# COIL FLEXIBILITY COMPARISONS

# II. RESULTS

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**The following set of Tables show a summary of results.**

**TABLE 1: Peaked/Peaked**
**TABLE 2: Peaked/Broad**
**TABLE 3: Broad/Peaked**
**TABLE 4: Broad/Broad**

**In each Table, results for $\beta = 1\%, 2\%$, and $3\%$ are shown.**

**TABLE 5 shows, for each profile pair, the results obtained from running with a new strategy on the optimization code allows the code to optimize the kink beta limit while it is optimizing for tranport.**

**TABLE 6 selects from the first 5 Tables the "best cases" for comparing the modulars with saddles for each of the profile pairs.**

**TABLE 7 shows results from the first iota scan experiment, which varies the coil currents in order to effect a change in the iota profile without adding shear.**

**TABLE 8 shows results from the attempts to vary the shear.**

# PROFILE VARIATION

**TABLE 1: Pressure/Current = Peaked/Peaked**

mfl = modular, sfl = saddle

Numbers in parenthesis are initial (iteration 0) values

| | pp1%-2-np | | pp2%-2-np | | pp3%-2-np | |
|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl |
| $\hat{\chi}^2_{B_{mn}}$ | 1.3(5.4) | 2.0(3.8) | 1.6(4.2) | 2.3(3.0) | 2.0(3.5) | 2.6(2.6) |
| -$\lambda_{Kink}$ | 1.1e-4(1.0e-4) | 1.3e-4(9.8e-5) | 1.7e-4(1.3e-4) | 2.8e-4(1.1e-4) | 5.5e-4(8.6e-4) | 8.1e-4(8.2e-4) |
| $\iota(0.)$ | 0.72 | 0.70 | 0.79 | 0.76 | 0.80 | 0.76 |
| $\iota(.5)$ | 0.69 | 0.68 | 0.73 | 0.73 | 0.73 | 0.72 |
| $\iota(1.)$ | 0.61 | 0.62 | 0.64 | 0.65 | 0.64 | 0.64 |
| ID | 0.19 | 0.26 | 0.15 | 0.04 | 0.01 | 0.01 |
| IQ | 0.13 | -0.46 | 0.25 | -0.28 | -0.03 | -0.03 |
| IH | -1.76 | -0.23 | -0.27 | -0.83 | 0.51 | 0.09 |
| IO | 0.28 | -0.37 | 1.45 | 0.30 | -0.34 | 0.07 |
| ITF | -0.09 | 1.00e-0 | -0.03 | 1.00e-0 | 0.00 | 1.00e-0 |
| I1 | 0.91 | 1.00 | 0.99 | 1.02 | 1.00 | 0.99 |
| I2 | 0.89 | 0.75 | 0.97 | 0.98 | 0.96 | 0.99 |
| I3 | 0.89 | 1.08 | 0.96 | 0.96 | 0.96 | 0.99 |
| I4 | 0.86 | 0.73 | 0.94 | 1.01 | 0.94 | 1.02 |
| RBtor | 2.02 | 2.04 | 2.01 | 2.01 | 1.95 | 1.98 |
| VV-dist(m) | -2.40e-2 | -5.65e-3 | -2.02e-2 | -2.87e-2 | -2.11e-2 | -1.86e-2 |

$\hat{\chi}^2_{B_{mn}} \equiv \chi^2(B_{mn})/\chi^2_{S_3}(B_{mn})$, where $\chi^2_{S_3}(B_{mn}) = 25.8$ is value for S3 baseline fixed boundary LI383 using same weights.
$\lambda_{Kink}$ = kink growth rate (stable for S3).
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx);$A = 4.30$
SIGMA-BMN=11*1.e+30 +.01 12*1.e+30 +.01 12*1.e+30 +.01 11*1.e+30
SIGMA-KINK = 1.e-4

# PROFILE VARIATION

**TABLE 2: Pressure/Current = Peaked/Broad**

mfl = modular, sfl = saddle

Numbers in parenthesis are initial (iteration 0) values

| | pb1%-ck | | pb2%-ck | | pb3%-ck | |
|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl |
| $\hat{\chi}^2_{B_{mn}}$ | 2.0(5.6) | 2.1(4.1) | 1.9(4.3) | 2.0(3.0) | 1.5(3.2) | 2.0(2.3) |
| -$\lambda_{Kink}$ | 4.9e-5(6.2e-4) | 0.0(6.7e-4) | 1.5e-5(7.0e-4) | 1.5e-6(5.4e-4) | 2.7e-4(7.0e-4) | 1.8e-4(5.4e-4) |
| $\hat{\chi}^2(Bal)$ | 0.7(0.0) | 0.4(0.0) | 0.0(0.0) | 0.5(0.0) | 0.7(0.7) | 0.5(0.4) |
| $\iota(0.)$ | 0.40 | 0.38 | 0.45 | 0.38 | 0.41 | 0.38 |
| $\iota(.5)$ | 0.55 | 0.54 | 0.55 | 0.54 | 0.54 | 0.54 |
| $\iota(1.)$ | 0.66 | 0.66 | 0.66 | 0.65 | 0.65 | 0.65 |
| ID | 0.13 | 0.30 | 0.75 | 0.11 | 0.13 | 0.20 |
| IQ | -0.02 | -0.15 | 0.35 | -0.22 | 0.35 | 0.03 |
| IH | -1.42 | 0.08 | -0.92 | -0.46 | -0.68 | -0.61 |
| IO | -3.38 | -2.74 | 0.52 | -2.01 | 0.87 | -1.83 |
| ITF | -0.01 | 1.00e-0 | -0.02 | 1.00e-0 | 0.01 | 1.00e-0 |
| I1 | 0.96 | 1.04 | 0.99 | 1.09 | 1.03 | 1.08 |
| I2 | 0.92 | 0.78 | 1.00 | 0.91 | 1.02 | 0.82 |
| I3 | 0.94 | 1.15 | 0.97 | 1.01 | 1.00 | 1.05 |
| I4 | 0.90 | 0.58 | 0.95 | 1.20 | 1.02 | 1.11 |
| RBtor | 1.92 | 2.03 | 2.03 | 2.01 | 1.97 | 1.98 |
| VV-dist(m) | -6.4e-3 | -0.6e-3 | -8.0e-3 | -1.2e-3 | -6.0e-3 | +2.2e-3 |

Hatted $\chi^2$ values are normalized by corresponding values for LI383 fixed boundary values.
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
Weights were: SIGMA-KINK = 2.e-4, SIGMA-BAL = 49*5.0,
SIGMA-BMN = 11*-1.0e+30 0.05 12*-1.0e+30 0.05 12*-1.0e+30 0.05 11*-1.0e+30 $\Rightarrow$
$\chi^2_{S_3}(Bmn) = 1.22$, $\chi^2_{S_3}(Kink) = 0$(stable), $\chi^2_{S_3}(Bal) = 0.14$

# PROFILE VARIATION

**Table 3: Pressure/Current = Broad/Peaked**
mfl = modular, sfl = saddle
Numbers in parenthesis are initial (iteration 0) values

| | bp1%-ck | | bp2%-ck | | bp3%-ck | |
|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl |
| $\hat{\chi}^2_{B_{mn}}$ | 1.4(4.9) | 2.0(3.4) | 2.0(3.9) | 2.2(2.7) | 2.1(3.1) | 2.5(2.3) |
| -$\lambda_{Kink}$ | 9.8e-5(1.5e-4) | 1.4e-4(8.9e-5) | 7.0e-5(1.1e-4) | 8.2e-5(1.1e-4) | 1.2e-4(5.2e-4) | 1.0e-4(4.7e-4) |
| $\hat{\chi}^2(Bal)$ | 0.1(0.0) | 1.1(0.0) | 1.2(9.9) | 1.3(5.1) | 2.0(23.4) | 2.9(15.4) |
| $\iota(0.)$ | 0.74 | 0.70 | 0.70 | 0.71 | 0.75 | 0.74 |
| $\iota(.5)$ | 0.71 | 0.68 | 0.66 | 0.69 | 0.69 | 0.71 |
| $\iota(1.)$ | 0.63 | 0.62 | 0.60 | 0.59 | 0.60 | 0.59 |
| ID | 0.29 | 0.35 | 0.44 | 0.26 | 0.08 | 0.17 |
| IQ | -0.06 | -0.61 | 0.03 | -0.55 | 0.35 | -0.69 |
| IH | -0.64 | 0.41 | -0.07 | 1.45 | -0.92 | 2.07 |
| IO | 0.71 | 1.90 | -1.39 | -1.28 | 0.52 | -4.83 |
| ITF | -0.06 | 1.00e-0 | -0.02 | 1.00e-0 | -0.02 | 1.00e-0 |
| I1 | 0.97 | 0.97 | 1.30 | 0.89 | 0.99 | 0.97 |
| I2 | 0.96 | 0.75 | 1.25 | 1.03 | 1.00 | 1.19 |
| I3 | 0.95 | 1.10 | 1.24 | 0.86 | 0.97 | 0.79 |
| I4 | 0.93 | 0.04 | 1.23 | 1.20 | 0.95 | 1.57 |
| RBtor | 2.08 | 2.05 | 2.62 | 2.03 | 2.29 | 2.02 |
| VV-dist(m) | -7.9e-3 | -6.6e-3 | -3.4e-3 | -3.4e-3 | -1.0e-3 | -3.1e-3 |

