Pedestal Characterization and Stability of Small-ELM Regimes in NSTX*

A. Sontag[1], J. Canik[1], R. Maingi[1], J. Manickam[2], P. Snyder[3], R. Bell[2], S. Gerhardt[2], S. Kubota[4], B. LeBlanc[2], T. Osborne[3], K. Tritz[5]

[1]ORNL, [2]PPPL, [3]GA, [4]UCLA, [5]JHU

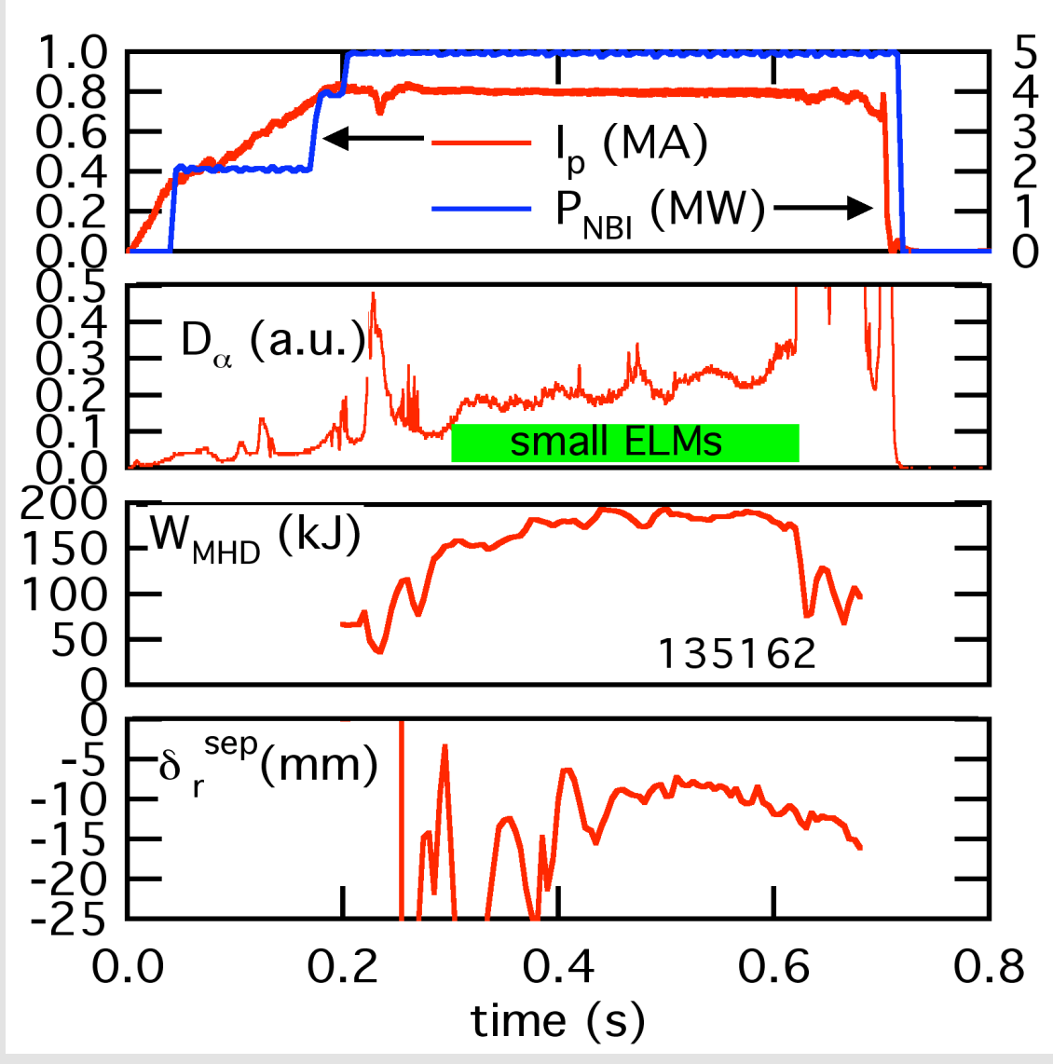
*This work was supported by U.S. DOE Contracts DE-AC05-00OR22725, DE-FG03-99ER54527, DE-FG03-95ER54309 and DE-AC02-09CH11466

Small-ELM Regime Observed Coincident with Edge Instability

- Small-ELM (Type-V*) operation highly desirable in NSTX
  - $\delta W_{MHD} < 1\%$ per ELM
  - no large oscillations at edge compared to Type-I

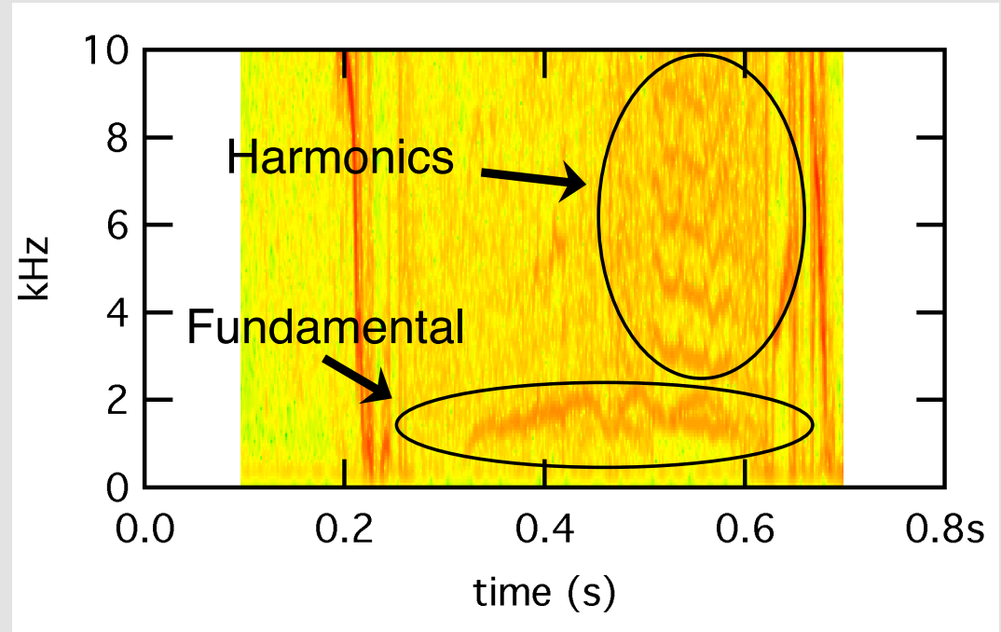
*R. Maingi, *et al.*, *Nucl. Fusion* **45** (2005) 264

