Erosion/redeposition experiments on DIII-D and EAST

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Plasma-Facing Components Meeting
PPPL
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DIII-D - DiMES Mo Erosion experiments

EAST - MAPES material migration experiment for ITER
- Fixed tile marker experiment

Sandia is a multi-program laboratory operated by Lockheed Martin Company,
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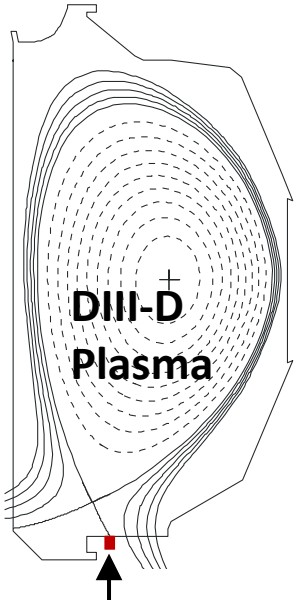
DiMES Mo Erosion experiments in DIII-D

Objective

- Local redeposition is expected to reduce net erosion.
- Measure both net and gross erosion of Mo at the OSP in DIII-D.
- This experiment provides a comparison of
  a) net vs. gross erosion and
  b) erosion vs. local redeposition.
- Net erosion is measured from the change in thickness of a thin Mo film determined by RBS.
- Gross erosion was determined from Mo I emission intensity, (not discussed here) N. Brooks et. al.
- Compared to simulations, J. Brooks et. al.



DiMES probe at OSP

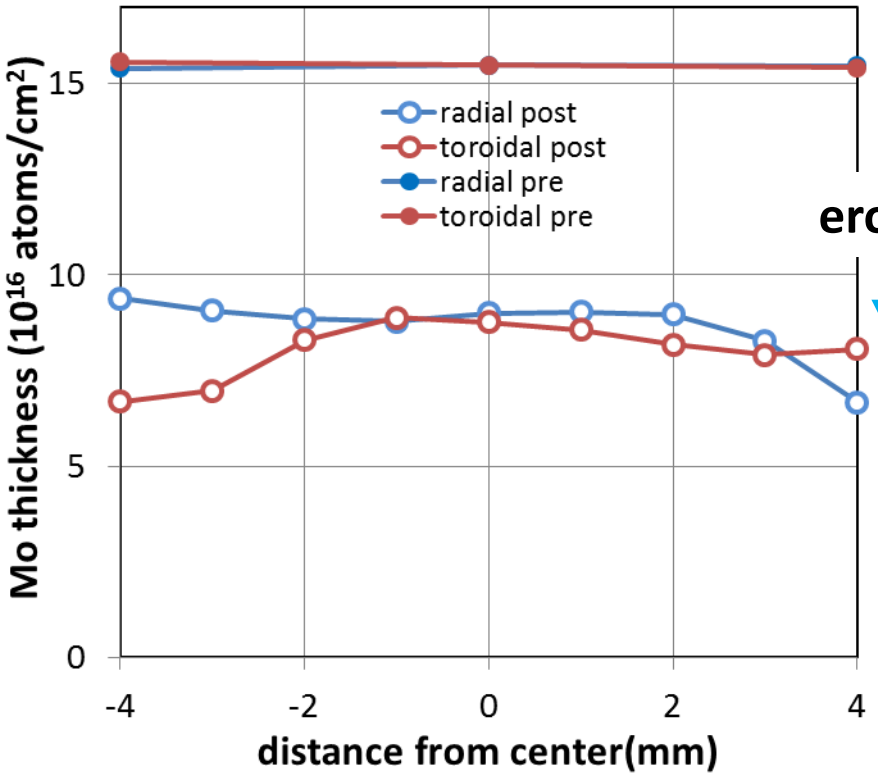
Experimental Method

- A thin Mo film 1 cm in diameter on silicon substrate was exposed to L-mode, low density, LSN, deuterium plasma in DIII-D.
- OSP was on DiMES from 1-5 sec, off during ramp up & down.
- Plasma conditions at OSP measured by Langmuir probes
  Te ≈ 30eV, Jsat ≈ 0.25A/cm^2 → ion flux ≈ 1.5x10^{18}/cm^{2}s.
- Net Mo erosion & deposition measured by RBS (2MeV ^{4}He), detection limit for Mo erosion ~ 10^{15} atoms/cm^2 (1 monolayer) .
- Deposition of D & C also measured by ^{3}He NRA.

20th International Conference on Plasma-Surface Interactions
Aachen, Germany, May 21-25, 2012

