Max-Planck-Institut für Plasmaphysik

Implementation of fast line ratio spectroscopy on helium as plasma edge diagnostic at ASDEX Upgrade

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1. Motivation

- In magnetically confined fusion devices large power fluxes cross the last closed flux surface (separatrix) and therefore reach the scrape-off layer (SOL).
- The local power deposited on the first wall depends strongly on the transport perpendicular to the magnetic field lines driven by filamentary turbulence.
- To investigate steady-state as well as fast transport processes, a thermal helium beam has been implemented as plasma edge diagnostic at ASDEX Upgrade (AUG).

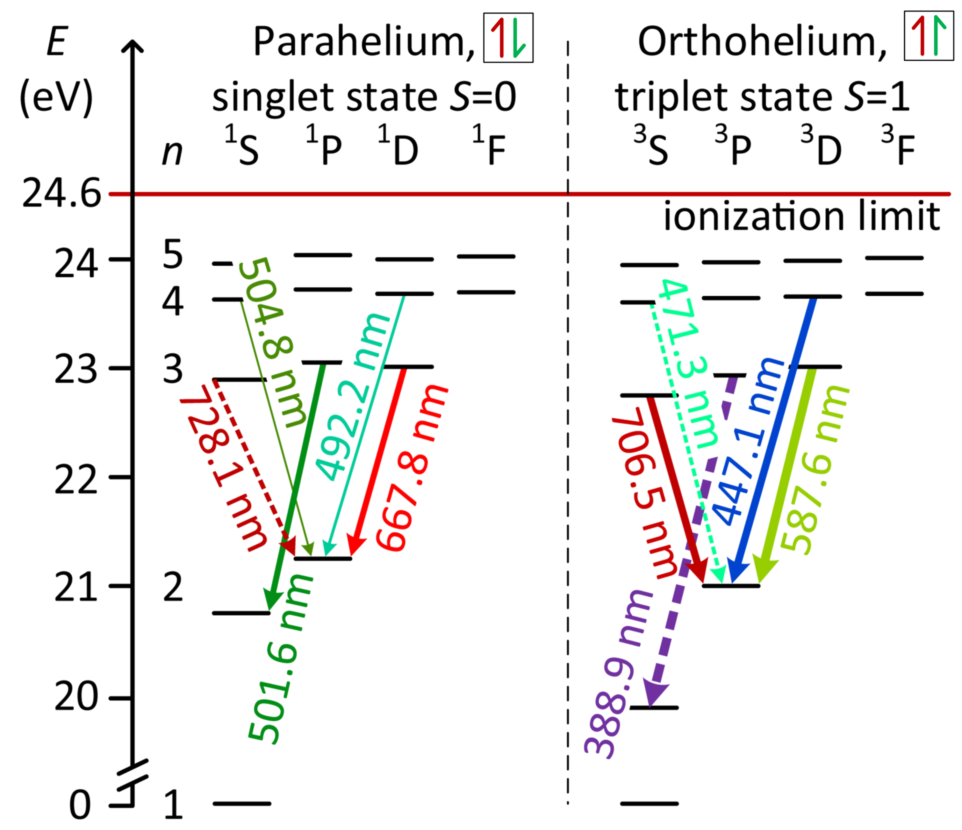
➔ **Simultaneous assessment of electron density n_e and temperature T_e information with high spatial and temporal resolution in the plasma edge region.**

