Target effects on the linear polarization of photons emitted in radiative electron capture by heavy ions

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Radiative electron capture by highly-charged, heavy ions is re-investigated within the framework of the first-order perturbation theory and impulse approximation. In this study, we focus especially on the polarization properties of the emitted radiation and on the effects which arise from the binding of the target electrons. In order to explore such effects, detailed calculations have been carried out for relativistic collisions of bare uranium U^{92+} projectiles with neutral low- and medium-Z atoms. From these calculations, it is shown that the linear polarization of K-REC (L-REC) photons [photons originating from radiative electron capture into the K shell (L shell)] can be very sensitive to the momentum distribution of bound electrons if the capture occurs selective for the different shells of the target. The most pronounced effect can be observed for collision studies as performed with well-defined impact parameters or upon suppression of the capture from the outer target shells.

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I. INTRODUCTION

The last decades have witnessed significant progress in the study of the photon emission from highly charged, heavy ions [1]. Owing to advances in detector technologies accurate measurements of not only energy spectra and angular patterns but also *polarization* properties of x rays become feasible nowadays [2,3]. A series of experiments have been recently performed at the GSI storage ring in Darmstadt, for example, to investigate the linear polarization of the photons emitted in the radiative electron capture (REC) of loosely bound target electrons by high-Z projectile ions [4,5]. This charge transfer reaction attracts much attention since it plays an important role for x-ray spectroscopy of heavy atomic species and provides a unique tool for probing the fundamental process of light-matter interaction in the realm of high energies and strong electromagnetic fields [6]. For such extreme conditions the x-ray polarization measurements may reveal important knowledge about the relativistic, many-body, and quantum electrodynamics (QED) effects on the structure and dynamics of few-electron, heavy ions. For a better understanding of experimental findings, however, a detailed theoretical study of the polarization properties of REC radiation appears to be desirable.

Rigorous theoretical analysis of the radiative electron capture process of quasibound electrons is not a simple task since it requires, in general, solution of time-dependent, two-center Dirac problem. For energetic collisions of high-Z projectile ions with low-Z target atoms, however, the influence of the target nucleus (i.e., the second center) on the capture dynamics might be considered negligible. Within such an approximation, the electron is treated as driven solely by the field of the projectile nucleus and, hence, the REC process can be envisaged as the radiative recombination (RR) of initially free electrons. Fully -relativistic calculations of the properties of RR radiation are well established within the framework of the first-order perturbation theory [6–9] and usually successfully employed to explain the observed total as well as angle-differential REC cross sections. The RR approximation has to be questioned, however, if one is interested in the polarization parameters of the REC radiation which are expected to be most sensitive to the target effects. Moreover, the account of the binding of electrons in low- and medium-Z target atoms is required for an accurate description of the REC measurements as performed at well-defined impact parameters. These experiments will be carried out at the future Facility for Antiproton and Ion Research (FAIR) that is under construction now in Darmstadt.

In this contribution, we apply the first-order perturbation theory based on the Dirac equation in order to explore the polarization of the photons emitted in the radiative capture of target electrons by highly-charged, heavy ions. The electron binding effects are described within the framework of the impulse approximation that is well justified for fast collisions of heavy projectiles with low- and medium-Z targets [10–12]. This approximation, which accounts for the momentum distribution of the electron in the target, will be briefly recalled in Sec. II A. In particular, we shall discuss in detail the evaluation of the REC transition amplitudes and outline their properties. In Secs. II B and III, these amplitudes are then employed to obtain the polarization properties of the emitted

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recombination photons. Detailed calculations are presented in Sec. IV for the radiative electron capture in relativistic collisions of bare uranium ions U^{92+} with neutral hydrogen, argon, krypton, and xenon atoms. As seen from the results obtained, the linear polarization of the REC radiation might appear to be very sensitive to the impact parameter of the collision and, hence, to the initial momentum distribution of the target electrons. In contrast, if no information on the impact parameter is available in particular collision experiment, the REC polarization properties become almost identical to those of the photons emitted in course of the radiative recombination of a free electron into bound states of heavy ions. The brief summary of these results will be given in Sec. V. The natural units ($\hbar = c = m_e = 1$) are used throughout the paper.

