EUROfusion

PWIE

PWIE, SP B.3
NCSRD activities in 2021: analysis of reference and plasma-exposed samples – plans and capabilities

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DEMOKRITOS

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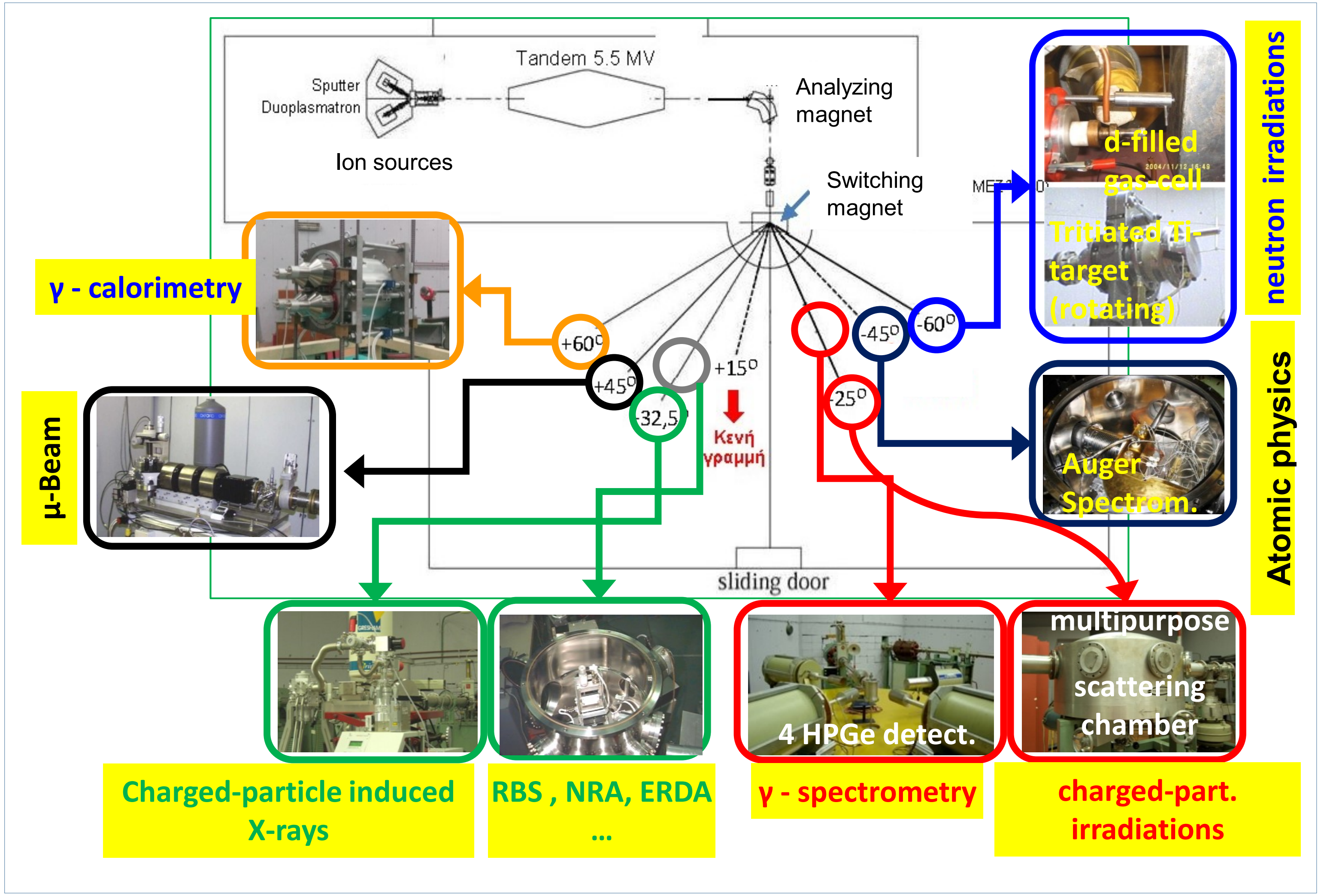
Experimental capabilities for surface analysis of plasma facing materials (1)

Ion Beam Analysis

- Rutherford Backscattering Spectroscopy (RBS)
- Nuclear Reaction Analysis (NRA)
- Particle Induced X-ray/Gamma-ray Emission (PIXE/PIGE) spectroscopy
- Time-of-Flight Elastic Recoil Detection Analysis (ToF-ERDA) from early 2022
- Milli- and micro-beam

New ion sources (TORVIS & SNICS II) to be installed in early 2022 providing the ability to use ions up to Iodine

5.5 MV TANDEM Accelerator



Contact: Tassos Lagoyannis, lagoya@inp.demokritos.gr

Experimental capabilities for surface analysis of plasma facing materials (2)

