11th SHiP Collaboration Meeting
7th June 2017

Status of BDF/SHiP target & target complex (TTC) studies

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for the BDF TTC WG

ENGINEERING DEPARTMENT

Outline

- Context of BDF TTC activities
- TTC integration & handling studies
- BDF target/dump design status
- BDF CV activities overview
- BDF T6 target test
- Target/dump material R&D
- HSE feedback on BDF

Status of BDF TTC studies

- Design & integration studies of the BDF TTC (including hadron absorber magnetisation (HAM) follow-up)
- BDF target/dump optimisation, design and manufacturing
- Realisation of the test area in T6 and design of a prototype target
- Design of cooling systems, ventilation and He-purification
- R&D on advanced materials
- Support in the muon flux replica target

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REFERENCE
BDF-PM-WD-0001

Date: 2017-04-24

WORK PACKAGE DESCRIPTION

Beam Dump Facility (BDF) Target Design & Target Complex Study

ABSTRACT:

This document summarizes the work packages and the main milestones associated to the design of the Beam Dump Facility target/dump as well as for the associated target complex. This document gives insights on the preferred concept for this system/equipment, on its deliverables, the interfaces with other systems and equipment.

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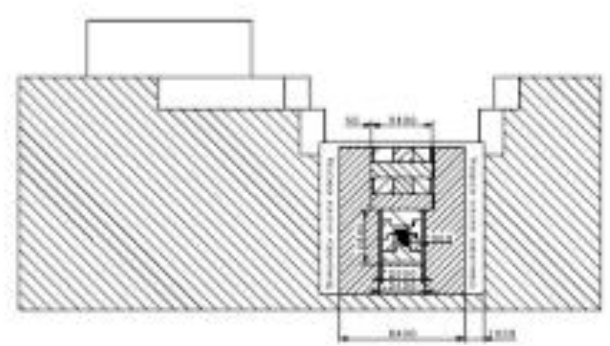
TTC design and handling studies

- Preliminary study specification based on two concepts
- **Crane handling concept**
  - Shielding, target, etc. moved by crane with pure vertical movement (SHiP TP)
- **ISIS/RAL facility concept**
  - Trolley and services on trolleys on rails (side movement)



K. Kershaw, J.-L. Grenard

TTC design and handling studies

- Contract placed with Oxford Technologies Ltd (OTL), Abingdon, UK
  - Work started officially 2 May 2017
  - Progress meetings already started
- CERN provided revised 3D models for both concepts with:
  - Single coil for HAM, located above shielding
  - Complete separation of the HAM (uncooled US1010) vs. proximity shielding (cooled cast iron)
- Close discussion with HSE/RP & HSE/SEE for key aspects of the TC design
- First review at CERN on July 25th

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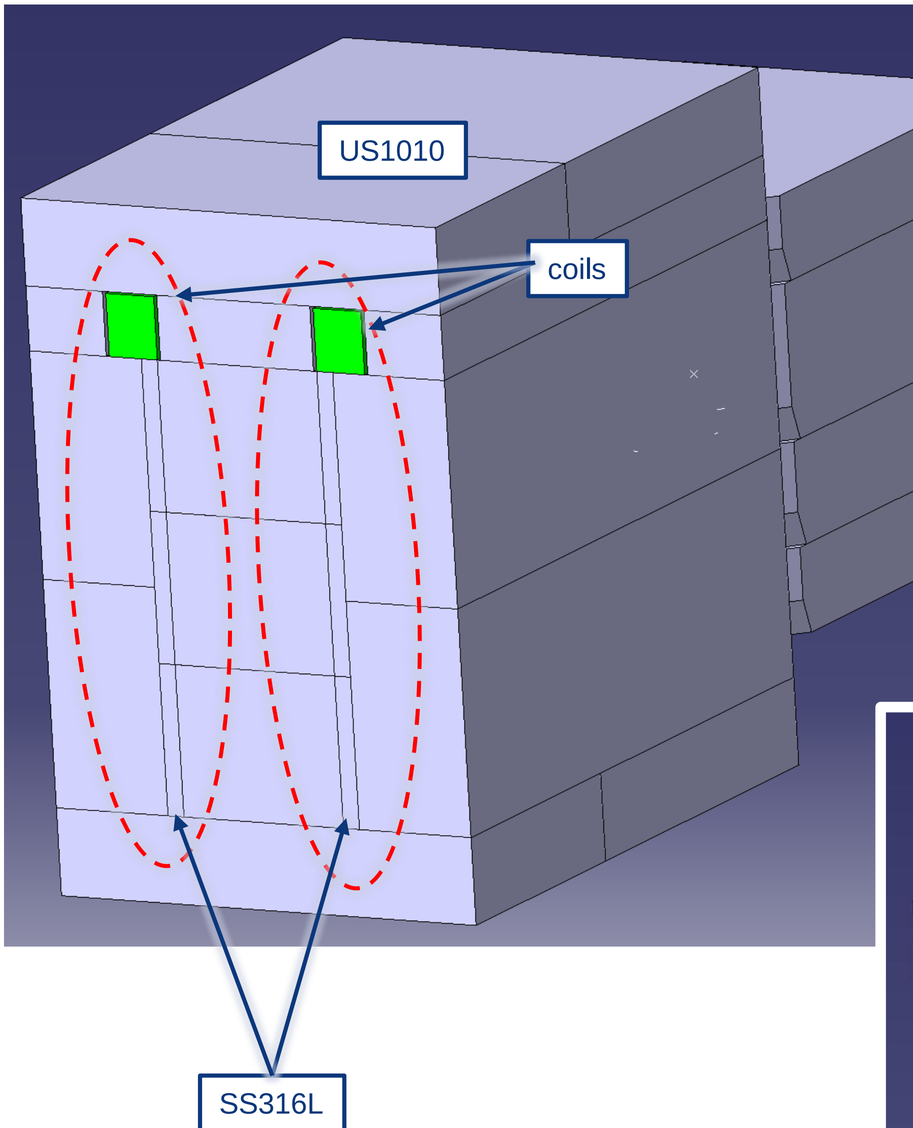
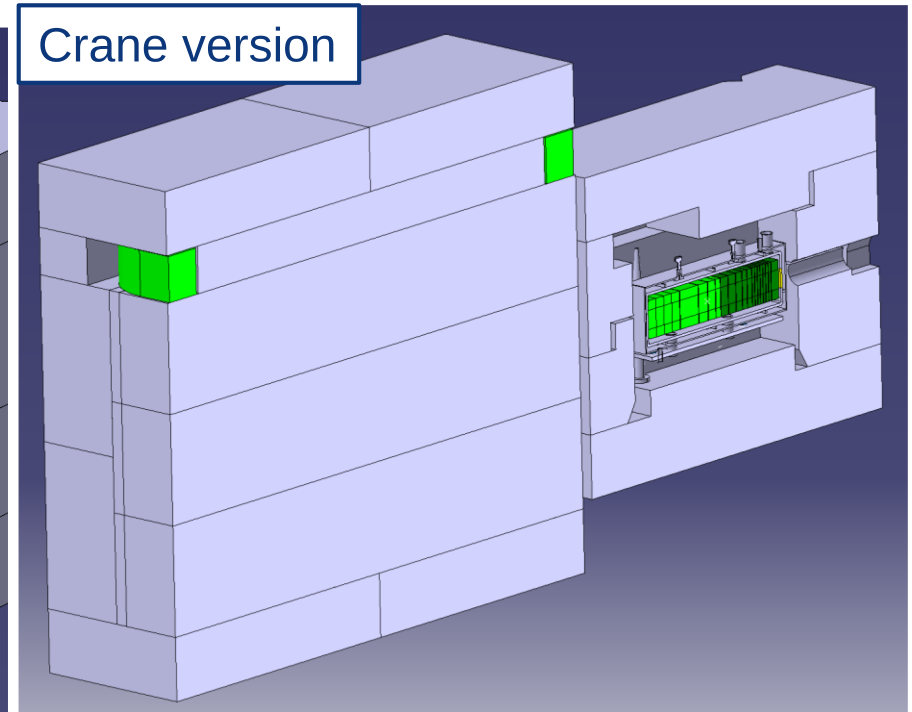
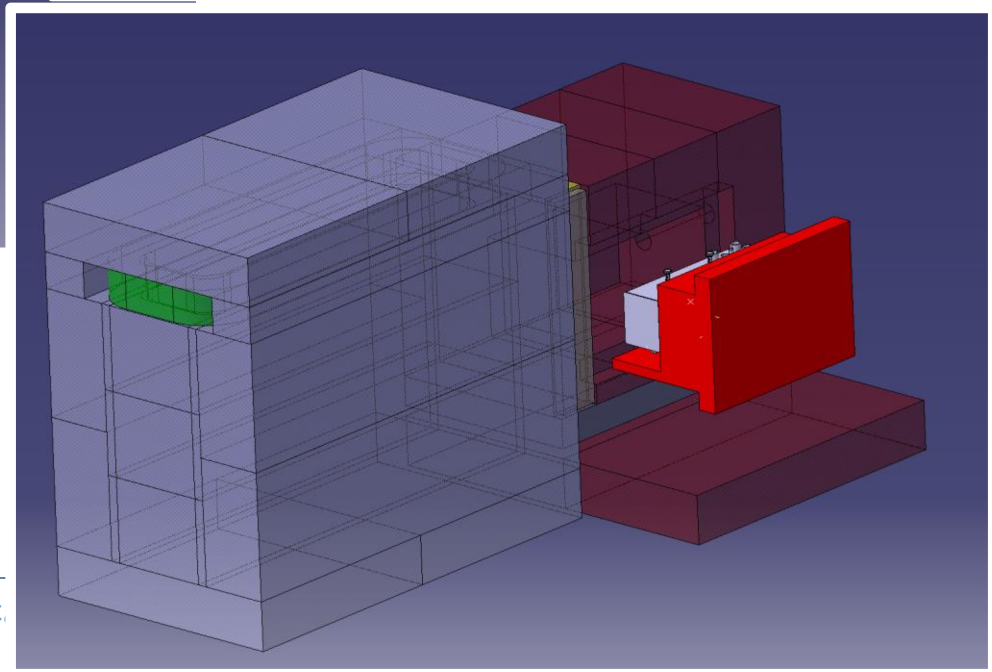
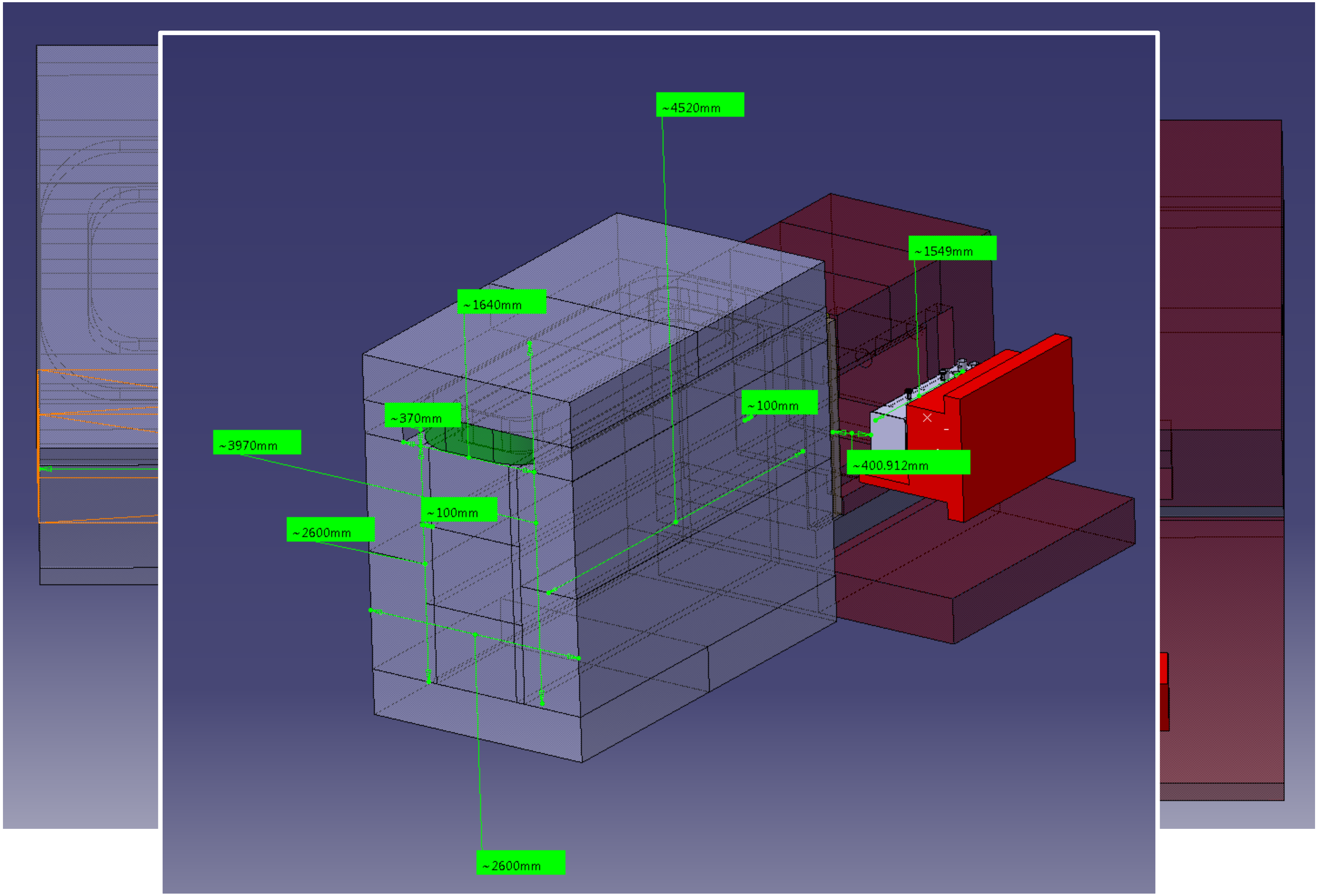

