NCSX
In-vessel Design Update

B. Nelson, T. Brown, M. Cole, A. Georgiyevskiy, P. Goranson, A. Grossman, P. Mioduszewski, W. Reiersen, A. Georgiyevskiy

NCSX Project Meeting

August 28, 2001

Presentation Outline

- **Review of PVR requirements, design concept and issues**
- **Status of divertor and “stay out zone” definition**
- **Examination of Poincare plots**
- **Revised plans for completion of PFC / VV concept update (due mid-August: *overdue*)**

PFC requirements - PVR

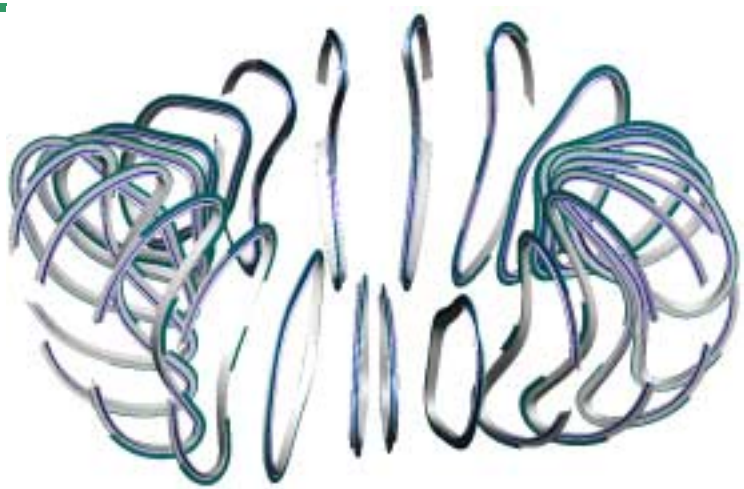
- Basic requirements
  - Carbon based, bakeable to 350C
  - NBI armor, limiters needed day 1 (at minimum)
  - 3 MW for 0.5 s
  - 2 cm from plasma inboard, 10 cm outboard (*TBR, working to maximize plasma-wall separation*)
  - Provide penetrations, accommodate in-vessel diagnostics mounted on VV

- Upgrade requirements
  - Full coverage of surfaces with carbon
  - 12 MW for 1.2 s
  - Provision for divertor

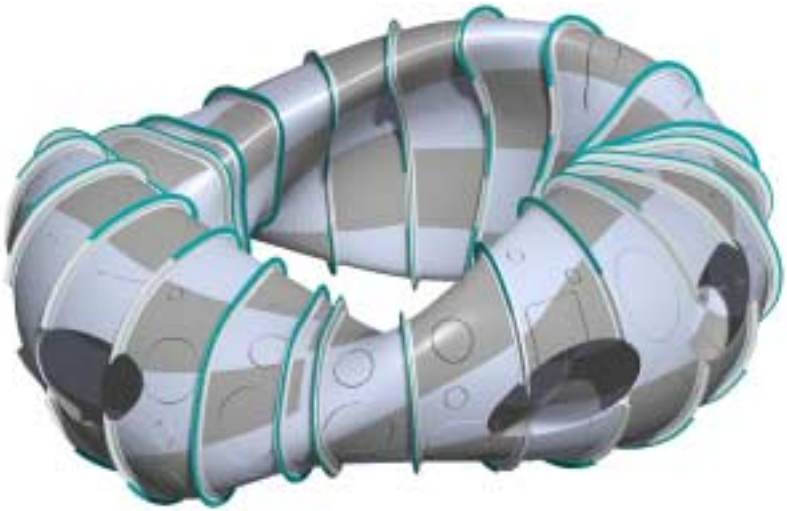
PFC design concept

- Staged implementation planned
  - Initial coverage with low Z tiles mounted on poloidal ribs to form array of poloidal limiters
  - Panels for NB armor will also be provided
- Full coverage provided by mounting molded carbon fiber composite (CFC) panels on poloidal ribs
  - Panel size based on advice from BFG aerospace (~ 60 cm square, 1 cm thick)
- Ribs are separately cooled / heated with He gas for bakeout (350C) and normal operation
- Ribs are registered toroidally to VV but allowed to grow radially and vertically

Poloidal ribs



CFC panels mounted on poloidal ribs



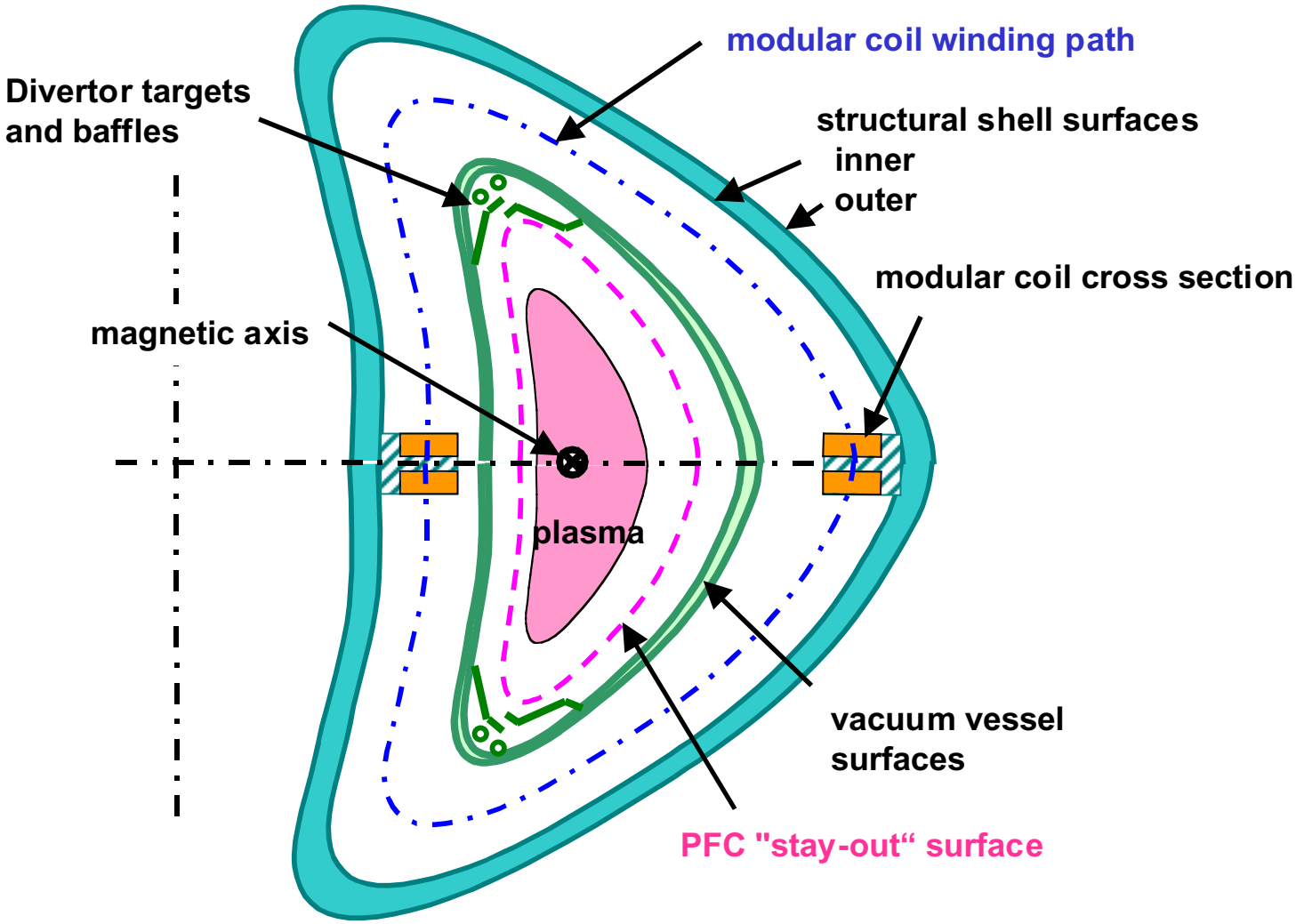
PFC issues

Requirements	Design	Fab.	Ass'y
• PFC stayout zone • NBI armor location • divertor parameters • Limiter geometry • In-vessel diagnostics (e.g., magnetic loops)	• pumped divertor envelope • transition from day 1 to full coverage • RF launcher integration with limiters, diag. • trim coil integration • low z rail covers • inboard limiter concept	• CFC cost • Low z coating	• personnel access for –installation –reconfiguration

Vacuum vessel issues

Requirements	Design	Fab.	Ass'y
• RF launcher envelope • PFC / divertor envelope • Diagnostic views, incl. symmetry plane access • Plasma current for disruption analysis	• smoother shape • port integration for diagnostics • segmentation • field joint flange envelope • stresses / buckling for disruption loads • mechanics of describing vessel shape to vendors	• Cost within est.? • Process and qualified vendors • Geometric tolerance • draft spec. for procure-ment	• sliding coils over vessel • distortion during and after port welding • personnel access for field joint • Leak checking

Reference geometry must be defined



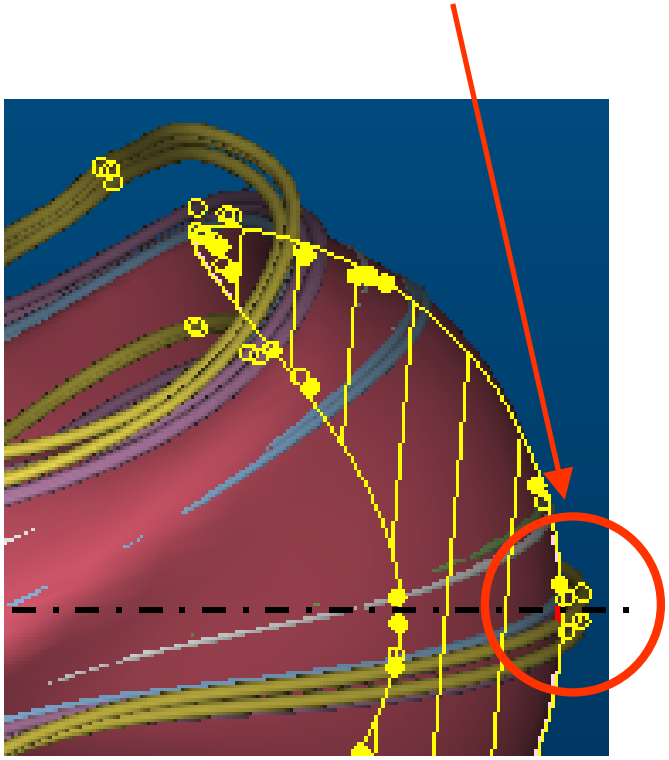
"Stay out zone"

