

Beam Dump Facility study at CERN

C.C. Ahdida , P. Avigni , F. Bardou , J. Bauche , J. Busom , M. Calviani , M. Casolino ,
L. Dougherty , Y. Dutheil , M.A. Fraser , L. Gaignon , J. Gall , B. Goddard , JL.
Grenard , D. Grenier , C. Hessler , R. Jacobsson , V. Kain , K. Kershaw , E.
Koukovini Platia , M. Lamont , E. Lopez Sola , S. Marsh , Y Muttoni , P Ninin ,
J.A. Osborne , A. Perillo Marcone , J. Prieto Prieto , F. Sanchez Galan , P. Santos
Diaz , L. Stoel , Heinz Vincke , Helmut Vincke , F.M. Velotti , T. Wijnands .

This Thursday - **BDF target: beam tests and material R&D** – Edmundo Lopez Sola

SPS super-cycles

2015 in a period without LHC filling

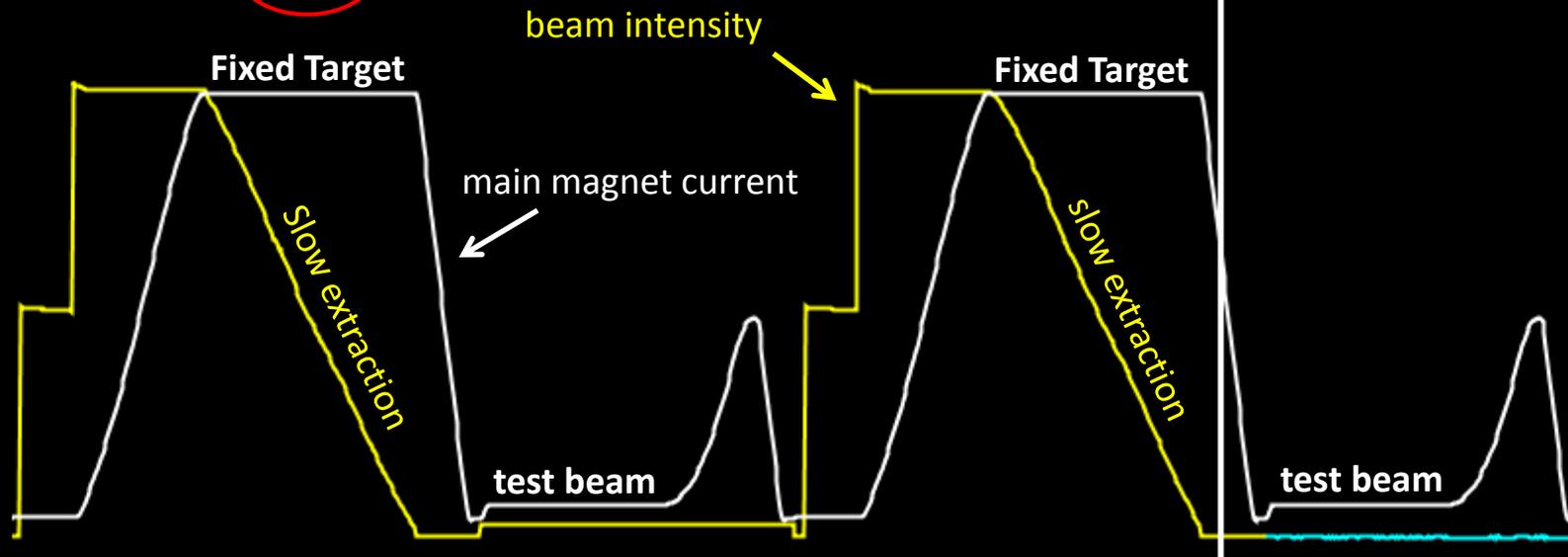
SPS-PAGE1

SC 24 (30BP, 36.0s)

Current user: SFTPRO2

30-10-15 22:35:35

Last update: 9 seconds ago



Target	I/E11	MUL	%SYM	Experiment
T2	44.4	9	96 a	H2/H4
T4	41.1	4	95 a	H6/H8
T6	110.8	14	98 a	COMPASS
T10	0.0	0	0	NA62

Phone: 77500 or 70475

Comments (30-Oct-2015 19:41:16)

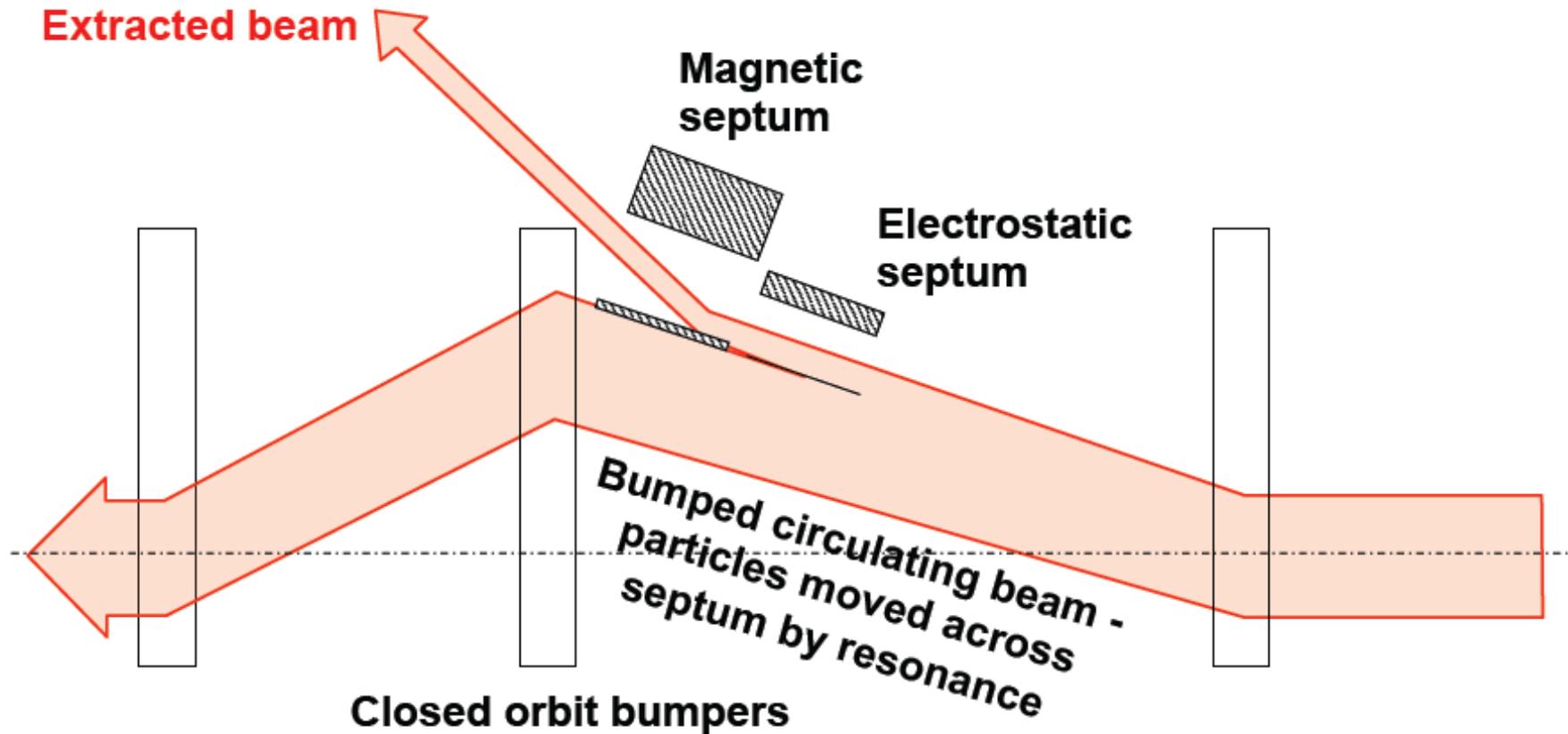
- Duty cycle of fixed target beam limited by **RMS power dissipation in SPS magnets**
- Different configuration during LHC filling ...

Key BDF beam parameters

Momentum [GeV/c]	400
SPS beam Intensity per cycle	4×10^{13}
Cycle length [s]	7.2
Spill duration [s]	1
Avg. beam power on target [kW]	355
Protons on target (POT)/year	4×10^{19}
Total POT in 5 years data taking	4×10^{20}