US1010
coils
SS316L


Crane version





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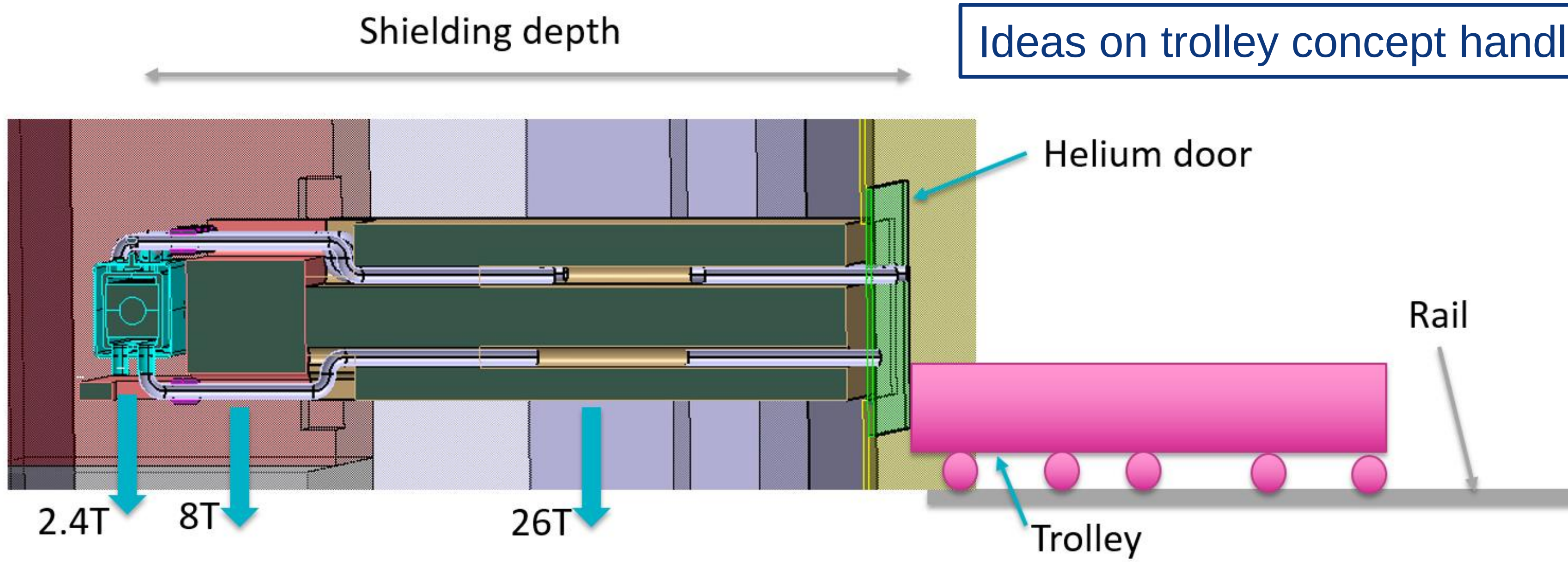
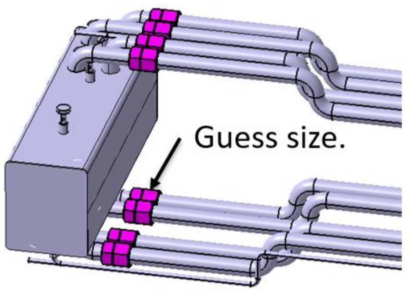
Outstanding items with SHiP on TTC

