XP512 NSTX/DIII-D RWM Similarity

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XP Review

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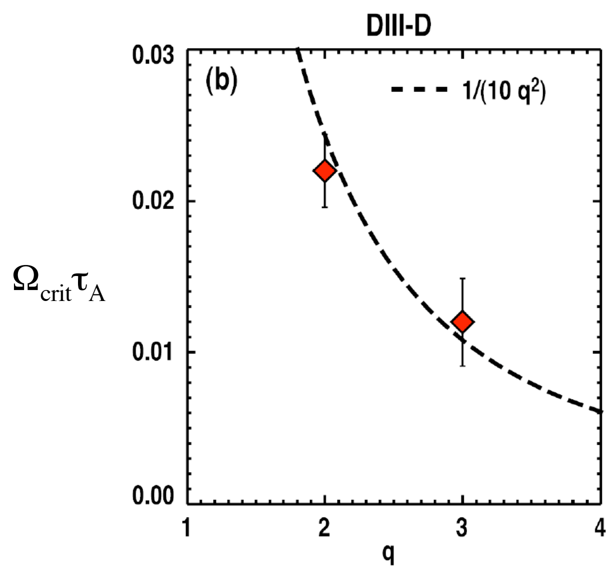
Similarity XP to Explore Aspect Ratio Effects on RWM Stability (1)

- Mode structure & dynamics
  - higher n coupling observed in NSTX
  - MSE constraint on NSTX profiles
    - increases accuracy of mode structure determination
  - rotation damping dynamics
    - dependent on perturbed B-field structure
    - neoclassical toroidal viscosity (NTV) used to determine torque
    - cross-machine comparison aids in NTV validation

$$T_{NTV} = R\frac{\pi^{1/2} p_i}{v_{ti}}\left(\Omega_\phi - \Omega_{mode}\right)\varepsilon^2 n^2 q\left(\frac{\delta B_r^{mn}}{B_\phi}\right)^2$$

- Critical rotation
  - $\Omega_{crit} \propto \alpha/q^2$ in both machines
    - coefficient α scales with ε
      - α = 0.25 in NSTX
      - α = 0.1 in DIII-D
    - consistent with theoretical predictions
  - magnetic braking will allow similar determination of Ω_{crit}



Similarity XP to Explore Aspect Ratio Effects on RWM Stability (2)

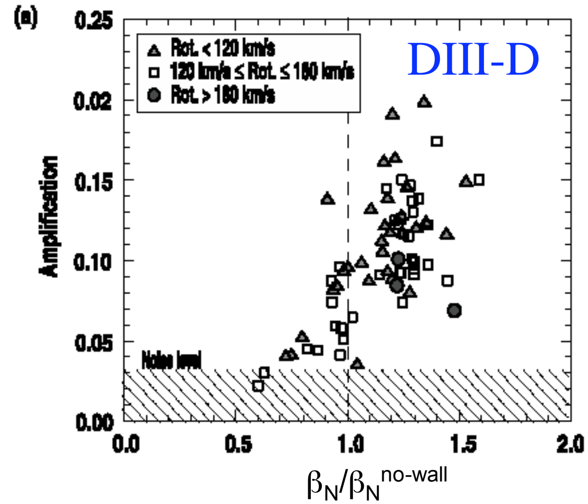
- Resonant field amplification (RFA)
  - theoretical prediction by Fizpatrick - Aydemir:

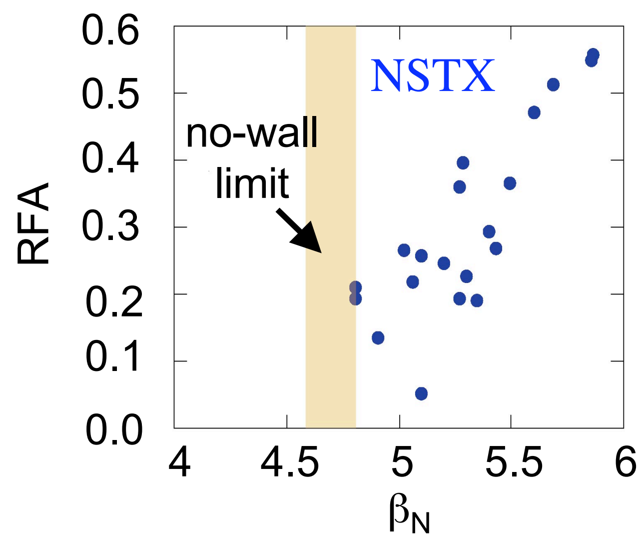
$$\frac{\left|\psi_{plasma}\right|}{\left|\psi_{ext}\right|} = \left(\frac{1-md}{1+md}\right)^{1/2} \frac{2md}{\left\{\left[\hat{\Omega}_{\phi}^{2} + \kappa(1-md)\right]^{2} + \left(\nu_{*}\hat{\Omega}_{\phi}\right)^{2}\right\}^{1/2}}$$

