Importance of X-point Physics on the H-mode Power Threshold in DIII–D

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Importance of X-point Physics on the H-mode Power Threshold in DIII-D[1] T.N. CARLSTROM, K.H. BURRELL, R.J. GROEBNER, A.W. LEONARD, T.H. OSBORNE, M.J. SCHAFFER, General Atomics — Edge parameters related to the density and temperature profiles are investigated in L–mode discharges where the only operational difference is the direction of the toroidal field. An examination of the edge plasma parameters for otherwise identical conditions of plasma current, toroidal field, heating power (1 MW), density, shape, etc., shows that there is very little change in the local edge parameters when the toroidal field direction is reversed, and yet the H-mode power threshold increases a factor of 3–5. Therefore, the increase in the power threshold with respect to the toroidal field direction is not due to a change in these local edge parameters. These results indicate that there is additional important physics of the L–H transition that is not associated with the outboard midplane plasma density and temperature profiles near the last closed flux surface. The divertor and x–point regions of the plasma show substantial changes with the toroidal field direction. We have begun to study these regions in the hope that they may provide insight into the physics of the L–H transition and further our understanding of the scaling of the H-mode power threshold.

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☐ Prefer Oral Session
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Special instructions: DIII-D Contributed Oral Session, immediately following EJ Doyle

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Thesis

- Additional physics, other than those involving the local edge profiles of n_e, T_e and T_i near the plasma midplane are needed to describe the L-H transition.
- Details of the edge E_r profile (the sign) are important for the L-H transition.
- Divertor and x-point region effects are important in determining the physics of the L-H transition.

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Search for a critical edge parameter at the L-H transition

- For many years, experimentalist have searched for a critical edge parameter at the L-H transition by slowly raising the input power until a transition occurred.
- Since many plasma parameters are correlated with the input power, it is difficult to separate cause from effect.
- New approach:
  - By changing the proximity to the L-H threshold while keeping the input power constant, we hope to more clearly identify conditions related to the transition.

Experiment

- Compare plasmas with the ion ∇B drift toward and away from x-point by changing the direction of B_T.
- All other control parameters held fixed.
- L-mode plasmas.
- Detailed plasma edge and divertor measurements.
- General result: Edge plasmas were very similar.
- Differences:
  - Edge E_r profiles had opposite sign
  - Divertor plasmas were very different.

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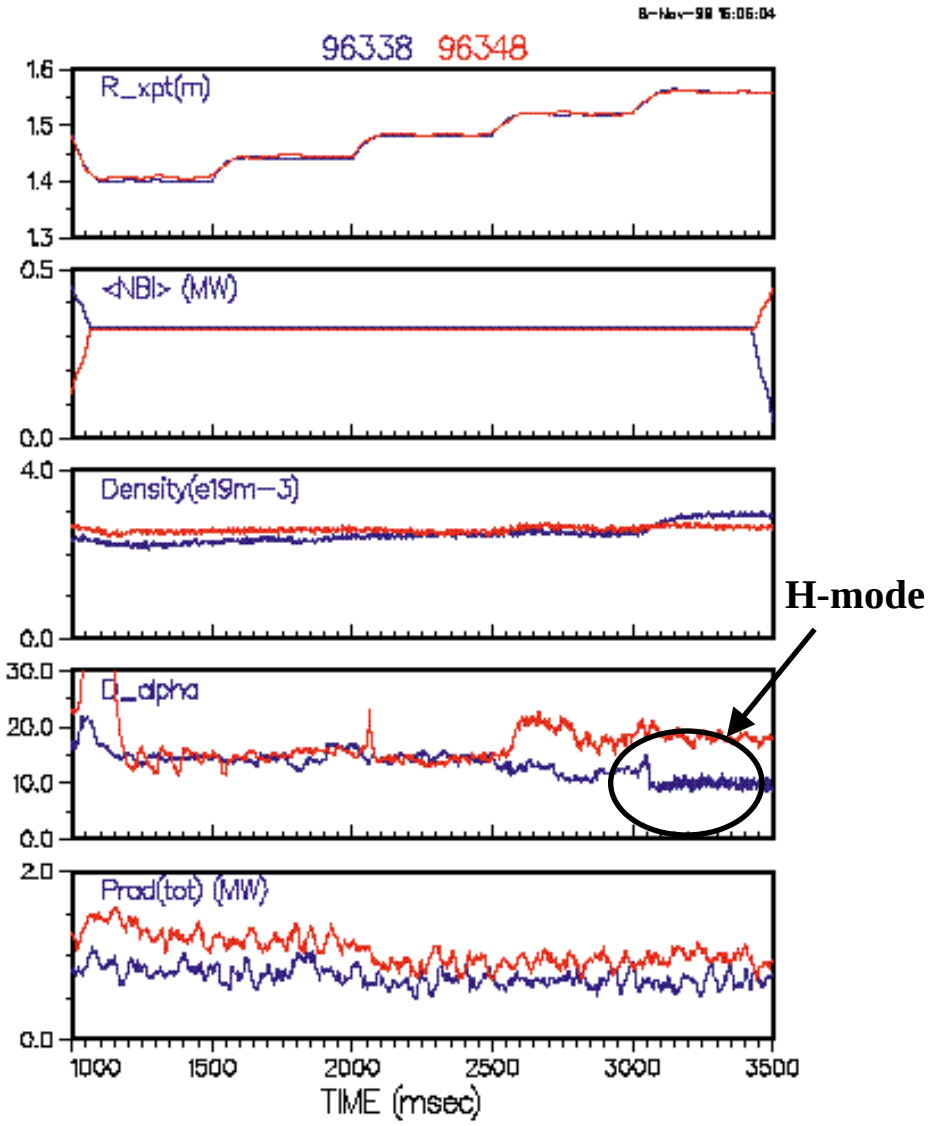
Good match between L-mode discharges

