Trim Coil Design Status

NCSX Project Meeting

January 30-31, 2001

Art Brooks

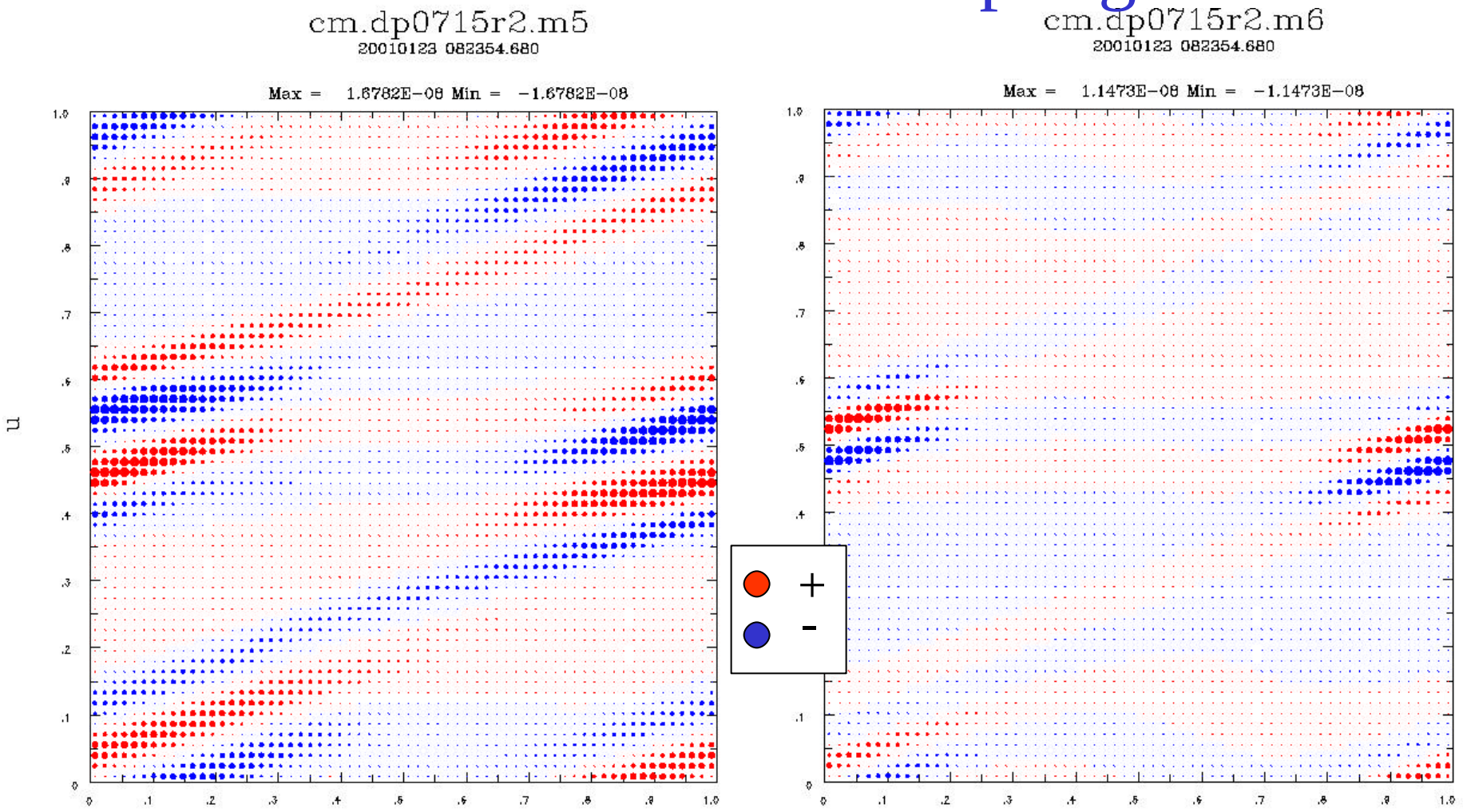
Overview

- Trim Coil Configuration
- Performance Evaluation

Trim Coil Configuration

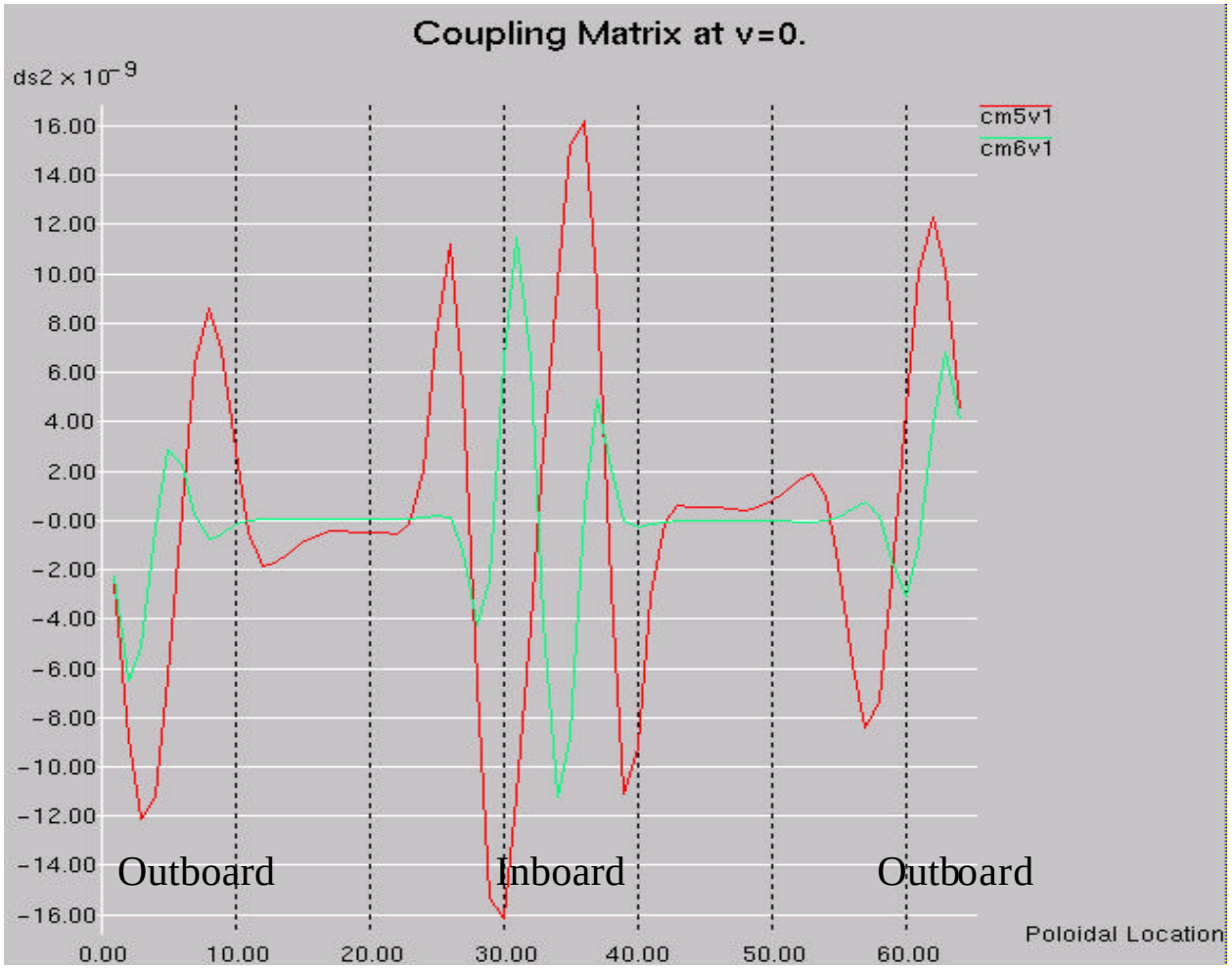
- Presentation (attached) to Engineering Group led to selection of in-vessel winding surface for Window Pane Coils (behind First Wall)
  - Surface 7cm off plasma inboard, 15 cm off plasma outboard
  - Will utilize space between NB at v=0.
  - Locate trim coils where they are most effective:
    - Four Window Panes Inboard and Four Outboard
    - Toroidal Extent to be explored

Region at v=0 Inboard and Outboard Most Effective Coupling

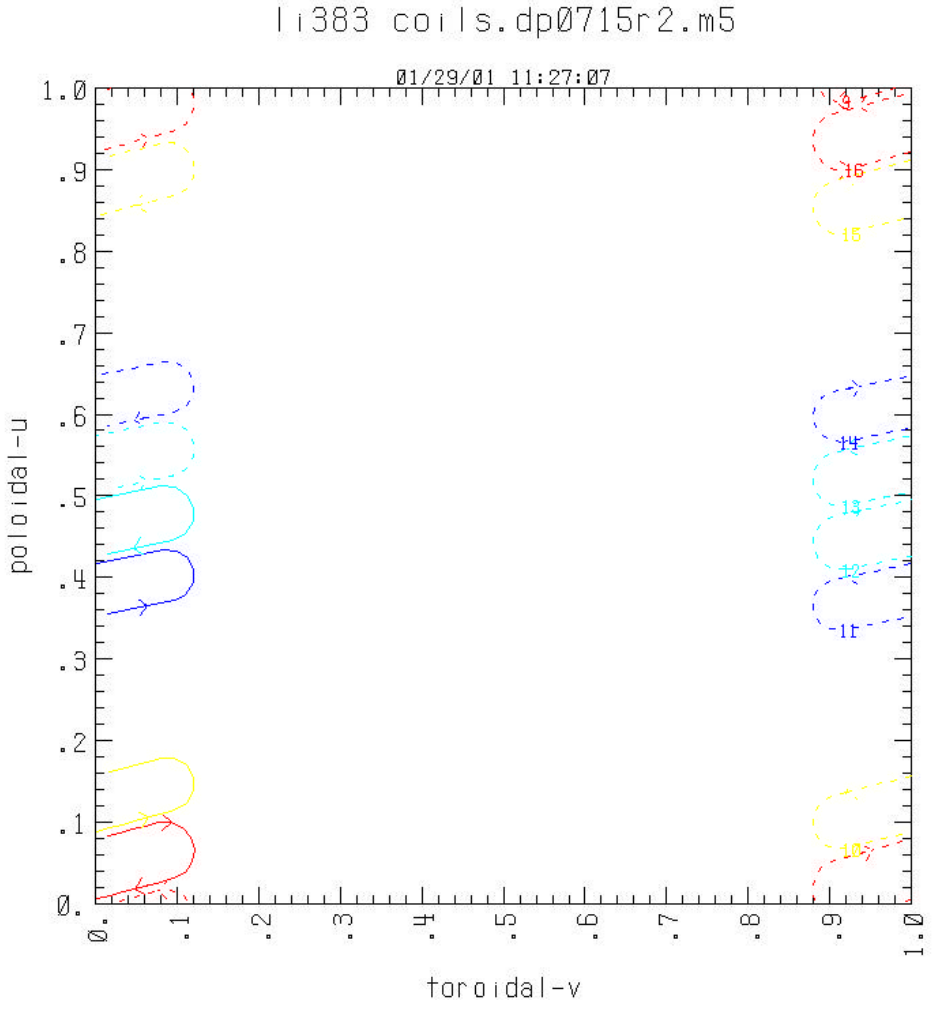


Coupling Matrix on surf0715

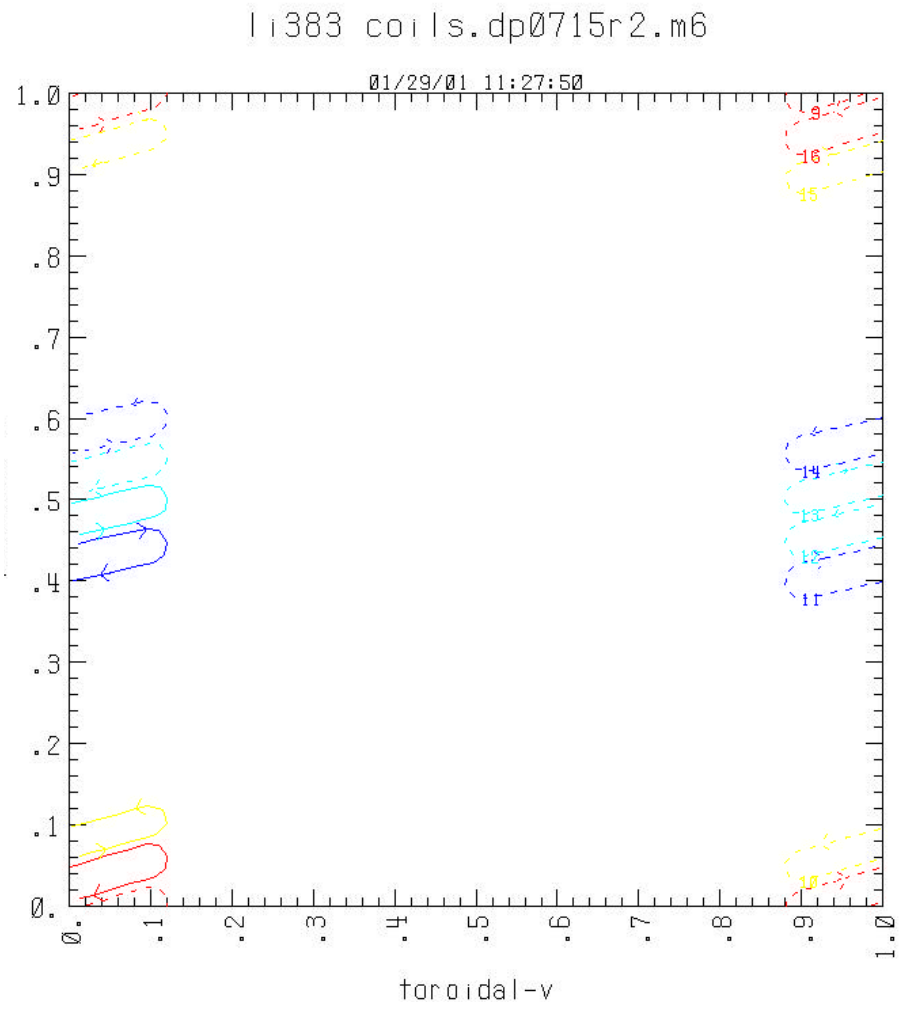
Region at v=0 Inboard and Outboard Most Effective Coupling