Resonant multi-turn (slow) extraction

Non-linear fields excite resonances that drive the beam slowly across the septum



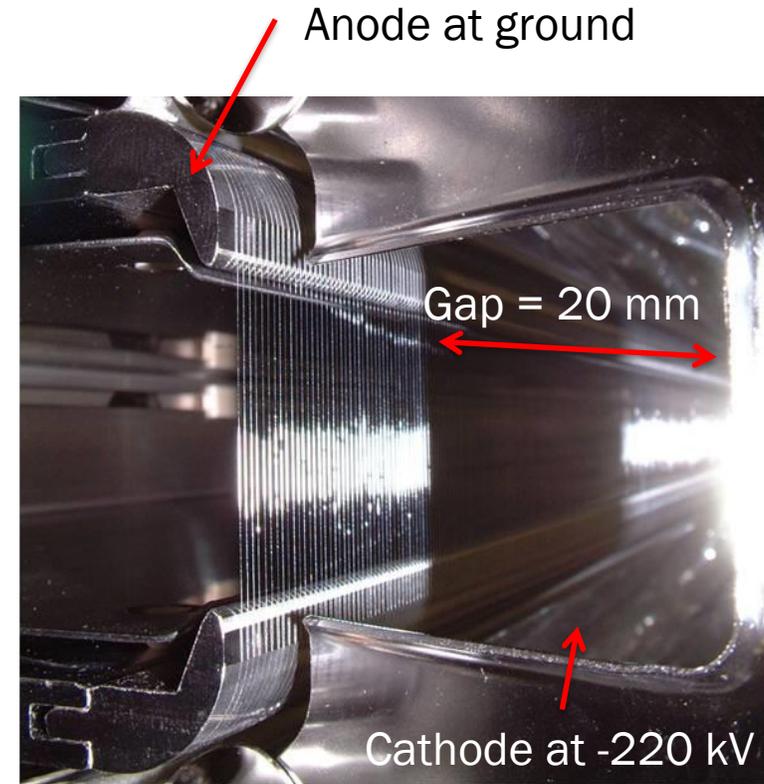
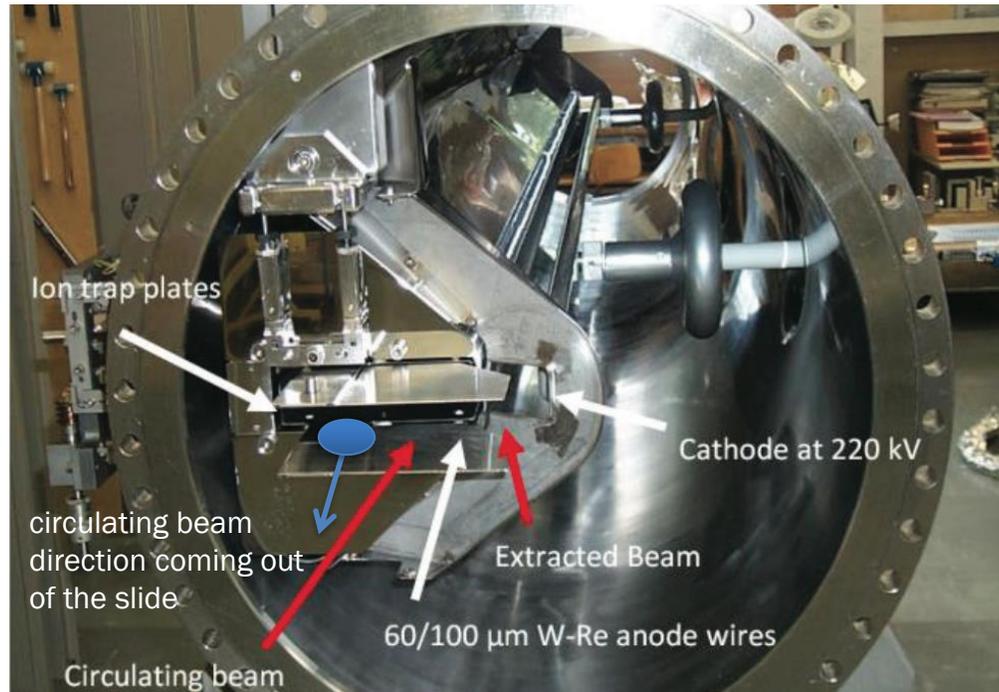
- Slow bumpers move the beam near the septum
- Tune adjusted close to n^{th} order betatron resonance
- Multipole magnets excited to define stable area in phase space, size depends on $\Delta Q = Q - Q_r$

Extraction from SPS to NA

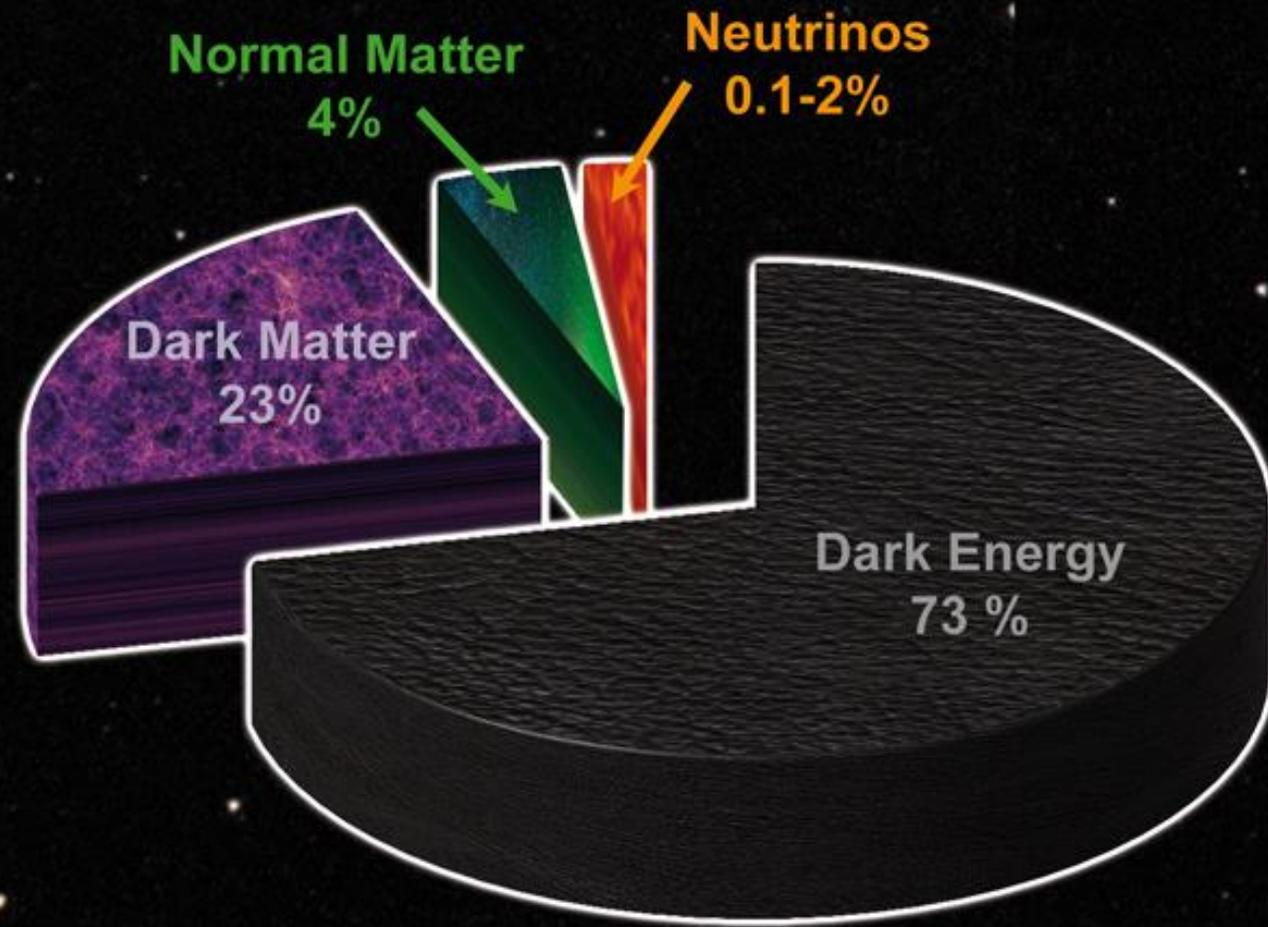
- Long Straight Section (LSS) 2:



- 5 electrostatic septa [ZS] aligned over ~20 m:



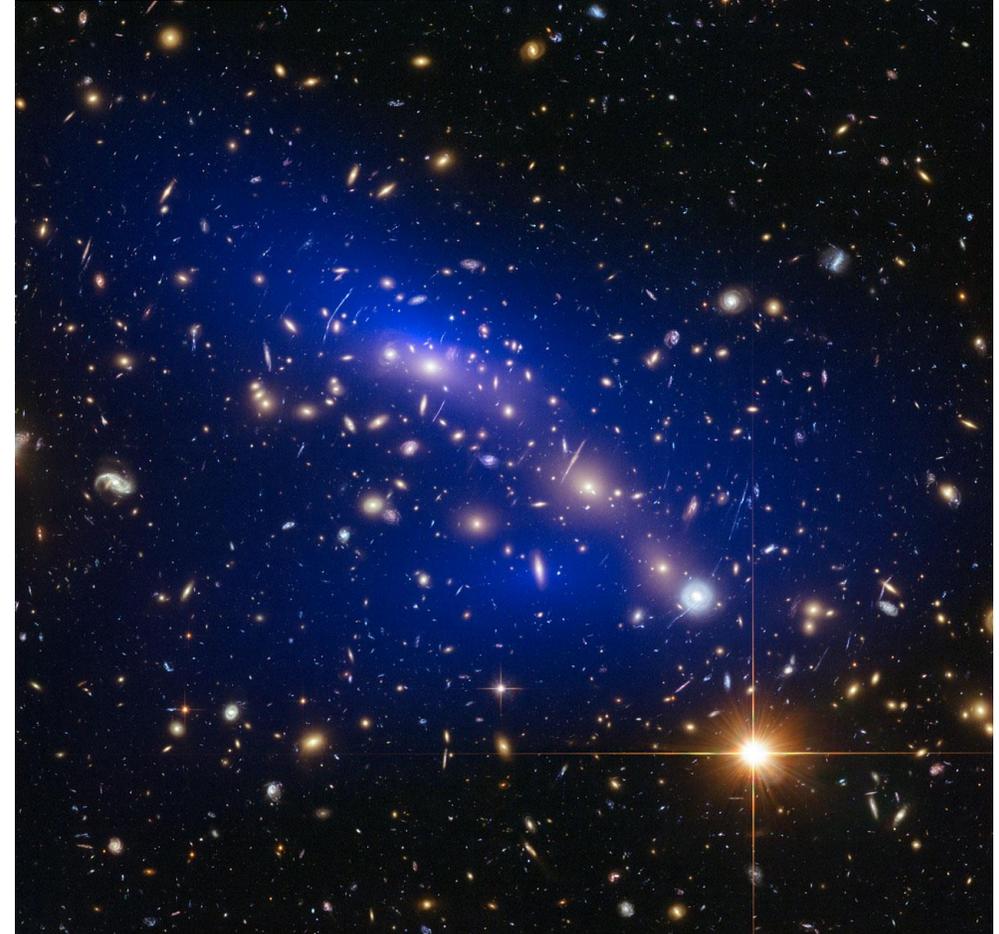
WHY?



