High Beta Compact Stellarator Configurations

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Abstract

Optimization of quasi-omnigeneous stellarator configurations has led to the discovery of a new class of compact configurations with high β ballooning stability limits. These configurations were found by targeting confinement, ballooning stability, and bootstrap current alignment (i.e., the equilibrium current is matched to the bootstrap current). These configuration have tokamak-like iota profiles with most of their rotational transform from internal bootstrap currents, but at reduced levels compared to tokamaks. We are investigating the effect of vertical stability vs. elongation and iota profile. The ballooning stability limit is over β~20% for some of these configurations. Configurations with $<\beta>$ of up to 10% have been shown to be kink stable as well. Energy confinement times calculated from a Monte Carlo code are larger than ISS95 times.

High β Configurations

- A class of configurations with high β MHD stability limits
  - Rotational transform primarily from plasma current
  - Better alignment with self-consistent bootstrap current than advanced tokamaks
  - Stable at higher β than comparable tokamak due to lower self-consistent bootstrap current

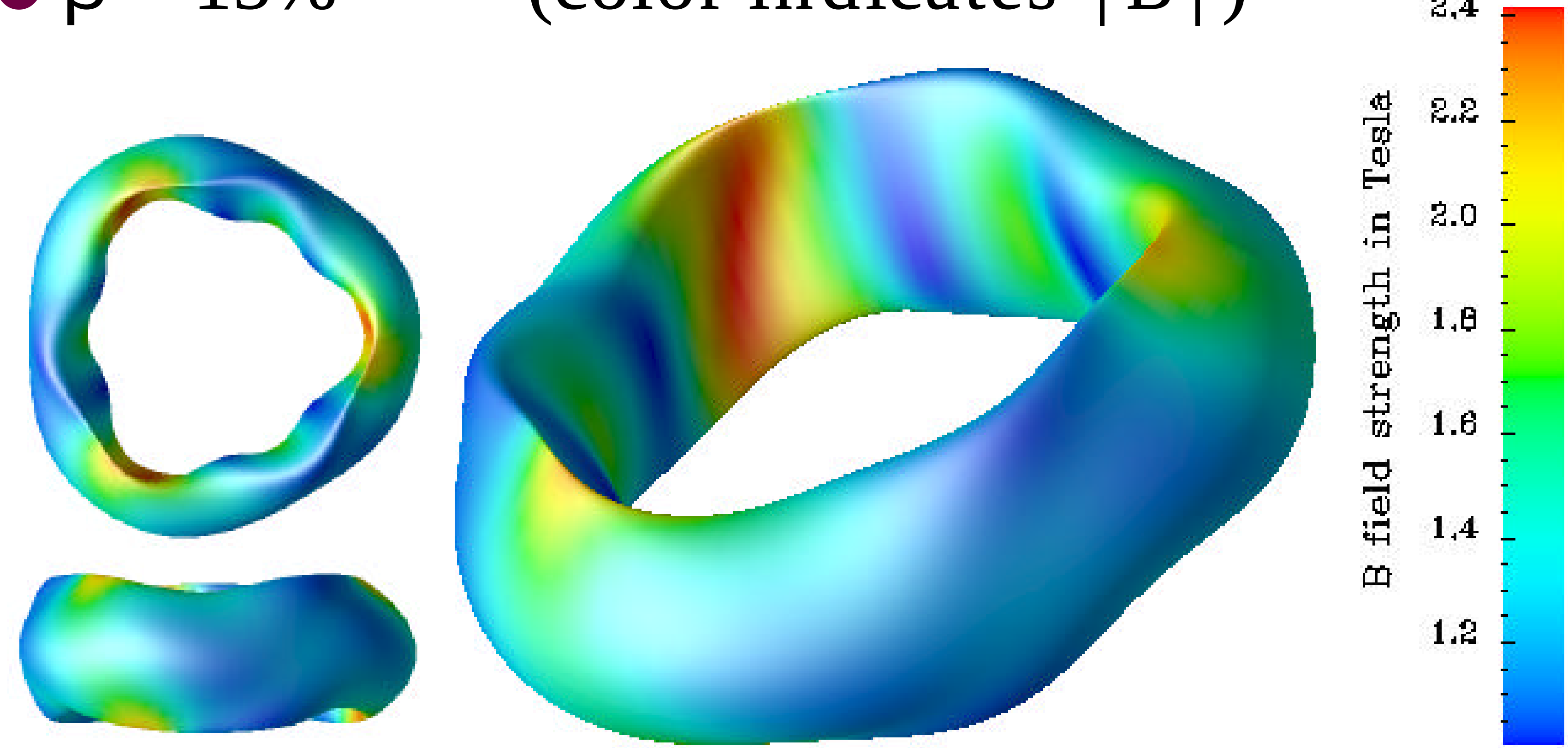
Configuration Properties

- Low aspect ratio: $2 < A < 4$
  - Compact, economically-sized design
- Low number of field periods: N = 2 - 4
  - Relatively simple modular coils
- High β MHD stability limits
  - Ballooning & Mercier stability up to β=23%
  - Vertical/Kink stability up to β =15%
- Confinement which improves with β

