HI-ECN3 Target station shielding Requirements, design, sustainability

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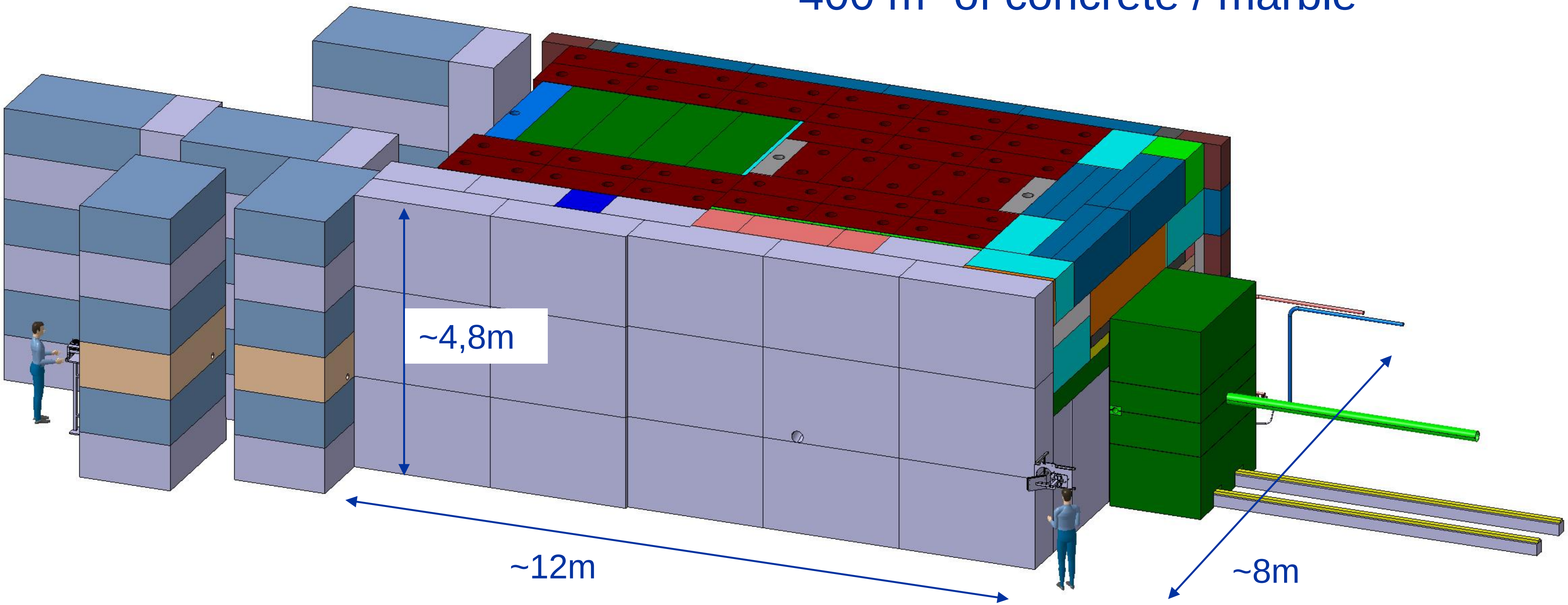
Introduction: what for ?

- New target station installed in TCC8 for BDF/SHIP requires large amount of shielding (cast iron, concrete and marble)

