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Disruption/NTM/EF/Shaping research in NSTX

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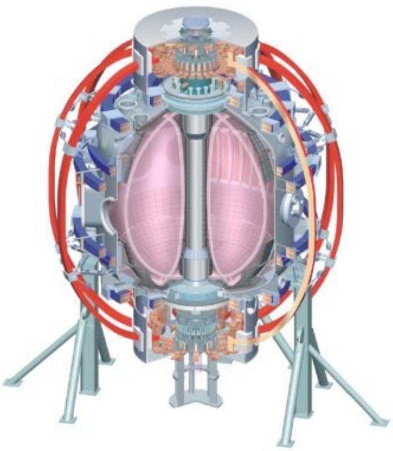
J-K Park

This Font For Active Experimental Effort in 2009

Science Focus Group
December, 2008



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U Quebec

A Program For Disruption Research

- Characterization of Disruptions
- Soft Landing Of Troubled Plasmas (not discussed here)
- *Fast Shutdown Techniques*

Important To Systematically Assess Disruption Consequences

- Halo Currents
  - Added magnetic vessel current sensors last year, ***4 instrumented tiles in lower divertor this year*** *(SPG, E. Fredrickson, H. Takahashi)* , more next year if design successful.
  - As data matures, need modeling capacity to match:
    - TSC & DINA are axisymmetric tools, M3D for toroidal peaking+HC fraction?

- Thermal Quench Heat Loading
  - ***This year : Fast IR thermography + fast USXR*** *(SPG)*.
    - Spatial & temporal structure of divertor and/or first wall transient heat loading.
  - Modeling of the thermal collapse field structure would be fascinating
    - Is it possible to predict the TQ timescale or SOL broadening?

- Disruption Runaway Electrons
  - Atypical in NSTX, though discharges can likely be made which generate a Dreicer tail.
  - Huge problem for ITER, due to large avalanche gain (~e^3 in JET, ~e^{15} in ITER)
  - ***This year: Proposal to develop scenario with disruption runaways, try to deconfine them with 3D fields*** *(SPG)*.

A Reactor Needs a Fast Shutdown Method

- ***This year : CHI for Fast Shutdown*** *(R. Raman, SPG)*
  - If an ST reactor has a CHI system, then could it be used for fast shutdown?
  - Axisymmetric injection of plasma and gas from the bottom of the device.
  - Can be very rapid (1-2 msec)
  - Test suitability in terms of rapid shutdown, *VDE avoidance,* VDE suppression
- Future Possibility: CT Injection
  - Can Be Very Fast
    - MGI limit by sound speed of gas down long tube, while CT limited by gas into injector (permanent magnet for bias flux, rapid translation).
  - Can Tailor the CT Properties
    - CT size, composition, velocity can be tailored to for deposition at the desired radial location.
  - Unclear that CHR density is achievable this way

- Question: Is it necessary to test massive gas injection on an ST?
  - Present understanding involves cold pulse which destabilizes 2/1 & 1/1 modes, leading to field stochastization and thermal collapse.
  - Does this largely carry over to low-A, or should we test it as well?
    - ITER question: radiation asymmetry at location of jet could melt 1st wall.

