EROSION AND RE-DEPOSITION OF W AND Ni IN THE DIVERTOR AND MIDPLANE REGIONS OF ASDEX UPGRADE

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INTRODUCTION

- Successful and safe operation of future fusion reactors requires
  - **Sufficiently long lifetime** of their plasma-facing components (PFCs)
  - **Low accumulation of tritium** in the reactor vessel
- We have addressed these issues by studying **erosion and re-deposition of tungsten and nickel** in **ASDEX Upgrade** during its 2008 and 2009 experimental operations

ASDEX Upgrade = full-W machine since 2007 ⇒ **ITER-relevant environment**
W high-Z material, Ni medium-Z material and a major component in steel

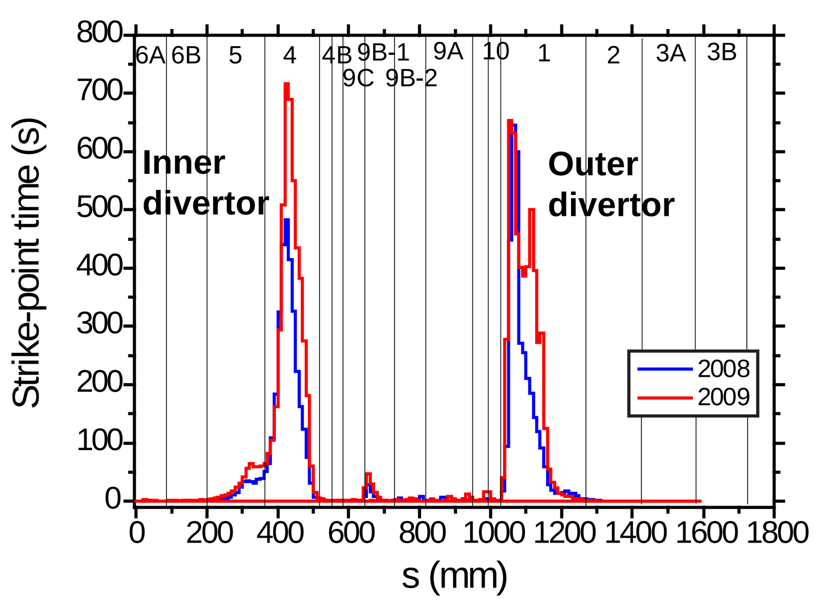
- Erosion/re-deposition investigated using
  - **Marker tiles** in the **divertor region**
    - ⇒ **campaign-integrated data**, comparison with earlier results
  - **Marker probes** exposed to L-mode discharges **at the midplane**
    - ⇒ **discharge-resolved data**, modelling with the ERO code
- Tiles analyzed using **Secondary Ion Mass Spectrometry (SIMS) and Rutherford Backscattering Spectroscopy (RBS)**, probes with RBS only

