A Beam Dump Facility (BDF) at CERN - The Concept and a First Radiological Assessment

M. Calviani[1], M. Casolino[1], R. Jacobsson[1], M. Lamont[1], S. Roesler[1], **H. Vincke**[1], C. Ahdida[2]

[1]CERN, [2]PSI

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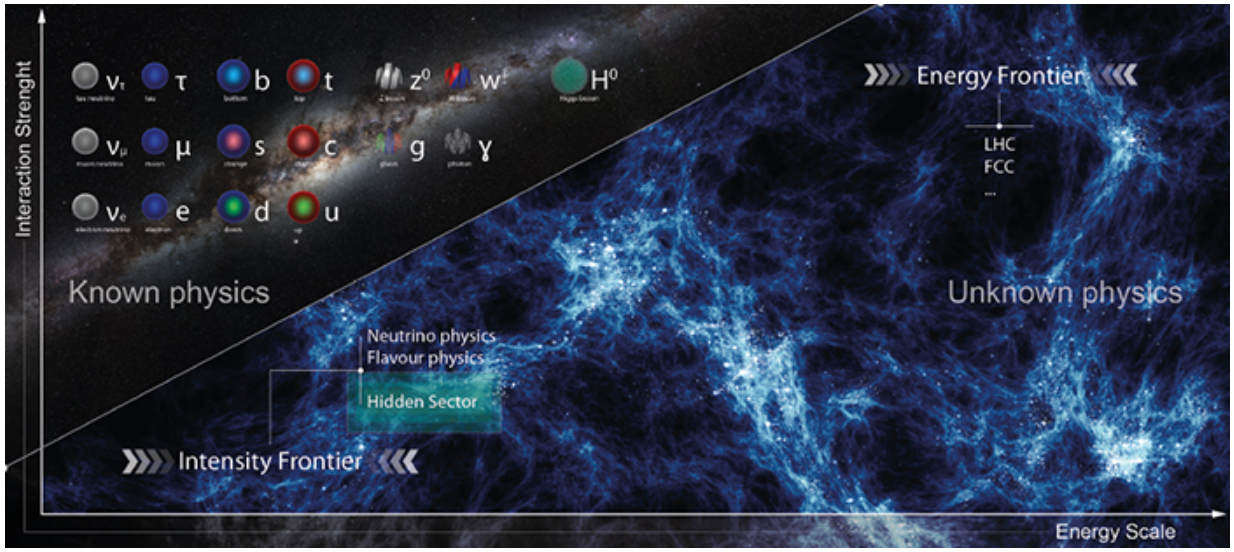
Outline

- Motivation
- Concept and requirements for the BDF
- Details about the target & target station
- A proposal of an experiment at BDF → SHiP

- Radiation Protection studies for BDF

Motivation



- The Standard Model provides an explanation for many subatomic processes
  - All SM particles have been observed so far
- Although very successful, it fails to explain several observed phenomena like,
  - Dark Matter
  - Neutrino oscillation and masses
  - Matter/antimatter asymmetry in the universe
  - ….
- BDFs at CERN ideal for exploring light super-weakly interacting particles and Light Dark Matter

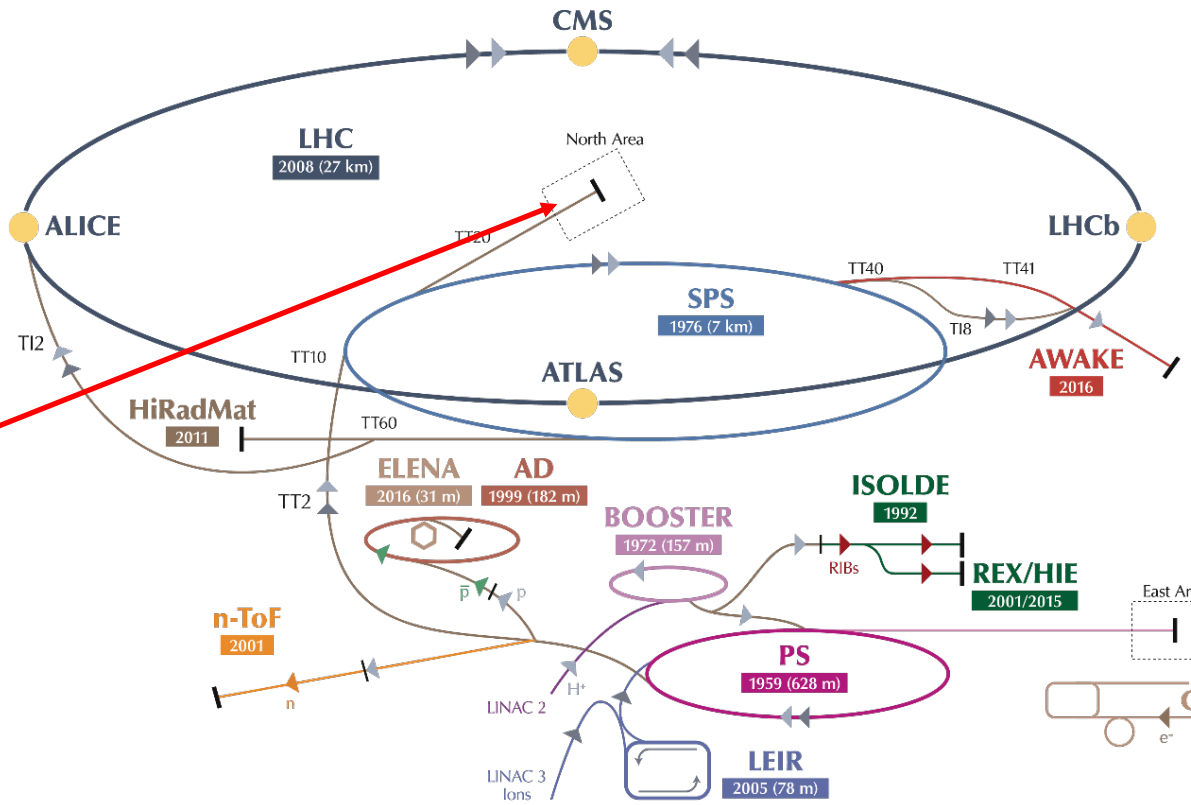
Requirements

- High intensity proton beam: **$4*10^{13}$ p^+/pulse, $4*10^{19}$ pot/year**
- Slow extraction (~1 sec. flat top)
- O(**400 GeV/c**) optimal beam momentum
- **355 kW** average beam power
- Goal **$2*10^{20}$ pot/ 5 years**
- Minimal impact on running the North Area physics program at CERN
- Dense target/dump to maximize production of the processes of interest & stop π and K to reduce the muon and neutrino background in the experiment

