PIES applications to NCSX

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Purpose of this Study

- Assessment of NCSX plasma configurations
- Assessment of 3-D MHD tools (PIES and VMEC)

Outline

- Description of new iteration procedure for PIES code
- C82 flux surface quality
  C82 is a QAS candidate configuration for the NCSX experiment.
- W7-AS flux surface quality at finite current
- Evidence of the violation of the Hamada Condition in VMEC equilibria

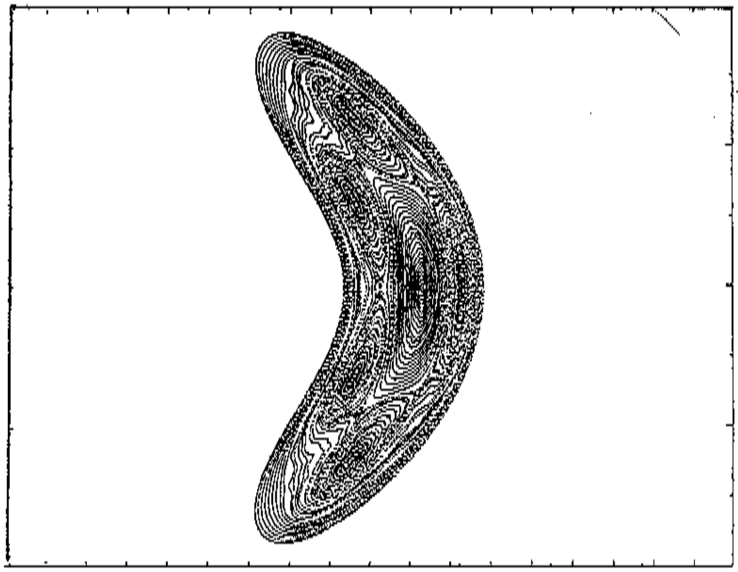
- New Blending Procedure in the PIES Code

Illustration of Problem
Using W7X Configuration

Results with old blending scheme
Large change in Poincare Plot from the VMEC solution
on the very first iteration

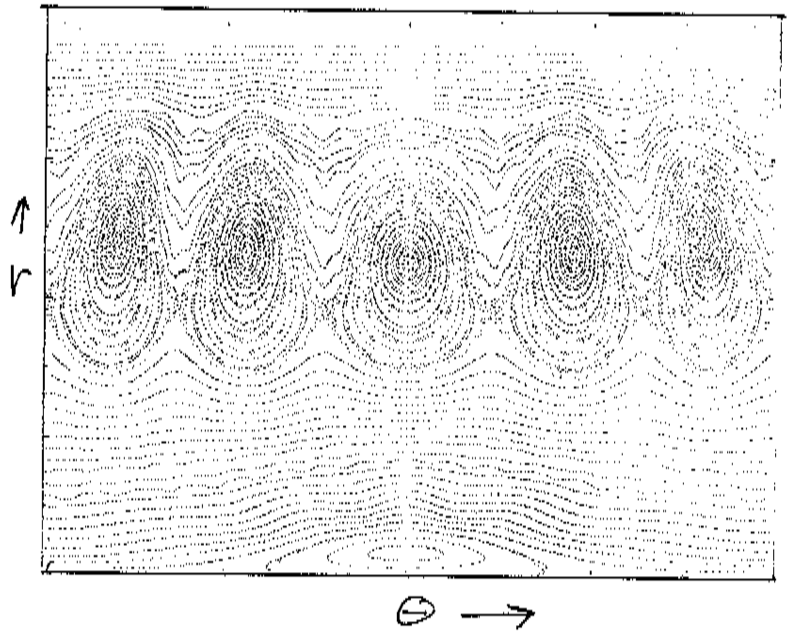
ITERATION 1

REAL SPACE

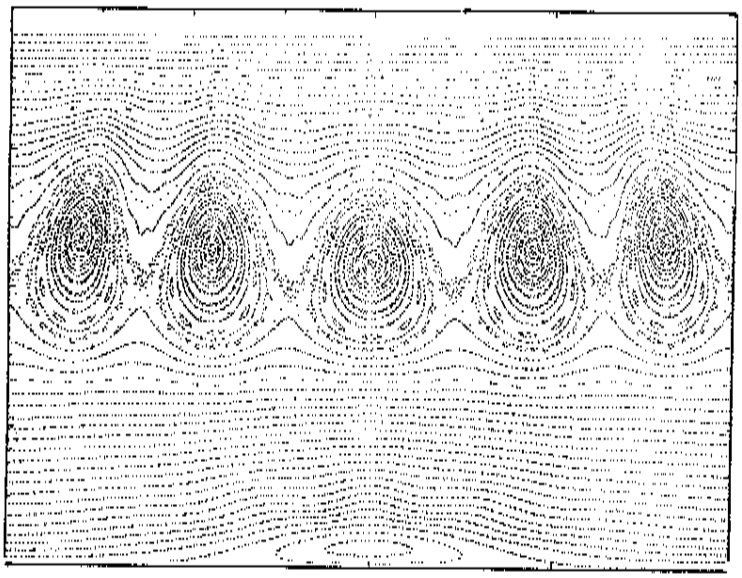


ITERATION 1

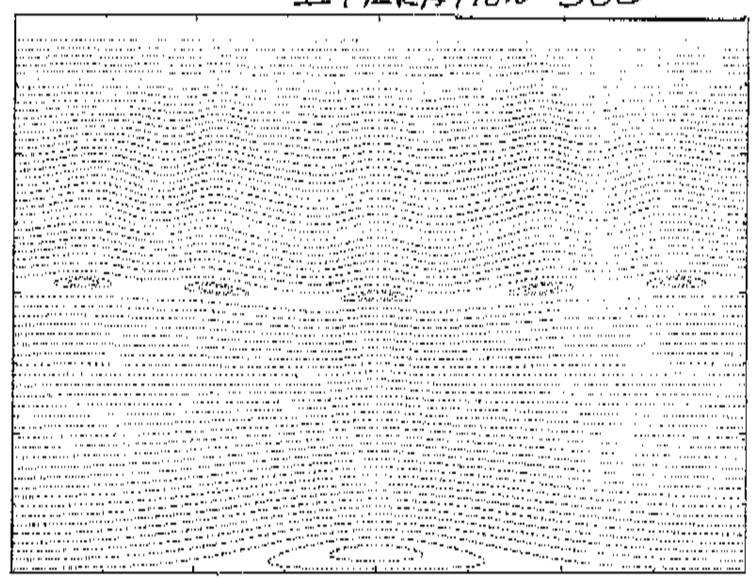
BACKGROUN COORDINATES



ITERATION 10



ITERATION 300



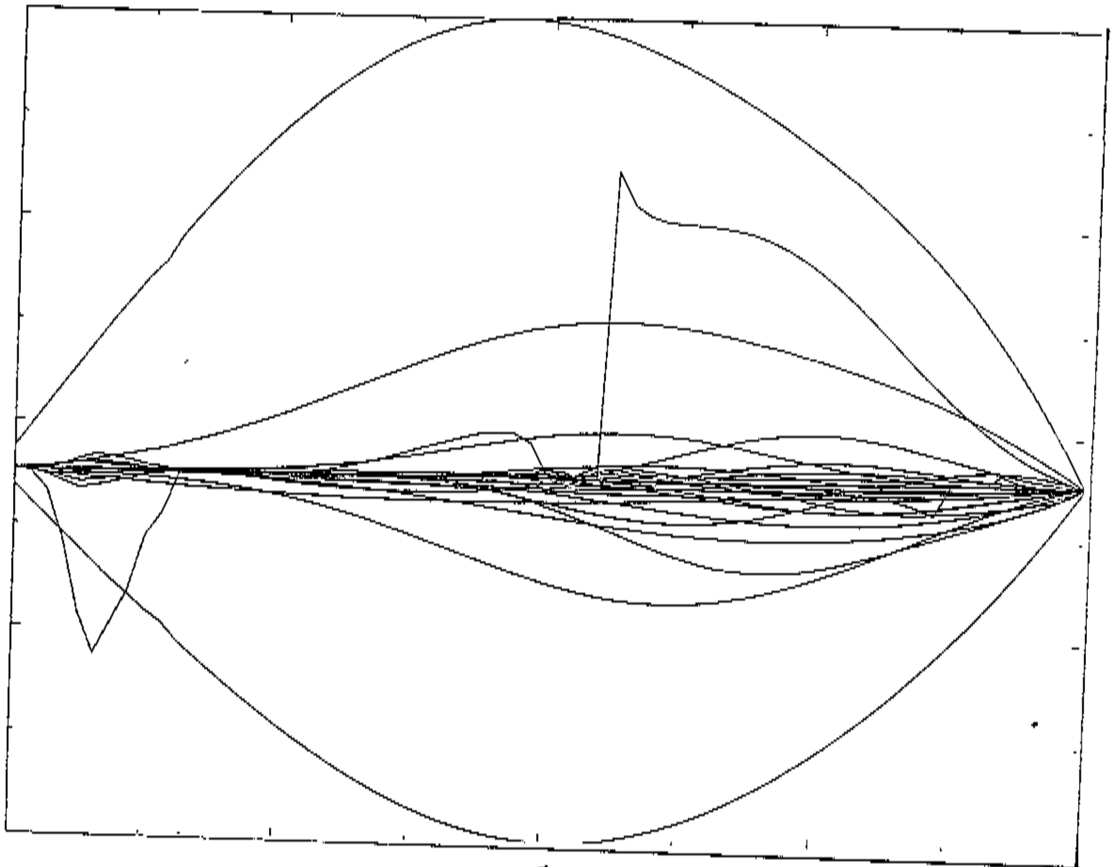
ITERATION ∅

- Reason for this large change on the first iteration:
  PIES calculates large Pfirsch-Schlüter currents on the 0th iteration.
  (These large currents are not present in VMEC solution -
  more on this subject later)

