8th International Symposium on Symmetries in Subatomic Physics (SSP2022)

Monday, 29 August 2022 - Friday, 2 September 2022

Book of Abstracts

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Testing CP and CPT symmetries in ortho-positronium decays with J-PET detector

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In the talk we demonstrate test of combined charge, parity, and time-reversal transformation (CPT) in the annihilations of the lightest leptonic bound system, the positronium atom. With the Jagiellonian Positron Emission Tomograph (J-PET) we have collected an unprecedented range of kinematical configurations of exclusively-recorded annihilations of the positronium triplet state (ortho-positronium) into three photons. Employing a novel technique for estimation of positronuium spin axis on the basis of a single event, we determined the complete distribution of an angular correlation between spin and annihilation plane of ortho-positronium. We present recently published result of determined expectation value of this correlation at the precision level of 10^{-4}, with an over three-fold improvement on the previous measurement.
Positronium being at the same time an eigenstate of the C and P operators is an unique probe to test the CP symmetry. This test is based on determination of polarization of photons from positronium annihilation. This allows exploration of a new class of discrete symmetry odd operators that were not investigated before. The novelty of the experimental setup is based on usage of plastic scintillators as active detection material and trigger-less data acquisition system. In the talk we describe a result of CP symmetry test at the precision level of 10^{-4} in a whole available phase-space and experimental techniques developed by the J-PET collaboration.

Scientific topic:

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Final results of the neutrinoless double-beta decay search with GERDA

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abstract provided as attached pdf-file

Scientific topic:

Symmetries

Poster Session / 5

ENUBET: a monitored neutrino beam for high precision cross section measurements

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The main source of systematic uncertainty on neutrino cross section measurements at the GeV scale is represented by the poor knowledge of the initial flux. The goal of cutting down this uncertainty to 1% can be achieved through the monitoring of charged leptons produced in association with neutrinos, by properly instrumenting the decay region of a conventional narrow-band neutrino beam. Large angle muons and positrons from kaons are measured by a sampling calorimeter on the decay tunnel walls (tagger), while muon stations after the hadron dump can be used to monitor the neutrino component from pion decays. This instrumentation can provide a full control on both the muon and electron neutrino fluxes at all energies. Furthermore, the narrow momentum width (<10%) of the beam provides a $\mathcal{O}(10\%)$ measurement of the neutrino energy on an event by event basis, thanks to its correlation with the radial position of the interaction at the neutrino detector. The ENUBET project has been funded by the ERC in 2016 to prove the feasibility of such a monitored neutrino beam and is cast in the framework of the CERN neutrino platform (NP06) and the Physics Beyond Colliders initiative.
The ERC project has entered its last year and the efforts are now devoted to the final tuning of the beamline shielding elements. These studies are being pursued exploiting a powerful genetic algorithm that scans automatically the parameter space of the focusing beamline in order to find a configuration minimizing halo particles in the tagger while preserving a large meson yield. Realistic particle identification algorithms have been setup to reconstruct muons and positrons in the decay tunnel with high signal to noise ratio on an event by event basis. A full Geant4 simulation of the facility is employed to assess the final systematics budget on the neutrino fluxes with an extended likelihood fit of a model where the hadro-production, beamline geometry and detector-related uncertainties are parametrized by nuisance parameters. In parallel the collaboration is building a section of the decay tunnel instrumentation ("demonstrator", 1.65m in length, 7 ton mass) that will be exposed to the T9 particle beam at CERN-PS in autumn 2022, for a final validation of the detector performance and as a proof of the effectiveness of the technique.
In 2019-2022 ENUBET has devised the first end-to-end simulation of the facility and demonstrated that the precision goals can be achieved in about three years of data taking employing neutrino detectors of moderate mass (ICARUS at FNAL, ProtoDUNE at CERN). The technology of a monitored neutrino beam has been proven to be feasible and cost-effective, and the complexity does not exceed significantly the one of a conventional short-baseline beam. The ENUBET results will play an important role in the systematic reduction programme of future long baseline experiments, thus enhancing the physics reach of DUNE and HyperKamiokande. In our contribution, we summarize the ENUBET design, physics performance and opportunities for its implementation in a timescale comparable with next long baseline neutrino experiments.

Scientific topic:

Future Facilities

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Novel mechanisms of electric dipole moments in atoms and molecules

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I discuss novel mechanisms for the generation of electric dipole moments in atoms and molecules, including via the exchange of low-mass axionlike particles between atomic electrons and nucleons **[1,2]**, as well as via two-photon exchange processes between atomic electrons and the nucleus in paramagnetic systems **[3]**. I also discuss how oscillating electric dipole moments may be induced

by an oscillating-in-time axionlike dark matter field **[3,4]**. Such oscillating electric dipole moments have recently been sought by using ultracold neutrons **[5]** and HfF+ molecular ions **[6]**.

References
[1] Stadnik, Dzuba and Flambaum, Physical Review Letters **120**, 013202 (2018).
[2] Dzuba, Flambaum, Samsonov and Stadnik, Physical Review D **98**, 035048 (2018).
[3] Flambaum, Pospelov, Ritz and Stadnik, Physical Review D **102**, 035001 (2020).
[4] Stadnik and Flambaum, Physical Review D **89**, 043522 (2014).
[5] Abel *et al.* (nEDM collaboration), Physical Review X **7**, 041034 (2017).
[6] Roussy *et al.*, Physical Review Letters **126**, 171301 (2021).

Scientific topic:

Symmetries

Poster Session / 8

Systematics of the PEN experiment, a precision measurement in the pion electronic decay branching ratio

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Electroweak
Lepton universality
Standard Model
Pion decay
V-A

Scientific topic:

Fundamental interactions

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Systematic effects in the search of the muon electric dipole moment using the frozen-spin technique

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At the Paul Scherrer Institute we are developing of a high precision instrument to measure the muon electric dipole moment (EDM) using the frozen-spin technique. The presence of a permanent EDM in an elementary particle implies Charge-Parity symmetry violation and, within the context of the Standard Model, the electric dipole moment of elementary particles is extremely small. However, many Standard Model extensions predict large electric dipole moments. Recently, the muon electric dipole moment has become a topic of particular interest due to the tensions in the magnetic anomaly of the muon and the electron and hints of lepton-flavor universality violation in B-meson decays. The frozen-spin method suppresses the anomalous precession of the muon spin, thus increasing the signal-to-noise ratio for signals due to an EDM allowing to reach a sensitivity that is unattainable by conventional g-2 muon storage rings. With this technique the expected statistical sensitivity for the EDM after a year of data taking is 6 x 10-23 e·cm with the
p = 125 MeV/c muon beam available at the PSI. To reach this goal it is necessary to perform a comprehensive analysis on spurious effects that mimic the EDM signal. This work discusses a quantitative

analysis of systematic effects for the frozen-spin method applied to the search of the muon EDM. Specifications of the required control of the precision of electric and magnetic fields as well as the detection efficiencies of the detectors were analytically derived and validated by simulation.

Scientific topic:

Future Facilities

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Searches for CP-violating effects with YbF molecules

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Scientific topic:

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A laser cooled beam of YbF for measuring the electron electric dipole moment

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Abstract in pdf

Scientific topic:

Symmetries

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The Mu2e experiment at Fermilab

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The Mu2e experiment at Fermilab will search for a neutrino-less muon to electron conversion with a single event sensitivity of ˜3E-17. This is an improvement of four orders of magnitude in sensitivity over the current best limit. Mu2e will indirectly probe a broad class of New Physics models with mass scales up to 10,000 TeV. The Mu2e is currently under the construction with a goal to start taking data in 2025. The first data taking period is aimed to improve the current best limit by a three orders of magnitude. After a two-year shutdown, the data collection will resume to reach the designed

Mu2e sensitivity. I will present the status update on the Mu2e fabrication in the preparation for the commissioning and future data taking.

