SPS Beam Dump Facility Project Design Challenges

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on behalf of the BDF Project team

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Outlook

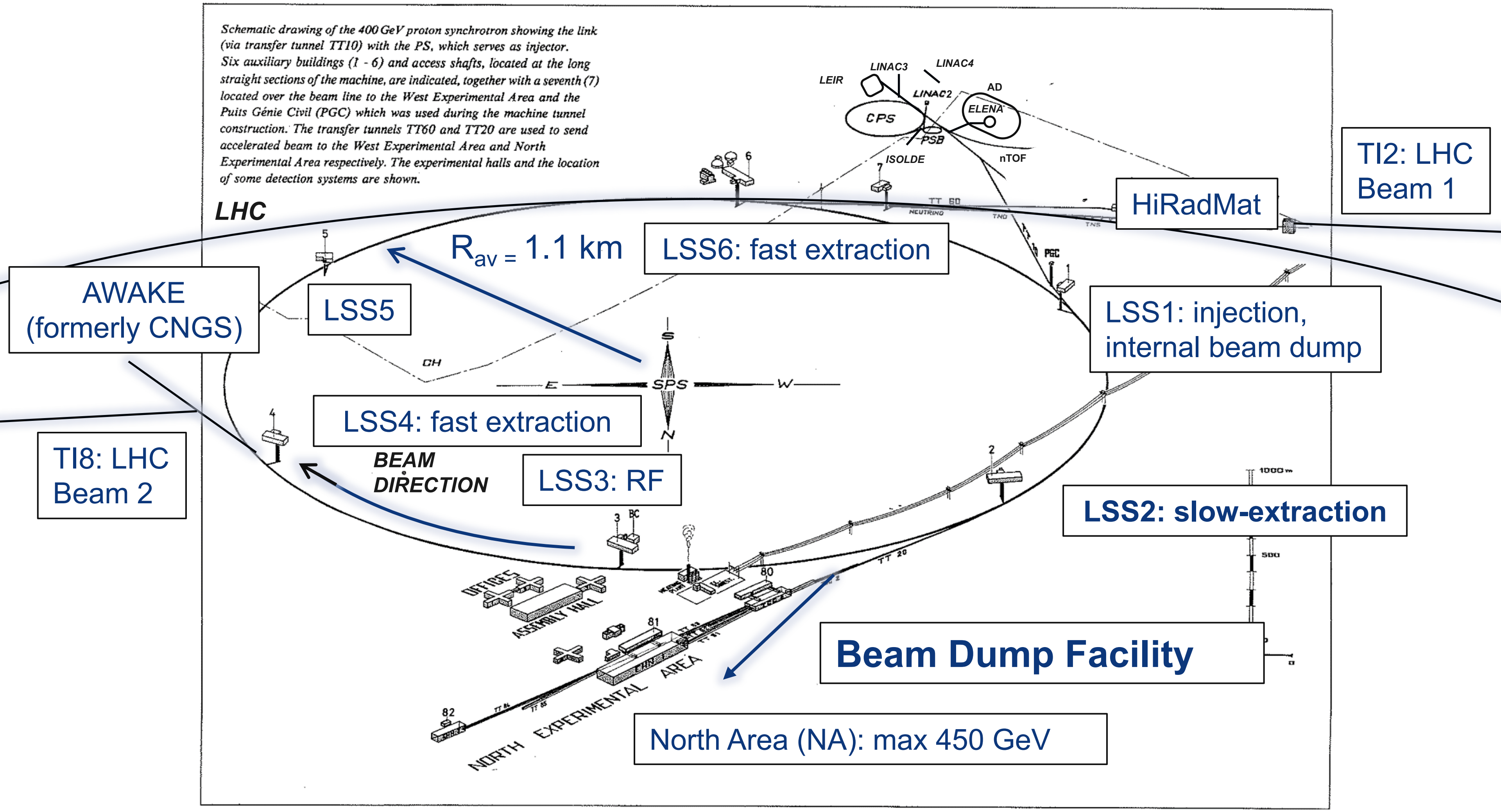
- BDF as a high intensity slow extracted beam in the CERN's NA
- Beam operational scenarios and compatibility with existing FT programs
- Design of the BDF target and prototyping
- Design process & optimization for the BDF target complex
- Conclusions

BDF work packages

- Defined based on the identified challenges:

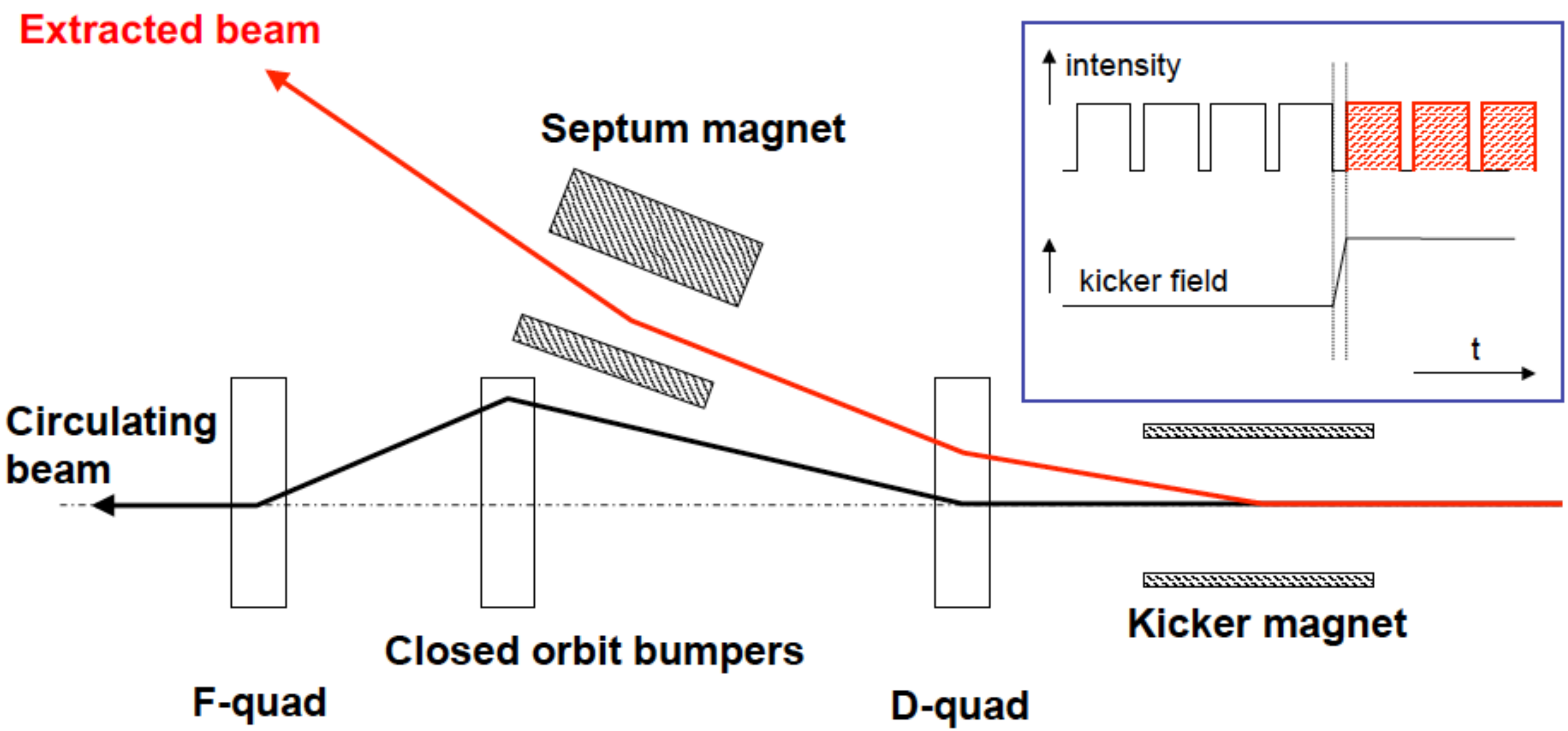
1. Extraction and beam transfer
2. Target and Target complex
3. Radiation protection
4. Safety engineering
5. Integration
6. Civil engineering

CERN SPS today



Fast single turn extraction

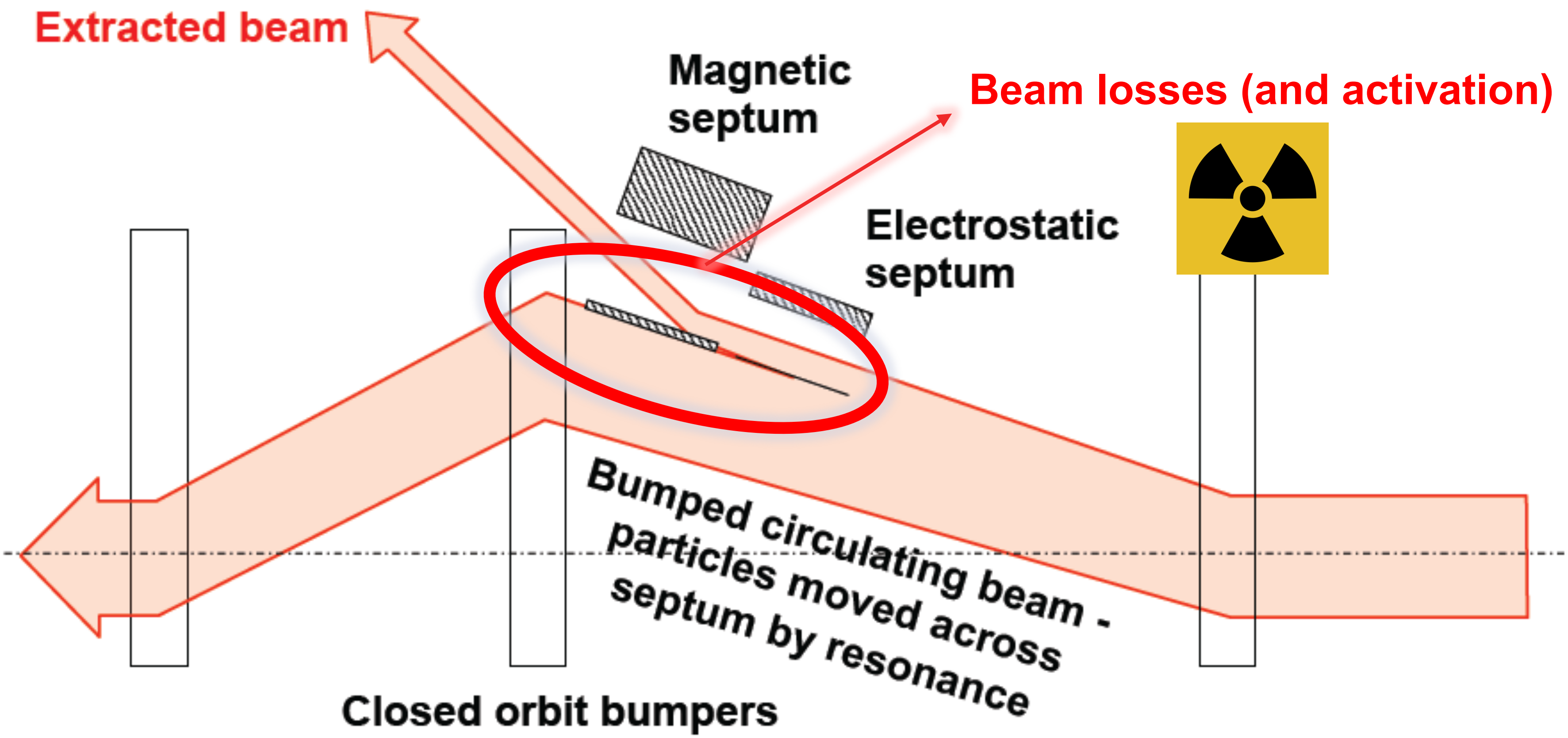
Entire beam kicked into septum gap and extracted over a single turn



- Bumpers move circulating beam close to septum to reduce kicker strength
- Kicker deflects the entire beam into the septum in a single turn
- Most efficient (lowest deflection angles required) for π/2 phase advance between kicker and septum

