NSTX-U

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MHD Ideas For the 5-Year Plans

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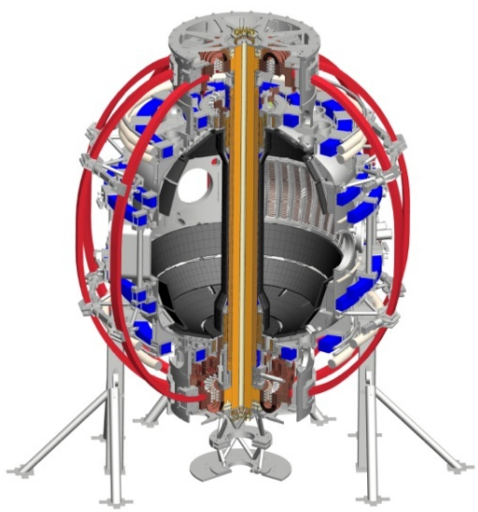
NSTX Team Meeting
B318
6/26/2012



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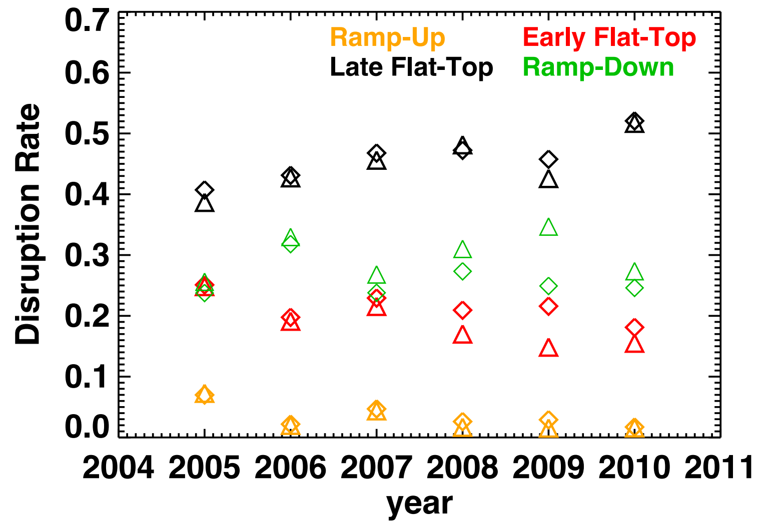
Comment on Disruptivity and the ASC/MS/BP TSGs

- NSTX-U should try to reduce its disruption rate compared to NSTX.
- MS primarily responsible for n>0 effects.
  - RWM physics/control.
  - Error field physics.
    - *Error field characterization and control should have a lead role in year 1 MS plans.*
  - Internal kink & tearing physics.
- ASC primarily responsible for n=0 effects.
  - Boundary & profile control
  - Ramp-up and ramp-down optimization and automation
    - Goal: at least attempt an intervention in every disruption



- BP & LRTSG responsible for fuelling and divertor physics
  - Cryo-pumps and lithium systems
  - Heat flux mitigation schemes that protect both the divertor and the plasma.

Need to prioritize profile diagnostics and associated control development

	Control Usage	Physics/Operations Benefit	Status/Prospects
Realtime V_{fl}	• Rotation Control • Disruption Detection	• Maintenance of optimal rotation profiles for global stability and thermal transport. • Earlier disruption detection.	• System hardware developed. • realtime & offline analysis with BL #2 yet to be developed.
Realtime MSE	•rtEFIT constraint •q_0/q_{min}/q-profile control	• Maintenance of optimal q-profile for global stability and thermal transport.	• Funded collaborator diagnostic. • Detailed system development occurring now.
Realtime MPTS	•rtEFIT constraint •Disruption detection •Density feedback	• Better rtEFIT reconstructions (outer gap). • Improved reliability of the startup. • Earlier disruption detection.	• MPTS will be present, but realtime development unclear. • Unclear how much effort is required to use as rtEFIT constraint.

- All this in the context of a first year operating campaign with reduced time for physics studies.
  - Diagnostic physicists placing highest priority on off-line diagnostic development.
- S{G Suggestion:
  - Focus on the realtime measurements during the first year.
  - Select most mature measurements for control loops in 2nd year.

Ideas

- Early MHD and lower density operation
- Internal kink / infernal mode dynamics
- Disruptions: halo currents

Collisionality is Most Strongly Impacted By Density

Temperature is calculated as:

$$T=\frac{P\tau}{n}=\frac{B_T\beta_N a}{f_{GW}}$$

Relate the power and β_N as:

$$\beta_N=\frac{nTa}{I_P B_T}=\frac{P\tau a}{I_P B_T}$$

$$P=\frac{I_P B_T \beta_N}{a\tau}$$

Plasma current and density in terms of q_{cyl} and f_{GW}.

$$I_P=B_T R_0 \varepsilon^2\left(1+\kappa^2\right)/q_{cyl}$$

$$f_{GW}=a^2 n_e/I_P \Rightarrow n_e=f_{GW} I_P/a^2$$

Solve for collisionality:

$$\nu^*=\frac{R_0}{\varepsilon^{3/2}}\frac{n_e}{T_e^2}q_\nu^\eta=\frac{R_0}{\varepsilon^{3/2}}\frac{f_{GW}I_P}{a^2}\frac{f_{GW}^2}{B_T^2\beta_N^2a^2}q_\nu^\eta=$$

$$\frac{R_0}{\varepsilon^{3/2}}\frac{f_{GW}}{a^2}\frac{f_{GW}^2}{B_T^2\beta_N^2a^2}\frac{B_T R_0\varepsilon^2\left(1+\kappa^2\right)}{q_{cyl}}q_\nu^\eta=$$

