Transient CHI Startup
Fy05 Run Plan

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Previous work:

- Using a new CHI specific capacitor bank, the method was tested in NSTX during Fy04 operations.
- Use of the capacitor bank allowed for reliable discharge initiation and operation over a wide range of gas pressure and injector flux conditions.
- Analysis of the results pointed to four areas for improvement.

These were:

(1) The need for improved pre-ionization so that the amount of injected gas could be reduced by a factor of at least four. This would provide more energy per particle (from the fixed capacitor bank energy). The required capacitor bank energy per particle should preferably be about 100eV so that after losses the resulting plasma could burn through radiation barriers and reach modest temperatures of about 30eV or higher.

(2) Increasing the capacitor bank voltage closer to the 2kV levels would allow breakdown at lower gas pressures and increase the available energy by a factor of four over what was available for Fy04 runs, while maintaining a short pulse time.

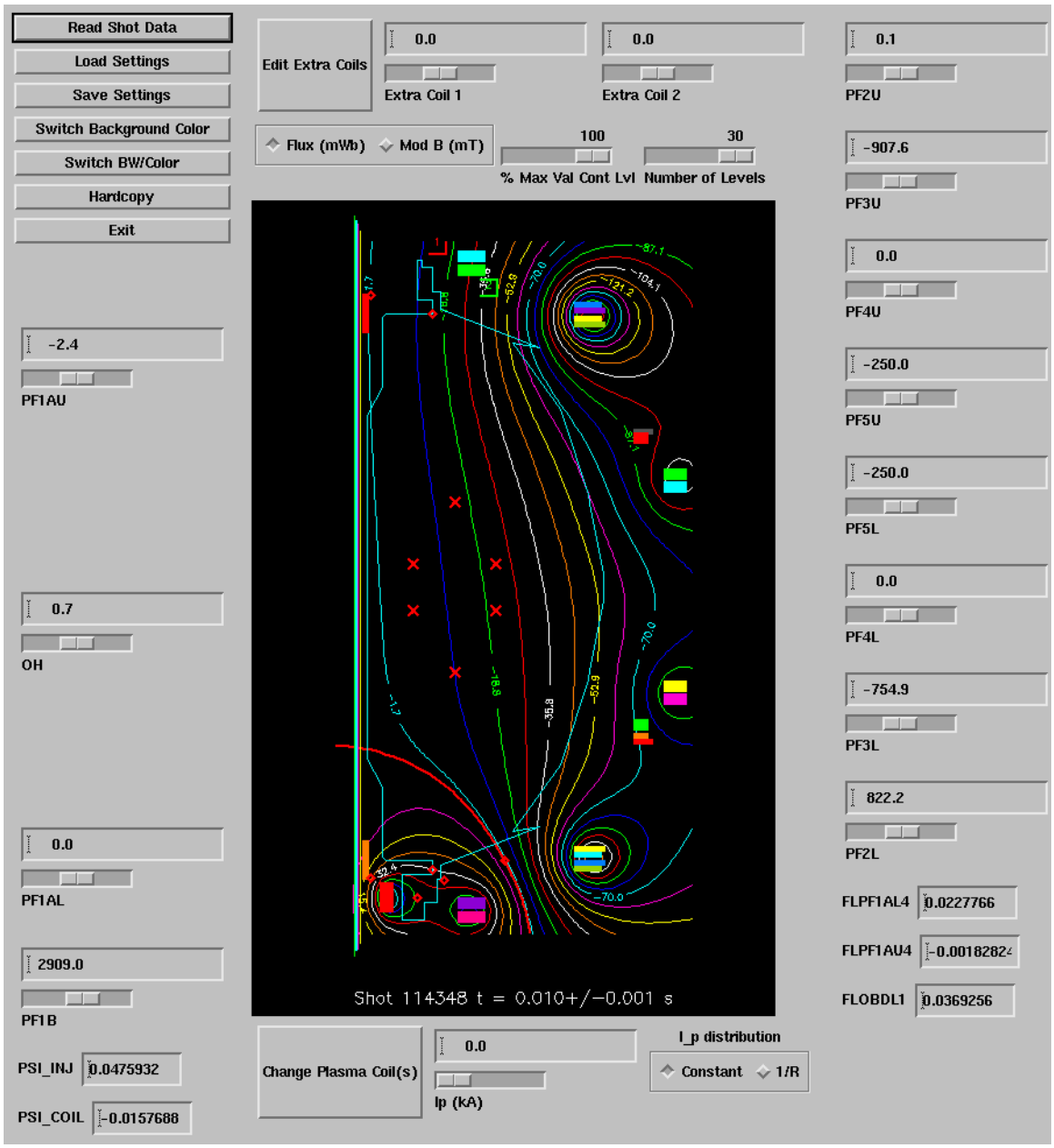
(3) Reducing the injector flux footprints, which has been made easier as a result of a redesign of the PF1A coil, to allow easier detachment of the CHI produced plasma and

(4) Improved equilibrium control.

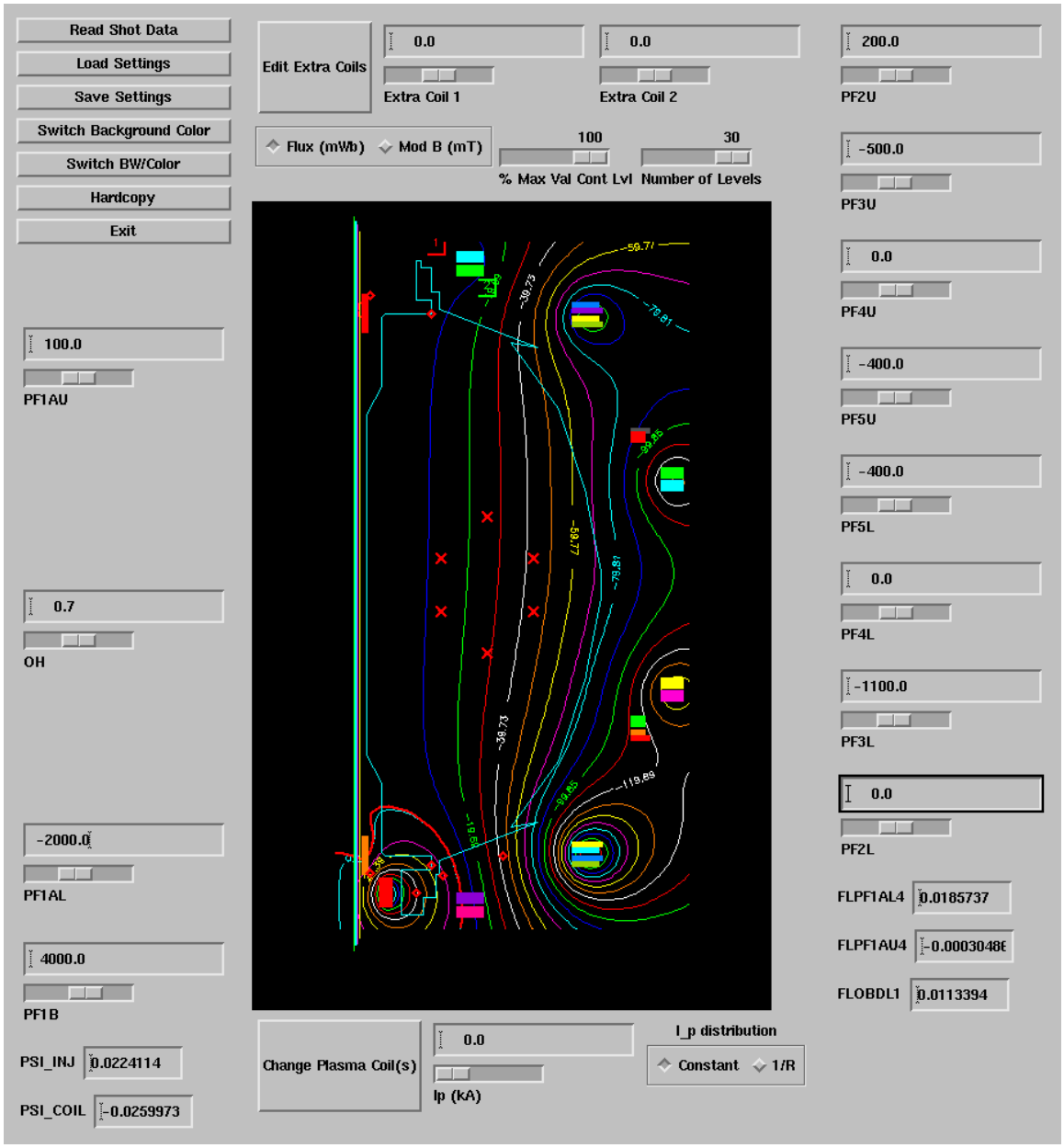
Reduction of flux footprint and equilibrium control

- Brian Nelson's XFLUXNSTX code used for vacuum field calculations
- Jon Menard's iSolver code used for equilibrium coil current calculations

