e-Beam Mapping (FY09) and Stability Studies Plans (FY11)

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For the NCSX Team

Outline

- e-beam mapping (FY09)
- Equilibrium Reconstruction (FY11)
- Stability Physics (FY11)

Goals of mapping and equilibrium studies

- e-beam mapping (FY09)
  - – Document vacuum flux surface characteristics
  - – Document control of vacuum field characteristics with coil currents
  - – Document and model as-built coils

- Equilibrium reconstruction (FY11)
  - – Develop equilibrium code for NCSX
  - – Validate with all diagnostics

Coil alignment testing program

- FY09 e-beam mapping (FY09)
  - Verify coil assembly accuracy
    - Measure error-field induced islands.
  - Document good surfaces over wide range of configurations (iota-scan)
  - Verify correct rotational transform; by location of rational surfaces (using islands)

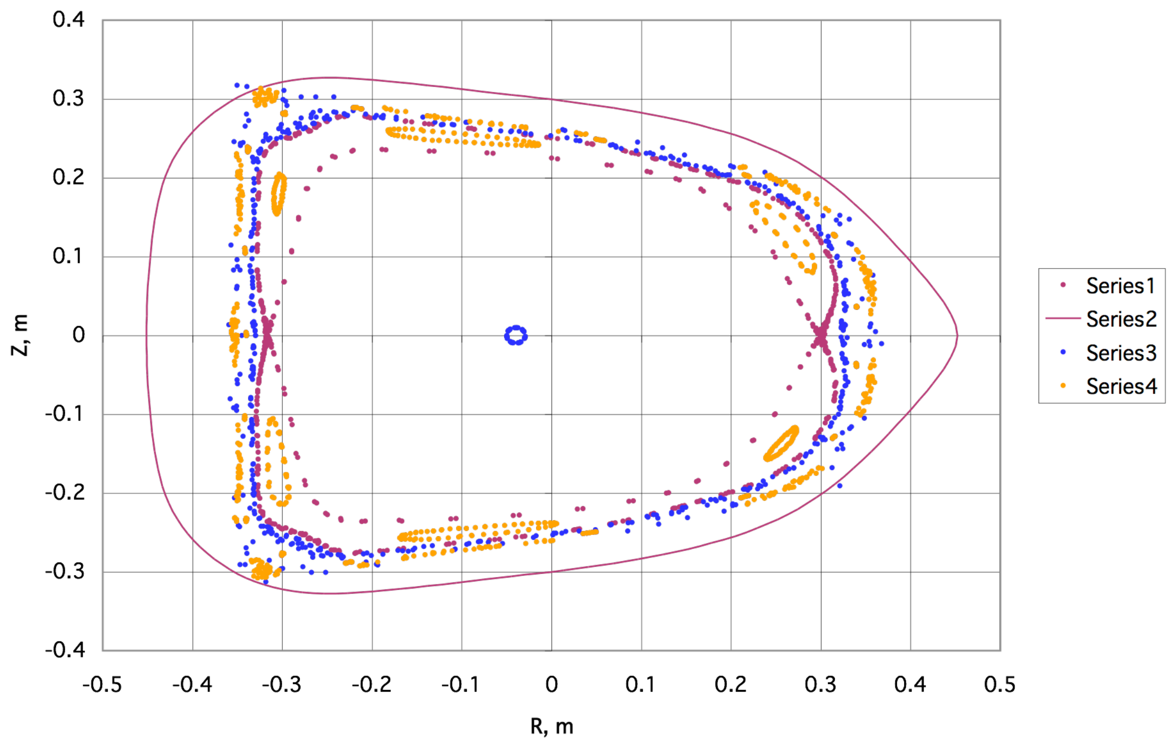
Auburn will collaborate lending e-beam hardware

- Movable electron gun, camera
- Evaluating options for detection apparatus:
  - Wire mesh
  - Sparse, jogged mesh
  - Fluorescent rod

