NSTX | Oak Ridge National Laboratory | Supported by U.S. Department of Energy Office of Science

Edge Stability of Small-ELM Regimes in NSTX

College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

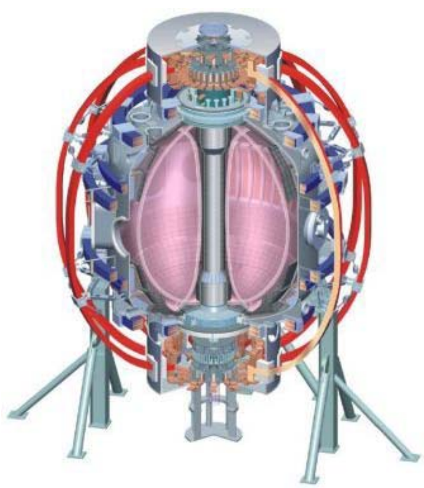
Aaron Sontag

J. Canik, R. Maingi, R. Bell, S. Gerhardt, S. Kubota, B. LeBlanc, J. Manickam, T. Osborne, P. Snyder, K. Tritz

and the NSTX Research Team

APS - DPP
Chicago, Il
Nov. 10, 2010

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec



Small-ELM Regime in NSTX Coincident with Edge Instability

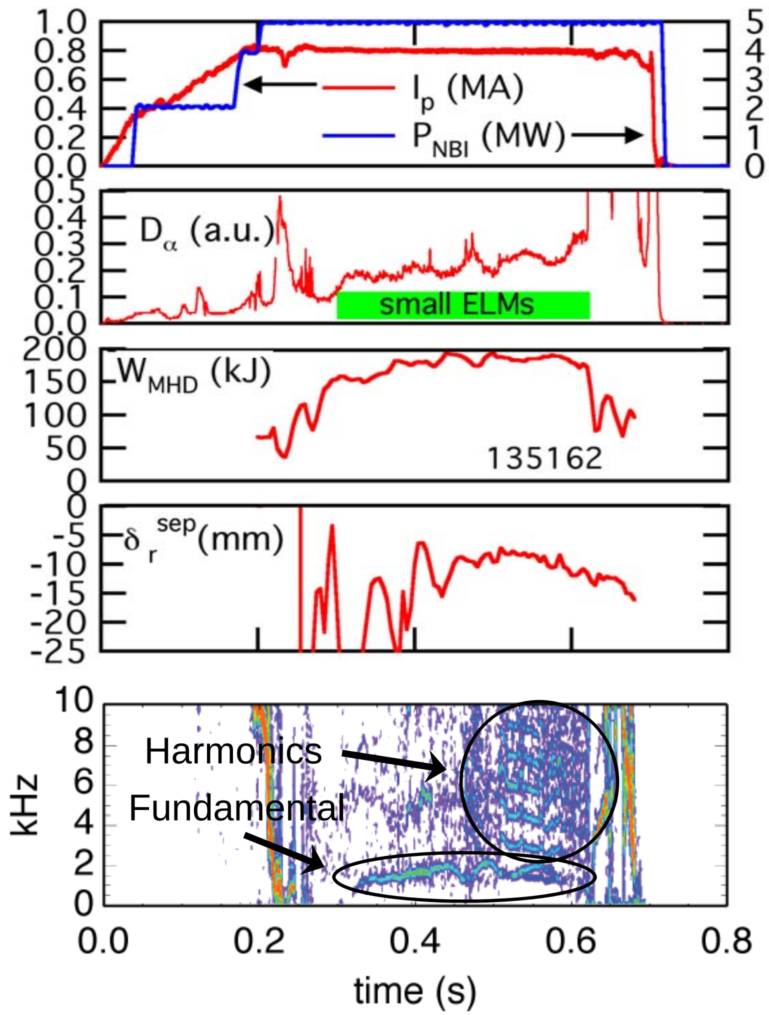
- Small-ELM (Type-V*) operation desirable
  - δW_{MHD} < 1% per ELM

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

- Stabilization of Type-I
  - Type-V always present?