The proposed BDF would be a **new permanent facility in the North Area** at CERN with unprecedented average beam power

Proposed location of the facility at CERN

Proposed siting of the SPS Beam Dump Facility



p (protons) ions RIBs (Radioactive Ion Beams) n (neutrons) $\bar{p}$ (antiprotons) e^- (electrons) proton/antiproton conversion proton/RIB conversion

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron AD Antiproton Decelerator CTF3 Clic Test Facility

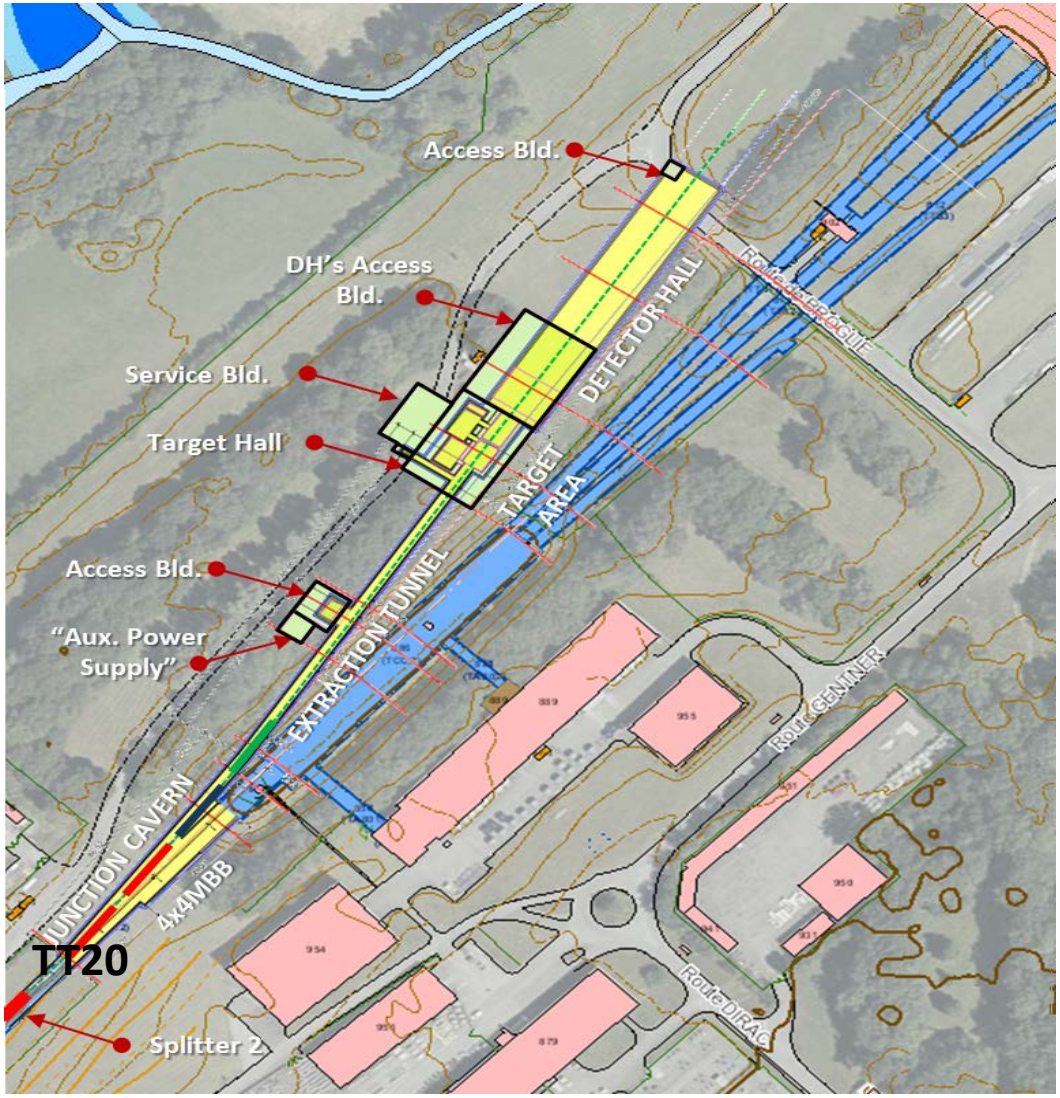
AWAKE Advanced WAKefield Experiment ISOLDE Isotope Separator OnLine REX/HIE Radioactive EXperiment/High Intensity and Energy ISOLDE

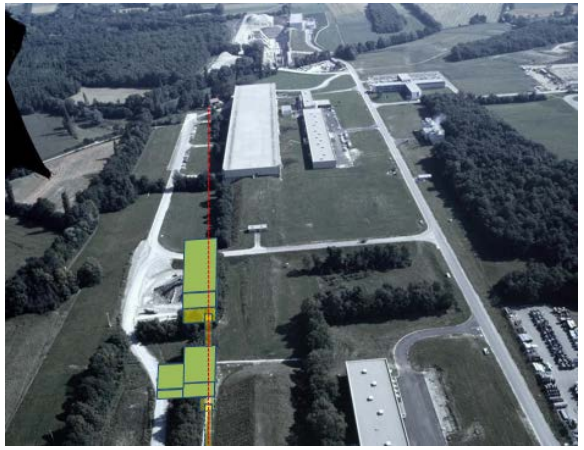
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight HiRadMat High-Radiation to Materials