NTM Research

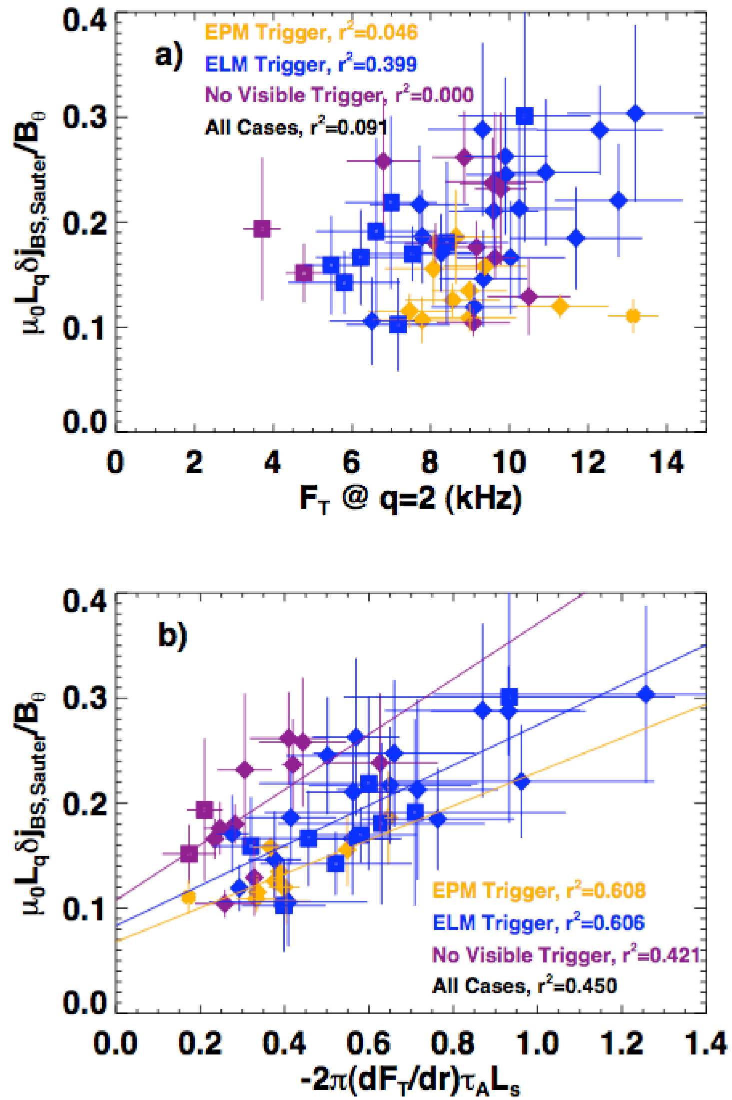
- *Rotation and EF Dependence of 2/1 Mode Onset*
- Coupling of 2/1 and 1/1 modes (not discussed here…backup slide)
- *Elimination of the 2/1 mode with Li Conditioning*
- *Aspect Ratio Scaling of 2/1 NTM physics (not discussed here)*

Onset of the 2/1 Mode Influenced By Rotation Shear

- Large database analysis of the NTM drive at time of 2/1 mode onset.
  - Compare onset drive to flow, flow shear, differential flow.
  - Best correlation is with flow shear, normalized by $\tau_A L_s$.

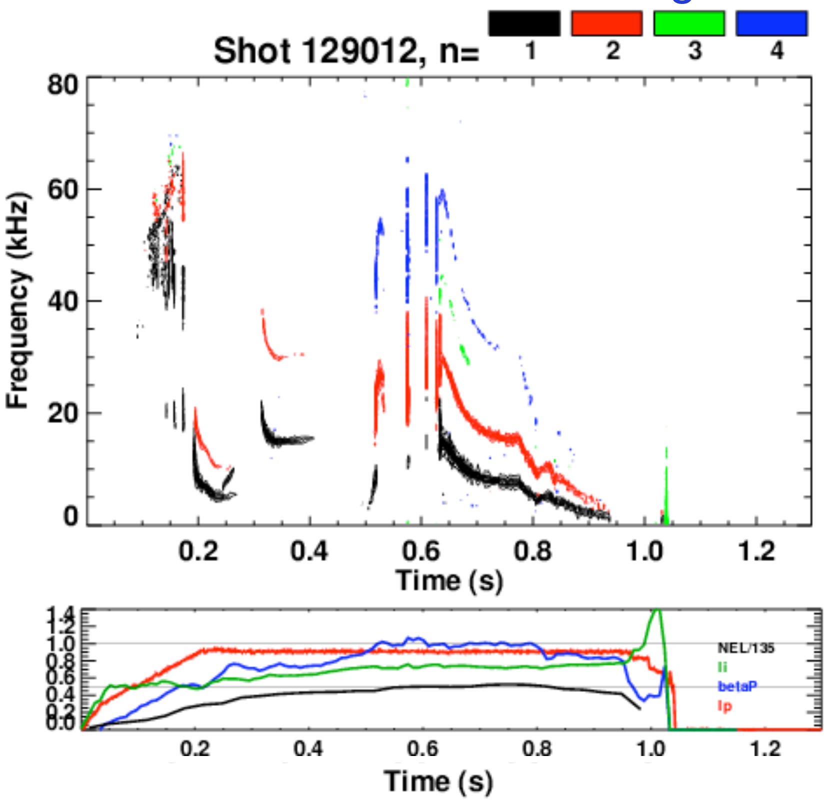
- Considerable literature on TMs and flow shear…and none of it is really applicable.
  - Chen & Morrison, slab geometry: Flow shear can be stabilizing or destabilizing, depending on its magnitude.
  - Coelho, cylinder: TM is stabilized with negative flow shear for large viscosity, but destabilized for small viscosity.
  - Chandra, cylinder: TM is either stabilized or destabilized, depending on details of flow profile (model with helical flow).
  - Could benefit from theory/simulation support.

