Using the Genetic Algorithm to Find Coils for Compact Stellarators

William H. Miner, Jr.,

on behalf of the NCSX coil team

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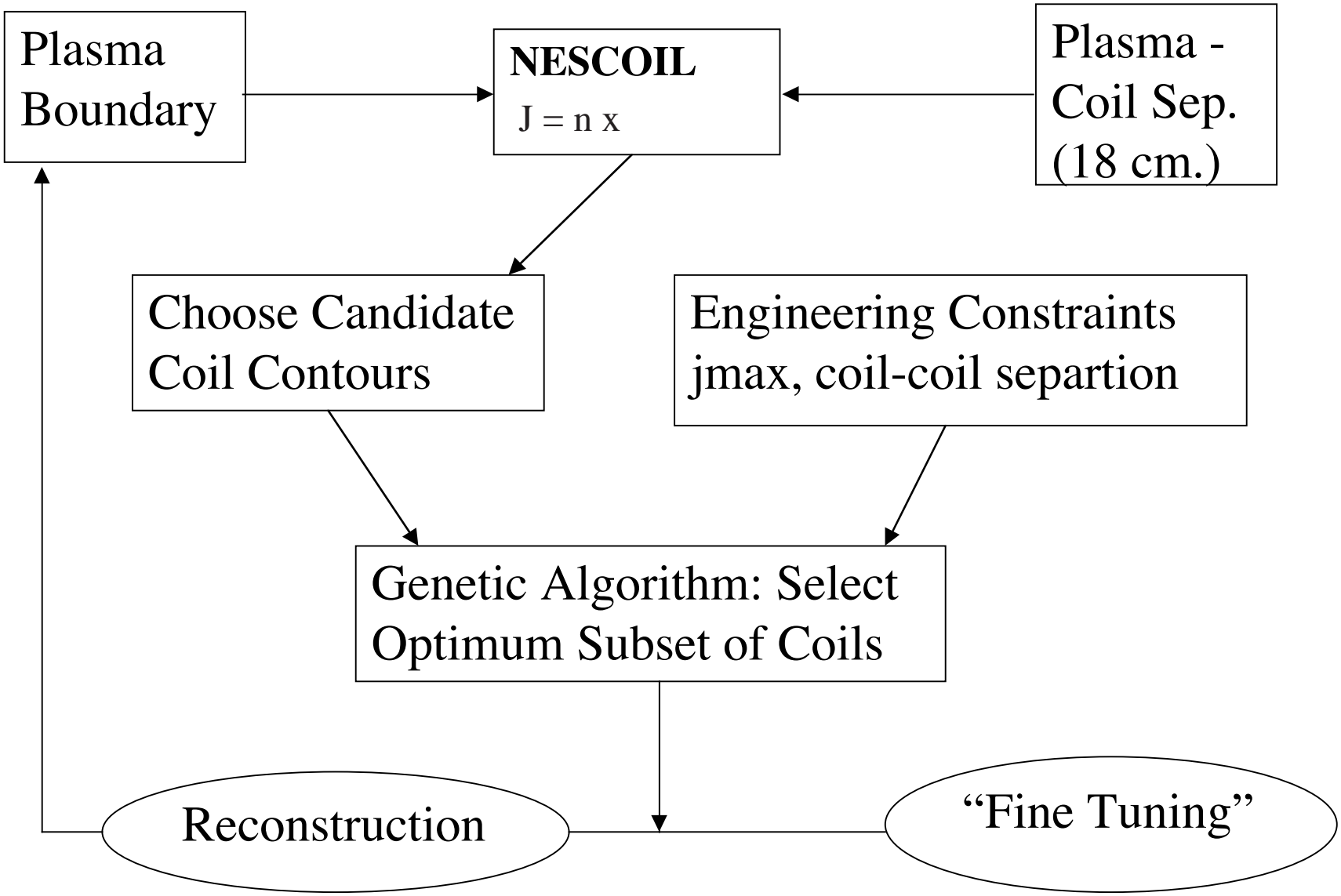
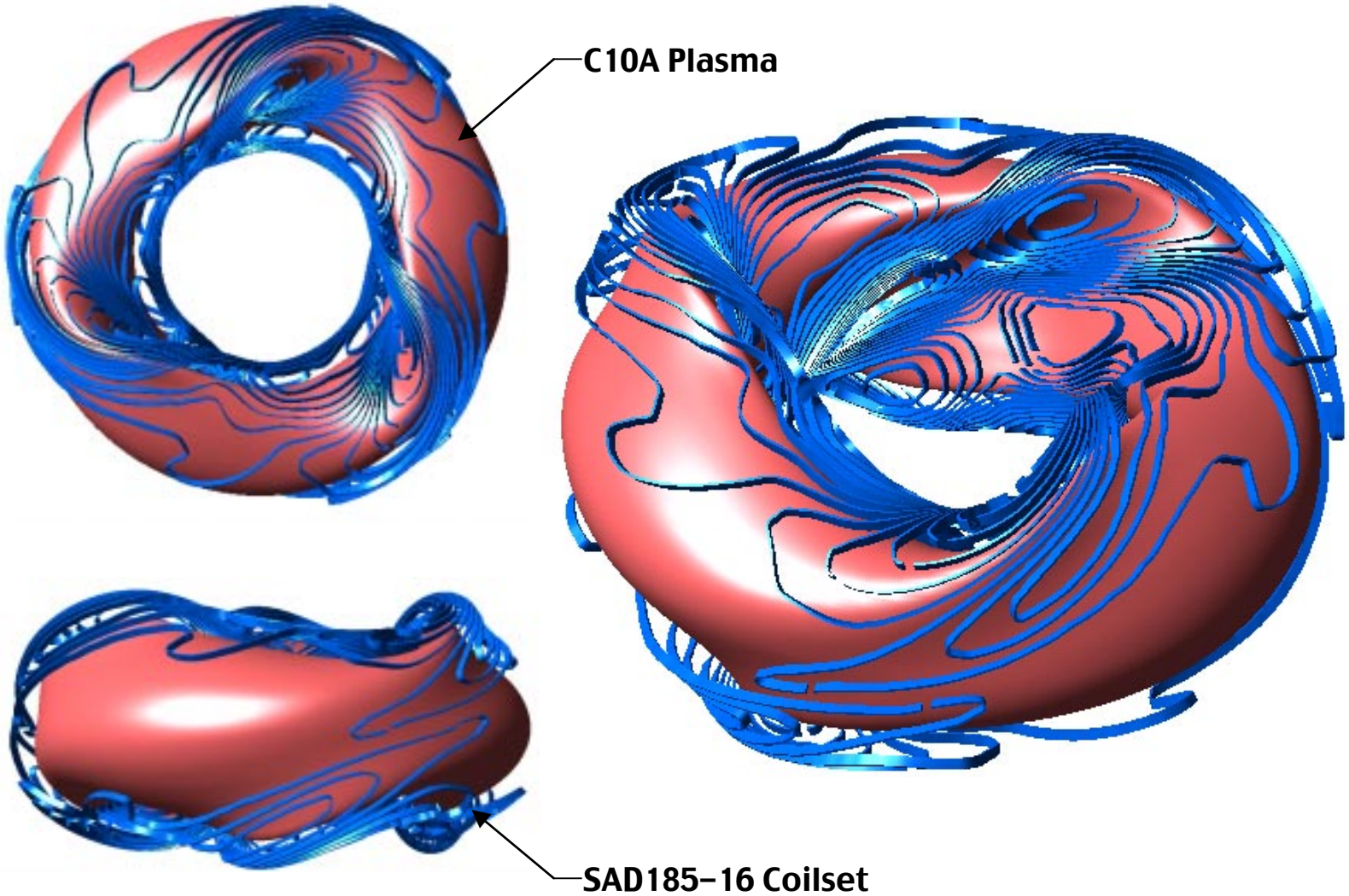
Coil Design Process



