B drift dependence of fluctuations and turbulent transport in DIII-D

presented by

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in collaboration with

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ABSTRACT

The B drift direction can change the H-mode power threshold by factors of 2-8. Reversing the B drift direction alters the divertor conditions and direction of flows in the boundary. Such boundary flow changes are predicted in BOUT simulations to change the boundary turbulence levels due to changes in the effectiveness of the magnetic shear damping associated with the X-point. Edge fluctuation measurements indicate that when the B drift is toward the dominant X-point, a region of sheared fluctuation propagation forms in the edge. When the B drift is away from the dominant X-point, the fluctuation propagation is relatively uniform across the edge. Probe measurements of the density and potential fluctuations in the far edge on the outboard midplane are reduced (density) or constant (potential) when the B drift is away from the dominant X-point, the configuration with lower sheared propagation and predicted by BOUT to have higher fluctuation levels. These fluctuation levels will be compared with measurements in the lower divertor for each magnetic field direction. Despite the differences in fluctuation levels, the turbulent transport on the outboard midplane is similar for the two magnetic field directions, consistent with the edge plasma profiles. Results will be discussed in terms of the possible impact on the H-mode power threshold, and will be compared with results from BOUT simulations.

Motivation

- **The B drift direction can change the H-mode power threshold by factors of 2–8.**
  - **Important issue for H-mode access**
  - **Opportunity for understanding the physics of the power thrshold for the L to H transition**
- **The B drift alters the boundary (edge, scrape-off layer, and divertor) plasma conditions**
  - **Opportunity to understand the role of boundary plasma conditions on the L to H transition**
- **The BOUT 3-D boundary turbulence code has the unique capability to handle realistic, diverted (X-point) tokamak boundary geometry**
  - **Opportunity for detailed experiment-simulation comparisons**

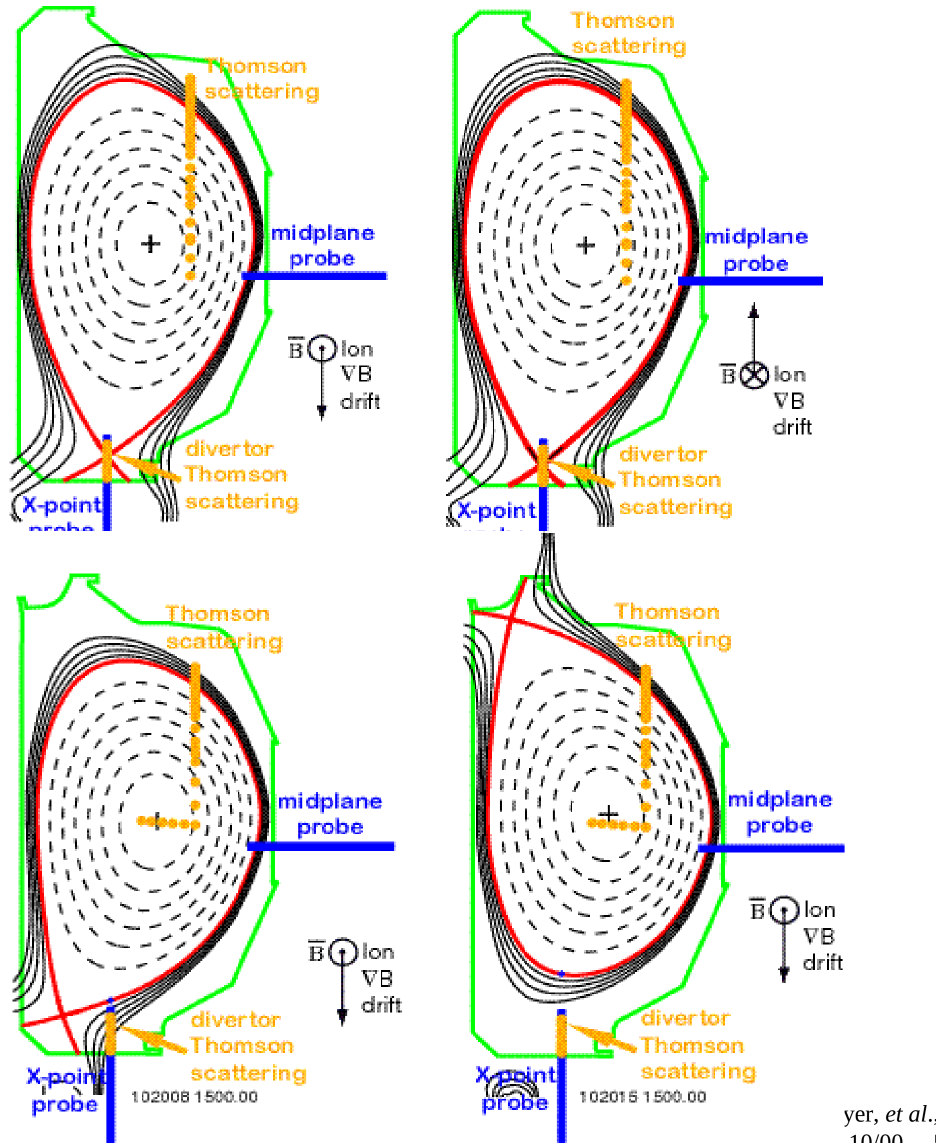
Summary

- **Neutral beam modulation can be bad news at low duty cycles:**
  - **For some reason, the plasma is robust to the NBI perturbation when the B drift is toward the X-point**
- **The B drift dependence of the H-mode power threshold isn't due to increases in turbulence and/or turbulent transport near the outboard midplane.**
  - **Outboard midplane fluctuation levels and turbulent transport are similar or a bit lower**
  - **Evidence for increased fluctuation levels near the X-points when the B drift is away from the X-point as predicted by BOUT**
- **The fluctuations propagate with a more highly sheared profile when the B drift is toward the X-point**
  - **May be the origin of the lower power threshold since E × B shear layer already partly established.**
  - **Begs the question why the propagation profile is different**

Compare discharges at similar power levels with the B drift toward and away from the (dominant) X-point

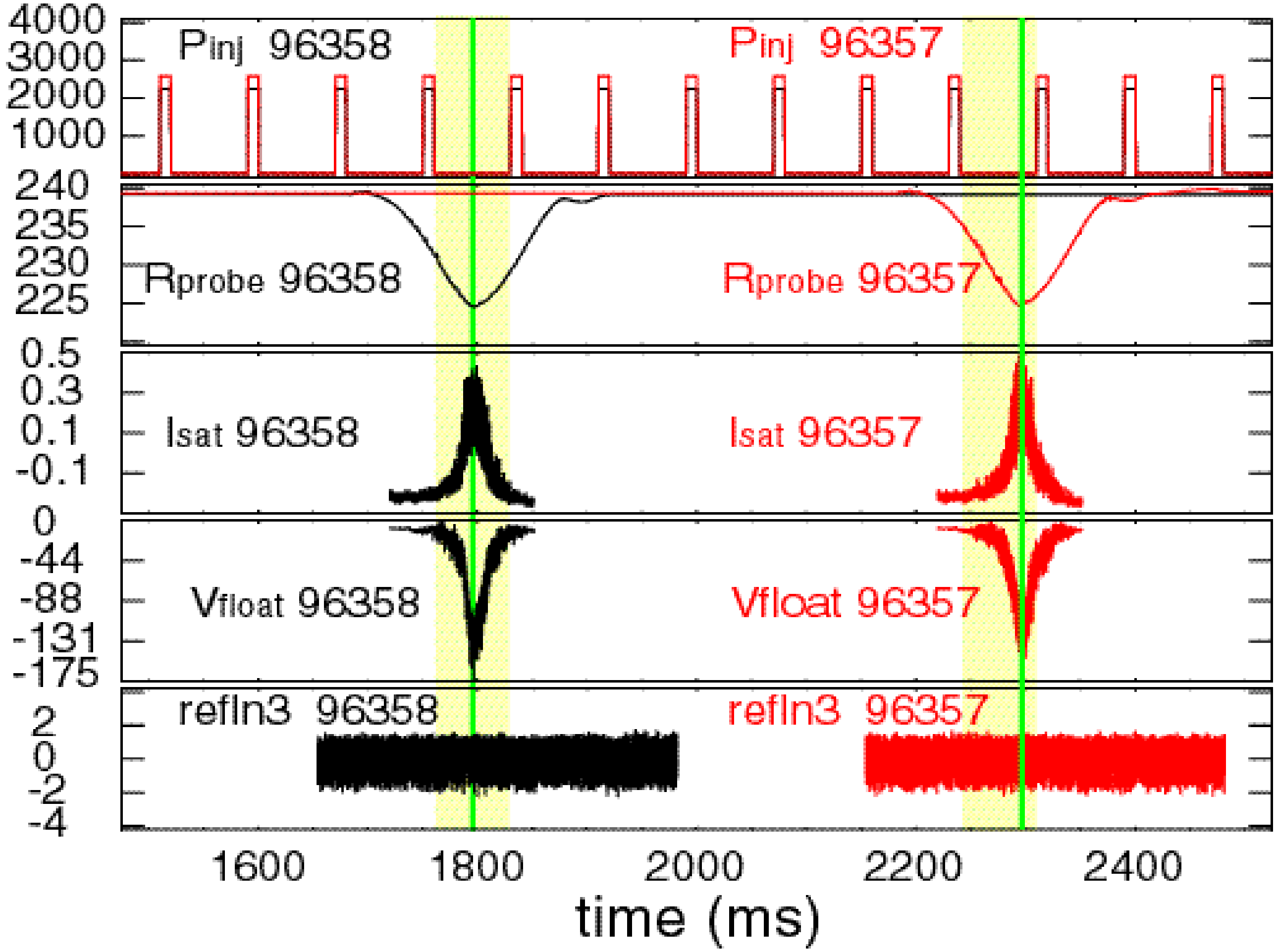
- **On separate days, study lower single null plasmas with opposite B_T directions (forward & reversed B_T)**