BDF facility siting

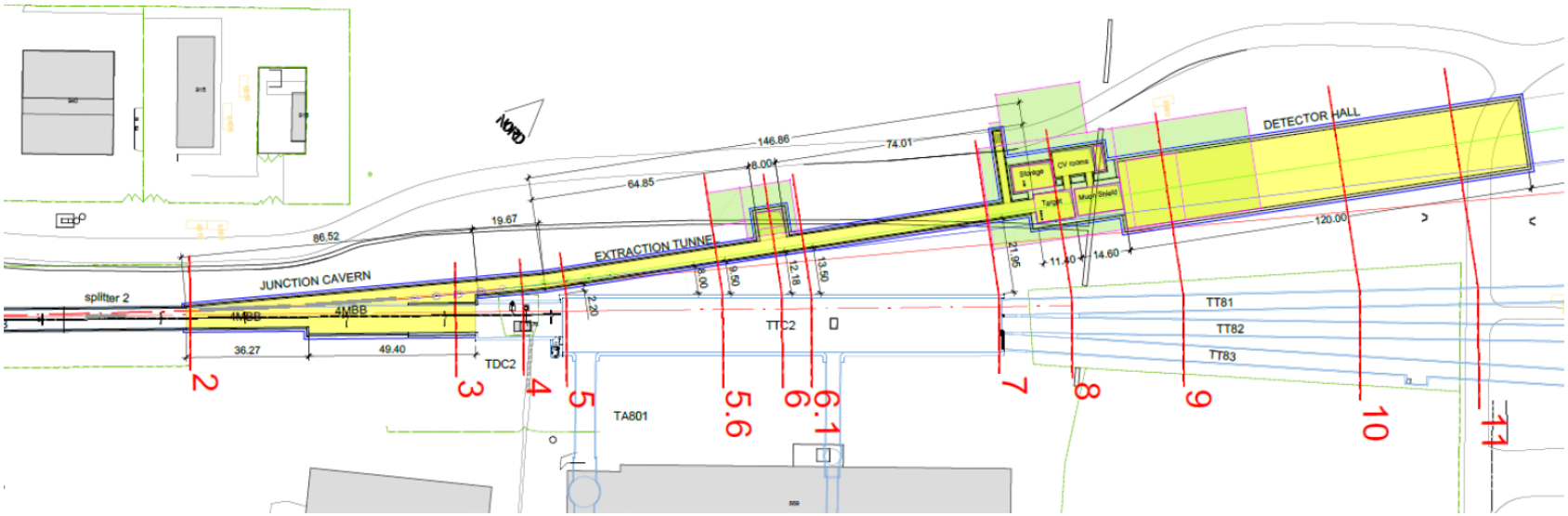
EXISTING SITUATION

BDF NEW FACILITIES

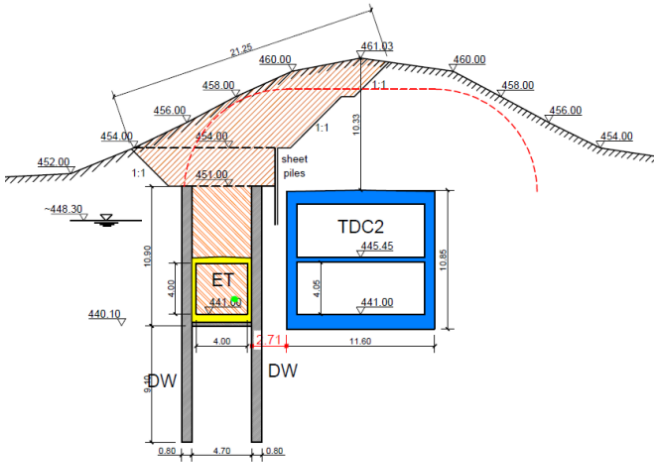




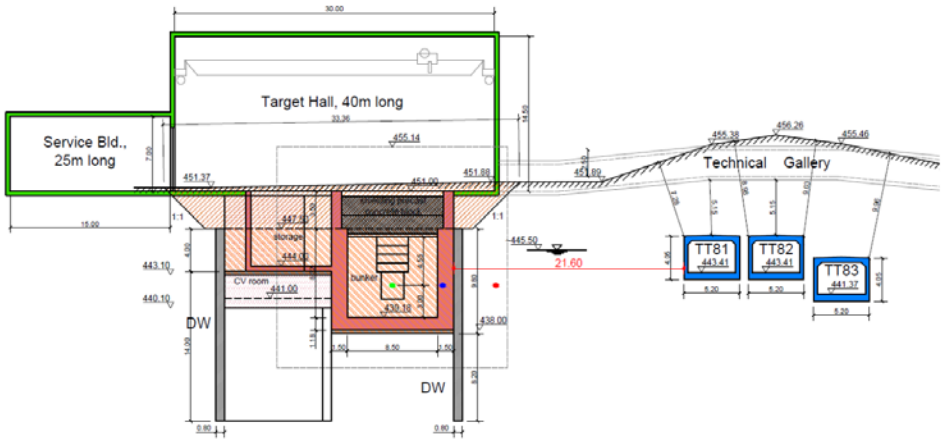
existing tunnels
existing buildings
new installations



Top view of the new BDF underground and surface areas with the main cross sections along the beam-line