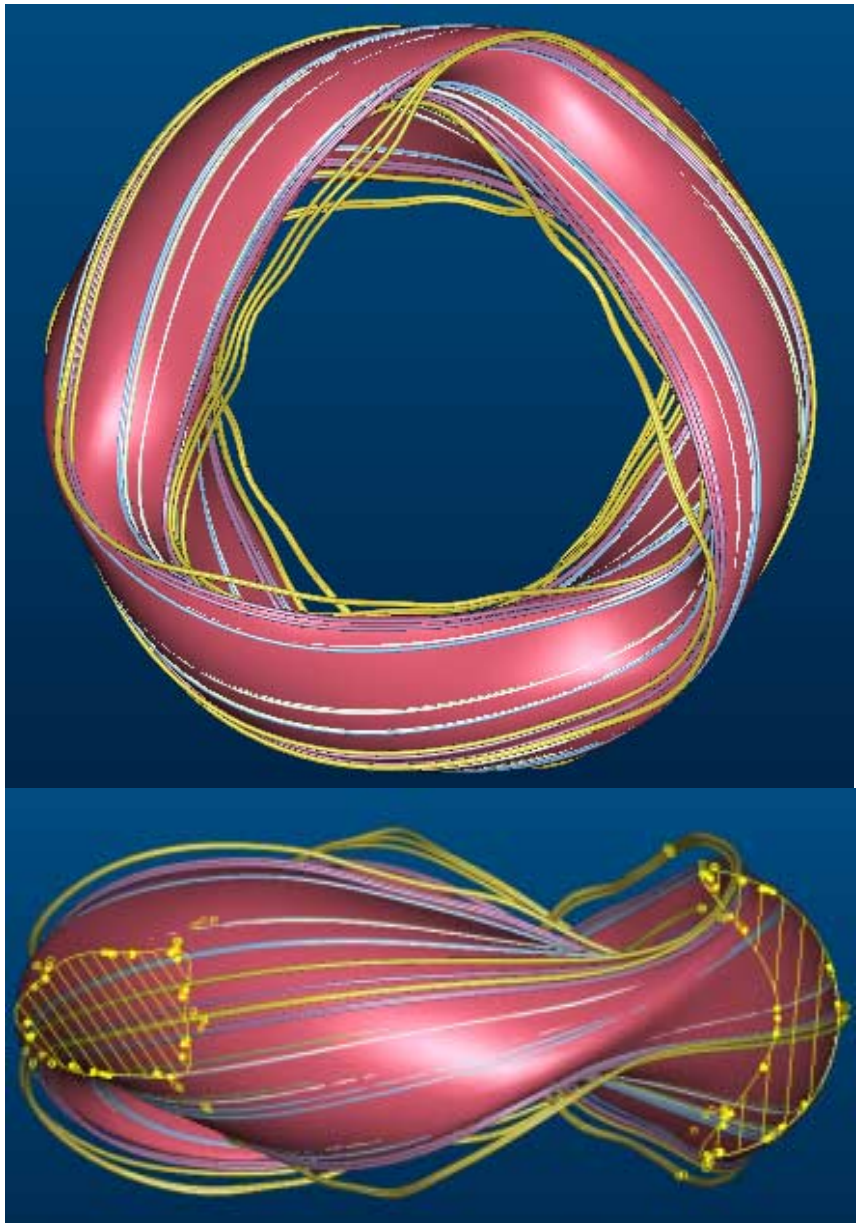
- Art Grossman developed field line data for:
  - 1.7 m case (MGRID_Li383_1017C2)
  - 1.4 m case (equilibria 66m field tracing case k)
- 1.7 m data has been scaled by 0.82 and field lines plotted in 3-D space using Pro-E for visualization
- 1.4 m case has been plotted as puncture data on radial planes, plotting 3-D lines not yet successful

- Issues include:
  - How far off the LCMS do we start the field lines?
    Provisional answer: within 2 cm of LCMS
  - Where should the divertor targets / baffles go?
  - How do we account for "flexibility" in the envelope?

Field lines started outside LCMS

- Plotted for 0, 0.2, 0.4, 1.8, and 3.8 cm offsets from OB midplane
- Followed for 120 m





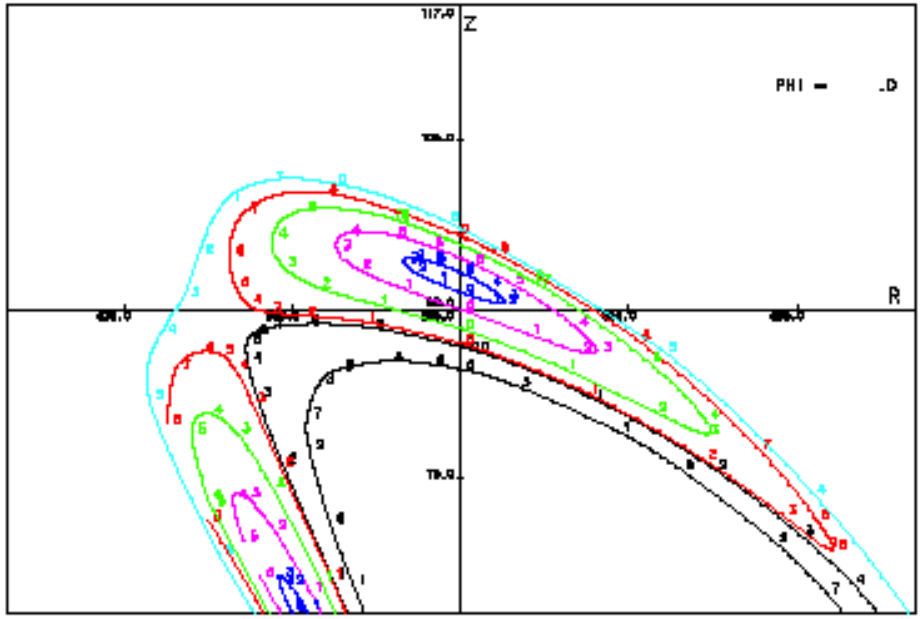
Limiter and divertor parameters

- **Limiter (day one)**
  - **3 inboard limiters, one at each bullet section**
  - **3 MW total load**
  - **Nominally 20 cm wide by 20 cm high**

- **Divertor**
  - **6 divertor assemblies, 3 top 3 bottom along ridge of plasma**
  - **Divertor includes strike plate that intercepts 60% of power, baffles that confine neutrals, and pumping surface**
  - **Pumping speed must be very high for short pulses, wall pumping is preferred (e.g. titanium gettering). Cryopumping is no longer required.**

W7-AS Divertor experience

- **Divertor solves density control problem on W7-AS, even without Ti gettering**
- **Some W7-AS field lines leaving LCMS intercept walls, but most get to divertor targets**

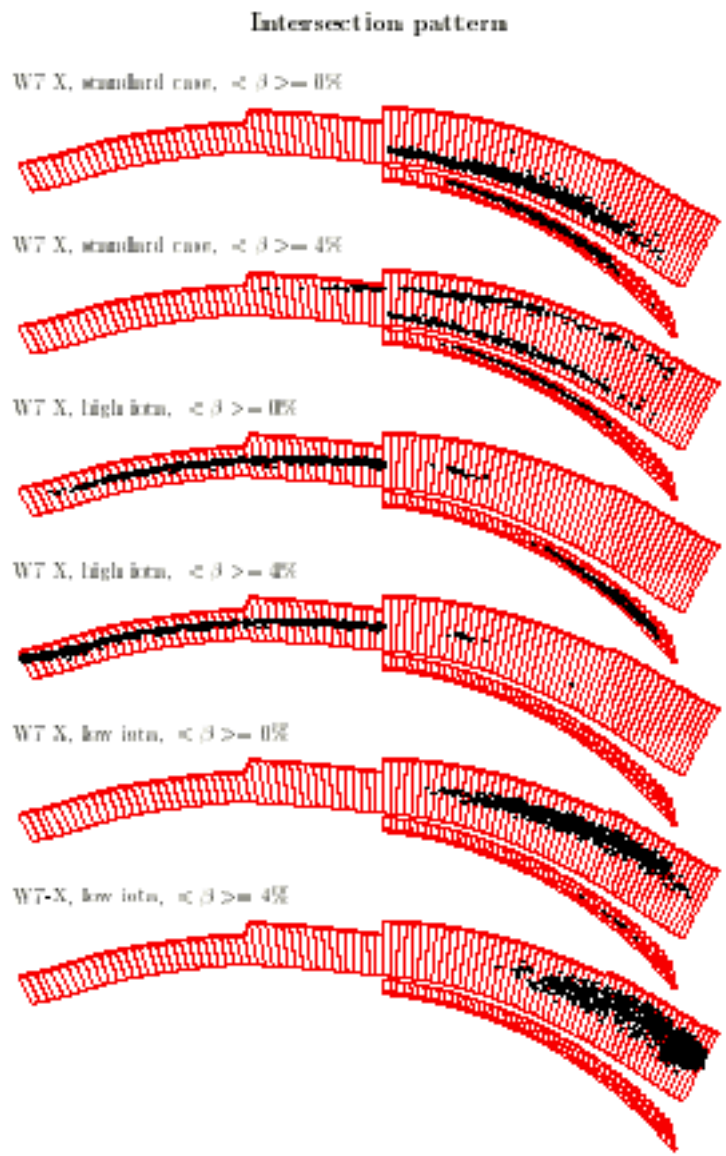


Poincarè plot of boundary islands for the standard case ι=1=5/5.
„Field line tracing“ at the toroidal angle φ=0°.
Note, the transits are indicated by the transit numbers.

