Startup Simulation for the C82 Configuration

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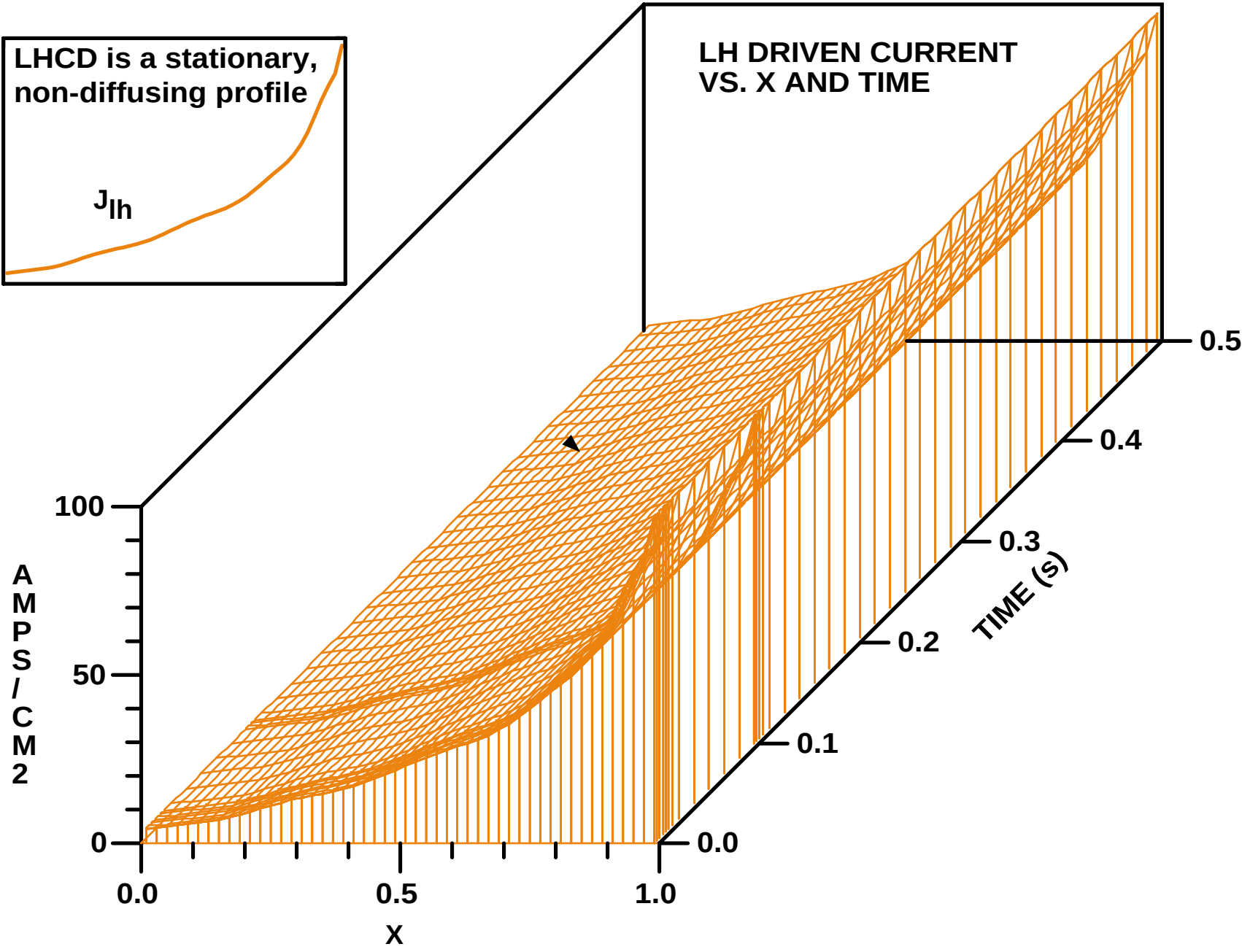
SIMULATING EVOLUTION OF THE CURRENT PROFILE