Hatted $\chi^2$ values are normalized by corresponding values for LI383 fixed boundary values.
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
Weights were: SIGMA-KINK = 2.e-4, SIGMA-BAL = 49*5.0,
SIGMA-BMN = 11*-1.0e+30 0.05 12*-1.0e+30 0.05 12*-1.0e+30 0.05 11*-1.0e+30 $\Rightarrow$
$\chi^2_{S_3}(Bmn) = 1.22$, $\chi^2_{S_3}(Kink) = 0$(stable), $\chi^2_{S_3}(Bal) = 0.14$

# PROFILE VARIATION

**Table 4: Pressure/Current = Broad/Broad**

mfl = modular, sfl = saddle

Numbers in parenthesis are initial (iteration 0) values

| | bb1%-2-rh | | bb2%-2-rh | | bb3%-2-rh | |
|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl |
| $\hat{\chi}^2(B_{mn})$ | 2.1(6.9) | 2.5(5.0) | 1.6(5.3) | 2.4(3.7) | 1.5(4.0) | 2.3(2.9) |
| -$\lambda_{Kink}$ | 7.8e-5(5.1e-4) | 0(5.6e-4) | 0(5.1e-4) | 2.7e-4(2.9e-4) | 6.3e-5(3.6e-4) | 1.8e-4(3.0e-5) |
| $\iota(0.)$ | 0.48 | 0.38 | 0.40 | 0.36 | 0.39 | 0.36 |
| $\iota(.5)$ | 0.62 | 0.54 | 0.56 | 0.54 | 0.55 | 0.56 |
| $\iota(1.)$ | 0.75 | 0.65 | 0.65 | 0.63 | 0.64 | 0.65 |
| ID | 0.40 | 0.27 | 0.21 | 0.22 | 0.13 | 0.08 |
| IQ | 0.51 | 0.24 | 0.65 | -0.05 | 0.56 | 0.02 |
| IH | -0.96 | -0.04 | -1.34 | -0.05 | -0.65 | -1.90 |
| IO | -2.04 | -0.57 | 0.45 | -4.39 | -0.66 | 0.20 |
| ITF | 0.05 | 1.00e-0 | -0.04 | 1.00e-0 | -0.05 | 1.00e-0 |
| I1 | 1.11 | 1.09 | 0.99 | 1.09 | 0.93 | 1.04 |
| I2 | 1.09 | 0.74 | 0.98 | 0.72 | 0.90 | 0.86 |
| I3 | 1.09 | 1.09 | 0.97 | 1.10 | 0.91 | 1.00 |
| I4 | 1.08 | 0.62 | 0.96 | 0.79 | 0.88 | 0.77 |
| RBtor | 2.14 | 2.05 | 2.07 | 2.03 | 1.93 | 2.01 |
| VV-dist(m) | -2.05e-2 | -1.07e-2 | -9.05e-3 | -9.46e-4 | -1.07e-2 | -.772e-3 |

$\hat{\chi}^2_{B_{mn}} \equiv \chi^2(B_{mn})/\chi^2_{S_3}(B_{mn})$, where $\chi^2_{S_3}(B_{mn}) = 25.8$ is value for S3 baseline fixed boundary LI383 using same weights.
$\lambda_{Kink}$ = kink growth rate (stable for S3).
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
SIGMA-BMN=11*1.e+30 +.01 12*1.e+30 +.01 12*1.e+30 +.01 11*1.e+30
SIGMA-KINK = 1.e-4

# PROFILE VARIATION

**TABLE 5: Beta Optimization**

mfl = modular, sfl = saddle

| | pp-beta-rh | | pb-beta-rh | | bp-beta-rh | | bb-beta-rh | |
|---|---|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl | mfl | sfl |
| $\beta$-final | 1.0% | 1.0% | 2.1% | 1.2% | 1.7% | 1.1% | 3.7% | 3.3% |
| $\hat{\chi}^2(B_{mn})$ | 5.3 | 3.8 | 2.1 | 6.7 | 1.8 | 3.8 | 1.9 | 2.3 |
| -$\lambda_{Kink}$ | -1.1e-4 | -9.0e-5 | -7.4e-6 | -7.0e-5 | -8.89e-5 | -8.21e-5 | -1.9e-6 | 0 |
| $\iota(0.)$ | 0.78 | 0.79 | 0.44 | 0.45 | 0.80 | 0.78 | 0.45 | 0.39 |
| $\iota(.5)$ | 0.72 | 0.74 | 0.56 | 0.57 | 0.75 | 0.74 | 0.58 | 0.57 |
| $\iota(1.)$ | 0.64 | 0.65 | 0.65 | 0.66 | 0.66 | 0.65 | 0.65 | 0.65 |
| ID | -0.00 | -0.00 | 0.08 | 0.01 | 0.09 | -0.00 | 0.04 | 0.06 |
| IQ | -0.00 | -0.00 | 0.50 | 0.18 | 0.16 | -0.00 | 0.62 | 0.09 |
| IH | 0.02 | -0.00 | -0.25 | -0.15 | -0.41 | -0.00 | 0.48 | -1.38 |
| IO | -0.02 | 0.00 | 0.04 | 0.69 | 1.04 | 0.00 | -1.36 | -1.90 |
| ITF | -0.00 | 1.00e-0 | 0.00 | 1.00e-0 | -0.01 | 1.00e-0 | 0.01 | 1.00e-0 |
| I1 | 1.00 | 1.00 | 1.01 | 1.01 | 1.00 | 1.00 | 1.05 | 1.13 |
| I2 | 1.00 | 1.00 | 1.01 | 1.00 | 0.95 | 1.00 | 1.01 | 0.85 |
| I3 | 1.00 | 1.00 | 0.97 | 1.00 | 0.97 | 1.00 | 1.02 | 1.00 |
| I4 | 1.00 | 1.00 | 0.97 | 2.57 | 0.95 | 1.00 | 0.99 | 1.20 |
| RBtor | 2.04 | 2.04 | 2.00 | 2.03 | 2.00 | 2.05 | 2.02 | 2.02 |
| VV-dist(m) | -4.16e-2 | -4.89e-2 | -1.40e-2 | -3.57e-2 | -3.07e-2 | -4.79e-2 | -1.07e-2 | -7.88e-3 |

$\hat{\chi}^2_{B_{mn}} \equiv \chi^2(B_{mn})/\chi^2_{S_3}(B_{mn})$, where $\chi^2_{S_3}(B_{mn}) = 25.8$ is value for S3 baseline fixed boundary LI383 using same weights.
$\lambda_{Kink}$ = kink growth rate (stable for S3).
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
BETA-TARGET = 10%, SIGMA-BETA = 6.71e-2
SIGMA-BMN=11*1.e+30 +.01 12*1.e+30 +.01 12*1.e+30 +.01 11*1.e+30
SIGMA-KINK = 2.236e-6

