MHD Stability of Candidate Configurations

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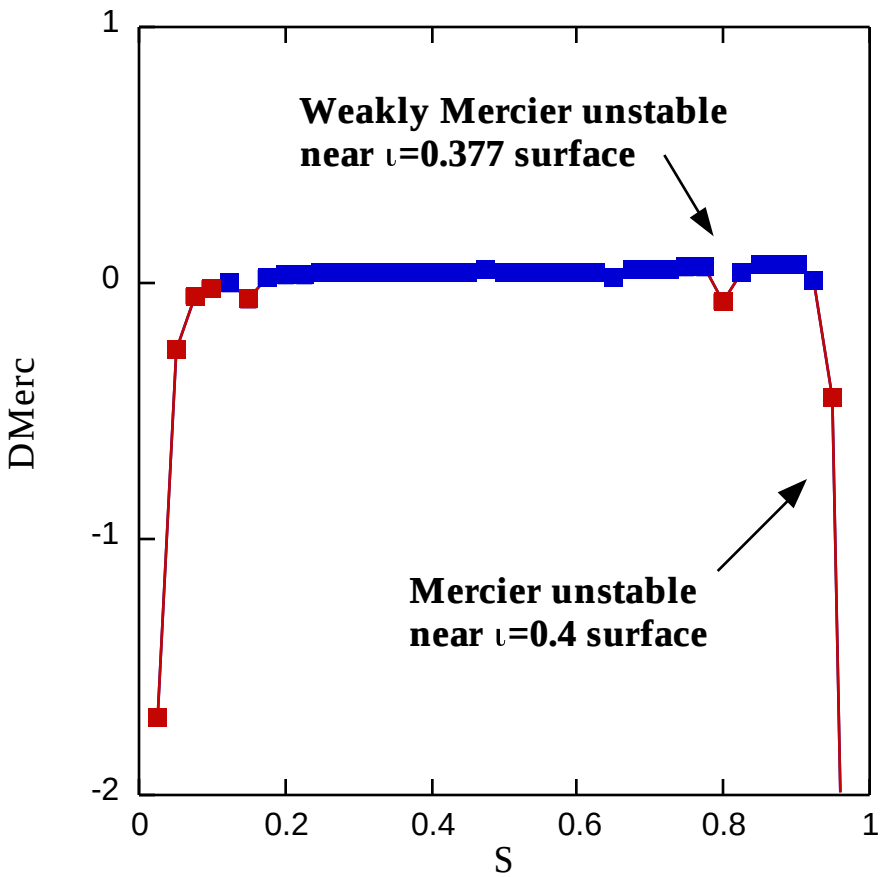
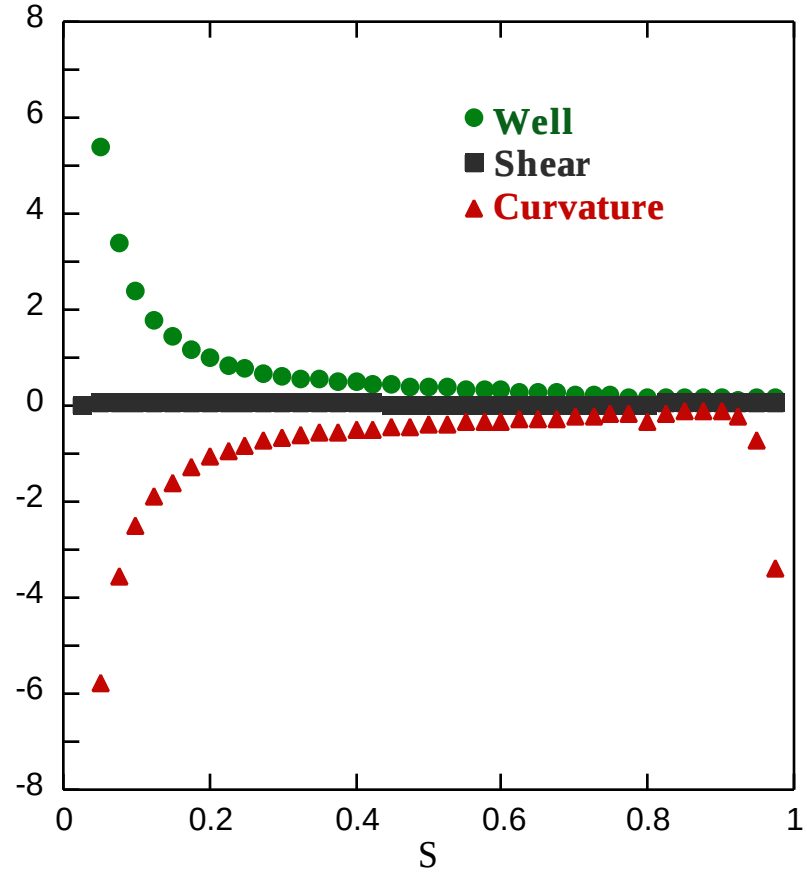
MHD Stability for Free and Fixed Boundary Calculations

