0.5 T and 1.0 T ECH Plasmas in HSX

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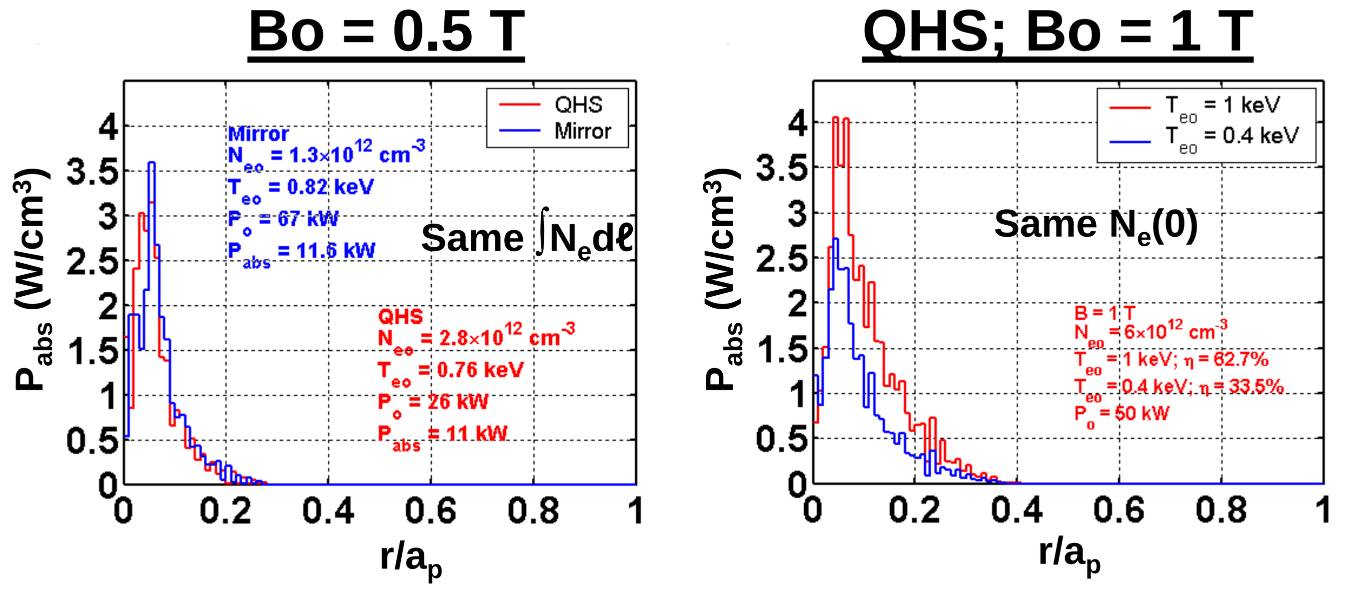
Overview

- A new microwave transmission line is in operation now (see the HSX poster by J.Radder)
- HSX operates at 0.5 and/or 1 T with X- / O-wave heating at the second and fundamental resonance, respectively
- 3-D ray tracing and CQL3D Fokker-Planck codes are used to simulate the electron cyclotron heating (ECH) in HSX
- Heating power and plasma density scans are performed in the quasi-symmetric configuration (QHS) and configuration with broken symmetry (Mirror)
- QHS and Mirror configurations have almost identical magnetic properties except the mod B effective ripple
- Dependence of HSX energy confinement time on plasma parameters and comparison with international database are presented

