University Stellarator Experiments

OFES BPM for FY 2006

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Universities & national labs have integrated plan of configuration optimization to improve confinement & stability in toroidal configurations using 3-D fields.

Helically Symmetric Experiment (HSX) at University of Wisconsin

- ⇒ **First test of confinement optimization through magnetic symmetry in stellarators => operating since 2001**

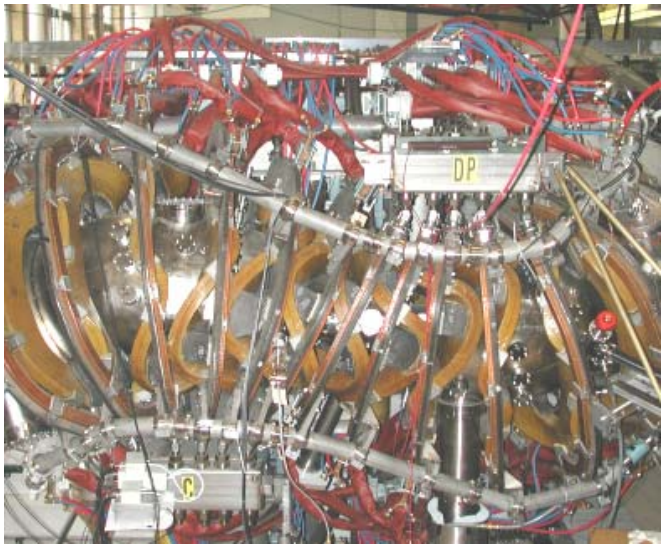
Compact Toroidal Hybrid (CTH) at Auburn University

- ⇒ **Passive disruption control in current-carrying stellarators**
- ⇒ **3-D reconstruction of experimental stellarator equilibria**

=> to operate in 2004

University experiments contribute directly to NCSX & QPS CS missions; are active participants in international stellarator program.

HSX: Quasi-helically Symmetric Stellarator



The first experimental test of stellarator optimization for improvement of neoclassical transport.

Thrust area: Fundamental Understanding
Concept Optimization

IPPA Goals: 3.2.3.2 Advance Stellarator Physics Using Small, Exploratory Experiments; 3.1.3.1 Plasma heating and current drive

Objectives: Show reduced flow damping with symmetry; demonstrate reduced direct loss with symmetry; test reduction of neoclassical electron thermal conductivity at low collisionality; E_r control through plasma flow and ambipolarity

Next Review: Renewal Feb 1, 2005

- **Staffing: 6 FTE Scientists, 1 Faculty, 3 Tech support, 1 Post-doc, 10 graduate students (1 graduating May, 5 passed qualifiers/prelims, 4 'in pipeline'), 5 undergrads as hourlies/indep. study**
- **Present Grant Budget (2/1/04-1/31/05): $1490K (original out-year budget $1770K)**
- **Recent Accomplishments: Factor of three reduction in flow damping with symmetry; Improved plasma breakdown, microwave absorption, and confinement of energetic particles with symmetry; T_{e0} of 600 eV at 50 kW ECH from Thomson scattering; Anomalous transport scales as 1/n for present powers and densities.**

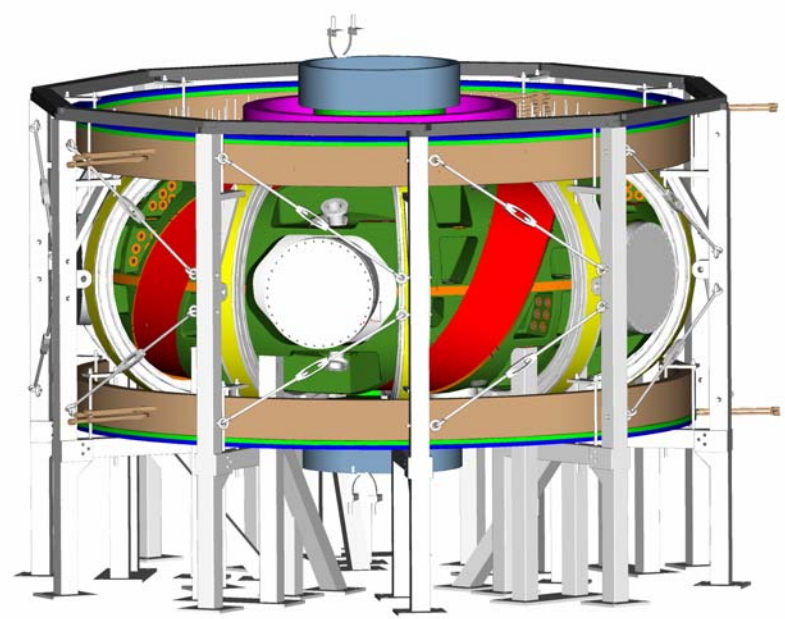
At threshold for observing predicted differences between symmetric/non-symmetric operation; a need for increased parameters/performance and electric field diagnostic to identify benefits of quasi-symmetry.

HSX FY 2006 Budget Planning Input

Program needs to accomplish physics objectives: Ability to measure electric field; Higher power (in progress), higher density operation; Fluctuation diagnostics for anomalous transport studies; upgrades of diagnostics and vessel conditioning.

