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Energy Distribution Measurements of Fast Particles Generated in Front of the LH Grill Mouth in Tore Supra

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A retarding field analyzer (RFA) was used during lower hybrid (LH) current drive experiments in the Tore Supra tokamak to characterize the supra-thermal particles emanating from the region in front of the LH grill. This work is the continuation of our previous efforts [1,2]. In addition to fast electrons, we tried to observe fast ions accelerated due to a positive charge accumulated (and measured in the CASTOR tokamak [3]) in front of the LH grill. In the RFA, the plasma particles pass through a slit and two grids to a grounded collector. The slit (30 µm by 5 mm section, cut in a 150 µm nickel plate) is biased negatively (-50 to -100 V) to repel thermal electrons. All ions, as well as electrons with energy greater than the slit voltage, pass through the slit. Both grids are biasable to ±1000V, allowing us to scan the particles according to their energy, and separate the ions from the electrons (if their energies are less than 1000 eV).

The RFA collects particles that flow along field lines from the outboard side of the tokamak. The measurements were performed when one of the wave-guide rows of the C3 launcher was magnetically connected to the RFA. First, in shot #35613, the top C3 waveguide row was connected to the RFA. We found that -400V applied potential was not large enough to repel all the fast electrons for the launched C3 power of P_{LH}=2 MW. The upper energy boundary of the fast electron beam is therefore higher than 400 eV for the 2 MW launched, which is consistent with modeling [4]. For the same magnetic connection, we found in shot #35616 that even +300V is not enough to repel all ions. However, the analysis of the ion current shows no traces of fast ion beams in this shot, and the observed ion current might be produced by the thermal ion acceleration in the near slit sheath voltage. We decided to try operating at lower power levels in order to be able to fully repel even the suprathermal electrons and try to identify any suprathermal ions. In the shot

#36791, we optimized the magnetic field connection by a coarse scan of the plasma current, for P_{LH}=0.75 MW, ion grid 0V, electron grid –100 V. The scan was performed from the top C3 waveguide row downwards, cf. Fig. 1. The fast electron RFA signal from the 3rd row from the C3 bottom was then optimized by a fine scan in shot #36792, Fig.2, ion grid 0V, and electron grid –100V, P_{LH}=1.5 MW.

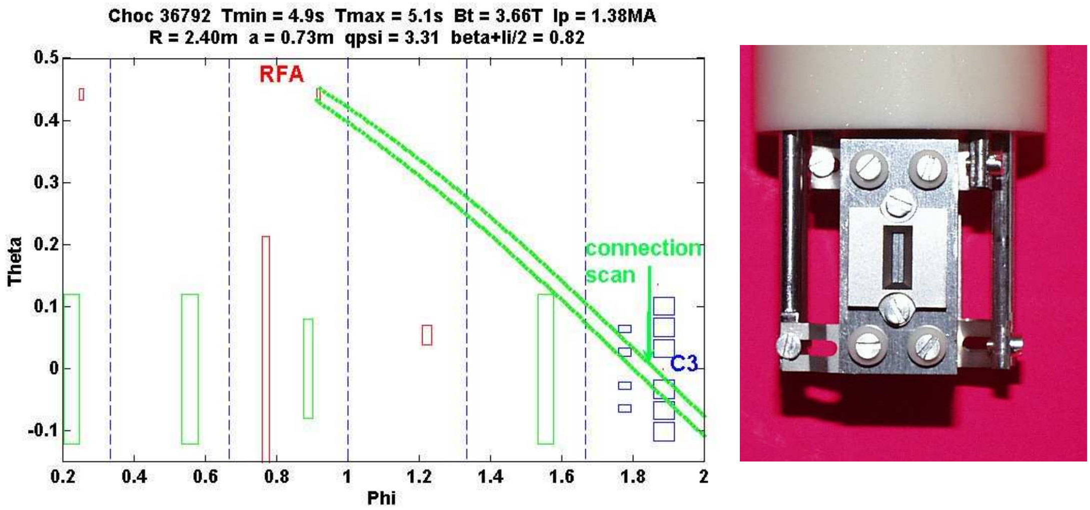


Fig.1. Schema of the connection scan between C3 LH launcher and RFA. On the right is a photograph of the RFA entrance slit.