Resonant multi-turn (slow) extraction

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



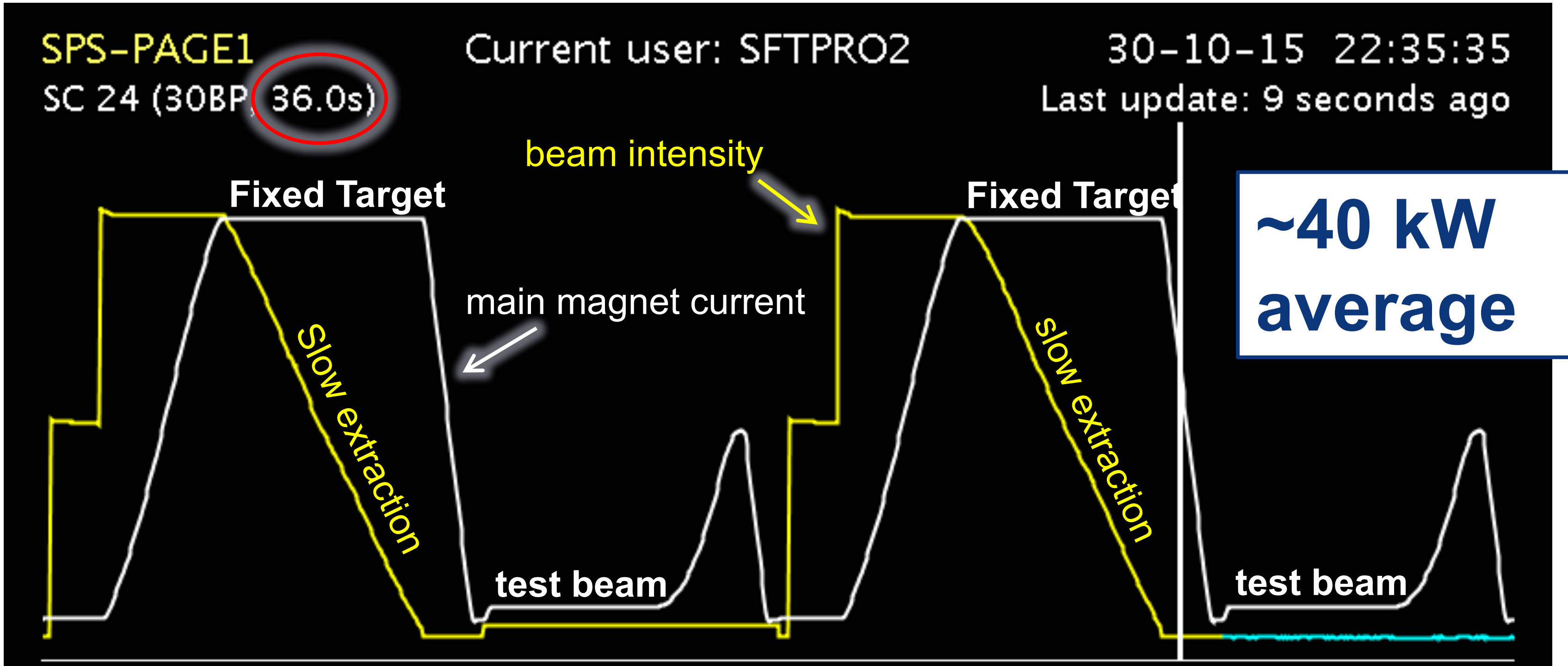
- Slow bumpers move the beam near the septum
- Tune adjusted close to n^{th} order betatron resonance
- Multipole magnets excited to define stable area in phase space, size depends on $\Delta Q = Q - Q_r$

Extraction from SPS for FT physics

- Slow extraction is used to deliver a **constant flux of particles** to FT experiments over many seconds:
  - From the SPS we typically extract up to ~$3*10^{13}$ p^+ over 4.8 s, i.e. while the beam circulates for over 200,000 turns
- Unlike single turn extraction, the slow extraction process is **intrinsically lossy**:
  - We cannot (yet!) create a clear temporal or spatial separation in the beam to extract cleanly
- Beam loss from slow extraction is **unavoidable** and has to be **controlled and optimized**:
  - Induced activation in SPS Long Straight Section 2 increases proportionally to the beam loss on the septum

SPS super-cycles

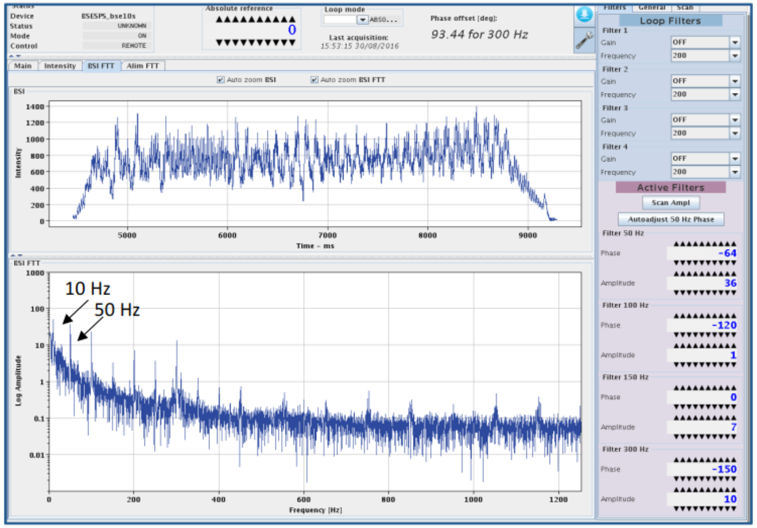
2015 in a period without LHC filling



- Duty cycle of fixed target beam limited by RMS power dissipation in SPS magnets
- Cycles for test beams with low power consumption are inserted in the sequence
- Different configuration during LHC filling

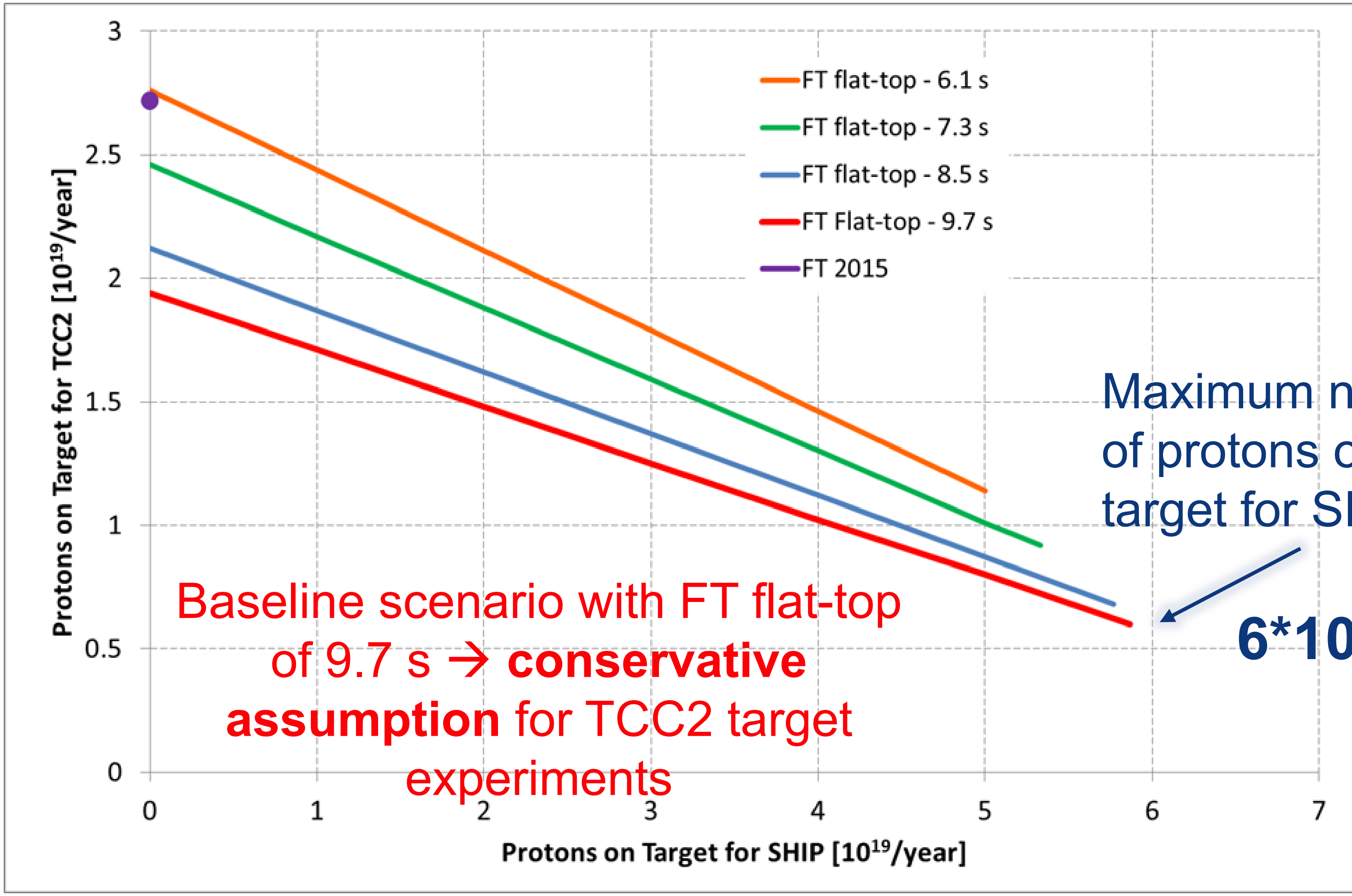
SPS – present challenges

- Regaining experience at SPS of operating slow-extracted beams for Fixed Target physics at high intensity
  - Optimisation of **extraction losses** and **induced activation**
  - Monitoring of **machine performances** and **interlocking**
  - Improving machine stability and reproducibility (**spill quality**)
  - Maintenance of equipment in activated areas
- Doing all the above with a truly **multi-cycling SPS**



A recent example of a relatively good spill with large n x 50 Hz components and another noise source at 10 Hz [8]

Proton sharing scenarios

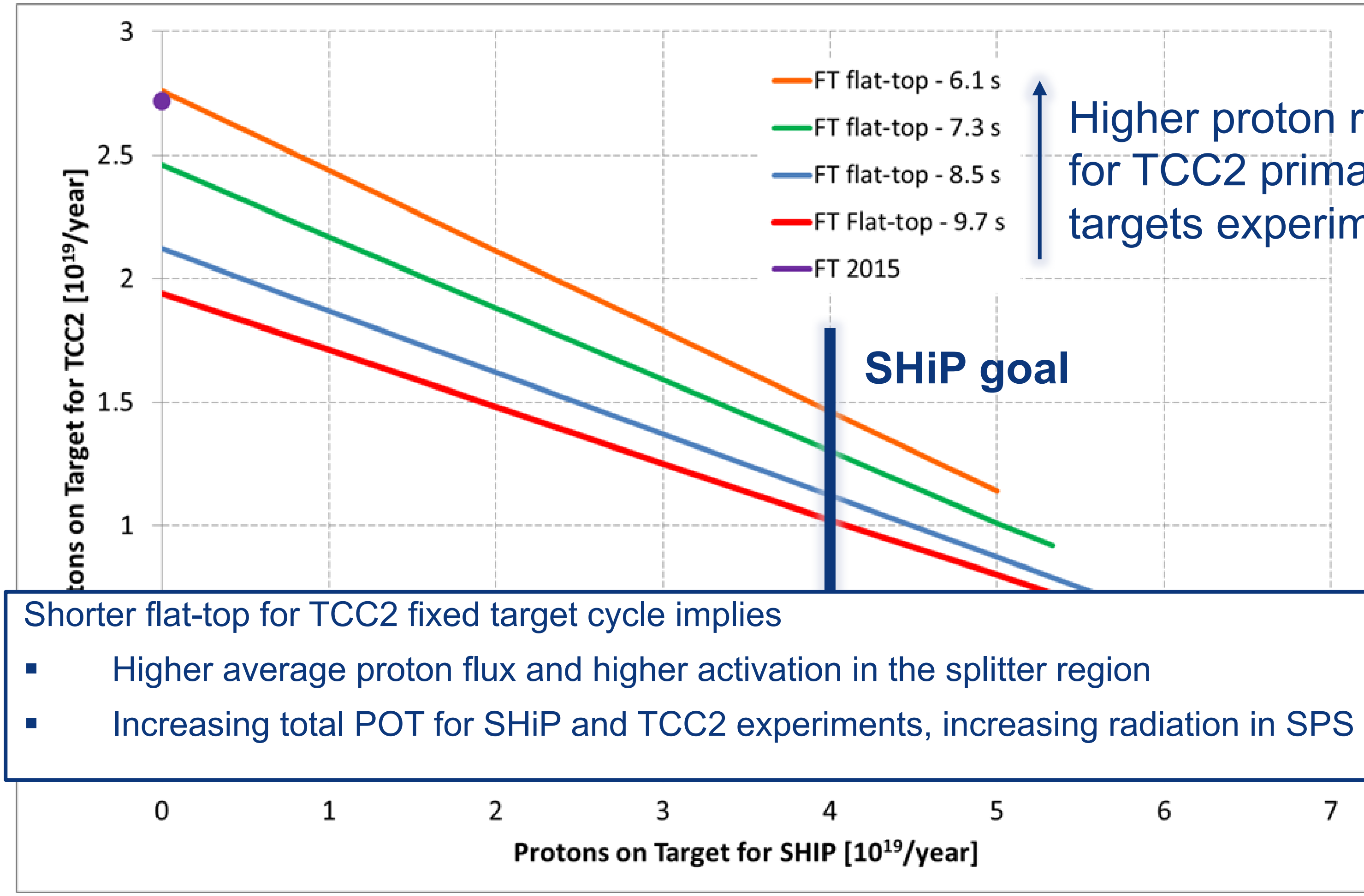


Maximum number of protons on target for SHiP

$6*10^{19}$ p/y

CERN-SHiP-NOTE-2015-004

Proton sharing scenarios



Higher proton rate for TCC2 primary targets experiment

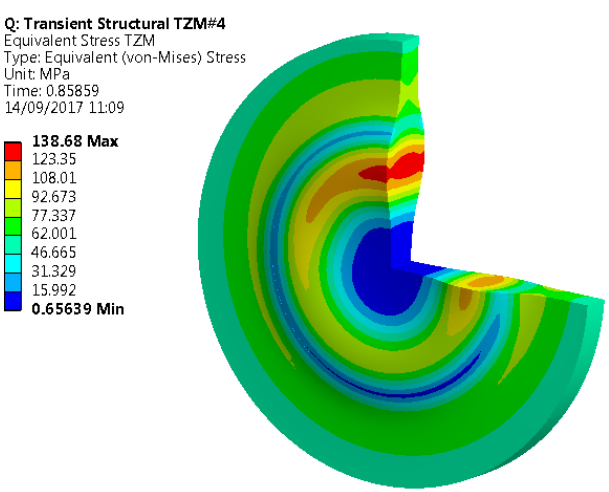
Shorter flat-top for TCC2 fixed target cycle implies

