

MODELLING OF RADIAL DISTRIBUTION OF ALPHA LOSS IN TFTR

V.Ya.Goloborod'ko^a, J.W.Edenstrasser^b, S.N.Reznik^a, K.Schöpf^b
V.A.Yavorskij^a, S.J.Zweben^c

^a*Institute for Nuclear Research, Ukrainian Academy of Sciences, Kiev, Ukraine*

^b*Institute for Theoretical Physics, University of Innsbruck, Austria*

^c*Princeton Plasma Physics Laboratory, New Jersey, United States of America*

ABSTRACT

Numerical simulation of radial distributions of high energy charged fusion product (CFP) fluxes observed in TFTR [1-4] near the outer limiter is carried out. The simulation is based on the numerical solution of the 3D Fokker-Planck equation for the distribution function of fast ions taking into account the main peculiarities of the TFTR geometry [5]. It is shown that the poloidal shadowing effect proposed in Ref. [5] to describe the "delayed" loss of alpha particles measured in TFTR explains also, at least qualitatively, the measurements of alpha collector and movable detector probes. In the case of high plasma currents it is shown that the main contribution to the measured signal arises from the confined fast fusion products.

INTRODUCTION

Measurements of the charged fusion product loss made by the radially movable midplane [1-3] and bottom alpha collector probes [4] in TFTR have shown a strong radial dependence of the detected loss near the outer limiter. This result can be partially explained by the poloidal shadowing effect, whereby the wall blocks some of the escaping TF ripple loss orbits before they can enter the detector apertures [5,6]. However, as these probes move inward past the limiter shadow, then confined alpha particles will also begin to contribute to the loss signal. The experimental observations presented in Refs. [1-4] indicate an essential increase of the measured signal by increasing the distance of the probe aperture position from the limiter (see Fig.1), a fact which is in contradiction with the first orbit (FO) loss model. On the other hand the alpha collector measurements presented in Ref. [4] demonstrate that for low plasma currents the measured alpha fluence is in good agreement with the first orbit loss model. At the same time for higher plasma currents the measured signal exceeds that expected from the first orbit alpha loss [4] (see Fig.2).

The aim of the present paper is the 3D Fokker-Planck modelling of the distribution of charged fusion product fluxes in the vicinity of a tokamak-reactor limiter and interpretation of the experimentally observed radial distribution of the energetic ion fluxes near the outer limiter in TFTR.

SIMULATION RESULTS

The present investigation is based on the assumption that the measured probe signals are determined by the fluxes of fast fusion products, i.e. that they are proportional to $\Gamma = \Gamma_{conf} + \Gamma_{FO} = \int d\mathbf{v}\mathbf{v}f + \Gamma_{FO}$, where f is the distribution function of the confined ions and Γ_{FO} the flux due to the FO loss of charged fusion products. The calculated radial

dependencies of Γ_{FO} for the fusion products of DD and DT discharges in TFTR at 90° are shown in Fig.3. From this figure it can be seen that in the case of low plasma currents the radial profiles of the measured fluxes are close to the one determined by FO losses [4]. In the case of plasma currents below 1 MA the poloidal shadowing effect is negligible [5,6] and therefore, the contribution of confined ions to this signal is small (in the order of 5% [4]).

Figs. 3, 4 and 5 show the calculated FO loss and fluxes of confined CFP's versus the distance from the limiter, where the "longitudinal flux" corresponds to the contribution arising from the guiding center velocity, whereas the so called "total flux" is due to the total particle velocity.

In the case of larger plasma currents the poloidal shadowing effect becomes dominant and the main contribution to the measured signal should come from the confined ions. In Figs.4 and 5 one can see the contribution to the fluxes arising from the confined energetic ions versus probe aperture position. Taking into account the smallness of the triton prompt loss signal at 20° [5] one may find that the calculated curves in Fig.5 are in qualitative agreement with the experimental measurements presented in Fig.1. Figs.3 and 7 demonstrate that with decreasing plasma current at 90° one may observe mainly the prompt signal distribution like that described in Ref. [4]. At the same time for moderate plasma currents at 20° the poloidal shadowing effect becomes important, where one may observe the decrease of the probe signal with increasing current (see Fig.6).

