Measurement of DIII-D X-Point Neutral Densities at the L-H Transition

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DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

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Measurement of DIII-D X-Point Neutral Densities at the L-H Transition[1] R.J. COLCHIN, R. MAINGI, R.C. ISLER, R.W. OWEN, Oak Ridge National Laboratory, M.E. FENSTERMACHER, Lawrence Livermore National Laboratory, T.N. CARLSTROM, R.J. GROEBNER, General Atomics — In most theoretical models, the effect of neutral atoms on the L–H transition is usually associated with the charge-exchange damping of the poloidal ion rotation accompanying the transition. This damping competes with neoclassical viscous damping and can only dominate if the neutral density $\bar{n}_0$ is above a modeling-predicted[2] threshold value of $\sim 10^{11}$ cm^{-3}. Although there has been some empirical evidence that neutrals play a role in the L–H transition, experiments have been ambiguous, in part due to the lack of measurements of the neutral density. This work describes results of neutral density measurements near the X-point, where simulations indicate a poloidal maximum in the vicinity of the separatrix. Measurements were made both before and after the L–H transition. Observed densities in DIII–D are found to be near the theoretically required threshold.

[1]Supported by U.S. DOE Contracts DE-AC05-96OR22464, W-7405-ENG-48, and DE-AC03-99ER54463.
[2]Carreras, B.A., *et al.*, Phys. Plasmas **5** (1998) 2623.

☐ Prefer Oral Session
☒ Prefer Poster Session

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Special instructions: DIII-D Poster Session 2, immediately following H Takenaga

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ABSTRACT

In most theoretical models, the effect of neutral atoms on the L-H transition is usually associated with the charge-exchange damping of the poloidal ion rotation accompanying the transition. This damping competes with neoclassical viscous damping and can only dominate if the neutral density is above a modeling-predicted[1] threshold value of ~ 10^{11} cm^{-3}. A lthough there has been some empirical evidence that neutrals play a role in the L-H transition, experiments have been ambiguous, in part due to the lack of measurements of the neutral density. This work describes results of neutral density measurements near the X-point, where simulations indicate a poloidal maximum in the vicinity of the separatrix. Measurements were made both before and after the L-H transition. Observed densities in DIII-D are found to be near the theoretically required threshold.

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Effect of Neutrals on the L-H Transition

Poloidal ion velocity rate of change (electrostatic turbulence, ignoring the complications introduced by toroidal geometry)

$$\frac{\partial \langle V_{\theta i} \rangle_s}{\partial t} = -\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \langle \tilde{V}_{ri} \tilde{V}_{\theta i} \rangle_s\right) - \mu_{neo} \langle V_{\theta i} \rangle_s - \langle v\sigma \rangle_{cx} \langle n_n \rangle_s \left(\langle V_{\theta i} \rangle_s - \langle V_{\theta n} \rangle_s\right)$$

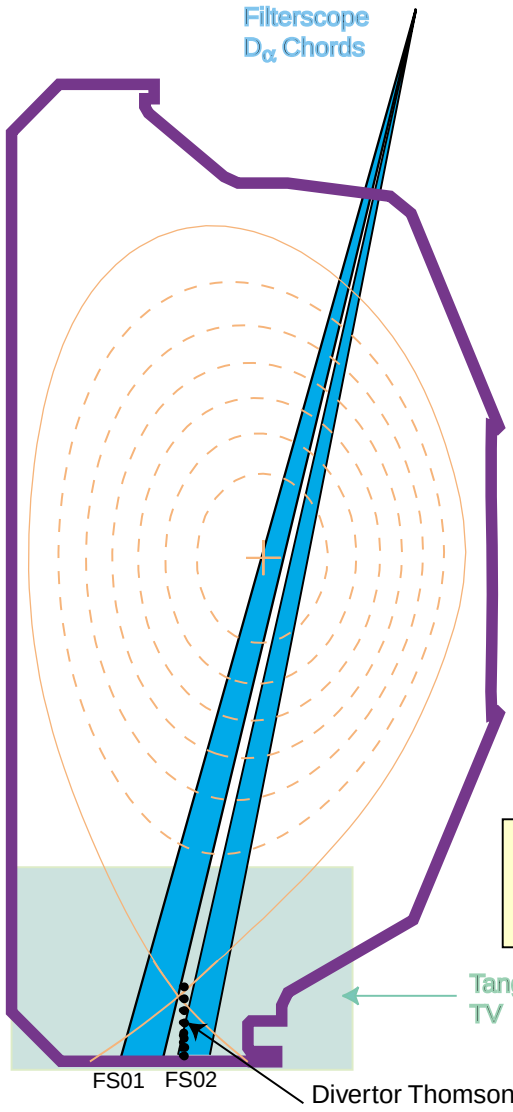
Reynolds stress

Neoclassical viscous damping

Neutral friction

2-D Modeling suggests that n_o near the X-point must be $\geq 10^{11}$ cm^{-3} for the neutral density to dominate the damping of the edge ion rotation