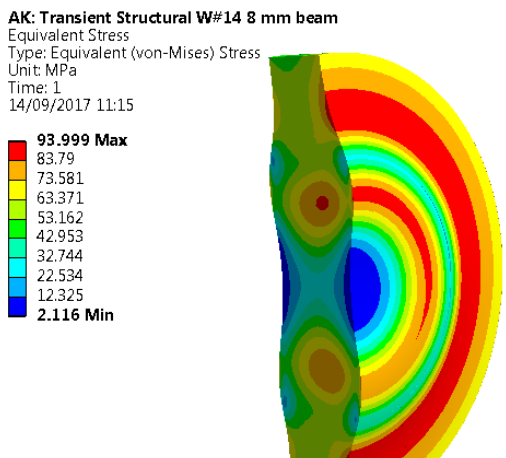
- Higher average proton flux and higher activation in the splitter region
- Increasing total POT for SHiP and TCC2 experiments, increasing radiation in SPS

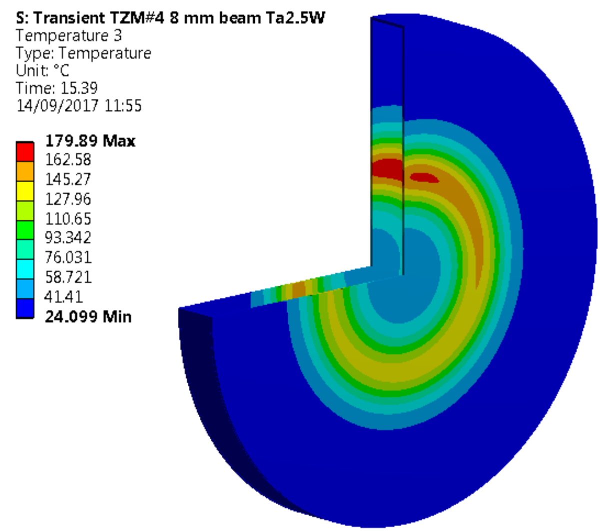
CERN-SHiP-NOTE-2015-004

Target design challenges and issues

- Long-optimisation for the design of the target sandwich
- Important compressive stress at the core centre
- Very high values of tensile forces on the cladding
- Initial Ta cladding removed in favour of Ta(2.5)W
- Target prototype beam tests during 2018 (PIE 2019)







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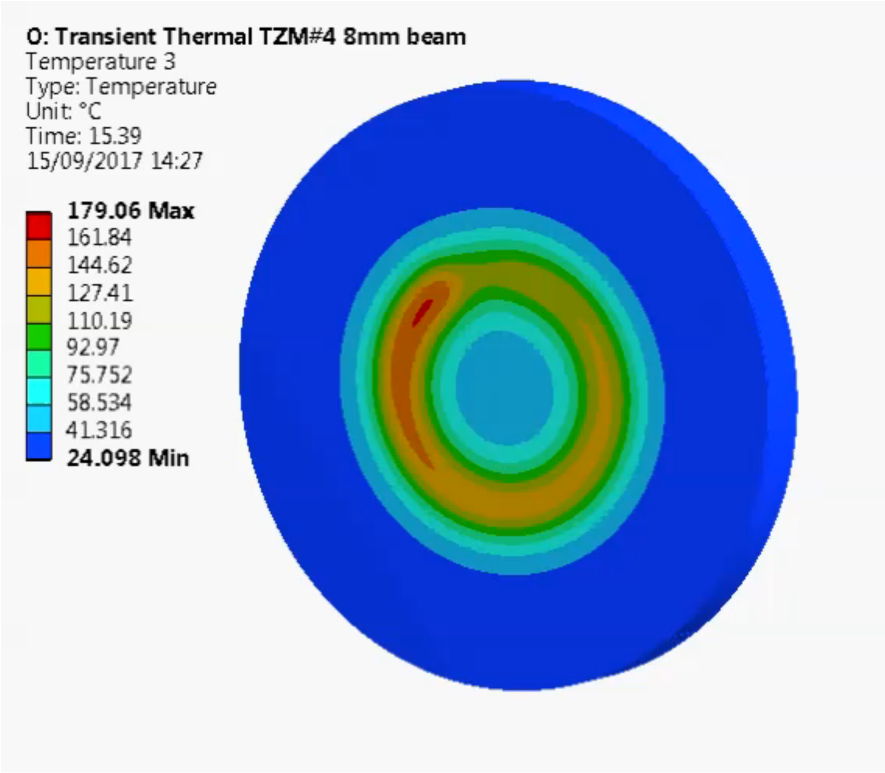
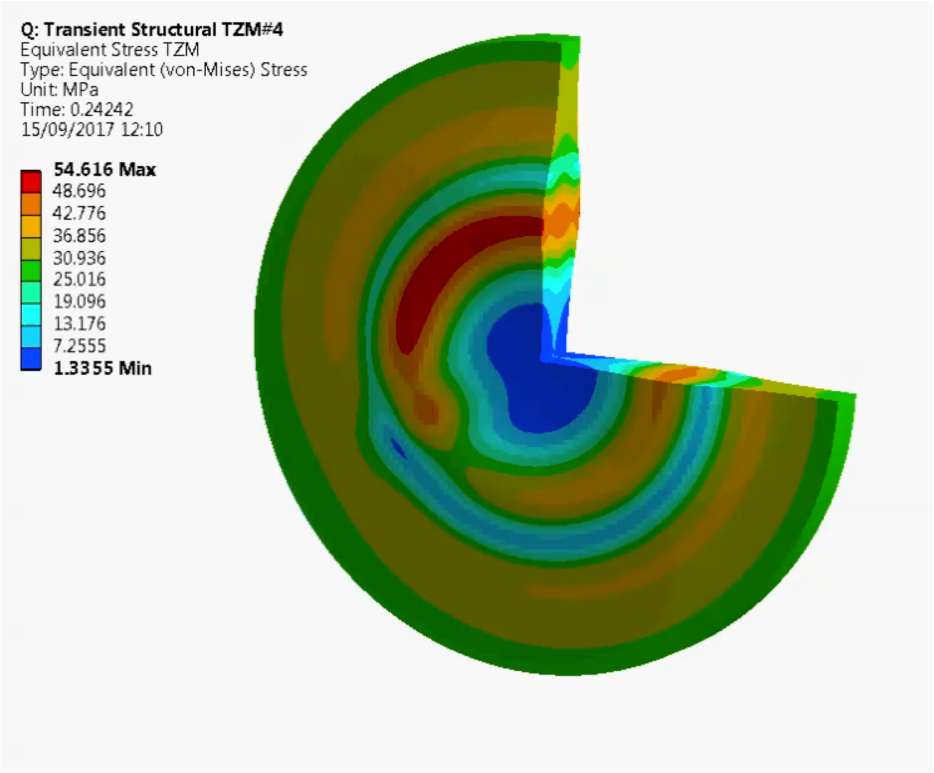
Dilution beam target images





50 mm radius, 8 mm 1sigma, 4 turns in 1 second

BDF T6 target test

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- HiRadMat c … n only
- A dedicated … ed
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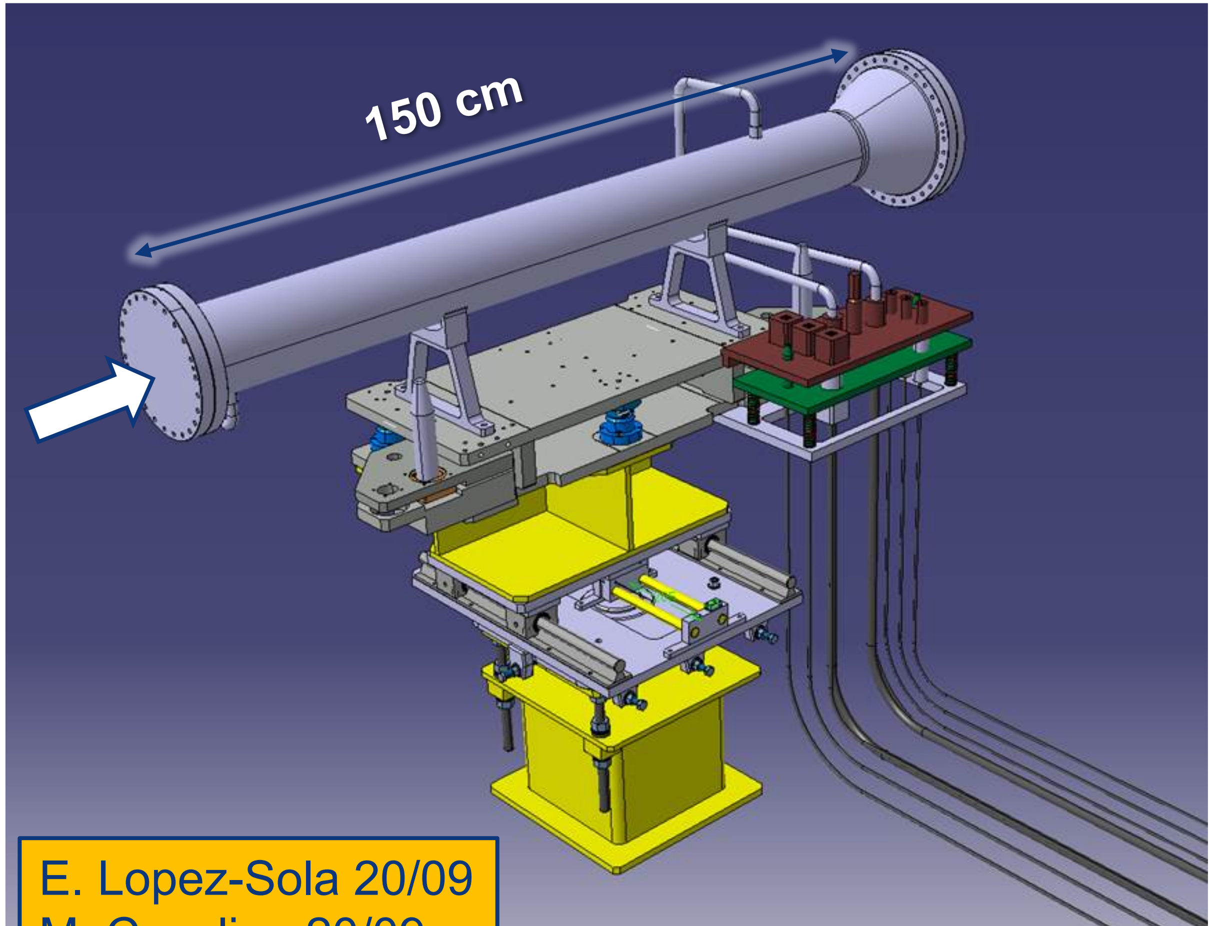
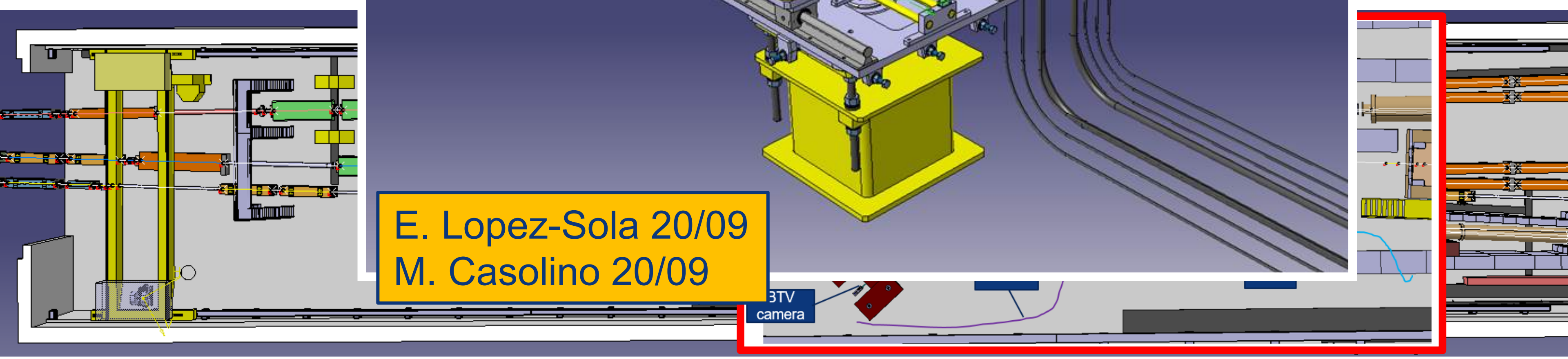
- Instrumente … 8





