Influence of the I-Phase on blob properties in ASDEX Upgrade

G. Fuchert, M. Bernert, G. Birkenmeier, U. Stroth, E. Wolfrum,
and the ASDEX Upgrade Team

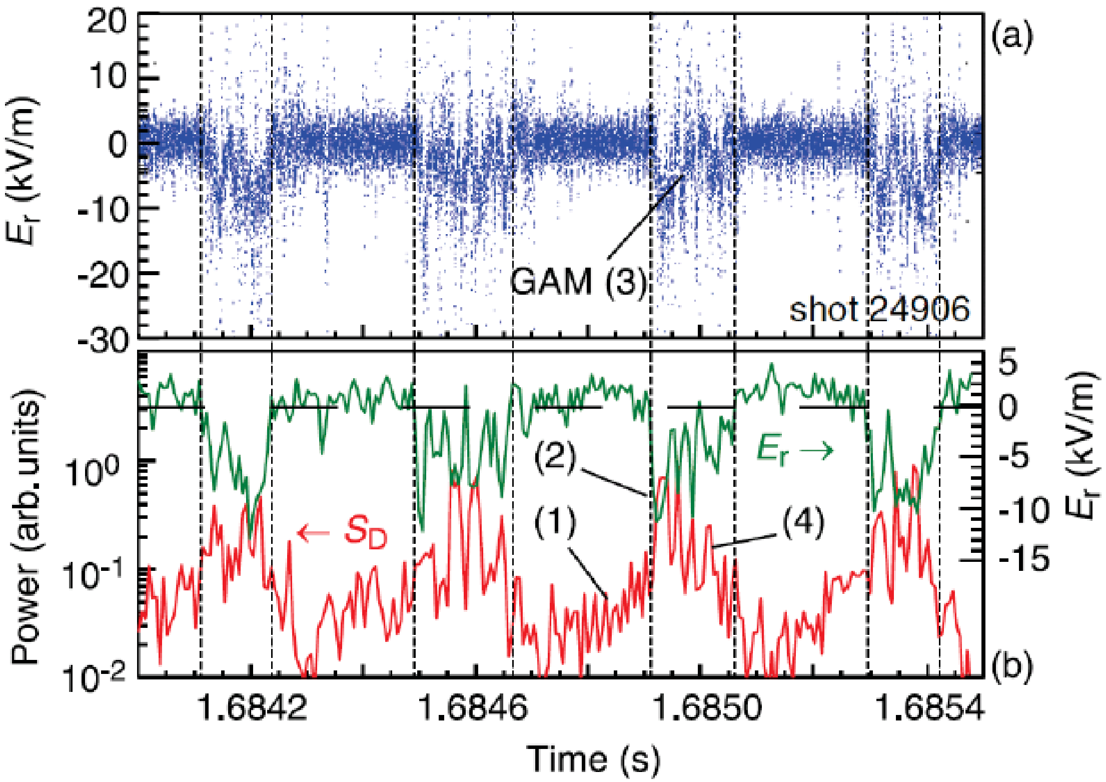
EFTSOMP Workshop 2015, Lisbon

Motivation

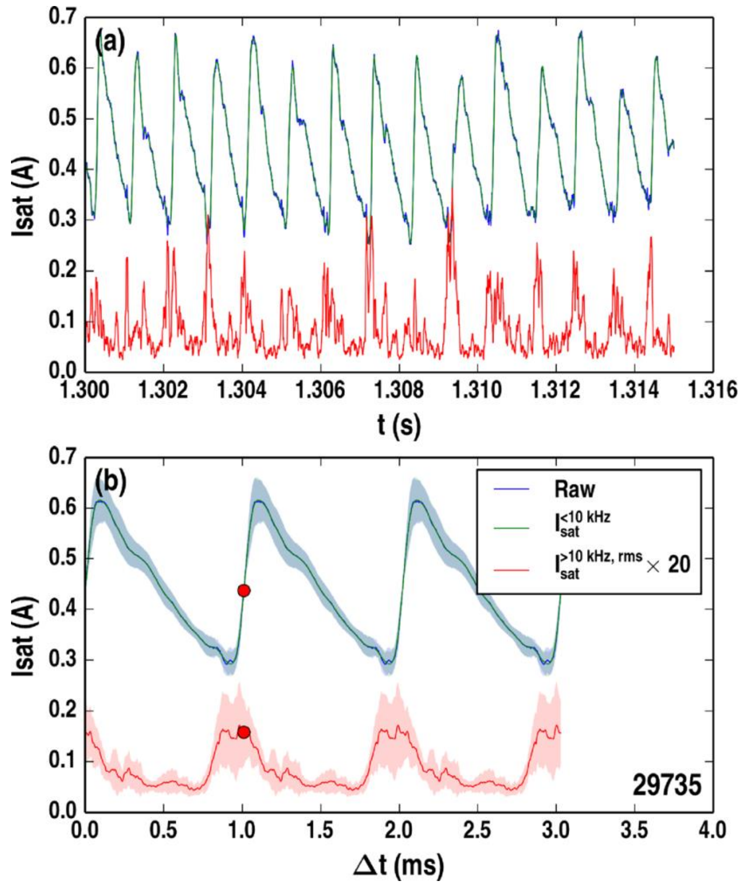
- Turbulence level is oscillating during the I-Phase.
- The I-Phase is probably related to the L-H transition physics.

→ Potential to learn more about plasma turbulence and L-H physics.

- Open questions: Role of SOL turbulence (active vs. passive) and spatial characteristic.



[G. D. Conway, PRL **106**, (2011)]



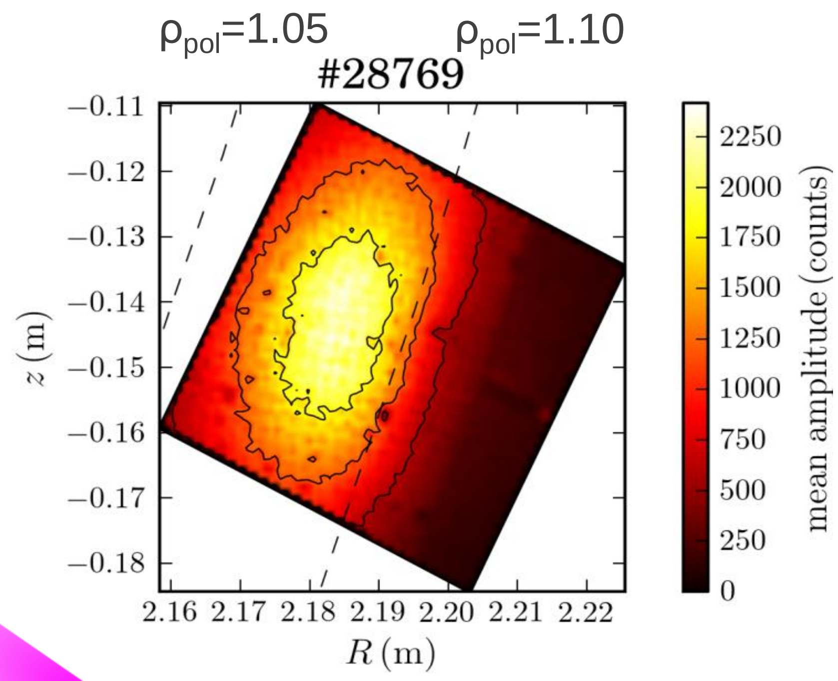
[S. H. Müller, Phys. Plasmas **21**, (2014)]

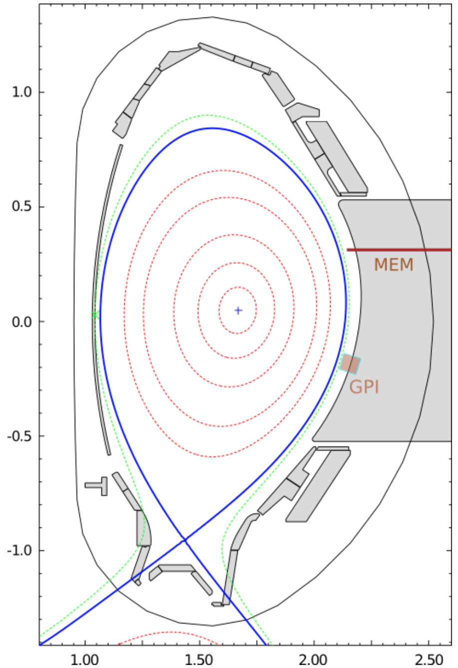
Overview

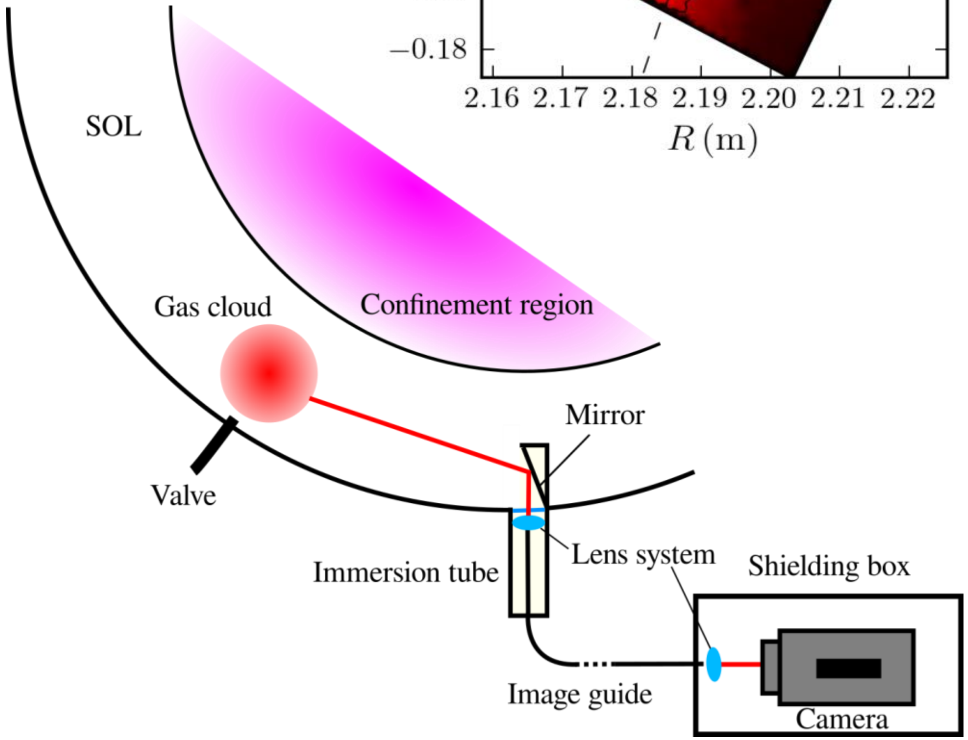
- Diagnostics and data analysis
- Experimental results
  - Effects in the far SOL
  - Blob properties during the I-Phase
  - Poloidal asymmetries
- Conclusion

Diagnostics

- Deuterium GPI in the far SOL:
  - Frame rate: 100 kfps
  - FOV ≈ 5x5 cm^2 near outer midplane
  - Resolution ≈ 1 mm ≈ 3 ρ_s
- I_{sat} measurements above the outer midplane.