μ-beam Facility

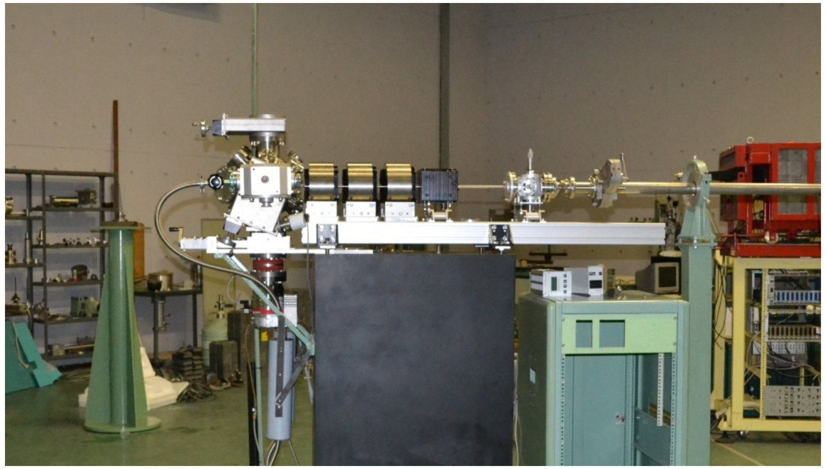
Spatial resolution 1.2 μm x 2 μm

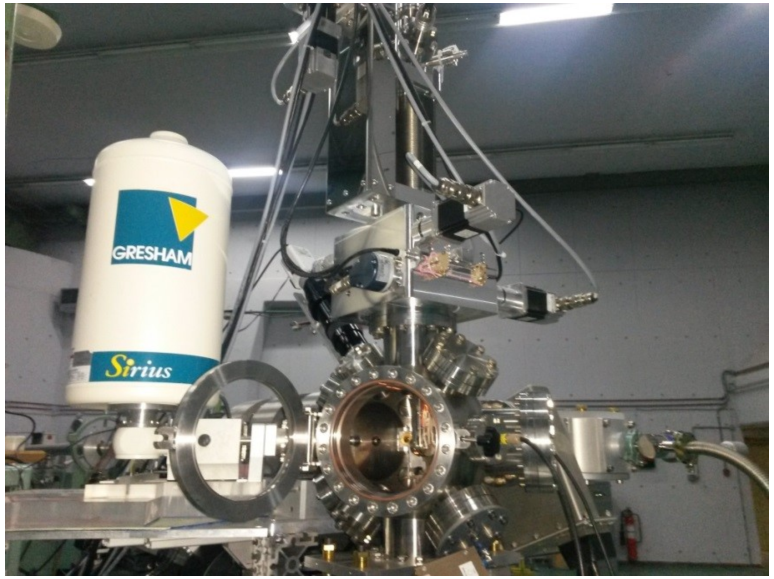
Chamber's features:

- Load – lock chamber
- 3 – axis motorized sample holder
- Rotatable target holder
- Heating / Cooling
- Long range microscope for precision
- CCD camera for sample Monitoring

Detectors:

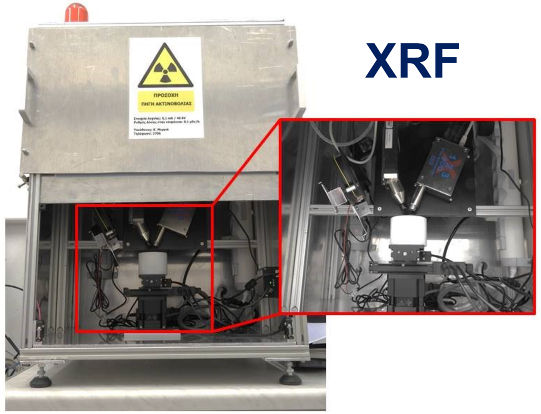
- PIXE low energy Si(Li) detector at 45^o
- PIGE HPGe detector at 45^o
- STIM detector at 0^o
- RBS SSB detector at 170^o
- NRA SSB detector at 150^o



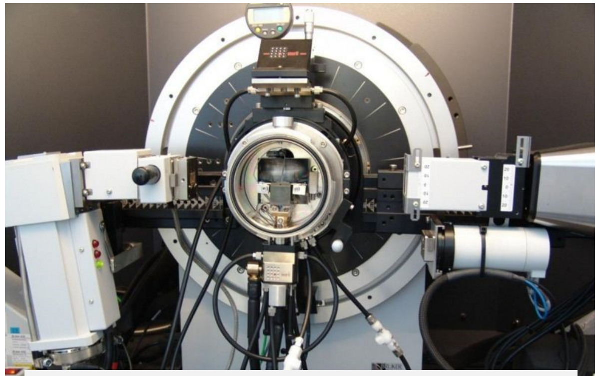


Experimental capabilities for surface analysis of plasma facing materials (3)

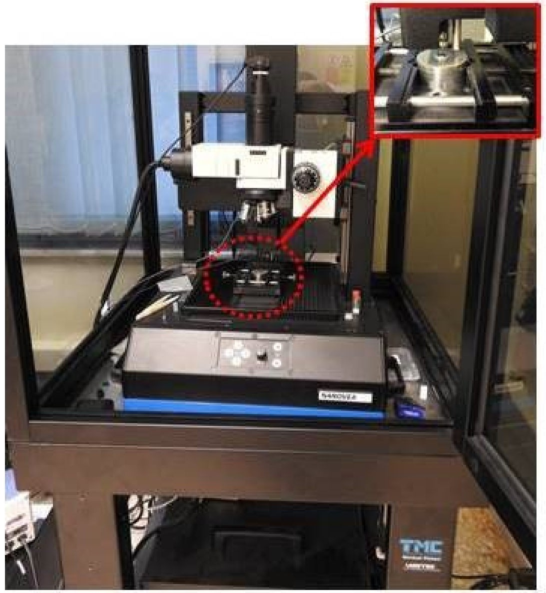
- **X-ray Fluorescence Spectroscopy (XRF)**
  - Elemental analysis for Z>11
- **X-ray diffraction/reflectivity (XRD/XRR)**
  - Normal and incidence angle
  - High speed linear position sensitive detector
  - In-situ studies from LN2 up to 1500°C (XRD) or up to 800 °C (XRR)
- **Scanning Electron Microscopy (SEM) with EDX spectroscopy**
  - <1 nm resolution 0.2-30 kV (new FEG-SEM microscope purchase under way)
- **Transmission Electron Microscopy (TEM)**
- **Atomic Force Microscopy (AFM)**
- **X-ray Photoelectron Spectroscopy (XPS)**
- **Mechanical properties using depth-sensing nano- & micro-indentation**