- Downward bias & high edge collisionality required for access
  - $\delta_r^{sep} < -5$ mm necessary (but not sufficient)
  - $\nu^*_{ped} > 1\text{-}2$
  - no correlation with edge rotation or rotation shear
    - still need to determine E x B shear correlation



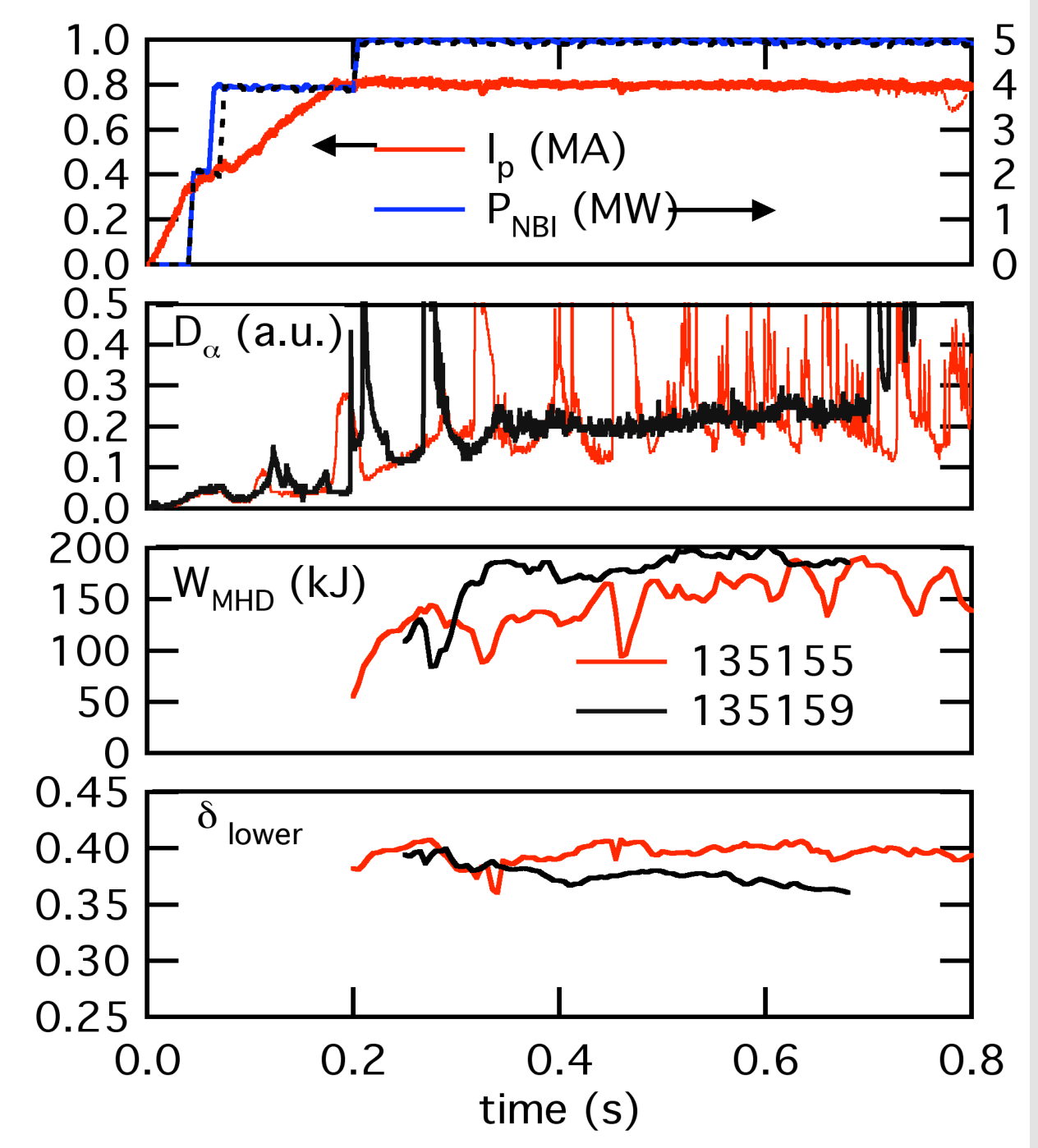
- Low-frequency (< 10 kHz) oscillations observed coincident with Type-V ELM transition
  - ST equivalent to edge harmonic oscillation (EHO)?
    - EHO allows access to ELM-free QH-mode at standard-A
      - possible saturated kink
      - rotation has complex role
      - edge collisionality important
    - EHO provides edge transport, reduces peeling-ballooning instability drive