Cross section 4



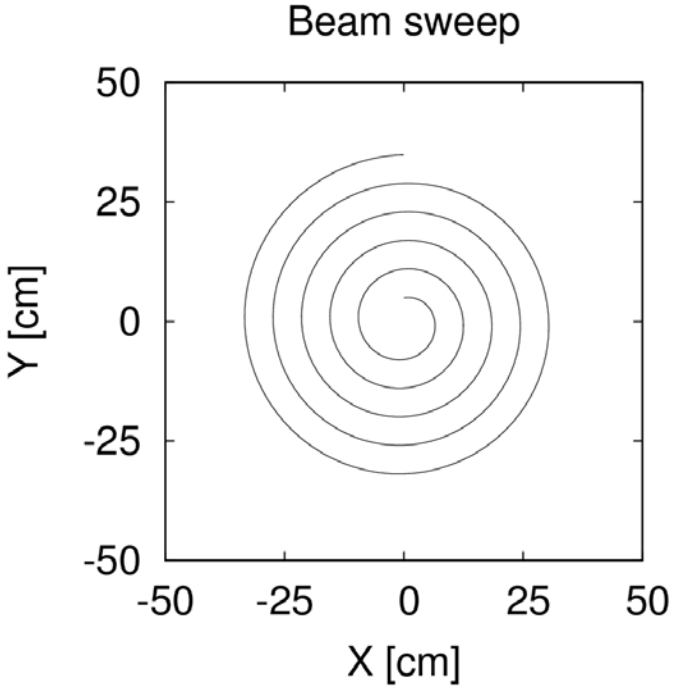
Cross section 8

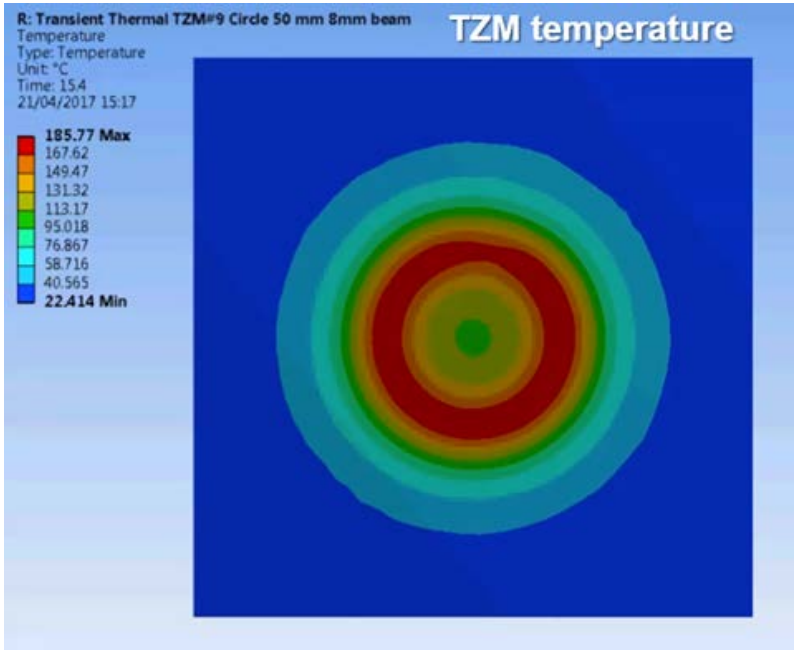
Issues related to Target/Dump

- Target must be as dense as possible to **maximize production** of the processes of interest and **reduce backgrounds**
- High energy deposition per unit volume → significant **heating due to beam**
- Beam power **355 kW,** 1 s spill up to **2.6 MW**
- Need of a challenging (water) cooling system
  - ~200 m^3/h, 15 bar (target)
- Material damage due to cumulated radiation

Beam dilution to target

- In order to avoid damaging the target beam dilution on the target is required
- Several beam dilution options were tested/simulated.
  - For example an Archimedean spiral, 5-35 mm radius (1σ = 6 mm) and a circular beam (50 mm radius, 8 mm 1σ)

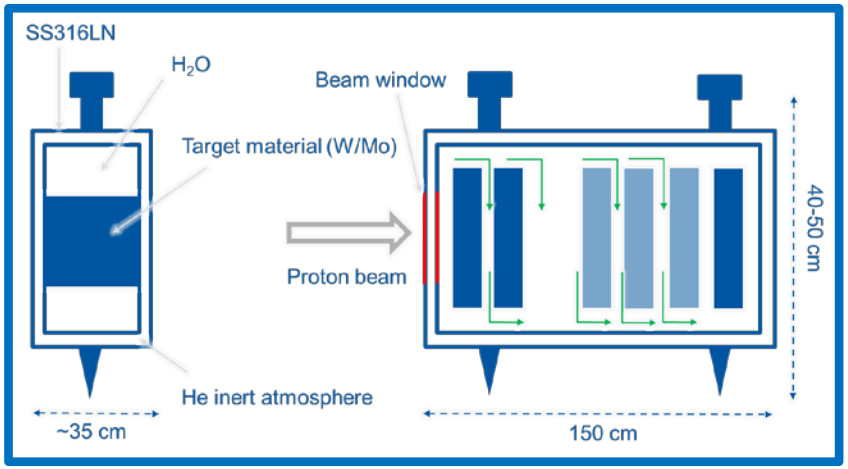


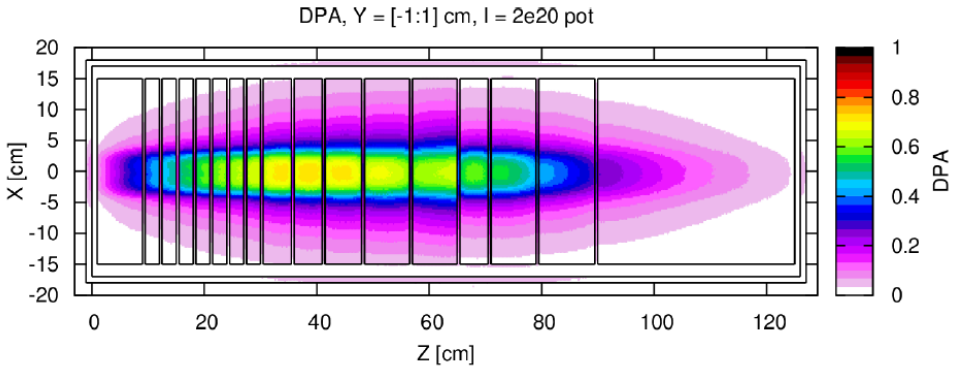


E. Lopez Sola

The proposed BDF target

- 150 cm long, hybrid configuration
- 60 cm TZM (4λ) + 80 cm W (8λ), Ta cladded
- 30 x 30 cm^2 transversal size … might switch to 25 cm diameter circular plates
- Target core in a double walled SS container, water cooled
- Radiation damage effect on mechanical properties → R&D
- Max temperature on Ta ~160 °C, TZM core 185 °C
- Max Von Mises equiv. stresses: Ta cladding ~120 MPa, TZM core 175 MPa