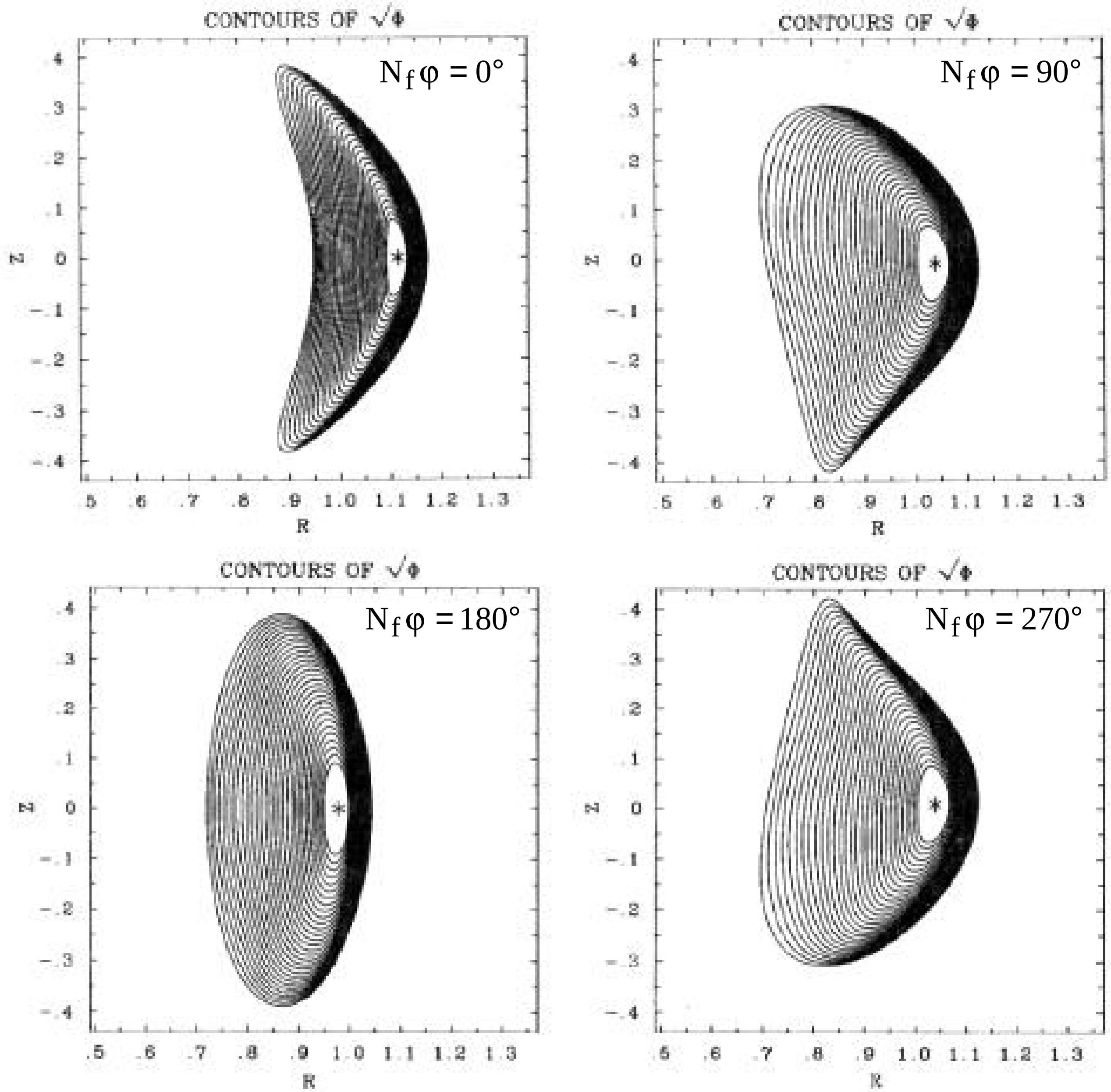
3 Field Period Configuration

- A = 3.7
- β = 15%

Outer Flux Surface
(color indicates |B|)