# PROFILE VARIATION

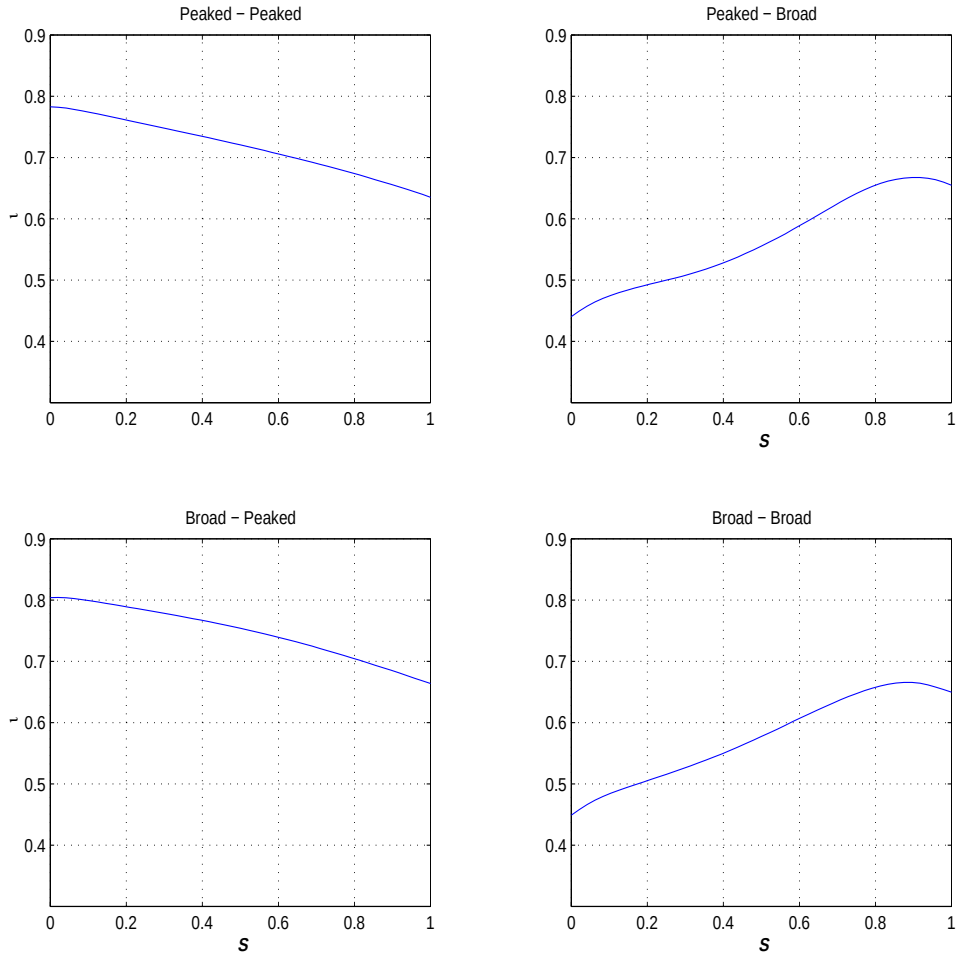
**TABLE 6: Summary of Best Cases**

mfl = modular, sfl = saddle

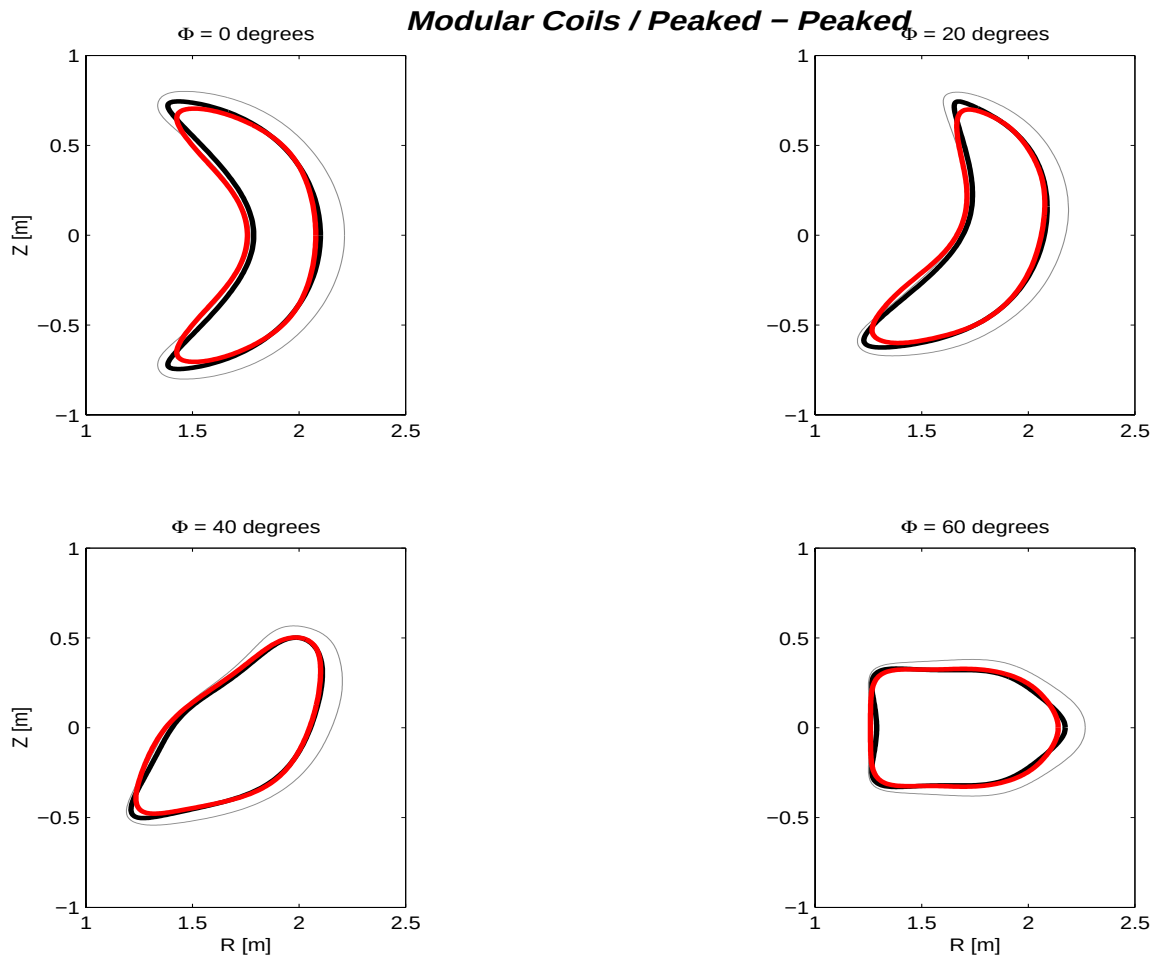
| | pp1%-2-np | | pb2%-ck | | bp-beta-rh | | bb-beta-rh | |
|---|---|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl | mfl | sfl |
| $\beta$ | 1.0% | 1.0% | 2.0% | 2.0% | 1.7% | 1.1% | 3.7% | 3.3% |
| $\hat{\chi}^2(B_{mn})$ | 1.3(5.4) | 2.0(3.8) | 1.9(4.3) | 2.0(3.0) | 1.8 | 3.8 | 1.9 | 2.3 |
| -$\lambda_{Kink}$ | 1.1e-4(1.0e-4) | 1.3e-4(9.8e-5) | 1.5e-5(7.0e-4) | 1.5e-6(5.4e-4) | 8.9e-5 | 8.2e-5 | 1.9e-6 | 0 |
| $\iota(0.)$ | 0.72 | 0.70 | 0.45 | 0.38 | 0.80 | 0.78 | 0.45 | 0.39 |
| $\iota(.5)$ | 0.69 | 0.68 | 0.55 | 0.54 | 0.75 | 0.74 | 0.58 | 0.57 |
| $\iota(1.)$ | 0.61 | 0.62 | 0.66 | 0.65 | 0.66 | 0.65 | 0.65 | 0.65 |
| ID | 0.19 | 0.26 | 0.75 | 0.11 | 0.09 | -0.00 | 0.04 | 0.06 |
| IQ | 0.13 | -0.46 | 0.35 | -0.22 | 0.16 | -0.00 | 0.62 | 0.09 |
| IH | -1.76 | -0.23 | -0.92 | -0.46 | -0.41 | -0.00 | 0.48 | -1.38 |
| IO | 0.28 | -0.37 | 0.52 | -2.01 | 1.04 | 0.00 | -1.36 | -1.90 |
| ITF | -0.09 | 1.00e-0 | -0.02 | 1.00e-0 | -0.01 | 1.00e-0 | 0.01 | 1.00e-0 |
| I1 | 0.91 | 1.00 | 0.99 | 1.09 | 1.00 | 1.00 | 1.05 | 1.13 |
| I2 | 0.89 | 0.75 | 1.00 | 0.91 | 0.95 | 1.00 | 1.01 | 0.85 |
| I3 | 0.89 | 1.08 | 0.97 | 1.01 | 0.97 | 1.00 | 1.02 | 1.00 |
| I4 | 0.86 | 0.73 | 0.95 | 1.20 | 0.95 | 1.00 | 0.99 | 1.20 |
| RBtor | 2.02 | 2.04 | 2.03 | 2.01 | 2.00 | 2.05 | 2.02 | 2.02 |
| VV-dist(m) | -2.40e-2 | -5.65e-3 | -8.0e-3 | -1.2e-3 | -3.07e-2 | -4.79e-2 | -1.07e-2 | -7.88e-3 |

