U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

Bifurcation to Enhanced Pedestal (EP) H-mode on NSTX

D.J. Battaglia
D.R. Smith, C.S. Chang, S.P. Gerhardt,
S.M. Kaye, R. Maingi and the NSTX team

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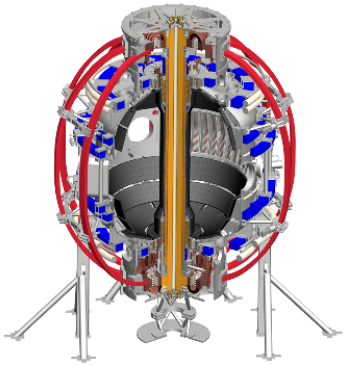
PPPL



Enhanced Pedestal (EP) H-mode is an Attractive Scenario for NSTX-U and Beyond

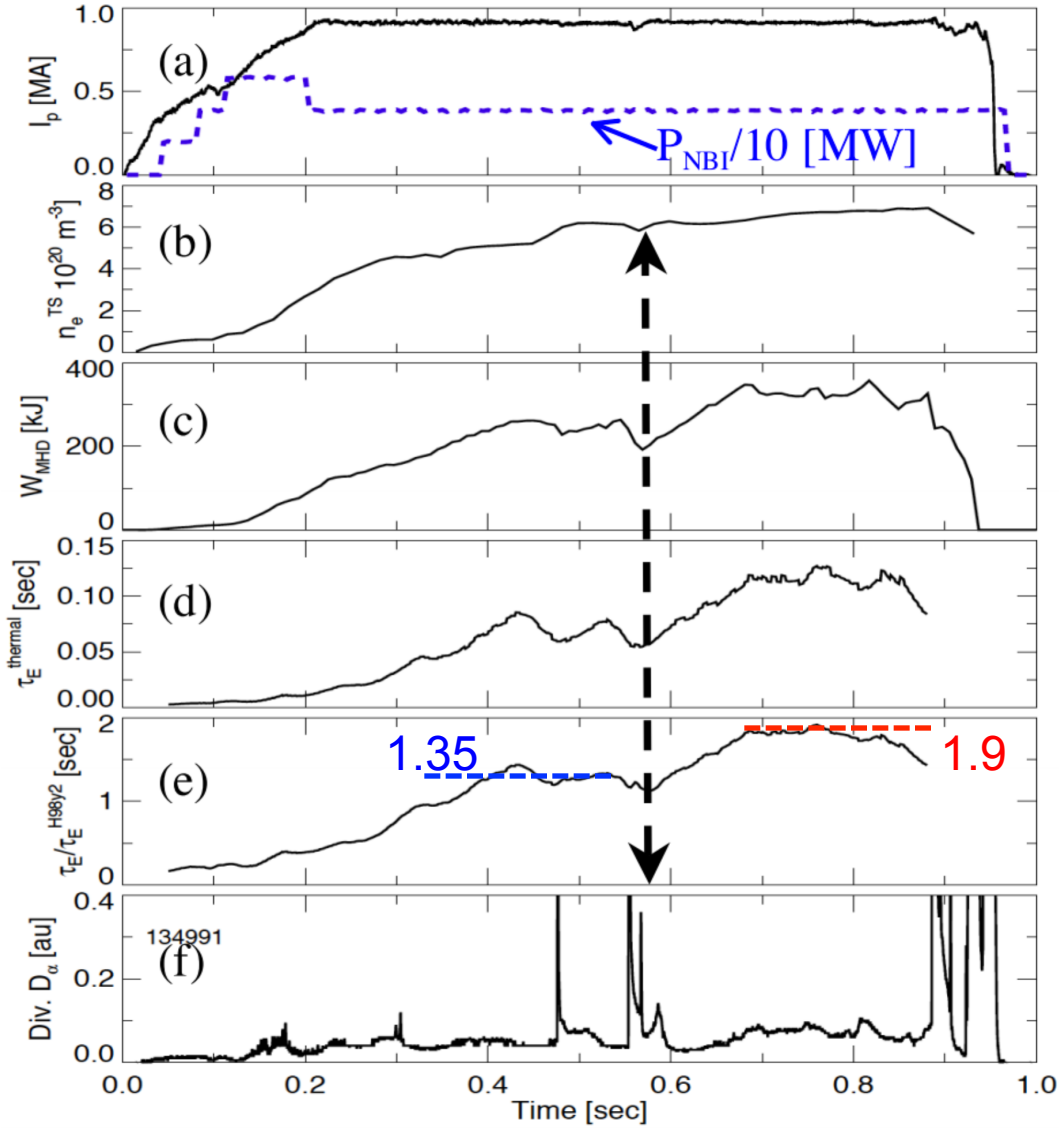
- Lithium wall conditioning improved global energy confinement on NSTX
  - H_{98} ~ 0.9 – 1.4
  - Primary increase in electron energy confinement
  - Without ELMs, particle confinement is too good

