Foreword

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Low-energy antiproton physics is an interdisciplinary field centred around the antimatter partner of the proton, ranging from particle, nuclear, atomic and astrophysics to applied physics. It confronts directly the symmetry between matter and antimatter and addresses many key questions of contemporary research: What are the fundamental symmetries of nature and in which way are they violated? Why is there basically no antimatter in the universe? How does the strong interaction and its symmetries shape the structure of hadrons? Does matter and antimatter respond in the same way to gravity?

The highly acclaimed synthesis and trapping of antihydrogen atoms at CERNs Antiproton Decelerator (AD) provides unique opportunities to probe the fundamental laws and symmetries. Satellite and balloon experiments are searching for cosmic antimatter, the results of which could have profound implications on cosmology. Antiprotons will be used to study the properties and structures of atoms, nuclei and hadrons at the upcoming Facility for Antiproton and Ion Research (FAIR) in Darmstadt.

In these very exciting times for antiproton research LEAP 2013, the 11th International Conference on Low Energy Antiproton Physics, was organised at the Ångström Laboratory, Uppsala University, Sweden, during 11 – 15 June. The conference was jointly hosted by the Dept. of Physics and Astronomy and the Dept. of Chemistry of Uppsala University with Tord Johansson as chair and Piotr Froelich as co-chair. The conference attracted nearly 100 participants and featured more than 20 invited plenary speakers, more than 20 contributed talks and a dozen posters with an emphasis on promoting young researchers. Some of the highlights of the packed programme are presented in the following.

Proceedings of the 11th International Conference on Low Energy Antiproton Physics (LEAP 2013)
held in Uppsala, Sweden, 10–15 June, 2013

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1 Symmetries and antihydrogen

The conference began with a session on symmetries covering theoretical and experimental overviews of testing fundamental symmetries. At the centre of this is the CPT symmetry, the combined action of changing particles and antiparticles (charge conjugation, C), parity transformation (P) and time reversal (T). A violation of this symmetry would have severe consequences for our understanding of the laws of nature since invariance under CPT emerges directly from quantum field theory and Lorentz invariance. Several approaches to test this symmetry at the AD were presented during the conference. Especially encouraging were the reports on the rapid progress in trapping and cooling antihydrogen atoms that allowed first experiments on the road towards tests of the CPT-symmetry in the domain of (anti)atomic physics. The ALPHA collaboration reported on the first measurement of hyperfine transition in ground state antihydrogen and reviewed their future plans. The ATRAP collaboration reported on a large improvement of the measured value of the antiproton magnetic moment, as well as their latest progress in antihydrogen formation using a double charge exchange process. The ASACUSA collaboration reported on the two-photon laser spectroscopy measurements on antiprotonic helium that has yielded the most precise measurement of the antiproton-electron mass ratio to date. They also reviewed their approach towards the hyperfine spectroscopy of antihydrogen. The Baryon Antibaryon Symmetry Experiment (BASE) presented their intent to make a test of CPT invariance by a precise comparison between the proton and antiproton magnetic moment.

2 Antimatter in the universe

The constraints on the presence of antimatter in the Universe were reviewed. An excess of antiparticles, compared to expectations in the cosmic radiation could be a signal from dark matter particles. The PAMELA satellite-borne experiment presented their results on the positron and antiproton flux in the cosmic radiation. The Alpha Magnetic Spectrometer Experiment (AMS) at the International Space Station presented high statistics result on positron and electron fluxes up to 350 GeV. The positron fraction in the data shows no fine structure or anisotropy but it seems as a large portion of the high-energy electrons and positrons originate from an unknown common source.

3 Gravity

The gravitational interaction of antimatter with matter was discussed both from the theoretical and experimental side. An antiapple is expected to fall down on earth exactly as an ordinary apple according to Einsteins Weak Equivalence Principle (WEP). This principle has, however, never been tested experimentally for antimatter and, as pointed out at the conference, there is room for a difference between matter-matter and antimatter-matter gravitational interaction within certain theoretical frameworks. The result from the TRAP collaboration on a gravitational redshift limit from simultaneously trapped protons and antiprotons was presented as a stringent test of the difference in the gravitational constant for matter and antimatter. The AEgIS and GBAR collaborations presented their approaches towards a measurement of the gravitational acceleration of antihydrogen at

the AD. The ALPHA collaboration presented the first measurement on the effect of gravity on an ensemble of antihydrogen atoms in a trap. The error bars, in this pioneering test, are too large to draw any definite conclusions, but the first experimental step has been taken.

4 Hadron physics

Antiprotons are also excellent tools for hadron physics, as already proven at the LEAR facility at CERN. The gluon rich antiproton-proton annihilation makes these reactions ideal to search for exotic hadrons with gluon content, i.e. glueballs (hadrons consisting only of gluons) and hybrids (hadrons having a gluon component). The FAIR facility will open up a new era in this field. The hadron physics programme of the PANDA collaboration at FAIR, that will address this topic, was presented. Charmed meson spectroscopy is also on its programme. This is a hot topic, that was reviewed during the conference, due to recently discovered narrow X,Y,Z charmonium-like mesons, some of which cannot be explained as being ordinary quark-antiquark configurations. Other topics that were covered both from theoretical and experimental points of view were double lambda hypernuclei and nucleon structure.

5 Facilities and instrumentation

The near-future upgrades for antiatomic physics were discussed, such as the construction of the Extra Low Energy Antiproton ring (ELENA) at the AD that will lower the energy of the antiprotons and thereby increase the number of useful antiprotons for stop experiments by up to two orders of magnitude.

The transfer of the storage ring CRYRING from Stockholm will allow for an early start of physics with low energy antiprotons at FAIR. Many developments towards a more efficient production of antihydrogen as well as the instrumentation of the PANDA detector were discussed.

6 Applications

Talks on applications and new techniques with antiprotons included the ACE experiment at the AD, which is studying the possible use of antiprotons for cancer therapy, and developments towards spin-polarized antiprotons and antihydrogen.

The conference included a boat trip to the 17th century renaissance castle Skokloster. At the conference dinner gave Prof. em. Gösta Ekspong a celebrated exposé of his first hand memories of the discovery of the antiproton at the Bevatron in Berkley. LEAP 2013 ended with two well-attended public lectures that presented the role of symmetries in physics, both from the experimental and theoretical perspective. Gerard Gabrielse, Harvard University talked about “Cold matter and antimatter – how similar are they?” and Ulf Danielsson, Uppsala University, “Mirror, mirror on the wall– the beauty of the universe and its symmetries”. The next LEAP meeting is planned for Kanazawa, Japan, in 2016, and will be chaired by Yasunori Yamazaki. For full details of the speakers and the presentations, see <http://www.physics.uu.se/leap2013>

In memoriam Paul Kienle (1931–2013)