BDF/SHiP at the High Intensity ECN3 (HI-ECN3) Facility

M. Fraser (SY-ABT-BTP)

presenting on behalf of the HI-ECN3 Study Project Team

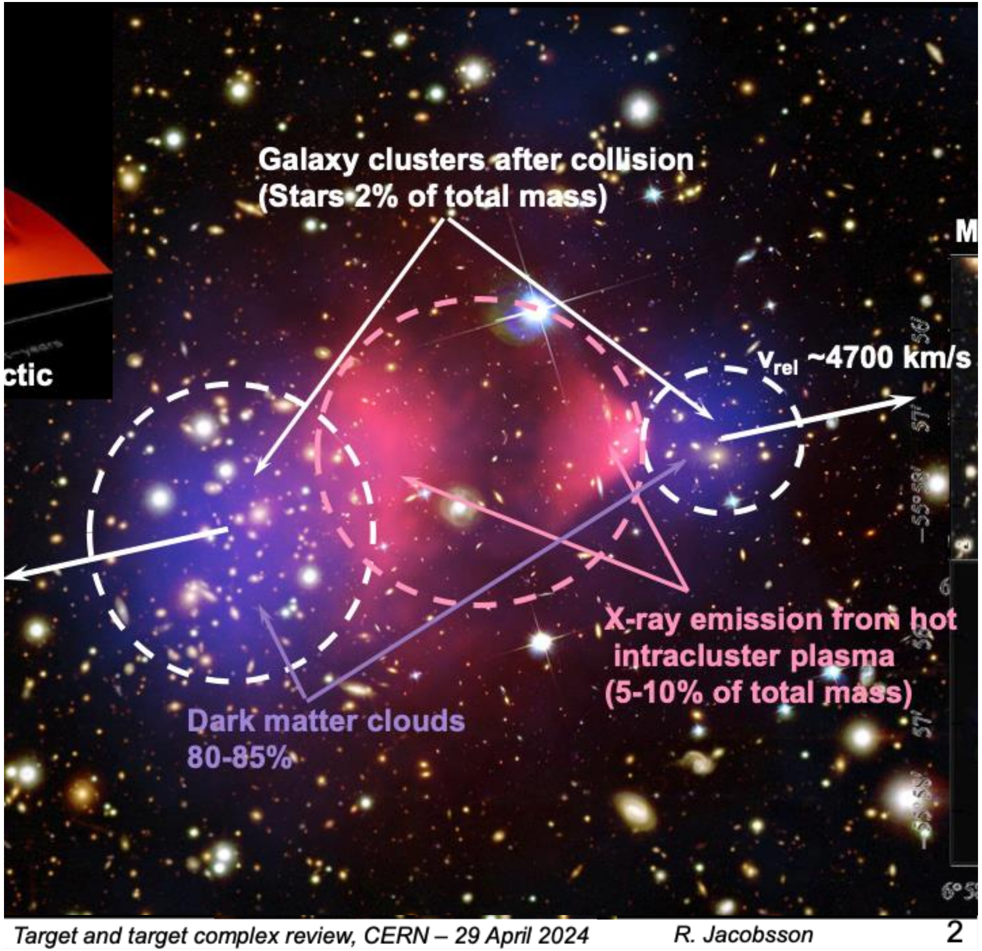
SY Technical Meeting

CERN, Geneva, Switzerland

18th June 2024

My charge from Simone…

- ***"Focus on the requirements from SY groups for ECN3 and hear the reactions from the groups"***
  - *TDR phase: some are well known from SPS BDF CDS, many others are currently being defined**
- ***"Clarify the interfaces between CONS and ECN3"***



SHiP
Search for Hidden Particles

Target and target complex

- *The Window to Hidden Sectors!* -

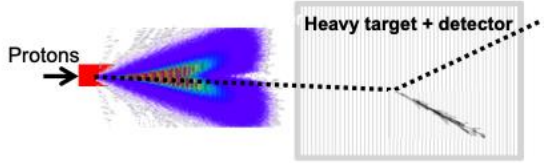
Target and target complex review, CERN – 29 April 2024

R. Jacobsson, *Introduction to SHiP,* presented at the HI-ECN3 BDF Target & Target Complex Initial Review, 29 April 2024

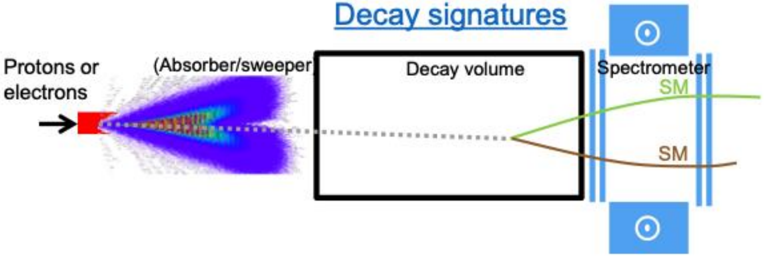
SHiP: two-in-one

Production — **Detection by decay or by scattering**

Scattering signatures



Decay signatures



→ BDF luminosity with the optimised target and 4×10^{19} protons on Mo target per year *currently available* in the SPS

- ➔ BDF@SPS $\mathcal{L}_{int}[year^{-1}]$ = >4 x 10^{45} cm^{-2} (cascade not incl.)
- ➔ HL-LHC $\mathcal{L}_{int}[year^{-1}]$ = 10^{42} cm^{-2}

E.g. ~ 2×10^{17} charmed hadrons (>10 times the yield at HL-LHC)

Target and target complex review, CERN – 29 April 2024 *R. Jacobsson* 6

BDF/SHiP Concept

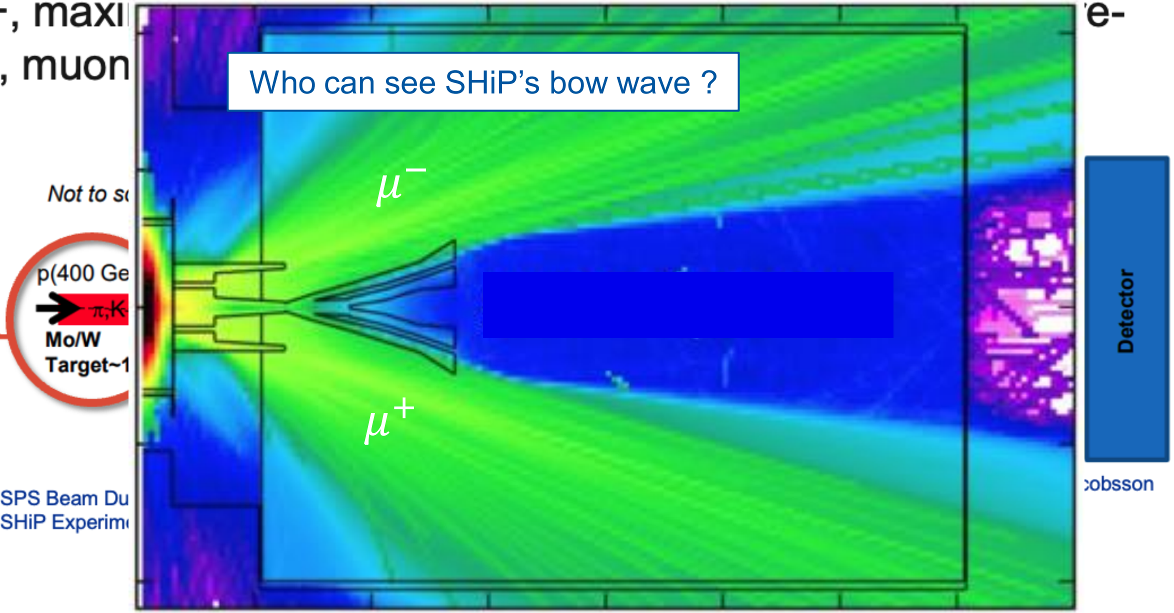
- **Beam Dump Target** / SHiP Target
  - Fully absorbe all p+, maxi … e- absorption of pions, muon …

High energy → production of charmed and beauty mesons

High ppp & POT → overcome small prod cross-section of extra rare events of hidden particles

High ρ, Z & A → Maximize p+ interaction

Shortest λ → Force absorption of K & π to reduce muon & neutrino background



SPS Beam Du
SHiP Experim
cobsson

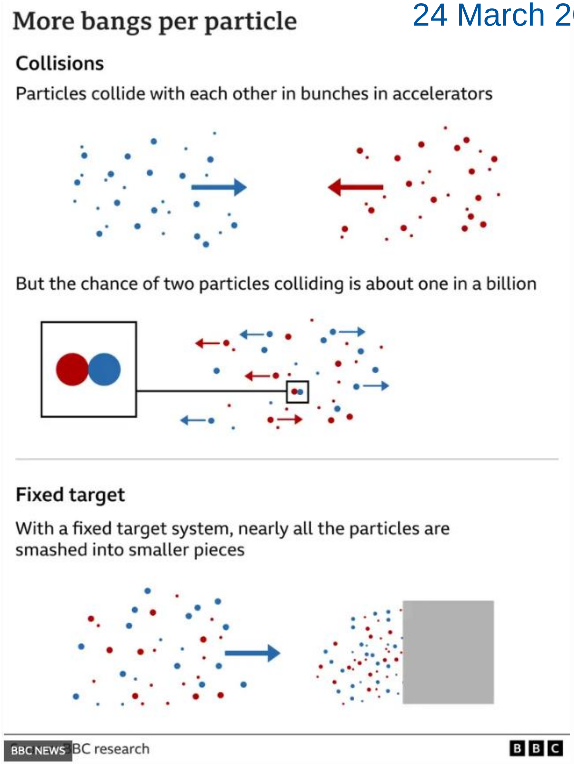
Target design baseline and challenges | HI-ECN3 WP3 | Target & Target Complex ICR 7

BBC News

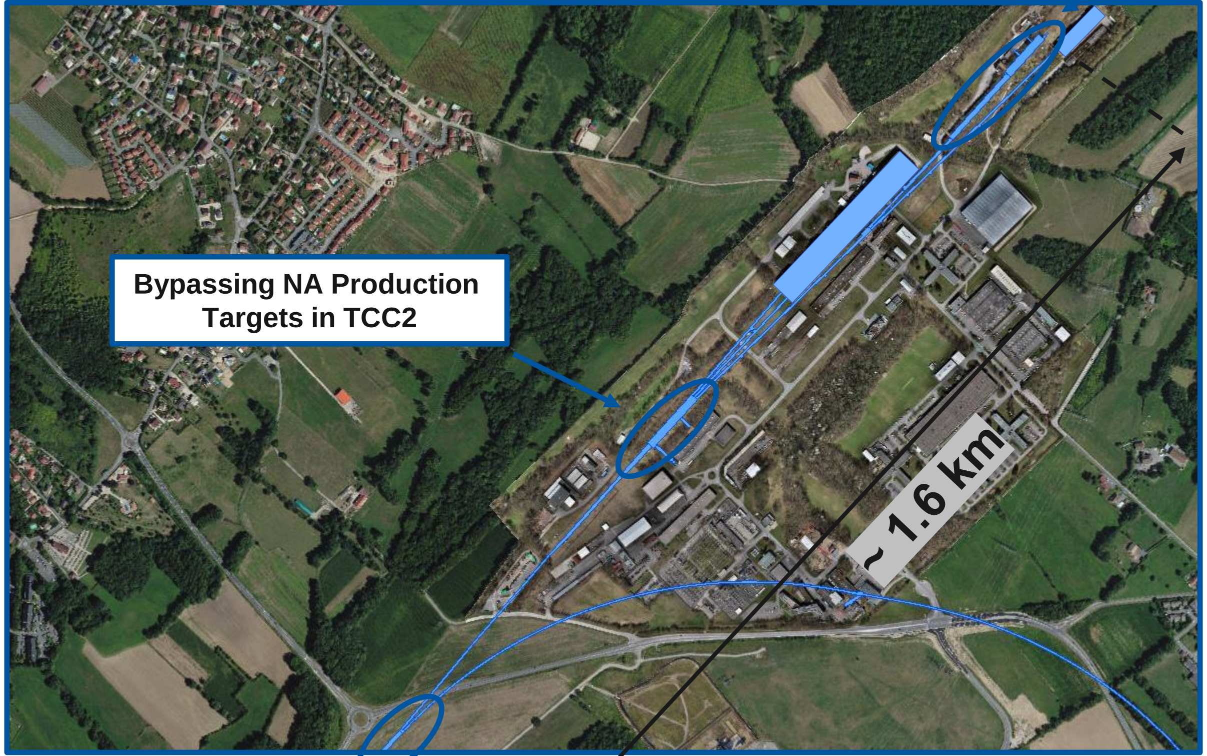
Cern: Scientists search for mysterious ghost particles

By Pallab Ghosh
24 March 2024

Artwork: Ghost particles can't currently be detected



Experimental Cavern North 3



Project Timeline

Inclusion in MTP2024: ratified by CERN Council this week (we hope!)

Research Board Decision for SHiP: March 2024

Civil Engineering for ECN3 is the critical path: ~ 3 – 4 years

Beam on target for Facility Commissioning:

2030

~ 2 years operation for SHiP before LS4

BDF/SHiP at HI-ECN3 - Indicative Schedule & Constraints

Machine/Facility/Experiments	2023	2024	2025	2026	2027	2028	2029	2030	2031
LHC				LS3			Commissioning		
SPS				LS3					
NA-CONS	Preparation & YETS Implementation Phase			NA-CONS Phase 1 (LS3)					
HI-ECN3 Beam Delivery via NA-CONS	Engineering & Implementation Phase			Installation (LS3)		Commissioning			
BDF Target Complex in TCC8	Engineering Design Phase			Final Opt. & PRR	Preparation, Dismantling	Procurement / Assembly	Procurement/ Installation	Installation/ Commissioning	
SHiP Experiment in ECN3	Proposal	TDR	TDR	TDR/PRR	Production	Construction	Installation/Commissioning		

HI-ECN3 TDR deadline

SHiP TDR deadline

Certain items cannot wait because of NA-CONS timeline!

Project Work Breakdown Structure v 0.1

…to be finalised with revised cost & resources by the end of the TDR phase (end 2025)

WP8 – Radiation field and R2E & R2M effects
Luigi ESPOSITO

WP1 – Project Management
Matthew FRASER; Deputy: Claudia AHDIDA
- Planning, Scheduling & Coord. — **Fernando PEDROSA**
- Budget & Resources — **Sylvie PRODON**
- Procurement
- Project Office — **Matthew FRASER**
- Technical Coordination — **Matthew FRASER**
- Configuration & Quality Management — **Giulia ROMAGNOLI**
- Installation
- Commissioning

WP2 – Beam Extraction, Transfer and Delivery
Francesco VELOTTI; Deputy: Laurie NEVAY
- Extraction — **Pablo ARRUTIA**
- Primary Beam Line — **Laurie NEVAY / Francesco VELOTTI**
- Magnets — **Philip SCHWARTZ**
- Power Converters — **Ivan JOSIFOVIC**
- Vacuum Upgrade — **Miguel SANTOS**
- Beam Instrumentation — **David BELOHRAD**
- Machine Protection — **Antoine COLINET**
- Operational Controls & Tools — **Kevin LI**
- Beamline Shielding Improvements — **Laurie NEVAY**
- Experiment Requirements — **Richard JACOBSSON**

WP3 – Target & Beam Intercepting Devices
Rui XIMENES
- Target Design & Engineering — **Rui XIMENES**
- BIDs Design & Engineering — **Rui XIMENES**
- XTAX Upgrade — **Miguel SANTOS**
- Experiment Requirements — **Richard JACOBSSON**
- Energy Deposition & Radiation Effects — **Luigi ESPOSITO**
- Detailled Design & Production — **Luca GENTINI**
- Target Instrumentation — **Jerome LENDARO**
- Material R&D — **Stefano SGOBBA**
- Prototype Target Beam Test — **Rui XIMENES**

WP4 – Target Complex
Jean-Louis GRENARD
- Target Complex Design & Engineering — **Jean-Louis GRENARD**
- TC & Surface Building Integration — **Jean-Louis GRENARD**
- Containment Systems — **Jean-Louis GRENARD**
- Service Cell Systems — **Jean-Louis GRENARD**
- Robotic Systems — **Luca BUONOCORE**
- Remote Handling Systems — **Roberto RINALDESI**
- Radioactive Components Storage & Disposal — **Jean-Louis GRENARD**
- Radiation to Electronics — **Ruben ALIA**
- Accelerator Interfaces — **Jean-Louis GRENARD**
- Magnetised Hadron Stopper — **Philip SCHWARTZ**

WP5 – Exp. Area, Interface & Integration
Francois BUTIN
- Expt Area Design & Engineering — **Francois BUTIN**
- Global Integration (inc. Exp. Area Integration) — **Francois BUTIN**
- TCC8/ECN3 Dismantling — **Nicolas QUINQUIS / Francois BUTIN**
- Shielding Proecurement & Recovery — **Michael LAZZARONI**
- Experiment Interfaces — **Richard JACOBSSON**
- Accelerator Interfaces — **Francois BUTIN**
- Experiment Installation — **Francois BUTIN / Richard JACOBSSON**
- Experiment Requirements — **Richard JACOBSSON**