~180 m³ of cast iron + US1010 (magnetic iron)
~400 m³ of concrete / marble

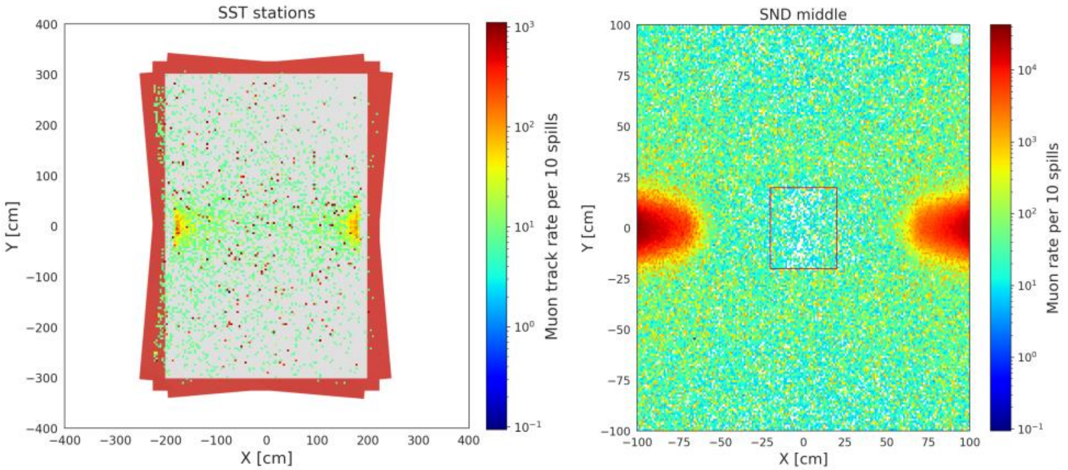


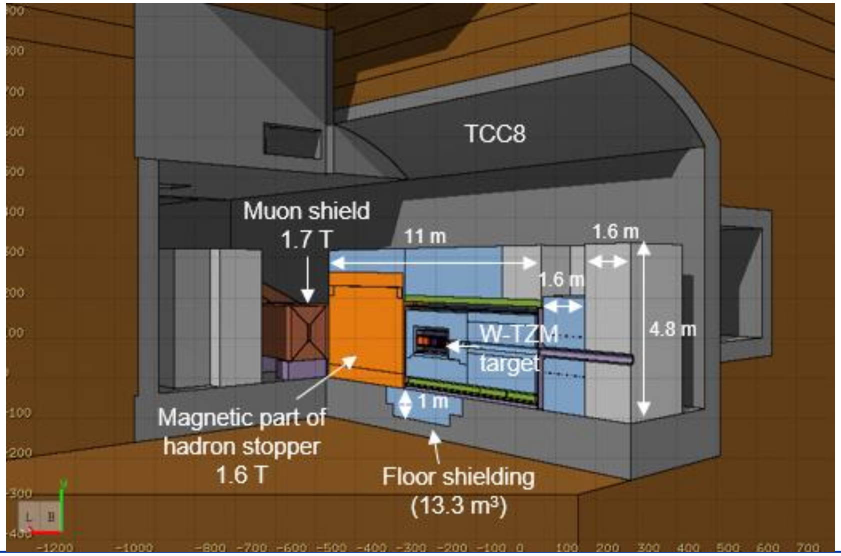
Shielding Requirements - 1

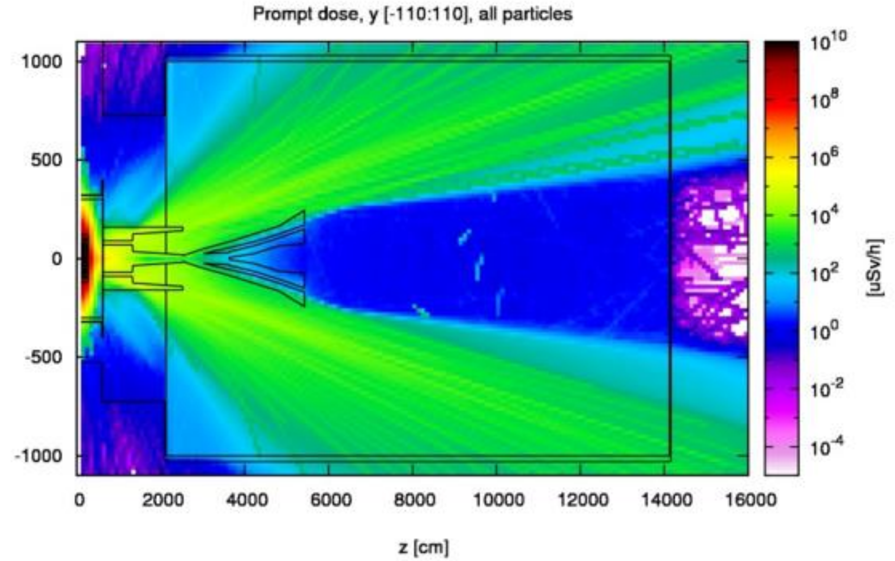
1. Experiments requirements

Keep the flux of particles emerging from the target station into the detector as low as possible (complex optimum to be reached)

Limit the flux into (possibly) super conducting magnets of the magnetic muon shield







Ref: CERN-SPSC-2023-033

Shielding Requirements- 2

2. RP requirements

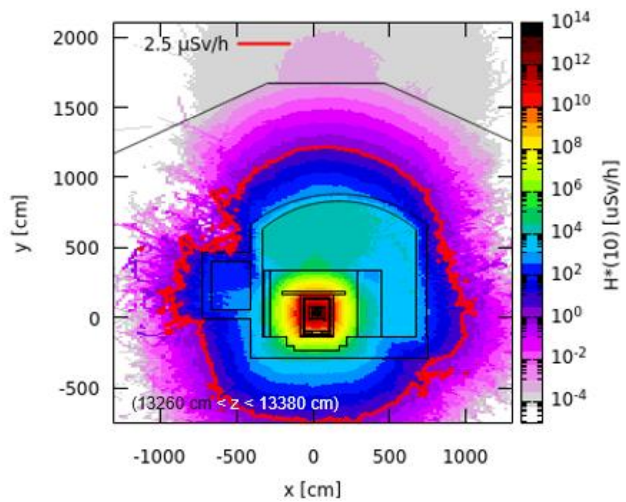
Keep surface within non-designated limits (2.5 μSv/h) during operation

Keep residual radiation downstream target station (SHiP environment) within supervised area limit (15μSv/h)

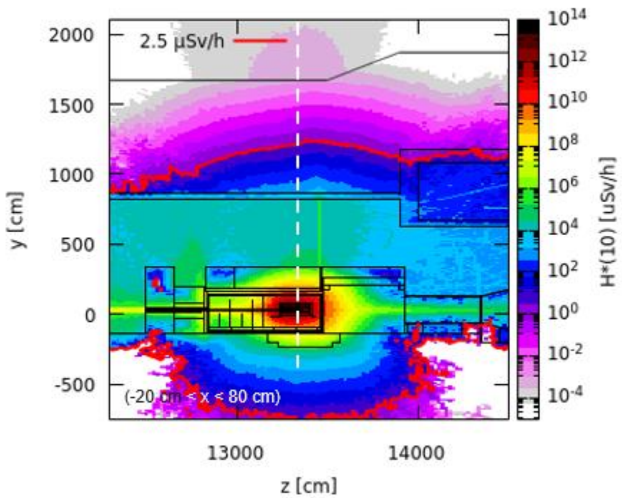
Limit environmental impact (soil + air activation)