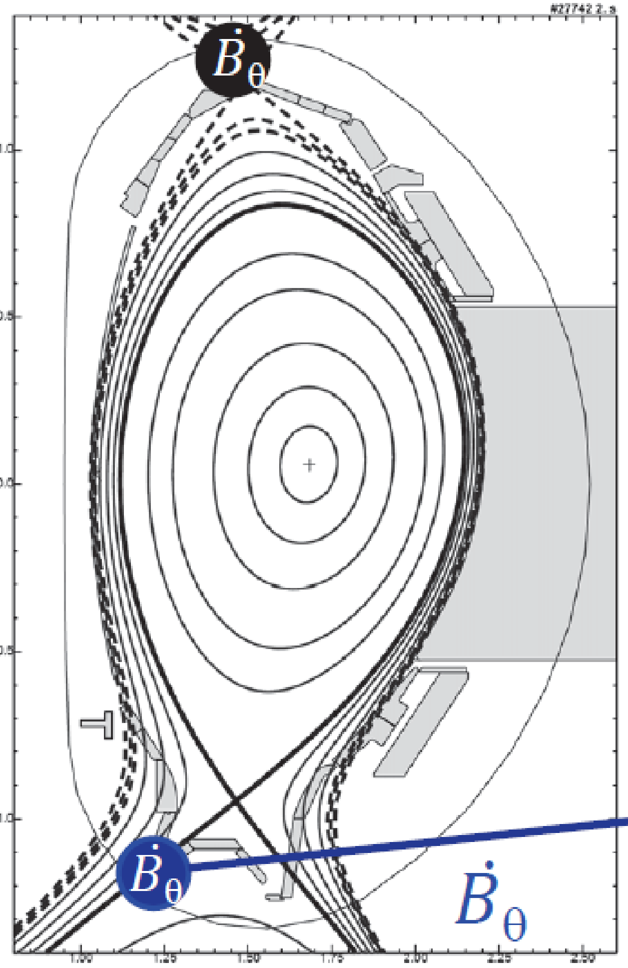




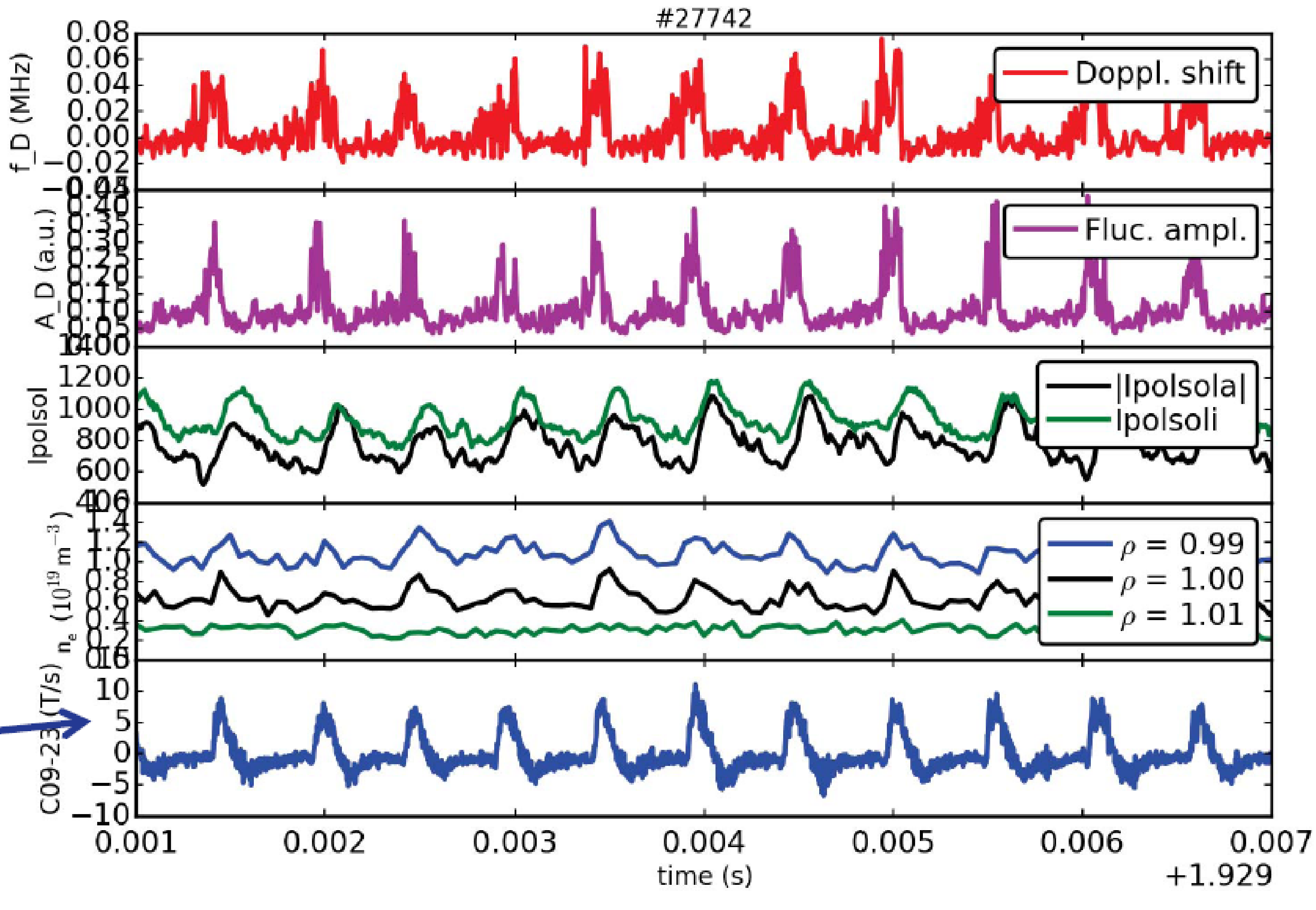


Reference signal

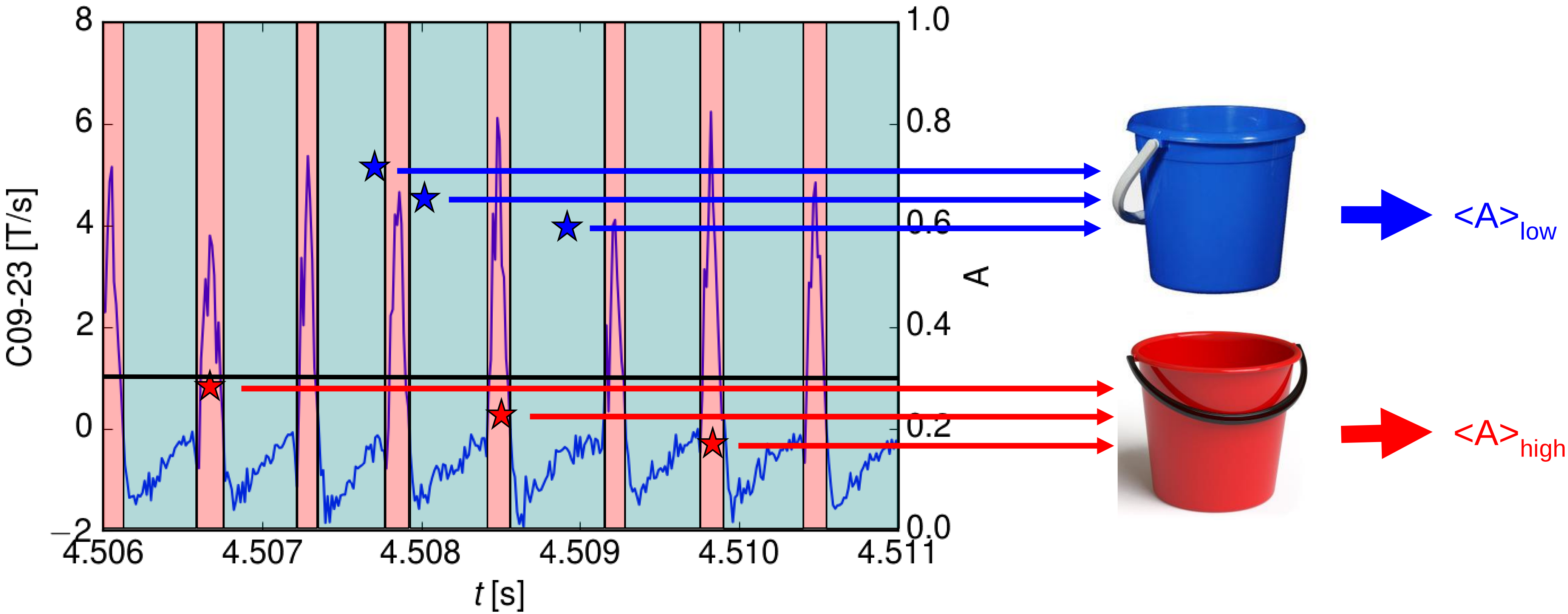
Density fluctuations (from Doppler) correlated with magnetics



[G. Birkenmeier]



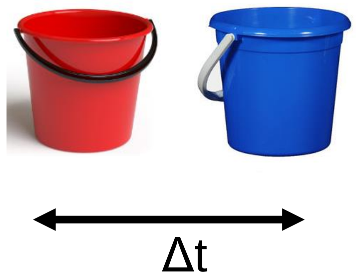
Phase-dependent average

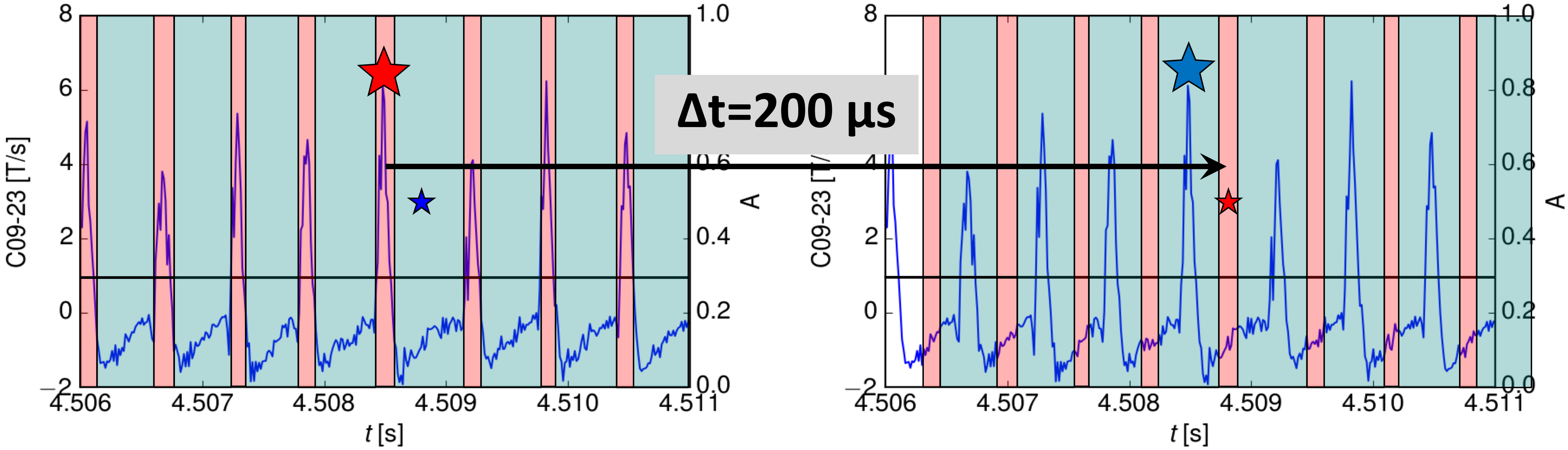


However:
Probably a time delay between A and the „phase signal“ due to blob propagation

