Experience with Be at JET

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Experience with Be at JET

History of Be in JET

- Be evaporation (started 1989)
- Be limiters (1990-1992) and Be divertor (1995)
- Transport of Be and analysis
- ITER-like Wall (ILW) (2011 onwards)

Future plans

- Analysis of tiles removed in 2012
- Opportunities for further experiments

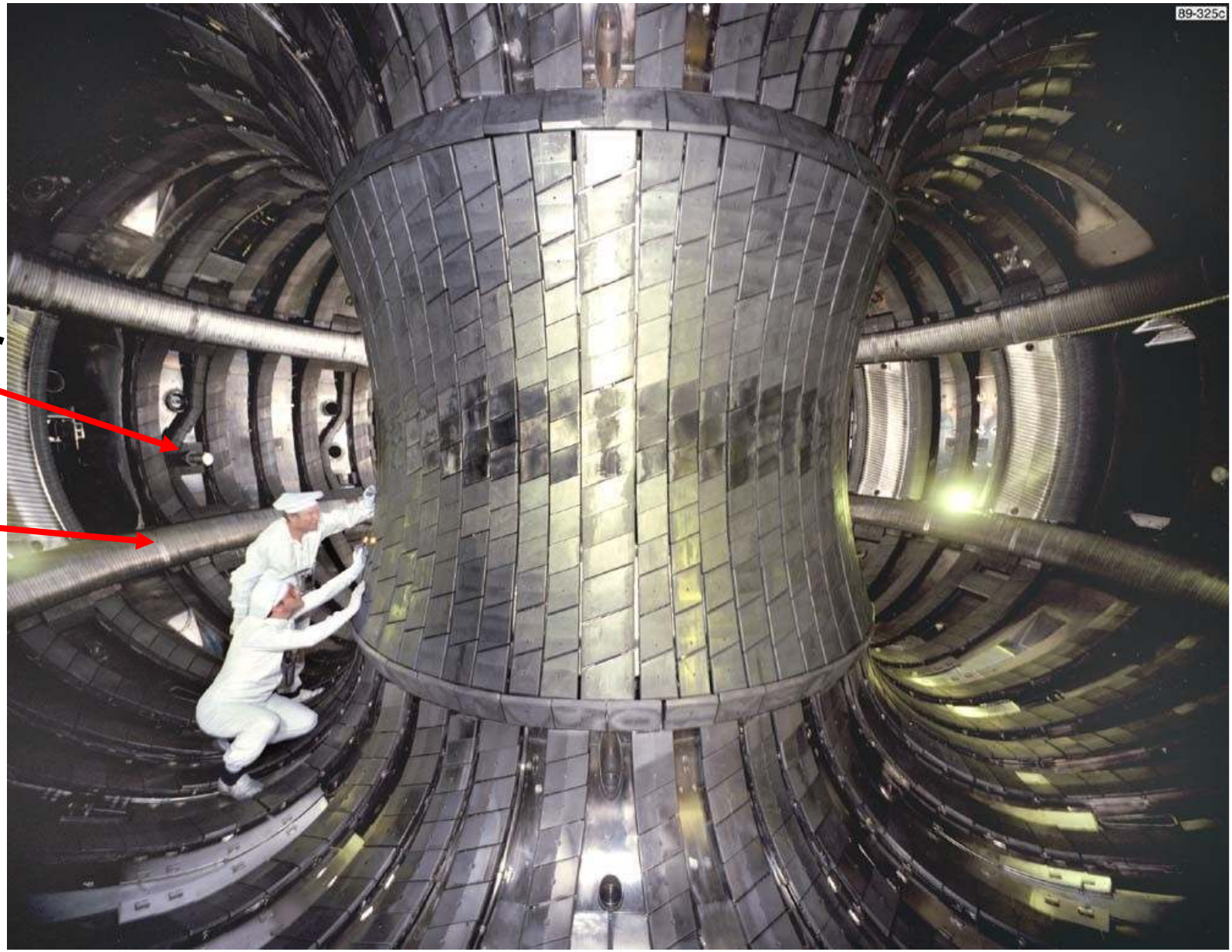
JET interior 1989

Be evaporation has been used ~every week of operation 1989-2009 and has also been tried during the ILW

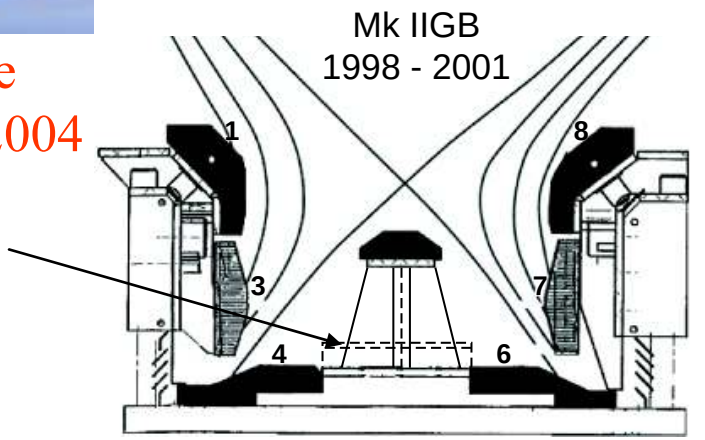
Be Evaporator

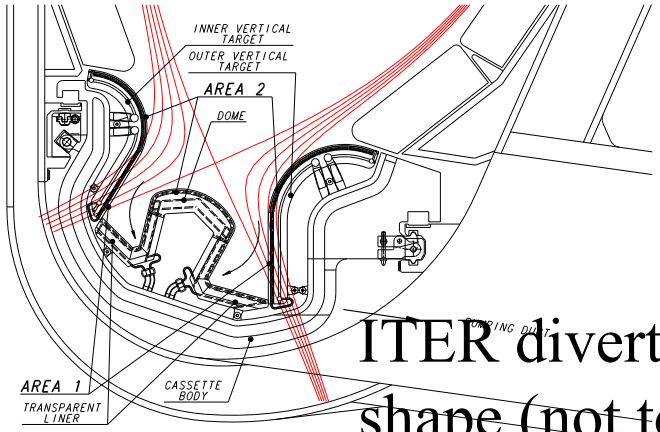
Belt limiter

Belt limiters were not successful due to edge erosion (C) and melting (Be) that limited power handling

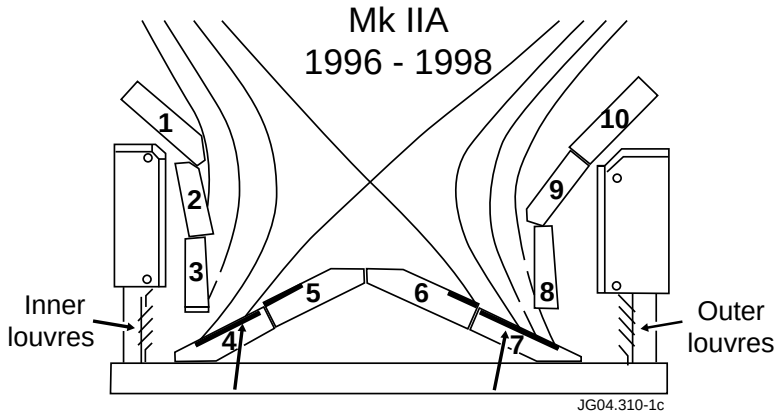


SRP plate replaced the septum for the 2001-2004 campaigns

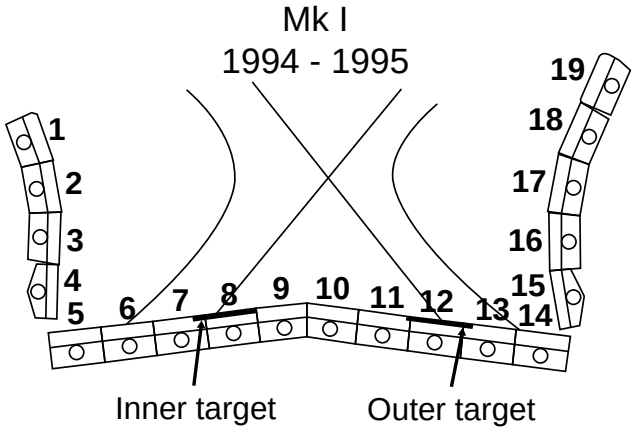




ITER divertor shape (not to same scale)