- Good match between shot 96338, ion B drift towards the x-point and shot 96348, ion B drift away from the x-point, during low power (0.3 MW) L-mode.
- During radial sweep of x-point, L-H transition occurs in normal B case when x-point is moved to the low field side.
- Edge parameters are very similar in both cases until the transition.



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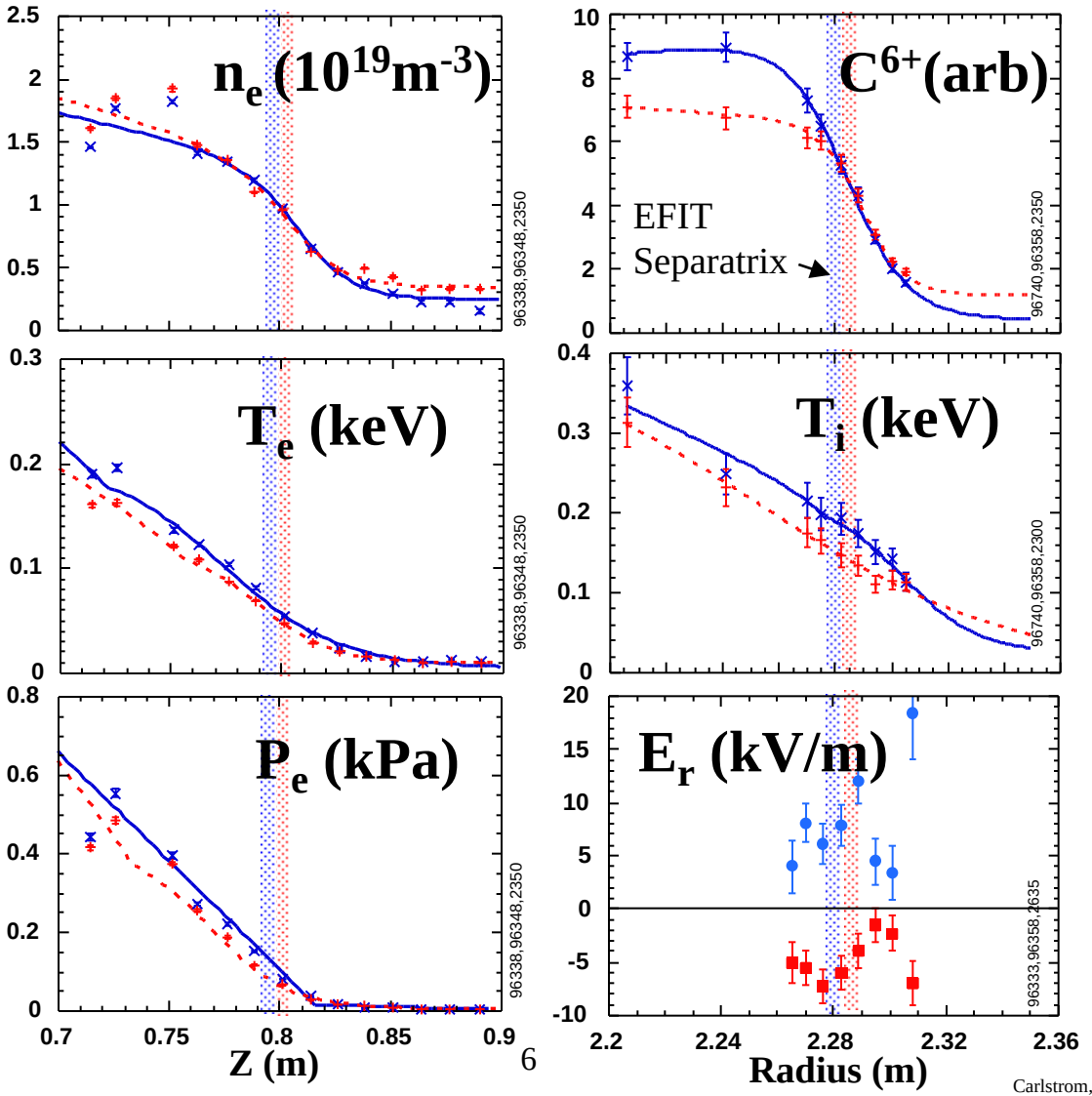
E_r changes sign while other midplane profiles are similar