Poloidal Mirnov



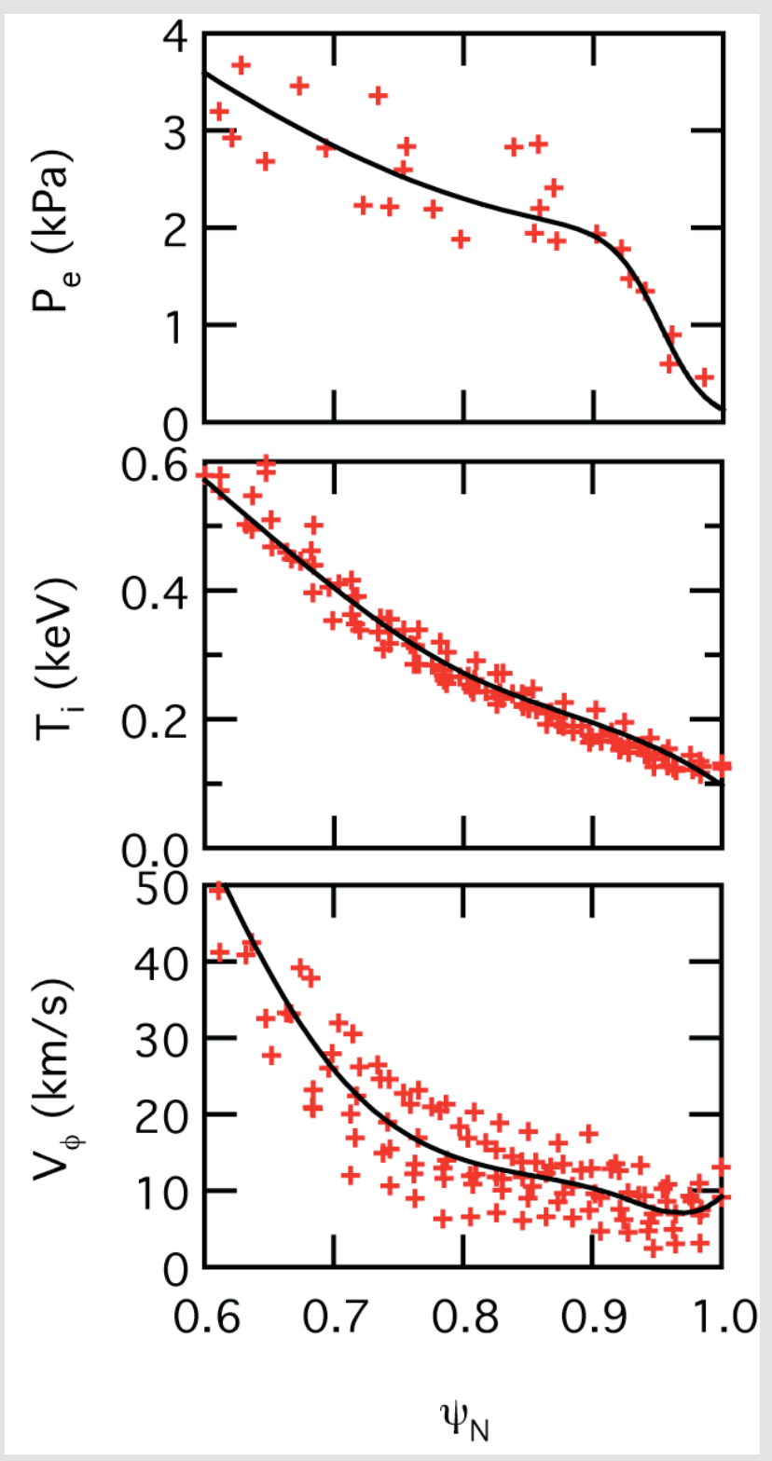
Similar Shots Examined for Causes of Transition to Small-ELM Regime

- Type-I ELMs stabilized with δ ramp-down
  - both shots have Type-I ELMs prior to 0.3 s
  - other shape parameters held constant
  - shape change will affect peeling-ballooning stability
- δ_r^{sep} reduction well after transition
  - both cases start with $\delta_r^{sep} < -5$ mm

