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XP1031: MHD/ELM stability dependence on thermoelectric J, edge J, and collisionality

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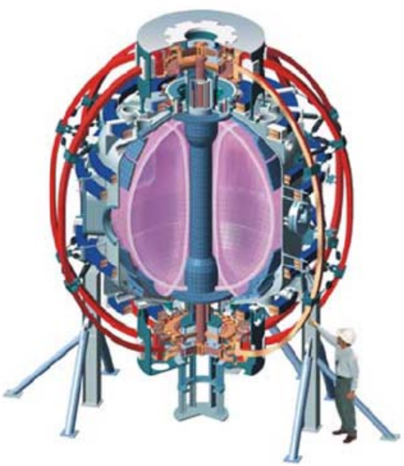

NSTX Team Meeting
June 2nd, 2010
Princeton Plasma Physics Laboratory

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XP1031: MHD/ELM stability dependence on thermoelectric J, edge J, and collisionality

- Motivation
  - Test the role of field-aligned and toroidal current and collisionality in ELM stability, making connection to general macroscopic stability
  - Verify a broader model of ELM stability that is consistent with existing work, and further explains apparent incongruities from present experiments
- Goals/Approach
  - Test expectations of expanded ELM stability theory using relatively straightforward machine capabilities
    - Focus on altering field-aligned and edge toroidal J, 3D field amplitude, collisionality
  - Determine if ELM stability follows theory
    - May provide understanding of ELM mitigation/excitation
    - Link expanded theory to peeling/ballooning model, link to general ideal stability
- Addresses
  - ITPA experiments R10-1, R10-3, MDC-2, PEP-25; ITER Urgent task re: ELMs

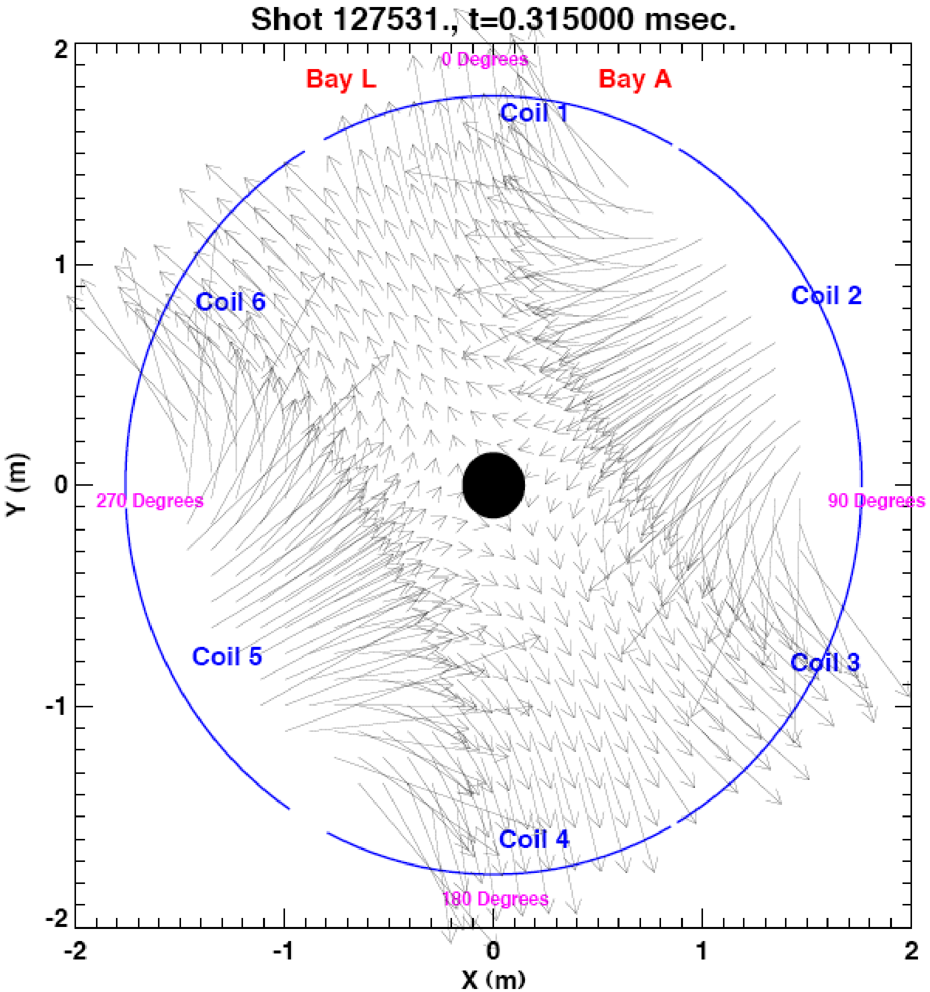
XP818: Successfully altered ELM stability, but left us with more questions than answers…