II. THEORETICAL BACKGROUND

A. Evaluation of the transition amplitude

Since the impulse approximation has been frequently applied in studying relativistic ion-atom collisions, we may restrict ourselves to a rather short account of the basic formulas and refer for all further details to the literature [10,12]. In a semiclassical picture, the projectile ion moves with fixed velocity along a straight-line trajectory characterized by a an impact parameter $\mathbf{b}$ with respect to the target atom. For the theoretical analysis of the collision dynamics, it is often more convenient to adopt the rest frame of the projectile as the reference frame. Within such a frame, the position of the nucleus of (target) atom *as seen* by the projectile varies with time as $\mathbf{R}(t) = \mathbf{b} + \mathbf{v}t$ where $\mathbf{b} = (b_x, b_y, 0)$ and $\mathbf{v} = (0,0,v_z)$. The wave function of an electron, initially bound to the target, can be written—upon transformation to the reference (projectile) frame–as [9]

$$\Psi_i(\mathbf{r},t) = \sqrt{\frac{1+\gamma}{2}}\left(I + \frac{\beta\gamma}{\gamma+1}\alpha_z\right) \times \varphi_i\big(x - b_x, y - b_y, \gamma(z-\beta t)\big)\mathrm{e}^{-i\varepsilon_i\gamma(t-\beta z/c)}, \quad (1)$$

where $\beta = v/c$ is the collision velocity in terms of the speed of light and $\gamma = 1/\sqrt{1-\beta^2}$ is the Lorentz factor. In Eq. (1), moreover, $\varphi_i(\mathbf{r}')$ and ε_i denote the wave function and the total energy of an electron in the target rest frame.

For the evaluation of the electronic wave function $\Psi_i(\mathbf{r},t)$ we may express $\varphi_i(\mathbf{r})$ in terms of its Fourier transform $\chi_i(\mathbf{p})$ and rewrite Eq. (1) as

$$\Psi_i(\mathbf{r},t) = \frac{1}{(2\pi)^{3/2}}\sqrt{\frac{1+\gamma}{2}}\left(I + \frac{\beta\gamma}{\gamma+1}\alpha_z\right)\mathrm{e}^{-i\varepsilon_i t/\gamma} \times \int d^3\mathbf{p}\chi_i(\mathbf{p}_\perp;\kappa_z)\mathrm{e}^{i\mathbf{p}\cdot[\mathbf{r}-\mathbf{R}(t)]}. \quad (2)$$

Here we introduce notations $\mathbf{p}_\perp$ and $\kappa_z = p_z/\gamma - \beta\varepsilon_i$ for the transverse and longitudinal components of momentum $\mathbf{p}$, correspondingly. In order to perform an integration in Eq. (2) we shall first agree about the particular choice of the wave function $\varphi_i(\mathbf{r})$ and, hence, of its transform $\chi_i(\mathbf{p})$. For the low-Z target atoms, for example, it is natural to approximate $\chi_i(\mathbf{p})$ by the function $\tilde{\chi}_i(\mathbf{p}) = u\phi_i(\mathbf{p})$ where $\phi_i(\mathbf{p})$ is the solution of the Schrödinger equation in momentum space and $u = u^{\pm}$ with $(u^+)^\dagger = (1,0,0,0)$ and $(u^-)^\dagger = (0,1,0,0)$ is the standard four-spinor. In this *nonrelativistic* limit for the (target) electron wave function we write Eq. (2) as

$$\Psi_i(\mathbf{r},t) = \frac{1}{(2\pi)^{3/2}}\sqrt{\frac{1+\gamma}{2}}\left(I + \frac{\beta\gamma}{\gamma+1}\alpha_z\right)\mathrm{e}^{-i\varepsilon_i t/\gamma}u \times \int d^3\mathbf{p}\phi_i(\mathbf{p}_\perp;\kappa_z)\mathrm{e}^{i\mathbf{p}\cdot[\mathbf{r}-\mathbf{R}(t)]}. \quad (3)$$