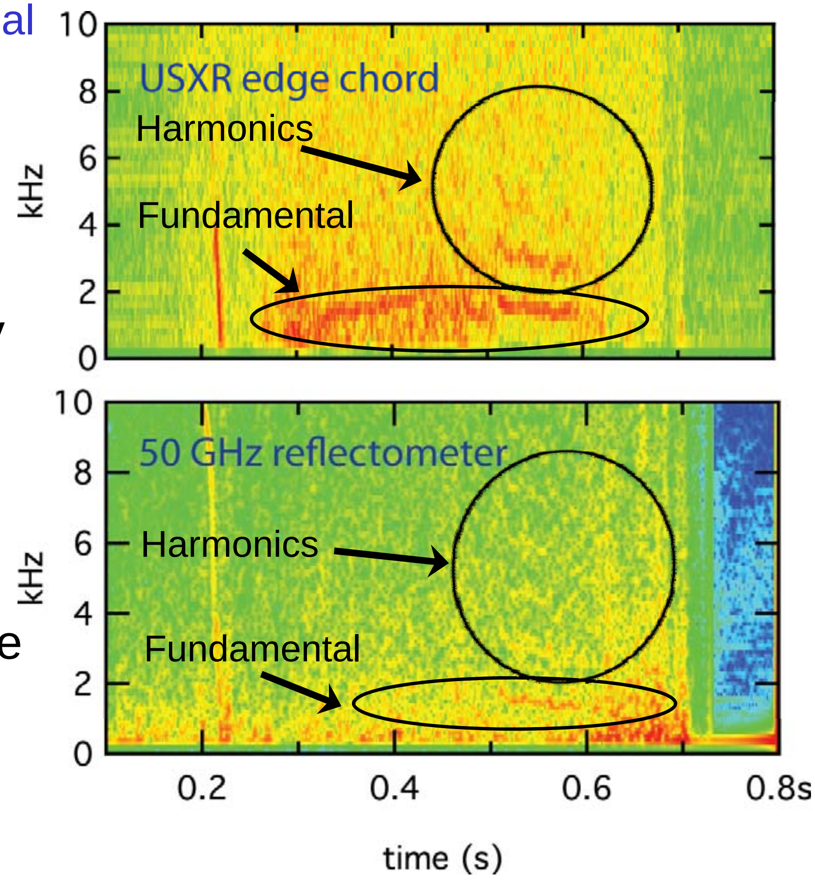
- Downward bias & high edge ν^* required
  - δ_r^{sep} < -5 mm necessary
  - ν^*_{ped} > 1-2

- Low-f (< 10 kHz) oscillations coincident with Type-I ELM transition
  - ST equivalent to edge harmonic oscillation (EHO)?
    - EHO allows access to ELM-free QH-mode at standard-A
    - EHO provides edge transport, reduces peeling-ballooning instability drive



Edge Instability Observed in Multiple Diagnostics

- USXR signal peaks in pedestal
  - peak amplitude in outermost channel with signal
  - 10 μm Be filter eliminates edge light
  - unfiltered USXR shows ELM spikes
  - oscillations not observed inside 130 cm