- **In one day, fix B_T direction and shift plasma vertically from upper single null to lower single null**



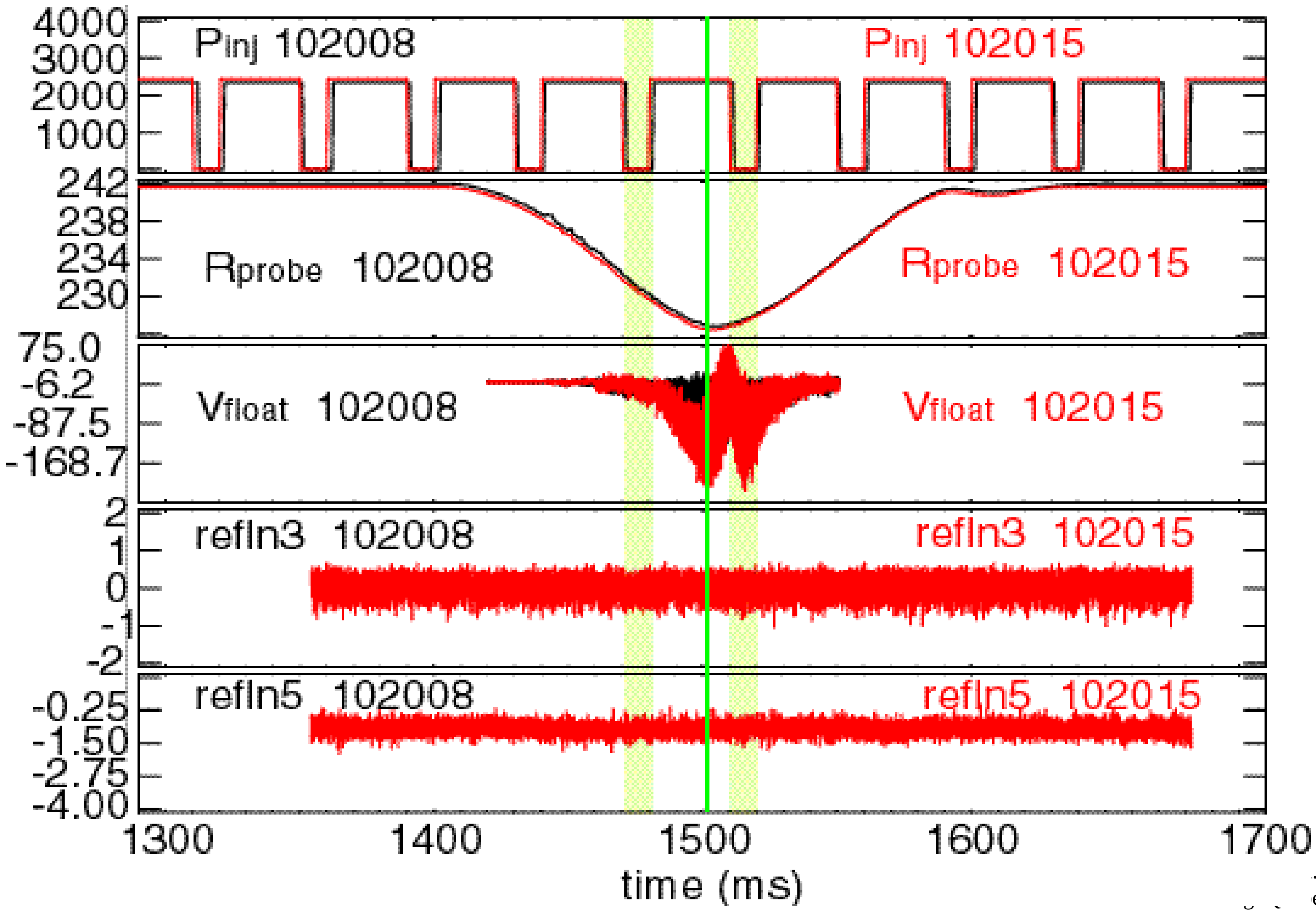
Reproducibility for B drift away from the X-point was poor in LSN “reversed B_T”shape.

- **Edge E_r and v_{phase} varied during off part of NBI duty cycle (plasma doesn’t “average” out the notches).**



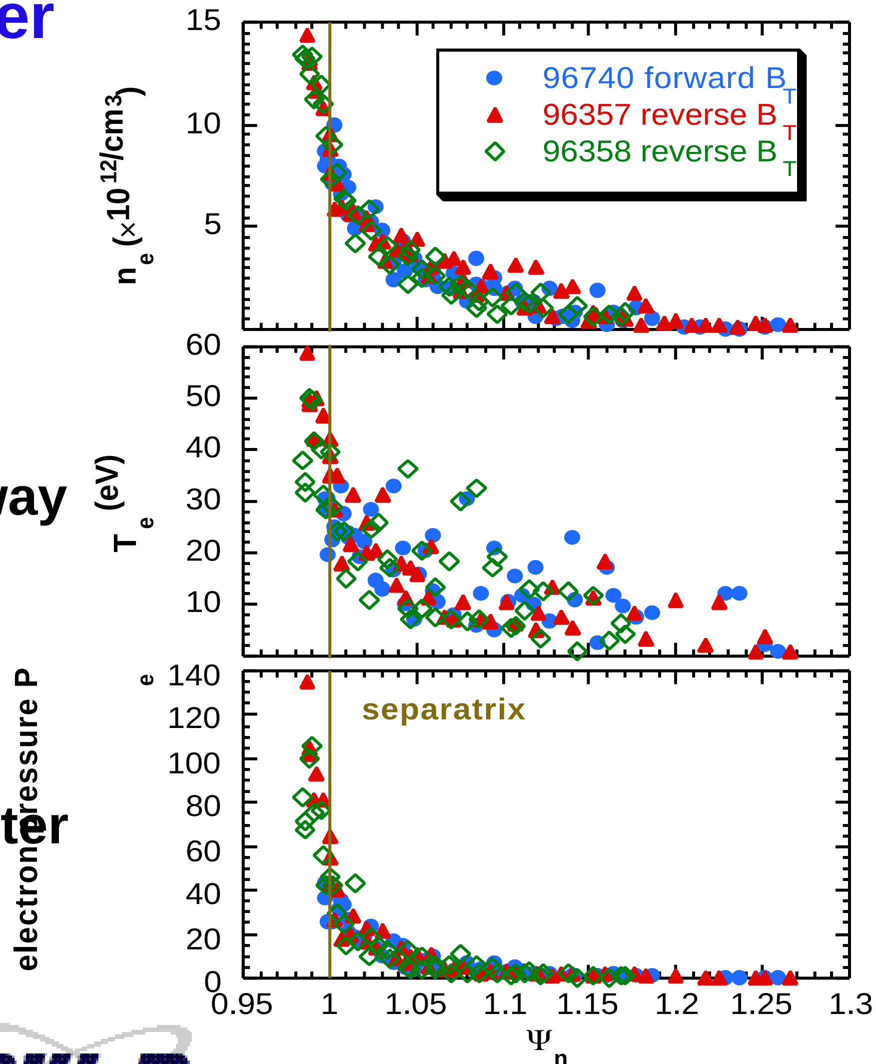
Improved reproducibility of edge conditions when B drift away from X-point in USN

- **Higher $P_{threshold}$ allowed higher neutral beam duty cycle but still a perturbation on edge φ during notch**



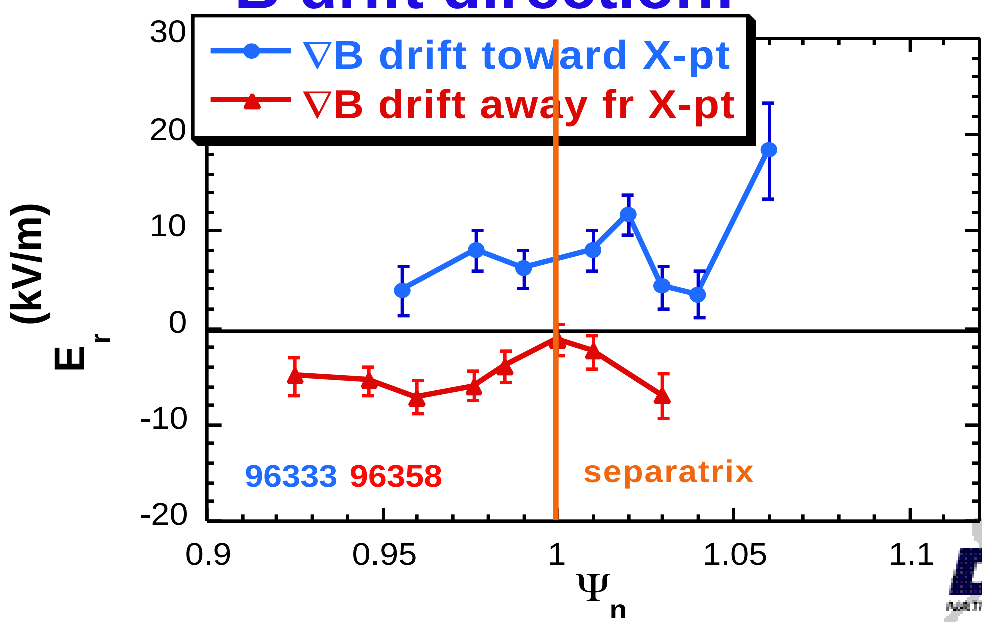
Many edge plasma parameters are well matched with both approaches

