NSTX H-mode Transitions and Comparison to Theory

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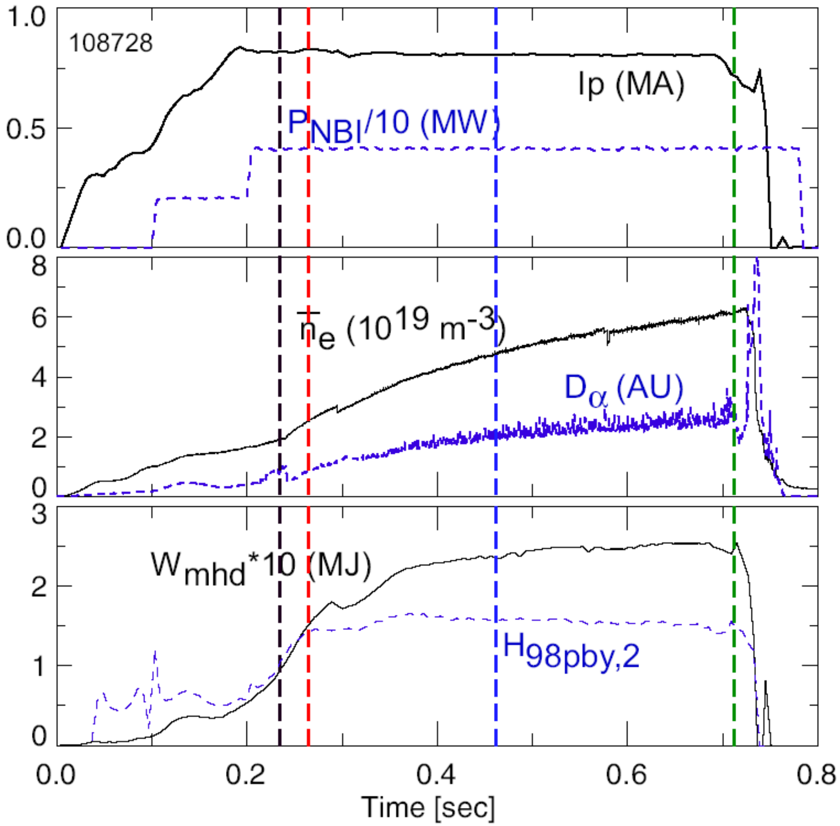
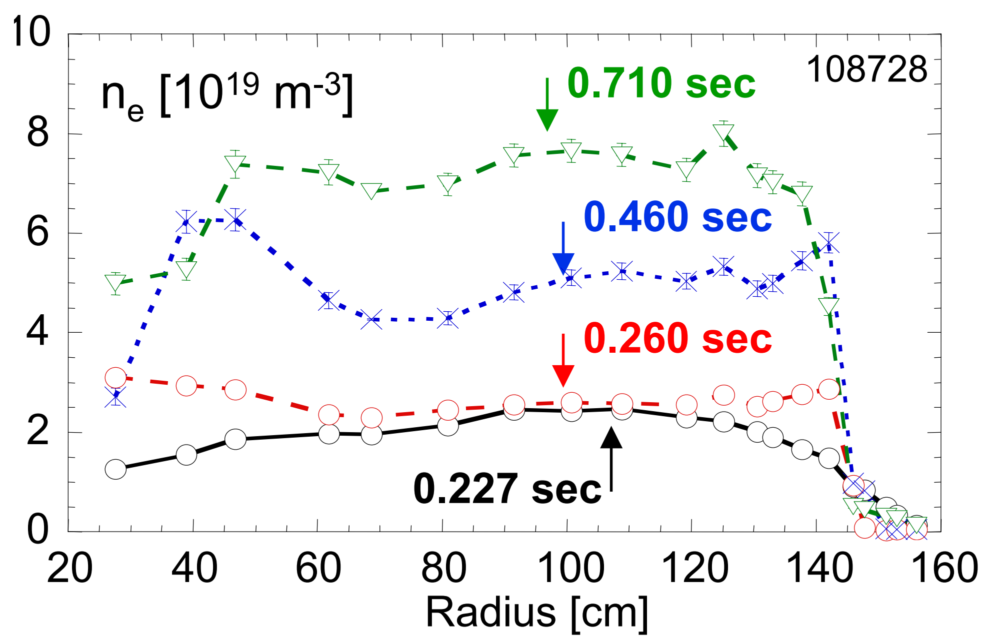
High Quality H-modes are Obtained on NSTX





- Density profile becomes hollow after transition, but then fills in in 0.3 to 0.5 s