EXPERIMENTS AND ANALYSES

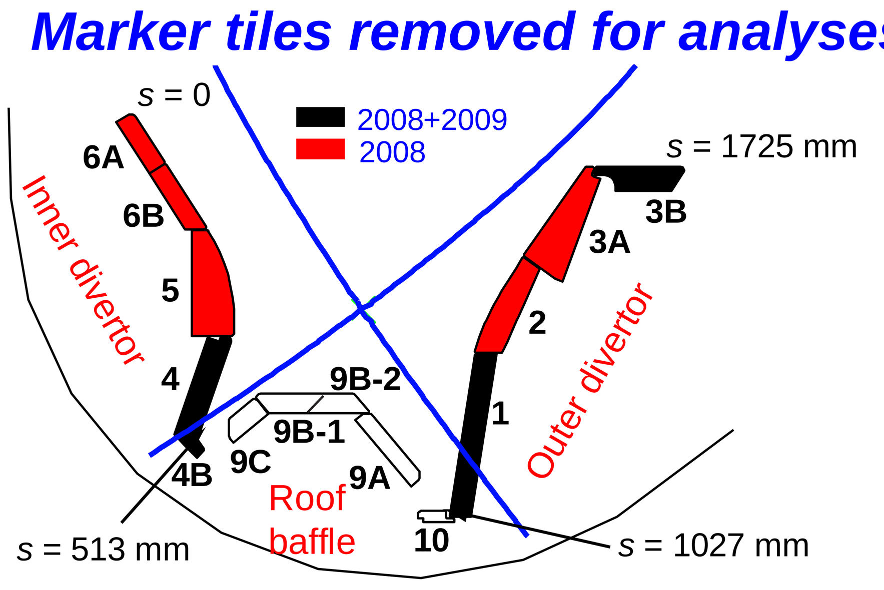
Plasma operations in 2008 and 2009

Campaign	Number of discharges	Plasma time	Number of boronizations
2008	726	3530 s	3
2009	1101	5275 s	3

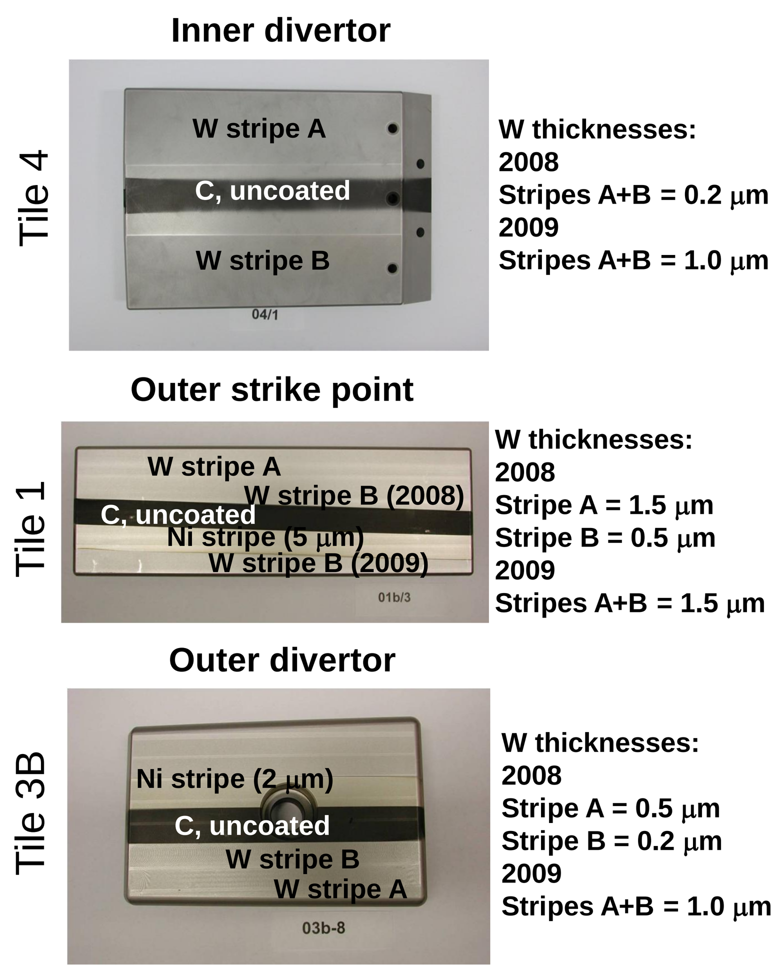
Strike-point distribution in 2008 and 2009