Ion B drift towards the x-point

Ion B drift away from the x-point

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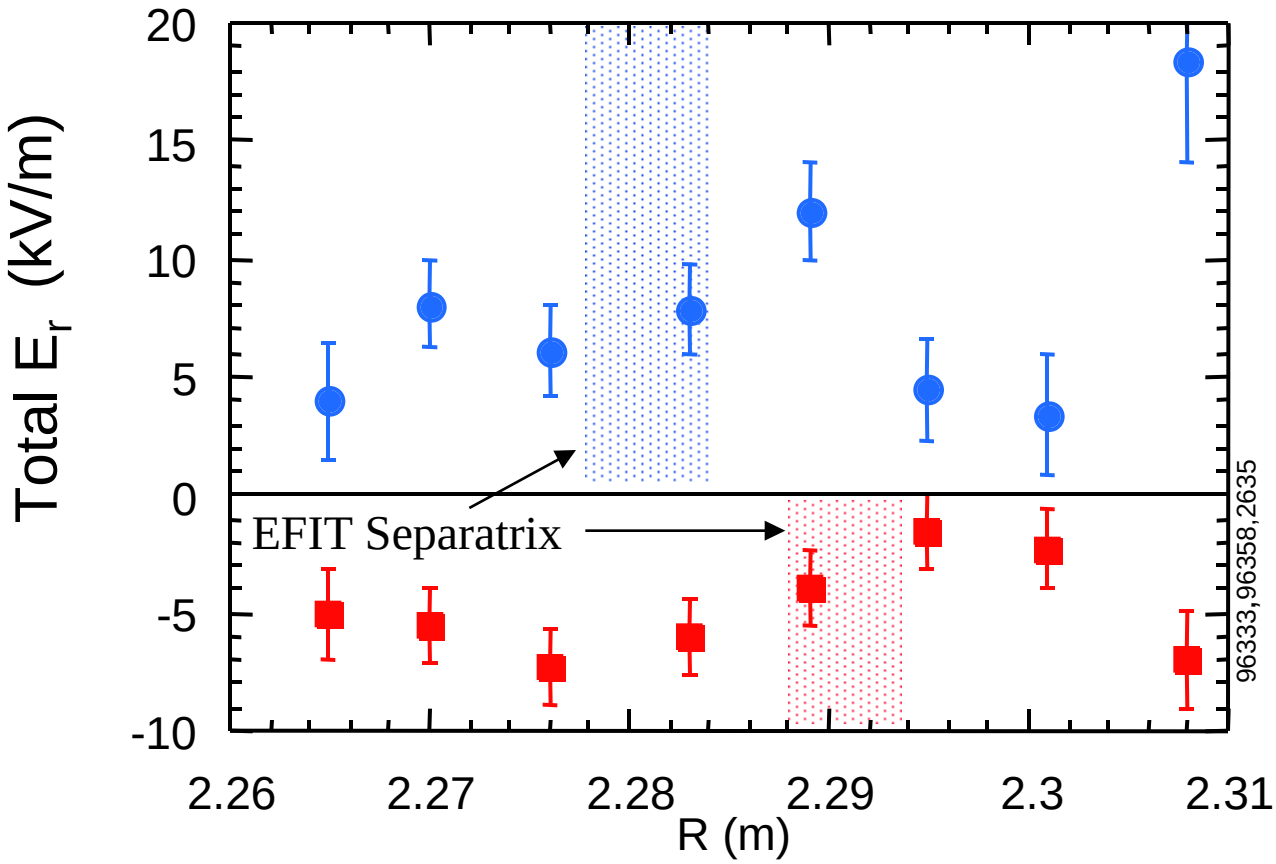
Edge E_r changes sign with the direction of the ion ∇B drift