Content of the Universe

Dark matter – we know...

- Is roughly 80% of the matter in the universe.
- Has mass (and hence gravity).
- Doesn't scatter/emit/absorb light (really “transparent matter”!)
- Interacts with other particles weakly or not at all (except by gravity).
- Is distributed through galaxies and the universe in a way that we can predict and map.



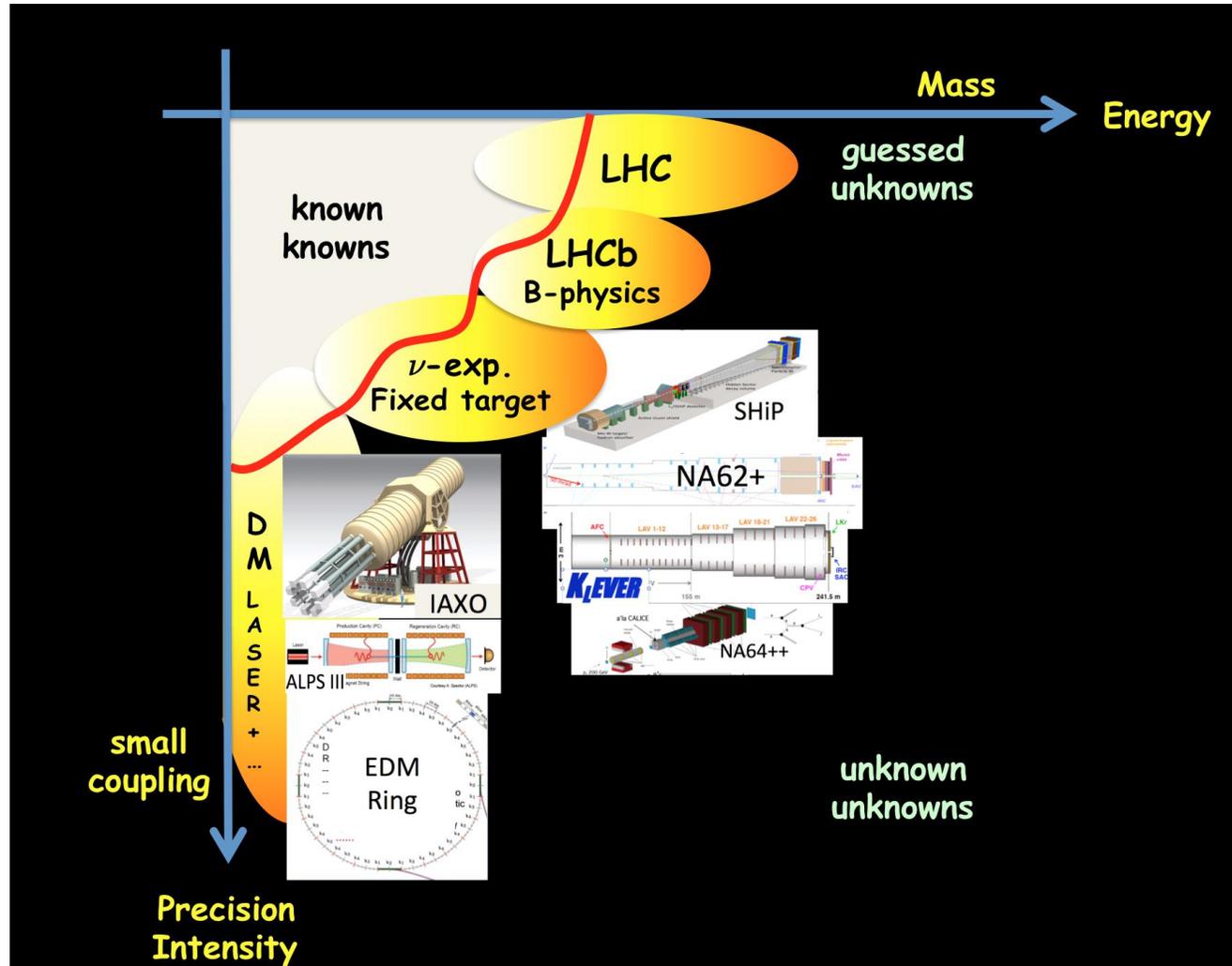
But we don't know what it is!

Nothing obvious at the LHC yet

WIMP searches have found nothing so far

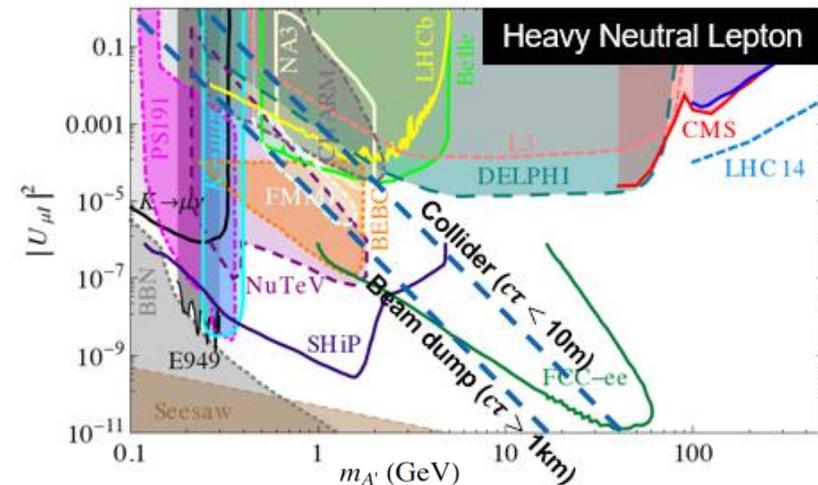
The search is on

Attention shifting to **weakly interacting light particles**

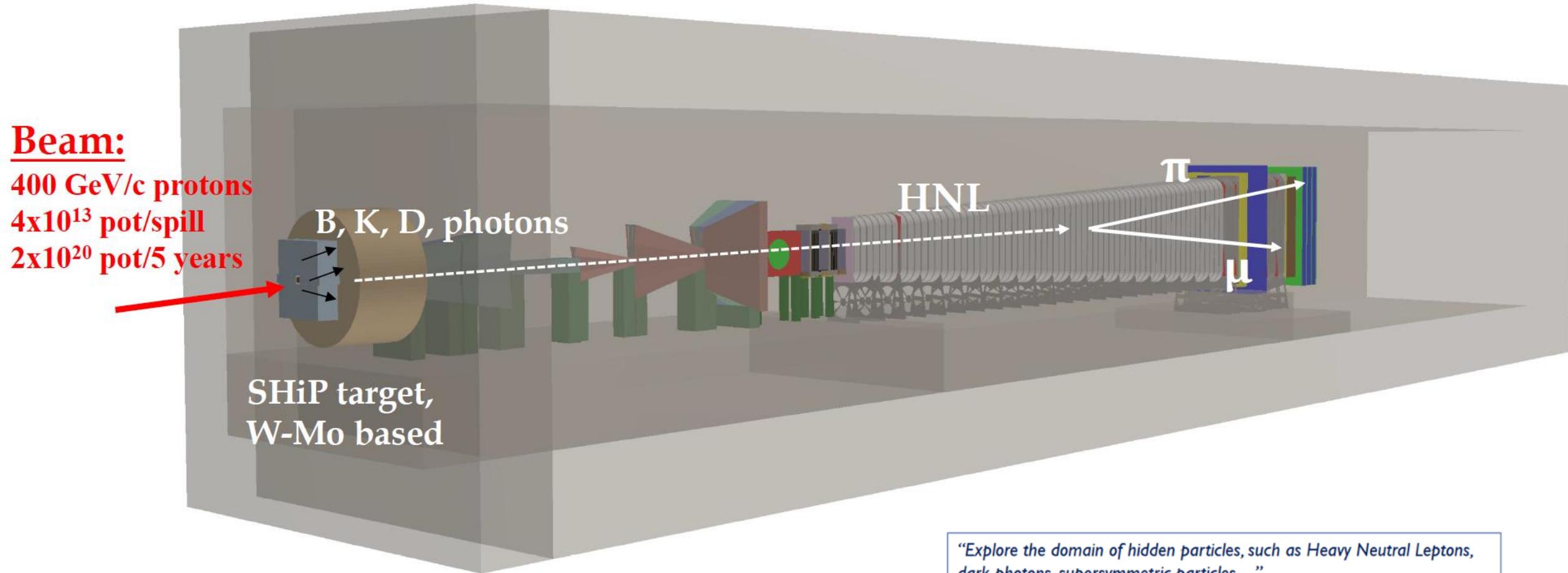


Beam Dump Facilities

- BDFs ideal for exploring light super-weakly interacting particles and Light Dark Matter
 - **Luminosity** (yield of π , K, D, B decay and photons):
 - HL-LHC: $\sim 10^{35} \text{ cm}^{-2}\text{s}^{-1} \times 10^7 \text{ s} = \mathbf{10^{42} \text{ cm}^{-2}}$
 - SPS (1 m long high A/Z target): $4 \times 10^{13} \times 6 \times 10^{24} \text{ cm}^{-3} \times 10^2 \text{ cm} \times 10^6 \sim \mathbf{2 \times 10^{46} \text{ cm}^{-2}}$
 - Superior lumi compensate for lower energy (e.g. yield of charm hadrons $\sim 10^{16}$ @HL-LHC vs $\sim 10^{18}$ @SPS)
 - **Geometrical acceptance**
 - **Long lifetimes**
 - **Background suppression**