$\hat{\chi}^2_{B_{mn}} \equiv \chi^2(B_{mn})/\chi^2_{S_3}(B_{mn})$, where $\chi^2_{S_3}(B_{mn}) = 25.8$ is value for S3 baseline fixed boundary LI383 using same weights.
$\lambda_{Kink}$ = kink growth rate (stable for S3).
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
BETA-TARGET = 10%, SIGMA-BETA = 6.71e-2
SIGMA-BMN=11*1.e+30 +.01 12*1.e+30 +.01 12*1.e+30 +.01 11*1.e+30
SIGMA-KINK = 2.236e-6

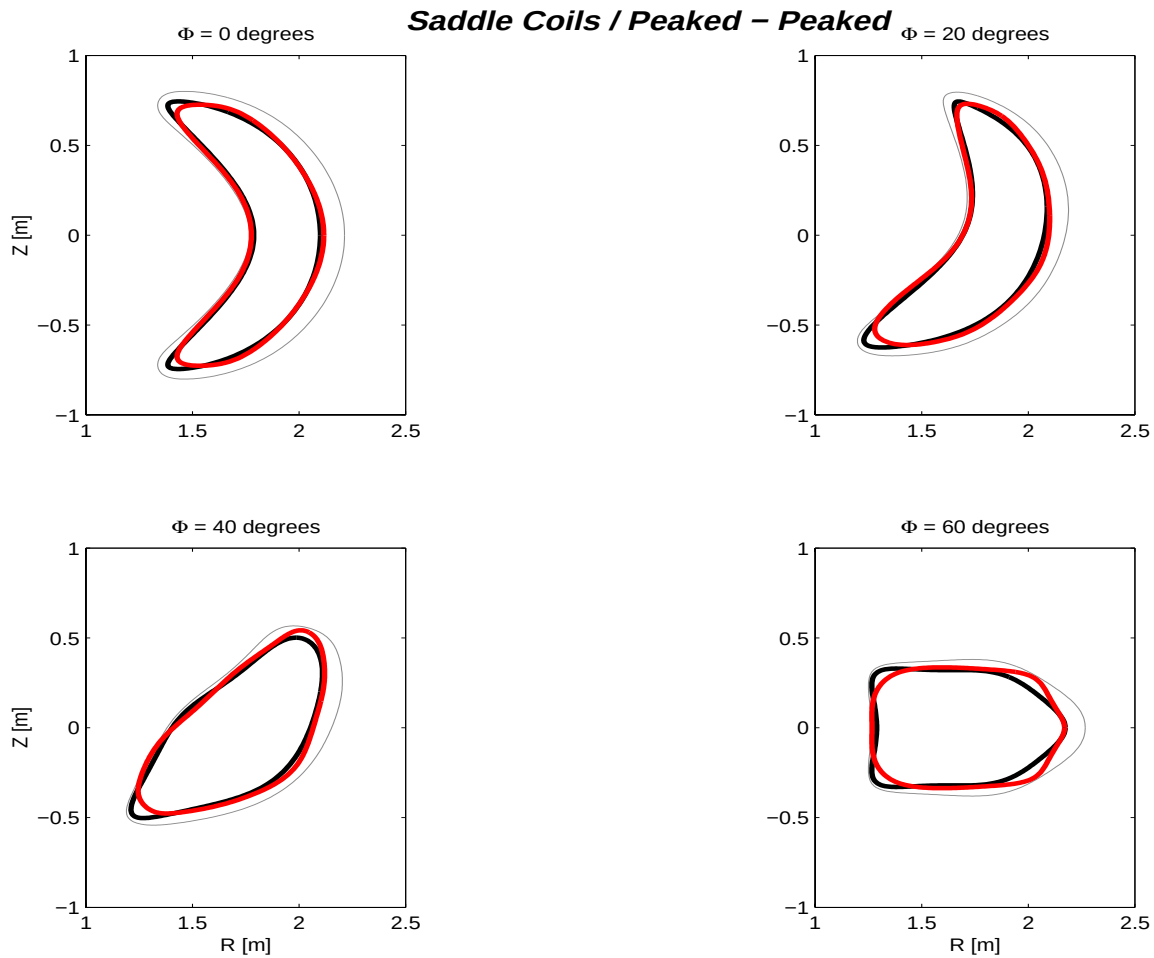
# Profiles of $\iota(s)$ for pp, pb, bp, and bb profile combinations



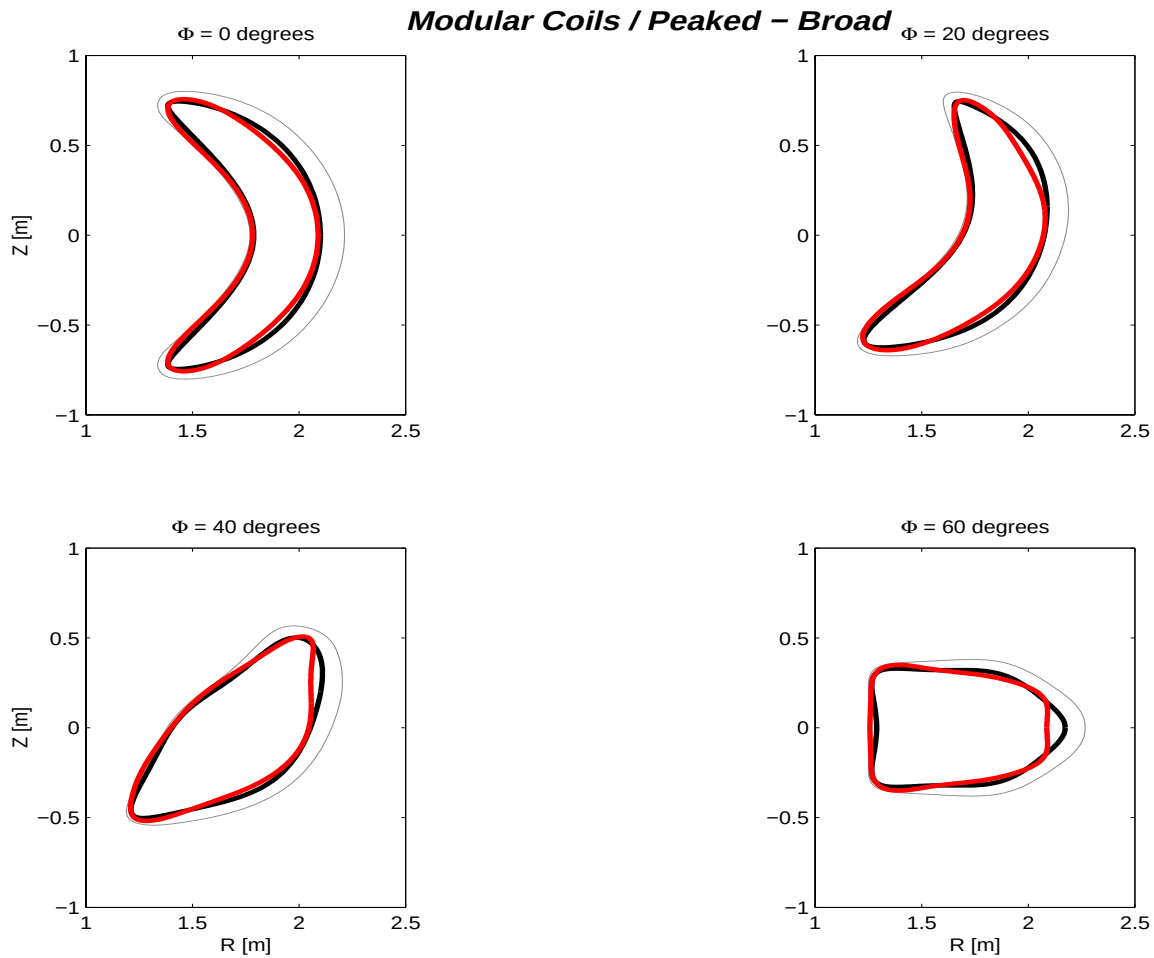
# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