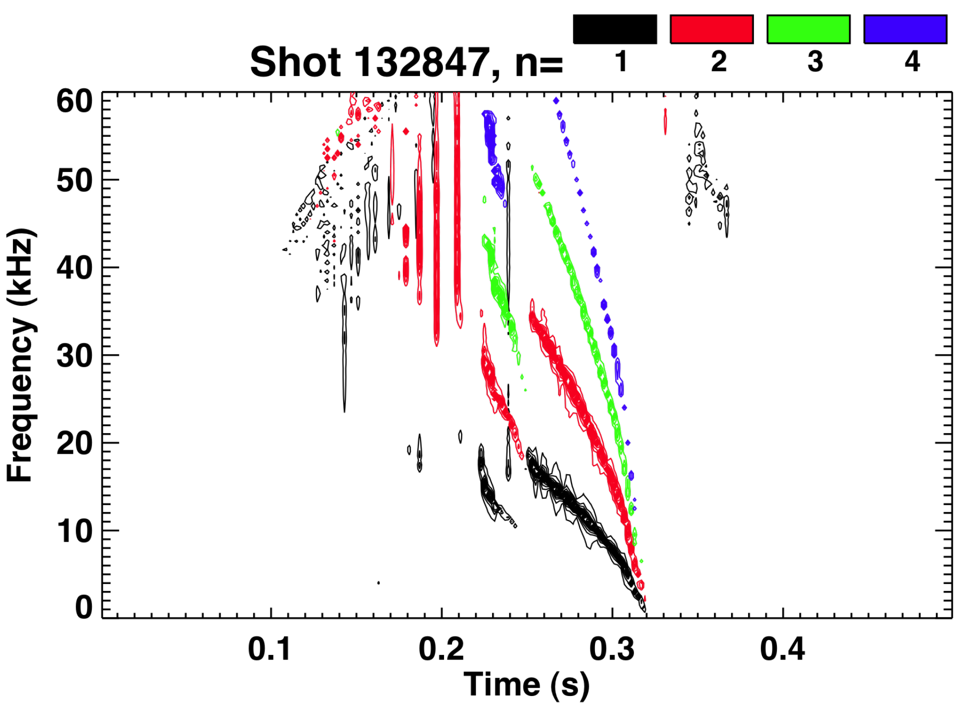
$$\frac{R_o^2}{}\frac{1}{a^4}\frac{f_{GW}^3}{B_T\beta_N^2}\frac{\varepsilon^{1/2}\left(1+\kappa^2\right)}{q_{cyl}}q_\nu^\eta$$

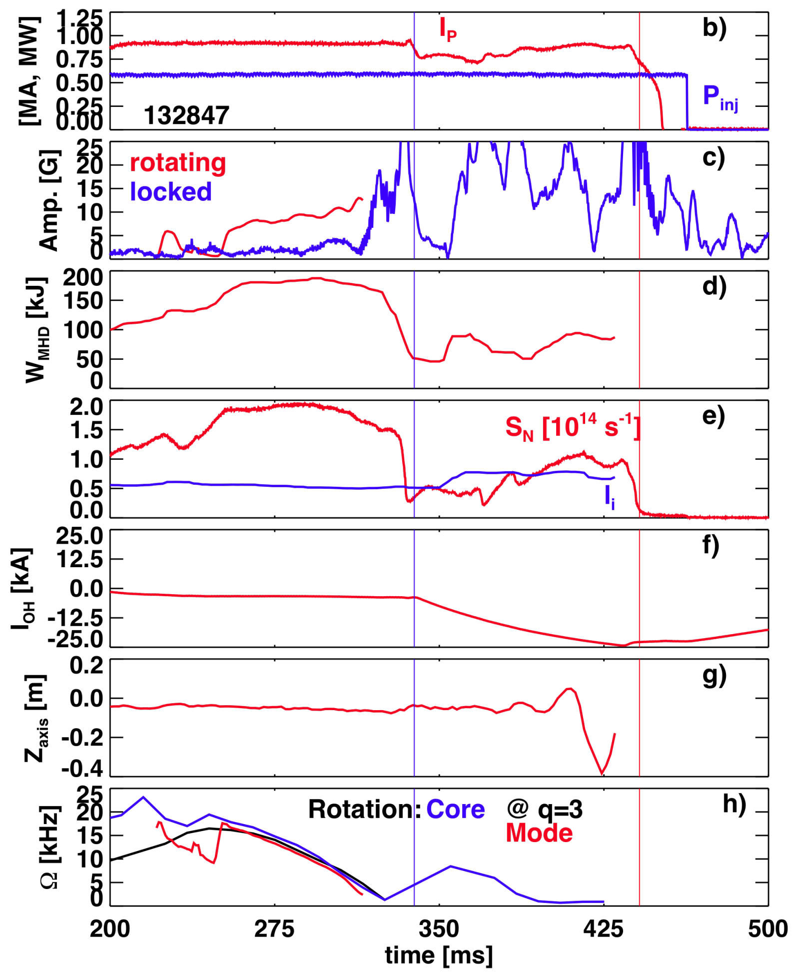
$$\nu^*=\frac{\left(1+\kappa^2\right)}{R_o^2\varepsilon^{7/2}}\frac{f_{GW}^3}{B_T\beta_N^2 q_{cyl}}q_\nu^\eta$$

