Section ??? Ohmic heating power, the central electron temperature, and the global electron energy confinement time - DRAFT

Daniela Kropackova

To compare all shots during the experimental campaigns, all quantities are calculated at the time when the plasma current reaches its maximum are selected.

Ohmic heating power:

The Ohmic heating power is calculated as: $P_{OH} = U_{loop} \cdot I_p,$ where U_{loop} is loop voltage and I_p is plasma current at the maximum of the plasma current

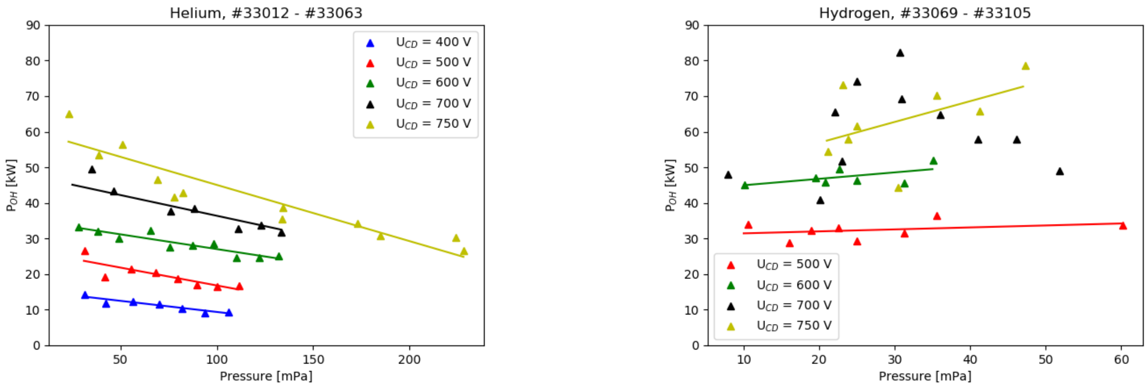

Figure 1: Ohmic heating power versus working gas pressure for helium discharges (left) and hydrogen discharges (right).

As it can be observed in **Error! Reference source not found.**, for helium discharges, the ohmic heating power increases linearly with higher current drive voltage U_{CD} and lower working gas pressure. For hydrogen discharges with low U_{CD} remains P_{OH} constant for all pressure values. For hydrogen discharges with higher U_{CD} is dependence rather irregular.

Central electron temperature:

The central electron temperature was estimated from the Spitzer formula as $T_e(0) = Z_{eff}\left(\frac{I_p}{a^2 U_{loop}}\right)^{2/3}$ where the effective ion charge Z_{eff} is estimated as $Z_{eff} = 4.1$ for helium or $Z_{eff} = 3$ for hydrogen. The actual plasma radius a is determined from magnetic diagnostics.

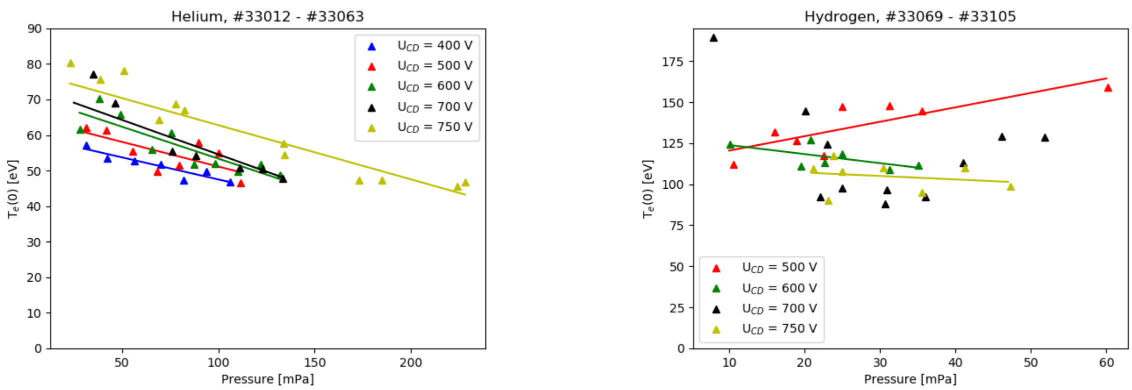

Figure 2: Central electron temperature versus pressure of the working gas for helium discharges (left) and hydrogen discharges (right).