- EP H-mode realized additional gains in confinement
  - H_{98} ~ 1.2 – 2.0
  - Primary increase in ion energy and momentum confinement
  - Decrease in particle confinement compared to H-mode

- Can NSTX-U achieve reliable access and sustainment of EP H-mode?

EP H-mode Typically Triggered by Transient Increase in Edge Rotation Shear

- Large infrequent ELMs with Li wall conditioning
  - EP H-mode begins after second ELM
  - Achieves H98y2 ~ 1.9

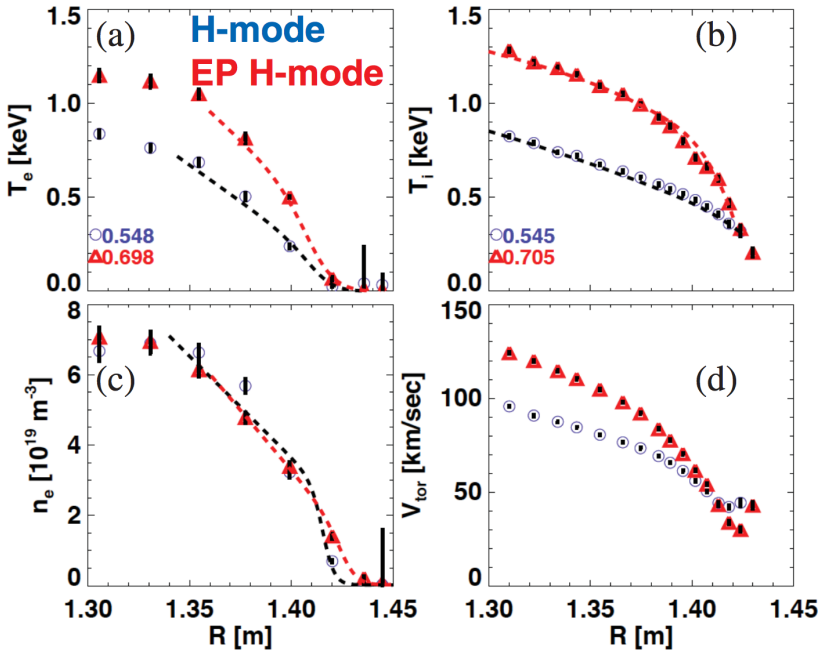


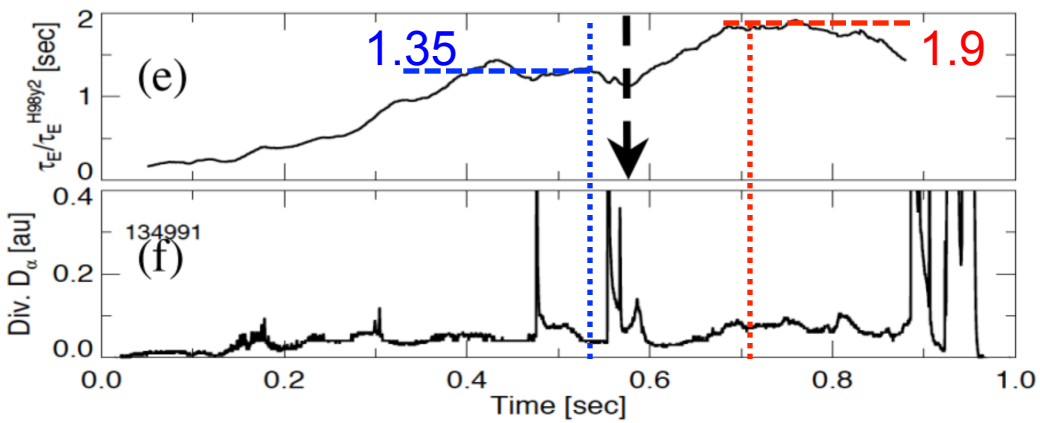
