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The EU Plasma Wall Interaction Task Force : Recent Achievements and Plans

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Special thanks to: E. Tsitrone (CEA) and R.Neu (IPP)
and EU TF on PWI

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Outline

1) What is EFDA and the EU PWI TF?

2) Recent achievements of the PWI TF: highlights of 2009

3) Work programme 2010-2011 : dust & fuel removal

4) Summary

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New Organisation in force end 2007

The overall fusion programme remains coordinated by the Commission in the frame of Euratom

Joint Undertaking for ITER "Fusion for Energy" (F4E)

- Domestic Agency to provide and manage EU contribution to ITER
- EU Contribution to Broader Approach
- Located in Spain (Barcelona)

European Fusion Development Agreement (EFDA)

- Agreement between all EU fusion labs and Euratom
- Coordinated research (physics in support to ITER, longer term technology) and JET
- Garching (D) and Culham(UK)

Associations:

European Fusion Laboratories associated to Euratom through "Contracts of Association"

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All EU Laboratories/Institutions working on Fusion are parties to EFDA

- ***Collective use of JET***

- ***Reinforced coordination of physics and technology in EU laboratories***

- ***Training***

- ***EU contributions to international collaborations outside F4E***

EURATOM : KEY ACTION FUSION Associated Laboratories, parties to EFDA

- **Euratom - Belgian State** (Brussels) - (Mol)
- **Euratom - CEA** TORE SUPRA (Cadarache)
- **Euratom - CIEMAT** TJ-II (Madrid)
- **Euratom - Conf. Suisse** TCV - SULTAN (Lausanne) - (Villigen)
- **Euratom - DCU** (Dublin) - (Cork)
- **Euratom - ENEA** FTU - RFX (Frascati) - (Milan) - (Padua)
- **Euratom - FOM** (Petten) - (Nieuwegein)
- **Euratom - FZJ** TEXTOR (Julich)
- **Euratom - FZK** TOSKA (Karlsruhe)
- **Euratom - Greece** (Athens) - (Heraklion) - (Ioannina)

- **Euratom - LEI** (Kaunas)
- **Euratom - CU** TOSKA (Bratislava)
- **Euratom - MHST** (Ljubljana)
- **Euratom - IPPLM** (Warsaw)
- **Euratom - INRNE** (Sofia)

- **Euratom - HAS** (Budapest)
- **Euratom - IPP** Asdex Upgrade - Wendelstein 7-AS Wendelstein 7-X (Garching) - (Greifswald) - (Berlin)
- **Euratom - IPP.CR** CASTOR (Prague)
- **Euratom - IST** ISTTOK (Lisbon)
- **Euratom - Latvia** (Riga)
- **Euratom - MEC** (Bucharest)
- **Euratom - ÖAW** (Vienna) - (Graz) - (Innsbruck)
- **Euratom - RISØ** (Roskilde)
- **Euratom - TEKES** (Helsinki) - (Tampere) - (Lappeenranta)
- **Euratom - UKAEA** MAST - JET (Culham)
- **Euratom - VR** EXTRAP T2R (Stockholm) - (Lund) (Gothenburg) - (Studsvik) - (Uppsala)

JG03.241-7c

Francesco Romanelli
EFDA Leader and EFDA Associate Leader for JET

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Coordination of R&D:
EFDA Task Forces & Topical Groups

Task Forces under EFDA

PWI Task Force: Leader	**R.Neu (IPP)**
ITM Task Force: Leaders	**P.Strand (VR), R. Coelho (IST), LG Eriksson (EC)**

Topical Groups under EFDA

Transport Topical Group:	**Chairman C.Hidalgo (CIEMAT)**
H&CD Topical Group:	**Chairman A.Becoulet (CEA)**
Materials Topical Group:	**Chairman S.Dudarev (UKAEA)**
	M. Reith (FZK)
Diagnostics Topical Group:	**Chairman T.Donné (FOM)**
MHD Topical Group:	**Chairman P.Martin (ENEA-RFX)**

EFDA Emerging Technologies and DEMO activities

What is the EU PWI TF ?

