Investigations of Discharge Evolution Scenarios for the C82 Configuration

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† 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 Boudary VMEC results*
- *Free Boundary VMEC results*
- *Future work*

Building a Startup

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

First the c82a configuration is modified to β=0, Ip=0 to get the vacuum iota.

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

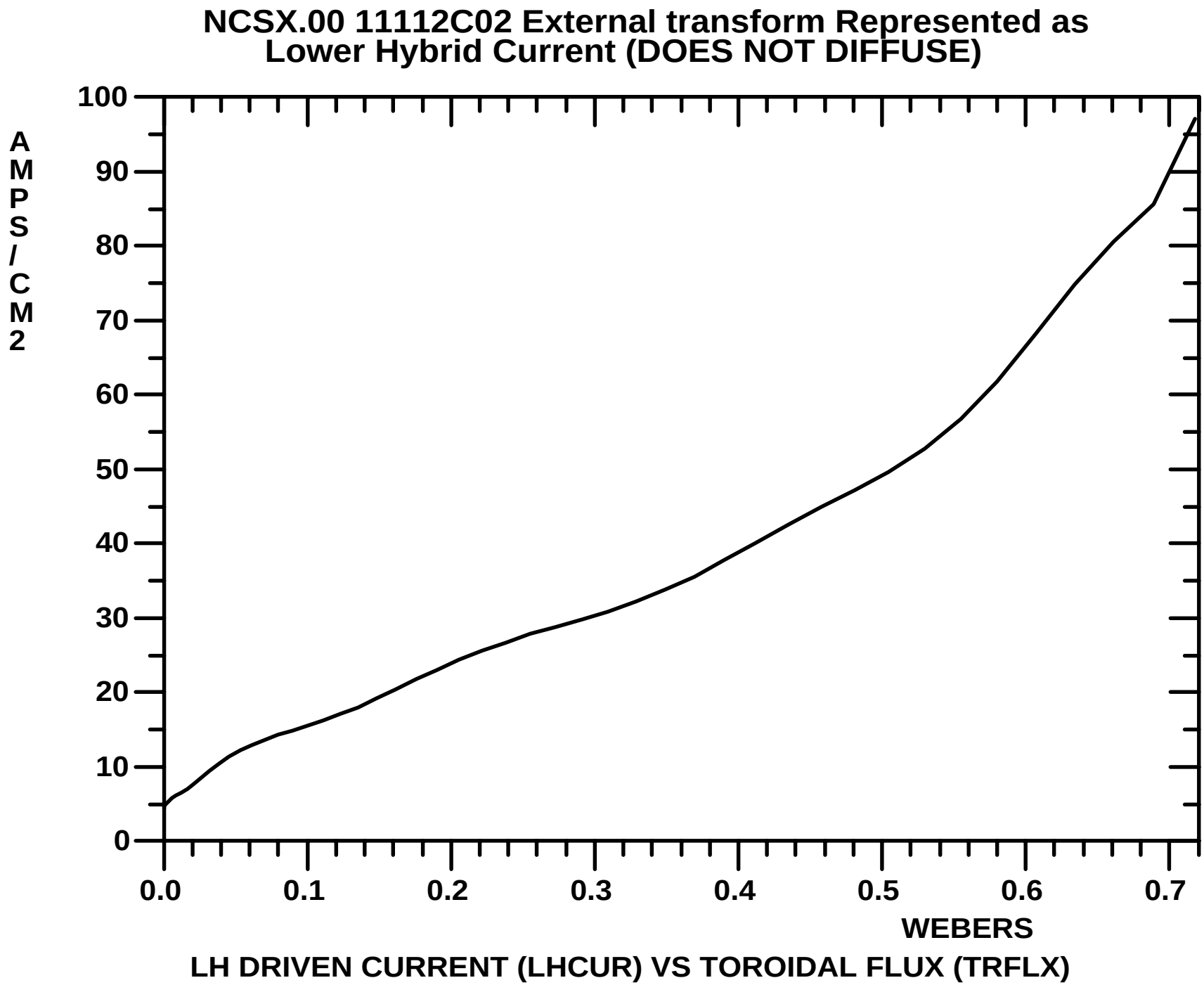
With fictitious profiles a discharge is evolved in TRANSP to a final state with low temperature, low density, and V=0 across the profile. All that remains is the LHCD current at $\beta\approx$0. Temperatures assumed are 50 eV at the center and 10 eV at the edge. Density is $\approx 5\times10^{13}$ cm^{-3}.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

