Investigations of Discharge Evolution Scenarios for the C82 Configuration

Ed Lazarus†

Oar Ridge National Laboratory

Presented at

NCSX Project Meeting

July 11, 2000

† with of LOTS of help from Mike Zarnstorff and Doug McCune

- The vacuum iota equivalent current
- Building discharge initiation in TRANSP as psuedo LHCD
- Plasma evolution in TRANSP - effects of NBI
- TRANSP profiles to VMEC
- Fixed Boundary VMEC results – limitations of a 2D approximation
- Free Boundary VMEC results
- Future

Building a Startup

The intent is to use TRANSP to model the current profile in <NCSX>

First the c82a configuration is modified to $\beta=0$, Ip=0 to get the vacuum iota.

The vacuum iota is put into a second VMEC run with RBC($n\neq0$)=0, ZBS($n\neq0$)=0

The resulting toroidal current profile is extracted, to be used as LHCD in TRANSP

LHCD is treated as source-driven in TRANSP - non diffusive.

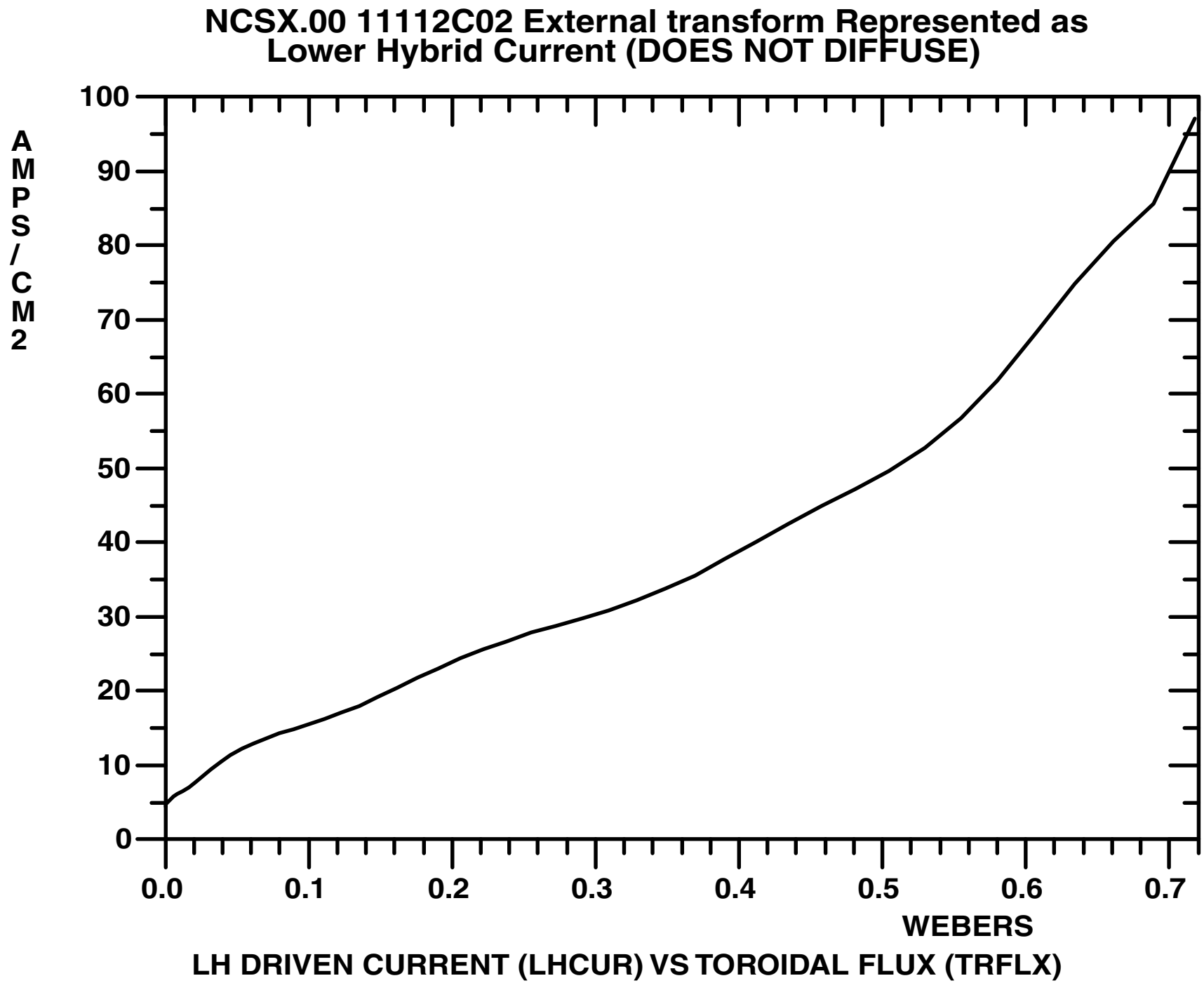
With fictitious profiles a discharge is evolved in TRANSP to a final state with low temperature, low density, and V=0 across the profile. All that remains is the LHCD current at $\beta\approx0$. Temperatures assumed are 50 eV at the center and 10 eV at the edge. Density is $\approx 5\times10^{13}$ cm^{-3}. These now become initial conditions.

