MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

Analysis of plasma dynamics in the island divertor of W7-X

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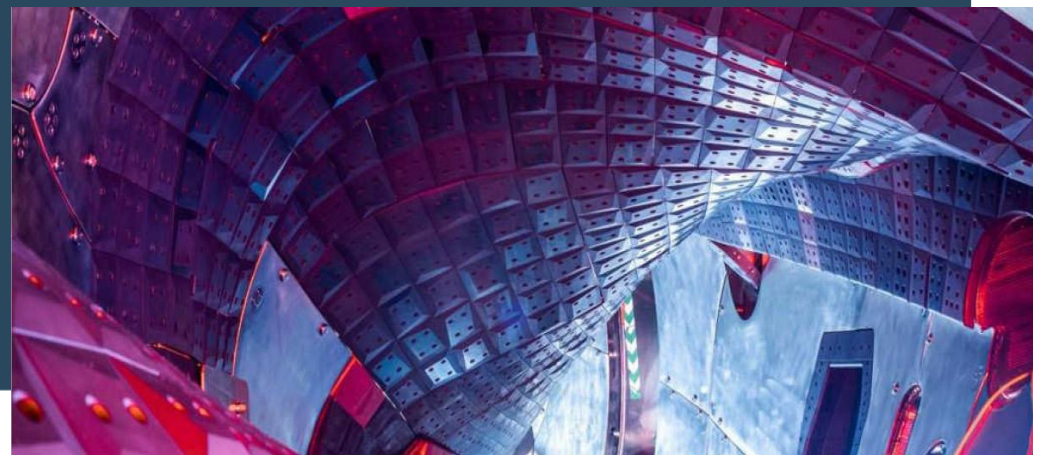

EUROfusion

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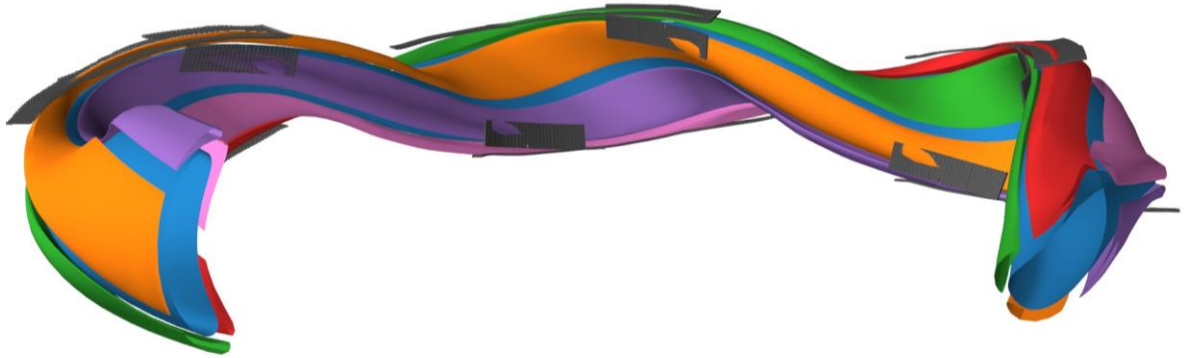
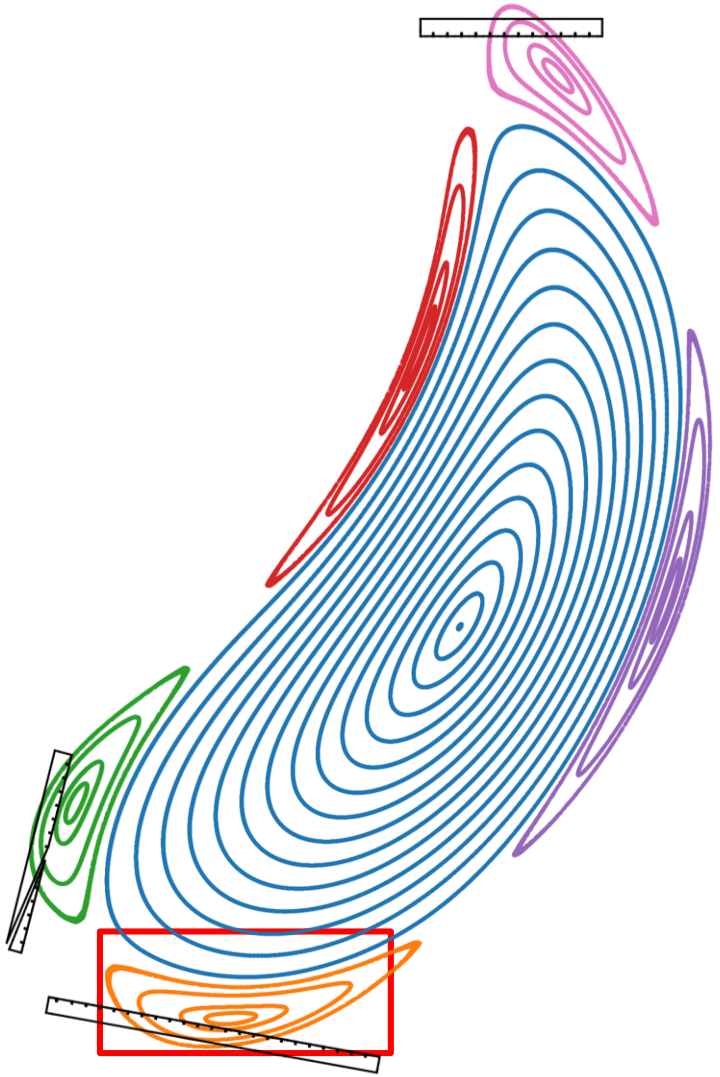
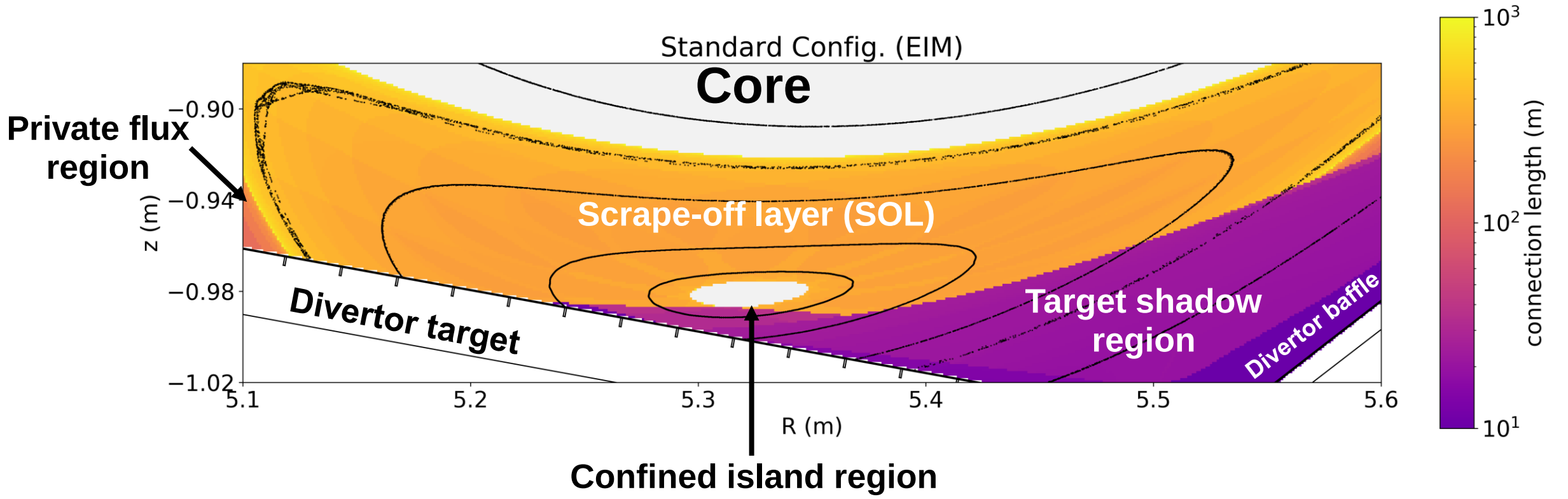
Scrape-off layer of Wendelstein 7-X



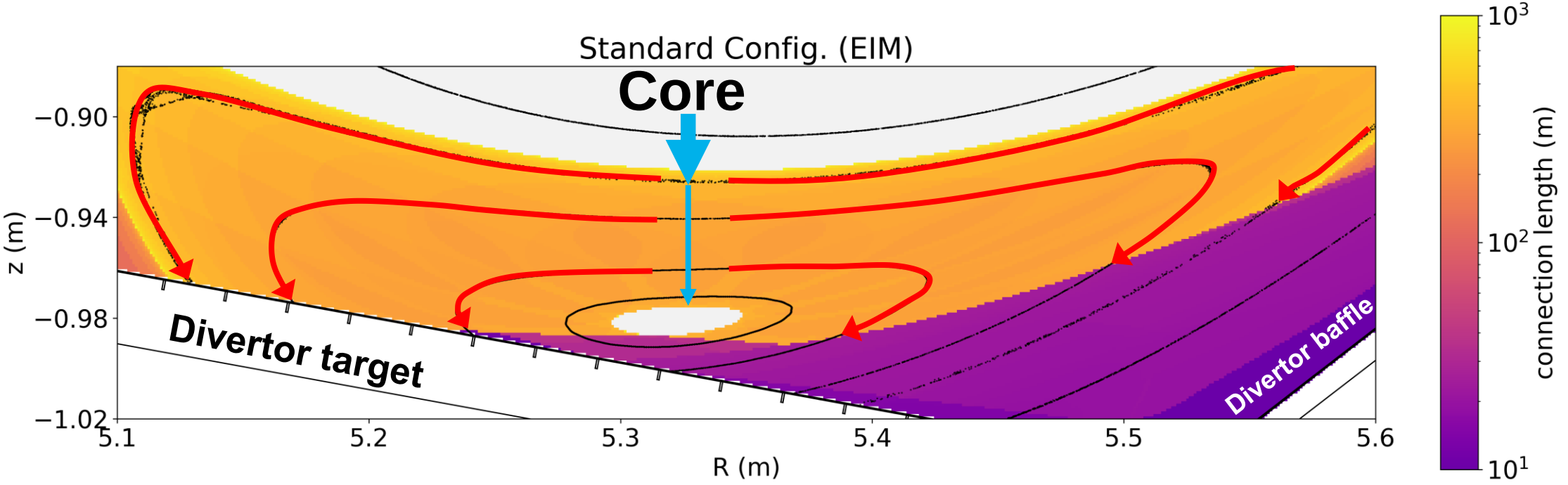


- Complex 3D shape
- Five fold symmetry
- Core plasma surrounded by five magnetic islands
- The islands are intersected by divertor plates which form the island divertor

