

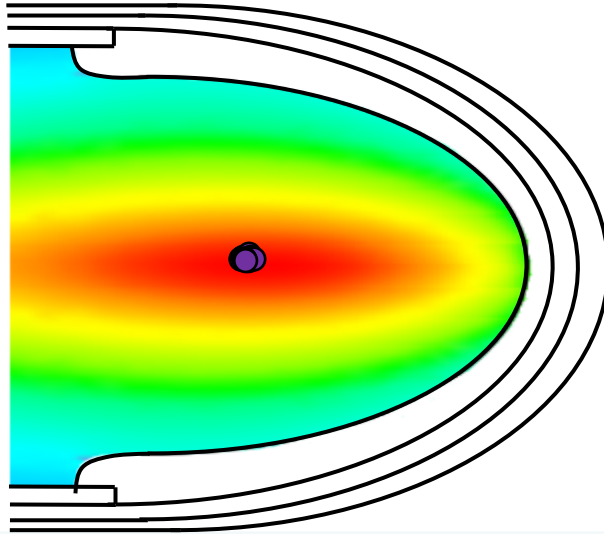


# **Design Modification of ISIS TS2 Target in order to Improve Longevity amid Spallation Reactions**

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# Target Station 2



## Beam Parameters

Frequency	10Hz	$2.5 \times 10^{13}$ proton/pulse
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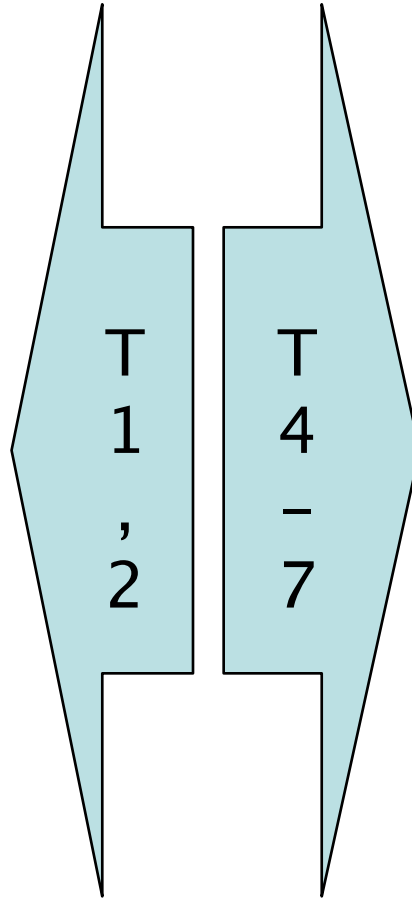
NB: Every 5th pulse goes to TS2

Current	40 $\mu$ A
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Energy	800MeV	$3.24 \times 10^{21}$ proton/year
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Expect	$\sim 10$ neutrons per proton
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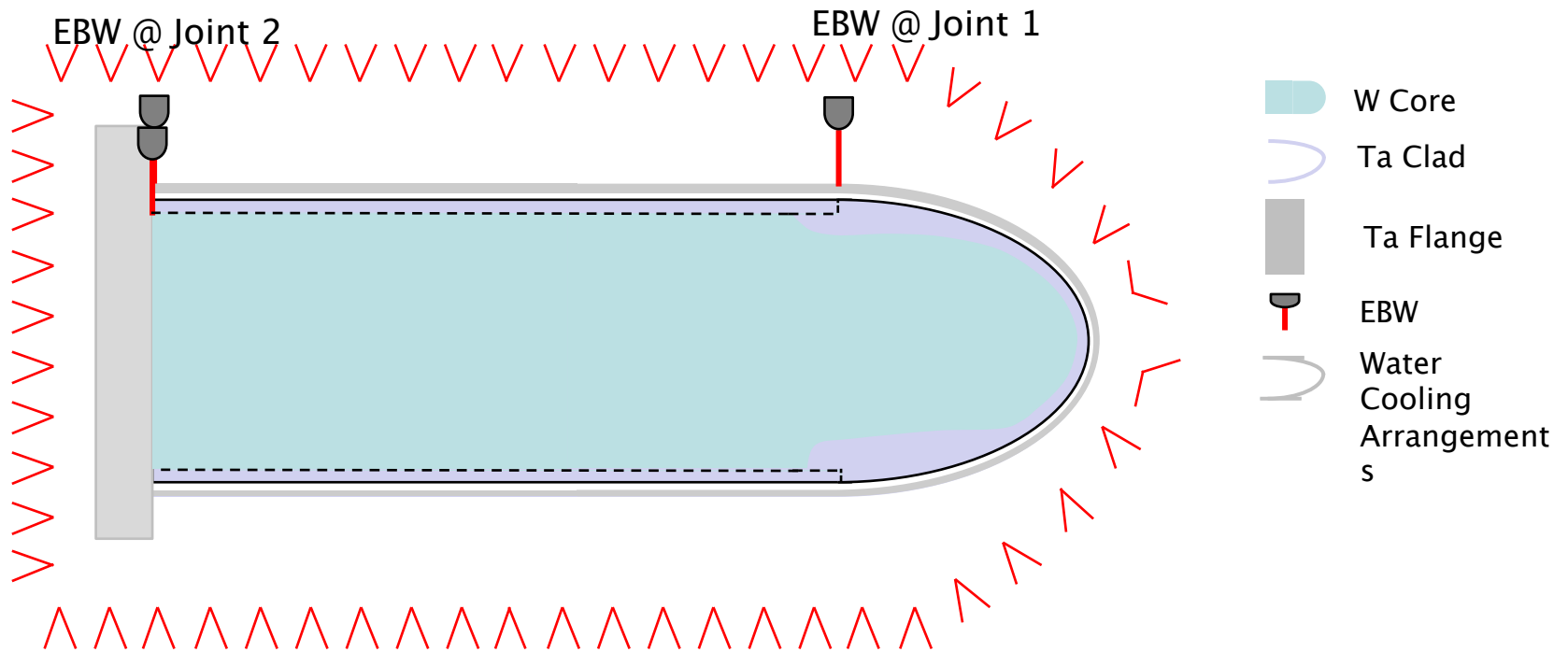
MK I



MK IIa



# Target Manufacturing Process (Target 4-7, MK IIa)



# Problems Encountered

The ISIS TS2 targets fail around 1 - 1.5 years of use. The aim is to achieve 5 years of service life

## MK IIa Design

- \*  **$\gamma$  spectral analysis:** Radioactive isotopes in the cooling water.  $^{172}\text{Lu}$ ,  $^{175}\text{Hf}$ ,  $^{182}\text{Ta}$ ,  $^{187}\text{W}$
- \* **Water leaks** during operations

