Trim Coils
Design and Performance
Status

NCSX Project Meeting

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Overview

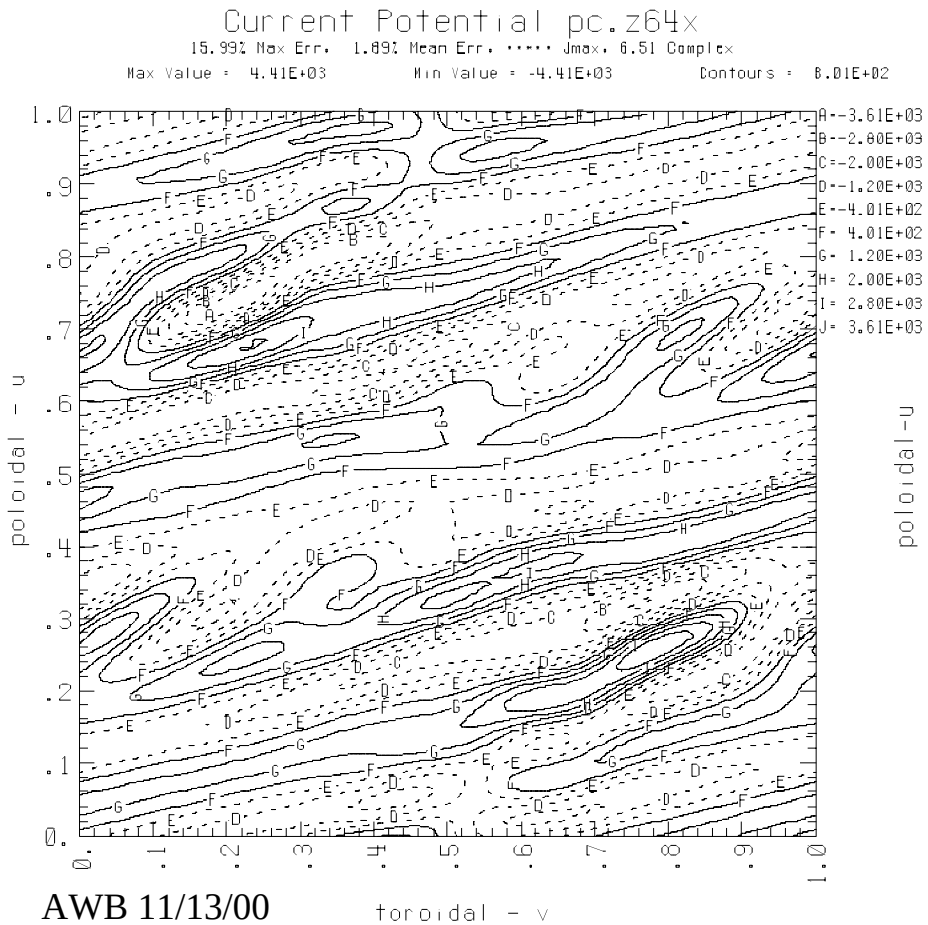
- Review Initial Investigations in Vacuum
- Present Recent Efforts at Full Current, Full Beta

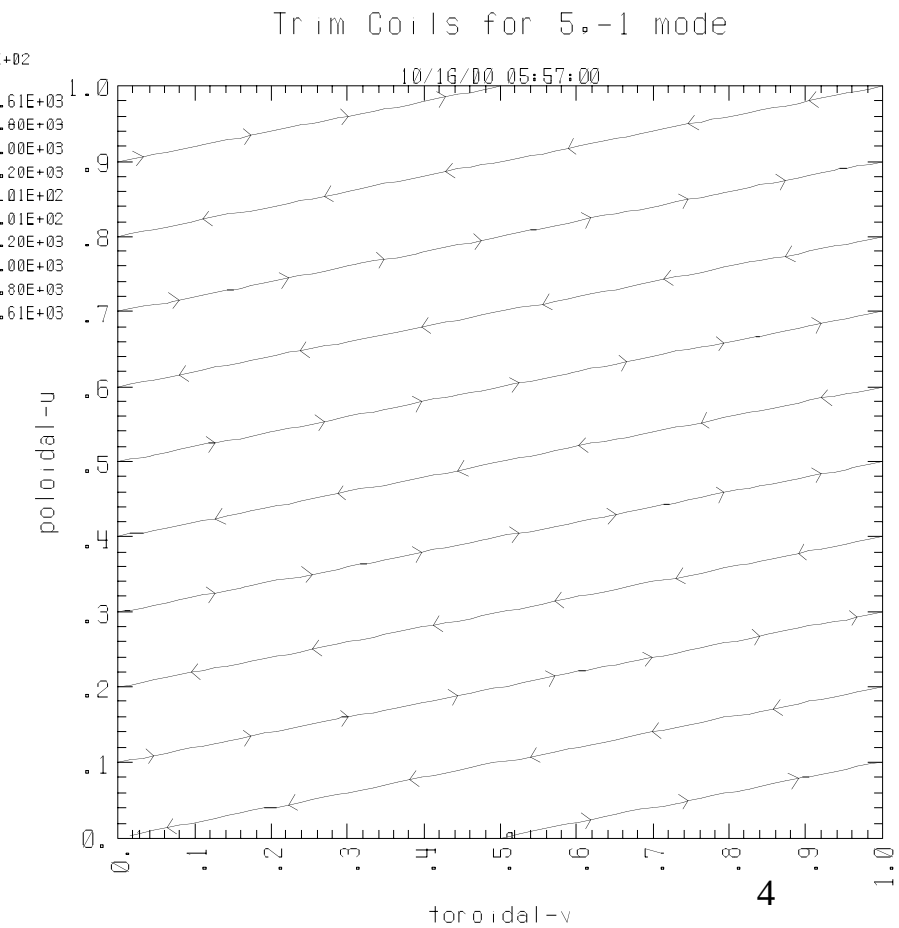
Suppressing Islands with Trim Coils in Vacuum

- Earlier efforts to design trim coils (for PG1) were successful but required very large currents
  - Targeted modes were large -> m=12
- Recent plasma designs have higher iota profiles
  - M=5 modes (iota = .6) near surface
  - Should require much less current
- Using a Vacuum Plasma with comparable iota, targeted m=5 islands
  - Plasma taken from Mike Z's optimized S1 state using modular 0907a1 coils (z64x)

Trim Coils

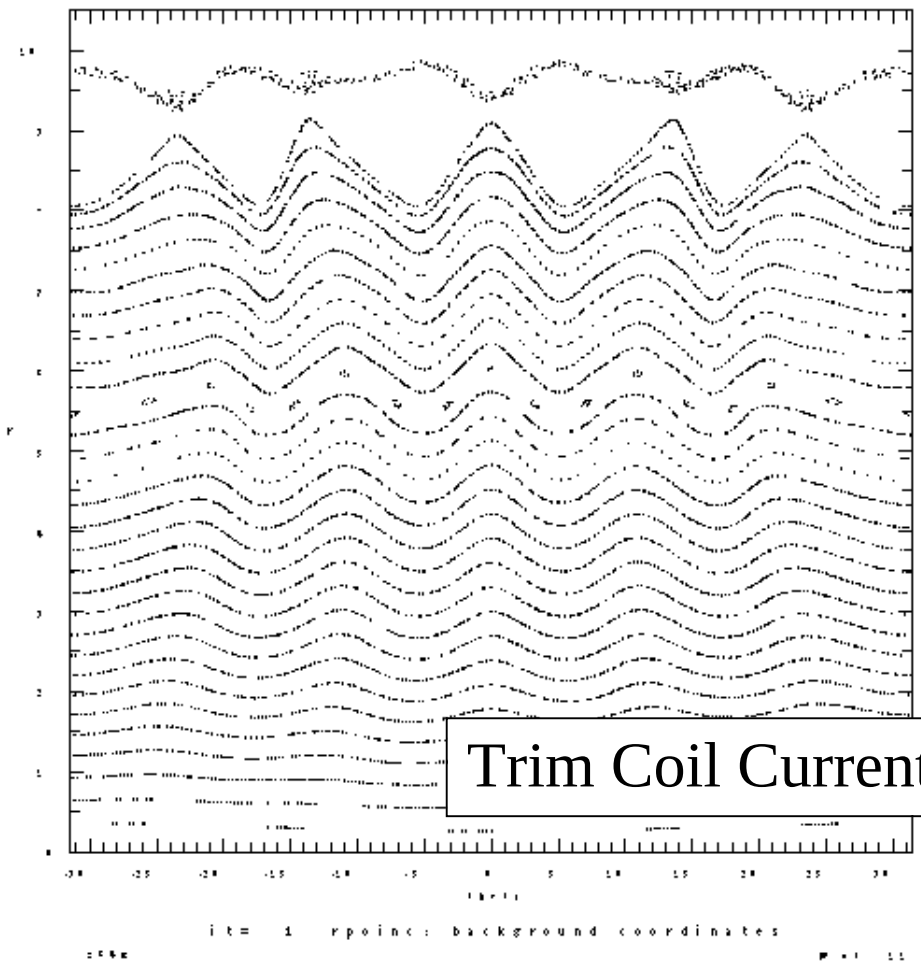
Current Potential (left) targeting Bnorm(5,-1) on resonant interior surface shows strong 5,-1 term. Coils cut (right) by throwing out all other terms.



