NCSX Plasma Configuration Design

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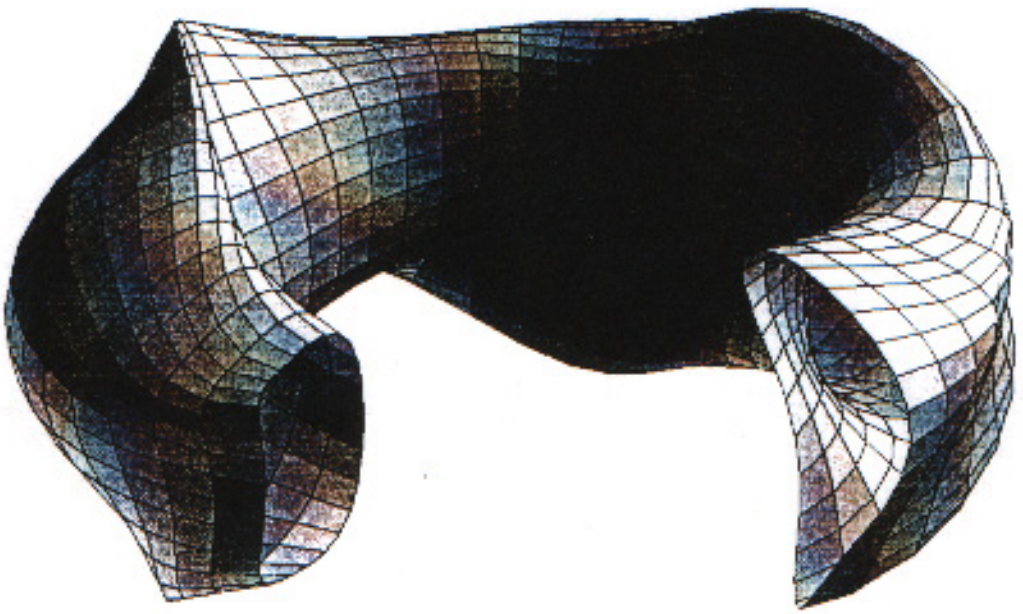
Major Configurations to be Discussed

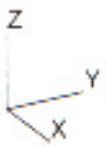
C10 Configuration discussed at last PAC.
Subsequently found kink unstable.

C82 Current reference configuration.
Stable at $\beta = 3.8\%$ with reference pressure and current profiles. (Higher β with other profiles).

C93 Study configuration aimed at lower coil current density.
Stable to kink at $\beta = 3.7\%$.

