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PITCH-ANGLE RESOLVED MEASUREMENT OF DD FUSION PROTONS ON THE T-10 TOKAMAK

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The DD fusion proton flux on tokamak vacuum vessel wall is formed by integration the fusion source along particle orbit. The latter and, accordingly, particle pitch-angle depends on the magnetic configuration only. Therefore the pitch-angle distribution of escaping 3 MeV fusion protons on the wall is defined by plasma current profile and by DD reaction source profile as well. This is the base of proposed method [1] to evaluate plasma current distribution and fusion source profiles from charged fusion products (CFP) detection.

To measure the pitch-angle distribution of charge fusion products prompt loss two methods are used: several collimated detectors (for example, [2]) and, in the case of high fusion yield, a single position-sensitive detector [3,4]. The T-10 tokamak narrow diagnostic port gives no possibility to install many individual detectors in one poloidal position, and the fusion reaction yield does not exceed 10^{10} 1/s. For these reasons the alternative approach was applied.

Three spectrometric PIPS (Passivated Implanted Planar Silicon) detectors are placed inside one detector head (Figs. 1, 2). Seven collimators oriented at different angles are placed in front of each detector, namely: three collimators - before central detectorI, nd two collimators - in front of each detectors II and III. Some collimators are covered with Al foils of 20 and 40 μm thickness. Fusion protons passing through these foils lose certain part of initial energy and additional wide lower energy peaks appear on the energy spectrum (Fig. 3). Their positions are determined by the foils thickness and correspond to the specific collimators, i.e. specific pitch-angles. Note that the ion temperature can be evaluated from the broadening of unbiased protons and tritons peaks. The first experiments have been performed heretofore on T-10 machine to study the practicability of this approach [5].

In the experiments described below two kinds of collimators were employed. Firstly, the pipe collimators formed by vertical sets of thin pipes were used. Secondly, the set of pipes have been replaced with vertical plane forming slot collimators (Fig. 2). Both collimators had effective toroidal aperture $\pm 5.7^{o}$. Thus the measurements of fusion proton flux were carried out for seven values of pitch angle from 46 to 134 degrees simultaneously

during one plasma shot. The detector head was located close to plasma bottom (Fig.4). The detailed description of the T-10 escaping charged fusion product diagnostics are given in [6].

At present the first pitch-angle resolved measurements of CFP fluxes have been made in Ohmic regimes with B_t=21÷26 kG, I_p=200÷340 kA, $\langle n_e \rangle$=(3÷4)·10^{13} cm^{-3}. The main goal of this stage of measurements was to test the sensitivity of pitch-angle distribution to variation of magnetic configuration provided by changes of toroidal magnetic field and plasma current direction. The observed pitch-angle distributions were unsymmetrical with regard to $\alpha=90^o$ (Fig.5) and inversed for opposite direction of plasma current (Fig. 6). As it turned out the employment of pipes collimator in comparison with slot one led to increase of pitch-angle distribution sensitivity but, unfortunately, deteriorated the signal magnitude. The optimal collimation level should be chosen as the compromize of these two factors.

Obtained pitch-angle distributions are in good agreement with results of numerical simulation.

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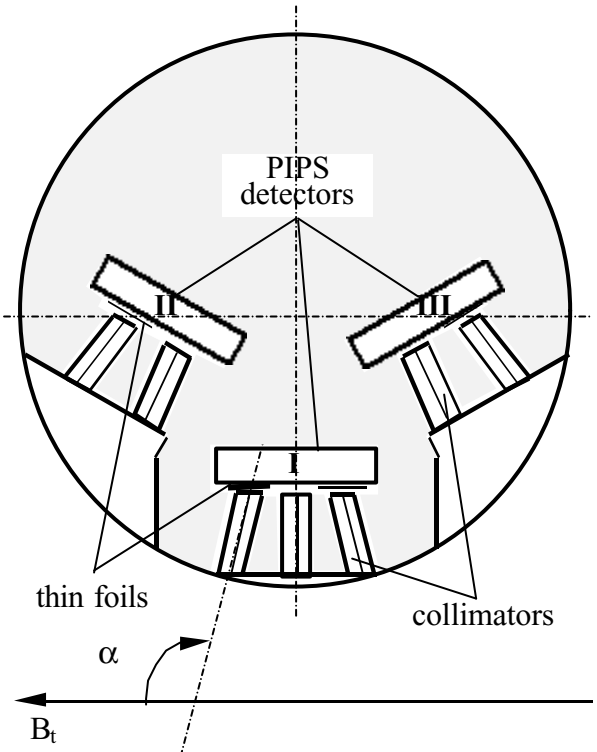

Fig. 1. Detector head (cross section).
α - toroidal pitch angle.

Fig. 2. Detector head (general view).

