EFFECTS OF ENERGETIC ELECTRONS ON THE EDGE PROPERTIES OF THE ETA BETA II REVERSED FIELD PINCH

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INTRODUCTION

It is commonly observed in Reversed Field Pinch (RFP) experiments that the power transport in the edge flows asymmetrically [1-4]. This asymmetry has been interpreted in terms of current carried by hot electrons generated in the core plasma [5], which have been suggested to be responsible for the anomalous resistivity, commonly observed in RFP's [6]. Combined measurements of heat and particle fluxes by means of calorimeter Langmuir probe and electron energy analyzer in ZT-40M [3], as well as by X-ray emission of targets inserted in the boundary plasma of TPE-1RM15 [7], have been performed to determine the flux and energy spectrum of fast electrons.

EXPERIMENTAL SET UP

On ETA BETA II (R=0.65m, a=0.125m), to investigate the edge plasma with a fine spatial resolution , a small calorimeter Langmuir probe has been developed. The equipment is shown in fig. 1: the electrode (shaped as a half cylinder 1.5 mm wide and 3.5 mm long) is made of tungsten and is supported by an alumina insulator tube, both protected by a graphite cylinder shaped so as to expose the electrode for a collection surface of 1.2 mm^2. The other end is welded to a chromel-alumel thermocouple junction and to a conductor wire. The experimental set up consists of three identical probes with the collector surfaces oriented toward opposite sides (fig.1). The probes can be inserted, through a vertical port, by means of a linear translator, operated by a rack and pinion system, allowing also a rotation around its axis [8]. During the present campaign one electrode was operated as a single Langmuir probe and two electrodes as calorimeters detecting simultaneously the heat fluxes on opposite sides. The probe orientation is defined by the angle α between the normal to the collector surface and the poloidal magnetic field direction. The edge parameters have been investigated in different magnetic configurations obtained varying the pinch ratio Θ ($\Theta = B_\theta(a)/<B_\Phi>$) and the reversal parameter F ($F = B_\Phi(a)/<B_\Phi>$). The experiment has been operated at toroidal current $I \approx 150$ kA and electron density $n_e \approx 5 * 10^{19}$ m^{-3} almost constant at normal Θ and slightly decreasing at higher Θ. To avoid other effects, during this operation the density has been varied so as to keep approximately the same I/N ratio (N is the electron line density). All of the data have been taken keeping the probe behind the bellows inner convolution ($r=0.125$ m). With this probe insertion, global confinement properties such as loop voltage, V_{loop}, toroidal current I, discharge duration, and electron density, n_e, did not show any change with the insertion depth within shot to shot deviations.

EXPERIMENTAL RESULTS AND DISCUSSION

The exposure of the collection area of the probes toward the magnetic field has been varied from normal to tangential incidence. The heat fluxes have been derived from the temperature increment measured by thermocouples, assuming thermal isolation. The heat flux q, incident on the exposed surface, exhibits a strong angular dependence, confirming the behaviour previously found on ETA BETA II [4]. A q shallow minimum found when the surface is parallel to the magnetic field, can be attributed to the partial screening of the incident fluxes by the up stream probe. From the current flow the electron drift side has been distinguished from the ion drift side [4]. The heat flux is maximum on the electron drift side at $\alpha \sim 170^{\circ}$ (fig.2), corresponding to the local pitch of the magnetic field lines at the edge as derived by the F/Θ ratio . The heat flux reaches, at $r \sim 0.13$ m, $q \sim 200$MW/m^2 on the electron drift side and $q \sim 40$MW/m^2 on the ion drift side, resulting in an asymmetric heat flux deposition between the opposite sides of ≈ 5.

Varying the insertion of the probes the spatial dependence of the heat flux has been investigated. In fig.3 the heat flux collected on the ion and electron drift side at normal incidence is shown as a function of the insertion parameter $X=r_W-r$ where r_W is the effective radius of the wall. The heat flux on the electron drift side exhibits a discontinuity at $r=13.2 \mp 0.1$cm, and this position has been assumed for the effective radius of the wall r_W. The discontinuity of the heat flux on the electron drift side at r_W is a common feature, independent on Θ, and it can be explained by the presence of fast electrons intercepted by the probe when protruded beyond the port hole. The ratio of the heat deposition between opposite sides changes suddenly from a value around or less than 1 for $X<0$, up to 7-3, depending on Θ, and almost constant for $X>0$. An e-folding characteristic scale length for the radial dependence of the heat flux, in the ion drift side has been estimated to be $\lambda_{qi} \approx 5$ mm, comparable with that found in TPE-1RM15 $\lambda_{qi} \approx 7$ mm [2].