Saddle Coil Design



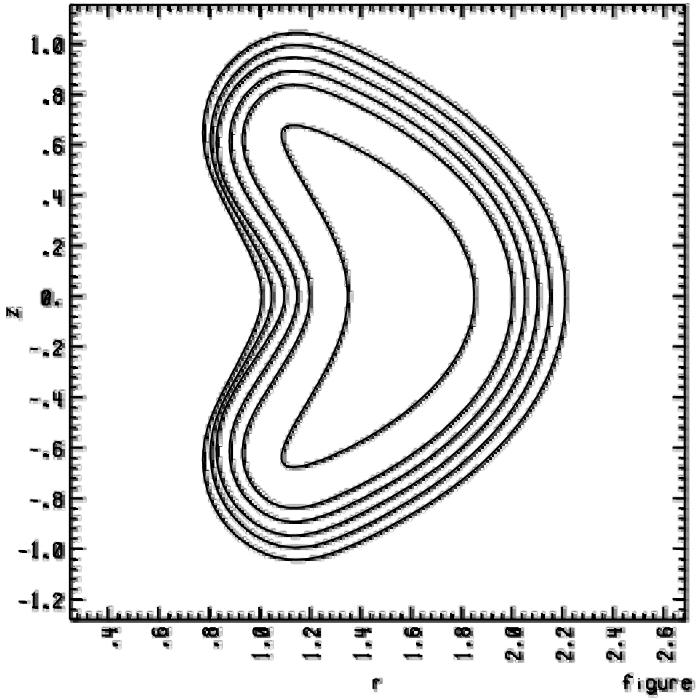


figure 1

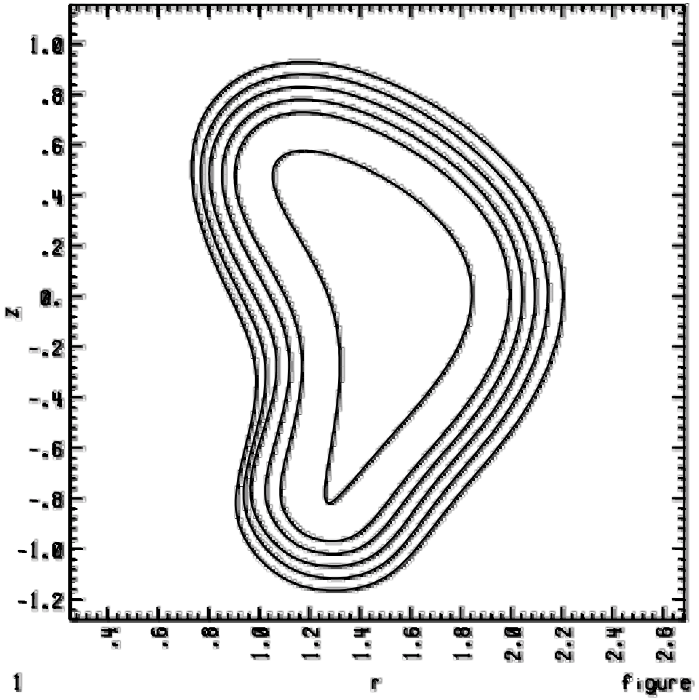


figure 5

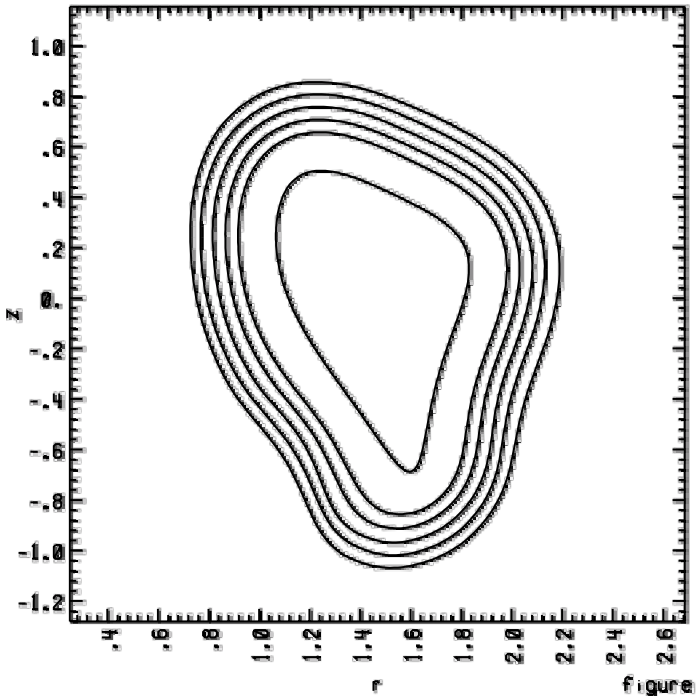


figure 9

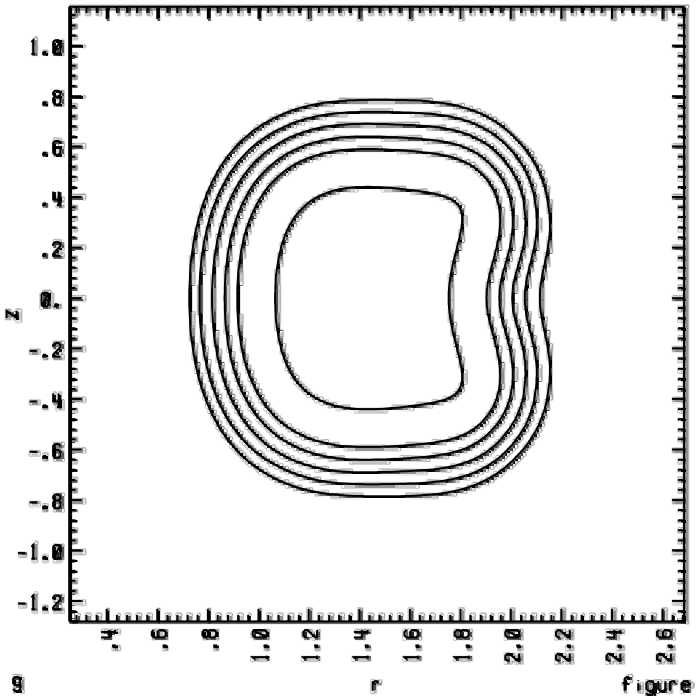


figure 13

Genetic Algorithm

- GA: an efficient way to find an optimized subset of coils by a obtaining a global minimum of a cost function
  - pick N_{coil} coils out of $N_{contour}$ contours (obtained from NESCOIL, where $N_{coil} << N_{contour}$)
  - contour selection based on minimizing physics and engineering criteria:
    - B_{error}, J_{max}, minimum coil-to-coil separation
  - rapid 2D analysis tool

Early coil cutting procedure

- Current sheet solution from NESCOIL