- Approach/Expectations
  - Mitigate ELMs by ergodizing plasma in the pedestal region using non-axisymmetric (3D) field, reducing pressure gradient drive of ELM
    - Expand past NSTX XP by Evans, et al., that used only n = 3 DC fields
  - Calculated favorable 3D field spectra for ELM mitigation, based on Chirikov profile and DIII-D experience
    - Vacuum and IPEC studies conducted by J-K. Park to determine best configurations
    - Various fields - odd and even parity, both AC and DC fields run in experiment
    - Lower q_{95} target plasma thought favorable
- Reality
  - Favorable NA applied fields triggered ELMs, *rather* than mitigating them
    - ELM frequency changed, compound ELM events produced
    - ELM dynamics changed for odd, even, mixed parity ("2+3") 3D fields, AC and DC fields produced similar results
    - Supported further studies by Canik, et al. to trigger ELMs "on-demand"

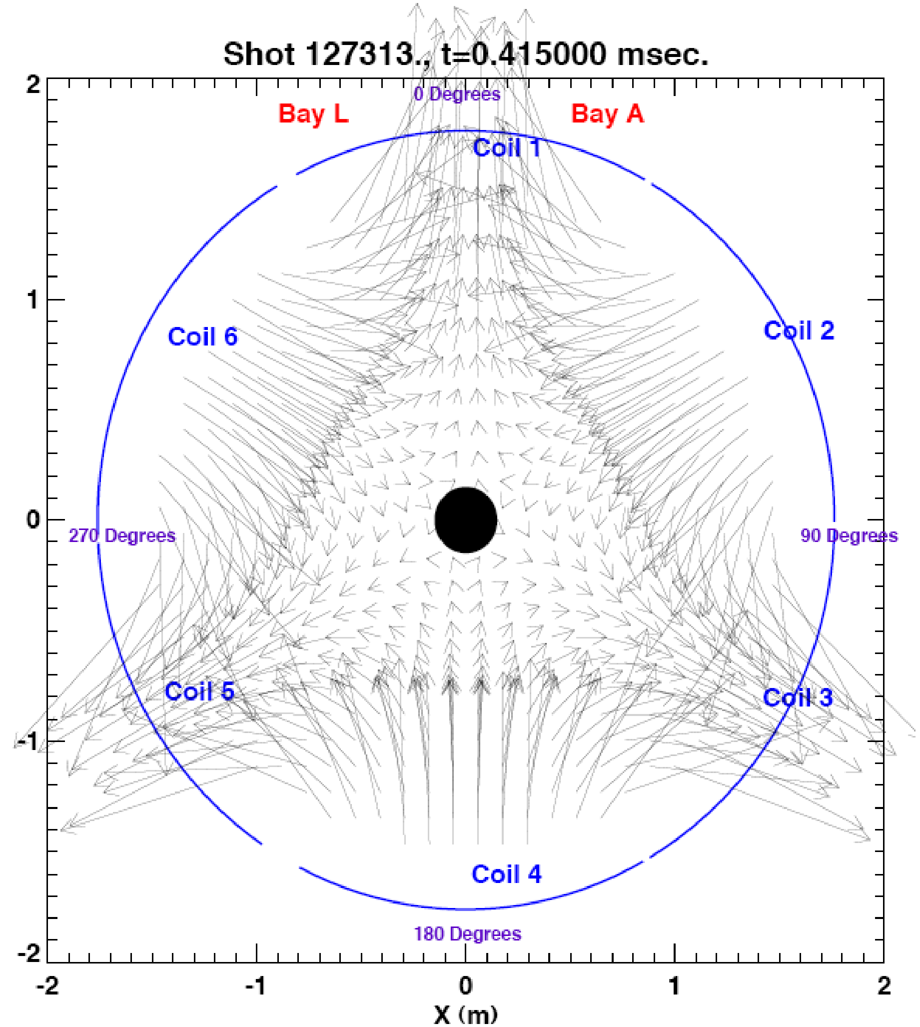
What physics model can explain these unexpected results?