- Parameter η controls which q is used for collisionality scaling
  - η=1 for edge q
  - η=0 for core q
- Collisionality is independent of confinement scaling when written in terms of these variables.
  - Safety factor also approximately cancels out.
- To decrease collisionality, we:
  - Raise β_N
    - Upper limit on betaN from global stability or confinement.
  - Lower f_{GW}
    - Will typically result in evolved q_{min}<1, early MHD is problematic.
  - Raise B_T
    - ***But the scaling is fairly weak.***

Early MHD Modes Locking to the Wall Are a Big Source of Low Density Disruptivity

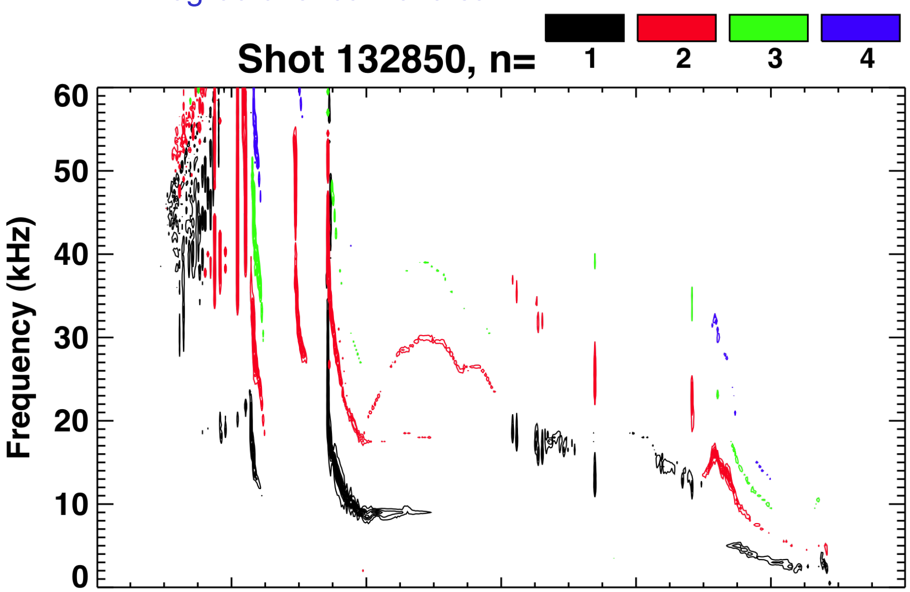
- Modes are always associated with the rational surfaces entering the plasma.
  - Have observed modes at q=2,3, & 4 to lock
- Large degree of variability in the rotation damping dynamics.