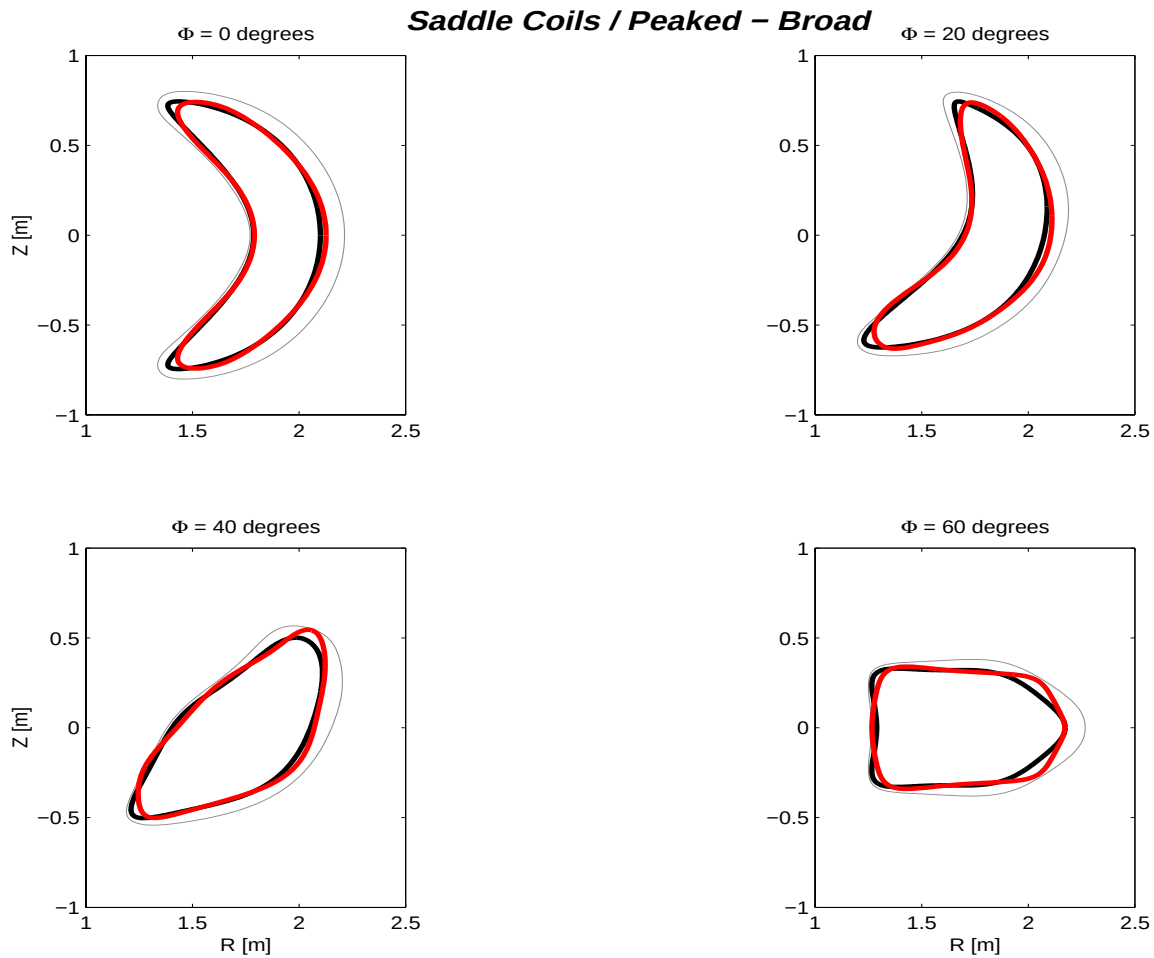
# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



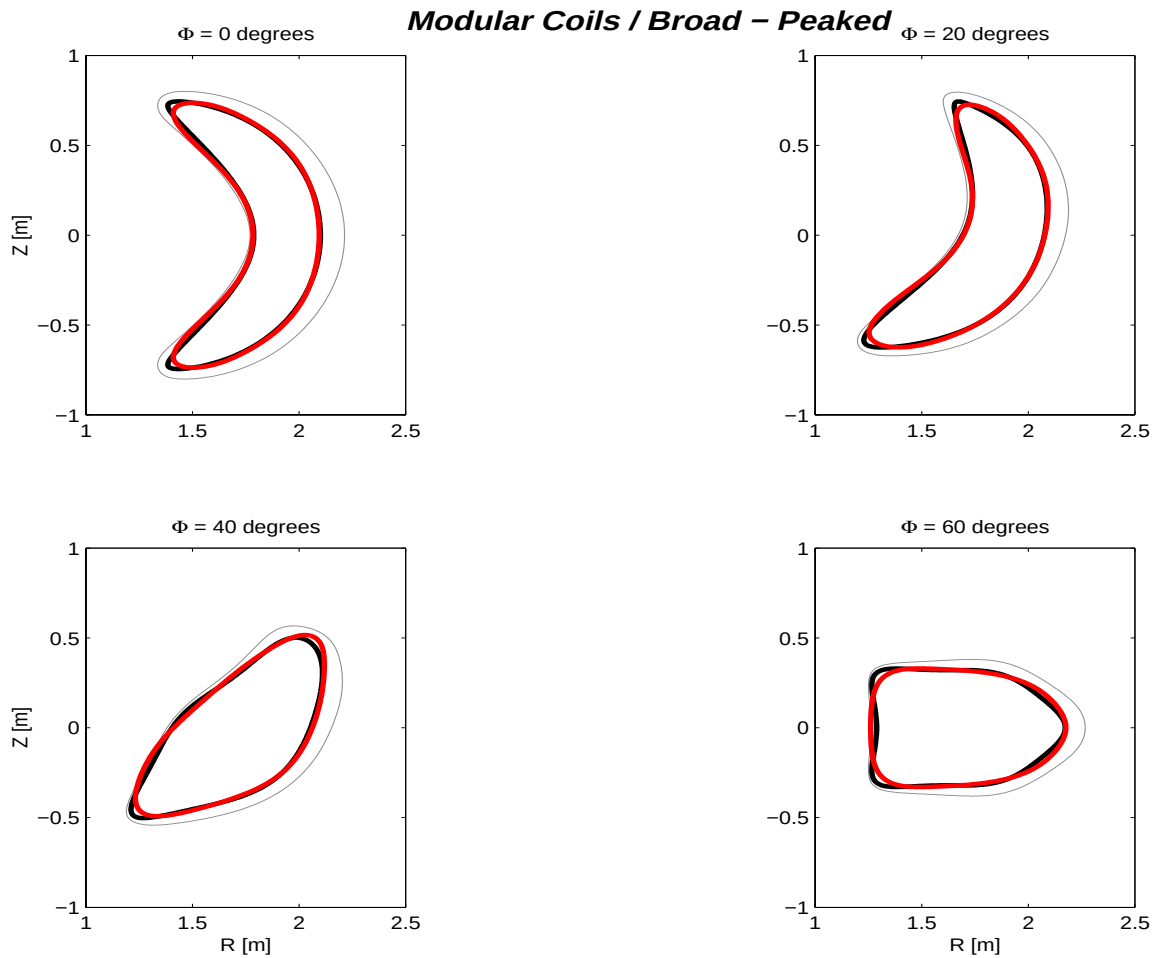
# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary,
# Thick Red - Free-Boundary Optimized



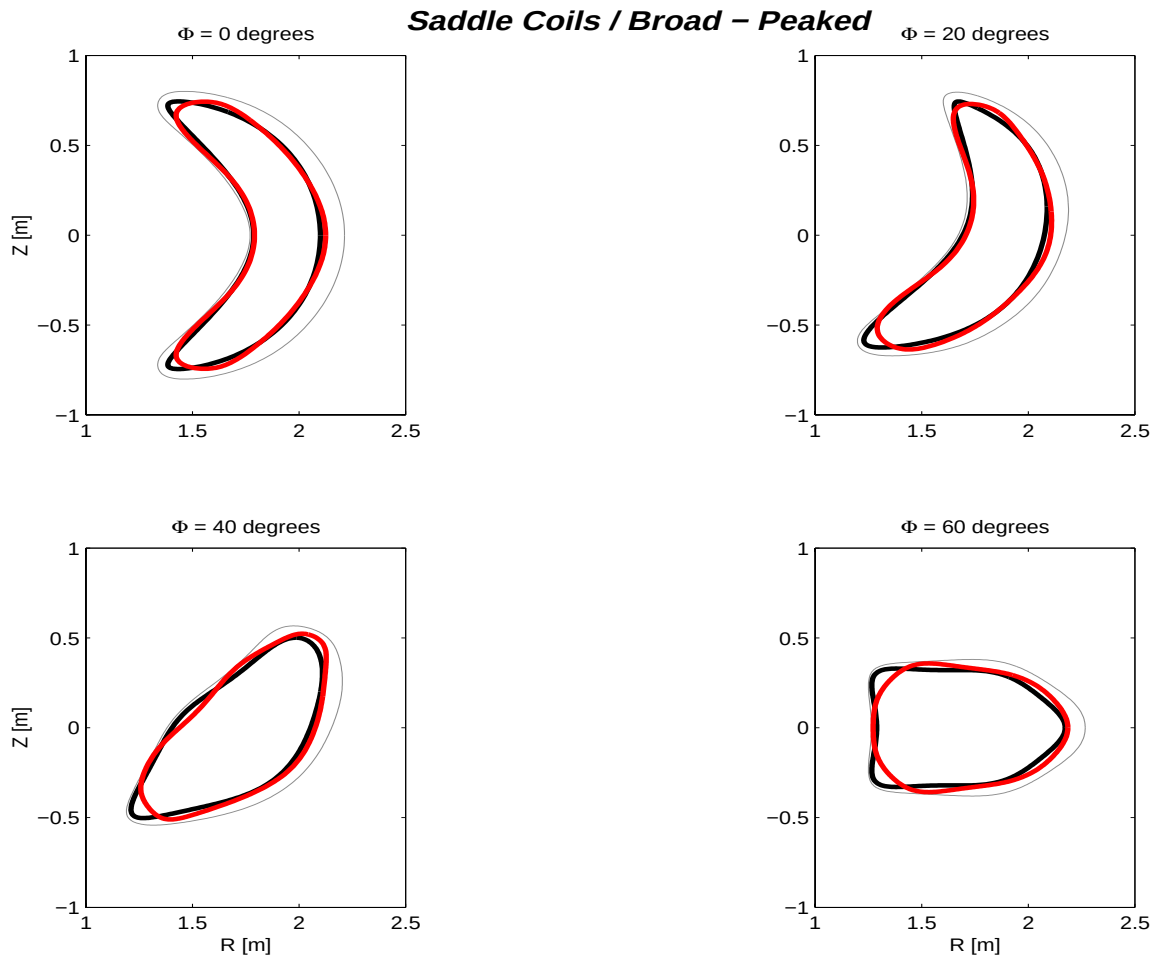
# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



