Tritium deposition patterns in TFTR

Presented by C. H. Skinner with key contributions from
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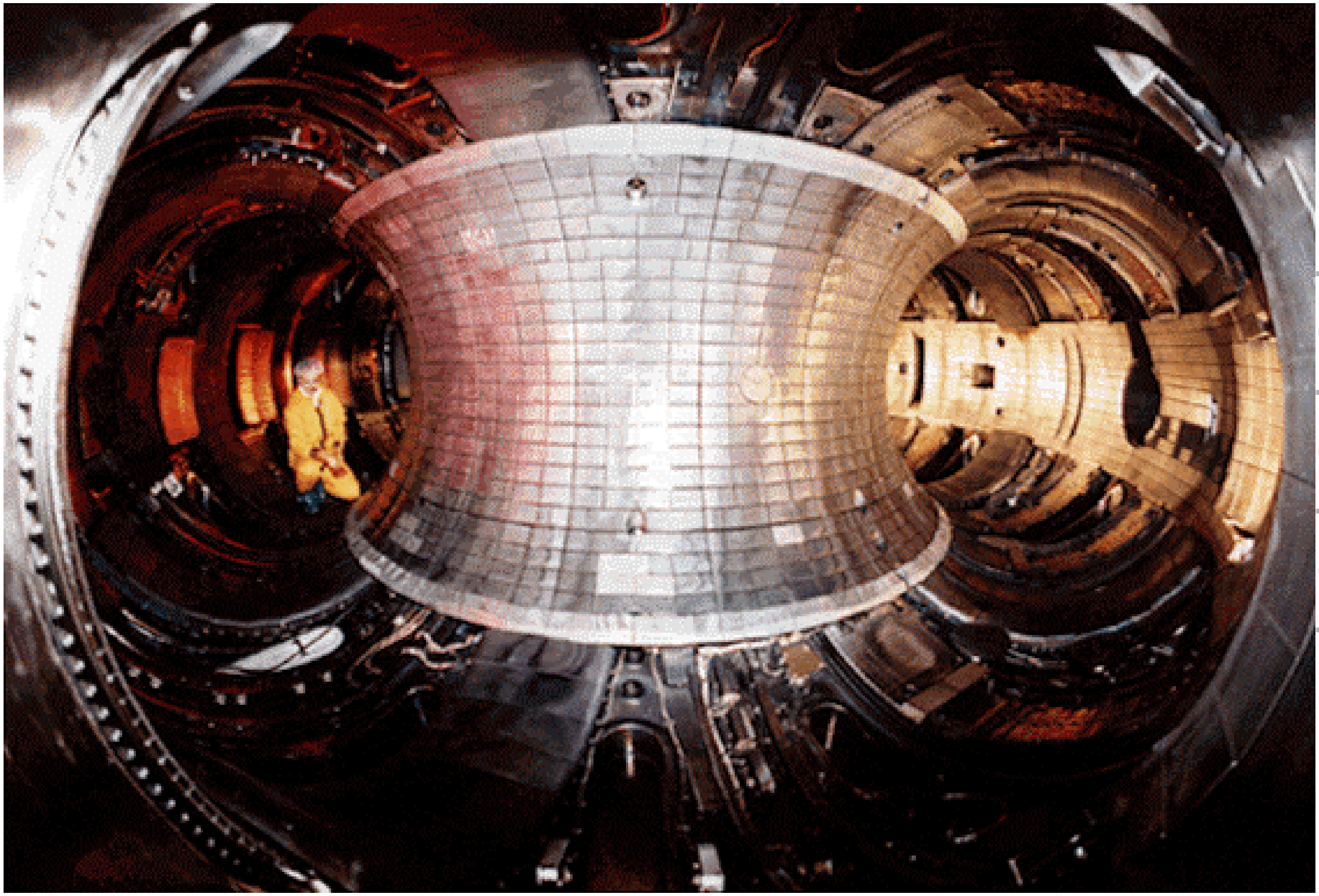
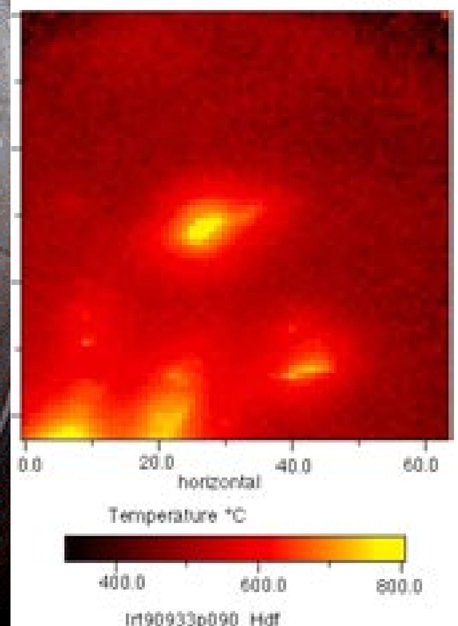
Mark Paffett, Robert Reiswig, Scott Willms, (LANL)
Nicolas Bekris (FZK Karlsruhe), Paul Coad(JET),
Tetsuo Tanabe, Kazuyoshi Sugiyama (Nagoya University).

4th ITPA Meeting on SOL and Divertor Physics Topical Group
13-16 January 2003, Naka, JAERI



Limiter Temperature @ 28 MW NBI



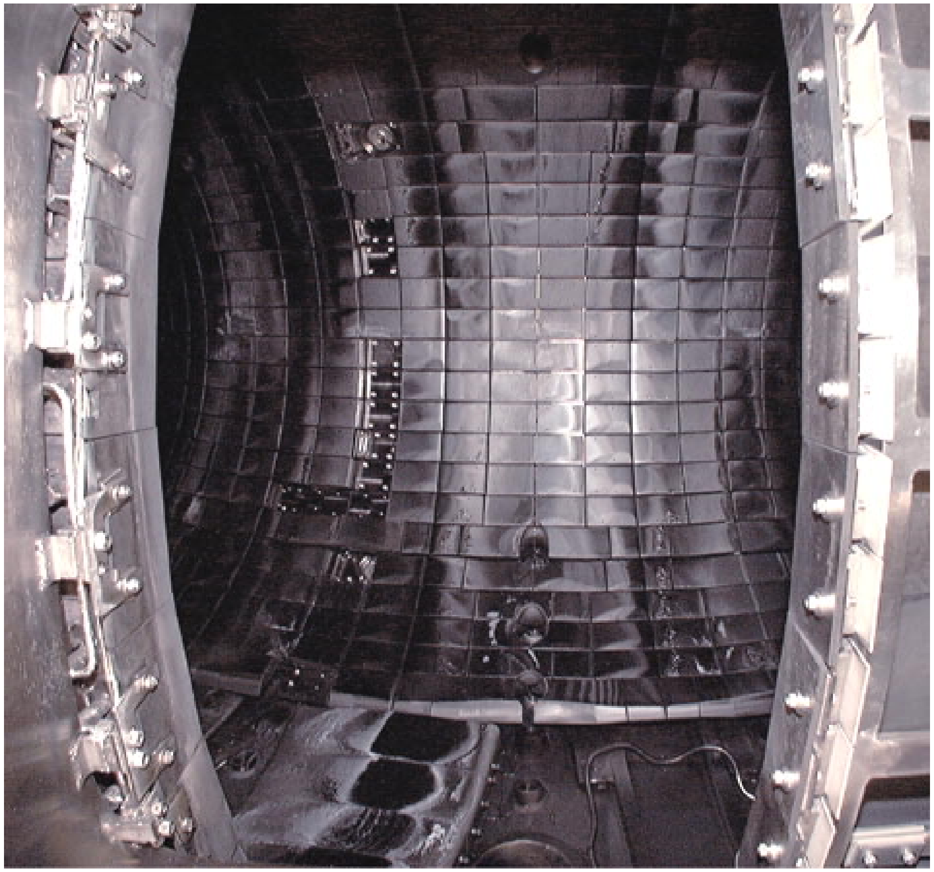
- TFTR was a limiter machine - no divertor.
- Operated with tritium Nov ‘93 - April ‘97.
- Net deposition on VV walls (not erosion).
- Walls heated only by plasma (limiter hotspots reached ≈ 800 C).