- Mercier Stability
  - Magnetic well provides stability
- Ballooning Stability
  - Sets the stability β-limits for the gb4 cases <β>=2.5% fixed; <β>=2.2% free
- Kink and Vertical Stability
  - Small amount of plasma current results in good kink and vertical stability

Mercier Stability: A Magnetic Well Provides Stability Except at Isolated Resonances

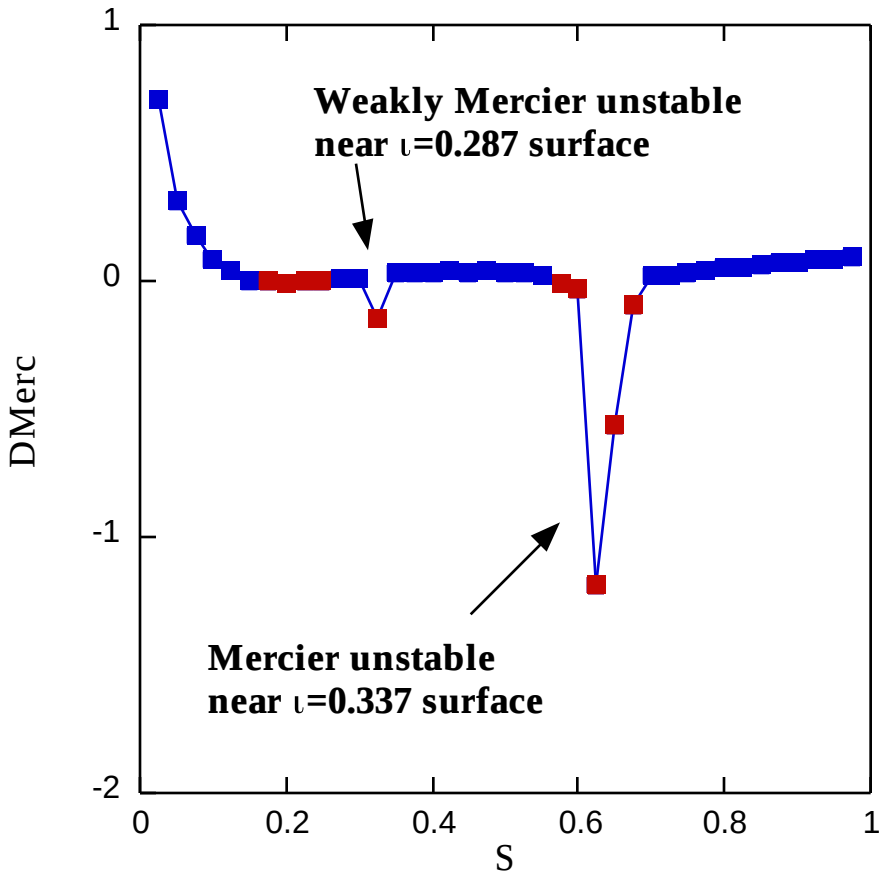
- **Mercier stability criteria for a fixed boundary case at <β>=2.5% (+ stable)**

