SAND2011-6846 C

Measurement of erosion and deposition in DIII-D and EAST

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In collaboration with
^{13}C and O bake experimental teams at GA & UTIAS,
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Plasma-Facing Components Meeting
ORNL
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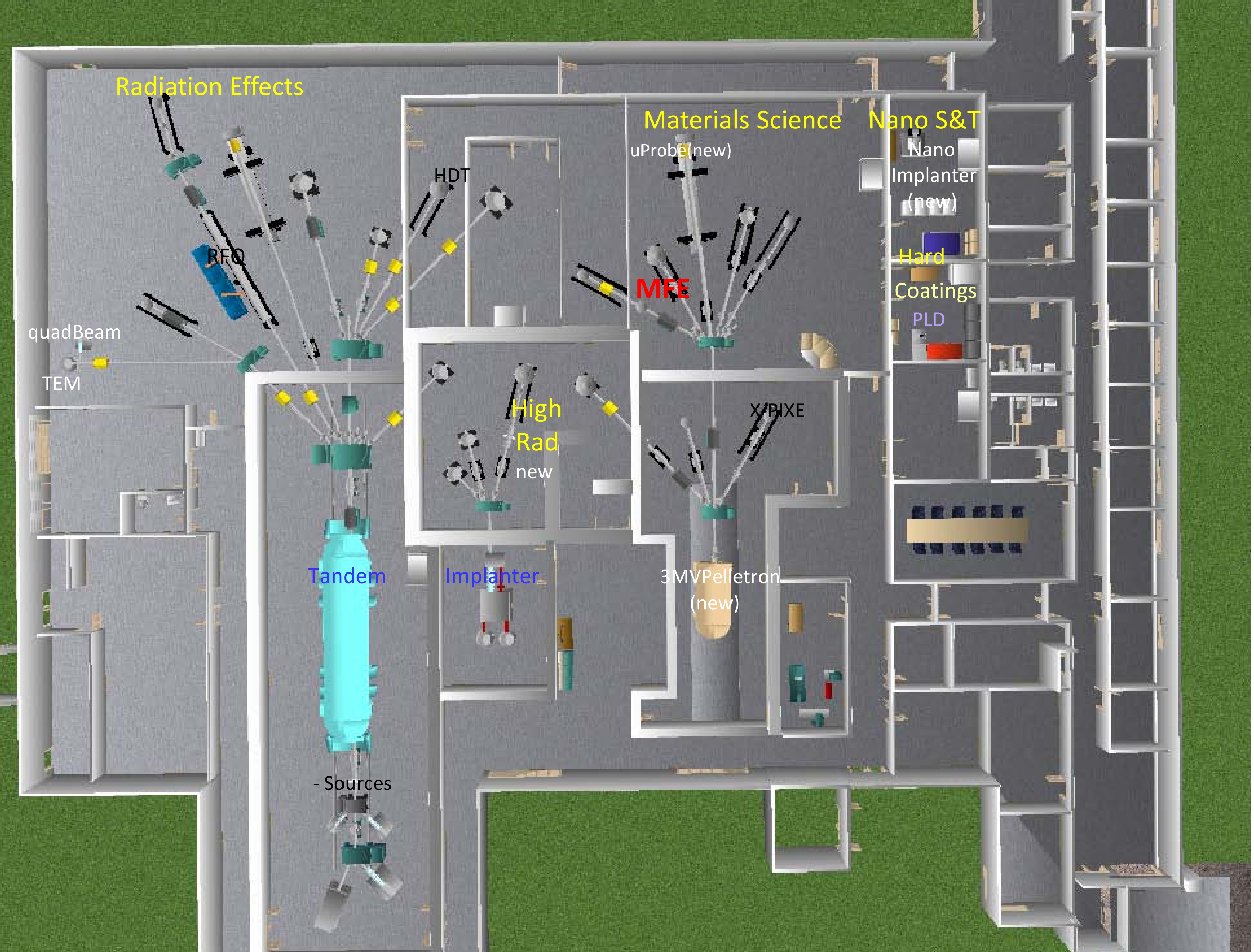
DIII-D ^{13}C injection experiments in DIII-D

Oxygen bake experiments in DIII-D

DiMES Mo Erosion experiment

EAST erosion experiment

New Sandia Ion Beam Laboratory



Ion beam analysis for fusion energy research
W.R. Wampler NIM B 219-220 (2004) 836

Capabilities

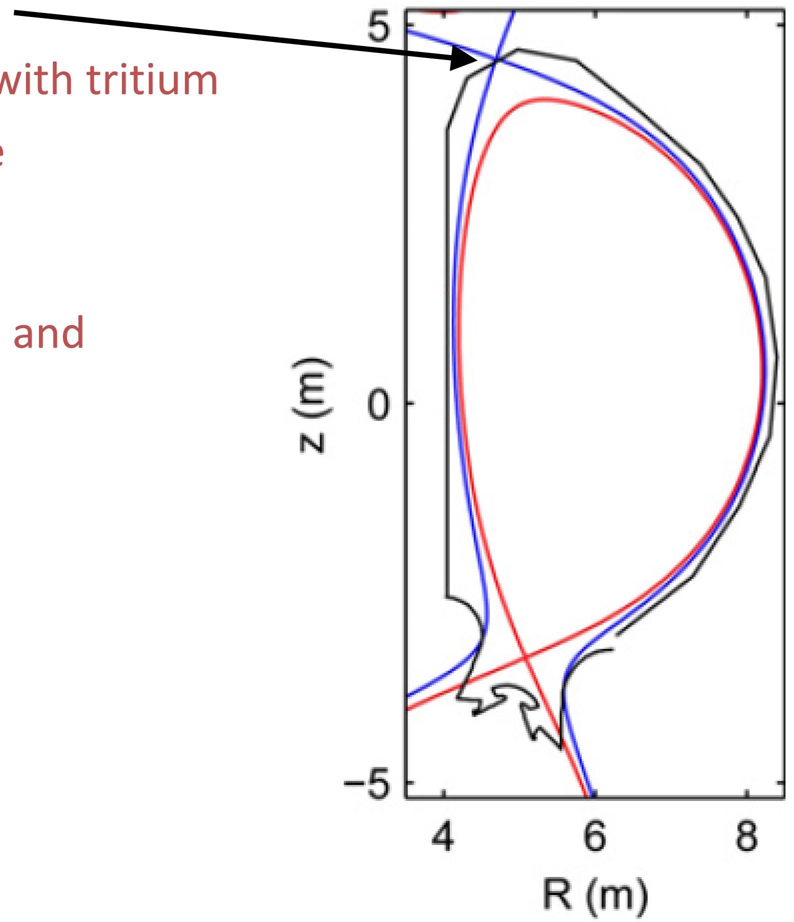
RBS
NRA
He ERD for HDT
HI-ERD
External beam IBA
PIXE
Microbeam
Ion channeling
Ion implantation
Nano-implanter
HI irradiation
RFQ linac
Multibeam TEM
High-rad area
UHV

