EM Design and Resistive Stability

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NCSX Physics Validation Review
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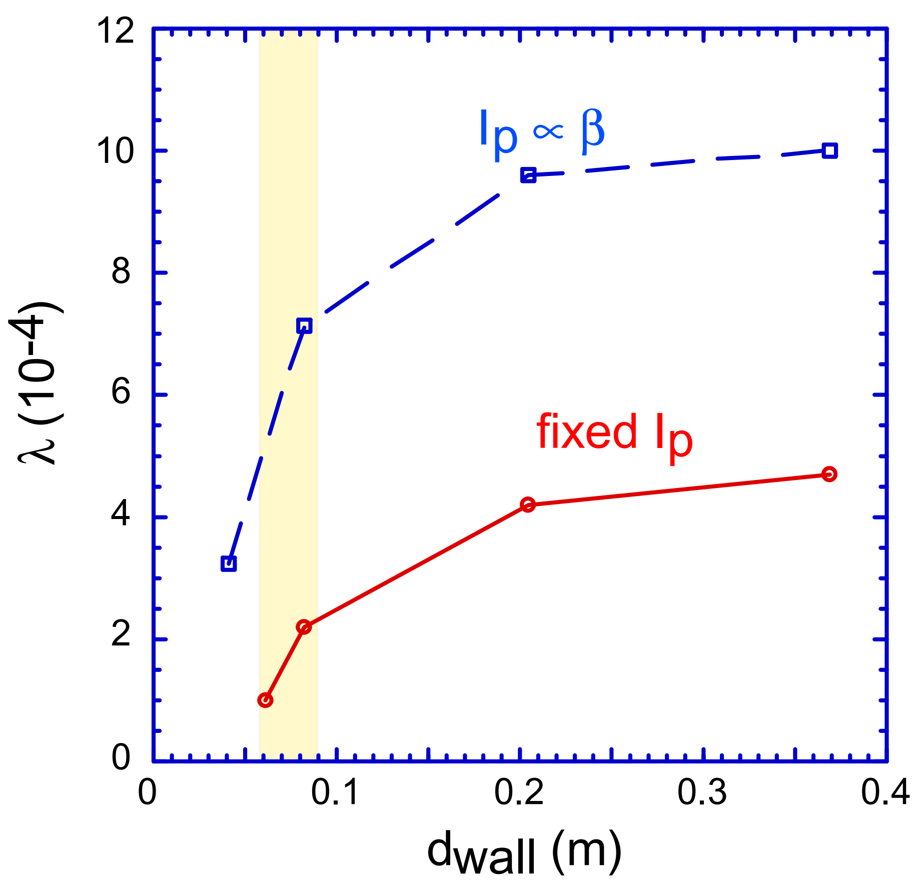
Overview

- EM requirements for NCSX
  - External kink stability should not be affected by vacuum vessel or plasma facing components.
  - Present design appears satisfactory; v.v. is outside marginal point and time constant is short.
- Tearing Mode Calculations
  - Simulated start-up and reference design equilibria analyzed with simple Δ' code.
  - Reference design equilibrium projected to have island 3.6% of minor radius; < 0.2% with neoclassical effects.

EM Requirements

- An important physics goal of NCSX is demonstration of an equilibrium intrinsically stable to the external kink.
- External kink growth rate should be shorter than pulse length; stability calculations (Fu) suggest:
  - wall time-constant should be less than $\approx$ 10 ms, or;
  - plasma-conducting wall separation should be greater than about 8-10 cm.
- Present design v.v. $\approx$ 9 cm on inboard side,
  - wall time-constant for m=2 is < 2 ms; much shorter than pulse length, as in many present tokamaks.

Stability calculations with conformal wall show marginal point ≈ 6-9 cm



- Marginal point depends somewhat on profiles.
- This calculation at β = 5%.
- Other equilibria have marginal points closer to plasma
- Vacuum vessel ≈ 9 cm on inside, further over all of outboard side.