Transport in the island divertor



Transport in the island divertor



Understanding of profiles and transport in island divertor is critical:

- gives boundary for core plasma
- determines particle and energy exhaust
- determines wall loads

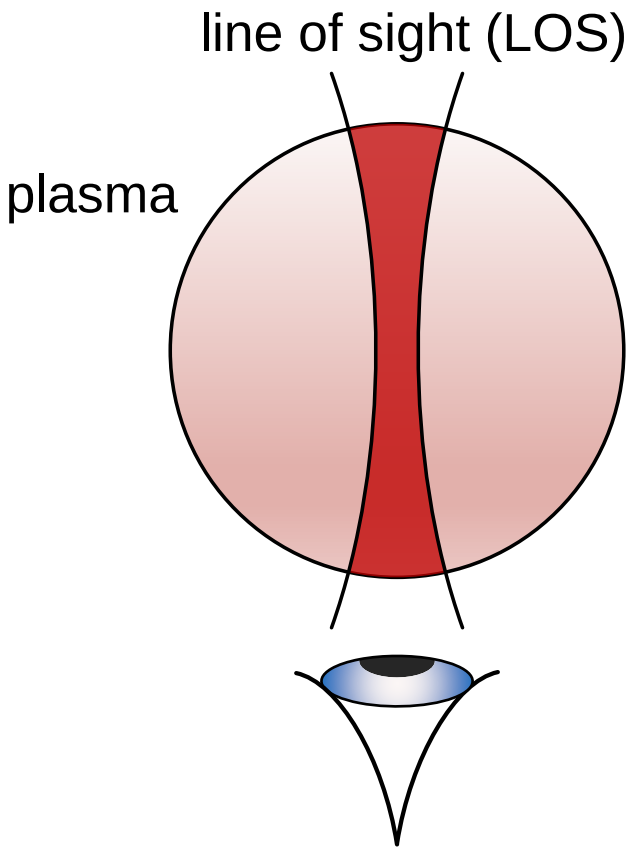
Turbulence and instabilities are key factors:

- drive perpendicular transport
- very efficient due to long connection length

Thermal helium beam diagnostic

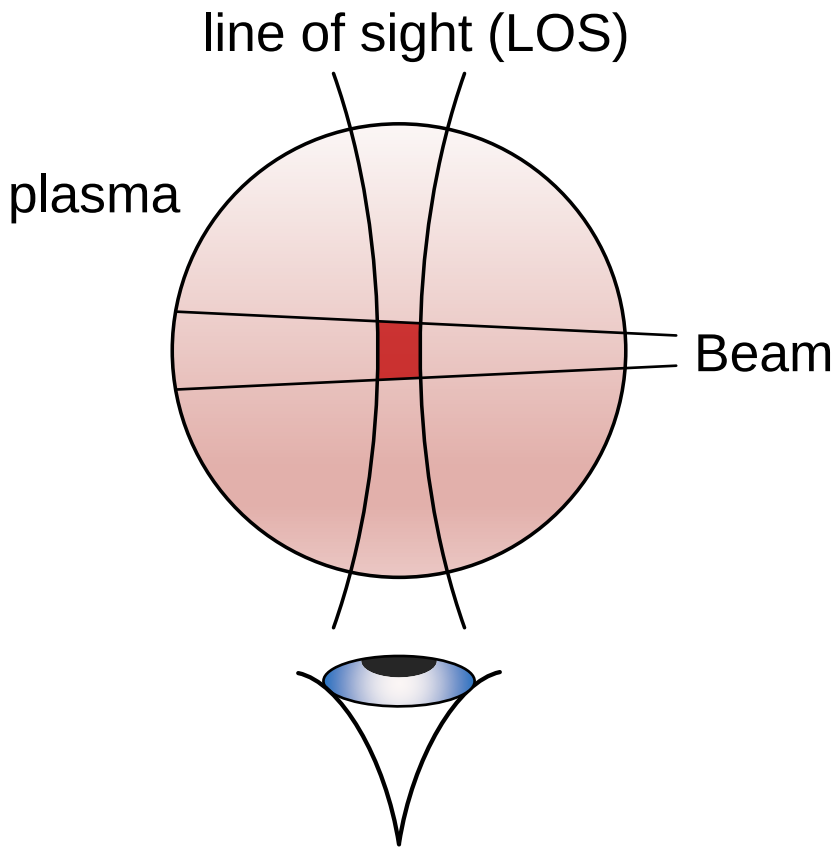
Passive and active spectroscopy

Passive spectroscopy



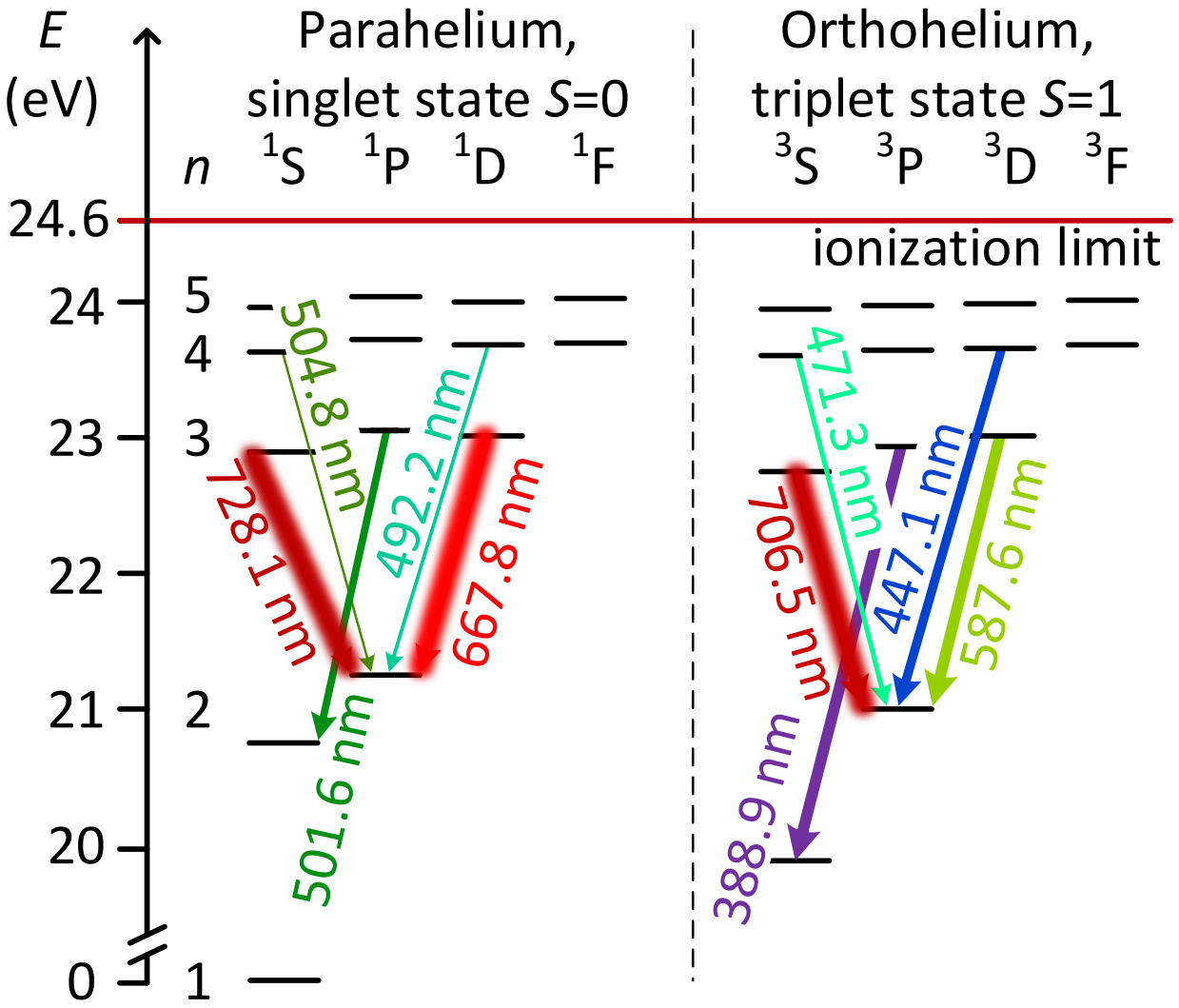
→ **Signal is integrated over the LOS**

Active spectroscopy



→ **Minimization of the observation volume**

Active line ratio spectroscopy

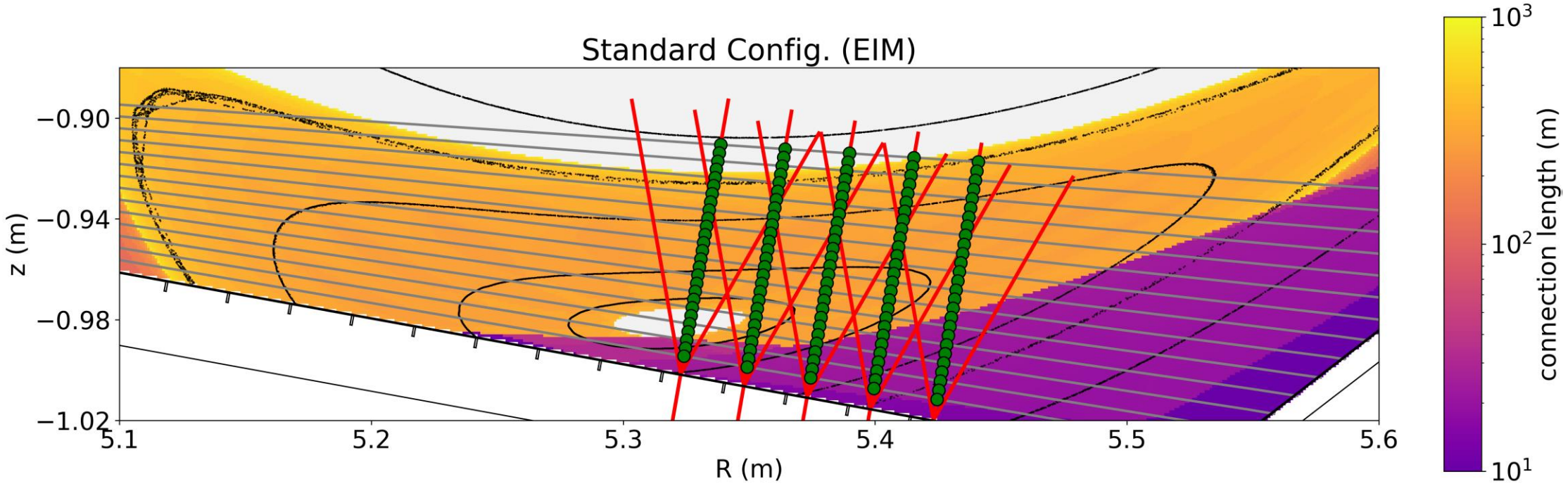


State population density from collisional radiative models (CRMs) dependent on

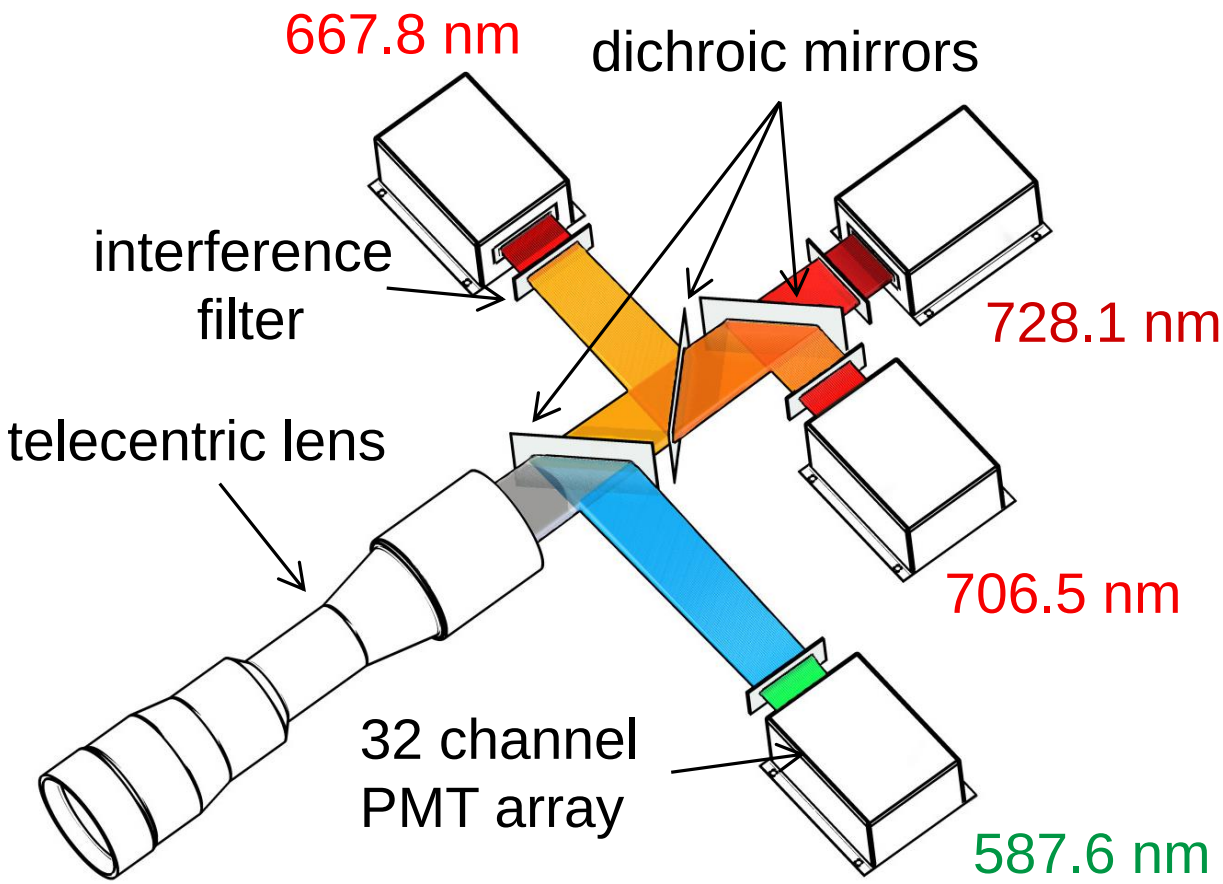
- **electron density n_e (I_{667nm} / I_{728nm})**
- **electron temperature T_e (I_{728nm} / I_{706nm})**

Implementation of the fast helium beam at W7-X

Thermal helium beam diagnostic at W7-X



Fast thermal helium beam diagnostic



- Use in vessel components and LOS of the existing helium beam system
- Existing system: **spectrometer**
  - 40 Hz time resolution
- New: **polychromator system**
  - 32 channels
  - 1 MHz time resolution (25000 faster)
  - 10 kHz T_e and n_e reconstruction (250 faster)
- First volumetric divertor diagnostic with high temporal resolution

Validation of fast system

Standard puff rate:

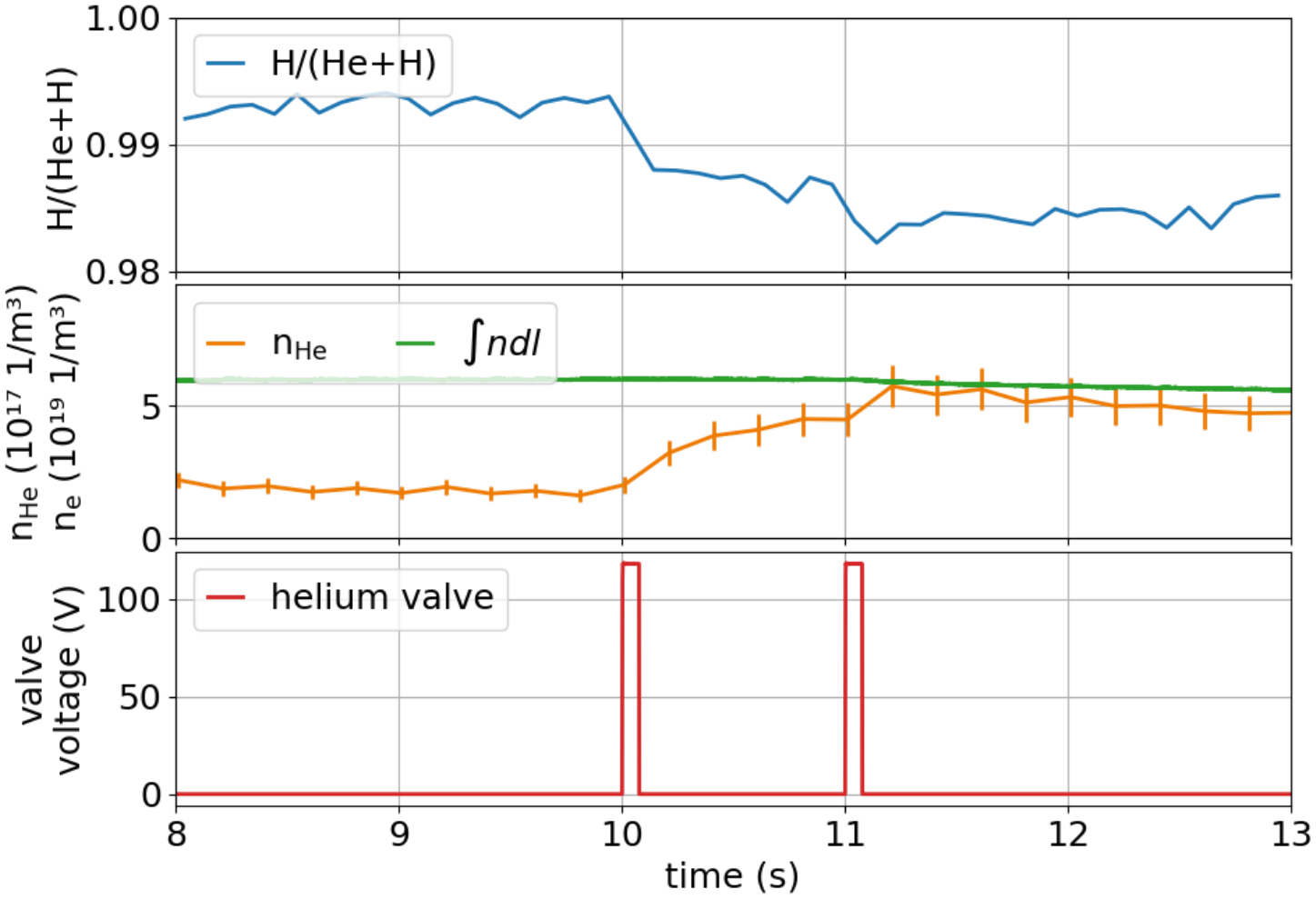
- HGW: $5 * 10^{18}\ 1/s$
- Garching: $2 * 10^{19}\ 1/s$