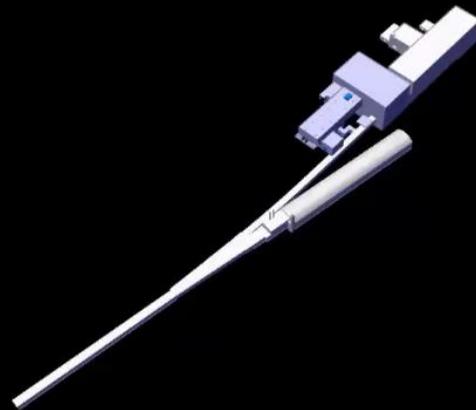
Search for Hidden Particles



“Explore the domain of hidden particles, such as Heavy Neutral Leptons, dark photons, supersymmetric particles...”

Video

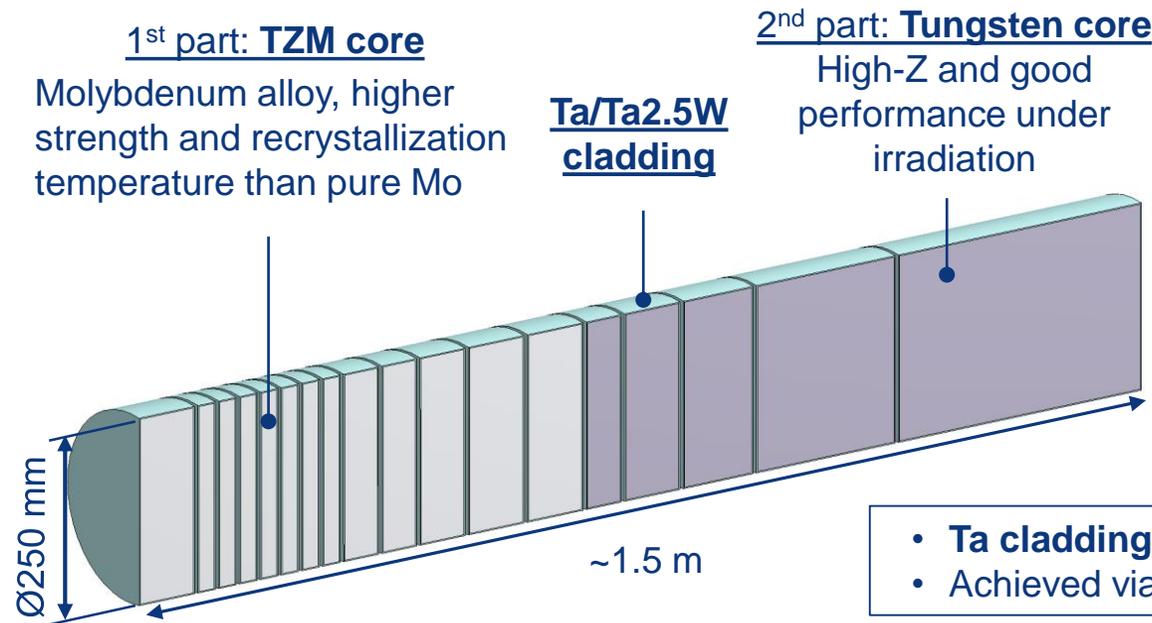
The Beam Dump Facility



Beam Dump Facility target

- Main functions:
 - **Full SPS 400 GeV/c beam absorption** → **Target/dump**
 - Maximize the production of **charmed mesons** → physics performance
- Material requirements:
 - **High-Z materials**
 - **Short interaction length**

⇒ Increase the reabsorption of pions and kaons

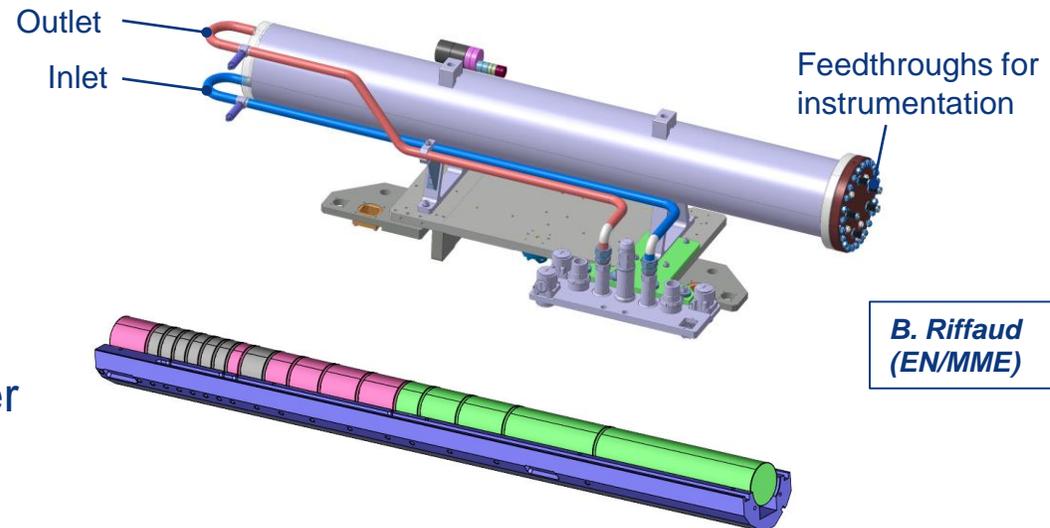
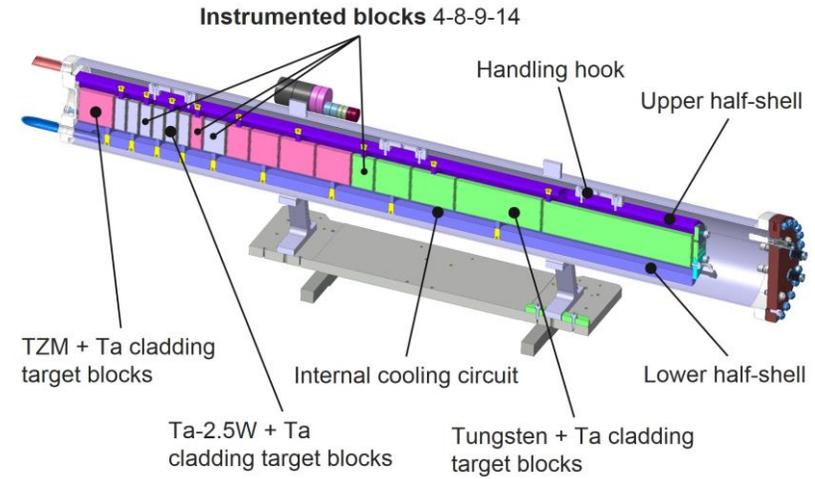


- **250 mm diameter cylinders**
- **Total length ~ 1.5 m**
- **Optimized segmentation** of the target to minimize the level of temperatures and stresses
- High power deposition
- forced water cooling required
- 5 mm gap between the blocks

- **Ta cladding** to avoid corrosion/erosion effects
- Achieved via **Hot Isostatic pressing (HIPing)**