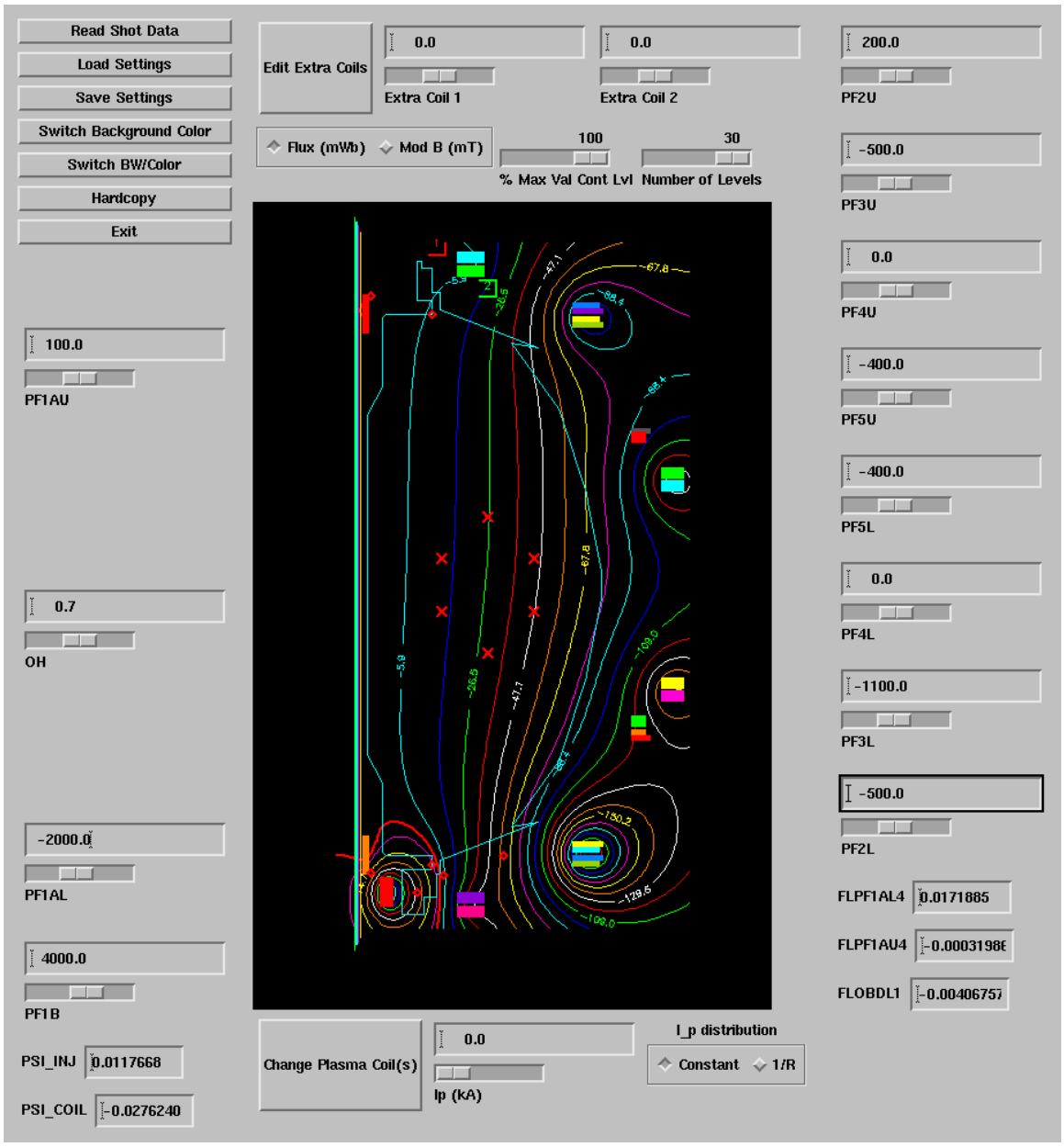
Fy 04 reference shot (114348 at 10ms) used wide footprints – No plasma detachment



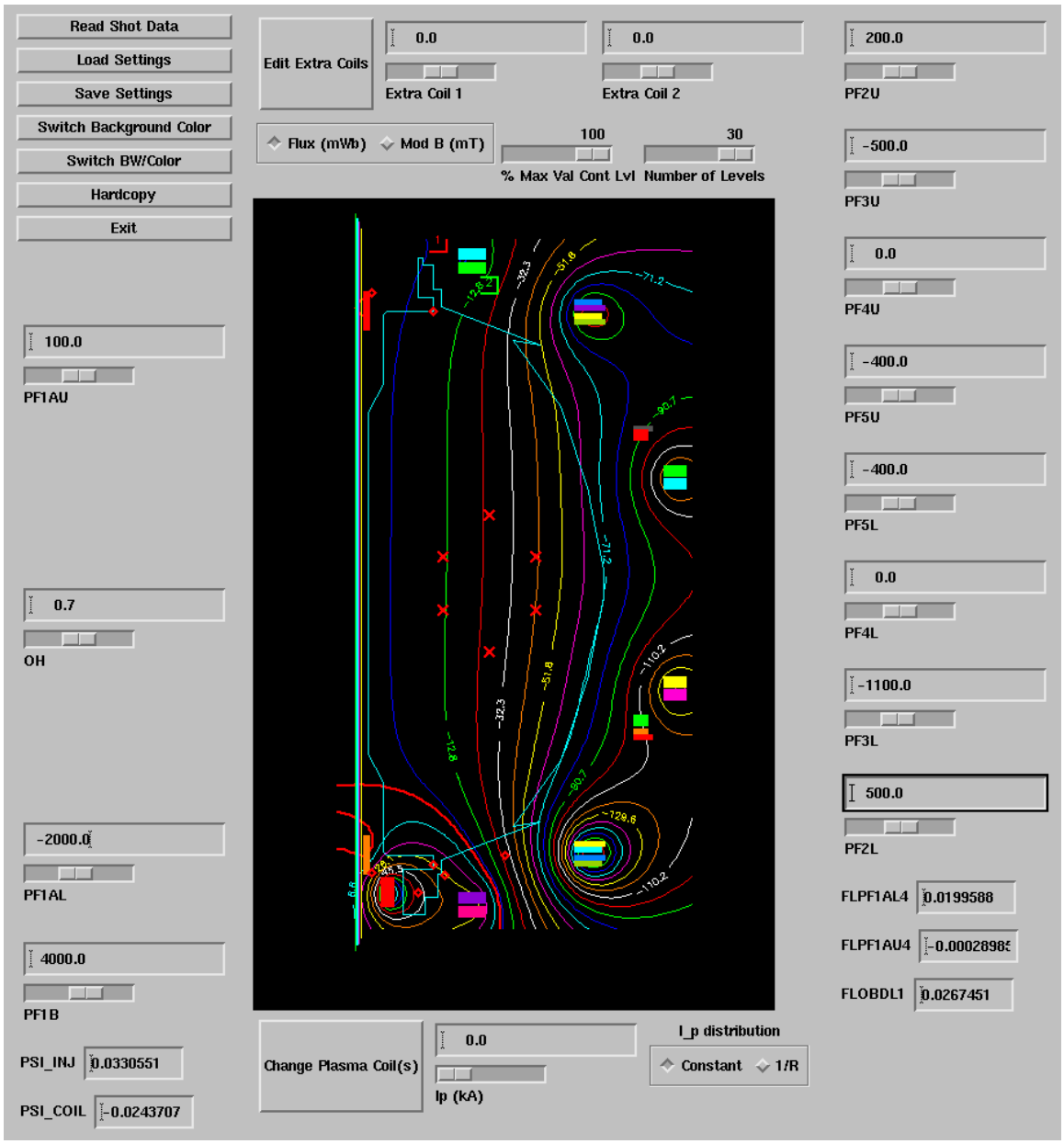
Run 10: **PF2L = 0**, PF1AL = -2, PF1B = +4 : Narrow footprint condition



Run 11: **PF2L = -0.5kA**, PF1AL = -2, PF1B = +4 : Small variation in PF2L possible



Run 12: **PF2L = +0.5kA**, PF1AL = -2, PF1B = +4 : : Small variation in PF2L possible



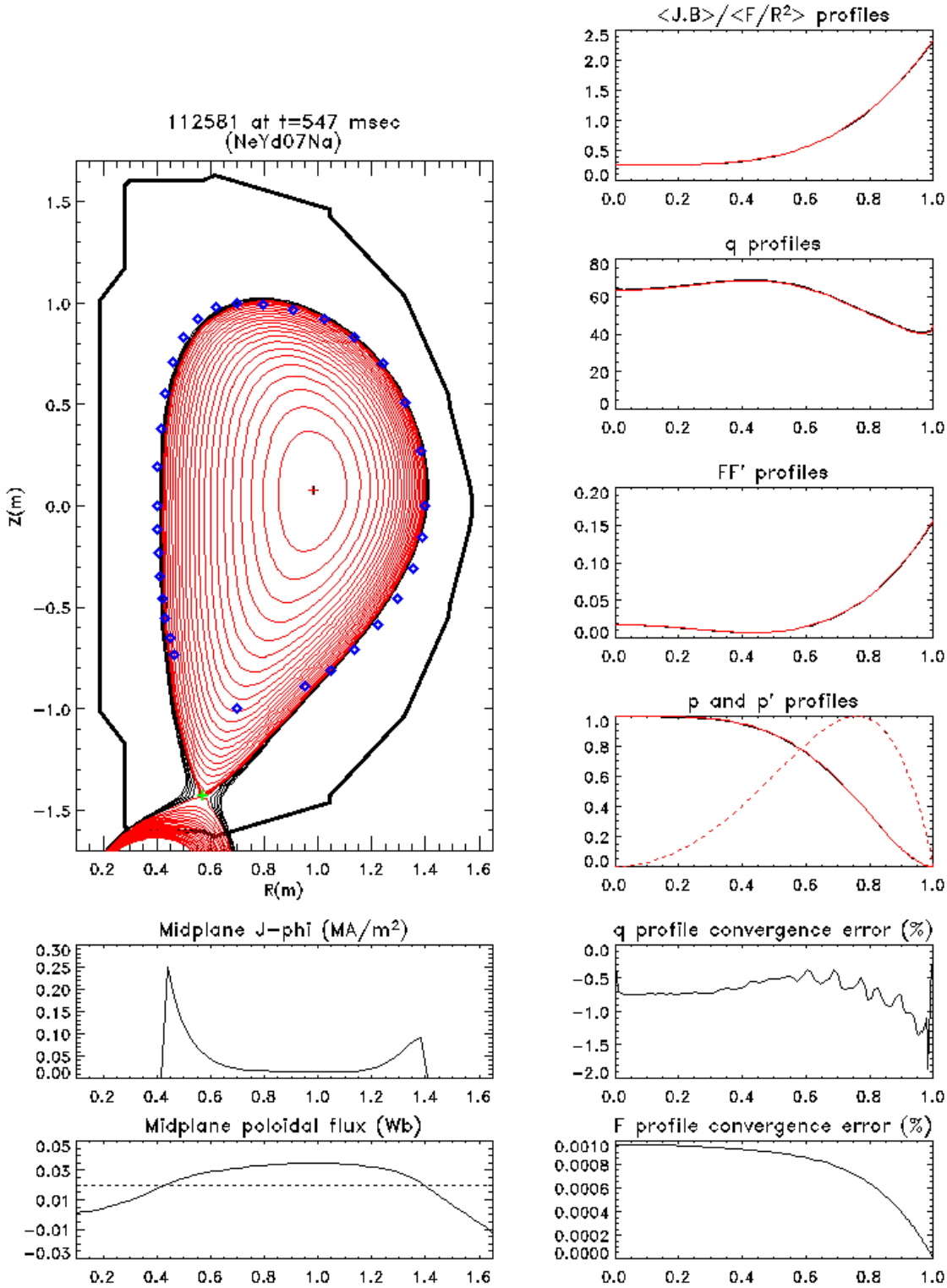
Equilibrium calculations:

Start with:

PF1B = +4kA
PF1AL = -2kA
PF2L = 0
Ip = 100kA, with plasma positioned at (R,Z) = (0.9m, 0m)
Minor radius = 0.5m, k = 2, ∂ = 0.4

