



WPJET2: Status and Next steps (2021 - XX)

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This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.



Status



- **The original scope of WPJET2 (2014) has been vastly broadened by new projects: (i) identified research needs, (ii) own ideas; (iii) ITER needs/requests.**
- **The majority of work has already been done or it is a very advanced stage.**
- **Most results have been published or submitted/prepared for publication.**
- **The remaining part (*not big but important for the project*) can only be done once laboratories are fully operational.**
- **The essential point is the availability of the Beryllium Handling Facility at JET where materials after sampling (cutting) are stored and then distributed to respective labs.**



Network of 13 laboratories working with PFCs and tokamakium containing Be and T.

Laboratories: 12 in EU and cooperation with IFERC within Broader Approach

- **Great human capital: experience and expertise.**
- **Developments (2014 – 2020) which extended research capabilities:**
 - *Sectioning (cutting) of metal PFCs (> 1000 samples)*
 - *Complex logistics system (shipment, sample book-keeping).*
 - *TDS and LID systems.*
 - *Chambers, detectors, use of D beam for IBA → C quantification on Be.*
 - *MEIS and LEIS systems.*
 - *In-situ systems: Ion irradiation and analyses, heating, exposure to gas.*
 - *Chemical methods in analyses.*
 - *All types of microscopy methods.*
 - *IFERC: Methods not available in EU.*
 - *Extended list of tritium analyses techniques.*
 - *Softwares for processing of IBA data*

WPJET2 Status: Completed and very advanced topics



1. *Summary/overview data for all campaigns:
Be limiters, W/CFC tiles, W bulk lamellae, Inner Wall Cladding, wall probes, dust*
2. *Advanced studies of bulk W lamellae (Tile 5) after all campaigns.*
3. *Preparation and use of reference samples /targets for TDS.*
4. *Dedicated programme on thermal desorption leading to cross-check and comparison of TDS and IBA methods.*
5. *Completed studies of dust and metal splashes.*
6. *Advances in analyses of properties of bulk W and Be.*
7. *Langmuir probes: material damage and nano-hardness.*
8. *Tritium analyses methods in/on bulk W and Be tiles and in dust.
Also in cooperation with Japan (IFERC) under umbrella of Broader Approach.*



Ongoing Tasks (covid-related delays)



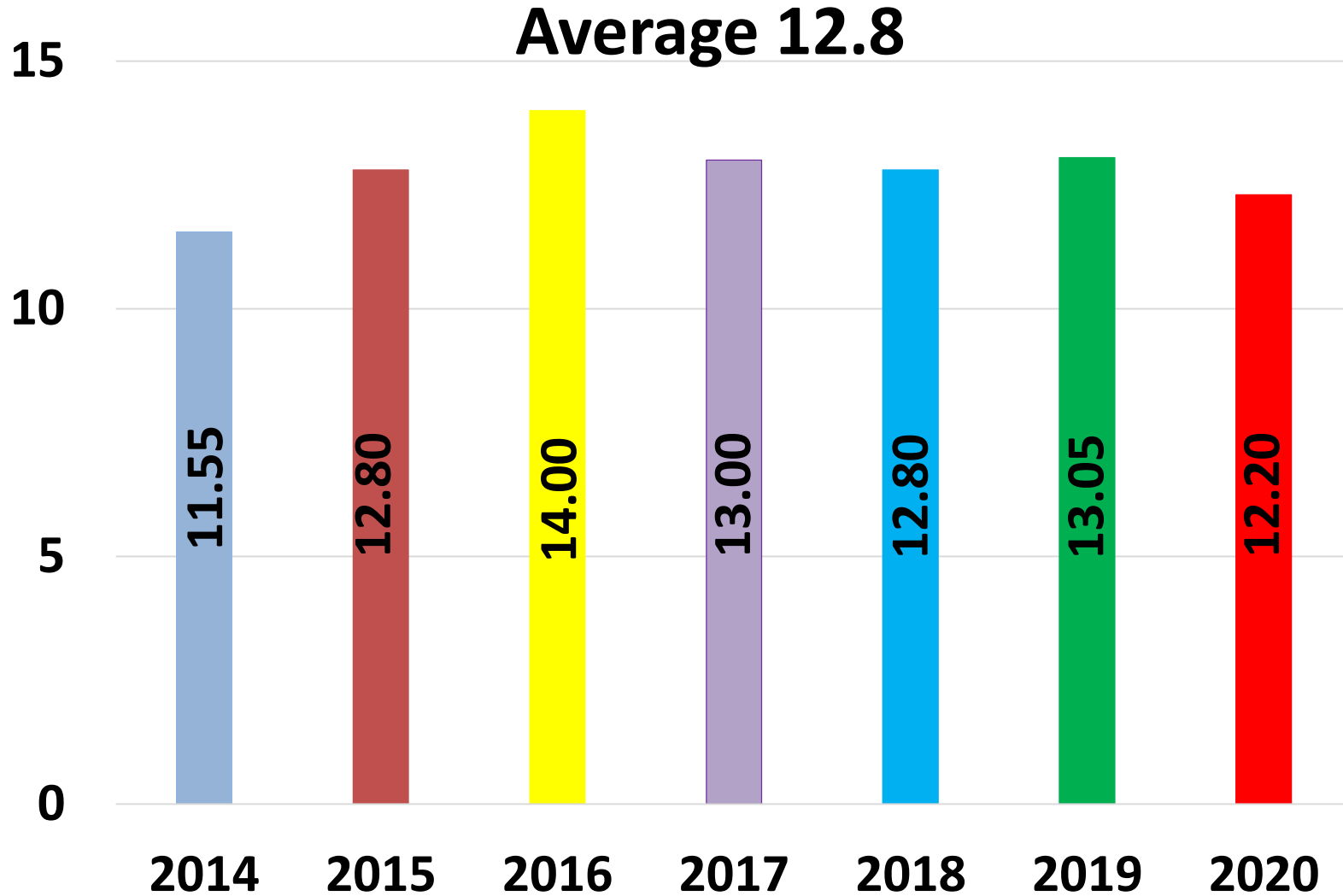
- Finishing of TDS and LID experiments.**
 - *Tiles*
 - *D and He implanted (reference) Mo targets.*