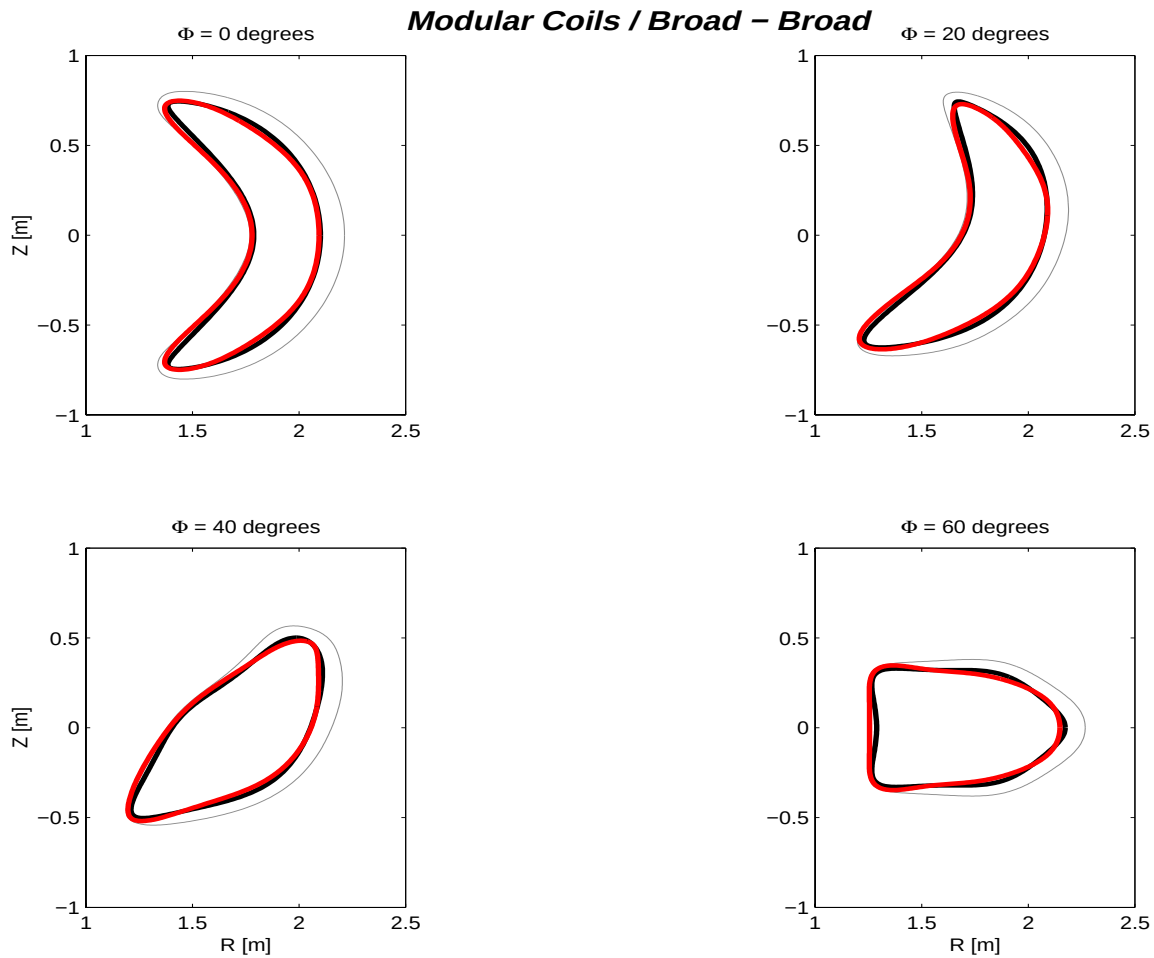
# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



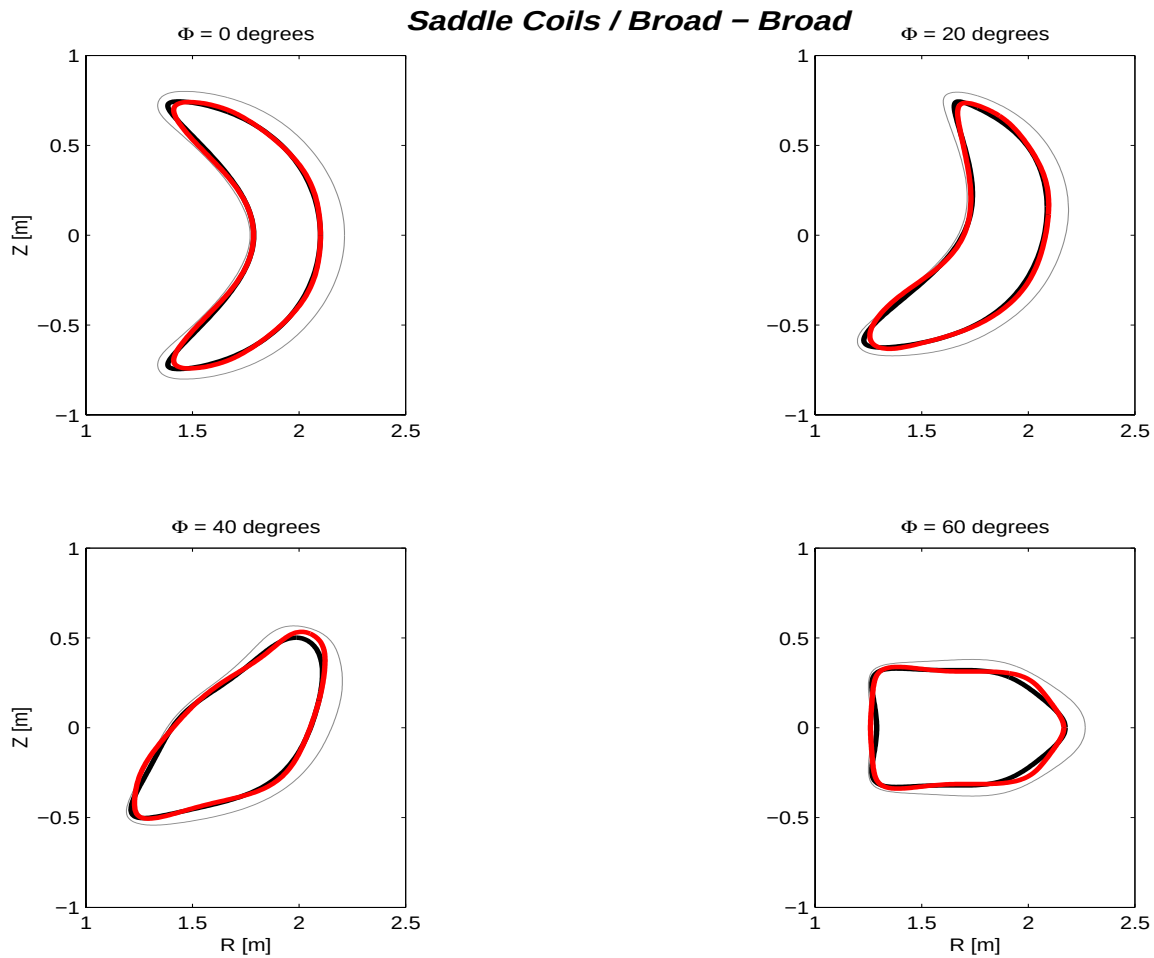
# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



