EFDA
EUROPEAN FUSION DEVELOPMENT AGREEMENT

Strategy and goals of the EU TF on PWI

R. Neu (IPP Garching)

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Programmatic Overview on EFDA Activities

The priorities of the EFDA Work Programme are prepared taking into account

- the ITER research plan,
- activities conducted under F4E, and
- the outcome of ITPA topical group meetings.

The EFDA Task Forces and Topical Groups play a key role in supporting the elaboration of the programme with specific reference to the seven *R&D Missions* proposed by EFDA

I. Burning Plasmas
II. Reliable Tokamak Operation
III. First wall materials & compatibility with ITER/DEMO relevant plasmas
IV. Technology and physics of Long Pulse & Steady State
V. Predicting fusion performance
VI. Materials and Components for Nuclear Operation
VII. DEMO Integrated Design: towards high availability and efficient electricity production.

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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

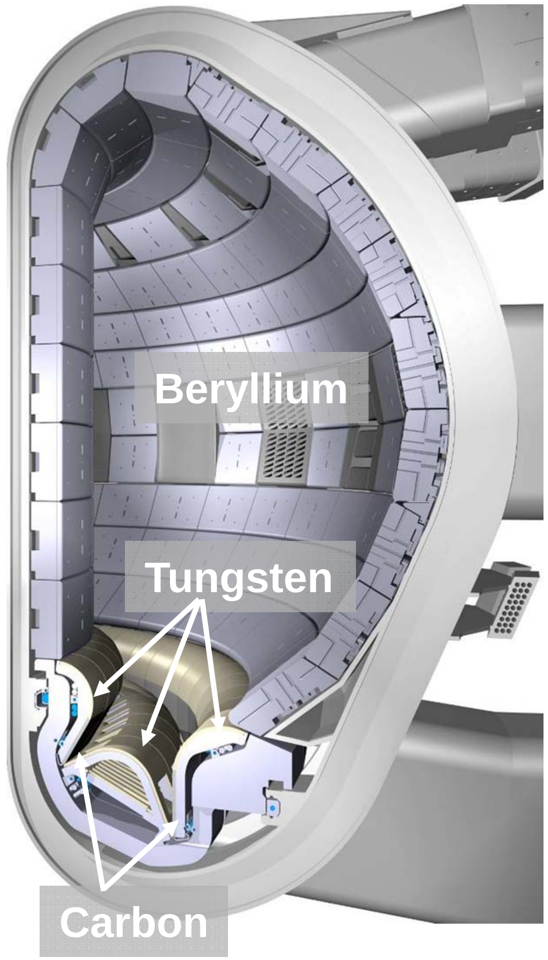
3. Plasma Facing Materials

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 6 Special Expert Working Groups

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ITER high priority research needs

ITPA Div SOL : 5 topics

1. Disruption/ Runaway Mitigation

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

2. ELM Control/ Mitigation

Transient heat loads

ELMs and disruptions

Heat loads

3. Plasma Facing Materials

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

Materials

Material migration	High-Z Materials	ITER-like Material Mix

Material Erosion

W R&D

5. Diagnostics

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

Dust

Fuel retention

Dust and Fuel Removal

Fuel retention

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EU PWI TF: mature organisation

ITPA Div/SOL

EFDA:

ITM-TF
TG MHD (Disrup.)
TG H&CD (ICWC)
TG diags
TG Mat (W alloys)
TG Transp

Emerging techno
(Dust & T, LIBS)

EFDA-JET:

TF-E1/E2
TF-FT (ILW)

Pisces B (US) (W, Be)
(Plasma Guns (RF))

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

↕

Associations
Baseline work programme : ≤20 %
Priority support : up to 40 %

Timeline for the Work of the PWI TF

Presentation of the n+1 annual WP
Reporting on n-1 WP
to EFDA SC (main lines – ceiling) (Feb-March)

EFDA SC (Feb-March)

Call for Participation for n+1 WP (summer)

SEWGs meetings

Answer to call (early Sept)
Call assessment by PWI TF (end Sept)
Presentation to EFDA SC for approval (Oct)

EFDA SC (October)

