Outline

- Why are tritium and dust important ?
- TFTR & JET tritium experience
  - H retention in other tokamaks
- Tritium removal
- Projections for ITER

Tritium safety

T inventory limit is derived from no public evacuation criterion (< 50 mSv dose)

GSSR analysis*

- Conservative weather, building wake, 1 km to site boundary

  => 90 g T tolerable ground level release.

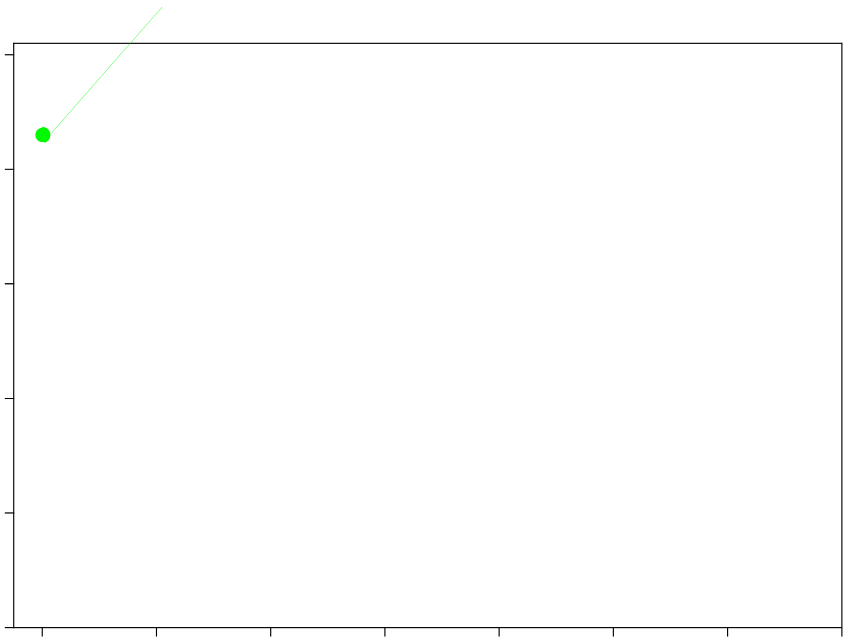
  ground level release = T release x building confinement factor

- Worst credible accident:
  - Vacuum vessel bypass event and
  - 8 hour blackout (8 h) and
  - In-vessel loss of coolant
- For 1 kg T inventory only 15 g tritium released to environment
  - good safety margin !

*Analysis now updated for Caderache site in Preliminary Safety Report.

- Tritium can be released in dust as well as T_2 and DTO gas
- W dust can also be activated

Tritiated dust more hazardous than HTO



Skinne

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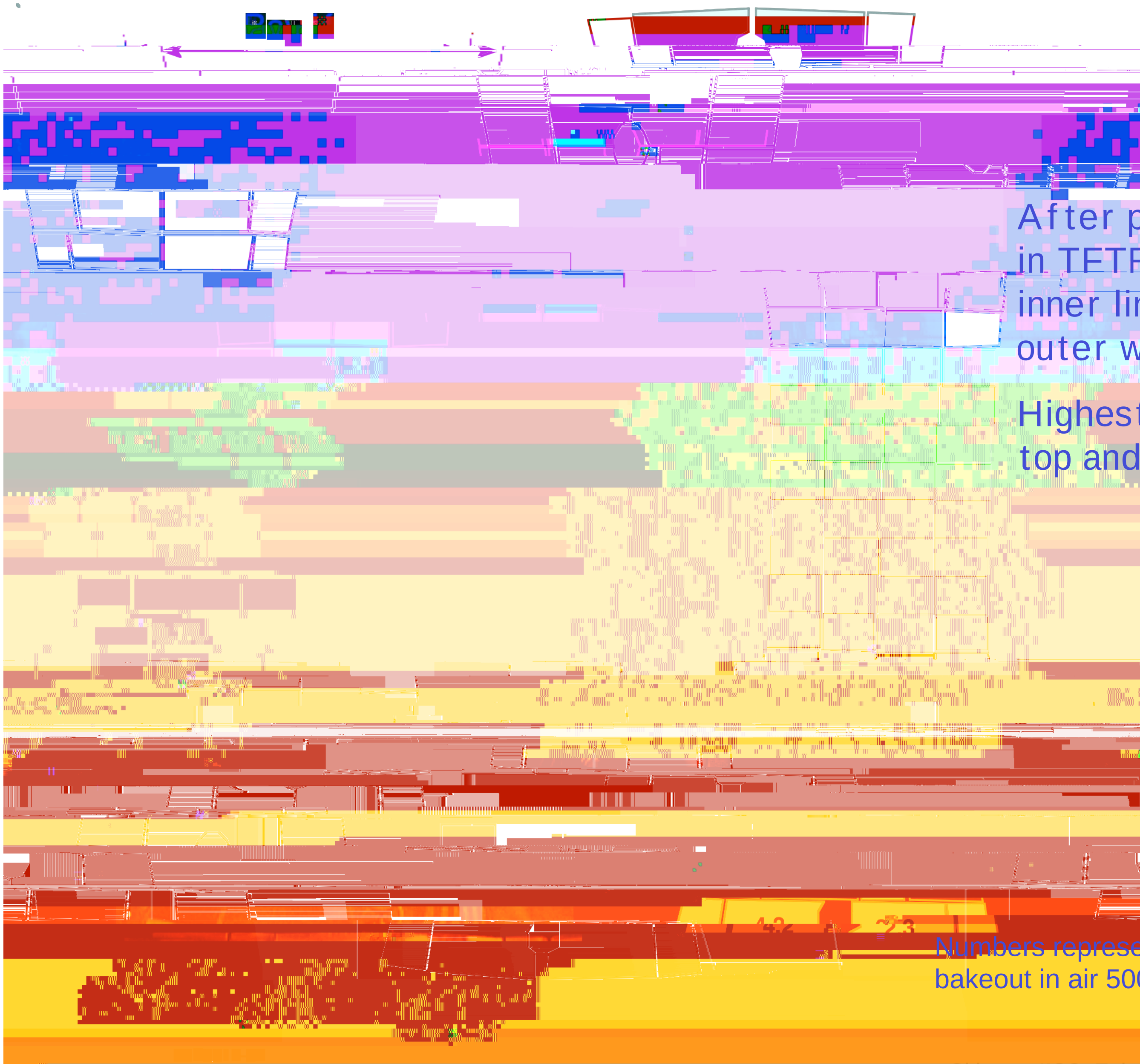
Basic mechanisms for retention

1. Short-term adsorption followed by outgassing!

Two complementary methods to measure retention (R).