Figure 2 demonstrates that the central electron temperature in hydrogen plasmas is significantly higher than that in helium. Furthermore, in helium plasmas a clear dependency of $T_e(0)$ on the current drive voltage U_{CD} and the pressure is observed.

Electron energy confinement time:

The global electron energy confinement time τ_e is defined as

$$\tau_e = \frac{W_e}{P_{OH}} \quad ,$$

Where $W_e = \int_V T_e n_e dV$ is the total kinetic energy of the electron component stored in the plasma column of the volume V. Determination of W_e requires knowledge of radial profiles of T_e and n_e, which are not measured at GOLEM To describe scaling of τ_e on measurable quantities, in particular on the pressure of the working gas p, we approximate W_e as ~Te(0)pV, where p ~ n_e, and the volume V ~a^2. Therefore, the electron energy confinement τ_e scales with the pressure *p* as:

$$\tau_e \sim \frac{T_e(0) \cdot p \cdot a^2}{U_{loop} \cdot I_p}$$

Scaling for helium and hydrogen discharges with the pressure is shown in Figure 3.

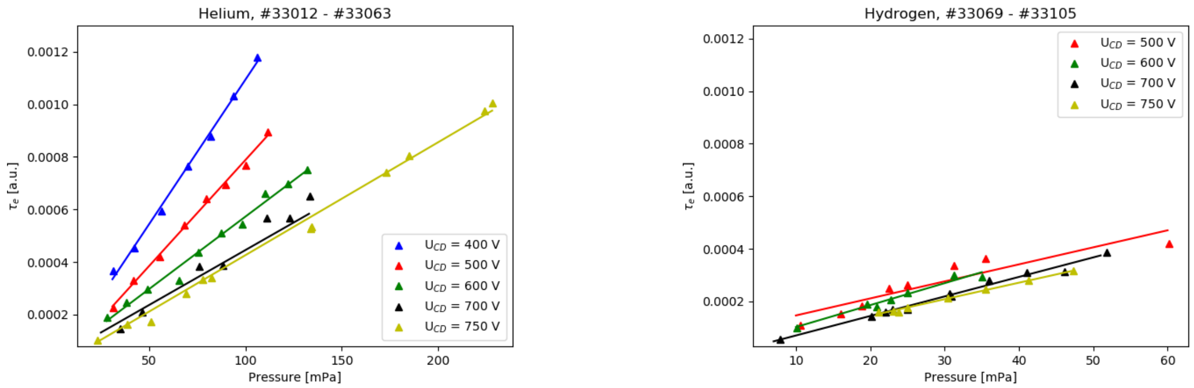

Figure 3: Global electron energy confinement for helium discharges (left) and hydrogen discharges (right).

We observe an linear increase of τ_e with the pressure (density) in both cases. A clear dependency of τ_e on the U_{CD} is evident for Helium shots τ_e ~$1/U_{CD}$. , which implies a dependency on the plasma current, see fig. ???.

It is interesting to compare our data with existing scaling of the global energy confinement time [1], where results from a number of experimental devices were compiled, and an overall scaling law for ohmically heated tokamaks was deduced:

$$\tau_E \sim n_e a^2 q^{1/2}$$

Alternatively Neo – Alcator scaling [??]:

$$\tau_E = 7 \cdot 10^{-22} a R^2 q_a n_e \qquad [\text{s, m, m, -, m}^{-3}]$$

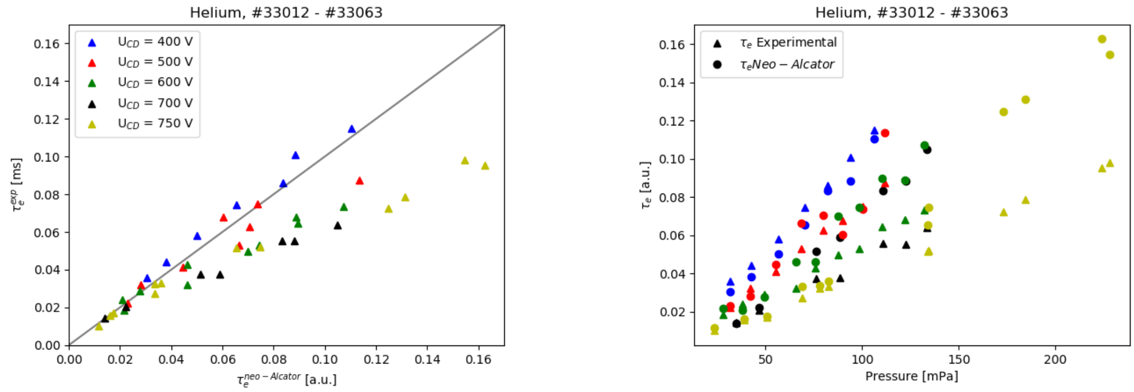

Figure 4: Experimental electron energy confinement time dependence on Neo –Alcator scaling (left) and comparison experimental and Neo-Alcator τ_e dependence on pressure of working gas (right)