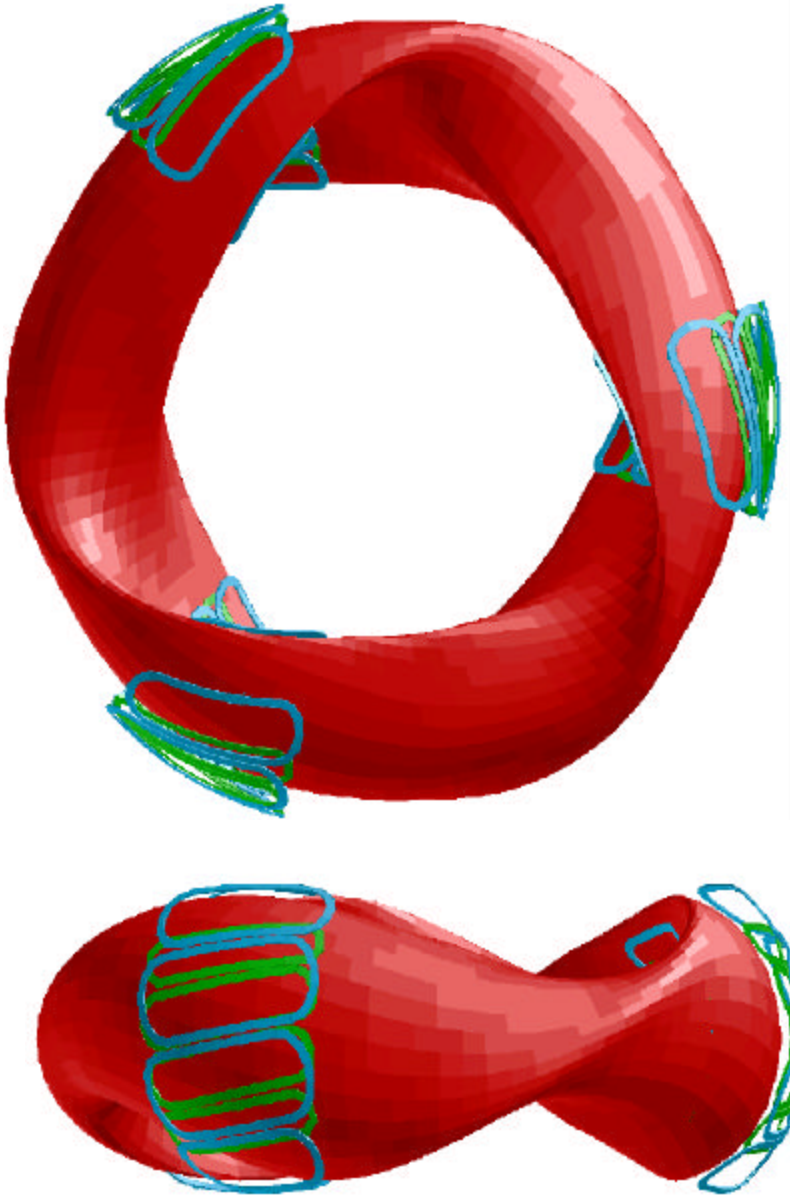
Window Pane Coils on Surf0715



M=5

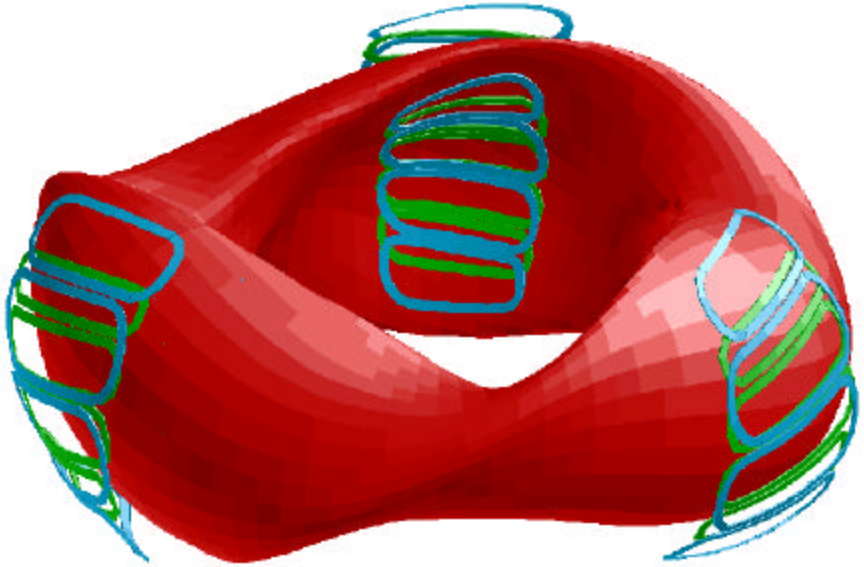


M=6

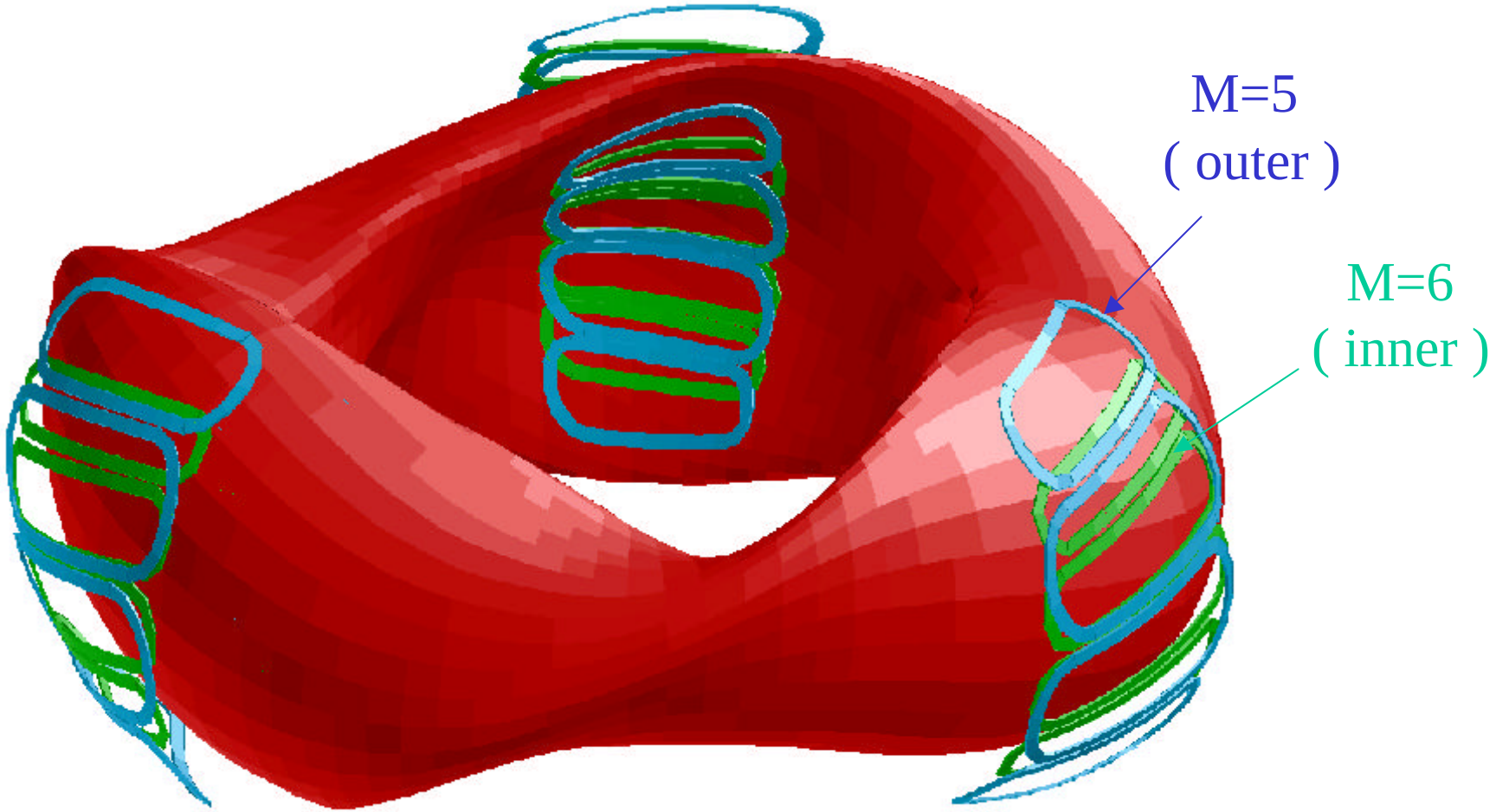


Window Pane Coils on Surf0715

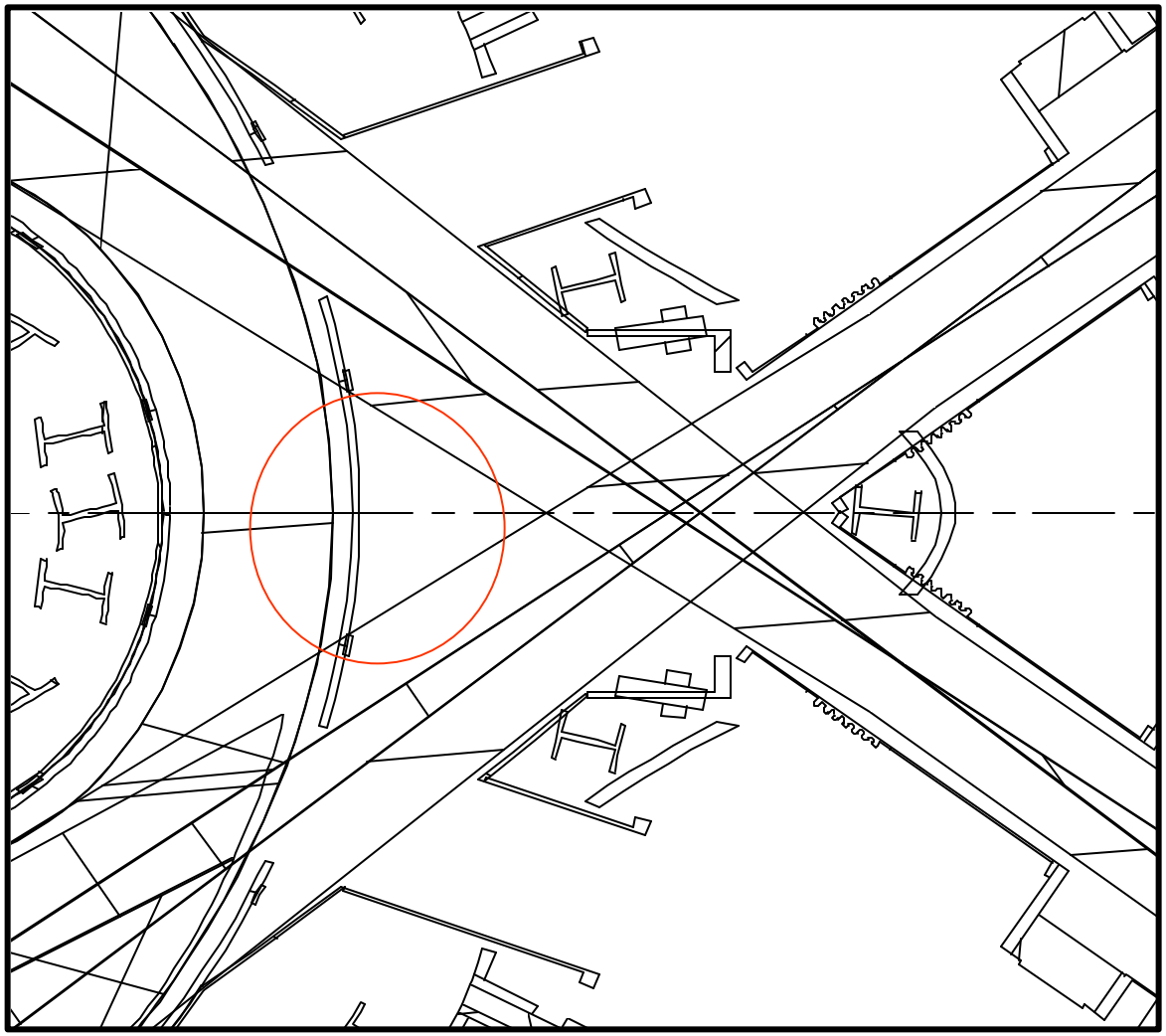
Rendered with 5x1 cm cross section



Window Pane Coils on Surf0715



Will utilize space between NB at v=0.