Very hollow current profile

Run 5: PF1AL = -2, PF1B = +4, PF2L=0, PF5 code calculated, Ip=100kA



```
RMS boundary error at this iteration (mm) =       187.45374
Cycle count =       80
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.91328630
Vacuum toroidal B at R0 (T) =      -0.42620806
Aspect ratio                =        1.8789112
Boundary elongation         =        2.4881657
Elongation at axis          =        2.2834862
Upper triangularity         =       0.27001494
Lower triangularity         =       0.66628123
q(0)                        =        63.615794
q(95)                       =        40.404489
q(99)                       =        42.069706
q(min)                      =        40.298698
rho q(min)                  =       0.96762596
Internal inductance         =       0.14176966
beta-t (%)                  =      0.047871459
beta-N                      =      0.099599193
Stored energy          (MJ) =    0.00045882341
Ip                     (MA) =      0.099573365
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =        1.0040242
Ip         specified/actual =        1.0042846
<J.B>      specified/actual =        1.0042847
-----------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.98200  0.07812
-----------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -0.6989
  PF1AU      0.130054       -8.6461
   PF2U      0.250236      -30.8245
   PF3U     -0.537535       -1.4814
    PF5     -0.440768       -0.7663
   PF3L     -1.076068       -0.1759
   PF2L      0.000000        1.1295
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        20.165364
-----------------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.98222  0.07820
   Iteration #, convergence error =   1,  1.529497e-01
   Iteration #, convergence error =   2,  1.520756e-03
   Iteration #, convergence error =   3,  1.698788e-04
   Iteration #, convergence error =   4,  1.726141e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.9279430 seconds.
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RMS boundary change during iteration (mm) =        1.0584487
RMS boundary error at this iteration (mm) =       185.23825
Cycle count =       81
IDL>
```
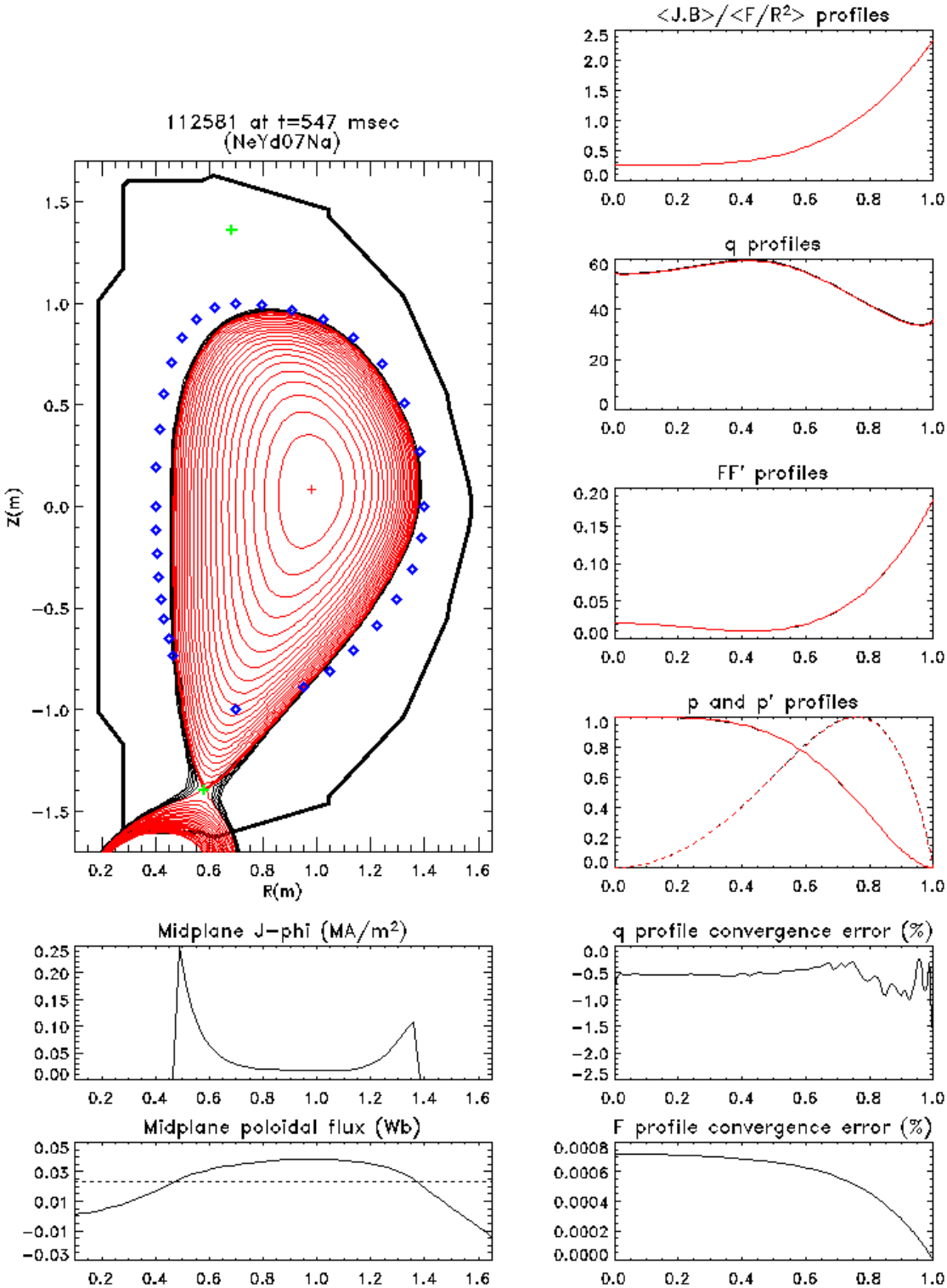

Run 6: Increase PF1B to +5kA



```
RMS boundary error at this iteration (mm) =       196.32584
Cycle count =       91
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.92333580
Vacuum toroidal B at R0 (T) =      -0.42156925
Aspect ratio                =        2.0431478
Boundary elongation         =        2.5646101
Elongation at axis          =        2.2682317
Upper triangularity         =       0.21734606
Lower triangularity         =       0.75773584
q(0)                        =        54.076050
q(95)                       =        33.683997
q(99)                       =        34.551809
q(min)                      =        33.487443
rho q(min)                  =       0.96757429
Internal inductance         =       0.15150653
beta-t (%)                  =      0.052431067
beta-N                      =      0.099983708
Stored energy          (MJ) =    0.00044146691
Ip                     (MA) =      0.099905241
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =        1.0001630
Ip         specified/actual =        1.0009485
<J.B>      specified/actual =        1.0009486
-----------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.97853  0.08301
-----------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000        0.7075
  PF1AU      0.247761       -1.3749
   PF2U      0.822921       -1.8783
   PF3U     -0.658078       -0.8266
    PF5     -0.464443       -0.0562
   PF3L     -1.192391        0.1956
   PF2L      0.000000        1.1822
  PF1AL     -2.000000        0.0000
   PF1B      5.000000        0.0000
RMS change in coil currents (A) =        5.5388650
-----------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.97835  0.08279
   Iteration #, convergence error =   1,  1.512781e-01
   Iteration #, convergence error =   2,  4.757620e-04
   Iteration #, convergence error =   3,  4.513077e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.7853670 seconds.
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===> DRSEP (cm) =       -10.979119
RMS boundary change during iteration (mm) =       0.32251286
RMS boundary error at this iteration (mm) =       196.56032
Cycle count =       92
```
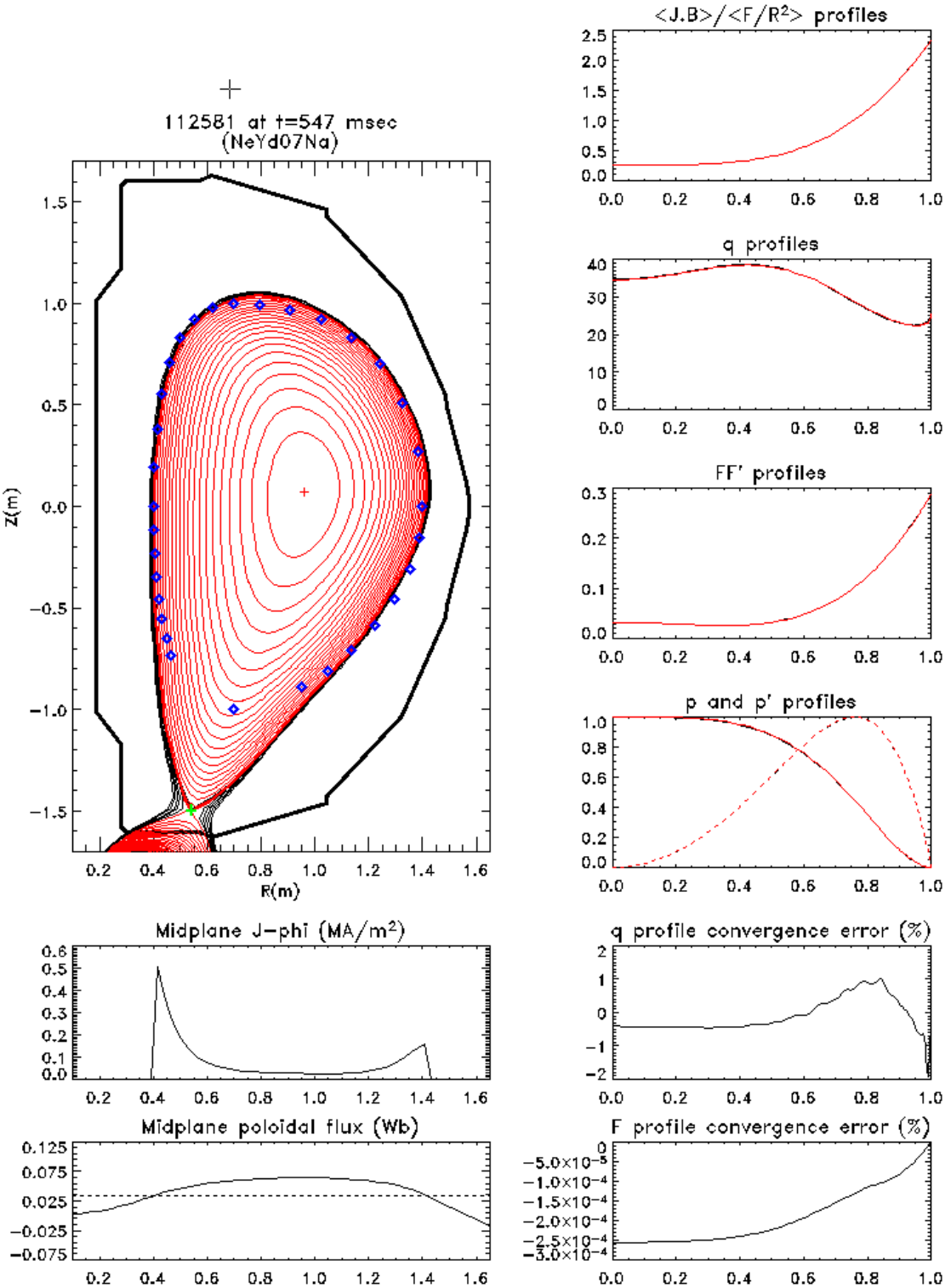