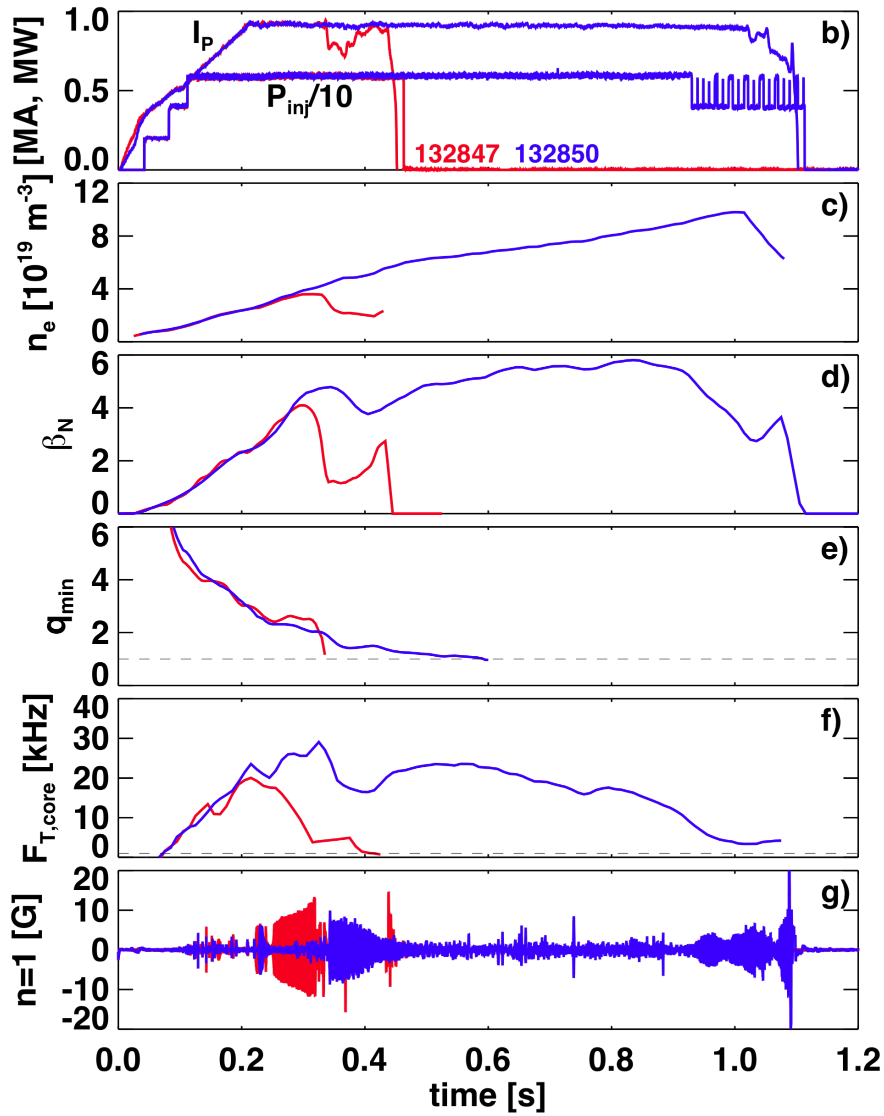




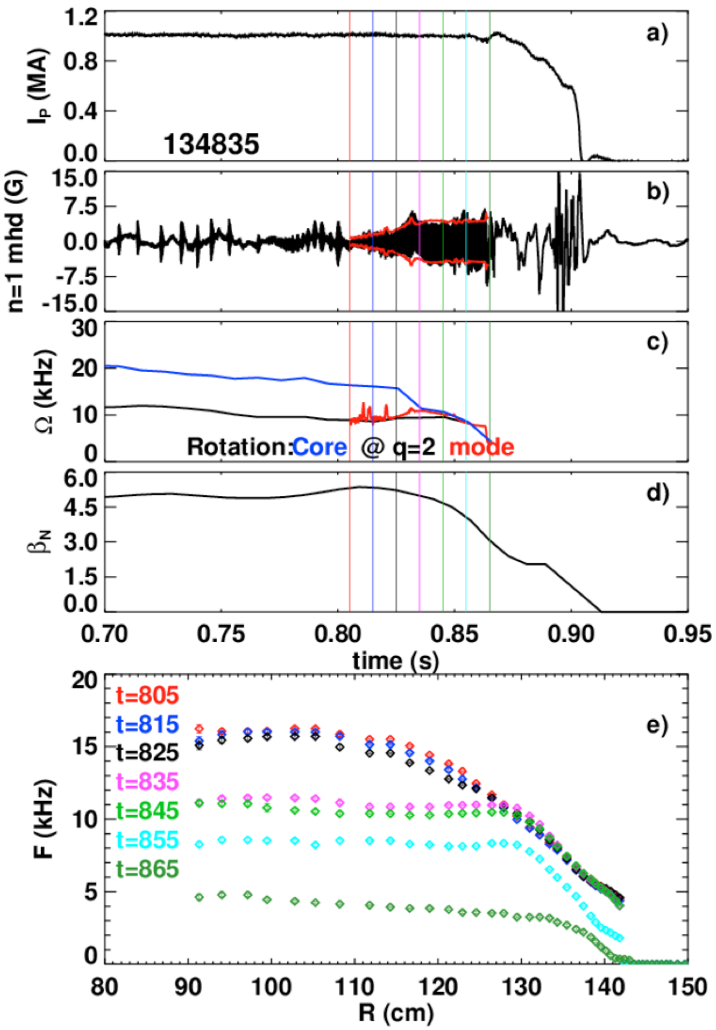
Empirical Change To the Fuelling are Used to Prevent Modes From Locking

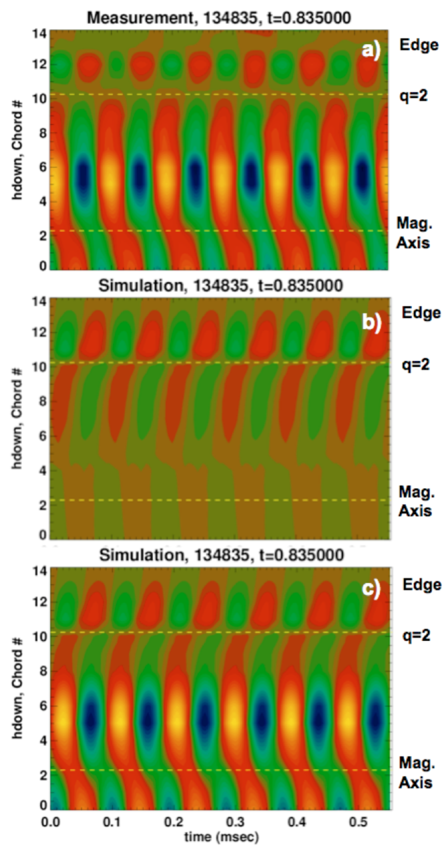
- Changes in global parameters due to fuelling changes are quite subtle.
  - But changes to rotation dynamics are profound.
- Need a better understanding of mode amplitude and torque dynamics.
  - Small changes in resistive current evolution?
  - Modification of the early EPMs?
- Is there a measurable quantity to put under feedback control?
  - Density is probably a surrogate for what really matters.
  - Degree of shear reversal?