Averaging procedure

Time delayed
phase-dependent average



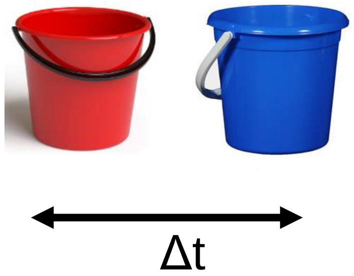


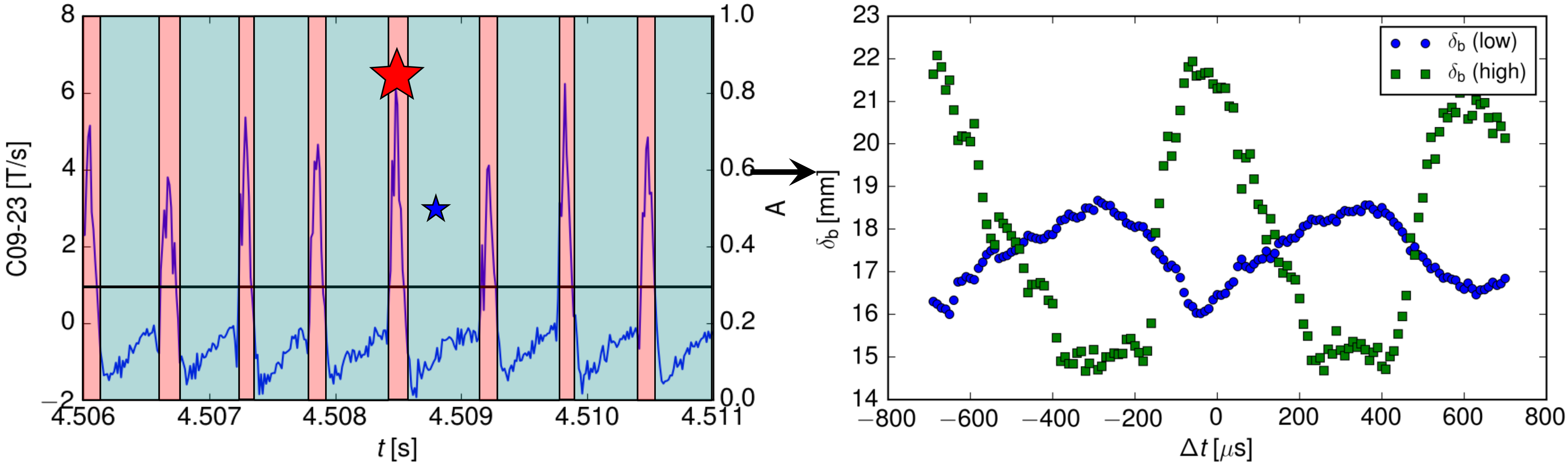
<A>$_{high}$(Δt=0 μs) <A>$_{low}$(Δt=0 μs) <A>$_{high}$(Δt=200 μs) <A>$_{low}$(Δt=200 μs)

Note:
A positive/negative Δt describes changes after/before the reference signal

Averaging procedure

Time delayed
phase-dependent average





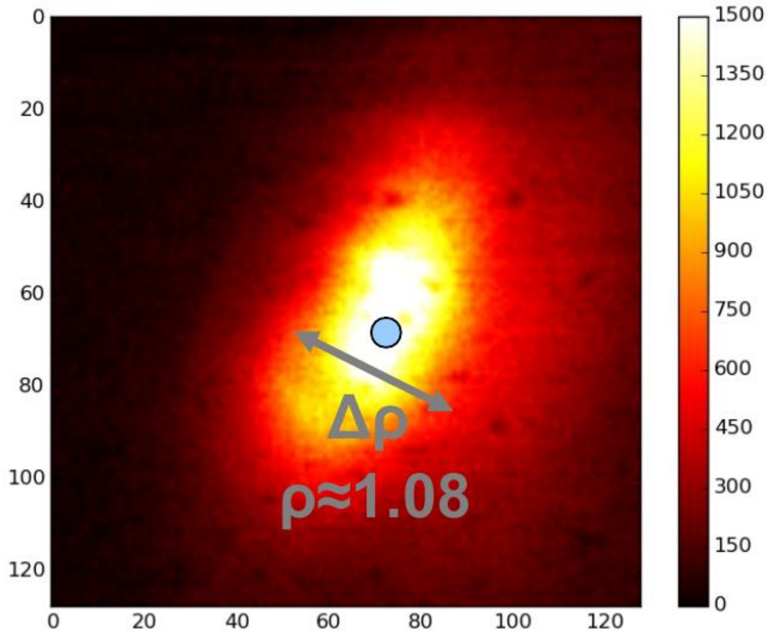
Note:
A positive/negative Δt describes changes after/before the reference signal

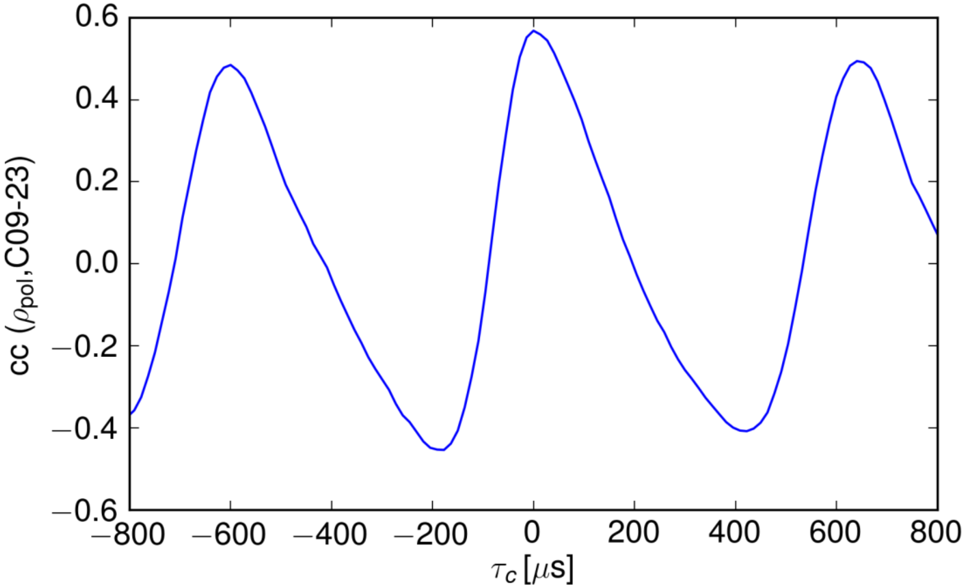
General observations

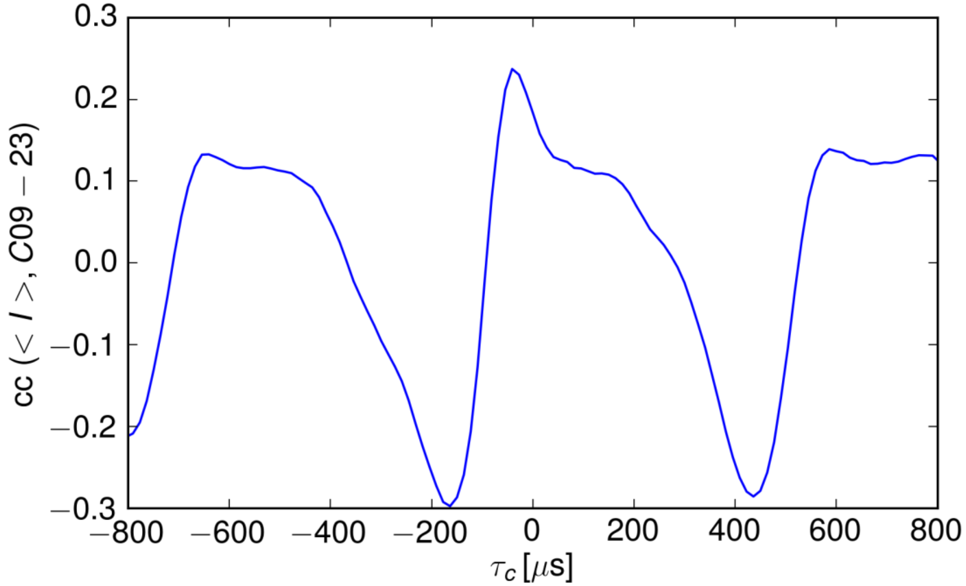
Observations during an I-phase (#31494)

- Center of the emission cloud „wobbles“ in phase with the magnetics.
- Pulsating emission intensity.
- Variations in n_e, T_e, or plasma shape/position.

