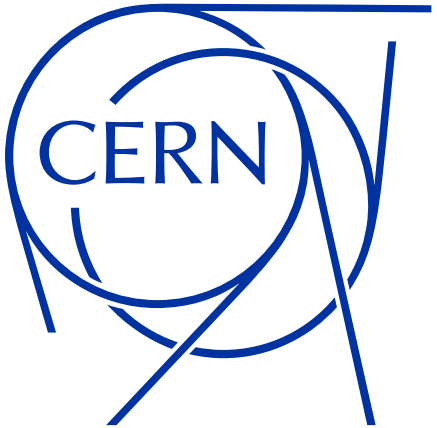

HI ECN3



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

M. Fraser & C. Ahdida
HI-ECN3 Study Project Leader & Deputy Project Leader

ESS - CERN Meeting, ESS, Lund, Sweden
20th September 2024

CERN | HI-ECN3

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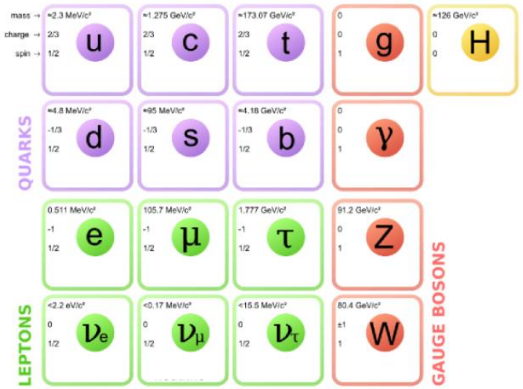
Motivation

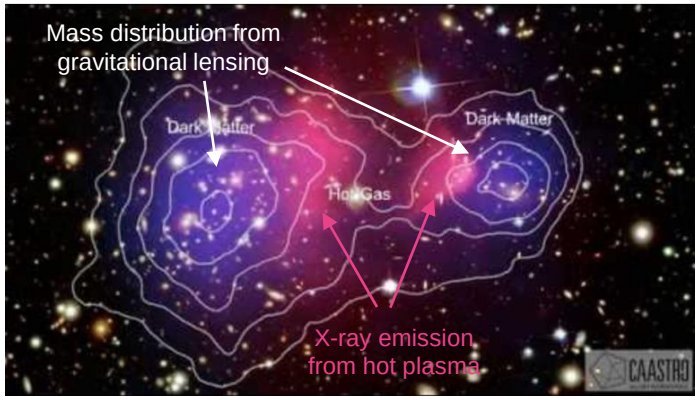
- **High Intensity ECN3 (HI-ECN3) project** for a new state-of-the-art high intensity experimental facility in ECN3
- HI-ECN3 will house the **Beam Dump Facility (BDF)** and the **Search for Hidden Particles (SHiP)** experiment to probe Beyond the Standard Model and to directly search for Feebly Interacting Particles

Standard Model of Particle Physics



Incomplete!

Evidence for Dark Matter
26% of universe!



Galaxy clusters after collisions → 80-85% dark matter clouds

Search for very weakly, long-lived interacting particles

?

SUSY,
sterile neutrinos,
etc.

BDF/SHiP Concept

Physics
SPS beam intensity and energy is unique for exploring and directly searching for Feebly Interacting Particles at SPS complementary to collider physics

Beam Dump Facility Concept

Beam

- **High energy** → production of charmed + beauty mesons
- **High ppp & POT** → overcome small prod cross-section of extra rare events of hidden particles

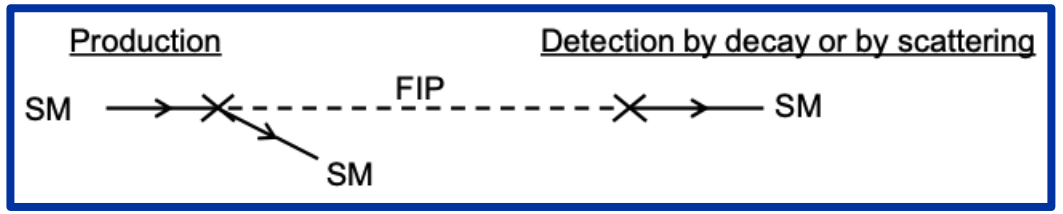
Target/dump

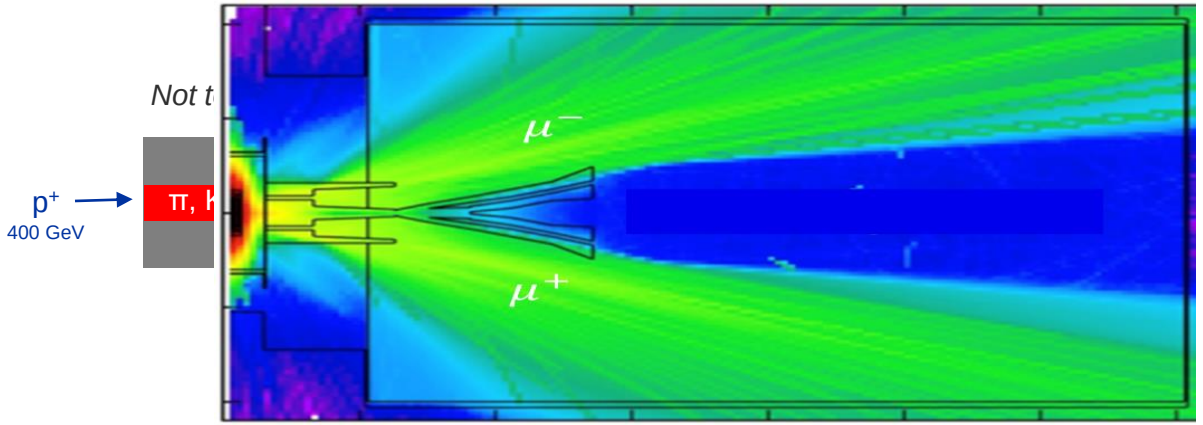
- **High ρ, Z & A** → Maximize p+ interaction
- **Shortest λ** → Force absorption of K & π to reduce muon & neutrino background

