



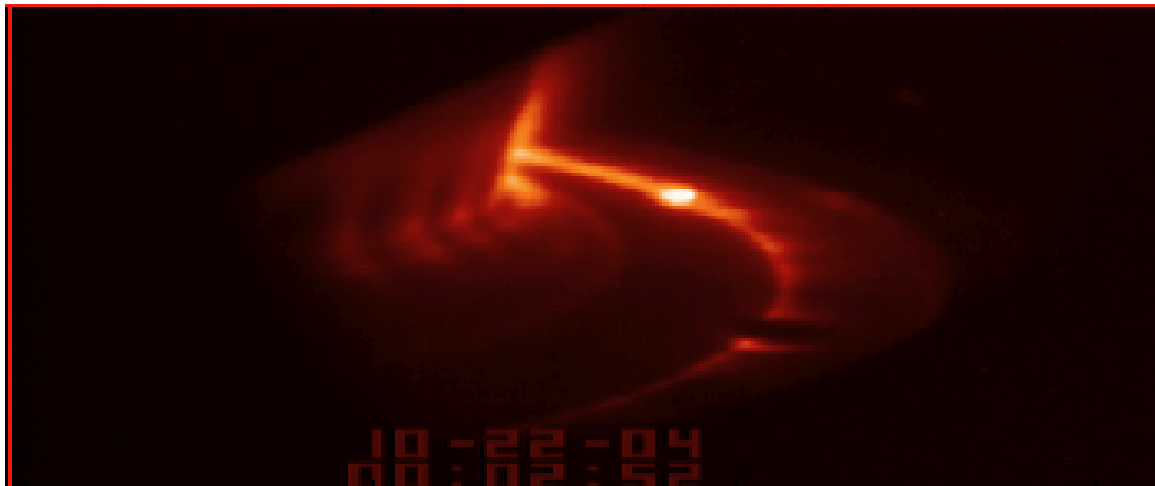
Institute for Aerospace Studies
UNIVERSITY OF TORONTO

Fusion Research Activities at the University of Toronto

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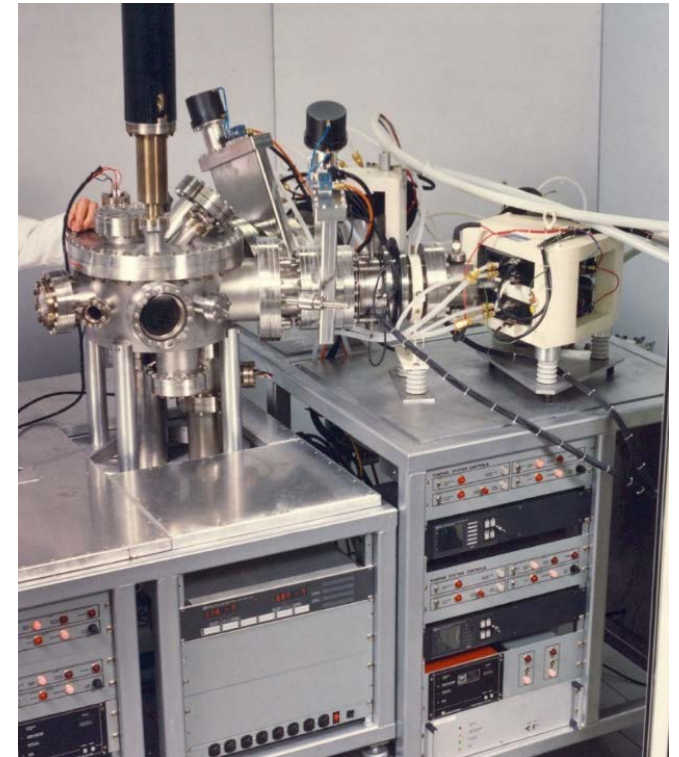


Plasma-Surface Interactions:

The effect on materials and on the edge plasma

Overview of activities:

- 1) Laboratory Materials studies
- 2) Tokamak Edge Plasma Modelling
- 3) Experimental Tokamak Studies





Laboratory Studies: Hydrogen trapping and transport in materials

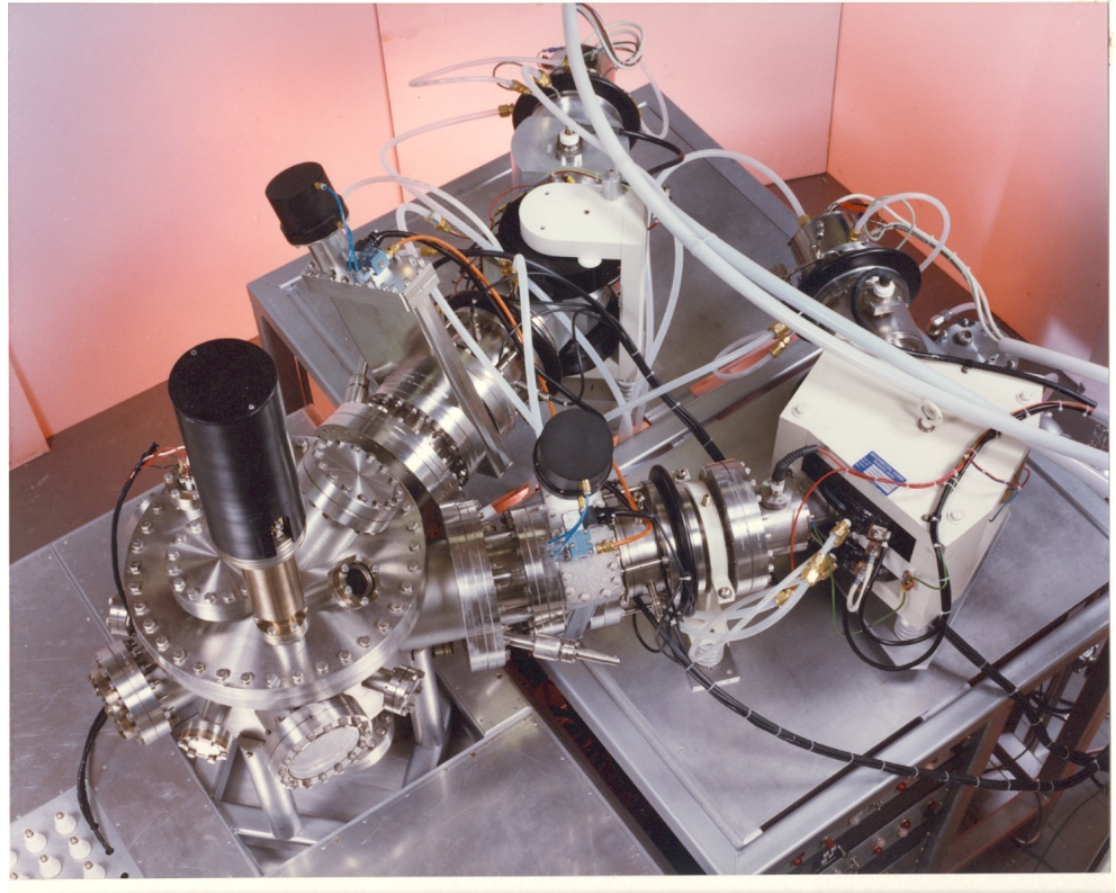
(Hydrogen/Deuterium as a proxy for Tritium)