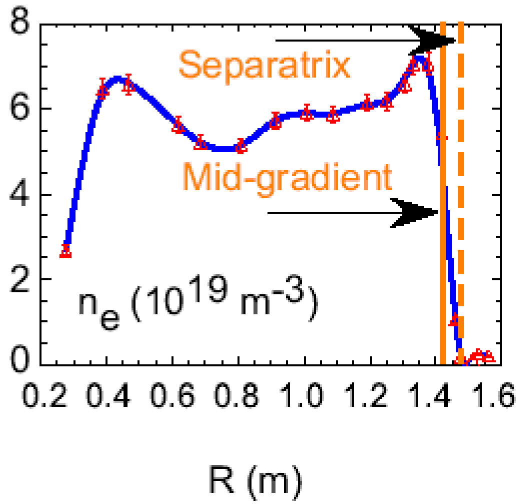
- $H_{98pby,2}>1$ observed routinely

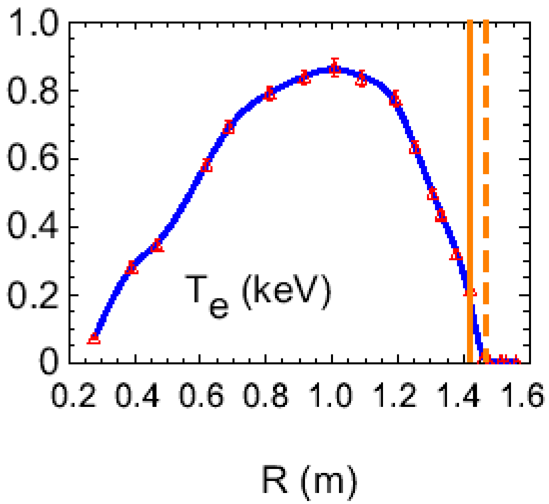
  (τ_E^{mag} ~ 60 msec)

Study L-H Transition Physics

- Compare measured edge parameters to those from L-H theories

Thomson Scattering





Kinetic data at mid-gradient
T_e, n_e, $L_{n,e}$, $L_{p,e}$, β ($\sim\beta_e$)

Magnetics info from EFIT
q, ψ, R_0, R_{sep}, B_T

Quantities taken locally

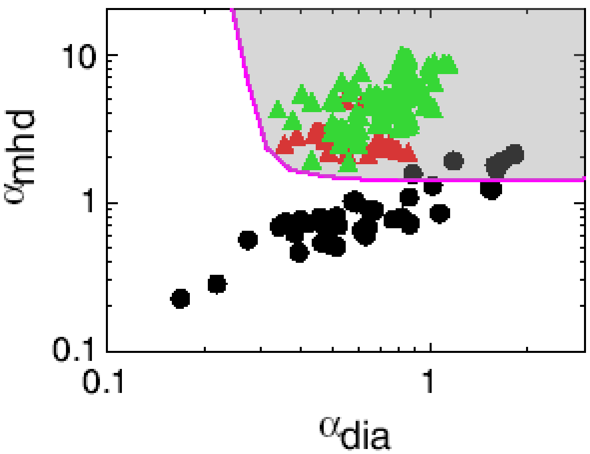
  – Theories show qualitative agreement, but no predictive capability

- Fast ion losses may influence transition

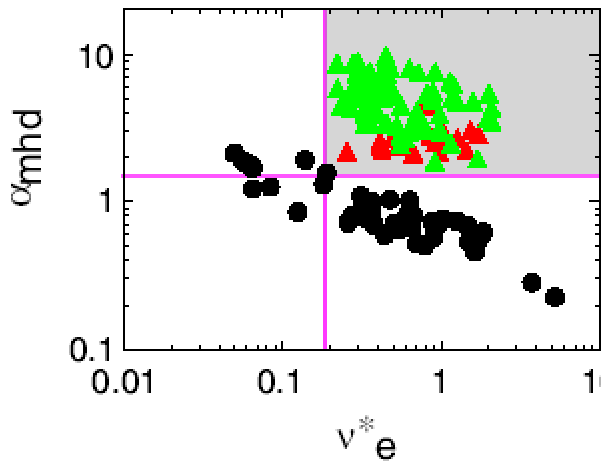
NSTX Edge Data Shows Qualitative Agreement With Theory

● L-mode ▲ H-mode ▼ HELM

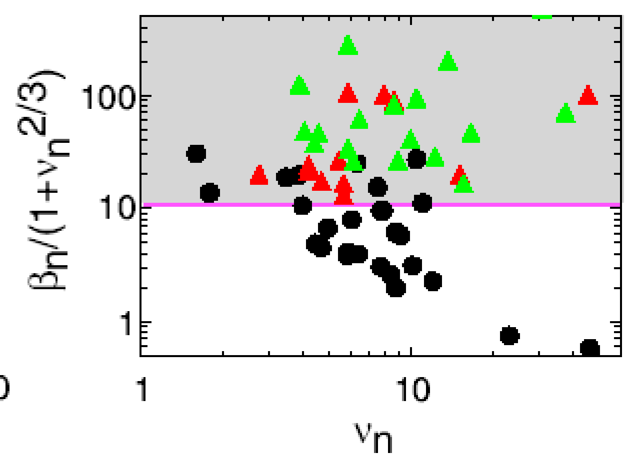
Drift-Ballooning
Rogers and Drake,
PRL, 1998



