Monte Carlo simulations of atomic processes at the gas jet target of the ESR storage ring

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In order to analyze x-ray spectra produced in collisions of fast ions with a gas-jet target of a storage ring, at a high level of accuracy, several information on beam and target geometry as well as on parameters of the detectors used (position, size, efficiency) has to be considered, in particular, for precise Doppler-shift assisted spectroscopy in atomic physics experiments [1]. In many cases a detailed response of the detectors upon variation of diverse parameters, can be known only if computer simulated events are modeled and analyzed [2]. It helps to reveal the significance of these parameters and, as a consequence, to optimize experimental setups.

In the following an universal Monte Carlo simulation of atomic collision experiments, conducted at the gas-jet target of a storage ring, is presented. The quality of the computer code was tested by comparing the Monte Carlo simulated data with experimental spectra obtained at the ESR storage ring of GSI in Dramstadt.

The developed Monte Carlo program generates x-ray spectra collected in the laboratory frame due to encounters of heavy ions with atoms or molecules of a jet target at projectile velocities close to the speed of light. The program takes into account most of the parameters which decide how does the spectrum look like. In particular, the overlap of an extended jet target and an extended ion beam is considered. The x-ray emitting target -region can be surrounded by an array of x-ray detectors [4]. We assumed that the target and the beam density are given by gaussian distributions with the center of the reference system located at the center of the collision chamber. The program can simulate radiative electron capture processes (REC) [3] and the emission of characteristic projectile x-rays. Besides that, background photons can be generated with the presumed energy distribution. A detailed description of the program was already presented [5].

As a test of the program the energy shape of the characteristic $Ly-\alpha$ radiation emitted in collisions of bare 358 MeV/u U-ions with N_2-target was analysed. In particular, influence of the position of the jet target on the $Ly-\alpha$ lines was investigated. For this test the x-ray data collected by one stripe of the sevenfold Ge(i) detector [1], placed at $\theta = 48^o$ with respect to the beam axis, were simulated for different jet-target positions with respect to the center of the collision chamber. The x-ray energy resolution of 940 eV (FWHM) at about 130 keV was applied in simulations for the considered detector stripe as measured with a standard radioactive source. In this experiment [6], the detector geometry was known very precisely.

In Fig. 1 the centroid energies of the simulated $Lyman-\alpha_1$ and α_2 lines in the laboratory frame are plotted versus jet-target position. One can observe that a change of the target position of about 2mm implies a shift of the observed centroid energy of about 0.5keV for both the $Lyman-\alpha$ components. For ilustration two simulated spectra for the two extremal target positions $(-1, +1)$ are shown in the inset of Fig. 1. The corresponding central positions of the two Ly lines, as extracted from the experiment [6], are marked in the inset of Fig. 1. The same positions are shown by arrows on the y axis of the figure. From this particular result, the jet-target position can be obtained from the plots in the figure. This can be done for $Ly-\alpha_1$ and $Ly-\alpha_2$ data, separately. The corresponding data points are ploted in Fig. 1 (triangles). It suggests that in the experiment the mean position of the jet target was $0.2\pm0.3mm$ for $Ly-\alpha_2$ and $0.1\pm0.3mm$ for $Ly-\alpha_1$ which is in accordance with the experimental observation.

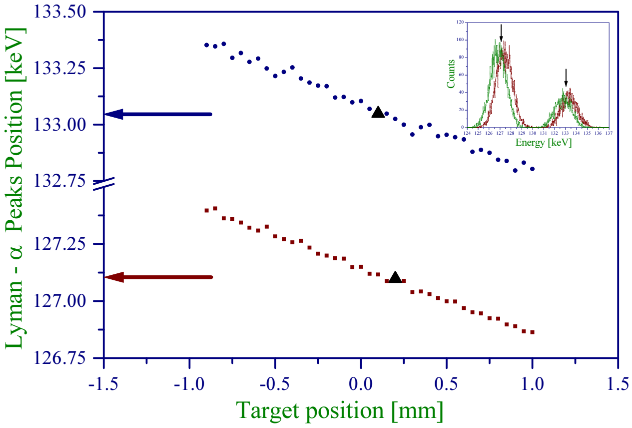

Figure 1: $Lyman-\alpha_2$ (upper points) and $Lyman-\alpha_1$ (lower points) peak positions obtained from the spectra simulated in the middle segment of the 7fold detector placed at 48^o for collisions of U^{92+} with N_2 at 358 MeV/u. The inset presents simulated spectra for the two extremal target position of -1mm and 1mm.

The Monte Carlo code discussed provides us with valuable information on the structure of x-ray spectra, which are produced in collisions of fast ions with a gas-jet target. A correct response of the program to the variation of experimental as well as physical parameters has been found. Thus, deviations of this Monte Carlo simulation from simplified models reflect the influence of the higher order effects. Currently, simulations of an already performed experiment on angular distribution of REC photons as well as on a planed experimental identification of higher-order corrections to the radiative electron capture process are in progress.

References

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