Fiber core diameter:

- HGW: $160\ \mu m$
- Garching: $400\ \mu m$

→ Factor of about 25 lower intensity

→ Desired puff for polychromator system: $5 * 10^{19}\ 1/s$



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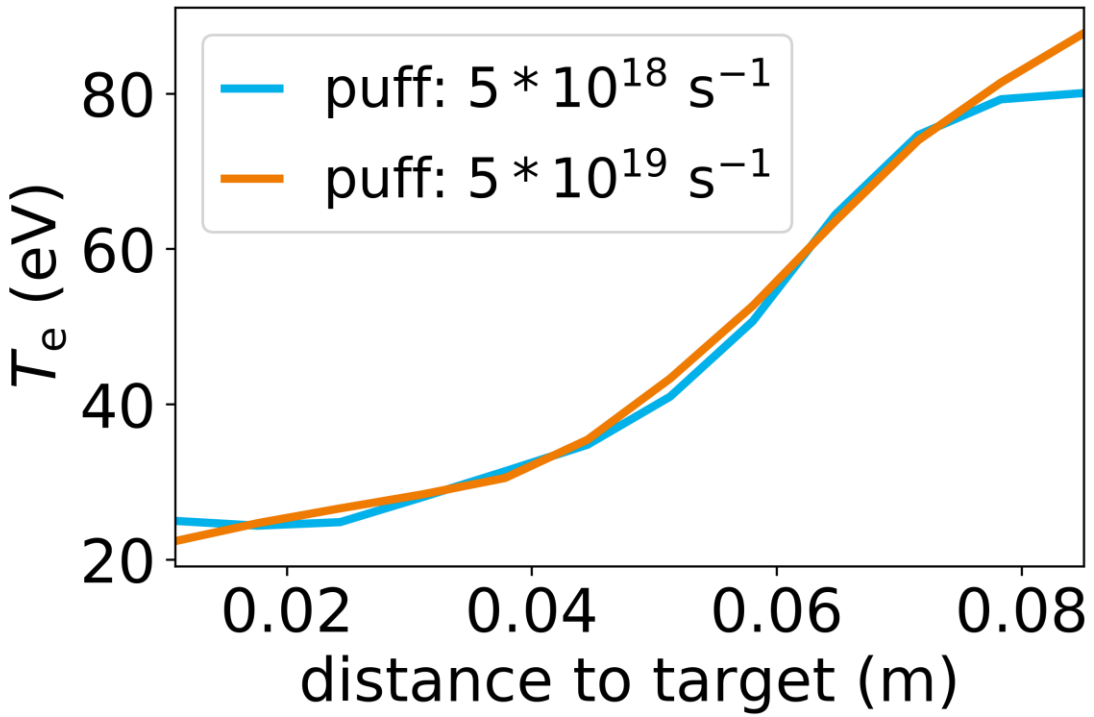


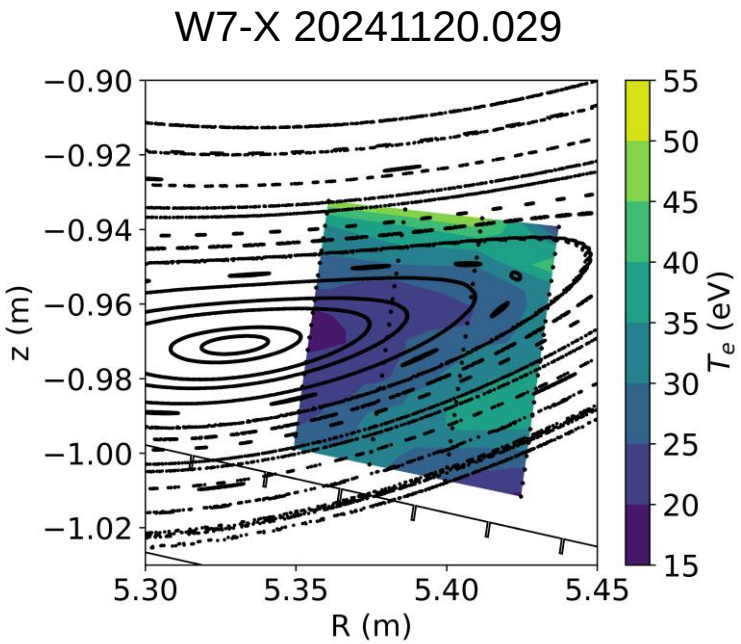
→ Factor of about 25 lower intensity

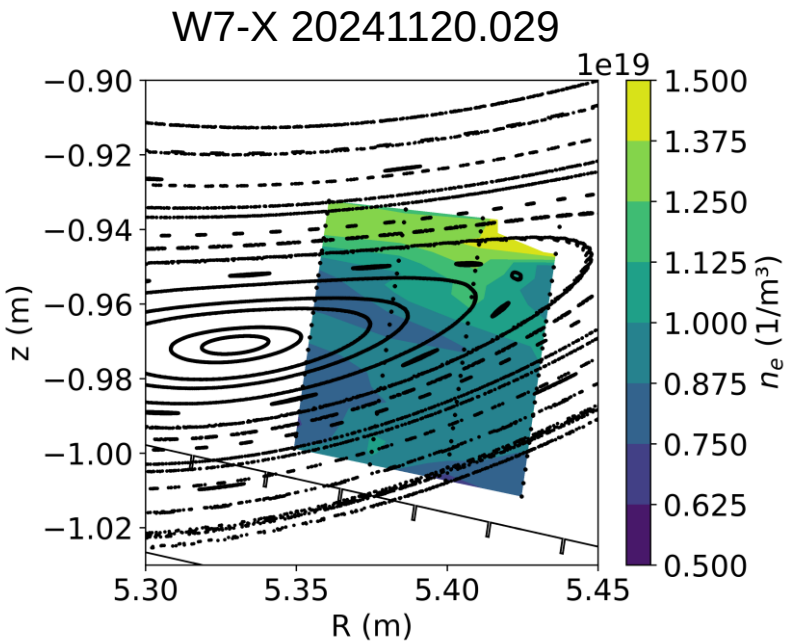
→ Desired puff for polychromator system: $5 * 10^{19}\ 1/s$

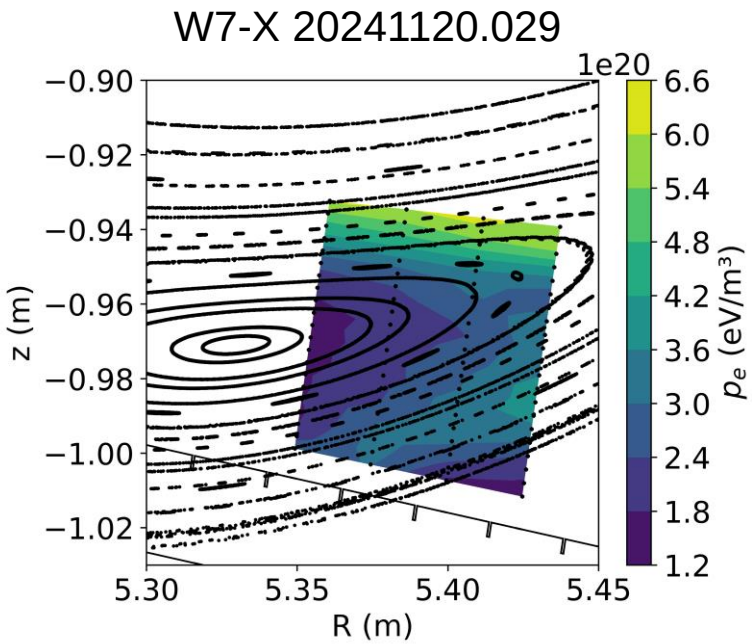
→ Desired puff is not perturbing the plasma globally or locally