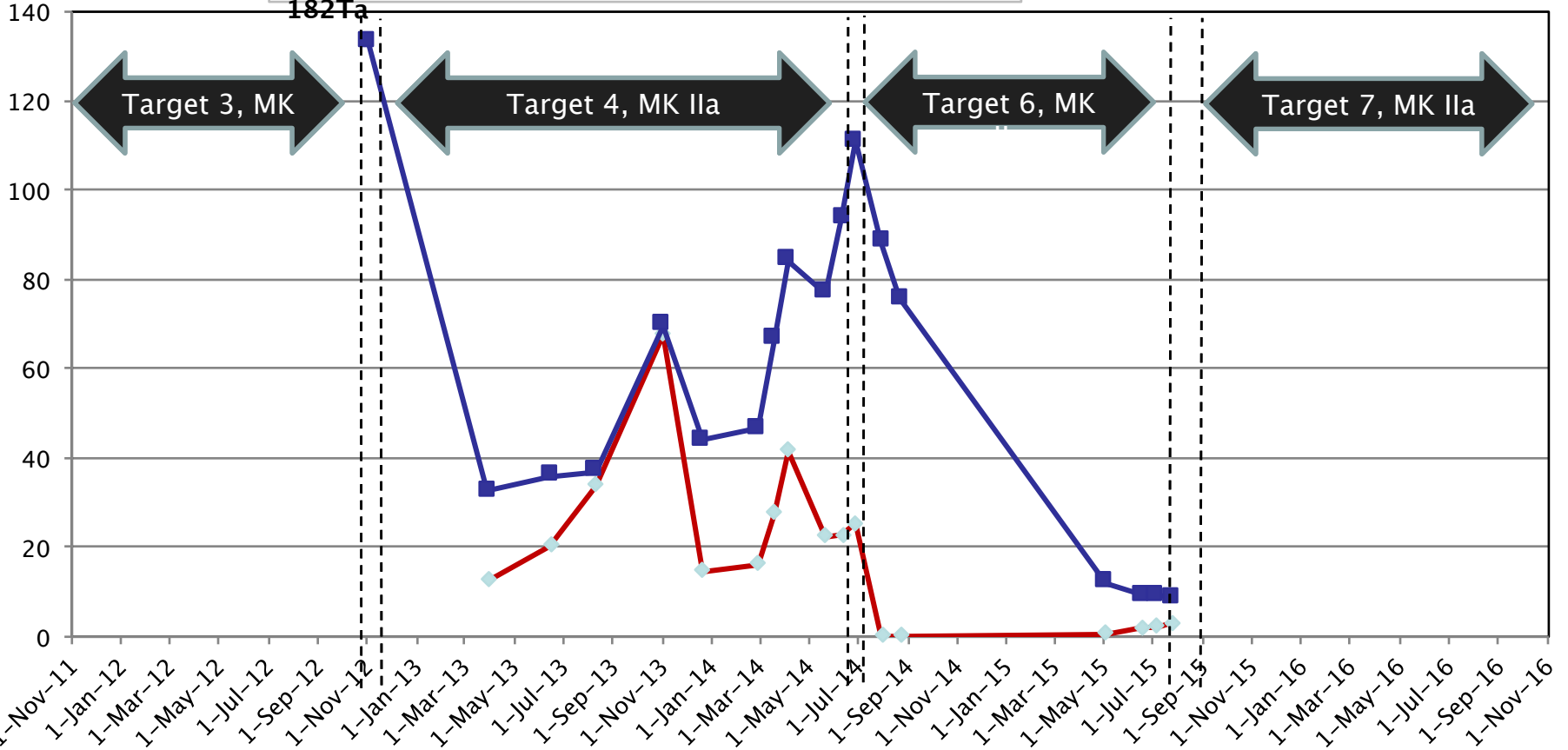
## MK I Design

- \* **Intergranular corrosion** due to lack of cooling



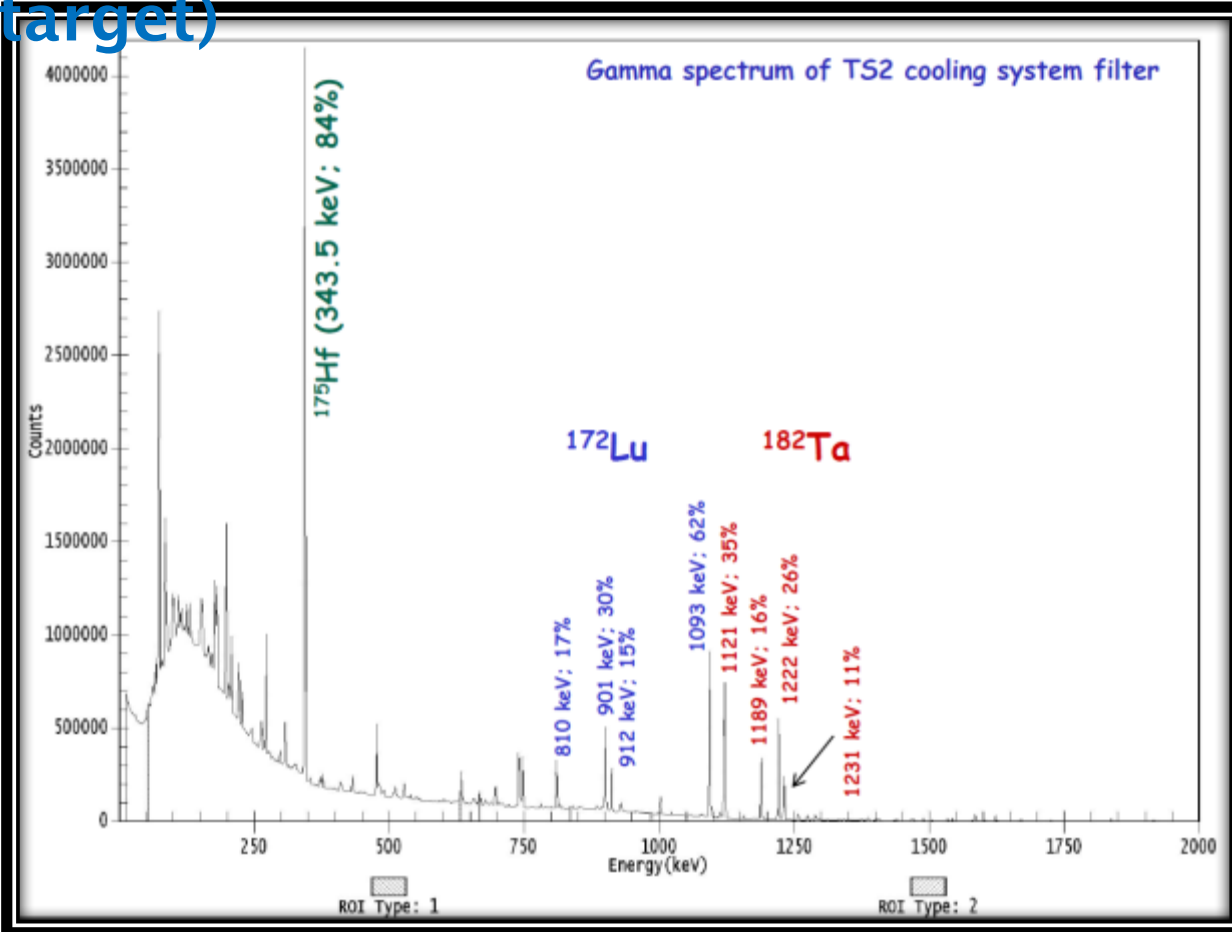
# Target Lifetime

Gamma Spectral Analysis vs. time for 187W and 182Ta



Target No.	3	4	6
Design	MKII	MKIIa	MKIIa
Days Run	297.4	266.8	123
Tptal mAH	208.3	229.7	101.8
Pulses	$1.8 \times 10^8$	$2.07 \times 10^8$	$0.9 \times 10^8$
Failure mode	High radiation level in water cooling/ ion exchange column	High radiation level in water cooling/ ion exchange column	Water leak

