Alternate Background Coils Study

Part II: Initial Findings

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A. Brooks, W. Reiersen

“Houston, we have a problem”

Actually, we have (at least) three

- access
- current density
- large resonant harmonics from 1/R background field

Access

- Compromises will be required to accommodate NB, RF, and diagnostic requirements (ref. Cole)

Current Density

- R&D results are encouraging (ref. Nelson)
- Large uncertainties abound
- Lower is better
  - Longer pulse length
  - Shorter time between pulses
  - More latitude in coil currents
  - More structural margin
  - Reduced power supply requirements
  - Less technical risk

Resonant field errors

- Harmonic analysis indicates that a 1/R background field introduces large resonant field errors
- Conformal coils (e.g., saddle coils) must reduce these to tolerable levels – limits flexibility
- Modifying background field appropriately might avoid this problem

Approach

- *Are there much better conformal coil solutions for a 1/R (PBX-like) background field?*

- *Can J in the conformal coils be reduced and access improved by modifying the background field?*

- *Can the conformal coils be eliminated?*

Are there much better conformal coil solutions for a 1/R background field? Probably not

I_toroidal

I_poloidal

	-0.39	-0.29	-0.24	0
1		**Helical (2/7)** Jmax=1.17 Javg=0.38 Complex=2.3		**Modular** Jmax=1.17 Javg=0.39 Complex=2.3
0.15			**Unconstrained** Jmax=1.04 Javg=0.23 Complex=2.8	
0	**Wavy PF** Jmax=1.05 Javg=0.24 Complex=2.5			**Saddle** Jmax=1.14 Javg=0.25 Complex=2.6

What do we hope to gain with new background field coils (BFCs)?

- Improved access with fewer BFCs, simple conformal coil (CC) design
- Longer pulse length with lower J in CCs
- More freedom for optimizing plasma configuration with PBX constraints removed

J_{max} can be substantially reduced with *3 simple* interlocked coils – from 1.04 (1/R) to 0.70

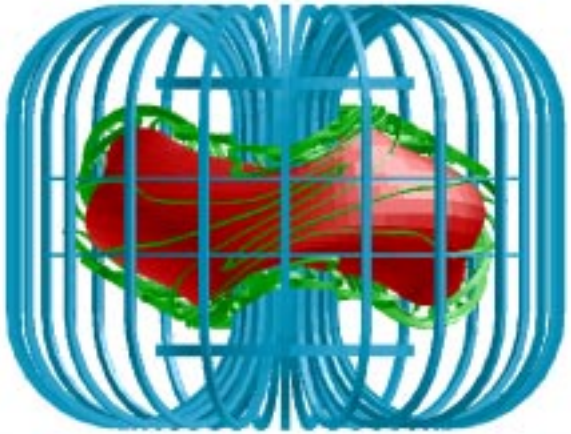
v	Conventional	Interlocked
0	Jmax=1.05 Javg=0.20 Complex=2.9 Normalized Amp-m=34	Jmax=0.70 Javg=0.20 Complex=3.4 Normalized Amp-m=51
0.5	Jmax=1.07 Javg=0.22 Complex=2.7 Normalized Amp-m=42	Jmax=1.05 Javg=0.20 Complex=2.9 Normalized Amp-m=34

