Mechanism for plasma blob generation in the TORPEX toroidal plasma

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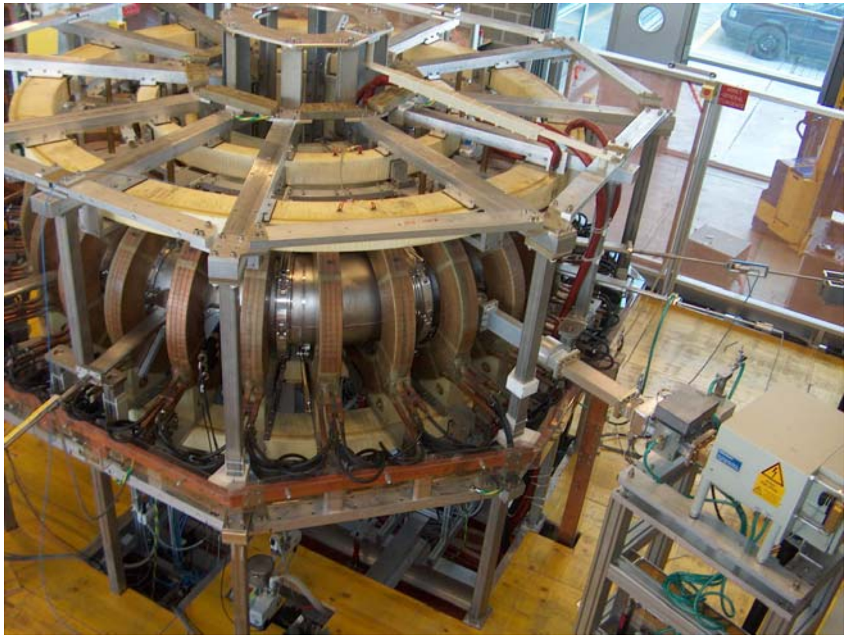
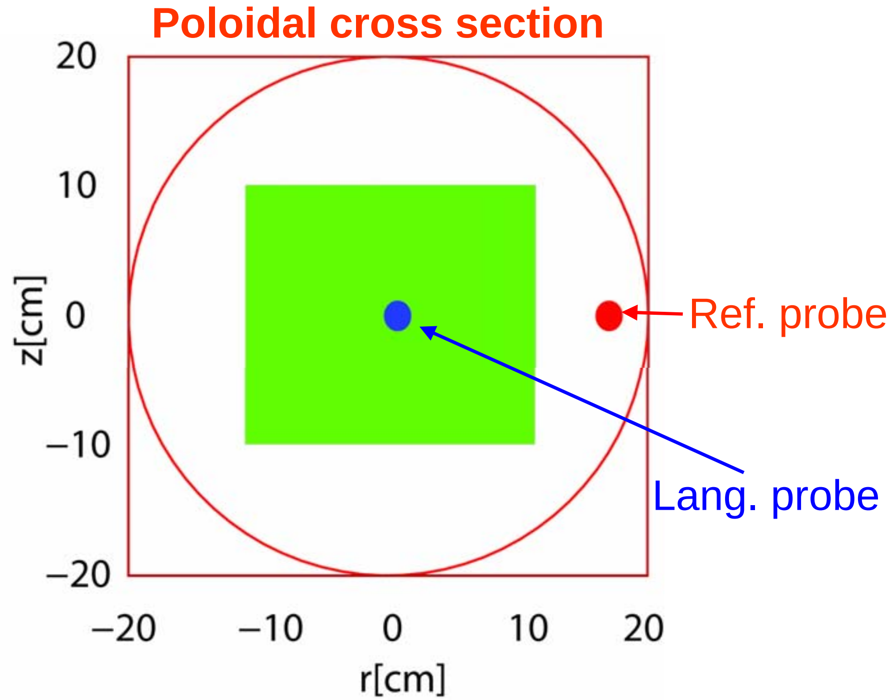
Outline

- Mechanism for blob ejection from the drift-interchange wave
  - E x B velocity shearing
  - link with $|L_{pe}^{-1}| = |\nabla_r p / p|$
- First simulations of TORPEX plasmas in the SOL-like configuration
- Conclusions and outlook