Peeling
Wilson et al.,
PoP, 1999



Drift-Alfven
Pogutse,
EPS, 1997



$\alpha_{mhd} = -Rq^2 d\beta/dr$

$\alpha_{dia} = (\rho_s \Omega_e/\nu_{ei})^{1/2}/(L_n R)^{1/4} q$

$\beta_n = (M/m)^{1/2} \alpha_{MHD}/rq'$

$\nu_n = \nu_e^* (M/m) L_p/rq'R$

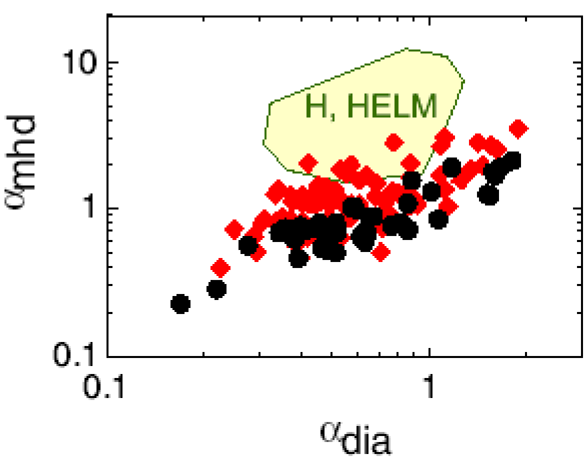
- *Clear distinction between L and H-mode groupings*
  - H, HELM groupings reflect smaller $L_{n,p}$, higher β

Theories Have No Apparent Predictive Capability

● L-mode ◆ L-H

L-H data taken 0-7 msec prior to LH transition

Drift-Ballooning
Rogers and Drake,
PRL, 1998



Peeling
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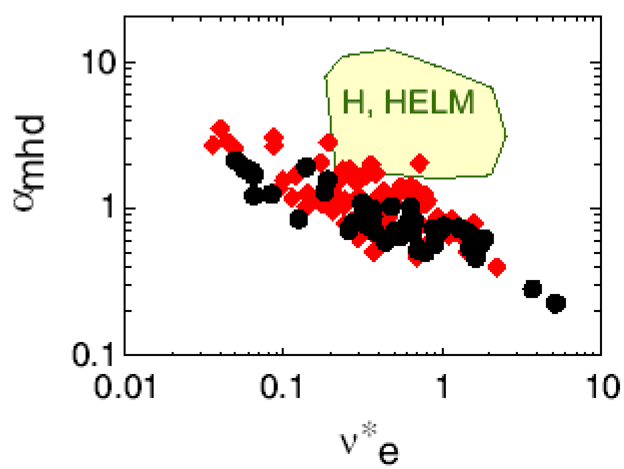
PoP, 1999



