ITPA会合（2012年1月，Aachen）
Dust / Retention

芦川直子（核融合研）

2012.7.24 @ 筑波大学

18. Dust Session

Main Topics : Dust monitoring

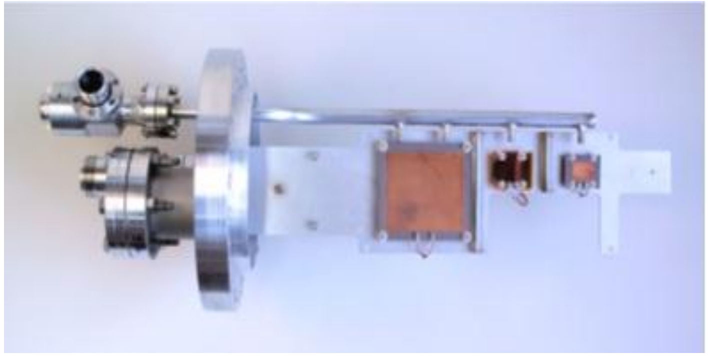
<Today's Talks>

- "Dust monitoring in Tore Supra" (C.Grisolia)
- ~~"Update on dust monitoring in DIII-D (T.Leonard)~~
- "Statistics on dust in KSTAR" (S.H.Hong)
- "Dust research in HT-7 and EAST" (J.S.Hu/G.N.Luo)
- "Evaluation of the dust monitor build in LHD/Qualification of F4E capacitative dust monitor for the operation in ASDEX Upgrade/IAEA Coordinated Researching Project on dust" (M.Balden)

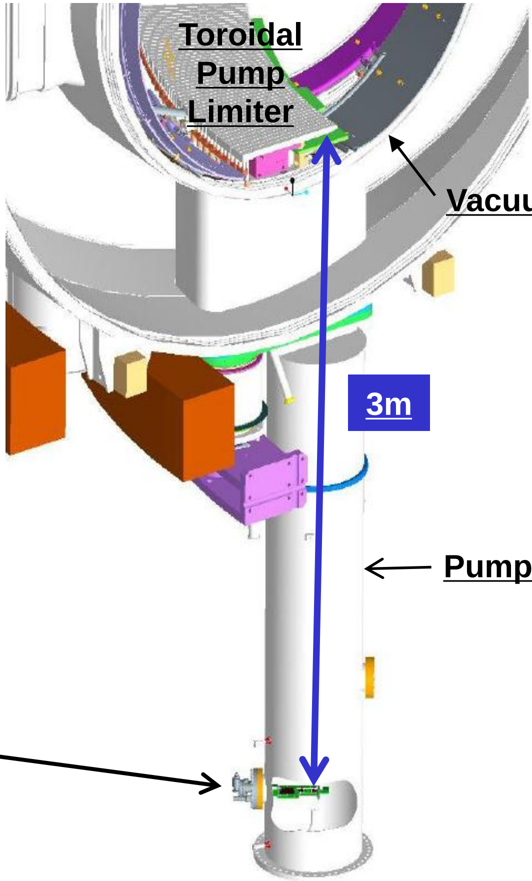
Dust : Grisolia

Electrostatic DUST diagnostic in Tore Supra

Goal:
Dust measurements during Tore Supra operation



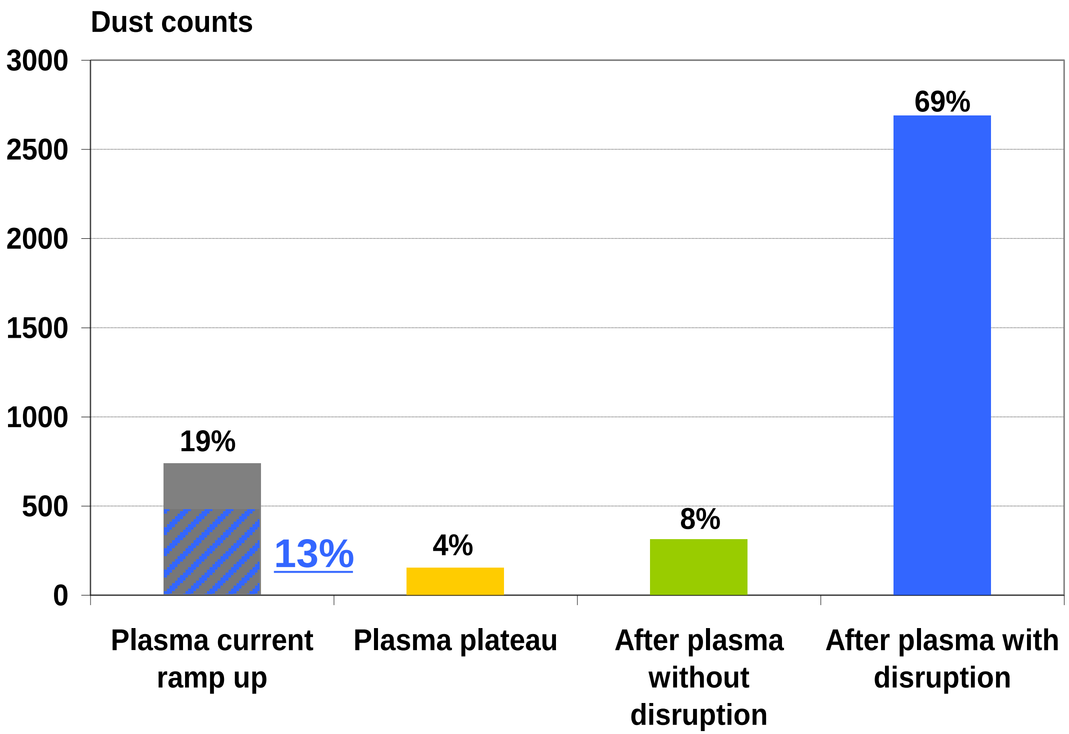
A set of electrostatic detectors



Dust : Grisolia

First results from DUST diag in Tore Supra

82% of the dust particles detected during disruptions



481 shots analyzed ~10000s
27 disruptions
101 shots with dust detected
Total dust particles detected = 3896