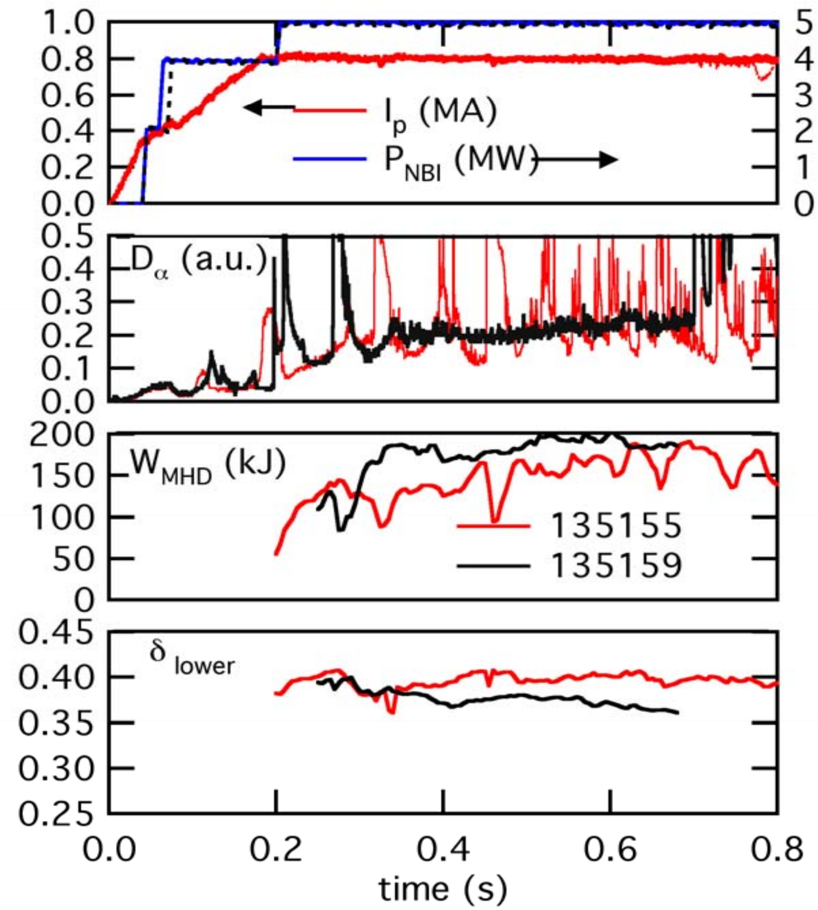
- Edge reflectometer shows very weak density fluctuations
  - R_{cutoff} ~ 142 cm during mode
  - relatively weak compared to core modes

- Edge transport analysis needed to determine if mode is affecting stability
  - accounting for particle sources and sinks

- ELM spikes may be manifestation of mode
  - stabilization of Type-I allowing mode to grow

Type-I ELM Stabilization Observed with Change in Triangularity

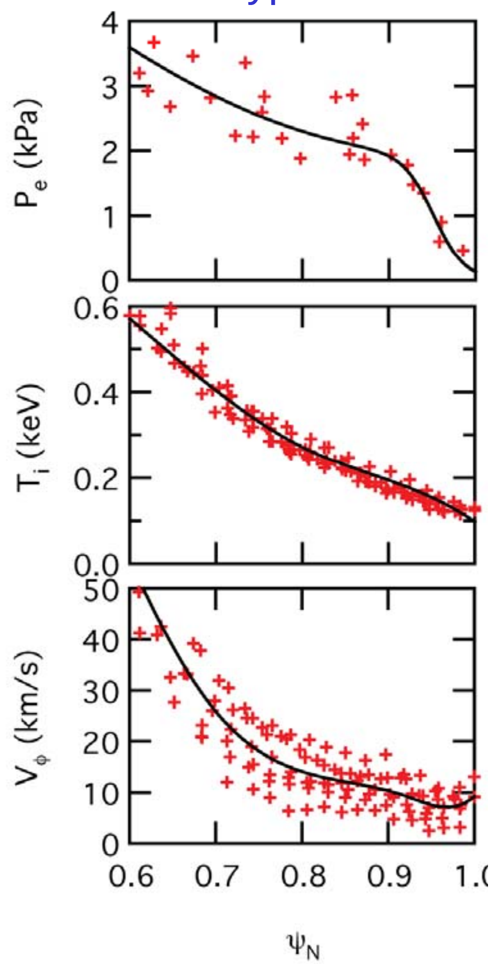
- Both shots have Type-I prior to 0.3 s
  - δW_{MHD} > 10% for Type-I
  - δW_{MHD} < 1% for Type-V
- δ ramp down triggers transition
  - other shape parameters constant
  - plasma moves down in vessel
- Multiple factors could be affecting edge stability
  - shape change affects peeling-ballooning stability
  - downward motion changing δ_r^{sep}
  - fueling affected by moving lower X-point near divertor plate