Drift-Alfven
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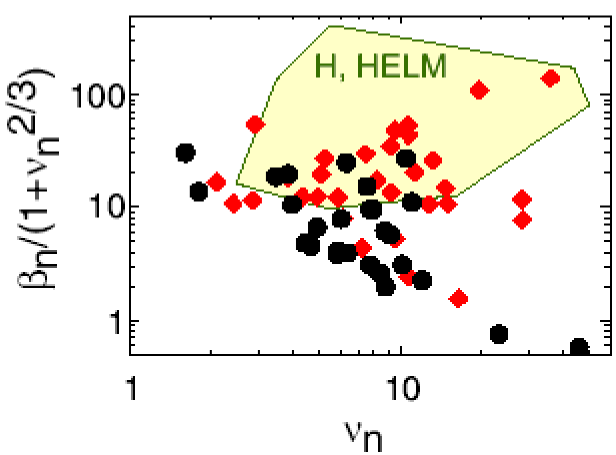
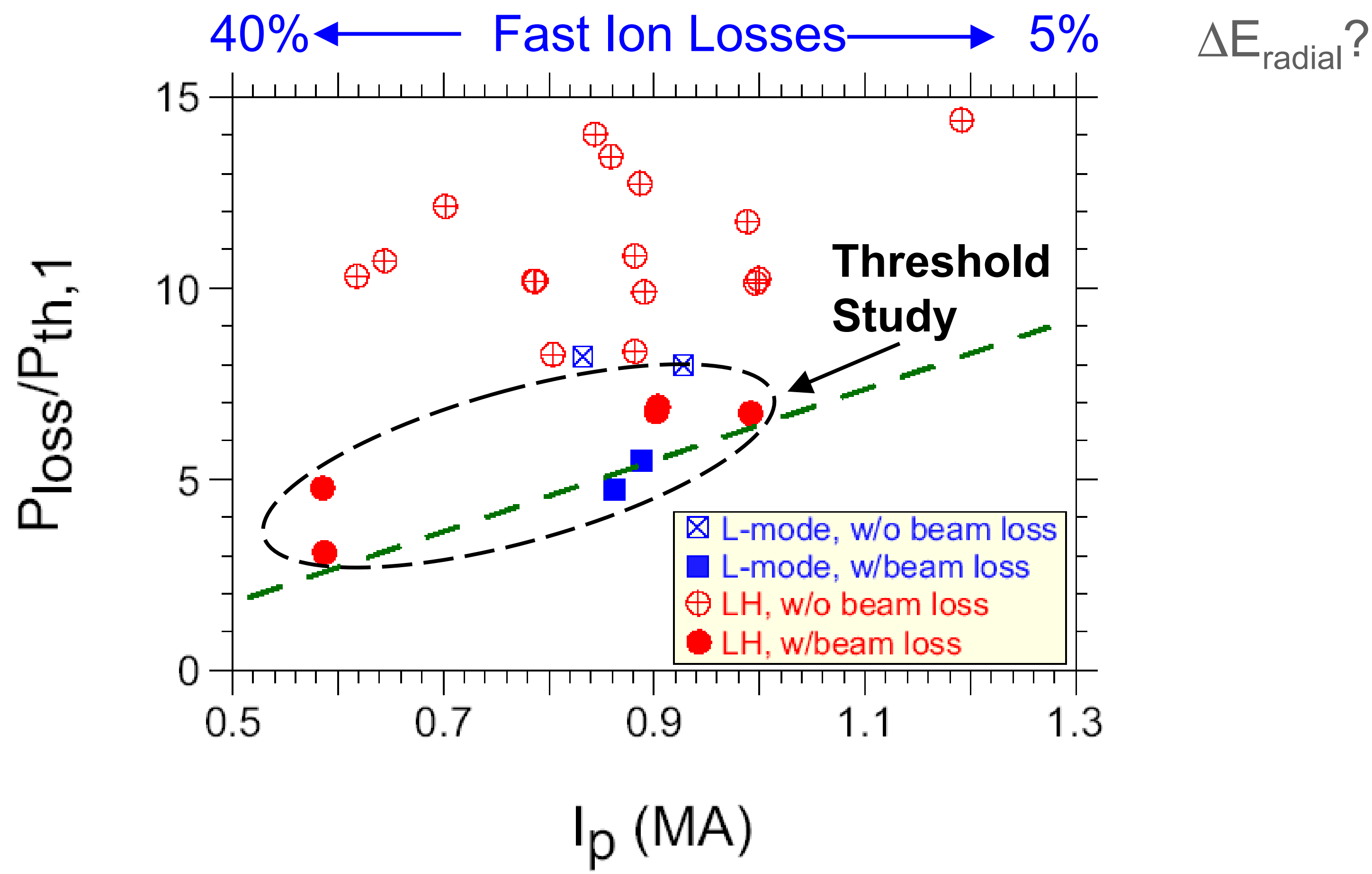


- *No clear separation between L & L-H groups*
  - *Theories cannot explain transition dynamics*

