Plasma Turbulence in the HSX Stellarator

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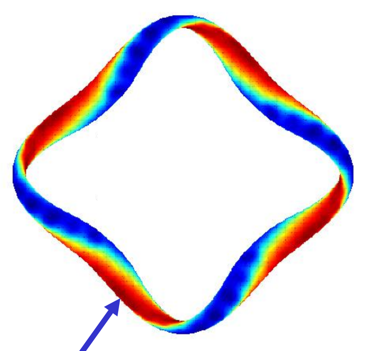
Overview

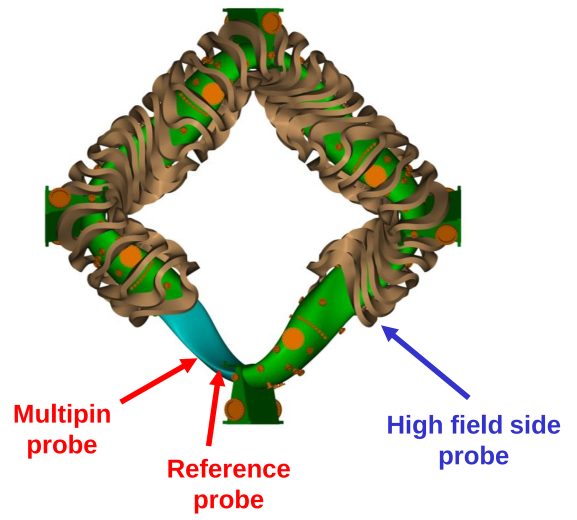
- **Look at fusion plasma edge turbulence with multiple multi-tip Langmuir probes**
- **Correlation with fixed reference probe on connecting field line gives 2D spatial resolution ⇒**
  - ⇒ **Propagating Blobs**
  - ⇒ **Relationship of density and potential structures (crossphase)**
  - ⇒ **First results**
- **Particle transport measurement with probes:**
  - ⇒ **Influence of magnetic Hill, Well and Mirror fields on the flux frequency spectrum**

Experiment and Probes

HSX has a Helically Symmetric Field

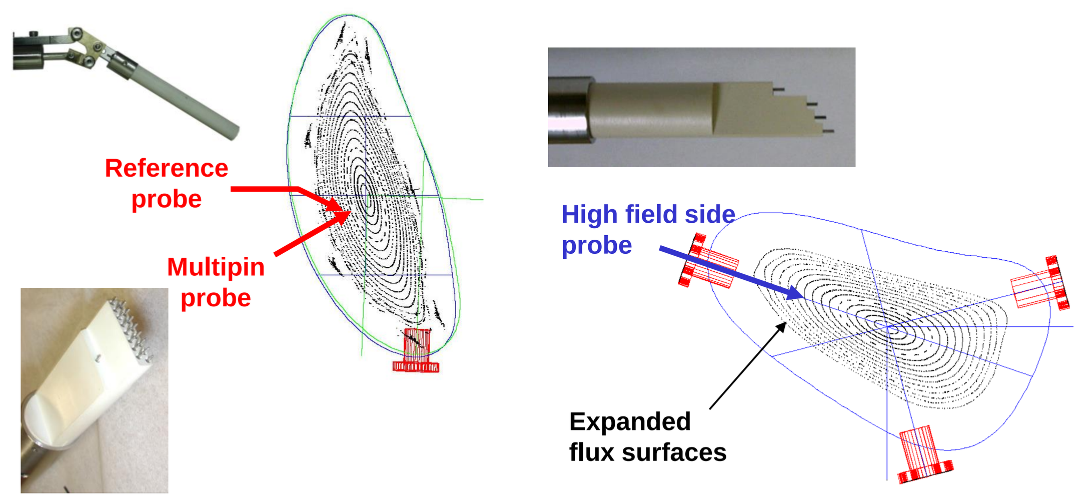
|B| Contours





- Region of high field strength (red) follows rotational transform
- HFS can be inboard or outboard
- Helical ripple is very low