6 simple coils provide additional improvement

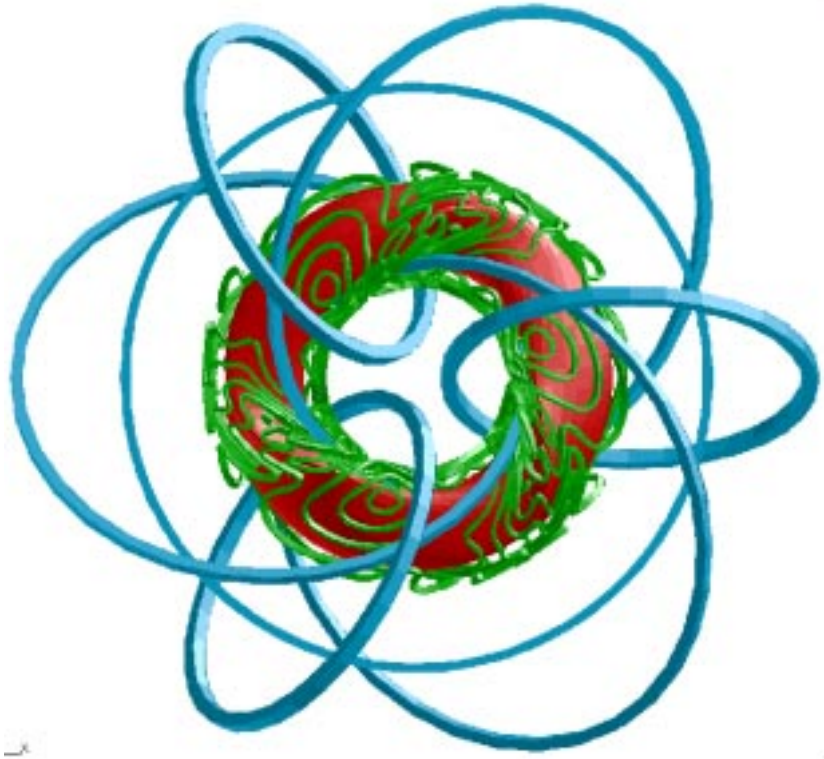
- Simple coils - circular, planar - constrained to symmetry planes

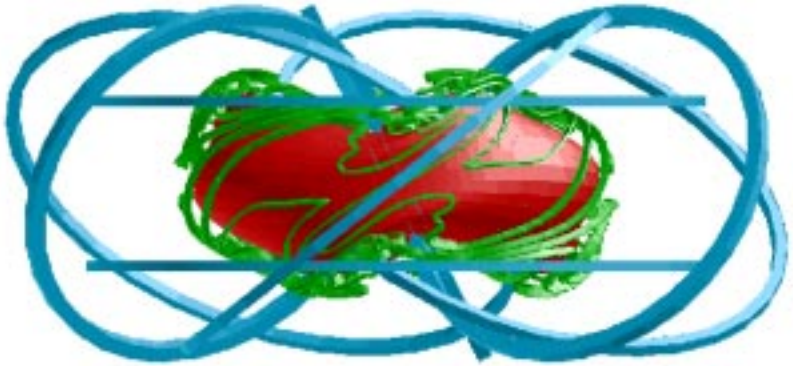
- Best case – interlocked and conventional TF coils at v=0
  - Jmax reduced from 0.70 to 0.56
  - Javg reduced from 0.20 to 0.18
  - Complexity reduced from 3.35 to 2.71
  - Normalized amp-m (in BFCs) reduced from 51 to 39

Access appears improved



PBX





New BFCs

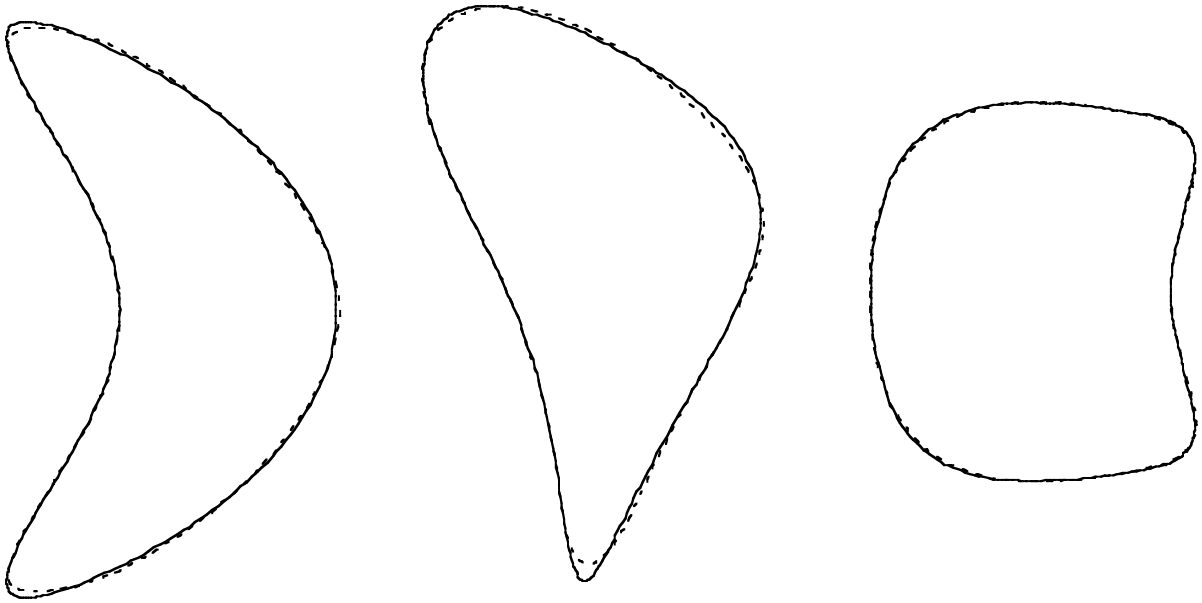
Current density is lower than in highly optimized PBX case (4064)