Task agreements drafted for n+1 WP (Nov)
Implemented by end of the year

Annual PWI TF meeting, reporting on current WP

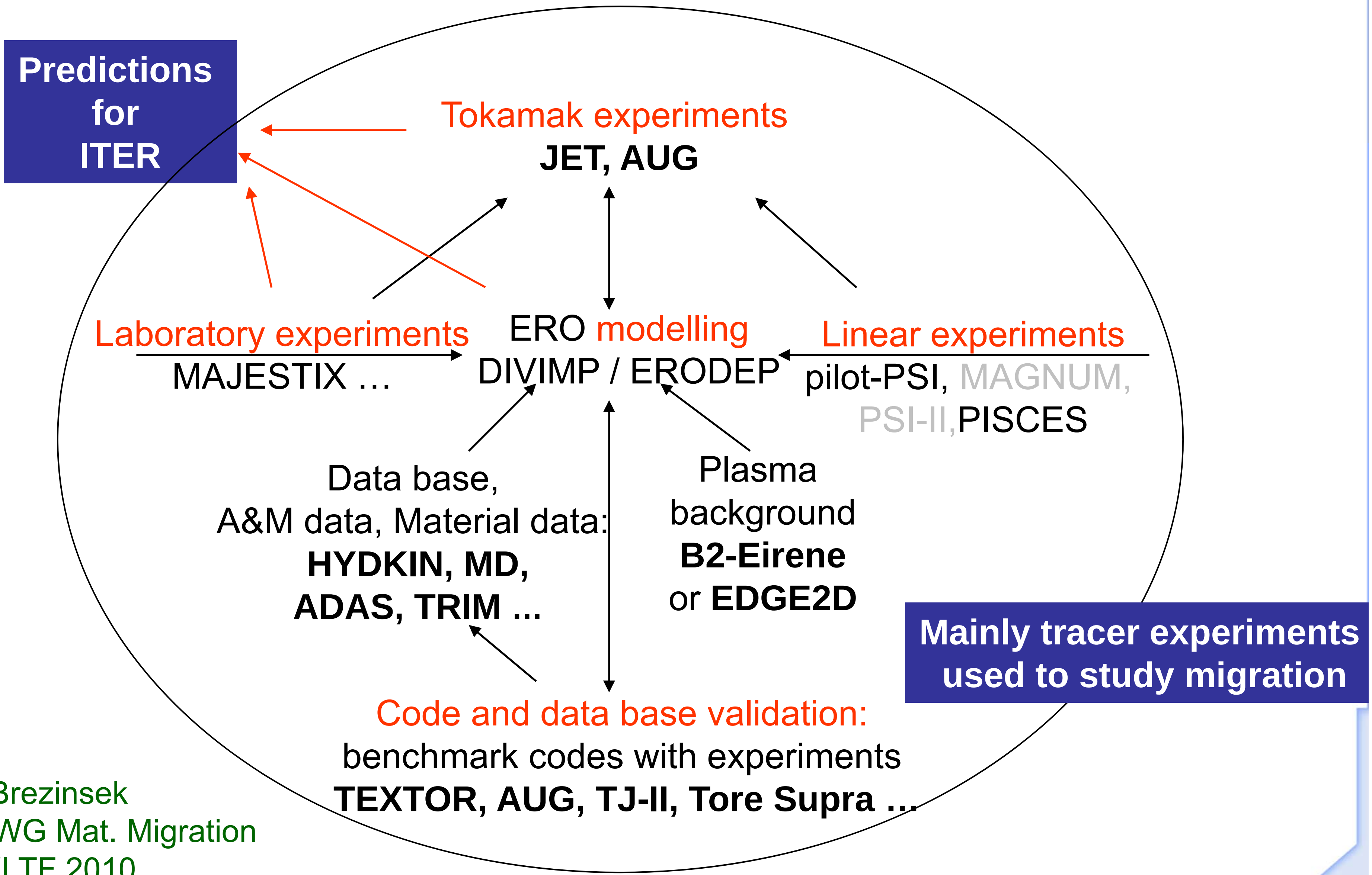
Definition of the Work Program for the next year(s)

Annual PWI meeting (November)

Main thrusts of the EU PWI TF

- Fuel retention as a function of wall materials foreseen for ITER
- Exploration of fuel removal methods compatible with retention in mixed materials and metals, including beryllium
- Dust generation and characterization in different devices, including the impact of fuel removal methods on dust production
- Erosion, transport and deposition of first wall materials
- Development of the PWI basis in support of integrated high-Z scenarios for ITER and demonstration of liquid plasma-facing components
- Investigation of material and reaction properties of alloys and compounds relevant under expected ITER conditions and their influence on PWI processes and fuel retention
- Mitigation of disruptions and investigation of ELM and inter-ELM heat