R. Maingi et al, PRL **105**, 135004 (2010)

EP H-mode Typically Triggered by Transient Increase in Edge Rotation Shear

- Large infrequent ELMs with Li wall conditioning
  - EP H-mode begins after second ELM
  - Achieves H98y2 ~ 1.9
- Transient drop in edge rotation with ELM
  - Region of larger T_i, T_e, v_t gradients grows inward
- $\Delta T_i > \Delta T_e$
  - Reduction in n_e gradient
  - Little change in core n_e

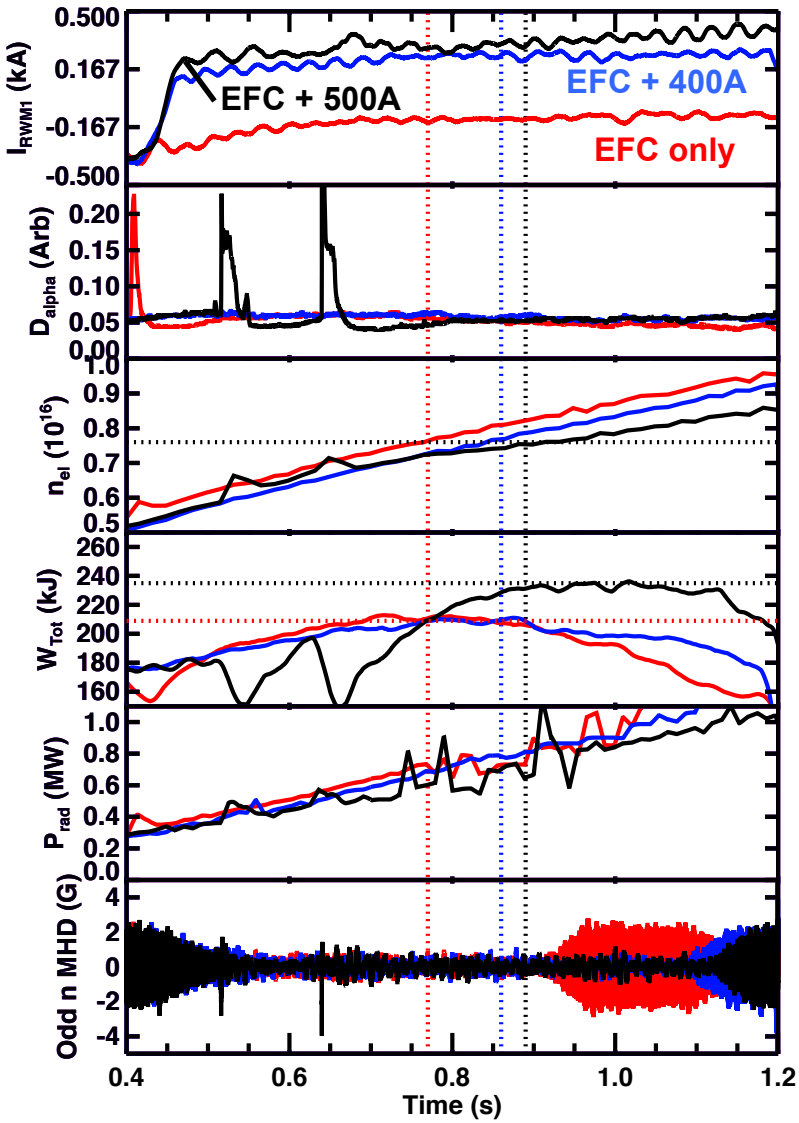
R. Maingi et al, PRL **105**, 135004 (2010)