Scientific topic:

Future Facilities

Poster Session / 13

Measuring the electron electric dipole moment using ultracold molecules

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Despite its many successes, the Standard Model of particle physics is thought to be incomplete, because it leaves unanswered several major questions. One of these is the origin of the observed asymmetry between the amount of matter and antimatter in the visible universe. While we cannot currently explain what caused the asymmetry, we know that it requires the presence of new interactions violating several fundamental symmetries. Electric dipole moments of elementary particles are one direct signature of such symmetry violation, that can be tested via precision measurements using heavy polar molecules. In this talk, I will discuss how to build an apparatus that uses molecules cooled to microkelvin temperatures to make extremely precise measurements. With very careful measurements, such table-top experiments will enable us to explore new physics up to PeV energy scale.

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Status and Prospects of the DUNE and JUNO Experiments

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DUNE and JUNO are two leading next-generation neutrino experiments that will address some of the most important open questions in neutrino physics. DUNE is a long baseline experiment consisting of two detectors placed in what will be the world's most intense neutrino beam: a near detector in Fermilab near the beam source, and a much larger far detector at the Sanford Underground Research Laboratory in South Dakota, 1300 km downstream. JUNO is an unprecedentedly large liquid scintillator detector placed at a baseline of 52.5 km from eight nuclear reactors in China. The physics goals of both experiments include making cutting-edge measurements of neutrino oscillations with unprecedented precision, studying astrophysical neutrinos, and searching for physics beyond the Standard Model such as a positive signal for nucleon decay. This talk will report the status and physics prospects of both experiments.

Scientific topic:

Future Facilities

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Future facilities in muon research at J-PARC

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Scientific topic:

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Fundamental interactions / 16

Double-beta decay and test of fundamental symmetries

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Abstract
Double beta decay (DBD) is a currently hot research topic as it can offer a wide range of physics investigations beyond the Standard Model (BSM). These refer to some fundamental neutrino properties, yet unknown (neutrino nature –is it a Dirac or a Majorana particle, the neutrino absolute mass and mass hierarchy, number of neutrino flavors, etc.), conservation of the lepton number and validity of Lorentz and CP symmetries, as well as to different BSM mechanisms that can contribute to the neutrinoless double-beta decay.
In my talk, I'll first summarize the current challenges facing the DBD study. Then, I'll focus on the DBD potential to test fundamental symmetries and, in particular, I'll present the current status of Lorentz invariance violation (LIV) searches. Such investigations are currently been conducted in several large experiments as EXO, GERDA, SuperNEMO, CUORE and CUPID-0, and are based, on one side, on precise measurements of the electron spectra and electron angular correlations and, on the other side, on reliable theoretical calculations of these spectra. I'll present the theoretical formalism and precise calculation of the single, summed energy and angular correlation electron spectra, along with their deviations due to LIV. Next, I'll show different LIV signatures that can be investigated in DBD experiments and the current constraints of the coefficient that governs the LIV strengths. Finally, I'll propose an alternative, new method to constrain this coefficient through the measurement of the angular correlation coefficient, and show that future DBD experiments can improve these limits significantly.

References
1. S. Stoica, Investigation of Lorentz symmetry violation in double-beta decay, MEDEX'19, Prague, May 28-June 2, 2019 (invited talk).
2. O. Nitescu, S. Ghinescu, and S. Stoica, J. Phys. G 47, 055112 (2020).
3. O. Nitescu, S. Ghinescu, and S. Stoica, Phys. Rev. D 103, L031701 (2021).
4. S. Stoica, Study of kinematic factors in double-beta decay, Conference on Neutrino and Nuclear Physics (CNNP2020), February 20-24, 2020, Cape Town, South Africa (invited talk).
5. S. Ghinescu, O. Nitescu and S. Stoica, Phys. Rev. D 105, 055032 (2022).

Scientific topic:

Symmetries and Interactions

Poster Session / 17

Improved Search for CP Violation in Ortho-Positronium Decay

Authors: Tom-Erik Haugen[None]; Elizabeth A. George[1]; Oscar Naviliat-Cuncic[2]; Paul A. Voytas[1]

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Abstract provided as attached pdf-file

Scientific topic:

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Measuring the electron's electric dipole moment using polyatomic YbOH molecules

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New fundamental particles at high energy scales that have not been reached by the Large Hadron Collider (LHC) could explain the observed matter-antimatter asymmetry that cannot be understood by the Standard Model of particle physics. These hypothetical particles, if they exist, will introduce a tiny electric dipole moment on the electron (eEDM), which can be probed by extremely sensitive measurement of the electron spin precession in a huge intra-molecular electric field. We plan to measure the eEDM using trapped polyatomic YbOH molecules. Polyatomic molecules may combine the advantages of laser cooling (long coherence), high sensitivity to CP violating physics, and robustness to systematic error. I will present our recent progress on the understanding of the structure of the YbOH molecule and how it can be used to improve the precision of eEDM measurement.

Scientific topic:

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The search for axion dark matter with a dielectric haloscope: MAD-MAX

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The QCD Axion is arguably the most elegant candidate to solve the strong CP problem and to explain missing dark matter in our universe. Some compelling theoretical models predict its mass to be around 100 μeV, a range that presently still evades experimental sensitivity. The dielectric haloscope concept has been proposed to change this. The motivation for post-inflationary dark matter axions with mass around 100 μeV will be discussed and the basic concepts of a dielectric haloscope will be introduced. The technological challenges to be solved in order to achieve the necessary sensitivity will be discussed on the basis of the MADMAX experiment.

Scientific topic:

Future Facilities

Poster Session / 20

Optimization of spin-coherence time for electric dipole moment measurements in a storage ring

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The JEDI experiment is dedicated to the search for the electric dipole moment (EDM) of charged particles using storage rings, which can be a very sensitive probe of physics beyond the Standard Model. In order to reach the highest possible sensitivity, a fundamental parameter to be optimized is the Spin Coherence Time (SCT), i.e., the time interval within which the particles of the stored beam maintain a net polarization greater than 1/e. To identify the working conditions that maximize SCT, accurate spin-dynamics simulations with the code BMAD have been performed on the lattice of a "prototype" storage ring which uses a combination of electric and magnetic fields for bending. This talk will present the results of these simulations addressing the impact on the SCT of different factors like horizontal betatron tune, chromaticity, momentum compaction and the electric bending field; as well as ideas on lattice modifications to further improve its value and ease of accessibility of the configurations in practice.

Scientific topic:

Future Facilities

Poster Session / 21

Towards a pulsed beam of antihydrogen for WEP tests

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abstract provided as attached pdf-file

Scientific topic:

Symmetries

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Fundamental Physics with Slow Neutrons

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Neutrons are electrically neutral and massive particles. They experience all known forces, which are electromagnetic, gravitation, weak, and strong forces. Slow neutrons with low kinetic energy are good tools for observing the effects of those interactions. They are used for various fundamental physics experiments, taking advantage of the property.
Depending on their kinetic energy, slow neutrons are called cold, very cold, and ultra cold neutrons. In this presentation, the property of such slow neutrons will be introduced. They are unique probes for exploring new physics beyond the standard model. I will also discuss the cutting-edge experiments using slow neutrons, such as neutron electric dipole moment searches, neutron lifetime measurements, gravity experiments, and so on.