Mo Erosion

8/1/2011 7 shots 28 sec

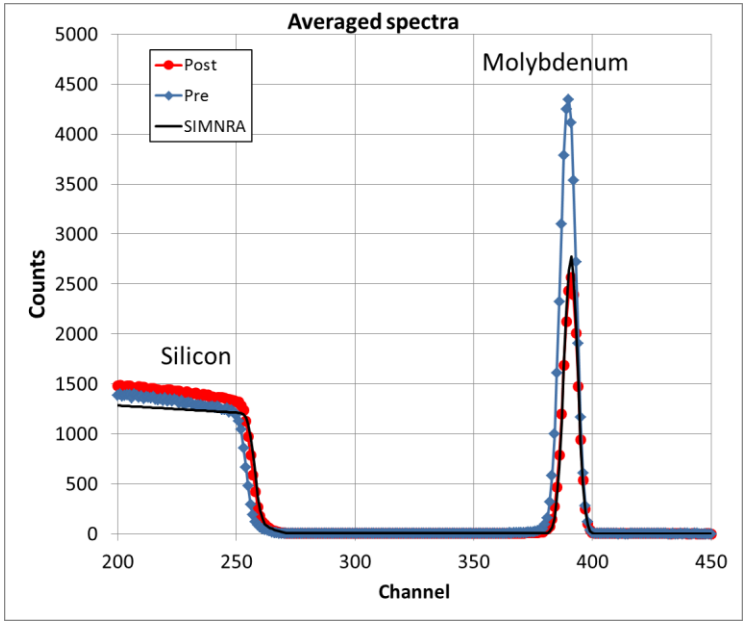


Mo film thickness before exposure to plasma

erosion

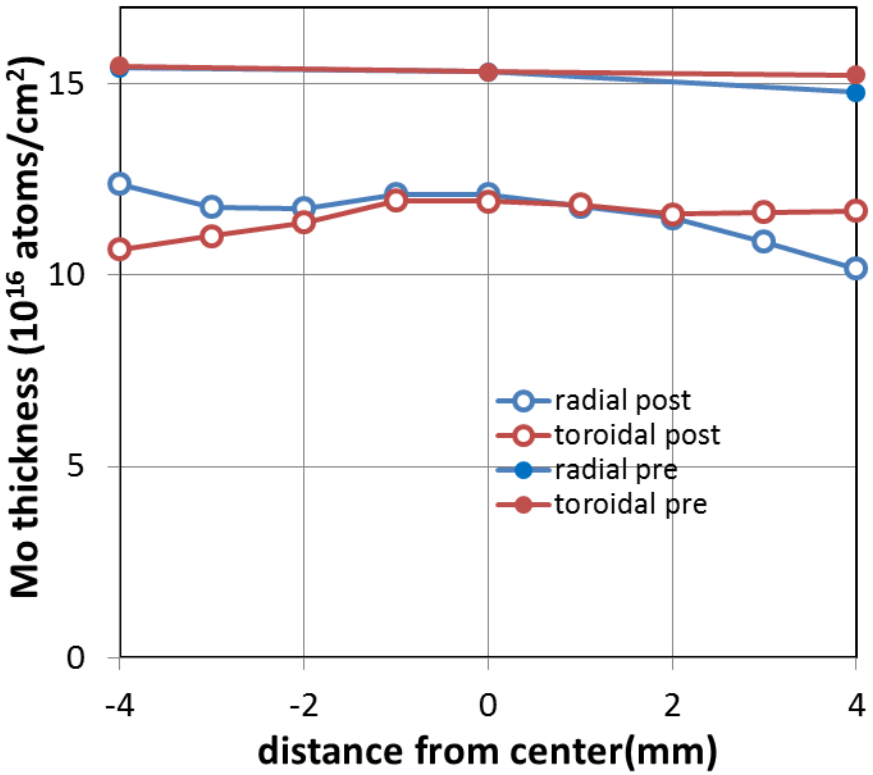
after exposure to plasma

2 MeV ^{4}He RBS

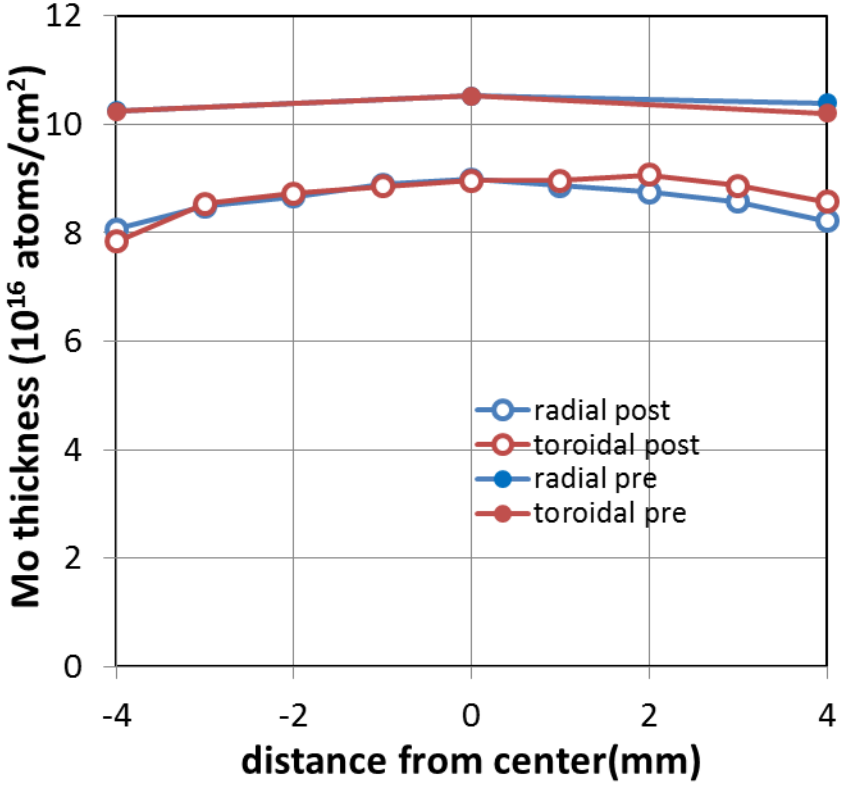


Mo Erosion

4/23/2012 3 shots 12 sec



5/1/2012 1 shots 4 sec

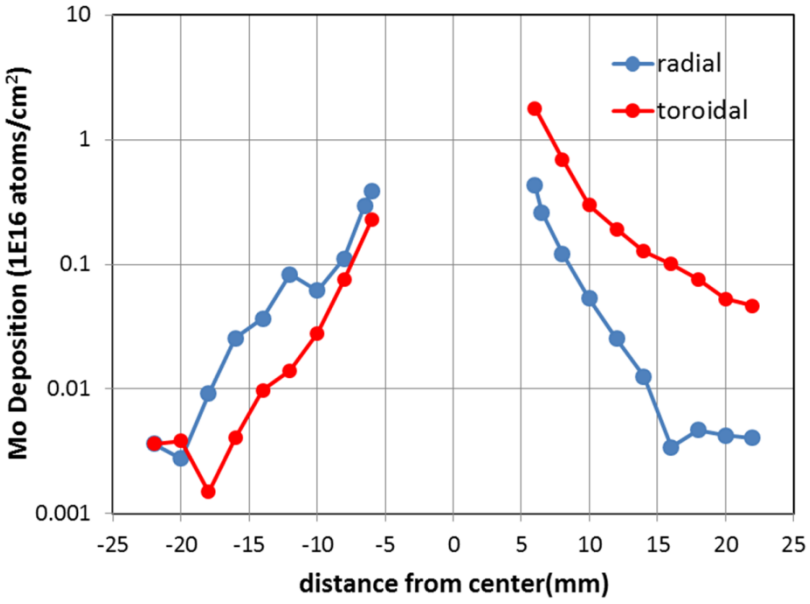


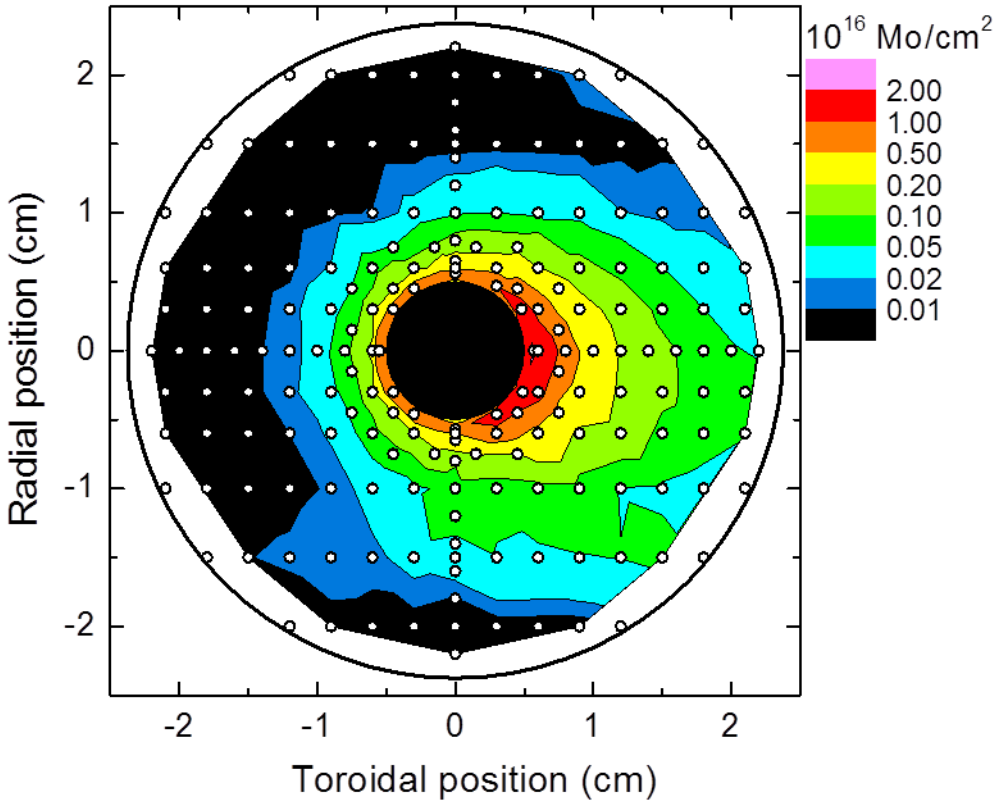
Date of exposure	shots	sec	initial thickness nm	net erosion 1e16 atoms	average erosion nm	erosion rate nm/s
