

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

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



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”

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**



Francesco Romanelli
 EFDA Leader and EFDA Associate Leader for JET

EURATOM : KEY ACTION FUSION Associated Laboratories, parties to EFDA				
Euratom - Belgian State (Brussels) - (Mol)	 <p>  Associated countries belonging to EFDA  JET Facilities JET-EFDA (Abingdon)  EFDA Garching </p>	Euratom - HAS (Budapest)	Euratom - IPP Asdex Upgrade - Wendelstein 7-AS Wendelstein 7-X (Garching) - (Greifswald) - (Berlin)	
Euratom - CEA TORE SUPRA (Cadarache)		Euratom - IPP.CR CASTOR (Prague)		
Euratom - CIEMAT TJ-II (Madrid)		Euratom - IST ISTTOK (Lisbon)		
Euratom - Conf. Suisse TCV - SULTAN (Lausanne) - (Villigen)		Euratom - Latvia (Riga)		
Euratom - DCU (Dublin) - (Cork)		Euratom - MEC (Bucharest)		
Euratom - ENEA FTU - RFX (Frascati) - (Milan) - (Padua)		Euratom - ÖAW (Vienna) - (Graz) - (Innsbruck)		
Euratom - FOM (Petten) - (Nieuwegein)		Euratom - RISØ (Roskilde)		
Euratom - FZJ TEXTOR (Julich)		Euratom - TEKES (Helsinki) - (Tampere) - (Lappeenranta)		
Euratom - FZK TOSKA (Karlsruhe)		Euratom - UKAEA MAST - JET (Culham)		
Euratom - Greece (Athens) - (Heraklion) - (Ioannina)		Euratom - LEI (Kaunas)	Euratom - CU TOSKA (Bratislava)	Euratom - MHST (Ljubljana)
		Euratom - IPPLM (Warsaw)	Euratom - INRNE (Sofia)	
			Euratom - VR EXTRAP T2R (Stockholm) - (Lund) (Gothenburg) - (Studsvik) - (Uppsala)	

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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

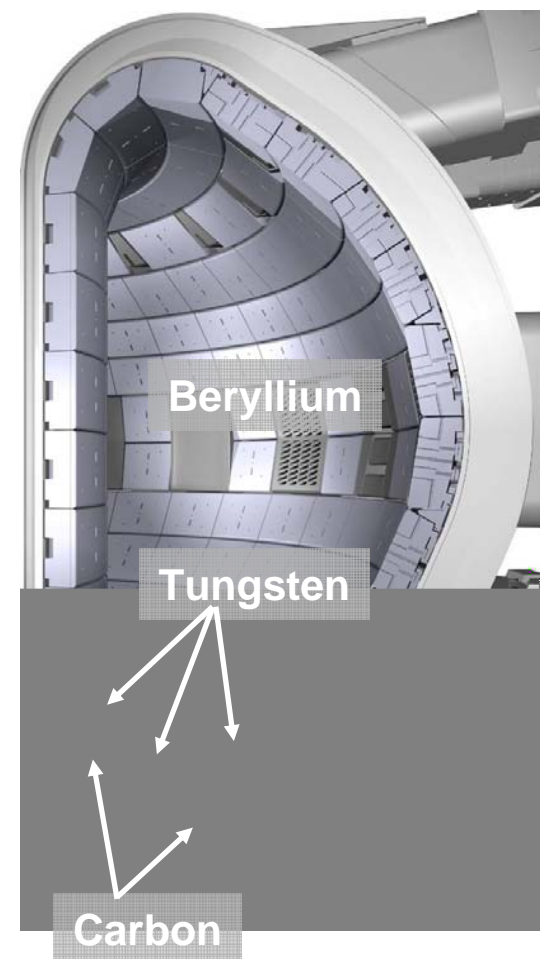
3. Plasma Facing Materials

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]

EU-PWI TF : targeted at ITER through 7 SEWGs

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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