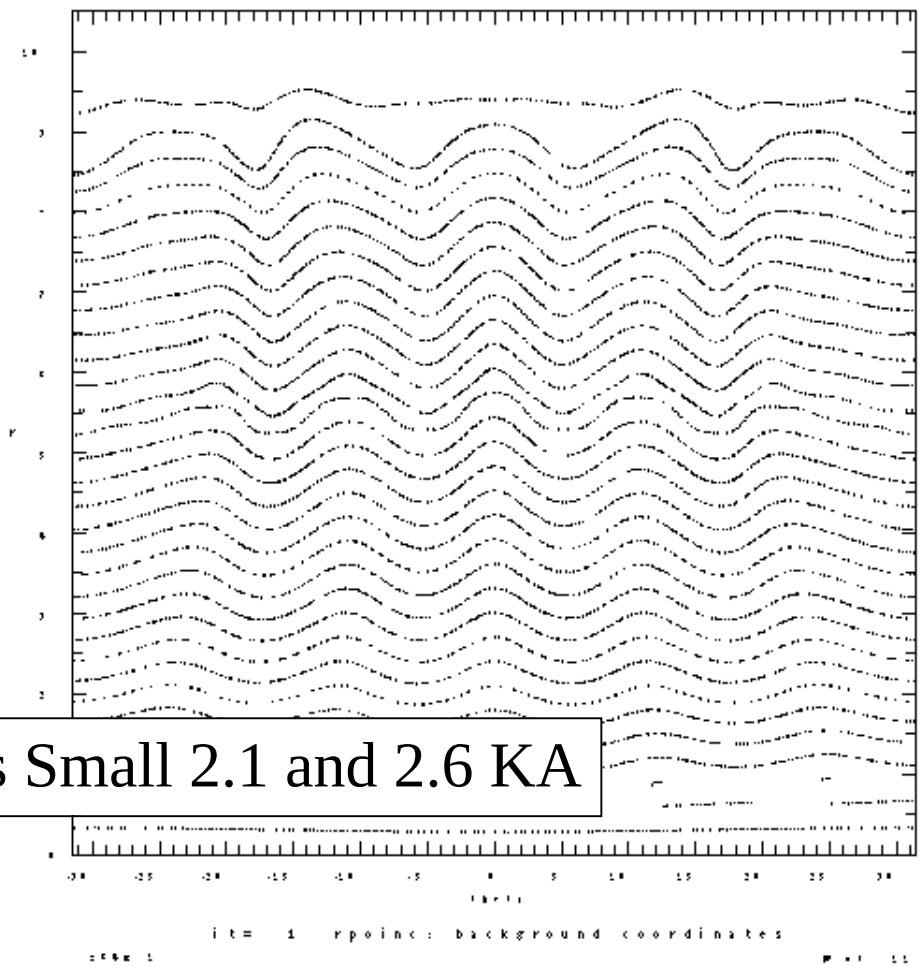


Modular Coils 0907 in Vacuum

without Trim Coils



with Trim Coils



Trim Coil Currents Small 2.1 and 2.6 KA

Small Trim Coils Currents hit m=5 resonance without impacting B•n on boundary. Higher modes difficult to control

- Without Trim Coils
  - Berr, max = 5.69 %
  - Berr, avg = 0.63 %
  - $\delta r[5,-1]$ = 0.038
  - $\delta r[10,-2]$ = 0.024
  - $\delta r[15,-3]$ = 0.005
  - $\delta r[20,-4]$ = 0.001

- With Trim Coils
  - Berr, max = 5.54 %
  - Berr, avg = 0.64 %
  - $\delta r[5,-1]$ = 0.0001
  - $\delta r[10,-2]$ = 0.026
  - $\delta r[15,-3]$ = 0.006
  - $\delta r[20,-4]$ = 0.001

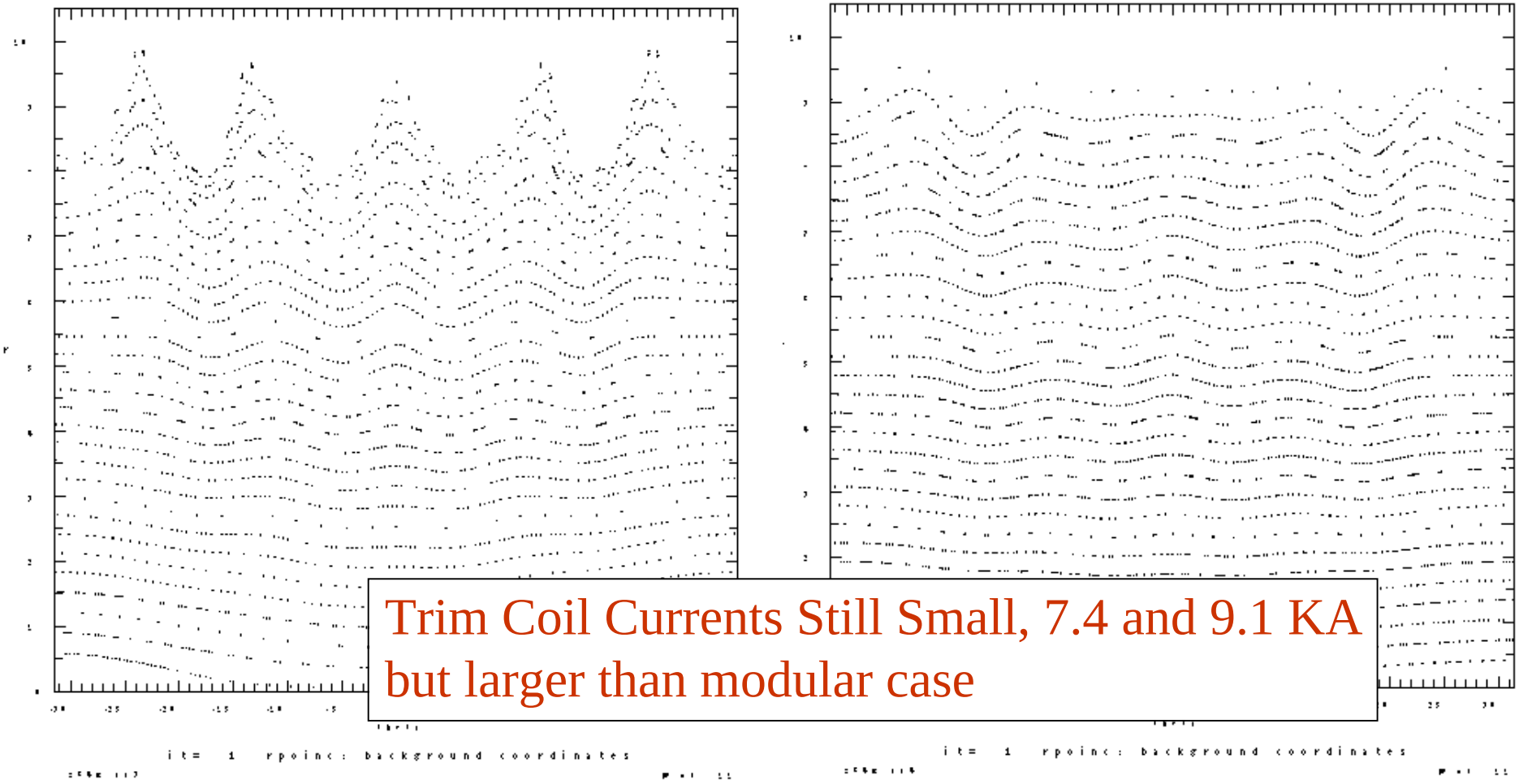
$\delta r[m,n]$ = calculated island size on resonant surface

Testing Saddles with Trim Coils

- Do not have a comparable Vacuum state with existing saddle coils (high iota, .6 near edge)
- Generated new saddles which reproduce modular field
  - Targeting z64x plasma
  - Difficult to reproduce similar starting plasma configuration
    - B•n from modular coils not zero on z64x as would be expected
    - Required 32 Uniform contours
  -