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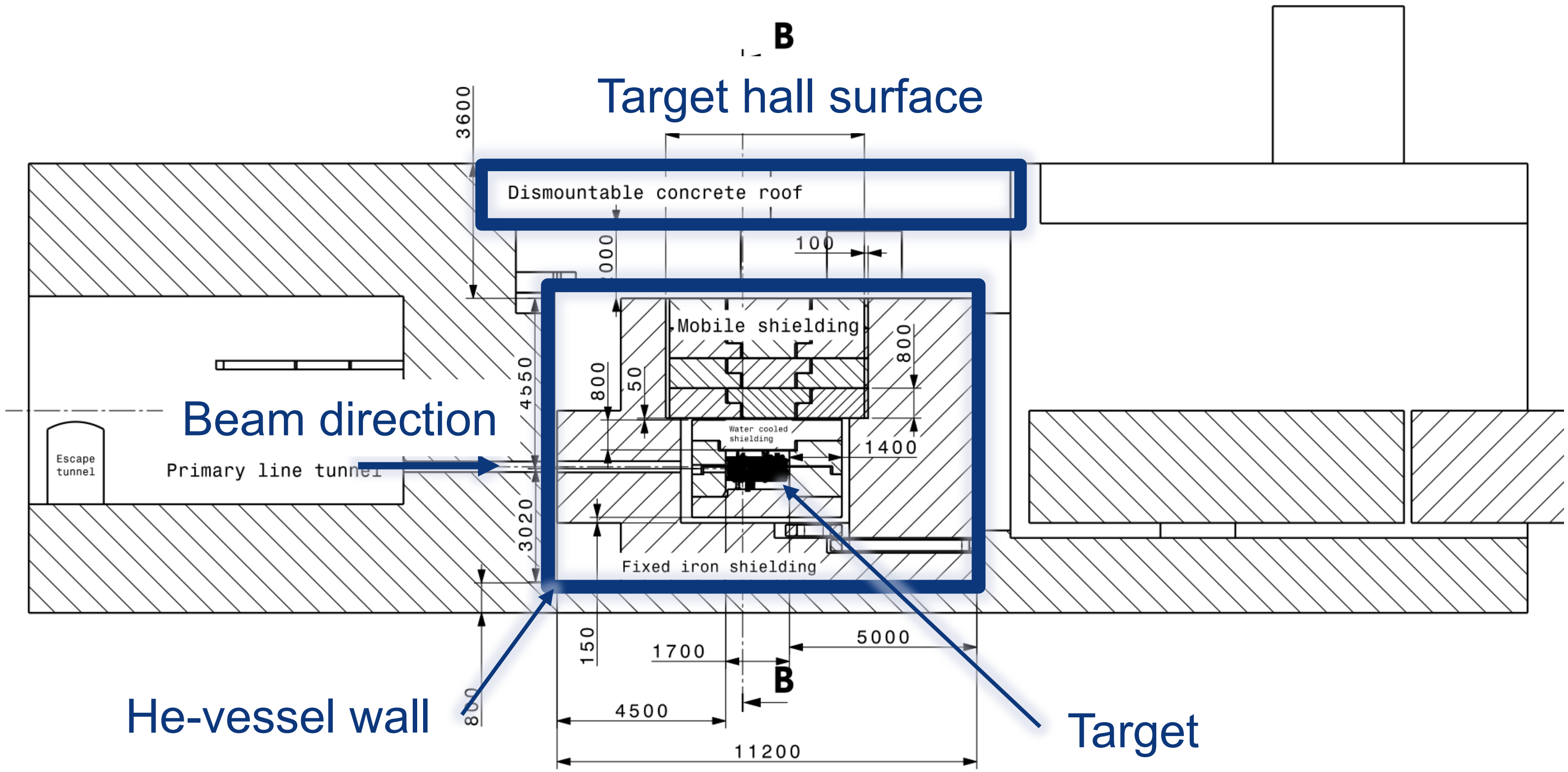
Requirement for BDF target shielding bunker



- Prompt dose on the top of the surface hall shall be such as to classify it as supervised area
- Concrete works of the target station must not be considered as radioactive (maintenance)
- Flexibility for future use and reconfiguration

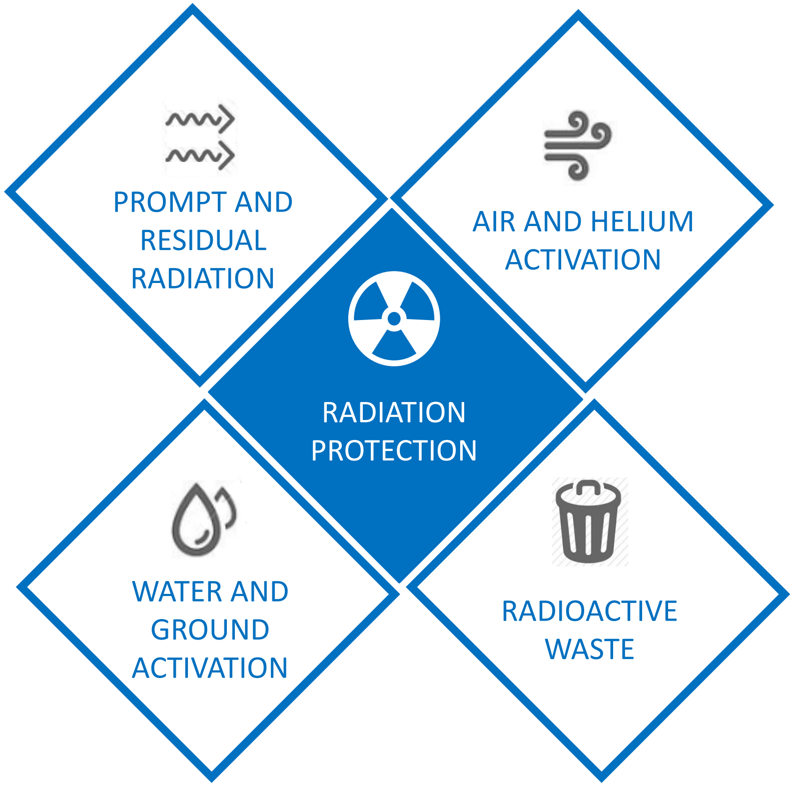
Cooling and ventilation aspects

- Ventilation scheme according to **ISO 17873:2004** implemented
- Reduction of environmental impact → target bunker will be embedded in a dynamic He-gas containment (online purification)
  - Detailed study in 2018, construction of a prototype tank and circulation in 2019

P. Avigni 19/09

General RP considerations for BDF

- Unprecedented prompt and residual dose rate values
- Radiation protection aspects are of paramount importance for the validation of the design and for the Project



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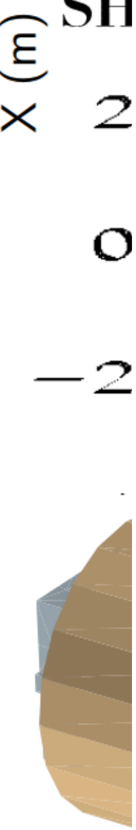
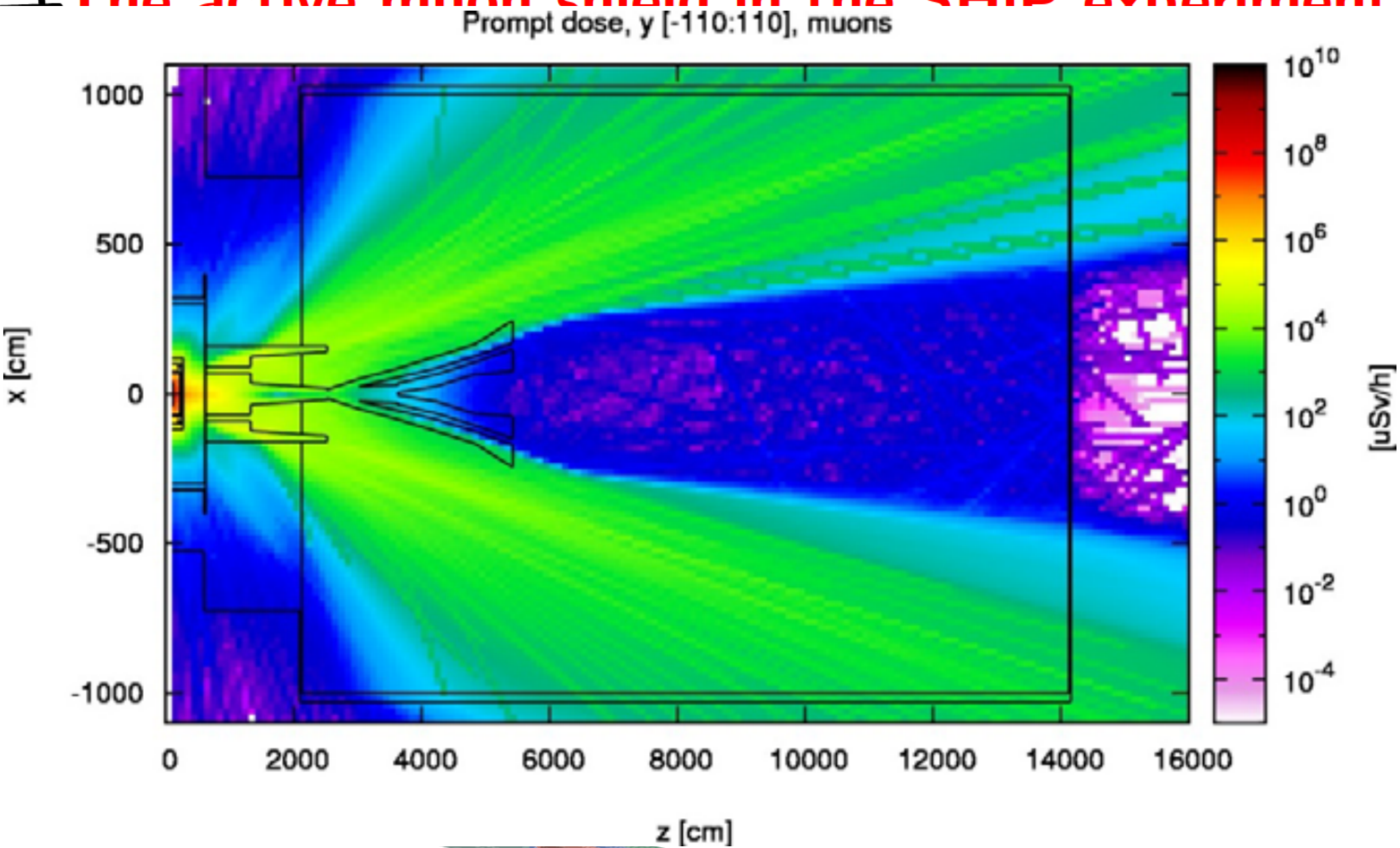
The active muon shield in the SHiP experiment





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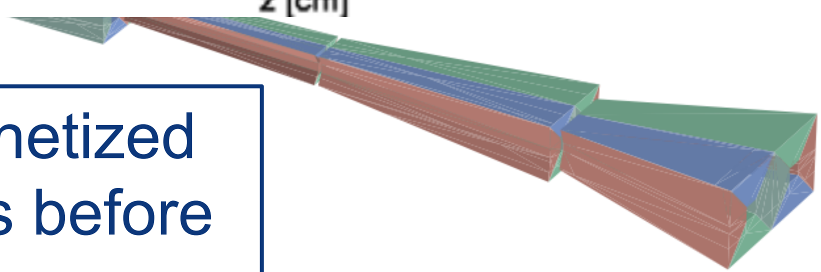
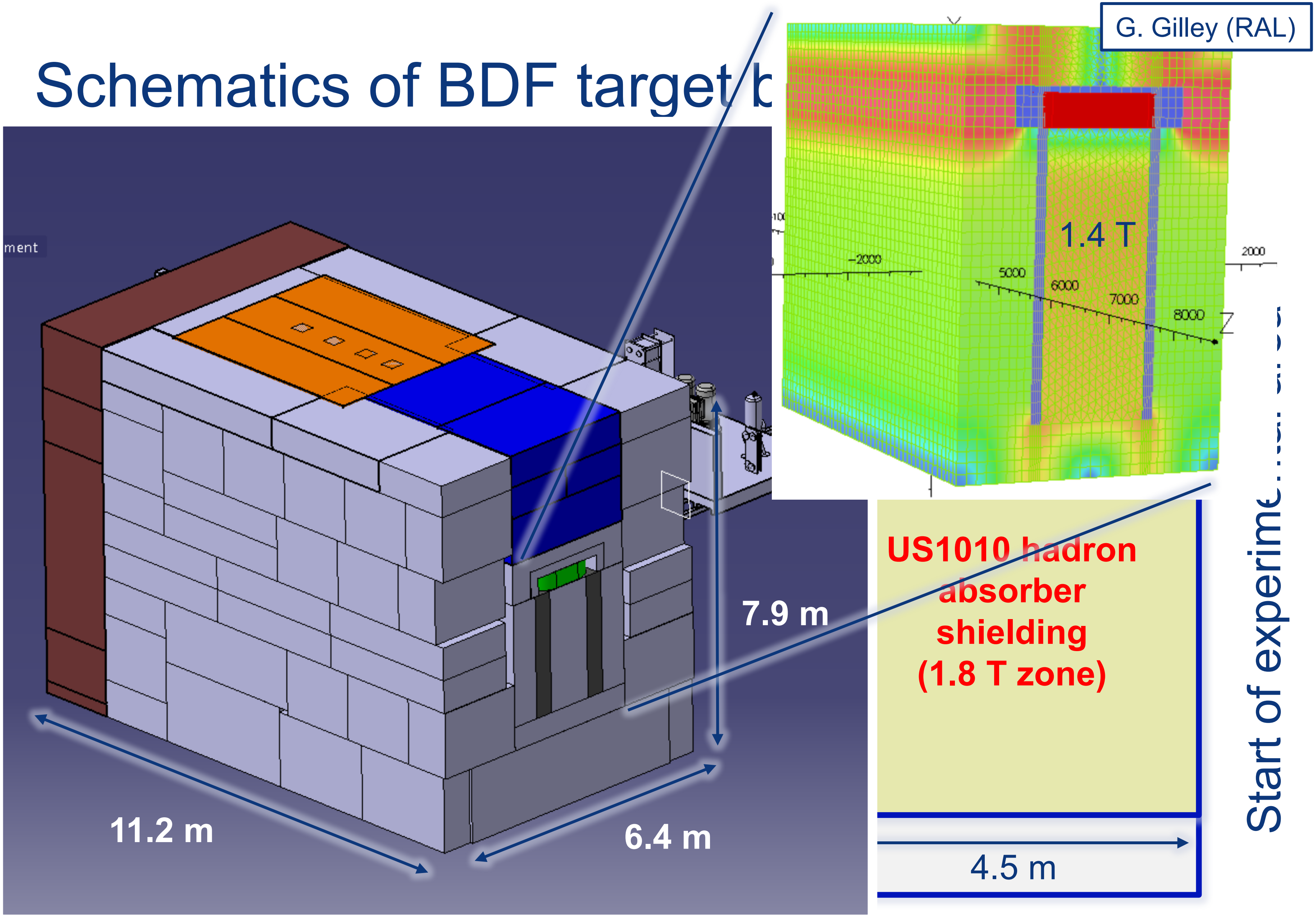