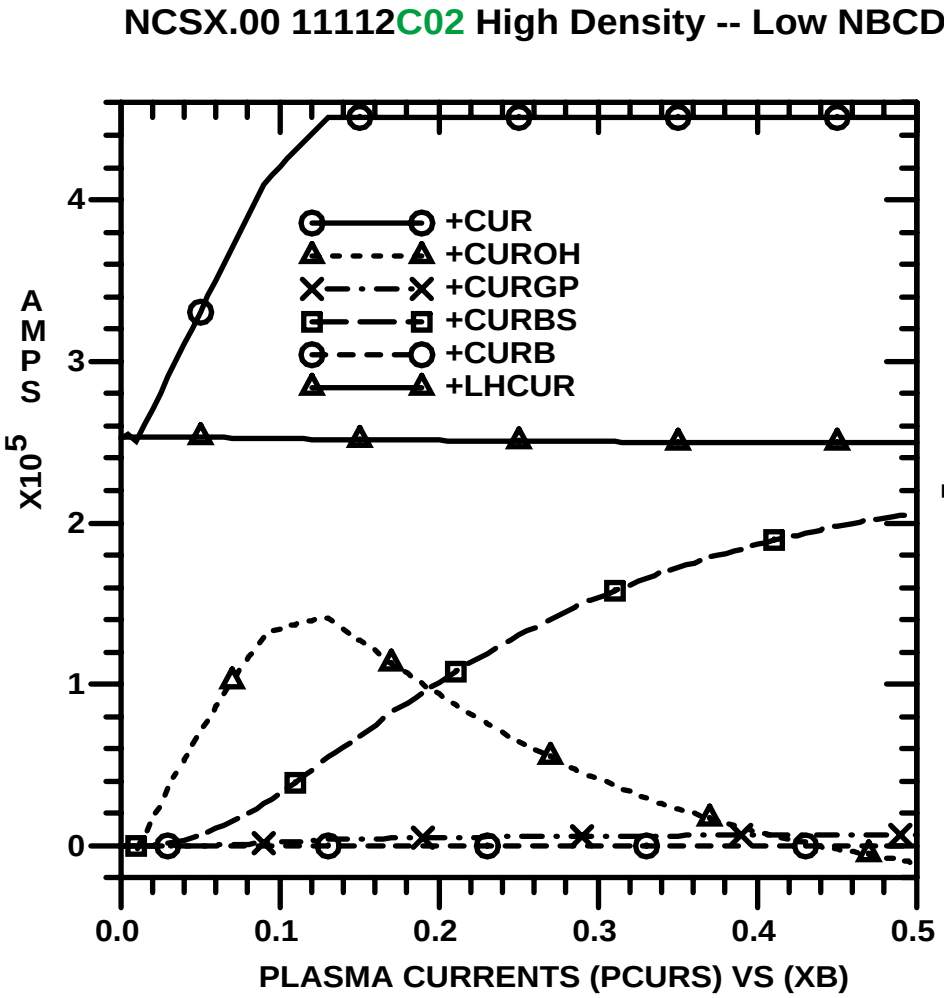
Building a Plasma

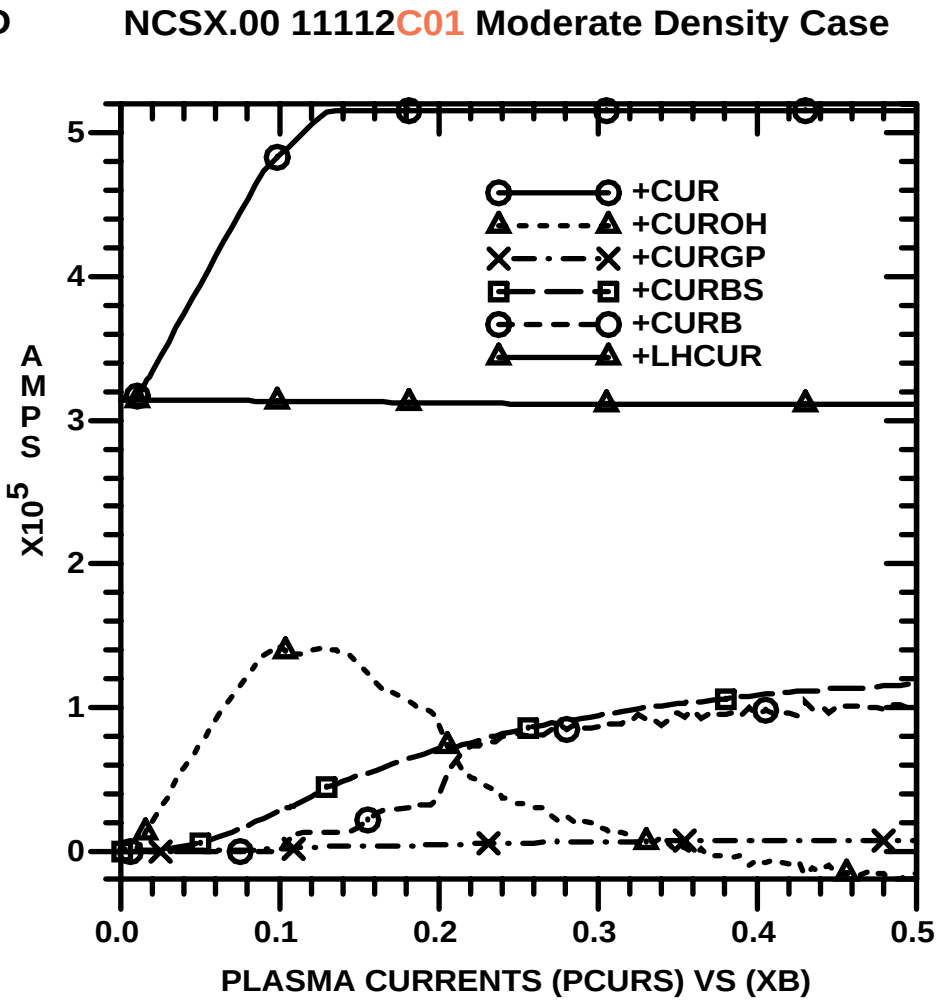
This is now the startup scenario and all plasma evolution begins at 10 ms, after these conditions are established. All profiles must evolve continuously from this startup. At this time I have two startups with equivalent currents of 250 and 309 kA - not sure which is correct. Of course, other startups 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.

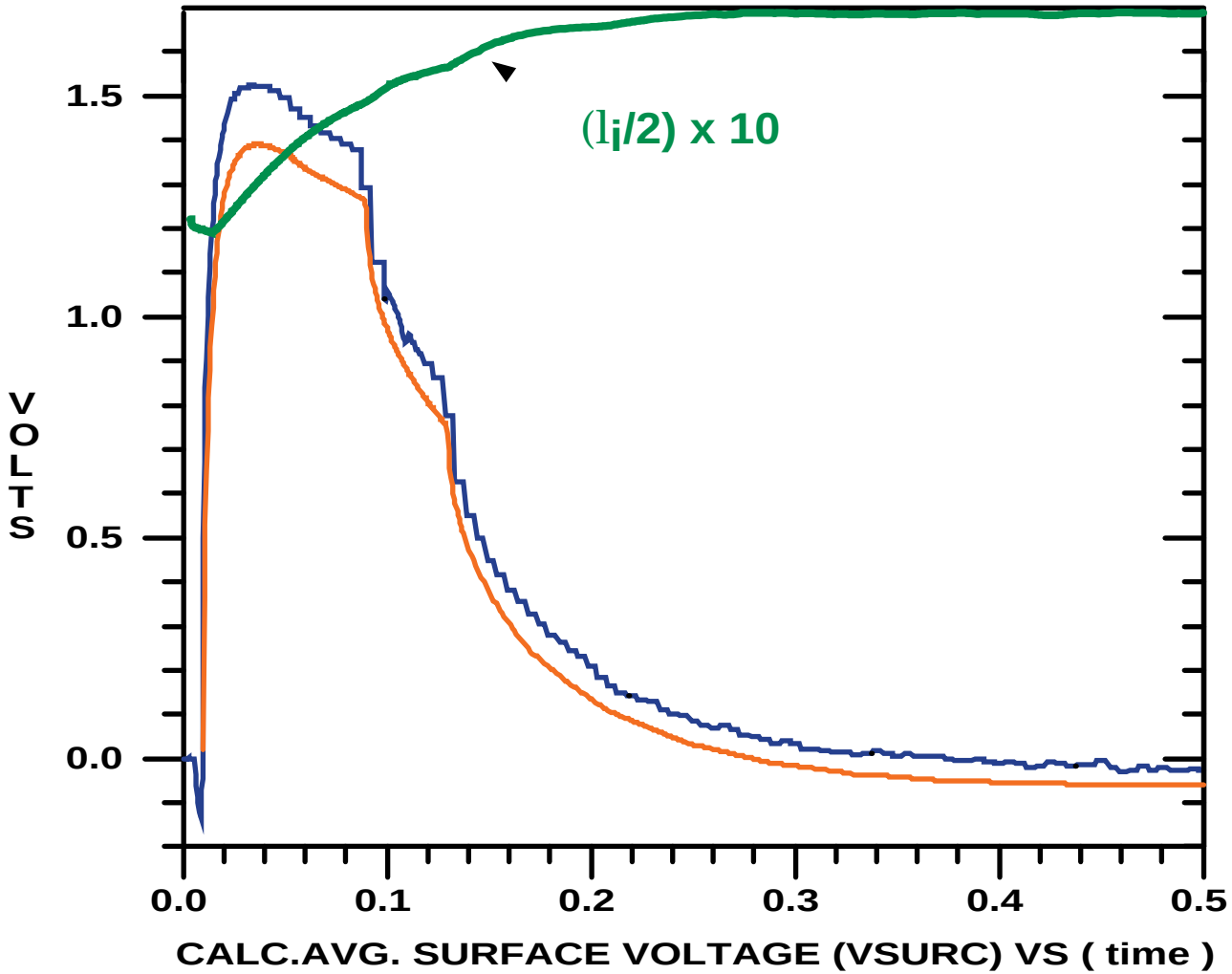
Thus far, all plasma profiles are assumed (asserted). I think the temperature profiles are plausible, the density is high, $\langle n_e \rangle = 7\times10^{13}$ and 11×10^{13} cm^{-3}.