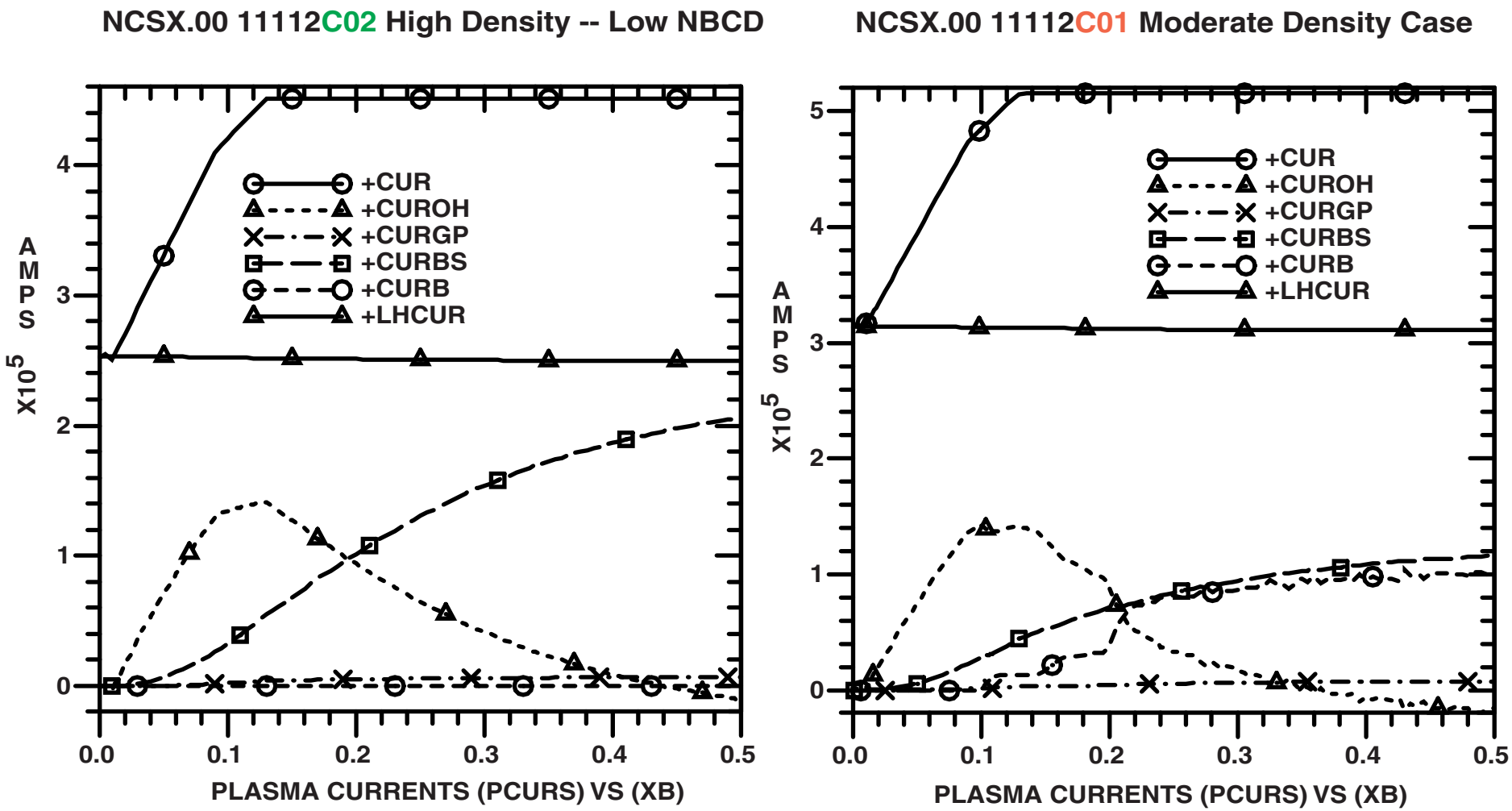
Building a Plasma

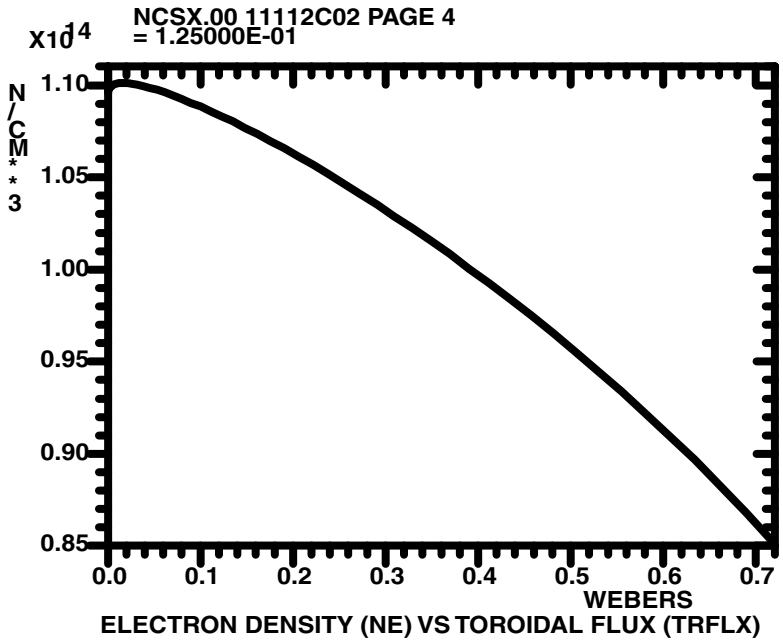
This is now the startup scenario and all plasma evolution begins at 10 ms, after these conditions are established. All profiles must evolve continuously from this startup. At this time I have two startups with equivalent currents of 250 and 309 kA - not sure which is correct. Of course, other startups at lower fractions of the external transform can be built. Startups involve manual iteration of TRANSP runs and can be tedious. Failures are similar to disruptions and need to be diagnosed. Then the plasma trajectory is altered to avoid the difficulty until the full evolution can be completed.

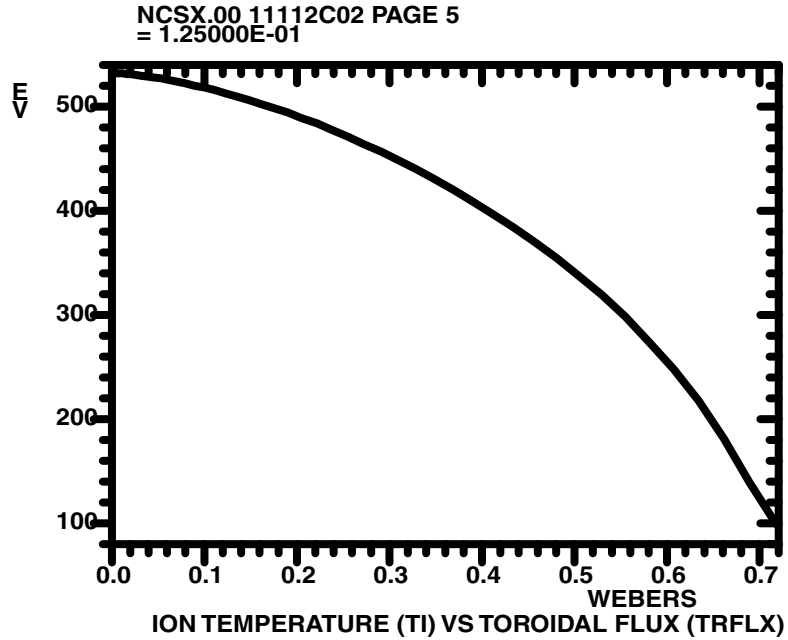
An IDL procedure was developed to merge the "startup" with the "plasma" evolution. The merge uses a hyperbolic tangent in h(t)#f(x). The I_p ramp is linear in time and the density ~ I_p^2. When we progress to programming transport and not its results, there will need to be a short transition with assumed profiles to avoid disruption. This is likely to be dependent on the transport assumptions. Disruption here usually means TRANSP-VMEC crashes, though other failures can occur.

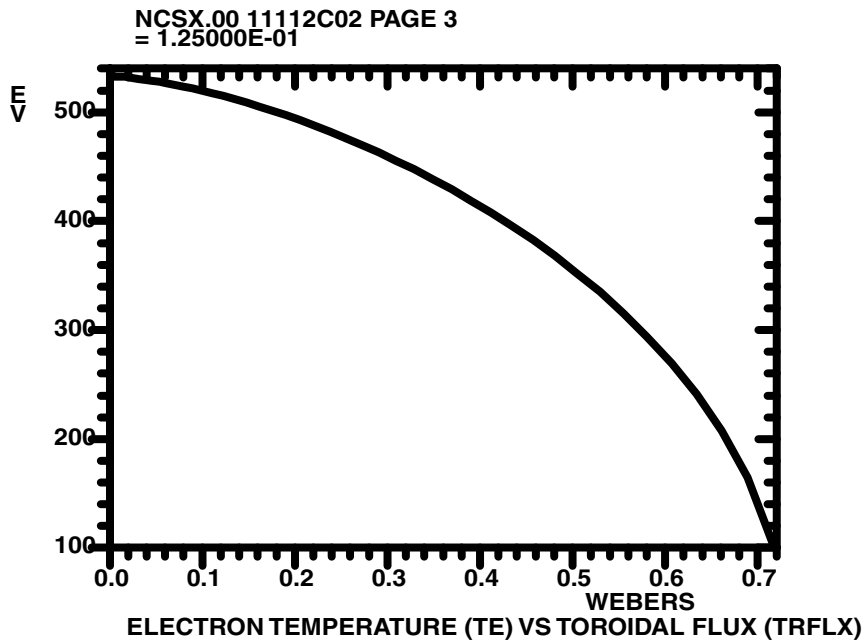
Thus far, all plasma profiles are assumed (asserted). I think the temperature profiles are plausible, the density is high, $\langle n_e \rangle = 7\times10^{13}$ and 11×10^{13} cm^{-3}.