Saddle Coils (designed for z64x)

without Trim Coils with Trim Coils



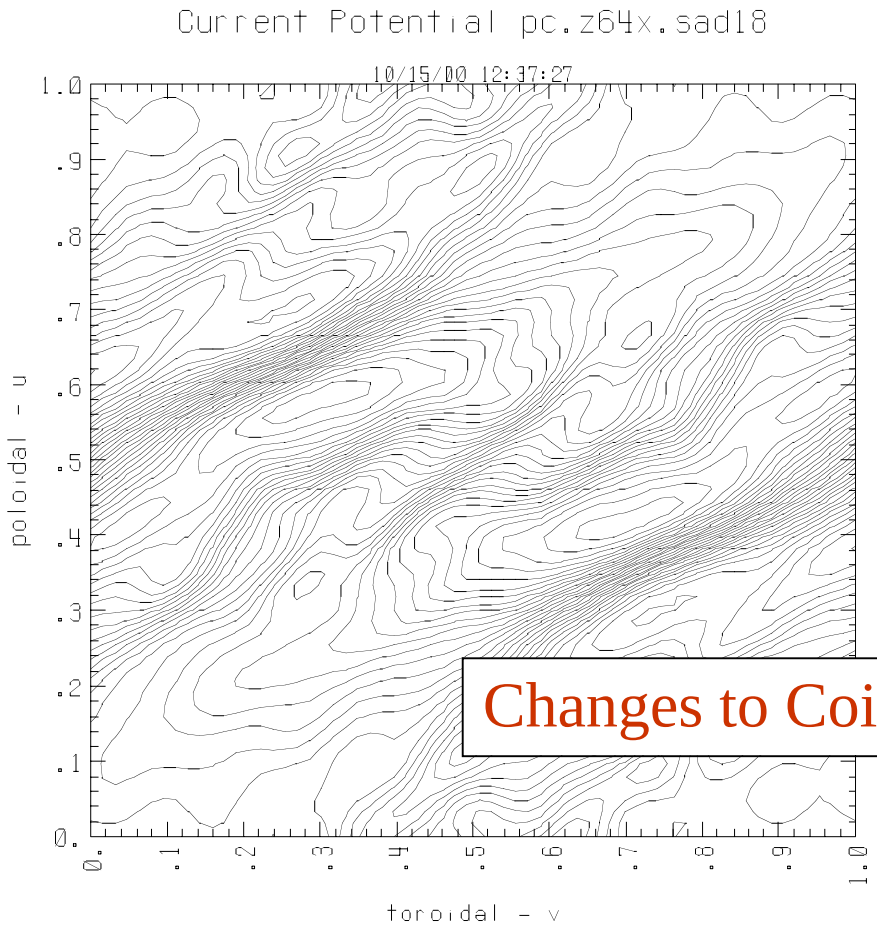
Trim Coil Currents Still Small, 7.4 and 9.1 KA but larger than modular case

Tweaking Coil Geometry to Target Islands

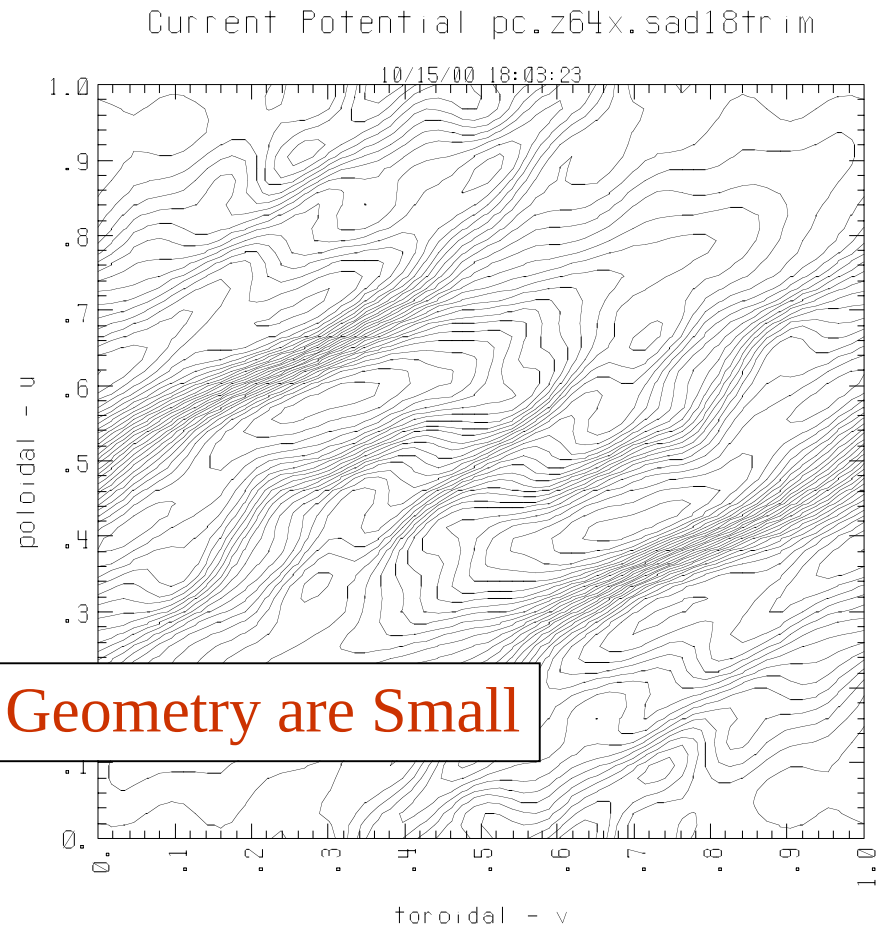
- Basic saddle geometry can be modified by adding the current potential used to create trim coils to the current potential used to create saddles and re-cutting coils.
- For coils not cut from NESCOIL current potential solutions, the geometry can be modified by adding perturbations in u-v space similar to that given by the trim coil current potential
  - dv = -pot*sin(2*pi*(m*u+n*v))
  - du = -dv * n/m