Current areas of interest:

- Deuterium retention in tungsten – the effect of multi-species implantation
- Removal/de-tritiation of tokamak codeposits

Multi-species Implantation of W

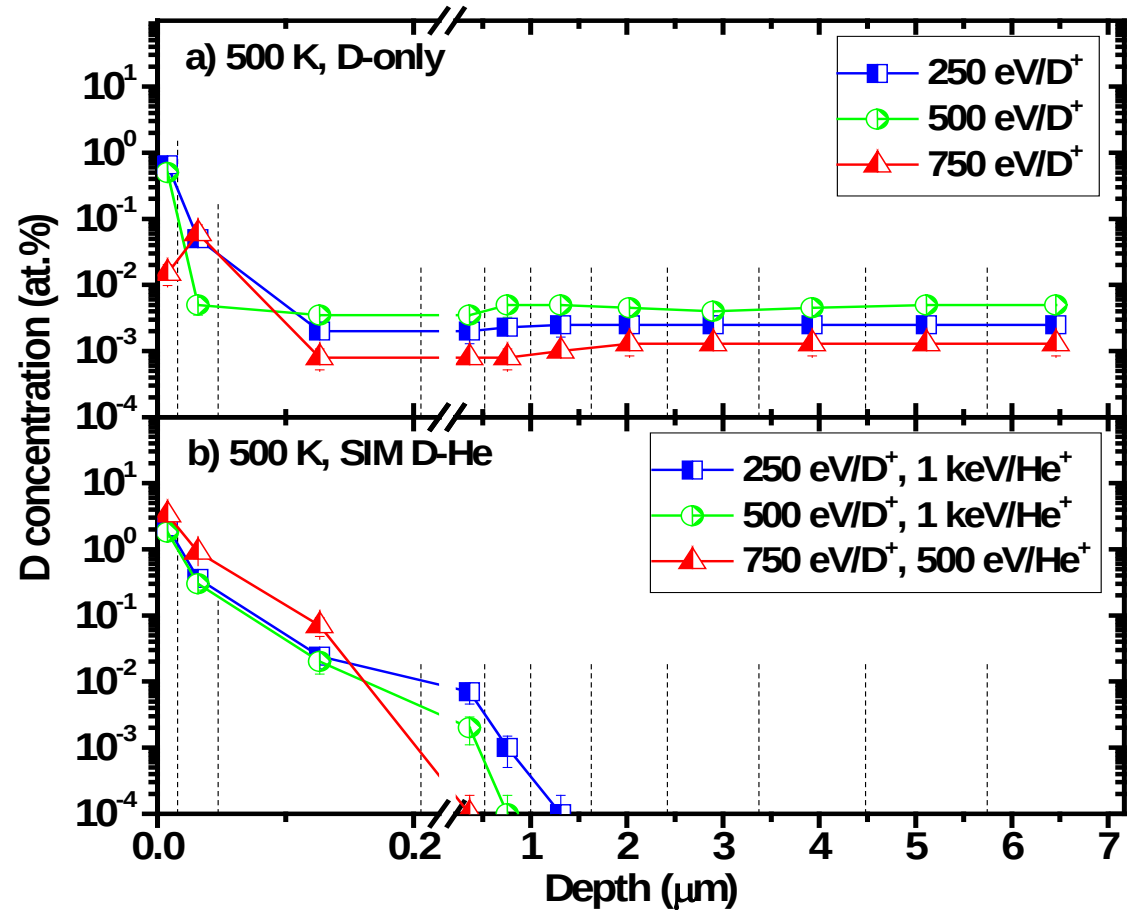
- Experimental simulation of the effect of He ash on D retention
- Experimental simulation of radiative cooling elements (N, Ne, Ar) on D retention



