TEC

# Modelling of ITER-relevant PSI processes using the ERO code: atomic data use and needs

## / ADAS workshop /

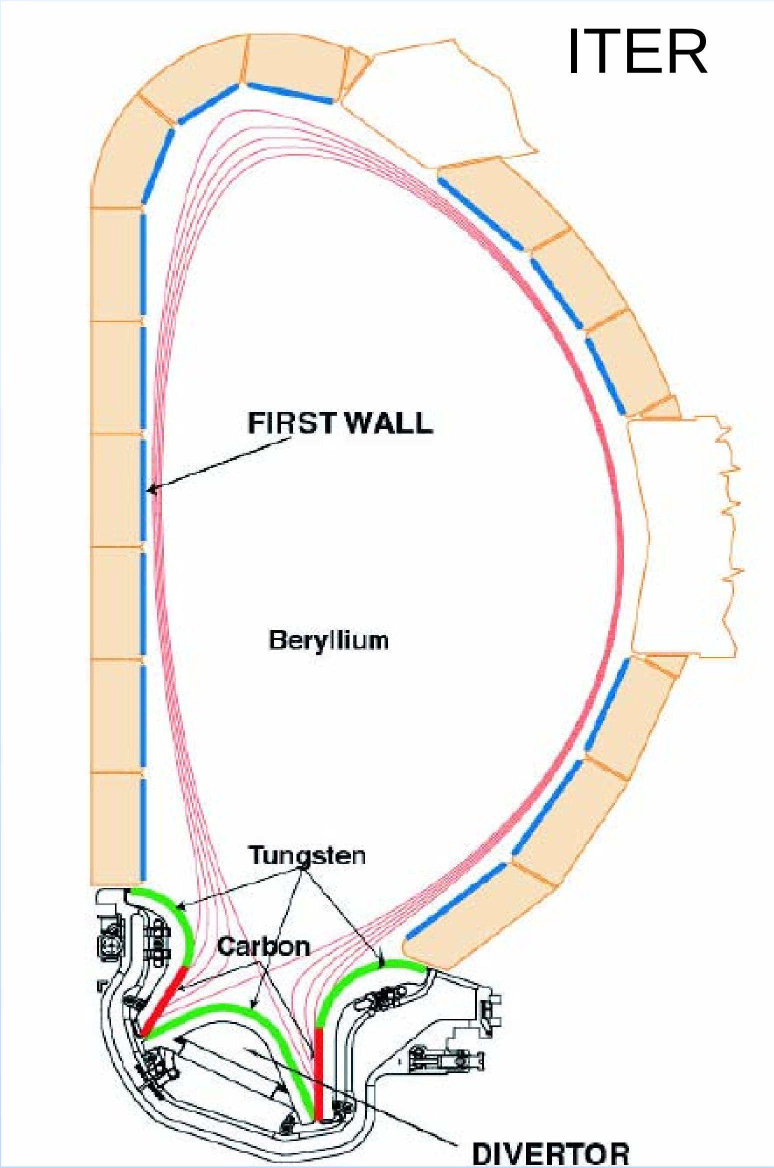
**D.Borodin, A.Kirschner, S.Droste, Ph.Mertens, V.Philipps, S.Brezinsek, A.Pospieszczyk**
***Institut für Plasmaphysik***, *Forschungszentrum Jülich, EURATOM-Association, TEC, Germany*

**R.Doerner, D.Nishijima and PISCES-B team**
***University of California***, *San Diego, CA, USA*

# Outline

1. Motivation: predictive modelling for ITER
2. Examples of benchmarking experiments
   - TEXTOR – test limiter of various shapes
   - PISCES-B
3. Recent changes in ERO atomic model
4. Summary

# Motivation




**700 m² beryllium first wall**
- **low Z**
- **oxygen getter**

**100 m² tungsten baffles, dome**
- **high Z**
- **low sputtering**

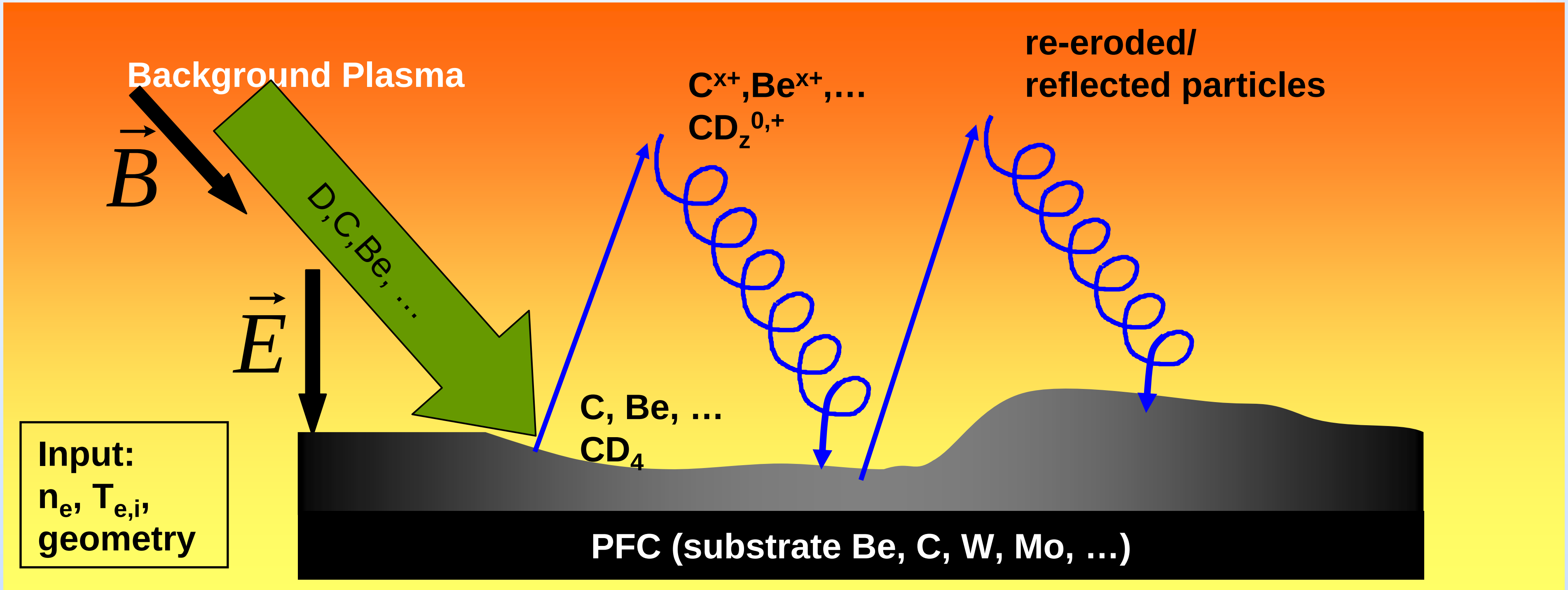
**50 m² graphite CFC target plates**
- **no melting**

**Erosion of wall materials, transport and re-deposition →**

**- Lifetime & tritium retention**

**- Material mixing effects**

# The ERO code



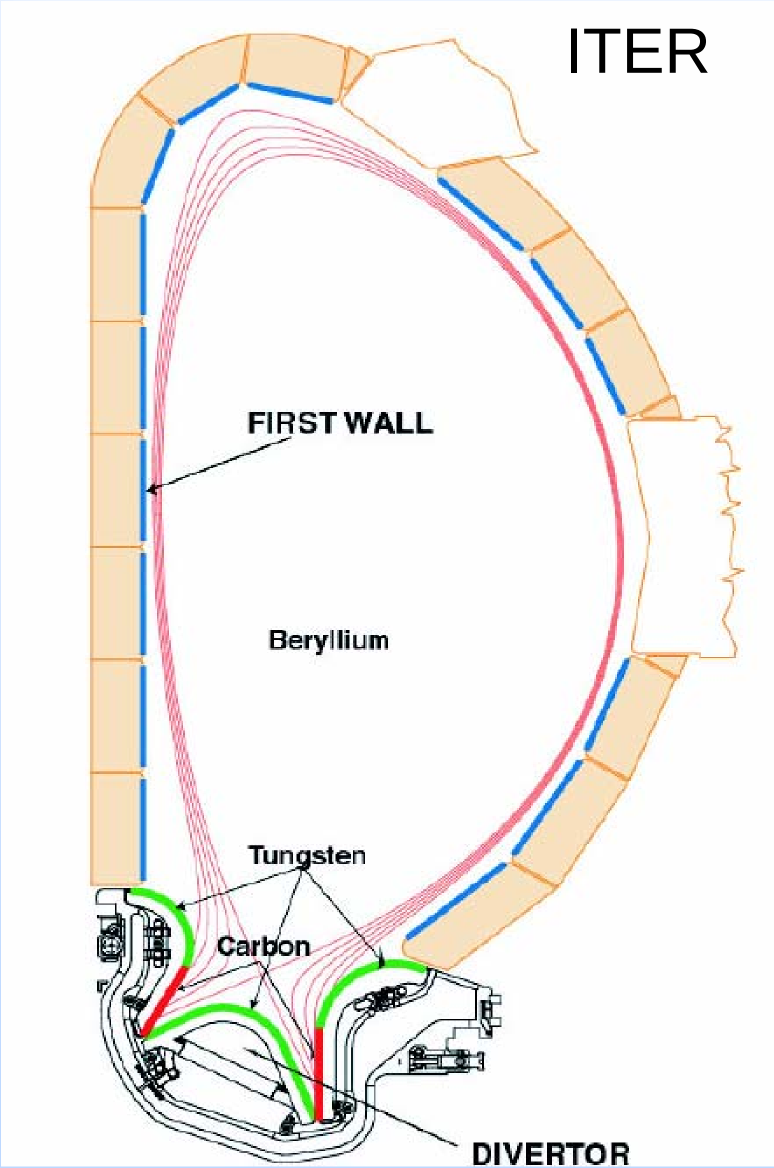

**Local transport:**

- ionisation, dissociation
- friction (Fokker-Planck), thermal force
- Lorenz force (including ExB component)
- cross-field diffusion