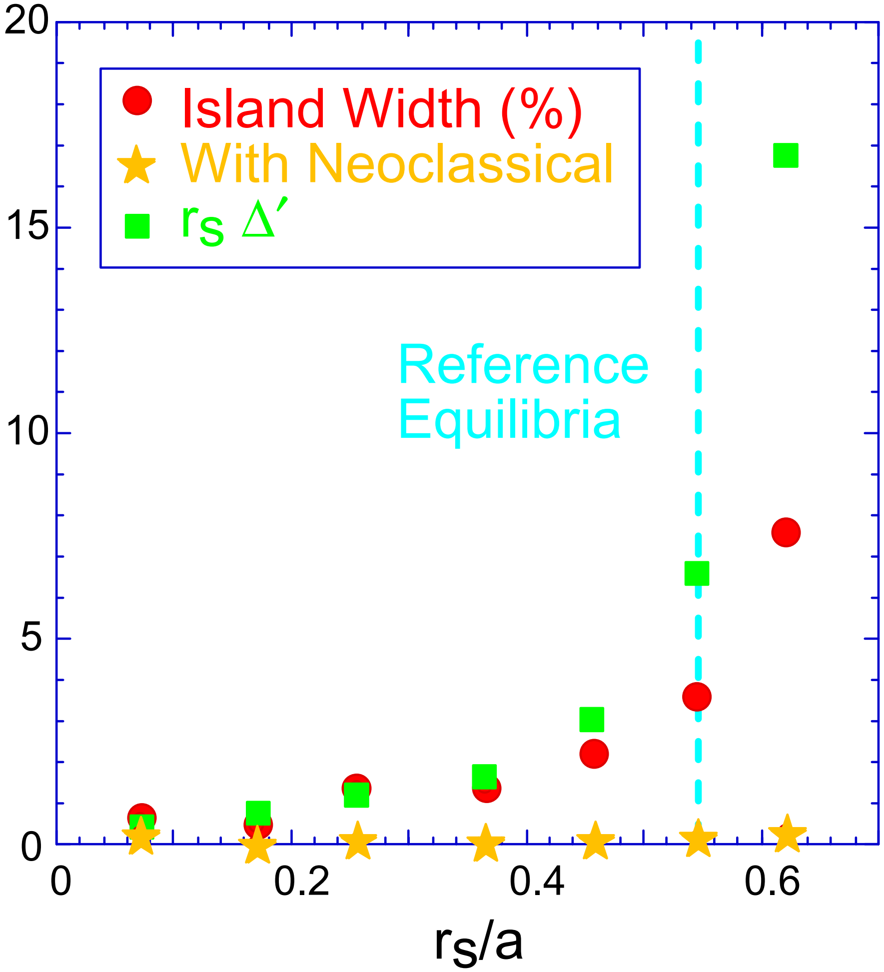
Tearing Mode Stability

- 100 - 200 kA of plasma current driven by bootstrap effect, inductively or NBCD.
- Current driven tearing modes possible, *e.g.*, $\iota = 0.5$ surface in plasma.
- For negative shear, the bootstrap current is predicted to be stabilizing.
- Stability calculations done on discharge evolution simulation (Lazarus) and "li383" equilibria.

Stability calculations use simple model, as successfully used in W7-AS

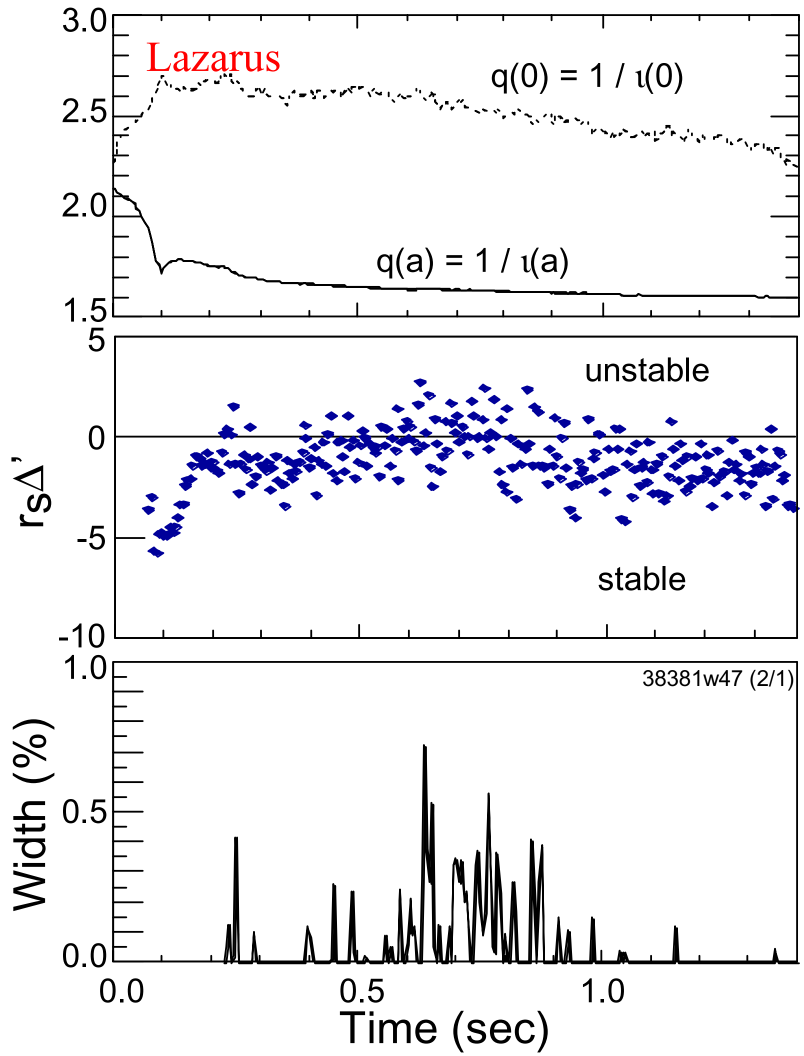
- The Δ' code is a quasi-cylindrical, low β model.
- Neoclassical terms added; benchmarked in normal shear, axisymmetric experiments.
- Single tearing modes not seen in negative shear regions for TFTR/DIII-D, but double tearing modes are seen.
- Shape and non-axisymmetry effects are not so well benchmarked; W7-AS studies found reasonable agreement.

Moving rational surface towards core reduces island size



- Island width is small in target equilibrium (3.6%).
- Island width is negligible with neoclassical corrections (<0.2% a).
- Calculations were done by scaling ι(r) in li383 reference design equilibrium.

Simulated islands small even without neoclassical term in start-up.



- TRANSP used to simulate bootstrap, ohmic currents through start-up.
- 2/1 mode marginally stable, other modes are stable.
- Island negligible without neoclassical term, even smaller with.
- Equilibrium slightly different than “li383”.

Summary

- Present vacuum vessel location is outside marginal stability point for external kink
- Wall time-constant short, much less than pulse length.

- Startup phase predicted stable to tearing modes.
- Equilibrium phase essentially stable with neoclassical effects.