ASACUSA collaboration Meeting : Proposal for Run 4 and beyond

Report of Contributions

https://indico.cern.ch/e/1512111

Contribution ID: **2** Type: **Antihydrogen**

Plasma and trap development to improve the properties of the antihydrogen beam

Wednesday 2 April 2025 15:00 (50 minutes)

Antiprotons:
The Double Cusp Magnet is optimized to focus ground state low-field-seeking (GS-LFS) atoms with kinetic energy equivalent to a temperature T in the range 5 < T < 20 K. If we can reduce the Hbar energy to this range, then at least x10 more GS-LFS atoms will escape the trap as a beam compared to 2024 (or more than x10, since lower T increases the time Hbar spends in the positron plasma → deexcitation).
With ALPHA-like mixing, we reduce Hbar T mainly by reducing pbar T, which is increasingly difficult as we increase the number of pbar in the plasma. Note: the ToF signal suggests that many Hbar are well below plasma T, which could be explained by collisional cooling in repeated passes through the positrons.
With the beam scheme, the pbar energy is set by the potentials and the scoop T, which is lower than for a large pbar plasma (˜100 K in 2024) because e-kick is done per-scoop, so that fewer e- are kicked at one time. This is further motivation to pursue the beam scheme, in spite of its technical challenges.

Positrons:
Reducing the temperature of the positrons reduces the average principal quantum number of the Hbar and increases the chances that a stable atom is formed at low radius. Thus, both the low-n fraction and the absolute number of beam-like atoms are greater with colder positrons. Increasing the number of positrons also means more chances to deexcite on the way out of the plasma.
In 2024 we used 120 Me+ at 44 K. Our trap should be able to fit at least x2 more positrons. We know of no fundamental reason why we should not be able to reach 25 K. With modifications to the trap, 10 K or lower may be possible.

Contribution area

Existing Hardware Upgrade

Author: HUNTER, Eric (CERN)

Presenter: HUNTER, Eric (CERN)

Contribution ID: **3** Type: **Antiprotonic Atom**

Antiprotonic atom x-ray spectroscopy at ASACUSA

Thursday 3 April 2025 11:05 (50 minutes)

The PAX project seeks to perform highest precision x-ray spectroscopy of Rydberg states in antiprotonic atoms in order to study strong-field QED effects in a region heretofore unexplored [1]. The project is based on the confluence of low-energy antiproton beams at ELENA, and newly available Transition Edge Sensor (TES) microcalorimeter detectors that allow for 10E-4 intrinsic energy resolution in the ˜100 keV regime, while maintaining high quantum efficiency [2].

I will present an overview of the PAX project, current status, and prospects for integrating the final experimental setup that includes a few mbar gas cell and large solid angle TES detector into the ASACUSA1 beamline.

[1] N. Paul et al, PRL 126, 173001 (2021)
[2] G. Baptista et al, arXiv:2501.08893 (2025)

Contribution area

New proposed Measurement

Author: Dr PAUL, Nancy (Laboratoire Kastler Brossel (FR))

Presenter: Dr PAUL, Nancy (Laboratoire Kastler Brossel (FR))

Contribution ID: **4** Type: **Antihydrogen**

Ramsey Spectroscopy

Thursday 3 April 2025 09:05 (50 minutes)

A grant application (FWF) is planned for this year. We will propose to develop the required techniques for Ramsey spectroscopy with hydrogen in a short (Rabi) setup in Vienna.
To achieve static magnetic fields of sufficient homogeneity over the increased volume of the Ramsey spectrometer a Type I superconducting tube shall be used. Providing the 1.42 GHz microwaves inside this tube without compromising the static field quality needs to be developed. The timeline would fit to finish developments and tests before the end of the next long shutdown in order to propose an built the Hbar Ramsey spectrometer based on the results.
(NB: the UHV requirements will benefit from such a cryogenic spectrometer beamline)

Contribution area

New Technical Development

Author: SIMON, Martin (Austrian Academy of Sciences (AT))

Presenter: SIMON, Martin (Austrian Academy of Sciences (AT))

Contribution ID: **6** Type: **Antiproton**

Antiproton Interferometry and the Aharonov-Bohm Effect (AIABE)

Thursday 3 April 2025 17:10 (50 minutes)

We propose a three-step program to address the issue of antiproton interferometry and the Aharonov-Bohm effect with the antiproton. In the first part of the development we will make use of the (100 keV) TELMAX beam to characterize the geometrical reconstruction by pions of the antiprotons impact point. The following step will be the first direct demonstration of antiproton interferometry, realized by means of dedicated gratings and a high resolution emulsion detector. Finally, once produced the interferometric pattern, we will study the Aharonov-Bohm effect, which has never been observed for any particles other than the electron. The second and third steps will require the very low energy (250 eV) ASACUSA antiproton beam from the MUSASHI system.