Experimental setup and diagnostics



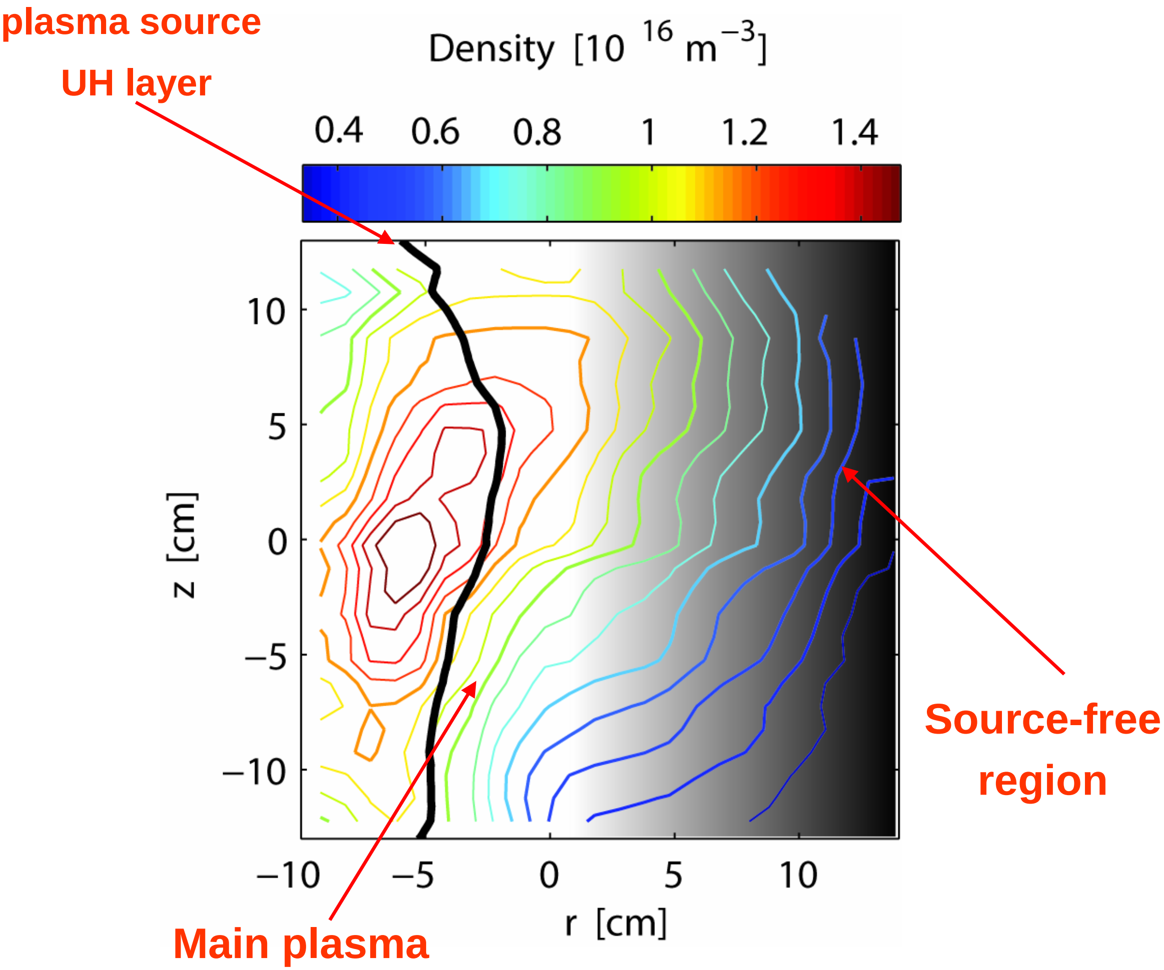


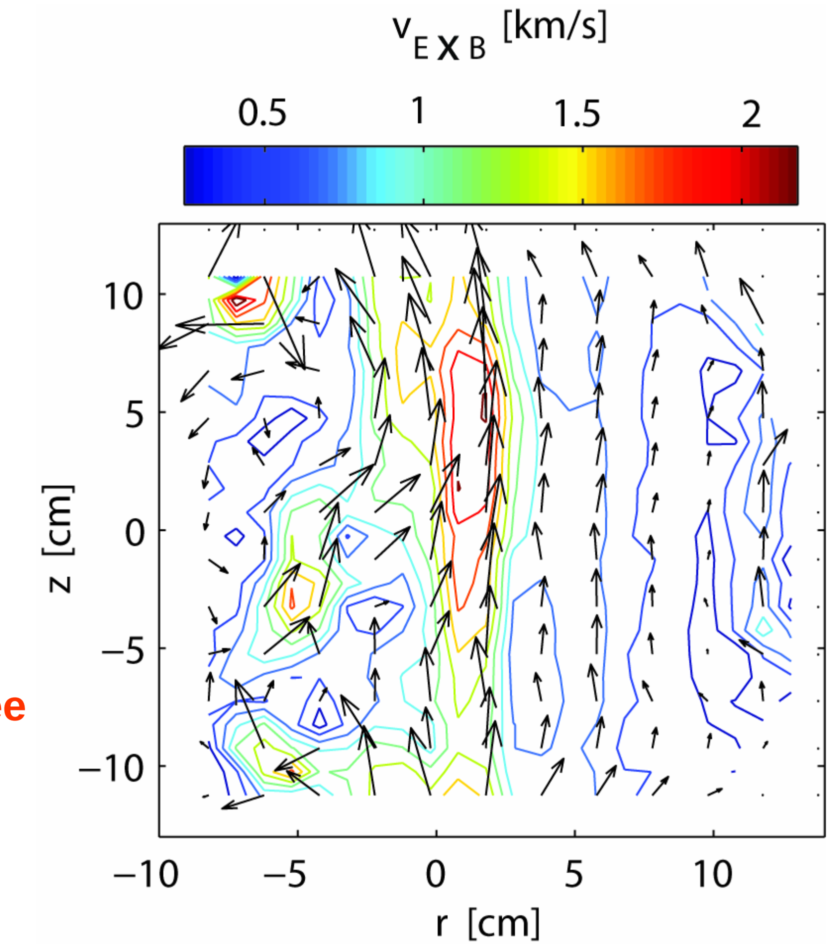
- TORPEX: SOL-like configuration
  - **H_2 plasma**
  - B_t=76 mT on axis, B_z=2.1mT

- Main diagnostics:
  - **2 movable Langmuir probes**
  - **Modified conditional sampling technique**

    ⇒ 2D profiles of $n_e(t)$, $T_e(t)$, $V_{pl}(t)$, E x B velocity

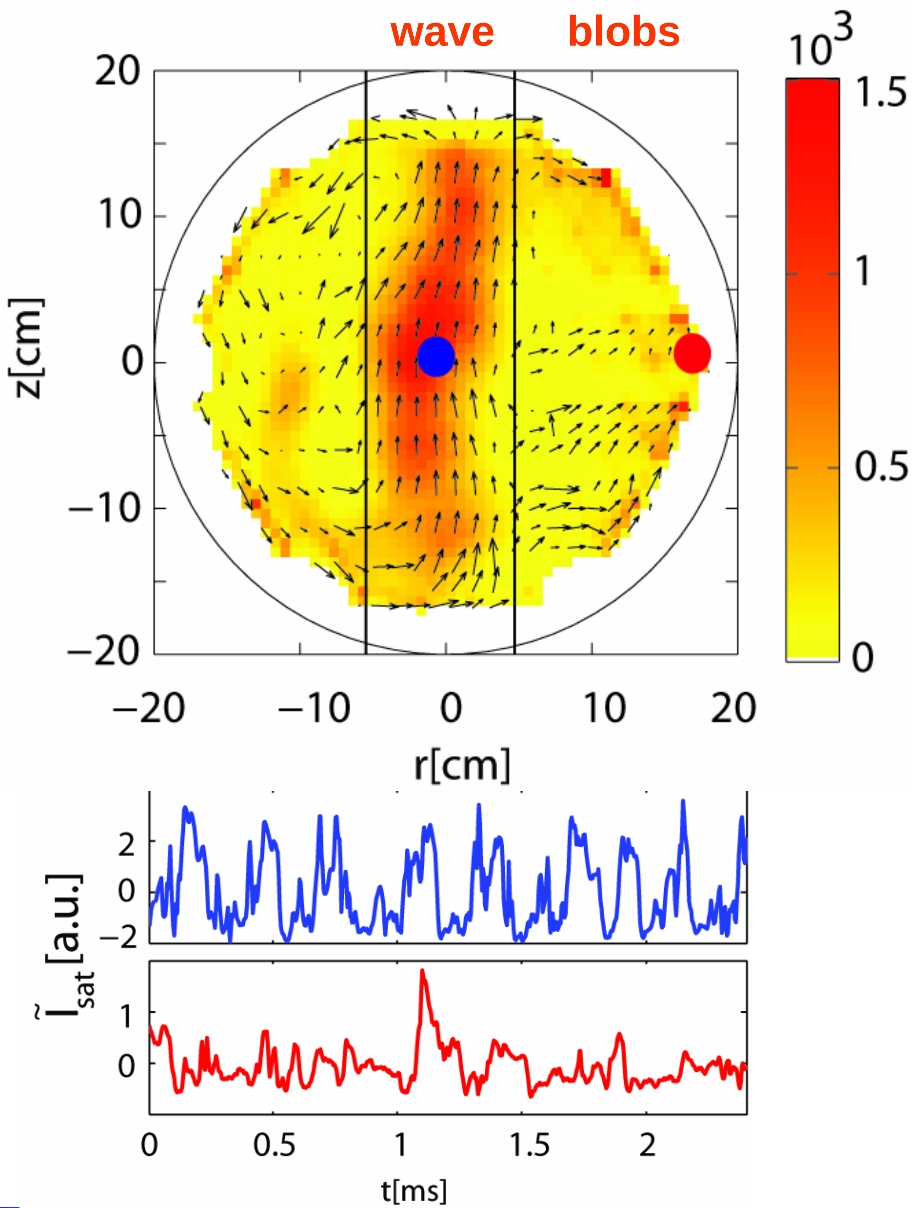
SOL-like configuration: time averaged profiles





