Transport Studies in HSX at 1 Tesla

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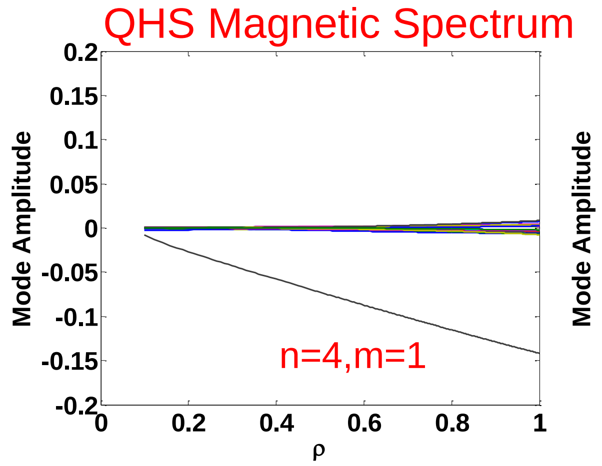
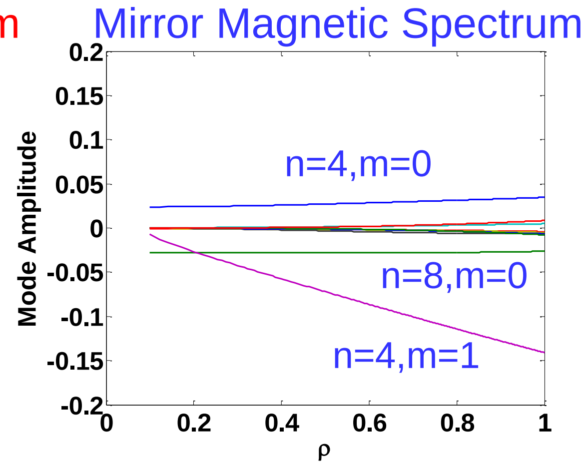
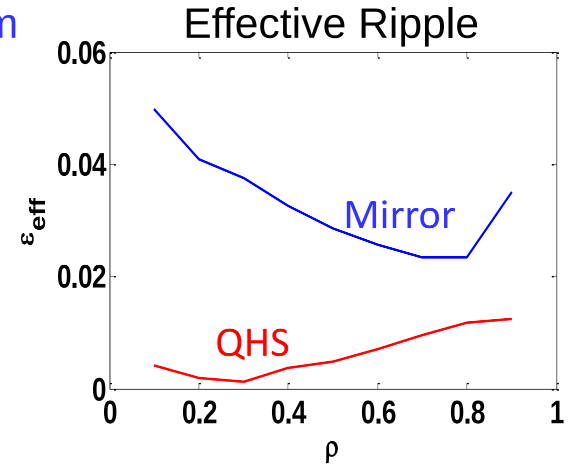
Overview

- **Thomson scattering profiles for several injected powers demonstrate that the core electron temperatures are 2-2.5x greater and that the density profiles are more peaked for the QHS as compared to Mirror for the same injected power.**
- **To match the QHS and Mirror profiles globally 2.3x the injected power (1.8x the absorbed power) is required for Mirror.**
- **The effective electron thermal diffusivity is 3-4x lower in the core for QHS when the profiles are matched.**
- **For a given temperature gradient the particle and heat fluxes in the core are lower for QHS.**
- **Several additional effects need to be taken into account to make comparisons between neoclassical and experimental values.**