XP818: New n = 2 config. used to compare to past n = 3 results

n = 2 field configuration (planform view)



n = 3 field configuration (planform view)

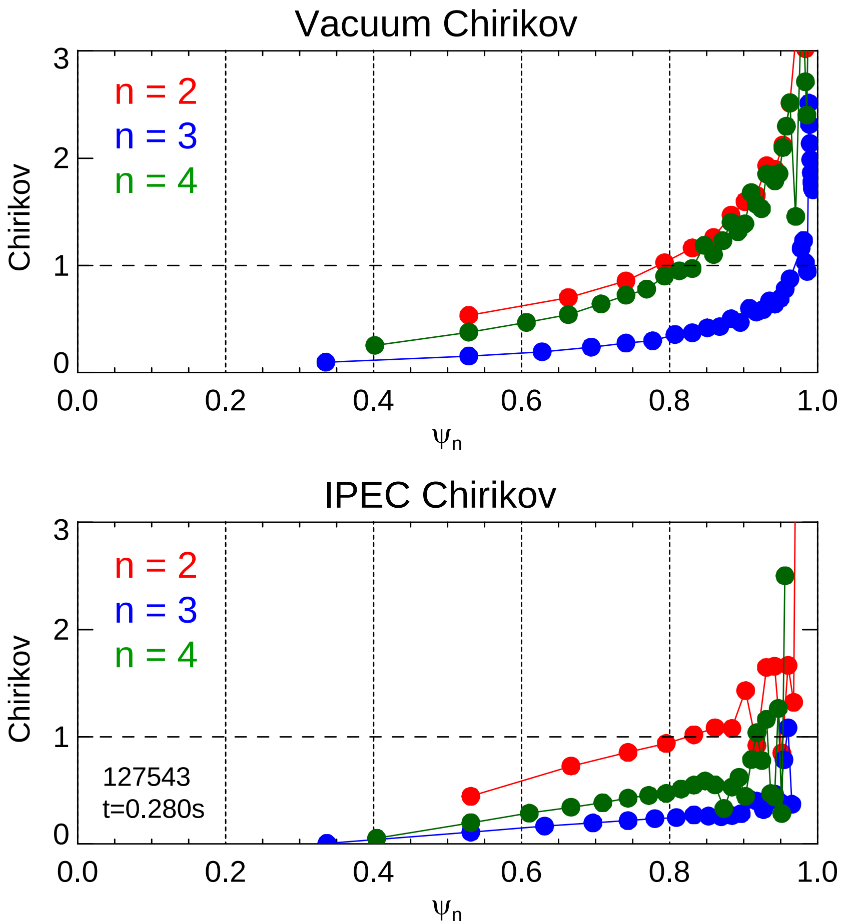


S.P. Gerhardt

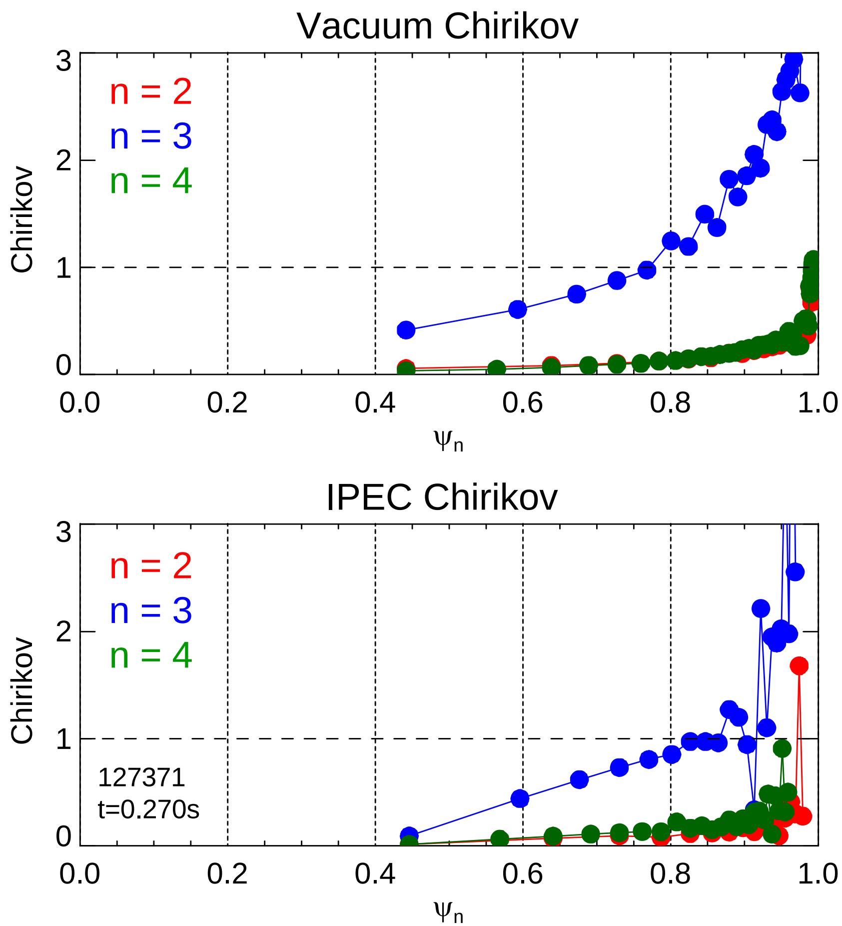
NSTX