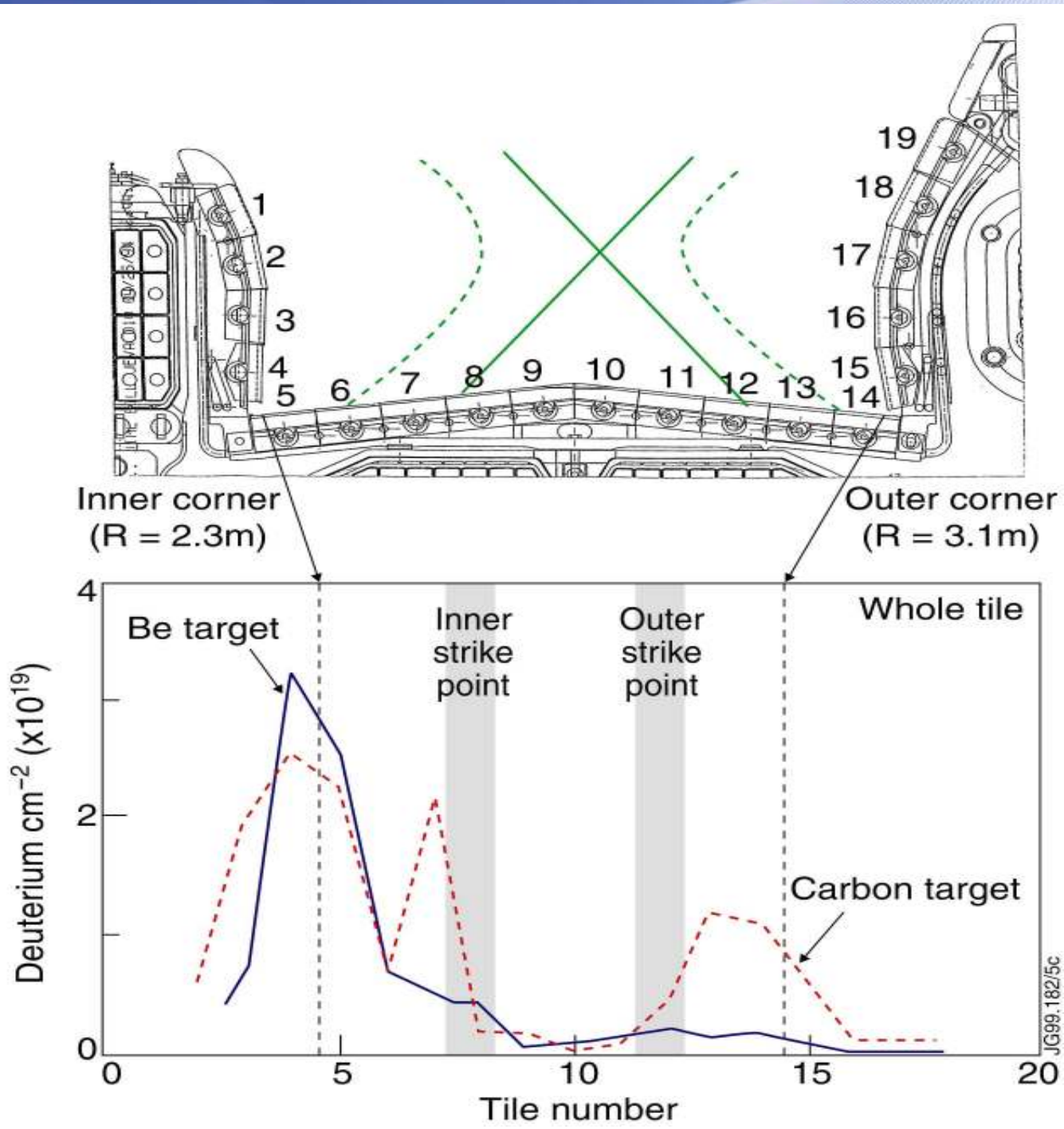


JET Divertors used in the period 1994 to 2004



Deposition at the JET Mk I divertor

Proved that material deposited in the divertor was eroded from the main chamber. Melt experiment performed on the Be divertor



Beryllium Plasma Spray - Repair

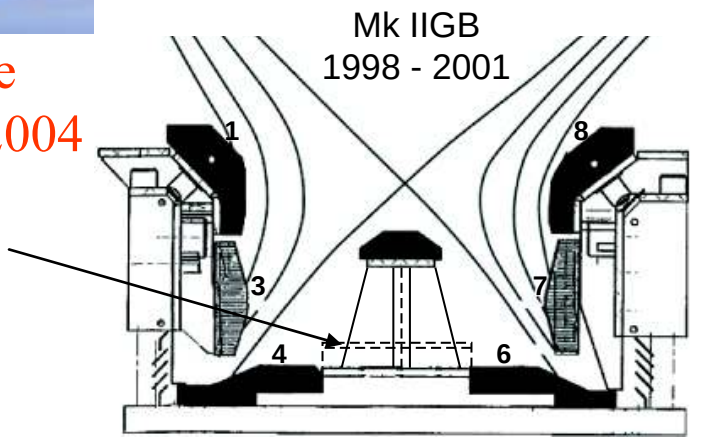
Indication of the possibility to repair the damaged components:

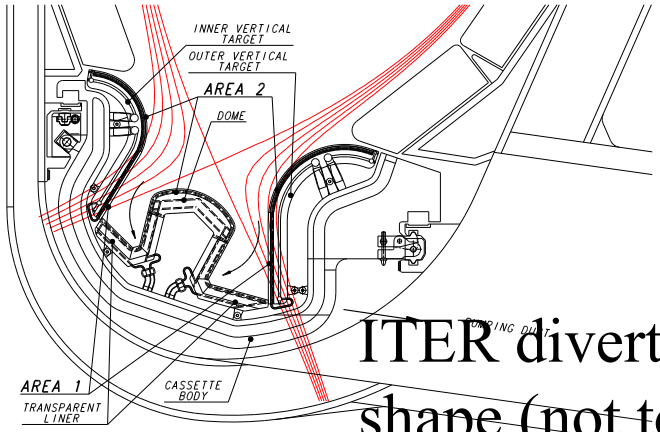
- PS applied on damaged (melted, cracked, contaminated surface)
- Coatings 1 mm to 1.5 mm thick with a porosity level on the order of 7-12% were deposited
- 5 MW/m^2 for 10 s/60 off pulses applied:
- Survived 500 cycles before cracking was observed, after 680 cycles – hot spots, test was terminated