- Choose equally spaced (equal current) contours
- Usually a large number required to meet Berror criteria

GENETIC ALGORITHM

POPULATION

010100010001000
011000000001100
000011000010100
011010000100000
010001110000000
010000011001000
000101000100100
010100010010000

MATING POOL

010100010001000
011000000001100
000011000010100
011010000100000

MATES SELECTED

01010 0010001000
01100 0000001100

MATING

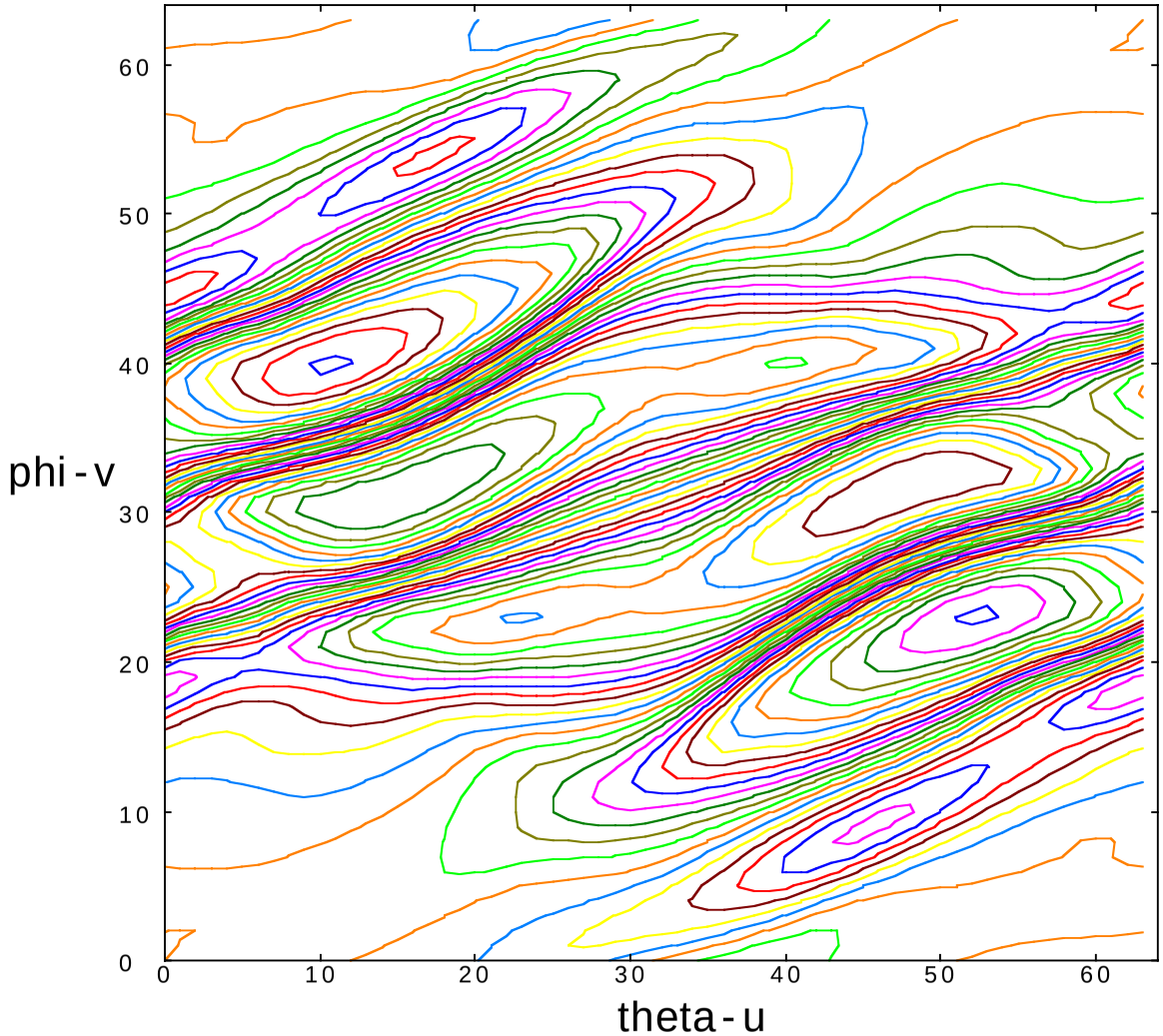
OFFSPRING

010100000001100
01100 0010001000

NEWPOPULATION

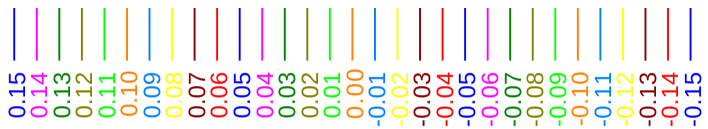
010100000001100
011000010001000
100001000010100
010010000100001
010001010000010
010100001001000
000100101000100
010100000010001