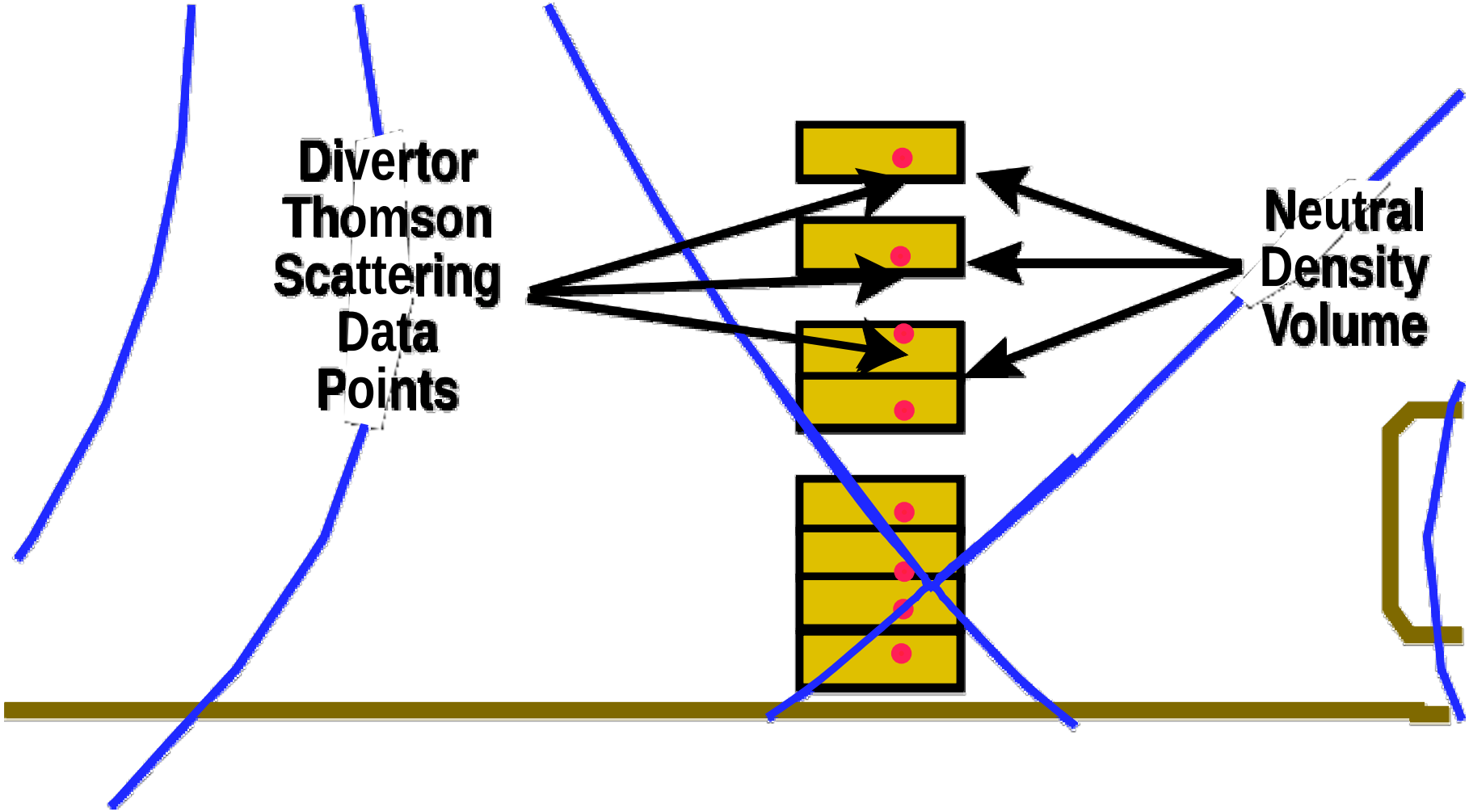
DIAGNOSTICS SETUP



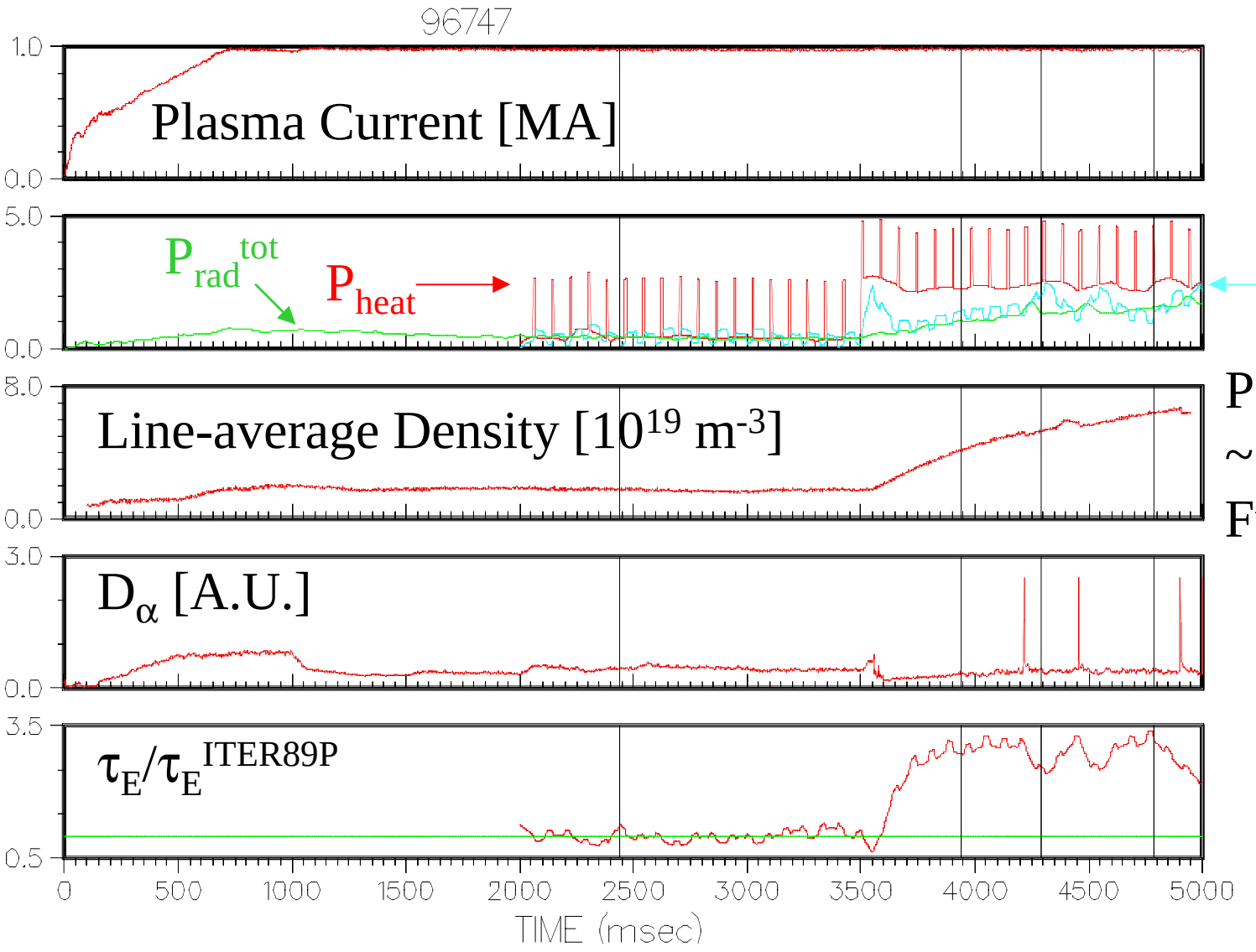
- Tangential TV semi-toroidal view inverted for poloidal D_α profile
- TTV intensity cross-calibrated with vertical D_α chords
- Divertor Thomson Scattering gives n_e and T_e for $\langle\sigma v\rangle_{exc}$
- Neutral density computed from:

$$n_0(z)=I_{D_\alpha}(z)/n_e(z)\langle\sigma v\rangle_{exc}(n_e(z),T_e(z))$$

Neutrals Measurements at Divertor Thomson Scattering Points

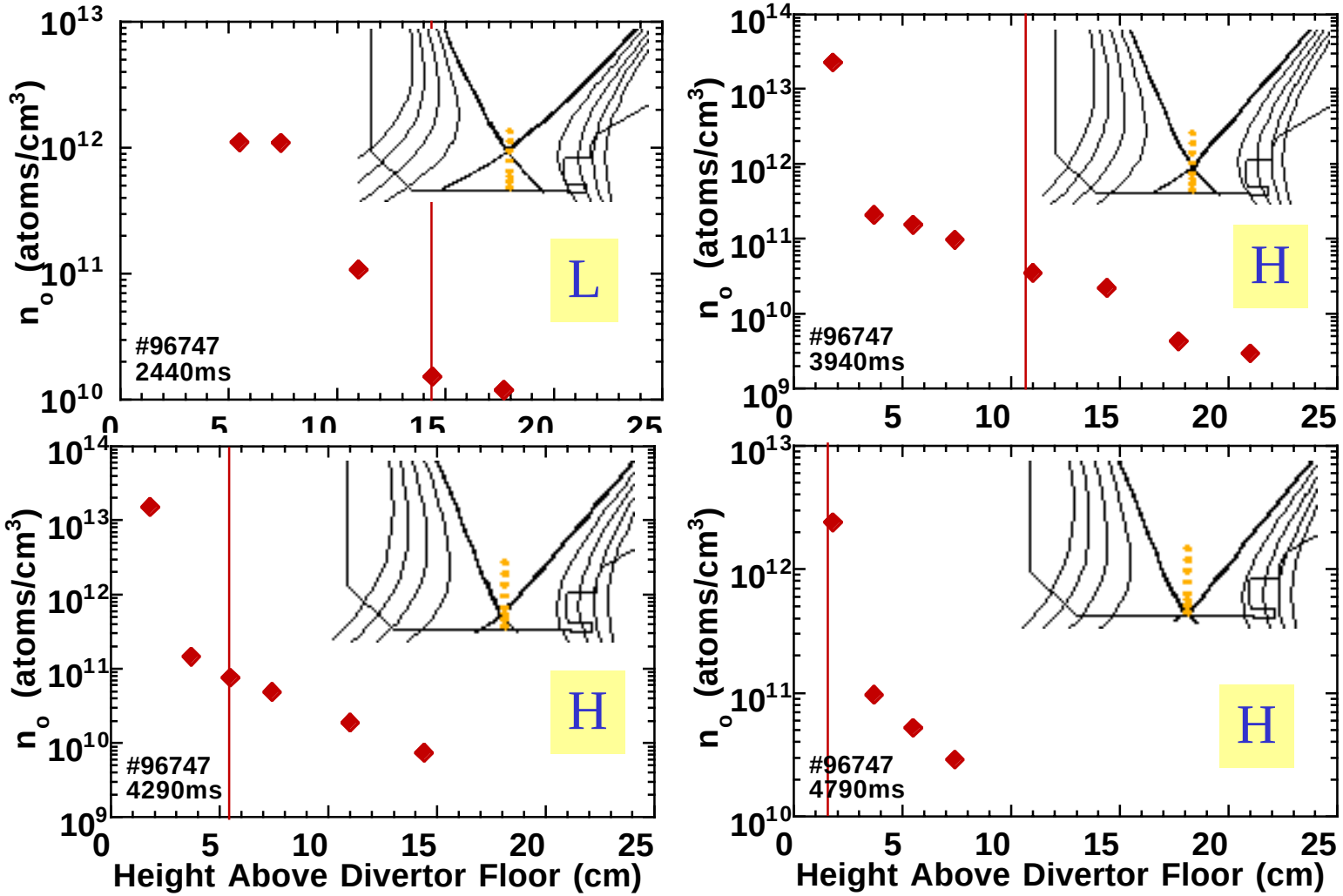


Discharge with L-H Transition Triggered by NBI Increase



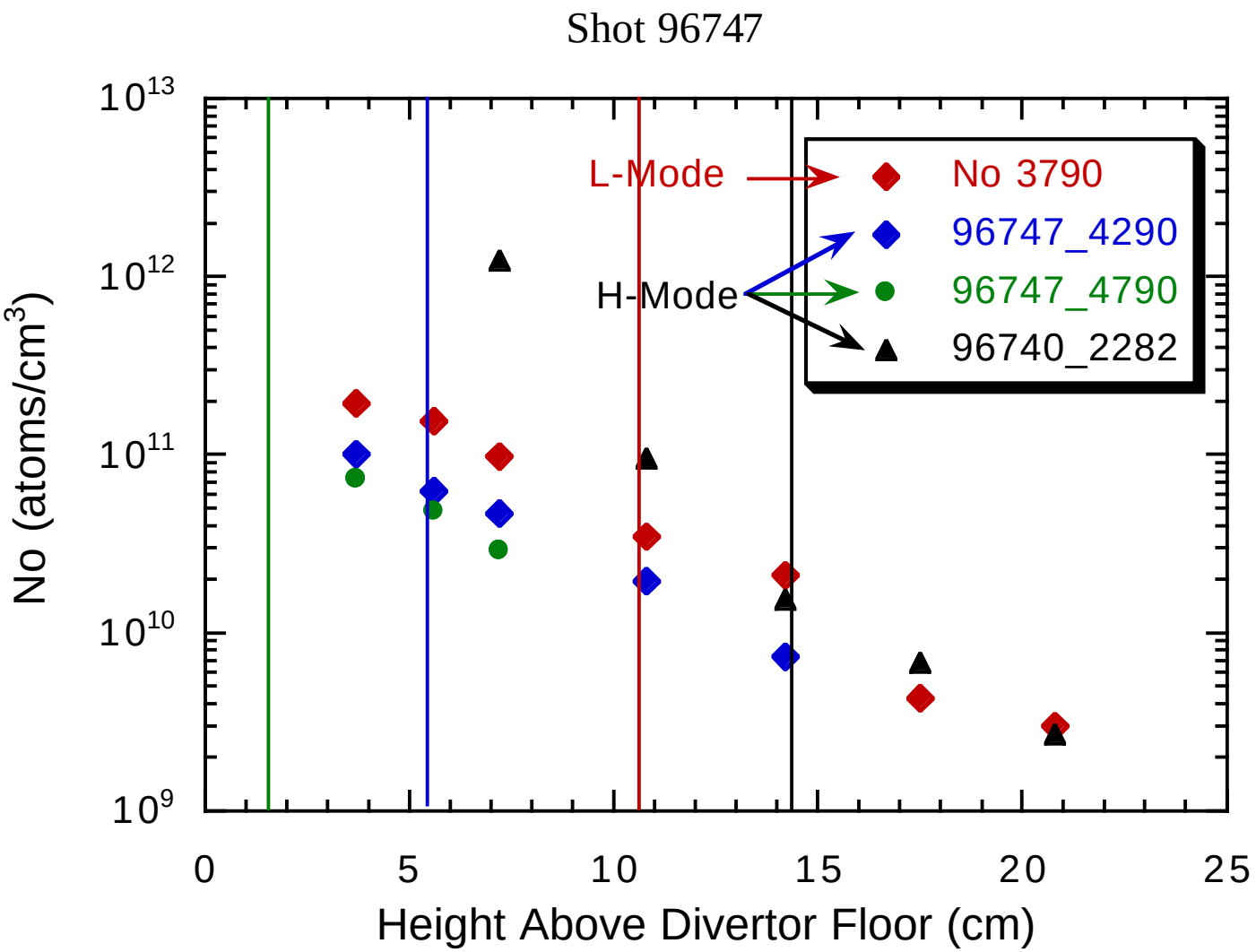
Peak dN_e/dt
~ 4 X Beam
Fueling Rate

H-MODE NEUTRAL DENSITY HIGHER THAN L-MODE



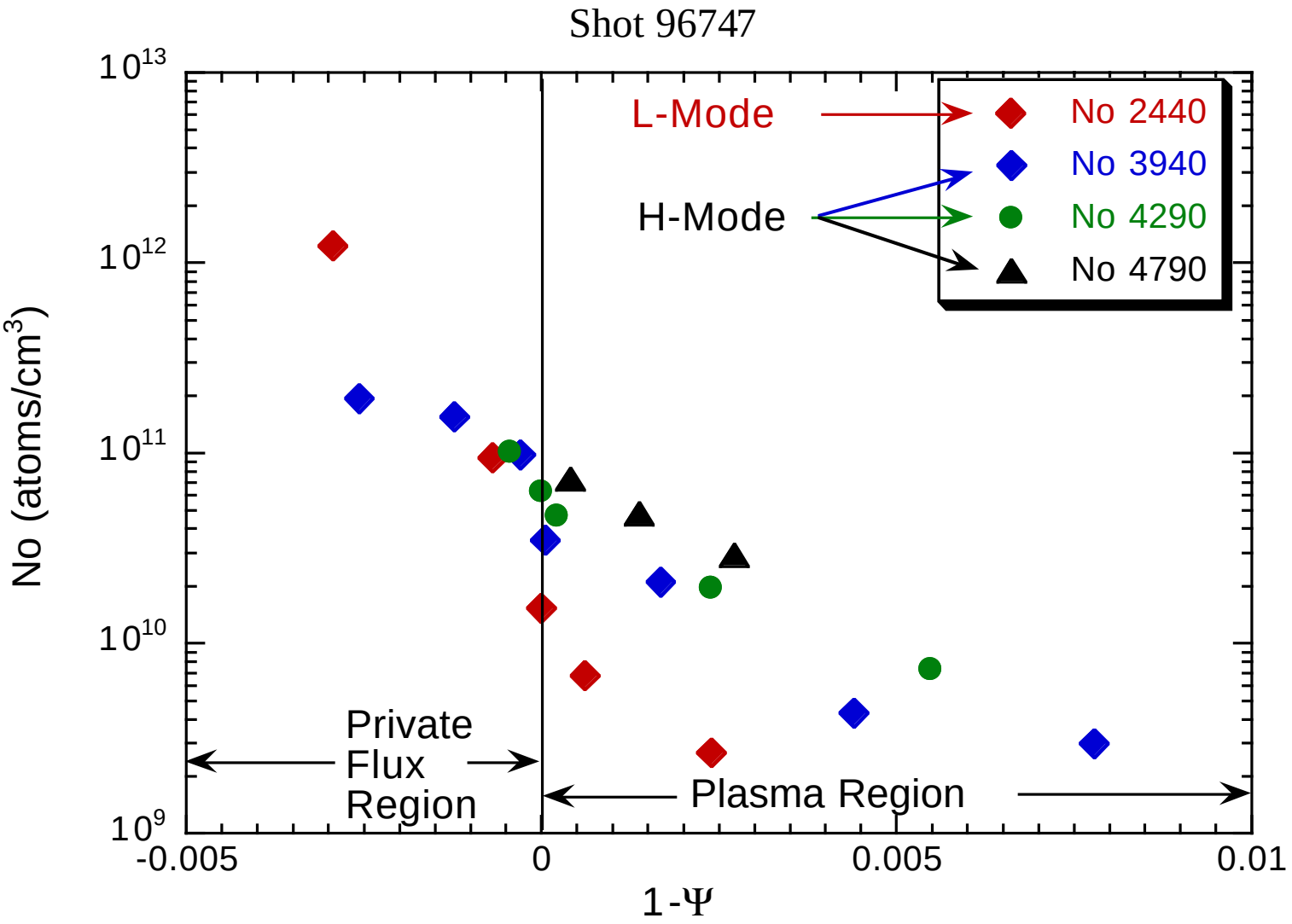
Neutral Densities at the L-H Transition

(Real Space)



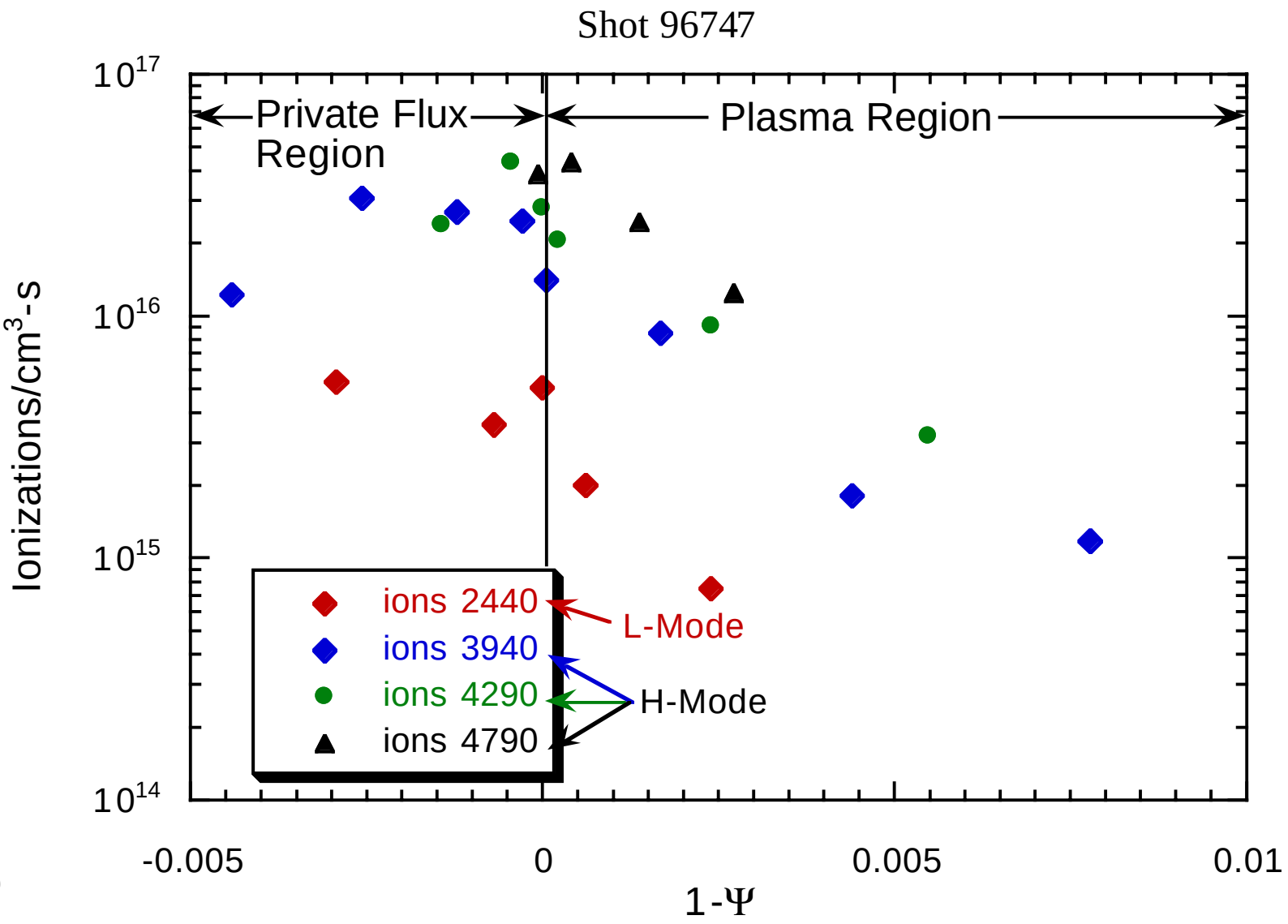
Neutral Densities at the L-H Transition

(Flux Coordinates)