Fast Ion Losses May Influence L-H Threshold

NSTX

Possible I_p dependence of P_{thresh}

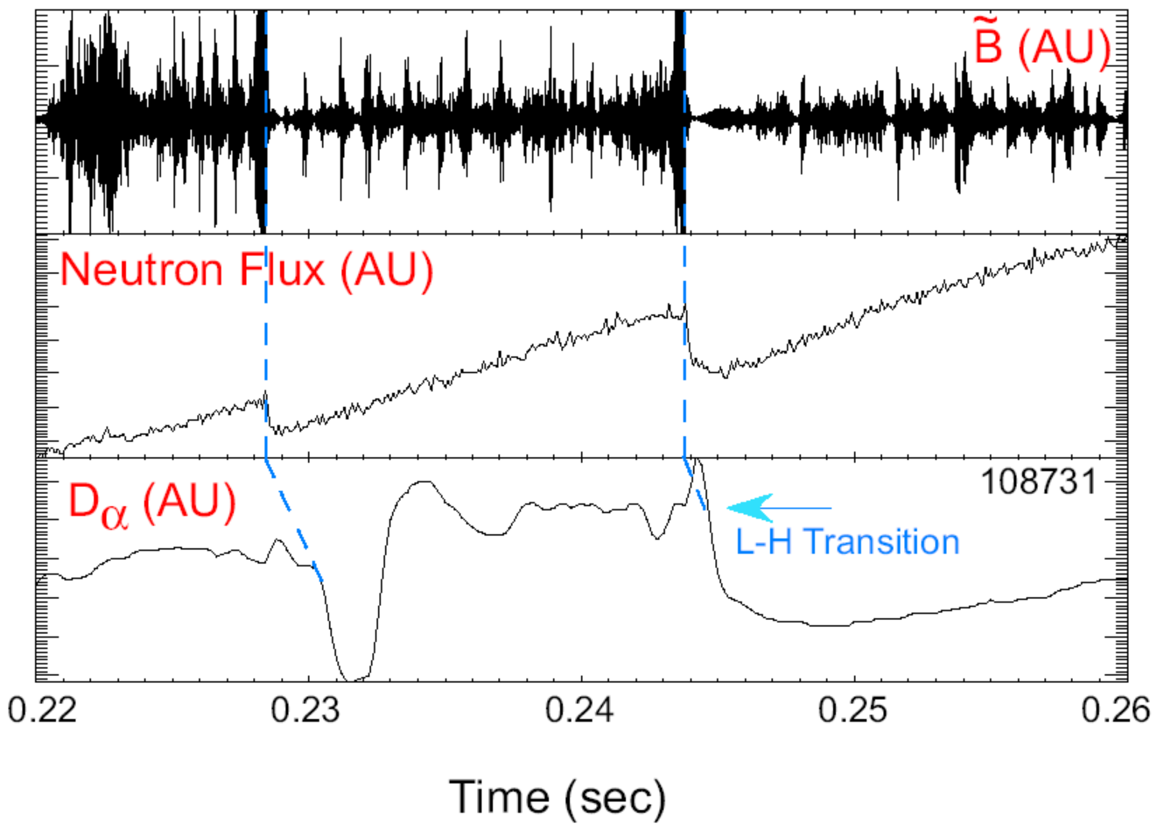


$P_{th,1} \sim n_e^{0.61} B_T^{0.78} a^{0.89} R^{0.94}$ (Snipes et al., IAEA 2002)

Bursty Fast Ion Loss May Induce Transition

D_α fluctuations prior to L-H transition associated with bounce-precession fishbone bursts (Chen, GI1.002, Tues PM)

L-H when significant fast ion loss (neutron drop) – E_{radial}?



Sawtooth-free

Conclusions

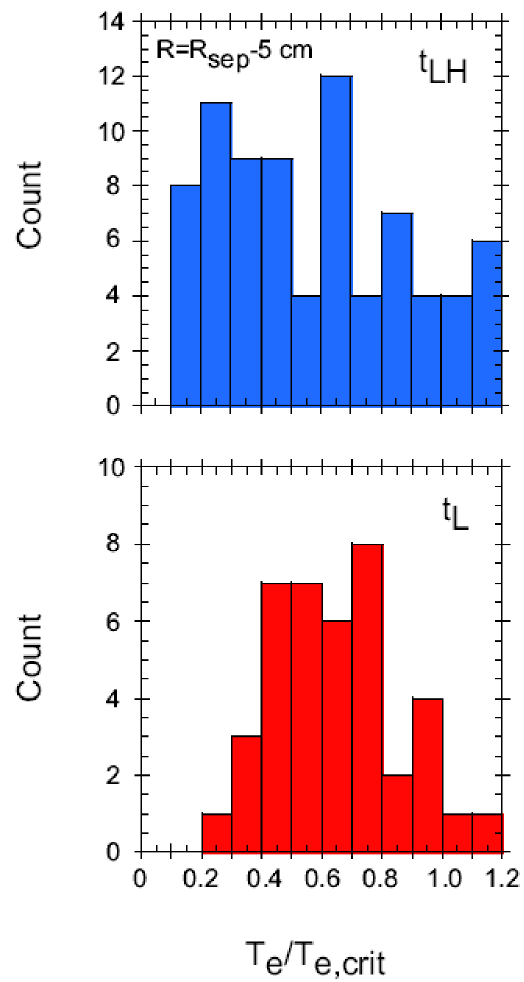
- Comparison of measured edge parameters to those from L-H transition theories indicates
  - Qualitative agreement
    - H/HELM groupings distinct from L group
  - Theories have no apparent predictive capability
    - No clear separation of L and LH groups
  - Low R/a corrections to theory?
- Fast ion losses and resulting $E_{radial}(r)$ may influence transition
  - Possible I_p dependence of threshold ($\tau_{beam} \sim I_p$)
  - Bursty losses (neutron drops) due to MHD activity induce L-H
- NSTX H-modes – C. Bush, KI2.003, Wed AM