UTIAS dual-beam accelerator



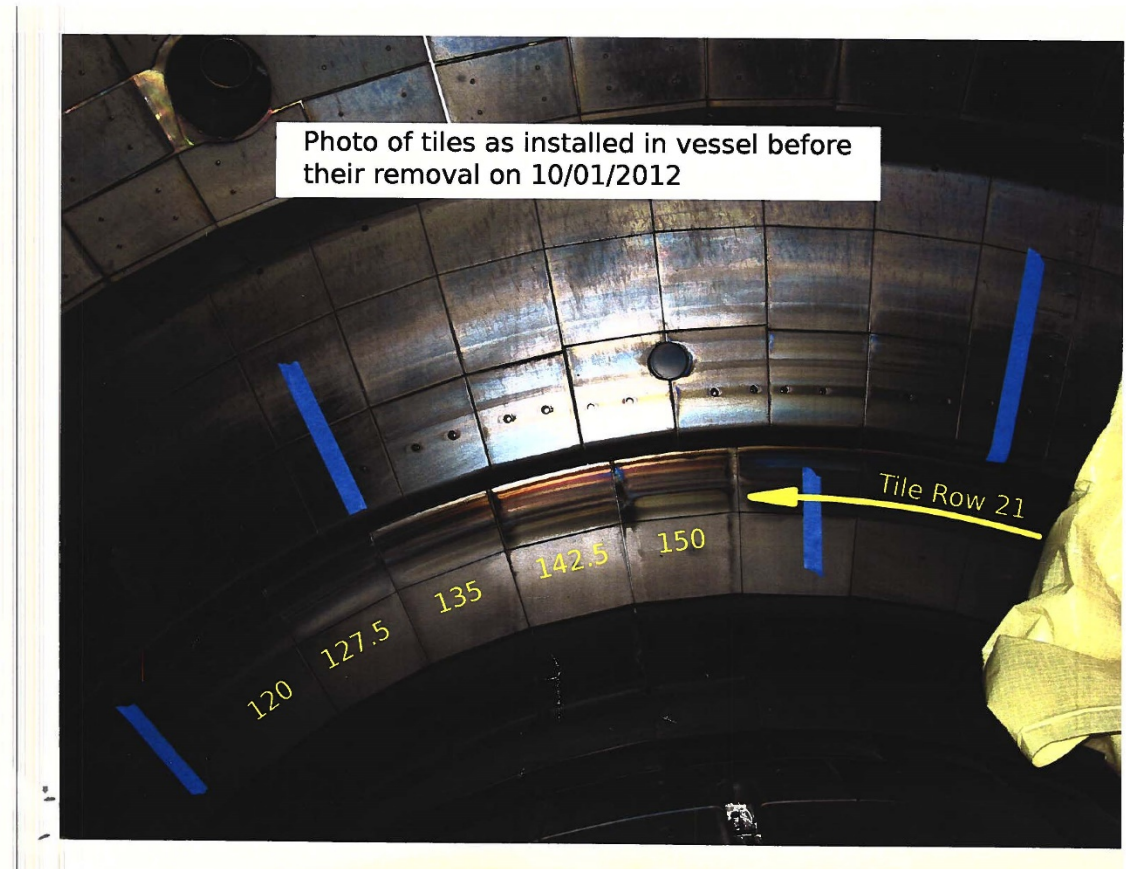
The addition of He leads to higher near-surface D concentrations, but also greatly reduced transport of D into the tungsten.





Removal of Carbon-Based Tokamak Deposits

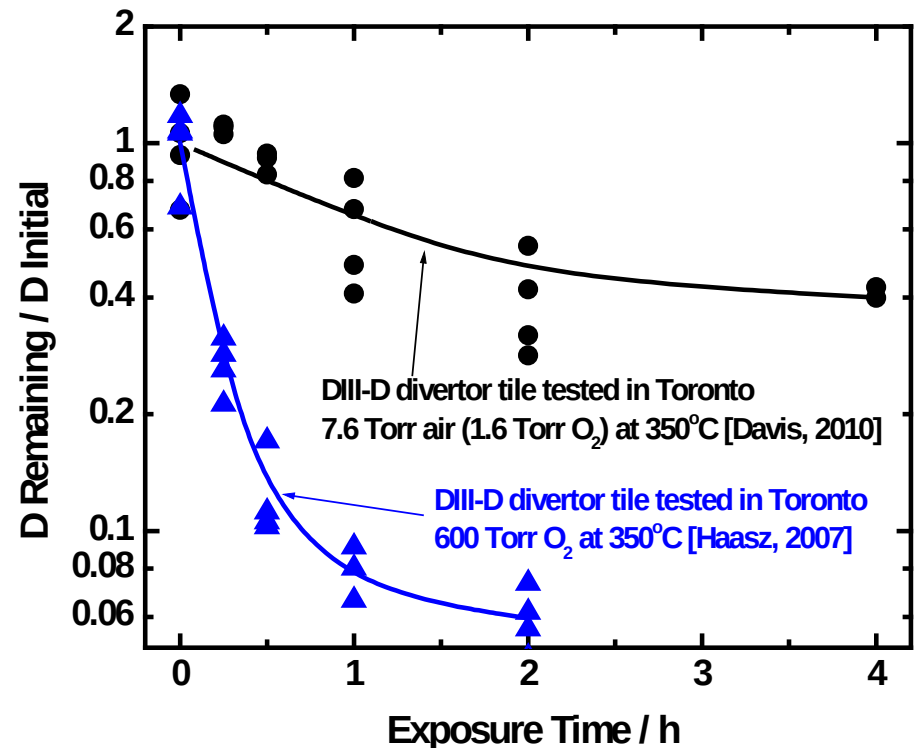
- Tiles from the DIII-D divertor are covered in carbon-based co-deposits
- Such deposits can contain a lot of hydrogen





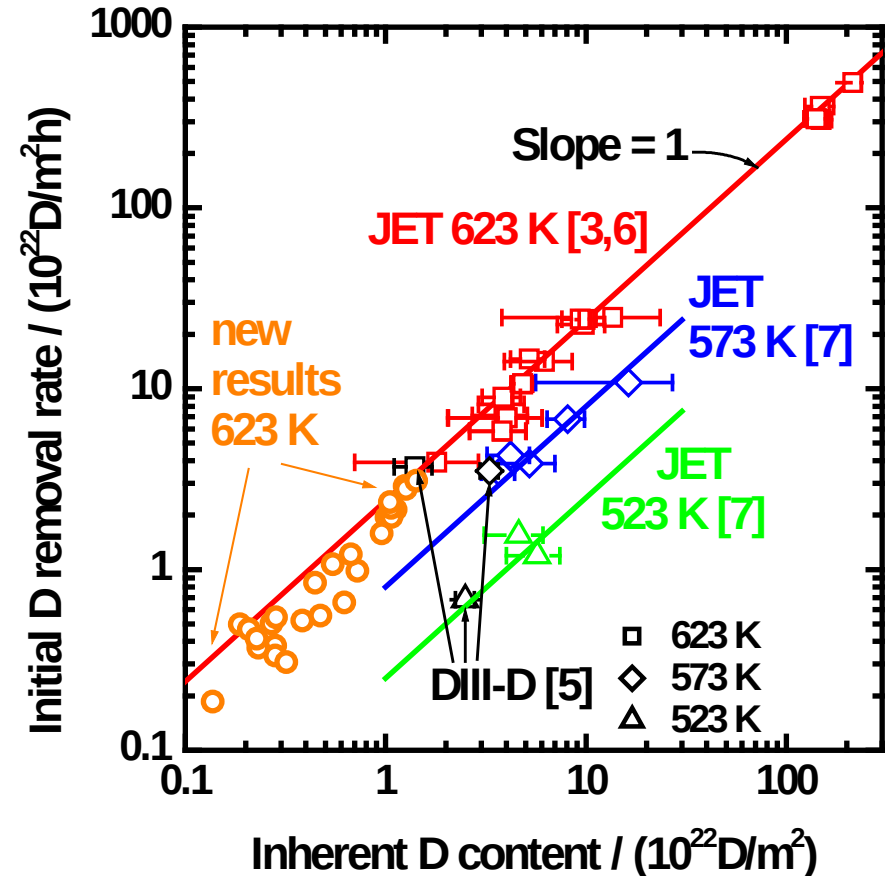
But deposits are easily removed by exposure to oxygen