The aim of the **PWI Task Force** is to **concentrate** European **research on the most urgent problems in the field of PWI for ITER** and future devices, and to propose scientific and technological concepts to overcome these problems.

ITER high priority research needs : strongly PWI related

1. Disruption/ Runaway Mitigation

Heat loads, runaway electrons:
reduction > 1 order of magnitude

2. ELM Control/ Mitigation

reduction > 1 order of magnitude

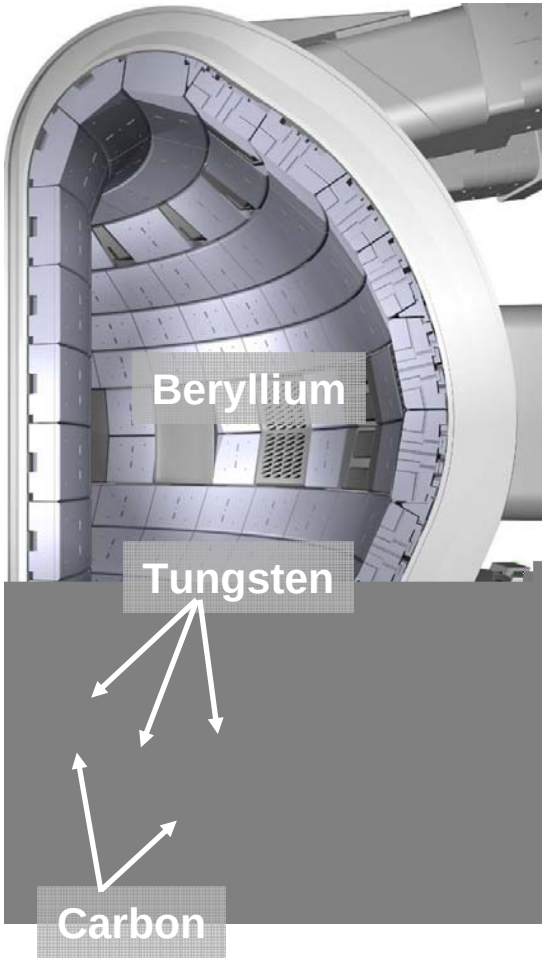
3. Plasma Facing Materials

Physics basis for ITER reference scenarios with W/ Be PFCs ; C removal

4. Scenario Development

5. Diagnostics

Dust / Hot dust ; divertor erosion ; mirrors ; H/D/T inventory



[D. Campbell, ITPA CC meeting June 2008]

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EU-PWI TF : targeted at ITER through 7 SEWGs

1. Disruption/ Runaway Mitigation

Heat loads, runaway electrons: reduction > 1 order of magnitude

2. ELM Control/ Mitigation

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ITPA Div SOL : 5 topics

Transient heat loads

ELMs and disruptions

Heat loads

Materials

Material migration

High-Z Materials

ITER-like Material Mix

Material Erosion

W R&D

Dust

Dust in fusion devices

Fuel retention

Fuel retention

Fuel Removal

Dust

Fuel retention

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EU PWI TF: mature organisation

ITPA Div/SOL

EFDA:

ITM-TF (codes)
TG MHD (disr.)
TG H&CD (ICWC)
TG diags (LIBS)
TG Mat (W alloys)
TG Trans (impur.)