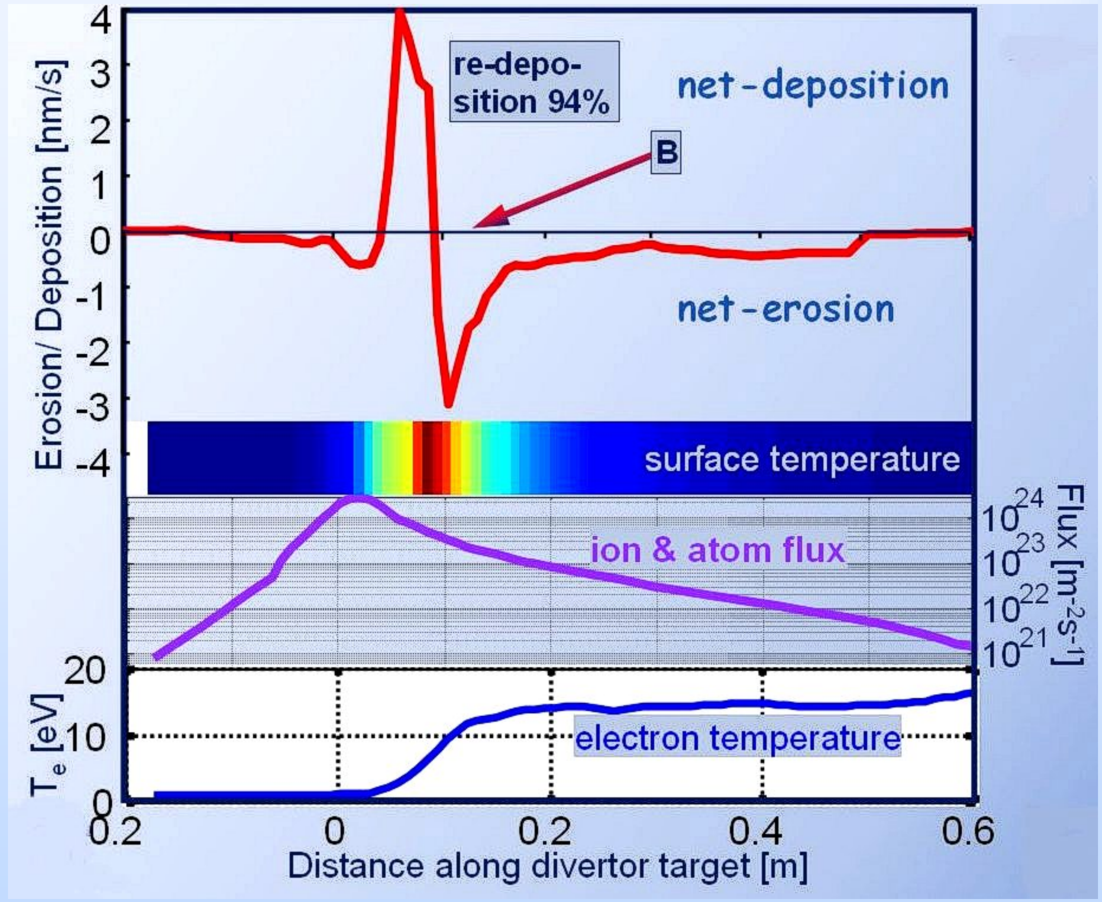
**Plasma-surface interaction:**

- physical sputtering/reflection
- chemical erosion ($CD_4$)
- (re-)erosion and (re-)deposition
- NEW: coupling with TRIDYN

# Predictive modelling



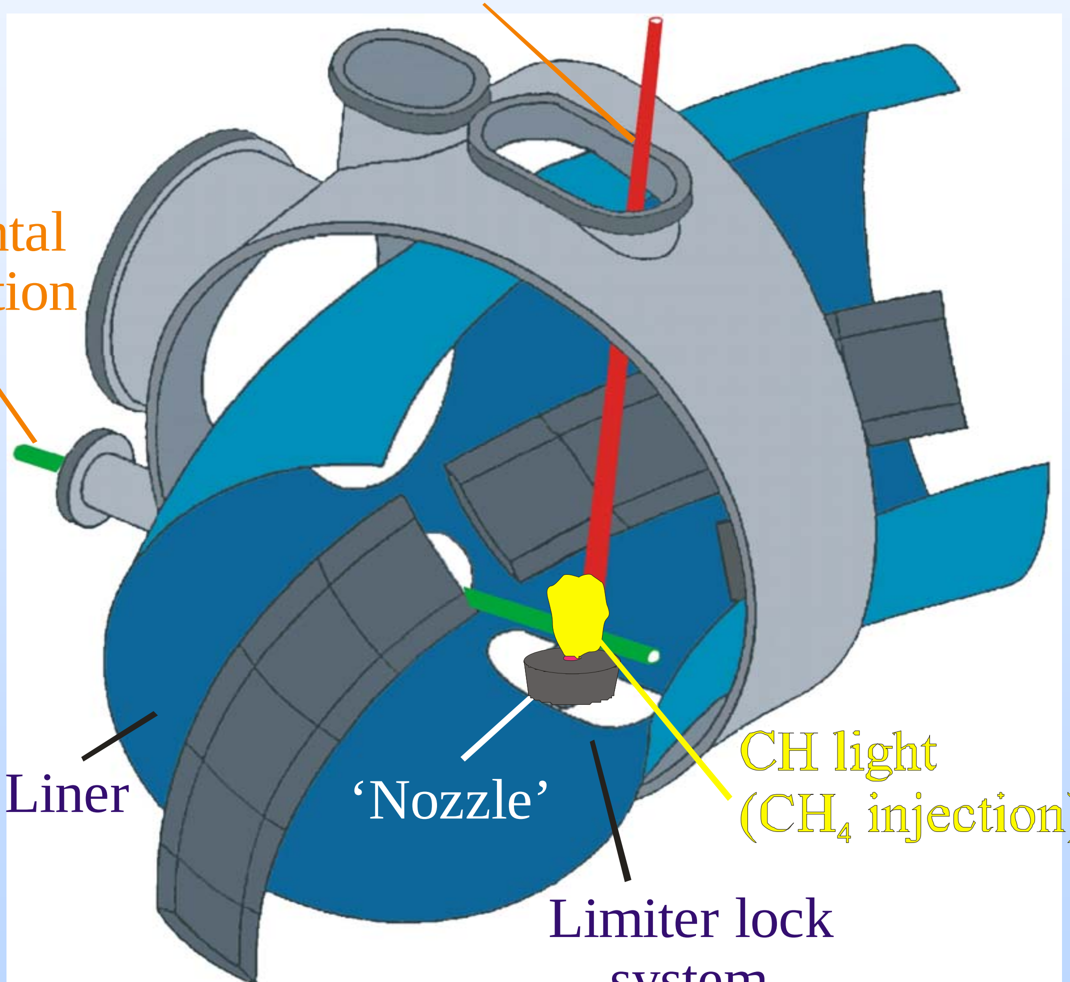

## Divertor plate



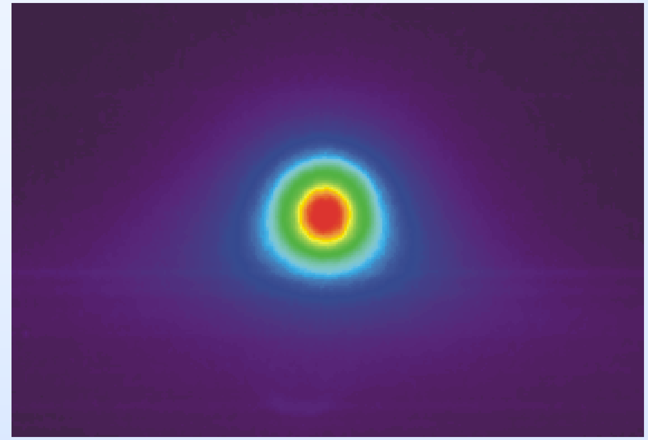

Predictions for ITER availability depend on model development . . .