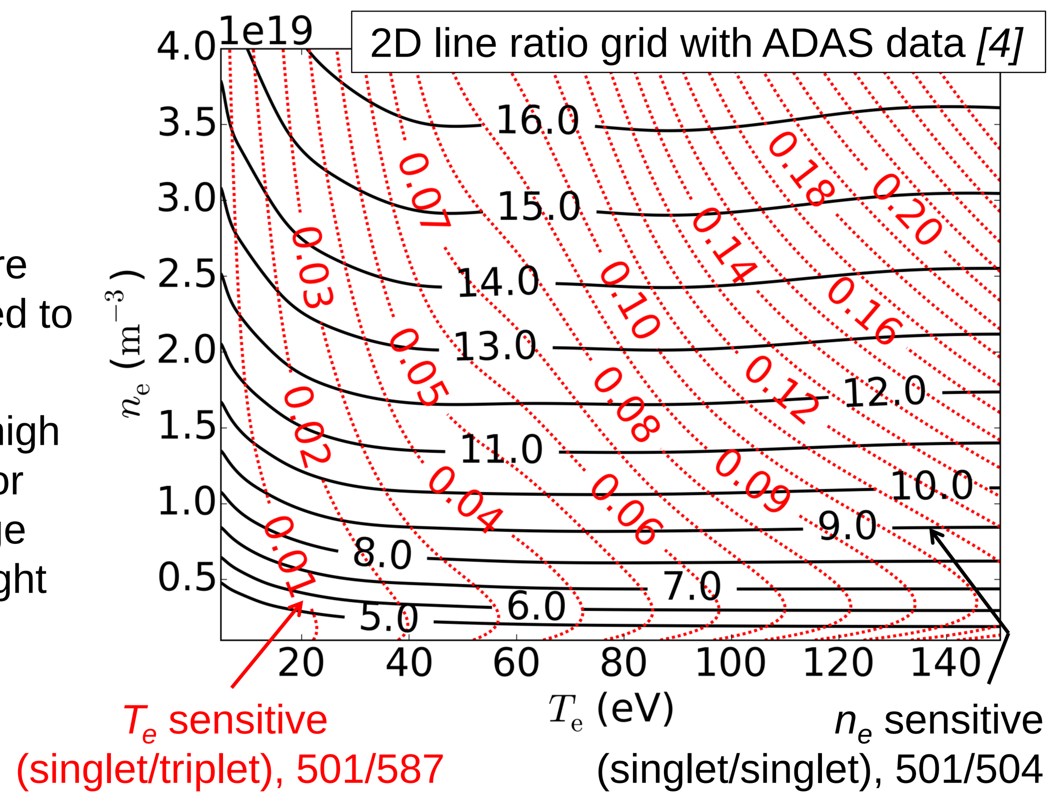
2. Helium Spectroscopy and Diagnostic Principle

- Helium is injected into the SOL by a fast piezo valve *[1]*.
- Helium gets excited by the plasma electrons and therefore emits light.
- The emission color changes dependent on the plasma temperature and density.
- Intensity of four emission lines is measured by a multichromator system.
- The optical system of helium is divided into singlet (s) and triplet (t) lines.
- Comparison of the measurement with a collisional-radiative-model (CRM) allows temperature and density reconstruction *[2,3]*:

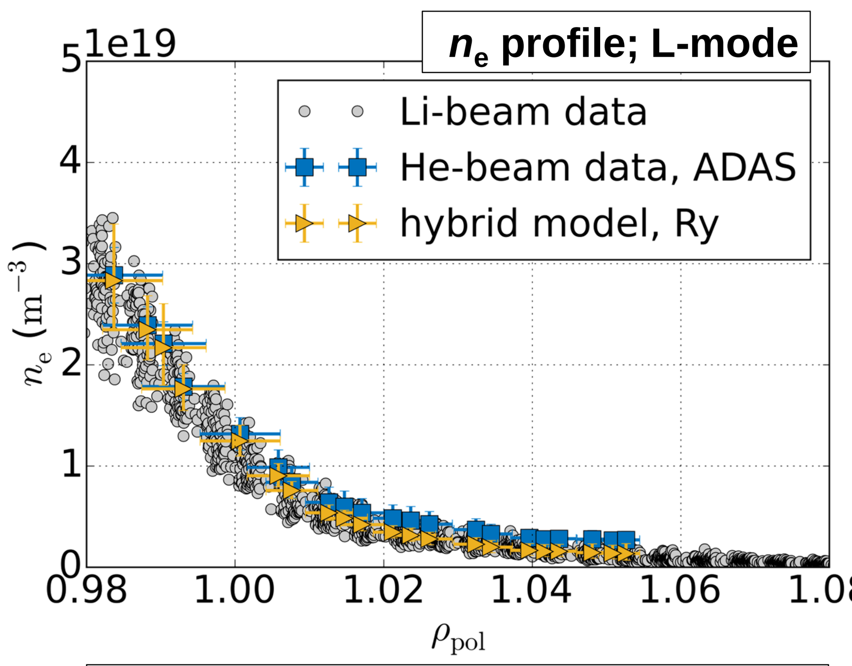
➔ singlet/triplet line ratios ➔ T_e
➔ singlet/singlet line ratios ➔ n_e