Emerging techno (Dust & T)

EFDA-JET:

TF-E1/E2 (ILW)
TF-FT

Task Force Plasma-Wall Interaction
Main orientations at
Annual General Meeting
Contact Persons from 23 associations
+ JET TF E1/E2 and FT, EFDA, F4E, ITER IO

Special Expert Working Groups
Annual specialised meeting of SEWG members
Joint meetings

Associations
Baseline work programme
Priority support

Task Agreements
Contracts between EFDA and Associations

PWI Meetings

SEWG Meetings:

Dust and Fuel Removal: 8-9 June, Garching
Material Mix & Material Migration: 30 June – 02 July, Jülich
Fuel Retention: 19-21 July, Garching
High Z Materials and Liquid Metals: 21-23 July, Garching
Transients and Heat Loads: 1- 2 September, Jülich

EFDA Meeting on modelling activities of EU-PWI Task Force 7-8 September 2010, Culham, JET

PWI Annual Meeting, 3-5 November, Vienna, Austria

Recent scientific achievements : highlights of 2009

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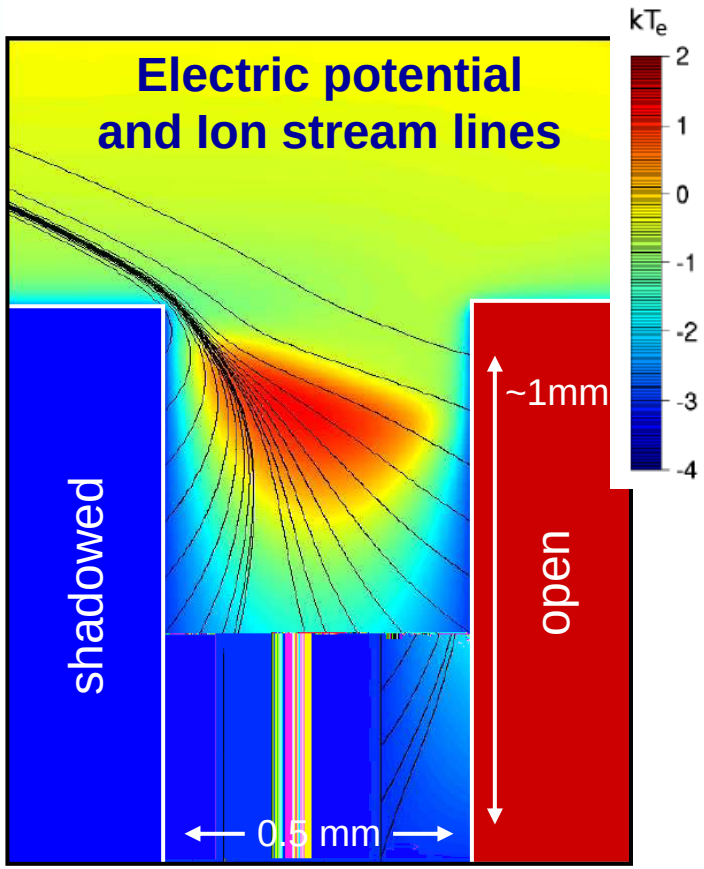
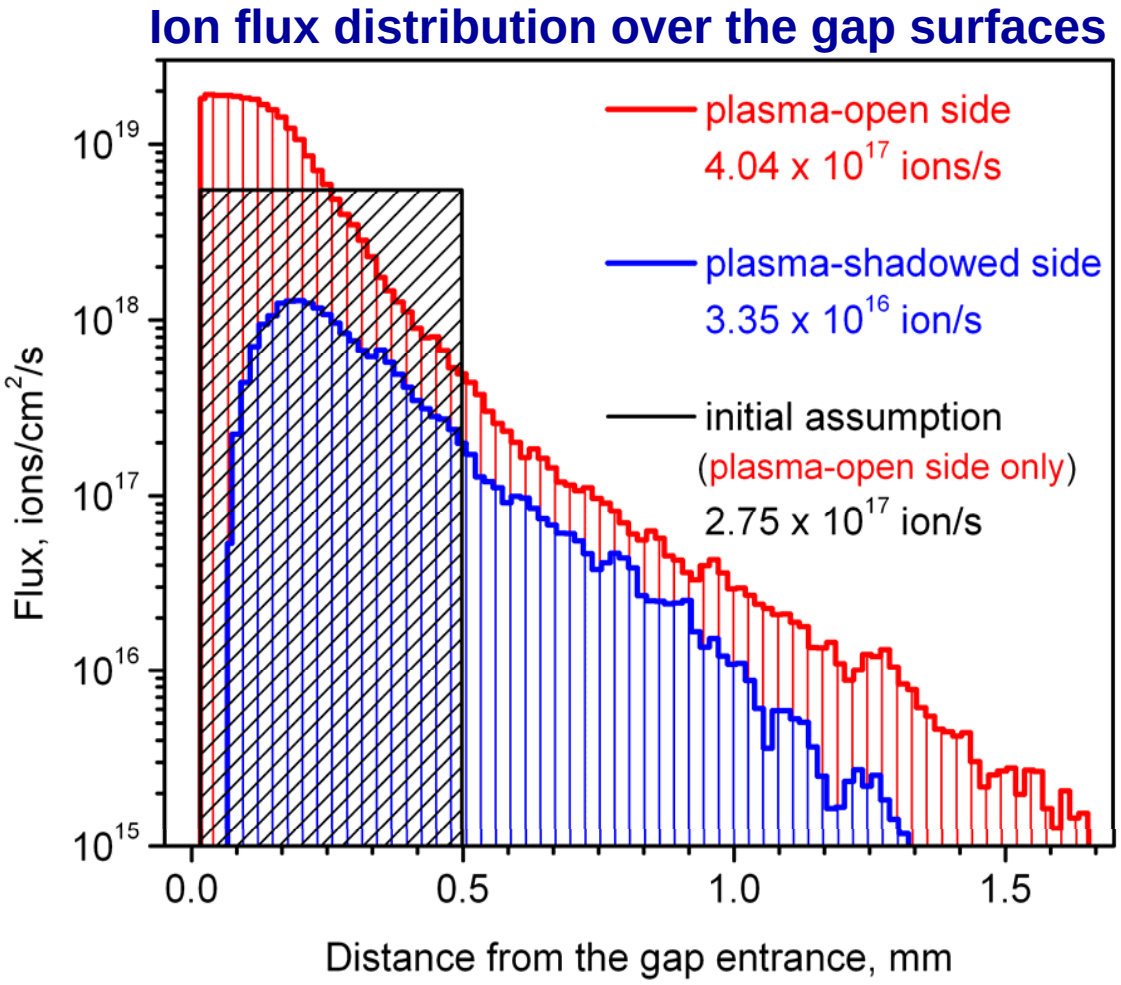
Scientific highlights for 2009