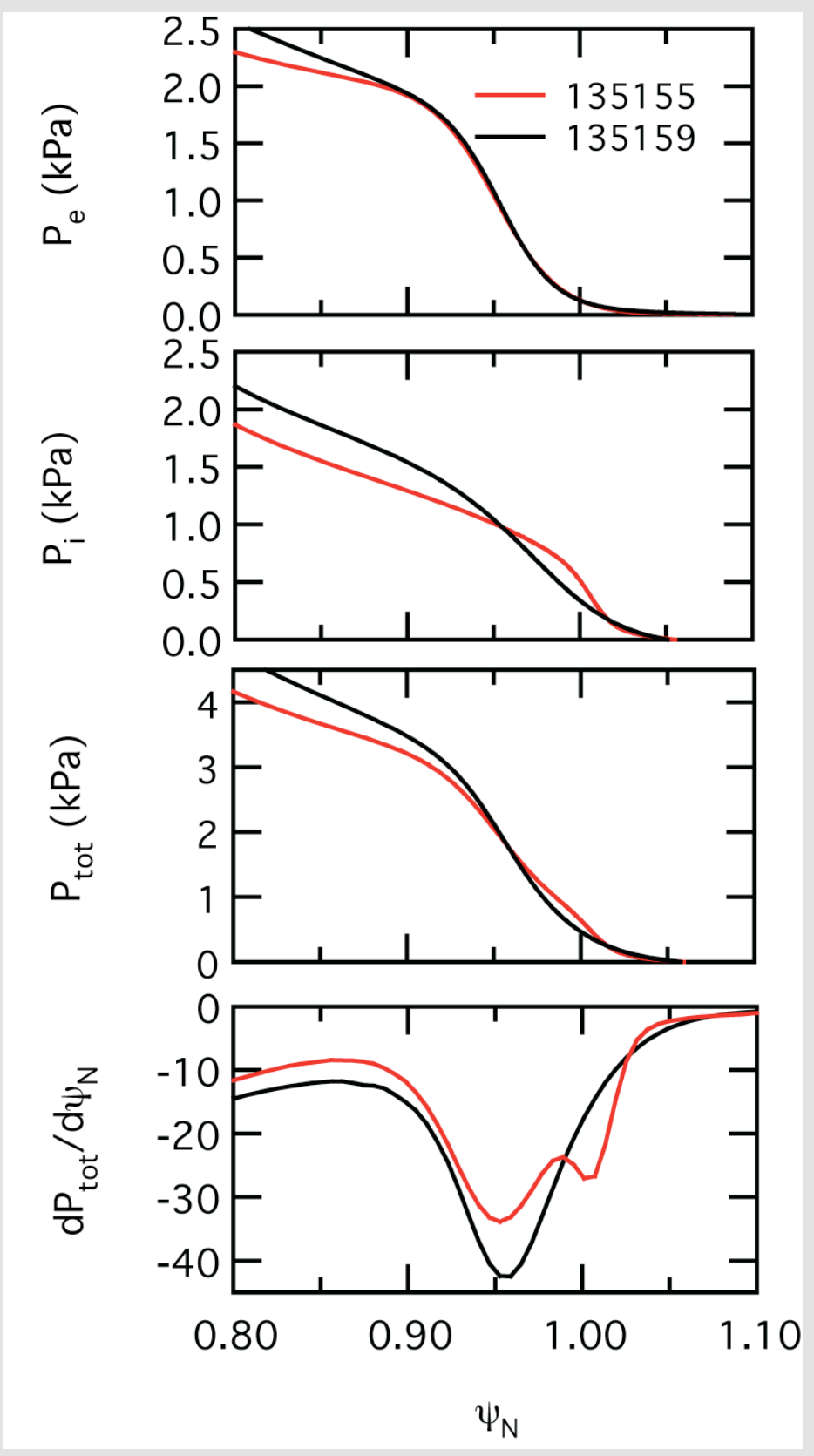


- Profiles determined using time-slice averaging kinetic equilibrium technique developed on DIII-D
  - run EFIT at TS laser times
  - map n_e, T_e, T_i to ψ_N space
  - fit tanh function to re-mapped profiles
  - compute kinetic EFIT using tanh fits
  - calculate j_{BS} form Sauter model
- Pedestal pressure peak shifted inward & increased for Type-V
  - P_e nearly identical
  - Type-I profile has increased pressure gradient magnitude near edge
    - Type-V case has largest magnitude
  - Type-V profile relatively constant throughout shot
    - small-ELMs have little effect on profiles