0th ITERATION

$\mu = \frac{J \cdot B}{B^2}$

(HARMONICS)

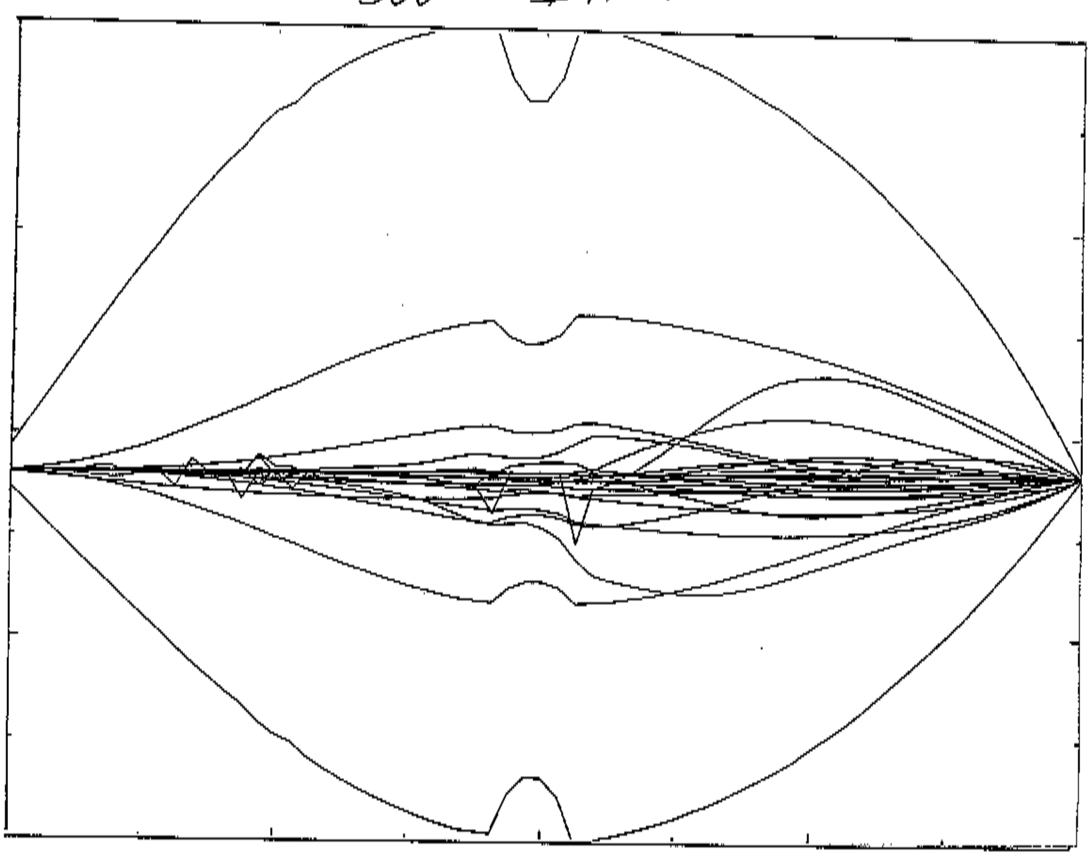


r/a →

300th ITERATION

$\mu = \frac{J \cdot B}{B^2}$

(HARMONICS)

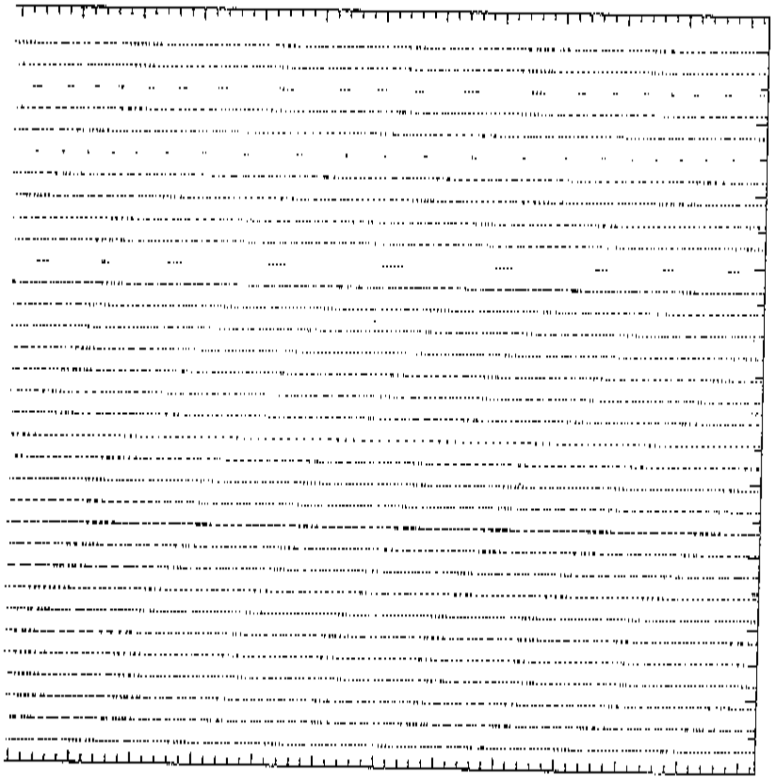


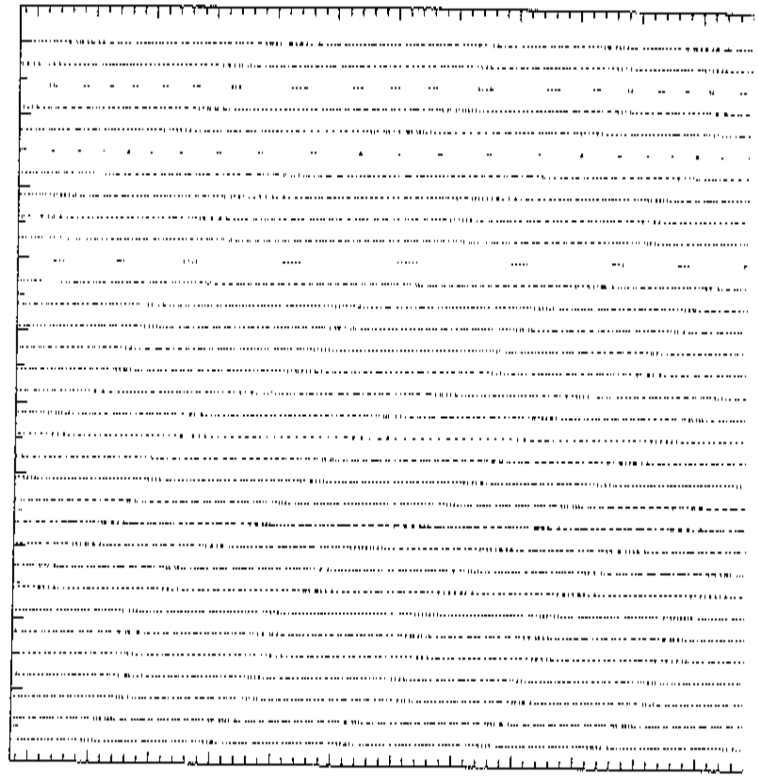
r/a

- Remedy is to blend magnetic fields rather than the currents as is presently done in PIES

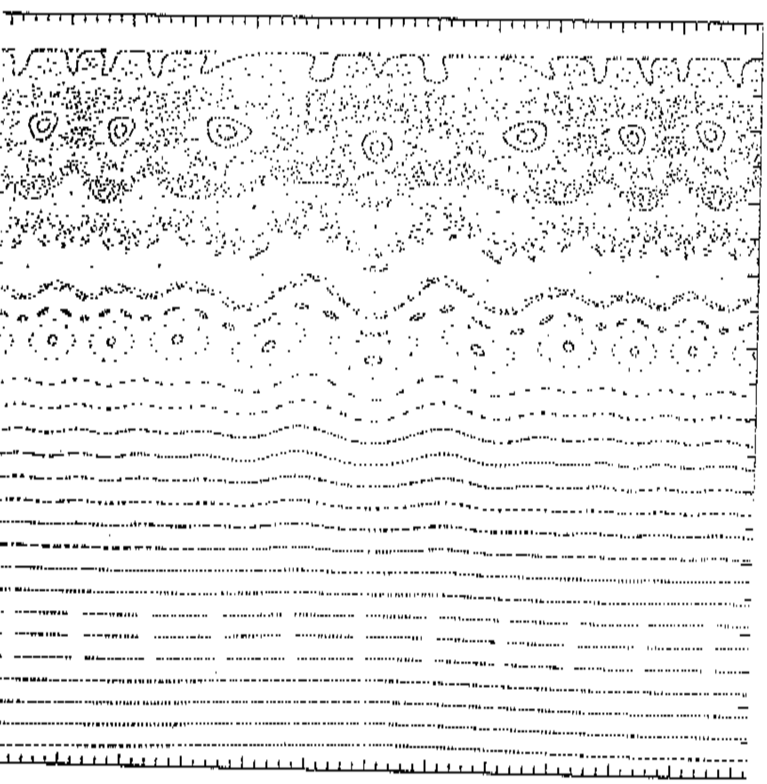
  Illustrate results using new scheme by applying it to C82 at Full Current and Full (4%) Beta