- Several line ratios and CRMs are tested. The results are compared to established diagnostics.
- Processes as the treatment of high Rydberg states in the CRM *[3]* or the inclusion of charge exchange between He⁺ and deuterium might be especially important for T_e evaluation.

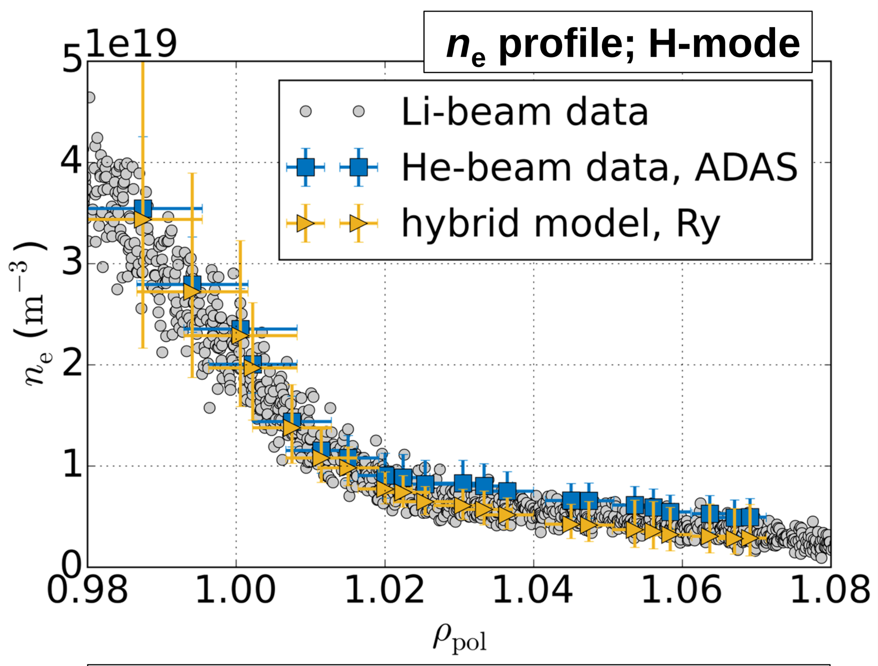




3. Rating and Comparison of Line Ratios

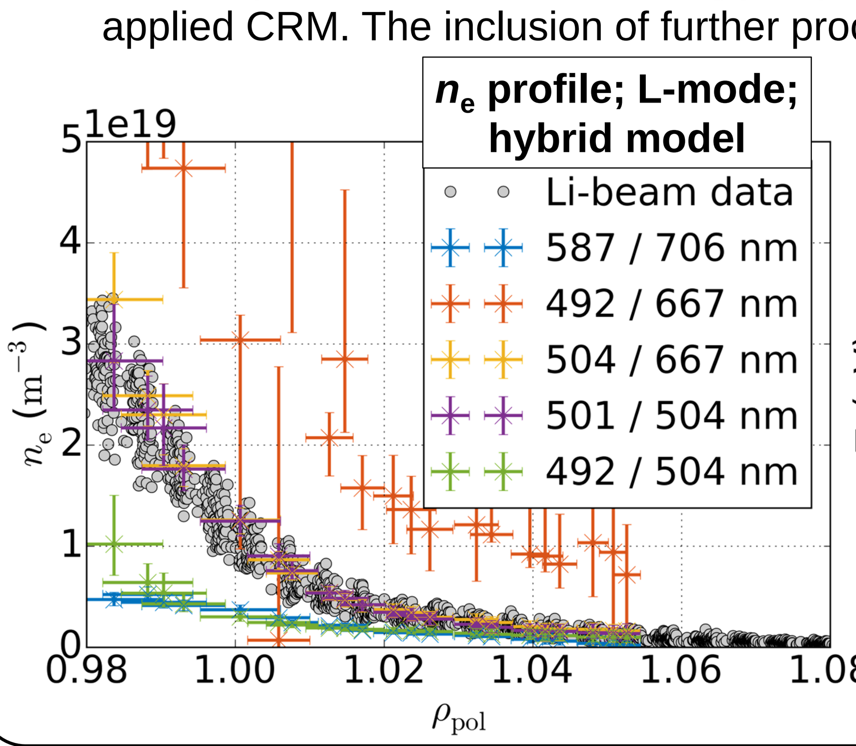


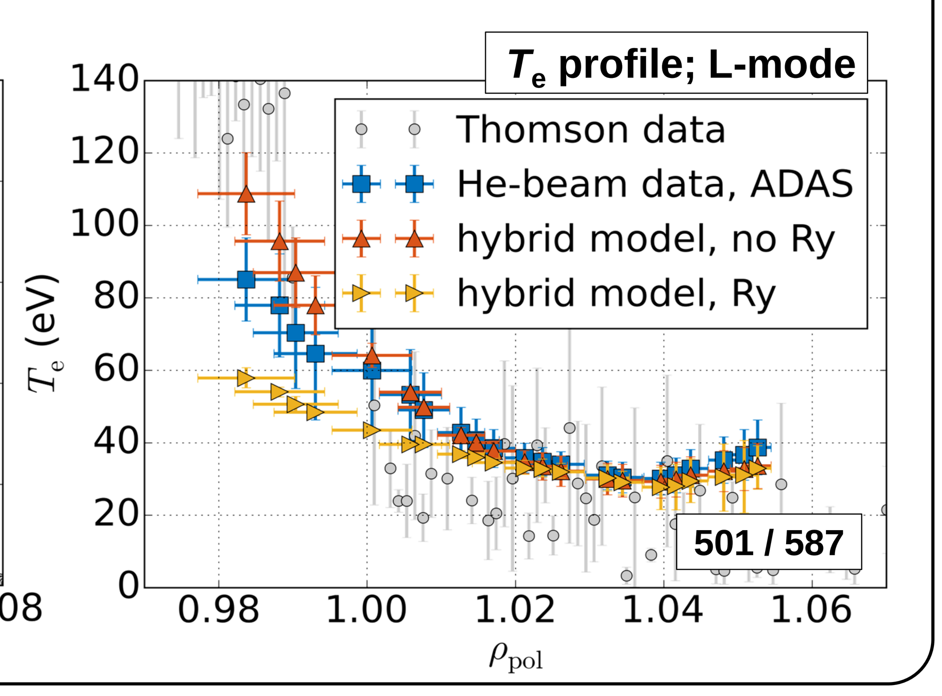
32030; L-Mode (2.1 – 2.5)s; **501 / 504**



32030; H-Mode (3.34 – 3.57)s; **501 / 504**

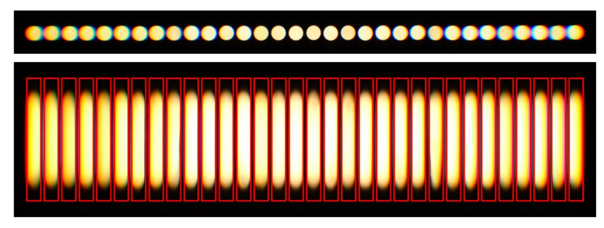
- The 501/504 and 504/667 s/s ratios show an excellent agreement with the lithium beam diagnostic for both CRMs for the density profile.
- The usage of other ratios does not lead to a consistent result.
- The temperature evaluation strongly depends on the singlet/triplet mixture and the applied CRM. The inclusion of further processes may lead to consistent results.