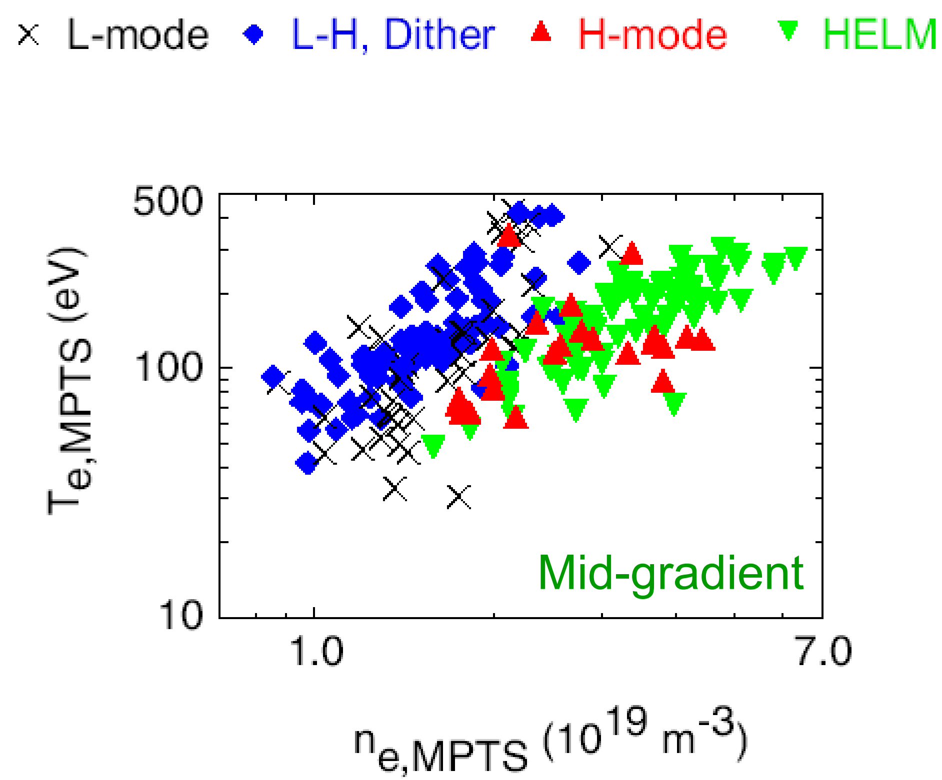
L-H Transition Theories

Theory	Key Parameters	Controlling Dependences	H-mode Access
Drift-Resistive Ballooning Mode (Rogers & Drake, PRL, 1998)	$\alpha_{MHD} = -Rq^2 d\beta/dr$ $\alpha_{DIA} = (\rho_s \Omega_e / \nu_{ei})^{1/2} / (L_n R)^{1/4} q$	β n_e, L_n	Diamagnetic ExB shear flow suppresses resistive ballooning growth High α_{MHD}, α_{DIA}
Peeling Mode (Wilson et al., PoP, 1999)	$\alpha_{MHD} = -Rq^2 d\beta/dr$ ν_e^*	β n_e, T_e	Collisionality reduces edge bootstrap drive, ∇p stabilizing High α_{MHD}, ν_e^*
Drift-Alfven Mode (Pogutse, EPS, 1997)	$\beta_n/(1+\nu_n^{2/3})$ $\beta_n = (M/m)^{1/2} \alpha_{MHD}/rq'$ $\nu_n = \nu_e^*(M/m) L_p / rq'R$	β, L_p, n_e, T_e L_p, n_e, T_e	∇p stabilizing $\beta_n > 1+\nu_n^{2/3}$

Determine predictive capability (compare L vs LH vs H)

Time Slice Data Do Not Indicate Obvious Critical Temperature for L-H Transition





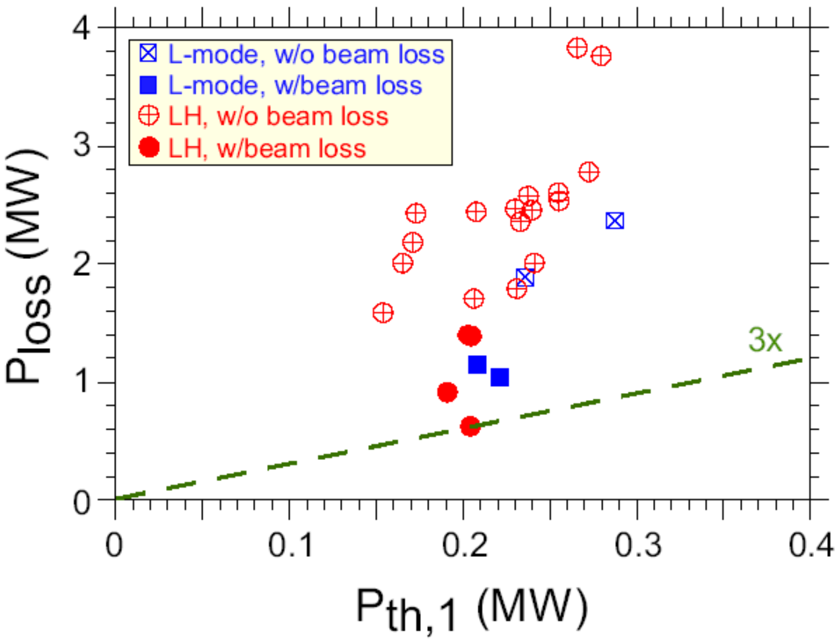
- $T_{e,crit} \sim L_n^{1/2} B_T^{2/3} (Z_{eff}^2/R)^{1/6}$ (Guzdar-zonal flow turbulence suppression)