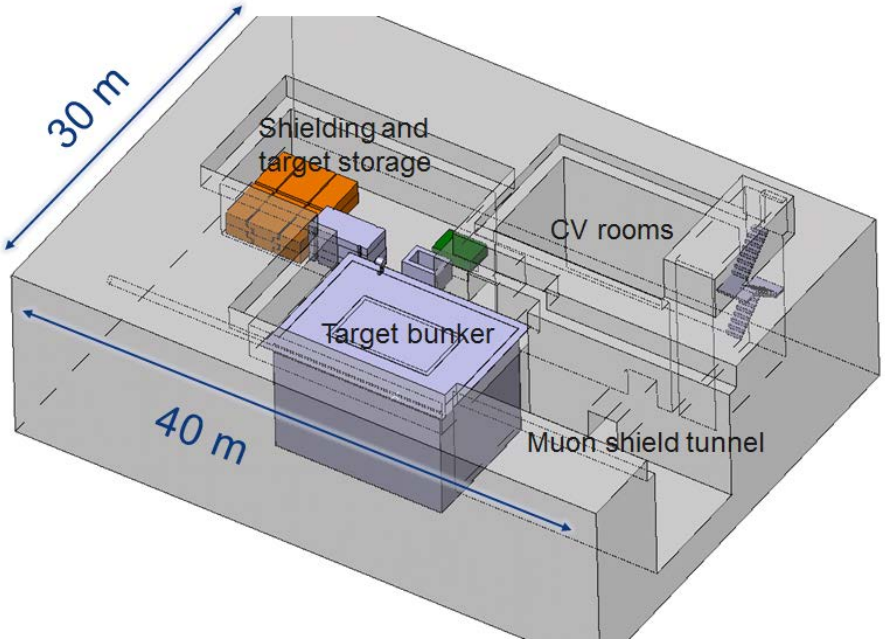


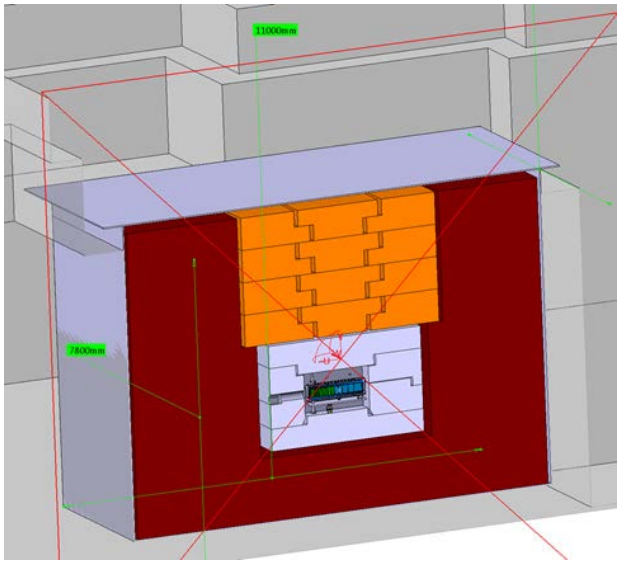


TZM is an alloy of 0.50% Titanium, 0.08% Zirconium and 0.02% Carbon with the balance Molybdenum

Target Complex

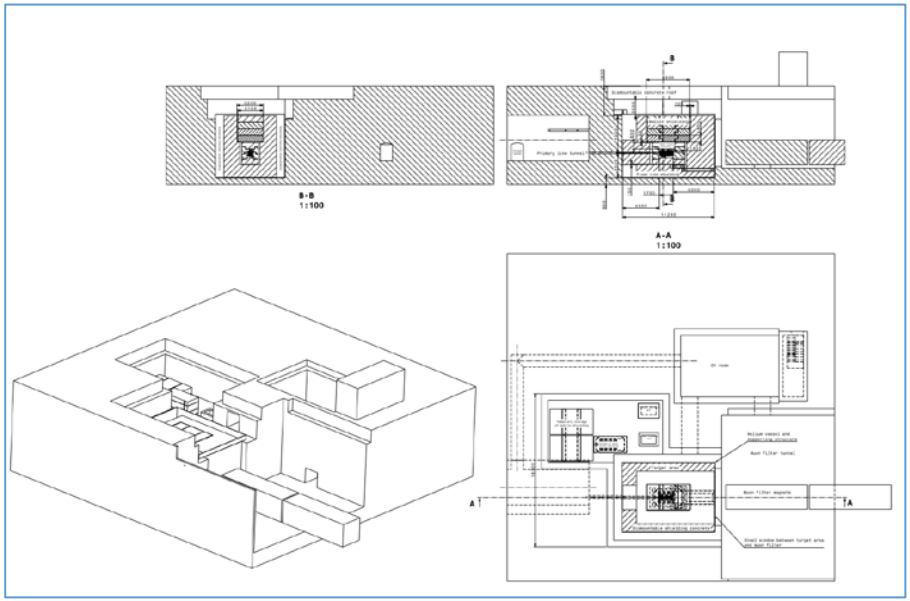
- Target is located 15 meters underground
- Iron hadron absorber encloses production target (460 m^3)
- Target and hadron absorber are inside an helium vessel
- Fully remote handling/manipulation
- Significant attention to radiation protection



