NEWS*letter*

MIRROR

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Dear friends of low energy antimatter and ion physics,

Feedback on the first edition of the MIRROR was outstanding and we are pleased to see that the number of recipients has already more than doubled in only two months. We would like to cordially thank you for your interest, good suggestions for further improvement, and active input. This shows that there is huge interest in all matters antimatter (sorry for the pun) and in particular the science programmes at the AD and future FLAIR facilities.

In this newsletter edition we highlight some very interesting studies that have recently been published and that are important for further progress in pbar physics. We also give an outlook on some upcoming conferences and present selected position vacancies.

We look forward to your contributions to future editions of MIRROR and hope that you will enjoy this one.

With our very best wishes

Carsten, Thomas and Jochen

News from F(L)AIR

FAIR Facility for Antiproton and Ion Research in Europe GmbH

We are delighted to inform you that the collaboration now has a new and modernized web page.

The webpage shall be the main communication platform of the FLAIR collaboration. It already contains information about the FLAIR facility and our research program, a list of selected publications and talks, as well as information about position vacancies and upcoming events. It also allows download of the quarterly MIRROR.

High-precision comparison of the antiproton-to-proton charge-to-mass ratio

In a paper published recently in *Nature* (524,196–199 (13 August 2015)), the Baryon Antibaryon Symmetry Experiment (BASE) at CERN's Antiproton Decelerator (AD), reported on a 69ppt comparison of the charge-to-mass ratio of the proton to that of its antimatter equivalent, the antiproton. The new result shows no difference between the proton and the antiproton. The measurement improves the energy resolution of previous measurements by a factor of four.

The Standard Model of particle physics – the theory that best describes particles and their fundamental interactions – is known to be incomplete. This inspires v arious searches for “new physics”. These include tests that compare the basic characteristics of matter particles with those of their antimatter counterparts. While matter and antimatter particles can differ, for example, in the way they decay (a difference often referred to as violation of CP symmetry), other fundamental properties, such as the absolute value of their electric charges and masses, are predicted to be exactly identical, apart from signs. Any measured difference between the charge-to-mass ratio of protons and antiprotons would break the fundamental CPT symmetry. This symmetry reflects well-established properties of space and time and of quantum mechanics, so such a difference would constitute a dramatic challenge not only to the Standard Model, but also to the basic theoretical framework of particle physics.

To perform the experiment BASE compared antiproton cyclotron frequencies to those of negatively charged hydrogen ions, which were used as a proxy for protons. The measurements were carried out in an advanced Penning-trap system. A single antiproton and a single H- ion were parked upstream and downstream of a measurement trap, respectively. Within 15s the particles were interchanged by adiabatic potential ramps. Together with the cyclotron frequency measurements one single frequency ratio comparison took only 240s. This fast shuttling approach has allowed BASE to carry out about 13,000 measurements over a 35-day campaign.

As a next step BASE will target the high precision measurement of the magnetic moment of the antiproton. Recently the collaboration performed the most precise measurement of the magnetic moment of the proton with a fractional precision of 3.3 parts in a billion. Application of this technique to the antiproton will improve the currently most precise value of the antiproton magnetic moment by more than a factor of 1000.

Read the paper.

Antiproton beam life time and stability

A particular challenge for low energy storage rings is th e question of achievable beam life time and beam quality. In a paper recently published in Journal of Instrumentation, J. Resta-Lopez et al. [1] address this question through long term beam dynamics simulations in ELENA, considering different effects limiting the achievable phase space volume.

The results provide a better understanding of the beam dynamics for the ELENA in particular, but are highly relevant for any other low energy ion storage ring as well.

