Electron energy distribution function in the divertor region of the COMPASS tokamak

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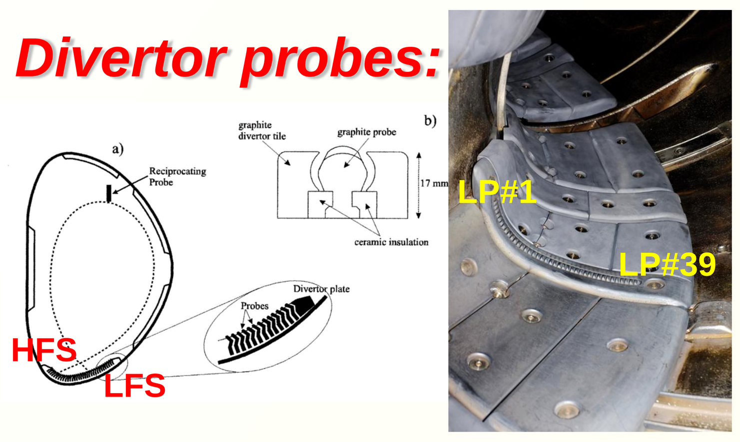
Abstract: The plasma parameters during an L-mode hydrogen discharge in the COMPASS tokamak with a toroidal magnetic field B_T =1.15 T and a line-averaged electron density $n_e = 6\times10^{19}$ m^{-3} and with a plasma current variation from 209 kA to 100 kA were studied in the divertor region. It is shown that as the plasma current decreases, the position of the outer strike point changes within a few millimeters. In contrast, the position of the inner strike point is shifted towards the high-field side by about 5 cm. The electron energy distribution function (EEDF) for 209 kA at the high-field side and the private region is Maxwellian with a temperature in the range of 5 - 9 eV, while around the outer strike point and the low-field side it is bi-Maxwellian with a low-energy electron group (4 - 5 eV) and higher energy electrons (10 - 20 eV). As the plasma current decreases, the appearance of the bi-Maxwellian EEDF is shifted towards the low-field side; at a plasma current of 100 kA the EEDF is Maxwellian in the whole divertor region.

COMPASS – Compact Assembly

Major radius	560 mm
Minor radius R	200 mm
Toroidal magnetic field	2.1 T
Plasma current	350 kA
Pulse length	~1s

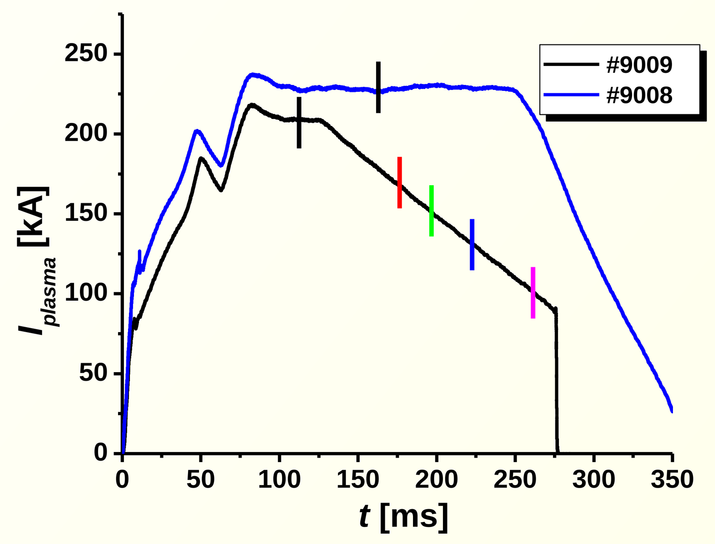
Divertor probes:



a) Poloidal cross-section of COMPASS with the position of the divertor probe system;
b) Toroidal cross-section through the divertor target showing a Langmuir probe.