Measurement results OP2.2

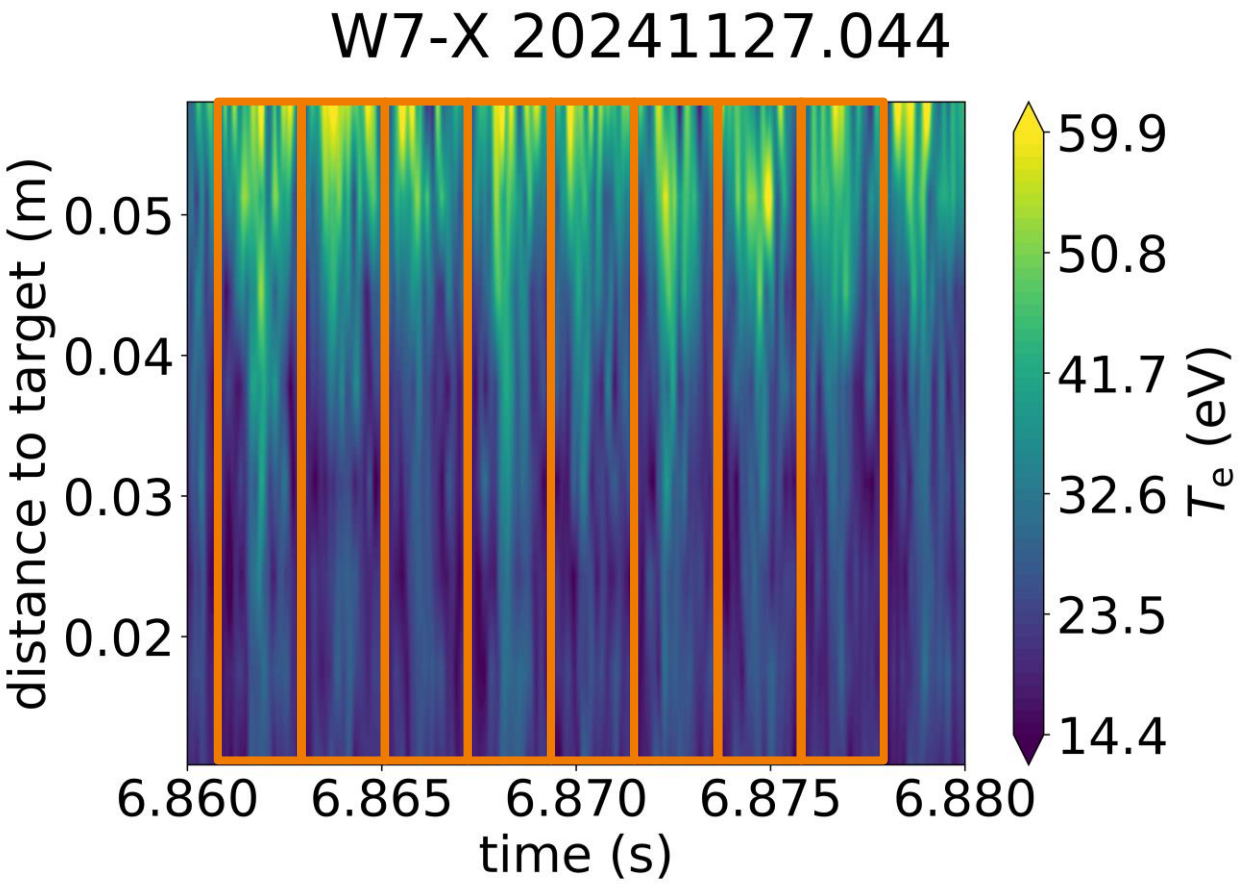
2D-profiles

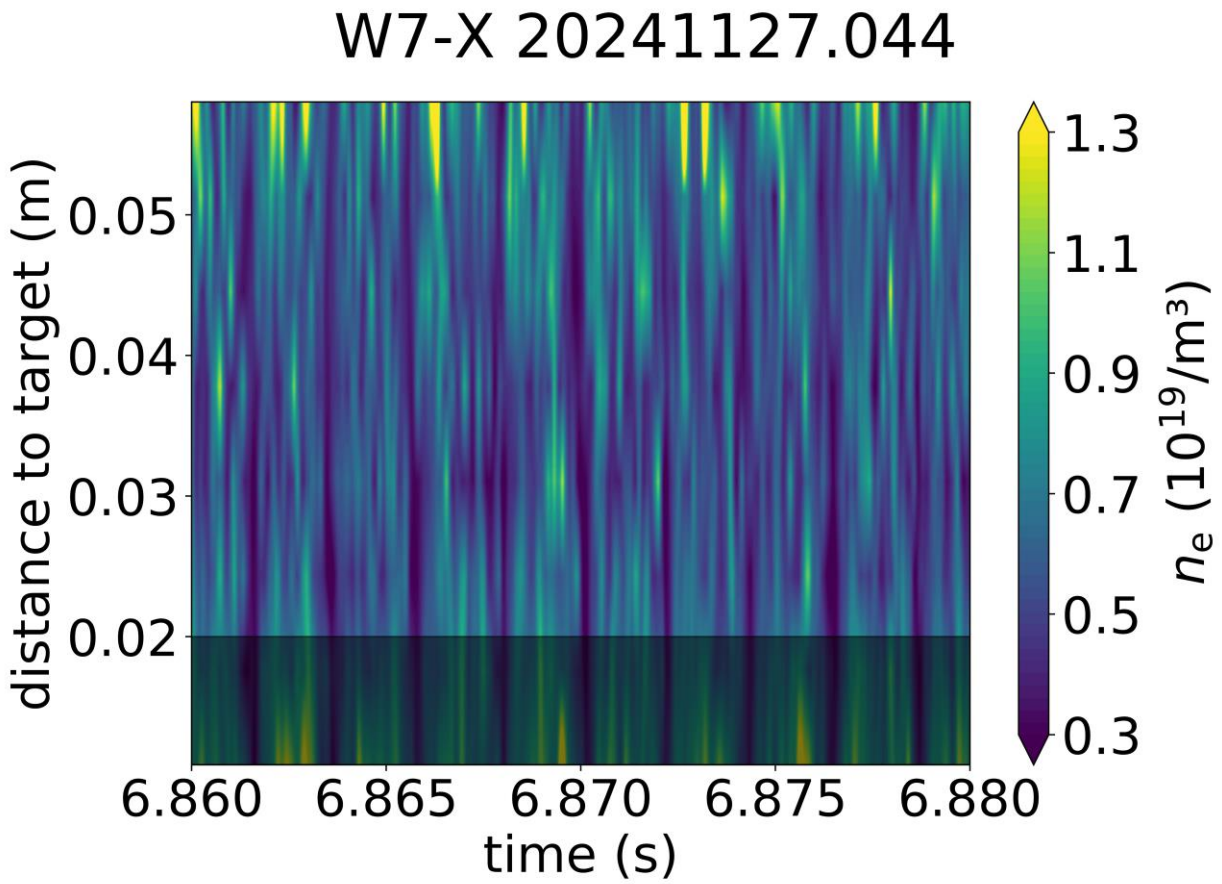

W7-X 20241120.029
z (m)
R (m)
T_e (eV)


W7-X 20241120.029
1e19
z (m)
R (m)
n_e (1/m³)

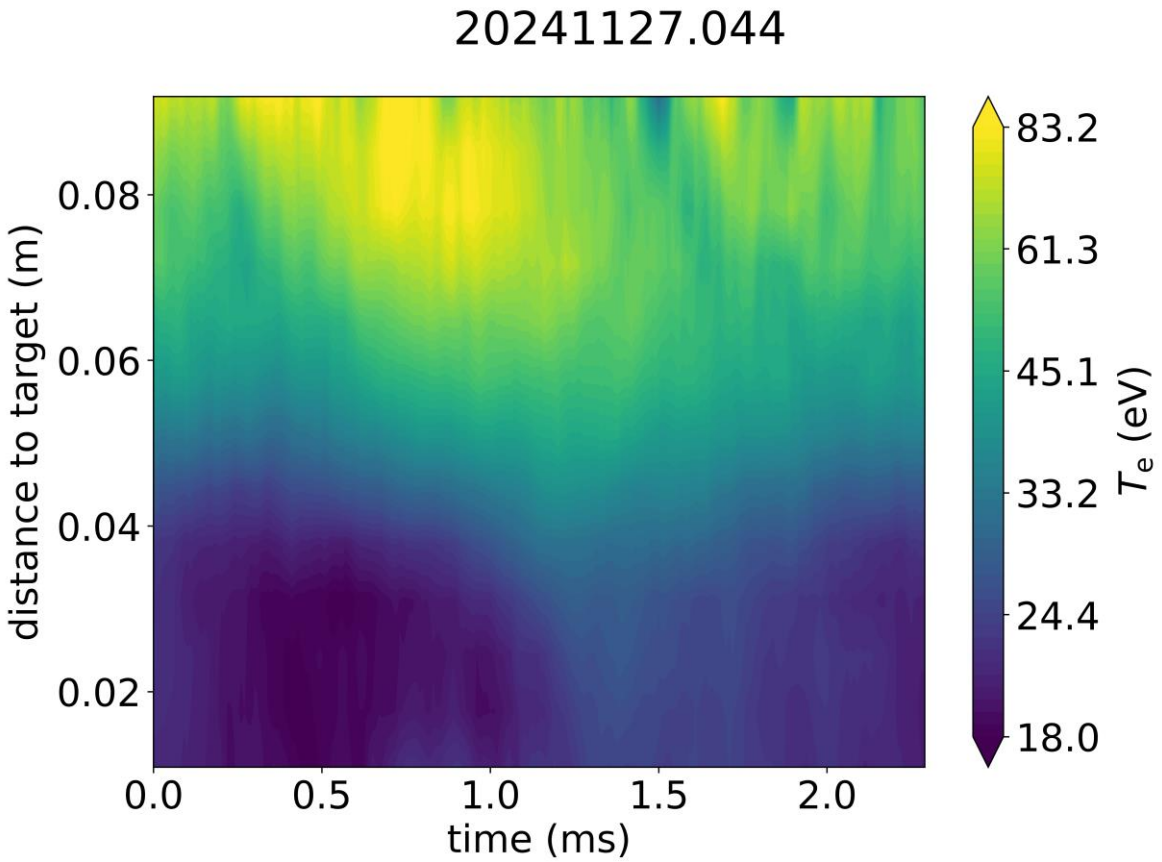

W7-X 20241120.029
1e20
z (m)
R (m)
p_e (eV/m³)