Primary support from NNSA, available for FES

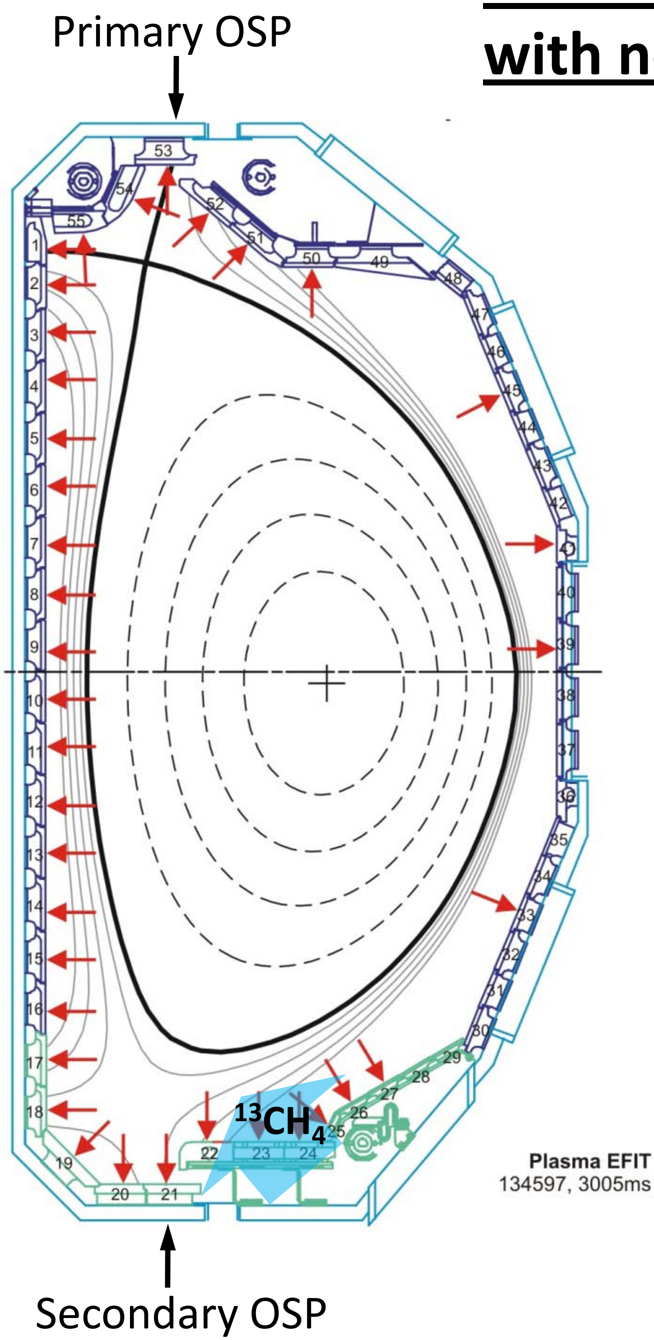
Focus is on erosion, deposition and DT retention in plasma-facing materials

Concern about steady state erosion/re-deposition in ITER

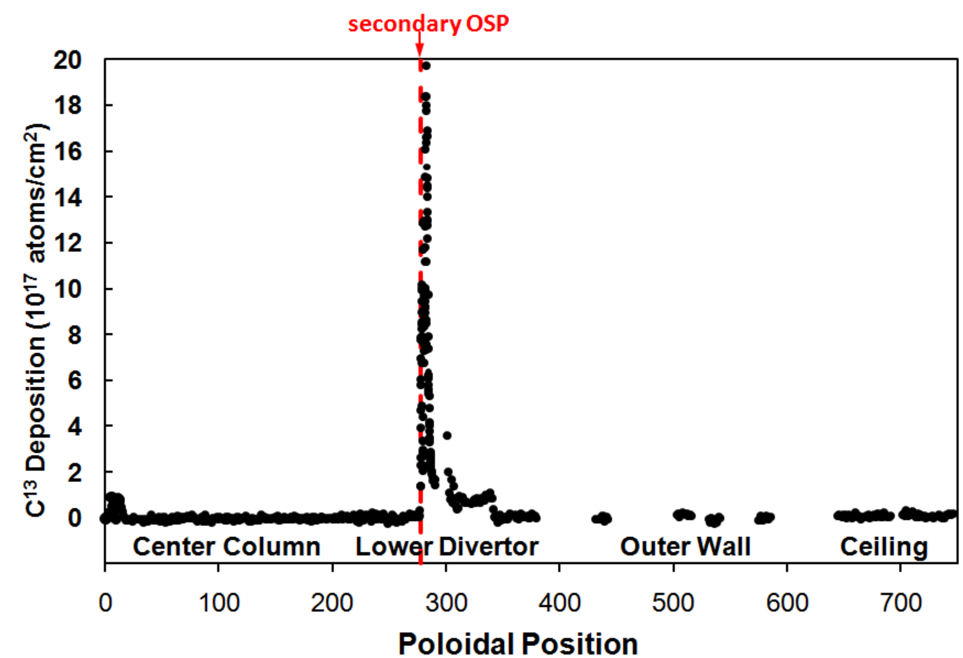
- On First Wall panels of blanket modules near top of the machine (secondary X-point region)
- Eroded material may redeposit locally along with tritium
- Codeposited tritium will be harder to remove than in the divertor (lower temperature and not designed for replacement)
- Seek a controlled benchmark for LIM-DIVIMP and ERO simulations being performed for ITER on realistic FW panel shapes.



