ATOMARE PRÄZISIONSMASSENSPEKTROMETRIE (SYAM)

gemeinsam veranstaltet von den Fachverbänden
Atomphysik (A),
Hadronen und Kerne (HK) und
Massenspektrometrie (MS)

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EINLEITUNG

Eine der charakteristischen Eigenschaften eines atomaren Systems ist seine Masse. Sie ist einzigartig wie ein Fingerabdruck und daher eine fundamentale Größe in der Atom- und Kernphysik. Präzisionsmassenmessungen an kurzlebigen exotischen Kernen haben eine enorme Anwendungsvielfalt. Sie reicht von der Überprüfung von Kernmodellen bis zum Beitrag zum Test der Schwachen Wechselwirkung und der Unitarität der Cabibbo-Kobayashi-Maskawa-Matrix und damit zum Test des Standardmodels. Massenmessungen an stabilen Atomen erreichen inzwischen relative Genauigkeiten im Bereich von 10^{-11} und ermöglichen damit Experimente u.a. zur Bestimmung von Fundamentalkonstanten, zur Neudefinition des Kilogramms und zum Test der Quantenelektrodynamik und der Einsteinschen Energie-Masse-Beziehung. Das Symposium wird einen Überblick und Statusbericht der weltweit führenden Gruppen auf dem Gebiet der Präzisionsmassenspektrometrie geben.
The mass of an atomic system is one of its characteristic properties. It is unique like a fingerprint and for this reason a basic quantity in atom physics and nuclear physics. High-precision mass measurements on short-lived exotic atomic nuclei have a huge field of application. It ranges from the verification of nuclear models to a contribution towards the test of the weak interaction and the unitarity of the Cabibbo-Kobayashi-Maskawa matrix and thus to the test of the Standard Model. By now, mass measurements on stable atoms reach a relative accuracy of about 10^{-11}, which allows, among others, to perform experiments for the determination of fundamental constants, for a new definition of the kilogram and for the test of quantum electrodynamics and Einstein's energy-mass-relation. The symposium will give an overview and status report of worldwide leading groups in atomic high-precision mass spectrometry.

ÜBERSICHT DER HAUPTVORTRÄGE UND FACHSITZUNGEN

(Hörsaal HU Senatssaal)

Hauptvorträge

SYAM 1.1	Mo	10:00	(HU Senatssaal)	**The history of mass spectrometry and the Atomic-Mass Evaluation**, Georges Audi
SYAM 1.2	Mo	10:30	(HU Senatssaal)	**High-Precision Mass Measurements on Radionuclides in Storage Rings and Ion Traps**, H.-Jürgen Kluge
SYAM 1.3	Mo	11:00	(HU Senatssaal)	**Precision Mass Spectrometry of Rare Isotopes in America**, Georg Bollen
SYAM 1.4	Mo	11:30	(HU Senatssaal)	**Theory and predictability of nuclear masses**, Piet Van Isacker
SYAM 2.1	Mo	14:00	(HU Senatssaal)	**Recent trends in the determination of nuclear masses**, Juha Äystö
SYAM 2.2	Mo	14:30	(HU Senatssaal)	**A Precision Mass Balance Using Highly Charged Ions**, Reinhold Schuch, Szilard Nagy, Birgit Brandner, Marcus Suhonen, Tomas Fritioff, Klaus Blaum, Ingmar Bergström
SYAM 2.3	Mo	15:00	(HU Senatssaal)	**Precision mass spectrometry with one and two ions in a Penning trap**, Edmund Myers
SYAM 2.4	Mo	15:30	(HU Senatssaal)	**Highly Accurate Measurements of Particle and Antiparticle Masses**, Gerald Gabrielse

Fachsitzungen

SYAM 1	**Atomare Präzisionsmassenspektrometrie**	Mo 10:00–12:00	HU Senatssaal	SYAM 1.1–1.4
SYAM 2	**Atomare Präzisionsmassenspektrometrie**	Mo 14:00–16:00	HU Senatssaal	SYAM 2.1–2.4

Fachsitzungen

– Hauptvorträge –

SYAM 1 Atomare Präzisionsmassenspektrometrie

Zeit: Montag 10:00–12:00 Raum: HU Senatssaal

Hauptvortrag SYAM 1.1 Mo 10:00 HU Senatssaal

The history of mass spectrometry and the Atomic-Mass Evaluation — •Georges Audi — CSNSM, IN2P3-CNRS, et UPS, Bâtiment 108, F-91405 Orsay Campus, France

After giving the large lines of the history of mass spectrometry, I will develop some general ideas about evaluations in nuclear physics and describe the most prominent features of the Atomic Mass Evaluation (Ame), the reasons for its complexity, how they are faced and solved. I will explain why it was found essential to create the Nubase evaluation and how we finally succeeded in having Ame and Nubase co-ordinated and published for the first time together in December 2003.