Fueling at the L-H Transition

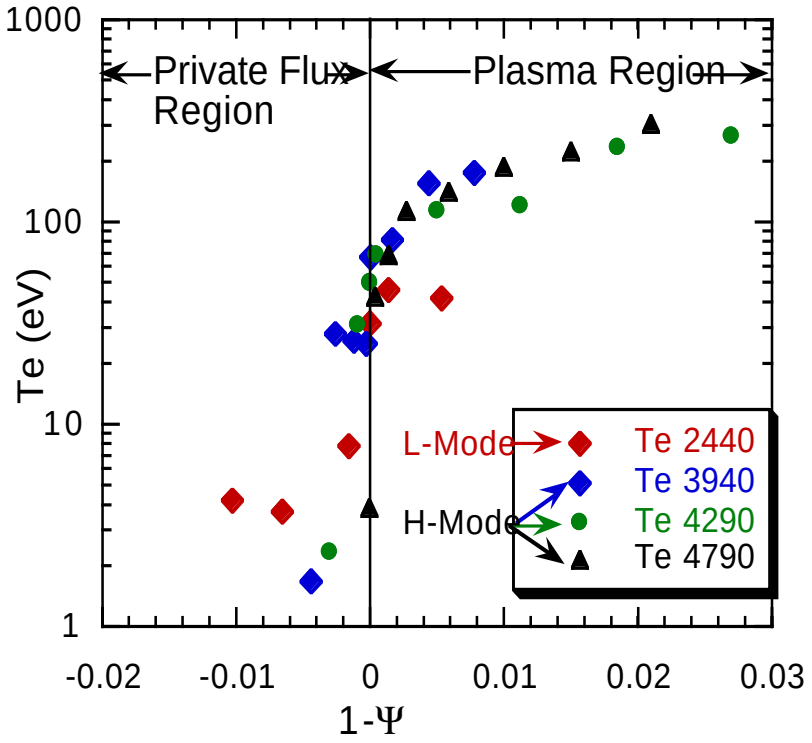
(Flux Coordinates)

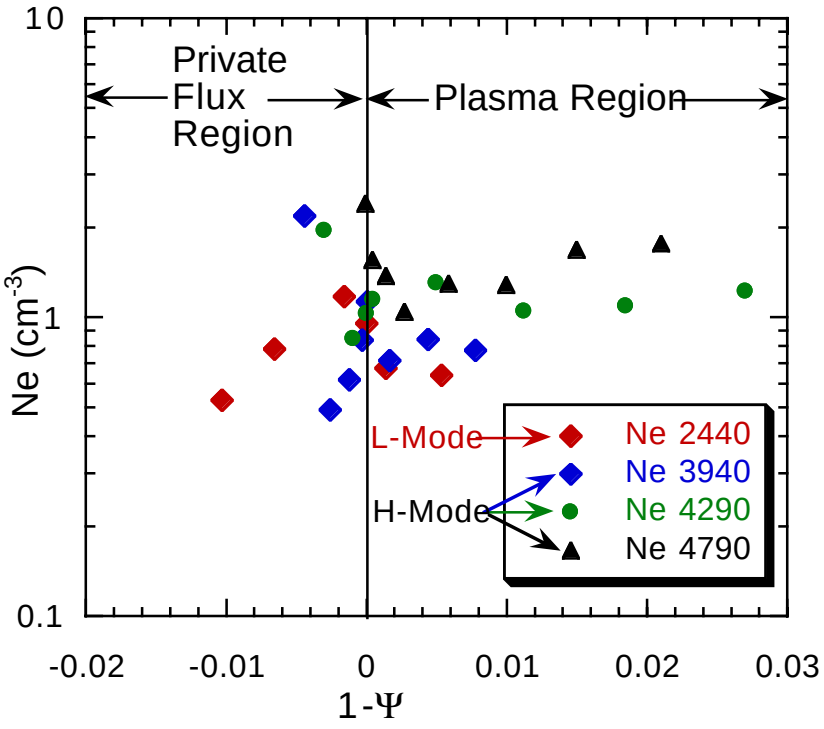


T_e and N_e at the L-H Transition

(Flux Coordinates)