Shot 135155 Profile Fits

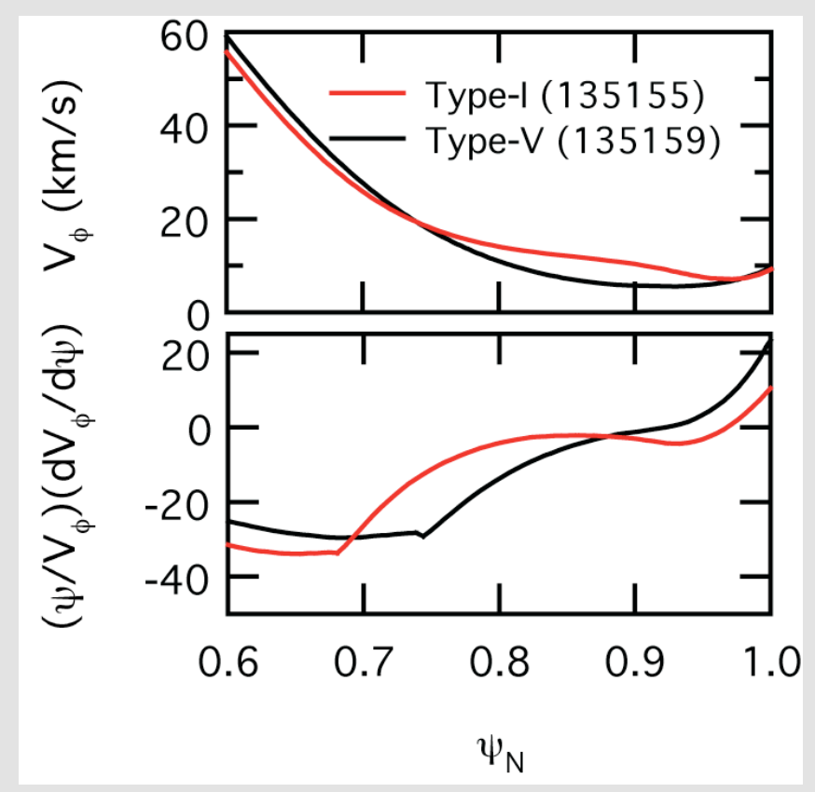


Pressure Profile Comparisons

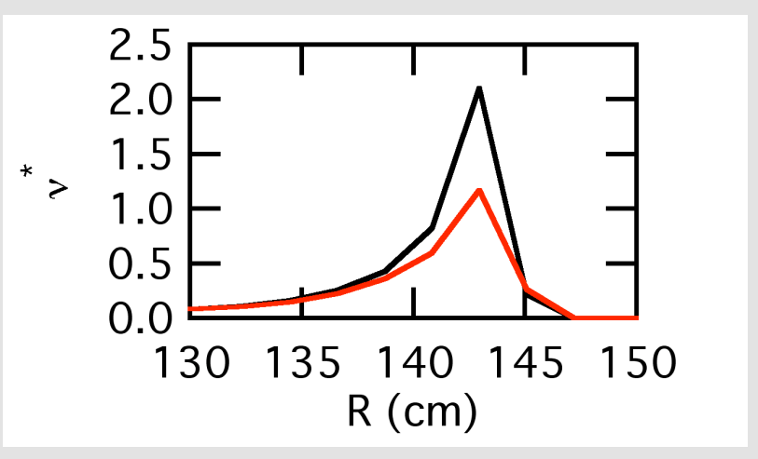


- Rotation magnitude similar
  - large error bars near edge
  - also large relative fluctuations in slowly rotating edge
  - analysis of wider range of shots shows wide variation in rotation and rotation shear for both Type-I and Type-V

Rotation Profile Comparison

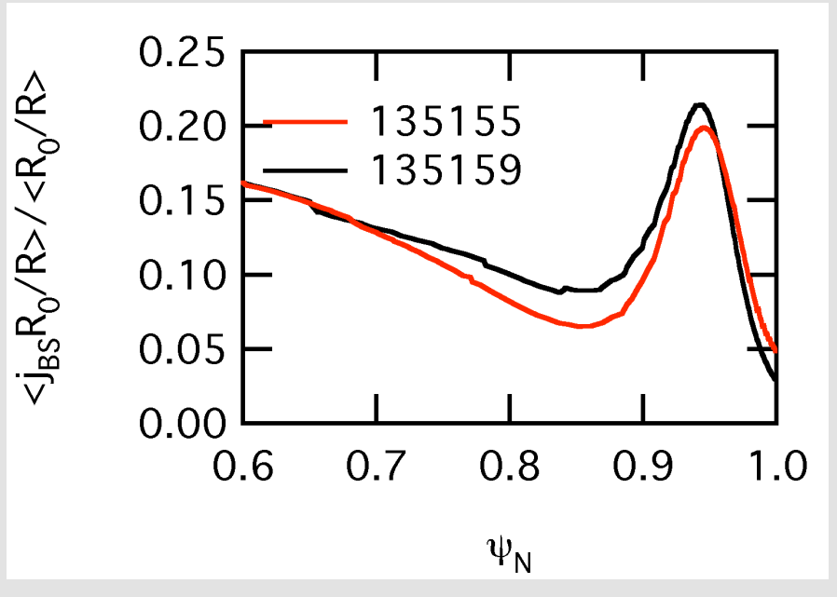


Collisionality Comparison

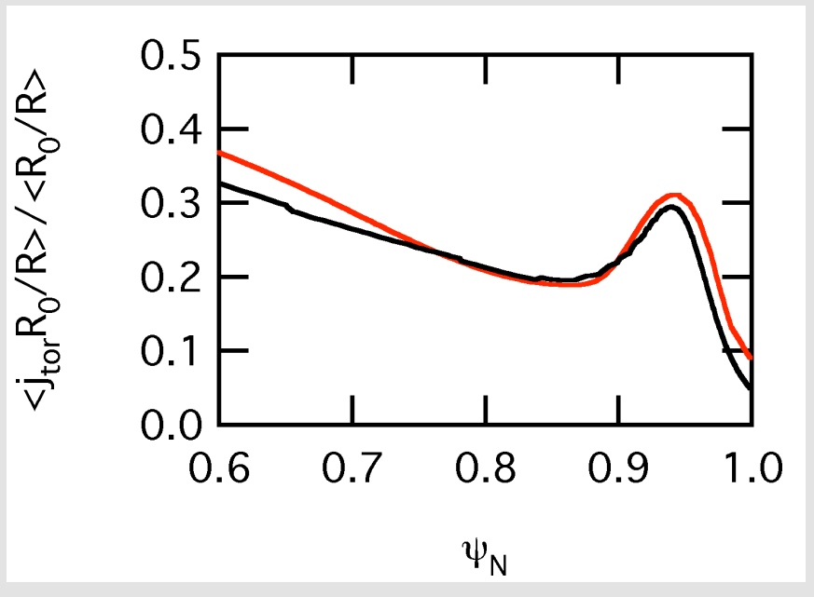


- Edge collisionality increased in Type-V case
  - previous observations show increased ν^* stabilizes Type-I
  - presumably due to reduced j_{BS} & peeling drive
- Edge current peak slightly reduced in Type-V case
  - j_{BS} slightly higher in Type-V case
  - peeling-ballooning stability calculations required