→ The far SOL „knows“ about the I-Phase

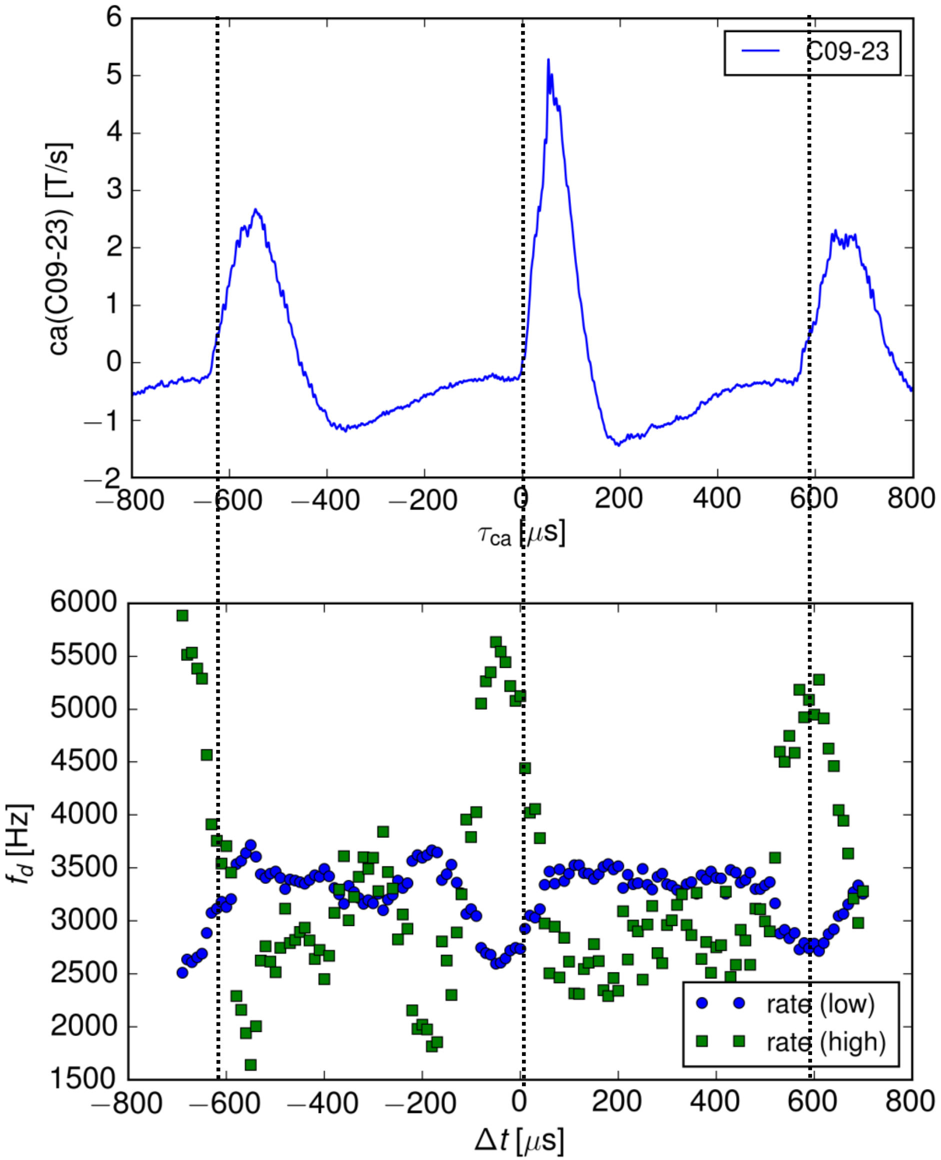




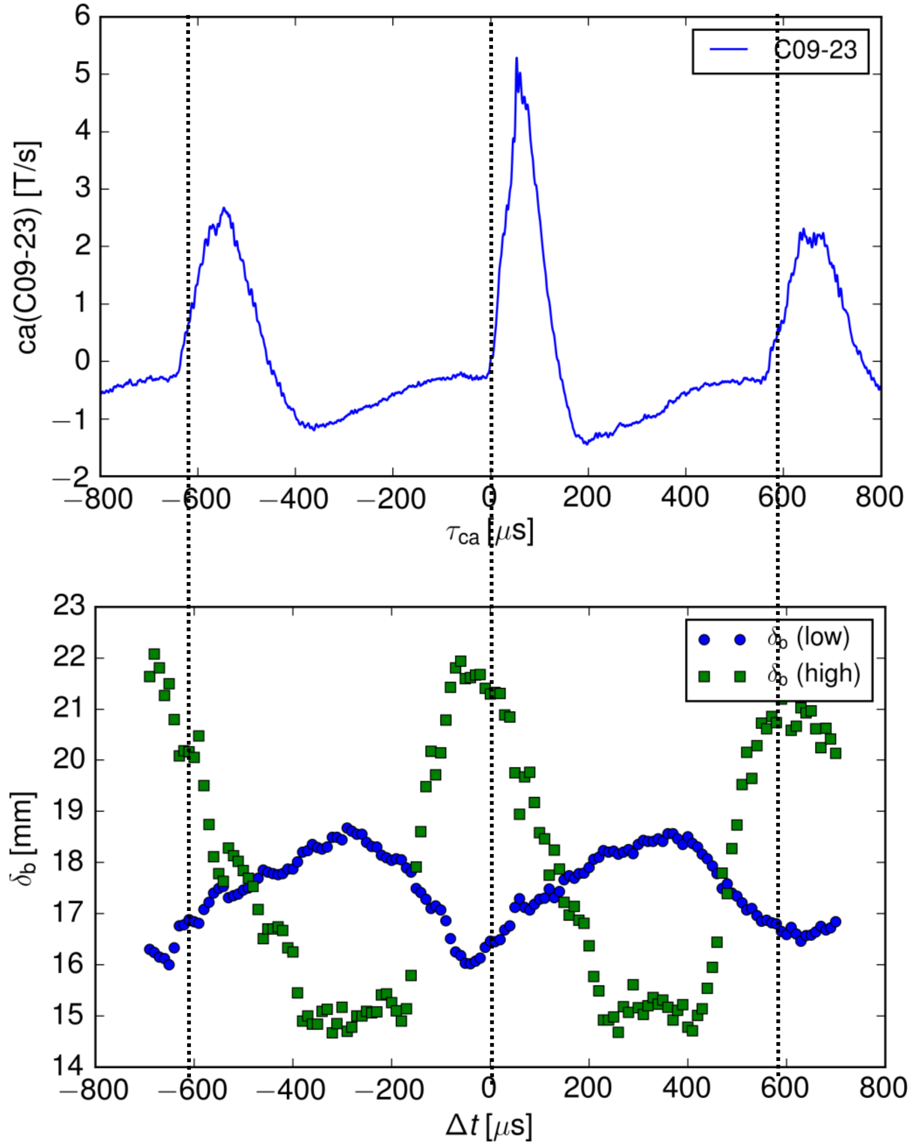


Blob properties: Detection rate and size

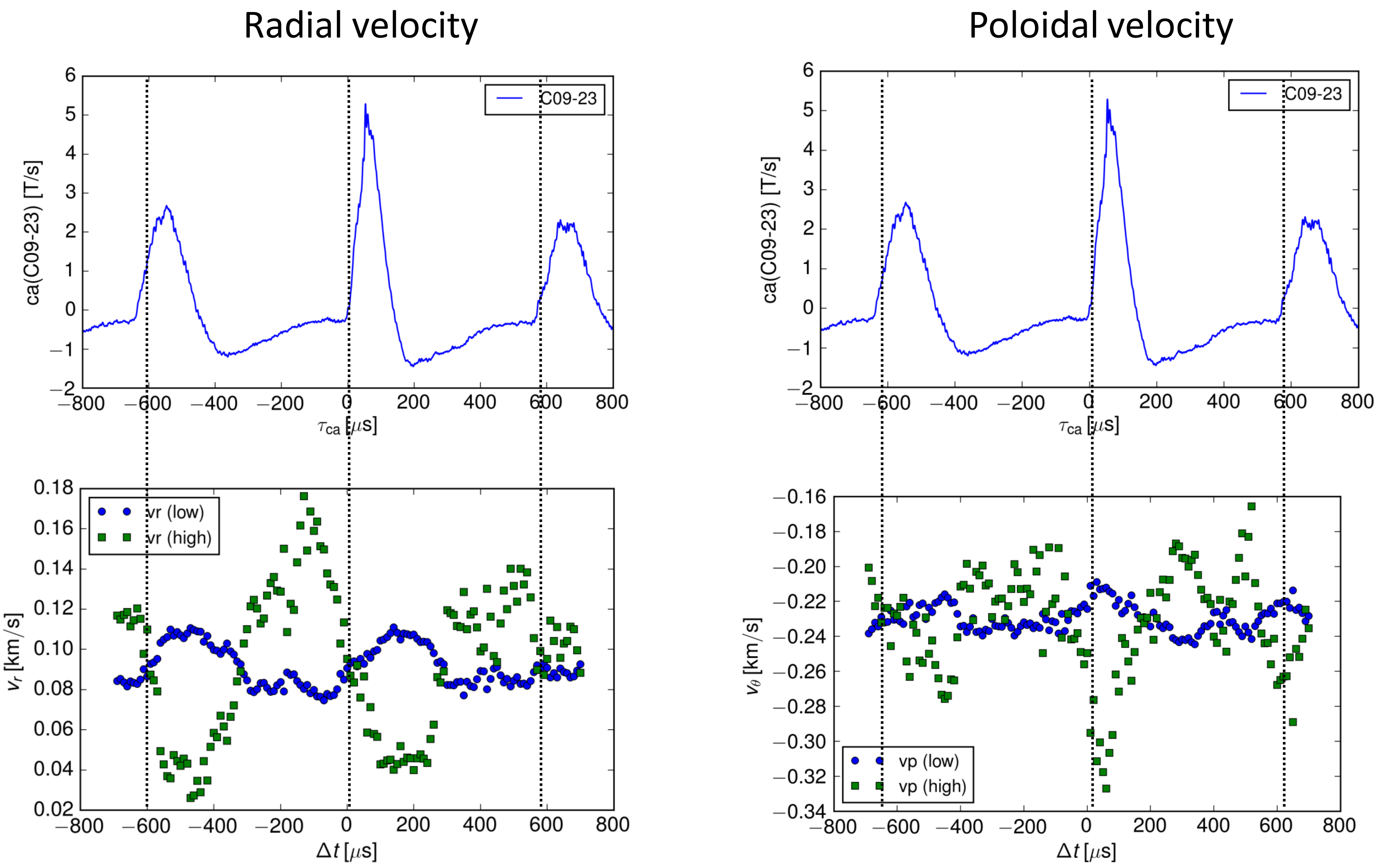
Detection rate



Poloidal blob size (FWHM)

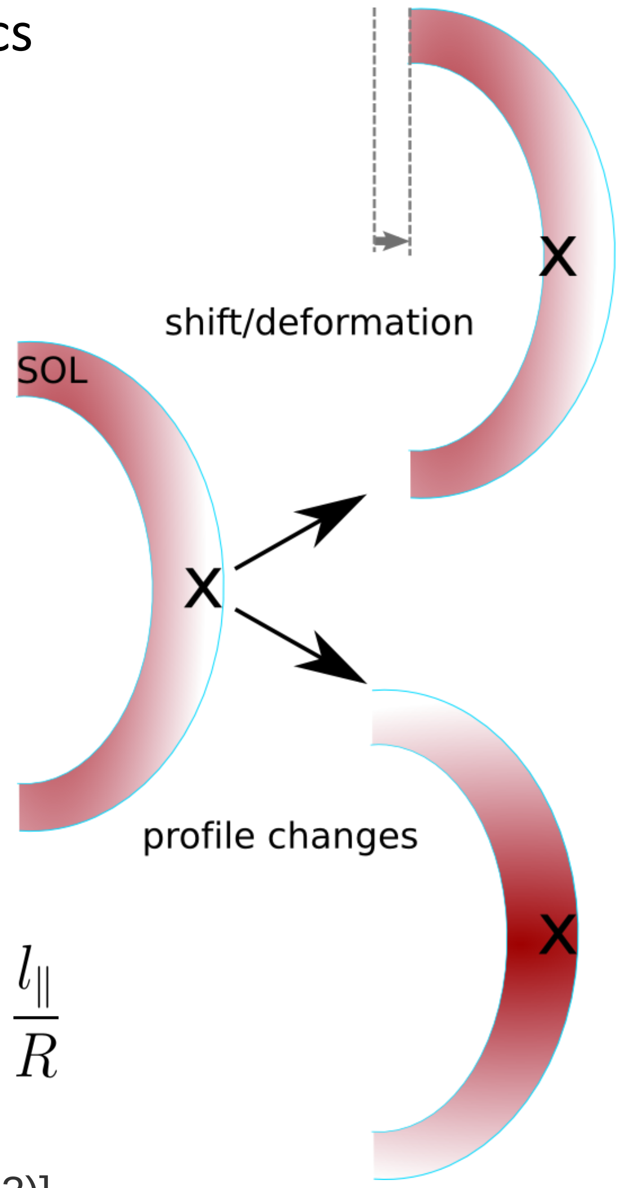


Blob properties: Radial and poloidal velocity



Blob properties

- Modulation with the I-Phase frequency or higher harmonics
- According to analytical scaling laws strong influence of
  - Electron temperature
  - Magnetic field strength and geometry (curvature, connection length,…)
- This leads to a radial variation of the blob properties.
- At a fixed location blob properties change due to:
  - Changes in the kinetic profiles
  - Displacement or deformation of the plasma