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)

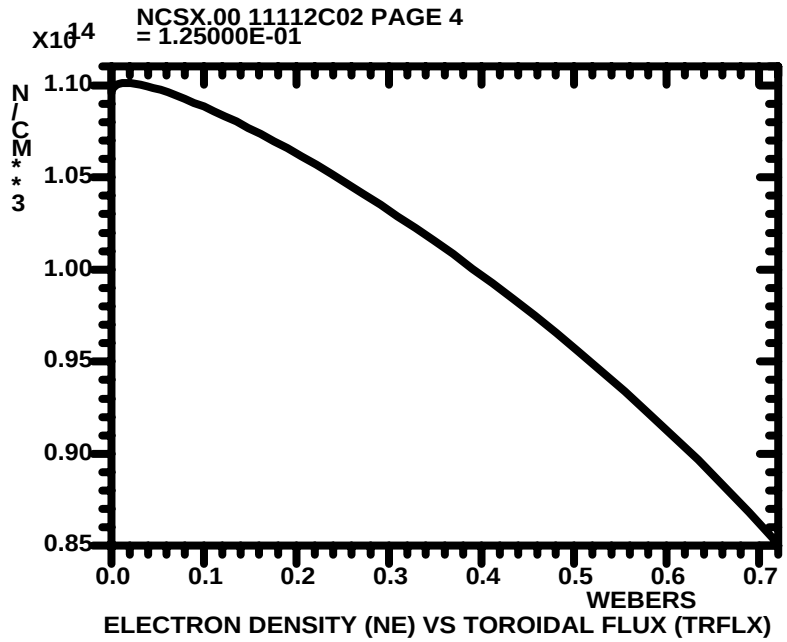

NCSX.00 11112C02 High Density -- Low NBCD
+CUR
+CUROH
+CURGP
+CURBS
+CURB
+LHCUR
AMPS
X10^5
0
1
2
3
4
0.0
0.1
0.2
0.3
0.4
0.5
PLASMA CURRENTS (PCURS) VS (XB)

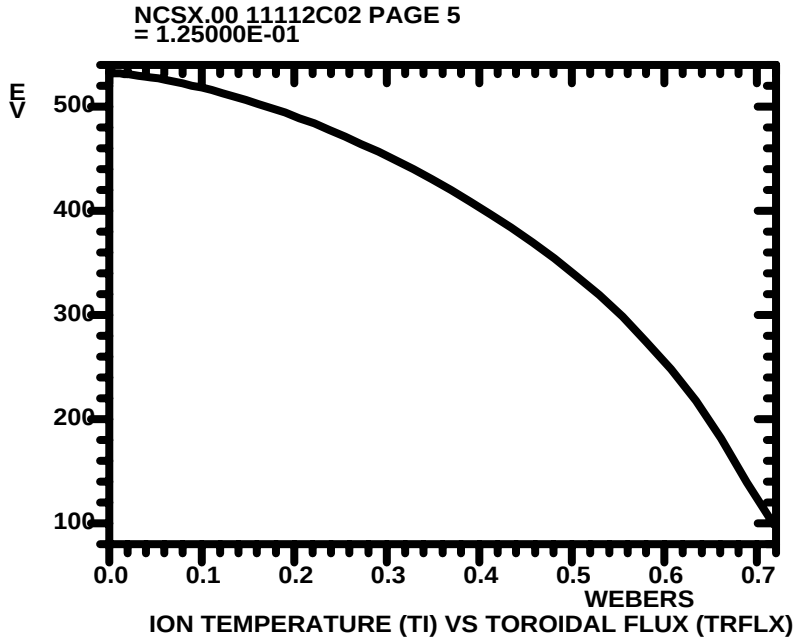

NCSX.00 11112C01 Moderate Density Case
+CUR
+CUROH
+CURGP
+CURBS
+CURB
+LHCUR
AMPS
X10^5
0
1
2
3
4
5
0.0
0.1
0.2
0.3
0.4
0.5
PLASMA CURRENTS (PCURS) VS (XB)

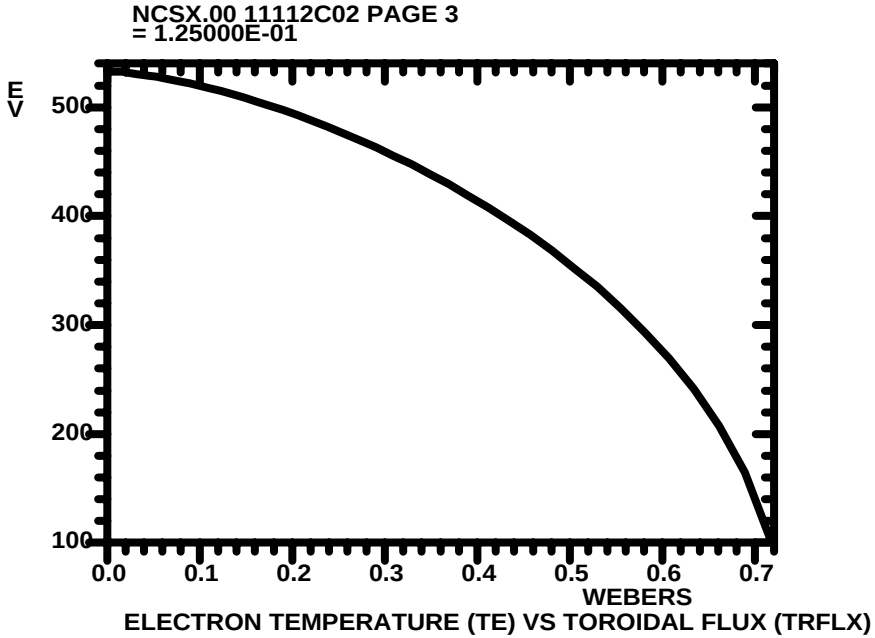
Loop voltage for dIp/dt = 2 MA/s. This shoud be realistic since the configuration does not rely on the avalanche to form the current channel. I would not expect a large breakdown transient as in a tokamak, assuming a significant external transform at t=0.

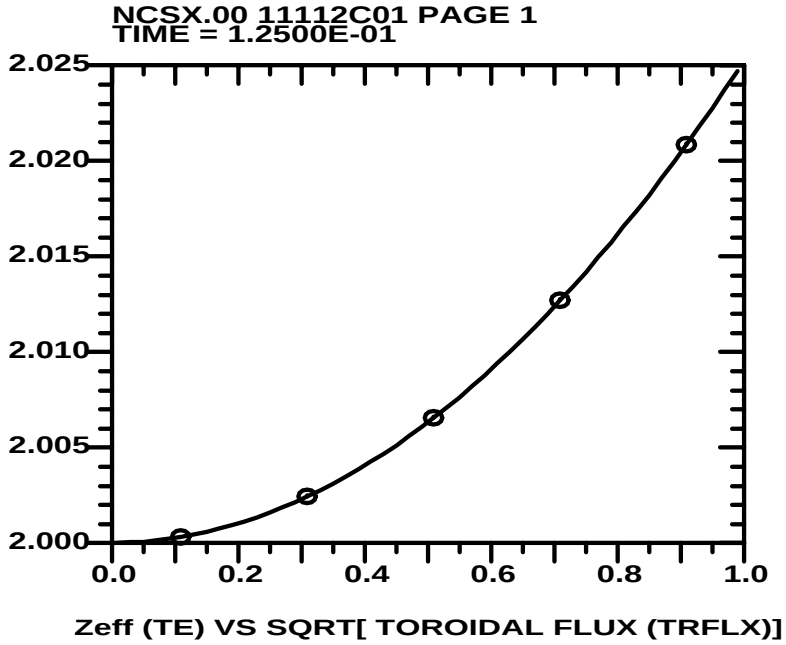


Negative voltage spike an artifact of switching from vacuum fields to plasma with imperfect matching conditions.

