Evidence for the role of velocity shear on the L-H transition

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ABSTRACT

The direction of the B drift is well known to have a large effect on the H-mode power threshold, P_{TH}. Recent measurements from DIII-D indicate the shear in the group velocity of the edge density fluctuations is at least partly responsible for this effect. High (low) shear in the poloidal velocity is associated with the low (high) P_{TH}. Comparisons at fixed heating power and density, but with opposite B drift directions with respect to the X-point location, resulted in edge profiles of density and temperature, as well as amplitudes of density and potential fluctuations, that were nearly identical. This indicates that the specific values of edge temperature, beta, or their gradients are not playing key roles in determining P_{TH}. Spatially resolved edge density fluctuation measurements show a change in the poloidal group velocity of the fluctuations when the X-point location was changed. These results suggest the shear in the edge poloidal group velocity of the turbulence is important in determining P_{TH}.

- Goal
  - Understand how the ion B drift direction influences the L-H power threshold and thereby learn more about the physics of the L-H transition.
- Experiment
  - Compare plasmas where the only operational difference is the ion B drift direction relative to the x-point.

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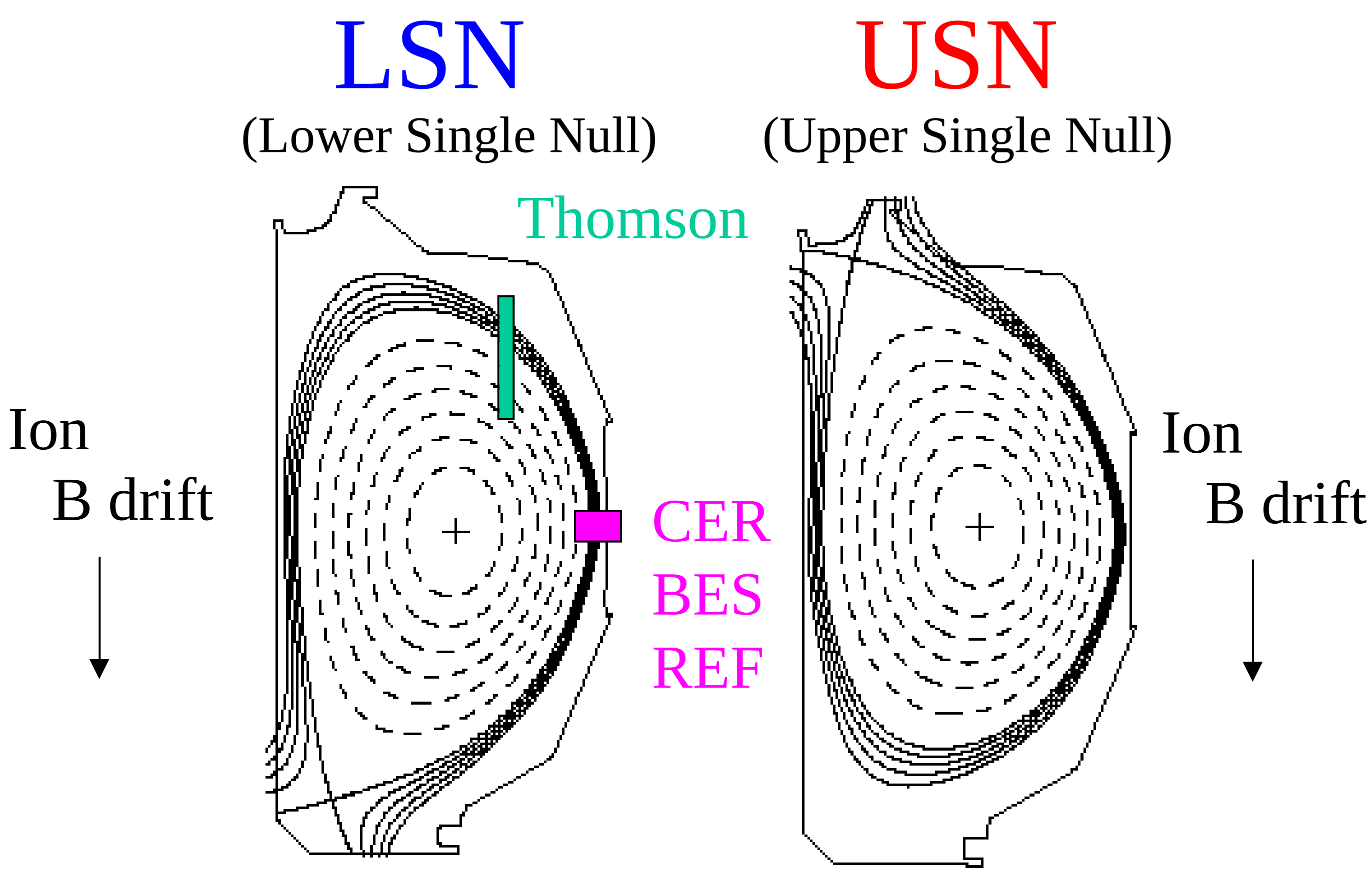
H-mode power threshold, P_{TH}, changes with plasma shape