Langmuir Probes in Good and Bad Curvature

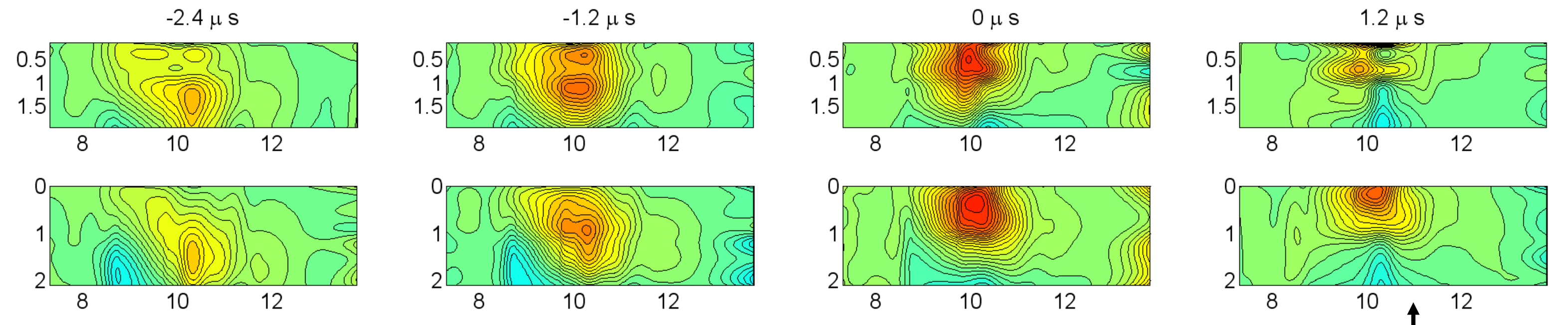


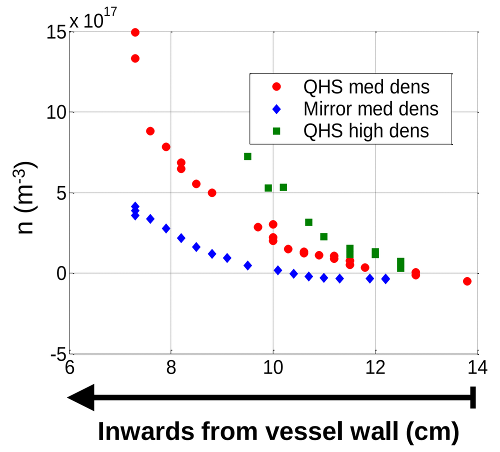
First Results from 2D Correlation

- Reference probe at fixed location, multi pin probe is moved radially between discharges
- Seven pins on the multi pin probe configured for ion saturation current measurement, eight for floating potential measurement
- Correlation function computed for 2D region