Scientific topic:

Fundamental interactions

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LUXE: A new experiment to study non-perturbative QED in electron-LASER and photon-LASER collisions

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The LUXE experiment (LASER Und XFEL Experiment) is a new large-scale experiment in planning at DESY Hamburg. LUXE is intended to study collisions between a high-intensity optical LASER and 16.5 GeV electrons from the XFEL electron beam, as well as collisions between the optical LASER and GeV-scale, high-flux photon beams. The main physics objective of LUXE is to experimentally study processes of Quantum Electrodynamics (QED) in a non-perturbative regime, including quantum radiation reaction and Breit-Wheeler pair production in a strong background field. The proposed experiment will be the first to provide high-precision and high-statistics studies of these iconic phenomena in an unprecedented regime. An overview of the LUXE experimental setup will be given, with a discussion of the foreseen detector systems and their expected performance. Finally, the prospects for experimentally studying physics beyond the standard model will also be discussed.

Scientific topic:

Future Facilities

Poster Session / 24

Towards the first demonstration of gravitational quantum states of atoms with a cryogenic hydrogen beam

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At very low energies, an atom above a horizontal surface can experience quantum reflection due to the attractive Casimir-Polder potential. The quantum reflection holds the atom against gravity and leads to gravitational quantum states (GQS), in analogy to what has been observed with ultracold neutrons [1]. The GRASIAN-collaboration pursues the first measurement of GQS of atomic hydrogen. For this purpose, an experiment has been designed and set up at ETH Zurich. In the past year, a cryogenic hydrogen-beam and a pulsed ultraviolet laser detection system were installed and characterized. The interaction region, where the actual GQS-measurement will be performed, is currently being installed.
The use of hydrogen is not only motivated by the fact, that GQS have never been observed with atoms. The enhanced statistics available through the use of hydrogen atoms (versus ultracold neutrons) will increase the sensitivity to deviations from Newtonian Gravity. For instance, short-range forces predicted in extensions of the Standard Model would alter the GQS, and would hence be detectable by a high-precision GQS-measurement.
Additionally, the measurement of GQS of hydrogen will serve as a benchmark demonstration for the measurement of gravitational properties of Antihydrogen. Furthermore, the extremely low velocities of atoms in GQS also promise improved accuracies in precision laser and microwave spectroscopy.

[1] V.V. Nesvizhevsky, H.G. Börner, Alexander Petukhov, Hartmut Abele, Stefan Baessler, Frank Ruess, Thilo Stöferle, Alexander Westphal, A. Gagarski, Gennady Petrov, and A. Strelkov. Quantum states of neutrons in the earth's gravitational field. Nature, 415:297–9, 02 2002.

Scientific topic:

Fundamental interactions

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Discrete symmetry tests using hyperon-antihyperon pairs at BESIII

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The hyperons from charmonia decays are produced with a non-zero spin polarization that is described by one global parameter in electron-positron annihilation into hyperon-antihyperon pair. This provides a method to measure precisely parity-violating (anti)hyperon decay amplitudes and directly test CP violation. These CP tests were performed for J/psi decays into Lambda Lambdabar, Sigma+ Sigmabar-, Xi Xibar and psi(2S) into Omega- Omega-bar+. For the Xi -> Lambda pi decay chain, the exclusive measurement allows for three independent CP tests and the determination of the strong and weak phase differences. Thanks to the large datasets in the tau-mass region, including the world's largest data samples at the J/psi and psi(2S) resonances collected at the BESIII experiment, the multi-dimensional analyses making use of polarization and entanglement have been performed for these processes. In the presentation the methods, the recent BESIII results and a roadmap for further CP-violation studies in hyperon decays will be discussed.

Scientific topic:

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Progress towards the TRIUMF ultracold neutron facility and neutron electric dipole moment experiment

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The TUCAN collaboration is building a next generation ultracold neutron (UCN) source, based on spallation neutron production using protons from TRIUMF's 500 MeV cyclotron. A large cold neutron flux is created via moderator shells of room-temperature heavy water and 20-K liquid deuterium surrounding a near-spherical volume of superfluid liquid helium-4. At around 1 K, the ultracold neutrons created in the superfluid have a long enough lifetime to be extracted to experiments using vacuum neutron guides.

The UCN will be used to search for the electric dipole moment (EDM) of the neutron using Ramsey's technique of separated oscillatory fields. The TUCAN EDM experiment will be operating at room temperature and using a double cell arrangement. A state-of-the-art magnetically shielded room will keep the main systematic effects caused by field inhomogeneity and instabilty low. Due to this and the large UCN yield expected from our source, we anticipate to reach a statistical sensitivity of 1e-27 ecm (1-sigma) within 400 days of beam time.

The presentation will cover the physics principles of source and experiment, and give an update on the design, status and plans.

Scientific topic:

Future Facilities

Poster Session / **27**

An electrostatic storage ring for fundamental physics measurements

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abstract attached as PDF

Scientific topic:

Symmetries and Interactions

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JEDI and beyond –the quest for EDMs of charged particles

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Scientific topic:

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Kaonic Atom X-Ray Spectrocopy with the SIDDHARTA-2 Experiment

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Kaonic atoms are ideally suited candidates to study the low-energy regime of QCD including strangeness, without the need to extrapolate to zero relative energy as for scattering experiments. The theoretical models describing the low-energy antikaon-nucleon interaction show significant differences, and experimental input is crucial to constrain them. The SIDDHARTA-2 experiment, located at the DAΦNE collider at LNF in Italy, can provide this input via X-ray spectroscopy of light kaonic atoms, in particular by measuring the $2p \rightarrow 1s$ transition in kaonic deuterium. A combination of the results from kaonic hydrogen measured by SIDDHARTA in 2009 and kaonic deuterium will enable the extraction of the isospin-dependent antikaon-nucleon scattering lengths a_0 and a_1 for the first time, which are vital parameters for constraining the models. By employing newly developed X-ray detectors in the form of Silicon Drift Detectors as well as sophisticated methods for background suppression, SIDDHARTA-2 is equipped to perform the challenging $\mathrm{K}^-\mathrm{d}$ measurement. During its commissioning in 2021, a first successful run with kaonic helium-4 was performed, and the $\mathrm{K}^4\mathrm{He}$ $2p$ level shift ϵ_{2p} and width Γ_{2p} were extracted and found to be $\epsilon_{2p} = (0.2 \pm 2.5_{stat.} \pm 2.0_{syst.})$ eV and $\Gamma_{2p} = (8 \pm 10)$ eV. The experimental apparatus will be presented and the results from the first data taking campaigns will be discussed.

Scientific topic:

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Optimisation of the energy resolution of Low- (LED) and High (HED) Energy Cadmium-Zinc-Telluride (CdZnTe) detectors

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Scientific topic:

Application of new technologies

Poster Session / 32

Search for Tensor Interactions in Nuclear Beta Decay

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Precision measurements in nuclear beta decay offer today a sensitive window to search for new physics beyond the standard electroweak model. The new physics signatures can be parametrized in terms of exotic phenomenological scalar and tensor interactions, which induce deviations on sensitive observables relative to their standard model predictions. In the past few years, it has been recognized that precision measurements in beta decay can be competitive with direct searches of new physics performed at particle colliders provided they address appropriate observables like for instance the full beta-energy spectrum. The long-term goal of this project is to perform the most precise measurement of the beta-energy spectrum in 6He decay in order to search for or constrain the presence of tensor type interactions.
Following the first experiments carried out at the National Superconducting Cyclotron Laboratory at Michigan State University, in the beta decay of 6He and 20F, we are performing measurements at the Grand Accélérateur National d'Ions Lourds (GANIL) with both, fast (50 MeV/nucleon) and slow (25 keV) beams of 6He. GANIL offers a unique opportunity since it is the only facility worldwide where both beam energies are available. The interest in using both energies resides in the associated systematic effects of the measurements, which have to be studied in great detail. A first measurement with the low energy beam has been carried out in 2021.
This contribution will introduce the general context of the project, describe the improvements of the experimental setup and report the current status of the data analysis.