The HSX Stellarator


QHS Magnetic Spectrum


Mirror Magnetic Spectrum


Effective Ripple

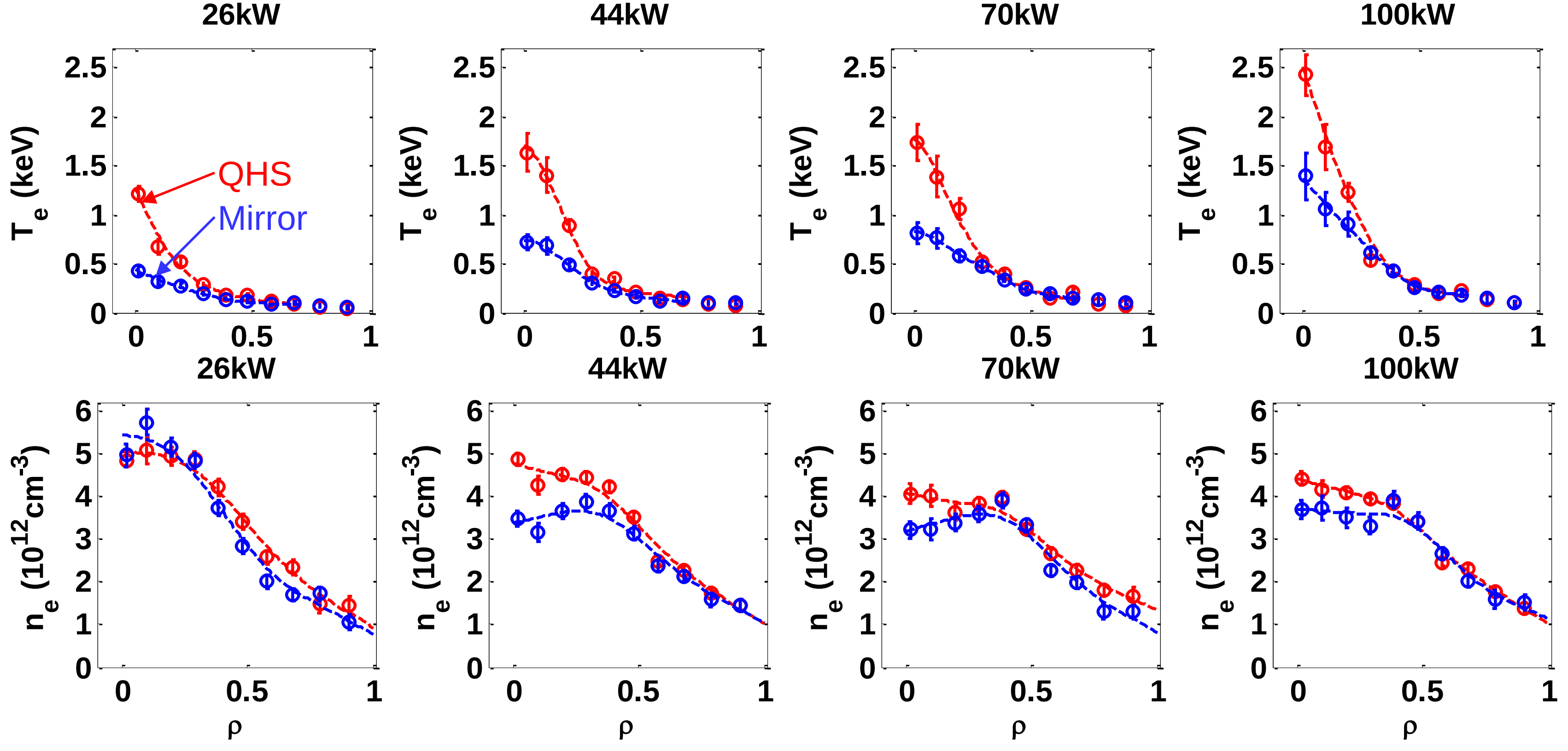
Parameters

<R>	1.2 m
<a>	0.12 m
ι	1.05 →1.12
B_0	0.5 -1.0 T
ECRH 28 GHz	100 kW

1. Profiles from Thomson Scattering

Power Scan Comparison

- For each injected power the core electron temperatures are 2-2.5x greater in QHS.
- Density profiles in QHS are more peaked than Mirror.
- The differences are greatest in the core, where neoclassical transport is important.
- The differences in these profiles indicate that the transport properties change between the two configurations.