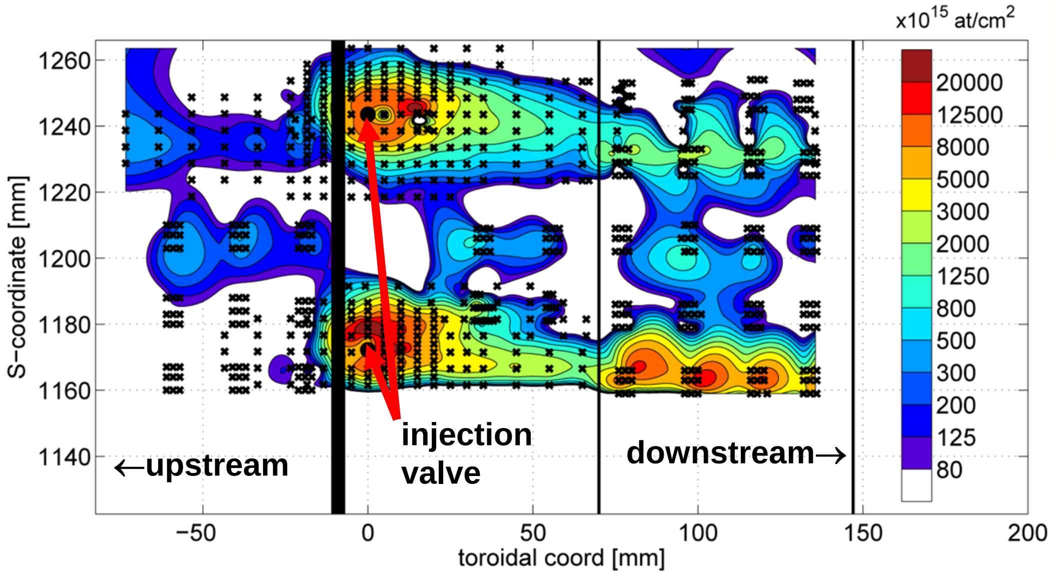
Predictions for Materials Migration



S. Brezinsek
SEWG Mat. Migration
PWI TF 2010

Global and local ^{13}C migration

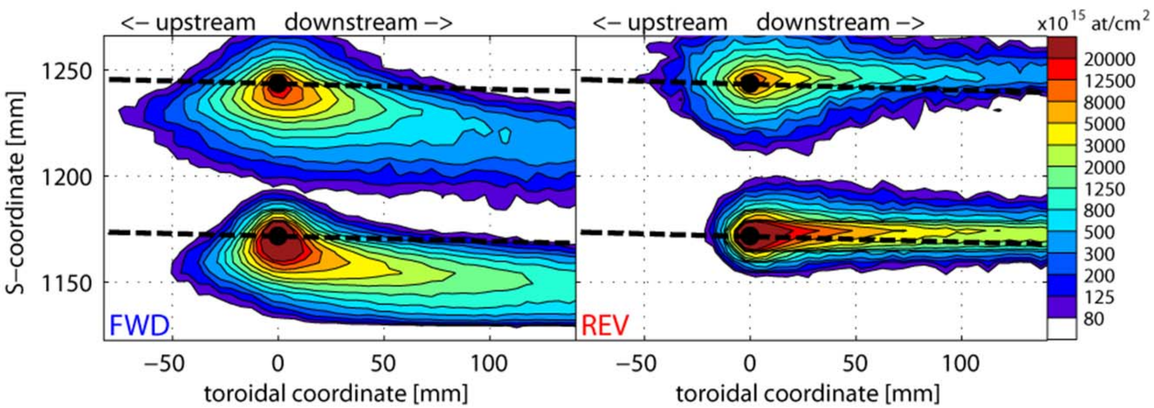
- local ^{13}C experiment performed in AUG (2009 campaign)
  - ⇒ injection from two valves close to the **outer strike point** (tile 1)
  - ⇒ ***B_t* and *I_p* reversed** compared to a similar experiment in 2007



- four adjacent tiles analyzed using SIMS and NRA (K. Krieger, IPP)

- SOLPS and ERO simulations benchmarked against both 2007 (forward) and 2009 (reversed) data

- ***E×B* drift** plays major role in ^{13}C divertor deposition

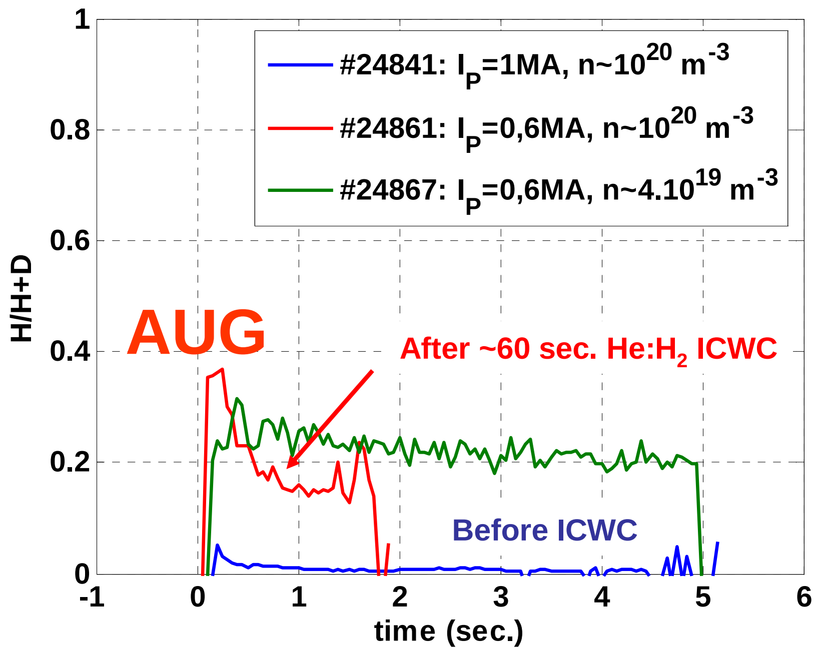


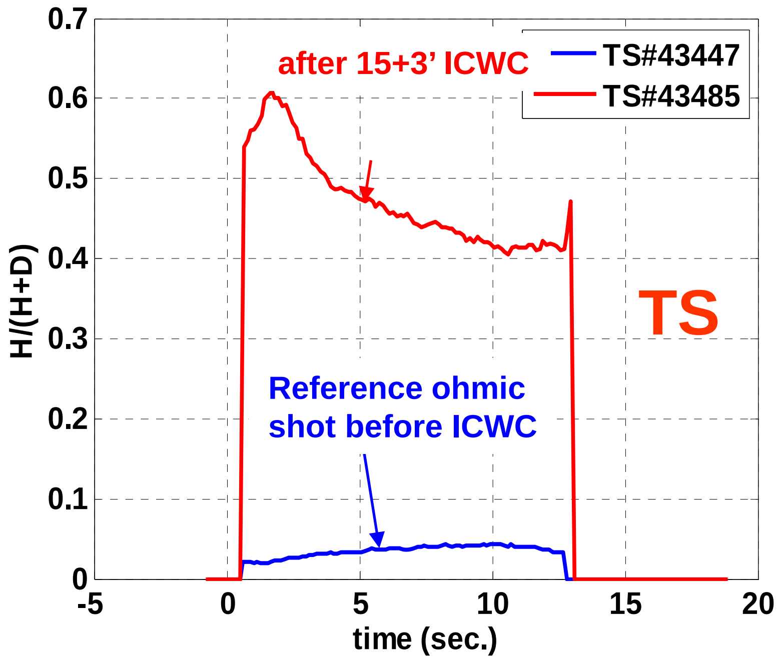
➢ **in 2011**: continuing modelling efforts, the effect of surface roughness?