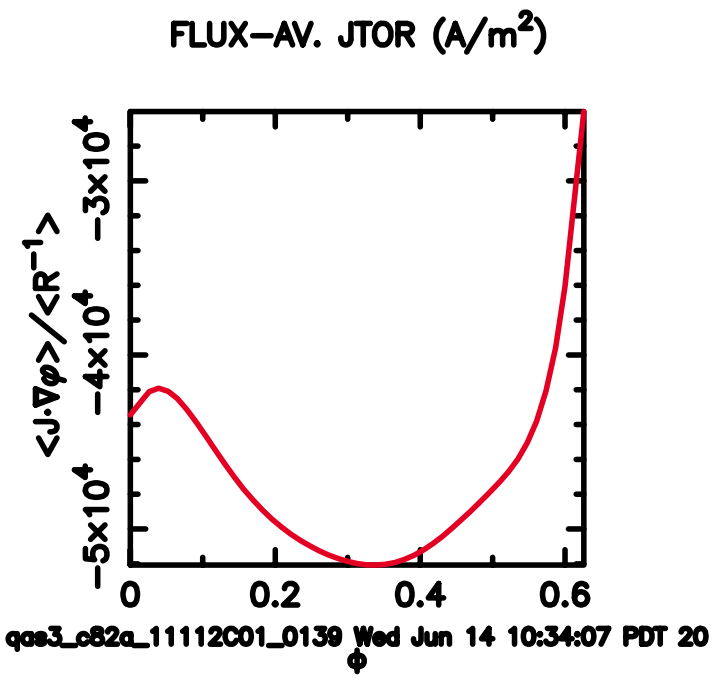


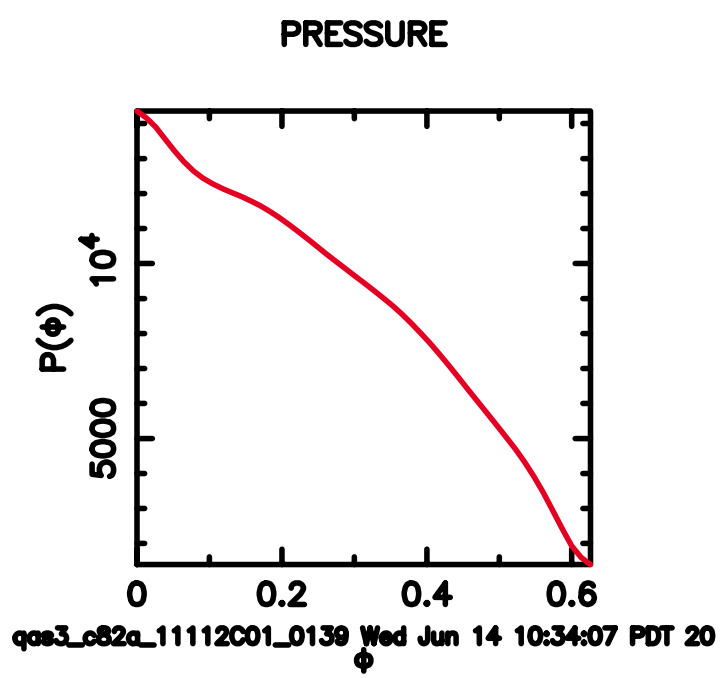




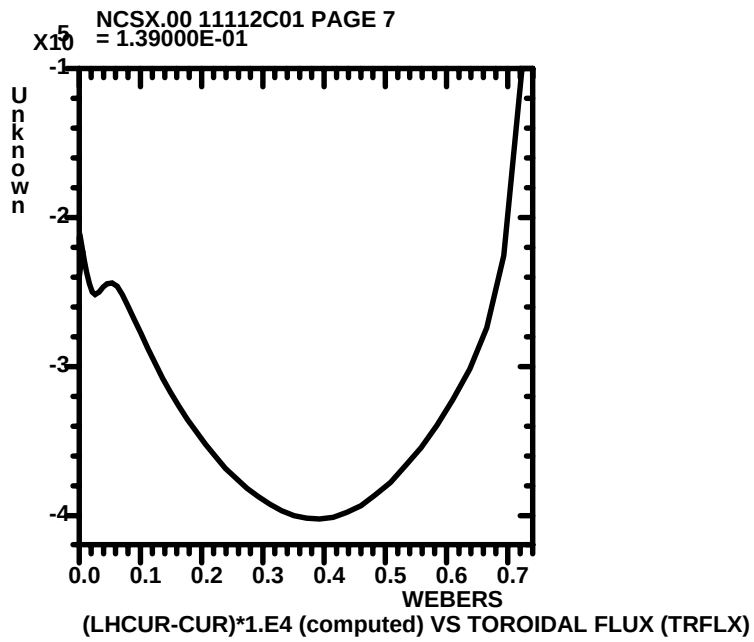


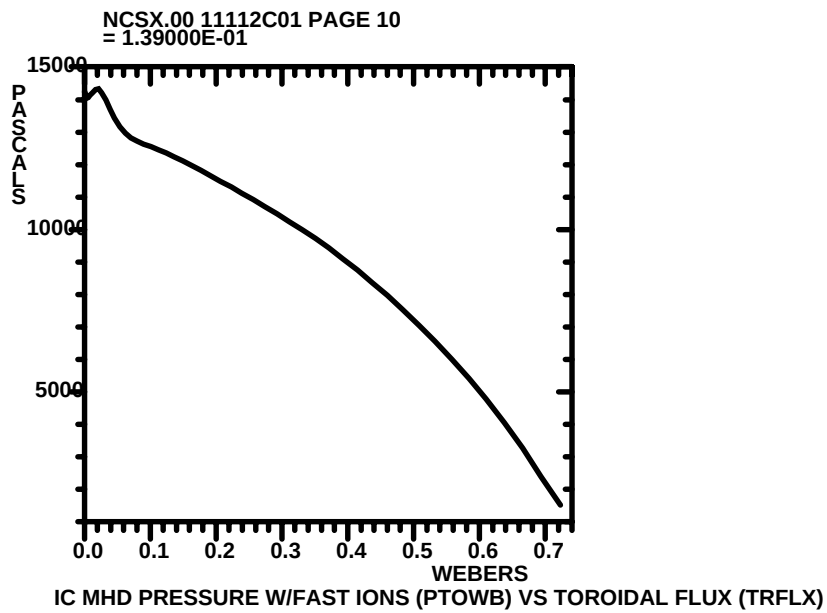
Profiles are imagined, simple functions of toroidal flux