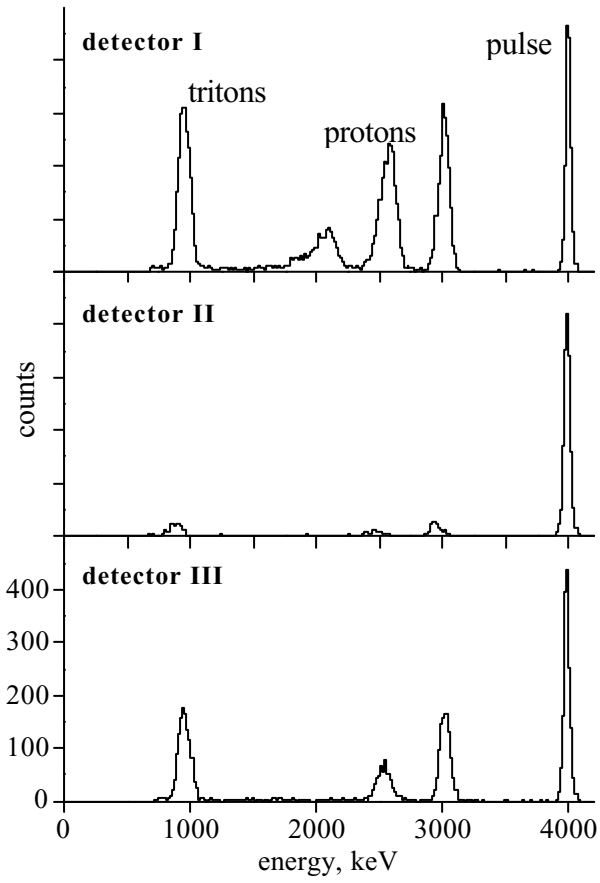

Fig. 3. Fusion product energy spectra (ohmic regime, B_t = 24.5 kG, I_p = 300 kA, $\langle n_e \rangle = 4.0 \cdot 10^{13}$ cm^{-3})

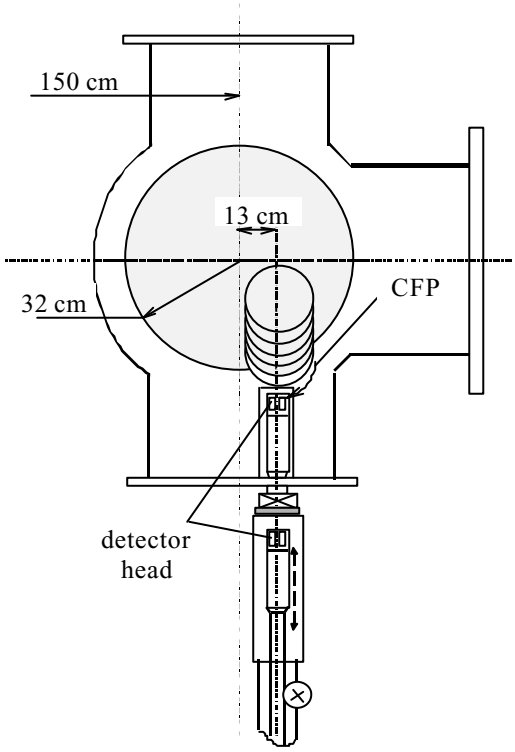

Fig. 4. T-10 CFP diagnostics (schematic view).