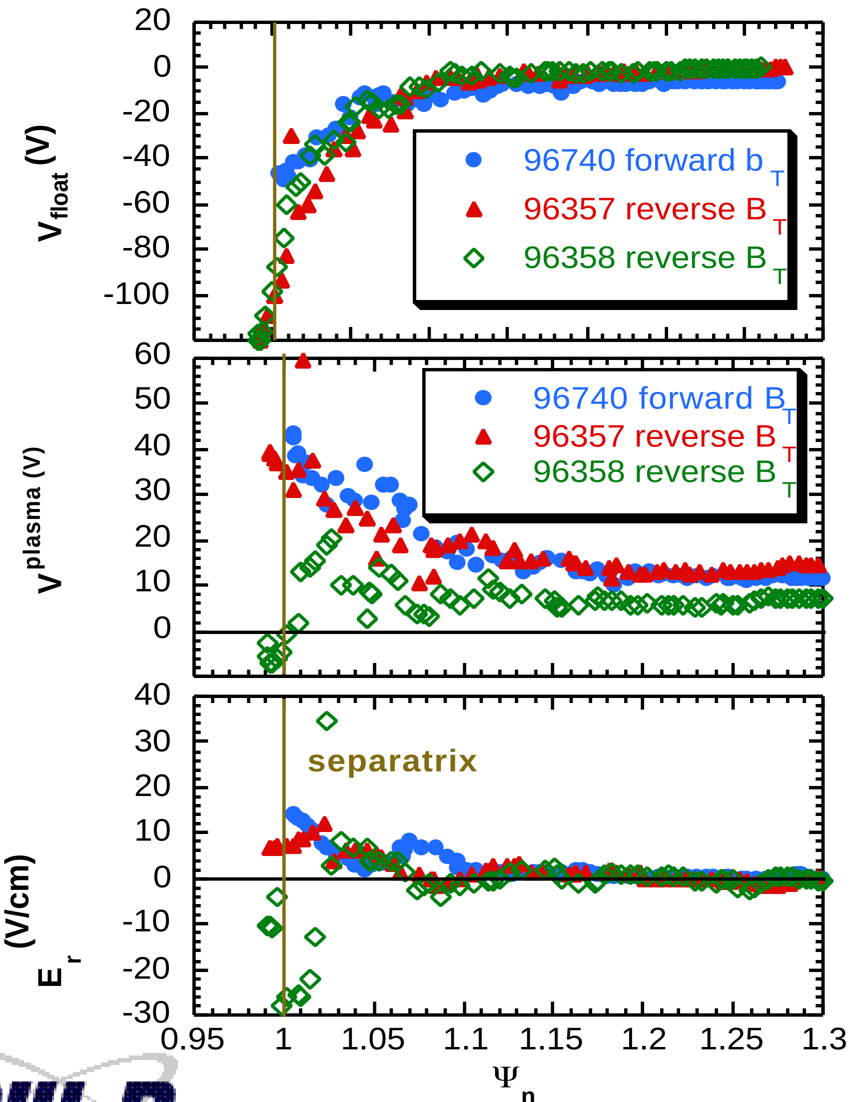
- **See Carlstrom et al. Poster GP1.129 this session.**
- **Example at left of edge electron profiles**
  - **“forward” B_T = B drift toward the X-point**
  - **“reverse B_T” = B drift away from the X-point.**
- **Also similar:**
  - **edge T_i profiles**
  - **recycling (Owen et al. Poster GP1.130 this session; Colchin et al., oral talk MO1.012 Wed. morning)**
  - **radiated power**



But there are some differences in the edge E_r

- **E_r from $T_e(r)$ & d.c. $V_{fl}(r)$ by midplane probe:**
  - **E_r reproducible for ∇B drift toward X-point, but not for ∇B drift away from X-point**
- **CER E_r changed sign with ∇B drift direction:**





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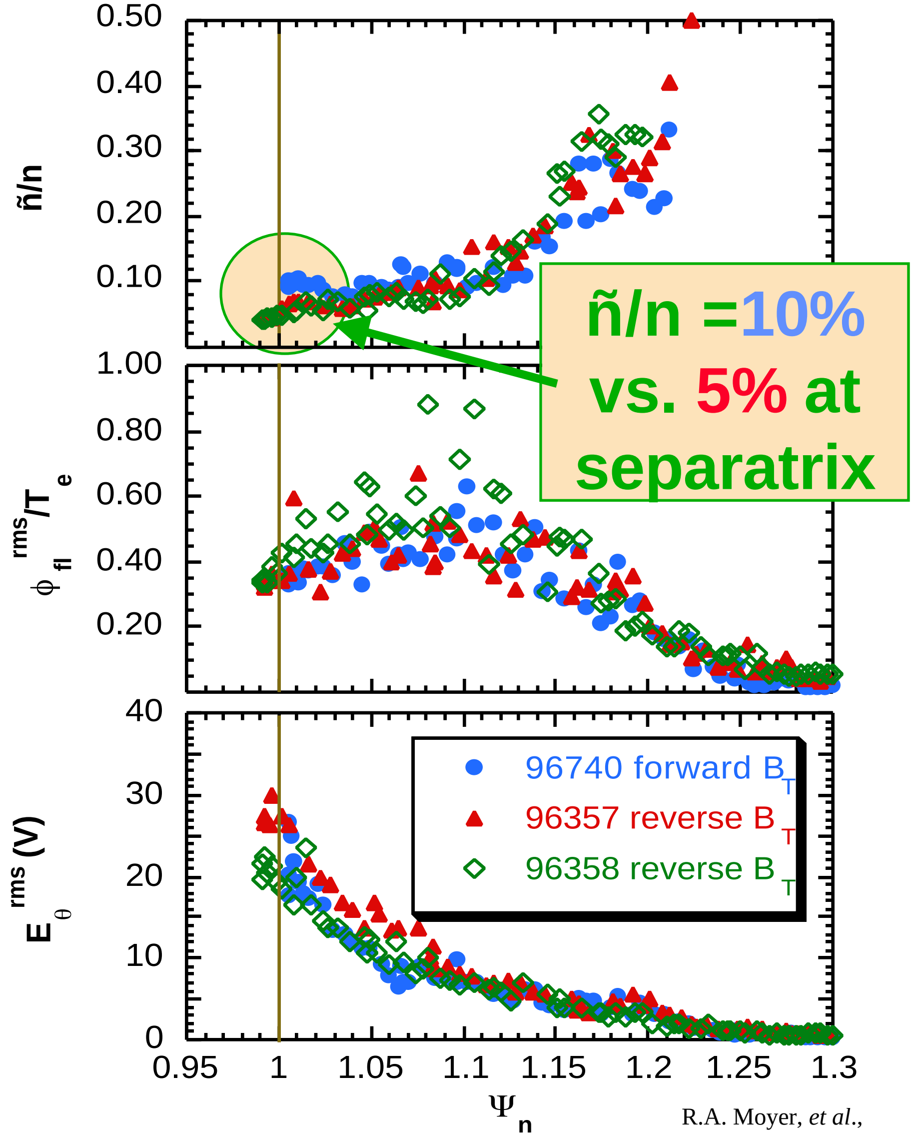
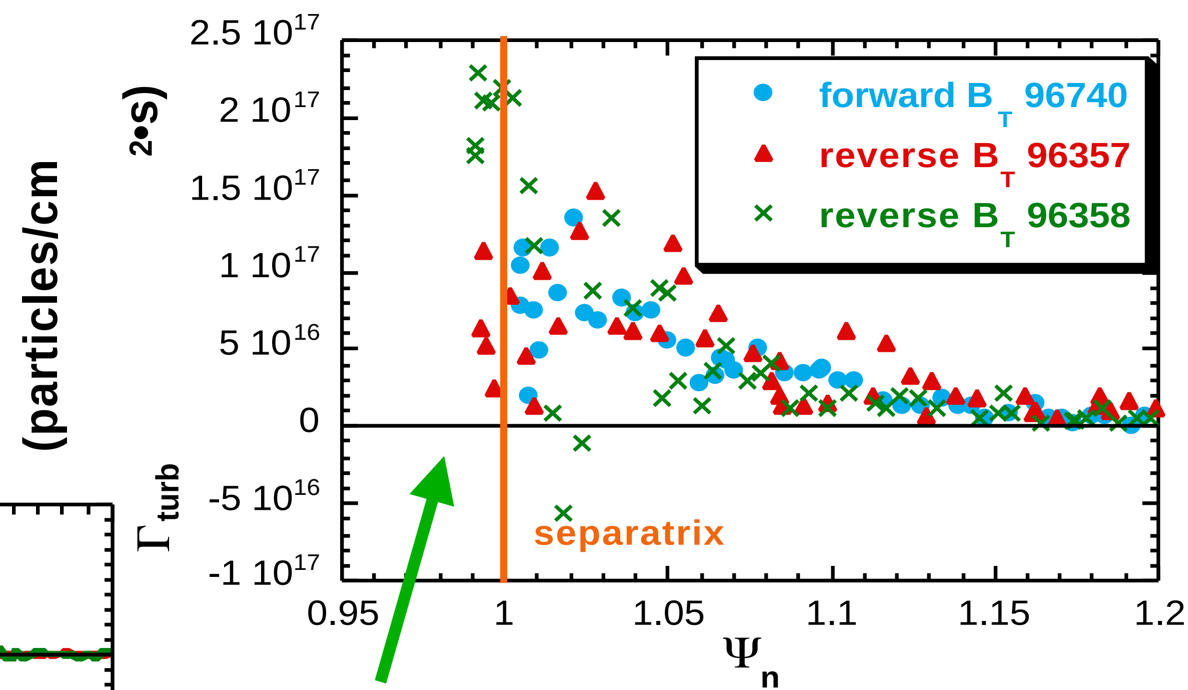
In earliest experiments, edge fluctuation amplitudes were similar