Bootstrap Current Profiles



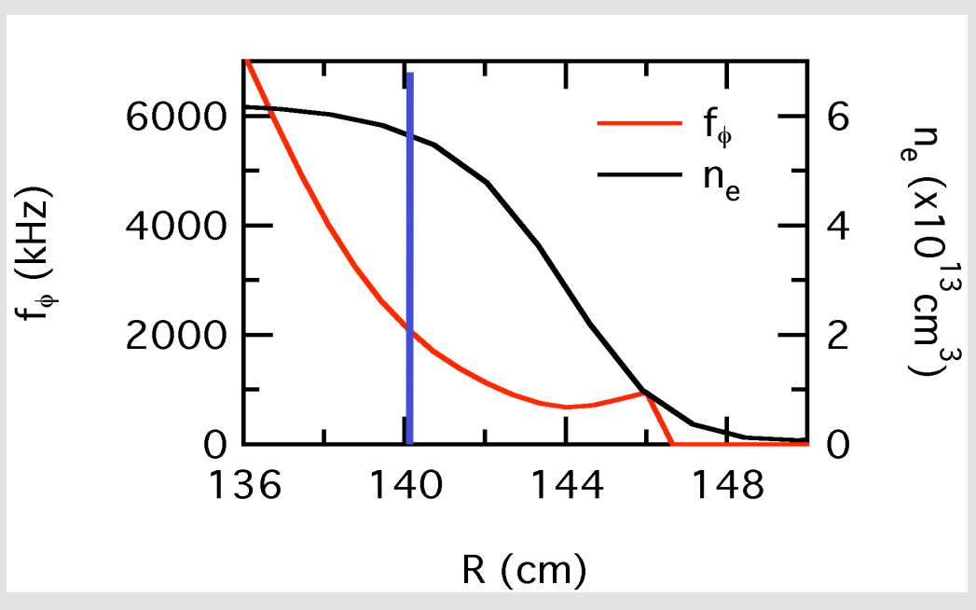
Toroidal Current Profiles



Edge Instability Observed in Multiple Diagnostics

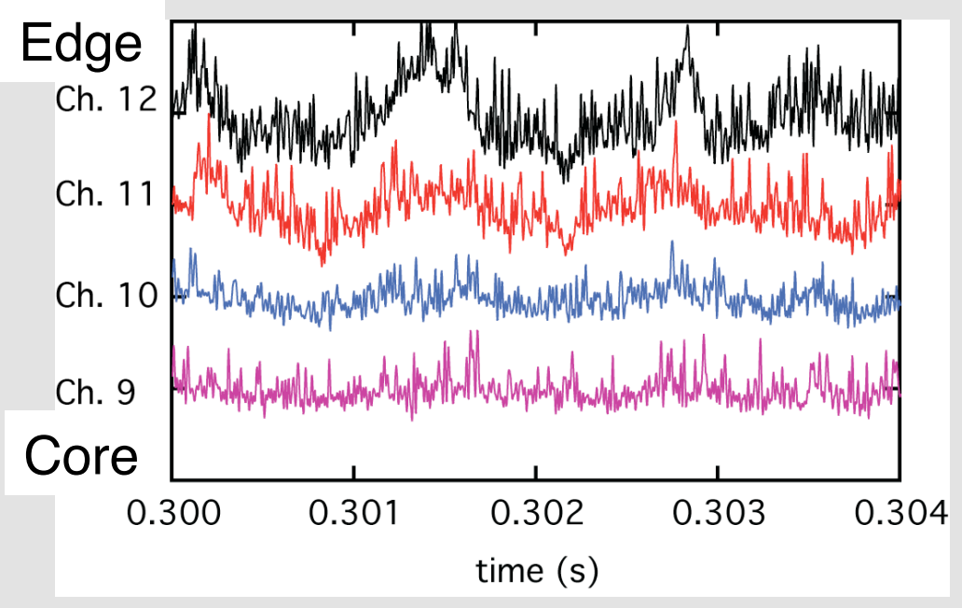
- Poloidal Mirnov array indicates n = 1 base freq.
  - multiple harmonics observed in some cases
  - higher harmonic base frequency in Li-induced ELM-free H-mode
  - rotating with plasma just inside pedestal