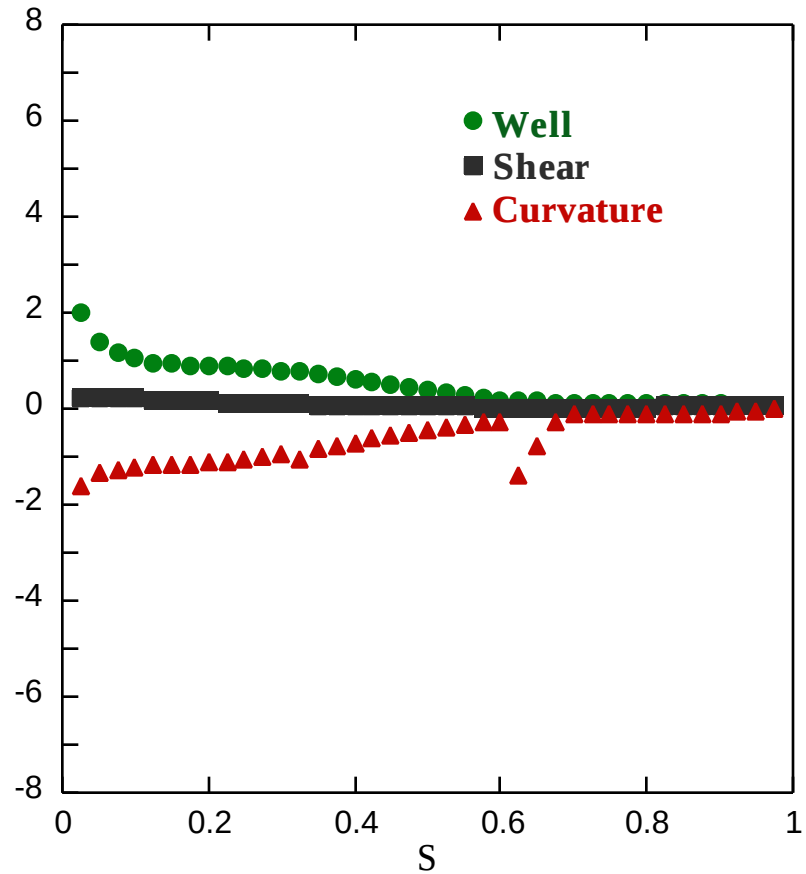




Mercier Stability: A Magnetic Well Provides Stability Except at Isolated Resonances