Leena Aho-Mantila (VTT) et al., PSI 2010

Hydrogen isotopic exchange in ICWC

$n_H/[n_H+n_D]$ in ohmic shots (by means of NPA)





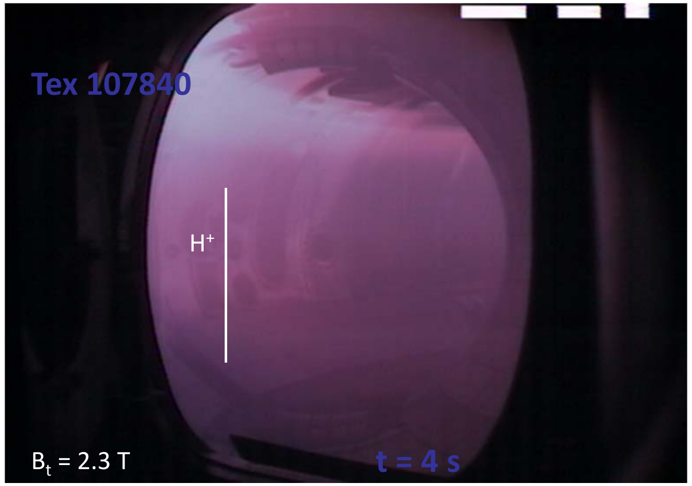
isotope ratio changes from 1 to 20% after 60 sec. ICWC
after that, one NSB due to wall saturation by H atoms

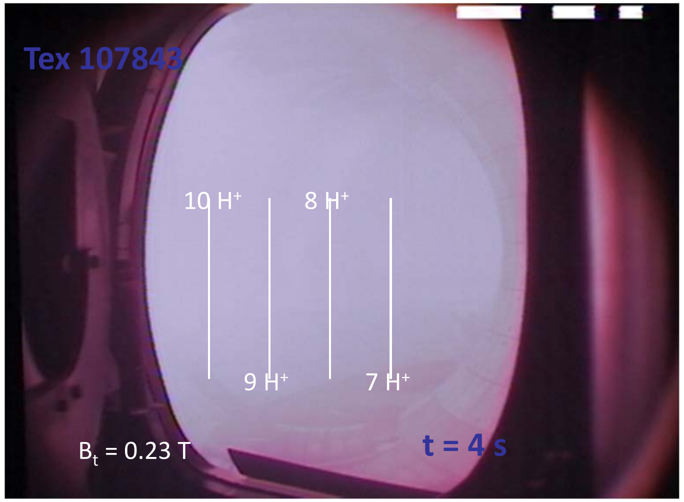
isotope ratio change from 1 to ~50% after ~900 sec. He-H_2 ICWC
3 min. He-ICWC needed to recover ohmic plasma

short pulses in Tore Supra and TEXTOR followed by pumping
→ reionization and retention only during RF ON, wall desorption in the post-discharge
→ short pulses reduce wall saturation with a moderate decrease of efficiency

D. Douai (CEA) et al, IAEA 2010

ICWC Experiments in TEXTOR





High Bt (2.3 T) inhomogenous poloidal distribution

Low Bt: homogenous

- Dependence on pressure

  Low pressure operation favourable for low release/retention ratio

- Influence of wall biasing (ALT limiter blades and testobjects)

  Biasing of small area wall components gives high local ion flux density at high particle energies

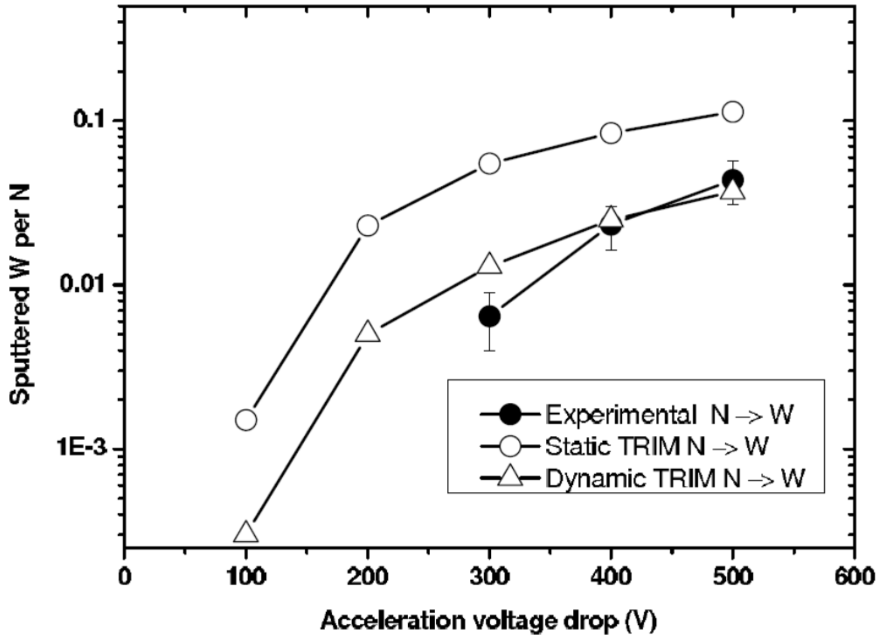
- Fast particle detection using high resolution Hα spectroscopy