Numerical Simulations

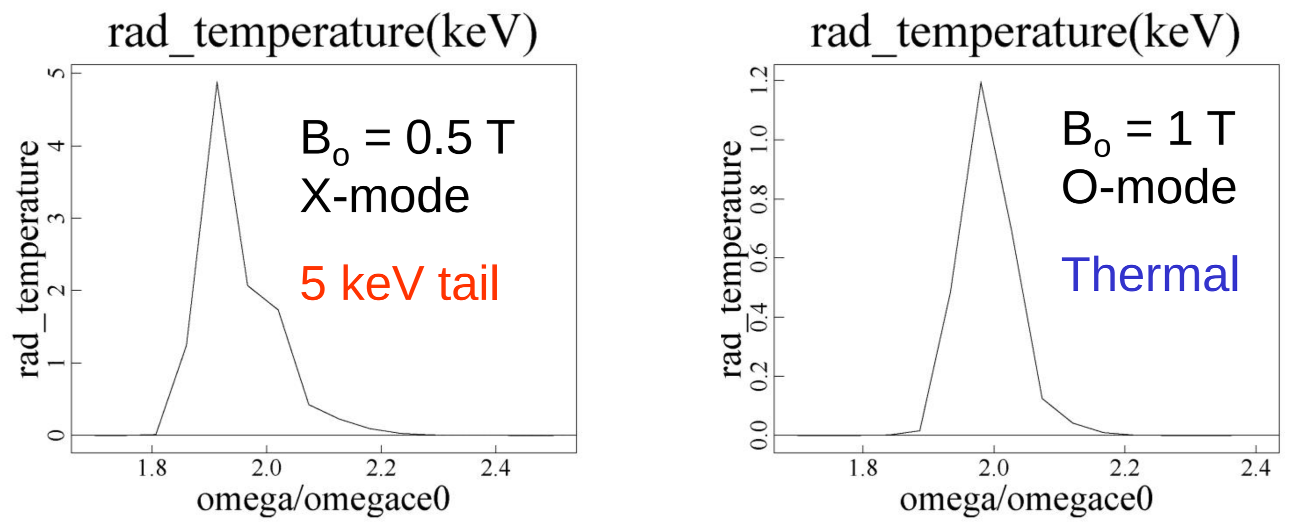
Absorbed Power from 3-D Ray Tracing Code



•In ray tracing runs at 0.5 T we use the profiles measured by Thomson scattering diagnostics while at 1 T, a parabolic plasma density, and exponential electron temperature profile is used

•The width of absorbed power profile is very narrow (< $0.2 \cdot r/a_p$). At 1 T the O-mode profile is slightly broader than X-mode profile at 0.5 T