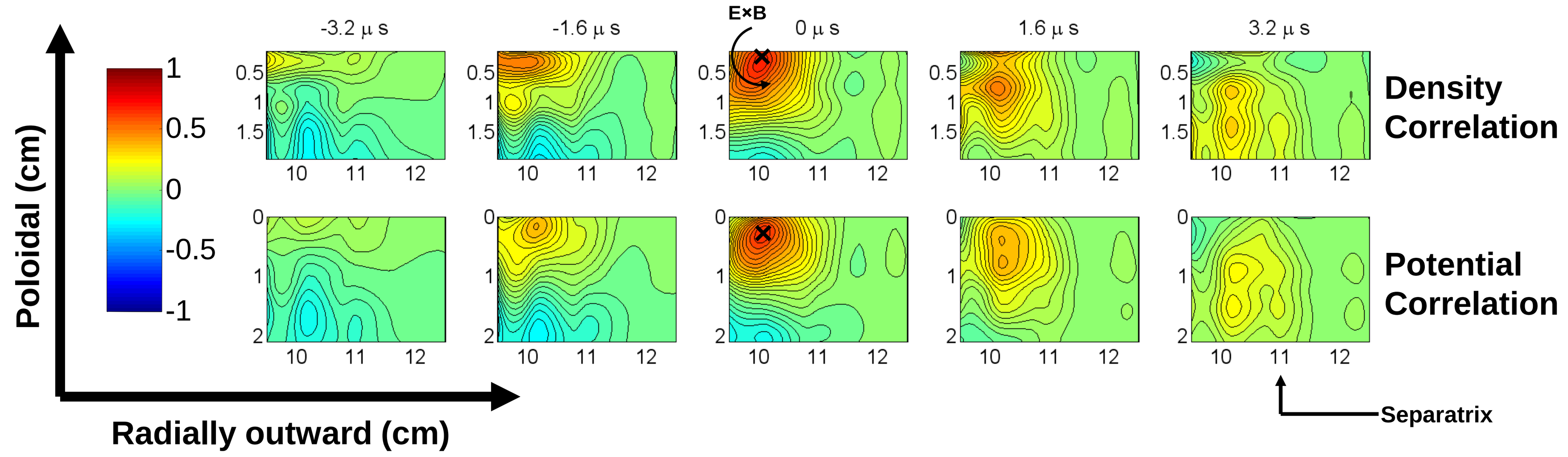
Quasi Helically Symmetric Mode (QHS)

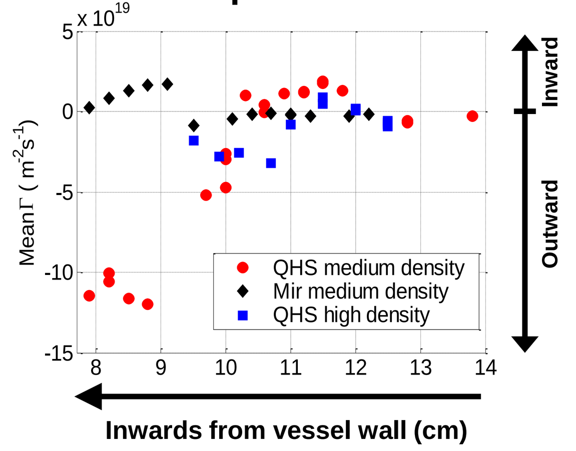
At medium density (10^{12}cm^{-3}), a Blob moves upward and slightly inward





At high density (2×10^{12}cm^{-3}), movement is reversed to downward and outward



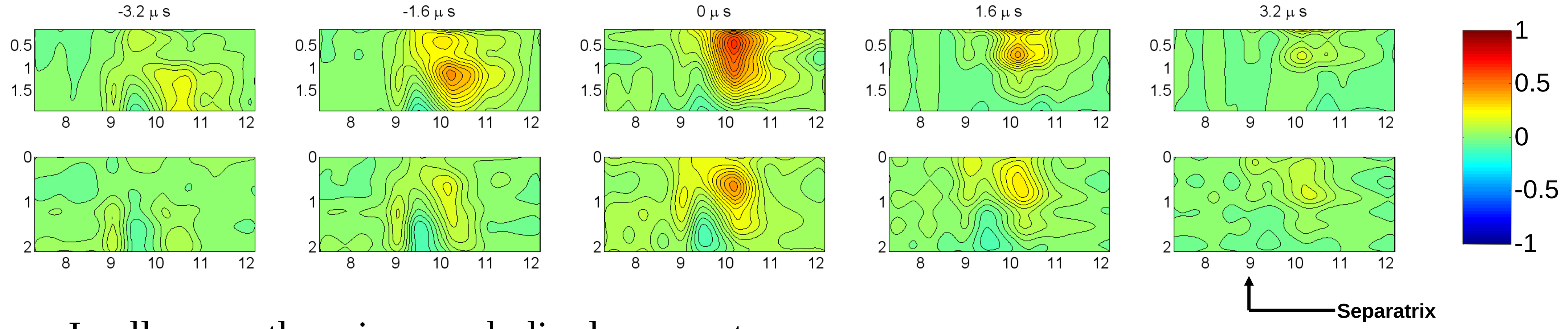


⇒ E×B drift from slightly displaced potential Blob causes radial flux

⇒ Earlier single probe measurements (see poster [PP1.046]) showed the same:
- a reversal from net inward to net outward transport at high densities
- a reversal of the poloidal phase velocity