Run 7: Increase Ip to 200kA



Run 7

```
RMS boundary error at this iteration (mm) =       209.49197
Cycle count =      102
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.91117620
Vacuum toroidal B at R0 (T) =      -0.42719507
Aspect ratio                =        1.8027735
Boundary elongation         =        2.4855548
Elongation at axis          =        2.2431849
Upper triangularity         =       0.24515133
Lower triangularity         =       0.70050381
q(0)                        =        34.595704
q(95)                       =        22.662630
q(99)                       =        23.684198
q(min)                      =        22.326258
rho q(min)                  =       0.95372952
Internal inductance         =       0.14976656
beta-t (%)                  =      0.092590970
beta-N                      =      0.099866078
Stored energy          (MJ) =    0.00095075963
Ip                     (MA) =       0.20018801
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =        1.0013410
Ip         specified/actual =       0.99906081
<J.B>      specified/actual =       0.99906043
-----------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.96016  0.06795
-----------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -0.0083
  PF1AU      0.244072        1.2152
   PF2U      0.426490        4.7607
   PF3U     -0.941260       -0.1691
    PF5     -0.754891       -0.7559
   PF3L     -1.797038       -0.4490
   PF2L      0.000000       -0.4586
  PF1AL     -2.000000        0.0000
   PF1B      5.000000        0.0000
RMS change in coil currents (A) =        7.9066637
-----------------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.96010  0.06823
   Iteration #, convergence error =   1,  1.558253e-01
   Iteration #, convergence error =   2,  1.202377e-03
   Iteration #, convergence error =   3,  2.327585e-04
   Iteration #, convergence error =   4,  4.642986e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 2.6757331 seconds.
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RMS boundary change during iteration (mm) =       0.51104998
RMS boundary error at this iteration (mm) =       210.95654
Cycle count =      103
IDL>
```
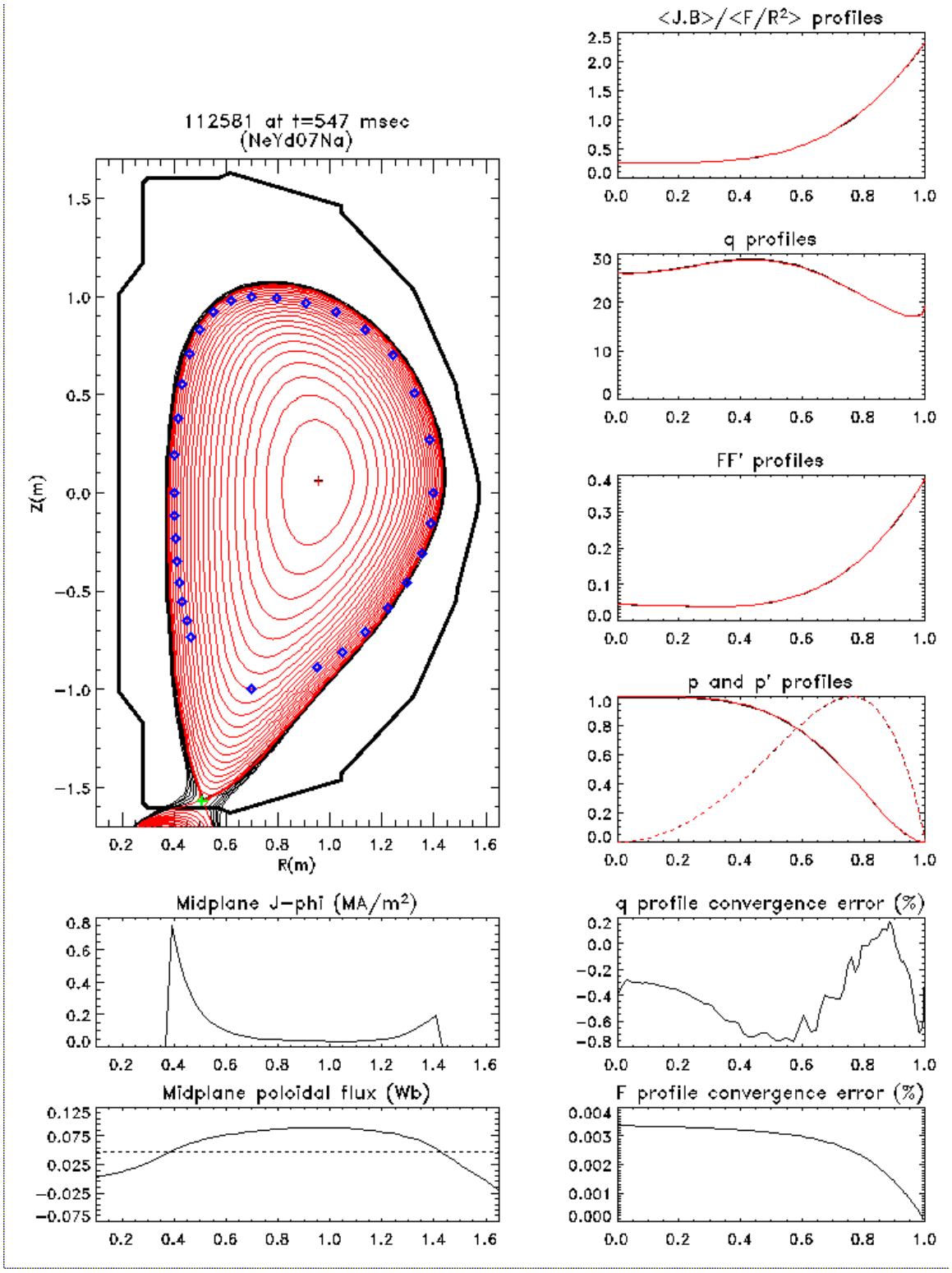

Run 8: Increase Ip to 300kA



Run 8

```
RMS boundary change during iteration (mm) =       1.7974832
RMS boundary error at this iteration (mm) =       232.85110
Cycle count =      113
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.90832703
Vacuum toroidal B at R0 (T) =      -0.42853506
Aspect ratio                =        1.7312587
Boundary elongation         =        2.4752600
Elongation at axis          =        2.2436139
Upper triangularity         =       0.25710899
Lower triangularity         =       0.69766775
q(0)                        =        26.054481
q(95)                       =        17.179782
q(99)                       =        18.013555
q(min)                      =        17.091565
rho q(min)                  =       0.95608577
Internal inductance         =       0.14096743
beta-t (%)                  =       0.13264634
beta-N                      =      0.099553758
Stored energy          (MJ) =     0.0014600416
Ip                     (MA) =       0.29957409
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =        1.0044824
Ip         specified/actual =        1.0014217
<J.B>      specified/actual =        1.0014210
-----------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.95460  0.06107
-----------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -1.7984
  PF1AU      0.282637       -1.3585
   PF2U      0.451006       -2.1044
   PF3U     -1.290352       -0.8740
    PF5     -1.029997       -0.5937
   PF3L     -2.501523       -1.1358
   PF2L      0.000000       -1.6363
  PF1AL     -2.000000        0.0000
   PF1B      5.000000        0.0000
RMS change in coil currents (A) =        10.810964
-----------------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.95460  0.06118
   Iteration #, convergence error =   1,  1.602544e-01
   Iteration #, convergence error =   2,  5.471442e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.4936631 seconds.
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RMS boundary change during iteration (mm) =       0.86909145
RMS boundary error at this iteration (mm) =       233.81972
Cycle count =      114
```
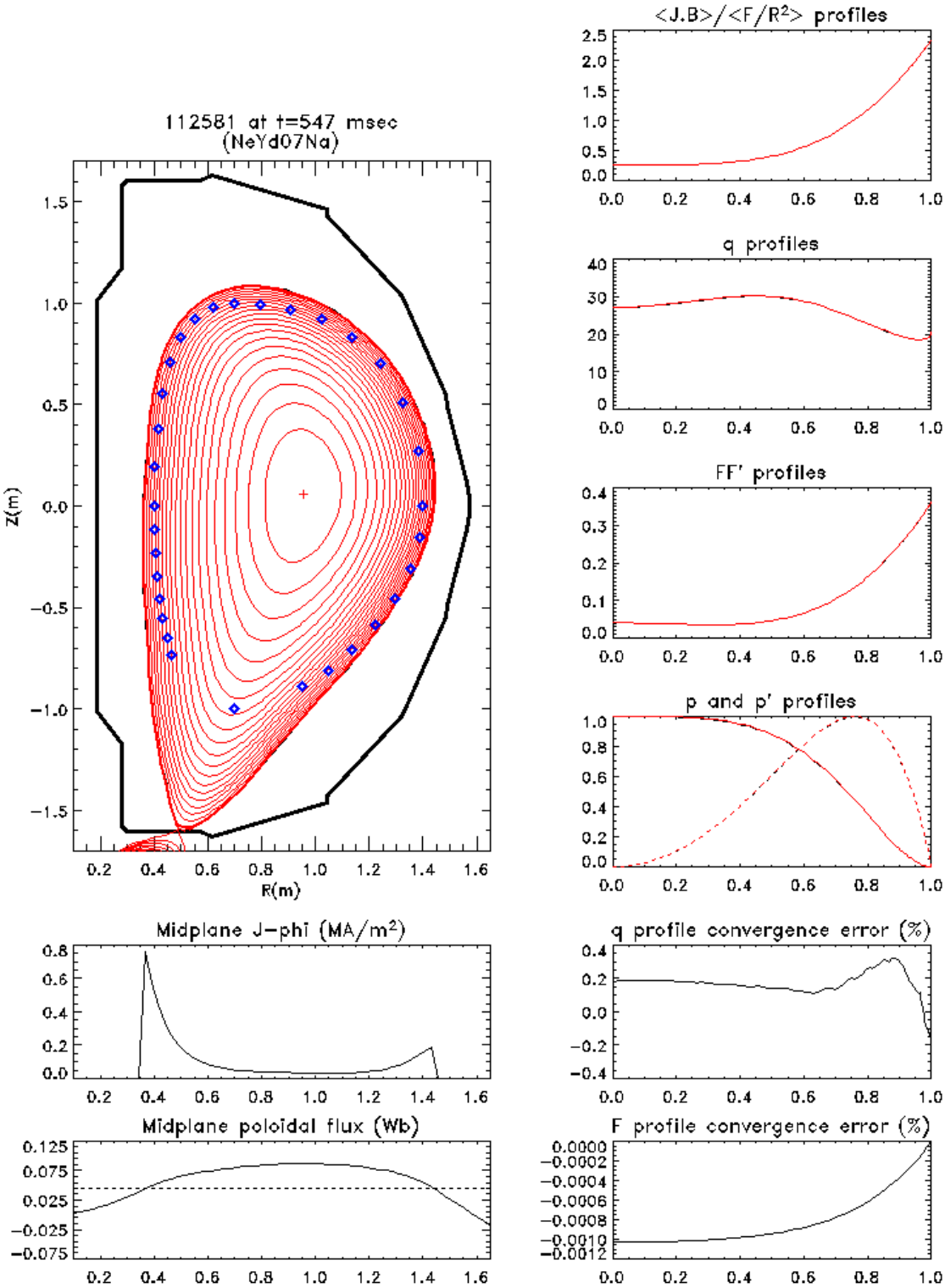