Note: PS coating on the undamaged Be tiles survived only 10 cycles at 5 MW/m^2

ISX-B Be limiter Tiles Used for Plasma-Spraying Tests

SRP plate replaced the septum for the 2001-2004 campaigns





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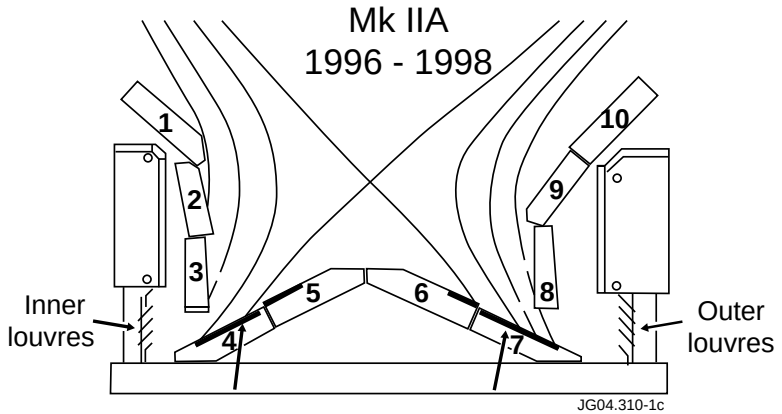

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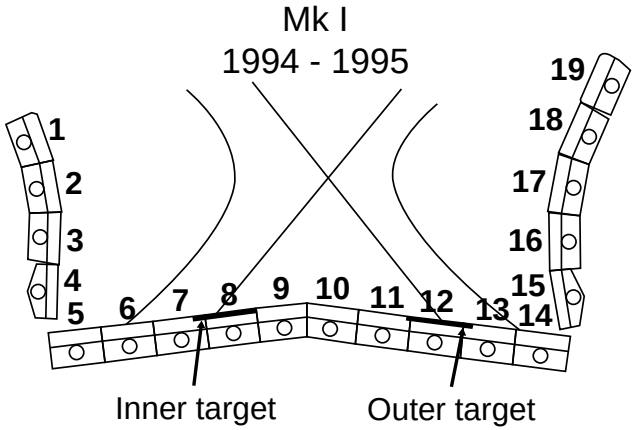
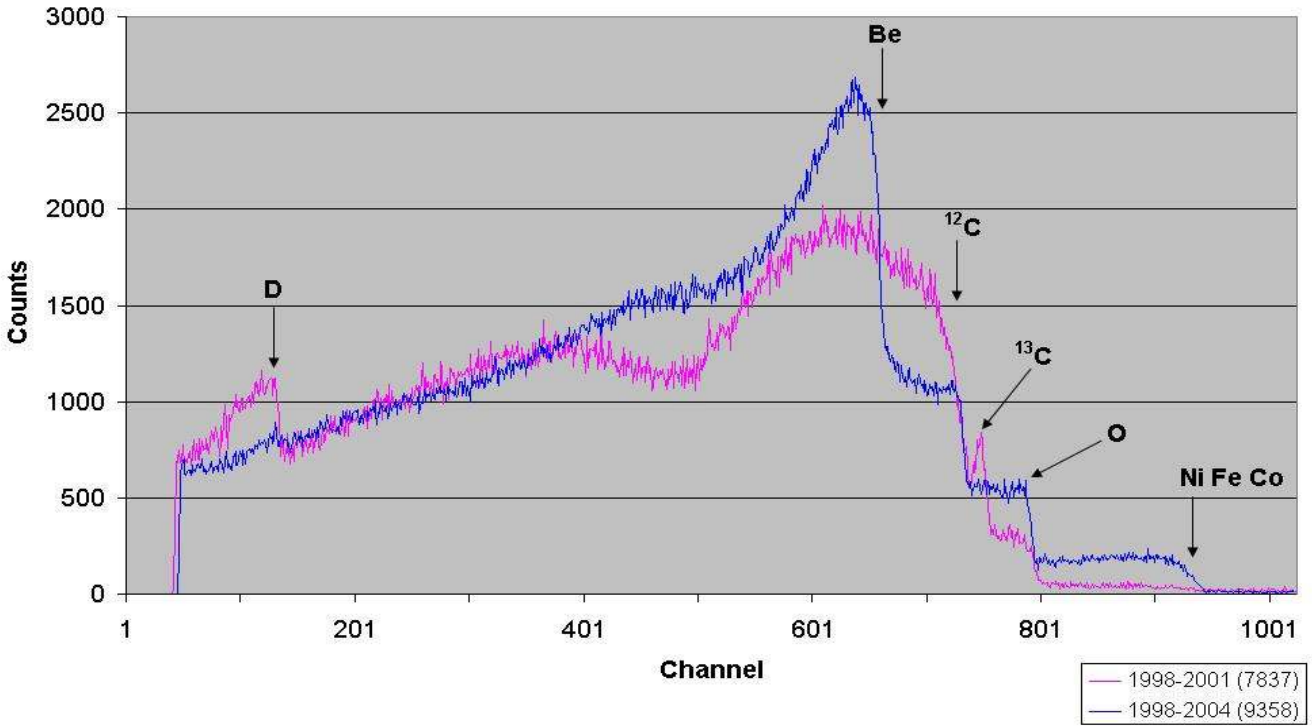


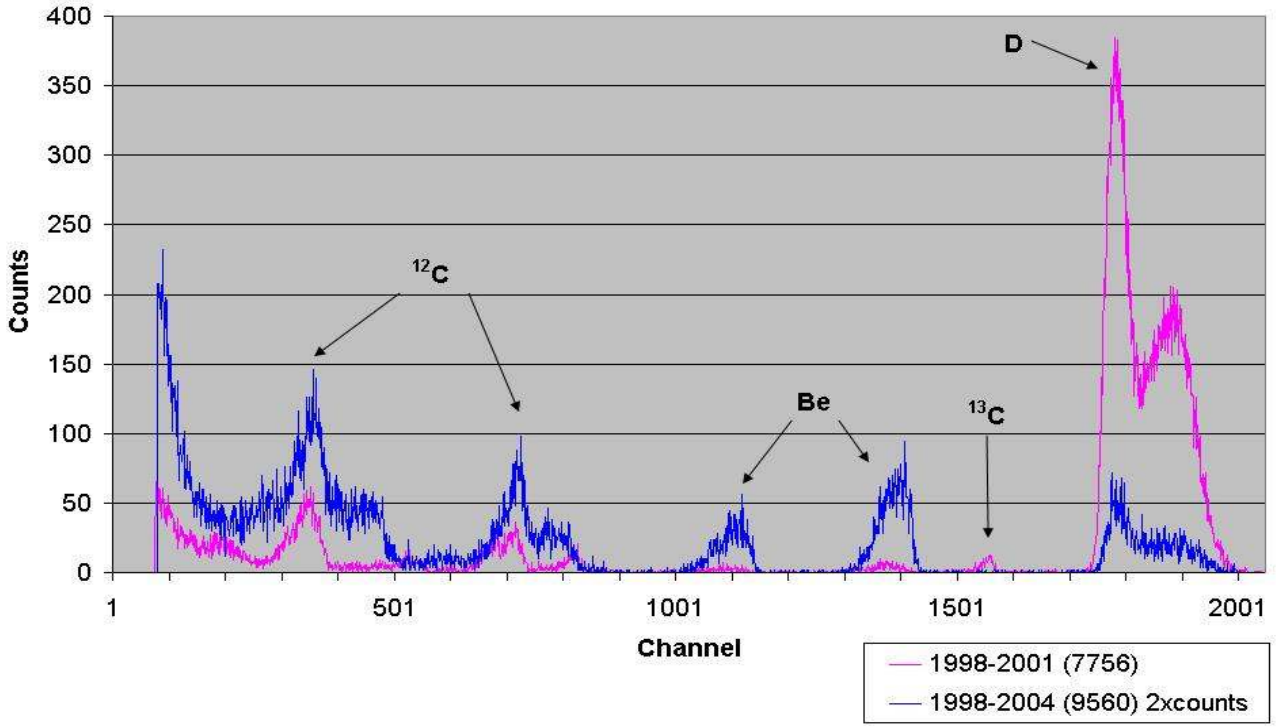
RBS of tile 3 removed in 2004 compared with one from 2001

