Effects of Quasisymmetry on Transport in HSX

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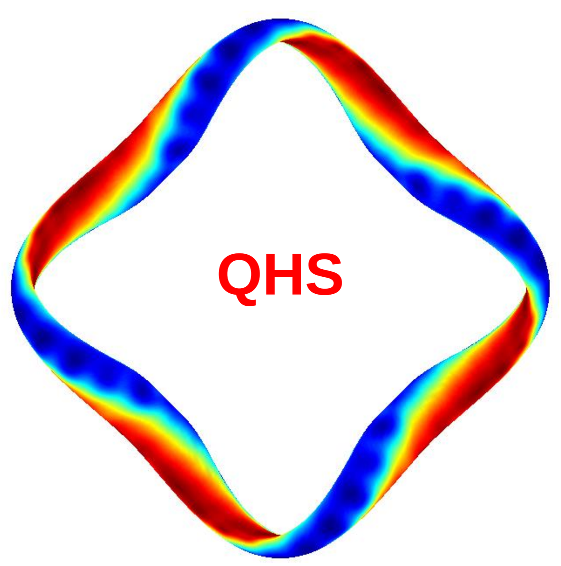
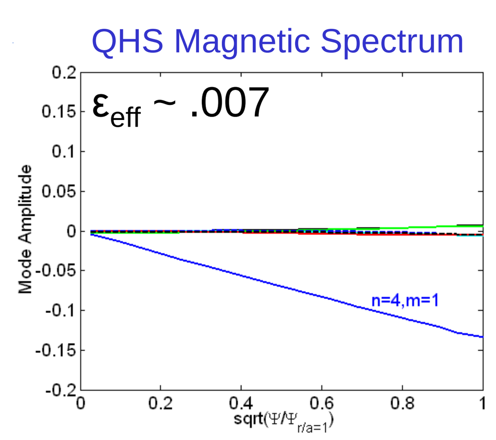
Overview

- For the first time, differences in transport between magnetic configurations with and without quasisymmetry have been measured
- Particle Transport
  - Without quasisymmetry, density profile is hollow due to thermodiffusion
  - With quasisymmetry, density profiles are peaked
- Electron Thermal Transport
  - With quasisymmetry
    - Central electron temperature is higher
    - Core electron thermal diffusivity is lower