Run 9: Reduce PF1B to 4kA, Keep Ip = 300kA



Run 9:

```
Cycle count =      124
=====> F^2 iteration change =        0.0000000
---------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.90405358
Vacuum toroidal B at R0 (T) =      -0.43056074
Aspect ratio                =        1.6692405
Boundary elongation         =        2.4565599
Elongation at axis          =        2.2436998
Upper triangularity         =       0.28399209
Lower triangularity         =       0.66512674
q(0)                        =        27.282222
q(95)                       =        18.636336
q(99)                       =        19.428502
q(min)                      =        18.545255
rho q(min)                  =       0.95744452
Internal inductance         =       0.14628895
beta-t (%)                  =       0.12856502
beta-N                      =      0.099960429
Stored energy          (MJ) =     0.0015055073
Ip                     (MA) =       0.29991929
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =        1.0003959
Ip         specified/actual =        1.0002691
<J.B>      specified/actual =        1.0002691
---------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.95677  0.05799
---------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000        1.0819
  PF1AU      0.125241        4.5503
   PF2U     -0.290673      -11.4971
   PF3U     -1.180518        0.0869
    PF5     -1.012627        0.0685
   PF3L     -2.439879       -0.3414
   PF2L      0.000000        0.4230
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        10.564421
---------------------------------------------------------------------------
===> Using limiter boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.95677  0.05806
   Iteration #, convergence error =   1,  1.613530e-01
   Iteration #, convergence error =   2,  1.449259e-03
   Iteration #, convergence error =   3,  2.732270e-04
   Iteration #, convergence error =   4,  5.144530e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 2.4742801 seconds.
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% Program caused arithmetic error: Floating overflow
RMS boundary change during iteration (mm) =       0.57166186
RMS boundary error at this iteration (mm) =        247.74061
Cycle count =      125
IDL>
```
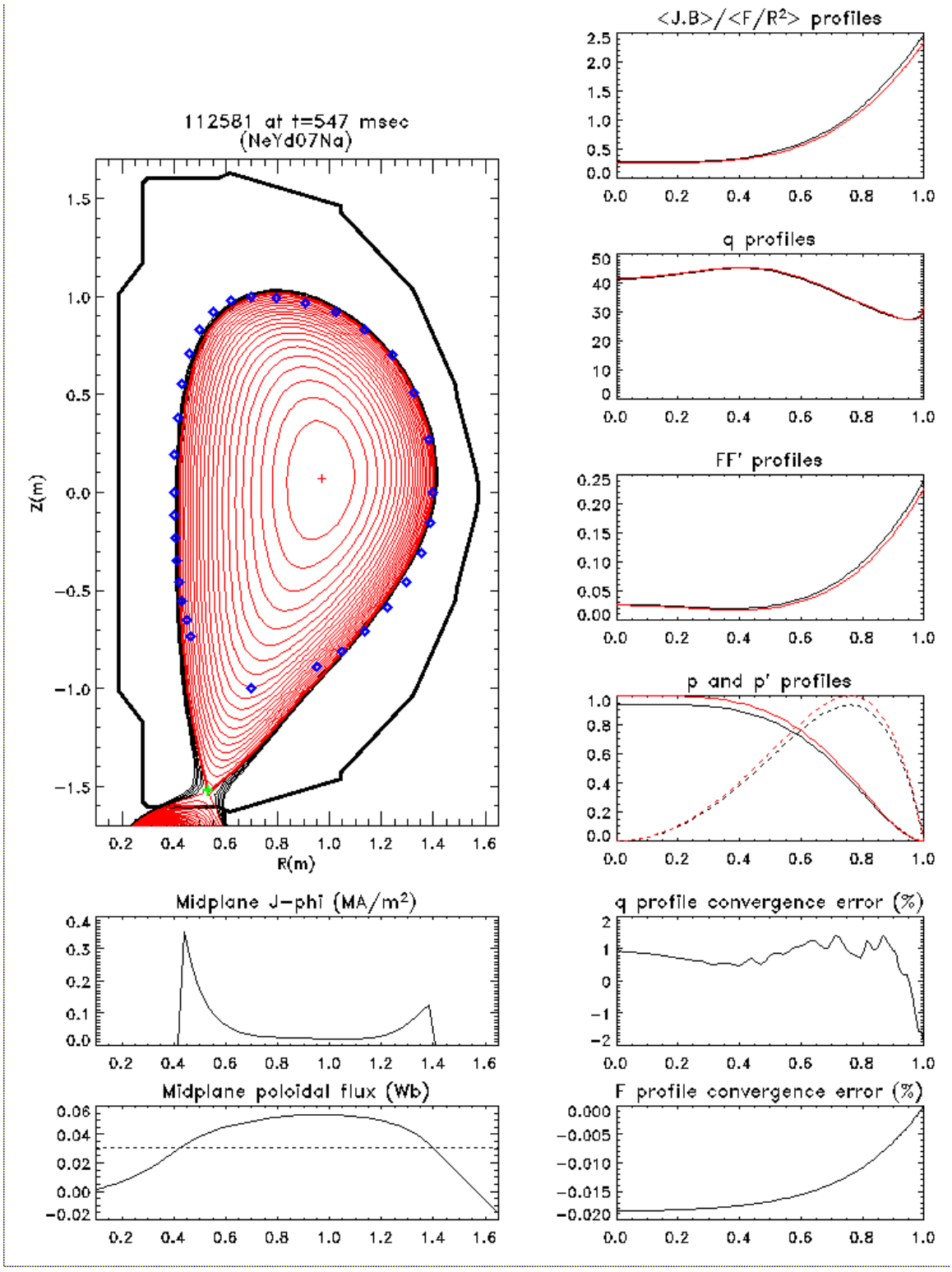

Run 10: Reduce Ip to 150kA



Run 10:

```
RMS boundary change during iteration (mm) =       2.1017685
RMS boundary error at this iteration (mm) =       220.28587
Cycle count =      135
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.91383989
Vacuum toroidal B at R0 (T) =      -0.42594987
Aspect ratio                =        1.8675207
Boundary elongation         =        2.5653100
Elongation at axis          =        2.3096436
Upper triangularity         =       0.25725670
Lower triangularity         =       0.73301097
q(0)                        =        41.639787
q(95)                       =        27.562991
q(99)                       =        29.563693
q(min)                      =        27.386255
rho q(min)                  =       0.95864488
Internal inductance         =       0.16741663
beta-t (%)                  =      0.076517473
beta-N                      =       0.10646597
Stored energy          (MJ) =    0.00074913521
Ip                     (MA) =       0.14980039
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =       0.93926724
Ip         specified/actual =        1.0013325
<J.B>      specified/actual =        1.0013415
-----------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.96822  0.06900
-----------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000        0.2682
  PF1AU      0.208666       -2.2932
   PF2U      0.395755       -6.0009
   PF3U     -0.797469        0.5235
    PF5     -0.631625        1.8997
   PF3L     -1.598596        0.8244
   PF2L      0.000000        0.8699
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        9.8186846
-----------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.96800  0.06908
   Iteration #, convergence error =   1,  1.545859e-01
   Iteration #, convergence error =   2,  1.511557e-04
   Iteration #, convergence error =   3,  5.999275e-06
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 2.1996930 seconds.
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RMS boundary change during iteration (mm) =       2.2765978
RMS boundary error at this iteration (mm) =       220.40039
Cycle count =      136
IDL> []
```
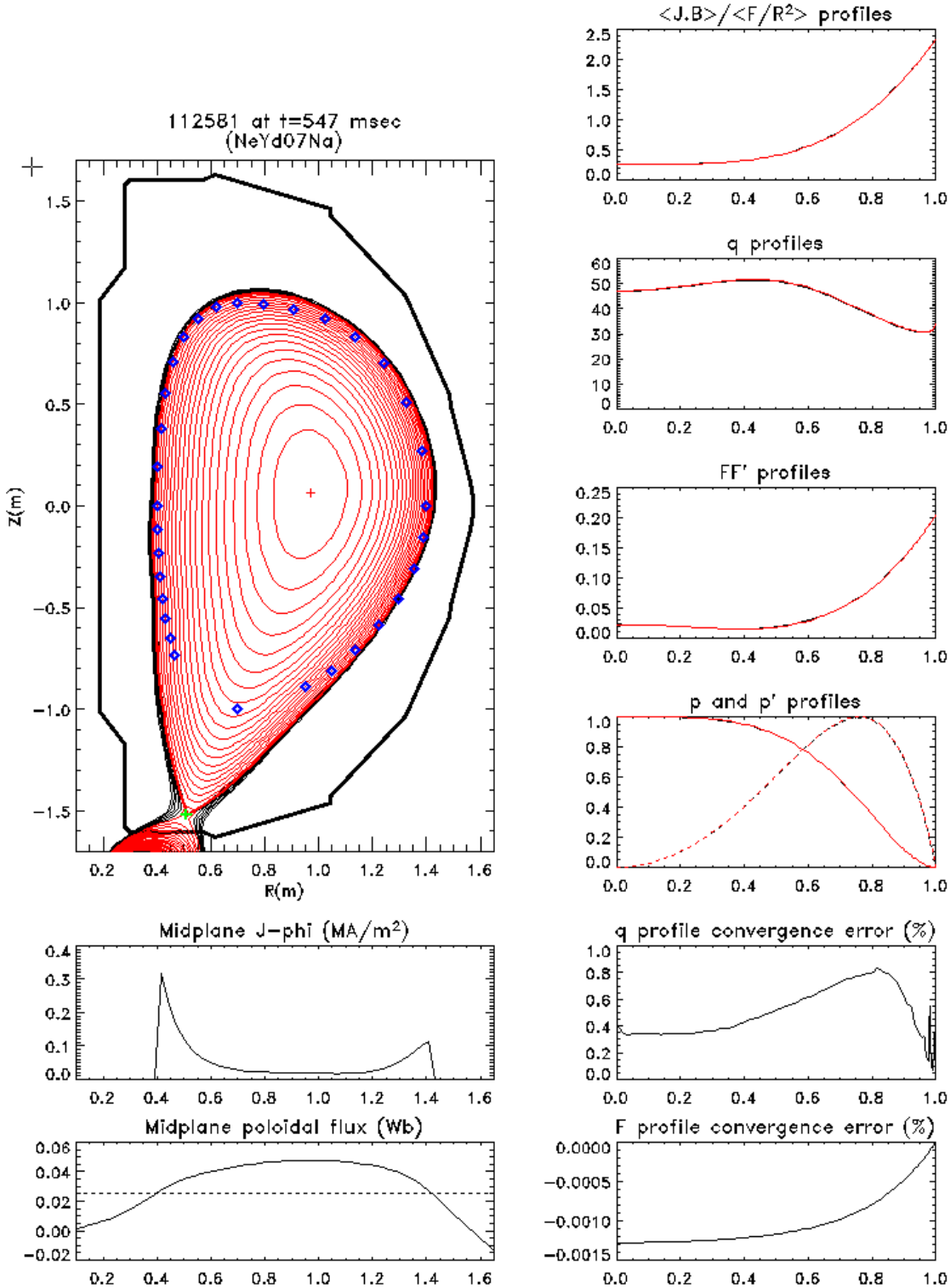