XRF



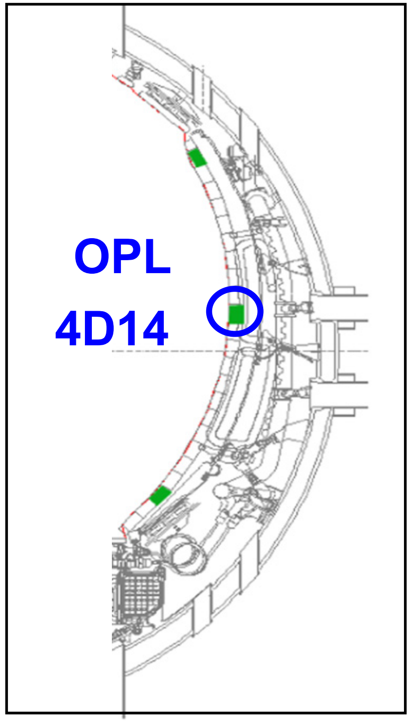
XRD/XRR - furnace setup



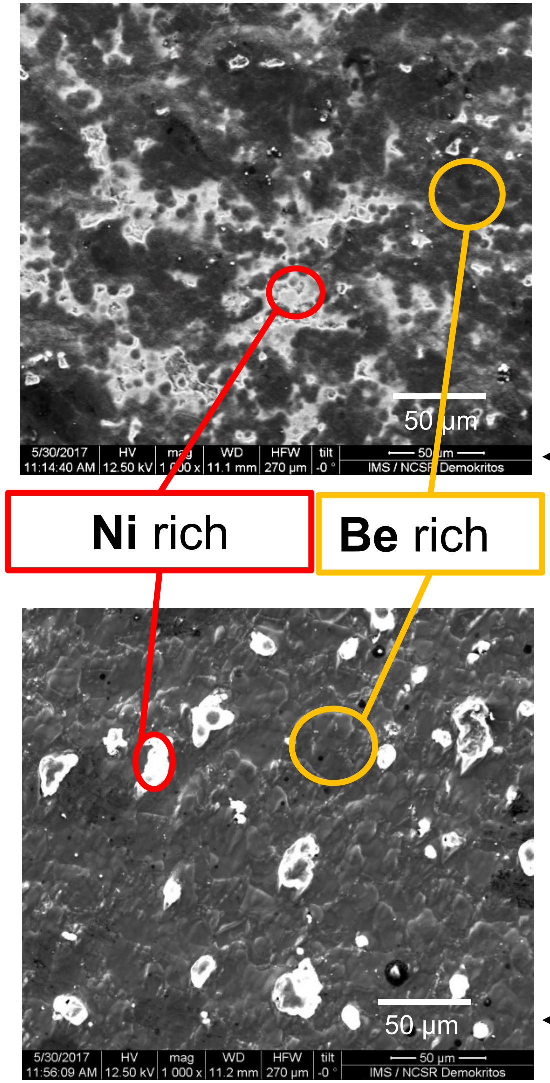
Depth Sensing Indenter

Be Tiles from JET tokamak: Erosion

Combined NRA and SEM investigation

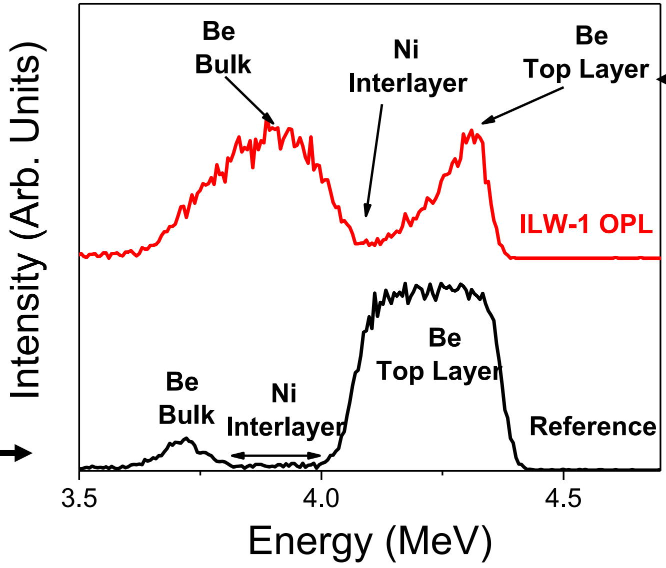


ILW-1
OPL

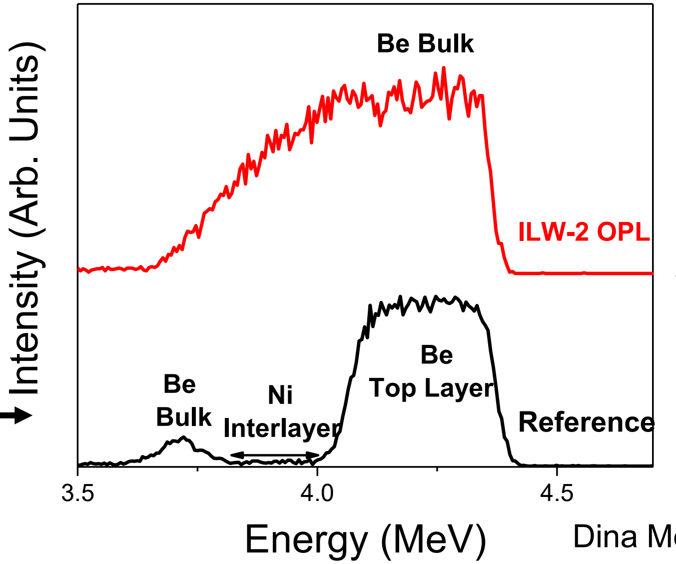


ILW-2
OPL

Comparison between **ILW-1** and **ILW-2**