Further simplification of the function $\Psi_i(\mathbf{r},t)$ can be achieved by replacing the (transformed) plane-wave solutions by the Dirac-Coulomb continuum waves:

$$\frac{1}{(2\pi)^{3/2}}\sqrt{\frac{1+\gamma}{2}}\left(I + \frac{\beta\gamma}{\gamma+1}\alpha_z\right)u\mathrm{e}^{i\mathbf{p}\cdot\mathbf{r}} \to \sqrt{\varepsilon_p}\psi_{\mathbf{p}m_s}(\mathbf{r}), \quad (4)$$

that describe the (free) electron with a definite asymptotic momentum $\mathbf{p}$ and total energy $\varepsilon_p = \sqrt{c^2p^2 + m^2c^4}$ in the field of the projectile ion. Such an *impulse approximation*, which is justified for the case of asymmetric high-energetic collisions with large change of electron momentum at transition from the target to the projectile, allows us to express finally the state of the incident electron in the projectile frame as

$$\Psi_i(\mathbf{r},t) = \frac{\mathrm{e}^{-i\varepsilon_a t/\gamma}}{\gamma}\int \mathrm{d}^3\mathbf{p}\phi_i(\mathbf{p}_\perp;\kappa_z)\sqrt{\varepsilon_p}\psi_{\mathbf{p}}(\mathbf{r})\mathrm{e}^{-i\mathbf{p}\cdot\mathbf{R}(t)}. \quad (5)$$

Below we shall employ this wave function for computation of the polarization properties of the recombination photons.

Having derived the (approximated) wave function (5) of the initial-state electron, we are prepared now to evaluate the amplitude

$$a_{fi}(\boldsymbol{k},\mathbf{b}) = -i\langle\Psi_f,\boldsymbol{k}\boldsymbol{e}_\lambda|\hat{R}_\gamma|\Psi_i\rangle, \quad (6)$$

that describes capture of an electron into the bound state $|\Psi_f\rangle$ of the projectile ion under the simultaneous emission of the photon with the momentum $\boldsymbol{k}$ and polarization vector $\boldsymbol{e}_\lambda$. The particular form of transition operator $\hat{R}_\gamma$ from Eq. (6) depends, of course, on the framework in which we describe the coupling of the radiation field to the electronic motion in the ion. Within the Coulomb (velocity) gauge, for example, the transition operator can be written as

$$\hat{R}_\gamma = \boldsymbol{\alpha}\mathbf{A} = \sqrt{\frac{2\pi}{V\omega_k}}\boldsymbol{\alpha}\boldsymbol{e}_\lambda[\hat{c}_{\boldsymbol{k},\lambda}\mathrm{e}^{i\boldsymbol{k}\cdot\boldsymbol{r}} + \hat{c}^\dagger_{\boldsymbol{k},\lambda}\mathrm{e}^{-i\boldsymbol{k}\cdot\boldsymbol{r}}], \quad (7)$$

where V is the normalization volume for the radiation field, ω_k is the photon energy and $\hat{c}_{\boldsymbol{k},\lambda}$ and $\hat{c}^\dagger_{\boldsymbol{k},\lambda}$ denote the annihilation and creation (photon) operators. By inserting now the operator (7) into Eq. (6) and by making use of the incident electron wave function (5) we obtain the REC transition amplitude:

$$a_{fi}(\mathbf{k},\mathbf{b}) = -i\sqrt{\frac{2\pi}{V\omega_k}}\frac{2\pi}{\gamma\beta}\int \mathrm{d}^2\boldsymbol{p}_\perp\phi_i\left(\boldsymbol{p}_\perp,\kappa_z^{(0)}\right)\sqrt{\varepsilon_p}\mathrm{e}^{-i\mathbf{p}_\perp\cdot\mathbf{b}} \times \int \mathrm{d}^3\boldsymbol{r}\psi_f^\dagger(\mathbf{r})\mathbf{e}_\lambda\boldsymbol{\alpha}\mathrm{e}^{-i\boldsymbol{k}\cdot\boldsymbol{r}}\psi_{\boldsymbol{p}}(\mathbf{r}). \quad (8)$$

In this expression, $\psi_f(\boldsymbol{r})$ and ε_f are the Dirac's wave function and eigenenergy of the (final-state) electron bound to projectile ion and $\kappa_z^{(0)} = (\varepsilon_f + \omega_k - \varepsilon_i \gamma)/\beta\gamma$.

