Coil Optimization for Aten Using New Curvature Functions

Presented by Thomas Kruger
Thanks to Caoxiang Zhu
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON
HSX

FOCUS Objective Functions

$$\min f = w_B f_B + w_L f_L + w_\kappa f_{\kappa,z}$$

$$f_B = \int_s \frac{1}{2}\left(\frac{\boldsymbol{B}\cdot\widehat{\boldsymbol{n}}}{B}\right)^2 ds \cong \sum_{i=1}^{N_\zeta}\sum_{j=1}^{N_\theta}\frac{1}{2}\left(\frac{\boldsymbol{B}\cdot\widehat{\boldsymbol{n}}}{B}\right)^2 \Delta\zeta\Delta\theta$$

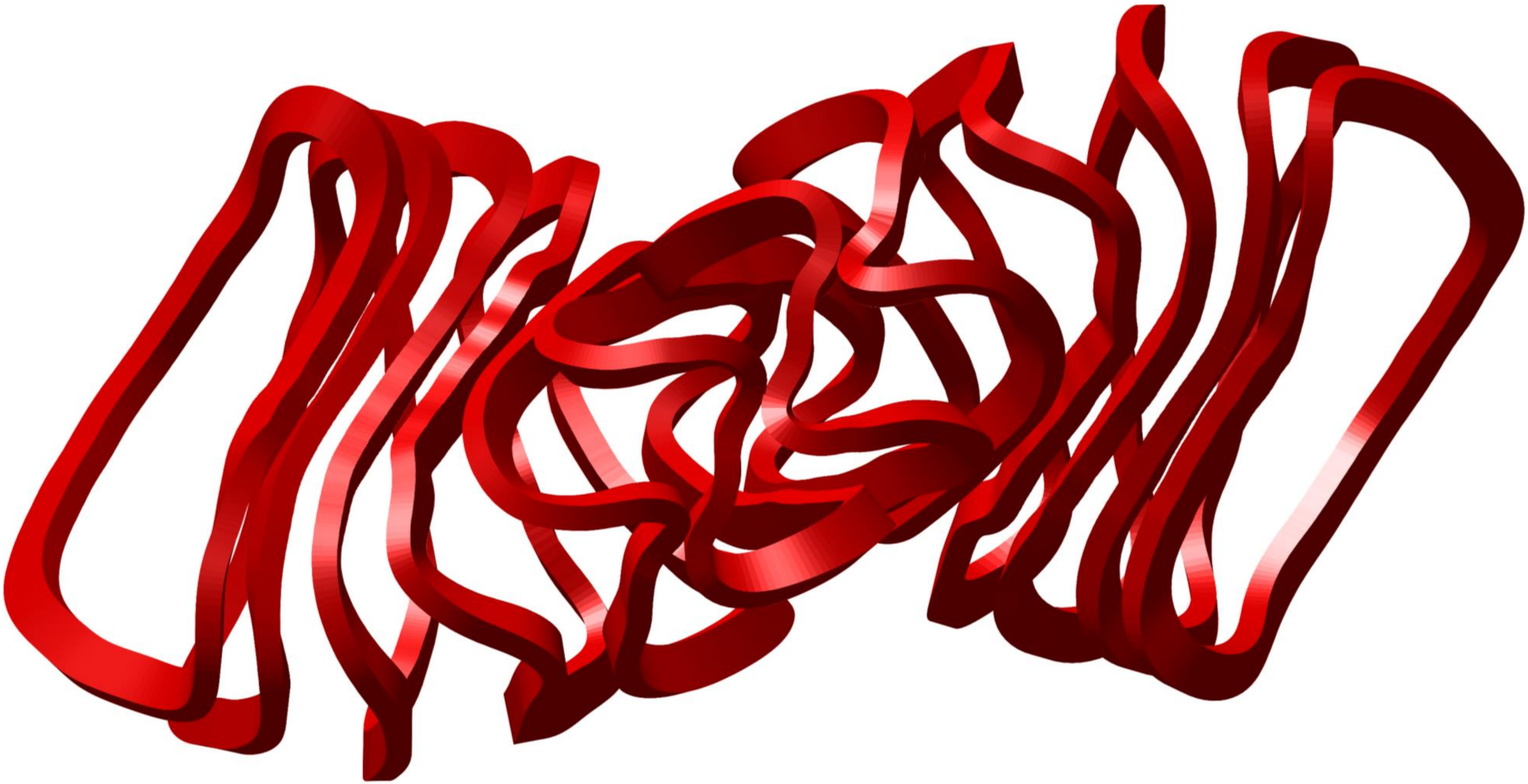
$$f_L = \frac{1}{N_c}\sum_{i=1}^{N_c}\frac{1}{2}\frac{\left(L_i - L_{i,o}\right)^2}{L_{i,o}^2} \cong \frac{1}{N_c}\sum_{i=1}^{N_c}\frac{1}{2}\frac{\left(\sum_{j=1}^{N_{seg}}\left|\boldsymbol{r}_{i,j}-\boldsymbol{r}_{i,j-1}\right| - L_{i,o}\right)^2}{L_{i,o}^2}$$