Mirror Mode (Symmetry Deliberately Broken by Mirror Fields)

At medium density (10^{12}cm^{-3}), a smaller Blob moves like in the QHS medium density case



- In all cases, there is a weak dipole present
- Potential and Density Blobs are nearly on top of each other (no large cross phase)
- This first result hints at the drift wave / trapped electron family of instabilities, not the ballooning / interchange kind

Transport

- Data taken with 4-pin probes at the low field side (LFS) and high field side (HFS), at r/a = 0.5—0.6 (much further in than the 2D correlation probes)
- Particle flux from electrostatic fluctuations is estimated with a three point Langmuir probe

$$\Gamma(t) = \langle n`(t)V_r`(t)\rangle = \langle n`(t)E_\theta`(t)\rangle/B_\phi$$

where

$$E_\theta = -\nabla V_{float} = (V_{f2} - V_{f1})/d$$

$$n = I_{sat}/(0.6eA_{probe}c_s)$$

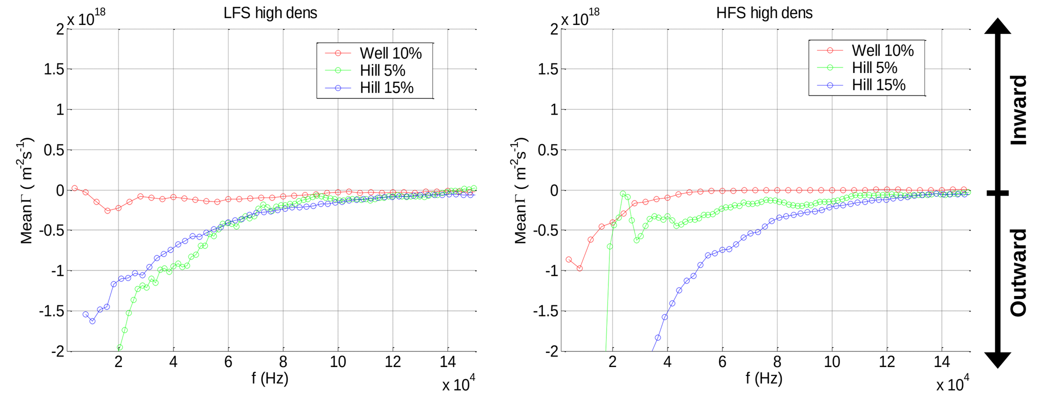
Te fluctuations are neglected

- Alternatively (Powers, Nucl. Fusion 14 (1974) 749)

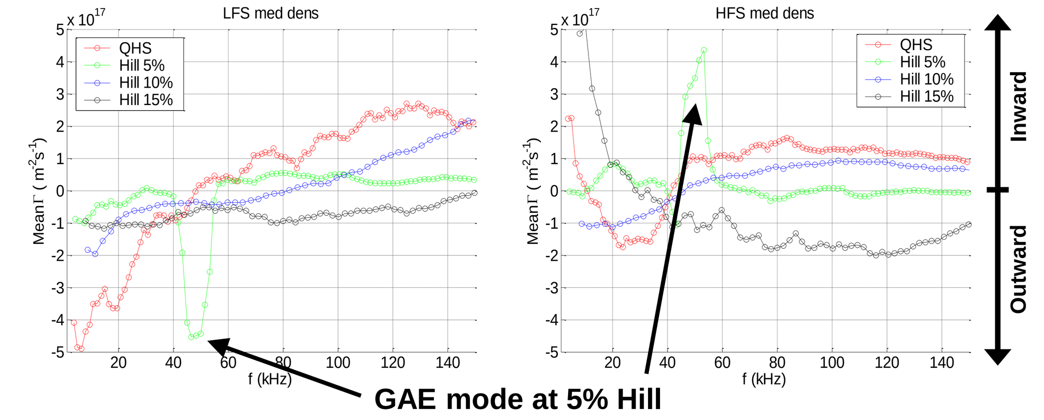
$$\Gamma(f) = \mathrm{Re}\{N^*(f)E_\theta(f)\}/B = |P_{nE\theta}(f)| \cos[\alpha_{nE\theta}(f)]/B$$