1. Gas balance, or fueling - exhaust (typically R≈ 10%-20%)
2. Analysis of components removed from vessel (typically R≈ 3% - 50%).

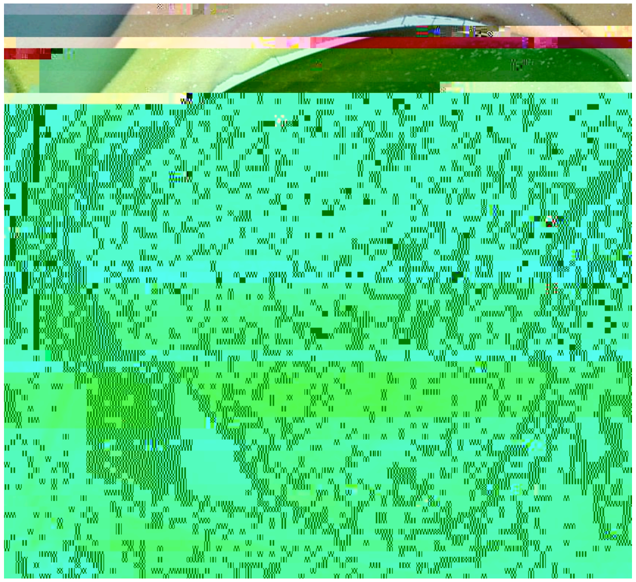


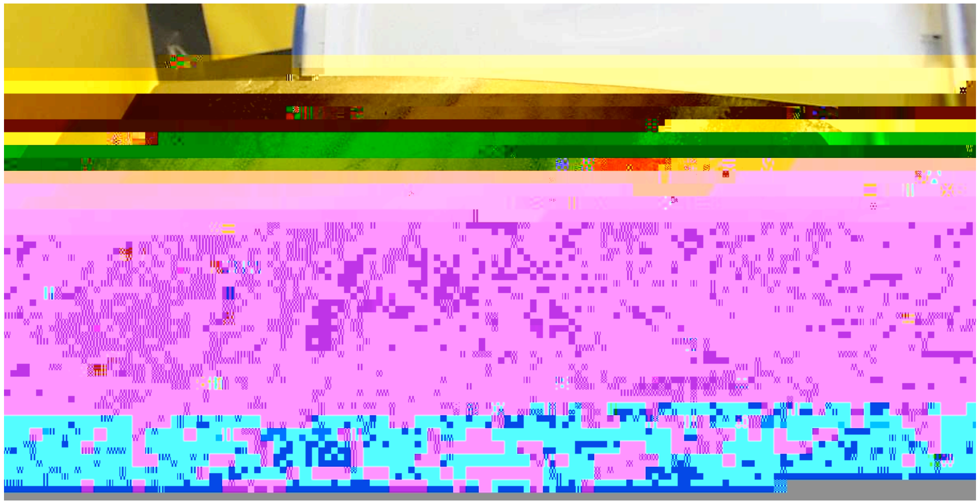
After plasma operations tritium in TETR was located on inner limiter (0.2 g), and outer wall (0.36 g).

Highest concentrations were at top and bottom of limiter.

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

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

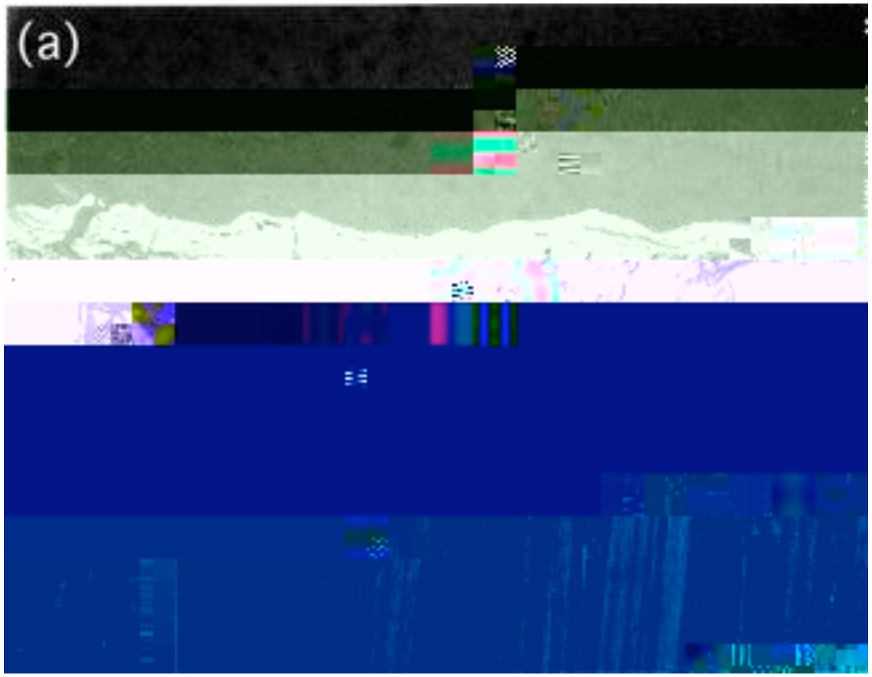




Images of tritium on TFTR tiles (2)

Penetration of T into gaps depends on magnetic field and population of high and low sticking probability hydrocarbons.

