

Pair creation in low-energy collisions of heavy nuclei beyond the monopole approximation

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Synopsis The creation of electron-positron pairs in slow collisions of heavy nuclei is considered beyond the monopole approximation. The nonperturbative calculations of pair-creation probabilities are performed with taking into account the full two-center potential of colliding nuclei.

In low-energy collisions of heavy ions, the electromagnetic fields of extremely high strength can be achieved. It gives an unique opportunity for investigation of quantum electrodynamics in supercritical regime, where the vacuum becomes unstable [1]. To date the nonperturbative calculations of pair creation in such collisions were mainly restricted to the monopole approximation, according to which only the spherically-symmetric part of the two-center potential is taken into account [2, 3, 4]. In the present work, we calculate the pair-creation probabilities beyond this approximation.

Our approach is based on the numerical solving of the two-center time-dependent Dirac equation in a finite basis set. The basis functions are obtained from B-splines according to the dual-kinetic-balance technique for the systems with axial symmetry [5]. The employed method allows us to take into account the full two-center potential. However, the rotation of the internuclear axis is neglected that enables to consider the Dirac equation only in two dimensions.

In Table 1, we present the obtained results for pair-creation probabilities with an electron captured in a bound state (bound-free pair creation). The calculations have been performed for the collision of bare thorium nuclei ($Z = 90$) at energy $E = 6$ MeV/u. The obtained values are compared with the corresponding ones calculated in monopole approximation using the method described in Ref. [4]. As one can see from the table, the results are close to each other. However, the two-center values are systematically larger than the monopole ones. One can also notice that the difference grows with the value of the impact parameter. It can be explained by the fact that

the monopole approximation works better for smaller internuclear distances.

The pair creation with the electron in the continuum requires more cumbersome calculations. These calculations are currently underway and the results will be presented at the conference.

This work was supported by SPSU-DFG (Grant N 11.65.41.2017) and FAIR-Russia Research Center. I.A.M. also acknowledges the support of the Dynasty foundation and the German-Russian Interdisciplinary Science Center (G-RISC).

Table 1. Probability of the bound-free pair creation in the collision of bare thorium nuclei as a function of the impact parameter b . The calculations have been performed for collision energy $E = 6$ MeV/u.

b (fm)	Two-center potential	Monopole potential
0	6.43×10^{-3}	6.18×10^{-3}
5	5.46×10^{-3}	5.21×10^{-3}
10	3.76×10^{-3}	3.52×10^{-3}
15	2.41×10^{-3}	2.20×10^{-3}
15	1.52×10^{-3}	1.35×10^{-3}
25	9.69×10^{-4}	8.29×10^{-4}

References

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