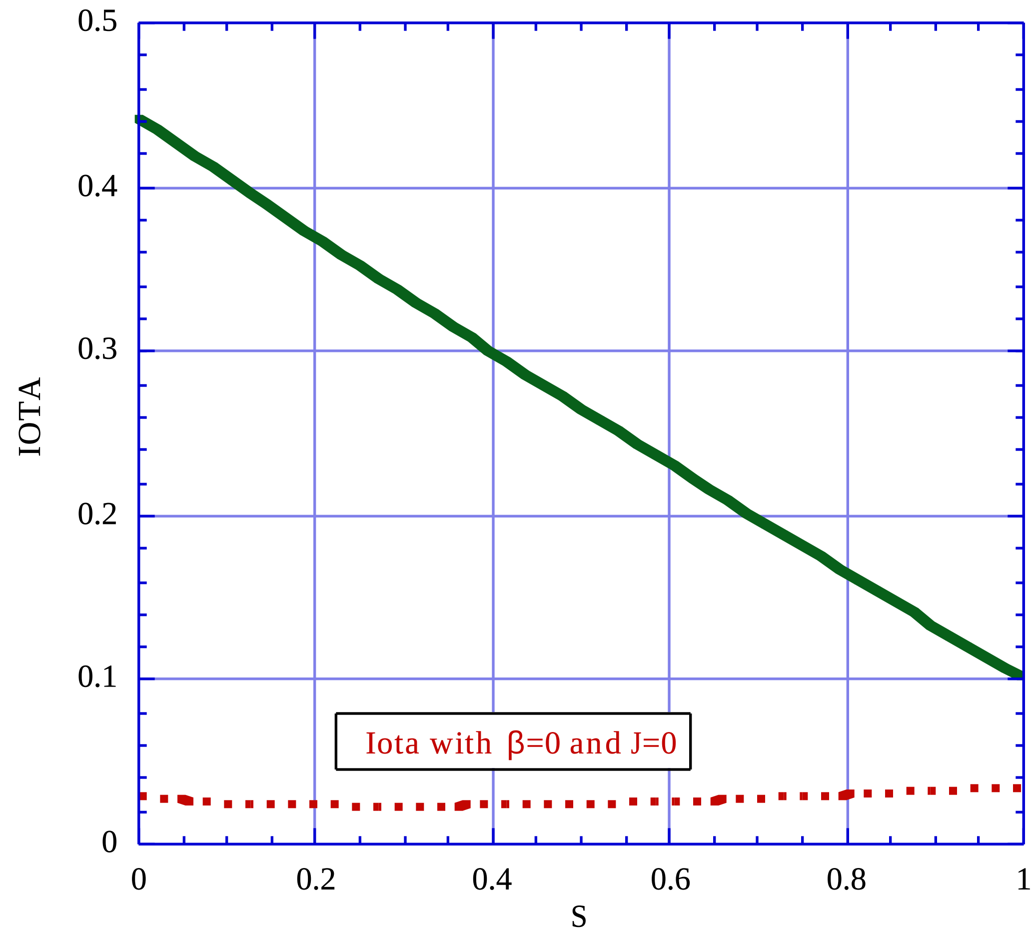


Flux Surfaces

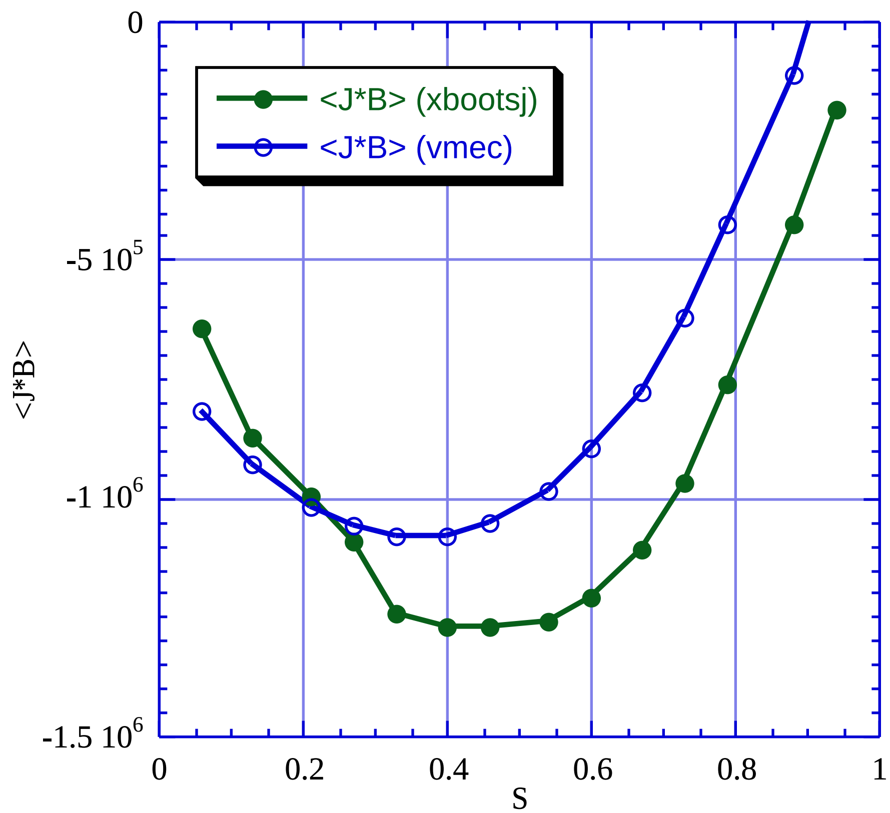


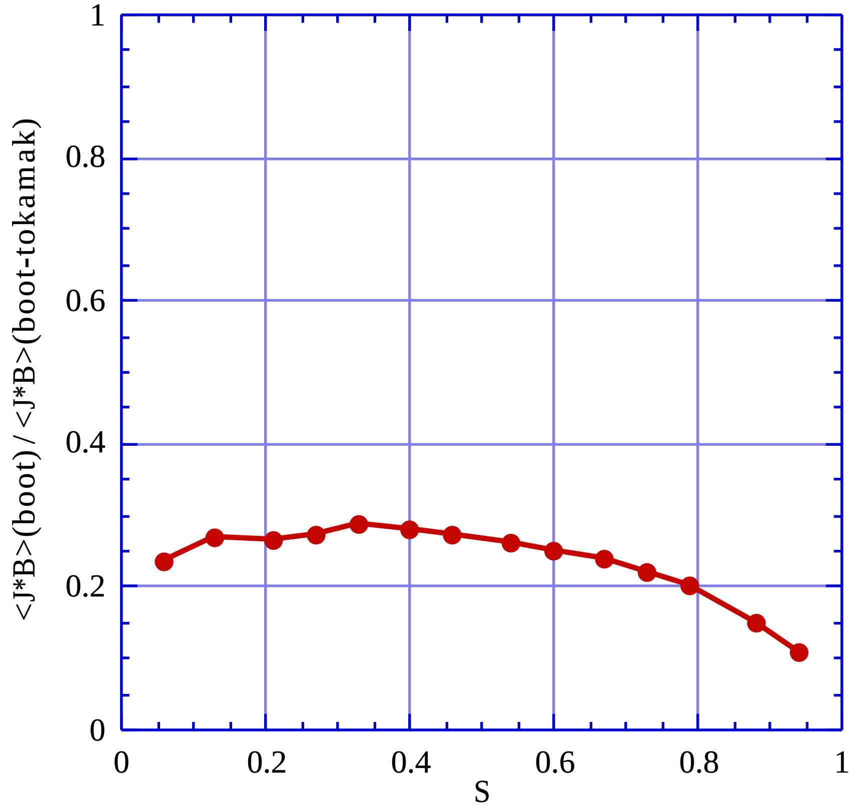
Rotational transform profile is related to the internal plasma current much like in a tokamak

- β=15%
- $\langle|B|\rangle = 1.0\,\mathrm{T}$
- Tor. Cur. = 155 kA



Predicted bootstrap current is in relative alignment with the VMEC current and is a fraction of that in a comparable tokamak

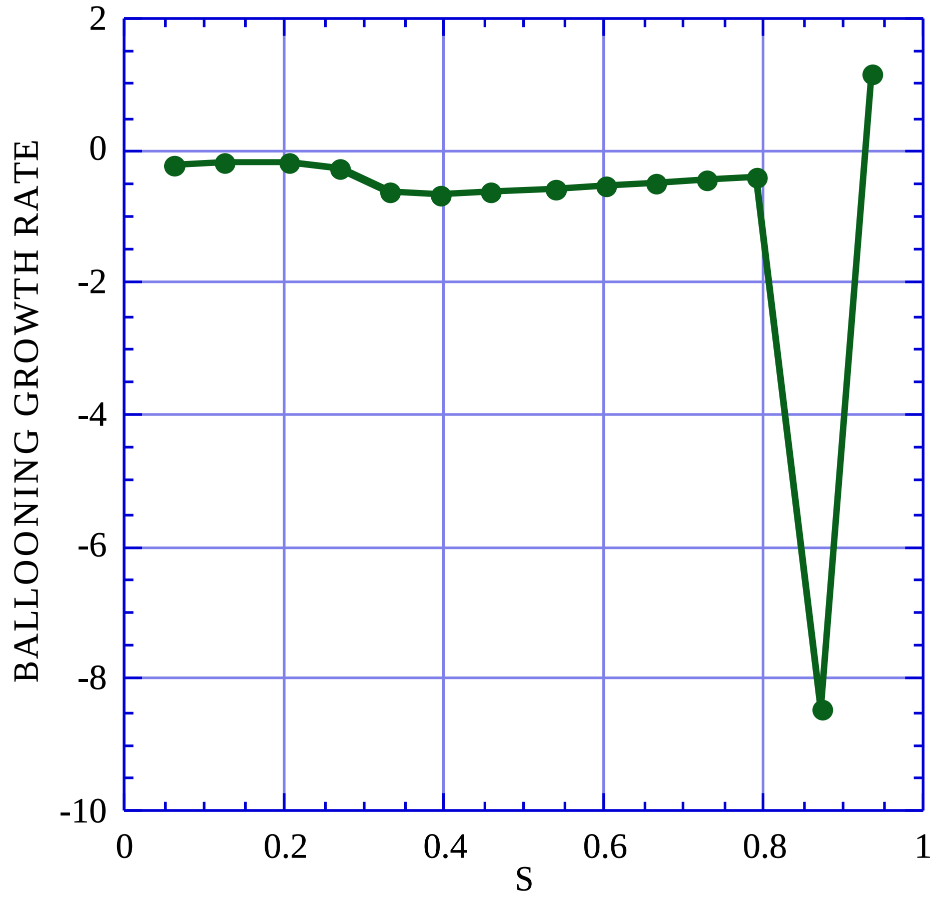




Ballooning stable at all points analyzed except for one point at the edge region

Ballooning stability calculated using the COBRA code.