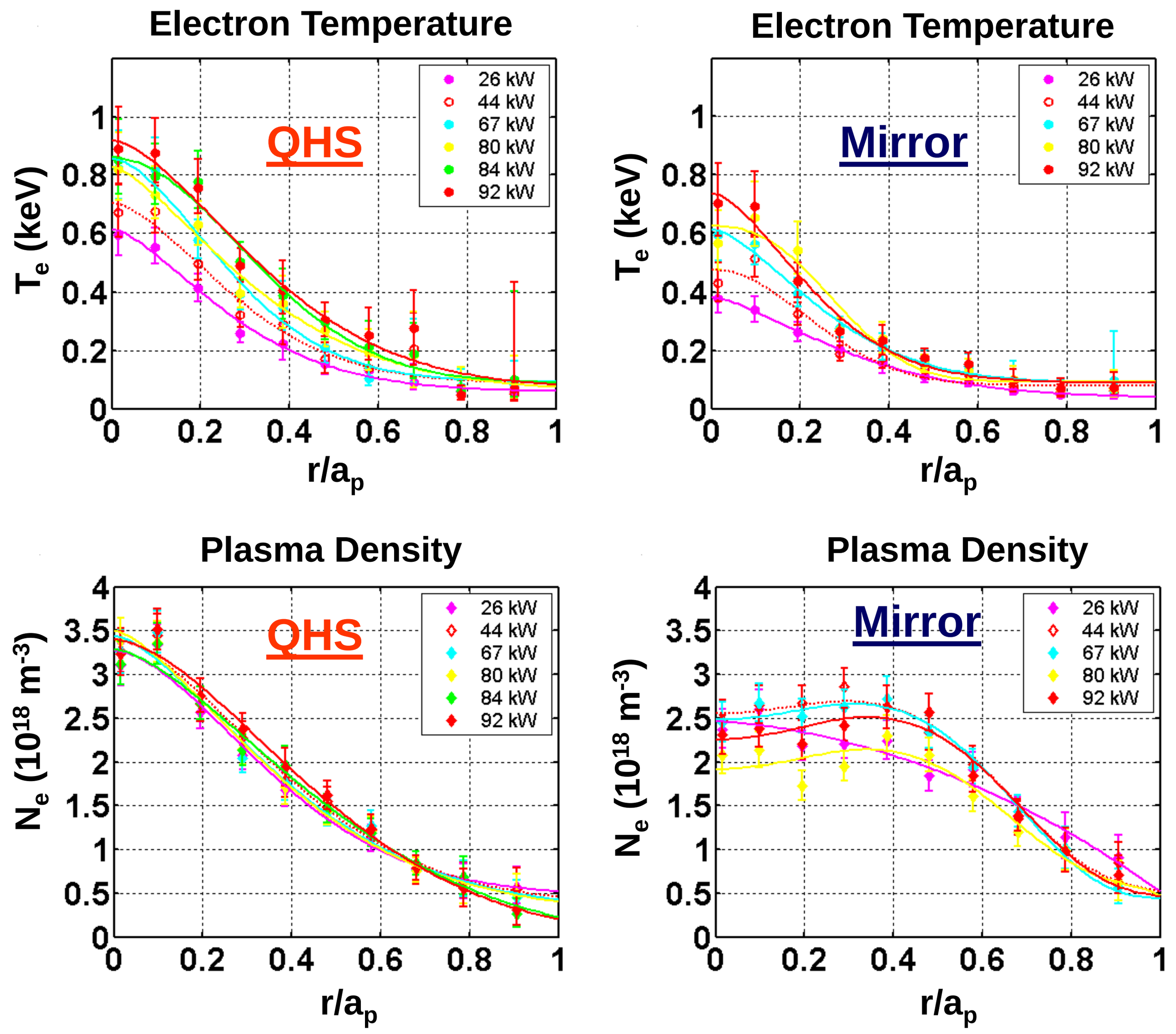
ECE from CQL3D Fokker-Planck Code



• CQL3D code predicts 5 keV tail in ECE at 0.5 T while the plasma stays Maxwellian with O-mode at 1 T (in both cases the central electron temperature is 1 keV)

Heating Power Scan at 0.5 T

Peaked Density in QHS and Hollow Profile in Mirror



•Power scan is presented at the same line average density ($\langle N_e \rangle = 2 \cdot 10^{18}$ m^{-3}) in both configurations