Modified Saddles to Target m=5 mode

original



modified

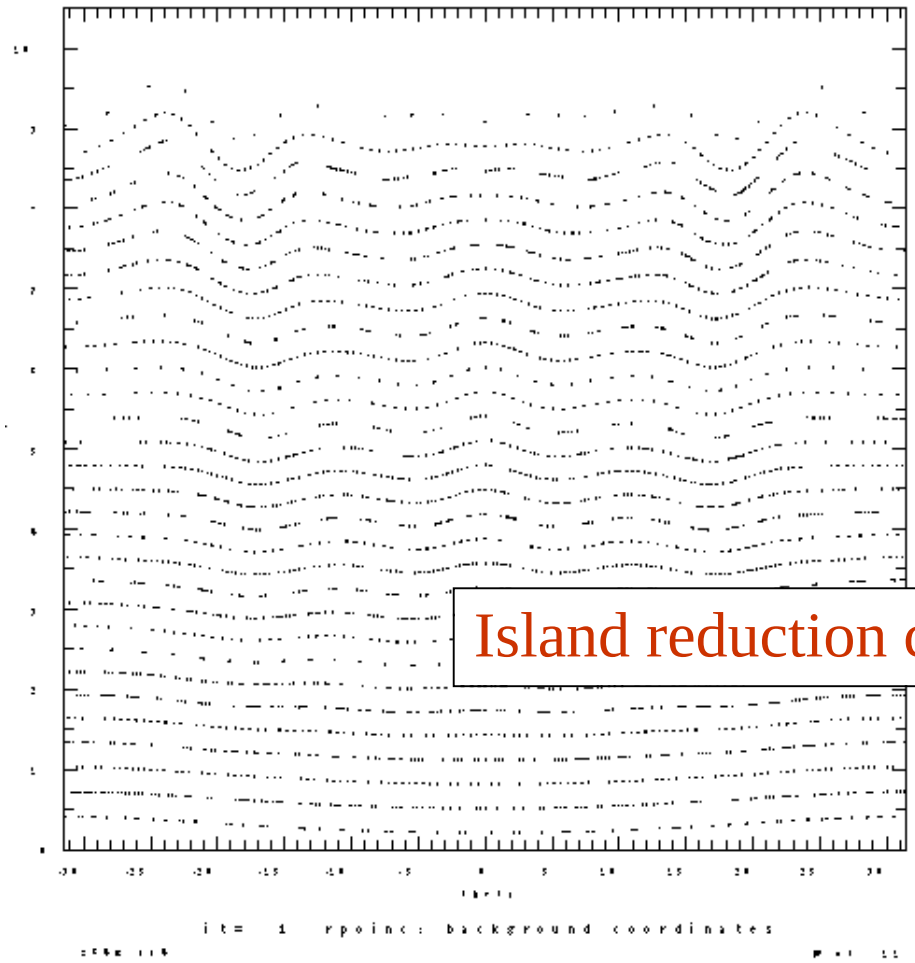


Changes to Coil Geometry are Small

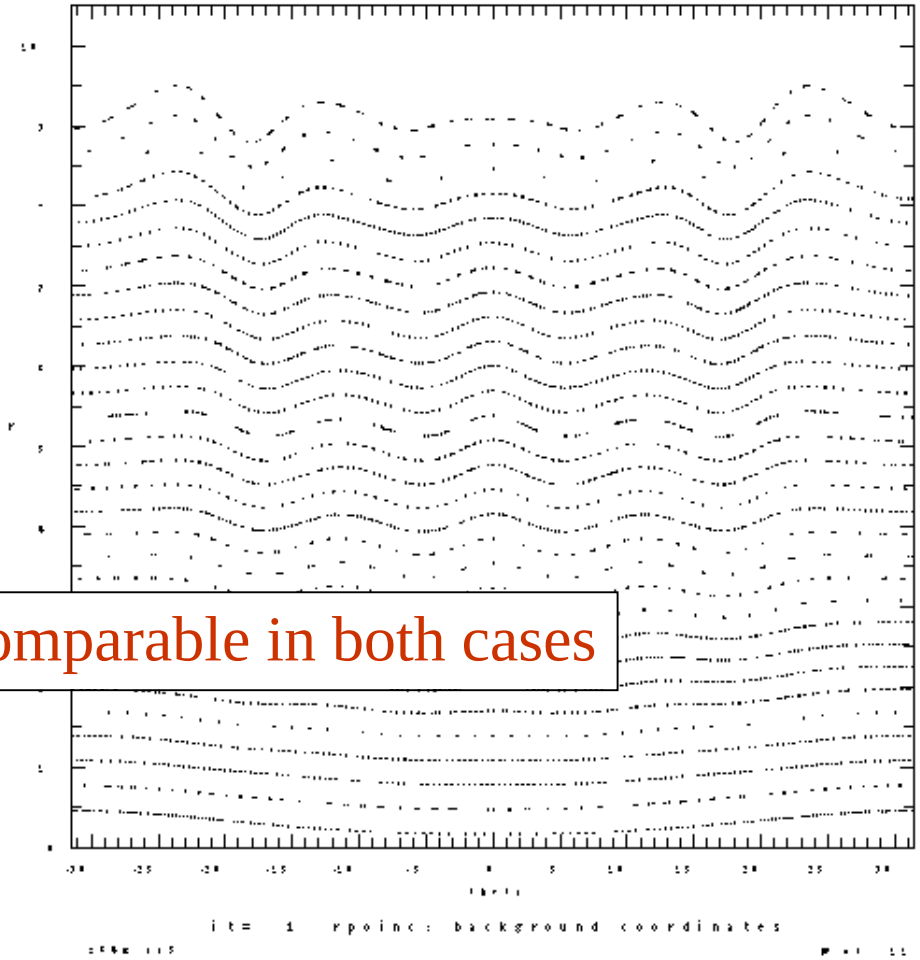
Saddle Coils (designed for z64x)

with Trim Coils

(same as earlier slide)