For details of the ballooning stability properties, see S. Hirshman, previous poster.



This configuration has good MHD stability properties

- Stable to vertical and kink modes
  - Vertical & kink stability analyzed with the TERPSICHORE code (G. Fu)

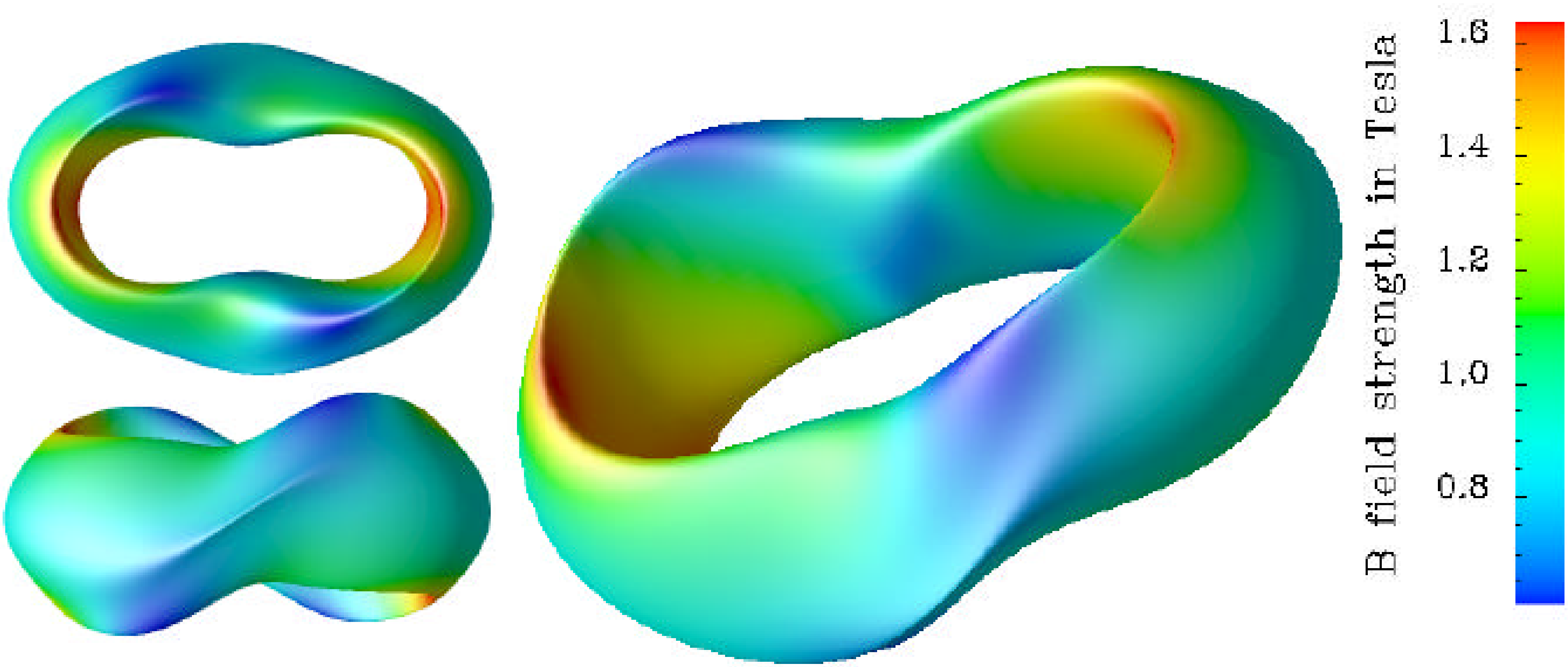
- Mercier stable except on a few isolated resonant surfaces