- Much more Be and other metals in 2004
- Much more D and ^{13}C in 2001 (13C comes from injection of methane at top of vessel during last pulses of the campaign)



NRA of tile 3 removed in 2004 compared with one from 2001

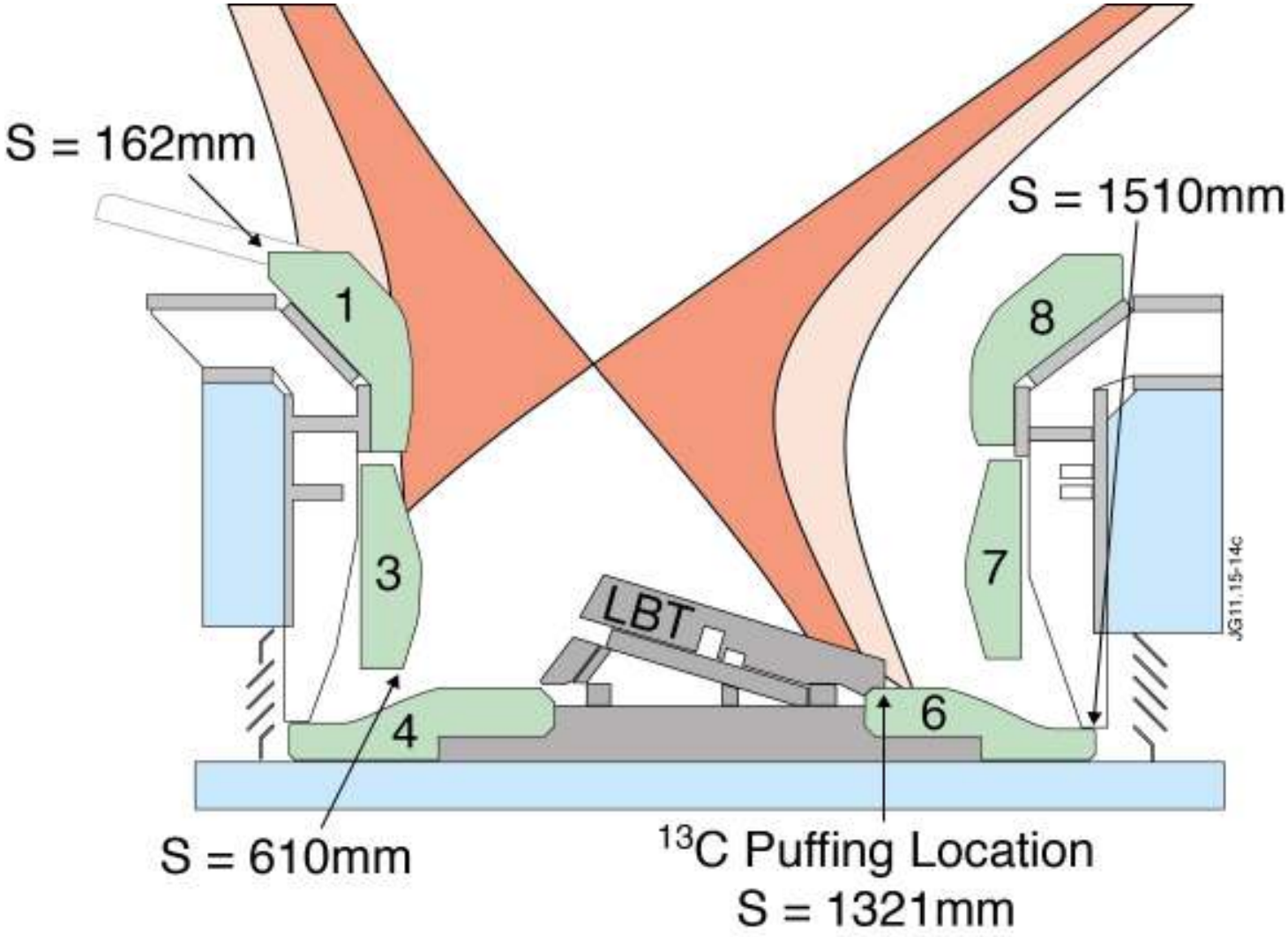
- Much more Be in 2004
- Much more D in 2001 and ^{13}C also detectable



JET-HD divertor (2004 onwards)