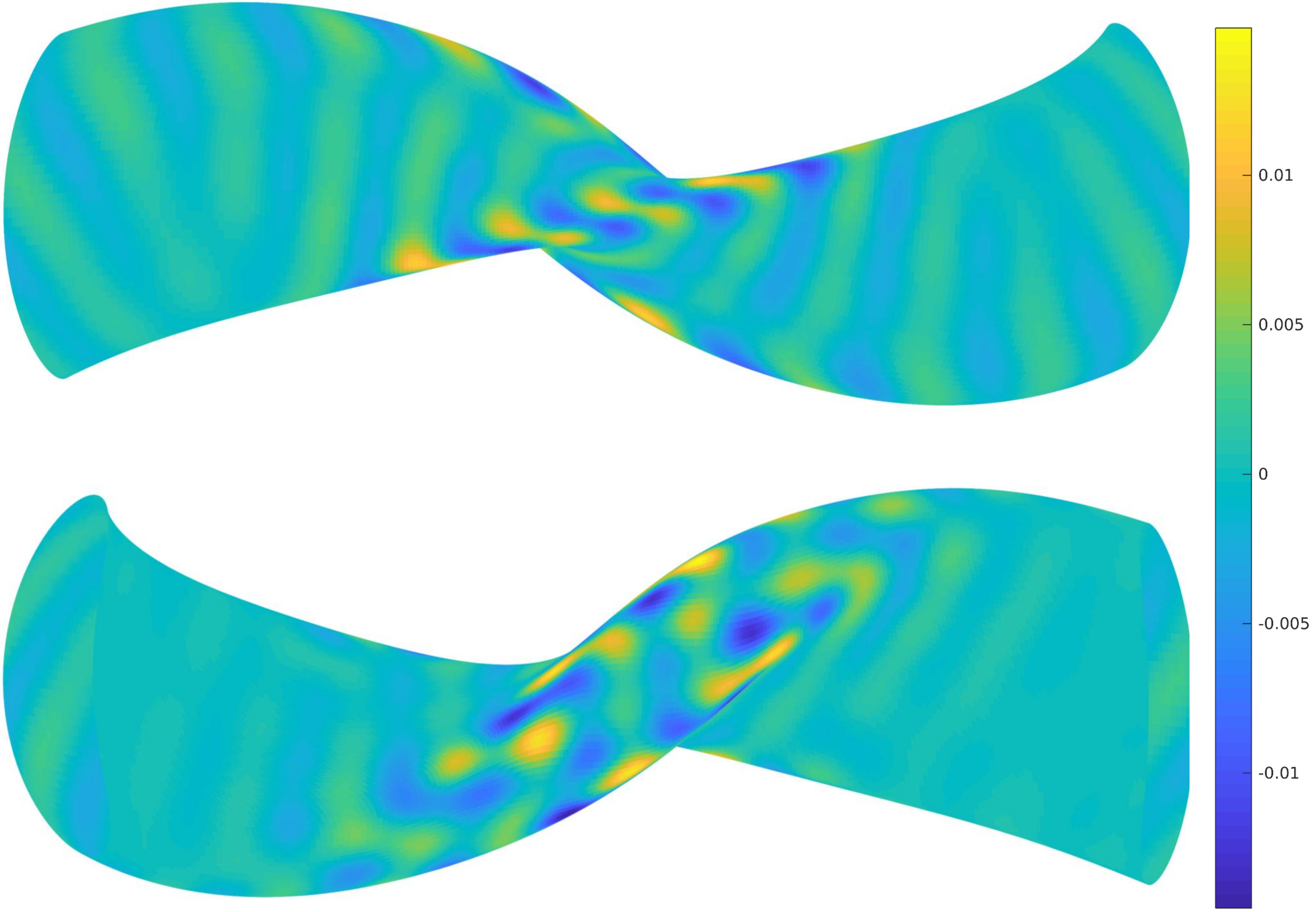
$$f_{\kappa,1} = \frac{1}{N_c}\frac{1}{2\pi}\sum_{i=1}^{N_c}\int_0^{2\pi}\kappa_i dt \cong \frac{1}{N_c}\frac{1}{N_{seg}}\sum_{i=1}^{N_c}\sum_{j=1}^{N_{seg}}\kappa_{i,j}$$