Important for tritium removal



codeposit

manufac
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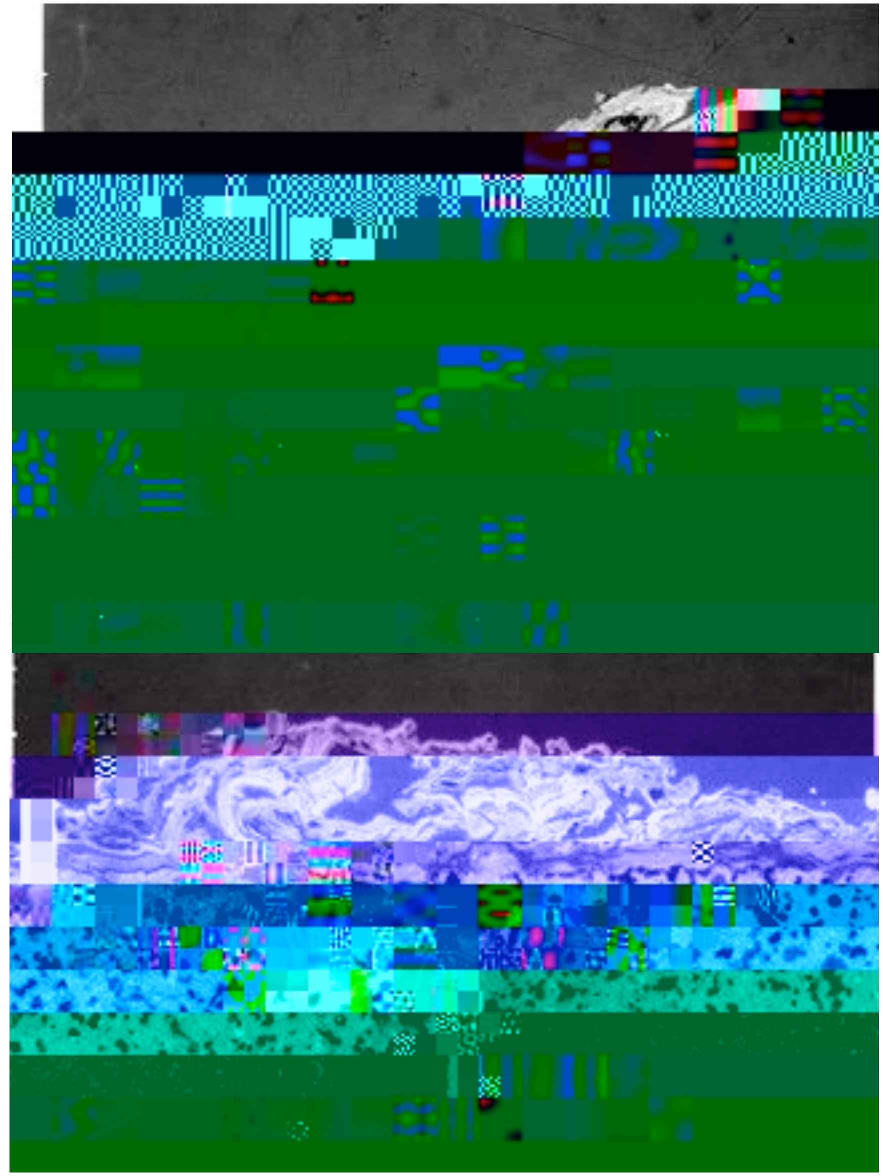
material



50 µm

TFTR tile samples

(John Hogan)

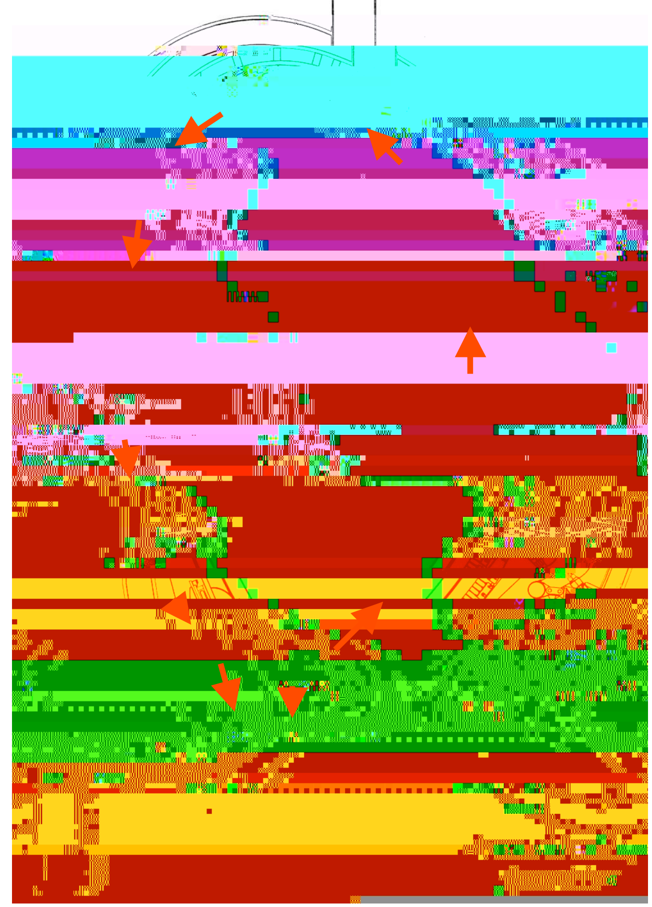
BBQ code describes:3D space, 3D velocity test particle Monte Carlo code for emitted C impurities from physical, chemical sputtering and radiation-enhanced sublimation (RES)

Parallel,

Location:	Area (m^2)	Average Ci/m^2 from bakeout + 10%	Inventory (Ci)	(g)
Bumper limiter	22	87	1,900	0.2
Outboard	110	32	3,500	0.36
Total			**5,400**	**0.56**
cf. fueling - exhaust			***6,***	

JET interior

Transport of impurities
(in Mk IIA configuration)



- JET DTE1 experiments 1997, (PTE 1991)
- JET has divertor.
- Walls are erosion areas
- Walls are heated 150-320 C.