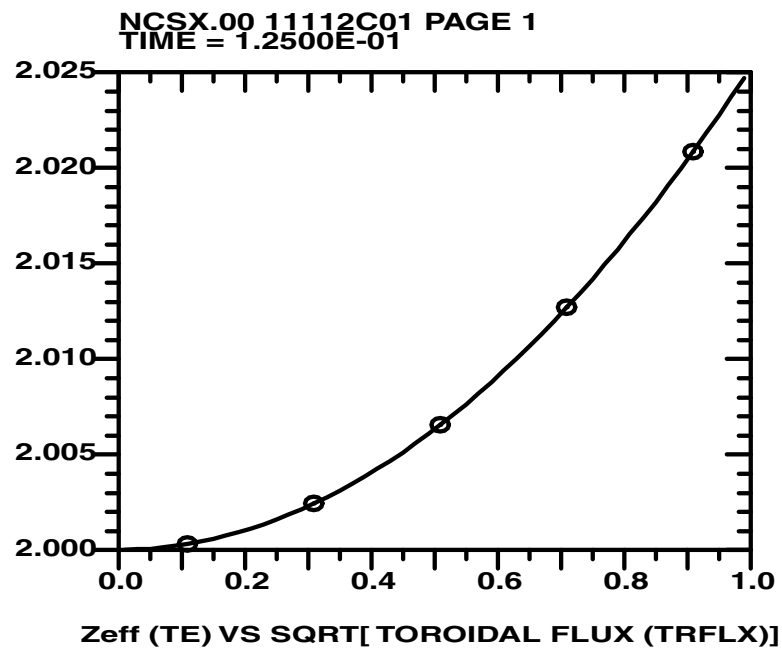

NCSX.00 11112C02 External transform Represented as
Lower Hybrid Current (DOES NOT DIFFUSE)
AMPS/CM2
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
WEBERS
LH DRIVEN CURRENT (LHCUR) VS TOROIDAL FLUX (TRFLX)


NCSX.00 11112C02 High Density -- Low NBCD
NCSX.00 11112C01 Moderate Density Case
+CUR
+CUROH
+CURGP
+CURBS
+CURB
+LHCUR
AMPS
X10^5
PLASMA CURRENTS (PCURS) VS (XB)
0.0
0.1
0.2
0.3
0.4
0.5
0
1
2
3
4
5