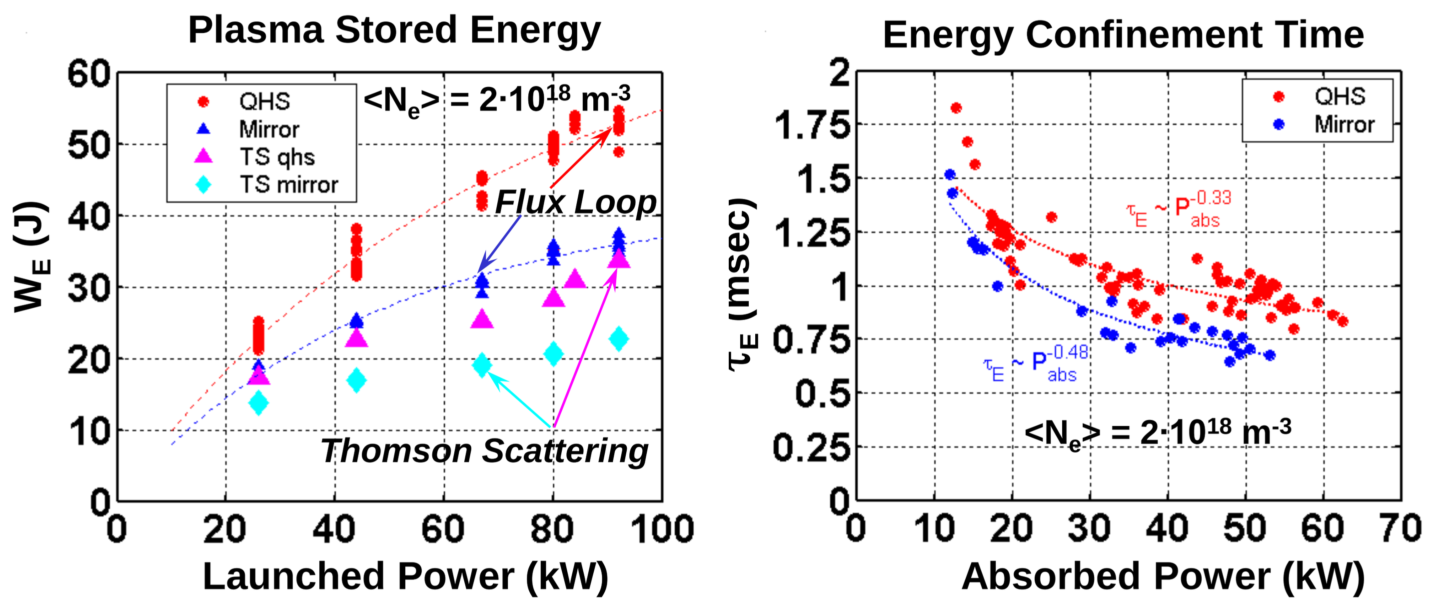
•The central temperature is higher in QHS than in Mirror

•The density profile is peaked (1) *always in QHS* and (2) *in Mirror only at a low power level* while it becomes hollow in Mirror at higher power

•Particle flux in Mirror plasma core is close to neoclassical and the steep temperature gradient makes the density profile hollow while neoclassical diffusion in QHS stays low

(Invited talk by John Canik, this Friday at 11 a.m.)

Stored energy is higher in QHS than in Mirror

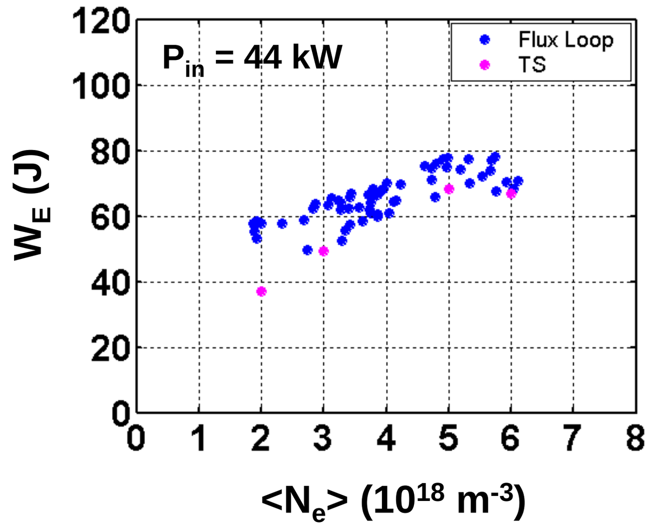


•At 0.5 T the energy confinement time varies more strongly with absorbed power in Mirror than in QHS

•A large difference between the flux loop and Thomson scattering data on stored energy indicates a presence of supra-thermal tail which is predicted by the CQL3D calculations and measured by ECE and SXR diagnostics as well