# γ spectral analysis (of cooling water after failure of a target)



(Comparison of intensity of gamma-lines):

- activity of  $^{175}\text{Hf}$  is higher than activity of  $^{182}\text{Ta}$  ;
- activity of  $^{172}\text{Lu}$  is below activity of  $^{182}\text{Ta}$ .

Monte Carlo simulations:

- activity of  $^{175}\text{Hf}$  is higher than activity of  $^{182}\text{Ta}$  (in Tungsten);
- activity of  $^{175}\text{Hf}$  is two orders of magnitude lower than activity of  $^{182}\text{Ta}$  (in Tantalum);
- activity of  $^{172}\text{Lu}$  is below activity of  $^{182}\text{Ta}$  (in Tungsten);
- activity of  $^{172}\text{Lu}$  is two orders of magnitude lower than activity of  $^{182}\text{Ta}$  (in Tantalum).

Conclusion:

Comparison of the gamma spectrum with Monte Carlo simulations strongly indicates that some radioactive isotopes in the TS2 water cooling system is predominantly Tungsten.

We look for **W187 signature** in the water which is a clear indication of **water in contact with W**.



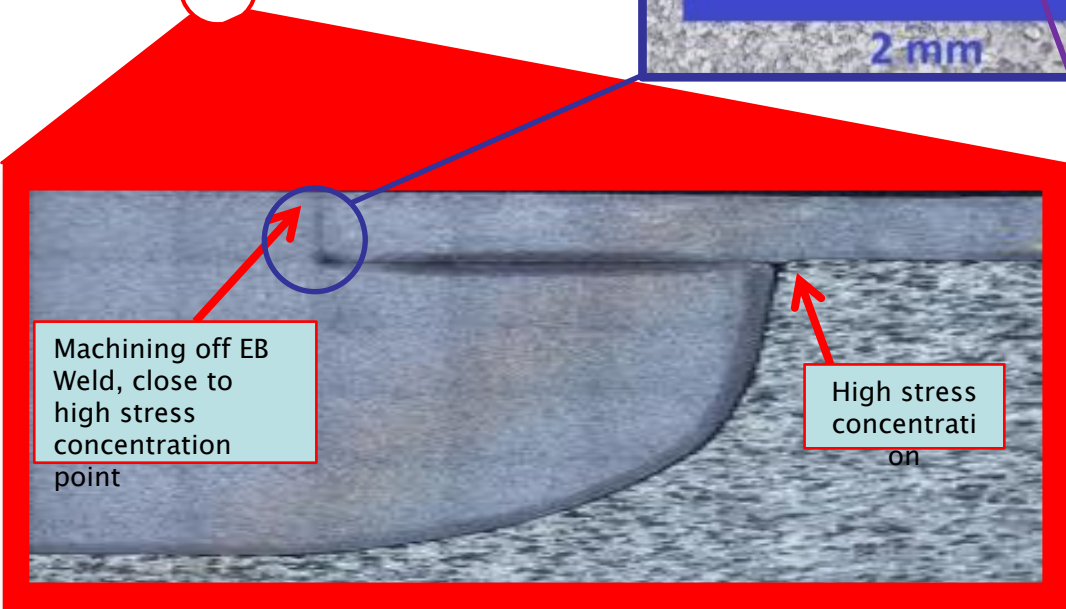
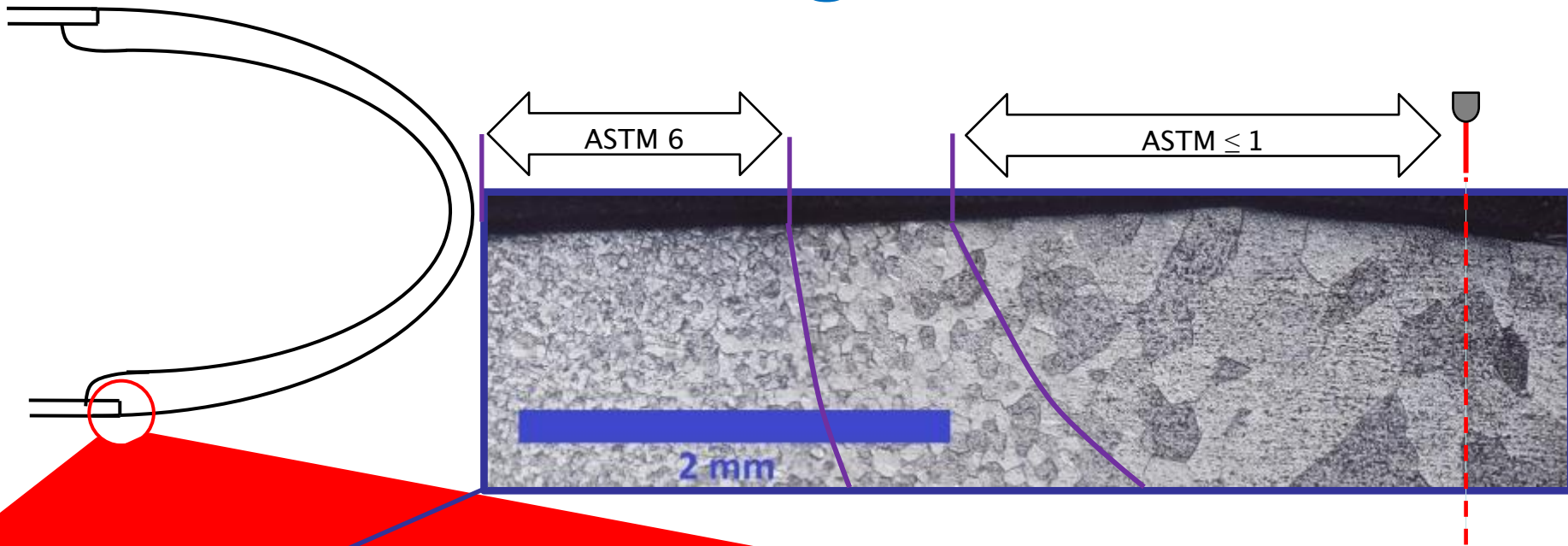
# Key modification in Target 7

In order to ensure a full circumferential weld on the previously manufactured target, a re-welding operation was carried out on the **current Target**.