Shot 96747

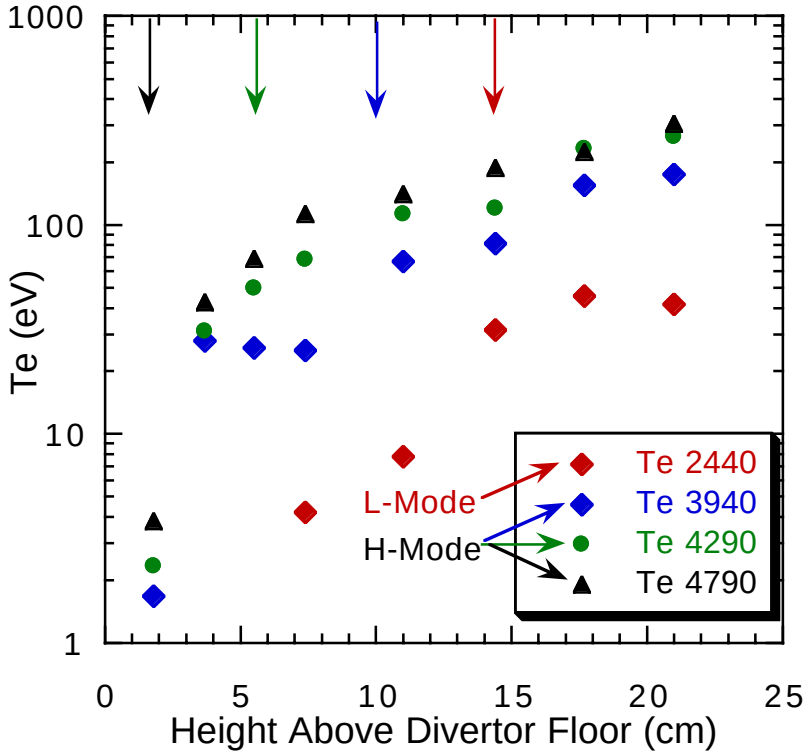


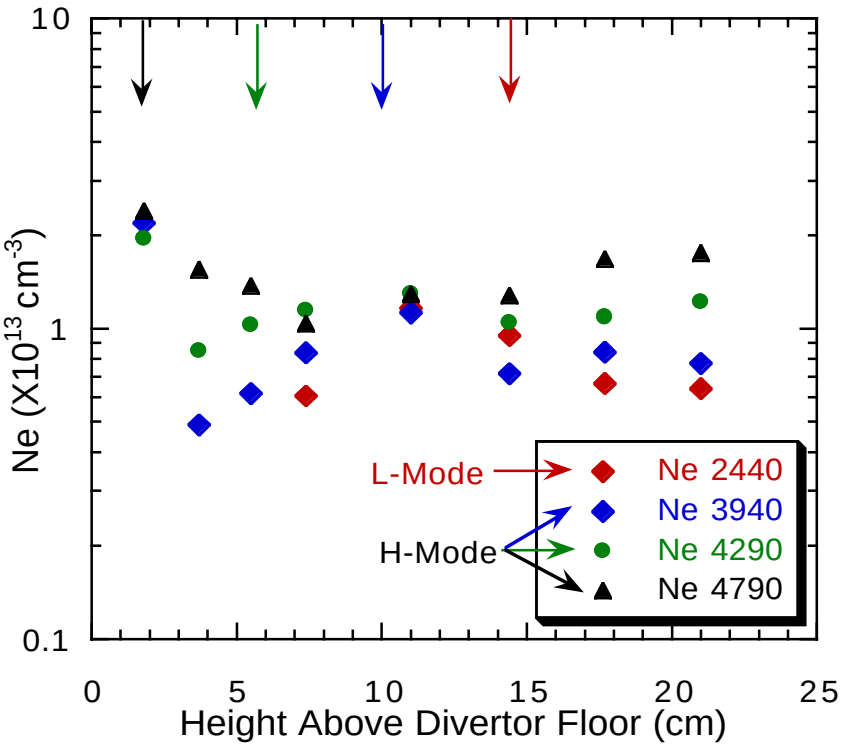


T_e and N_e at the L-H Transition

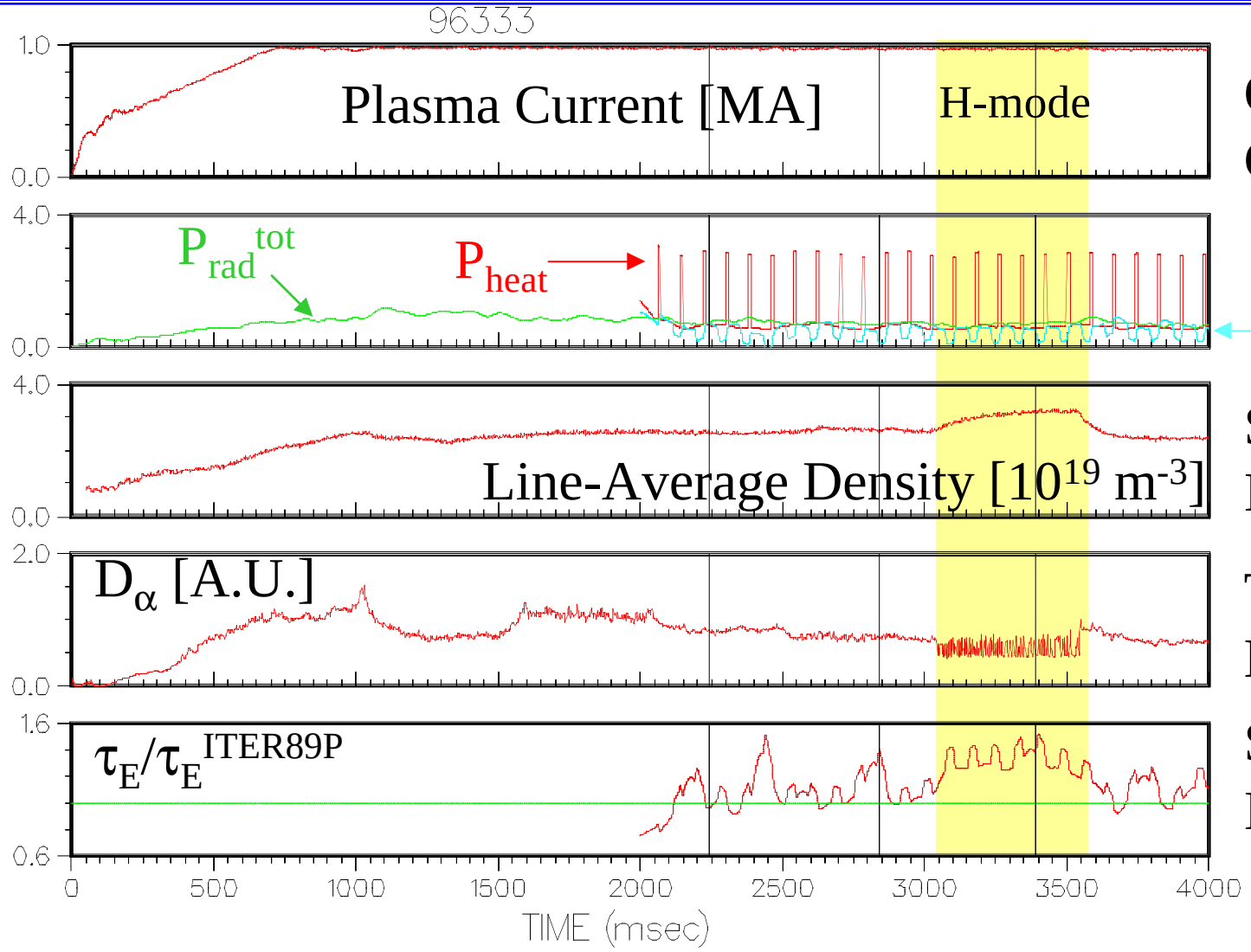
(Real Space Coordinates)

Shot 96747





Discharge With L-H Transition Triggered by X-point Radius Increase



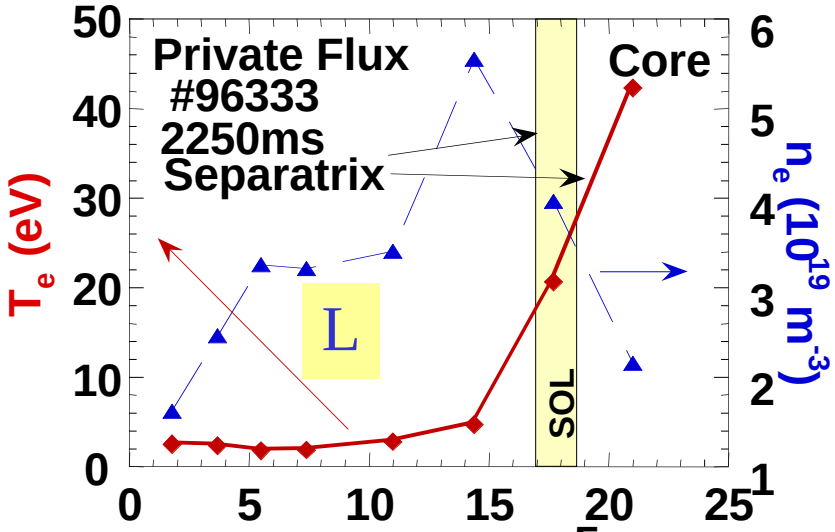
Only OSP Changed

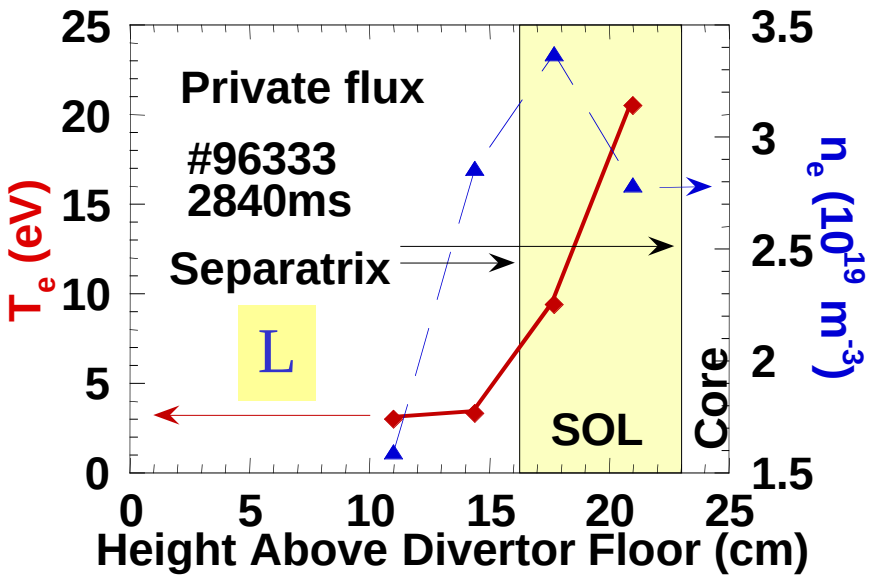
Small n_e Increase

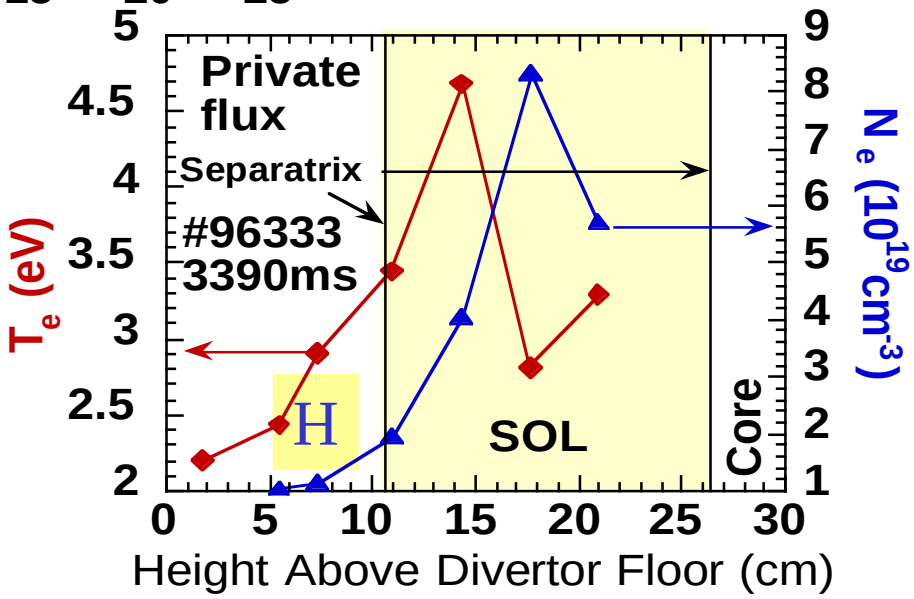
Threshold ELMs

Small τ_E Increase

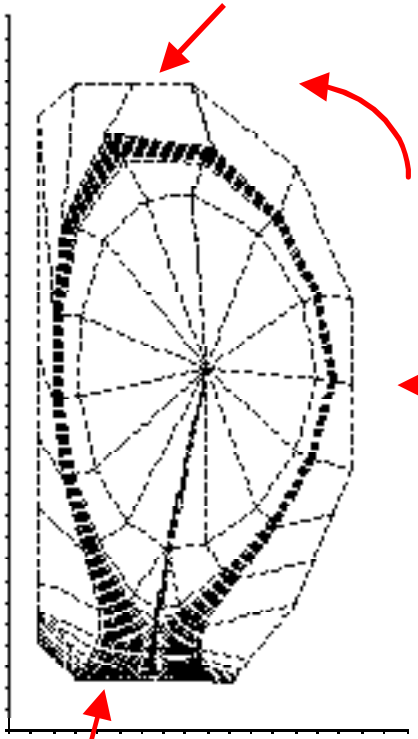
T_e and N_e Away from the X-Point Private Flux Marf