5/1/2012	1	4	16.13 ± 0.3	1.47 ± 0.15	2.93 ± 0.3	0.732 ± 0.08
4/23/2012	3	12	23.81 ± 0.5	3.04 ± 0.3	6.05 ± 0.6	0.504 ± 0.05
8/1/2011	7	28	24.16 ± 0.5	5.84 ± 0.3	11.62 ± 0.6	0.415 ± 0.02

Erosion is consistent with sputtering by ~ 1% C^{3+}

Mo deposition on graphite

(8/1/2011 experiment)

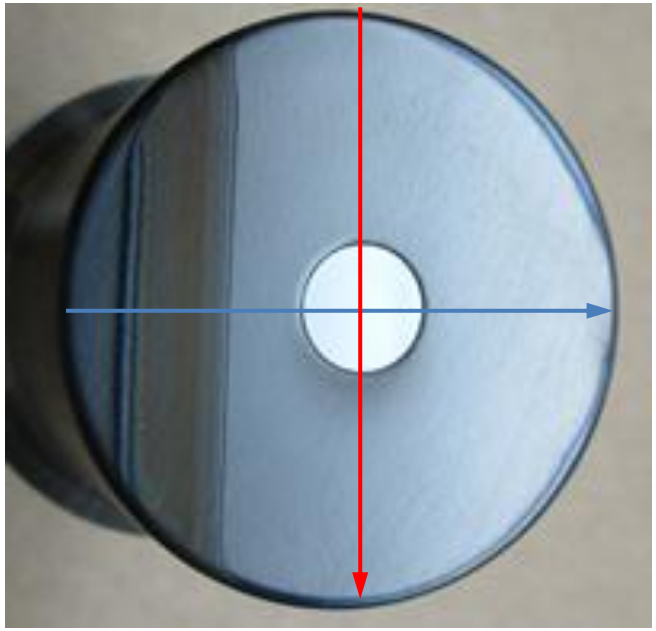


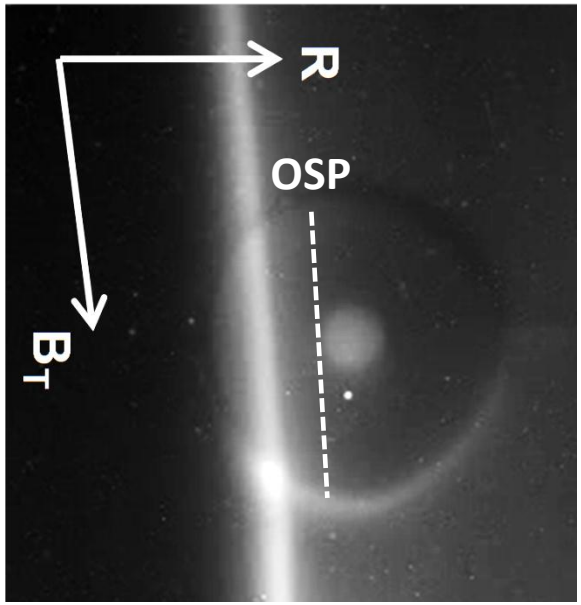


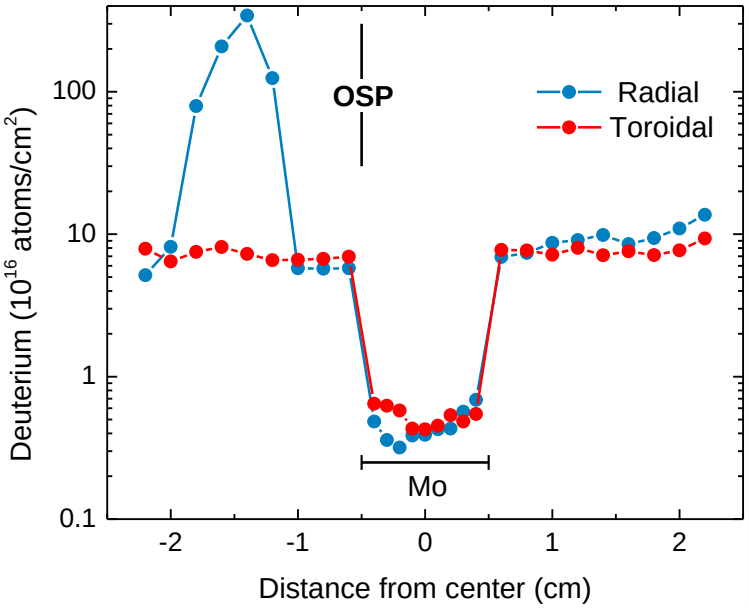
e-folding length ~ 2 mm
consistent with short MFP
for ionization of sputtered Mo