HSX is the World's First Quasisymmetric Stellarator

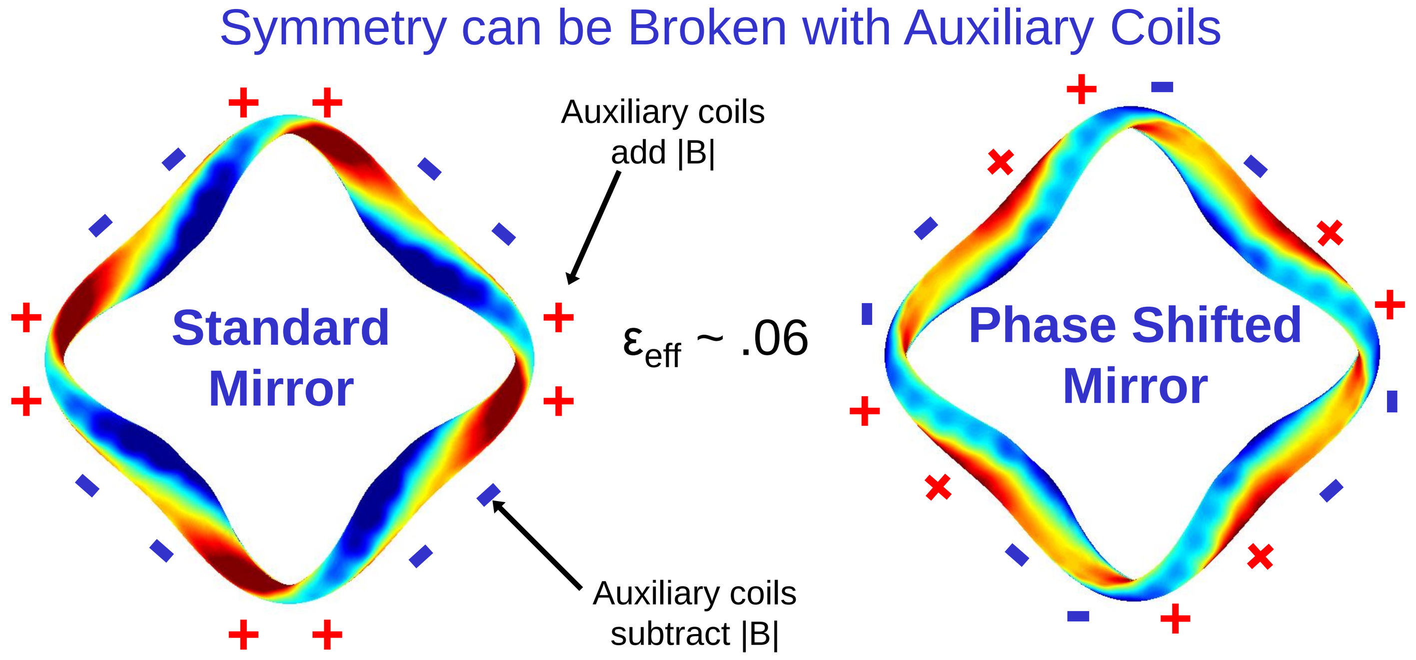


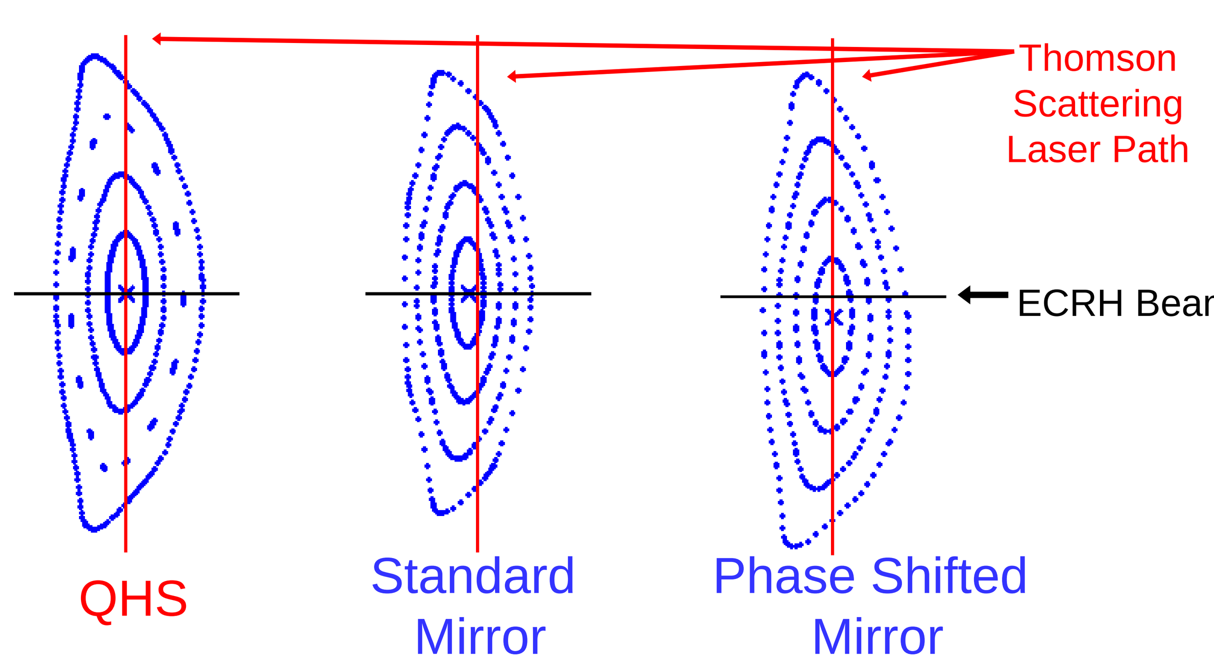


HSX has a helical axis of symmetry in |B|

⇒ **Very low level of neoclassical transport**

Symmetry can be Broken with Auxiliary Coils

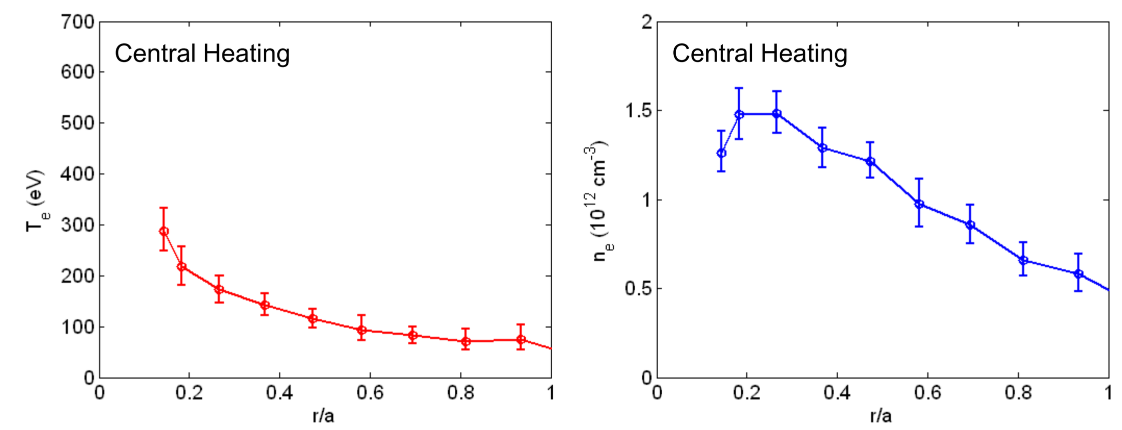




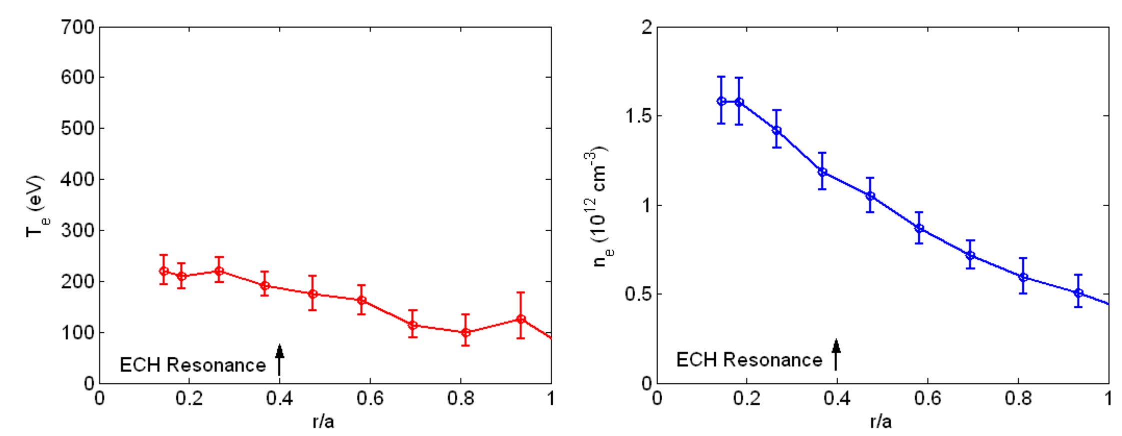
Quasisymmetry Leads to Peaked Density Profile…

Mirror Plasmas Show Hollow Density Profiles with Central Heating, Peaked with Off-axis Heating

- Thomson scattering profiles shown for plasma with central heating in Standard Mirror
  - On-axis heating, no on-axis Thomson scattering
- Density profile in Mirror is similar to those in other stellarators with ECRH: flat or hollow in the core
  - Evidence of outward convective flux -> Thermodiffusion?