- **TRANSP is used to simulate the discharge evolution.**
- **Profiles for Te and n_e are assumed , based on tokamak and stellarator experience.**
- **In the context of TRANSP, the external transform is simulated as a lower hybrid driven current, i.e. the LHCD does not diffuse, it is fixed in time.**
- **To determine this LHCD current profile , first the c82a configuration is modified to $\beta = 0$, $I_p = 0$ 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**
- **Now TRANSP is started with this current profile and $\beta \approx 0$**

  ($T(0) \approx 50$ eV, $\langle n_e \rangle \approx 5 \times 10^{12}$ cm^{-3}).

$$x = \sqrt{s} = \sqrt{\Phi / \Phi_B}$$

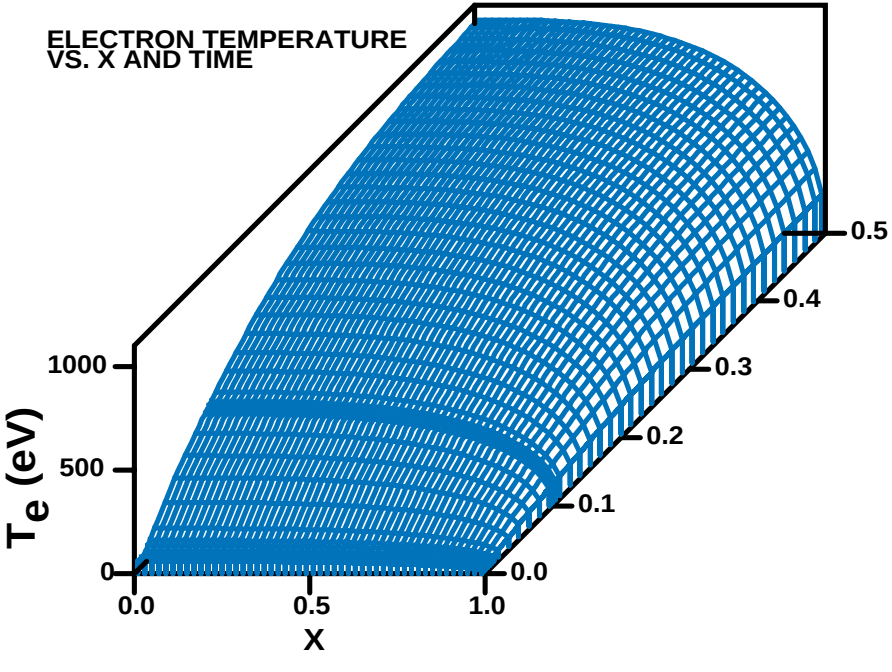
The external transform of C82 is simulated as LHCD in Transp.



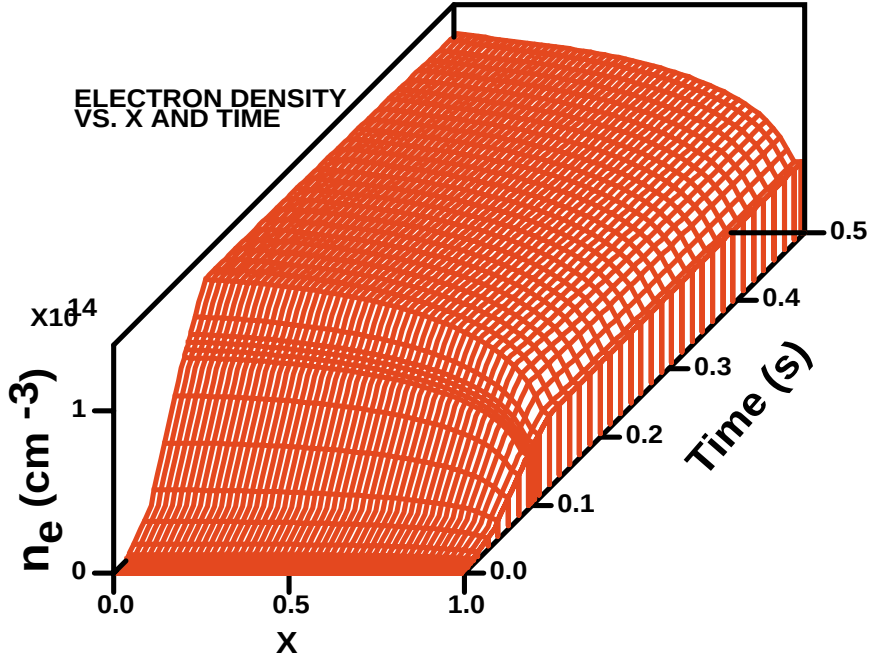
- **The first results I will show have no NBI applied.**
  - **(As will be seen, NBCD for coinjected beams presents problems.)**
- **As the profiles are simply assumed here, I will begin without the heating. (The assumed profiles do give the expected $\beta \approx$ 4% at $\langle n_e \rangle \approx 11 \times 10^{13}$ cm^{-3}.)**
- **The focus here is on the evolution of iota and the various contributions to it.**