Muon shield

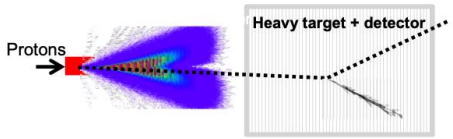
- **Active muon shield** to sweep muons out of detector location

Concept of BDF/SHiP

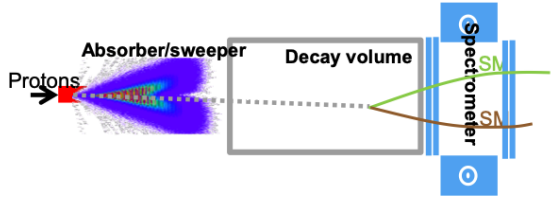




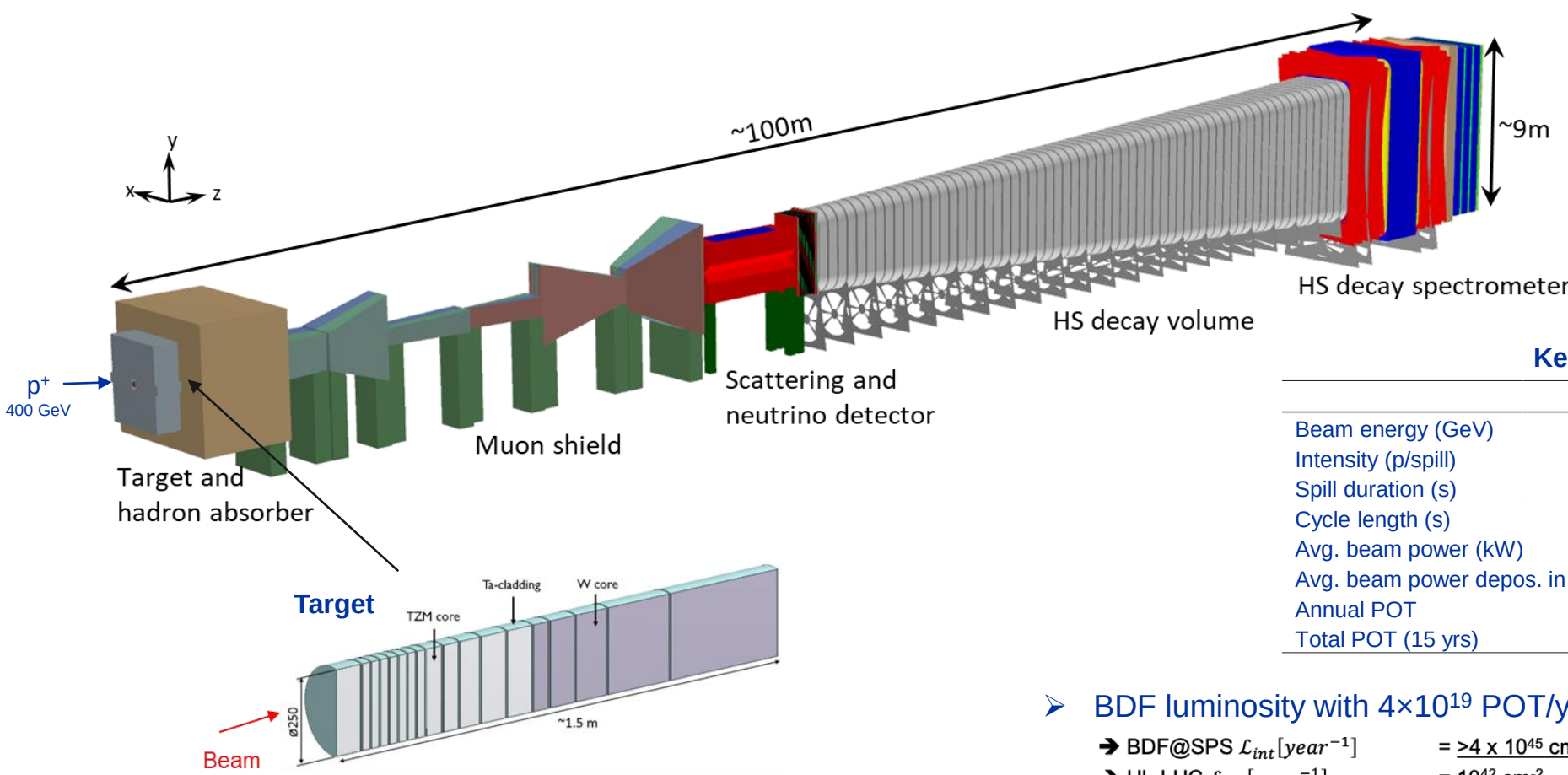
scattering events



decay events



BDF/SHiP Layout and Beam Parameters



TZM: 0.08% titanium – 0.05% zirconium – molybdenum alloy

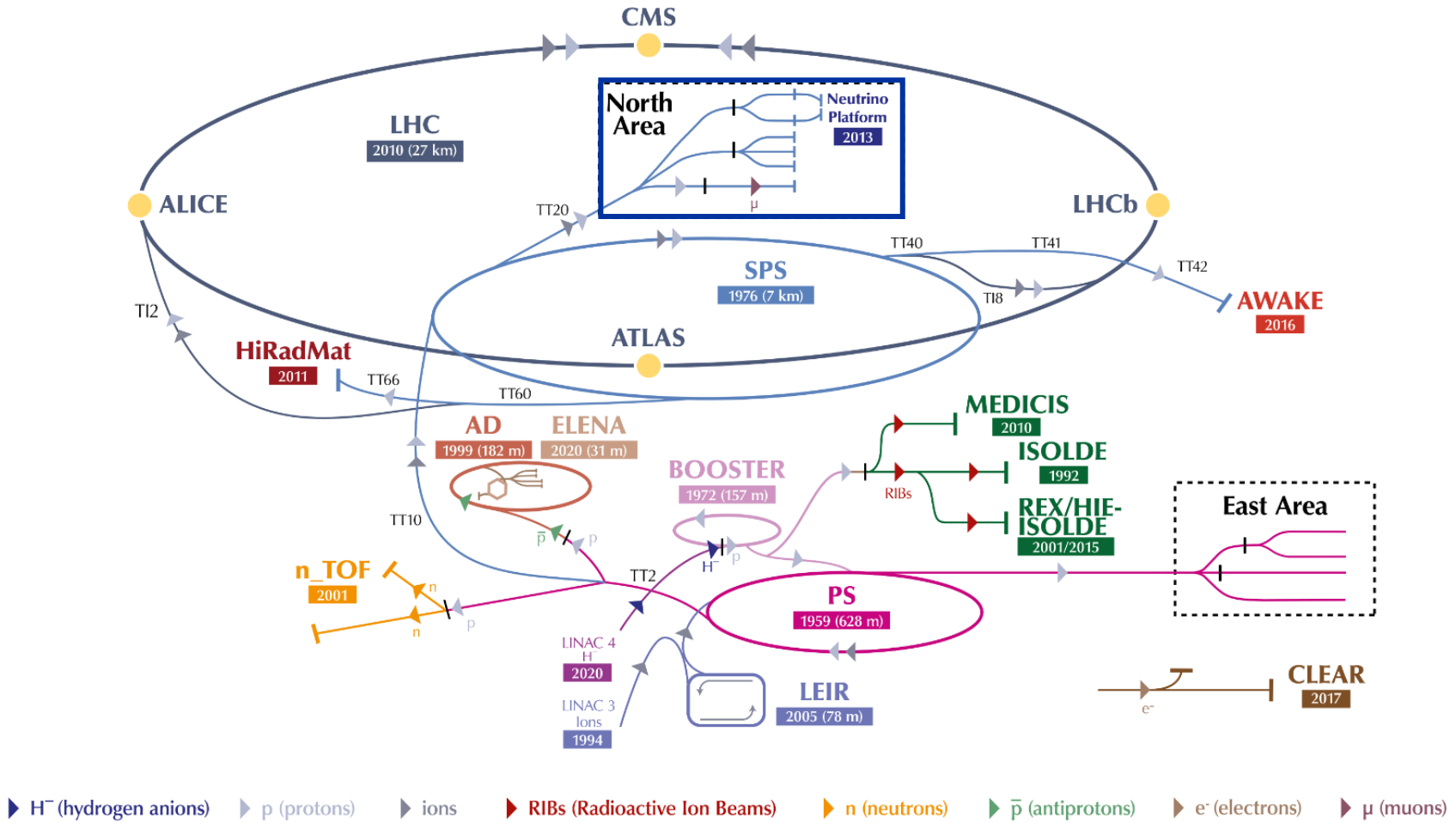
Key beam parameters of BDF/SHiP

	BDF
Beam energy (GeV)	400
