Institut national de physique nucléaire et de physique des particules

COLLABORATION AGREEMENT

IN2P3 - COPIN

I. Identification of the laboratories	
Partner	COPIN
IN2P3 laboratories	**IJCLab** / LPNHE
Partner laboratories	National Centre for Nuclear Research,Pasteura 7, 02-093 Warsaw, Poland

II. Identification of the collaboration	
Title of the collaboration	Study of antiproton-nucleus interactions at low energy
Number of the collaboration	22-154
IN2P3 spokesperson	G. HUPIN
COPIN spokesperson	S. WYCECH
Scientific Domain	Nuclear Physics

Status of the collaboration	
Status	The renewal of the collaboration is requested for the period January 1st - December 31st, 2023

III. Status report for the period January 1st to December 31st, 2022	
III.1 IN2P3 scientists in COPIN	
Total time approved for 2022	14
Total time used for 2022	14
List of scientists	1. Jaume Carbonnell (7 days) 2. Benoît Loiseau (7 days)
III.2 COPIN scientists in France	
Total time approved for 2022	14
Total time used for 2022	14
List of scientists	1. Wycech Slawomir (14 days)
III.3 Scientific results of the above-mentioned collaboration	
Description	

We have pursued the update of the Paris N N potential, ”Paris2009”, [1], in particular we have

put in place a smooth regularization towards r ! 0. The smoothed intersection between the phenomenological short-range and the long-range part of the potential is performed using spline functions. The latter is determined by state-of-the-art theoretical framework using dispersion relation. The new version avoids occurance of derivative discontinuities present in [1] at the junction points which make difficult the numerical treatment of loosely-bound antiprotonic atomic states. Plots comparing the total, elastic, annihilation and charge-exchange cross-section of pp between Paris2009 and its smoothed version show some small differences. These differences could be suppressed by changing slightly the short-range parameters. The next step is to compare the 2 of these observables. The 2 calculation will allow to keep a good fit to the observables while readjusting the short-range part to obtain better positions of the quasi-bound and/or resonant nucleon-antinucleon states as required by the study of the light antiprotonic atoms performed in [2].

S. Wycech has been working on a phenomenological method to analyse former pionisation experiments in nuclei [3, 4]. The idea is to extract: atomic capture state properties (notably angular momenta), the Rn/p ratio, and neutron haloes directly from the 9 data obtained for each nuclear target. The related numerical code, still in preparation will be left in Orsay for analyses of PUMA experimental results.

Scientific dissemination

Presentations given at ”Nuclear physics with antiprotons: a theory endeavor ESNT” on November 15-19, 2021 and organized by the spokeperson:

- B. Loiseau, ”The Paris nucleon-antinucleon potential and Baryonia”.
- S. Wycech, ”Antiprotonic Atom - A Tool to Study Nuclei Hadronisation, Analysis of Old Experiments”.

P.S. : B. Loiseau has obtained, in the LPNHE, a status of volonteer at Sorbonne University, campus Pierre et Marie Curie, up to August 31, 2023.

References

[1] B. El-Bennich, M. Lacombe, B. Loiseau, and S. Wycech, “Paris N N

potential constrained

by recent antiprotonic-atom data and np total cross sections,” Physical Review C, vol. 79,

p. 054001, 5 2009.

[2] B. Loiseau and S. Wycech, “Extraction of baryonia from the lightest antiprotonic atoms,”

Physical Review C, vol. 102, p. 034006, 9 2020.

[3] W. M. Bugg, G. T. Condo, E. L. Hart, H. O. Cohn, and R. D. McCulloch, “Evidence for a neutron

halo in heavy nuclei from antiproton absorption,” Phys. Rev. Lett., vol. 31, pp. 475–478,

Aug 1973.