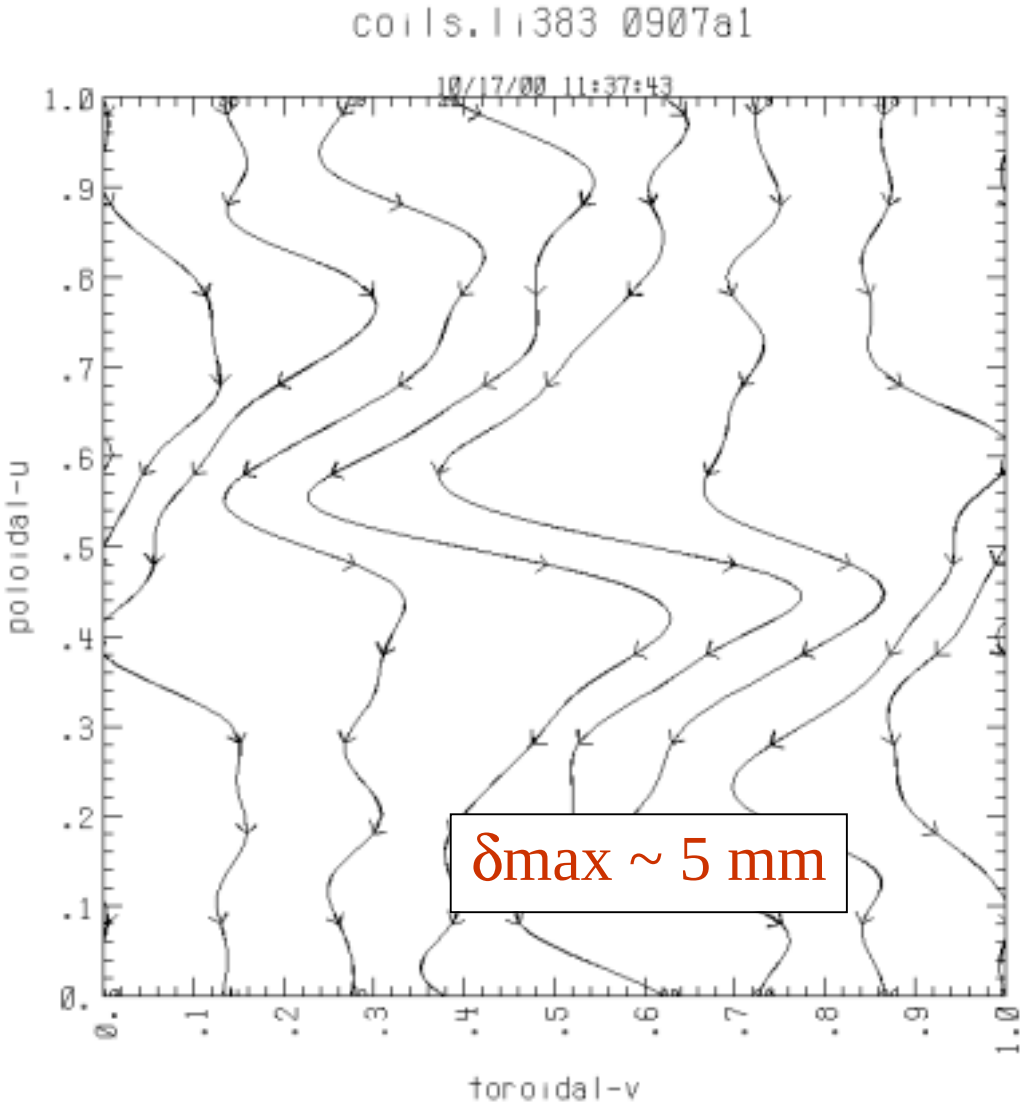


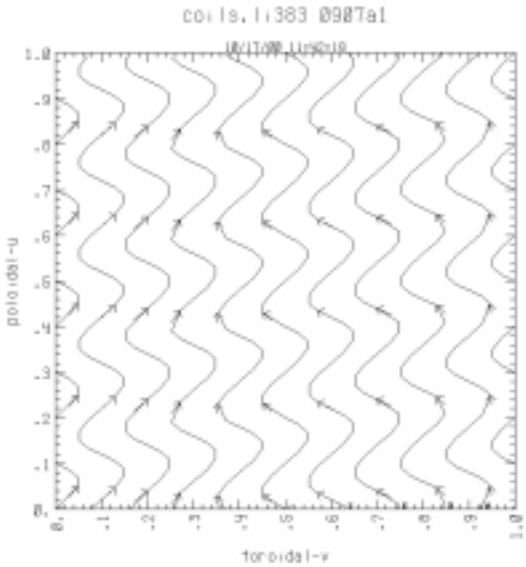
modified Saddles



Island reduction comparable in both cases

Modified Modular Coils overlaid on original

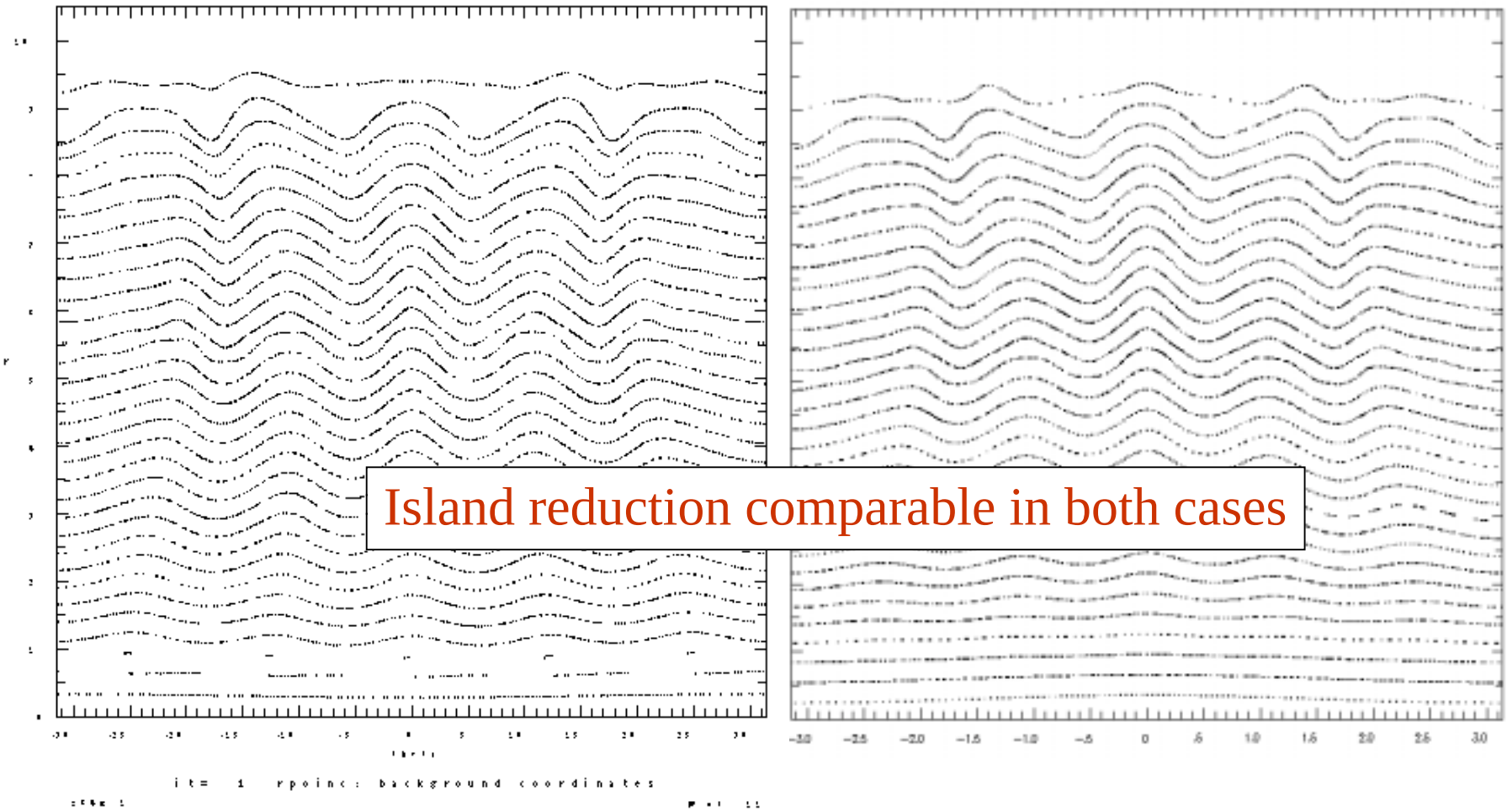




Exaggerated m=5 perturbation on a TF coil set

Modular Coils (in Vacuum)

