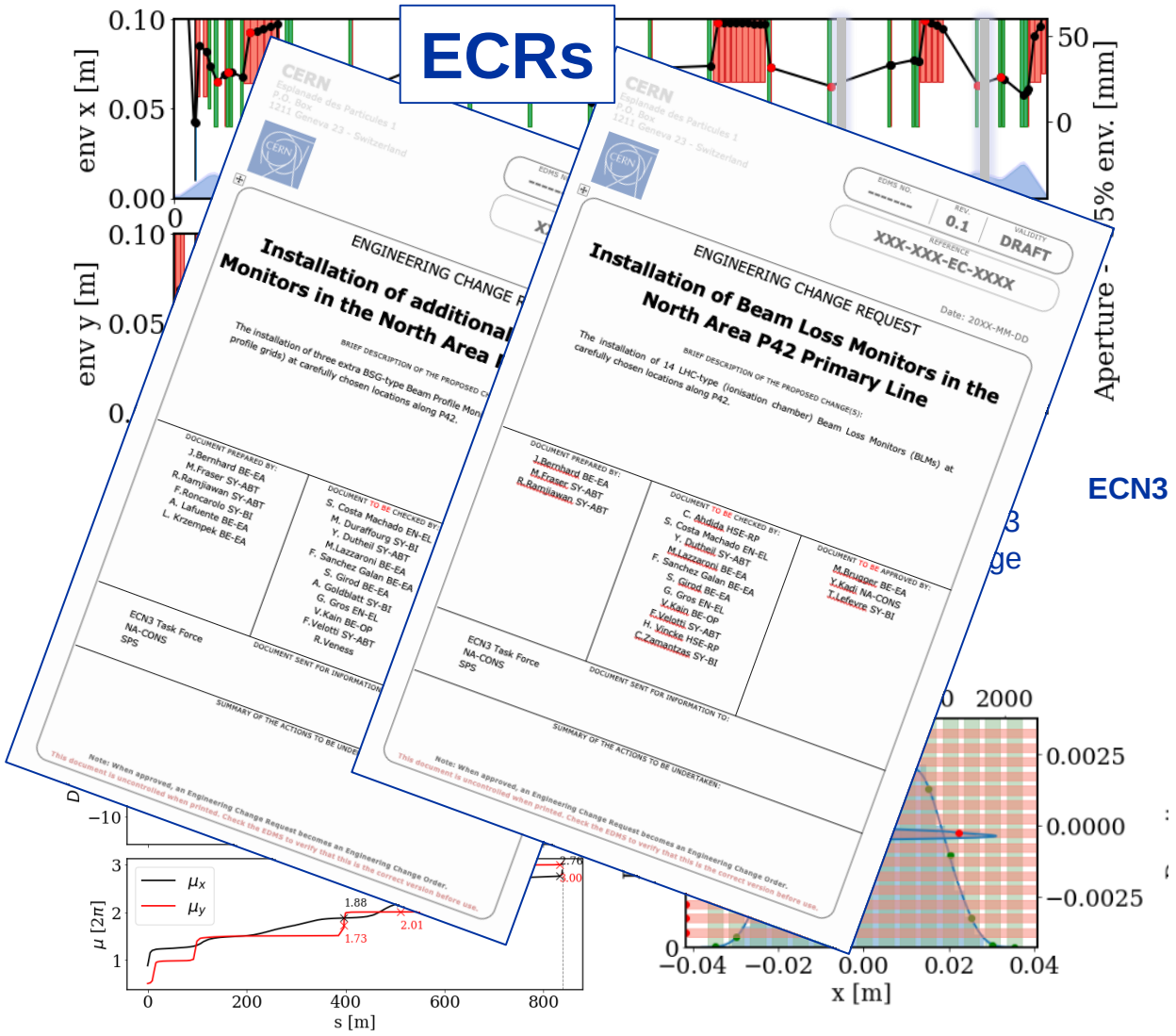


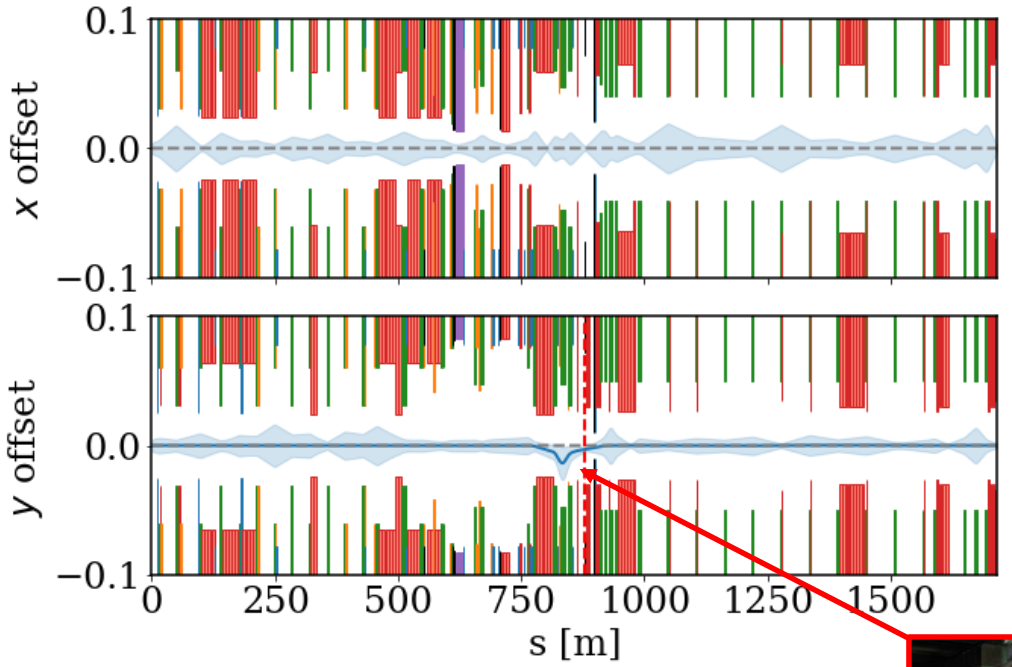
Figure 8: Model and data changing QNL and QTL by 1 and 3.5% respectively.

