The HSX Experimental Program


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**Program**

HSX – Designed to demonstrate the potential benefits of quasiisometry in general, and specific properties of quasihelical symmetry

- **HSX** has resumed operation after repairs to a failed coil feed region, realignment, and redesign of an improved coil feed was implemented on all coils.
- Measurements of the Bootstrap current and the helical nature of the Pfirsch-Schliuter current have been made and compare well to calculations using V3FIT.
- Strongly peaked electron temperature profiles and large positive radial electric field and flow predictions support the presence of a neo-classical central transport barrier (CERC) for QHS plasmas.
- Turbulent transport simulations reproduce full radial $T_e$ profiles – thermal transport is dominated by ITG/TEM turbulence in the outer region and core ExB shear stabilization.

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**Coil repair and Feed/Bus Redesign**

One coil feed failed under Tiota operation - 11kA/3s, 14 turn/coil, current risetime 1 second.
- High mechanical stress caused by new thin cable to bus connection
- Failed area repaired, and new feed and cabling implemented on all 48 coils
- Water cooled flexible cables, with internal triplex of twisted pair conductors
- Safety jumper from cable to central coil pack conductors (2 out of 6) can carry load under main feed failure
- COIL-14 turns, 2 layer, 6 conductors per turn
- Redesigned feed and safety jumper
- Original stiff & coaxial cabling
- Flexible cabling

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**Current Measurements (J Schmitt)**

- An array of 16 3-axial pick-up coils are used to measure the current evolution at two toroidal locations
- Magnetic signals are analyzed using the V3FIT code suite for 3D toroidal device equilibrium reconstruction
- Pfirsch-Schliuter currents calculated from VMEC using measured Thomson scattering $T_e, n_e$ profiles – helical nature demonstrated by $B_i$ phase at 16 and 12 Field Period locations
- Bootstrap current calculated using BOOTSJ code – evolves on a slower timescale seen by increasing $B_i$, effect magnitude and direction compared with V3FIT calculation

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**Neoclassical and Anomalous Thermal Transport (J. Lore)**

- **T Profile Comparison**
  - Electron temperature profiles are strongly peaked in the core in QHS
  - Sharp temperature gradients indicate Core Electron Root Confinement (CERC) in QHS configuration

- **Quasi-linear Weiland model has been used to model turbulent transport**
  - With local geometry considerations, good agreement with 3D gyrokinetic DKS results.

- ExB shear turbulence suppression needed to model core heat transport
decoupling, shear and toroidal rule in model can explain $T_e$ peaking

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**The HSX Stellarator**

HSX has a helical axis of symmetry in $B$, low magnetic field ripple, high effective transform, and very low toroidal curvature
- Reduction of direct loss orbits
- Improvement in low $n$ neo-classical transport
- Small viscous damping of plasma flow

For experimental flexibility, the quasi-helical symmetry can be broken by adding a mirror field.

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**Future Plans and Directions**

- **Extend plasma current studies**
  - Internal toroidal and poloidal $B$-dot pickup arrays have been implemented for better time response and broader machine and field-potential coverage
  - Include $E_i$ in Current magnitude calculations, and improve bootstrap current modeling

- **Continue examination of transport barrier, $T_e$, flows and neoclassical and anomalous transport**
- Electric field measurements through ChERS in QHS and Mirror and under scaling studies
- Microwave reflectometer to obtain density fluctuation profiles
- 16 channel ECE system to look for electron root jumping and temporal $T_e$ evolution
- Density and power scans to look for threshold behavior

- **Examine effects of non-representative field on flows in helically symmetric system**
  - Expanded operational capabilities
    - Implement profiled limiter plasma for control and edge recycling and edge interaction studies (C. Clark poster) - ORNL collaboration
    - Implement new ICRF source with parasitic launch capabilities, and improve modeling (J. Raskin poster)
    - Implement ICH to test for root in core – efforts in confinement and flows - ORNL collaboration

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