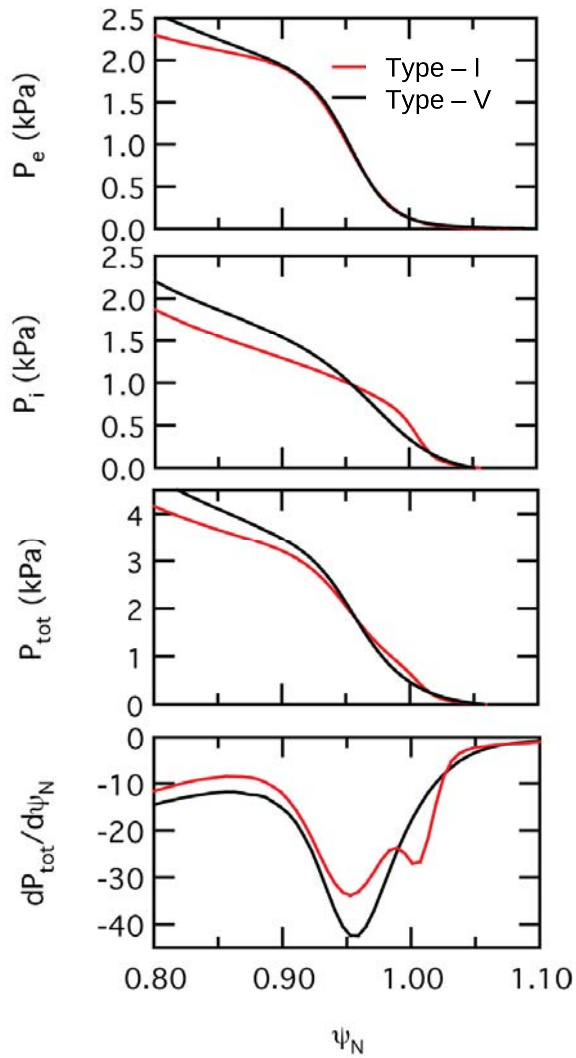
Multiple Time Slice Averaging Used to Analyze Profiles

- 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
  - kinetic EFIT using tanh fits
  - calculate j_{BS} from Sauter model
- Pedestal pressure peak shifted inward & increased for Type-V
  - P_e nearly identical
  - P_i most strongly affected
- Type-V case has higher magnitude pressure gradient
- Need more shots for statistics