# Examples of ERO application ("benchmarking experiments")

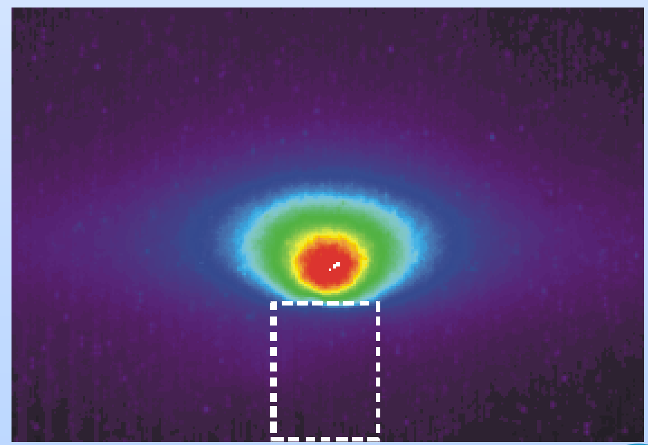
# ‘Limiter lock’ experiments at TEXTOR



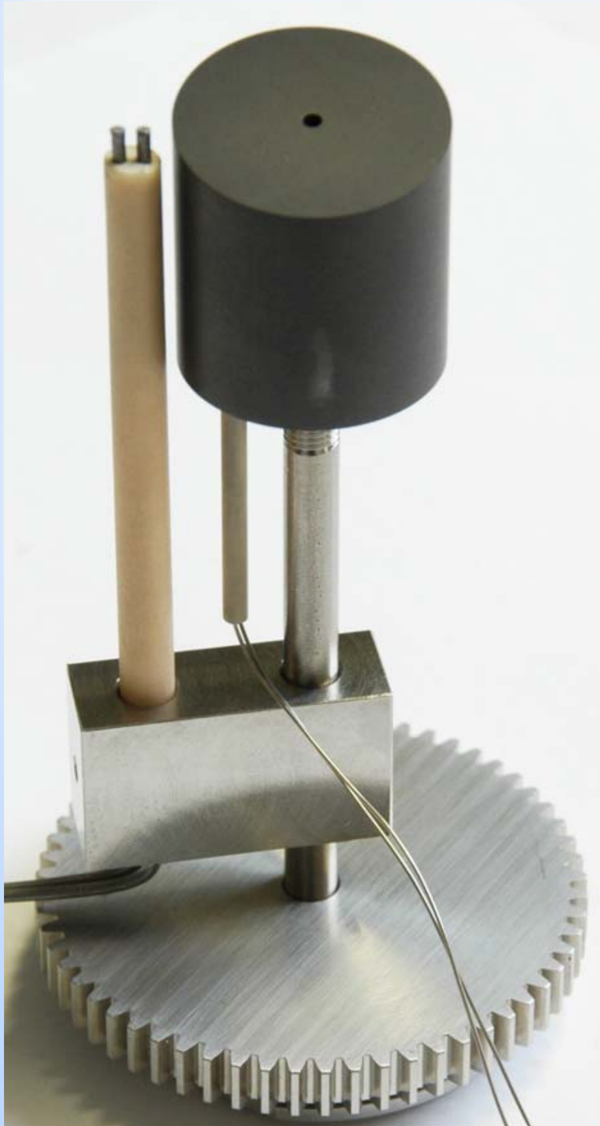

CH emission top view



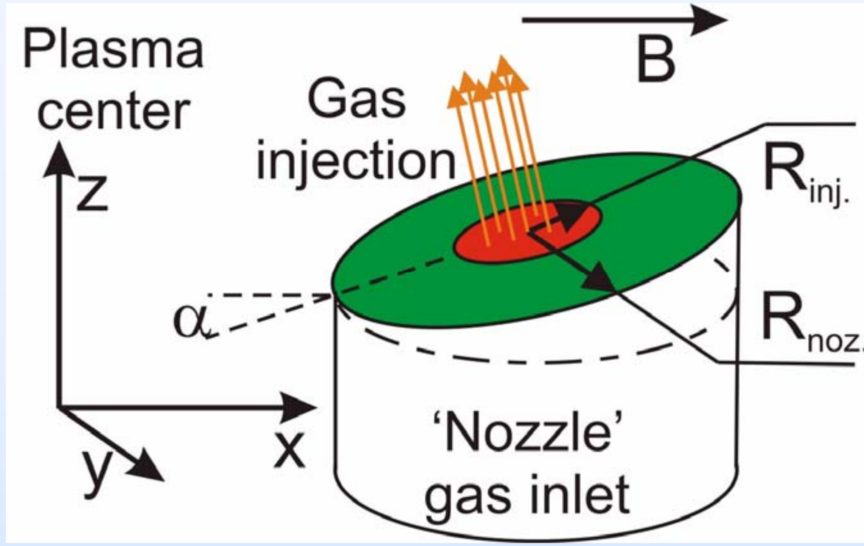
CH emission side view

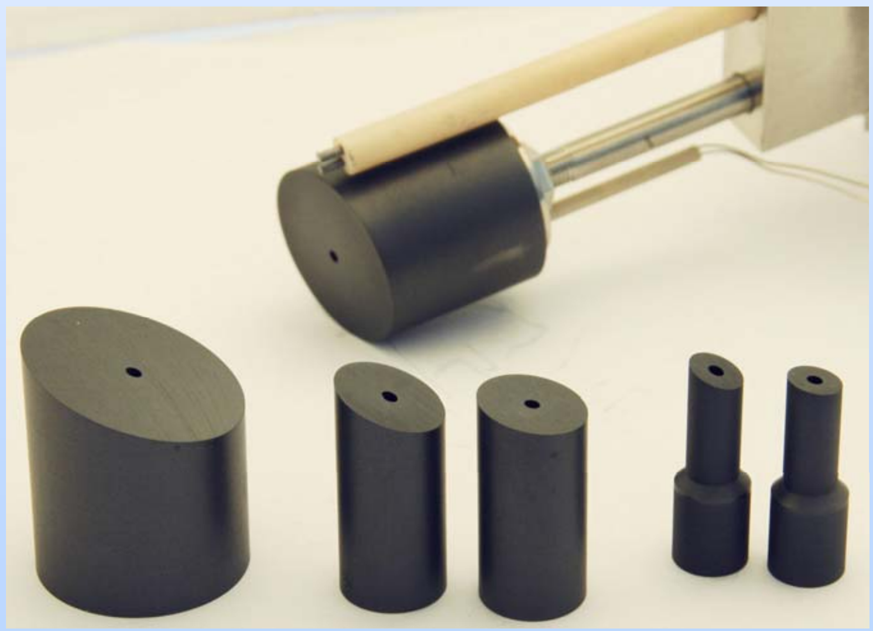


# New $C_xH_y$ injection experiments at TEXTOR



Photos: Harry Reimer



**Diameter:**

7, 14, 28 mm

**Angle α:**

10°, 20°

**Material:**

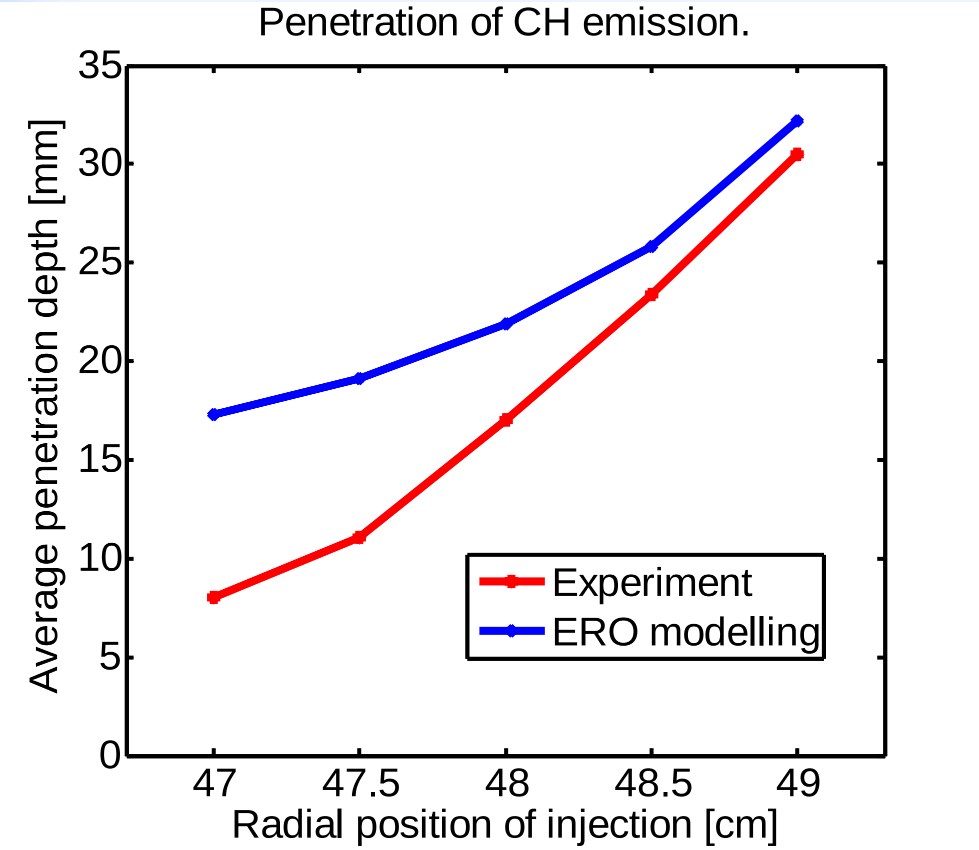
carbon

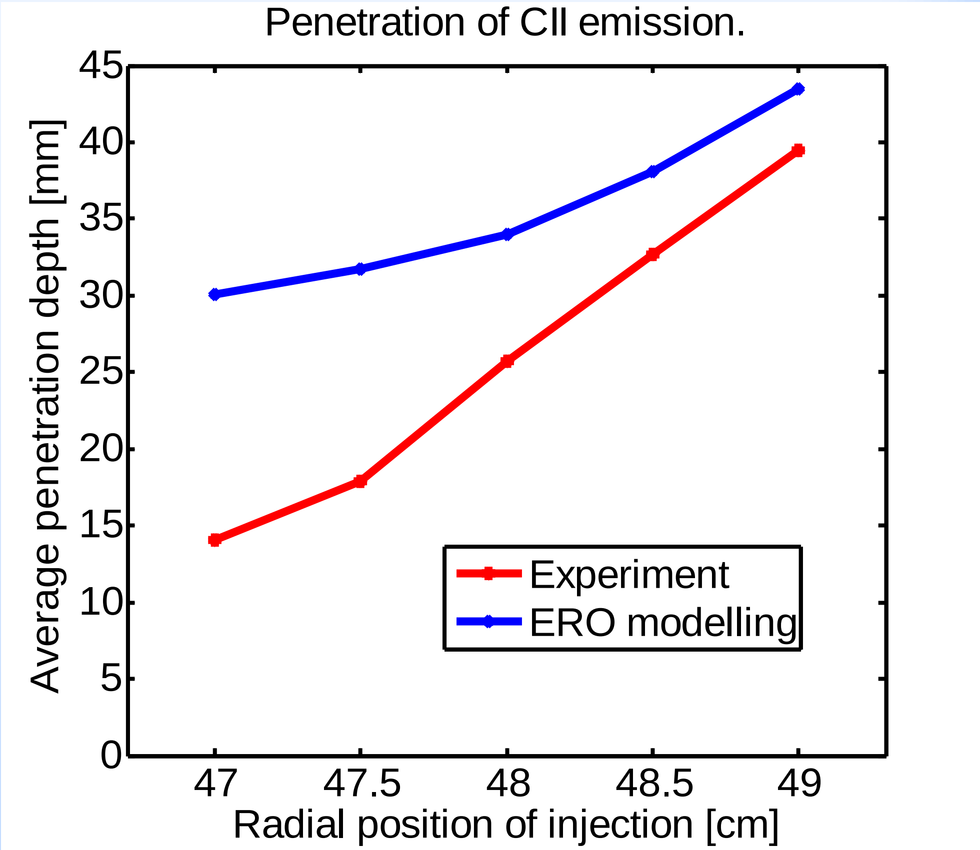
**Outlook:**

different materials, e.g. tungsten