XP818 Vacuum, IPEC computed Chirikov parameter > 1 near edge for n = 2, n = 3 field configurations used in experiments

n = 2 field configuration, q_{95} = 7.4



n = 3 field configuration, q_{95} = 7.7



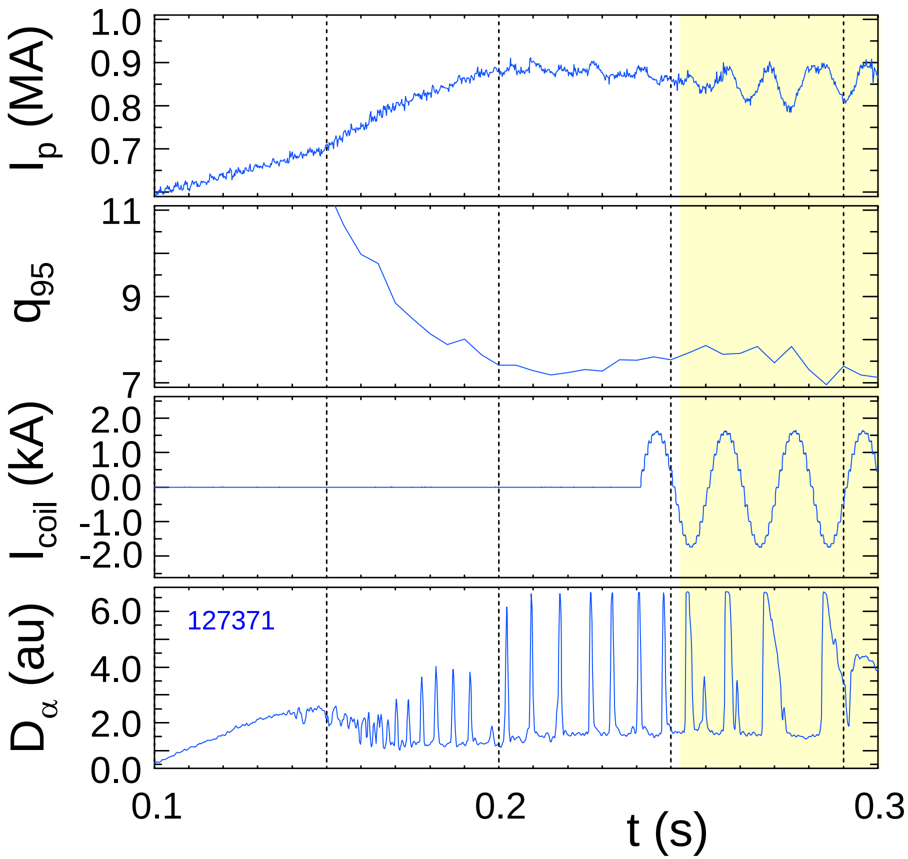
- IPEC shows n = 4 significantly reduced
- n = 3 Chirikov > 1 at ψ_N ~ 0.8