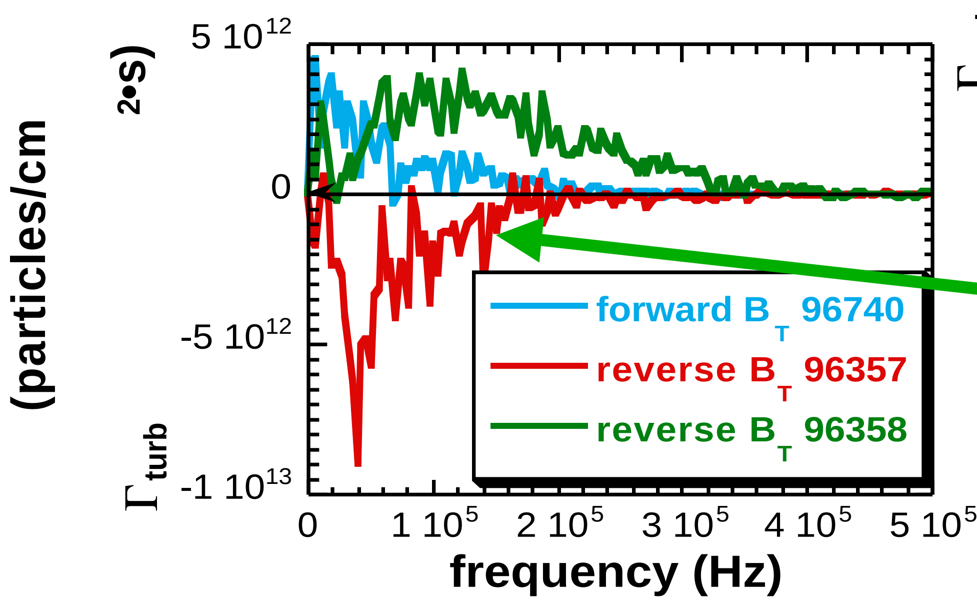
- $n(\Psi_n)$ and $Te(\Psi_n)$ are identical for the two B drift directions, so the normalized amplitude profiles here indicate absolute rms amplitude differences.
- ñ 2× lower with B drift away from X-point
  - That's right, outboard midplane fluctuations are lower for the case with the higher H-mode power threshold!
- $\tilde{\Phi}$ and $\tilde{E}_\theta$ similar



The two B drift directions have similar turbulent particle transport on the outboard midplane

- **Consistent with the similarity in edge profiles**



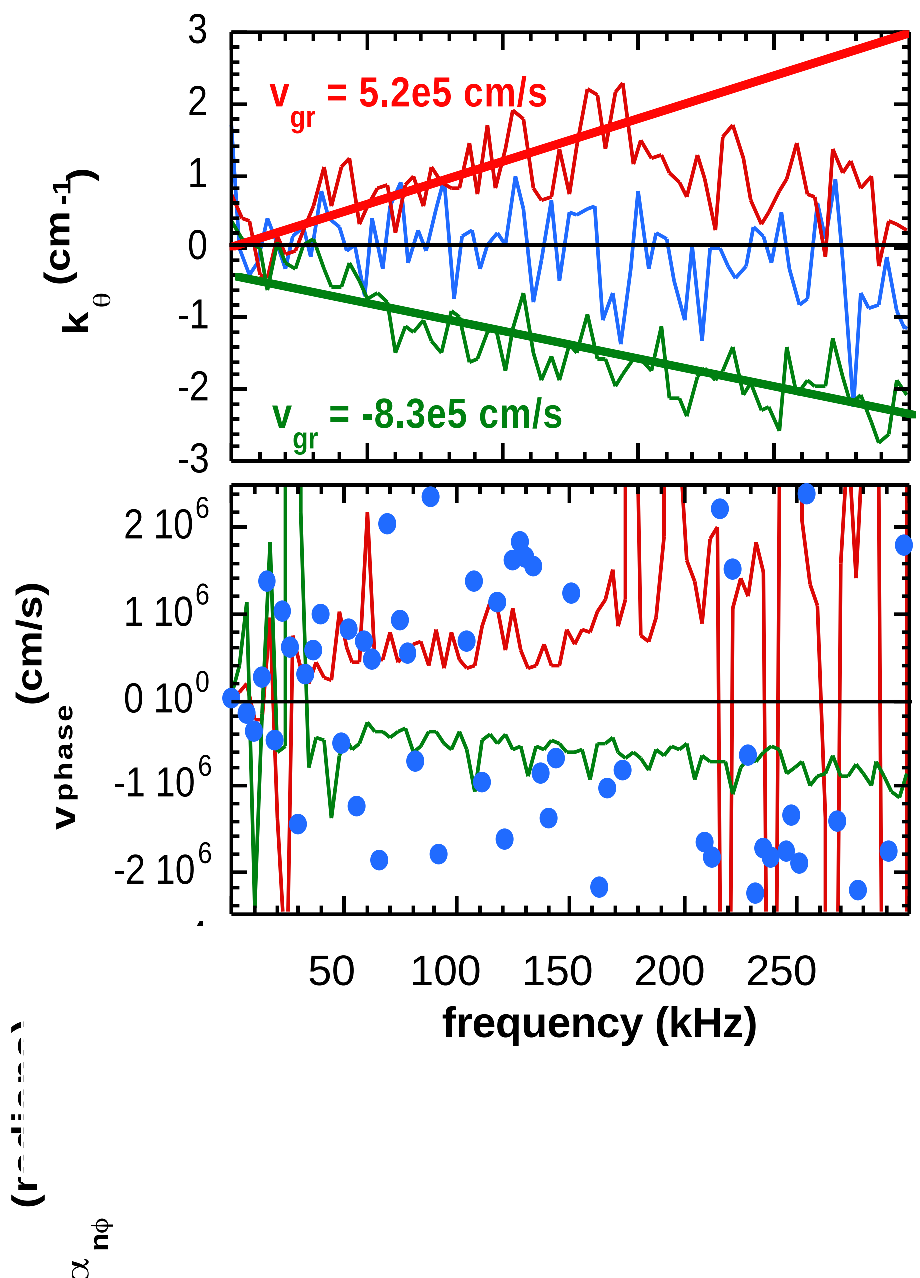


- **Particle flux may be radially inward near the separatrix when the B drift is away from the X-point.**

Forward B_T is bi-modal while reverse B_T propagates in either direction depending upon time from beam notch