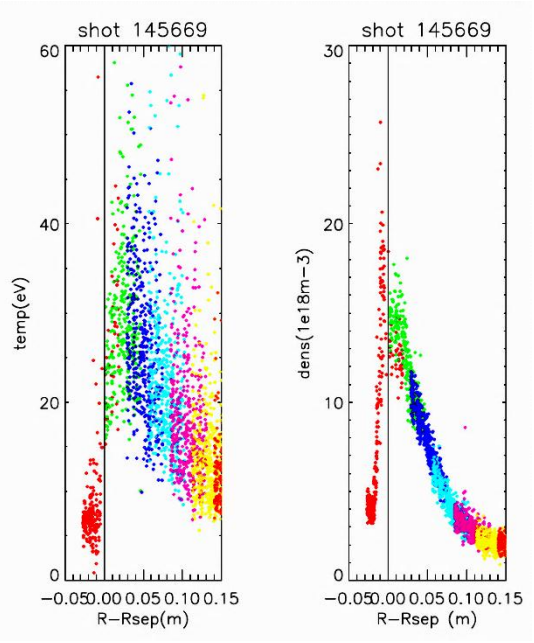
- Preferential Mo deposition downstream from source.
- Total amount of Mo on DiMES probe = 1.1 ± 0.1 x10^{16} atoms.
- 19 ± 2 % of eroded Mo still on DiMES cap indicates rapid re-erosion & transport of Mo from C.
- Surface is C+D+Mo mixed material, which influences erosion & redeposition.

Deuterium and carbon deposition





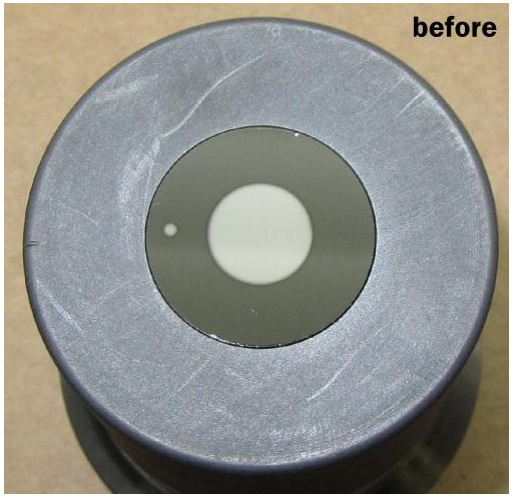




- Co-deposit in PFZ ~ 1 µm thick with D/C=0.7 where Te < 10eV.
- D coverage elsewhere consistent with implantation into C undergoing net erosion.
- D coverage is lower on Mo than on C because it diffuses out as interstitial solute.

Direct measurement of gross and net erosion by IBA

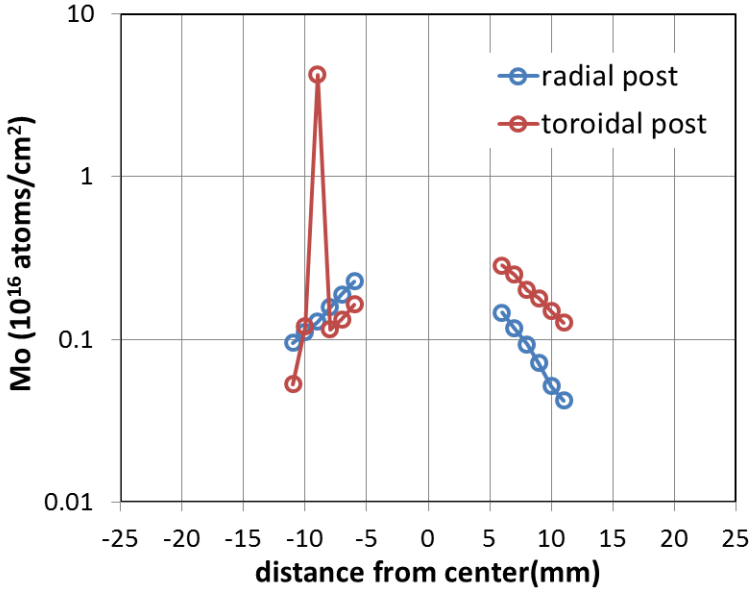
- Experiment on 5/1/2012 included
  10 mm and 1 mm diameter spots of Mo on Si disk.
- Si covered by 300 nm carbon film.
- Expect little local redeposition of Mo on 1 mm spot,
  i.e. measures gross erosion (J. Brooks REDEP)



Measured erosion: (from 1 shot):
Mo (1 cm) 1.9e16 atoms/cm^2
Mo (1mm) 3.4e16 atoms/cm^2
Carbon 33e16 atoms/cm^2

Net/gross = 0.55
C erosion ~ 10 x Mo erosion

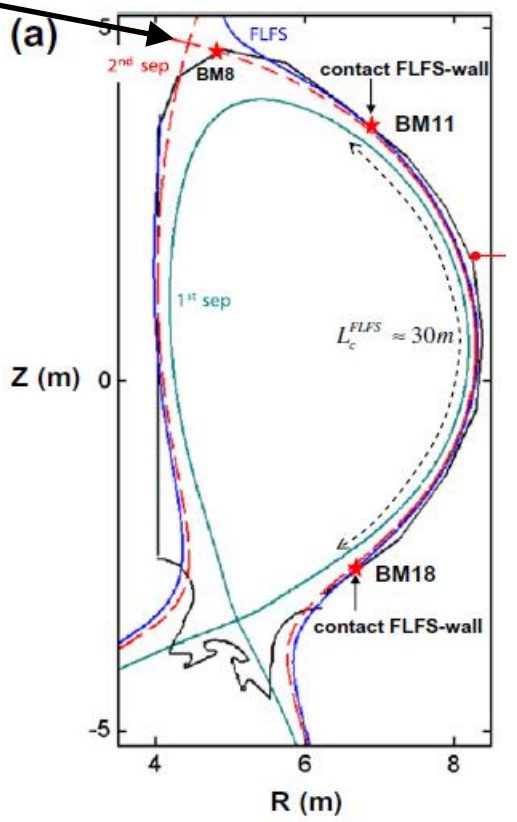
Similar exposures have been done for W & Al but post-exposure IBA is not yet available.