Shot 135155
Type - I

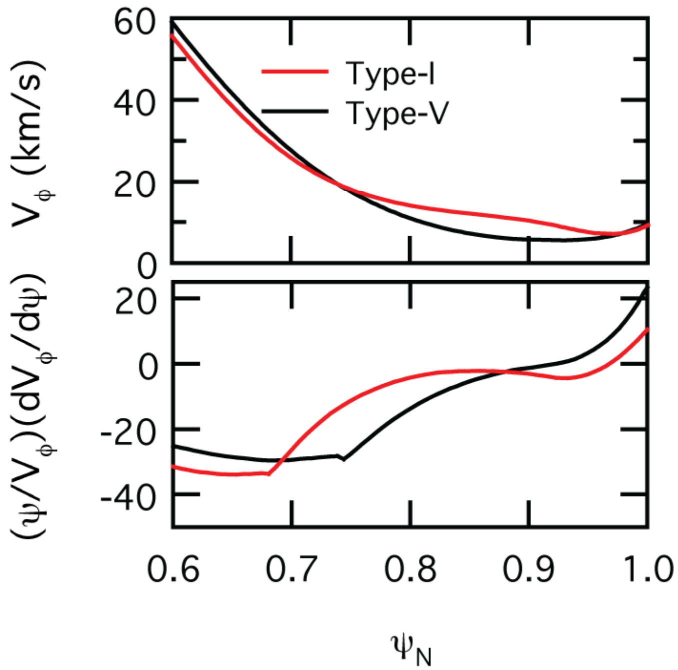


Profile Comparison

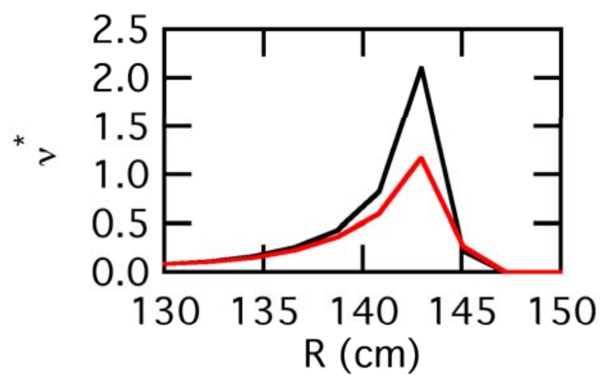


Increased Collisionality May Affect Edge Stability

- No correlation with toroidal rotation or rotation shear
  - consistent across single time database and multi time slice averaged profiles
  - large error bars near edge
  - large relative fluctuations



- Edge collisionality increased in Type-V case
  - consistent with previous observation of increased ν^* stabilizing Type-I*
  - is collisionality altering j_{BS} or indicative of increased edge pressure?

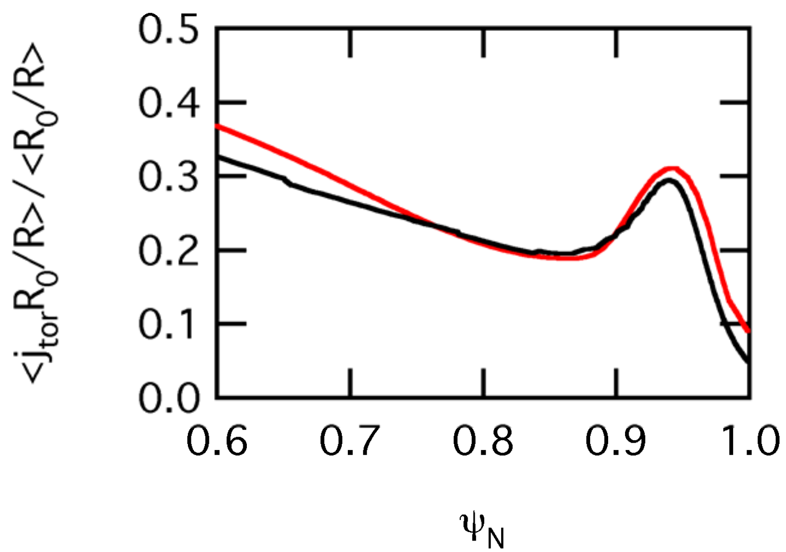


*R. Maingi, *et al.*, *Nucl. Fusion* **45** (2005) 264

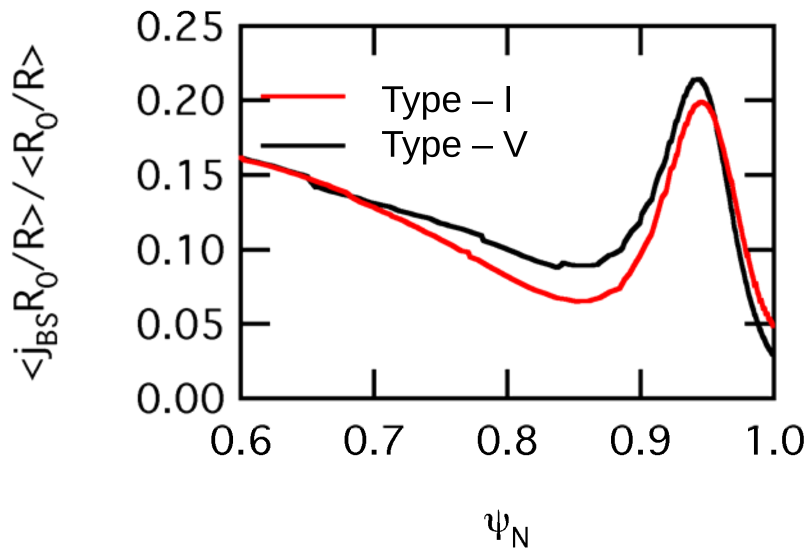
Reduced Edge Current Consistent with Type-I Stabilization