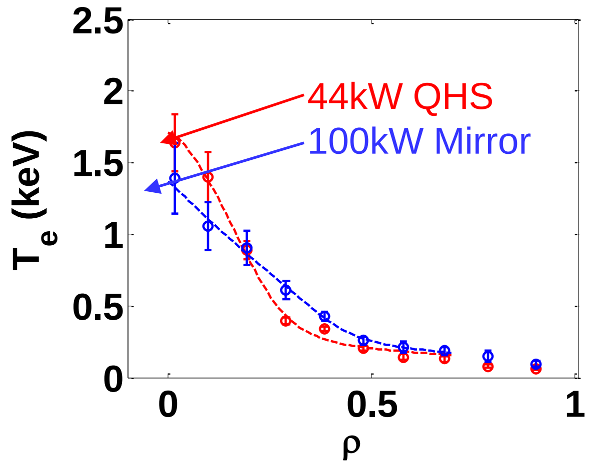


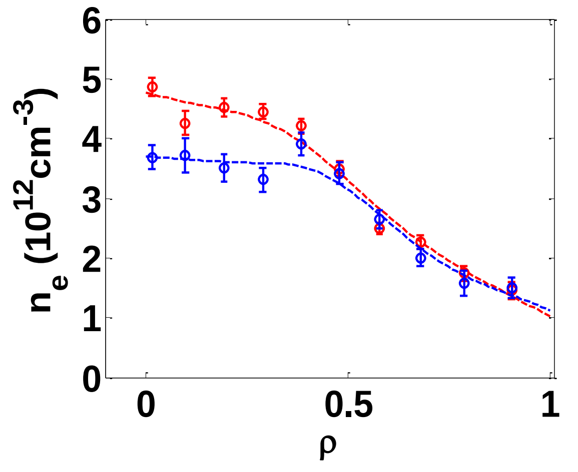
Matching Profiles

- Due to the difference in the temperature gradients, the profiles cannot be exactly matched between the configurations.

$$\sum_n \left(T_n^{QHS} - T_n^{Mirror}\right) = 2eV$$

- To minimize the difference between the profiles globally, 2.3x the injected power (1.8x the absorbed power) is needed for Mirror.