Marker tiles removed for analyses



Marker stripes on the tiles



SIMS analyses

5-keV O_2^+ ions, analysis area 0.3   0.4 mm²

⇒ **depth profiles** for H, D, ^{10}B, ^{12}C, Ni, and W

⇒ **qualitative** re-deposition patterns as a function of the *s* coordinate

RBS analyses

2.5-MeV or 3-MeV protons, beam diameter 1.8 mm

⇒ **erosion of the marker stripes**

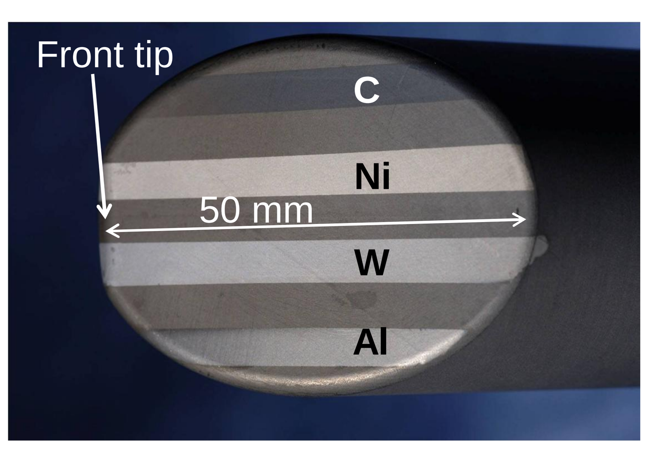
⇒ **quantitative** re-deposition patterns (in at/cm²)

Probe experiment in 2009

- five consecutive **L-mode discharges** (#24664-24669) **in deuterium**:

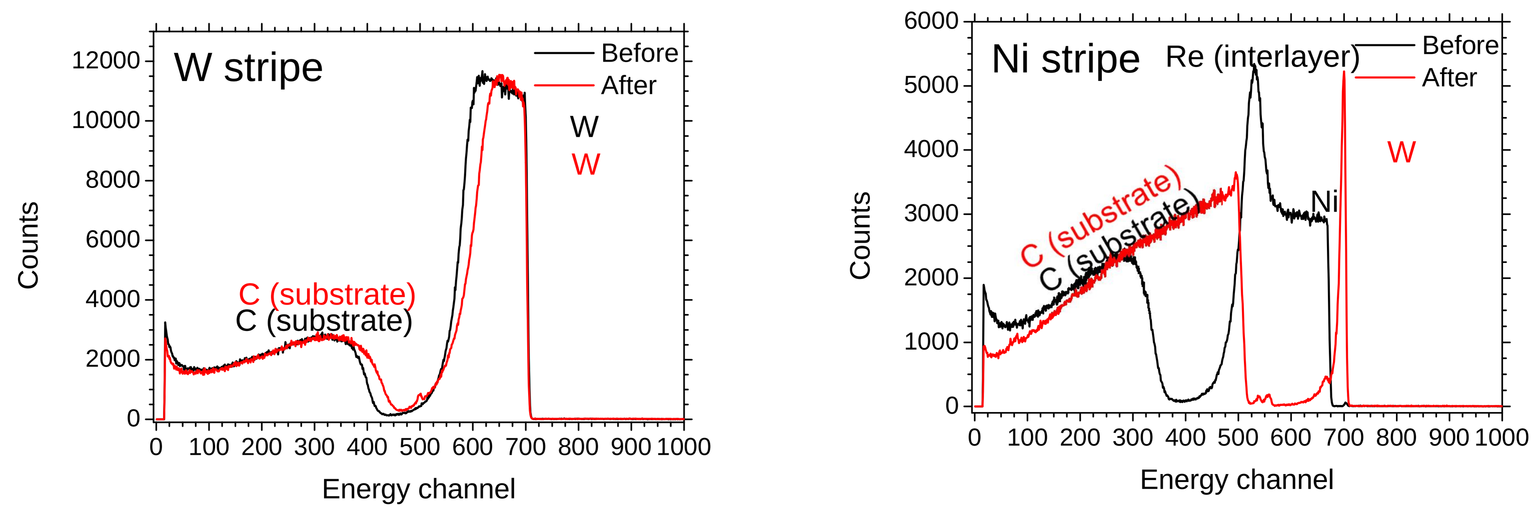
$\tau_{flat\text{-}top} \approx 3$ s, $I_p = 0.8$ MA, $B_t = -2.3$ T,
$n_e \approx 6\times10^{19}$ m^{-3}, $P_{aux} = 1.3$ MW

- graphite probe head coated with **50-nm thick W, Ni, Al, and C marker stripes**
- probe attached to the **midplane manipulator**, the surface with the markers facing magnetic field lines (angle 45°)
- front tip of the probe ≈ 10 mm outside the limiter in the SOL plasma, distance from the separatrix ≈ 50 mm