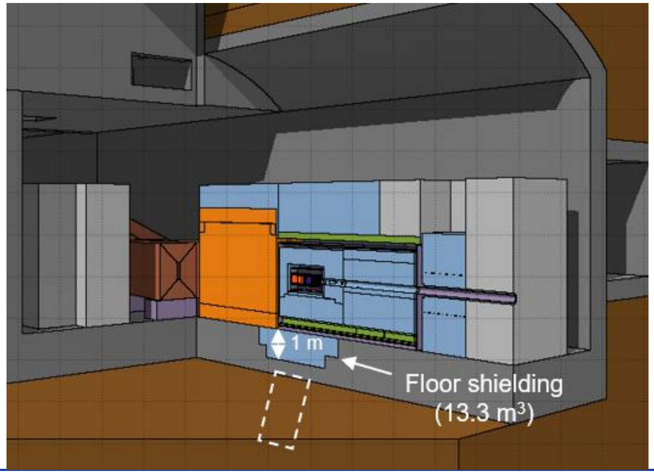
Avg. intensity of 5.6×10^{12} p/s

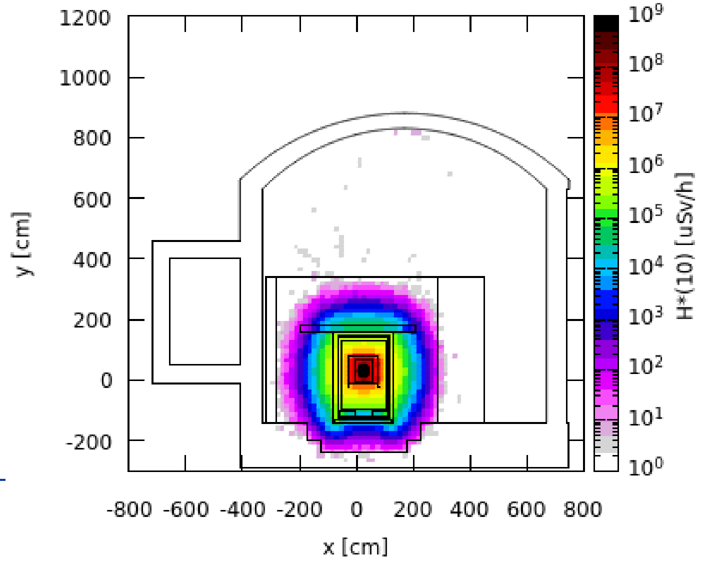
Cross-sectional view



Side view







See C. Ahdida's talk for RP details

Shielding Requirements- 3

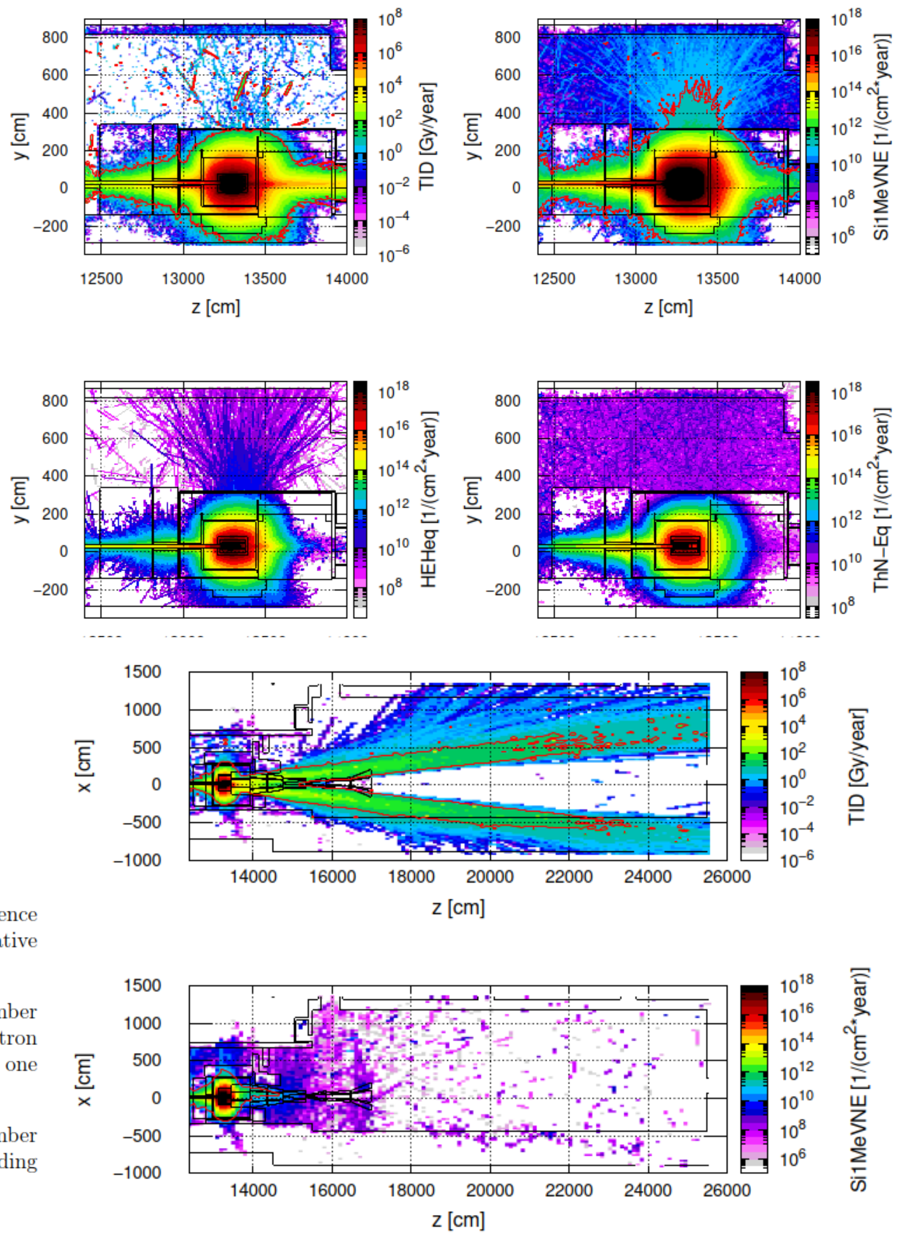
3. R2E requirements

Keep radiation dose within limits of «standard electronics» limits

-	R2E Quantity	Upper limit
Cumulative Effects	TID	1÷10 Gy/10 years
	Si1MeVNE	$10^{10} \div 10^{11}$ 1/(cm^2×10 years)
Single Event Effects	HEHeq	3×10^6 1/(cm^2×year)
	ThN-Eq	3×10^7 1/(cm^2×year)

R2E safe area requirements

1. **Total Ionising Dose (TID)**
2. **Silicon 1-MeV Neutron Equivalent Fluence (Si1MeVNE)** - Particle fluence weighted by the damage function for silicon. The quantity is used for cumulative effects estimation.
3. **High Energy Hadron Equivalent Fluence (HEHeq)** - Proportional to the number of SEUs. It considers fluence of hadrons with energy higher than 20 MeV and neutron of lower energies weighted according to the ratio of their SEU cross section to the one of > 20 MeV hadrons.
4. **Thermal Neutron Equivalent Fluence (ThN-Eq)** - Proportional to the number of SEU's due to thermal neutrons. Neutrons of higher energies are weighted according to the ratio of their capture cross section to the one of thermal neutrons.



Credit: Luigi Esposito

Required Shielding blocks listing

Concrete blocks: ~400 m3

	BDF needs	TCC2	TCC8
BLOC STANDARD BETON TYPE 421	16		16