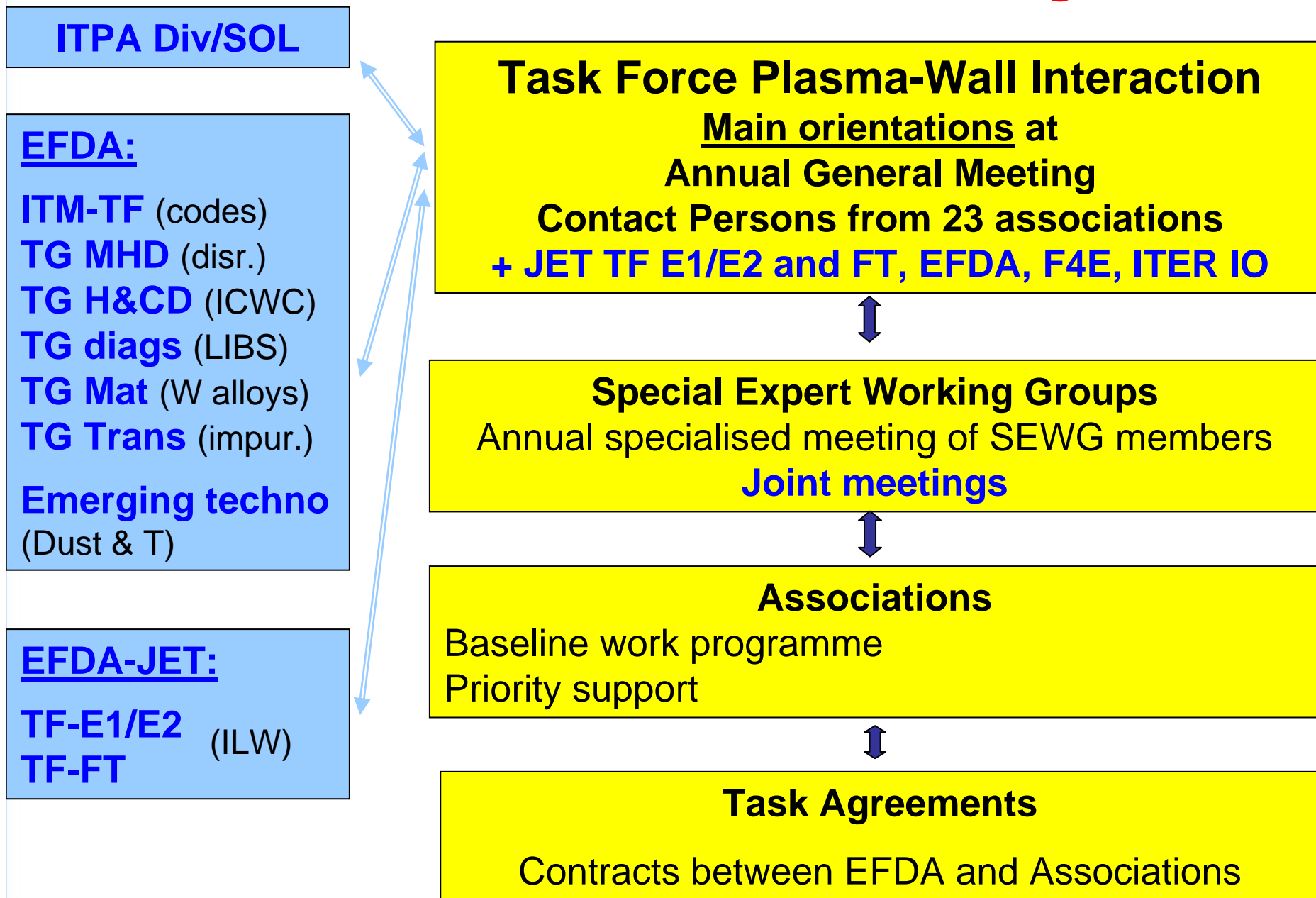
Fuel retention

Fuel Removal

Dust

Fuel retention

EU PWI TF: mature organisation



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