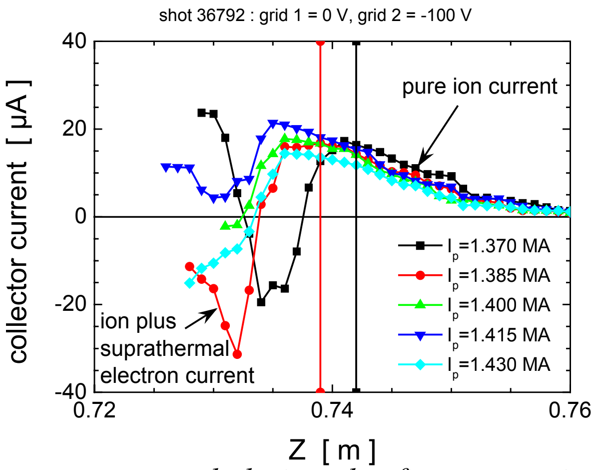
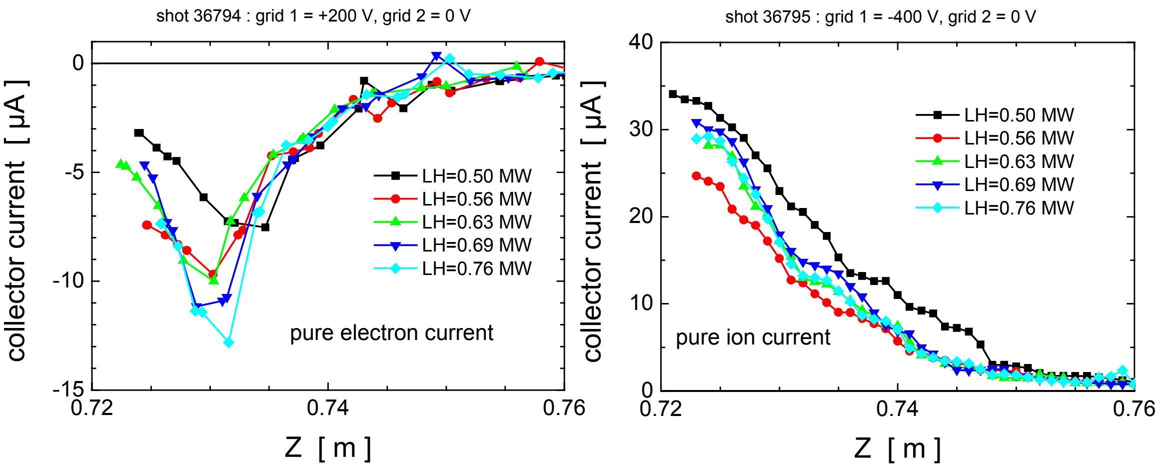


Fig.2. Collector current measured during the fine connection scan between C3 LH launcher and RFA. The negative dips are caused by electrons with energy greater than 100 eV. The black and red vertical lines indicate the magnetic connection to the leading edge of the LH launcher for the first and second reciprocations respectively. The 3mm shift is due to slight outward drift of the plasma at the beginning of the discharge. The magnetic connections for the later reciprocations (I_p≥1.4 MA) are identical to the second one (red).

The collector current is composed of electrons with energy greater than 100 eV, and ions. It should be noted that we plot here the time-averaged current at each position. Both inward and outward phases of the probe reciprocation are included in the average. The time window for averaging is 2 ms. In reality the electron current signal is extremely bursty, with nearly 100% variance, but we will not discuss this aspect in this paper. Within experimental uncertainties (<5 mm), the fast electron beam does indeed seem to be created immediately in front of the LH launcher. The peak current lies between 5 and 10 mm in front. The beam, as seen in the past, is about 10 mm wide. Even though the RFA did not fully penetrate the beam in each case, we see a clear variation of the beam strength caused by the poloidal scan of the magnetic field line in front of the wave guide row. In the future we will try to make a more detailed poloidal scan and produce a 2D poloidal-radial map of the electron current. In shot 36793, we observed that +400V on the ion grid is not enough to repel all ions at the LH power of 1.5 MW.



a) *b)*

Fig.3: Dependence of the fast electron and ion signal on LH power: a) ion grid +200V, electron grid at 0V; b) ion grid at 0V, electron grid at –400V. The first profile (black) is slightly shifted outward due to a slow movement of the plasma at the beginning of the discharge, as in Fig. 2.

The variations of the fast electron and ion signal as a function of the LH power were studied in shots #36794 and 36795, cf. Fig. 3. Fig. 3a shows growth the fast electron signal with LH power, the ion grid was at +200V, so that all thermal ions should be stripped from the signal; the electron grid was at 0V due to a technical problem, so only the entrance slit at -80 V repelled thermal electrons. The electron signal is mostly due to suprathermals, but it cannot be excluded that a small fraction of thermals is present. It is clear that the electron current increases roughly as the square of the LH power. When the electron grid is at –400V (shot #36795), the fast electron signal disappears, Fig. 3b. This means that, as we hoped, it is possible to repel all suprathermals at low values of LH power. Here, the ion grid was at 0V, allowing all ions to flow to the collector (that is, thermals as well as any suprathermals that might exist). There do not appear to be any singular features that would indicate the presence of suprathermal ions. It would be necessary to scan the ion repelling voltage to increasingly positive values in order to gradually strip away the thermals and see if any radial structure exists at large energies. Unfortunately the experiment session was terminated by a technical problem and we were unable to continue. We plan to try again in the near future.

The main results are: By varying the edge safety factor, we optimized the connection between RFA and the LH grill to obtain a maximum intensity of the fast electron beam. Clear indications of a fine poloidal structure were obtained for the first time. A strong variation of fast electron beam current with lower hybrid power was identified. For high power levels (greater than 1 MW), the electron energy is greater than 400 eV. Fast electrons exist even at low power levels (between 0.5 and 0.75 MW), and their energy is lower than 400 eV. These fast electron energy limits are consistent with a simple model of electron acceleration in the near-field of LH antennas [4]. After separating those fast electrons from the RFA signal, we observe pure ion current. No clear evidence of suprathermal ions was found on the ion current profiles, but the decisive experiment that will separate thermals from suprathermals could not be performed due to technical problems. These original results are quite encouraging, and will be further explored in the near future.

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[1] M.Goniche, et al., 31th EPS Conference, London, June 2004, P-4.110.

[2] V. Petrzilka , EPS 2005 Conference, Tarragona, Spain, P-2.096.

[3] F. Zacek, V. Petrzilka, M. Goniche: Plasma Phys. Contr. Fusion 47 (2005) No.7, L17.

[4] M. Goniche, et al., Nuclear Fusion **28** (1998) 919.