As seen from Eq. (8), the REC amplitude $a_{fi}(\mathbf{b})$ is obtained by convolution of (i) the matrix element that describes the radiative recombination of a *free* electron having asymptotic momentum $\boldsymbol{p} = (\boldsymbol{p}_\perp, p_z^{(0)}) \equiv (\boldsymbol{p}_\perp, (\varepsilon_b + \omega_k - \varepsilon_a/\gamma)/\beta)$ and (ii) the momentum distribution of electron in the target atom. Within the impulse approximation, therefore, the projectile ion and target atom are treated in an asymmetric fashion. Namely, while the motion of the electron in the initial-continuum and final-bound states is considered as driven solely by the field of the projectile nucleus, the target charge just provides the electron momentum distribution in the initial channel. Such an approximation is usually well justified for relativistic collisions of heavy projectile ions with low-Z atoms. Below we make use of it to explore polarization properties of x-ray photons emitted due to the capture of electrons from light gaseous targets into the K shell of bare uranium projectiles.

B. Linear polarization of the REC photons

The matrix element (8) derived in the previous section provides the *building block* from which most REC properties can be calculated. Apart from the total as well as differential cross sections, in particular, this amplitude can be utilized in order to investigate the linear polarization of emitted radiation. Most naturally, such a polarization is described by its degree:

$$P_L = \frac{I_0 - I_{90}}{I_0 + I_{90}}, \tag{9}$$

where I_0 and I_{90} are the intensities of the light that is linearly polarized parallel and perpendicular to the reaction plane as spanned by the directions of the incident beam and the emitted photons. The intensities I_χ are, in turn, proportional to the differential REC probabilities:

$$P_\chi(\hat{\mathbf{k}},\mathbf{b}) = \frac{V}{8\pi^3} \int k^2 dk |a_{fi}(\mathbf{k},\mathbf{b})|^2, \tag{10}$$

which depend not only on the emission angles $\hat{\boldsymbol{k}} = (\theta,\phi)$ and particular polarization state $\mathbf{e}_\chi$ of the recombination photons but also on the parameter $\boldsymbol{b}$. Equation (10) might help us, therefore, to understand the impact parameter dependence of the polarization properties of the recombination photons.

The probability (10) has been evaluated for the electron transfer between a particular bound state $\varphi_i(\boldsymbol{r})$ of the target atom and some well-defined projectile state $\psi_f(\boldsymbol{r})$. In reality, however, electron can be captured from *any* filled shell of the target. Since for low-Z (target) atoms the energy splitting between the levels is below the energy resolution of the x-ray detectors available, one can observe only incoherent superposition of the radiation emitted due to the REC from various atomic levels. In order to calculate the linear polarization (9) of such a superposition we shall evaluate "effective" probabilities for the emission of the REC photons, being linearly polarized either in parallel or perpendicular to the reaction place:

$$P_\chi^{\rm eff}(\hat{\mathbf{k}},\mathbf{b}) = \frac{V}{8\pi^3} \sum_i \int k^2 dk |a_{fi}(\mathbf{k},\mathbf{b})|^2, \tag{11}$$

with $\chi = 0^\circ$ and 90°, respectively. In this expression, summation runs over all the filled target states while the (final) state $\psi_f(\boldsymbol{r})$ of an electron bound to the projectile remains fixed. This is due to the fact that the energies of recombination x-ray photons emitted due to the electron capture into the ground as well as first excited states of heavy projectiles are usually well resolved. In the following we shall employ Eq. (11) together with definition (9) in order to investigate the degree of linear polarization of REC photons for the relativistic collisions of heavy, highly-charged ions with low-Z atomic targets for a wide range of collision energies and impact parameters.

III. COMPUTATIONS

As seen from the formalism above, the computation of the REC polarization properties can be traced back to the transition amplitude $a_{fi}(\mathbf{k},\mathbf{b})$ which describes—within an impulse approximation—transfer of an electron between the bound states of target atom and projectile ion accompanied by the photon emission. Besides the single-particle Dirac wave functions [6,9], which are specific to the radiative recombination of a *free* electron and which are employed in the second line of Eq. (8), we shall briefly discuss a particular choice of the target wave functions $\phi_i(\boldsymbol{r}')$ and, hence, of their Fourier transform. In our computations below, the (nonrelativistic) Roothaan-Hartree-Fock approach from Ref. [13] is used to generate the atomic wave functions:

$$\varphi_i(\boldsymbol{r}) = \sum_k C_k^i R_k^{l_i}(r) Y_{l_i m_i}(\hat{\boldsymbol{r}}). \tag{12}$$