- Finishing of Mechanical characterisation of Langmuir probes.**

- Analyses of Be limiter facing all three campaigns.**

- Plasma-assisted mirror cleaning.**

Budget (PPY): 2014 - 2020





Future

JET-PFC under PWIE



Proposed JET Projects and Tasks in PWIE: 2021 - XX

Projects and tasks listed below do NOT stem from any delays in JET2.

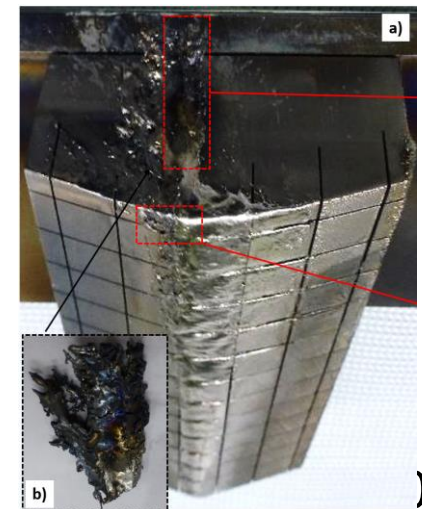
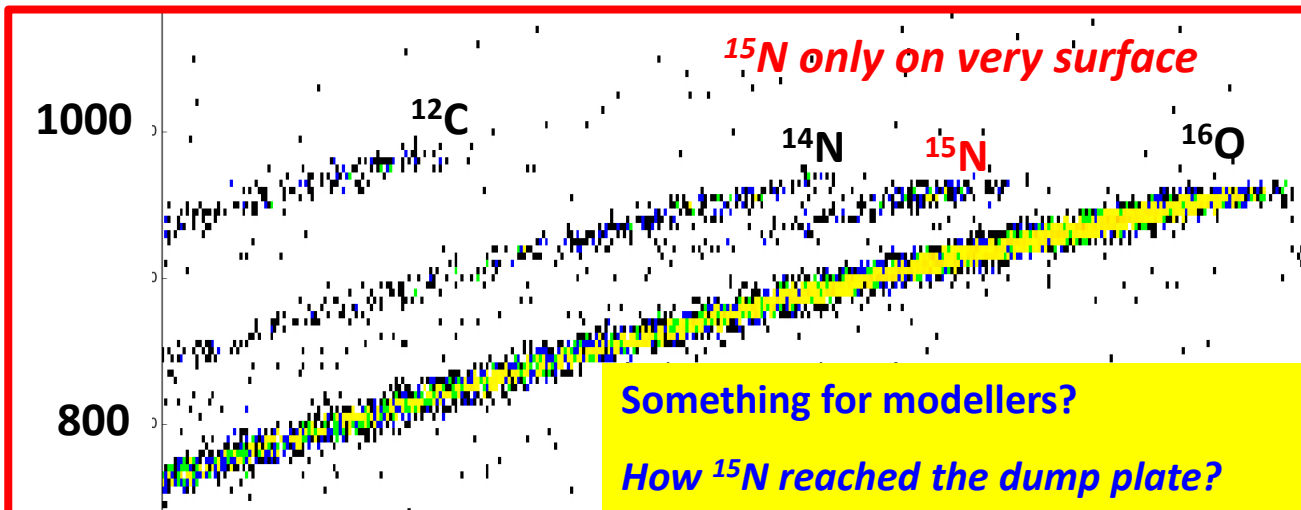
They represent:

- *Logical continuation of tasks started only in 2019-2020.*
 - *New ideas linked to research needs and opportunities (apparatus development).*
- **Impact of ion-induced damage (pre-irradiation) on fuel retention:** *pre-damaged mirrors are already in JET (voluntary CCFE and VR action).*
 - **Deposition monitors inside JET:** *a large number installed (voluntary from CCFE, IPP, VR)*
 - **Tungsten:** *Damage and surface state of Langmuir probes, 15 pieces (ITER, DEMO)*
 - **Beryllium:** *Damage of limiters (ITER)*
 - **Beryllium:** *Water and steam impact on dust generation (ITER)*
 - **Beryllium Dust:** *Accumulation in the JET torus ventilation filters (ITER)*
 - **Tritium analyses** *(Expertise for JET, ITER, DEMO)*
 - **Long-term retention in Be (W):** *Re-analyses of selected PFC*
 - **Cross-check of TDS and IBA:** *Further perfection of analytical approach*
 - **Modelling:** *Dust and metals transport to remote areas (and other topics)*

Modelling of Material Migration: Data available



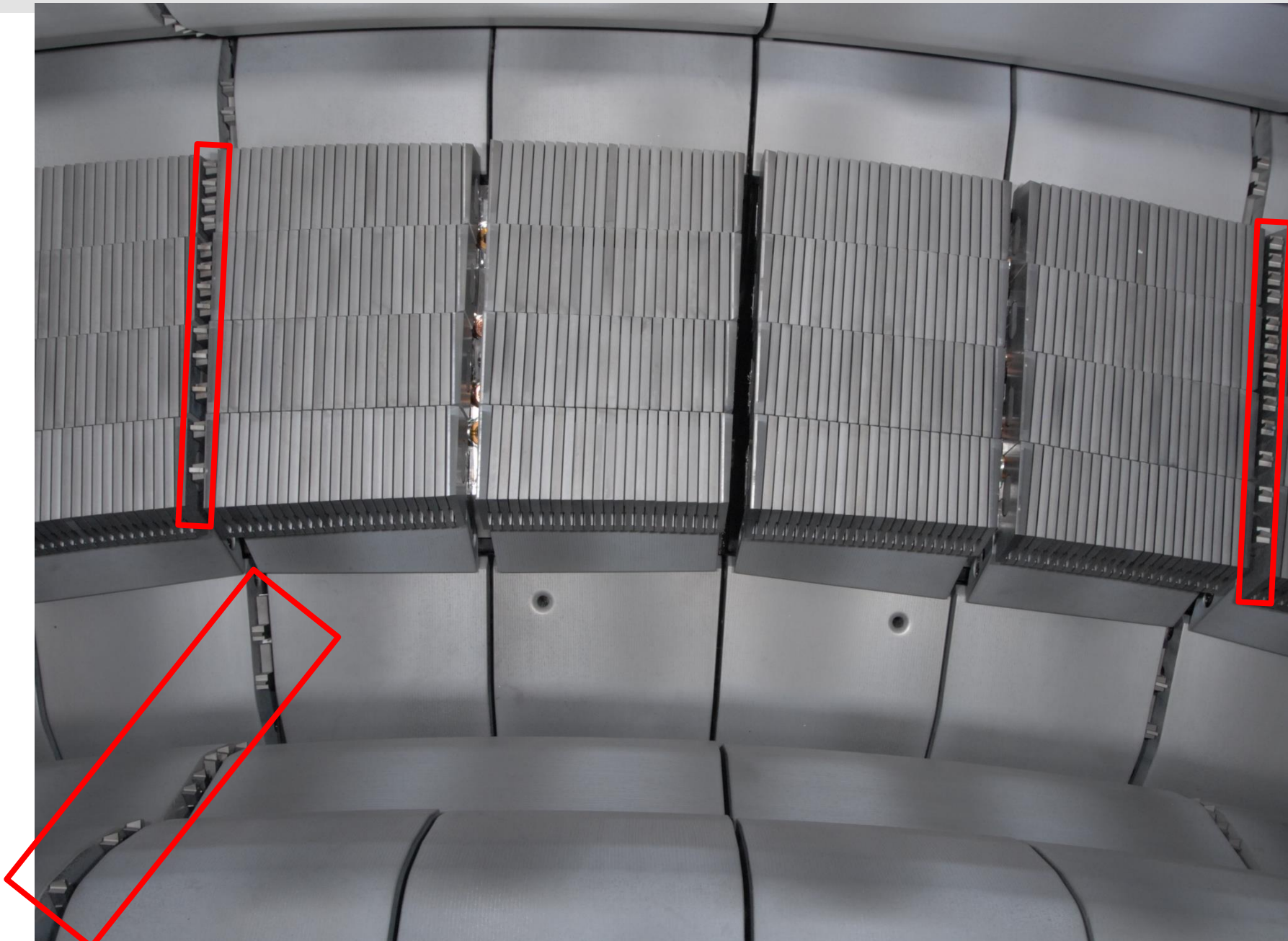
- Louvre clips, spatial blocks, rotating collectors: **data not modelled.**
- Transport of metals (Be, W) to shadowed zone in divertor: **not modelled.**
- Transport inside channels of cassettes for test mirrors: **not modelled.**
- **Dust:**
 - *Be droplets and splashes after run-away electron generation,*
 - *Tungsten ball-like structures formed from W flakes,*
 - *Dust transport to shadowed regions in the divertor.*
- **Transport of N to upper limiters of JET, tracer ^{15}N . (*Ne may behave similarly*).**