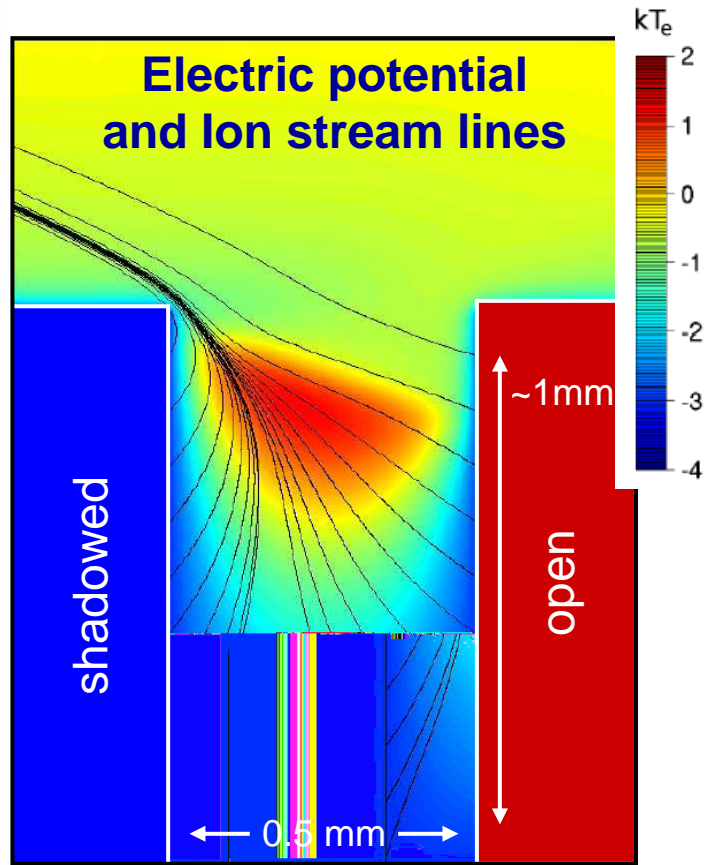


Recent scientific achievements : highlights of 2009

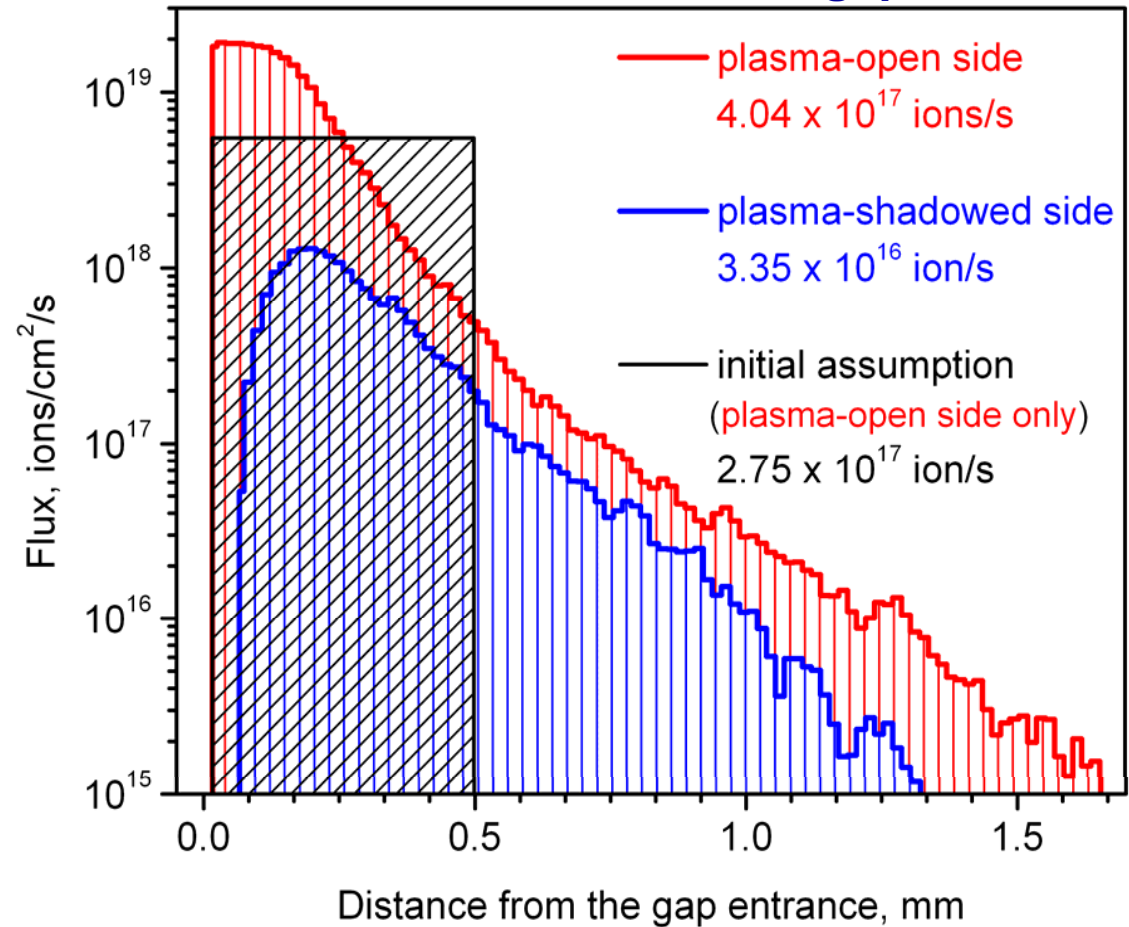
Scientific highlights for 2009