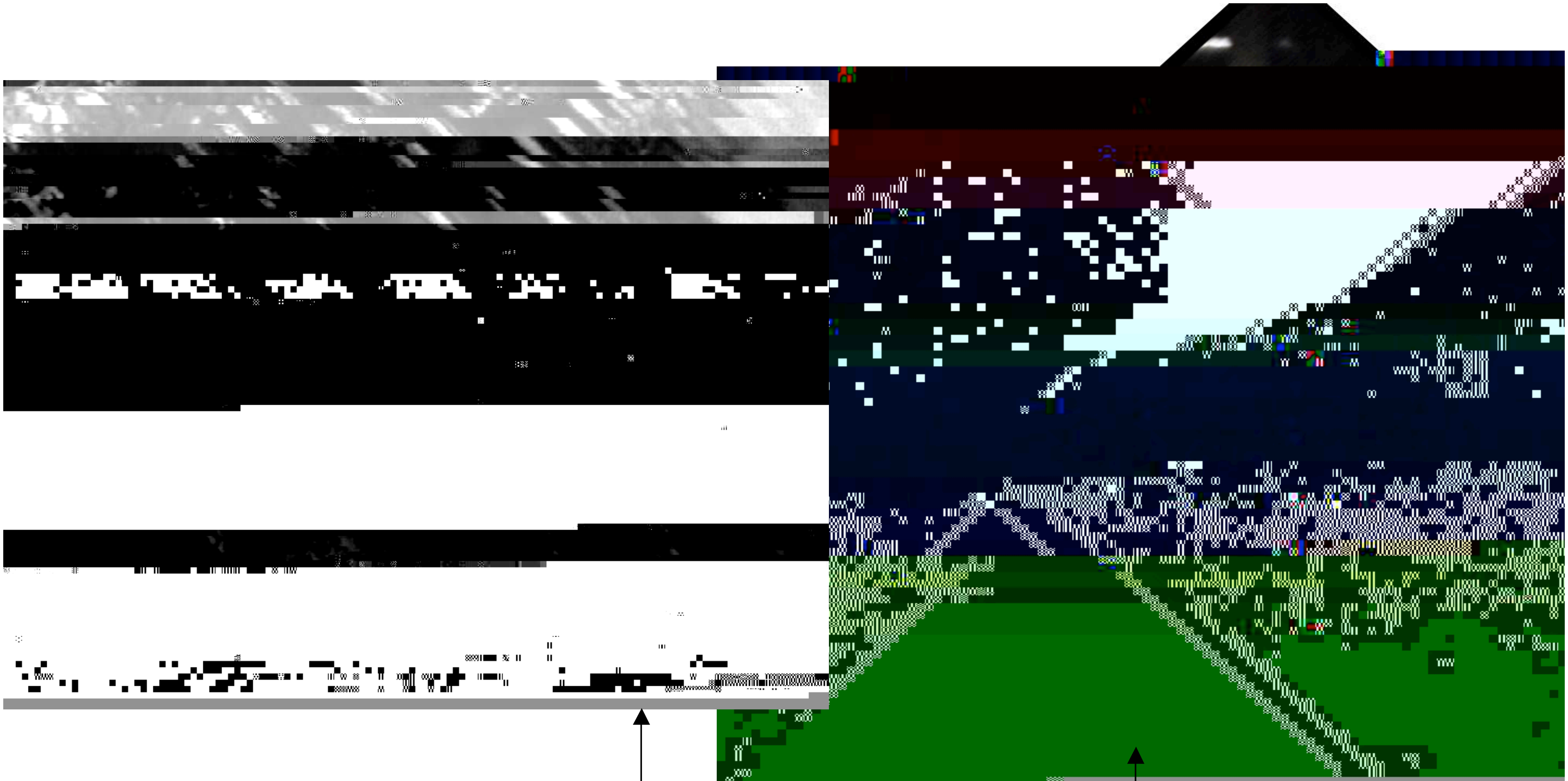
	TFTR edge plasma	JET divertor plasma
Ne	0.1 e19 – 1 e19 m-3	! 10 e19 m-3
Te	200 - 600eV	<30 eV

Prompt retention rate higher than expected

1r10 0 0 0 0 3 5 . 9 2

P. Andrew et al., Fus. Eng. Des., 47 (1999) 233

Flakes at inner louvres of Mk IIA divertor



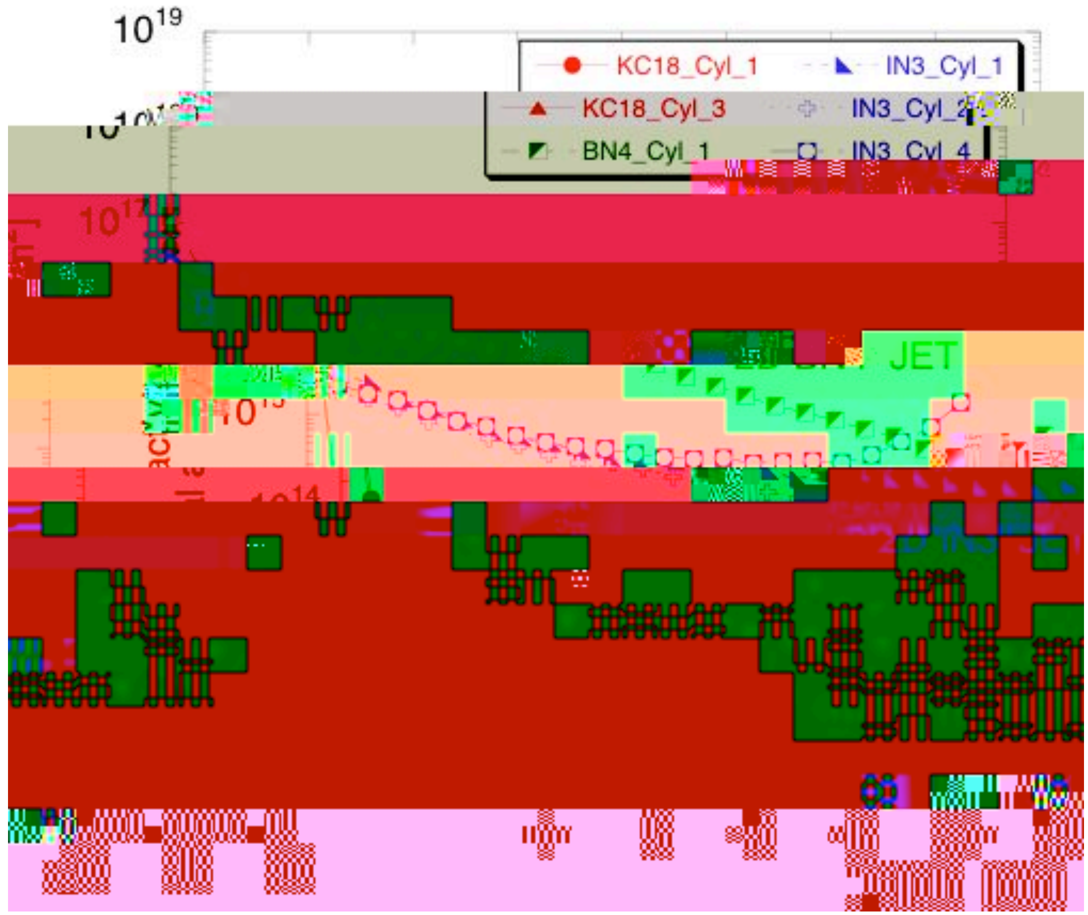
Tritium on the inner divertor louvres (0.5g) and sub divertor region (3.4 g).