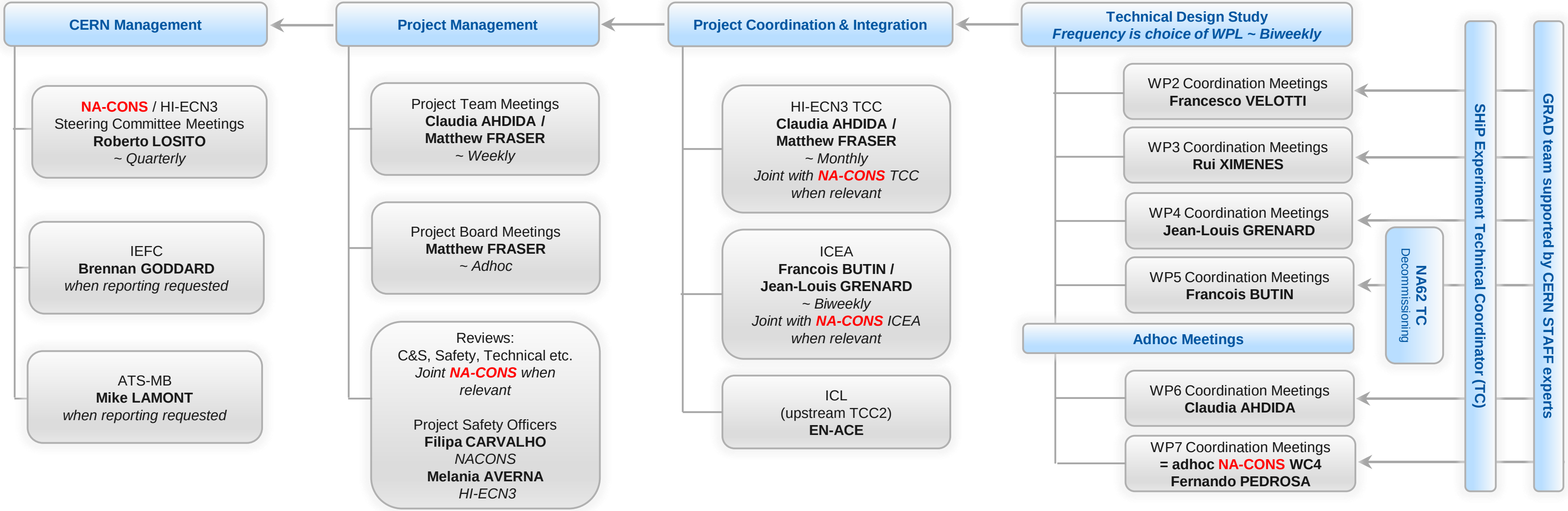
WP6 – Radiation Protection & Safety
Claudia AHDIDA
- Safety Files — **Melania AVERNA**
- Radiation Protection — **Claudia AHDIDA**
- Radioactive Waste Management & Transport — **Philippe BERTREIX / Renaud CHAROUSSET**
- Fire Safety — **Oriol RIOS**
- Access & Safety Systems — **Tomasz LADZINSKI / Anna SUWALSKA**
- Occupational Safety — **James CURRIE**

WP7 – Infrastructure, Services & Civil Eng.
Fernando PEDROSA
- NA-CONS Synergism — **Fernando PEDROSA**
- Civil Engineering — **John OSBORNE**
- Gas Distribution — **Davide JAILLET**
- Cooling & Ventilation — **Roberto BOZZI**
- Electrical & Fiber Infrastructure — **Eva CANO GONZALEZ**
- Cryogenics
- Survey & Alignment — **Camille VENDEUVRE**
- Handling Systems & Operational Support — **Roberto RINALDESI**
- Telecom & Network

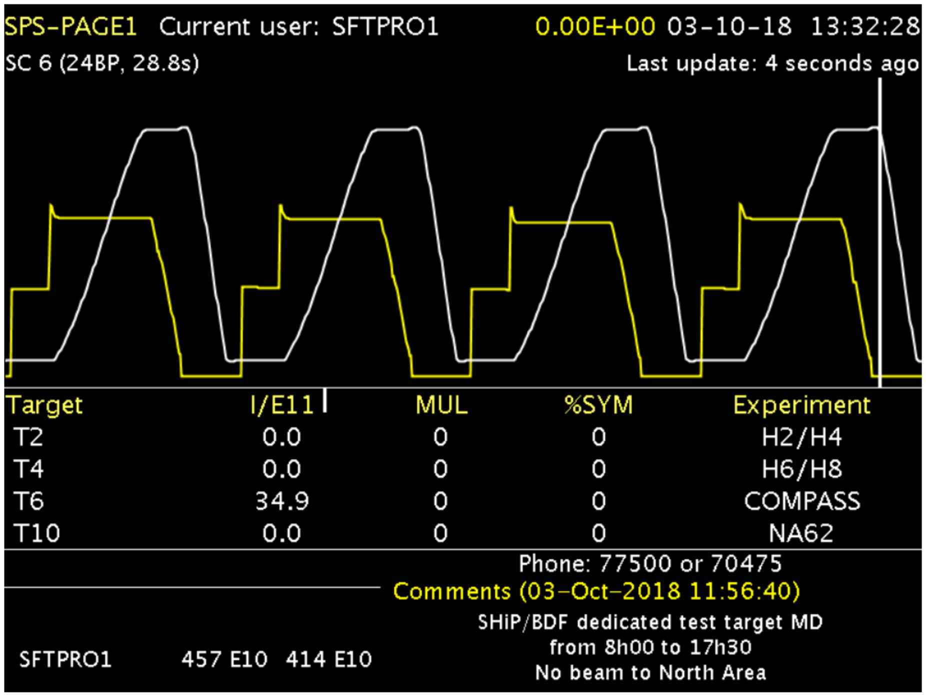
Work Package Descriptions drafted during TDR phase!

Project Organisation: Modus Operandi

TDR work happening in dedicated WP meetings



How many protons for BDF / SHiP? (i)



SPS Page 1 during BDF prototype target test at T6 in 2018

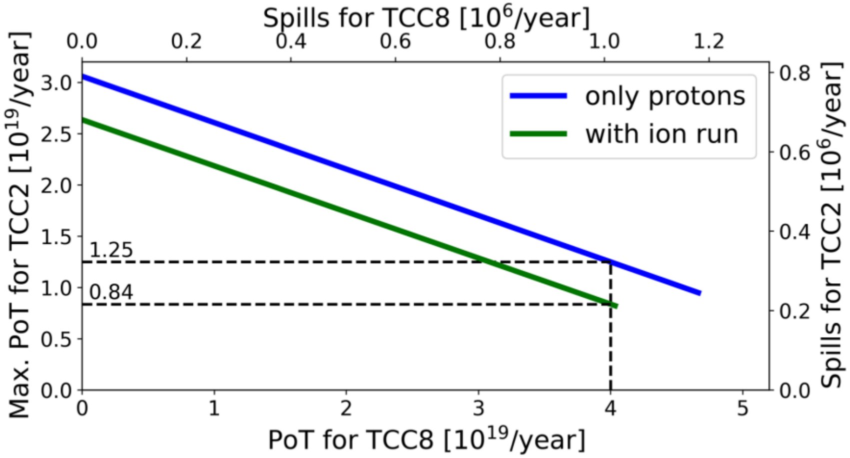
Short CNGS-like 7.2 s SFTPRO cycle with a 1.2 s FT (~ 1 s spill)

Compared to 10.8 s SFTPRO cycle and 4.8 s FT (~4.5 s spill): actually limited in repetiation rate by RMS power limit of SPS mains dipoles to one cycle every 14.4 s.

How many protons for BDF / SHiP? (ii)

- **North Area Sharing:**
  - Assuming 80% availability with transmission assumptions, RMS power limit and including other SPS constraints like LHC filling, AWAKE, HiRadMat etc.: 35 weeks, 2x 30h TS's

Protons other NA users



Protons to BDF/SHiP

North Area wants ~ 5×10^{19} protons/year… a la CNGS (~4×10^{19} p^+/y)

… but, slow extracted…

…unprecedented !

How many protons for CERN facilities?

Complex – full and diverse physics programme

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
L4, PSB, PS						LS3							LS4			
L3, LEIR						LS3							LS4			
SPS						LS3							LS4			
LHC		Run 3				LS3			Run 4				LS4			
CLEAR	Review			Review												
ISOLDE						BD							LS4			
HIE-ISOLDE													LS4			
MEDICIS			Review													
n_TOF													LS4			
EAST AREA													LS4			
ELENA													LS4			
AWAKE	AWAKE Run 2a,b			Review	CNGS			Run 2c		Run 2d						
North Area						NA-CONS Ph1							NA-CONS Ph2			
ECN3																

..?

BDF/SHiP requests high flux for 15 operational years

Dedicated Project to follow higher intensity FT beams ? (IPP collecting input now)

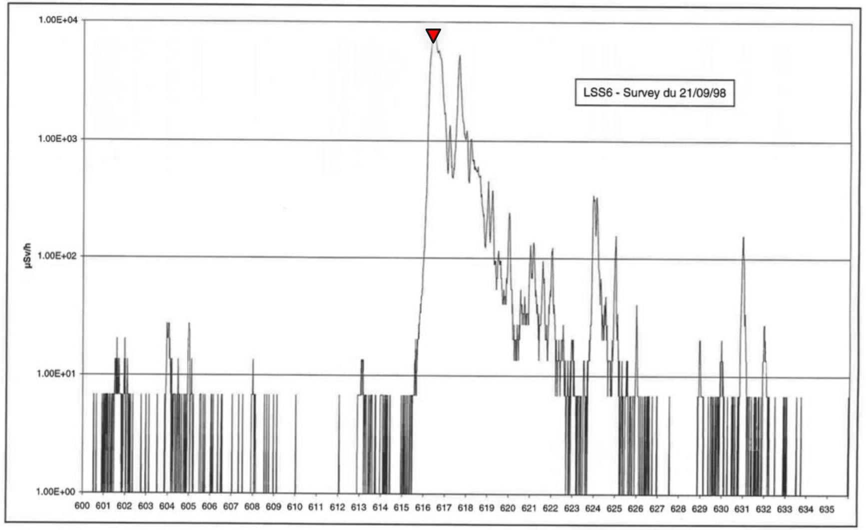
SY equipment likely implicated across the complex, to find creative solutions to increase flux e.g. PS barrier bucket, parasitic ISOLDE users, multi-bunch n_TOF beams, etc.

57

Is SFTPRO > 4 × 13 ppp interesting for CERN?

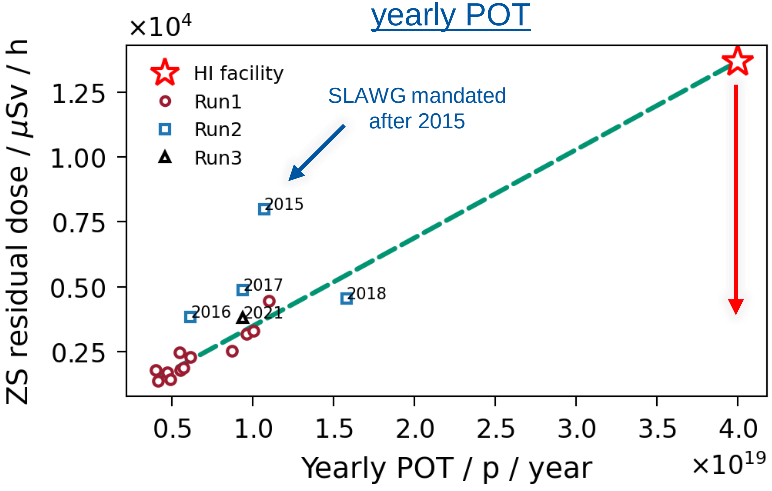
Slow extraction beam loss reduction

SY challenge: achieve a beam loss reduction factor of ~ 4 in stable, in long-term operation



An example data set found in the RP archive
(30h survey after 1998 WANF operation in LSS6)

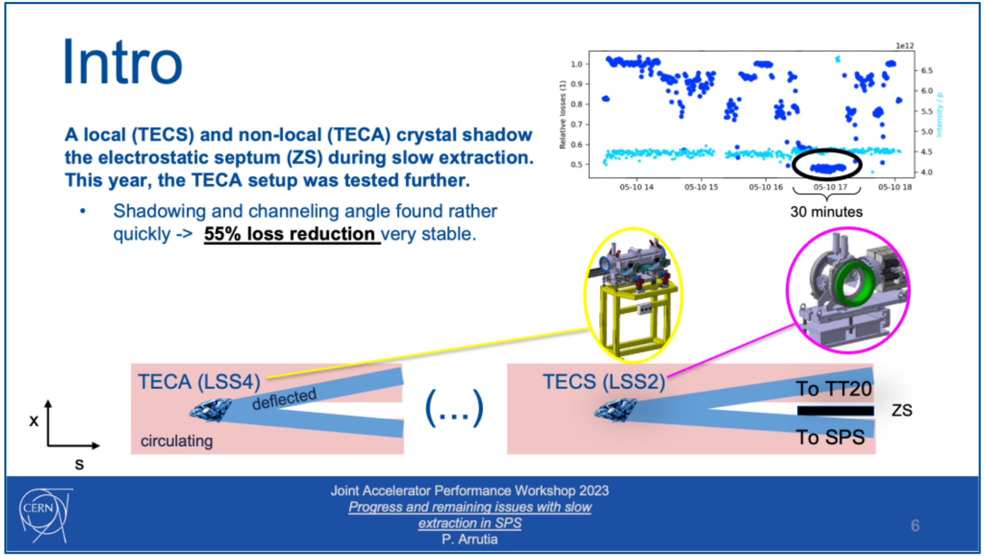
Rough correlation between end of year activation peak in LSS2 and yearly POT

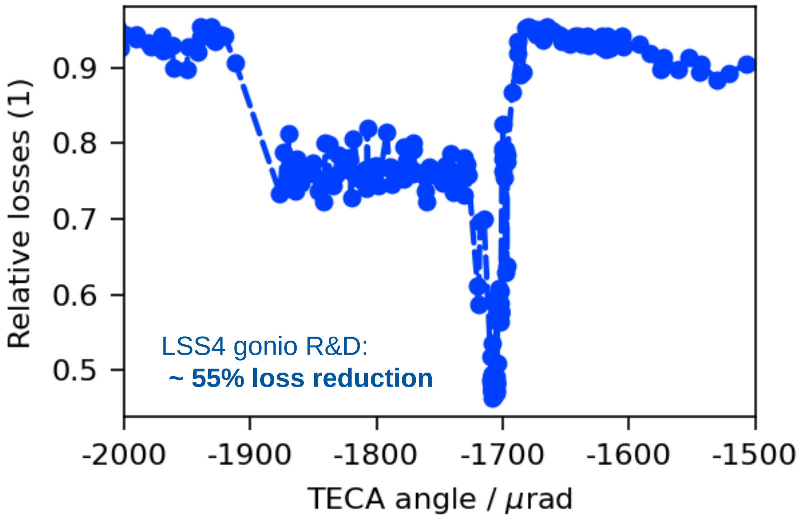


Slow extraction beam loss reduction (ii)

SY challenge: achieve a beam loss reduction factor of ~ 4 in stable, in long-term operation

- Crystal “shadowing” technique (LSS2 & LSS4)
- Phase-space folding using octupole magnets already installed in SPS
- Improved electrostatic septa (straightness and low density)

