



Quasi-poloidaly Symmetric and Isodynamic Stellarator Configurations

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Abstract

Two approaches towards confinement optimized compact stellarator configurations are tested; quasi-poloidal symmetry and isodynamic flux surfaces. The $|B|$ spectrum of recent high beta drift-optimized stellarator configurations have been dominated by $m=0$ components, i.e., the poloidally symmetric components of the spectrum. By using an optimization which targets a $(0,1)$ helicity in the $|B|$ spectrum, this feature can be accentuated while still maintaining Mercier and ballooning stability. Concurrently, in a separate line of investigation, the optimizer has been modified to target a minimum variation in $|B|$ on a flux surface. This is equivalent to keeping only the $m=0, n=0$ component of the $|B|$ spectrum. These quasi-isodynamic configurations[1], in which $|B|$ becomes nearly constant on a flux surface, minimizes the guiding center drifts away from flux surfaces. The effect of these two optimizations on particle transport will be reported.

[1] D. Palumbo, Nuovo Cimento B 53, 507 (1968)

I. Introduction

- The goal of this project was to test the effects of **quasi-poloidal symmetry** and **quasi-isodynamic symmetry** on particle confinement in high beta, compact stellarators
 - Quasi-poloidal symmetry: $|B| = |B|(\theta, \zeta)$
 - Quasi-isodynamic symmetry: $|B| = |B|(\zeta)$

Introduction (cont.)

- Continued to target other parameters throughout the optimization
 - Compact, high beta configuration
 - Ballooning and Mercier stability
- The Oak Ridge Stellarator Optimization Code [Hirshman, et. al., Phys. Plasmas **6**, 1858 (1999)]
 - targets a minimum χ^2 (where χ^2 is a measure of the deviation from a target plasma)

II. Quasi-poloidal Symmetry

- Modification of the $|B|$ Spectrum
 - Described by Fourier Series:

$$B(\theta, \phi) = \sum_n \sum_m B_{m,n}(\theta) \cos(m\theta - n\phi)$$

- Poloidal symmetry requires that B is function of θ and ϕ only
 - $|B|$ has no ϕ dependence

II. Quasi-poloidal Symmetry

- Goal:

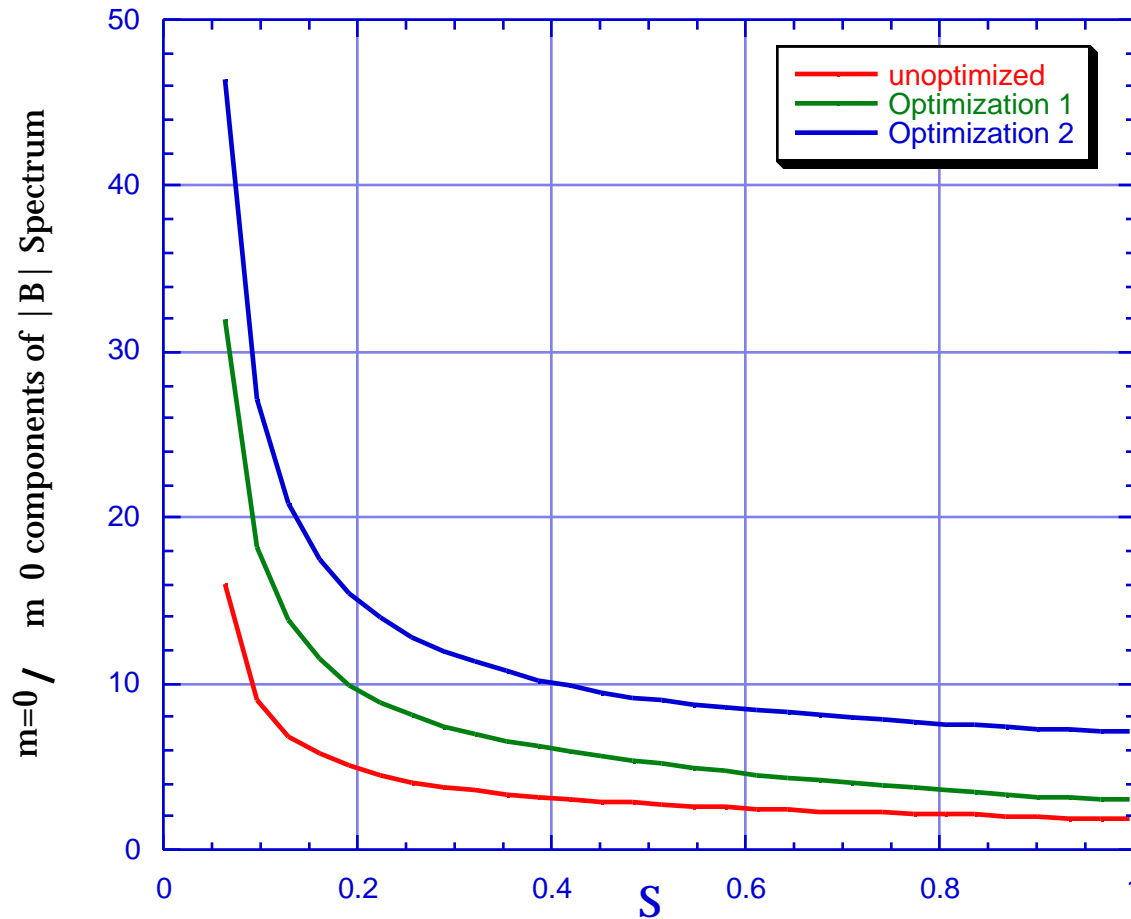
- Maximize the ratio:

$$\frac{B_{m=0,n}}{B_{m,n}}$$

- Method:

- Target a helicity of (0,1)
- Other targets: ballooning and Mercier stability, bootstrap current alignment, $A = 3.40$, $\beta = 10\%$