Low density, high temperature edge

	TFTR SOL (TRANSP/DEGAS)	JET divertor (EDGE2D)
Ne	0.1 e19 – 1 e19 m-3	≈ 10 e19 m-3
Te	200 - 600eV	<30 eV

Tritium deposition patterns in TFTR

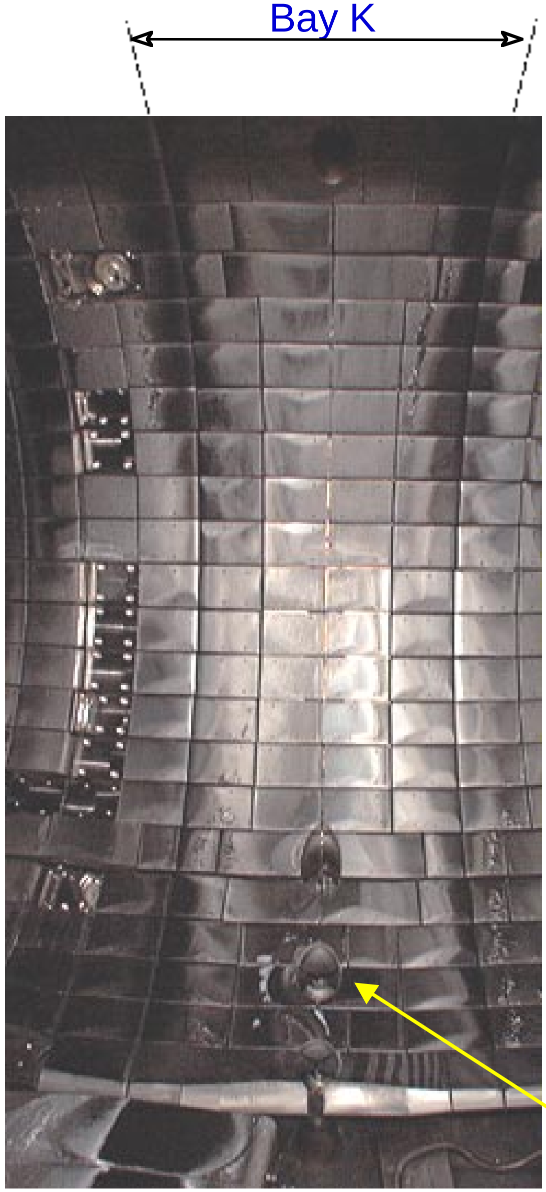
- Codeposition of tritium with eroded carbon both inboard & outboard
- Dust and debris observed
- Tiles, coupons, dust samples retrieved for analysis
- Tritium spatial distribution consistent with modeling...

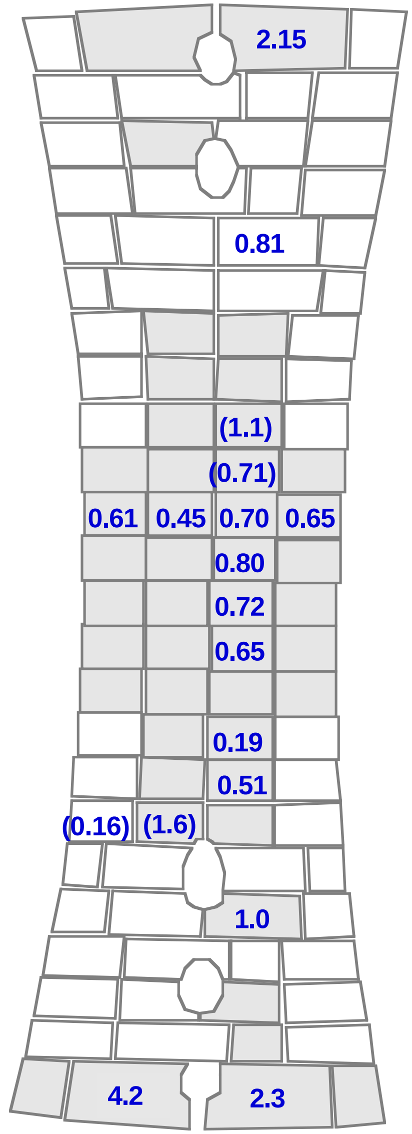


Co-deposition, flaking, deposits inside vessel.

Debris and dust on TFTR vessel floor

Tritium co-deposition on bumper limiter.





Diagonal pattern on inner limiter segments due to geometry of 'scalloped' shape and connection length of field lines (Brooks et al.,)

After plasma operations tritium in TFTR was located on inner limiter (0.2 g), and outer wall (0.36 g).

Highest concentrations were at top and bottom of limiter.

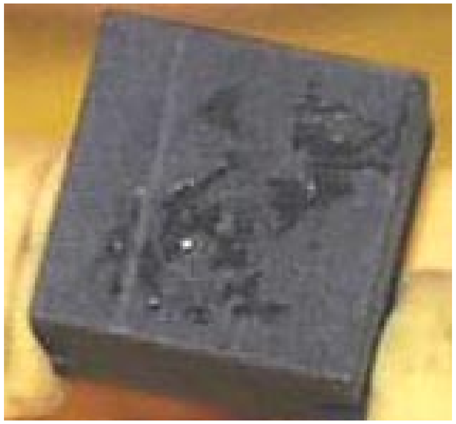
Numbers represent T (Ci) released by bakeout in air at 500 C for 1 hour.