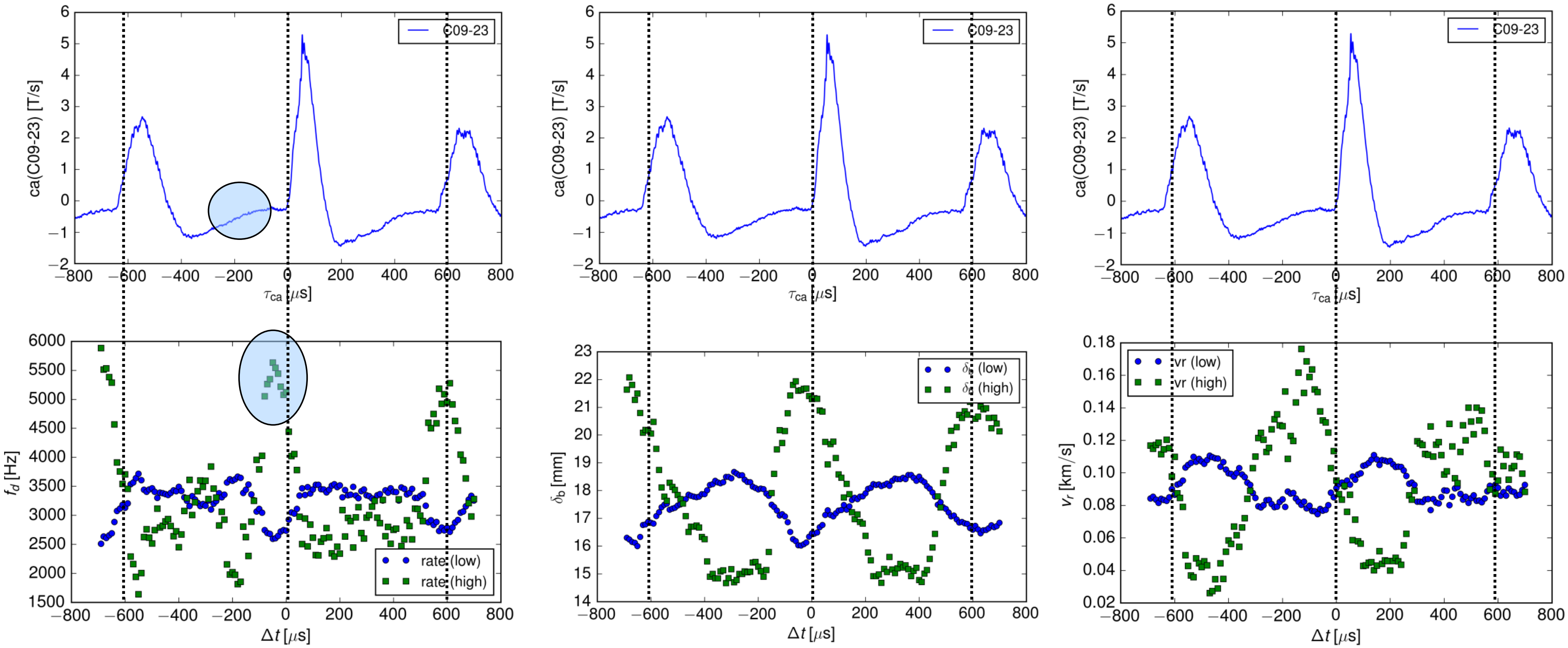
$$\delta = \rho_s \left(8(1+\tau_i)\right)^{1/5} \cdot \left(\frac{l_\parallel^2}{\rho_s R}\right)^{1/5}$$

$$v_r \approx (1+\tau_i) c_s \left(\frac{\rho_s}{\delta_b}\right)^2 \frac{l_\parallel}{R}$$

$$\rho_s = \frac{\sqrt{m_i T_e}}{eB}$$

[P. Manz *et al.*, Phys. Plasmas **20**, (2013)]

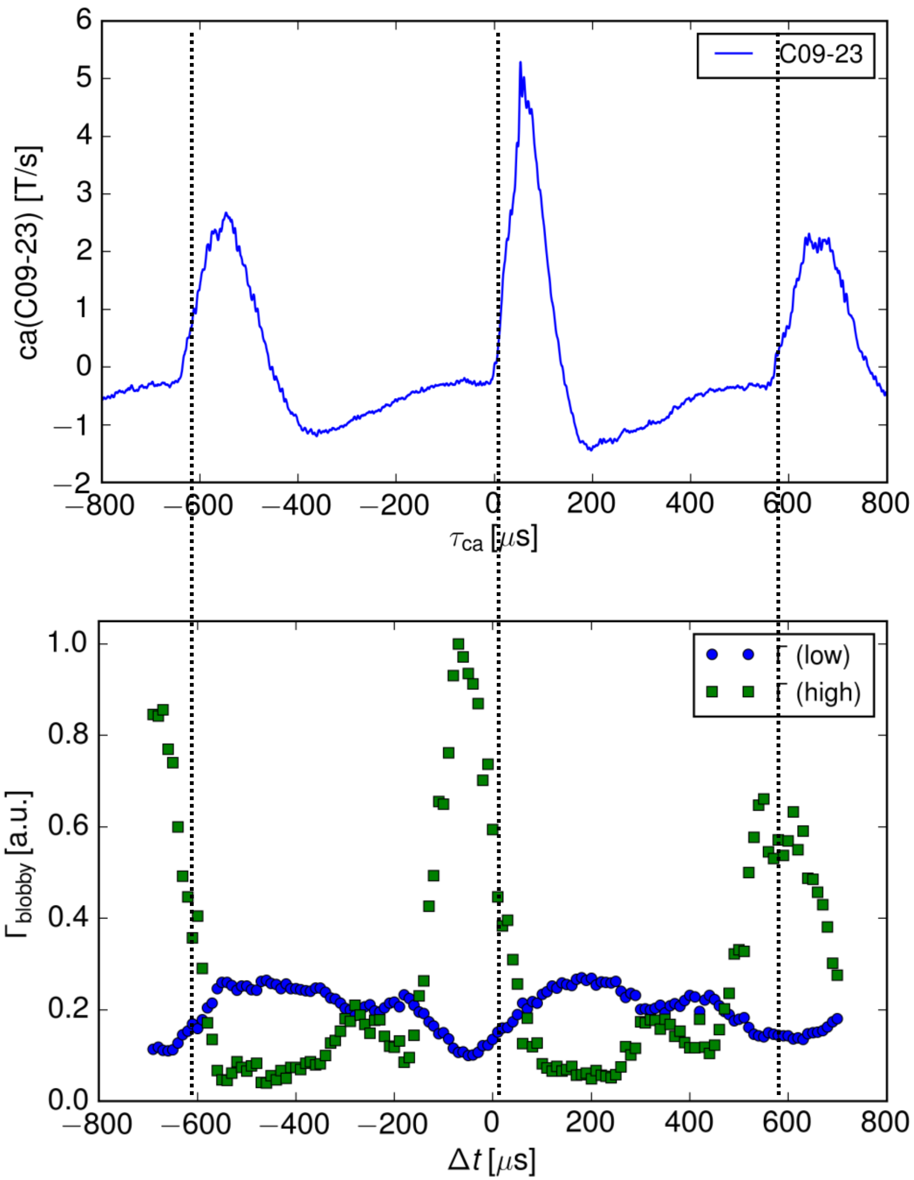
Chronological order



- All blob properties (except poloidal velocity) „peak“ before the reference signal.
- Blob speed: ~10-100 µs to reach the far SOL from the separatrix.
- Blob propagation introduces a shift in the “wrong” direction.

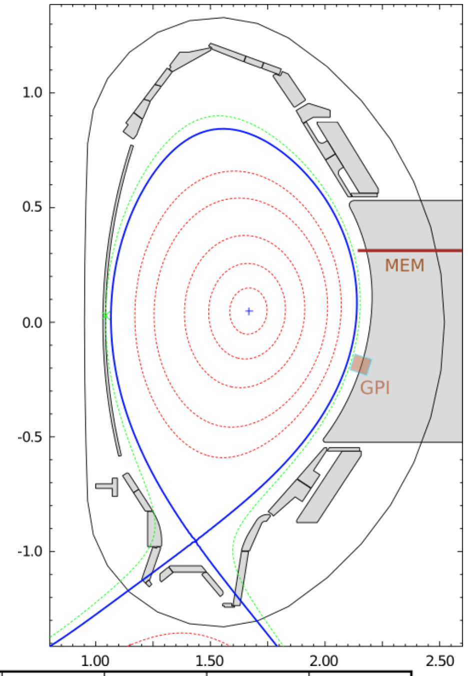
Blobby transport

- Estimate blobby transport as $\Gamma \propto f_d I_{max} \delta_b^2 v_r$
- Blobby transport modulated with I-phase frequency (+ higher harmonic?)
- Time shift consistent with observations made with X-point manipulator

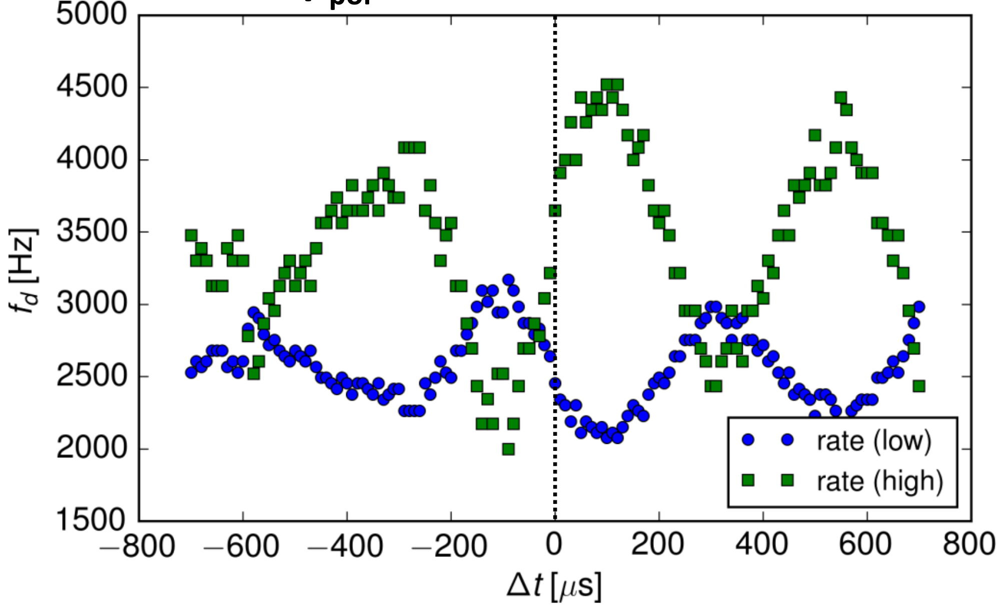


Comparison with Langmuir probes

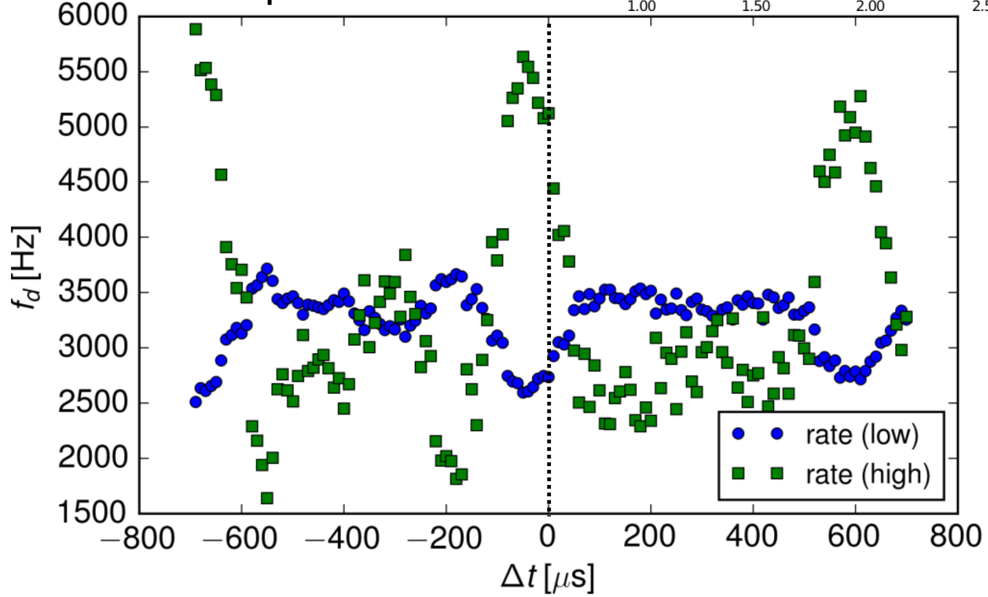
- Periodic change of blob properties also observed with LPs
- Different chronological order compared to camera data
- Poloidal asymmetry?