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Symmetries in charm mesons and baryons from Belle/Belle II

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We present recent results of charm CP symmetry violation (CPV) based on about 1 ab^{-1} collected at the Belle experiment, including the decay asymmetry parameters (α) and α-included CP asymmetry (A^{α}_{CP}) for decays of Λ_c^+ and Ξ_c^0 baryons, search for CPV via time-integrated CP asymmetry in D three-body decays and T-odd asymmetry in D four-body decays, lepton flavor universality test in Ξ_c^0 and Ω_c^0 semileptonic decays, etc. We also introduce the status of Belle II and prospects of charm CPV.

Scientific topic:

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Towards In-beam spectroscopy of Deuterium and constraining Standard Model Extension parameters

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The Standard Model Extension (SME) [1, 2] serves as a motivation for many experiments performing precision tests of the CPT symmetry. It includes all CPT and Lorentzviolating operators in addition to the Standard Model Lagrangian and hence, manifesting Lorentz and CPT violating signals in different experimental searches.

According to the SME, the shifts in the hyper-fine energy levels of deuterium depend on the exponents of the relative momentum of the proton in the deuteron core. This enhances the sensitivity of certain coefficients for Lorentz and CPT violation by 9 orders of magnitude and even up to 18 orders of magnitude for certain other coefficients as compared to that of hydrogen [3]. SME also predicts experimental signals at twice the sidereal frequency, which can be measured in the hyper-fine Zeeman transitions with $\Delta F \neq 0$ in deuterium [3]. One of these transitions which we aim to measure is $(F = \frac{3}{2}, M_F = -\frac{1}{2}) \rightarrow (F = \frac{1}{2}, M_F = -\frac{1}{2})$, which has a minima at 3.889 mT. The simulations and experimental progress towards this measurement using an in-beam Rabi type spectroscopy technique will be presented. A double split ring resonator [4, 5] will be used to drive these hyper-fine transitions. The characterisation and performance of the prototype of this resonator shall also be discussed.

References
[1] Don Colladay and V. Alan Kostelecký. CPT violation and the standard model. Phys. Rev. D, 55:6760–6774, Jun 1997.
[2] V. Alan Kostelecký. Gravity, lorentz violation, and the standard model. Phys. Rev. D, 69:105009, May 2004.
[3] V. Alan Kostelecký and Arnaldo J. Vargas. Lorentz and cpt tests with hydrogen, antihydrogen, and related systems. Phys. Rev. D, 92:056002, Sep 2015.
[4] W Froncisz and James S Hyde. The loop-gap resonator: a new microwave lumped circuit esr sample structure. Journal of Magnetic Resonance (1969), 47(3):515–521, 1982.
[5] M. Mehdizadeh, T. K. Ishii, J. S. Hyde, and W. Froncisz. Loop-gap resonator: A

lumped mode microwave resonant structure. IEEE Transactions on Microwave Theory and Techniques, 31(12):1059–1064, Dec 1983.

Scientific topic:

Symmetries and Interactions

Symmetries / 37

The MOLLER and P2 Experiments; High precision tests of the running of the Weak mixing angle

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The so called Standard Model is a phenomenological model, in the sense that it relies on experimental input and has been continuously refined, based on that input, for the better part of a century. It is generally accepted that the Standard Model is incomplete,for various reasons.

The Standard Model is a gauge theory, which produces floating parameters, called couplings, or "charges", for which the values can only be determined through measurement and that set the strength of a particular type of interaction (e.g. the Weak interaction). The MOLLER (Jefferson Lab) and P2 (Mainz MESA facility) experiments, are fully funded and currently in the development and construction phase. They aim to measure the so called "Weak-charge" of the electron and proton respectively to the highest precision yet. MOLLER and P2 exploit the fact that the Weak interaction violates parity (has a preferred handedness), which means it has the potential to uncover new, parity violating, interactions for electrons and protons (among other new physics sensitivities). The two measurements are complementary since they couple to potential new physics in different ways. I will explain the motivation for the experiments and give an overview of the design and the technologies it will use.

Scientific topic:

Symmetries and Interactions

Poster Session / 38

Detailed analysis of lepton flavor violating deep-inelastic scattering by (pseudo-)scalar mediator

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We revisit charged lepton flavor violating (CLFV) scattering $\ell_i N \to \ell_j X$ mediated by scalar interaction. We point out that a new subprocess $\ell_i g \to \ell_j g$ via the effective interactions of CLFV mediator and gluon gives large contribution. Furthermore, in the light of quark number conservation, we consider quark pair-production processes $\ell_i g \to \ell_j Q\bar{Q}$ (Q denotes heavy quarks) instead of $\ell_i Q \to \ell_j Q$. We discuss model discrimination by analyzing final state distributions.

Scientific topic:

Symmetries

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Tests of lepton flavour universality with (semi-)leptonic decays of charmed mesons

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The BESIII experiment has collected an integrated luminosity corresponding to 2.93 fb^{-1} of data at 3.773 GeV, and 6.3 fb^{-1} of data between 4.18 and 4.23 GeV, respectively, which allows for precision tests with D meson decays. We will present an overview of the recent results on lepton flavour universality tests with (semi-)leptonic decays of charmed mesons. We will also report the latest precision measurements of the decay constants fDs+ and the CKM matrix elements $|V_{cs}|$ via $D^+_{(s)} \to l^+\nu$ $(l = \mu, \tau)$ decays, which are important to test the LQCD calculations and the CKM matrix unitarity.

Scientific topic:

Symmetries and Interactions

Fundamental interactions / 40

Symmetry tests with clocks

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We use frequency comparisons between highly accurate optical clocks for tests of fundamental principles. In particular, the 171Yb+ optical clock based on an electric octupole transition between the S-ground state and the lowest excited F-level (radiative lifetime 1.58 yr) provides a favorable combination of low systematic uncertainty and high sensitivity to relativistic effects and potential new physics. Using this system we have established improved limits for violations of Lorentz invariance in the electron sector and for violations of local position invariance, including the presently most stringent limits for temporal variations of the fine structure constant and the electron-proton mass ratio [1]. I will give an outlook on the development of a 229Th nuclear optical clock that will open new perspectives for fundamental tests in the domain of nuclear physics [2].

[1] R. Lange, N. Huntemann, J. M. Rahm, C. Sanner, H. Shao, B. Lipphardt, Chr. Tamm, S. Weyers, and E. Peik, "Improved limits for violations of local position invariance from atomic clock comparisons", Phys. Rev. Lett. 126, 011102 (2021).
[2] E. Peik, T. Schumm, M. Safronova, A. Palffy, J. Weitenberg, P.G. Thirolf, „Nuclear clocks for testing fundamental physics", Quantum Sci. Technol. 6, 034002 (2021).