Here, $Y_{lm}(\hat{\boldsymbol{r}})$ denotes the standard spherical harmonics and the radial components are given by

$$R_k^l(r) = N_k r^{k+l-1} \exp(-\xi_k r), \tag{13}$$

with the normalization constant $N_k = (2\xi_k)^{k+l+1/2}/\sqrt{[2(k+l)]!}$. Moreover, in Eqs. (12) and (13) the parameters ξ_k and C_k^i have been found from variational principle to satisfy the Hartree-Fock equation.

By making use of Eqs. (12) and (13) we were able to find the target electron wave functions $\phi_i(\boldsymbol{p})$ in the momentum space and, hence, to calculate REC transition amplitude (8). Since in general case no analytical representation of such an amplitude is known, the calculations have been accomplished numerically with the help of Gauss-Legendre quadratures. For details of these computations which have been performed with the help of the RADIAL package [14], we refer the reader to our previous paper [15].

IV. RESULTS AND DISCUSSION

The polarization measurements of hard x rays emitted during the electron capture by heavy projectiles are no longer impractical today. Owing to the advances in design of position-sensitive solid state detectors, a series of experiments have been performed recently at the GSI storage ring on the polarization of K-REC photons following relativistic collisions of (initially) bare uranium ions U^{92+} with light targets. Although in these—first—experiments there was no control of the impact parameter $\boldsymbol{b}$, a better understanding of their results requires a detailed knowledge of the $\boldsymbol{b}$ dependence of

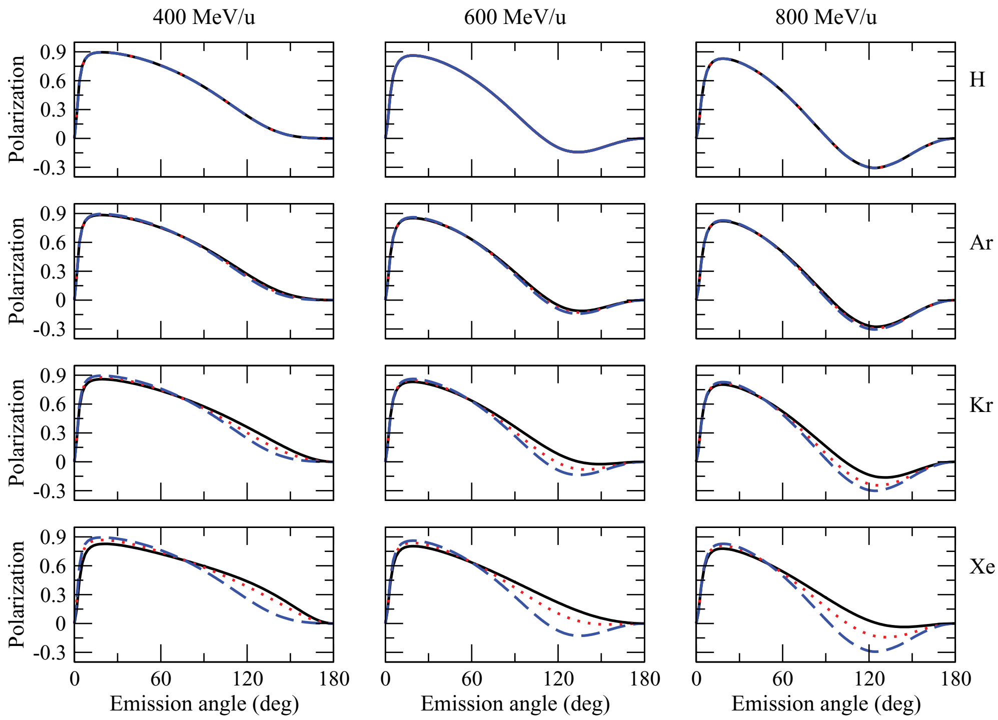

FIG. 1. (Color online) The degree of linear polarization of the photons which are emitted in the radiative electron capture into the K shell of initially bare uranium U^{92+} ions with projectile energies $T_p = 400$, 600 and 800 MeV/nucleon. Calculations have been performed for the collisions with neutral hydrogen, argon, krypton, and xenon atoms and for three impact parameters: $b = 1/Z_t$ (solid line), $2/Z_t$ (dotted line), and $9/Z_t$ (dashed line), respectively. Results are presented in the rest frame of the projectile ion.