2 Field Period Configuration

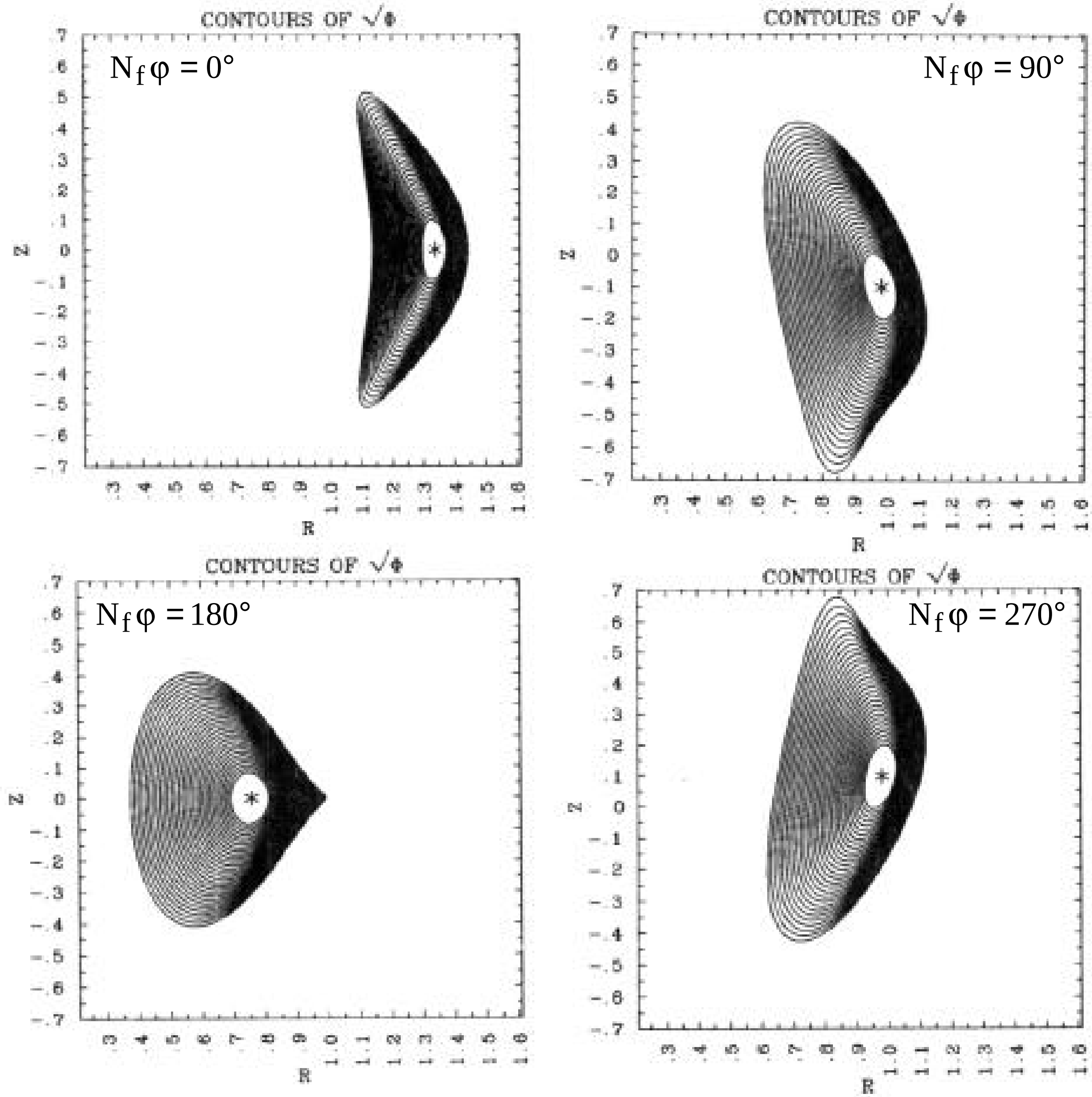
- A = 2.7
- β = 5%

Outer Flux Surface

(color indicates |B|)