Potential Contour plot



Chromosome

0000000000000000



Nonstandard Feature
Continuous vs. Fixed binary

		parameter value			
		0.55	0.11	0.95	0.63
1.000					
	111			•	
0.875					
	110				
0.750					
	101				•
0.625					
	100	•			
0.500					
	011				
0.375					
	010				
0.250					
	001				
0.125					
	000		•		
0.000					

Fixed number of bits “on”

000111000000010
000100010001100
000000010000100
010100010001000
100001001000010
010100010000001
001100010001000
001100010000100

Pairing and Mating Process for Single Point Crossover

Chromosome	Family	Binary String	Cost
1	$parent_1$	0011000010000100	-0.0142
2	$parent_2$	0101000010000100	-0.0159
7	$offspring_1$	0011000010000100	-0.0142
8	$offspring_2$	0101000010000100	-0.0159
3	$parent_1$	0001000010001100	-0.0167
4	$parent_2$	0001000010001100	-0.0167
9	$offspring_1$	0001000010001100	-0.0167
10	$offspring_2$	0001000010001100	-0.0167
5	$parent_1$	0100100010001000	-0.0188
6	$parent_2$	0101000001000100	-0.0195
11	$offspring_1$	0100100001000100	-0.0122
12	$offspring_2$	0101000010001000	-0.0172

Mutations

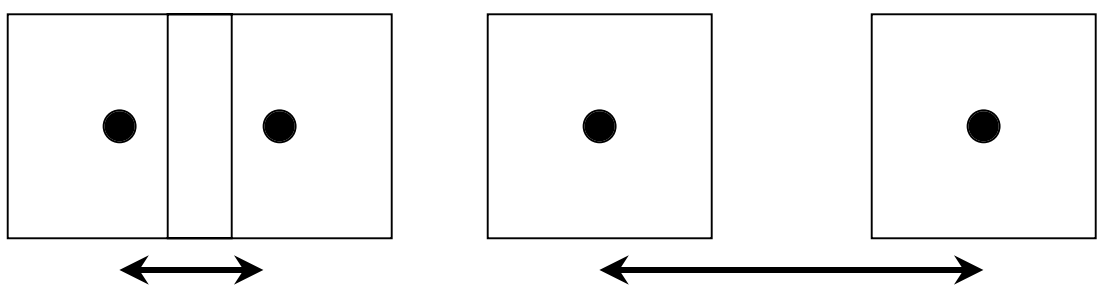
Original Chromosome	Mutated Chromosome	Cost
010100010001000	010100010001000	-0.0188
000000011001100	000000101001100	-0.0298
000011000010100	000011000010100	-0.0221
011010000100000	010010000100001	-0.0322
010001110000000	010001110000000	-0.0459
010000011001000	010000010101000	-0.0206
000100000000100	000100000000100	-0.0261
010100010010000	010100010010000	-0.0229
010100010010000	010100010010000	-0.0288
000111000000010	000101000010010	-0.0429
000100010001100	000100010001100	-0.0167
000000010000100	000000010000100	-0.0355

Jump mutation Creep mutation

Cost Function

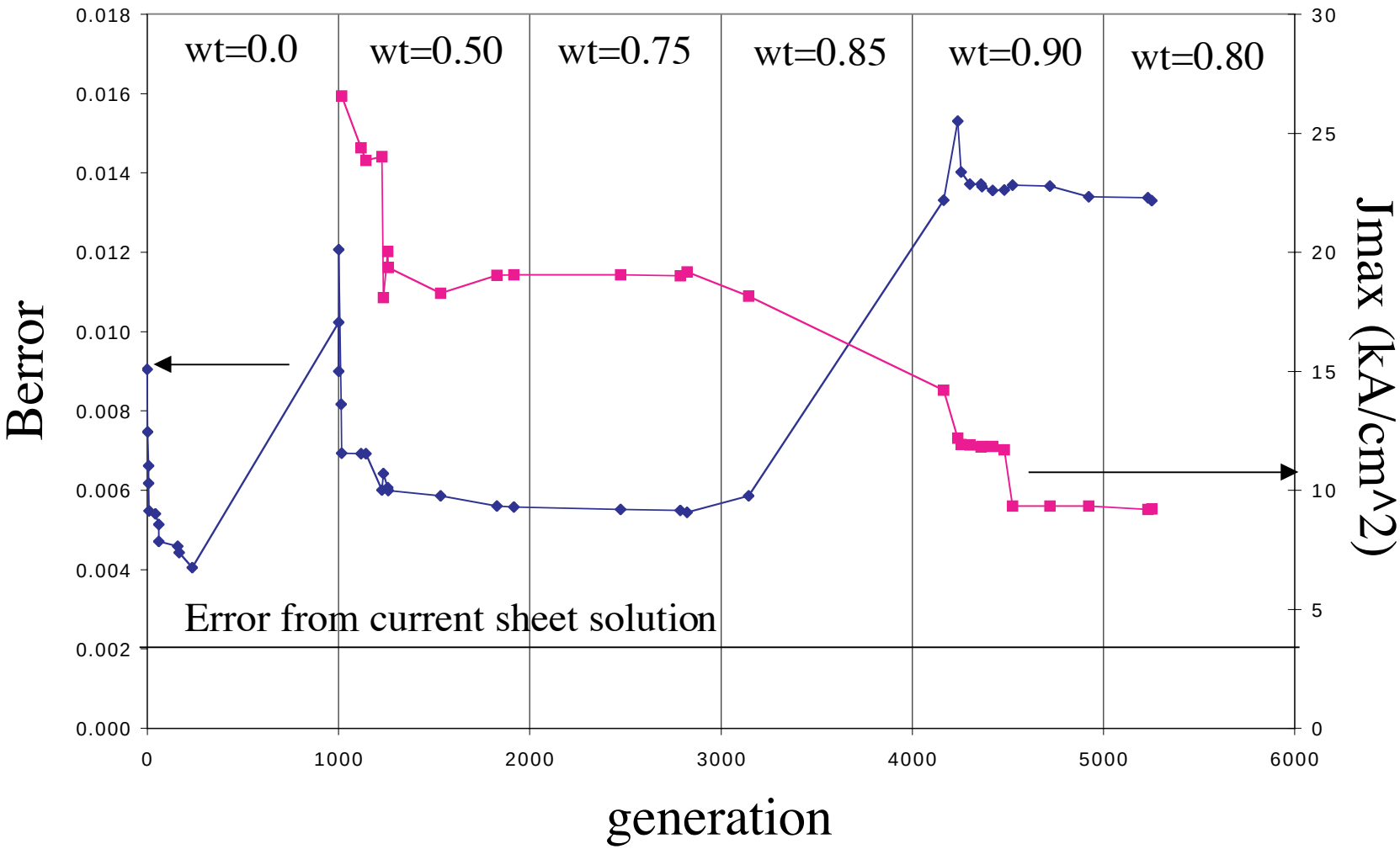
$$\text{Cost} = (1 - \text{wt})*B_{error} + \text{wt}*J_{max}*\text{Normalization}$$