0th ITERATION

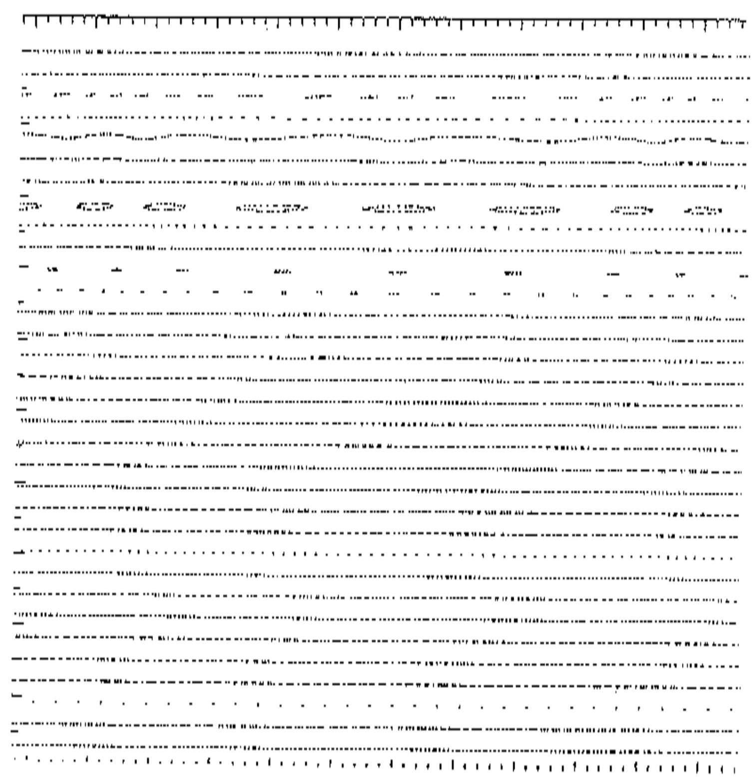




1st ITERATION

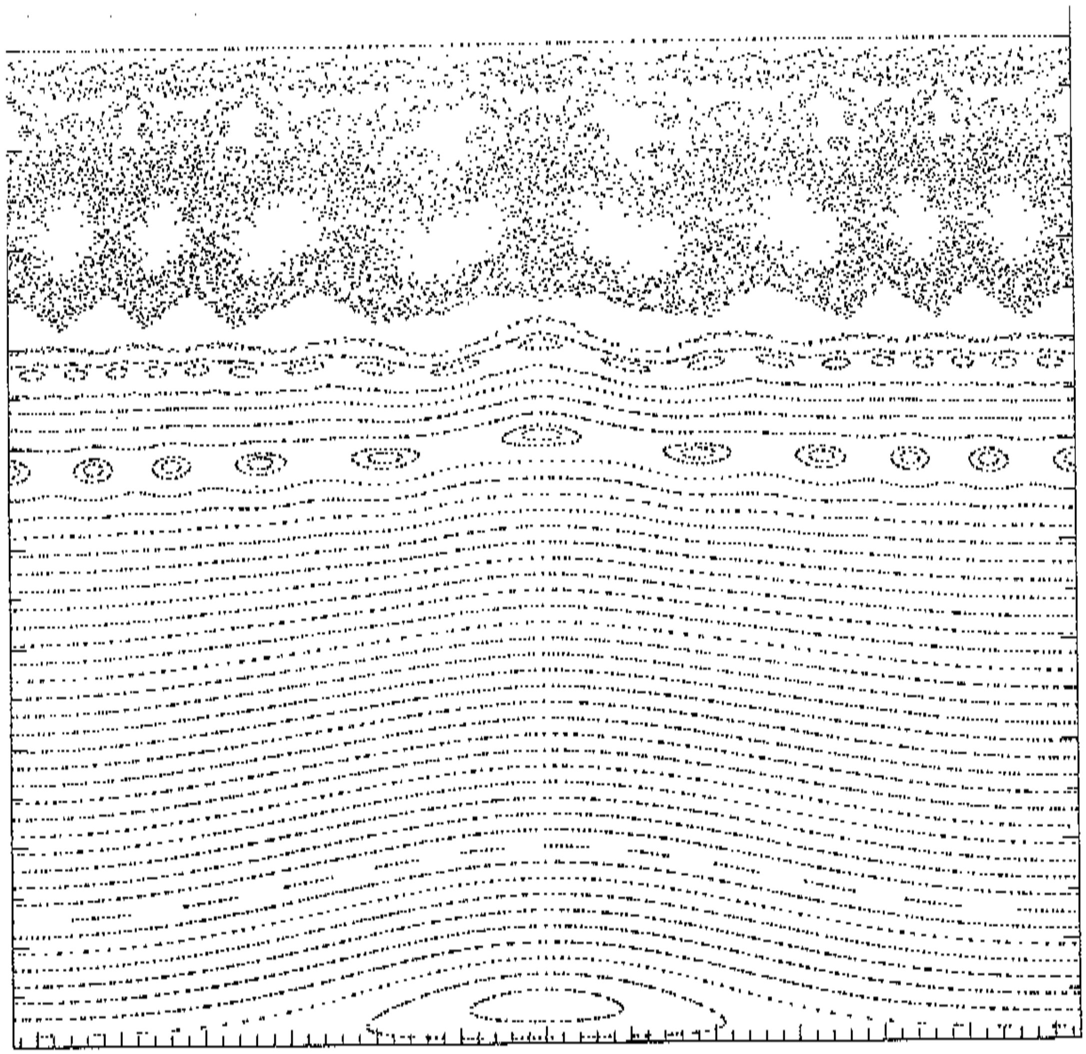


1st ITERATION



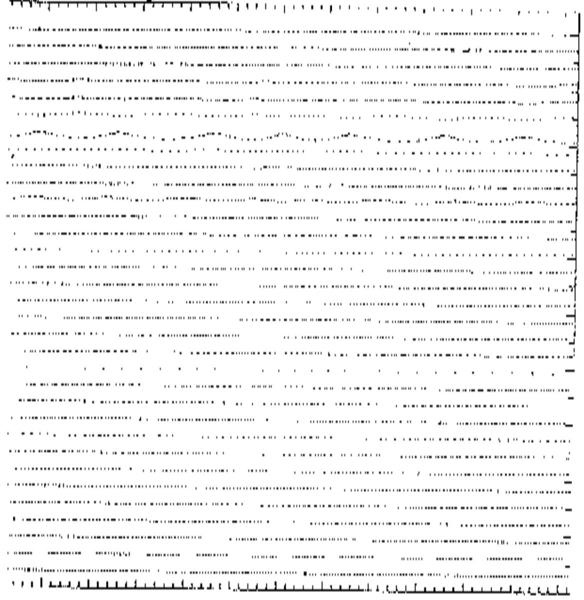
- Unfortunately, the END results are the same for C82! However, this result is pessimistic for C82 since we have not include the effects of the neoclassical bootstrap current, which for our negative shear configuration should be stabilizing.

56th ITERATION

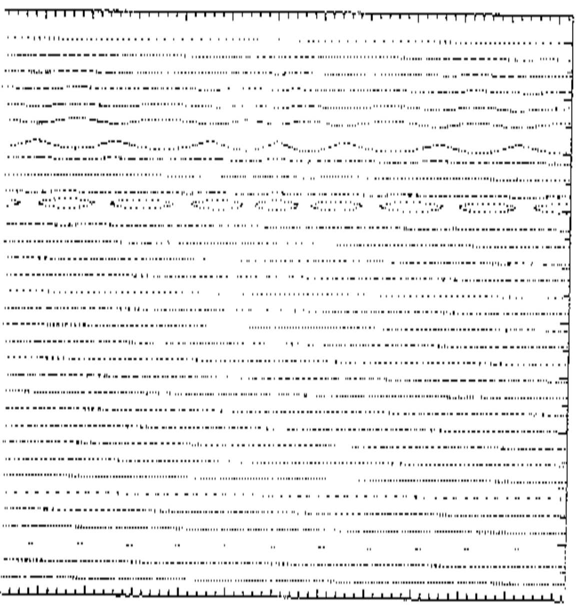


- Application of new blending scheme to: C82 at Full Current and 0% Beta shows reasonably good flux surface quality at both LOW (33 radial zones and 357 modes) resolution and at HIGH (60 radial zones and 525 modes) resolution