Profiles are simple functions $(1-x^m)^n$
T_i, similar to T_e, is obtained by the constraint $\chi_i=\chi_e$

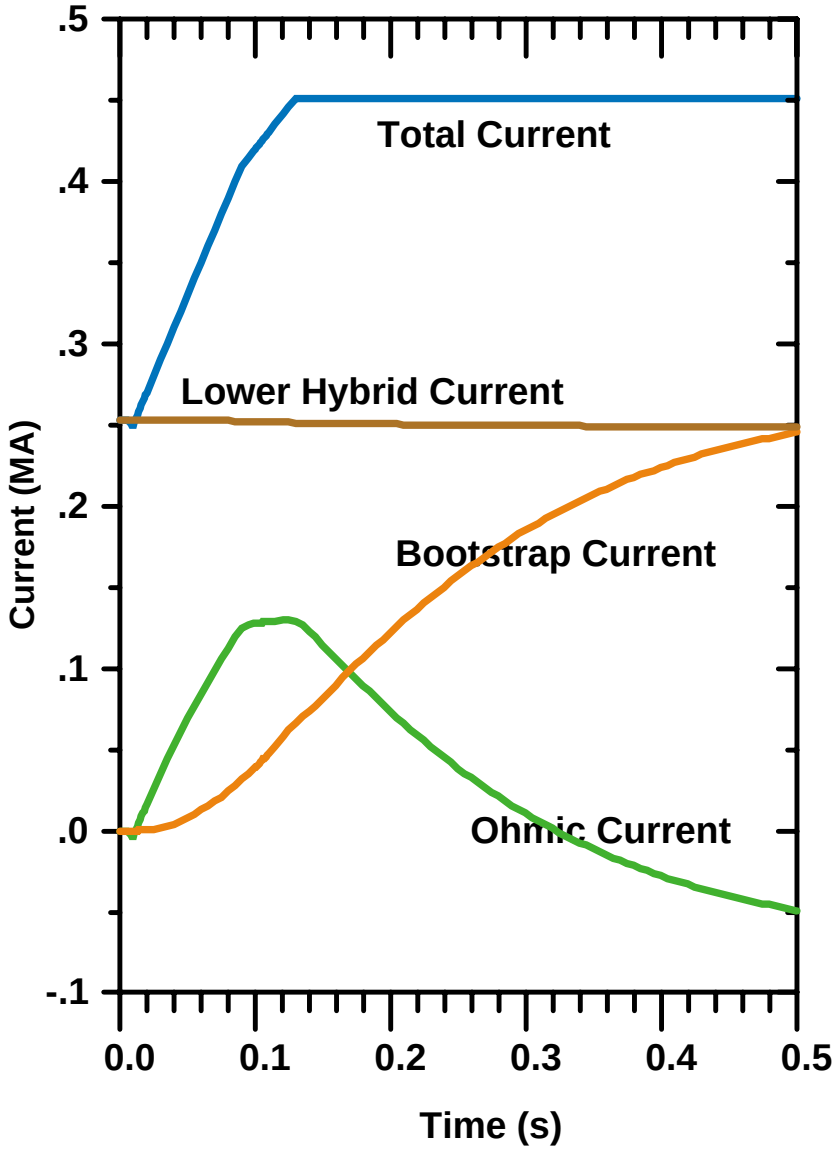
$m = 2,\ n = \frac{3}{2}$