Scientific topic:

Symmetries

Poster Session / 41

Understanding of Systematic Effects in eEDM Searches with diatomic molecules

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Doing high-precision measurements on molecules is a promising way to explore physics beyond the Standard Model of particle physics. One such measurement is the search for the P,T-violating electric dipole moment of the electron (eEDM). The effect if the eEDM is expected to be strongly enhanced in diatomic molecules with one heavy atom, because of small rotational splittings and an enhanced electron density near a highly charged nucleus. Indeed, currently the best limit of d_e<1.1× 〖10〗 ˆ(-29) e cm is measured in the diatomic molecule ThO [1]. In the NL-eEDM collaboration, the eEDM induced contribution to the ground state of BaF is investigated [2]. The eEDM manifests itself as a splitting between the magnetic substates due to the electric field, in addition to the Zeeman effect in magnetic fields. To measure the effect of a possible eEDM, a spin prec ession experiment is set up in well-controlled electric and magnetic fields. A superposition of two eEDM-sensitive hyperfine substates is created with a two-photon transition. In the magnetic and electric field, a phase difference between the two hyperfine states is accumulated, which has an extra contribution due to the electric field if the eEDM exists. The contributions to this phase from known-physics, in particular from the magnetic moment, require understanding of the molecular structure. The derived value for the eEDM is limited by statistics and the understanding of systematic effects.
To increase the statistical sensitivity, an intense source of ultracold BaF molecules will be used, produced in a cryogenic source. The molecules will be transversely laser cooled and decelerated with a Stark decelerator [3].
To have control over the systematics, it is crucial to understand how the eEDM signal depends on the experimental parameters, such as the magnetic field and laser intensities. For this a description of the dynamics of our spin-precession experiment is developed, based on the Optical Bloch Equations. With this tool the precision to which the experimental parameters need to be controlled and measured during the experiment can be calculated.

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ACME Collaboration. Improved limit on the electric dipole moment of the electron, Nature 562, 355–360 (20

The NL-eEDM collaboration., Aggarwal, P., Bethlem, H.L. et al. Measuring the electric dipole moment of th

P. Aggarwal, Y. Yin, K. Esajas, H. L. Bethlem, A. Boeschoten, A. Borschevsky, S. Hoekstra, K. Jungmann, V.
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Scientific topic:

Symmetries

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Welcome - Opening

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Welcome - LOC

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Recent results on T, CP and CPT tests with KLOE-2

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KLOE and KLOE-2 full data sample, corresponding to 8 fb−1, has been collected at the Frascati DAΦNE φ–factory of INFN Laboratories and repre- sents the world largest data sample of this kind: about 2.4 × 1010 φ mesons and 8 × 109 K0K̄ 0 entangled pairs. The neutral kaon system has unique properties such as entanglement, flavour oscillations, charge-parity (CP) and time-reversal (T) violation allowing us to test quantum mechanics coherence and fundamental discrete symmetries T, CP, CPT at the utmost sensitivity. KLOE-2 Collabo- ration just published a study on the quantum interference between the decays of entangled neutral kaons in the φ ⟶ KSKL ⟶ π+π−π+π− process by using KLOE data statistics of about 1.7 fb−1 . This channel exhibits the characteris- tic Einstein–Podolsky–Rosen correlations that prevent both kaons to decay into π+π− at the same time. It constitutes a unique tool for testing and constrain, at an unprecedented precision, parameters of various theoretical models, and to search for tiny decoherence and CPT violation effects which may arise, in a quantum gravity picture, due to space-time fluctuations at Planck scale. With the same data sample, KLOE-2 Collaboration is also performing the first di- rect test of the T and CPT symmetries in neutral kaon systems, by comparing neutral meson transition rates between flavour and CP eigenstates. The anal- ysis exploits the φ ⟶ KSKL ⟶ π+π−π∓e±ν and φ ⟶ KSKL ⟶ π∓e±ν 3π0 processes which allow to build discrete symmetry-sensitive observables and per- form model independent tests. Moreover, a new measurement of the KS ⟶ πeν branching fraction, using ~ 1.6fb−1 of KLOE data, has been combined with the previous KLOE result (0.4 fb−1) improving the total precision by almost a factor of two, and allowing a new derivation of f+(0)|Vus|.

Scientific topic:

Symmetries

Symmetries / 47

The quest for leptonic CP violation

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Particle/Antiparticle asymmetry (CP violation) was discovered almost six decades ago in quark bound states. CP violation was the only experimental evidence of matter and antimatter behaving differently in the Standard Model of particle physics. The discovery of neutrino oscillations at the end of the last century opened the window for similar phenomena in leptons. It has taken the neutrino community almost two decades to be able to start the exploration of this phenomenon using neutrino oscillations. The race for leptonic CP violation has already started with the running experiments T2K and NOvA and will provide definitve results with the new generation of experiments, Hyper-Kamiokande and DUNE. I will discuss the fundaments of CP violation in neutrinos, describe the experimental approaches and the main challenges faced by the experimental research community.

Scientific topic:

Symmetries

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Lepton flavour universality at Belle and Belle II

Author: Seema Choudhury[None]

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The rate of semitauonic and electroweak penguin decays in the B sector show hints of lepton-flavour universality violation. Belle and Belle II data is well suited to probe such anomalies. The low-background collision environment along with the possibility of partially or fully reconstructing one of the two B mesons in the event offer high precision measurements of semileptonic and electroweak B decays. This talk presents recent Belle and Belle II results on lepton flavor universality tests.

Scientific topic:

Symmetries

Symmetries and Interactions / 49

Measurement of the □□ process in Pb+Pb collisions and constraints on the □-lepton anomalous magnetic moment with the ATLAS detector at LHC

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The ATLAS experiment has measured the □-lepton pair production in ultraperipheral lead–lead collisions, Pb+Pb □Pb(□ □ □□□)Pb. From this measurement, constraints on the □-lepton anomalous magnetic moment, □□, have been extracted. The used dataset corresponds to an integrated luminosity of 1.44 nb-1‘ of LHC Pb+Pb collisions at □□NN = 5.02 TeV recorded by the ATLAS experiment in 2018. Selected events contain one muon from a □-lepton decay, an electron or charged-particle track(s) from the other□-lepton decay, little additional central-detector activity, and no forward neutrons. The □□□□ □
process is observed with a significance exceeding 5 standard deviations, assuming the Standard Model value for □□. To measure □□, a template fit to the muon transverse-momentum distribution from □-lepton candidates is performed, using a dimuon (□□ □□□) control sample to constrain systematic uncertainties. The observed 95% confidence-level intervals for □□ are □□ □(-0.058,-0.012) □ (-0.006. 0.025). These limits are compared with previous □□ –measurements obtained at LEP and Belle electron-positron colliders.

Scientific topic:

Symmetries and Interactions

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Low-energy experiments in search for new physics

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The high measurement precision attainable in experiments within the so-called low-energy, precision frontier can be employed to carry out a range of tests of fundamental physics and search for beyond-standard-model physics. After a brief overview of precision, low-energy tests, I will discuss two related experiments. In one of these, we study isotope shifts in an optical transition in ytterbium (Yb) [1], to check a hint for new physics that resulted from precision spectroscopy in ionic Yb [2] and help identify the origin of the possible new-physics signal. In another work, we study the effects of the weak force in atoms, through measurements of atomic parity violation in Yb [3]. Within this project, we aim to provide a test of the electroweak sector of the standard model, as well as study intra-nuclear weak forces and the distribution of neutrons in the Yb nucleus.

Scientific topic:

Symmetries

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Tests of physics beyond the Standard Model with the g factor of few-electron ions

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In this contribution, we discuss the precision theory of the bound-electron g factor. This quantity can be measured nowadays to high precision with the combination of Penning traps and electron beam ion traps. The collaboration of theory and experiment enables impactful and detailed tests of quantum electrodynamics in a strong background field, and a competitive determination of fundamental constants [1] and nuclear properties [2]. Very recently, we have shown that such studies also allow to test certain extensions of the Standard Model of particle physics, and set bounds on the strength of a hypothetical fifth force [3,4]. We summarize our ongoing calculations of radiative corrections in the non-perturbative Coulomb potential, which are necessary for further improvements in this field.