1.0 T Operation in QHS

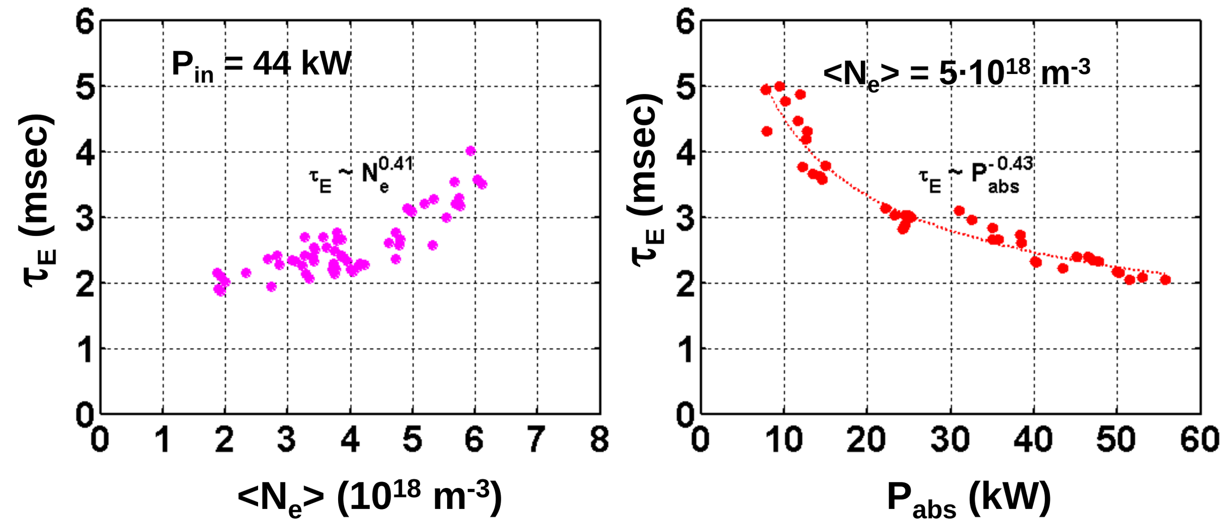
Stored Energy in Plasma Density Scan



•For a plasma density scan the central electron temperature does not vary much ($T_e(0) \sim 1.4$ keV) within $(2\text{-}5) \cdot 10^{18}$ m^{-3} and drops at a high density when strong high density wave refraction takes place

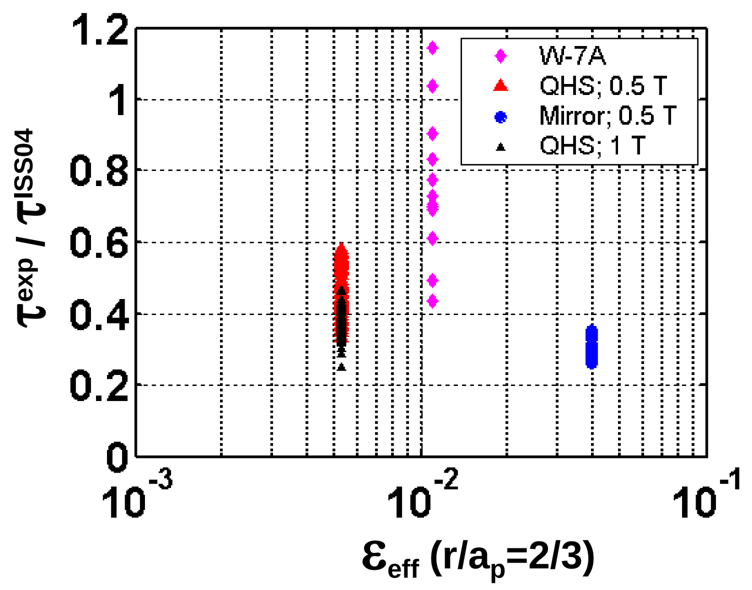
•Diamagnetic loop and TS data are in good agreement indicating a thermal plasma

Energy Confinement Time



International Stellarator Scaling Law

$$\tau_{ISS04} = 0.134 \cdot a^{2.28} \cdot R^{0.64} \cdot P_{abs}^{-0.61} \cdot n_e^{0.54} \cdot B^{0.84} \cdot \iota^{0.41}$$