  - single mode model:
    - adequate in NSTX with n > 1 coupling?

$$RFA = \alpha \frac{1+\gamma_0 \tau_w}{i\omega_{ext}\tau_w - \gamma_0 \tau_w}$$

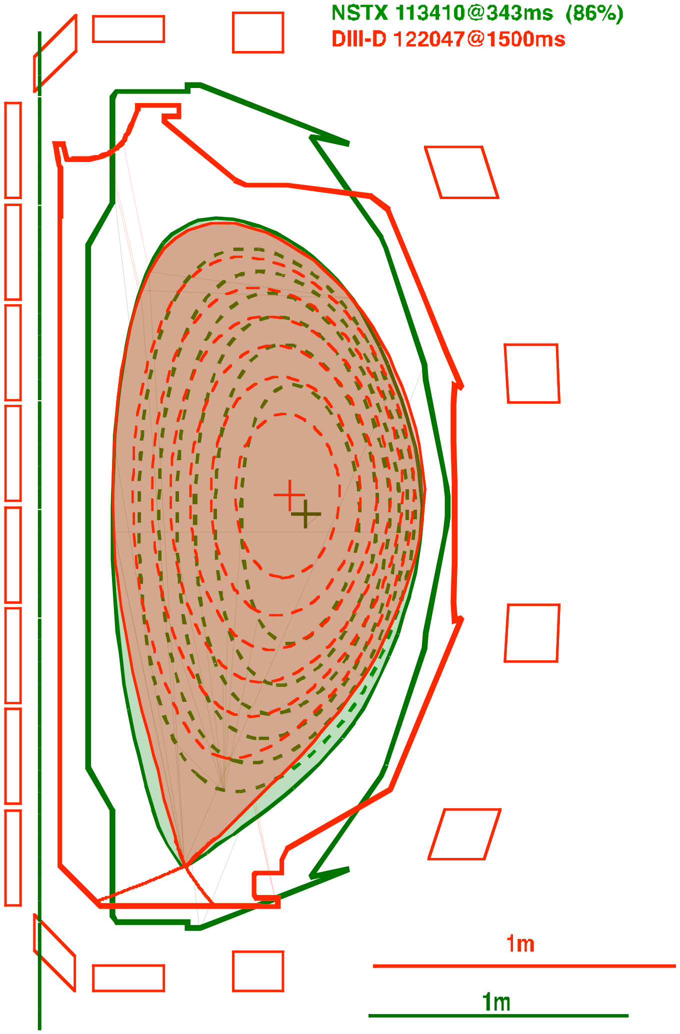
- Critical rotation dependence on v_A and C_s
  - v_A and C_s determine dissipation magnitude
    - $C_s \propto [T_e/m_i]^{1/2}$
    - $v_A = B/[4\pi n_i m_i]^{1/2}$
  - examine dependence on A, q





DIII-D / NSTX Boundary already well matched

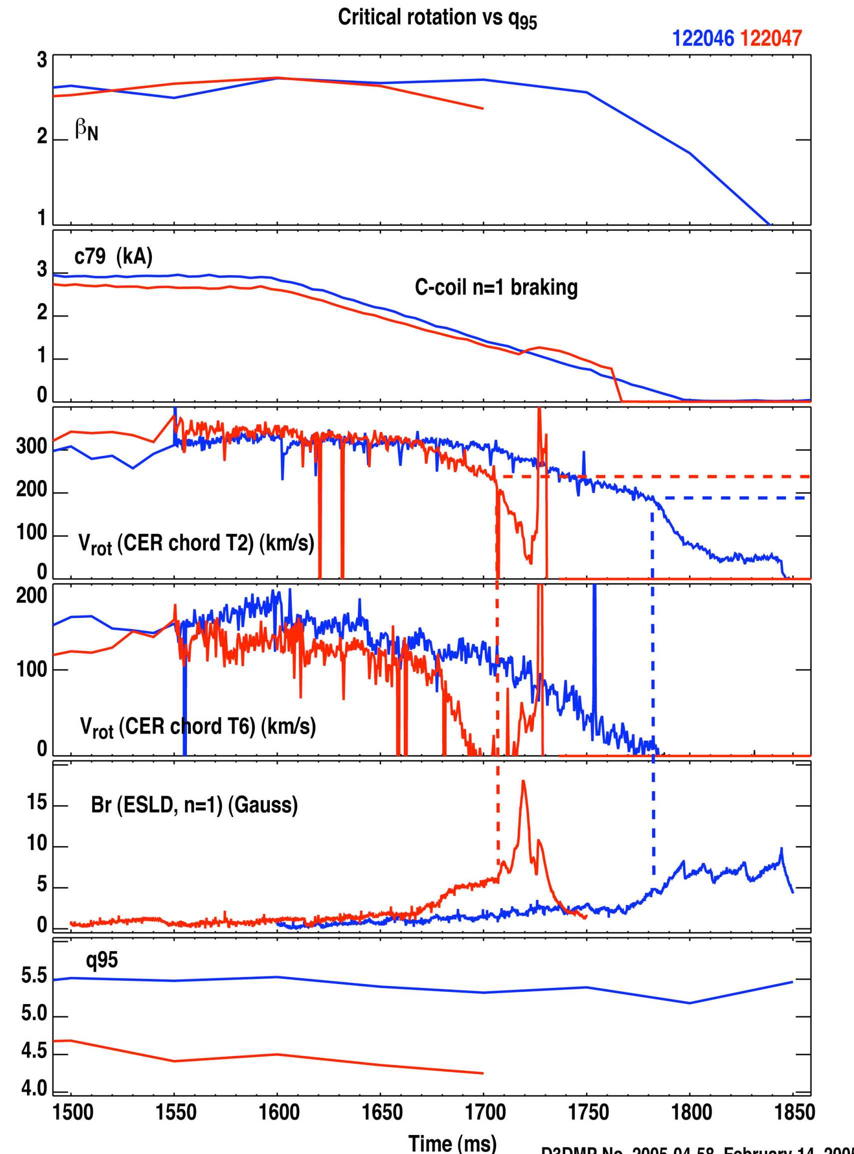
(Sontag, Reimerdes, Garofalo, Sabbagh, Strait, LaHaye, Okabayashi, Buttery, etc.)