EAST/MAPES material migration experiment (R. Pitts ITER)

Concern about steady state erosion/re-deposition in ITER

- On First Wall panels of blanket modules near top of the machine (secondary X-point region)
- Eroded material may redeposit locally along with tritium
- Codeposited tritium will be harder to remove than in the divertor (lower temperature and not designed for easy replacement)
- Conduct a controlled benchmark experiment for LIM-DIVIMP and ERO simulations being used for ITER on realistic FW panel shapes.
- Toroidally shaped tiles (like ITER FW)
- Instrumented for local plasma parameters
- Dedicated shot sequences with retractable probe (MAPES)
- Measure erosion of carbon film (as proxy for Be) on Mo tiles with He plasma to reduce chemical erosion.

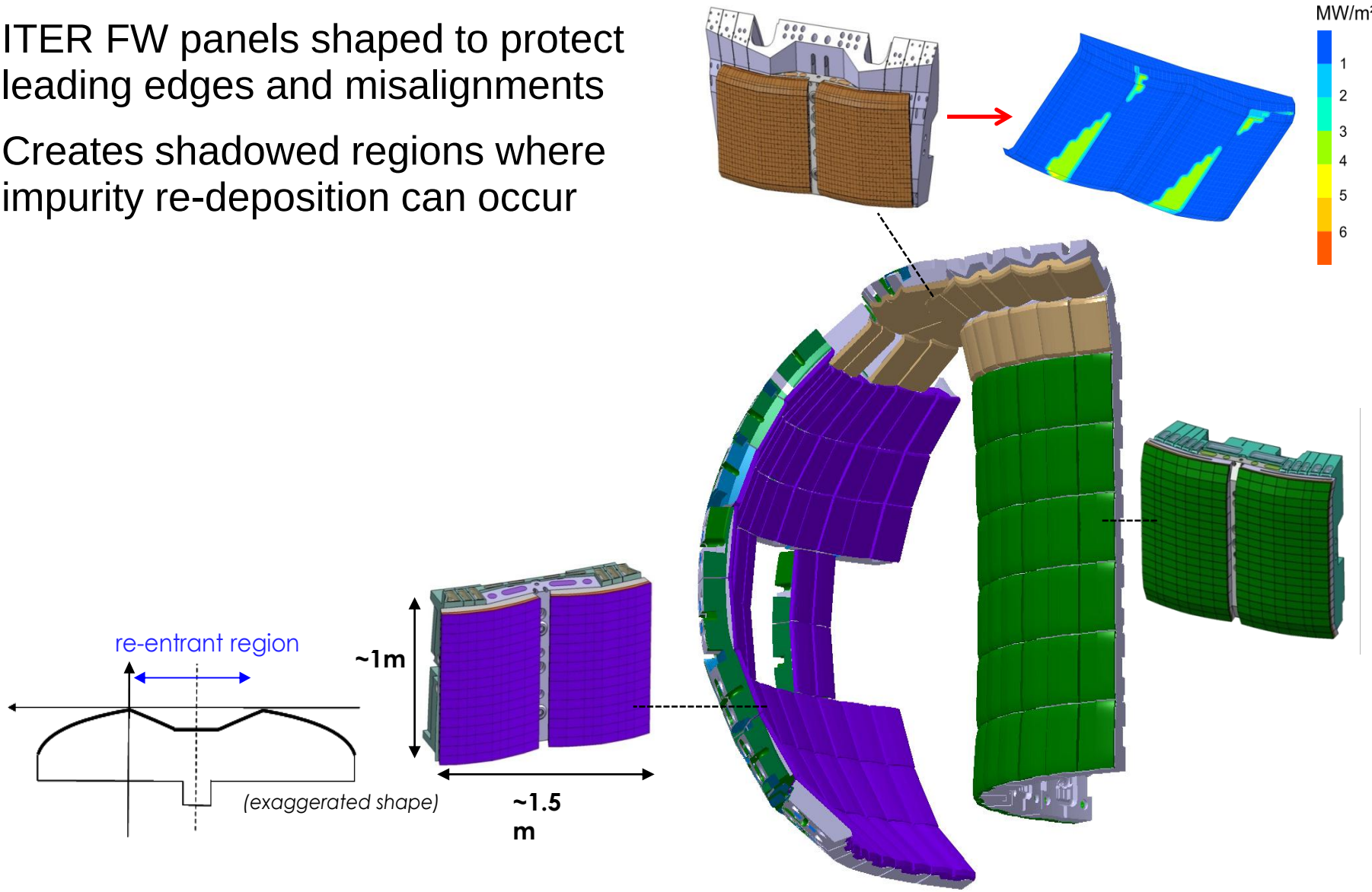


Modelling of beryllium erosion–redeposition on ITER first wall panels
S. Carpentier, R.A. Pitts , P.C. Stangeby, J.D. Elder, A.S. Kukushkin, S. Lisgo, W. Fundamenski, D. Moulton
Journal of Nuclear Materials 415 (2011) S165–S169