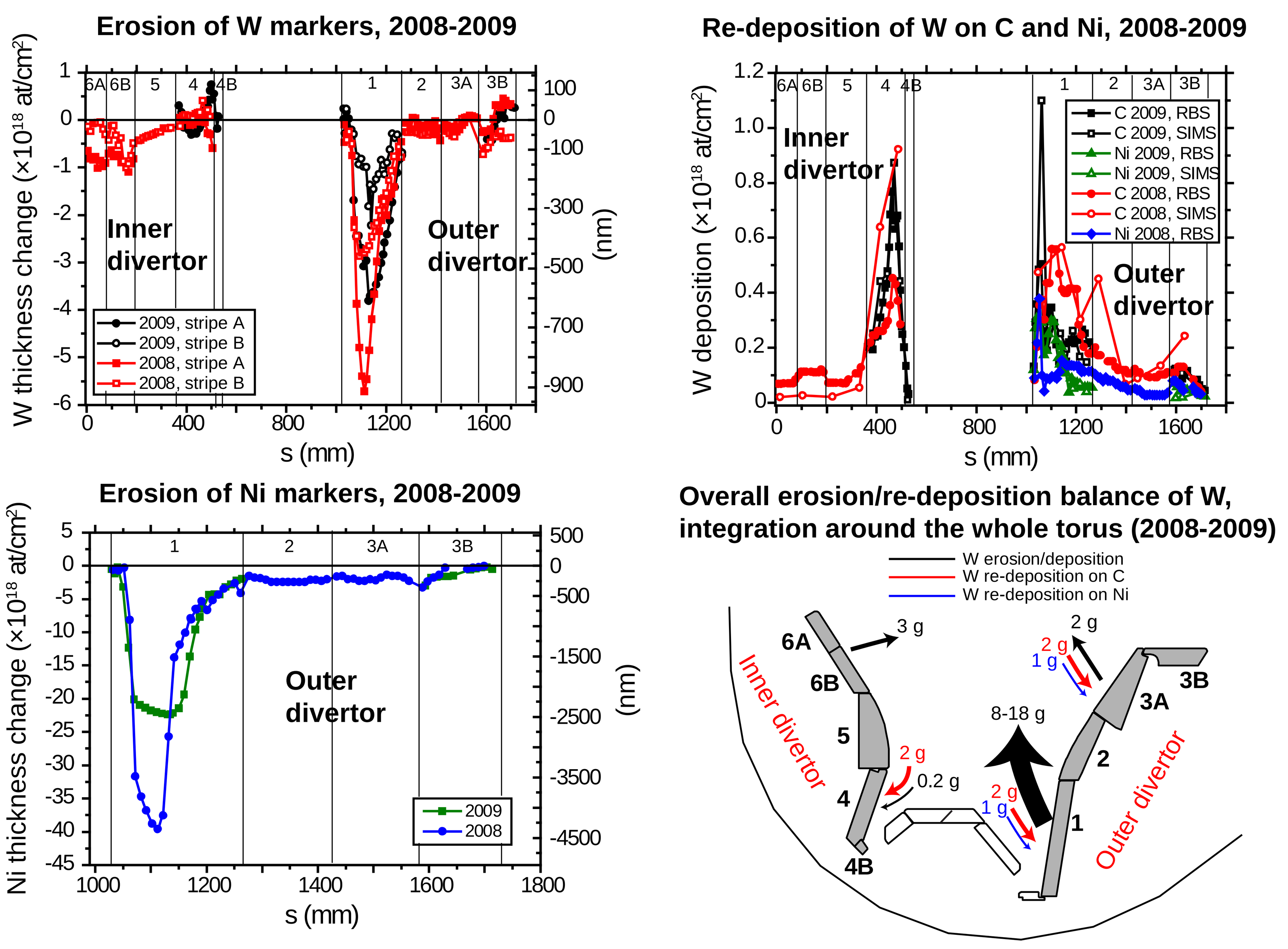
RESULTS

Examples of RBS profiles (2009 tile 1, s = 1100 mm)