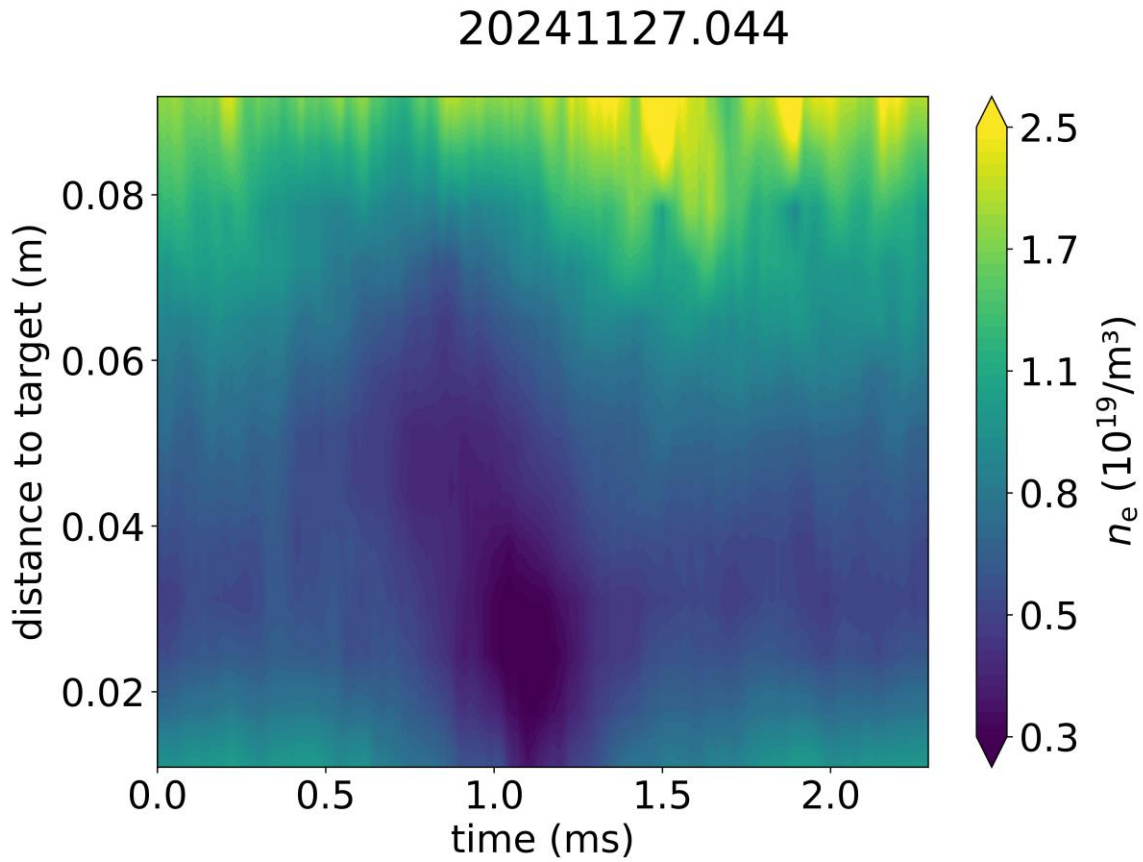
Fast profile analysis: n_e and T_e modulation with 480 Hz





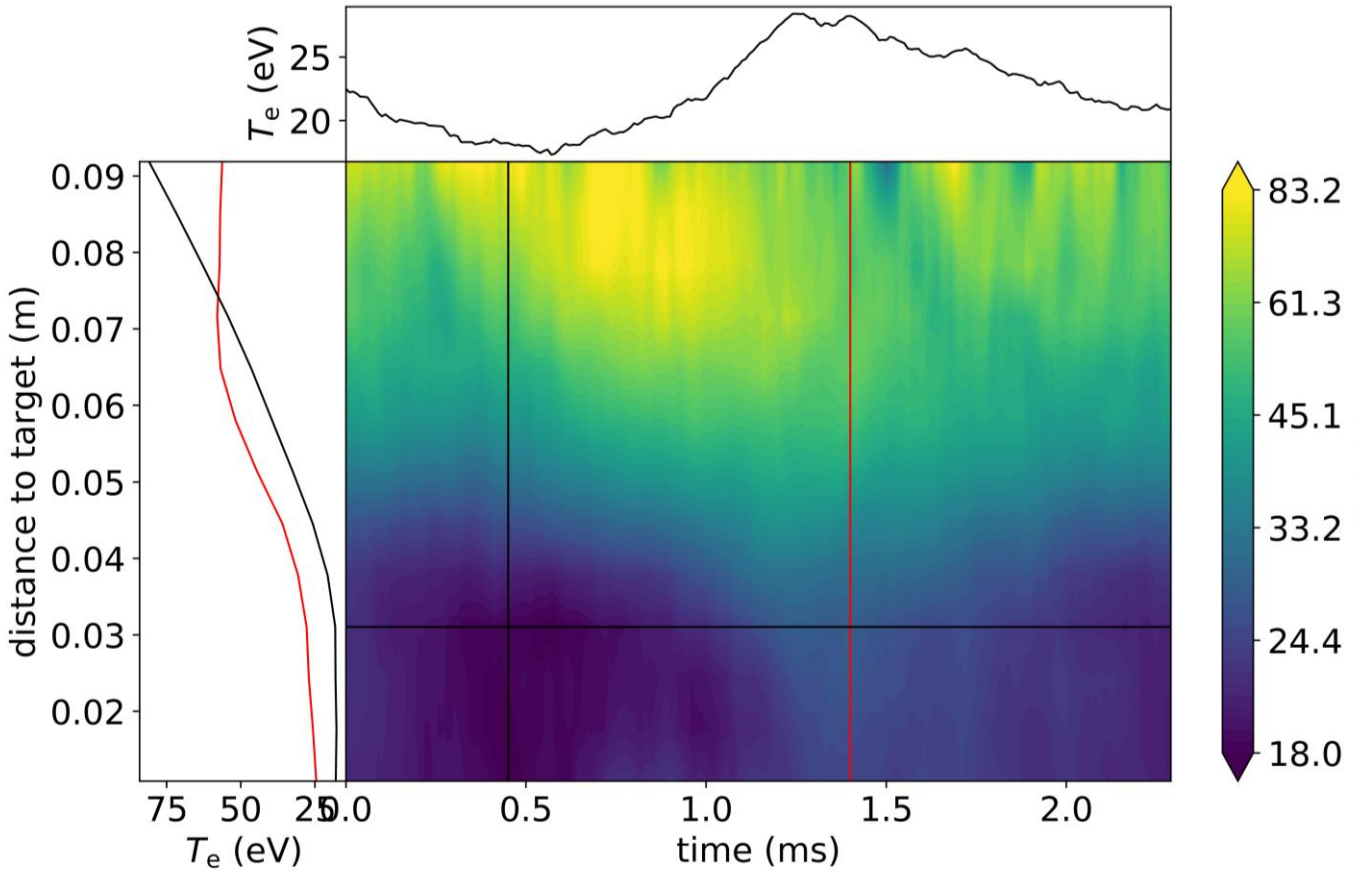
Mode averaging (preliminary)