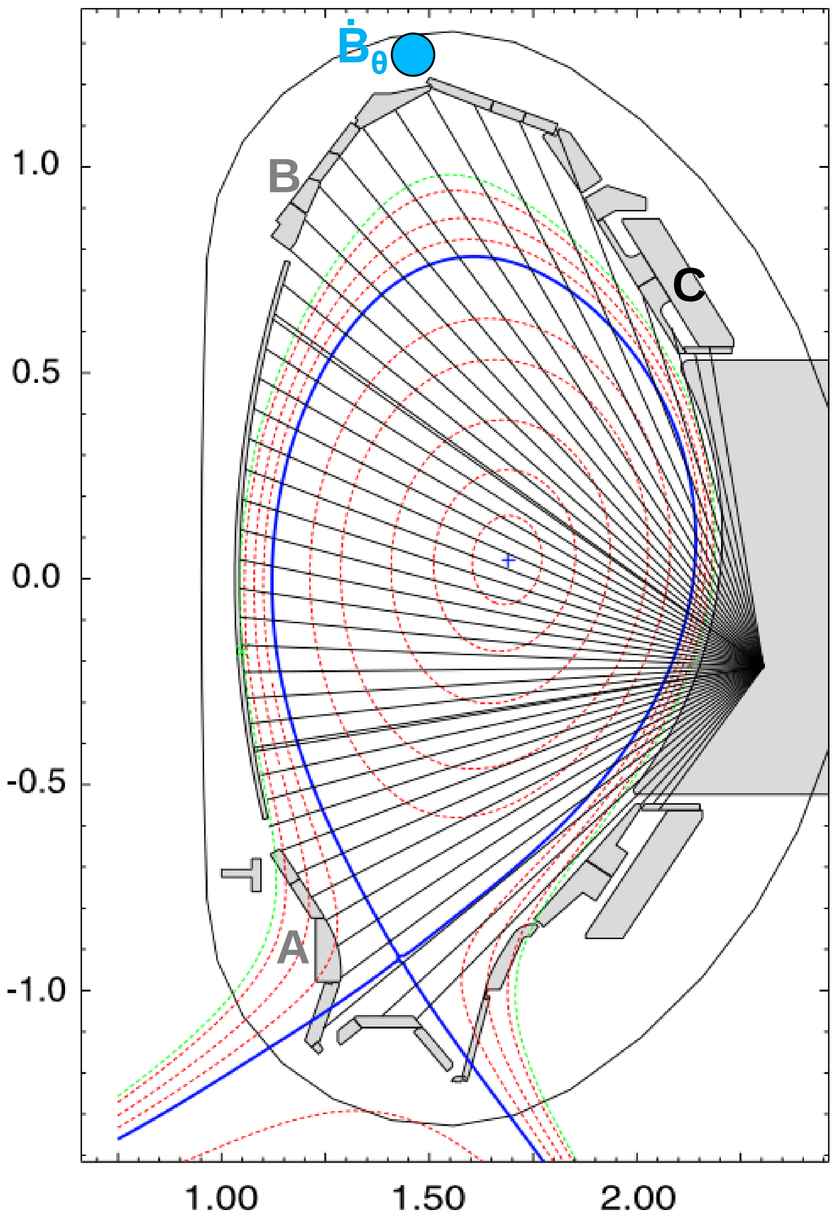
#25438:
MEM: ρ_{pol}≈1.07

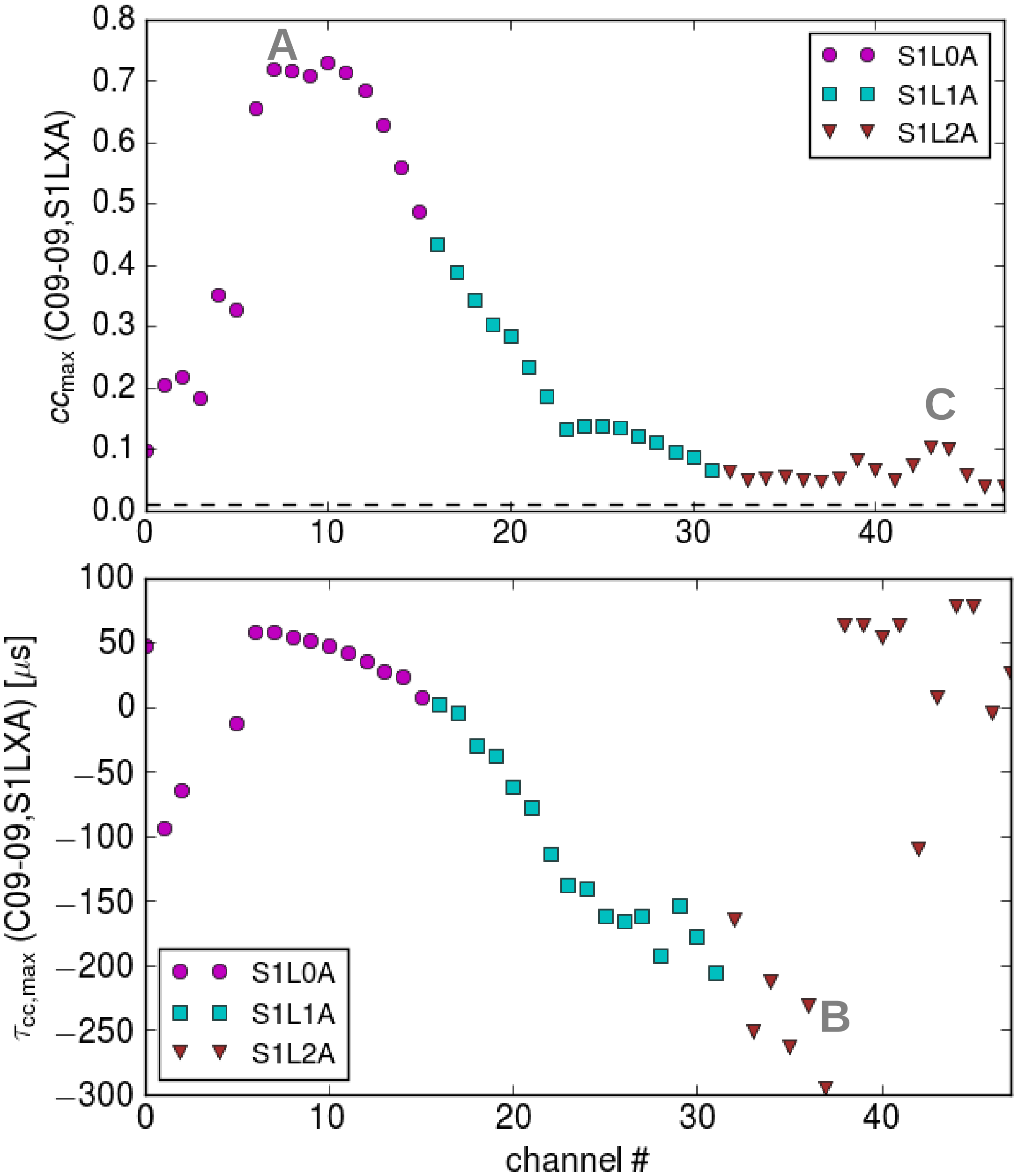


#31494:
GPI: ρ_{pol}≈1.08

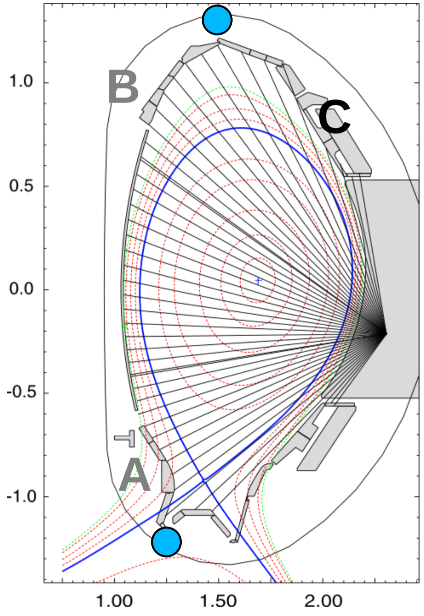


Bolometry results



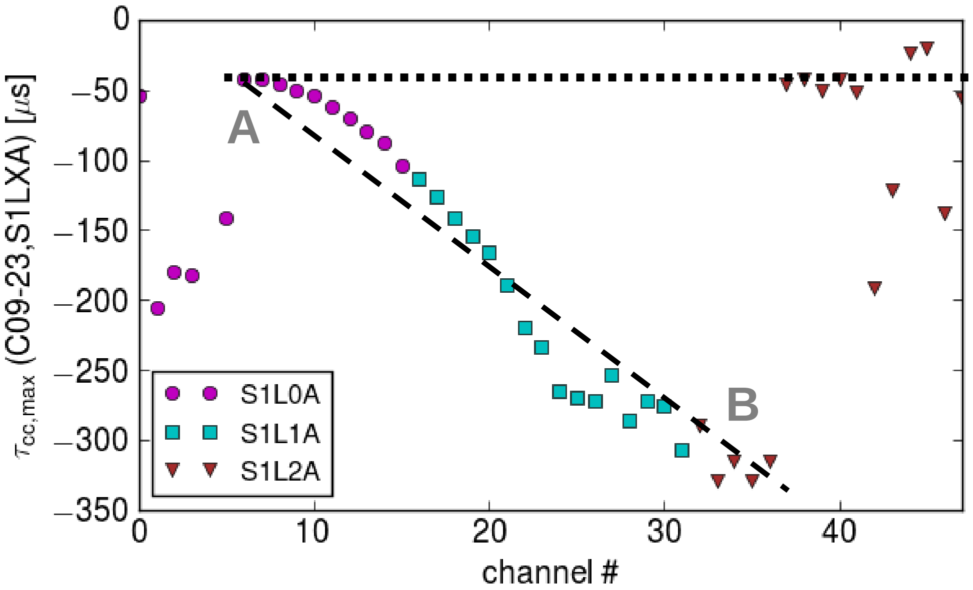


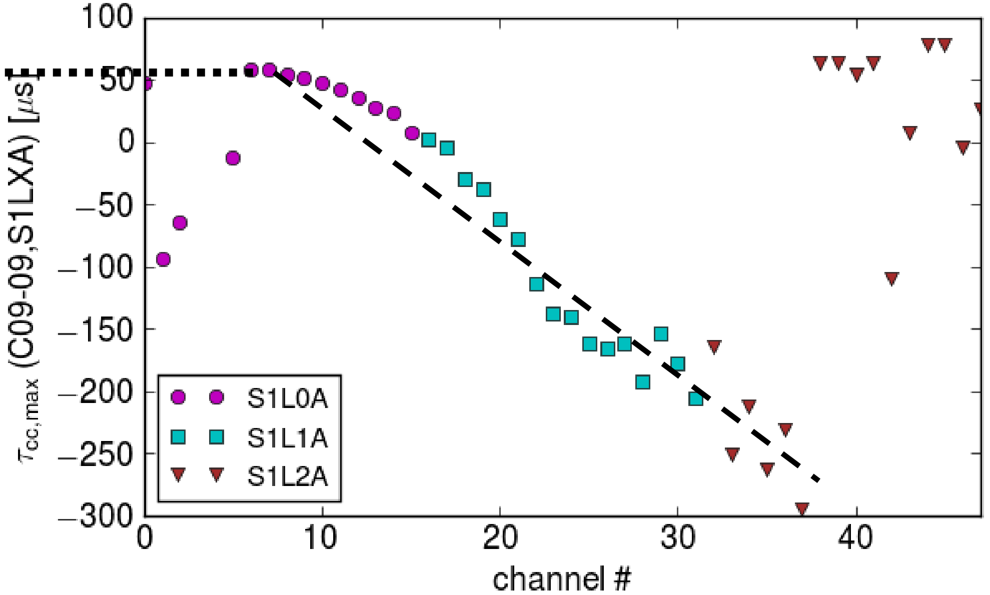
Poloidal propagation



- Observed propagation from A to B:
  - Time scale for the magnetic signal ~ 0.1 ms
  - Time scale for the radiation signal ~ 0.3 ms

→ Poloidal asymmetries in I-phase dynamics expected





Conclusion

What we have learned:

- The I-Phase influences the far SOL dynamics at a fixed location.
  - Shift and pulsation of light emission of neutral gas cloud
  - Blob properties are modulated with the oscillation frequency or higher harmonics.
- There is evidence for poloidally asymmetric dynamics/a poloidal propagation.