“Footprints” define divertor plates

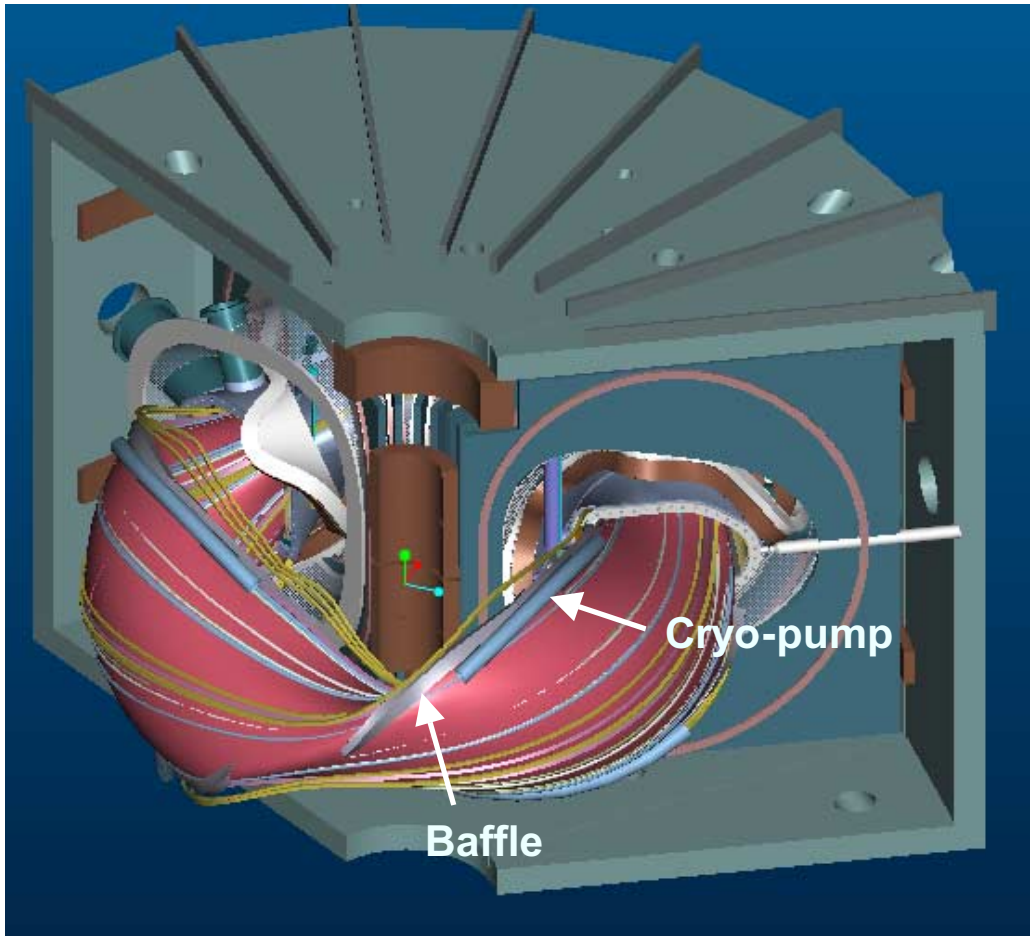
- **Divertor targets tailored to intercept field lines for range of operating scenarios**

- **Deposition on the defined target area of one divertor unit, variation of**
  - **rotational transform (std, “high” and “low”)**
  - **beta (0 and 4%)**

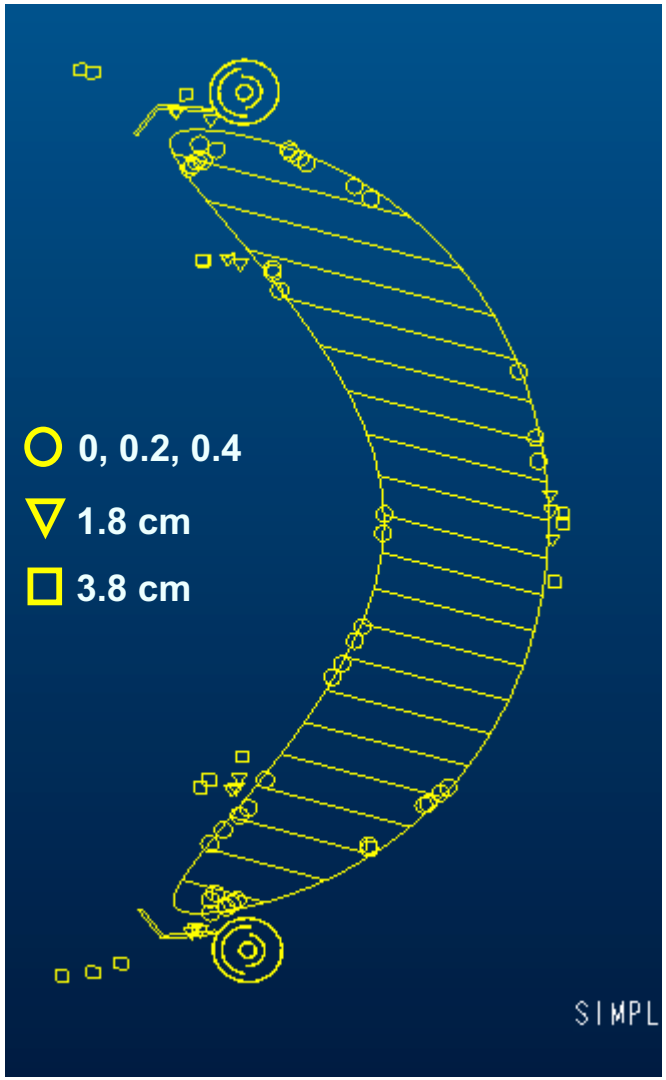


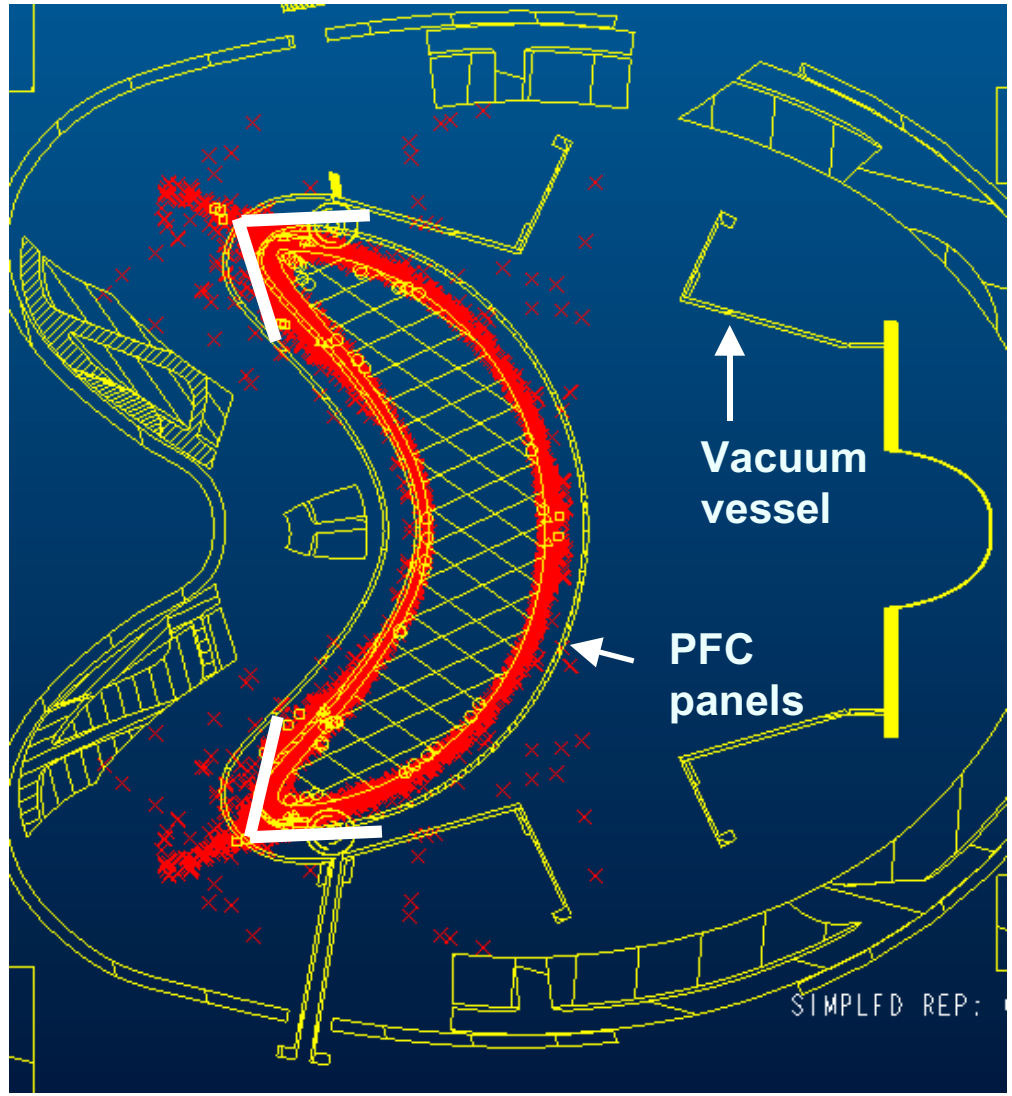
How does this translate to NCSX?