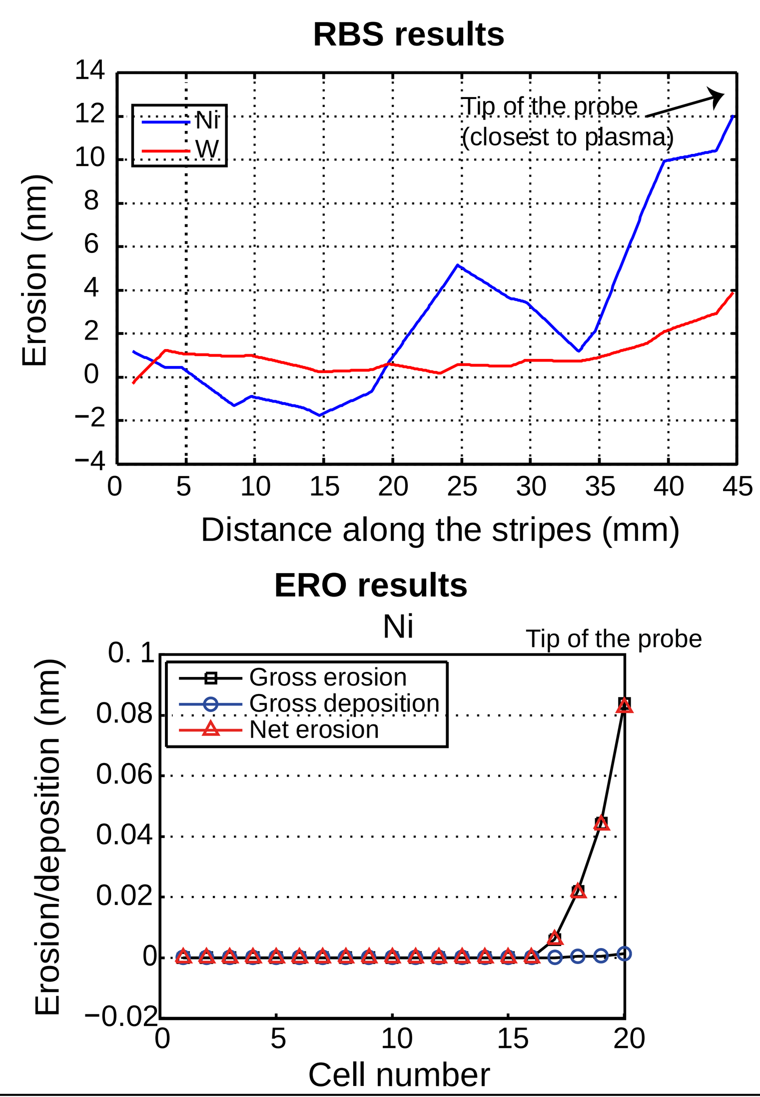
- spectra fitted using the **SIMNRA program**
- in the example above (outer strike-point region), **W remarkably eroded** during the 2009 campaign and **almost the whole Ni coating is gone**

Erosion of W and Ni in the divertor region (results normalized to 3000 s of plasma time)



- erosion of W up to 1 μm, largest erosion **around the outer strike point** (tile 1)
- erosion by arcing in tiles 6A, 6B, and 5; net deposition on tile 4
- **Ni eroded 5 times faster than W**
- re-deposition of W **largest in the private flux regions** below the strike points, **re-deposition on C larger than on Ni** by a factor of 2
- saturation of erosion in 2009? But sharper outer strike-point distribution in 2008!

Erosion of W and Ni at the midplane



- W eroded by up to **2-4 nm**, Ni by a factor of **3-5 times more**
- ERO simulations carried out
  - using radially varying plasma parameters, based on measured n_e and T_e data
  - varying the amount of C impurities
- simulations predict
  - (i) erosion largest **close to probe tip**
  - (ii) practically **no erosion for W**
  - (iii) only **up to 0.1 nm for Ni**
  - ⇒ effect of **fast ions?**
  - ⇒ effect of **heavier impurities**, e.g., Ar?
- new experiments in AUG in 2011 and 2012 with the probe tip closer to separatrix; 2011 experiments done in April

CONCLUSIONS

1. Largest erosion close to the **outer strike point**
2. Ni eroded by a **factor of 5** more than W
3. ERO simulations explain the **exponentially decaying erosion profiles** but the amount of erosion much **smaller than experimentally observed**

ACKNOWLEDGEMENTS

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