9600 Ci = 1 g T

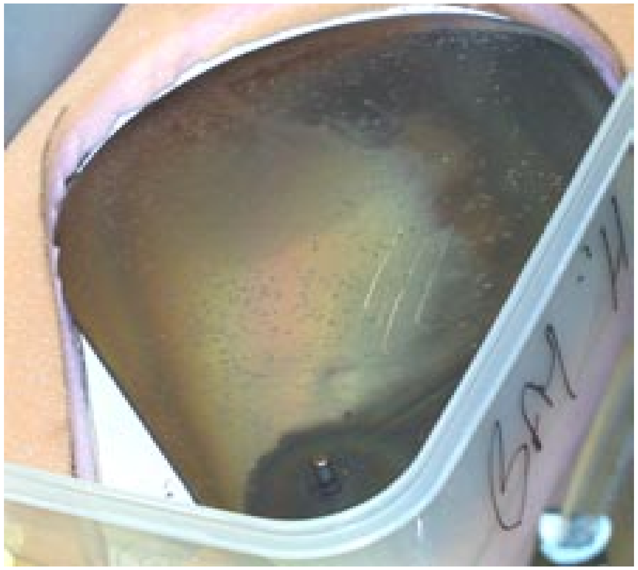
Tritium on outboard side of vessel

From bakeout:

Bay H midplane graphite coupon: 24 Ci/m^2
Bay N bottom graphite coupon: 65 Ci/m^2
Bay P midplane graphite coupon: 16 Ci/m^2

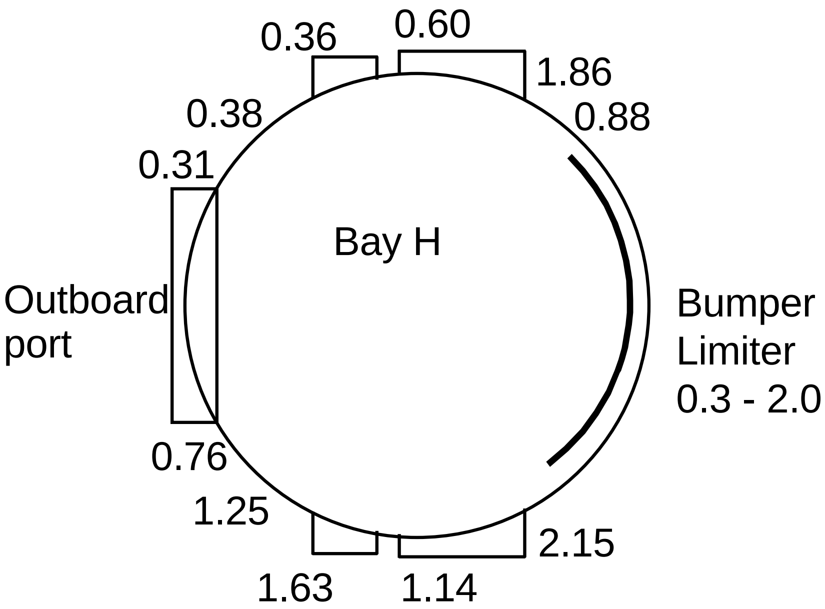


Bay H shutter (stainless steel) 9 Ci/m2



Tritium in top micron of surface (β range) measured by open wall ion chamber on vessel wall

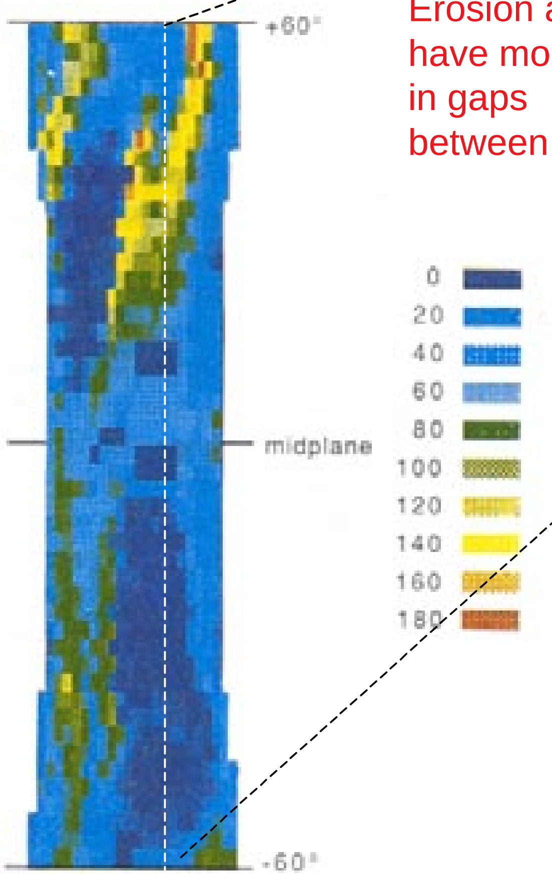
Maximum closest to limiter and on bottom of vessel.



Units Ci/m^2 [9,600 Ci/g T]

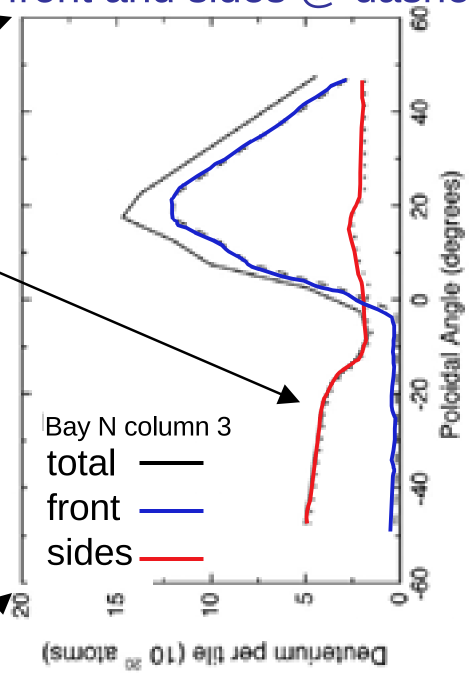
Nuclear reaction analysis of deposited deuterium in DD phase

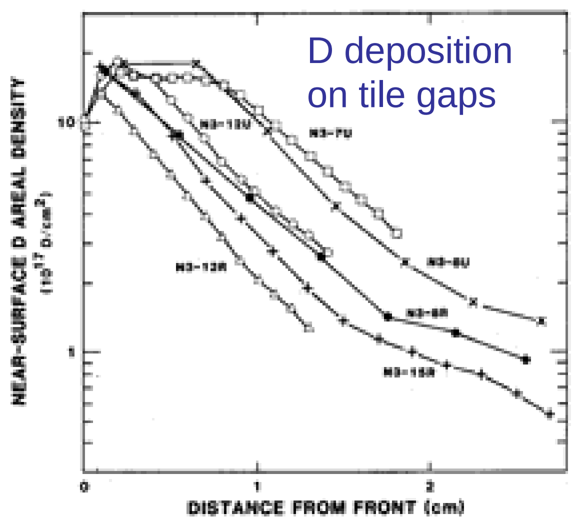
Metals deposition on plasma facing surface of bumper limiter
(Beta backscattering)



D on tile front and sides @ dashed line.