Program to validate coil accuracy developed with field-line tracing

- Modular coils plus TF gives configuration sensitive to Modular coil displacements or tilts
  - Configuration is insensitive to TF misalignments.
- The PF coils can be tested in pairs;
  - The ratios of the TF, PF and MC currents are varied to explore different configurations.
  - Insensitive to alignment errors for PF coils 1 - 3.
- PF coils may also be added singly

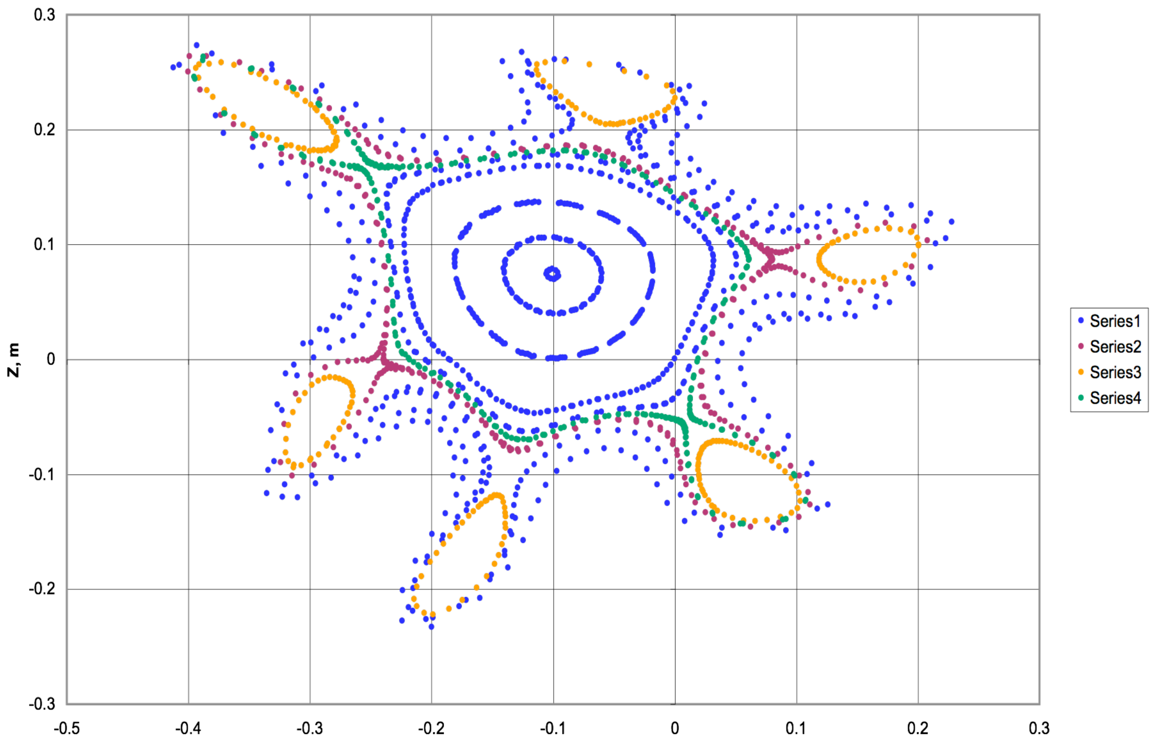
Configurations sensitive to error-fields have intrinsic islands