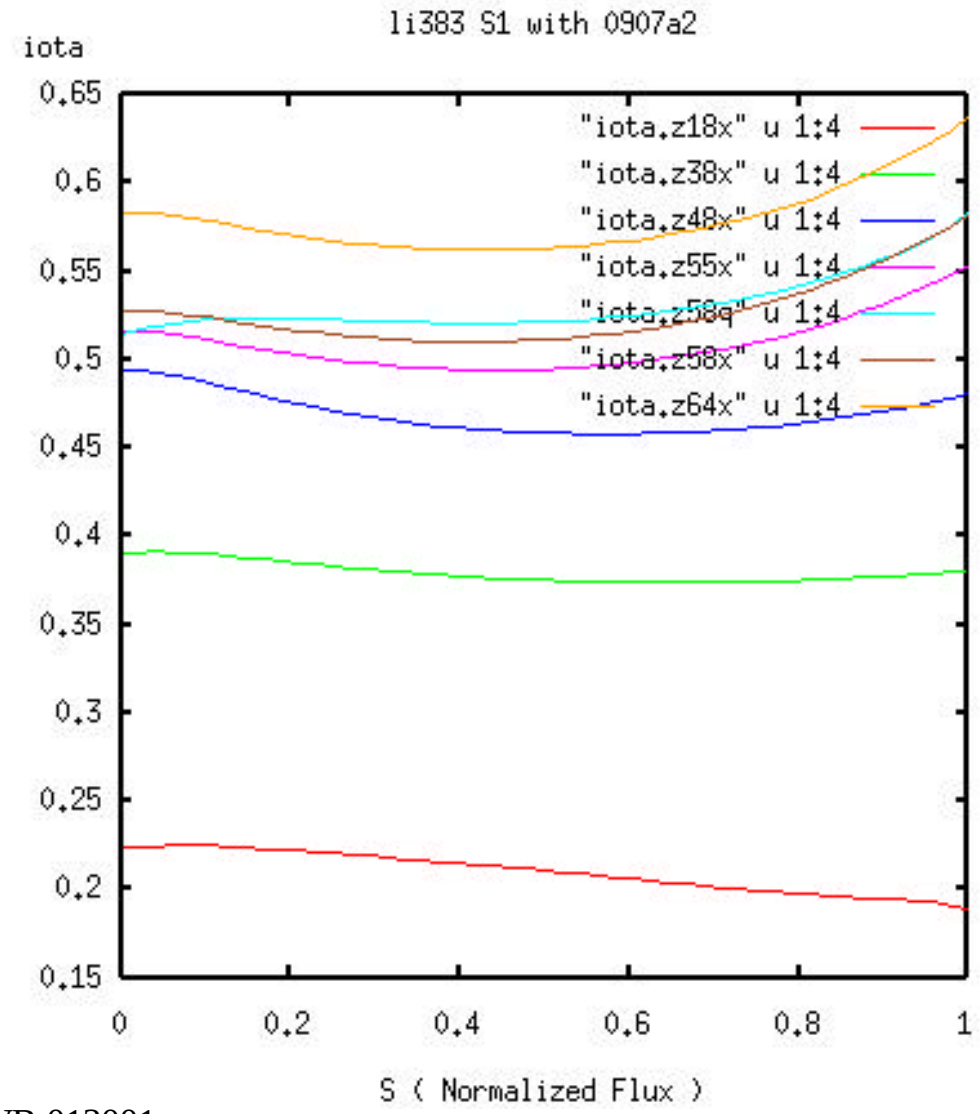


Courtesy of
Mike Cole

Performance Evaluation

- As suggested by Mike Z,
  - Use the 0907 coils which were “hudsonized” to be Island free at full current, full beta
    - Stuarts’ coils.li383_25
  - Assign currents to coils from the VMEC free boundary iota scan for vacuum (s1 state) – should be close
- Target m=5 & m=6 resonances in CURROPT to set trim coil currents
- Verify with PIES