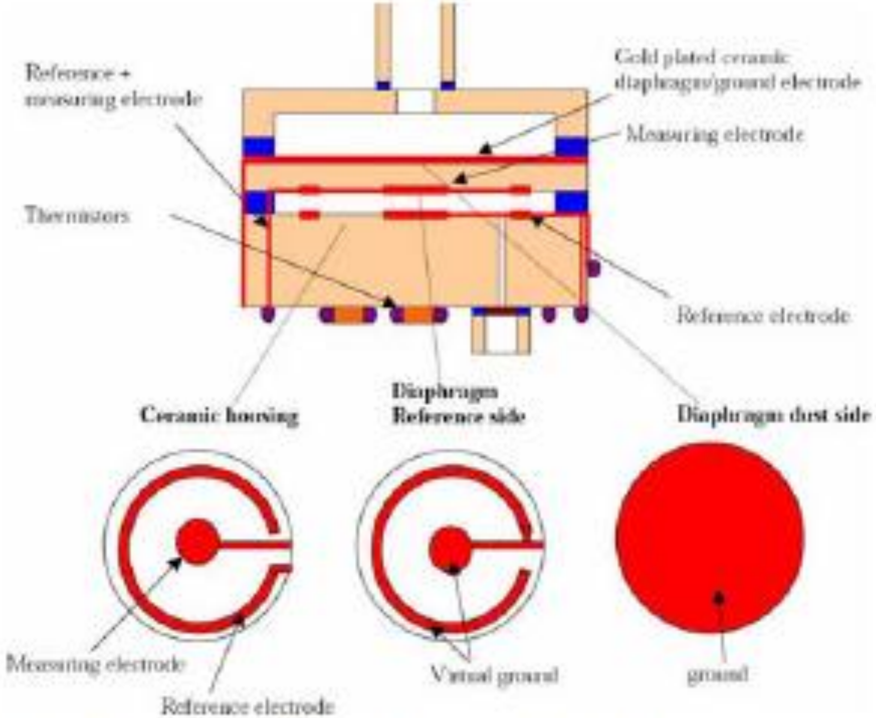
Plasma events:

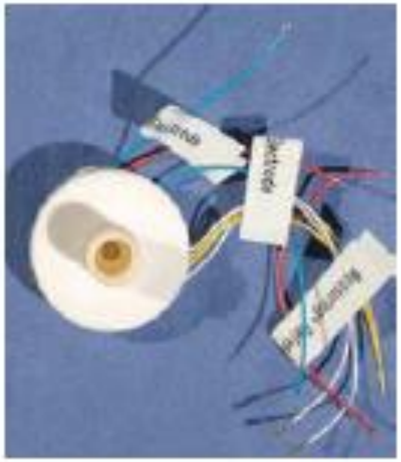
- Plasma current ramp up
- Plasma current plateau
- After plasma without disruption
- After plasma with disruption
- Plasma current ramp up following a disruption

Dust : Balden

Capacitative dust monitor: Shot-based

- **Measurement problem: small capacity change by dust**
  - *- 40 m cable required by ITER (gauge: 30 pF; cable 3000 pF)*
  - *- second electrode and cable for compensation*





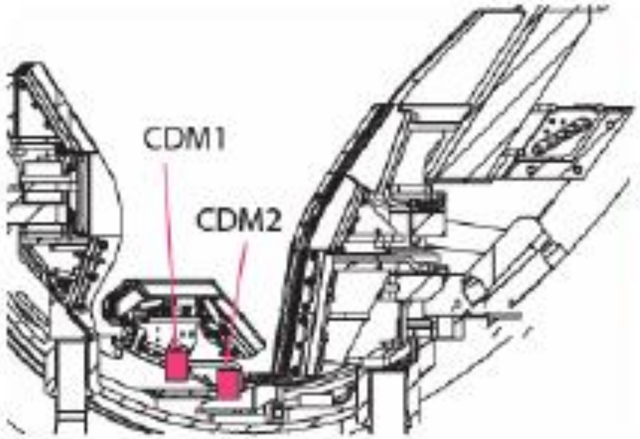
4 gauges exist

Martin Balden@ipp.mpg.de

Dust : Balden

Capacitative dust monitor: Shot-based

- Installation and testing in AUG
  - *2 CDM are installed below AUG divertor (with & without radiation)*
  - *no measurable dust expected* (loaded during campaign)
  - *long-term stability*
  - *more than shot-based possible?*



- *Feb 2012: AUG restart*
- *Mar 2012: first results*
- *Autumn 2012: dismounting*

Martin.Balden@ipp.mpg.de

Dust : Balden

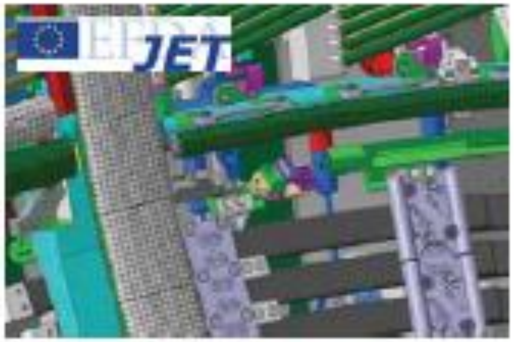
Dust collectors and analysis: Example LHD

- **IPP collection and analysis strategy: campaign-based**
  - *collect dust only during plasma operation*
  - *simple design (5 collectors used in AUG)*
  - *Si wafer for automated SEM/EDX analysis*

⇨ *Classification of dust from AUG*

(see 14th ITPA Oct. 2010 Seoul, PSI-2010, PMFC-2011)

- **Applied in other devices**
  - *LHD: analyzed / DIII-D: exposed / JET design phase for 2012 build-in*



