EUROfusion

Erosion and deposition in the JET divertor corners with carbon and ITER-like walls

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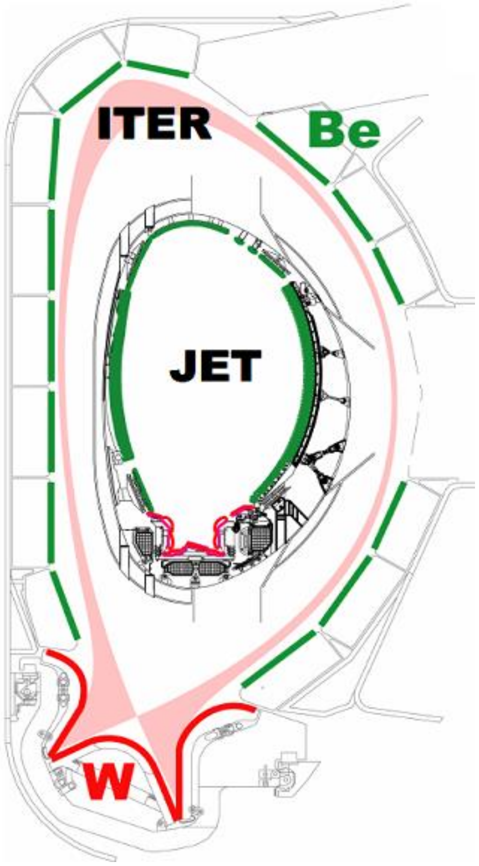
- Diagnostics
  Rotating collectors, QMBs
- Modelling
  Modelling approach, use of experimental data
- Results
  JET-C, JET-ILW, aggregate deposition, QMBs
- Summary



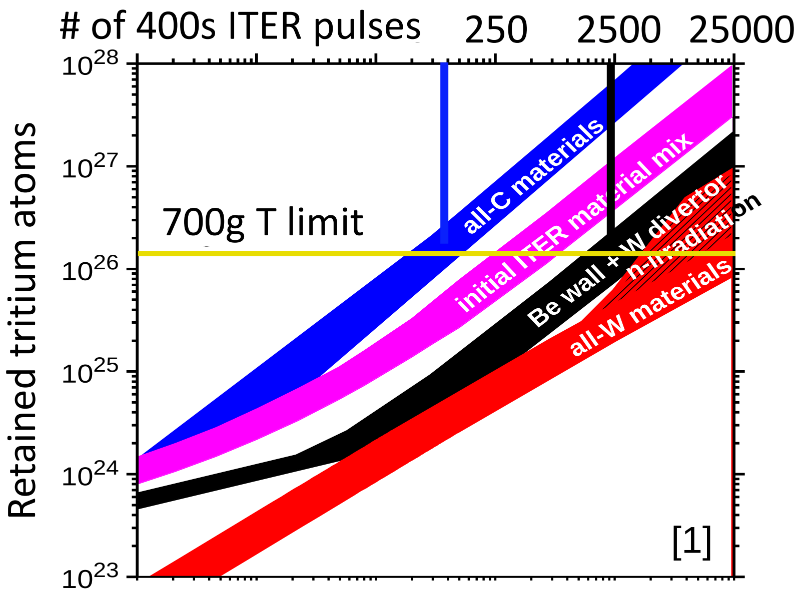
Motivation

Plasma performance

- Impurities in core radiate energy ~Z^2 – limits core temperatures.
- Fuel dilution: D and T ions in core replaced by impurities.