- Separation between main plasma and source-free region.
- Slab-like E x B vel. profile for r > 0. Presence of velocity shear.

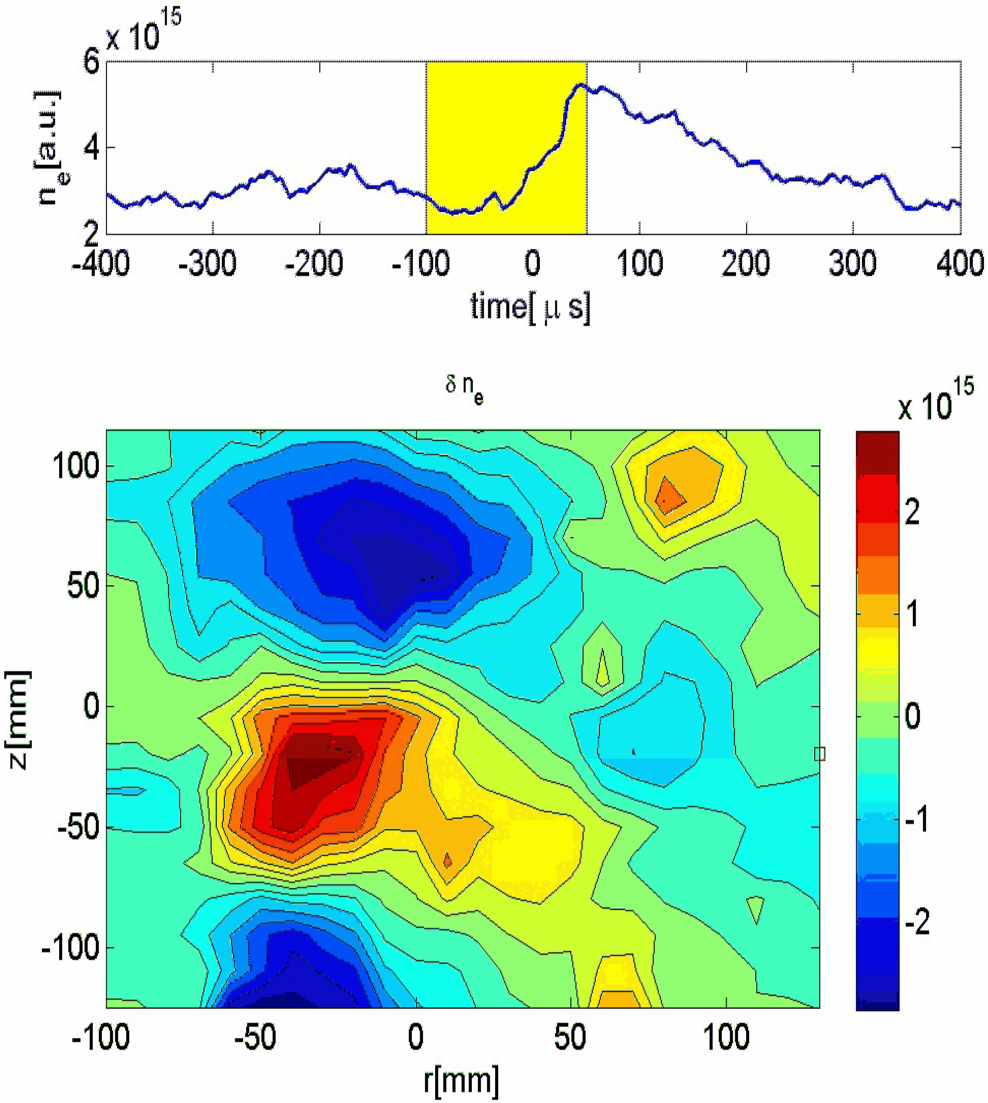
SOL-like configuration: waves and blobs



- Two regions with different plasma dynamics.
- Main plasma: coherent drift-interchange wave
  - localized around $|L_{pe}^{-1}| = |\nabla p / p|$
  - $k_z \sim 30\ m^{-1}$, $k_{//} < 0.046\ m^{-1}$
  - $\langle V_{E \times B} \rangle_t$ propagation
- Source-free region: blobs
  - Intermittent transport
  - Blob propagation is not consistent with $\langle V_{E \times B} \rangle_t$