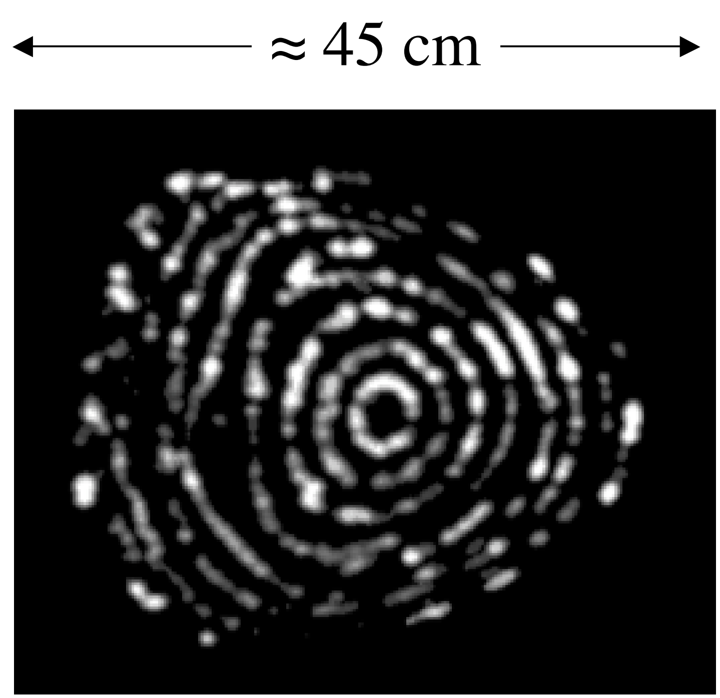


- Separatrix of initial 3/6 island chain is "split" by 1/2 error field.
- Modular Coil #1 shifted by 3mm.
- Mapping near the separatrix requires many passes, high resolution.

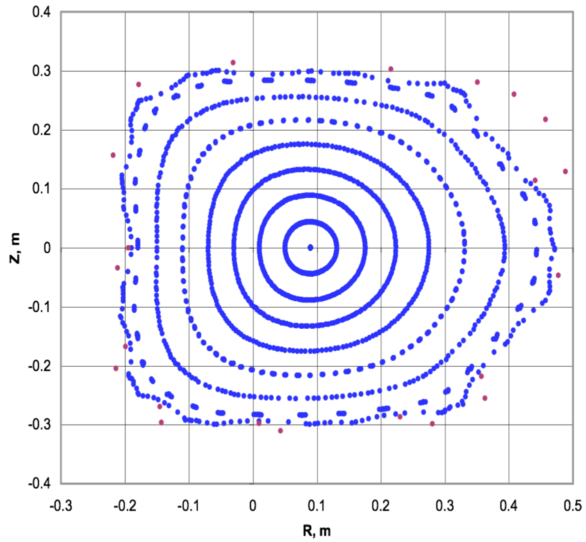
Configurations with single PF coil offer potential to isolate errors

- PF6 lower and TF currents adjusted to give ι = 0.5 surface.
- Intrinsic island separatrix is split, as in previous cases.