Configuration C82



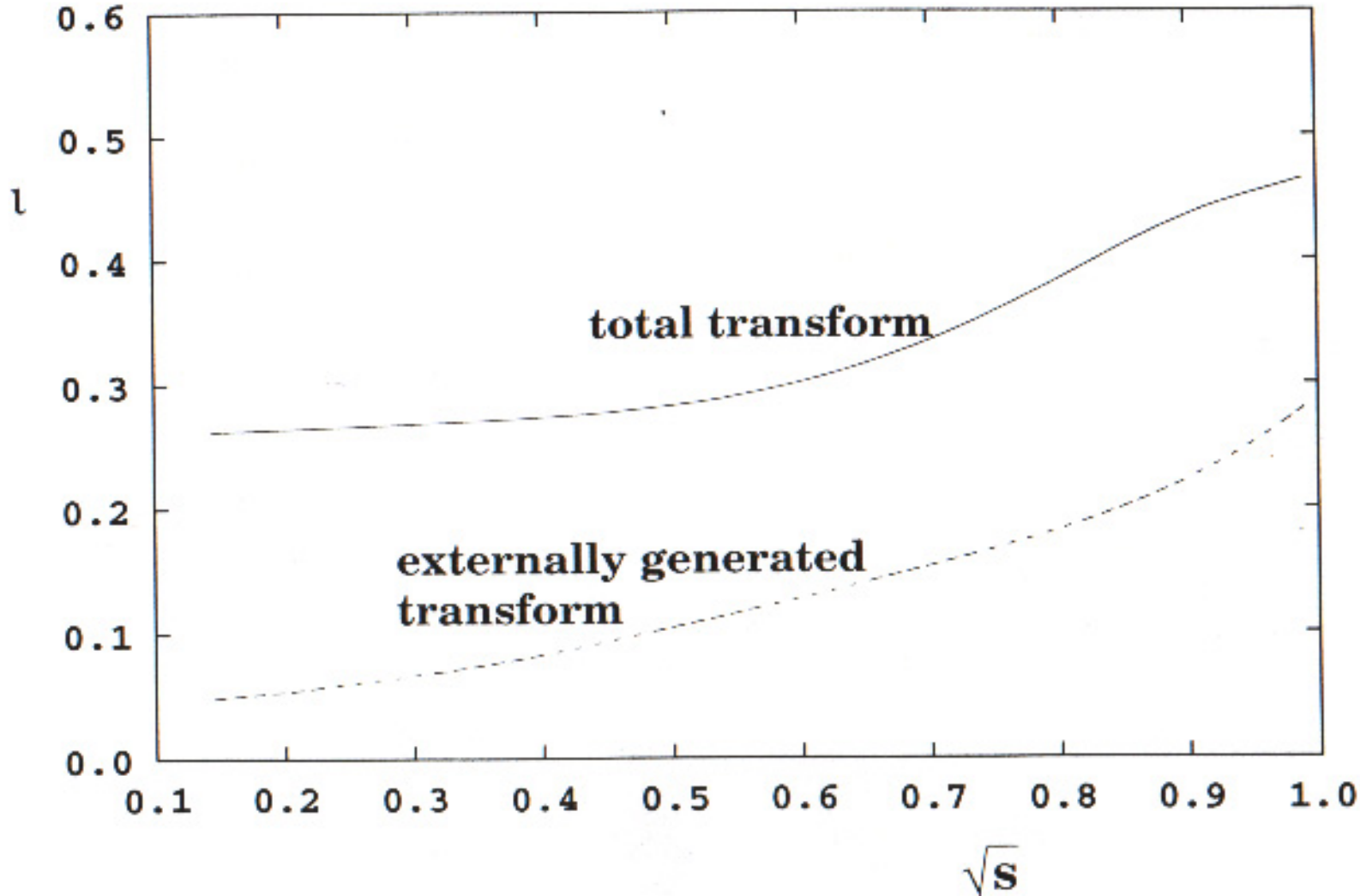


Outline

- Key physics requirements satisfied.
- Issues being addressed.
- Some additional details on MHD stability, with initial robustness results.

Configuration C82 satisfies the key physics requirements we have imposed:

1. Monotonically increasing ι. Places lower bound on required externally generated shear near edge.
   (Current by itself generates ι' of wrong sign in outer region.)



Configuration C82 Satisfies the Key Physics Requirements We Have Imposed (continued)

1. Monotonically increasing ι.

2. Substantial fraction of externally generated transform. (PAC1)

3. Kink stable at $\beta = 3.8\%$ (reference profiles) with wall at $3.5a$. Higher β with other profiles. Configuration shown at last PAC meeting (C10) was subsequently found to be kink unstable (higher resolution kink calculation).

4. Robustly stable to vertical modes. (New calculations).

5. Ballooning stable at $\beta = 3.8\%$. (Axisymmetric shaping.)

6. Adequate quasi-symmetry (neoclassical confinement). (New calculations.)
   As of PAC 2, even axisymmetric piece of thermal neoclassical confinement a concern. (Adequacy of poloidal flux.)
   Resolved by calculations with gyrokinetic code.

Issues Being Addressed

1. Saddle coil current density reduction continues to be design goal.
   - Coil designers continue to bring down current density.
   - Modified configuration may help. (C93)
2. In presence of imperfect symmetry, measure of deviation from quasi-symmetry not unique.
   - Neoclassical confinement in recent configurations does not correlate well with changes in ripple measure.
   - Improved transport modules under development for application to thermal and energetic ion transport.
3. Reduced neutral beam losses continue to be a design goal.
   - Losses: 34% at 1 T, 28% at 1.5 T.
   - To be addressed with improved transport target function.

4. Robustness and flexibility studies beginning.
   - Effect of profile and configuration modifications on configuration properties.
   - Develop configurations to be targeted by changes in coil currents for fixed set of coils.
5. More work planned on reactor scenario to establish reactor relevance.
6. Bootstrap currents: discrepancies between codes.
   - NIFS code used in design of C82. Predicts $\sim$ 170 kA for C82 with ARIES profiles and reactor relevant collisionality.
   - Even though $n \neq 0$ terms small, NIFS code predicts $\sim$ 300 kA when neglected. (With ARIES reference profiles. Adjustment of n and T profiles gives some latitude.)
   - Discrepancies with Monte Carlo calculations.
     Earlier benchmarks validated NIFS code.
     Recent Monte Carlo calculations do not see effect of small $n \neq 0$ terms.