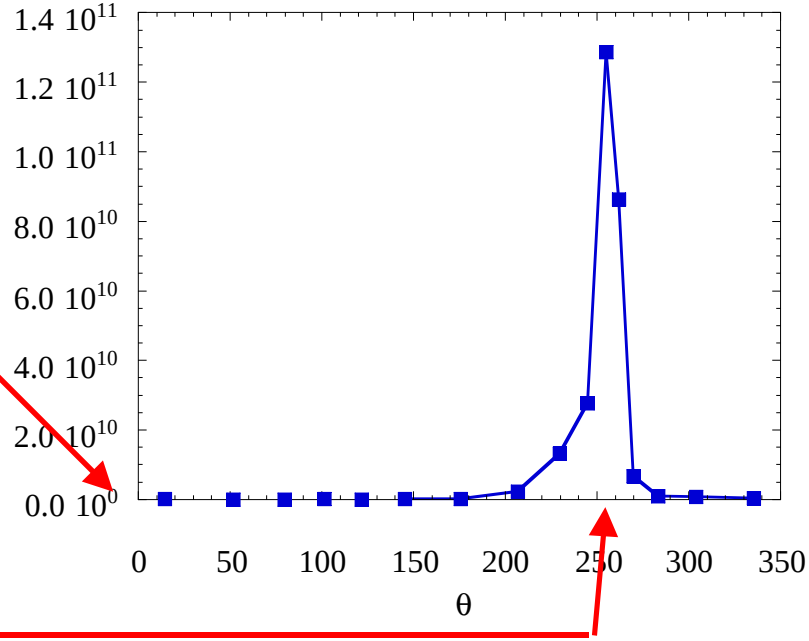




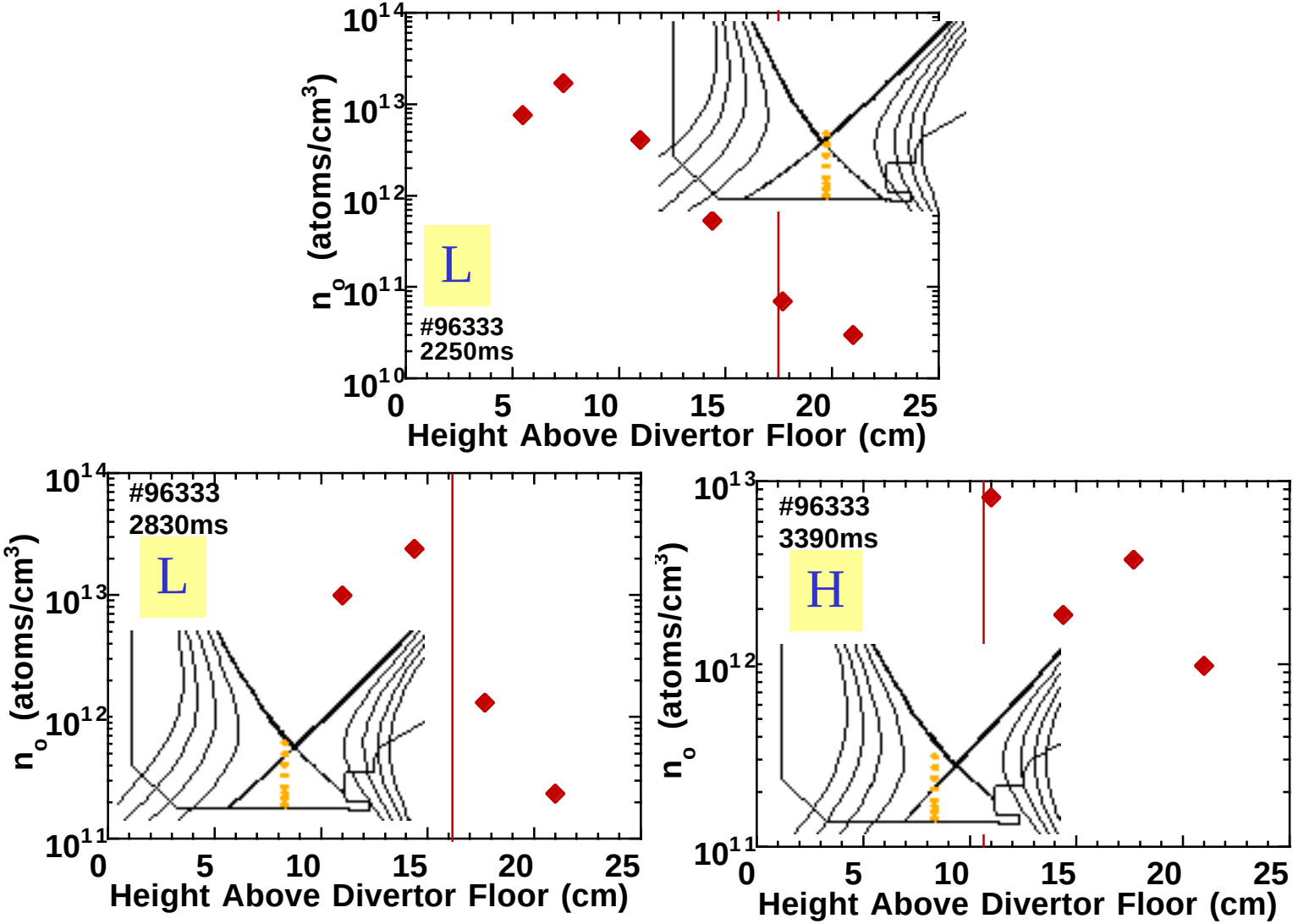
Poloidal Distribution of the Neutral Density in Single Null Divertor Discharges



- There is strong poloidal variation of the neutral density over a flux surface with a peak near the inner divertor leg.