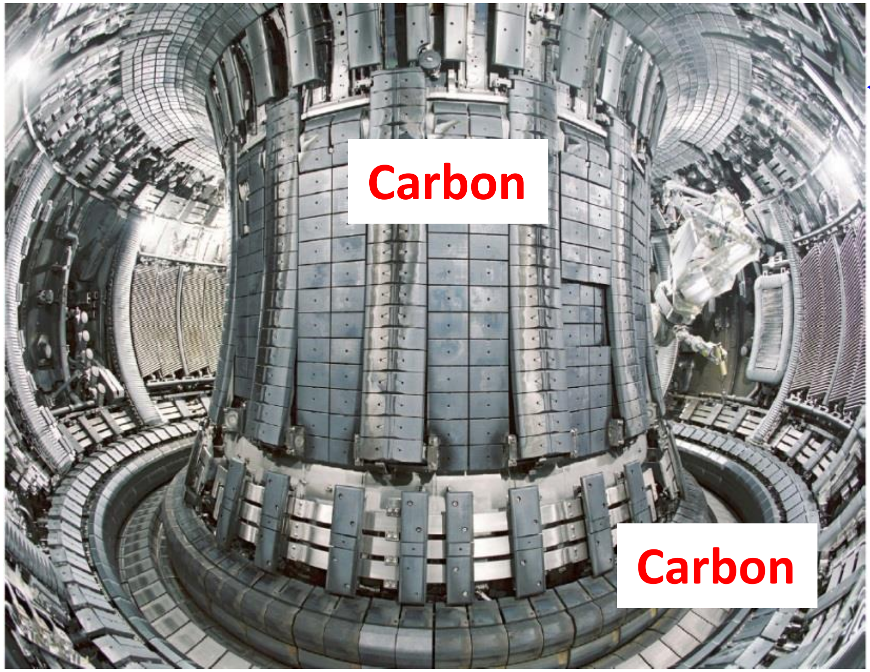
Vessel lifetime

- Walls can be eroded physically, chemically and thermally.
- First walls need to last long enough for fusion to be competitive economically.
- Tritium retained in deposits – 700g limit in ITER.