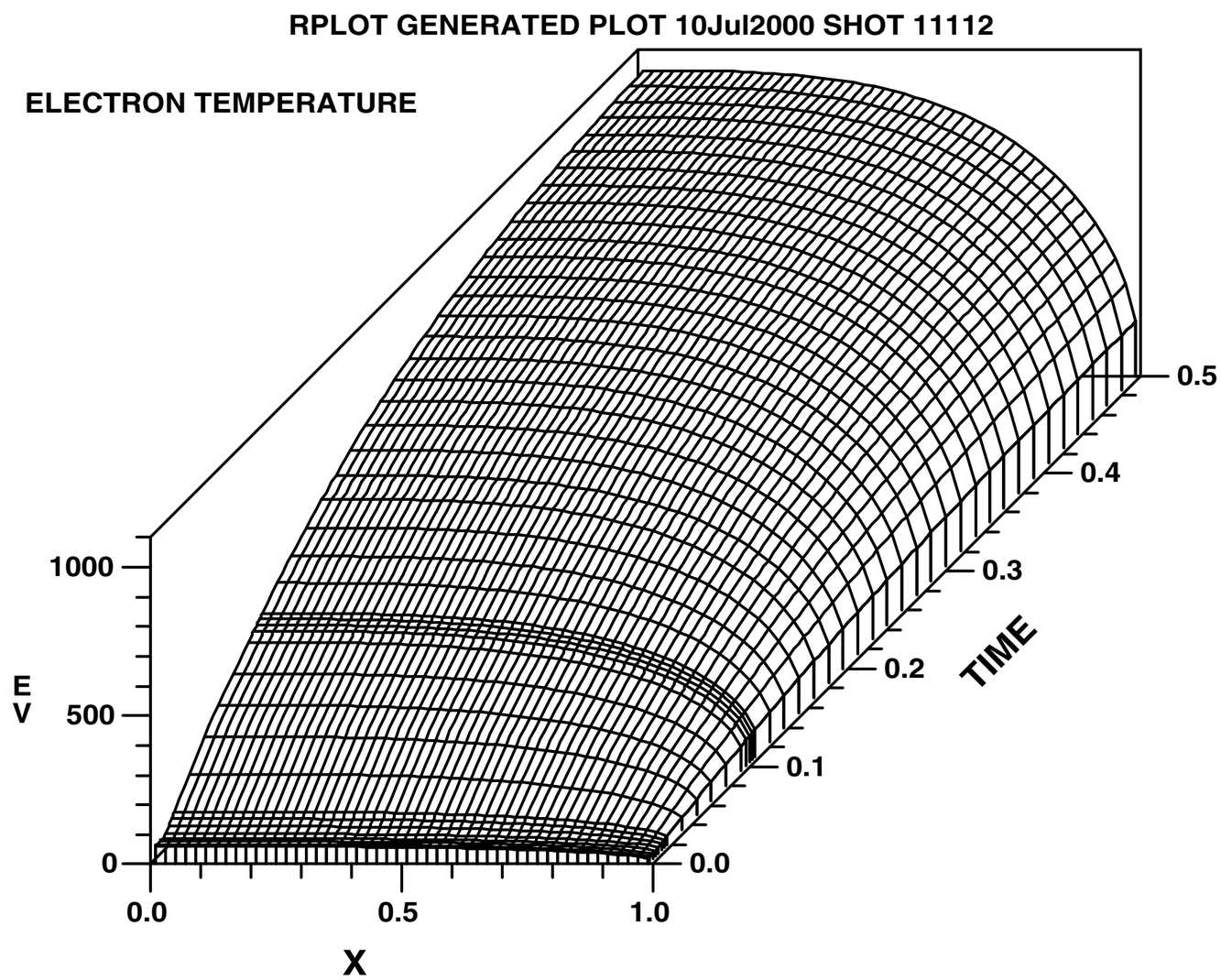


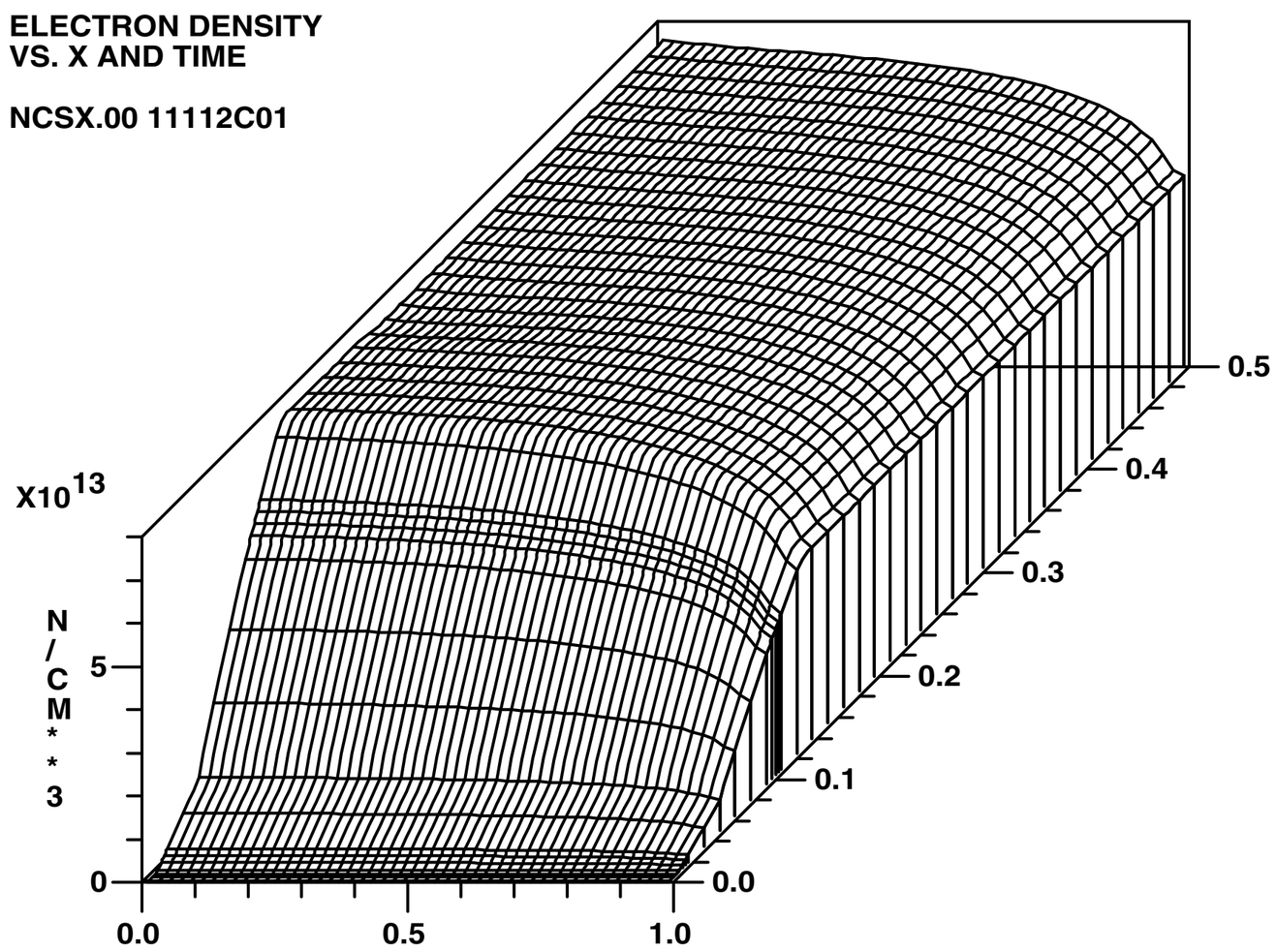




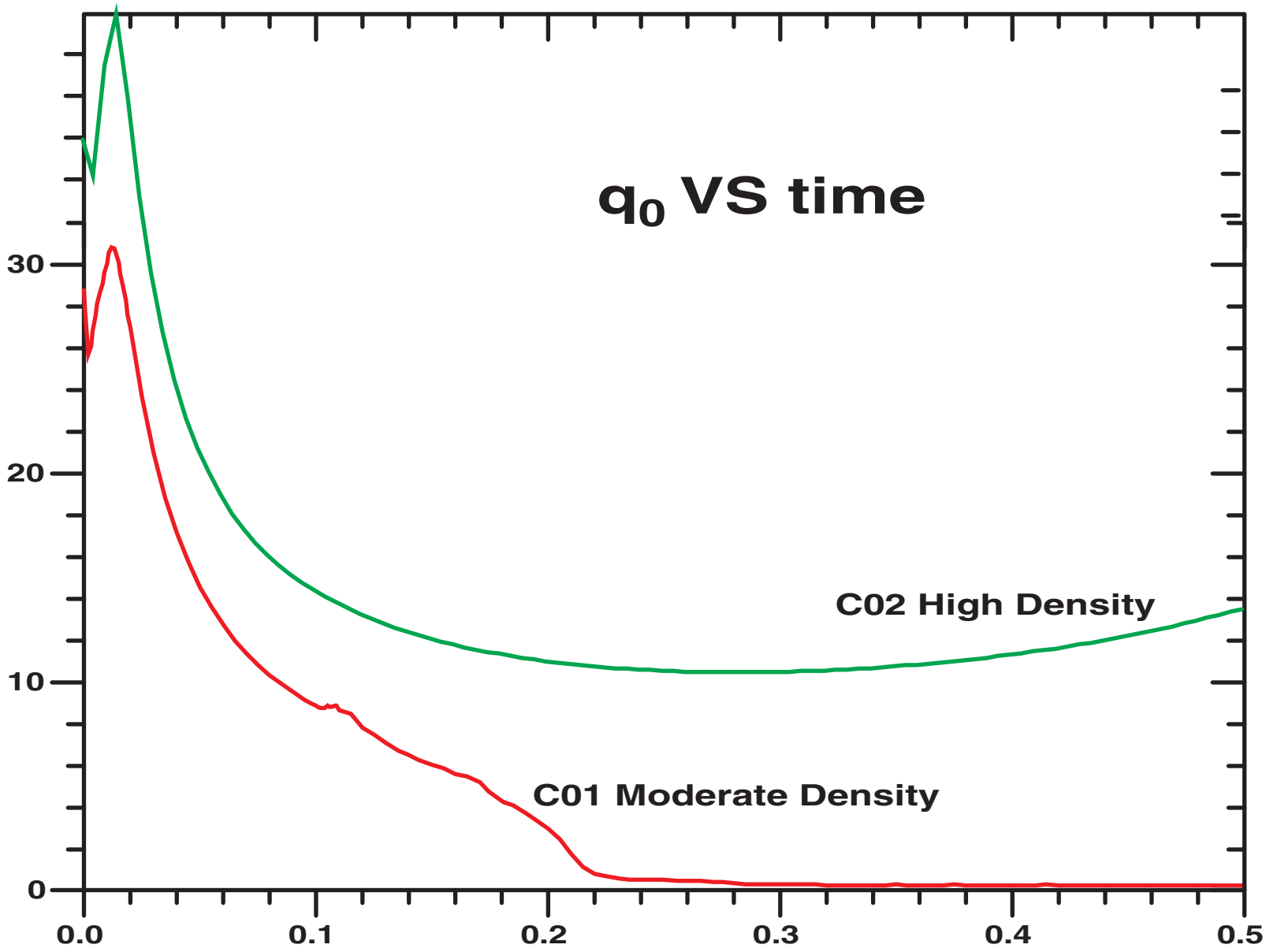


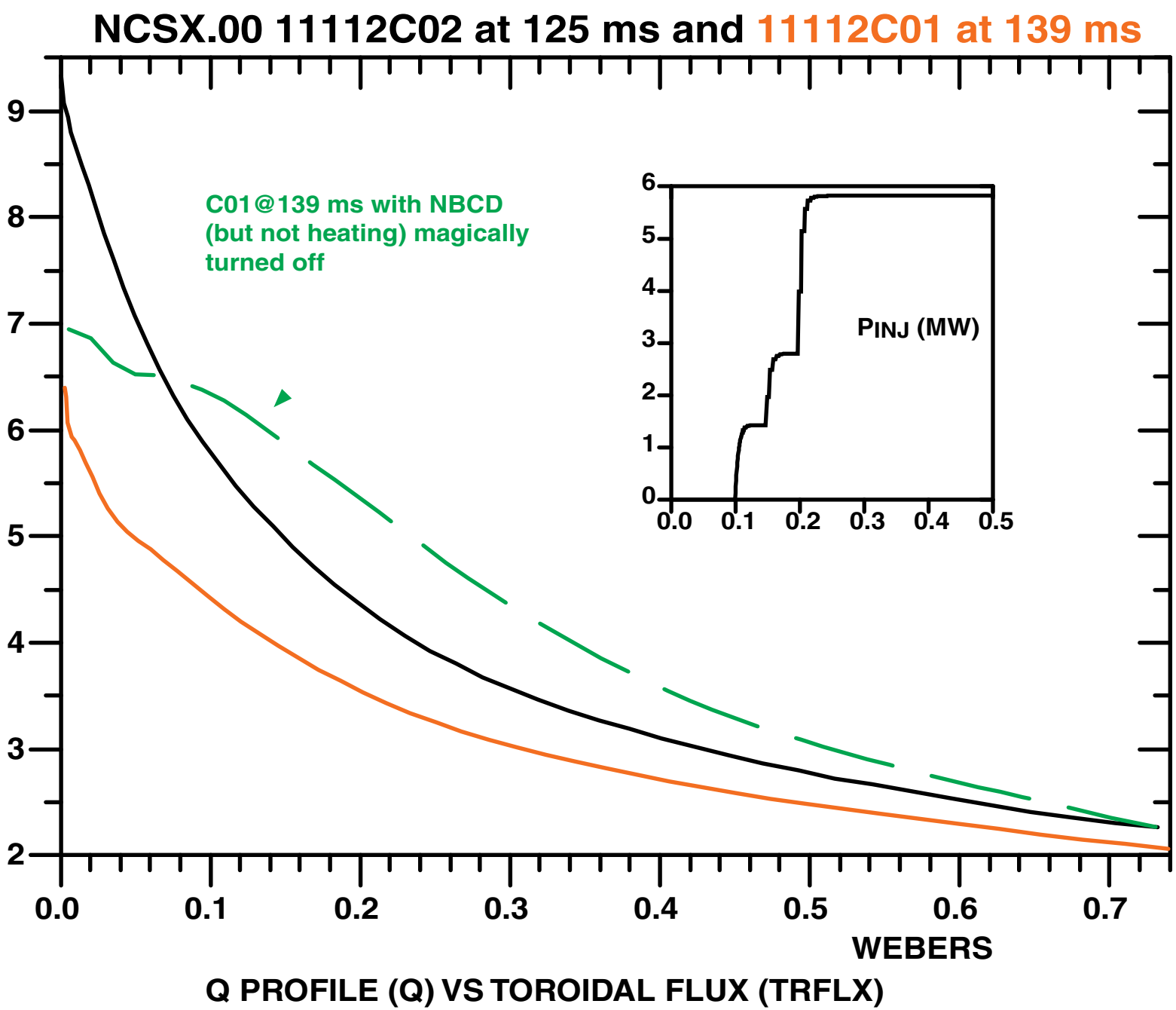
Profiles are imagined, simple functions of toroidal flux


RPLOT GENERATED PLOT 10Jul2000 SHOT 11112
ELECTRON TEMPERATURE
1000
500
0
E
V
0.0
0.5
1.0
X
0.0
0.1
0.2
0.3
0.4
0.5
TIME


ELECTRON DENSITY
VS. X AND TIME
NCSX.00 11112C01
X10^13
N/CM**3
5
0
0.0
0.5
1.0
0.0
0.1
0.2
0.3
0.4
0.5

NBCD drives central q down for a reasonable operating density




NCSX.00 11112C02 at 125 ms and 11112C01 at 139 ms
C01@139 ms with NBCD
(but not heating) magically
turned off
PINJ (MW)
WEBERS
Q PROFILE (Q) VS TOROIDAL FLUX (TRFLX)

The pressure and current density (or iota) are fit to 11 term polynomials for VMEC input

1) Read PTOWB, CUR, LHCUR, DAREA, XC, XB PCUR & q from TRANSP

2) Integrate (LHCUR -CUR) dA to boundary to get CURTOR

3) Integrate (CUR-LHCUR) to XC to get $I_{tor}(\rho)$, $\rho=\sqrt{(s)}$ (=XC)