- **Pro-E model created that includes:**
  - **Discrete field lines**
  - **Puncture plot points for field lines launched between 0-2 cm from LCMS**
  - **Li383 plasma surface**
  - **Crude baffle plate and cryopump model**
  - **PVR models for VV, PFCs, Modular coils and structure, etc.**

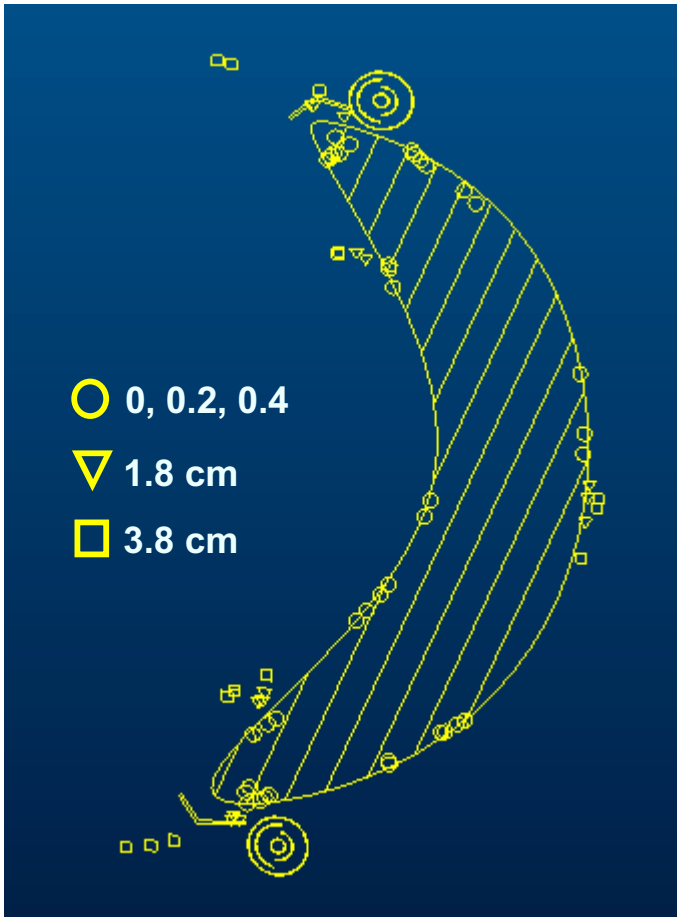


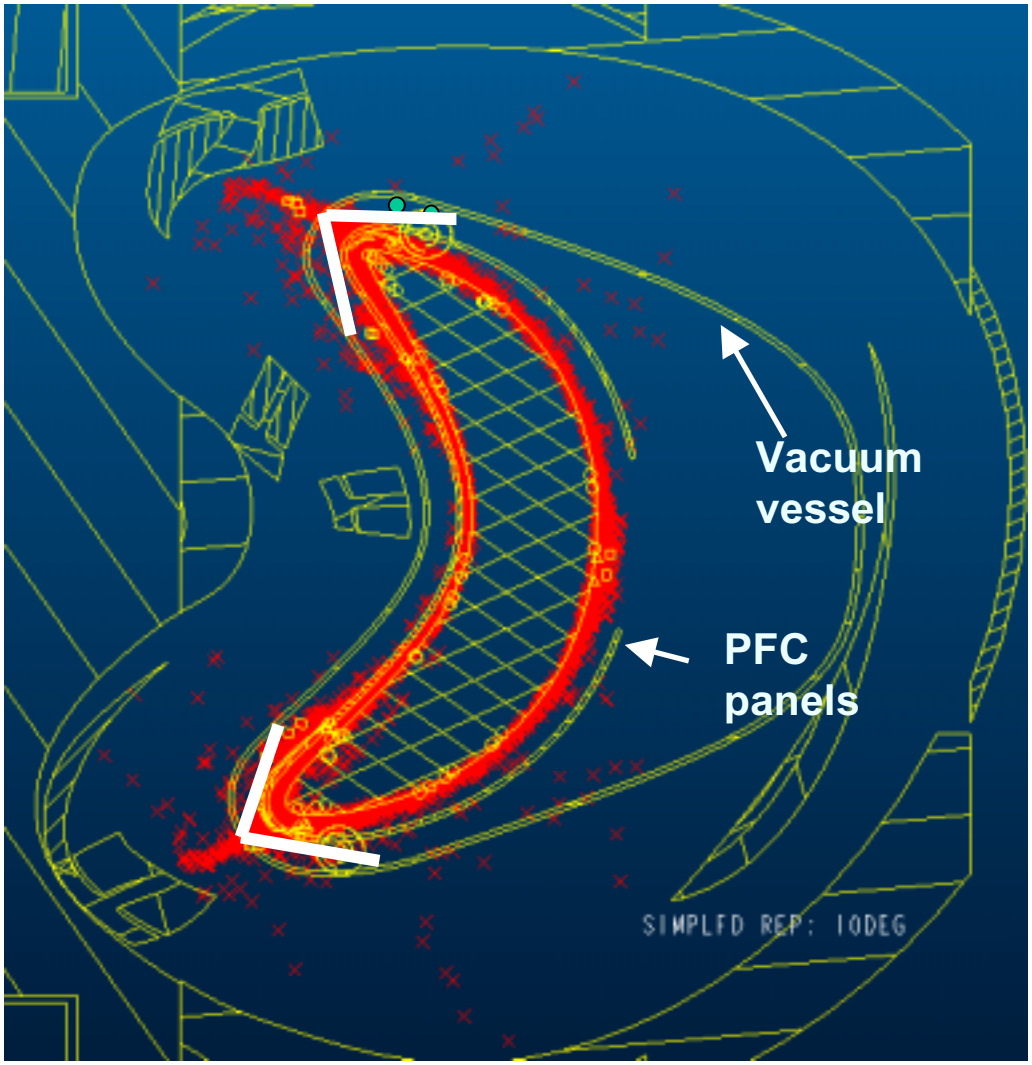
0 degrees "bean section"



