ASCOT simulations of ^{13}C transport in ASDEX Upgrade

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ASDEX Upgrade

Introduction

- Typically, numerical **modelling of global impurity transport in tokamaks is based on the plasma fluid picture** (e.g., the DIVIMP code)
- Impurities belong to **fluid elements that are affected by forces**

$$F_Z = -\frac{1}{n_Z}\frac{dp_Z}{ds_\parallel} + m_Z\frac{v_i - v_Z}{\tau_s} + ZeE_\parallel + \alpha_e\frac{d(k_BT_e)}{ds_\parallel} + \beta_i\frac{d(k_BT_i)}{ds_\parallel} \quad (1)$$

- **Commonly**, the fluid approach **has certain limitations**:
  - Tokamak wall geometry and magnetic field are assumed 2D
  - Computational grid does not extend to the wall in all regions
  - Drifts are neglected

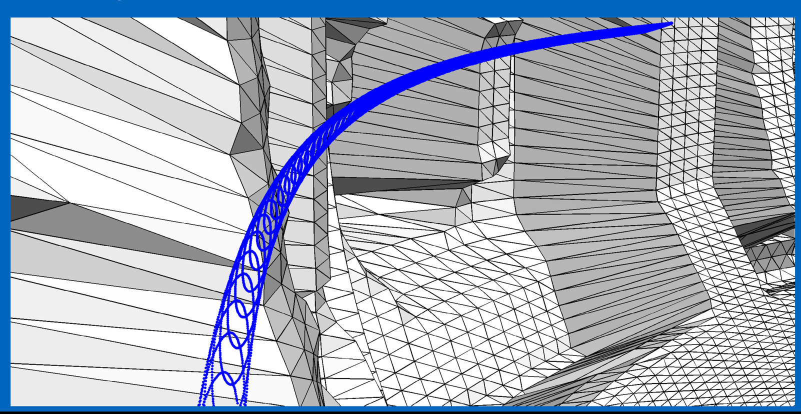
Kinetic test particle approach – the ASCOT code

- ASCOT is a **Monte Carlo code for following individual plasma particles**, called test particles, on static plasma and magnetic backgrounds
- **Collisions** between the test particles and the background plasma are **calculated using collision operators** for energy E and pitch $\xi = v_\parallel/v$:

$$\Delta E = -\sum_j 2\nu_{E,j}\Delta t\left[E - \frac{3}{2}\gamma k_BT_j - p\frac{k_BT_j}{2}\frac{d\gamma}{dp} - \frac{1}{2}\frac{\gamma k_BT_j p}{\nu_{E,j}}\frac{d\nu_{E,j}}{dp}\right] + \delta_2\sqrt{\sum_j 4\gamma k_BT_jE\nu_{E,j}\Delta t} \quad (2)$$

$$\Delta\xi = -\nu_\xi\xi\Delta t + \delta_1\sqrt{(1-\xi^2)\nu_\xi\Delta t} \quad (3)$$

- **Anomalous transport** in the radial direction is modelled as **diffusion**
- **ASCOT naturally avoids the common restrictions** related to the fluid approach:
  - Both the tokamak wall geometry and the magnetic field can be included in full 3D
  - Computational grid is unrestricted
  - Drifts are inherently included in orbit following