BLOC STANDARD BETON TYPE 844	6		4
BLOC STANDARD BETON TYPE 882	2		8
BLOC STANDARD BETON TYPE 884	7		15
BLOC STANDARD BETON TYPE 888	1		13
BLOC STANDARD BETON TYPE 1682	3		9
BLOC STANDARD BETON TYPE 1684	4		35
BLOC STANDARD BETON TYPE 1688	43		15
BLOC STANDARD BETON TYPE 2484	37		
BLOC STANDARD BETON TYPE 2488	2		
BLOC STANDARD BETON TYPE 24168	92		94

Special blocs BDF needs

BLOC BETON 1681 special	1
BLOC BETON SPECIAL 3250x1600x800	1

Iron blocks: ~180 m3

	BDF needs	TT7	TCC2	TCC8
BLOC STANDARD SEUL ACIER TYPE 442	5			
BLOC STANDARD ACIER 842 TARAUDE	44			2
BLOC STANDARD SEUL ACIER TYPE 844	8			4
BLOC STANDARD SEUL ACIER TYPE 882	22	130		
BLOC STANDARD SEUL ACIER TYPE 884	32		~5	2
BLOC STANDARD SEUL ACIER TYPE 1682	33	8		12
BLOC STANDARD SEUL ACIER TYPE 1684	45	56	~55	3
BLOC STANDARD SEUL ACIER TYPE 1688	111	52		12
POUTRE 200x200	32			

Special blocs BDF needs

BLOC ACIER 16608 non standard	56
BLOC SPECIAL 55016	12
STEEL BLOCK WITH RABBIT	1

Special blocks: holes, round shape, specific dimensions etc. : to be produced on demand
Installation layout not finalized yet

CERN Standard shielding blocks

Raw material specs:

Concrete: according to the standard EN 206
Limit to absolute minimum Natrium, Manganese, Magnesium, Cobalt, Europium, Caesium, Hafnium, Iridium, Silver, and Scandium

Cast iron: spheroid-graphite cast iron EN-GJS-400-18U-RT:
Better resilience than Laminal Graphite cast iron.
Maximum cobalt content below 0.10%