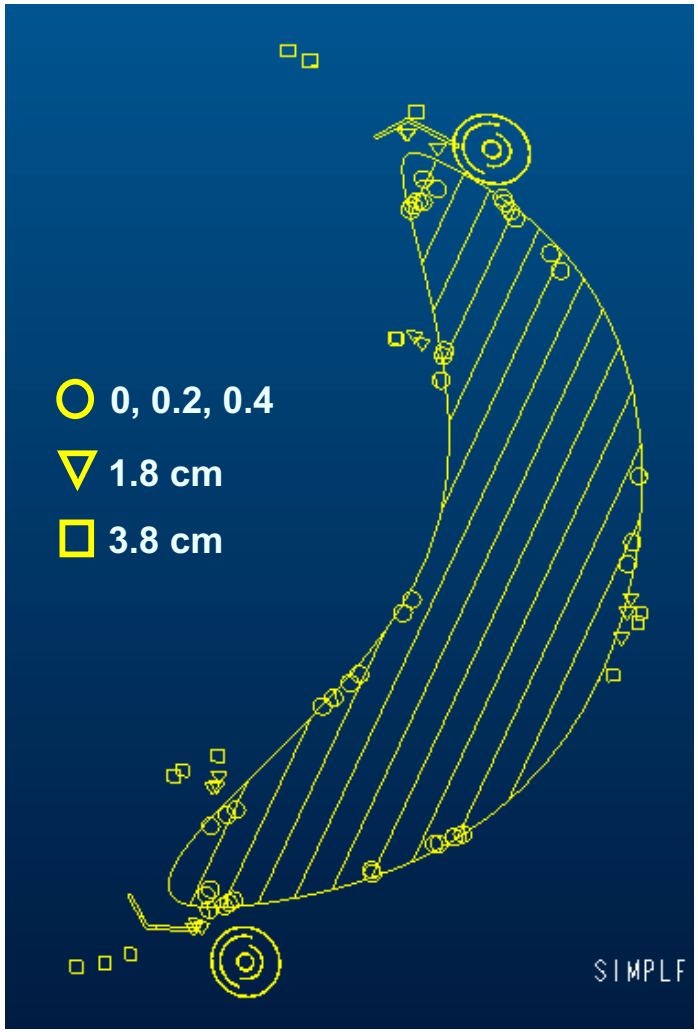


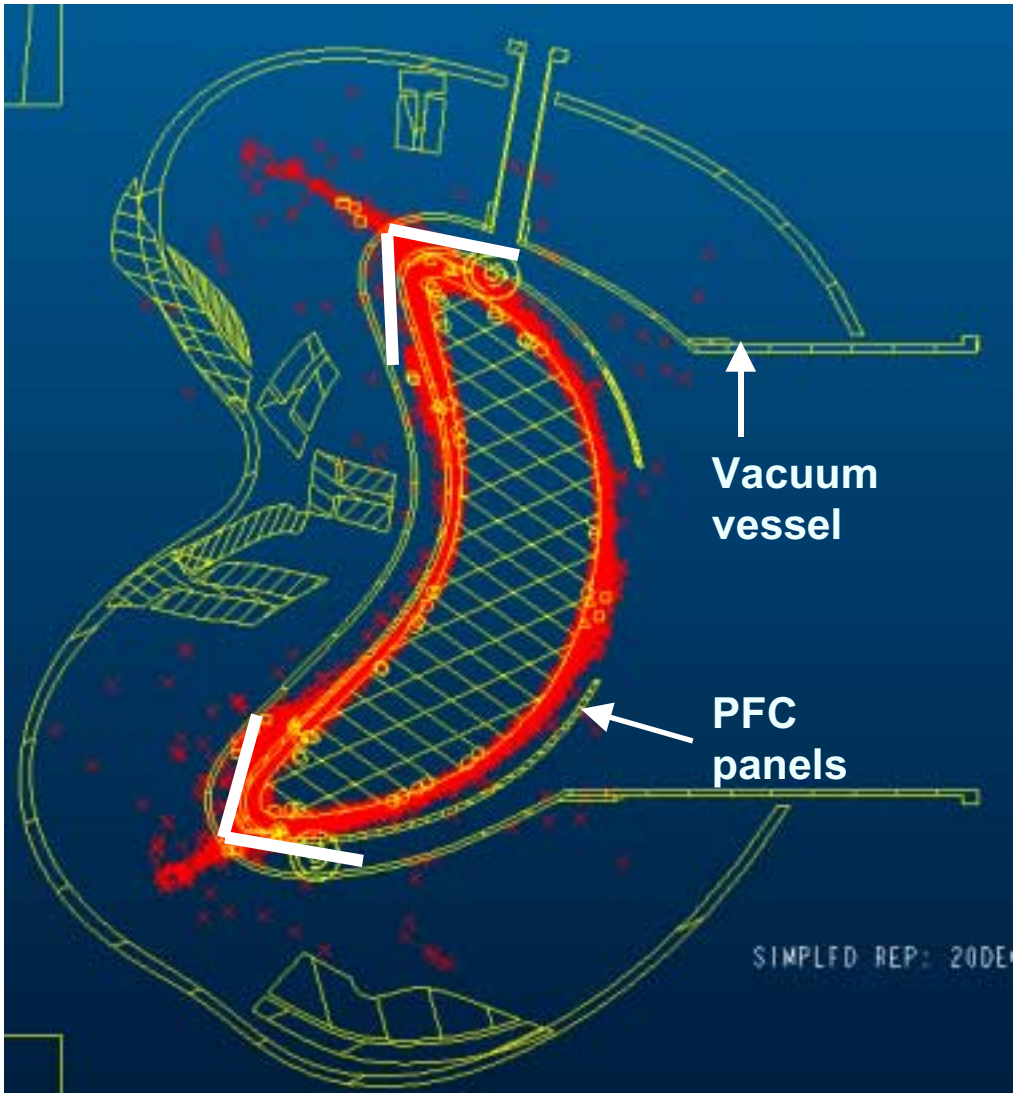
10 degrees



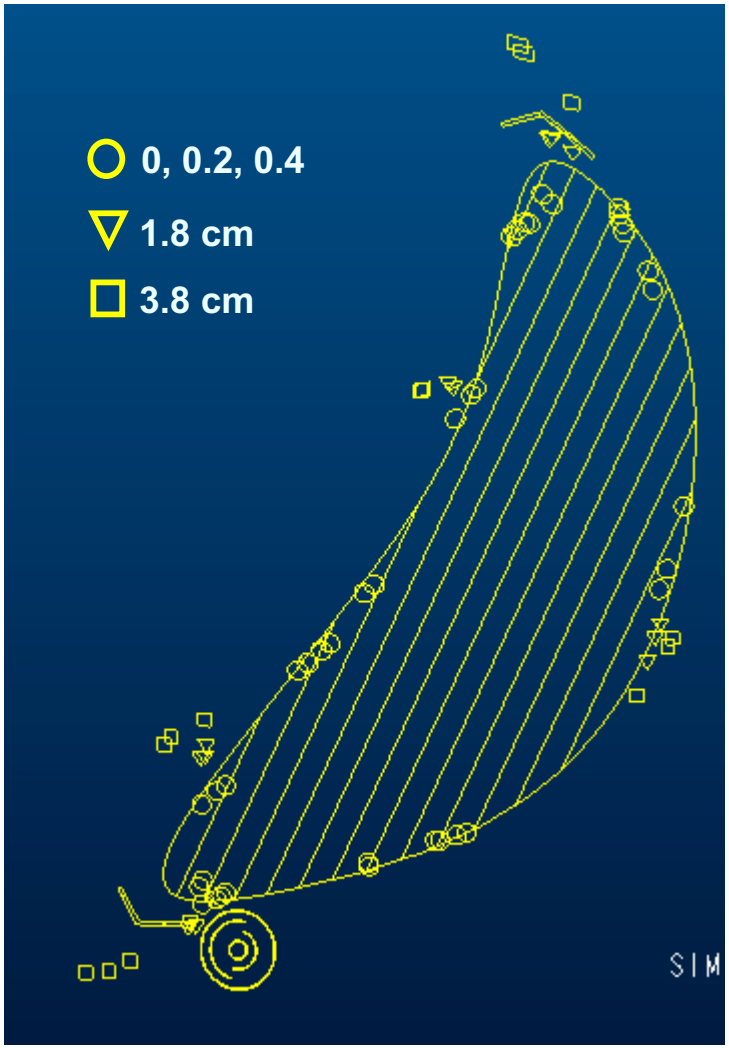


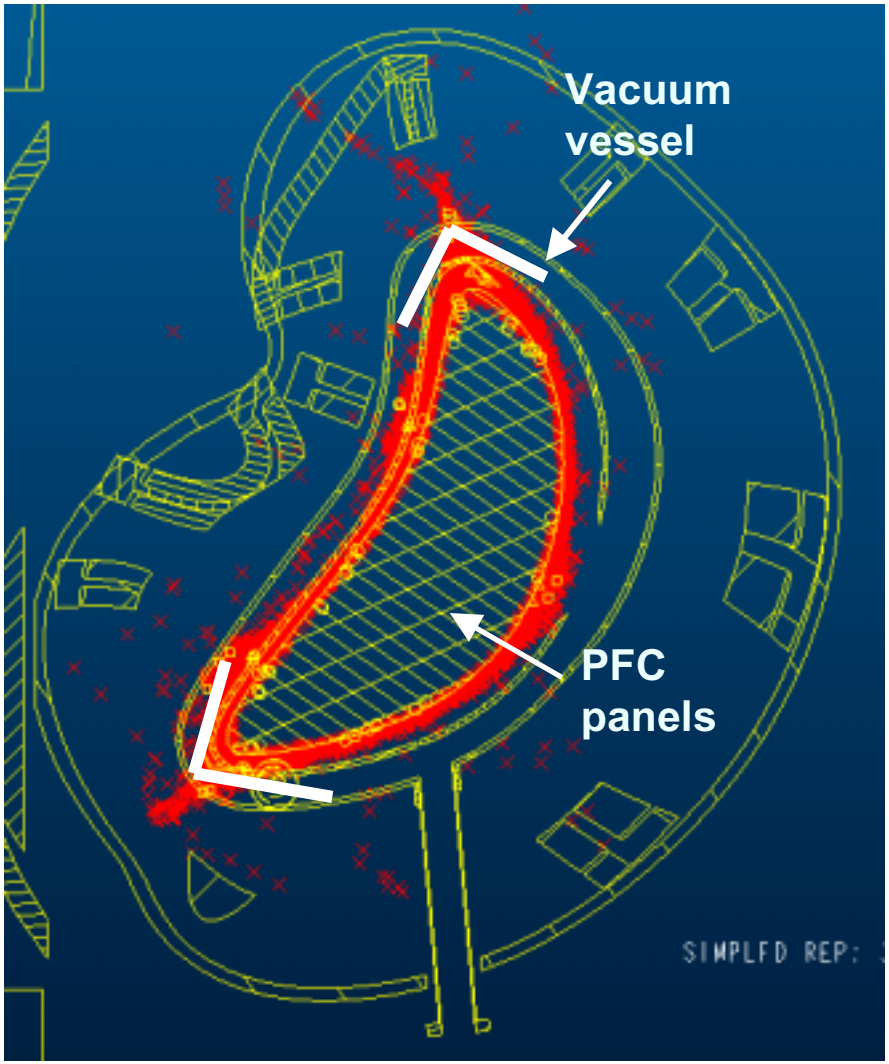
20 degrees


0, 0.2, 0.4
1.8 cm
3.8 cm
SIMPLF

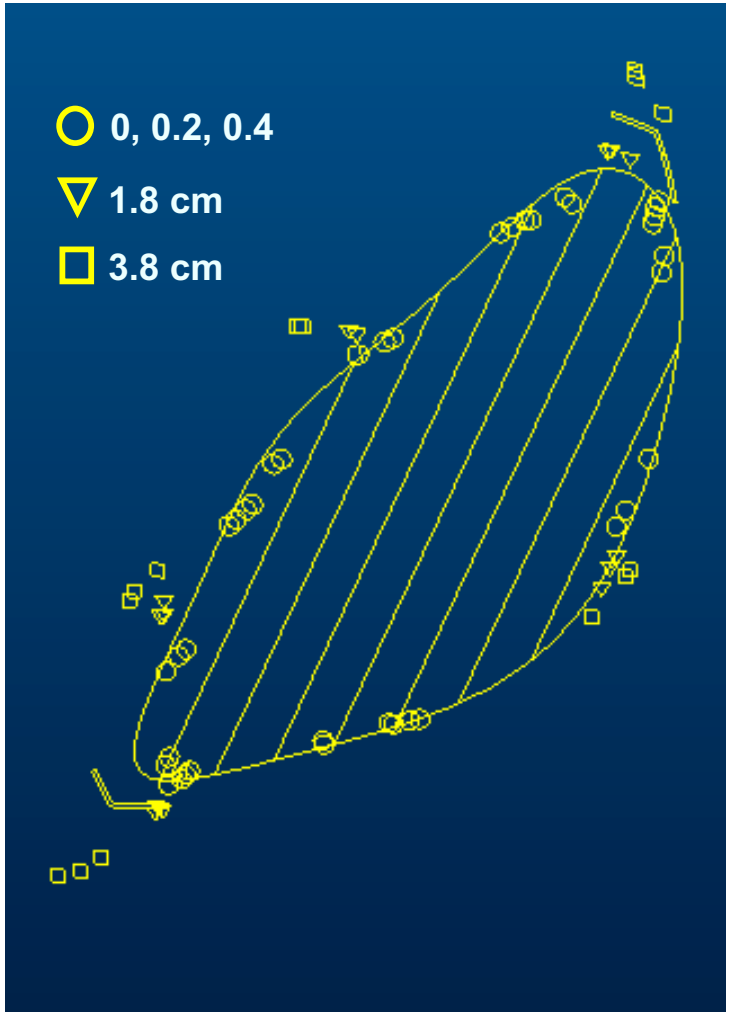

Vacuum vessel
PFC panels
SIMPLFD REP: 20DE

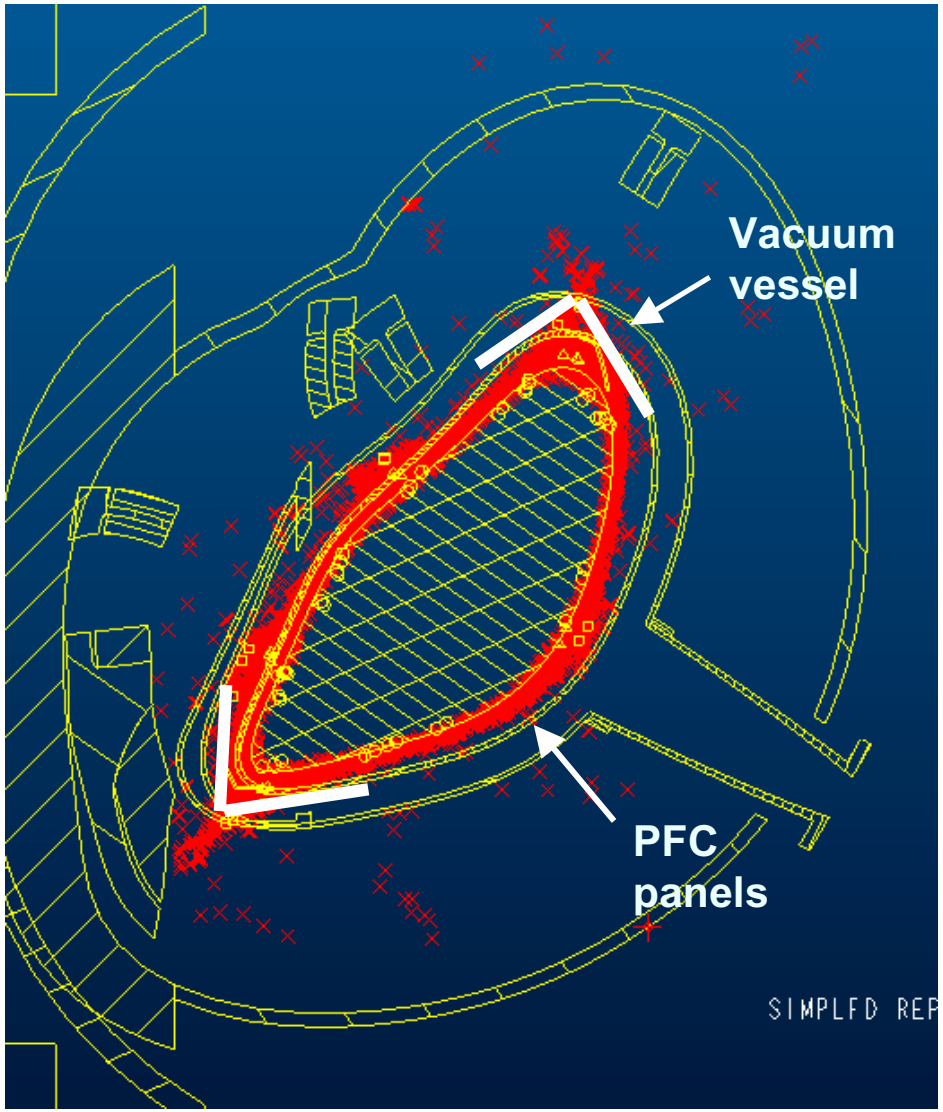
30 degrees





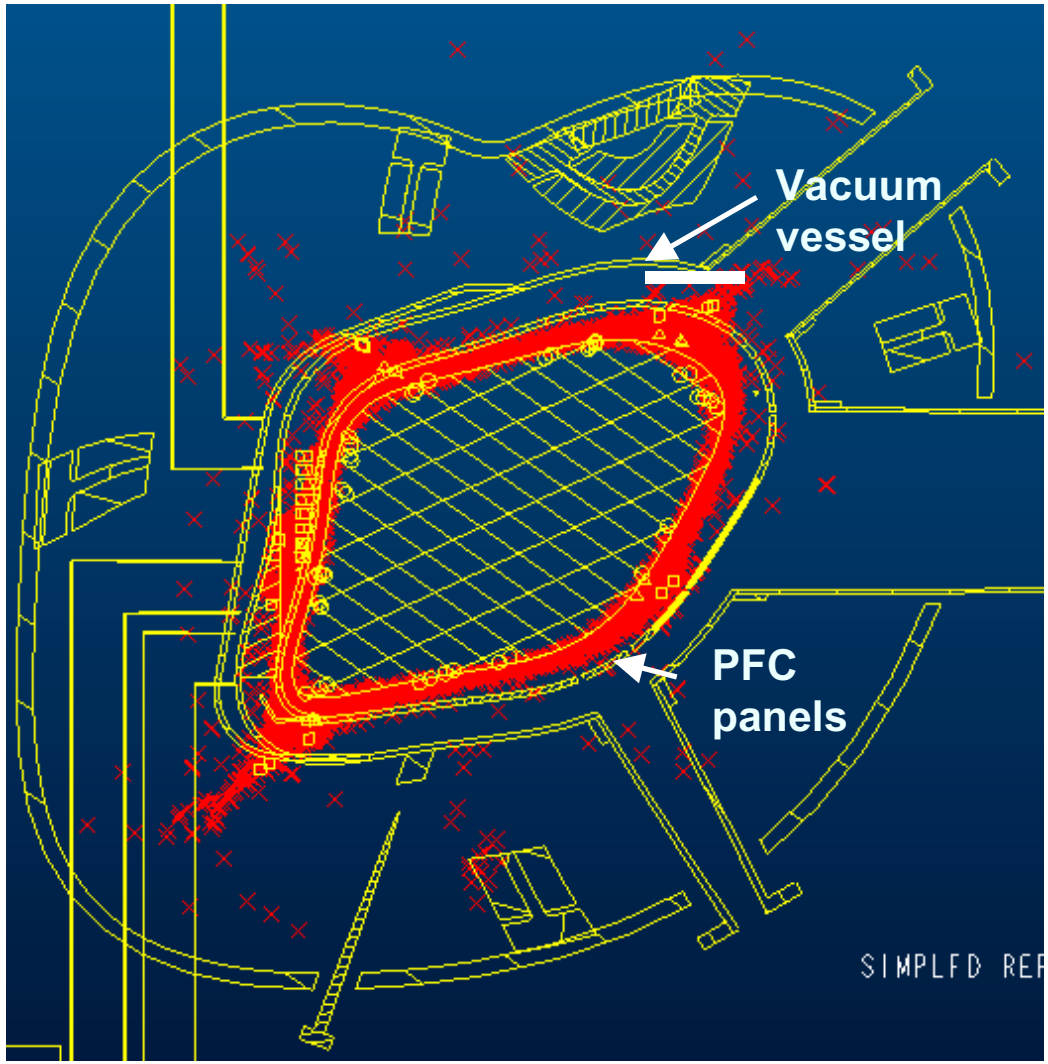
40 degrees



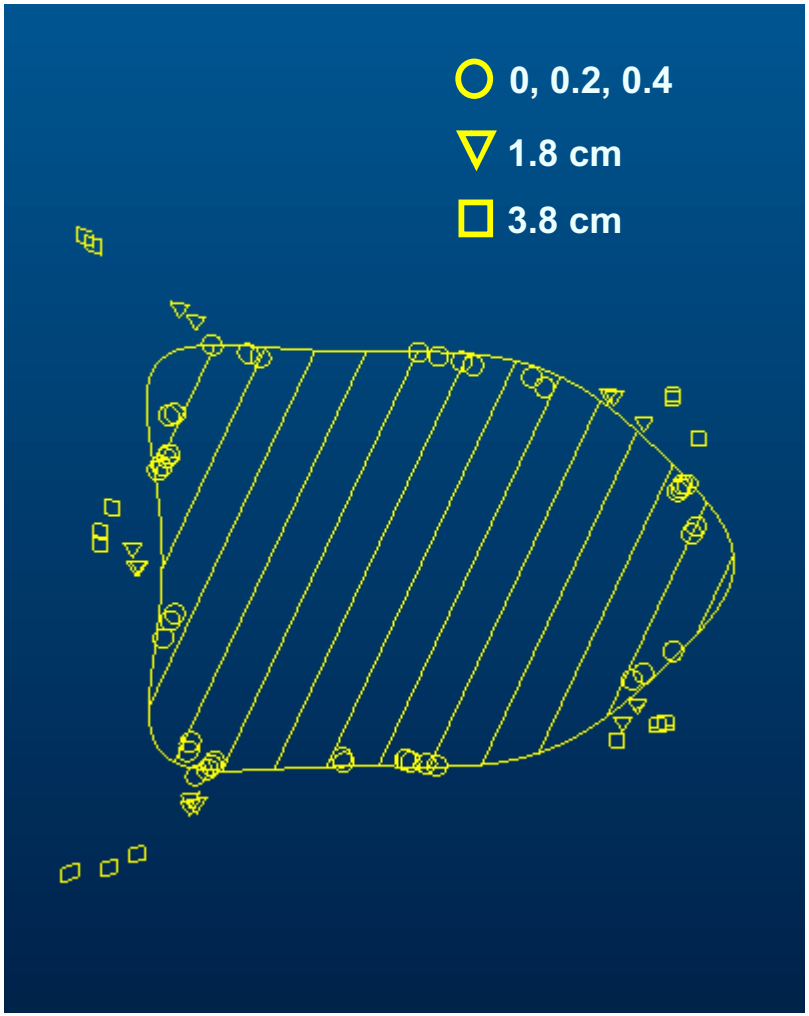


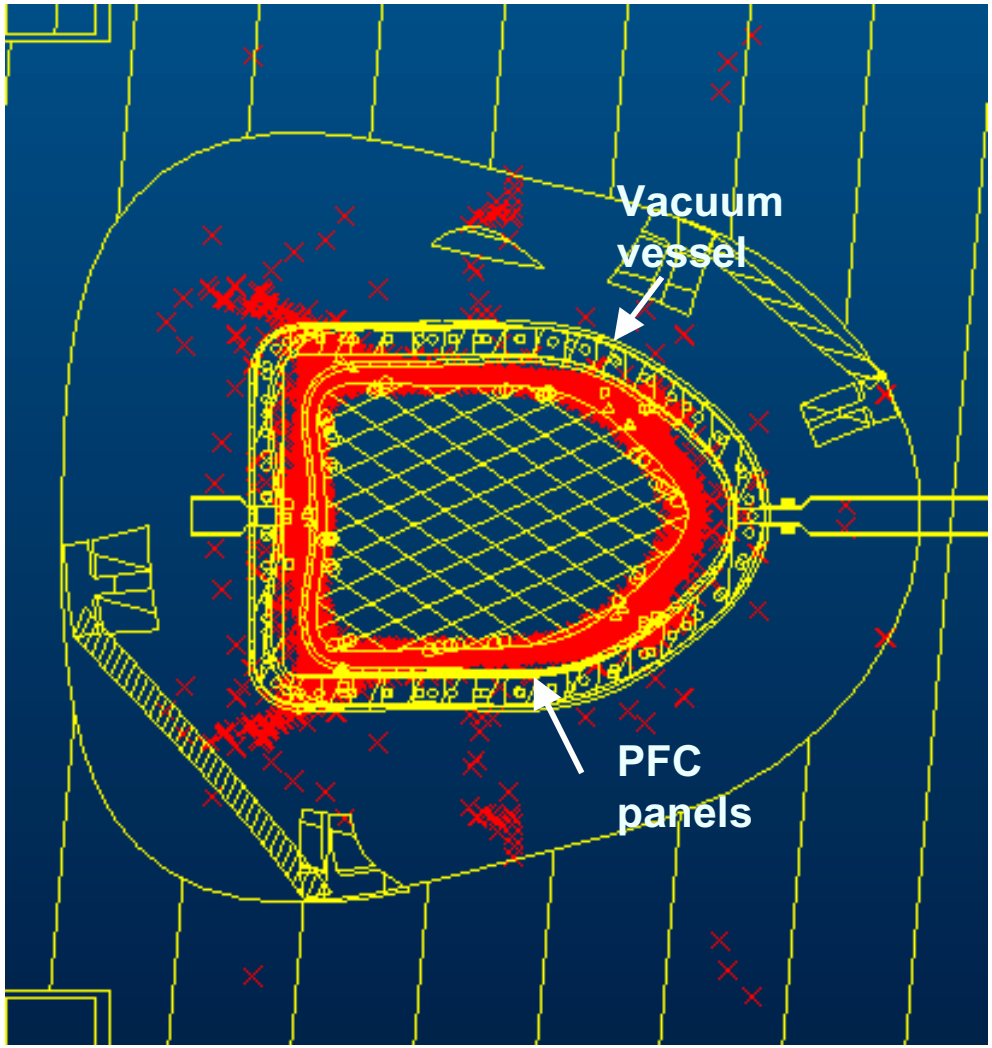
50 degrees

0, 0.2, 0.4