Filaments too close - artificial value
Separated by coil width - actual value

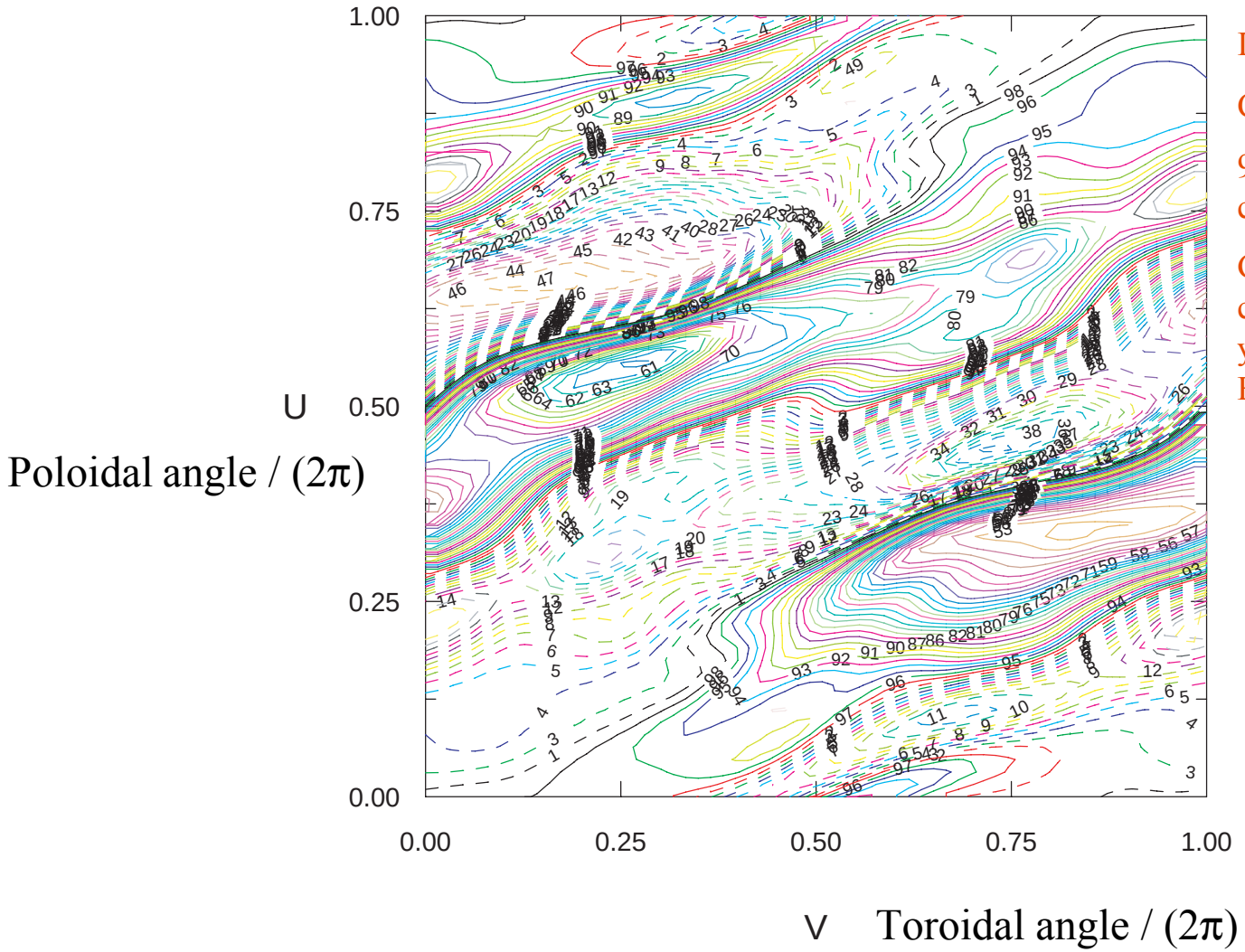


Filament separation

Target Berror and Jmax



Genetic Algorithm for Coil Selection
Discrete Potential Contour Evolution



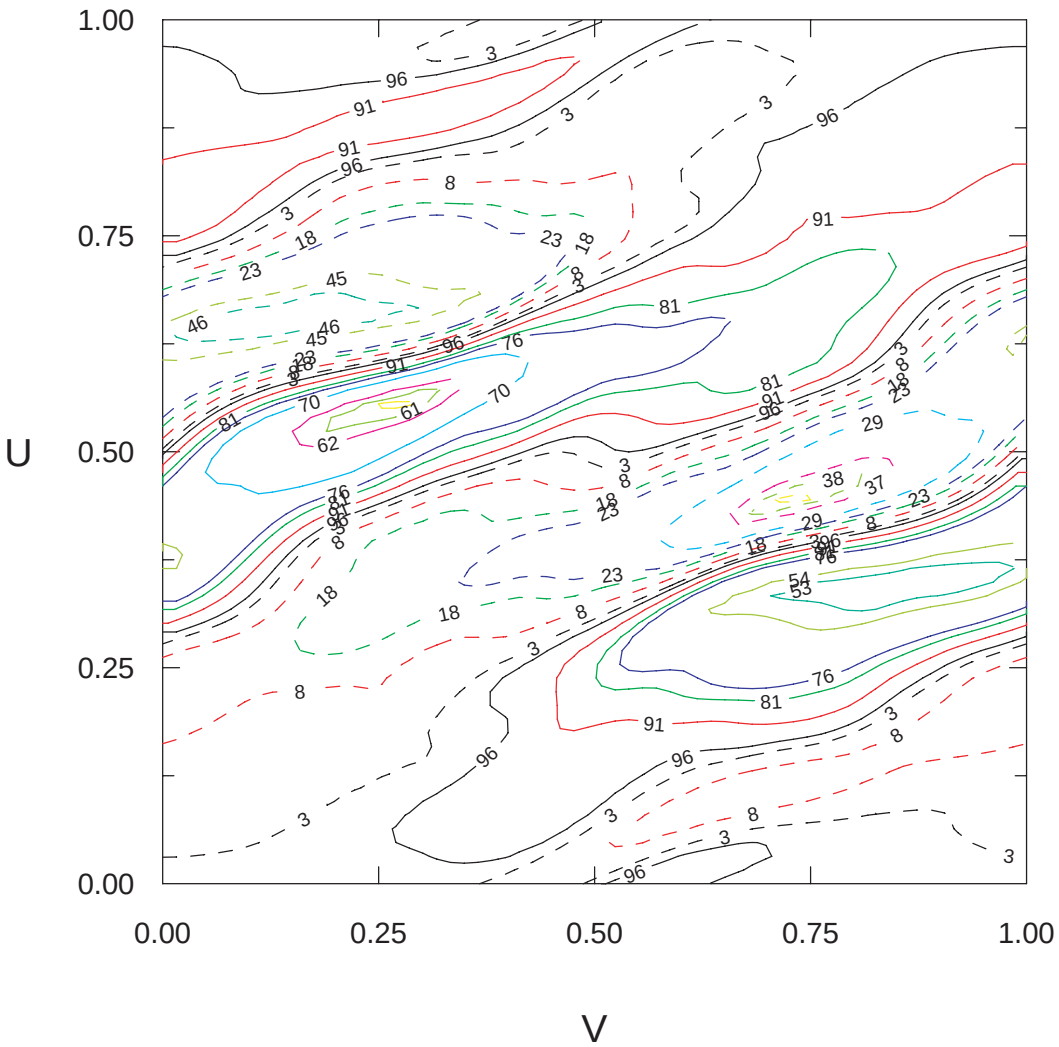
Initial conditions:

Current sheet Berror = .2%