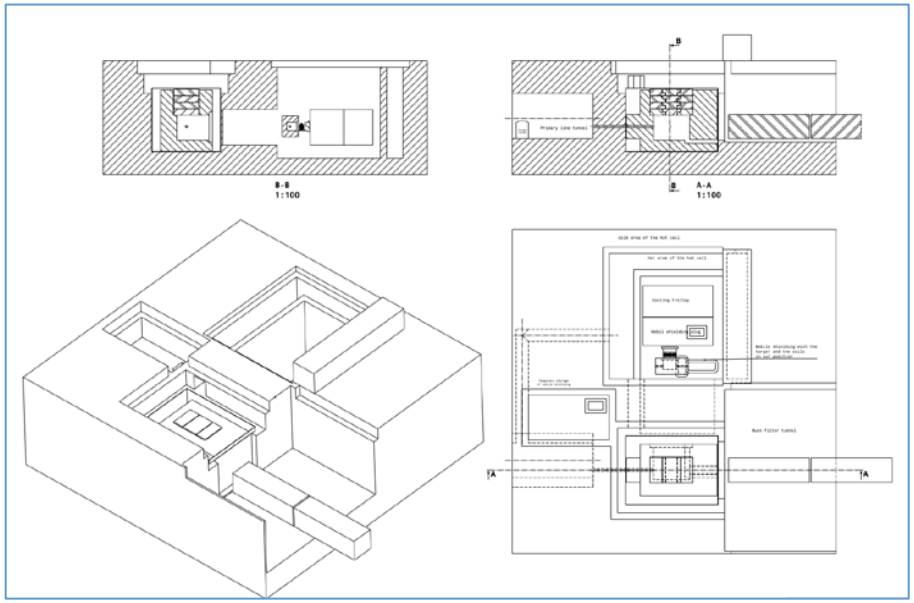


Target Complex - Crane version & trolley version

- During the initial preliminary design phase, a single concept (crane version) was developed
- In the meantime, the “trolley” solution has been conceived and found application at ISIS/JSNS/SNS, etc. with a lot of operational experience
- Thus, both options will be studied, in order to have two “mature” design option



Crane



trolley

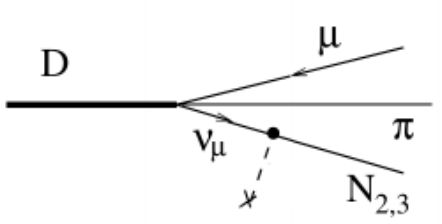
Search for Hidden Particles (SHiP) at BDF

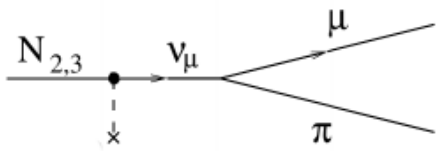
SHiP is aimed at exploring the domain of hidden particles and make tau neutrino measurements

http://ship.web.cern.ch/ship/

"Zero background" experiment
- Muon shield
- Surrounding Veto detectors

$>10^{18}$ D, $>10^{16}$ τ, $>10^{20}$ γ for 2×10^{20} pot (in 5 years)





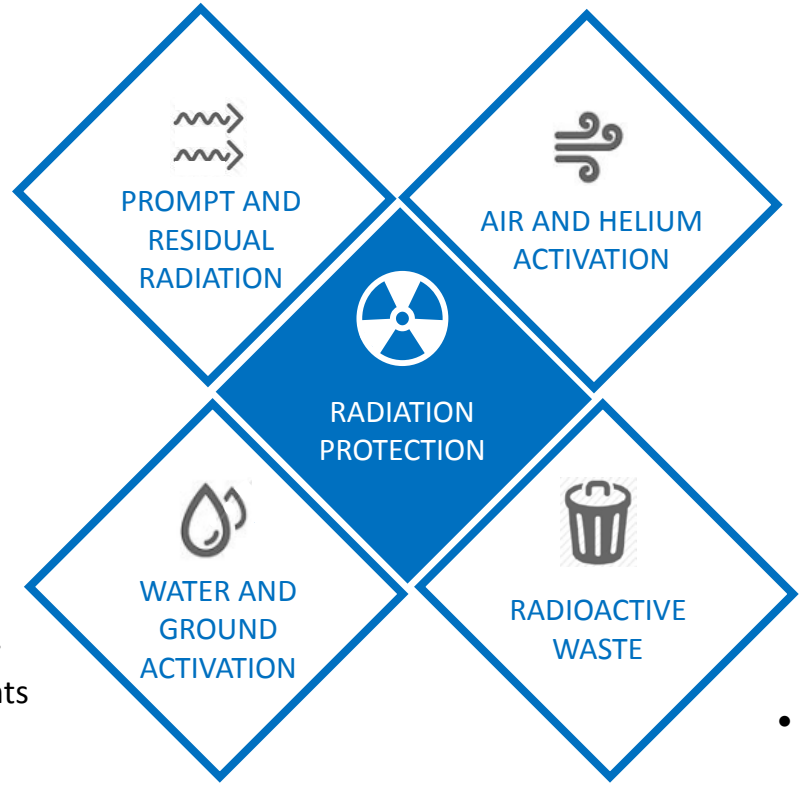
Search for Hidden Sector particles (decays in the decay volume)

ν_τ physics (specific event topology). Search for DM (scattering on atoms)