Hauptvortrag SYAM 1.2 Mo 10:30 HU Senatssaal

High-Precision Mass Measurements on Radionuclides in Storage Rings and Ion Traps — •H.-Jürgen Kluge — GSI, Darmstadt and Universität Heidelberg

Mass spectrometry is a very well established technique in many disciplines of pure and applied science. In nuclear physics, high-precision mass determinations are important to directly observe nuclear structure effects such as shell closures, pairing, onset of deformation or the limits of nuclear binding. In nuclear astrophysics, the mass of radionuclides is a crucial parameter for reliable calculations of nucleosynthesis processes. Furthermore, highly precise measurements of beta-decay energies are mandatory for nuclear-physics tests of the Standard Model as, for example, the verification of the conserved-vector-current hypothesis or the check of the unitarity of the quark mixing Cabibbo-Kobayashi-Maskawa matrix. In the last decade, new ideas have been realized for high-precision mass measurements of short-lived radionuclides which both use the principle of trapping and cooling. These were pioneered on the small scale of ion traps by setting up the triple-trap mass spectrometer ISOLTRAP at ISOLDE/CERN and on the large scale of storage rings by developing the Schottky and isochronous mass spectrometry for the experimental storage ring ESR at GSI/Darmstadt. In the mean time, a large fraction of all known masses in the chart of nuclei have been determined by both devices, and throughout the world many other Penning trap facilities at accelerators are operational, in the building-up stage, or planned.

Hauptvortrag SYAM 1.3 Mo 11:00 HU Senatssaal

Precision Mass Spectrometry of Rare Isotopes in America — •Georg Bollen — Michigan State University, National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, East Lansing, MI, USA

Precise masses of nuclides far away from the valley of beta-stability are important for a better understanding of the nuclear many-body system, as input for the modelling of the synthesis of the elements in the universe, and for testing of fundamental symmetries. Penning trap mass spectrometry offers unprecedented accuracy and a very high sensitivity. In America, several Penning trap mass spectrometer projects make use of unique rare isotope production facilities and contribute to the worldwide effort to enhance our knowledge of nuclear binding energies. This talk will give an overview of on-going activities and discuss the perspectives of reaching even more exotic isotopes.

Hauptvortrag SYAM 1.4 Mo 11:30 HU Senatssaal

Theory and predictability of nuclear masses — •Piet Van Isacker — GANIL, BP 55027, F-14076 Caen cedex, France

The status of modern nuclear mass formulas is reviewed. This includes the elementary Weizsaecker liquid drop formula and its up-to-date refinements, such as the finite-range droplet model, as well as more microscopically founded attempts based on Hartree-Fock theory and the shell model. Special attention is paid to the recent suggestion that there might be a limit to the accuracy with which nuclear masses can be calculated in a mean-field approach and that chaotic motion inside the atomic nucleus is responsible for this lack of predictability. In view of the important implications of this claim (e.g., for nuclear astrophysics), its meaning is clarified with an empirical study of more than 2000 nuclear masses. With use of Garvey-Kelson relations, correlations among neighbouring masses are established that are satisfied with an rms deviation of less than 100 keV. This can be considered as a upper limit for the current predictability of nuclear masses.

SYAM 2 Atomare Präzisionsmassenspektrometrie

Zeit: Montag 14:00–16:00 Raum: HU Senatssaal

Hauptvortrag SYAM 2.1 Mo 14:00 HU Senatssaal

Recent trends in the determination of nuclear masses — •Juha Äystö — Department of Physics, University of Jyväskylä, Finland

Mass of a nucleus results from its binding energy and masses of its constituent nucleons. Strength of binding, a result of strong interaction acting in a finite many-body system of protons and neutrons, carries fundamental information on the microscopic structure of the nucleus. Measurement of binding energy with relative precisions in the range from 10-6 to 10-8 is necessary to unravel predicted new phenomena in nuclear structure of exotic nuclei with abnormal proton to neutron number ratios. Precision measurements of nuclear masses have also important role in nuclear astrophysics and fundamental symmetries and interactions.