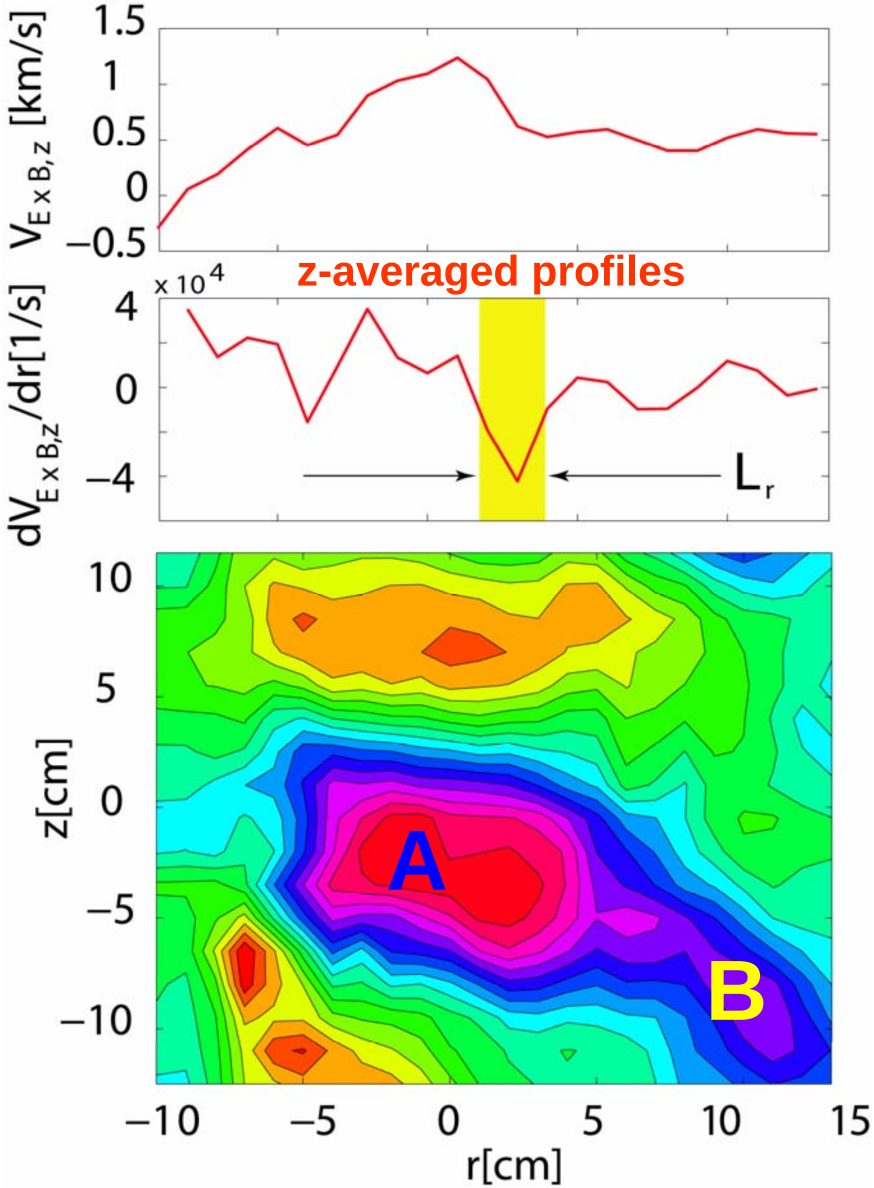
CRPP

Dynamics of blob ejection



- Coherent structures (interchange mode) move upwards with E x B velocity.
- A radially elongated structure forms from a positive cell.
- The structure breaks into two parts in ~100 μs
  $\Rightarrow$ formation of the blob on LFS.

The density structure is sheared off by the E x B flow

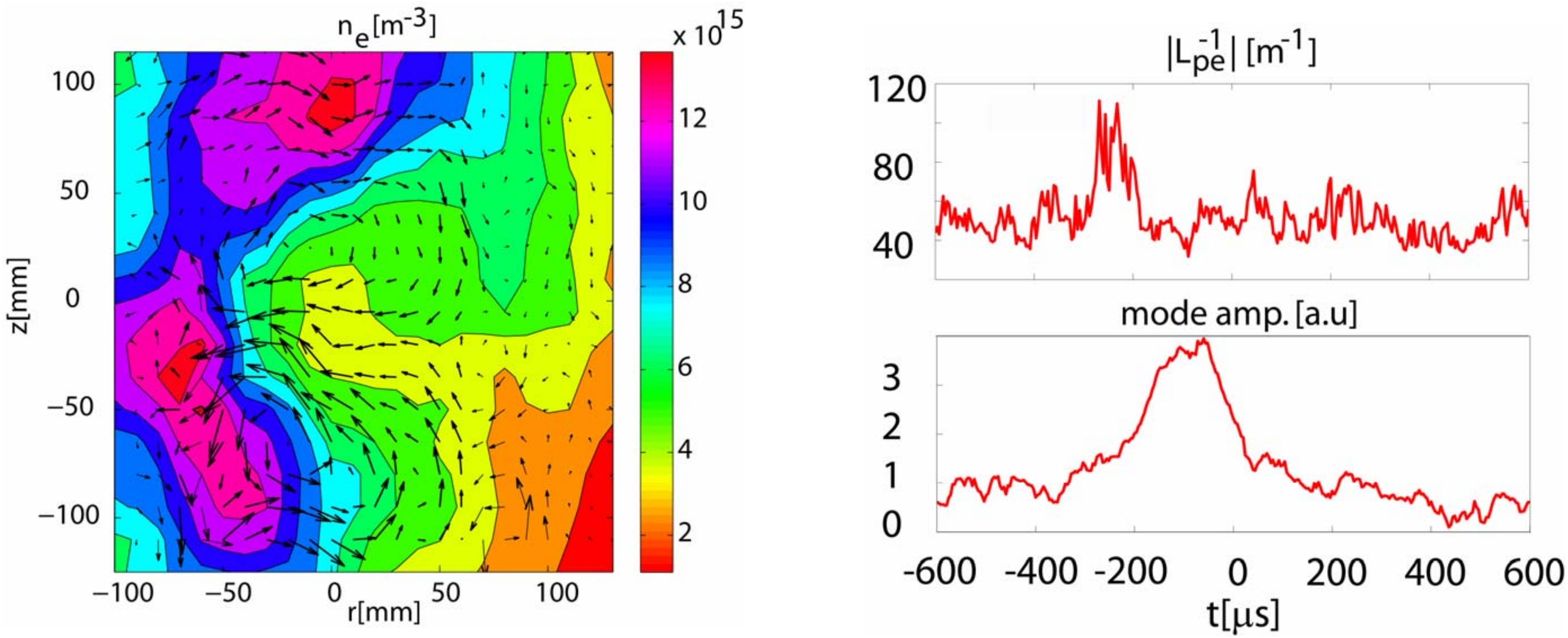


- Structures are convected by E x B flow.
- Strong shear in the E x B flow:
  - Region **A** moves at ~ 1200 m/s
  - Region **B** moves at ~400 m/s
- Estimate of the shearing time [H. Biglari, et al., Phys. Fluids B 2, 1 (1990)]:

$$\tau_{sh} = \left(\frac{k_z L_r}{2\pi} \frac{\partial V_{ExB,z}}{\partial r} \right)^{-1} \sim 100\,\mu s$$

The **E** x **B** flow shears off the structure and forms the blob.

