Compact Stellarator Role in Magnetic Fusion Development

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Stellarators Offer Solutions For Practical Magnetic Fusion Systems

External coils can provide up to 100% of the rotational transform.

- Can be steady state with no recirculating power for current drive.

3D-shaped plasma can be made passively stable to troubling instabilities, while keeping the collisionless particle orbits well confined.

- Can avoid disruptions without active feedback or rotation drive
- Can realize enhanced confinement.

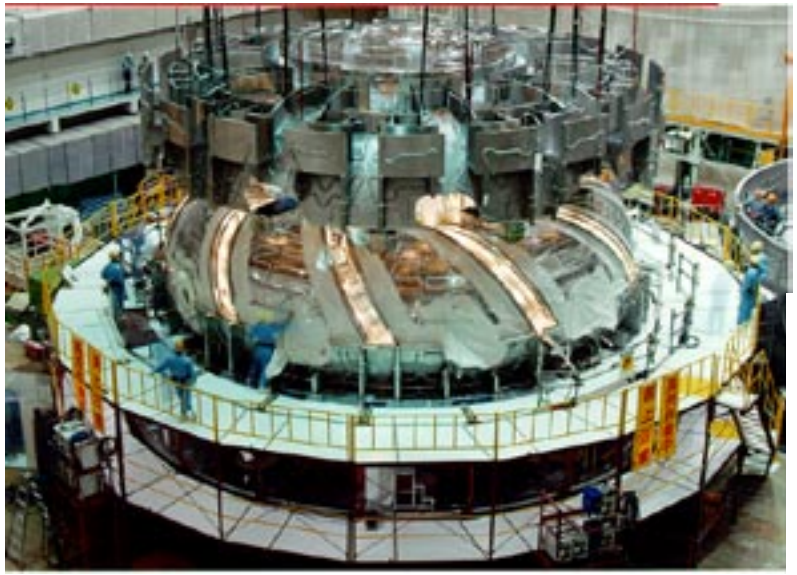
Magnetic symmetry (axial, helical, or poloidal) can be used to combine stellarator and tokamak benefits (Compact Stellarators).

- Low aspect ratio ($\leq$4.4) and high beta ($\geq$ 4%) $\Rightarrow$ high power density.
- Sheared flows for stabilizing turbulence.
- Bootstrap current for supplying some of the rotational transform.

Cost: complexity of coil and structure geometry.

Research program for next 10 years: test physics, quantify benefits *vs* costs, evaluate long-term potential, decide on next steps beyond PoP.

Stellarators Are Making Great Progress



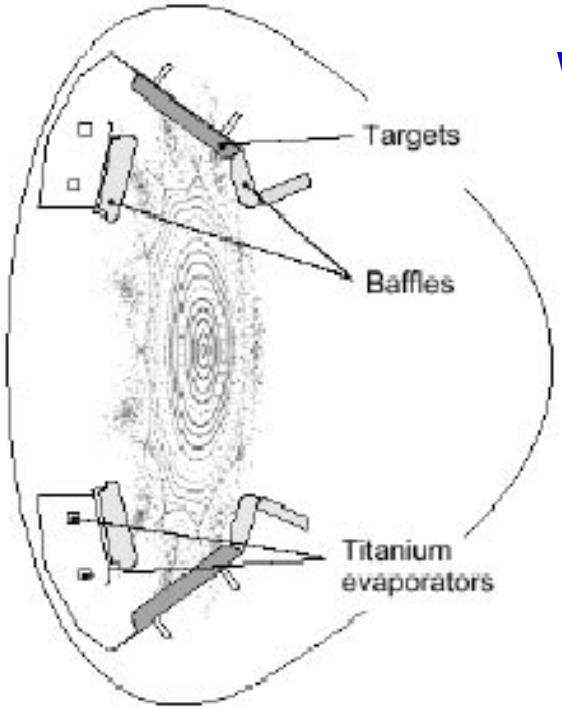
Large Helical Device (Japan)

$\beta > 3\%$.

$T_e \approx 10$ kev, $T_i \approx 5$ keV.

enhanced confinement.

2-minute pulses.

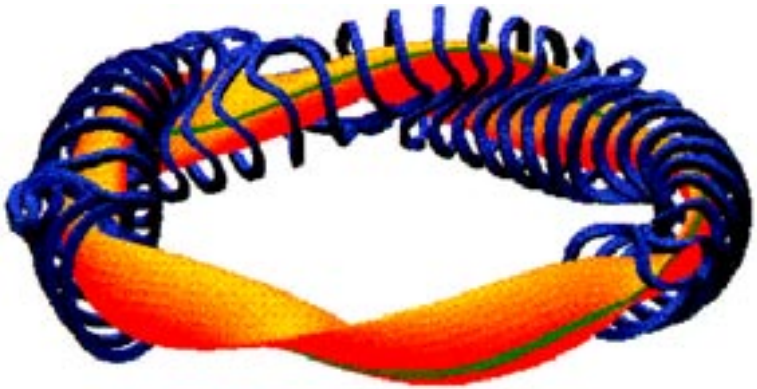


Wendelstein 7-AS (Germany)

$\beta > 3\%$.

enhanced confinement.

density control & enhanced performance w/island divertor.