Cordial thanks for the whole JET2 Team

JET Projects and Tasks in PWIE: 2021 - XX

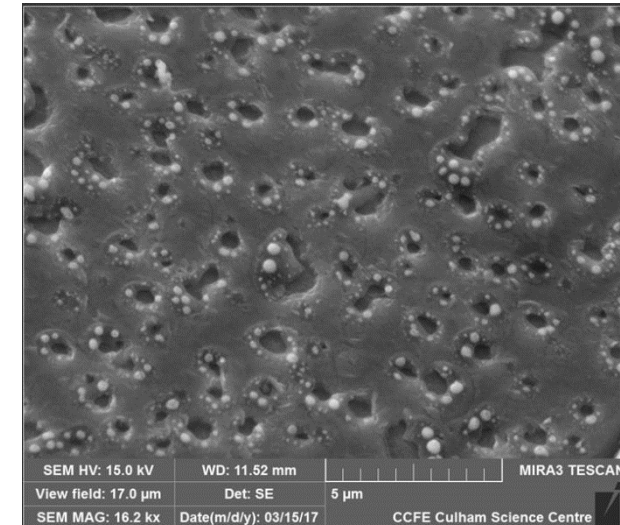
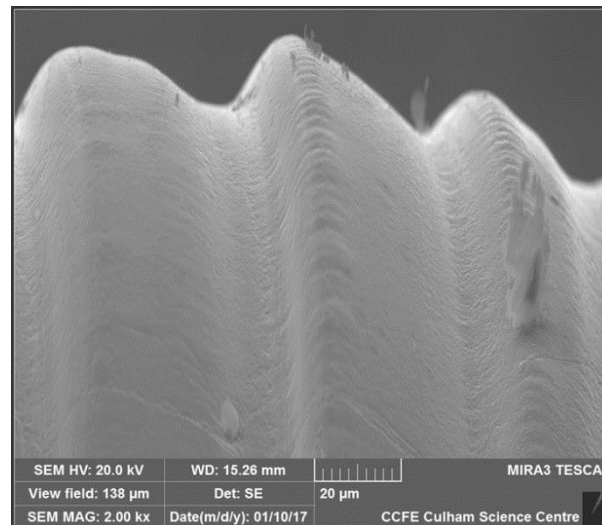
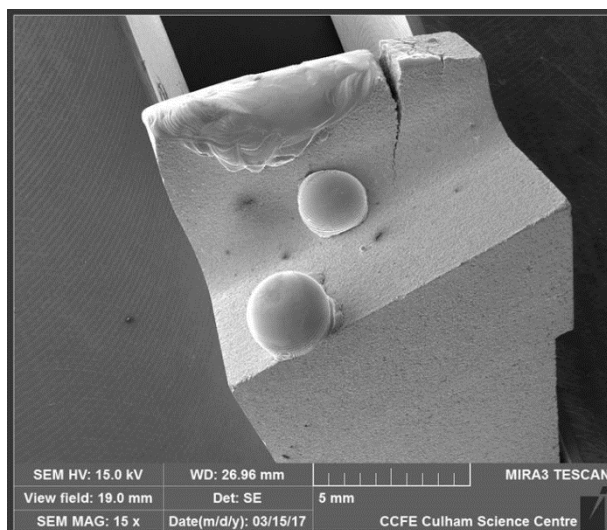
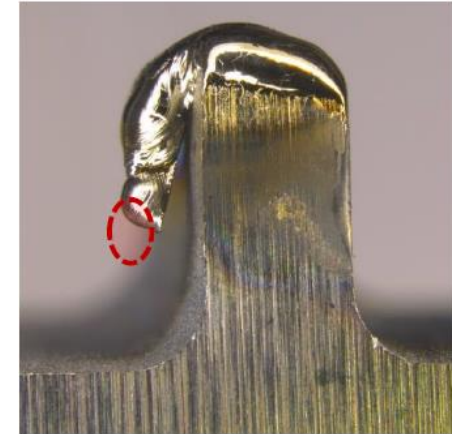




Tungsten:

Langmuir probes which are the most relevant to determine mechanical and structural properties/modification:

- Nano-indentation
- Micro-indentation
- Metallography
- X-ray diffraction
- SEM/EDX (FIB/TEM)
- IBA for co-deposits (deposition in gaps between tiles)



Mo Ion-damaged mirrors



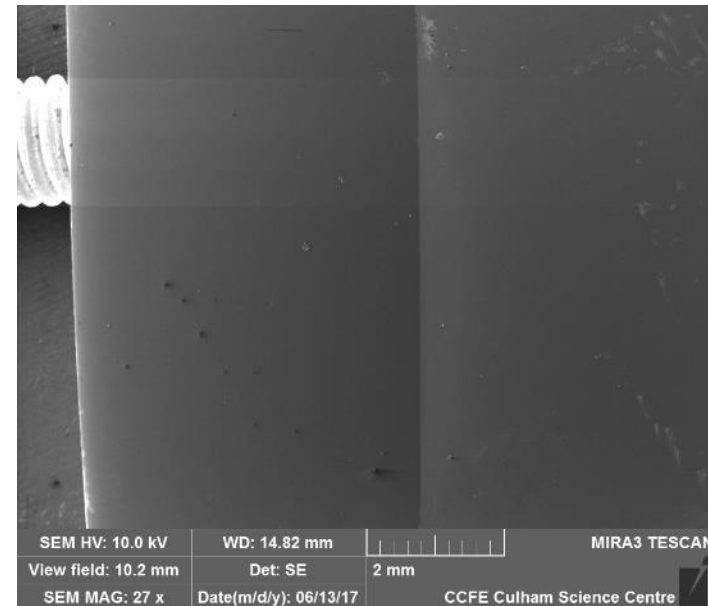
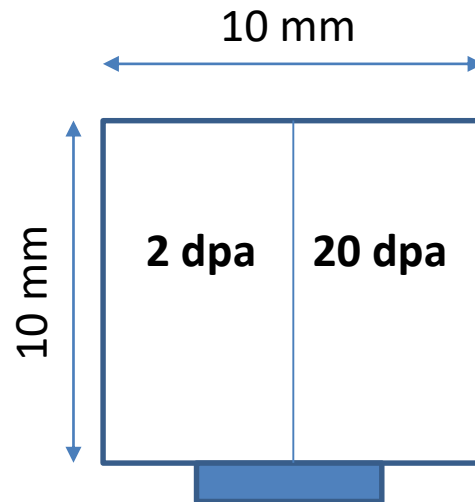
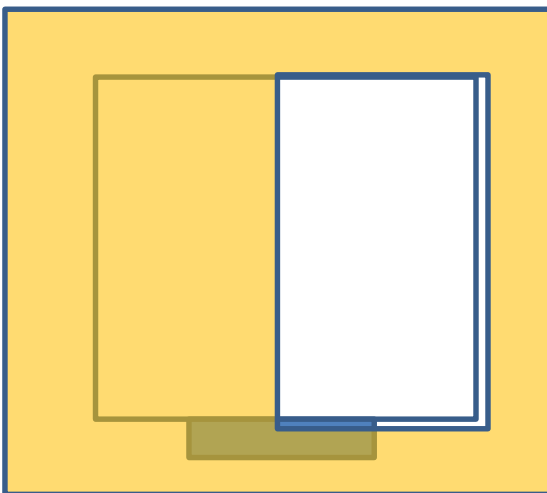
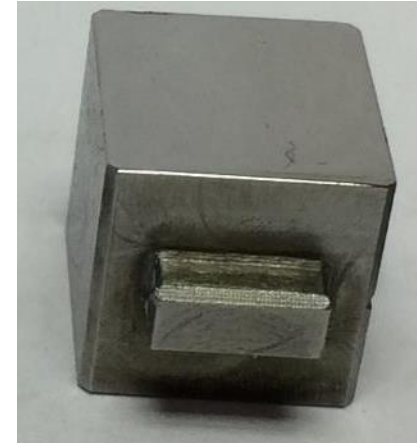
Task: Assess impact of radiation damage on fuel retention.

Installation of ion-damaged mirrors in the main chamber.

Mo mirrors irradiated with $^{98}\text{Mo}^{3+}$ to 2 dpa and 20 dpa.