Be top layer became **thinner**: **erosion** <11 µm

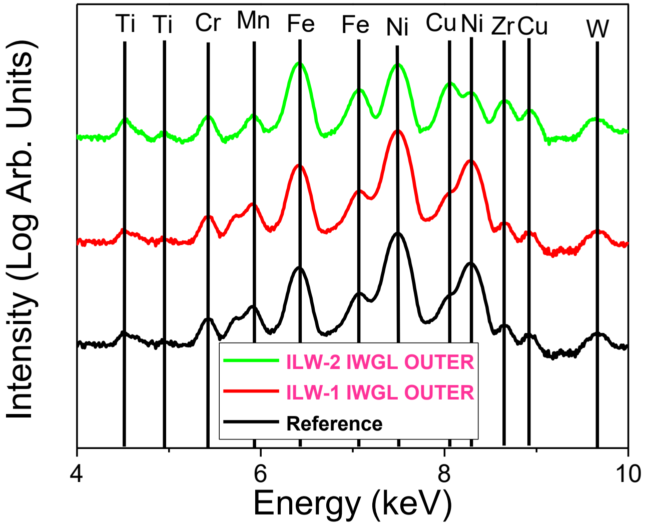


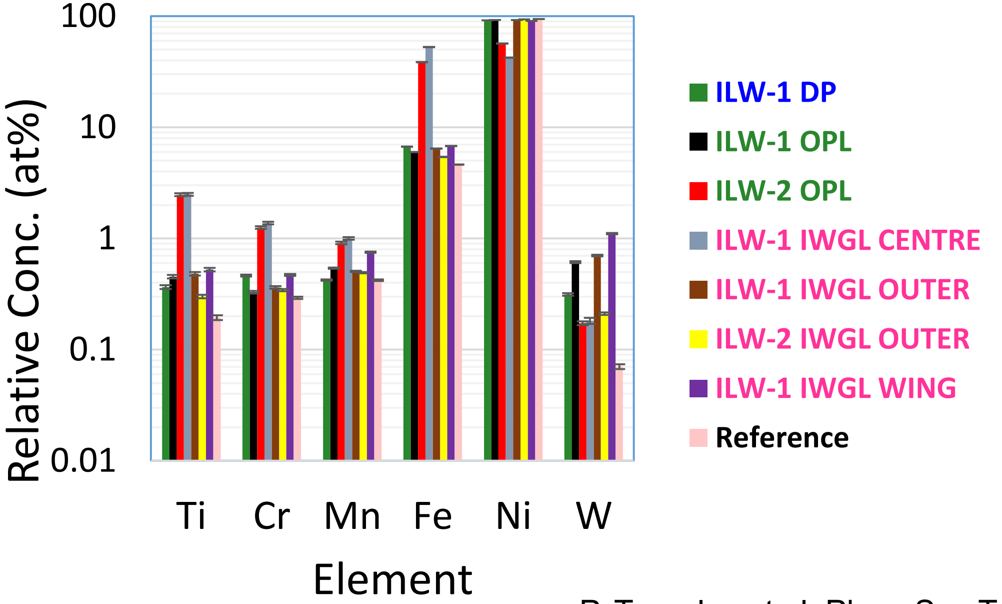
Enhanced erosion (>11 µm) and deposited particles rich in Ni are observed.

P. Tsavalas et al, Phys. Scr. T170 (2017) 014049

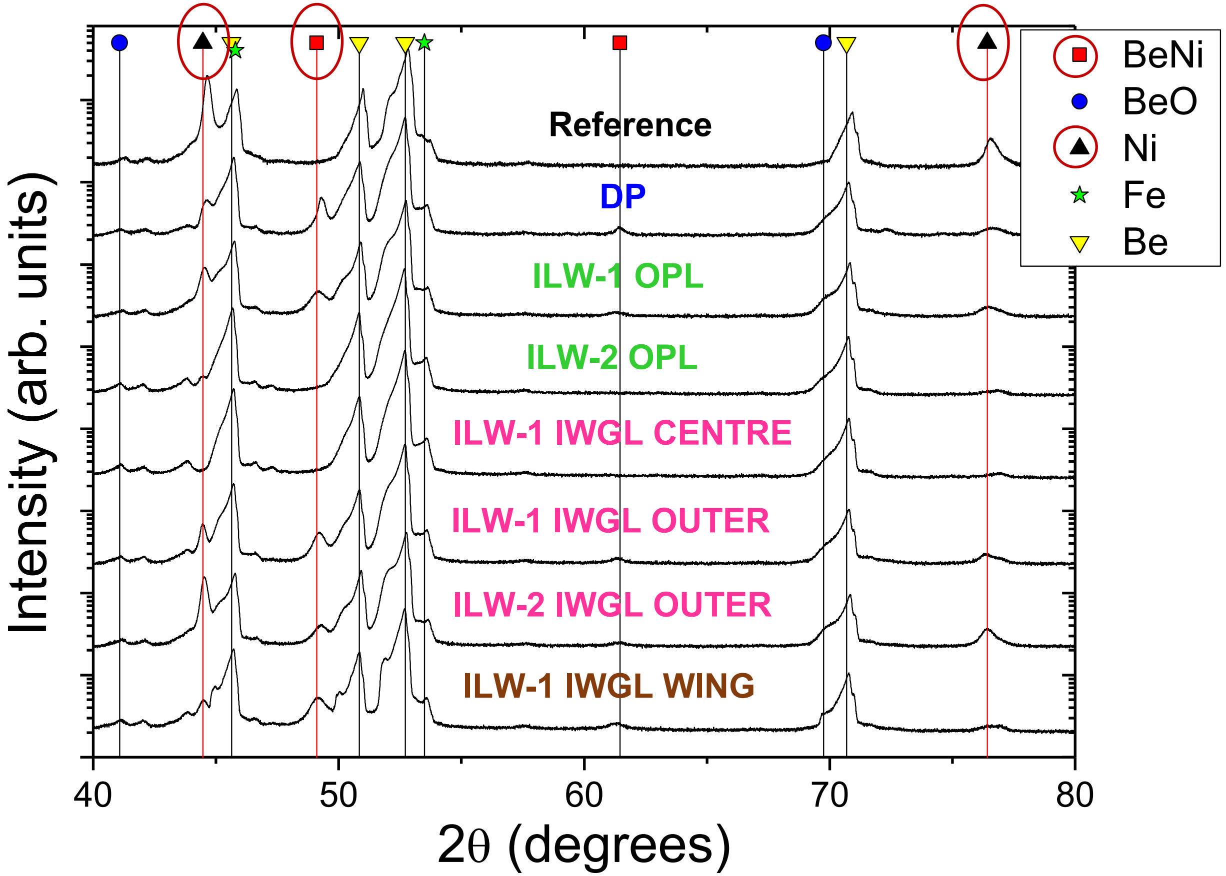
Be Tiles from JET tokamak: Material deposition & compound formation XRF & XRD investigation