- **Mercier stability criteria for a free boundary case at <β>=2.0% (+ stable)**



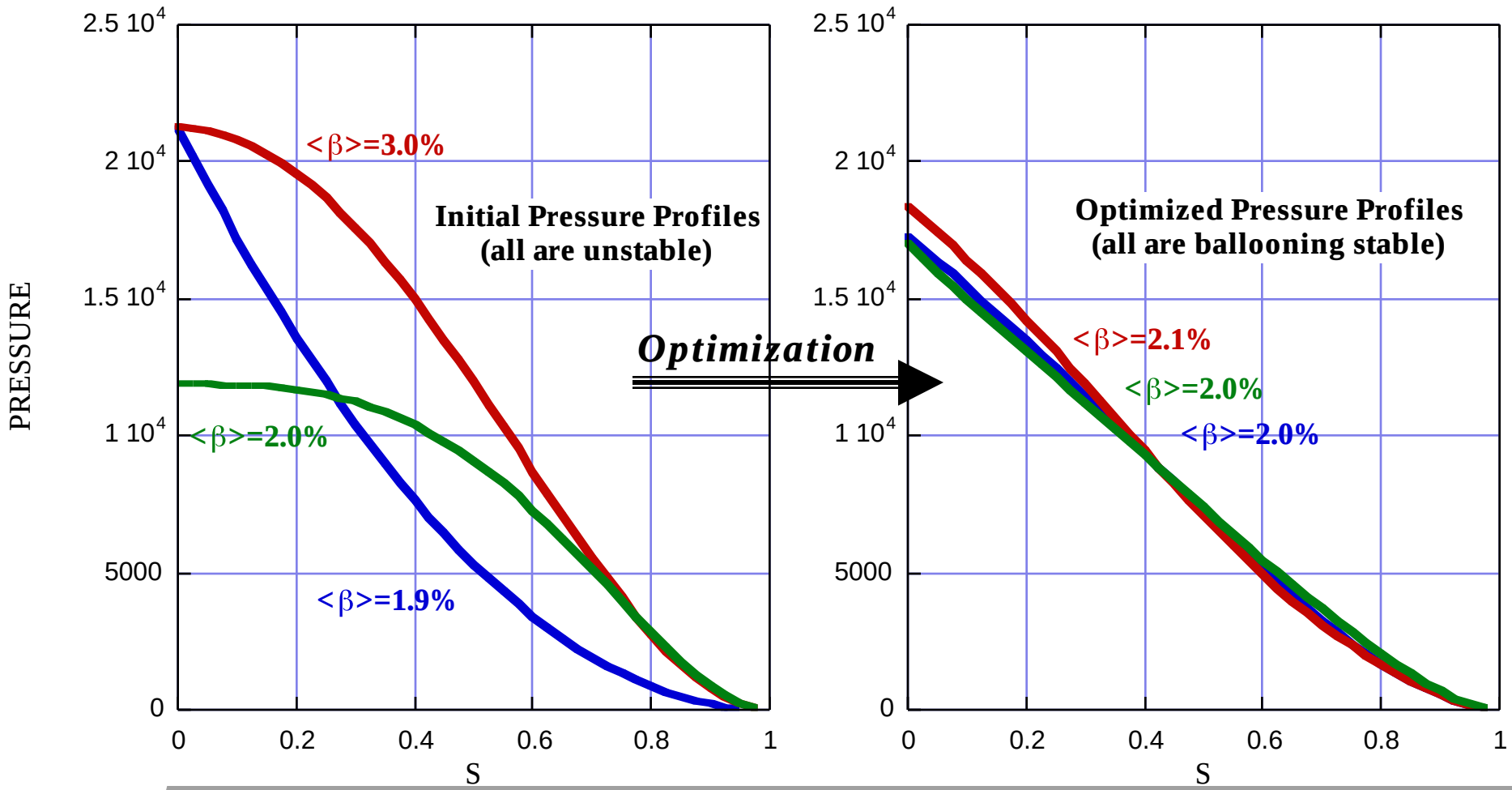


Ballooning Stability: What sets the β-limits for these configurations?

- Line-bending term is slightly weaker than in previous cases for similar β and current
  - possibly a result of smaller number of field periods but this effect is somewhat alleviated by the lower iota
- Same competition (lower NFP vs. lower ι) controls the width of the potential well
  - result is a slightly wider ballooning potential well than in the previous cases

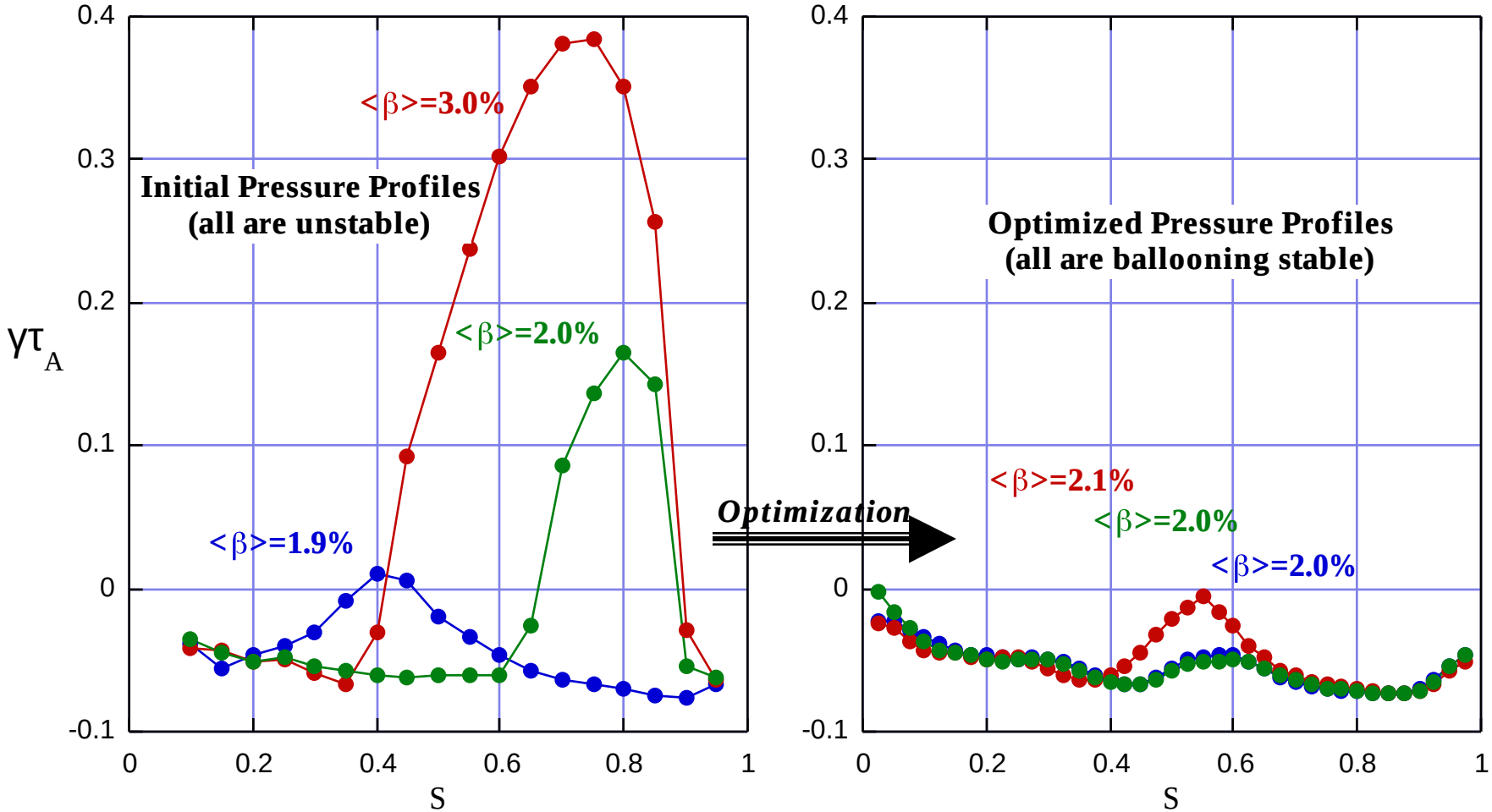
Ballooning Stability: β-limits improved by modifying the pressure profile