the degree P_L. Moreover, such a dependence is likely to be observed in future (polarization) measurements that will be carried out at the FAIR facility. In the following, therefore, we analyze the linear polarization of the REC photons emitted in ion-atom collisions which proceed with various impact parameters $\boldsymbol{b}$. Detailed calculations have been carried out, in particular, for electron capture from low- and medium-Z atomic targets into the K shell of U^{92+} projectiles with energies $T_p = 400$, 600, and 800 MeV/nucleon. For these energies and for the hydrogen, argon, krypton, and xenon target atoms, we display in Fig. 1 the degree of polarization (9) as a function of the photon emission angle. To explore the influence of the impact parameter on the K–REC polarization properties the degree $P_L(b,\theta)$ has been evaluated for three different values of $|\boldsymbol{b}|$: $b = 1/Z_t$, $2/Z_t$, and $9/Z_t$ where Z_t is the nuclear charge of target atom. Such a Z_t scaling is motivated by the fact that the REC occurs preferably on the distances of the order of the Bohr orbit that scales as $1/Z_t$ in the nonrelativistic framework.

As seen from Fig. 1, calculations performed for the different impact parameters b yield virtually identical results for hydrogen and argon targets while they start to differ as the nuclear charge Z_t is increased. The effect of the (particular choice of the) impact parameter becomes most pronounced for the backward photon emission ($\theta > 90^\circ$) for which the degree of linear polarization P_L is significantly reduced with the increase of b. Such a behavior follows from the fact that while at small impact parameters, $b \leqslant 1/Z_t$, REC proceeds mainly from the K shell of the target atom, the role of higher-lying atomic levels becomes more significant if collision occurs at larger distances $b > 1/Z_t$. For the first case, the momentum distribution of the incident (inner-shell) electron wave packet is rather broad for heavy targets, resulting in a number of *low-energy* electrons captured by the projectile. Therefore, since the capture process is more probable for lower collision energies for which, moreover, recombination radiation is known to be strongly polarized (see, e.g., Refs. [6,16]), large positive degree of polarization $P_L(b,\theta)$ can be observed for ion-atom collisions performed at small b parameters. In contrast, narrow momentum distribution of the outer-shell target electrons that are usually captured at large-impact-parameter collisions leads to a decrease of fraction of low-energy electrons and, hence, to significant reduction of the degree of polarization. As seen from Fig. 1, such a reduction may result in large *negative* values of parameter $P_L(b,\theta)$ which implies, according to Eq. (9), emission of K-REC photons that are (predominantly) linearly polarized in perpendicular to the reaction plane. This so-called "crossover" effect was predicted first in theoretical photoionization studies [7,17] and is planned to be observed at the future FAIR facility.

After discussing the b dependence of the degree $P_L(b,\theta)$ let us now turn to analyzing the polarization properties of the K-REC photons for the case when no information is available on the impact parameter of the collision. The corresponding degree of linear polarization $P_L(\theta)$ can be again obtained from Eqs. (9) and (11) where effective probabilities should be integrated over the b parameter:

$$P_\chi^{\rm eff}(\hat{\mathbf{k}}) = \int d\boldsymbol{b}\, P_\chi^{\rm eff}(\hat{\mathbf{k}},\boldsymbol{b}). \tag{14}$$