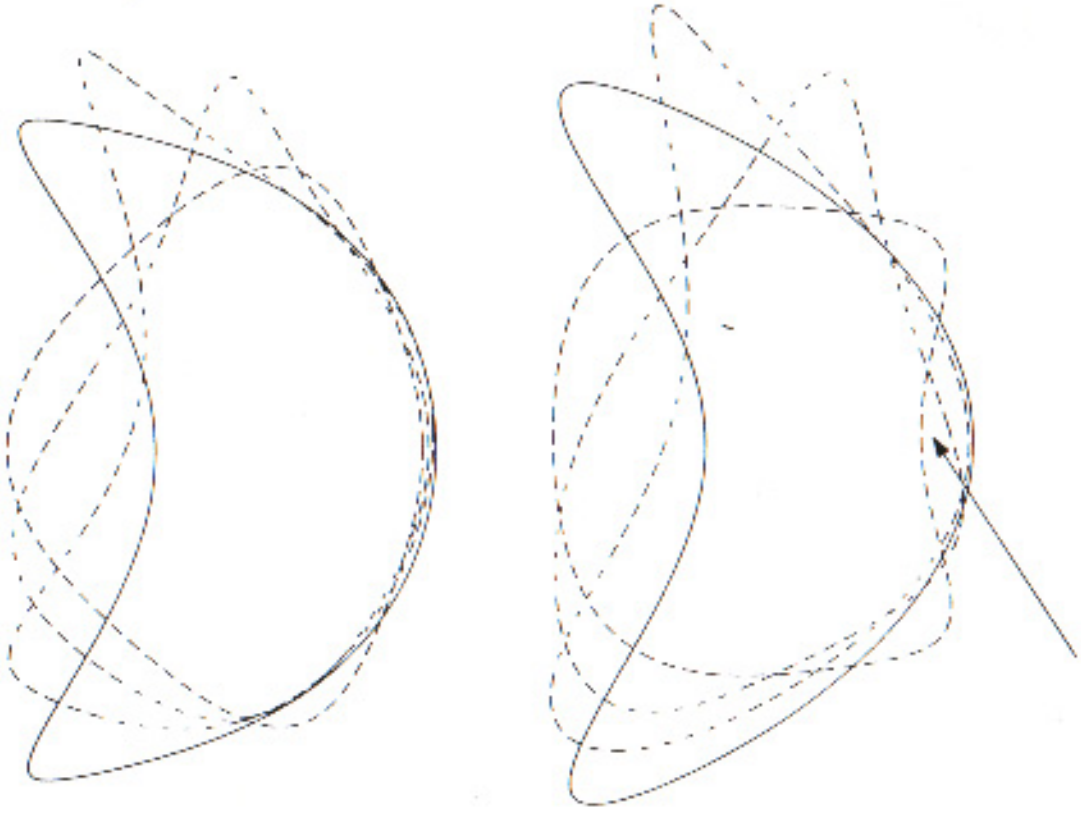
– May be able to do calculation with NIFS code by retaining only $n = 0$ components. Being confirmed by further calculations.

Some Additional Details on MHD Stability and Robustness

- Kink Stability
- Vertical Stability
- Ballooning Stability

External Kink stabilized without need for wall stabilization by combination of externally generated shear and corrugation of boundary.

