Physics of fundamental Symmetries and Interactions - PSI2022

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PSI

Book of Abstracts

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The high-intensity muon beam (HIMB) project at PSI

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At the Paul Scherrer Institut (PSI) muon rates of up several 10^8 μ^+/s are available, produced by its 1.4 MW proton accelerator complex HIPA. While these are currently among the highest muon rates available worldwide, projects in the US and Japan are underway that will be able to surpass these intensities by several orders of magnitude.
In order to maintain PSI's position at the intensity frontier in muon physics, to utilise the unique DC machine structure and to offer exciting new possibilities for particle physics and materials science, a project has started to create a next-generation muon beam by modifying the existing Target M station and attached beamlines. Simulations showed that surface muon rates of the order of 10^10 μ^+/s can be achieved by placing two normal-conducting capture solenoids close to a slanted graphite target and transporting the muons to the experimental areas with a beamline consisting of large-aperture solenoids and dipoles.
This contribution will present the current status of the project and the next steps towards its realisation.

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COMET - mu-e conversion search at J-PARC

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The COMET experiment aims at achieving the sensitivity of mu-e coversion search better than 10^-14 in Phase I and better than 10^-16 in Phase II using highly intense pulsed proton beam provided at J-PARC. The COMET experiment plans to start its engineering run in early 2023 followed by physics data acquisition in 2024. In this presentation, we will report the current status and future prospect of the experiment.

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The Search for Charged Lepton-Flavour Violation with the Mu3e Experiment

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The Mu3e experiment will search for the charged lepton-flavour violation decay of the muon into two positrons and one electron. With a vanishingly small branching ratio in the Standard Model, any observation of this process will be clear evidence for new physics. A first phase of the experiment aiming for a single event sensitivity of one in $2 \cdot 10^{15}$ muon decays is currently under construction at the πE5 secondary muon beam-line area at the Paul Scherrer Institute. To achieve the envisioned sensitivity, we are building a low-mass pixel tracker complemented by timing detectors surrounding a muon target to reconstruct the full kinematics of candidate $\mu^+ \rightarrow e^+e^+e^-$ events. An online FPGA- and GPU-based filter farm allows us to process over 10^8 muon decays per second. With all detector prototypes meeting specifications, sub-detectors are being constructed and integrated in the experimental apparatus during the ongoing engineering runs. In this presentation we report on the current status of the experiment, and our plans towards full detector commissioning and first physics data taking in two years from now.

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Constraining CP violation within effective field theories

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The baryon asymmetry of the universe points towards CP-violating sources beyond the Standard Model. If these consist of heavy new particles, their effect at low energies can be described by effective field theories. I will describe theoretical challenges and recent progress within this framework for the extraction of bounds on CP violation from neutron EDM searches. In particular, I will discuss the connection to lattice-QCD as an input for hadronic matrix elements.

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EDM searches in atoms and molecules: an overview

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Electric dipole moments (EDMs) are a convenient low-energy observable with high-energy implications. They induce violations of parity and time-reversal symmetry in atoms and molecules, which lead to experimental signatures that be precisely measured using atomic physics techniques.

I will provide an overview of EDM searches with atoms and molecules, discuss recent developments, and guess at what the future holds for this vibrant field.

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An Overview of the n2EDM Experiment at PSI

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The Standard Model is a well-tested and successful theory of particle physics. However, it does not fully explain the lack of anti-matter observed in the universe. A possible mechanism that could explain this is from new sources of CP violation. This could lead to the existence of a permanent electric dipole moment (EDM) in fundamental particles, through beyond Standard Model interactions. Historically, neutrons have been very successful at setting stringent limits on beyond Standard Model theories. The current limit on the neutron EDM is set by our collaboration, |d_n| < 1.8x10^-26 ecm (C.L. 90%). Presently, we are constructing the next generation experiment, n2EDM. With this, we aim to achieve an order of magnitude improvement in the sensitivity of the neutron EDM. This presentation will provide an overview of the experiment as well as the status towards commissioning for data taking.

