Double Electron Capture in Relativistic U^{92+} Collisions Observed at the ESR Jet Target

A. Warczak[1], G. Bednarz[1], P. Swiat[1], Th. Stöhlker [2], H. Beyer[2], F. Bosch[2], R.W. Dunford[3], S. Hagmann[2], E.P. Kanter[3], C. Kozhuharov[2], A. Krämer[2], D. Liesen[2], T. Ludziejewski[2,4], X. Ma [2], P.H. Mokler[2], Z. Stachura[5], Z. Sujkowski[4]

[1] *IFUJ-Cracow (Poland),* [2] *GSI-Darmstadt (Germany),* [3] *ANL-Argonne (USA),* [4] *INS Swierk (Poland),* [5] *INP Cracow (Poland)*

Radiative Electron Capture (REC) observed in fast collisions of fully stripped high-Z ions with light target atoms is well established as a dominant charge-exchange process [1]. Here, the fundamental electron-photon interaction mechanisms can be studied complementary to photoionization experiments when considering REC as time reversal of the photoeffect. Recently, considerable efforts devoted to electron-photon interaction went into the details of double photoionization of two-electron systems. This phenomenon, in particular, provides us with very challenging problems of atomic physics where electron-electron interaction should be taken into account, thus entering the area of correlation effects [2].

Collision experiments with bare ions should provide us again with a unique possibility for investigation of double photoionization under time reversal conditions i.e. via registration of the expected Radiative Double Electron Capture (RDEC) [3] which, so far, has not been confirmed experimentally. Emission of a photon with twice the energy of single REC photons, in coincidence with double charge exchange, would be a signature of the process. Our previous experiment aiming at observation of RDEC photons suffered from x-ray background and multiple collision contributions both induced by the solid target used [3]. The main intention of the present experiment was to detect RDEC photons by taking full advantage of the excellent beam conditions at the ESR and of the thin gas jet-target installed at the ESR target chamber [4]. In the experiment (Fig. 1) bare uranium ions at an energy of 286 MeV/u have been used. The target area has been viewed by an array of x-ray detectors [5] gated with signals from the particle detector mounted behind the bending magnet, next to the gas-jet target. The trajectory of the circulating ion beam was especially tuned in order to enable registration of ions which captured two electrons. N_2- and Ar-targets have been used with densities ranging from $4.7\times10^{11}/cm^3$ up to $5.9\times10^{12}/cm^3$. In the experiment, first, single collision conditions for double electron capture were tested. Fig. 2 shows unambiguously that the ratio of the double charge-exchange yield over the number of ions passing through the gas target depends linearly on the target density. It points clearly to single collision conditions, a crucial requirement of the measurement. In the case of U^{92+} -> N_2 collisons, single electron capture is fully determined via REC, with the measured cross section of (780 ± 100 barn), in accordance with theory and with our previous experimental results [1]. In this collision system double capture should be mediated mainly by two uncorrelated REC processes. The cross section value for the process (8 ± 3 mb) measured, for the first time, in this experiment is nicely reproduced (10.4 mb) by means of the formula proposed by Meyerhof in [6]. In the case of U^{92+} -> Ar collision about 75% of the cross section for single electron capture is only due to REC [1]. The

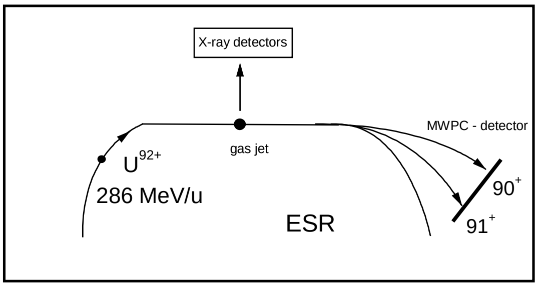

Fig.1. Experimental setup

other part of the cross section is due to Nonradiative Electron Capture (NRC). Therefore, the measured cross section for double electron capture (360 ± 70 mb) is most probably composed of the cross sections for all the possible combinations of the uncorrelated REC and NRC transitions. According to [6] the contribution consisting of two uncorrelated REC transitions amounts to 54.9 mb.

During the whole experiment only a few events related to the correlated RDEC have been observed. At the present point of data analysis the only statement considering the cross section for this extremely rare atomic process is that its value is certainly below 1 mb. This is in contradiction to the theoretical values expected [3], [7].

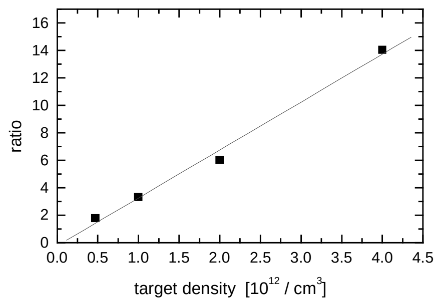

Fig. 2. *Ratio of double capture yield over the number of ions passing through the gas target (in arbitrary units).*

Finally, we would like to express many thanks to the ESR staff for excellent tuning of the machine anticipating extreme requirements of the experiment.

[1] Th. Stöhlker et al., Phys. Rev. **A 51**, 2098 (1995).
[2] *Electron Correlation Dynamics in Atomic Collisions*, J.H. McGuire, Cambridge University Press (1997).
[3] A. Warczak et al., Nucl. Instr. Meth, **B98**, 303 (1995).
[4] H. Reich et al., Nucl. Phys. A 626, 417c (1997).
[5] Th. Stöhlker et al., Phys. Rev. Lett. **82**, 3232 (1999).
[6] W.E. Meyerhof et al., Phys. Rev. **A 23**, 3291 (1985).
[7] V.L. Yakhontov, M.Ya Amusia, Phys. Rev. **A 55**, 1952 (1997).