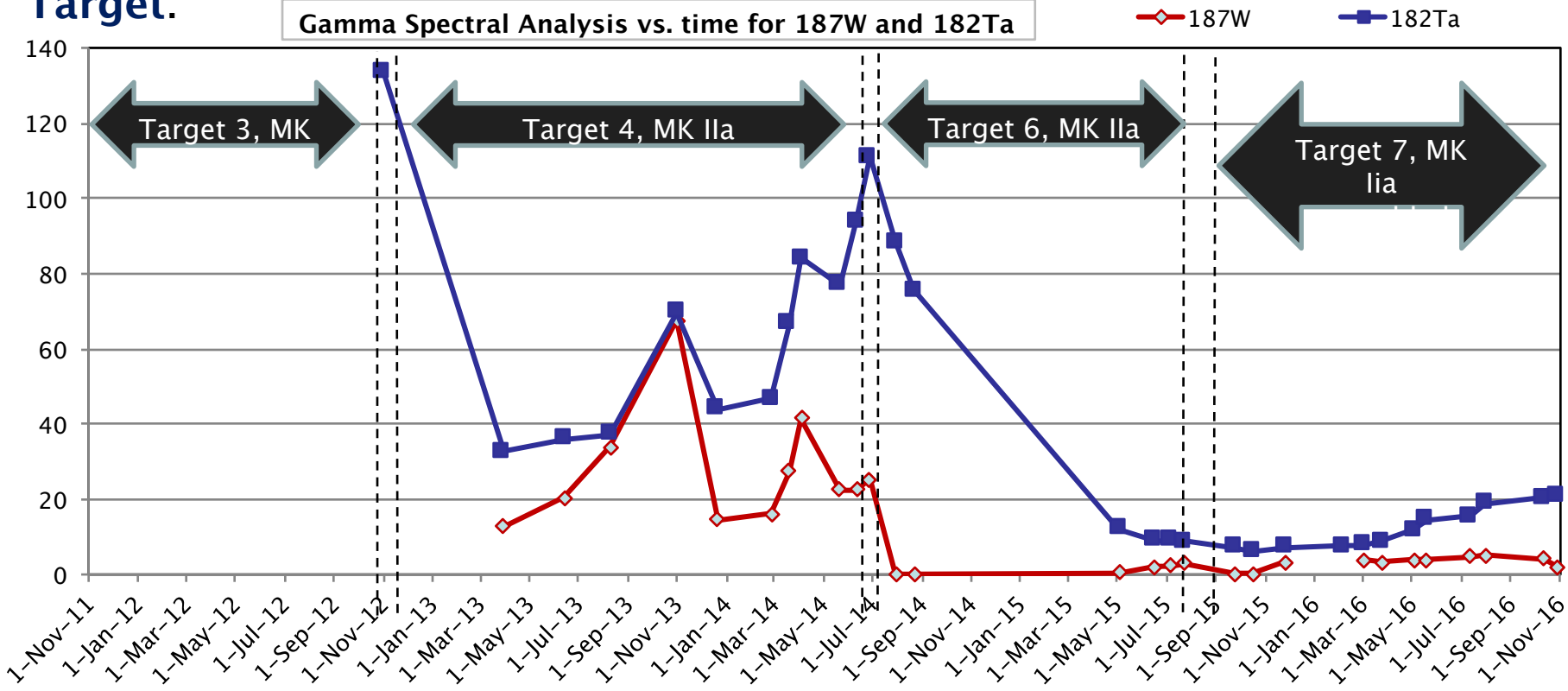
# Ta Cladding – EBW



# Result: Key modification in Target 7

In order to ensure a full circumferential weld on the previously manufactured target, a re-welding operation was carried out on the **current Target**.

Gamma Spectral Analysis vs. time for 187W and 182Ta

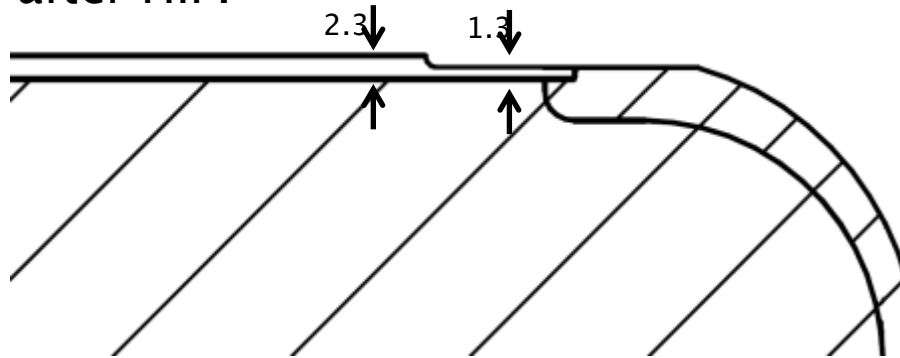


Target No.	3	4	6	7
Design	MKII	MKIIa	MKIIa	MKIIa + EBW
Days Run	297.4	266.8	123	234
Tptal mAH	208.3	229.7	101.8	192.7 (estimated)
Pulses	$1.8 \times 10^8$	$2.07 \times 10^8$	$0.9 \times 10^8$	$1.73 \times 10^8$
Failure mode	High Radiation level in water cooling/ ion exchange column	High Radiation level in water cooling/ ion exchange column	Water leak	still in use

# Key modifications for future Targets

## MK IIa\*

- For all of the future targets, the material thickness at the weld joint is reduced down to 1.3mm from 2.3mm. Only 0.3mm material to be removed after HIP.