The interchange drive increases with $|L_{pe}^{-1}|$



- Existence of convective cells associated with plasma potential.
- The maximum (in space) $|L_{pe}^{-1}|$ increases.
- The interchange mode increases following the increase of $|L_{pe}^{-1}|$.
- The mode increase leads to a higher outflow $V_{E \times B}$ and therefore to the elongation of the wave crest.

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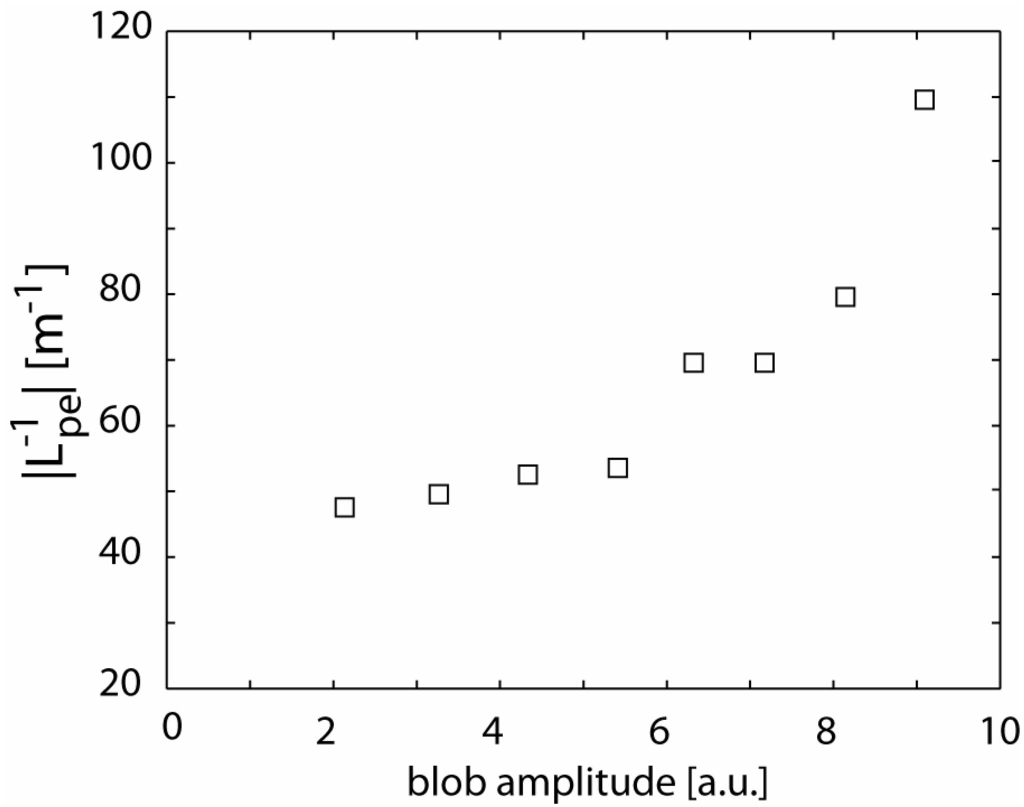
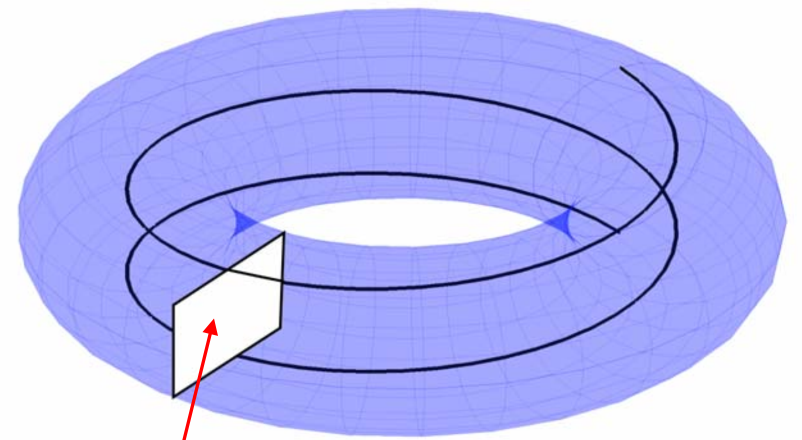
Link between gradient and blob size



- Select 8 classes of blob amplitudes.
- Same qualitative behavior of $|L_{pe}^{-1}|$ is observed for the different classes.
- $|L_{pe}^{-1}|_{max}$ increases monotonically with blob size.

Fluid model



2D domain

- 2-Fluid model, evolving N, ϕ, T_e.
- ∇B and curvature taken into account.
- 2D geometry with parallel dissipation.
- Diffusion coefficients from Braginskii equations.
- Source terms from the experiment.

Density

$$\frac{dN}{dt} = D_n \nabla^2 N + \frac{2}{R}\left(N\frac{\partial T_e}{\partial z} + T_e \frac{\partial n}{\partial z} - n\frac{\partial \phi}{\partial z}\right) - \sigma N \sqrt{T_e}\, e^{\Lambda - \phi/T_e} + S_n$$