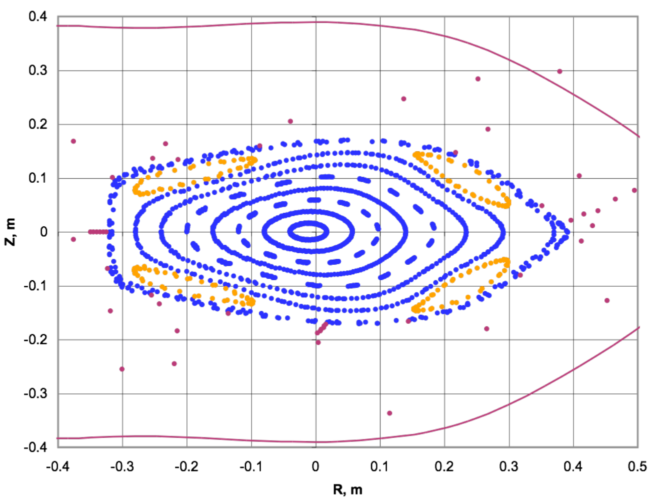


- PF6 tilted 0.2° ≈ 10mm
- 1mm displacement requires 1cm resolution

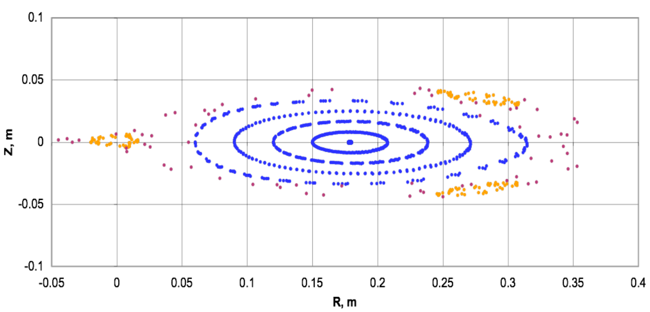


iota range
0.205-0.238

Vacuum configurations will be tested with ι = 0.2 to ι = 0.82



iota range
0.68-0.80



iota range
0.80-1.00

- Scans in shear will also be explored.
- Verification of transform is goal, as well as shape and good surfaces.
- Very flexible coil set gives large range of configurations.

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Equilibrium Studies in FY11

- Goal is to apply tokamak-like equilibrium reconstruction code to NCSX
  - Benchmark V3Fit (being developed under separate grants)
  - Validate modeling of PIES and other codes
  - Document variation with plasma pressure and current

- Experiments to address goals in FY11
  - Test consistency of V3Fit with full diagnostic set

    Magnetics (extensive saddle coil array and B probes)

    Mapping of profile diagnostics (Thomson scattering, Chers, SXI)

    Contact with PFCs (thermal imaging)
  - Look for effects correlated with low-order resonant surfaces
  - Compare with modeling by PIES and other codes

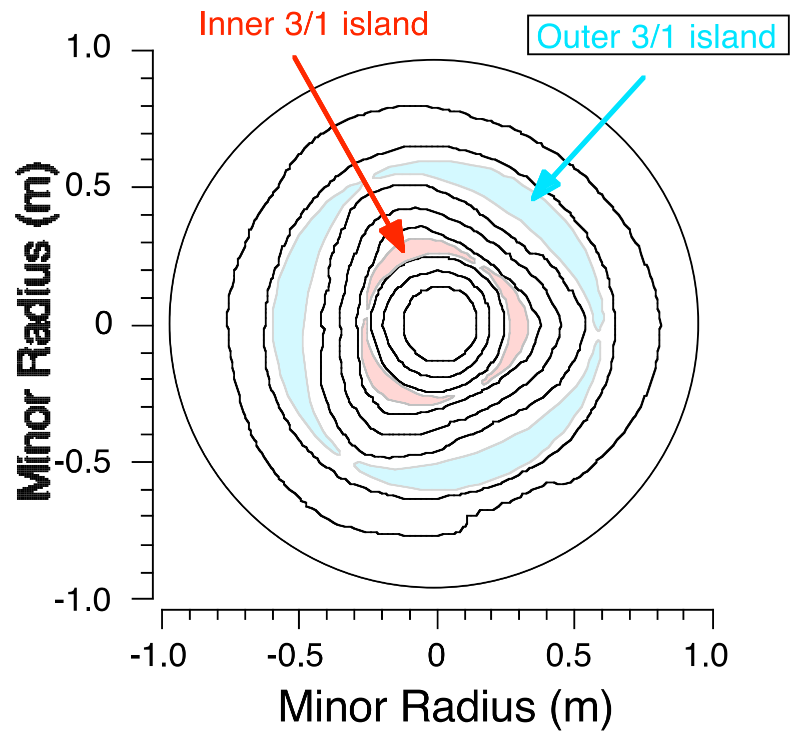
Stability Studies Goals

- Tearing modes (neoclassical effects):
  - Verify neoclassical stabilization of tearing modes in negative shear plasmas
- Beta limits
  - Document pressure-driven MHD dependence on configuration.
  - Test whether pressure driven MHD limits beta.
- Alfvénic instabilities
  - First exploration of *AE activity.