- ***This year : Extend these studies to examine the sensitivity of NTM onset to n=1 EFs at high and low rotation.*** *(R. Buttery, SPG)*

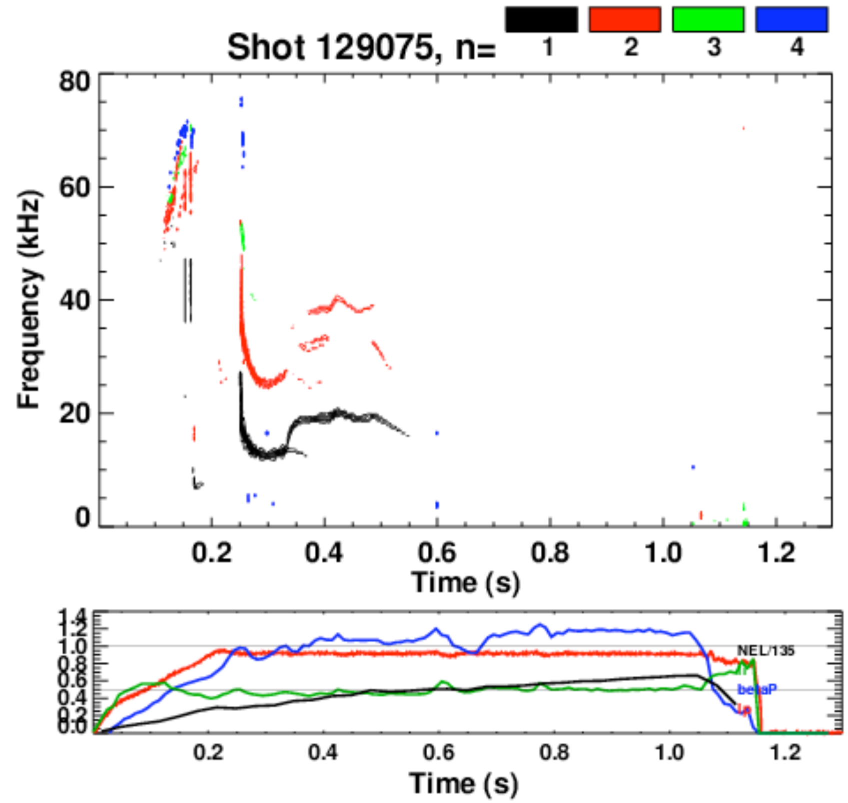


Lithium Surface Coating Cause Coupled 2/1+1/1 Modes to Disappear

Before Lithium Conditioning



After Lithium Conditioning



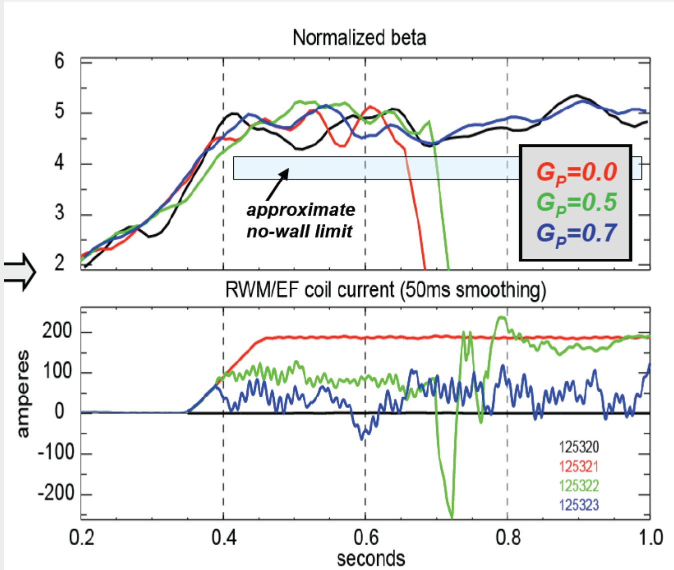
- "Identical" shots from the NSTX control perspective, but evolution is different (n_e, l_i, β_P)
- Possible hidden variables:
  - Triggers may be different (NTM is often metastable). For instance, ELMs disappear with lithium.
  - Current profile variations may modify classical tearing stability (Δ')
- ***This year : Add a study of impurity effects and Li conditioning on 2/1 onset** (F. Volpe, SPG)*

