# Total and Subshell Differential Cross-Sections Measured for Electron Capture into Decelerated Bare Uranium Ions

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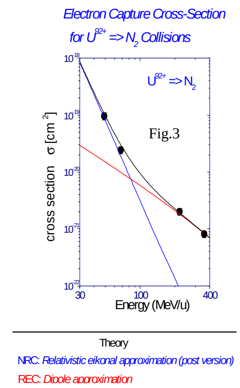
The heavy-ion storage-ring ESR at GSI in Darmstadt provides the unique possibility to decelerate highly charged, heavy-ions up to bare uranium down to energies which are far below the energy required for the efficient production of high charge states. The successful planing of experiments dealing with high-Z, decelerated ions requires a precise estimation of beam losses caused by charge exchange processes between the stored ions and the residual gas atoms (molecules). In particular, when the gasjet target is needed, the large cross-section for NRC (Non-Radiative Electron Capture) and REC (Radiative Electron Capture) at low energies may drastically reduce the lifetime of the stored ion beam.

In the first experiment conducted with decelerated bare uranium ions, precise cross-section data were obtained by normalizing the total charge exchange rates to the measured K-REC x-ray intensities[1]. In Fig.3 the resulting cross-section data for $U^{92+} \rightarrow N_2$ collisions (solid circles) are compared with a theoretical calculation (full line) based on the relativistic eikonal approximation for NRC (dashed line) [2] and the dipole-approximation for REC [3]. As seen in the figure, excellent agreement between the experimental results and the theoretical predictions is found. In contrast to total charge-exchange cross-section data, the characteristic x-ray radiation produced by electron capture into bare projectiles allows us to measure state selective cross-sections which provide a stringent test of electron-capture theories. In particular, strong Balmer transitions show up which provide a unique means for a test of electron capture theories dealing with NRC. Here, due to the large fine structure splitting in high-Z ions, *n,l,j*-sensitive population cross-sections can be obtained. This is depicted in figures 7, where the Balmer spectrum of H-like uranium is shown. This was recorded for initially bare uranium ions colliding with a $N_2$ gasjet target at an energy of 68 MeV/u. The full line in the figure, overlayed to the measured spectrum, represents the result of a spectrum simulation. The latter is based on the post-version of the eikonal approximation. For completeness, the REC process was also taken into account. Moreover, all projectile shells up to $n=40$ were considered in order to describe the high energy part (transitions from Rydberg levels). We emphasize, that the appearance of such Ryberg transitions is a unique feature of the gasjet target since in solid target experiments high-n levels are almost completely depopulated in subsequent collisions. As can be seen in the figure 9, the applied theoretical approach is in excellent agreement with the experimental spectra. The Oppenheimer-Brinkman-Kramers (OBK) approximation, however, which is commonly used in order to predict the *n,l*-distribution of NRC, is in strong variance with the post-version of the eikonal approach and fails in describing the measured x-ray spectra. Therefore, we conclude that such detailed information, like the final *n,l* distribution, cannot be derived from the OBK approximation in a proper way.

## Total capture cross-sections normalized to K-REC



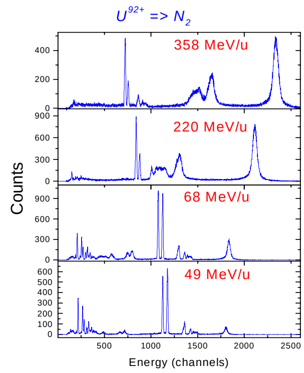
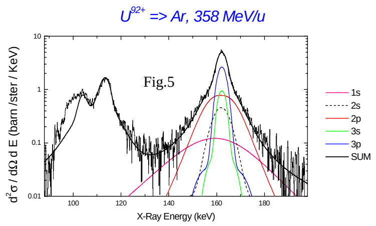
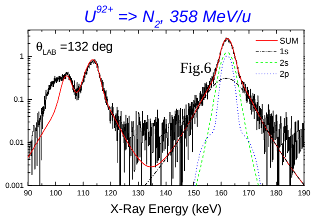
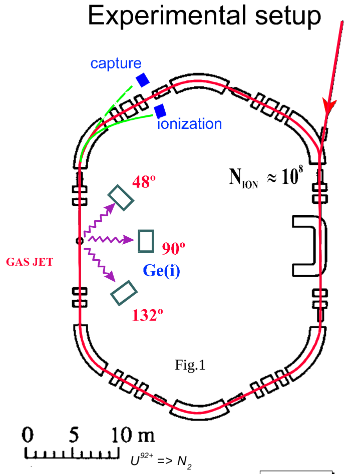



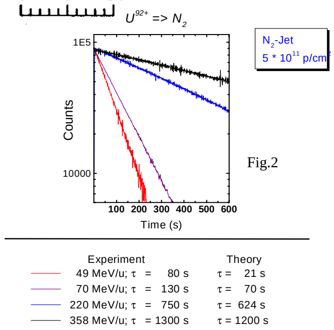
Fig.4



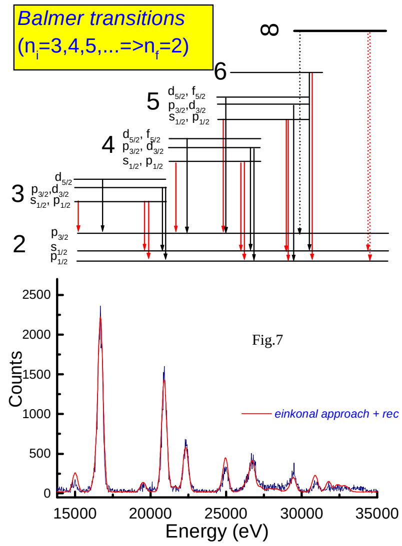

## Experimental setup

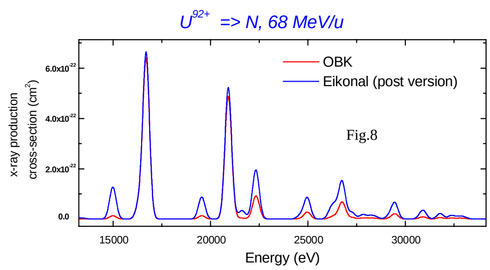


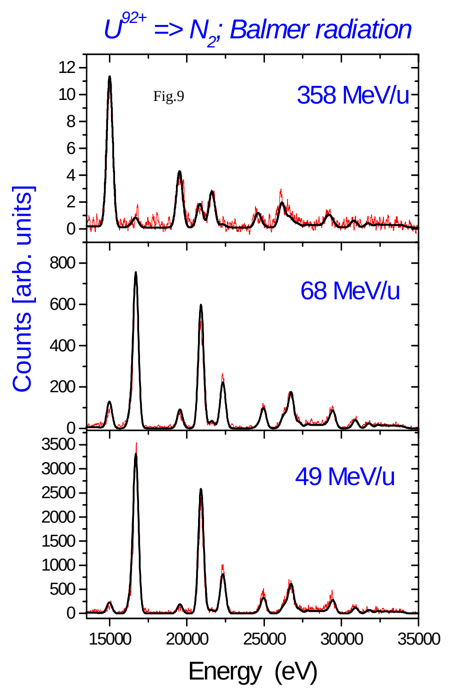

*By choosing the appropriate gas target and gas target density the time constant for charge exchange can be less than one minute.*

*Balmer transitions* ($n_i$=3,4,5,...=>$n_f$=2)




## State selective cross-sections




*theory: eikonal approximation + complete REC calculations*