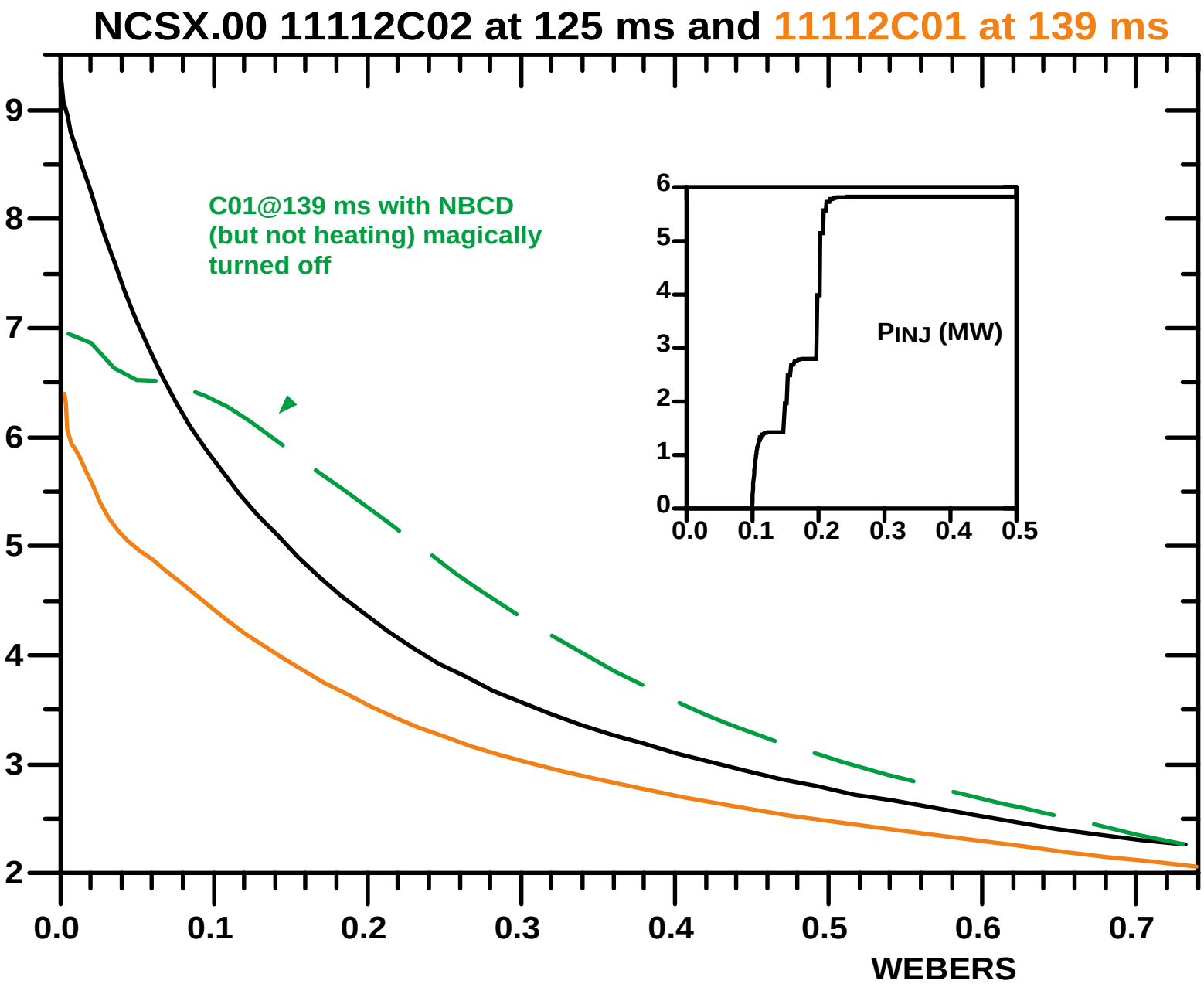




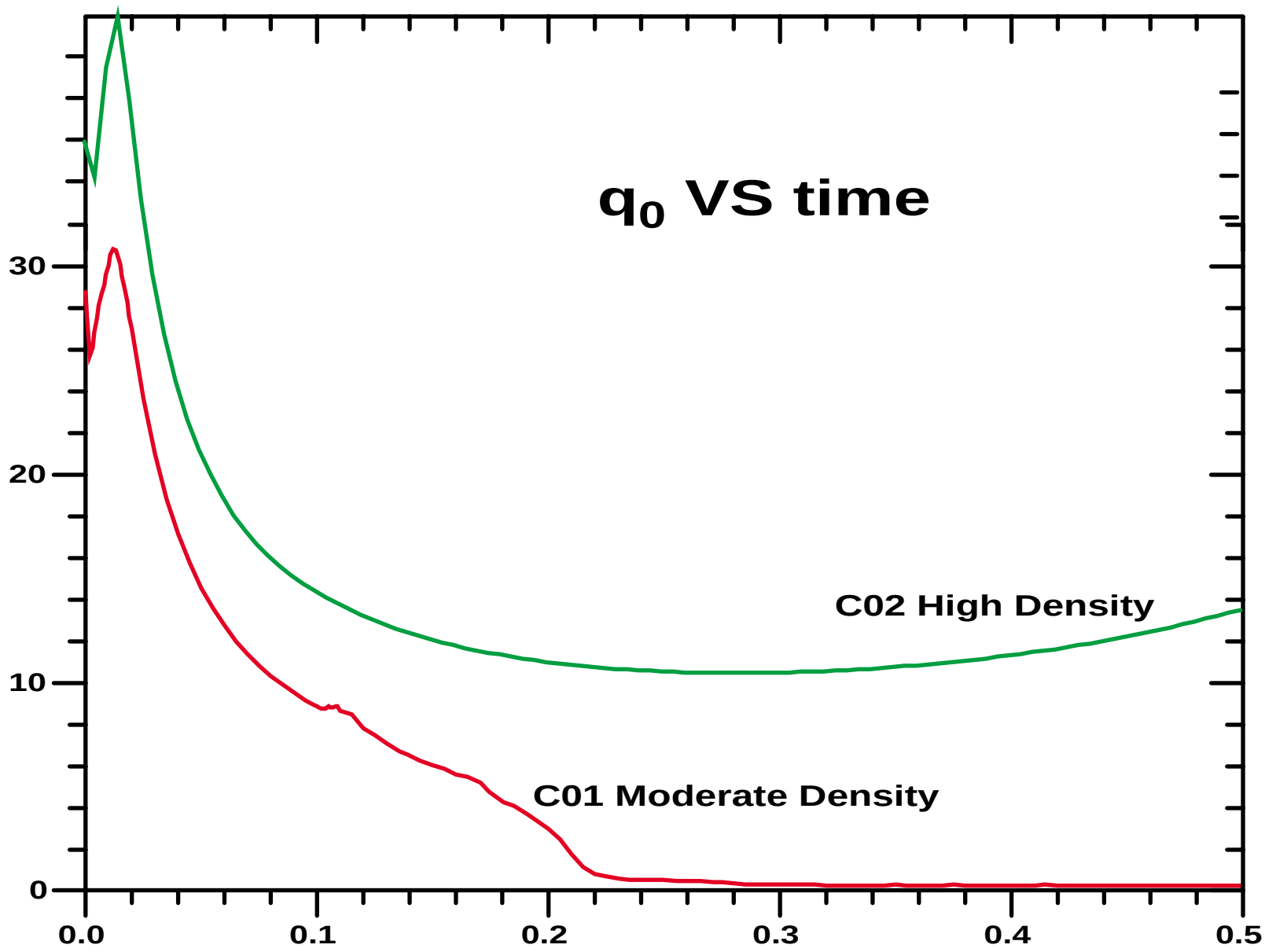
VMEC input and TRANSP output profiles are similar