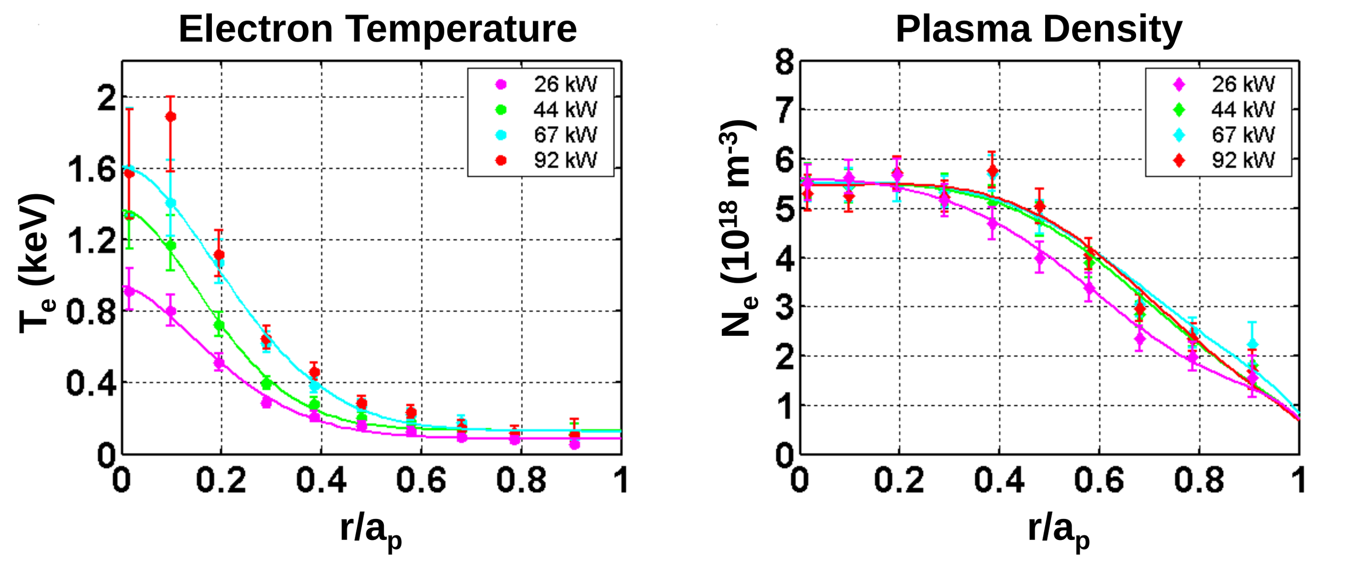


•Ratio between the experimental energy confinement time and ISS04 is shown in the left panel versus the effective ripple

•Data at 0.5 T show that the confinement in QHS is better than in the Mirror configuration

•At 1 T the dependence of τ_E on plasma density and absorbed power is slightly weaker than the ISS2004 scaling law predicts

Heating Power Scan



•Kinetic stored energy is close to that measured by the diamagnetic loop at all power levels to date

•At 92 kW of launched power the stored energy is about 110 J and the central electron temperature appears to be higher than 2 keV (TS limit at the moment)

•Plasma density is peaked and quite independent of absorbed power

•Plasma density profile is broader than that at 0.5 T

Summary

- 3-D ray tracing code predicts a narrow absorbed power profile in HSX plasmas
- CQL3D Fokker-Planck code predicts a distribution function close to Maxwellian at 1 T while at 0.5 T ECH produces a high energy electron tail
- At 0.5 T the diamagnetic loop measures higher stored energy than the integrated Thomson scattering profiles whereas at 1 T they agree
- The HSX scaling is roughly in agreement with ISS04
- With the same injected power the plasma stored energy and the central electron temperature are higher in QHS than in Mirror configuration

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