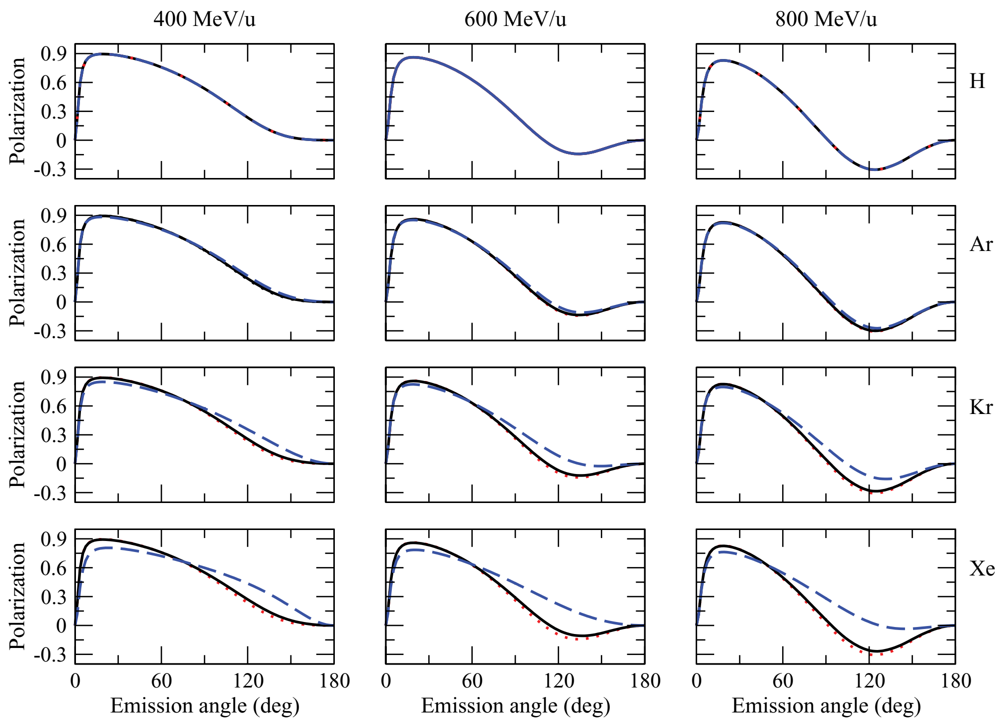

FIG. 2. (Color online) The degree of linear polarization of the photons which are emitted in the radiative electron capture (solid line) into the K shell of initially bare uranium U^{92+} ions with projectile energies $T_p = 400$, 600, and 800 MeV/nucleon. Apart from the REC results, calculations are also presented for the linear polarization of radiative recombination photons (dotted line) and the photons emitted in course of the K-K radiative transfer (dashed line). Results are presented in the rest frame of the projectile ion.