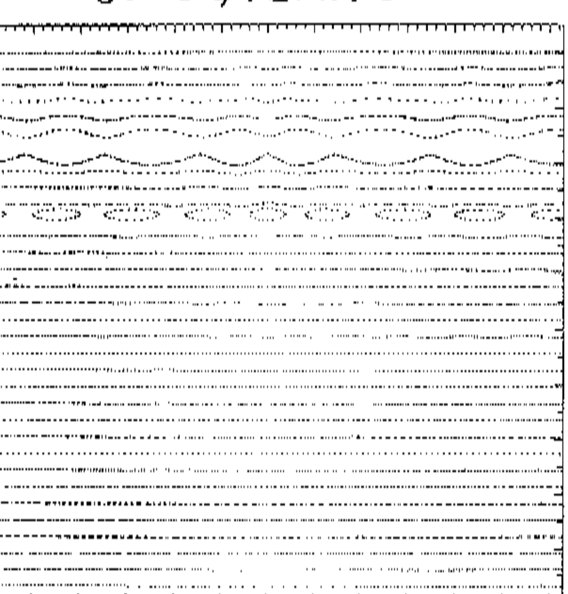
20th ITERATION



40th ITERATION

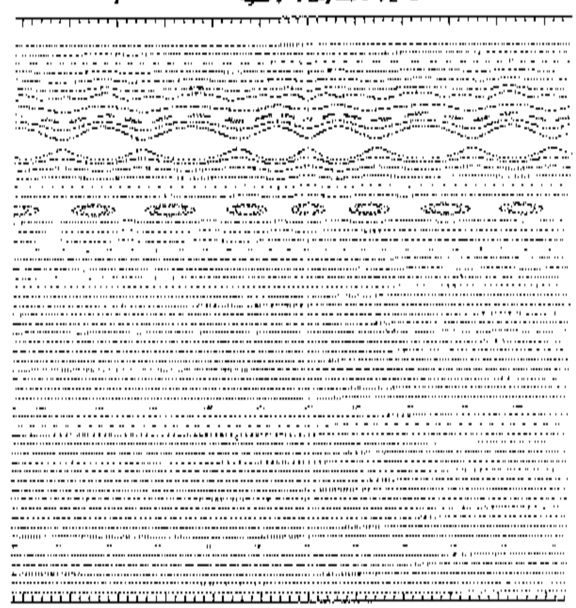


80th ITERATION

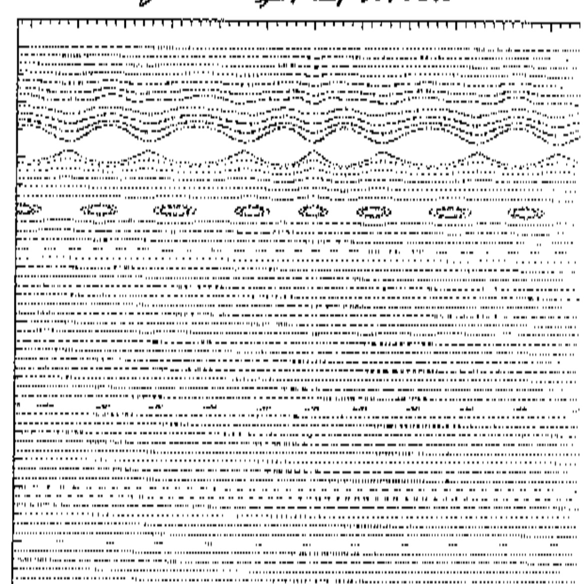


20th ITERATION

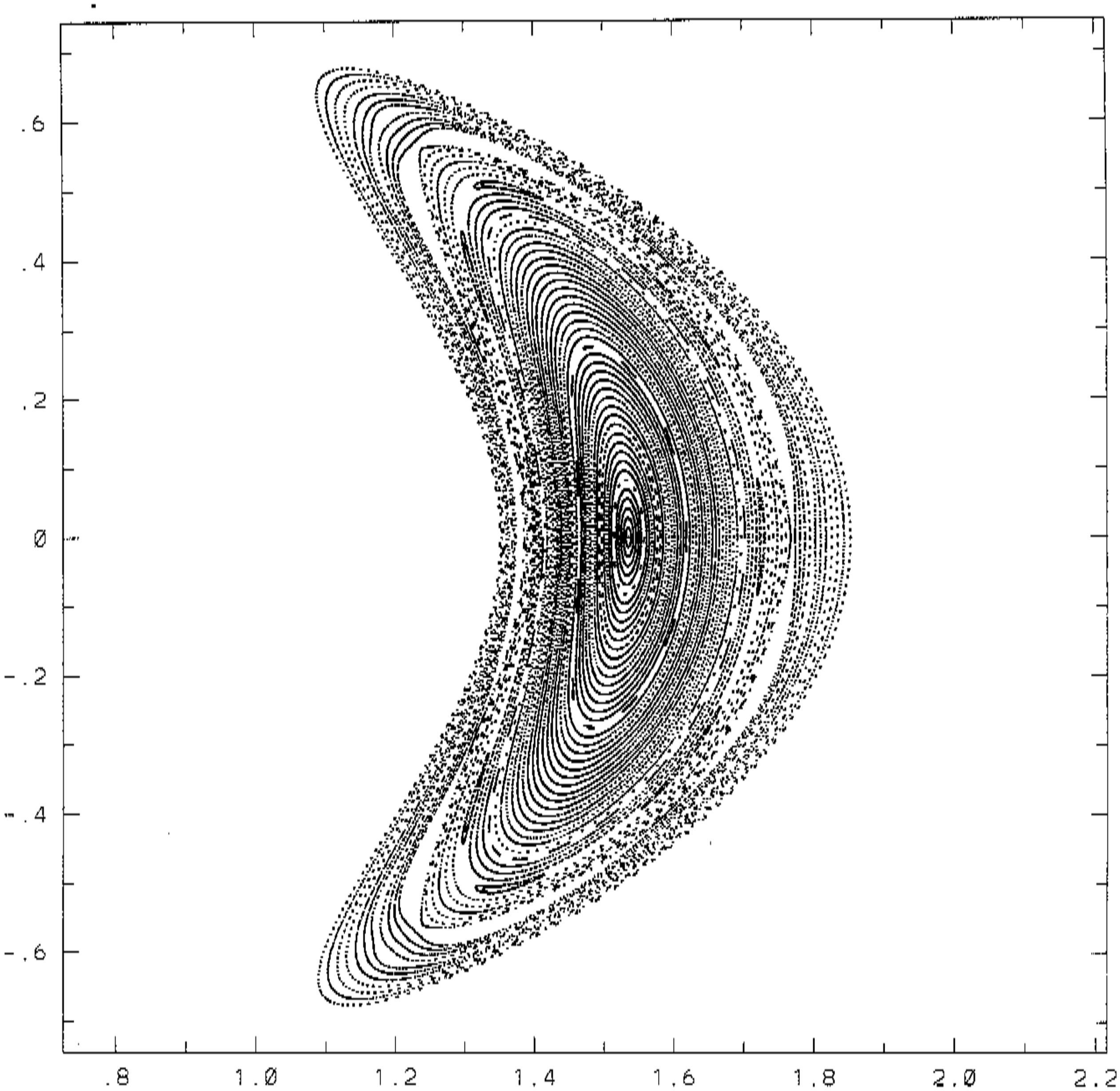
40th ITERATION



80th ITERATION



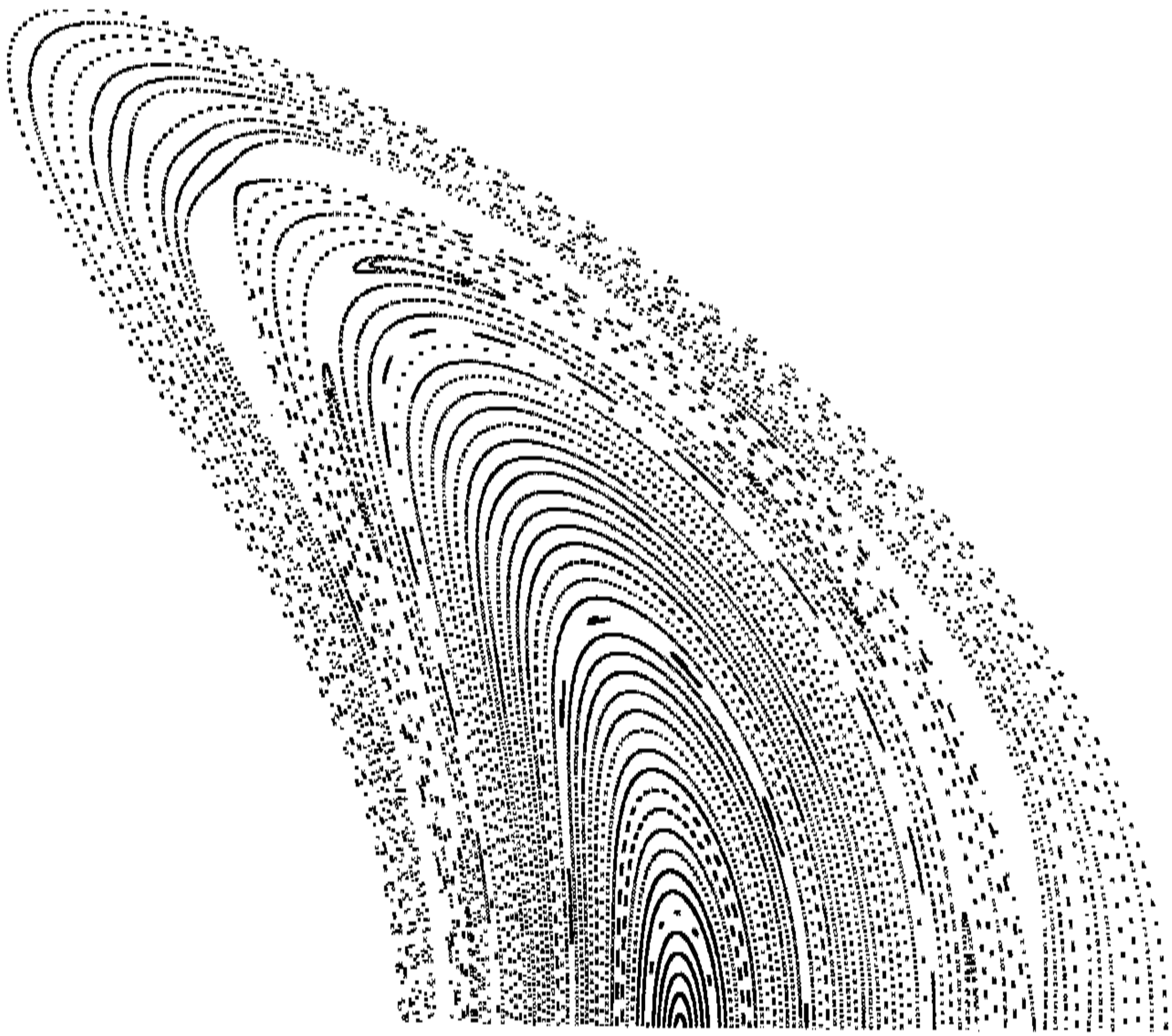
- **Real space plot of C82 at Full Current and 0% Beta**