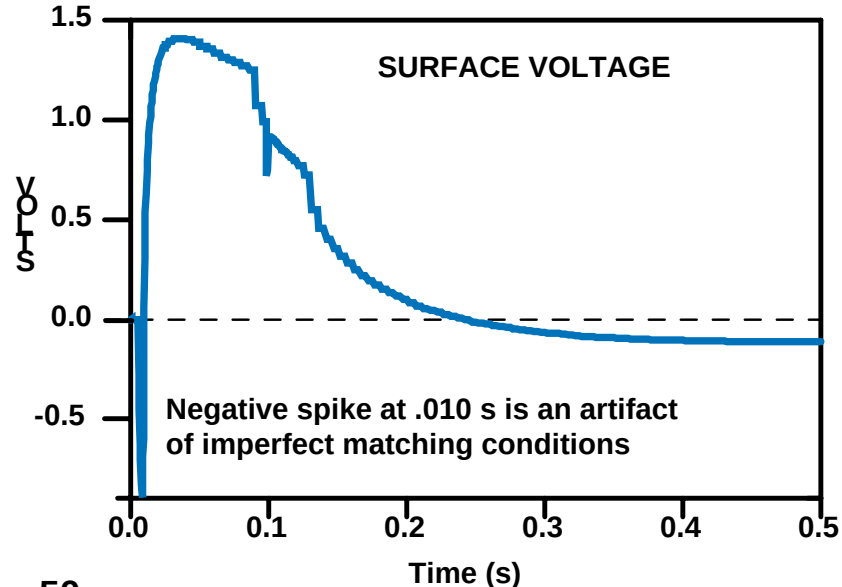
$m = 2,\ n = \frac{1}{2}$

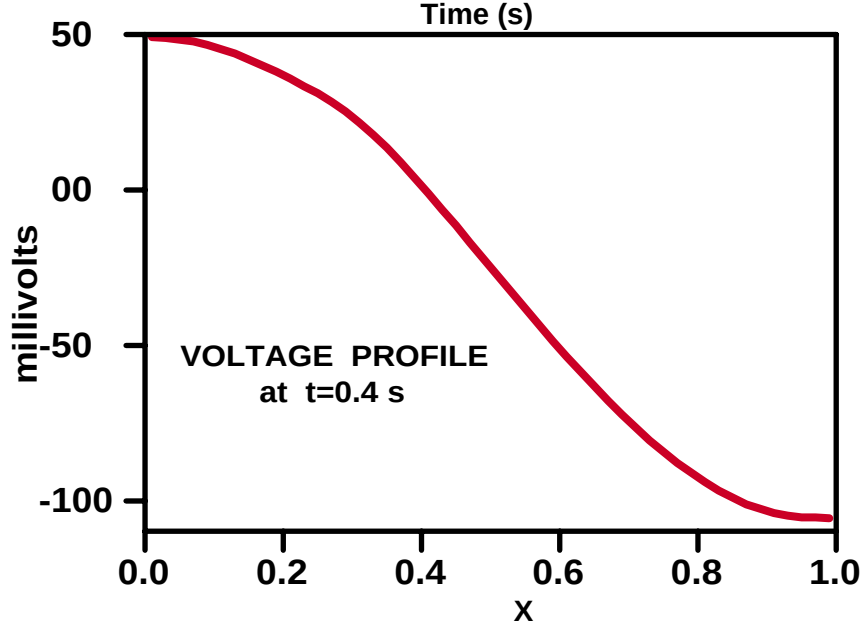


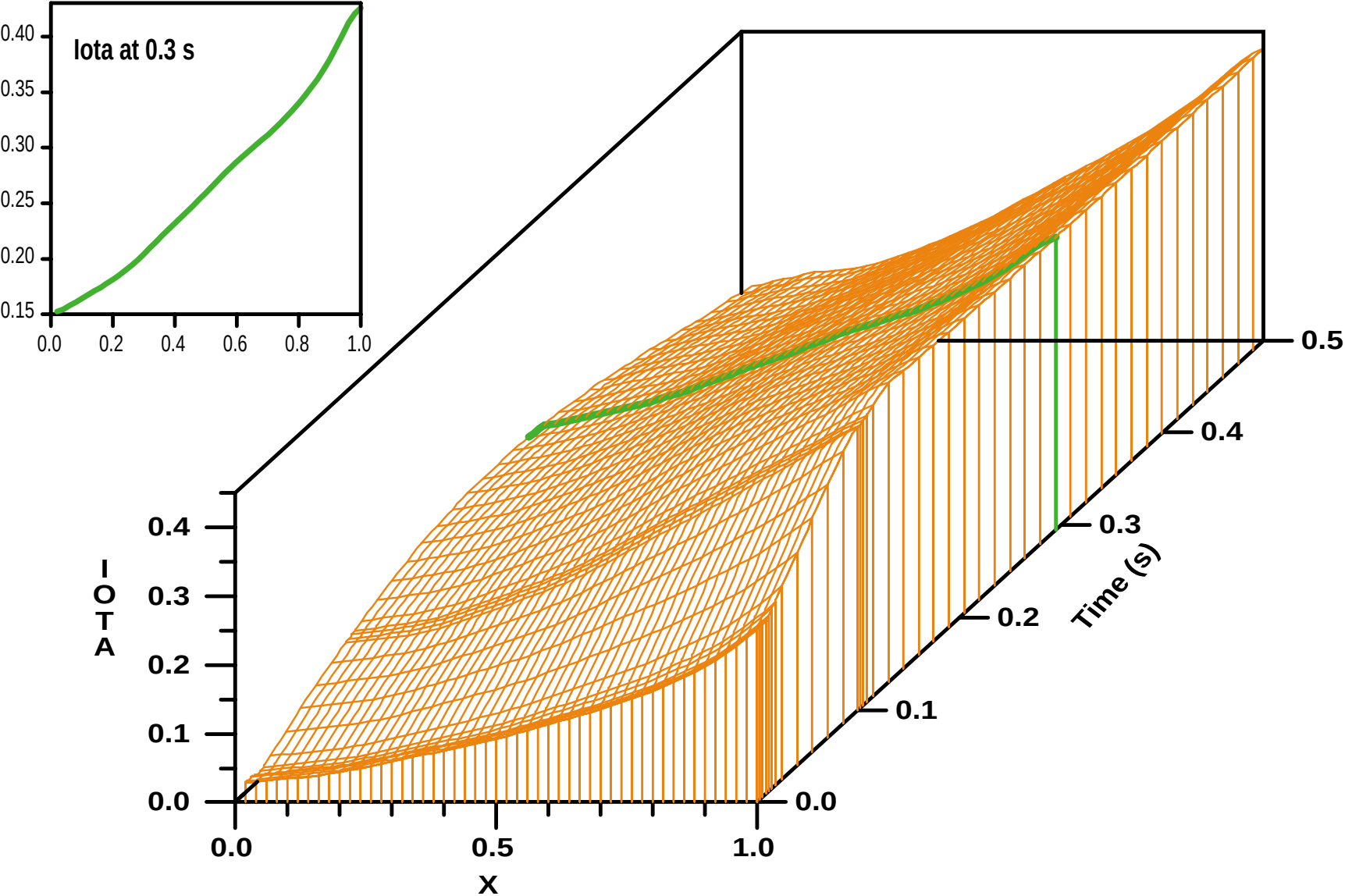
Time Evolution of Plasma Current Components



($\beta \approx$ 4.4% at t=0.4 s)







In the case of no NBI the evolution of ι will depend on confinement. Profiles similar to those desired in C82 seem plausible. Equilibration in 0.5 seconds also appears plausible.