NCSX.00 11112C02 at 125 ms and 11112C01 at 139 ms
C01@139 ms with NBCD
(but not heating) magically
turned off
PINJ (MW)
9
8
7
6
5
4
3
2
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
WEBERS
Q PROFILE (Q) VS TOROIDAL FLUX (TRFLX)

NBCD drives central q down for a reasonable operating density



VMECINPUT Reads TRANSP output and prepares VMEC input

1) Read PTOWB, CUR, LHCUR, DAREA, XC, XB PCUR

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

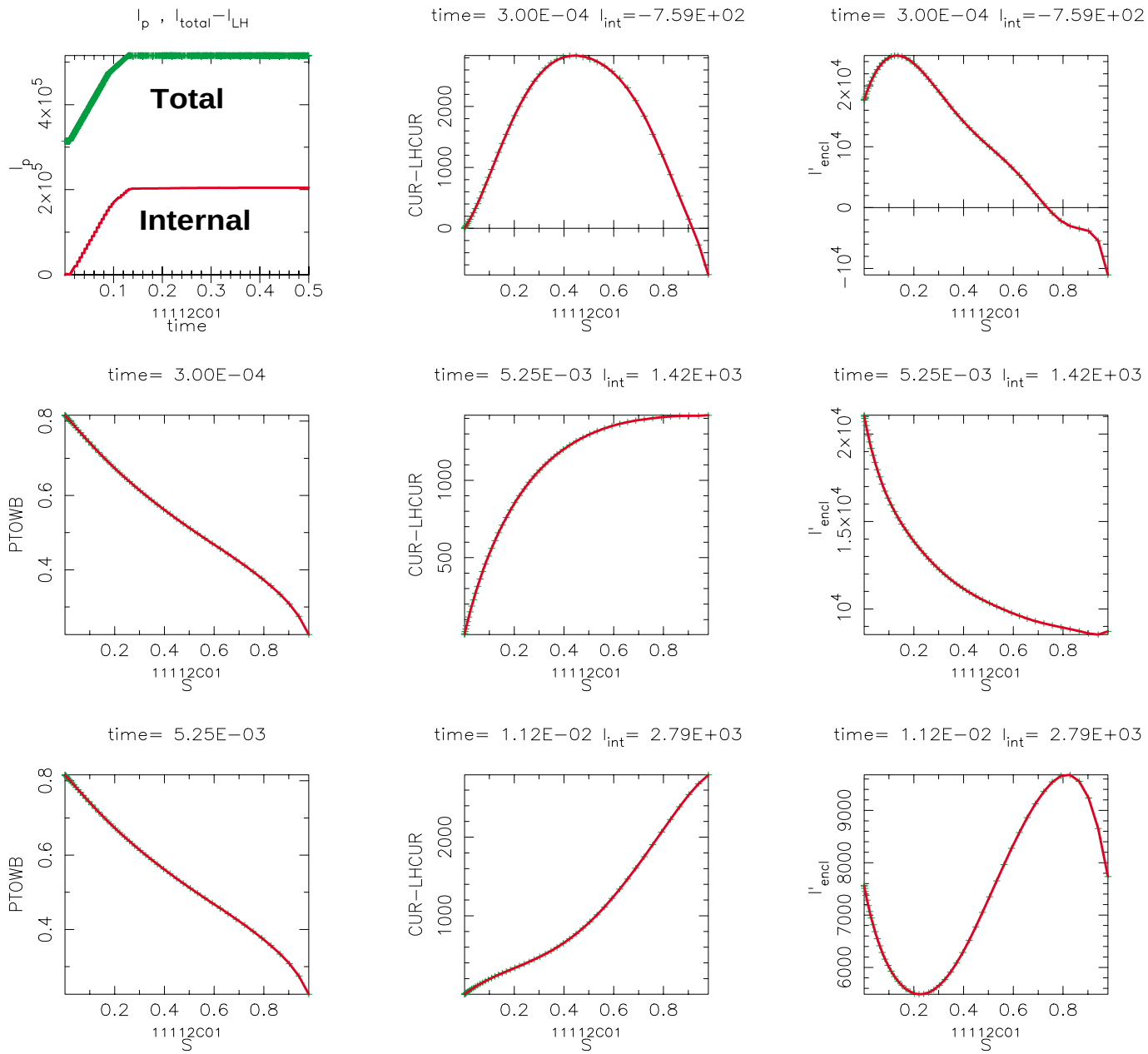
5)Take $d/d(xc^2)$ of SVD

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

7) Some problem when beam adds central peak to pressure - might be better to fit to XC then transform coefficients.

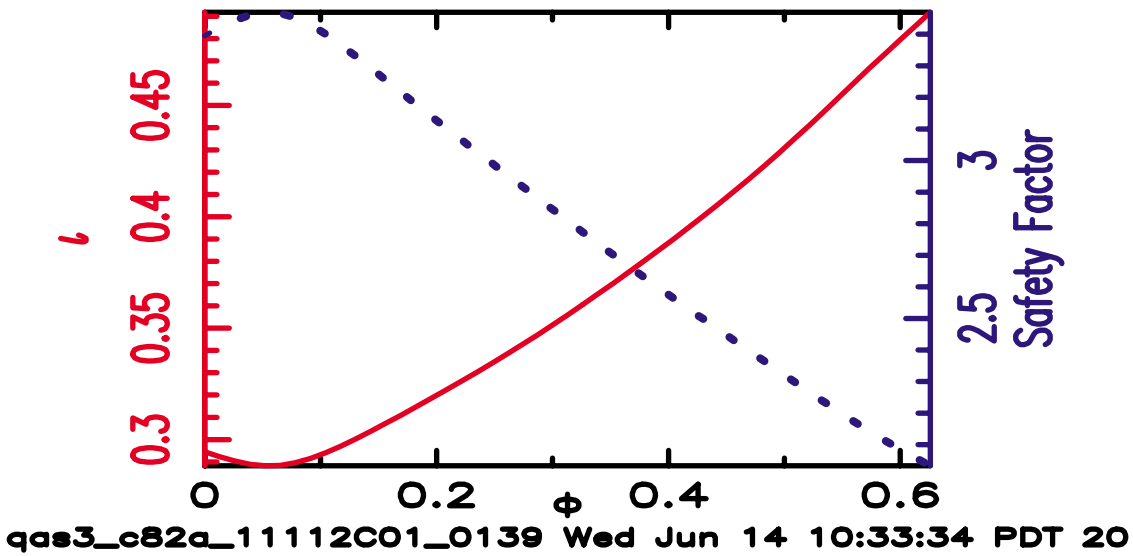
8) All fits are 11 terms to conform to VMEC.

