

Abstracts

Wednesday , January the 11th. 2012

Presenter : Marcelo Baquero-Ruiz

Title: Autoresonant-spectrometric determination of the residual gas composition in the ALPHA experiment apparatus.

Description:

The ALPHA antihydrogen trapping apparatus uses a cryogenic vacuum system that allows us to work at very low pressures and neutral particle densities. Nevertheless, it has been seen that the few neutral gas particles remaining in the trap have a small but noticeable effect on some of our experiments. This makes it interesting for us to know the density and composition of the neutral particles. Here we report the implementation of a system for measuring the composition of the residual gas inside the apparatus based on autoresonant ion extraction from an electrostatic potential well. The system uses the setup already in place for the experiment and offers an effective and non-invasive way of measuring the substances present inside our apparatus.

Presenter: Alexander Wunderle for the α SPECT Collaboration

Title: Trapped particles in the α SPECT spectrometer as a source of background.

Description:

The retardation spectrometer α SPECT is designed to determine the electron-antineutrino angular correlation coefficient a in the free neutron decay with high precision. This is achieved by measuring the proton recoil spectrum precisely, which then allows to test several parameters of the Standard Model of particle physics with high precision. The spectrometer itself is set up at the Institut Laue-Langevin (ILL) in Grenoble/France, the strongest source of neutrons in the world.

α SPECT uses a system of electrodes mounted inside a system of superconducting magnets to measure the angular coefficient a . The electric potential of these electrodes in combination with the magnetic field create particle traps of different depth inside the spectrometer. Field emission or decay products of the neutron beam can ionize residual gas and the resulting ions and electrons be caught in such a trap. They in turn can ionize residual gas, which may leave the trap. Reacceleration of some of the charged particles can lead to a self-sustaining process with a constant production of ionized particles, or even worse to a discharge burning inside the spectrometer.

Discharges inside the spectrometer have to be avoided, as they can seriously damage or destroy the silicon drift detector used to count the protons. But even a low production rate of ions from these traps is problematic, as these ions constitute a major source of background in α SPECT. However, traps in the spectrometer cannot be avoided, as the conditions leading to traps are essential for the operating principle of α SPECT. Therefore, the filling mechanisms of the traps have to be reduced as far as possible. The vacuum has to be as good as possible to reduce the residual gas. Additionally, several mechanisms have been and will be installed to empty the traps to avoid discharges and reduce the background.

Presenter: Ingo Baumgart

Title: Quantum Gates and Memory using Microwave Dressed States

Description :

We demonstrate basic building blocks of a quantum memory based on microwave dressed states of trapped ions. These dressed states are immune against decoherence induced by external noise fields. We measure dressed states lifetimes and a coherence times enhancement of more than 200 times compared to the bare states. This generic scheme can be applied to microwave- or laser-based ion trap schemes for quantum information science and also to other physical systems suffering from magnetic noise.

Presenter : Vanessa Simon

Title: The TITAN cooler Penning trap -- a new approach to high precision mass measurements

Description :

Accurate mass measurements provide vital information and offer key knowledge for the description of nuclear astrophysical processes, nuclear structure, and for tests of fundamental symmetries. Many of the relevant isotopes, for example isotopes involved in the nucleosynthesis of the heavy elements in the universe, are radioactive and short-lived.

TITAN is an experimental setup at ISAC dedicated to high precision mass measurement of nuclei with short half-lives. The lifetime of radioactive nuclei restricts the achievable mass resolution, which is proportional to the observation time in resonance-based mass spectrometry in Penning traps. One way to overcome this restriction is by increasing the charge state. TITAN has demonstrated this capability and is presently the only facility with an operational online charge breeding Electron Beam Ion Trap (EBIT), performing mass measurements on n-deficient Rb, n-rich Rb, Sr and Ga. Using an EBIT results in an energy spread of the ions of tens of eV/q, which in turn is negatively reflected in the mass measurement in the precision Penning trap.

A Cooler Penning Trap (CPET) is presently being developed to cool highly charged ions prior to the mass measurement which will increase the efficiency and precision. This is a novel concept and both electron and proton cooling will be tested. Additionally, CPET will incorporate mass selective cooling techniques, which provide specific mass-to-charge ratios for the extracted ion. The concept of preparing highly charged ions in a Penning trap as well as the status of the project will be presented.

Presenter : Alexander Windberger

Title :

Description :

Presenter : Philipp Schmid

Design of a cold nanoparticle source for quantum experiments

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The generation of cold samples of neutral, large molecules, clusters or nanocrystals in the gas phase is an important challenge for experiments that aim at probing the foundations and applications of quantum physics, especially in matter wave interferometry [1,2], quantum metrology [3] and other quantum optics experiments.