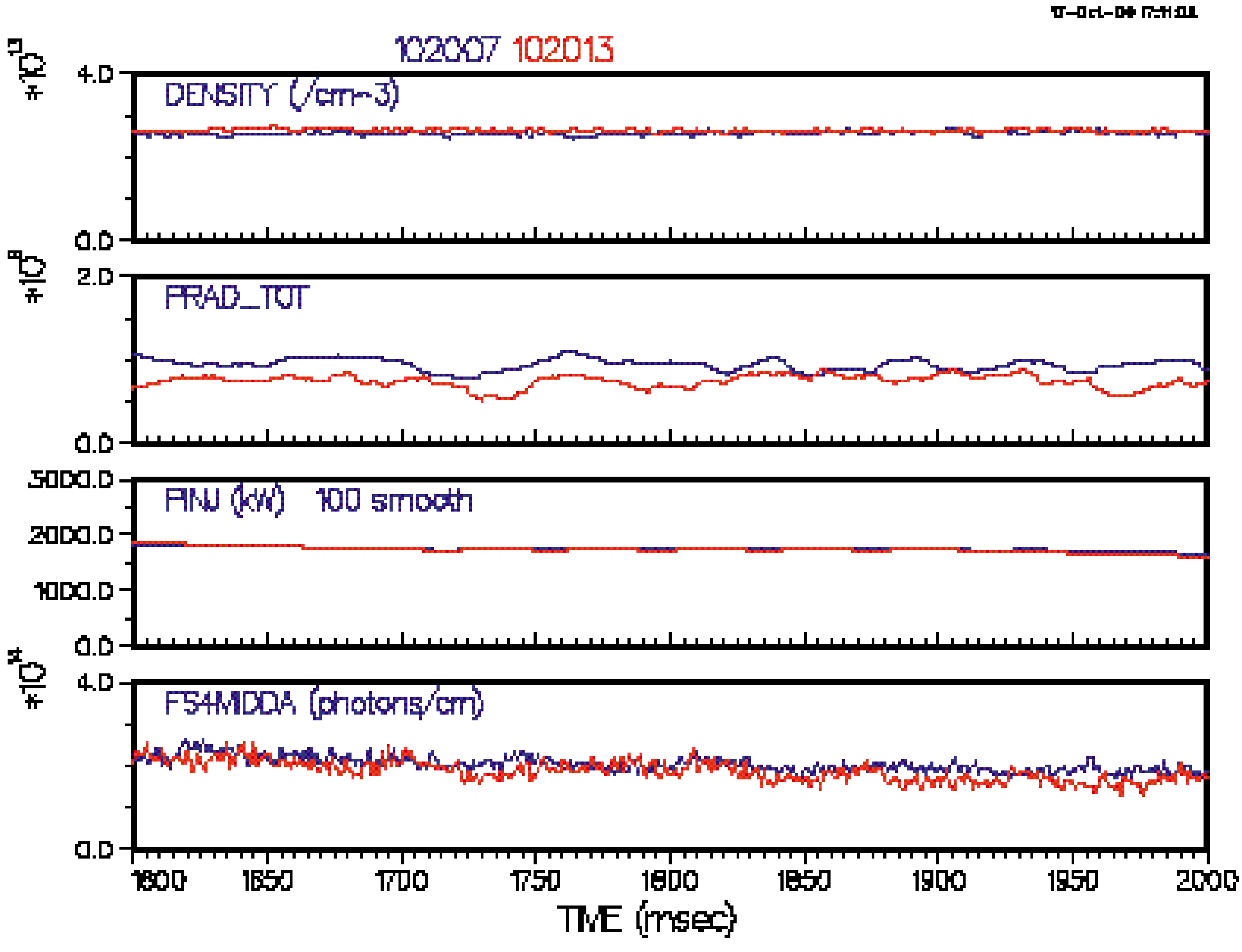
$P_{TH} = 2.7$ MW $\qquad$ $P_{TH} = 6.8$ MW

- Well known, robust effect
- Observed in all diverted tokamaks

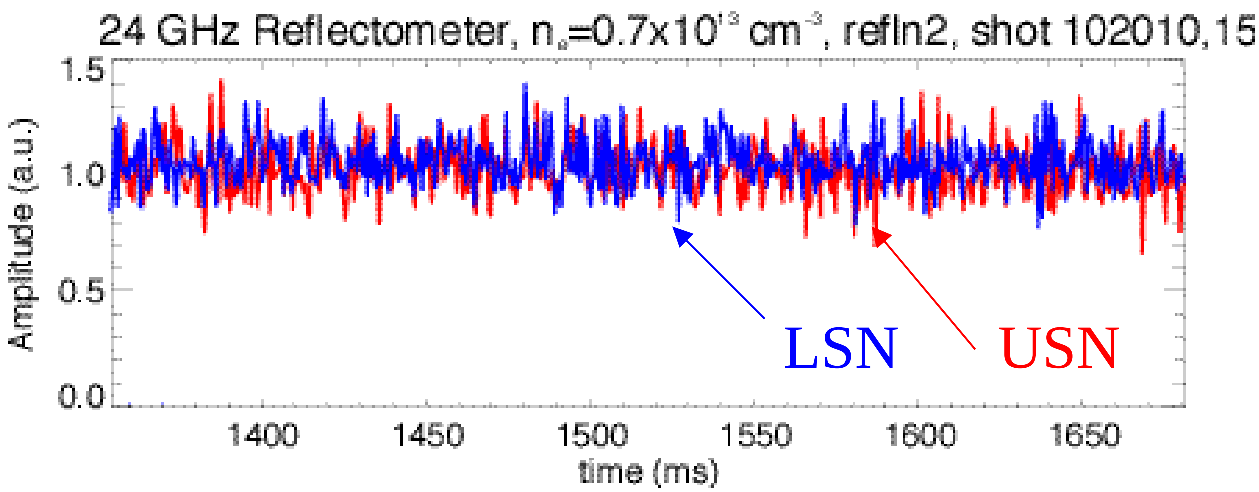
Many Plasma Parameters are similar between LSN and USN

- Edge T_e and n_e profiles
- Edge T_i
- Density fluctuations
- Recycling
- Radiated power

Plasma Parameters are similar between LSN and USN



Edge density fluctuation level approximately same for equal power USN and LSN



- RMS fluctuation level (near separatrix) vs. time shown above.
  - Monitored by homodyne reflectometer on outboard midplane.
  - Fluctuation level also unchanged on either side of separatrix.
- Density profiles approximately same.

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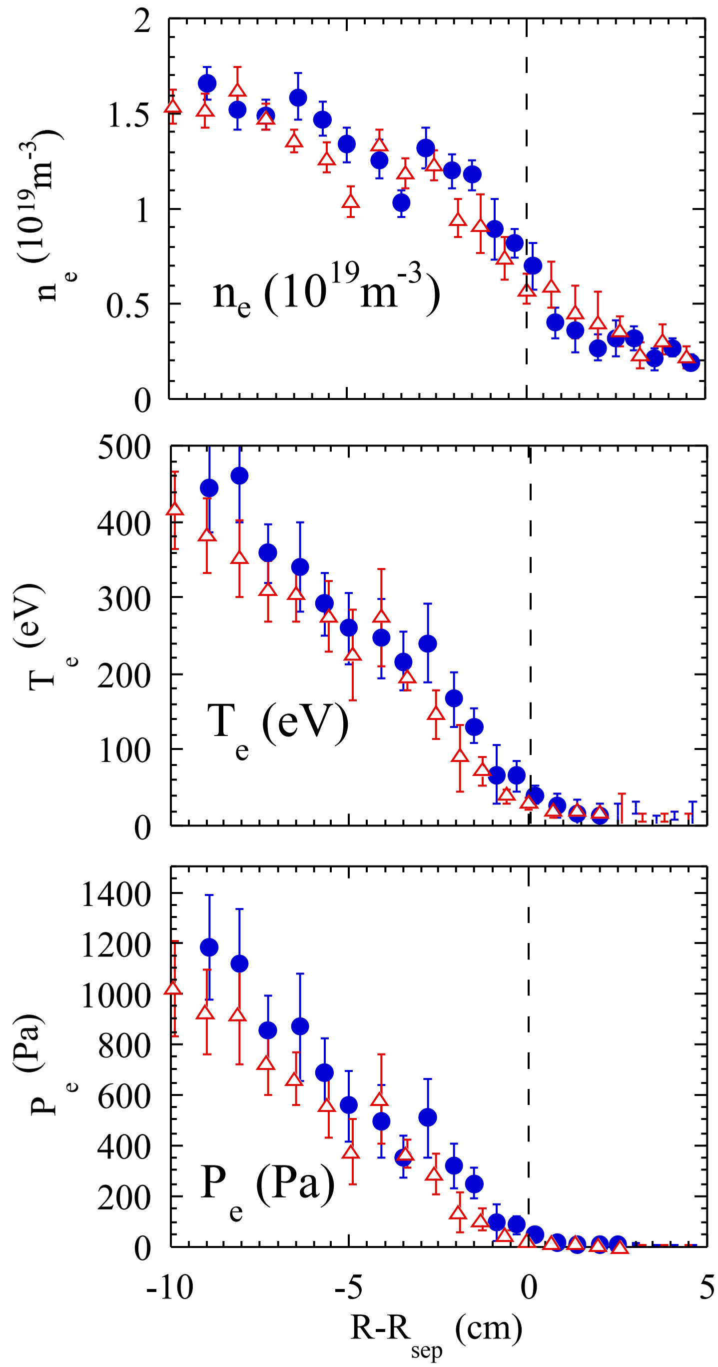
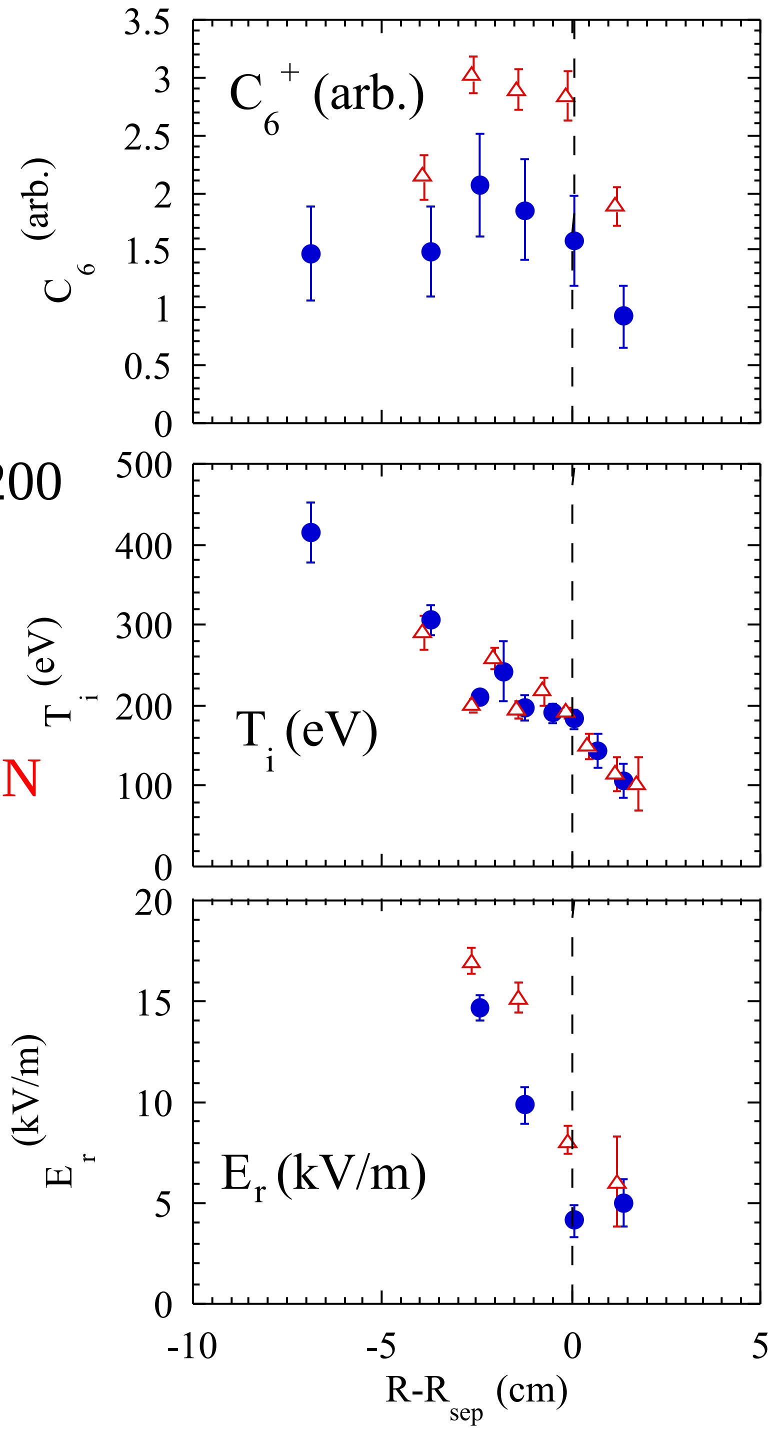
Edge Profiles are nearly identical for both X-point locations, LSN vs. USN

- Plasma parameters
  - I_P = 1.0 MA
  - B_T = 2.1 T
  - Nel=2.5e^{19}m^{-3}
  - NBI = 1.9 MW
- Average of 42 measurements over 400 ms
- Error bars = std dev
- Slight shift in position between LSN and USN is probably due to mapping errors.



Edge T_i profiles are also nearly identical LSN vs. USN

- Plasma parameters
  - I_P = 1.0 MA
  - B_T = 2.1 T
  - Nel=2.5e^{19}m^{-3}
  - NBI = 1.9 MW
- Average of 8 measurements over 200 ms
- Error bar = std dev
- Carbon density is slightly higher in USN (probably due to different divertors)
- T_i profiles are nearly identical
- E_r profiles (force balance) are slightly different (See next section)



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TN Carlstrom et al., APS 2000

Proximity to H-mode does not depend solely on edge T_e, n_e, T_i profiles

- Comparison of ion B drift towards the x-point, (LSN), and away from the x-point, (USN), shows that at NBI = 1.9 MW the edge profiles are nearly identical.
- Yet P_{TH} for LSN = 2.7 MW
- And P_{TH} for USN = 6.8 MW
- Therefore, the higher P_{TH} for USN is not required to achieve the same T_e or T_i edge condition.

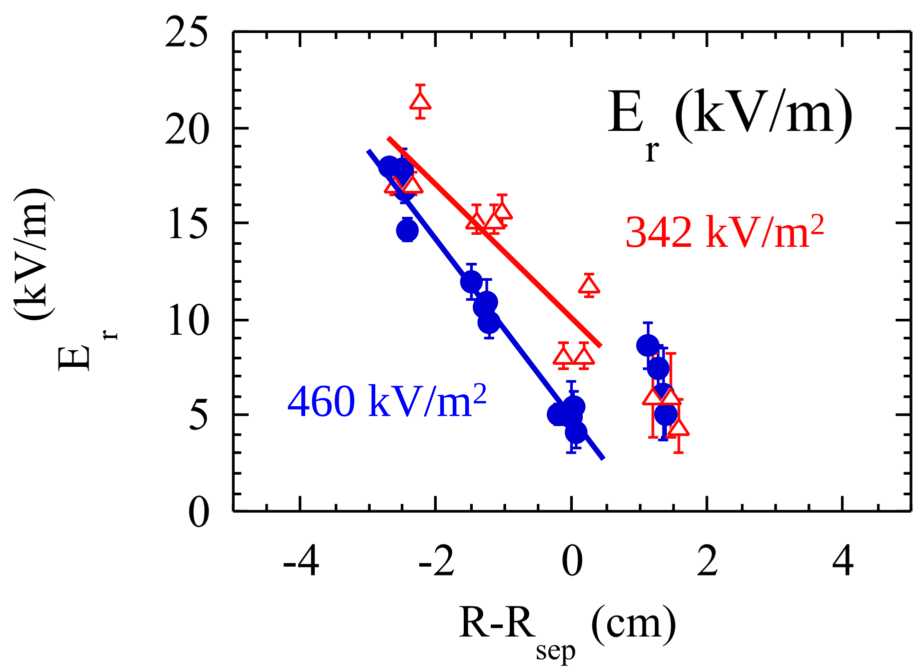
Some Plasma Parameters are different between LSN and USN

- Magnitude and gradient of E_r
- Poloidal group velocity of edge density fluctuations

Supports hypothesis of shear flow stabilization of turbulence at the L-H transition

- Greater shear in E_r or poloidal velocity => closer to the L-H transition

Edge E_r shear may be important in determining the H-mode power threshold



- E_r shear is greater in LSN than in USN
- E_r is calculated from radial force balance using CER measurements
- Shearing rate ω_{ExB} = 3.4, 2.5 (10^5 s^{-1})
- 4 LSN and 3 USN discharges are shown
- L-mode plasma, 1 MA, 2.1 T, NBI =1.9 MW

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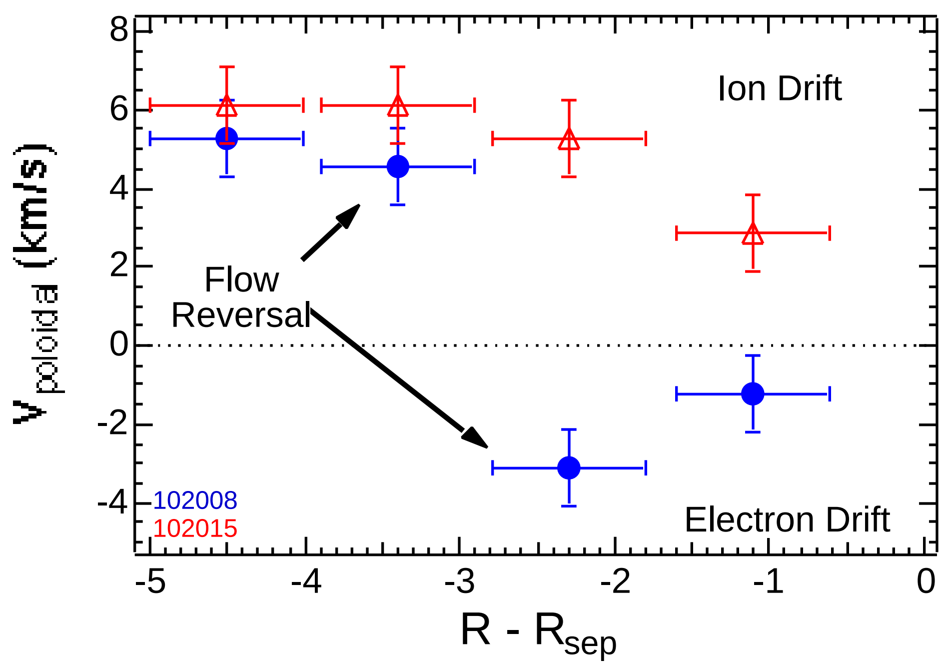
Phase velocity of edge density fluctuations depends on LSN vs. USN

- Observed on different diagnostics
  - BES
  - Reflectometer
  - Fast Stroke Langmuir Probe
- Differs from $E_r x B_T$ velocity
  - Magnitude and sometimes direction
  - Shows dispersion
  - Possible evidence for Reynolds stress driven flows

Velocity shear inside separatrix correlates with low H-mode power threshold

BES measurement
(C. Fenzi, G. McKee, Univ. Wis.)



↑ SOL flow toward LSN

SOL flow toward USN ↓

- Poloidal phase velocity of the edge n_e
- Operationally identical discharges except
- Upper single null vs. Lower single null
- L-mode plasma, 1 MA, 2.1 T, NBI =1.9 MW

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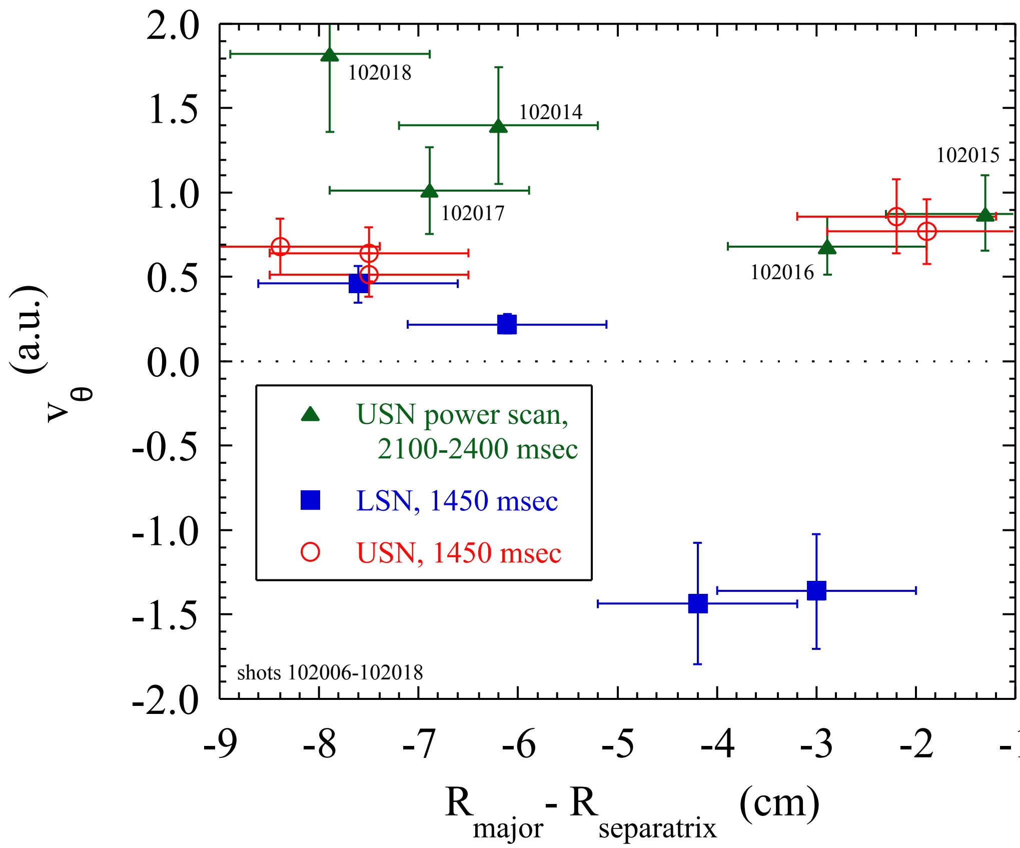
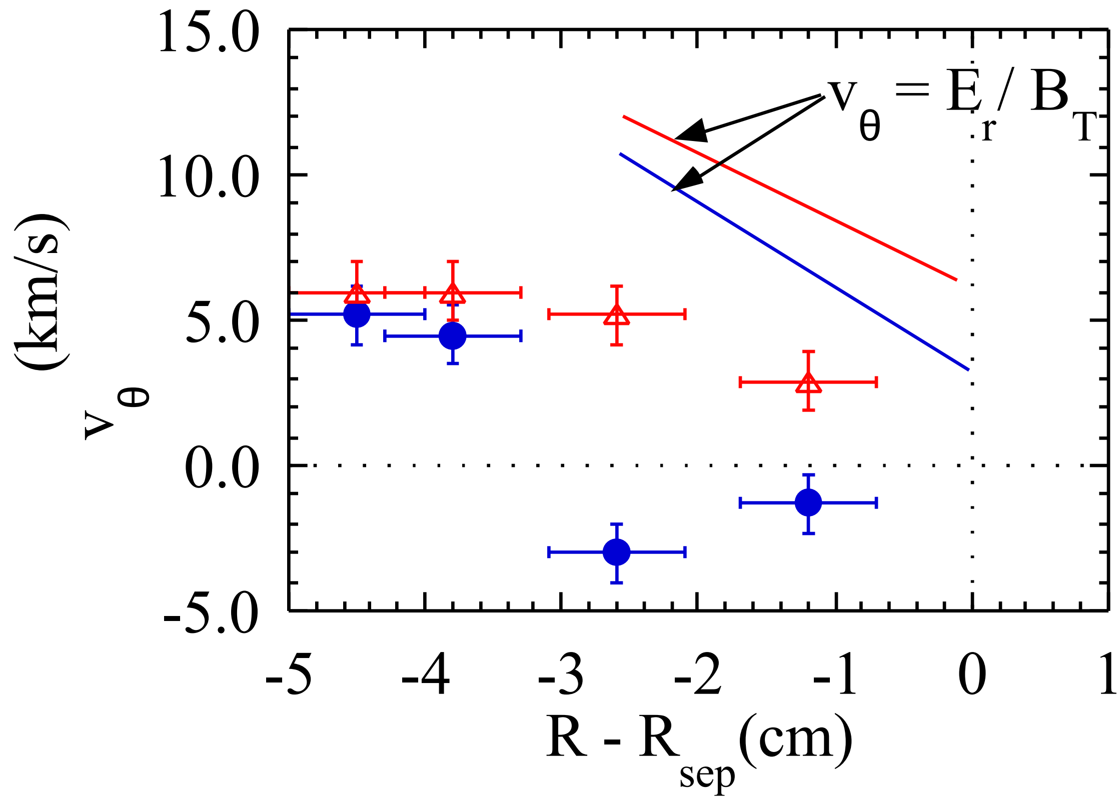
Radial shear in phase velocity of fluctuations larger for LSN vs USN



- Measured using two poloidally separated reflectometer signals.
- Note that in two-point technique simultaneous counterpropagating modes can increase apparent phase velocity.