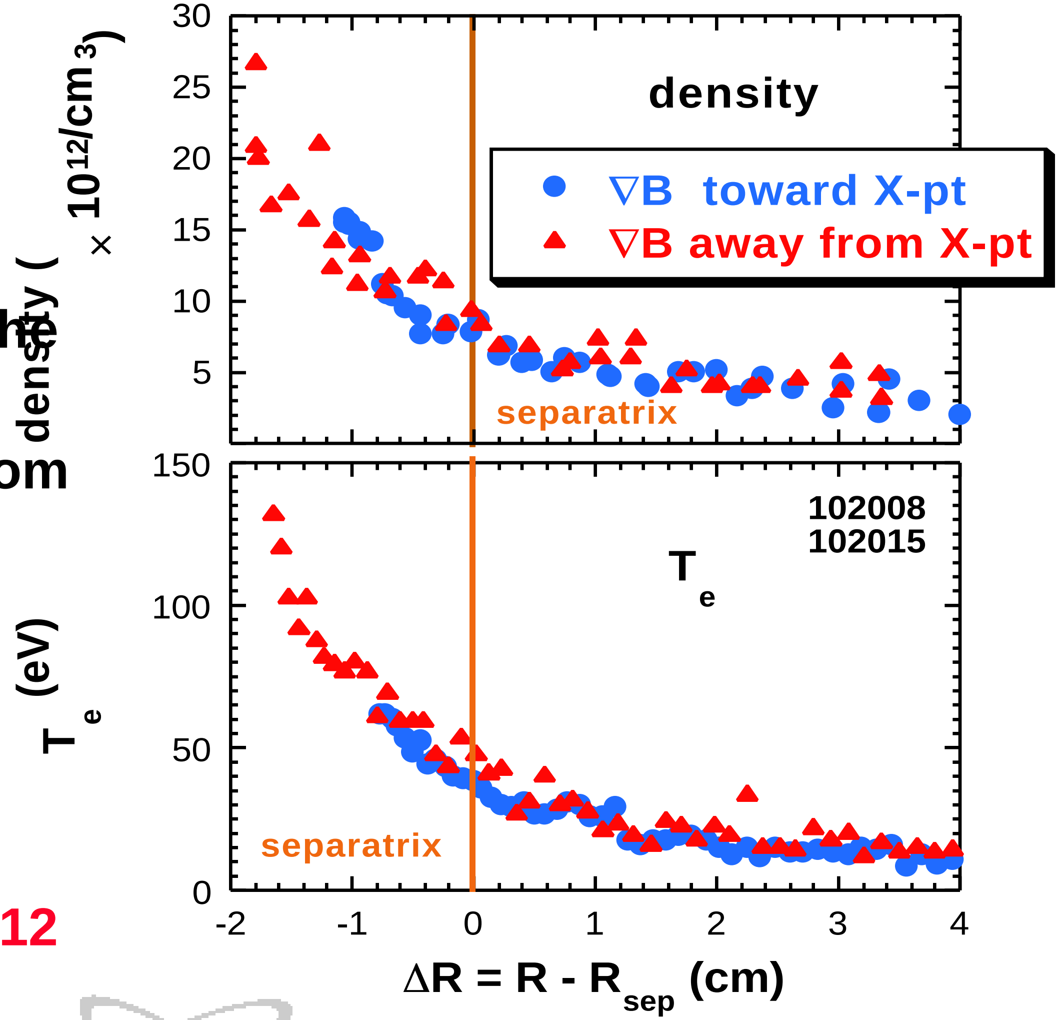
- **Blue —>"forward B_T"**
  B drift toward X-point
- **Red —>"reverse B_T"**
  B drift away from X-point 50 ms after NBI notch (96357)
- **Green —>"reverse B_T"**
  B drift away from X-point 30 ms after NBI notch (96358)

Edge relaxation after NBI turn-off



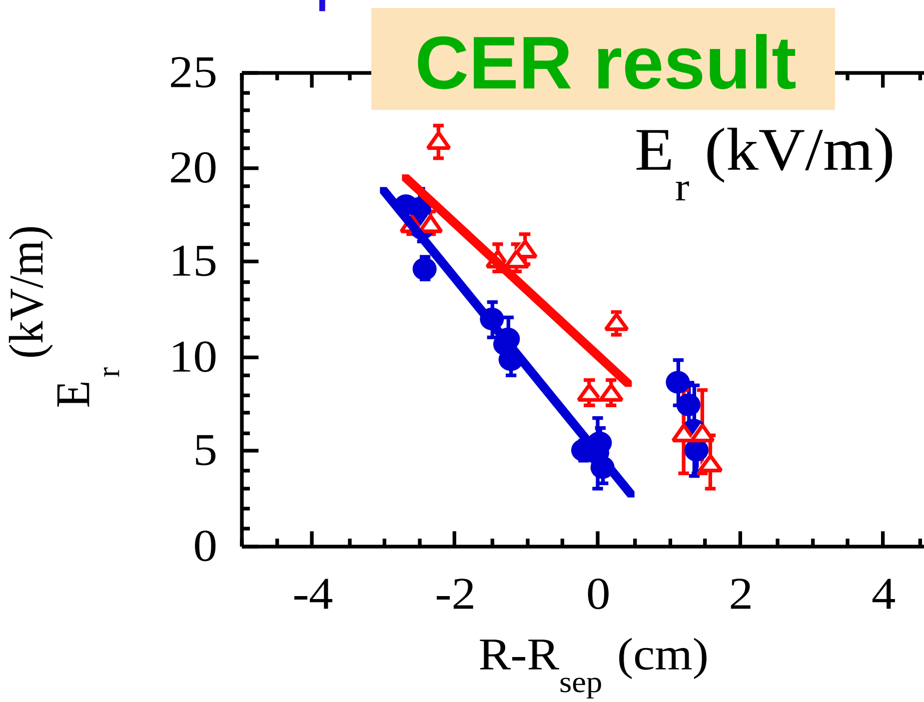
Edge profiles matched for the two B drift directions on one day without reversing B_T

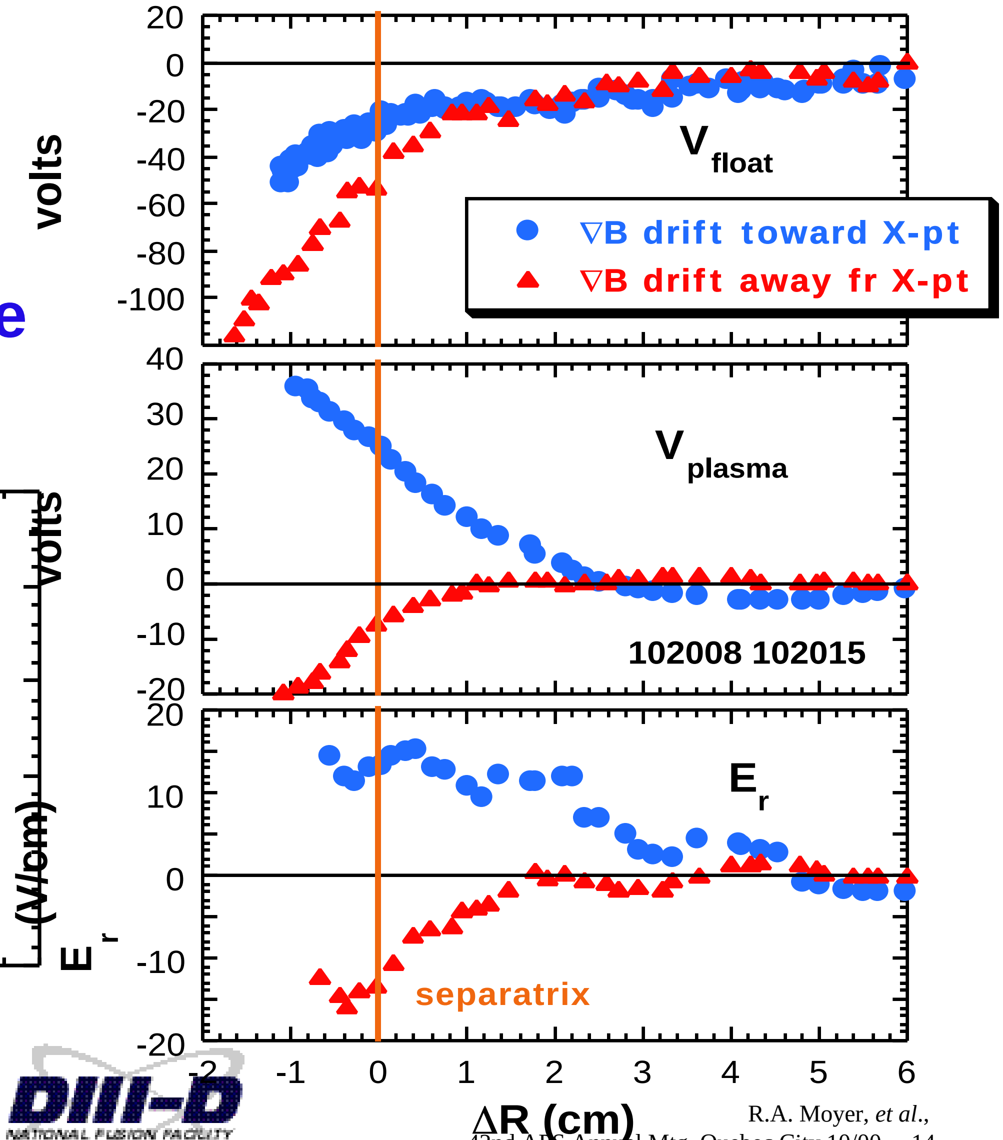
- **See Carlstrom Poster GP1.129 this session.**
- **Ex: edge electron profiles**
  - **LSN = B drift toward the X-point**
  - **USN = B drift away from the X-point.**
- **Also similar:**
  - **edge T_i profiles**
  - **recycling (Owen Poster GP1.130 this session; Colchin oral talk MO1.012 Wed. morning)**
  - **radiated power**



E_r differs between B drift directions: some differences between probe and CER.

