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Monte Carlo event generators in atomic physics: A new tool to tackle the few-body dynamics

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Synopsis The Monte Carlo Event Generator technique is applied to study the reaction dynamics of atomic processes induced by ion and electron impact as well as by strong laser fields.

Monte Carlo event generators (MCEG) have been proven to be a very powerful tool to analyze the fragmentation dynamics driven by ions [1], and recently, electrons [2]. To this end, single ionization (SI) by ions and double ionization (DI) by ions and electrons have been extensively explored. One of the main goals of studies of DI by ion and electron impact is to disentangle the different mechanisms that can lead to this process. Using the MCEG technique, in conjunction with various theoretical models, we have achieved significant progress on this goal.

The MCEG method is based on computing fully differential cross sections (FDCS) for the process of interest with the theoretical model of choice. Using random generators an event file is then generated where the number of events with a given set of momentum components of all collision fragments is proportional to the FDCS for this particular kinematic set. This event file can then be analyzed in exactly the same manner as corresponding experimental event files and any type of cross section that can be extracted from experiment can also be calculated.

Another advantage MCEG offer is the possibility to include in a direct way the experimental conditions, like e.g. the resolution in the momentum components of all involved particles, in the theoretical calculations. Furthermore, additional physics can be incorporated retroactively.

In this work we present a summary of the progress that has been accomplished already on the reaction dynamics in collisions involving charged-particle impact. Furthermore, we outline how MCEG are able to open new avenues in advancing our understanding of the few body dynamics further and we give brief details about the numerical implementation using high performance computing facilities [3]. Additionally we show new results of the MCEG applied to single ionization of H atoms by laser pulses (see Fig. 1) employing the Coulomb-Volkov approach (CVA) [4]. As in the case of the ion and electron induced dynamics, the incorporation of experimental conditions could be crucial in some cases in order to compare theory and experiments.

Finally we discuss briefly how we plan to extend the MCEG to more complex laser induced processes, namely double ionization of He by laser pulses.

Figure 1. Doubly-differential electron momentum distributions (logarithmic scale) in cylindrical coordinates ($k_z, k_r$) using the CVA. a) bare calculation, b) calculation including a typical experimental resolution. The parameters of the field are $F_0 = 0.05$ a.u., $\omega=0.25$ a.u., and $\tau = 151$ a.u. which comprises six complete optical cycles.

References