c.f. tiles (<0.1 g)

P. Coad, UKAEA/JET

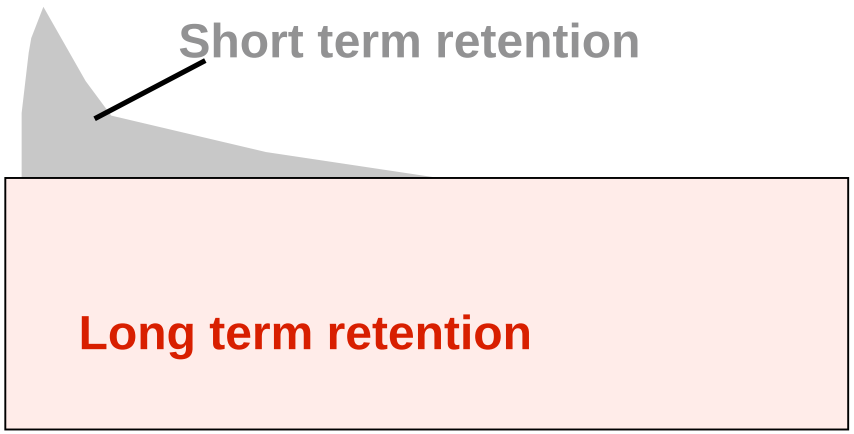
Tritium can diffuse into carbon tiles

- Core samples of tiles are sliced into 1 mm discs
- These are incinerated to release all tritium.
- Tritium is measured by liquid scintillation counting.
- Results show 61% of retained tritium had diffused deep into bulk of JET 2D CFC tiles.
- This is a concern since removal from bulk is practically impossible.

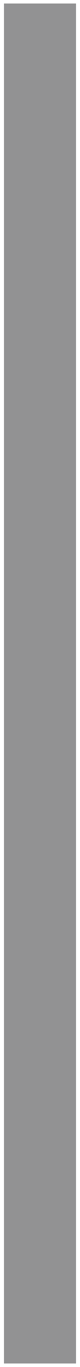


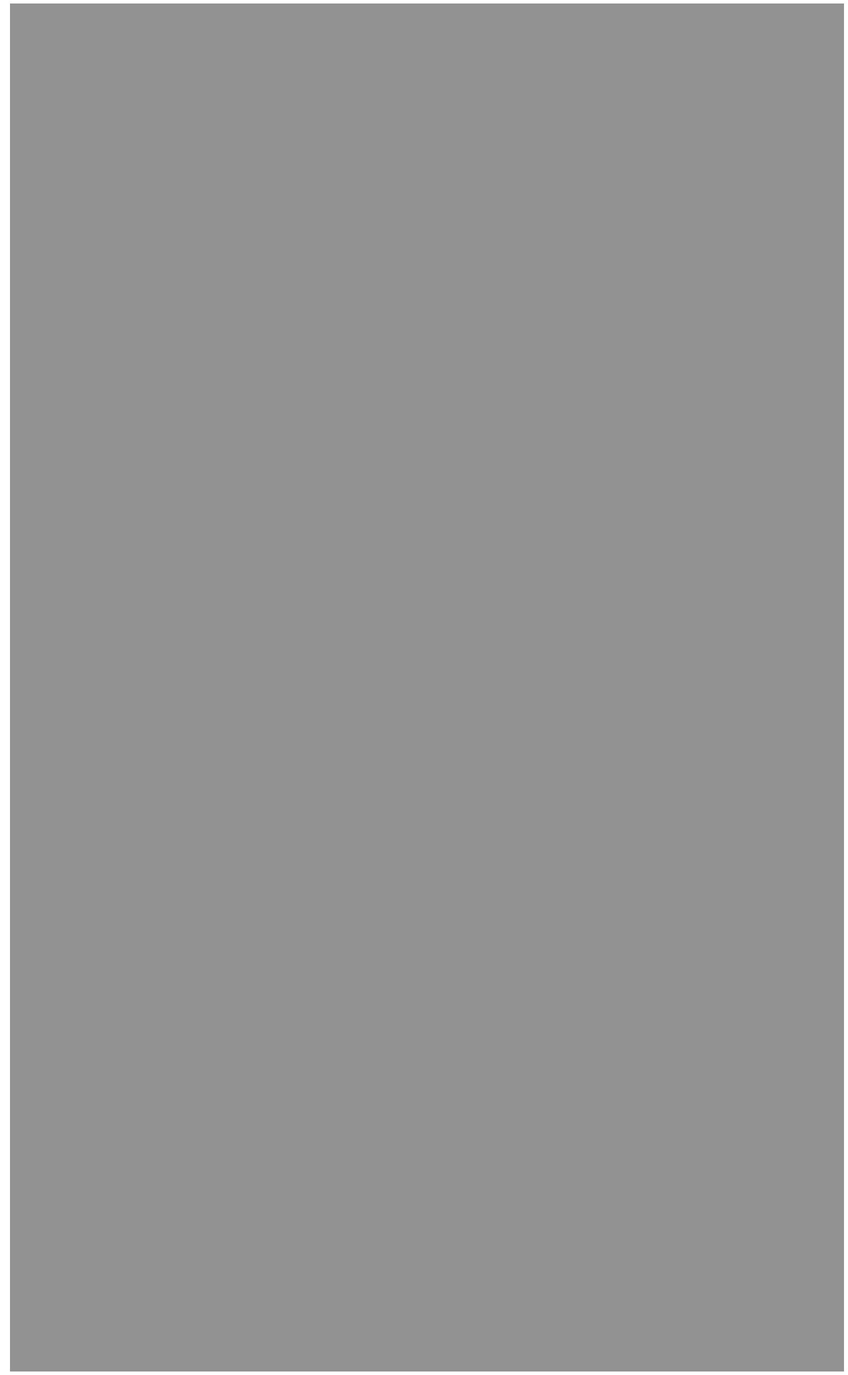
N. Bekris et al., J. Nucl. Mater., 313-316, 501, (2003)

