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Neutron incident angle and energy distribution to first wall in beam-injected helical plasmas
ビーム入射ヘリカルプラズマにおける第一壁への中性子入射角分布及びエネルギースペクトル

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Assuming a deuterium beam-injected deuterium plasma in the Large Helical Device, neutron incident angle distribution and energy spectrum to first wall are evaluated using a kinetic model combined with the orbit calculation. Emitted neutrons from beam-thermal reactions have an anisotropic spectrum because beam particles are injected in a particular direction. The anisotropy also appears when the neutrons collide with the first wall. Relations between neutron incident angles and energies to the first wall are examined.

1. Introduction

Energetic ion tails in ion velocity distribution functions are formed by energetic ions, and neutron emission spectrum is distorted from Gaussian distribution [1,2]. By detecting non-Gaussian component in the neutron emission spectrum, the energetic ion tail can be diagnosed [2,3]. Estimation and diagnostics of the ion velocity distribution functions are important to understand effects of energetic ion tail formation including heating characteristic, transport and confinement of the energetic ions [4].

In neutral beam injection (NBI) heated plasmas, the energetic ion tail in the ion velocity distribution function and non-Gaussian component in the neutron emission spectrum have an anisotropic spectrum, because beam particles are injected in a particular direction. An effect of the anisotropy of emitted neutrons appears when they collide with first wall. Even for isotropic neutron emissions, it is known that the neutron flux and wall loading depend on wall positions [5,6]. Since the neutrons are anisotropically emitted, the energetic ion tail formation affects not only the neutron flux distribution but also incident angle distribution of neutron. It can be expected that to examine relations between the neutron incident angle distributions and ion velocity distribution functions is effective for the energetic ion diagnostics, for instance.

In this study, we assume a deuterium beam-injected deuterium plasma confined in the Large Helical Device (LHD). The neutron incident angle distribution and energy spectrum to the first wall are evaluated using a kinetic model combined with the orbit calculation.

2. Analysis Model

We assumed that the deuterium beam was tangentially injected at the magnetic axis R_{ax} = 3.6m, and the energetic ion tail in the deuteron velocity distribution function was formed in the beam-injected direction. Positions, directions and energies of energetic deuterons when fusion reactions are occurred were calculated by the orbit calculation with the LHD field B_{ax} = 2.74T. Neutron emission directions and energies were calculated using the positions, directions and energies of deuterons. Then, neutron collision points with the first wall (i.e. intersections of the neutron emission direction vectors and the first wall) and neutron incident angles were calculated. In this study, the wall position is denoted by poloidal angle θ. The shape of vacuum vessel as the first wall was assumed as a torus. Incident angle of neutron to the first wall is calculated as the angles between the neutron emission direction and wall surface. We defined the incident angle in meridian plane as poloidal incident angle ι_p, and in equatorial plane as toroidal incident angle ι_t. In Fig.1, relations between the first wall shape and (a) the poloidal incident angle ι_p, and (b) the toroidal incident angle ι_t are shown.

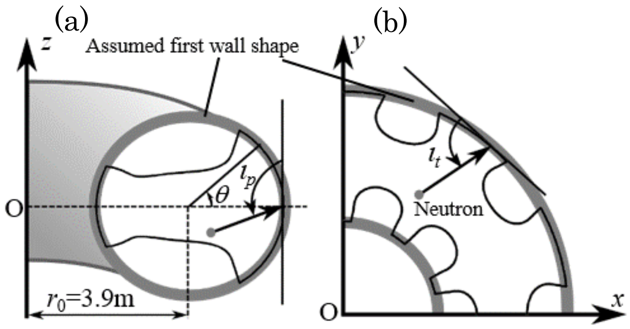

Fig.1. Relations between the first wall shape and (a) the poloidal incident angle ι_p in the meridian plane, (b) the toroidal incident angle ι_t in the equatorial plane

3. Result and Discussion

In this proceeding, only 180-keV monochromatic deuterons are examined. The neutron incident energy spectra by reactions between 180-keV and thermal deuterons at each wall position are shown in Fig.2. At the wall position $\theta = 0°$, neutrons with a range of energies from about 2.1 to 3.0 MeV are observed, and two peaks are seen at about 2.1 and 3 MeV. These energies are the minimum and the maximum neutron emission energies for neutrons by reactions between 180-keV and thermal deuterons, respectively. Neutrons emitted in the same direction of the energetic ions have the maximum energy, and neutrons emitted in the reverse direction have the minimum energy. Since the NBI is tangentially injected in equatorial plane, the maximum and minimum neutron energies can be observed only at the $\theta = 0°$ plane.

The toroidal incident angle and energy distribution of neutron at the wall position $\theta = 0°$ is shown in Fig.3. A relationship between the neutron incident angle and energy is confirmed. It is recognized that peaks exist at the maximum and minimum neutron energies. The neutron incident angle is determined by geometric relationship between the first wall shape and the neutron emission direction vector. The neutron emission energy depends on the neutron emission direction. An effect of this triangular relationship, i.e. the relationship among the neutron energy, emission direction and incident angle can be understood in Fig.3.

We examined the neutron incident angle and energy distribution for neutrons emitted by reactions between 180-keV and thermal deuterons. In this conference, a neutron incident angle and energy distribution for an assumed energetic deuteron tail is going to be presented.

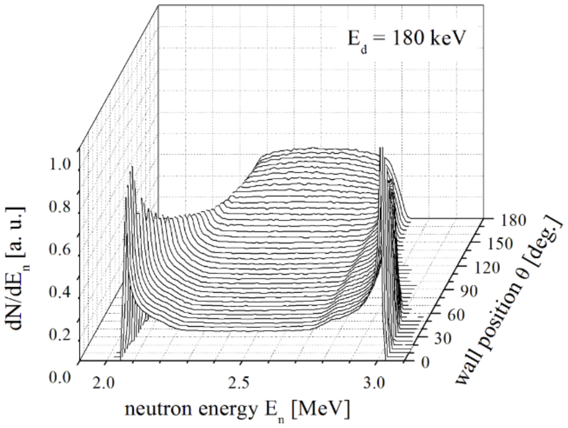

Fig.2. The neutron incident energy spectra at each wall position θ

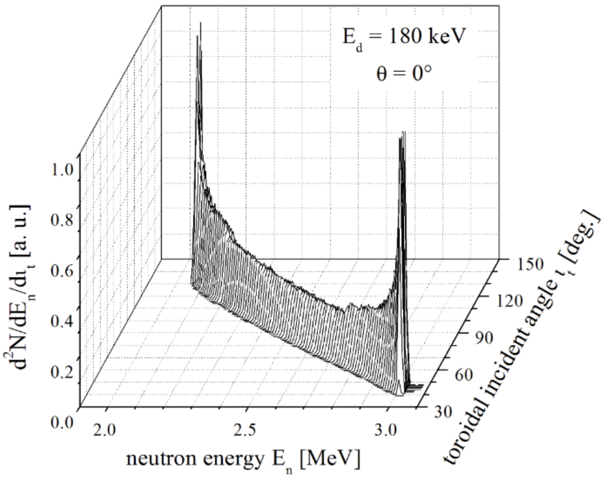

Fig.3. The neutron toroidal incident angle and energy distribution at the wall position $\theta = 0°$

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