- NSTX shape matched during DIII-D run
  - need high-β_N NSTX discharge with correct shape
    - κ = 2-2.1
    - $\delta_{upper} \leq 0.35$, $\delta_{lower} \leq 0.6$
    - $\ell_i \sim 0.8$
  - DIII-D EFITs for shape matching
- Experience from XP501 will provide guidance
  - field amplitudes
    - controlled rotation damping
    - MHD spectroscopy
  - coil waveforms
    - pulse shapes for braking
    - frequencies for spectroscopy

DIII-D Run Completed with Good Results

- Two 1/2 day run periods on DIII-D
  - day 1: 13 shots with NSTX similar shape
  - day 2: 8 shots with NSTX similar shape
    - MHD spectroscopy
    - rotation braking to induce RWM
- q_{95} & β scans performed
- Higher-κ than previously accessed in similar shape
  - $\kappa \leq 2.1$
  - easier to match in high-performance NSTX discharges



Courtesy H. Reimerdes

XP512 Shot List

Task	Number of Shots
1) Establish DIII-D similar shot - *RWM stable*	
▪ Ip = 1.0 MA, LSN , $\kappa \leq 2.1$, $\delta_{lower} \leq 0.6$, $\beta_N > \beta_{N\ no\text{-}wall}$	5
▪ need period with no large tearing modes	
2) Scaling of Ω_{crit} with A	
▪ apply DC n=1 braking pulse in steps to induce RWM - use XP501 experience for field magnitude/timing - $\Delta t_{step} \geq 5\tau_{wall}$ if possible ($\Delta t_{step} \geq 2\tau_{wall}$ is minimum)	2
▪ adjust beams to scan β_N - proximity to β limits will determine adjustments	3
▪ scan q_{95} by varying I_p - attempt to match q_{95} from DIII-D run ($3.6 \leq q_{95} \leq 5.4$)	4
▪ repeat braking with $\beta_N < \beta_{N\ no\text{-}wall}$ - reduce NBI power to stay below no-wall limit	1

XP512 Shot List (cont.)

Task	Number of Shots
3) RWM growth rate & rotation frequency dependence on A & β_N	
▪ scan rotation frequency of applied field	6
- take guidance from XP501	
- scan frequency around expected max. response	
▪ repeat at frequencies with max. response with $\beta_N < \beta_{N\ no\text{-}wall}$	2
▪ apply static field to observe RFA dependence on β_N	3
- use DC pulse lengths short enough and field magnitudes small enough to avoid destabilizing RWM	
- Ω_{crit} studies to provide guidance	
- adjust NBI power to vary β_N	
3) Ω_{crit} dependence on v_A and C_s	
▪ adjust B_t and I_p together to maintain const. q	5
- apply n = 1 braking pulse to induce RWM	
- try to maintain high temperature	
- stop when field too low to control MHD and maintain high T & β	
	31 total

Duration and Required / Desired Diagnostics

- XP could be completed in 1.5 run days (one long run day)
  - leveraging experience from XP501
- Required
  - Magnetics for equilibrium reconstruction
  - Internal RWM sensors
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - Diamagnetic loop
- Desired
  - USXR diagnostic at two toroidal positions
  - MSE
  - Toroidal Mirnov array