Ku, Fu



c3

unstabilized

c82

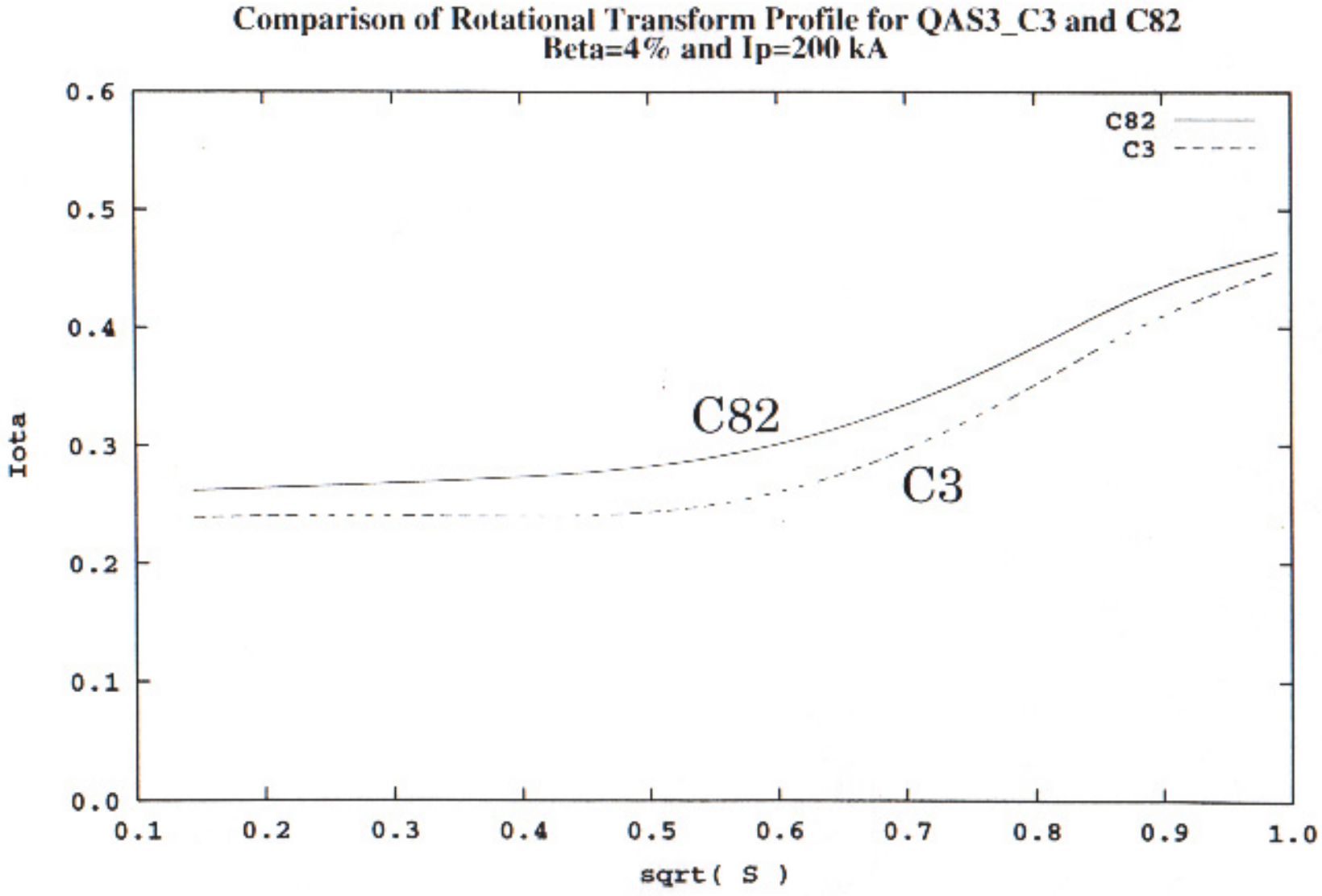
stabilized

Stabilizing Corrugation with little effect on shear

Indentation controllable with outside pusher coil.

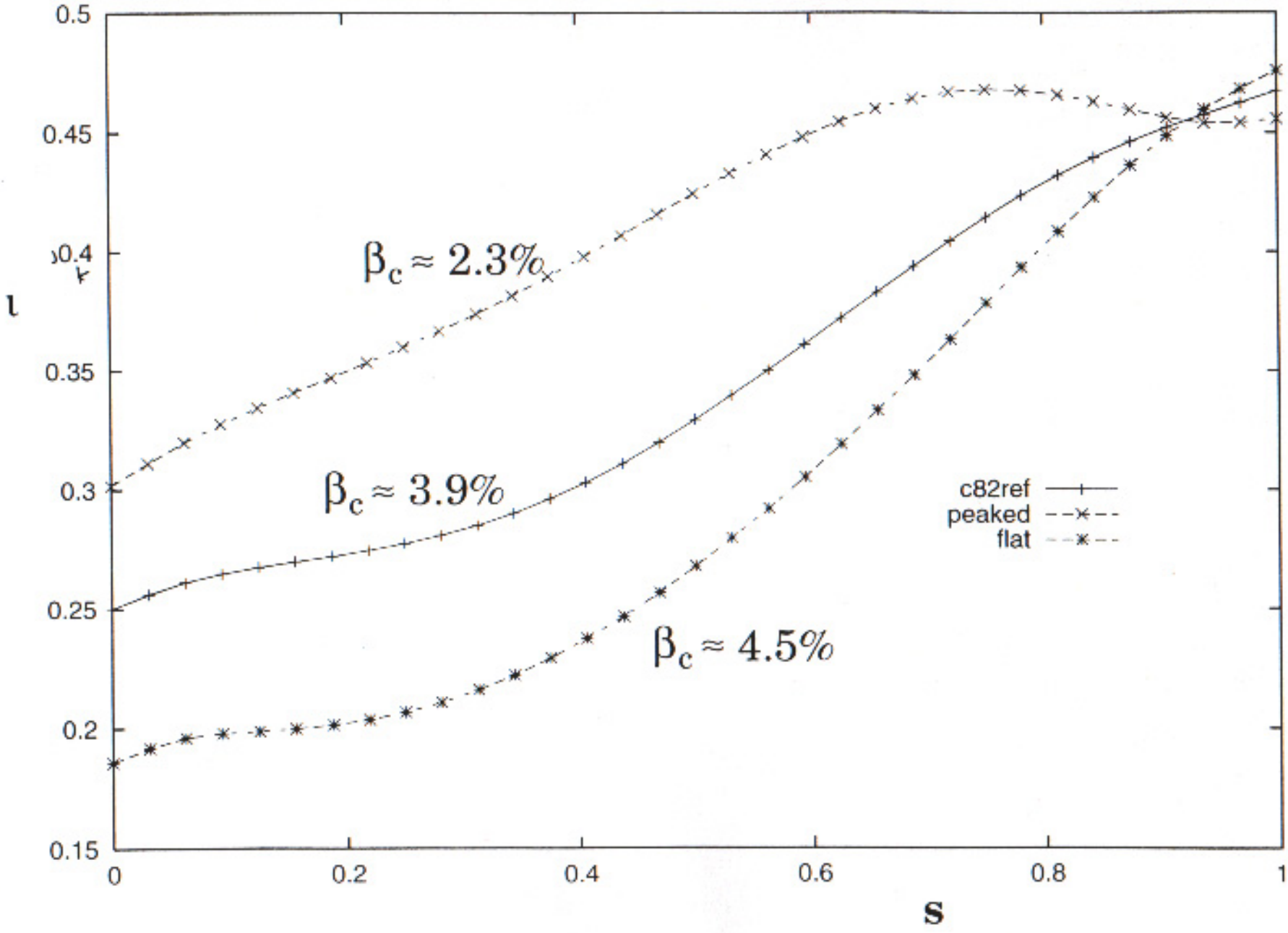
ARIES requires conducting wall at 1.3a.