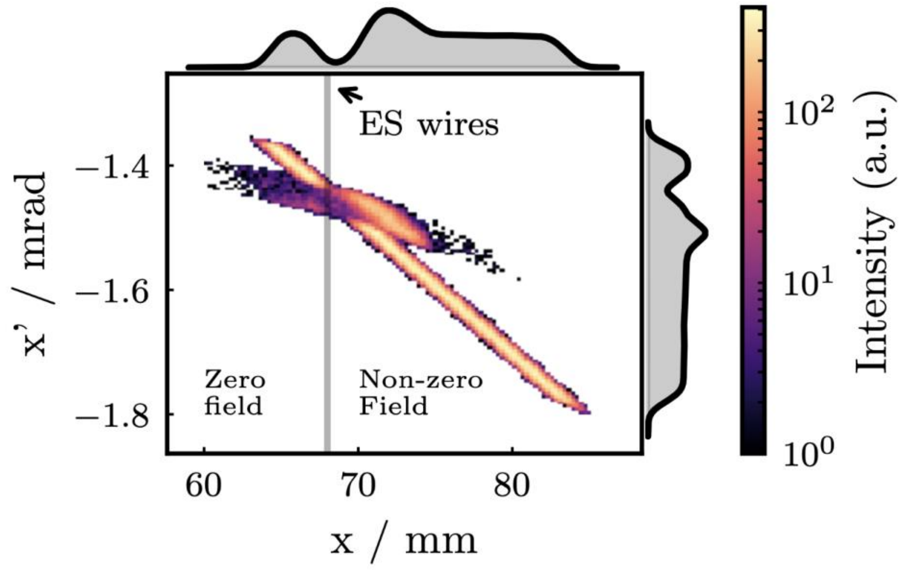


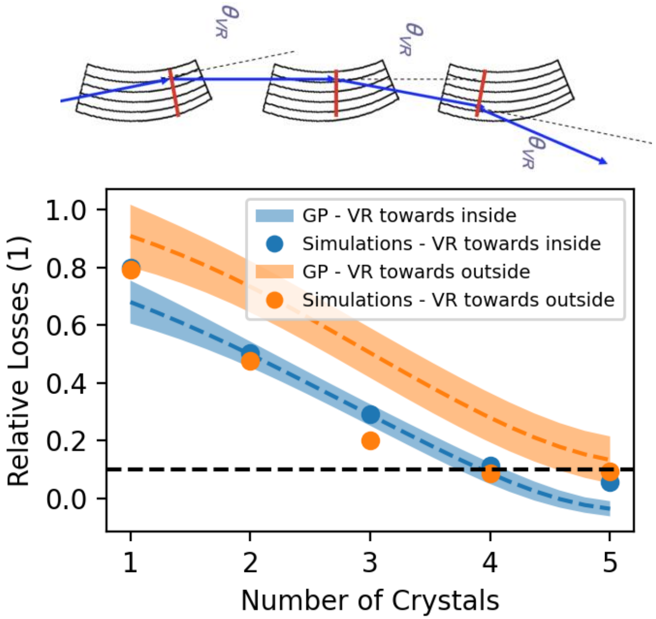


Slow extraction beam loss reduction (iii)

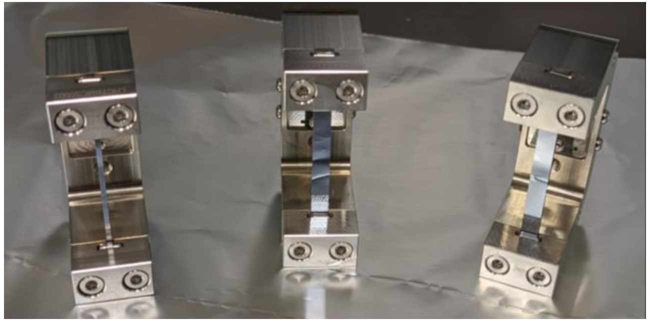
Longer-term R&D challenge: achieve an even higher loss reduction factor (x10?!) with advanced crystal technology installed in SPS LSS4 ("shadowing" the electrostatic septum):

Multiple thin, bent crystals aligned for Volume Reflection





DECRYCE project



DEvelopment of CRYstals for Collimation and Beam Extraction (DECRYCE) project for in-house development of crystals:

- Procurement
- Cutting & polishing
- Engineering the bender system
- Validation of crystals:
  - ✓ X-ray diffractometry for crystal characterization
  - ✓ Beam characterisation in NA
  - ✓ Development of Timepix4 based telescope

WP1	**Project Management**	**STI**
WP2	**Crystal/wafer preparation**	**CEM**
WP3	**Design & construction of the crystal bender**	**STI**
WP4	**Characterization of crystal assembly with X-rays**	**CEM**
WP5	**Validation of crystal assembly with beam**	**STI**
WP6	**Telescope and data acquisition system for beam validation**	**BI**

A critical SY effort for the future of SPS's Fixed Target programme!

Slow extraction spill quality

Spill quality is already long running saga at SPS (SY-EPC investigations):

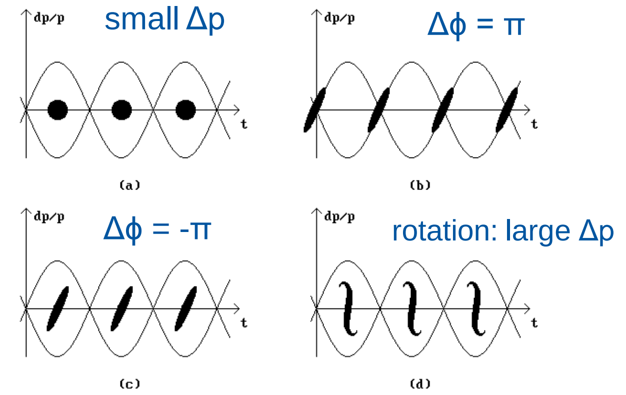
- SY-BI has already developed spill monitors for 200 and 800 MHz via OTR
- SY-RF involved in using advanced RF techniques to improve spill quality, e.g. 800 MHz RF system now used operationally for "empty bucket channeling"

TDR challenges:

- Identify techniques to increase speed of de-bunching, critical for SHiP? **(SY-ABT/RF)**
- Identify other RF techniques to improve spill quality (transverse / longitudinal noise) ? **(SY-ABT/RF)**
- Can we revive the Schottky monitor for SX R&D / operation ? **(SY-BI/RF)**

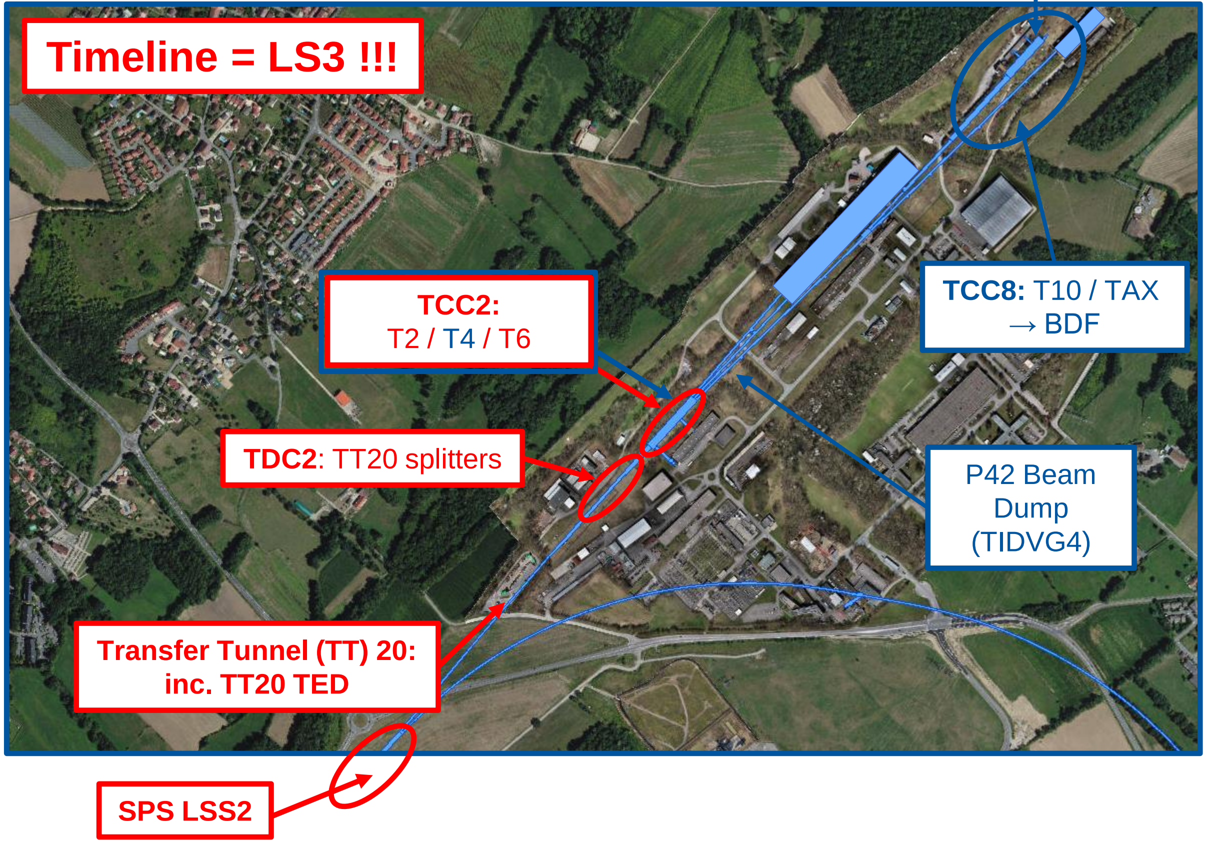
Develop a fast spill monitor (up to 10 GHz?) together with the SHiP Collaboration (EP & SY-BI)

Today's RF gymnastics for debunching



CONSOLIDATION Phase 1
UPGRADE

NA-CONS & HI-ECN3



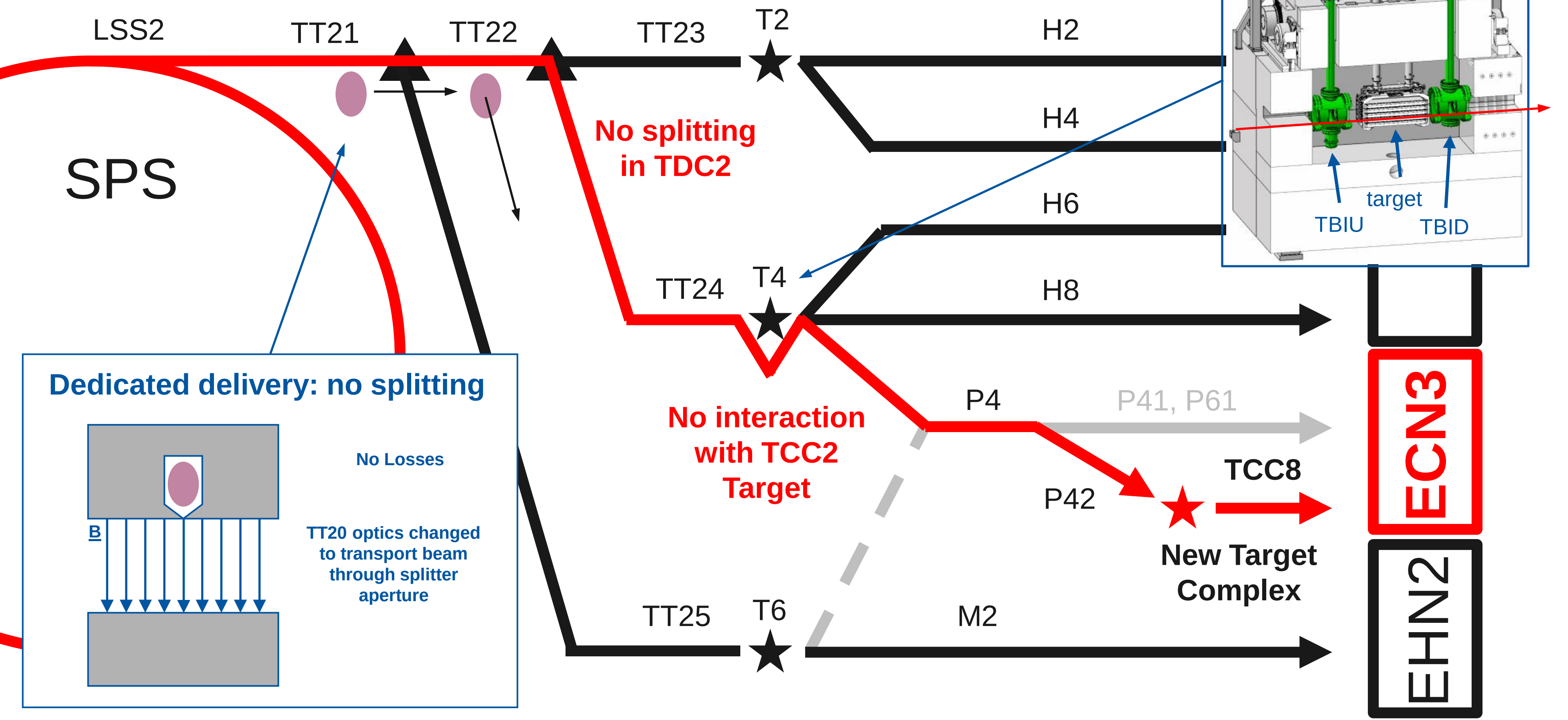
BDF/SHiP requirements affect:
(i) Scope of NA-CONS project
(ii) Upgraded items needed

Impacted NA-CONS items:

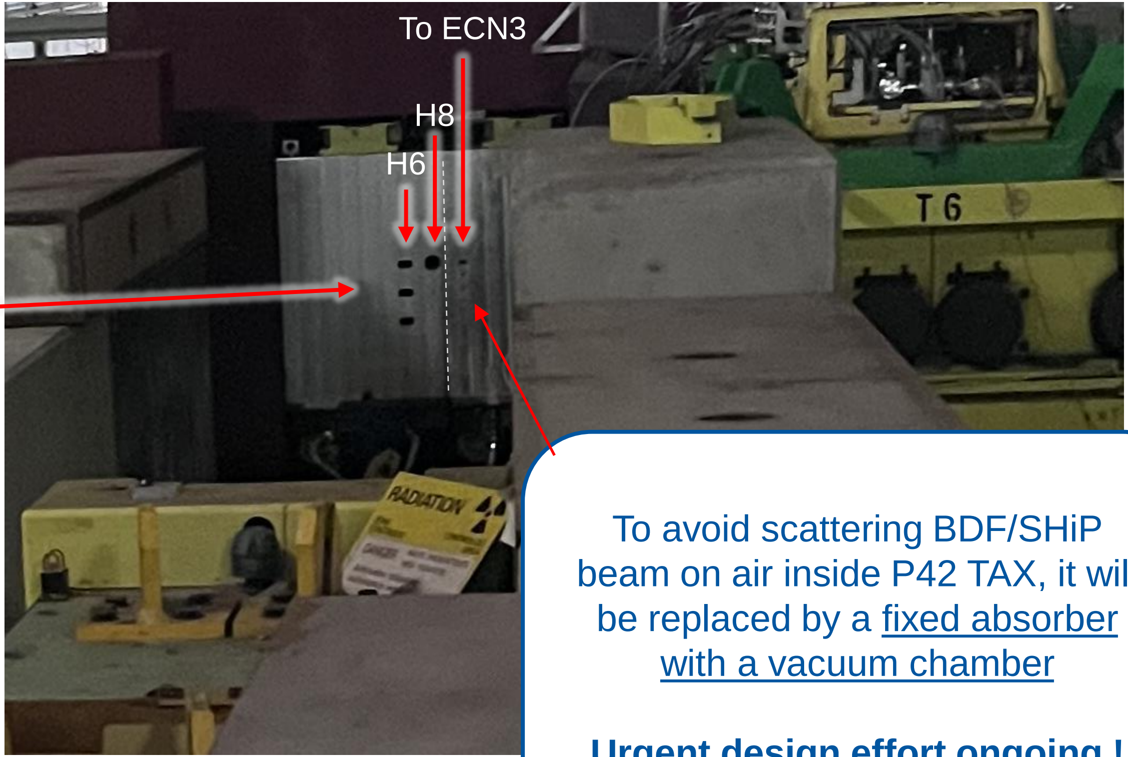
- T4 target system (inc. XTAX)
- Beam instrumentation
- Magnets / power converters
- Infrastructure & services (BAs)
- Machine protection

SY Groups: SY-EPC an additional PC for T4 target bypass, ready after LS3

Dedicated Beam Delivery to ECN3



Major impact on T4 in TCC2: XTAX (ii)



Looking downstream from on top of T4 target

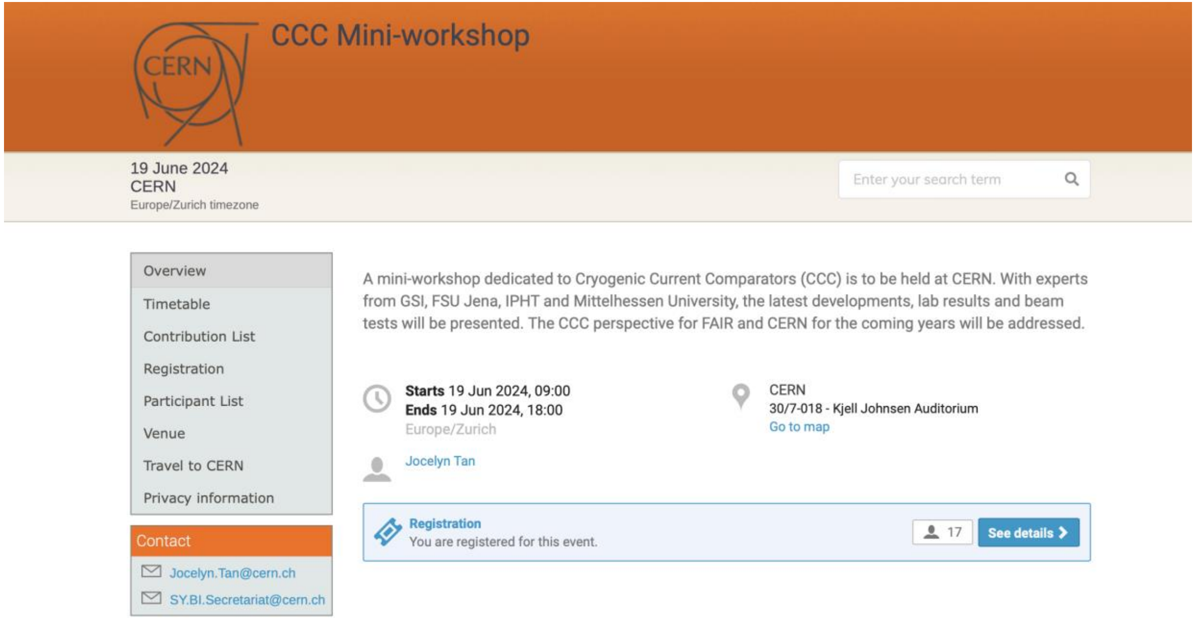
To avoid scattering BDF/SHiP beam on air inside P42 TAX, it will be replaced by a fixed absorber with a vacuum chamber

Urgent design effort ongoing !