^{13}C methane injection experiment in DIII-D with near-double null H-mode plasma

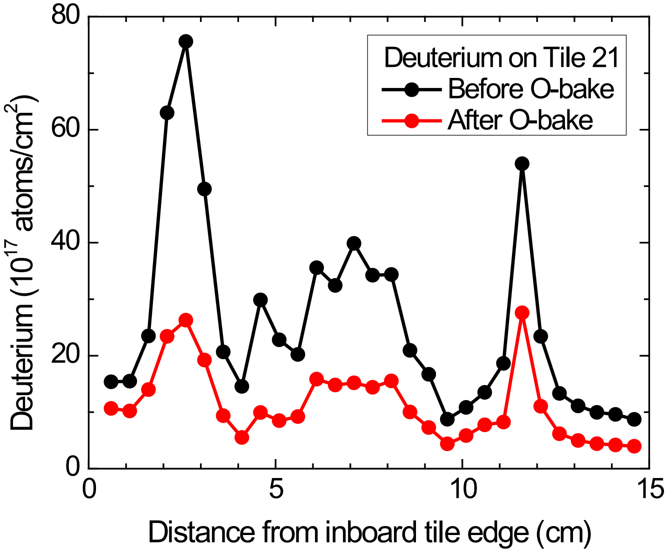


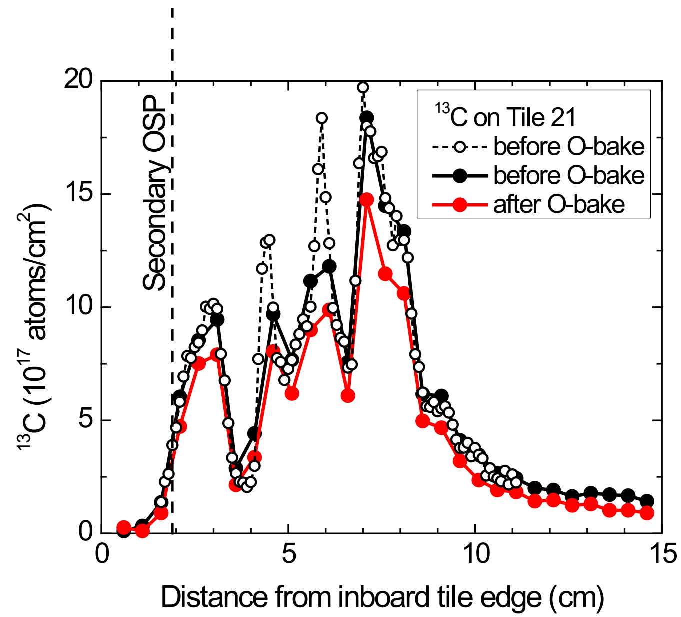
- Examine carbon deposition from plasma-wall interaction at the secondary separatrix in the main chamber with biased double null plasmas similar to that planned for ITER.
- Inject $^{13}CH_4$ from the lower outer plenum (toroidally symmetric) into 18 ELMy H-mode plasmas.
- ^{13}C and D coverage measured by NRA on 37 tiles (red arrows).
- **44% of injected ^{13}C was found mainly near secondary OSP.**
- **This indicates that material sputtered from the wall in ITER may deposit near the secondary OSP in the upper main chamber. Potential for T codeposition.**