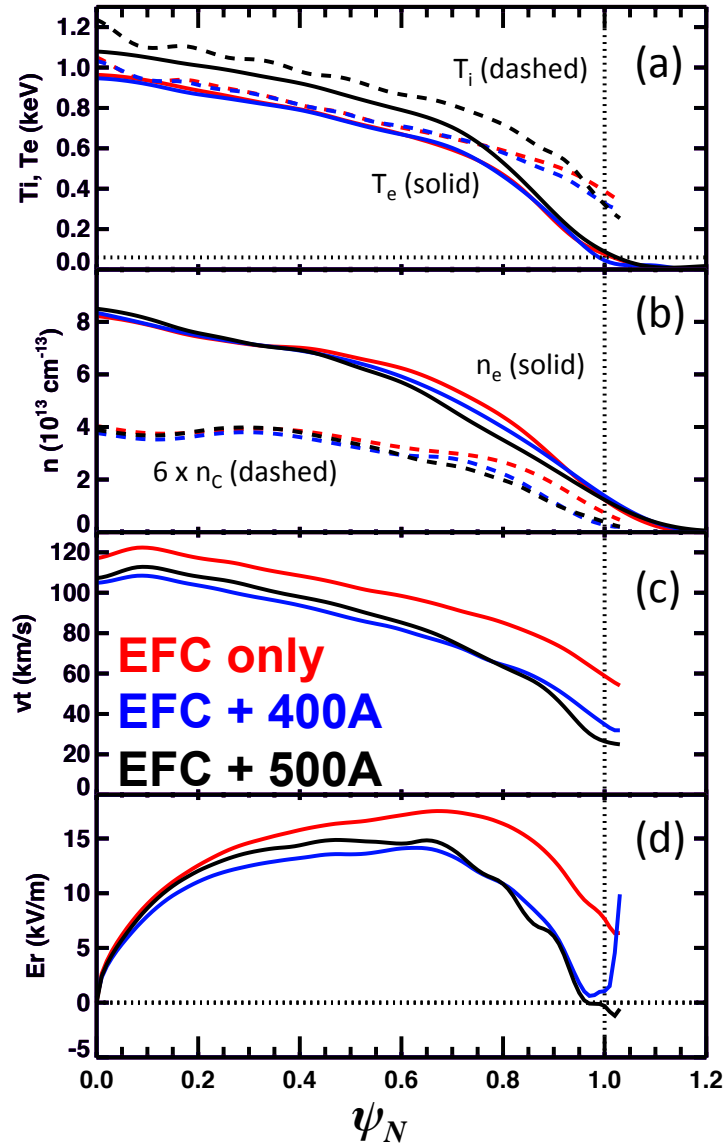
Marginal EP H-mode Example Provides Opportunity to Examine Critical Parameters

- Three matched discharges except for n=1 current in RWM coils
  - **EFC only (H-mode)**
  - **EFC + 400A offset (H-mode)**
  - **EFC + 500A offset (EP H-mode)**
- Discharge with 500A offset bifurcates to EP H-mode
  - H-mode: H98y2 ~ 1.1
  - EP H-mode: H98y2 ~ 1.3
    - Slower rise in n_e, P_{RAD}
    - ELM-free, MHD quiescent for 250ms
- Larger offset current leads to many ELMs