Run 11: Reduce PF2L from 0 to -0.5kA



Run 11

```
RMS boundary change during iteration (mm) =       0.49307943
RMS boundary error at this iteration (mm) =        217.17831
Cycle count =      146
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.90577329
Vacuum toroidal B at R0 (T) =      -0.42974328
Aspect ratio                =        1.7497576
Boundary elongation         =        2.4560751
Elongation at axis          =        2.2915915
Upper triangularity         =       0.24743813
Lower triangularity         =       0.70416717
q(0)                        =        47.034180
q(95)                       =        30.799807
q(99)                       =        32.350219
q(min)                      =        30.735726
rho q(min)                  =       0.96871048
Internal inductance         =       0.15703620
beta-t (%)                  =      0.067522307
beta-N                      =       0.10006342
Stored energy          (MJ) =    0.00072878751
Ip                     (MA) =       0.15011450
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =       0.99936625
Ip         specified/actual =       0.99923724
<J.B>      specified/actual =       0.99923722
-----------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.97039  0.06306
-----------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000        0.5727
  PF1AU      0.131146        1.9808
   PF2U      0.116203        6.6257
   PF3U     -0.684184        0.2370
    PF5     -0.602338       -0.0233
   PF3L     -1.223196        0.3647
   PF2L     -0.500000        0.0000
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        3.2951068
-----------------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.97062  0.06325
   Iteration #, convergence error =   1,  1.625745e-01
   Iteration #, convergence error =   2,  9.942827e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.6165009 seconds.
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Finishing PostScript file creation and stopping ...

RMS boundary change during iteration (mm) =       0.31608064
RMS boundary error at this iteration (mm) =        216.86487
Cycle count =      147
IDL> []
```
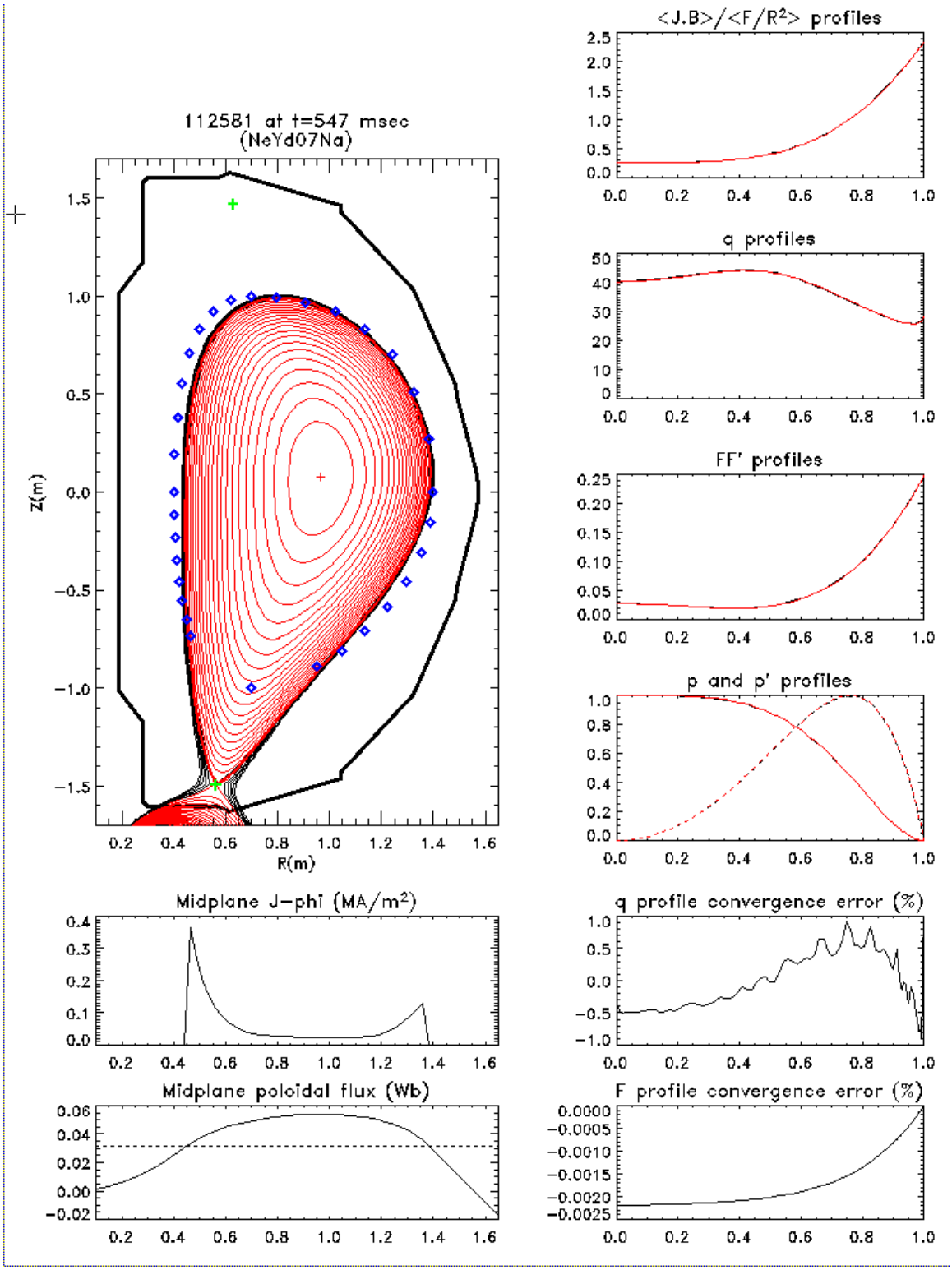

Run 12: Increase PF2L from -0.5 to +0.5kA



Run 12

```
RMS boundary error at this iteration (mm) =        221.19153
Cycle count =      157
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.91886578
Vacuum toroidal B at R0 (T) =      -0.42362006
Aspect ratio                =        1.9537604
Boundary elongation         =        2.6187655
Elongation at axis          =        2.2916696
Upper triangularity         =       0.26207912
Lower triangularity         =       0.73412869
q(0)                        =        40.092758
q(95)                       =        25.830426
q(99)                       =        27.131055
q(min)                      =        25.771577
rho q(min)                  =       0.96695398
Internal inductance         =       0.15454144
beta-t (%)                  =      0.075290217
beta-N                      =       0.10032696
Stored energy          (MJ) =    0.00068398098
Ip                     (MA) =       0.14951273
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =       0.99674105
Ip         specified/actual =        1.0032590
<J.B>      specified/actual =        1.0032599
-----------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.96729  0.07607
-----------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -0.9951
  PF1AU      0.270326       -0.3760
   PF2U      0.704829       -0.3915
   PF3U     -0.876115       -0.3209
    PF5     -0.611173        0.0476
   PF3L     -1.761239       -0.2567
   PF2L      0.500000        0.0000
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        2.0237461
-----------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.96752  0.07649
   Iteration #, convergence error =   1,  1.504693e-01
   Iteration #, convergence error =   2,  4.049771e-04
   Iteration #, convergence error =   3,  1.152766e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.8291728 seconds.
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===> DRSEP (cm) =       -13.288852
RMS boundary change during iteration (mm) =        1.4966480
RMS boundary error at this iteration (mm) =        220.53362
Cycle count =      158
```
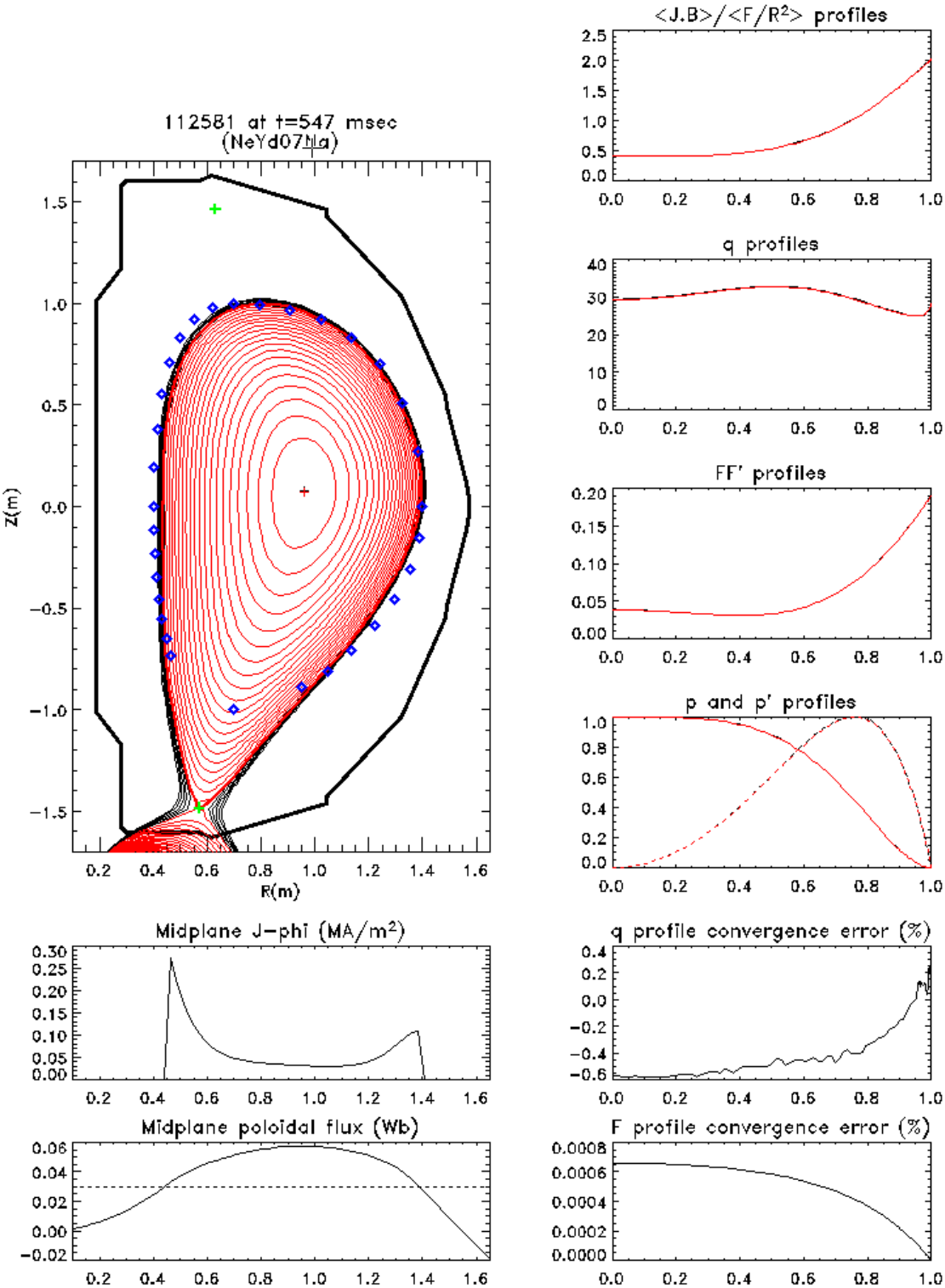