# Boundary Shapes:
# Thin - First Wall, Thick Black - LI383 S3 Fixed Boundary, Thick Red - Free-Boundary Optimized



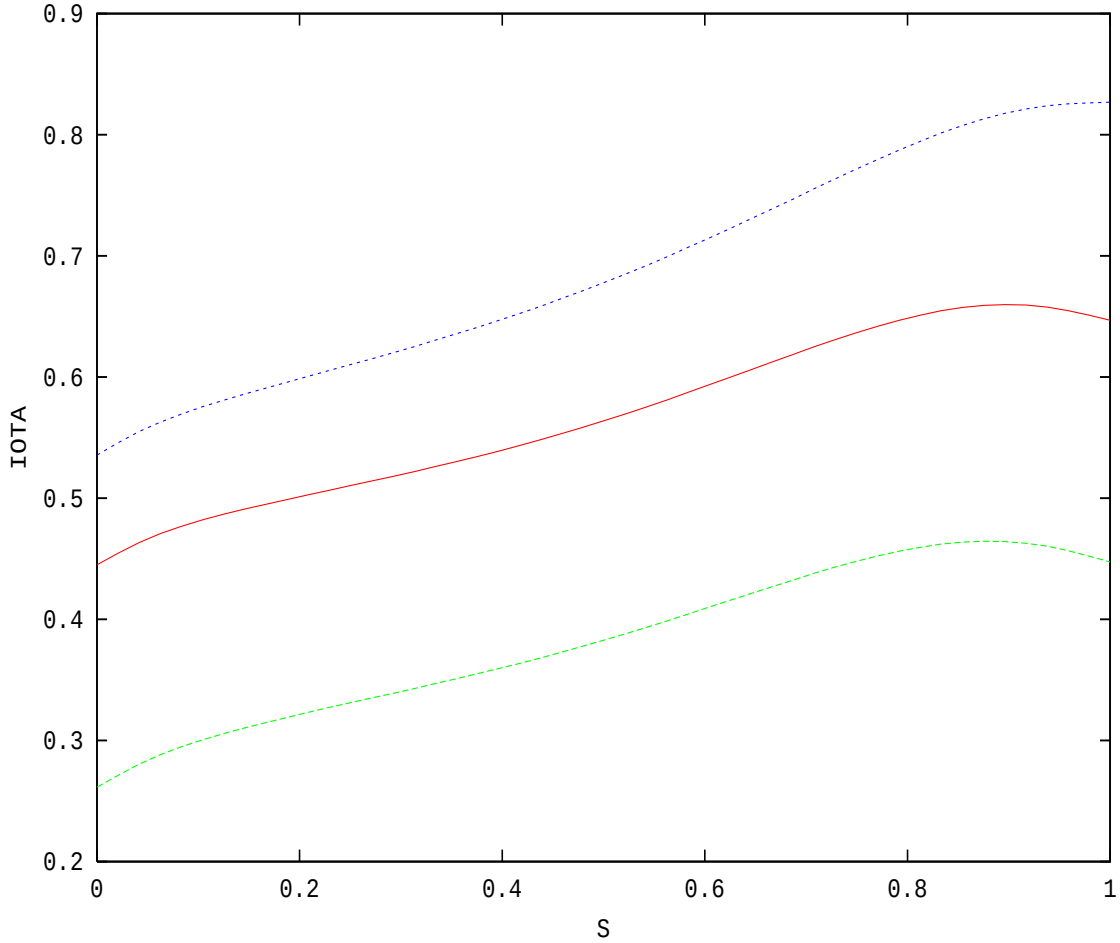
# TABLE 7: IOTA SCAN EXPERIMENTS- I

Target $\iota(1)$ only. to seek $\iota$ profiles that are
(a) straddle $\iota = 0.5$, (essentially the baseline $\iota$ profile at this $\beta$) (see ss1%-2.1-np)
(b) everywhere $< 0.5$, (ss1%-2.2-np) and
(c) everywhere $> 0.5$ (ss1%-2.3-np).
No attempt to control shear. In fact shear profile pretty much constant in this scan.
All cases use standard S3 current and pressure profile shapes, with $I_p = 150kA$, but assume $\beta = 1\%$.

| | ss1%-2.1-np | | ss1%-2.2-np | | ss1%-2.3-np | |
|---|---|---|---|---|---|---|
| | mfl | sfl | mfl | sfl | mfl | sfl |
| $\hat{\chi}^2(B_{mn})$ | 2.0(6.8) | 2.5(4.8) | 1.8(6.8) | 5.3(4.8) | 2.3(6.8) | 2.9(4.8) |
| -$\lambda_{Kink}$ | 4.5e-5(5.2e-4) | 3.2e-5(5.6e-4) | 1.6e-4(5.2e-4) | 2.5e-4(5.6e-4) | 2.6e-4(5.2e-4) | 9.3e-5(5.6e-4) |
| $\iota(0.)$ | 0.45 | 0.38 | 0.26 | 0.34 | 0.54 | 0.53 |
| $\iota(.5)$ | 0.56 | 0.54 | 0.38 | 0.40 | 0.68 | 0.70 |
| $\iota(1.)$ | 0.65 | 0.65 | 0.45 | 0.47 | 0.83 | 0.80 |
| ID | 0.30 | 0.25 | 0.37 | 0.60 | 0.36 | 0.12 |
| IQ | 0.77 | 0.26 | -0.03 | -1.18 | 0.94 | 0.11 |
| IH | 0.52 | -0.30 | 3.24 | 1.01 | -1.01 | -3.11 |
| IO | -4.43 | 0.02 | -4.61 | -6.57 | -0.01 | 3.48 |
| ITF | -0.01 | 1.00e-0 | -0.23 | 1.00e-0 | 0.09 | 1.00e-0 |
| I1 | 1.06 | 1.11 | 0.77 | 0.69 | 1.11 | 1.45 |
| I2 | 1.03 | 0.70 | 0.78 | 0.86 | 1.07 | 0.94 |
| I3 | 1.04 | 1.10 | 0.78 | 1.27 | 1.08 | 0.91 |
| I4 | 1.00 | 0.70 | 0.75 | 0.19 | 1.07 | 0.95 |
| RBtor | 2.14 | 2.05 | 2.05 | 2.04 | 2.05 | 2.05 |
| VV-dist(m) | -1.46e-2 | -1.05e-2 | -4.48e-2 | -8.78e-2 | -4.69e-2 | -4.55e-2 |

$\hat{\chi}^2_{B_{mn}} \equiv \chi^2(B_{mn})/\chi^2_{S_3}(B_{mn})$, where $\chi^2_{S_3}(B_{mn}) = 25.8$ is value for S3 baseline fixed boundary LI383 using same weights.
$\lambda_{Kink}$ = kink growth rate (stable for S3).
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
SIGMA-BMN=11*1.e+30 +.01 12*1.e+30 +.01 12*1.e+30 +.01 11*1.e+30
SIGMA-KINK = 1.e-4