SEM像を自動分析することで，多数のダストの表面分析（組成を含む）のデータ取得が可能（第14サイクル）

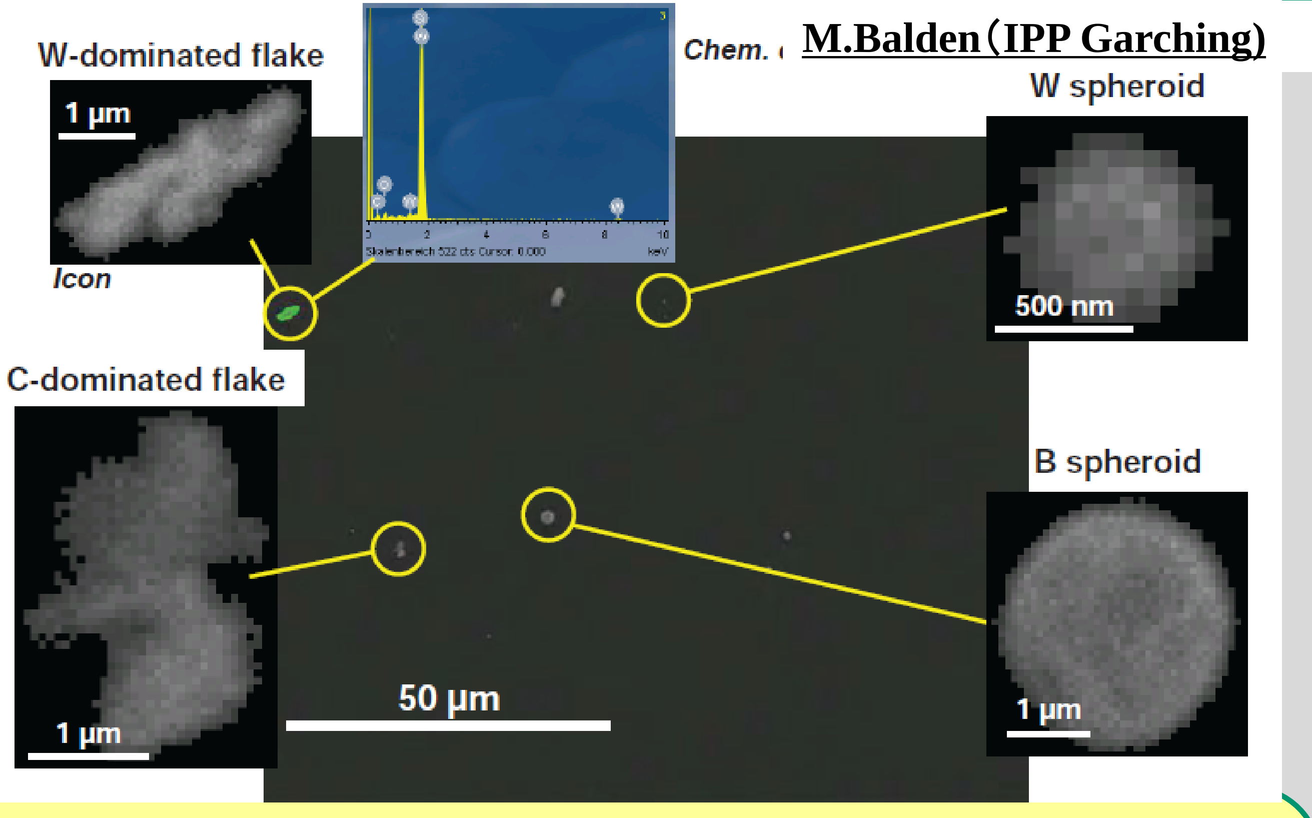
◆自動分析により表面形状と組成を同時にデータ取得>>多数のダストを短時間に分析可能

◆Si基板を1サイクルLHD内へ設置（4.5セクション）

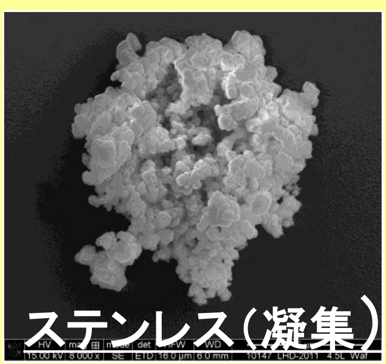
＊平坦なSi基板上へ堆積したダストを分析.