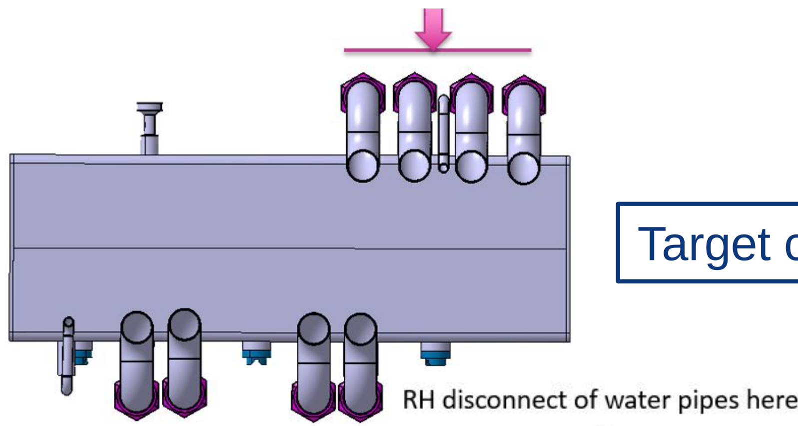
- Need to work hand in hand with SHiP on the design/optimisation of the HAM, since handling/support/cooling will have to be secured within the framework of the TTC design
- Important aspects:
  - Forces, assembly of the magnets, global optimisation, cooling connection of coil, reliability, etc.

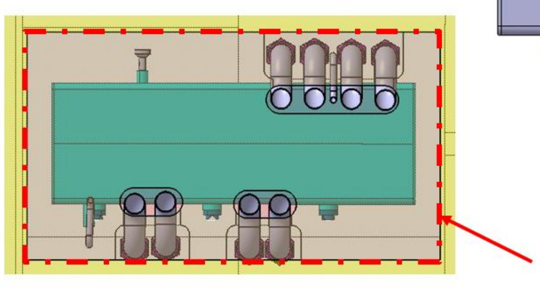
Ideas on trolley concept handling

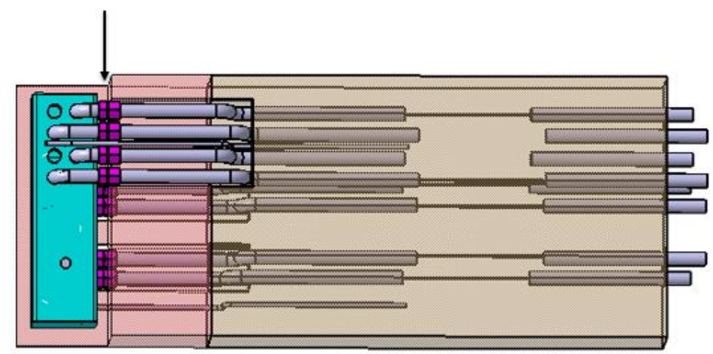


Target cooling connections



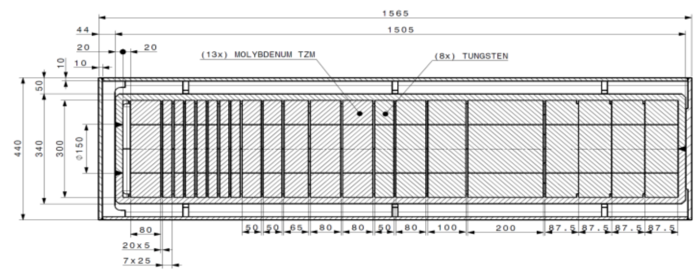


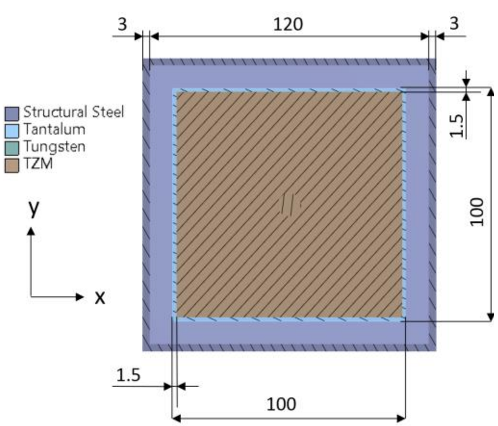


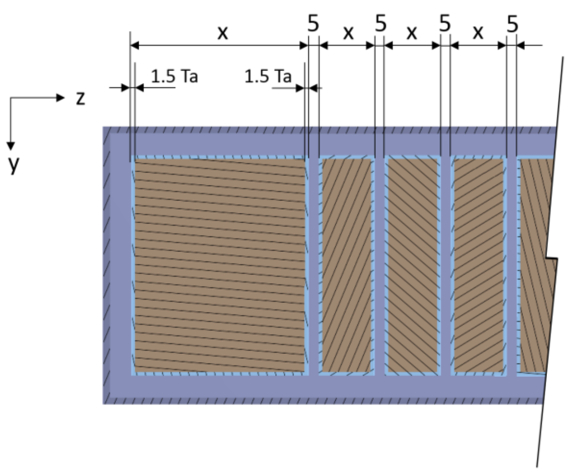


BDF target mechanical design status

- 13 TZM blocks + 5 tungsten blocks. All blocks are Ta-cladded
- 30x30 cm^2 rectangular plates with variable thickness
  - Highly probable to **switch to 25 cm diameter circular plates**
  - Total target length = 1.445 m
- 5 mm longitudinal gap between the blocks





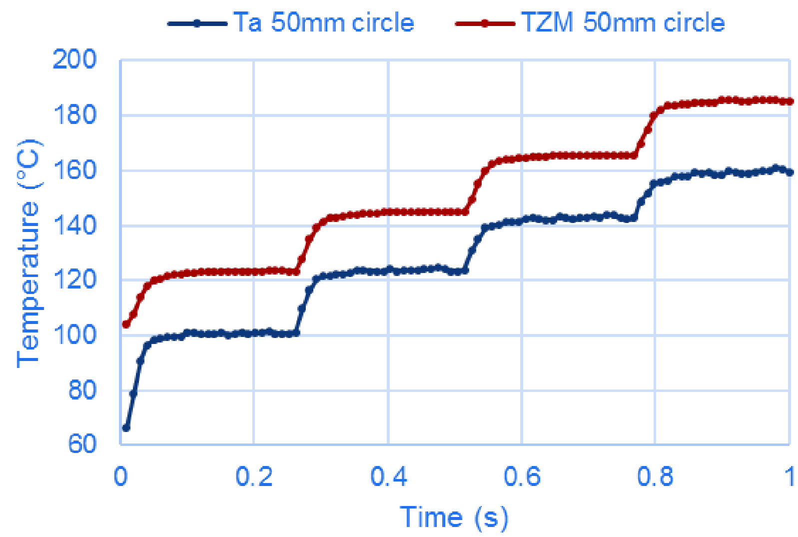


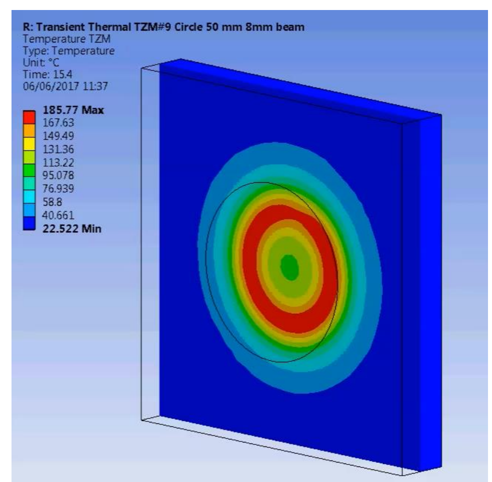
Layer	Material	Thickness x (mm)	Layer	Material	Thickness x (mm)
1	TZM+Ta	80	10	TZM+Ta	50
2	TZM+Ta	25	11	TZM+Ta	65
3	TZM+Ta	25	12	TZM+Ta	80
4	TZM+Ta	25	13	TZM+Ta	80
5	TZM+Ta	25	14	W+Ta	50
6	TZM+Ta	25	15	W+Ta	80
7	TZM+Ta	25	16	W+Ta	100
8	TZM+Ta	25	17	W+Ta	200
9	TZM+Ta	50	18	W+Ta	350