- Conformal coils (CCs) cut using “old” method
  - Number of contour levels selected, coils given equal current (1% avg, 5% max error criterion)
  - Further improvements possible using GA

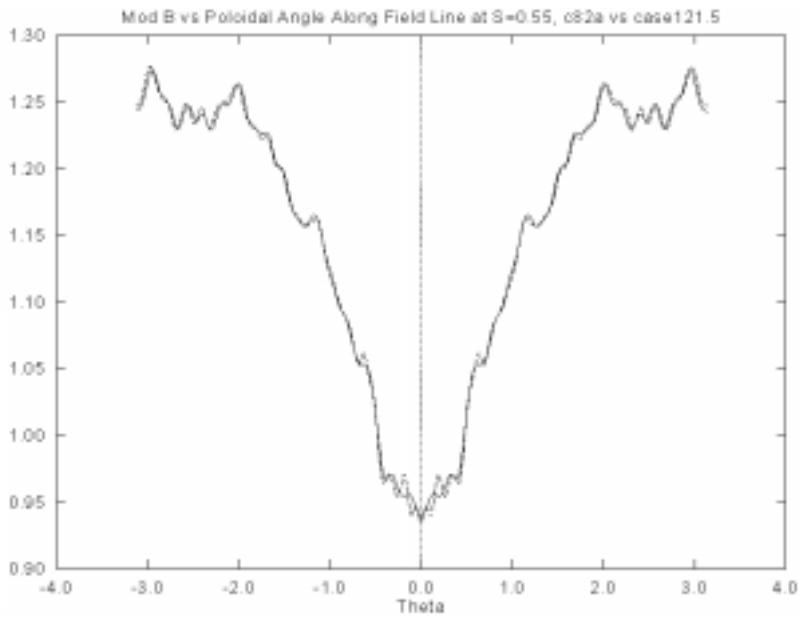
- Current density (at B=1.2T) reduced from 12.2 kA/cm^2 to 5.7 kA/cm^2 with lower error

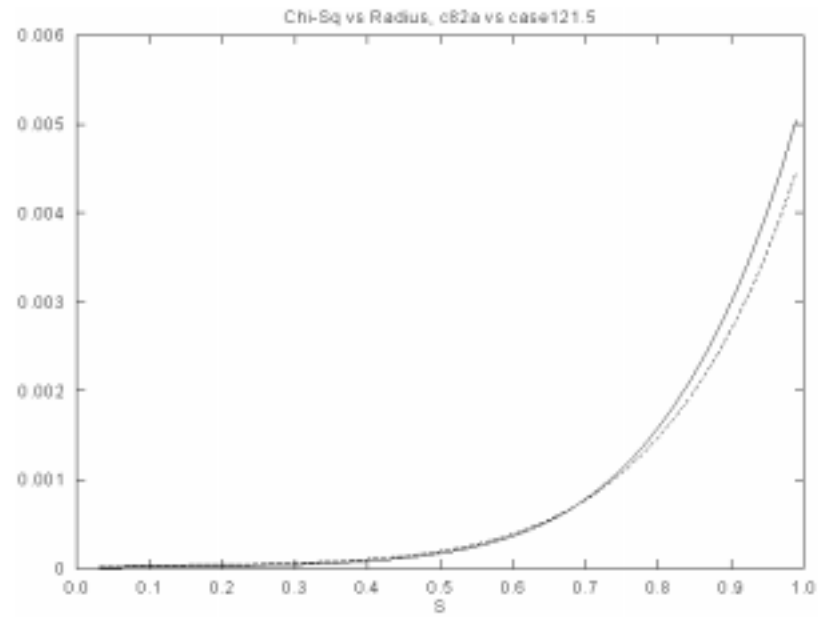
Free-boundary reconstructions with VMEC are promising