Run 13: Change Ip profile index from 9 to 5 [(1-psi^4)+5psi^2]



Run 13

```
RMS boundary error at this iteration (mm) =       210.59763
Cycle count =      168
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.91792673
Vacuum toroidal B at R0 (T) =      -0.42405343
Aspect ratio                =        1.9190908
Boundary elongation         =        2.5660527
Elongation at axis          =        2.2406000
Upper triangularity         =       0.24627489
Lower triangularity         =       0.72341529
q(0)                        =        29.196210
q(95)                       =        25.141539
q(99)                       =        26.788273
q(min)                      =        25.053377
rho q(min)                  =       0.96938125
Internal inductance         =       0.19838548
beta-t (%)                  =      0.074133272
beta-N                      =       0.10000653
Stored energy          (MJ) =    0.00069319687
Ip                     (MA) =       0.15035500
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =       0.99993473
Ip         specified/actual =       0.99763889
<J.B>      specified/actual =       0.99763853
-----------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.96164  0.07385
-----------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -3.1855
  PF1AU      0.270568       -0.7179
   PF2U      0.701676       -1.3385
   PF3U     -0.842170       -0.0720
    PF5     -0.650691        0.2627
   PF3L     -1.700764        0.1007
   PF2L      0.500000        0.0000
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        3.2635440
-----------------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.96169  0.07399
   Iteration #, convergence error =   1,  1.196981e-01
   Iteration #, convergence error =   2,  1.596610e-03
   Iteration #, convergence error =   3,  5.525091e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.7867959 seconds.
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===> DRSEP (cm) =       -11.518207
RMS boundary change during iteration (mm) =        1.2716053
RMS boundary error at this iteration (mm) =        208.80193
Cycle count =      169
IDL >
```
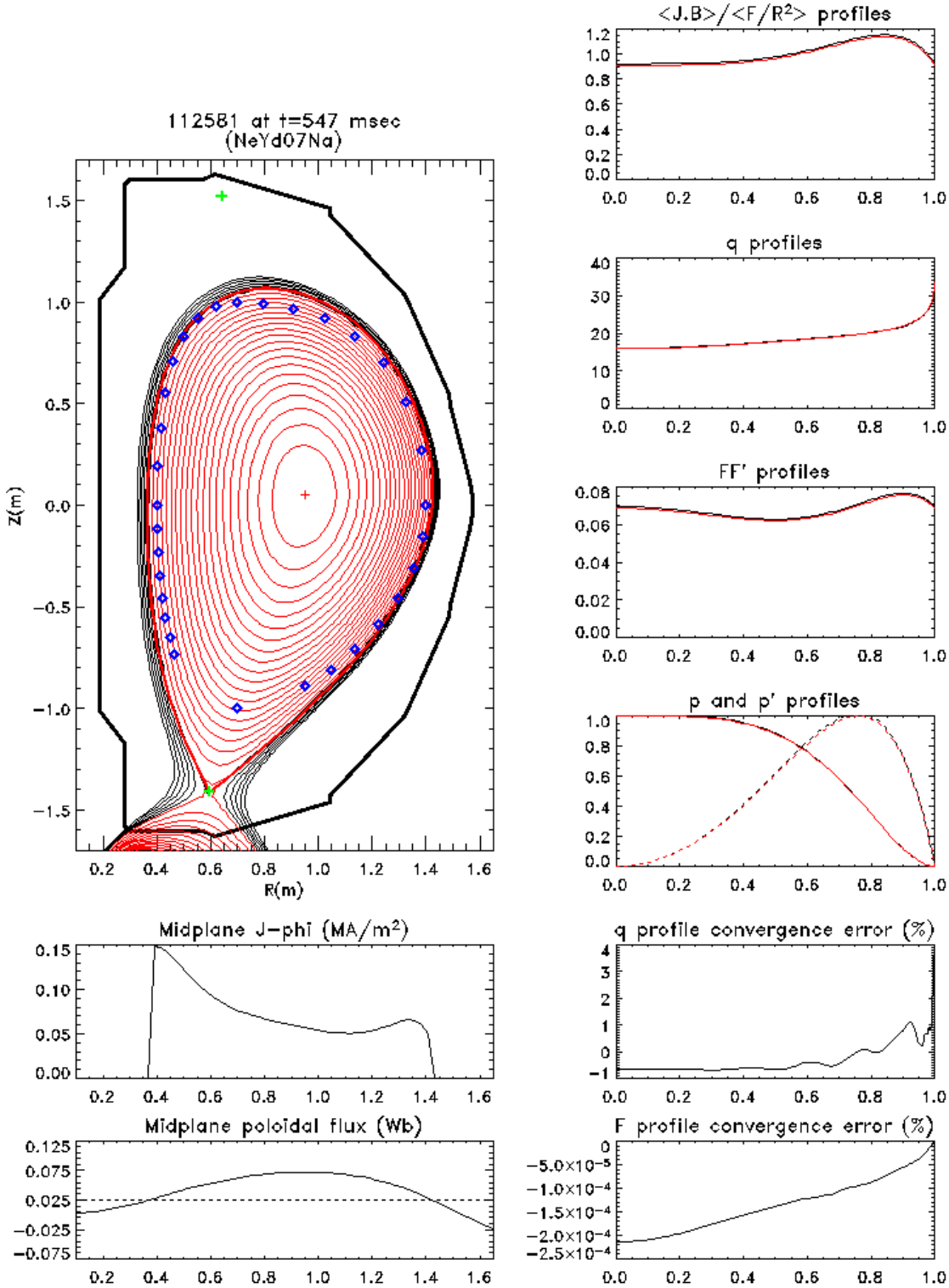

Run 14: Change Ip profile index from 5 to 1



Run 14:

```
RMS boundary change during iteration (mm) =        4.0084944
RMS boundary error at this iteration (mm) =        166.43220
Cycle count =      179
=====> F^2 iteration change =        0.0000000
-----------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.89816226
Vacuum toroidal B at R0 (T) =      -0.43338492
Aspect ratio                =        1.7013744
Boundary elongation         =        2.3117162
Elongation at axis          =        2.0823674
Upper triangularity         =       0.20886647
Lower triangularity         =       0.54050901
q(0)                        =        15.921850
q(95)                       =        25.872526
q(99)                       =        29.778580
q(min)                      =        15.842806
rho q(min)                  =      0.036055513
Internal inductance         =       0.36618559
beta-t (%)                  =      0.066556821
beta-N                      =       0.10034434
Stored energy          (MJ) =    0.00073364529
Ip                     (MA) =       0.15174990
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =       0.99656843
Ip         specified/actual =       0.98846855
<J.B>      specified/actual =       0.98846688
-----------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.94922  0.04858
-----------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -2.4545
  PF1AU      0.262511        3.1779
   PF2U      0.488286        8.2538
   PF3U     -0.618412        2.0944
    PF5     -0.873384       -0.1944
   PF3L     -1.336294        1.0088
   PF2L      0.500000        0.0000
  PF1AL     -2.000000        0.0000
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        16.217979
-----------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.94908  0.04829
   Iteration #, convergence error =   1,  1.593350e-01
   Iteration #, convergence error =   2,  4.398246e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.5238521 seconds.
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Finishing PostScript file creation and stopping ...

===> DRSEP (cm) =       -7.9252368
RMS boundary change during iteration (mm) =        3.6584188
RMS boundary error at this iteration (mm) =        167.27963
Cycle count =      180
IDL> []
```
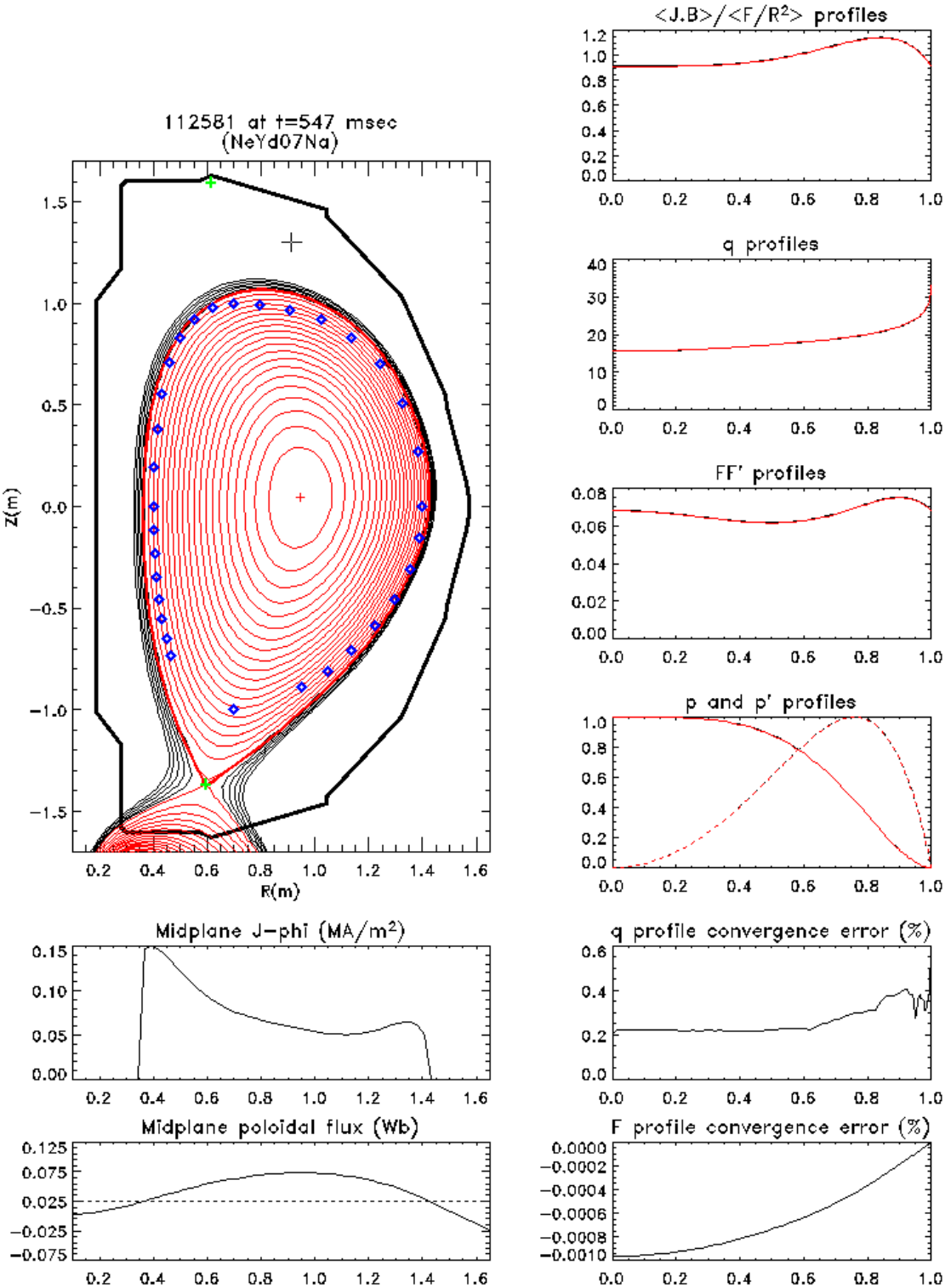