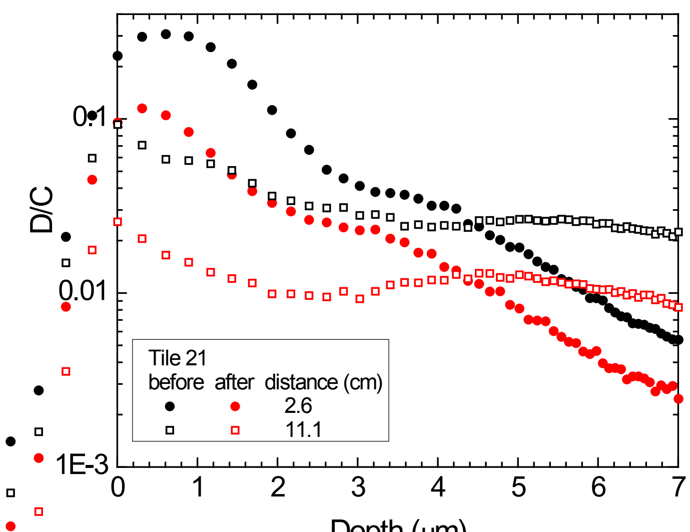


In-situ oxygen bake removed 20% of ^{13}C and 54% of D

2 hours at 350°C and 2 Torr O_2







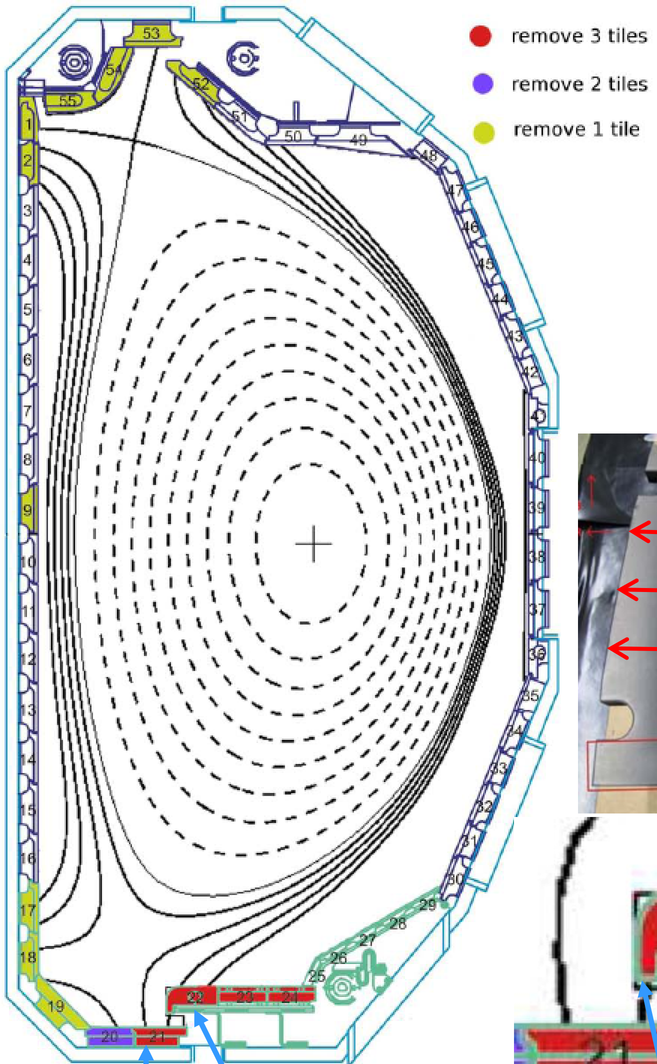
D is removed throughout the deposit

Tile	Measured ^{13}C (10^{20} atoms)		Average D within 4 μm (10^{17} atoms/cm²)	
	Before	After	Before	After
1	2.96	3.32	60.45	23.17
9			11.76	9.56
21	69.14	54.83	24.07	10.47
21T	1.28	0.80	3.09	1.03
22	14.61	10.84	17.36	8.19
22L	7.66	5.15	12.23	3.99
23	9.94	7.97	12.34	7.27
24	5.17	5.03	18.19	9.80
Total measured	110.77	87.92	159.49	73.49
Injected	255			
Fraction measured	**0.44**			
Fraction removed by O-bake		**0.206**		**0.54**

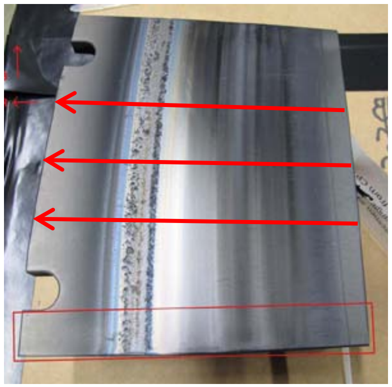
Oxygen Bake experiment was repeated in 2010

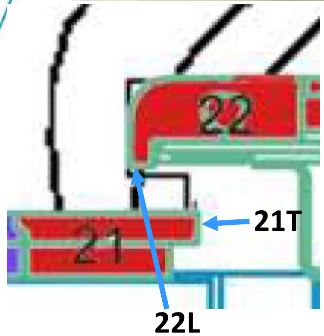
Same conditions as 2009 experiment but with in-situ O-bake before removing tiles.