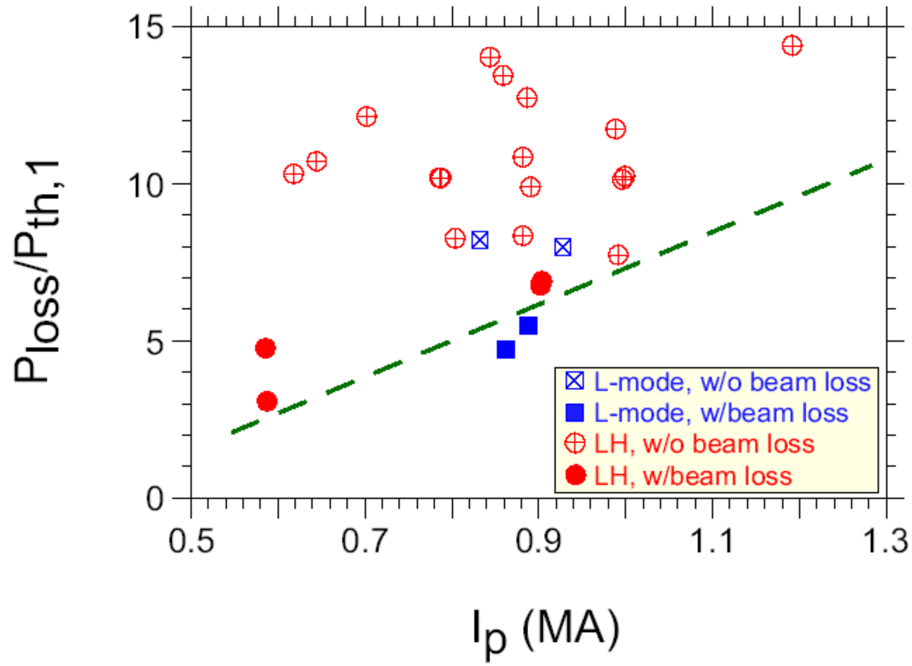
Fast Ion Losses May Introduce Variability in L-H Threshold

NSTX

Variability in L-H threshold Apparent
- $P_{loss}/P_{th,1} \geq 3$

Fast ion losses may result in possible I_p scaling
- Larger E_{radial} at lower I_p





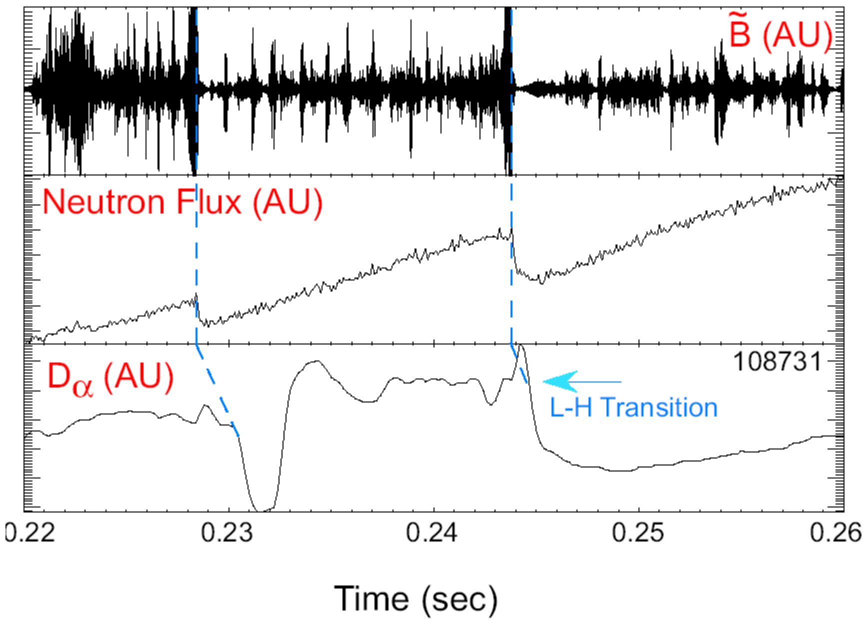
$P_{th,1} \sim n_e^{0.61} B_T^{0.78} a^{0.89} R^{0.94}$ (Snipes et al., IAEA 2002)

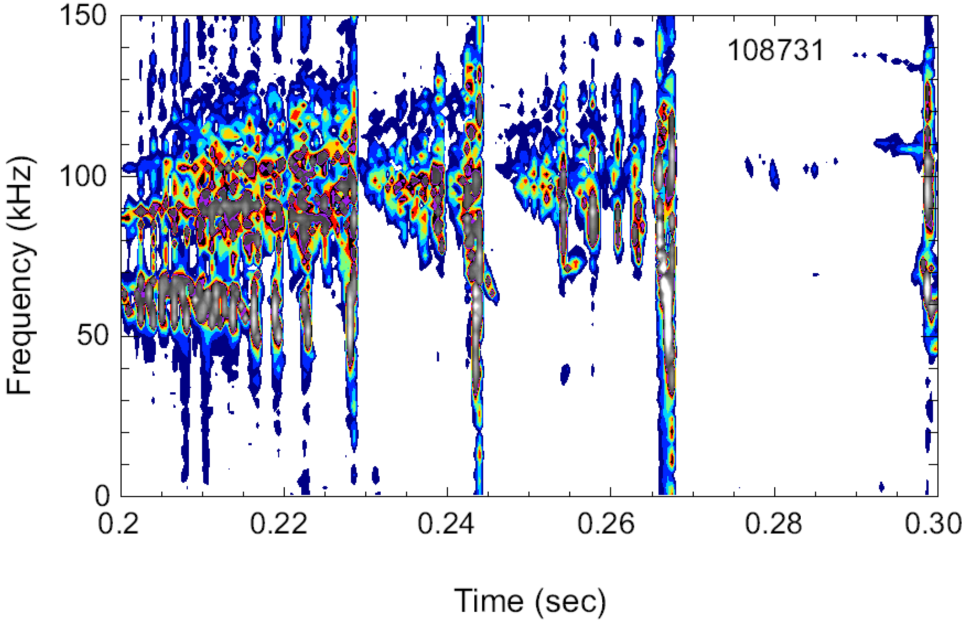
Bursty Fast Ion Loss May Also Induce L-H Transition