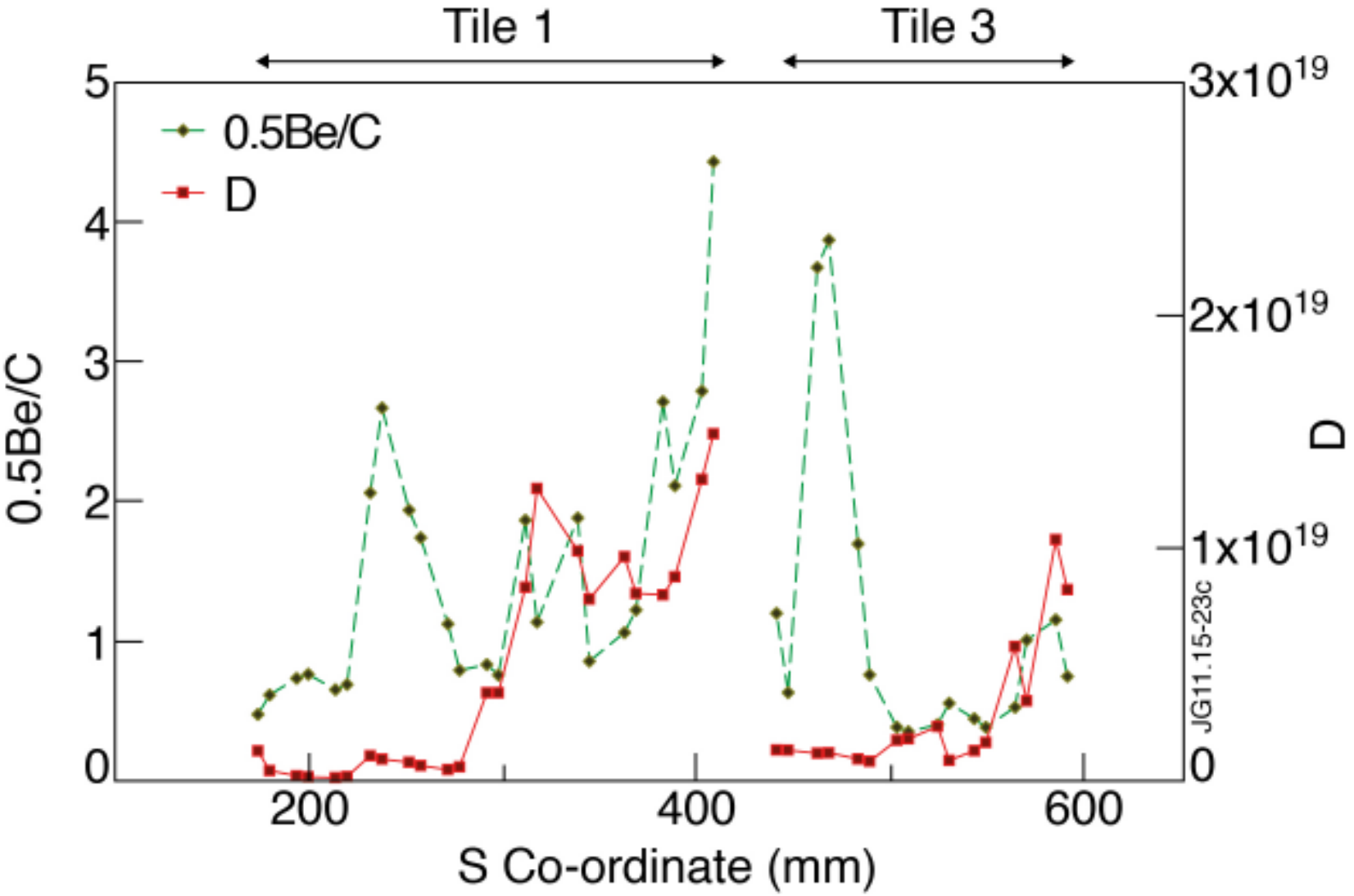
2004-9 All tiles made of CFC

For ILW (2011onwards) Tiles 1-8 are W-coated CFC, LBT made with solid W lamellae

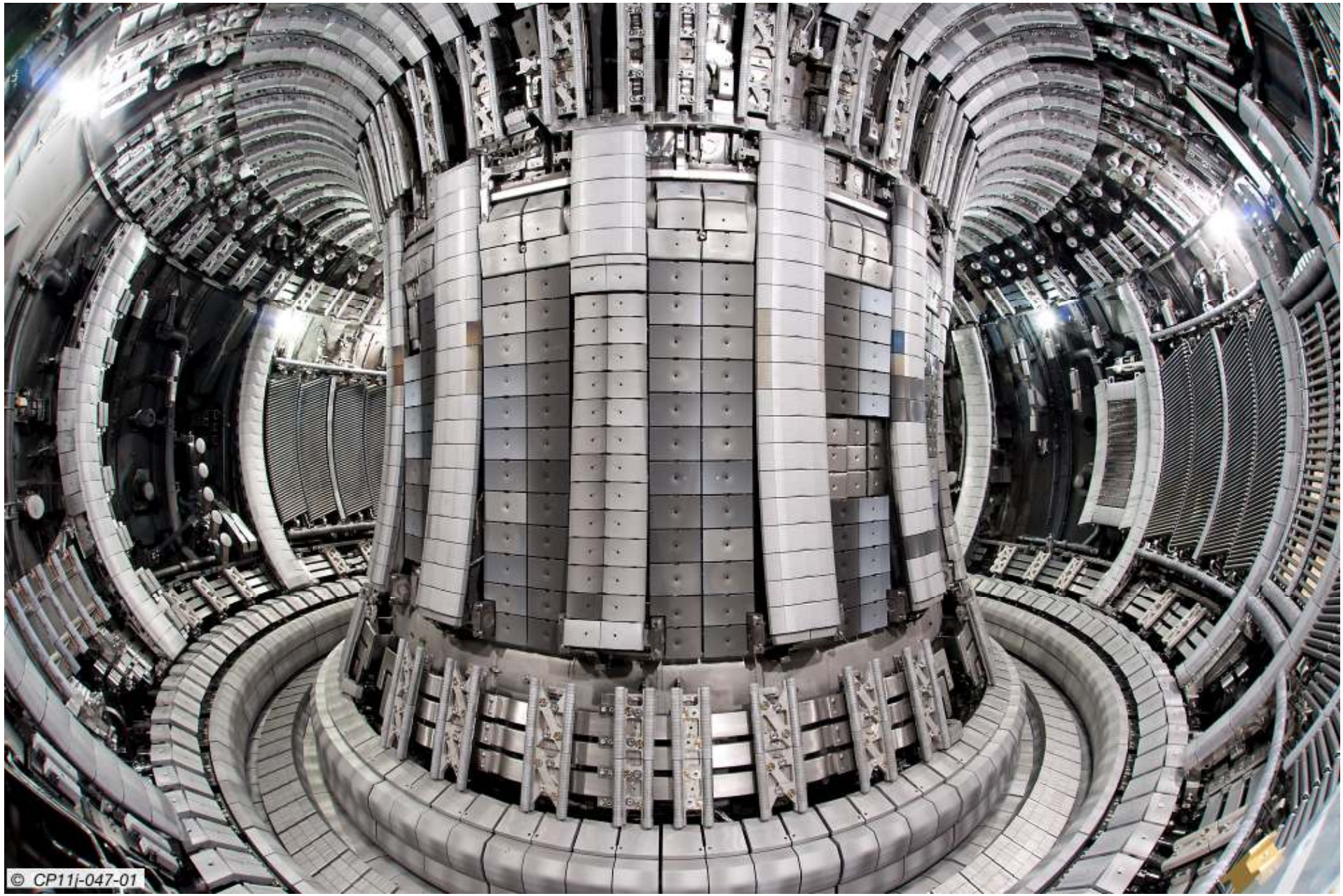


Analysis of tiles 1 & 3 after 2007-9 operations

Be/C can exceed 1, so film not stabilised by carbide



ITER-Like Wall in JET from 2011

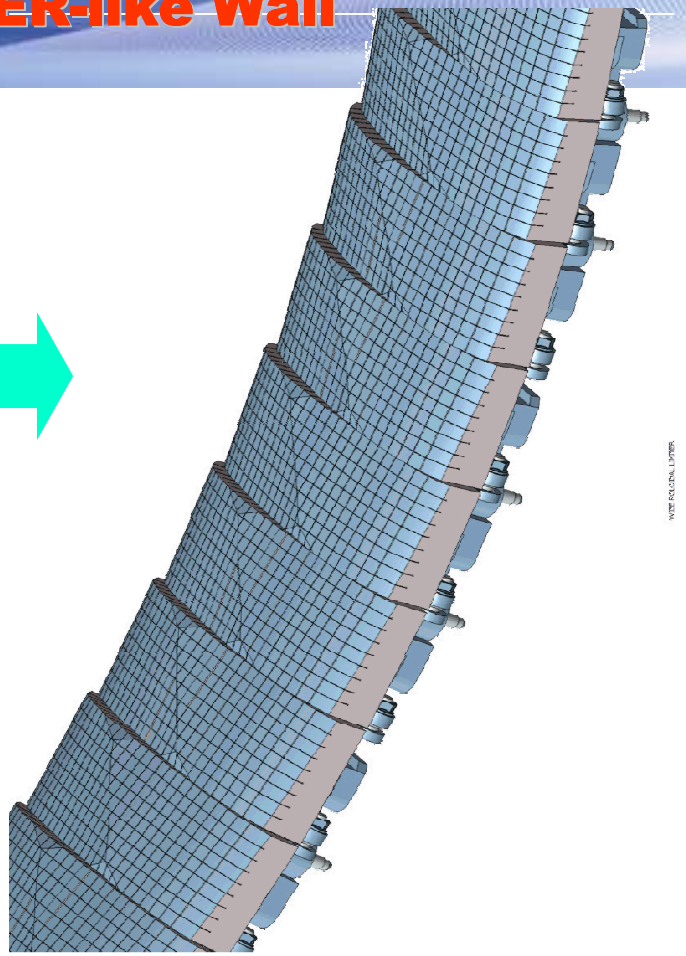


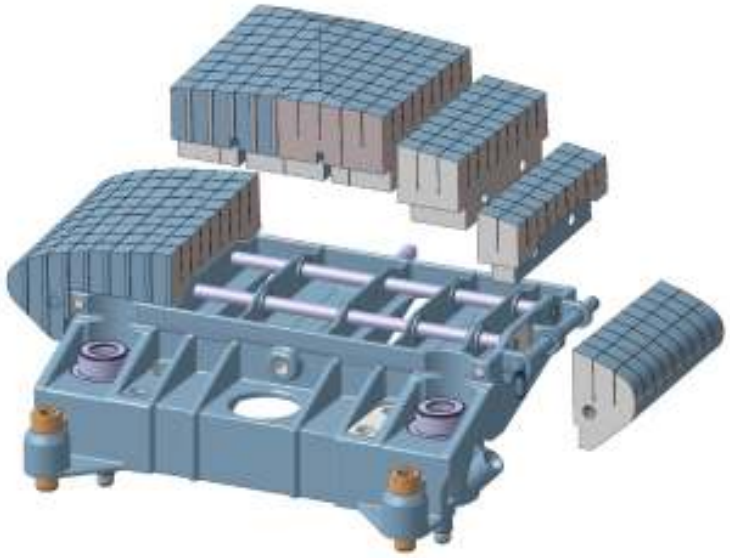
Engineering the ITER-like Wall

Project Goal - Limits ≥ existing CFC

Example: Wide Outer Poloidal Limiter

- ⇨ Eliminate bolt holes (power)
- ⇨ Optimised profile (power)
- ⇨ Large format tiles (power)
- ⇨ Single helicity (power)
- ⇨ Interlocking carriers (power)
- ⇨ S65J HIP Be (mechanical integrity)