Absolute beam intensity measurements

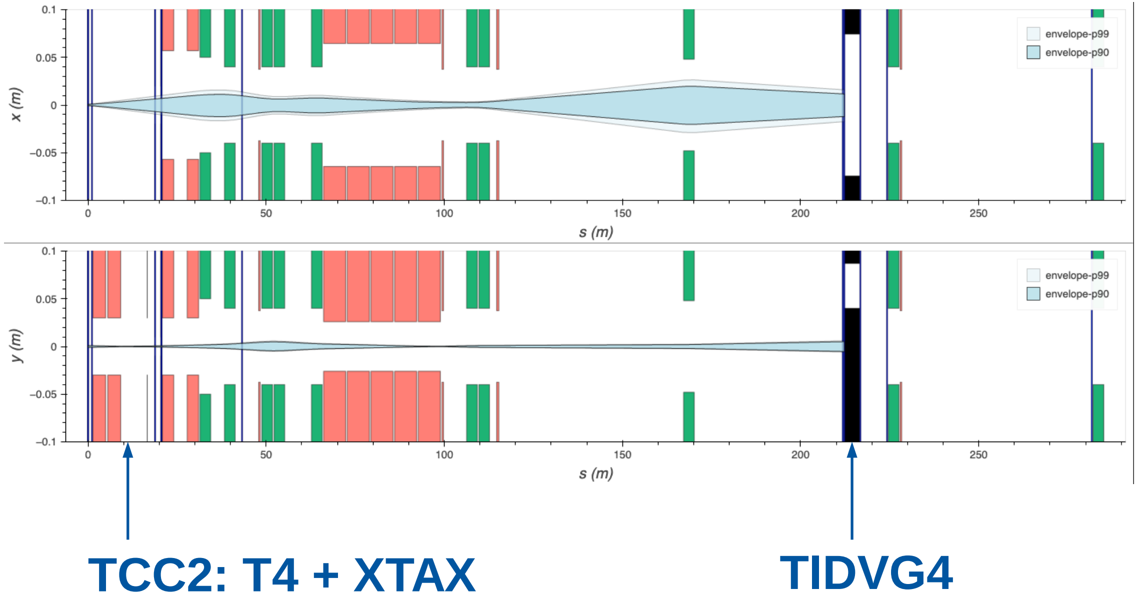
Strategy needed to attain a measurement accuracy of ~ % in the North Area:

- Consolidation of SEM intensity monitors foreseen as part of NA-CONS
- Renewed importance now we consider 5 $\times 10^{19}$ POT/year



P42 beam dump: TIDVG4

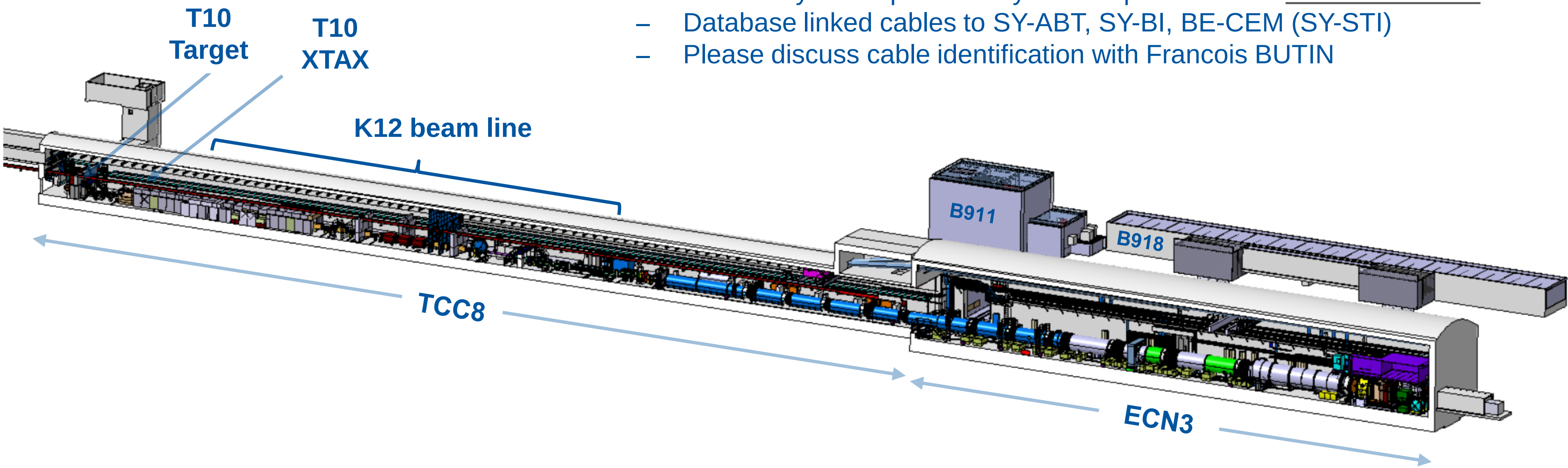
- **Permanently blocking aperture after Long Shutdown 3**
- **To commissioning of TCC2 in 2028 – 2030 & prepare for high intensity before BDF/SHiP operation**



NA62 in ECN3

- **Dismantling will start immediately in LS3 to allow civil engineering works to get underway ASAP**

- **Do you have equipment in the zone?**
  - We need your help to identify cables: please check EDMS#3073915
  - Database linked cables to SY-ABT, SY-BI, BE-CEM (SY-STI)
  - Please discuss cable identification with Francois BUTIN



TCC8 / ECN3 Dismantling for HI-ECN3

To be circulated….

CERN

Date 10.06.2024
EDMS 3104537

MEMORANDUM

To	: Francois BUTIN, Hans DANIELSSON, Jean-Louis GRENARD
Cc	: Melania AVERNA, Dipanwita BANERJEE, Cedric BAUD, Olga BELTRAMELLO, Markus BRUGGER, Benoit DELILLE, Marco CALVIANI, Anne FUNKEN, Christelle GAIGNANT, Brennan GODDARD, Richard JACOBSSON, Rhodri JONES, Yacine KADI, Manfred KRAMMER, Karl Gunnar LINDELL, Roberto LOSITO, Laurence NEVAY, Thomas OTTO, Federico RAVOTTI, Stefan ROESLER, Jean-Philippe TOCK, Francesco VELOTTI, Kurt WEISS
From	: Matthew FRASER / HI-ECN3 Study Project Leader, Claudia AHDIDA / HI-ECN3 Deputy HI-ECN3 Study Project Leader
Subject	**: Responsibilities for the TCC8/ECN3 Dismantling for HI-ECN3**

Hans Danielsson
NA62 Dismantling Project Leader

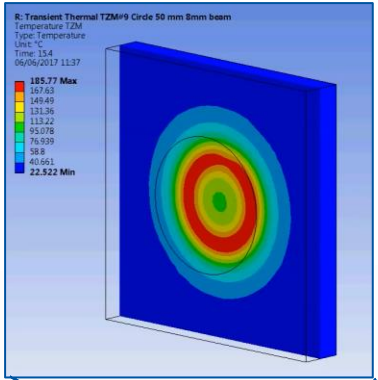
Francois Butin
HI-ECN3 WP5 WPL
ECN3 Dismantling

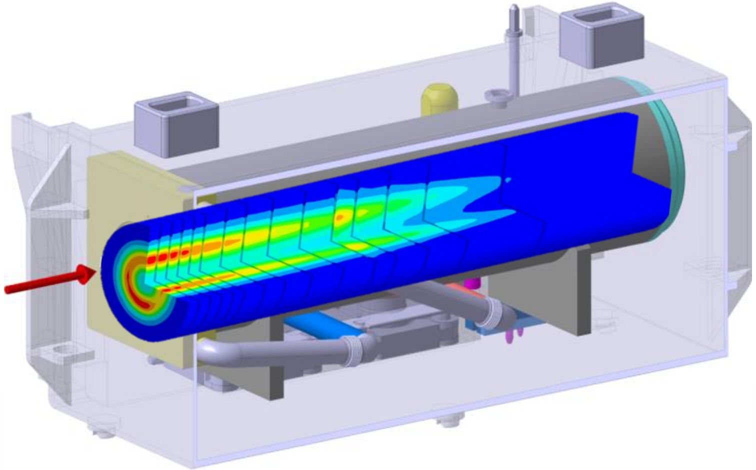
Jean-Louis GRENARD
HI-ECN3 WP4 WPL
TCC8 Dismantling
T10 target - XTAX

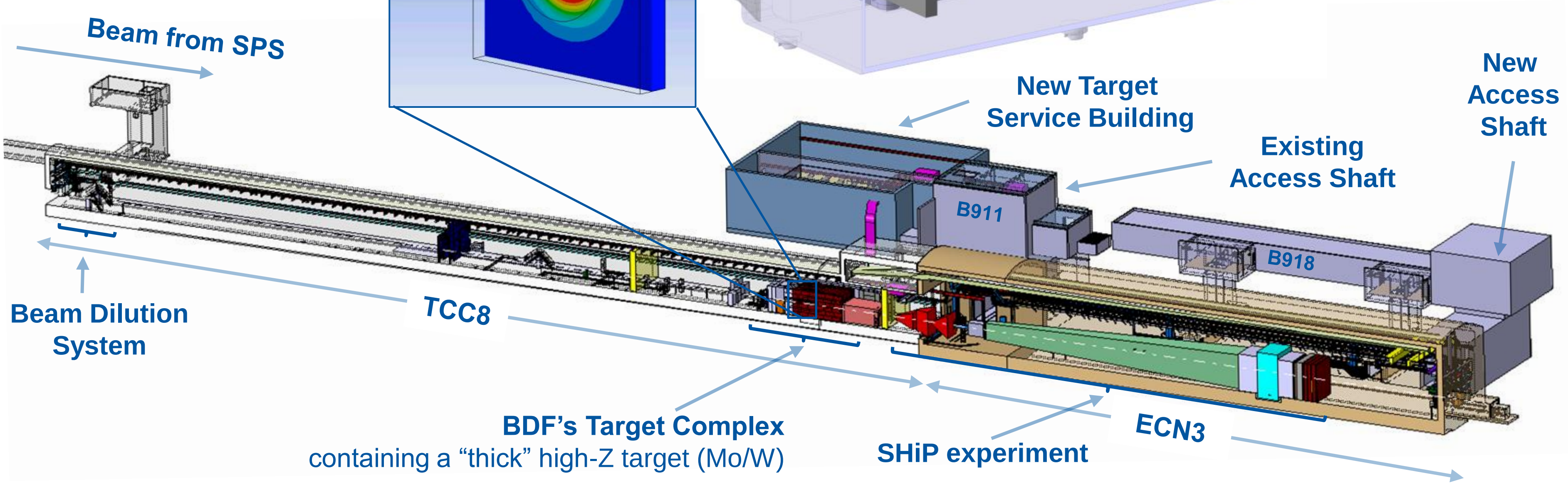
RP studies underway
SY strongly supporting the dismantling effort in the radioactive area

BDF/SHiP at ECN3

~ 350 kW (avg.)
~ 2.3 MW (spill)





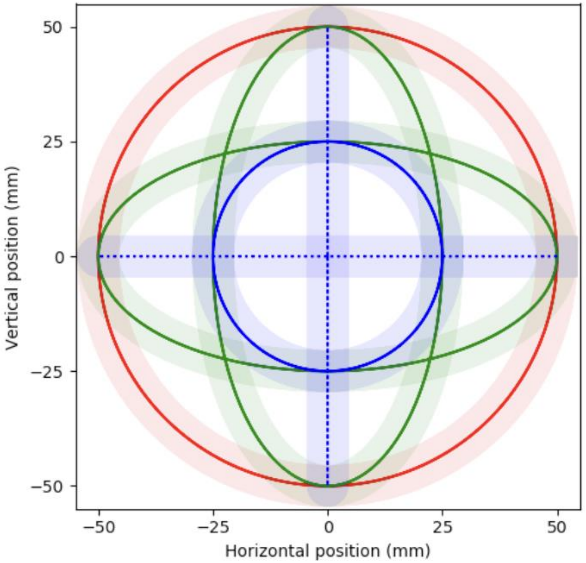


BDF dilution system

TDR challenge: protection of the target critical, loss of dilution during single spill will likely damage the target

Present baseline:

- $\pi/2$ scheme: independently powered laminated dipole magnets:
  - 2H + 2V magnets (~ 0.5 mrad, 0.7 Tm per plane)
  - de-phased by 90 degrees to give circular spill
  - “slow” sweep = 4 Hz over a 1 second spill
- Protection on needed from FGC current interlock **(SY-EPC)**
- Beam profiler(s) to check beam position, size & sweep post-operation (like LHC IPOC) **(SY-BI)**
- Independent interlock system likely needed for redundancy:
  - Independent DCCTs current measurement at magnets ?
  - Dedicated “live” monitoring of beam during its sweep ? **(SY-BI)**

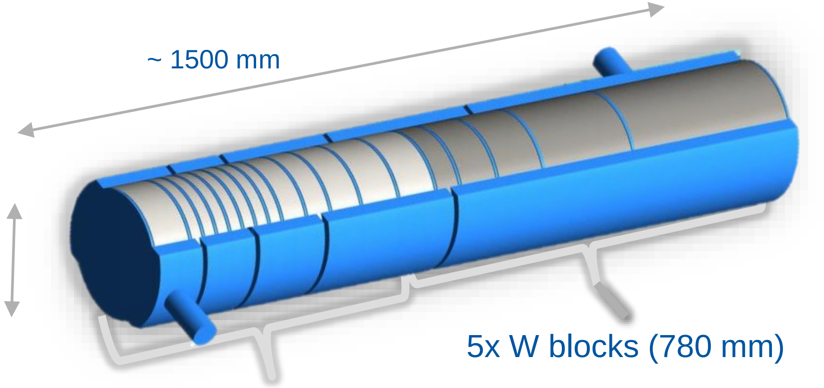


Failure Scenario:

- Failure 2H OR 2V (dashed line)
- Failure 1H OR 1V (green line)
- Failure 1H AND 1V (blue line)

R. Ximenes et al., *Target design baseline and challenges*, presented at the HI-ECN3 BDF Target & Target complex Initial Review, 29 April 2024

BDF Target Baseline Design



Baseline beam parameters of the BDF Target operation. *https://doi.org/10.23731/CYRM-2020-002*

Proton momentum (GeV/c)	400
Beam intensity (p^+/cycle)	4×10^{13}
Cycle length (s)	7.2
Spill duration (s)	1.0
Beam dilution pattern	Circular
Beam sweep frequency (turns/s)	4
Dilution circle radius (mm)	50
Beam sigma (H, V) (mm)	(8, 8)
Average beam power (kW)	356
Average beam power deposited in target (kW)	305
Average beam power during spill (MW)	2.3

~ 4.0×10^{19} p^+/y

Baseline design:

- Water-cooled, Mo & W blocks (cladded with Ta)
- Tested with beam in 2018 & PIE

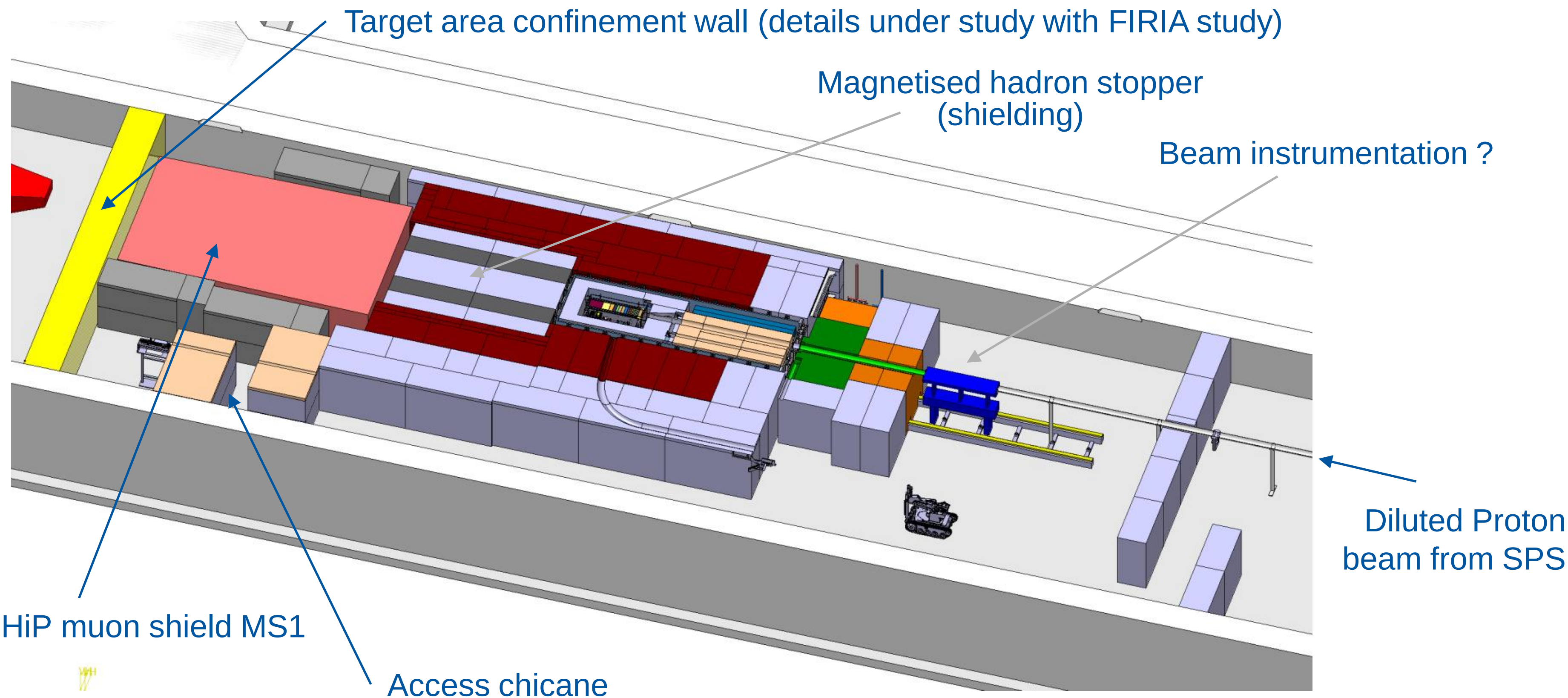
TDR phase needed to improve CDS design:

- Alternatives to water-cooling to avoid cladding and the risk of development of free radicals (hydrogen)

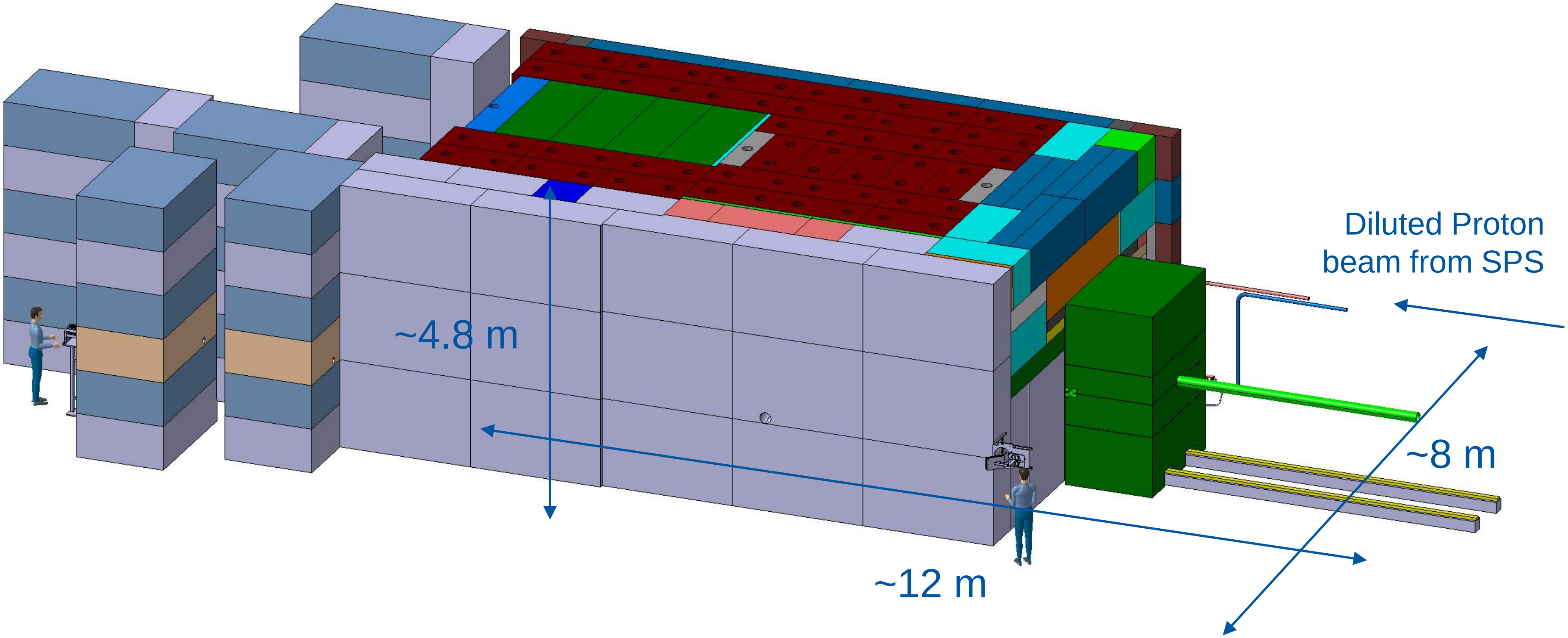
Very similar requirements to a neutron spallation target, synergies with other labs are being pursued:

He rather than H_2O cooling?

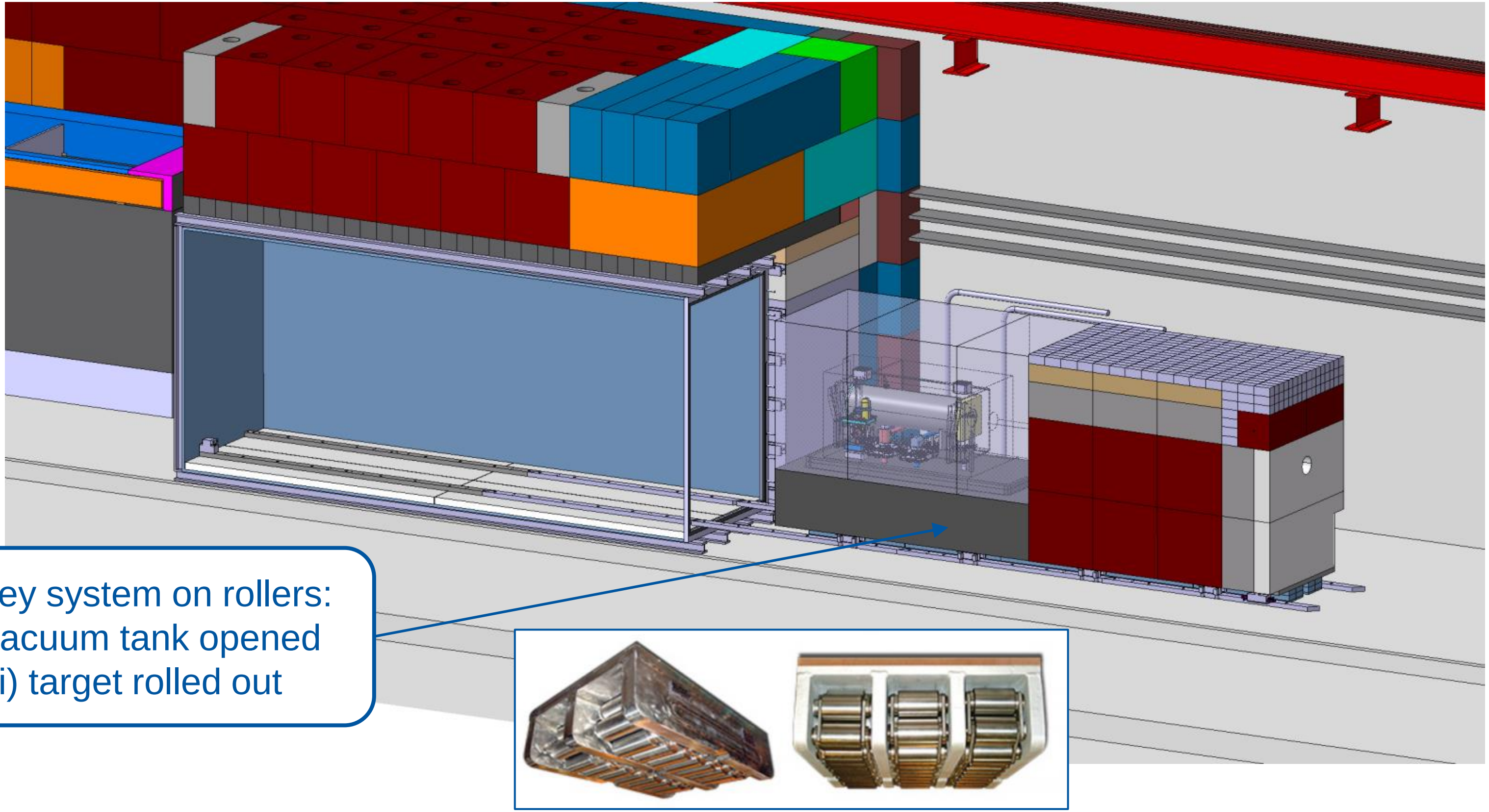
BDF Target Complex in TCC8 (i)



BDF Target Complex in TCC8 (ii)

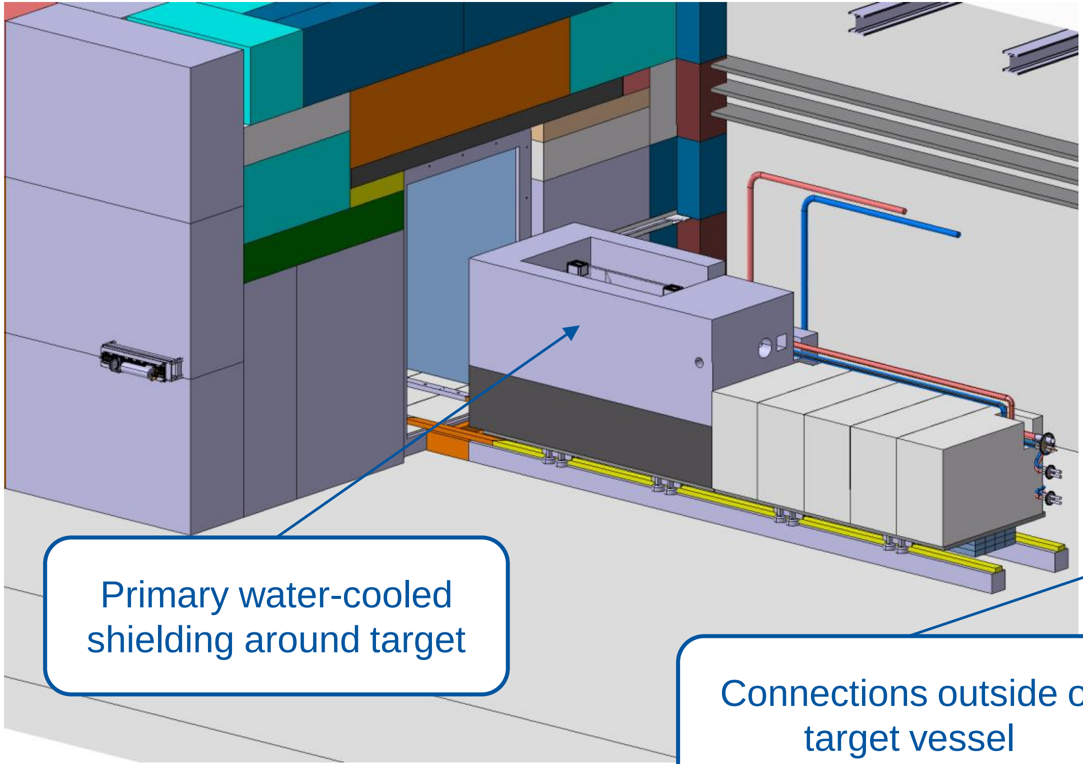


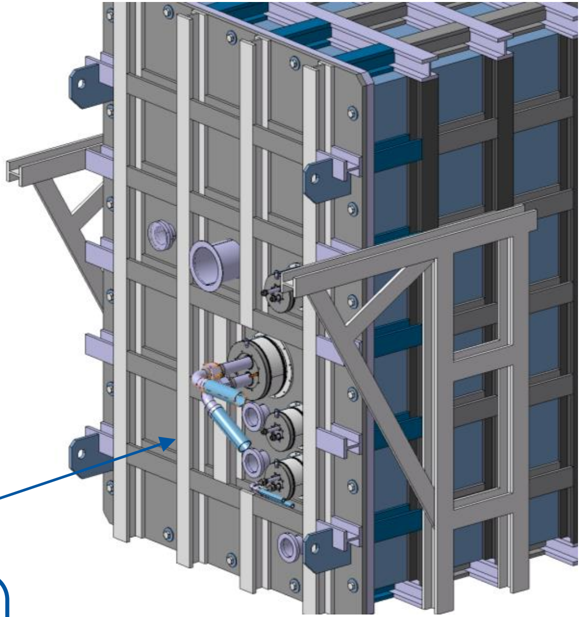
BDF Target Complex in TCC8 (iii)



Trolley system on rollers:
(i) vacuum tank opened
(ii) target rolled out

BDF Target Complex in TCC8 (vi)



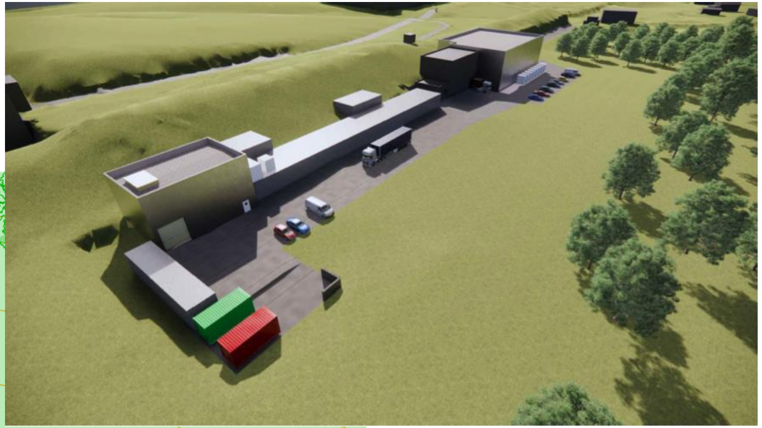


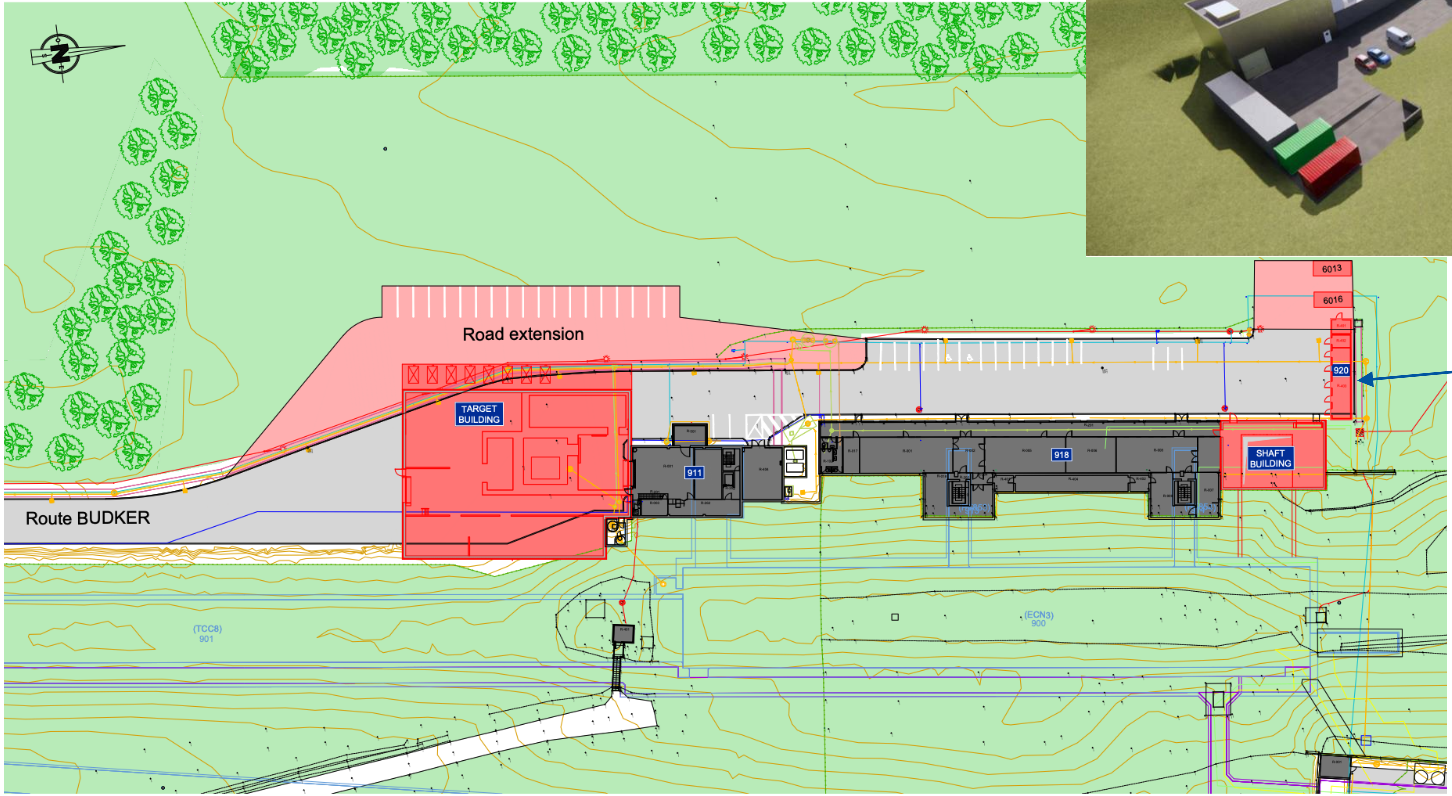
Primary water-cooled shielding around target