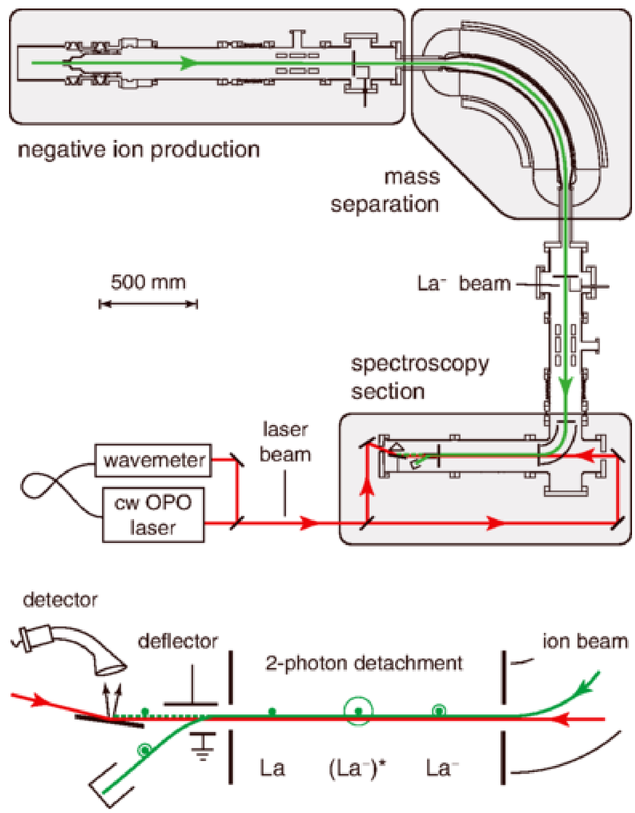
You can read the article here.

[1] J. Resta Lepz, et al., “Simulation studies of the beam cooling process in presence of heating effects in the Extra Low ENergy Antiproton ring (ELENA)”, JINST 10 E08001 (2015).

Lanthanum a promising candidate for anion laser cooling

Anions play an important role in many research fields ranging from plasma physics to atmospheric science and astrophysics. Despite their relevance, it is as of yet impossible to study them at ultracold temperatures. With presently available cooling techniques (such as electron, buffer gas, or resistive cooling), anions can at best be cooled to the temperature of the surrounding environment, typically a few kelvin. An indirect cooling technique for negative ions, involving laser cooling of atomic anions, holds the potential to overcome that restriction [1]. Ultracold ensembles of any negative ion species could be produced by sympathetic cooling. Ultimately it is planned to apply the technique to antiprotons and thus to produce ultracold antihydrogen for the antimatter gravity experiment AEGIS [2]. However, until recently no atomic anions with suitable strong electric-dipole transitions – a prerequisite for laser cooling – were known to exist.

Over the last few years a very small number of such systems have been identified and studied both theoretically and experimentally. After Os^- and Ce^-, current investigations concentrate on the lanthanum anion, which has been predicted to sustain a strong bound–bound electric-dipole transition. The group of Alban Kellerbauer at the MPI for Nuclear Physics in Heidelberg has studied this transition, between the $5d^2\,6s^2\,{}^3F_2$ ground state and the $5d\,6s^2\,6p\,{}^3D_1$ excited state, by high-resolution laser spectroscopy [3]. They resolved the hyperfine structure and unambiguously assigned the recorded peaks in the spectrum to transitions between the HFS levels of the ground and excited states. The experimental results suggest that La^- is an excellent candidate for the first laser cooling of anions, assuming the transition rates are as high as theoretically predicted. Measurements on the resonant cross-section of the transition are forthcoming.



[1] A. Kellerbauer and J. Walz, New J. Phys. **45** (2006) 8, http://dx.doi.org/10.1088/1367-2630/8/3/045 .
[2] M. Doser *et al.* (AEGIS Collaboration), Class. Quantum Grav. **29** (2012) 184009, http://dx.doi.org/10.1088/0264-9381/29/18/184009 .
[3] E. Jordan, G. Cerchiari, S. Fritzsche and A. Kellerbauer, Phys. Rev. Lett. 115 (2015) 113001, http://dx.doi.org/10.1103/PhysRevLett.115.113001 .

International Workshop on Antiproton Physics and Technology at FAIR

From 16th-19th of November 2015 the Budker Institute of Nuclear Physics (BINP) will host an International Workshop on Antiproton Physics and Technology at FAIR.
The workshop will be devoted to the physics, detector and accelerator instrumentation and data handling at the future Facility for Antiproton and Ion Research in Europe (FAIR). It will have a special focus also on the scientific program of FLAIR.
To find out more and register visit http://fair15.inp.nsk.su

LEAP 2016

Interview with the Chair of the Organizing Committee, Prof. Yasunori Yamazaki, RIKEN

Dear Prof. Yamazaki, you will chair the next LEAP conference which will be held in the historic town of Kanazawa in Japan. What will be the main focus of this conference edition ?
Prof. Yamazaki: As the conference name tells the main focus is on the physics research pursued with low energy antiprotons which covers fundamental physics, nuclear physics, as well as atomic physics. Of course, various related fields such as antimatter in the universe, dynamics of strong interaction and hadronic matter are in the scope of the conference.