Intensity (p/spill)	4×10^{13}
Spill duration (s)	1
Cycle length (s)	7.2
Avg. beam power (kW)	356
Avg. beam power depos. in target (kW)	305
Annual POT	4×10^{19}
Total POT (15 yrs)	60×10^{19}

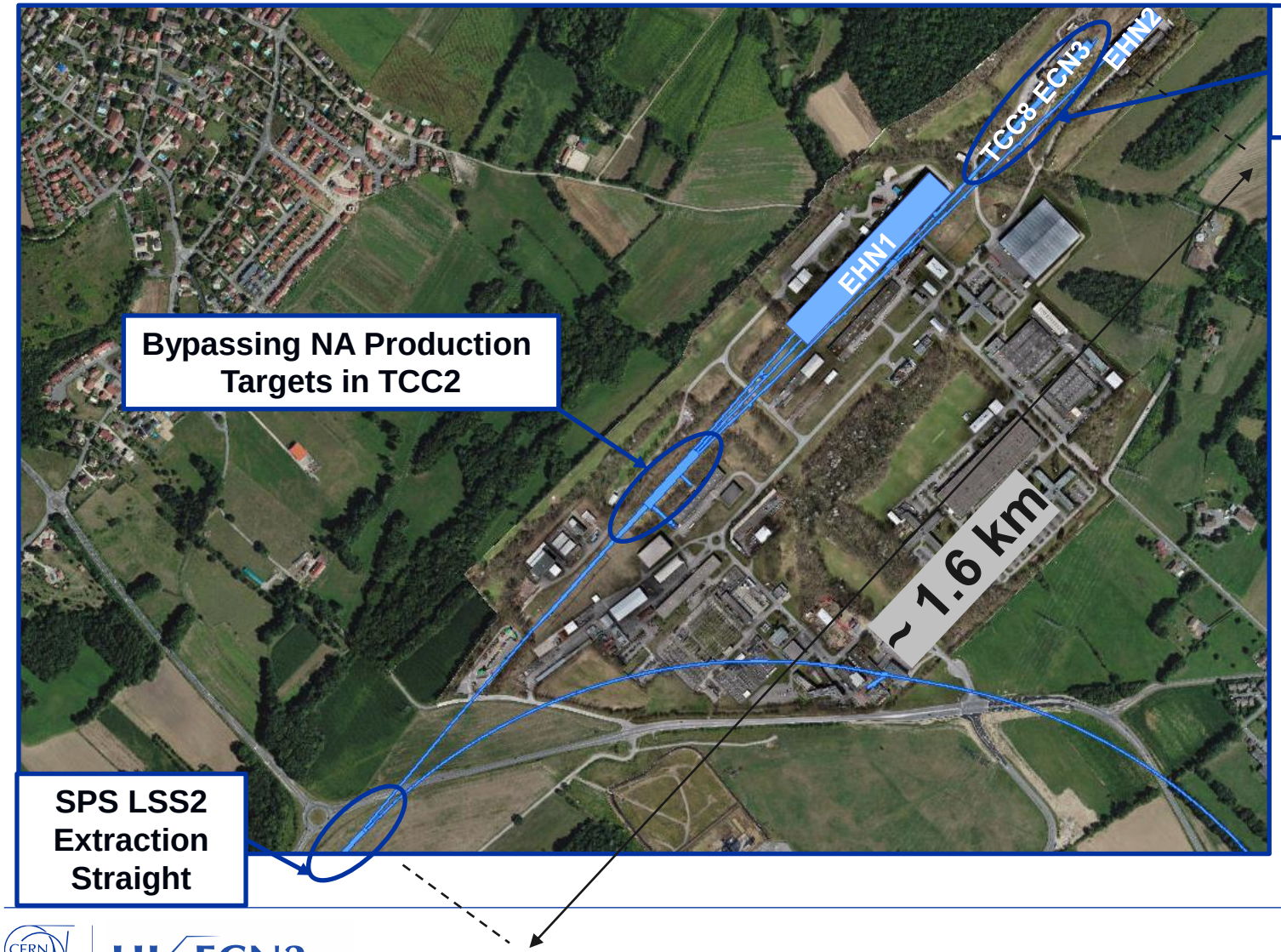
- BDF luminosity with 4×10^{19} POT/y currently available at the SPS
  - ➔ BDF@SPS $\mathcal{L}_{int}[year^{-1}]$ = >4 x 10^{45} cm^{-2} (cascade not incl.)
  - ➔ HL-LHC $\mathcal{L}_{int}[year^{-1}]$ = 10^{42} cm^{-2}