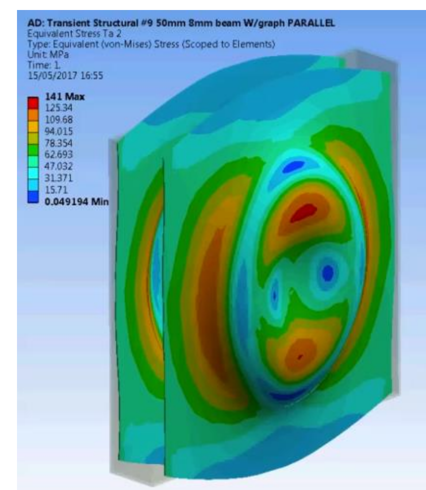
E. Lopez Sola

Target configuration

- Circular beam dilution:
  - 50 mm radius circle
  - 1 second extraction in 4 turns
  - 8 mm 1σ beam
- Maximum temperatures:
  - Tantalum cladding: 160°C
  - TZM core: 185°C
- Maximum Von Mises equivalent stress:
  - Tantalum cladding: 120 MPa
  - TZM core: 175 MPa





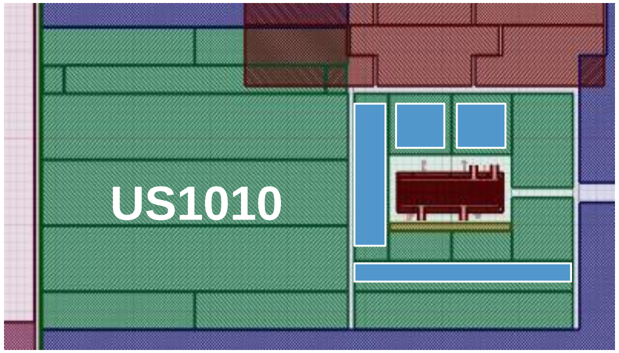


E. Lopez Sola

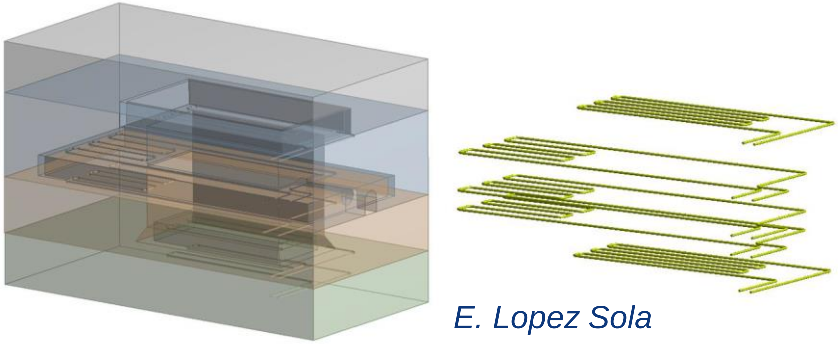
Proximity shielding design status

- Around 25 kW deposited in the proximity shielding blocks
- Active cooling necessary in the cast iron blocks
- Proposed design avoids active water cooling in the US1010 part

- Trolley concept:
  - Proximity shielding blocks cooled by conduction through horizontal and vertical plates



- Crane concept:
  - Proximity shielding blocks cooled by embedded SS pipes



E. Lopez Sola

Overview of CV activities

- He-vessel design
  - Task 1: Design of He circulation/purification system
  - Task 2: Economic study on purification vs. flushing
  - Task 3: Study of purification system by external partner
  - Task 4: Procurement and operation of prototype
- Ventilation systems
  - Task 5: Conceptual design and pre-integration of ventilation systems
- Cooling systems
  - Task 6: Conceptual design and pre-integration of cooling systems
  - Task 7: Optimization of target cooling

P. Avigni

Status – He vessel design

- Started preliminary design of He circulation system
  - Setup of preliminary CAD models for CFD simulations
  - Preliminary considerations on blocks and gaps distribution; He volumes; He source and sink locations; He flowpath
  - Started discussion on concrete/iron releases and vessel leak-tightness for definition of purification requirements
- Defined options for purification approaches and respective economic analysis
- Established preliminary contact with external partner for study of purification system
  - Definition of He purification general requirements
- Started procedure for procurement of He gas purification system (MS, IT)

P. Avigni

Status – Ventilation systems

- Defined preliminary pressure cascade according to nuclear ISO standard and CENF experience
  - He-vessel room: -140 Pa
  - Handling area / CV room: -80 Pa
  - Access staircase: -40 Pa
  - Target hall: -20 Pa
- Setup of integration approach
  - Defined preliminary list of ventilation components needed
  - Started calculation of volumes for integration (OTL)

P. Avigni

Status – cooling systems

- Started preliminary design of cooling systems:
  - Target cooling: 350 kW, ~200 m^3/h
  - Proximity shielding: 25 kW, ~2 m^3/h
  - Magnetic coil: 150 kW, ~15 m^3/h
- Setup of integration approach
  - Component list based on work performed for CENF
  - Calculation of piping/system and fluid volumes for
    - integration (OTL)
    - water activation (RP)
- Target cooling
  - Performed single-channel water CFD analysis
  - Assessment of He target cooling feasibility

P. Avigni

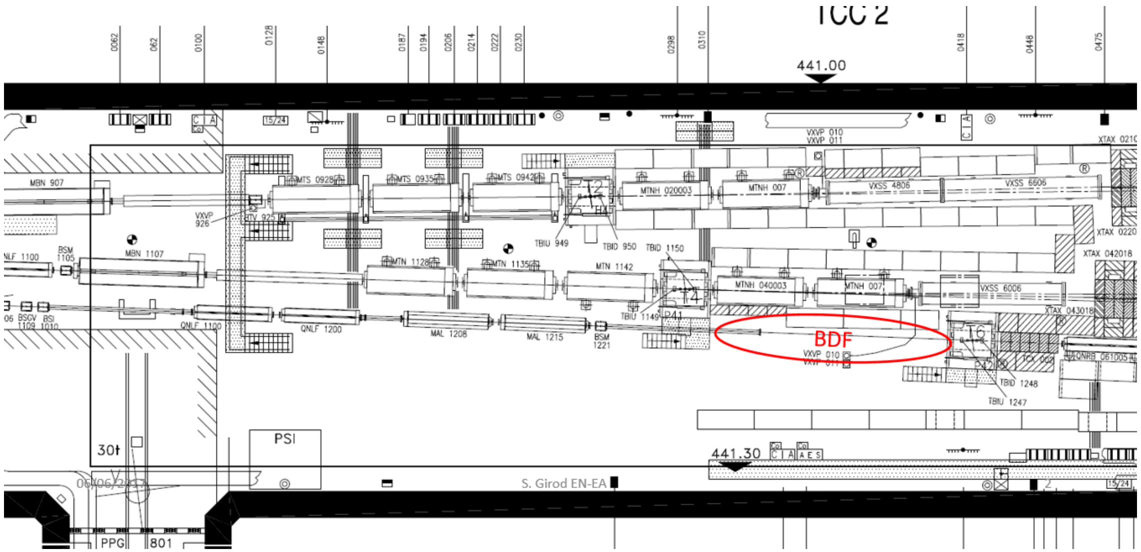
Short-term plans

- Run preliminary CFD simulations for He circulation
  - Needed to establish requirements for He circulation system
- Perform He circulation study with external contract
  - Needed to establish requirements for prototype procurement
- Define baseline cooling and ventilation systems
  - Preliminary P&ID
  - Calculation of volumes for integration and activation calculations