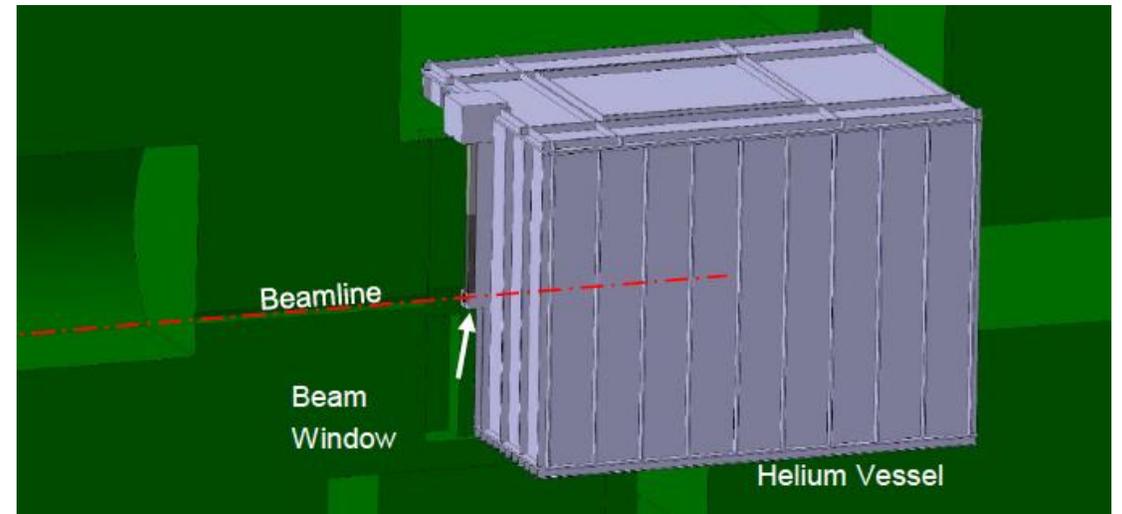
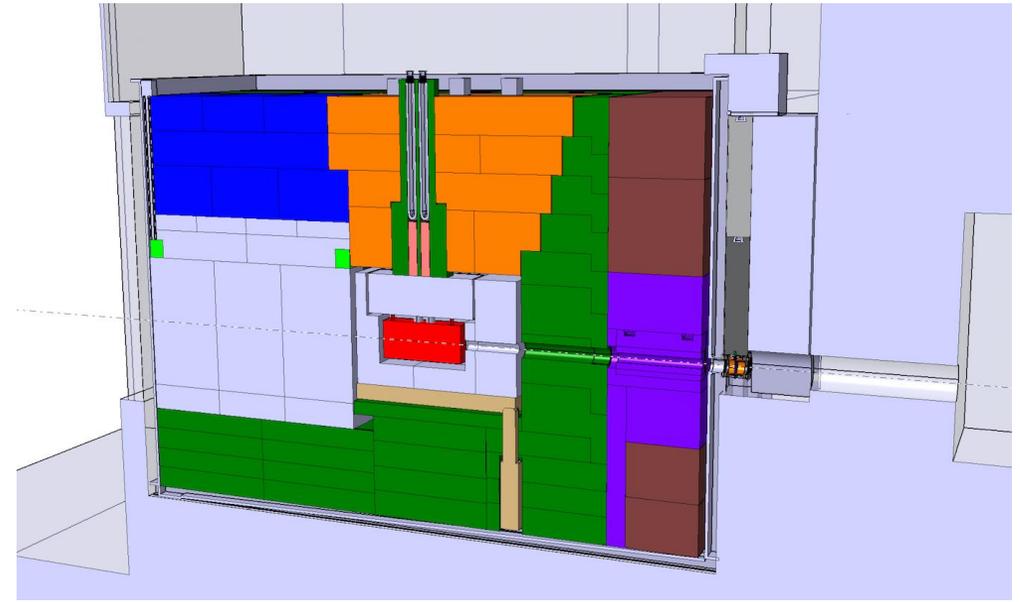
Target prototype design

- **Reduced scale prototype**
 - Same total length (~1.5 m)
 - Reduced diameter (**80 mm**)
 - Same block length distribution
 - TZM/W core, Ta/TaW cladding
- **Two concentric tanks**
(~ final target)
 - Outer tank:
 - Leak tightness
 - Connections interface
 - Inner tank: two half shells
 - Target core blocks holder
 - Enclosing cooling circuit



Target shielding and helium vessel

- Target surrounded by iron shielding to stop hadrons
- Target and shielding are underground to reduce radiation levels in the building and the surroundings ...
- ... and housed in a helium vessel to prevent air activation and corrosion
- After 5 years of irradiation and 1 week of cooling time, residual dose rates are hundreds of Sv/h around the target and the proximity shielding



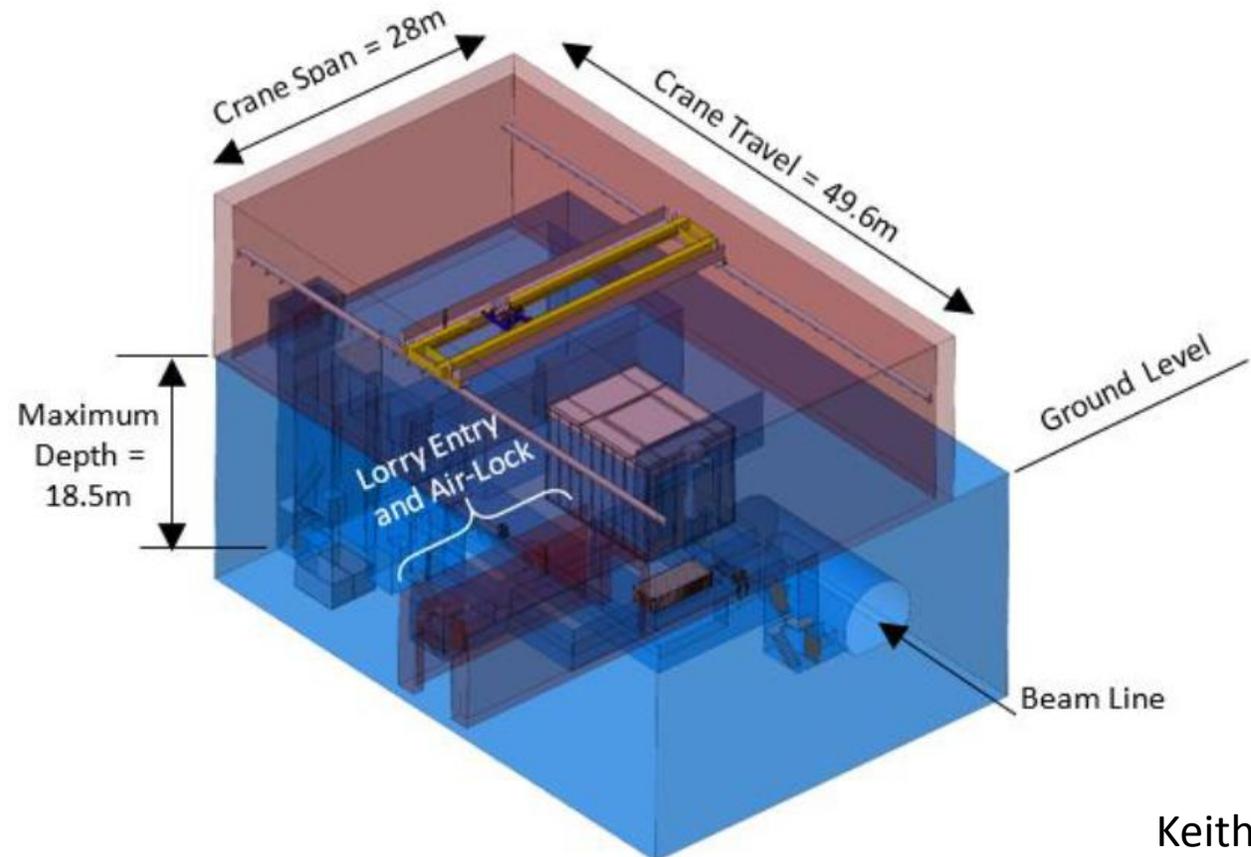
Integration and remote handling study

Study aims

- Develop integration design of target complex
- Considering key handling and remote handling operations during the life of the facility

CERN + Oxford Technologies
"Foreseen" and "unforeseen"
handling operations
(consider failures and
damage)

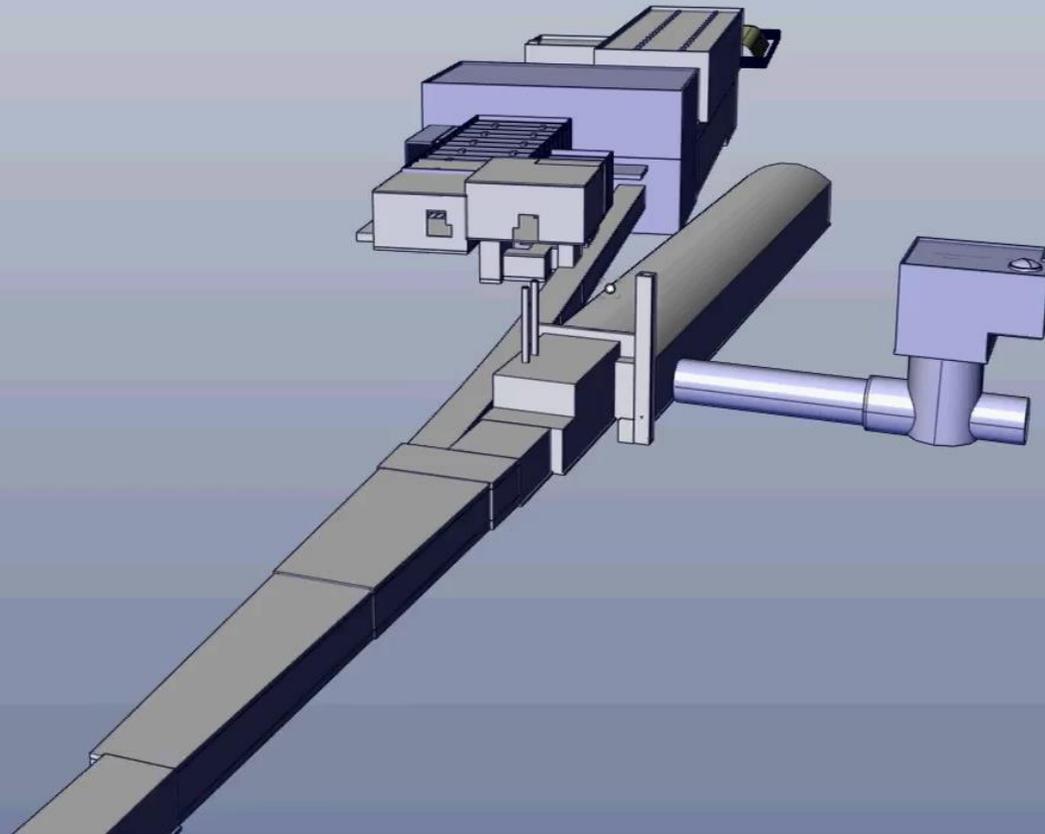
Outputs: 3-D models, layout
drawings, reports, animations