Stabilizing effect of corrugation is independent of externally generated shear.

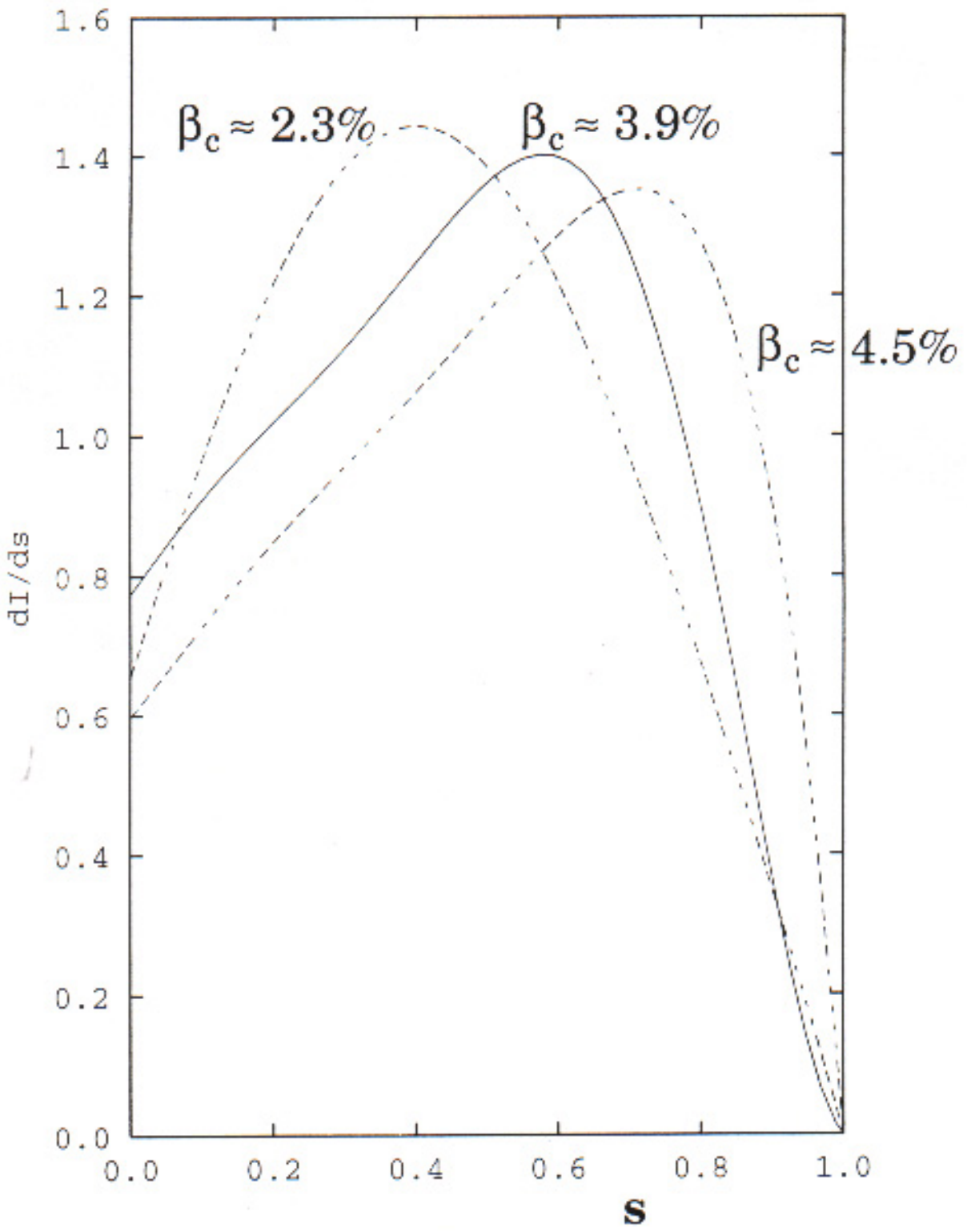


Isaev Xu, Monticello

Kink stability is strongly affected by shear in outer region.