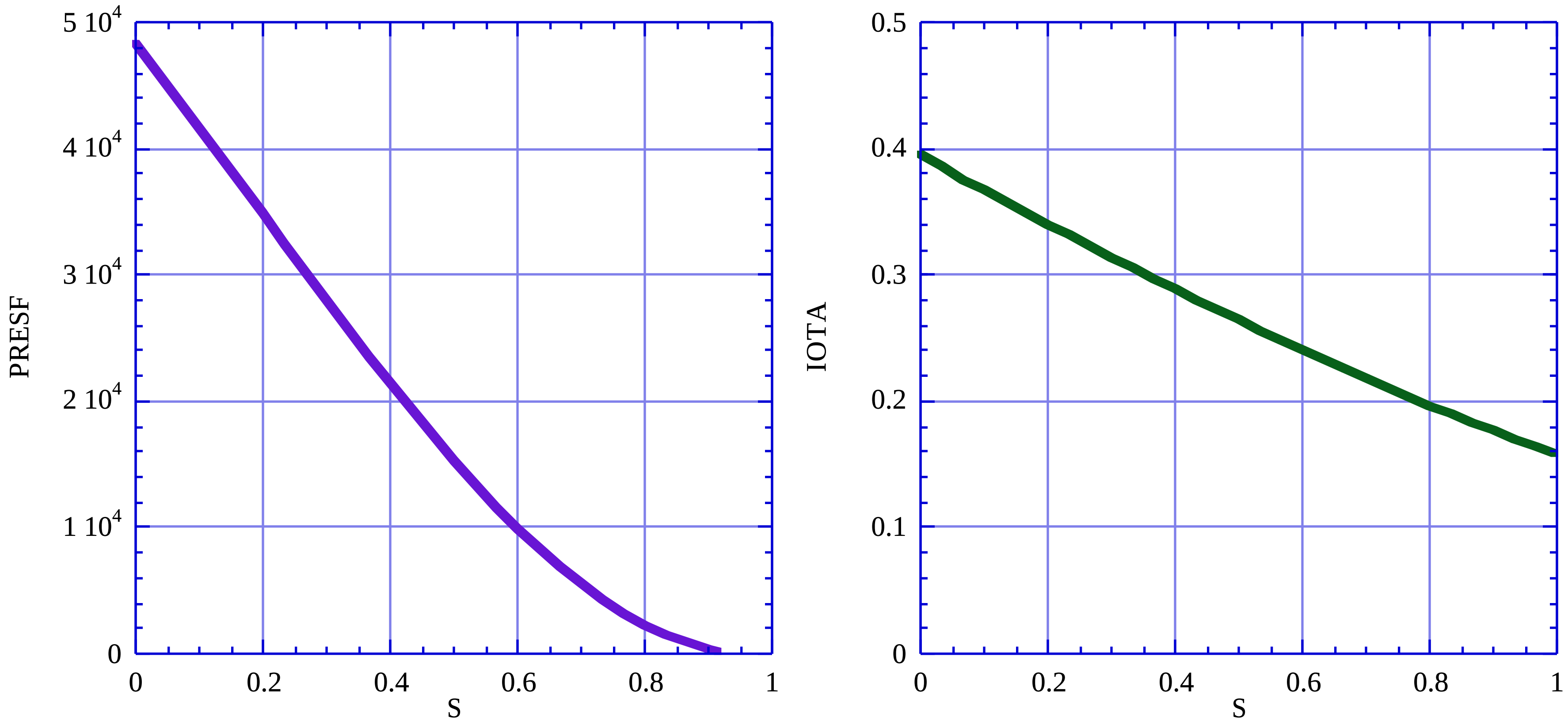


Flux Surfaces

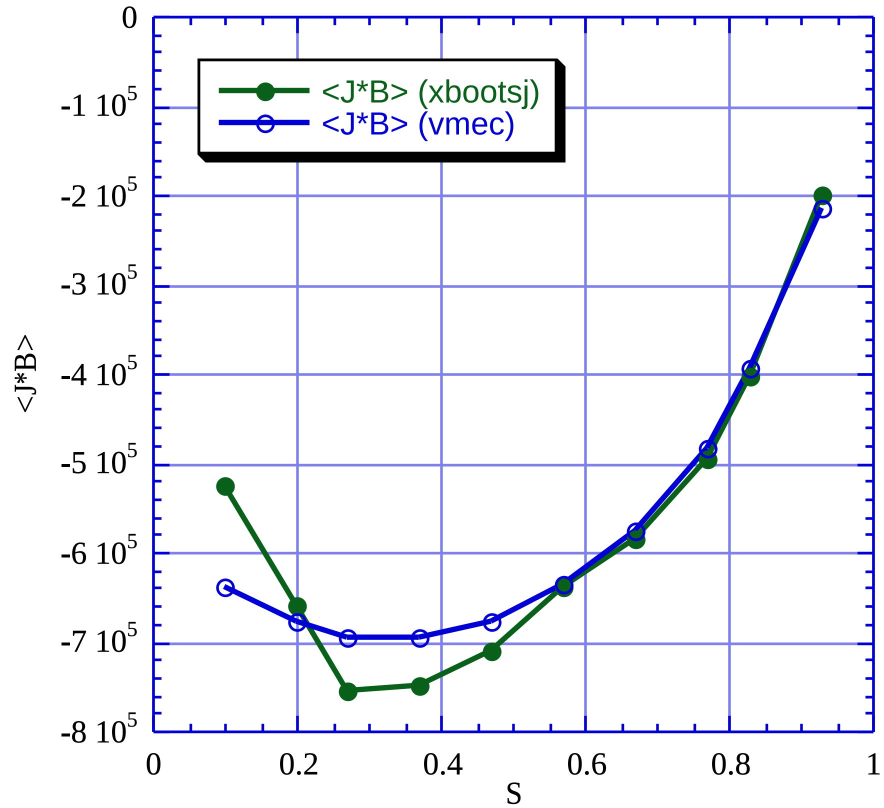


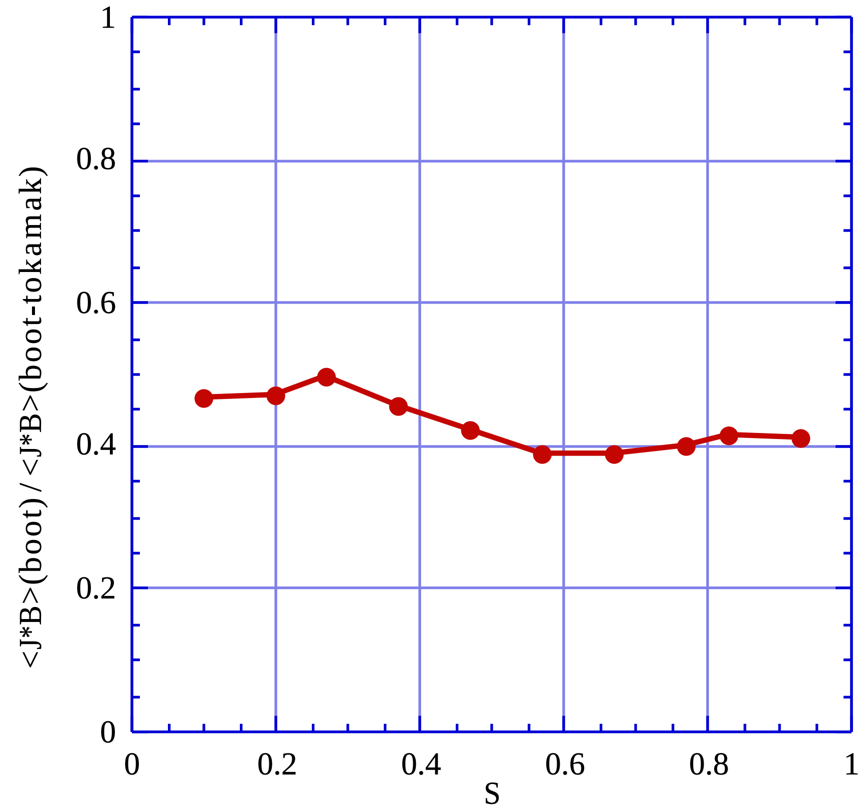
Pressure and rotational transform profiles for this 2-field period configuration

- β=5%, $\langle|B|\rangle = 1.0\,\mathrm{T}$, Tor. Cur. = 160 kA



Predicted bootstrap current is in excellent alignment with the VMEC current and is a fraction of that in a comparable tokamak

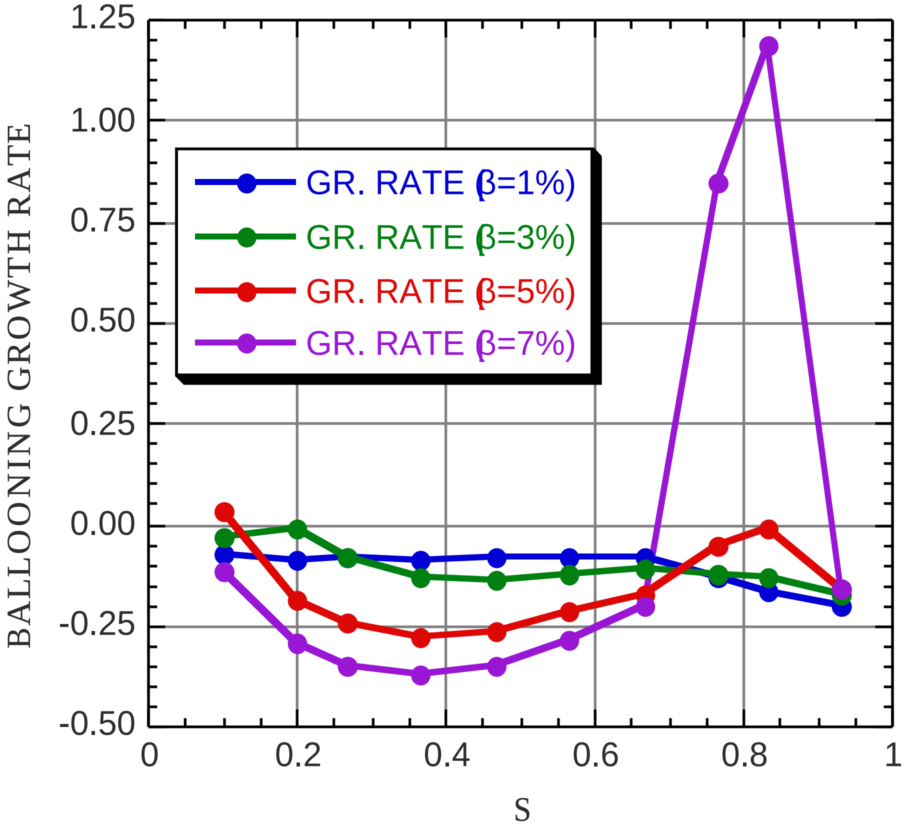




Core region is second stability regime for ballooning stability - have scanned β for a fixed boundary calculation