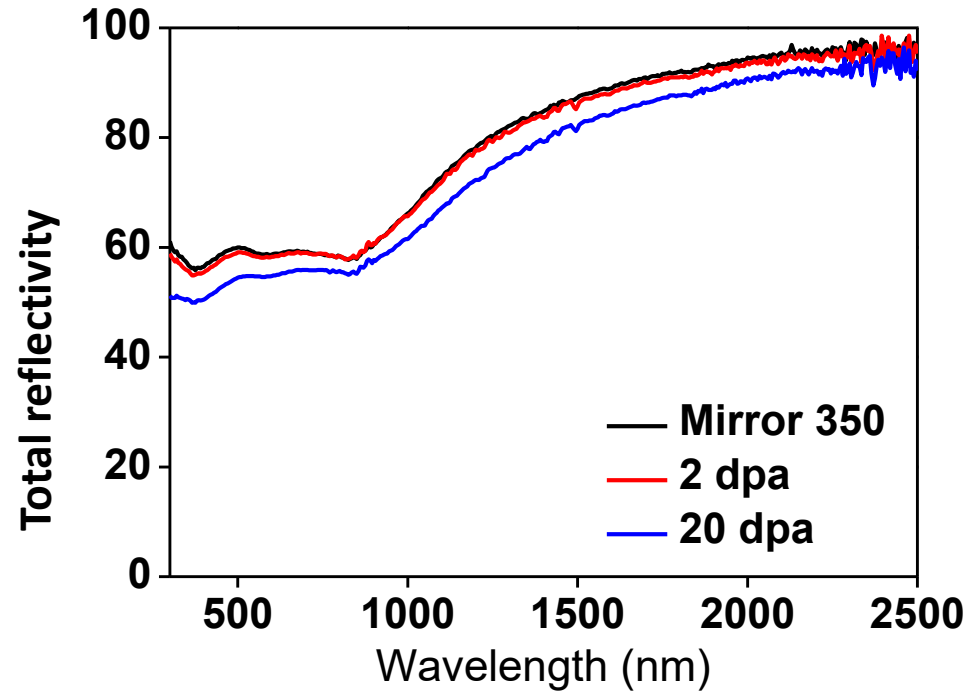
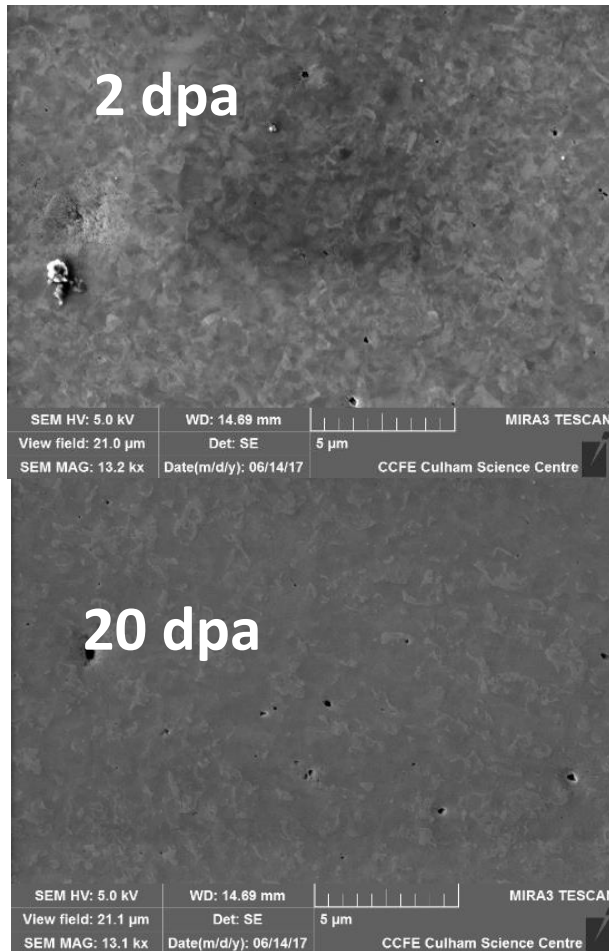
Uniform damage up to $0.3\ \mu\text{m}$ with 1.6 MeV ions.

2 dpa whole surface + 18 dpa 5 mm x 10 mm





- Optical pre-characterisation: total and diffuse reflectivity.
- Microscopy.