Bounce-precession fishbone

bursts →

(Chen, GI1.002, Tues PM)





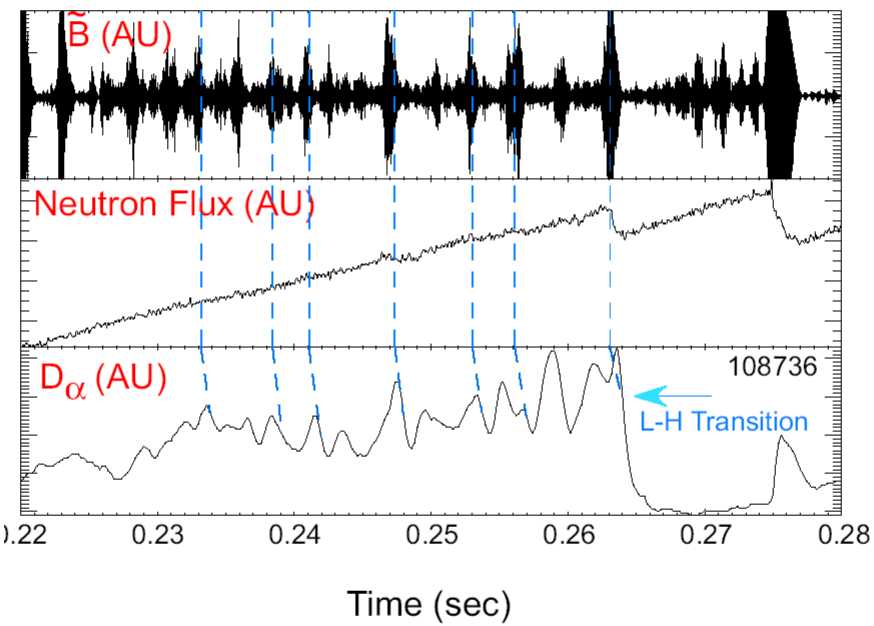
D_α fluctuations prior to L-H transition

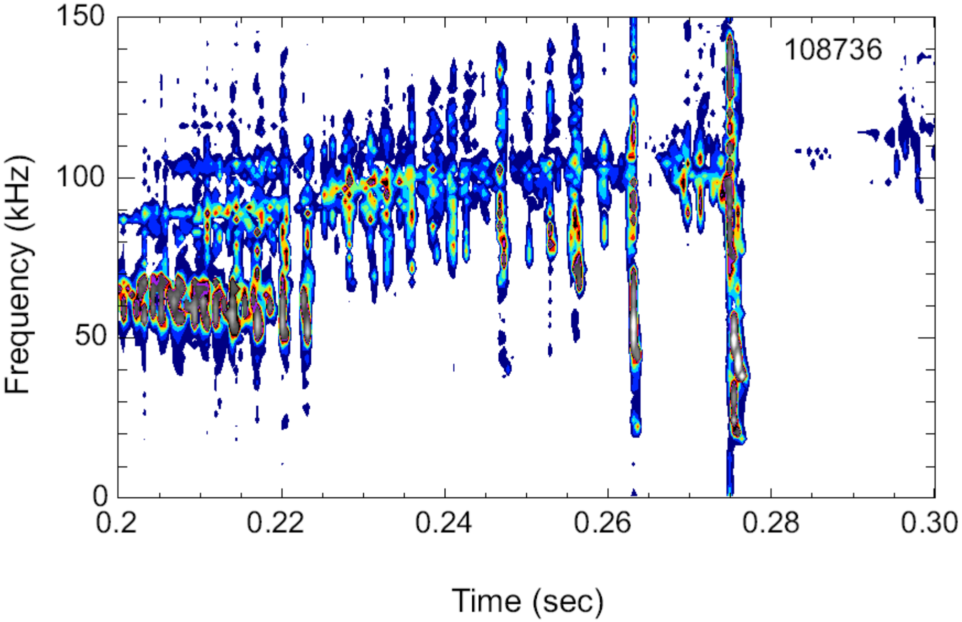
- Associated with fishbone bursts
- L-H when significant fast ion loss (neutron drop) – E_{radial}?

Variability in P_{thresh}, Dithering

Bursty Fast Ion Loss May Also Induce L-H Transition

Bounce-precession fishbone bursts $\rightarrow$ (Fredrickson 1PE23)





D_α fluctuations prior to L-H transition

- Associated with fishbone bursts
- L-H when significant fast ion loss (neutron drop) – E_r?

Variability in P_{thresh}, Dithering