Poloidal Location of Tiles Selected for Removal and Analysis, may 2010

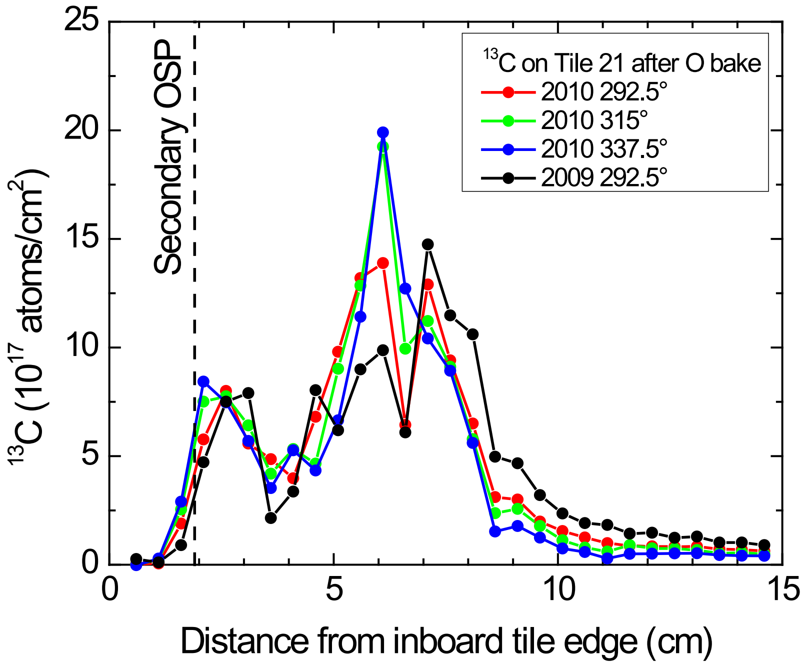


Tile #21 & 22 from 3 toroidal positions were analyzed





^{13}C was deposited on surfaces shadowed from ion flux

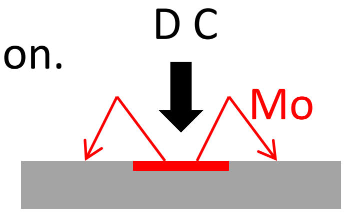


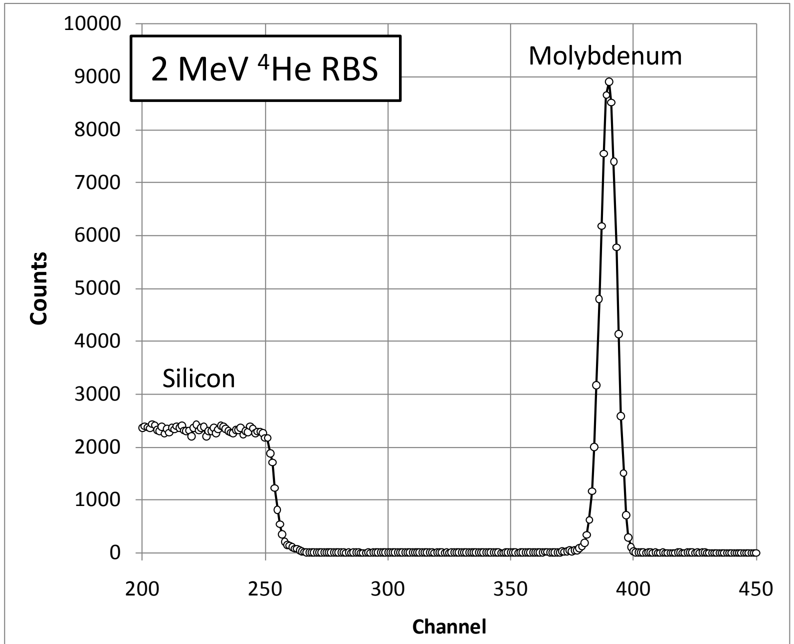
Measured ^{13}C after O-bake (10^{20} atoms)				
	2009	2010		
Toroidal position	292.5	292.5	315	337.5
21	54.83	53.23	54.59	51.78
21T	0.80	0.40	0.53	0.47
22	13.34	9.80	9.60	8.99
22L	5.15	3.33	2.97	2.71
Total measured	74.12	66.76	67.70	63.95

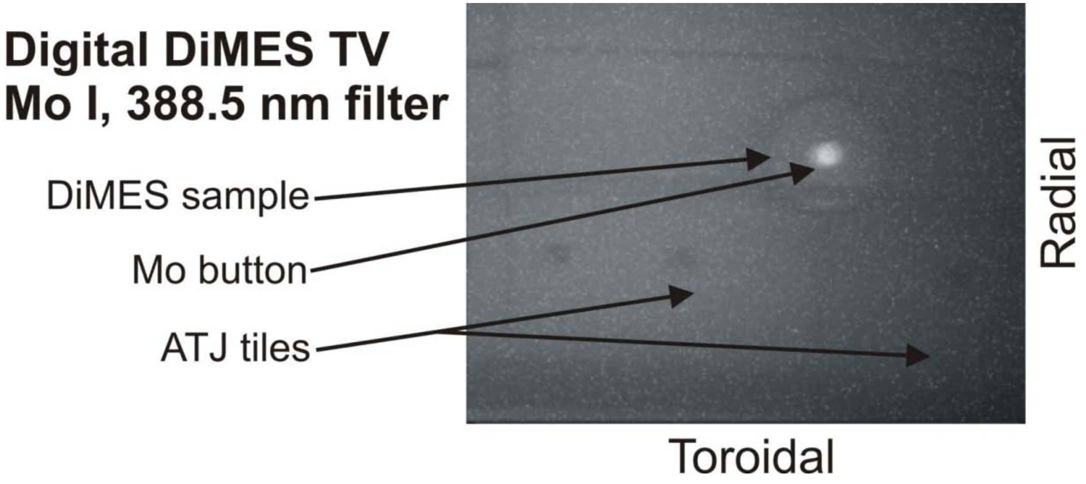
^{13}C remaining is similar in 2009 & 2010 and toroidally symmetric