it=120 poincm: cartesian coordinates phi=0

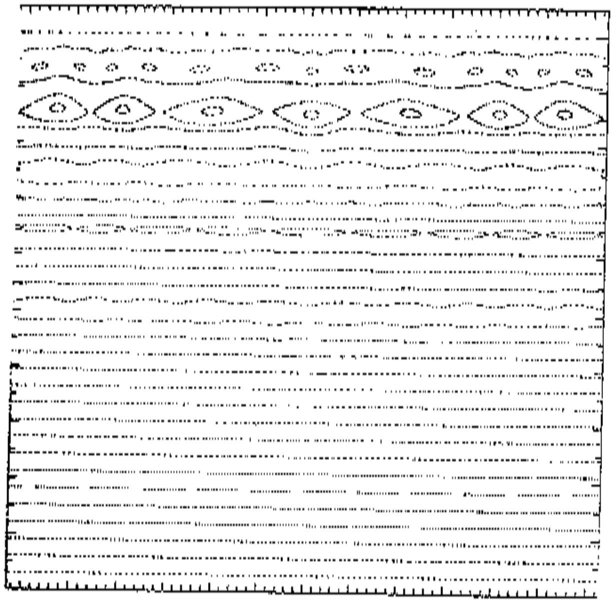
c82c3_3

Plot 704

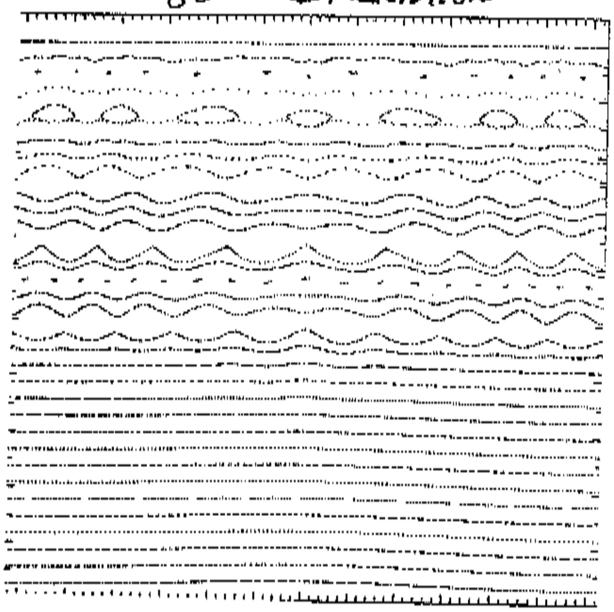


- In searching for the critical beta for C82 we have also examined C82 at Full Current and 3% Beta This snap shot also shows poor surface quality. However, we again point out the fact that these results are pessimistic because they do not include the effects of the neoclassical bootstrap current.

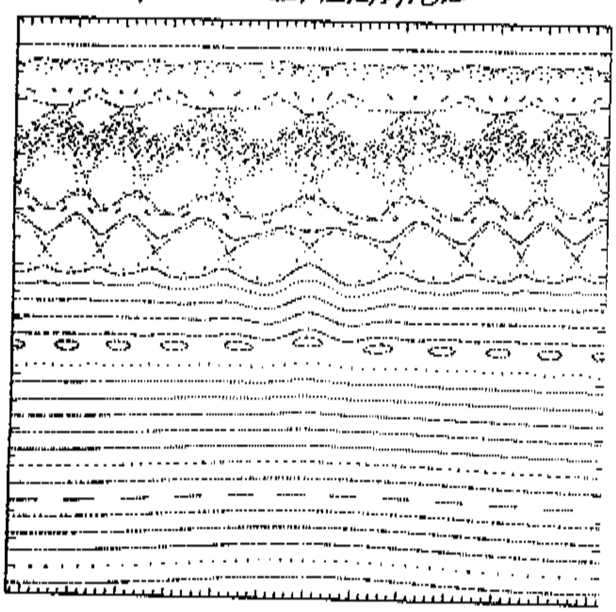
40th ITERATION



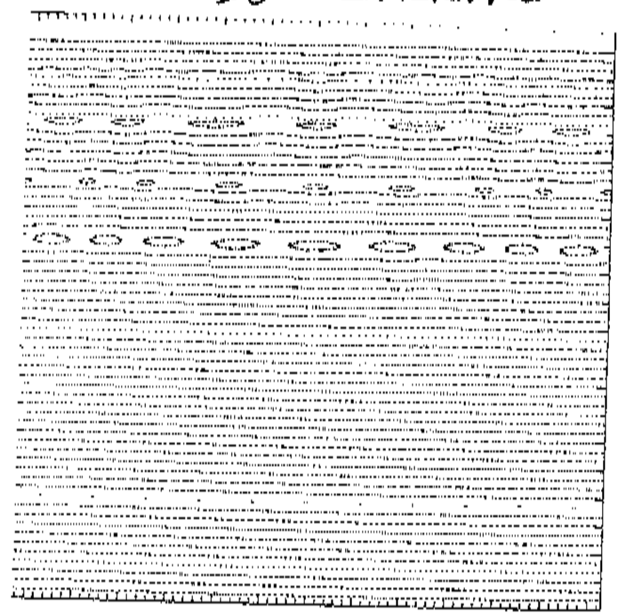
80th ITERATION



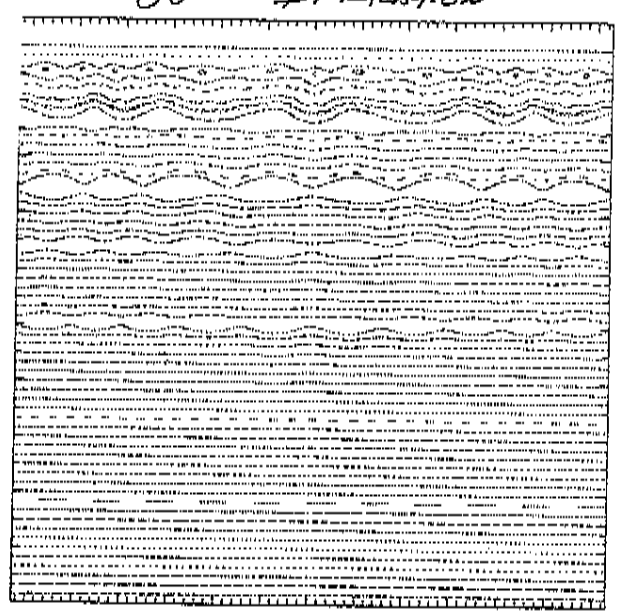
120th ITERATION



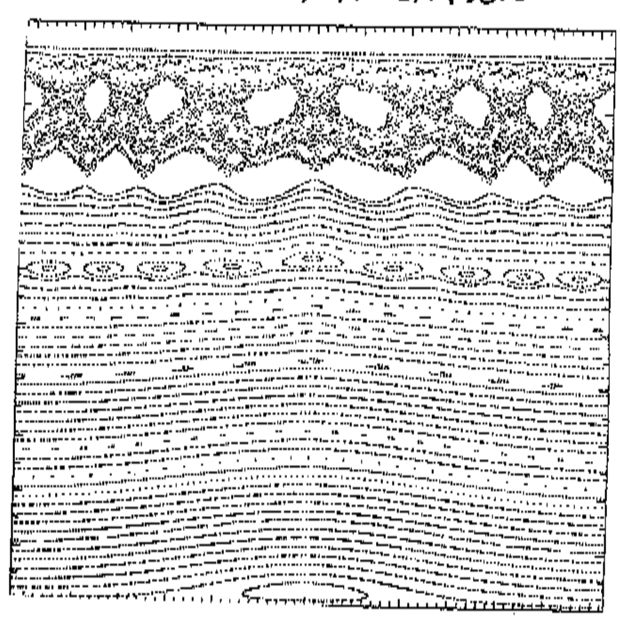
20th ITERATION



80th ITERATION



120th ITERATION



- W7-AS (Erckmann, et al, IAEA, 1996)