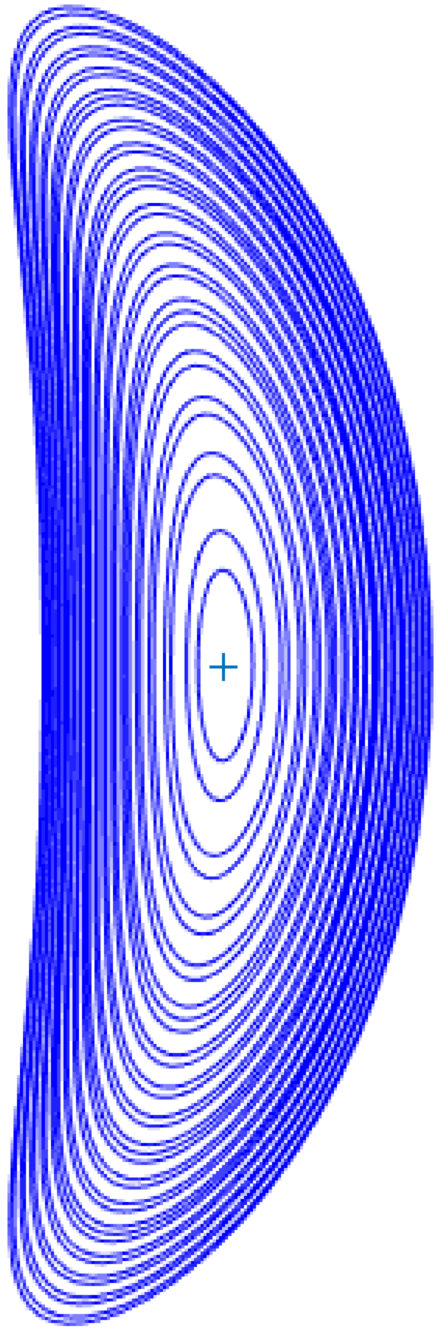
Penalty method

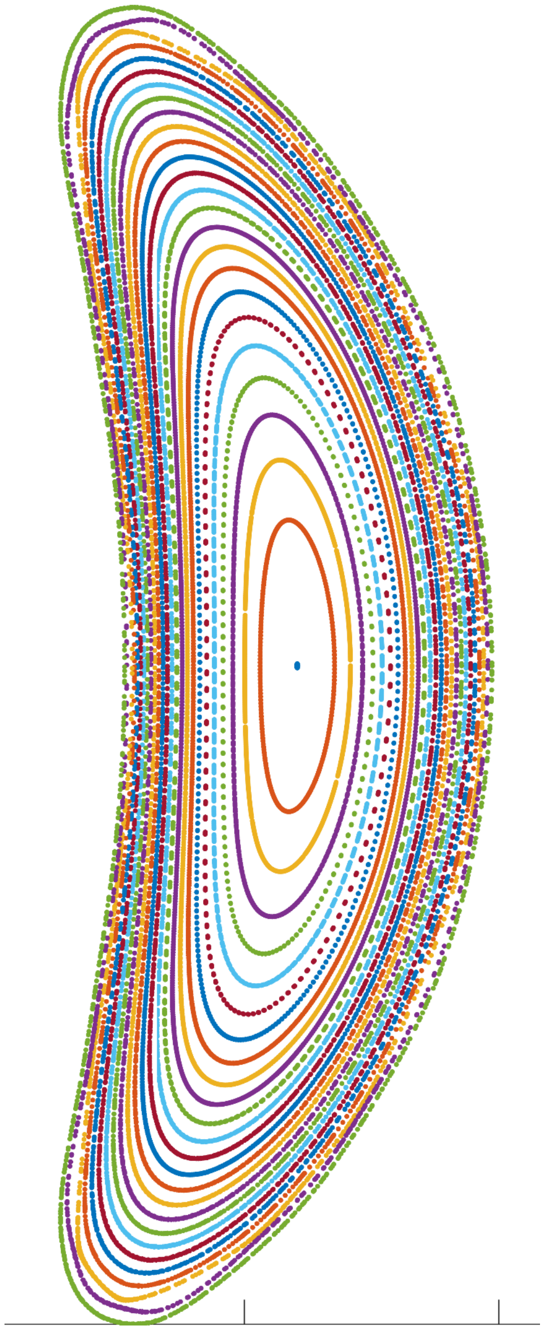
$$f_{\kappa,3} \cong \frac{1}{N_c}\frac{1}{N_{seg}}\sum_{i=1}^{N_c}\sum_{j=1}^{N_{seg}}\begin{cases} 0 & if\ \kappa_{i,j} < \kappa_o \\ \left(\kappa_{i,j}-\kappa_o\right)^\alpha & if\ \kappa_{i,j} \geq \kappa_o \end{cases} \qquad \alpha \geq 2$$