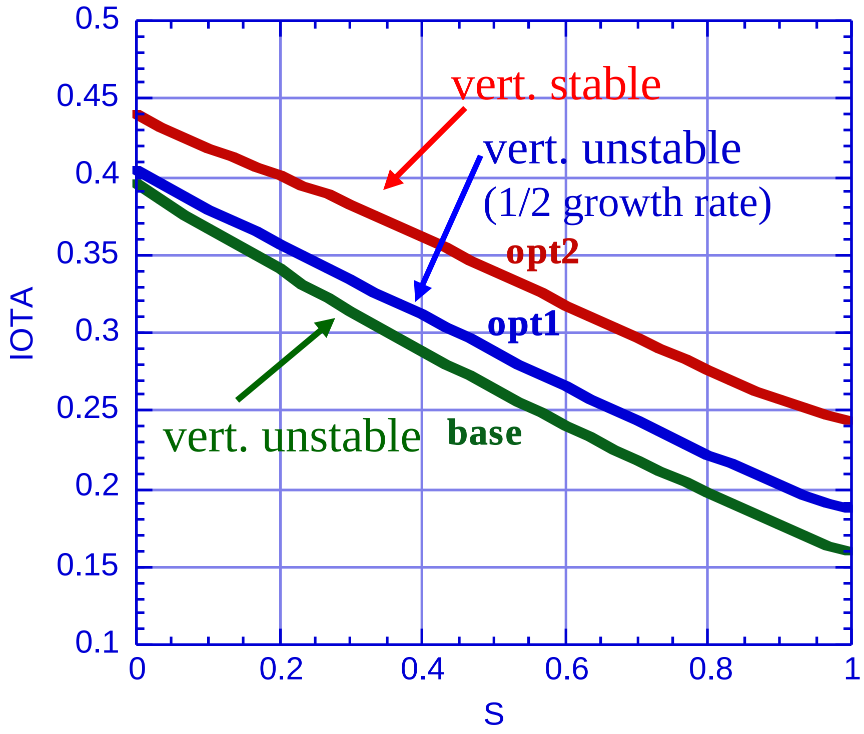
Ballooning stability improves in the core with increasing β.

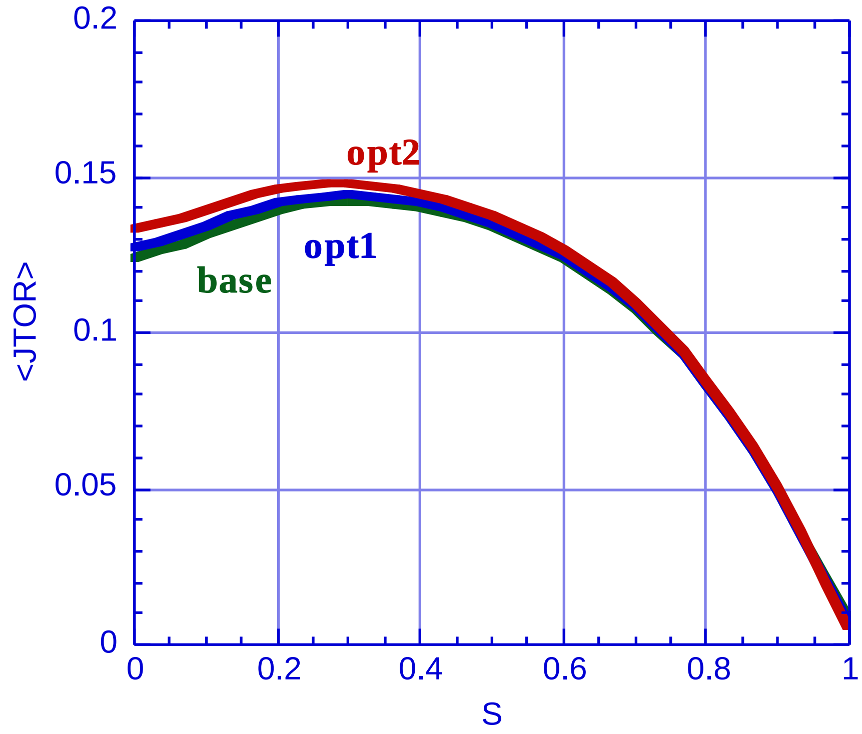
Edge region is still in the first stability regime - goes unstable with increasing β.



Can improve vertical stability by increasing the amount of external rotational transform

➢ Increased the amount of external transform by targeting a higher edge iota at fixed current