YETS22/23 P42 equipment installation

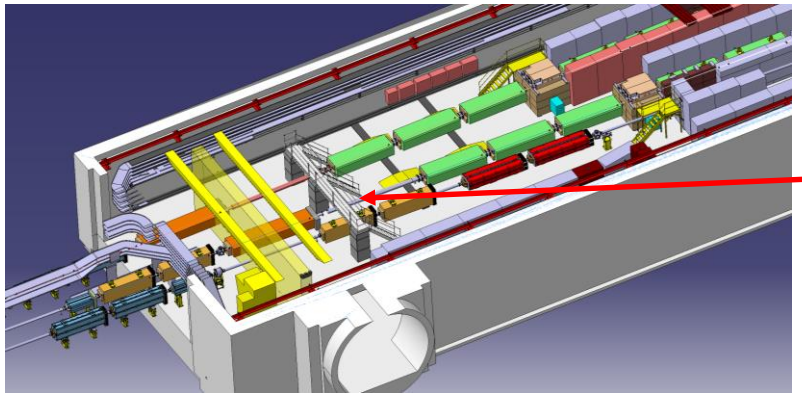
- **Beam Loss Monitors:**
  - 14 monitors chosen at critical locations
  - Include EHN1 ramp and ECN3 bridge locations (RP)
  - Compatible with future installation of 40 monitors
- **Beam Profile Monitors:**
  - 3 additional monitors advanced from NACONS
  - To perform optics and dispersion measurements
  - Vacuum solution found
- **CBH50 cable procurement was critical for YETS22/23 installation**
- **Passive optical fibre (dosimeter) at critical locations along P42:**
  - Installation planned after commissioning is completed with short accesses needed



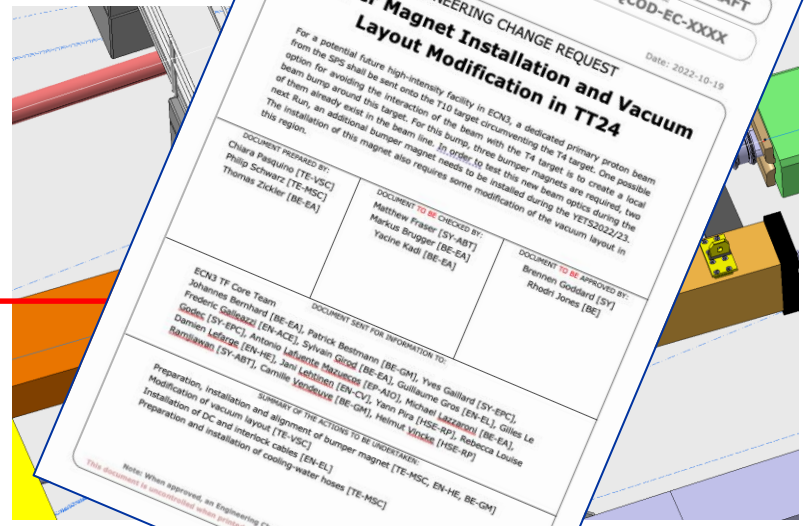
YETS22/23 TCC2 equipment installation



- **Vertical by-pass of T4 target: magnetic bump?**
  - New optics design with bump to be tested
- **Solution found for tests in 2023:**
  - Integration and vacuum layout solution
  - Non-PPM magnet (dedicated MD's only)
  - Magnet and power convert emporary cabling for power and coo
  - ECR being prepared