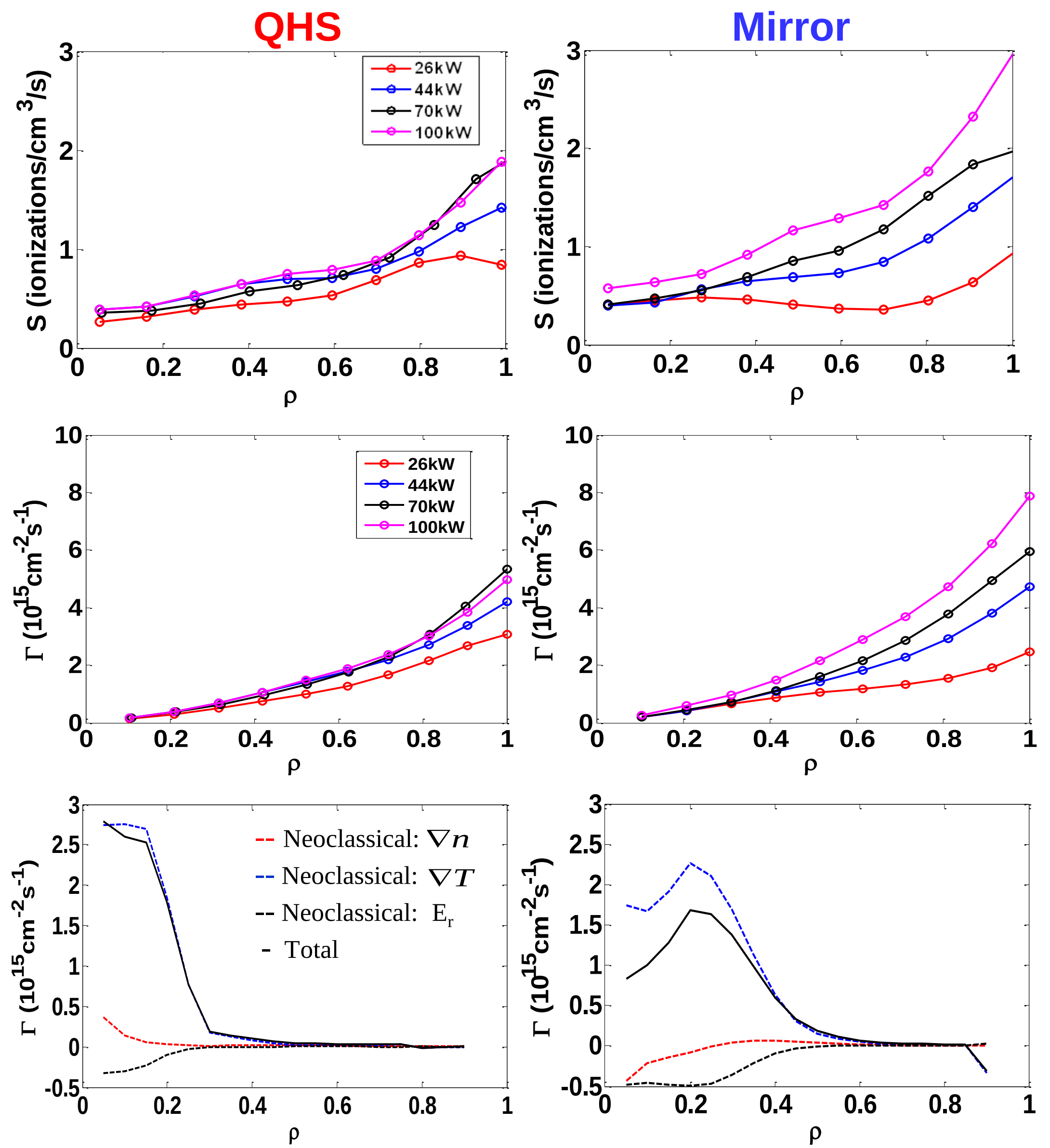
2. Particle Transport

Experimental Calculations

- The 3D neutral transport code DEGAS has been used to calculate neutral quantities including the particle source rate and H_α emission.
- The results are then coupled to measurements from a suite of absolutely calibrated H_α detectors to yield the source rate in absolute units.
- Due to the plasma densities (n_e $<6\cdot10^{12}$ cm^{-3}) , the source rate remains significant into the core.
- Both the particle source rate and the particle flux scale with injected power in each configuration.

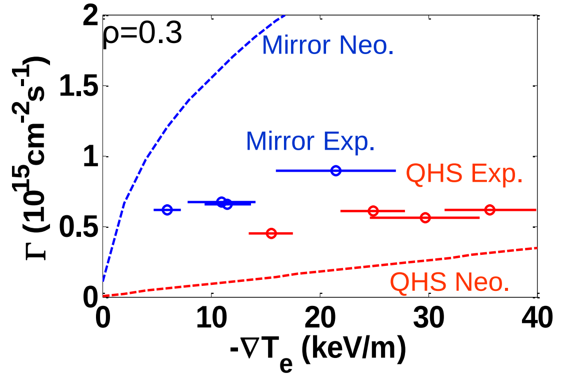
Neoclassical Calculations

- In each configuration the neoclassical particle flux in the core is dominated by thermodiffusion.



Core Particle Flux Scaling

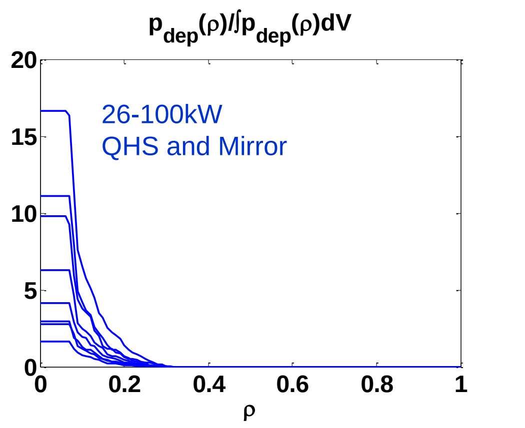
- For a given temperature gradient the particle flux is larger in Mirror. This would result in a more hollow density profile.



3. Electron Thermal Transport

Heat Flux Calculation

- A ray-tracing code is used to calculate the power deposition profiles based on the local plasma density and temperature from the Thomson scattering profiles.
- The normalized power deposition profiles have the same width for each configuration for the Thomson profiles of interest.
- The power deposition profiles are volume integrated and scaled to the absorbed power measured from the diamagnetic loop.
- The scaled power deposition profile is integrated to find the heat flux.