- **Probe sees opposite signs of E_r between configs.**
- **CER sees small increase in E_r shear**

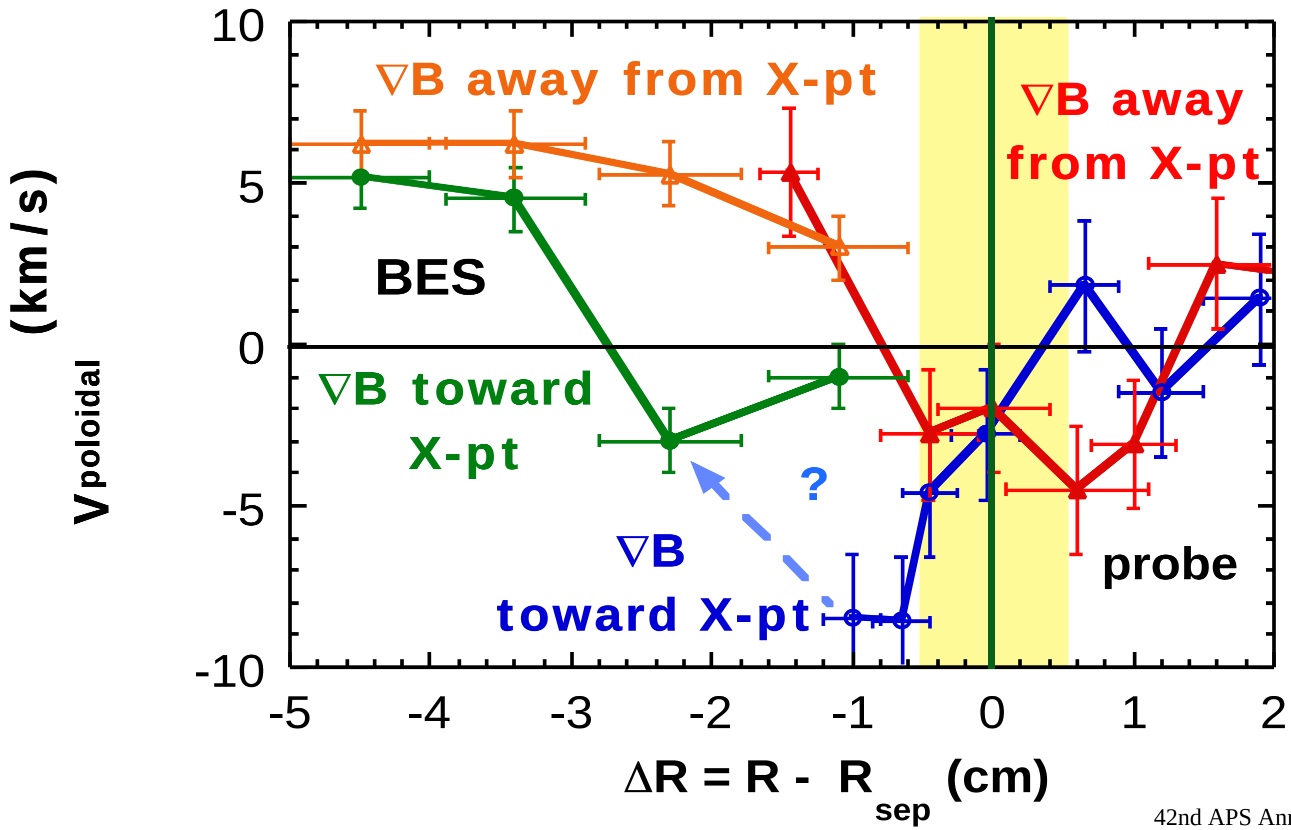




The poloidal velocity of the fluctuations is more sheared with the ∇B drift toward the X-point

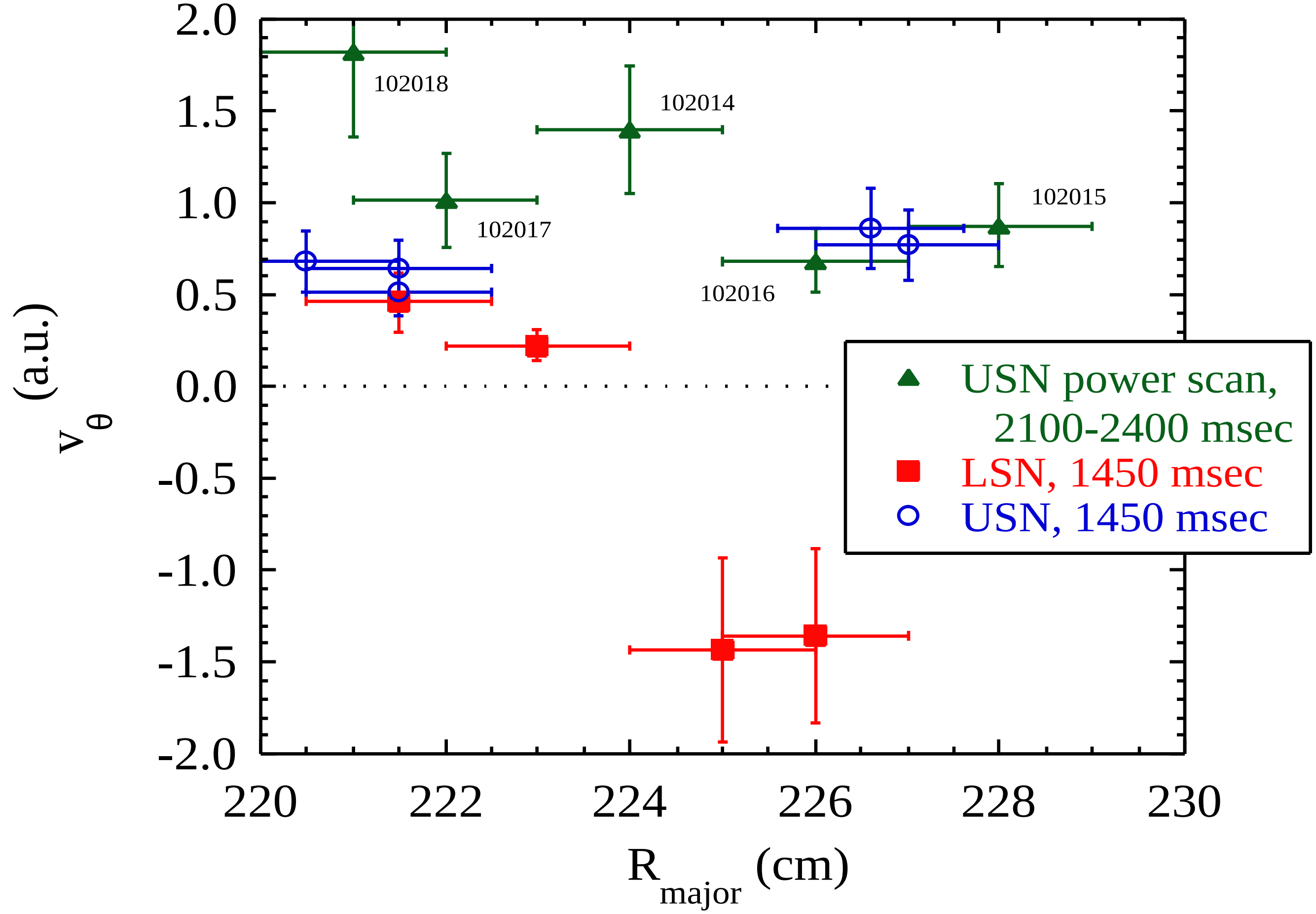
- probe $V_{phase} \approx v_{E\times B}$ using probe E_r
- $V_{poloidal}$ (BES; probe) different from $v_{E\times B}$ using CER E_r

BES: C. Fenzi, G. McKee, UW-Madison Poster GP1.126



$V_{poloidal}$ measurements from dispersion reflectometry agree qualitatively with BES.

