Configuration c10

- Background
- Issues
- Tasks Required for Generating a c10-like Reference Design

Background

c10 developed in late August.
Evaluated for 9/23 project meeting:

- Fits in PBX.
- $|B|$ along field line appeared adequate.
  Monte-Carlo calculations and analytical estimates appeared to confirm that neoclassical transport dominated by axisymmetric contribution.
- Calculated to be ballooning and kink stable at $\beta = 4\%$.
- Estimates of energetic particle losses appeared ok. (20 – 30%)
- Concern about axisymmetric neoclassical confinement.
  Viewed as the critical physics issue.
  (Coil current density appeared to be critical engineering issue.)

Axisymmetric neoclassical confinement: evaluated by Lin's GTC code for c10. Appears to be adequate.

But, more refined evaluation of other issues has exposed problems:

Kink stability

- Convergence studies revealed inadequate no. of modes had been kept in Terpsichore calculation.
- Kink restabilized with adequate Fourier resolution. c76. (Jan.)
  Increased ripple: An issue for confinement and coils.
- Modification in radial weighting of objective function gives c82, with improved ripple approaching that of c10. coils? transport?
- Kink can be stabilized in c10 by modification of current profile, but bootstrap self-consistency an issue.
- Recent clarification of dependence on magnitude of current:
  - c10, c76 and c82 have 200 kA current.
  - For fixed β, Fu finds kink stability when current reduced to about 130 kA.

  - Taking $\beta \propto I$, Ku also finds kink stability at about that level of current.
  - 3D bootstrap code gives bootstrap driven current of about that level for c10. (Not self-consistent.)

- Further improvements in ripple and in coil desirability likely with: further refinement of objective function, modification of ι and current profiles. Density and temperature profiles in bootstrap code. Couple bootstrap code to optimizer.

Confinement of energetic particles.

- Improvements in ORBITMN modeling led to increased estimate of neutral beam losses. Energy loss of 50% in c10.
- If a small number of resonances are responsible for stochastic passing particle loss, may be able to suppress those components with little effect on other properties of configuration.
- Will improved understanding of trapped particle loss lead to improved objective function for optimizer?

Additional Issues to be Evaluated

- Vertical stability.
- Ballooning stabilization requires p' reduction near edge. Raises bootstrap current issue.
  - Verified to be ok for configuration where p' reduction small. Can reconverge to self-consistent bootstrap profile.
  - Configurations with large ballooning growth rates, requiring small p' near edge, likely to collapse inward as self-consistent bootstrap current removed near edge. Ballooning stabilization for these configurations not reactor prototypical.
- Startup and robustness.

Tasks Required for Generating a c10-like Reference Design

Some required plasma configuration design tasks if we move ahead with a c10-like configuration:

- Continued optimization studies to generate kink-stable configurations with sufficiently low ripple, reasonable coil current densities, and adequate poloidal flux.
  - Explore refinements in objective function, modification of ι and current profiles. Density and temperature profiles in bootstrap code. Couple bootstrap code to optimizer.
  - Coil current density optimization. Can we use $|B|$ ripple or curvature of plasma boundary as indicator of coil current density? Couple small NESCOIL to optimizer?
- Feedback from thermal transport calculations for new configurations.
- Feedback from coil designers for new configurations.

- Energetic ions:
  - Elucidate mechanism of loss.
  - Can we reduce energetic ion losses by modification of objective function (e.g. suppressing resonant Fourier components)?
  - α confinement in reactor scale device?
- Vertical stability.
  If unstable, may require optimization effort to stabilize.
- Self-consistent bootstrap currents, including p' ballooning modification.
  May require additional optimization studies to reduce ballooning growth rate if required p' flattening unacceptable.

Need reactor configuration at least by Snowmass. Will likely want to go to lower aspect ratio for this.