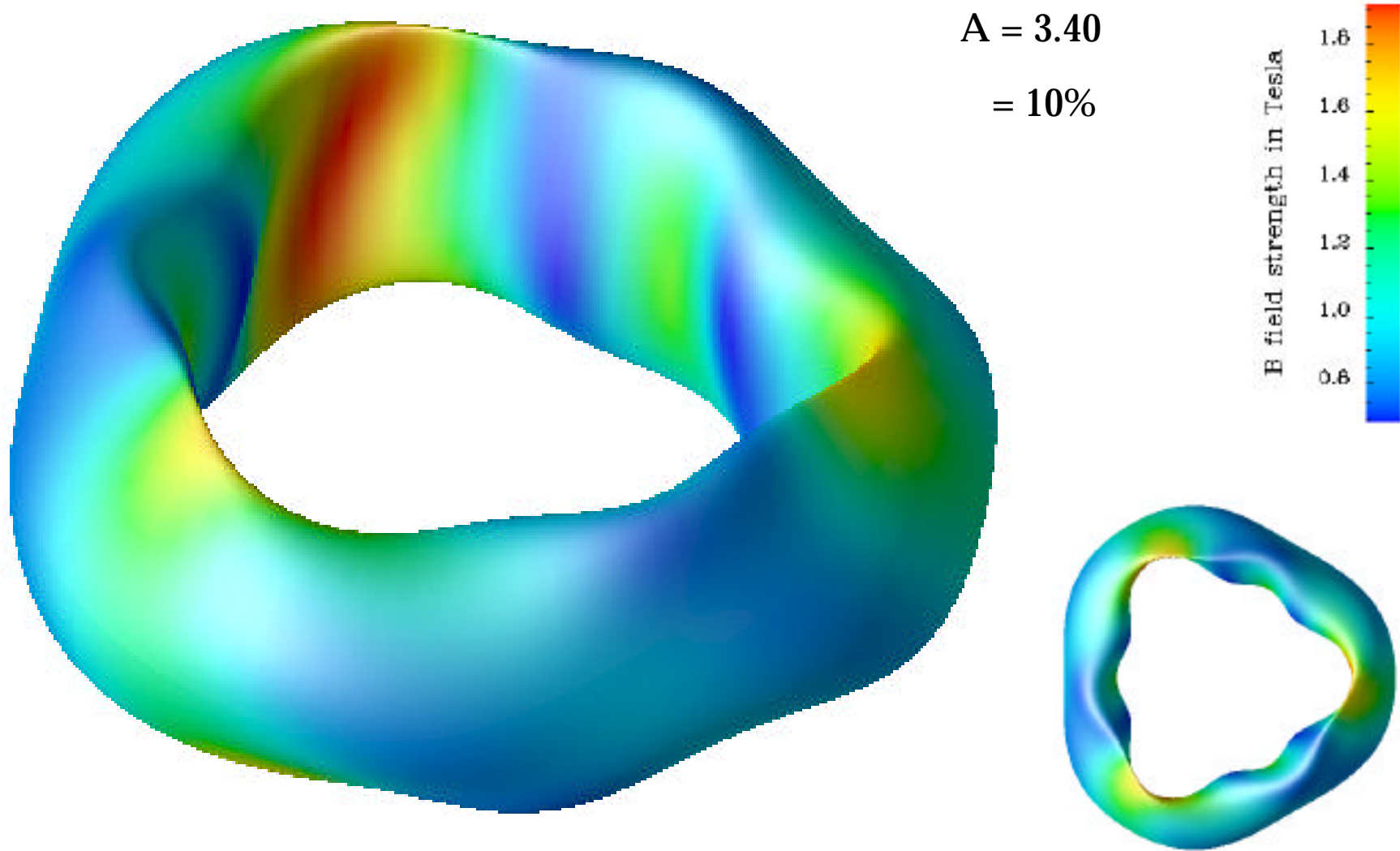
The optimizer was able to adjust $|B|$ Spectrum to increase poloidal symmetry



