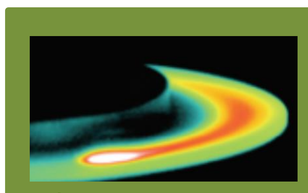

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Last Updates of the R&D Activities for the Redesign of the CERN's AD-Target

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1) INTRODUCTION: THE AD-TARGET

- Antiprotons are produced by the collisions of 26 GeV/c proton beams coming from the CERN Proton Synchrotron (PS) with a **fixed target (the AD-Target**).

Primary beam energy = 26 GeV. Time-averaged power = 1 kW. Pulse power = 11.7 GW

- A redesign of the AD-Target is on-going to guarantee antiproton physics at CERN during next decades.
- Antiproton production requires a very compact target, leading to the use of a **very high density core material** (iridium, ρ = 22.5 gr/cm3) to enhance the interaction with the primary beam in a short length.
- The 3 mm diameter target core made iridium is **subjected to extremely rapid heating (max ΔT=2000 °C in less than 0.5 µs)** and dynamic stresses (several GPa in compression and tension) when impacted by the primary proton beam.

Several R&D activities triggered over the past years to learn about the dynamic response of the target core and to propose a new design

2) PREVIOUS NUMERICAL AND EXPERIMENTAL STUDIES OF THE TARGET RESPONSE TO PROTON BEAM IMPACTS

I. Use of **hydrocodes** for simulating the extreme dynamic response of the target core when subjected to proton beam impacts.

Simulations predicted **fracture of the target core and potentially the graphite containment matrix,** which could eventually lead to a drop of antiproton production yield

II. An **Experiment called HRMT27** exposed several high density materials such as **Ir, W, W-La, Mo, TZM and Ta to equivalent dynamic conditions as reached in the AD-Target** core by using the HiRadMat facility.

Simulations were validated ✓

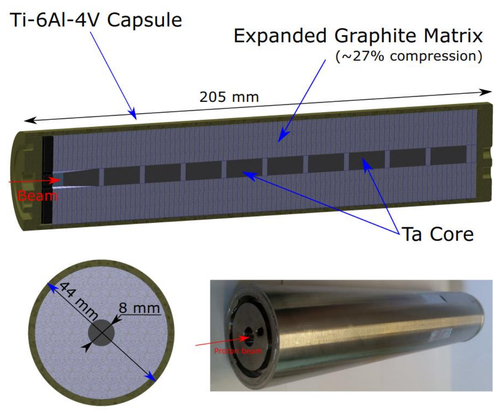
- Most of the materials suffered damage from conditions 7-5 less demanding than the present in the AD-Target
- **Only Ta apparently survived AD-Target** conditions without internally cracking

→ **Ta** became the baseline core material for the new design

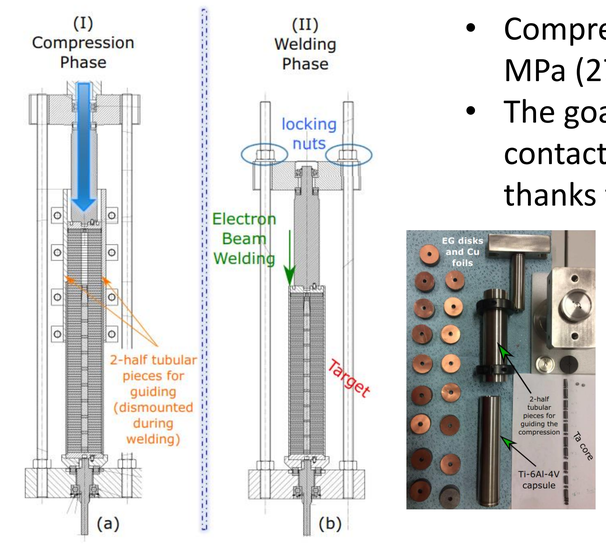
3) HRMT-42 TARGET: A FIRST SCALED TARGET PROTOTYPE

A first scaled prototype of the core and matrix of the target has been built:

- Core of made of ten 8 mm diameter **Ta** rods.
- Embedded in a matrix made of compressed layers of **Expanded Graphite (EG).**
- Encapsulated in a Ti-6V-4Al e-beam welded container.