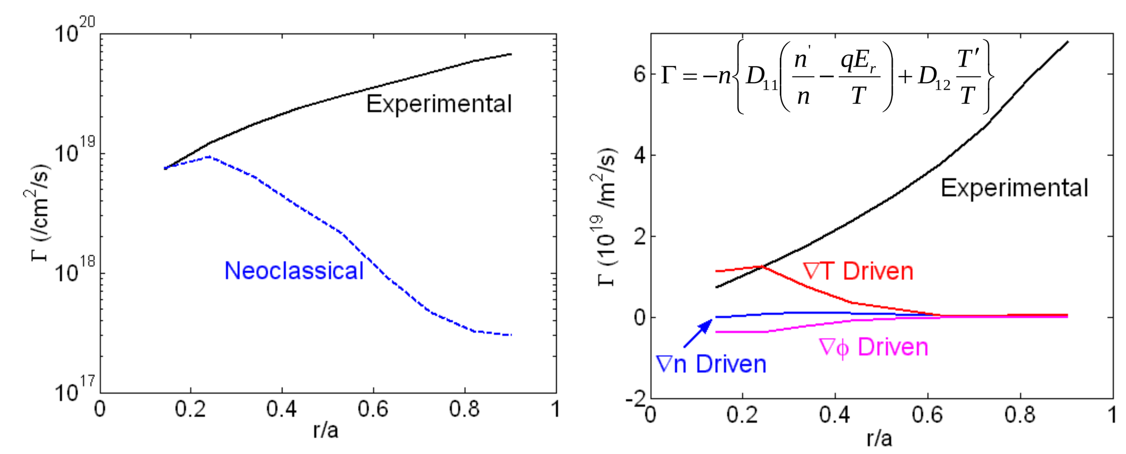
- With off-axis heating, core temperature flattened, density profile peaked
  - Anticorrelation between temperature and density gradients
- Support for large thermodiffusive flux with on-axis heating



⇒Thermodiffusive particle flux causes hollow density profile in Mirror with central heating

Neoclassical Thermodiffusion Accounts for Hollow Density Profile in Mirror Configuration

- Experimental particle flux from DEGAS calculations calibrated to H_α measurements
- In region of hollow density profile, neoclassical and experimental fluxes comparable
- The ∇T driven neoclassical flux is dominant