Erosion areas have more D in gaps between tiles





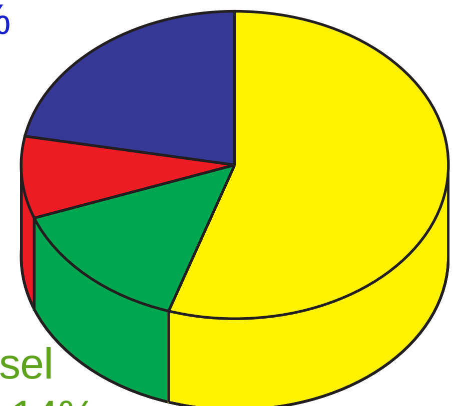
Summary of DD phase

Plasma facing tile surface 22%

Gaps between tiles 9%

Vessel wall 14%

D not retained 55%

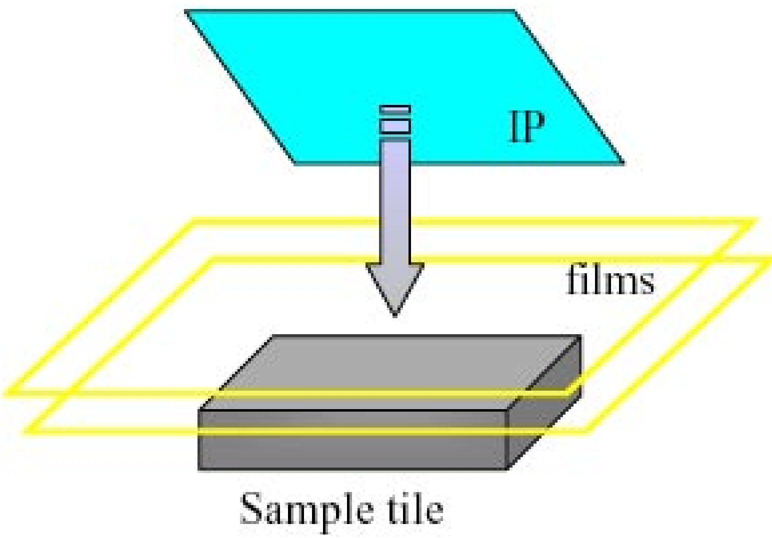


W. Wampler et al., J. Vac. Sci. Technol, A6 (**1988**) 2111,
B E. Mills et al J. Nucl. Mater, 162-164 (1989) 343.

Early demonstration of material migration in tokamaks

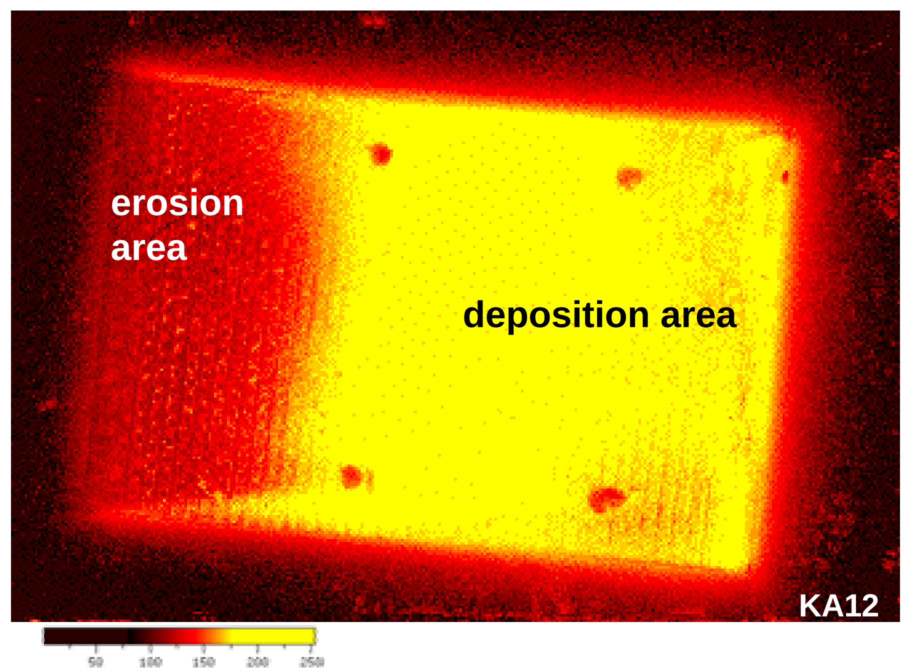
Historical note: In 15 years we have not demonstrated an ITER relevant way to remove tritium in a tokamak!

High resolution T mapping



Photograph of CFC tile KC12

Imaging plate: tritium and ^{60}Co on TFTR CFC tile



Fuji Imaging Plate(IP) provides high resolution contact image of tile radioactivity

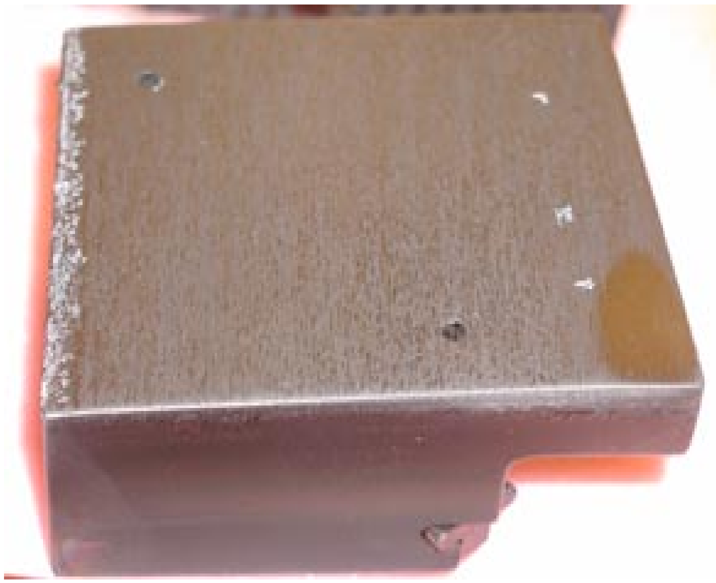
1 hour exposure, IP remains behind contamination barrier of two 1.2 µm films placed in contact with tile.

Image read out by laser
(photo stimulated luminescence of BaFBrdoped Cu^{2+}).

Collaboration with T Tanabe and K Sugiyama, Nagoya U.

Tritium on graphite tile in deposition area

Photograph of graphite tile KC21 from deposition area.