- ⇨ Segmented construction (eddy)
- ⇨ Castellation (thermal fatigue)
- ⇨ Vacuum cast In 625 carriers (strong, high resistivity + low cost)

Long term retention: Main results

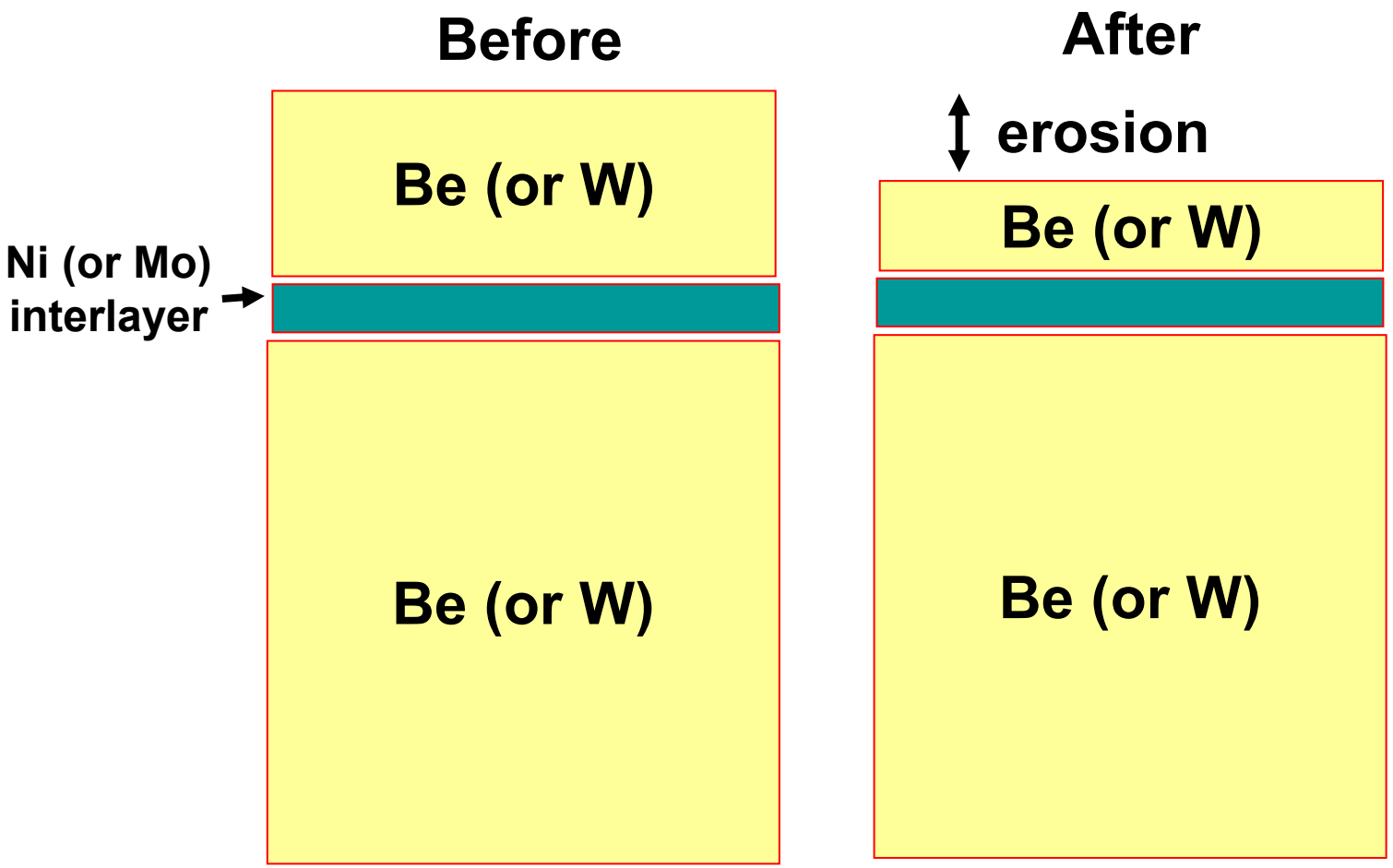
All pulses Ip/BT=2.0MA/2.4T
Integral Gas balance: ~10 hours and 10-20 repetitive pulses

Pulse type	Carbon Heating Phase (Ds^{-1})	Be/W Heating Phase (Ds^{-1})	Carbon X-point phase (Ds^{-1})	Be/W X-point phase (Ds^{-1})
Limiter (inner) 0.5 MW ICRH (#82626)		1.35×10^{20}		8.9×10^{19}
L-mode 0.5-1.5 MW ICRH (#81282)	2.40×10^{21}	3.9×10^{20}	1.05×10^{21}	2.5×10^{20}
Type III 5 MW ICRH (#81624)	2.40×10^{21}	1.9×10^{20}	1.37×10^{21}	7.7×10^{19}
Type I 11MW NBI (#82670)	2.83×10^{21}	7.0×10^{20}	1.7×10^{21}	4.0×10^{20}