All iron blocks need to be painted (corrosion protection) and identified

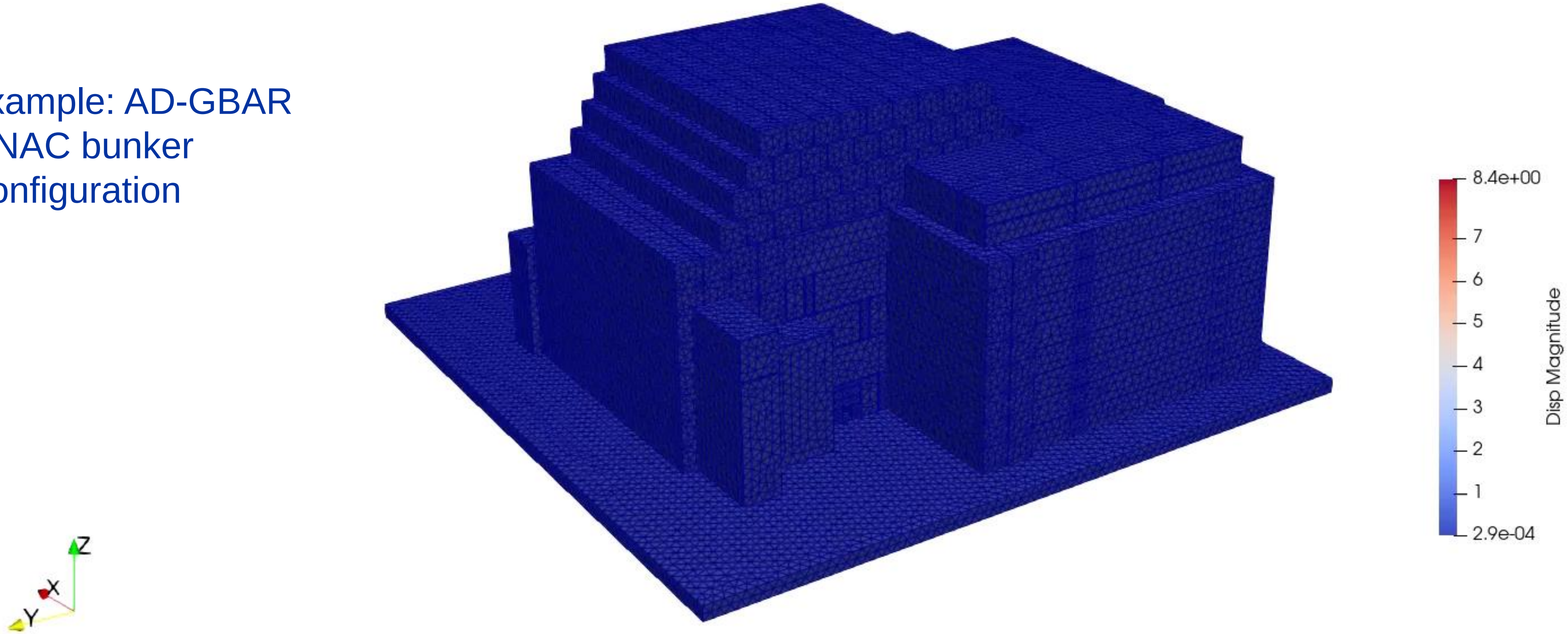
Item	Type	Weight(Kg)	Dimensions(mm)
Concrete blocks	24168	7500	2400x1600x800
	23168	7200	2300x1600x800
	1688	2500	1600x800x800
	1684	1250	1600x800x400
	1682	630	1600x800x200
	888	1250	800x800x800
	884	630	800x800x400
	882	325	800x800x200
	844	325	800x400x400
	842	160	800x400x200
	421	20	400x200x100

Item	Type	Weight(Kg)	Dimensions(mm)
Cast Iron blocks	1688	7500	1600x800x800
	1684	3700	1600x800x400
	1682	1850	1600x800x200
	884	1850	800x800x400
	882	925	800x800x200
	844	925	800x400x400
	842	465	800x400x200
	822	230	800x200x200
	442	230	400x400x200
	211	16	200x100x100

Stability assesement of the shielding assembly

The assembly scheme will be subject to Finite Element Analysis for seismic assessment by CERN safety department
Complex calculation due to nature of pile-up (no mechanical link only friction)

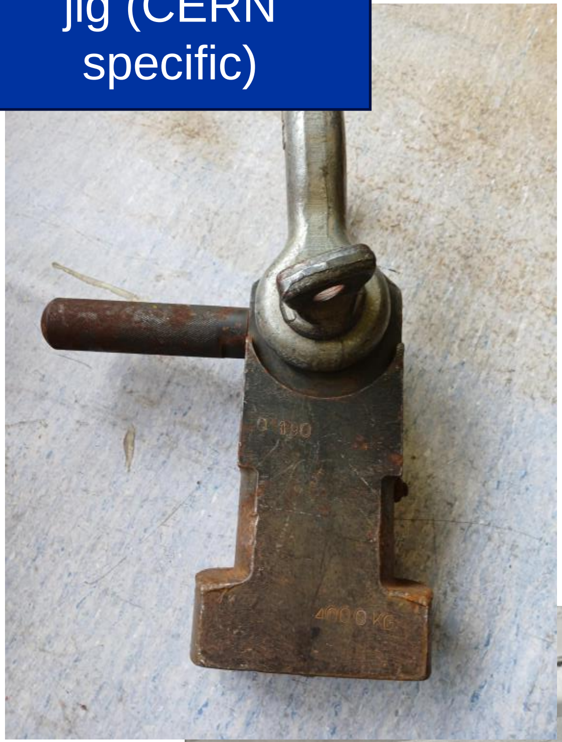
Example: AD-GBAR
LINAC bunker
Configuration