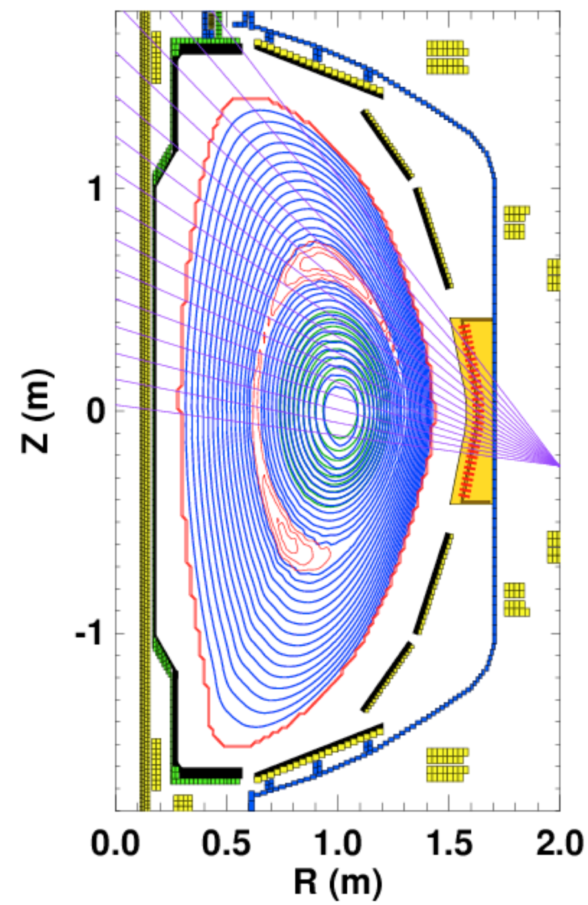




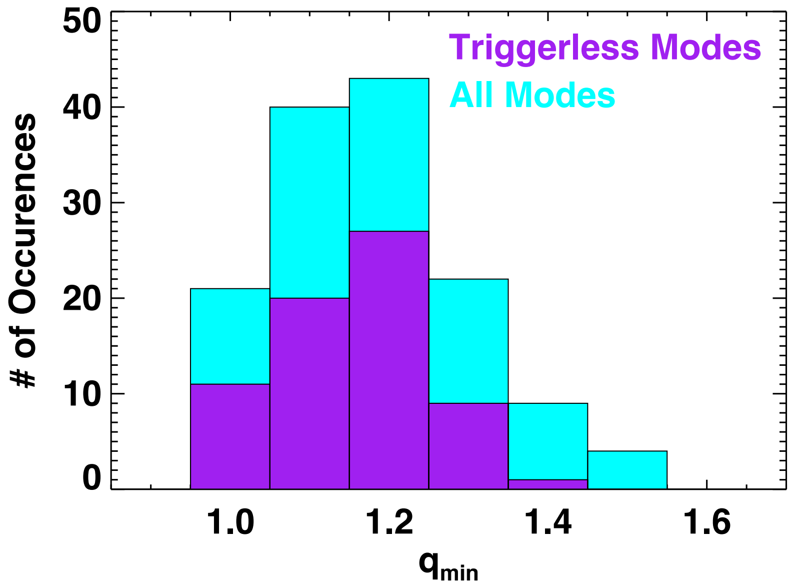
Coupled m/n=1/1+2/1 Modes Limit Many Long-Pulse Scenarios





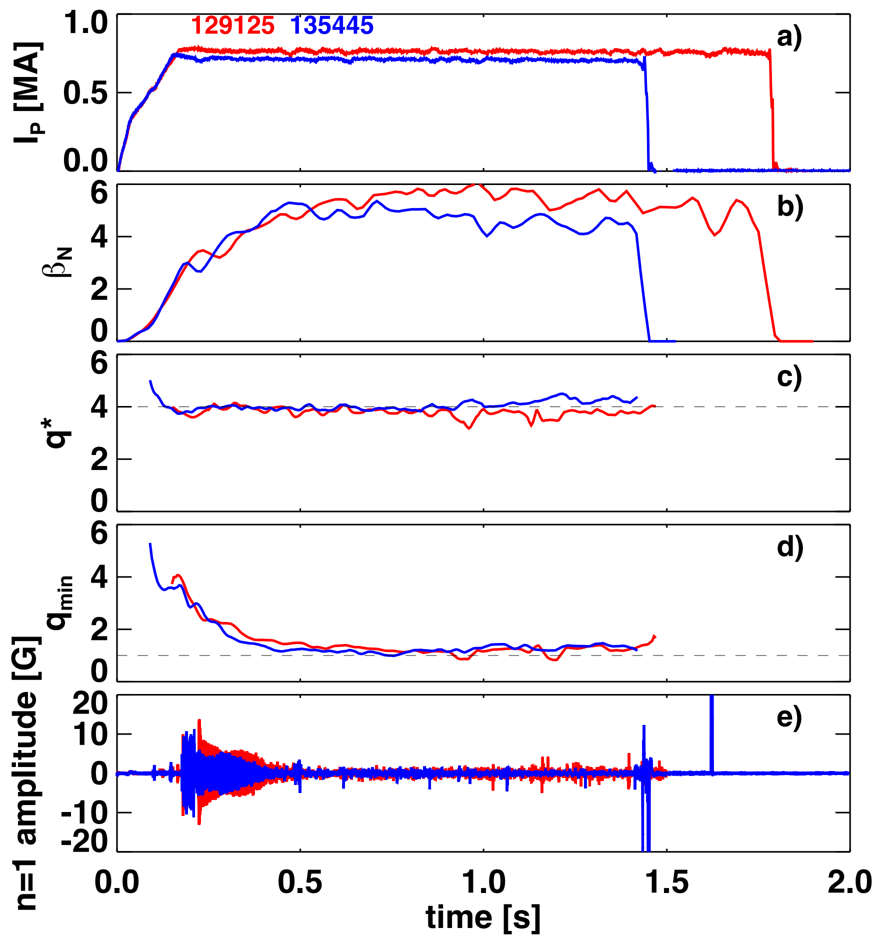


What is q_{min} when core n=1 modes turn on?