Discharges information:

- magnetic field B_T = 1.15 T;
- plasma current I_p = 209 kA ÷ 100 kA
- average electron density $n_e = 6\times10^{19}$ m^{-3}



Temporal profiles of the plasma current

First derivative probe technique (FDPT):

Electron probe current for a cylindrical probe of the radius R and length L at negative probe potentials is given by:

$$I_e(U) = -\frac{8\pi e S}{3m^2}\int_{eU}^{\infty}\frac{(W-eU)\,f(W)\,dW}{\gamma\left[1+\frac{(W-eU)}{W}\psi(W)\right]} \qquad (1)$$

where W is the total electron energy, $\Psi(W)$ is a diffusion parameter, e, m and n are the electron charge, mass and density, S is the probe area, U is the probe potential with respect to the plasma potential U_{pl}. The geometric factor γ assumes values in the range $0.71 \le \gamma \le 4/3$. The isotropic EEDF is normalized by:

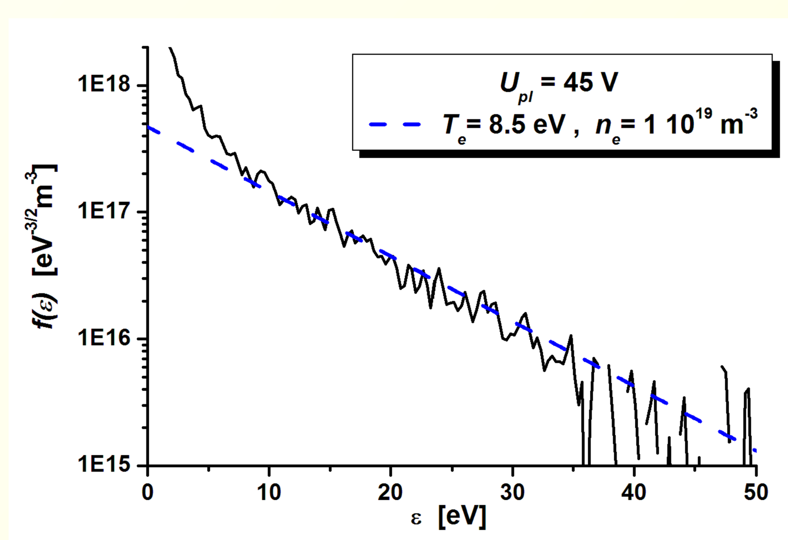
$$\frac{4\pi\sqrt{2}}{m^{3/2}}\int_0^{\infty} f(W)\sqrt{W}\,dW = \int_0^{\infty} f(\varepsilon)\sqrt{\varepsilon}\,d\varepsilon = n \qquad (2)$$

At (ψ >> 1), the EEDF, is represented not by the second derivative of the electron probe current (Druyvesteyn formula), but rather by its first derivative. For the divertor probes, which are parallel with respect to the magnetic field:

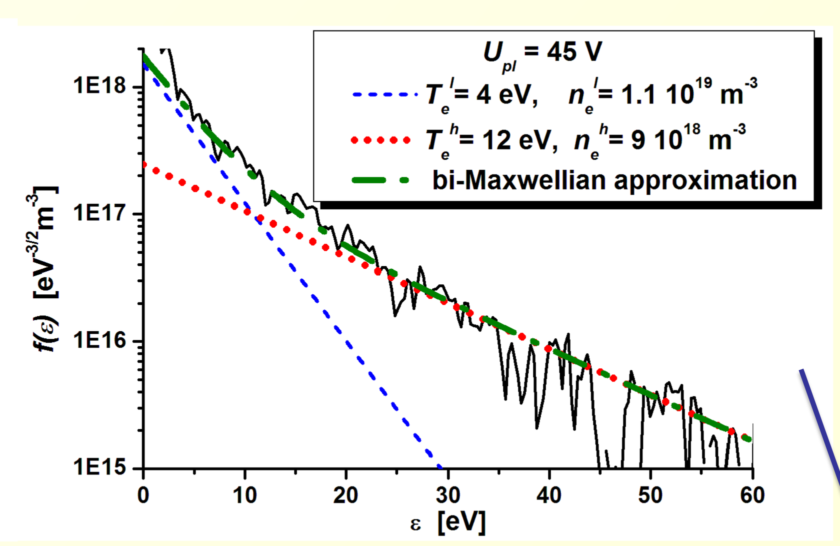
$$\psi(W) = \frac{\pi L'}{64\gamma R_L(W,B)} \quad \Rightarrow \quad f(\varepsilon) = -\frac{3\pi\sqrt{2m}\,L'}{128 e^3 S R_L(\varepsilon,B) U}\frac{dI}{dU} \qquad (3)$$

Here L' and $R_L(W,B)$ are the characteristic length of the turbulences and the electron Larmor radius.