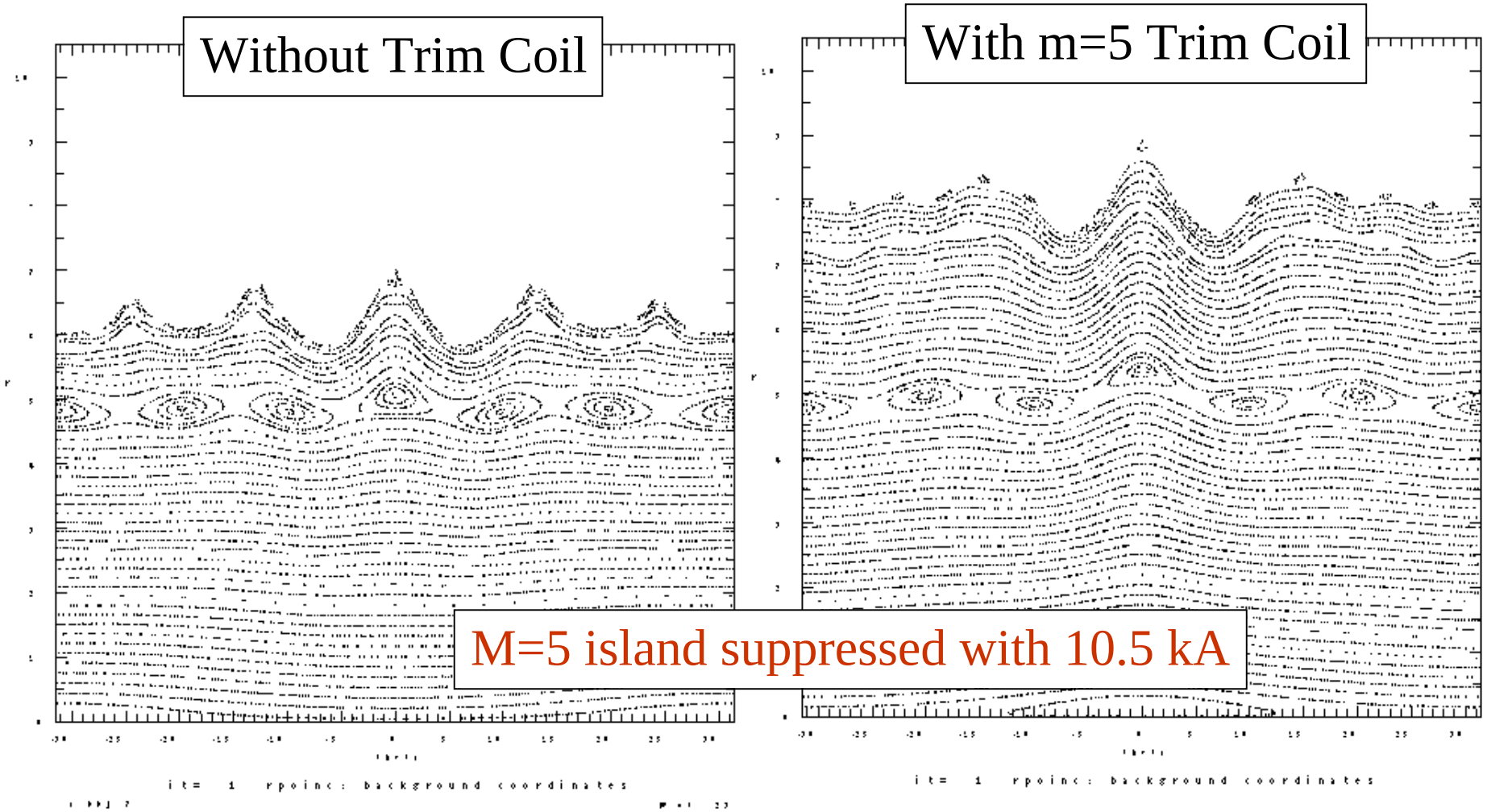
with Trim Coils with Perturbation



Applying Trim Coils to Saddles at Full Current, Full Beta

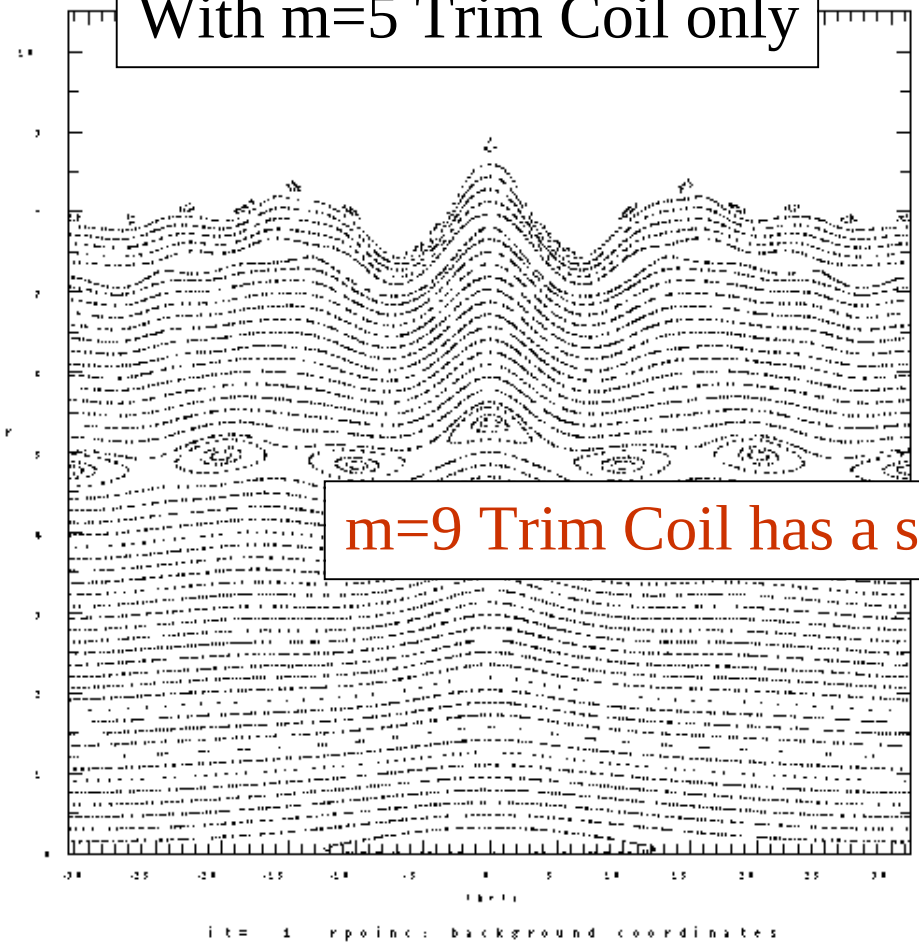
- Start with NESVD/GA Saddle coils
  - D1826.11.126.60.7.9 - 14 coils/period
  - Berr targeted in NESVD, Berr & Jmax Targeted in GA
- Add trim coils
  - m=5, n=-1 helical coils targeting iota=3/5
  - m=9, n=-2 helical coils targeting iota=3/9
- Run PIES for single iteration without blending
  - Vary currents in trim coils (manually)
  - Iterate until m=5 island suppressed
- Compare to full PIES run