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

The CERN accelerator complex



ECN3 – Experimental Cavern North 3

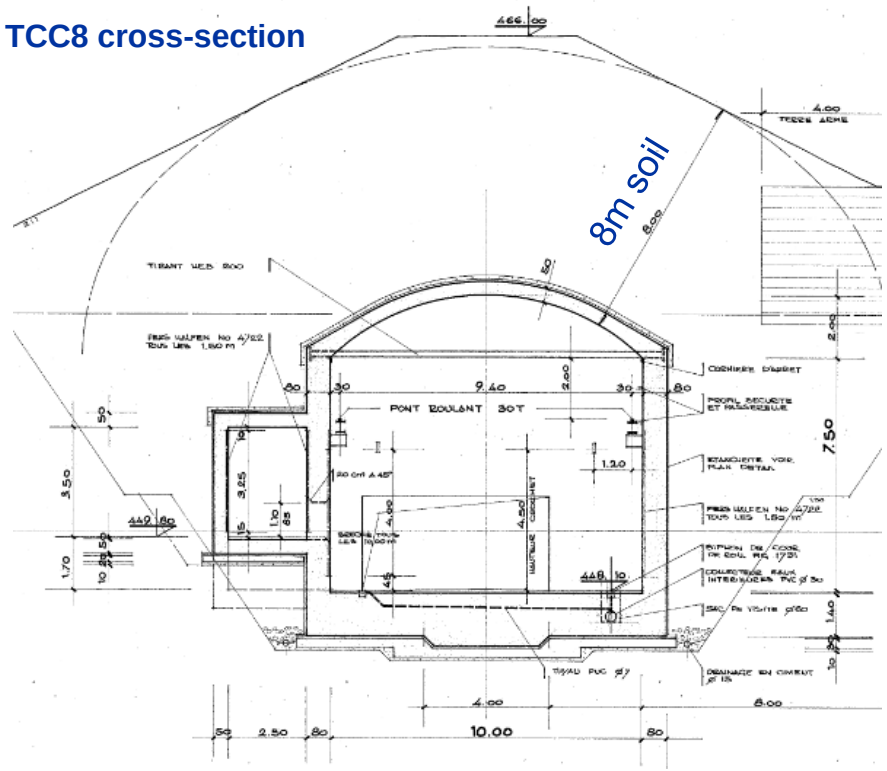


TCC8 & ECN3 (SPS's only underground experimental cavern!)