- Removal is found to be very effective at temperatures 300 – 350 °C
- By comparison, self-cleaning ovens work at ~ 500 °C





We have also found that the deposit removal time is independent of initial thickness. This implies the deposits are highly porous, and that oxidation takes place throughout the layer.



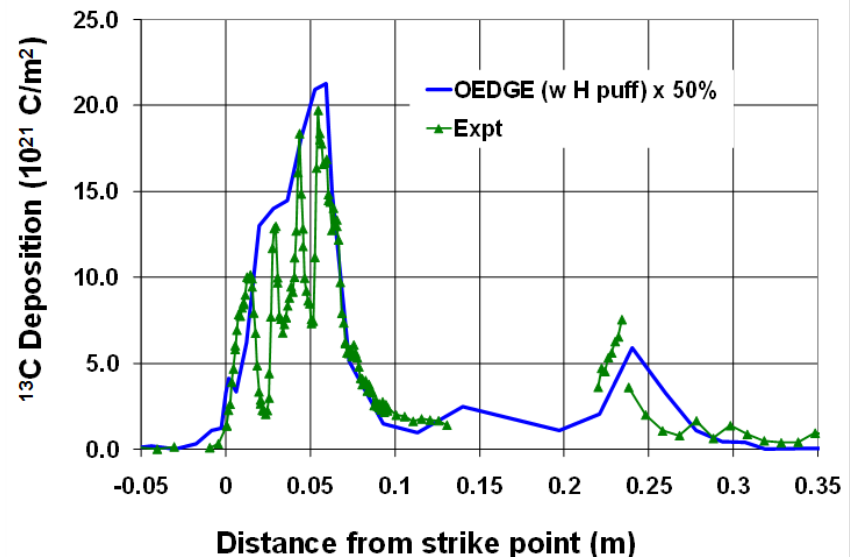
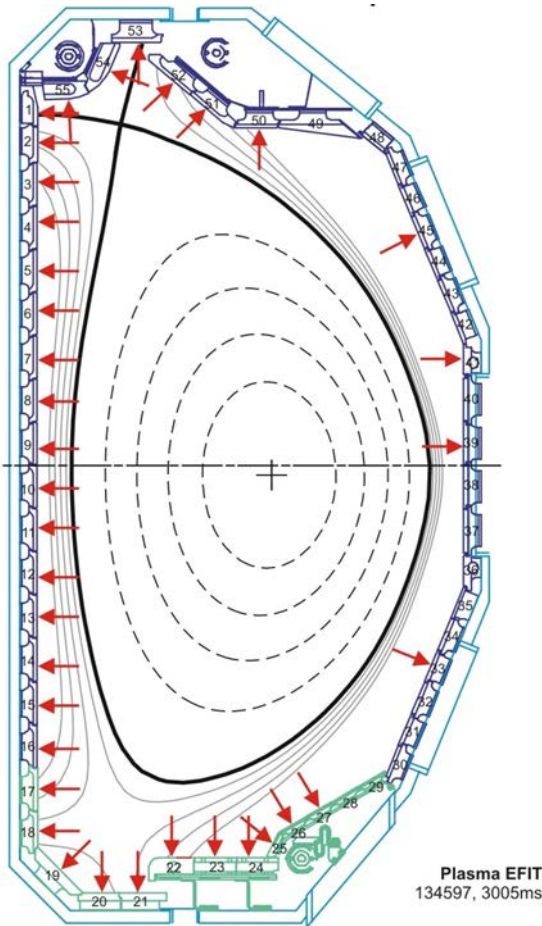


Tokamak Edge Plasma Transport Calculations

- The OEDGE (Osm-Eirene-Divimp edGE) modeling code is an interpretive modeling code for the edge plasma of magnetic fusion devices.
- The suite of codes was originally developed in the early 1980's by the UTIAS fusion research group (in collaboration with JET).
- The code has been used by researchers at JET, ASDEX Upgrade, Aalto University (Finland), ITER, General Atomics (DIII-D), MIT (CMOD), ORNL, China (EAST, CFETR, SWIP, DLUT) and elsewhere.