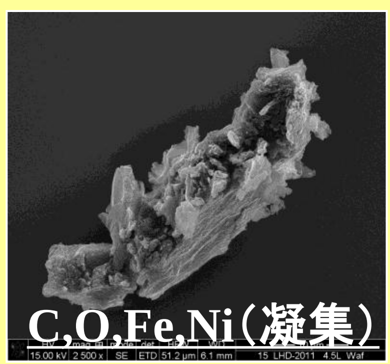
◆組成，特徴的な形状で分類

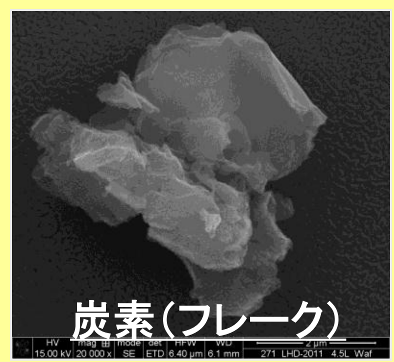
分析例（ASDEX）

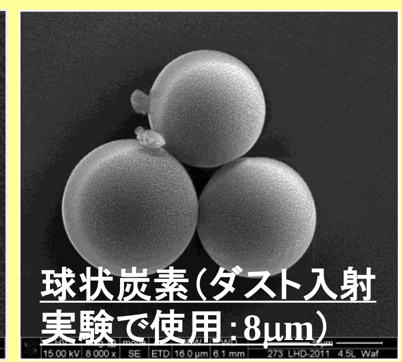


LHDダスト（新しいタイプ）

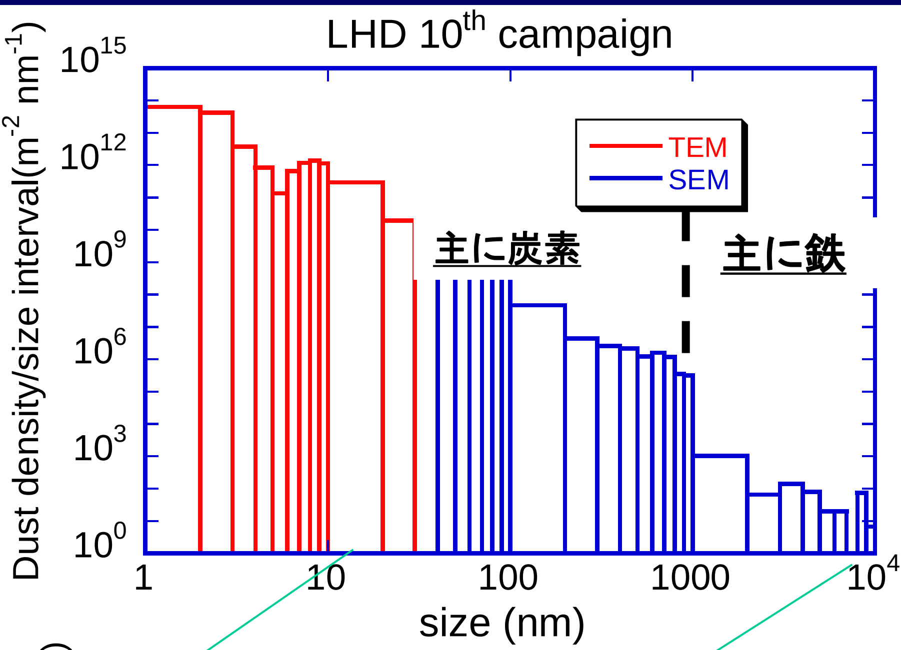


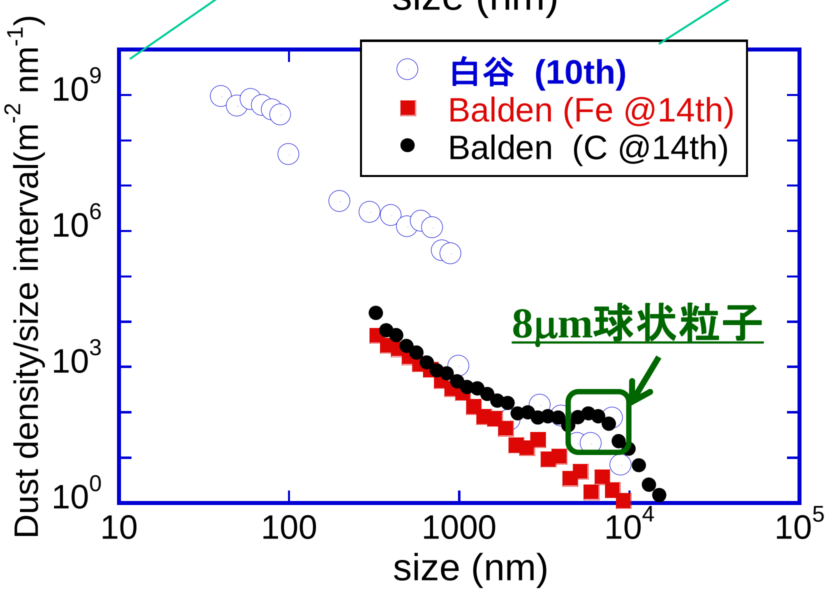






LHDにおいても，微小サイズ（1μm以下）の鉄ダストが検出



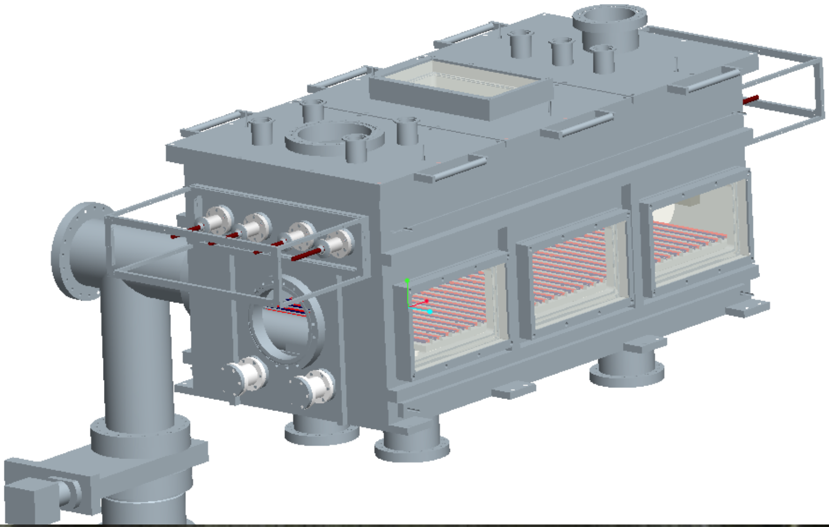


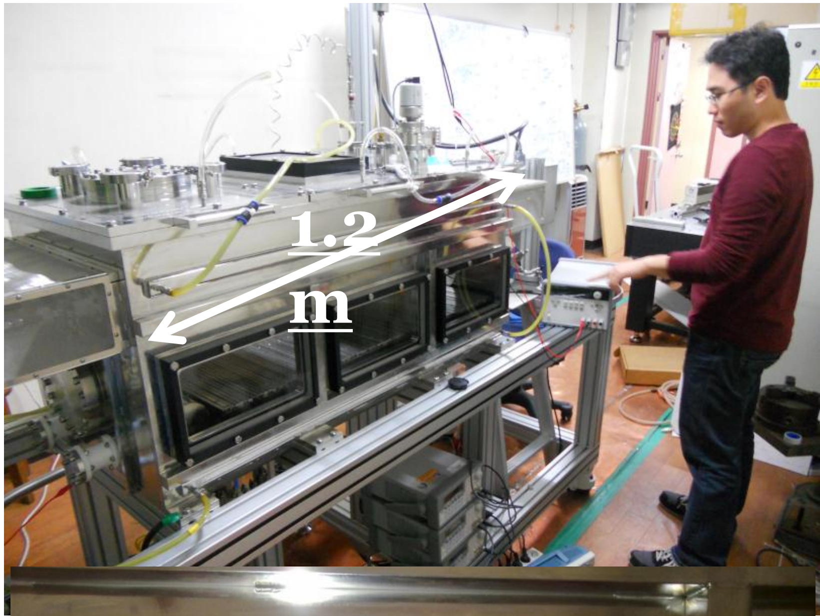
- ◆ 白谷（九大）らは，SEM（30nm~）とTEM（1~30nm）を併用することで，nmオーダーまでのダスト・サイズ分布を明らかにしJunge分布に従うことを示した．
- ◆ 組成は，一部のダスト粒子について分析し炭素と鉄（ステンレス）の典型的な形状を明らかにし，これを元に分類．主に1μm以下を炭素，1μm以上を鉄とした．
- ◆ 今回の分析では，全ダスト粒子に対して組成分析を実施．29%が鉄主成分，59%が炭素主成分（うち1割は球状粒子@直径8μm）
- ◆ 1μm以下の鉄ダストが新たに多数検出．
- ◆ 10~数100nmのダストは互いのクーロン力により成長し凝集形状を生成しやすい．炭素，鉄ともに同形状のダストが検出．＞＞同様の成長過程であることを示唆