1.8 cm
3.8 cm
SIMPLFD


Vacuum vessel
PFC panels
SIMPLFD REF

60 degrees "bullet section"





Interpretation of field line data (Reiersen and Georgiyevskiy)

Uragon-3M has 4 classes of field lines:

1. Lines forming magnetic surfaces around the plasma (in green)
2. Lines forming magnetic surfaces around individual helical windings (in blue)
3. Lines forming magnetic surfaces enveloping all the helical windings
4. Lines that do not form surfaces but rather, start outside the last closed magnetic surface (LCMS) wrapping around the plasma and then transition to wrapping around a helical winding. The separatrix (5) is the boundary marking the transition between wrappingaround the plasma and wrapping around an individual helical winding. (in red)

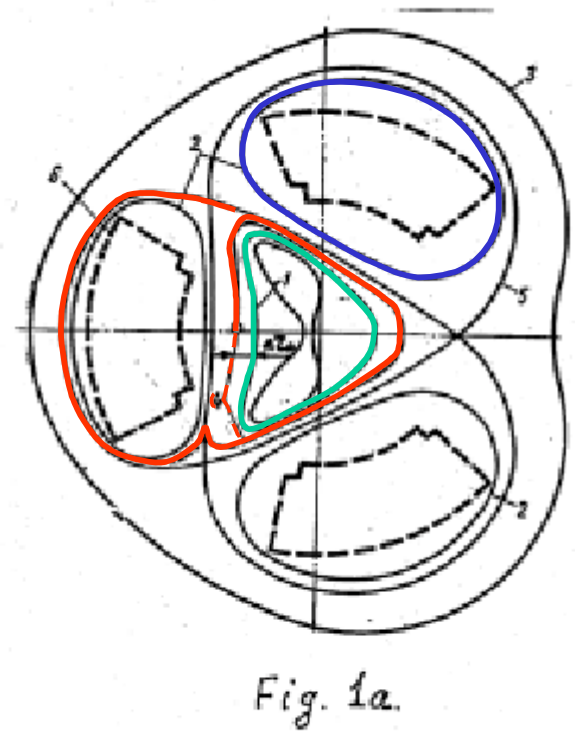
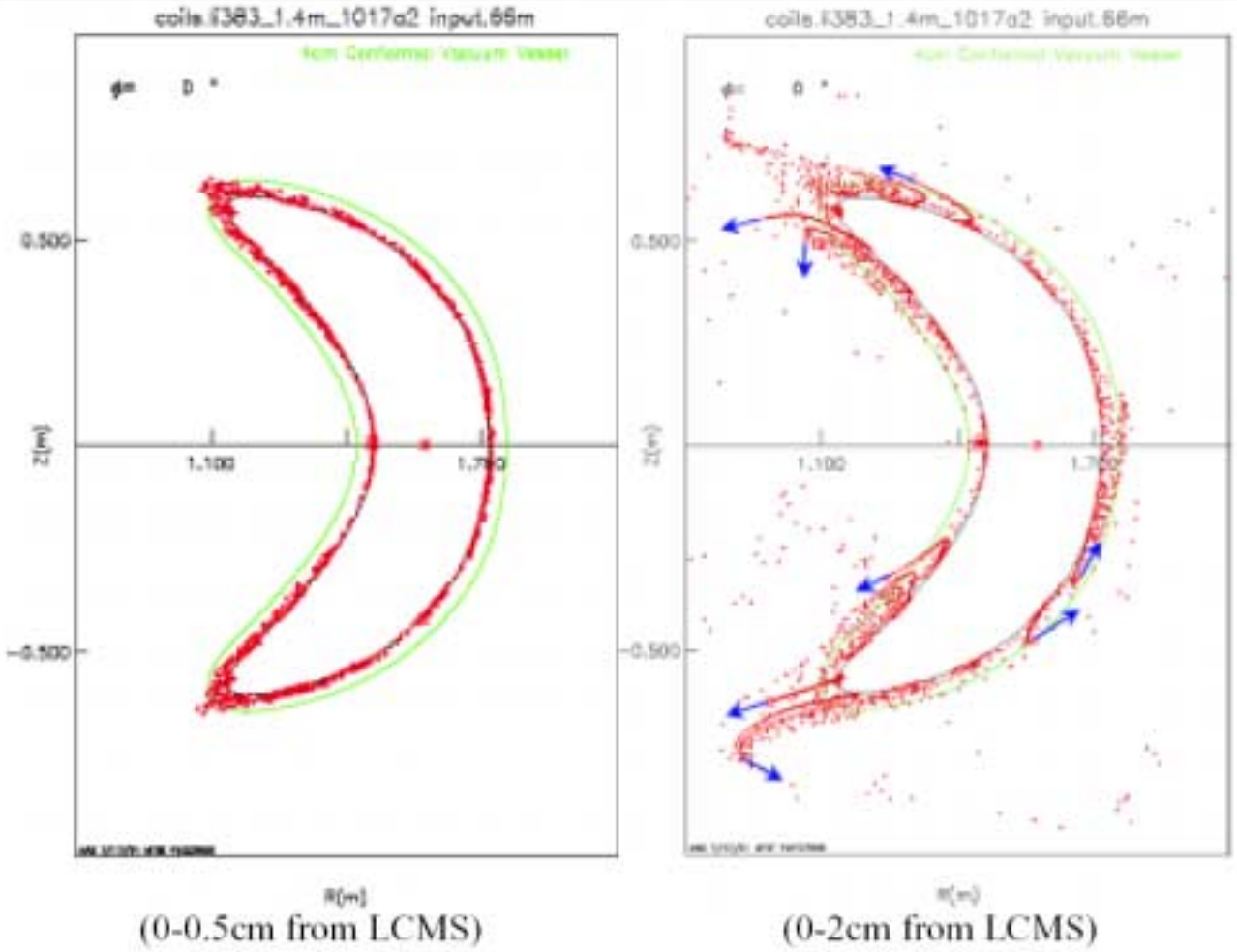


Figure 1 – Field line classes on Uragan-3M

NCSX whiskers are type 4 lines?



(0-0.5cm from LCMS) (0-2cm from LCMS)

Figure 2 – "Whiskers" become observable outside 0.5cm from LCMS

Islands on rational 3/5 surface with iota = 0.6?