- evidence for threshold in chemical erosion at 1-2 eV;
- development of transport codes: ELMs and gaps in ERO, grid extension to the wall ongoing in SOLPS
- H retention in W confirmed to be low:
  impact of He bombardment, simulation of neutron damage;
  porosity network in CFC characterized by high resolution tomography
- first characterization of runaway electrons in Tore Supra and TEXTOR;
  similar valves in MAST, TEXTOR and JET for massive gas injection (MGI) studies; modelling effort started for runaways and MGI (FZK)
- performance of N seeded scenarios well established in full W AUG
  and nitrogen wall pumping evidenced;
  improved plasma performance with liquid lithium limiter in FTU
- coordinated experiments on ICRF cleaning in TEXTOR, Tore Supra, AUG as well as in JET under TFE/H
- dust trajectories investigated in several devices using fast cameras
- exploration of ternary systems (Be-C-W, Be-O-W) (IPP, MedC);

benchmarking of ERO-TRIDYN ongoing (collab. with the PISCES-B)

Modelling of Deposition in Gaps

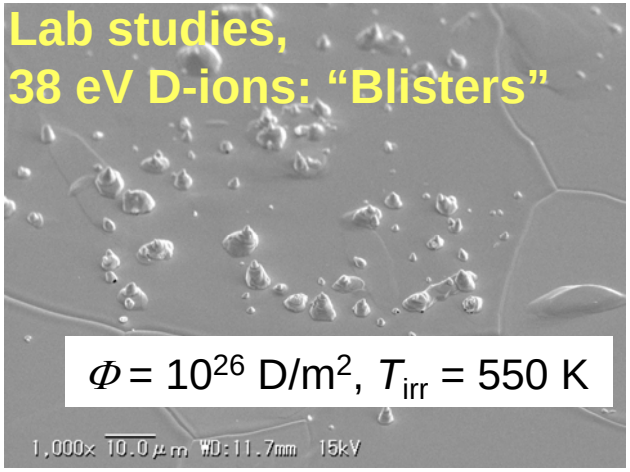


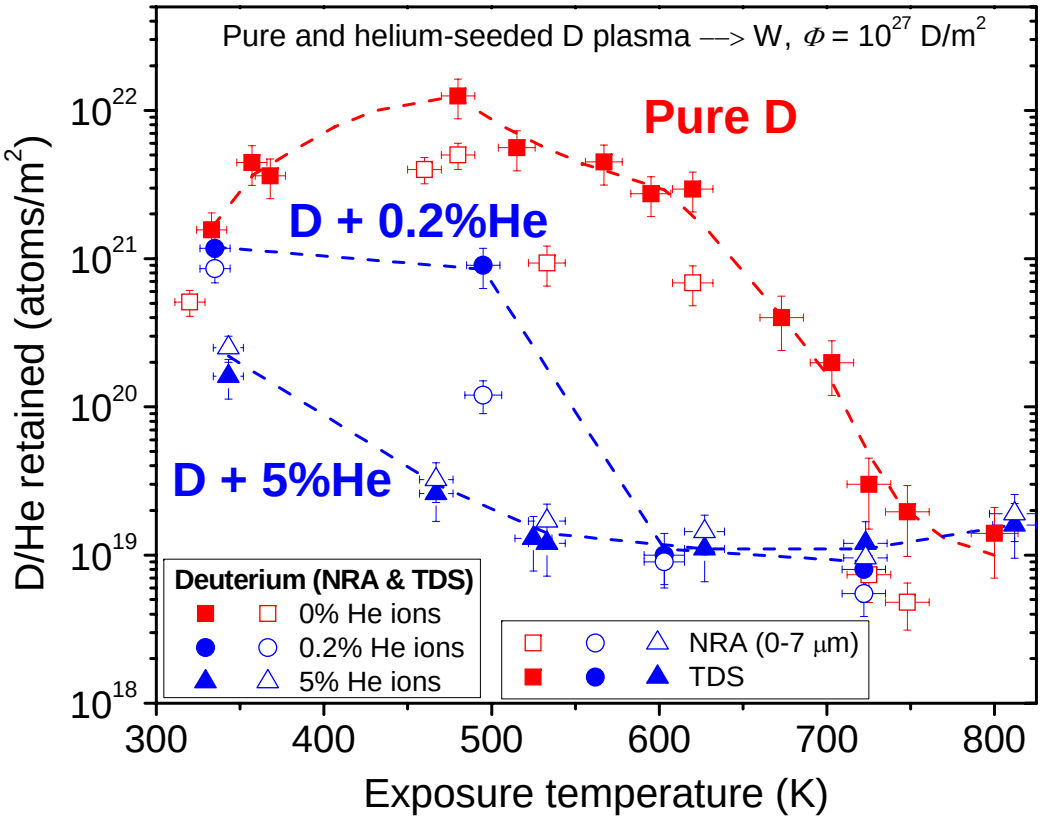


Deposition inside a poloidal gap of a castellated limiter in TEXTOR from PIC simulations