EF Research

- Continued optimization of n=1 DEFC (SAS talk, not discussed here)
- Non-resonant EF correction
- Plasma response studies using the IPEC code

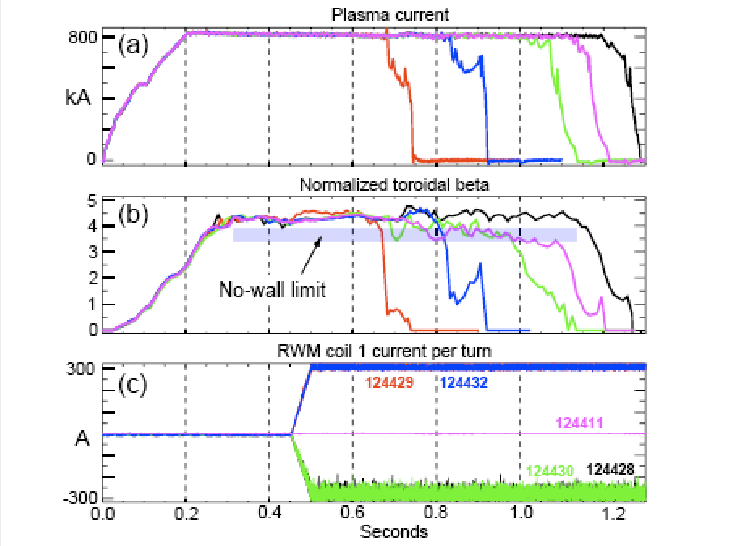
n=1 feedback Trained by RFA Suppression

Feedback System Trained for n=1 DEFC



- Apply preprogrammed n=1 error fields
- Adjust feedback gain, phase, so that feedback cancels those currents.
- *Turn off preprogrammed n=1 and retain optimal RFA suppression!*

Important to Correct Non-Resonant Error Fields



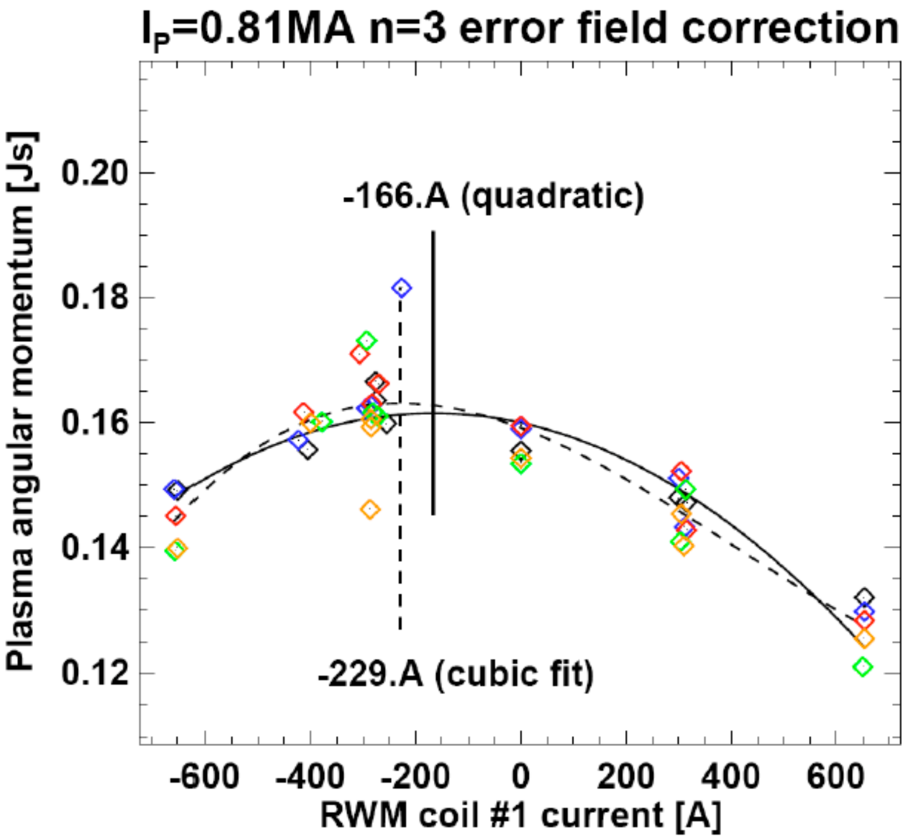
- Pre-programmed n=3 fields, two possible phases
- Asymmetric response in rotation and pulse length
  - There is an n=3 error field!
- Appears to be related to PF5 or TF, preprogrammed correction now routinely utilized
- n=2 error fields found to be less important