Connections outside of target vessel

* Already out of date! IRP Due Diligence to be presented to IRP Board #11 on 4th July

TCC8 & ECN3 future



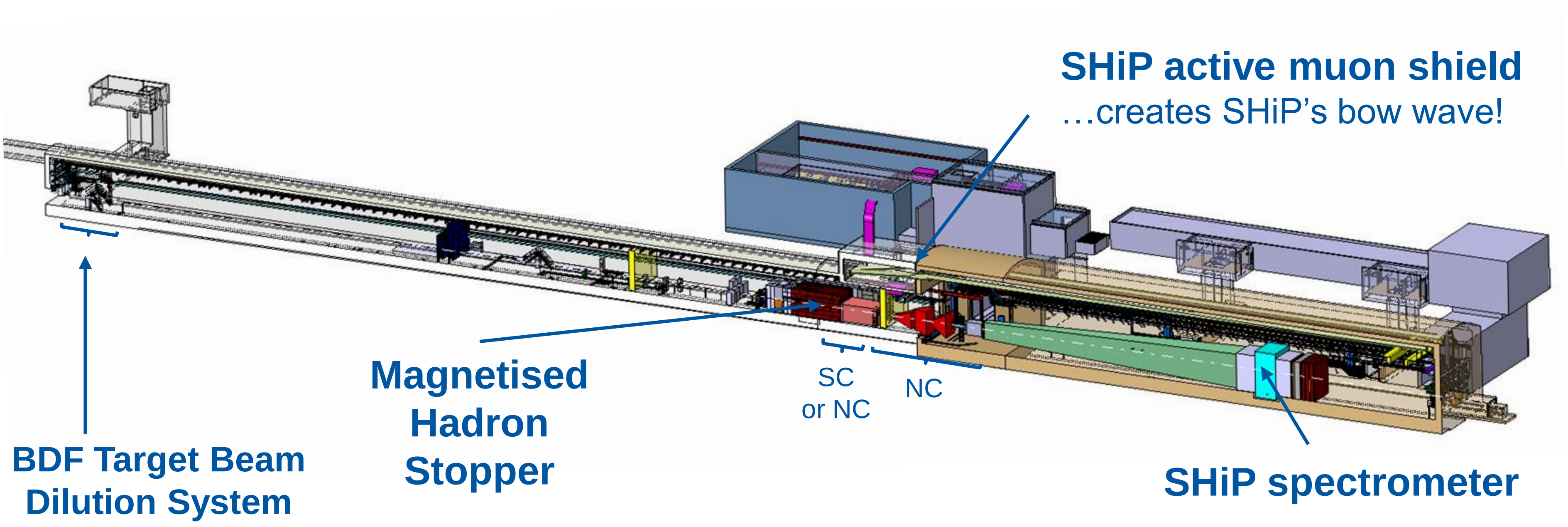


Gas Building

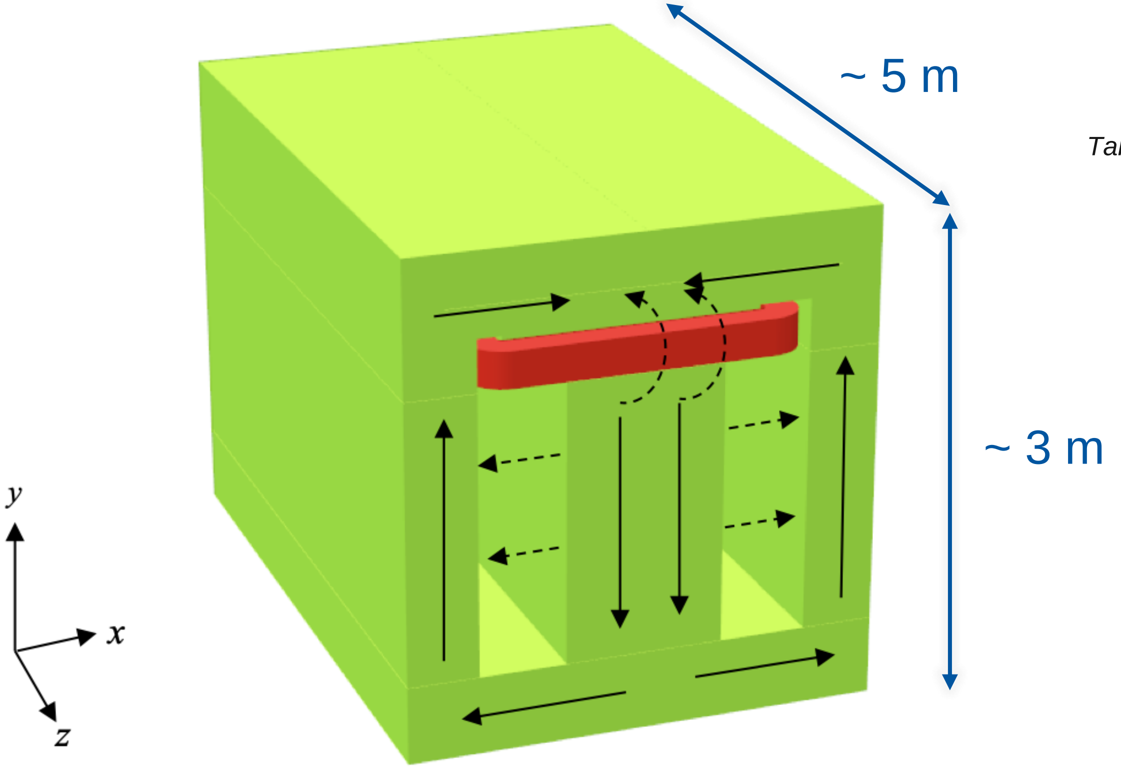
PROJECT
PLAN VIEW 1:500

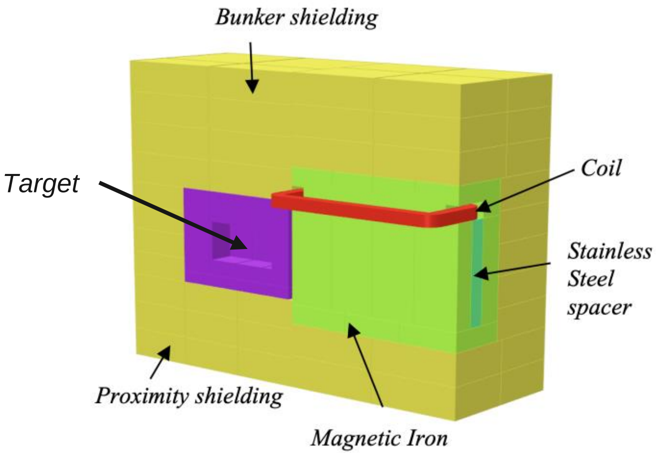
Powering of the BDF/SHiP magnets

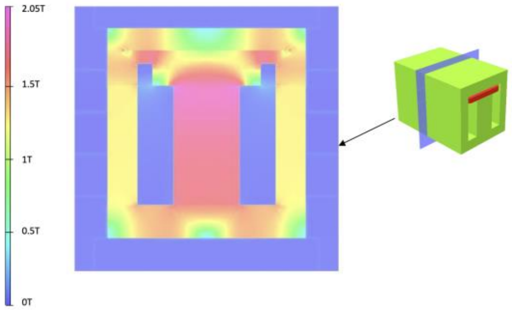
TDR challenge: to find standard powering solutions & integrate them in synergy with the NA-CONS (BA82?), with the required infrastructure & services, and scope & timeline



BDF/SHiP magnetised hadron stopper

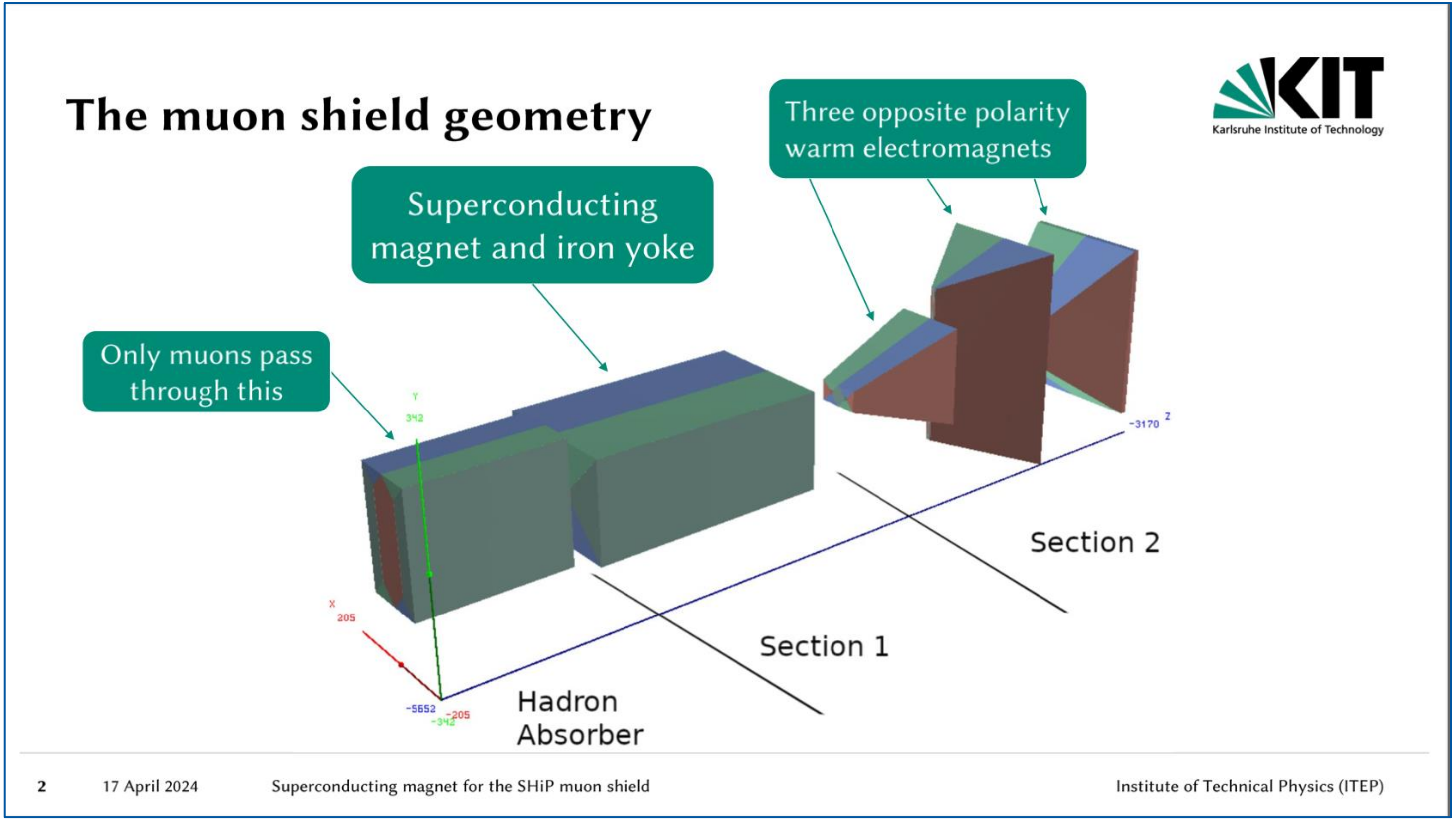






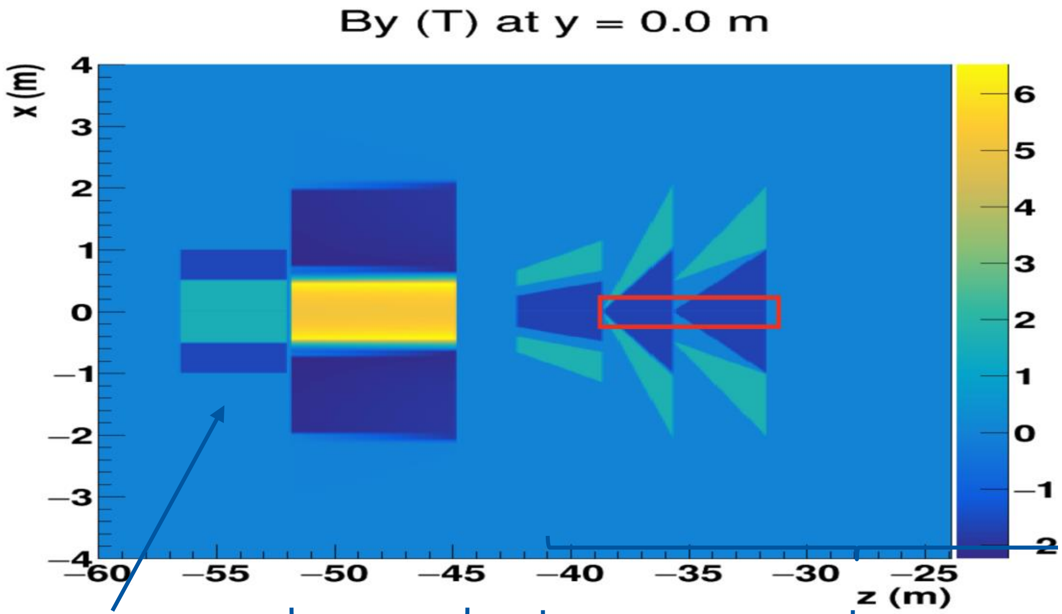
RAL: now to be developed at CERN by TE-MSC

SHiP “active” muon shield



SHiP "active" muon shield

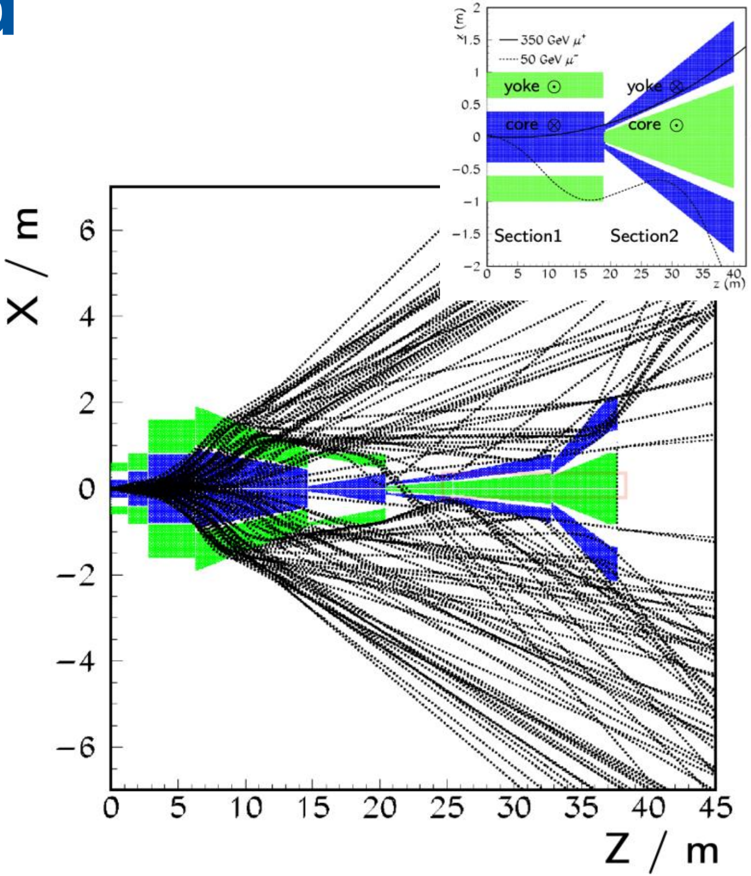
Hybrid superconducting option under study:



BDF/SHiP magnetised hadron stopper

Superconducting
KIT-ITEP
5T HTS

Normal Conducting
RAL + UK
1.6 T iron



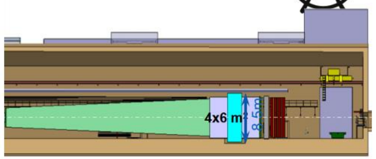
SHiP spectrometer

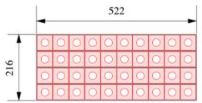
Spectrometer Magnet Requirements and Initial Design Proposal(s)

Courtesy of R. Jacobsson (CERN/EP-DI)

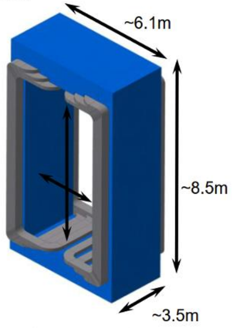
SHiP spectrometer magnet

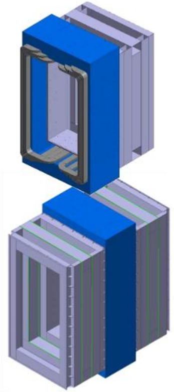
- Initial studies with aperture 5x10m² (now 4x6m²)
  - H. Bajas, D. Tommasini, EDMS 2440157 (21 April 2020)
  - P. Wertelaers, CERN-SHiP-INT-2019-008
- Requirements:
  - Physics aperture 4 x 6 m²
  - Bending field 0.6-0.7 Tm , nominal on axis ~0.15T
  - Integration of vacuum chamber





Coil's cross-section
Aluminium hollow conductor





- Resistive baseline option 1.2 MW
- What about superconductive with coil of same dimensions?