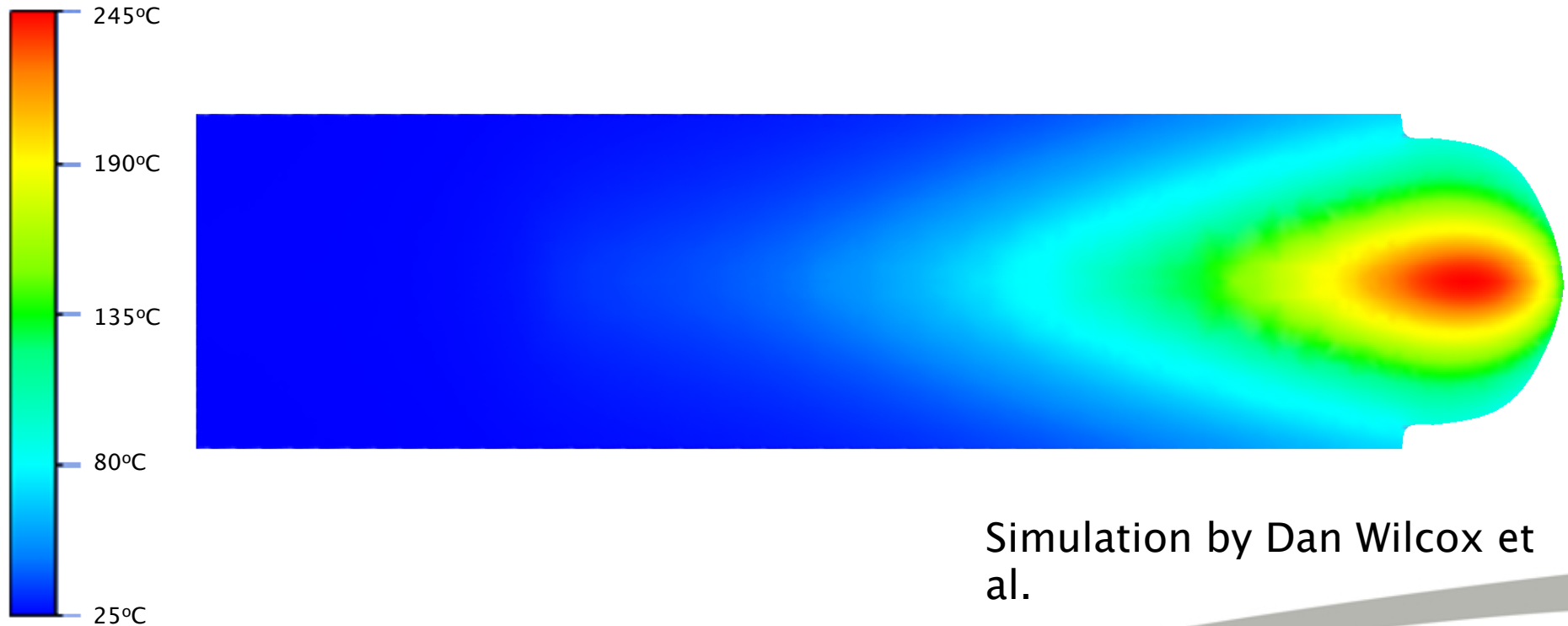


- Multi-pass weld using 15 - 30mA (900-1800W power).
- EBW by Focusing the electron beam below the surface.
- A rotation of the electron beam is used during welding.



# Further improvement Scheme

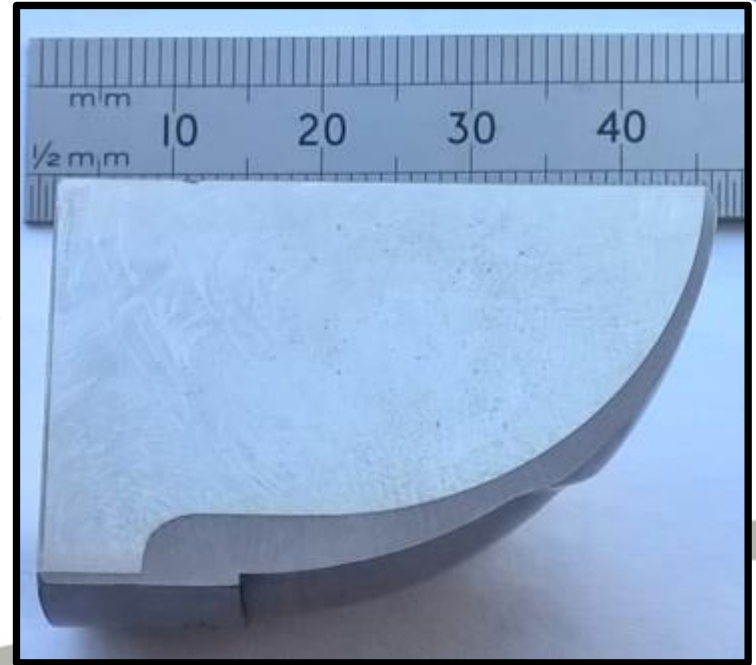
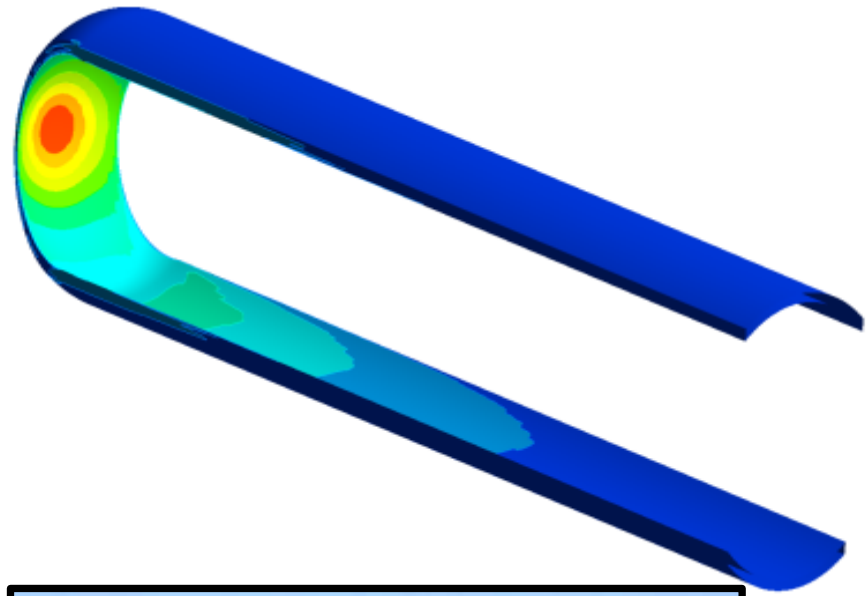
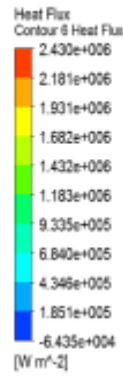
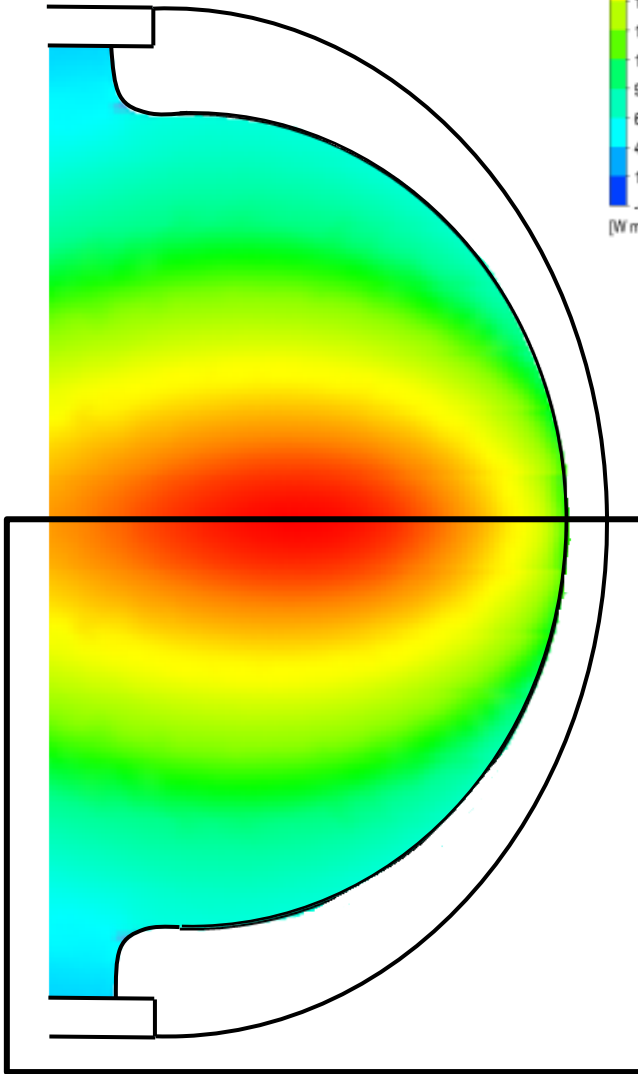
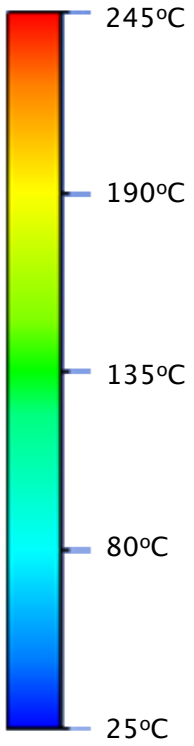
Improvement of the heat transfer at Target nose