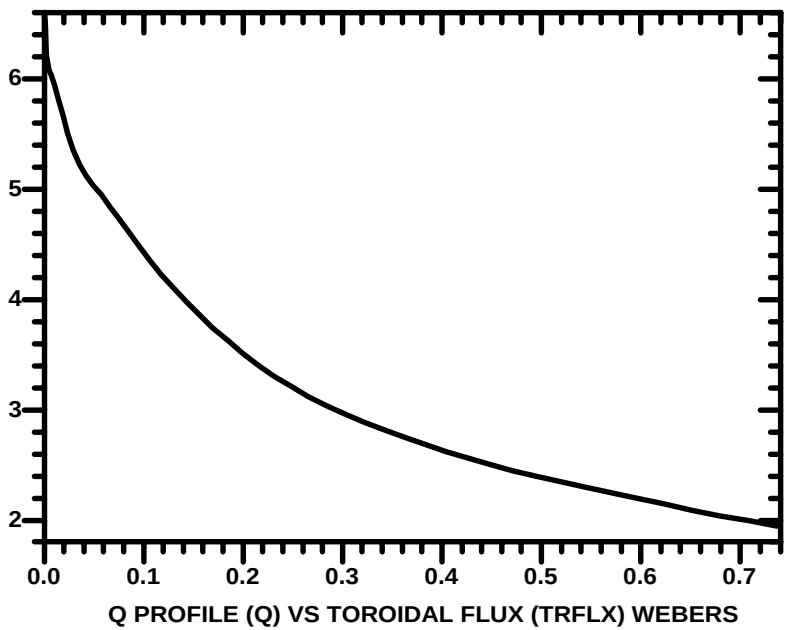
9) 2 dozen fits at equally spaced times from TRANSP run