Low fuel retention in W confirmed in dedicated lab experiments

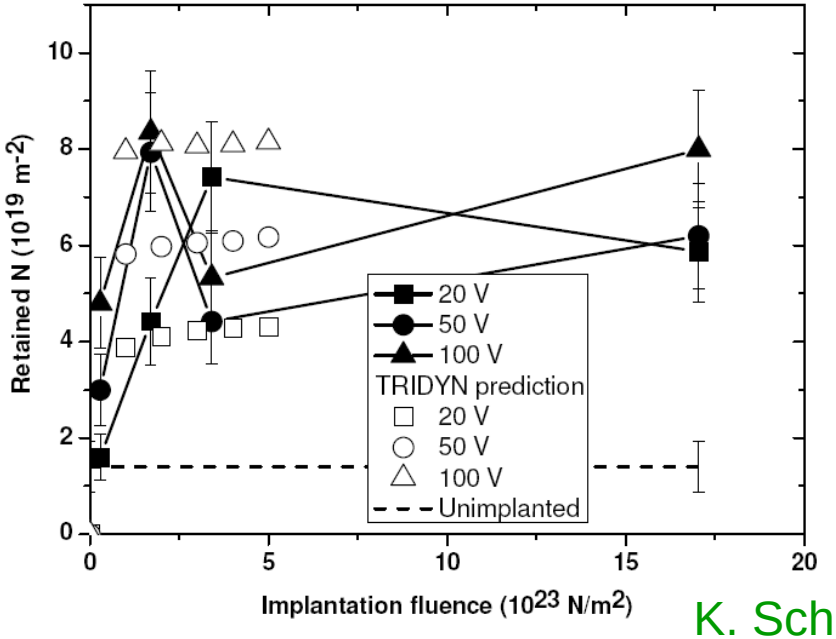
- **Temperature dependence explored : complex behaviour**
  ➔ blisters formation
- **Simultaneous He bombardment : retention reduced**
- **Impact of neutrons : damage simulated by heavy ions bombardment**
  ➔ moderate increase

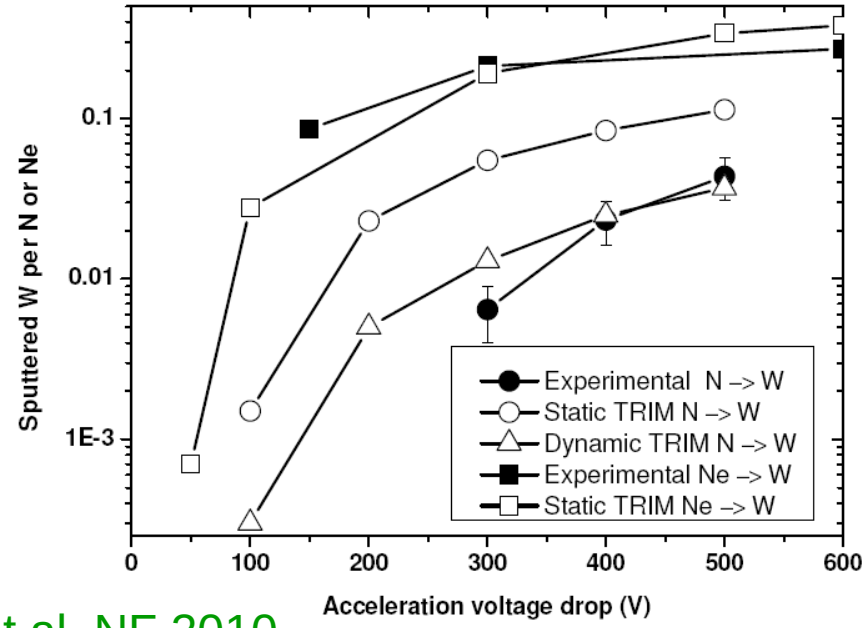




Retention in W under He bombardment [IPP Garching]