XRF





XRD

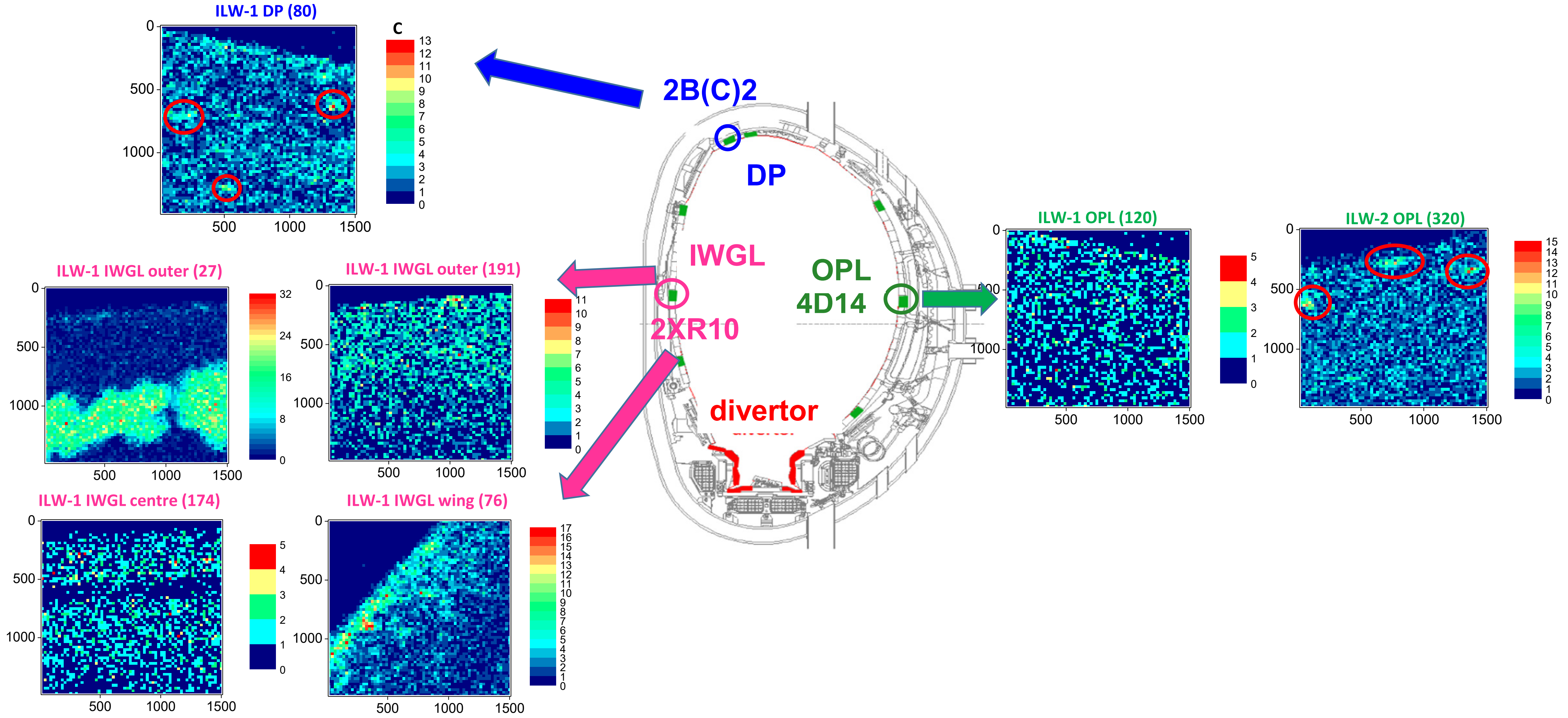


- Presence of **BeO** compound
- Formation of **BeNi** compound

P. Tsavalas et al, Phys. Scr. T170 (2017) 014049

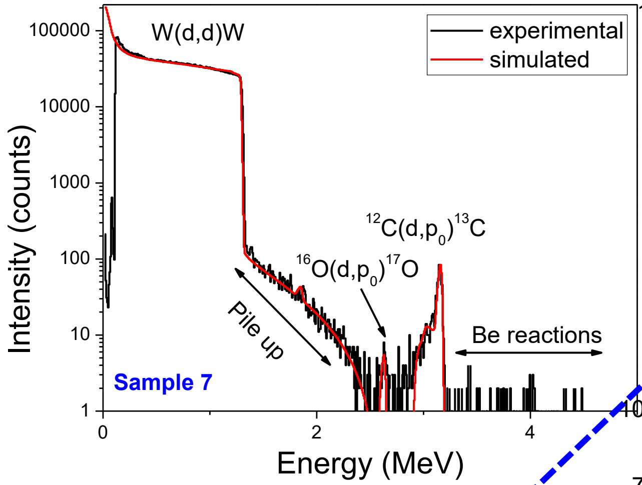
Be castellated Tiles from JET tokamak

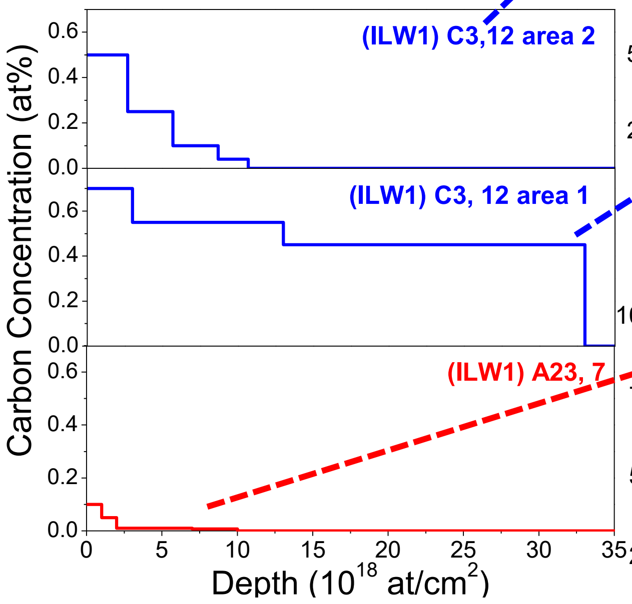
Carbon deposition on the castellated sides - μ-beam NRA using a deuterium beam



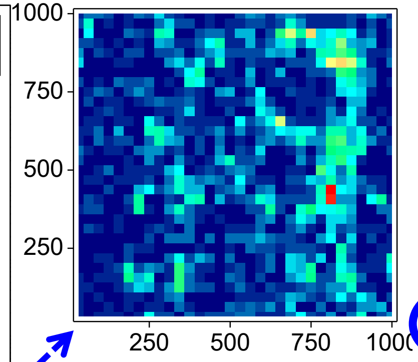