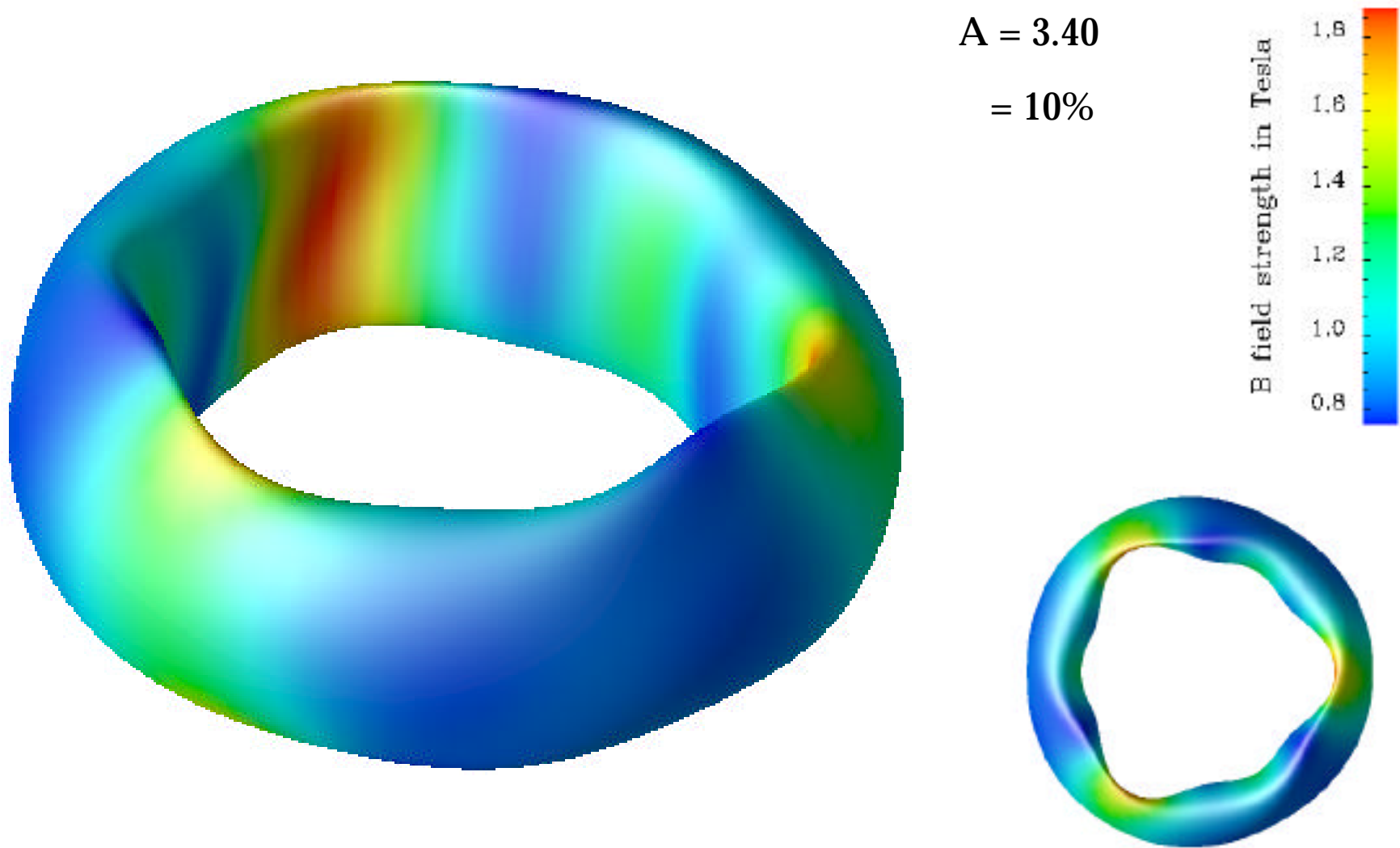
Chi-sq Bmn Contributions

Unoptimized	17,855
Optimization 1	7,471
Optimization 2	1,835

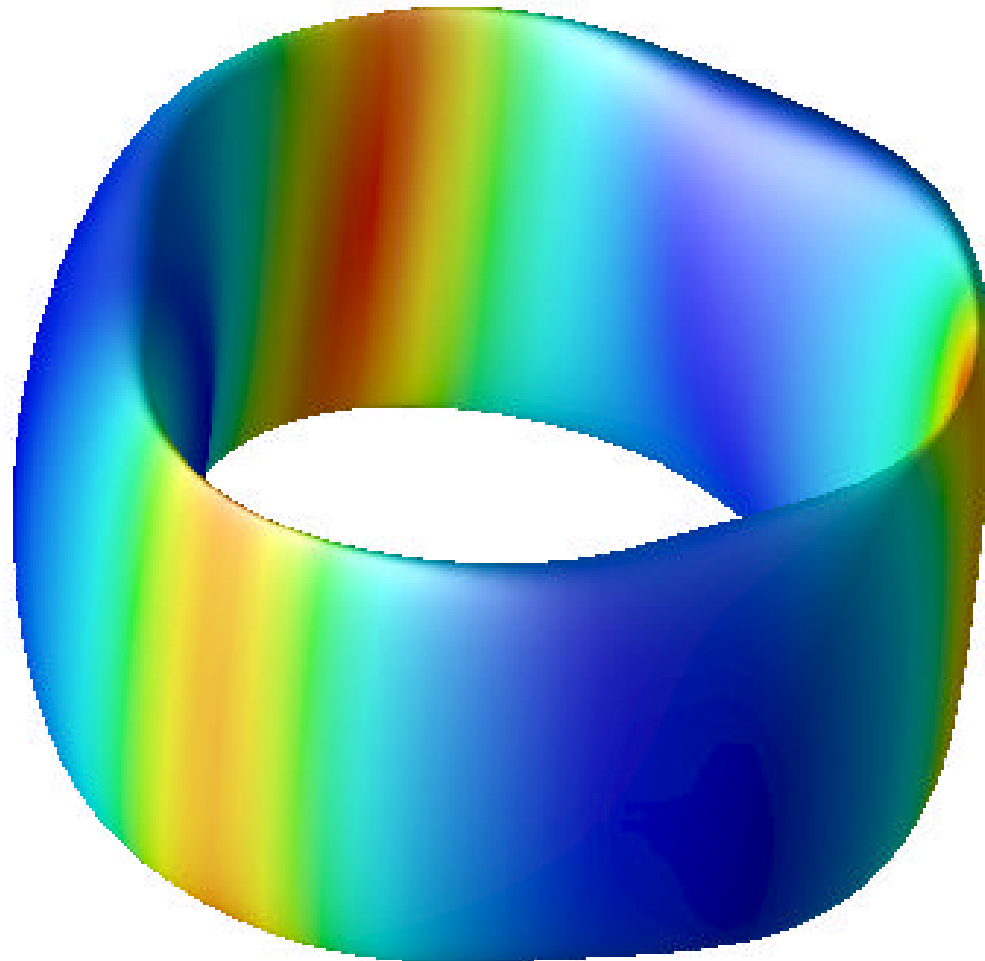
Unoptimized



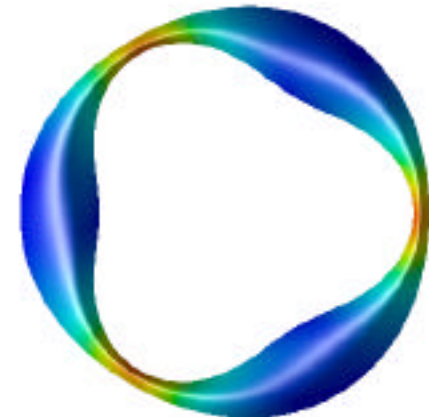
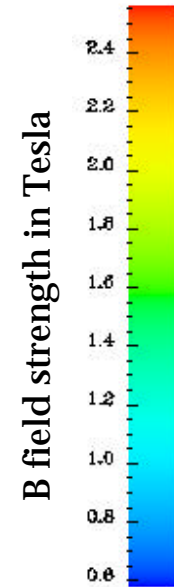
Optimization 1