# 'Nozzle' radial position - penetration depths

Absolute values!

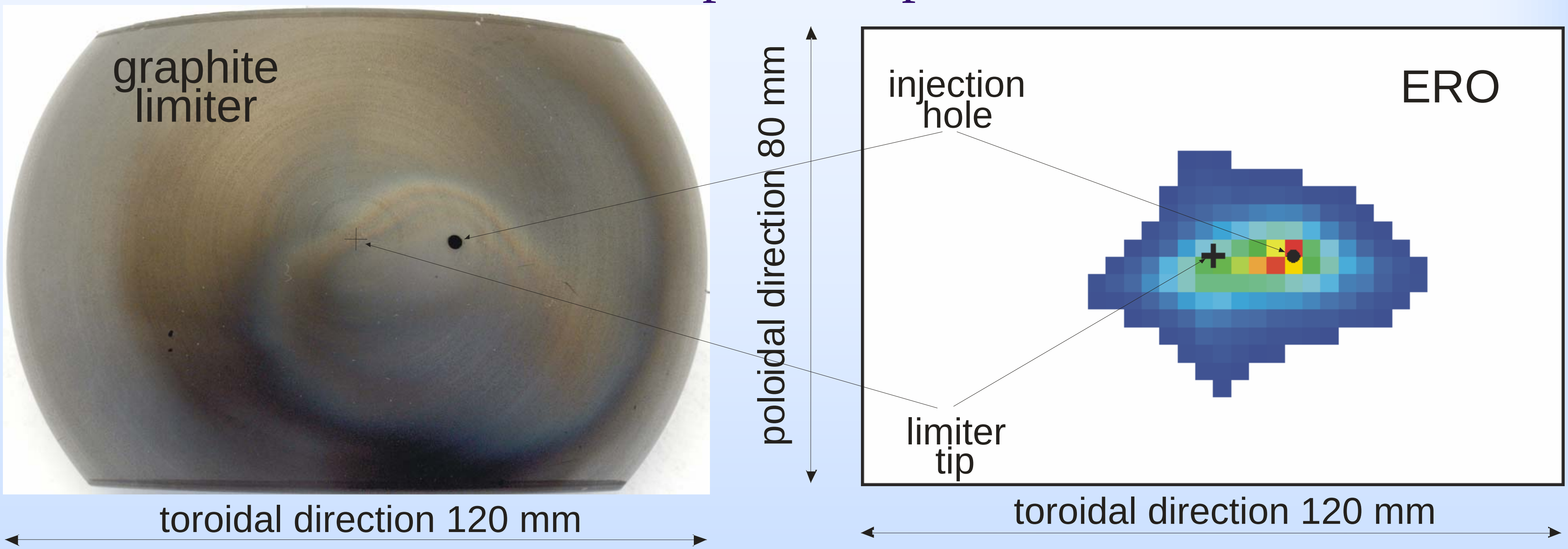


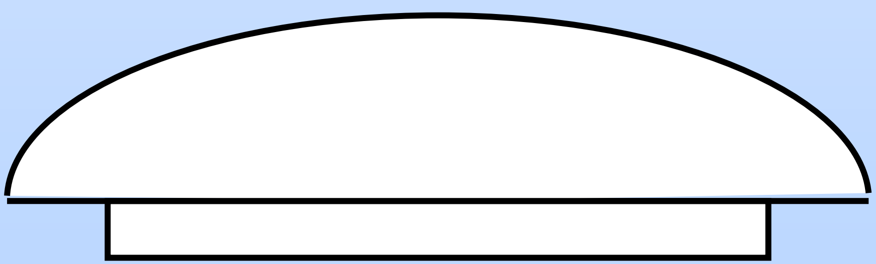

Large part of deviation can be explained by the uncertainty in the radial position

# Example 2: $^{13}CH_4$ injection in TEXTOR (mushroom test-limiter)

## Carbon deposition pattern




## Limiter side view

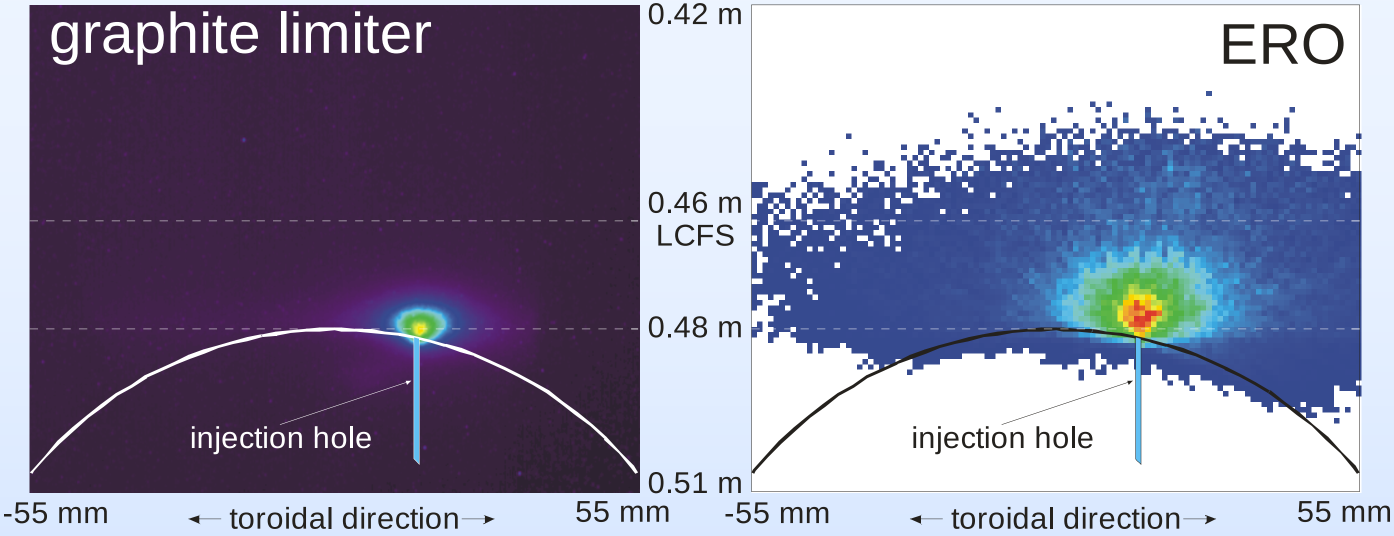


## Surface analysis:

NRA (Nuclear Reaction Analysis), RBS (Rutherford Back-Scattering), SIMS (Secondary Ion Mass Spectrometry), interference fringe analysis, …