P. Avigni

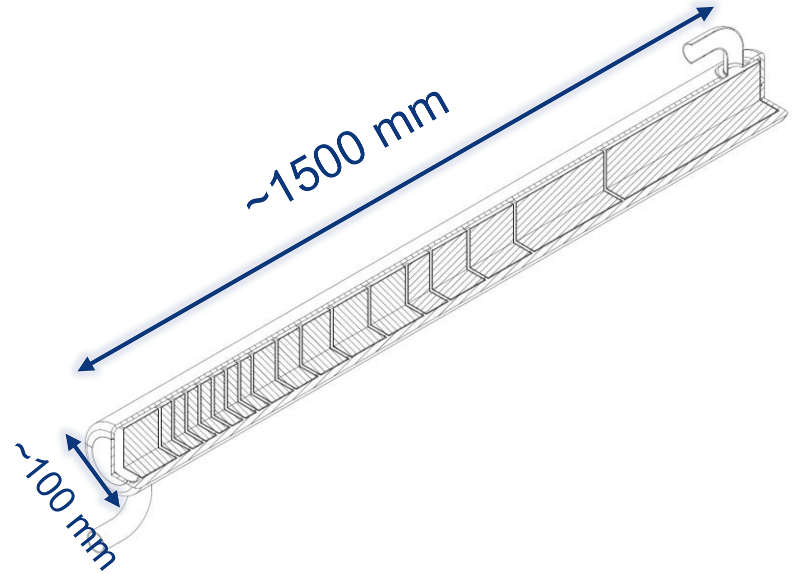
BDF beam test prototype in T6

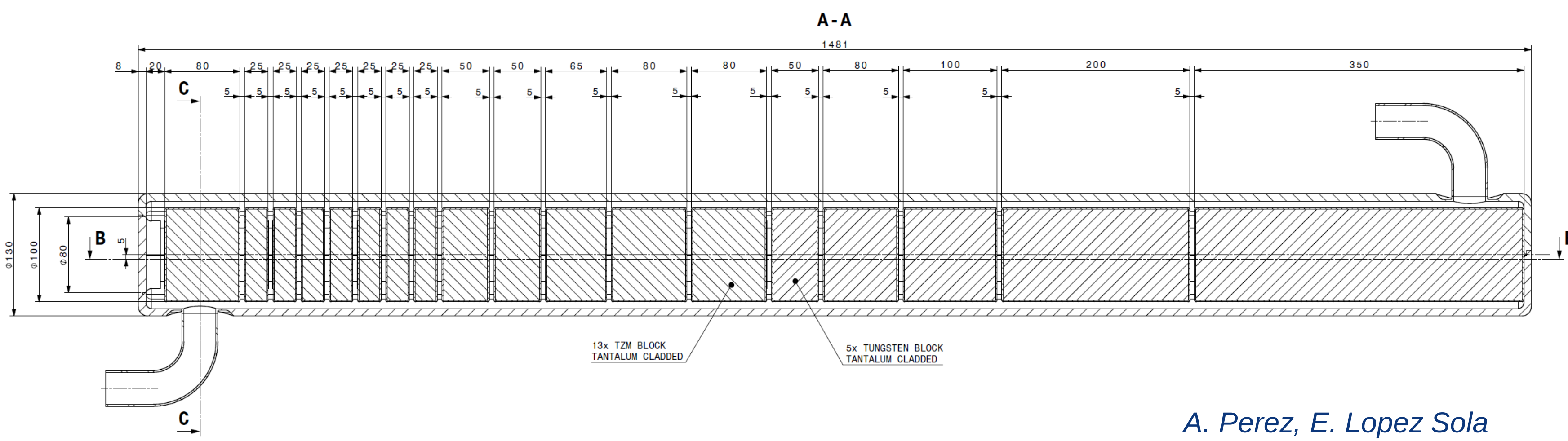
- Proposition to run a dedicated high intensity (O(10^{12}-10^{13})) test in TCC2 during 2018 → slow extraction & high intensity
- Possibly need for dedicated NA beam – collaboration with TE/ABT to define the optics and with PS/SPS coordination to assess the scheduling
- Memo to SPSC to be prepared for August 2017
- Preparation of the area in collaboration with EN/EA



BDF beam test prototype in T6

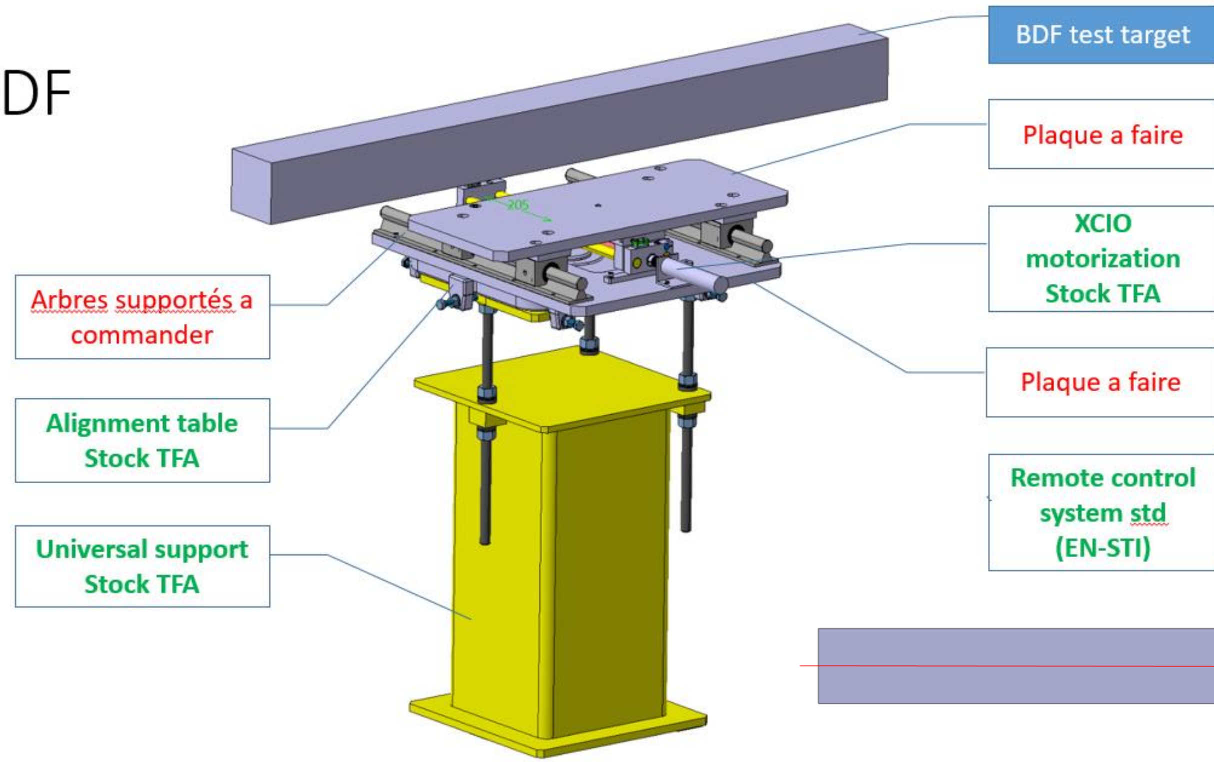
- Reduced scale prototype
  - 100 mm diameter plates, same thicknesses as the final target
  - Recreate level of T and stresses during operation
  - PIE foreseen after irradiation