Ion B drift towards the x-point

Ion B drift away from the x-point

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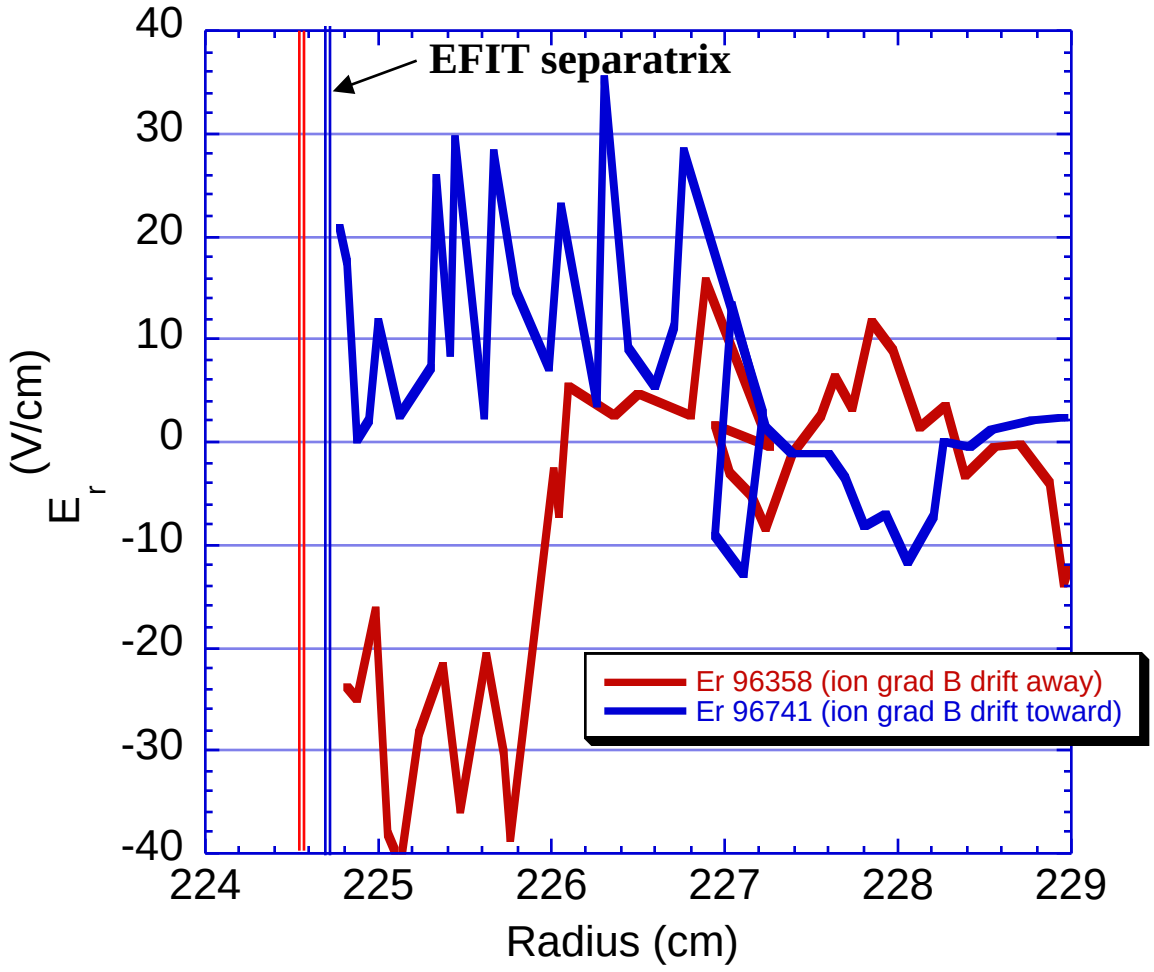
Midplane Langmuir probe measurements also show at change in the sign of E_r