PIES Single Iteration, No Blending

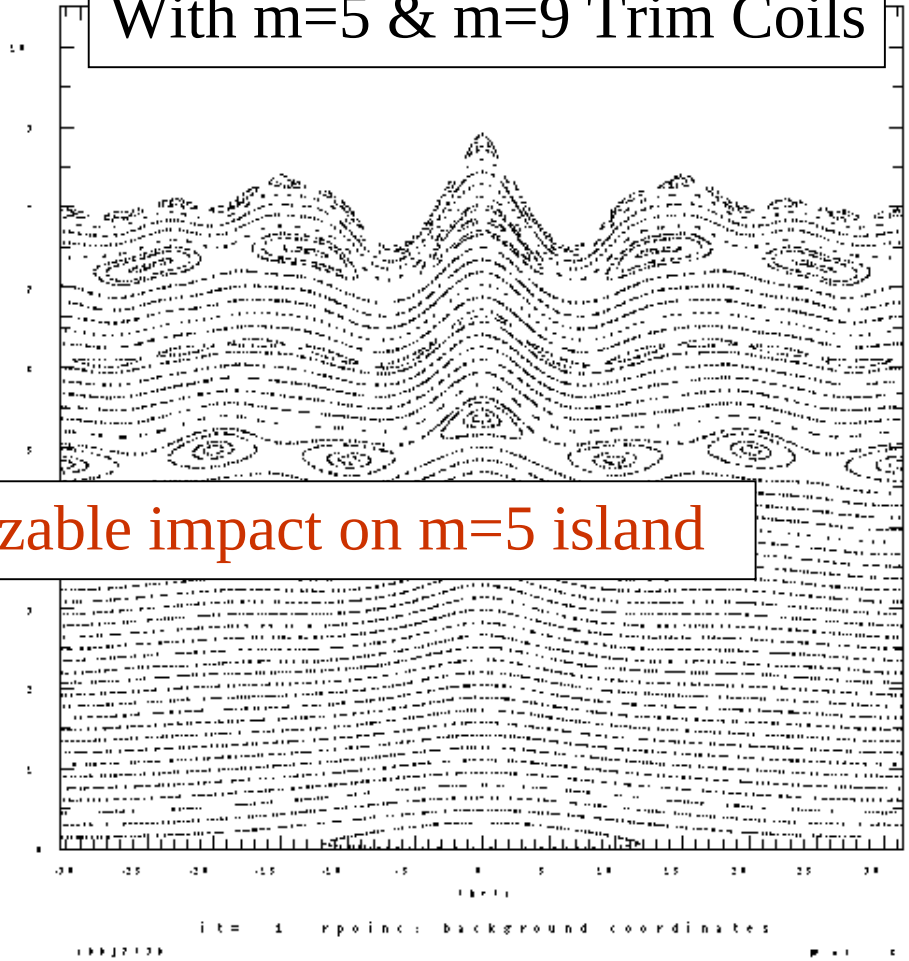


PIES Single Iteration, No Blending

With m=5 Trim Coil only

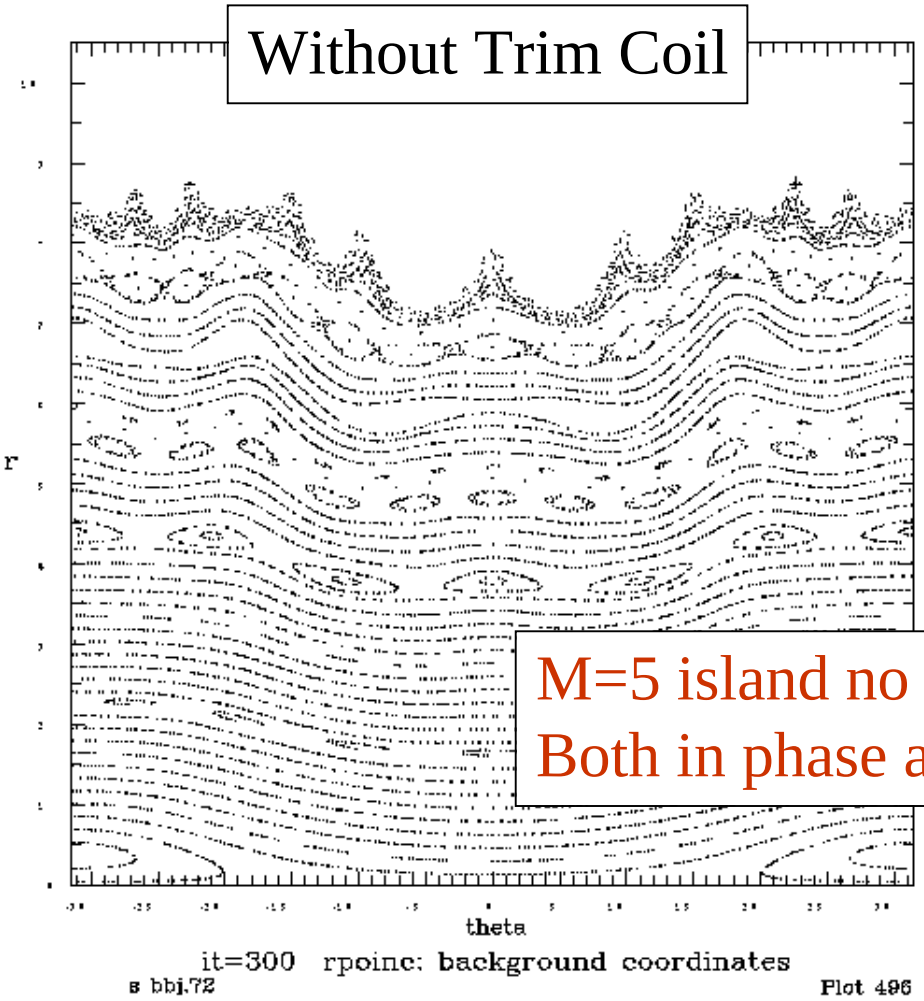


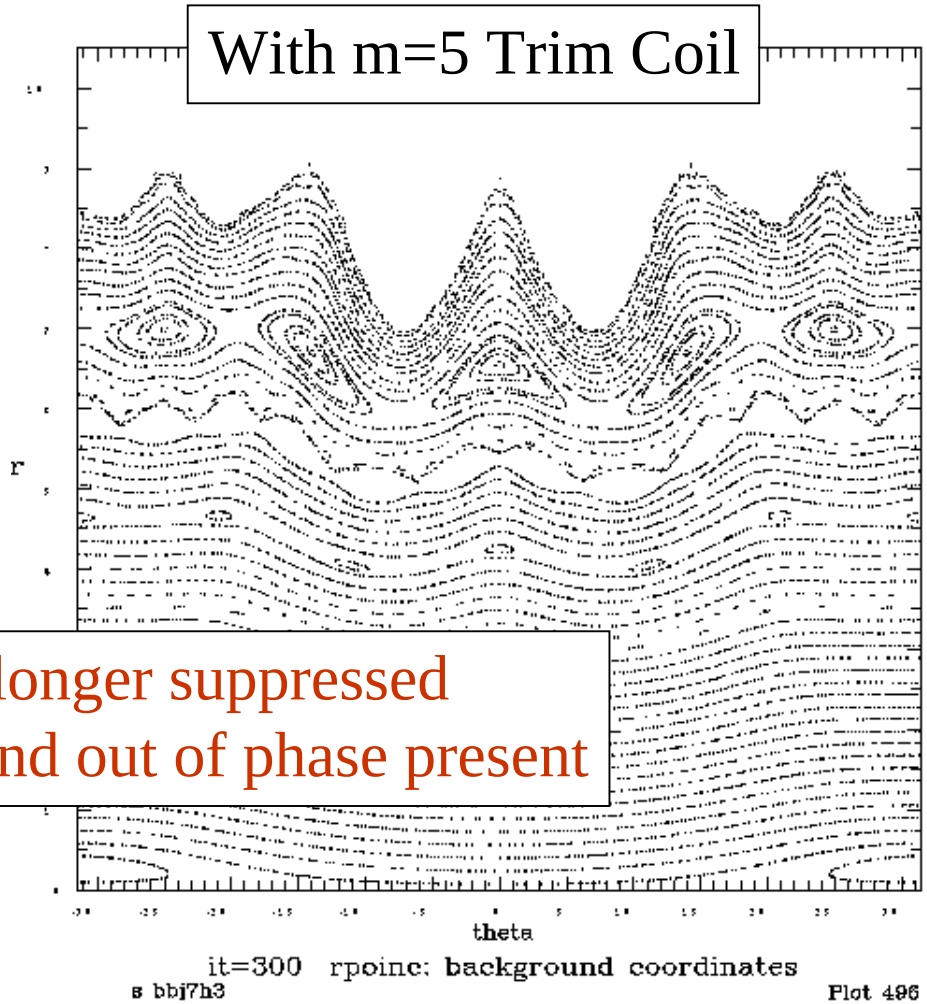
With m=5 & m=9 Trim Coils



m=9 Trim Coil has a sizable impact on m=5 island

PIES after 300 iterations (Fully Converged?)





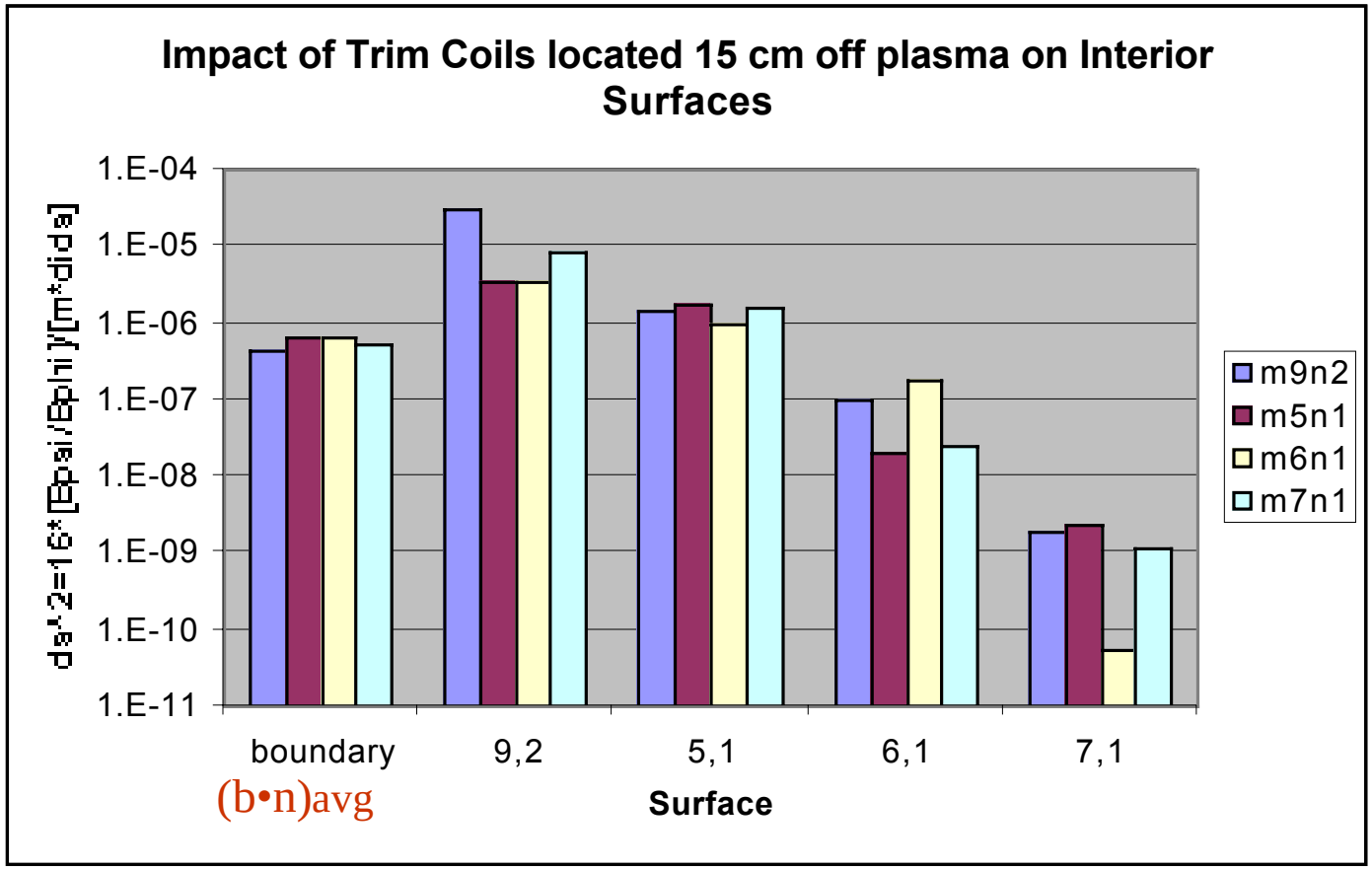
M=5 island no longer suppressed
Both in phase and out of phase present

Multiple Trim Coils, Multiple Resonances Influence Matrix

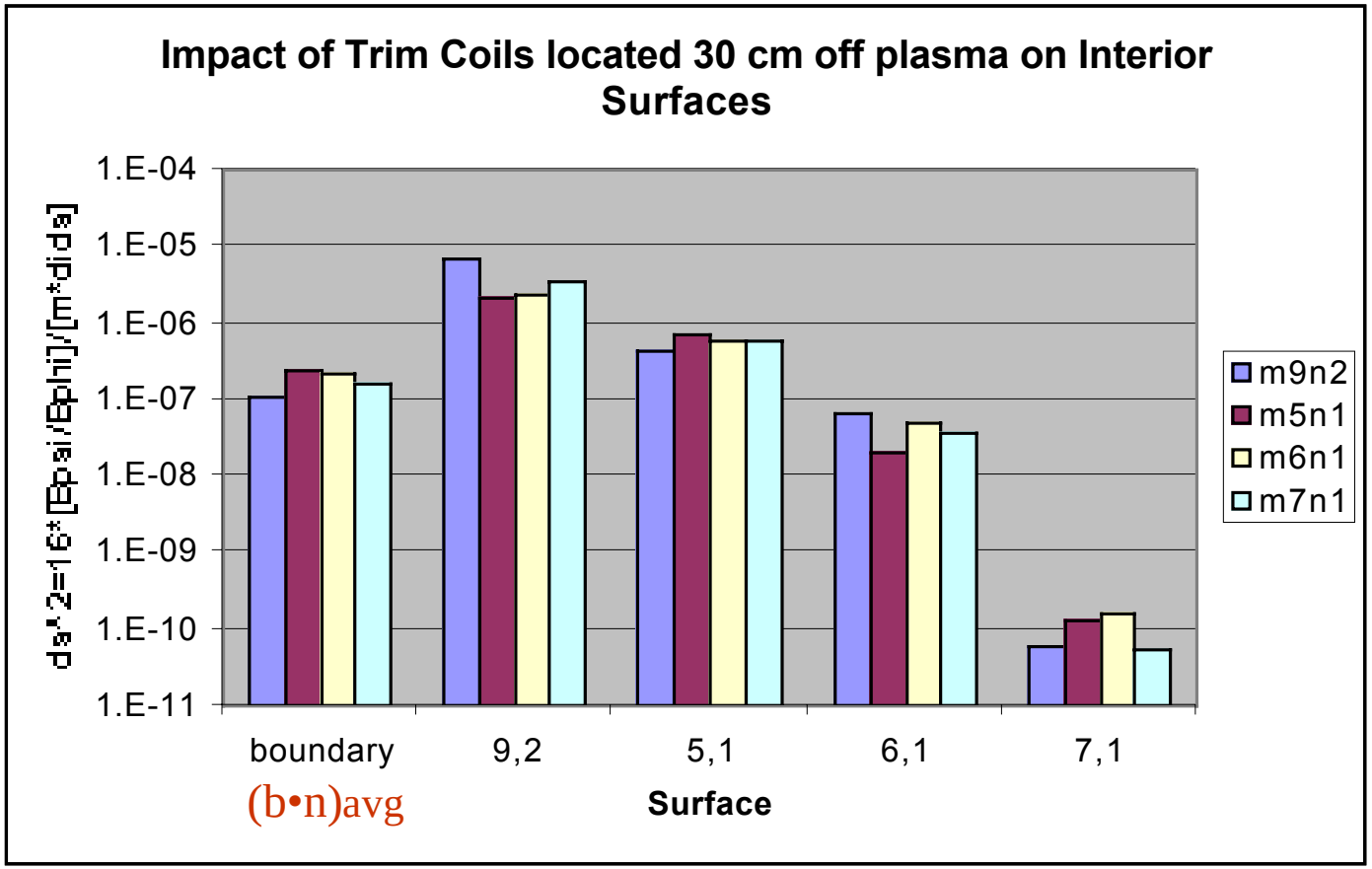
- CURROPT cannot presently be used to solve for trim coil currents to target islands with plasma current
  - It lacks a way of calculating fields from plasma current
- CURROPT can be use to calculate contribution of coils to Island size on resonant interior surfaces observed in PIES
  - It augments inductance matrix (b•n on boundary) with contributions to

