

§ 3. Suprathermal Proton Distribution Measurements with Neutral Particle Diagnostics on LHD

Goncharov, P.R., Ozaki, T.
Lyon, J.F. (Oak Ridge National Laboratory, U.S.A.)

During the period under report the application of passive and active neutral particle diagnostic methods to studying the fast ion component properties of the toroidally non-axis-symmetrical LHD plasma has been the main subject of investigations.

The multidirectional passive neutral particle analyzer described in [1] has been applied to investigate the behavior of anisotropic distributions of suprathermal protons. Temporally and angularly resolved measurements of $f(v, \vartheta, t)$ have been made in experiments with tangential hydrogen neutral beam injection into hydrogen and noble gas target plasmas. Experimental H^+ / He^+ charge exchange cross-section data and the asymptotic behaviour of H^+ / Ne^{4+} and H^+ / Ar^{1+} charge exchange cross-sections at high energies were used for σE -correction of measured neutral particle spectra.

A simplified kinetic model was employed for the data interpretation. The model is based on the Fokker-Planck equation with Landau-Trubnikov collision operator. It assumes a Maxwellian background plasma in a uniform magnetic field and does not take into account either radial electric field effects or the spatial inhomogeneity. Two groups of experimental observations have been studied: (a) those that can be interpreted in terms of this Coulomb collisional model as the effects of the frictional drag force and the diffusion tensor and (b) the influence of the magnetic configuration on the fast ion distribution.

The time development of the energetic distribution tails in NBI-heated plasma has been measured. The behaviour of tangential spectra shows that the slowing down time scale is consistent with the Coulomb collisional slowing down time τ_s and the evolution of the spectrum can be seen from a peaked one to an equilibrium distribution. Such a time evolution is governed by the frictional drag force in the Fokker-Planck equation.

The influence of the target plasma Z_{eff} on the intensity of the pitch angle scattering of NBI-produced fast ions has been studied. A substantial enhancement of the pitch angle scattering of fast ions from tangential NBI has been observed for plasmas with higher Z ion species in comparison with hydrogen plasma. The interpretation of this effect is that the Legendre operator describing the angular spread on the right hand side of the Fokker-Planck equation contains the ion contribution proportional to Z_{eff} . The value of the effective charge $Z_{eff} = \sum_i Z_i^2 n_i / n_e$ strongly depends

on the ion species. The corresponding term originates from the diffusion tensor in the velocity space.

The velocity diffusion effect on energetic ion distributions has also been observed. On the spectra of NBI-produced energetic particles measured tangentially noticeable tails above the injection energy have been found. This effect attributed to the velocity diffusion is governed by another term originating from the diffusion tensor in the velocity space.

The dependence of the energetic particle distributions on LHD magnetic configuration has been investigated in experiments with combined hydrogen NBI and hydrogen minority ICRF heatings of low density helium target plasmas with the magnetic axis shifted inwards and outwards in major radius. The measurements were made at similar values of the H minority density (estimated $H/(H+He)$ density ratio about 0.3). The magnetic field B_t was adjusted in order to preserve the ICR layer position. A clear difference could be seen between the different configurations. The relative values of the distribution increase and the spectra extend further for inward shifted plasmas. This is interpreted as a reduction of fast particle losses in comparison with the outward shifted case. Thus, the effect of increased fast ion population in inward shifted magnetic axis configuration has been verified experimentally on LHD.

The important issue of localization of neutral particle measurements on LHD has been investigated. A numerical method has been formulated that can be used to restore the radial distributions from line-integrated passive measurements in case when the structure of the nested magnetic surfaces, i.e. the plasma parameter isolines, is known. The problem is reduced to a numerical solution of an integral equation with the kernel determined by the geometry of experiments and the magnetic equilibrium data available from computer modeling by VMEC code. The speed of the plasma column vertical angular scan limited by mechanical capabilities of the diagnostic is 1° per 30 s. The required input data set can be obtained by fan-shaped chord measurements either during a steady state of a long plasma discharge or during a sequence of identical short plasma discharges in LHD.

Local measurements of the plasma ion distribution function by detecting charge exchange neutrals from an impurity pellet ablation cloud require a fast operating energy analyzer as it is shown in [2]. Currently a solid state detector in the counting/PHA mode is used for such measurements on LHD. A mathematical algorithm has been proposed for digital processing of noisy data series containing detector signals with discontinuities corresponding to incident particles. The algorithm is based on the modified Tikhonov regularization technique known as the detection-estimation approach. Such an approach should allow to realize an ultrafast particle energy spectroscopy at high count rates by taking advantage of detector capabilities without limiting the system throughput by subsequent electronics. This method can be used in digital signal processors for semiconductor detectors.

References

- 1) Lyon, J.F. et al., Rev. Sci. Instrum., **74** (2003), 1873
- 2) Goncharov, P.R. et al., Rev. Sci. Instrum., **74** (2003), 1869