While matrix assisted laser desorption (MALDI) [4] or cluster sources [5] are dedicated tools for the preparation of singly charged gas-phase ions even in excess of 1 MDa, the preparation of neutral mass selected particle beams still proves to be difficult, in particular if the molecules shall be internally cold, well collimated and slow ($T \approx 10$ K).

We discuss our experimental approach towards preparing such samples: A laser desorption source fills a cryogenic buffer gas loaded ion trap with negatively charged ions. Neutral particles can be obtained from the internally and externally cold ions by subsequent laser detachment and post-neutralization.

We will present furthermore the current development status of this dedicated trap setup in our laboratory. Ideas for loading, trapping and detecting such particles will be shown – with an eye on minimized heating and the flexibility to be coupled to various particle sources and quantum optics experiments.

[1] S. Gerlich, S. Eibenberger, M. Tomandl, S. Nimmrichter, K. Hornberger, P. J. Fagan, J. Tüxen, M. Mayor, and M. Arndt, *Nature Communications* 2, 263 (2011)

[2] O. Romero-Isart, A.C. Pflanzer, F. Blaser, R. Kaltenbaek, N. Kiesel, M. Aspelmeyer, J.I. Cirac, *Physical Review Letters* 107, 020405 (2011)

[3] S. Gerlich, M. Gring, H. Ulbricht, K. Hornberger, J. Tüxen, M. Mayor and M. Arndt, *Angew. Chem. Int. Ed.* 47, 6195, (2008)

[4] M. Karas and F. Hillenkamp, *Anal. Chem.* 60, 2299 (1988).

[5] H. Haberland, M. Mall, M. Moseler, Y. Qiang, T. Reiners and Y. Thurner, *J. Vac.Sci.Technol. A* 12, 2925 (1994).

Presenter : Florian Leupold

Title: Development of a cryogenic surface-electrode ion-trap setup

Authors:

F. Leupold, L. de Clercq, F. Lindenfesler, J. Alonso, R. Habluetzel,
B. Keitch, D. Kienzler, H.-Y. Lo, M. Sepiol, and J. Home

Description:

We are developing a cryogenic ion-trap setup for investigating quantum control of trapped ions in micro-fabricated surface-electrode traps. The experiments we will perform involve quantum control of both beryllium and calcium ions, which presents a challenge for trap design due to the different ion masses. Among other things the experiments we want to carry out require:

A cryogenic UHV system and achromatic imaging system for which we have designed a high-numerical aperture reflective single-piece objective.

Stable lasers for state preparation and manipulation of calcium ions.

We have developed home-built ultra-low-expansion-glass (ULE) Optical cavities and used them to stabilize one of our diode lasers using the Pound-Drever-Hall locking scheme.

A high level of computer control. As a first step we are developing a home-built FPGA-based servo controller with an embedded microprocessor which can run without interruption and be updated by a computer interface.

Presenter : Weibin Li

Title: Electronically excited cold ion crystals

Description:

The laser excitation of an ion crystal to high lying and long-lived electronic states is a genuine many-body process even if in fact only a single ion is excited. This is a direct manifestation of the strong coupling between internal and external dynamics and becomes most apparent in the vicinity of a structural phase transition. Here we show that utilizing highly excited states offers a new approach to the coherent manipulation of ion crystals. This opens up a new route towards the creation of non-classical motional states in a Paul trap and permits the study of quantum phenomena that rely on a strong coupling between electronic and vibrational dynamics.

Presenter : Mayerlin Nuñez Portela

Title: Towards Measuring Atomic Parity Violation in a single trapped Ra⁺

Authors: M.Nuñez Portela, H. Bekker, J.E. van den Berg, G.S. Giri, D.J. van der Hoek, K. Jungmann, W. L. Kruithof, C.J.G. Onderwater, B. Santra, R.G.E. Timmermans, O.O. Versolato, L.W. Wansbeek, L. Willmann, H.W. Wilschut
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Description:

The Ra⁺ ion is a promising candidate for high precision experiments, in particular, atomic parity violation can be measured in a single trapped and laser cooled Ra⁺, enabling a precise measurement of the electroweak mixing angle in the Standard Model of particle physics. Laser spectroscopy of trapped short-lived ²⁰⁹⁻²¹⁴Ra⁺ isotopes in a linear Paul trap has been performed. The Hyperfine Structure of the 6d² D_{3/2} states and Isotope Shift of the 6d² D_{3/2}-7p²P_{1/2} transition have been measured. These results are essential experimental input for improving the precision of atomic structure calculations. Trapping and laser cooling of few ions using an hyperbolic Paul trap is in progress, single ion spectroscopy comes next.

Presenter : Andrii Borodin

Title : Vibrational spectroscopy of a trapped and sympathetically cooled biomolecular ion species

Description :

We demonstrate vibrational spectroscopy of polyatomic ions that are trapped and sympathetically cooled by laser-cooled atomic ions. We use the protonated dipeptide tyrosine–alanine (HTyrAla+) as a model system, cooled by barium ions to less than 800 mK secular temperature. The spectroscopy is performed on the fundamental vibrational transition of a local vibrational mode at 2.74 mm using a continuous-wave optical parametric oscillator (OPO).