ECR



ENGINEERING CHANGE REQUEST

Bumper Magnet Installation and Vacuum Layout Modification in TT24

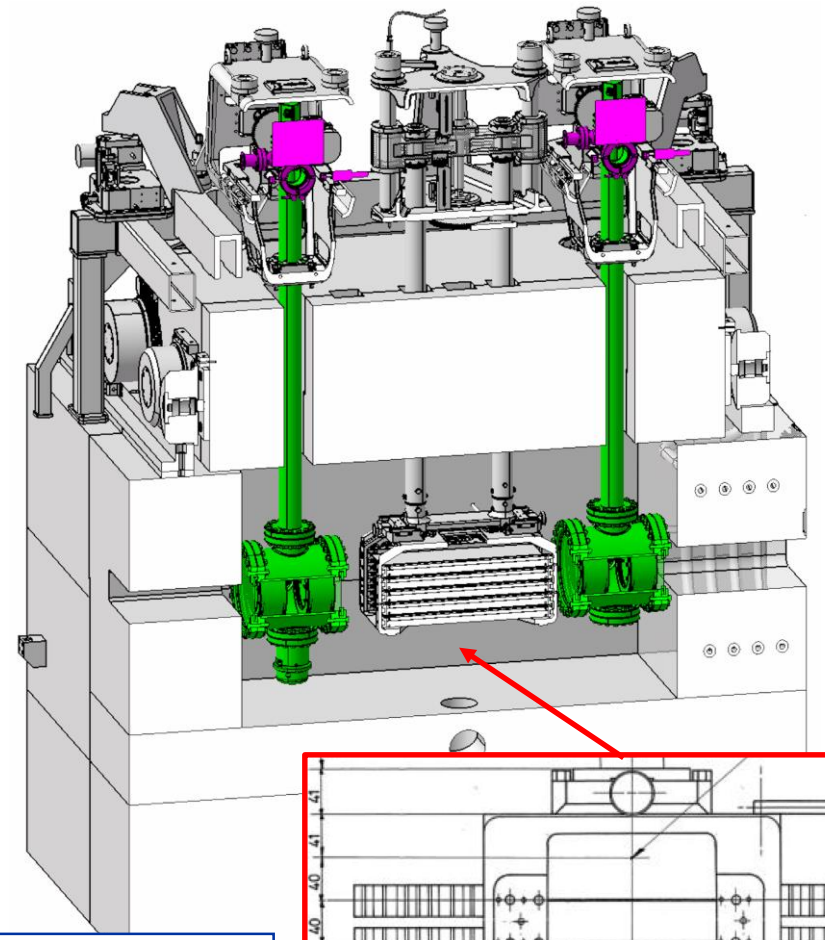
SPSX-EQCOD-EC-XXXX

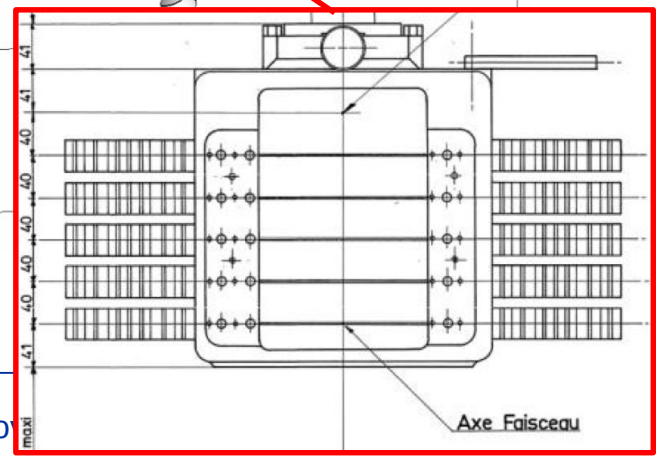
DRAFT

Vertical T4 bypass: target actuation?

- **Plan of action for backup solution:**
  - Evaluation of engineering limits of current movement systems
  - Feasibility studies for a rapid (40 mm/s) (beam in between 2 plates within 0.5s) and high-duty (O(10)M) cycling assembly to allow target switch within cycles of the SPS SC

- **Prototype test timeline:**
  - New gear box ordered and installed
  - Mechanical assembly of gear box on motor completed
  - Installation of new motor on target box completed
  - Test with a gradual approach ongoing
  - Cycling from W44 onwards