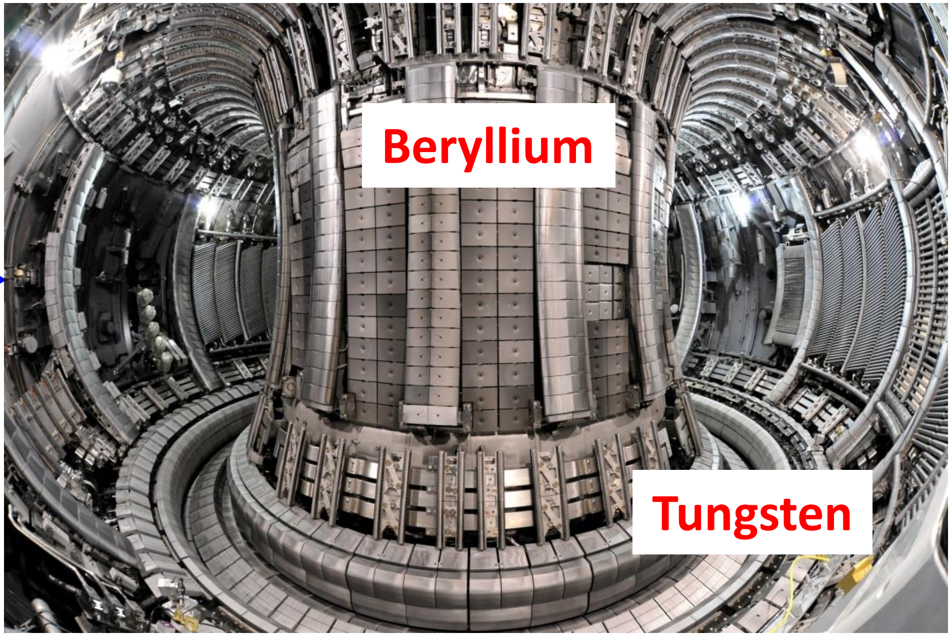
[1] J Roth *et al* J. Nucl. Mater. 2009

Erosion and deposition in JET



Pre-2010 carbon wall

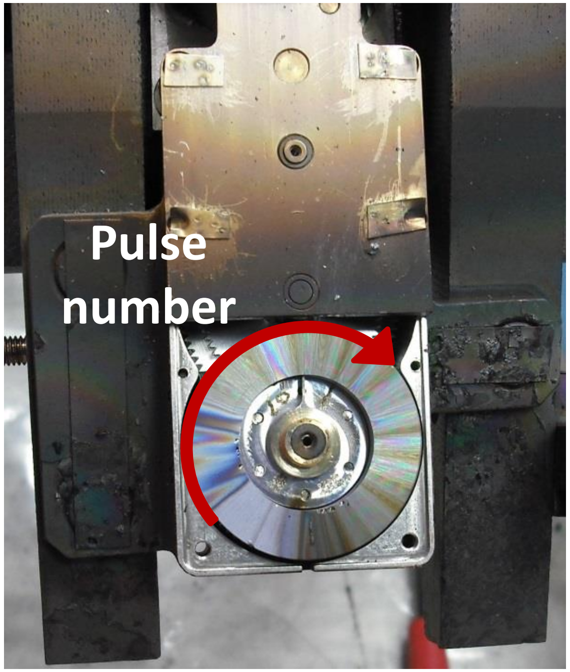
- Good thermal properties
- High chemical erosion
- Codeposition of carbon with deuterium/tritium



Post-2010 ITER-like wall

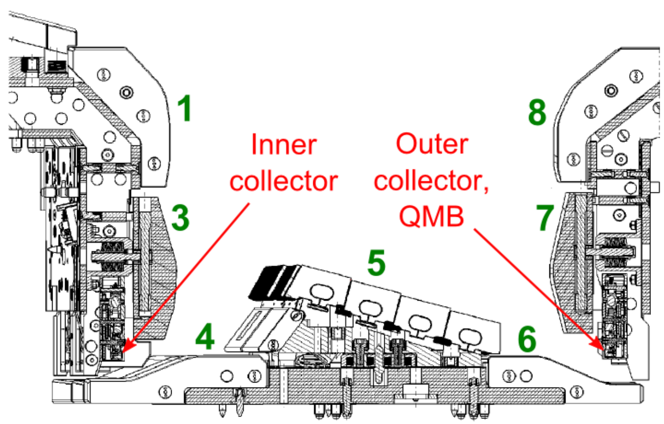
- Main chamber beryllium not chemically eroded.
- Tungsten divertor has low physical sputtering, high melting point.

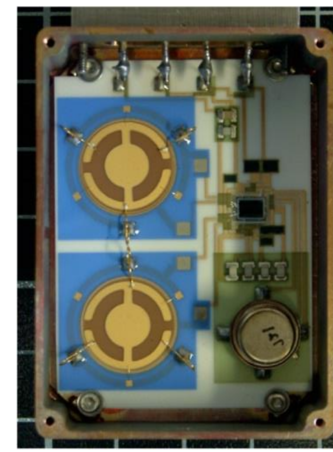
Diagnostics



Rotating collectors[1]

- Previously eroded material deposits on silicon disc.
- Disc driven to rotate behind aperture by toroidal field.
- Deposition profile around disc measured using NRA, mapped to pulse number.





QMBs[2]

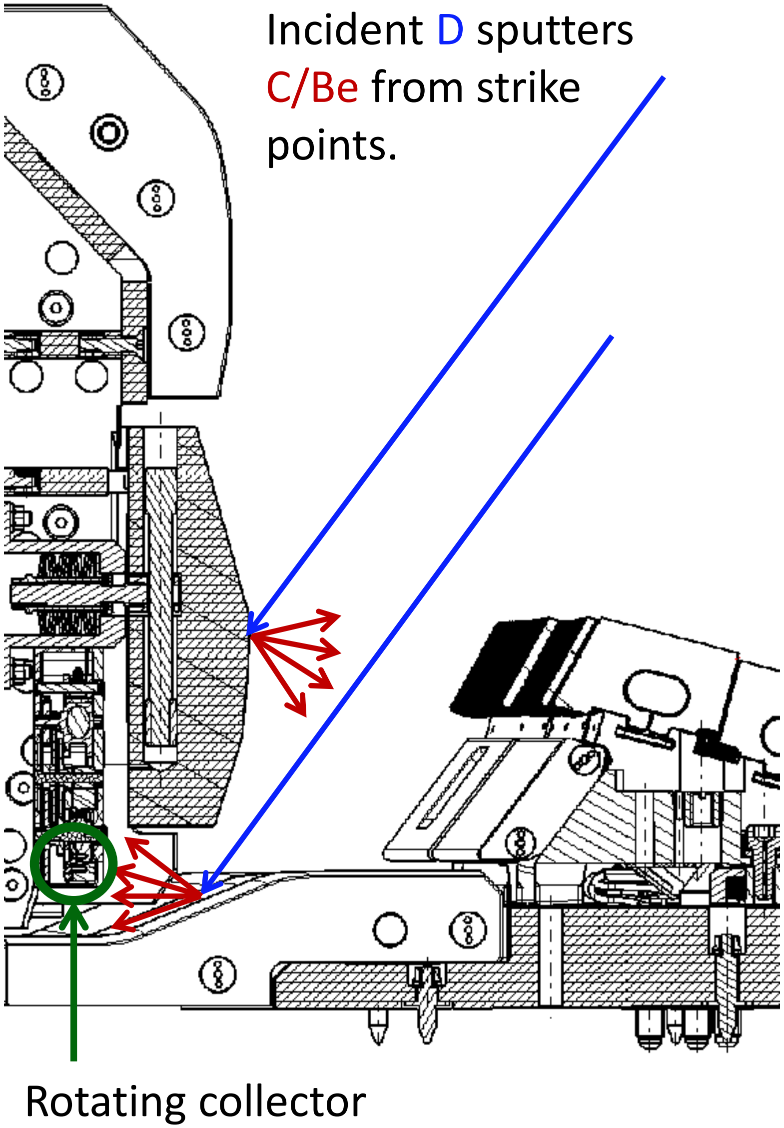
- Frequency of vibrating crystal varies with mass → measure erosion/deposition.
- Remove temperature effects by subtracting frequency change of second, unexposed crystal.