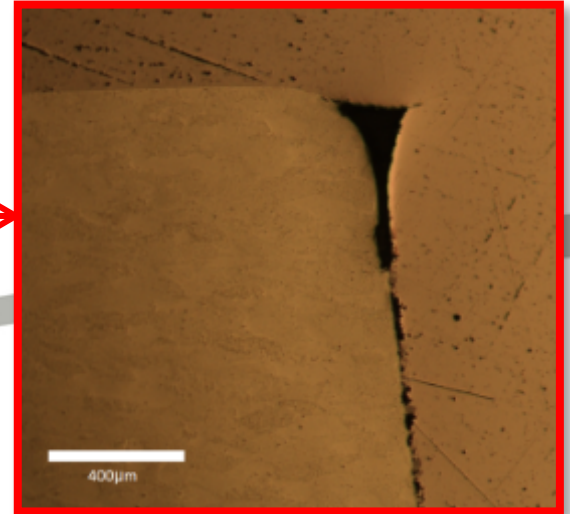
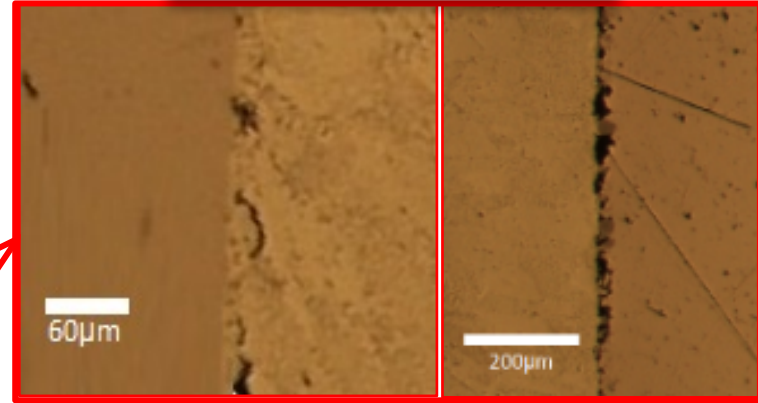
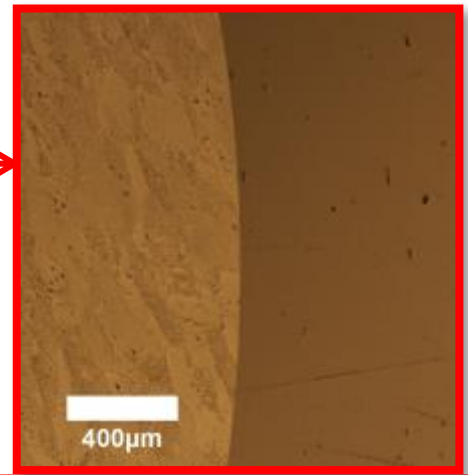
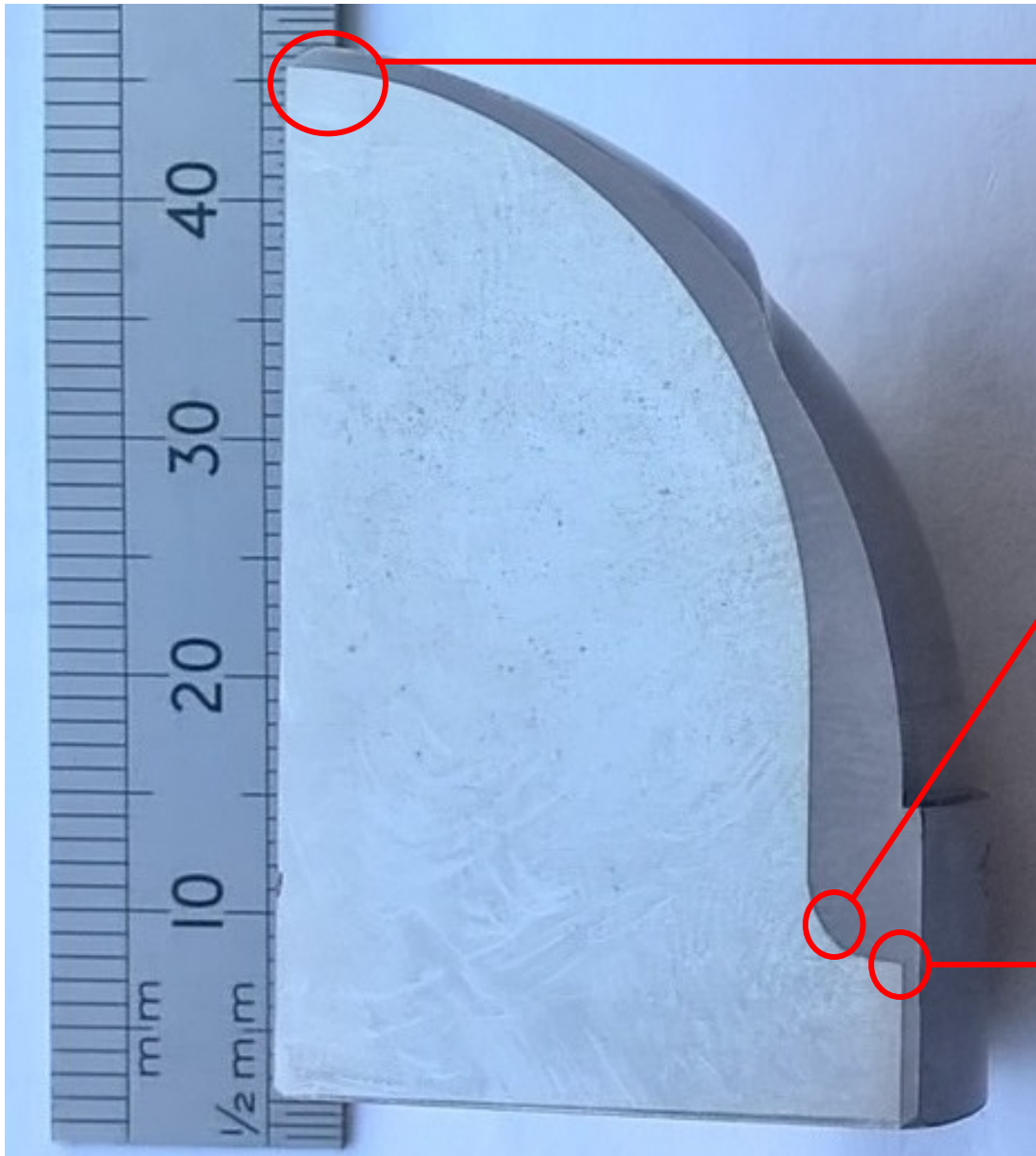


Simulation by Dan Wilcox et al.