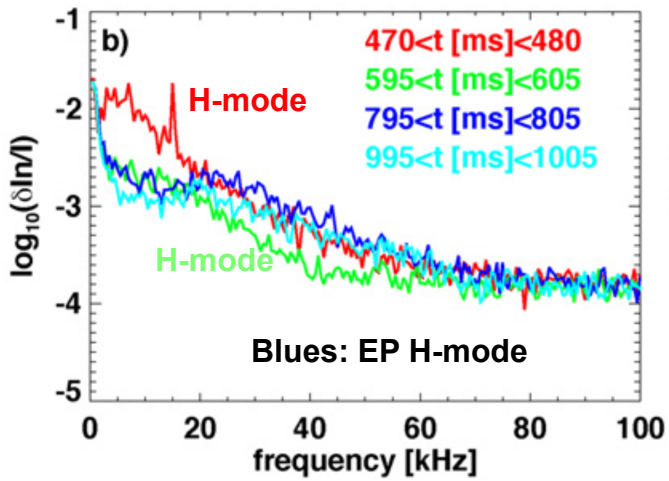
Bifurcation to EP H-mode Evident in Temperature Profiles

- Profiles averaged over 100ms periods at matched n_{el}
- Application of 3D fields
  - Reduces edge rotation, E_r
  - Reduces n_e gradient
  - Shifts n_C profile inward
- Subtle change in n_e, n_C, v_t and E_r with 100A more RWM coil current + ELM
  - About 15% increase in energy & momentum confinement



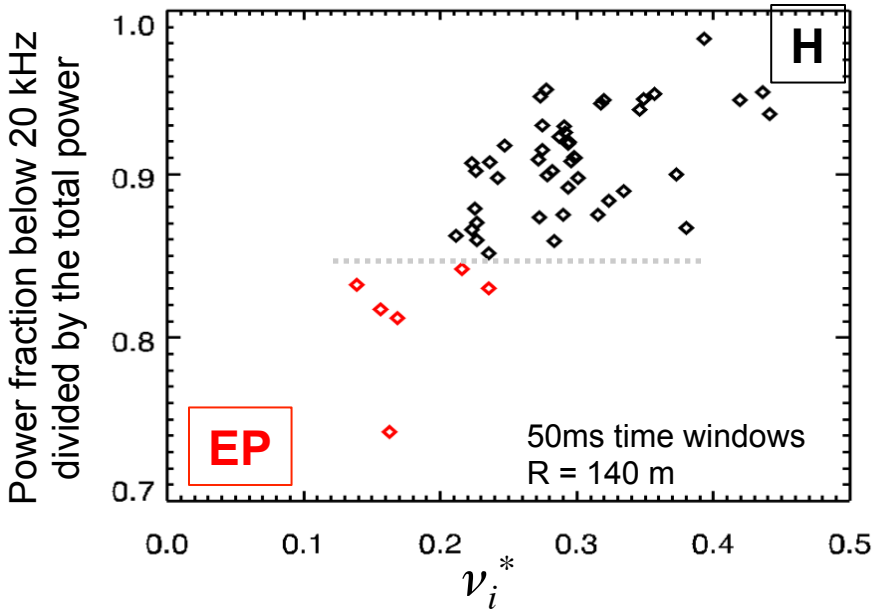
Ion-scale Density Fluctuations Below 20kHz are Suppressed at Lower ν_{ii}

- Low frequency density fluctuations decrease during EP times
  - Localized around BES chord at $\psi_N = 0.9$