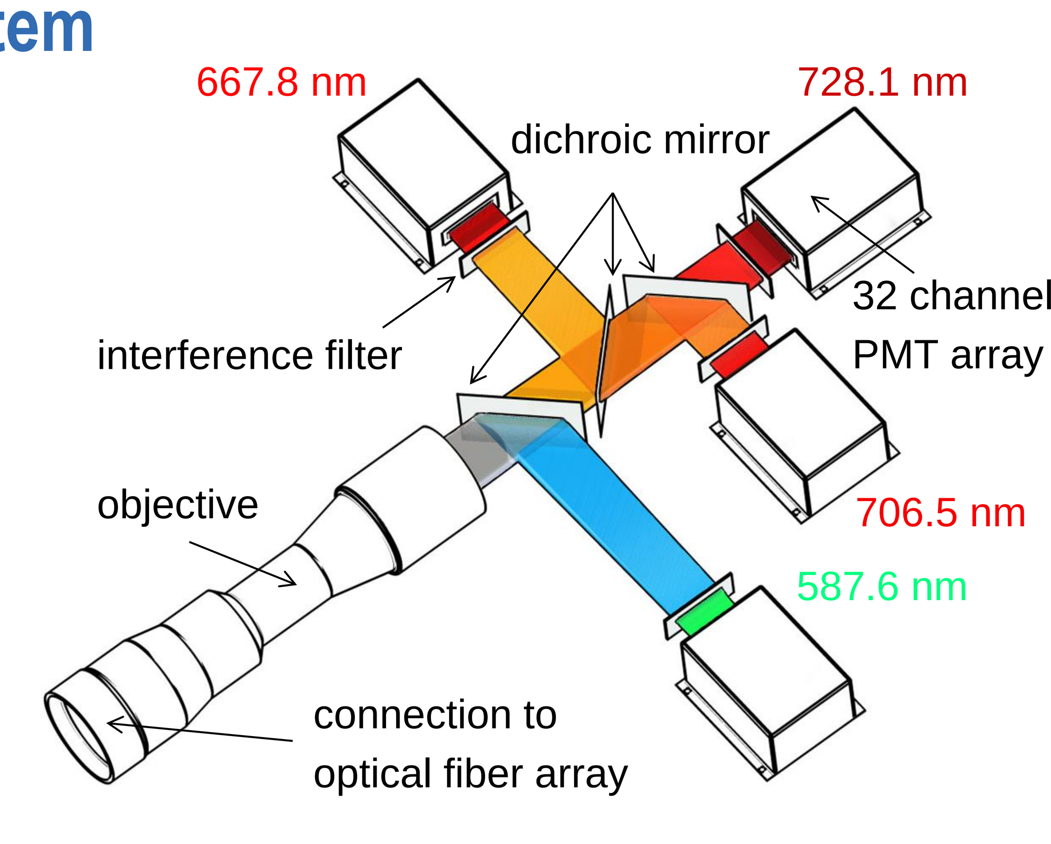


4. Multichromator System

- Newly developed four color 32 channel multichromator system
- A telecentric lens creates a 1:1 image of a 1D-32 fiber array (fibers: Ø 0.8 mm, NA = 0.11).



- A cylindrical lens (f = -500 mm) elongates the images to fit the detector geometry.
- The light is split into four wavelength regions by dichroic mirrors.
- Small band interference filters (FWHM = 1.5 nm; transmission >90%) are placed in front of the 32 channel photomultiplier tubes (PMT; HAMAMATSU H11460-20).



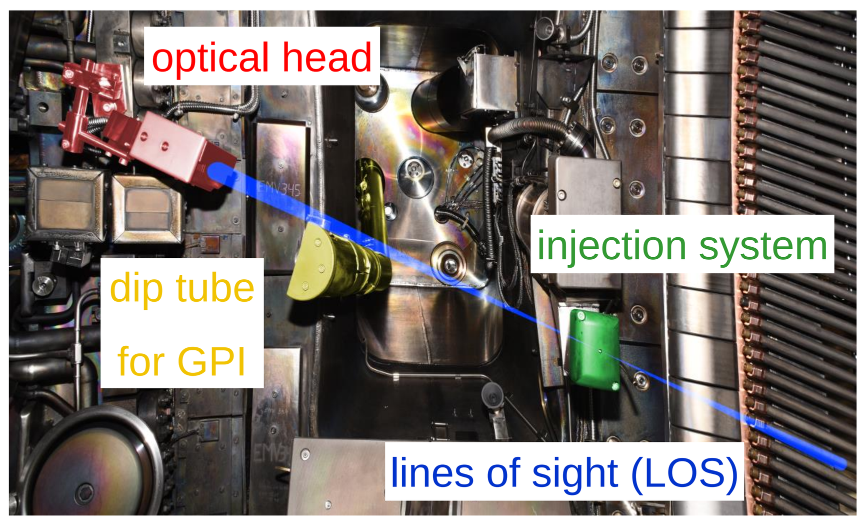
- The triple of red helium lines and the strongest helium line with 587.6 nm are measured.
- The 587.6 nm filter can be replaced to measure the He⁺ signal at 468.6 nm.