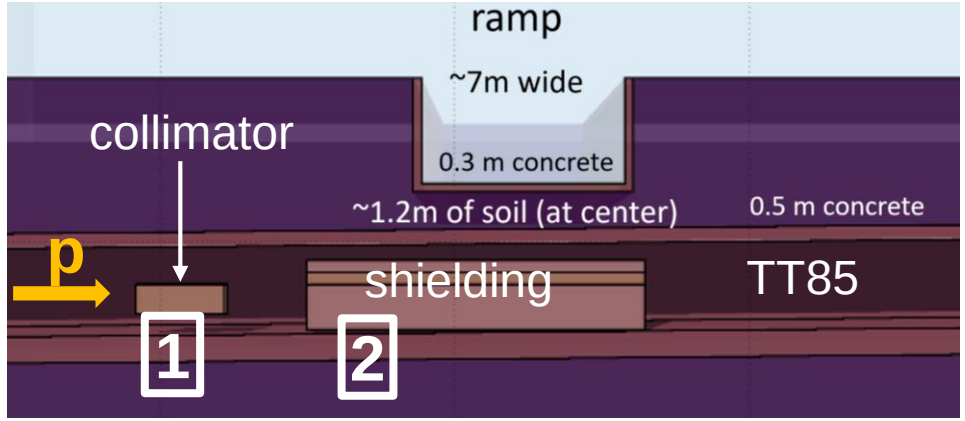




40 mm interpolate distance
2 mm thick
160 mm width
40-500 mm length

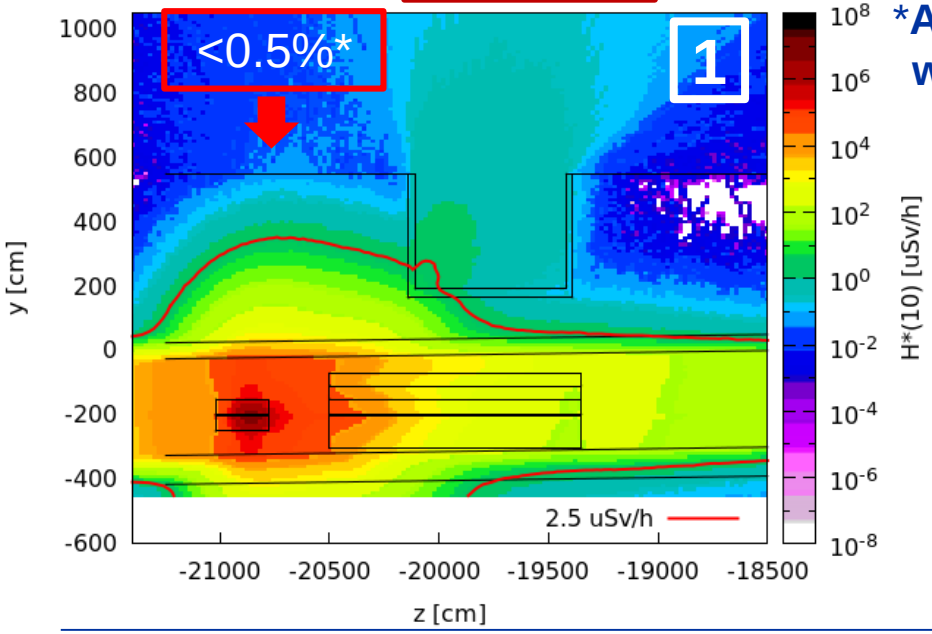
P42 RP FLUKA studies (i)

Beam loss study - impact
on the radiation levels **at EHN1 ramp**



Loss in the collimator

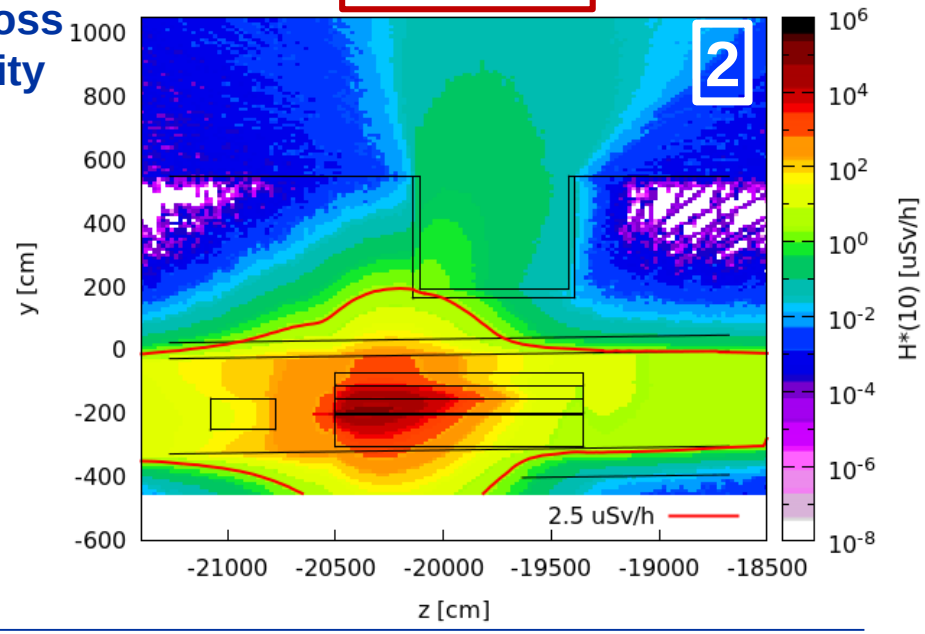
1e-2%*



***Acceptable percentage of beam loss wrt. current nominal NA62 intensity (2×10^{11} p/s)**

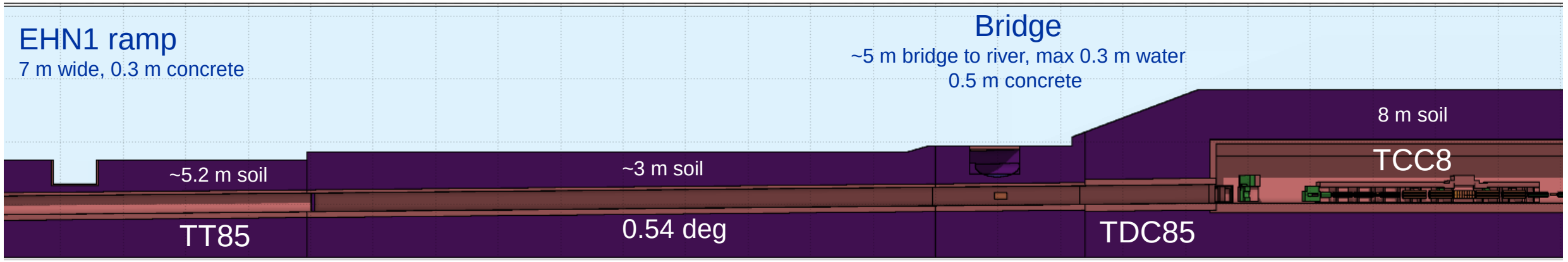
Loss in the shielding

1e-3%*



P42 RP FLUKA studies (ii)

- **P42 and TCC8 implemented in FLUKA showing challenging prompt beam loss rates:**