# Iota Profiles from IOTA SCAN I EXPERIMENTS



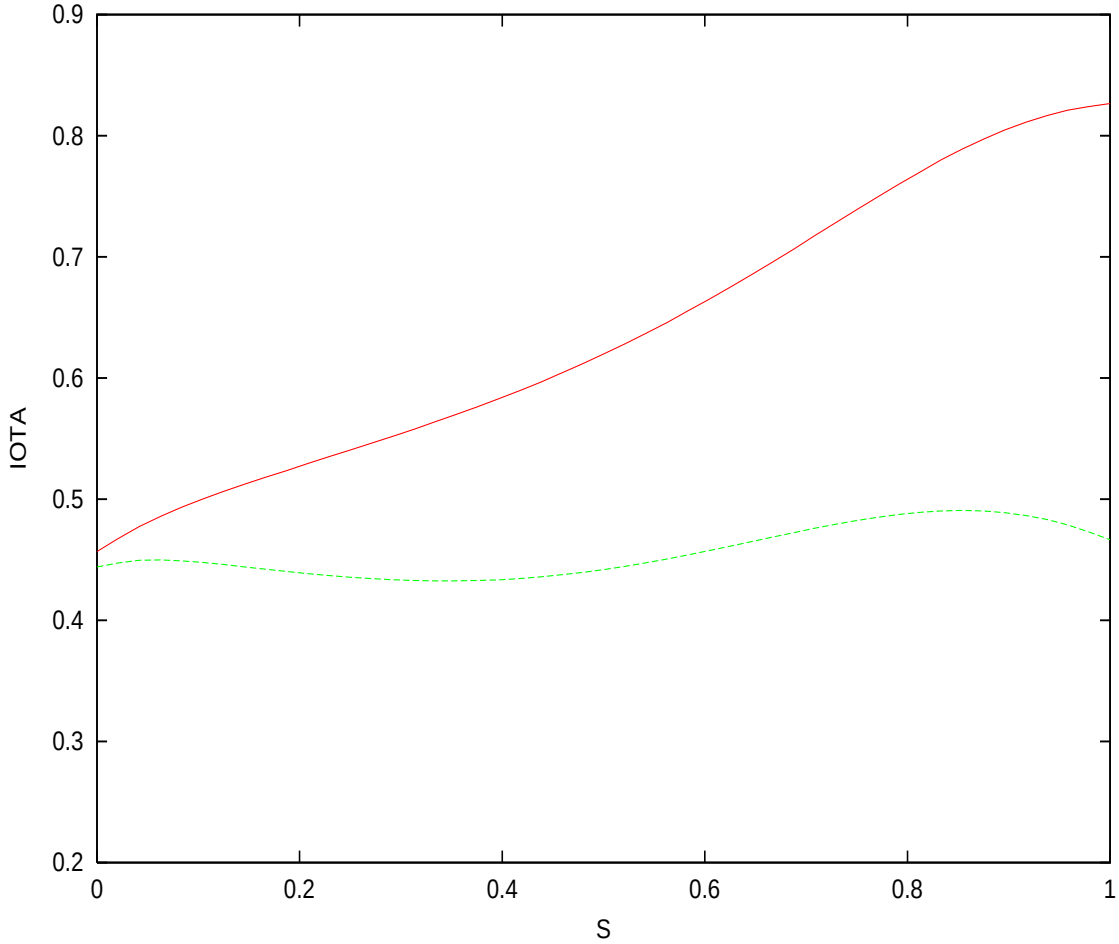
# TABLE 8: IOTA SCAN EXPERIMENTS- II

Use coil currents to control the shear: $\iota(0)$ and $\iota(1)$ are targeted.
Two cases, each uses standard S3 current and pressure profile shapes, with $I_p = 150kA$, but assume $\beta = 1\%$.
(a) Increase shear: $\iota$ targets are $\iota(0) = 0.45, \iota(1) = 0.85$ (see shear.1.2-np).
(b) Decrease shear: $\iota$ targets are $\iota(0) = 0.45, \iota(1) = 0.45$ (shear.2.2-np).
(Note: standard $\iota$ profile has $\iota(0) \approx 0.45, \iota(1) \approx 0.65$).

| | shear.1.2-np | | shear.2.2-np | |
|---|---|---|---|---|
| | mfl | sfl | mfl | sfl |
| $\hat{\chi}^2(B_{mn})$ | 3.1(6.8) | 3.3(4.8) | 6.5(6.8) | 6.7 4.8) |
| -$\lambda_{Kink}$ | 0.0(5.2e-4) | 4.3e-4(5.6e-4) | 6.9e-5(5.2e-4) | 5.7e-4(5.6e-4) |
| $\iota(0.)$ | 0.46 | 0.47 | 0.44 | 0.44 |
| $\iota(.5)$ | 0.62 | 0.65 | 0.44 | 0.44 |
| $\iota(1.)$ | 0.83 | 0.82 | 0.47 | 0.43 |
| ID | 0.53 | 0.31 | 0.00 | 0.14 |
| IQ | -0.67 | -0.24 | 2.03 | 1.45 |
| IH | 0.71 | 0.41 | 4.93 | 5.61 |
| IO | -3.45 | -0.11 | -3.43 | -7.15 |
| ITF | 0.09 | 1.00e-0 | -0.10 | 1.00e-0 |
| I1 | 1.10 | 1.04 | 0.96 | 1.03 |
| I2 | 1.08 | 1.01 | 0.88 | 0.81 |
| I3 | 1.09 | 1.29 | 0.94 | 0.81 |
| I4 | 1.09 | 0.26 | 0.79 | 1.77 |
| RBtor | 2.05 | 2.05 | 2.05 | 2.05 |
| VV-dist(m) | -5.3e-2 | -5.4e-2 | -9.4e-2 | -8.0e-2 |

$\hat{\chi}^2_{B_{mn}} \equiv \chi^2(B_{mn})/\chi^2_{S_3}(B_{mn})$, where $\chi^2_{S_3}(B_{mn}) = 25.8$ is value for S3 baseline fixed boundary LI383 using same weights.
$\lambda_{Kink}$ = kink growth rate (stable for S3).
Iota values quoted at $s = 0.0$,$s = 0.5$ and $s = 1.0$.
Stellarator coil currents are given as ratio to free-boundary S3 design values.
ID, IQ, IH, IO are multipole moments expanded about $R_0 = 1.7m$, with $\mu_0 B_0 = 1$.
$RB_t$ is constrained to 2.05 (approx); $A = 4.30$, $I_p = 150$kA
SIGMA-BMN=11*1.e+30 +.01 12*1.e+30 +.01 12*1.e+30 +.01 11*1.e+30
SIGMA-KINK = 1.e+30 ****ie NOT TURNED ON HERE

# Iota Profiles from IOTA SCAN II EXPERIMENTS



# TABLE SUMMARIES

## Table 1:

Peaked/Peaked configuration is unstable even at $\beta = 1\%$

Modulars and Saddles do a comparably good job of lowering the QA measure $\hat{\chi}^2{}_{Bmn}$

The variation (from S3 values) of the saddle coil currents is greater than those of the modulars (particularly as we lower $\beta$).

## Table 2:

With the broader current profile the kink mode is stable up to at least 2%.

Again, the modulars and saddles do comparable jobs with regard to performance with these profiles.

Again the saddle current variation is greater for saddles than for modulars.

## Table 3:

Stability of Broad/Peaked similar to Peaked/Peaked (unstable even at 1%).

Once again, the modulars and saddles do comparable jobs with regard to performance with these profiles.

Again the saddle current variation is greater for saddles than for modulars.

## Table 4:

Beware of stability results here!! It looks like modulars are doing much better than saddles at $\beta = 2\%$. But this is misleading when take into account beta optimization runs shown in Table 5. There we find Broad/Broad STABLE at $\sim 3.5\%$ for both modulars and saddles.

Again, current variation greater for saddles than modulars.

## Table 5:

This is a bit of a mixed bag! The final $\hat{\chi}^2{}_{B_{mn}}$ values for the peaked/peaked are not so good as shown in Table 1 although the $\beta$ values are the same! Also , we struggle in most cases to satisfy the first wall (VV) constraint. Only the Broad/Broad results are good, and they show comparable physics performance from the modulars and saddles AND BETTER THAN SHOWN IN TABLE 4.

This leads us to select from this and the previous four Tables the "best" cases in the sense of how well the optimizer worked. These are shown in Table 6.

## Table 6:

Same story! No clear choice (based on physics) between modulars and saddles

## Table 7:

Not too proud of the quality of the First Wall constraint here, and it shows why we should have this constraint as a RIGOROUS CONDITION WITHIN VMEC, not as an optimization constraint! In any case, it will not change the conclusions:

BOTH modulars AND saddles are able to produce substantial changes in the iota profile. The question is whether the currents are acceptable from an engineering standpoint!

## Table 8:

Both coilsets are able to produce substantial changes in the shear.

The saddle current variation is much more than the modular

The greatest current variation here, and in other cases, is in the SHORT saddle No. 4. Saddle No. 2 also shows significant variation

## Conclusions

The point of this study was to assess whether (a) the modular coilset, or (b) the saddle coilset shows the greatest flexibility.

A number of "experiments" were run to compare their ability to optimize various profile combinations, as well as to control the iota profile.

Our studies are independent of those which deal with with the issue of flux surface quality.

With this in mind, the results presented here show NO clear advantage of one coilset over the other. Although it appears that the saddle coil currents vary over the profile sets by a greater amount than the modulars, no attempt has yet been made to assess the significance of this observation.

Both PRIMARY coilsets show a surprising amount of flexibility in the narrow sense of the studies presented here. However, it is important to consider the additional gains we will get from adding SECONDARY contol coils in the sense of the L=3 coils mentioned earlier.