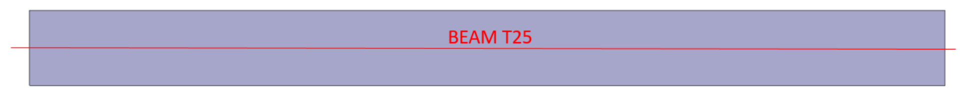




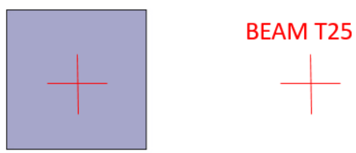
A. Perez, E. Lopez Sola

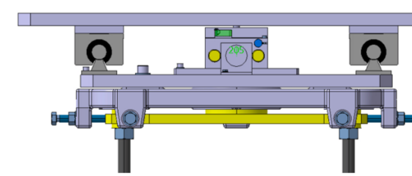
BDF

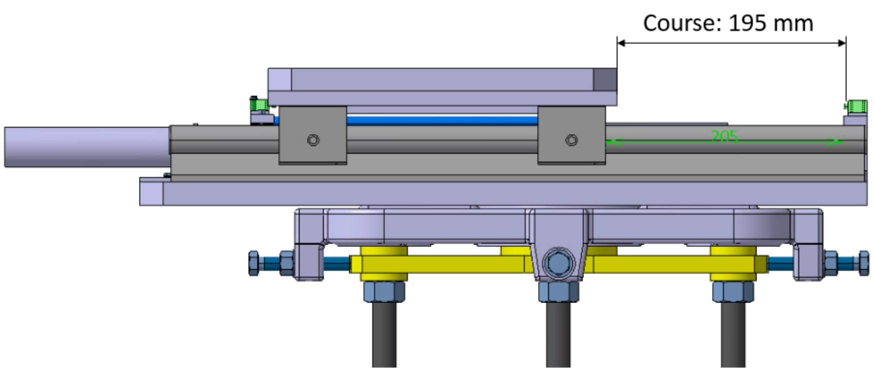




BDF section

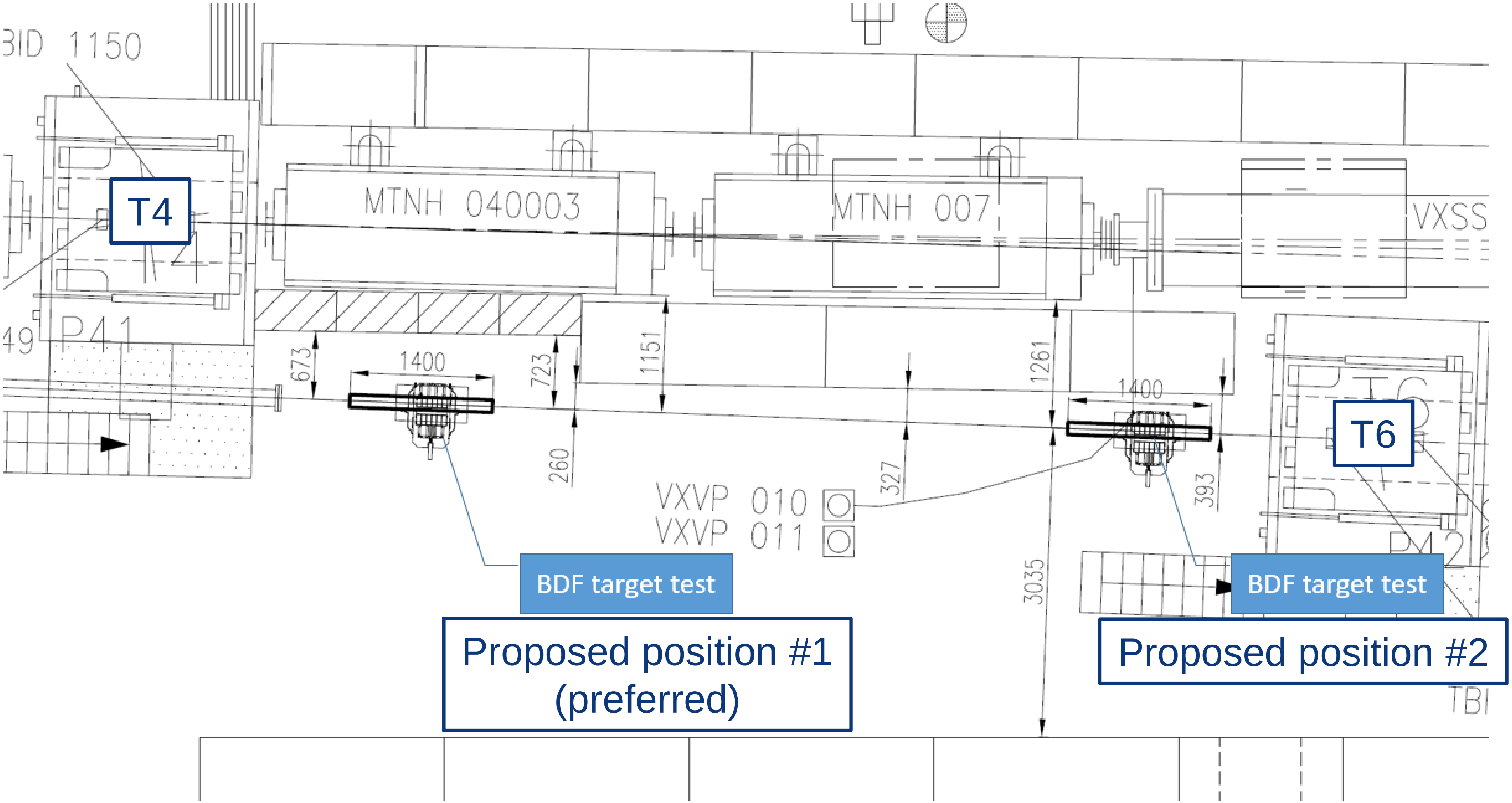






S. Girod, O. Aberle

BDF T6 test location(s)



S. Girod, O. Aberle

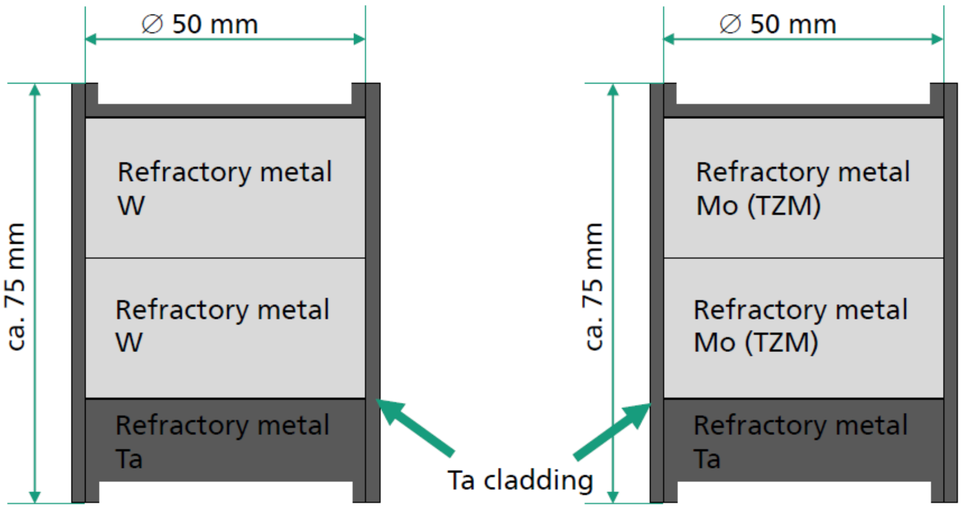
BDF materials R&D status

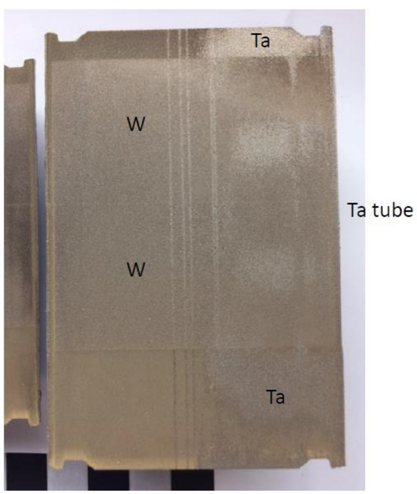
Several ongoing parallel sub-projects:

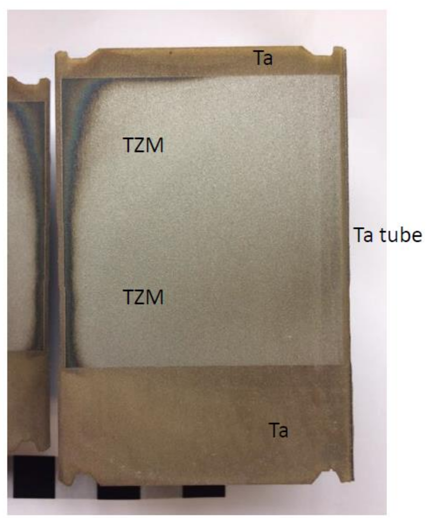
- Intermetallic bonding follow-up
- Raw material characterisation campaign
- Evaluation of Ta gettering properties
- Investigation of W/Gr as a candidate material to substitute TZM