In performing the 3D Fokker-Planck simulation of the distribution function of high-energy fusion products (alpha particles and tritons) $D=kD_{sb}$ has been used as the radial diffusion coefficient. Here D_{sb} is the superbanana diffusion coefficient and $k<1$ the factor which takes into account the number of resonant particles as well as the position of the resonance regions in the phase space [7]. The sensitivity of the radial signal profile to the radial diffusion rate is presented in Figs.8 and 9, where the dependence of the calculated profiles on the parameter k is shown. In Fig.8 one can see that at the 20° probe practically no dependence on the radial diffusion rate exists. It is due to the dominant contribution of the CFP's with energies close to the birth energy to the flux measured at this probe [5] and also due to the high rate of the Goldston-White-Boozer stochastic diffusion. On the other hand at the 90° probe, where the partially thermalised particles contribute mainly to CFP's fluxes, the profiles of the latter are more sensitive to the diffusion rate. The dependence of the flux profiles on k is rather complex (see Fig.9), mainly because of the poloidal shadowing effect and the reduction of the contribution of stochastic diffusion.

CONCLUSIONS

The radial profiles of the DD and DT CFP fluxes in the vicinity of the limiter are calculated and shown to be in at least qualitative agreement with the radial profiles of CFP loss measured by the radially movable midplane and bottom alpha collector probes.

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REFERENCES

- [1] R.L.Boivin, S.J.Zweben, Phys. Fluids b 5 (5) (1993) 1559.
- [2] S.J.Zweben, et al, Nucl. Fusion 35 (1995) 893.
- [3] S.J.Zweben, et al, Nucl. Fusion 38 (1998)739.
- [4] H.W.Herrmann, et al, Nucl. Fusion 37 (1997) 293.
- [5] V.A.Yavorskij, et al, Nucl. Fusion 38 (1998) 1565.
- [6] J.W.Edenstrasser, et al, Czech. J. Phys. 48 (1998) 177.
- [7] V.A.Yavorskij, et al, "3D Fokker-Planck equation for fast ions in a tokamak with weak TF ripples", Proc. 25th EPS Conf. on Contr. Fusion and Plasma Phys., Praha, 1998, P1.193.

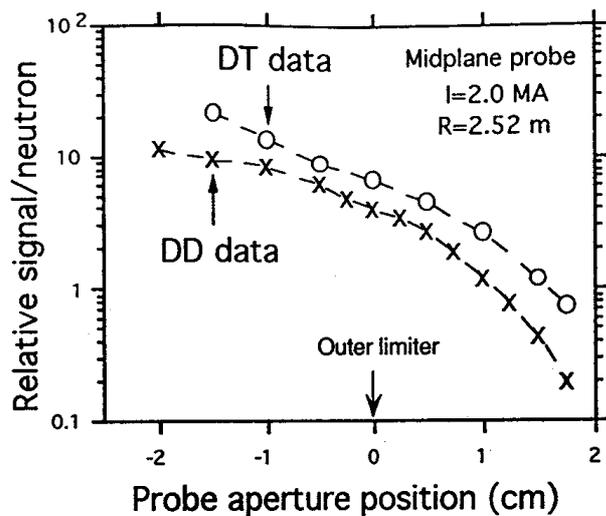


Fig.1 Radial profiles of the neutron normalized CFP loss to the midplane probe [2].