Shot #9009, hydrogen



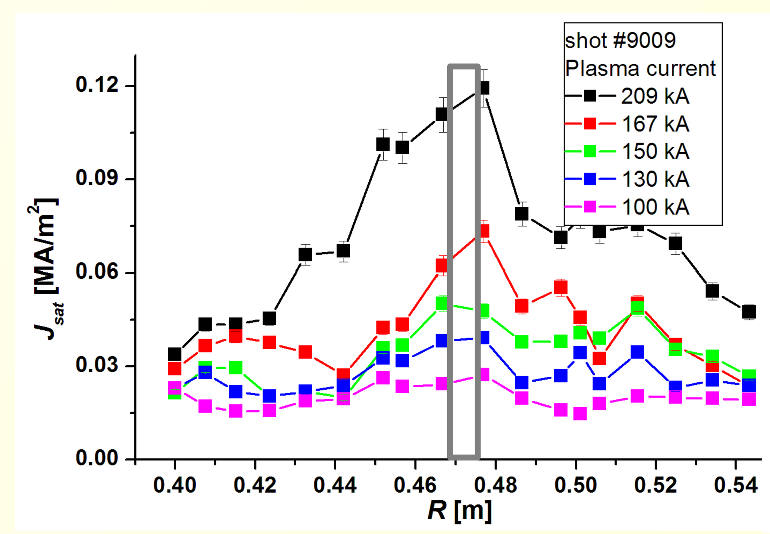
Experimental EEDF (black line) and the Maxwell model line (dashed) for **LP#12**, R = 0.4421 m.



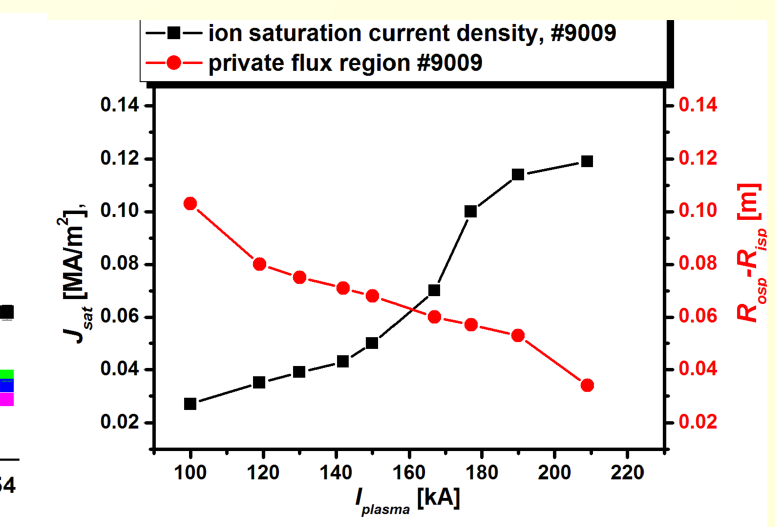
Experimental EEDF (black line) and the sum of the model ones for two electron temperatures (dashed dotted line) for **LP#15**, R = 0.4569 m.