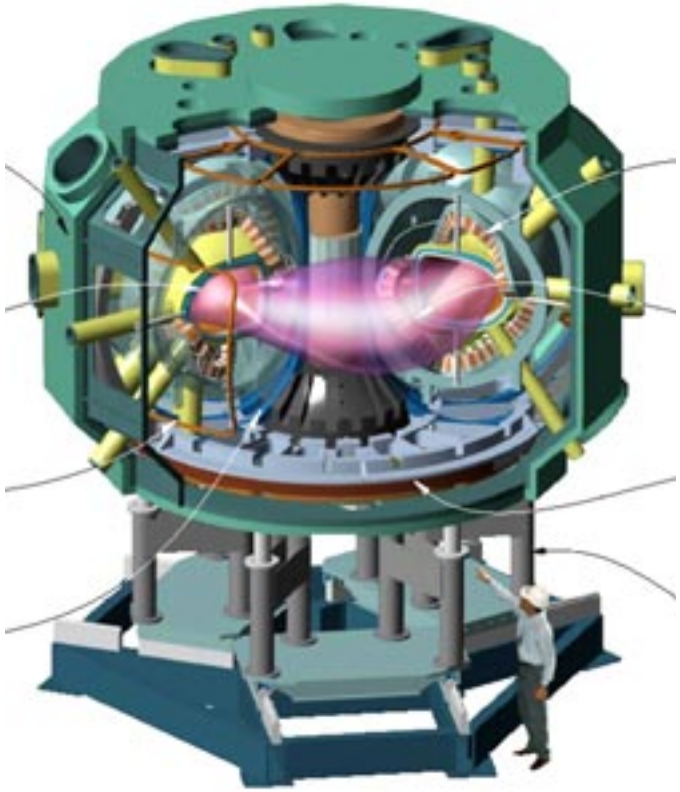


Wendelstein 7-X (Germany)

non-symmetric optimized design.

Under construction (operates 2007).

The U.S. Stellarator PoP Program Is Moving Forward



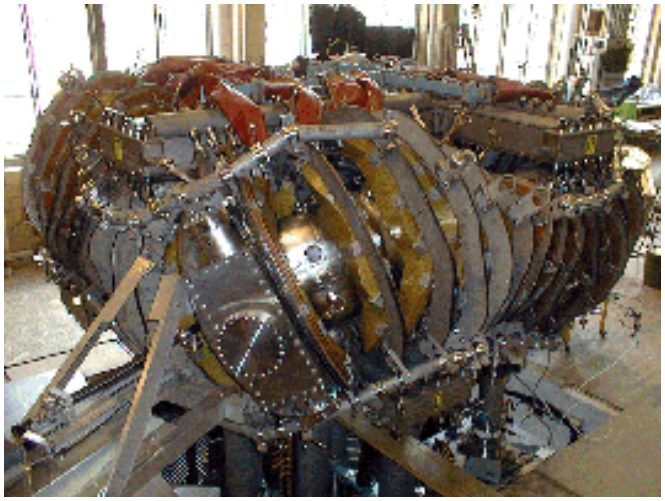
NCSX (PPPL-ORNL)

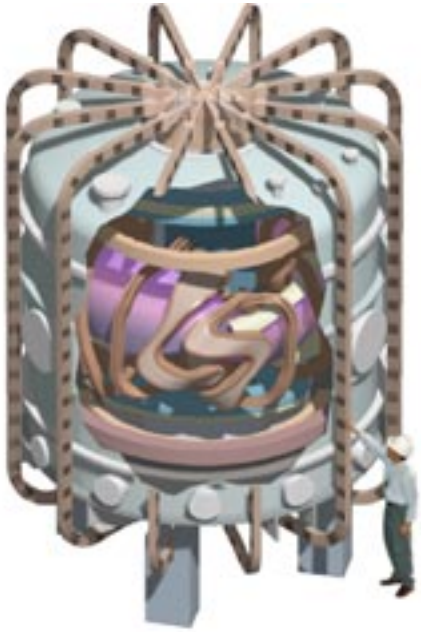
PoP test of high-β, low-R/a, quasi-axisymmetric stellarator.

Passed CDR in May.
Fab. project starts this October.

HSX (Wisconsin)

Successful test of quasi-helical symmetry.





QPS (ORNL)

CE test of quasi-poloidal symmetry at R/a=2.7

in conceptual design

CTH (Auburn)
Under construction; operates 2003.