- Edge current slightly reduced when Type-I stabilized
  - j_{BS} slightly increased in Type-V case
    - increased pressure dominating over increased ν^*
- Additional shots being analyzed for statistics
  - need peeling-ballooning stability calculations, not just <j> comparison

Toroidal Current Profiles



Bootstrap Current Profiles

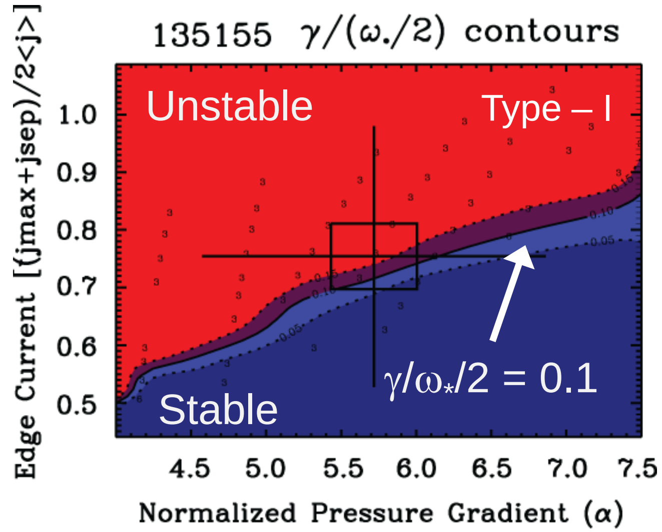


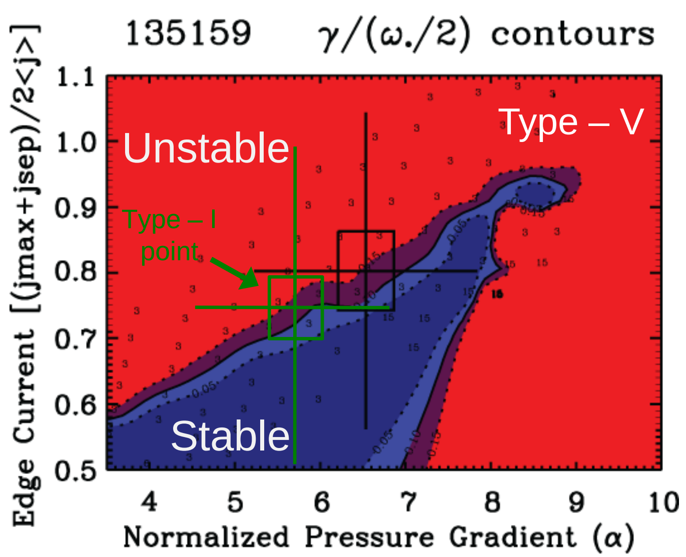
ELITE Shows Type-V Case Closer to Ballooning Boundary

- n = 3 most unstable for both cases
  - calculation run for n = 3, 6, 9, 12, 15
  - PEST also shows n = 3 most unstable
  - NSTX typically on peeling side of curve
    - ST geometry naturally leads to higher j_{BS}
    - high shaping stabilizing to ballooning

- Decreased δ moves ballooning boundary closer to operating point
  - near to n = 15
  - n = 1 or 2 seen in USXR due to Type-V filaments

- Change in stability space not the same as ELMy to QH-mode change
  - EHO moves operating point across peeling boundary in DIII-D
  - both NSTX cases still on peeling boundary





Note different scales!

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
  - mode may be source of Type-V ELM spikes
- 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-I ELM stabilization
  - 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
  - is mode just the result of stabilizing Type-I ELMs?