DiMES experiment to compare net vs. gross erosion of Mo

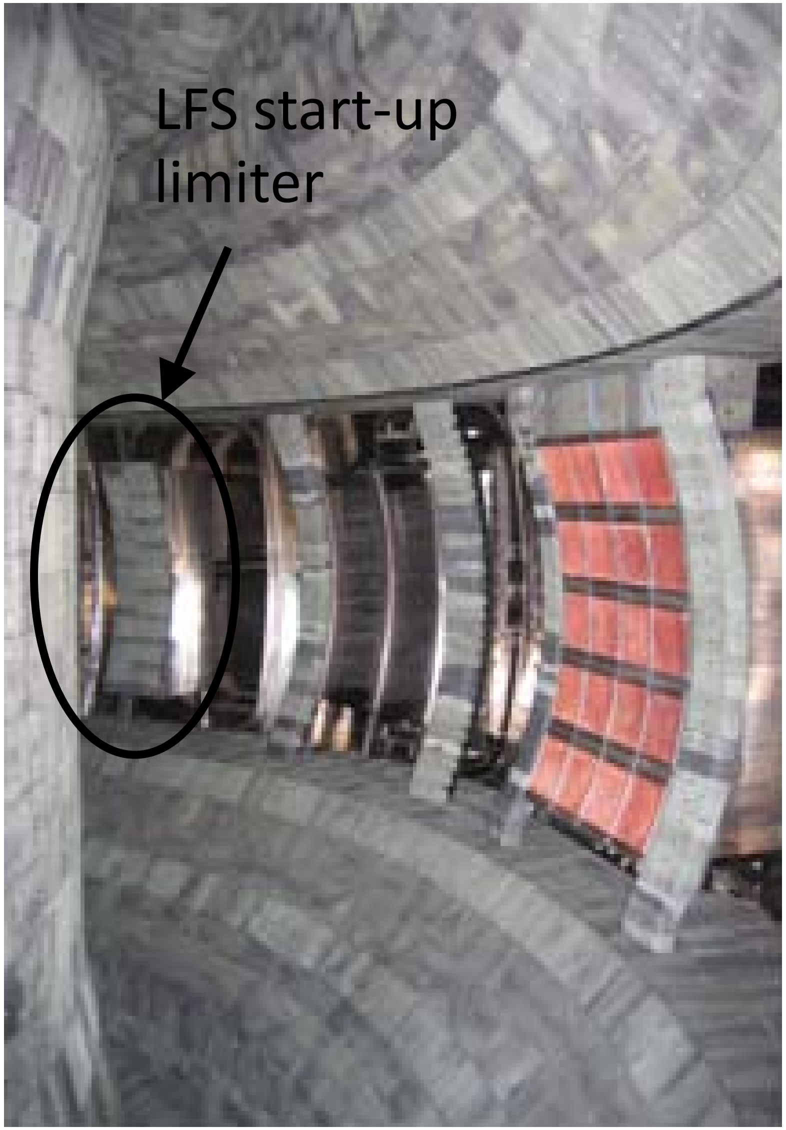
- A silicon disc 1 cm diameter with 25 nm thick Mo
  was exposed on 8/1/2011 to 7 repeat shots, L-mode, low density, LSN, 1.1 MA.
  OSP on DiMES from 1-5 sec, off during ramp up & down.
  Plasma conditions at OSP measured by Langmuir probes.
- Net Mo erosion & deposition measured by RBS,
  detection limit for Mo erosion ~ 1 ML.
  Deposition of D&C measured by NRA.
  Gross erosion determined from intensity of Mo light emission.
- Measurements enable first comparison of
  net vs. gross erosion and erosion vs. local redeposition.
- Models predict net erosion<< gross erosion.







An outboard migration experiment on EAST



Use outboard, moveable start-up limiters → proceed in two stages:

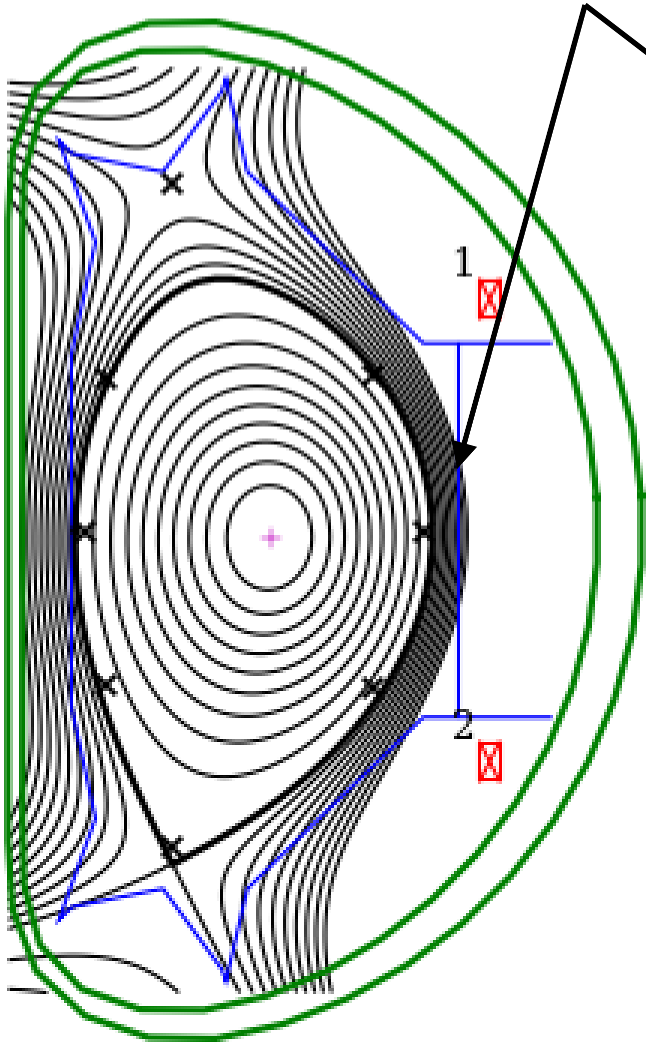
Test of concept:

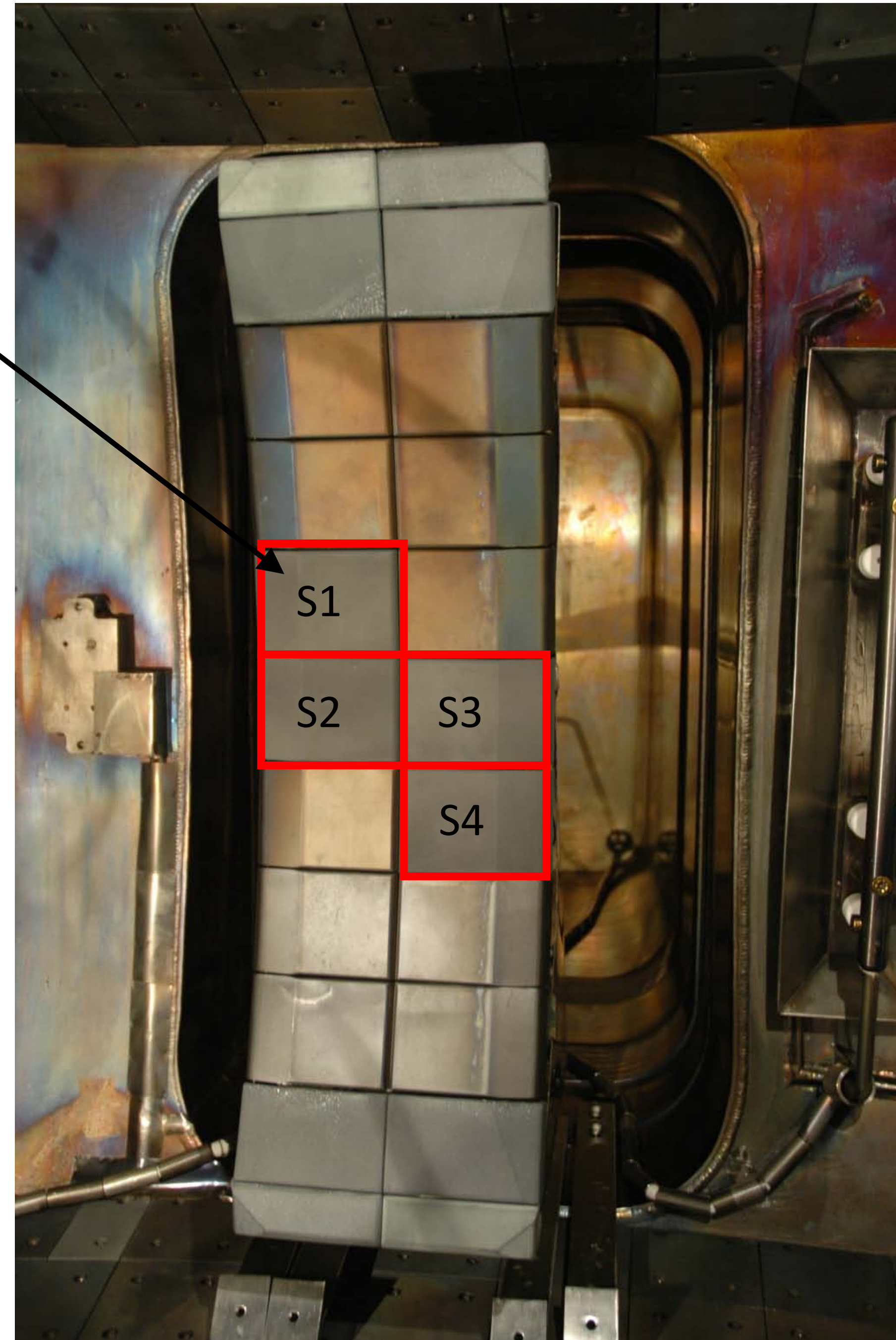
- Use current start-up limiters on LFS with existing tile geometry
- Campaign averaged
- Test depth marker technique
- Use existing diagnostics to probe edge parameters

Design new experiment:

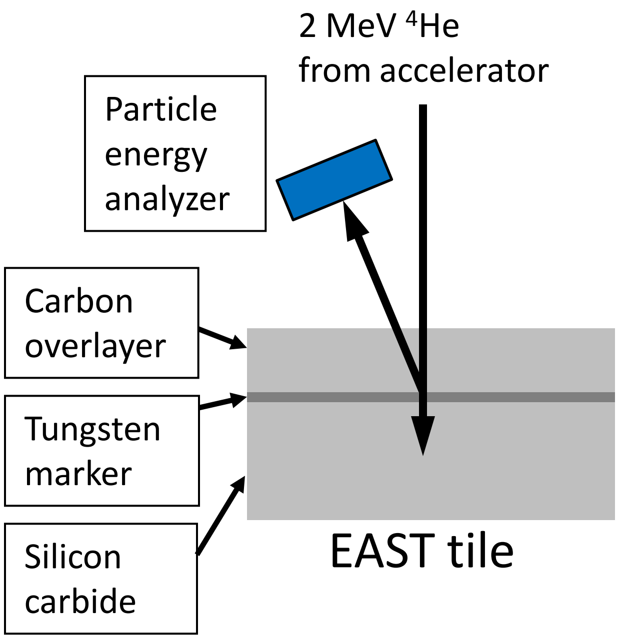
- Toroidally shaped tiles (like ITER FW)
- Instrumented for local plasma parameters
- Dedicated shot sequences with retractable limiters – avoid campaign average
- Work in He to avoid chemistry in all-C EAST

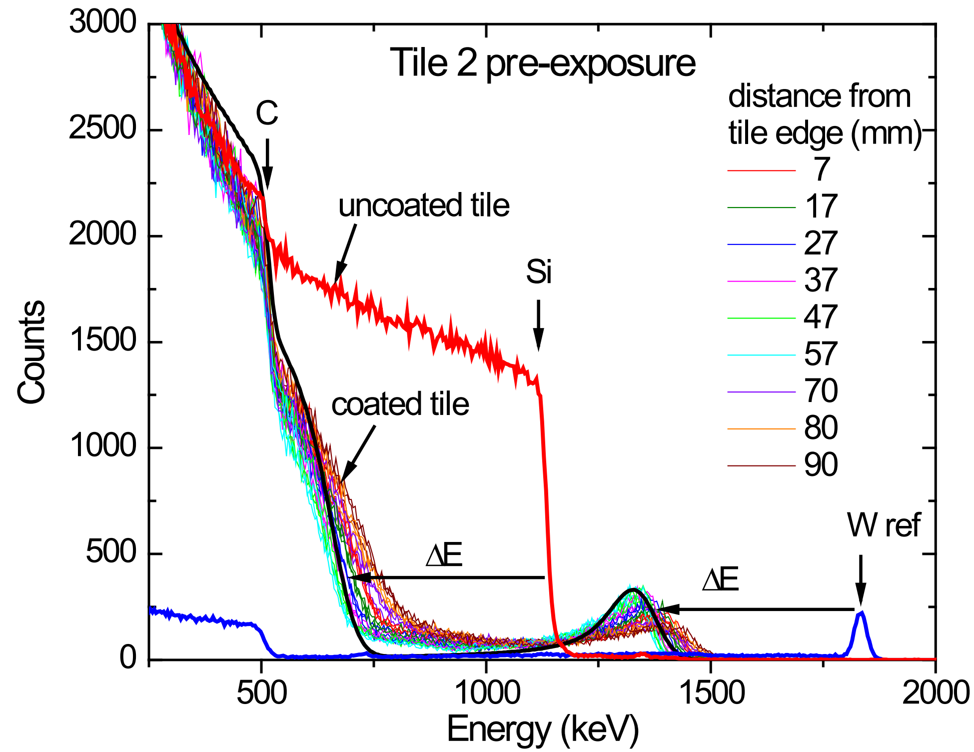
Four prepared tiles were exposed on the EAST moveable Limiter