測定データ>>実時間モニターを考えた場合，飛来するダスト粒径の推定は重要

Dust : Hong

- Dust removal by TReD

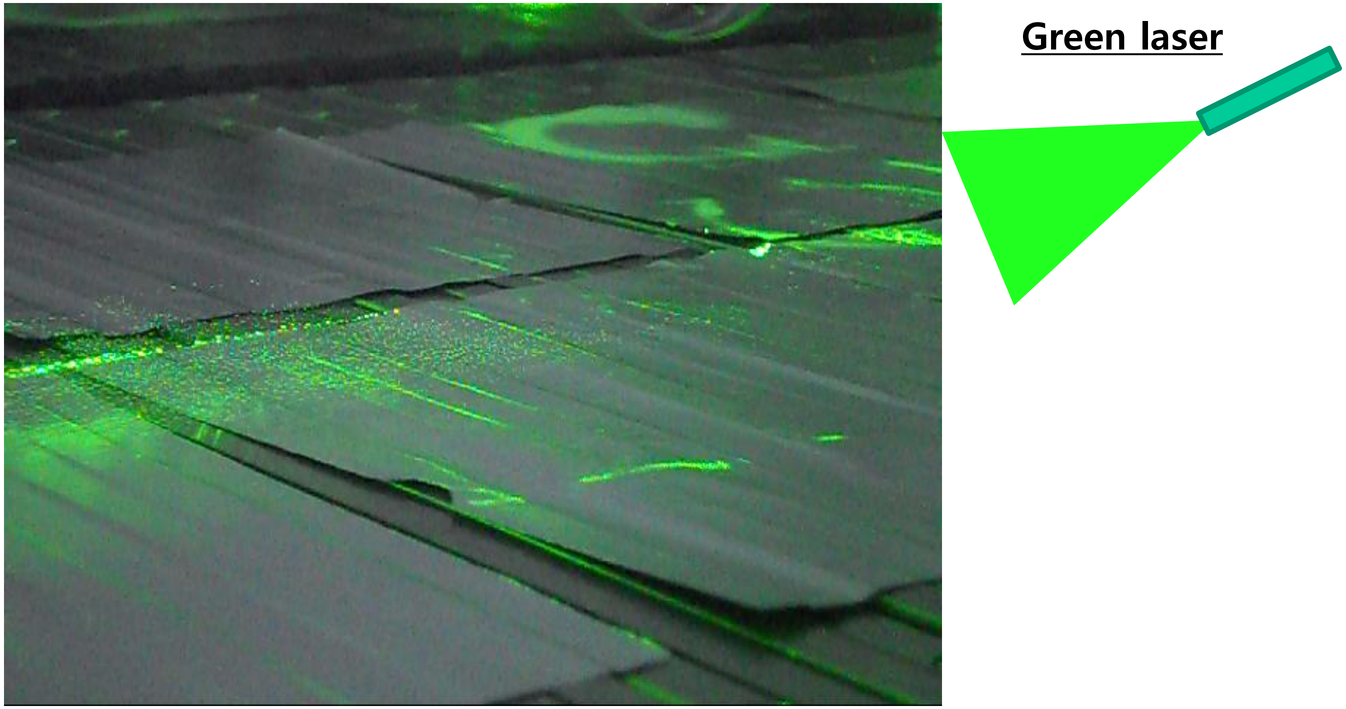




Dust : Hong

Experimental Setup

- Powder : Al_2O_3, 5um
- Operation pressure : 2.5 * 10^{-1} Torr, MFC 200 SCCM He
- RF Power 34W : rf 7W



- About 10-15% of injected dusts from dispenser reach the collector.
- Dust removal rate is about ~10 mg per hour (unoptimized).

18. Dust Session

Main Topics : Dust monitoring

Requirement for dust monitoring data

- Total amount of deposited dust during plasma discharge, in-situ measurement (per a shot, per a day, per a campaign ..)
- Compassion with different events

In-situ measurement

- Electrostatic dust detector in NSTX, ASDEX-U, Tore Supra, (LHD), @ plasma facing, under dome
- Capacitative dust monitor in ASDEX, @under dome
- Laser Scattering (* stray light by plasma disturbed） @plasma facing

Integration of deposited dust

- Dust monitor (Si target) in ASDEX, LHD, DIII-D (JET) (related 3.1)
  - IAEA coordinated Researching Project >>Dust Data base

Dust R&D

ITERでは炭素ダイバータが計画されており，炭素バルク・堆積層へのトリチウム(T)蓄積，およびそれに関連する炉内T保持量が問題となっていた

＜ITPA SOL/Div：Dust R&D での課題は下記の5点＞

1. Characterization of dust production rates, recover conversion factor from erosion/damage to dust production — High priority

   TEXTOR, AUG, TS, JT-60U, DIII-D, LHD, MAST, NSTX, FTU, EAST, JET

   R&D(~2012Jan)
   IAEA CRP data base

2. Characterisation of ejection velocities, sizes of molten droplets and the morphology and size distributions of collected dust with high heat load — High priority

   TRINITI, QSPA, PISCES

   <<Organized by IO

3. Study the role of T removal techniques in dust creation : — Medium priority

   U. Toronto, Pilot-PSI, NSTX….

   <<Common issue

4. Cross-machine studies of dust injection — priority

   DIII-D, TEXTOR, LHD, MAST, NSTX, AUG

   DSOL-21

5. Dust measurements — Medium priority

   NSTX, TEXTOR, DIII-D, FTU, LHD, UCSD, HT-7, AUG, MAST, J

   ITPA Diag

Retention

Retention : Schmid

Fuel retention R&D agenda

E. Tsitrone	Closing the particle balance in Tore Supra
T. Leonard	Fuel retention in DIIID
J Hu	Fuel retention in EAST and HT7
M Yoshida	Evaluation of fuel retention in a full-carbon machine, based on JT-60U post mortem analysis
V. Philipps	First results on fuel retention in JET ILW
T. Schwarz-Selinger	Recent results on isotope exchange in Tungsten and beryllium
E. Tsitrone	Multi machine fuel retention : what is the best scaling ?