[1] J P Coad *et al* Phys. Scr. 2009
[2] H G Esser *et al* Fus. Eng. Des. 2003

Modelling

Simple, geometrical model using experimental data

- Model collector deposition over whole campaigns.
- Generate sputter cones of C/Be impurities from strike points.
- Strike point locations from EFIT, ion fluxes from Langmuir probes, tile temperatures from IR/thermocouples.
- Impurity sources from analytical yield equations[1,2], spectroscopy.
- Scale deposition magnitudes by constant attenuation factors.

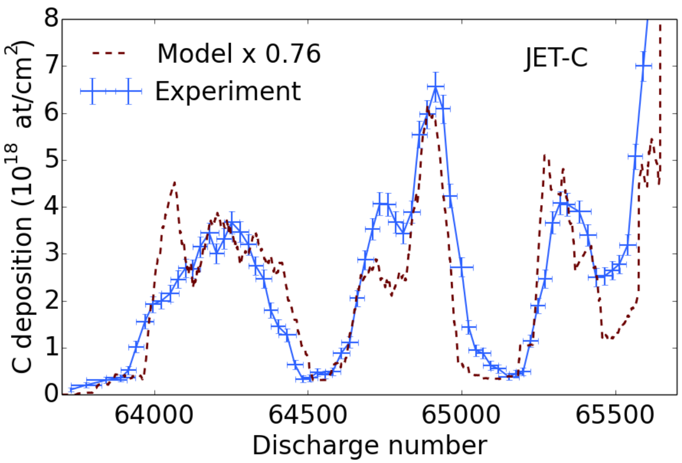


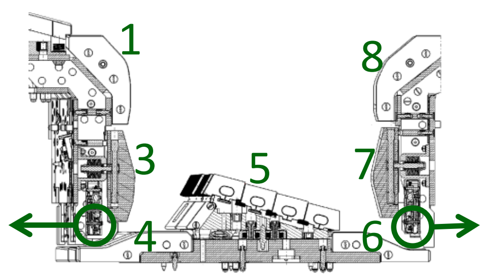
[1] J Roth, C Garcia-Rosales Nucl. Fusion 1996
[2] W Eckstein, R Preuss J. Nucl. Mater. 2003