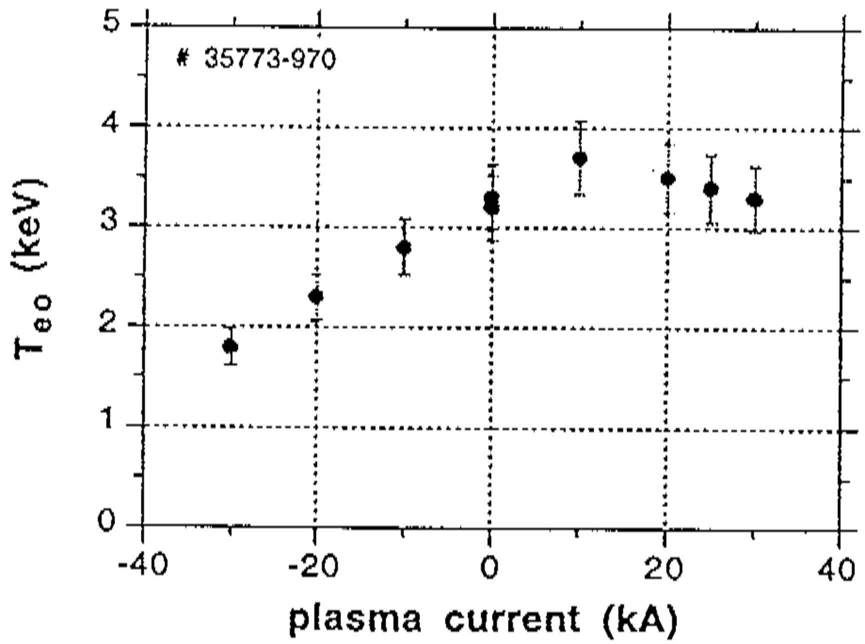
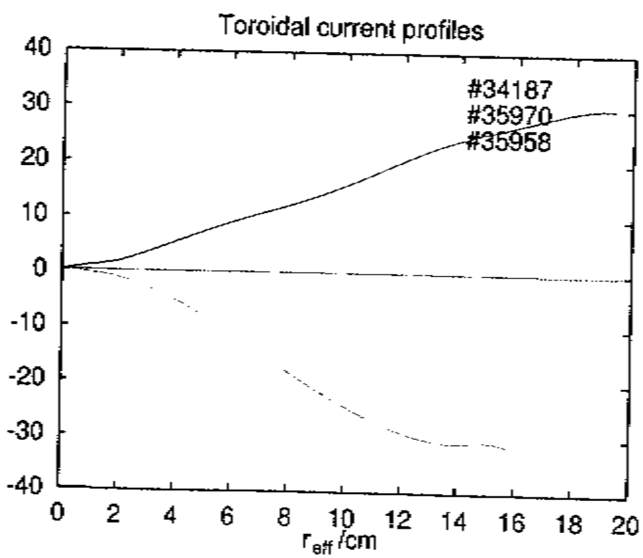


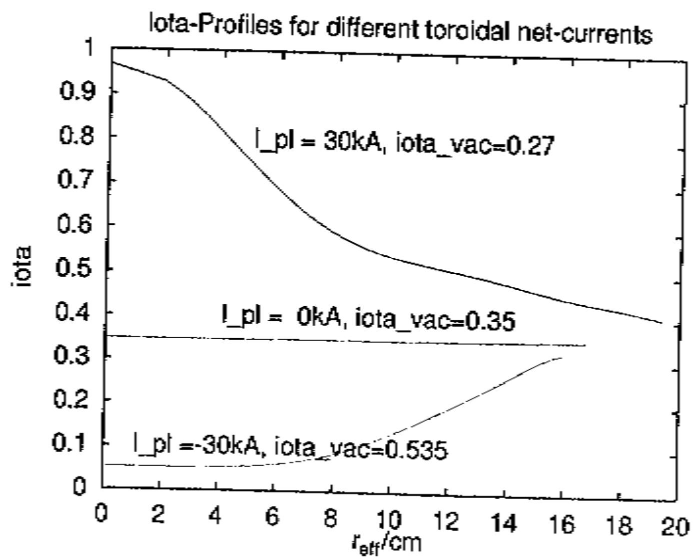
FIG. 6. Central electron temperature for discharges with different plasma current.

Equilibrium Calculations(2) : effects by toroidal net-current

- toroidal net-currents: bootstrap current (internal drive),
  inductive currents, Okhawa current, ECCD current (external drives).
- change of ι-profile: $\Delta\iota(r_{\rm eff}) \approx I_{\rm pl}(r_{\rm eff})R/(2\Phi(r_{\rm eff}))$ for large aspect ratio.
- change of plasma boundary

Examples: Toroidal current and ι profiles (color coded)