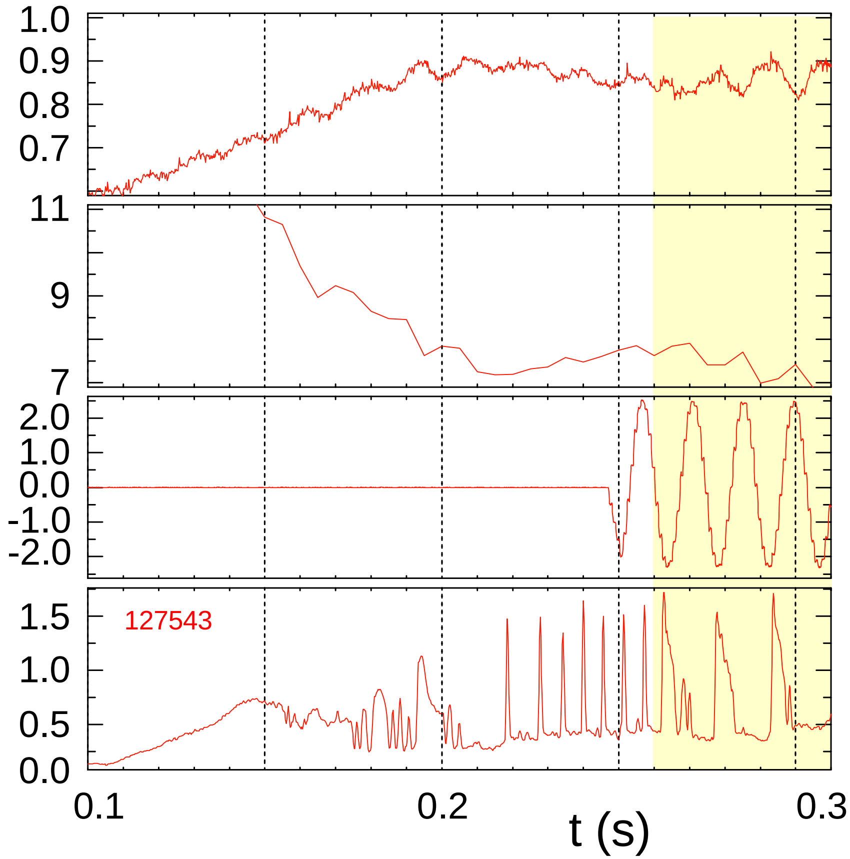
J-K. Park

XP818: Reduced ELM frequency, increased D_α duration observed in AC applied field configurations

n = 3 AC field, 70 Hz, 3.8 kA peak-to-peak

n = 2 AC field, 70 Hz, 5.5 kA peak-to-peak





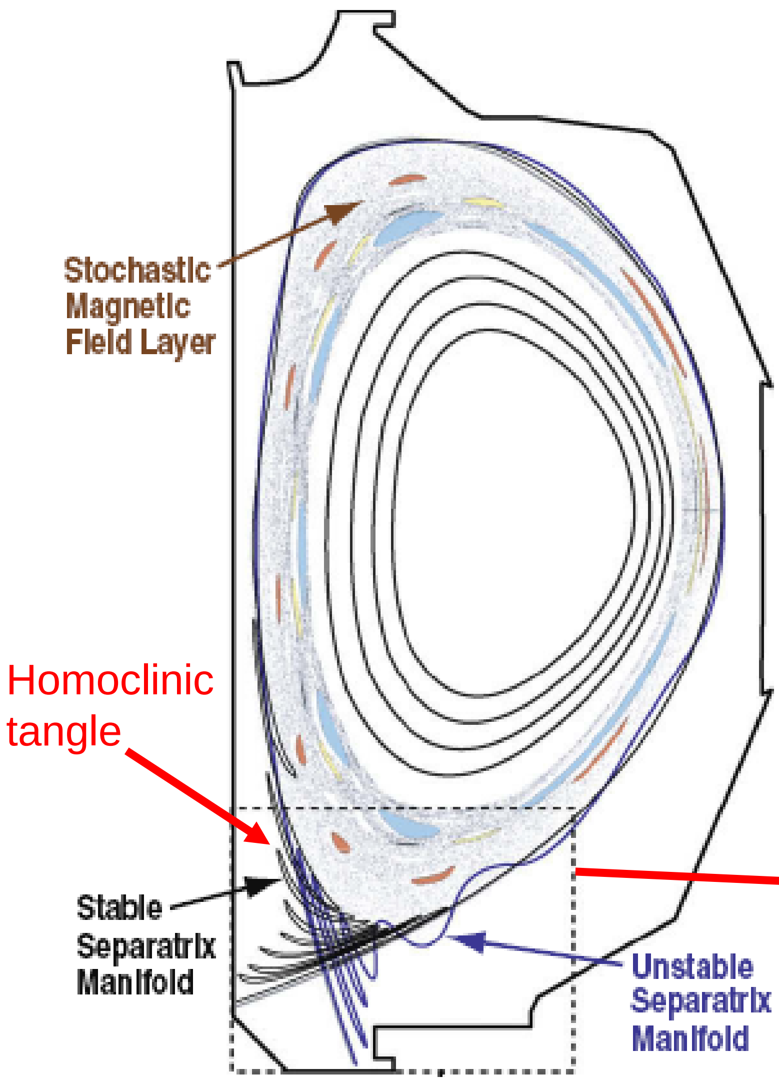
- ELMs broaden, roughly match frequency of applied field
- Broadening due to multiple ELMs/filaments “compounded” together
  - effectively decreases frequency