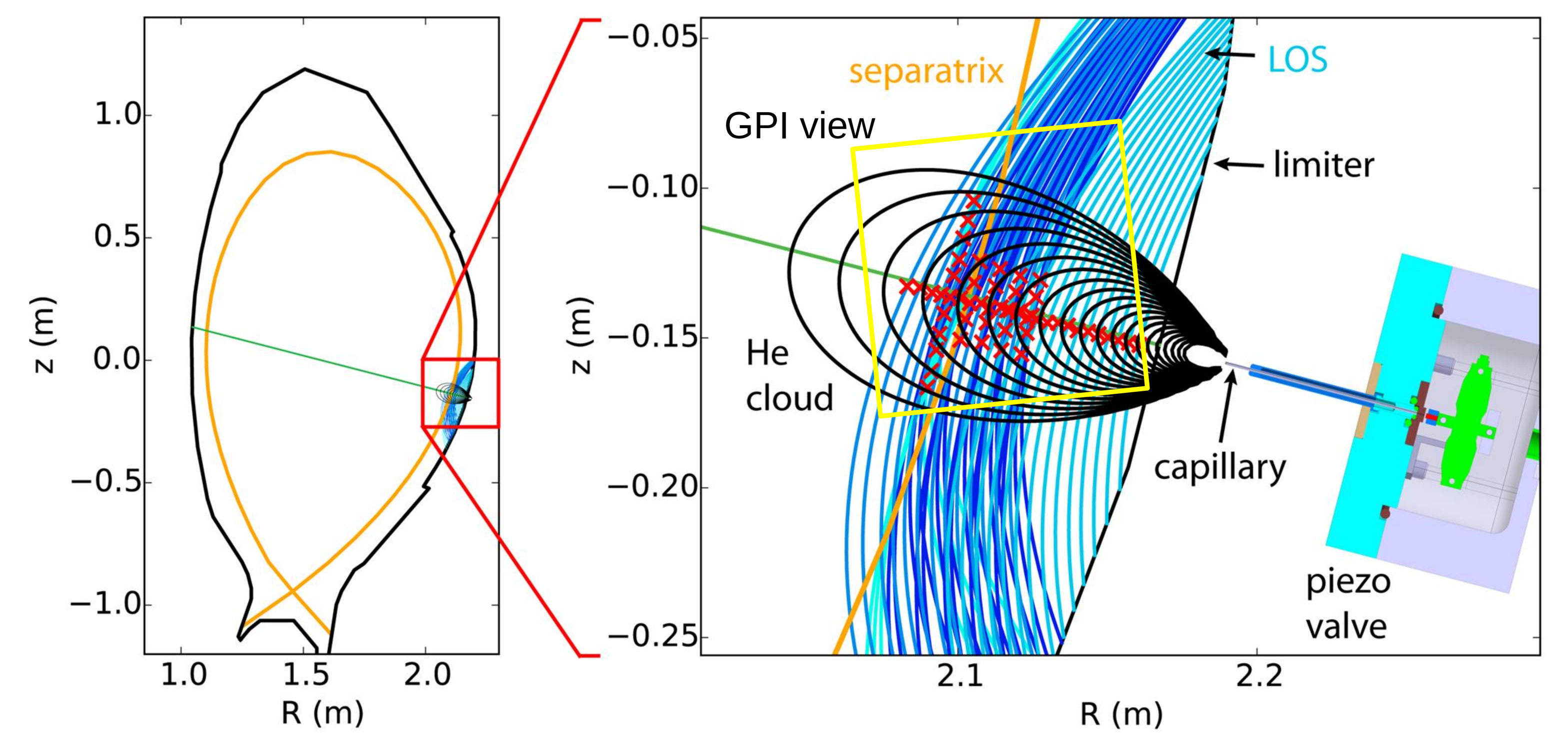
5. Measurement Geometry - Combination with GPI