Ion B drift towards the x-point

Ion B drift away from the x-point

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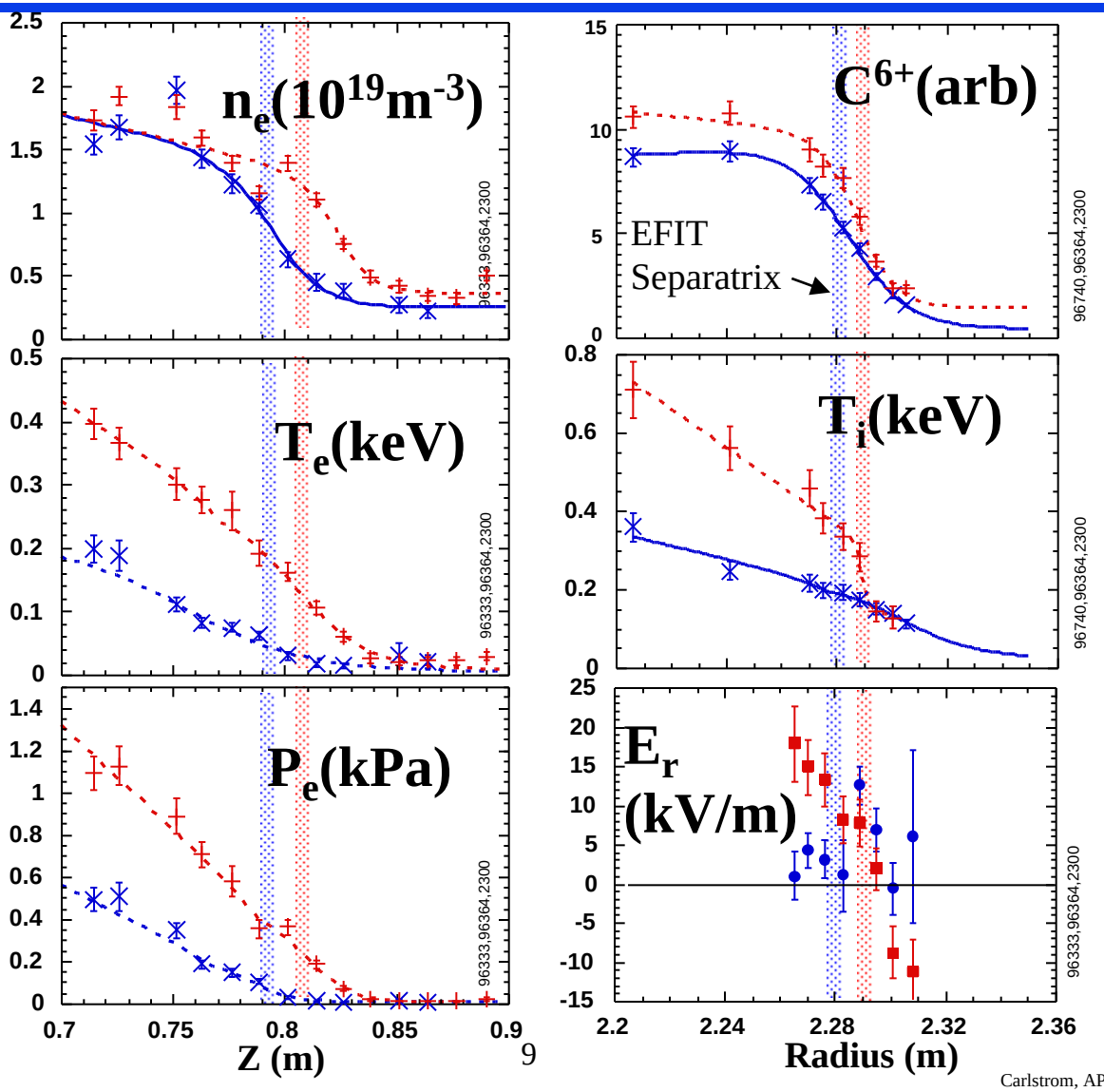
At power levels just below L-H threshold, the temperature profiles are very different