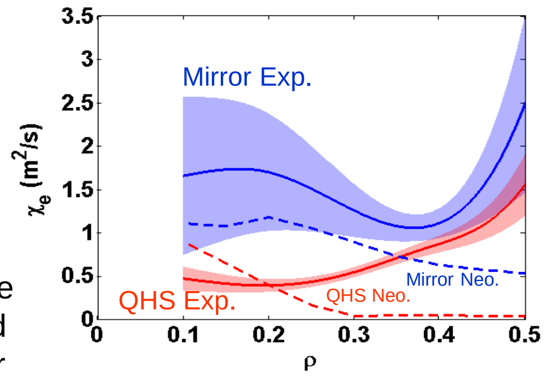


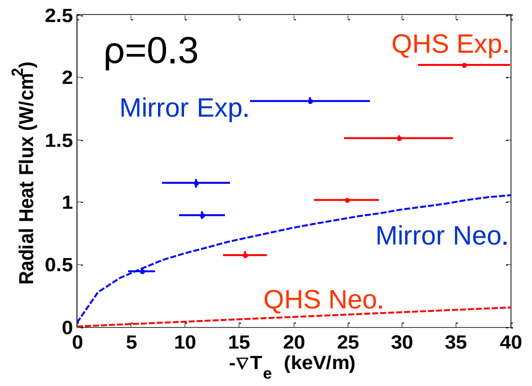
Effective Electron Thermal Diffusivity

- For the matched profile case χ_{eff} is lower in the core for the QHS configuration.

Core Heat Flux Scaling

- For a given heat flux the temperature gradient is larger in QHS. This would result in a larger core temperature for similar edge conditions.





4. Neoclassical Calculations

Future Improvements

- For several cases the neoclassical calculations result in values larger than the experimental values.
- Several additional effects can be taken into account to reduce this discrepancy.

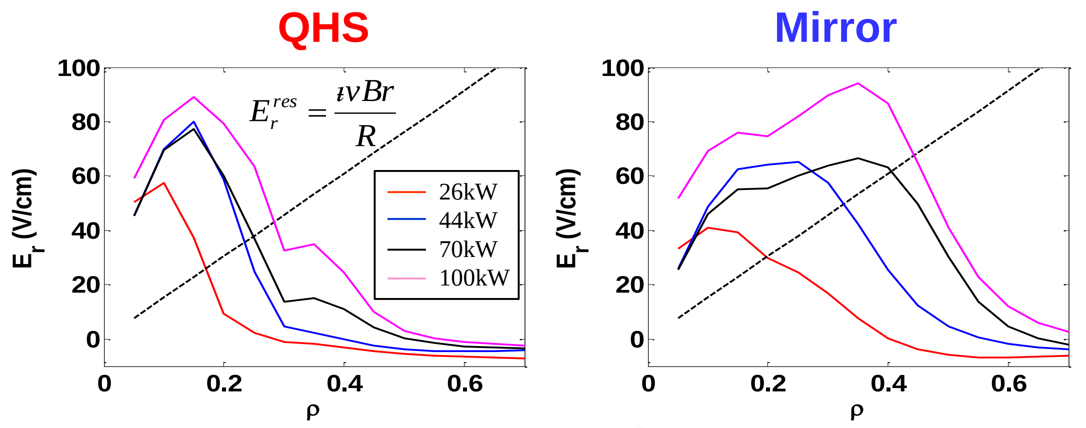
1) **Proper accounting of flows and momentum conservation using PENTA (Spong, 2005).**

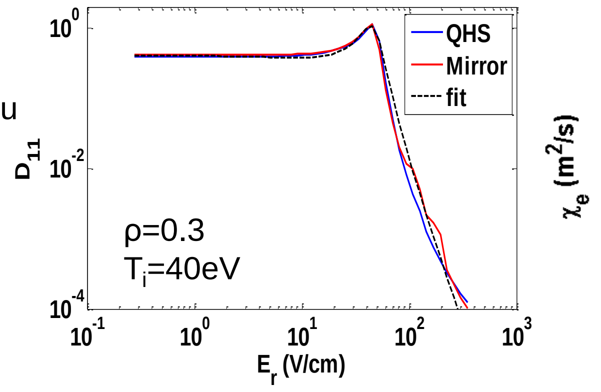
2) **The effect of the poloidal resonance on ions in the plateau regime (Maassberg *et al.*, 1993).**