Open questions:

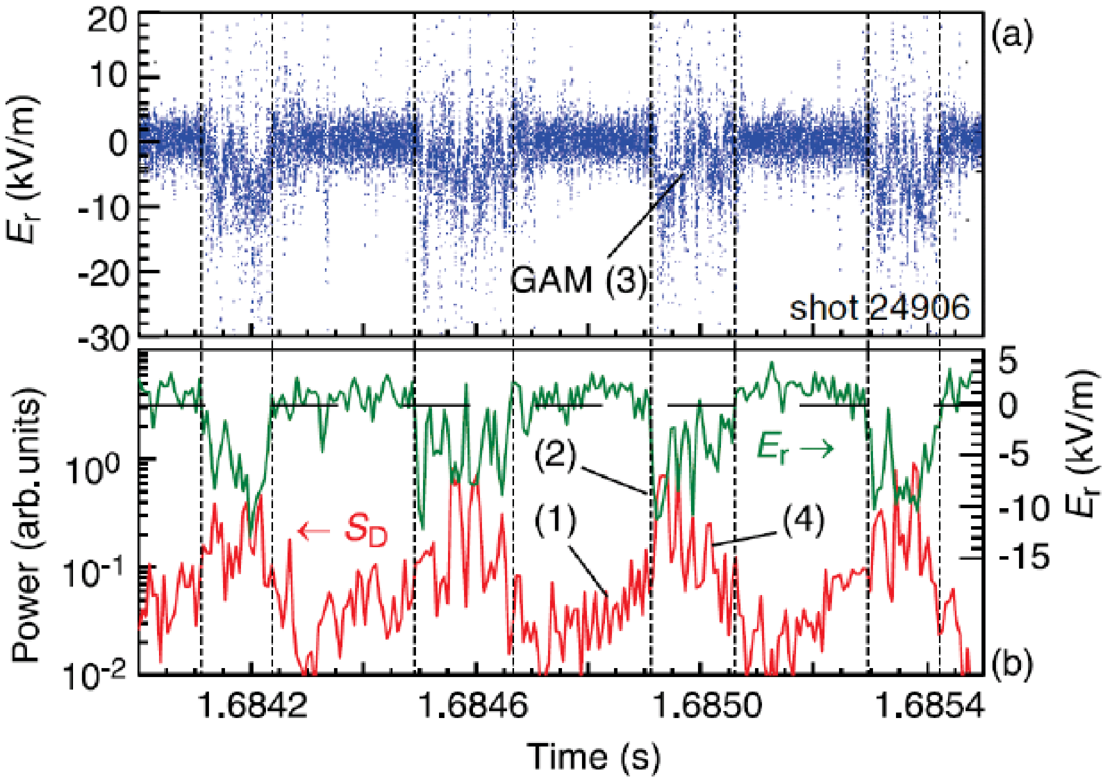
- What influences the blob properties during the I-Phase?
  - Blob models suggest T_e fluctuations in the SOL during the I-Phase.
  - Fluctuations may also be due to changes in the plasma shape/location.
- Is there any feedback between blob dynamics and the I-phase?
- What kind of effect is responsible for the observed poloidal asymmetry?
- Is there a relation between the observed dynamics and the L-H transition physics?

Variability of blob properties

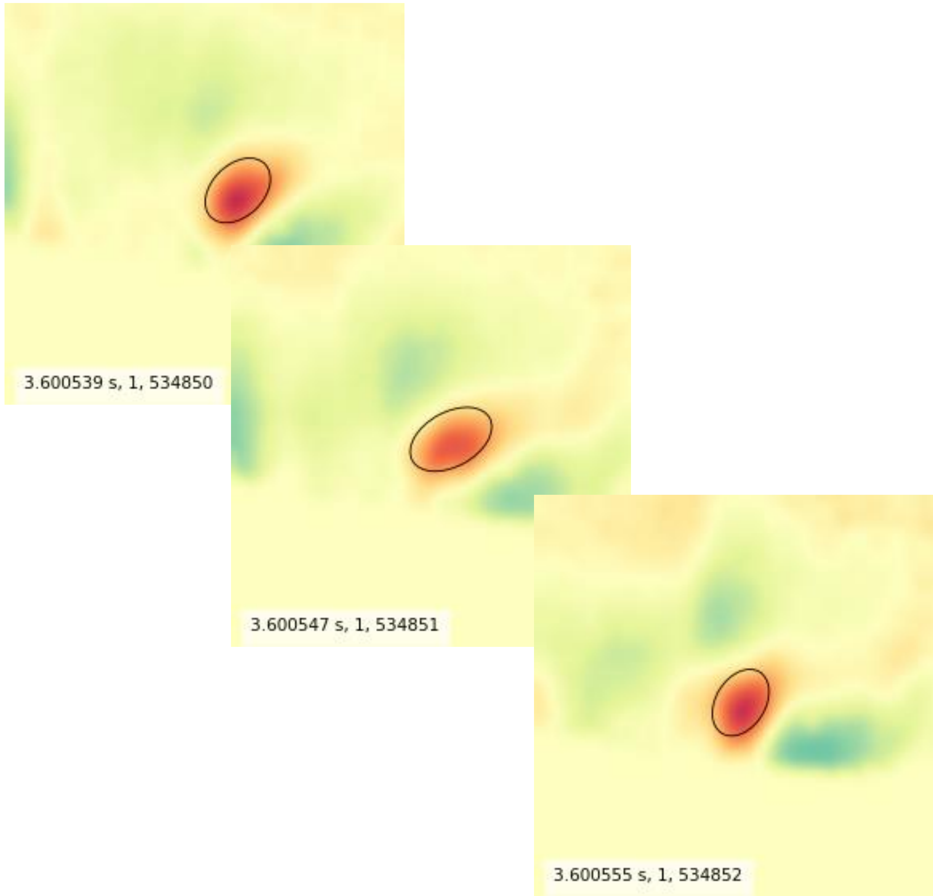
Question: How does a blob property A change during the I-phase?

Needed:

- Reference „phase“ signal
- Time resolved measurement of A



[G. D. Conway, PRL **106**, (2011)]

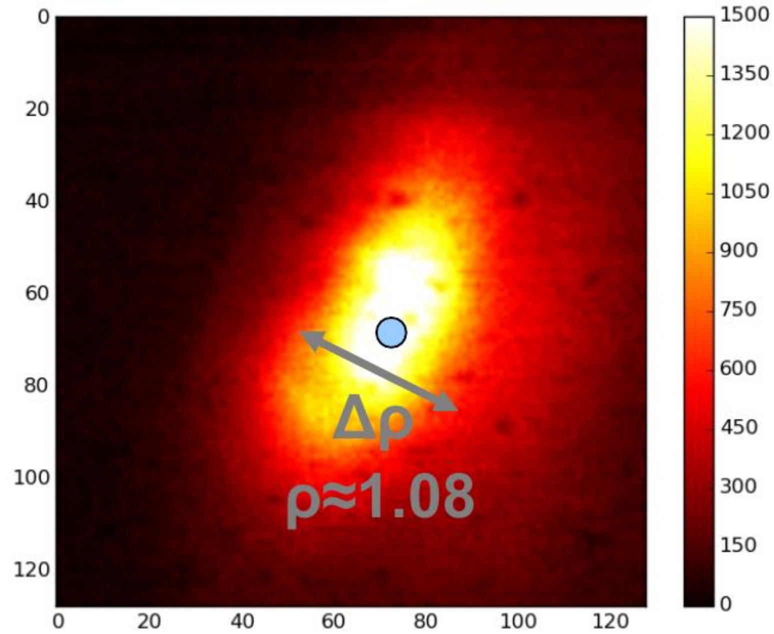


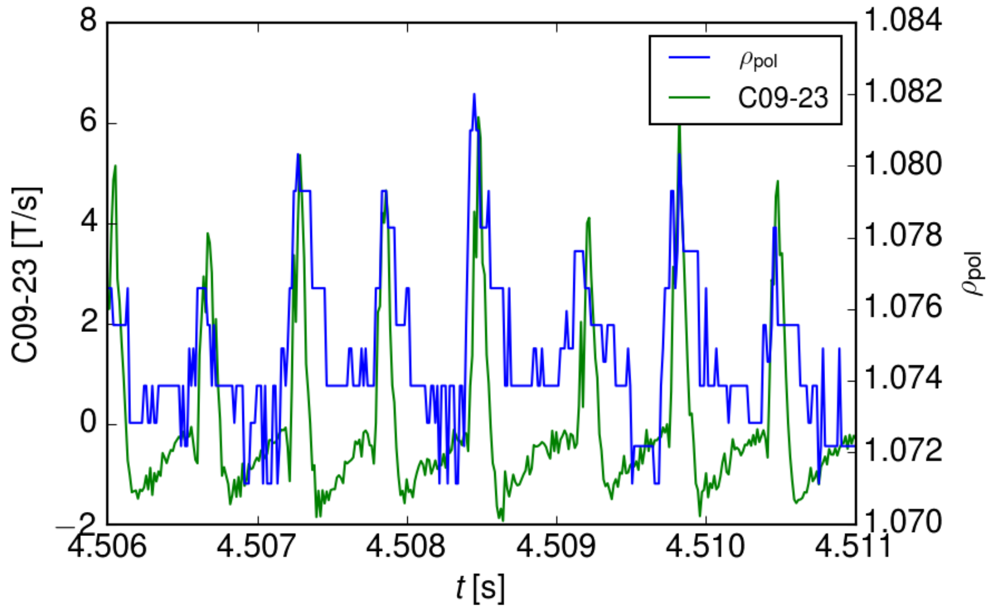
General observations

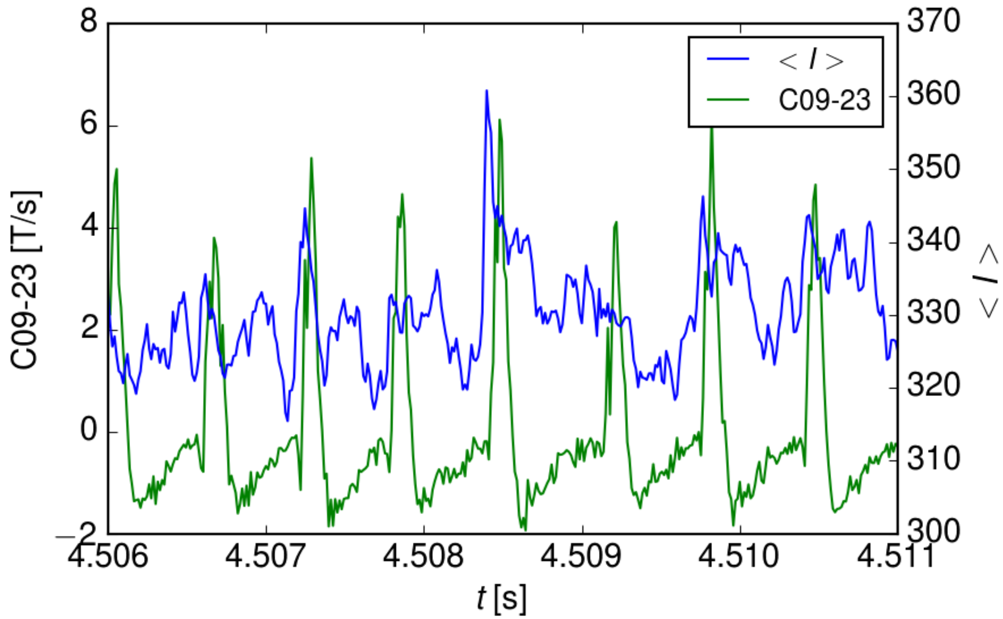
Observations during an I-phase (#31494)

- Center of the emission cloud „wobbles“ in phase with the magnetics.
- Pulsating emission intensity.
- Variations in n_e, T_e, or plasma shape/position.