Ion B drift towards the x-point, **NBI=0.3 MW**

Ion B drift away from the x-point, **NBI=5 MW**

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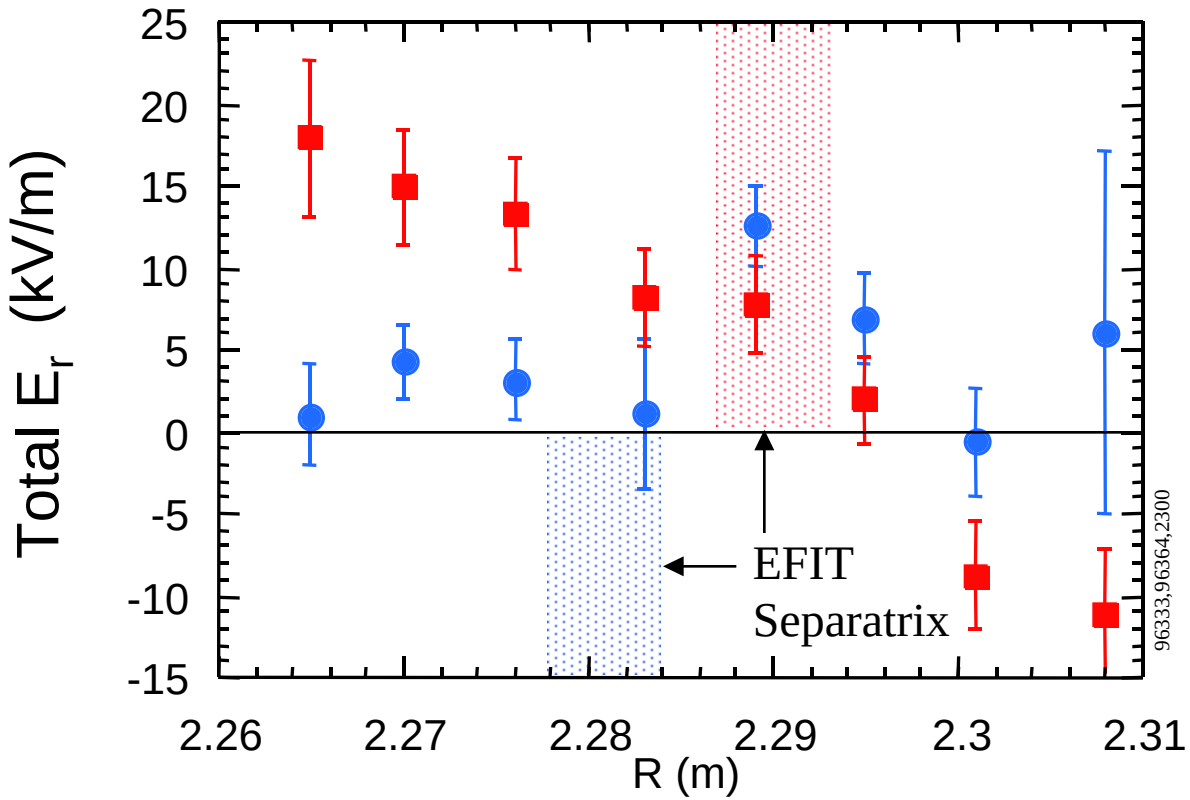
E_r becomes positive at high power