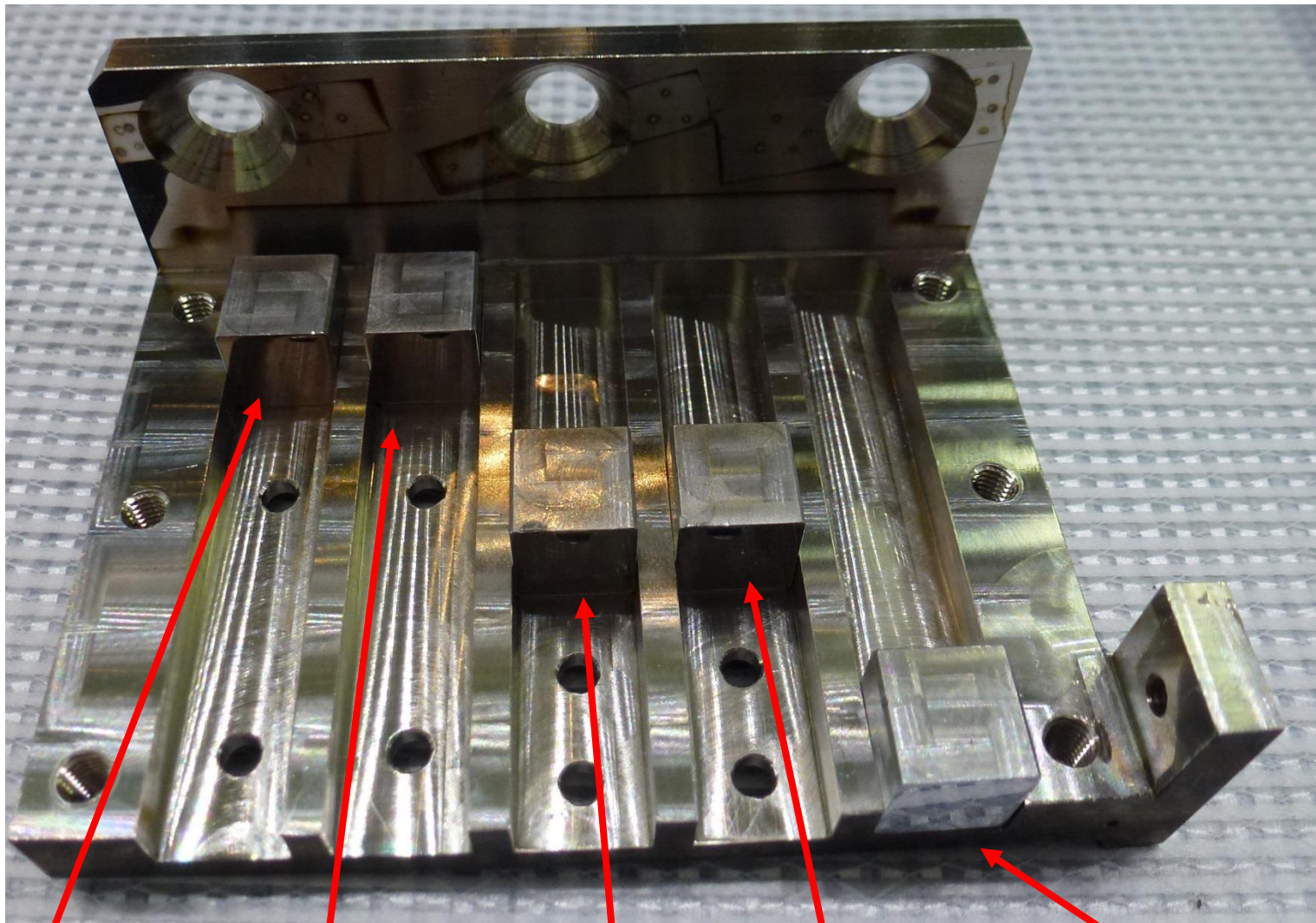
Total reflectivity decreased by 5-10% at 20 dpa

Diffuse reflectivity increase at 20 dpa:

UV and VIS range: 1.5 % -> 3.0 %

NIR range: 0.2% -> 1.0%

Mirror cassette installed at 4B outer wall location



354: 2 dpa/20 dpa

357: mirror

353: 2 dpa/20 dpa

356: mirror

352: 2 dpa/mirror



EXTRA

WPJET2: Grant Deliverables in WP 2019-2020



Ref.	Title	Due Date	Forecast	Comments
1	Manufacture and application of calibration samples to facilitate H, D and T measurements by Thermal Desorption Spectroscopy: preparation of implanted metal samples with H, D, He.	Sep.19	Methodology is known. Work requires manufacture of metal mirror surfaces, coating with W and implantation.	Manufacture - Done 2020 Experiments – ongoing
2	Determination of the impact of moisture on dust generation (in the case of water leaks into a reactor).	Jun.20	Methodology in studies is being prepared.	Ongoing (covid impact) Coherent results obtained in two labs
3	Complete set of results on material migration in three JET-ILW campaigns. Provide the final report on characterisation of PFCs, wall probes and dust after ILW-operation	Dec.20	All probes are available for studies. The number is greater than after earlier shutdowns. Preparation of samples (cutting) will be completed only by October 2019.	Ongoing in good pace covid impact on sending materials from BeHF