Toroidal Rotation & Density Profiles

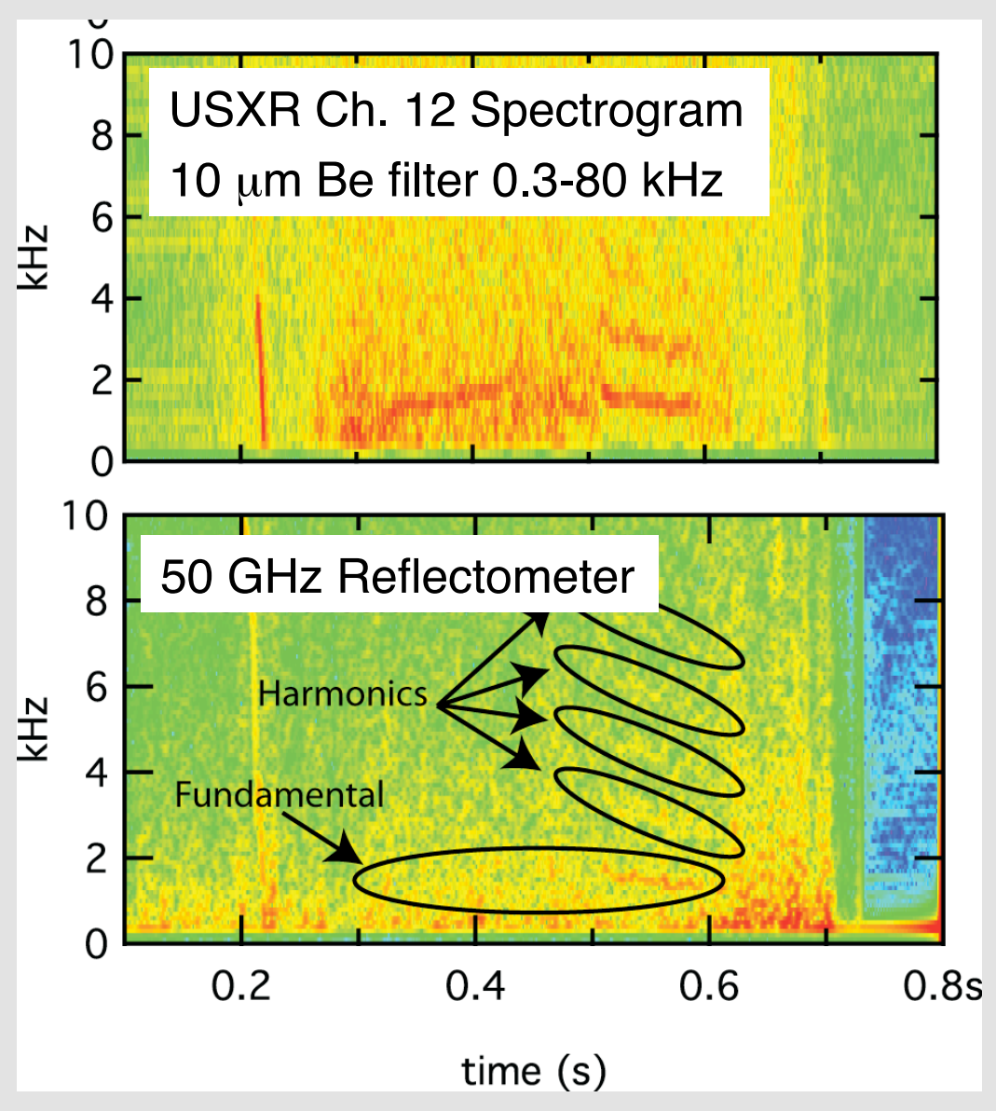


- USXR indicates mode near top of pedestal
  - oscillations peak near 141 cm
    - Ch. 12 near top of pedestal (R_{tan} ~ 141 cm)
    - Ch. 13 in scrape off – no signal
    - inside Ch. 9 – no low-freq. oscillations
  - 10 μm Be filters eliminate edge radiation
  - unfiltered USXR shows ELM spikes independent of coherent mode

USXR Diode Array

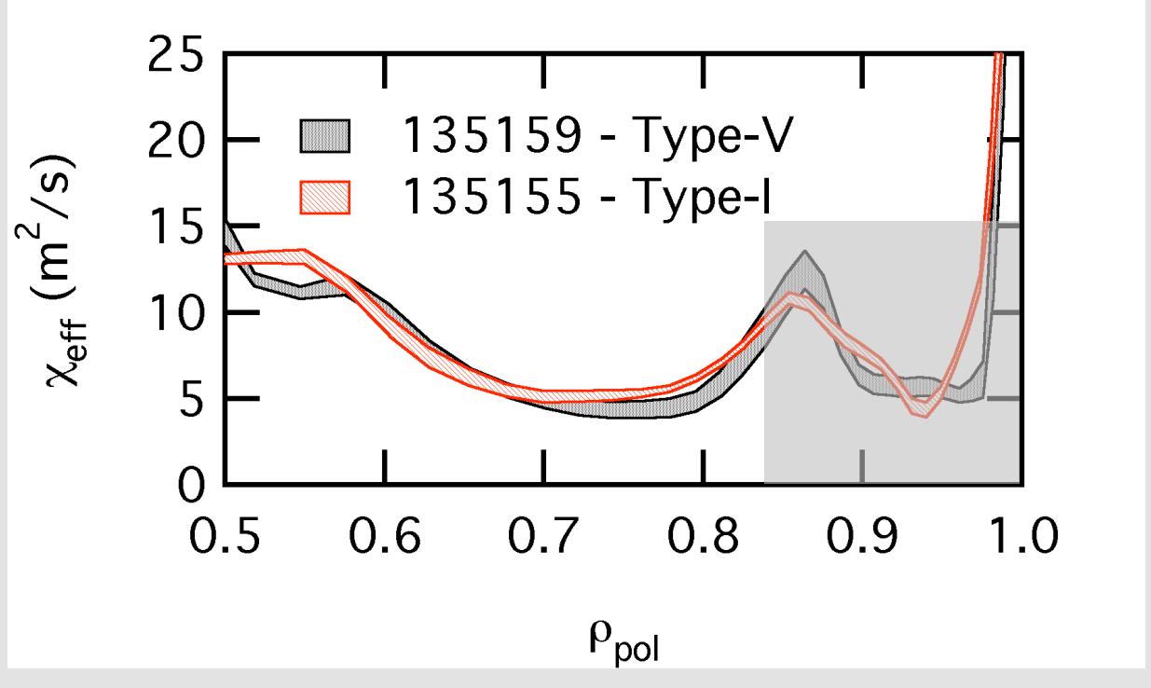


- Edge reflectometer shows density fluctuations
  - R_{cutoff} ~ 140 cm during mode
  - fluctuations at same frequency as Mirnovs/USXR
  - relatively weak compared to core modes