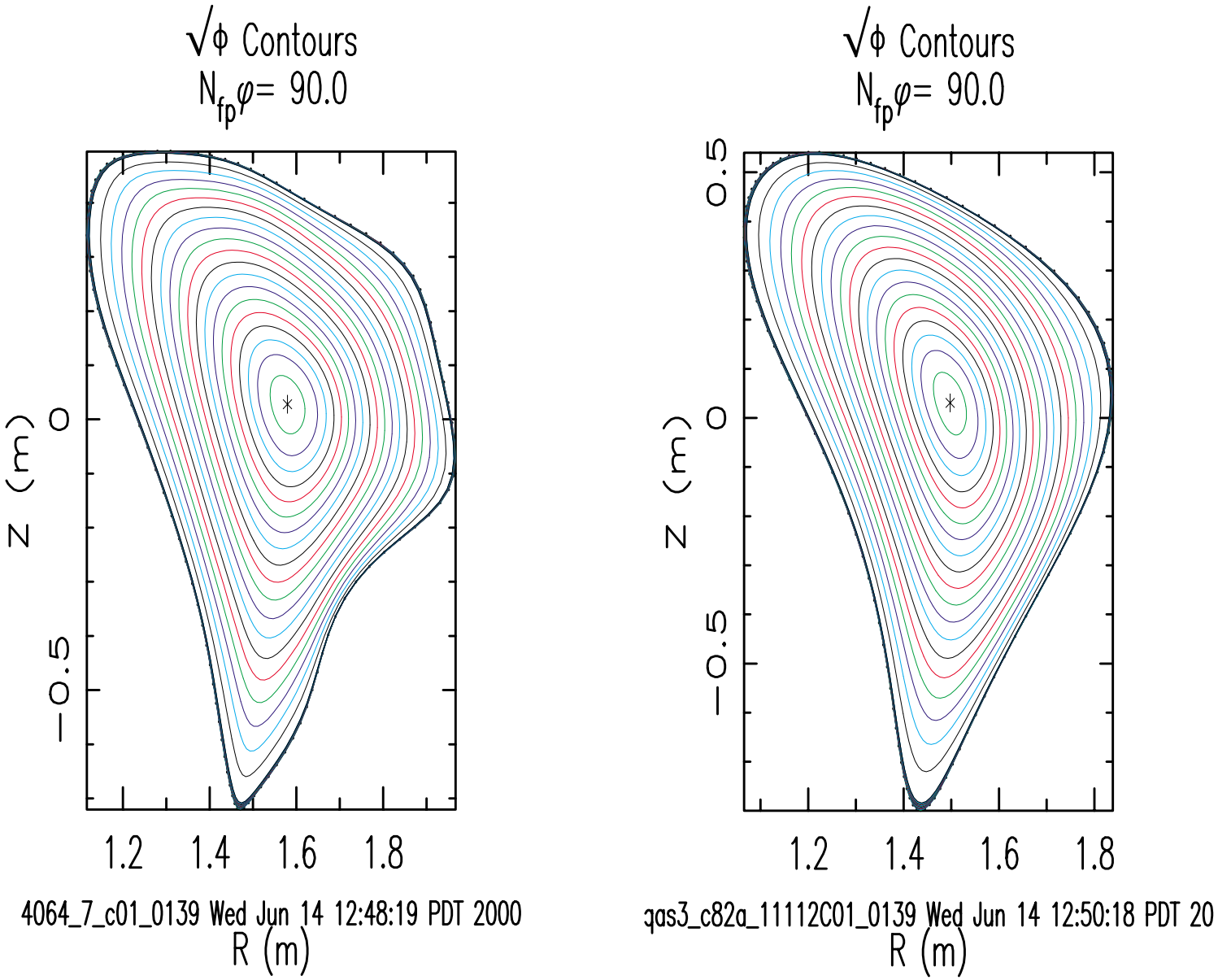
Green = Transp, Red = SVD

There is considerable difference between TRANSP and VMEC q profiles



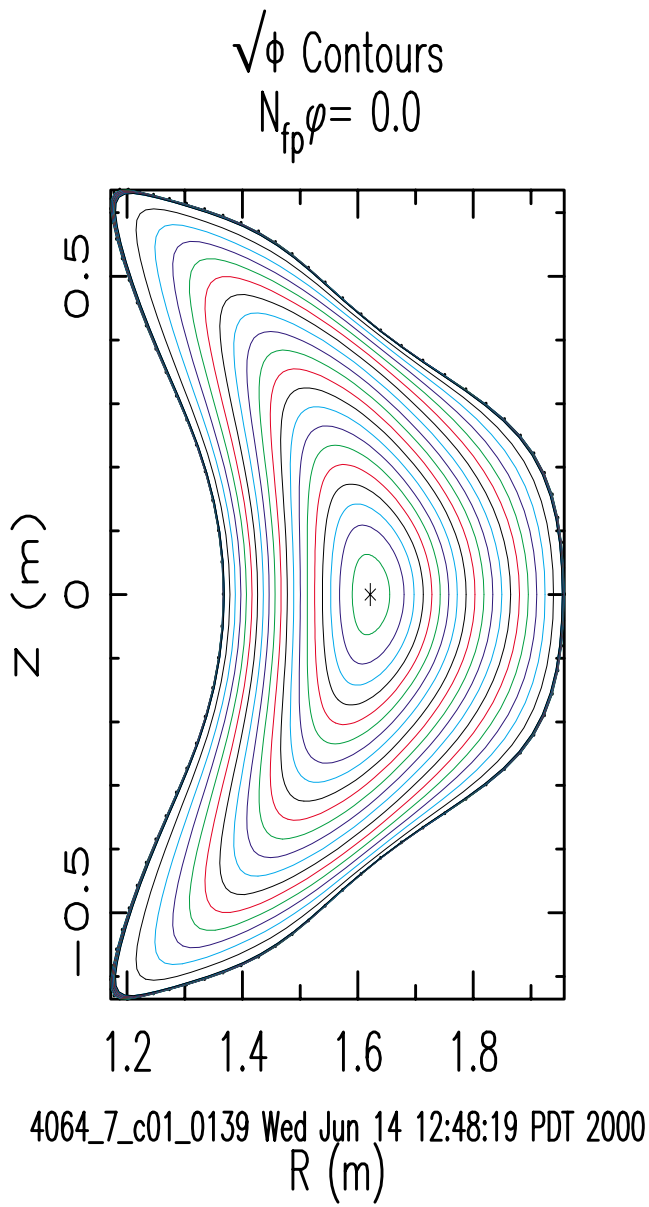


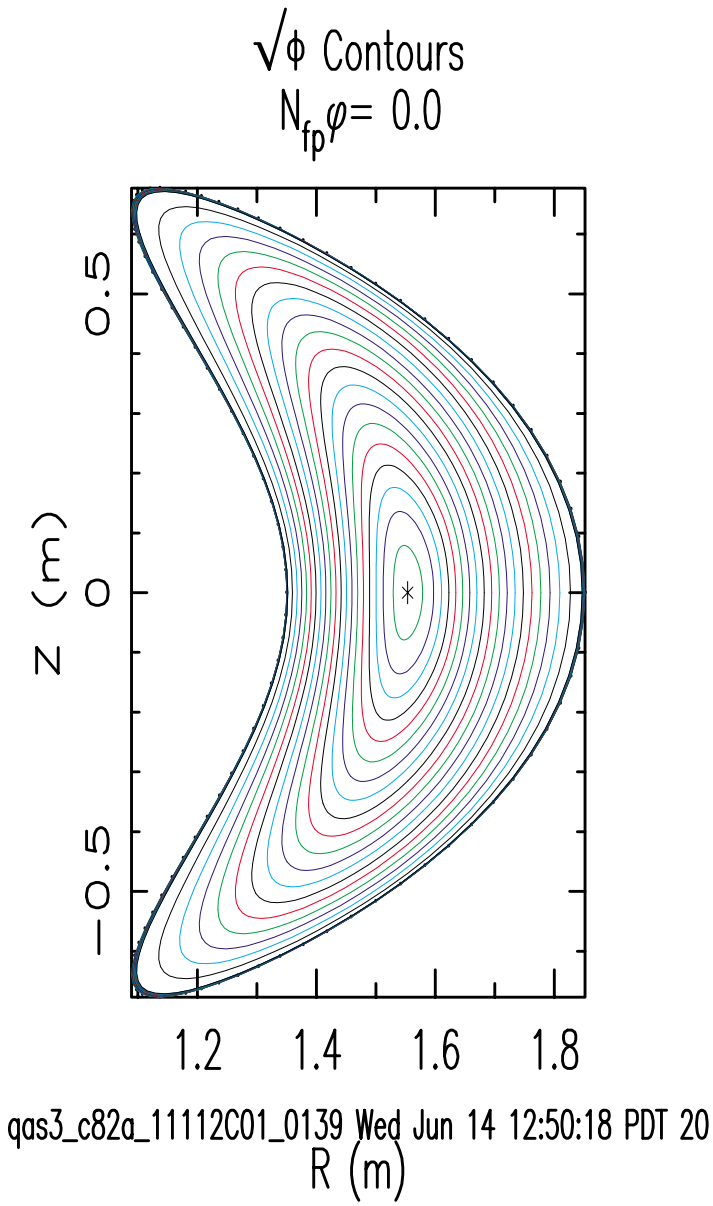
Free and Fixed Boundary Solutions Show Differnces in Shape Which are Likely to Have Consequences for Stability



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

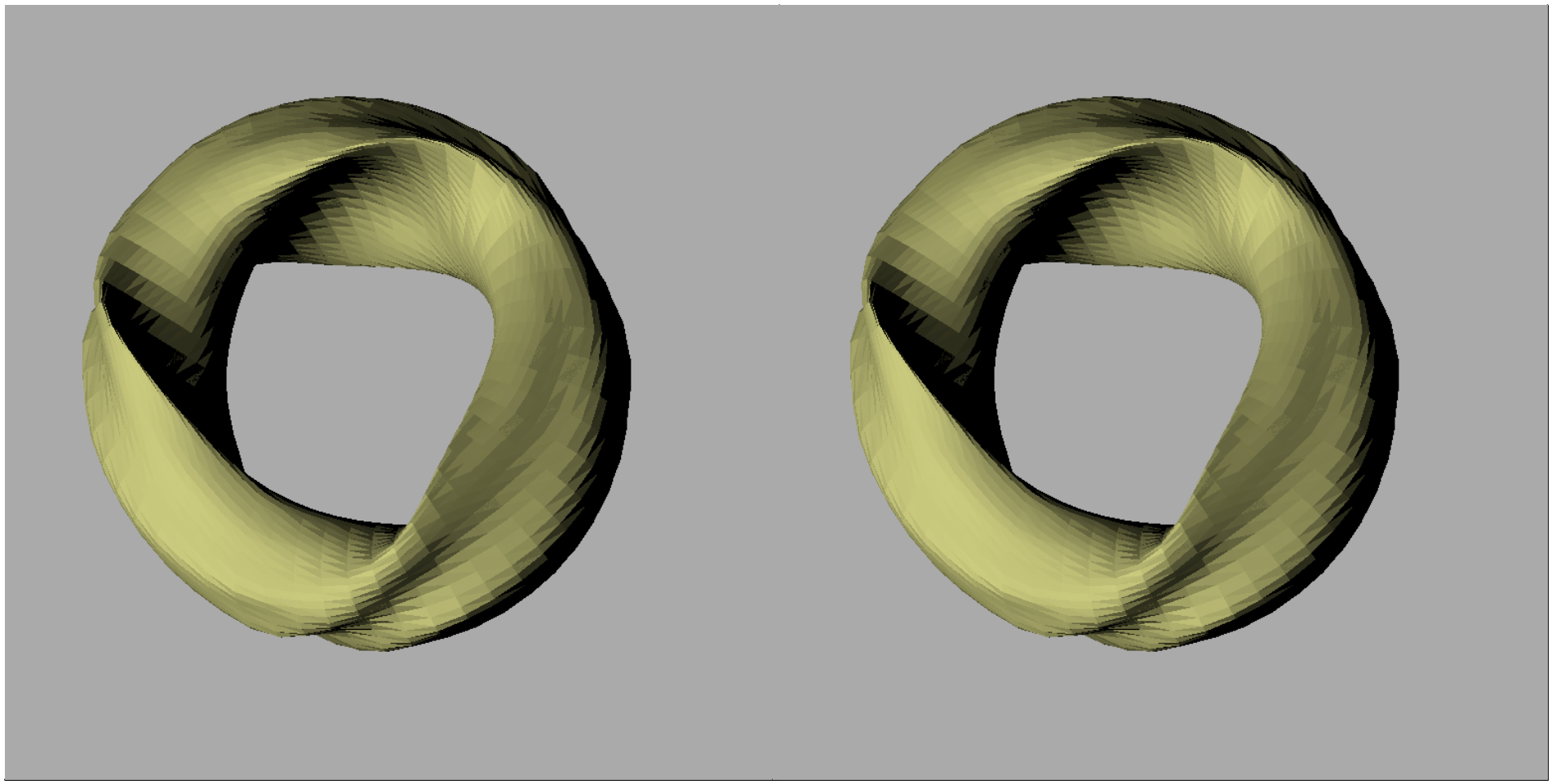
Comparison of Free and Fixed Boundary VMEC solutions
Flux Surface Shape





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

Free Boundary **Fixed Boundary**



Some Comments on Results

The effects of NBCD seem to me quite difficult to overcome. Even the “moderate density is probably too high for the device. It is too soon to say that this is overwhelming, but we need to be thinking about ways to overcome these effects and/or alternative heating.

The difference between q from TRANSP and q from 3-D VMEC needs investigation. Is it real?
If there is a real difference and one is trying to model a discharge evolution which does not introduce rational values, TRANSP may give misleading results.

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. On the other hand, β is lower, perhaps the stability will not be an issue.

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.