- Dispersion reflectometry by T.L. Rhodes, UCLA



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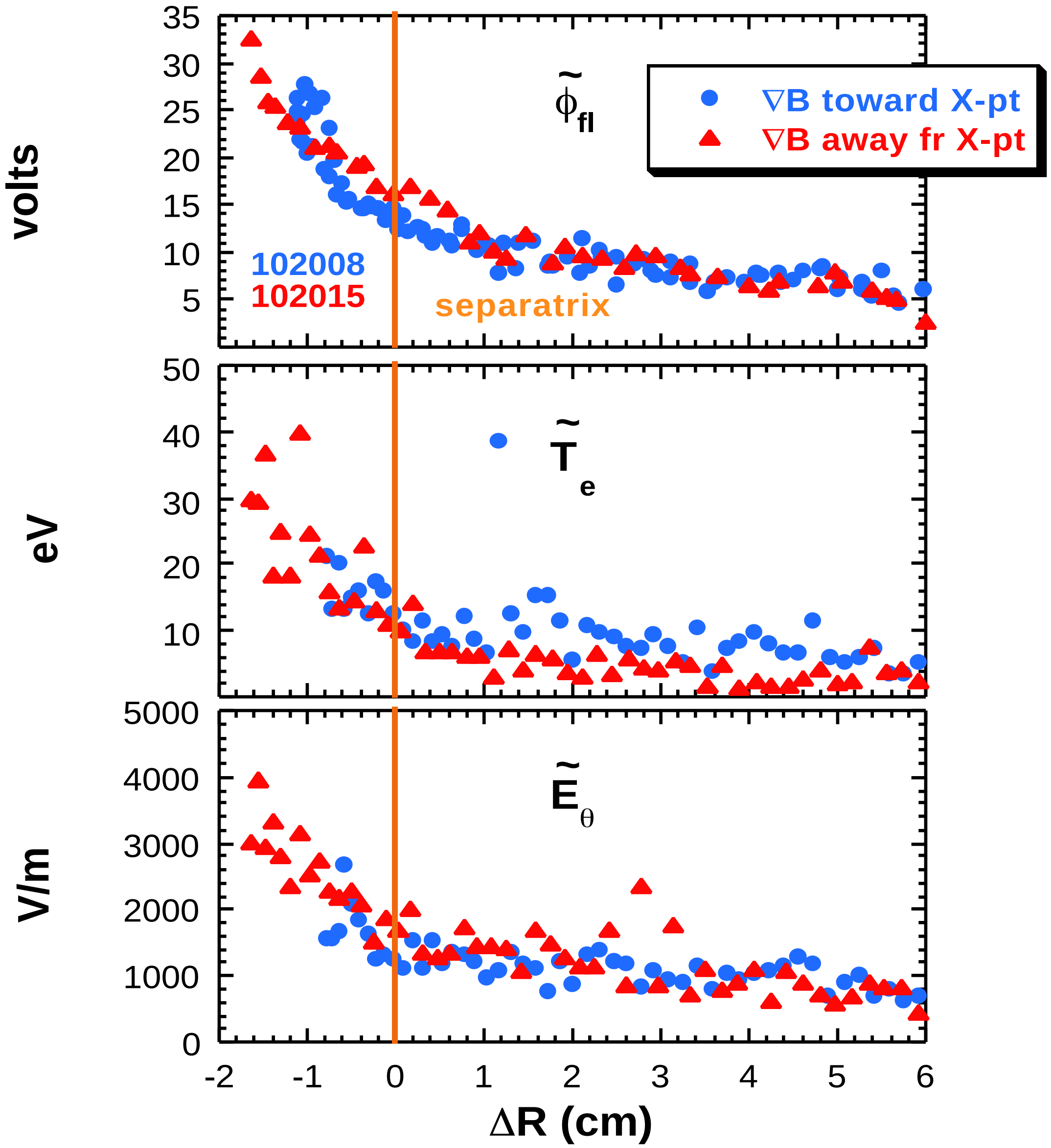
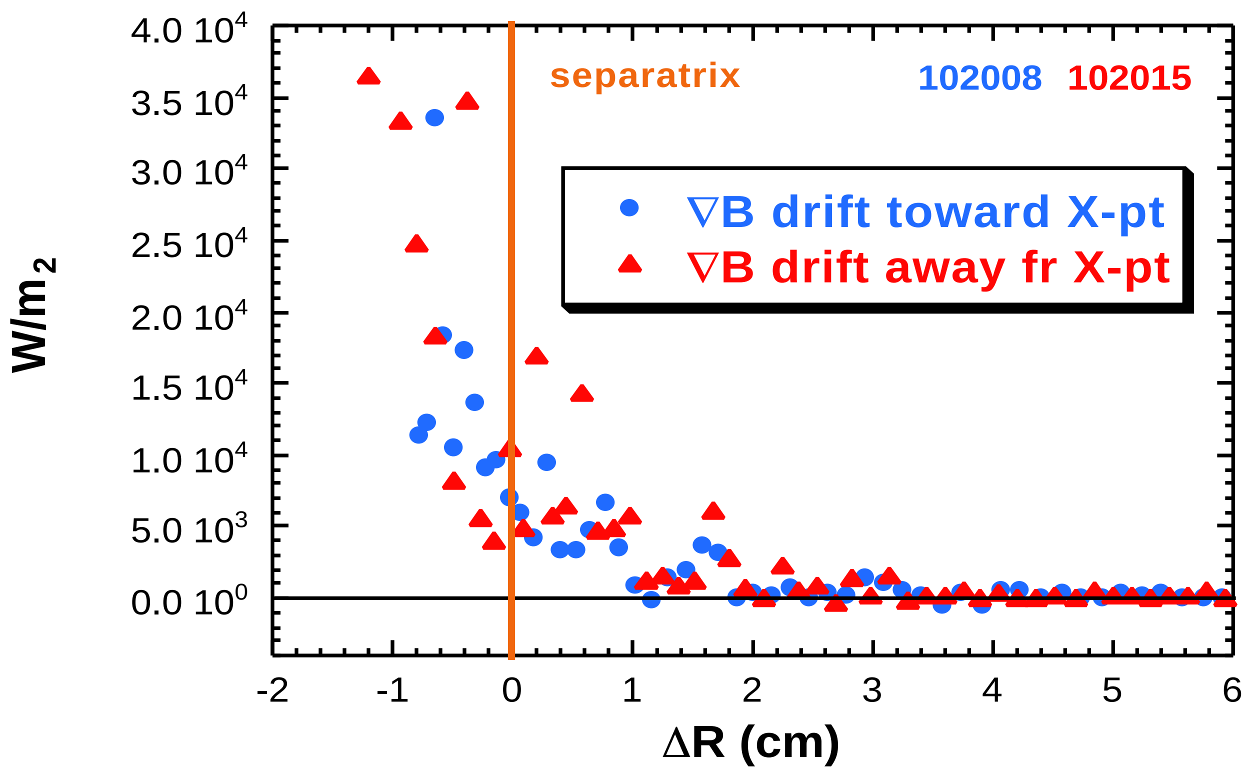
Fluctuation amplitudes on outboard midplane are similar.



- **Homodyne reflectometry indicates ñ no more than 20% lower in USN B drift away from the X-point.**
- **Probe φ, T_e and E_θ rms amplitudes similar.**

The turbulent conducted heat fluxes Q_{cond} on the outboard midplane are similar.

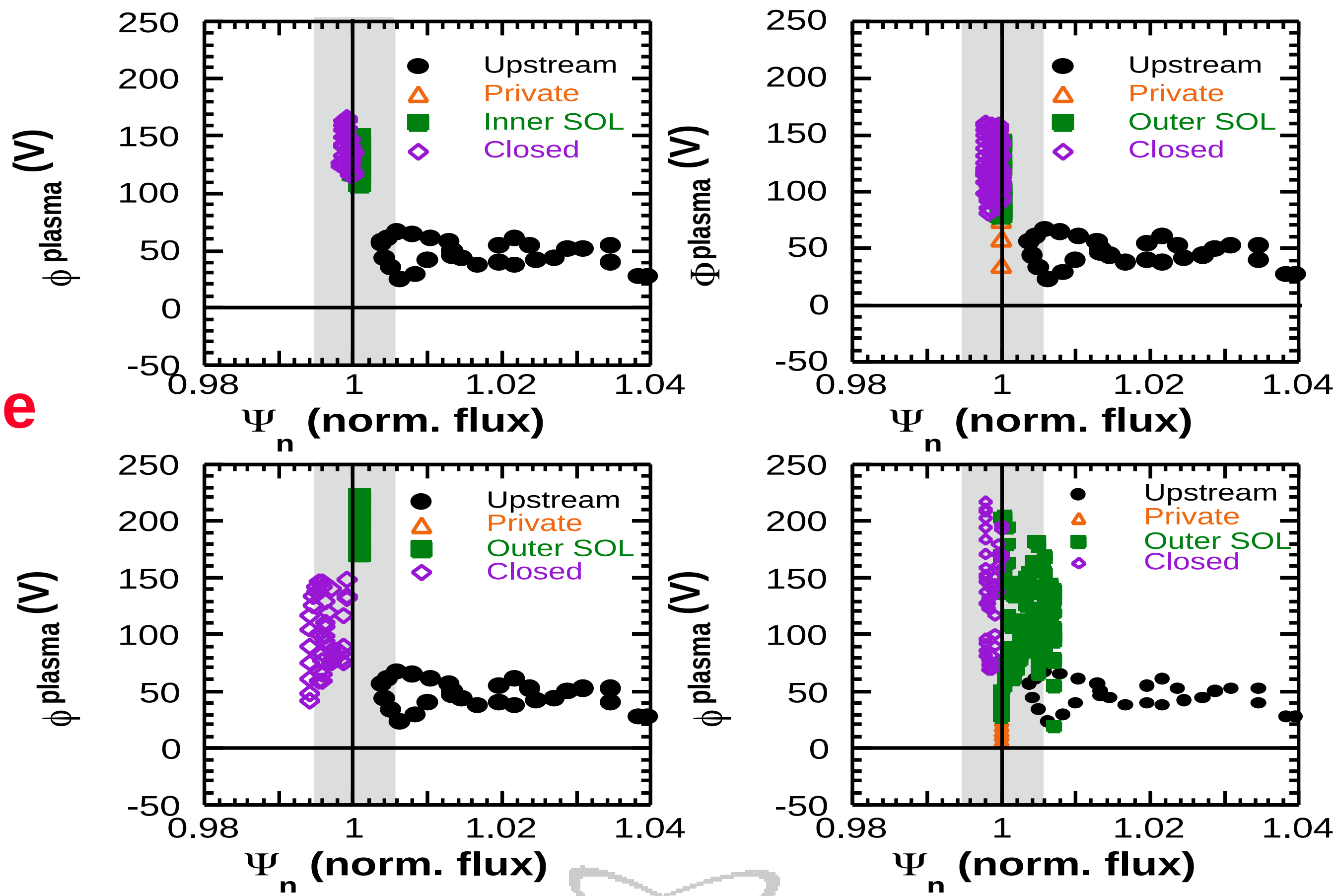
- **See Rudakov Poster GP1.132 this session for more information.**



Strong E × B convection circulates around the X-point for both B drift directions.