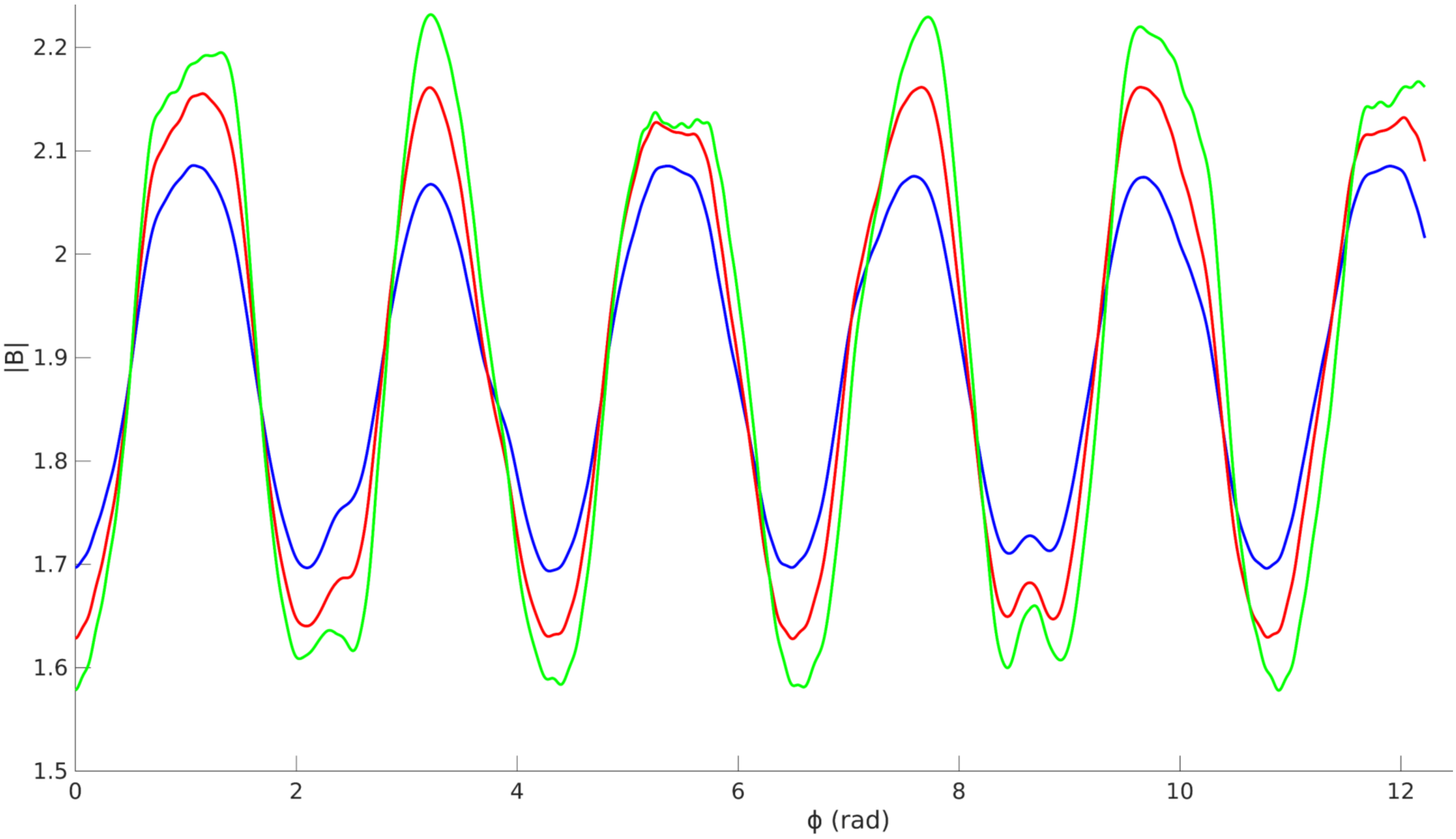
Single Filament	$<\frac{B \cdot n}{B}>$	Min radius of curvature	Min coil to coil separation
FOCUS	.0021	9.9 cm	8.5 cm