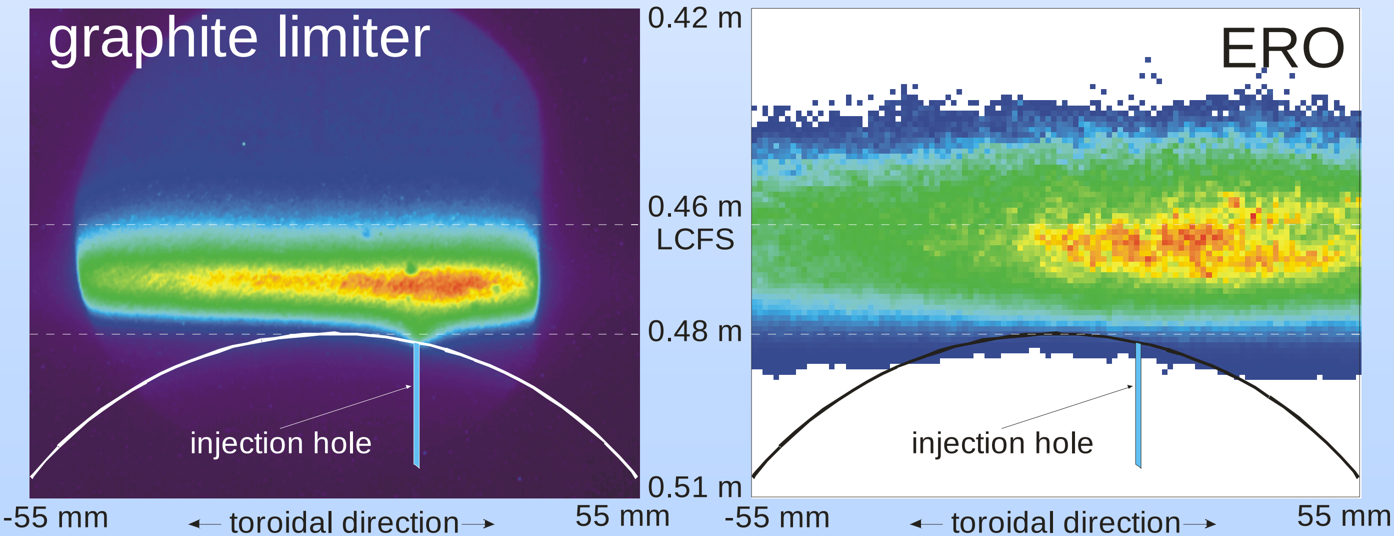
# $^{13}CH_4$ injection through mushroom limiter

## CH+CD emission




The ERO modelling results are in a general agreement with the experiment

## C III emission



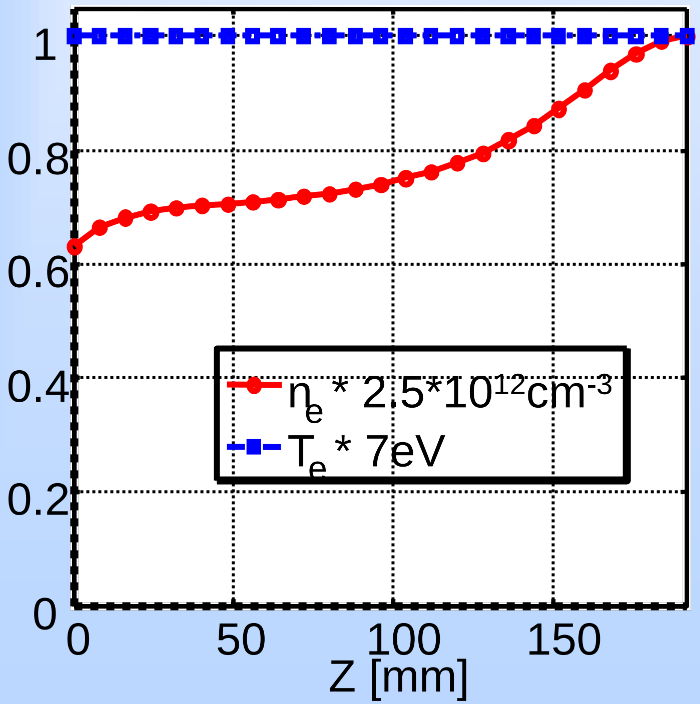

***Are the existing deviations caused by plasma parameter uncertainties or by the crudeness of our spectroscopy model?***

# PISCES-B

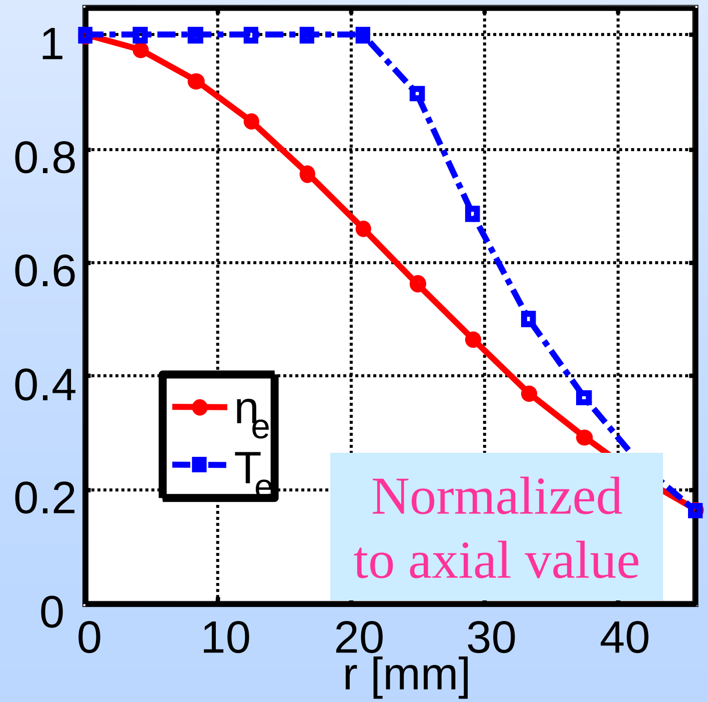
- Linear divertor plasma simulator
- ITER-relevant plasma conditions
- An oven to seed Be into the plasma.
- Exchangeable targets made of C, Be, W, etc.

## Plasma parameters in PISCES

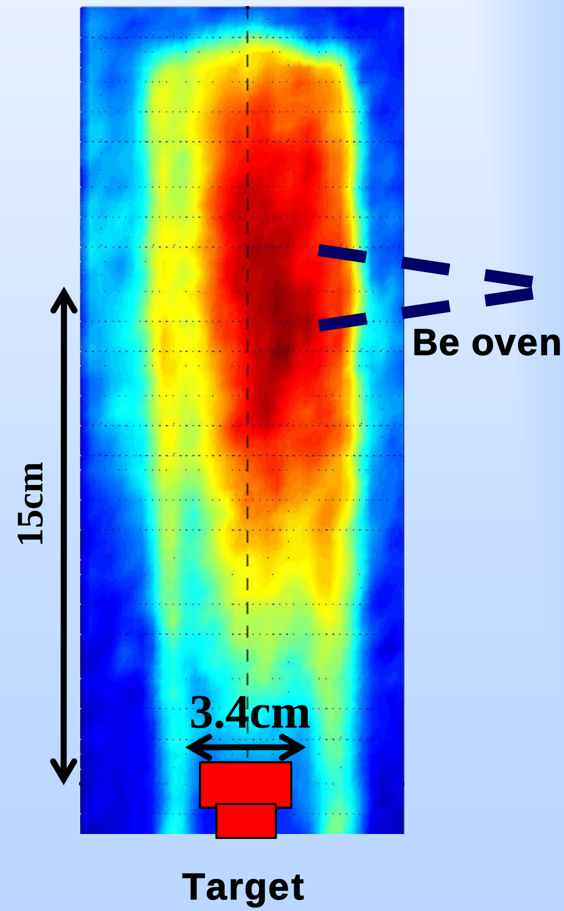
Axial dependence:




Radial dependence:

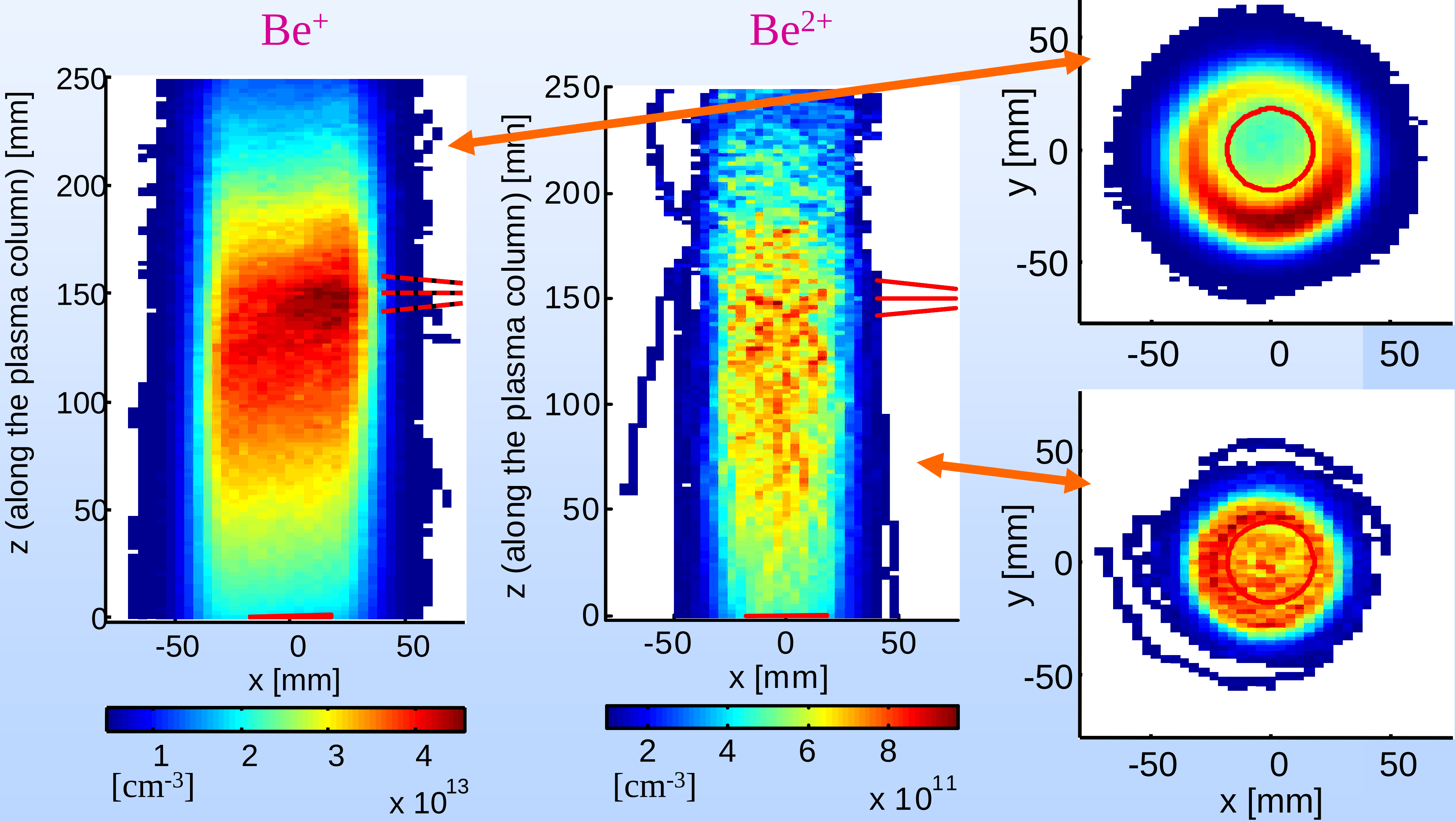



**BeI emission pattern (example)**



# Modelling of Be transport: $Be^{+}$ and $Be^{2+}$

## Be density



# Be transport (EPS 2006, Rome) – summary

1. **Angle distribution** of injected Be from oven **can not itself help** to reproduce spectroscopy patterns observed at PISCES: Be and $Be^+$ density have strong peak near oven.

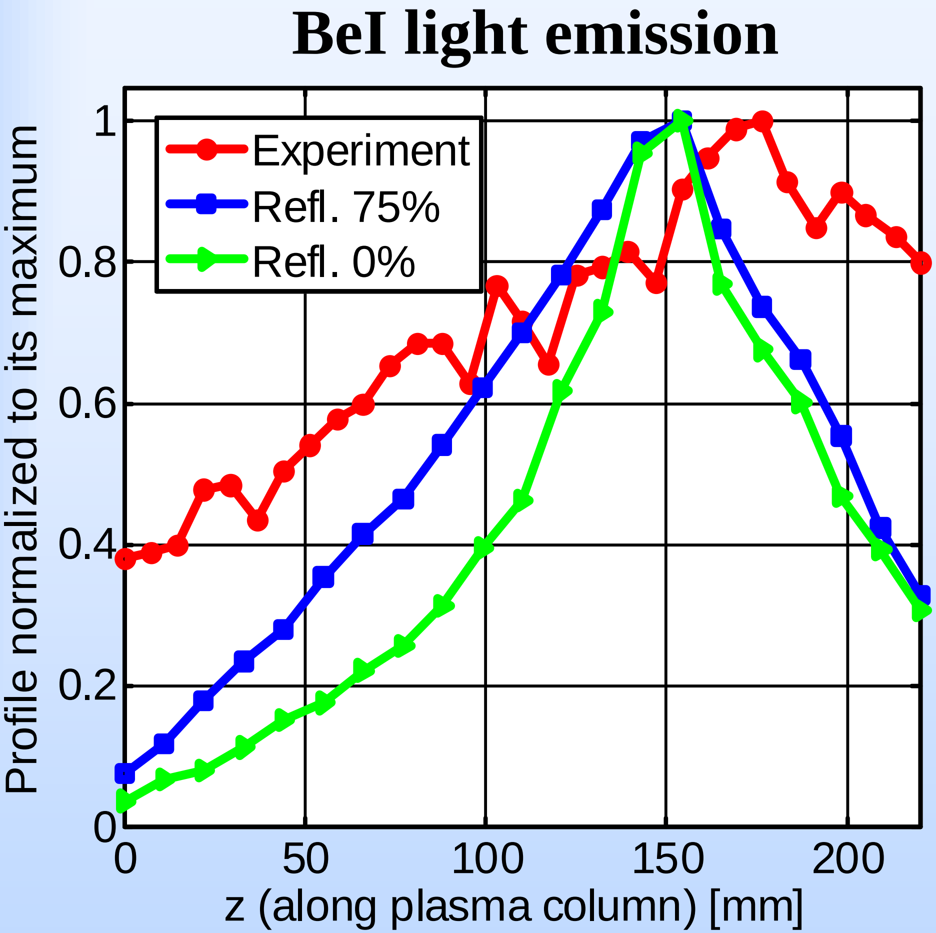
2. **Collisions with neutrals** lead to broadening of modelled Be density. At that the angle distribution looses its importance.

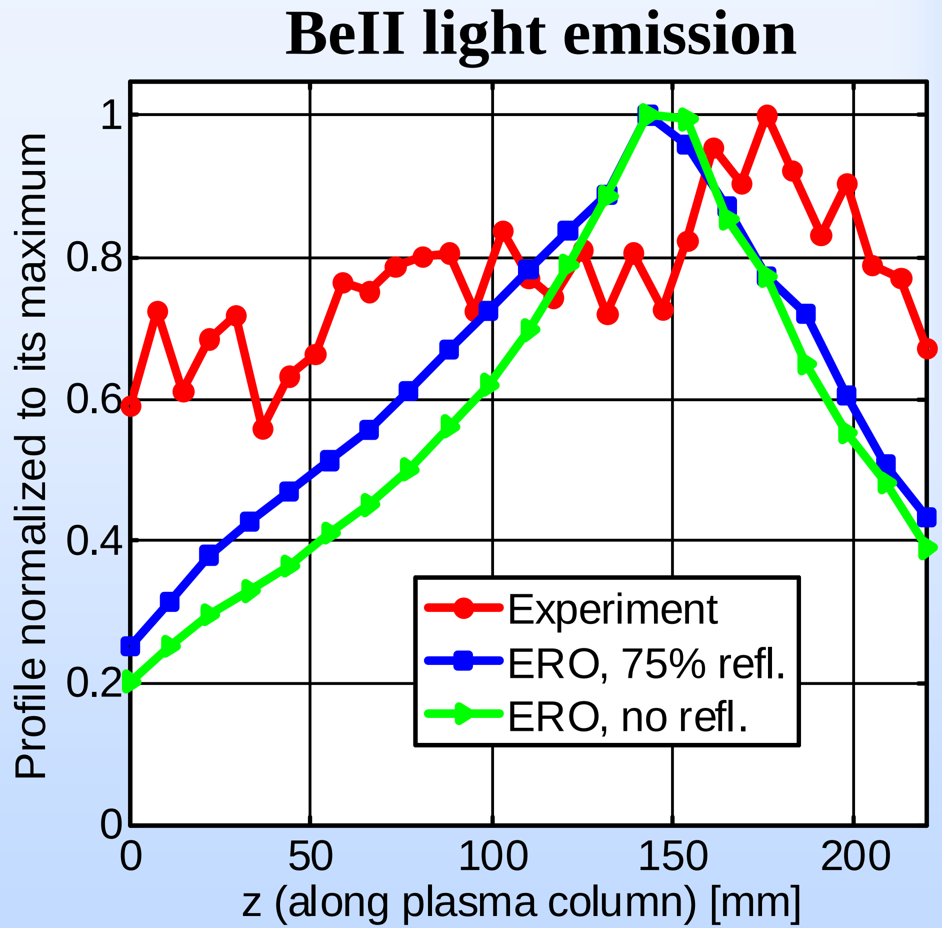
3. Effective **reflection** (> 75%) of Be from wall is necessary to reproduce high density of neutral Be near target.