NSTX

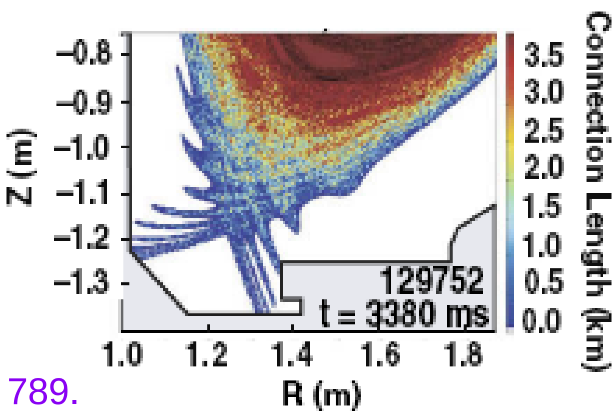
Test an expanded model for ELM stability in NSTX

- Stability model / Features
  - Consider a model that addresses non-linear ELM dynamics
    - Highlight of present model is instability drive due to thermoelectric (TE) currents (Evans, et al., JNM 2009)
      - 3-D field splits smooth separatrix surface into two unique invariant manifolds
      - Overlap of these invariant manifolds creates a “homoclinic tangle”, enhances TE current
    - Behavior of model can be tested in controlled NSTX experiment
      - Higher 3D field amplitude increases TE current – DESTABILIZING (XP818)
      - TE current connection length decreases as X-point moved closer to wall – DESTABILIZING
        - » LSN vs. USN should be differ due to grad(B) drift – scaling unknown
      - as pedestal electron collisionality decreases: (i) ELM size / depth of penetration increases, (ii) ELMs become larger, have lower frequency
  - Model is complementary to standard peeling/ballooning model
    - Results of peeling/ballooning linear growth model for NSTX (R. Maingi, et al. PRL 2009) examine grad(p) drive; present study expands to other sources of instability
- Test / compare TE current drive to toroidal current instability drive
  - Positive edge toroidal current drives macroscopic MHD instabilities
    - Grad(p) drive already tested by Maingi, et al. Focus here on current drive and collisionality aspects of the instability