Manufacturing:



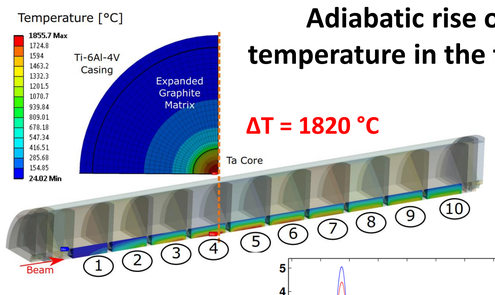
- Compression of the EG graphite up to 30 MPa (27% compression)
- The goal is to guarantee a continuous contact between the Ta core and the matrix thanks to Poisson's effect.

The goal is that EG matrix can adapt to the permanent deformation of the Ta core taking place during operation

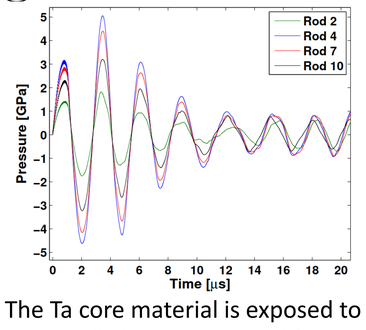
The HIRADMAT-42 Experiment: Testing the target under 440 GeV/c proton beam impacts using the CERN's HiRadMat facility

(exposed to equivalent conditions as reached in the AD-Target facility)

Adiabatic rise of temperature in the target



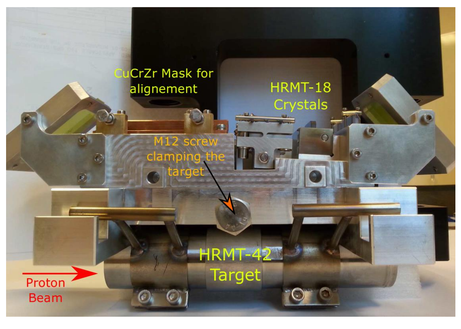
Generated radial wave in the Ta core



Estimation of pressures reached in the Ta core:
5 GPa (compression)
4.6 GPa (tension)

The Ta core material is exposed to stresses well above its the yield strength

Experimental Setup



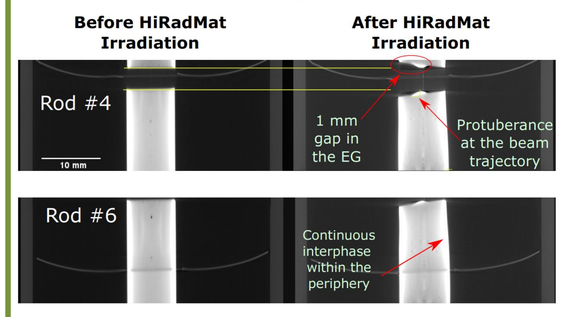
Especially designed robot-friendly clamping system for disassembling the target by just removing one M12 screw

4) NON-DESTRUCTIVE PIE OF THE HRMT-42 EXPERIMENT

Non-destructive Post Irradiation Examinations:

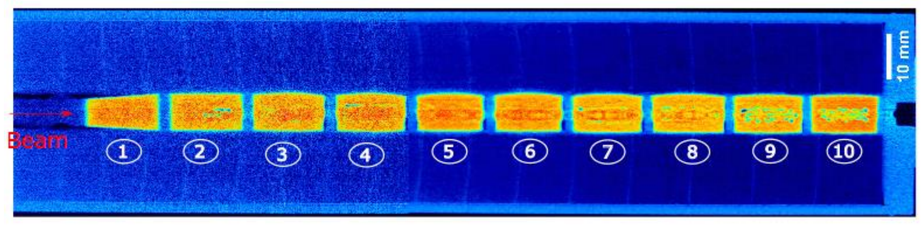
- Complementary approach consisting in:
  - **X-ray Tomography** (at European Synchrotron Radiation Facility) High Resolution, evaluating EG-Ta interface
  - **Neutron Topography** (at Neutra line in Paul Scherrer Institut) Penetration through the Ta core to reveal its internal state

Results X-ray Tomography:

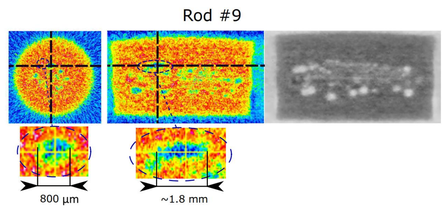


- Extensive plastic in the Ta
- It seems that the EG matrix can adapt to changes in the Ta shape ✓

Results Neutron Tomography:



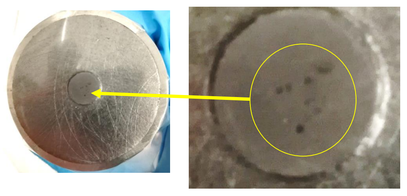
- Neutron tomography shows the formation of voids in the Ta core, especially in the downstream ones.
- These voids did not appear in HRMT-27 experiment (successive plastic deformation may play an important role)
- Voids appear to be similar to "spalling" mode of fracture for Ta described in literature.