Bypassing NA Production Targets in TCC2

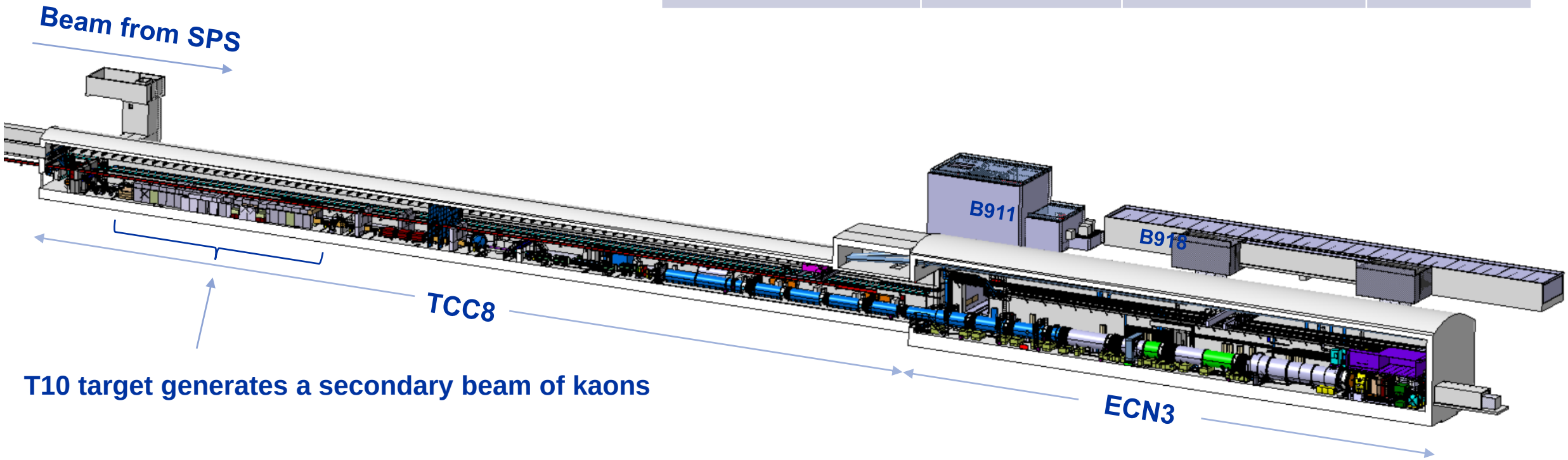
SPS LSS2 Extraction Straight

TCC8 cross-section



ECN3 today: NA62 experiment

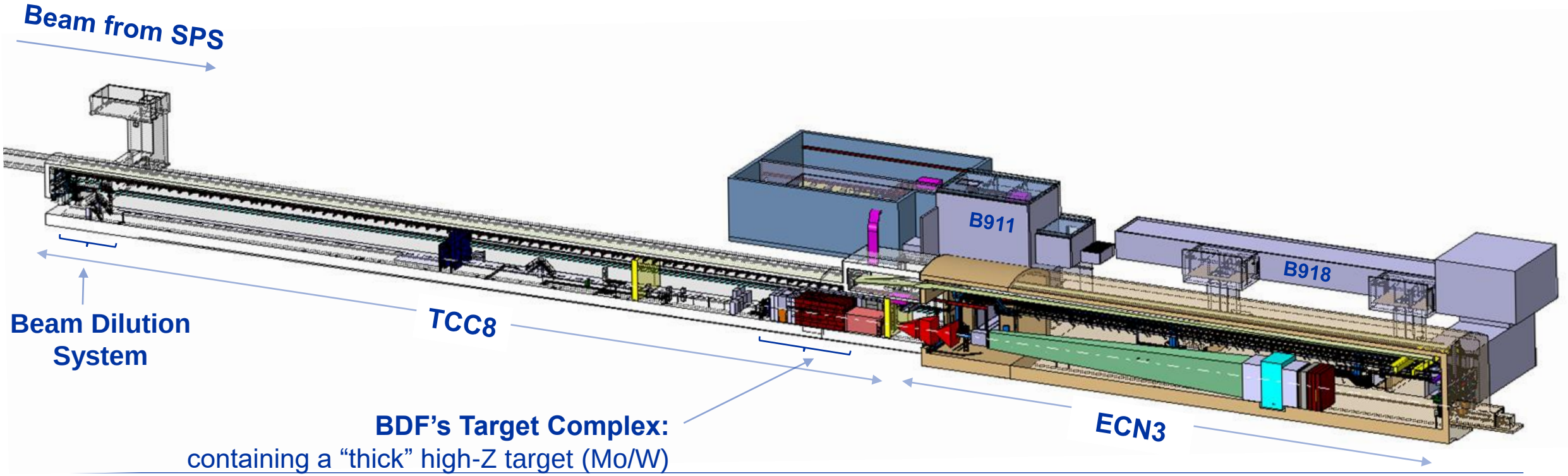
Experiment	p^+ [10^{12} /spill]	p^+ flux (avg.) [10^{11} Hz]	POT [10^{18} /yr]
NA62	~ 3	~ 2	2.6



ECN3 in 2031: BDF / SHiP

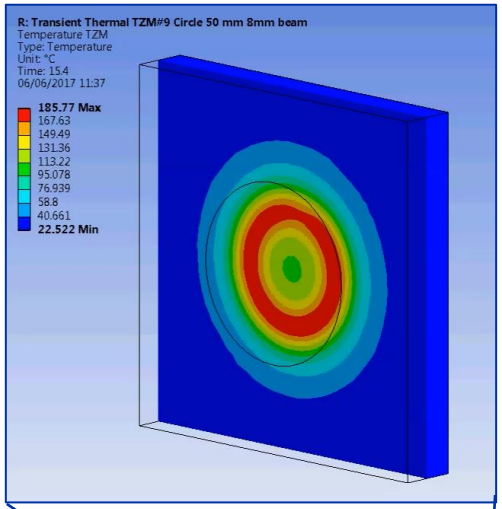
An order of magnitude intensity upgrade

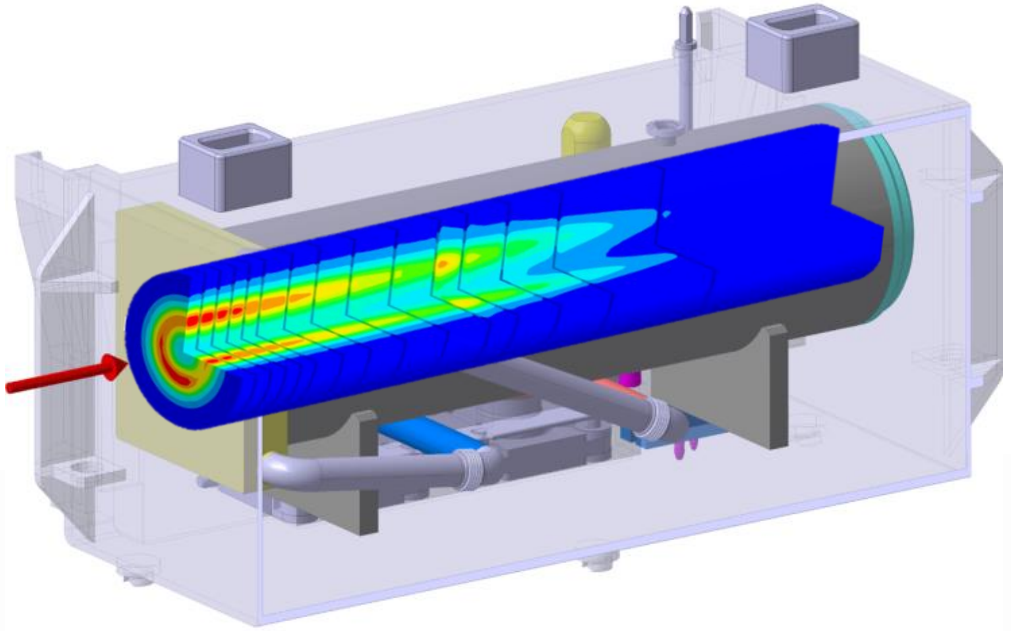
Experiment	p^+ [10^{12} /spill]	p^+ flux (avg.) [10^{12} Hz]	POT [10^{19} /yr]	SHiP POT request [10^{20} /15 yr]
NA62	~ 3	~ 0.2	0.26	-
SHiP (baseline)	40	~ 2.5	4.00	6.0