Lab Experiments on N-W interaction





K. Schmid et al, NF 2010

- N wall storage saturates after a fluence a few 10^{23}N/m²
- saturation depending on injection energy
- N deposition depth ~ implantation range ≤2 nm (negligible diffusion)
- saturation density $D_{N,sat} \leq 10^{20}$ N/m², compatible with the formation of WN
- strong reduction of N content at higher sample temperatures, in line with decomposition of W nitride above 600K
- reduction of W sputter yield in N saturated samples (‘surface dilution‘)

Similar investigations for Be-N under way

SEWG Fuel removal

ICWC optimization, first trial on gaps

Chemical Methods – O_2, N_2, NH_3 → ITER

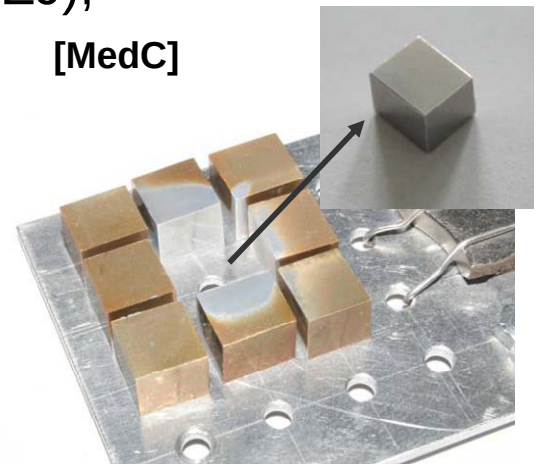
Fuel removal efficiency of ICWC explored in coordinated experiments (Textor, Tore Supra, AUG)

- Optimisation ongoing (pulsed cycle ICWC on/off, pressure, gas mixture, B field etc)
- First trials for recovery after disruption promising

Removal in gaps

thermo-oxydation (CIEMAT), ECR or GDC (IPP, FZJ),
laser (CEA), plasma torch (MedC)

[MedC]



Dust production during cleaning processes :

laser cleaning (CEA, IPPLM, VR) : dust/flake production with significant fuel content

SEWG Dust

Dust measurements during plasma, dust injection experiments

Dust collection ongoing : JET, AUG, Textor, Tore Supra

Complex structure for C dust, spherical for W (droplets from transients ?)

⇒ Conversion factor: 5-8 % in TS

Dust measurements during plasma operation :

CCD (TS, AUG), fast IR (AUG), electrostatic detector (TS),

Thomson scattering (FTU)

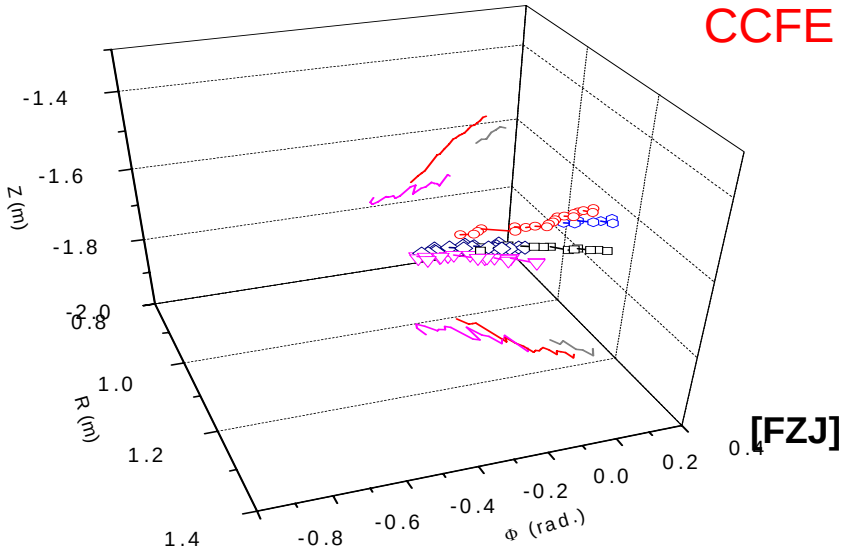
Preliminary dust injection experiments in Textor