⇒ **Direction of transport depends on sign of crossphase $\alpha_{nE\theta}$.**

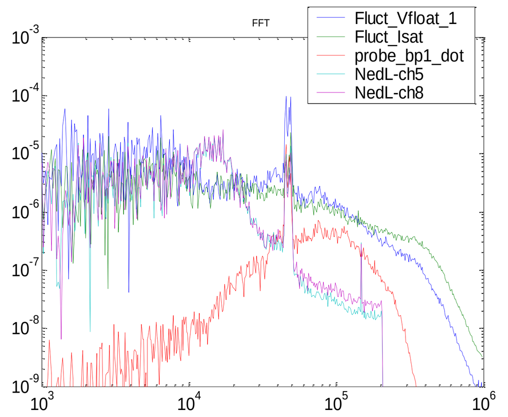
Adding a magnetic Hill increases turbulent transport at high densities



High and Low Field Side have similar spectra Except at GAE Mode ⇒ Flux Reversal



Mode at 45—50 kHz is seen on:
- Langmuir probes
- Interferometer
- Magnetic Probe



Between LFS and HFS, crossphases $\alpha_{nE\theta}$ differ by more than π (at mode frequency and elsewhere)

This could mean that in this case, MHD instabilities are dominant (sensitive to good/bad curvature)

Conclusions

- Multi pin multi probe operation possible without disrupting macroscopic plasma parameters
- 2D correlation analysis yields density and potential structures
- Radial Blob motion qualitatively explained by E×B drifts from potential Blobs
- High densities ⇒ reversal of flux
- Increasing magnetic Hill increases turbulent flux
- A Hill discharge with a GAE shows sensitivity to good/bad curvature

Future Work

- More in-depth look at influence of Mirror fields and magnetic Hill and Well on Blob dynamics
- Comparison with turbulence models (see poster [PP1.046] in this session)
- Parallel correlation and phase difference for long connection lengths, GAE mode (see posters [PP1.044] and [PP1.045])
- Wave number spectra and scaling
- New fluctuation diagnostic for core turbulence: Reflectometry

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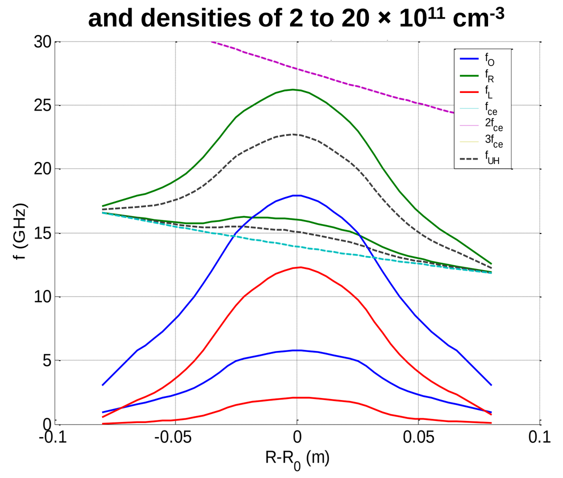
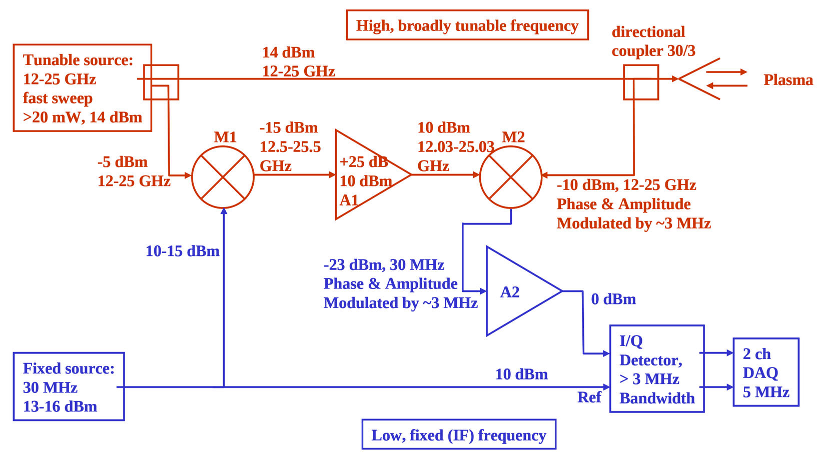
Planned Reflectometer