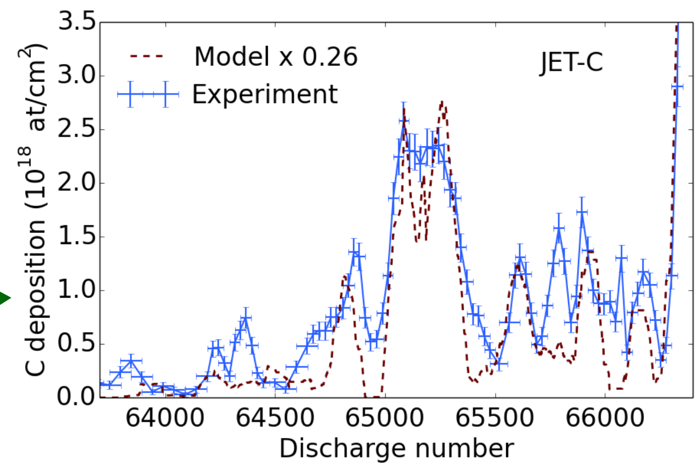
Results: JET-C

Carbon impurities dominate in JET-C

- In inner divertor, good qualitative agreement between experiment and model.
- High inner deposition when strike point on tile 4 close to collector.
- In outer divertor, could only achieve good agreement by assuming deposition only occurred when strike point was on tile 5.
- Implies simplified geometrical approach not fully appropriate here.



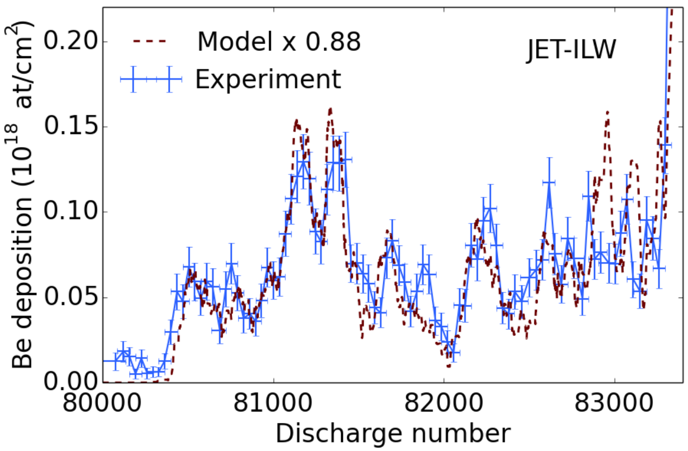


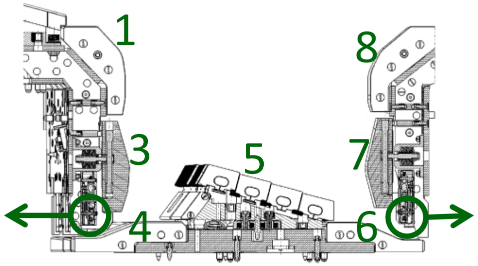


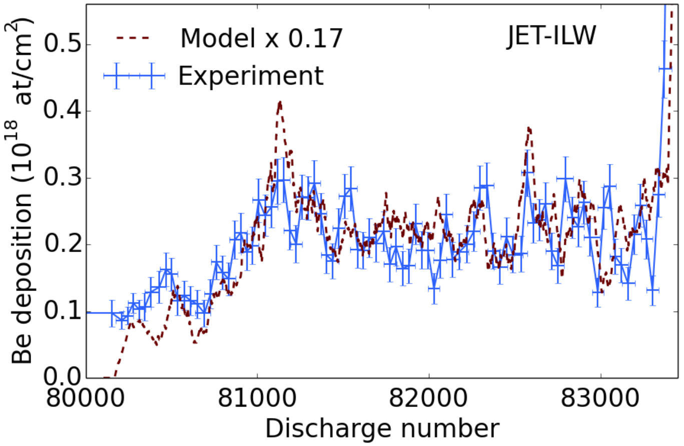
Results: JET-ILW

Beryllium replaces carbon in JET-ILW

- Tungsten only sputtered by incident beryllium or by ELMs[1] – very little seen on collectors.
- Deuterium retention in deposits reduced relative to JET-C collectors.
- Allowing deposition on outer collector for both tile 5 and tile 6 strike points gives good fit, contrary to JET-C case.
- Implies different erosion/deposition balance for Be relative to C.