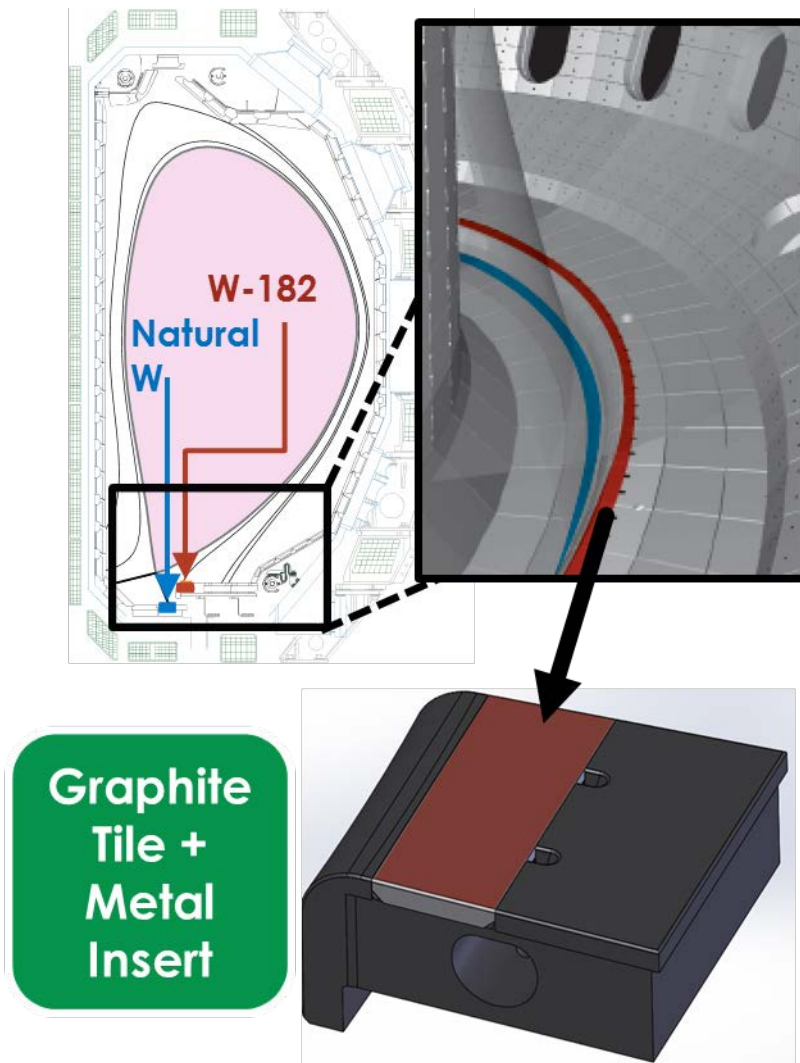
OEDGE Simulation of ^{13}C Deposition

- $^{13}\text{CH}_4$ puffed into 18 consecutive identical DIII-D discharges for 2s in each discharge
- Tiles immediately removed from the vessel and ^{13}C content measured using nuclear reaction analysis

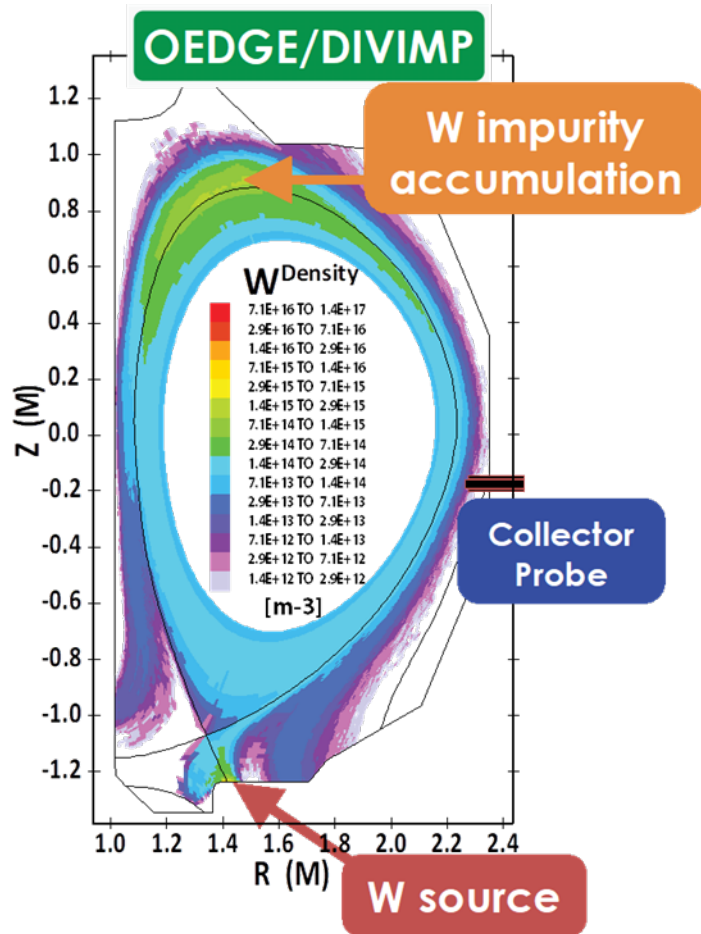




The DIII-D tungsten metal rings experiment



- Two toroidally symmetric rings of tungsten inserts were installed on the shelf and outer divertor floor on DIII-D.
- A set of 24 repeat L-mode discharges was run with the strike point on the shelf tile ring to measure both local and long range Tungsten transport.
- The outer midplane SOL tungsten content was measured by the insertion of a Collector Probe.



Simulation procedure:

- Background plasma consistent with experiment is reconstructed (modelled) from measurements
- OEDGE carbon simulations are run to determine charge state resolved carbon flux and impact energies
- W sputtering source is calculated from carbon ion flux and energy data
- W neutrals are launched in the Monte Carlo simulation and are followed through ionization and transport until deposited on a solid surface.
- OEDGE simulations find some W to be transported upstream from the outer target, accumulate above the collector (exact location not determined from modeling), and then transport into the peripheral plasma where it can deposit on the collector probe.