Poloidal distribution of the plasma parameters:

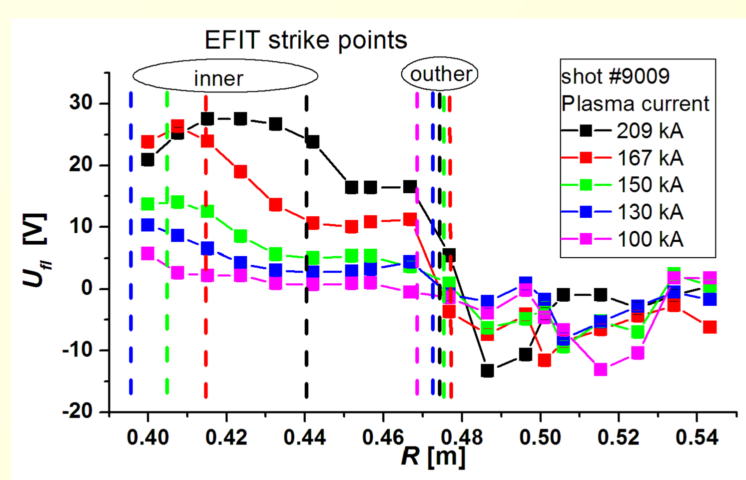
Shot #9009, hydrogen



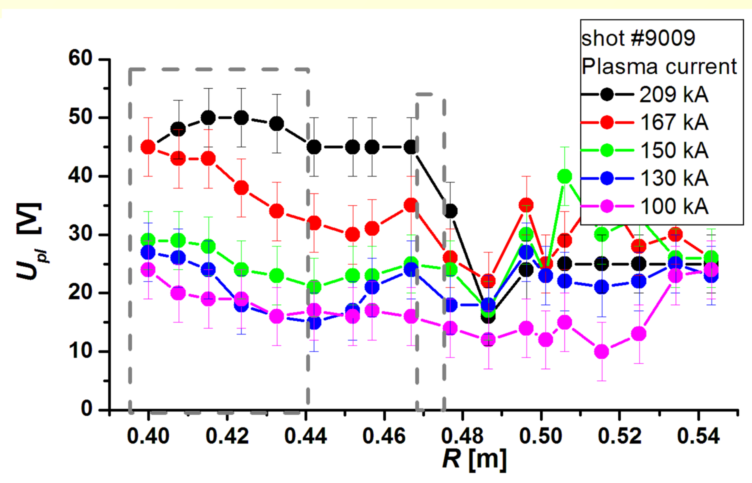
Ion saturation current density.



Dependence of the ion saturation current density and the width of PFR of the plasma current.

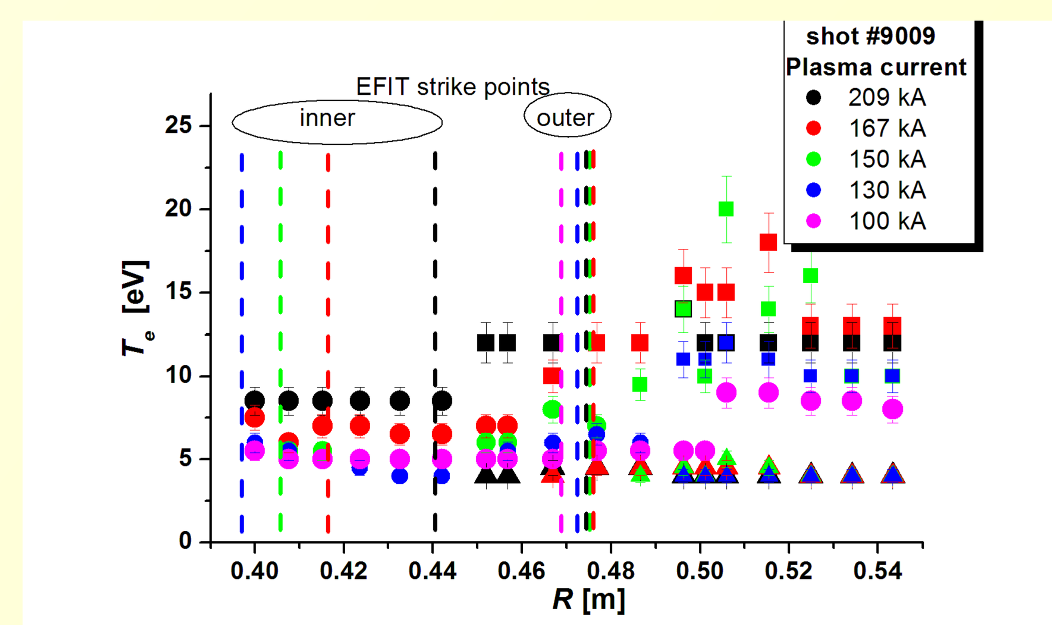


Floating potential at different plasma currents.



