Computational Analysis of Neutral Particle Fluxes from Non-Axisymmetric Magnetically Confined Plasmas

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Energy and angle-resolved measurements of neutral particle fluxes provide information about T_i. as well as non-maxwellian anisotropic ion distribution tails from NBI and ICH. The correct interpretation of such measurements in a complex toroidally asymmetric geometry requires a careful numerical modeling of the neutral flux formation and the knowledge of the charge exchange target distributions, relevant cross-sections and the magnetic surface structure.

The atomic flux $\Gamma(E,t)$ [erg^{-1}s^{-1}] measured by passive diagnostics is an integral along the sightline $\mathcal{L}$ of the local differential atomic birth rate in the plasma $g(E,\mathbf{r},t)$ [erg^{-1}cm^{-3}s^{-1}], which contains the sought ion distribution:

$$\Gamma(E,\vartheta,t)=\frac{\Omega S_a}{4\pi}\int\limits_{(\mathcal{L})} g(E,\vartheta,\mathbf{r}(\xi),t)e^{-\int\limits_0^{\xi}\frac{d\xi'}{\lambda_{mfp}(E,\mathbf{r}(\xi'),t)}}d\xi\,, \tag{1}$$

where Ω is the observable solid angle and S_a is the diagnostic aperture area. The exponential factor describes the attenuation of the atomic flux in the plasma. $\lambda_{mfp}{}^{-1}(E,\mathbf{r}(\xi'),t)$ is the mean number of ionizations per unit path length. Changing the integration variable in (1) from ξ to the effective minor radius ρ yields [1, 2]

$$\Gamma(E,\vartheta,\zeta)=e^{\int\limits_{\rho_{\min}}^{1} Q^-(\tilde\rho,\zeta)\lambda_{mfp}^{-1}(E,\tilde\rho)d\tilde\rho}\,\frac{\Omega S_a}{4\pi}\int\limits_{\rho_{\min}}^{1} g(E,\vartheta,\rho)\times\left[Q^+(\rho,\zeta)e^{-\int\limits_{\rho_{\min}}^{\rho} Q^+(\tilde\rho,\zeta)\lambda_{mfp}^{-1}(E,\tilde\rho)d\tilde\rho}-\right.$$
$$\left.-Q^-(\rho,\zeta)e^{-\int\limits_{\rho_{\min}}^{\rho} Q^-(\tilde\rho,\zeta)\lambda_{mfp}^{-1}(E,\tilde\rho)d\tilde\rho}\right]d\rho\,. \tag{2}$$

The functions $Q^+(\rho,\zeta)=dX'/d\rho>0$ and $Q^-(\rho,\zeta)=dX'/d\rho<0$ on the intervals between $\rho=1$ and $\rho=\rho_{\min}$ are obtained from the structure of the isolines $\rho=const$ known from a numerical solution of Grad-Shafranov equation. This enables one to use the relation (2) for computer simulations of the neutral particle diagnostic data. The ion temperature profile retrieval from the thermalized spectra and modeling results for suprathermal high energy tails from NBI and ICH induced $f_i(E,\vartheta,t)$ will be discussed for LHD heliotron configuration.

[1] P.R. Goncharov, J.F. Lyon et al.,J.Plasma Fusion Res. Series, **6** (2004), 314

[2] P.R. Goncharov et al., Proc. 31st EPS Conf. on Plasma Phys. ECA Vol.**28G**, P-5.112 (2004)