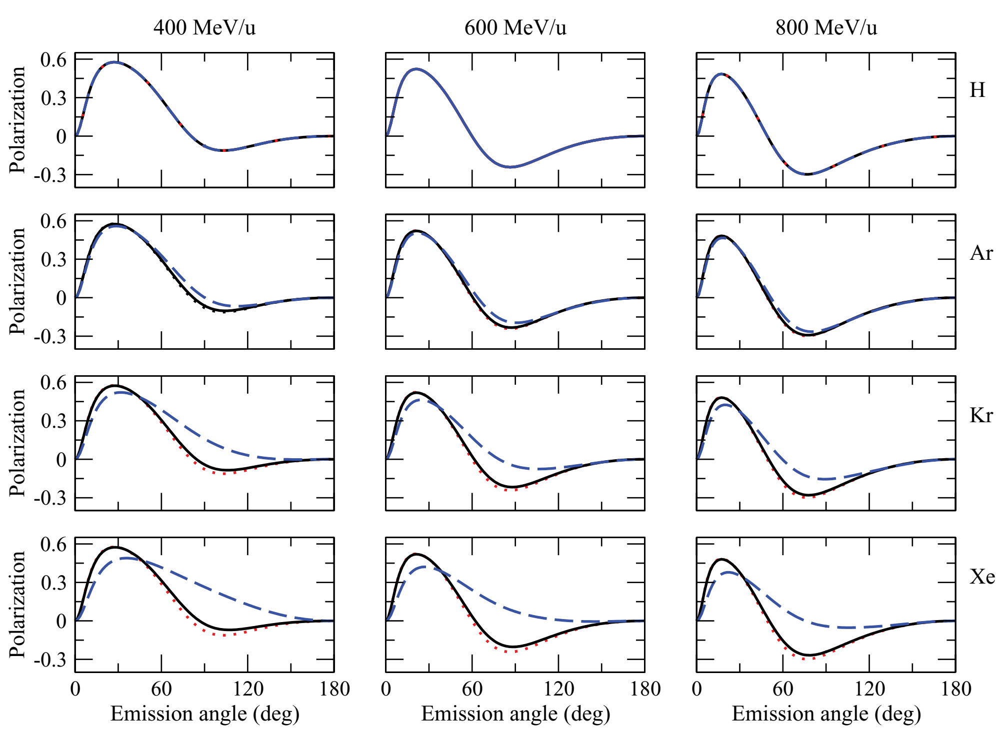

FIG. 3. (Color online) The degree of linear polarization of the photons which are emitted in the radiative electron capture (solid line) into the $2p_{3/2}$ state of initially bare uranium U^{92+} ions with projectile energies $T_p = 400$, 600, and 800 MeV/nucleon. Apart from the REC results, calculations are also presented for the linear polarization of radiative recombination photons (dotted line) and the photons emitted in course of the K-L_3 radiative transfer (dashed line). Results are presented in the rest frame of the projectile ion.

Linear polarization of the K-REC radiation obtained after this averaging is displayed in Fig. 2. Similarly as before, calculations have been performed for (initially) bare uranium ions U^{92+} with energies $T_p = 400, 600$, and 800 MeV/nucleon and colliding with hydrogen, argon, krypton, and xenon neutral atoms. Moreover, we compare our REC calculations with the predictions obtained for the capture of (i) a free electron (radiative recombination) and (ii) an electron initially bound in the $1s$ state of target atom (K-K-shell radiative charge transfer). As seen from the figure, while both RR and REC results basically coincide not only for low- but also for medium-Z target atoms, the K-K-transfer calculations indicate an enhancement of the degree of polarization; the effect which becomes most pronounced for Kr and especially Xe. Again, this can be attributed to a broadening of momentum distribution of the (target) K-shell wave function with increasing of the nuclear charge Z_t. The polarization studies on the K-K radiative transfer, that can be performed by observing the characteristic emission from target atoms, are expected, therefore, to be very sensitive to electronic structure of atomic inner shells. In contrast to the K shell, momentum distributions of the outer electrons remain narrow even for (relatively) heavy targets atoms. The radiative capture of these electrons "masks" the effect of the K-K transfer and results, as mentioned above, in almost identical RR and REC predictions. Our calculations justify, therefore, application of simple and well-established RR theory [6,7,16] for analysis of polarization properties of photons emitted in course of electron capture from low-Z neutral atoms into a bound state of heavy projectile ions.

The influence of the capture from the valence shells of the target can be observed also for the L-REC. As seen from Fig. 3, while the K-L_3 transfer might result in remarkable enhancement of the degree of linear polarization for the emission angles $\theta > 30^\circ$, the L-REC and RR calculations basically coincide if outer-shell electrons are also involved in the charge-transfer process.

V. SUMMARY

In conclusion, we have reinvestigated the radiative electron capture from neutral atoms into bound states of bare, high-Z projectiles. In our theoretical analysis, special emphasis was placed on the influence of the momentum distribution of target electrons on the linear polarization of K- and L-REC photons. To take the target effects into account we have implemented the impulse approximation based on Roothaan-Hartree-Fock approach while the projectile electron states were treated fully relativistically.

Detailed calculations have been carried out for the polarization of the REC photons emitted in relativistic collisions of bare uranium U^{92+} projectiles with low- and medium-Z neutral atoms. As seen from the results obtained, degree of linear polarization P_L might be very sensitive to the impact parameter at which the ion-atom collision occurs and, hence, to a momentum distribution of particular atomic (target) orbitals. For medium-Z target atoms and backward photon emission, for example, significant enhancement of the degree P_L has been predicted for small collision distances which reflects the broad momentum distribution of K-shell electrons.

Not much information on the target momentum distribution can be extracted, however, if one does not have a control over the collision impact parameter. For this case, the polarization properties of the REC radiation are almost equivalent to those of the RR photons emitted due to the recombination of a *free* electron. Such an agreement between RR and REC results is caused by very narrow momentum distributions of the outer-shell electrons whose contribution to the capture process is dominant for relativistic ion-atom collisions. Only if discrimination of the capture from outer atomic shell becomes possible by observing, for example, characteristic emission from a target, linear polarization of K- and L-REC photons may again serve as a very sensitive tool for probing the structure of atomic inner shells. Such coincidence measurements are likely to be carried out at the future FAIR facility in Darmstadt and will provide more insight into the structure and dynamical properties of many-electron systems.

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