Run 15: Reduce PF1AL to 0



Run 15

```
RMS boundary change during iteration (mm) =       1.0234413
RMS boundary error at this iteration (mm) =       155.54060
Cycle count =      190
=====> F^2 iteration change =        0.0000000
---------------------------------------------------------------------------
Plasma geom. center  R0 (m) =       0.89651113
Vacuum toroidal B at R0 (T) =      -0.43418310
Aspect ratio                =        1.6900465
Boundary elongation         =        2.2711077
Elongation at axis          =        2.0883849
Upper triangularity         =       0.19935220
Lower triangularity         =       0.54261493
q(0)                        =        15.552056
q(95)                       =        25.788142
q(99)                       =        29.018385
q(min)                      =        15.518850
rho q(min)                  =      0.052915026
Internal inductance         =       0.36407926
beta-t (%)                  =      0.065394075
beta-N                      =       0.10009835
Stored energy          (MJ) =    0.00072598371
Ip                     (MA) =       0.15046707
ITF                    (MA) =       -1.9462499
beta-N     specified/actual =       0.99901753
Ip         specified/actual =       0.99689587
<J.B>      specified/actual =       0.99689544
---------------------------------------------------------------------------
Rescaled equilibrium profiles: p' and <J.B>/<Bt/R2>
Computing new plasma Jphi...
Computing poloidal flux from new plasma Jphi...
Finding optimal coil currents for boundary match...
Found possible poloidal field O-point at R,Z (m) [1] =   0.94809  0.04691
---------------------------------------------------------------------------
   Coil  Current (kA)      % Change
     OH     -0.000000       -0.1964
  PF1AU      0.238338        2.0932
   PF2U      0.351187        6.6232
   PF3U     -0.586211        0.4945
    PF5     -0.883993        0.1858
   PF3L     -1.315466        0.0505
   PF2L      0.500000        0.0000
  PF1AL      0.000000       -0.3600
   PF1B      4.000000        0.0000
RMS change in coil currents (A) =        8.5511102
---------------------------------------------------------------------------
===> Using x-point boundary <===
Found possible poloidal field O-point at R,Z (m) [1] =   0.94821  0.04660
   Iteration #, convergence error =   1,  1.523482e-01
   Iteration #, convergence error =   2,  6.235370e-05
  Changing theta coordinates to:  EQUAL-ARC...
Flux coordinates computed in 1.5239172 seconds.
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===> DRSEP (cm) =       -9.1028403
RMS boundary change during iteration (mm) =       0.94343025
RMS boundary error at this iteration (mm) =       155.36533
Cycle count =      191
```
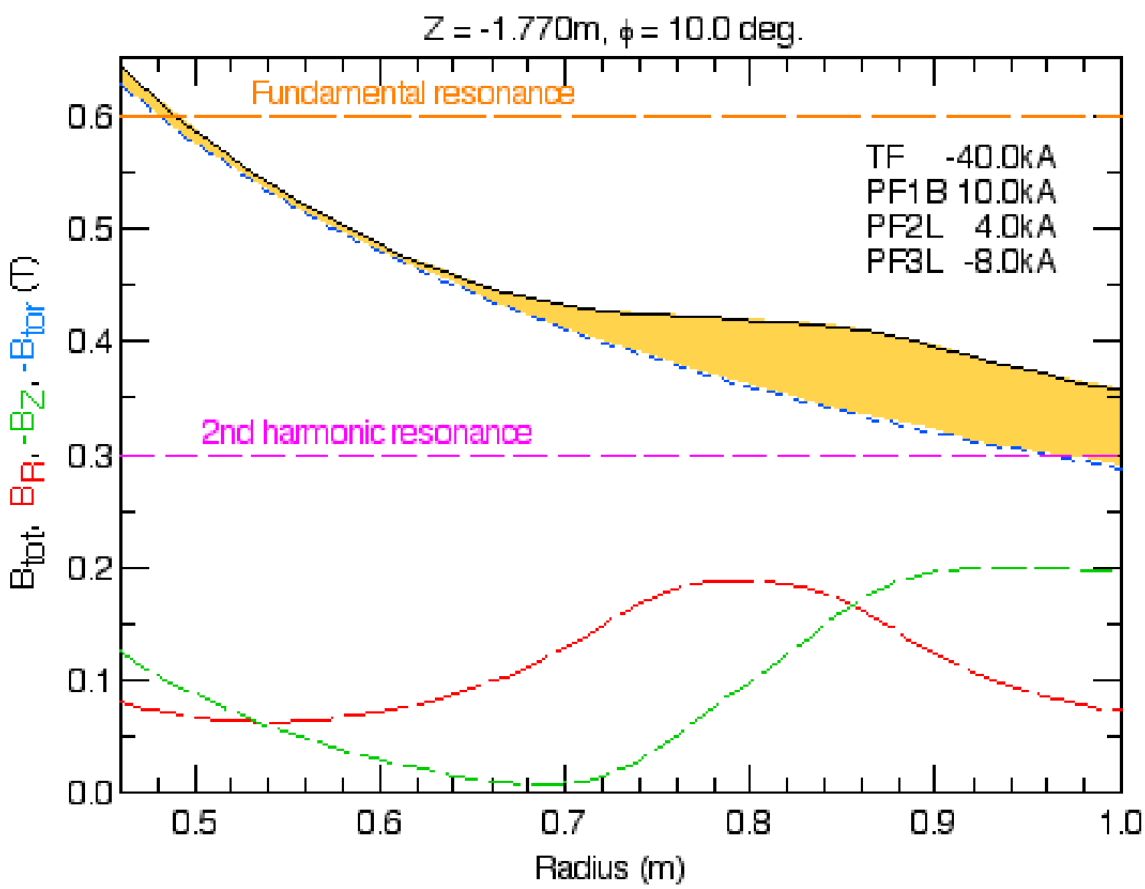

Summary table

Run No	Ip	PF1B	PF1AL	PF2L	PF3L	PF5	PF3U	PF2U	PF1AU	I_index
5	100	4	-2	0	-1.1	-0.44	-0.54	0.25	0.13	9
6	“	5	“	“	-1.2	-0.46	-0.66	0.82	0.25	9
7	200	“	“	“	-1.8	-0.75	-0.94	0.43	0.24	9
8	300	“	“	“	-2.5	-1.0	-1.3	0.45	0.28	9
9	“	4	“	“	-2.4	-1.0	-1.2	-0.3	0.13	9
10	150	“	“	“	-1.6	-0.63	-0.8	-0.4	0.21	9
11	“	“	“	-0.5	-1.2	-0.6	-0.68	0.12	0.13	9
12	“	“	“	+0.5	-1.8	-0.6	-.87	0.7	0.27	9
13	“	“	“	“	-1.7	0.65	-0.84	0.70	0.27	5
14	“	“	“	“	-1.3	-0.87	-0.61	0.49	0.26	1
15	“	“	0	“	-1.3	-0.88	-0.59	0.35	0.24	1

Magnetic field calculations near the ECH window (M. Bell)



Shown are the field components and the total field as a function of radius along the port tube for a TF current of -40kA and for PF currents we might expect in CHI experiments at the time when the ECPI would be applied. The yellow shaded area represents the range where the total field could be as the PF currents are varied (together) from zero to the values shown. With the fundamental resonance inside the divertor chamber, the second harmonic resonance could indeed be right at the window. We need to assess the risk that this might pose.

Commissioning day

Configure TF for 0.4T and other coil currents as calculated in the summary table.

Inject from Branch 5 (500 to 2000 Torr in 500 Torr steps) at t = -15ms. Reduce to < 500 Torr if possible.

Inject ECH from –3 to +7ms.

Vary gas injection from –15 to 0ms to optimize discharge initiation time. Check for pressure pulses in lower divertor with the Penning gauge and for light between the lower divertor plates using a fast visible camera.

If discharge promptly initiates at 0ms, reduce the duration of ECH after t=0ms.

Using the 2 capacitor configuration, test for breakdown as a function of flux footprint width and voltage.

PF1B=+4, PF1AL = -2, PF2L (-1,-2, 0, 0.5, 1)
Initially try to obtain breakdown at 1kV.

Main XP

Using 2 capacitors, establish the maximum current that can be achieved while minimizing the gas pressure and flux footprint width. Then increase the number of capacitors and couple to induction and diagnose as described in Fy04 run plan.

Operation at higher voltage

Take the best conditions obtained at 1kV and increase the voltage in steps of 100V (in the 2 capacitor configuration), while reducing the gas pressure.

If plasma detachment is still not observed, further reduce the flux footprint.