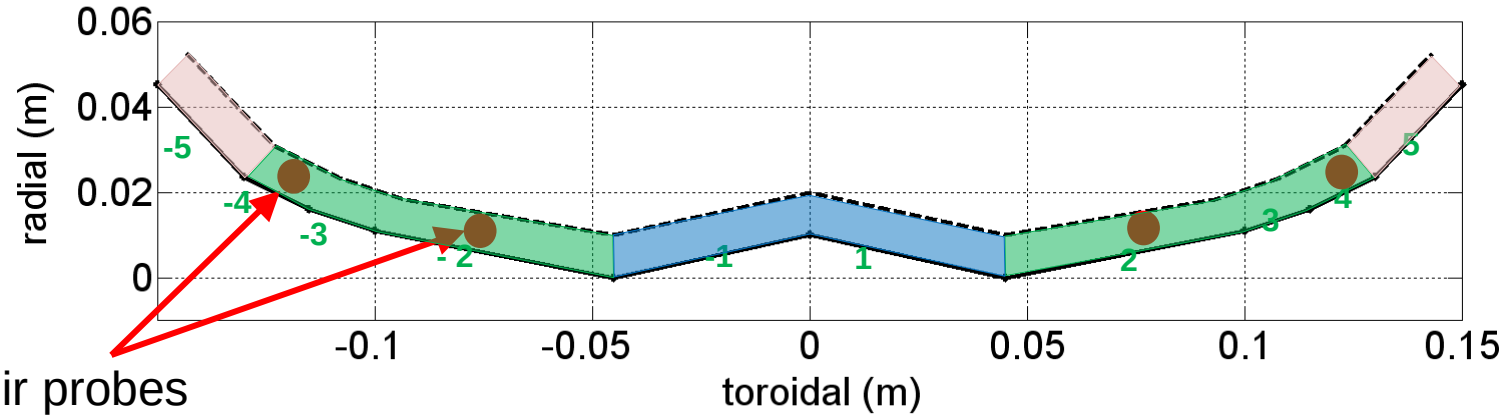
ITER first wall shaping

ITER FW panels shaped to protect leading edges and misalignments

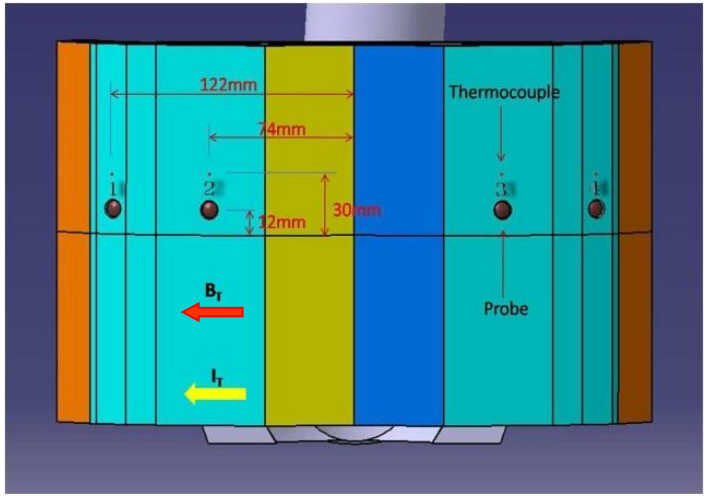
Creates shadowed regions where impurity re-deposition can occur



EAST/MAPES material migration experiment



Langmuir probes

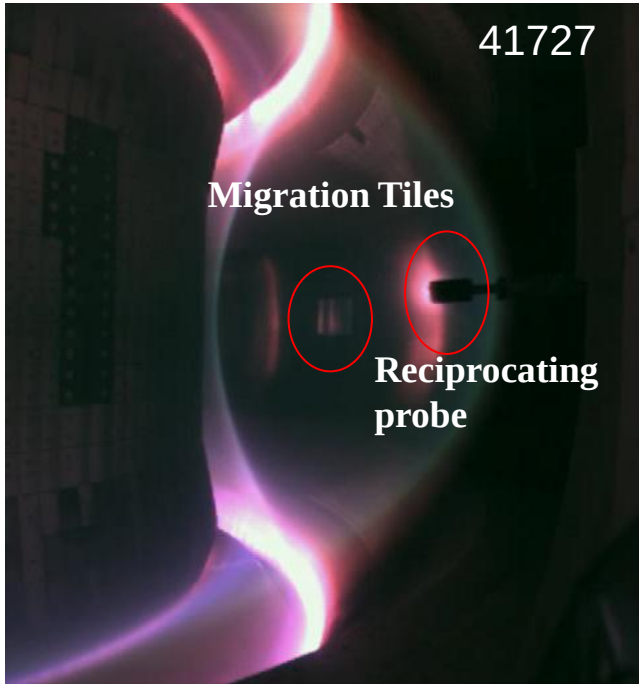


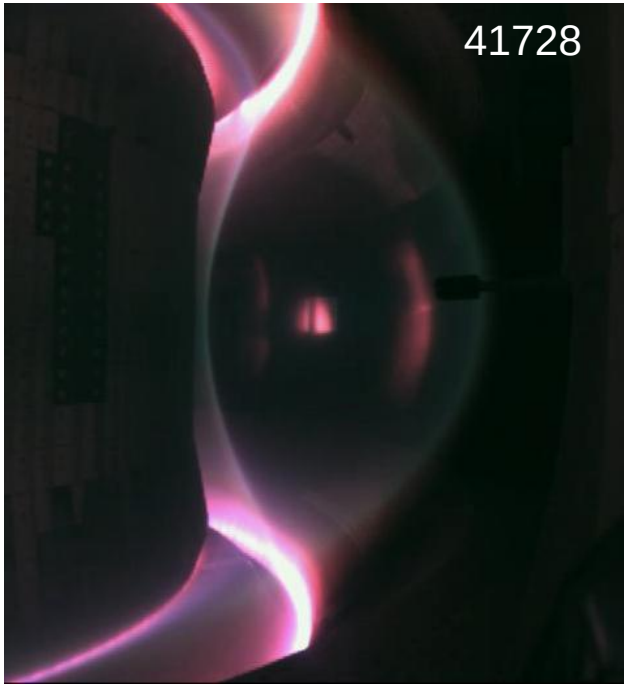
20x30 cm
12 tiles

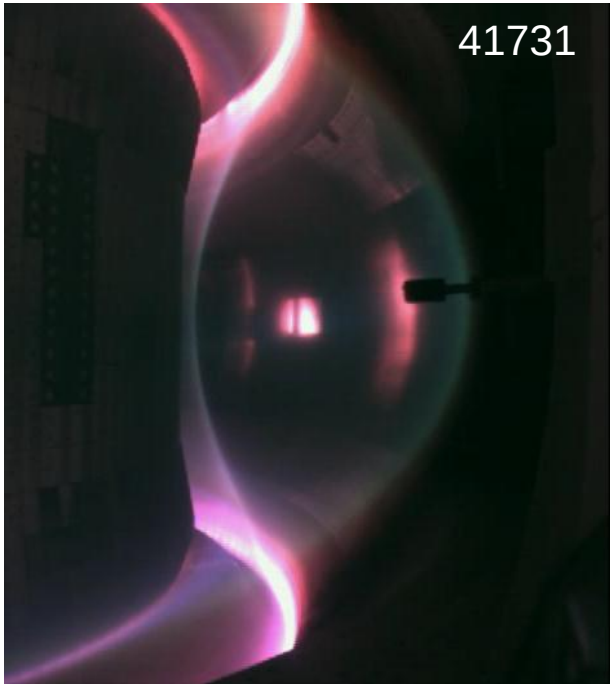
- Proxy for ITER first wall panel toroidal profile
- Will use Mo substrate tiles fabricated at ASIPP
- Carbon coating deposited at Sandia
- Plasma exposures on retractable MAPES in EAST
- Erosion & deposition determined by IBA at Sandia