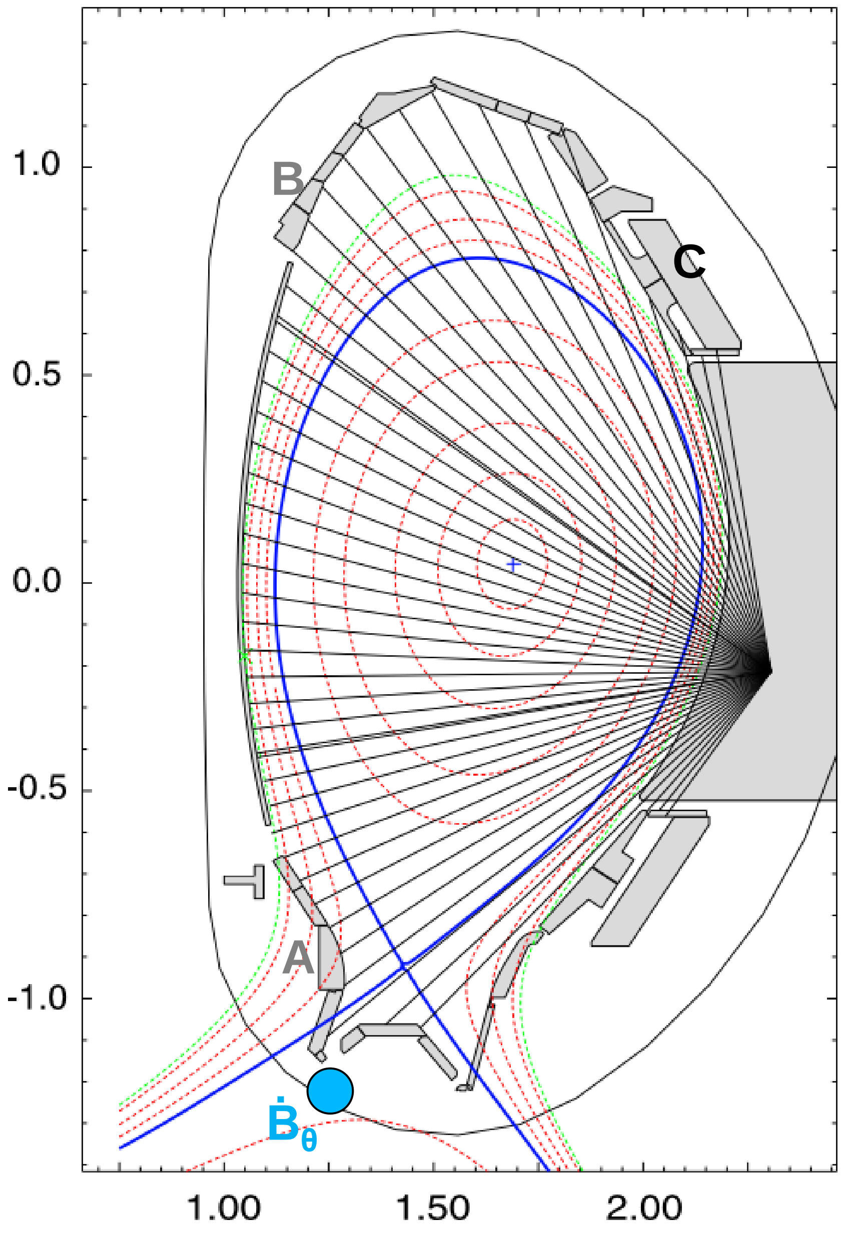
→ The far SOL „knows“ about the I-Phase

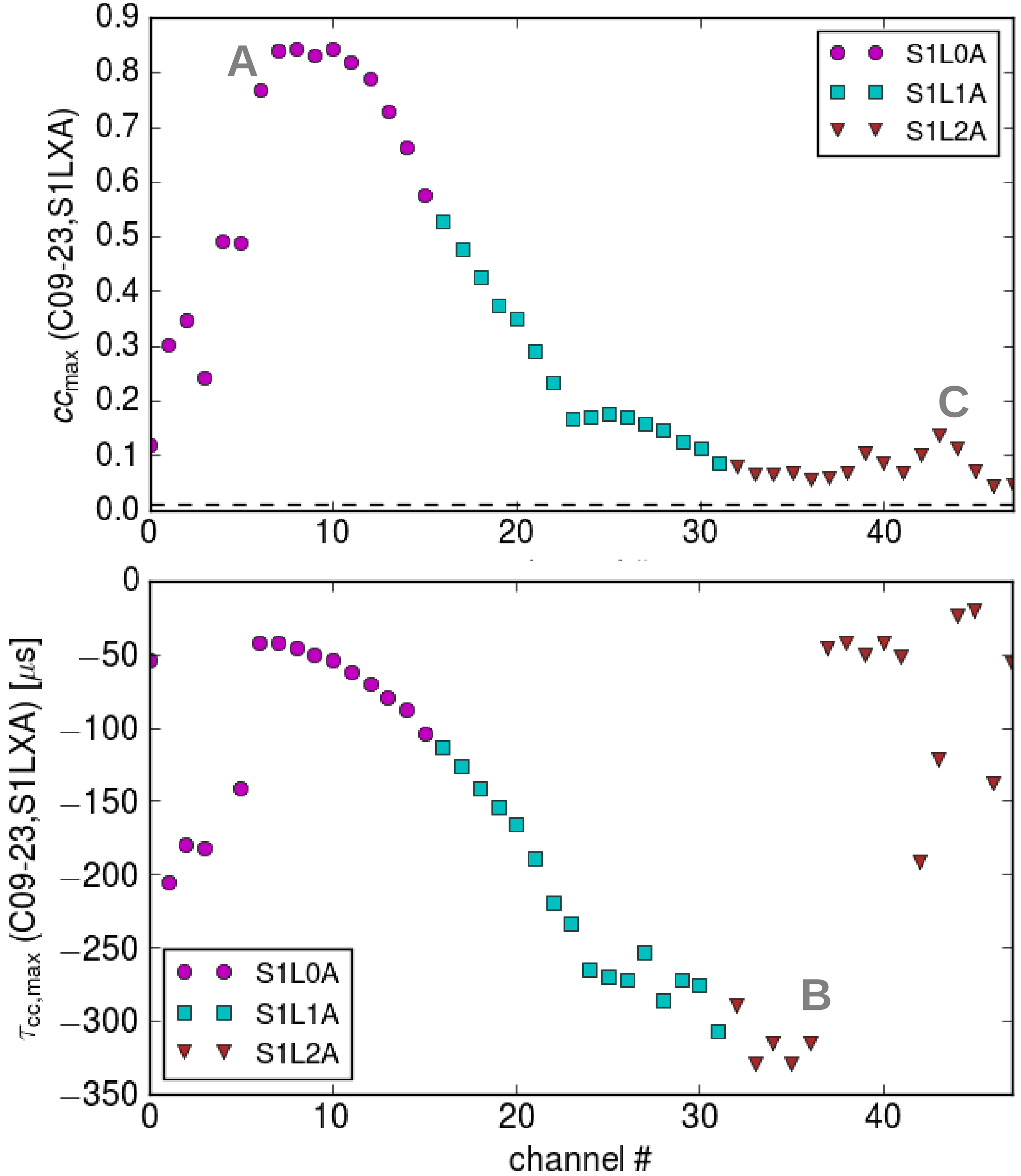






Bolometry results

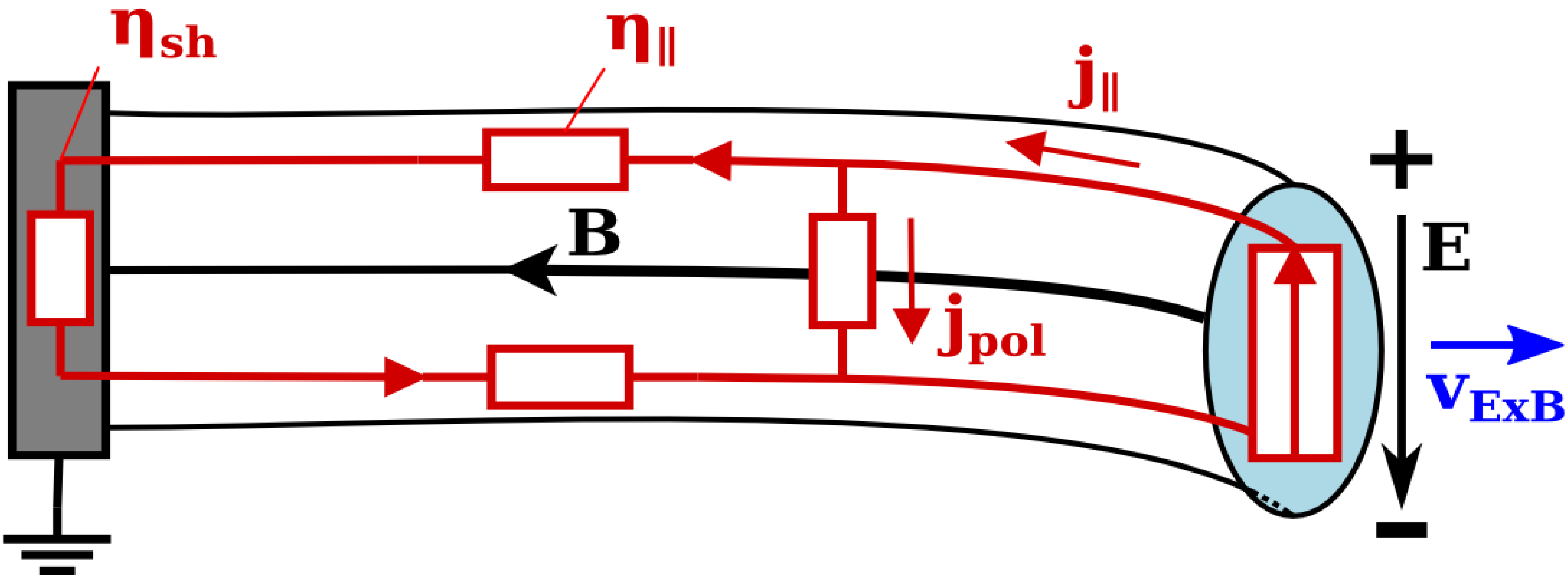




Simple blob model

Predicts velocity (and size), not generation rate

[S. Krasheninnikov et *al.*, J. Plasma Physics **74** 5, 2008]



$$\nabla_{\perp} \cdot \mathbf{j} = -\nabla_{\|} \cdot \mathbf{j}$$

Blob detection

- Subtract mean and normalize images.
- Determine standard deviation for every pixel.
- Detect connected structures with $I_{max} > I_t$ (e.g. $I_t = 2\sigma$) and $I > I_{max}/2$.
- Fit an ellipse to any detected structure to get the location and size of the blob.
- Track structures over time to get their velocities.