Compact Stellarator Reactor Vision, FESAC Goal, and Program Requirements

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Compact Stellarator Reactors

Vision: A steady-state toroidal reactor with

- No disruptions
- No conducting structures or active feedback control of instabilities
- No current drive ($\Rightarrow$ minimal recirculating power)
- High power density (~3 MW/m^2)

Likely (based on today's knowledge) configuration features

- Rotational transform from a combination of bootstrap and externally-generated. (how much of each?)
- 3D plasma shaping to stabilize limiting instabilities. (how strong?)
- Quasi-axisymmetric to reduce helical ripple transport, alpha losses, flow damping. (how low must ripple be?)
- Power and particle exhaust via a divertor. (what magnetic topology?)
- $R/\langle a \rangle \leq 4.4$ (how low?) and $\beta \geq 4\%$ (how high?)

Optimum design involves tradeoffs among features. Need to understand the physics to quantify mix, assess attractiveness.

Assessing Compact Stellarator Attractiveness

Reactors based on today's physics understanding

- Scaleups of NCSX plasma designs to 1-2 GW, R=7-8 m power plants show potential attractiveness. (Chapter 14)

Better physics understanding is needed to guide the tradeoffs ⇒ optimize reactor designs ⇒ assess attractiveness ⇒ decide on next steps.

The compact stellarator program, led by NCSX, aims to provide the needed knowledge base in ~10 years.

- Understand β-limits, β-limiting mechanisms and behavior.
  - Determine how high β can be. **(NCSX)**
  - Determine how much shaping and external iota are needed. (**NCSX, QOS)**
- Understand anomalous transport reduction mechanisms.
  - Determine if tokamak mechanisms transfer. **(NCSX)**
  - Determine how low the effective ripple has to be. **(NCSX)**

cont'd.……

Assessing Compact Stellarator Attractiveness, cont'd.

Compact stellarator physics goals, cont'd.

- Understand equilibrium limits with strong toroidicity.
  - Determine how low the aspect ratio can be. **(QOS)**
- Understand effects of 3D field structures on the boundary plasma and plasma-material interactions?
  - Determine what the divertor looks like. (**NCSX)**
- Understand conditions for high-beta, disruption-free operation.
  - Determine how much externally-generated iota is needed. **(NCSX)**
  - Determine how much internally-generated iota is possible. **(NCSX, CTH)**

Complementary approaches broaden the knowledge base and explore potentially high-payoff alternatives ⇒ more knowledge ⇒ better decisions.

- Benefits of QH symmetry? **(HSX);** of QP symmetry? **(QOS)**
- Value of non-toroidal component of flow? **(HSX, QOS)**

Summary

- Compact stellarators could be the most attractive solution for MFE.
- The physics needs to be better understood in order to quantify the tradeoffs, optimize designs, make meaningful assessments of attractiveness.
- The compact stellarator program as proposed is the best way to acquire the knowledge needed to assess concept attractiveness in ~10 years and decide on next steps.
  - NCSX is key.
  - CE's are both supportive and complementary. Both roles important.
  - Theory is critical for design and for understanding experimental results.
  - Collaboration on foreign stellarator takes advantage of unique capabilities.
  - Reactor design studies will be used to project implications of what is learned and to identify critical issues for further study.