TE-MSC seminar – 23 March 2023 *R. Jacobsson* 24

- **Design requirements**
  - aperture: **4 x 6 m²;**
  - bending strength: **0.6-0.7 T.m;**
  - Integration of **vacuum chamber** (can be simplified with He option).
- **Initial design** developed by P. Wertelaers and A. Perez in **2019**, relying on **normal conducting magnets**

⇒ **~1.2 MW** power consumption!

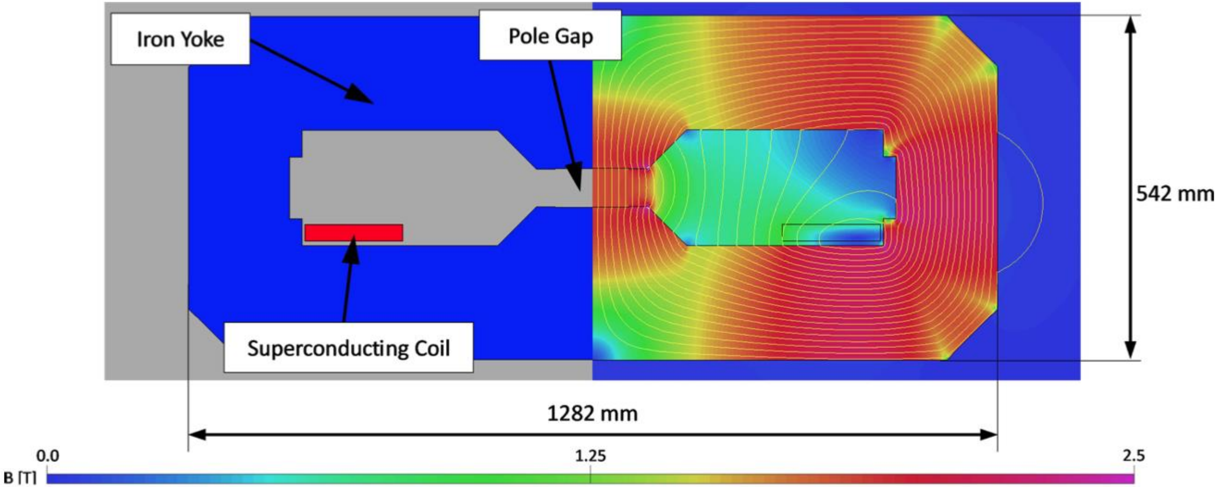
- First study of **superconducting options** by D. Tommasini and H. Bajas in **2020** (incl., **Nb–Ti**, $\mathbf{Nb_3Sn}$, $\mathbf{MgB_2}$ and **ReBCO**)

⇒ all options feasible; choice to be made on **conductor availability** and **cooling type.**

18 April 2024 A. Devred, *et al.* | Proposal for SHiP Spectrometer Magnet 3

SHiP spectrometer

Potential application for HL-LHC R&D to **superferric magnets.** Proof-of-principle demonstrator for an energy-efficient, iron-dominated magnet (large gap and moderate fields < 2T) relying on a HTS MgB_2 superconducting coil:



Factor ~100 energy saving targeted compared to typical ~ MW NC magnets

Thanks…

Thanks to everyone who supported the PBC ECN3 Beam Delivery Task Force effort…

… the BDF & CB WGs…

… the NA-CONS project…

… including all CERN's equipment & service groups…

…and the HIKE, SHADOWS and SHiP collaborations

CERN-PBC-REPORT-2023-001

11 March 2023

Findings of the Physics Beyond Colliders ECN3 Beam Delivery Task Force

C. Ahdida, H. Bartosik, J. Bernhard, M. Brugger, M. Calviani, A. Colinet, L.S. Esposito, R. Franqueira Ximenes, M.A. Fraser, F. Gautheron, J.L. Grenard, Y. Kadi, V. Kain, A. Lafuente, I. Josifovic, K. Li, G. Mazzola, E. Nowak, K. Pal, T. Prebibaj, R. Ramjiawan, I. Romera Ramírez, F. Roncarolo, P. Schwarz, F.M. Velotti, C. Vendeuvre, M. van Dijk, H. Vincke, C. Zamantzas, T. Zickler
CERN, CH-1211 Geneva, Switzerland

Keywords: PBC, NA-CONS, ECN3, beam delivery, task force, high intensity upgrade

Summary

The ECN3 Beam Delivery Task Force was mandated by the PBC Study Group to assess the technical feasibility of increasing the proton beam intensity to the ECN3 hall of the North Area to satisfy the demands of a compelling set of PBC experimental physics proposals. This report summarises the findings of the Task Force that converge on a technically feasible solution with an implementation timeline that could exploit and build upon the investment already foreseen as part of Phase 1 of the NA-CONS project, and take the SPS complex into a new intensity frontier for Fixed Target physics in Run4.

Thank you !

HI-ECN3 *Study* Project Mandate

Mandate for Project Leader of ECN3 High Intensity Study

The proposed ECN3 High Intensity (HI) facility will provide unique capabilities for delivering high-intensity, high energy beam for fixed target physics. The funding for the initial Technical Design Report (TDR) phase of the beam delivery and facility study was approved by Council in September 2023 Council following recommendation by the Research Board. A decision on the specific experimental implementation and overall approval is expected in late 2023 early 2024.

The overall feasibility has already been investigated and documented by the ECN3 Task Force, with the following working assumptions:

- ECN3 beam delivery via T4 target with magnetic bump bypass
- Dedicated HI mode with no splitting in TDC2 or impact on TCC2 targets Readiness in Run 4 with no impact on EHN1 and EHN2 NA operation post-LS3
- New target complex for TCC8 using ALARA principles for operation, maintenance and decommissioning
- Use of new target complex service building for additional power converters (instead of BA82)
- Recovering iron shielding blocks from CNGS hadron absorber, TT7 neutrino facility dump and Opera

The formation of an HI-EC3 Project Team to deliver the facility TDR is requested by the ATS Director. The Project Leader's mandate is to define and implement the project structure and team, finalise the technical studies and present the coherent upgrade proposal (including timeline and resource and budget needs) in the form of the TDR.

It is important to note the close links to NACONS, and the imperative to minimise the extra work for the technical teams - this needs to be a guiding principle of the organisation, including the common coordination with NACONS.

The following items will form the basis for the deliverables for the TDR phase, which for the ATS aspects needs to be completed by the beginning of LS3. This list includes a number of decisions already needed in 2023.

- Technical specifications and engineering studies of equipment and infrastructure systems for high intensity beam delivery
- Agreement with CERN groups to recruit GRADs by November 2023, along with required STAFF resources for their supervision
- Manage HW expenditure linked to some aspects of beam delivery and infrastructure in parallel to TDR phase
- Define the detailed implementation schedule
- Construct efficient project interface and workflow to NACONS
- Finalise cost and resource estimates and profiles (update of EDMS #2825627) Perform ECN3 hydrological study
- Proposal for ECN3 bridge and EHN1 ramp RP shielding
- Oversee 2023 and 2024 beam tests

- **Form a Project Team:**
  - Project structure and team being created with synergy of NA-CONS at its heart
  - **Aggressive schedule:** necessary project structures put in place in anticipation of formal approval in 2024
  - Positive discussions with CERN groups, **recruitment underway: GRAD (with STAFF supervision agreed)**
  - EN-ACE support project planning/scheduling
  - BE-EA support configuration management
  - SY support Project Admin & Project Safety

- **Deliver a TDR by end of 2025:**
  - Despite delays, technical work on Beam Delivery (experiment-independent) continues in earnest
  - Need to get going on Target Complex & Experimental Area ASAP!
  - Refined timeline with resource and budget needs
  - **Already on the critical path for Civil Engineering: careful optimisation of schedule needed**

SY linkpersons for TDR phase

Support from CERN groups:

i. GRAD support (2 yr) TDR phase only if STAFF supervision guaranteed **(no STAFF M2P)**
ii. Synergy to NA-CONS key (if possible, same STAFF member on both projects)
iii. WP descriptions (agreed deliverables & resources) to be written with the GRAD support

Group	Contact	Activity	GRAD Support 2024/25
SY-BI	David BELOHRAD	BI	✓
SY-AR	Katarina SIGERUD	Project Admin Support: Ane-Mona BRANZA (SY-ABT)	
SY-ABT	Francesco VELOTTI	WP2	✓
SY-EPC	Yves GAILLARD	TDR	
SY-EPC	Ivan JOSIFOVIC	TDR	
SY-RF	Giulia PAPOTTI	TDR (RF support for slow extraction)	
SY-STI	Rui FRANQUEIERA XIMENES	WP3	✓
SY-STI	Jean-Louis GRENARD	WP4	✓
SY-STI	Nicolas QUINQUIS	TCC8 Dismantling	
SY-STI	Ruben ALIA	R2E support TDR	
SY-HDO	Anne FUNKEN	Safety Support	
SY-STI	Melania AVERNA	Project Safety Officer	
SY-STI	Luigi ESPOSITO	FLUKA support for TDR	✓

Study Project (TDR) GRAD Team

Person	Role	Group	Supervisor	Programme	BC Description	PRQ	Start Date
Ixone VAQUERO	Planning & Coordination	EN-ACE	Fernando PEDROSA	ORIGIN	HI-ECN3 / NA-CONS	Completed	1/10/2023
Xavier PALLE	Planning & Coordination	EN-ACE	Fernando PEDROSA	ORIGIN	HI-ECN3 / NA-CONS	Completed	1/3/2024
Kincso PAL	TDR	SCE	John OSBORNE	TEMP	HI-ECN3	Completed	1/1/2024
James CURRIE	TDR	HSE-OHS	Simon MARSH	ORIGIN	HI-ECN3	Completed	1/2/2024
TBC	FIRIA	HSE-OHS	Saverio LA MENDOLA	QUEST	HI-ECN3 / HSE	2024	Q3 2024
TBC	TDR → Implementation	SCE	Natacha LOPEZ	QUEST	HI-ECN3	2025	Q1 2025
Nikola ZARIC	TDR	EN-CV	Roberto BOZZI	QUEST	HI-ECN3	Completed	1/2/2024
Angelo PETRELLESE	Secondary Vacuum	BE-EA	Miguel SANTOS	ORIGIN	HI-ECN3 / NA-CONS / PBC	Completed	1/4/2024
Fabian METZGER	TDR	BE-EA	Laurence NEVAY	GRAF	HI-ECN3	Completed	1/4/2024
TBC	TDR / LS3 prep	BE-EA	Francois BUTIN	ORIGIN	HI-ECN3	2024/25	TBC
Beatriz MARTINEZ	TDR	BE-EA	Michael LAZZARONI		HI-ECN3	Completed	2/5/2024
Ming LIU	TDR	EN-EL	Eva CANO GONZALEZ	QUEST	HI-ECN3 / NA-CONS	Completed	2/5/2024
Cristina DURAN GUTIERREZ	TDR	EN-HE	Roberto RINALDESI	ORIGIN	HI-ECN3	Completed	1/6/2024
Olin PINTO	TDR	HSE-RP	Claudia AHDIDA	QUEST	HI-ECN3	Completed	1/2/2024
Mike PARKIN	TDR	SY-STI	Rui FRANQUEIRA XIMENES	QUEST	HI-ECN3	Completed	1/3/2024
Giuseppe MAZZOLA	R2E / FLUKA	SY-STI	Luigi ESPOSITO	QUEST	HI-ECN3	Completed	1/2/2022
TBC	BLM	SY-BI	Christos ZAMANTZAS	ORIGIN	HI-ECN3	?	?
TBC	TCSC CONS	SY-STI	Nicolas SOLIERI	QUEST	NA-CONS	?	?
TBC	TDC2 / TCC2	HSE-RP	Helmut VINCKE	QUEST	NA-CONS	2024	TBC
Luke DYKS	TDR	BE-EA	Dipanwita BANERJEE	GRAF	PBC / HI-ECN3	Completed	1/9/2022
Alexander GORN	TDR	SY-ABT	Matthew FRASER	GRAF	PBC / SY	Completed	1/10/2023
Tamara BUD	ECN3 tasks on request	SCE	John OSBORNE	QUEST	PBC	Completed	1/1/2024
Francesca LUONI	ECN3 tasks on request	HSE-RP	Claudia AHDIDA	FELL	PBC	Completed	1/9/2023
Tirsi PREBIBAJ	ECN3 tasks on request	BE-ABP	Hannes BARTOSIK	GRAF	PBC	Completed	1/3/2023

C. Ahdida et al., *Findings of the Physics Beyond Colliders ECN3 Beam Delivery Task Force*, **CERN-PBC-REPORT-2023-001**

Project Resources: quick reminder (i)

- **PBC ECN3 Task Force:** budget estimate (~ Class 3 - 4)
  - Agreed by CERN groups at 324th IEFC meeting 3 March 2023 **(no project STAFF M2P)**
  - Presented to the 244th CERN Research Board 6 March 2023
  - **Beam Delivery = 14 MCHF**

Cost Categories	**Resource Context (including M2P)**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**Total**
		*[kCHF rounded to closest 25k]**									
Beam Delivery	**Operation Critical (NA-CONS**) and HI specific**	125	450	1150	2525	3550	2875	575	225	0	**11475**
	TDR: Engineering & Optimization Phase (GRAD)***	550	1125	1125	0	0	0	0	0	0	**2800**
	Sub-Total:	*675*	*1575*	*2275*	*2525*	*3550*	*2875*	*575*	*225*	*0*	***14275***

* Budget profiling is a very rough estimate (peaking after LS3) and needs to be iterated in TDR phase

** NA-CONS new baseline items motivated by risk to reliability of HI-ECN3 operation after LS3

*** TDR GRAD request based on same ratio of GRAD/CtC of NA-CONS project working out at ~ 2.8 MCHF or 10 FTE for 3 years

Project Resources: quick reminder (ii)

- **PBC ECN3 Task Force:** budget estimate (~ Class 3 - 4)
  - Agreed by CERN groups at 324th IEFC meeting 3 March 2023 **(no project STAFF M2P)**
  - Presented to the 244th CERN Research Board 6 March 2023
  - **Beam Delivery = 14 MCHF** + **BDF/SHiP facility (50 MCHF)** → **Total = 64 MCHF**

Cost Categories	Resource Context (including M4P)	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total	%
		*[kCHF rounded to closest 25k]**										
BDF/SHiP	Civil Engineering	0	100	200	300	500	2450	3350	2450	500	**9850**	**20**
	Target Station & beam dilution	0	200	425	625	1050	5250	7150	5250	1050	**21000**	**42**
	Infrastructure & Services	0	150	300	475	775	3850	5250	3850	775	**15425**	**31**
	Integration, Dismantling, Installation	25	150	375	825	1150	925	175	75	0	**3700**	**7**
	Sub-Total:	*25*	*600*	*1300*	*2225*	*3475*	*12475*	*15925*	*11625*	*2325*	***49975***	***100***

* Budget profiling is a very rough estimate (peaking after LS3) and needs to be iterated in TDR phase

