K-shell ionization cross sections of atoms by muons

Takeshi Mukoyama[1] **and Károly Tőkési**[2]

Institute for Nuclear Research of the Hungarian Academy of Sciences (ATOMKI),
Bem tér 18/c, H-4026 Debrecen, Hungary

Synopsis The K-shell ionization cross sections of atoms by positive and negative muons have been calculated with the classical trajectory Monte Carlo method and the plane-wave Born approximation with corrections for the Coulomb and binding effects. The obtained results are compared with the coupled-channels calculations.

The inner-shell ionization processes by heavy charged particles have been extensively studied. In the first Born theory, such as the plane-wave Born approximation (PWBA), the ionization cross sections are proportional to the square of the projectile charge and do not depend on its sign. However, when higher-order corrections to the PWBA are introduced, the cross sections change when the sign of the projectile changes. It is interesting to study the dependence of the ionization cross sections on the sign of the projectile charge. For this purpose, muons are considered as more suitable projectiles than other particles, but studies on inner-shell ionization by muon impact are scarce.

In the present work, we calculate the K-shell ionization cross sections of atoms by positive and negative muons with the classical trajectory Monte Carlo (CTMC) method [1] and the PWBA corrected for the Coulomb deflection of the projectile and the binding-energy change due to presence of the projectile (ECPSSR) [2].

The CTMC is a non-perturbative method based on the classical dynamics [1]. We consider the target atom in the screened hydrogenic model. Then the system consists of three particles: the incident muon, K-shell electron and the target nucleus. The classical equations of motion for the three-body system are numerically solved for large number of trajectories with initial conditions selected randomly. The ionization cross section is proportional to the ratio of the number of ionization events to the total number of trajectories.

The PWBA cross sections are the same for positive and negative muons. On the other hand, the ECPSSR is based on the PWBA, but modified by taking into account the energy-loss, Coulomb-deflection, binding-energy, polarization and electronic relativistic effects [2]. Originally this model is valid for projectiles with positive charge. In the case of negative muon, we use the Coulomb-deflection factor developed for antiproton by Brandt and Basbas [3].

[1] E-mail: mukoyama@atomki.mta.hu

[2] E-mail: tokesi@atomki.mta.hu

In Fig. 1 we present the calculated K-shell ionization cross sections of Cu by positive and negative muons and compare with the results of the coupled-channels (CC) method [4]. For comparison the PWBA cross sections are also shown.

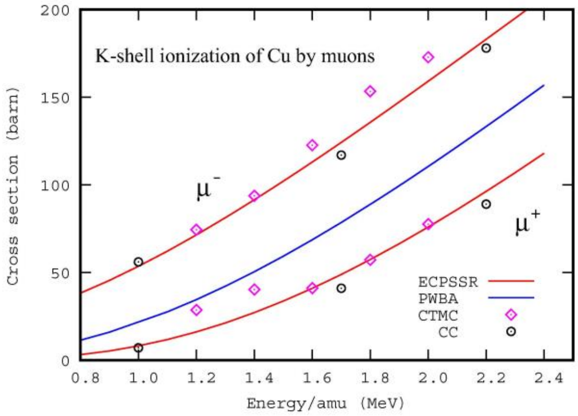

Figure 1. K-shell ionization cross sections of Cu by positive and negative muons. .

It is clear from the figure that the ECPSSR is in good agreement with the CC. The CTMC is in agreement with the ECPSSR and the CC for negative muons and also for positive muons in high energy region. At low energies the CTMC values by positive muons are larger than other theoretical ones. Owing to small ionization cross sections for positive muons statistical uncertainties are larger in this energy region.

References

[1] K. Tőkési and G. Hock 1997 *Nucl. Instr. Meth. Phys. Res. B* **124** 398

[2] W. Brandt and G. Lapicki, 1981 *Phys. Rev. A* **23** 1717

[3] W. Brandt and G. Basbas 1983 *Phys. Rev. A* **27** 578

[4] M.H. Martir *et al.* 1982 *J. Phys. B : At. Mol. Phys.* **15** 2729