- 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



Ion flux distribution over the gap surfaces

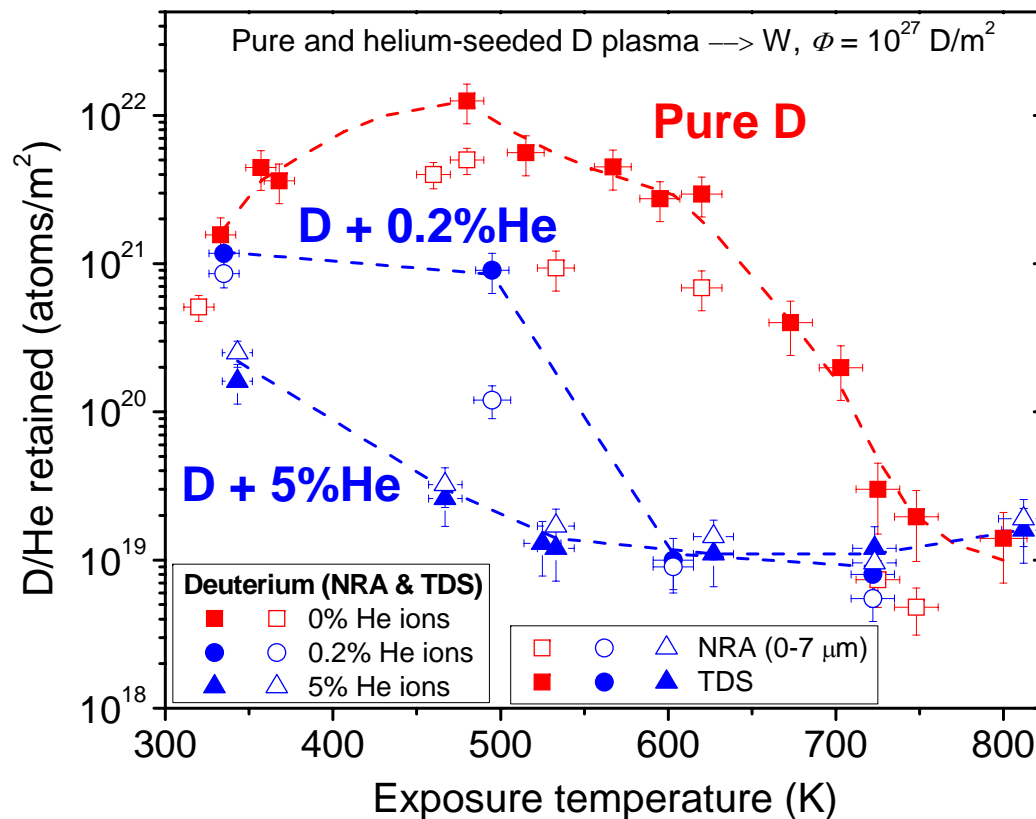
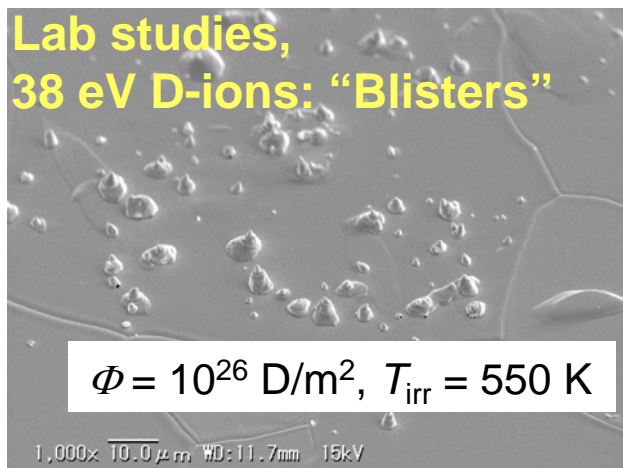