Project Resources: quick reminder (iii)

- **PBC ECN3 Task Force:** budget estimate (~ Class 3 - 4)
  - Agreed by CERN groups at 324th IEFC meeting 3 March 2023 **(no project STAFF M2P)**
  - Presented to the 244th CERN Research Board 6 March 2023
  - **No significant cost difference between experiment options**
  - **Beam Delivery = 14 MCHF + HIKE/SHADOWS facility (46 MCHF) → Total = 60 MCHF**

Cost Categories	Resource Context (including M2P)	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total	%
		[kCHF rounded to closest 25k]										
HIKE / SHADOWS	Civil Engineering *(no additional access shaft requested)*	0	50	125	175	300	1500	2025	1500	300	**5975**	**13**
	Target Station	0	175	325	500	825	4150	5650	4150	825	**16600**	**36**
	Infrastructure & Services	0	175	350	525	850	4300	5850	4300	850	**17200**	**37**
	Integration, Dismantling, Installation	25	150	375	825	1150	925	175	75	0	**3700**	**8**
	Phase-II Beamline & Infrastructure Changes	0	0	0	0	0	0	0	0	2500	**2500**	**6**
	Sub-Total:	*25*	*550*	*1175*	*2025*	*3125*	*10875*	*13700*	*10025*	*4475*	***45975***	***100***

MTP 2023 request

- **MTP 2023 request of 2.85 MCHF for 2023 & 2024:**
  - This **included additional NA-CONS items** deemed critical for the future operation of the HI-ECN3 facility: ***we requested an increase in the Cost-to-Completion of NA-CONS***

No	Classification for MTP document	Sector /Unit	Department	Project Name/ Operation	Type of Budget	Request short description	Request Justification / Comments	Requested budget per year in [kCHF] 2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total 2023 - 2033 [kCHF]	Total 2023 - 2028 [kCHF]	Total 2024 - 2033 [kCHF]	Total 2024 - 2028 [kCHF]	Total 2023-2024 [kCHF]
41	MTP Funding Request	ATS	ATS	ECN3	Materials	HI-ECN3 facility	Outcome of the ECN3 TF Study -> high-intensity beamline: ~14MCHF -> experiment dependent implementation (figures presented here as request for the SHIP case as the slightly more expensive one) SHIP ECN3: ~50MCHF HIKE/SHADOWS: ~46MCHF Resource summary: EDMS #2825627 ECN3 TF Study report: CERN-PBC-REPORT-2023-001	225	1,225	2,400	4,100	6,150	13,950	15,250	11,000	2,175			56,475	28,050	56,250	27,825	1,450
42	MTP Funding Request	ATS	ATS	ECN3	Grad	HI-ECN3 facility	see comments above	450	950	1,175	625	875	1,400	1,250	850	150			7,725	5,475	7,275	5,025	1,400
Total								**675**	**2175**	**3575**	**4,725**	**7,025**	**15,350**	**16,500**	**11,850**	**2,325**	**0**	**0**	**64,200**	**33,525**	**63,525**	**32,850**	**2,850**

MTP 2023 arbitration

- **MTP 2023 decision by the DG:**
  - *'Allocate **2.5 MCHF for 2023 and 2024** for the preliminary works, waiting for the project to be officially approved.'*

								Allocated budget per year in [kCHF]															
No	Classification for MTP document	Sector /Unit	Department	Project Name/ Operation	Type of Budget	Request short description	Request Justification / Comments	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total 2023 - 2033 [kCHF]	Total 2023 - 2028 [kCHF]	Total 2024 - 2033 [kCHF]	Total 2024 - 2028 [kCHF]	Total 2023-2024 [kCHF]
41	MTP Funding Request	ATS	ATS	ECN3	Materials	HI-ECN3 facility	Outcome of the ECN3 TF Study -> high-intensity beamline: ~14MCHF -> experiment dependent implementation (figures presented here as request for the SHIP case as the slightly more expensive one) SHIP ECN3: ~50MCHF HIKE/SHADOWS: ~46MCHF Resource summary: EDMS #2825627 ECN3 TF Study report: CERN-PBC-REPORT-2023-001	225	**875**	0	0	0	0	0	0	0			1100	1100	875	875	1100
42	MTP Funding Request	ATS	ATS	ECN3	Grad	HI-ECN3 facility	see comments above	450	950	0	0	0	0	0	0	0			1400	1400	950	950	1,400
Total								**675**	**1825**										**2500**				

Budget Transfer to NA-CONS

- **700 kCHF was transferred from HI-ECN3 to NA-CONS to advance on many new LS3 critical consolidation items requested for HI-ECN3:**
  - TCSC (Transfer Line Splitter Collimator) consolidation
  - RP support for primary NA zones
  - Transfer line magnets (magnetic measurements, spares, etc.)
  - Beam instrumentation
- **HI-ECN3 Study Project therefore has a shortfall in 2023/24 of 350 kCHF requested:**
  - 1.8 MCHF approved vs. 2.85 MCHF requested (after items assigned NA-CONS)

Type	Funding	Total
Goods	CERN	**278**
Grad	CERN	**1,521**
Total		**1,799**

TDR GRAD team budget

- **Discussion continue with CERN groups:** the team is now reaching the 2.8 MCHF TDR GRAD budget request:

Dep	Group	WP	Category	BC Description	Detailed Description	2023	2024	2025	2026	Total
SY	SY-STI	3&4	QUEST	TDR preparation: SY-STI	Target R&D		82.5	110	27.5	220
EN	EN-ACE	1	ORIGIN	TDR preparation: EN-ACE	Planning/Scheduling	10	40	30	0	80
EN	EN-ACE	1	ORIGIN	TDR preparation: EN-ACE	Planning/Scheduling		30	40	10	80
HSE	HSE-RP	6	QUEST	TDR preparation: HSE-RP	Including 25% RP source term contribution		101	110	9	220
EN	EN-CV	3&4&5	QUEST	TDR preparation: EN-CV	TDR		110	110	0	220
EN	EN-EL	4&5	QUEST	TDR preparation: EN-EL	TDR		55	55	0	110
EN	EN-HE	4&5	ORIGIN	TDR preparation: EN-HE	TDR		60	80	20	160
EN	EN-HE	4&5	TEMP	TDR preparation: EN-HE	External Contractor 4 months at average of 30%		11			11
BE	BE-EA	2	GRAF	TDR preparation: BE-EA-LE	TDR: Beam Line Support		110	110	0	220
SCE	SCE-PPM	7	QUEST	TDR preparation: SCE-PPM	Supporting handover to implementation phase		55	110	55	220
SCE	SCE-SAM	7	TEMP	TDR preparation: SCE-SAM	4-month handover to new PBC FELL		37			37
HSE	HSE-RP	6	QUEST	TDR preparation: HSE-OHS-RP	FIRIA - RP Environmental Engineer, FIRIA 25% contribution:			27.5	27.5	55
HSE	HSE-OHS	6	QUEST	TDR preparation: HSE-OHS-IB	FIRIA - Fire Safety Engineer, Shared 50:50 with HSE		14	55	41	110
HSE	HSE-OHS	6	QUEST	TDR preparation: HSE-OHS-PE	Technical Safety Engineer		101	110	9	220
SY	SY-STI	3&4&5	QUEST	TDR preparation: SY-STI	R2E / FLUKA studies			110	110	220
SY	SY-BI	2	ORIGIN	TDR preparation: SY-BI	Electronics for BLM work (oBLMS &ICs)		20	80	60	160
BE	BE-EA	2	ORIGIN	TDR preparation: BE-EA	Supporting P42 Vacuum upgrade, Shared with PBC and NA-CONS:		27	27		53
SY	SY-BI	2	TECH	TDR preparation: SY-BI	P42 BLM Part 2 TECH			42		42
BE	BE-EA	5	ORIGIN	TDR preparation: BE-EA	Integration support for dismantling and shielding recovery			80	80	160
BE	BE-EA	5	ORIGIN	TDR preparation: BE-EA	Integration support for ICEA		20	80	60	160
Total						**10**	**872**	**1'366**	**510**	**2'758**

Urgent Items (in view of approval)

Dep	Group	WP	M / P Category	HI-ECN3 Category	BC Description	Detailed Description	2023	2024	2025
SY	SY-ABT	1	Material	TDR	Project Management			150	150
HSE	HSE-RP	2	Material	Beam Delivery	Additional RP Monitors for Beam Delivery		35	10	
BE	BE-GM	4&5	M+P	Experiment - HIKE/SHADOWS	TDR preparation: BE-GM			65	65
SY	SY-STI	3	Material	Experiment	Target R&D including Prototype Beam Test			230	470
TE	TE-MSC	2	Material	Beam Delivery	Production of Laminated Magnets for T4 Bump and P42 Dump			45	45
SY	SY-BI	2	Material	Beam Delivery	Repayment of P42 BLM Part 1				130
SY	SY-BI	2	Material	Beam Delivery	P42 BLM Part 2		0	39	27
HSE	HSE-RP	2	M+P	Beam Delivery	EHN1 ramp Classification RP			50	100
HSE	HSE-RP	2	M+P	Beam Delivery	ECN3 bridge shielding			50	150
SY	SY-STI	3	Material	Beam Delivery	P42 Beam Dump		20	180	
TE	TE-MPE	2	M+P	Beam Delivery	Machine Protection for Beam Delivery			100	100
SY	SY-ABT	2	M+P	Beam Delivery	Low-Z Electrostatic Septa			100	100
TE	TE-MSC	2	Material	Beam Delivery	Production of 11 Laminated MDX for P42			15	240
BE	BE-EA	2	Material	Beam Delivery	XTAX High Intensity Upgrade - Design			10	
SY	SY-EPC	2	Material	Beam Delivery	Production of 2 POLARIS for T4 Bump and P42 Dump				150
BE	BE-EA	2	Material	Beam Delivery	P42 Vacuum upgrade				200
SY	SY-ABT	2	QUEST	Beam Delivery	Extraction and Beam Transfer				28
SY	SY-STI	4	M+P	Experiment	TT7 shielding recovery			200	700
SY	SY-STI	4	M+P	Experiment	Target and coil handling system			25	25
SY	SY-STI	4	M+P	Experiment	Vacuum Vessel containing target system			35	55
SY	SY-STI	4	M+P	Experiment	Target system integration & R&D			50	50
BE	BE-EA	5	MPA	Experiment	Cable Identification Campaign Pre-LS3			10	10
EN	EN-HE	4&5	M+P	Experiment	TCC8/ECN3 transfer table refurbishment				100
EN	EN-HE	4	M+P	Experiment	Complete upgrade of the TCC8 crane				400
SCE	SCE-PPM	7	M+P	Experiment	SCE pre-studies needed in 2025			3	100
Total							**55**	**1'367**	**3'395**

HI-ECN3 Study Project Budget Request 2024/25

	2023 [kCHF]	2024 [kCHF]	2025 [kCHF]	…	Project Total [kCHF]
TDR GRADs	10	872	1366		-
Reprofile of Urgent HI-ECN3 Items	55	1367	3395		-
To NA-CONS	*206*	*495*	*920*		4733
HI-ECN3 Study Project	**271**	**2734**	**5681**		**65083**
MTP 2023 Request	**700**	**2175**	**3575**		**64250**
	-429	**+559**	**+2106**		**+833**

Proton sharing: ECN3 super-cycles

Realistic supercycle composition for physics production, e.g. night/weekend operation without HL-LHC filling

TCC2 (SFTPRO)			ECN3 (HIKE / SHADOWS)			SC length [s]	TCC2 & ECN3 FT Duty Cycle [%]
FT Length [s]	N_{cycles} [/SC]	Duty Cycle [%]	FT Length [s]	N_{cycles} [/SC]	Duty Cycle [%]		
4.8	1	11.1	4.8	2	22.2	43.2	**33.3***
9.6	1	11.4	4.8	4	22.9	84.0	**34.3***

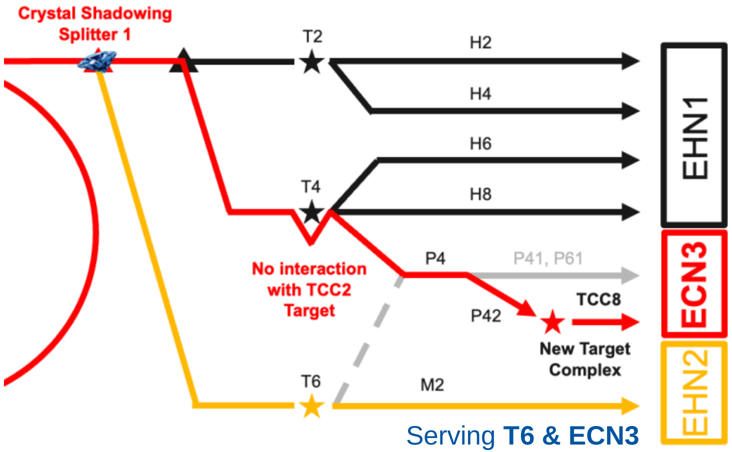
TCC2 (SFTPRO)			ECN3 (SHiP, CNGS-like)			SC length [s]	TCC2 & ECN3 FT Duty Cycle [%]
FT Length [s]	N_{cycles} [/SC]	Duty Cycle [%]	FT Length [s]	N_{cycles} [/SC]	Duty Cycle [%]		
4.8	1	11.1	1.2	4	11.1	43.2	**22.2**
9.6	1	17.4	1.2	4	8.7	55.2	**26.1**

***SPS MBA/B RMS power limit @ 400 GeV**

*M. Tat, *TT20 beam loss reduction*, **CERN-STUDENTS-Note-2019-219**
*P. Arrutia, *Optimisation of Slow Extraction and Beam Delivery from Synchrotrons*, **CERN-THESIS-2020-259**

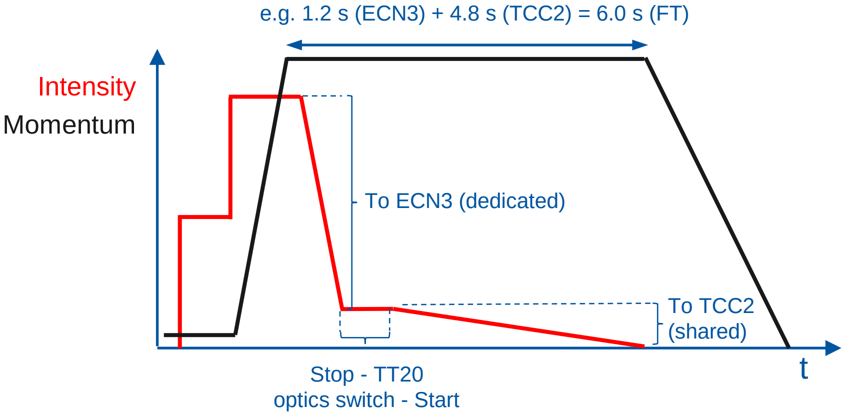
Proton sharing: upgrades

- **We could investigate more complex solutions to ease proton sharing via targeted R&D if we can push the SPS pulse intensity:**
  - **Splitting dedicated ECN3 cycles:**
    - Splitting **>4×10^{13} ppp** with **crystal shadowing*** on splitter 1 to serve **T6 & ECN3**, or splitter 2 to serve **T2 & ECN3**



Serving **T6 & ECN3**

  - **Multi-PPM "multi-user" spills:**
    - Exploit margin on RMS power available in SPS, extract to ECN3 on longer FT before stopping extraction (changing optics & destination) and sharing to TCC2 and **pushing > 4×10^{13} ppp**



Very preliminary power converter specs

<u>Magnetisation of hadron stopper (RAL, taken over by TE-MSC)</u>

- 24 mΩ @ 20°C, DC 135 A ➔ Bipolar 50V, 200A (POLARIS?)

<u>Muon shield SC magnets (T. Arndt, KIT-ITEP)</u>

- 5-7 PCs, DC 3000A/10V, 3phase 400V/63A grid connection and simple air-cooling, 7 kW power loss to air
- Note: Cu-current leads might need some additional power/ water-cooling, potentially aim for higher voltages for faster ramping

<u>Muon shield NC magnets (3 x) (RAL+UK)</u>

- 0.5 – 2 Ω @ 20°C, 50-100 A, DC, air cooled ➔ Unipolar Combo, no water cooling, 2 units?

<u>Spectrometer magnet (L. Baudin, A. Devred, TE-MSC)</u>

Accounting for 100 m of Cu supply cable, and rough estimation of the resistance in the current leads:

- Super-ferric: 10 mΩ @ 20°C, 4000A, DC, Tset 30s ➔ BOREAL 4P for DC operation, 330 V / 6000 Arms (Source 18kV) OR "BOREAL 4P-mini" for DC operation, 50 V / 4000 Arms (Source 400V)

- Resistive OPTION: 100 mΩ @ 20°C, 3000A, DC, Tset 30s ➔ BOREAL 2P for DC operation, 330V / 3000 Arms ?

- # Important job for F. Butin in WP5: