Effect of ion ∇B drift direction on edge plasma physics in diverted DIII-D discharges

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Abstract

The direction of the ion ∇B drift is known to have a significant effect on the H-mode power threshold in DIII-D (e.g. ion ∇B towards the x-point of diverted discharges decreases the power threshold). Experiments performed with different ion ∇B drift directions have shown similarities in T_e and n_e with some differences in the radial electric field (from Langmuir probes) and the poloidal phase velocity of the density fluctuations. These experiments were performed at both similar input power levels and similar proximity to the H-mode transition as well as with a dynamic variation of the magnetic configuration from upper to lower single null. If the source of these similarities and differences is understood a better understanding of the edge plasma should emerge. BOUT edge turbulence code simulations of these various conditions are underway to both benchmark and test the code as well as to provide insight into the experiment.

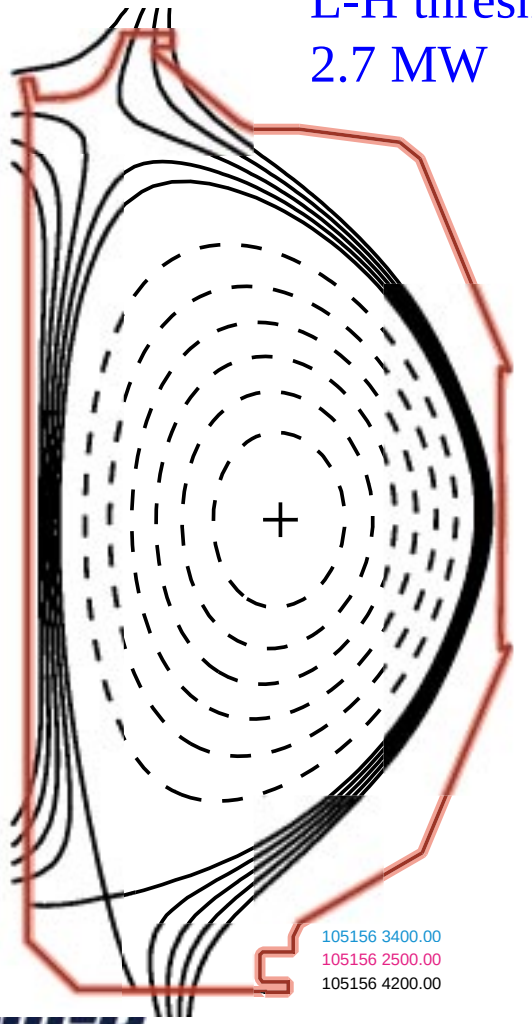
Overview

- L-H transition occurs at different threshold powers depending on magnetic shape and direction of ion ∇B drift.
- Observe changes in edge and core fluctuation parameters as shape changes.
  - Doppler shift (V_θ) increases as plasma goes from USN to DN.
  - Fluctuations decrease as V_θ increases in discharge that makes L-H transition
- Observations are consistent with shear in fluctuation V_θ affecting L-H transition behavior.
  - These changes linked to plasma shape - not yet known why.
    - Answer could help us understand edge turbulence and L-H transition.

H-mode power threshold changes with plasma shape

Lower Single Null (LSN)

L-H threshold power
2.7 MW

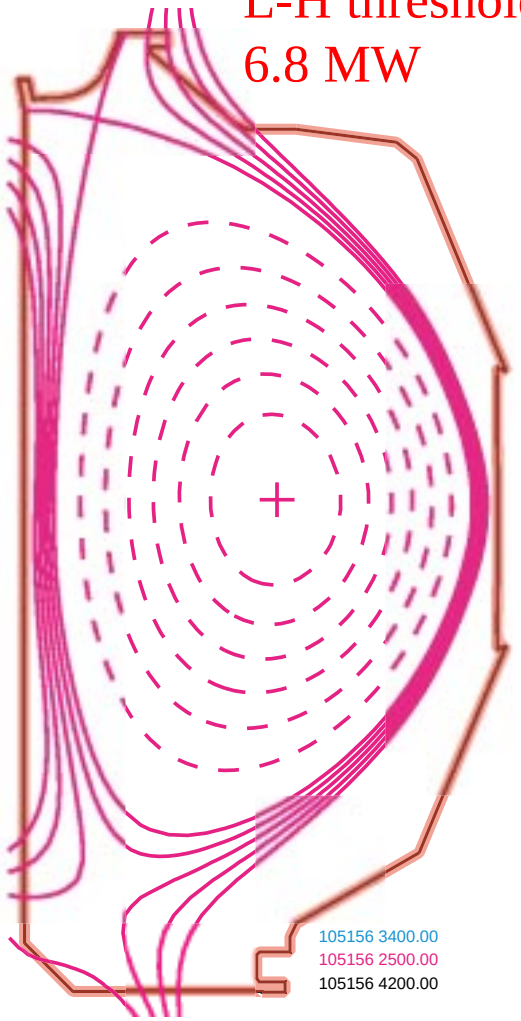


H-mode power threshold larger when ion ∇B drift direction away from x-point.

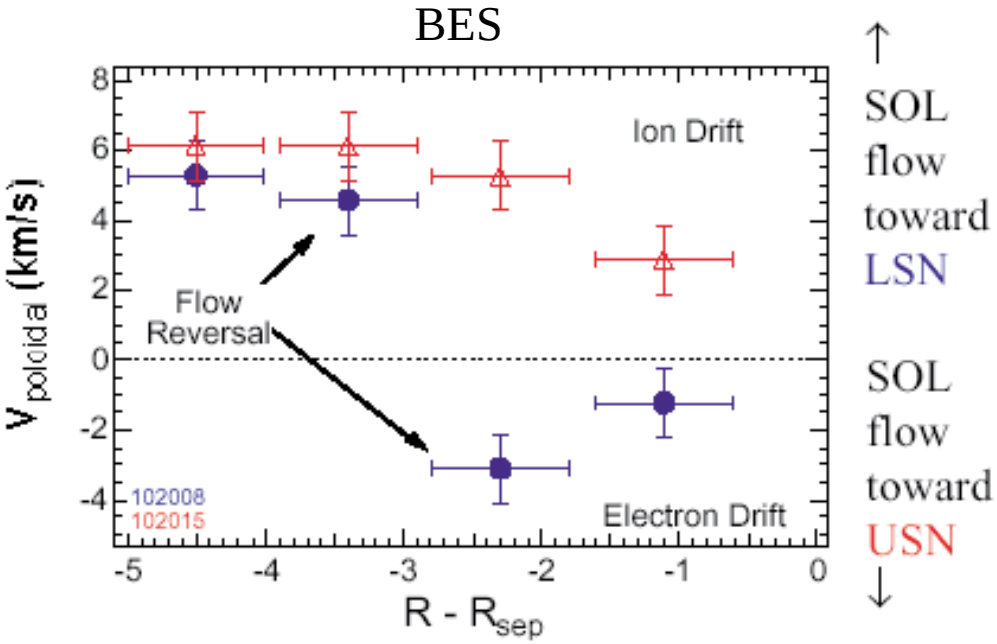
Ion ∇B drift direction

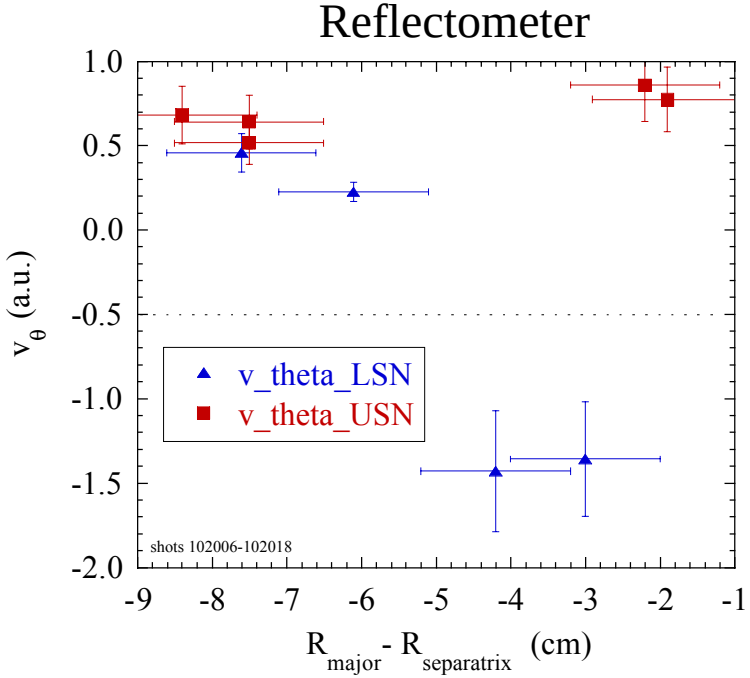
Upper Single Null (USN)

L-H threshold power
6.8 MW



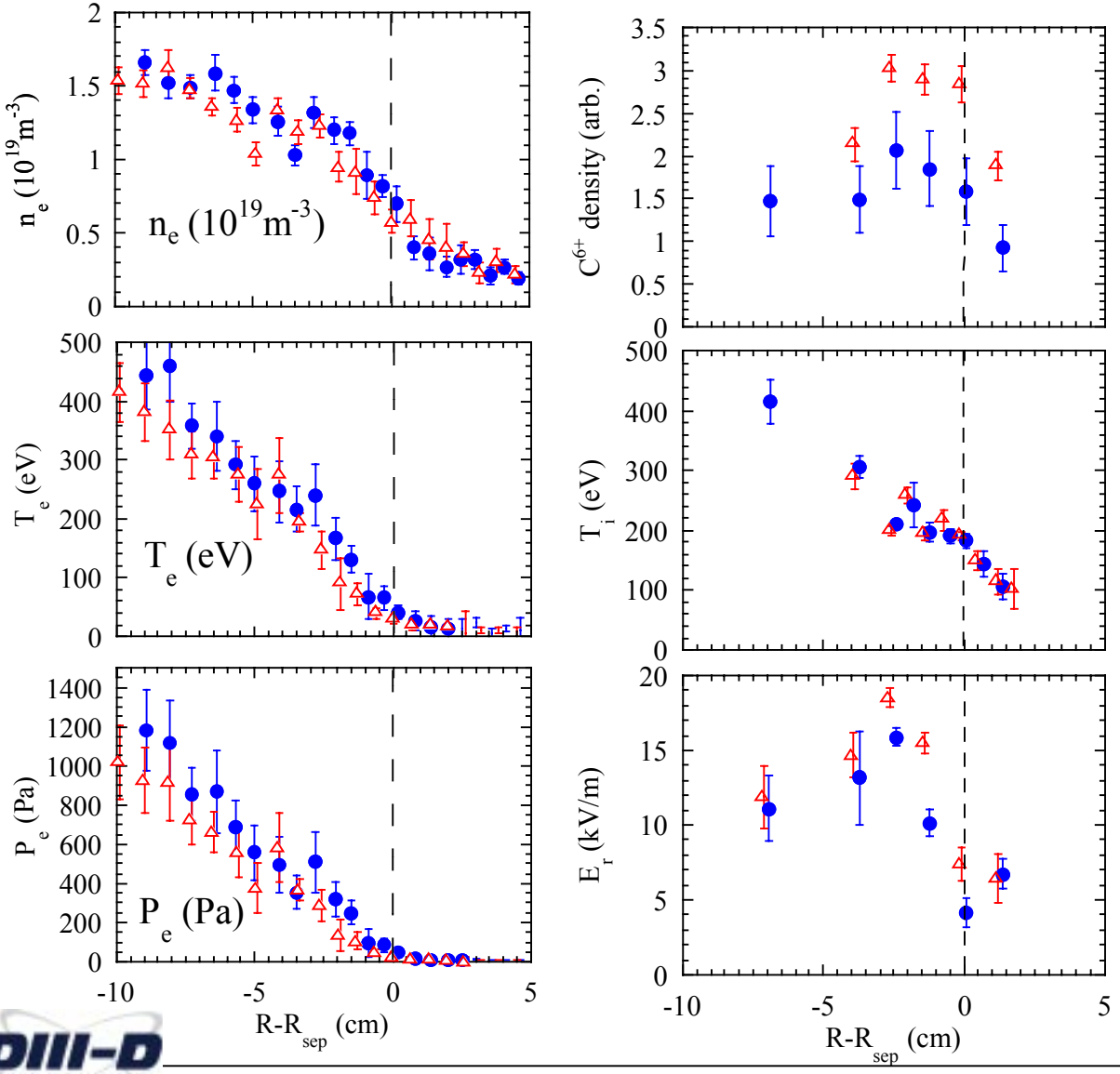
Velocity shear of density fluctuations inside separatrix correlates with low H-mode power threshold





- LSN plasmas show V_θ reversal and increased shear as compared to upper single null case.
  - Consistent with decreased L-H power threshold in LSN case due to velocity shear reduction of transport (Carlstrom, et al., 27th EPS (2000)).
- Qualitative agreement seen between reflectometry and BES measurements.
  - Reflectometer position scanned shot to shot while BES data from two discharges.
  - Quantitative differences due to position calibration and/or Shot to shot differences.

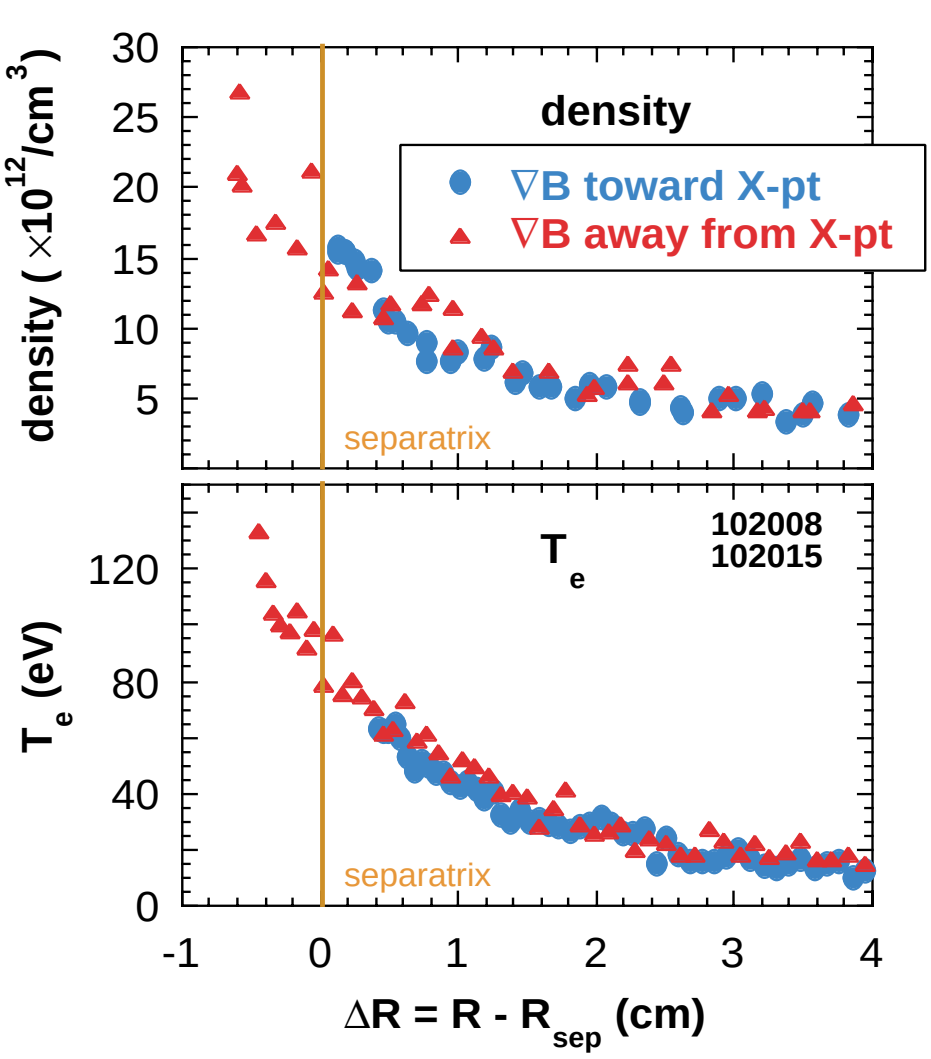
Edge Profiles are very similar for LSN vs. USN

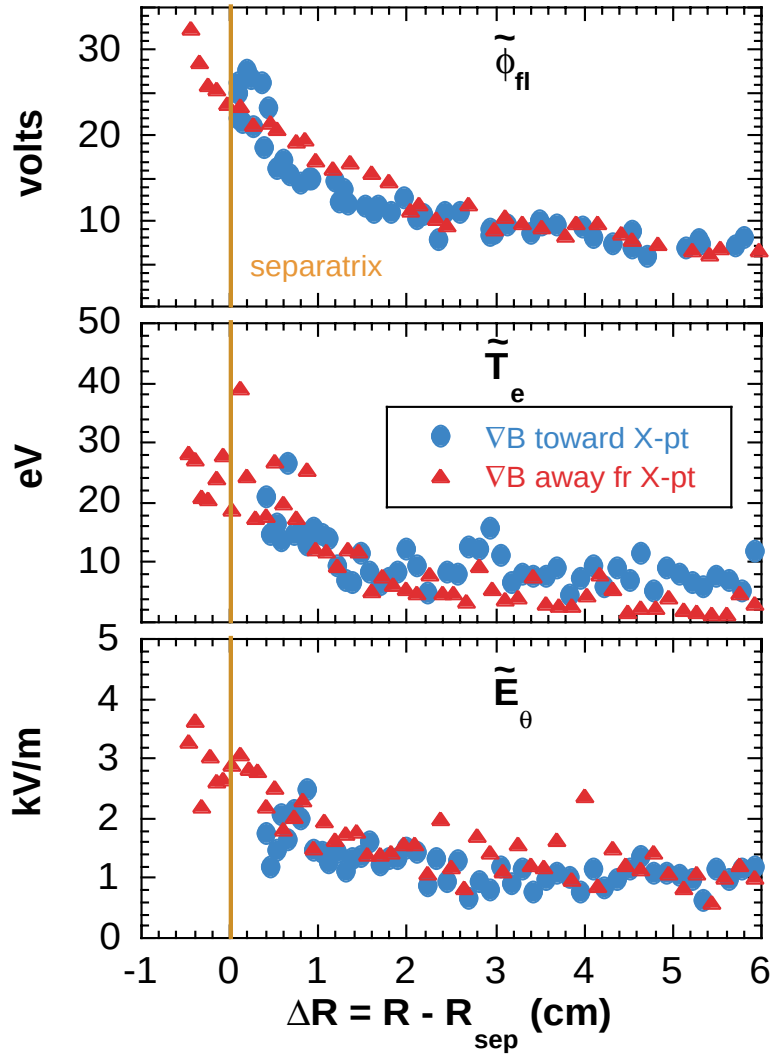


I_P = 1.0 MA
B_T = 2.1 T
n_e= 2.5e^{19}m^{-3}
NBI = 1.9 MW

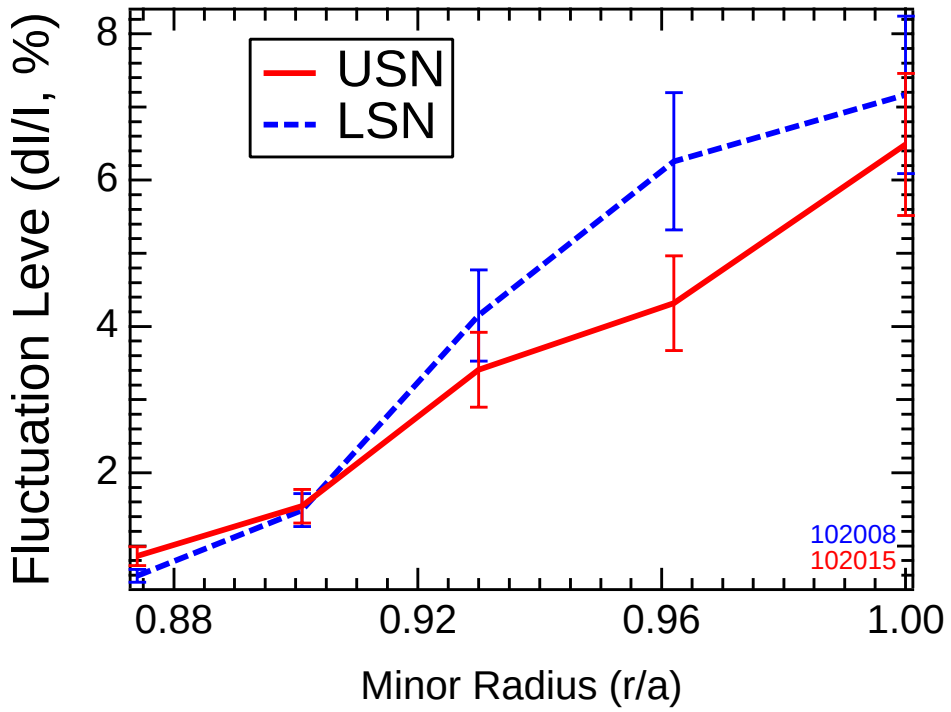
Same input power levels.

Langmuir probes show similar outboard midplane edge parameters for LSN vs. USN



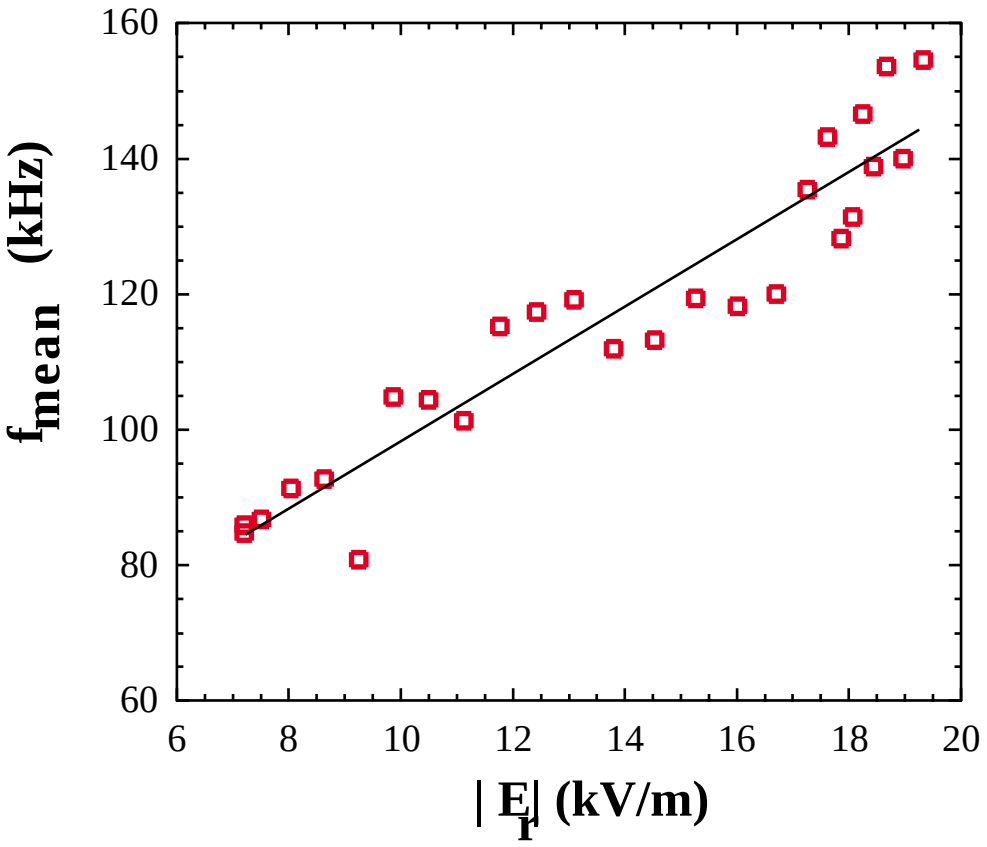


BES density fluctuations similar for USN vs LSN



- dI/I is proportional to ñ/n for BES.
- ñ/n for USN case is perhaps slightly lower at one point inside the separatrix.
- Homodyne relectometry indicates no more than 20% lower in the USN case.

Doppler shift of fluctuations related to local ExB velocity



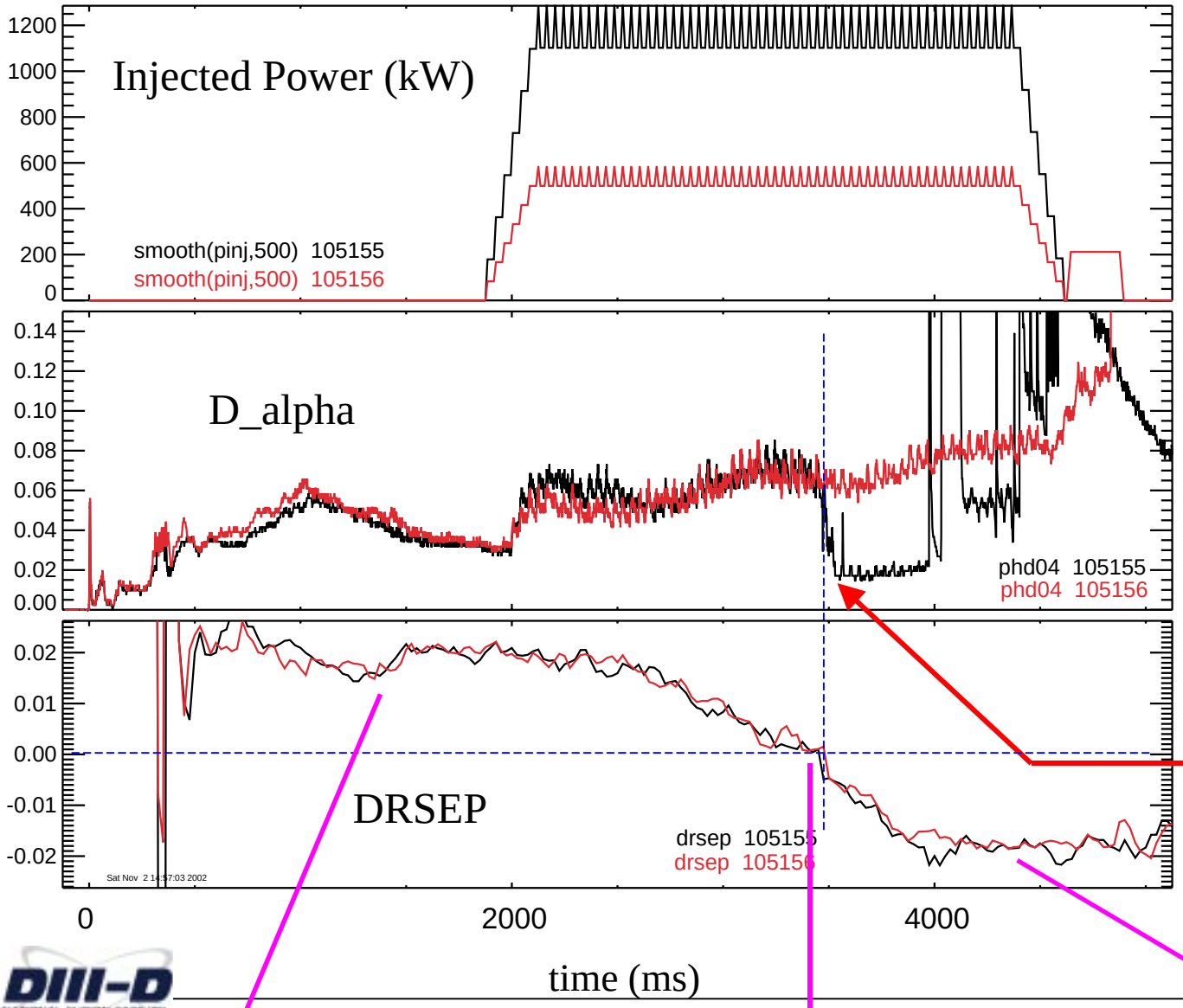
- Find f_{mean} proportional to local E_r
  - likely due to ExB velocity changes of fluctuations
  - See Y. Kim, et al. Phys Fluids B 1991.
- Use this in investigation.

$$f_{mean} = \int f\, P(f)\, df / \int P(f)\, df$$

Shape dynamically varied between USN-DN-LSN and L-H transition occurs with ~1.2 MW NBI

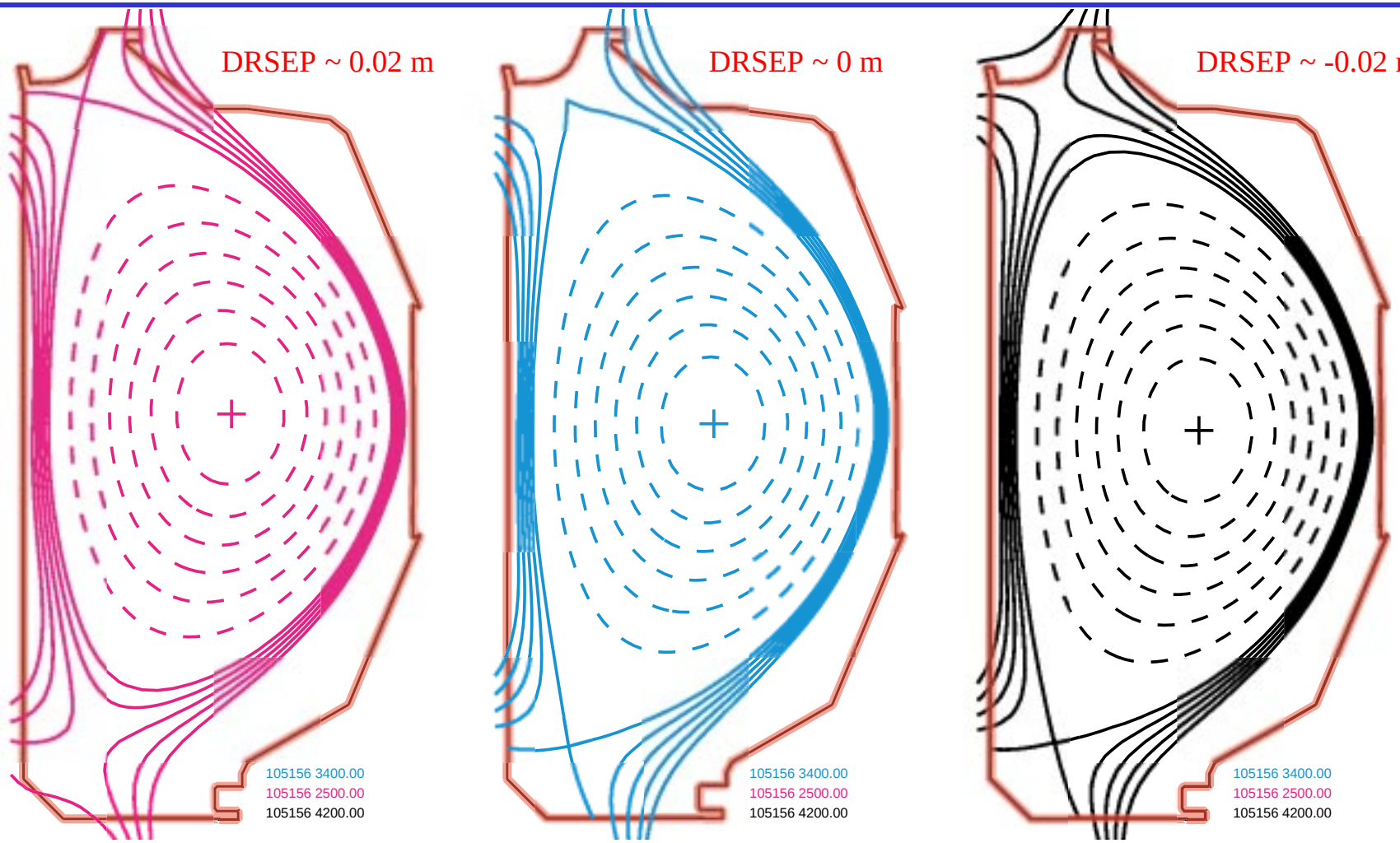
- Experiment designed to investigate effect of shape on physics of L-H transition.
- Magnetic configuration dynamically varied between USN ⇒ DN ⇒ LSN.
- DRSEP parameter shown:
  - = distance (measured at outboard midplane) between separatrices of upper and lower x-points.
  - Is a measure of balanced vs. unbalanced configurations.
  - DRSEP = 0 ⇒ balanced double null configuration.
- Two NBI powers shown: 0.5 MW and 1.2 MW.
  - L-H transition occurs at P_{inj}~1.2 MW and as magnetic configuration goes to DN.
- Shape strong determinant of threshold power.

Shape dynamically varied between USN-DN-LSN and L-H transition occurs with 1.2 MW NBI

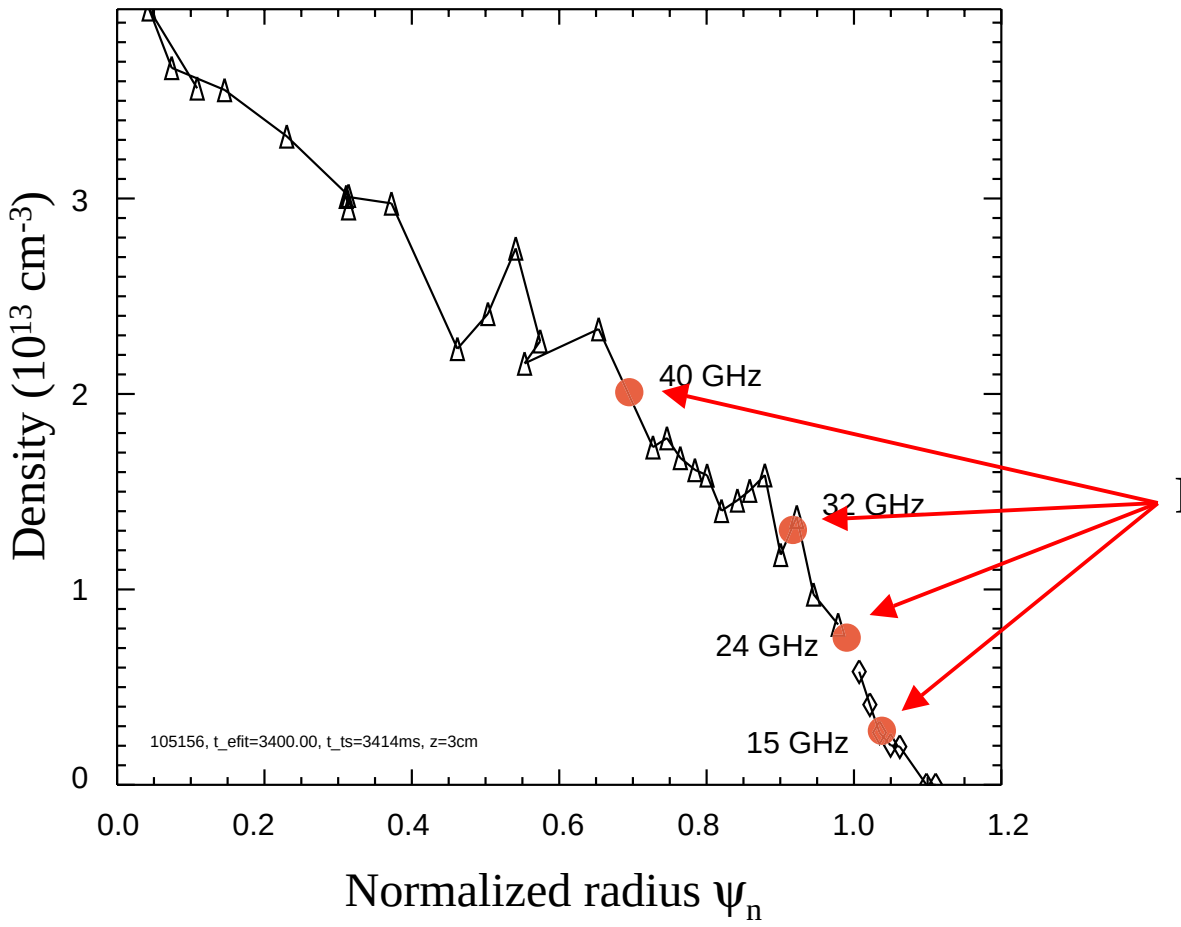


L-H transition occurs near DRSEP=0

Shape varied between USN-DN-LSN



Reflectometer detection positions cover SOL to ρ ~ 0.7

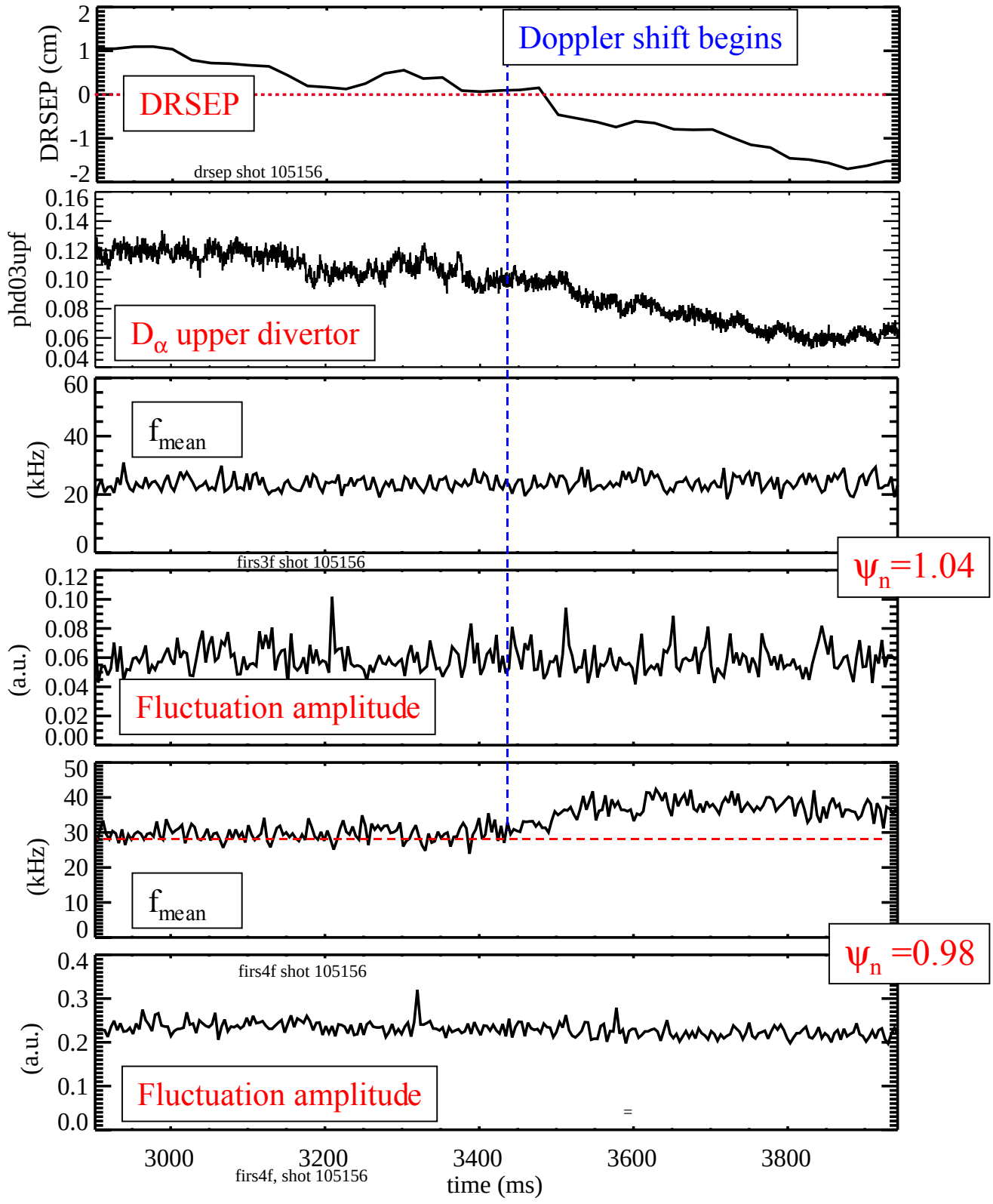


Reflectometer detection positions

No L-H transition at lower P_{inj} but Doppler shifts change near magnetic balance time

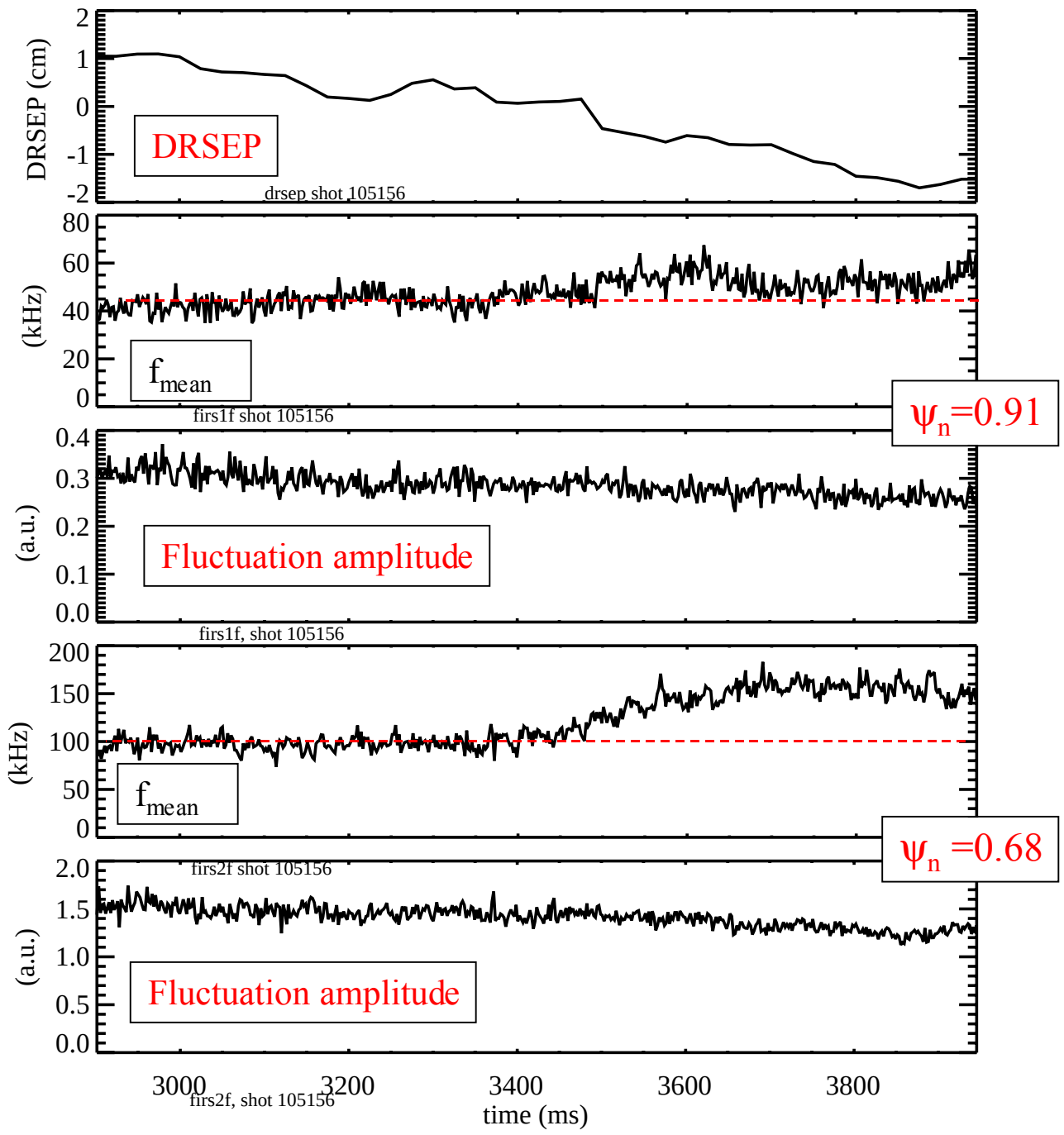
- Changes in V_θ occur at and just inside separatrix.
  - Channel inside separtrix may change slightly later in time.
  - Note this is a pure Doppler shift since fluctuation amplitude doesn't change (energy conserved).
- Clear indication of effect of shape on edge plasma parameters.
- Do V_θ change simultaneously?
- E_r from CER and probes being analyzed.
- What determines change in V_θ ?
  - ion/electron transport
  - Divertor variations

Doppler shift begins near DN balance point



$f_{mean} = \int f\, P(f)\, df / \int P(f)\, df$

Doppler shifts occur futher in as well

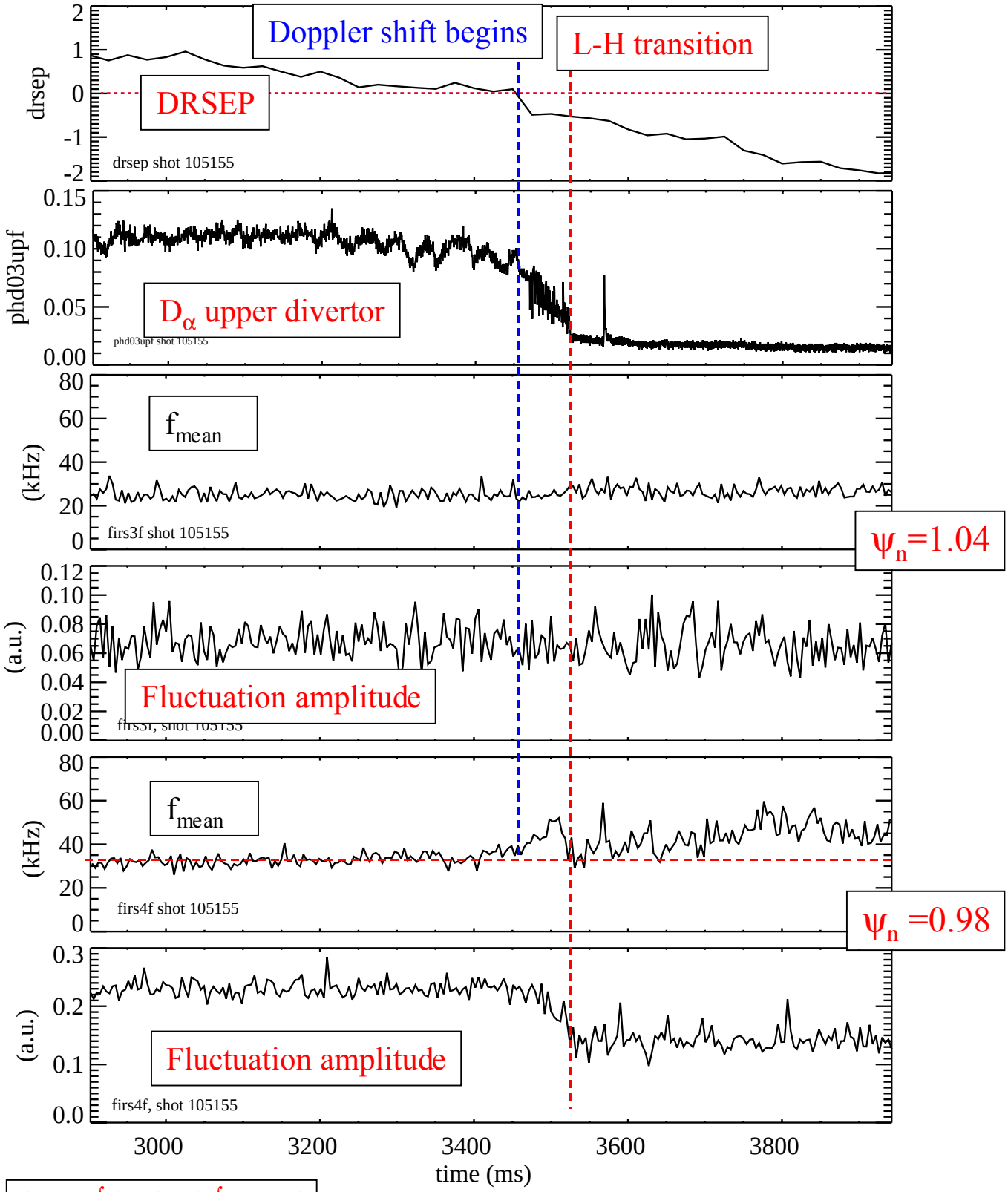


$f_{mean} = \int f\, P(f)\, df / \int P(f)\, df$

L-H transition occurs for higher P_{inj} near time of magnetic balance

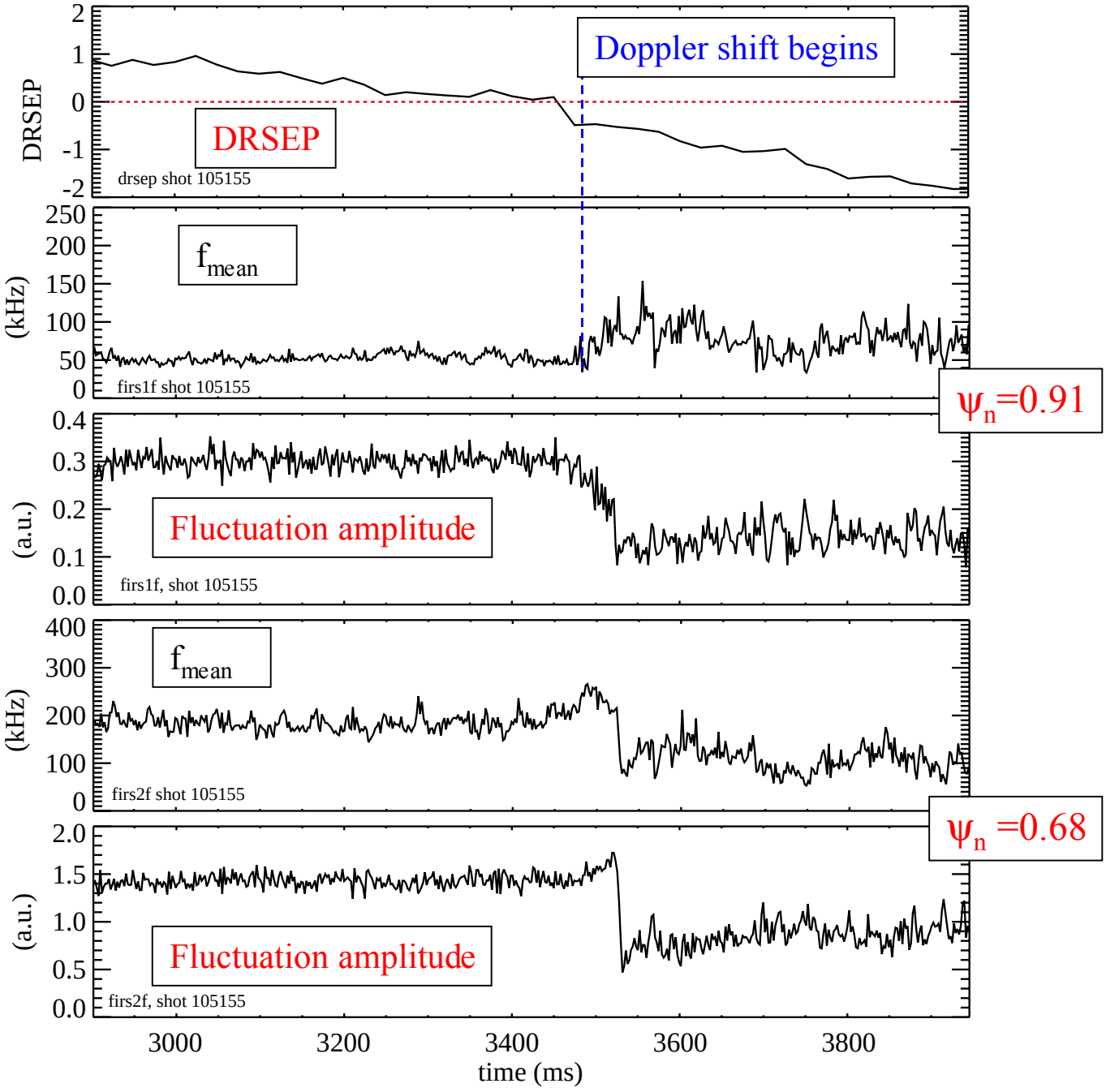
- V_θ increases when plasma shape is near magnetic balance point.
- Fluctuation levels decrease as V_θ increases.
  - Then L-H transition occurs.
  - Consistent with shear flow reduction of fluctuations.
- Change in V_θ appears to be earlier near $\rho = 1$.
  - Changes occur later at interior points.
- As in earlier case there is a clear effect as magnetic shape is changed.
  - Variation of fluctuation parameters not due to NBI power levels.

Doppler shifts begin near DN balance point, D_α decreases more rapidly



$f_{mean} = \int f\, P(f)\, df / \int P(f)\, df$

Doppler shifts change further in as well.



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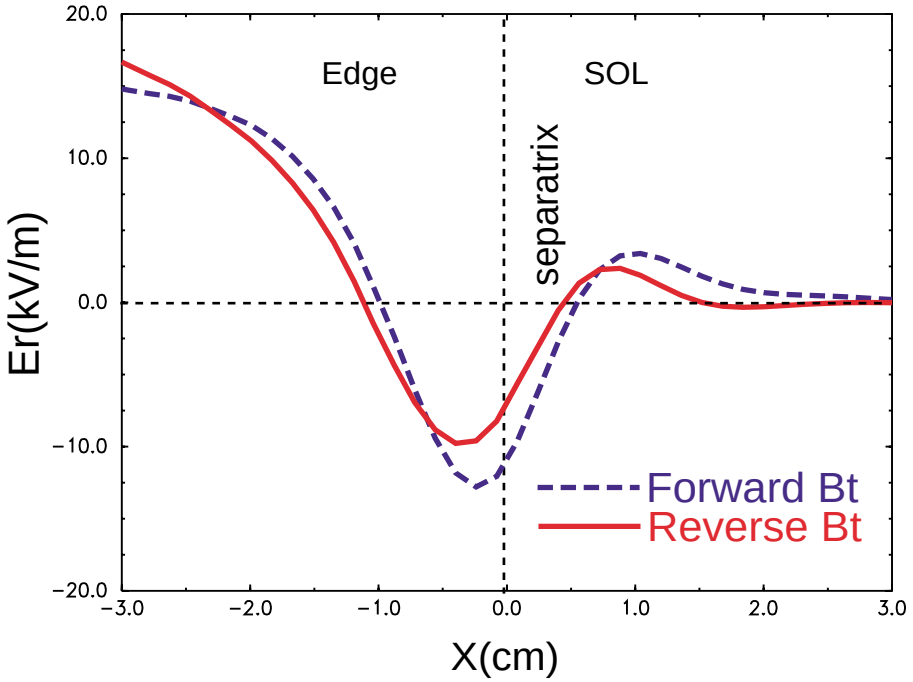
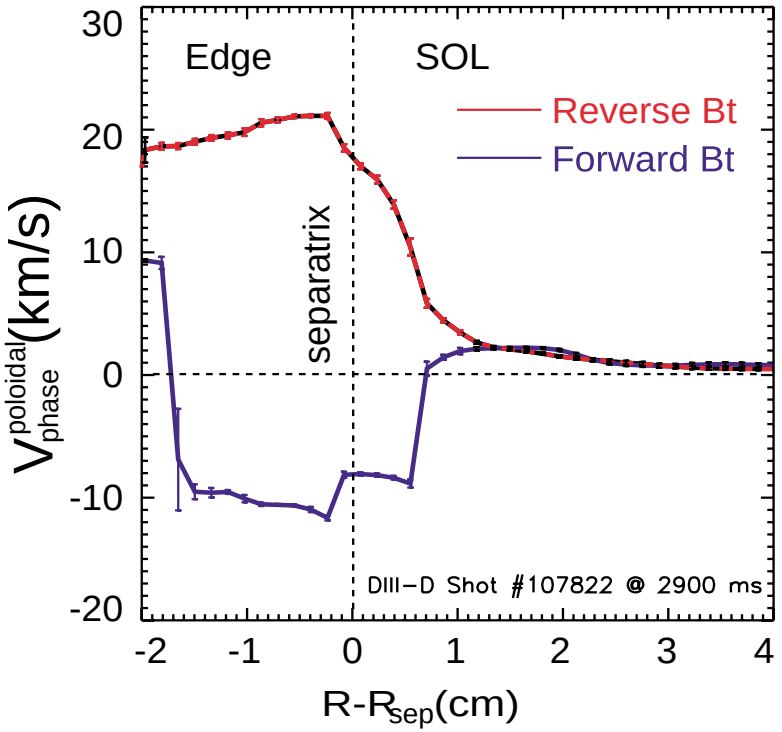
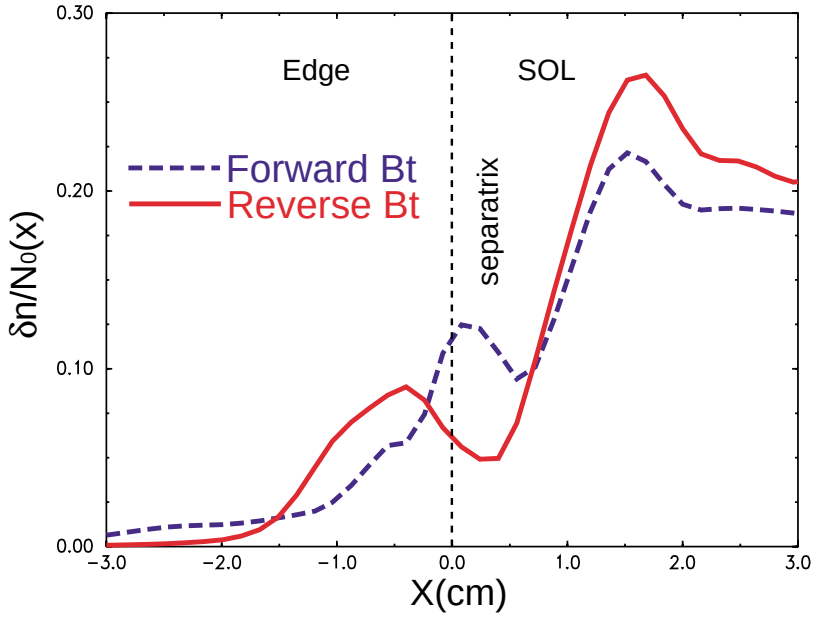
BOUT simulations show phase reversal of density fluctuations

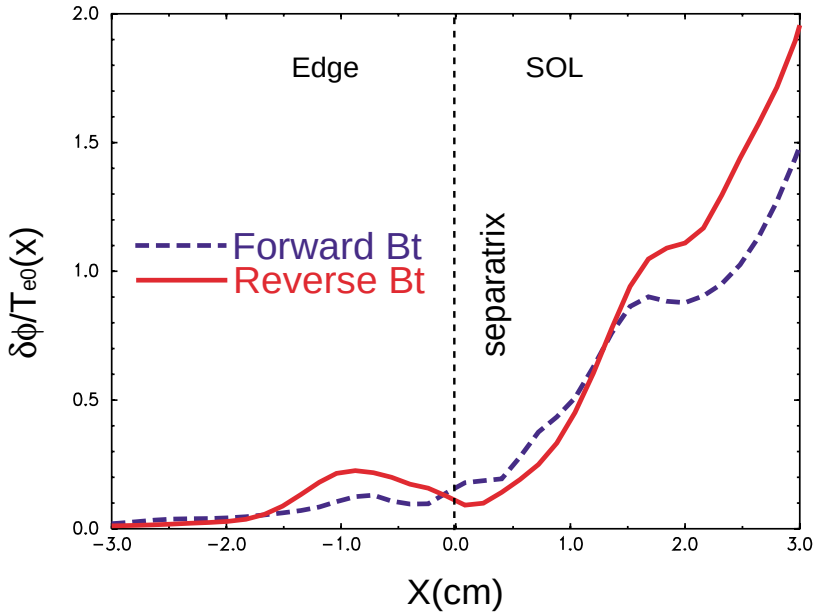




- Simulations of these plasmas underway using BOUT edge turbulence code.
- Shown are two simulations with only difference being the direction of B_T
- Phase velocities change sign but shear in E_r not dramatically different.
  - Shear in V_θ higher on average in reverse Bt case (corresponds to LSN)
  - Counter propagating mode observed in forward B_T case near R-R_{sep} = -2 cm.
- This E_r result appears to be different than experiment - investigation still underway.

BOUT simulations show similar levels of fluctuations for forward and reverse B_T





- Similar to experiment.

Summary

- L-H transition occurs at different threshold powers depending on magnetic shape and direction of ion ∇B drift.
- Observe changes in edge and core fluctuation parameters as shape changes.
  - Doppler shift (V_θ) increases as plasma goes from USN to DN.
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- Observations are consistent with shear in fluctuation V_θ affecting L-H transition behavior.
  - These changes linked to plasma shape - not yet known why.
    - Answer could help us understand edge turbulence and L-H transition.
- Simulations using LLNL BOUT edge turbulence code underway.