- Good approximation to plasma boundary
- Same iota profile



Quasi-symmetry appears preserved

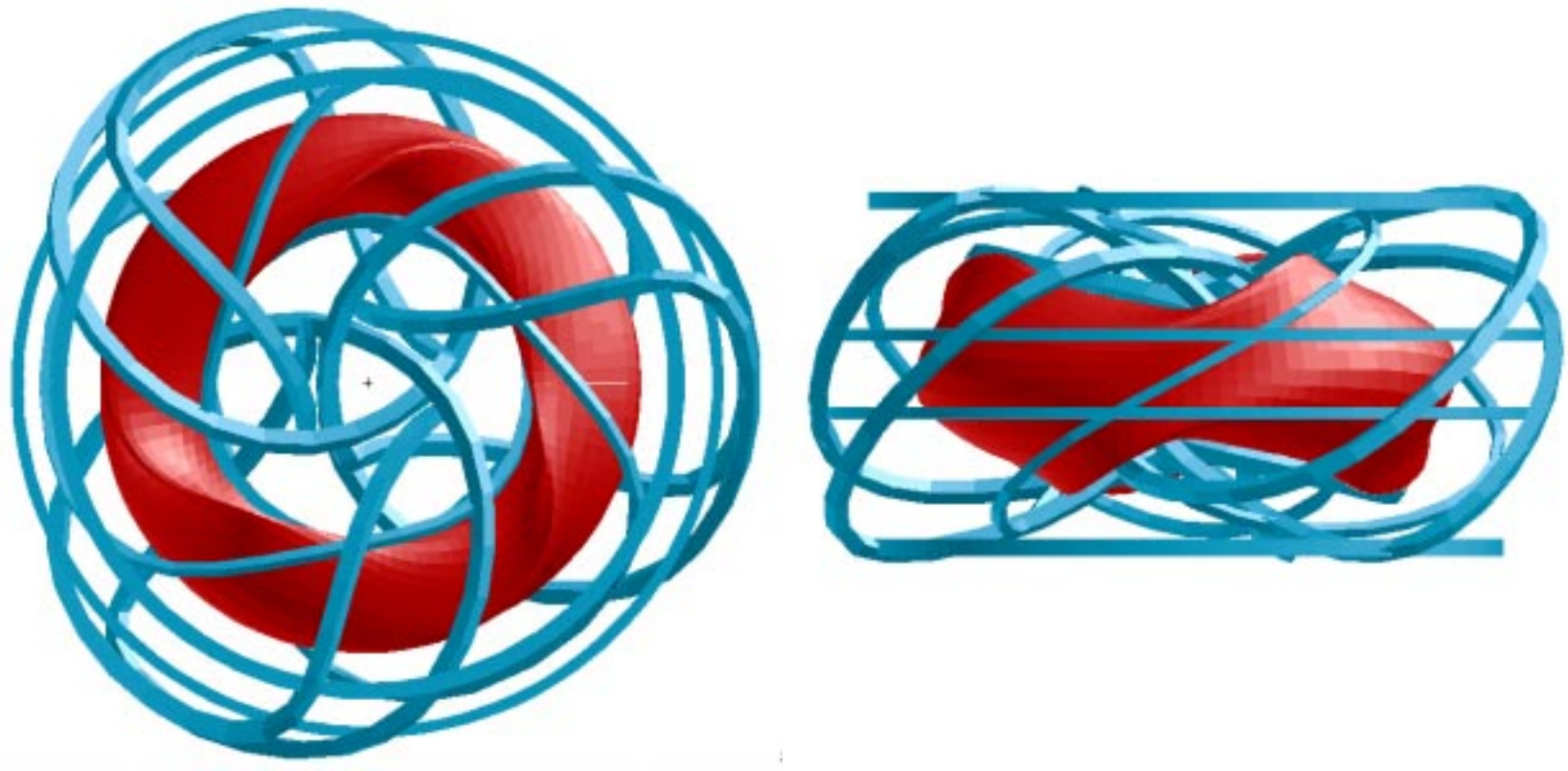




What do we hope to gain by eliminating conformal coils?