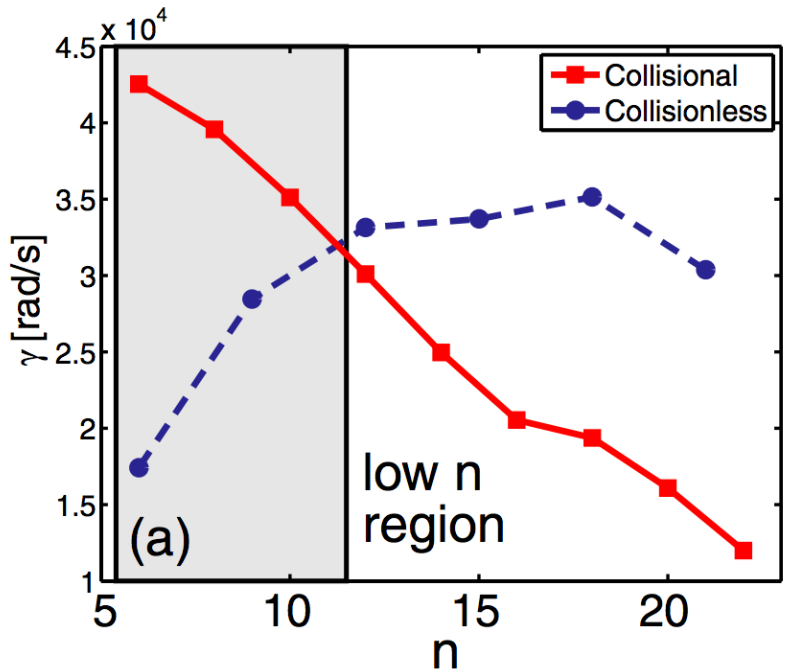
S. Gerhardt et al, NF **54**, 083021 (2014)

- EP H-mode observed at lowest ν_i^*
  - Consistent with lower recycling with Li
  - Consistent with ELM flushing impurities in edge

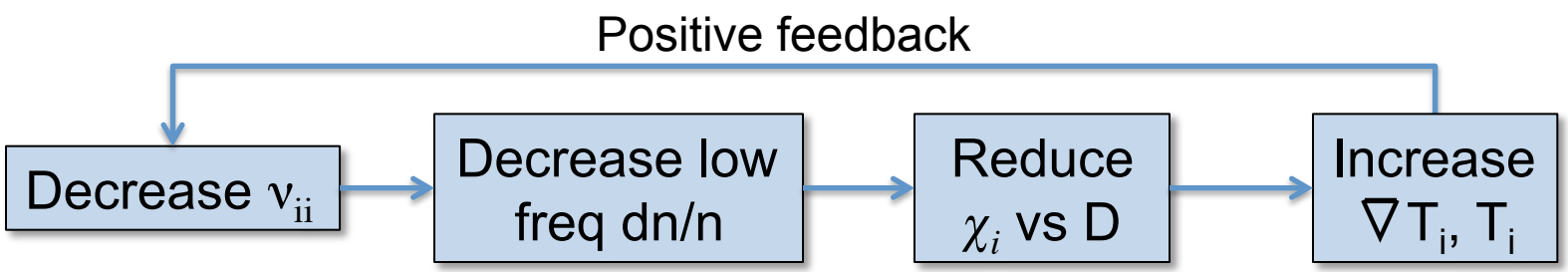


Shift in Fluctuations to Higher Frequency Consistent with GEM Simulation

- GEM calculations find low-n instabilities destabilized by collisions
  - Linear gyrokinetic simulations with NSTX pedestal profiles
- Hypothesis: EP bifurcation due to positive feedback loop
  - Larger n instabilities have diminished impact on transport of high-energy ions



D.R. Smith et al, NF **53**, 113029 (2014)



Summary

- EP H-mode is an attractive scenario for NSTX-U and future devices
  - Increase in energy and momentum confinement (H_{98y2} up to 2) with beneficial increase in particle transport
- EP H-mode observed at lowest ion collisionality
  - Bifurcation in T_e, T_i, little change in E_r, n_e in marginal cases
  - BES shows shift in density fluctuations to higher frequency consistent with GEM prediction of larger-n instabilities
- Connection between ν_{ii}, frequency shift of dn/n and ion transport will be tested on NSTX-U
  - Develop control tools to access and sustain EP H-mode