Temperature

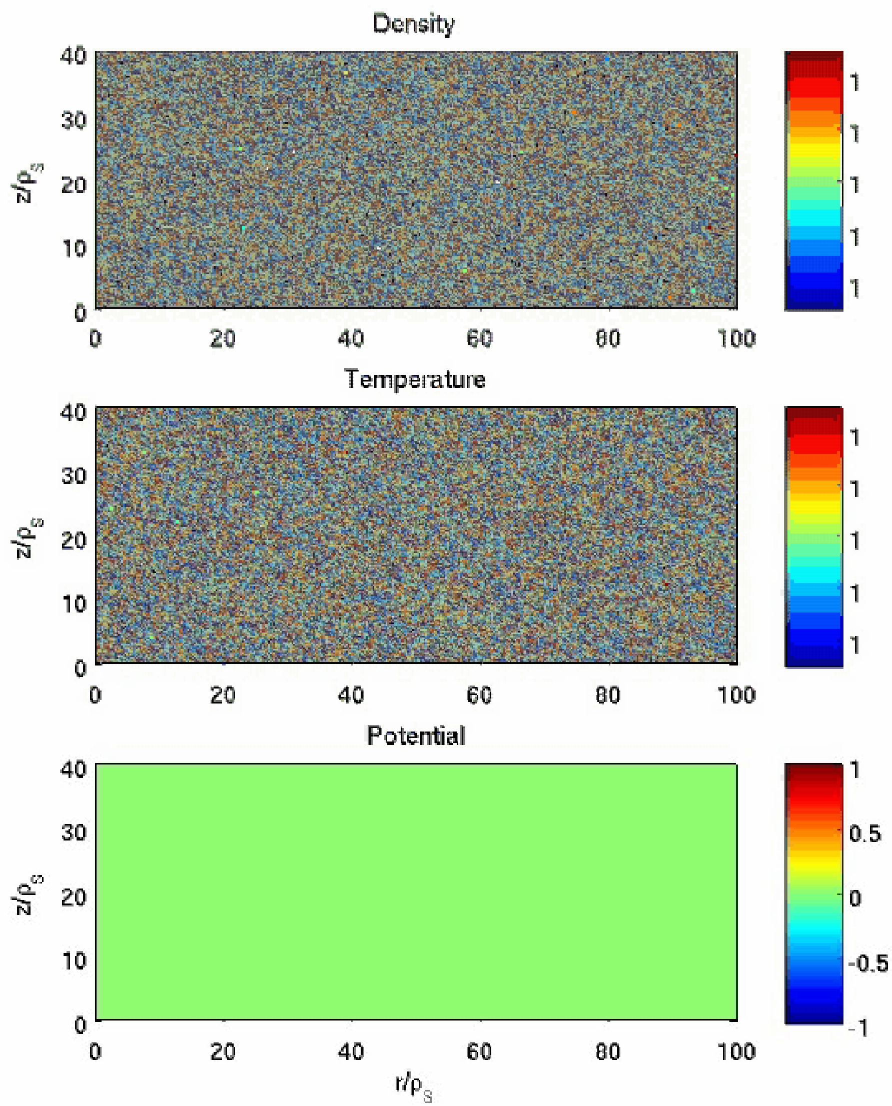
$$\frac{dT_e}{dt} = D_T \nabla^2 T_e + \frac{4}{3R}\left(\frac{7}{2} T_e \frac{\partial T_e}{\partial z} + \frac{T_e^2}{n}\frac{\partial n}{\partial z} - T_e \frac{\partial \phi}{\partial z}\right) - \sigma \sqrt{T_e^3}\, e^{\Lambda - \phi/T_e} + S_T$$

Potential

$$\frac{d\nabla^2 \phi}{dt} = D_\phi \nabla^4 \phi + \frac{2}{R}\left(\frac{T_e}{n}\frac{\partial n}{\partial z} + \frac{\partial T_e}{\partial z}\right) + \sigma \sqrt{T_e}\left(1 - e^{\Lambda - \phi/T_e}\right)$$

Advection | Diffusion | Interchange drive | Parallel losses | Source

Simulation of TORPEX plasmas in the SOL-like configuration



- The simulation is started from constant values.
- Energy and particles increase during first phase.
- An interchange mode is destabilized.
- During the non linear stage, the generation of blobs is observed.

Numerical code based on ESEL, numerical schemes in V. Naulin, J. Sci. Comput. **25**, 104, 2003.

Conclusions and outlook

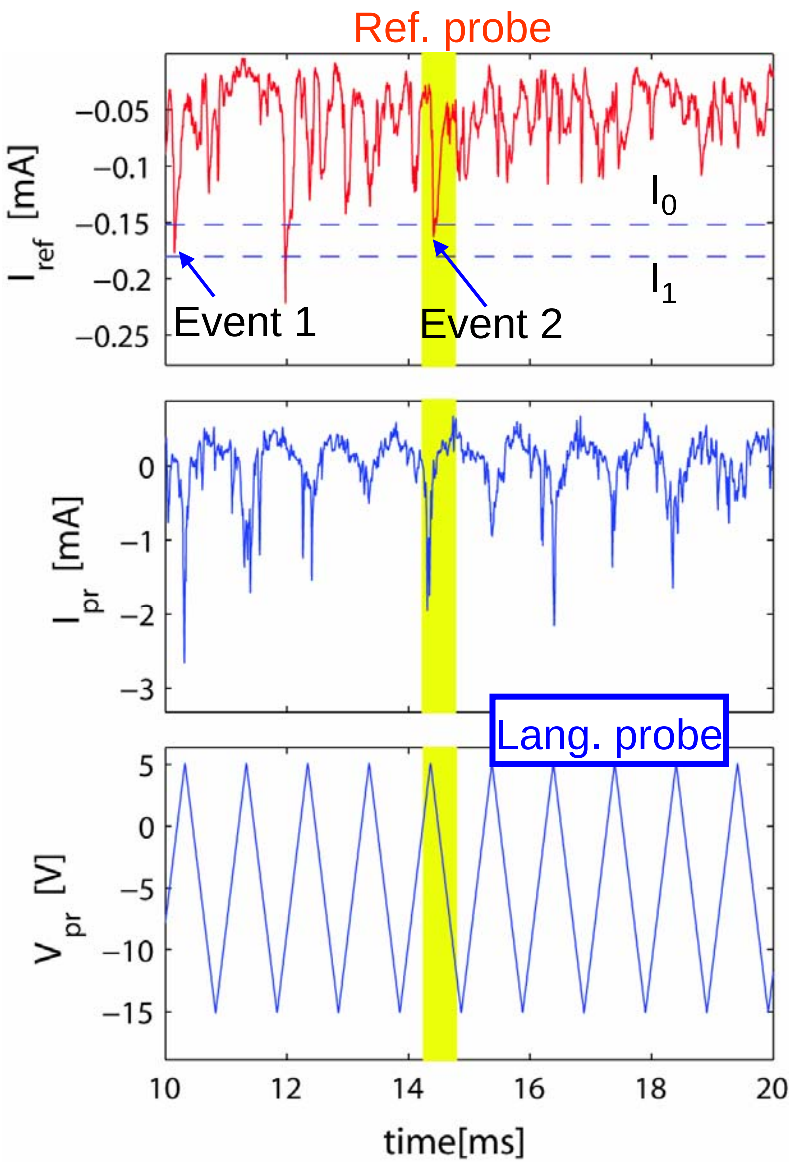
- We have studied the blob generation mechanism using CS 2D profiles of n_e, T_e, V_{pl} and **E** x **B** velocity in the SOL-like configuration in TORPEX.