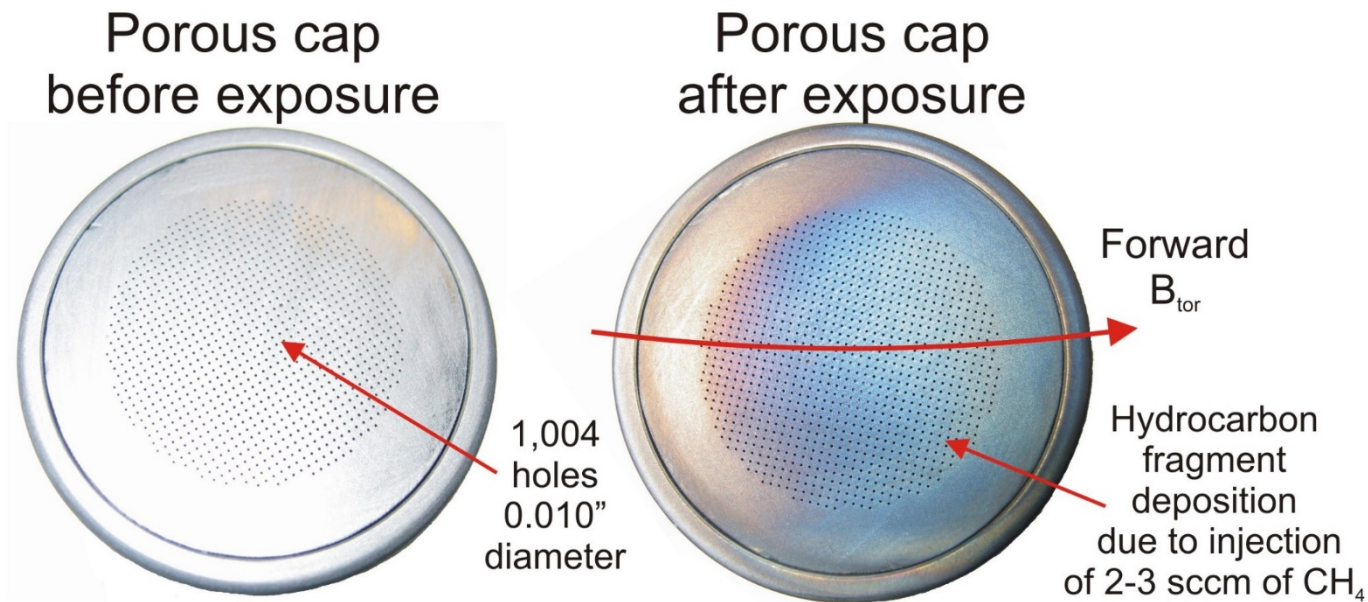


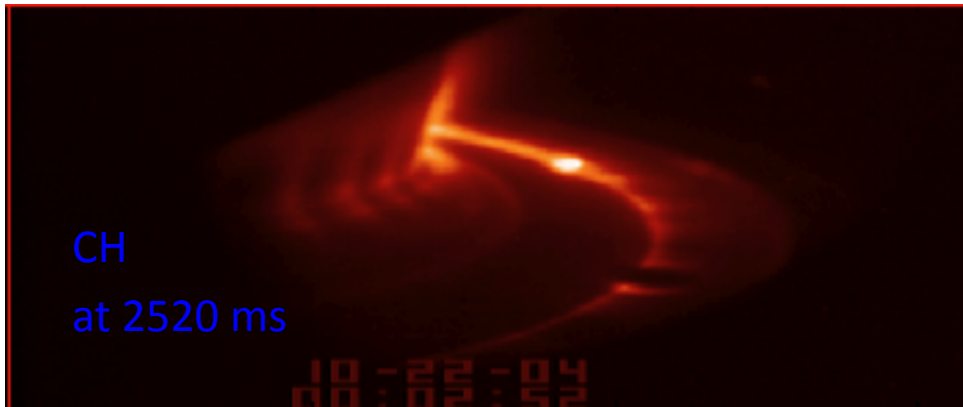
Tokamak Experiment Studies: Collaborations with DIII-D

- Porous plug gas injection system
- Swing probe
- DIII-D oxidation

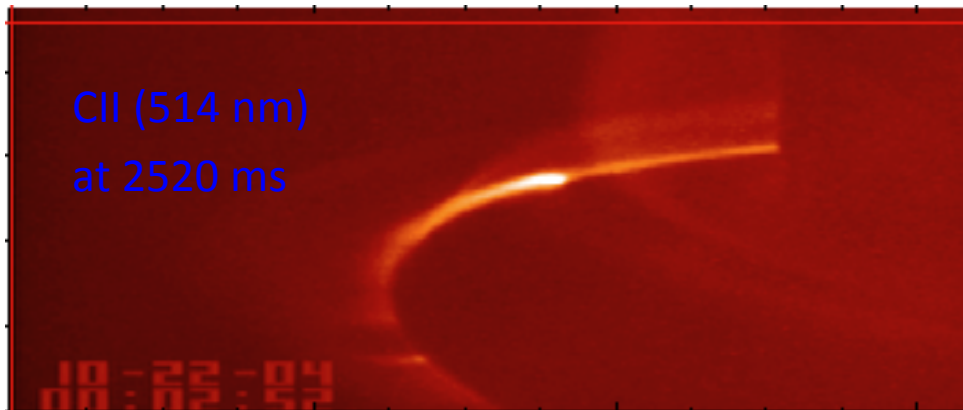
Porous plug gas injection system

- Gas can be injected into the tokamak edge plasma without significant disruption to the local plasma properties