This and Further Optimization Lead to a Set of Standard Feedback Parameters

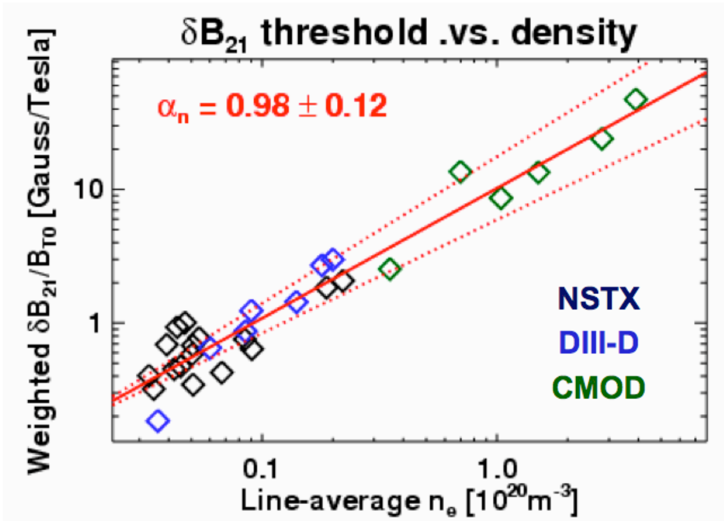
τ_{LPF}=0.002, G=0.7, ϕ_{FB}=270, $I_{n=3}$=300A

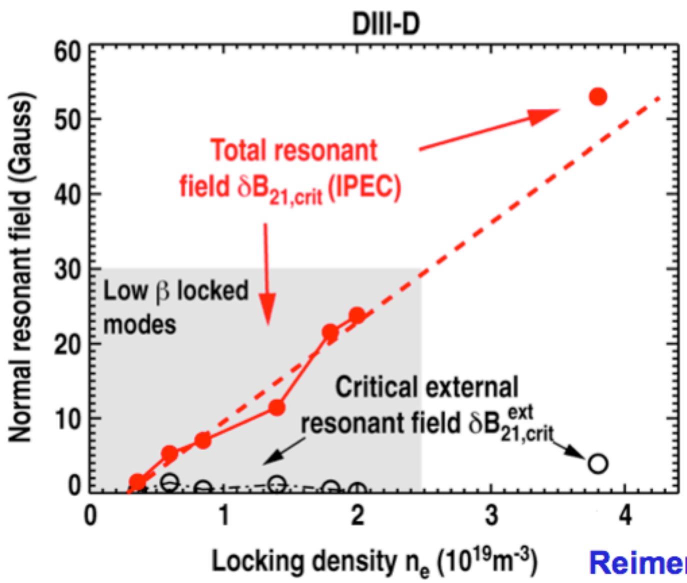
Cause of n=3 EF Likely the Main VF Coil (PF5), But TF Coil Remains a Possibility

- Optimal n=3 correction found for three configurations ($I_P \rightarrow I_{PF5}$, I_{TF})
- Optimal correction correlates better with PF5 than TF.
  - R^2=0.99 for the PF5
  - R^2=0.71 for the TF
- ***This year : continued effort to break the degeneracy in the dataset, pin down the culprit coil.*** *(SPG)*
- Improve the realtime EF correction:
  - Now: preprogrammed n=3.
  - Future: tie the correction to the offending coil.
- However, with 6 midplane coils, impossible to perfectly match the toroidal phase or poloidal spectrum of the n=3 perturbation.



