Plasma Configuration Design: Criteria and Approach

Outline

- Requirements we are imposing on reference design.
- Requirements we have backed off on for reference design. To be revisited for PVR.
- Approach for generating candidate configurations.
  - A key step: settle on general features based on general considerations and experience evaluating a range of configurations.

Requirements for Reference Design

Neoclassical Transport:
Require near quasi-axisymmetry, adequate poloidal flux.

- Evaluate transport via Monte-Carlo calculations. (Mynick)
  As we gain experience, refine rules of thumb.
- Near QA measured in terms of $B_{n\neq 0}$ in optimizer. (Ku)
  Adequacy crudely measured by $|B|$ along field line.
- Poloidal flux: min $\langle\iota\rangle$ suggested by analytical calculations (Boozer,Zarnstorff). May be marginal. (But, how many orbit widths do we need? Effect of co-injection.) Revisit for PVR.
- Energetic particle confinement: Orbit (Redi, White, Zarnstorff)

Ballooning

- Evaluated with Cooper's Terpsichore ballooning code. (Ku)

- Benchmarked against German code.

External Kink

- Terpsichore (Fu, Ku)
- Would like to benchmark against CAS3D (Redi)

Requirements We Have Backed Off On (Revisit for PVR)

Coils

- What constraints do they place on configuration?

Bootstrap Self-Consistency

- Analytic estimate (tokamak) gives rough estimate of magnitude and profile.
- Retain Aries profiles for bootstrap alignment.
- NIFS bootstrap code (Monticello & Hughes) and Monte Carlo (White) give more sophisticated evaluation. Is large cancellation calculated from NIFS code real?
- Have backed off on demanding strict self-consistency for reference design. Uncertainty in calculations.
  Current not modified for flattened p.
  Have not studied removal of seed current.

Vertical Stability

- Import CAS3D capability. (Redi)

Generating Configurations

- Optimizer target function now includes measures of quasi-axisymmetry, ballooning stability, and kink stability.
- Running optimizer is an art:
  - Local optima. Sensitive to initial guess. (Contradicts W7X experience?)
  - Sensitive to relative weights of terms in target function, form of target function. e.g. Helps to add one term at a time ot target function.
- A key step: settle on general features based on general considerations and experience evaluating a range of configurations.
  Generating desirable configurations still requires skilled, manually controlled exploration with optimizer.

General Features

$\iota \approx .25 \rightarrow .45$

- Want ι monotonically increasing.
- Need shear for kink and ballooning stability.
- For fixed ι_e, don't want to push ι_0 too low.
  - Poloidal flux requirement.
  - Equilibrium shift of axis.
- Avoid $\iota = .5$. Entire transform profile below or above.
- ι_e limited by helical excursion (reduces $a_{\min}$ that fits in PBX vacuum vessel), by number of periods, and by bootstrap current.

Number of Periods: 2 – 4

- Higher numbers of periods have increasing number of coils, and are also increasingly difficult to symmetrize.

- Lower number of periods requires increased transform per period. Larger distortion and larger helical excursion.
- 3 periods best compromise right now?
- Hybrid 2 + 4 promising but numerically challenging.

$\iota_{\mathrm{vac}}/\iota \geq .\mathbf{4}$

n = 0 shaping for ballooning stability.

- Adopt Aries shape.

Start with **Aries pressure and current profiles.**

- Gives good bootstrap alignment.
- Modify slightly as needed.