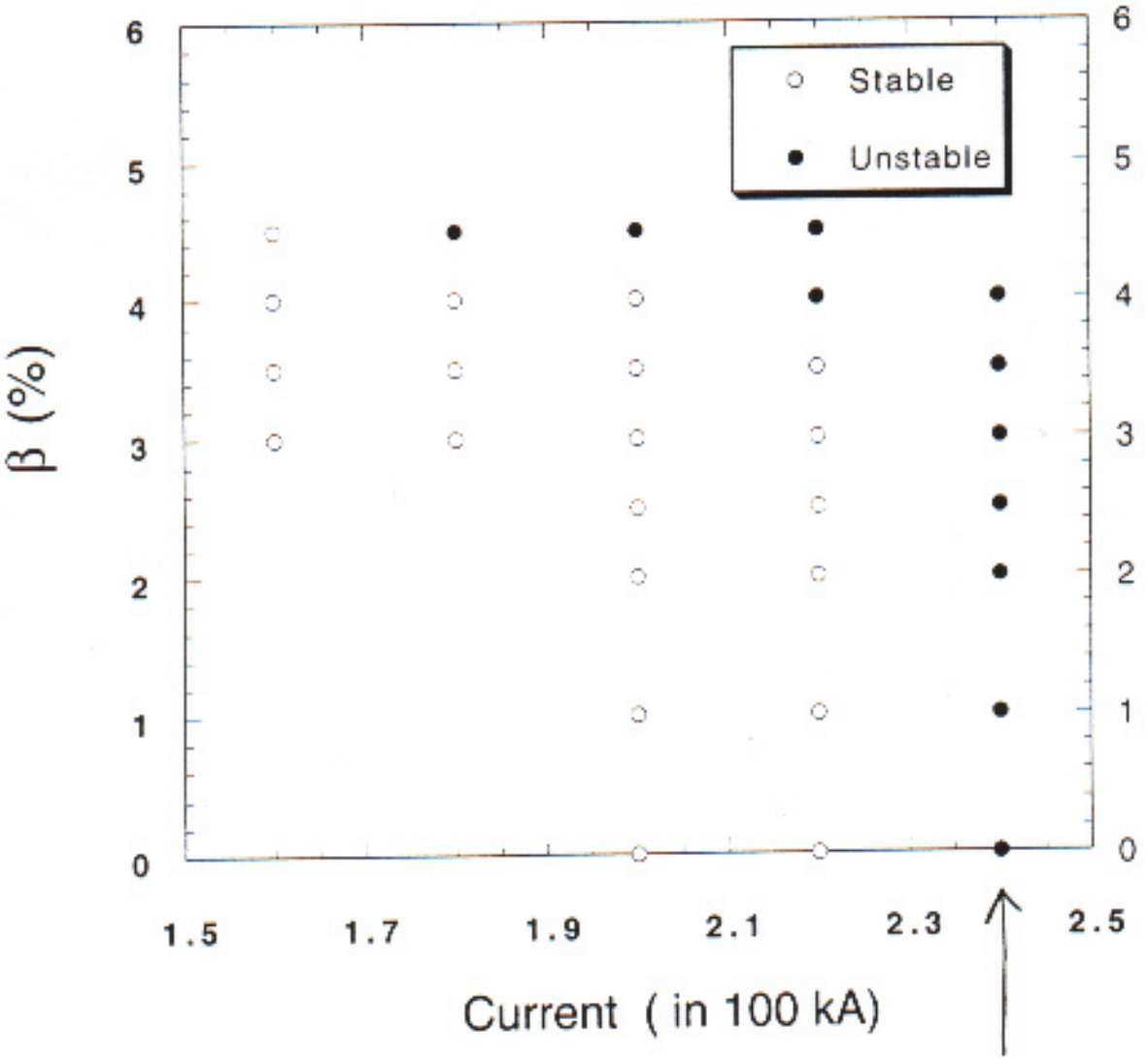


Broader current profiles have higher shear.