Optimization 2

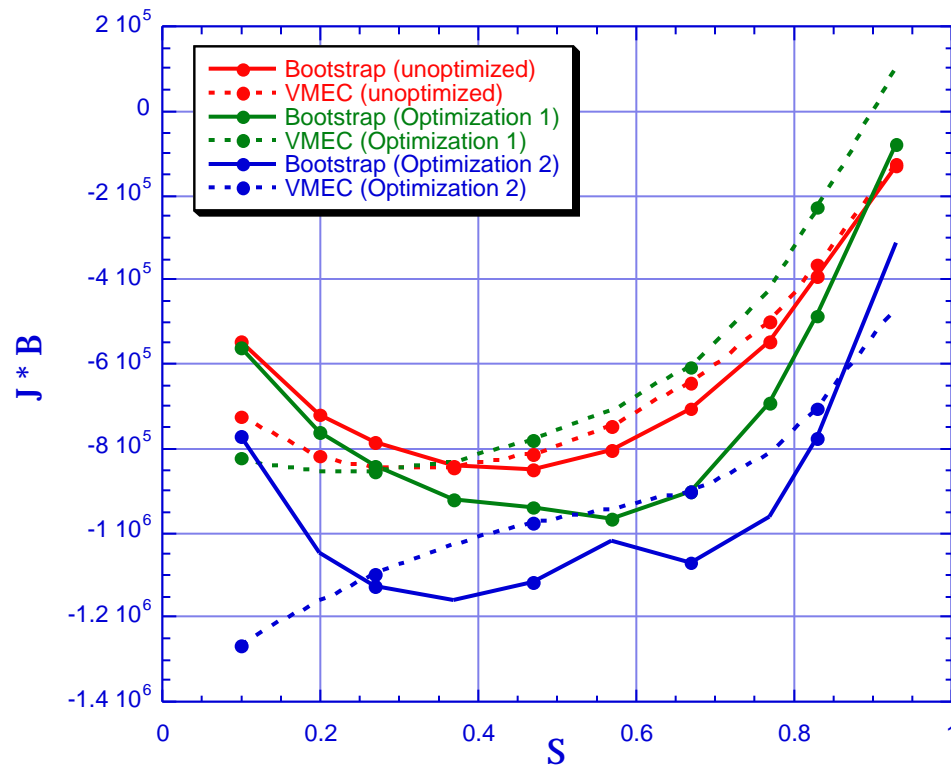


$A = 3.40$
 $= 10\%$

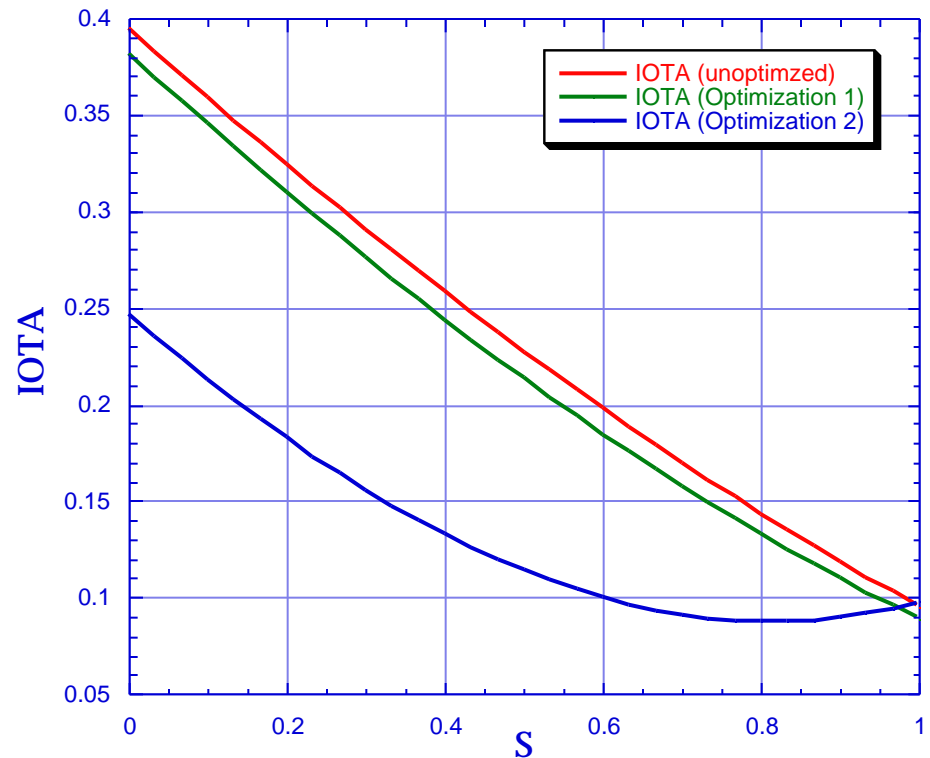


Optimization of $|B|$ spectrum did affect the $\langle J*B \rangle$ and iota profiles