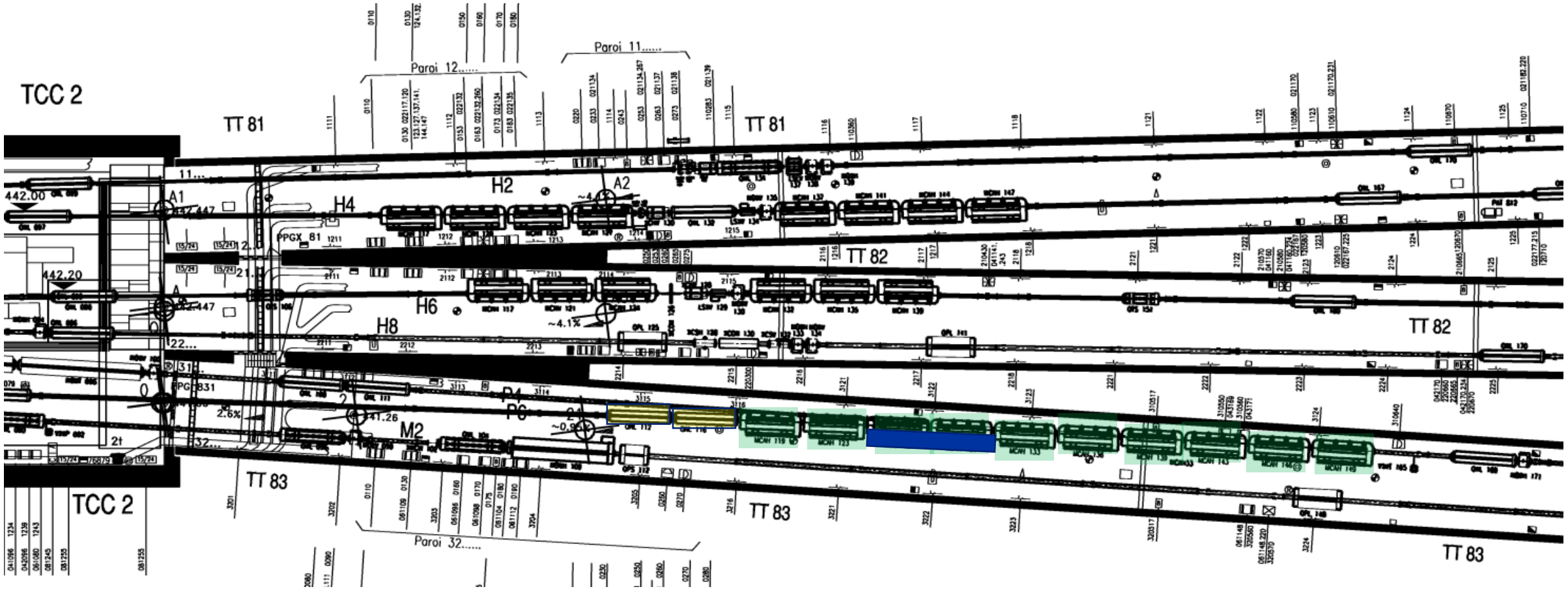
H*(10) at ramp/bridge for different accident scenarios per 1 lost spill and % losses complying with the 2.5 µSv/h limit

	@RAMP (loss at collimator)		@RAMP (loss below)		@Bridge (loss below)	
	H*(10) /spill (µSv)	% of beam lost to comply with 2.5 µSv/h	H*(10) /spill (µSv)	% of beam lost to comply with 2.5 µSv/h	H*(10) /spill (µSv)	% of beam lost to comply with 2.5 µSv/h
NA62	100	5e-3%	300	1e-3%	200	2e-3%
HIKE/ SHADOWS	350	1.4e-3%	1050	2.8e-4%	700	5.7e-4%
KLEVER	1400	7e-4%	4200	1.4e-4%	2800	2.8e-4%
BDF	1400	3.57e-4%	4200	7e-5%	2800	1.4e-4%

P42 -> EHN1 Ramp and ECN3 Bridge RP limitation

- **Detailed RP measurements (online, survey, mobile monitors, etc.):**
  - Problem identified -> mitigation measures were already required today !
- **Major improvements already achieved:**
  - Critical (accessible) area fenced off and trench shielding improved
  - P42 (and TT20) monitors found in continuous IN position -> moved OUT
  - P42 vacuum degradation check (first trial performed, to be performed at end of run)
- **P42 re-alignment and installation of BLMs agreed upon for this YETS**
- **Detailed FLUKA model with beam line prepared and further shielding improvements currently studied:** (i) maze around present B6 position, (ii) improved shielding close to ramp (to be confirmed by FLUKA calculations)
- **Option of additional collimator (horizontal between C3/C5):**
  - To decided if we go forward in this YETS (ECR in preparation)
- **Long-term:** EHN1 ramp modification to supervised area, improved ECN3 bridge shielding

YETS22/23 equipment removal: P6 magnets



Removal of present aperture bottleneck:

2 QNL Magnets to be removed (in yellow) → still need to be confirmed

10 MCAH Magnets to be removed (in green)

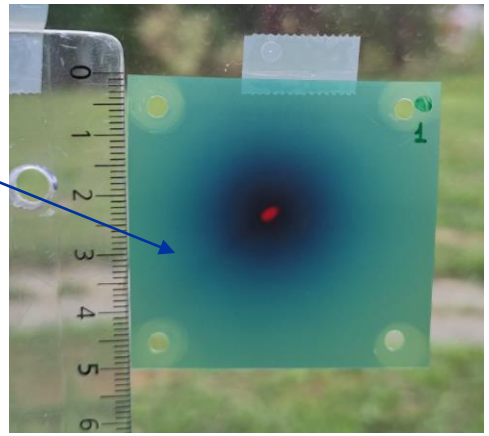
Installation of new shielding wall in between M2 and P42 lines (in blue)