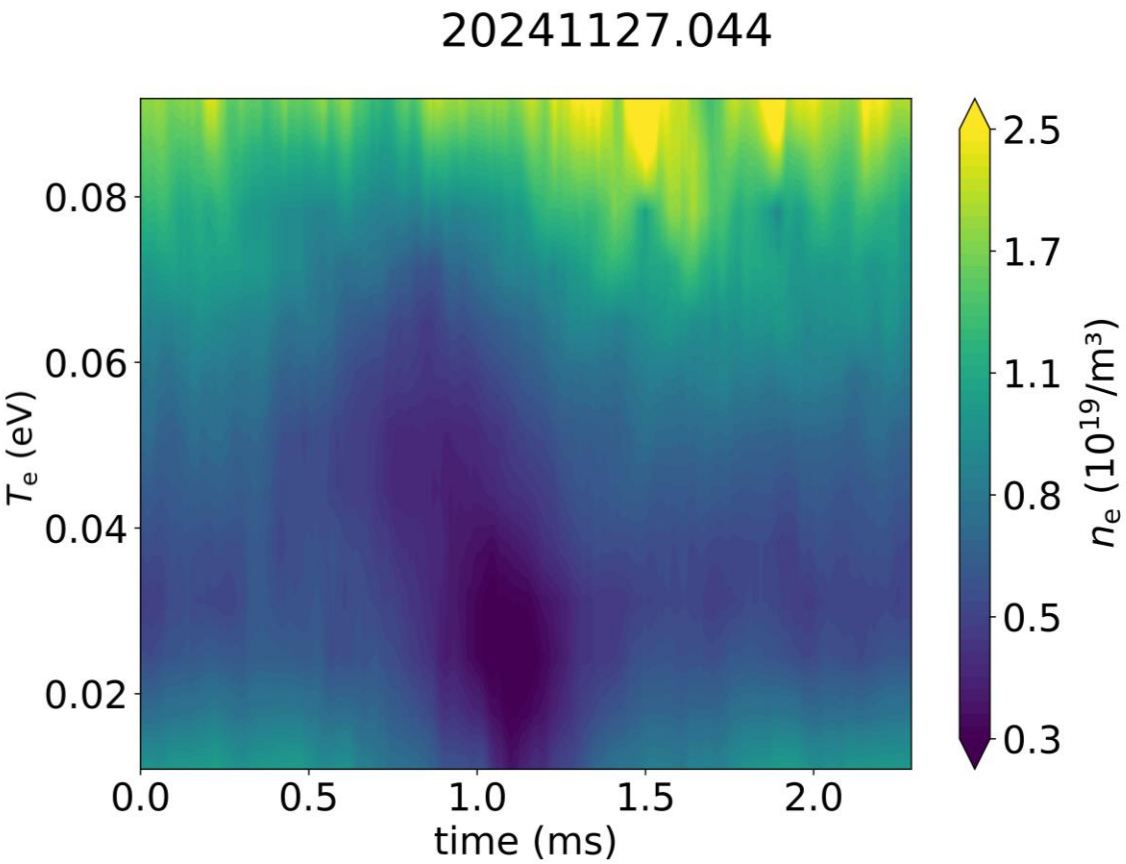




- Averaged over 39 cycles

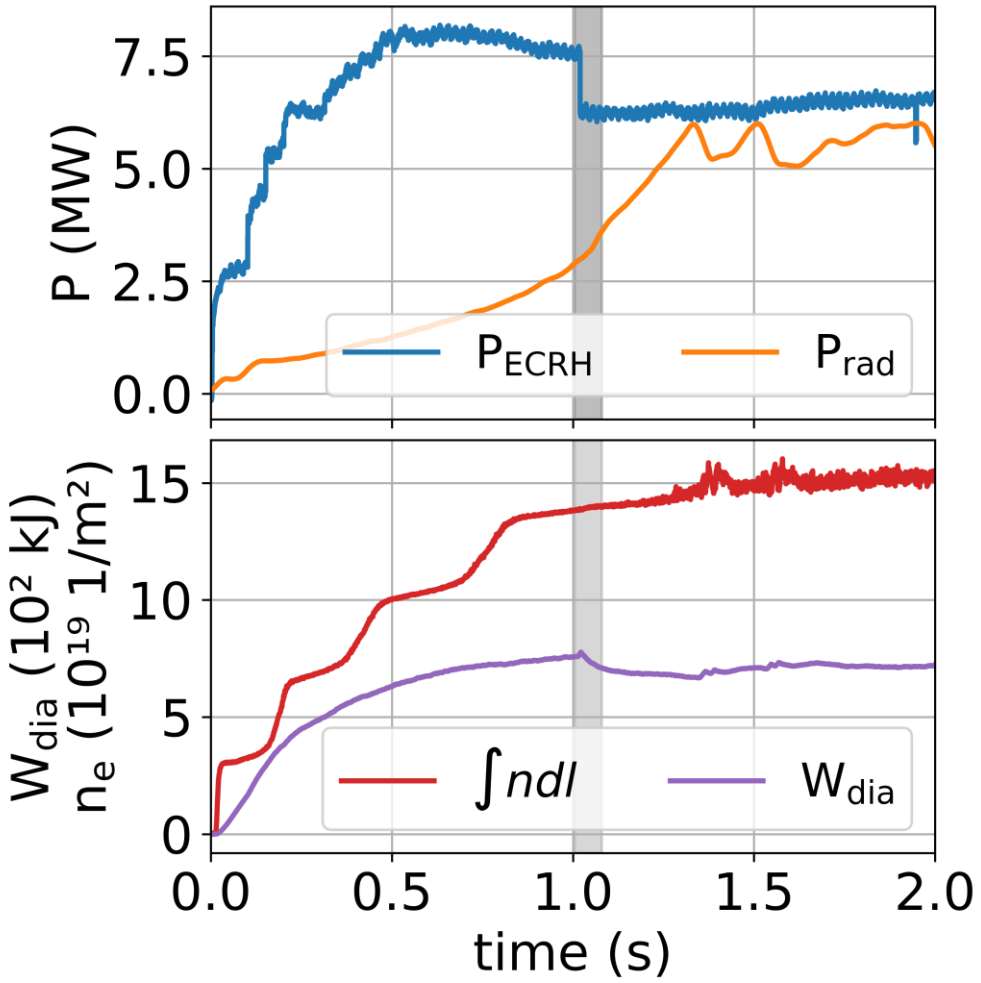
Mode averaging (preliminary)