In vessel components in AUG:

- Dip tube for gas puff imaging (GPI) provides a 2D image, recordable with a filter fast camera (Phantom v711)
- A two lens optical head provides:

➔ 52 LOS, radially and poloidally distributed
➔ Measurement range ~ 8.5 cm
➔ Spatial resolution ~ 3 - 6 mm
➔ Temporal resolution ~ 1.1 µs (≅ 900 kHz)

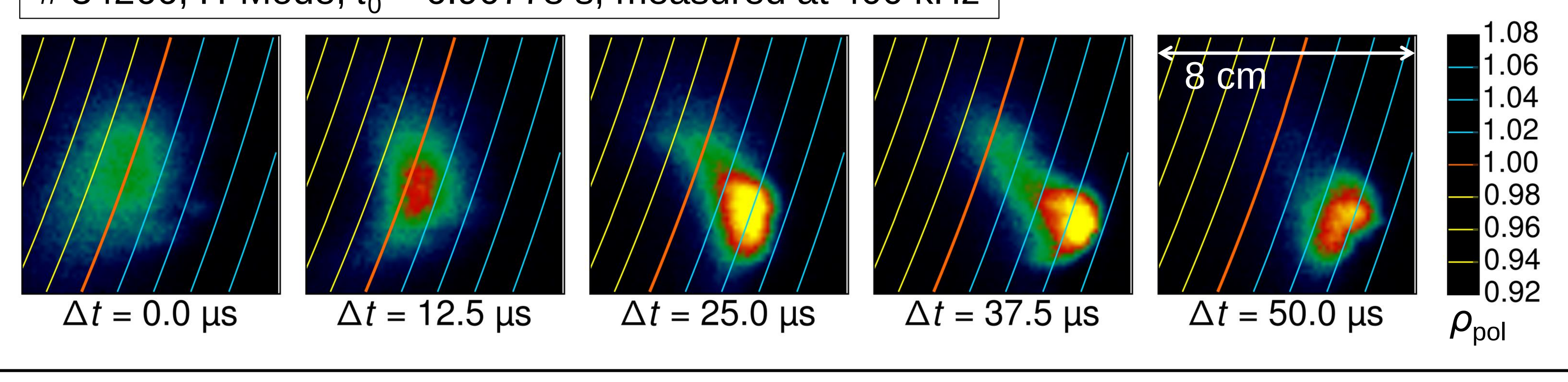




- **With the high spatial and temporal resolution, the thermal helium beam is best suitable to perform turbulence measurements in plasma edge region.**
- T_e and n_e information can be combined with a full 2D picture from GPI.
- This example shows the total emission of the He I 587.6 nm line.

GPI video

34266; H-Mode; t_0 = 6.90778 s; measured at 400 kHz



6. Outlook

- Detailed comparison of the new fast helium line ratio diagnostic with established. diagnostics at AUG as probe measurements, Li-beam and Thomson scattering diagnostic
- Testing of the extended CRM and rating of the additionally implemented processes.

Selected applicational prospects of the thermal helium beam:

- Characterisation of SOL T_e profiles and decay lengths
- Temperature fluctuation in I-mode, density and temperature cross-phase measurements
- Origin and propagation of filaments, origin of SOL turbulence

[1] M. Griener, Rev. Sci. Instrum. *88*, (2017), 33509
[2] O. Schmitz, Plasma Phys. Control. Fusion *50* (2008), 11500 (23pp)
[3] J.M. Muños Burgos, Physics of Plasmas *19* (2012), 012501
[4] http://www.adas.ac.uk/faq.php (Feb. 2016)

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