Two handling concepts studied

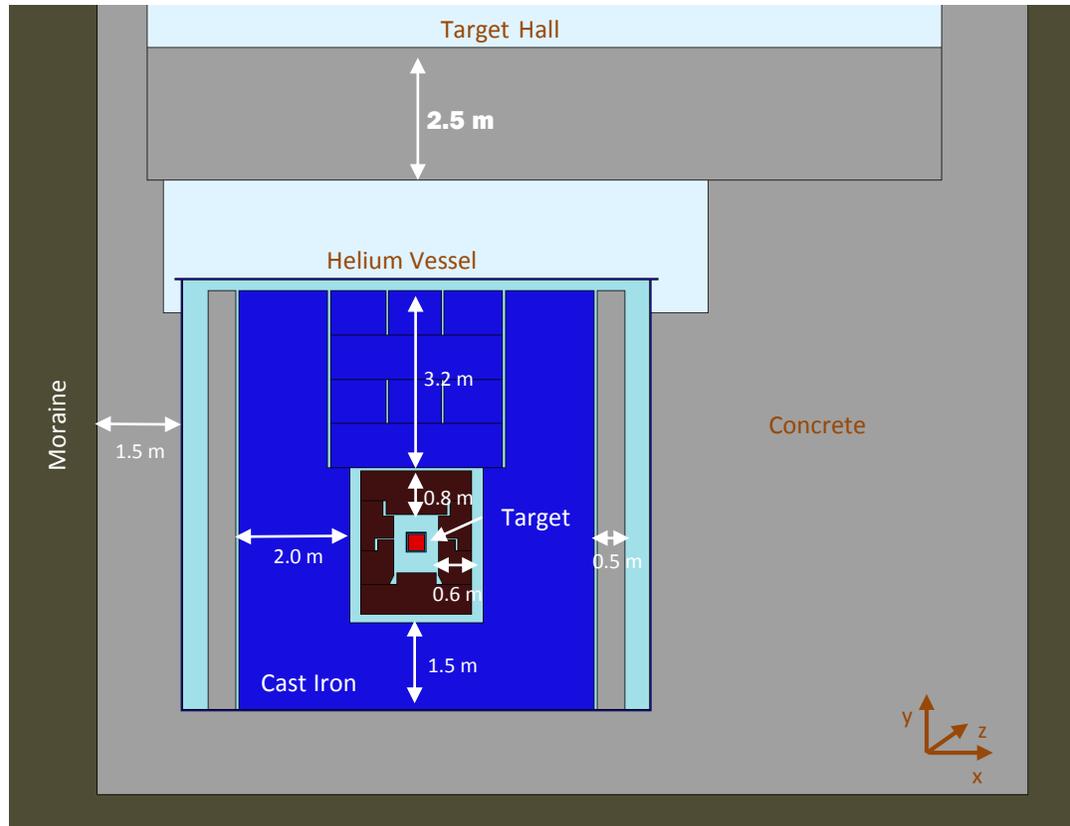
- **Crane concept** – all foreseen handling by overhead travelling crane.
- **Trolley concept** – target and its services mounted on trolley (as ISIS)





RP evaluation based on FLUKA simulations

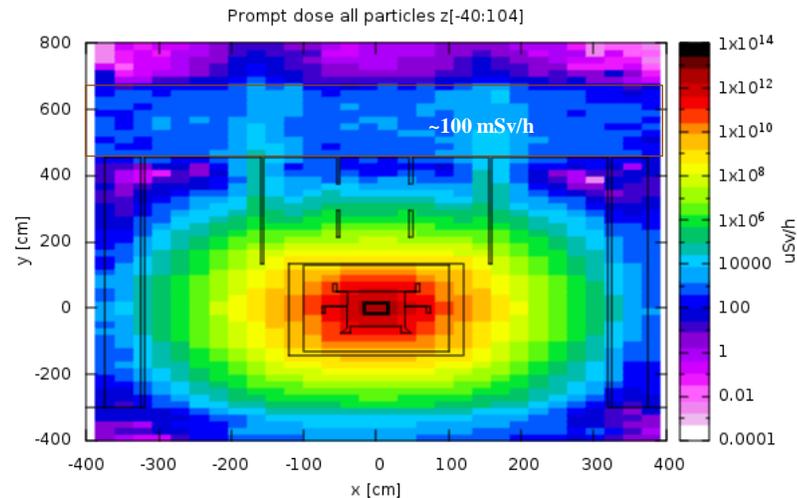
BDF/SHIP as Implemented In FLUKA - Cross-sectional view



- Most critical area embedded in He-environment
- Shielding optimized to reduce ground activation to negligible levels
- Accurate material compositions were used (AISI316LN w 0.1% Cobalt, ASTM A48 w 0.04% Cobalt, US1010, CENF moraine, ...)

RP evaluation based on FLUKA simulations

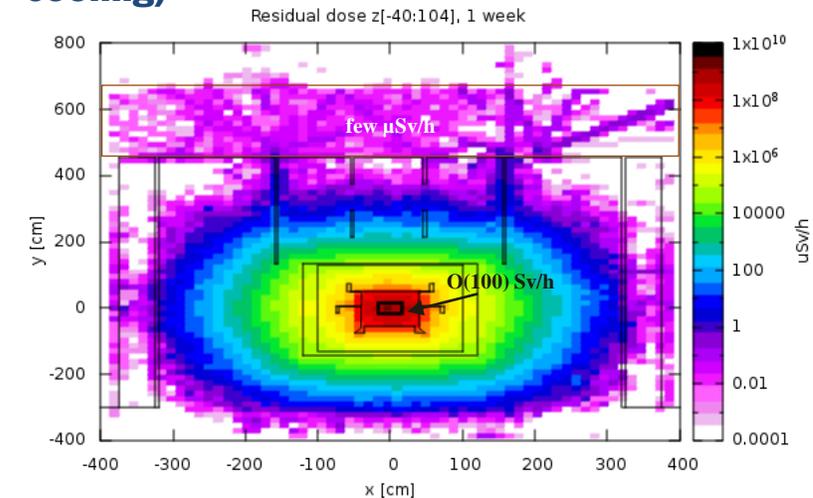
Prompt dose rate for 4×10^{13} p / 7.2s



Prompt dose rates reach ~100 mSv/h above He-vessel and drop down to < 1 μSv/h above top concrete shielding (conservative gaps)

→ **Expected classification: Supervised Radiation Area (up to 2000h/year) (< 3 μSv/h) in the target hall**

Residual dose rate for 2×10^{20} pot (1 week cooling)



Residual dose rates of a few μSv/h above and next to He-vessel

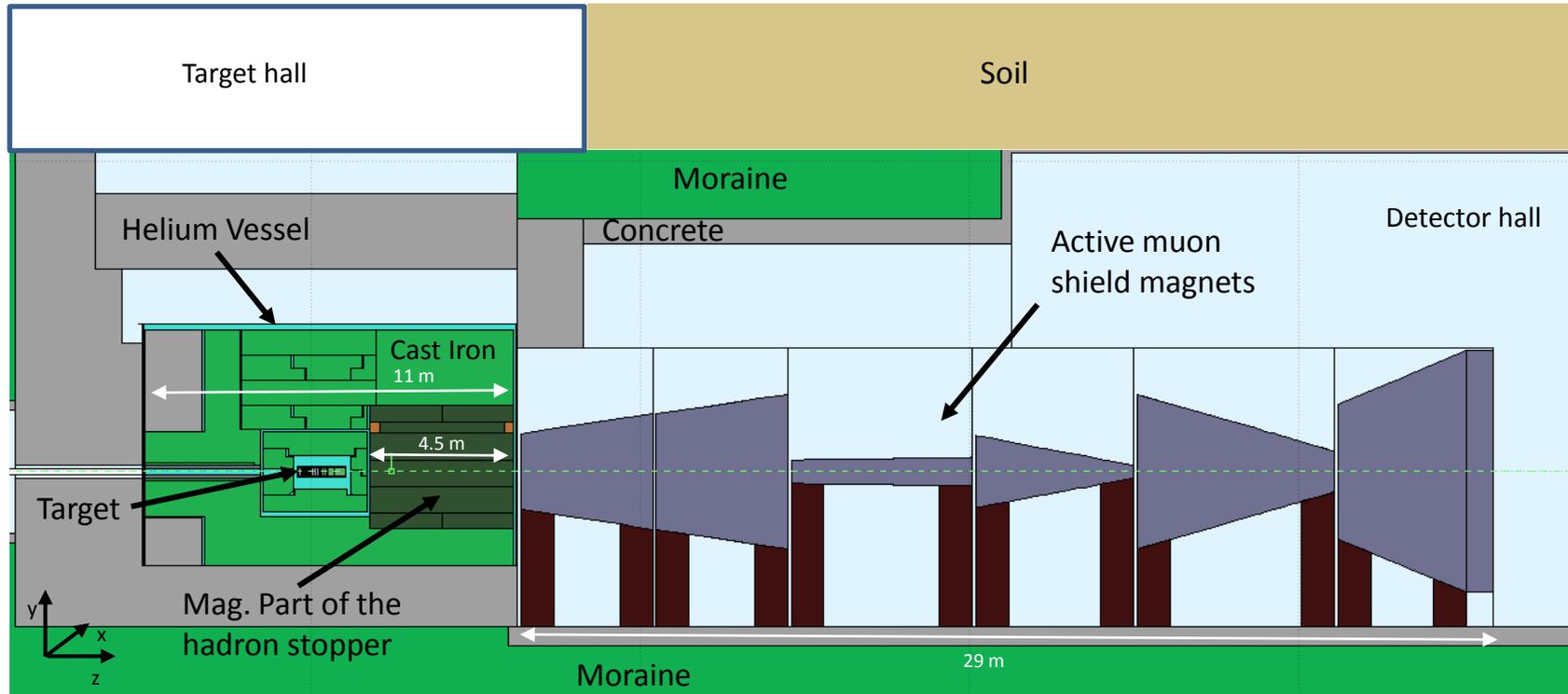
Very high residual dose rates next to target and cast iron shielding O(100) Sv/h