Bootstrap current in reversed shear should stabilize islands

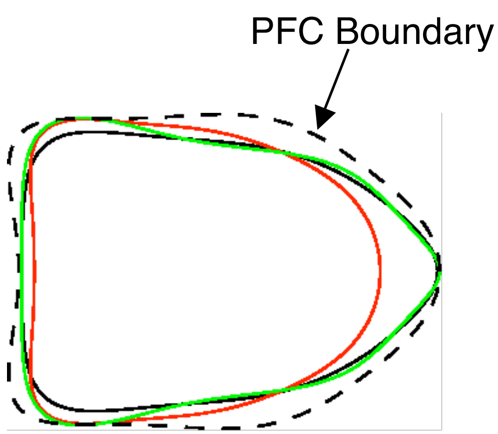
- Double-tearing modes have been studied in tokamaks, but physics complicated by the two islands.
- Soft x-ray camera and Mirnov coil diagnostics, together with Thomson, Chers, etc. should be adequate diagnostic set.

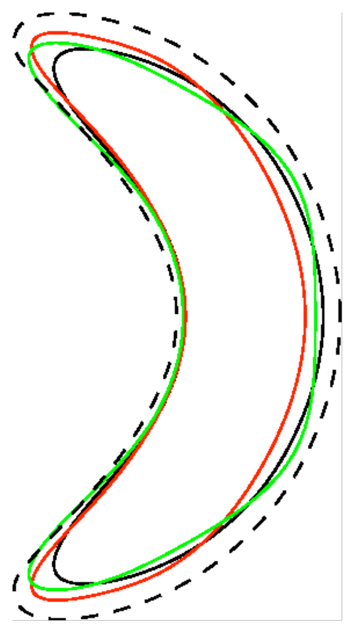
- Double tearing mode on TFTR in reversed shear

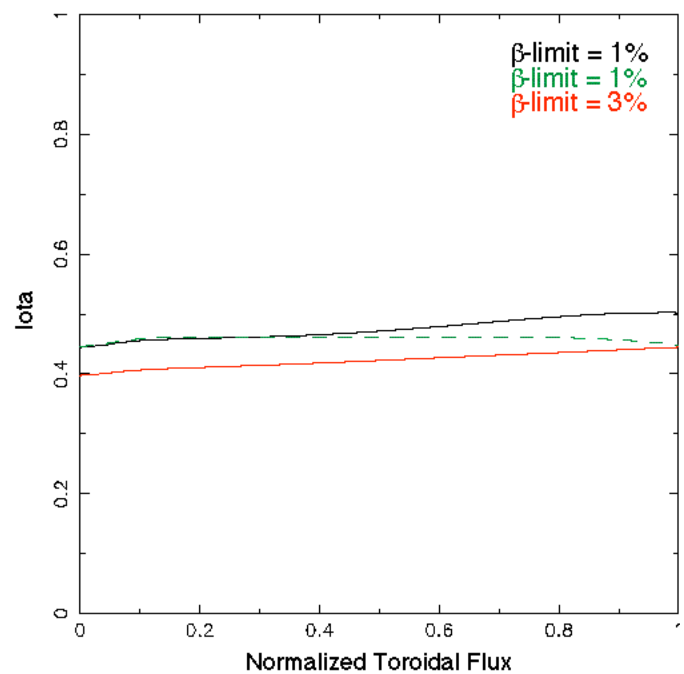


Coil Flexibility Gives Control of Kink β-limit

- External-kink critical-β changed from 3% to 1% by modifying plasma shape
  - either at fixed shear or fixed edge-iota !
- Free-boundary equilibria, fixed pressure and current profiles
- Test understanding of 3D effects in theory & determine role of iota-profile
- Soft x-ray camera, Mirnov coils and saddle coils to detect external kink.