The parameters of the background cold plasma at the edge measured by Langmuir probes at low Θ are $n_o \sim 10^{19}$ m $^{-3}$, and $T_o \sim 10$ eV [8]. If the distribution function of the hot electron component is expressed by a half Maxwellian with temperature T_h [3], thus current density j_h and particle density n_h can be plotted as a function of T_h keeping the heat flux constant (fig.4). In the case of ETA BETA II, a heat flux $q = 300$ MW/m^2 at $r \sim 0.125$ m, and an estimated edge current density $j = 0.5$ MA/m^2 , assuming 100% of the current density at the edge carried by the hot electrons, give a minimum estimate for T_h of 280 eV and a maximum estimate for n_h of $5.6 \cdot 10^{17}$ m^{-3}. In the case of TPE-1RM15 where $q =$ 500-600 MW/m^2 and $j = 0.5$ MA/m^2, it results $T_h >$ 480-580 eV and $n_h <$ 3.8-4.3$\cdot 10^{17}$ m^{-3} [7]. It is worth noting that these minimum estimates for T_h, assuming a half Maxwellian distribution, are roughly comparable to the electron temperature of the core plasma in both machines (200-250 eV in ETA BETA II and 450-650 eV in TPE-1RM15).

In fig.5 the heat flux collected on the ion and electron drift side is shown at different values of Θ. The data refer to X~2mm, and since the F/Θ ratio did not change significantly, the exposure angle has been kept constant at normal incidence. It appears that the heat flux on the electron drift side is strongly affected, whereas on the ion drift side is almost constant. The asymmetry thus decreases from 7 to 3 moving towards higher Θ. In the present context the balance between total input power and heat flux on the probes is not discussed since it would require to consider also the change of the connection lenght due to the change of the magnetic field line pitch. However the heat flux decrease at higher Θ on the electron drift side is suggested to be accounted by a corresponding reduction in the fast electron energy.

Since fast electrons at the edge have been suggested to be directly related to the degree of stochasticity of the plasma, and the magnetic field diffusion coefficient D_m is related to the normalized magnetic fluctuation amplitude b/B, thus the heat flux has been investigated as a function of b/B. Magnetic fluctuation amplitude has been changed by varying the pinch parameter, Θ, while keeping I/N almost constant. In fig.6 the heat flux deposition on the electron drift side is shown as a function of the magnetic fluctuation amplitude. The heat flux in the electron drift side decreses with b/B , and a simple fit shows a dependence as $(b/B)^{-0.8}$, confirming a relationship between fast electron energy and magnetic fluctuations.

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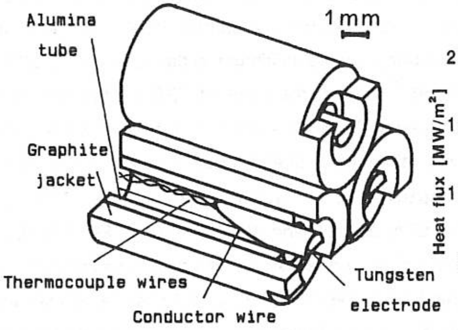

Fig.1

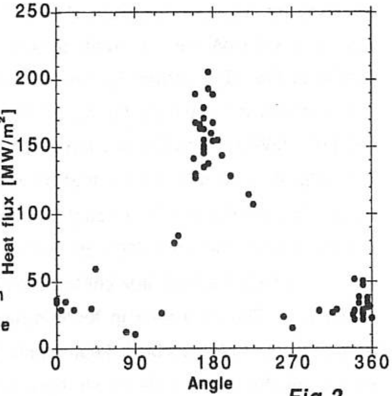

Fig.2

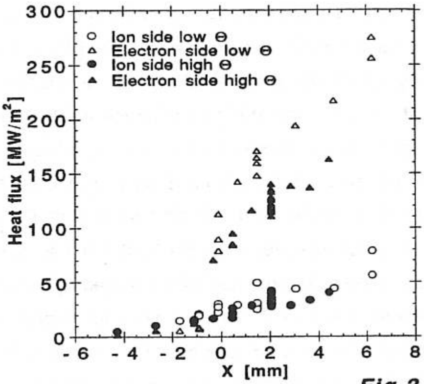

Fig.3

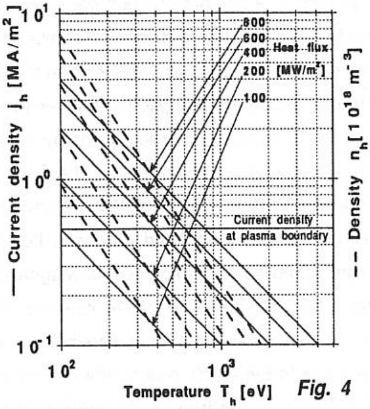

Fig. 4

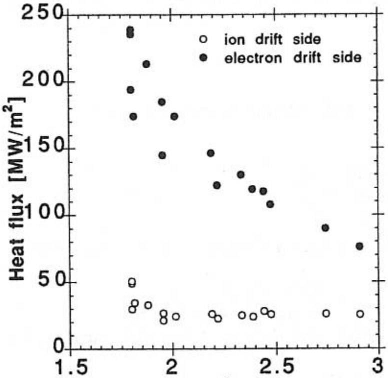

Fig.5

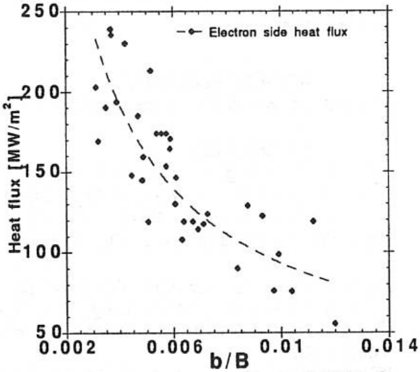

Fig.6