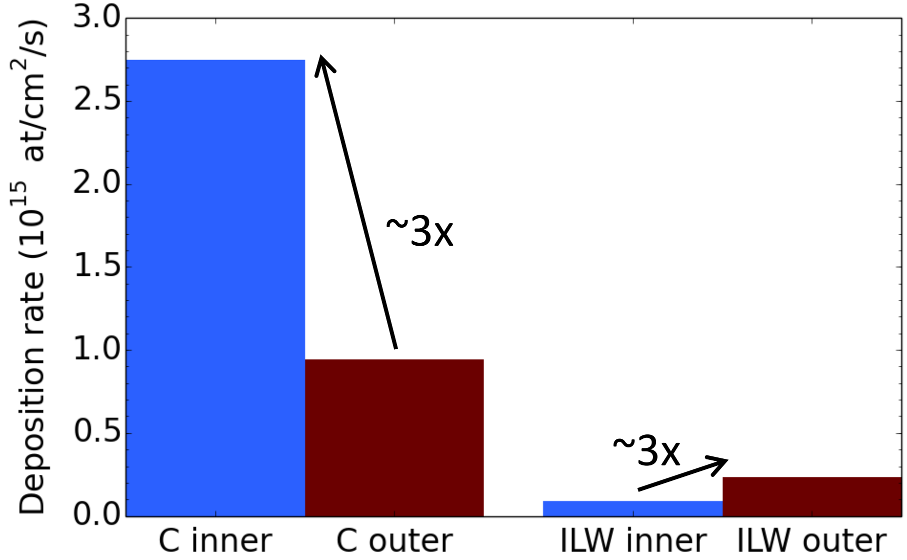


[1] G J van Rooij *et al* J. Nucl. Mater. 2013

Results: Aggregate deposition

Order of magnitude lower deposition rate on JET-ILW collectors

- Lower impurity source from main chamber[1].
- Reduced chemical sputtering/erosion[2].
- Different strike point distributions.



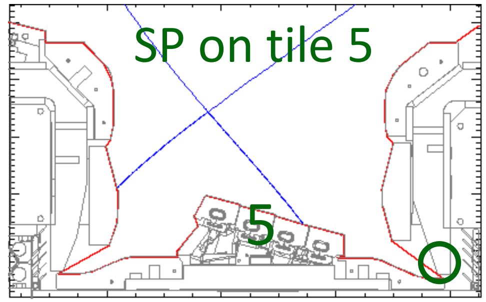
Reversal of deposition asymmetry in JET-ILW

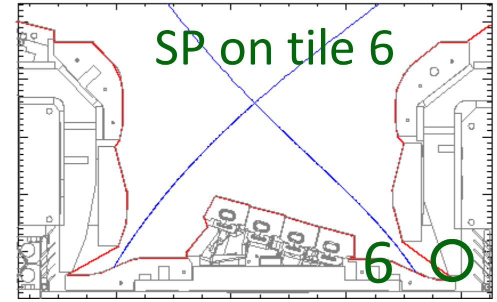
- Inner divertor dominates deposition in JET-C divertor[3].
- But outer divertor collector shows more deposition than inner for JET-ILW.
- → C and Be impurities exhibiting different erosion/deposition/transport behaviour.

[1] S Brezinsek J. Nucl. Mater. 2015
[2] S Brezinsek *et al* Nucl. Fusion 2014
[3] J P Coad *et al* J. Nucl. Mater 2001