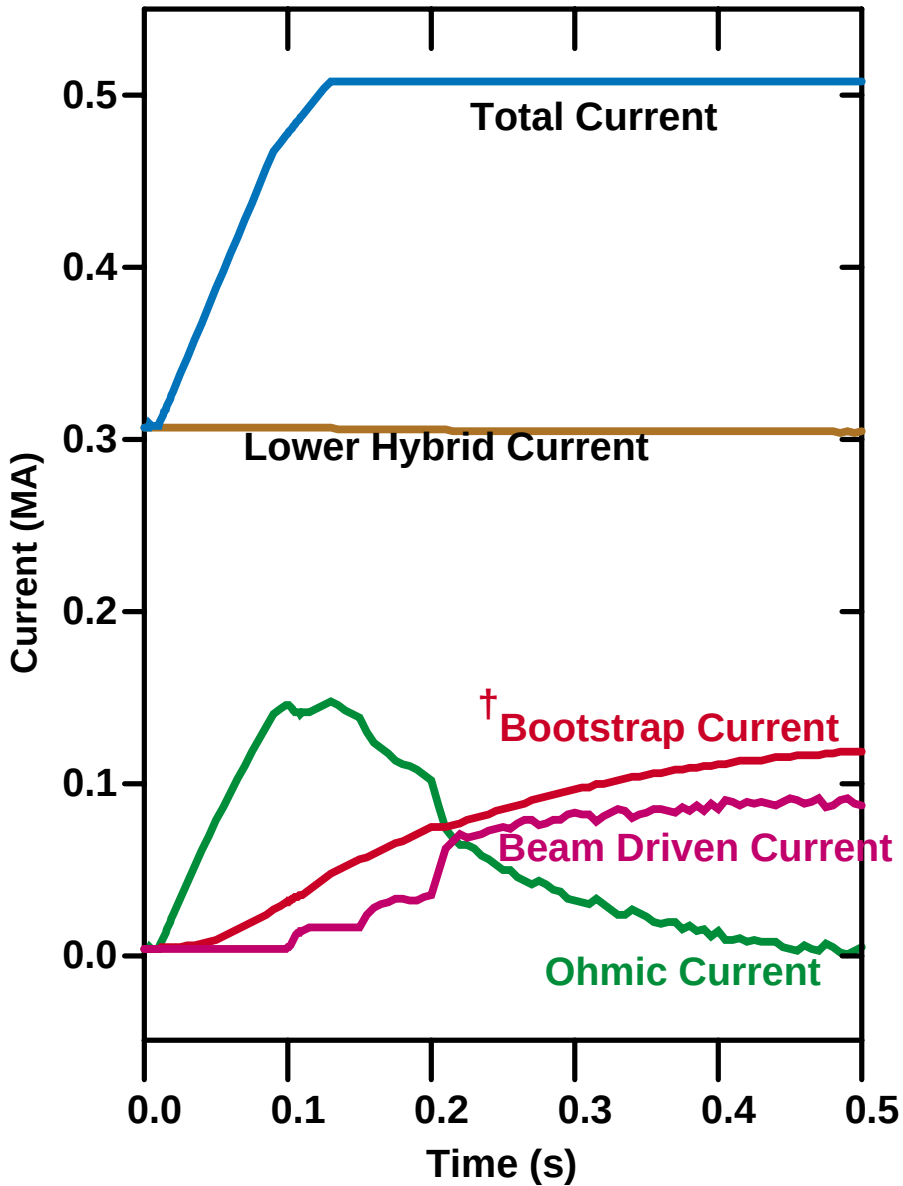
IMPLICATIONS OF SYSTEM REQUIREMENTS

- **In the absence of neutral beams it appears that reaching equilibration with an iota reasonably close to the reference point might be done in 400 ms,**
- **The case shown is somewhat over driven in that the plasma current demand is too small to accommodate the LHCD and bootstrap current. When a better match is made we have seen loop voltage of less then 70 mv across the plasma**
- **In a real experiment the capability to switch from plasma current control to loop voltage control would be needed.**
- **The voltage requirements with an I_p ramp rate of 2 MA/s are modest.**