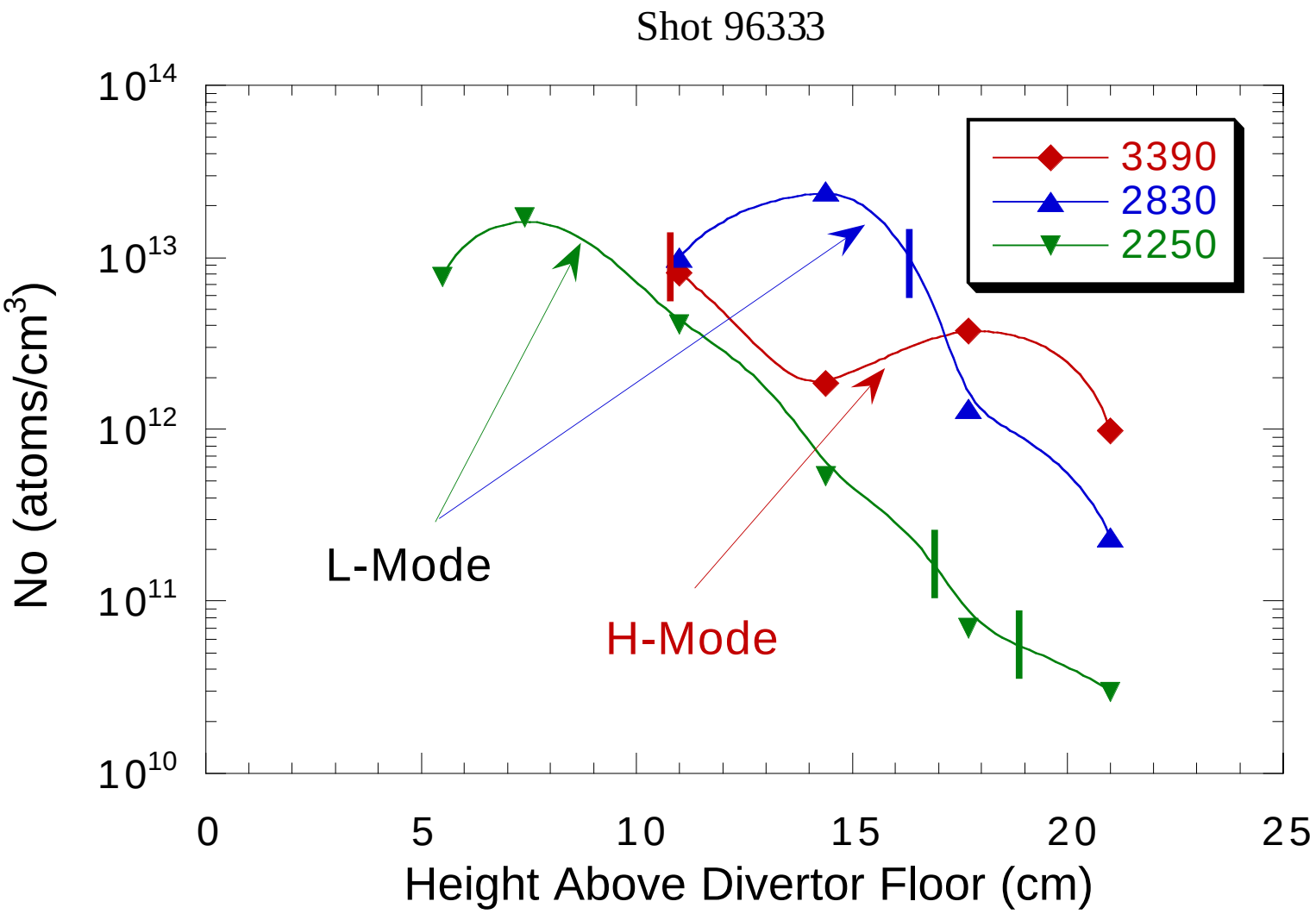


Neutral Densities Away from the X-Point (Private Flux Marf Present)



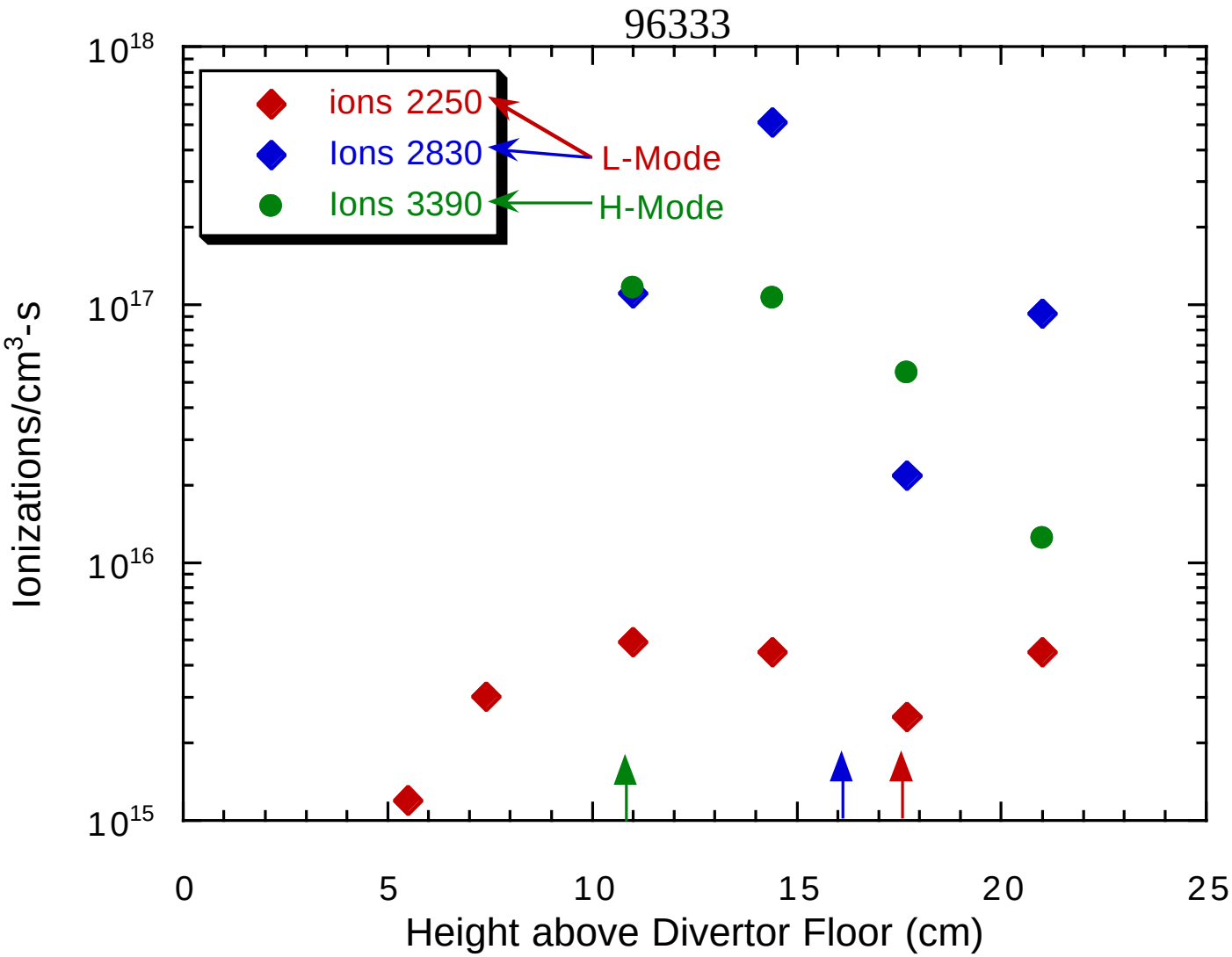
Neutral Densities Away from the X-Point

(Private Flux Marf Present)



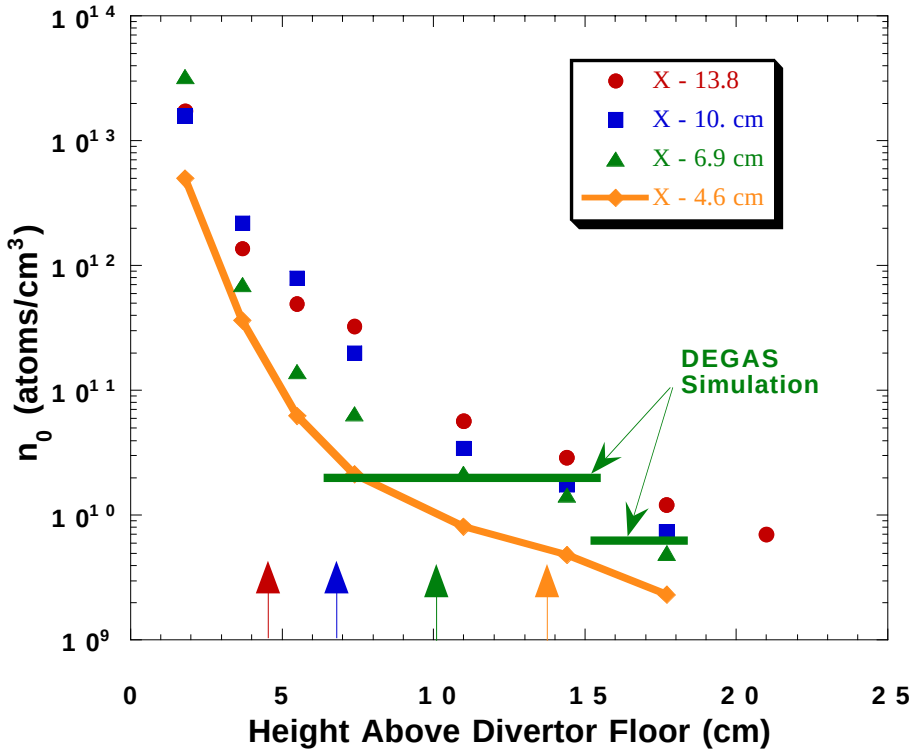
Fueling Rate Much Higher at Inner Separatrix Leg

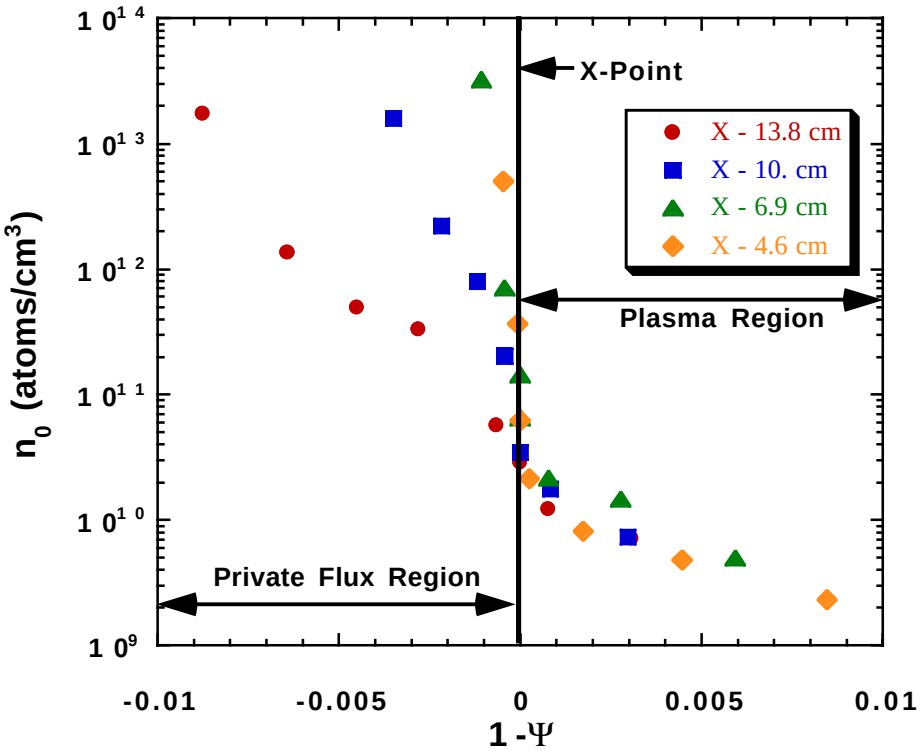
(Private Flux Marf Present)