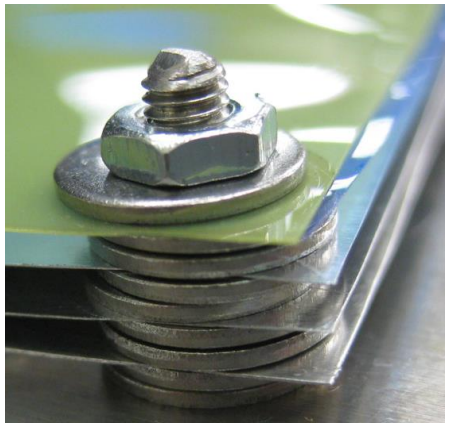
Possible shielding location

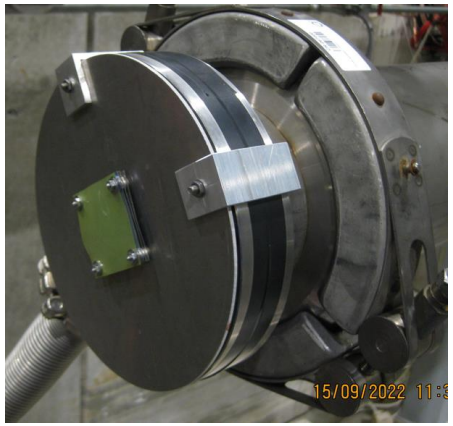
Calibration of beam intensity at T10

- **Activation Al foil studies vs BSI (Secondary Emission Monitor, SEM) at T10**
  - Two results for the two interaction cross-section values (1 unit = 10^{11} POT)
  - SEM measured value 31.3 (error to be evaluated)
  - CERN value 31.5 +/- 1.0 (calibration factor 1.008 +/- 0.033) (not including SEM error)
  - Fermilab value 34.0 +/- 2.6 (calibration factor 1.087 +/- 0.083) (not including SEM error)

- Significant halo observed on GAFchromic films
- Source of halo appears to be scattering on BI devices: retracting them reduced RP dose levels by factor ~30 !





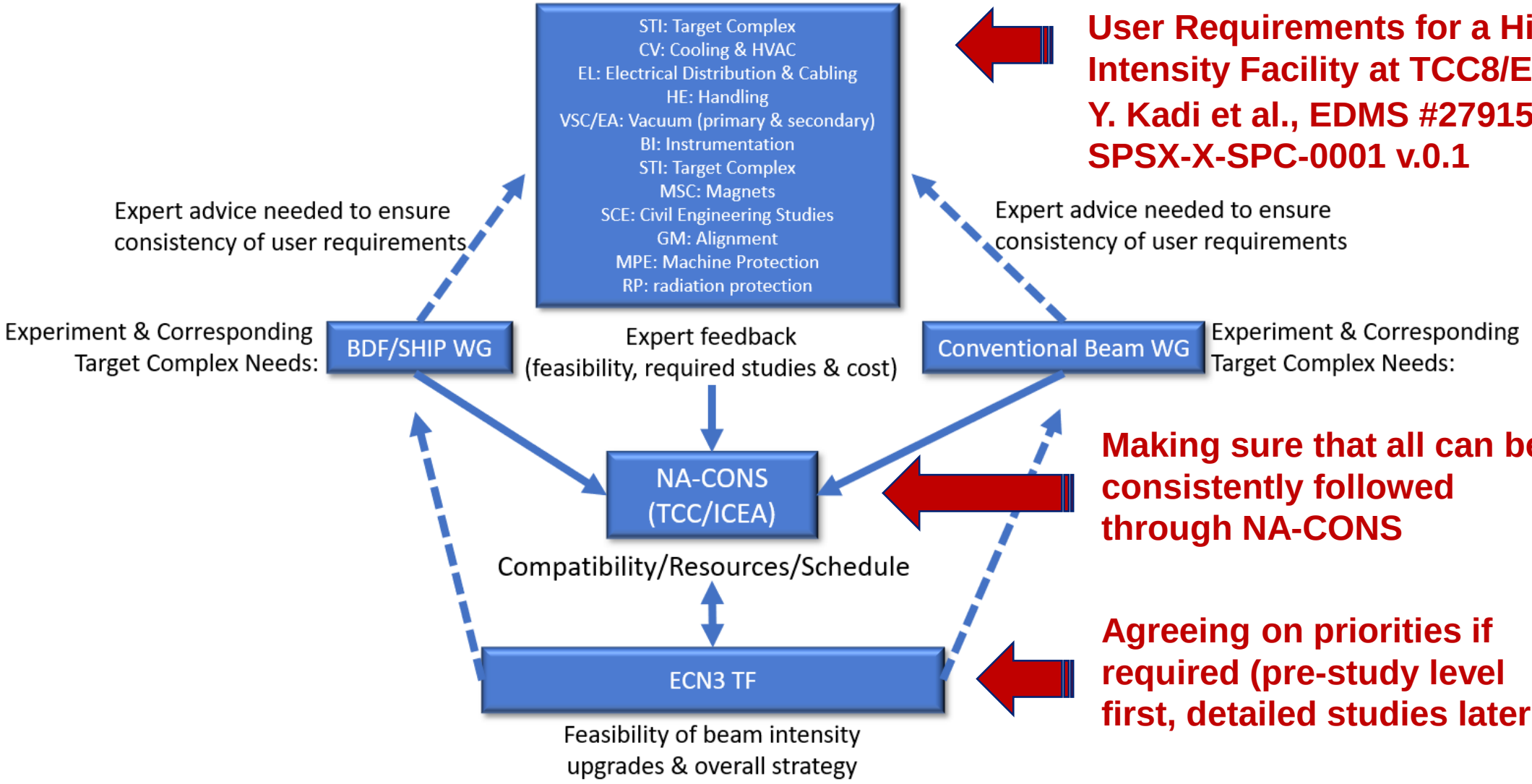


- **Procedure repeated with high purity Al abd Cu foils and analysis ongoing**
  - To be repeated at T4 (also T2, T6) early in 2023, synergy with East Area studies with fBCT
  - Long term calibration strategy to be agreed and developed with SY/BI