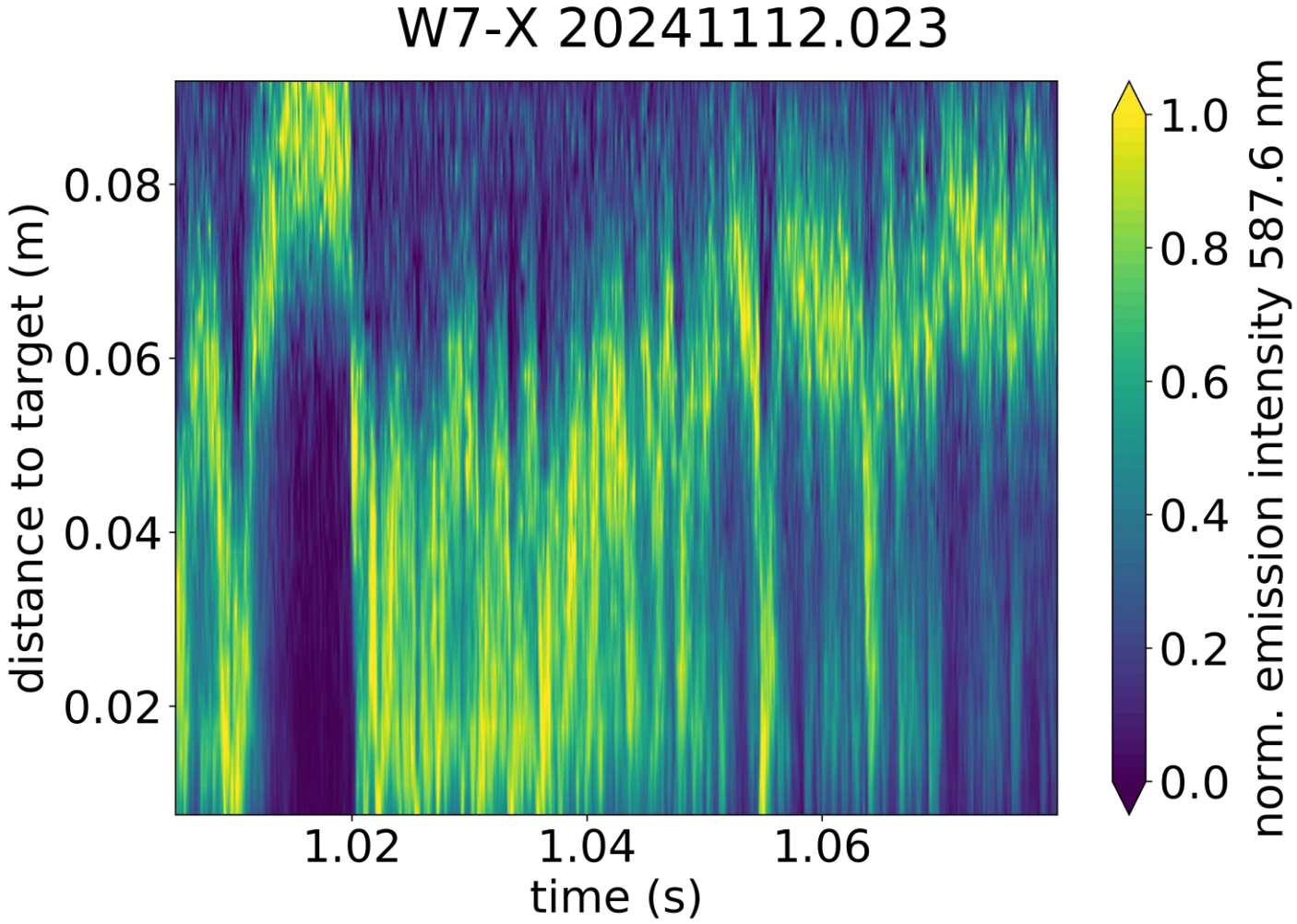




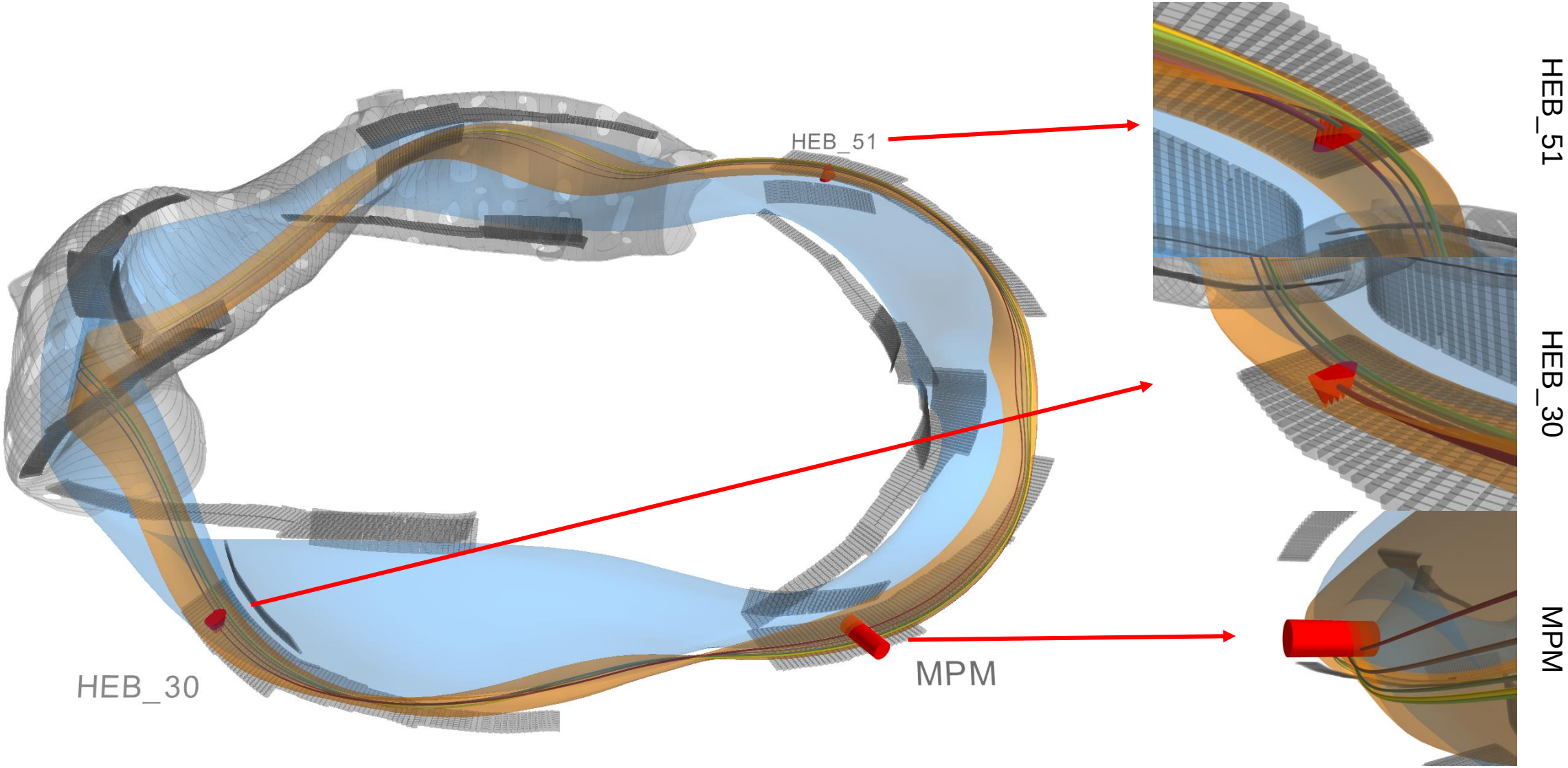
- Averaged over 39 cycles

Fast detachment analysis

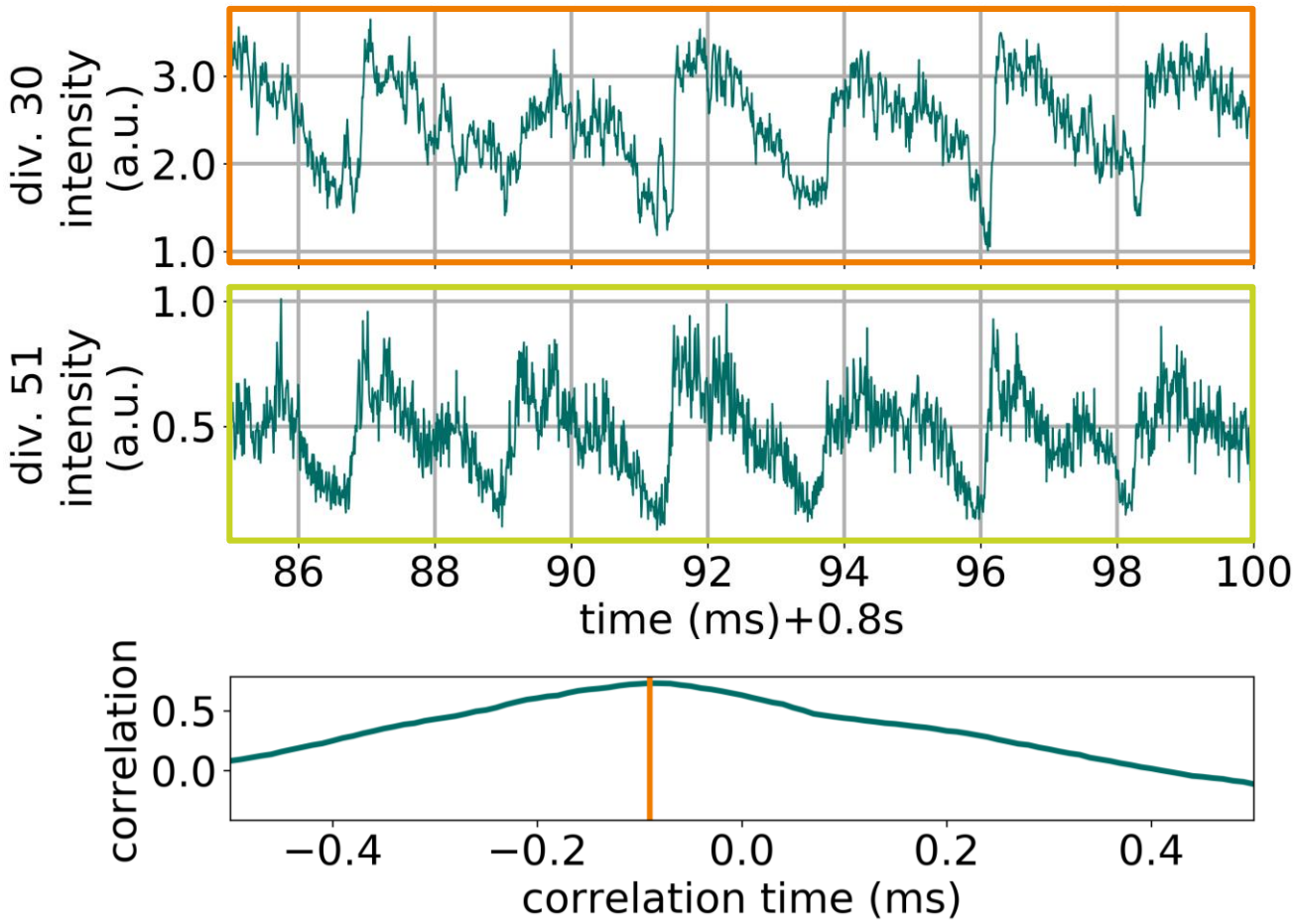


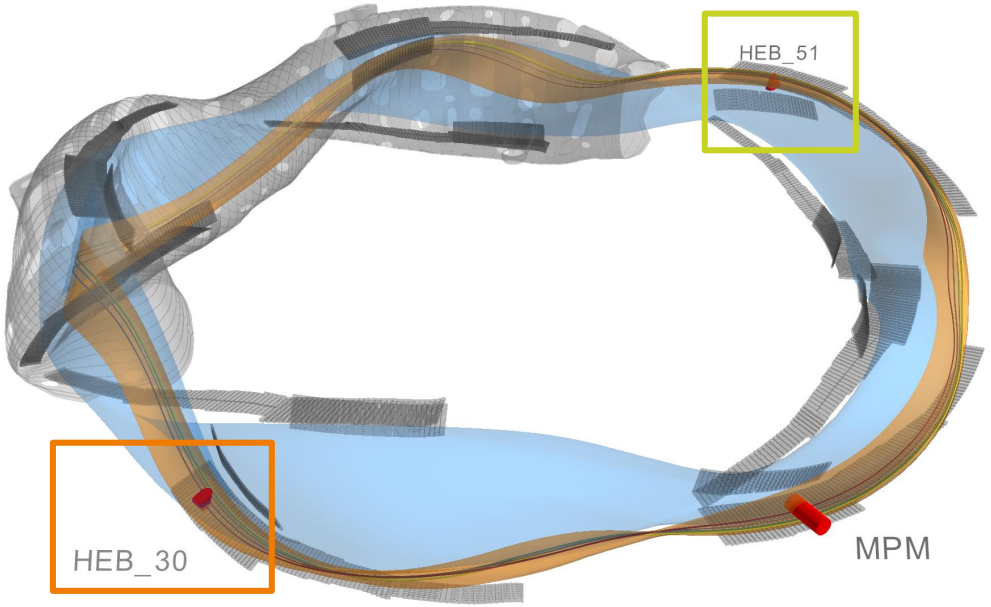


Long range correlation of two divertors



Long range correlation of two divertors





Conclusion

New helium beam polychromator with 1 MHz time resolution at W7-X:

- Required gas puff does not perturb the plasma
- Fast 1D T_e and n_e reconstruction in the divertor
- Measurement of T_e and n_e mode and burst propagation
- Investigation of fast detachment process and burn-through
- Long-range correlation measurements and determination of toroidal propagation and wavenumbers

Similar measurements are being conducted at ASDEX Upgrade