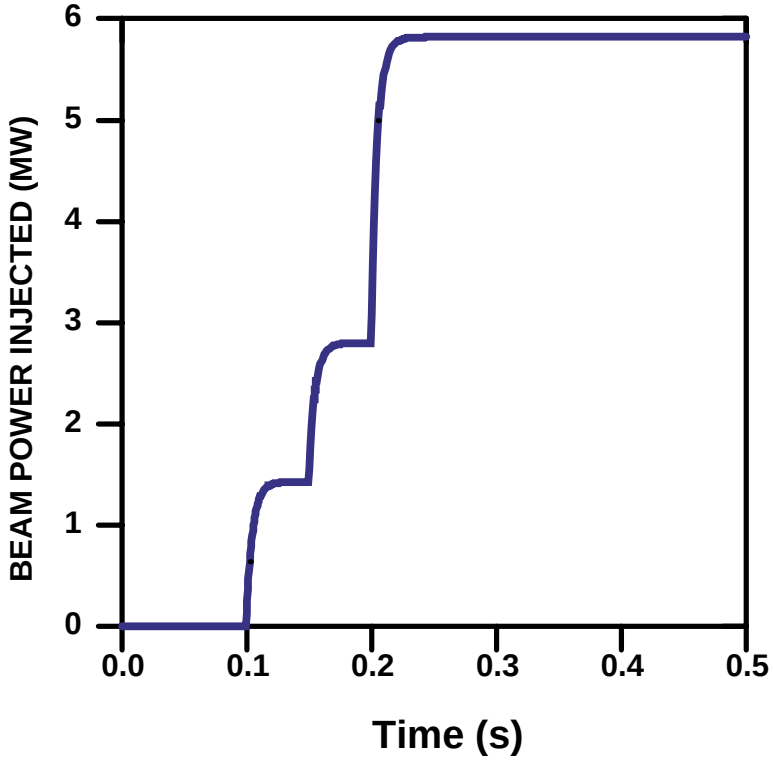
EFFECTS OF CO INJECTED NEUTRAL BEAM

- **TRANSP has a very convenient switch which allows the user to deny the existence of neutral beam current drive while including heating and a fast ion pressure.**
- **We can use this to directly observe the effects of NBCD on the q profile.**
- **To more clearly show the effects of NBCD, we have lowered the density to $\langle n_e \rangle \approx 7 \times 10^{13}$ cm^{-3}. At still lower density the direct effect of peaking the pressure profile and the current drive effect will worsen.**
  - **NBCD ~ 1 / n^2**

In this lower density case, <ne>=7x10^{13}, with 6 MW NBI, the NBCD becomes comparable to I_{BS} , but centrally peaked.