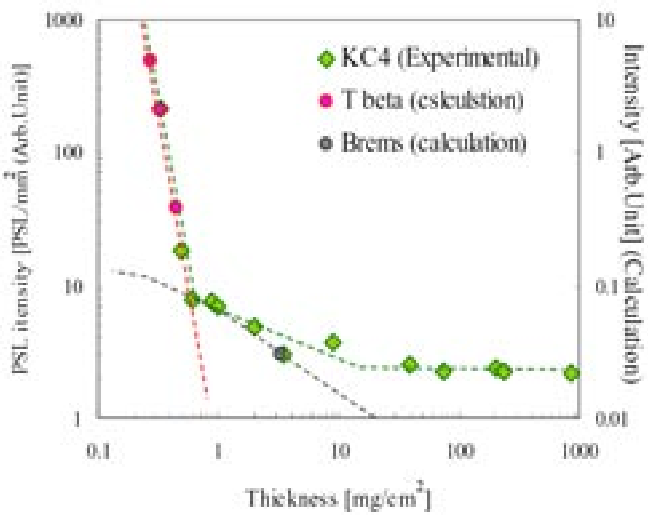
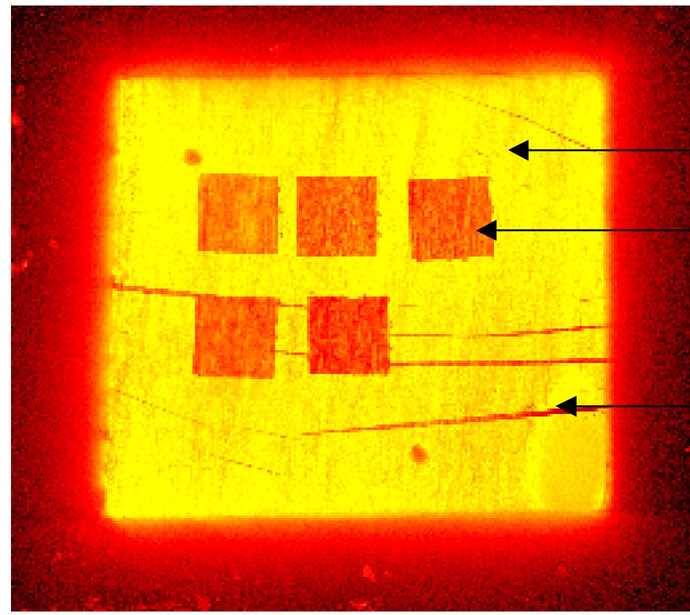


Image of tritium and ^{60}Co (from stainless steel debris) on plasma facing surface and side of tile KC21

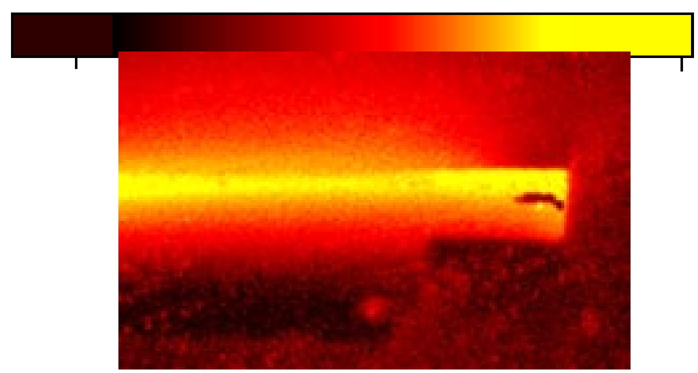
Additional film and Al square filters to identify 5keV betas from tritium and 318keV betas from ^{60}Co.
[^{60}Co and ^{57}Co also identified by gamma spectroscopy.]



Tß

^{60}Co ß

crease in film

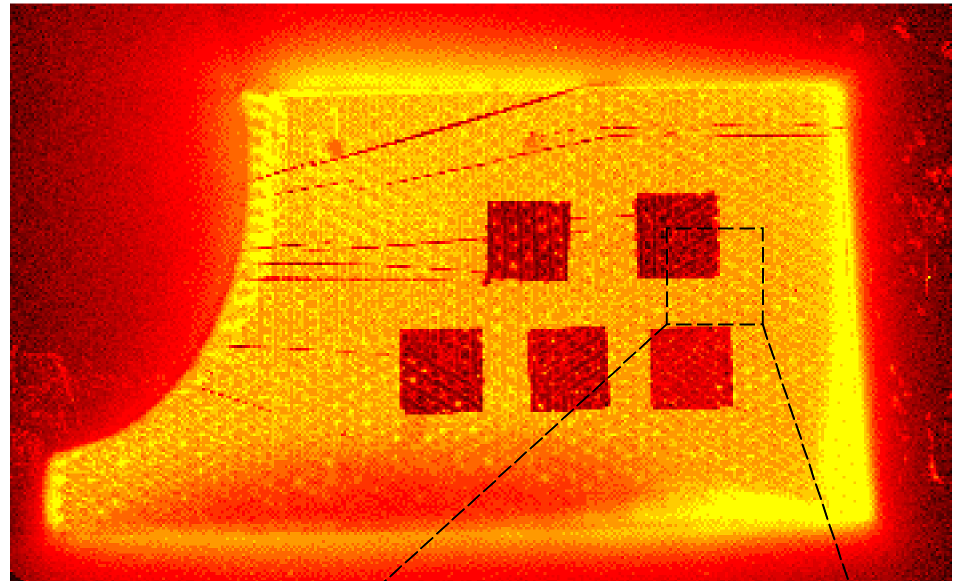


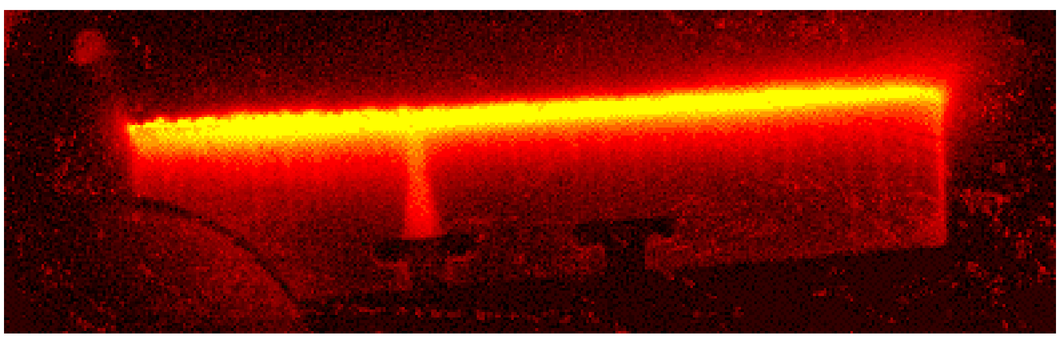
side of tile

Tritium on CFC tile in erosion area (KC3)