Contribution area

New proposed Measurement

Author: GIAMMARCHI, Marco (Università degli Studi e INFN Milano (IT))

Presenter: GIAMMARCHI, Marco (Università degli Studi e INFN Milano (IT))

Contribution ID: **8** Type: **Antihydrogen**

Spectroscopy of excited states of Hbar & wild ideas in Antimatter chemistry

Wednesday 2 April 2025 14:10 (50 minutes)

Experiments on excited states of antihydrogen already present in the beam will be proposed and presented including Lamb shift measurements (sensitive to antiproton radius) and spectroscopy of Ry states (sensitive to anti-Rydberg constant). Far future prospects for making different low energy antimatter species may be presented if I have time.

Contribution area

New proposed Measurement

Author: Dr MURTAGH, Daniel James (Austrian Academy of Sciences (AT))

Presenter: Dr MURTAGH, Daniel James (Austrian Academy of Sciences (AT))

Contribution ID: **9** Type: **Antihydrogen**

Future ideas for Hbar Detection

Friday 4 April 2025 09:00 (30 minutes)

In this talk I will discuss options for upgrading the antihydrogen detector.

Contribution area

Existing Hardware Upgrade

Author: KRAXBERGER, Viktoria (Austrian Academy of Sciences (AT))

Presenter: KRAXBERGER, Viktoria (Austrian Academy of Sciences (AT))

Contribution ID: **11** Type: **Antiprotonic Atom**

Antiproton Impact Ionisation and Antiprotonic Atom Formation

Thursday 3 April 2025 14:00 (50 minutes)

MUSASHI can provide 1-1000 eV pbar beams that enable the study of elementary atomic processes of ionisation by antiproton impact and antiprotonic atom (pbarA) formation under single collision conditions. ASACUSA had measured ionisation cross sections of atomic or molecular targets such as D2, He, Ar, etc., down to 2.4 keV. However, atomic collisions at lower energies, especially below 1 keV, remain experimentally unexplored.
The theories of atomic collisions do not agree with each other. Atomic/Molecular collision experiment with MUSASHI beam will provide a unique opportunity to study at further low collision energies and to reveal atomic collision dynamics down to eV region with pbar impact. Possible targets are H, H2, He, Ar, etc., to measure ionisation cross sections and
pbar capture cross sections of H and He.

Contribution area

New proposed Measurement

Author: KURODA, Naofumi (University of Tokyo (JP))

Presenter: KURODA, Naofumi (University of Tokyo (JP))

Contribution ID: **13** Type: **Antiproton**

Measurements of Antiproton-Nucleus Cross-Sections

Thursday 3 April 2025 15:50 (50 minutes)

This proposal outlines a two-part experimental campaign aimed at improving our understanding of antiproton-nucleus interactions. In the first part, we propose the measurement of annihilation cross-sections of antiprotons at 100 keV using the ELENA decelerator in mini-bunch mode, using a time-of-flight technique. In the second part, we extend the study to energies of 5.3 MeV and above using antiprotons from the Antiproton Decelerator. The higher energy phase will target both annihilation cross-sections and elastic scattering cross-sections, providing complementary data on nuclear structure and interactions. These experiments will fill gaps in current datasets, offering insights into nuclear physics, particle physics, and cosmology.

Contribution area

Existing Hardware Upgrade

Author: VENTURELLI, Luca (Universita di Brescia (IT) and INFN)

Presenter: VENTURELLI, Luca (Universita di Brescia (IT) and INFN)

Contribution ID: **14** Type: **Antihydrogen**

A buffer gas free positron trap

Wednesday 2 April 2025 17:40 (30 minutes)

In this presentation, a new idea for producing a buffer gas free higher efficiency positron trap will be presented

Contribution area

Existing Hardware Upgrade

Authors: Dr MURTAGH, Daniel James (Austrian Academy of Sciences (AT)); Dr SINGER, Martin (MPIPP)

Presenter: Dr SINGER, Martin (MPIPP)

Contribution ID: **15** Type: **not specified**

H-Beam Reference Measurements (possibly before LS3?)

I would like to discuss options to build and operate a parallel H-Beam experiment at the AD.
As we have a second cavity with McKeehan coils now, this could be doable with reasonable effort.
To make it a cost-efficient, low-maintenance apparatus I would propose a room temperature beam and discuss detection methods where multi-stage differential pumping can be avoided.
A simultaneous hydrogen measurement at the same place, time and orientation would be the best reference for our anti-hydrogen spectroscopy.

Contribution area

Other

Author: SIMON, Martin (Austrian Academy of Sciences (AT))

Presenter: SIMON, Martin (Austrian Academy of Sciences (AT))

Contribution ID: **16** Type: **not specified**

Road to highest precision CPT tests

Thursday 3 April 2025 09:55 (50 minutes)

I will discuss the accuracy of current CPT tests and argue that the highest resolution for spectroscopy will require a fountain.