0.01
0.005
0
-0.005
-0.01

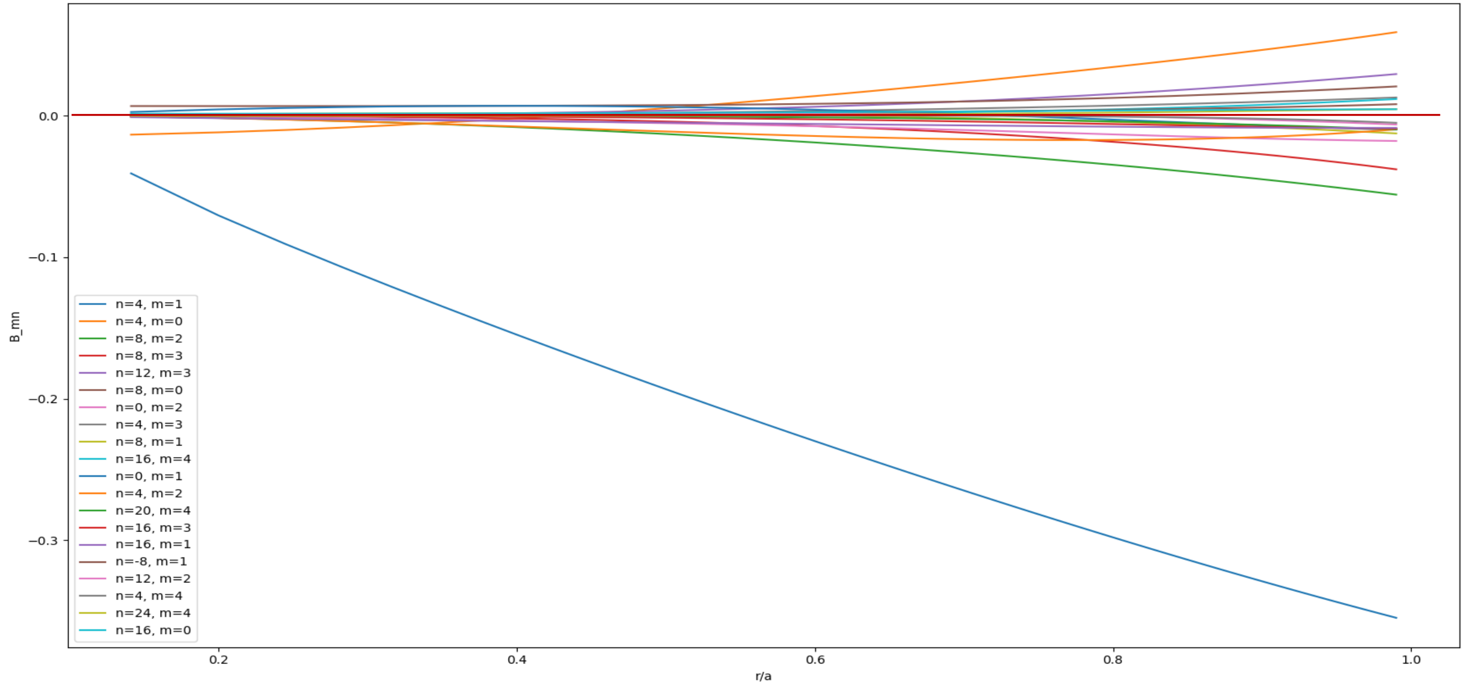






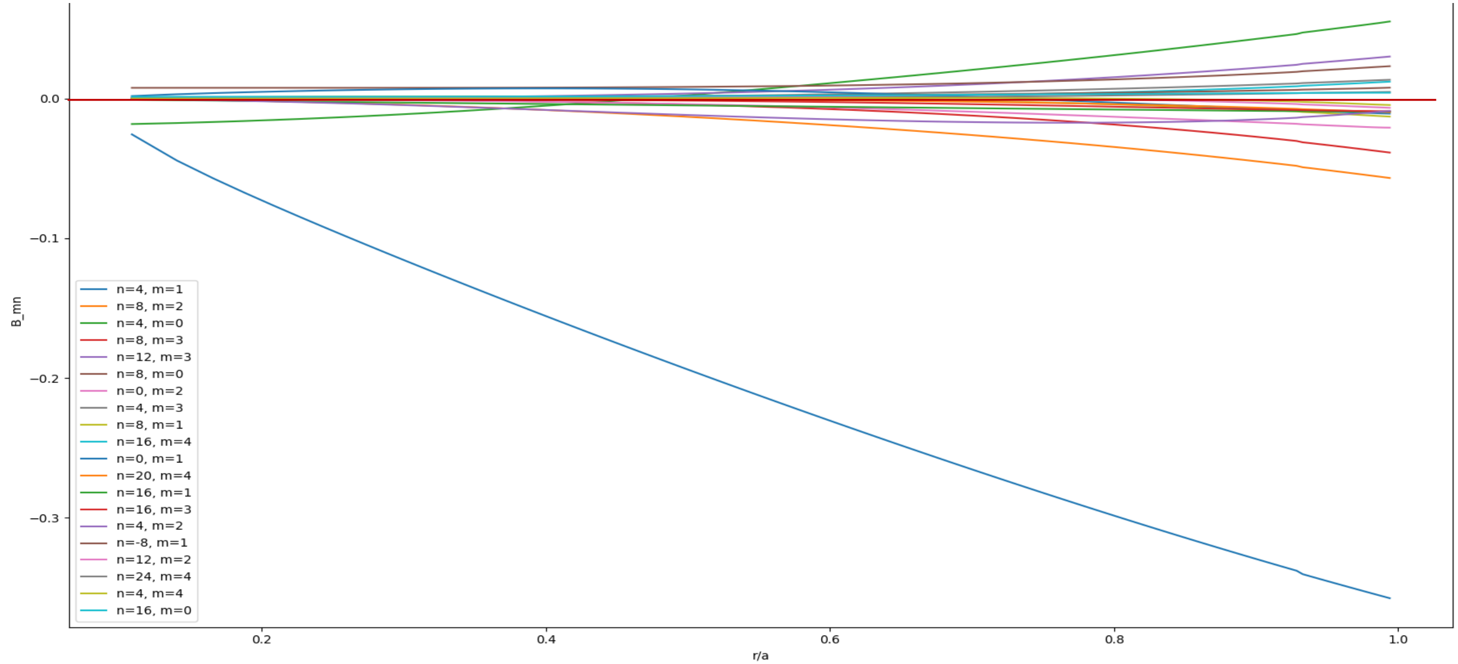
- Large ripple at |B| well is from fixed boundary
- Coil ripple is small