Ion B drift towards the x-point, **NBI=0.3 MW**

Ion B drift away from the x-point, **NBI=5 MW**

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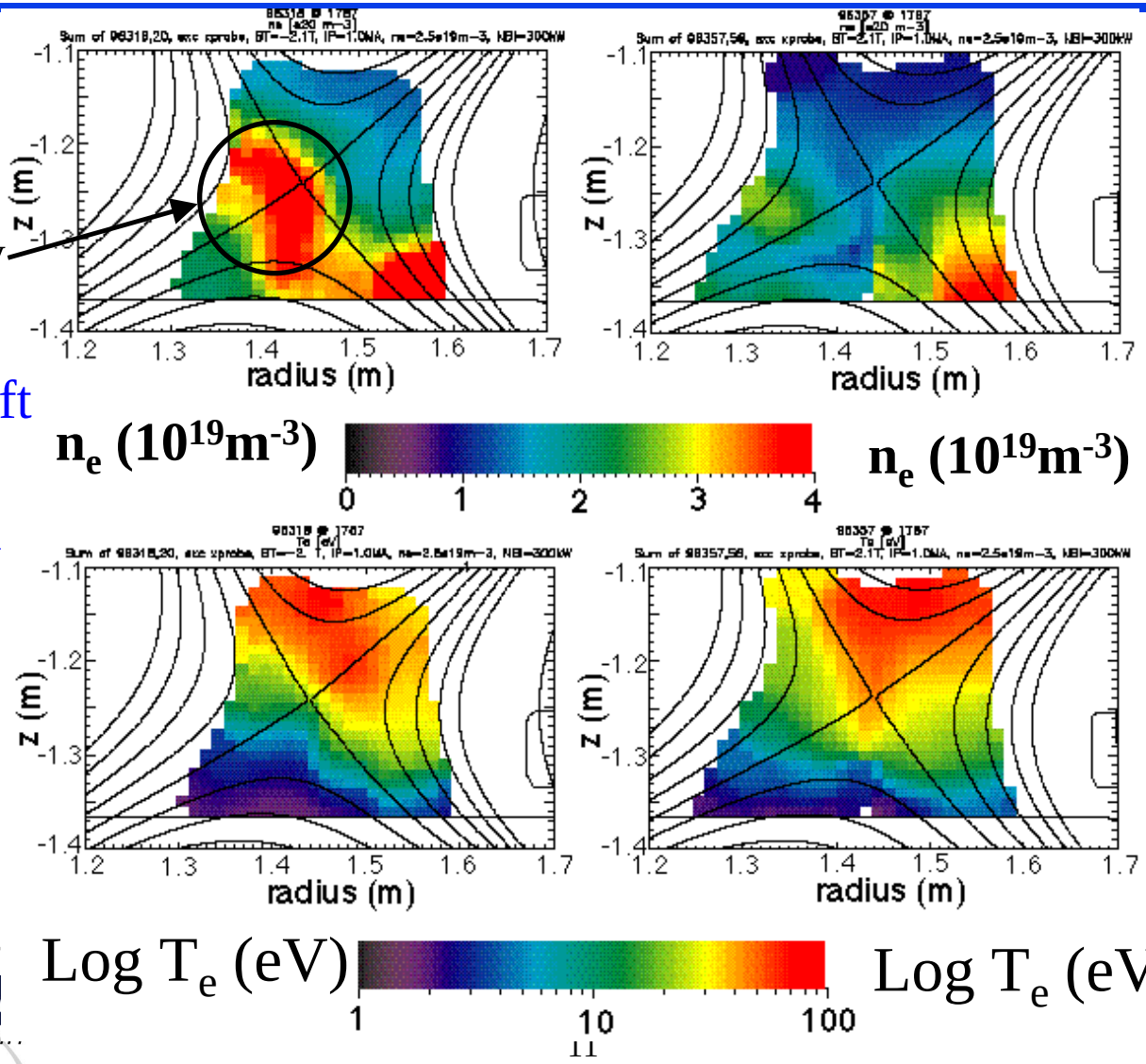
X-point region changes with ion ∇B drift direction