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Recent activities of the Nuclear and Particle Physics group of the ILL

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he Nuclear and Particle Physics (NPP) group of the Institut Laue Langevin (ILL) is operating five public instruments providing an international user community competitive and often unique experimental conditions. We operate the PF1B cold neutron facility – the neutron beam with the worldwide highest flux of cold neutrons, including polarization capability and a large, background free experimental zone. Further, the PF2 ultra-cold neutron source provides four Ultra- (UCN) and one Very (VCN) Cold Neutron beam to users. This source optimized for high flux is complemented by SuperSUN and SUN2, two UCN sources based on superfluid Helium and aiming to deliver a maximum density of UCNs. The group is also operating two nuclear physics instruments: LOHENGRIN - a fission fragment separator with ultra-high mass and energy resolution, FIPPS - a Germanium detector array providing today a worldwide unique gamma ray spectroscopy setup around a slow-neutron pencil beam. Additionally to these permanent NPP neutron instruments, the ILL is contributing to neutrino physics. The STEREO campaign – searching for a short baseline neutrino oscillation has just been finished. RICOCHET – a new experiment looking at coherent neutrino scattering is under construction.

Following a short presentation of the instruments and their most recent upgrades, the talk is giving an overview on selected experiments and technical developments. I will touch recent activities searching for mirror neutrons using PF2, PF1B and STEREO, results from neutron decay experiments at PF1B and PF2, recent measurements of the qBounce collaboration at PF2 using neutron quantum states in the earth gravitational field. On the technical side, I will report on the status of the SuperSUN UCN source hosting the PanEDM experiment, recent progress in optics for cold and ultra-cold neutrons and the first feasibility demonstration of a split-crystal interferometer at a thermal neutron beam.

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Testing QED and Beyond with Exotic Atoms

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Despite decades of effort, quantum electrodynamics (QED) is poorly tested in the regime of strong coulomb fields due to a confluence of difficulties linked to experimental limitations in highly-charged ion spectroscopy and nuclear uncertainties. I will present a new paradigm for probing higher-order QED effects using Rydberg states in exotic atoms, where orders of magnitude stronger field strengths can be achieved while nuclear uncertainties may be neglected [1]. Such tests are now possible due to the advent of quantum sensing detectors and new facilities providing low-energy intense beams of exotic particles for precision physics. I will present first results from experiments with muonic atoms at JPARC within the context of the HEATES collaboration, and discuss new ideas for synergies with muonic and antiprotonic atom spectroscopy in Europe.

[1] N. Paul et al, Physical Review Letters 126, 173001 (2021)

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Zero-Field and High-Field Precision Measurements of Muonium Hyperfine Structure at J-PARC

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The muonium atom is a bound state of a positive muon and an electron, and is one of the hydrogen-like atoms which consists purely of leptons. By measuring the muonium hyperfine structure, the muon mass and the magnetic moment ratio of the proton to the muon can be determined. These values are used to determine the experimental value of muon $g-2$, for which a discrepancy of 4.2σ between the theoretical and experimental values in the Standard Model has been reported [1], and the importance of these measurements is increasing. We plan to measure the hyperfine structure of muonium with ten times higher precision than the previous experiment [2] by using high-intensity muon beam at J-PARC [3]. For zero-field measurements, a new analytical method named Rabi-oscillation spectroscopy has been developed [4], the gas pressure shift dependence has been improved using mixed gas of krypton and helium. Also for high-field experiments, we are developing probes that precisely measure the magnetic field of in an ellipsoidal spherical region. In this talk, we will report on these developments and preparations.

[1] T. Albahri *et al.*, (The Muon g 2 Collaboration) Phys. Rev. A **103**, 042208
[2] W. Liu *et al.*, Phys. Rev. Lett. **82**, 711-714.
[3] S. Kanda *et al.*, Phys. Lett. B **815** 136154.
[4] S. Nishimura *et al.*, Phys Rev. A **104**, L020801.

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The Mu-MASS experiment at PSI: Current status and latest results

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I will present our recent measurement of the n=2, Muonium Lamb Shift of 1047.2(2.5) MHz, which comprises an order of magnitude 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.