Fu

Kink Beta Limit Goes Up at Lower Current

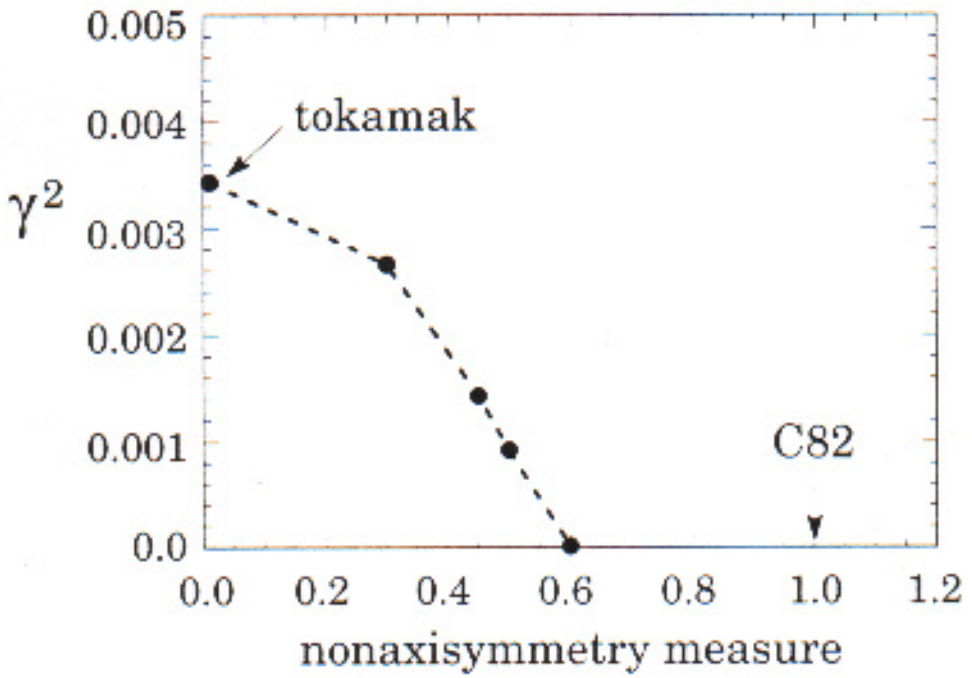


$\iota = .5$ surface moves into plasma

Fu, Cooper

Configuration C82 is robustly stable to the vertical mode.

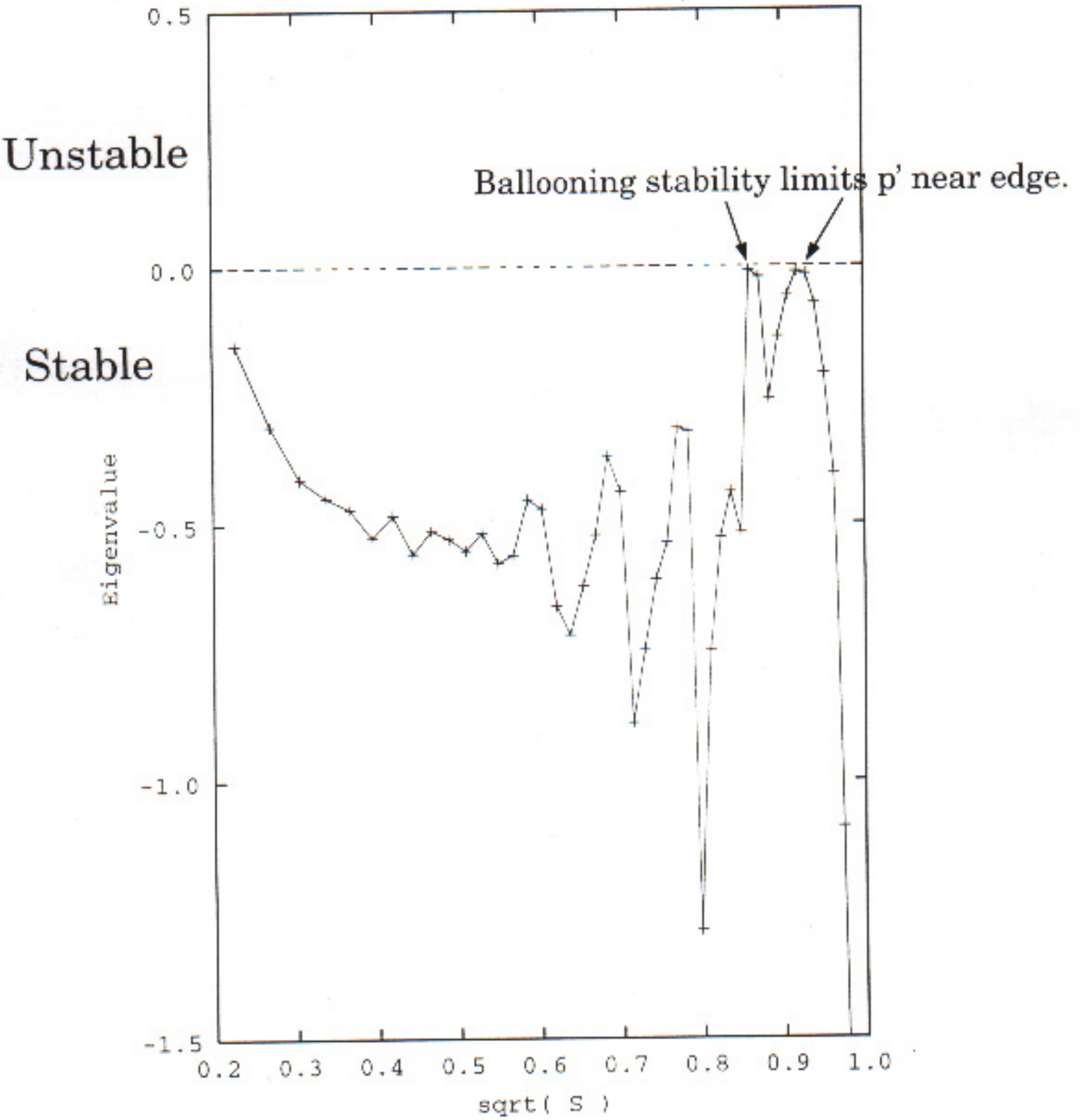
Vertical Stability for a Series of Configurations Interpolated Between C82 and a Tokamak