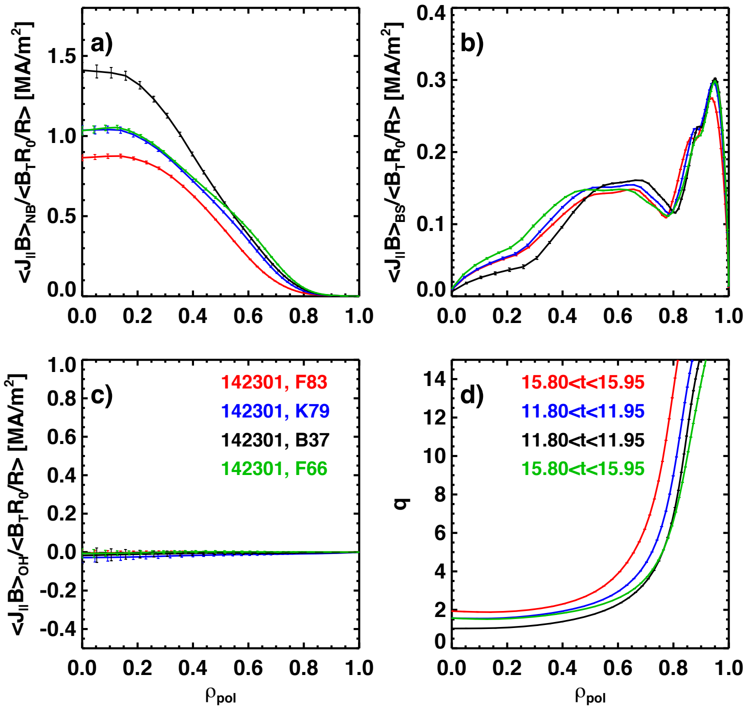


•Database of 138 MSE constrained reconstructions.
•EPM and ELM triggers cause modes to onset at large values of q_{min}.
•Rotation shear at q=2 likely plays a role in the cases with ELM or EPM triggers.
•“Triggerless” modes probably initiated by internal kink or infernal modes as qmin approaches 1.

But also possible to have discharges that sit with q_{min} just above one for long periods.



Use NBCD To Understand What is the Required Increment of q_{min} above rational values to avoid internal/infernal modes.



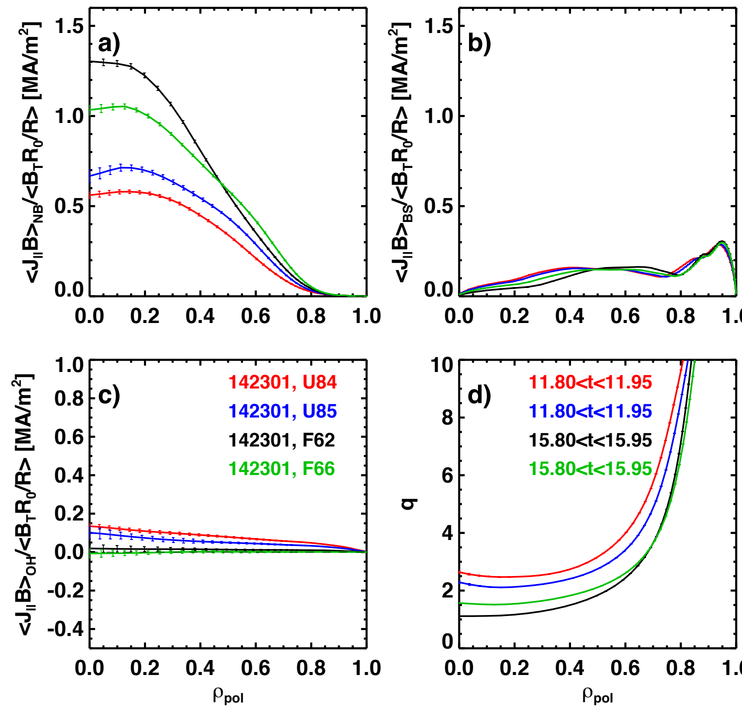
All: E_{inj}=90 kV, P_{inj}=8.4 MW, B_T=1.0 T, $H_{98y,2}$=1, f_{GW}=0.7, f_{NI}=100%

R_{tan}=[50,60, 70, 130] cm, I_P=675 kA, q_{min}=1.88

R_{tan}=[50,60, 120,130] cm, I_P=740 kA, q_{min}=1.54

R_{tan}=[60,70, 110,120] cm, I_P=770 kA, q_{min}=1.03

R_{tan}=[70,110,120,130] cm, I_P=800 kA, q_{min}=1.51



All: E_{inj}=90 kV, P_{inj}=8.4 MW, I_P=800 kA, B_T=1.0 T, $H_{98y,2}$=1, f_{GW}=0.72

R_{tan}=[50,60, 70, 130] cm, q_{min}=2.47, f_{NI}=0.87

R_{tan}=[50,60, 120,130] cm, q_{min}=2.11, f_{NI}=0.92

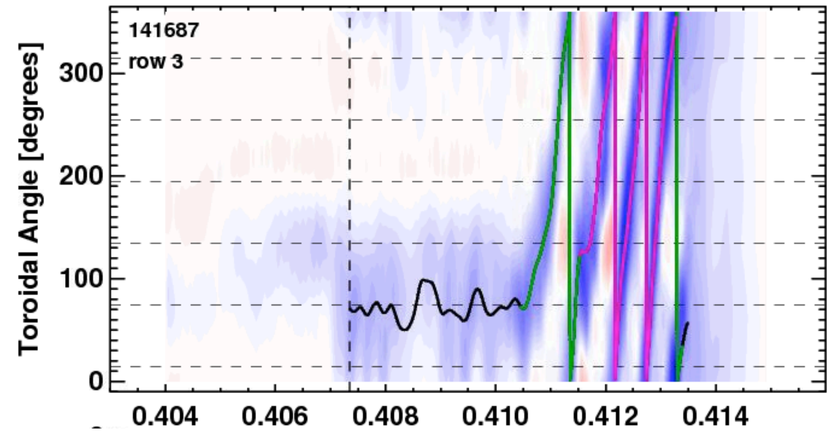
R_{tan}=[60,70, 110,120] cm, q_{min}=1.11, f_{NI}=0.98