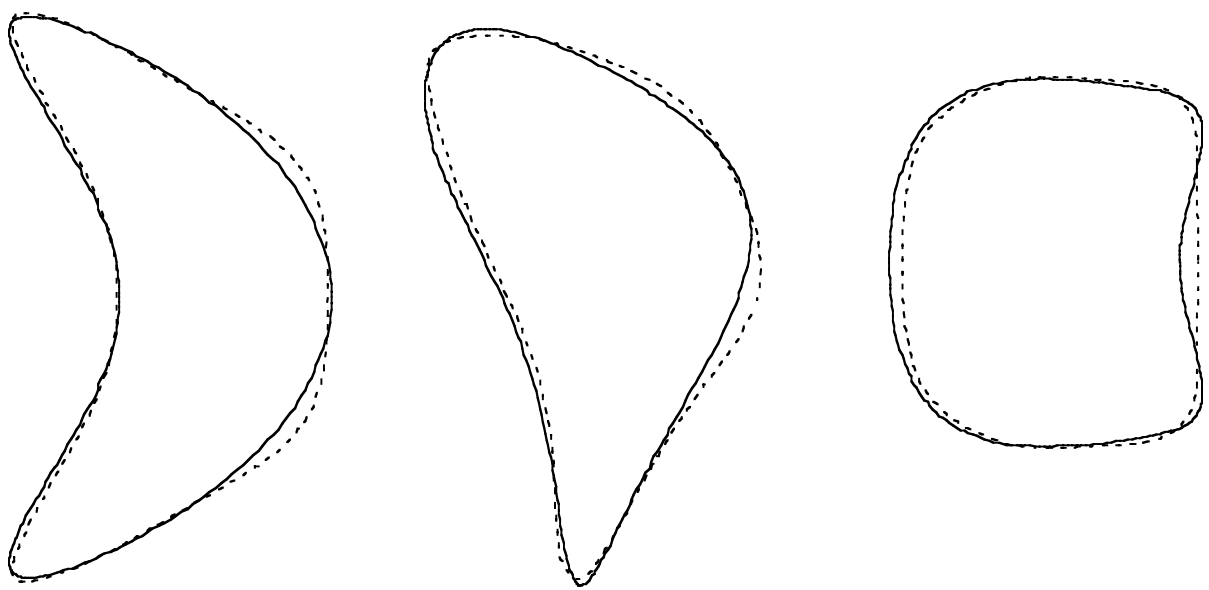
- Improved access with CCs and cryostat eliminated
- Longer pulse length with CCs gone
- Improved shape flexibility with expanded vessel
- Reactor relevant development path

Look, Ma! No saddles!