- **Pressure profiles optimized for ballooning stability at <β>=2.0% (fixed)**



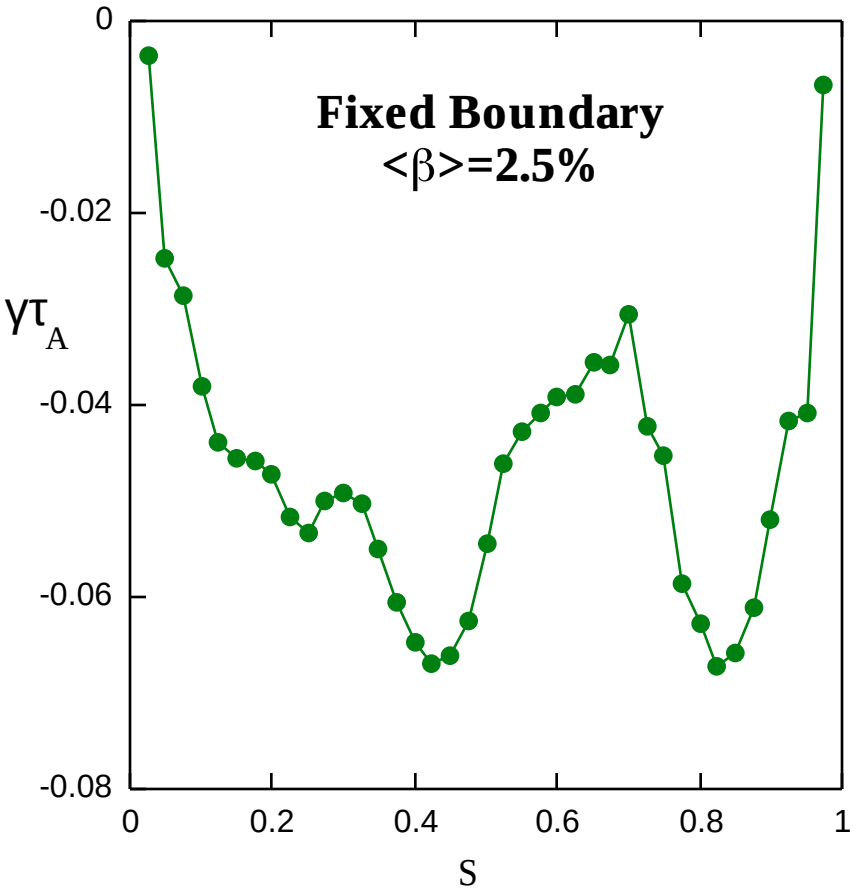
Ballooning Stability: β-limits improved by modifying the pressure profile