Resonant IR multiple-photon dissociation spectroscopy (R-IRMPD) (without the use of a UV laser) generates charged molecular fragments, which are sympathetically cooled and trapped, and subsequently released from the trap and counted. We measured the cross section for R-IRMPD under conditions of low intensity, and found it to be approximately two orders smaller than the vibrational excitation cross section. The observed rotational bandwidth of the vibrational transition is larger than the one expected from the combined effects of 300 K black-body temperature, conformer-dependent line shifts, and intramolecular vibrational relaxation broadening (J. Stearns et al., J. Chem. Phys., 2007, 127, 154322–154327). This indicates that as the internal energy of the molecule grows, an increase of the rotational temperature of the molecular ions well above room temperature (up to on the order of 1000 K), and/or an appreciable shift of the vibrational transition frequency (approx. 6–8 cm⁻¹) occurs.

Presenter : Olivier Morizot

Title: Active optics for the interrogation of a single ion

Authors:

Olivier Morizot, Gaetan Hagel, Emeline Bizri, Didier Guyomarc'h,
Caroline Champenois, Marie Houssin, Jofre Pedregosa, Martina Knoop

Description:

The signal-to-noise ratio in the detection of a single ion is one of the determining factors in the speed of the detection of the ion's internal states. Its value defines the necessary interrogation time to distinguish between an ion in the "on" and an ion in the "off" state. The improvement of the detection signal by means of active optics is a new approach in single-ion experiments. They accompany further progress in the stabilization of the clock laser for the single ion interrogation.

Presenter : Daniel Krasnicky

Title: Ultracold antihydrogen production and gravity measurement in AEGIS experiment

Description:

An overview of new experiment AEGIS, which is currently under construction at CERN's Antiproton Decelerator, is presented. The primary goal of the experiment is to measure the local gravitational acceleration g of antihydrogen in earth's field with 1% precision. This would be the first direct measurement of antimatter - matter gravitational interaction. The experiment combines many areas of modern physics.

An emphasis is given on the experimental aspects of AEGIS, as for example charged particle trap system, the method of producing cold antihydrogen and the cold beam formation mechanism. A short description of the gravity measurement is also presented along with the possible prospective measurements.

Presenter : Petar Jurcevic

Title: Quantum simulation with ions in a linear Paul Trap

Description:

An introduction into the field of quantum simulations using trapped ions is given and the concept of analog and digital quantum simulations is introduced. Three recent representative experiments in both areas performed in our group are given as examples, namely the Quantum Simulation of the Dirac Equation, the Klein Paradox and the implementation of an universal digital quantum simulator.

Presenter : Vladimir Manea

Title: ISOLTRAP: a four-trap atomic-mass spectrometer

Description:

ISOLTRAP is the pioneering Penning-trap mass spectrometer. It routinely measures the masses of exotic nuclei produced by the ISOLDE facility at CERN, with a precision of 1-2 keV. Its aims are long-standing physics topics, like the nucleon-nucleon interaction, nuclear-shell evolution and nuclear collectivity, as well as providing critical inputs for the studies of extreme nuclear environments, like neutron stars and supernova explosions.

Presenter: Mikhail Goncharov

Title: High-precision mass measurements of stored and cooled highly charged ions for fundamental studies at PENTATRAP

Description:

Precise values of atomic masses are of a great importance in many fields of physics. The cryogenic Penning Trap mass spectrometer PENTATRAP is currently under construction at the Max-Planck-Institut für Kernphysik (Heidelberg, Germany). This facility aims for high-precision mass measurements of single stable nuclides with q/m up to bare uranium.

Measurements on PENTATRAP will, e.g., open a way to an experimental determination of an upper limit for the neutrino mass in the electron capture sector with accuracy ~ 1 eV. PENTATRAP aims for a relative mass precision below 10^{-11} , which is required for QED in strong electric fields and some other tests for the determination of fundamental physical constants.

PENTATRAP R&D has been done to minimize major problems, common for Penning Trap mass spectrometers. The setup consists of five Penning Traps connected in series and put into cryogenic environment together with detection electronics. One of the traps can be used to monitor the magnetic field. This will minimize a systematic error caused by the drift of the magnetic field in time. Measurements of two ions at the same time (the ion of interest and the reference ion) will exclude the magnetic field from the resulting mass formula coming from the definition of the cyclotron frequency, which will also increase the final precision. Low-noise cryogenic amplifiers together with high quality factor tuned circuits will provide an extremely high frequency resolution.

Among the basis mentioned above poster presents a sketch of the measurement procedure, a detection principle used, and gives current overall status of the experiment.