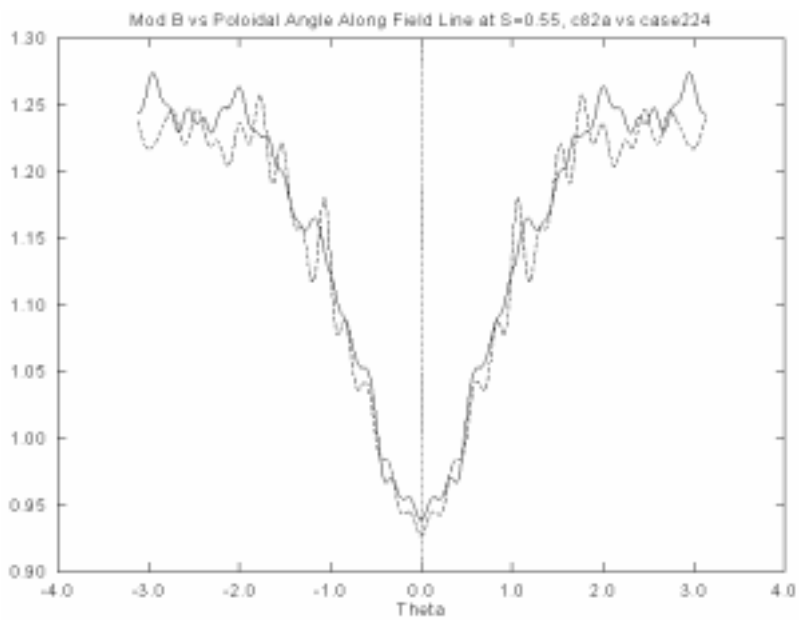


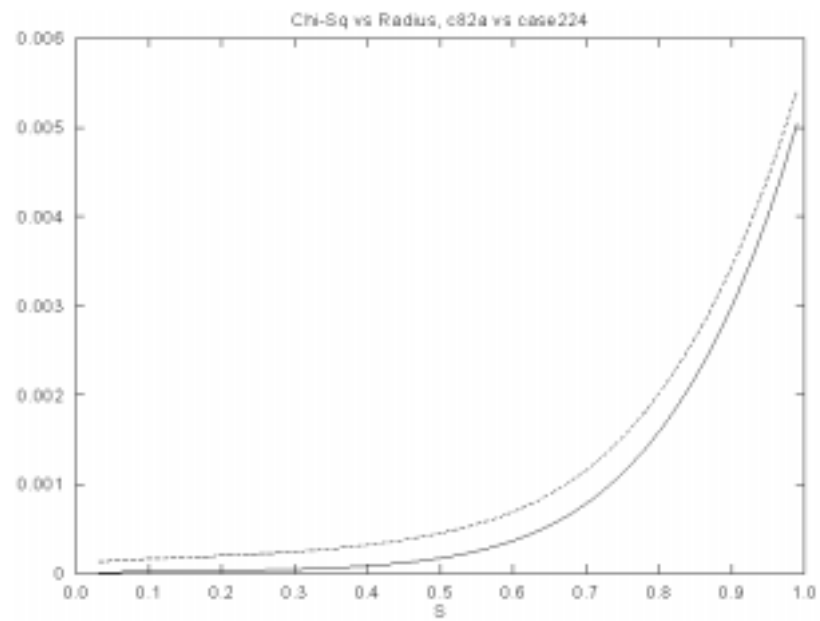
Recent progress is encouraging

- Access further improved
- Iota profile is close – 0.26 to 0.44
- Approximation to plasma boundary needs to be improved – 1.3cm avg, 4.4cm max error