→ **Remote handling** and designated storage areas are therefore foreseen for these elements

100 rem = 1Sv

RP evaluation based on FLUKA simulations

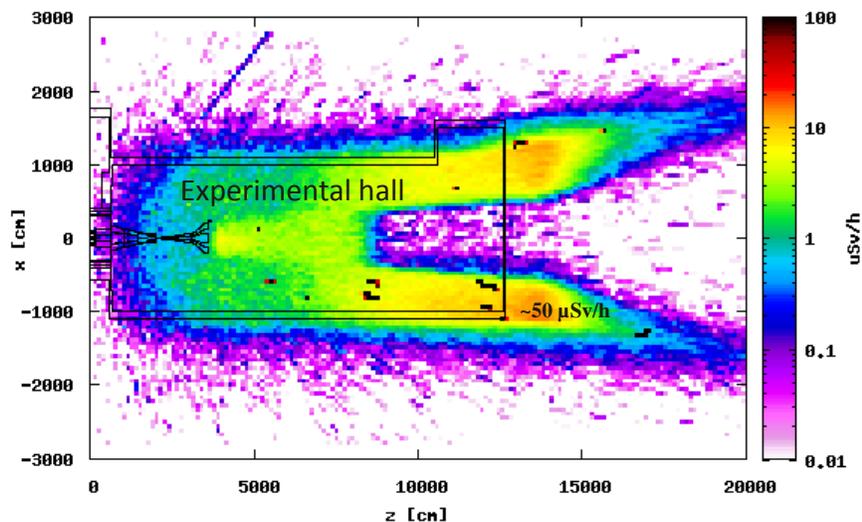
BDF/SHiP as implemented in FLUKA
Side view



- **No access during operation** into the detector hall is the main condition for current design
- **Massive shielding** to keep prompt/residual dose rate and airborne **radioactivity as low as possible**
- Active muon shield with magnets (1.8 T) from the SHiP experiment was included

Expected muon dose rates in the surrounding areas

Prompt muon dose rate for 4×10^{13} p / 7.2s

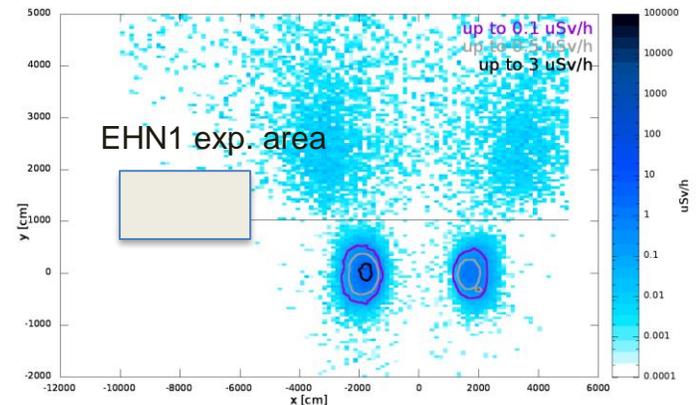
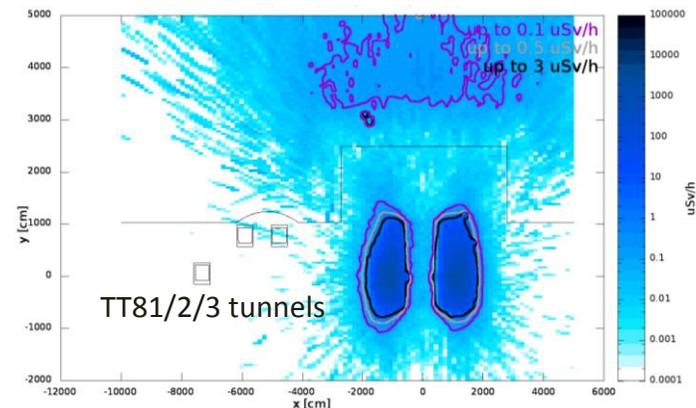


Prompt muon dose rate above experimental hall $\sim 50 \mu\text{Sv/h}$

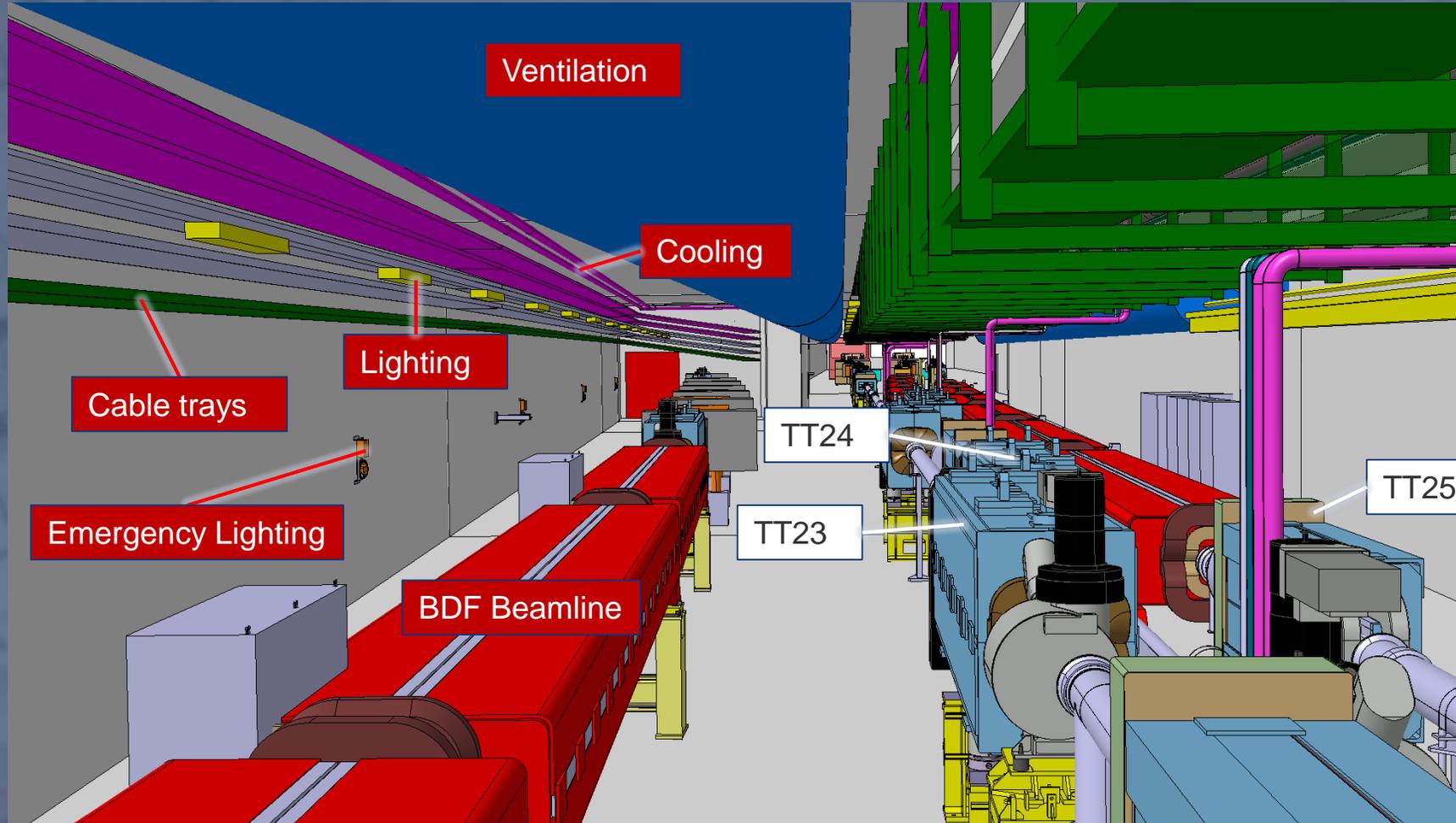
→ **Need to cover** area with at least 3 m of soil on top to allow for non-designated area level ($< 0.5 \mu\text{Sv/h}$)

