Nuclear physics with antiprotons: a theory endeavor

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Schedule – Link: http://esnt.cea.fr/Phocea/Page/index.php?id=92
http://esnt.cea.fr:80/Phocea/Page/index.php?id=92

I. SCIENTIFIC ISSUE

J. Chadwick discovered almost a century ago the existence of the neutron, immediately recognized as one of the constituents of nuclei. While nuclear charge densities can be routinely obtained with electron scattering, few direct measurements have been made of the neutron distribution inside nuclei. Recent studies [1, 2] *favor larger neutron radii than predictions from both ab-initio and mean-field methods.*

An ambitious new experimental project at CERN, PUMA [3] *seeks to open up this experimental domain by probing the neutron distribution in exotic nuclei with antiprotons. Such a project is uniquely possible due to the advent of the new CERN-ELENA facility that provides low-energy antiproton beams, unavailable since the closing of the LEAR facility in 1997. Due to its complexity and current experimental scarcity, this domain of physics remains very little understood and vastly unexplored.*

The study of antiprotonic atoms is ***at the confluence of atomic, nuclear and particle physics****. The antiprotons are captured onto highly excited atomic orbitals (n~30) and cascade through Auger and x-ray emission to lower orbits until they annihilate in the nuclear field. Both the details of the atomic cascade and the annihilation products may be used to probe the nuclear density distributions* [4, 5] *and to study high-field QED. However, both these experimental signatures require interpretation with reliable theoretical models i.e., calculations that may supply uncertainty quantification.*

The theoretical description of antiprotonic systems also requires surmounting many challenges. There are different scales at play in the nucleon-antinucleon system including an open channel (annihilation) at zero energy, which requires additional, complex short-range parameters.
Most of the scattering lengths/volumes seem to be natural on the scale set by pion physics, suggesting that a perturbative Pionless EFT holds at small momenta and Chiral EFT, in a simpler form than for NN, applies at higher momenta. As one progresses towards heavier

nuclei, one is obliged to further simplify the problem by matching the results of ab initio methods to Halo EFT, which is designed for systems where neutrons orbit outside a compact core.

II. GOALS OF THE WORKSHOP

The main motivation for organizing this workshop is to bring together some of the specialists of the different aspects of the PUMA project to review the state-of-the-art of the theoretical developments.

Goal 1: Disseminate the status and planned progress of the work of each attendee.
Goal 2: Make practical steps on formal and numerical implementation of the modeling of antiprotonic states and reactions.
Goal 3: Foster an international collaboration on nuclear physics with antiprotons around the theory groups of Orsay/Saclay and Strasbourg.

References

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[2] M. Cadeddu et al., Phys. Rev. Lett. **120**, 072501 (2018). *https://doi.org/10.1103/PhysRevLett.120.072501*

[3] A. Obertelli, *CERN report*, no. CERN-INTC-2018-023. INTC-M-018, 2018.

[4] B. Klos *et al.*, Phys. Rev. C **76**, 014311 (2007). *https://doi.org/10.1103/PhysRevC.76.014311*

[5] M. Wada and Y. Yamazaki, Nucl. Instr. Meth. B **214**, 196 (2004). *https://doi.org/10.1016/j.nimb.2003.08.019*