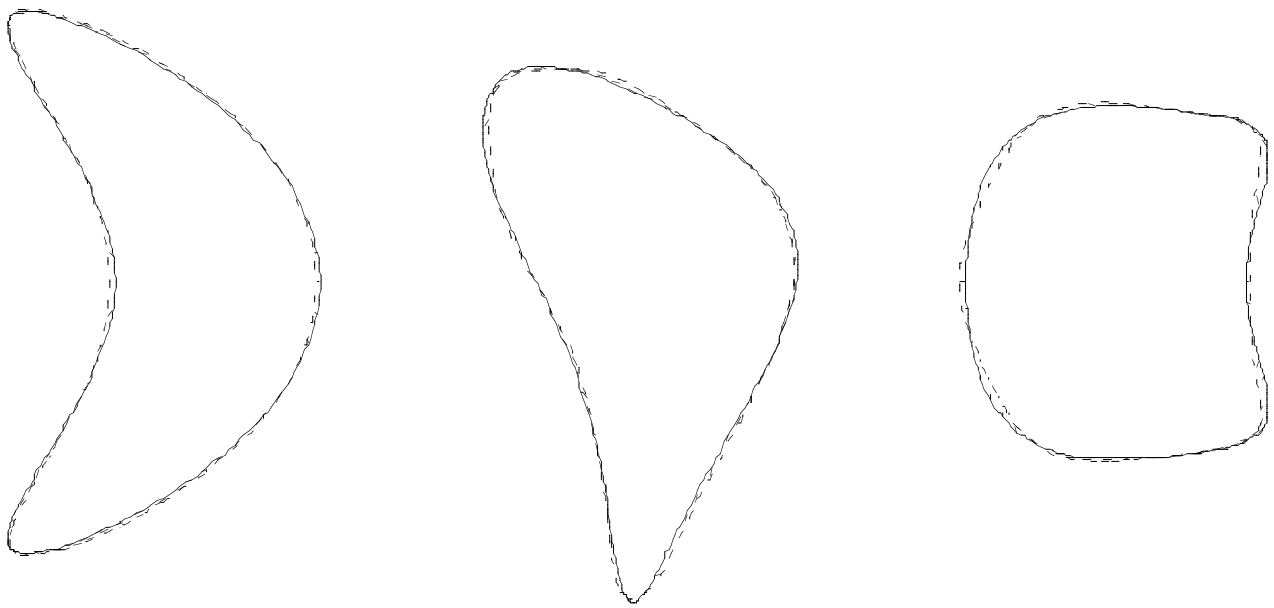
Quasi-symmetry needs some work



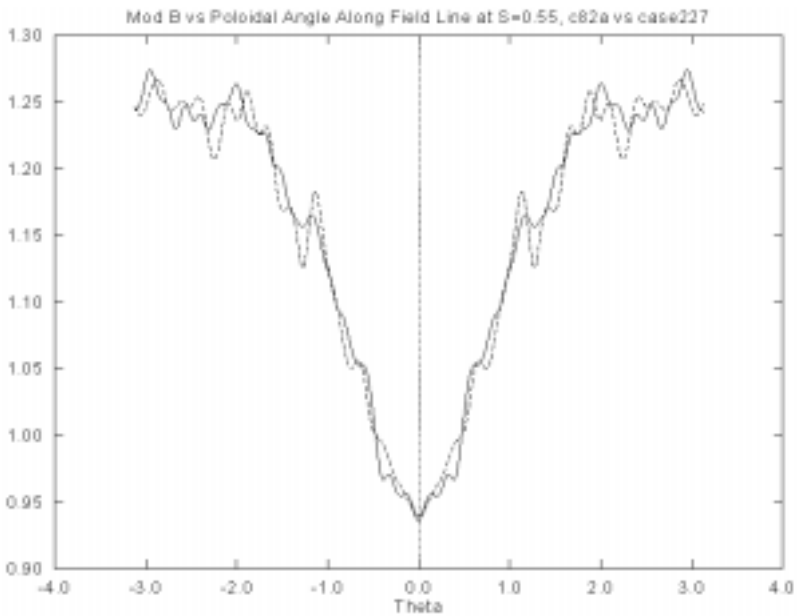


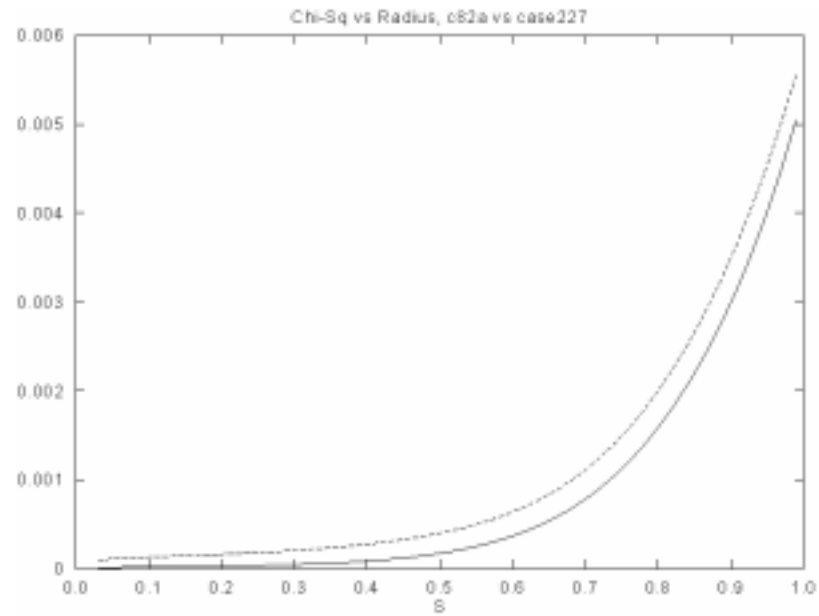
Adding more modes helps

- Boundary errors reduced to 0.7cm avg, 2.5cm max



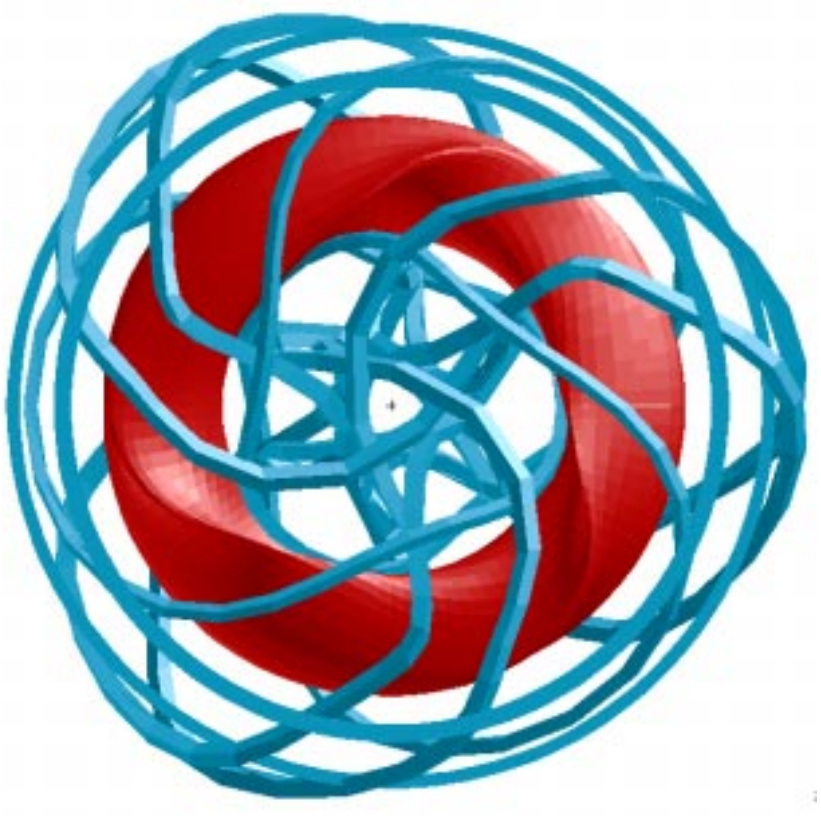
Quasi-symmetry is slightly improved

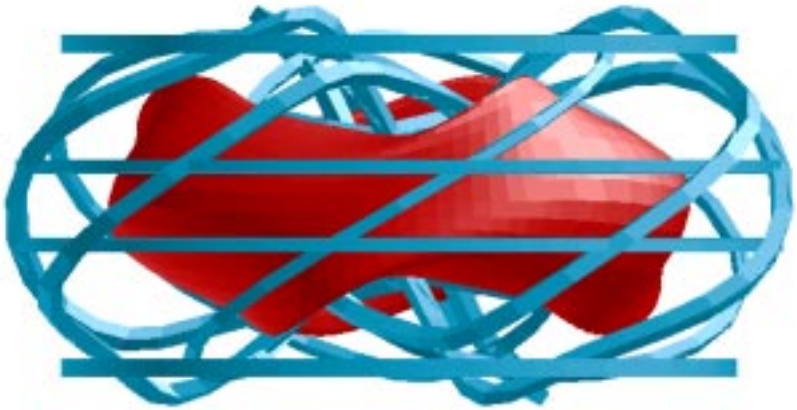




But the coils get squirrellier near the major axis

- An artifact of the coil representation?





Back to our 3 questions…

Are there much better conformal coil solutions for a 1/R background field? Probably not

Can J in the conformal coils be reduced and access improved by modifying the background field? Probably so

- *Many features yet unexplored*
- *GA not yet used to improve discrete coil solution*

Can the conformal coils be eliminated? TBD

- *Greatest upside potential*
- *Concurrent engineering approach would facilitate developing a solution*