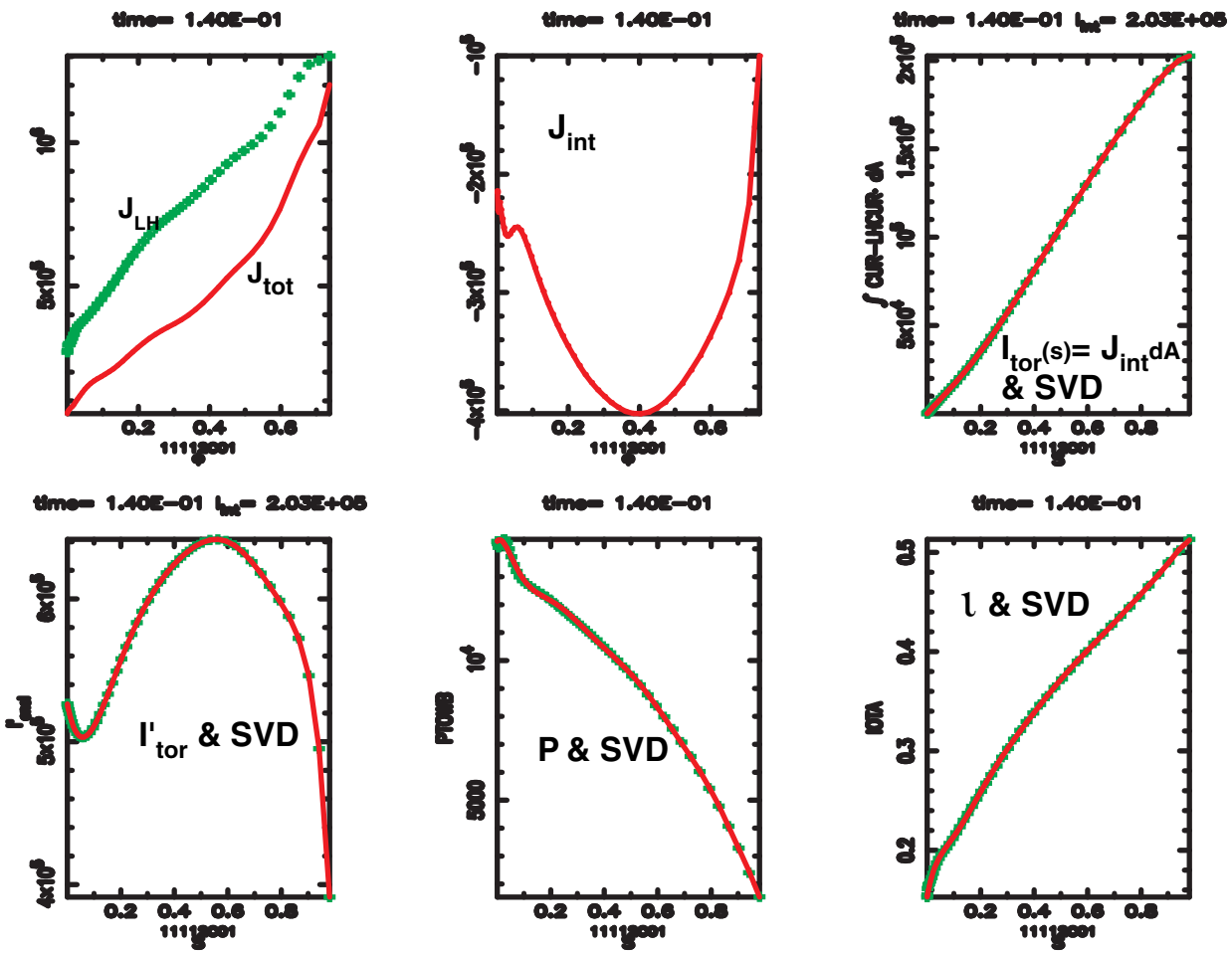
4)SVD $I_{tor}(\rho)$ vs xc^2

5)Take $d/d(xc^2)$ of SVD

6) SVD derivative to get $I'_{tor}(s)$

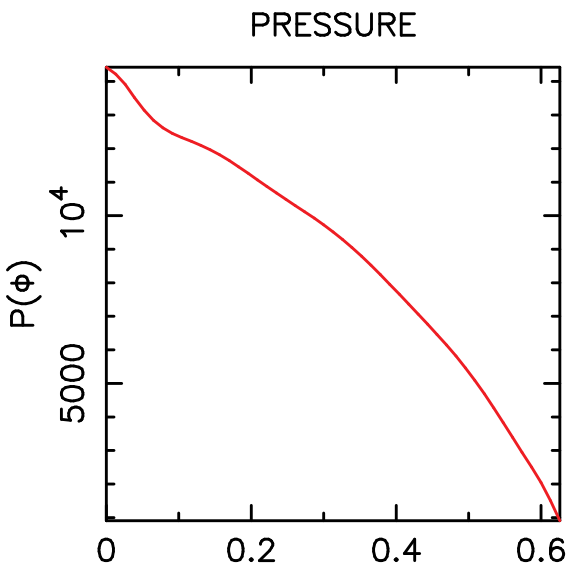
7) Some problem when beam adds central peak to pressure

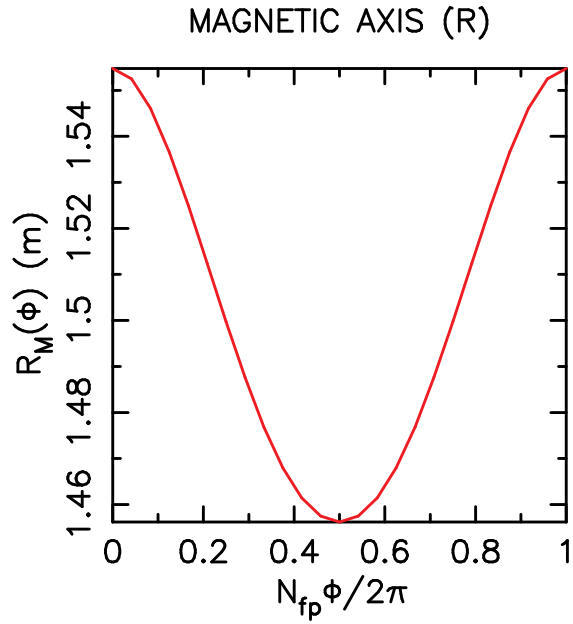
8) All fits are 11 terms to conform to VMEC.

