Angular Distribution Studies of the Time Reversed Photoionization Process

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Introduction

The *atomic photo effect* can be considered as one of the most fundamental effects in quantum mechanics. Recently, it has been proposed that the study of its time reversed analog which occurs in ion-atom collisions, i.e. Radiative Electron Capture (REC), can be applied for the investigation of the atomic photo effect in the domain of high-*Z* ions [1,2,3]. Here, the magnetic field generated by the relativistic projectile motion induces spin-flip transitions which are not accessible in photoionization studies. In particular, angular distribution studies of the *K*-REC process are very sensitive to these effects since only spin-flip transitions can produce *K*-REC radiation at observation angles close to 0^{O} or 180^{O} [3]. Until now, there is no other process known in which magnetic effects in relativistic ion-atom collisions show up in such an unambiguous way.

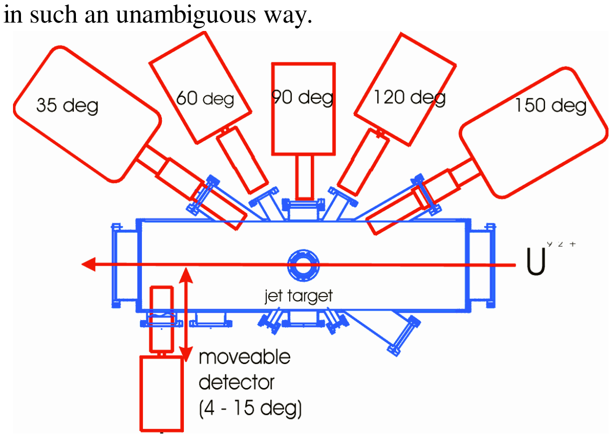

Fig. 1: *Layout of the new scattering chamber at the ESR gas-jet target used for the angular studies for K-REC into bare uranium ions. Various x-ray detectors view the target zone at different observation angles ranging from almost 0^{O} to 150^{O}.*

With the new target chamber at the ESR gas-jet target (see Fig. 1) such investigations are now accessible for the first time experimentally. The design of this chamber is in particular adopted to the requirements of x-ray spectroscopy as well as for the study of atomic reaction dynamics. Now, various observation angles, ranging from almost 0^{O} up to 180^{O}, are accessible for experiments and also target recoil-ion experiments can now be performed at the jet target. The broad range of observation angles available, allows now for a new generation of atomic collision studies. Beside magnetic effects also QED corrections may get detectable by angular-distribution studies. Presently, such a potential is theoretically investigated for the process of *K*-REC [4].

Experimental Setup at the New Gas-Jet Chamber

During the last uranium beam time at the ESR gas-jet target, the *K*-REC angular distribution was studied for collisions at an energy of 310 MeV/u by using various Ge(i) and NaI x-ray detectors at the different observation angles. For x-ray detection at almost 0^{O}, a moveable Ge(i) detector was used. Periodically, after the stacking procedure was finished, it was positioned very close to the circulating ion beam. In the measurement position, the detector was only 1 cm apart from the ion beam viewing the projectile-target interaction zone from a distance of about 50 cm. This corresponds to an observation angle of about 4^{O}.

X-ray Spectra Observed at Almost Zero Degree

In Fig. 2 x-ray spectra, measured at almost 0^{O} observation angle, are displayed. Most remarkably, due to the unprecedented clean conditions at the jet target of the storage ring, the spectra are almost free of background. This is in contrast to standard single-pass experiments utilizing solid targets and high-*Z* ions at relativistic energies. There the huge secondary electron production and its related bremsstahlung prevents photon detection in the forward hemisphere.

Close to an x-ray energy of 660 keV, the K-REC is clearly visible. Already the presence of a measurable photon intensity at this energy along with an observation close to 0^{O} is a clear evidence for magnetic transitions from continuum states into a bound projectile state.

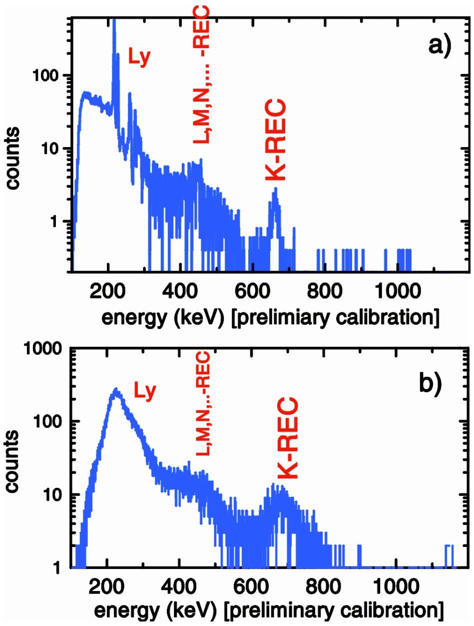

Fig. 2: *X-ray spectra obtained at almost 0^{O} observation angle for $U^{92+} \rightarrow N_2$ collisions at 310 MeV/u:*
a): recorded with a Ge(i) detector
b): recorded with a NaI detector.

References:

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