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7.15 Calculation of the uncollided neutron fluence on the first wall of the JET (Joint European Torus) machine with polarized DT plasmas.

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Kulsrud et al.[1)] have recently shown that a polarized deuterium-tritium (DT) plasma could be of interest from the viewpoint of a fusion reactor based on plasma magnetic confinement. Polarization would imfluence both the fusion rate and the angular distribution of the fusion products (14 MeV neutrons and 3.5 MeV alpha particles). Particularly attractive would appear the following two cases: parallel polarization, in which all the deuteron and triton magnetic moments are parallel to the confining magnetic field $\vec{B}$ (Fig.1); and transverse polarization, in which all the deuteron spins are perpendicular to $\vec{B}$ regardless of the tritons orientation. In the first case, there would be a 50% increase in the DT fusion cross section and the angular distribution would be described by the numerical factor $f_{PAR}(\alpha) = (3\sin^2\alpha)/2$ where α (pitch angle) is the angle between $\vec{B}$ and the line of flight of either fusion product (Fig.1). In the second case, there would be no enhancement of the fusion rate and the angular distribution would be given by $f_{TRA}(\alpha) = (1 + 3\cos^2\alpha)/2$.

As far as the angular distributions of the fusion products are concerned, an experimental verification of the theoretical predictions could be attempted by measuring the poloidal distribution of the 14 MeV neutrons on the first wall of a Tokamak machine. Since an experiment of this kind appears to be conceivable in JET, we thought that calculating the uncollided neutron fluence on the JET first wall, whose geometry is reported in Table I, might be useful. The DT plasma was assumed to have circular cross

Table I. Geometry of the first wall of JET (see also Fig.1).

Circular arc	Radius (cm)	Coordinates of center R (cm)	Z (cm)
FD	594.0	759.16	0.0
DE	80.0	262.8	133.5
EG	221.4	216.3	0.0

section (with major radius $R_o = 296$ cm and minor radius $a = 125$ cm) and to be both unpolarized (in which case the neutron emission is isotropic, i.e. $f_{UNP}(\alpha) = 1$) and polarized according to the above specified angular factors.

Elementary considerations lead to express the uncollided neutron fluence at the point W of the first wall (Fig.1) as

$$\psi(\theta) = (Y/V_p)\int_{V_o}\left[g(r)\ f(\alpha)/(4\pi X^2)\right]dV_o \tag{1}$$

where $Y = 10^{20}$ neut/shot is the neutron yield; $V_p = 2\pi^2 R_o a^2$ is the plasma volume; X is the distance between W and the plasma element $dV_o = r(R_o + r\cos\theta)dr\,d\theta\,d\phi$ from which the fusion products are emitted with angular distribution $f(\alpha)$; $g(r) = 3(1 - (r/a)^2)^2$ is the radial profile that we have assumed for the neutron emission;

and V_o is the fraction of V_p "seen" from W, that we have approximated with an obliquely truncated plasma column determined by the procedure described in refer.2. For calculating the integral appearing in eq.(1) the distance $r_f(\theta)$ of W from the point M (Fig.1) was determined by three formulas (one for each arc FD, DE and EG) derivable from the data of Table I.

The results of the calculations are shown in Fig.2. We have verified that the deepening of the curves for poloidal angles comprised between ~60° and ~140° is due to the vertical elongation of the JET vacuum vessel.

Obviously, the experiment suggested above can only be taken into consideration if polarized plasmas are proved to be feasible and if the mechanisms of plasma depolarization anticipated by various authors[1,3,4] turn out to be unimportant on the time scale of deuteron and triton confinement (a few seconds). In any case, the interpretation of poloidal neutron measurements would require the evaluation of scattering effects due to the vacuum vessel and to the surrounding structures; this correction could be made by using the calculated uncollided neutron fluence as source in appropriate transport codes[5]. Furthermore, notice that if the neutron detectors are located outside the vacuum vessel, beyond a not-negligible thickness of neutron absorbing and scattering material, also the effect due to the variable incidence angle γ (Fig.1) must be evaluated.

The results shown in Fig.2 refer to a plasma with circular cross section; calculations for a D-shaped plasma are under way and will be reported elsewhere.

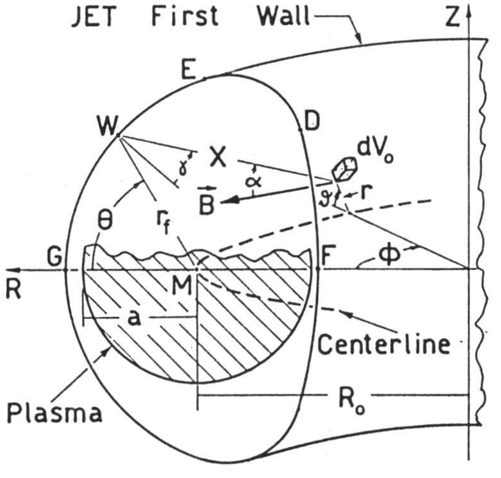

Fig.1 - Geometry used in the calculations (section RZ in scale).

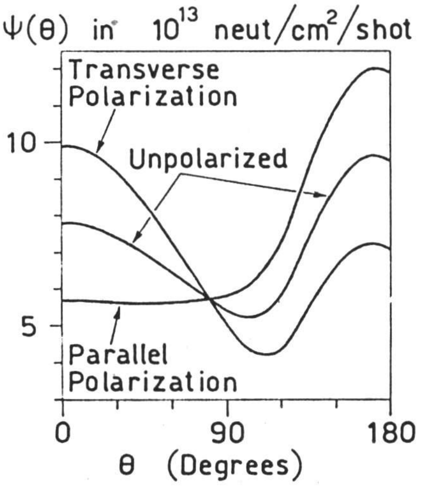

Fig.2 - Neutron fluence vs. θ for polarized and unpolarized DT plasmas.

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