[1] H. Cakir, N. S. Oreshkina, I. A. Valuev et al., arXiv:2006.14261 (2021); V. A. Yerokhin, E. Berseneva, Z. Harman et al., Phys. Rev. Lett. 116, 100801 (2016).
[2] A. Schneider, B. Sikora, S. Dickopf et al., Nature 606, 878 (2022).
[3] V. Debierre, C. H. Keitel, Z. Harman, Phys. Lett. B 807, 135527 (2020); arXiv:2202.01668 (2022); V. Debierre, Natalia S. Oreshkina, Igor A. Valuev, Z. Harman, C. H. Keitel, arXiv:2207.04868 (2022).
[4] T. Sailer, V. Debierre, Z. Harman et al., Nature 606, 479 (2022).

Scientific topic:

Symmetries

Future Facilities / 52

Future facilities at PSI, the High - Intensity Muon Beams (HIMB) project

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Currently PSI delivers the most intense continuous muon beam in the world with up to a few 10ˆ8 μ+/s. The High Intensity Muon Beam (HiMB) project aims at developing a new target station and muon beam lines able to deliver 10ˆ10 μ+/s, with a huge impact for low-energy, high-precision muon experiments.

While the next generation of proton drivers with beam powers in excess of the current limit of 1.4 MW still requires significant research and development, the focus of HiMB is to improve the surface muon yield with a new target geometry and to increase capture and transmission with a solenoid-based beamline in order reach a total efficiency of approximately 10%.
We present the current status of the HiMB project.

Scientific topic:

Future Facilities

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Sterile neutrinos with the KATRIN Experiment, current status and prospects

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The KATRIN experiment is designed to measure the mass of the electron anti-neutrino by investigating the energetic endpoint of the tritium spectrum. KATRIN recently release it's latest results and is the rst direct experiment to report a sub-eV neutrino mass limit. As a complementary result, KATRIN also reported its rst limits for eV-scale sterile neutrinos.
The TRISTAN (TRitium Investigation on STerile to Active Neutrino mixing) project aims at searching for keV-sterile neutrinos in the full beta decay spectrum of tritium using a novel detector system at the KATRIN experiment. This detector is now in production and the commissioning of the rst phase of the project is expected to begin in 2025. Thanks to the high tritium source activity of KATRIN a statistical sensitivity at the level of sin2θ ˜ 10-6 can be reached.
In this talk, I will report the latest results of the KATRIN experiment and the on-going e orts to search for keV-sterile neutrino with TRISTAN.

Scientific topic:

Fundamental interactions

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The Base Experiment

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Throughout its existence, the Standard Model has proven very successful in describing fundamental interactions of elementary particles. However, the asymmetry between the abundance of matter and antimatter in the universe has yet to be understood.
The BASE experiment, located at CERN's Antiproton Decelerator (AD) facility, measures the fundamental properties of protons and antiprotons to test CPT symmetry with high precision. In the past, the BASE collaboration has compared the charge-to-mass ratio of protons and antiprotons at a fractional precision of 16 parts-per-trillion (p.p.t.) [1]. Additionally, the first ever non-destructive observation of spin flips with a single trapped antiproton was demonstrated [2], allowing the measurement of the antiproton's magnetic moment to a fractional precision of 1.5 parts-per-billion (p.p.b.) [3], which improved results by other groups by about a factor of 3000 [4].
Within this contribution I will present an overview over the BASE experiment and review the two-particle triple-trap measuring scheme that was used to measure the antiproton's magnetic moment with a fractional precision of 1.5 p.p.b. I will review the main systematic limitations of this previous antiproton g-factor measurement, and present recently implemented experiment upgrades. These contain a dedicated cooling trap for ultra-fast sub thermal cooling cycles of the cyclotron modes, and the implementation of a magnetic shimming and shielding system for stabilization and homogenization of the magnetic field of the measurement trap. Together with the implementation of phase sensitive detection methods, these improvements will enable an antiproton g-factor measurement with a fractional uncertainty of 100 p.p.t.
[1] Ulmer, S. et al., Nature 601, 53-57 (2022)
[2] Smorra, C. et al., Phys. Lett. B 769, 1 (2017)
[3] Smorra, C. et al., Nature 550, 371 (2017)
[4] DiSciacca, J. et al., Phys. Rev. Lett. 110, 130801 (2013)

Scientific topic:

Symmetries

Fundamental interactions / 55

Recent Higgs boson analysis results

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The latest results on the Higgs boson properties from the ATLAS and CMS experiments will be reviewed, 10 years after its discovery and
with 30 times larger statistics.
Searches of Higgs boson pair production will be presented.
In addition a few projections for the end of the high luminosity operation of the LHC will be shown.

Scientific topic:

Fundamental interactions

Symmetries and Interactions / 56

Current status and latest results of the Mu-MASS experiment at PSI

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Being purely leptonic, i.e. made of constituents which have (to the best of our knowledge) no internal structure, Muonium (M) is an excellent candidate to probe b-QED. I will present our recent measurement of the n=2 M Lamb Shift of 1047.2(2.5) MHz, which comprises an order of magnitud improvement upon the last determinations and matches with theory within one sigma. This allows us to set limits on Lorentz and CPT violation in
the muonic sector, as well as on new physics coupled to muons and electrons which could provide an explanation of the muon g-2 anomaly. I will discuss the future prospects of such a measurement and the current status of the 1S-2S experiment.

Scientific topic:

Symmetries and Interactions

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Lepton flavour violation and symmetry searches at PSI

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Scientific topic:

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Perspectives of EDM searches in Atoms and Molecules

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Scientific topic:

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Parity violation with neutrons

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Scientific topic:

Symmetries / 84

Measurement of the free neutron decay: status and prospects

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Scientific topic:

Symmetries / 91

The ASACUSA Experiment

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Scientific topic:

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The ALPHA Experiment

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Scientific topic:

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Public Lecture @ Austrian Academy of Sciences

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Scientific topic:

Future Facilities / 104

The MESA facility

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Scientific topic:

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Closing remarks

Scientific topic:

Fundamental interactions / 109

Gravity studies with neutrons

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Scientific topic:

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The g-2 experiment at FNAL

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The Fermilab muon g-2 experiment recently released its first measurement of the positive muon magnetic moment anomaly, a_mu = (g_mu-2)/2 to an accuracy of 0.46 ppm. The anomaly a_mu is of interest since it can be predicted with impressive precision and its value is sensitive, via quantum corrections, to the interactions of the muon with the other particles of the Standard Model. Comparison of measurement results and theoretical predictions tests the completeness of the Standard Model, and a significant discrepancy would indicate the need for new physics. Details of the Fermilab experiment and its first result will be presented, along with a comparison with the theory and future prospects.

Scientific topic:

Symmetries

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CPT invariance and neutrinos

Author: Gabriela Barenboim[1]

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CPT symmetry, the combination of Charge Conjugation, Parity and Time reversal, is a cornerstone of our model building strategy and therefore the repercussions of its potential violation will severely threaten the most extended tool we currently use to describe physics, i.e. local relativistic quantum fields. However, limits on its conservation from the Kaon system look indeed imposing. In this talk I will show that neutrino oscillation experiments can improve this limit by several orders of magnitude and therefore are an ideal tool to explore the foundations of our approach to Nature.

Scientific topic:

Symmetries

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Status of the COMET experiment

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COMET is an experiment at the Japan Proton Accelerator Research Complex (J-PARC), which will search for coherent neutrinoless tran- sition of muons to electrons in the coulomb eld of atomic nuclei (⊠– + N ⟶ ⊠– + N). Since this process violates charged lepton avor conservation it is highly suppressed in the Standard Model and thus provides a promising channel to probe new physics.
In order to realize the stringent requirements on detector system and muon beam the COMET experiment will follow a staged approach.
Phase-I is currently under construction at J-PARC and is aiming to improve the current branching ratio limit of 7×10−13 by two orders of magnitude. On top of the physics measurement a precise muon beam measurement will be conducted.
In Phase-II the branching ratio limit will be additionally improved by at least two orders of magnitude. Re nements of the experimental design based on ongoing investigations and experience gained from Phase-I will be used to push this even further for a total improvement of ve orders of magnitude.
This talk will give an experimental overview of both phases, along with recent updates of the facility and the current detector develop- ment status.