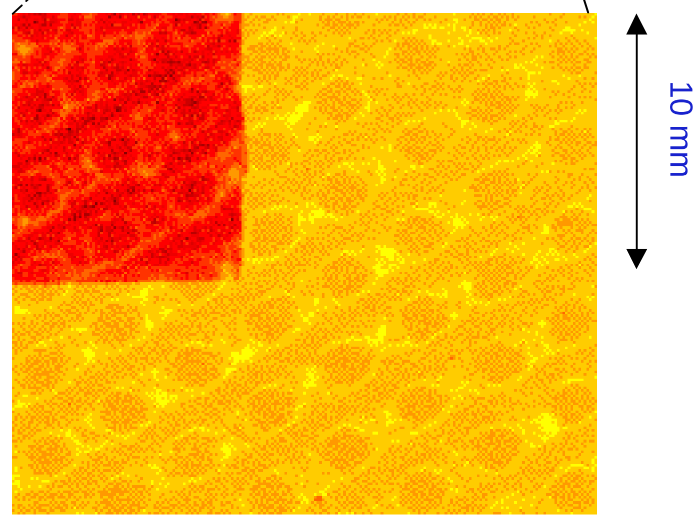
Photo of KC3

Imaging plate: Tritium & ^{60}Co





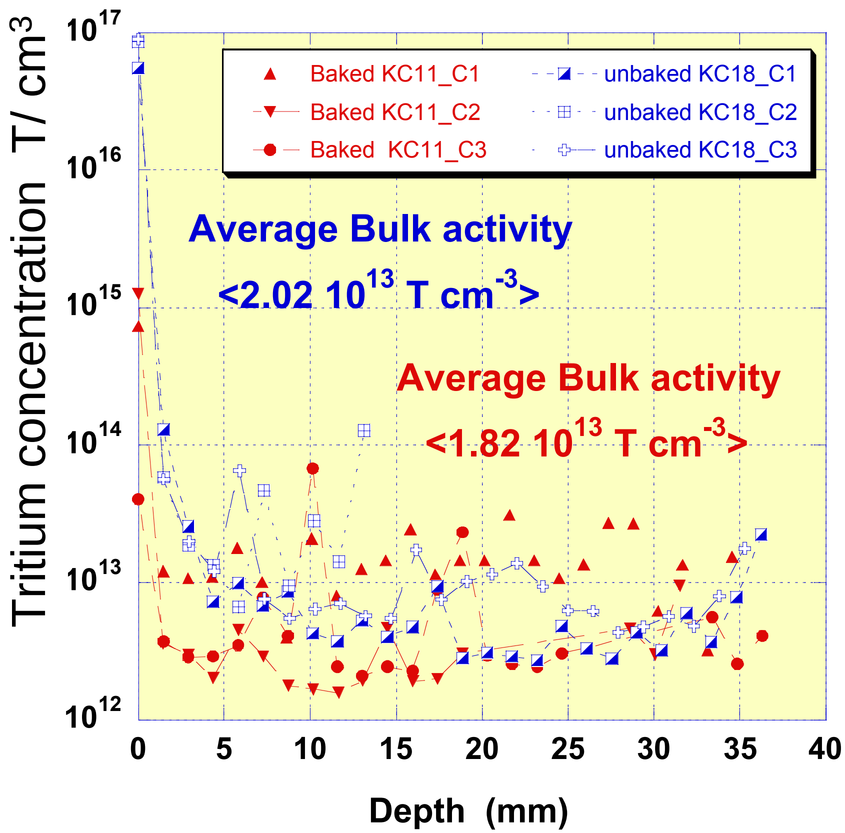
T + ^{60}Co on tile side



Note tritium concentrated on fiber boundaries

Tritium found in tile bulk

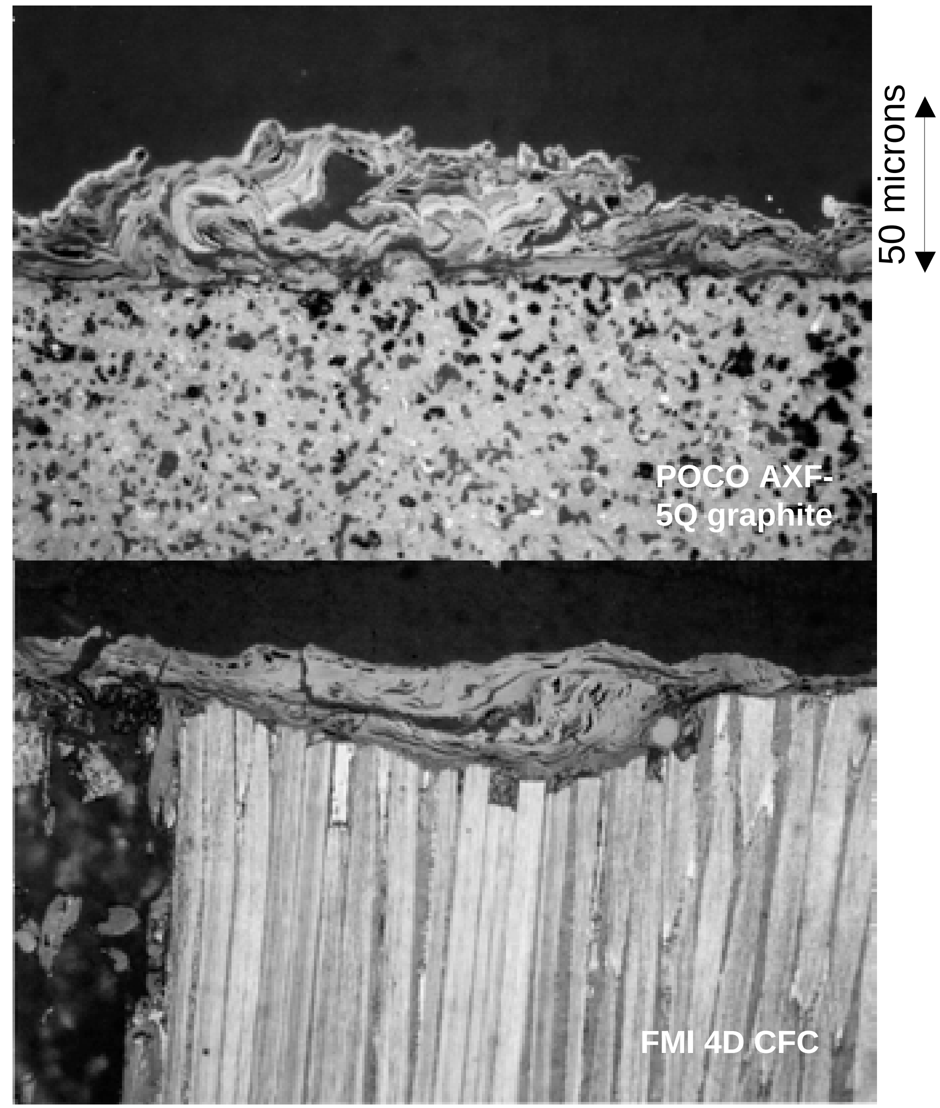
Tritium depth profile comparison for the CFC tiles KC18 (unbaked) and KC11 (baked)



Core sampling shows 0.5 - 1% of tritium has diffused to bulk of tile and is not released by baking

Nicolas Bekris FZK

Cross Section of TFTR co-deposit.