Long pulse effects: Tore Supra experience

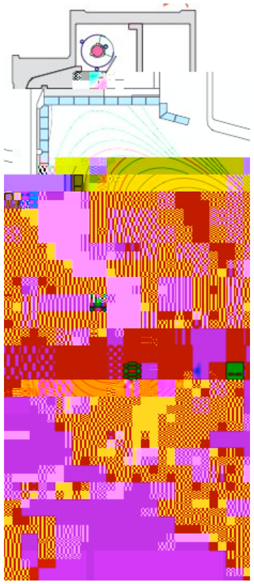


Th. Loarer PSI-18





Surprising results from C-mod w



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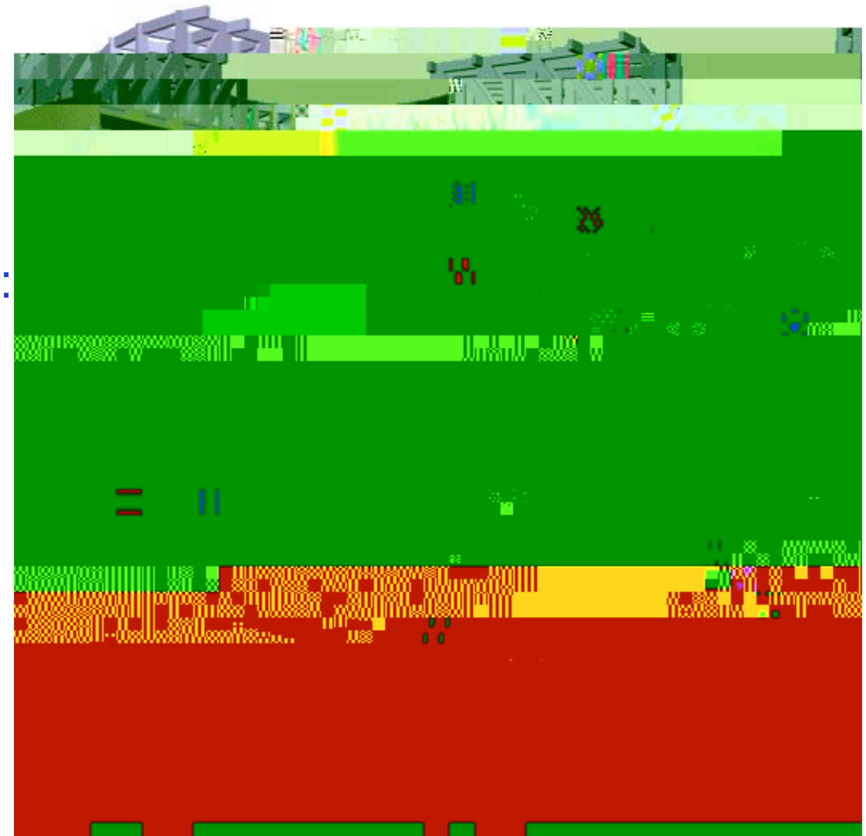
Tritium removal options

Potential Options

1) Remove whole codeposit by:
   - oxidation (maybe aided by RF)
   - ablation with pulsed energy (laser or flashlamp).
2) Release T by breaking C:T chemical bond:
   - Isotope exchange
   - Heating to high temperatures e.g. by laser

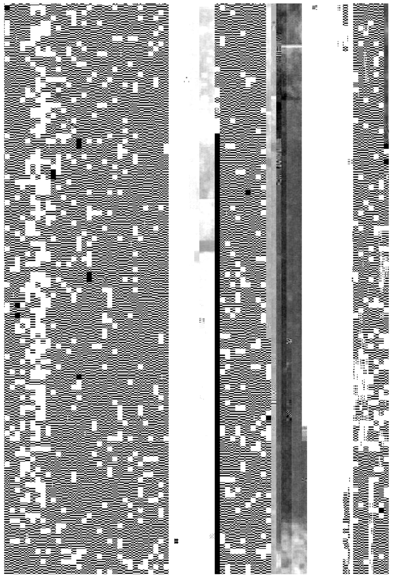


- Constraints:
  - 6.1 Tessla field at inner divertor
  - 10,000 Gy/hr gamma field from activation, 3 h after shutdown, after 20 years DT ops.
  - Access difficult, especially to hidden areas

Tritium removal by oxidation:

- Oxygen can remove carbon codeposits by oxidation to DT0, CO_2, CO.