Using Vacuum State to Test Trim Coils

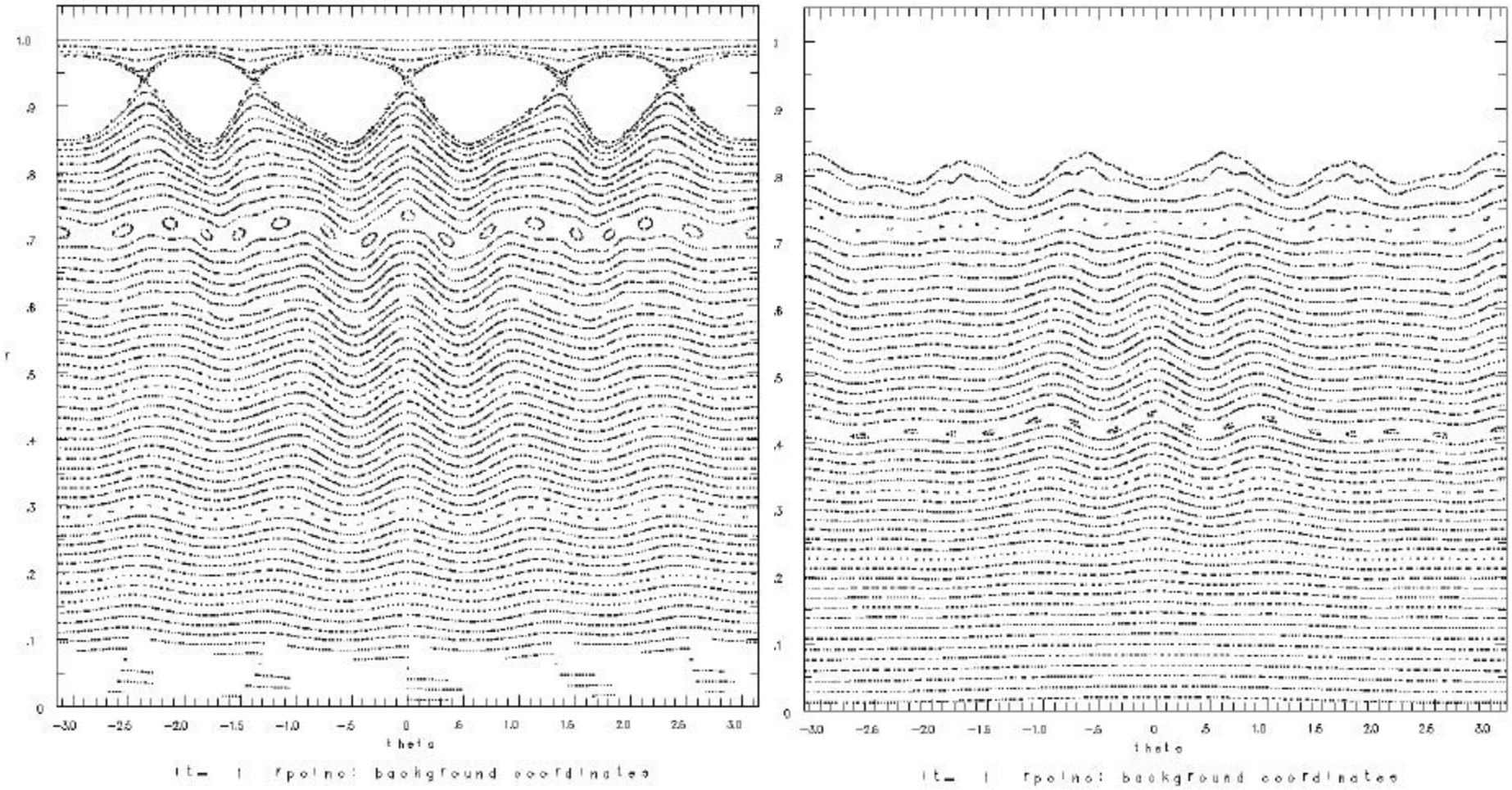


Data from iota
Scan by Mike Z

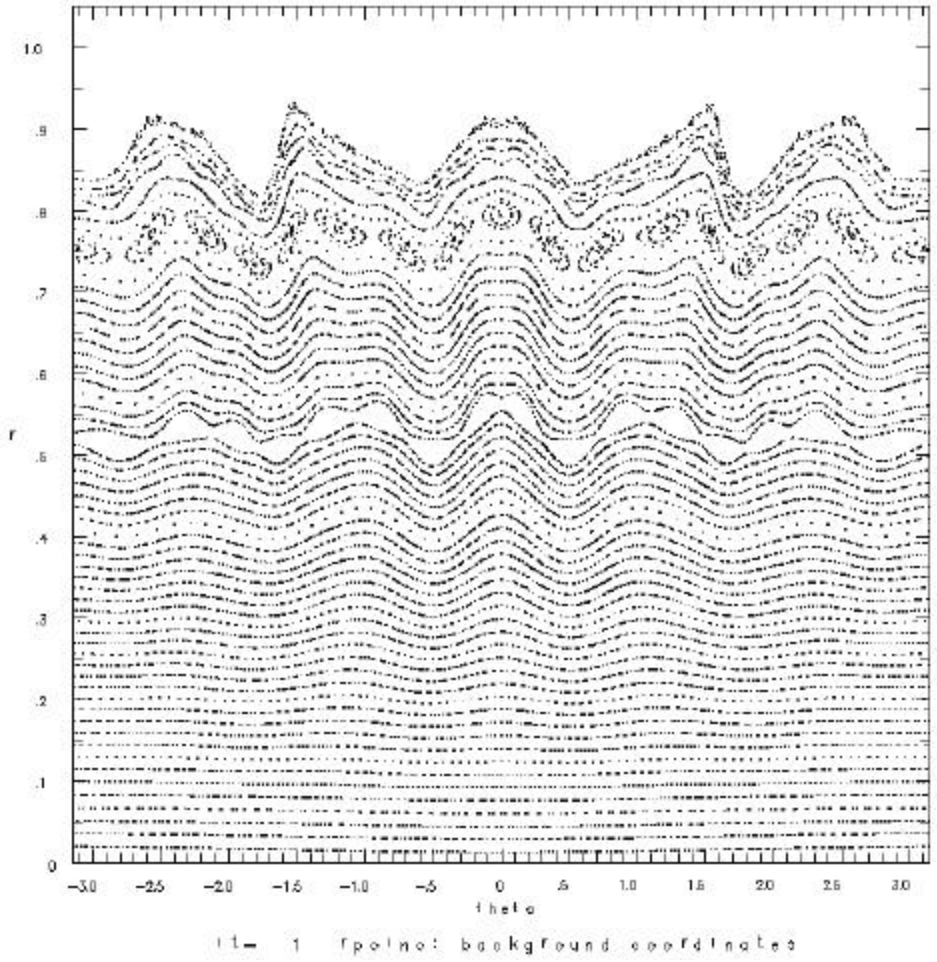
Only z64x and z55x
Cross iota= .6 or .5

All present difficulties due to low shear

Z64x Fixed and Free Boundary Pies



Z64x with Trim Coils

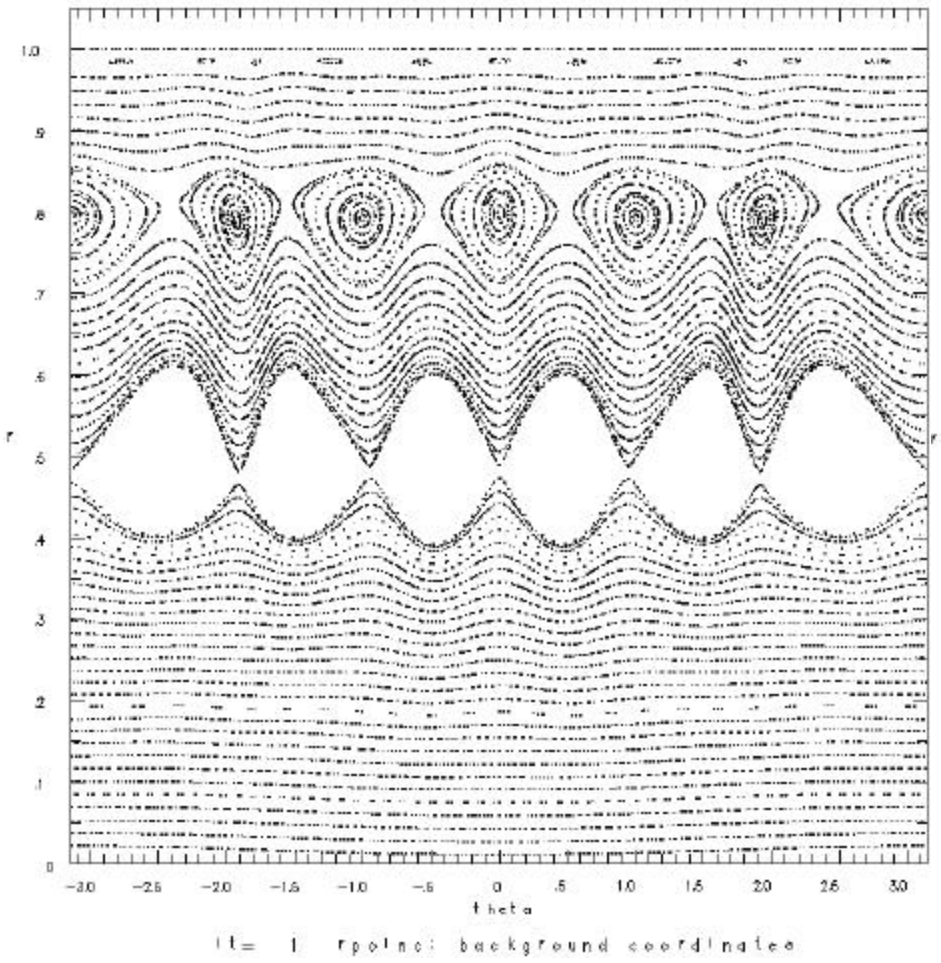


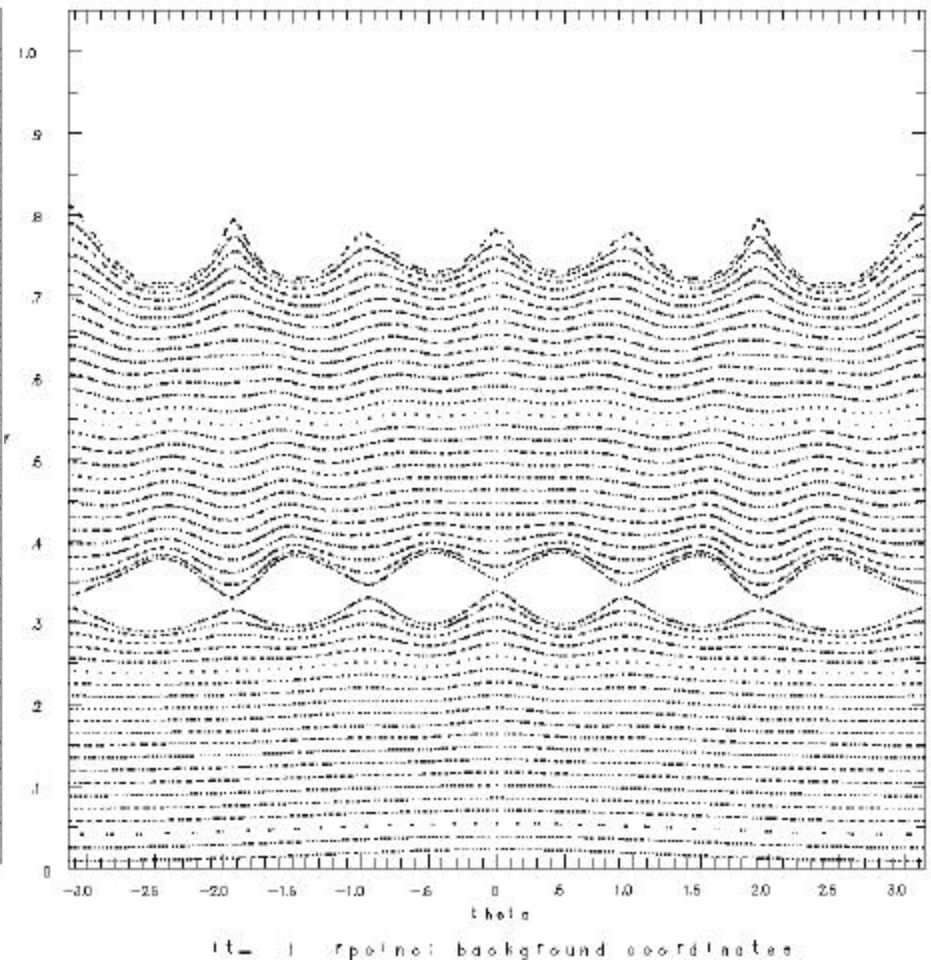
Strong m=10, n=2
still present

Max Trim Coil Current
= 4.8 KAT

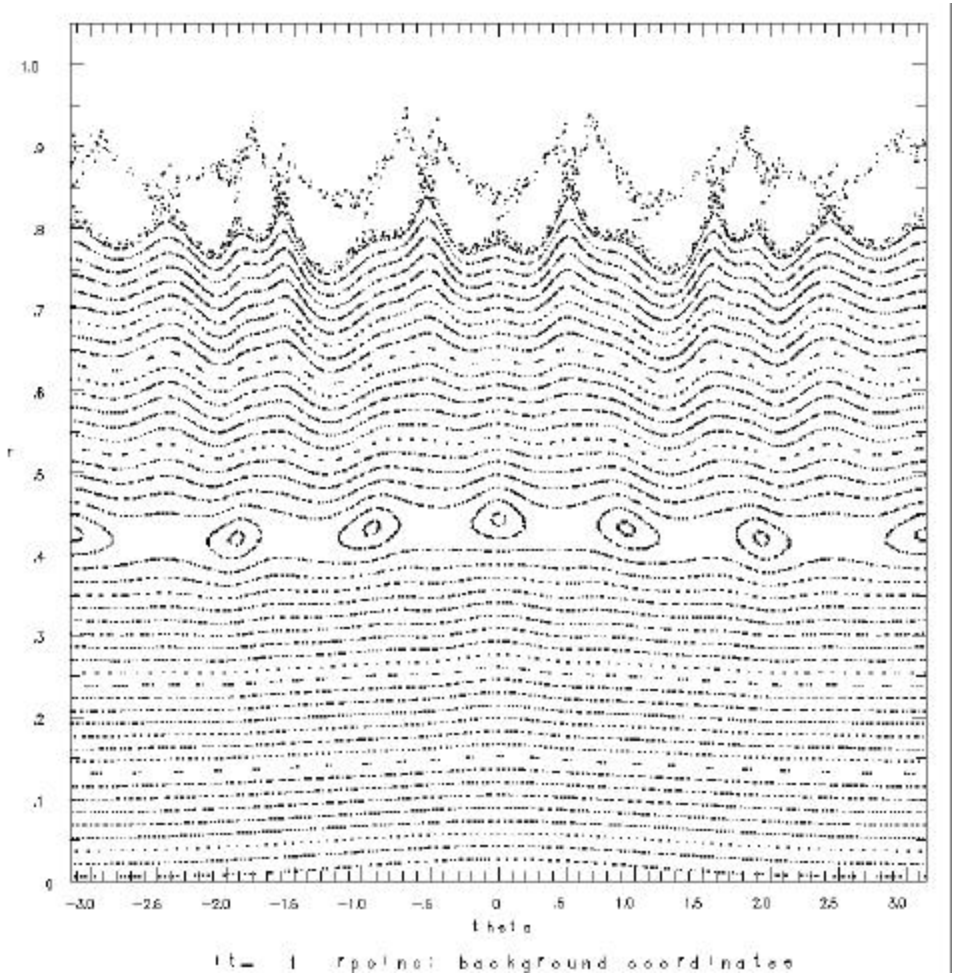
Trim Coil Currents set with CURROPT

Z55x Fixed and Free Boundary Pies





Z55x with Trim Coils



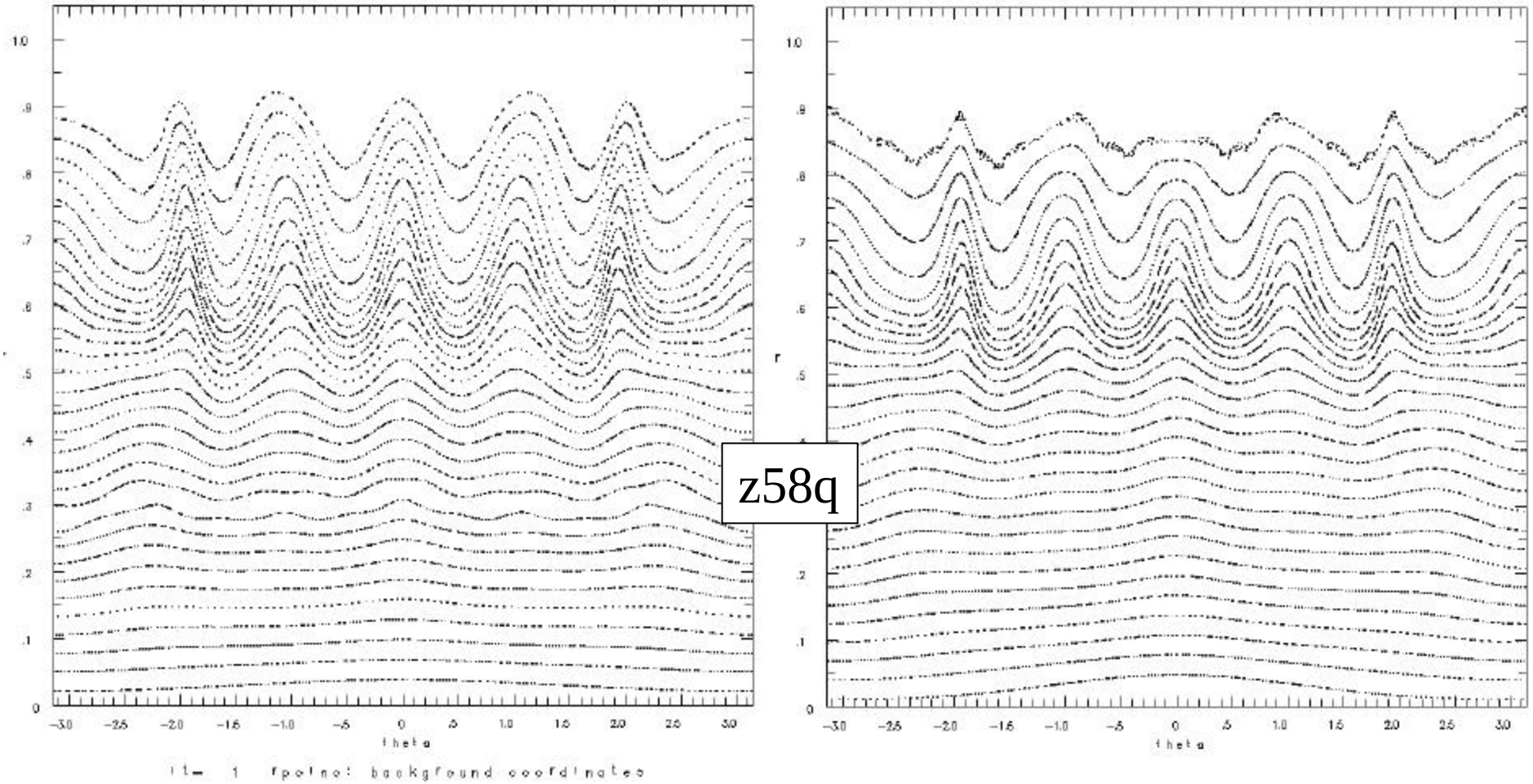
m=12, n=2 persists

Interior islands
less of a concern

2.5 KAT Max Current

Trim Coil Currents set with CURROPT

Some Impact of Using 0907 Currents in ‘Hudsonized’ Coils (without Trim Coils)



0907

‘Hudsonized’ 0907

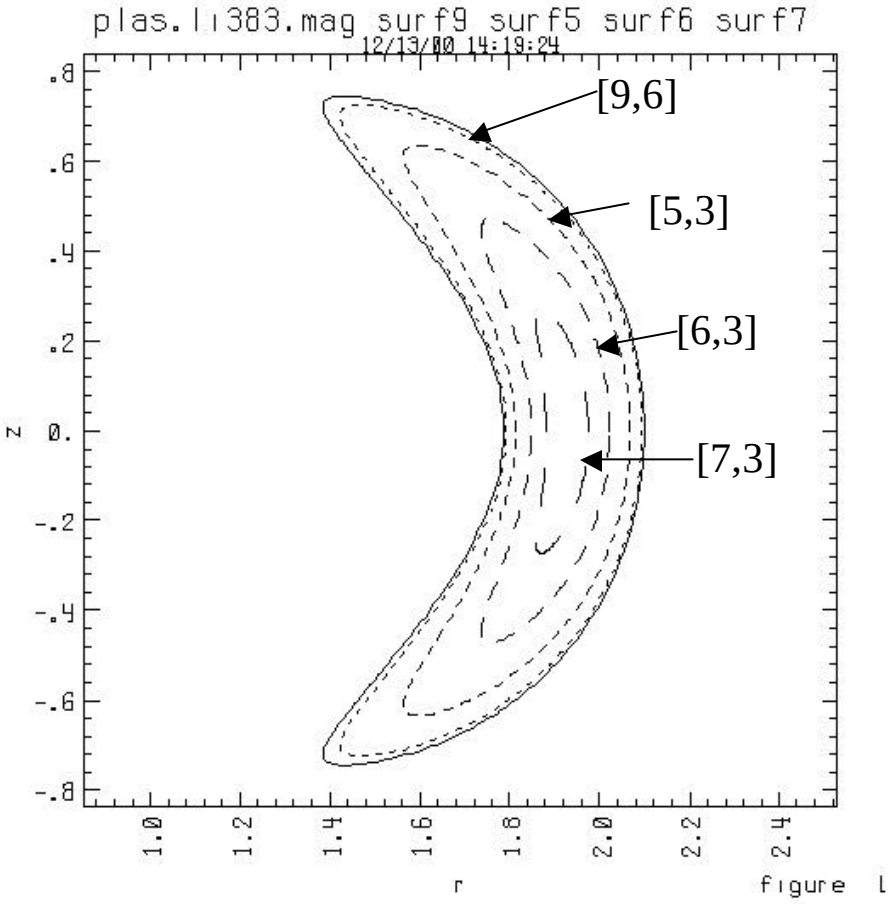
Summary/Plans

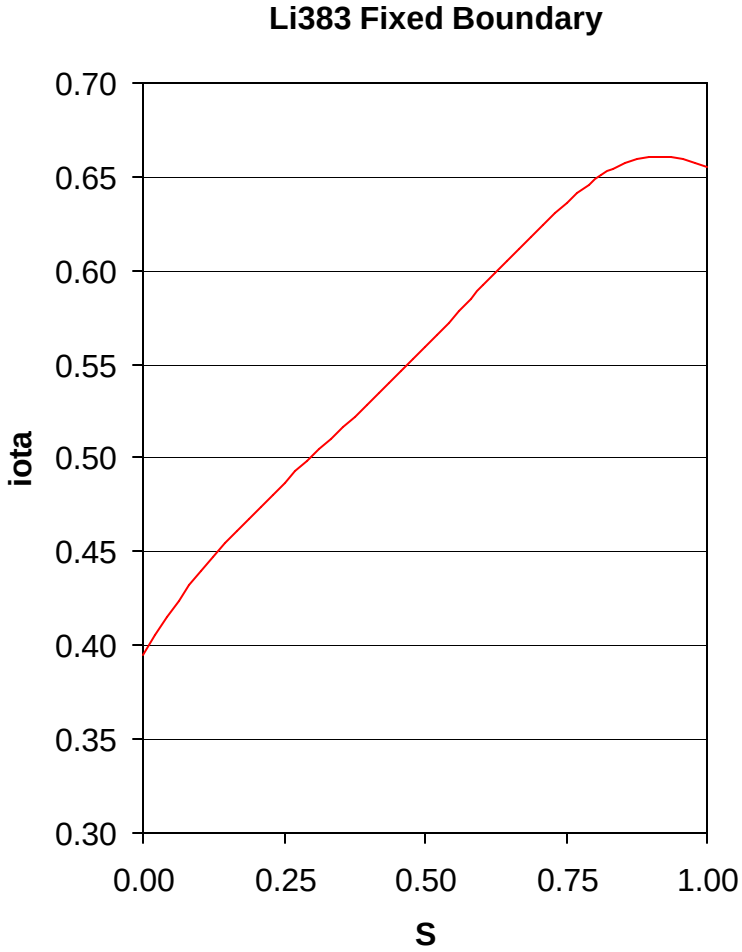
- A Trim Coil Configuration given to Engineering for their assessment.
  - Can we increase toroidal extent in regions away from NB? (Can we live with what we have at NB?)
- More effort needed to demonstrate adequacy for Physics
  - Next step is to apply Hudson's approach to setting trim coil currents
  - Need to examine if proximity of trim coils to plasma is hurting high order modes
- Continue to explore possibility of a single layer of trim coils