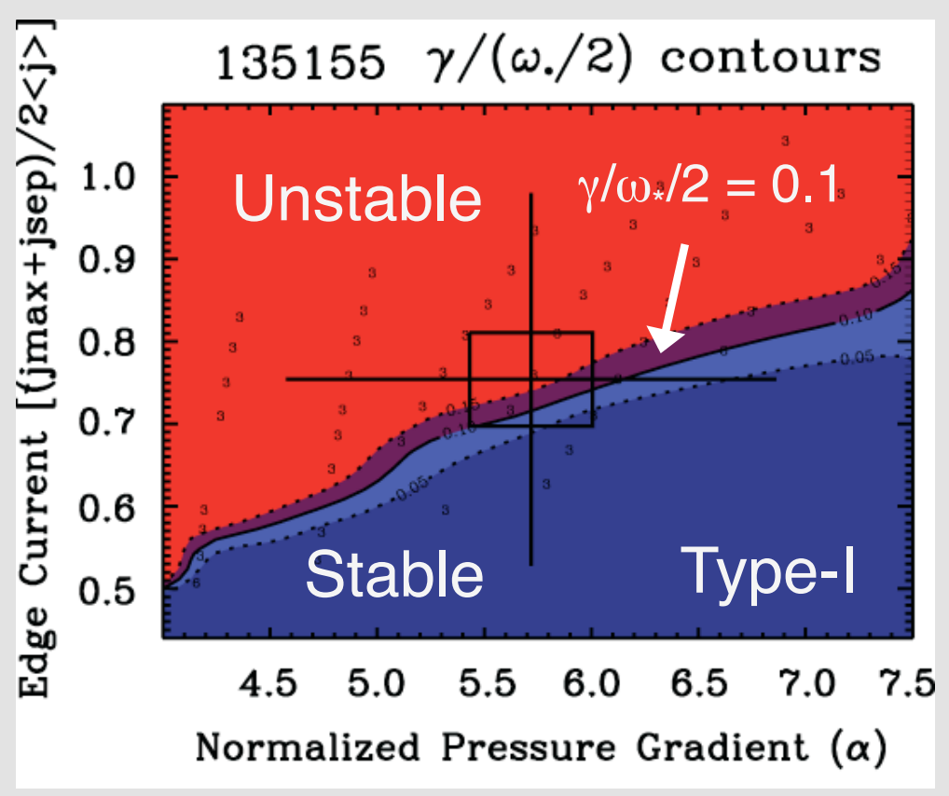
- TRANSP analysis not able to determine level of increased transport from mode
  - increased transport required if mode is stabilizing Type-I
  - analysis only reliable up to ρ ~ 0.85
  - more detailed analysis required
    - must account for particle sources and sinks

TRANSP Single Fluid χ_{eff}

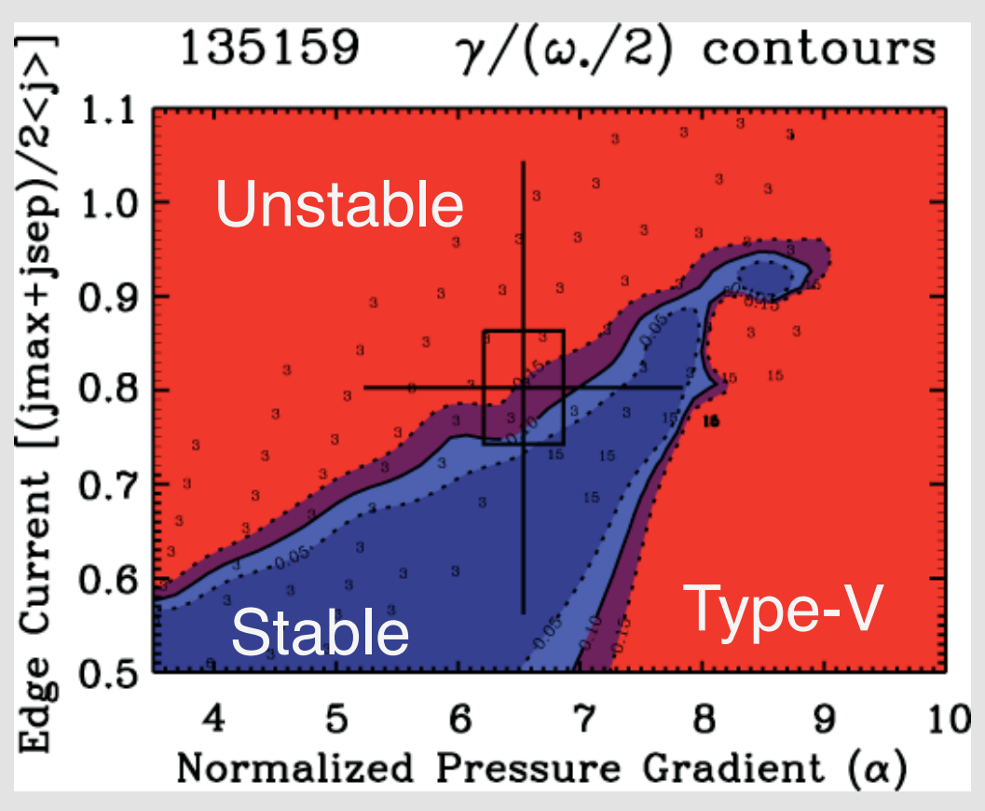


Stability Analysis Indicates Type-V Case Closer to Ballooning Boundary

- ELITE* indicates n = 3 most unstable mode for both cases
  - run for n = 3,6,9,12,15
  - initial PEST calculations also show n = 3 most unstable
  - NSTX is typically on peeling (current driven) side of stability curve
    - ST geometry naturally leads to higher j_{BS} than at standard-A
    - strong shaping stabilizing to ballooning modes



- Decreased triangularity moves operating point closer to ballooning boundary
  - close to n = 15
  - lower δ decreases ballooning stabilization
- Change in operating point not the same as transition from ELMy to QH-mode with EHO
  - EHO moves operating point across peeling boundary
  - both NSTX cases still on peeling boundary
  - need more statistics for NSTX



Further Analysis Required to Determine Cause of Stabilization of Type-I ELMs

- Edge instability observed coincident with small-ELM transition
  - observed in many NSTX discharges
  - may have similar role to EHO at normal-A ➔ need to determine how instability affects transport
- No correlation with toroidal rotation or rotation shear
  - need to examine ExB shearing rate
- Increased collisionality ($\nu_e^* > 2$) and $\delta_r^{sep} < -5$ mm needed for Type-V ELMs
  - Type V cases have increased pedestal pressure
- Stability analysis shows Type-V case closer to ballooning boundary
  - need to include MSE in equilibrium reconstructions
  - need to analyze more shots for better statistics
- Need to include particle sources and sinks to determine if mode is affecting transport

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Supported by U.S. DEPARTMENT OF ENERGY