< 7k muons / spill ($E_\gamma > 3$ GeV), from 10^{10}

General RP considerations for the BDF

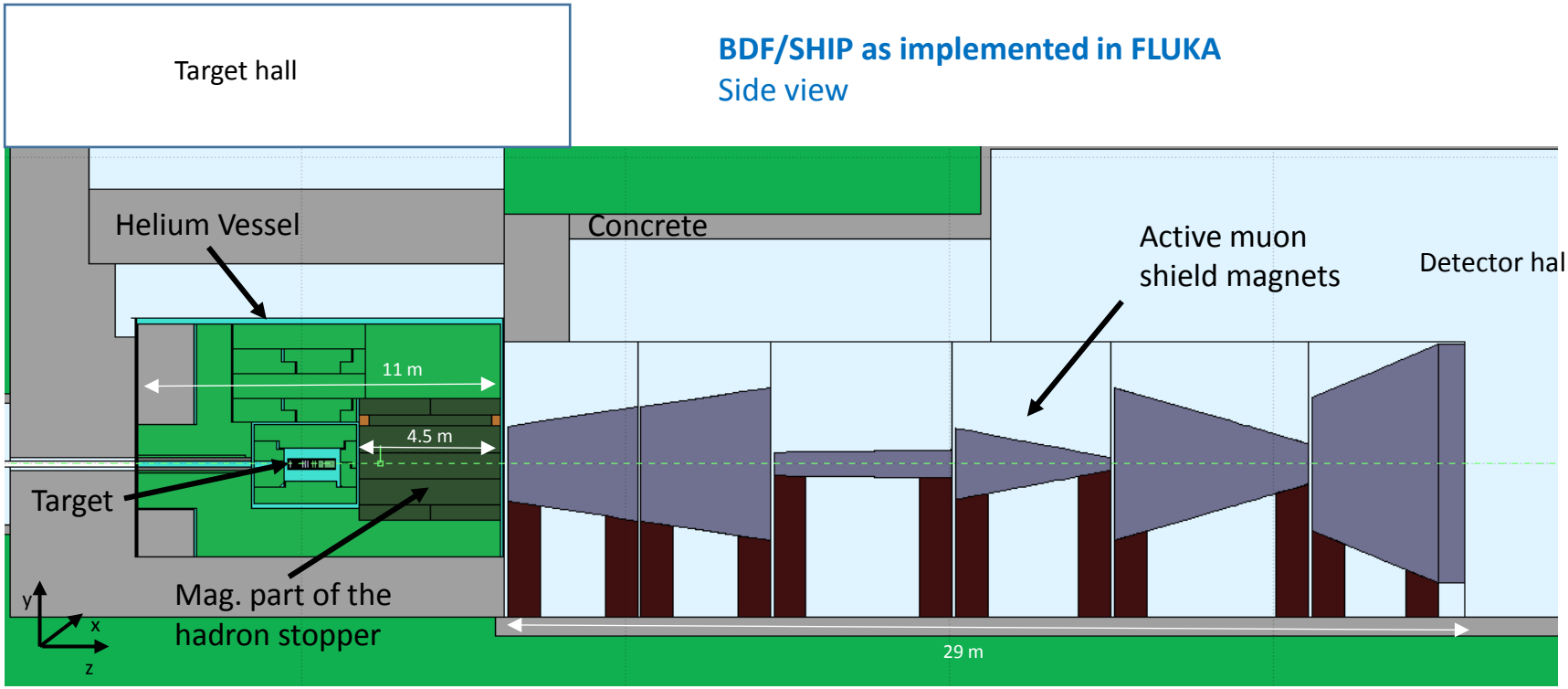
- **High prompt dose** in the BDF target area calls for adequate shielding around the target
- **Only** absolute **necessary equipment** should be installed in **“hot” areas**
- Depending on residual dose and tasks, **manual interventions** should partially/completely be **replaced** by **remote maintenance or repair**



- **Air volumes** to be **minimized** in ‘hot’ areas or to be **replaced by He/vacuum** environment
- **Static confinement** of air by physical barriers to separate air in contaminated areas from outside
- **Dynamic confinement** by a ventilation system guaranteeing a pressure cascade from low to high contaminated areas

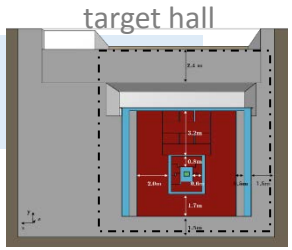
- **Water cooling circuits** for highly radioactive elements should be **closed and separated** from others
- **Activation** and **contamination** of ground water and earth to be **avoided**
- The **design** must consider **minimization, decommissioning and dismantling of radioactive waste**