Status of Trim Coil Design

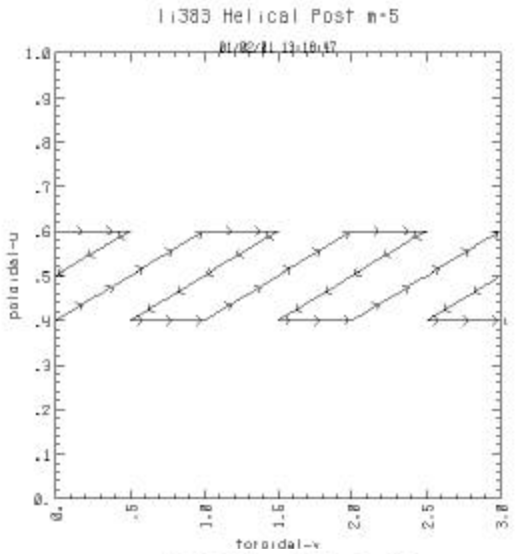
- Topology Scan - Helical Post , Sawtooth, Wavy Modular Coils and Saddles
  - Perceived as truncated helical windings
  - How large do they need to be?
    - Generate series of windings of varying height centered on inboard mid-plane and compare coupling matrices
- Window Pane (alias Picture Frame) Coils
  - Where are they most effective?
    - To answer, cover a winding surface with small window pane coils (effectively dipoles) and calculate coupling matrix
    - Use 1826 surface for now until better surface(s) defined by engineering

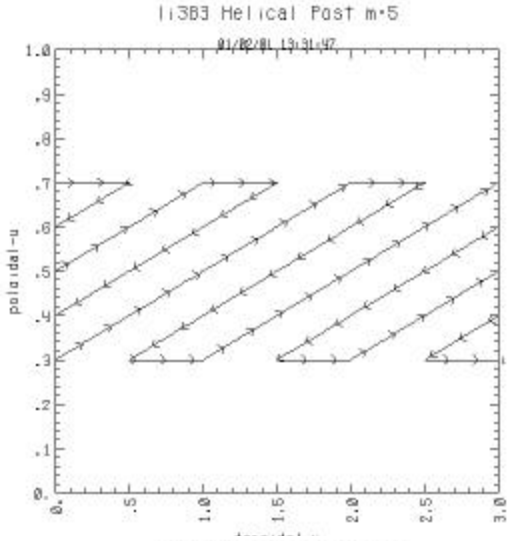
Li383 Resonances
For PVR, focus is on [5,3] and [6,3]

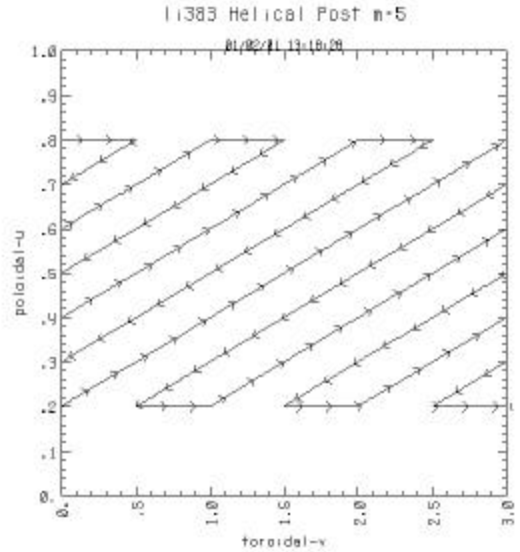


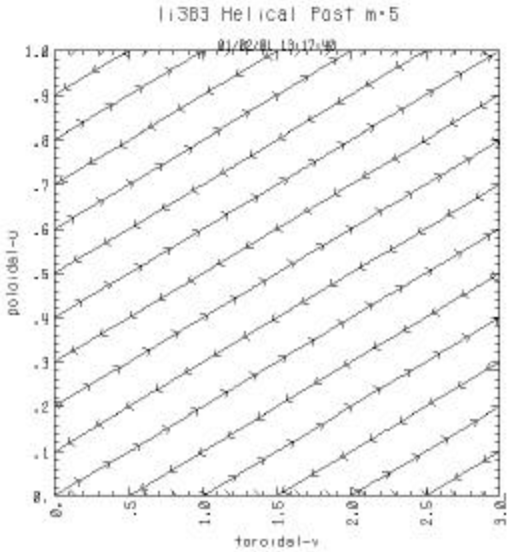


Helical Post for m=5





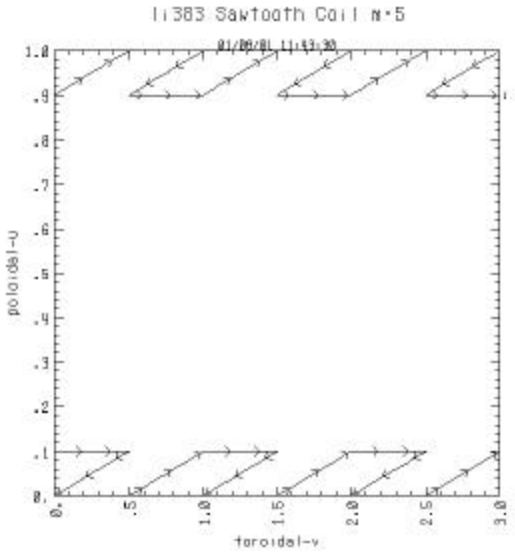


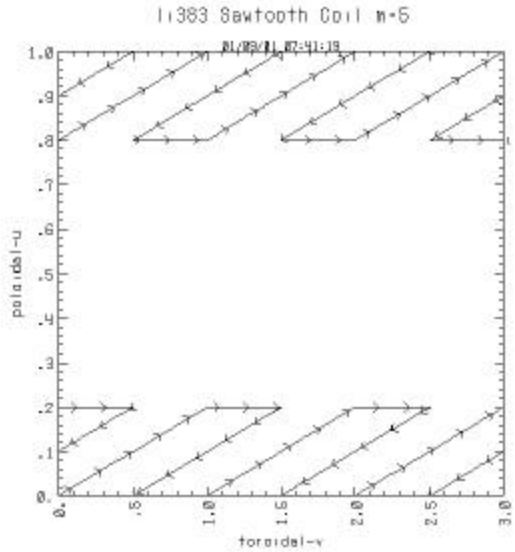


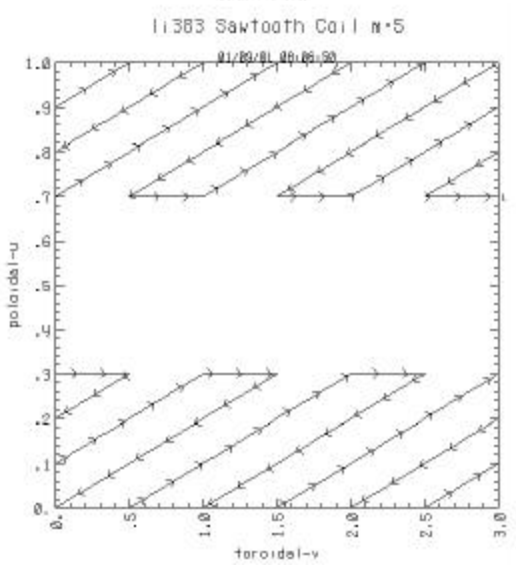
Shown for
3 Periods

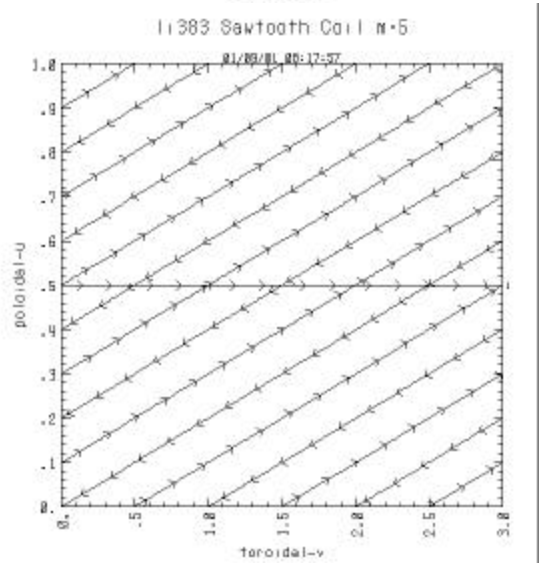
360 deg
Helical Post
Equivalent to
Helical Winding
and Wavy PF at
u=0.