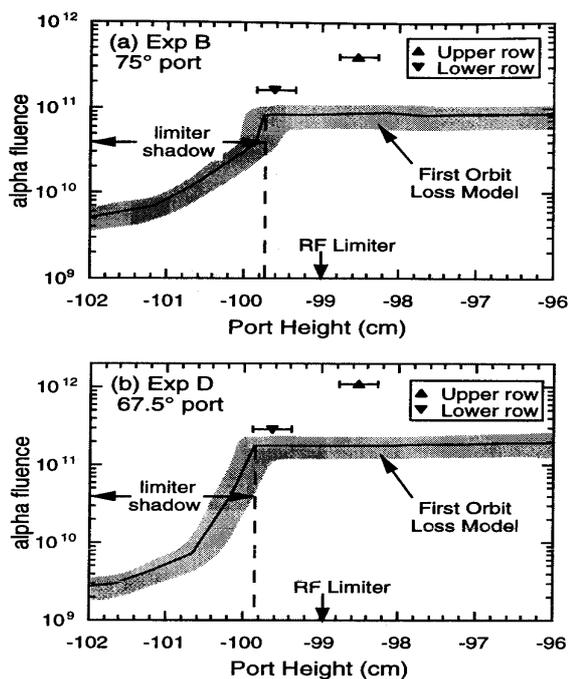


Fig.2 Alpha collector measurements at 90° [4].

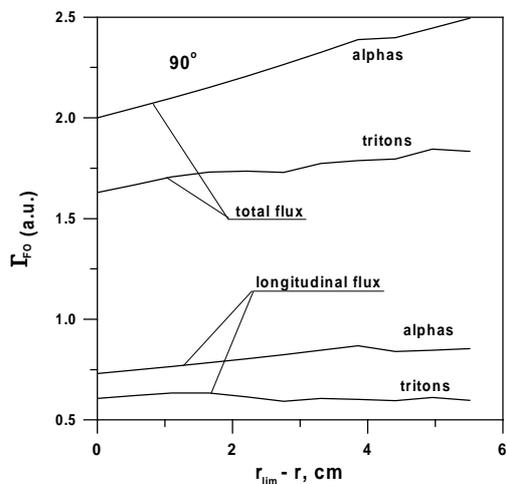


Fig.3 Radial profiles of FO loss. r_{lim} is a limiter radial position.

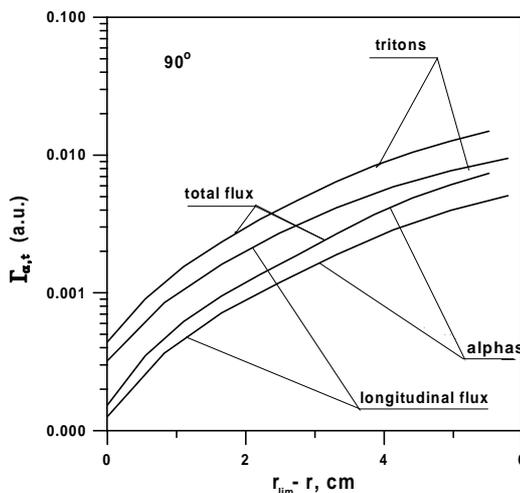


Fig.4 Radial profiles of confined CFP fluxes at 90°.

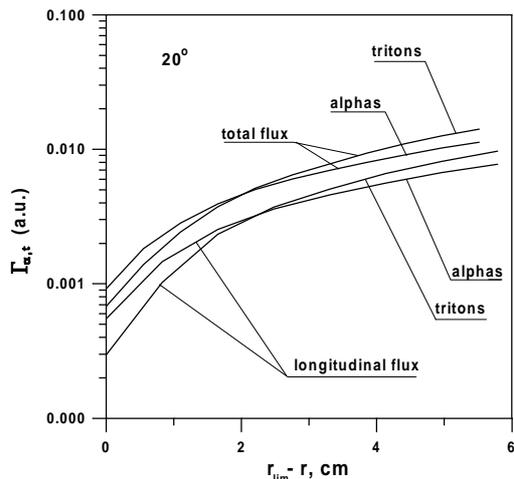


Fig.5 Radial profiles of confined CFP fluxes at 20°.