NRA results from W lamellae – use of ^{2}H micro-beam

Carbon deposition

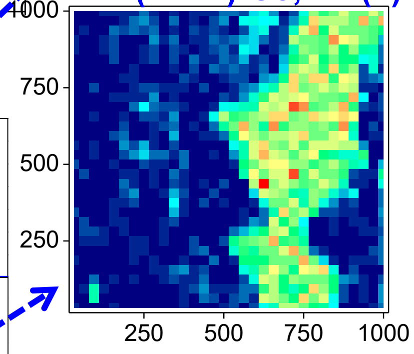




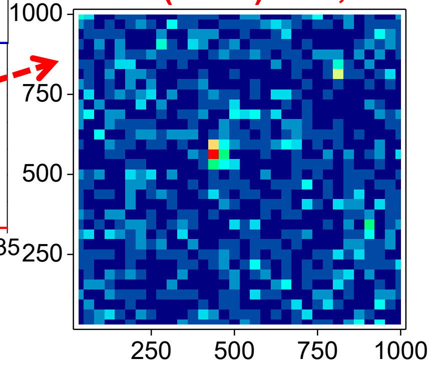
(ILW1) C3,12 (2)

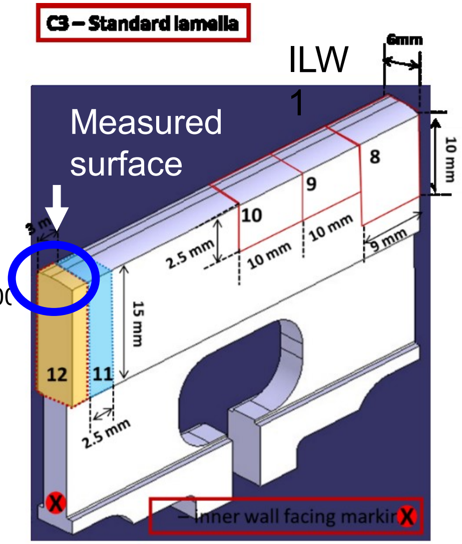


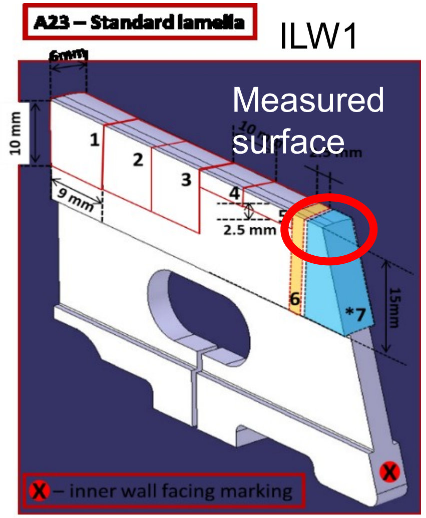
(ILW1) C3, 12 (1)



(ILW1) A23, 7







P. Tsavalas et al. PFMC-18, 2021

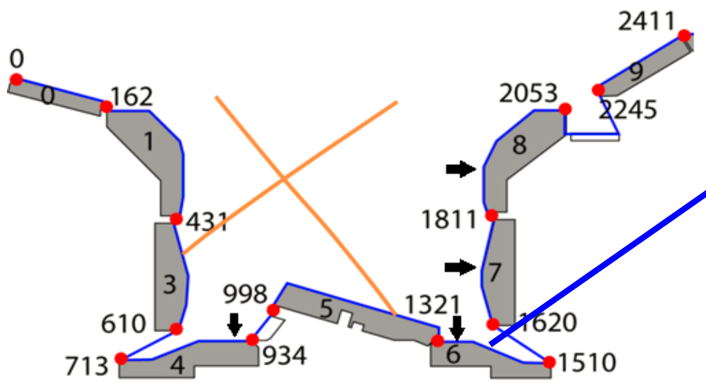
Investigation of carbon deposition & carbon depth profile in W lamellae from JET tokamak