TE current connection length decreased by 3D field

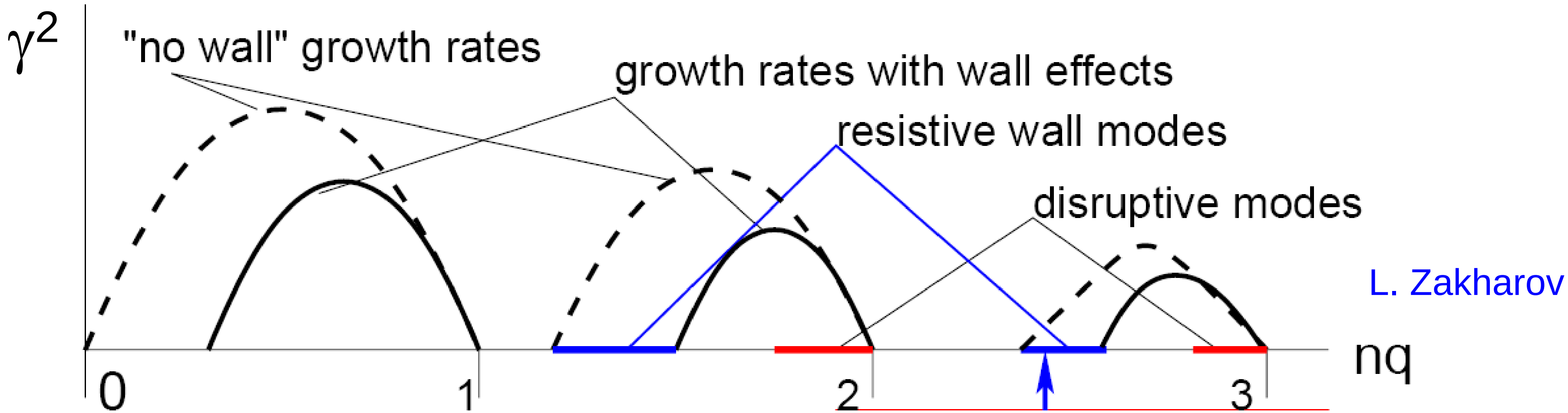


- Straightforward experimental approaches to vary key physics parameters in XP
  - Vary TE current connection length
    - Shift plasma vertical position (LSN, DND, USN)
    - Closer proximity to the wall is destabilizing
  - Vary 3D field amplitude
    - Larger field amplitude is destabilizing
  - Vary toroidal current density near the edge
    - Increased J increases peeling mode drive
    - Compare ramped vs. fixed q cases
      - Examine possible resonance effect
      - Homoclinic tangle rotates when |dq/dt| > 0, can change TE, changing stability
  - Vary collisionality with LLD (when pumping)



T.E. Evans, et al., Jour. Nucl. Mat. **390-391** (2009) 789.

Ideal MHD model expects stabilizing/destabilizing resonance effect near marginal stability



- Connect peeling/ballooning mode current drive to q resonance variation
  - Slow I_p ramps at fixed B_t will scan q
    - Examine "which q" matters
      - If plasma is ergodized from the pedestal outward, then it's the first key rational outside of the pedestal position
    - Note that finite |dq/dt| will lead to rotation of homoclinic tangle and modulation of the striations – observable by fast IR camera (TE current modulated as well)
  - Slow I_p ramps at fixed q is an important comparison to finite |dq/dt| case

XP1031: MHD/ELM stability dependence on thermoelectric J, edge J, and collisionality – shot plan

Task	Number of Shots	
1) Generate target		
A) Preferable is LSN ELMing plasma target (shot 137564), suitable for +/- Z movement	2	
- (choose 3D field magnitude based on XP818 experience: n = 3 configuration also allows use of n = 1)		
- Plasma control: suggest (i) PF3-boundary position (squareness), (ii) DRSEP, (option: use outer SP control)		
2) Vary TE current connection length at fixed 3D field		
A) LSN: vary Z until ELMs appear or disappear (three Z positions)	5	
B) DND:	2	
C) USN: (two Z positions) - (contrast grad(B) drift direction / effect to condition (2A))	4	
3) Vary 3D field amplitude		
A) near marginal condition from (2), still ELMing, decrease n = 3 field until ELMs go away	3	0.5 day
B) near marginal condition from (2), not ELMing, increase n = 3 field until ELMs return	3	
4) Vary toroidal current density near the edge		
A) near marginal condition from (2), still ELMing, decrease I_p with slow ramp, attempt ELM stabilization	3	
B) near marginal condition from (2), not ELMing, increase I_p with slow ramp, for ELM destabilization	3	
C) redo (A) and (B) with TF ramp up/down to keep q approximately fixed	4	0.5 day
5) Vary collisionality with LLD		
A) Rerun successful conditions above at reduced collisionality with LLD	16	

Total: 29; 16

XP1031: MHD/ELM stability dependence on thermoelectric J, edge J, and collisionality – Diagnostics, etc.

- Required diagnostics / capabilities
  - RWM coils in standard n = 1,3 configuration
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - MSE
  - Standard magnetics / diamagnetic loop
- Highly desired diagnostics
  - LLD shunt tile measurements of SOL currents
  - Langmuir probes set up for edge current measurement
  - Fast IR camera and/or LLD fast cameras
  - USXR