Neoclassical Confinement

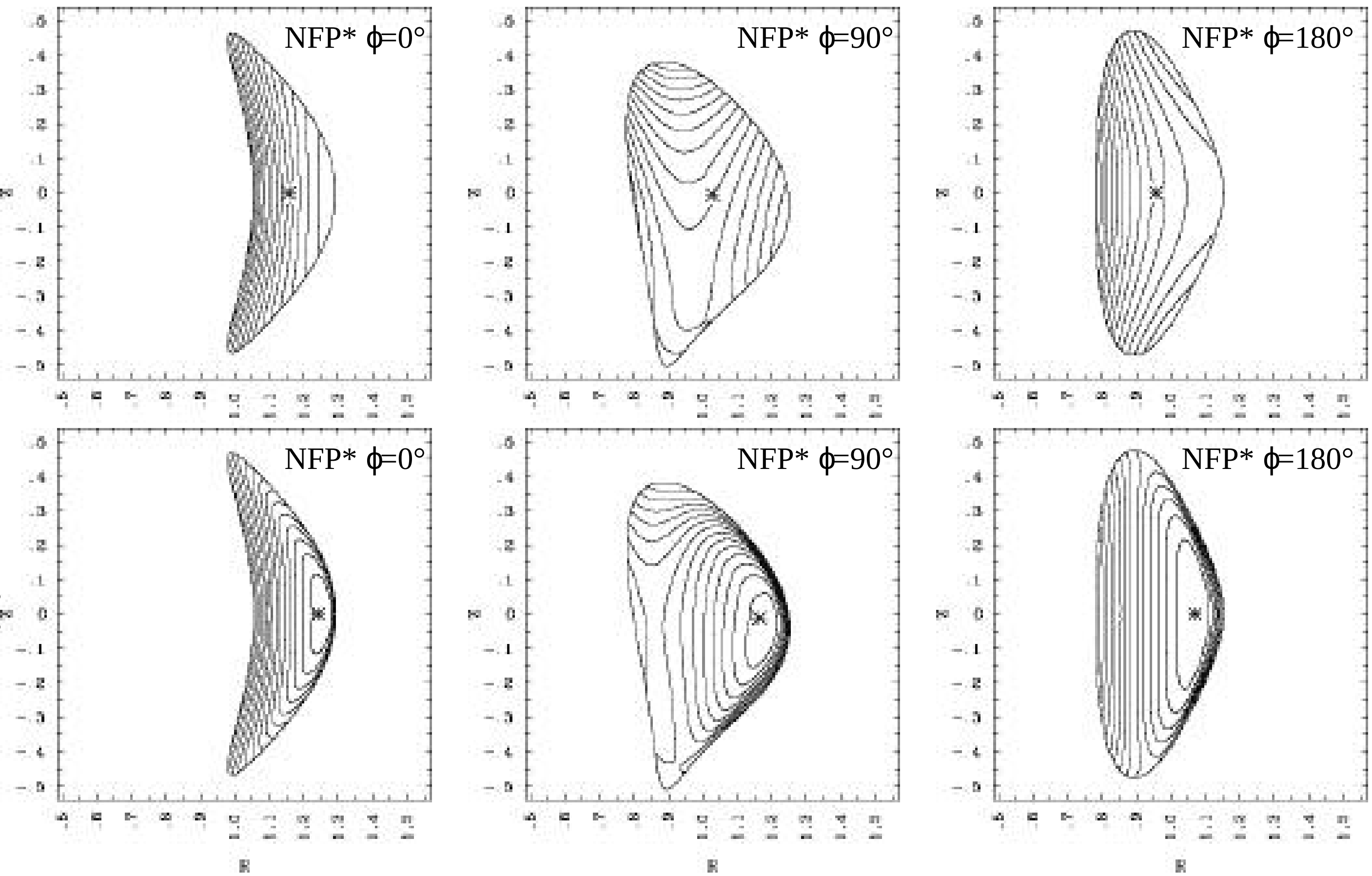
- Neoclassical confinement improves with increasing β
- See D. Spong, Poster HP1.038 for details on the neoclassical confinement for QOS configurations
- As β increases, the surfaces of constant $|B|$ become closed, more in alignment with the flux surfaces

Alignment of |B| surfaces with flux surfaces improves at higher β

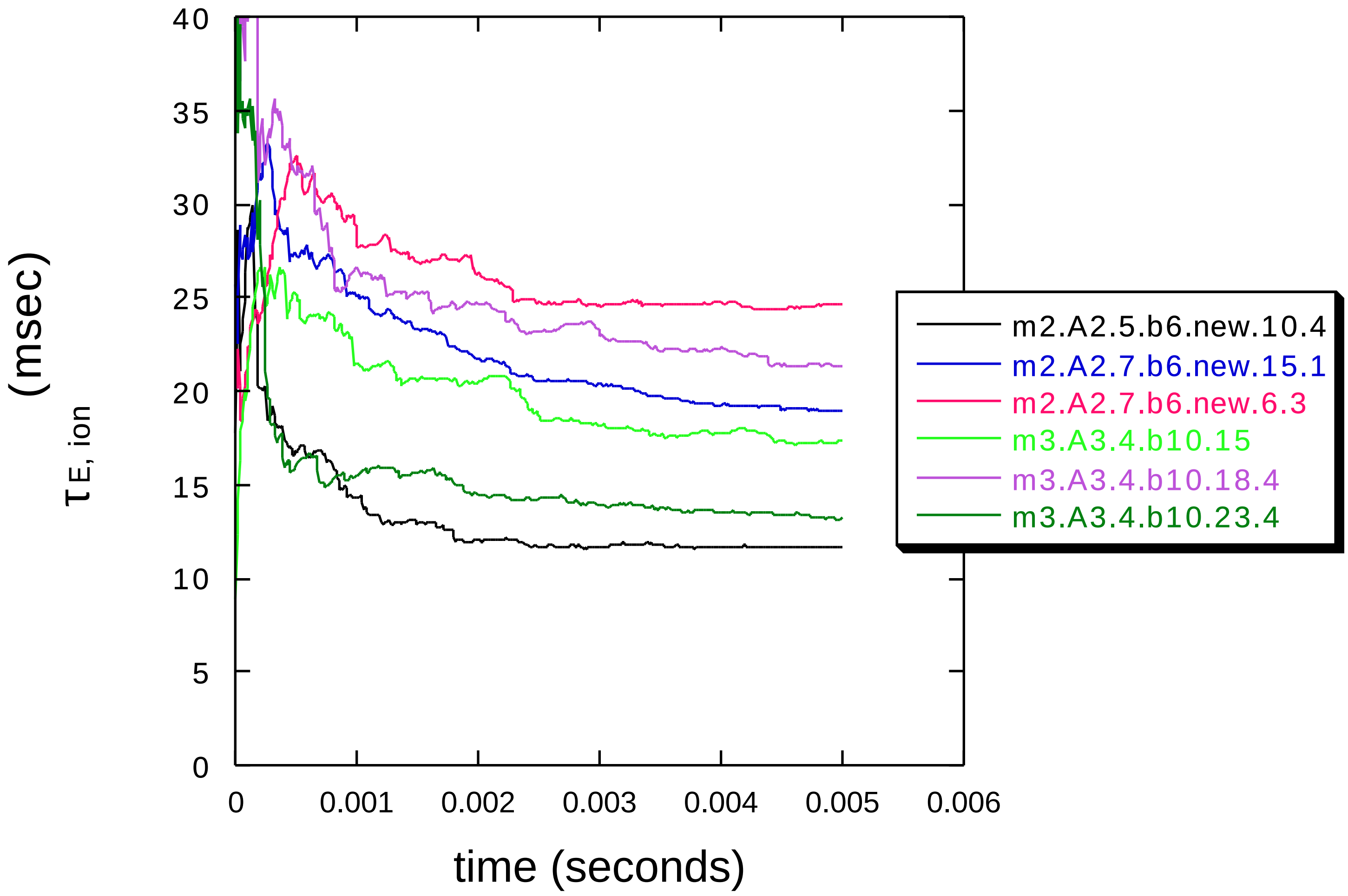
Surfaces of constant |B| at β =0% and β =23%

β=0%:

β=23%:



Neoclassical ion confinement times for the cases shown in the next poster



Conclusions

- Have obtained compact, high β, MHD stable configurations with good neoclassical confinement
  - Tokamak-like rotational transform primarily from plasma current
  - Stable at higher β than comparable tokamak due to lower self-consistent bootstrap current
  - Confinement improves with increasing β