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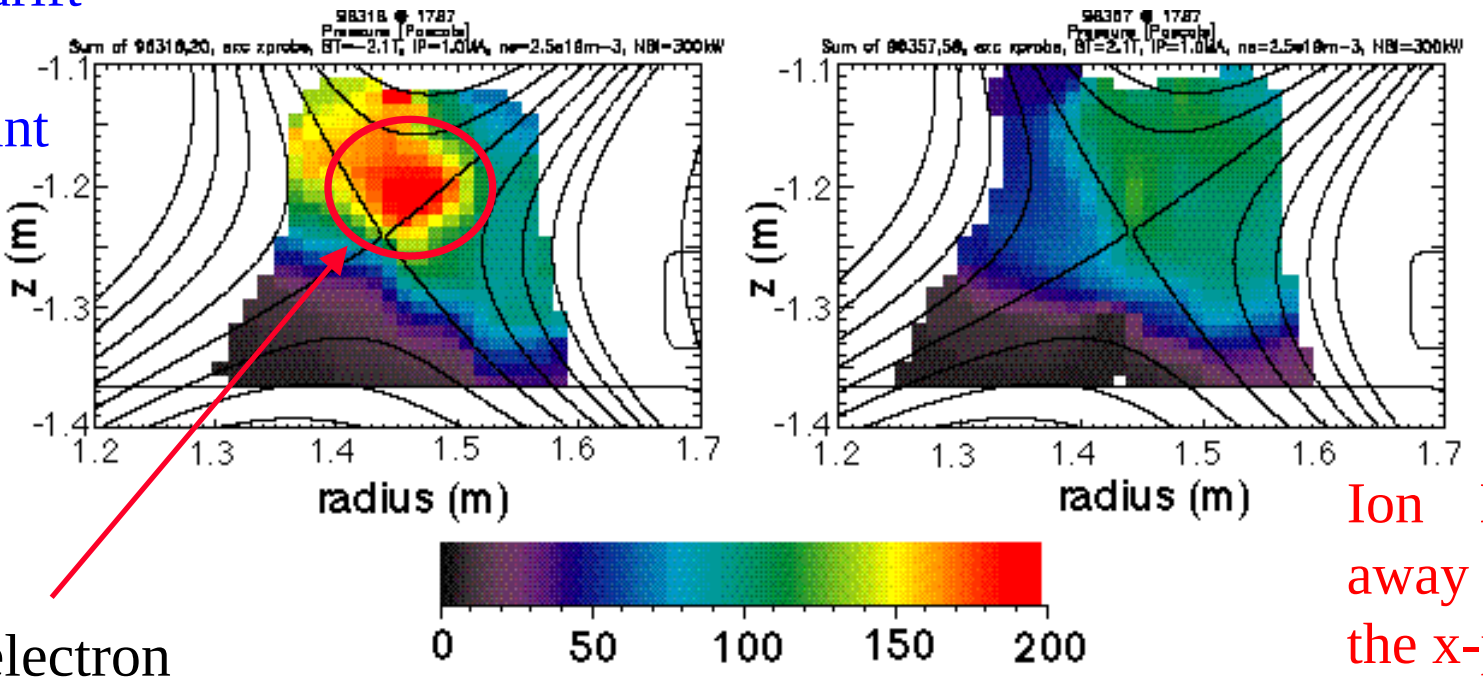
High P_e region above x-point when ion ∇ B is toward x-point

Ion B drift towards the x-point



Ion B drift away from the x-point

High electron pressure region

The high x-point electron pressure is consistent with equilibration of the colder midplane electrons with the hotter midplane ions.

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∇B effect and H-mode physics

- ExB shear flow stabilization of turbulence is a leading model for H-mode.
- ∇B effect may be important to the L-H transition through its contribution to E_r near the x-point region.
  - Change in the ∇B drift direction of ions either into or out of the plasma
  - Ion orbit loss effects
- Plasmas flows on the open field lines.

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Conclusions

- Changes in H-mode power threshold are not correlated with changes in the midplane profiles of n_e, T_e,and T_i.
- Changes in the power threshold are correlated with changes in E_r and plasma conditions near the x-point.
- Additional physics, other than those involving the local edge profiles of n_e, T_e and T_i near the plasma midplane, are needed to describe the L-H transition.

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