Hadron absorber magnetized as well to catch muons before they open up

H.Dijkstra

CERN

Schematics of BDF target b



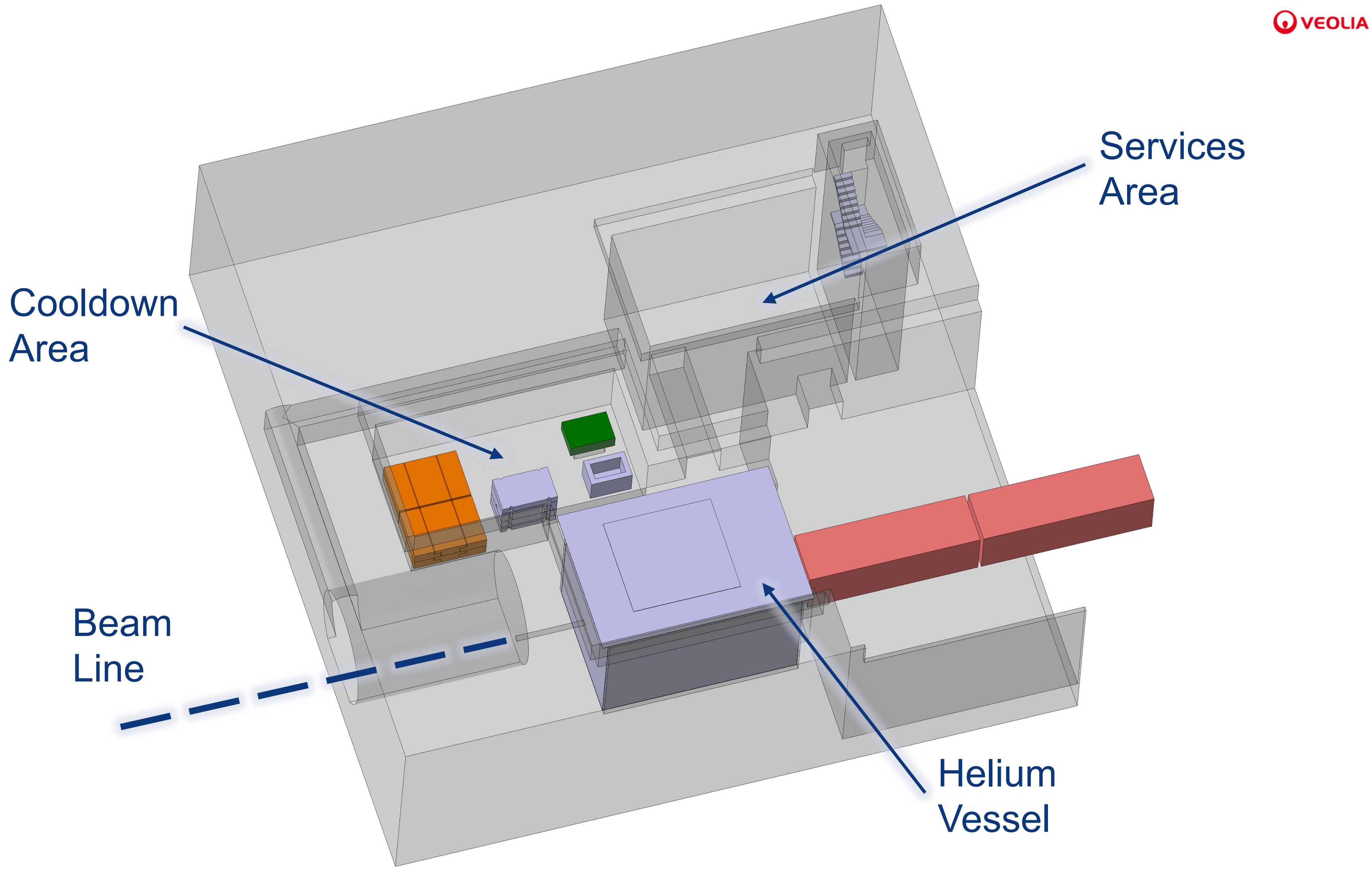
Target complex design challenges

- **Demonstrate the feasibility of the construction, operation and maintenance of the BDF TC along with decommissioning**

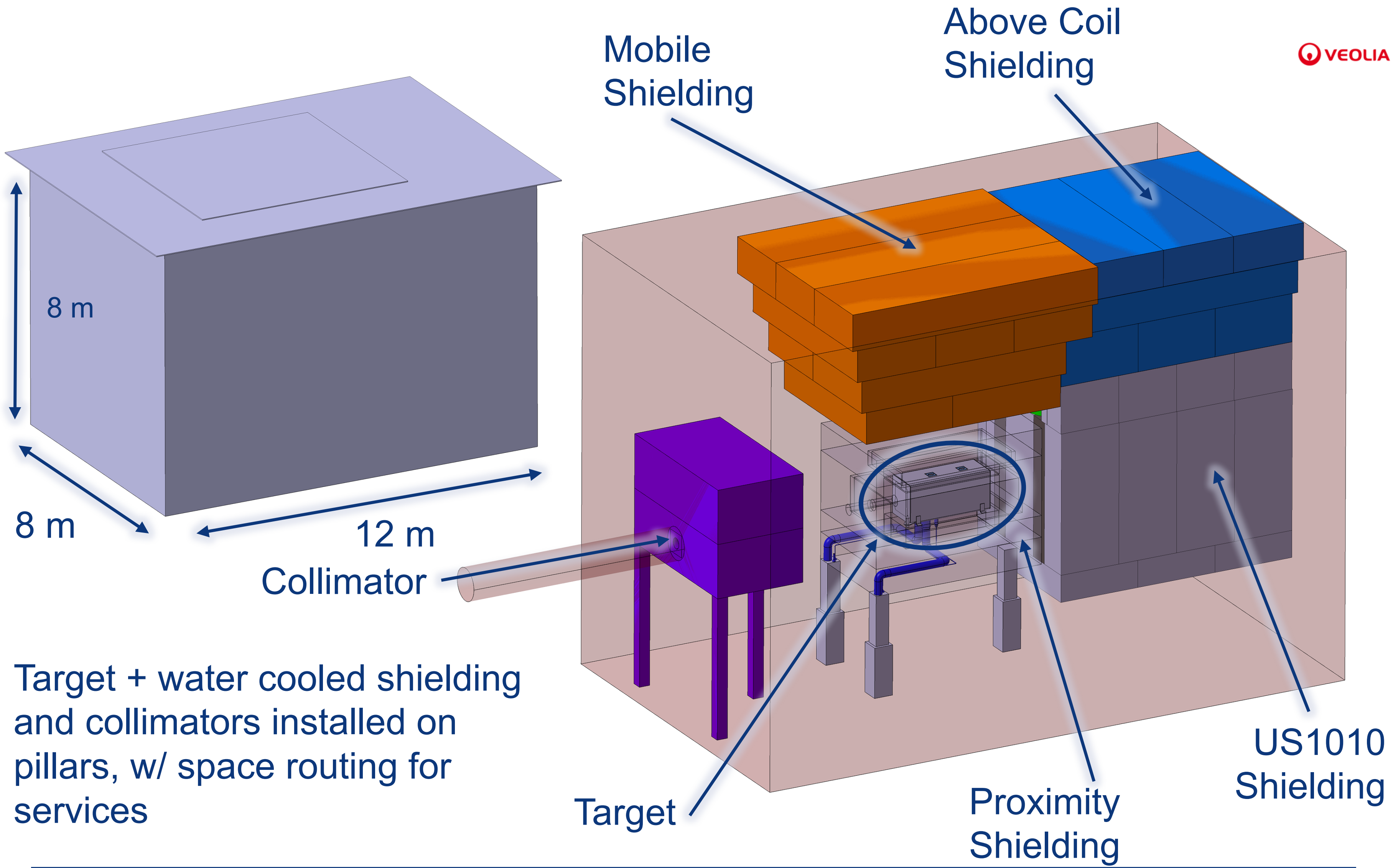
1. **Crane handling**
   - TC travelling crane for the movements of all critical elements
2. **Trolley concept**
   - Target and main services installed on mobile trolleys running on rails (similar to standard spallation sources, but **lateral**)

- Hadron absorber magnetization
- CERN placed a contract with Oxford Technologies (UK) early 2017 for the joint execution of the study – to be completed in 02/2018 to feed into CERN's service integration studies