Scientific topic:

Future Facilities

Poster Session / 113

Simulations of Beam Dynamics and Beam Lifetime for the Prototype EDM Ring

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The matter-antimatter asymmetry may be explained through CP-violation by observing a permanent electric dipole moment (EDM) of subatomic particles. An advanced approach to measure the EDM of charged particles is to apply a unique method of "Frozen spin" on a polarized beam in an accelerator. To increase the experimental precision step by step and to study systematic effects, the EDM experiment can be performed within three stages: the magnetic ring COSY, a prototype EDM ring and finally all electric EDM ring. The intermediate ring will be a mock-up of the final ring, which will be used to study a variety of systematic effects and to implement the basic principle of the final ring. The simulations of beam dynamics of prototype EDM ring with different lattices are performed to optimize the beam lifetime and to minimize the systematic effects. The preliminary design of prototype EDM ring helped to estimate the beam losses by using analytical formulas. Further investigations on enhancing EDM measurement precision and reducing systematic effects are in process.

Scientific topic:

Symmetries

Poster Session / 114

In-beam measurements of the hydrogen hyperfine splitting to constrain SME coefficients

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The ASACUSA-CUSP experiment located at CERN's antiproton decelerator aims at measuring the ground state hyperfine splitting of antihydrogen ($\bar{H}$) using a beam technique to test CPT symmetry. For this purpose, a beam of cold (˜50K) hydrogen has been developed to characterize the antihydrogen spectroscopy apparatus [1]. Beyond serving as a test bench for the $\bar{H}$ experiment, the hydrogen beamline offers on its own a variety of possible measurements especially in the context of the Standard Model Extension (SME). The SME is an effective field theory that allows CPT and Lorentz symmetries to be broken [2]. A precise measurement of the hydrogen ground state hyperfine splitting was realized in 2017 using the extrapolation of a single hyperfine transition (σ1) reaching a relative precision of 2.7 ppb [3]. Since then several additions to the setup were made allowing the precise measurement of the π1 transition which provides sensitivities to some SME coefficients [4, 5]. A new measurement campaign on hydrogen started in 2021 and focused on π1 precision measurements with swapping external magnetic fields using the σ1 transition as a reference to constrain SME coefficients. The results of these measurements will be presented and an overview on the underlying theory and the experimental setup will be given.
[1] Malbrunot C, et al. 2019 A hydrogen beam to characterize the Asacusa antihydrogen hyperfine spectrometer. Nucl. Instrum. Methods A 935: 110-120.
[2] D. Colladay and A. V. Kostelecký 1998 Lorentz-violating extension of the Standard Model. Phys. Rev. D, 58:116002.
[3] Diermaier M, et al. 2017 In-beam measurement of the hydrogen hyperfine splitting and prospects for antihydrogen spectroscopy. Nat. Commun. 8, 15749.
[4] Malbrunot C, et al. 2018 The ASACUSA antihydrogen and hydrogen program: results and prospects, Phil. Trans. R. Soc. A 376: 2116.
[5] Kostelecký A. V. and Vargas A. J. Lorentz and CPT tests with hydrogen, antihydrogen, and related systems. Phys. Rev., D92(5):056002, 2015.

Scientific topic:

Symmetries

Poster Session / 115

Progress towards a positron trap at SMI

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A positron trap is a powerful and adaptable tool for performing experiments with positrons and positronium. These devices use a strong magnetic field, a stepped potential well and Nitrogen and CF4 buffer gas. Positrons are initially trapped via the electronic excitation of N2, CF4 is added for efficient cooling via vibrational and rotational excitations. This type of positron trap can typically produce ˜105 e+/s in

bunches with a diameter of 1-2 mm and an energy spread of approximately 50 meV [e.g. 1,2].
We aim to use the positron pulses from such a trap to observe molecules containing positronium, such as PsH [3] and PsO [4] via collisions in gases such as methane and carbon dioxide. By using a high mass resolution ion spectrometer to detect fragments from dissociation, precise measurement of their binding energy will be performed.
This poster will describe the progress on the construction of the positron beamline, trap, and ion spectrometer under construction at the Stefan Meyer Institute in Vienna.
[1] J. P. Sullivan, A. Jones, P. Caradonna, C. Makochekanwa, and S. J. Buckman , "A positron trap and beam apparatus for atomic and molecular scattering experiments", Review of Scientific Instruments 79, 113105 (2008).
[2] J. Clarke, D.P. van der Werf, B. Griffiths, D.C.S. Beddows, M. Charlton, H.H. Telle, P.R. Watkeys, Design and operation of a two-stage positron accumulator, Review of Scientific Instruments. 77 (2006) 063302.
[3] D.M. Schrader, F.M. Jacobsen, N.-P. Frandsen, U. Mikkelsen, Formation of positronium hydride, Phys. Rev. Lett. 69 (1992) 57–60.
[4] X. Cheng, D. Babikov, D.M. Schrader, Binding-energy predictions of positronium- atom systems, Phys. Rev. A. 85 (2012) 012503.

Scientific topic:

Symmetries

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Fermion number violation with heavy neutrinos

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Three mysteries stand after the discovery of the Higgs boson: (i) the origin of the masses of the neutrinos; (ii) the origin of the baryon asymmetry in the universe; and (iii) the nature
of dark matter. High energy colliders provide an exciting opportunity to resolve these mysteries with the possible discovery of heavy neutral leptons (HNLs), both at the HL-LHC from neutrinos produced in semi-leptonic decays, or at a later stage using the large sample (510ˆ12) of Z bosons with 20% neutrino decay fraction, produced in circular e+e- Higgs factories running at the Z pole.

The mixing between light and heavy neutrinos is expected to be very small, resulting in very long lifetimes for the HNL, and in spectacular signal topology. Even from Z decays, although the final state in this reaction appears to be charge-insensitive, it is possible to distinguish the Dirac vs Majorana nature of the neutrinos, by a variety of methods that will be discussed. A Majorana nature could have considerable implication for the generation of the Baryon Asymmetry of the Universe.

Scientific topic:

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Future Facilities / 117

Precise measurements of fundamental quantities of muon at J-PARC

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Various measurements aiming at the precise determination of the fundamental physical quantities of muons (mass, magnetic moment) are underway at the J-PARC Materials and Life Science Experimental Facility, Muon Facility (MUSE). These include muonium HFS and 1s-2s measurements, HFS measurements of muonic helium and muon trapping. Preliminaries results have already been obtained for the first two. This talk will report on the current status and future prospects activities

Scientific topic:

Symmetries

Symmetries and Interactions / 118

Chiral symmetry breaking: Current experimental status and prospects

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Chiral symmetry, linked to the smallness of the quark masses compared to the QCD bound states, and its breaking pattern are exploited in effective field theory to describe a multitude of phenomena by a few low-energy constants. Those concern light-meson dynamics and decays, their couplings to photons and meson-nucleon interactions. Special emphasis is given to the pion properties, in terms of pion-pion low-energy scattering, the pion polarizability and the chiral anomaly, which describes the coupling of three pions to a photon. These properties are studied by the COMPASS collaboration at CERN since first data taking with pion beams in the year 2004, and several following campaigns. In the framework of the upcoming AMBER collaboration, it is planned to extend the studies to the kaon sector.