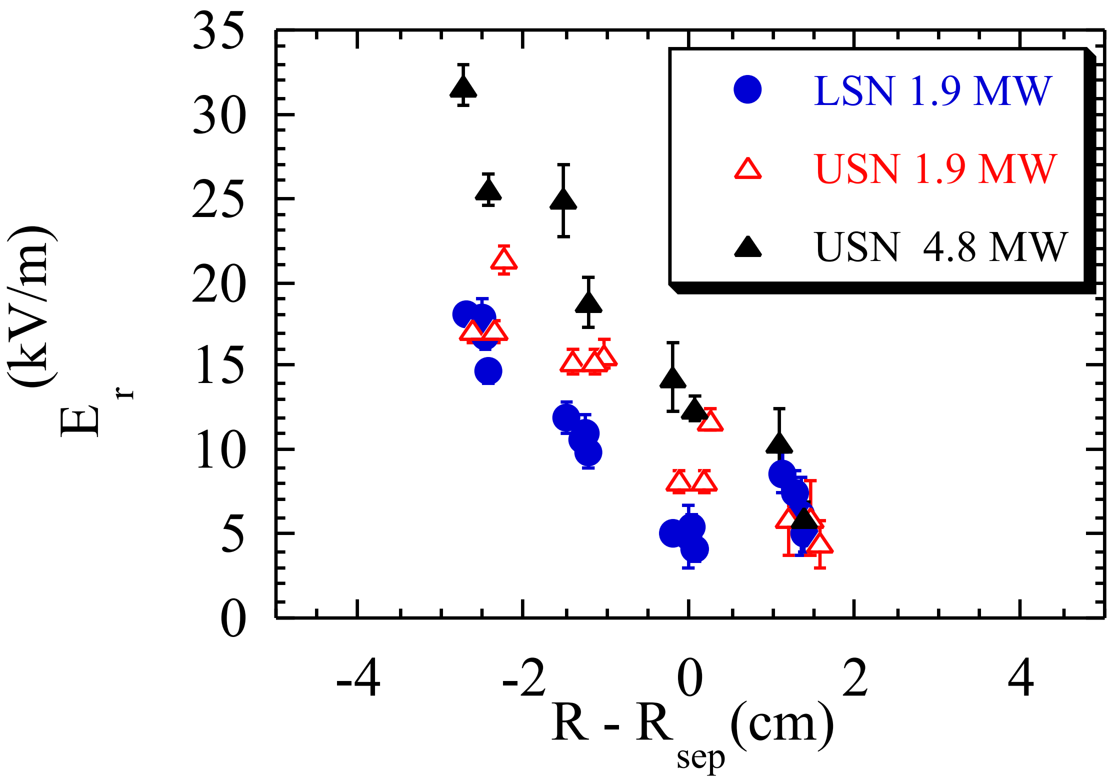
TN Carlstrom et al., APS 2000

Phase velocity of edge fluctuations and $E_r \times B_T$ velocity do not agree



- E_r calculated from force balance using CER measurements
- Operationally identical discharges except
- Upper single null vs. Lower single null
- L-mode plasma, 1 MA, 2.1 T, NBI =1.9 MW

E_r shear increases in USN as the power threshold is approached



- E_r shear increases in USN as the power increases from 1.9 MW to 4.8 MW
- P_{TH} was about 6.8 MW for USN
- Shear in the poloidal phase velocity of the density fluctuations measured by reflectometry also increases (but further into the core plasma).

Summary/Conclusions

- P_{TH} increases >2x from LSN to USN, all other operational parameters held constant.
- At fixed NBI power, edge profiles of n_e, T_e, T_i are nearly identical.
  - Proximity to H-mode is not just an edge profile effect of these quantities.
- Low P_{TH} is correlated with higher shear in edge E_r and the poloidal group velocity of edge density fluctuations.
  - Supports hypothesis of shear flow stabilization of turbulence as cause of the L-H transition.
- Poloidal group velocity differs from edge $E_r x B_T$ velocity in magnitude and sometimes direction.
  - Possible evidence for dispersion and Reynolds stress driven flows.

Future Issues

- What determines the edge poloidal flows?
- How do the edge and divertor effects that influence the L-H power threshold scale?
- Can we identify a critical parameter for the L-H transition?