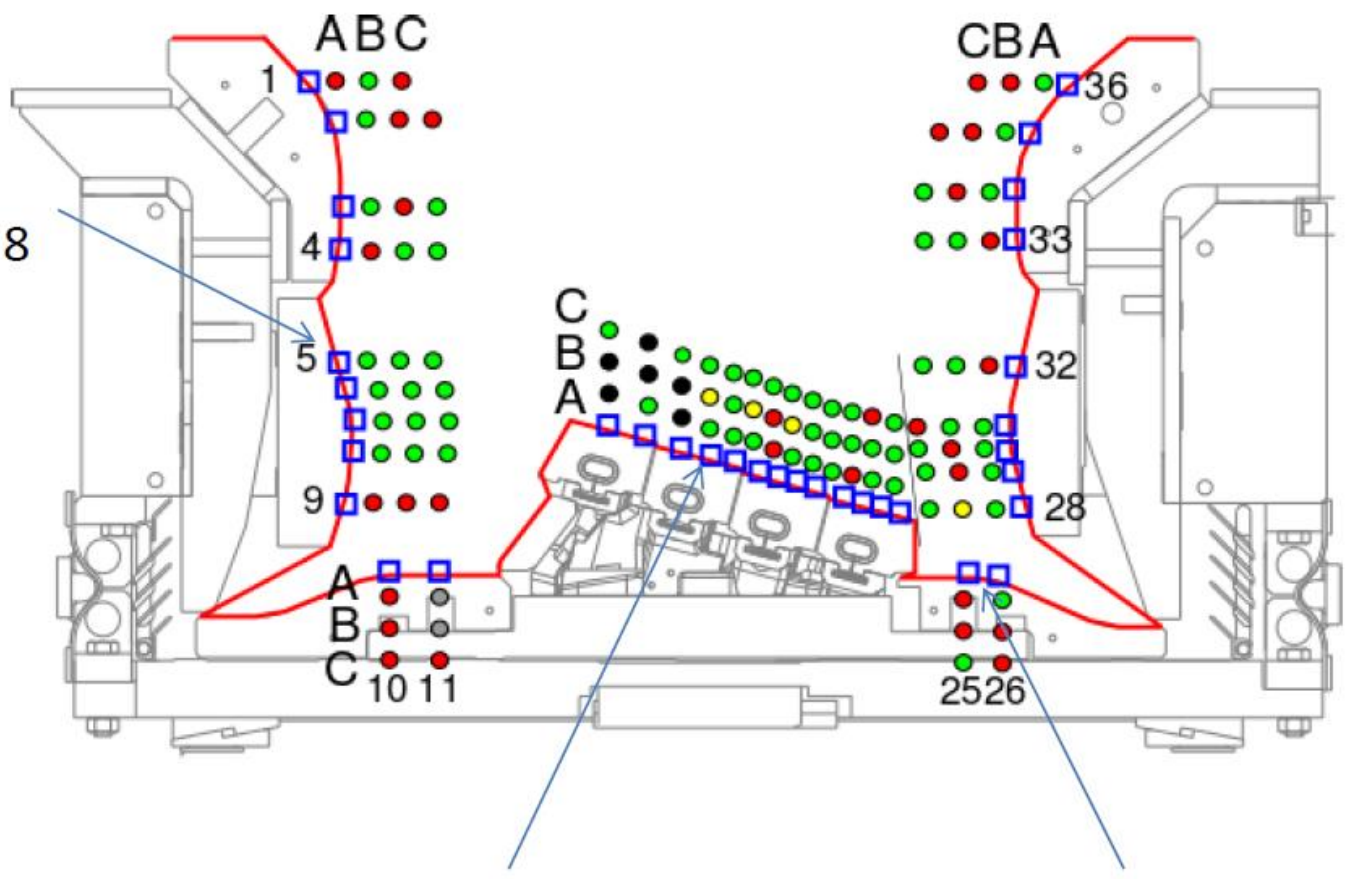
Solved issues

All materials are available for cutting of tiles: *W-coated CFC tiles, Be, W, Be-coated Inconel (IWC) : provision of samples.*

- Comprehensive dust studies: dust on RH arm
- Chemical methods in dust analyses: ICP-OES at IAP (2019)
- Broad programme on tritium measurements is ongoing (2019 --)
- Metallography and mechanical testing – no dramatic messages
- Bulk W lamellae (divertor Tile 5): availability & analysis (all campaigns)
- XRD – no dramatic messages
- TDS of dust – at IFERC, Rokkasho
- μ -NRA with deuterium beam: carbon mapping on beryllium
- High-resolution with MEISS and LEISS (also implantation of H,D,He)
- High-resolution HIERDA: quantitative depth profiling, ${}^6\text{Li}$, ${}^7\text{Li}$, ${}^{15}\text{N}$, ${}^{18}\text{O}$
- FIB – STEM – TEM on selected items at IPPLM and IFERC
- LID, large tile TDS
- HIERDA and D-beam micro-NRA: carbon, oxygen on Be



16IN and 17IN
Probes 5, 6, 7, 8



15W and 16W
Probes 15, 16, 19, 23

15BW and 16BW
Probes 25, 26



In September 2019 a letter was sent to all JET2 laboratories with a request to assess research capabilities after D-T.

- *Replies were received in October.*
- *Some Research Units plan to enhance capabilities of hot labs.*
- *One additional laboratory (Řež, Czech Republic) announced interest to participate.*
- *As expected, a detailed analysis program can be constructed once the tritium and activation levels have been known.*