   - ***Effective parameter! The physics behind it is not yet understood . . .***
   - ***Possible explanations: recombination or charge exchange, self-sputtering, neutrals density gradient, . . .***

**We understand transport of injected Be well enough to proceed with next modelling steps!**

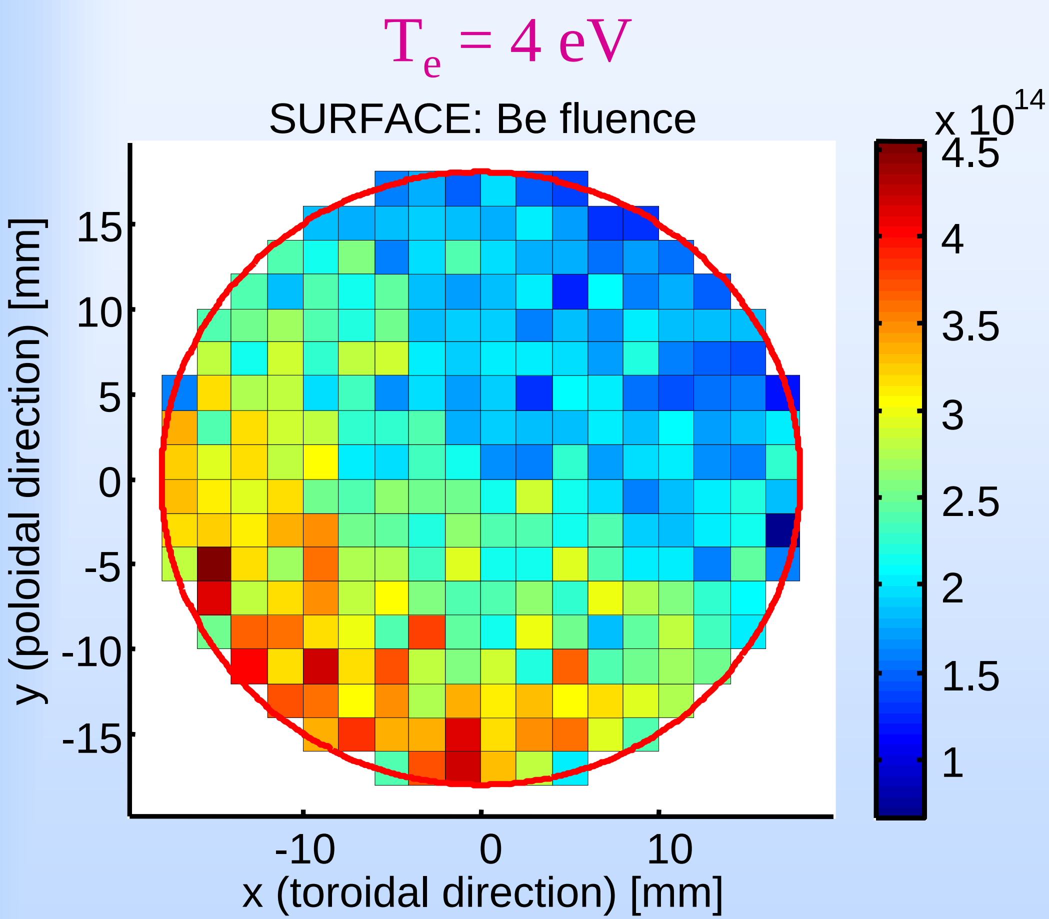
# Modelling of spectroscopy pattern – axial profiles

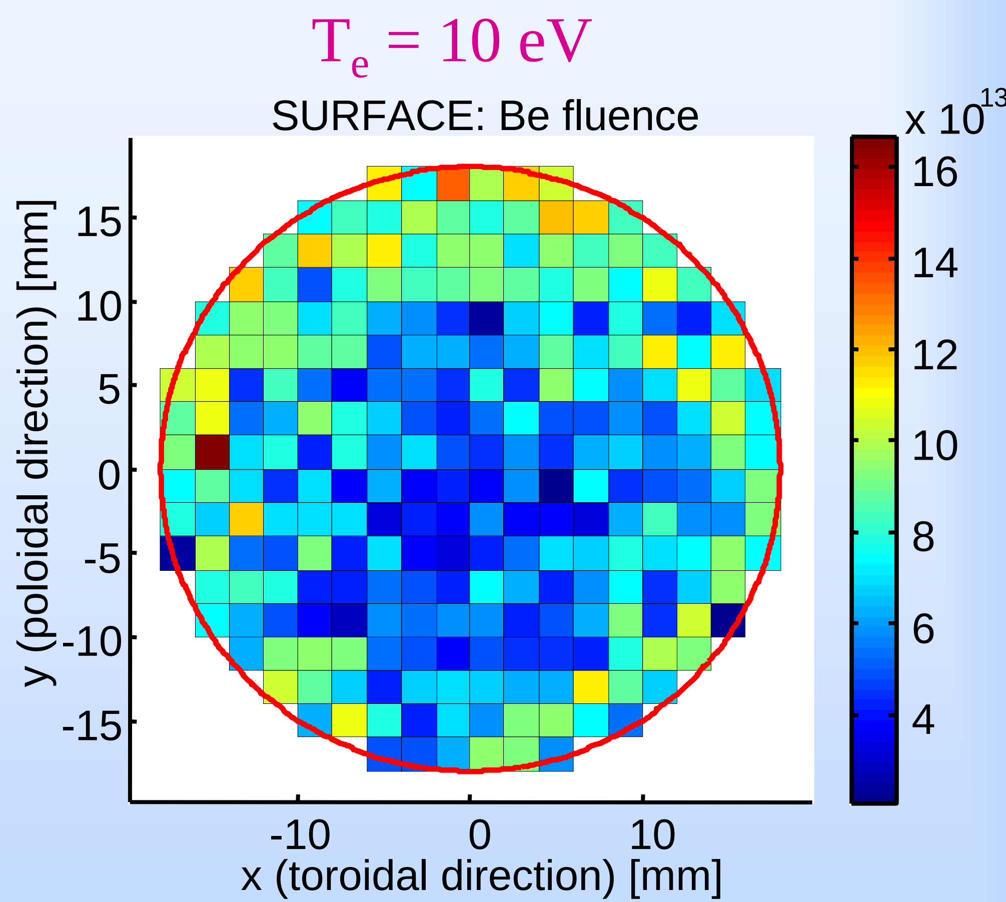



Now modelled profiles are in reasonable agreement with experiment – remaining deviations can be explained by changing plasma parameters (EPS-2006).

# Fluence of Be – illustration for influence of $T_e$

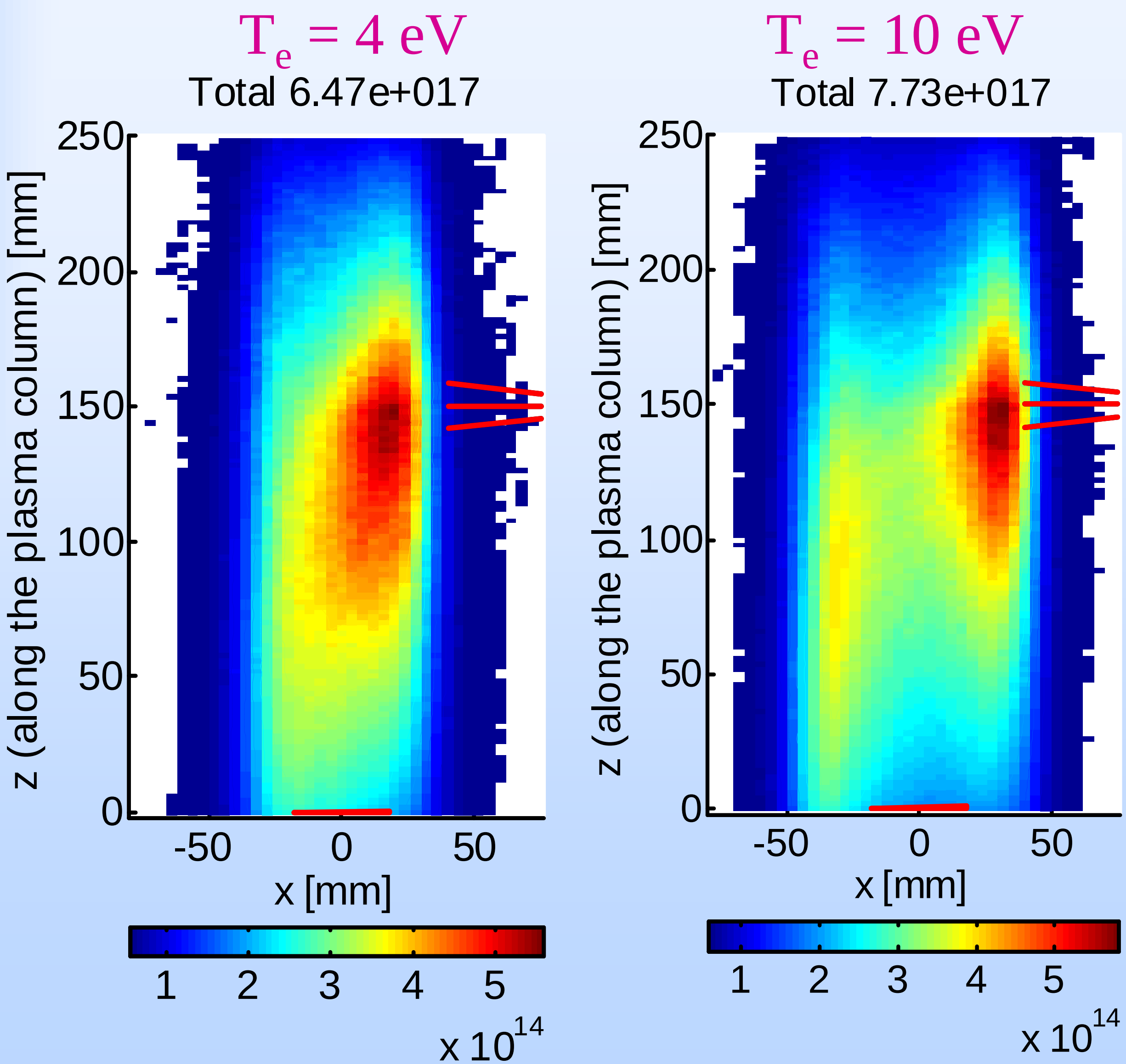



Essential difference in distribution of fluence along the surface for different ***plasma parameters***