  Existence of fast particles confirmed at ICWC resonant conditions

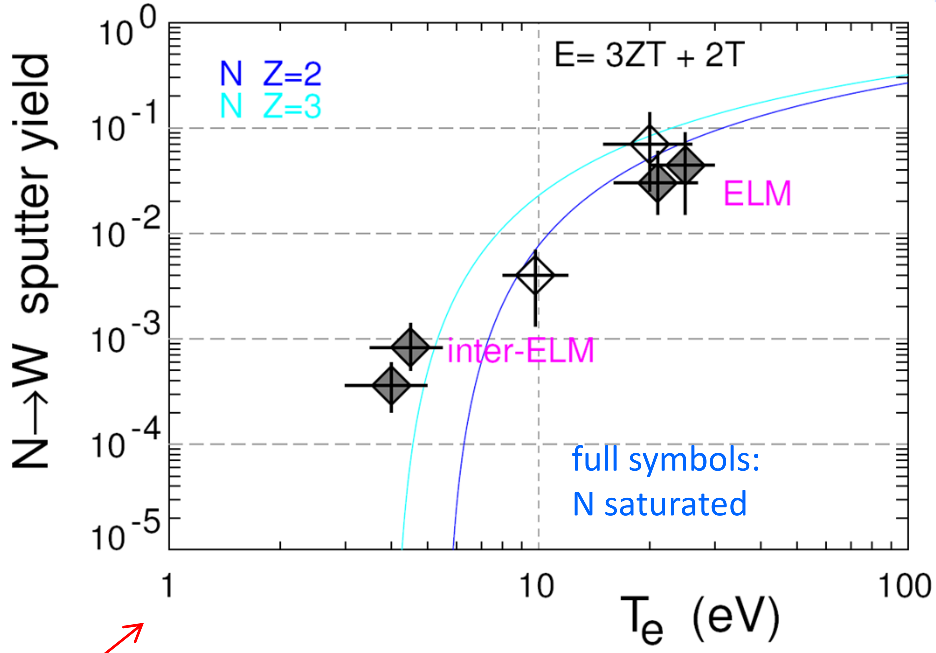
V Philipps et al (FZJ)

Influence of N Seeding on W Properties

K. Schmid et al., NF 52 (2010)

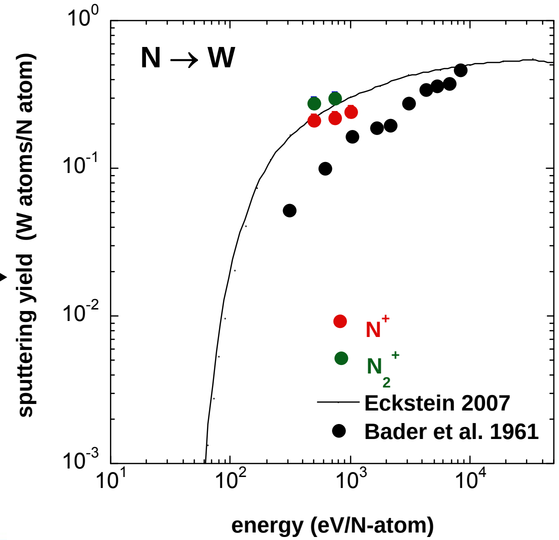


A. Kallenbach et al., PSI2010



Reduction of yield observed in lab, but no significant evidence for reduction in AUG

- QCM measurements of sputtering yields for impact of nitrogen seeding gas ions
- Comparison between atomic N^+ and molecular N_2^+ ions (at equal impact velocities): molecular effect?



F. Aumayr et al., 2010

Influence of N Seeding on W Properties

- Study of N co-deposition and compound formation by N injection in TEXTOR at W test limiter.
- Post mortem analysis of W surface by RBS, NRA, XPS and 40 MeV ToF HIERDA ($^{127}J^{9+}$)

➢ N is present both in W and in C co-deposits on the W surface.

➢ XPS shows the presence of: WN, W_2N, WC and WO_3.

➢ no obvious detrimental effects on W erosion or integrity.