Which shows that the global energy confinement time is proportional to plasma density (n ~ pressure of the working gas), and inversely proportional to the plasma current (or its the square root). Our results indicate that this scalings would correspond to our results in Helium plasmas.

On the other hand, slightly modified scaling was proposed (Neo-Alcator scaling) [??]

$$\tau_E = 1.92 \cdot 10^{-21} R^{2.04} a^{1.04} n_e \quad [\text{s; m, m, m}^{-3}]$$

Which again shows proportionality of t_E with the plasma density, but dependency on the safety factor (or plasma current) is missing. This scaling seems to correspond to our results in Hydrogen plasmas.

Comparison of the global energy confinement in H and He plasmas was studied experimentally on FT-2 tokamak [2].

Figure 4 shows that Neo-Alcator scaling prediction can be used only by helium discharges with low current drive voltage. Therefore the GOLEM scaling of electron energy confinement time obtained in the past was used and modified.

Scaling law of electron energy confinement time on GOLEM was found as [3]:

$$\tau_E = 3 \cdot 10^{-22} \cdot I_p^{0.95} \cdot B_t^{0.31} \cdot P_{OH}^{-1.33} \cdot n_e^{1.04} \qquad [\text{s; A, T, W, m}^{-3}],$$

where electron density of helium was estimated using the Loschmidt number as:

$$n_e = 2.69 \cdot 10^{20} \cdot p \qquad [\text{m}^{-3}\text{; Pa}]$$

To obtain electron density of hydrogen the equation was multiply by a factor of 2 because of

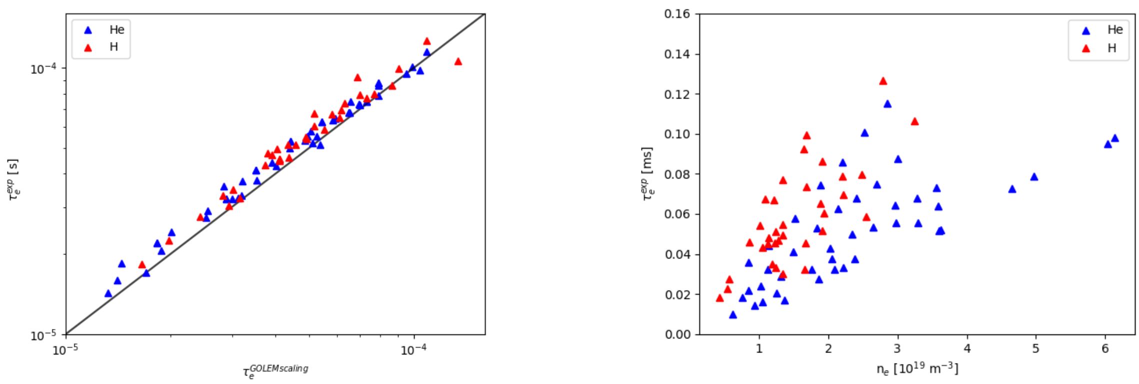

Figure 5: Electron energy confinement time dependence on GOLEM scaling prediction (left) and electron energy confinement time dependence on density (right).

dissociation of H2 molecules.

[1] Robert J. Goldston, ENERGY CONFINEMENT SCALING IN TOKAMAKS: SOME IMPLICATIONS OF RECENT EXPERIMENTS WITH OHMIC AND STRONG AUXILIARY HEATING, PPLR 1984 https://www.osti.gov/servlets/purl/5208115

[2] D. Kouprienko , et al, Energy confinement time study at the FT-2 tokamak., 44th EPS Conference on Plasma Physics P4.179

[3]J Hillaret, http://golem.fjfi.cvut.cz/wiki/Experiments/TokamakRegimes/NeoAlcaltorScaling/0119_JullHil/JHcode/GOLEM_Tau_scaling_law.png.