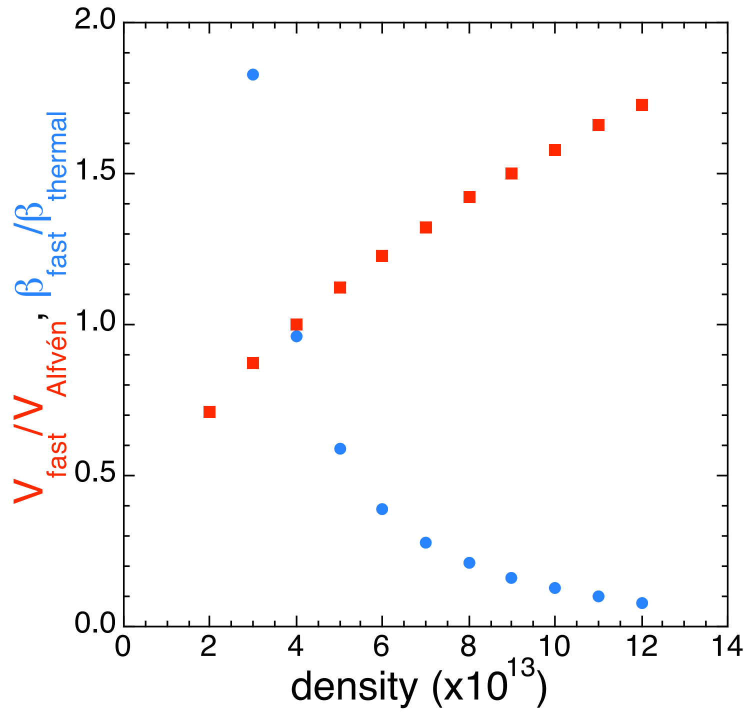




Density window for TAE studies

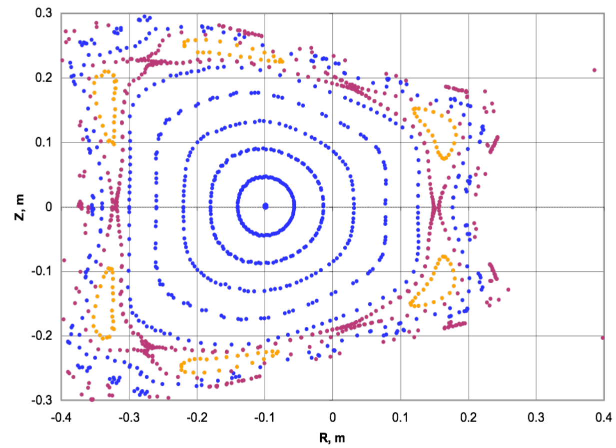
- Density scan controls β_{fast} and $V_{Alfvén}$.
- Window around $4–6 \times 10^{13}/cm^3$ for Alfvén mode studies:
  - beam ions should be super-Alfvénic.
  - $\beta_{fast}/\beta_{thermal} > 30\%$.
- Configuration scans (shear) explore continuum damping.

ISS04v3 confinement
1.2 T and 3 MW
45 kV hydrogen beams



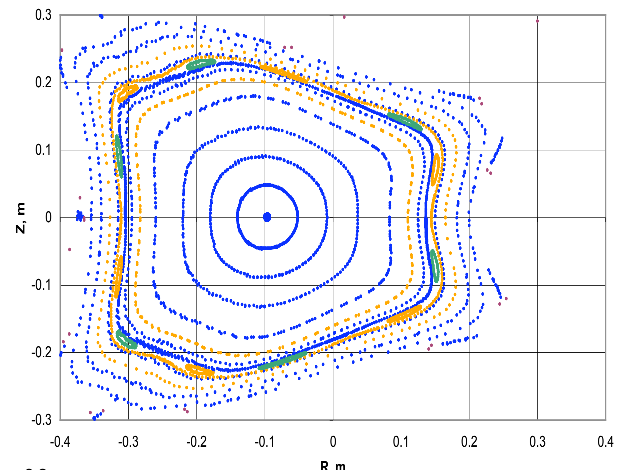
We will have the tools to make significant progress towards goals

- We have identified a path forward to verify accurate assembly of the major coil sets.
- Program to develop stellarator equilibrium code is moving forward;
  - Benchmarking the code will be done in FY11
- The diagnostic set planned for FY11 operation is adequate for initial stability studies of:
  - Neoclassical tearing modes in negative shear
  - Configuration-dependence of stability limits
  - Initial investigations of fast ion driven instabilities