The amount of field alignment increased with optimization

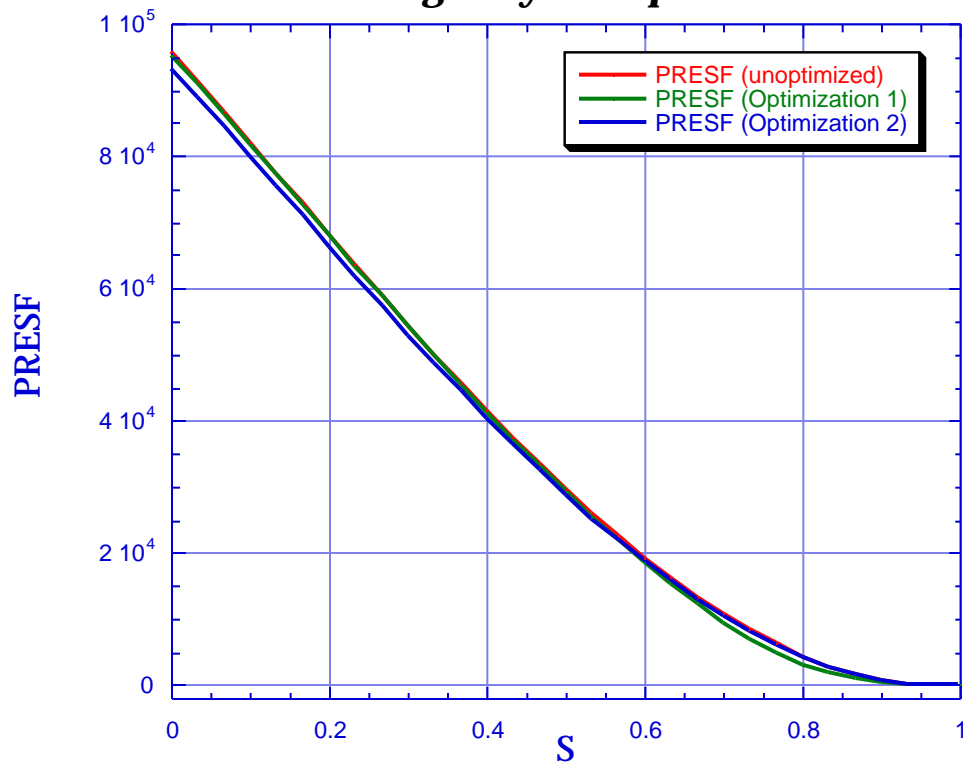


The iota profile of Optimization 2 is lower

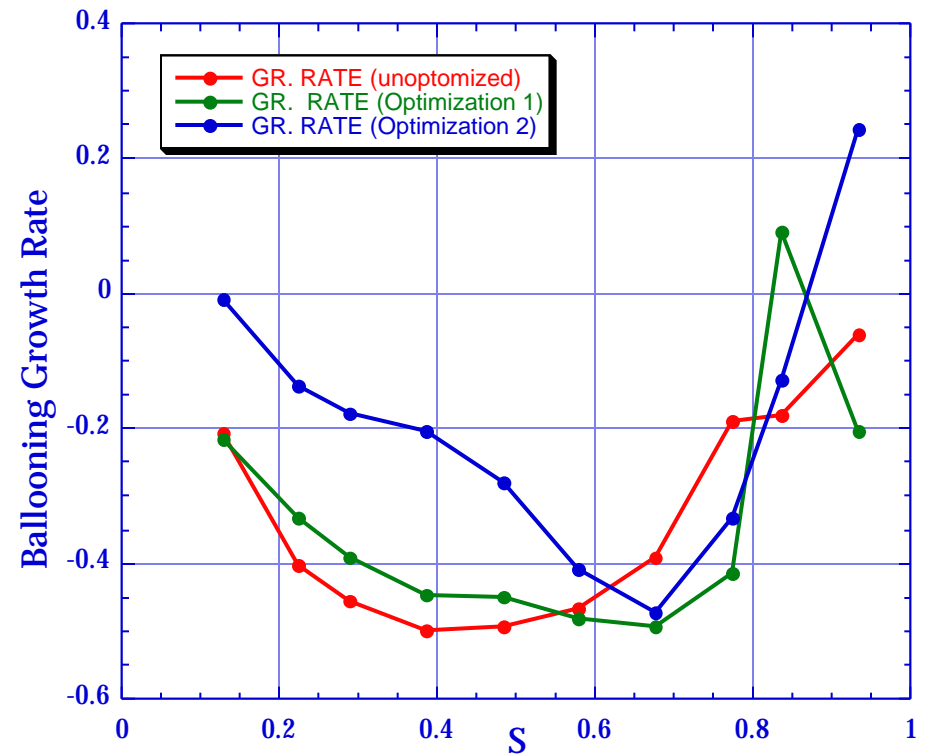


Optimization of $|B|$ spectrum had little affect on pressure and ballooning stability

The pressure profiles remain relatively unchanged by the optimization



The optimized cases each had one surface ballooning unstable.



Optimization of $|B|$ spectrum increased ellipticity & variation of $|B|$ on a flux surface

- Axis-symmetric ellipticity increased during the optimization:

Unoptimized	2.14
Optimization 1	2.74
Optimization 2	4.59

- Optimization 2 is approaching a toroidally linked mirror configuration
 - Large variation of $|B|$ on the outer surface

Effect of Quasi-poloidal Symmetry on neoclassical ion confinement

	A		τ_{neo}^*
Unoptimized	3.40	10%	17.3 ms
Optimization1	3.40	10%	21.4 ms
Optimization2	3.40	10%	13.4 ms

The details of the calculation of τ_{neo} are available from D. A. Spong HP1.038

III. Isodynamic Stellarator Configurations

- Goal:

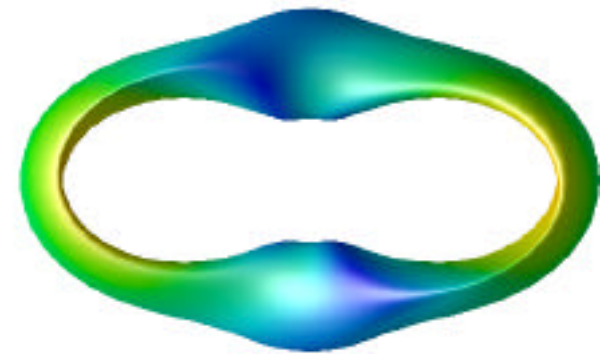
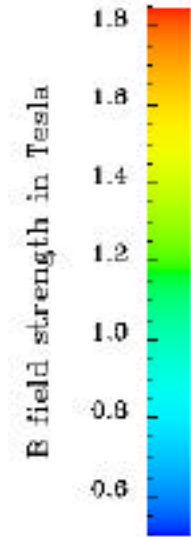
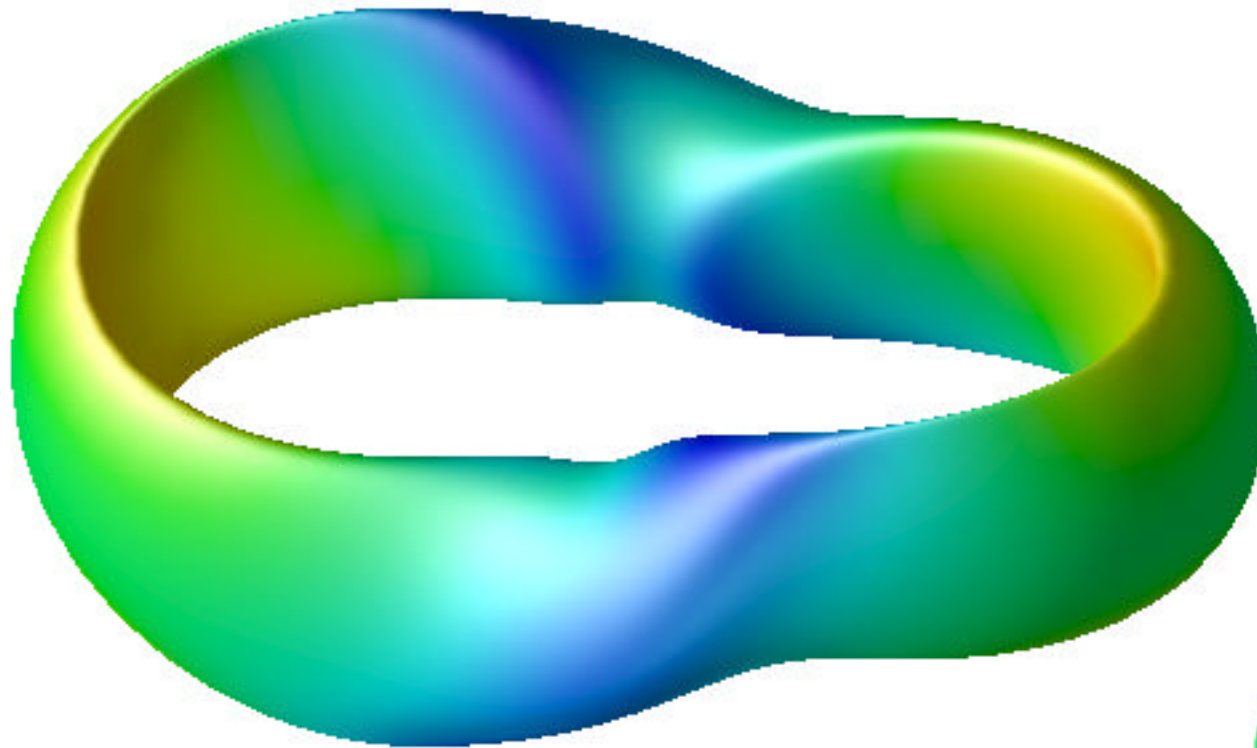
- Minimize variation of $|B|$ on each flux surface