Deposition inside a poloidal gap of a castellated limiter in TEXTOR
from PIC simulations

Low fuel retention in W confirmed in dedicated lab experiments

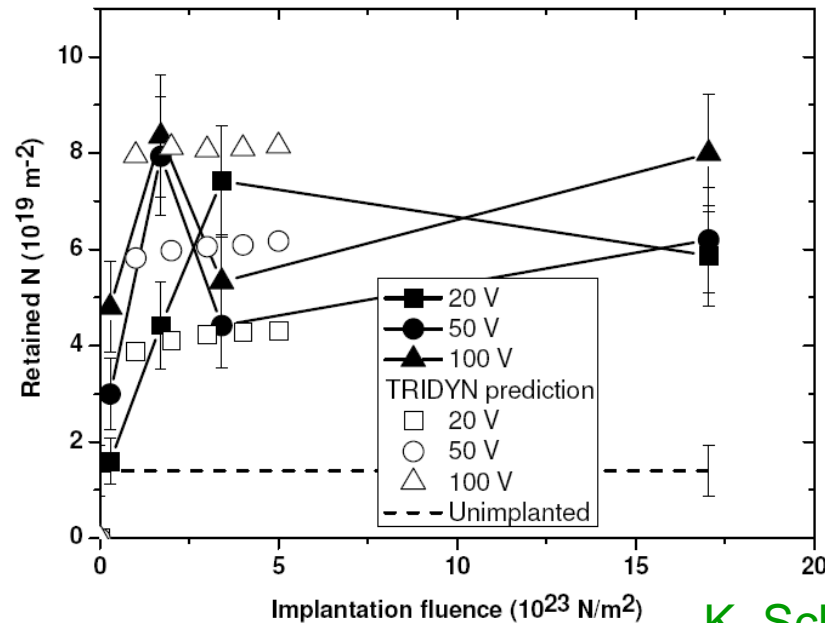
- Temperature dependence explored : complex behaviour
→ blisters formation
- Simultaneous He bombardment : retention reduced
- Impact of neutrons : damage simulated by heavy ions bombardment
→ moderate increase

Lab studies,
38 eV D-ions: "Blisters"