J. Busom

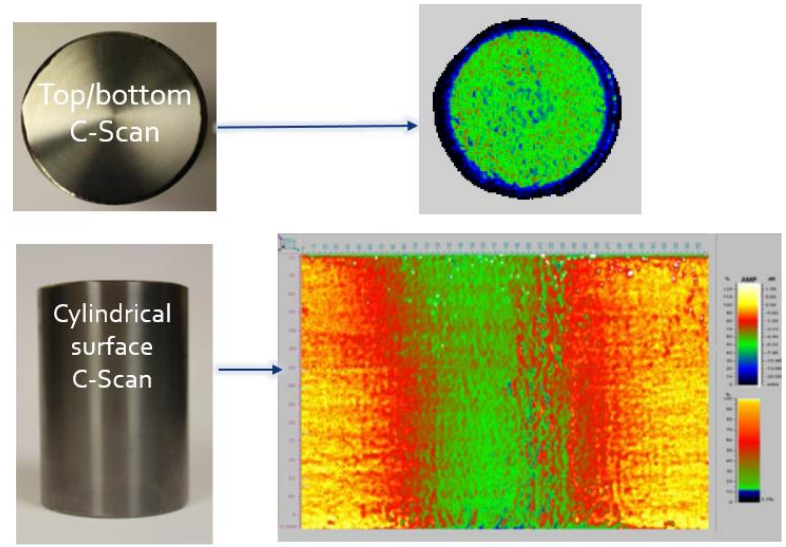
Just some flavour…

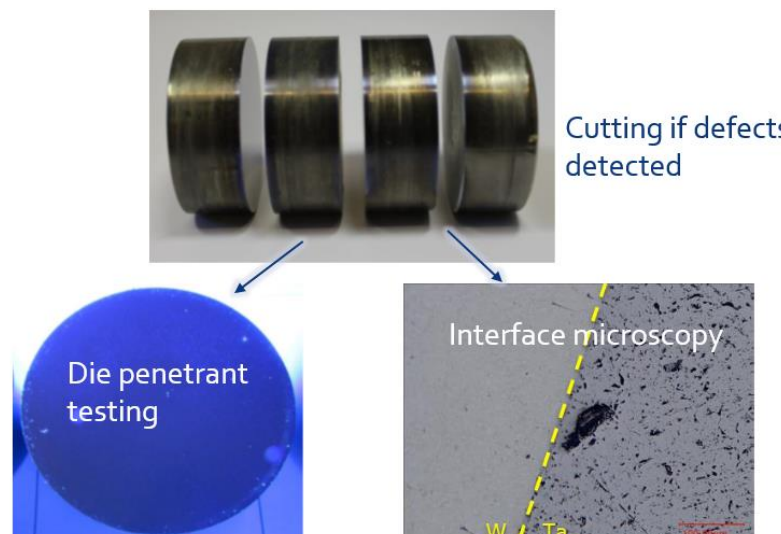






J. Busom

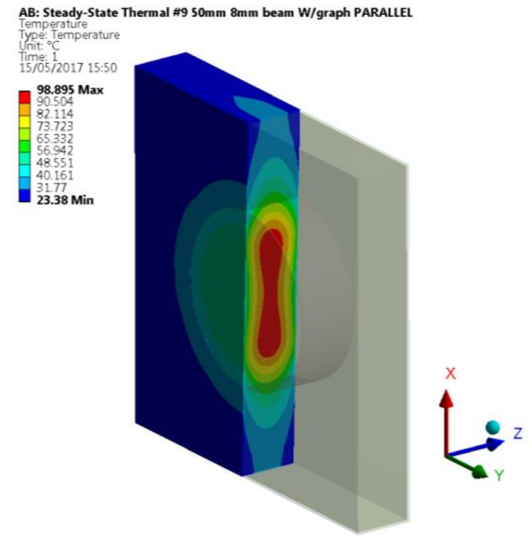


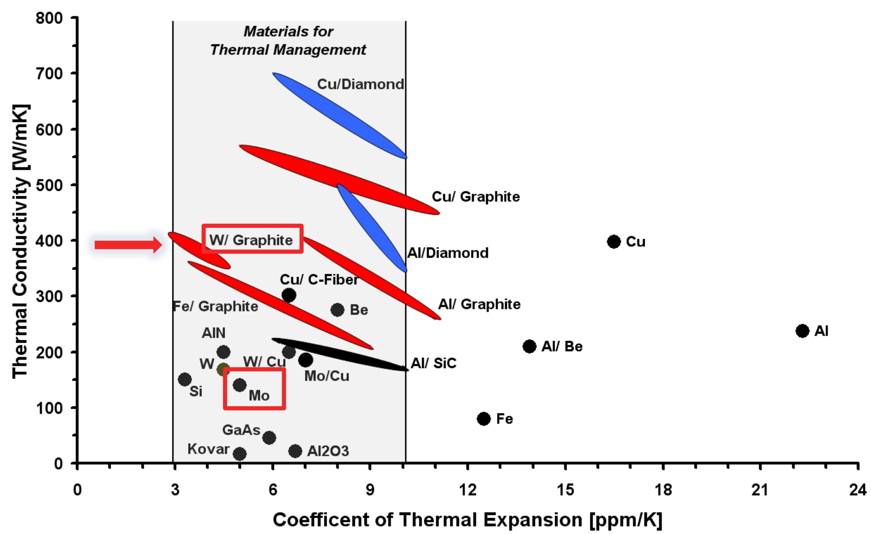


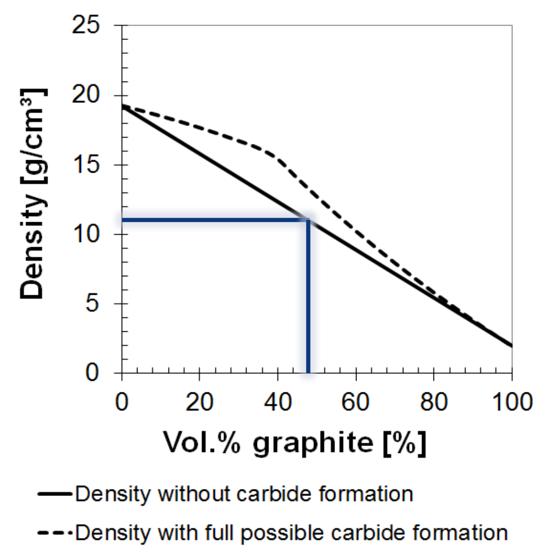
W/Gr studies

High thermal conductivity in the XY plane

- Sintered from powder metallurgy – tunable density – possible alternative to TZM
- Thermal conductivity and CTE improved in the pressing direction
- Density around 11 g/cm^3 (50 vol% of graphite)
- Material complete characterization launched







Material irradiation

Motivation

- Radiation damage study of various critical accelerator component materials, using high energy proton beams from the Brookhaven Linac Isotope Production facility.
  - Beam windows, secondary particle production targets, beam dumps

Objectives

- Long-term irradiation of several materials of interest
- Perform PIE to characterize radiation-induced property changes
  - Strength properties (tensile, bend, fatigue) and micro-mechanics (nano-indentation, micro-cantilevers)
  - Thermal properties (CTE, conductivity) and annealing effects
  - Microstructural analyses (SEM, TEM, EBSD)
- Compare HE proton irradiation to LE ion irradiation effects
- Generate irradiated specimens for thermal shock testing

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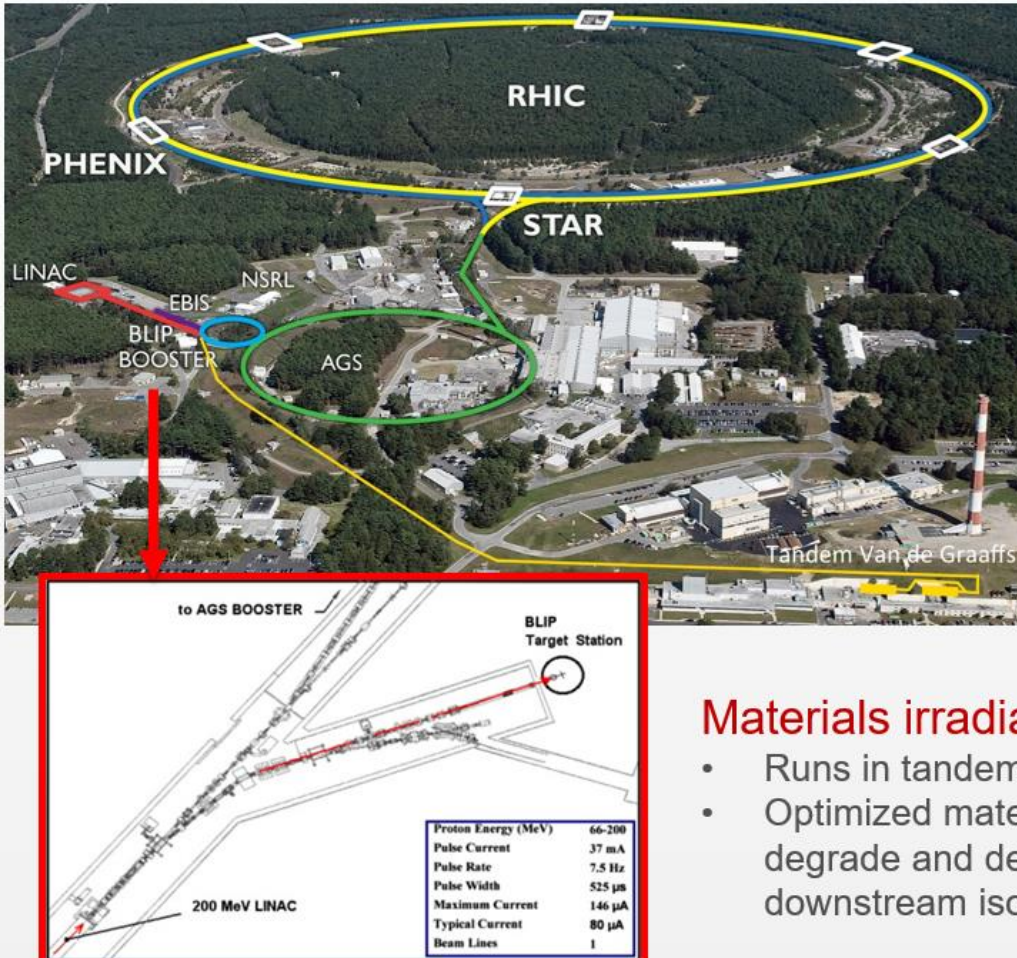
BLIP Facility at BNL



