Ab-initio description of few-particle collisions

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Theoretical description of the quantum-mechanical collisions turns out to be one of the most important and complex problems in theoretical physics. In the last years, following the fast evolution of the computing power, strong effort has been made to solve this problem rigorously for systems containing several particles. **During the PhD, student will explore this rapidly developing field with many possible multidisciplinary applications in nuclear, atomic, molecular physics and astrophysics [1-2].**

First realistic application is related with some ongoing projects in CERN [3], which aim to produce and manipulate antihydrogen atoms. One of such projects is called GBAR (Gravitational Behaviour of Antihydrogen at Rest), aiming to perform the first test of the Equivalence Principle with antimatter by measuring the free fall of ultra-cold antihydrogen atoms. Success of these experiments strongly depends on the production rate of the antihydrogen ions ($\overline{H}^+$) via two-step process: $\overline{p} + Ps \rightarrow \overline{H} + e^-$ and $\overline{H} + Ps \rightarrow \overline{H}^+ + e^-$. Good knowledge of the reaction mechanism is required in order to optimise the possible experimental setup [4-5]. Resonance positions and respective production rates must be calculated exactly for these processes, treated as 3- and 4-particle collision, respectively.

Second project aims to determine the neutrino spectrum in beta-decay of ^{9}Li and ^{8}He nuclei by using three-cluster model. Small quantities of these exotic nuclei are produced in scintillating neutrino detectors by the impact of the cosmic rays. Knowledge of the $\beta^- + \bar{\nu}$ energy distribution would improve significantly the background subtraction in these experiments. In particular, it might help to improve the accuracy of the neutrino mixing angle θ_{13} measured at DoubleChooz by a factor 2.

In the further perspective we would like to solve rigorously for the first time 5-body scattering problem, in particular helping to describe the fusion reaction $^2H + {}^3H \rightarrow {}^4He + n$ of interest for ITER and other nuclear fusion facilities.

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[3] P. Debu for the GBAR collaboration, Hyperfine Interactions (2011).
[4] P. Comini and P. A. Hervieux, *New Journal of Physics* **15** (2013) 095022.
[5] Y. Abe *et al., Phys. Rev.* **D 87** (2013) 011102.