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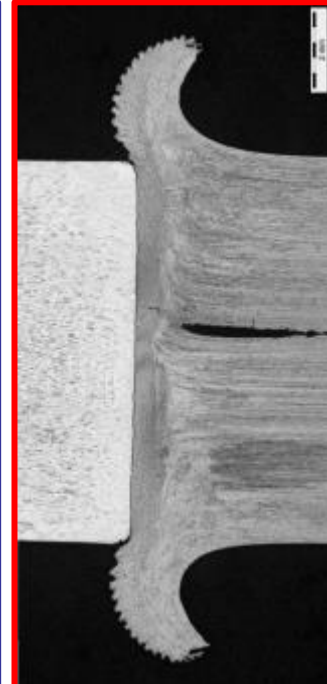
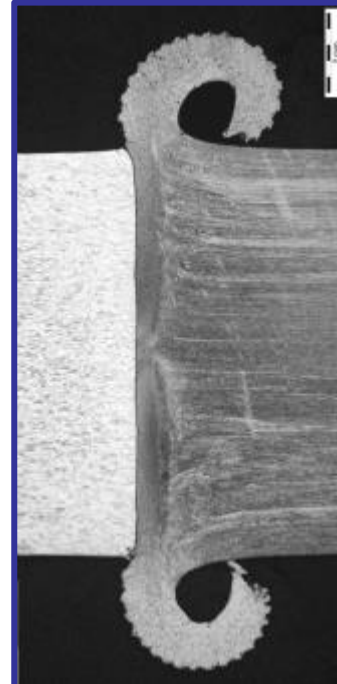
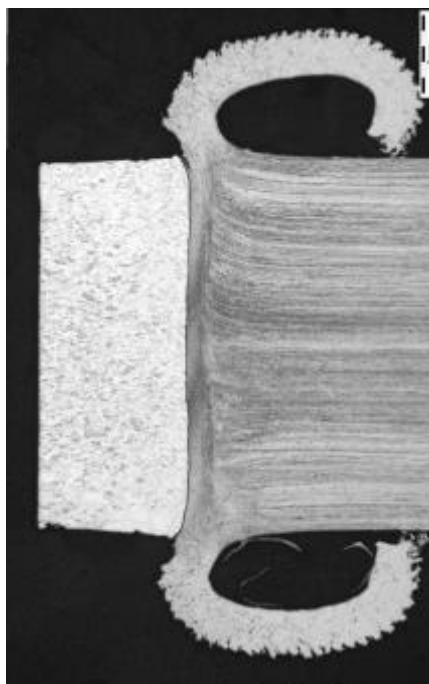
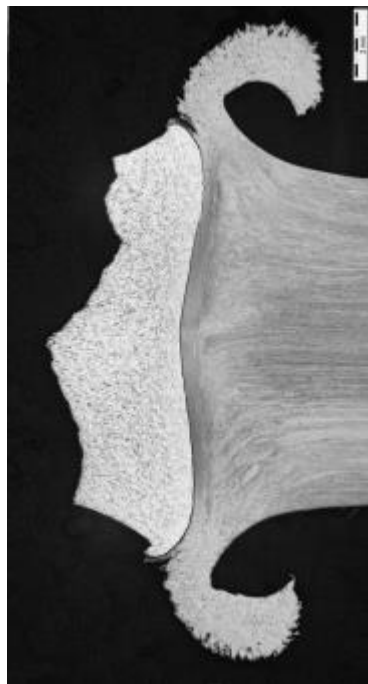
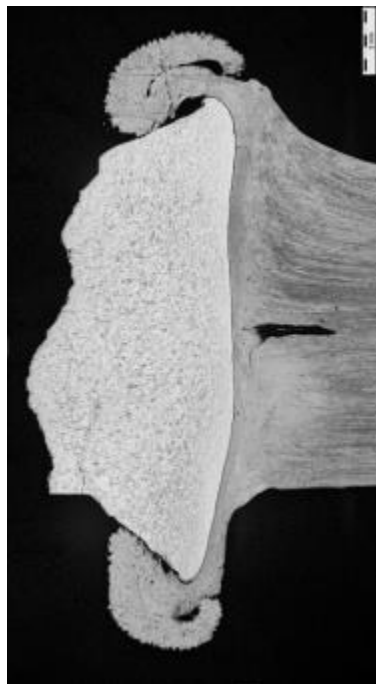
Heat flow at the nose of the target is another area of concern in order to improve the longevity of the targets. Although the nose itself is appeared to have a good interfacial contact. But some voids or broken W was found in the surrounding interfacial area.

- Improvement R&D work (ongoing)
  - (a) RFW at the front cap – nose of the core
    - (Concerns: weldability W-Ta, stress, grain growth, Oxide generation etc.)
  - (b) Cold spray of Ta at 800–1000°C
    - (Concerns: adherability of Ta on W, W substrate fracture, surface treatments, Oxide generation entrapment of impurities etc.)



# RFW for the front cap

## - R&D stage



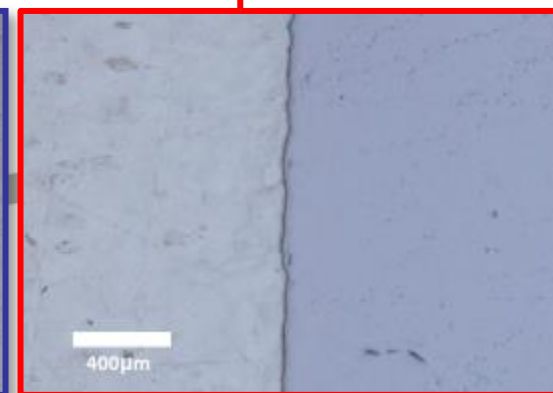
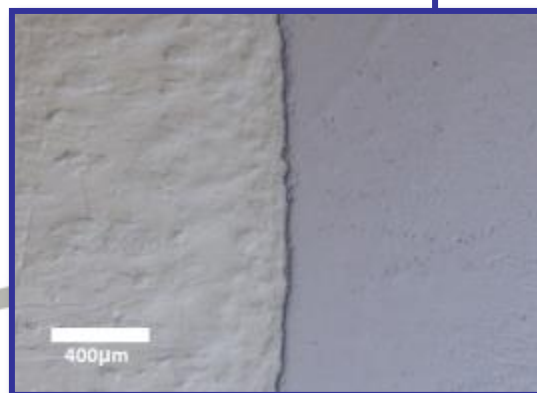
Trial 1