98 coils generated from 60 contour levels.

GA selects the "optimal" 20 coils per period which yield a joint minimum in Berror and Jmax.

Genetic Algorithm for Coil Selection
(lowest Berror state)

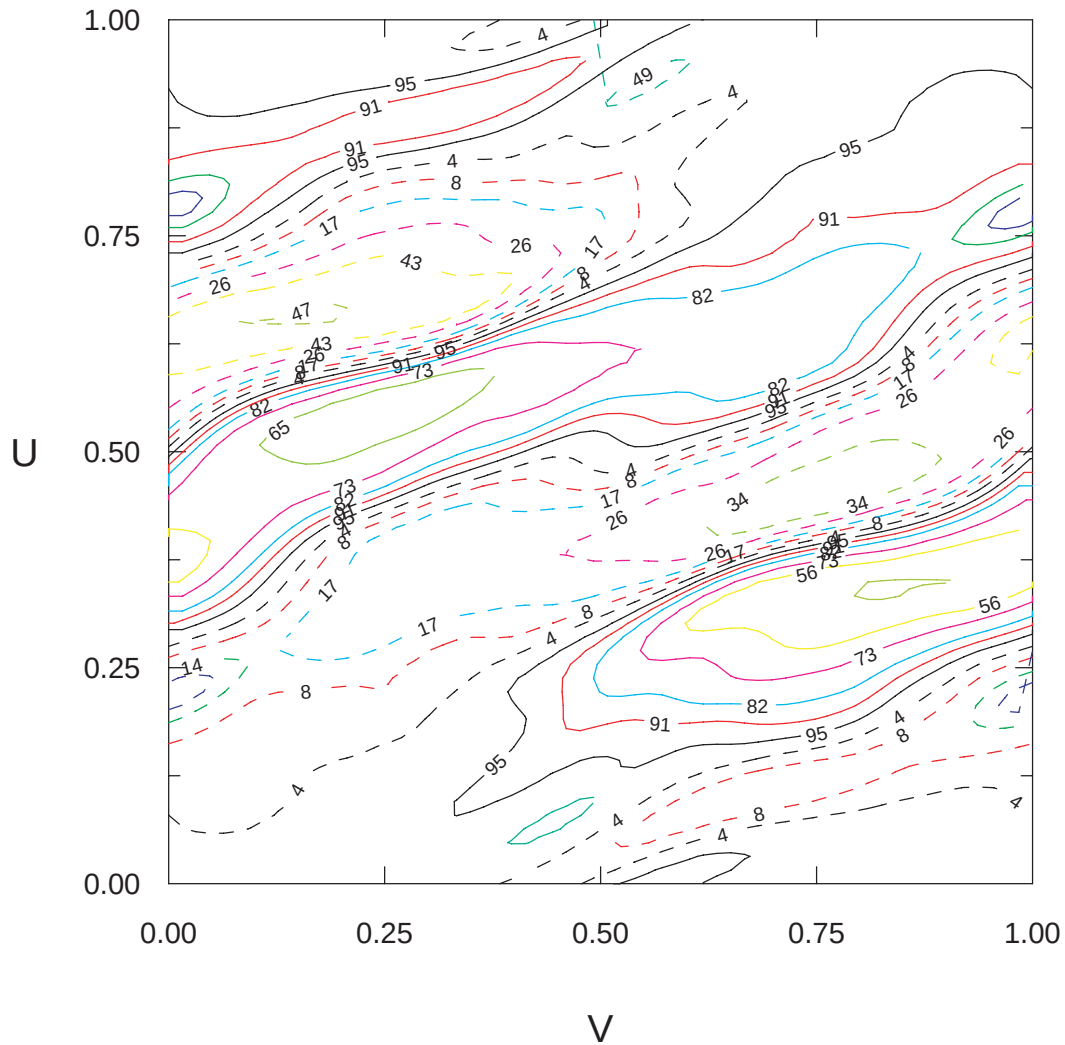


Generation = 236

Berror = .0041

Jmax =

Genetic Algorithm for Coil Selection
(lowest Berror state with coils)