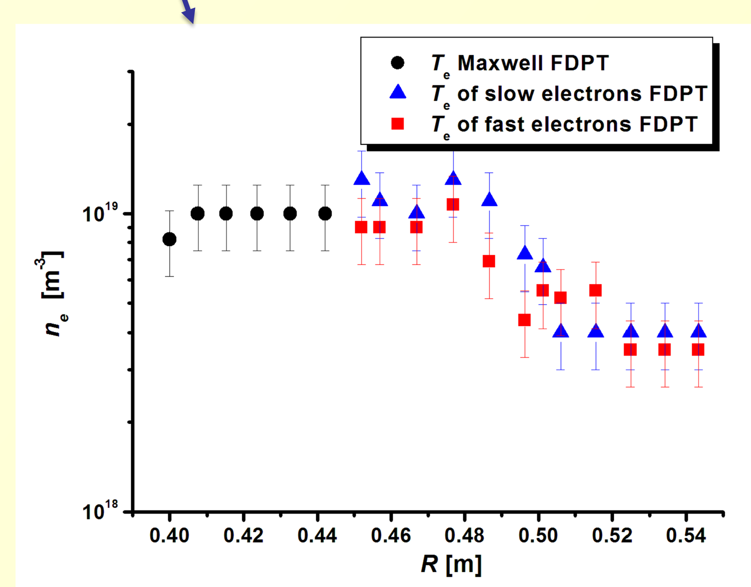
Plasma potential at different plasma currents.

T_e

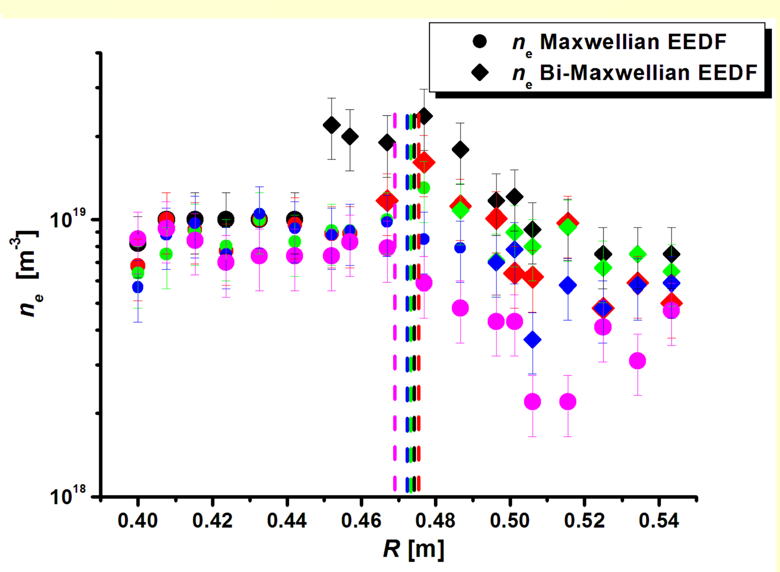


Electron temperature T_e for different discharge currents for shot #9009.