RP evaluation of BDF/SHiP target complex is based on FLUKA simulations

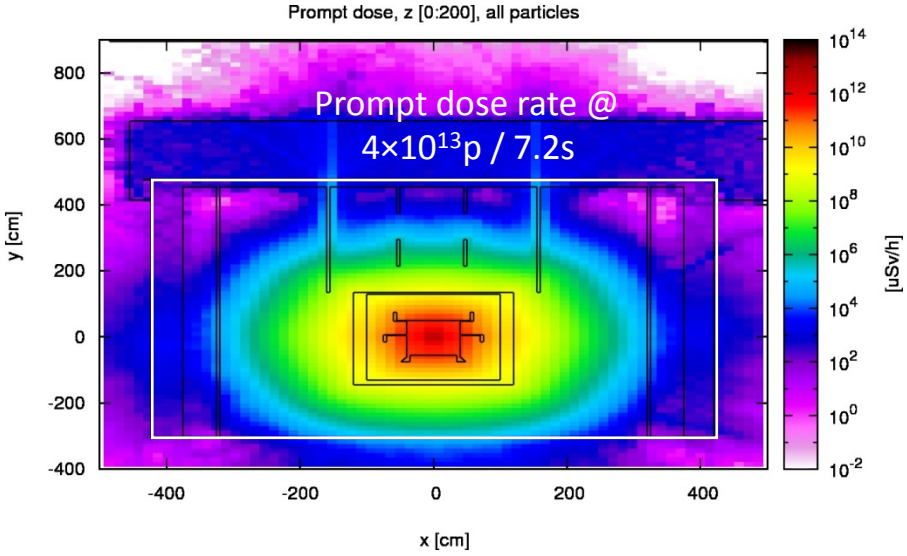


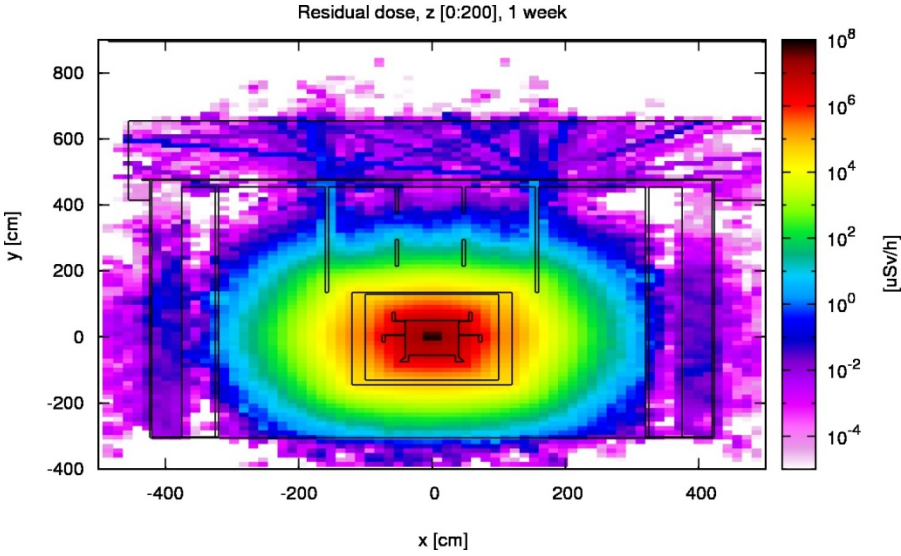
- FLUKA was used to evaluate the radiation protection requirements for the BDF/SHiP target complex
- Design is based on the condition that there is no access during operation into the experimental hall
- Objective of shielding is to keep prompt/residual dose and airborne radioactivity as low as possible
- Active muon shield with magnets and magnetic field of 1.8 T was included

Prompt and residual dose rate



- Prompt & residual dose rates “under control” in accessible areas





Prompt dose rates reach **~100 mSv/h** above the He-vessel and drop down to **below 1 µSv/h** above the top concrete shielding (conservative assumption due to non-optimized gaps)

→ **Supervised Radiation Area (<3uSv/h)** in the target hall

Residual dose rates are at the level of **a few µSv/h** above and next to the He-vessel

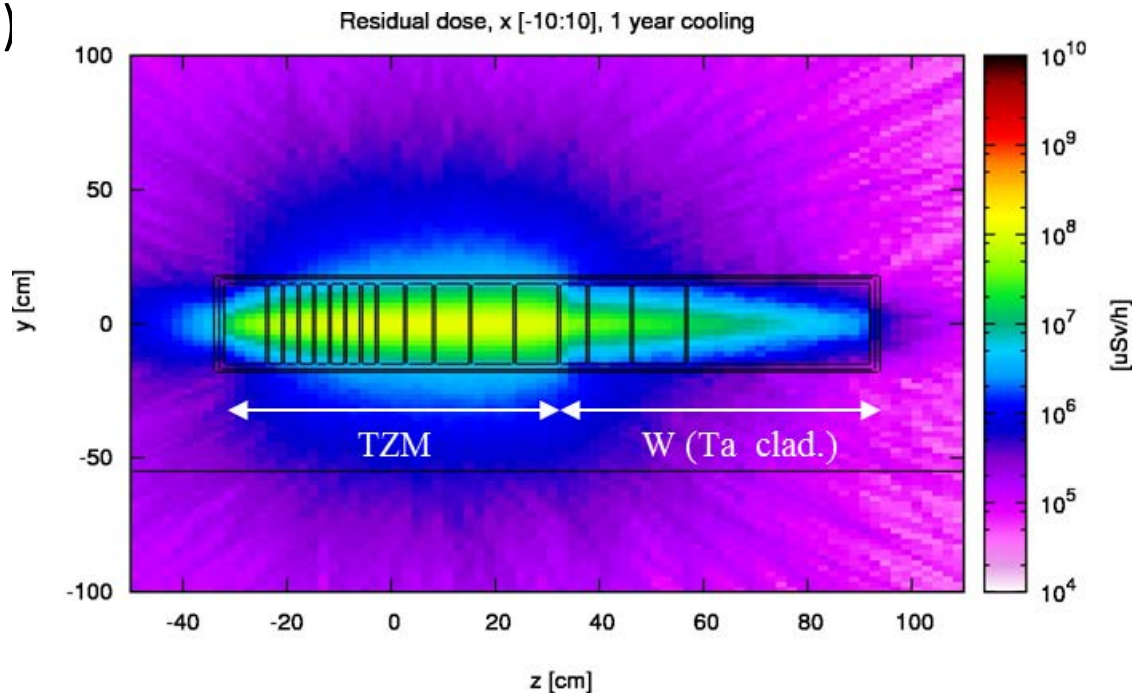
Very high residual dose rates next to the target and to the cast iron shielding **O(10) Sv/h (1 week cooling)**

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

100 rem = 1Sv

BDF target H*(10)

- Target **residual dose rate ~10 Sv/h** after 1 week of cooldown @40cm
  - Handling of the target an outstanding item
- Target station design foresees temporary storage location close by (for cool down)



- **Residual dose rates** reach **~5 Sv/h (500 rem/h)** on the target surface after 1 year of cooling

Summary & conclusion

- BDFs at CERN ideal for exploring light super-weakly interacting particles and Light Dark Matter
- The proposed BDF would be a **new permanent facility in the North Area** with unprecedented average beam power
- An in-depth study of the proposed BDF at CERN's SPS is underway.
  - Target design needs careful studies and R&D
  - Target area particularly critical – embedded in a Helium vessel
  - High prompt & residual dose rates → massive shielding and remote interventions
- The BDF project team aims to produce a comprehensive design study by end 2018 to accompany the SHiP proposal to be considered in the next update of the European Strategy for Particle Physics (ESPP).