Proton Energy (MeV)	66-200
Pulse Current	37 mA
Pulse Rate	7.5 Hz
Pulse Width	525 µs
Maximum Current	146 µA
Typical Current	80 µA
Beam Lines	1

Primary mission of BLIP is for medical isotope production - 6 months uptime per year.

High Energy Protons
- Energy: 66 - 200 MeV
- Current: 165 µA max.

Materials irradiation
- Runs in tandem and upstream of isotope target
- Optimized materials target array needed to degrade and deliver precise beam energy/flux to downstream isotope target

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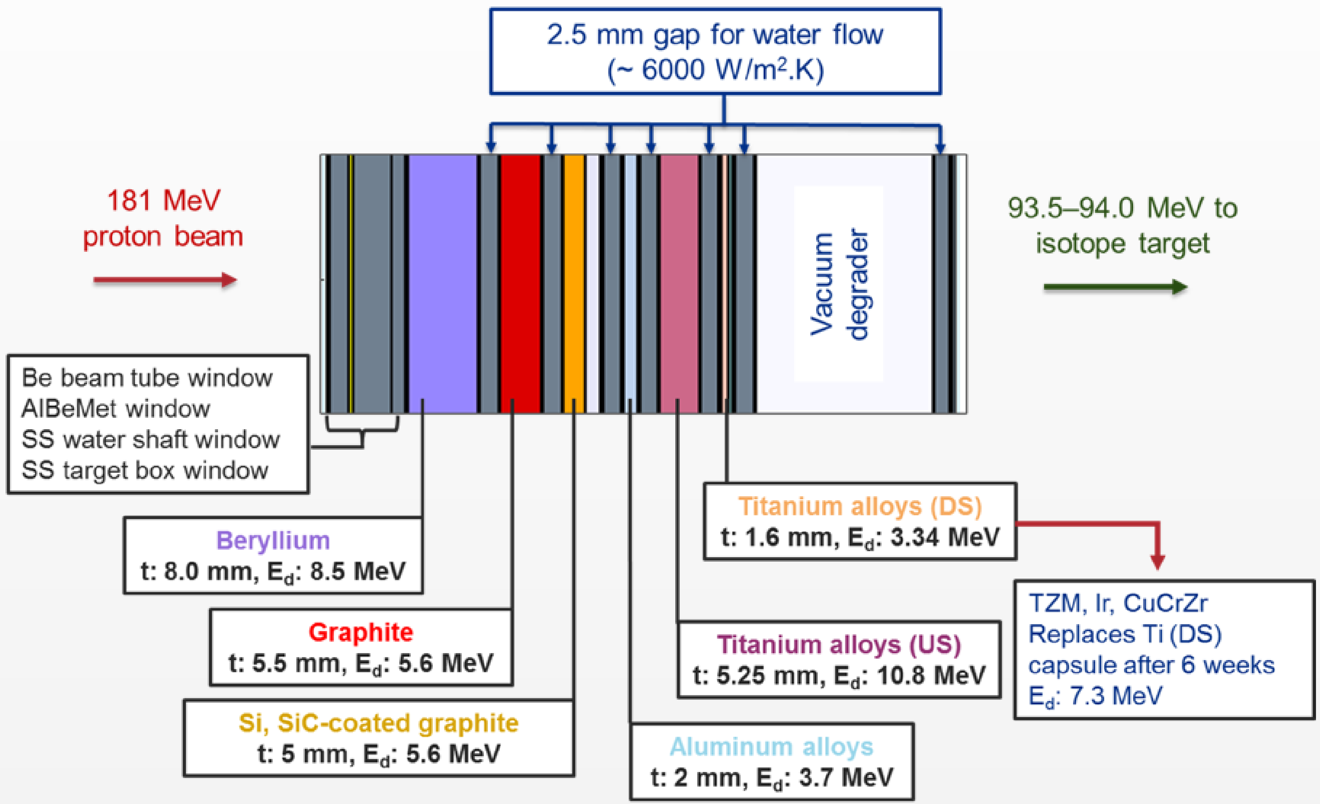
3 6/6/2017 K. Ammigan | High Energy Proton Irradiation Experience and Challenges at BNL BLIP

RaDIATE Irradiation Run (2017)



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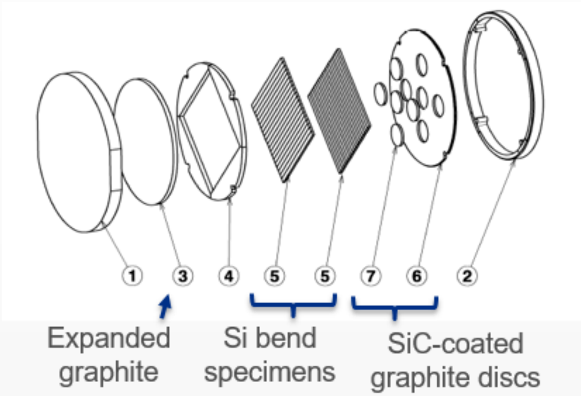
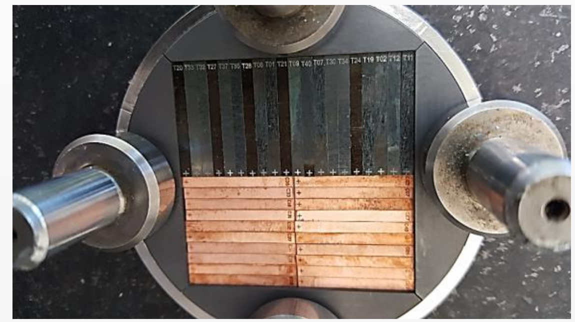
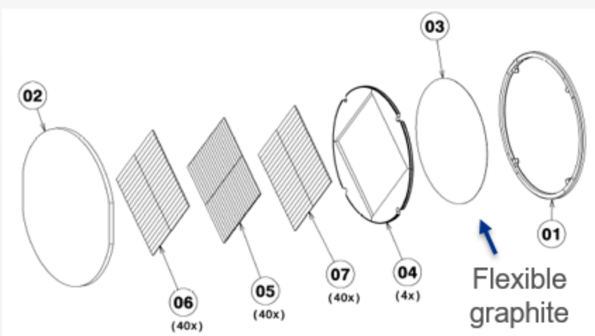
Silicon Capsule (CERN, KEK)



- 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

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HSE-SEE

- ***Ongoing***
  - Organize the hydrogeological study for the area where the BDF will be implemented
  - Flooding risk assessment due to internal and external sources for the BDF and the SHiP experimental hall
  - Helium vessel discussions on possible ways of making it leak tight, and the options between under pressure or over pressure vessel
  - Fire risk analysis for the BDF ventilation compartments as required by the ISO 17873 chapter 7.3 (some data is still needed)
  - Helium release into the atmosphere

- ***Other subjects under discussion***
  - Use of tritium reducer materials in some of the existing infrastructures affected by the BDF connection to the SPS
  - Ventilation and environment emissions optimization for the TT20, TDC2, TCC2, new junction cavern, new transfer tunnel and BDF
  - Definition of a unique hazard list for all PBC projects

F. Pedrosa

Conclusions

- Good progresses on all fronts – starting from BDF Target Complex integration studies
- Important "starting point/agreement" for the design of the hadron absorber magnetisation between BDF WG and SHiP reached
- Target/dump configuration "stabilized", including beam dilution requirement on target
- Material irradiation (TZM) ongoing

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