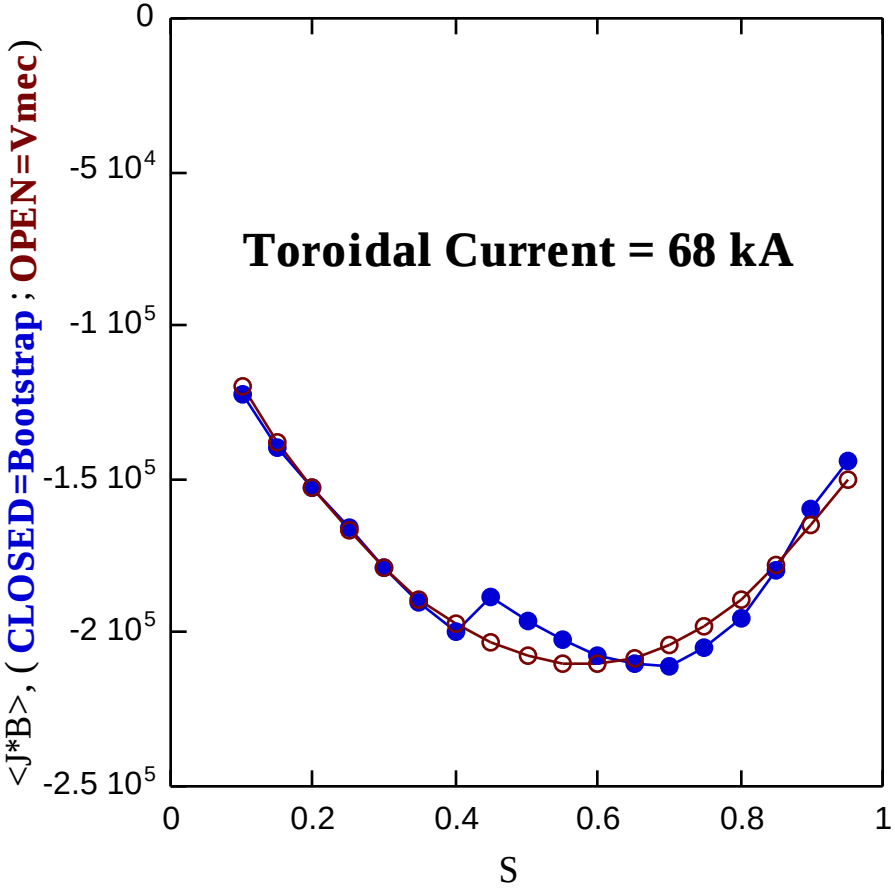
- **Ballooning stability for unoptimized and optimized cases (- stable)**