Lamella	Exp. Period	Sample	C Amount (10^{17} at/cm^2)	Deposition Thickness (10^{18} at/cm^2)
C3	ILW1	12 (2)	24.8	10.7
C3	ILW1	12 (1)	166	33
A23	ILW1	7	2.21	10

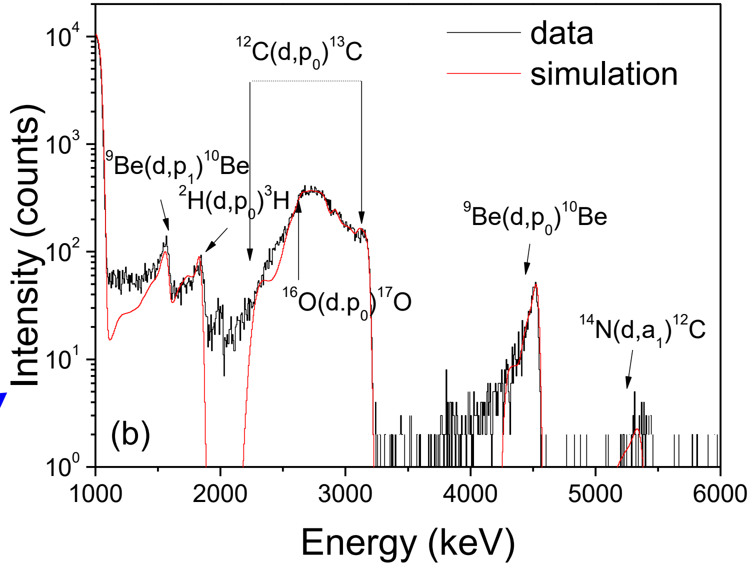
NRA and XRD results from W/CFC Tiles from the JET divertor

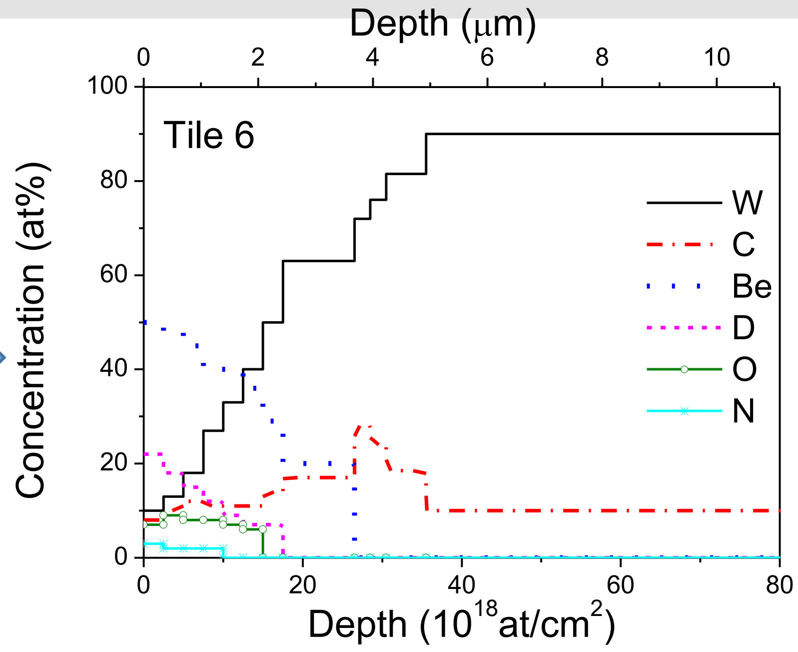
Assessment of

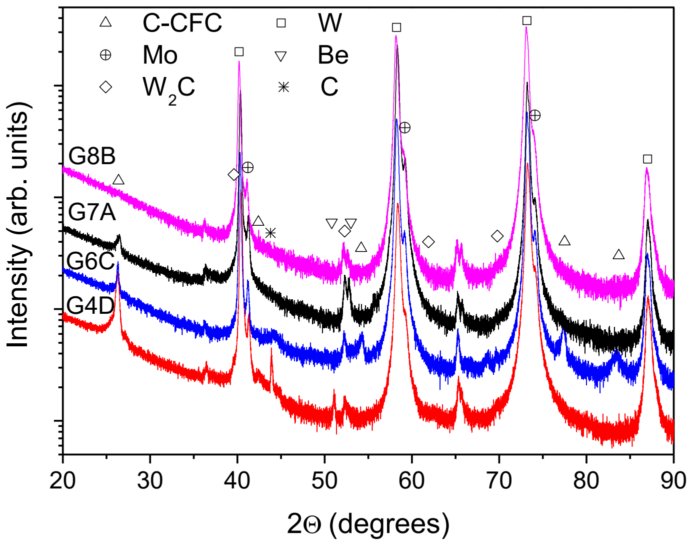
- Fuel retention
- Seeding species retention
- Material migration