Driving force = j x B

Edge C increased, no effect in core

Dust trajectories investigated in several devices using fast cameras

CCFE



[FZJ]

Work programme 2010-2011 (dust & fuel removal):

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Main orientations for 2010/11

- **Bilateral collaborations :**
  - mixed materials : PISCES (US) ➔ EFDA PWI TF
  - material damage : plasma guns (RF) ➔ F4E, but modelling + dust = PWI TF
- **Including recent ITER requests**
  - disruptions/runaways
  - W R&D
  - divertor re-attachment heat loads
  - IC wall conditionning
- **Integrated plasma operation : impact of impurity seeding**
  - erosion, mixed material, fuel retention …

- **Strengthening of modelling for extrapolation to ITER and DEMO**
  - Interpretative modelling for benchmarking tools used for ITER simulations (SOLPS, ERO, DIVIMP …)
  - in close connection with ITM-TF (code development)

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7 TAs for 2010

Resources: 25.2 PPY PS, 430 kEuro Hardware

•Fuel retention :

TA-1: Fuel retention as a function of wall materials foreseen for ITER

• Fuel removal : (2.75 ppy, 20 kEuro hardware)

TA-2: Fuel removal compatible with retention in different and mixed first wall materials

• Dust : (1.9 ppy, 32 kEuro hardware)

•TA-3: Dust generation and characterization in different devices

• Material migration : TA-4: Erosion, transport and deposition of first wall impurities

• High Z :

•TA-5: Development of the PWI basis in support of integrated high-Z scenarios for ITER. Liquid plasma-facing components

• Mixed materials :

TA-6: Expected alloys and compounds and their influence on PWI processes

•Transients :

•TA-7: Mitigation of disruption loads for ITER. Heat load in ITER relevant ELM scenarios

Fuel Removal - WP2011

Resources: 2.5 PPY PS, 40 kEuro Hardware

- **Wall conditioning and discharge tailoring:** Assessment of wall conditioning techniques with emphasis on fuel removal, H-isotope exchange, dust production and plasma restart.
- **Investigations of chemical cleaning methods:** Explore the impact of repetitive oxidising plasmas (GDC/RF) on beryllium bulk properties and other in-vessel components, Study the effect of sample temperature and impact of nitrogen-containing molecules.
- **Further development of photonic cleaning methods:** Study film break-up processes in photonic “cleaning”, optimising gaseous release, and preventing spread of dust.
- **Fuel removal in gaps:** Removal of deposited films in tile gaps and castellations with glow discharge cleaning in oxygen or O-based gas mixtures or plasma torch.

Dust generation-WP2011

Resources: 2.5 PPY PS, 70 kEuro Hardware

- **Assess dust generation (in particular conversion factor from material erosion to dust) and dust properties in tokamaks:** Carbon and Metal dust formation (W and Be), the fuel content, size distribution, surface specific area and reactivity.
- **Improve detection of dust in the plasma. Improve understanding of the impact of dust formation on the plasma performance and operation:** Relate the dust generation to discharge conditions and the impact of dust formation and mobilization on plasma performance and machine operation.

Summary

- **ITER : several top priority issues are PWI related** (disruptions, ELMs, W R&D, diags for dust and T)
- **EU PWI TF** : well **targeted** and **reactive** to ITER requests (ICWC, divertor reattachment, disruptions/runaways)

- **Coordination** : European (other **EFDA** TF/TGs, **F4E**) and international (bilateral collaboration with **US**, **ITPA** DivSOL)

- **Workprogramme 2011 established** (Call in preparation)
  Effort to **strengthen modelling** for extrapolation to ITER
  Emphasis on **issues raised by ITER** and formulated within ITPA

Thank you for your attention