CH band emissions in the DIII-D tokamak



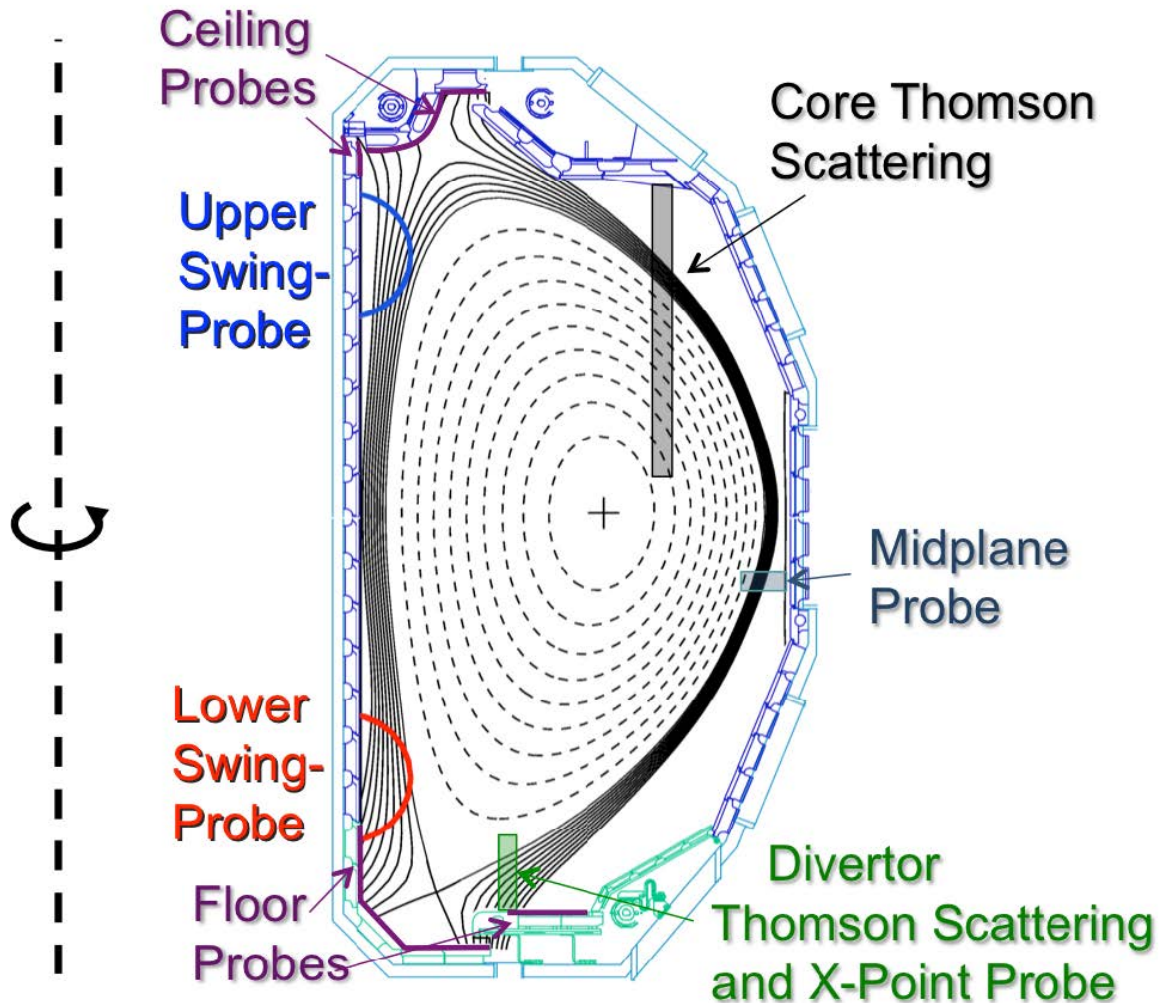
C⁺ line emissions in the DIII-D tokamak

- Modelling of the emissions allows us to evaluate plasma transport parameters
- A key result was a calibration of spectrometer measurements for hydrocarbon influx



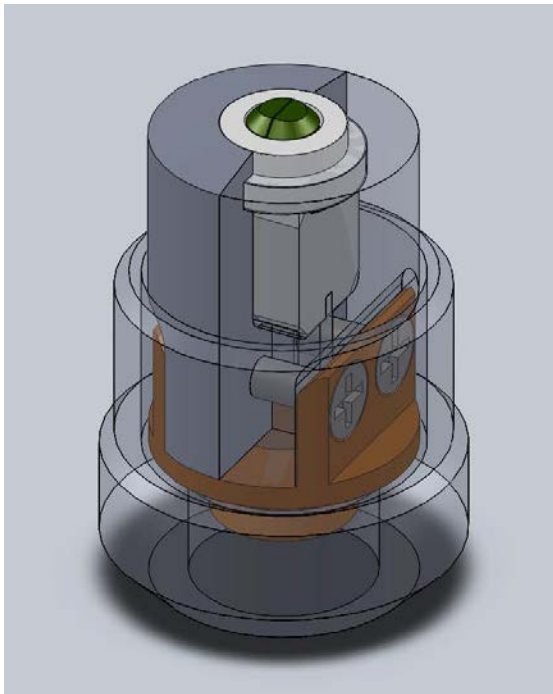
Swing Probes

Measurements of
plasma properties
across the inboard
separatrix





Double probe tip
provides a measure of
 n_e , T_e and $M_{\parallel}$

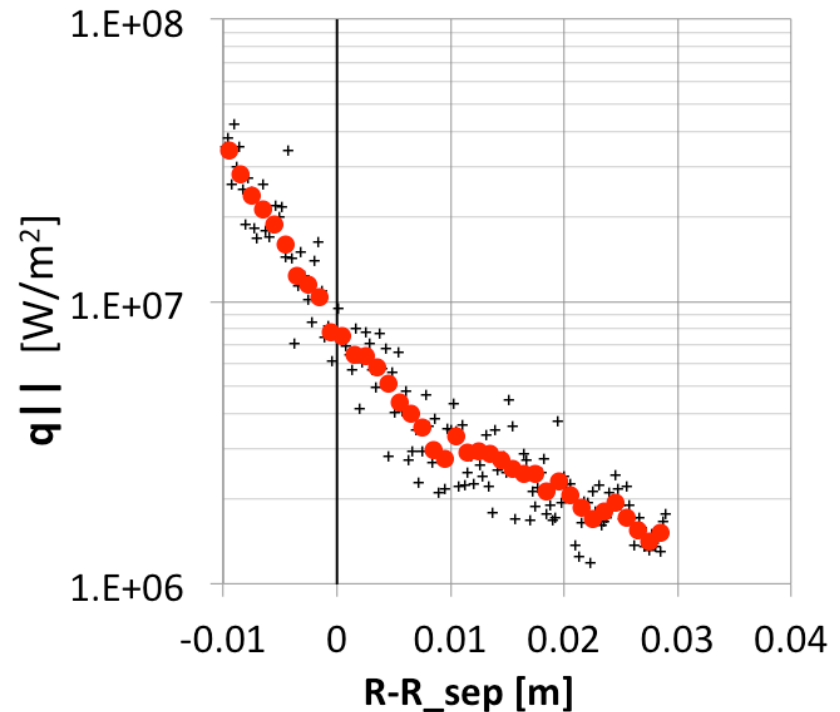


Probe was flush-mounted
behind center-post wall
tiles





A key result was the finding that the parallel heat flux beyond the separatrix has a two-component exponential fall-off