Sawtooth Coils for m=5





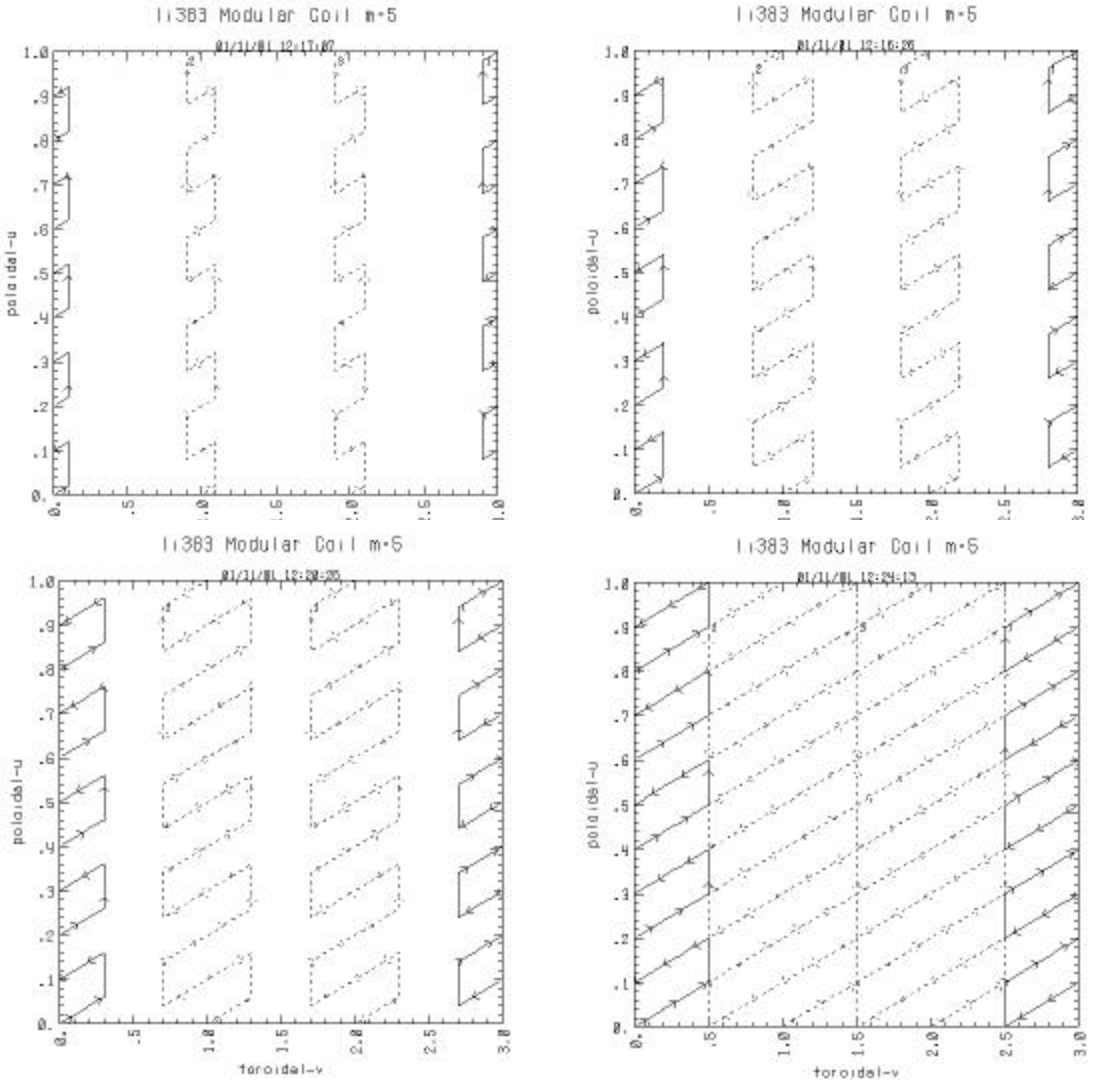




Shown for
3 Periods

360 deg
Sawtooth
Equivalent to
Helical
Winding and
Wavy PF at
u=0.5

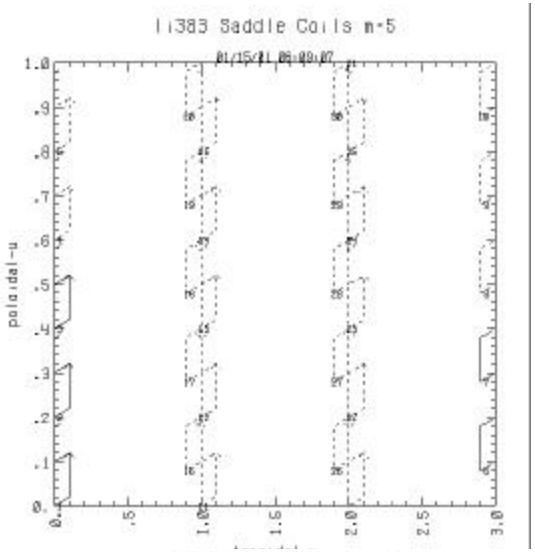
Wavy Modular for m=5

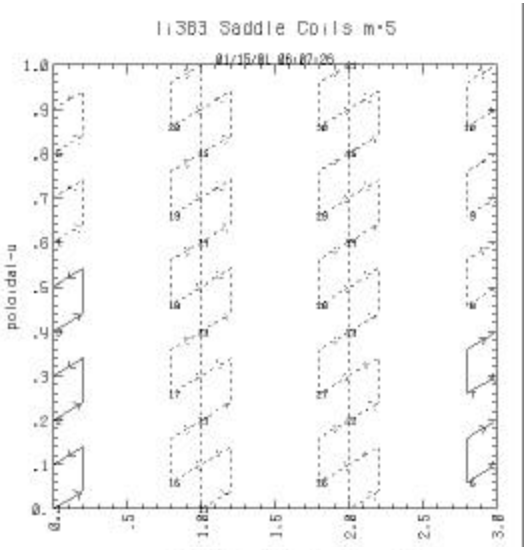


Shown for
3 Periods

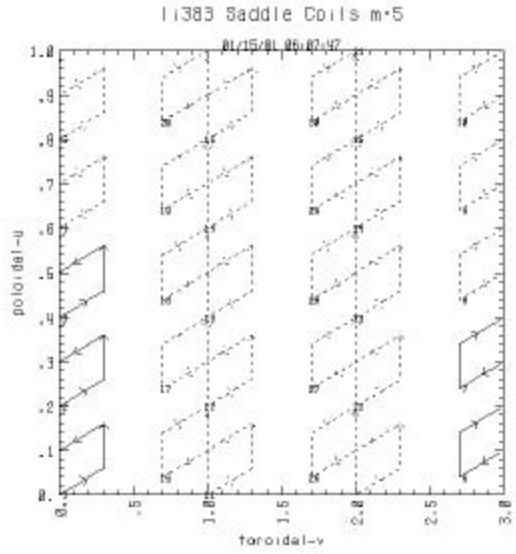
360 deg Wavy Modular Equivalent to Helical Winding and Planar Mod at v=0.5

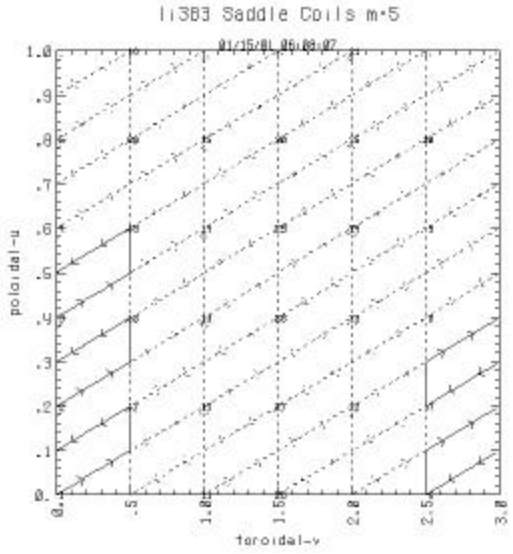
Saddles for m=5





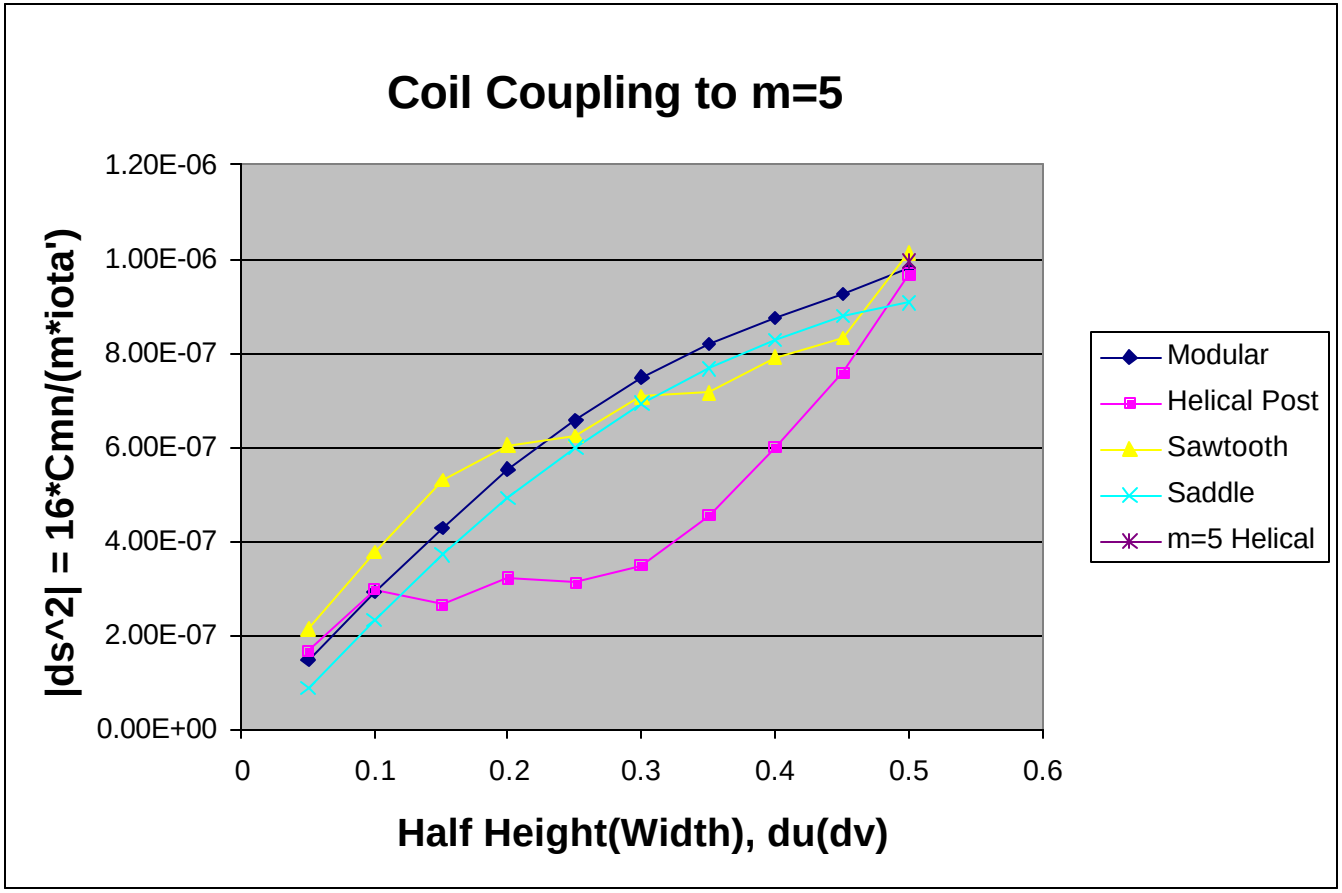
Shown for
3 Periods





360 deg Saddles
Equivalent to
Helical Winding
and Planar Mod at
v=0.0 & 0.5

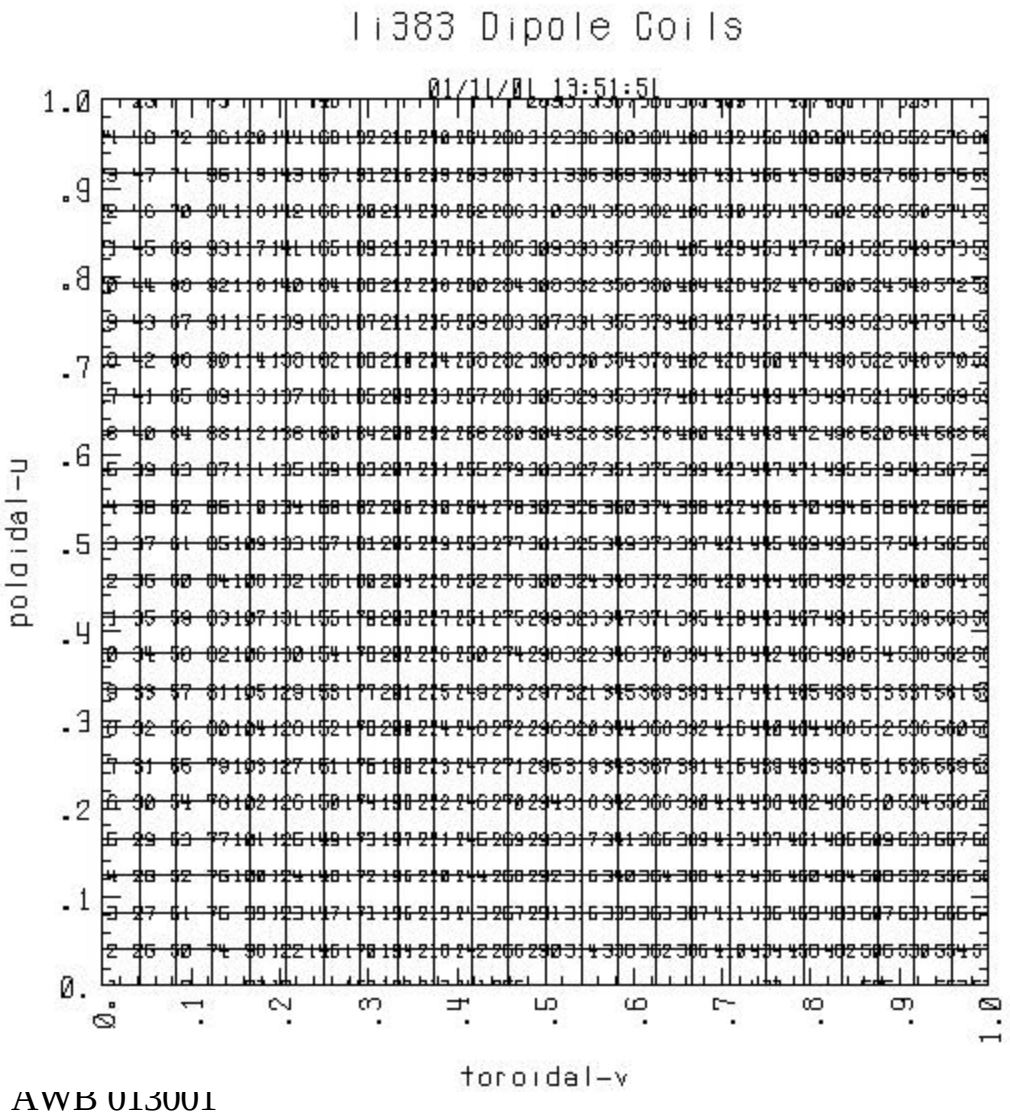
Impact of Extent on Coupling



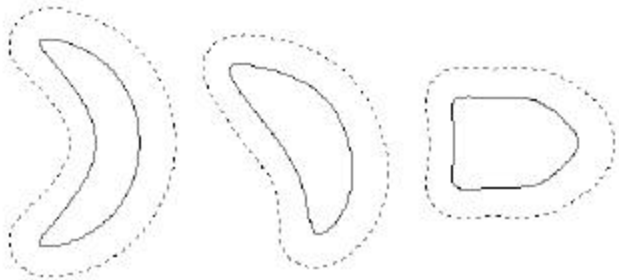
1) |ds^2| = 1.e-7 corresponds to 1 kA to control a 1% flux island

2) Coil extent given in u-v space. Real space comparison may differ.