# Fluxes – illustration for influence of $T_e$

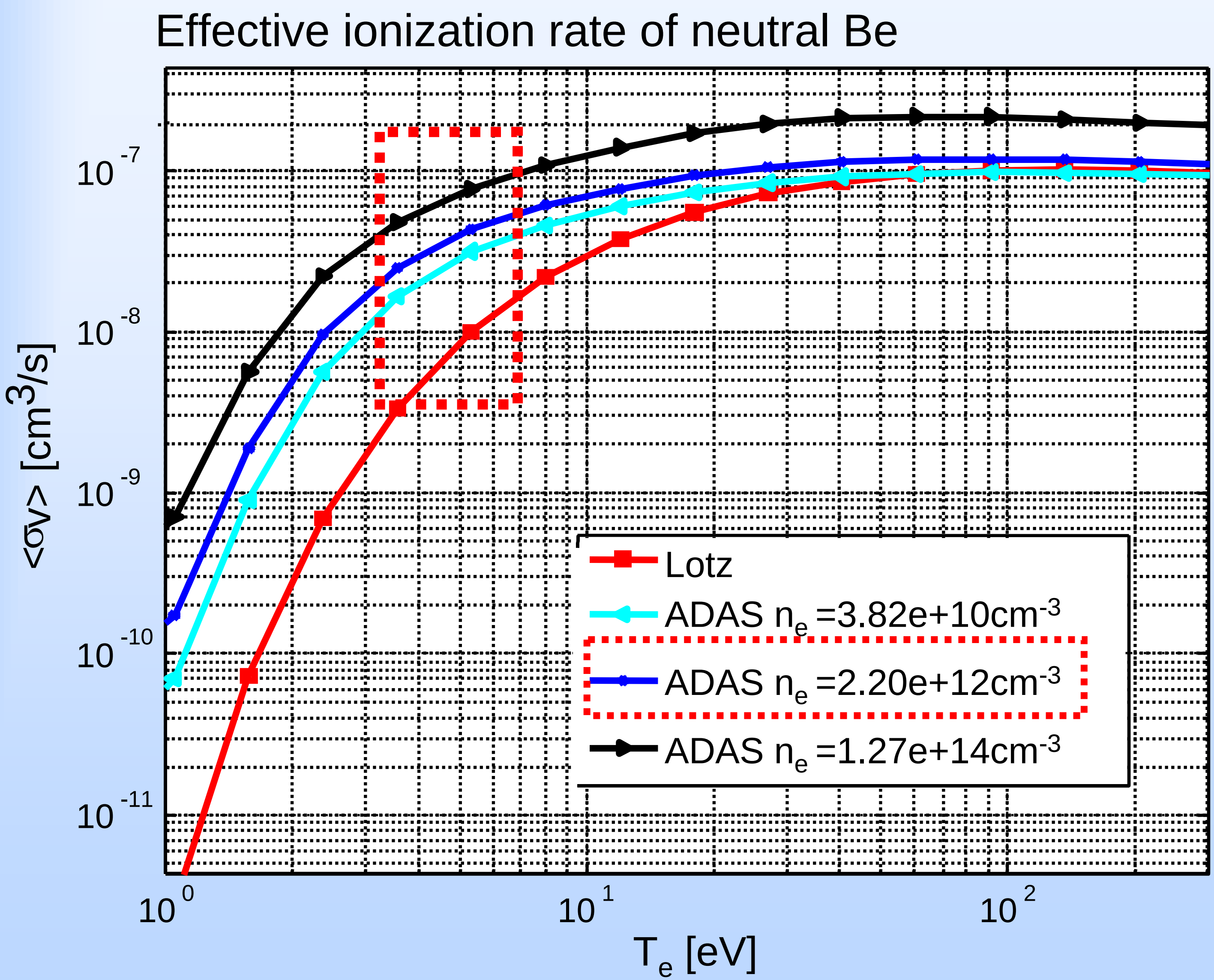
## $Be^+$ density




The distribution of flux impinging the target is defined by transport pattern

The transport pattern is obviously affected by the ionization

# Implementation of ionization data from ADAS

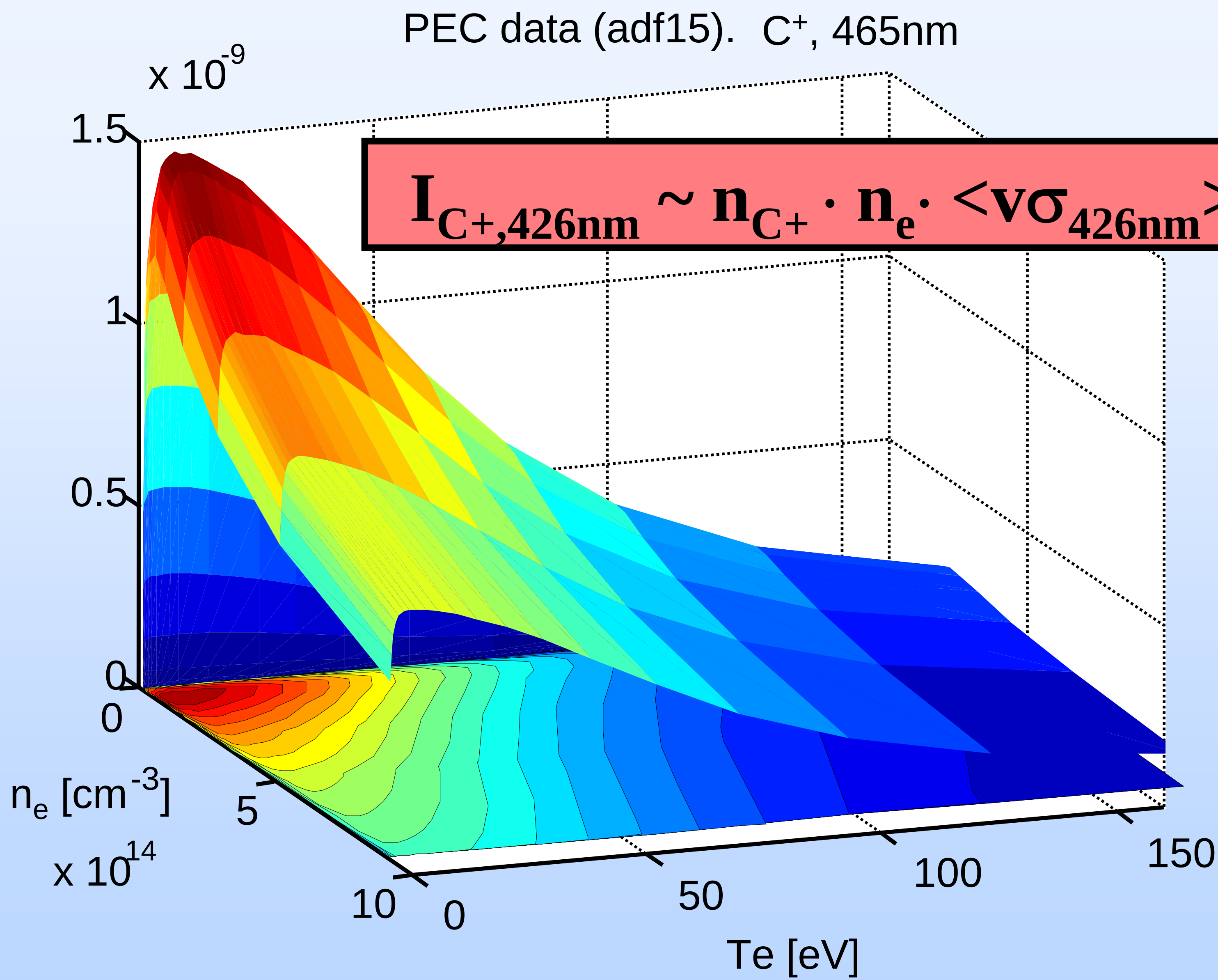



Dependence of rates also on $n_e$ provided

Changes in the ionization data are of great importance for PISCES modelling

# Effective rates: dependence on density (example)

$$I_{C+,426nm} \sim n_{C+} \cdot n_e \cdot \langle v\sigma_{426nm} \rangle_{eff.}(T_e, n_e)$$



# ADAS data used in ERO already

1. Effective emission (PEC) – adf15
2. Effective ionization – adf11
3. Effective recombination –adf11

# Reorganization of database

1. Back-compatibility with the data used before
2. The data is imported according to special files containing references to a) old ERO data b) dummy data c) data in Matlab format d) ADAS data
3. Conversion and 2D interpolation provided
4. Object-oriented programming (C++) makes easier further improvement (multi-D, metastables)
5. Output and control

# Conclusion

1. Atomic data are essential the ERO modelling, even in cases where we are mainly interested in other (e.g. PSI) processes.

2. ERO enables interpretation of the spectroscopy pattern in cases, in which geometry, transport, volume distribution of parameters are involved.

3. We need an improvement and an extension of our light emission model. We hope for further data input from ADAS.

   - ***Reorganization of ERO data base (mostly done):***
     *providing more ADAS formats.*

   - ***Extension of ERO data base:***
     *data reduction routines (metastables), tungsten, molecules.*

# The end