- **Projected FY06 Main Work Elements:**
  - **Addition of 2nd 200 kW gyrotron for total power of 0.4 MW (funded and in progress)**
    - **Increase neoclassical transport to levels above anomalous w/o symmetry**
    - **Power modulation for electron thermal conductivity experiments**
  - **Implement reflectometer for core density fluctuation measurement**
- **Budget Scenarios:**
  - **Operations funds already well below optimum**
  - **10% decrement from $1490k to $1340k**
    - **Cut 1/2 FTE Scientist and 3 graduate students and no new diagnostics.**
- **Level budget at $1490k**
  - **Operation at higher power but stretch out turbulence research program**
- **Incremental Activities (Prioritized)**
  - **$150k Diagnostic neutral beam for E_r measurement**
  - **$120k Boronization and ECE imaging**
  - **$120k Alternate plasma production (ICRF in collaboration with ORNL/PPPL)**
  - **$100k Upgrade interferometer to laser-based system**

CTH: Compact Toroidal Hybrid



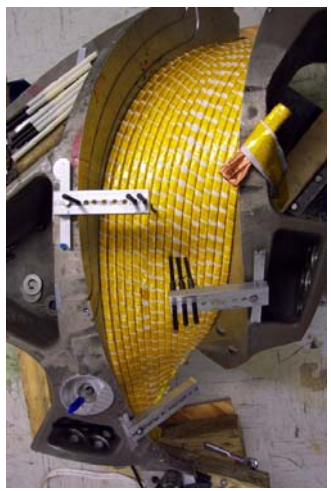
=> Test of 3D equilibrium reconstruction

=> Test of passive disruption suppression & increased low-n stability in 3D systems

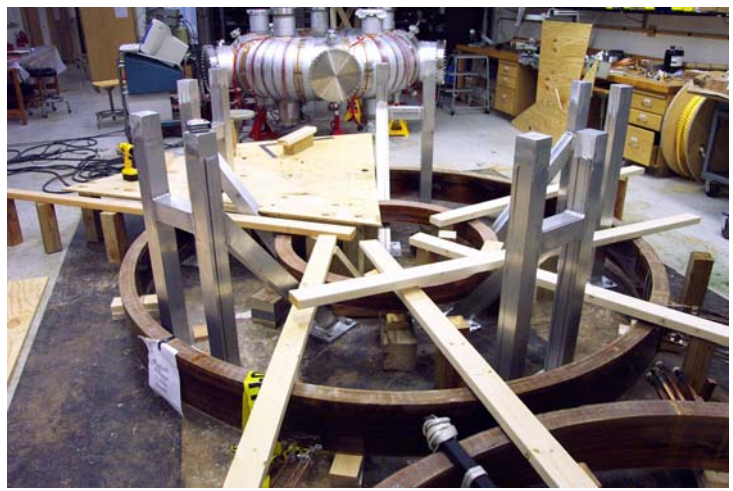
Thrust area: Concept Optimization

IPPA goals: 3.1.2.2 Understanding physics underlying external stability control; 3.2.3.2 Advance stellarator physics using small exploratory experiments to test the understanding of current-driven disruptions in stellarators; 3.3.2.4 Disruption control/amelioration

Helical coil frame at J.P. Pattern Inc. 2/2004; delivered to Auburn 3/2004



Test of winding, insulation & potting of copper rope



Ready for HF coil winding; followed by TF coils

Compact Toroidal Hybrid

Objectives:

- **Demonstrate ability to reconstruct 3D plasma equilibrium with V3FIT code & magnetic measurements**
- **Determine stable operating scenarios and disruption behavior in current-carrying helical plasmas -> investigate kink, vertical, & tearing instabilities vs.** t_{VAC}/t_{TOT}

Present Budget: **$500K**
Next review: **3-year renewal Dec. 1, 2004**
Staff: **1 FTE scientist, 1 FTE tech, 1.3 faculty**
Students: **3 graduate, 5 undergraduate**

Accomplishments:

- **Successful on-going V3FIT 3D eq. reconstruction collaboration (Auburn/GA/ORNL)**
- **All PF coils built on-site or delivered; VV instrumented & ready; precision helical coil frames delivered; initial power systems and data acq. system ready; ECH system development (w/ ORNL & PPPL) proceeding well.**

FY 2005 goals (1st full year of operation)

- **3D reconstruction with external magnetic measurements (loops, probes, etc.)**
- **Increase scientific staff (DOE MFE post-doctoral fellowship)**
- **Initial stability studies w/ ohmic operation in EC-generated plasmas**

CTH FY2006 Budget Planning Input

Projected FY2006 work:

- Advanced 3D reconstruction w/ internal B measurement
  - –MSE/LIF or μwave interferometer/Faraday rotation
- Better-diagnosed stability studies w/ SX arrays & other diagnostics
- Higher density & temperature plasma (higher plasma currents, better diagnostic response) w/ ICRF or additional ECH

Budget scenarios:

10% decrement to $450K

Constrict focus to 3D reconstruction -> reduce scope of disruption studies (reduced diagnostics & cut one graduate student); delay add'l heating

Level at $500K (5% below original out-year budget)

+$ 25K Graduate student

+$ 25K SX array diagnostics & DAQ

Increment

+$ 20K Error field control power supplies

+$ 80K Improved power supply control with IGBT's

+$ 100K Post-doc

Concluding Remarks

- **US stellarator science program geared to improve toroidal configurations through flexibility of controlled 3D fields**
  - *Seeks to combine best features of tokamaks and stellarators*
  - *Improved understanding of general toroidal systems*

- **National laboratory and university stellarator projects constitute cohesive, integrated program to address:**
  - *benefits of quasi-symmetry*
  - *advantages and limitations of plasma current in 3-D systems*
  - *low-A 3-D plasmas*

- **University stellarator programs contribute cost-effectively to US program at appropriate exploratory level**
  - *Need to be maintained at an adequate level*
  - *Entry of students into field of plasma physics*