Plan To Study High-β Locked Modes Using IPEC





Reimerdes et al, IAEA (2008)

- IPEC=Ideal Perturbed Equilibrium Code
- US tokamaks have a similar density scaling for low-β locked mode threshold, when IPEC is used.
- DIII-D shows linear scaling into high-β regime if IPEC is used to calculate total 2/1 field.
- ***This year: Extend these studies to high-β in NSTX*** *(J.K. Park)*
  - Scaling the vacuum response implies that 10 kA of EF coil current are required for locking.
  - IPEC "total field" predicts that ~2kA will cause locking.
  - Control room experience is indeed that 2kA of n=1 is deadly, but systematic scans will be done.

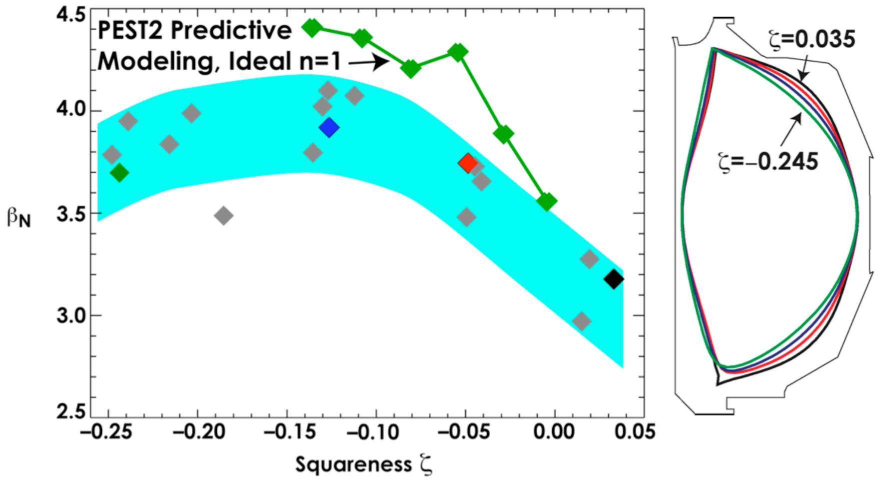
Improved Performance Through Plasma Shaping

- Optimization of high-elongation plasmas for:
  - high non-inductive fractions ((D. Gates) not discussed here)
  - high toroidal-β ((SPG) not discussed here)

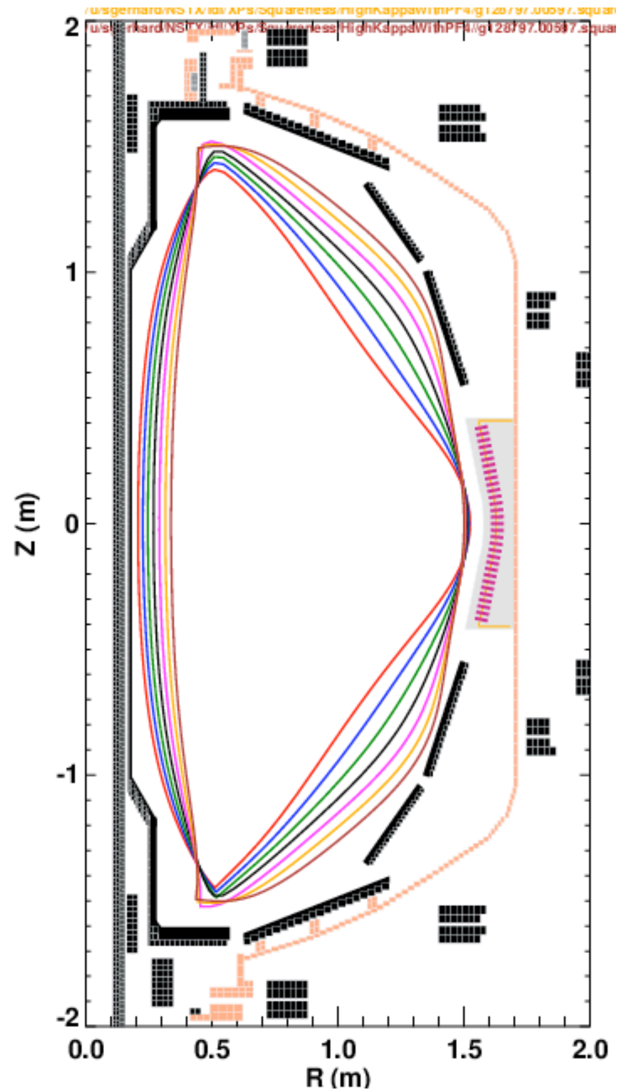
- Role of discharge squareness in modifying stability and confinement. (SPG)