Blank test on uncoated tiles now underway in EAST to determine exposure conditions

CCD image







R_{tr}=2.335 m

R_{tr}=2.310 m

R_{tr}=2.300 m

Shot	R_{tr} (main radius _ tile ridge)
41727	2.335 m
41728	2.310 m
41731	2.300 m

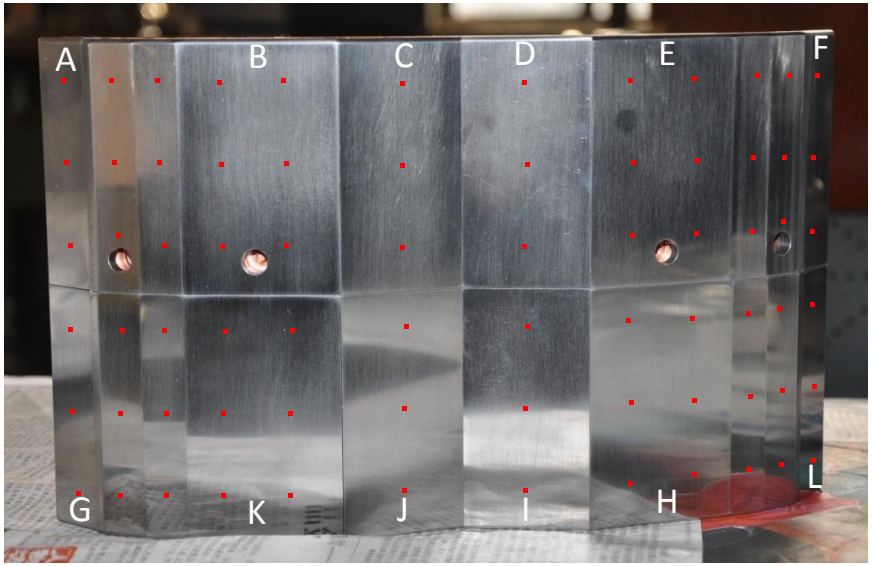
He-Plasma, Ohmic discharge, Double Null

Ip ~ 300 kA,

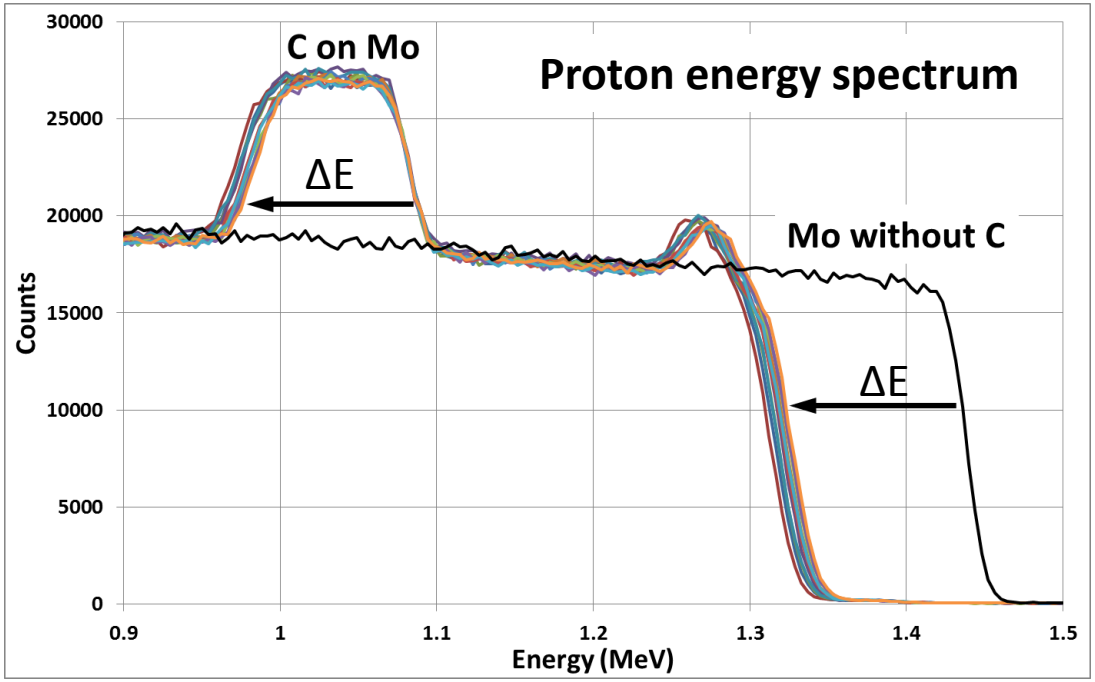
IT ~ 8000 A,

$R_{limiter}$ ~ 2.335m

Mo tiles Carbon-coated & pre-exposure IBA at Sandia

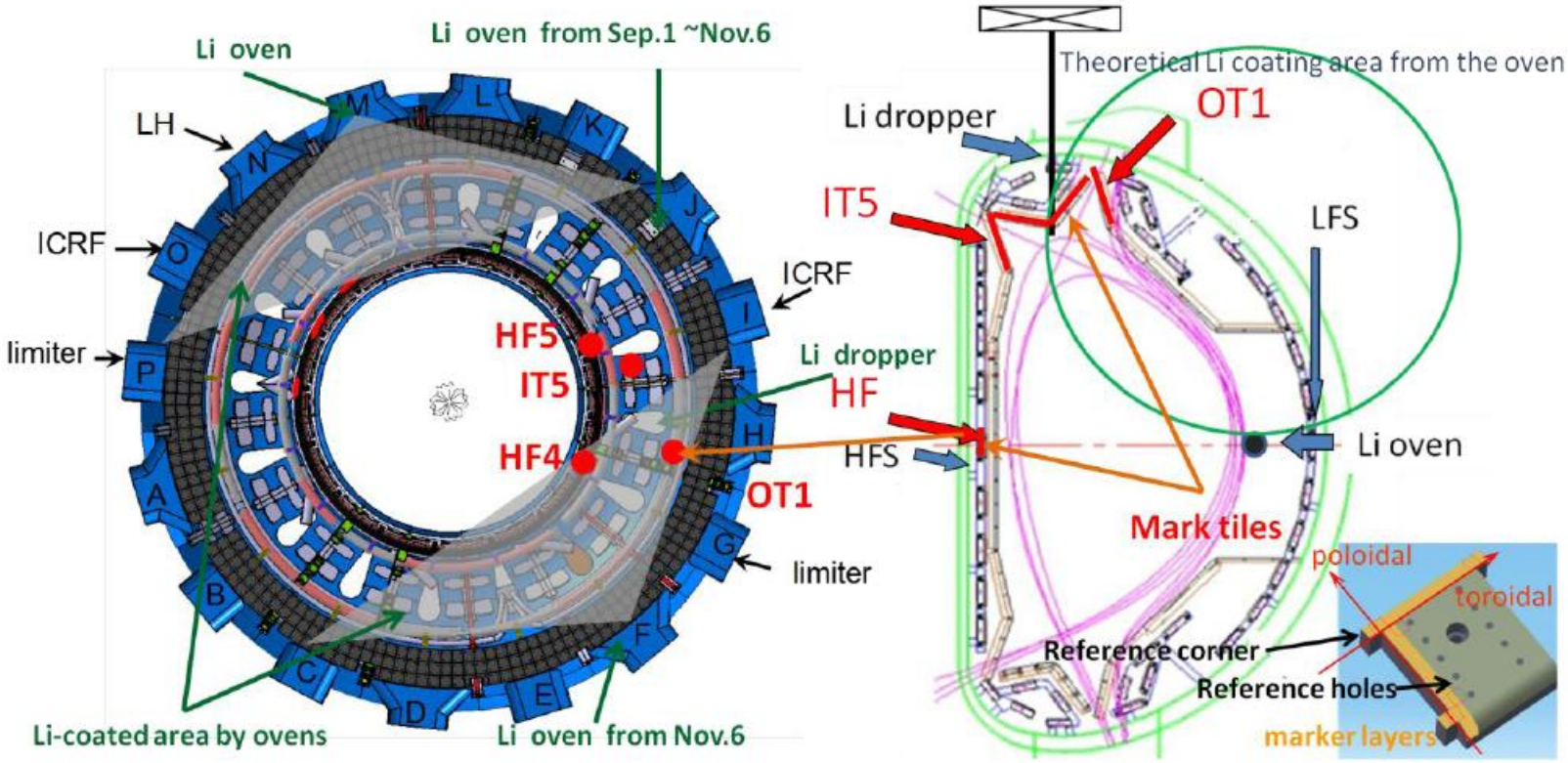


- Carbon film deposited in Sandia magnetron sputter deposition system.
- Thin Ti interface layer for adhesion.
- C thickness measured by IBA (red dots) (1.5 MeV proton backscattering)
- Tiles now at ASIPP for exposure to plasma