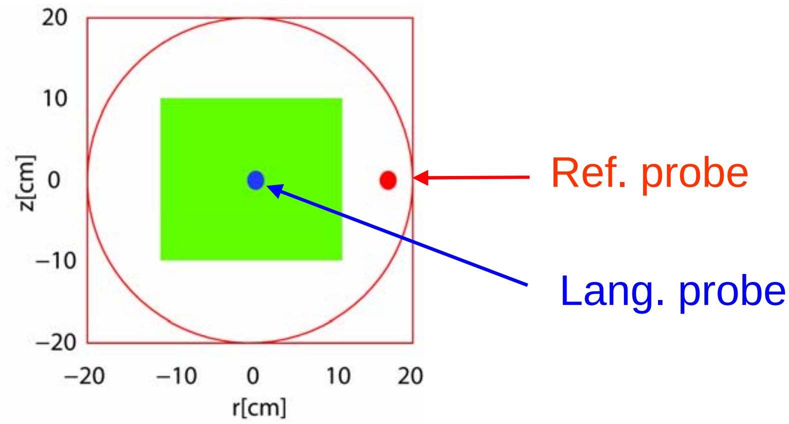
- When a blob is generated the following sequence of events occurs: 1) $|L_{pe}^{-1}|_{max}$ increases providing an increased drive for the mode; 2) the mode increases in amplitude and expands radially; 3) the radially elongated (n_e,T_e,V_{pl})-structure is sheared off by the **E** x **B** flow and forms the blob.

- We have implemented a 2-fluid model of TORPEX plasmas in the SOL-like configuration. First numerical simulations show the formation of blobs.

- Outlook: validation of simulations against data. Implementation of virtual diagnostics to extract *experimental data* from the code. Application of the same technique and definition of metrics for the comparison.

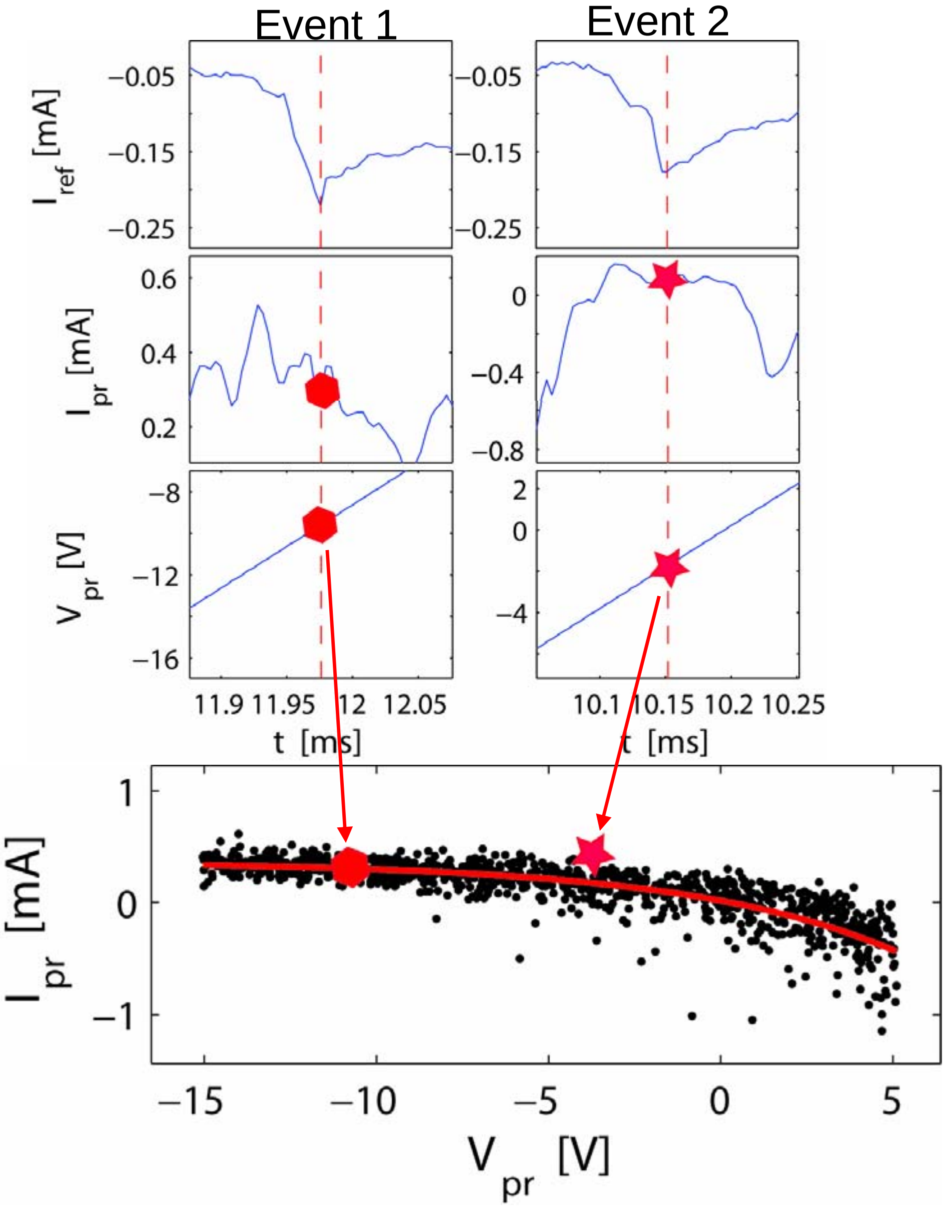
Conditional-sampled I-V curves provide $V_{pl}(t)$, $T_e(t)$, $n_e(t)$





- Edge probe measures ion sat. current I_{ref}.
- Movable Langmuir probe in swept mode (toroidally space by 45°)
  - f_{pr} ~ 1 kHz, V_{pr} = [-15, 5] V
- Selection rule for detecting blobs: $I_0 < I_{ref} < I_1$.
- N_{blob} events can be detected (N_{blob} ~ 600 in 2.7s discharge)
- Select time window around the blob event containing n_t temporal points.