Plan to Vary Discharge Squareness With Other Shape Parameters (Almost) Fixed

2008 APS Invited Talk by C.T. Holcomb,



NSTX Squareness Variation in DN, High-κ,δ

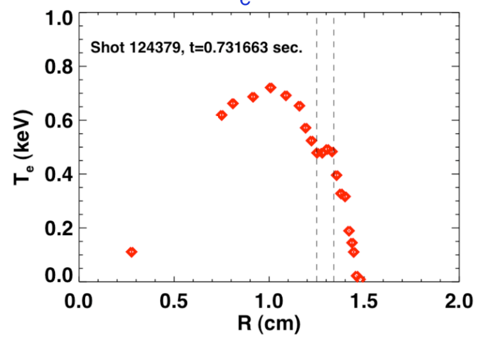


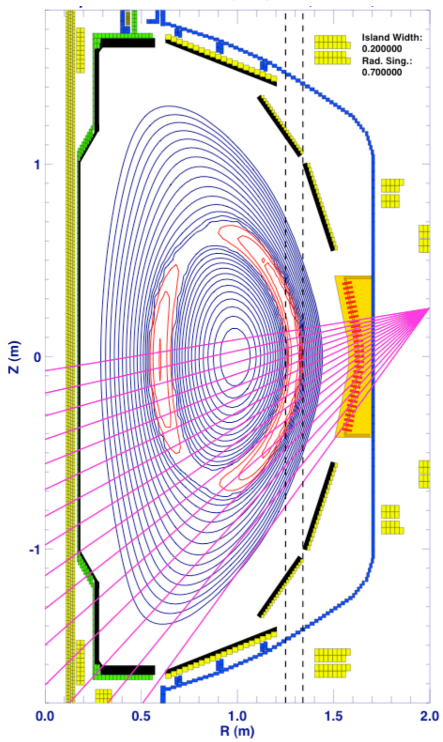
- In DIII-D, low-squareness observed to:
  - Improve global n=1 β_N limits
  - Increase the pedestal stability
  - Improve core transport
- NSTX can modify the outer squareness, though something else must change as well.
- ***This year: Systematically scan this parameter, studying confinement and stability.*** *(SPG)*

Backup

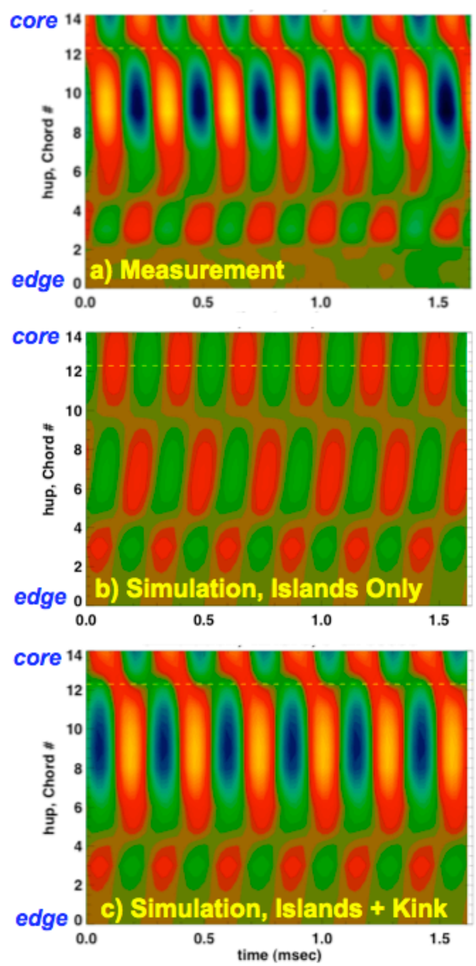
2/1 Modes Coupled to 1/1 Kinks
How does this impact

Constrain Island Model By T_e Profile





Simulate USXR Emission



Add “Ideal Kink” to Island Model