[4] J. Riedlberger, C. Amsler, M. Doser, U. Straumann, P. Truöl, D. Bailey, S. Barlag, U. Gastaldi,

R. Landua, C. Sabev, K. D. Duch, M. Heel, H. Kalinowsky, F. Kayser, E. Klempt, B. May,

O. Schreiber, P. Weidenauer, M. Ziegler, W. Dahme, F. Feld-Dahme, U. Schaefer, W. R.

Wodrich, S. Ahmad, J. C. Bizot, B. Delcourt, J. Jeanjean, H. Nguyen, N. Prevot, E. G. Auld,

D. A. Axen, K. L. Erdman, B. Howard, R. Howard, B. L. White, M. Comyn, G. Beer, G. M.

Marshall, L. P. Robertson, M. Botlo, C. Laa, and H. Vonach, “Antiproton annihilation at rest

in nitrogen and deuterium gas,” Phys. Rev. C, vol. 40, pp. 2717–2731, Dec 1989.

IV. Renewal of the collaboration for 2023

IV.1 Proposed scientific program

Description

Despite the century since the discovery of the neutron by E. Rutherford, few details are known for certain about this particle. Our goal is to provide theoretical guidance to answer key questions for probing neutron distributions with antimatter as pursued by the CERN/PUMA experiment [5]. Our approach relies on high-fidelity ab initio reaction methods and aims to develop theoretically controlled uncertainties with Effective Field Theory.

First, this requires to revisit the knowledge already gathered with microscopic phenomenological potential models. We focus on the Paris nucleon-antinucleon potential of [6]. We have built a smooth version. Furthermore, while keeping a good fit to the scattering observables, we will readjust the parameters to the position quasibound and/or resonant nucleon-antinucleon states as suggested by the study of the light antiprotonic atoms carried out in [7].

The final goal of this collaboration, required to understand the results of [7], is to predict the rate of the antiproton capture on proton relative to the antiproton capture on neutron, Rn/p. This is an input into PUMA experimental analysis. Past antiprotonic measurements of Rn/p in light elements yield puzzling results. So far, Paris potential [6] predicts reasonable values for Deuteron and Helium but only within 10 to 20% precision [7].

This collaboration also offers a unique pipeline for the ANR project of the spokeperson and the hired PhD student working on the ab initio calculation for s- to p-shell nuclei. We will profit from knowledge gather in the earlier days of the antimatter physics and create new bridges with collaborator in Poland.

References

[5] T. Aumann, W. Bartmann, O. Boine-Frankenheim, A. Bouvard, A. Broche, F. Butin, D. Calvet, J. Carbonell, P. Chiggiato, H. D. Gersem, R. D. Oliveira, T. Dobers, F. Ehm, J. F. Somoza, J. Fischer, M. Fraser, E. Friedrich, A. Frotscher, M. Gomez-Ramos, J.-L. Grenard, A. Hobl, G. Hupin, A. Husson, P. Indelicato, K. Johnston, C. Klink, Y. Kubota, R. Lazauskas, S. Malbrunot-Ettenauer, N. Marsic, W. F. O. Müller, S. Naimi, N. Nakatsuka, R. Necca, D. Neidherr, G. Neyens, A. Obertelli, Y. Ono, S. Pasinelli, N. Paul, E. C. Pollacco, D. Rossi, H. Scheit, M. Schlaich, A. Schmidt, L. Schweikhard, R. Seki, S. Sels, E. Siesling, T. Uesaka, M. Vilén, M. Wada, F. Wienholtz, S. Wycech, and S. Zacarias, "Puma, antiproton unstable matter annihilation," The European Physical Journal A, vol. 58, p. 88, 5 2022.

[6] B. El-Bennich, M. Lacombe, B. Loiseau, and S. Wycech, “Paris N N

potential constrained

by recent antiprotonic-atom data and np total cross sections,” Physical Review C, vol. 79,

p. 054001, 5 2009.

[7] B. Loiseau and S. Wycech, “Extraction of baryonia from the lightest antiprotonic atoms,”

Physical Review C, vol. 102, p. 034006, 9 2020.

IV.2 Estimated duration for IN2P3 scientists in COPIN	
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Comment Validation	
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