M Paffett, R Reiswig, S Willms, LANL

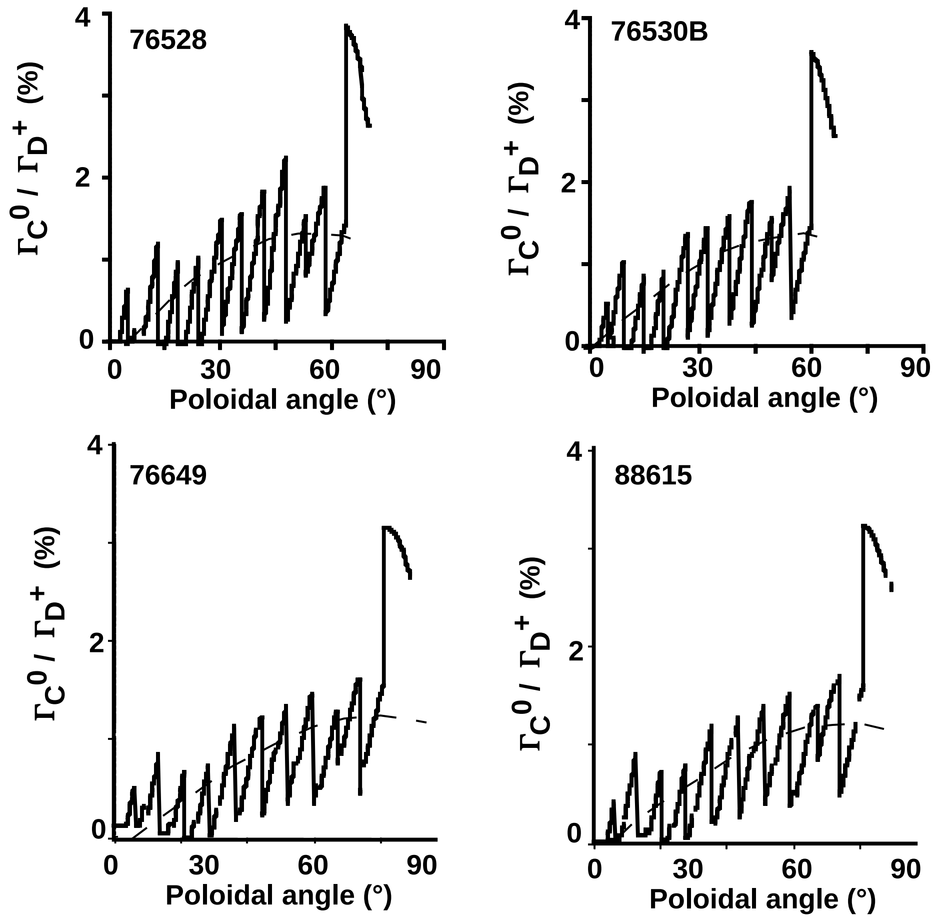
Modeling of C production and Tritium retention in TFTR

BBQ code by John Hogan describes:

3D space, 3D velocity test particle Monte Carlo code for emitted C impurities from physical, chemical sputtering and radiation-enhanced sublimation (RES)

Parallel, perpendicular diffusion, electrostatic fields, friction with SOL flow, atomic/molecular physics *(includes Erhardt-Langer database for CD4 breakup)*

Combines detailed TFTR Bumper Limiter geometry (CAD) with impurity SOL transport and redeposition



Local effective sputtering yield distribution on bumper limiter
(emitted impurity flux / incident D+ flux) for 4 representative discharges.

Extrapolate carbon erosion from selected representative discharges

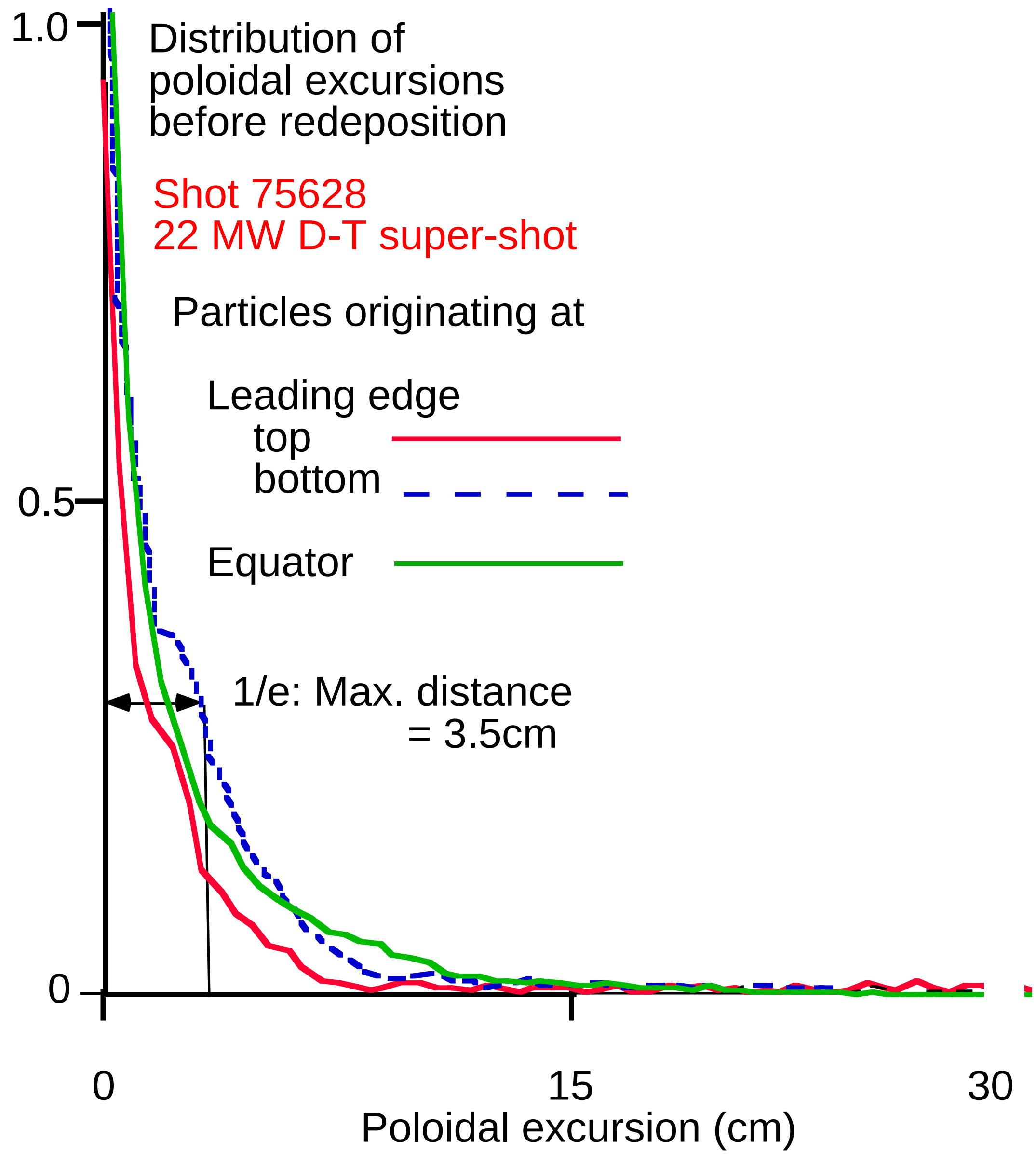
H-isotope/C ratio in co-deposits approximately 0.2 (NRA) – estimate retention….