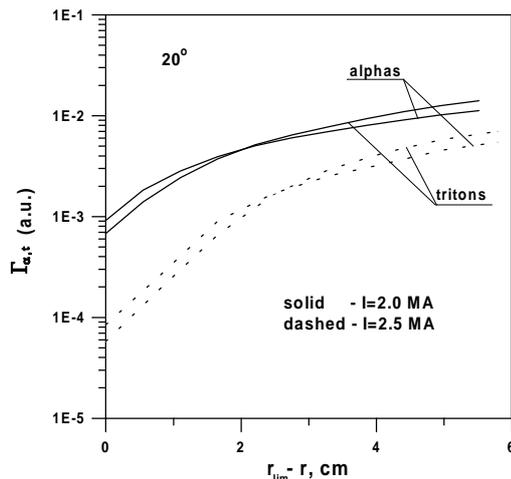


Fig.6 Radial profiles of confined CFP fluxes at 20° for different plasma currents.

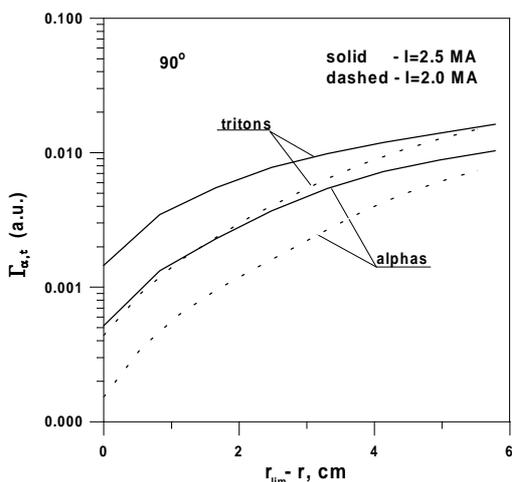


Fig.7 Radial profiles of confined CFP fluxes at 90° for different plasma currents.

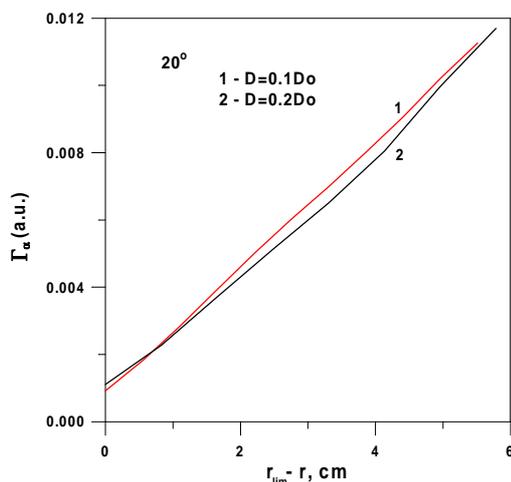


Fig.8 Radial profiles of confined CFP fluxes at 20° for different diffusion rates. D_o is the superbanana radial diffusion rate.

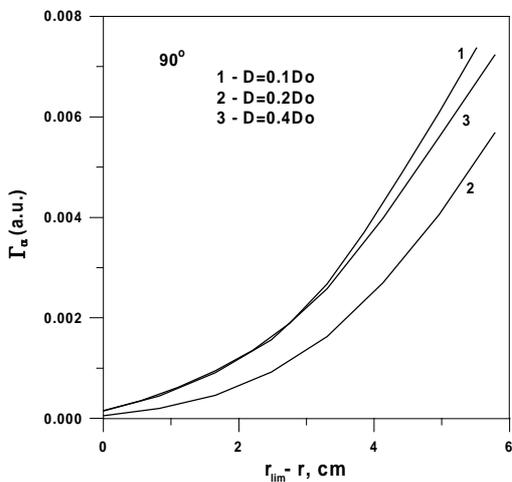


Fig.9 Radial profiles of confined CFP fluxes at 90° for different radial diffusion rates.