24 x 24 ‘Dipole’ Array with Unit Currents

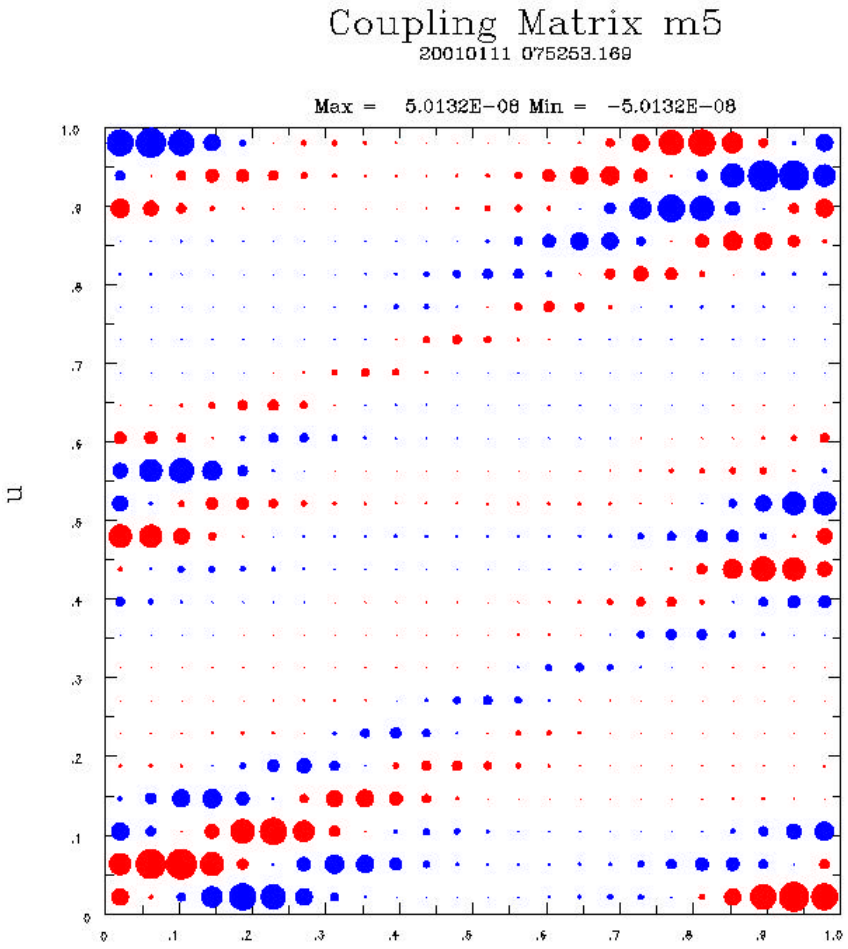


Finer Mesh with full coverage on 1826 surface

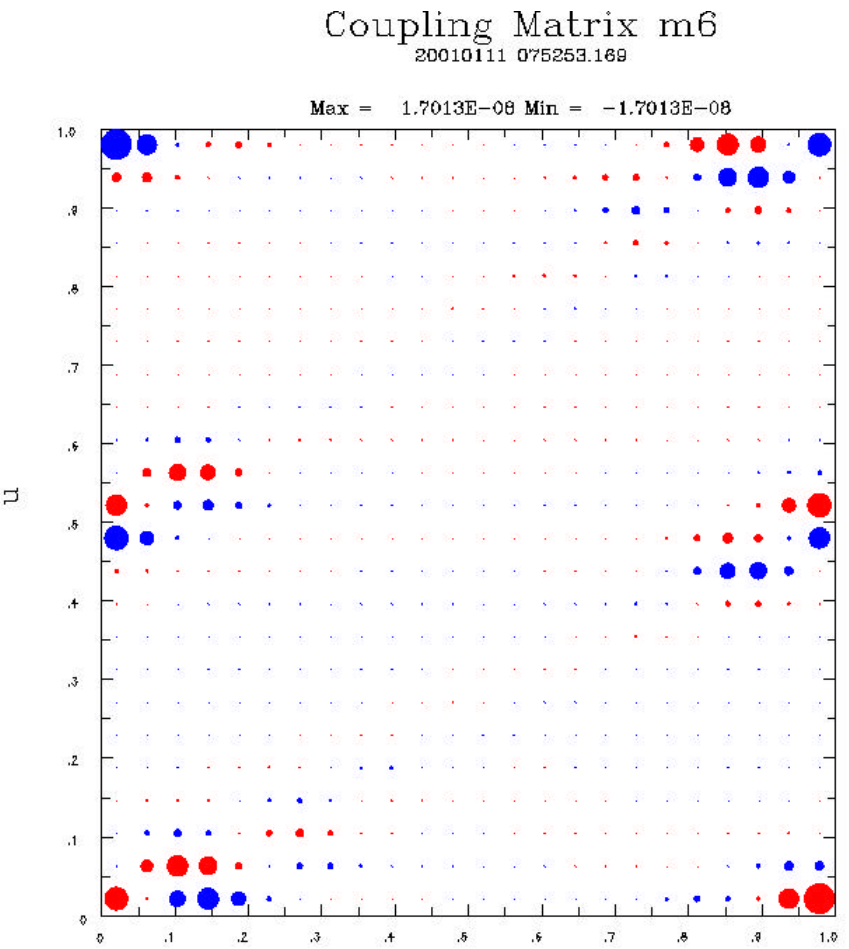


Still finer mesh requires code modifications not yet complete

24 x24 Dipole Array Coupling Matrix

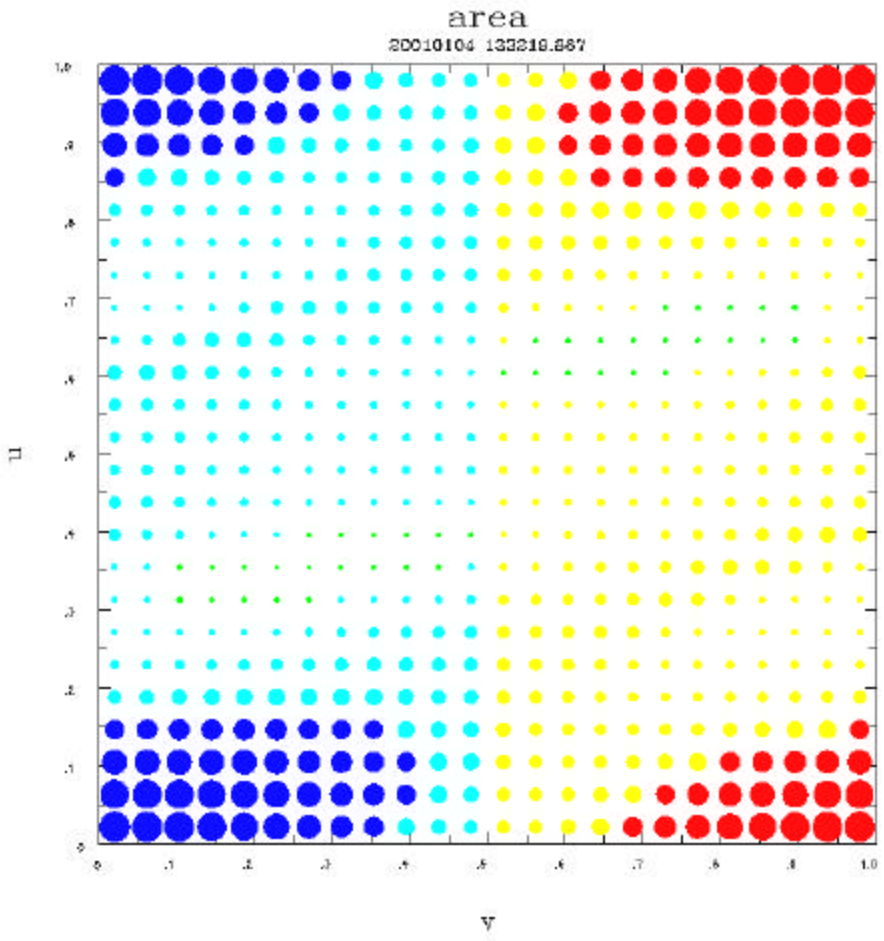


ds^2=2.81e-6



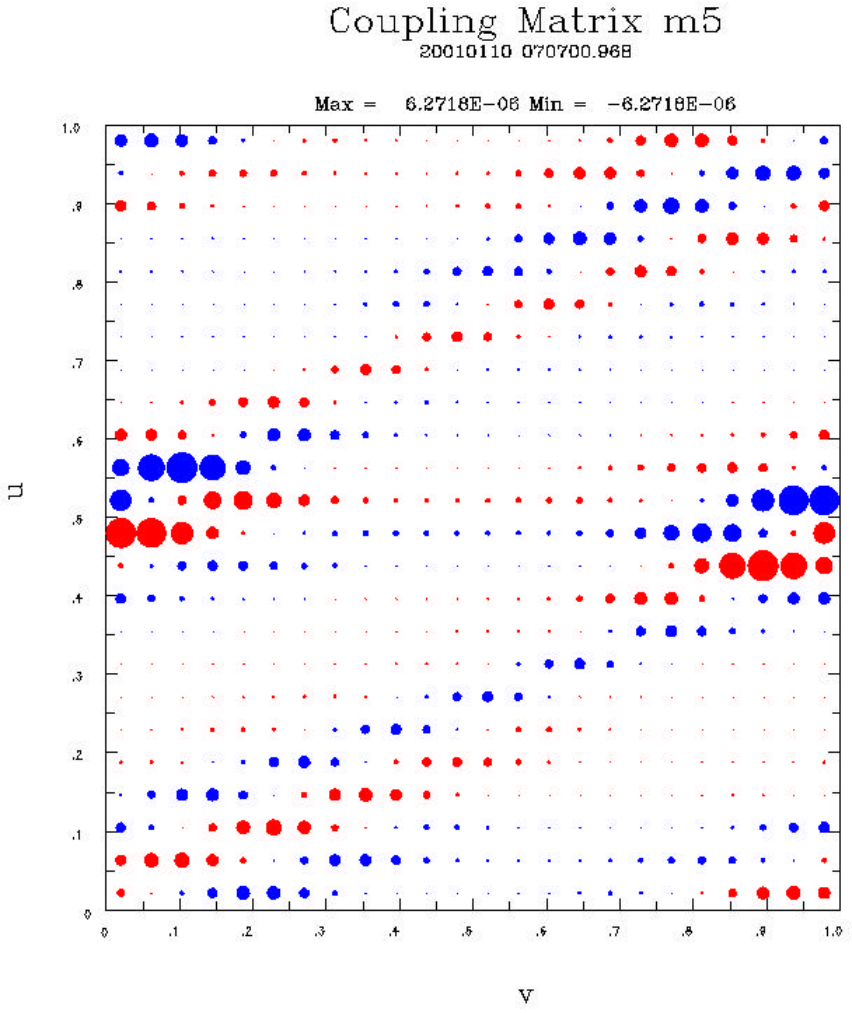
ds^2=3.59e-7

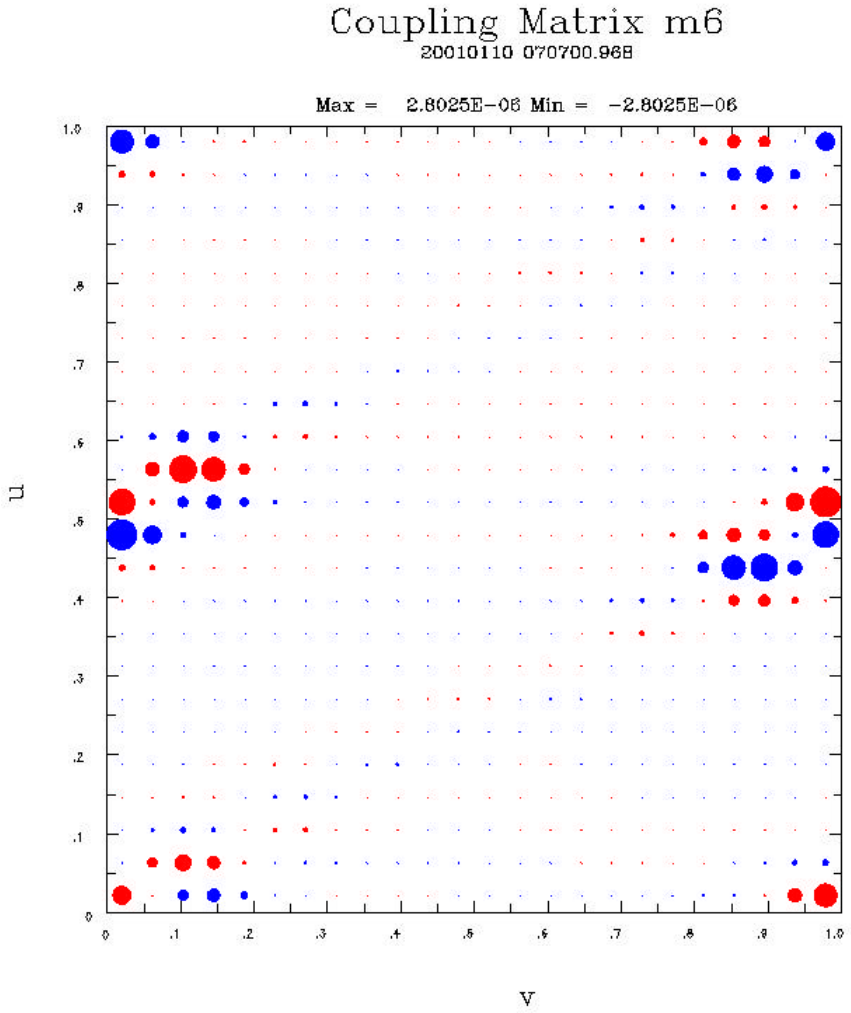
Dipoles Uniform in u-v, Not Real Space



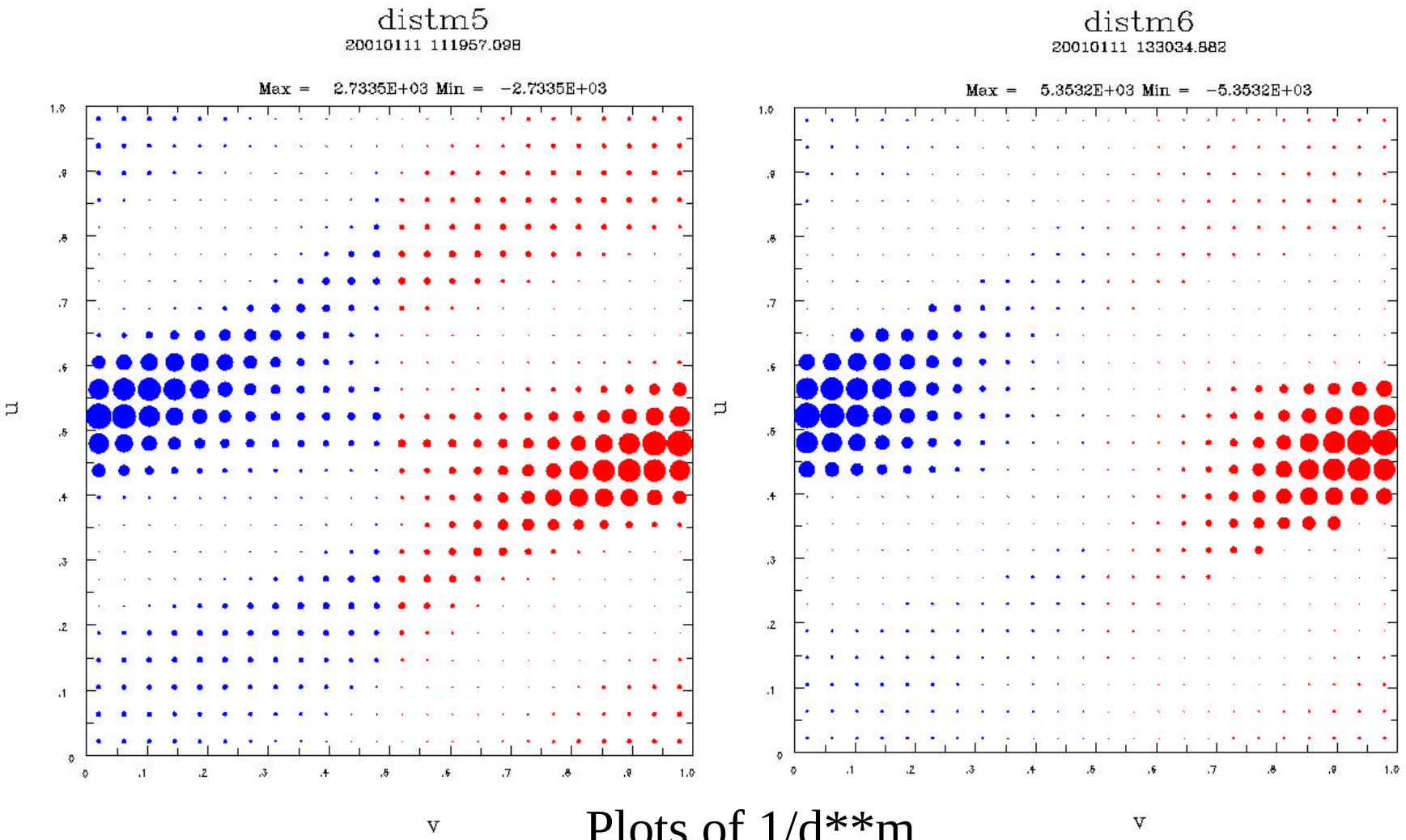
Real Space Area Distribution for uniform du*dv