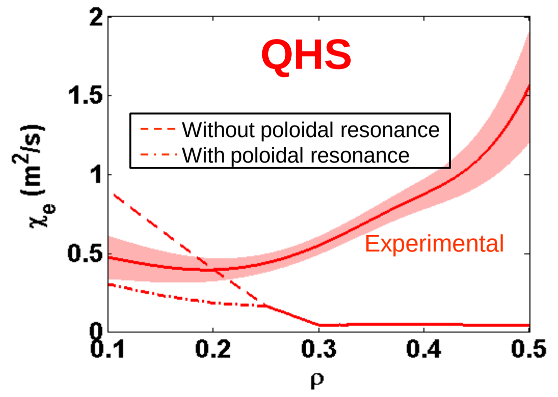
- When the radial electric field is much larger than the resonant electric field value the ion flux is greatly reduced.
- This effect has been calculated to be important in the plasma core for both configurations.
- Ions in the core are in the plateau regime in HSX for both configurations.

$$\upsilon^* = \frac{\upsilon R}{\iota v_p \varepsilon^{3/2}} \approx 5-10$$

- A simple filter form has been fit to DKES results and applied to the plateau component of the monoenergetic diffusion coefficient.
- This effect has a large effect on the calculated neoclassical transport (right plot).

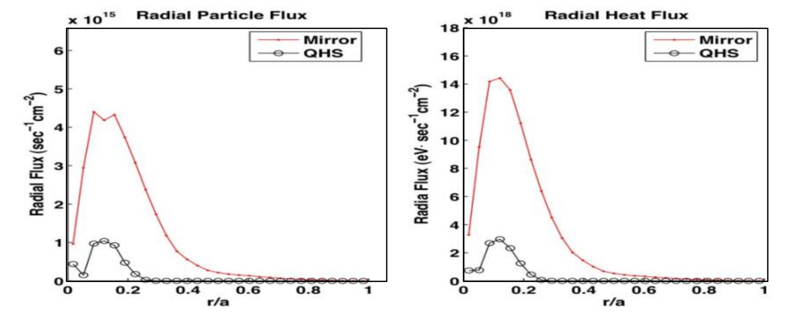






3) **The ECRH driven flux can be calculated using the 5-D Fokker-Planck code GNET (Murakami, 2000).**

- Results at B=0.5 Tesla (2nd Harmonic X-mode heating) indicate that this is an important effect in the core.
- The effect is predicted to be smaller at B=1.0 T (fundamental harmonic O-mode heating), but may still be significant.



4) **Drift kinetics may not be valid near the core.**

5. Confinement Scalings

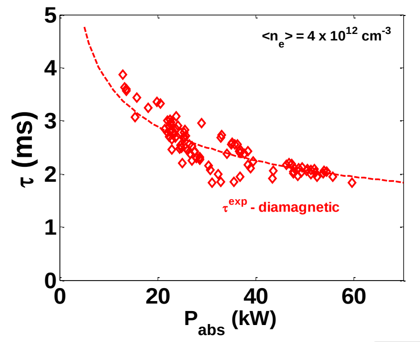
Confinement time scaling for QHS

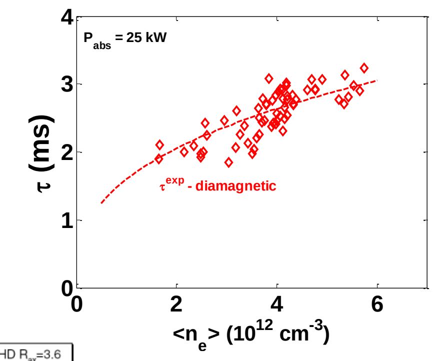
$$\tau^{exp} \sim n^{0.36\pm0.04} P^{-0.36\pm0.03}$$

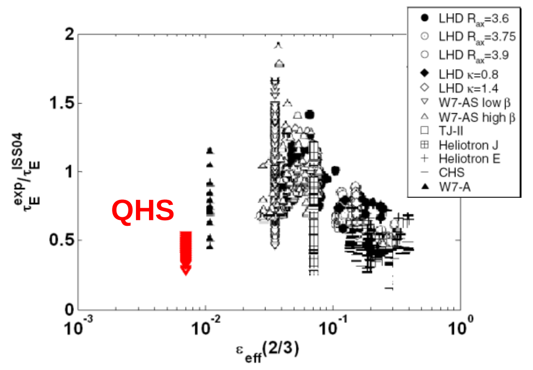
N=244

RMSE=10.5%

- The scaling is weaker than ISS95/04
- Enhancement factor: $\frac{\tau_{QHS}}{\tau_{ISS04}} = 0.42$







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