Retention : Schmid

- Multi machine scaling for ITER of retention in FULL METAL machines

Carbon

  - Difficult due to limited number of devices
    - Currently data from AUG
    - Soon data from JET ILW
  - Available results suggest that retention is very low
    - At the limits of gas balance accuracy
    - Effect of adsorption at non plasma wetted areas
  - Issue of wall flux scaling
    - Do we know the wall fluxes?
    - Shouldn't one distinguish different plasma facing areas (Main wall vs. Divertor)?
    - For W scaling is different (Diffusion limited uptake)
      - Can W ignore retention in W compared to Be
    - Error bars to large for extrapolation?
      - More detailed scaling required:

$$\text{Total co-dep.} = \sum_{\text{Wall area } i} Y_i \Gamma_i A_i \left(D/C \right) \Big|_{\text{At deposition location}}$$

Retention : Schmid

Current issues: Removal

- Wall conditioning and discharge tailoring
  - ICWC vs. GDC
    - Homogeneity, Efficiency
    - Will not work in gaps
- Chemical cleaning methods
  - Baking in O_2 and N_2
    - ITER will not use O_2
    - Only tested for a-CH, not effective for Be containing compounds
    - Works in gaps
- Photonic cleaning methods
  - Works on C-deposits not so much on Be-deposits
- Isotope exchange
  - Mainly near surface (depending in temperature)
  - Potential "good housekeeping" method

See talk by T. Schwarz-Selinger

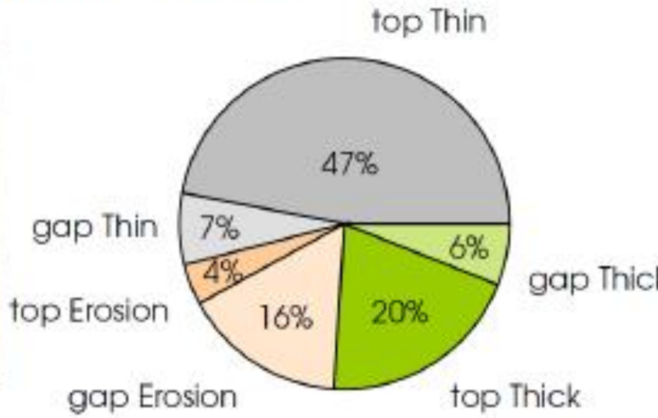
The progress in fuel removal is rather slow.

Retention : Estrone

D-inventory from post - mortem analyses

Euratom cea

Combined TDS and NRA measurements



	atoms	
TPL	1.8E+24	6.2g
inner bumper & outboard limiter	6.4E+23	2.1g
vessel wall	xx	<~1.7g
Total	**≈3E+24 D**	**≈10g**

Post - mortem :
8-10 g of D

Retention : Estrone

Main results

Euratom

For period 2002 - 2007 (1.4×10^5 s of cumulated plasma time)

Carbon balance characterized:
-~ 1800 g of gross erosion
-~ 900 g of net erosion / redeposition (~ 25 g of C / h)
-~ 50 % of local redeposition rate
+ TPL maps of erosion and redeposition (top surface and gaps) …

Deuterium balance closed:
-~ 45 g stored during plasmas
-~ 30-40 g outgassed due to conditionning, in between discharges and during vents
-~ 5-15 g still remain in deposits, in agreement with post mortem (8-10 g)
-~> 1 - 2 year for the gas stored during a discharge to be removed

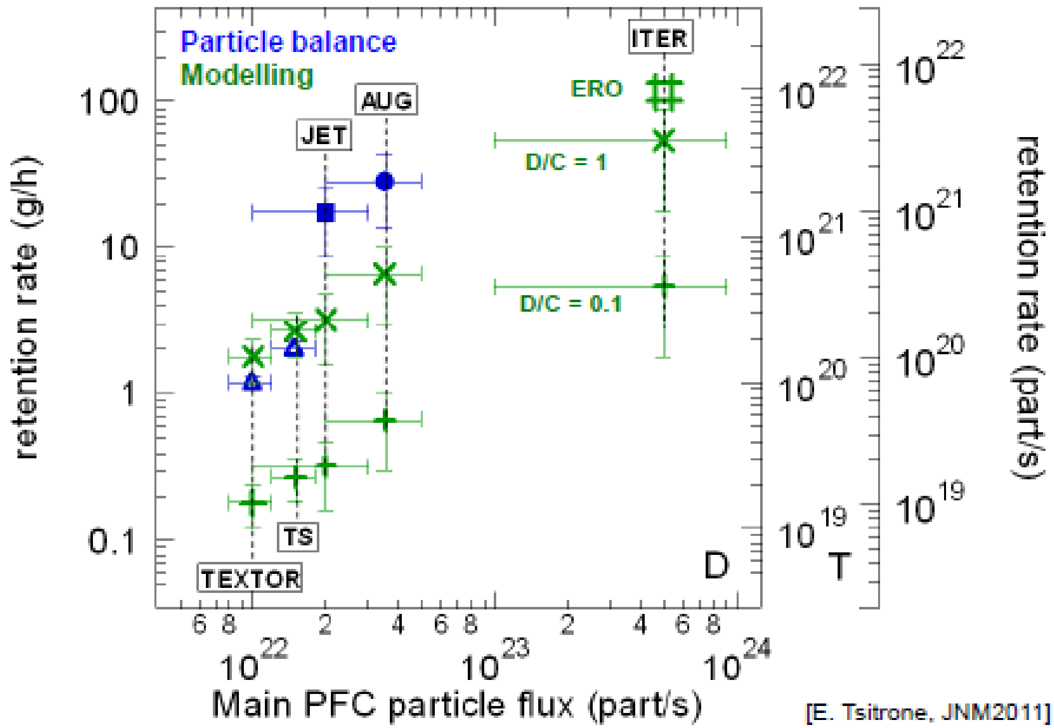
Coupled carbon / deuterium balance understood :
[D]/([D]+[C]) profile understood:
-~ 25-35 % of D concentration at the deposit formation
-Decrease with increasing depth due to long term outgassing

[cf. B. Pégourié & al., proposed for PSI 2012]