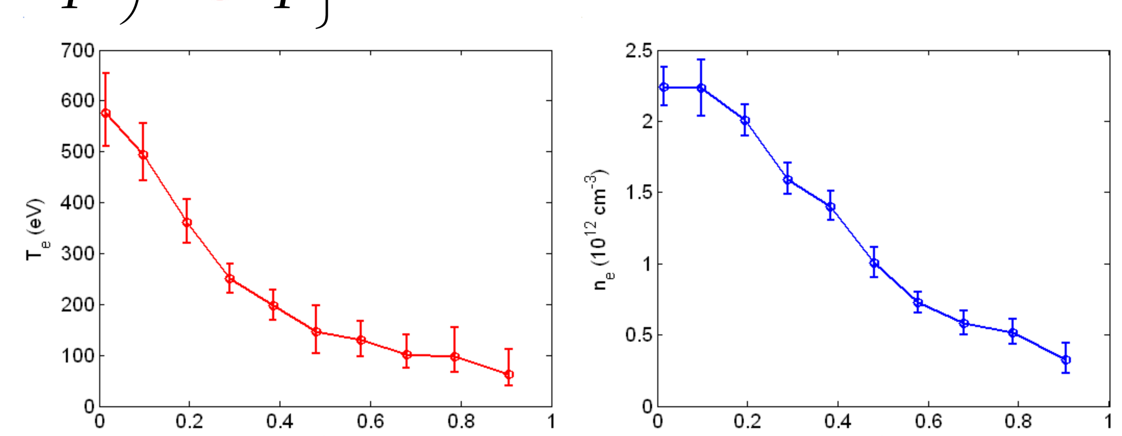


Quasisymmetric Configuration has Peaked Density Profile with Central Heating

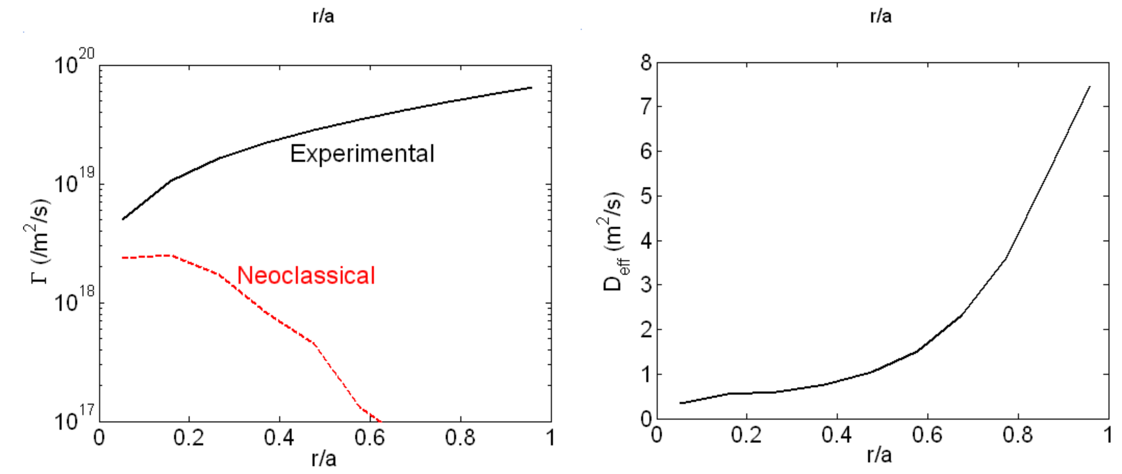
$$\Gamma = -n\left\{D_{11}\left(\frac{n'}{n} - \frac{qE_r}{T}\right) + D_{12}\frac{T'}{T}\right\}$$

D_{12} is smaller due to quasisymmetry

- Both the temperature and density profiles are centrally peaked in QHS
  - ⇒ **Thermodiffusive flux not large enough to cause hollow profile**

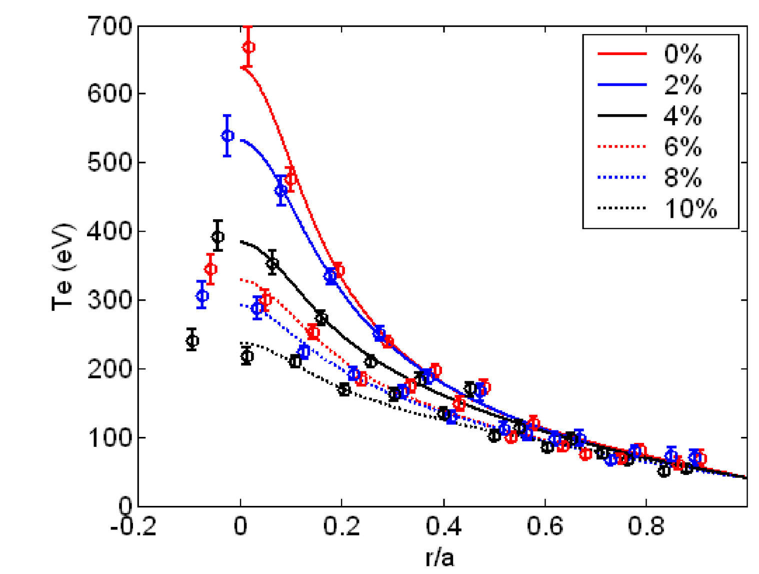


- Neoclassical particle flux in QHS much less than experiment
- Assuming diffusive anomalous transport, effective diffusion coefficient can be estimated:
  $D_{eff} = -\Gamma/\nabla n$
- D_{eff} ~ 0.5 m²/s in core, increases towards edge