$$ds^2 = 16 \cdot \left[\frac{B^s / B^\phi}{m\iota'} \right]$$

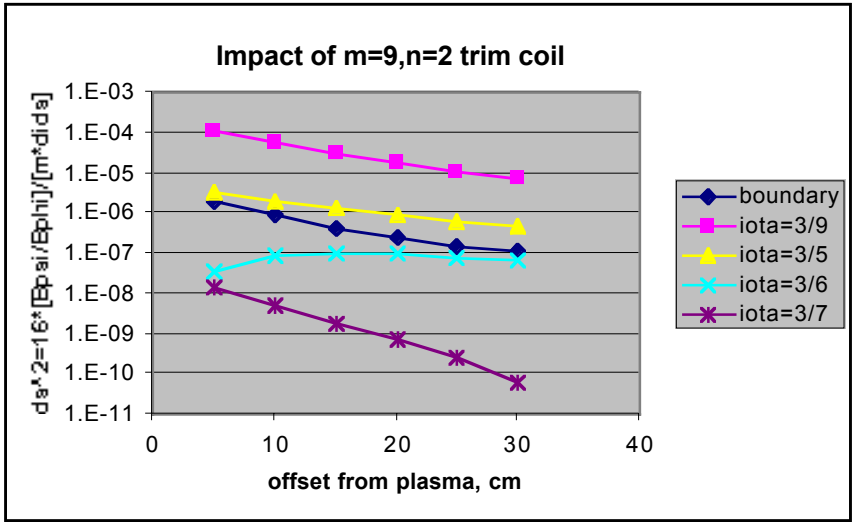
Trim Coils not “pure”, impacting other resonances

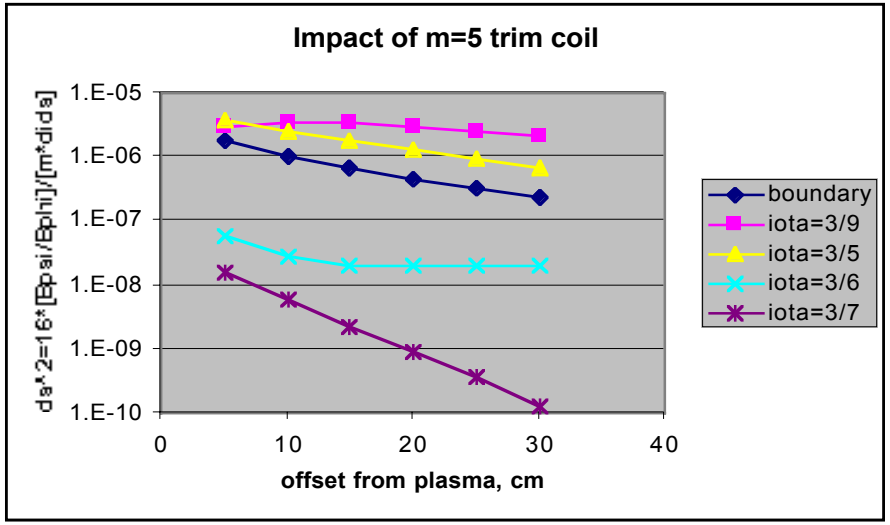


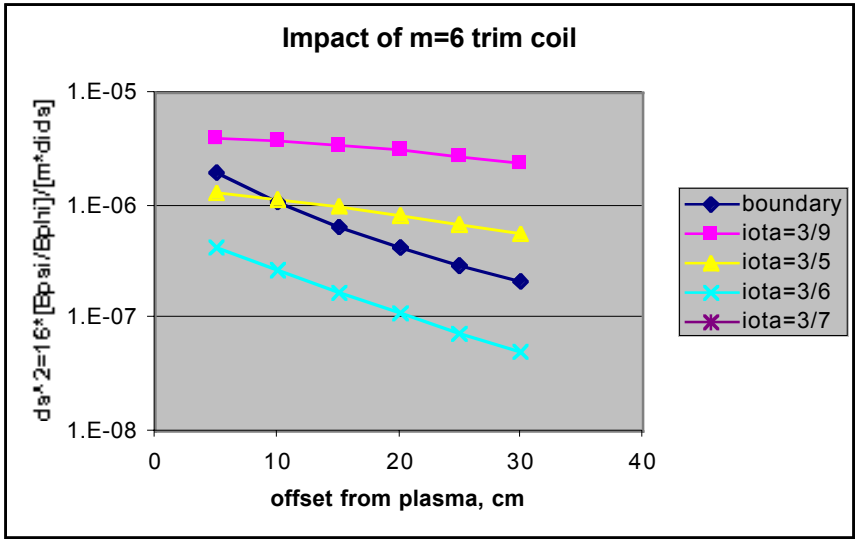
Trim Coils not "pure", impacting other resonances

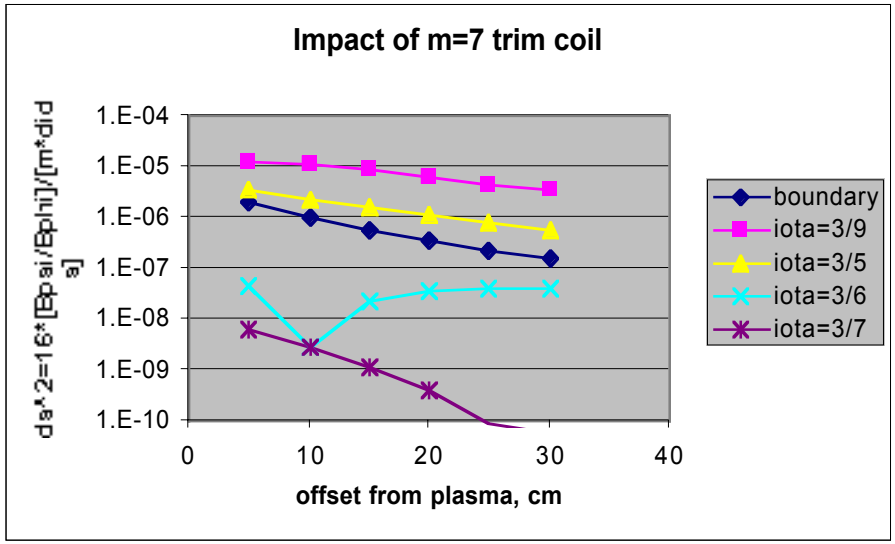


Required Trim Currents are larger if located further from plasma









Conclusions / Plans

- Improving first iteration, unblended results did not guarantee improved converged solution
- Coupling of trim coils needs to be understood.
  - Manual approach for setting currents too tedious and slow for more than 1 trim coil set
  - Curropt, successful in vacuum, being used to calculate influence matrix to guide full current, full beta design
  - Method proposed by Bob Woolley to determine field from plasma current on interior surfaces may allow curropt to be used at full current, full beta to set trim coil currents
- Alternate trim coil topologies need to be explored
  - Propose using influence matrix to compare options