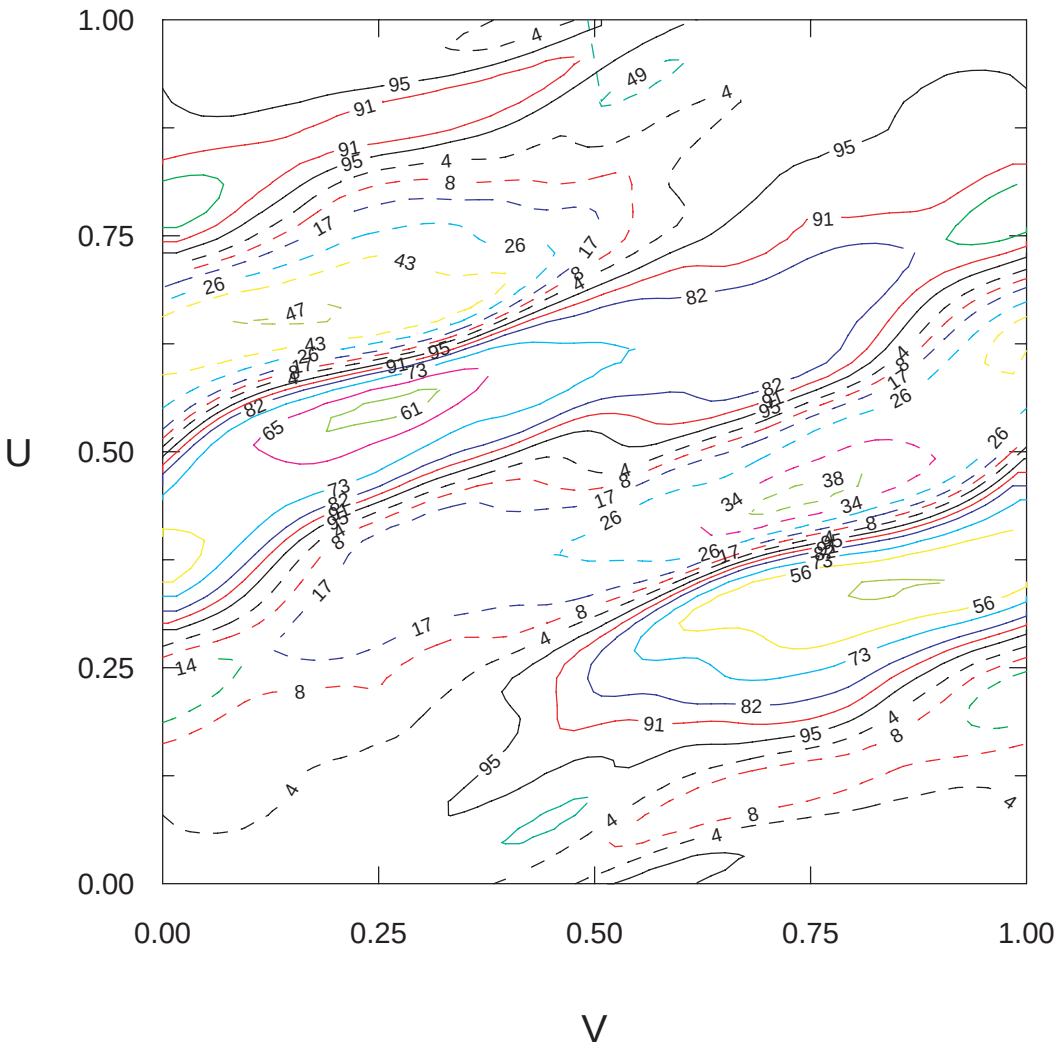


Generation = 2795

Berror = .0050

Jmax = 20.47

Genetic Algorithm for Coil Selection



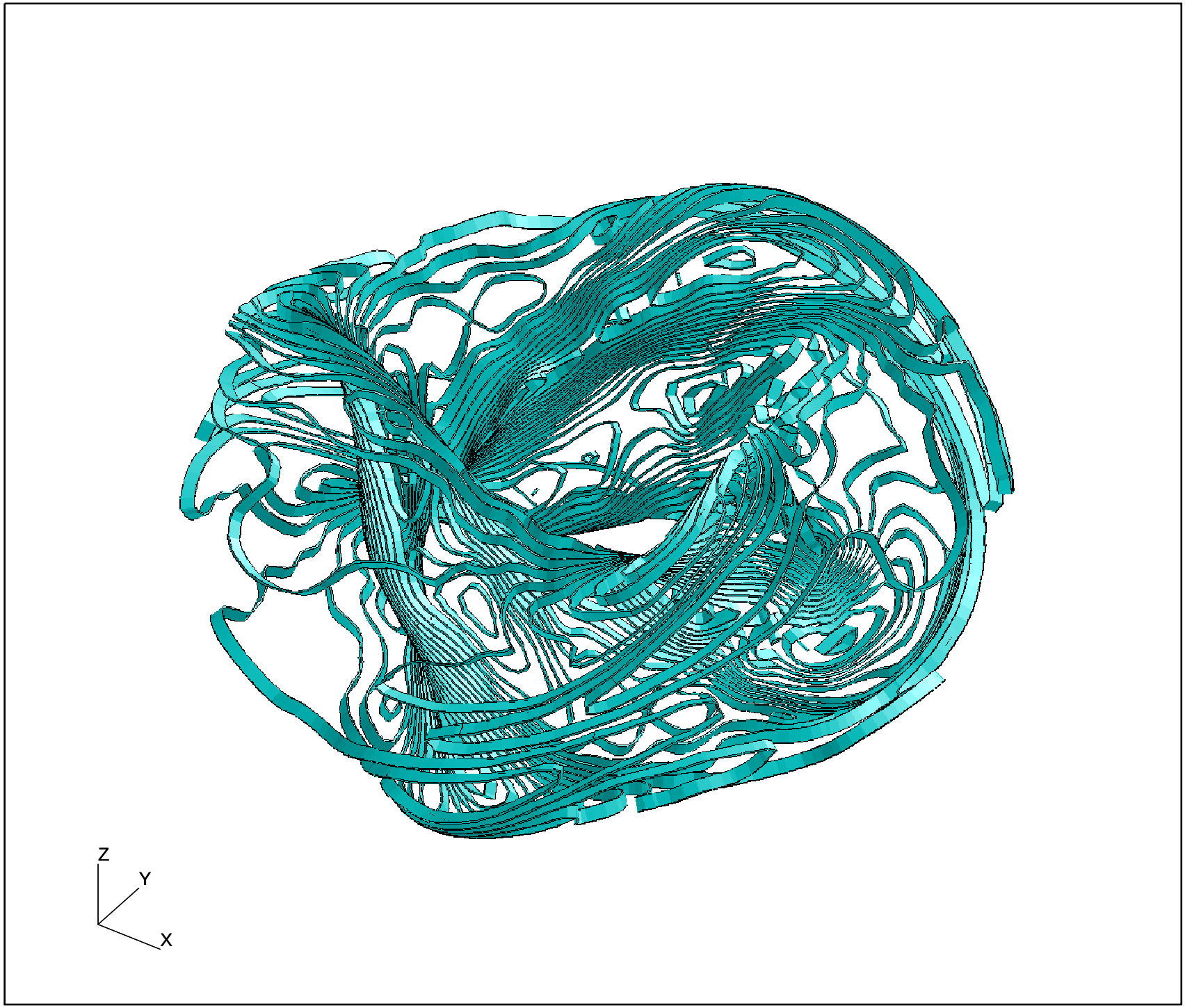
Generation = 4064

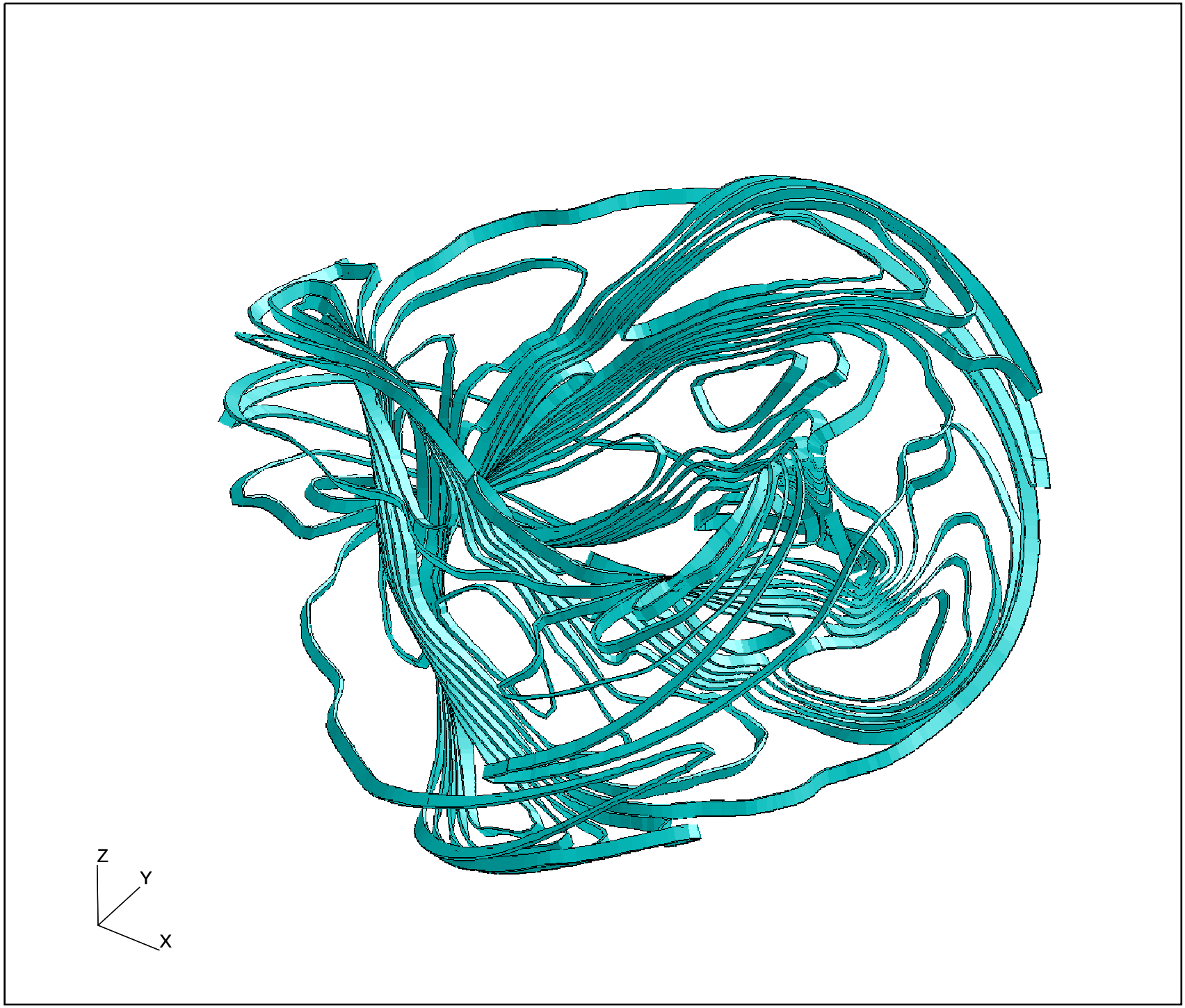
Berror = .0143

Jmax = 11.86

Comparison

Case	Description	No. Coils Per Period	Jmax (kA/cm**2)	Berror % (ave., max)	Current Variation
C82 with ef					
121	Equal Current (A. B. Tuning)	26	14.70	.95, 7.0	none
	New GA code Gen 2627	8	14.99	.89, 5.2	factor of 5


Z
Y
X


Z
Y
X