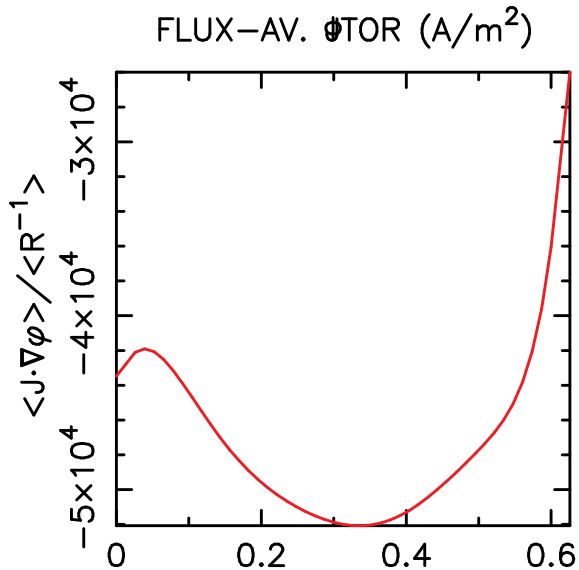


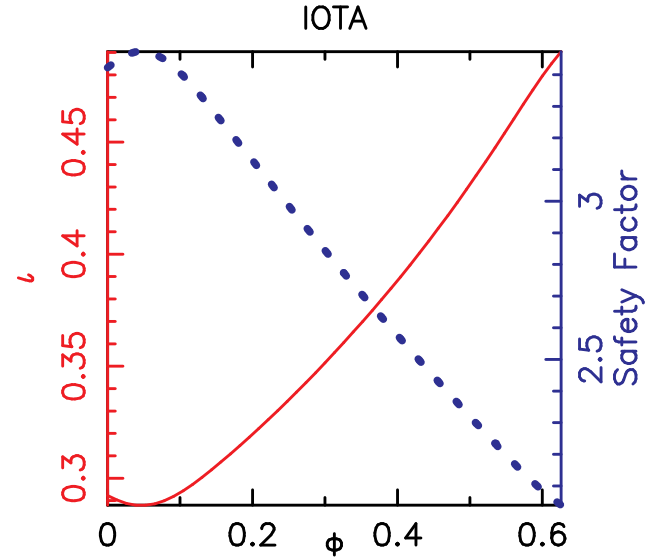
In from TRANSP

Out from VMEC



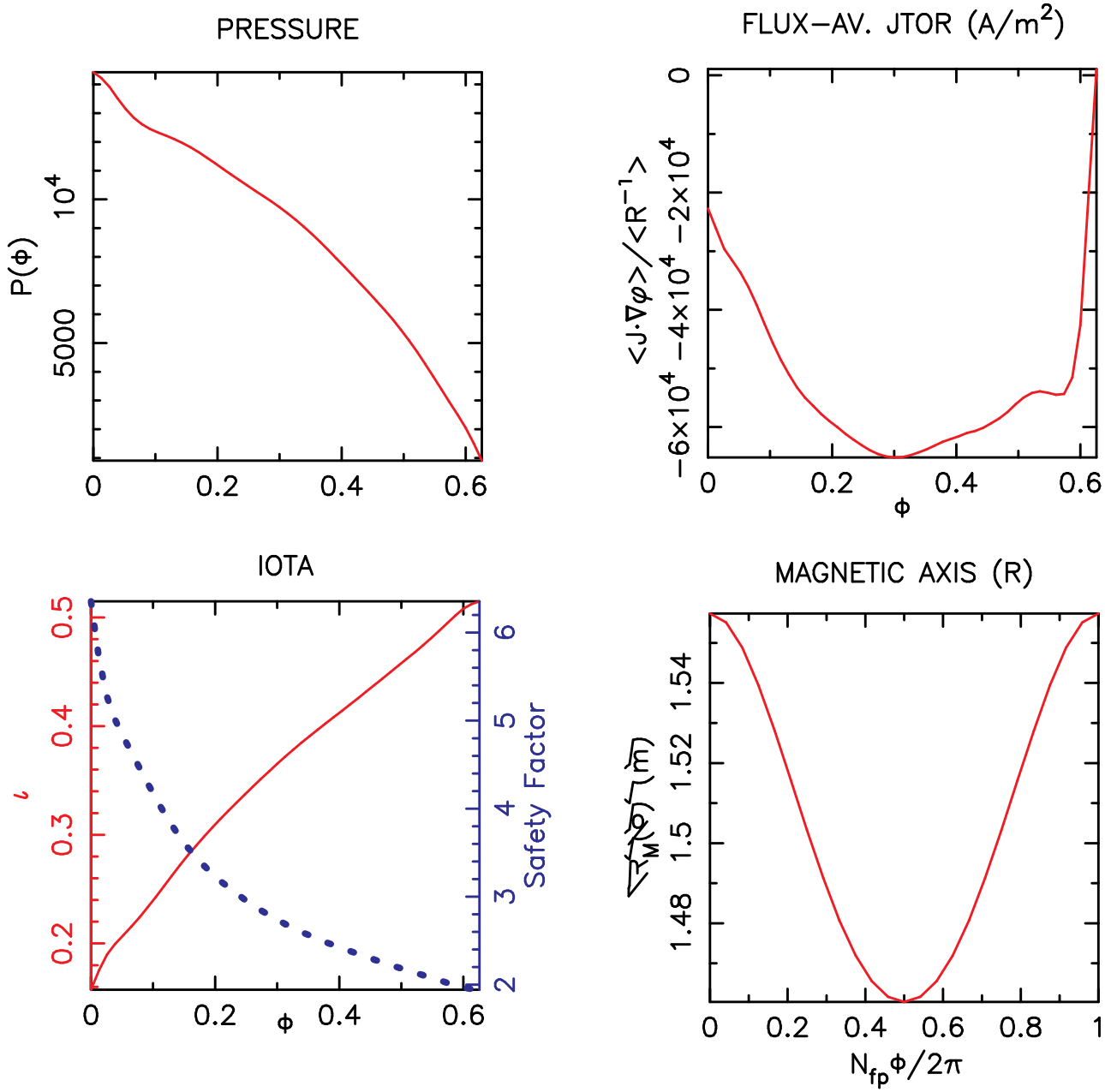




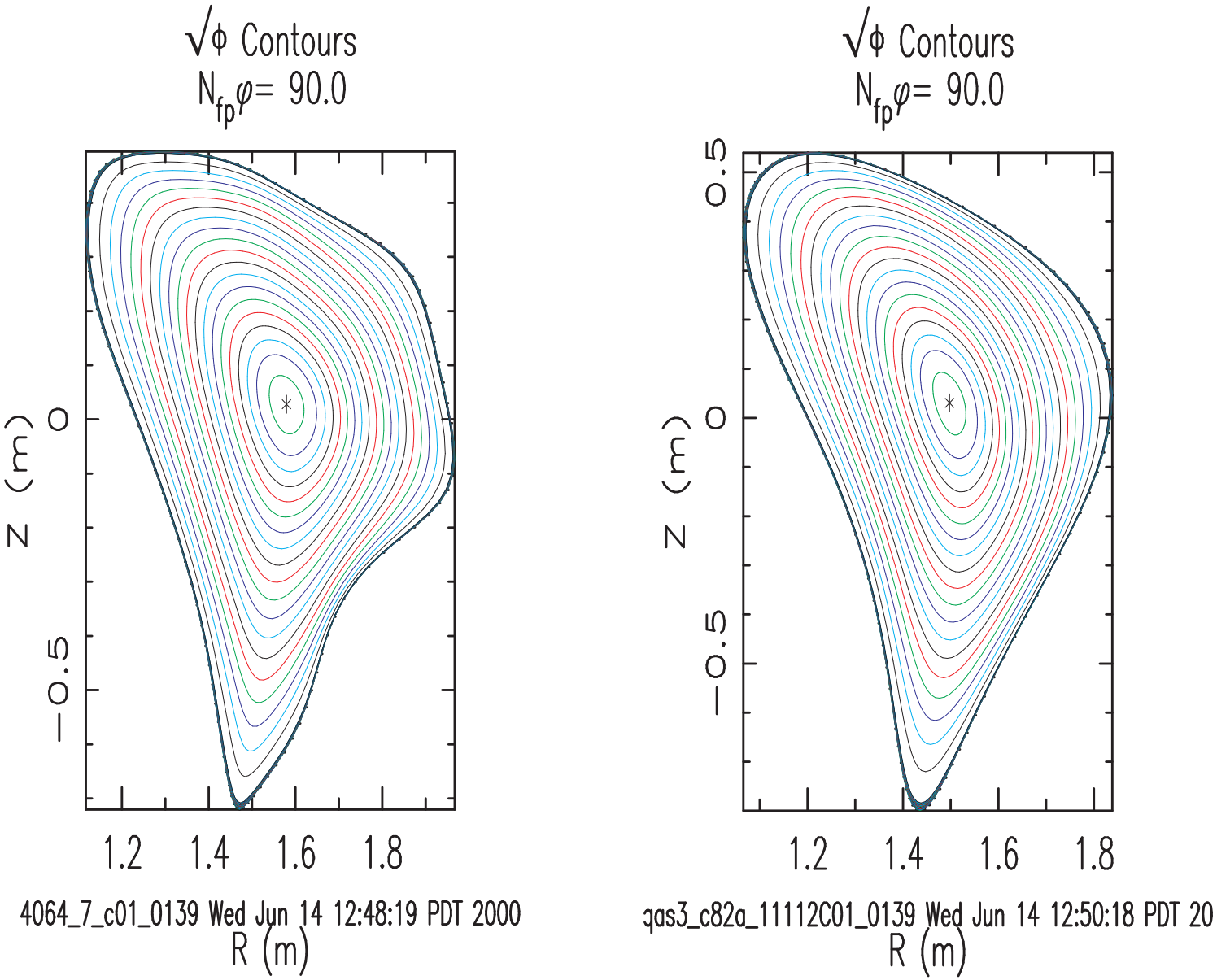


In from TRANSP

Out from VMEC

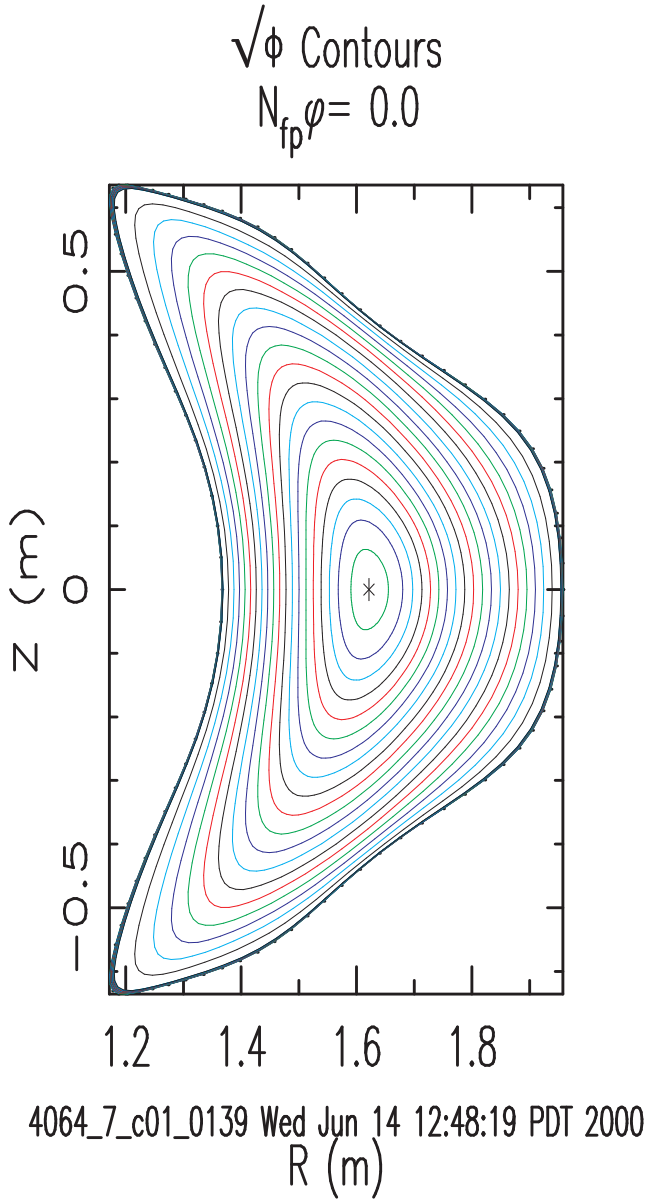


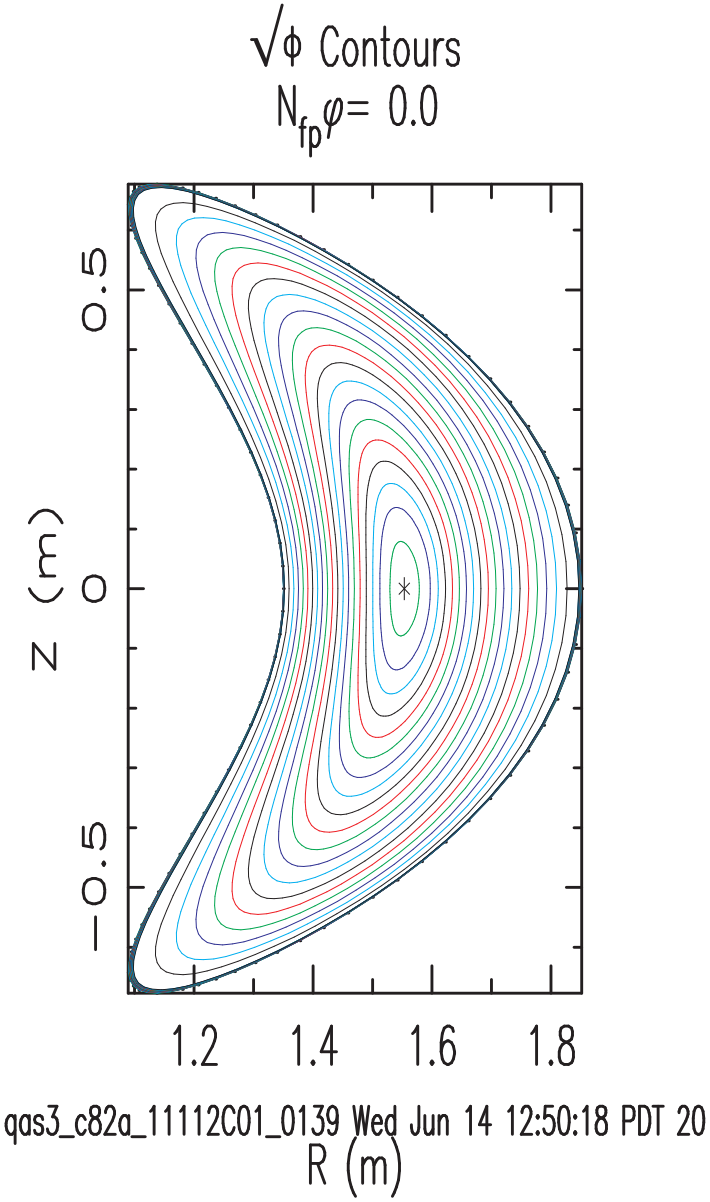
Free and Fixed Boundary Solutions Show Differnces in Shape Which are Likely to Have Consequences for Stability



I suspect much of this difference could be removed with a different positions for the VF coils

Comparison of Free and Fixed Boundary VMEC solutions
Flux Surface Shape





Since the shapes differ and the profiles are the same functions of s, the q profiles differ.

Some Comments on Results

A 500 ms discharge using 300 ms heating pulse, with dI_p/dt=2 MA/s produces nearly steady-state conditions with a loop voltage of ~ -0.1 v on axis and ~ -0.01 v at the LCS.

The startup loop voltage requirements are expected to be modest – better than a tokamak as there are some closed surfaces at t=0.

The effects of NBCD seem to me quite difficult to overcome. Even the “moderate density is probably too high for the device. At lower density (5 10^{13} cm^{-3}) the effect of NBCD is increased further. Co-injected beams will likely be ruinous to the q profile.

The difference between q from TRANSP and q from 3-D VMEC arises from the fact that there are fundamental differences between the 2D and 3D equilibria and the relationship of internal current to total transform is really different. Modeling in 2D will have important limitations – the results cannot be evaluated for stability in a meaningful way . The difference [q(1)-q(0)] contains different low-order rational values. <u>I am still not certain of this, the surfaces for the two cases line up awfully well.</u>

There are differences between the fixed and free boundary results if the only freedom is to adjust a “vertical” field to balance the hoop force. For the single case examined, a casual judgement is the deviation from the QAS shape is unlikely to be a stabilizing effect. Plasma shape control, critical for the stability properties will require controlling the helical fields, not just the axisymmetric fields. (I would be very disappointed if it turned out to be otherwise.) This in turn will necessitate a 3D equilibrium reconstruction code.

Future Work (not ordered)

Do free boundary optimization on the shape and see if the original shape can be regenerated. If so, how much were the coil currents altered and are the current densities in the coil acceptable?

Now that tools and techniques have been developed, we can look at other scenarios.

- Different I_p ramp rates and different programming of the external transform need examination.
- Some transport model is needed to replace asserted profiles.

Verify that the differences in iota between 2D and 3D are correct. Having looked at the change in axis wobble between the two cases I am uncomfortable that there is an error somewhere.

Compare results to the Houlberg-Strand 3D flux evolution code.