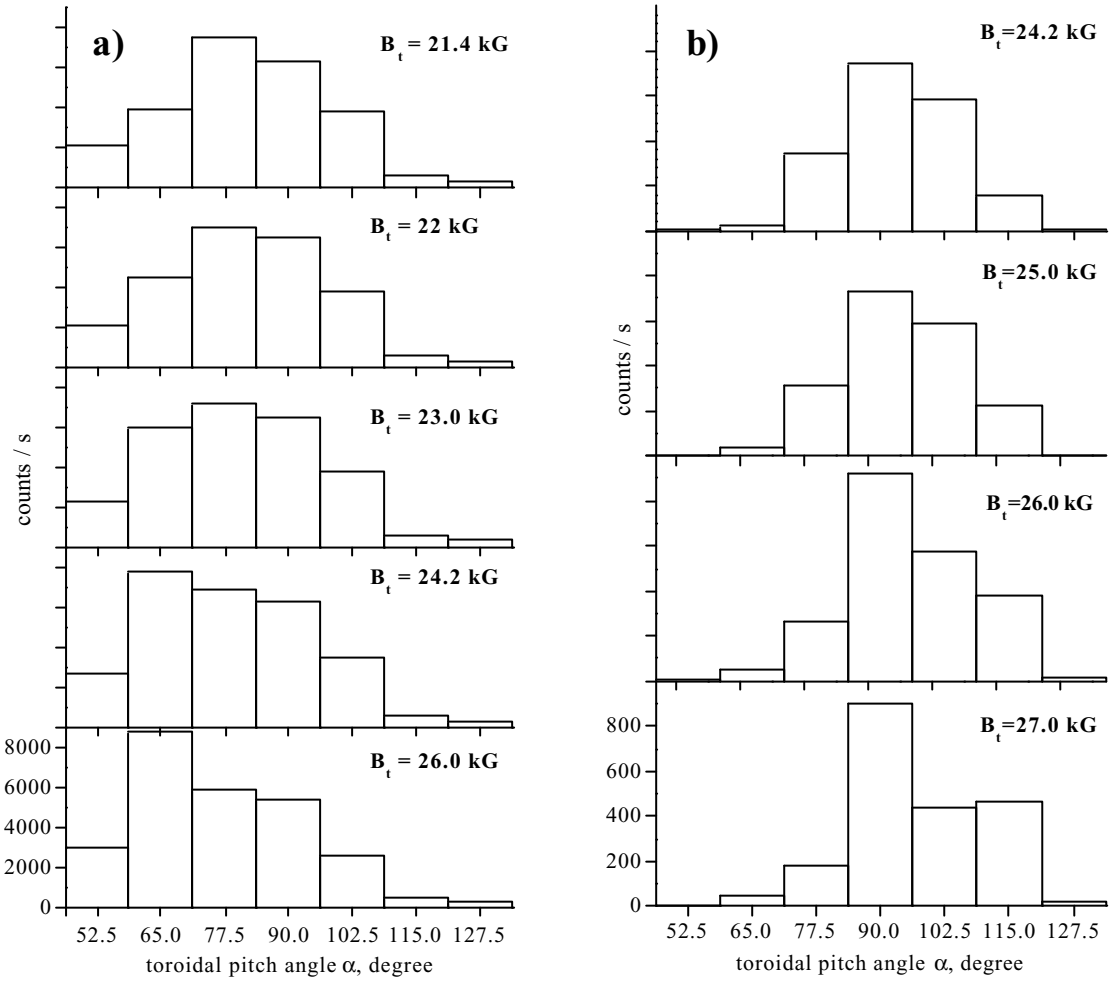

Fig. 5. Pitch-angle distributions obtained at different toroidal fields (ohmic regime, I_p = 320 kA, $\langle n_e \rangle = 4.0 \cdot 10^{13}$ cm^{-3}, slot collimators): a) slot collimators, b) pipes collimators.

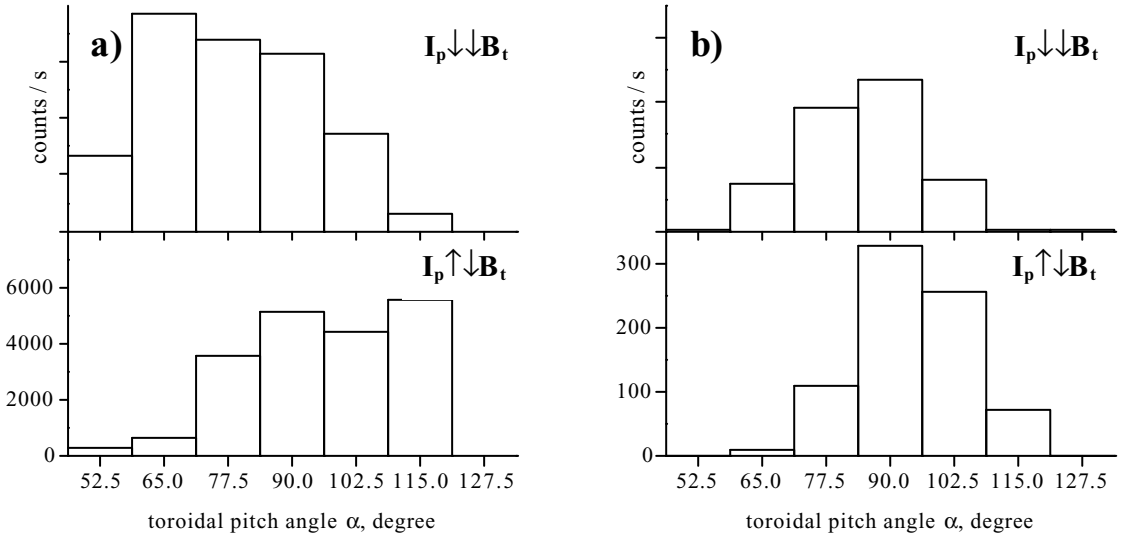

Fig. 6. Pitch-angle distributions obtained at different directions of plasma current (ohmic regime, B_t= 24.2 kG, I_p = 300 kA, $\langle n_e \rangle = 3.1 \cdot 10^{13}$ cm^{-3}): a) slot collimators, b) pipes collimators.