Scientific topic:

Symmetries and Interactions

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Origin of the Proton Mass

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Atomic nuclei lie at the core of everything we can see; and at the first level of approximation, their atomic weights are simply the sum of the masses of all the neutrons and protons (nucleons) they contain. Each nucleon has a mass mN ≈ 1 GeV, i.e. approximately 2000-times the electron mass. The Higgs boson - discovered at the large hadron collider in 2012 - produces the latter, but what generates the masses of the neutron and proton? This is a pivotal question. The answer is widely supposed to lie within quantum chromodynamics (QCD), the strong-interaction piece of the Standard Model. Yet, it is far from obvious. In fact, removing Higgs-boson couplings into QCD, one arrives at a scale invariant theory, which, classically, can't support any masses at all. This presentation will sketch forty years of developments in theory that suggest a solution to the puzzle and highlight an array of experiments that can validate the picture.

Scientific topic:

Fundamental interactions

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Penning trap precision experiments for fundamental physics

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Experiments with single ions confined in a Penning trap enable access to a broad range of observables that are of fundamental importance for our understanding of fundamental physics. In the magnetic field of the trap, the cyclotron frequency of an ion can be determined with unique precision and gives direct access to the charge-to-mass ratio. Furthermore, we have access to the gyromagnetic g-factor via a measurement of the (Larmor) spin precession frequency. This way, we have determined a number of fundamental parameters, such as the electron, proton, neutron and deuteron atomic masses with leading precision.
Moreover, the continuous Stern-Gerlach effect gives us the possibility to determine the internal (spin-) state of the ion non-destructively. Consequently, we can measure the g-factors of almost arbitrary, also highly charged ions. Since the electric field found in such ions can reach extreme values up to 1016 V/cm, a comparison of the measured g with the prediction by theory yields the most stringent tests of quantum electrodynamics (QED) in strong fields. Recently, we have used our new generation experiment ALPHATRAP to push these measurements up until hydrogenlike tin 118Sn, where the field strength is two orders of magnitude higher than in any previous comparable measurements.
Also, our development of a novel technique to determine the g-factor difference of two simultaneously crystallized ions has led to a leap by two orders of magnitude on the precision frontier. With this technique, we have recently determined the isotopic effect of the g-factor in hydrogenlike neon ions, at 13 digits precision with respect to g and are consequently sensitive to previously invisible contributions, such as the QED recoil, and can set limits on hypothetical new physics such as dark matter mediated couplings.
Finally, the possibility to determine the internal state of a single ion gives us access to systems that were previously difficult to handle, such as the molecular hydrogen ions. Currently, we are performing spectroscopy on HD+ and soon H2+. The development of the necessary toolbox will be a seminal step towards a possible future spectroscopy of the antimatter equivalent, Hbar2-, which will enable a unique test of charge-parity-time (CPT) reversal symmetry.

Scientific topic:

Symmetries and Interactions

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Standard-Model Extension

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Lorentz and CPT symmetry represent cornerstones of our present understanding of nature, but may be violated in various theoretical approaches to underlying physics. Testing these symmetries therefore establishes a promising avenue to search for physics beyond the Standard Model. The canonical theoretical tool to identify possible experimental signatures of such violations is an effective-field-theory framework known as the Standard-Model Extension. This talk provides an overview of this topic with focus on efforts involving low-energy atomic and subatomic systems.

Scientific topic:

Symmetries

Application of new technologies / 122

Extreme precision magnetometry

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Searches for electric dipole moments (EDM), axion-like particle searches, ultra-cold atom experiments in space, atomic fountains or a new neutron-antineutron oscillation search at the European Spallation Source require precisely characterized and also very small magnetic fields. Some of these experiments actually are the most accurate and precise magnetic field sensors ever built.

Developments triggered by gradient-induced so-called "geometric phase"effects in the PanEDM experiment to search for the neutron EDM, the magnitude of magnetic fields over cubic meter dimensions has been reduced to few 10-12 T, with noise below 10-15 T and a stability of 10-14 T over several 100 s.

At this level of precision, it is difficult to disentangle properties of the magnetic field from the behavior of a probe to actually measure the field. In this talk I will discuss the state-of-the-art in small magnetic field research: (i) the best magnetic fields outside of superconductors and the level of understanding of how to generate and control these fields; (ii) recent advances of sensors to measure magnetic field stability and a 129-Xe EDM experiment with a sensitivity of 10-44 eV sensitivity, as well as a novel electrostatic storage ring to search for axion-like particles at TUM; (iii) transfer of these technologies being transferred to applications, in particular an example where a new diagnostic method for fetal heart diseases using atomic magnetometry has recently been developed.

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Towards Annihilation Studies with Slow Extracted Antiprotons

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A number of experiments at CERN's Antiproton Decelerator aim to measure the properties of antihydrogen to find structural differences hinting at CPT symmetry breaking that would explain the observed baryon-antibaryon asymmetry in our universe. These experiments detect antihydrogen through annihilation making the antiproton-nucleus (pbar-A) annihilation one of the main processes of interest.
The Monte Carlo simulations of these events rely on physics models developed for high energies and theoretically extrapolated to lower energies. Previous measurements from the AD experiments, including the ASACUSA-Cusp collaboration, show that the simulations do not reproduce the measured data. As even the annihilation mechanism itself is not well understood, a permanent parasitic beamline for slow extraction of antiprotons is being set up at the ASACUSA facility, in order to measure the p̄A annihilation at rest for fifteen nuclei.
The design of this beam line relies on bending and focusing elements, including an electrostatic quadrupole deflector and steering Einzel lenses that were simulated and designed using the SIMION simulation software. The aim of the simulations is to achieve a design capable of a 90° bend while providing good beam characteristics with minimal transmission losses. The optimization of the geometry and the applied voltages was achieved using a combination of several methods, such as geometry sweeps, the Nelder-Mead method and simulated annealing.
The total multiplicity of the annihilation prongs and their kinetic energy distribution will be measured with a novel detection system using Timepix4 pixel detectors covering most of the solid angle. Individual annihilation events will be reconstructed by extrapolating the recorded pion tracks, revealing their angular distribution. This poster will give an overview of the current status and progress of the experiment whose results will be implemented in a new simulation code for antiproton-nucleus reaction.

Scientific topic:

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Ultra-precise mass measurements for fundamental studies

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The Penning-trap mass spectrometer PENTATRAP [1] located at the Max Planck Institute for Nuclear Physics in Heidelberg is able to determine mass-ratios of highly charged ions of long-lived nuclides with a relative uncertainty of a few ppt [2, 3]. With a broad measurement program PENTATRAP did and continues to contribute to several fields of physics, e.g. test of bound-state QED [2] with direct measurements of binding energies and meta stable electronic states, neutrino-physics [3] and test of special relativity [4] by determining Q-values of nuclear reactions and 5th force research [5,6] with mass-ratios of isotope chains. Achieving ppt-precision requires a cryogenic ion trapping system in a stabilized, cold-bore 7 T superconducting magnet as well as applying image-current detection systems with single-ion phase-sensitive detection methods. Highly charged ions provided by external ion sources increase detector signal-to-noise as well as measurement precision due to higher frequencies. Simultaneous measurements in two traps allow for direct crosschecks of systematic effects. Presented will be the latest results and the status of the experiment.

[1] Repp, J. et al., Appl. Phys. B 107, 983 (2012).
[2] Schüssler, R.X. et al., Nature 581, 42–46 (2020).
[3] Filianin, P. et al., Phys. Rev. Lett. 127, 072502 (2021).

[4] Rainville, S. et al., Nature 483, 1096 (2005).
[5] Counts, I. et al., Phys. Rev. Lett. 125, 123002 (2020).
[6] Rischka, A. et al., Phys. Rev. Lett. 124, 113001 (2020).

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Best Poster Award - Ceremony

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Conference Photo