Could you summarize some of the scientific highlights delegates can expect to learn about during LEAP?
Prof. Yamazaki: The latest results from all collaborations at AD after the long shutdown of the CERN accelerator complex in 2013 will be comprehensively presented for the first time. The status of the new decelerator, ELENA (Extra Low Energy Antiprotons) will also be presented. ELENA is scheduled to start its operation in 2017 providing 100keV antiproton beams. This is a big step toward the next generation low energy antiproton research. New results from AMS (Alpha Magnetic Spectrometer) launched in 2011 are expected to present exciting information on the dark matter and antimatter in the universe. It is also noted that the community is still growing, and two new collaborations (Gbar and BASE) have been established after the last LEAP in Uppsala, 2013.

You have been a driving force behind fundamental experiments with low energy antiprotons for more than two decades. Which are the milestones that were achieved that you remember most ?
Prof. Yamazaki: It is of course almost impossible to pick up a few examples out of a large number of various important achievements. If however the answer is limited in the last decade, the trapping of antihydrogen as well as the formation of cold antihydrogen beam would be very important achievements. Actually, both have paved a way to make physics study with antihydrogen atoms. It is also noted that the success of the direct measurements of proton and antiproton magnetic moments was a big jump toward cold antimatter physics.

There has been enormous progress in the physics with low energy antiprotons. Where do you currently see the main remaining challenges for the AD and FLAIR user communities ?
Prof. Yamazaki: Actually, various big improvements have been realized in the field of antiproton and antihydrogen handling techniques. Because of these improvements, various physics research such as the spectroscopy of antihydrogen atoms, the magnetic moment of antiproton, the gravitational interaction between antimatter and matter are now within reach. We are at last at the entrance of these fruitful physics.

Kanazawa seems to be an unusual conference destination. What made you chose this particular venue?
Prof. Yamazaki: Kanazawa is known to be one of the most beautiful traditional cities in Japan , which still keeps the atmosphere of Edo period started about 400 years ago and even before. At the same time, Kanazawa is well-modernized so that foreign visitors can enjoy the city well-relaxed. Another important point is that Shinkansen (bullet train) has started its operation from 2015, and Kanazawa can be directly reached from Tokyo in ~3hours. It is also noted that Shirakawa-go, one of the world heritages in Japan, is in one hour trip by car and bus. We will organize the conference excursion to Shirakawa-go.

Yasunori Yamazaki was born in Osaka, Japan, in 1949. He graduated from the Department of Physics, Osaka University, in 1973, received his master degree in 1975, and obtained his doctoral degree in 1978 from the Department of Applied Physics at the same institute. He was appointed research associate of the Tokyo Institute of Technology in 1978, associate professor of The University of Tokyo in 1988, and professor at the same university in 1993. He was jointly appointed as chief scientist at RIKEN in 1997. From 2010, he has held the title of distinguished senior scientist of RIKEN and professor emeritus of The University of Tokyo. His research interests are cold antimatter science with antihydrogen atoms as well as applications of beam physics to various fields of natural science, including living cell surgery, micromodification of liquid–solid interfaces and virtual x-ray spectroscopy of relativistic highly charged heavy ions channeling through crystalline targets.

The LEAP (Low Energy Antiproton Physics) **conference** is held every two or three years since 1990 to discuss the latest findings and exchange information in the interdisciplinary fields with low energy antiprotons. The intent of LEAP 2016 is to actively stimulate the overlap and dialogue between various research forefronts in the diversified field of antiproton physics and related field involving meson and baryon with strangeness. You can find out more and register for the conference via this website.

Selected Research Papers

In the future, we will list selected R&D highlights here – please email us your publications for consideration.

Position Vacancies

Professor/Reader in Novel Methods of Particle Acceleration
Lancaster University, Uk

Scientist (f/m) accelerator physics permanent position
DESY, Germany

Fellowship within the OMA European Training Network
The OMA network is currently offering 15 fellowships at partner institutions across Europe

Please keep us informed about vacancies at your institution.

Selected Events

International Conference on Accelerator Optimization
7–9 October 2015, CNA, Seville, Spain

International Workshop on Antiproton Physics and Technology at FAIR
16-19 November 2015, Budker Institute of Nuclear Physics, Novosibirsk, Russia

12th International Conference on Low Energy Antiproton Physics (LEAP2016)
6-11 March 2016, Kanazawa, Japan

7th International Particle Accelerator Conference
8-13 May 2016, Busan, Korea

The collaboration is often requested to present research highlights and suggest good speakers to various program committees. If you think you or your work should be highlighted, please do not hesitate to get in touch with us.

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