- Method:

- Introduce a new δ^2 contribution for variation of Mod B on a flux surface
- Other targets: $A=2.70$, 5.40%, ballooning stability, bootstrap current alignment

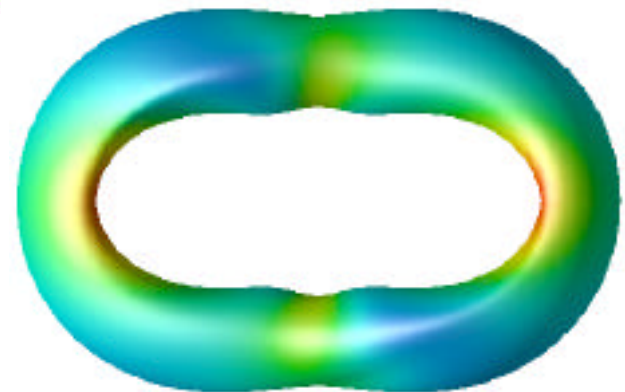
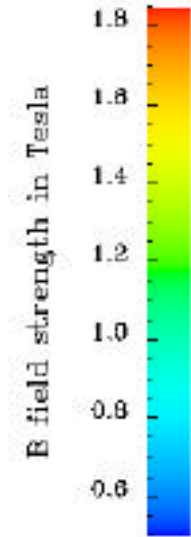
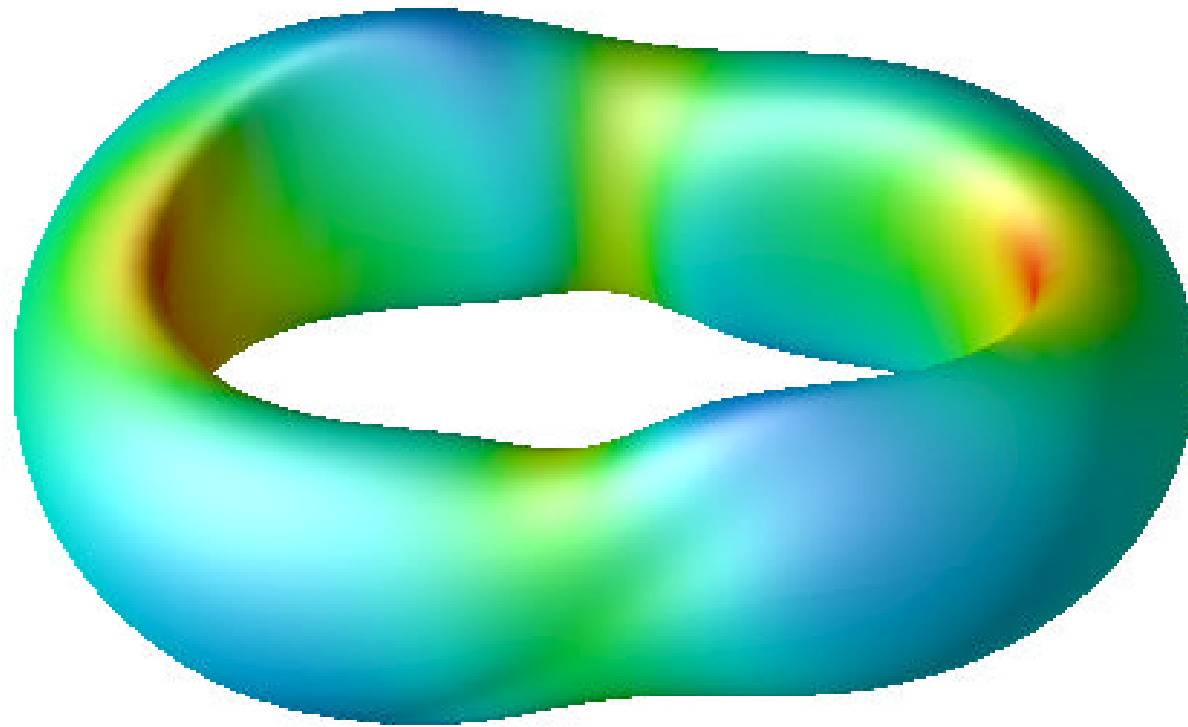
Unoptimized