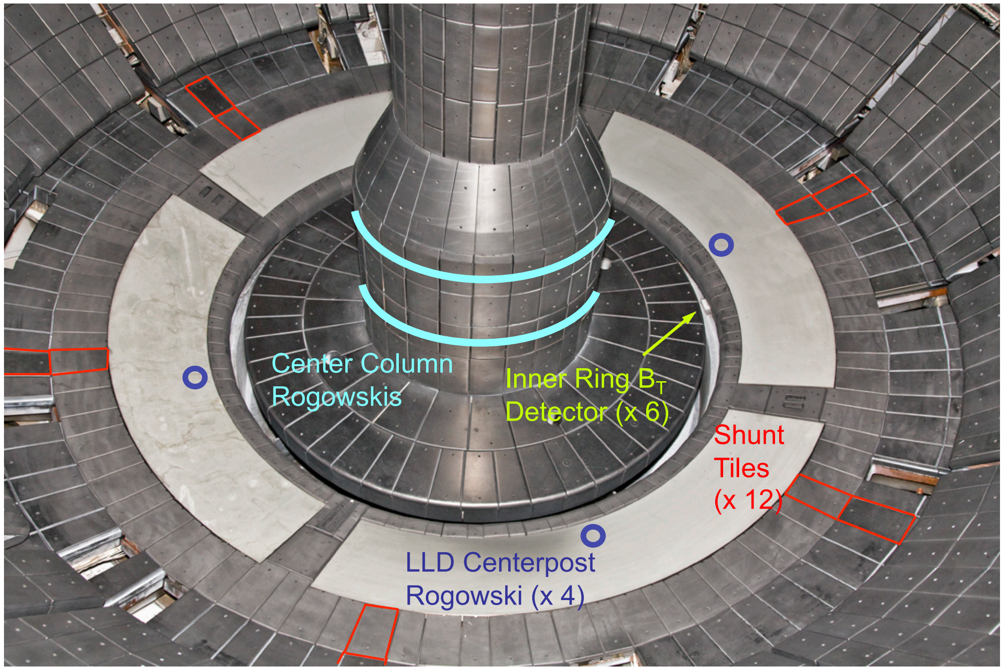
R_{tan}=[70,110,120,130] cm, q_{min}=1.51, f_{NI}=0.99

How high must q_{min} be above 2.0 to avoid the 2/1 infernal mode?

Diagnostics for Divertor/Halo/Hiro/Evans/SOL Currents on Outer Vessel Not Yet Specified

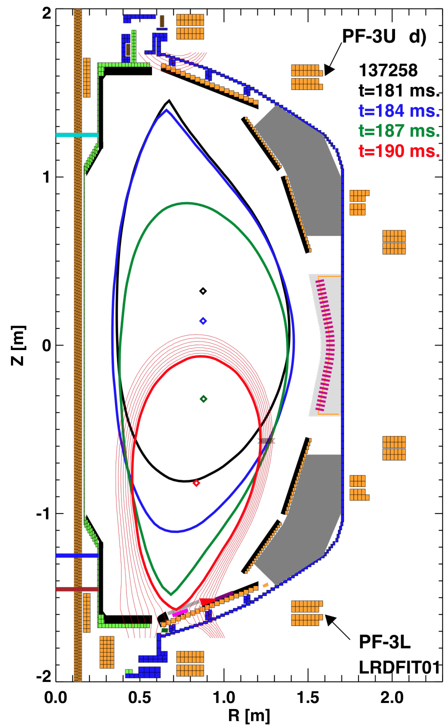
- FY-10/11 run had 12 shunt tiles and 4 LLD rogowskis.
  - Used for disruption, ELM, SOLC, HHFW studies.
- LLD removal eliminates the rogowskis and 6 of the shunt tiles.
- Need a plan for what to do on the outer vessel.
  - Inner vessel largely fixed in scope.



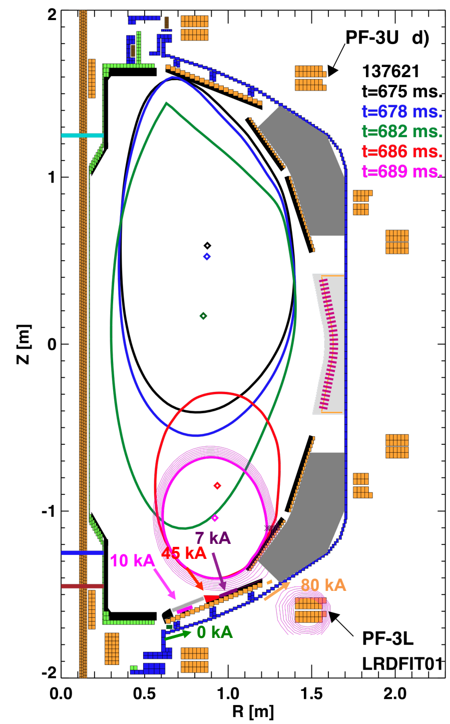


Ideas for "Optimal" Detection System for Poloidal Halo Current

- Should have sufficient toroidal resolution for higher-n components of the HC.
  - 6 toroidal locations is likely the minimum for good measurements.
- Would like to measure on both sides of the limiting point.
  - Measure toroidal phase of n=1 perturbation where current enters and exits.
    - Could be all on OBD.
    - Or on OBD and lower SPPs
- Must digitizer at >20 kHz