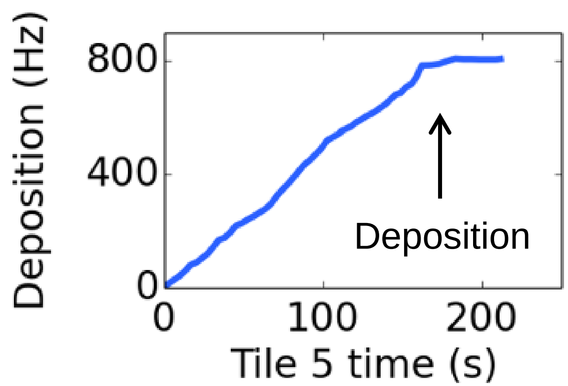
Results: QMBs

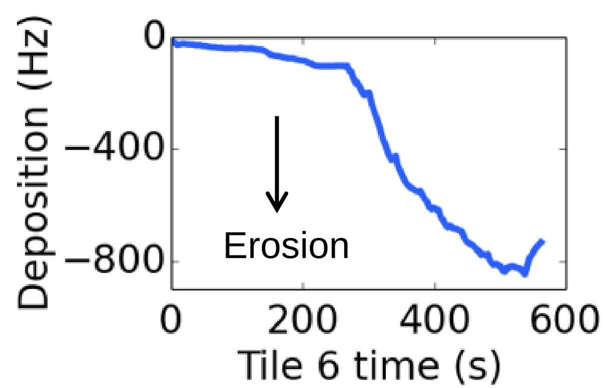
Cumulative frequency changes of outer divertor QMBs, split by strike point location.



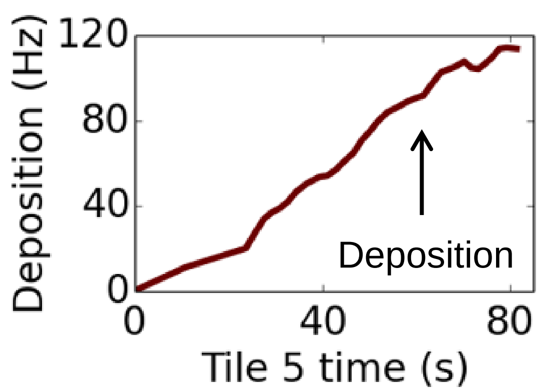


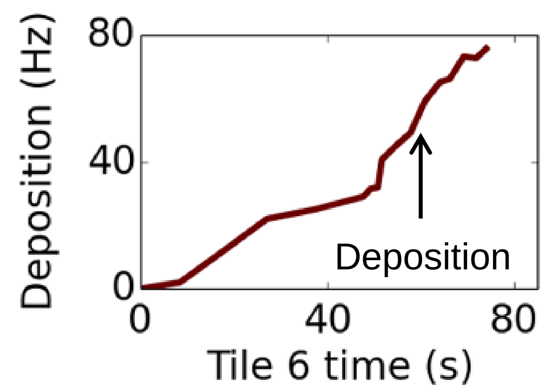
JET-C: net deposition when strike point on tile 5, erosion when on tile 6.





JET-ILW: net deposition for both tile 5 and tile 6 strike points.



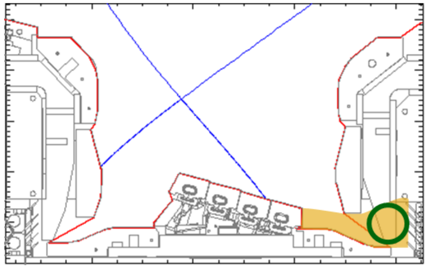
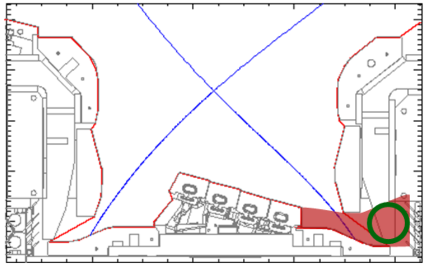


Results: Explanation of mechanism

- Both collector results/modelling and QMBs suggest the same general dependencies for outer corner deposition:

	Tile 5 strike point	Tile 6 strike point
JET-C	✓	✗
JET-ILW	✓	✓

- Tile 6 strike points → high corner surface temperatures.

- Higher temperatures drive chemical/thermal C re-erosion[1] from collector, QMB.
- Be not chemically re-eroded → net deposition for both configurations.
- Gives high aggregate Be deposition on outer collector, reversal in deposition asymmetry.

[1] J Roth, C Garcia-Rosales Nucl. Fusion 1996

Summary

- Erosion/deposition can limit vessel lifetimes and degrade plasma performance.
- Deposition in JET-C/JET-ILW divertor corners investigated using time-dependent diagnostics, geometrical modelling approach.
- Reduction in deposition rate by factor 10 in JET-ILW.
- Reversal of deposition asymmetry in JET-ILW.
- Attributed to the different chemical properties of beryllium and carbon and the response to high temperatures.
- Ongoing Monte Carlo modelling of erosion, deposition and transport in the ITER-like wall divertor.