Long term retention has decreased by nearly one order of magnitude

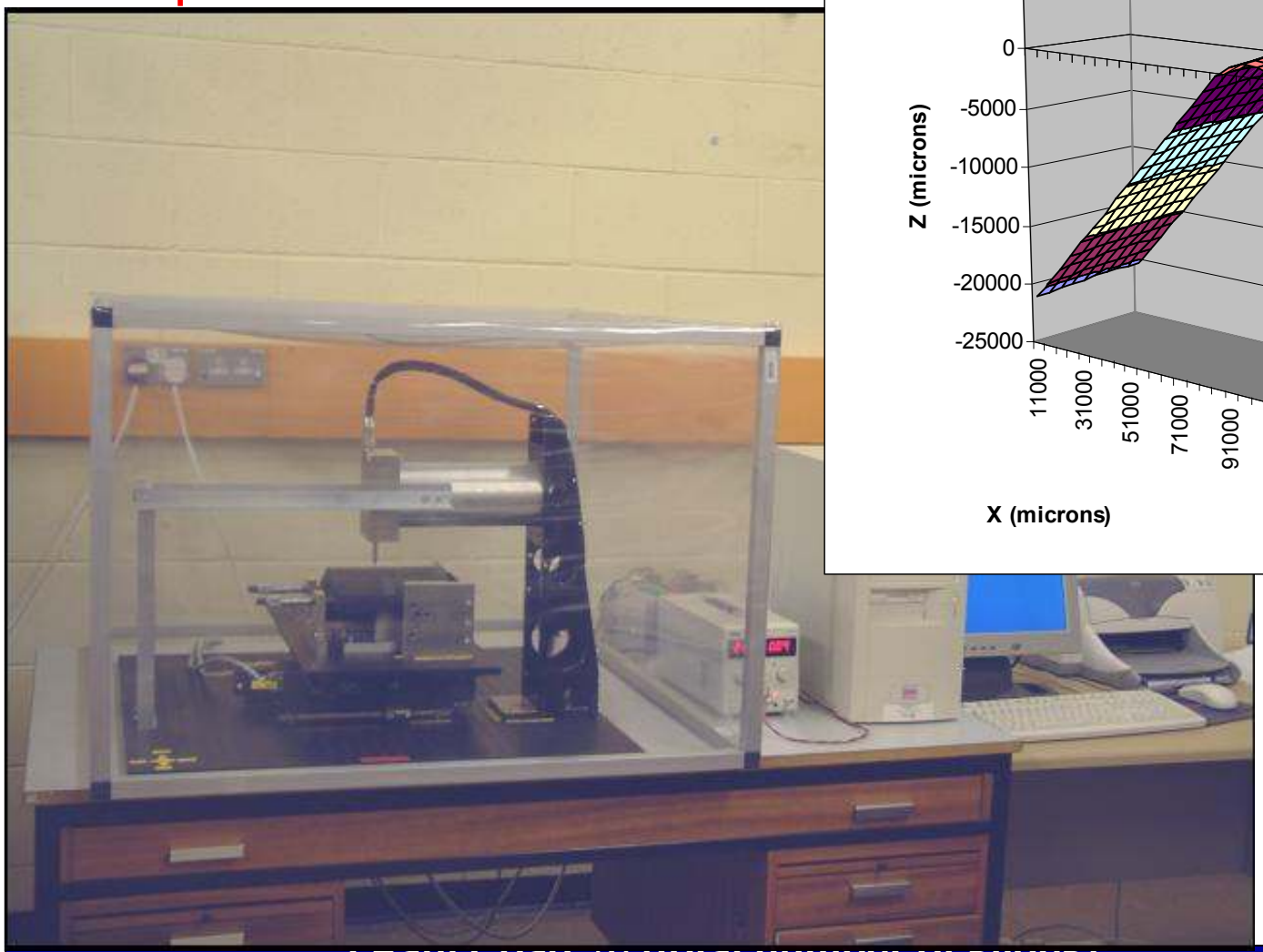
Marker tiles

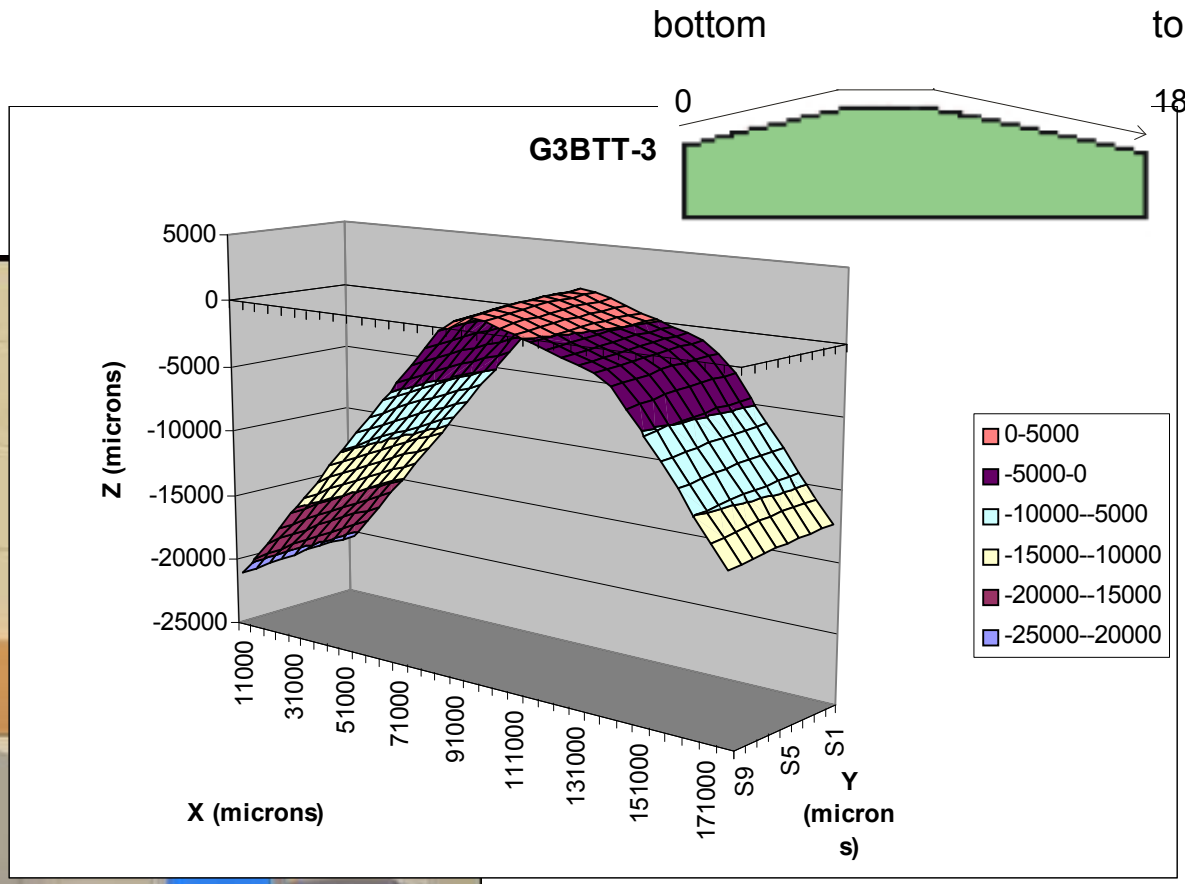
IBA can compare thickness of the top layer before and after exposure, using the interlayer as a marker, to determine the erosion of the layer (~=bulk)