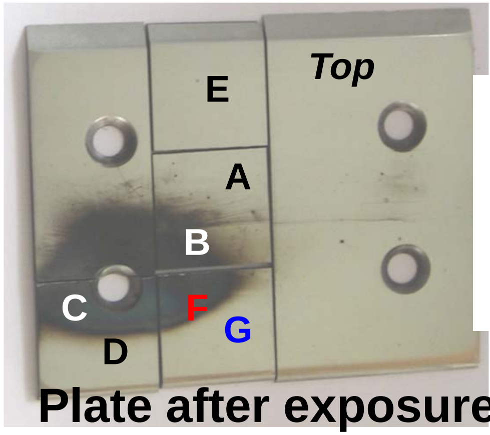
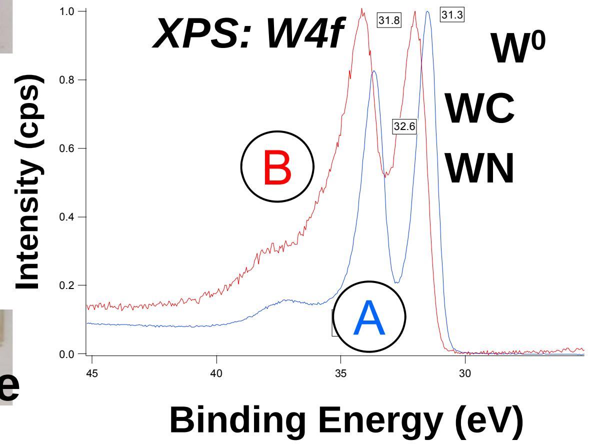
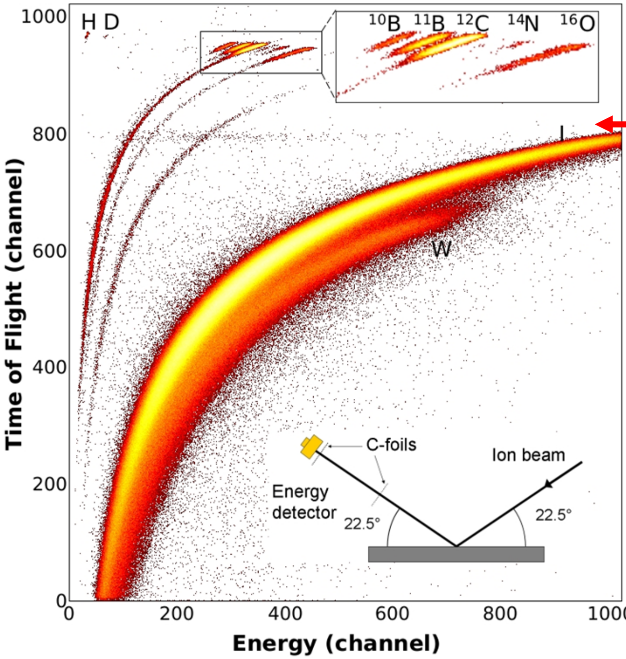


Plate after exposure





HIERDA spectrum

Nitrogen content:

1.3×10^{15} cm^{-2} (G)
(no deposit)

3.4×10^{15} cm^{-2} (F)
(thick deposit)

M. Rubel, P. Petersson (VR), V. Philips (FZJ), L. Marot (CRPP), 2010

Influence of Material Mixing on H Retention

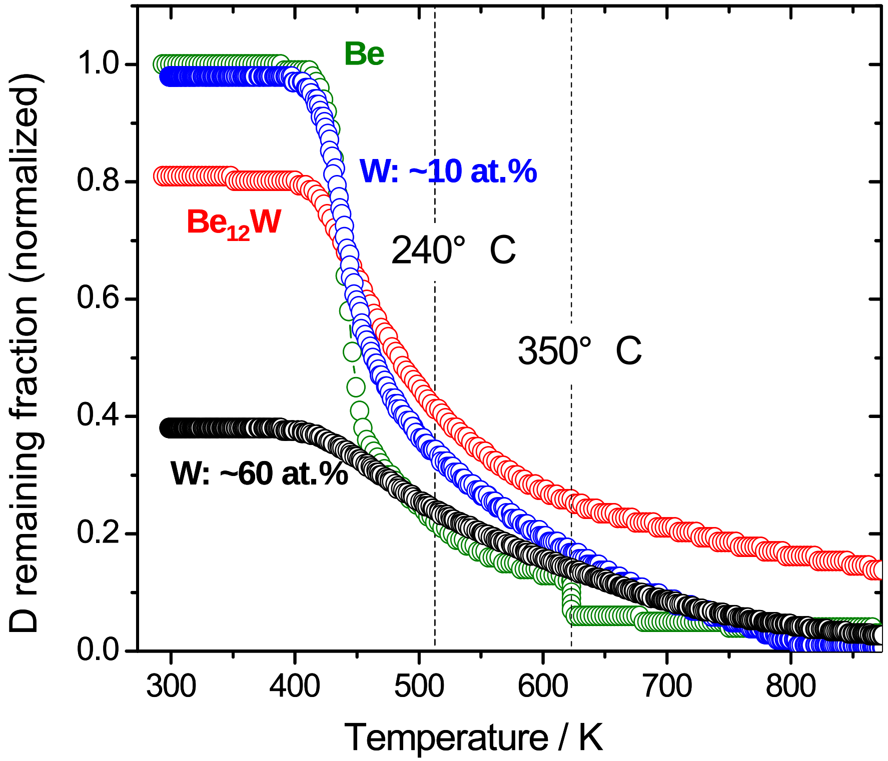
D release from Be-W simultaneously deposited layer

Layers were prepared by Thermionic Vacuum Arc (TVA) deposition at MEdC

- 200 eV D ion implantation in IPP High Current Ion Source
- Flux ≈10^{19} D/m^{2}s, fluence up to ≈5×10^{23} D/m^2
- D release analysis by Thermal Desorption Spectroscopy (TDS)
- Quantitative analysis by Nuclear Reaction Analysis using D(3He, p)4He reaction