Retention : Estrone

Simple scaling for C dominated devices

Euratom cea



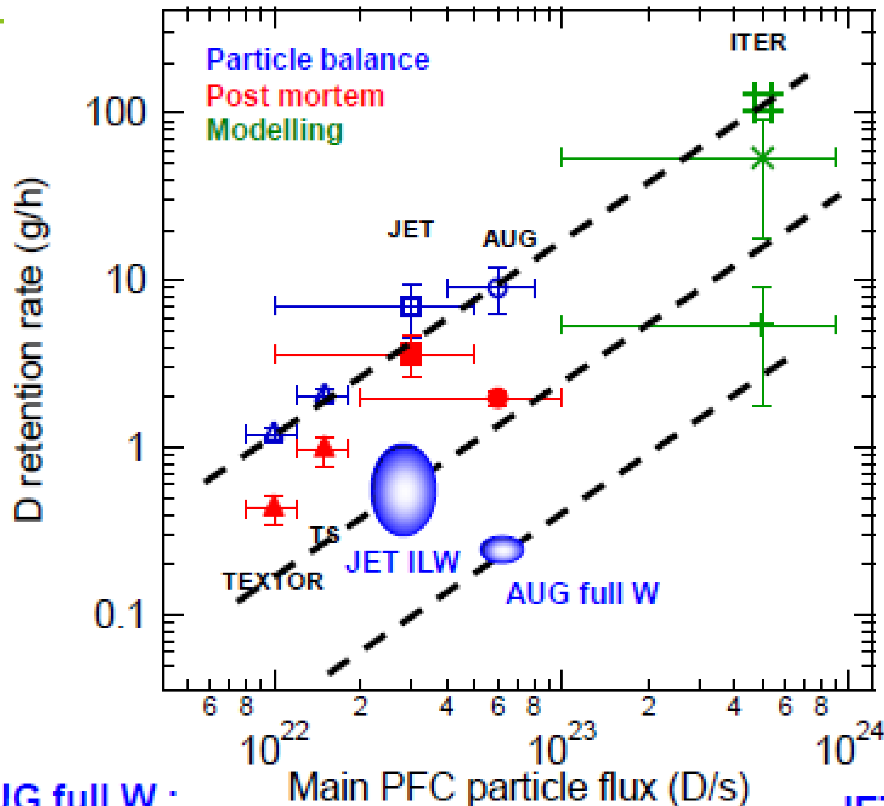
[E. Tsitrone, JNM2011]

➔Right order of magnitude but ~ 100 % C erosion source redeposited and D/C ~ 1 needed

Retention : Estrone

New data for Be/W : Preliminary results

Euratom



ITER full C ~ 100 g T /h

ITER Be/W ~ 10's g T /h ?

ITER full W ~ few g T /h ???

NB :
10 shots 400 s ➔ ~1h / day

AUG full W :
0.2-0.3 g/h
[courtesy V. Rohde, J. Roth and AUG team]

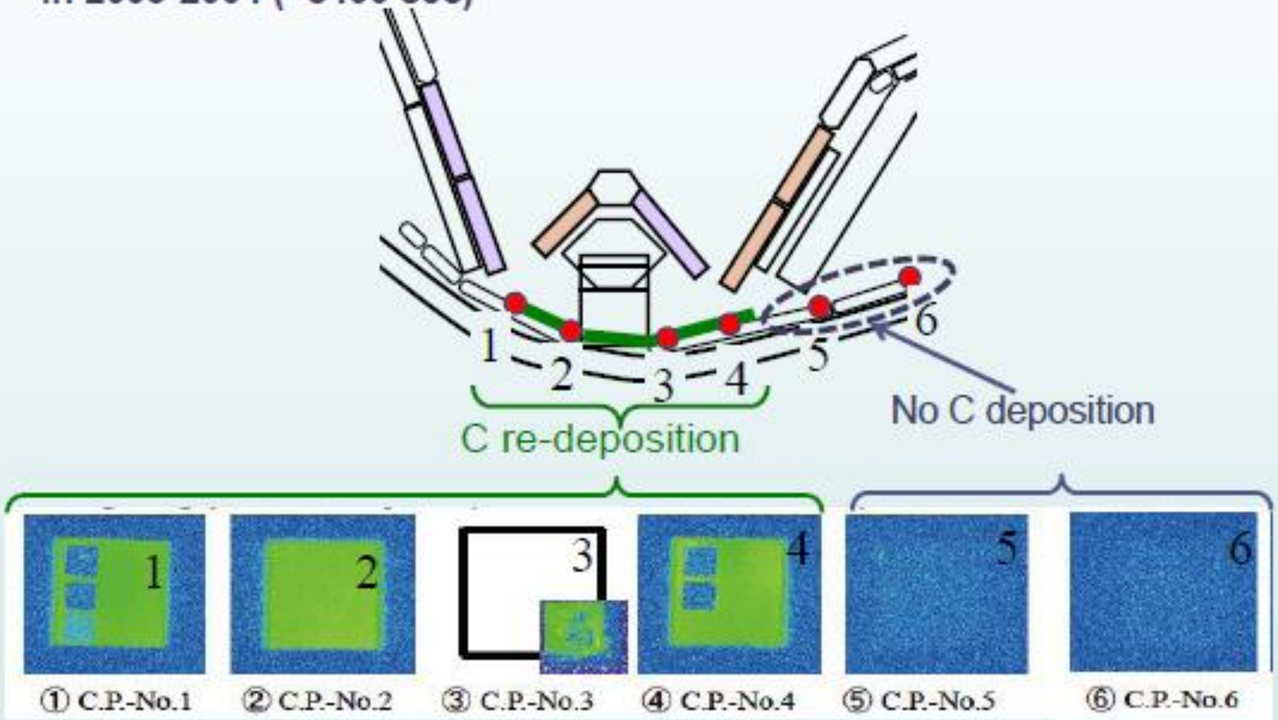
JET ILW :
0.3-1 g/h
[courtesy T. Loarer and JET team]

Retention : Yoshida

T retention (Carbon re-deposition) on remote area

K. Masaki, et al., *Nucl Fusion* **47** (2007) 1577

In 2003-2004 (~8400 sec)