Ballooning Stability: Highest β Case - stable & bootstrap aligned at <β>=2.5%

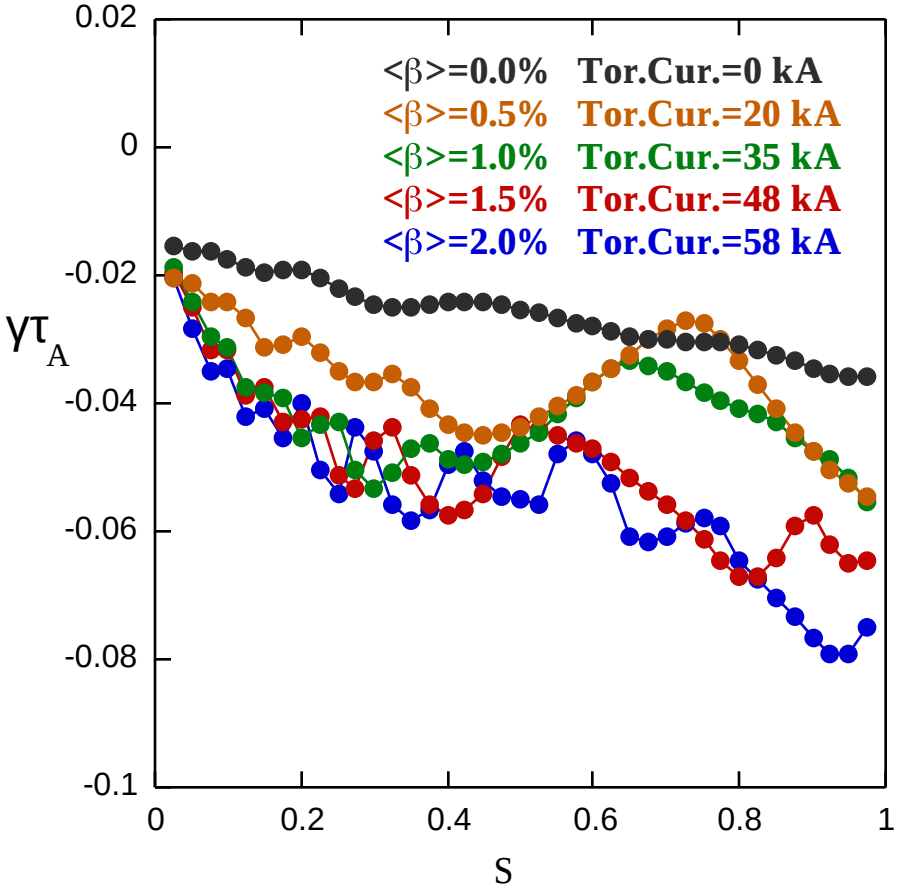
- **Ballooning stability & bootstrap alignment at <β>=2.5%, fixed boundary**

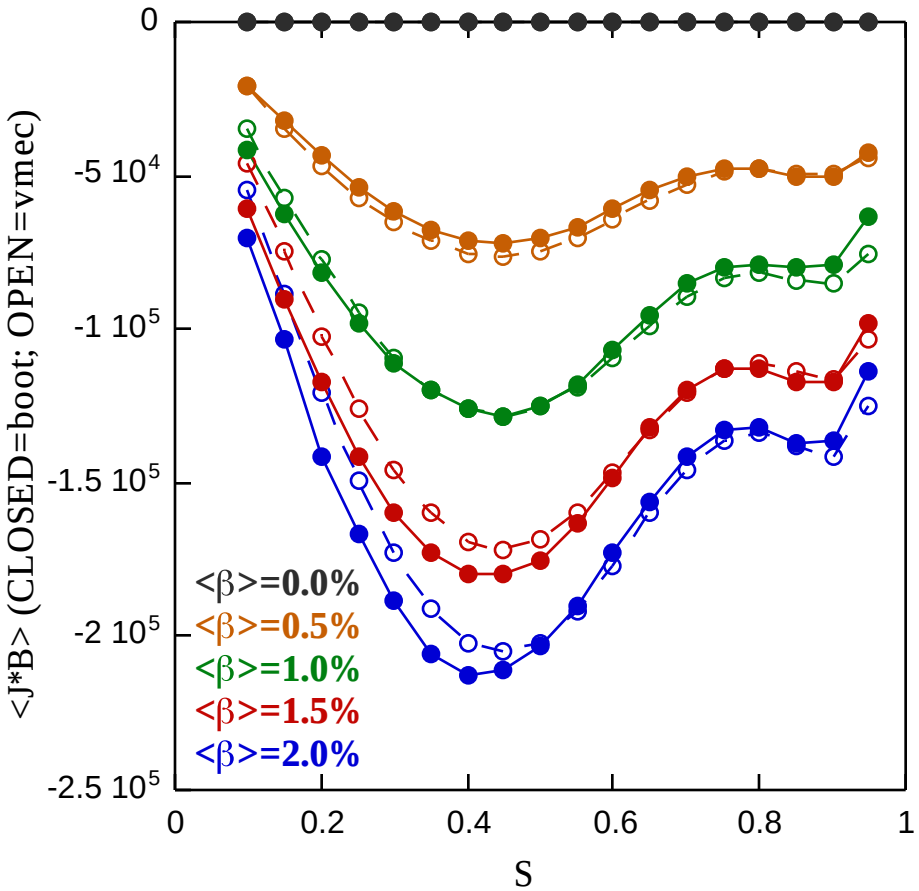




Ballooning Stability: Free boundary β-scan, stable & bootstrap aligned for 0 ≤ <β> ≤ 2.0%