Neutral Density Variation with X-Point Height

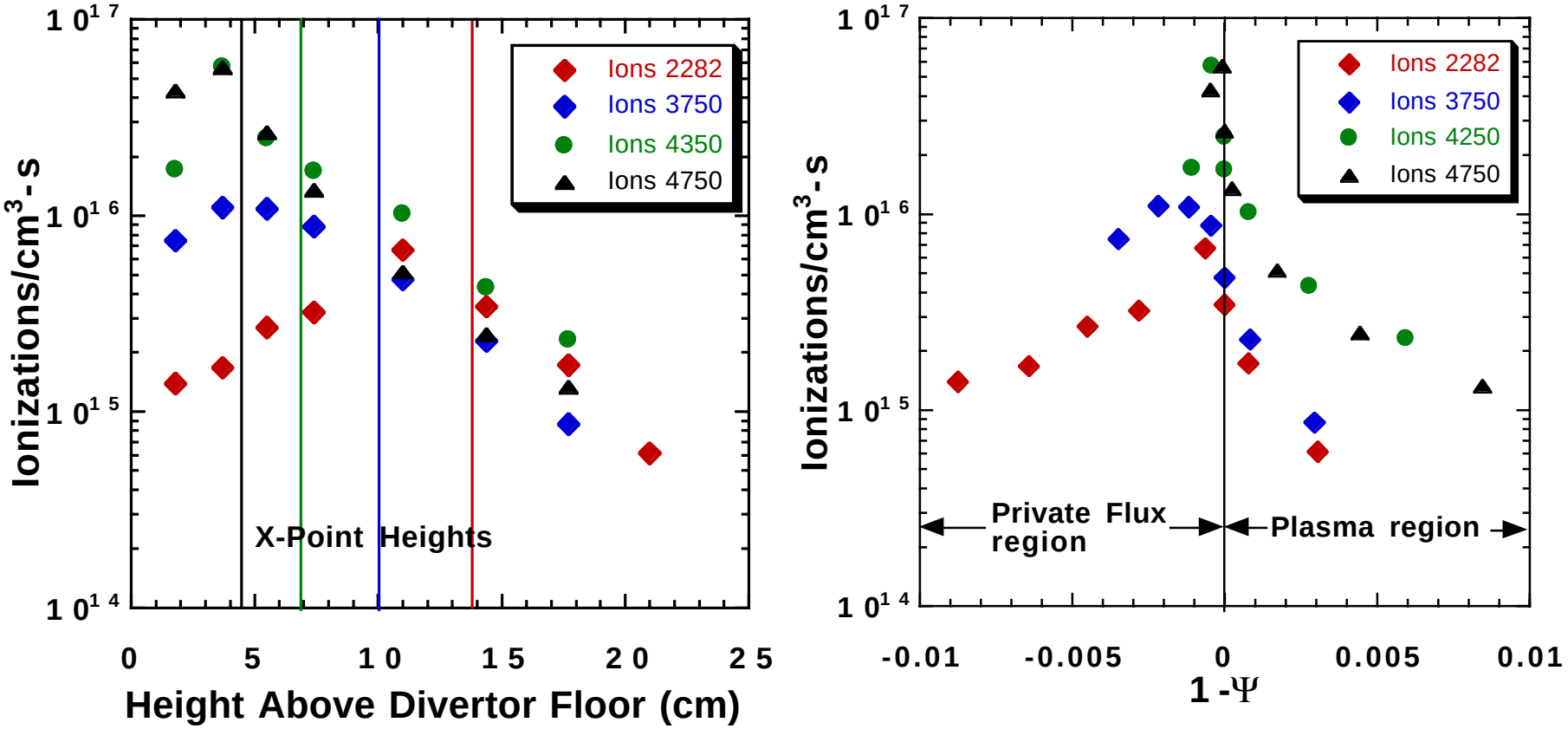
96740



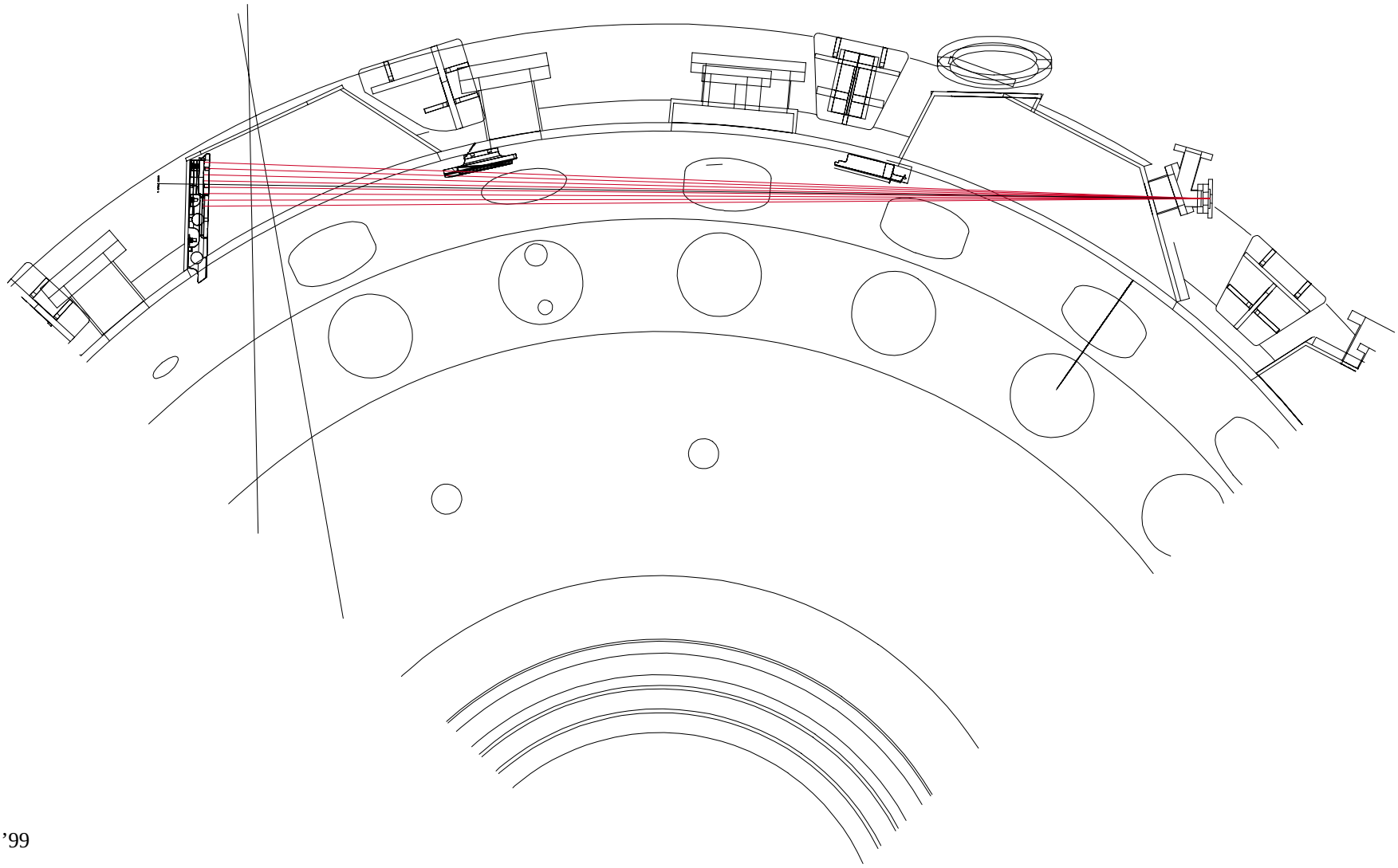


Fueling versus X-Point Height

96740



New Filterscope for Midplane Neutrals Data



Results

- Neutral density at the L-H transition
  - Neutral density increases in the H-mode (shot # 96747)
  - Neutrals damp the plasma rotation, thereby increasing the L-H power threshold
- Fueling
  - DEGAS calculations show that fueling takes place near the inner divertor separatrix leg
  - Measurements show neutral densities are much higher near the inner leg (shot #96333)
  - Ionization rates in the private flux region are peaked at the X-point (shot # 96740)