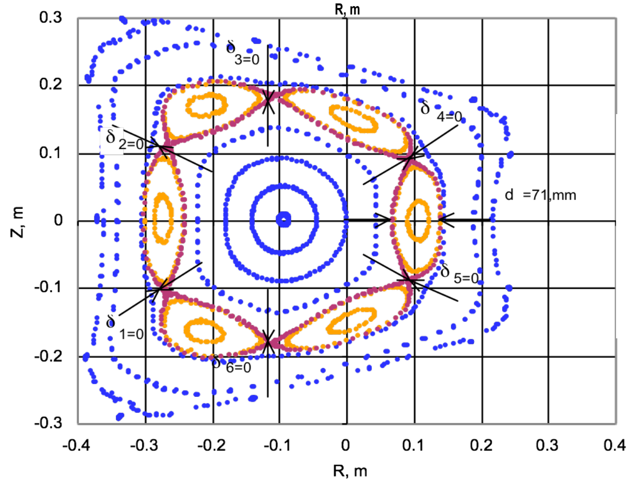
10.20%

Configurations with small intrinsic islands exist, but…



10.06%

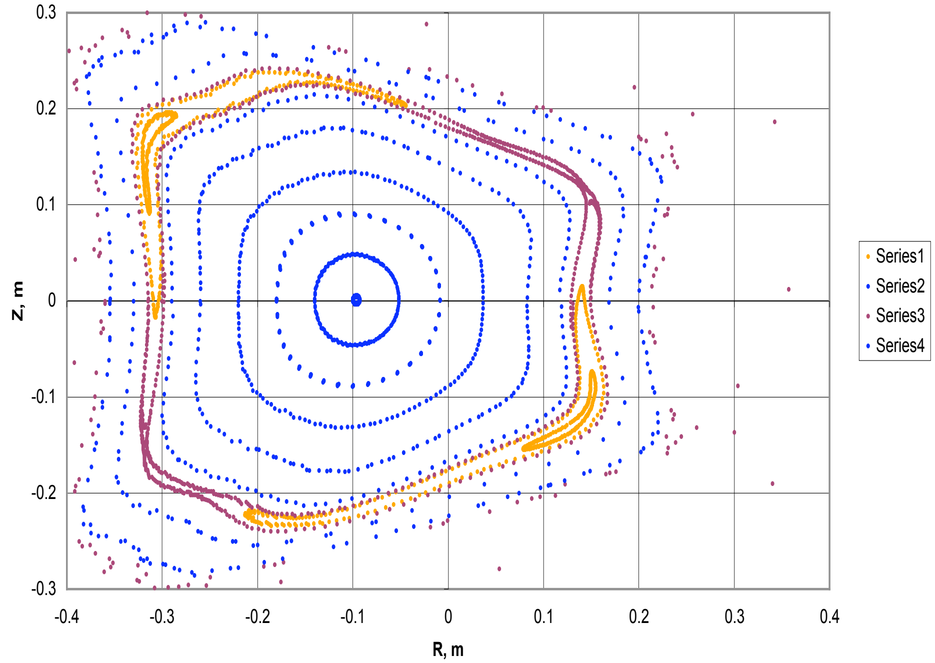
- *Small* increase/decrease (≈0.15%) in vertical field creates large islands.
- Questionable whether control of fields will be good enough to exploit this configuration.



9.84%

The null configuration is very sensitive to poloidal field coil tilts

- Net tilt of ≈ 1 cm, gives 4 cm island.
- Assuming linear scaling of error field with tilt, and a minimum detectable island of ≈ 1 cm; minimum detectable tilt of PF6 is ≈ 1 mm.



- K_{φ} =1.118, B_z(1.4)=10.06%.
- PF6 tilted around X direction with angle 6'.

"Bean" offers best access for scanning fluorescent rods

- Full coverage requires multiple probes.
- But rods can be relatively short, allowing fast scan times.
- Other cross-sections are being evaluated.