- Post-exposure IBA will determine net erosion & deposition from change in C thickness.



Carbon thickness:
1.5×10^{19} atoms/cm^2 or 3 g/m^2
from proton energy loss ΔE.

Fixed tile marker experiment in EAST



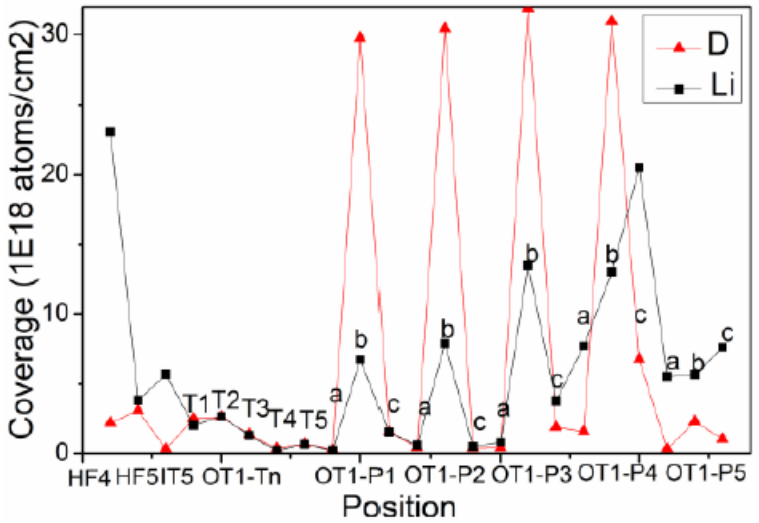
Tiles with W marker under 2.5 μm SiC overlayer were prepared at ASIPP & exposed in EAST to ~ 6400 plasmas (with 1020 grams of Li injection).

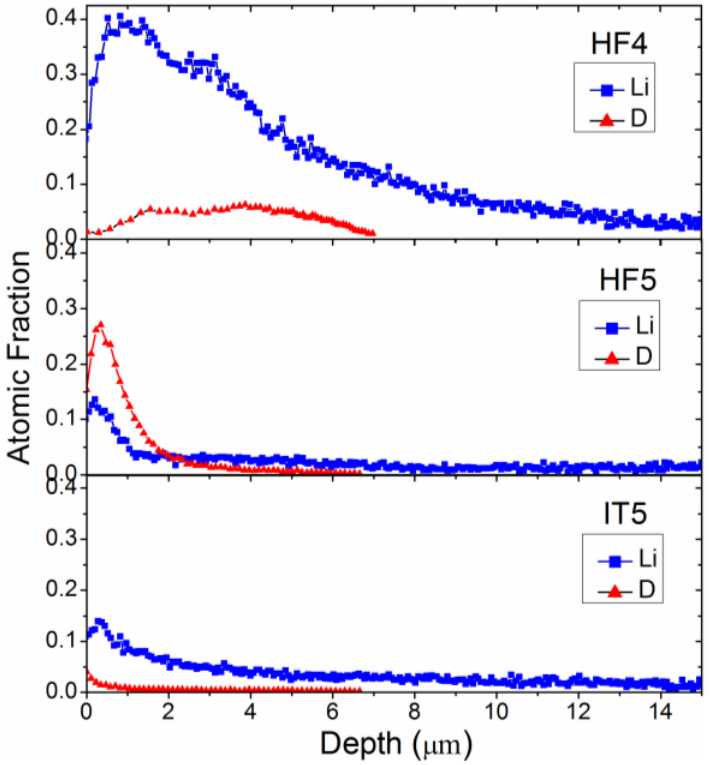
Tile pieces were analyzed at Sandia by:

^{4}He & H RBS for erosion & deposition

^{3}He & H NRA for D & Li deposition

Fixed tile marker experiment in EAST





Main results:

Most of the SiC overlayer & W marker were eroded,

Heavy deposition of Li & D in some areas.