§56. Improvement of Physical Basis of PCX Diagnostics Using NIOS Data on LHD

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The Pellet Charge Exchange (PCX) diagnostic method was proposed in Ref. 1) to measure the energy spectrum of fast α-particles using carbon pellet injection. PCX diagnostic was used for measuring the energy distributions of alphas and minority-heated ions on TFTR with Li pellets[2)] and of the NBI injected ions on Large Helical Device (LHD) with polystyrene (-C8H8-)n pellets[3)]. To obtain the spectra of fast ions entering the cloud from the measured fluxes of fast neutralized particles leaving the cloud, it is necessary to evaluate the neutral fraction F_0(E, Sn) as a function of the particle energy E and the cloud "optical thickness" Sn corresponding to a certain composition of ion species in the cloud. Particularly for LHD conditions, F_0(E, Sn) was obtained and used in Ref. 3) for a variety of cloud compositions, taking into account cloud plasma density values evaluated in Ref. 4) averaged over the whole cloud. Recently, 2D distributions of both polystyrene cloud electron density and temperature have been measured during TESPEL ablation in LHD by means of 9 channel filter-lens imaging polychromator (NIOS system) [5)]. Present investigation is devoted to improvement and validation of physical basis of the PCX diagnostics using the newest NIOS data on LHD. The geometry of PCX measurements in 14th LHD experimental cycle is illustrated in Fig. 1. One can see that the viewing angle of the compact neutral particle analyzer (CNPA) of about 6 cm in diameter is a part of the luminous (in Balmer-beta H_β line) pellet cloud in the direction of the magnetic field line (z axis) and obviously exceeds the transversal cloud dimension (r axis). The measured pellet cloud electron density and temperature were used to evaluate the heavy particle composition of the pellet cloud. We used following 2 assumptions: that the pellet cloud is optically thin and that LTE conditions are valid over the whole cloud. Estimations for ionization lengths based on data of Ref. 6) show that for H^0,C^0,C^+,C^{2+} the lengths are less than cloud dimensions while for C^{3+}, C^{4+} they are comparable and may exceed cloud size. It means that a validity of LTE approach (or existence of the partial LTE) for these high carbon charge states is questionable. For instance, ionization from excited levels could decrease values of these ionization lengths[7)]. It should be noted that existence of LTE in a case of the pure hydrogen cloud was revealed in Ref. 8). Spatial distributions of heavy particles charge states were used as input data for calculations charge states along of the fast ions path within the cloud. For simplicity, the assumption of the infinite gyro radii of the incident protons was made that allows us to calculate the neutral fraction without Monte-Carlo calculations, although this assumption is actually valid in real experimental conditions for rather energetic ions (> several 100 keV). Let's consider a flat homogeneous monoenergetic flux of fast protons H^+ of energy E entering the cold dense cloud surrounding an ablating solid pellet; l is the transversal distance across the cloud. Due to the charge changing collisions with cloud particles, i.e. electron and ion impact ionization and charge exchange, the total hydrogen flux within the cloud will consist of F_0 and F_1 fractions of the H^0 and H^+ species.

A contour plot of the calculated neutral fraction (in %) for LHD shot #97814 is shown in Fig. 2 together with the CNPA viewing area. One can see that F_0 values vary by more than one order of magnitude in the detection area. This fact should be taken into account when calculating the fast ion energy distribution function from the CNPA signals.

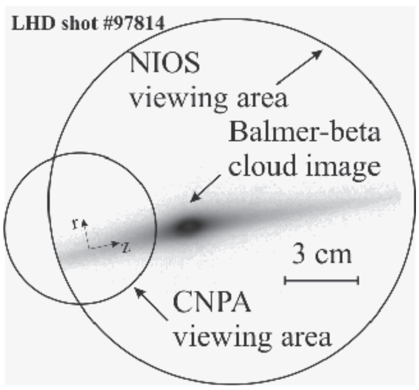

Fig. 1. The geometry setup of the PCX measurements in 14th LHD experimental campaign.

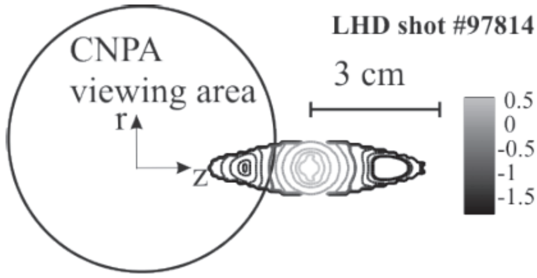

Fig. 2. Contour plot of the logarithm of the calculated line-averaged neutral fraction for LHD shot #97814 and for incident ion flux of 100 keV energy.

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