Beam Intercepting Devices

- **A range of devices being studied to assess present scope of NACONS and potential need for upgrade:**
  - **Transfer Line External Dump (TED):** already scoped in NACONS, optimised design on-going
  - **Transfer Line Beam Stopper (TBSE):** unlikely that modification needed
  - **Transfer Line Collimator for Splitter (TCSC):** only CONS of plug-in table scoped to improve water cooling handling, upgrade needed to reduce beam loss (crystal shadowing) and reduce ALARA impact (low-Z materials etc.)
  - **Primary Targets**: re-evaluation of intensity limitations on the Be plates (FLUKA + ANSYS), request to submitted to NACONS for consolidation of Target Box and TBI (remember T2 failure this year)
  - **TAX:** intensity limits unknown, build FLUKA + ANSYS model with upstream target, assessment of limits and upgrade scope for PBC, joint STI/EA working group launched for CONS & upgrade of devices

Critical Equipment/Service Groups & WGs/TF



User Requirements for a High Intensity Facility at TCC8/ECN3
Y. Kadi et al., EDMS #2791543, SPSX-X-SPC-0001 v.0.1

Making sure that all can be consistently followed through NA-CONS

Agreeing on priorities if required (pre-study level first, detailed studies later!)

ECN3 TF TimeLine -> NA-CONS/MTP

Deliverables/Targets

- **ECN3 Beam Delivery Task Force (December 2022)**
  - First draft document on ‘physics agnostic’ feasibility for high intensity facility in ECN3 (with preliminary cost envelope)
- **IEFC (January 2023)**
  - To scrutinise outcome of feasibility study on facility side
- **Scope, Cost & Schedule Review for NA-CONS (31 January 2023)**
  - Final input to ECN3 Task Force on additional needs for the high intensity upgrade
- **MTP 2023 Iteration**
  - ATS to discuss an upgrade plan for high intensity beam delivery to ECN3
- **PBC draft document on ECN3 post-LS3 options to SPSC and Management (June 2023)**

SPSC in Parallel

- **First:** a recommendation from the SPSC on the need of a high intensity facility in ECN3 (experiment/physics agnostic) to preparations needed upstream of TCC8 to be submitted in time for the MTP exercise next year

- **Second:** a recommendation from the SPSC by the end of 2023 on which experiment(s) will be housed in ECN3

ECN3 Beam Delivery TF Summary

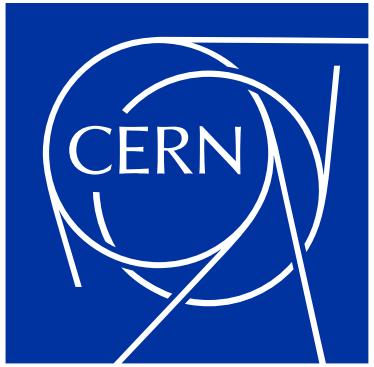
- **No show-stopper has been identified for an increased intensity towards ECN3**

- **Technical challenges remain for further investigation in 2023:**
  - Many activities are planned during the YETS22/23 to facilitate MD studies with beam early 2023
  - Understanding of TT20 optics issue (or mitigation with an adapted optics model)
  - Demonstration of T4 target bump bypass, together with blown-up beam option
  - Validation of target rapid movement as a backup to T4 target bump bypass
  - Demonstration of low-loss transport in P42
  - Evaluation of BIDs in present scope of NACONS and need for upgrade

- **ECN3 Beam Delivery TF will provide input for PBC document on ECN3 post-LS3 options**

- Next year will be an important transition from conceptual, feasibility and technical studies, to a detailed preparation phase in synergy with NACONS – **counting on cont. support from PBC**