Identification of the most vulnerable mechanisms
EQ3 – PGA scaled to 0.5 g

Most common lifting systems (non exhaustive…)

Twist lock lifting jig (CERN specific)



Cast-in loop (plus shackle)

Spherical head anchors

See C. Duran’s talk for handling details

Considered shielding supply sources

Main source is recovery from decommissioned projects:

-Stocks of clean / slightly activated iron and concrete blocks are centrally managed at CERN. Limited quantities can be made available at a cost

-Other recovery possibilities:

Shielding / dump assemblies exist throughout CERN, that can be interesting to recover after decommissioning or reconfiguration:
CNGS target, TCC2, TT7 dump, T10 shielding etc.

-Purchase for special cases: Specific dimensions / shapes / large quantities etc.

CNGS target blocks to be possibly recovered

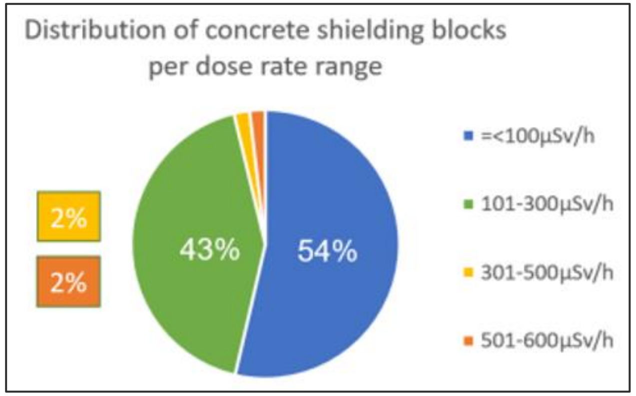
Sustainability of the projet:

Strong effort to re-use existing activated blocks (economical / environmental interest)

Financial aspect: limit number of new blocks to be purchased

Sustainability aspect: avoid generating more future activated waste by re-using already slightly activated blocks

Intelligent arrangement «hiding» the more activated blocks



Main sources for BDF project: Recover ancient blocks from decommissioned project:

- -TT7 neutrino beam line dump (iron)
- -T10 target station in TCC8 (concrete + iron)
- -TCC2 (iron, quantity TBC)
- -CNGS target (concrete + marble)
- -Radio-active waste recovery

Expected savings, still tentative:
~150 m3 out of 180 m3 of iron
~350 m3 out of 400 m3 of concrete

Recovery from current T10 target station (TCC8)

~15 m³ of **standard** cast iron blocks (activated)

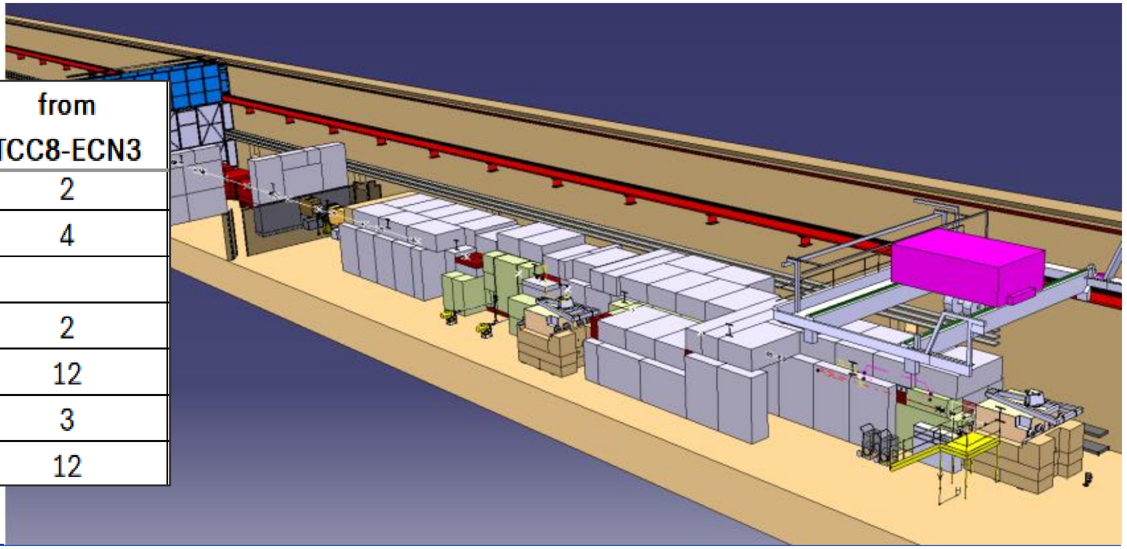
~400 m³ of **standard** concrete blocks (activated)
Not all can be re-used (special shales needed).

Max dose rate 160 μSv/h.

