
CERN

Beam target tests in TCC2

1st Beam Dump Facility (BDF) Targetry Systems Advisory Committee (TSAC)

4th – 6th March 2025

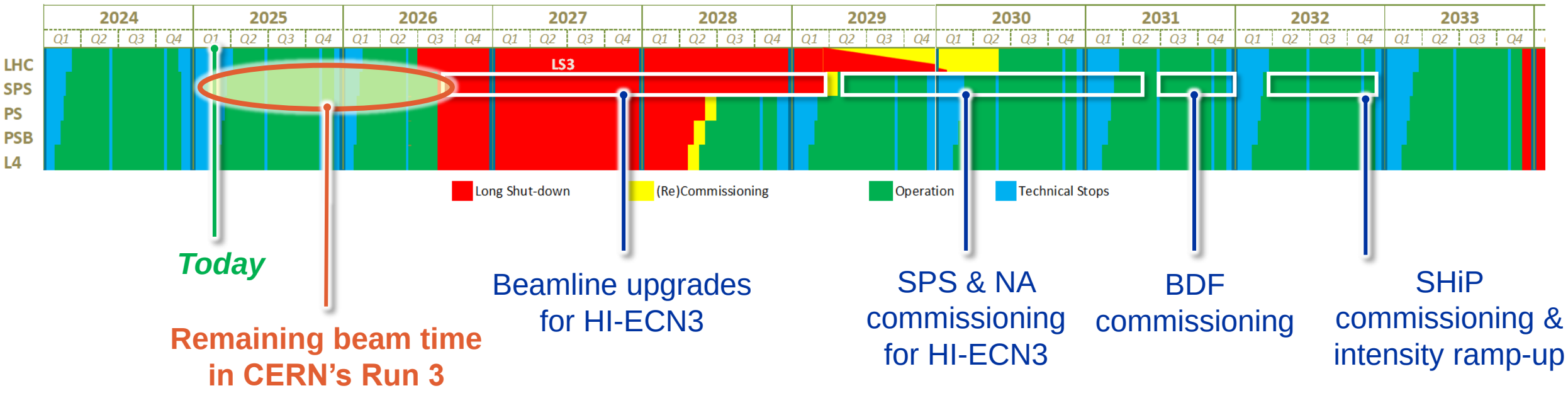
Rui F. Ximenes on behalf of WP3 & HI-ECN3 Project team

04/03/2025

Take-home objectives of this talk

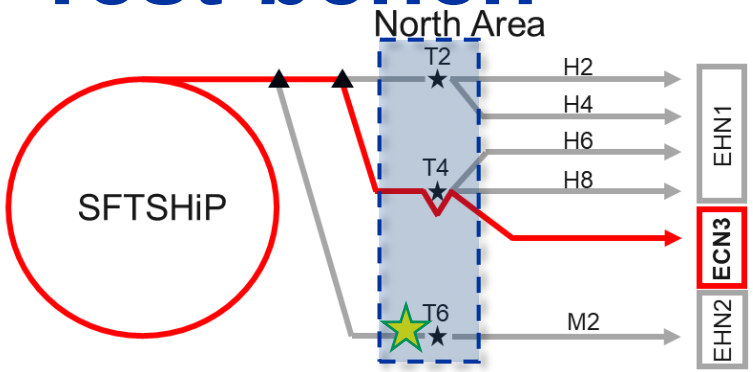
- ❑ **Recap material challenges and pair importance of material characterization w/ beam tests**
- ❑ **Show when (& why), where (& why) we will do beam tests**
- ❑ **Present the strategy and motivation for staged testing**
- ❑ **Overview of the 2025 prototypes** target design & scope of testing (& PIE). What will we learn
- ❑ **Overview of the 2026 prototype** target testing & scope of testing (& PIE). What more will we learn
- ❑ **Reflection if more (or different) beam tests should be carried out** (e.g. post LS3) particularly **balancing the risks** in the current timeline

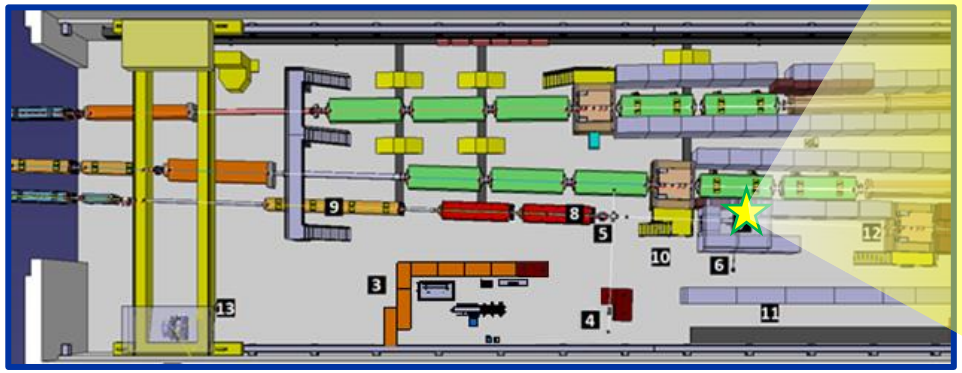
CERN's accelerator schedule & Timeline constrain



- Only time-compatible opportunity to test prototypes with beam at CERN and feed lessons learnt into final design is in Run3 → 2025 & 2026
- Given that the project was approved in March 2024, timeline for beam testing is very challenging!

North Area Slow-eXtraction Test-bench





T6 SX test-bench

→ **Ease with beam parameters**

- **400GeV/c** beam as for BDF.
- **Slow-extracted** with **same spill/cycle** time structure
- **Small and undiluted beam** to match energy density
- **High pulse intensity** (up to 1.5e13) **and average power** (~15kW w/ current water skid).
- **High number of shots**, 10000(O) (depending on MD).

→ **Existing test-bench adapted to BDF-like prototypes.**

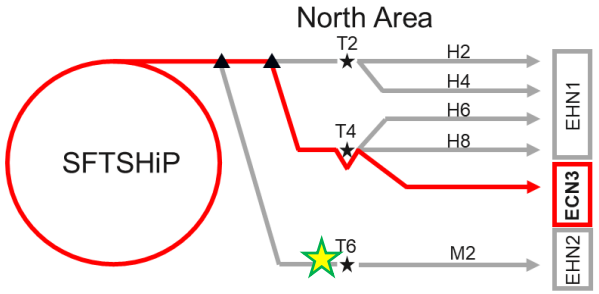
e.g HiRadMat

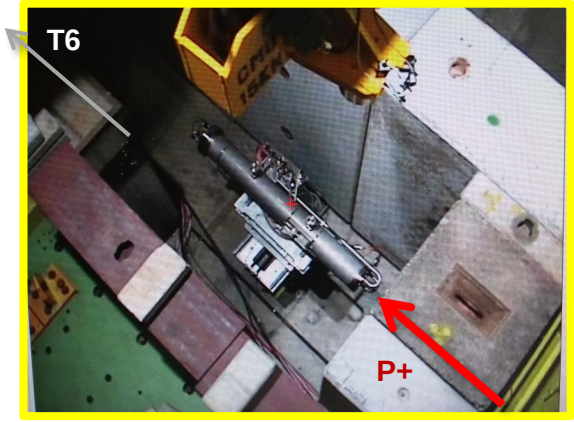
→ **Non-ideal beam parameters**

- **440GeV/c** beam as for BDF.
- **High pulse intensity & fast extraction** (288 b @ 2.1e11ppb in 8us) **& small beam spotsize** (~1mm)
- Matching energy density would be easy, but would **induce dynamic effects → BDF has no** dynamic stresses
- **Small nr of shots 10(O) & low frequency rate → cannot reach steady-state conditions**

→ **Multi-purpose tanks, but would require substantially more design work to adapt**

BDF Prototype Target & importance of beam testing





- Tested in NA T6 on the existing SX test-stand
- **Staged approach with tests in 2025 and then 2026:**

2025 – Static He, 2x W Targets

- Few O(50) shots/target → pulse temperature & stress conditions. Low activation.
- W-W integrity
- Thermocouples performance
- FEM benchmark
- (possibly) outgassing measurement
- Light PIE in YETS25/26

2026 – Actively He-cooled, W Target

- O(2000-3000) shots→ SS + pulse temperature & stress conditions. More data.
- W-W integrity (complementary, building up on 2025 tests & material R&D). Low cycle fatigue.
- He skid operational experience.
- High speed He +Temperature effects on W
- FEM/CFD benchmark
- Outgassing/contamination measurements
- Comprehensive PIE >2026

- 2025 provides pre-validation and earlier inputs for technical specification & ensures at least some level of testing is done (2026 is a short run!)
- 2026 builds on top of 2025 material R&D and beam tests. Provides a comprehensive testing/validation of the target core & cooling system

2025 Prototype Target(s)

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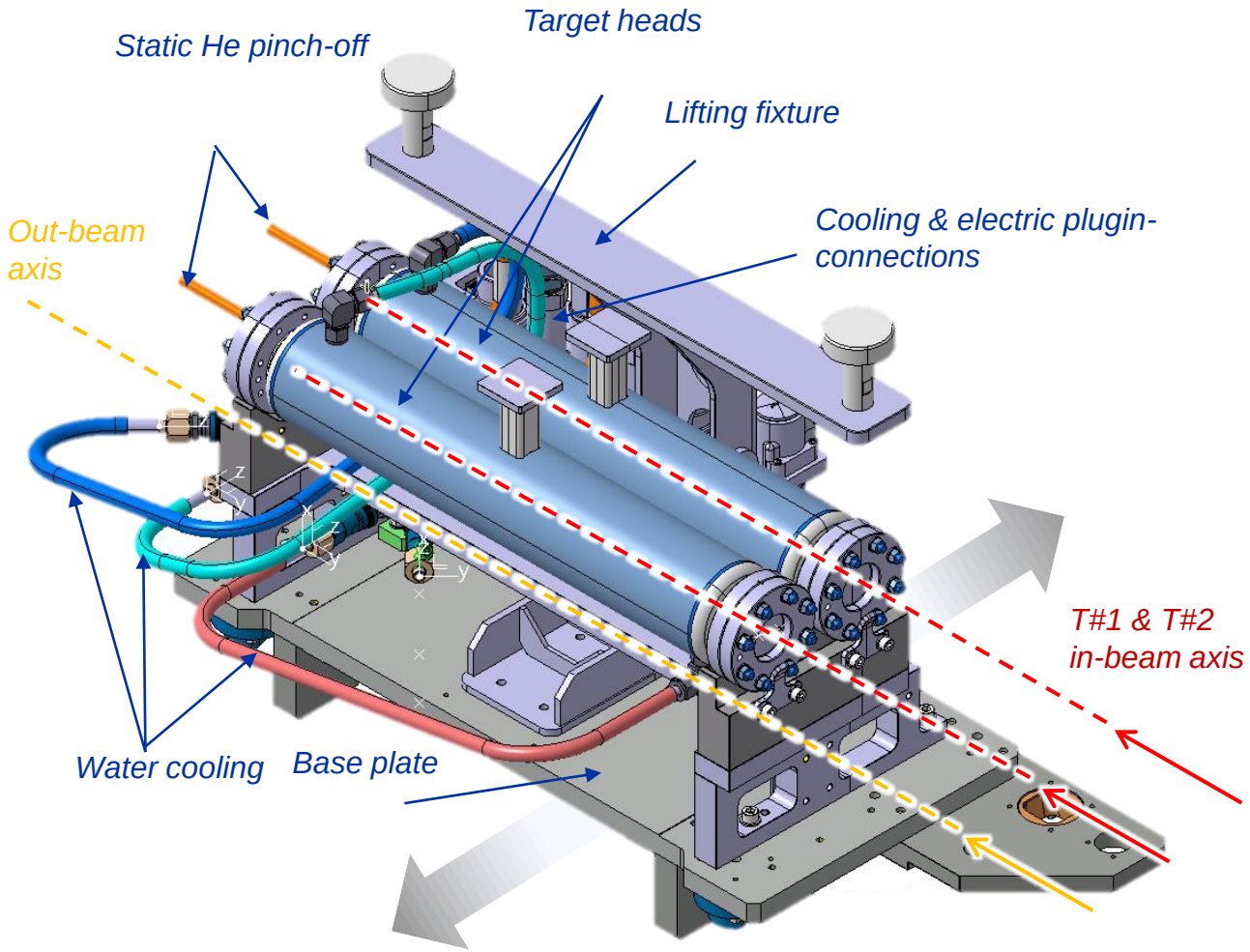


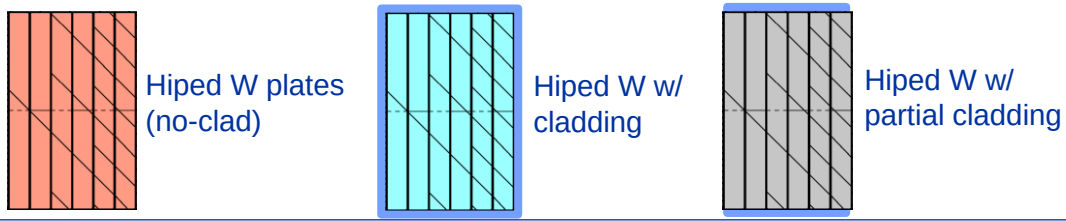
Prototype plugin table (lower table allows transversal horizontal movement)

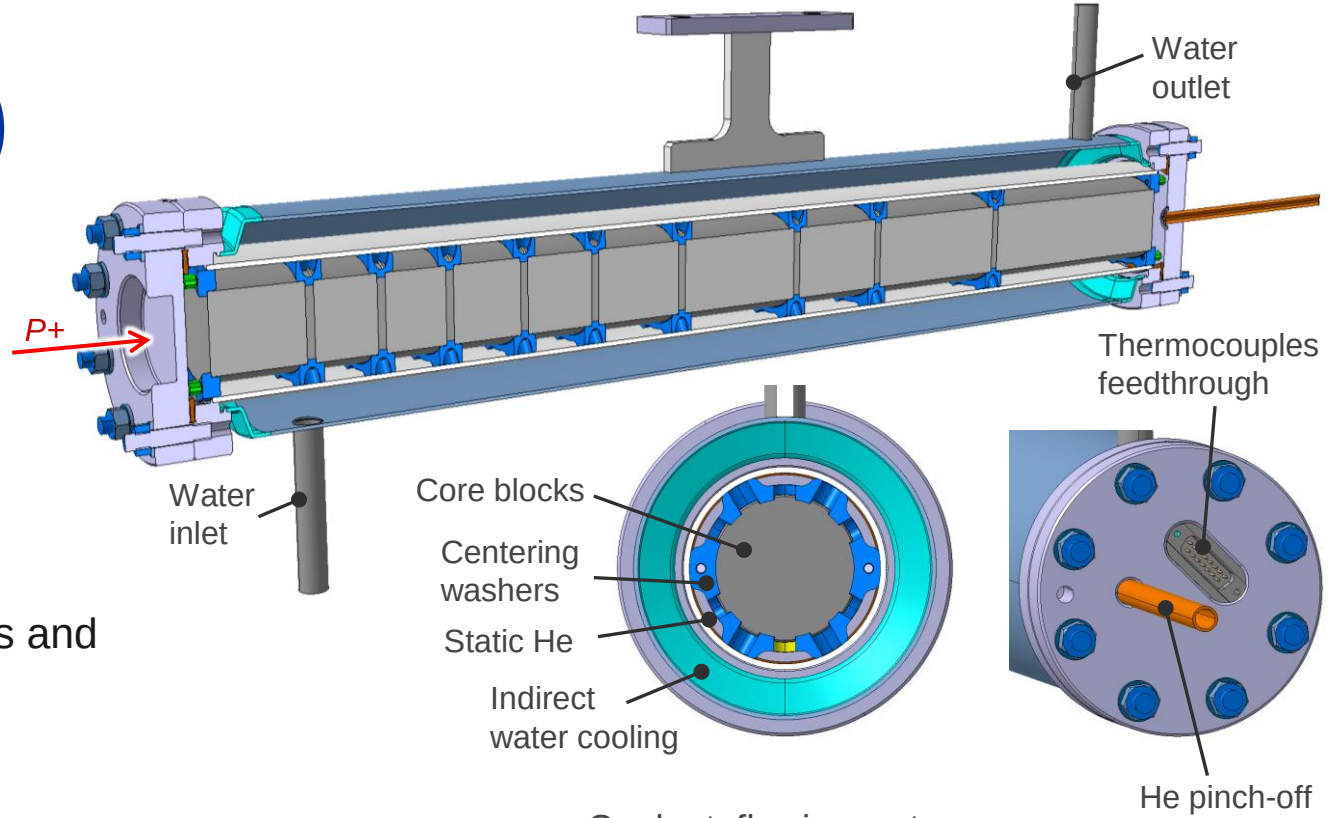
Parameters	Nominal (per target)
Beamline	North Area T6
Particle & momentum	400 GeV/c protons
Spill intensity [e10 ppp]	150 – 450
Spill lenght [s]	1.0
Beam size [σ, mm]	~1
Time between shots [min] (minimum)	~ 5-10 (can be longer! E.g.1h)
POT [e13] / (Nr of shots) / Total time	7.5 – 45 / (50-100) / 8-17h
MD slots (dedicated MDs but shared with other SHiP related studies)	MD 1→July 23rd MD 2→August 13th MD 3→ September 24th
Installation	**June 24th Technical Stop →** Prototype **installation**, BTV screen and any other pending item **July 16th -->> Backup**

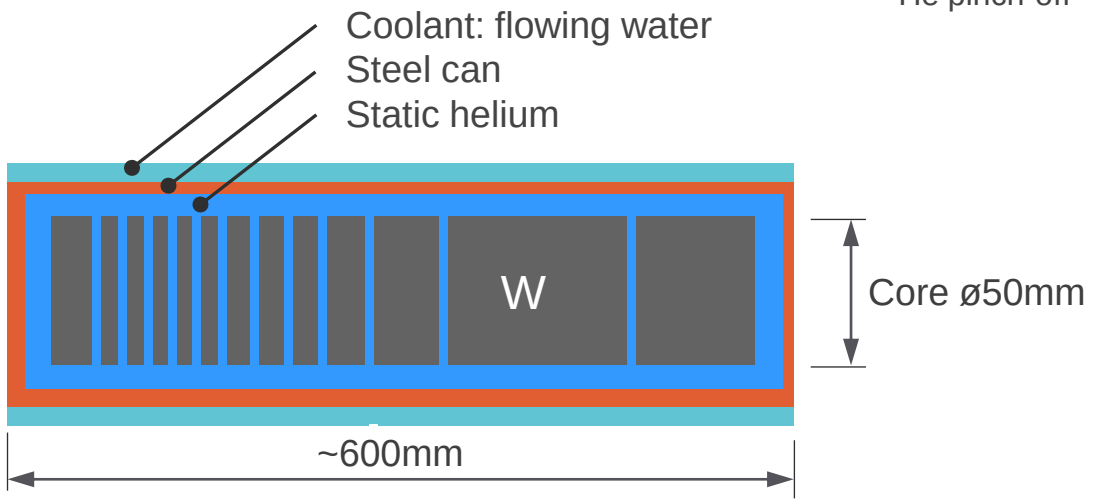
2025 Prototype Target(s)

Full W, Static Helium, indirect cooling

- **Design**
  - → W in static Helium.
  - → Indirectly cooled with a water jacket
  - → 3 Thermocouples per Target (+1 extra)
  - → Block spacing defined to match maximum stresses and temperatures and stress type.
    - Beam σ 1 – 3 mm, Intensity 5e11 - 2e13 ppp
    - Poor cooling → low pulse frequency and POT
- **Main objective**
  - → W-W Interface & cladding test @ different stress/temperature conditions **+** “Light” PIE / visual inspection
  - 3 different core block combinations

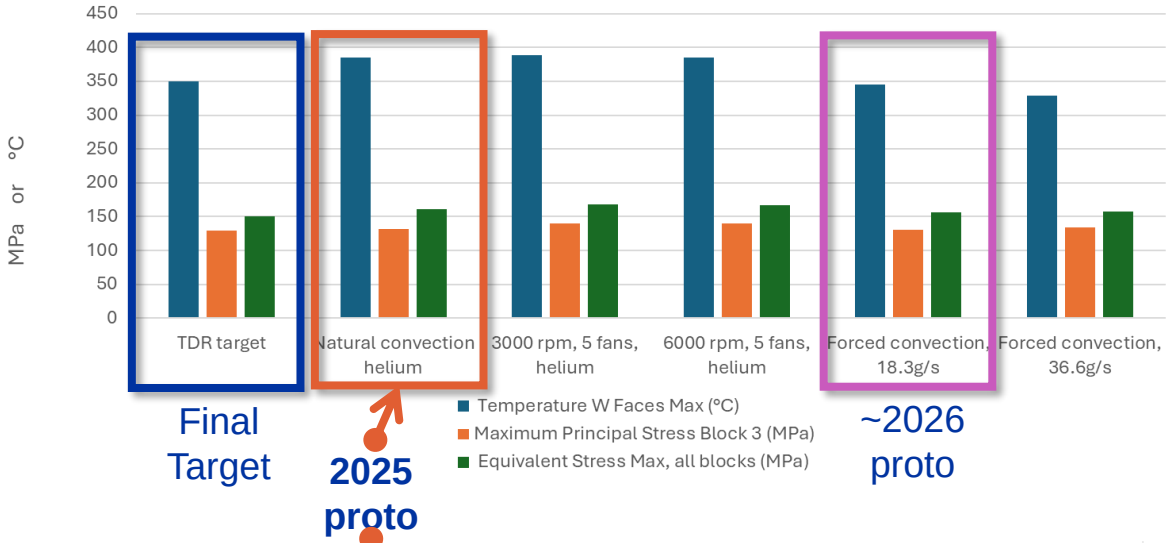




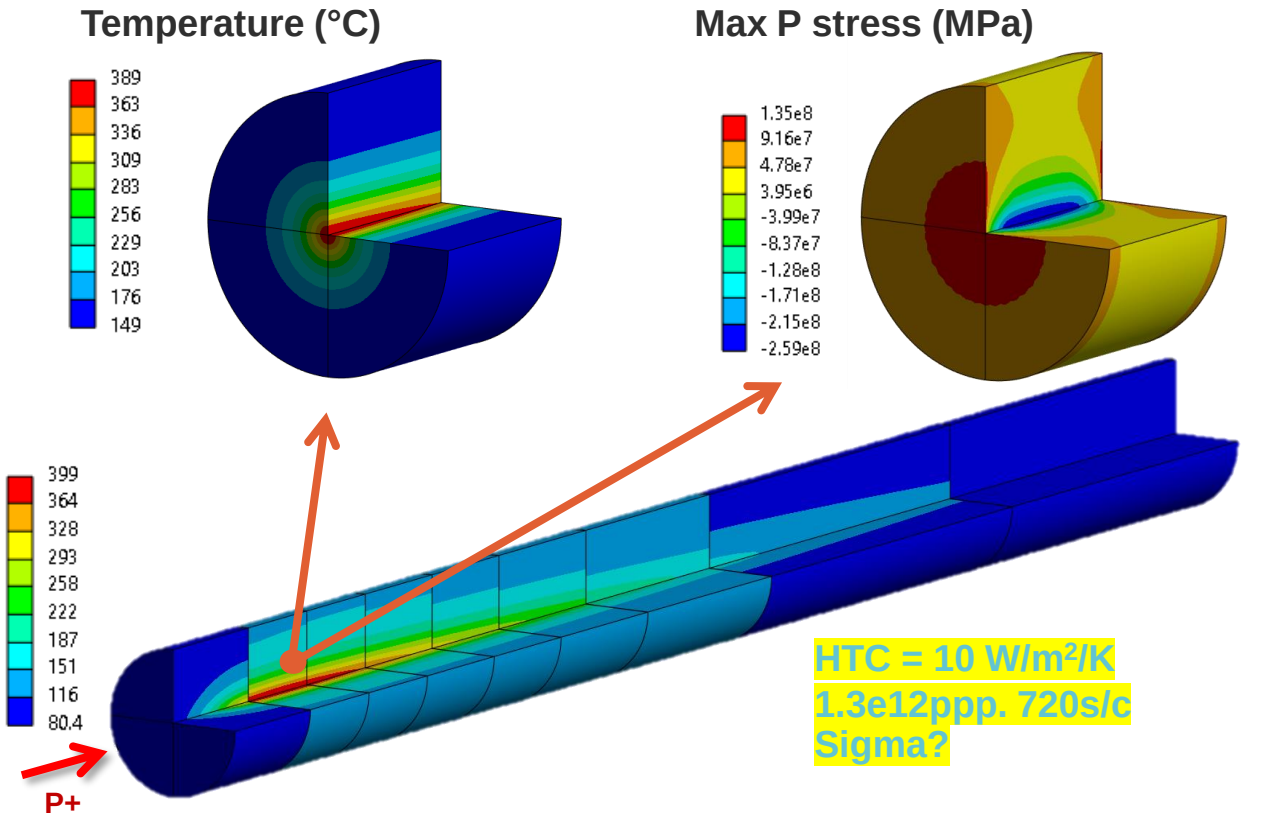


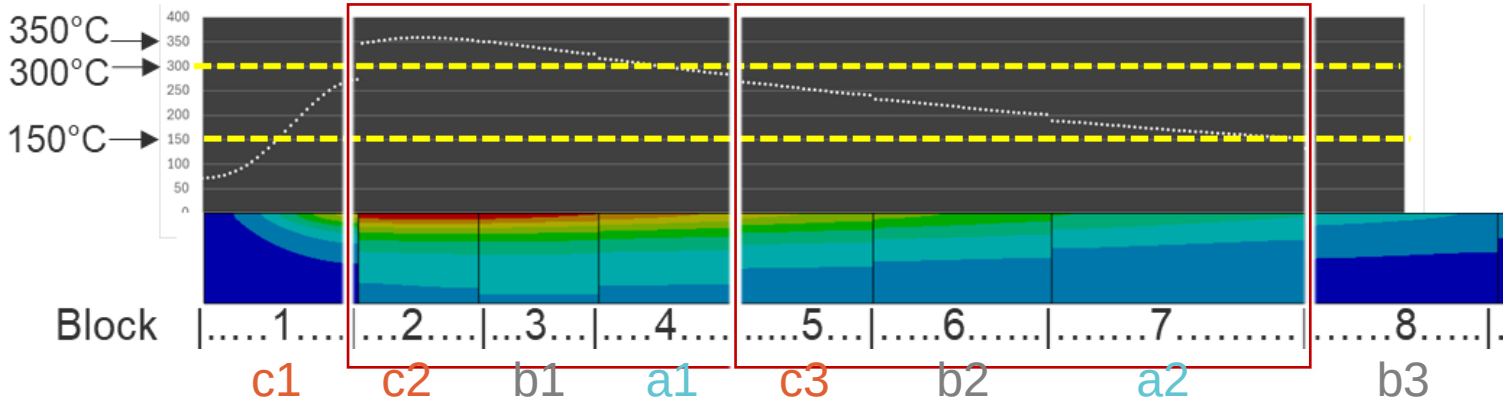
2025 Prototype Target(s)

Thermo-mechanical conditions

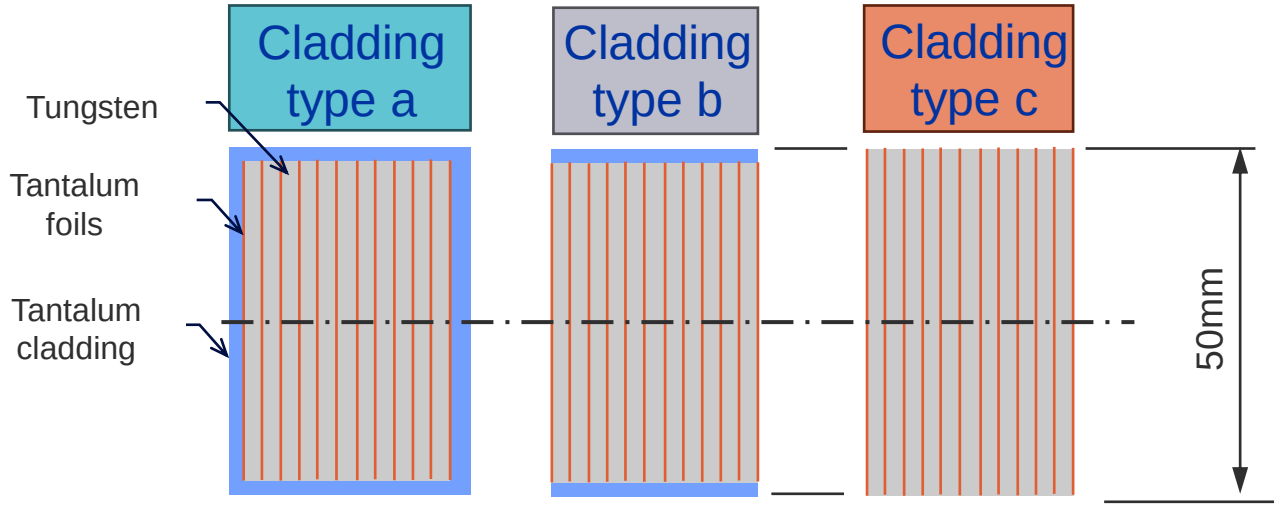


	Cycle length (385°C max Temperature at pulse)	Number of 7.2 s periods
natural convection	432 seconds (7.2 mins)	60
5 fans at 3000 rpm	350 seconds (5.8 mins)	48.6
5 fans at 6000 rpm	200 seconds (3.3mins)	27.8
Mass flow 18.3g/s	43.2 seconds (0.72 mins)	6
Mass flow 36.6g/s	21.6 seconds (0.36 mins)	3



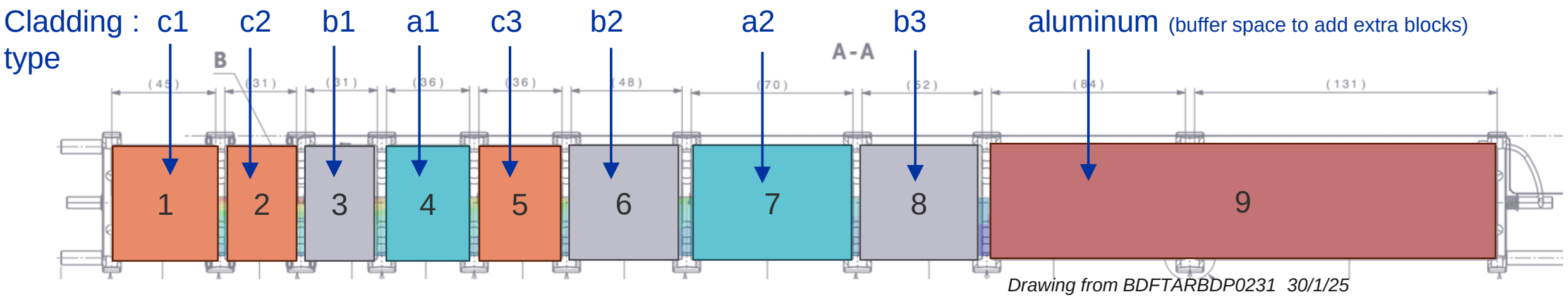


2025 Prototype Target(s)



Core combinations

- 3 block types & 2 Targets
- Can probe multiple temperature and stress levels along the target's length



Drawing from BDFTARBDP0231 30/1/25

Testing strategy → by playing with pulse intensity & multi-target setup

Target #1

C B A — Stress & temperature **==** Final Target
C B A — Stress & temperature **<** Final Target
\+ C — Stress & temperature **==** 1st block final Target
\+ B — Stress & temperature **<<** Final Target

Target #2

C B A — Stress & temperature **> (x2)** Final Target
C B A — Final Target **<** Stress & temperature **< (x2)** Final Target
\+ C — Stress & temperature **<(x2)** 1st block final Target
\+ B — Stress & temperature **>=** Final Target

2025 Prototype Target(s) - Status

Planning dates

- Fixed SX setup refurbished & re-cabled – **done**
- Water skid re-commissioning – **ongoing**
- Target table re-used and adapted – **almost done**
- BTV setup preparation – **end YETS24/45**
- Pre-alignment – **ongoing**
- Target vessel in production – **April**
- Core blocks procurement – **now**
- Core blocks manufacturing – **~May**
- Instrumentation & assembly – **June**
- Target and BTV installation – **24th of June**
- Installation backup – **16th of July**
- Beam Tests MDs – **23/7, 13/8, 24/9**
- Removal and “light” inspection – **YETS25/26**

Planning criticality: OK, Critical, Very Critical

2026 Prototype Target

2026 target

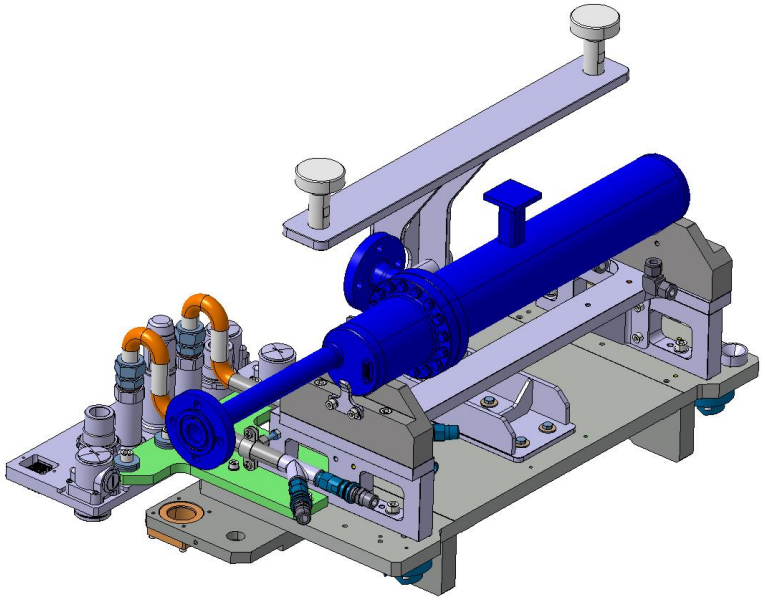
Full W, He-cooled

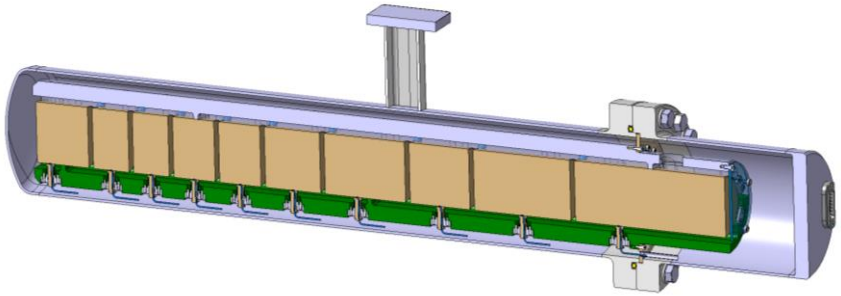
Design – work in progress

- 1x Target
- Small-scale. Design as close as possible to final He-cooled concept
- Likely same core/cladding configuration as 2025 target(s)
- Possibly beam parameters tunned for slightly above/below temperature & stress conditions
- High POT, O(1000s) pulses

(main) Objectives

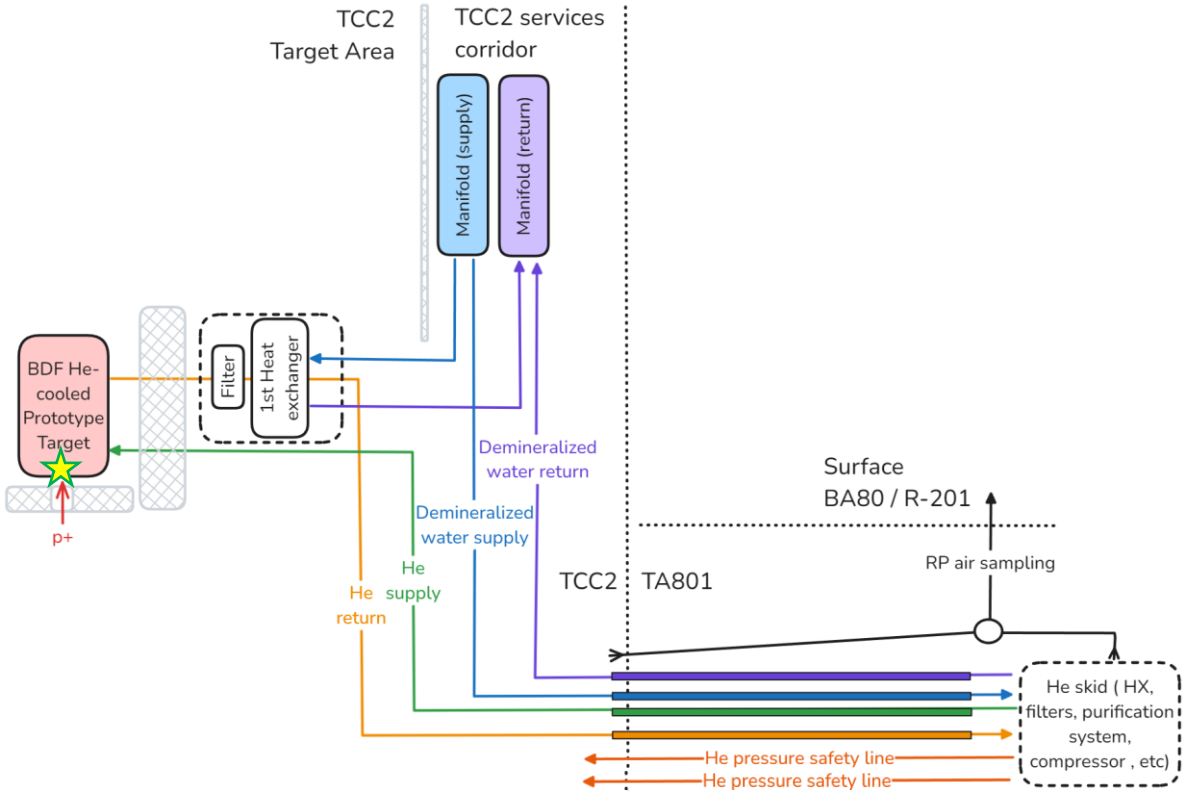
- Benchmark of models
- He skid operational experience
- Material testing build-up on top of 2025 tests
- Followed by more extended PIE (possibly together with 2025 blocks)

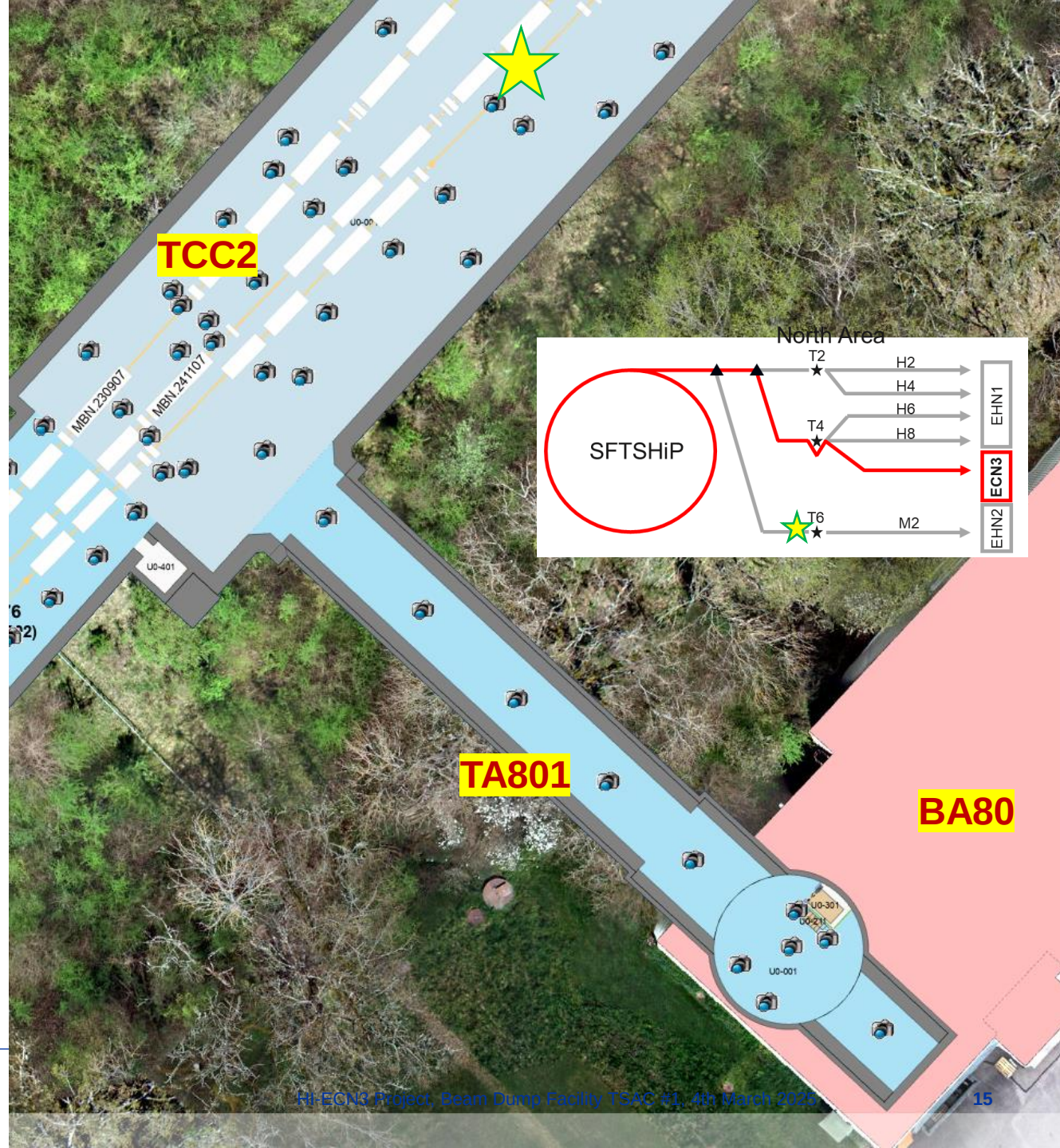




More details in Luca's presentation, to make parallel with Final target design

Layout BDF prototype setup in 2026





Conclusions

Conclusions & brief comments on risks

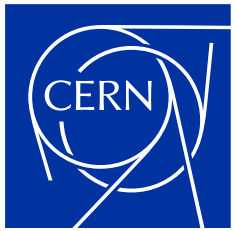
- **Staged testing choice requires extra resources but provides valuable & highly complementary data while mitigating risks on both prototype runs (2025 & 2026)**
- **2025 prototype(s)**
  - 2025 prototype(s) aim at scanning stress & temperature conditions, both above and below design values.
  - Mostly a beam material testing campaign of the different core manufacturing ideas
  - Design done with production ongoing but in the (very) critical path

  What if we cannot make it on time?
  - Blocks can be used in 2026 and in offline material characterization campaigns.
  - Upgrades and refurbishment of the SX testbench are applicable to 2026, as well as BTV and cabling.
- **2026 prototype**
  - Builds on top of 2025 material testing with higher POT
  - Brings a much closer to final target design, operational experience with He cooling systems. Allows exhaustive FEA benchmark and possibly RP studies.
  - Currently designing (tight timeline!) & cooling skid procurement ongoing

  What if we cannot make it on time? (e.g. either planning or risks associated to having a short 6 months run)
  - Skid can be used for offline testing & can be employed as economy/safety skid for the final facility
  - Target manufacturing exercise will provide valuable experience in all cases

What if non of the tests happen?
- We would likely have to test at the start of Run4 and “try” to workout the planning to have a change to feed the lessons learnt into the final design

Thank you



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