n_e

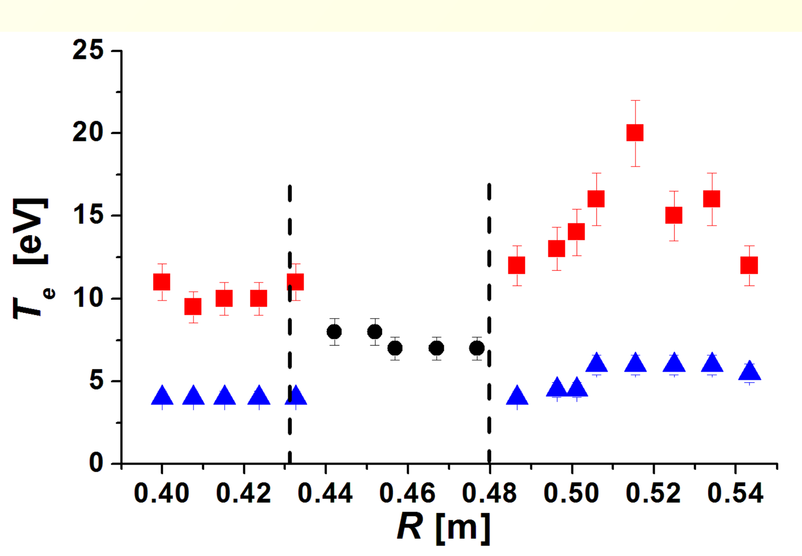


Electron densities n_e at discharge current of 210 kA.

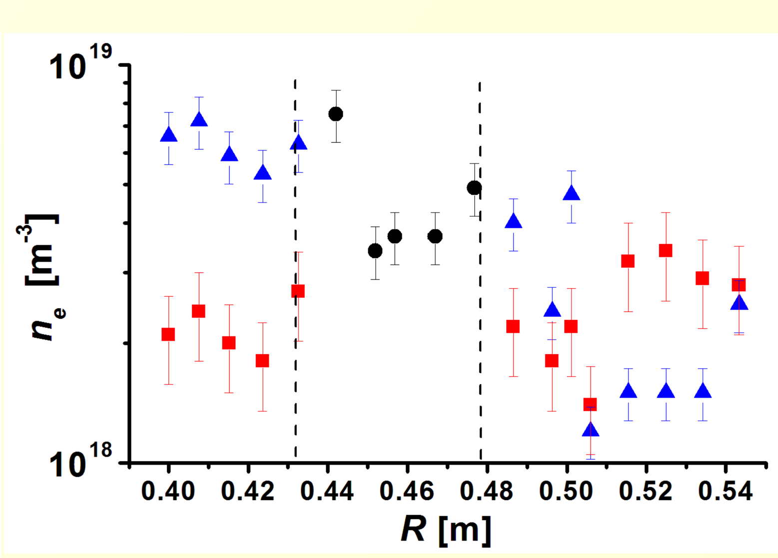


Total electron densities n_e for different discharge currents.

Shot #9008, hydrogen



Electron temperature



Electron densities

Acknowledgements:

This research has been supported by the International Atomic Energy Agency (IAEA) Research Contract No 17125/R0, R1 and R2 as a part of the IAEA CRP F13014 on "Utilisation of a Network of Small Magnetic Confinement Fusion Devices for Mainstream Fusion Research", by the JOINT RESEARCH PROJECT between the Institute of Plasma Physics v.v.i., AS CR and the Institute of Electronics BAS BG; by a project BG051 PO001-3.3.06-0057 and by MSMT Project # LM2011021.

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ИНСТИТУТ ПО ЕЛЕКТРОНИКА при БАН
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Conclusion:

This paper reports the electron energy distribution function (EEDF) in the divertor of the COMPASS tokamak as determined by the first-derivative probe technique. The current-voltage probe characteristics measured were processed by this technique, which gives information about the plasma parameters. The effect of the plasma current on the plasma parameters was studied.

The poloidal profile of the electron temperatures show that at a plasma current of 100 kA the EEDF is Maxwellian with temperatures in the range of 5 - 9 eV. As the plasma current increases, the behavior of the EEDF changes. It was found that in hydrogen plasmas in the vicinity of the strike points the EEDF can be approximated by a bi-Maxwellian distribution, with a low-energy electron group (4 - 5 eV) and higher energy electrons (10 - 20 eV). The dependence of the strike point position when the bi-Maxwellian distribution appears was also studied. When the plasma current decreases, the appearance of the bi-Maxwellian EEDF is shifted to the LFS direction.