Removal by ablation using excimer lasers or flashlamps

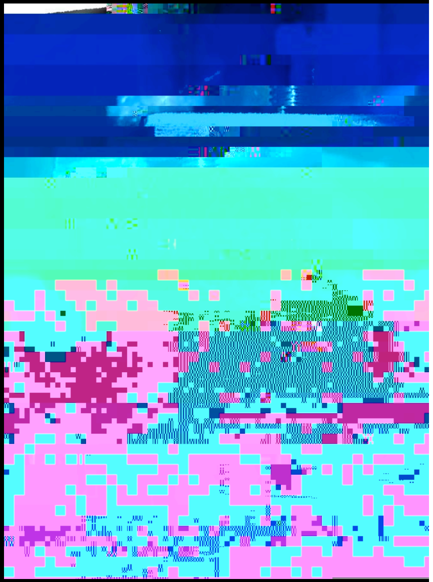


Flashlamp ablation:

CFC tile coated with a 28 μm aC:H film (darker regions). The lower region was masked during film deposition to act as a Tj ET Q q 0.2400000 0 0 0.2400000 35.92002 -7.6 control. Deposition was removed in-vacuo by 82 Tj ET Q q 0.24000001 0 0 0.2400000 35.92002 -7.649941cm

Detritiation by laser

Nd laser in action:



7/8” cube cut
from

Nd laser power only 6 w to avoid camera damage (300 w available)
TFTR DT tile cube KC17 2E in air at 200 mm/s.

Application to ITER ?

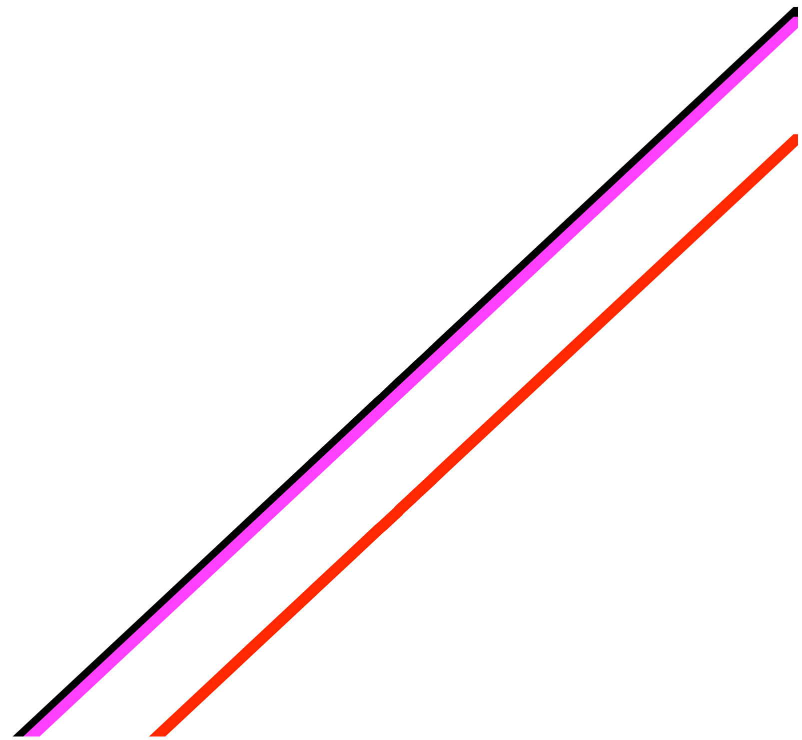
- Fast cleanup - 6 kW laser can deliver energy to heat 50 m^2 surface in 3 hours in next-step device.
- Convenient fiber optic coupling.
- no HTO to process (HTO is 10,000x more hazardous than T_2 and expensive

J. Nucl. Mater 313-316 (2003) 496.

Other methods:

Ski

Dust generation



ITER retention depends on material choice

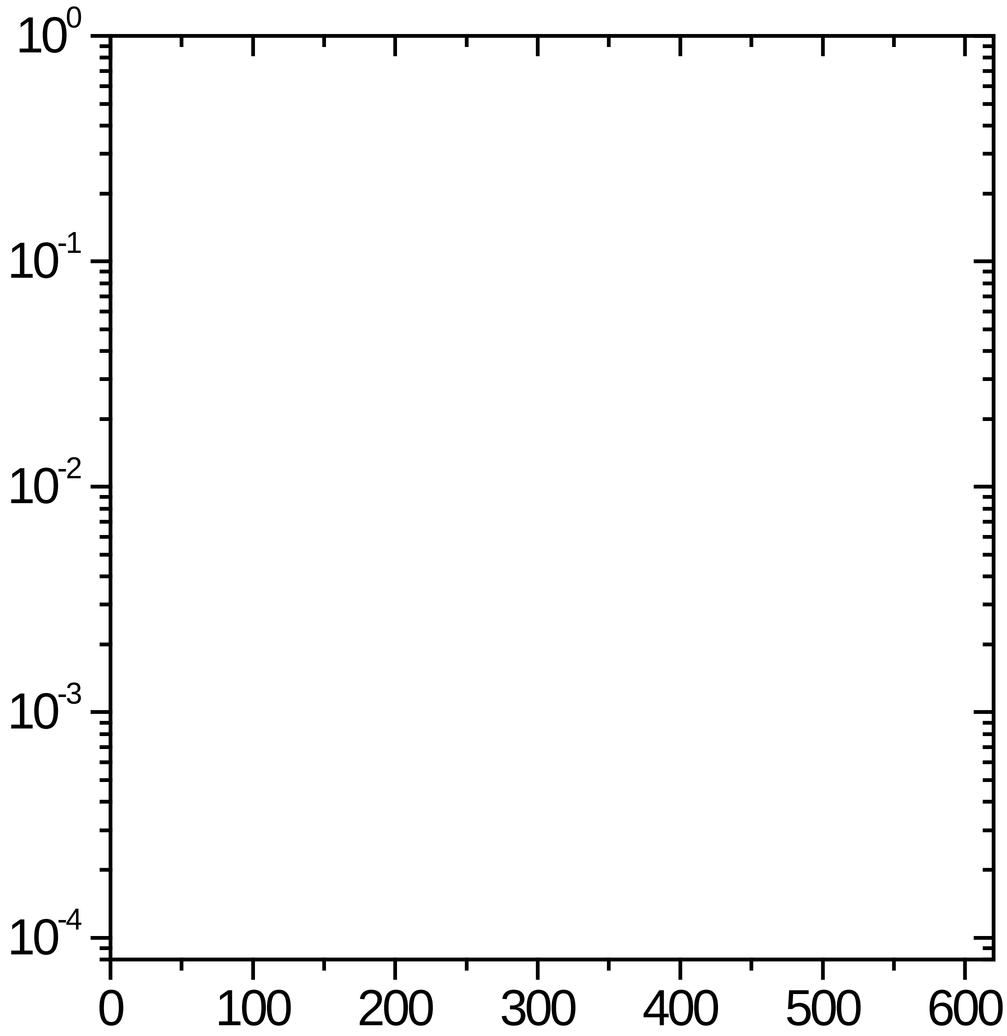
Present ITER strategy:

Initial hydrogen/deuterium phase:

- Beryllium wall, 700 m^2
  (low Z = low radiation losses, oxygen getter,

ITER

Erosion > co-deposition > tritium inventory



Implantation: D in W divertor tiles

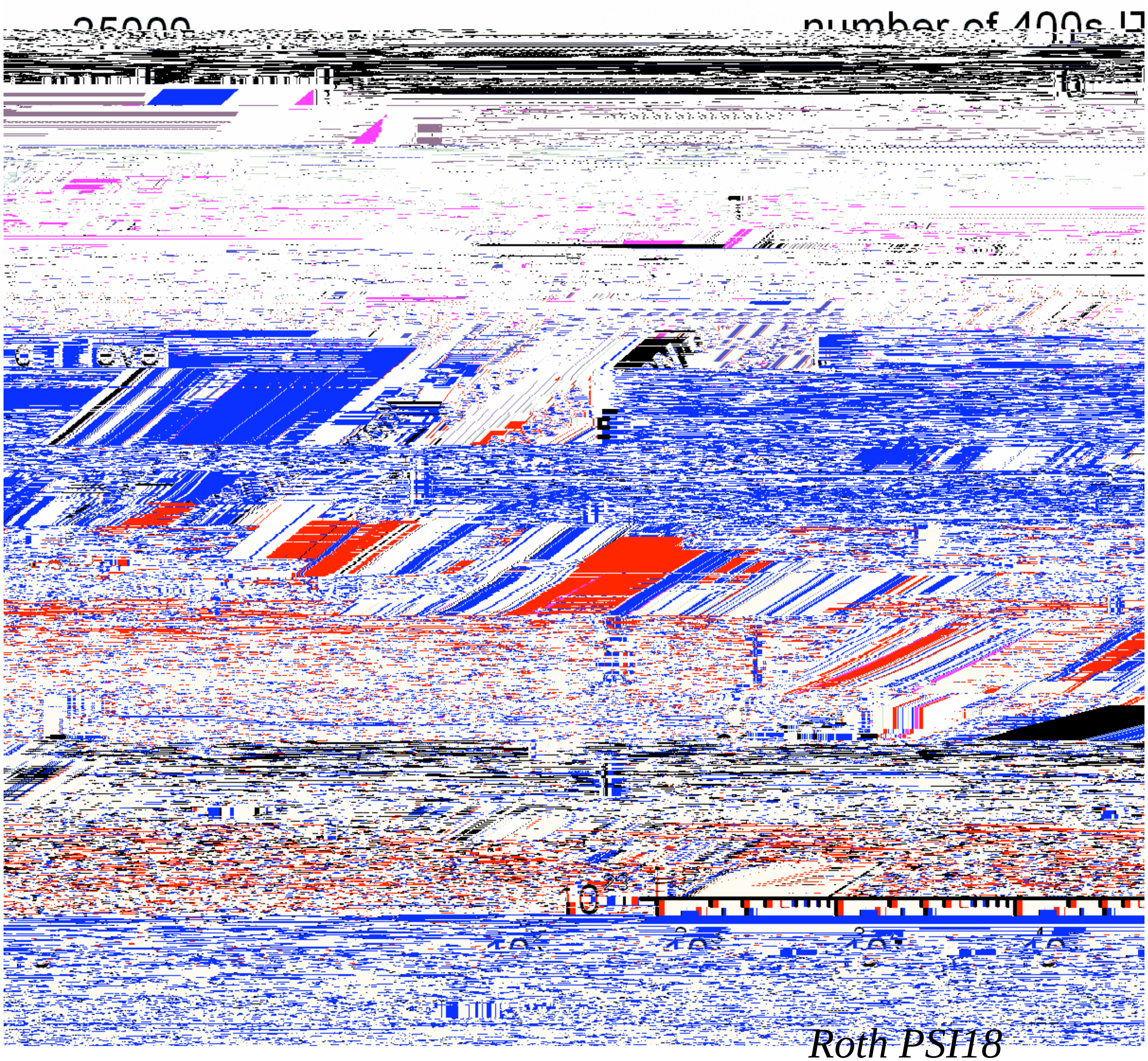
- Code calculations (Ogorodnikova) based on experiments.
- Neutron irradiation assumes saturation at 1% additional trap sites.
- DIFFUSE code (Causey)

Roth PSI18

Implantation + codeposition

Recent EU assessment of tritium inventory in ITER for various PFC material options
(to appear in PPFC)

Similar, independent plot by ITPA SOL/Div group (to appear in 2008 IAEA proceedings).



Roth PSI18

Summary:

- Managing tritium inventory is a challenge for ITER and future DT reactors.
-

¥ • The :92002 -7.649941cm BT 4(ic perennial ice cover has been decreasing at 9 to

References in Literature:

1. "Recent advances on hydrogen retention in ITER's plasma-facing materials: Be, C, W."