- **Ballooning stability & bootstrap alignment free boundary β scan**





Kink & Vertical Stability: Higher β-limits for kink and vertical stability (<β> > 5%)

- Finite plasma current in these configurations makes them potentially susceptible to low-*n* MHD modes
- Terpsichore Code used to evaluate *n*=0 (vertical) and *n*=1 (kink) stability
- All the cases tested in the gb4 series have been stable to kink and vertical modes (fixed and free boundary)

Kink & Vertical Stability: Terpsichore Code used to test kink and vertical stability

- Terpsichore evaluates the MHD energy principle:

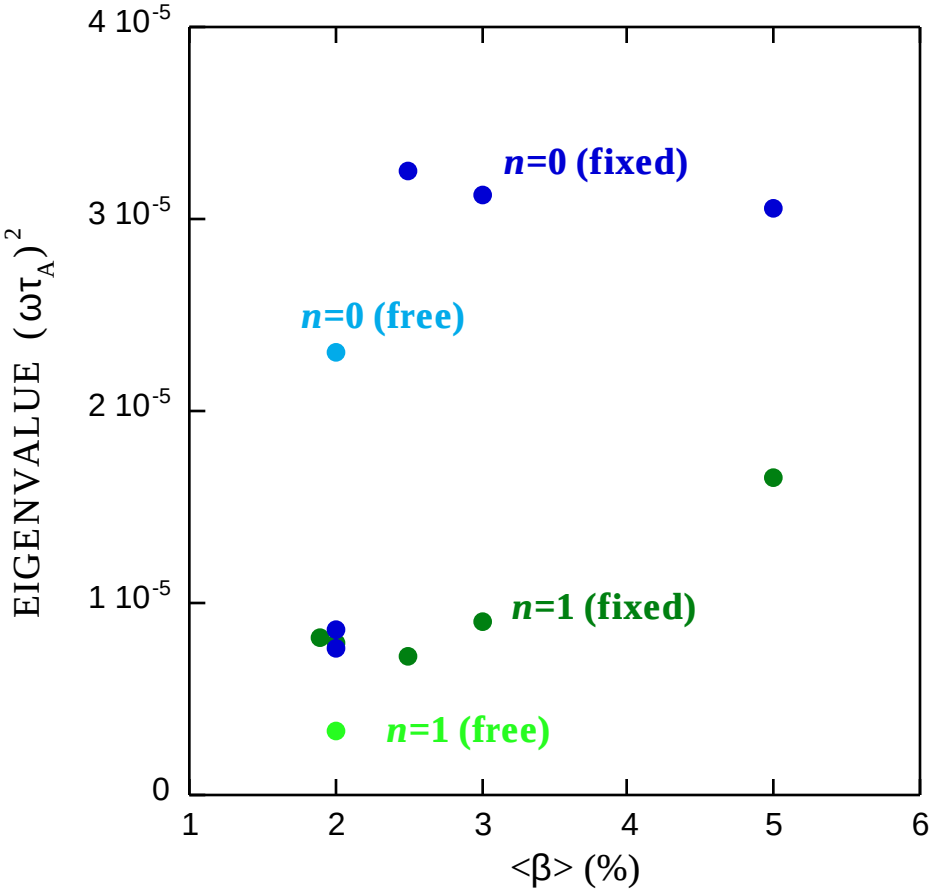
$$\omega^2 \delta W_k = \delta W_p + \delta W_{vac}$$

$$\delta W_p = \frac{1}{2}\int d^3x \left[\delta \mathbf{B}^2 + \left(\delta \mathbf{B}_{\parallel} - \mathbf{B}\frac{\xi \quad p}{B^2} \right)^2 + \mathbf{j}_{\parallel} \quad \xi \times \delta \mathbf{B} - 2\xi \quad p\xi \quad \kappa \right]$$

- Positive values of the eigenvalue, ω^2, implies stability

Kink & Vertical Stability: All the cases tested in the gb4 series have been stable

- n=0 and n=1 eigenvalues for the gb4 cases tested



Future Work

- Primary focus will be to push towards higher β-limits for ballooning stability
  - Can small changes in the shape of gb4 series have an impact on ballooning stability (have focused on profile optimization)?
  - In free boundary, can modification of the external currents improve the ballooning stability?
  - An open question: what β-limit should we be targeting for this CE device?