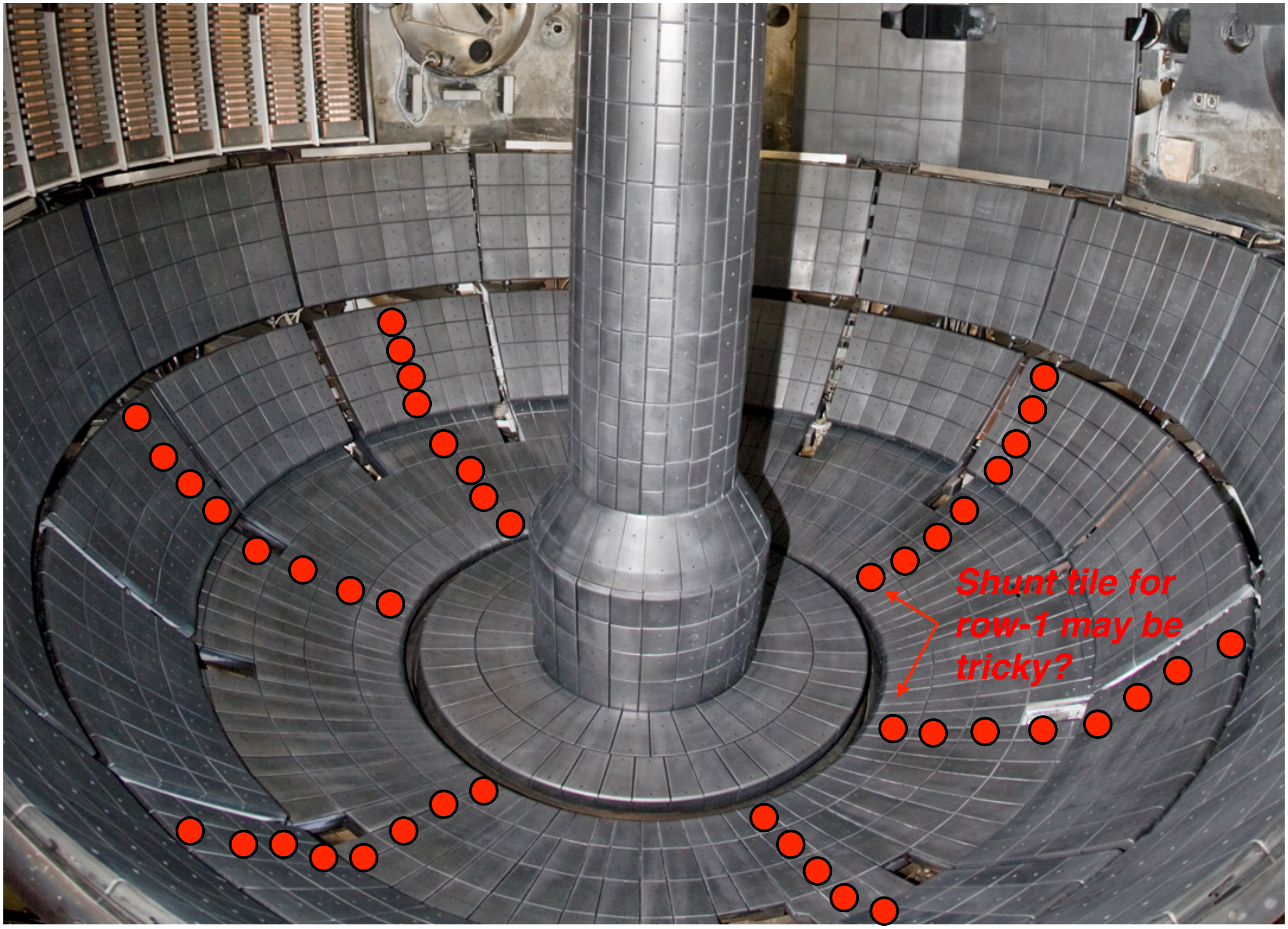


Limits on OBD



Limits on SPP

Shunt tile arrays on both the OBD and the SPPs would allow good halo current inventory and dynamics measurements



Need to consider HC diagnostics in the broader context

- Recent interest has included not only the poloidal current, but also:
  - The direction of the toroidal part of the halo current.
  - Plasma kink displacements during the disruption.
- These would mandate additional divertor magnetics.
  - Could be synergistic w/ other physics desires…need a careful study.
- But, should we invest time/money in the divertor if it will be changed out for Lithium systems and/or cryopumps?
- Who will take responsibility designing/installing/ troubleshooting all those additional sensors?

Other disruption topics…

- Unlikely that NSTX-U will generate runaway electrons.
- If fast camera data is available, can get thermal loading data.
  - Must rely on BP group.
- Already have a decent understanding of H-mode disruption precursors from NSTX database analysis.
  - Need to translate that information into PCS requirements.
    - What additional diagnostics are required in realtime? rtMPTS appears to be most pressing.
  - Need PCS programmer time to code it up, but no runtime for the detection algorithms.
  - Should be part of a larger "event handling" code infrastructure to be developed in ASC.