Tile Profiler

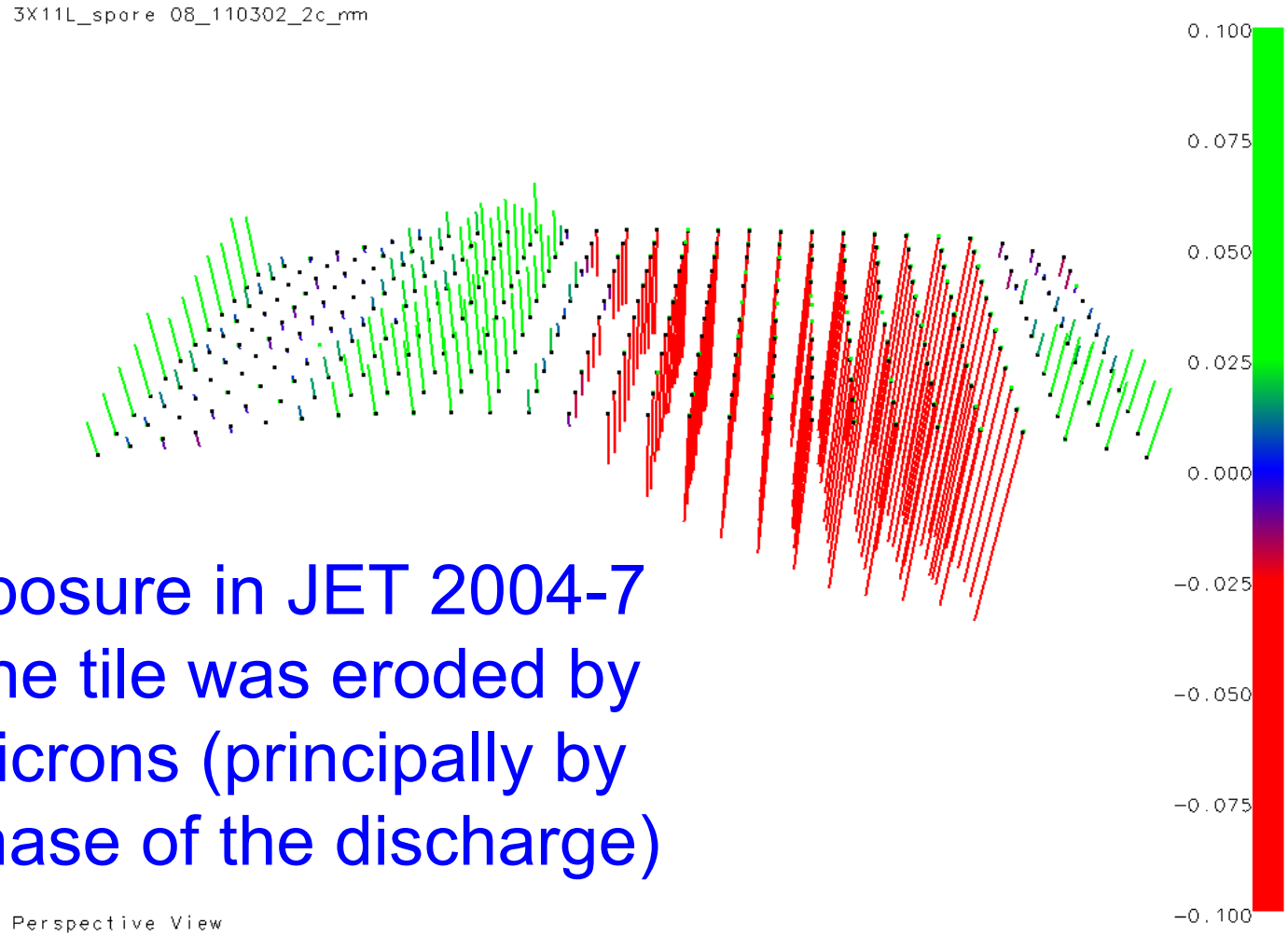
If erosion >thickness of marker layer, change to tile profile is measurable





Surface profile for tile G3B

Profiler results for IWGL tile



After exposure in JET 2004-7 part of the tile was eroded by ~200 microns (principally by limiter phase of the discharge)

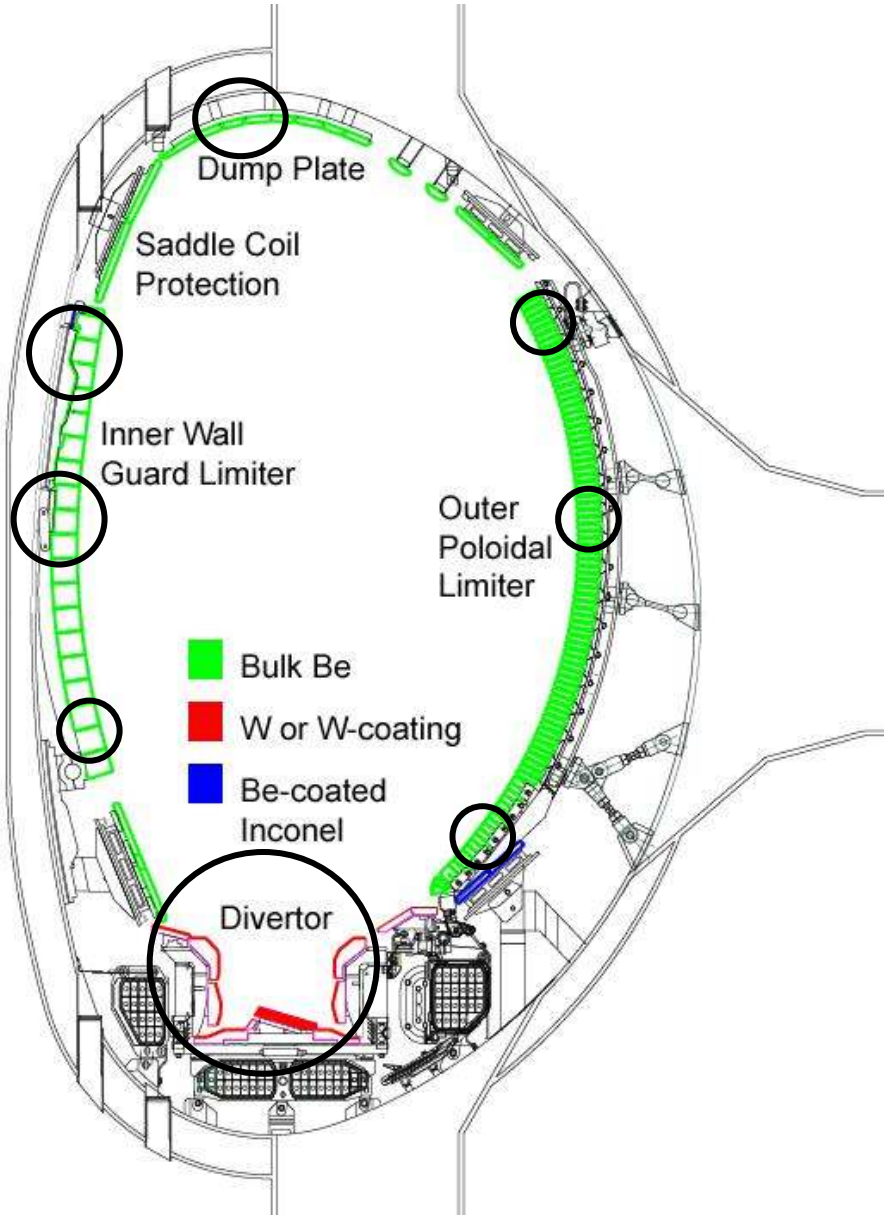
Marker tiles installed in the ILW

To study H-isotope retention and erosion/deposition a sub-set of special marker tiles will be removed during "quick" interventions

Be-10 tracer from a IWGL source tile

Tiles to be removed include:

- **A full poloidal set of divertor tiles**
- **Outer poloidal limiter tiles**
- **Inner wall guard limiter tiles**
- **Dump plate tiles**
- **Inner Wall Cladding tiles**



Tile analysis for ILW

- Interventions are planned during the ILW campaign to exchange a limited number of tiles for which spares exist. The first is now underway (end of 2012) and the next is planned for early 2014
- Tiles will be used to measure erosion/deposition, H-isotope retention, etc
- The analysis programme will be arranged and co-ordinated through Task Force Fusion Technology (TFFT)
- All Associations are invited to participate, but the final programme will be limited by the number of tiles available

Possible topics for investigation

- Erosion/deposition and material transport
- H, D, T, He retention in co-deposits and evaluation of composition/properties
- Damage and T-retention in bulk Be and W
- Alloying between deposited Be and W tiles
- Carbidisation (of the W-coated CFC tiles)
- Phase transformation/material property changes in W lamellae and components of the solid-W target unit
- Melt damage