- 12-25 GHz band chosen
- X-Mode for 5000 Gauss operation
- O-Mode for high density 1 T operation possible
- Core fluctuation levels may necessitate Microwave Imaging Reflectometry (MIR)

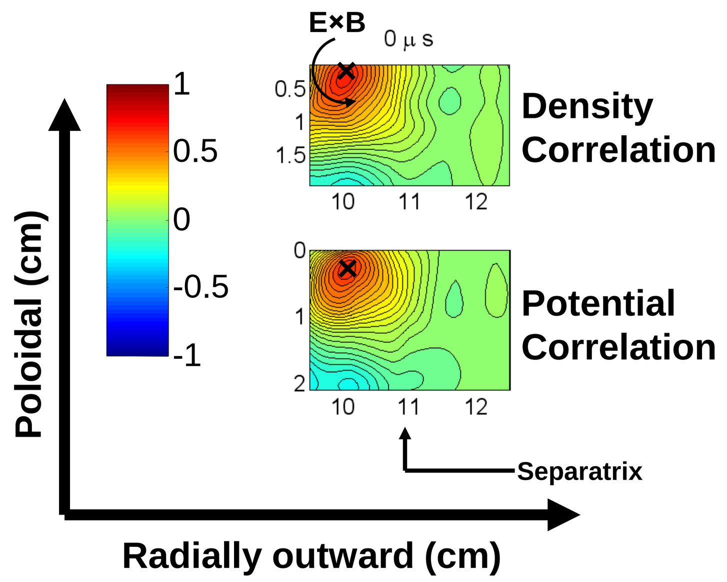
Cutoffs and Resonances for 5000 Gauss and densities of 2 to 20 × 10^{11} cm^{-3}



Proposed HSX Heterodyne Reflectometer Schematic

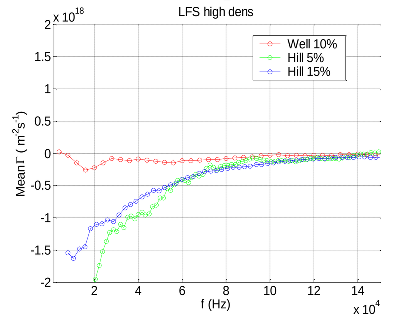


2D Correlation

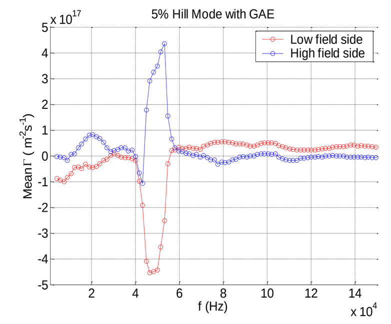


- Radial Blob moved by E×B drift from accompanying potential blob
- Net radial flux because density blob slightly off-center
- Reversal of motion going from low to high density

Flux Spectra



- Transport increases with Hill strength



- Flux at GAE mode reverses at high field side
➔ MHD/interchange