$A = 2.70$
 $= 5.48\%$

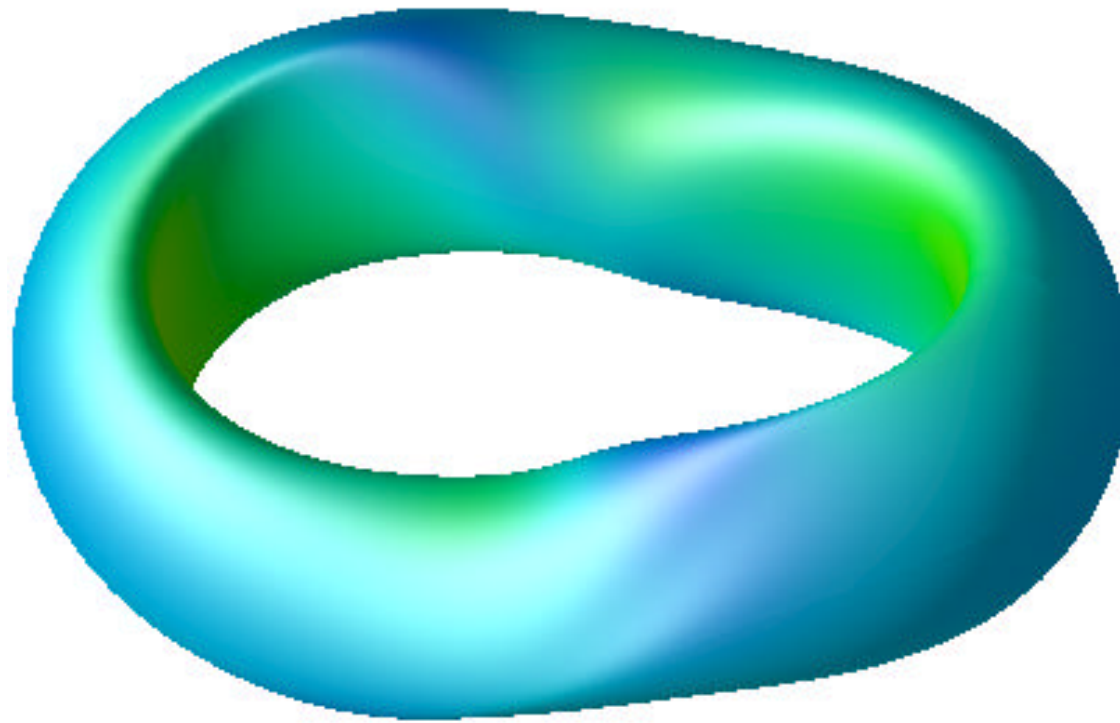


Optimization 1

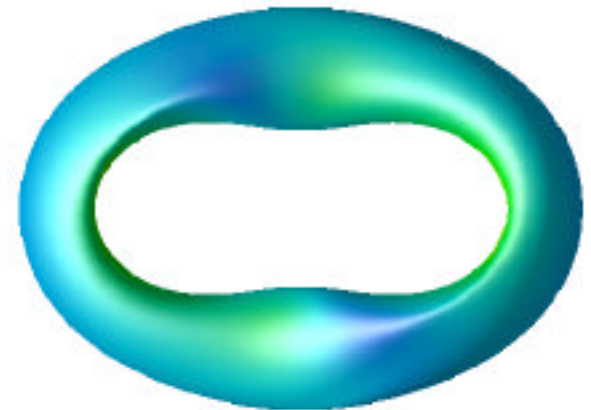
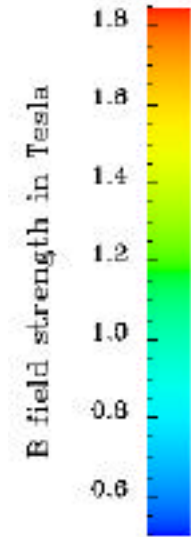
$A = 2.70$
 $= 5.38\%$



Optimization 2

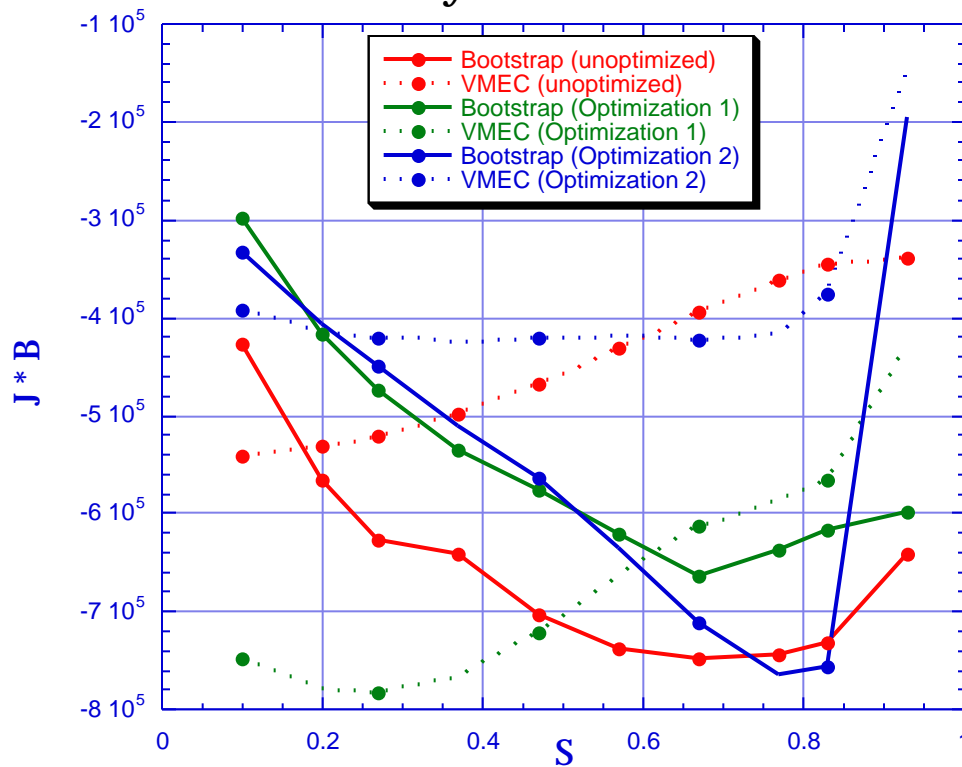


$A = 2.69$
 $= 4.96\%$

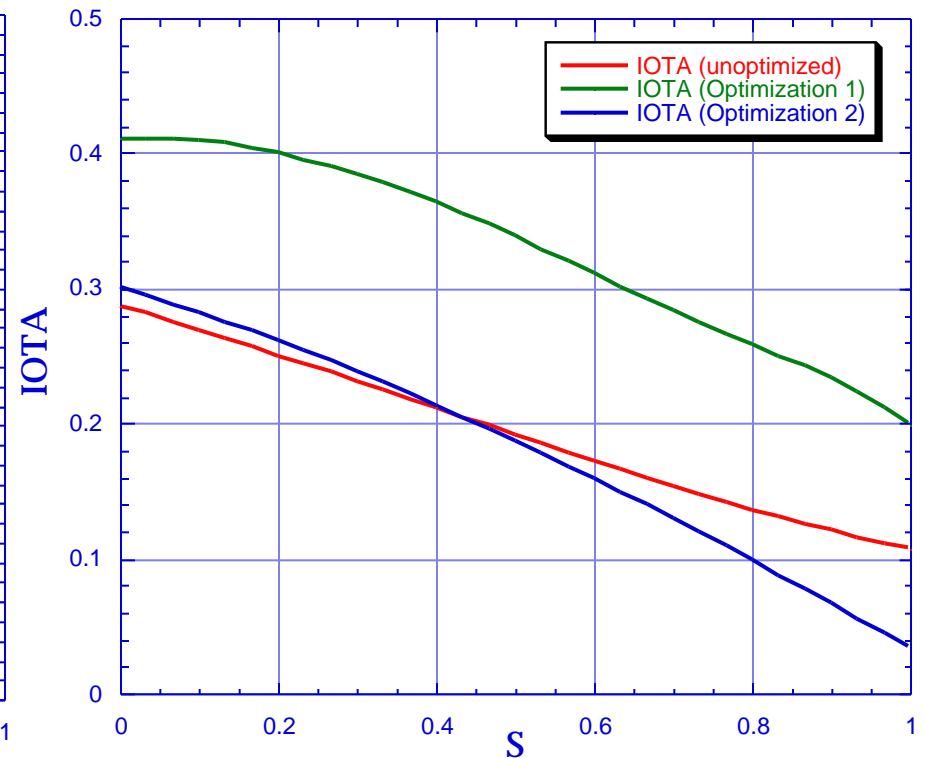


Minimization of $|B|$ variation had a large affect on the $\langle J^*B \rangle$ and iota profiles