…and Higher Electron Temperature

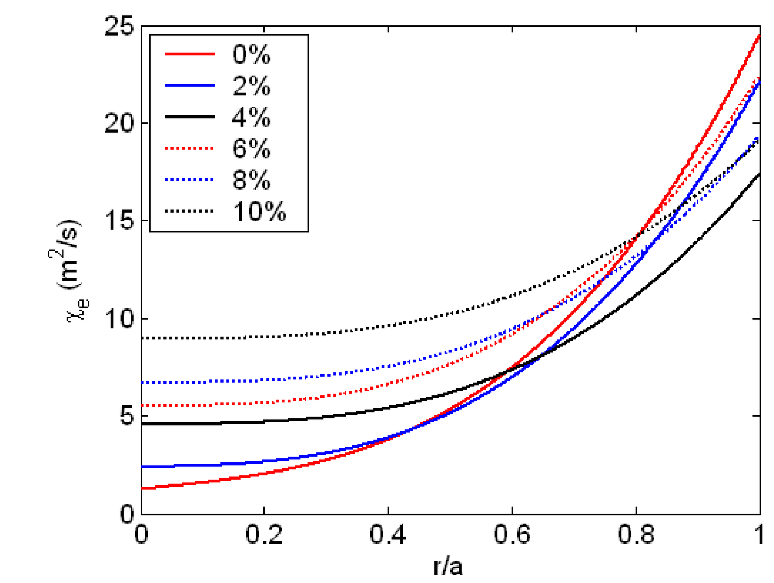
- Temperature profiles have been measured as the toroidal mirror term is increased in the Phase Shifted Mirror configuration (0% is QHS)
- The core temperature drops from almost 700 eV in QHS to less than 300 eV as the symmetry is broken
- All temperatures shown are at a line-averaged density of 1.5×10^{12} cm^{-3}



Transport Analysis indicates Reduced Thermal Diffusivity in QHS

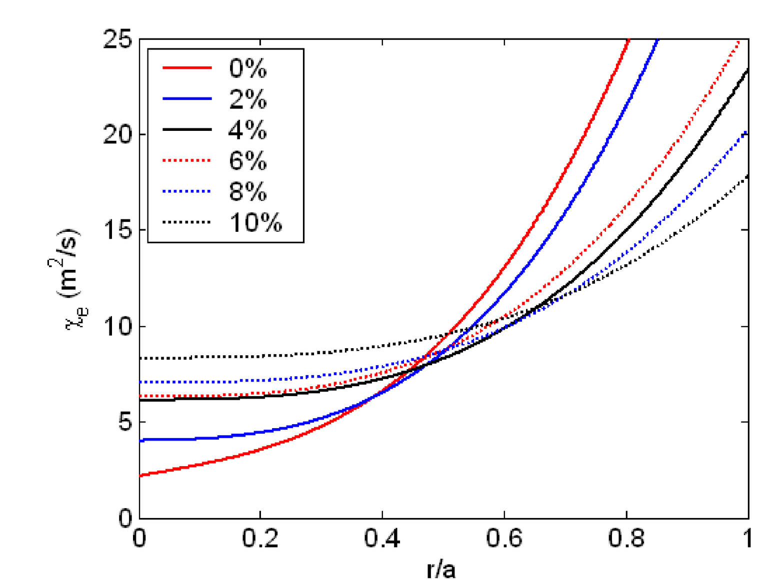
- Ray tracing indicates that the power is localized inside r/a = 0.2 for all configurations shown
  - Absorbed power profile shape is assumed to be parabolic and localized within this radius
  - Total absorbed power is assumed to be ~10 kW in all configurations
- Density, temperature and absorbed power profiles yield electron thermal diffusivity:

$$q_e = \frac{1}{r}\int_0^r r' p_{abs}(r')dr' = -n\chi_e \nabla T_e$$



Diamagnetic Measurements Show Higher Absorbed Power in QHS

- The diamagnetic loop measures ~15 kW in QHS, vs. 10 kW with a symmetry breaking level of 10%
- Including this in the transport analysis has two effects:
  - The core transport remains lower in QHS, although not to the same degree
  - The edge transport becomes higher in QHS
- This measurement may include the power absorbed by superthermal electrons in QHS, which may not be relevant to the power balance of the bulk plasma
  - Needs further investigation



Phase Shifted Mirror Plasmas also have Broader Density Profiles than QHS

- When toroidal mirror term is added the QHS field, the core density decreases, and the edge density increases
- Similar to Standard Mirror case, but with Thomson scattering measurements on-axis (one point on other side of axis)
- Clear difference in the core density profile
  - Particle transport analysis pending