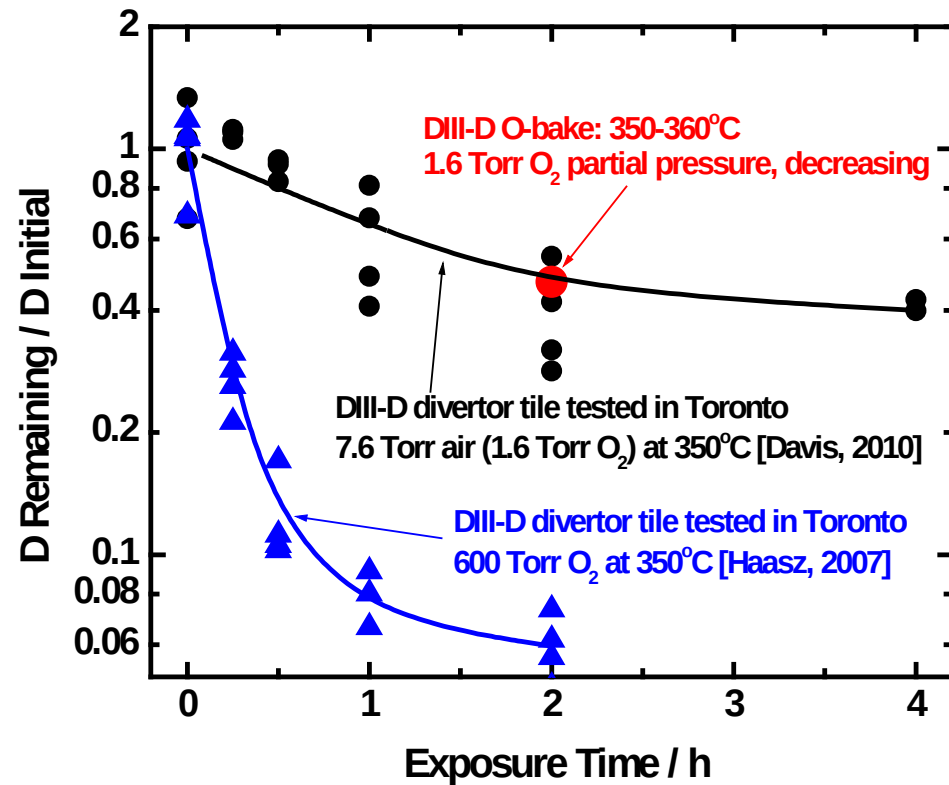


Thermo-Oxidation in the DIII-D tokamak



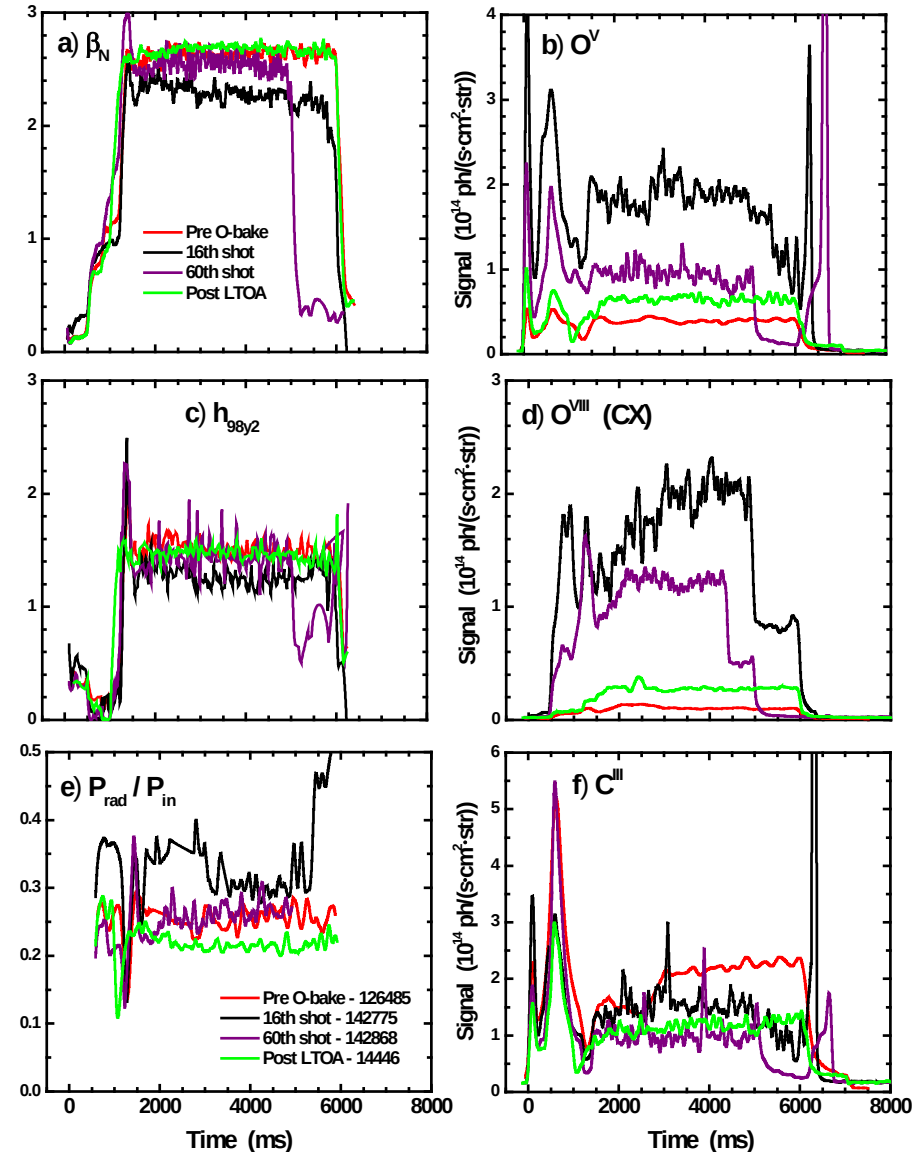


In-situ results were found to be consistent with laboratory measurements



A key finding was the demonstration that the oxidation had no long-term impact on plasma operation

- Impurity radiation levels were actually found to decrease





Summary

For more than 4 decades, the Fusion Group at the University of Toronto has worked in the area of plasma-surface interactions

- Laboratory measurements of material erosion and hydrogen retention
- Numerical studies of impurity transport in tokamak edge plasmas