THANKS FOR YOUR ATTENTION

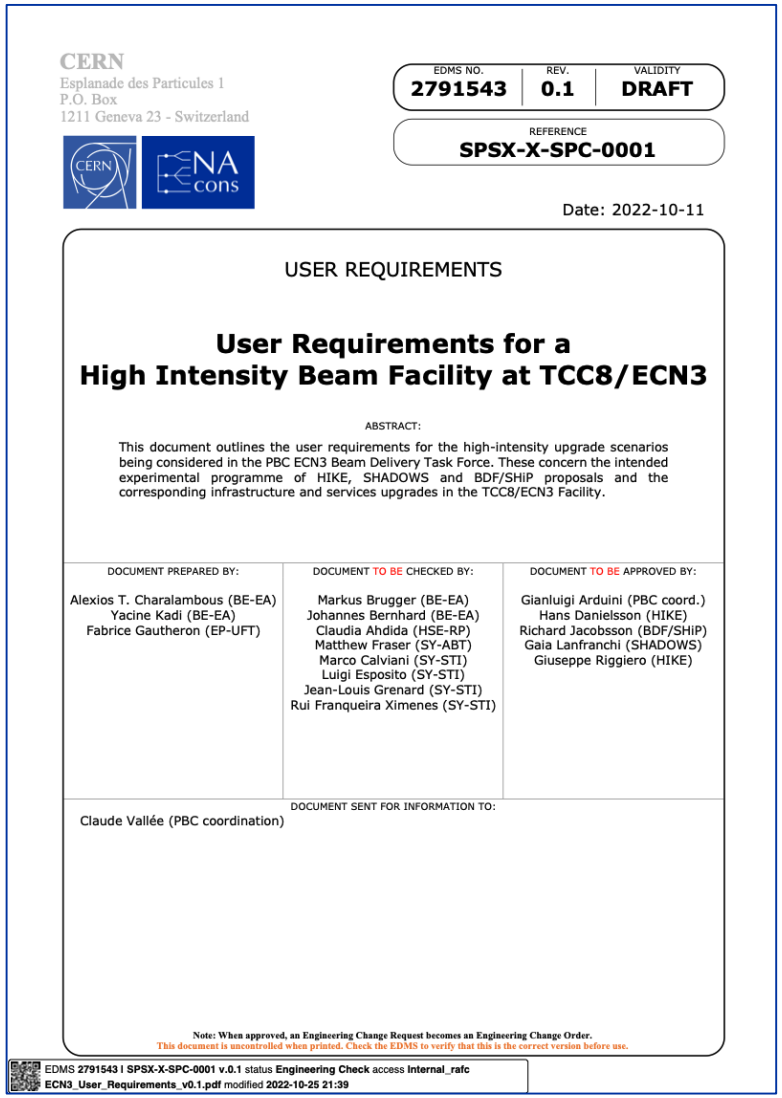


https://pbc.web.cern.ch/

Technical requirements for experiments

- **CERN groups to assess impact on ECN3 experimental requirements on NACONS: cost & schedule (phasing)**
  - Technical input from BDF and CB WG only received recently
  - Compiled by NACONS team:
    - EDMS #2791543, SPSX-X-SPC-0001 v.0.1
  - To be approved by Experiment Representatives and PBC coordination
  - Aiming for a first analysis as input to the NACONS Cost and Schedule Review end of January 2023

- **We thank all CERN groups for their valuable input and support !**
  - Agreed support from all concerned CERN groups based on the current best knowledge/understanding (no detailed studies)



CERN
Esplanade des Particules 1
P.O. Box
1211 Geneva 23 - Switzerland

EDMS NO. 2791543 | REV. 0.1 | VALIDITY DRAFT

REFERENCE SPSX-X-SPC-0001

Date: 2022-10-11

USER REQUIREMENTS

User Requirements for a High Intensity Beam Facility at TCC8/ECN3

ABSTRACT:

This document outlines the user requirements for the high-intensity upgrade scenarios being considered in the PBC ECN3 Beam Delivery Task Force. These concern the intended experimental programme of HIKE, SHADOWS and BDF/SHiP proposals and the corresponding infrastructure and services upgrades in the TCC8/ECN3 Facility.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
Alexios T. Charalambous (BE-EA) Yacine Kadi (BE-EA) Fabrice Gautheron (EP-UFT)	Markus Brugger (BE-EA) Johannes Bernhard (BE-EA) Claudia Ahdida (HSE-RP) Matthew Fraser (SY-ABT) Marco Calviani (SY-STI) Luigi Esposito (SY-STI) Jean-Louis Grenard (SY-STI) Rui Franqueira Ximenes (SY-STI)	Gianluigi Arduini (PBC coord.) Hans Danielsson (HIKE) Richard Jacobsson (BDF/SHiP) Gaia Lanfranchi (SHADOWS) Giuseppe Riggiero (HIKE)

DOCUMENT SENT FOR INFORMATION TO:

Claude Vallée (PBC coordination)

Note: When approved, an Engineering Change Request becomes an Engineering Change Order.
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EDMS 2791543 | SPSX-X-SPC-0001 v.0.1 status Engineering Check access Internal_rafc
ECN3_User_Requirements_v0.1.pdf modified 2022-10-25 21:39

NACONS Infrastructure

- **Important: TCC8/ECN3 separation:** We can assume that work on the experiment side can/will last into Run4

- **Cooling & Ventilation:**
  - In principle OK for Run4 with LS3 baseline: 2nd cooling tower possibly beneficial (cost/resources) to be done at same time
  - ECN3 HVAC to be reviewed
- **Electrical distribution:**
  - Powering requirements: OK from beamline perspective (TBC for 9.6 s SFTPRO option), experiment -> iteration with EL required to see impact on EL-CONS/NA-CONS
  - Cabling: limited on beamline side -> important modifications required on the experiment side
- **Magnets / Power Converters:**
  - Laminated/not-laminated, measurements, cycling/refurbishment needs imply redesign, available spares
  - Including ECN3 is not 'major', P42 would be simpler for BDF/SHiP case, rather similar to today for SHADOWS/HIKE
- **Interlocking**
  - Looks compatible with NA-CONS
- **Access & Safety:**
  - Not a major change of NA-CONS baseline in TCC2/TT2/TCC8 -> ECN3: new shaft likely required, CONS, Safety etc.
- **SCE:**
  - Requiring additional shaft likely in any case, routing of services to be looked at, KLEVER only post LS4