Contribution area

Other

Author: WIDMANN, Eberhard (Austrian Academy of Sciences (AT))

Presenter: WIDMANN, Eberhard (Austrian Academy of Sciences (AT))

Contribution ID: **17** Type: **Antiproton**

Pontecorvo reaction

Thursday 3 April 2025 14:50 (40 minutes)

We propose to study annihilation on three nucleons, p3He⟶ pn, for which no data exist. The annihilation mechanism is not well known with two competing models on the market, rescattering which involves hadrons, and fireball which involves quarks. The branching fraction is predicted to be around 10**(−6) for the latter, compared to 10**(-7)–10**(-8) for rescattering. The experiment requires a continuous (DC) antiproton beam of 100 –200 keV which is not available at this time, but is part of a possible consolidation programme of the AD/ELENA complex. The anticollinear 1 GeV nucleons will be detected by a detector made of scintillation counters. The detection efficiency forp 3He⟶ pn is 11% and the background rejection 10**8. The counting time for the fireball model is roughly estimated to be around 10 minutes for 1 Pontecorvo event.

Contribution area

New proposed Measurement

Author: AMSLER, Claude (SMI)

Presenter: AMSLER, Claude (SMI)

Contribution ID: **18** Type: **Antihydrogen**

Pulsed antihydrogen beams: Rydberg manipulation and charge exchange

Wednesday 2 April 2025 16:10 (45 minutes)

Charge exchange between an antiproton and a positronium atom can produce antihydrogen. If Rydberg positronium is used a resonant mechanism can produce Rydberg antihydrogen in well defined states. The feasibility of using this mechanism to produce a pulsed antihydrogen beam will be explored.

Contribution area

New Technical Development

Author: SHELDON, Ross Edward (Austrian Academy of Sciences (AT))

Presenter: SHELDON, Ross Edward (Austrian Academy of Sciences (AT))

Contribution ID: **19** Type: **Antiproton**

MCP counting efficiency vs. antiproton reflections

Thursday 3 April 2025 16:40 (30 minutes)

Antiprotons can reflect from MCP surfaces. We aim to characterize this effect to inprove our diagnostics. By extracting particles from a pure antiproton plasma from the Cusp trap to the Cusp MCP in short bunches, we are able to measure their arrival times. If we make a histogram of arrival times, we expect a main peak upon first arrival, as well as multiple smaller peaks from reflections between the MCP and the trap. Biasing the MCP front would allow us to investigate this effect in different energy regimes.

Contribution area

New proposed Measurement

Author: BUMBAR, Marcus (University of Vienna (AT))

Co-authors: HUNTER, Eric David (University of California Berkeley (US)); HORI, Masaki (Imperial College London)

Presenter: BUMBAR, Marcus (University of Vienna (AT))

Contribution ID: **20** Type: **Antihydrogen**

Non-destructive diagnostics and manipulation techniques - overview and perspectives

Wednesday 2 April 2025 16:55 (45 minutes)

An array of diagnostic and manipulation methods share the use of trap-wall electrostatic perturbations and/or induced-charge signals. Possibilities include measurement of basic sample properties (number, density, temperature) as well as their control (e.g., feedback- or autoresonant positioning, collective mode cooling). Some of these possibilities have been tossed around and partially tested in the last runs, highlighting critical aspects of their exploitation. Indeed, as these techniques are based on the detection of single-particle and collective-mode signals, their effective implementation may become harder (or at least different) as the particle number and temperature is reduced, and thus require hardware development and setup modifications. A discussion about the collaboration's long-term scientific plan seems the right time and place to evaluate pros and cons of endeavours in this direction.

Contribution area

New Technical Development

Author: MAERO, Giancarlo (Università degli Studi e INFN Milano (IT))

Presenter: MAERO, Giancarlo (Università degli Studi e INFN Milano (IT))

Contribution ID: **21** Type: **not specified**

Welcome

Wednesday 2 April 2025 14:00 (10 minutes)

Presenter: HORI, Masaki (Imperial College London)

Contribution ID: **22** Type: **not specified**

Coffee break

Contribution ID: **23** Type: **not specified**

Mainboard closed session

Thursday 3 April 2025 11:55 (20 minutes)

Contribution ID: **24** Type: **not specified**

Antiprotonic helium atoms, PAX incorporation into ASACUSA-1 beamline, status of antideuteron R&D at AD, and other ideas

Friday 4 April 2025 09:30 (50 minutes)

Presenter: HORI, Masaki (Imperial College London)

Contribution ID: **25** Type: **not specified**

ASACUSA proposal discussion

Friday 4 April 2025 10:40 (1h 50m)

Contribution ID: **26** Type: **not specified**

ASACUSA proposal discussion and any other business (ends earlier if possible)

Friday 4 April 2025 13:30 (1h 30m)

Contribution ID: **27** Type: **not specified**

Logistics

Thursday 3 April 2025 09:00 (5 minutes)

Presenter: HORI, Masaki (Imperial College London)