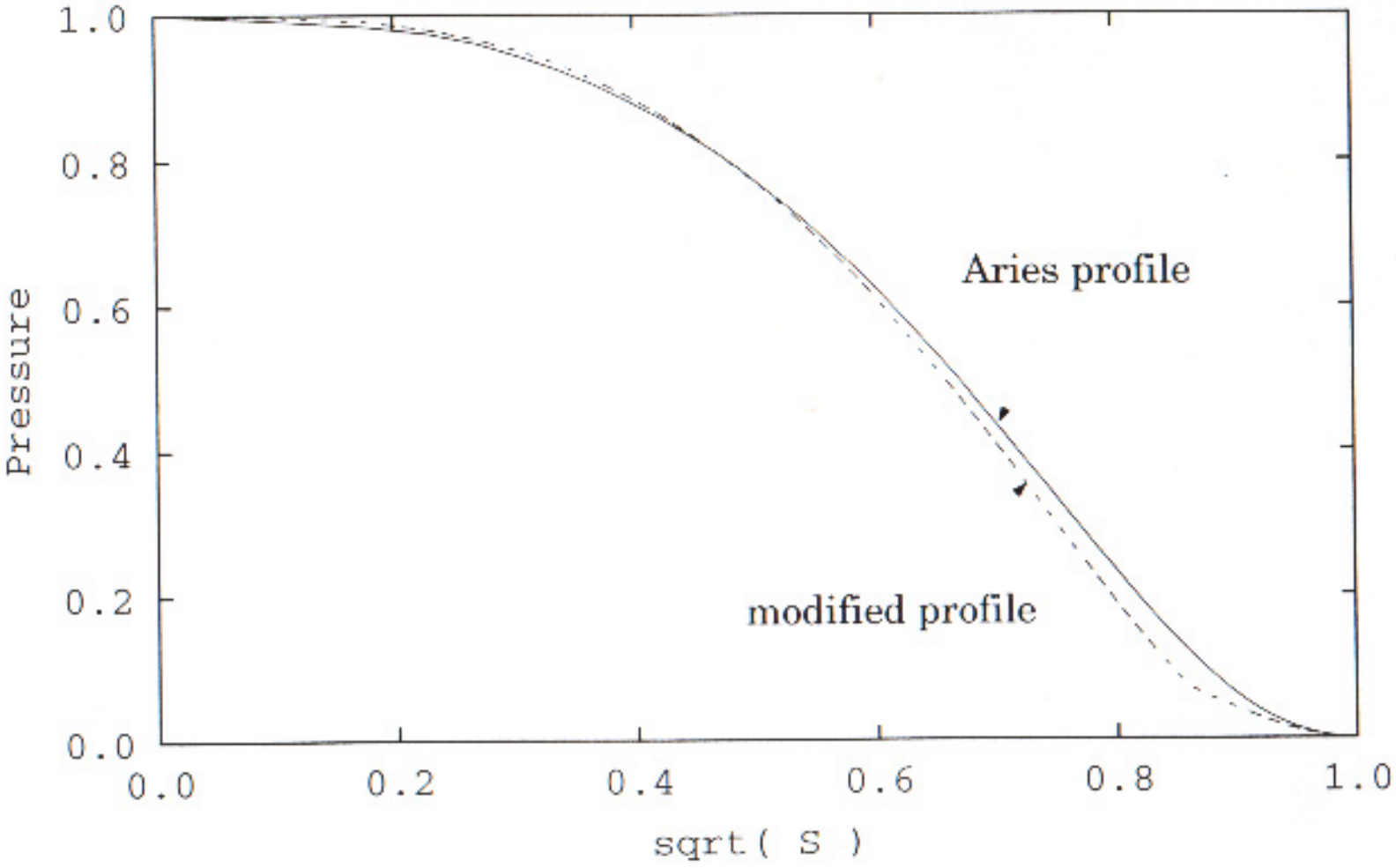
Increasing C82 elongation finds vertical stability up to elongations of 4.
May be able to improve design by going to higher elongation.

Ku, Cooper, Monticello

Ballooning is robustly stable in C82 through most of cross-section.



Comparison of Reference and Ballooning Stable Pressure Profiles
QAS3_C82



Aries p' above ballooning threshold in region near edge. (Large p' at edge adopted by Aries to increase bootstrap current there.) Local reduction in p' restabilized ballooning.

Conclusions

Significant progress since last PAC:

- Verification of robust vertical stability.
- Gyrokinetic calculations show adequate neoclassical confinement.
- Kink stable configuration with wall at $3.5a$.

C82 satisfies key configuration requirements:

- Monotonic, substantial ι.
- Stable to external kink, vertical mode, ballooning mode.
- Adequate quasi-symmetry.

Remaining issues being addressed.