→ Area behind experimental hall fenced

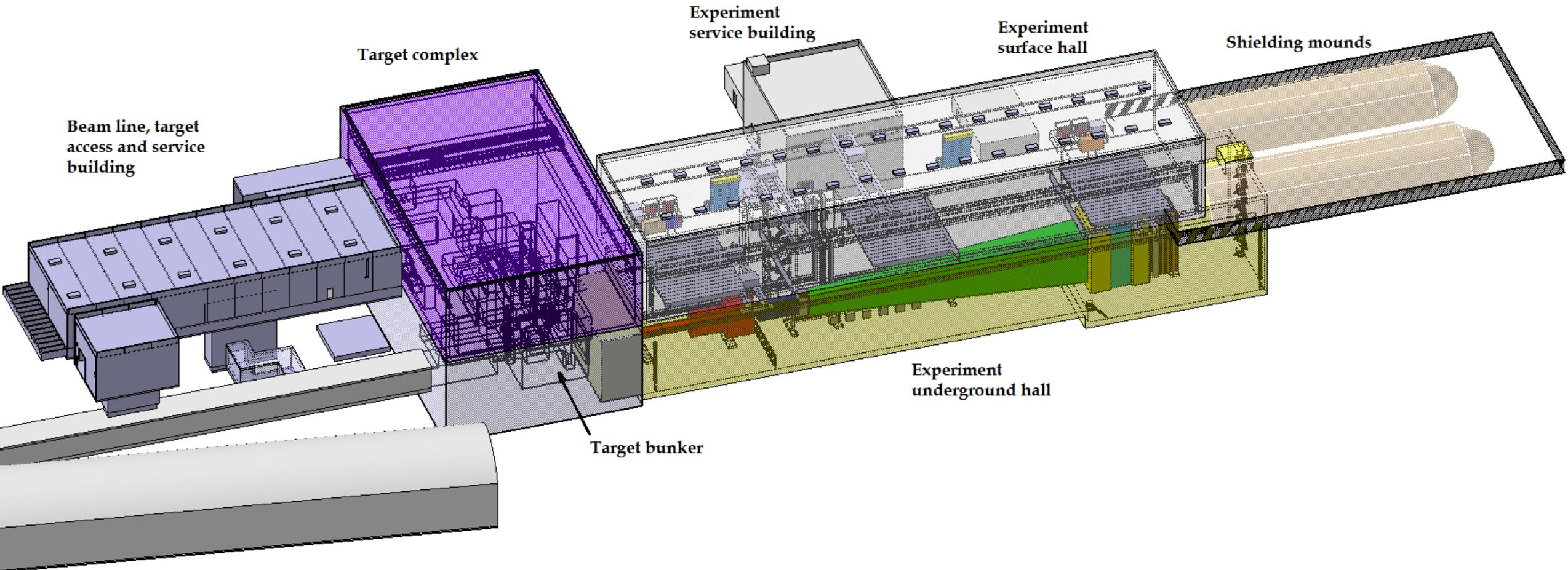
100 rem = 1Sv



Prompt muon dose around existing facilities **below** non-designated area level ($< 0.5 \mu\text{Sv/h}$)



Integration – Target Complex & Exp. Area

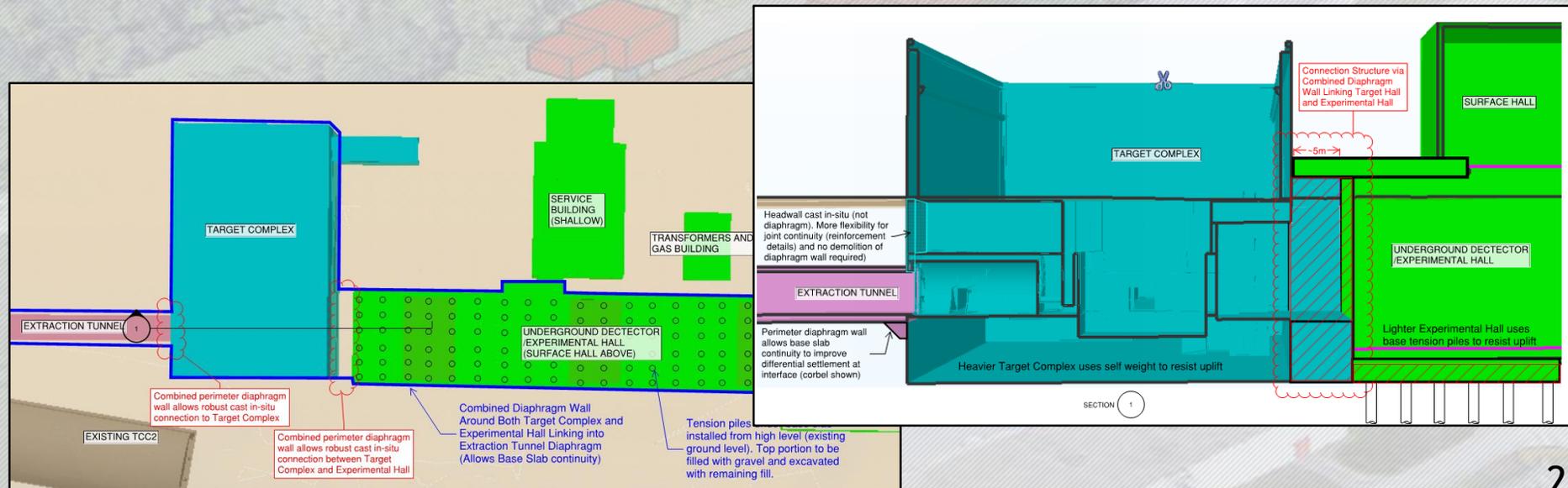


Civil engineering - preliminary studies just signed off

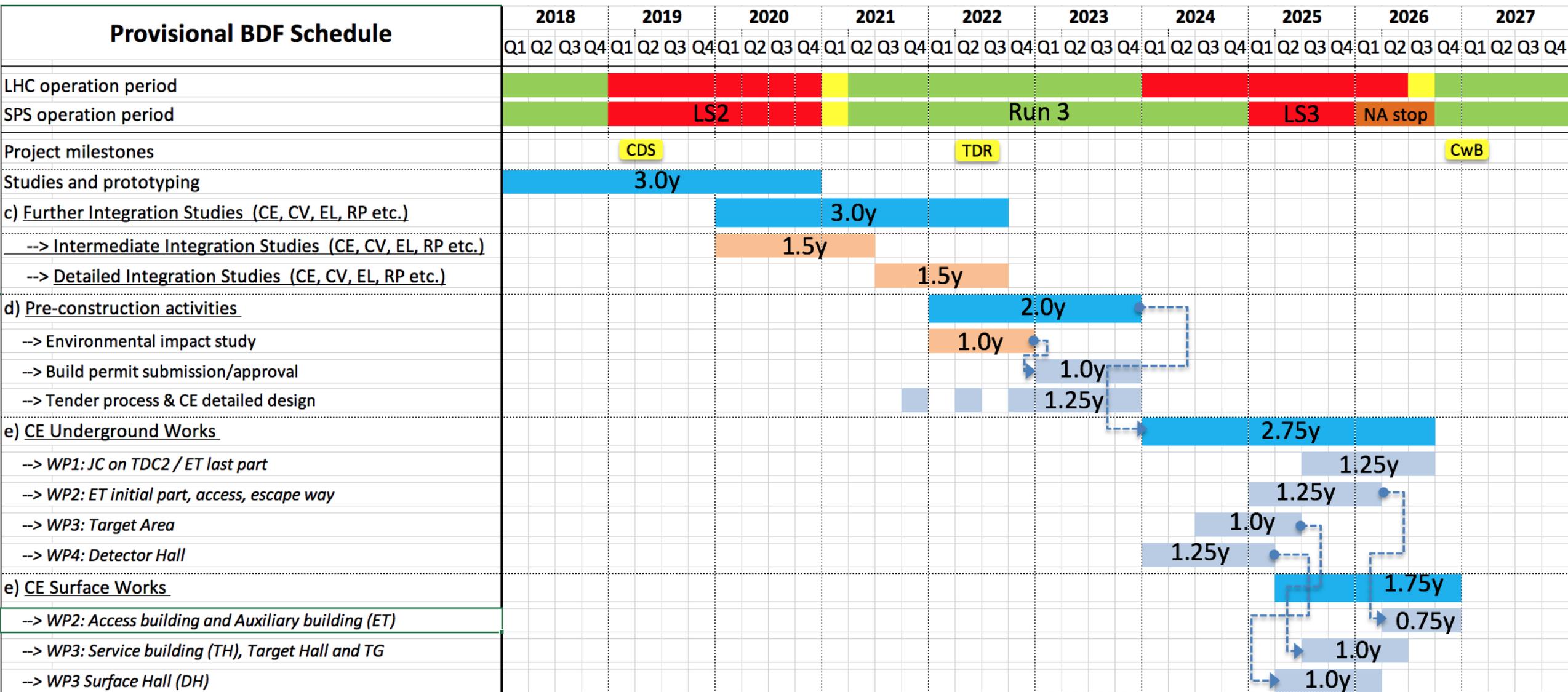
e.g. Task 2 - Target Complex

Jonathan Gall

- Combined perimeter diaphragm wall
- 'Bottom up' construction sequence to allow complex internals to be built
- Shared cast in situ connections to minimise ground movement and settlement
- Foundation analysis - 'Floating' raft foundations due to weight of building (heavy internal structure) or possible tension piles



Planning



Conclusions 1/2

- Well motivated physics case with strong experiment collaboration in place (SHiP).
- **Challenging: extraction losses, target, target complex, radiation protection**
- Since study inception, good progress all round:
 - Extraction and beam transfer
 - Target and target complex
 - Radiation protection
 - Safety engineering
 - Integration
 - Civil engineering
- Submitting proposal tomorrow (!) to the Update of the European Strategy for Particle Physics including costing:
 - TDR around 2022, seek approval 2023, ground breaking 2024...

Conclusions 2/2

- **High energy**: search for new heavy particles with strong couplings:
 - LHC
- **High intensity**: indirect search for new heavy particles with small couplings leading to deviations from the SM through the loops:
 - LHCb, NA62, BELLE, flavour physics experiments,...
- **High intensity**: search for new light particles with small couplings:
 - SHiP, NA62, NA64...
- CERN is an ideal place to search for Hidden Sector at SPS North Area with SHiP and NA62 in $< O(10)$ GeV range

Aerial picture of the North Area

NA62⁺⁺ @ K12
KLEVER →

← NA64⁺⁺ (μ) @ M2

NA64⁺⁺ (e) @ H4
→

SHiP, tauFV @ BDF
→

HSC

The hidden sector “campus”