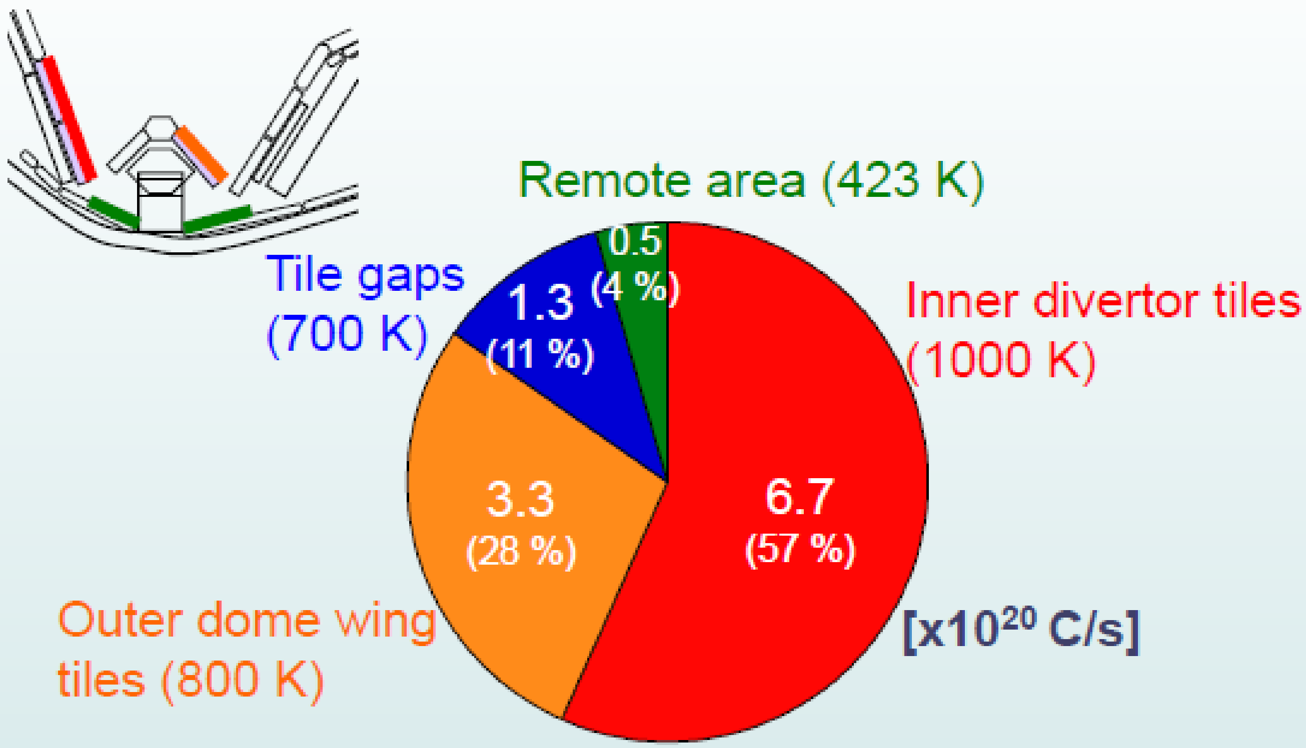
(C thickness: ~2 μm, Area of remote area: ~5 m^2)

Carbon re-deposition rate on remote area: 0.5 $x10^{20}$ C/s

Retention : Yoshida

Carbon re-deposition rates in divertor region

M. Yoshida, et al., *Phys. Scr.* **T145** (2011) 014023

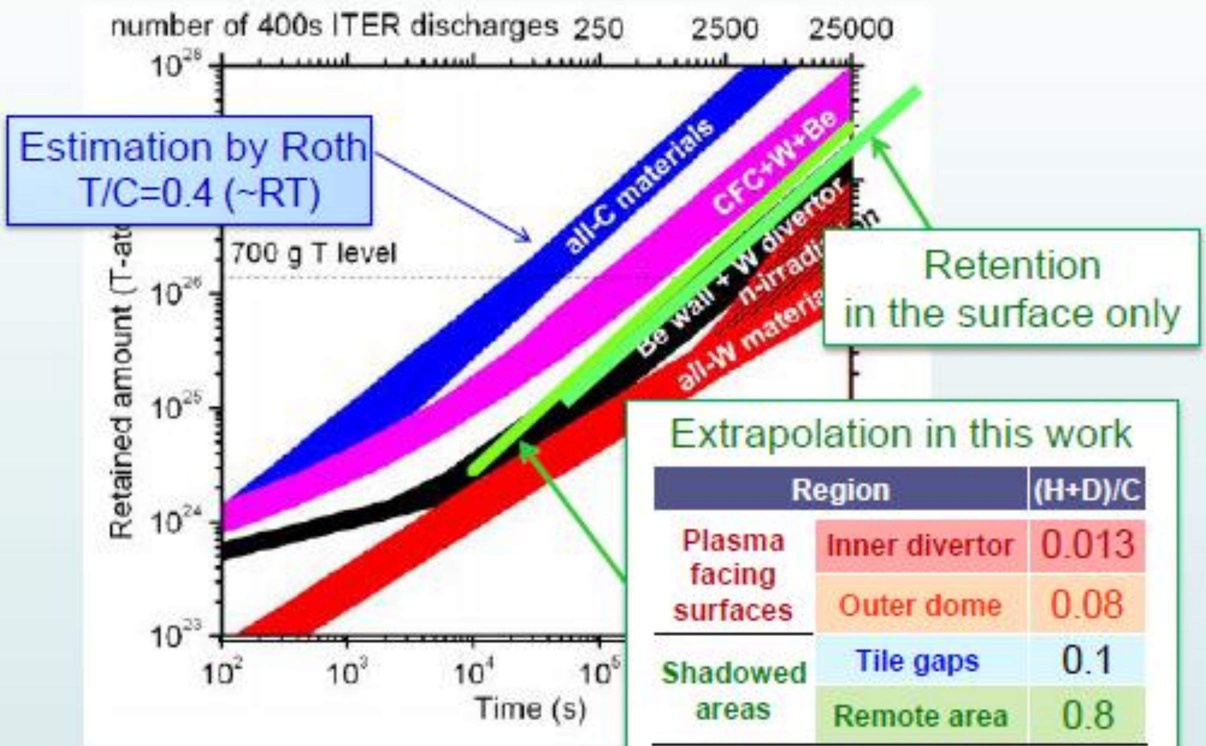


Total C re-deposition rate in divertor: 1.2×10^{21} C/s

Plasma facing surfaces / Shadowed areas = ~11/1.8

Retention : Yoshida

For an ITER scale full carbon machine operated at ~600 K



Extrapolation in this work

Region		(H+D)/C
Plasma facing surfaces	Inner divertor	0.013
	Outer dome	0.08
Shadowed areas	Tile gaps	0.1
	Remote area	0.8

- Higher tile temperature operation would significantly reduce the T retention in carbon as PFM.