A Tokamak Burning Plasma Experiment Can Benefit the Development of Stellarators

Example: Technology Benefits

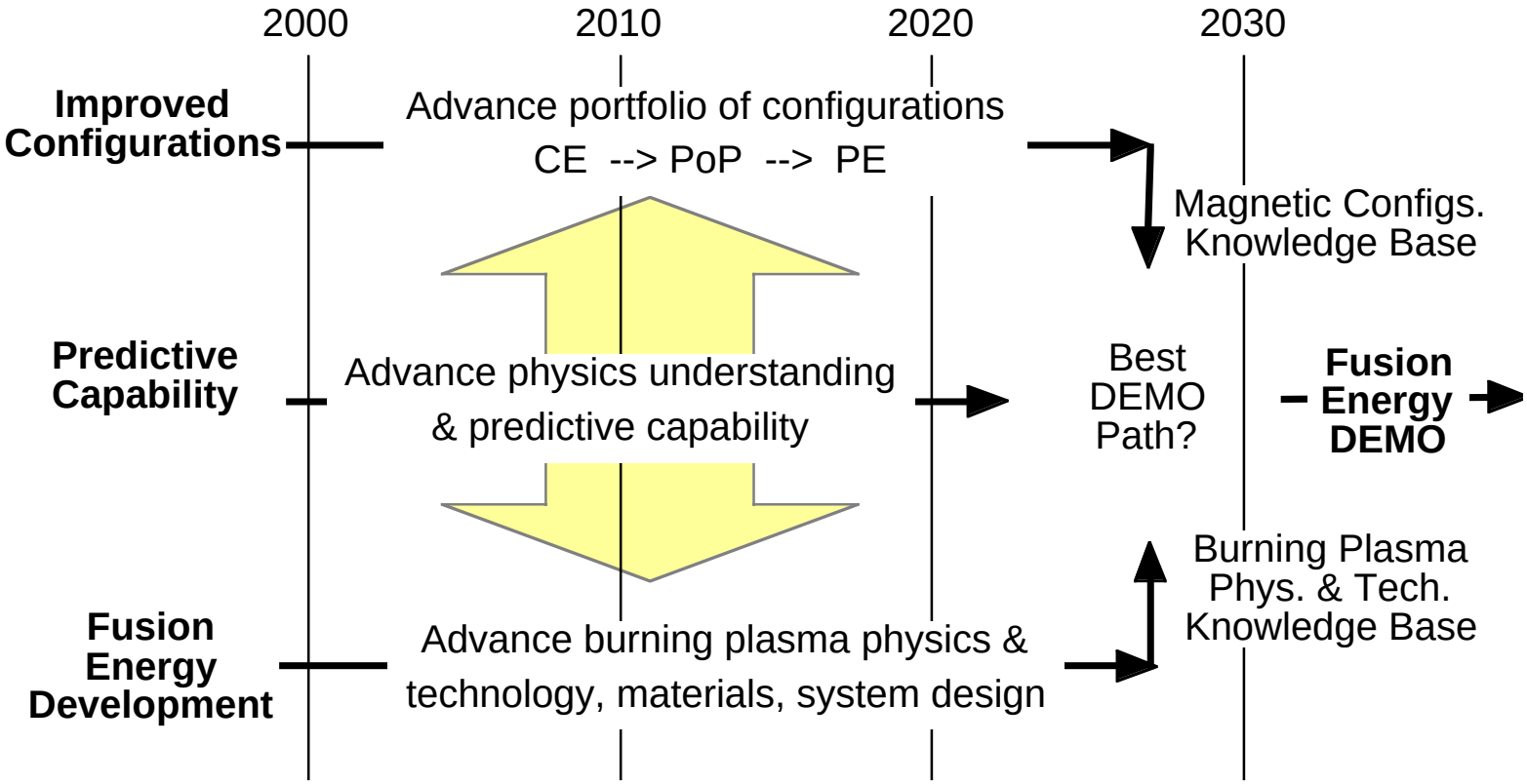
Operating Experience with Fusion Reactor Components in a Burning Plasma Environment

- Plasma-facing components
- Heating and fueling components
- Diagnostics
- Remote maintenance
- Magnets
- Tritium and safety

A BPX will provide a data base on operational performance, reliability, and maintenance of fusion components that will benefit stellarator reactors.

Achieving levels burning-plasma availability and duty factor approaching those required for practical fusion would be a major BPX accomplishment.

A Well-Integrated Program Provides a Path to a Stellarator DEMO (I)



Program Requirements:

- Advancement of a portfolio of concepts for practical fusion.
- Advancement of fundamental understanding resulting in a predictive modeling capability that spans the portfolio.
- Flexible, well-diagnosed BPX that provides fundamental understanding and physics and technology data for the entire toroidal portfolio.

With a Well-Integrated Program, a Stellarator DEMO Could Be the Next Step After a Tokamak BPX.

By 2025, there will be a substantial knowledge base on stellarator physics and long-pulse integration from 2-3 PE-class stellarators (LHD, W7-X, and a possible "CS-PE").

The BPX will provide a knowledge base on toroidal physics in the regime of alpha-dominated, large-size plasmas.

- **Pulsed tokamak, or "modest AT" (f_{BS}<<1), physics may be sufficient for stellarator purposes. Stellarator needs may actually be easier to satisfy than steady-state tokamak needs!**

Validated predictive capability for tokamak and stellarator physics will be vastly improved by virtue of expanded data base from large machines, theory advances, exploitation of advanced computation, and commitment to cross-portfolio integration.

The BPX can provide a knowledge base on the operation of fusion-relevant technologies in a burning-plasma environment, readily applicable to stellarators.