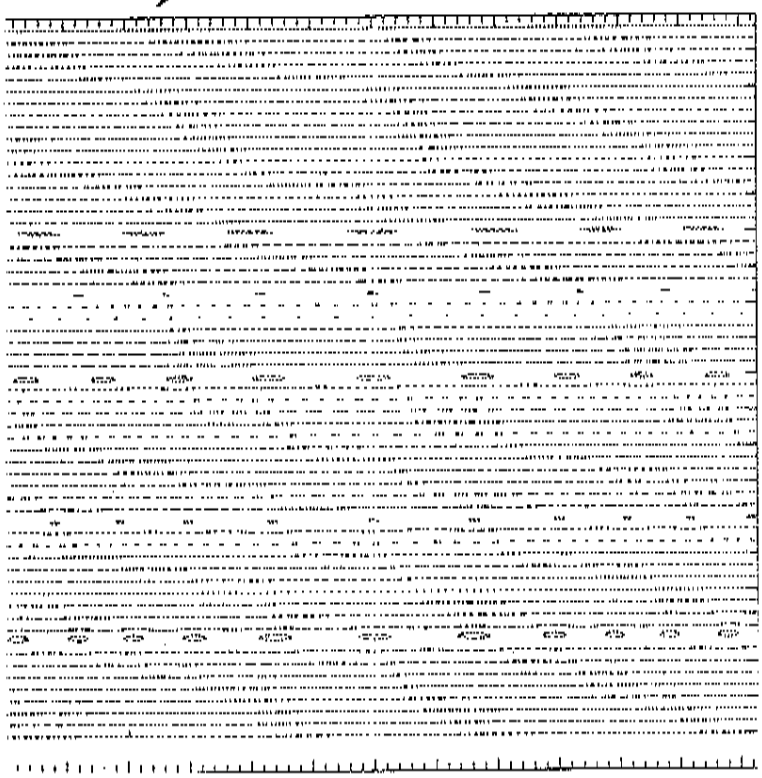




- **W7-AS +30KA Current and .1% β (Data from J. Geiger)**

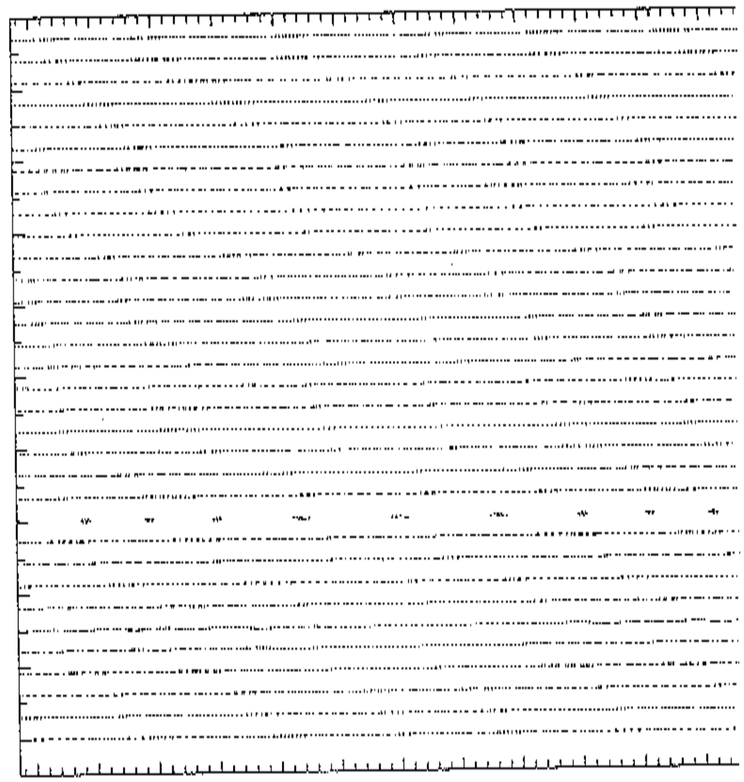
HIGH RESOLUTION

20TH ITERATION



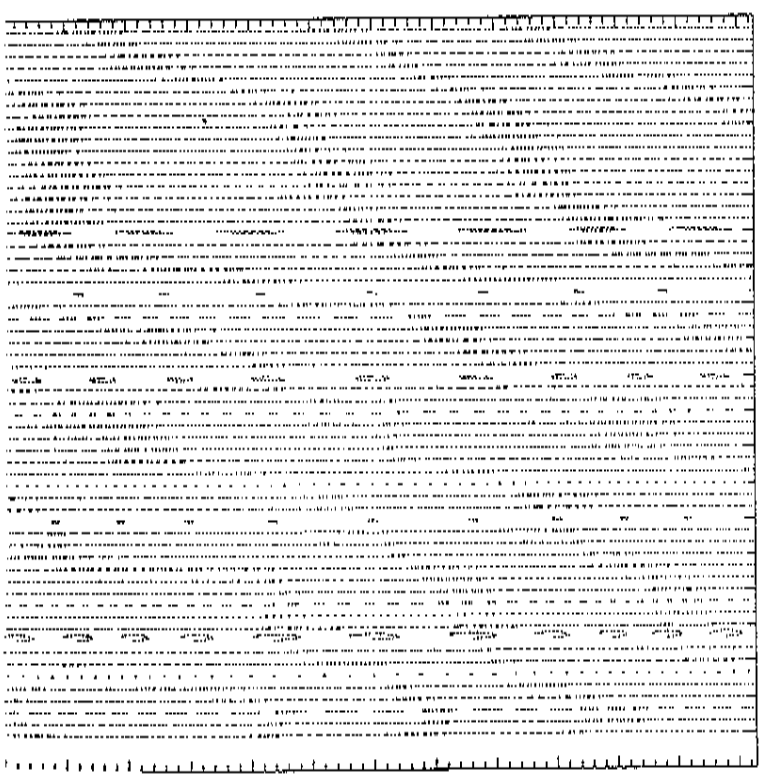
LOW RESOLUTION

20TH ITERATION



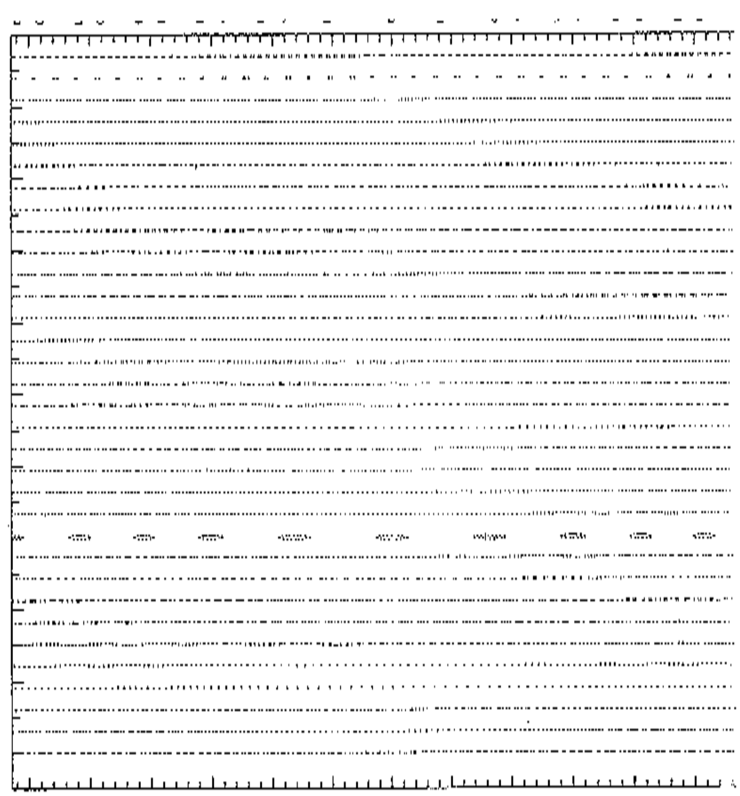
HIGH RESOLUTION

40TH ITERATION

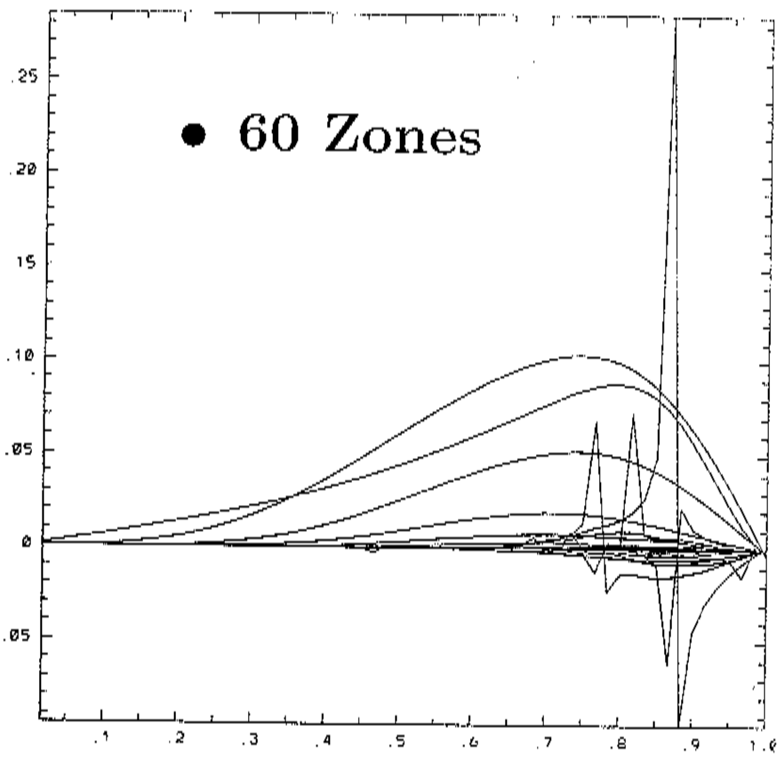


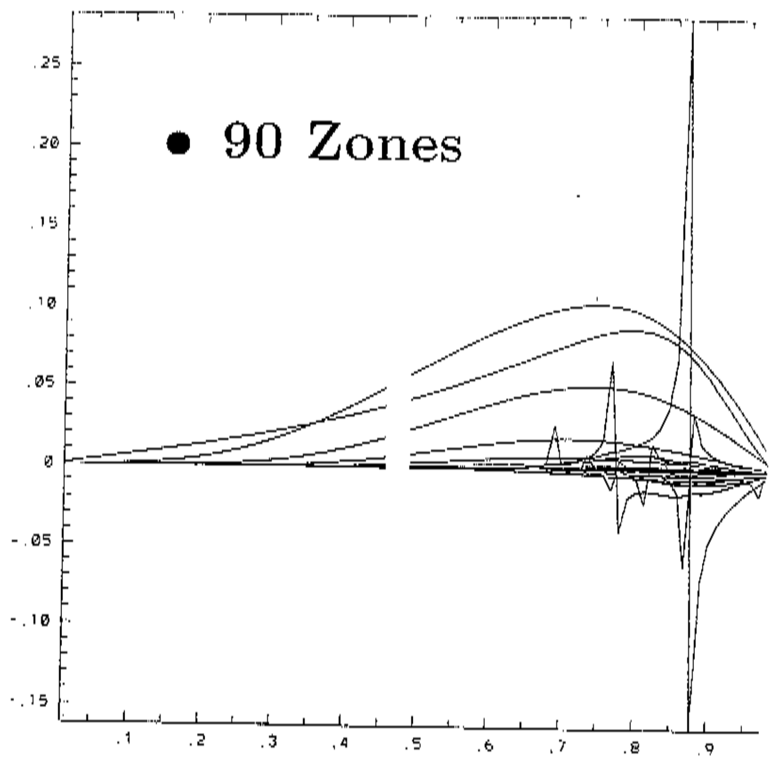
LOW RESOLUTION

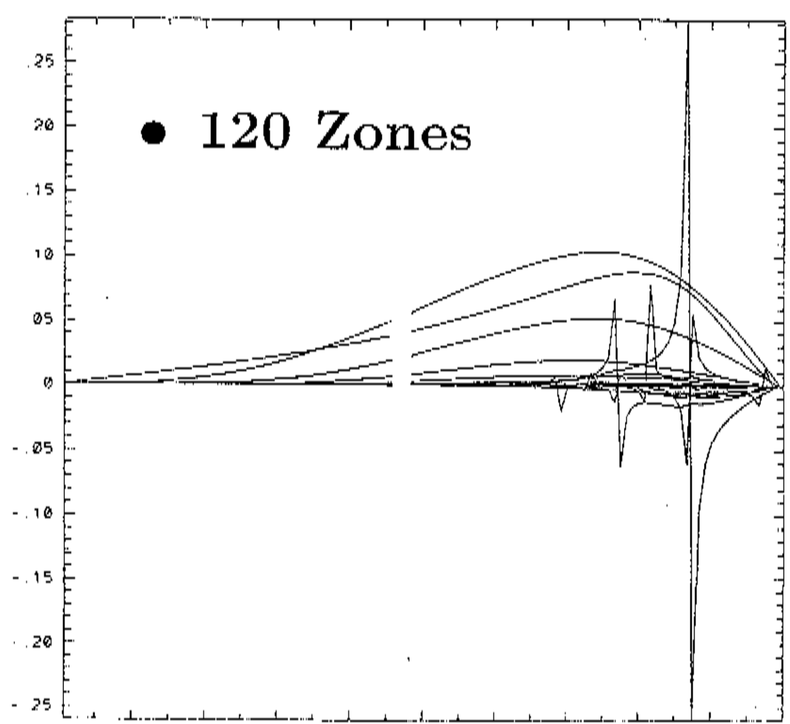
40TH ITERATION



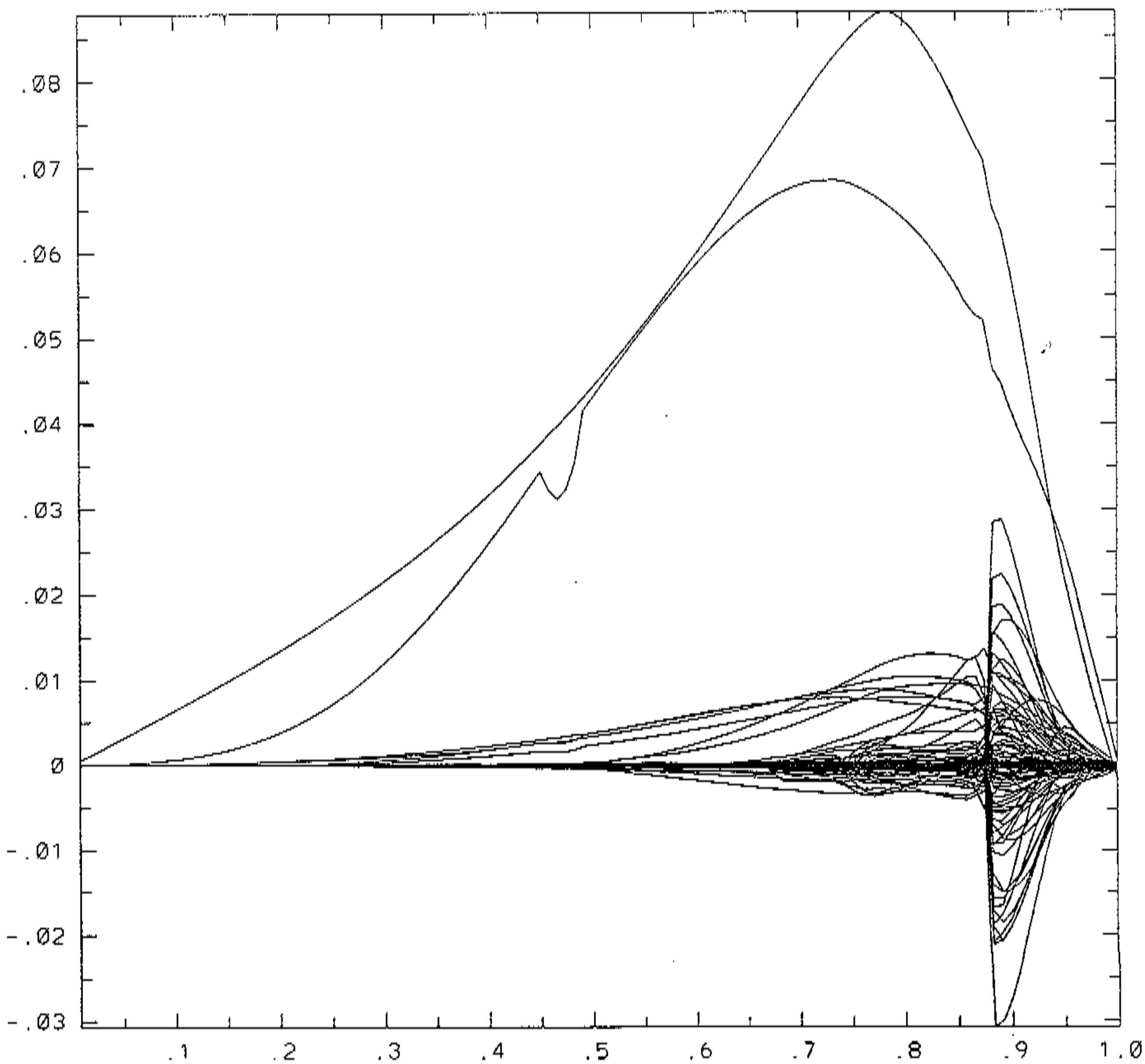
- Harmonic amplitude of $Jacobian * J^{\phi}$ vs radius for the C10 Plasma in Magnetic Coordinates at Full Current and Full β for Various Radial Resolutions Showing Evidence of Resonant Pfirsch-Schlüter Currents



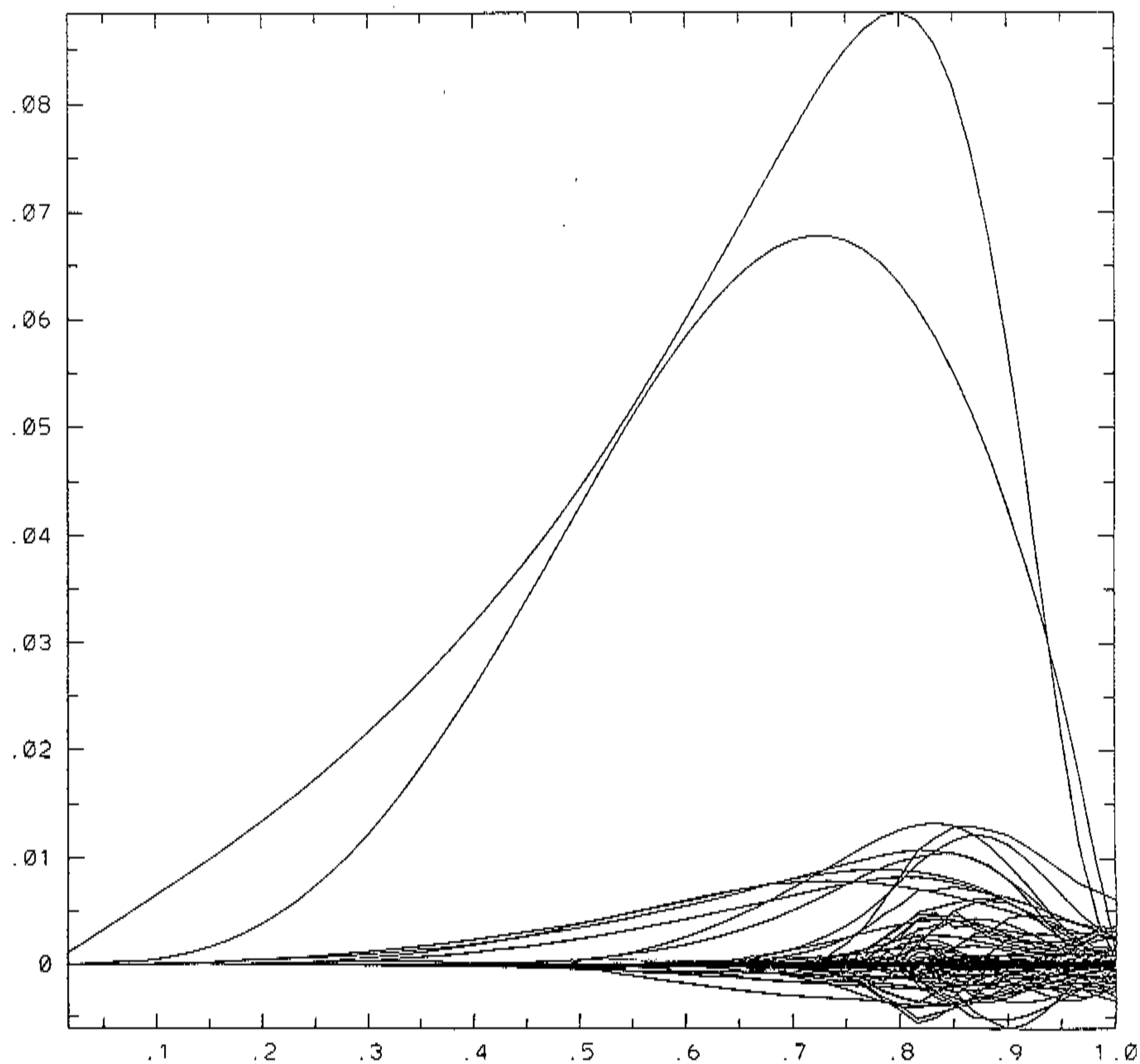




- Harmonic amplitude of $Jacobian * J^{\phi}$ vs radius for the C10 Plasma in Background Coordinates at Full Current and Full β Showing Evidence of Resonant Pfirsch-Schlüter Currents (120 radial zones in PIES)



- Harmonic amplitude of $Jacobian * J^{\phi}$ vs radius for the C10 Plasma in Background Coordinates at Full Current and Full β Showing No Evidence of Resonant Pfirsch-Schlüter Currents (400 radial zones in VMEC)



Summary and Remarks

- We have used the PIES code to examined the equilibrium of the C82 plasma for various snapshots without the constraint of simply nested flux surfaces used in the VMEC evaluation of these equilibria.
- At both full beta (4%) and 3% beta, the C82 plasma shows poor surface quality. We have started a convergence study in the number of radial zones and number of harmonic modes and have reported on this study in this poster. We feel further study at an even higher number of modes and radial zones is needed before we can be sure we are correctly modeling these configurations. We are enlisting two other MHD equilibrium codes, M3D and HINT, to confirm these PIES results. These results on flux surface quality in C82 are pessimistic because the stabilizing influence of the neoclassical bootstrap effects are not included in the present runs. We are presently making modifications to the PIES code to model this effect.

- In order to validate the PIES results, we have begun to look at experimental results of stellarator equilibria. We presented here a low beta, high current discharge from W7-AS. We plan to examine higher beta cases from W7-AS and other stellarators equilibria such as LHD and CHS.
- We have presented evidence that the VMEC equilibria are not converging to the weak solution. We are searching for the source of the discrepancy between the PIES code and the VMEC code by doing convergence studies with both codes. However, we point out that it has been noted by Gardner and Blackwell (Nuclear Fusion, Vol.32, No.11 (1992)) that VMEC solutions do not show resonant behavior.