Fixed boundary



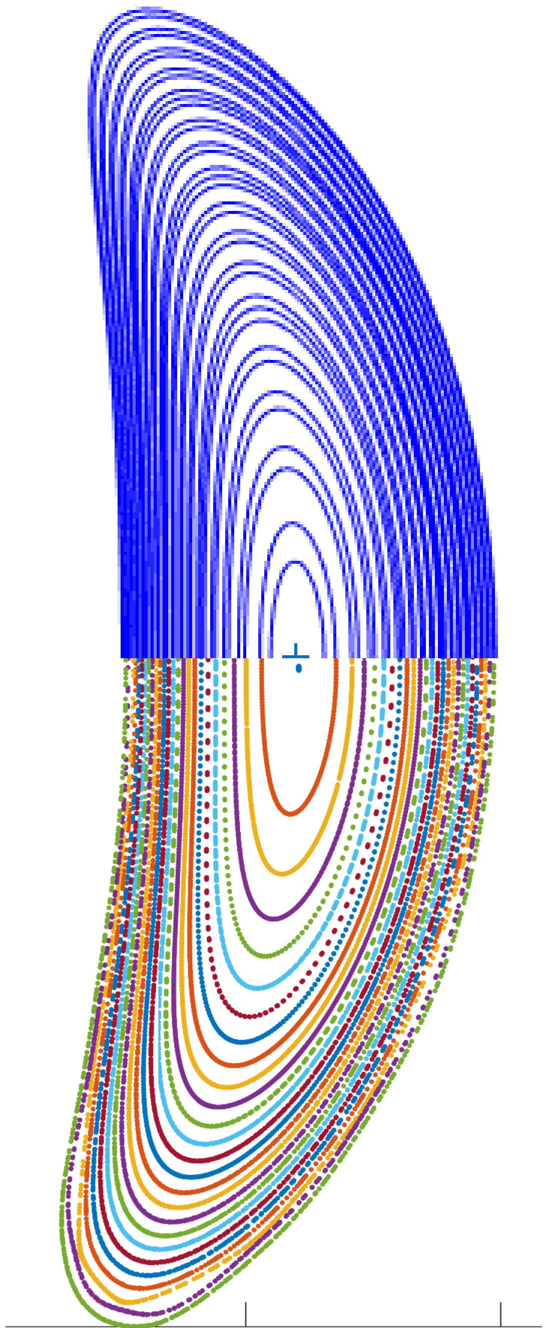
MPOL = 10
NTOR = 14
128 surfaces
converged at
FTOL = 10^-12