Bootstrap alignment was not great in any of the cases

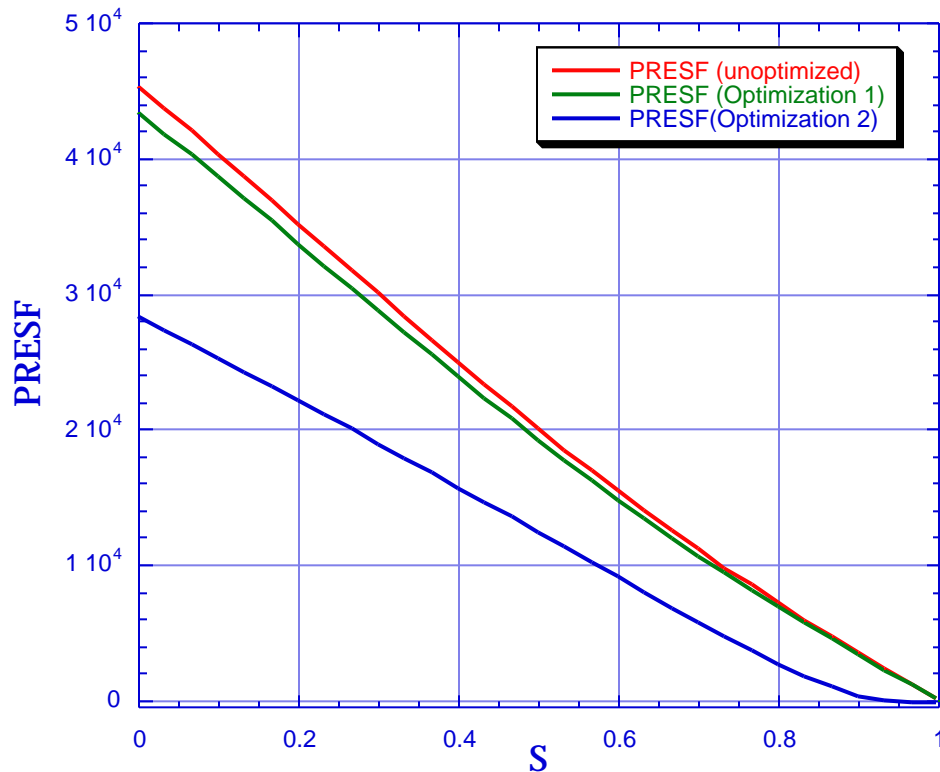


There was no clear trend in iota during the optimization.

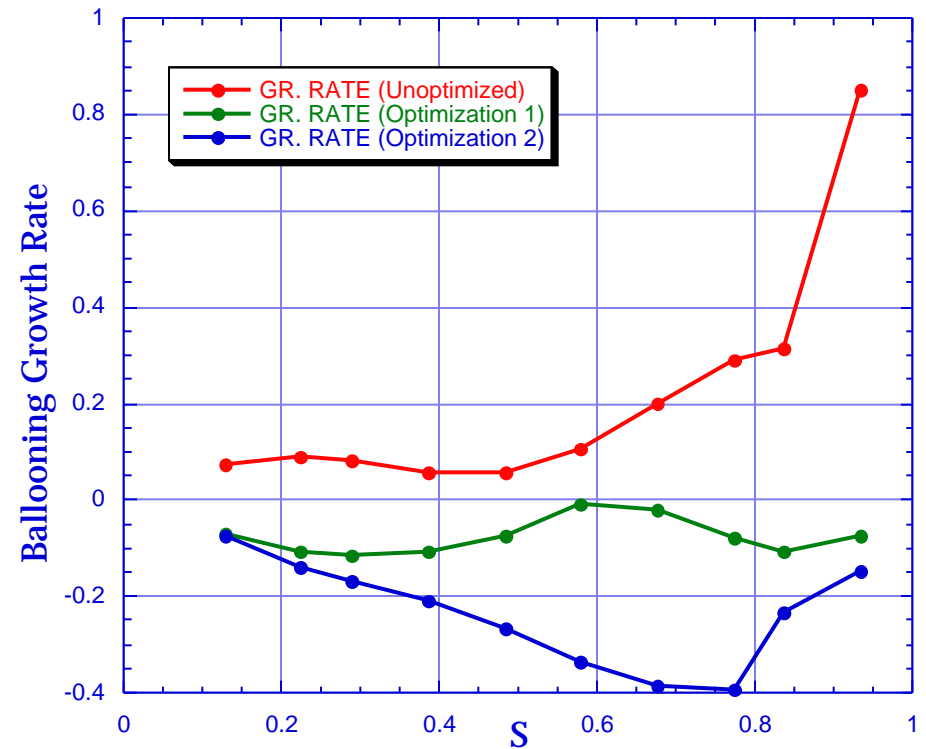


Minimization of $|B|$ variation also affected the pressure and ballooning stability

The pressure profile of Optimization 2 is lower than the other cases



The optimized cases are ballooning stable on every flux surface evaluated



Effect of minimized variation of $|B|$ on neoclassical ion confinement

	A		neo
Unptimized	2.70	5.48%	24.6 ms
Optimization 1	2.70	5.38%	19.0 ms
Optimization 2	2.69	4.96%	11.5 ms

The details of the calculation of τ_{neo} are available from D. A. Spong HP1.038

IV. Conclusions

- Targeting quasi-poloidal symmetry initially improved confinement but then degraded it due to thin cross sections.
 - Need to target lower ellipticity (work in progress).
- Targeting quasi-isodynamic symmetry degraded the neoclassical confinement!
 - Still working on this.