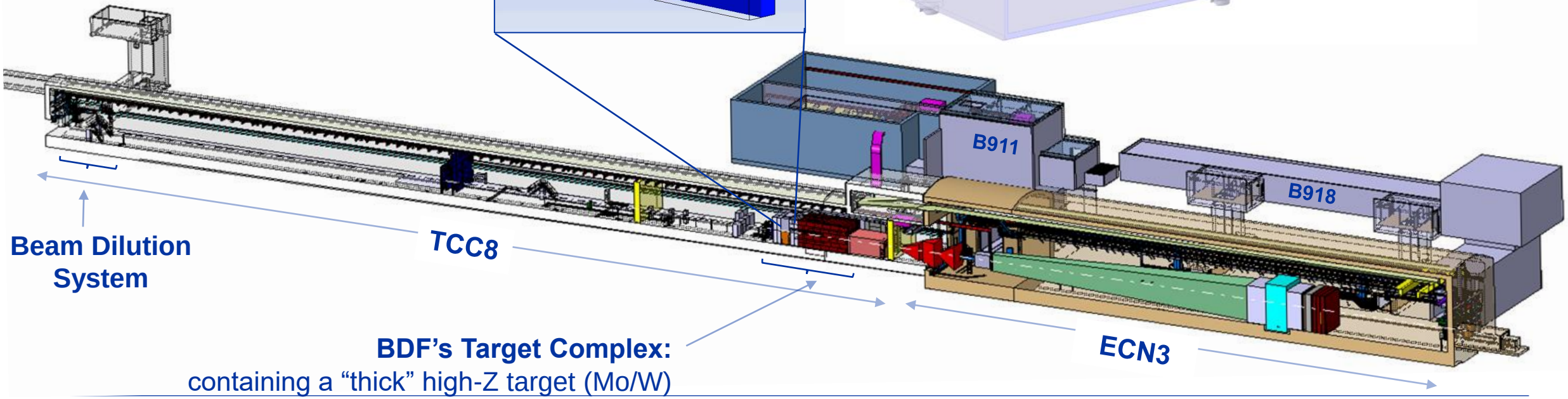


ECN3 in 2031: BDF / SHiP

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







BDF's Target Complex:
containing a "thick" high-Z target (Mo/W)

ECN3 in 2031: BDF / SHiP

An order of magnitude intensity upgrade

Experiment	p^+ [10^{12} /spill]	p^+ flux (avg.) [10^{12} Hz]	POT [10^{19} /yr]	SHiP POT request [10^{20} /15 yr]
NA62	~ 3	~ 0.2	0.26	-
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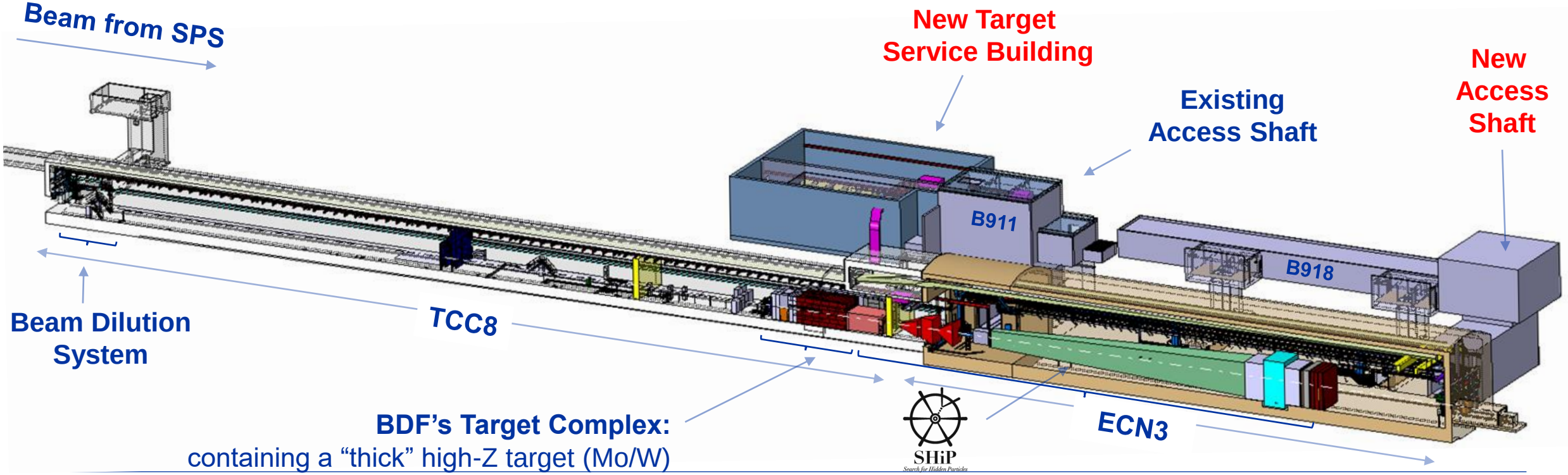
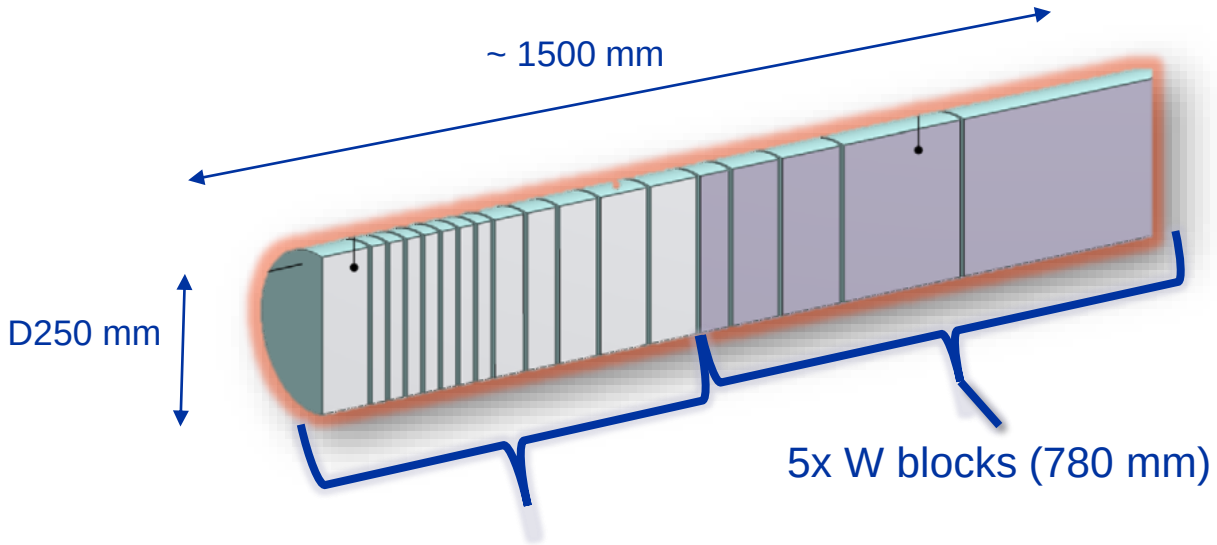