→ ***Modeling can account for order of magnitude of retention***

John Hogan ORNL

Carbon + H-isotopes codeposited close to erosion point

- BBQ shows strong localization of D+ flux at top/bottom leading edges of TFTR limiter.
- Data consistent with considerable number of TFTR discharges with large (≈10cm) radial decay length of the D+ flux due to inner wall recycling and flux amplification.
- Flight of sputtered carbon tracked in radial, poloidal and toroidal dimensions.
- Higher effective sputtering yield at high latitudes and prompt local redeposition leads to high codeposition in these areas.
- Significant concentrations of T predicted on upper and lower leading edges of limiter.

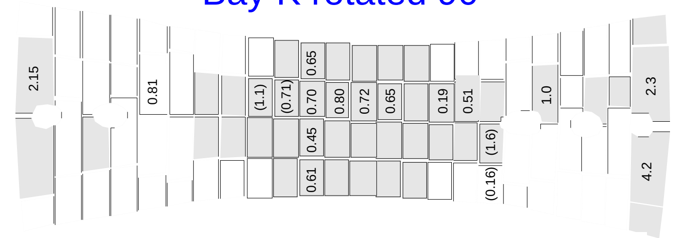


John Hogan

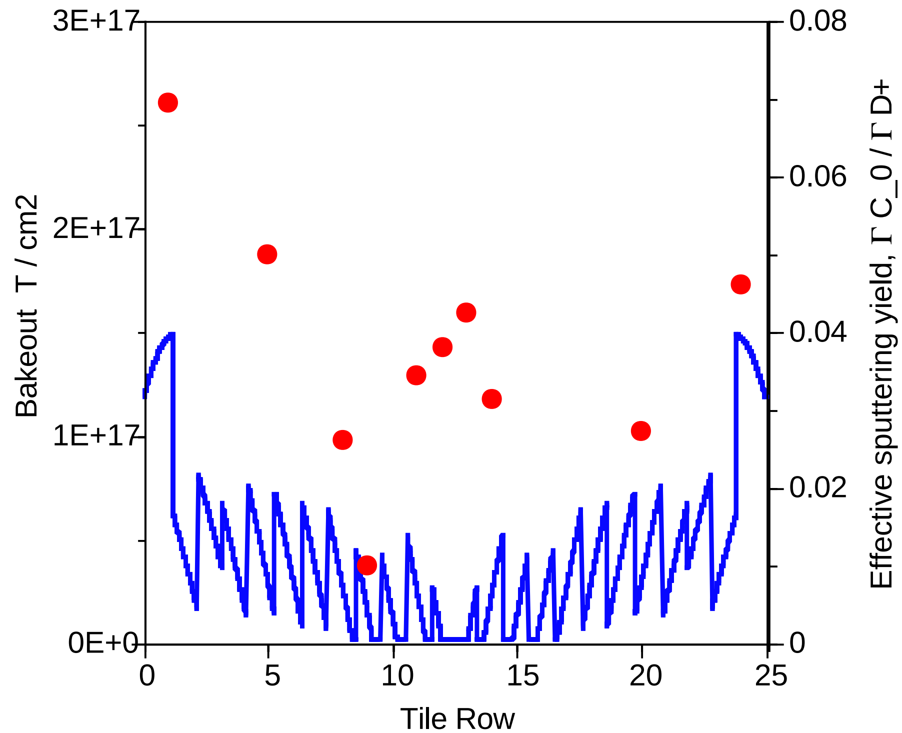
Modelling appears to be on right track

- Higher effective sputtering yield at high latitudes and prompt local redeposition leads to high codeposition in these areas
- Data consistent with considerable number of TFTR discharges with large (≈10cm) radial decay length of the D^+ flux due to inner wall recycling and flux amplification.
- Li deposition at same locations may enhance retention (Li used for wall conditioning).
- Observed tritium concentrations (measured after modeling predictions) suggest model is on right track.

Bay K rotated 90°



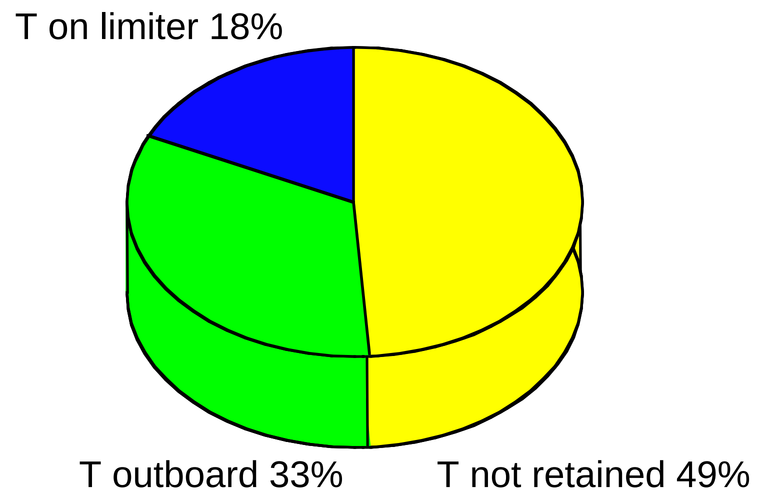
Measure tritium in selected tiles



Row averaged tritium release / plasma facing area (cm^2) compared to effective sputtering yield for # 76528

Overview: Tritium retention in TFTR

Location:	Area (m^2)	T conc. mg/m^2	(g)
Bumper limiter	22	9	0.2
Outboard	110	3.3	0.36
Total			**0.56**
cf. fueling - exhaust			***0.64***



- *Retention fraction ≈ 51% much much too high for ITER*
- *1/3 tritium on bumper limiter, 2/3 on outboard wall*
- *Remarkably good agreement between extrapolation from tile measurements and fueling less exhaust.*
- *Retained tritium consistent with modeling.*
- *0.5 - 1% of tritium in bulk of tile*
- *Some tritium trapped at fiber boundaries*