Most will be re-used in situ

Concrete	TCC8
BLOC STANDARD BETON TYPE 421	16
BLOC STANDARD BETON TYPE 844	4
BLOC STANDARD BETON TYPE 882	8
BLOC STANDARD BETON TYPE 884	15
BLOC STANDARD BETON TYPE 888	13
BLOC STANDARD BETON TYPE 1682	9
BLOC STANDARD BETON TYPE 1684	35
BLOC STANDARD BETON TYPE 1688	15
BLOC STANDARD BETON TYPE 2484	
BLOC STANDARD BETON TYPE 2488	
BLOC STANDARD BETON TYPE 24168	94

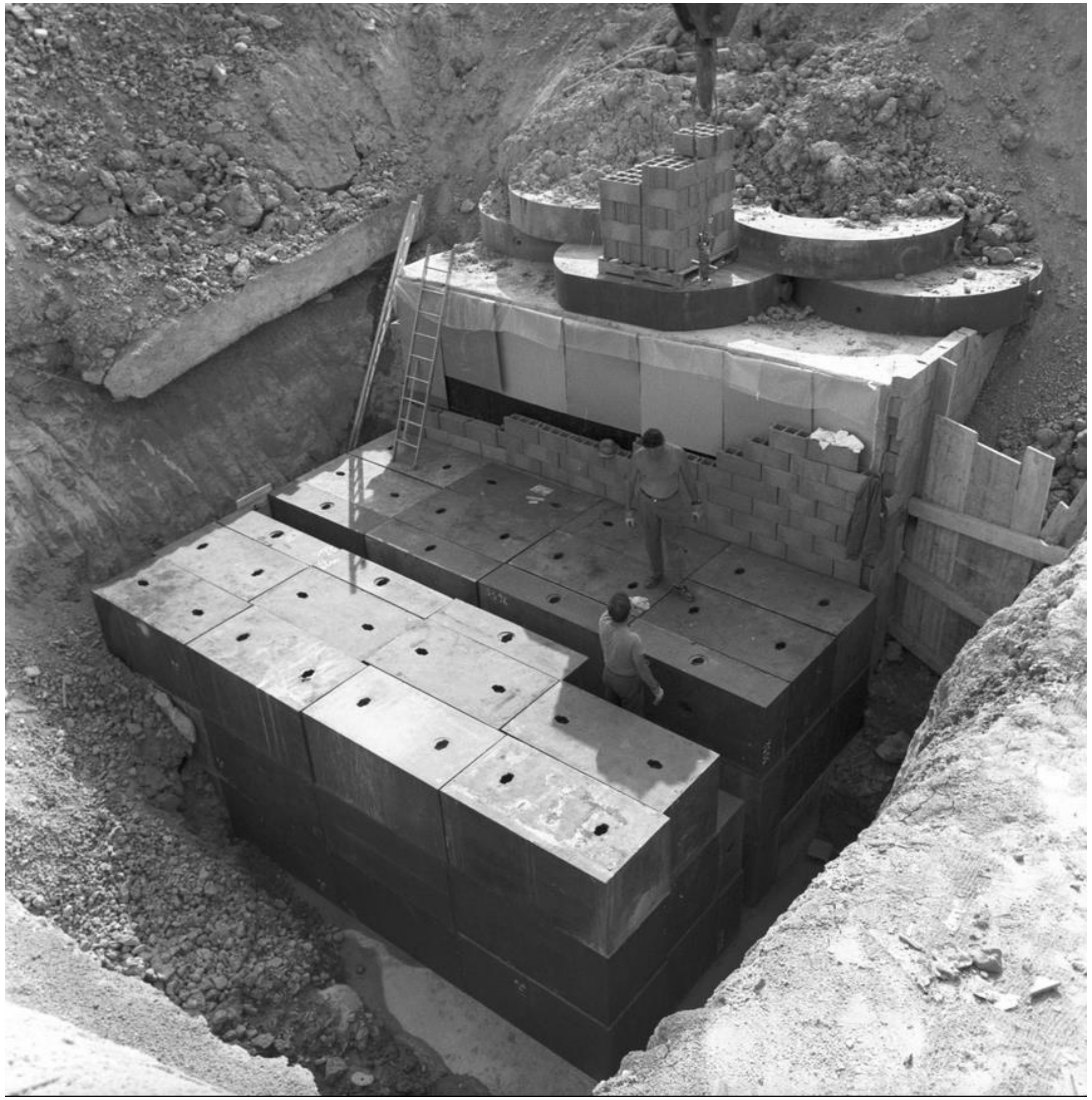
Iron Type of blocks	from TCC8-ECN3
842	2
844	4
882	
884	2
1682	12
1684	3
1688	12