Crane concept - overview

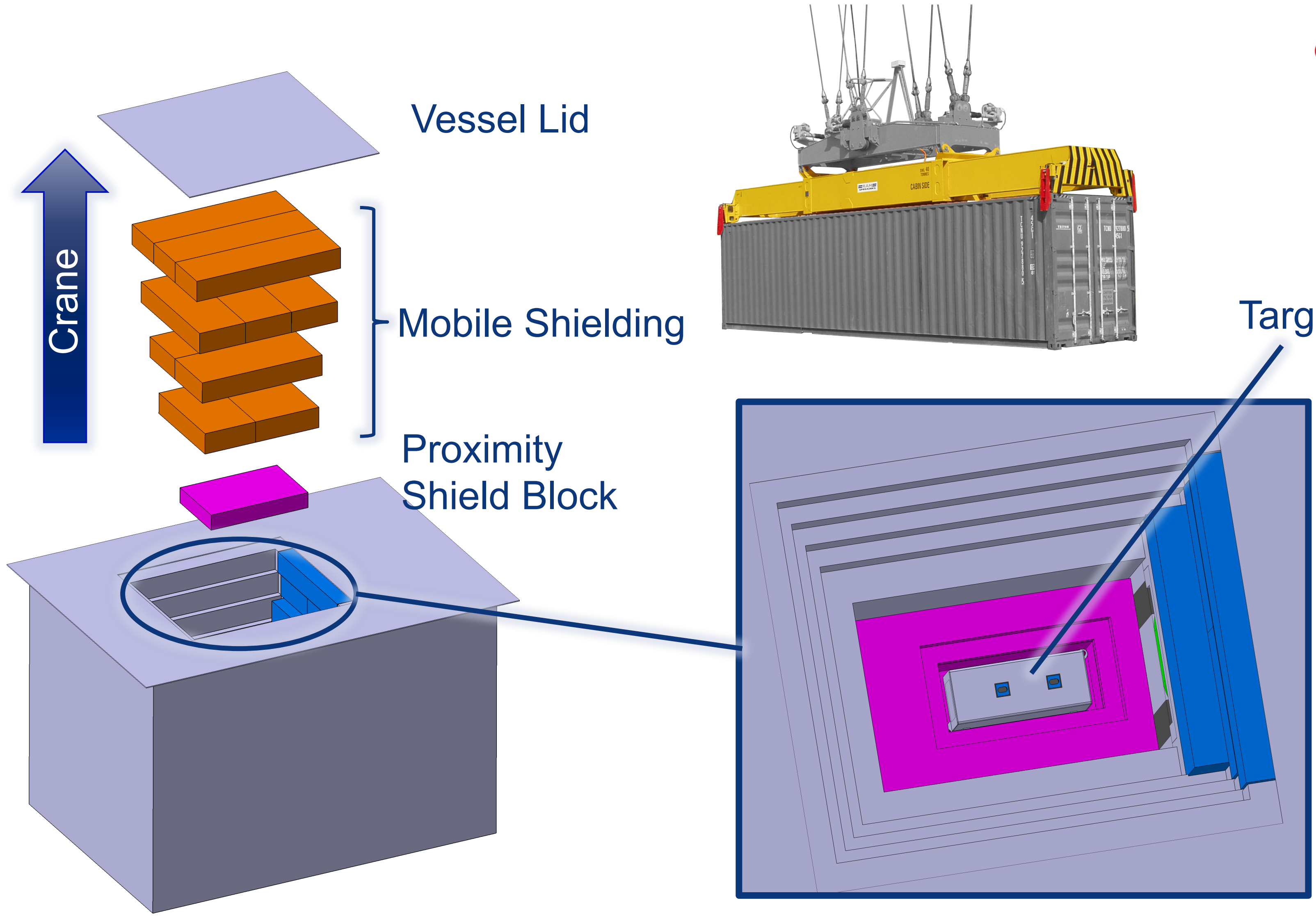


Crane concept – helium vessel components

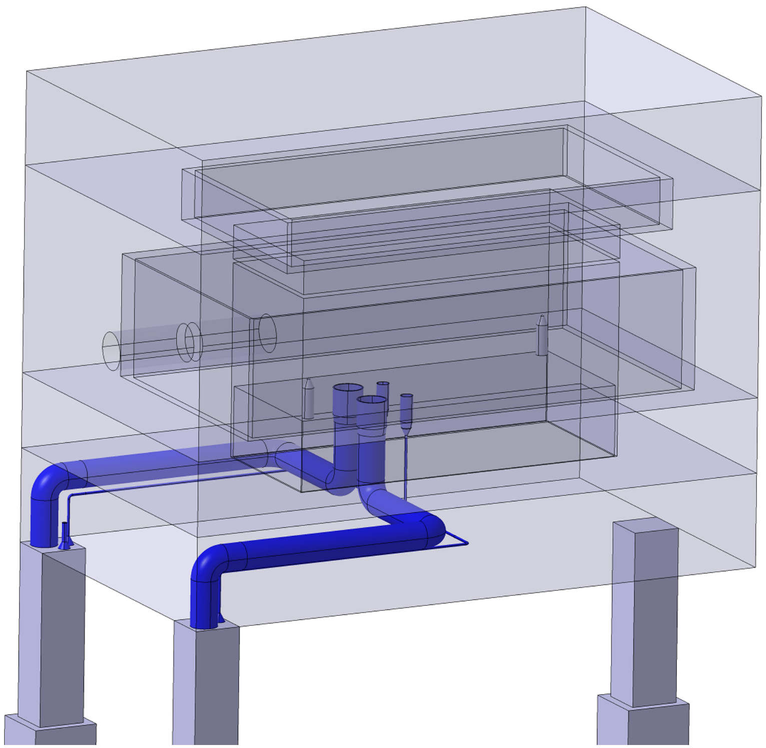


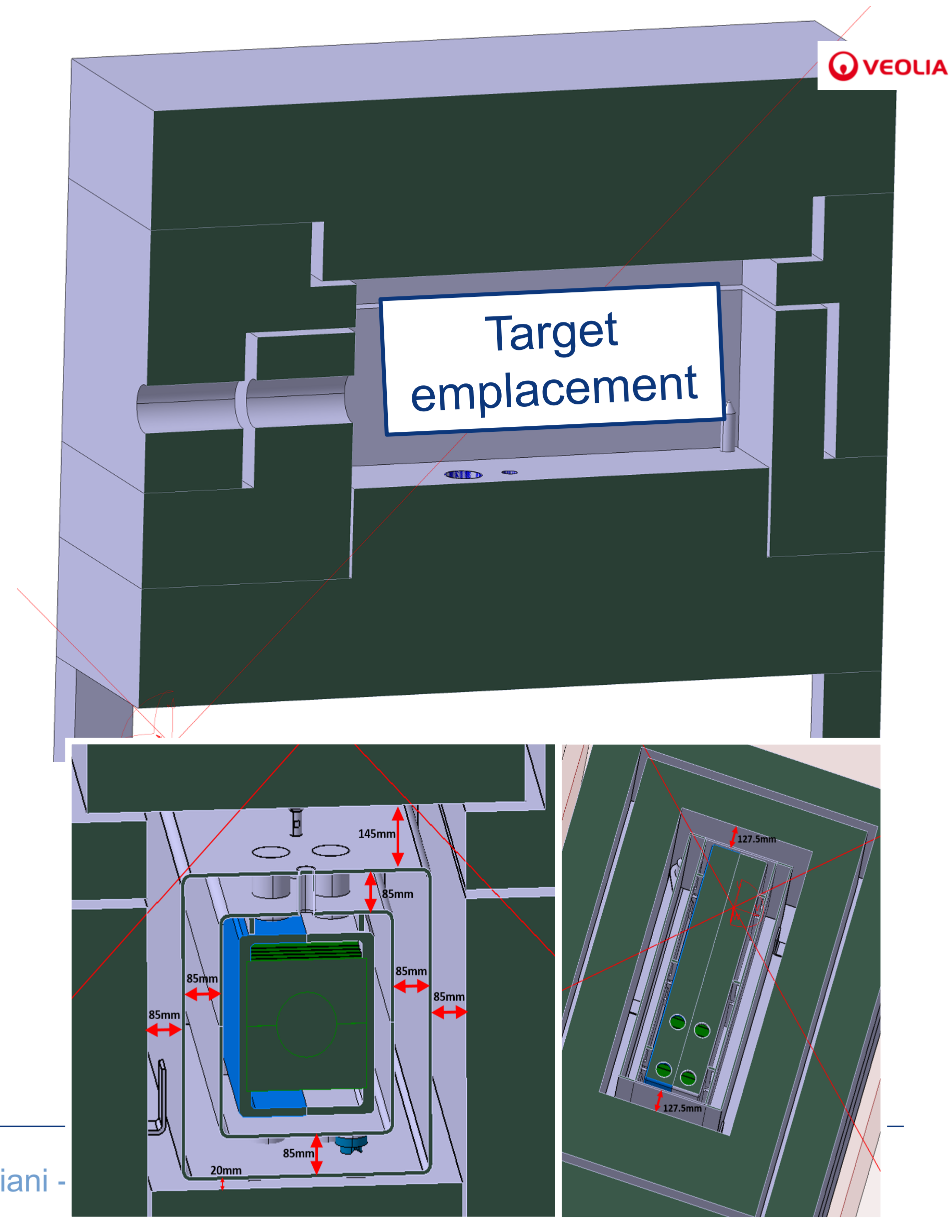
Target + water cooled shielding and collimators installed on pillars, w/ space routing for services

Crane concept – target access



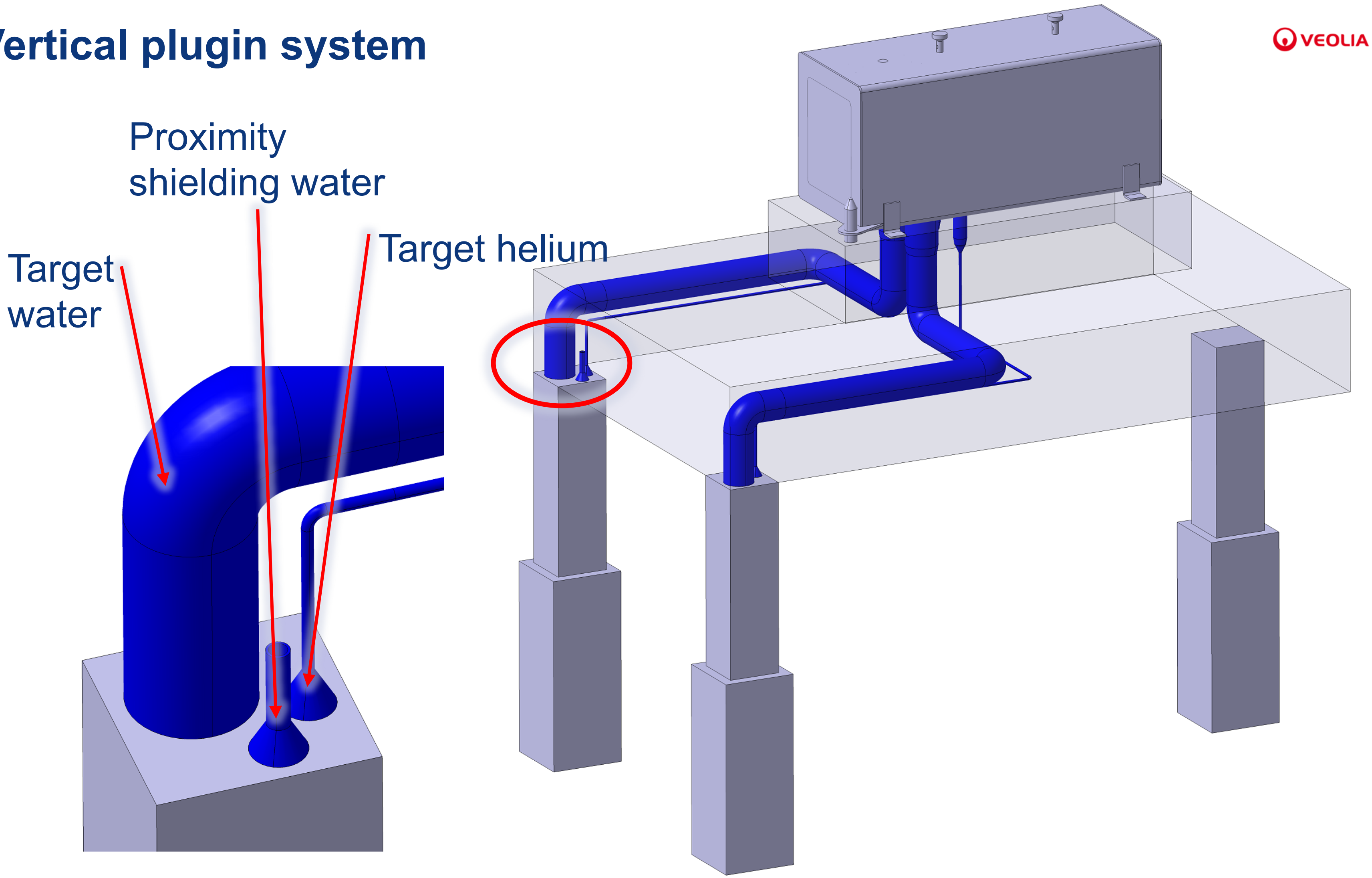
Crane concept – Proximity shielding





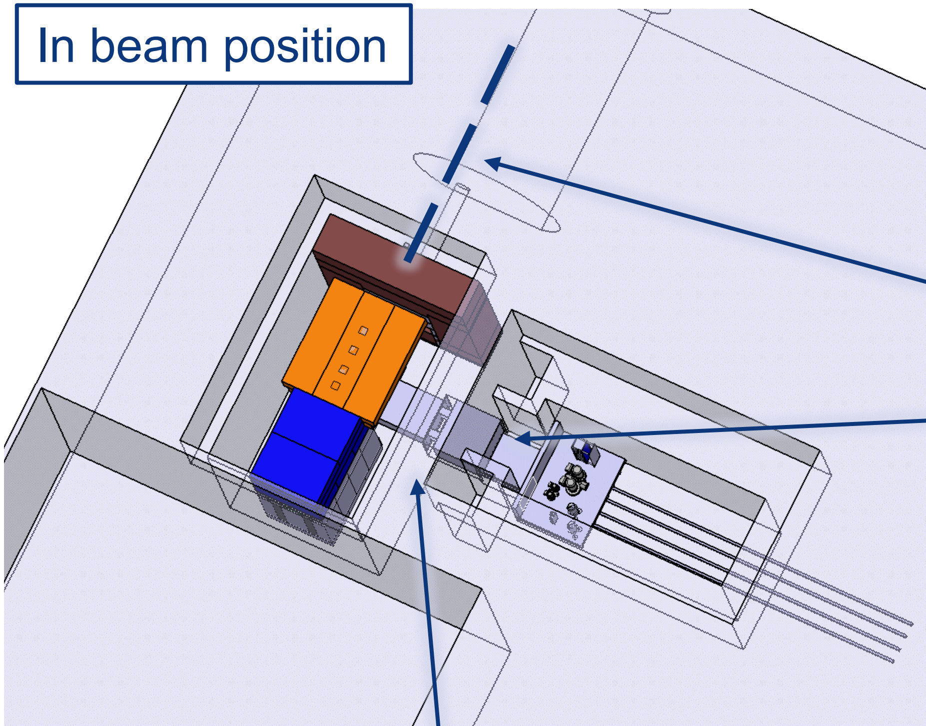
Crane concept – target pipework

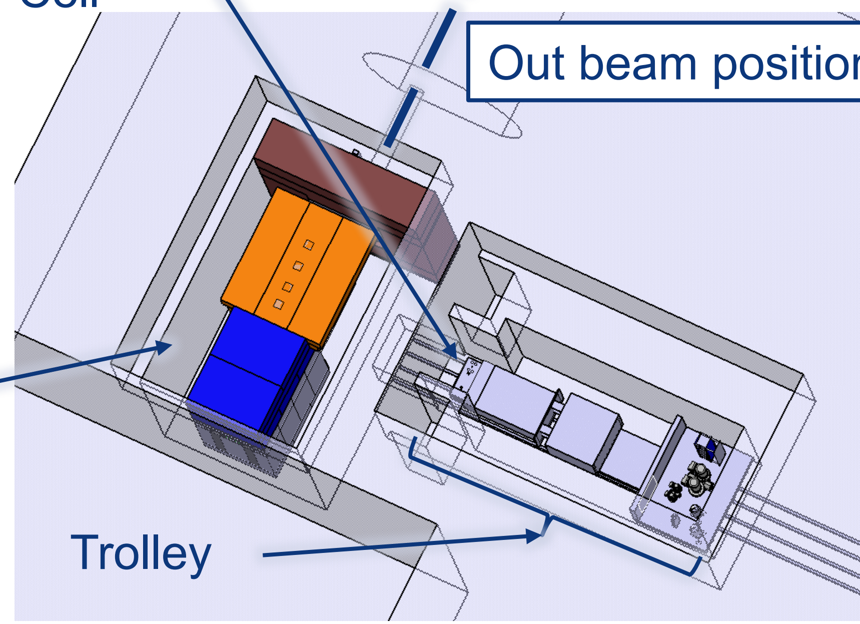
Vertical plugin system



Trolley concept - overview

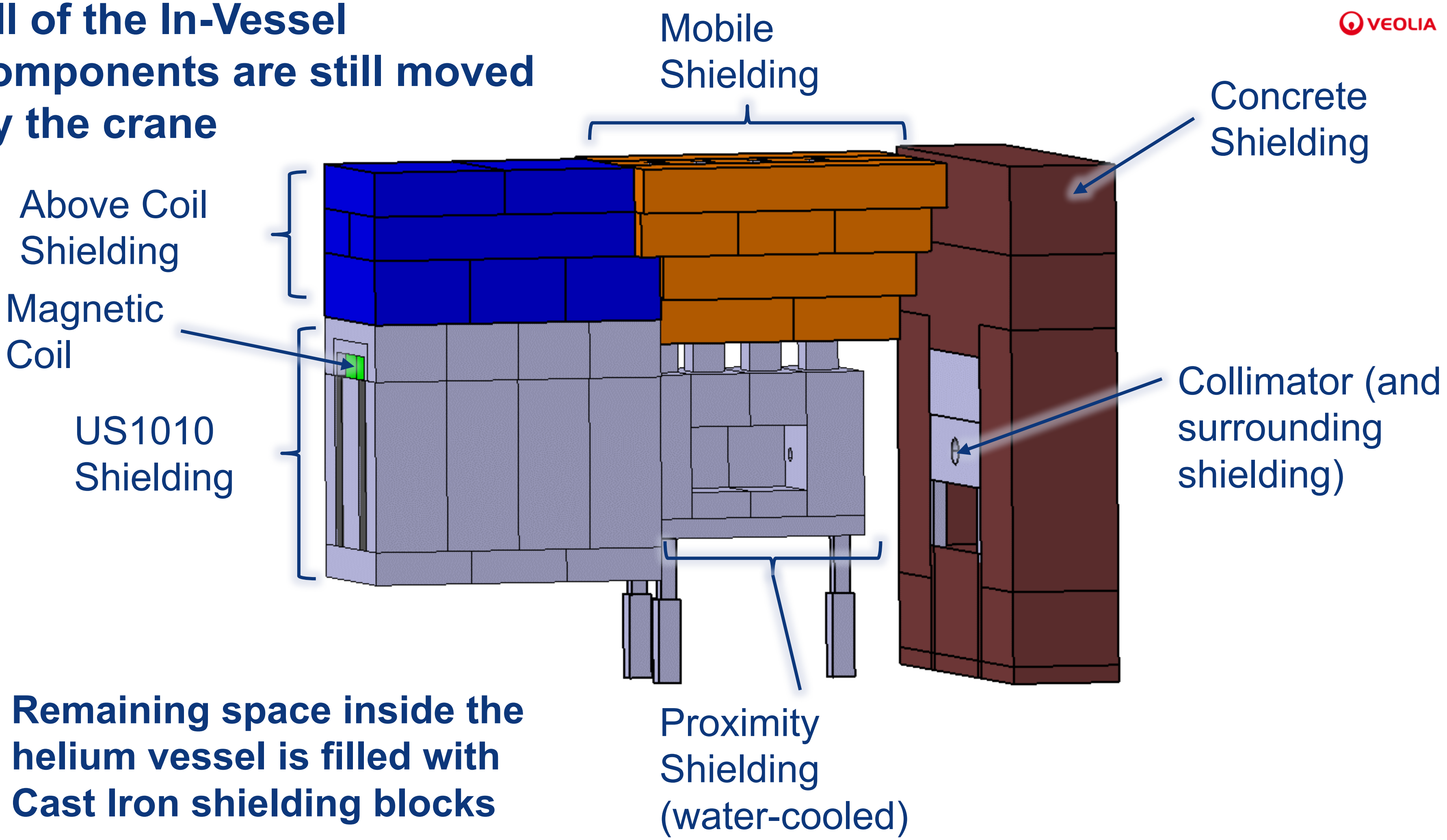
Smaller cool-down area and services room included for non-target operations.





Trolley concept – helium vessel

All of the In-Vessel components are still moved by the crane



Remaining space inside the helium vessel is filled with Cast Iron shielding blocks

Trolley concept – proximity shielding

- "Chimneys" added to the top of the proximity shielding for water cooling
  - Less connection inside the vessel

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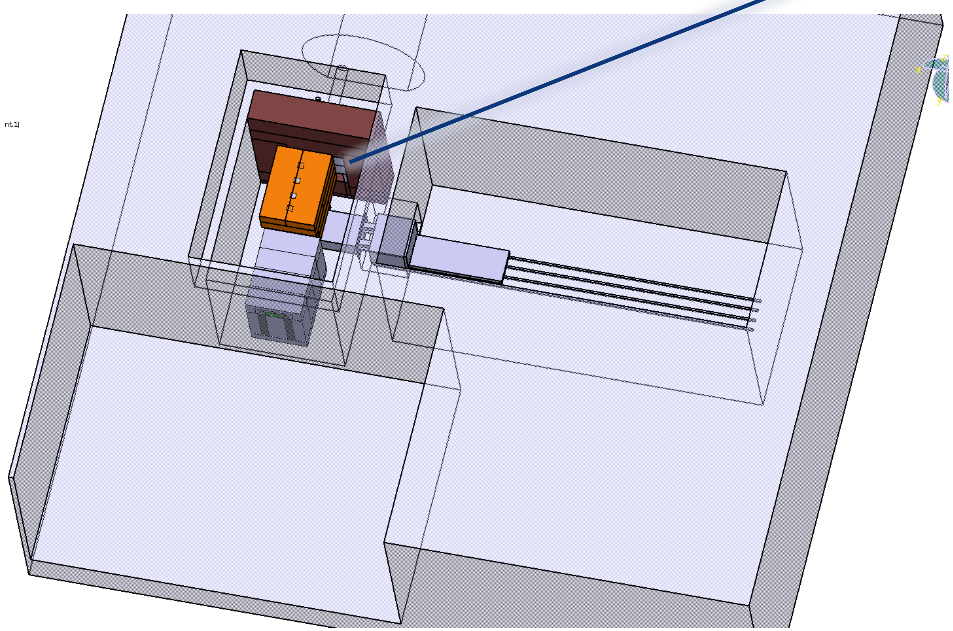
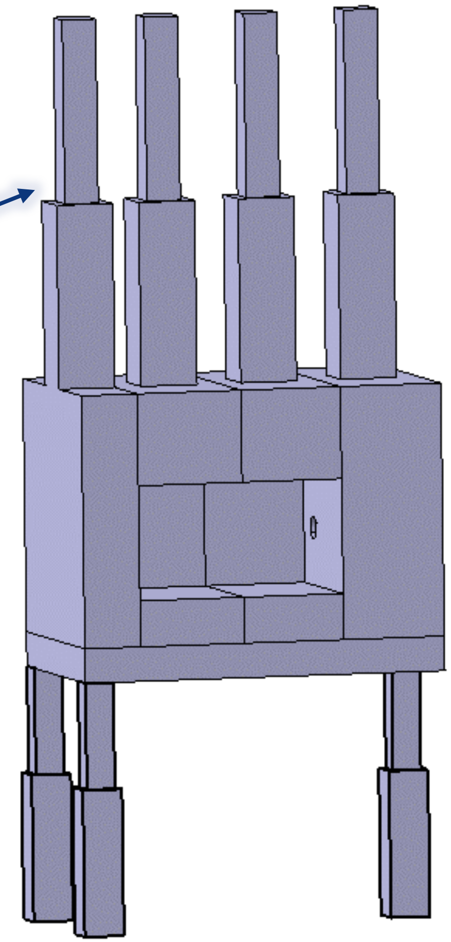
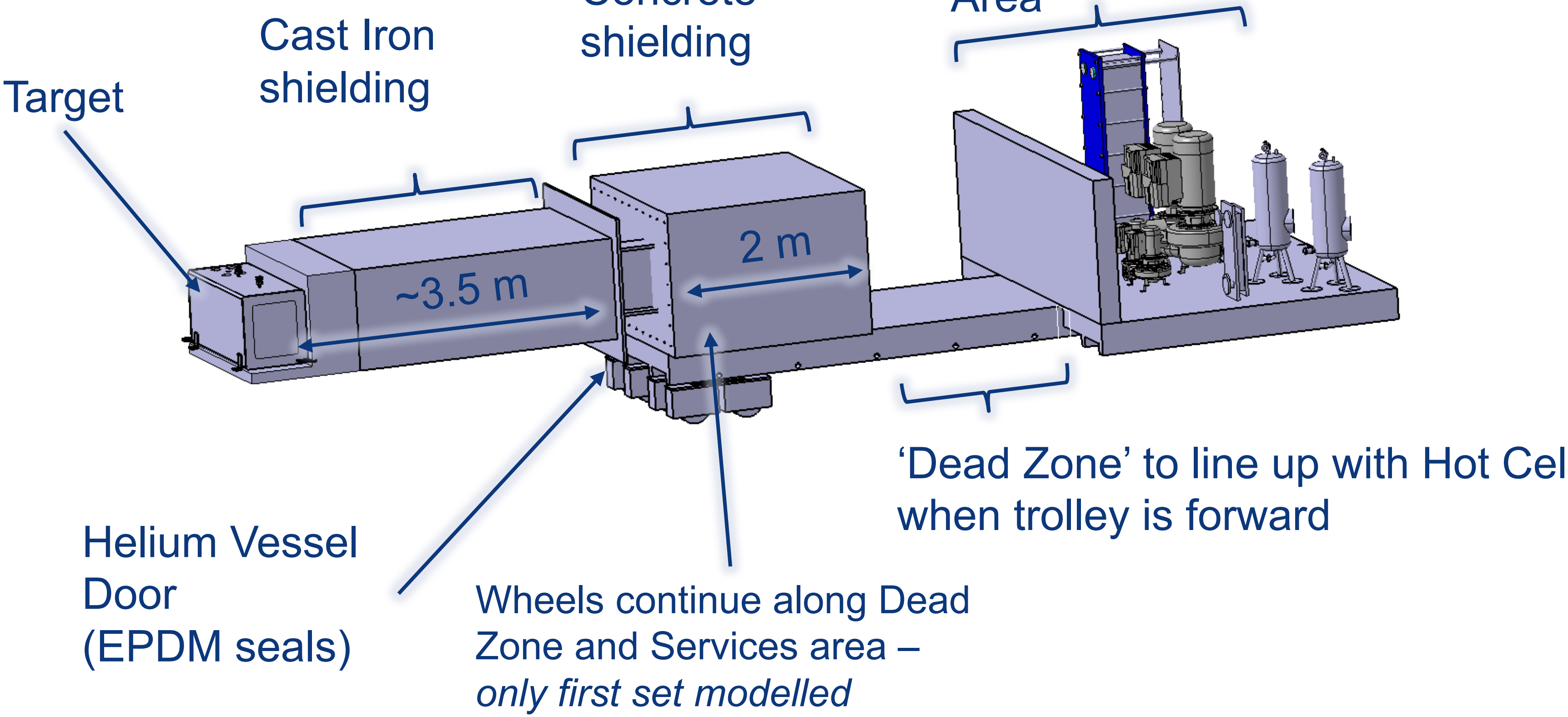




Trolley concept – helium vessel



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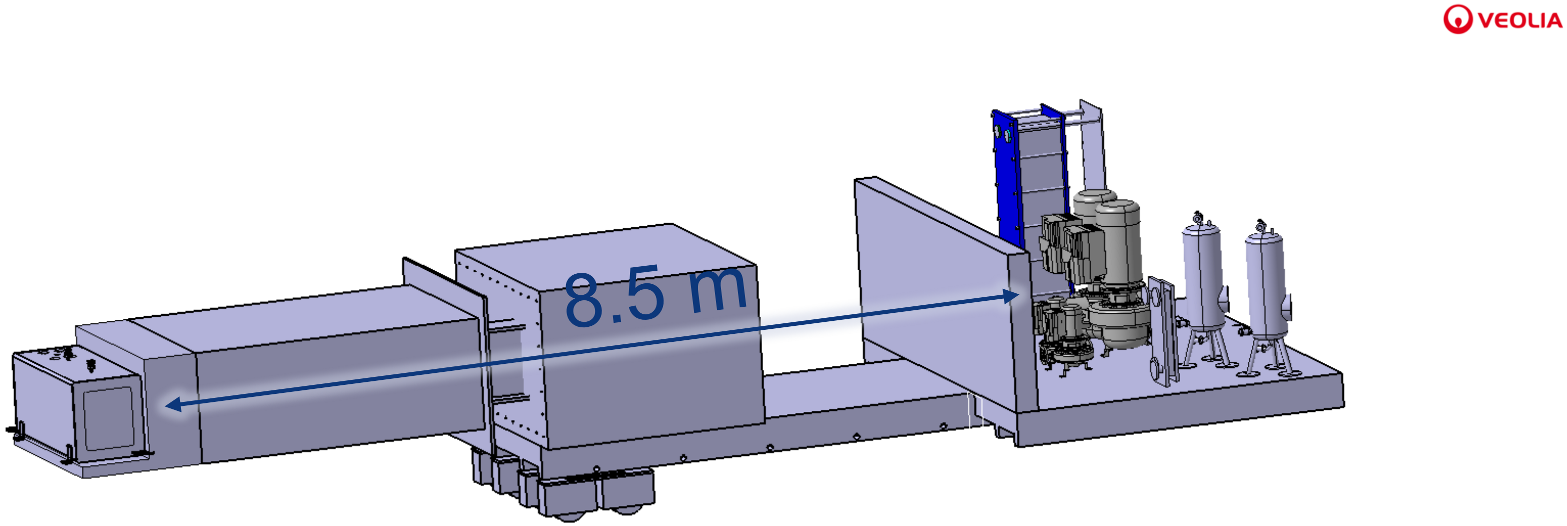
Counterbalanced system → no active part of the trolley inside the target area

Trolley concept – helium vessel



- Services to the Target (Helium / Water cooling and sensor connections) are fed from the services area and pass along the trolley.
- Fresh water (non-activated) and Helium feed are passed to the trolley on the backpart

Trolley concept – hot-cell

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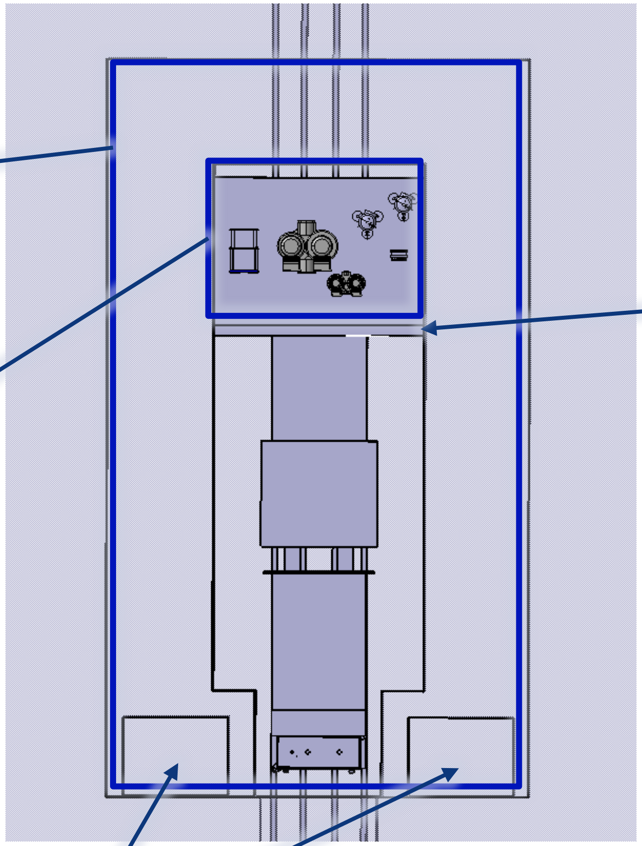
In-Cell crane operating area (TBC)

Man-Accessible area (TBC)



Containment between services and Hot Cell (TBC)

2x twin MSM workstations

A "hot-cell" is being foreseen in the Project to be able to work on potential broken target

Comparison between different design

Factor	Crane	Trolley
Component installation	Simple crane positioning	Complicated by requirement to seal the vessel
Service Connections	Complex passive sealing design	Simpler connection with MSMs
Risk	Ability to make/break leak-proof seals remotely	Concept - Feasibility of the cantilever Operational - Reliability of the wheels.
Radiation Protection	All operations involve exposure of activated elements within cooldown area	More contained operations on target – performed in hot cell (except for target disposal)
Operation Duration	Any operations require the removal of shielding blocks	Target can be removed directly using the trolley
RH Operations	Only simple operations effected through crane deployed tooling and spreaders	More complex operations via MSMs

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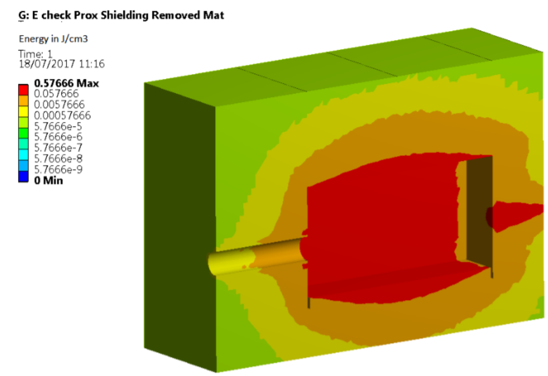
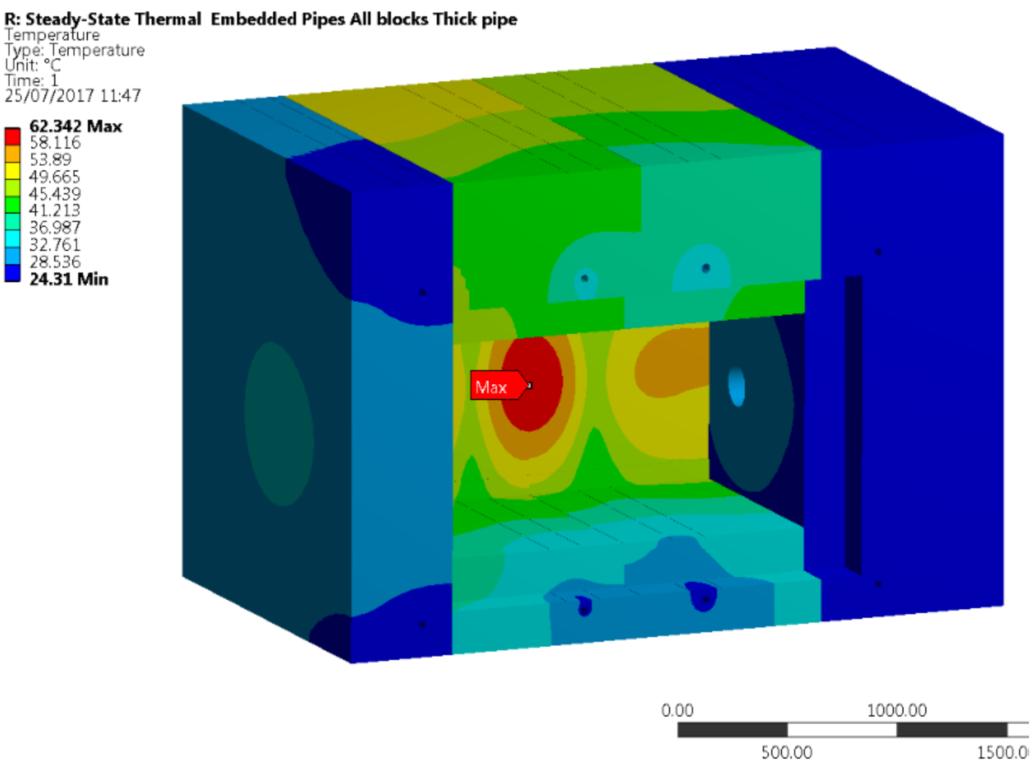
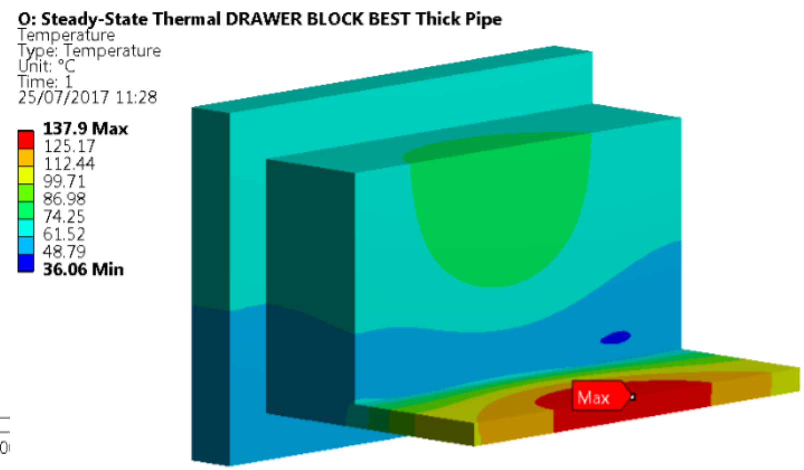
Proximity shielding

- Each proximity shielding block (4 + drawer) are cooled by a water circuit connected in series (few m^3/h)
- Stainless steel pipes embedded in cast-iron (proven technology)

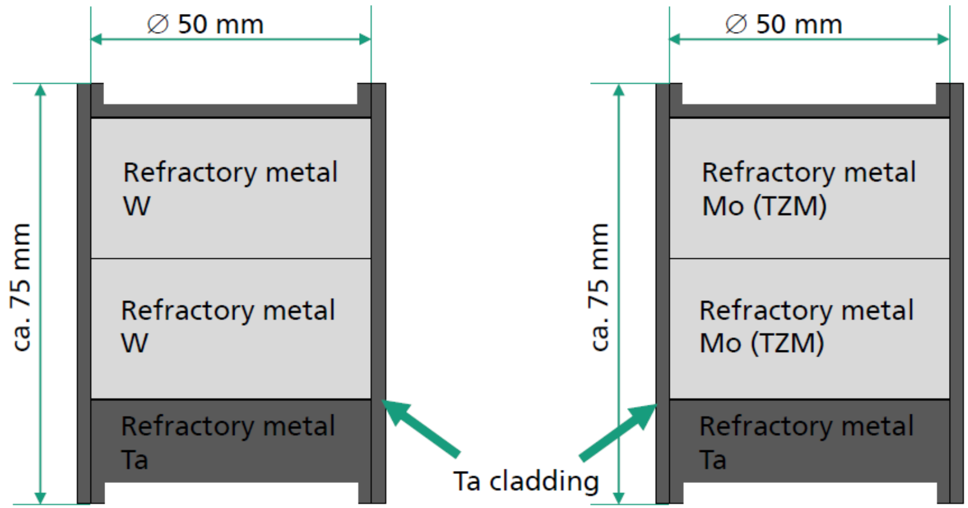


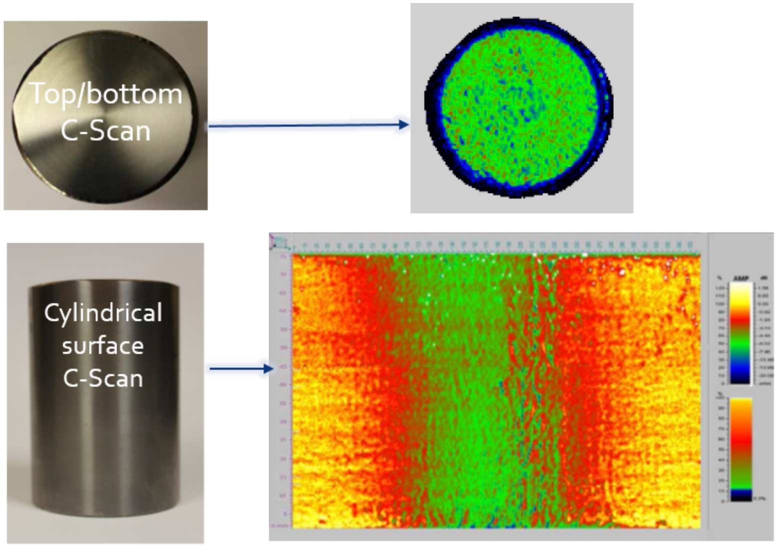


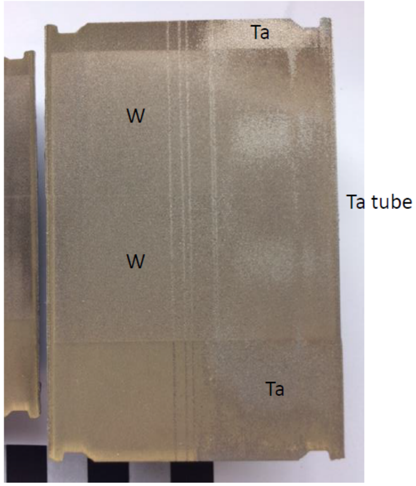


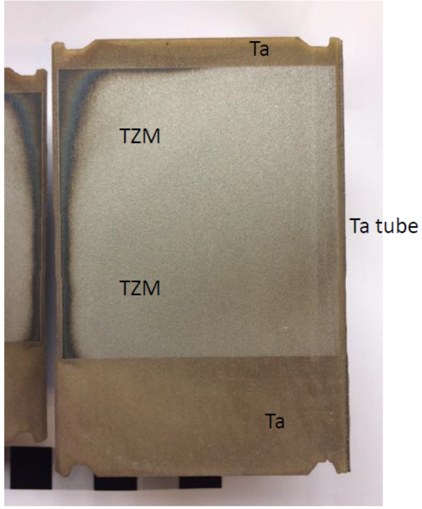
Material R&D studies

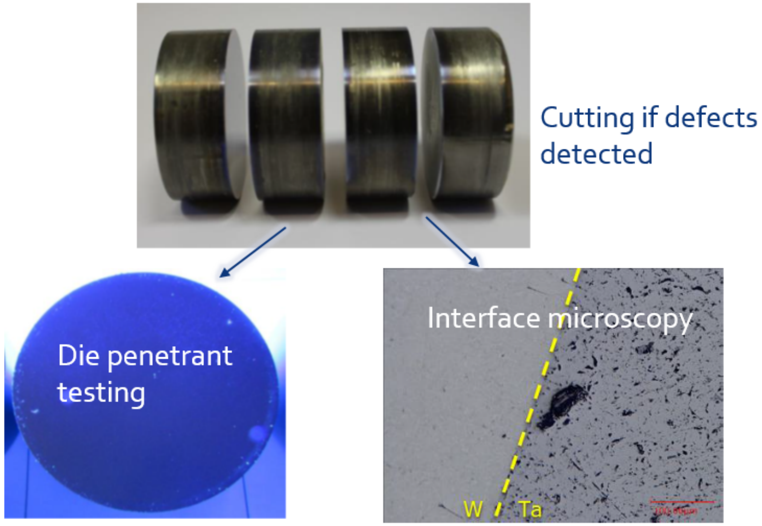
M. Calviani 22/09





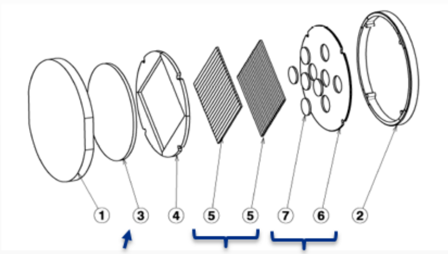






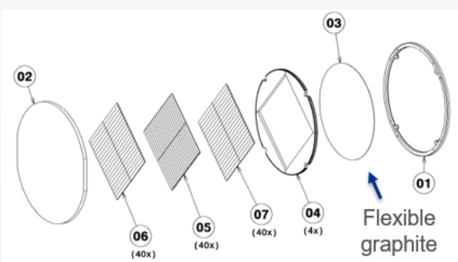
Material irradiation – long-term damage

Silicon Capsule (CERN, KEK)



- CERN SPS internal dump (Si) & KEK muon production target material (SiC-coated graphite)
- Vacuum atmosphere, T_{peak} ~ 240 °C
- PIE at PNNL

High Z Capsule (CERN)

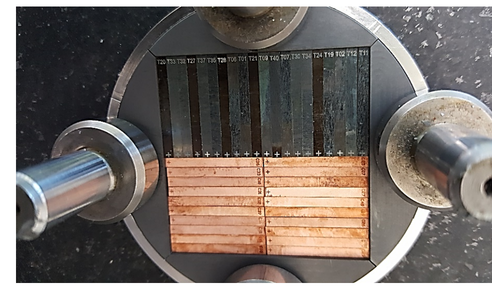


TZM, Ir and CuCrZr bend specimens

- SPS internal dump (CuCrZr), AD & SHiP targets (Ir, TZM)
- Vacuum atmosphere, T_{peak} ~ 610 °C
- PIE at PNNL
- Only 2 weeks of irradiation

Fermilab

8 6/6/2017 K. Ammigan | High Energy Proton Irradiation Experience and Challenges at BNL BLIP



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K. Ammigan 22/09

- Additional interest in Ta(2.5)W material for 2018 BLIP run

Conclusions

- BDF Project addressing critical aspects associated to the feasibility of a new high-intensity fixed target facility at CERN
- Focusing on critical aspects such as **beam extraction** and **transport**, **proton availability**, **target design** and **target complex**, **radiation protection** and **cooling** and **ventilation** aspects
- CDR available end of 2018 with more technical documents to follow in 2019

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