BDF Target Baseline Design



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)

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

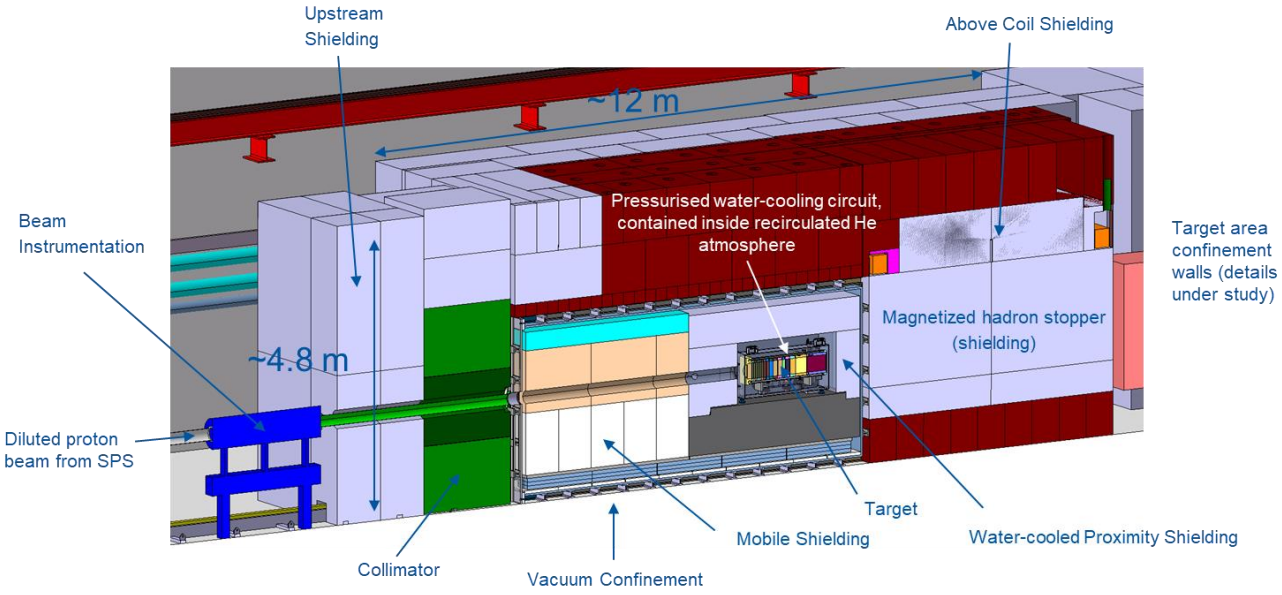
~ 4.0×10¹⁹ p⁺/y

See talks:

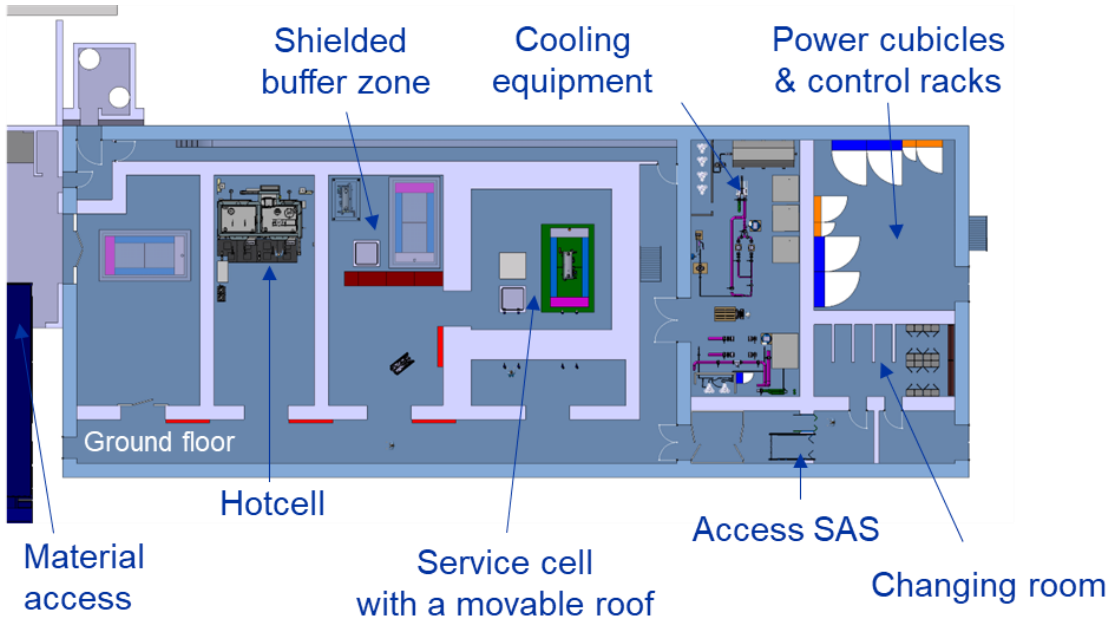
- Status of the BDF Target Design (R. Ximenes)
- Preliminary Considerations for the Target He Systems (F. Dragoni, N. Zaric)
- Radiation Protection Considerations (C. Ahdida)

BDF Target Complex and Service Building

BDF target complex layout



Service building layout



See talks:

- Considerations for the Design of the BDF Target Station and Annex Services (J.L. Grenard)
- Radiation Protection Considerations (C. Ahdida)

Project Timeline

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

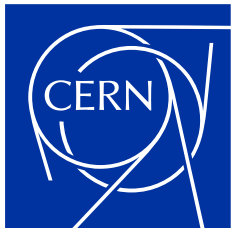
Machine/Facility/Experiments	2023	2024	2025	2026	2027	2028	2029	2030	2031
LHC				LS3			Commissioning		
SPS				LS3					
NA-CONS	Preparation & YETS Implementation Phase			NA-CONS Phase 1 (LS3)					
HI-ECN3 Beam Delivery via NA-CONS	Engineering & Implementation Phase			Installation (LS3)		Commissioning			
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

Summary

- The HI-ECN3 project exploits the available SPS beam intensity and existing CERN infrastructures for a cost-effective, novel approach to explore the intensity frontier and launch a unique (worldwide), direct search for dark matter to be performed by the SHiP experiment
- Detailed studies and optimization to be carried out in the Technical Design Phase until end of 2025, to achieve first beam on target in 2030
- Safety is at the core of the Technical Design Phase
- **Very similar requirements to a neutron spallation target, wherefore synergies with ESS are being pursued**



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HI-ECN3 Study Project Team

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Project Budget Officer:
Sylvie PRODON

Project Planning Officer (PPO):
Fernando PEDROSA

Configuration & Quality Assurance Manager:
Giulia ROMAGNOLI

Integration Support via ICEA:
Michael LAZZARONI

North Area Operation & Experiment Liason:
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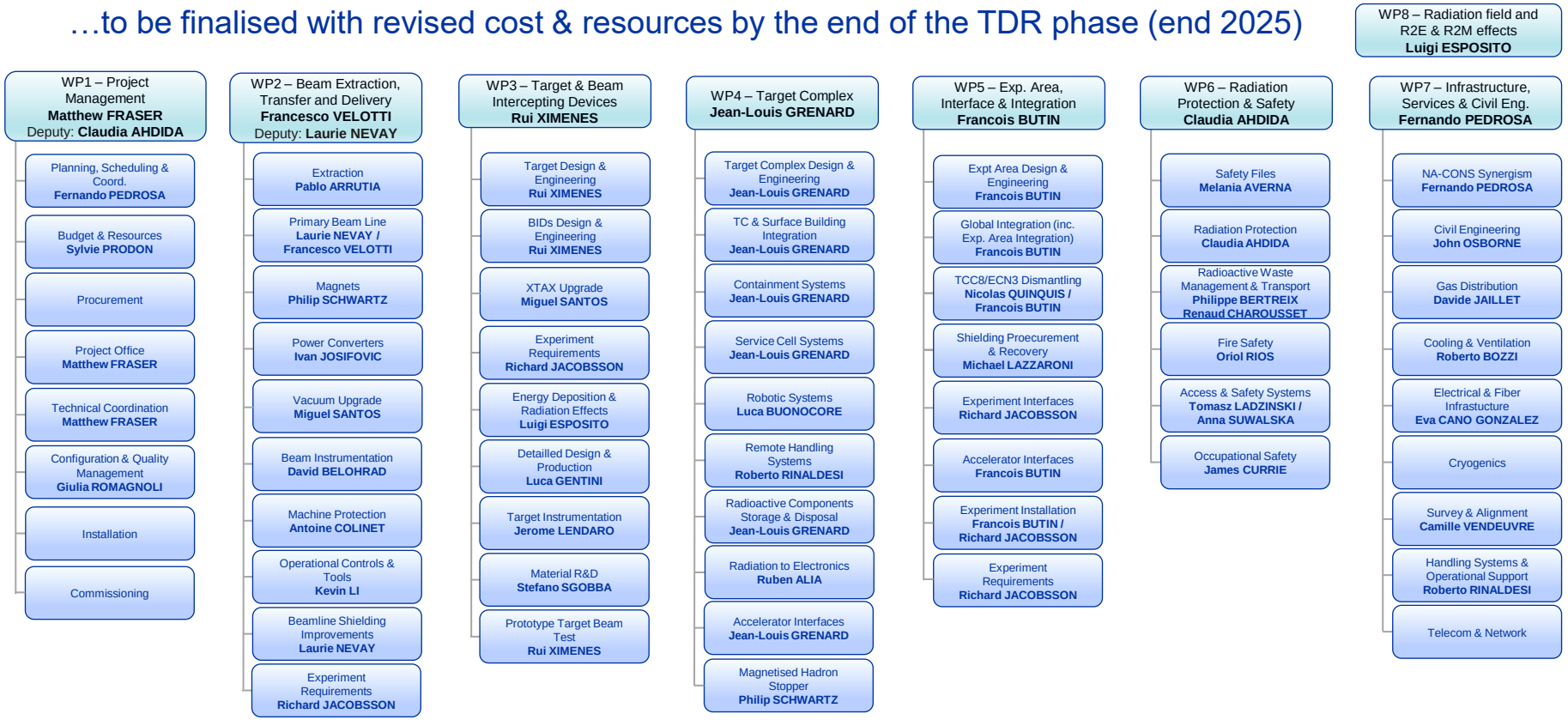
Katarina SIGERUD & Ane-Mona BRANZA

WP1 – Project Management **Matthew FRASER** Deputy: **Claudia AHDIDA**	WP2 – Beam Extraction, Transfer and Delivery **Francesco VELOTTI** Deputy: **Laurie NEVAY**	WP3 – Target & Beam Intercepting Devices **Rui XIMENES**	WP4 – Target Complex **Jean-Louis GRENARD**	WP5 – Exp. Area, Interface & Integration **Francois BUTIN**	WP6 – Radiation Protection & Safety **Claudia AHDIDA**	WP7 – Infrastructure, Services & Civil Eng. **Fernando PEDROSA**	WP8 – Radiation field and R2E & R2M effects **Luigi ESPOSITO**

Project Work Breakdown Structure v 0.1

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



Work Package Descriptions to be drafted during TDR phase

HI-ECN3 Project Master Schedule & Critical Path