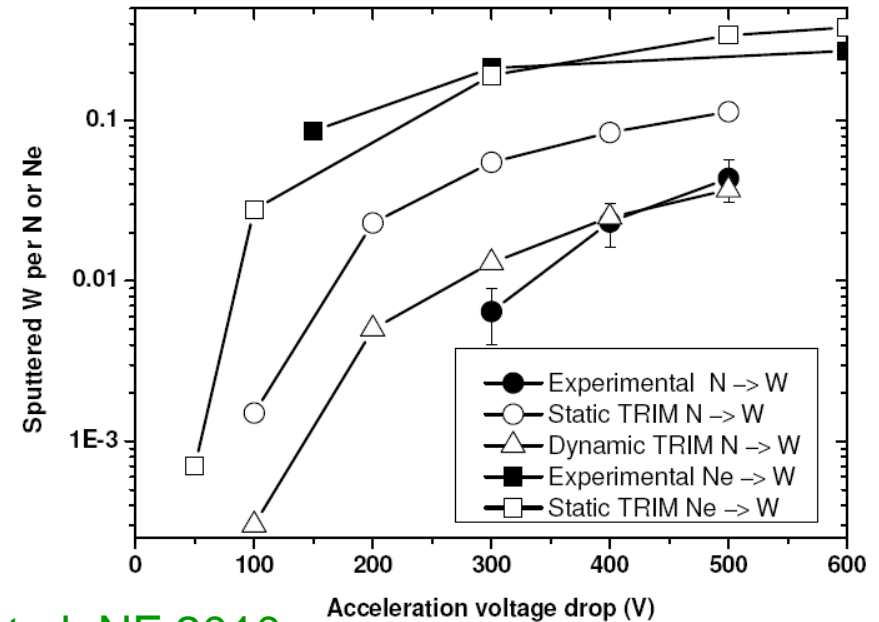


Retention in W under He bombardment [IPP Garching]

Lab Experiments on N-W interaction



K. Schmid et al, NF 2010



- **N wall storage saturates** after a fluence a few 10^{23} N/m^2
- saturation depending on injection energy
- N deposition depth \sim implantation range $\leq 2 \text{ nm}$ (**negligible diffusion**)
- saturation density $D_{\text{N,sat}} \leq 10^{20} \text{ N/m}^2$, 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

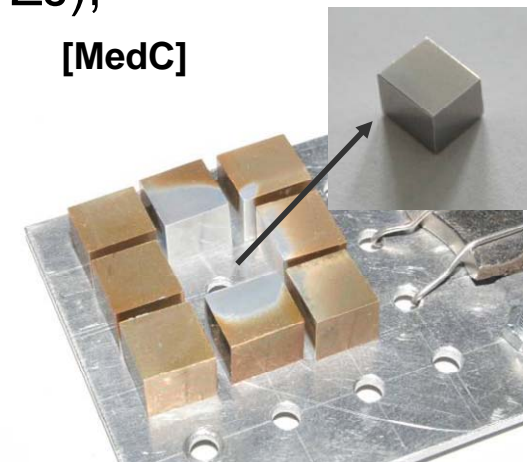
Chemical Methods – O_2 , N_2 , $NH_3 \rightarrow$ ITER

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)



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 :

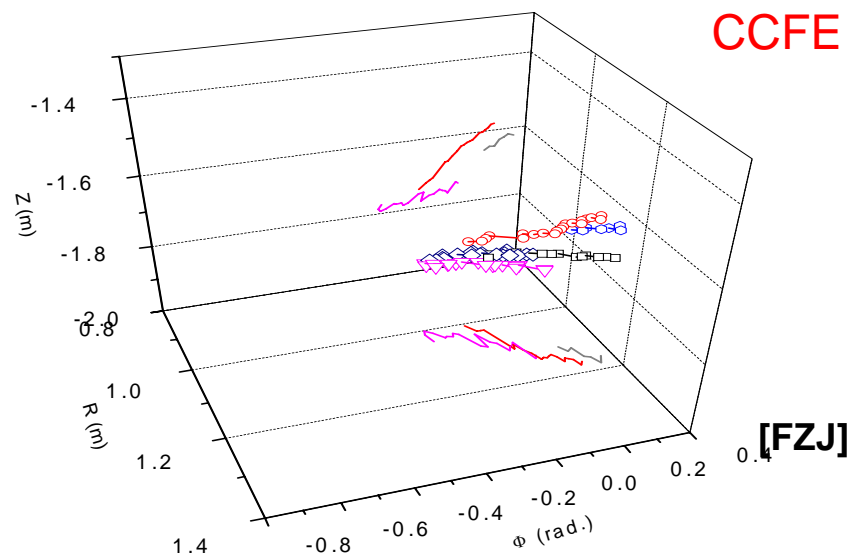
CCD (TS, AUG), fast IR (AUG), electrostatic detector (TS),
 Thomson scattering (FTU)

Preliminary dust injection experiments in Textor

Driving force = $j \times B$

Edge C increased, no effect in core

Dust trajectories investigated in several devices using fast cameras





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

- **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 conditioning

- **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)

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

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.

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