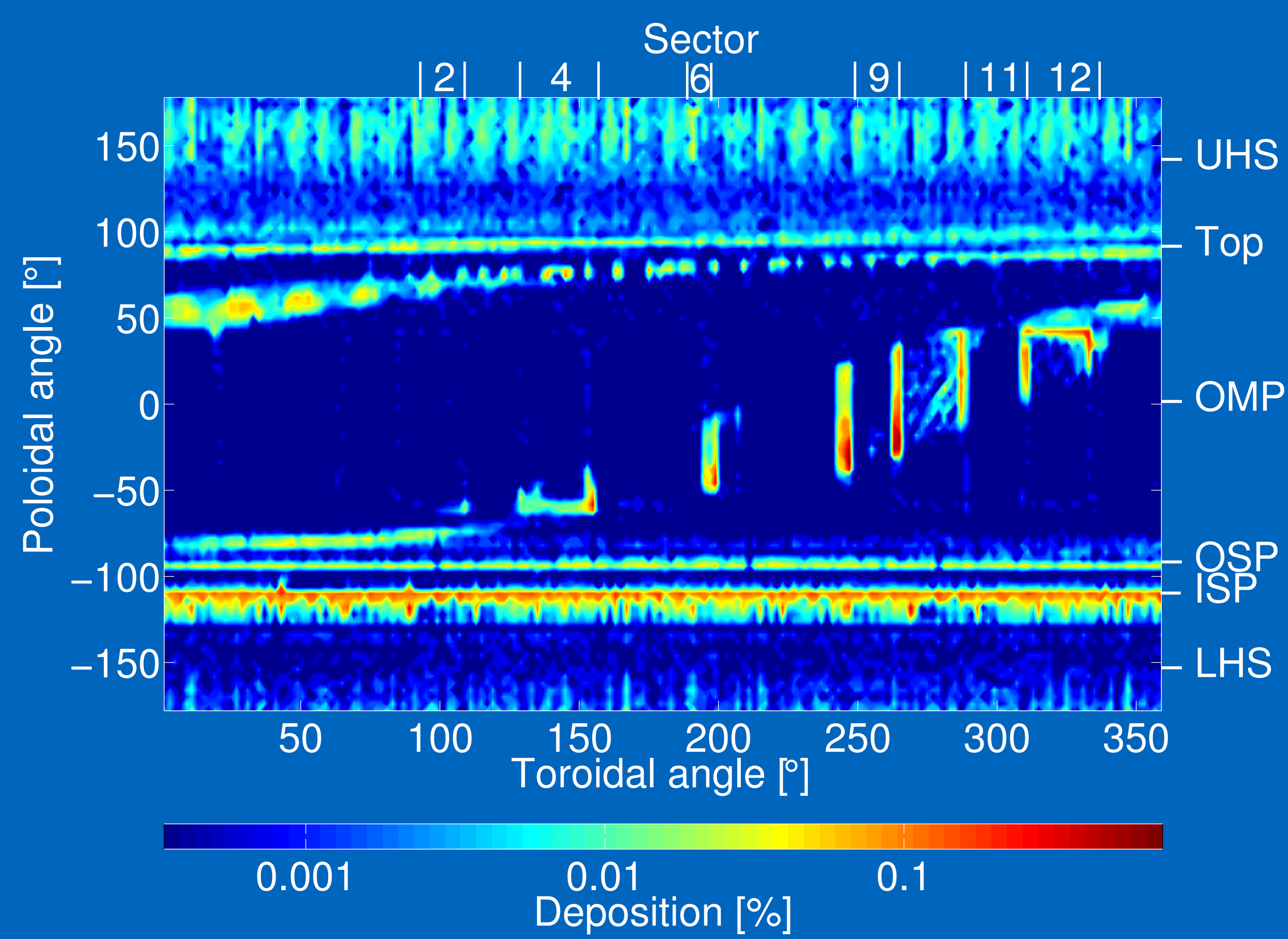


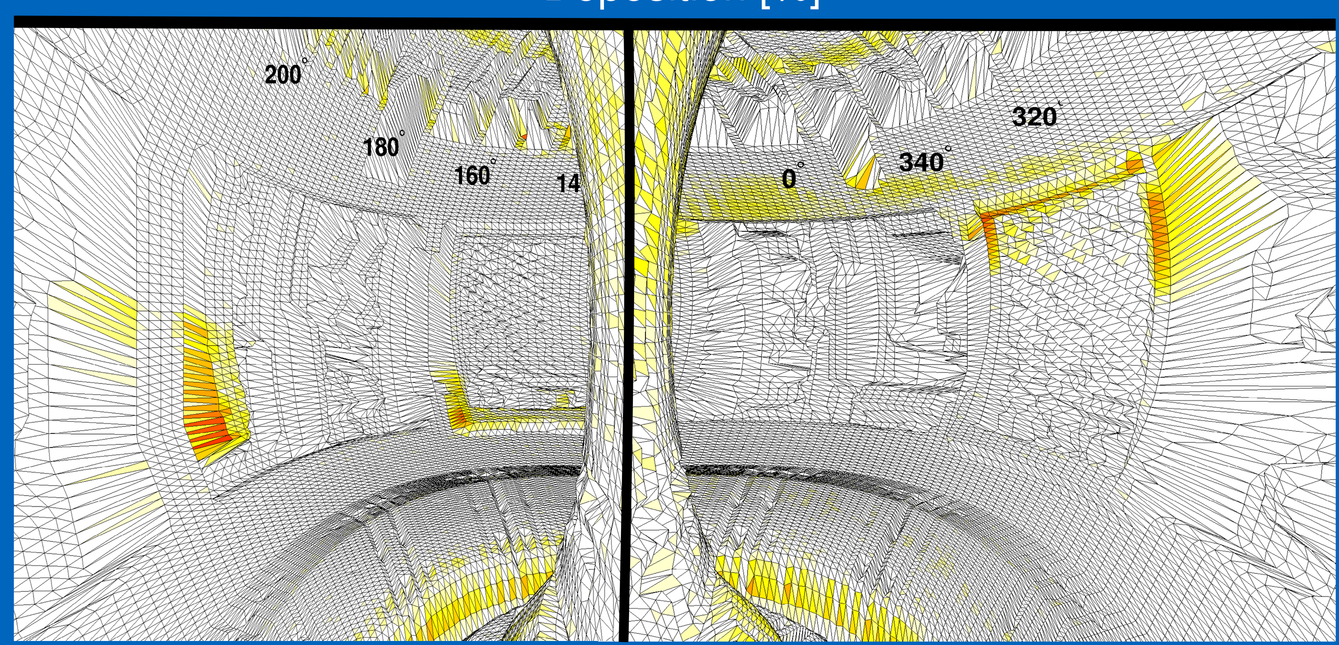
Trace-element injection experiments on AUG

- In 2007 on the ASDEX Upgrade tokamak, the migration of carbon was studied with **trace-element injection experiments** [1]
- **Methane** ($^{13}CH_4$) was **injected** into the torus during L-mode discharges, and carbon deposition on the wall surfaces was studied with post mortem **analysis of samples from selected wall tiles**
- **Deposition** was observed to be **strongest at the inner divertor**
- **Only less than 10 % of the injected carbon could be accounted for when the deposition was assumed to be toroidally symmetric**

Modelling of ^{13}C transport with ASCOT

- ASCOT has been **upgraded** to permit simulations of **impurity transport**
  - Plasma flow is now taken into account in Coulomb collisions
  - An atomic physics model has been developed
- **The experiments were modelled with ASCOT** using a background plasma from DIVIMP onion-skin model solver [2]
- Notable deposition at the inner divertor was achieved only when imposing a more realistic background plasma flow field
- **Protruding wall structures** such as limiters were observed to collect **highly localised deposition**
- **Magnetic ripple** caused **periodic deposition patterns** in the toroidal direction
  - However, the effect was significant only when using an axisymmetric wall geometry





Conclusions

- The results **highlight the importance of toroidal asymmetry**, especially regarding wall geometry, in impurity transport studies
  - A possible explanation for the missing carbon in the experiments
- **Further development** is still needed in order to acquire **a more realistic model**
  - The effect of a **parallel-B temperature gradient** on transport needs to be considered (the temperature gradient force)
  - Modelling of **sticking and erosion of deposited particles** is required for **extending the studies towards migration** of impurities

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References

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