Adjusting for Area, Dipoles want to be inboard at bean section



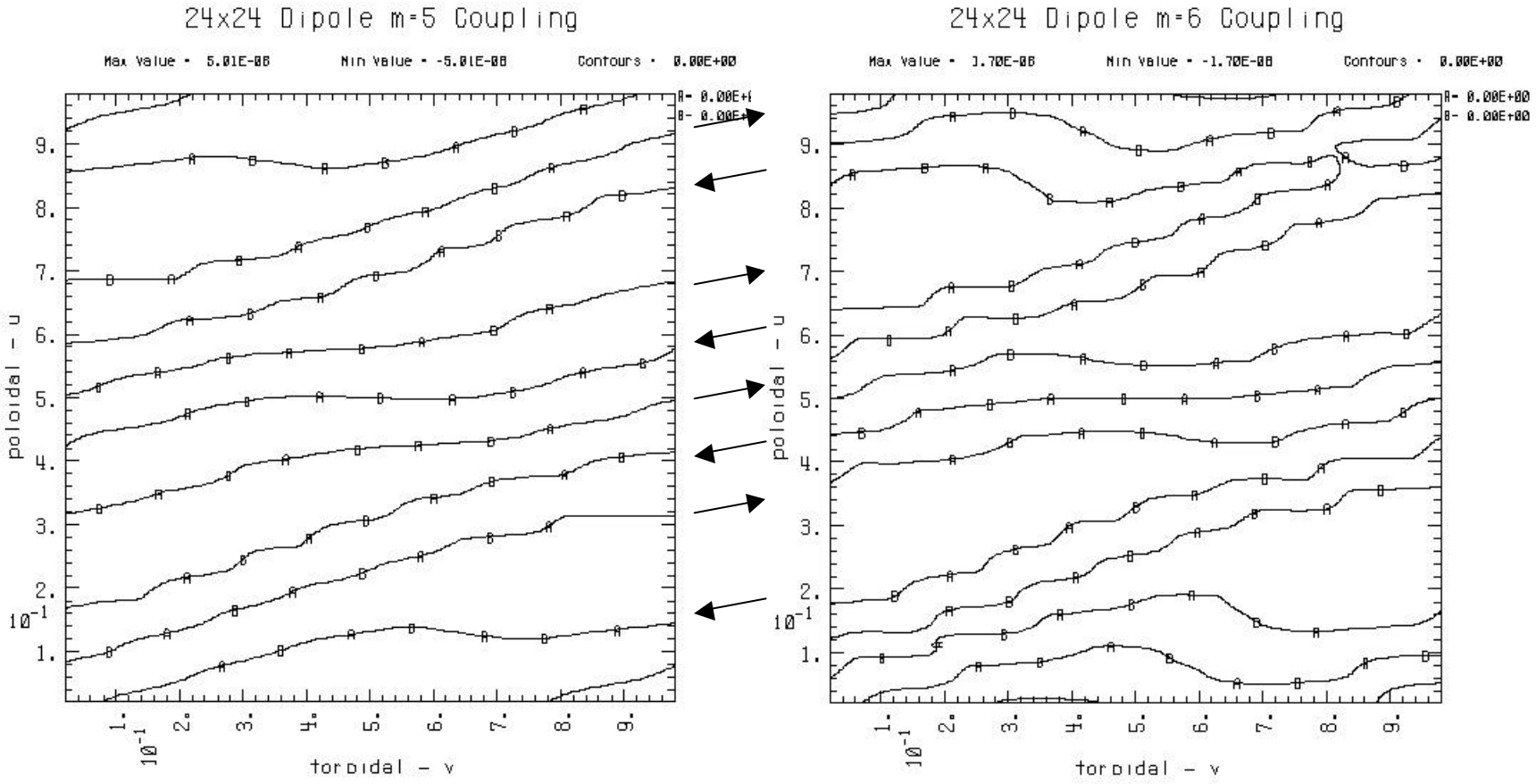


Coupling Strength Appears Driven by Local Distance to Resonance Surface



Plots of 1/d**m

Grouping Of Like Sign Dipoles Reveals Helical Winding with some Modulation

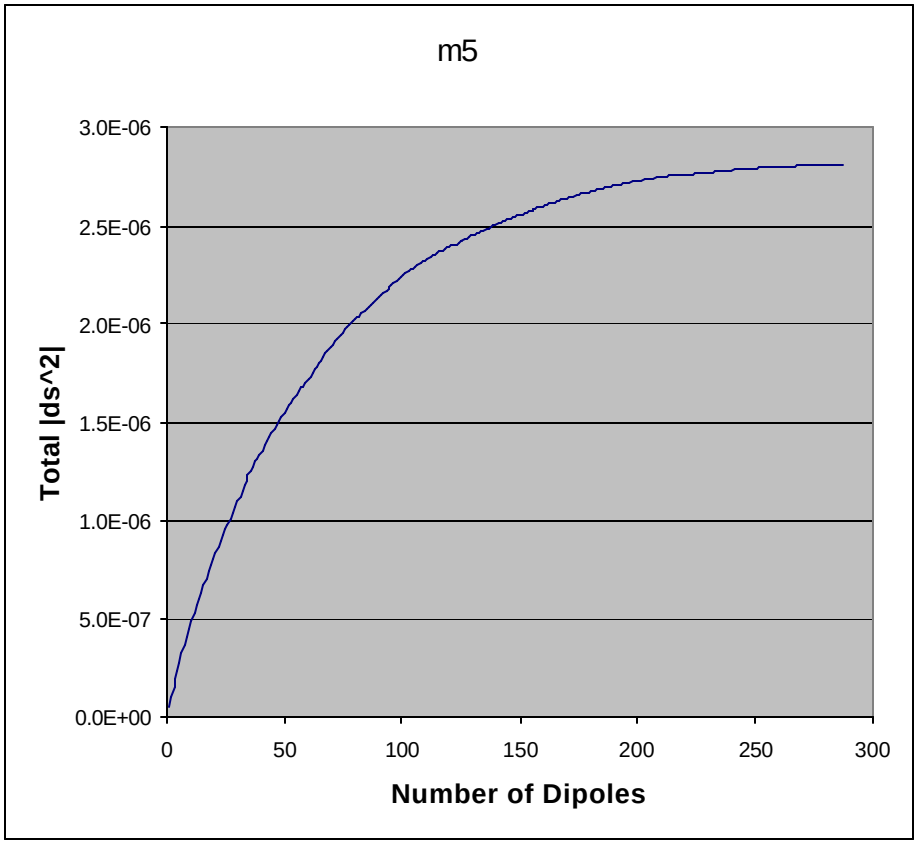


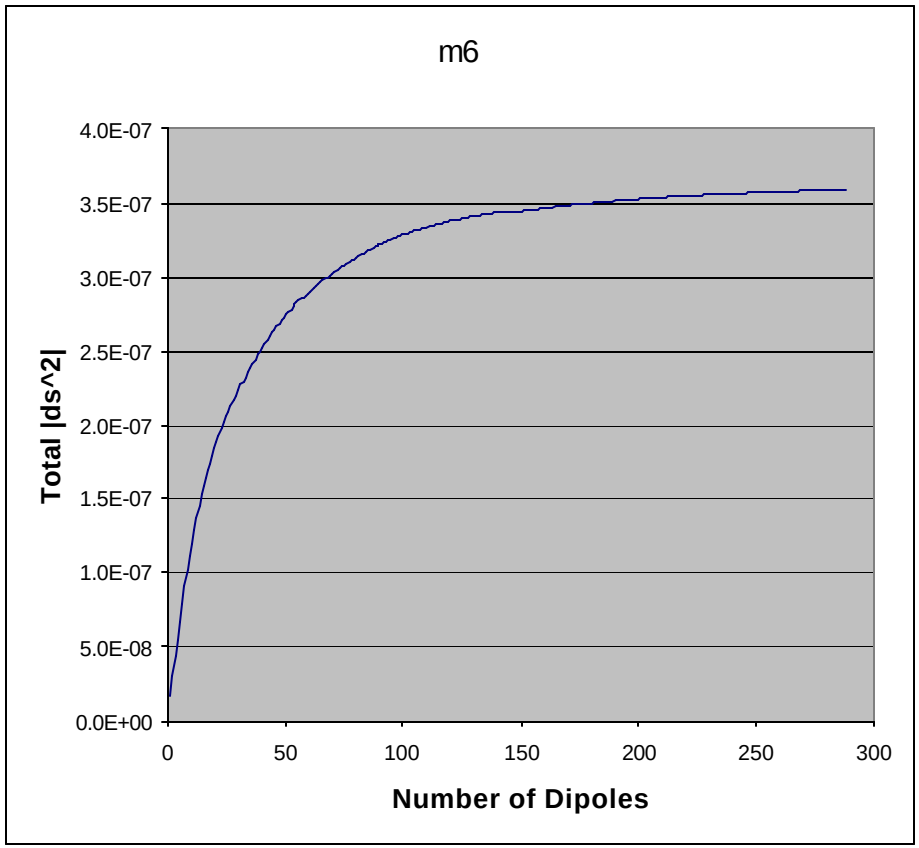
M = 5 Helical Winding

M = 6 Helical Winding

Contours of dipole currents shows same pattern

Should be able to Realize ~50% of Coupling for only ~20% of coverage





24x24 Dipole Array
Currents for Assumed Island Sizes

All Dipoles Retained

Target (ds^2)	I_max, KA	I_min, KA	Sum(I**2)
m5 = .0025 only	1.9	-1.9	9.71E+07
m5=.0025, m6=0.	1.9	-1.9	9.87E+07
m6=.0025 only	18.6	-14.4	2.74E+09
m6=.0025, m5=0.	17.8	-13.9	2.78E+09

ds^2 = .0025 is a 5% flux island

Bn on boundary not targeted
(or evaluated - TBD)

24x24 Dipole Array
Currents for Assumed Island Sizes

Dipoles eliminated at [-.125 < u < +.125], [-.250 < v < +.250]
For NB access

Target (ds^2)	I_max, KA	I_min, KA	Sum(I**2)
m5 = .0025 only	3.0	-2.8	1.86E+08
m5=.0025, m6=0.	3.8	-4.5	2.11E+08
m6=.0025 only	37.7	-33.2	6.98E+09
m6=.0025, m5=0.	41.1	-37.6	9.25E+09

ds^2 = .0025 is a 5% flux island

Bn on boundary not targeted
(or evaluated - TBD)

24x24 Dipole Array
Currents for Assumed Island Sizes

Dipoles eliminated at [-.125 < u < +.125], [-.250 < v < +.250]
for NB access plus all inboard dipoles [.25 < u < .75]

Target (ds^2)	I_max, KA	I_min, KA	Sum(I**2)
m5 = .0025 only	4.8	-5.3	3.75E+08
m5=.0025, m6=0.	5.3	-4.8	3.92E+08
m6=.0025 only	72.2	-92.7	4.84E+10
m6=.0025, m5=0.	69.4	-80.5	4.98E+10

ds^2 = .0025 is a 5% flux island

Bn on boundary not targeted
(or evaluated - TBD)

Further Plans

- Resolve difficulties representing winding surface received from engineering
- Pursue alternate locations proposed (ie inside VV)
- Identify additional block-out regions on winding surface dictated by machine access needs
- Discretize dipoles into larger Window Panes (or other topology) based on results
  - Verify ability to target multiple resonances is retained with (hopefully) a single layer of coils
  - Complete code modifications required to refine dipole mesh (needed to provide smoother solution)
- Demonstrate effectiveness of resultant coil set by running thru PIES

Summary

- Topology scan did not reveal any strong preference when targeting individual m=5 mode
- Dipole investigation has so far shown:
  - Most effective regions are those closest to resonance which for li383 occurs at v=0 section inboard and outboard (neither of which is very accessible)
  - By excluding those regions, current demands increase significantly (~ 3 – 5 x)
  - Whether this is acceptable depends on target requirements (ds^2 TBD) and final surface location