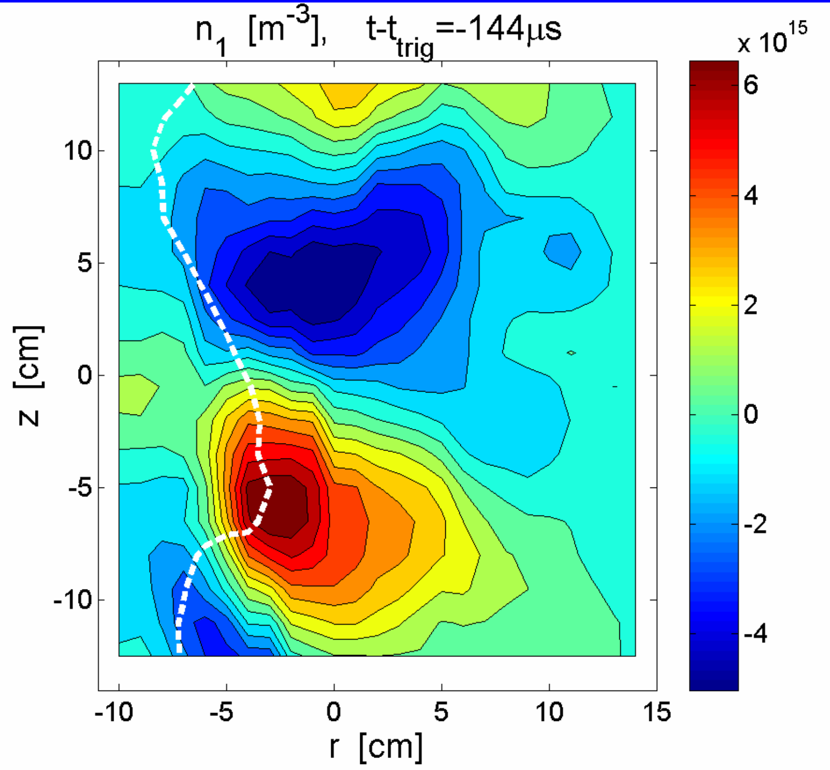
CS profiles over multiple discharges ⇒ velocity fields

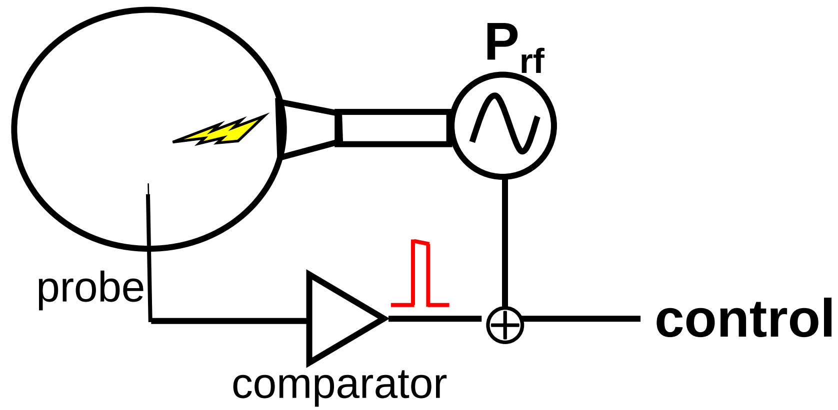


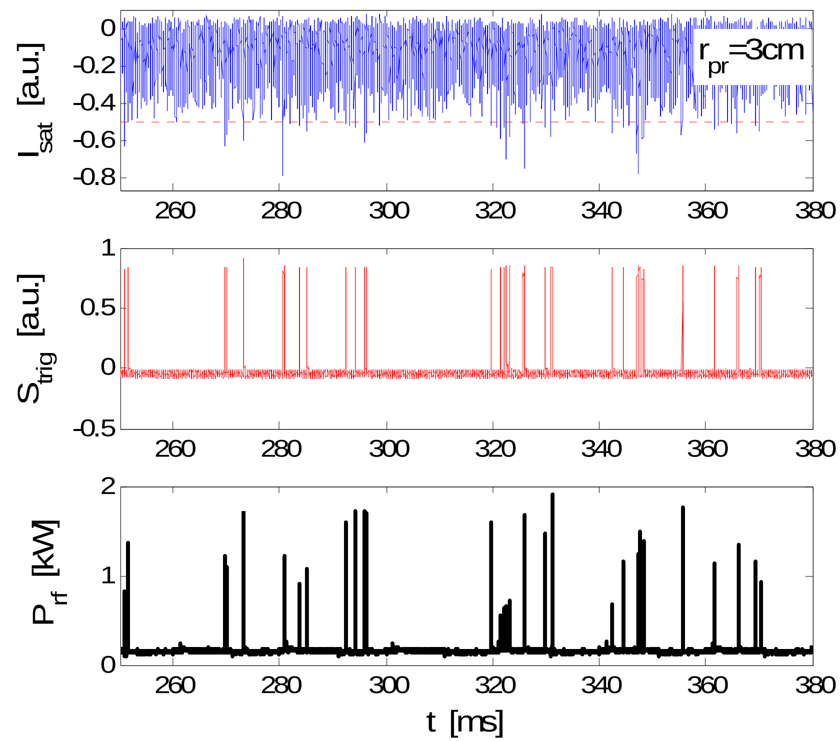
- Ensemble of N_{blob} time windows.
- In each time window, $[I_{pr,i}, V_{pr,i}]$ for each t_i.
- For each time t_i, we construct the ensemble $\{I_{pr,i}, V_{pr,i}\}$ (N_{blob} *elements)*
- Fit with I-V characteristic ⇒ $T_e(t)$, $n_e(t)$, $V_{fl}(t)$.
- $V_{pl}=V_{fl} + 3.1\ T_e/\ e$.
- 2D profiles by moving the Langmuir probe between identical discharges.
- $V_{E\times B}(t) = -\nabla V_{pl}(t) \times \mathbf{B} / B^2$.

This technique allows reconstructing the CS 2D dynamics during a event.

Blob modification via EC power control







- Particle source (UH layer) slightly at HFS with respect to shear layer
- Detect blob in its early formation phase
- Send P_{rf} pulse (positive/negative)
- Act on:
  - Particle source (gradient)
  - Plasma potential (shear)