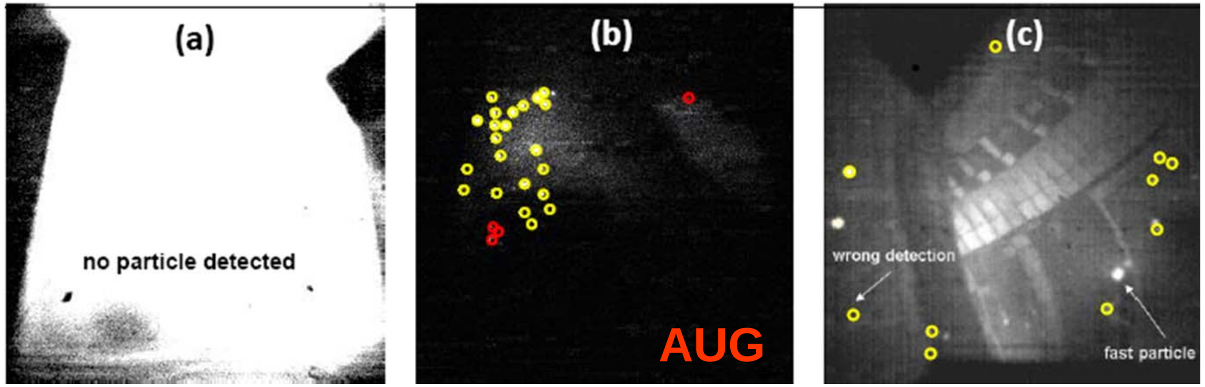
➩ Mixing of W in Be slightly changes D desorption pattern.

➩ D retention decreases with increasing W fraction in Be.



K. Sugiyama (IPP), A.Anghel (MEdC) et al., PSI2010

Tracking of Dust in Plasma Discharges

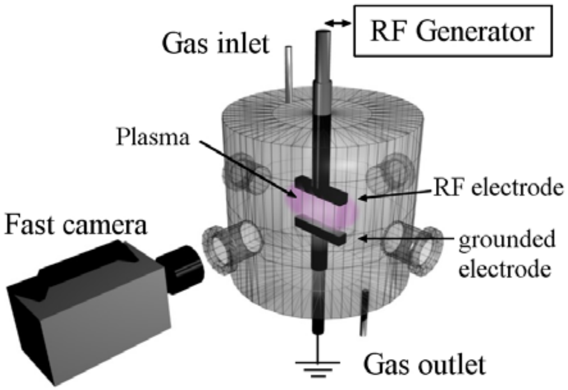


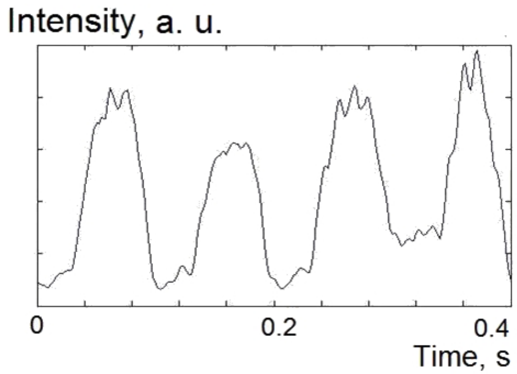
Tracking in different discharge conditions: (red circles=hot spots, yellow circles = dust particles)

S. Bardin, F Brochard et al EPS2010

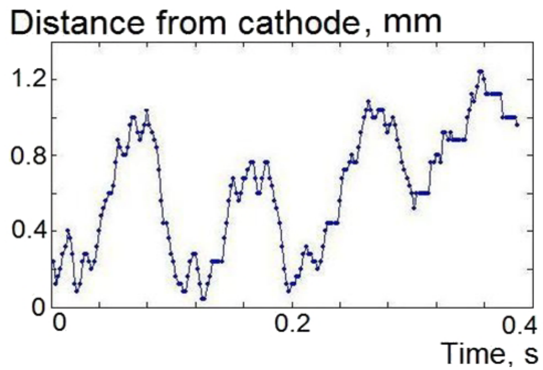
Identification software developed and benchmarked in laboratory experiments adapted to needs of AUG fast camera data

automatic classification into real fly-by dust particles (velocity: 10-100 m/s), hot spots or single frame events.