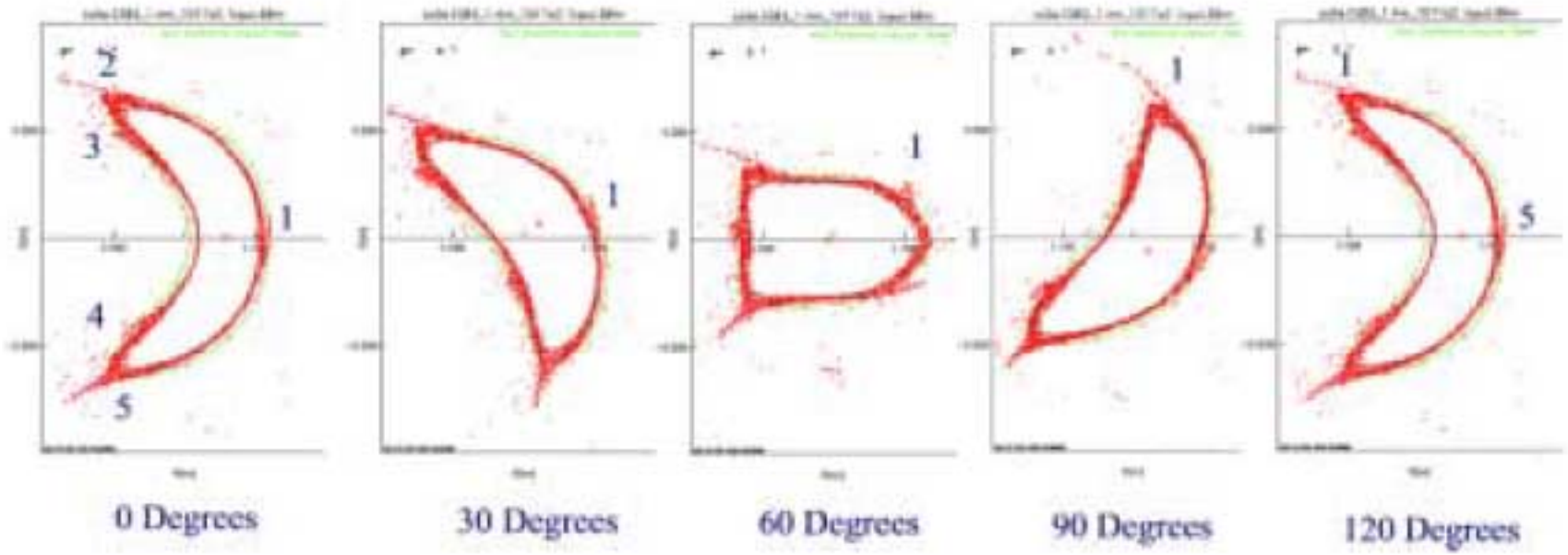


Figure 3 – Precession of "whiskers" with iota of 0.6

Can we infer a separatrix and see the partial islands?

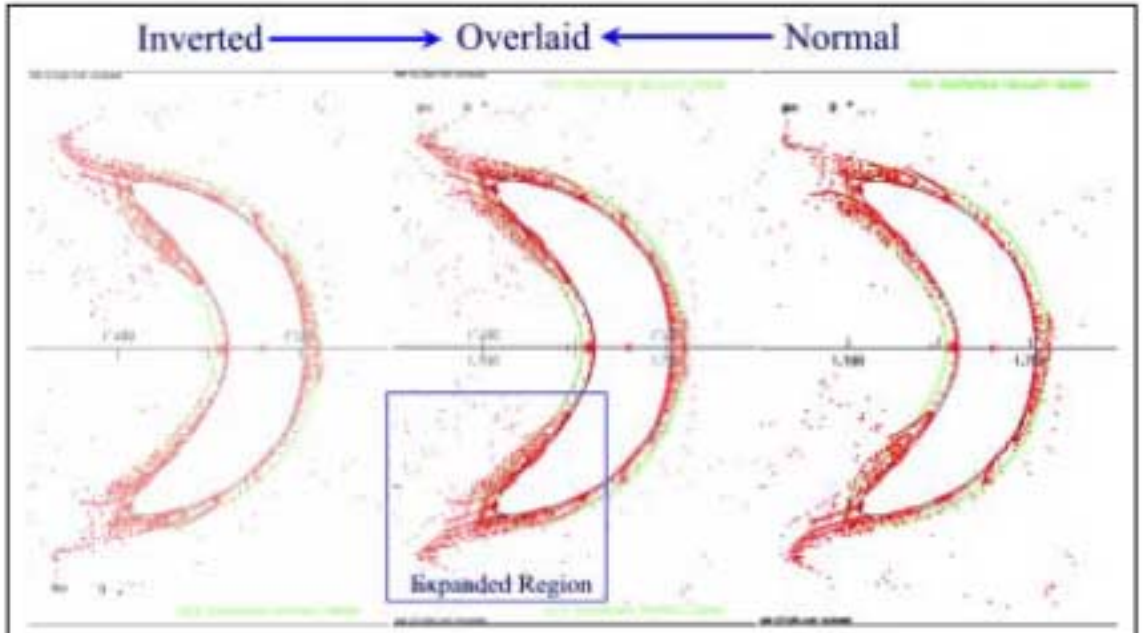
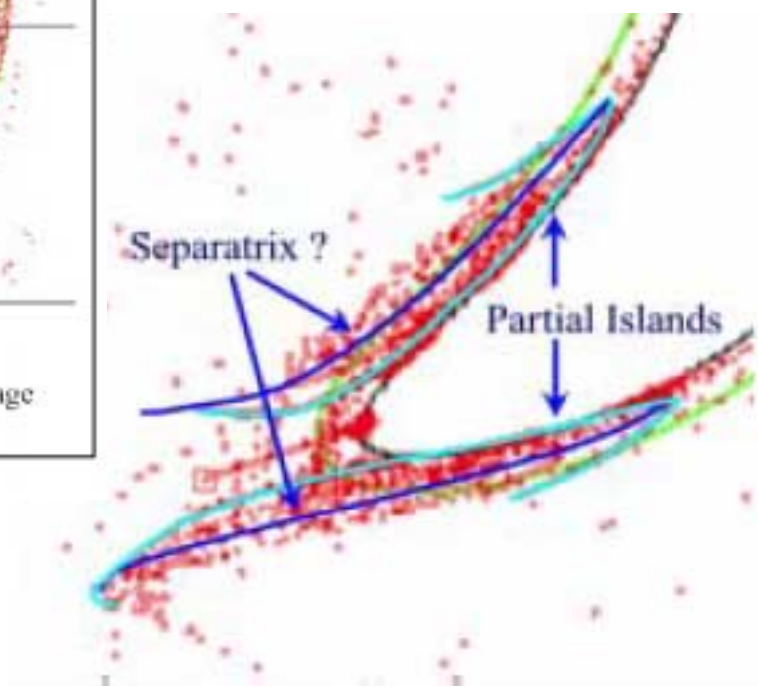
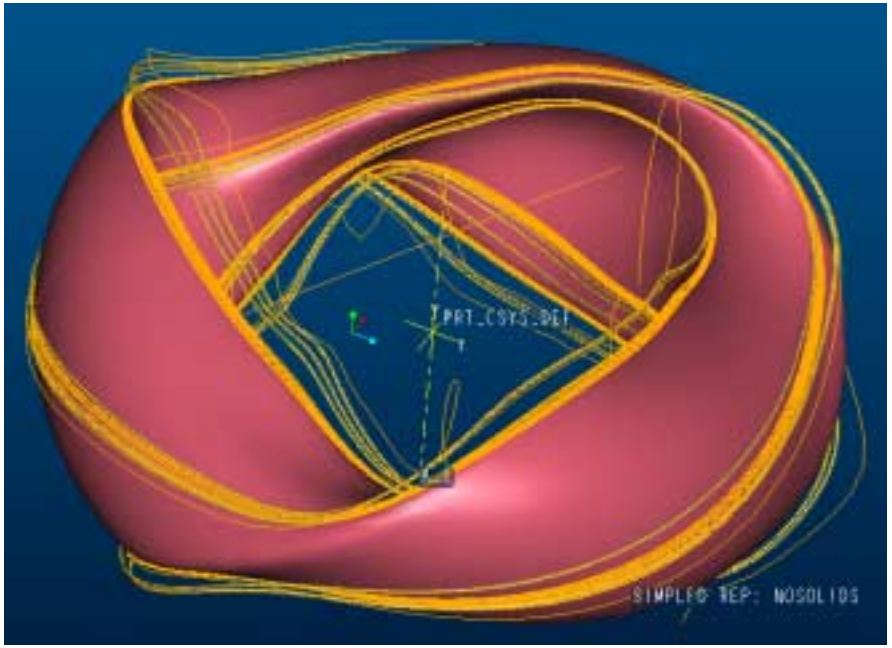


Figure 4 – Overlay of forward field line Poincare plots with their inverted image



Do 3-D field lines show “type 4” structure?

- Data from scaled field lines may hint at “type 4” field lines
- Field lines appear to flare out in a few spots and then return to a surface



New Plan

- Provide provisional divertor target surfaces to field line followers (Nelson)
- Calculate "footprints" of field lines and thus power deposition on divertor targets (Grossman, et al)
- Adjust target surface locations so $\geq$ 60% of power is getting to divertor targets (Grossman, et al)
- Using new puncture plots (with intercepted lines terminated at divertor surfaces), develop/modify "stay out zone" and adjust PFC surface (Nelson)
- Adjust the rest of the divertor envelope (baffle and pumping surface geometry) to be consistent with new "stay out zone" (Mioduszewski, Nelson)
- Re-do vacuum vessel to provide room for divertor envelope (T. Brown)
- Check clearance around vessel for modular coil assembly (Cole/Brown)
- Adjust modular coil winding surface, if needed

VV / PFC deliverable status

milestone		deliverable		who	when
5	update concept of VV/PFCs	5a	Define "stay-out" surface for PFCs (scrape-off layer using VMEC that includes expansion of divertor region, outboard region)	P. Miodu-szewski	24-Aug-01 (plan is modified)
		5b	Define day 1 limiter requirements	P. Mio.	Draft 6/1
		5c	Define day 1 divertor baffle requirements	P. Mio.	Revised 8/24
		5d	Define inboard RF launcher envelope	Cole/ Majeski	Draft 6/12
		5e	Define VV assembly segmentation, joint envelope and seal concept	Cole et al	Draft of options 8/28
		5f	Define day 1 rail "covers" / limiters concept	Goranson	
		5g	Define trim coil attachment/alignment concept	Brown/ Cole	
		5h	Issue updated models and drawings of VV/PFC concept	Cole et al	10-Sep-01

Summary

- Revised requirements for divertor pumping: no cryopumps
- New plan for defining “stay out” zone based on divertor target location to intercept > 60% power
- Vessel geometry may require mods to accommodate divertor baffle/target envelope