- **Due to local maximum in T_e, φ_{plasma} at X-point: Schaffer invited BI1.005 Mon morning; Boedo Poster GP1.137**

B drift toward the X-point



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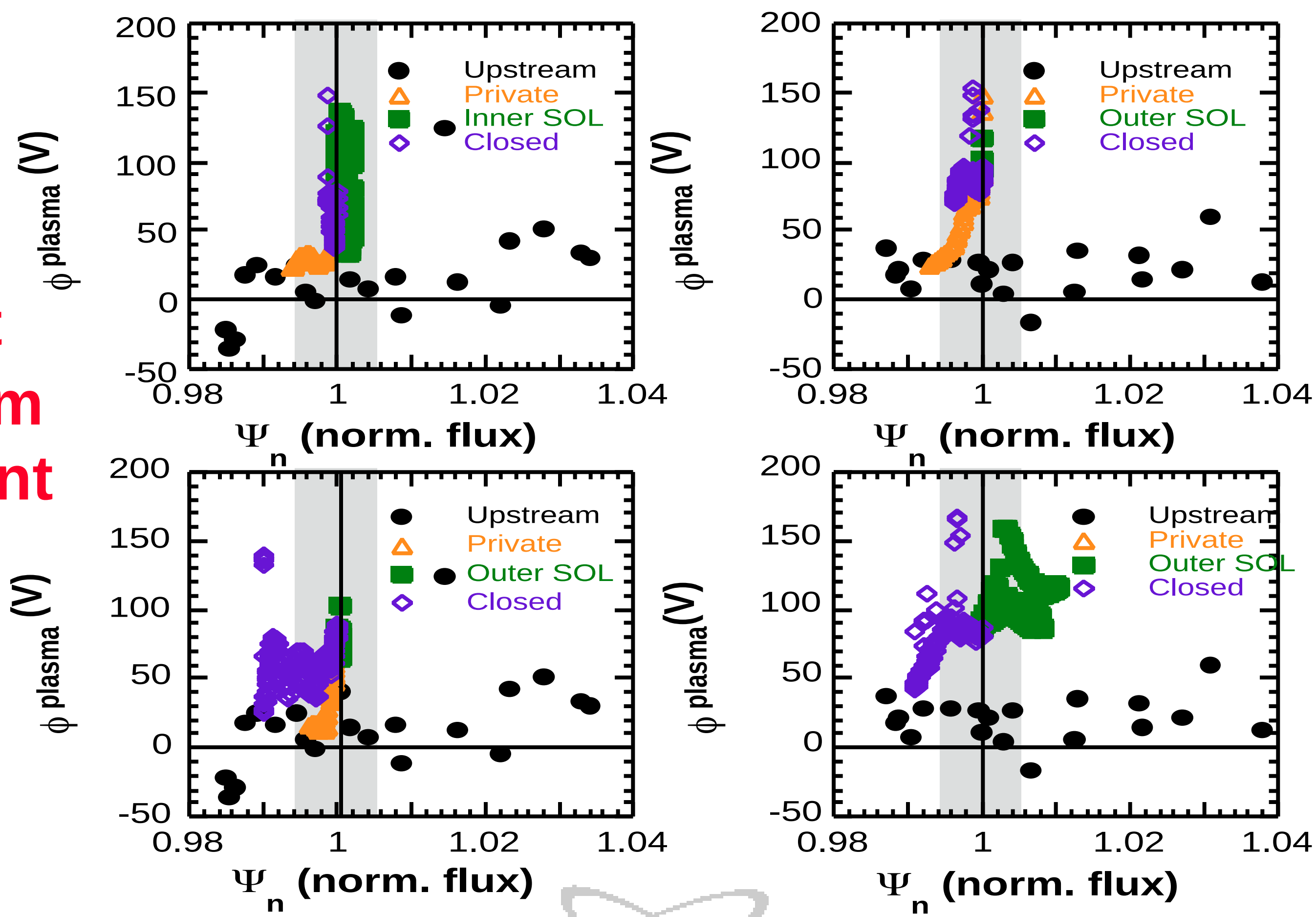
Circulation in opposite rotation sense in each B drift directions.

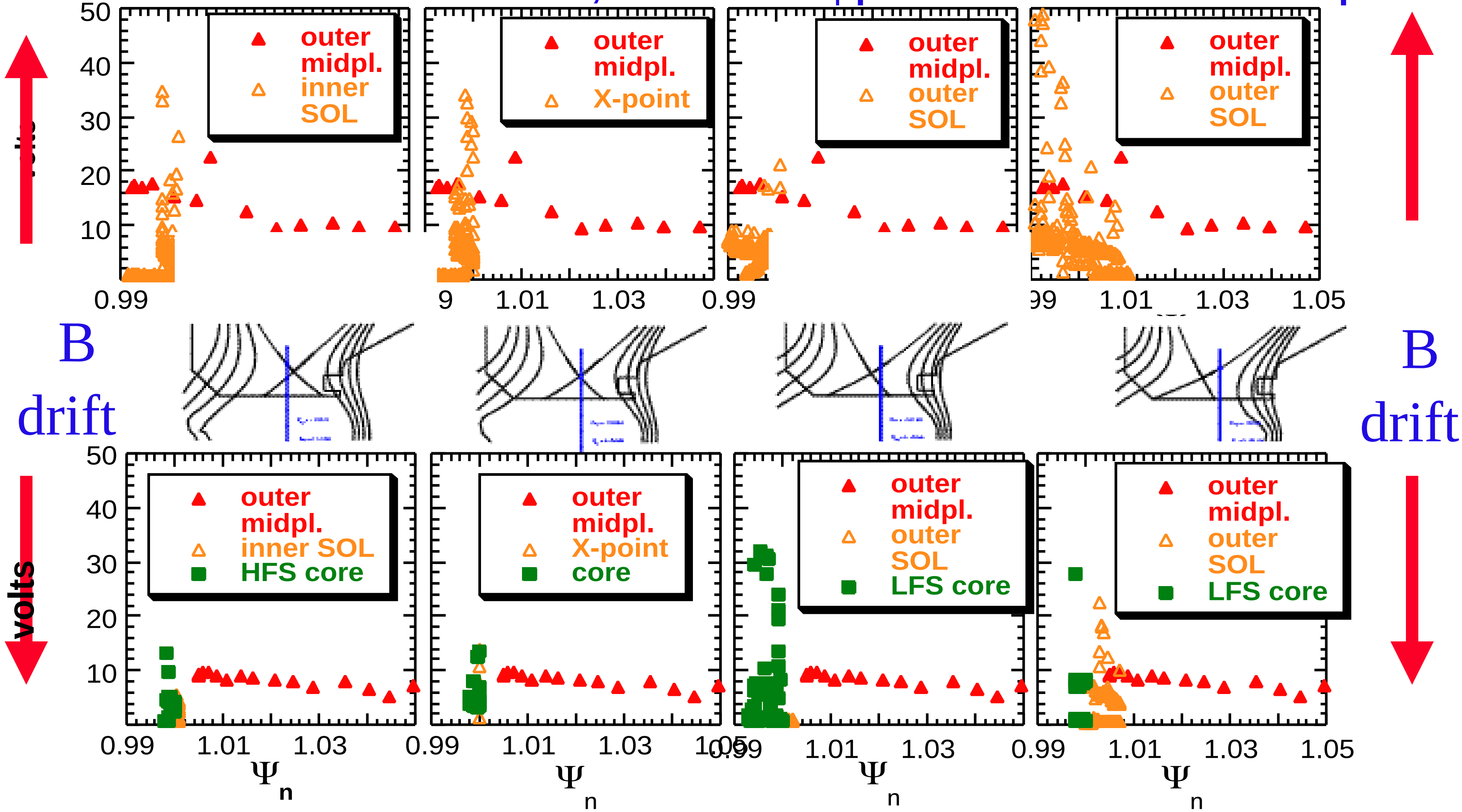
- B drift breaks circulation symmetry, with increased particle, momentum & heat transport when B drift is away from the X-pt.

B drift away from the X-point



Potential fluctuations are higher near the X-point for B drift away from X-point.

- $\tilde{\varphi}$ higher in SOL & core when B drift is away from X-point
- For both B drift directions, SOL & core $\tilde{\varphi}$ peak on low field side of X-pt



Comparison with BOUT modeling results.

- BOUT code predicts that the H-mode power threshold is higher when the B drift is away from the X-point due to increased fluctuations and turbulent transport near the X-points for this drift direction.
  - Consistent with experiment
- BOUT code predicts similar fluctuation levels and turbulent transport at the outboard midplane with both drift directions.
  - Consistent with experiment
- BOUT code predicts that the fluctuations propagate with a phase velocity that differs significantly from $v_{E\times B}$.
  - Need to resolve the E_r profiles measured by CER, probe

Summary

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  - **For some reason, the plasma is robust to the NBI perturbation when the B drift is toward the X-point**
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