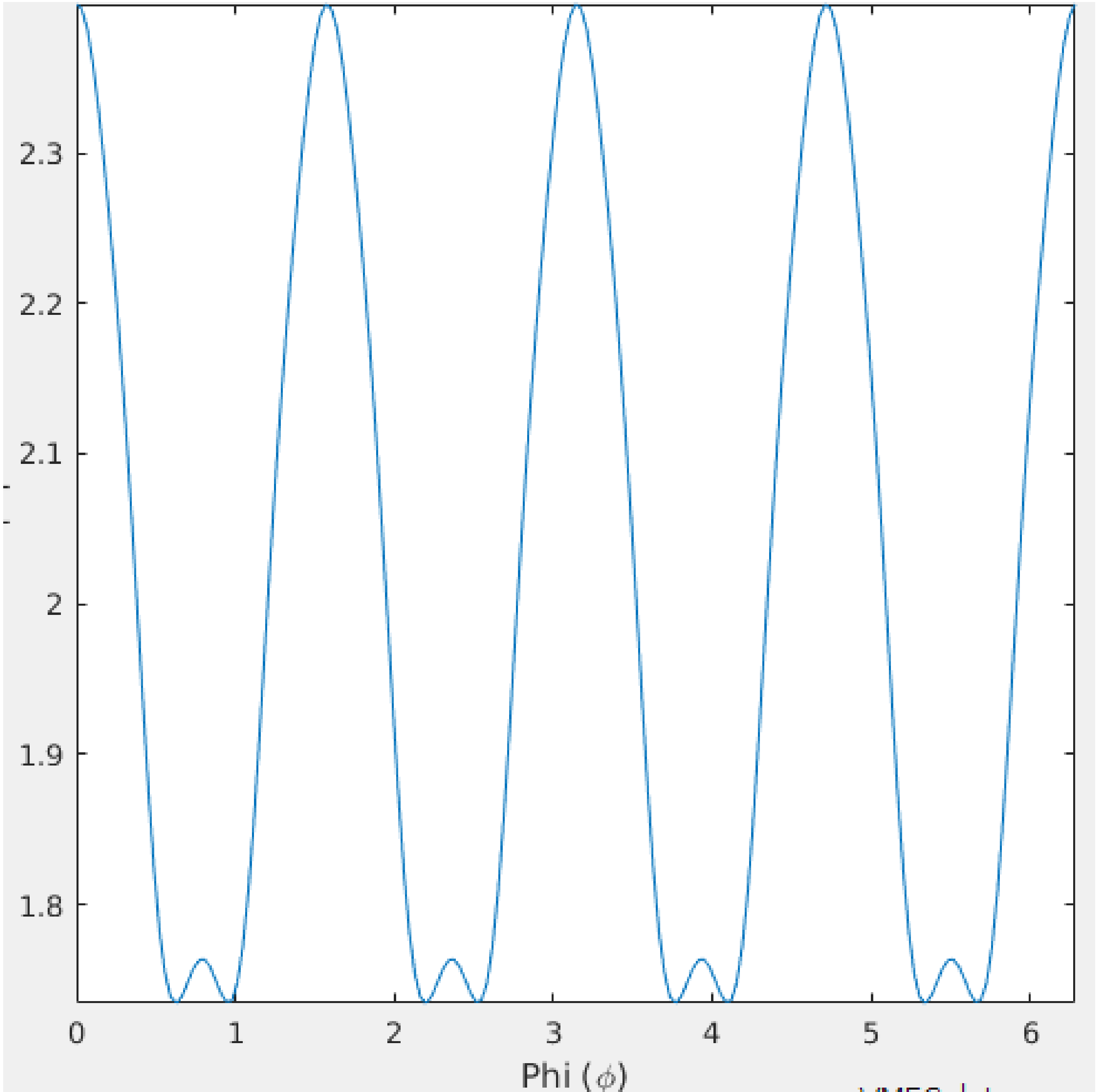
Free boundary

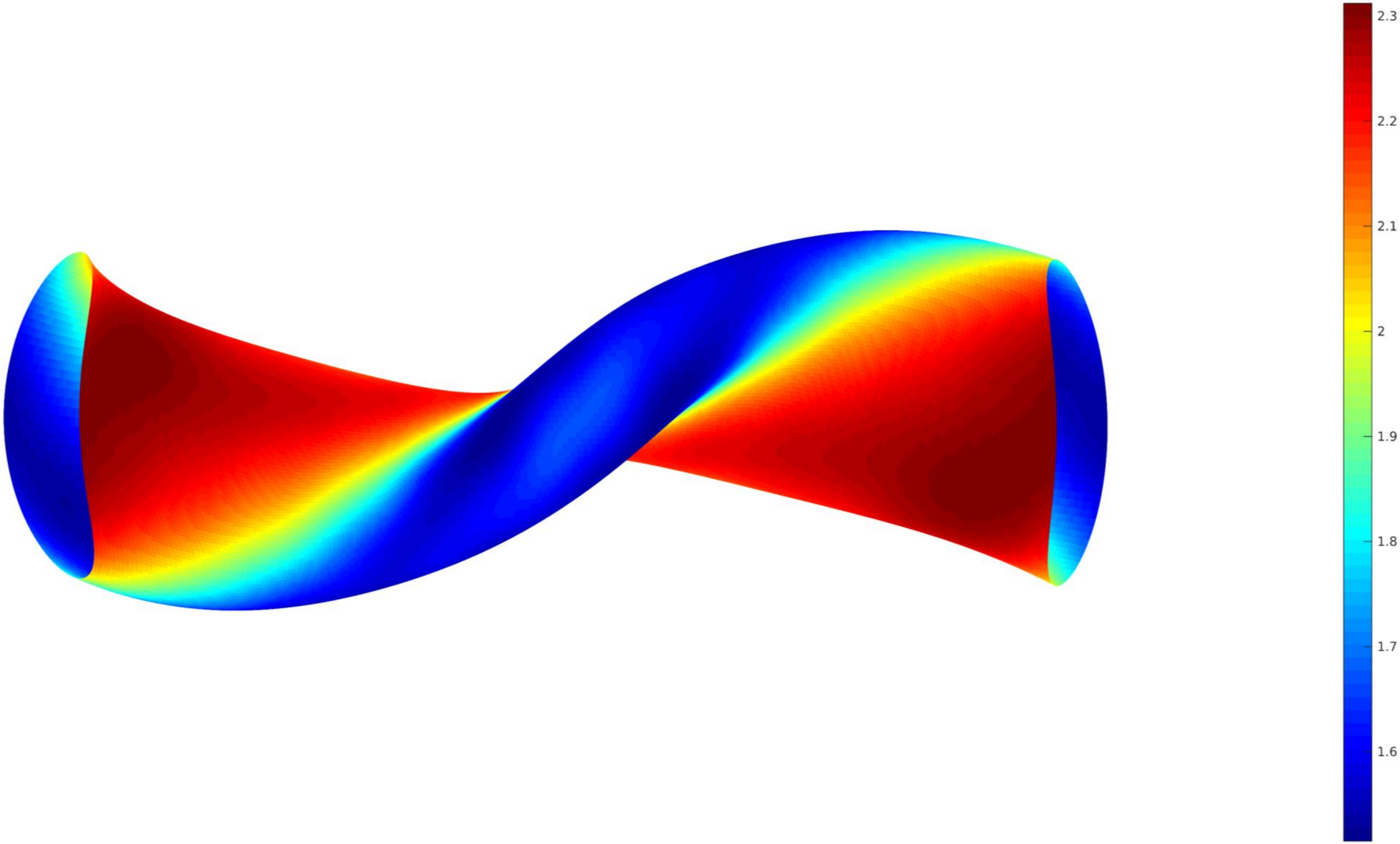


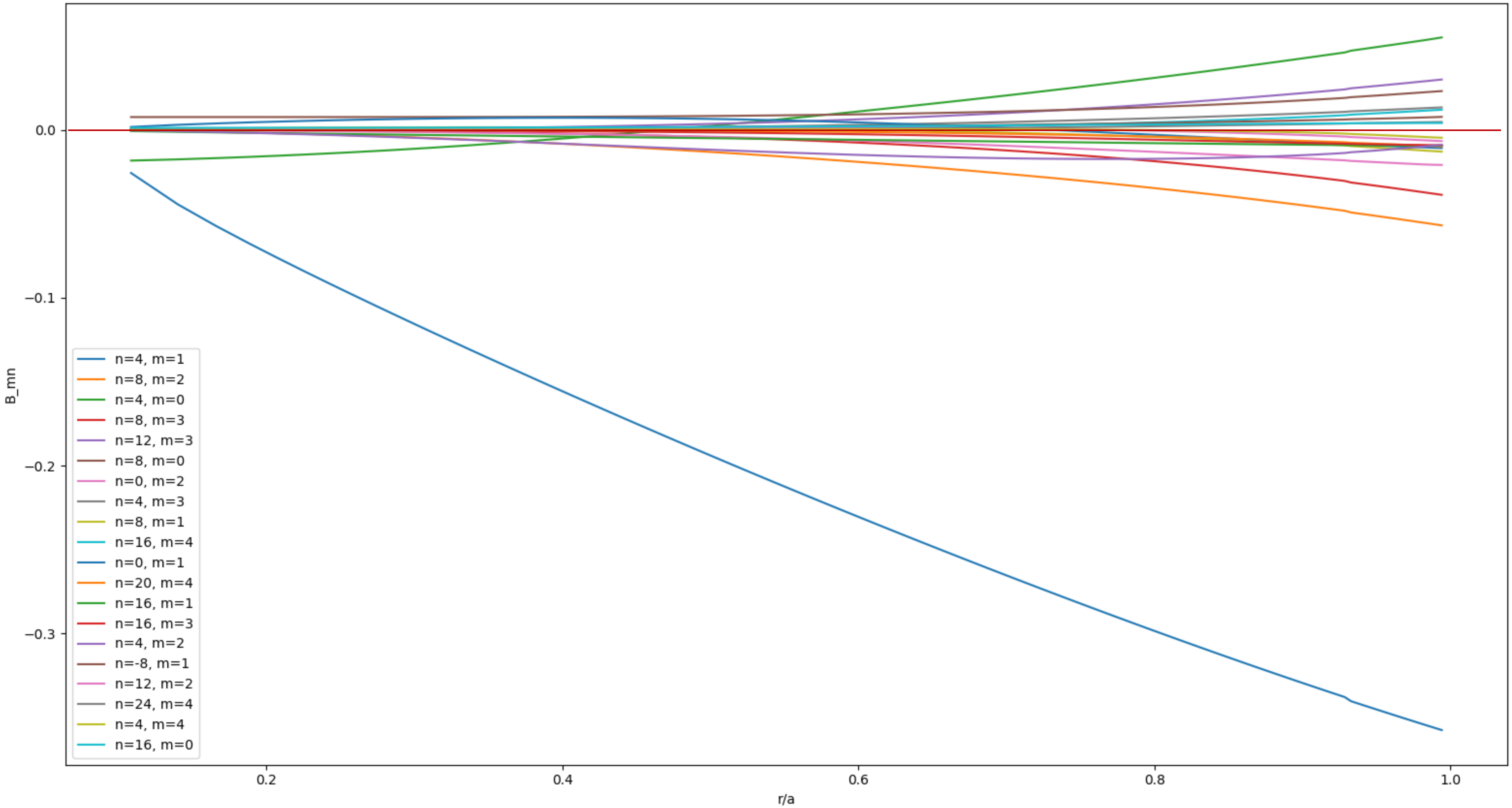
Conclusions

- Aten coils reproduce the fixed boundary fields with limited coil ripple
- Coil engineering constraints are reasonable
- Good candidate coils for multi-filament optimization
- Future work
  - Higher resolution free boundary VMEC
  - Multi-Filament optimization
  - Fast particle confinement with ANTS
  - gamma_c
  - Eps_eff
  - Etc.




2.3
2.2
2.1
2
1.9
1.8
0
1
2
3
4
5
6
Phi (ϕ)


2.3
2.2
2.1
2
1.9
1.8
1.7
1.6


0.0
−0.1
−0.2
−0.3
0.2
0.4
0.6
0.8
1.0
r/a
B_mn
n=4, m=1
n=8, m=2
n=4, m=0
n=8, m=3
n=12, m=3
n=8, m=0
n=0, m=2
n=4, m=3
n=8, m=1
n=16, m=4
n=0, m=1
n=20, m=4
n=16, m=1
n=16, m=3
n=4, m=2
n=-8, m=1
n=12, m=2
n=24, m=4
n=4, m=4
n=16, m=0