Trial 2

Trial 3

Trial 4

Trial 5





# RFW for the front cap - Evaluation

Tensile test:

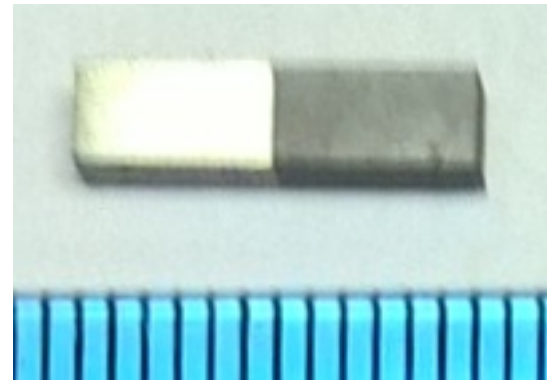


UTS at the weld  $>120$   
 $\text{N/mm}^2$

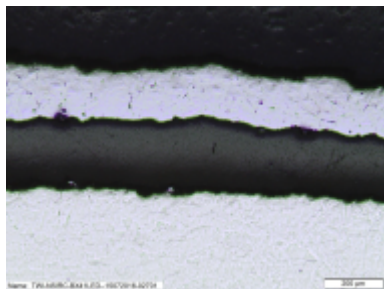
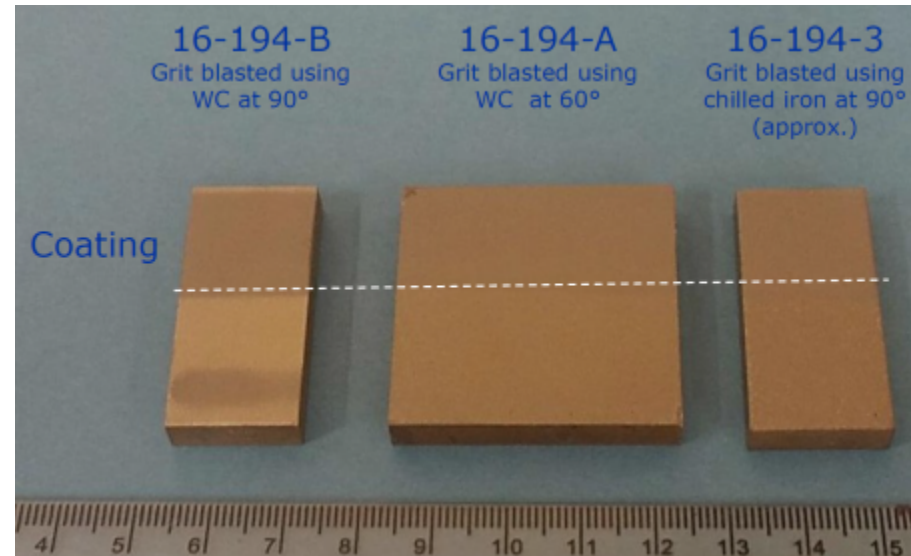
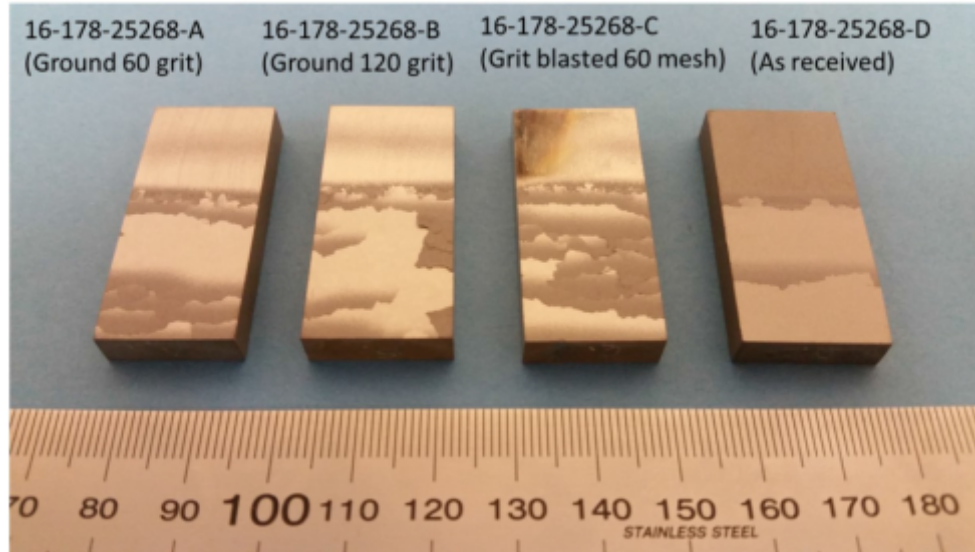
Interfacial Resistance  
test:

(Planned)

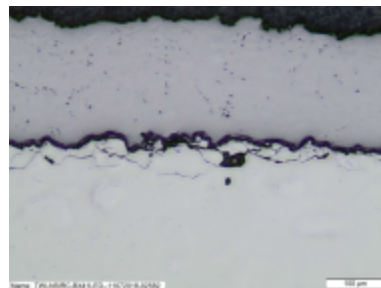
- Electrical resistance
- Thermal resistance



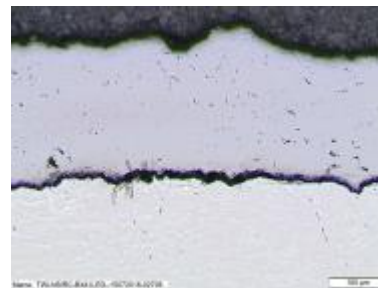
# Cold Spray - R&D stage



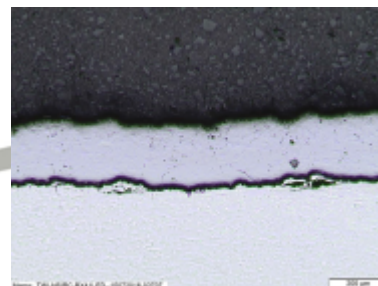
16-194-3



16-194-B



16-194-A



Delamination  
Pores  
Broken substrates



# Conclusions

- EB welds are the area of interest in order to improve poor Target lifespan.
- A re-welding on the EBW spots has shown a positive impact on the  $^{187}\text{W}$  pickup by cooling water
- Heat flow at the nose of the target is another area of concern in order to improve the longevity of the targets.
- Improvement R&D work
  - (a) RFW at the front cap – nose of the core
  - (b) Cold spray



# Thank you



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