NRA spectrum using a ^{2}H beam





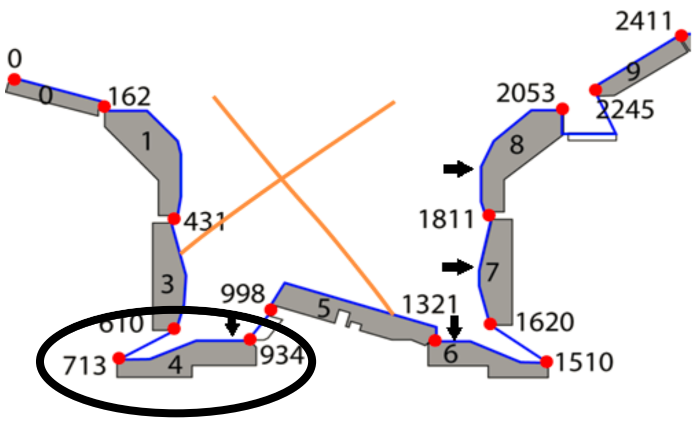


XRD spectra

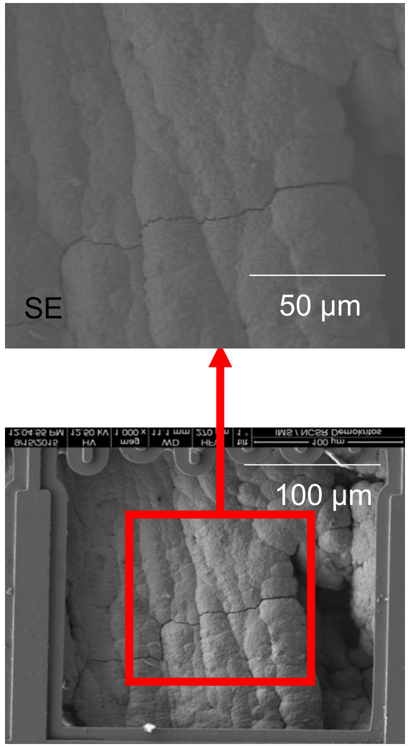
Absence of Be-W intermetallics that could affect the thermomechanical properties

A. Lagoyannis et al, Nucl. Fusion (2017) 076027 (7pp)

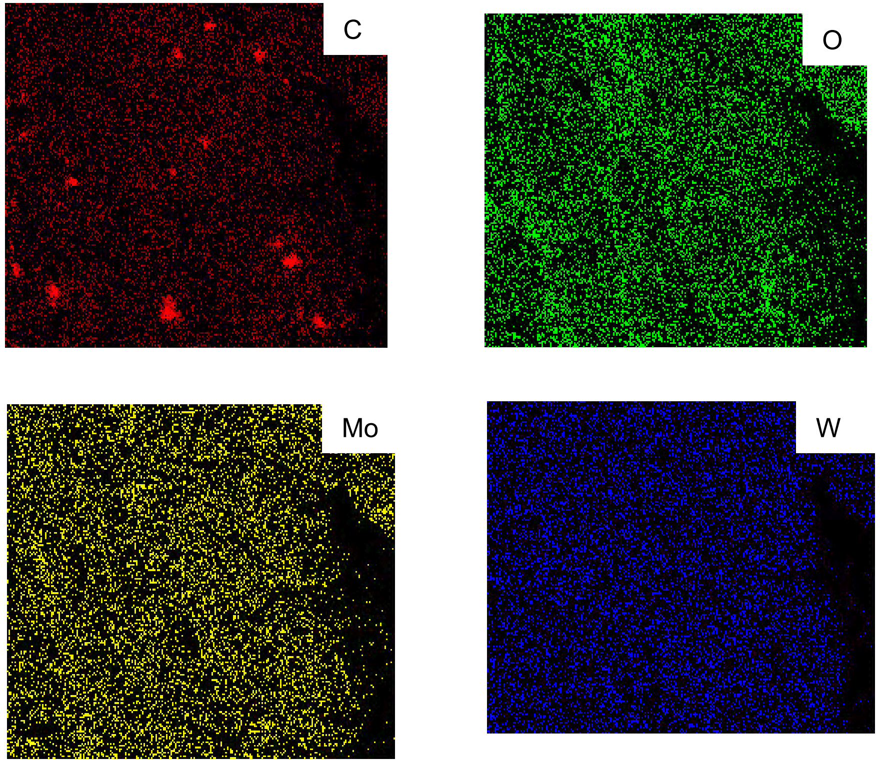
Elemental mapping from W/CFC Tiles from the JET divertor



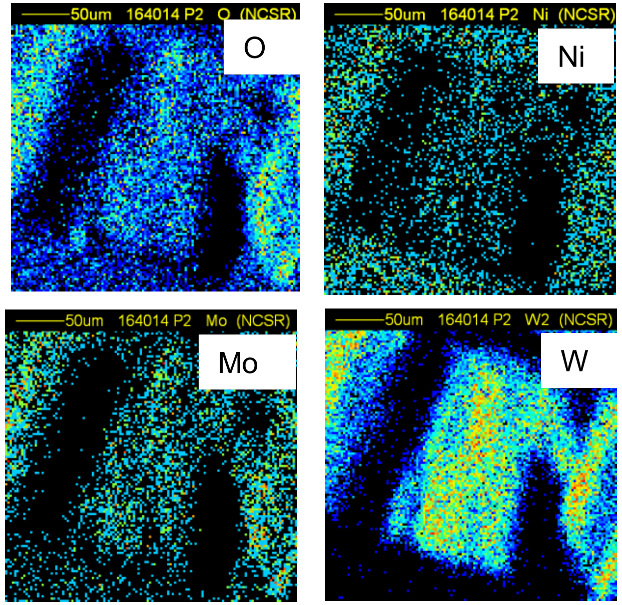
SEM Images



EDX Mapping



µ-PIXE mapping



2021 workplan

D007	RBS, SEM, XRD and XRF characterization of selected Be reference coatings and plasma-exposed samples

Analysis of reference and plasma exposed Be or W samples from the various devices
Problems to be addressed

- Material deposition, depth profiles, compound formation
- Erosion
- Fuel retention
- Seeding species retention
- Microstructural changes
- Mechanical properties using depth-sensing indentation techniques

In-situ XRD annealing of plasma exposed samples to assess

i) temperature effects on compound formation due to material deposition
ii) microstructural changes.

Samples to be identified and specific problems to de defined

Suggestions for collaborations welcome (please send an email to kmergia@ipta.demokritos to discuss)