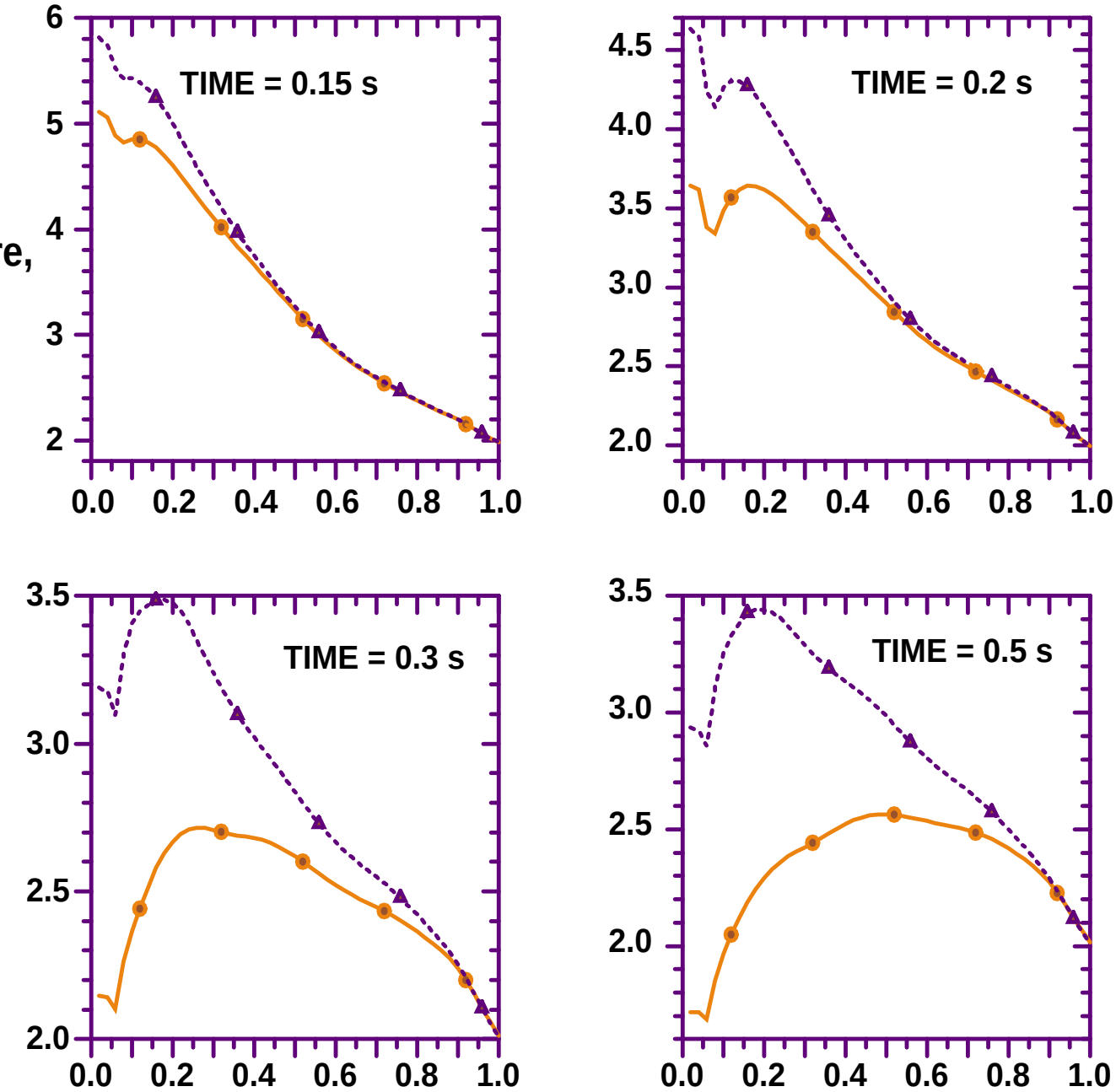
($\beta \approx$ 3.3% at t=0.4 s)



†Lower I_{BS} lies mainly in *grad* n term

Q - Profiles at selected times with NBI

- Dashed line has NBCD magically turned off, but not the fast ion pressure, in order to illustrate the effect of NBCD on the safetey factor.
- The solid line has the NBCD turned on.



CONCLUSIONS

- **A 300 ms heating pulse should be adequate for equilibration of the current profile at Te(0) ~ 1 keV**
- **Loop voltage requirements are expected to be modest for dI_p/dt ~ 2 MA/s**
- **Co-injected NBI may not be attractive for the current profile evolution**

NEXT STEPS

The first thing we need to do is to extract the results from a TRANSP run and use the profiles of pressure and (total current – lower hybrid current) in VMEC to produce free boundary equilibria.

- **This will allow us to that it is possible to preserve the plasma shape with these profiles with coil currents which are within acceptable limits.**

- **Once this is done, the time series of equilibria need to be studied/reoptimized for transport and stability. Making the same shape as the c82 configuration may not be the desired trajectory of the discharge.**
- **The surface quality will need to be examined with PIES**

Then there are other tasks:

- **varying the I_p ramp rate and profile shapes**
- **replace the profile shapes with transport models**
- **work on the most likely configuration.**