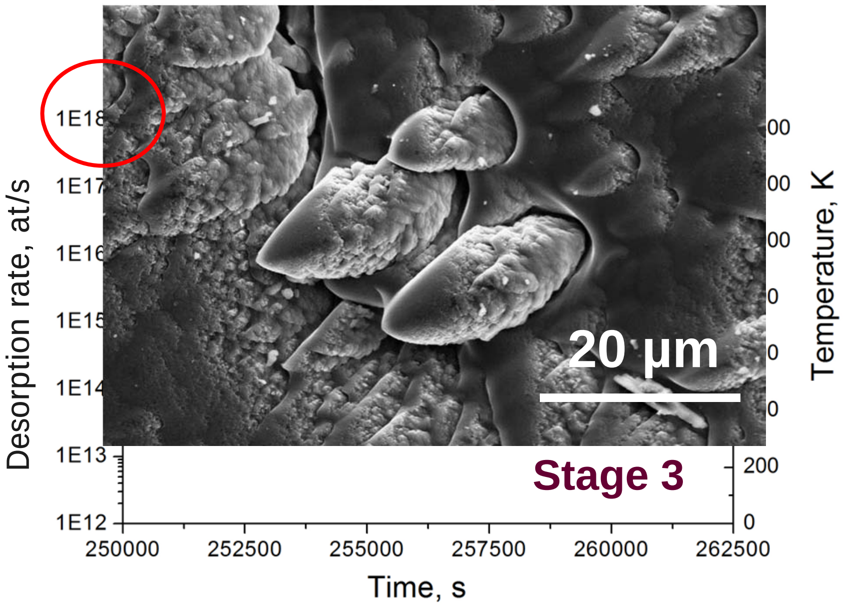
sheath oscillations



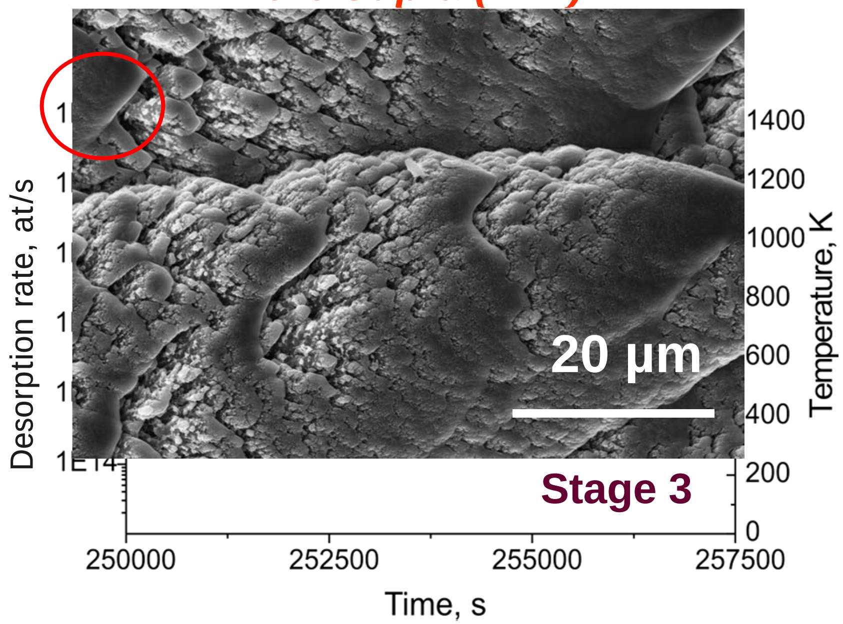
vertical displacement of a single particle, mm

Fuel Retention in C Dominated Dust

TEXTOR (ALT-II)



Tore Supra (TPL)



Release of fuel during the long-term desorption

T [K]	Limiter	H_2 [%]	HD [%]	D_2 [%]
623	ALT-II	34.1	11.9	5.2
	TPL	28.8	7.8	4.5
1273	ALT-II	65.9	88.1	94.8
	TPL	71.2	92.2	95.5

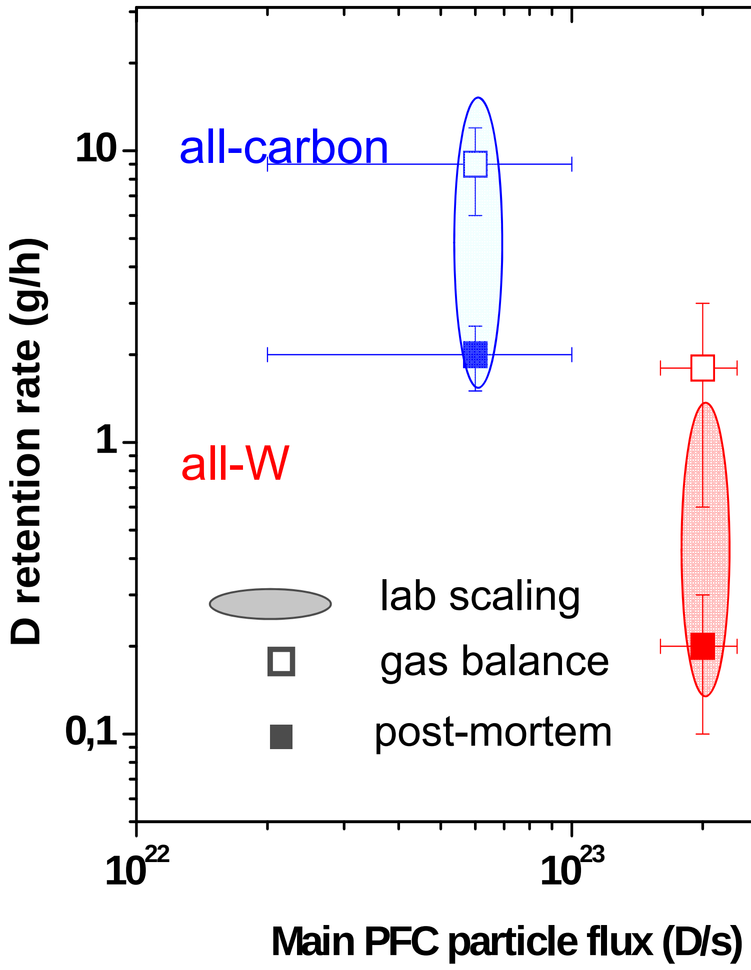
- **consistent results from TEXTOR and Tore Supra samples**
- **only around 10-15% of fuel is removed by baking at 623 K**

Darya Ivanova et al., 2010

Multi Machine Scaling of Fuel Retention in ITER

Only one machine available for validation of methodology: AUG

- Particle balance from literature:
  (V. Rohde, NF 49(2009)085031)
  long term retention 4% of injected about 2 ± 1.5 g/h
  Integration over 30 discharges compared with 23% in all carbon
- Post-mortem results in dominantly divertor retention of 0.2 ± 0.1 g/h
  (K. Sugiyama, NF 50(2010)035001)
- Lab scaling for W: Implantation and trapping
  (B. Lipschultz, J. Roth et al., MIT Report PSFC/RR-10-4)
- Retention reduced by about a factor of >10 compared to all-C



J. Roth, 2010

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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)
- **Priority support** (additional funding) available for activities critical for the achievements of the programmatic priorities (true added value from European collaborations)