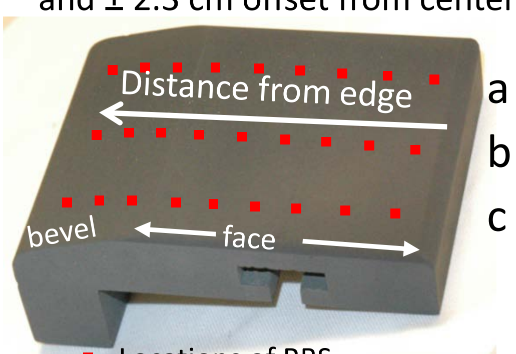


Erosion was determined from the change in thickness of a thin carbon film measured by RBS





3 scans (abc) along center and ± 2.3 cm offset from center



▪ Locations of RBS
Analysis beam spot 1x1mm
Tile size 7x10 cm

- A tungsten depth marker was prepared on four tiles by vapor deposition of W (~1nm) followed by C (~1µm).
- Exposed to plasma for 37100 seconds during 2010 run campaign .
- RBS spectra were measured at 27 points on each tile before & after exposure in EAST.
- Thickness of carbon film is determined from energy loss ΔE of particles scattered from W and Si.
- Erosion/deposition is determined from change in depth of W and Si.

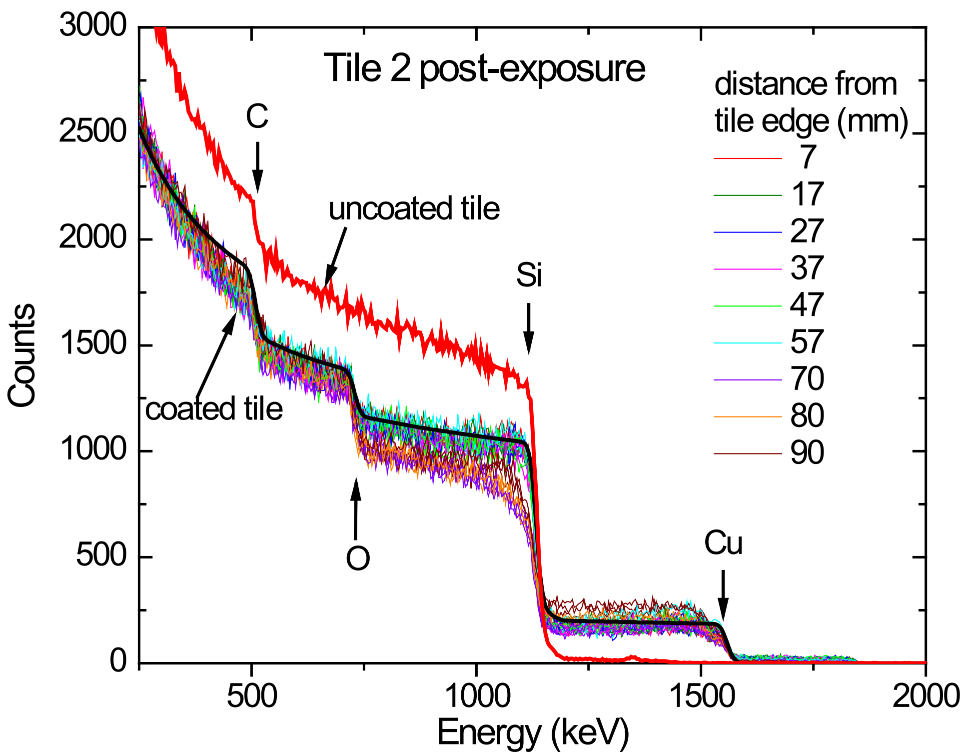
Post-exposure RBS shows erosion & deposition

Heavy red curve is spectrum for EAST tile before deposition of W, C coating

Heavy black curve is simulation using SIMNRA.

Height of Si edge gives fraction of area which is bare SiC (~ 50%).

Remaining fraction of area is covered by deposit of C, O, and transition metals (Cr - Cu) (plus HD not measured by RBS)



1. The carbon film was completely removed over ~ 40% to 60% of the area.
2. Deposition was also observed, containing carbon, oxygen and transition metals, with average metal concentration = 0.006 to 0.03 atom fraction.
3. Erosion & deposition both occur due to surface roughness, localized erosion from peaks, deposition in valleys.
4. Erosion/deposition is fairly uniform over the four tiles.
5. Method worked. Can proceed to second improved experiment.

Summary

- **^{13}C injection experiments:**
  High deposition at secondary OSP,
  in contrast to previous experiment with single null
  where deposition was mainly at primary ISP.
  Higher plasma density at secondary strike point causes higher local re-deposition.
  Reinforces concern over tritium inventory in ITER main chamber.
- **O-bake experiments:**
  50% of D removed from entire depth of CD co-deposit
  with no adverse effects on plasma operation.
  Lab studies show more D is removed with higher T, P, t.
- **DiMES Mo erosion experiment:**
  Thin film Mo sample prepared & successfully exposed to well characterized plasma.
  Erosion/deposition will be measured by IBA .
- **EAST erosion experiment:**
  1 µm carbon film removed by long exposure to LFS plasma in EAST.

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