TT7 dump recovery project

- Unused shielding blocks left on “old” CERN locations, among which TT7 dump

What to expect



What to expect

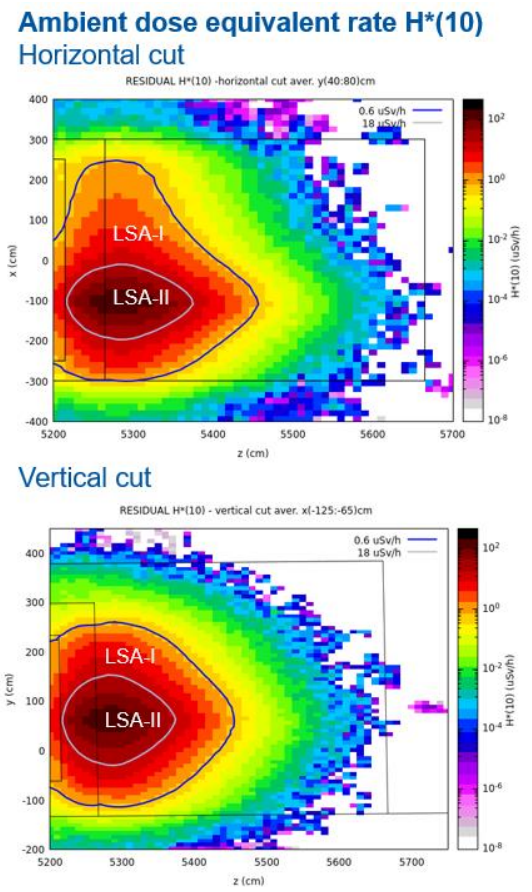
The scope of the TT7 recovery project

100m³ of **standard** cast iron blocks (+**non-standard** cast iron blocks)

- Activated blocks (dose rate TBC after extraction, expected to be rather low for vast majority of blocks)
- Excavation of backfill mound required + rerouting of networks; recovery of the blocks + transport to NA
- Scraping + painting process to be finalized

Dimensions

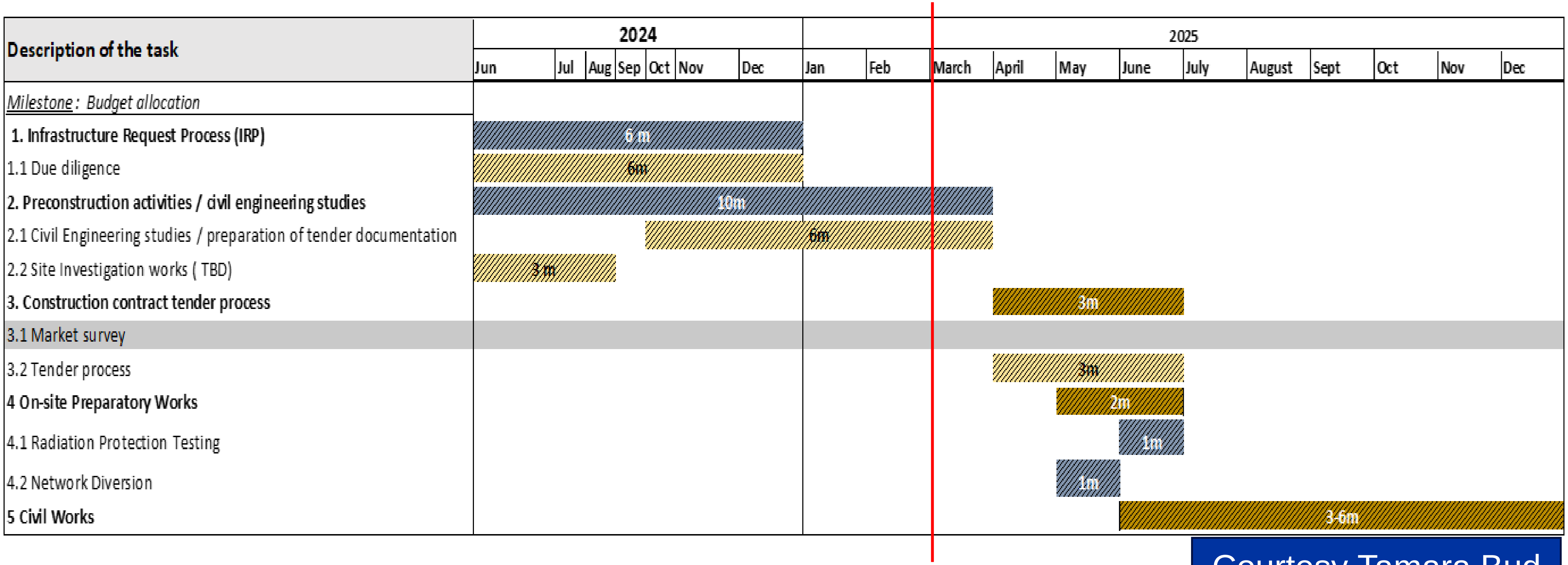
a) 1.6m x 0.8m x 0.8m (7.5t) – 52 blocks (390t)
b) 1.6m x 0.8m x 0.4m (3.8t) – 56 blocks (213t)
c) 1.6m x 0.8m x 0.2m (1.6t) – 24 blocks (39t)
d) 0.8m x 0.8m x 0.2m (0.8t) – 131 blocks (105t)



TBC after extraction (end 2025) !

Status / planning

Objective : Project completed before LS3 – Number + condition + dimension of blocks to be known before end 2025
Budget secured
Tender document produced, in approval loop before being sent out



Courtesy Tamara Bud

Conclusion

About 180m^3 of cast iron and 400 m^3 of concrete / marble shielding block will be required for the BDF target station

Most of the required blocks will be retrieved from existing stocks and ancient facilities (TCC8, TT7, CNGS target, TCC2), essentially already activated

This will result in large savings in terms of money but also in terms of future radioactive wastes for the future

The fraction to be purchased (essentially non-standard blocks) remains to be clearly defined, linked to the detail design of the shielding layout, yet to be finalized https://cern.ch/be-dep-ea