This talk presents recent trends and some precision studies of masses of exotic nuclei with high neutron-excess of interest for nuclear structure and shapes of nuclei, as well as of neutron-deficient nuclei of interest for nucleosynthesis in stellar processes. These measurements have become possible only recently due to employment of Penning traps coupled to fast injection of ions. The talk will discuss selected results from the ISOLTRAP facility at CERN and the IGISOL facility at the University of Jyväskylä in Finland.

Hauptvortrag SYAM 2.2 Mo 14:30 HU Senatssaal

A Precision Mass Balance Using Highly Charged Ions — •Reinhold Schuch[1], Szilard Nagy[1], Birgit Brandner[1], Marcus Suhonen[1], Tomas Fritioff[2], Klaus Blaum[2], and Ingmar Bergström[3] — [1]Atomic Physics Division, Stockholm University, AlbaNova, S-10691 Stockholm, Sweden, e-mail: schuch@physto.se — [2]CERN, 1211 Geneva, Switzerland — [3]Manne Siegbahn Laboratory(MSL), 104 05 Stockholm, Sweden

Precision mass measurements are done with the SMILETRAP Penning trap mass spectrometer, located at MSL in Stockholm. It exploits the merits of highly charged ions retrapped from an electron beam ion source. These ions are retarded in a first cylindrical Penning trap and a fraction of them is sent to the hyperbolic precision Penning trap. There it is possible to measure the cyclotron frequencies of such ions with 10-8 resolution [1] using the time-of-flight technique. The relevant observable in our mass measurement is the ratio of the cyclotron frequencies of the ion of interest and an ion used as a mass reference. In order to reduce the influence of changes to the magnetic field, both frequencies are measured within as short a time as two minutes. Several mass measurements with a relative uncertainty in the region of 0.3 to a few ppb have been performed,

using ions with charge states 1+ to 52+[2]. The latest achievements will be reported.

[1] I. Bergström, C. Carlberg, T. Fritioff, G. Douysset, J. Schönfelder and R. Schuch, NIM A487, 618-651 (2002)
[2] T. Fritioff, H. Bluhme, R. Schuch, I. Bergström and M. Björkhage, Nuclear Physics A, Volume 723, 3-12 (2003)

Hauptvortrag

SYAM 2.3 Mo 15:00 HU Senatssaal

Precision mass spectrometry with one and two ions in a Penning trap — •Edmund Myers — Florida State University

In the 1990's the development of the MIT atomic mass spectrometer produced 13 atomic masses at 10^{-10} relative precision. These results formed the MIT precision atomic mass table with application to fundamental constants. This mass spectrometer has several special features such as a detector based on a dc-SQUID, and the use of a 'pulse and phase' technique, analogous to the Ramsey Separated-Oscillatory-Field method, for measuring the cyclotron frequency. In the last few years another new and unique technique has been developed. The two ions to be compared are created in the same trap and positioned in a coupled magnetron orbit. Their cyclotron frequencies are then measured simultaneously. This method suppresses sensitivity to magnetic field fluctuations and uncertainty in the measurement of the axial frequency by two or three orders of magnitude. Successful demonstration of this technique at MIT has led to mass comparison at 7×10^{-12} precision, discovery of rotational-state-dependent polarization-induced cyclotron frequency shifts, and a new test of Einstein's '$E = mc^2$'. In 2003 the system was relocated to Florida State University. In Tallahassee additional mass measurements at the 10^{-10} level using single-ion techniques have been completed. Further development of the sub-10^{-11} two-ion technique, for a high precision atomic mass comparison of tritium/helium-3 relevant to neutrino mass, is in progress.

Hauptvortrag

SYAM 2.4 Mo 15:30 HU Senatssaal

Highly Accurate Measurements of Particle and Antiparticle Masses — •Gerald Gabrielse — University of Harvard, 17 Oxford Street, Cambridge, MA 02138, USA

The mass of individual elementary particles can be probed with exquisite precision by listening to the radio signal from a single elementary particle. The annihilation of antimatter particles can be avoided by suspending them in electric and magnetic fields. Examples of direct and indirect mass measurements of particles and antiparticles will be given.