→ Further microstructure analysis after target opening will investigate this mode of fracture

5) DESTRUCTIVE PIE OF THE HRMT-42 EXPERIMENT (on-going)

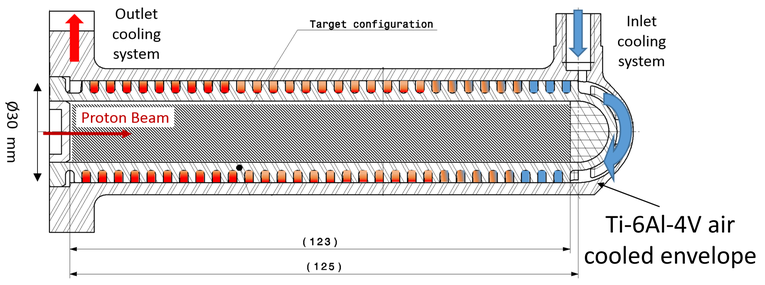
Opening of the target at CERN in a dedicated machine adapted to cut activated material

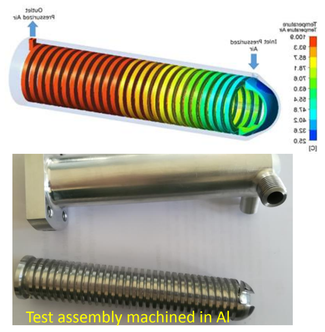


Further PIEs
- Microscope and SEM
- Micro-indentation

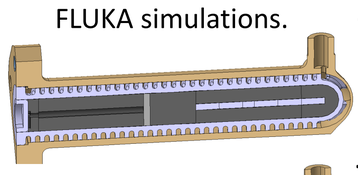
6) PROTAD EXPERIMENT: TESTING REAL SCALE PROTOTYPES

- Real scale prototypes, including a pressurized air cooling system, are currently being manufactured.

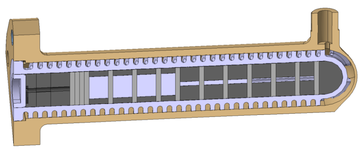




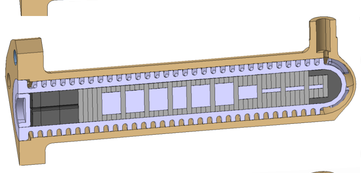
- Six targets with different core and matrixes configurations will be tested under proton beam at the HiRadMat facility in August 2018.
- The core configurations are selected based on pbar optimization studies performed by FLUKA simulations.



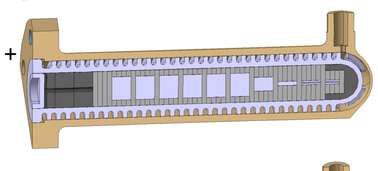
Target 1:
Core: Ø 3 mm Ir
Matrix:
Isostatic graphite



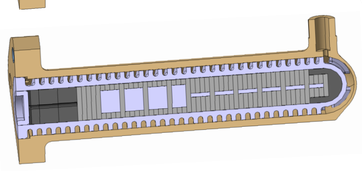
Target 4:
Core: Ø 10 mm Ta2.5W
+Ø 2 mm Ta2.5W
+ Ø 2 mm Ir tube
Matrix: Isostatic graph



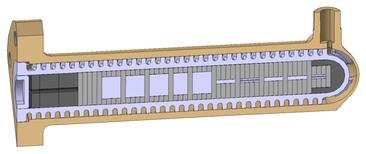
Target 2:
Core: Ø 10 mm Ta +
Ø 2 mm Ir
Matrix:
Compressed EG



Target 5:
Core: Ø 10 mm Ta +
Ø 10 mm W + W-1.1TiC
Ø 10 mm Ir
Ø 2 mm Ta tube
Matrix: Compressed EG



Target 3:
Core: Ø 10 mm Ta
+ Ø 2 mm Ta
+Ø 2 mm Ir
Matrix: Compressed EG



Target 6:
Core: Ø 10 mm Ir
Ø 10 mm Ta +
Ø 2 mm Ta tube
Matrix: Compressed EG

The six targets will be placed in a large Multipurpose Aluminum tank, together with other targets tested in HiRadMat for CERN target applications