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MUSE, the MUon proton Scattering Experiment

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The proton radius puzzle began in 2010 when the CREMA Collaboration released their measurement of the proton radius (Pohl et. al (2010)) from muonic hydrogen spectroscopy: rp=0.84184(67) fm, This was five standard deviations smaller that the accepted CODATA value at that time (0.8768(69) fm), and sparked an enduring and intriguing puzzle. This puzzle has been addressed in repeated electron scattering measurements seeking to go lower in Q2, such as PRad at Jefferson Lab, and the Mainz Initial State Radiation experiment. There have also been a plethora of new atomic hydrogen spectroscopy experiments, and some more muonic atom spectroscopy. MUSE, the MUon proton Scattering Experiment, was first proposed in 2012 to be the first muon proton elastic scattering experiment with sufficient precision to address the proton radius puzzle. MUSE, measuring in the PiM1 area of the Paul Scherrer Institute, has the capacity to simultaneously measure elastic muon-proton, and electron-proton scattering, and switch polarities to measure with opposite charge states, giving access to cross sections, extracted radii, and two-photon measurements for muons and electrons. As such, MUSE can directly measure the two-photon effect by comparing charge-states, and compare muon and electron scattering. This will allow reduction of the systematic uncertainty due to the partial cancellation of uncertainties by simultaneous and / or subsequent measurements within the same apparatus. We will review the motivation for and status of MUSE.

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MUSE, the muon science facility in MLF J-PARC

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New Measurements of Muonic Helium Atom Hyperfine Structure at J-PARC MUSE

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Measurements of the muonic helium atom hyperfine structure (HFS) is a sensitive tool to test three-body atomic system, bound-state quantum electrodynamics (QED) theory, and determine fundamental constants of the negative muon magnetic moment and mass. The world most intense pulsed negative muon beam at J-PARC MUSE gives an opportunity to improve previous measurements and to test further CPT invariance through the comparison of the magnetic moments and masses of positive and negative muons (second generation leptons).
Muonic helium is a hydrogen-like atom composed of a helium atom with one of its electrons replaced by a negative muon. Its ground-state HFS, resulting from the interaction of the remaining electron and the negative muon magnetic moment, is very similar to that of muonium (a bound state of a positive muon and an electron) but inverted. New precise measurements of the muonium ground-state HFS interval using a microwave magnetic resonance technique are now in progress at J-PARC by the MuSEUM collaboration. The same technique as with muonium can be used to precisely measure the muonic helium HFS interval and the negative muon magnetic moment and mass. So, it is a timely opportunity to take advantage of the technical developments and experience gained by Museum to perform new precision measurements of muonic helium HFS [1].
Already, test measurements at D-line are in progress utilizing MuSEUM apparatus at zero field. Muonic helium HFS were measured at different helium pressures to determine the pressure shift using methane as an electron donor. The obtained results have already better accuracy than previous measurements [2,3]. Muonium HFS was also measured to investigate the isotopic effect on the pressure shift. Futhermore, a new experimental approach to improve HFS measurement accuracy is also being investigated by repolarizing muonic helium atoms using a spin exchange optical pumping (SEOP) technique [4,5].
An overview of the different aspects of these new muonic helium HFS measurements and the latest results will be presented.

[1] P. Strasser, et al., JPS Conf. Proc. 21 (2018) 011045.
[2] H. Orth, et al., Phys. Rev. Lett. 45 (1980) 1483.
[3] C.J. Gardner, et al., Phys. Rev. Lett. 48 (1982) 1168.
[4] A.S. Barton, et al., Phys. Rev. Lett. 70 (1993) 758.
[5] S. Fukumura, et al., EPJ Web Conf. 262 (2022) 01012.

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Muonic atom spectroscopy with radioactive targets

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Experimental efforts to probe new physics by measuring atomic parity violating transitions in a trapped radium ion require at least $0.2\,\%$ knowledge of the radium nuclear charge radius. An experiment at the Paul Scherrer Institute (PSI), pursued by the muX collaboration, aims to determine for the first time the absolute nuclear charge radii of $^{226}\mathrm{Ra}$ and other radioactive elements, such as $^{248}\mathrm{Cm}$, employing the muonic atom spectroscopy method. A muonic atom is formed when a negatively charged muon stops and is captured by the surrounding nuclei in a target. The muon, first captured at some high orbit, cascades down to the ground state of the atom by emitting X-rays. Due to its mass, the muon experiences considerably stronger binding energies compared to the electron with its low-lying states largely overlapping with the nuclear charge distribution. As a result, the energies of the low-lying muonic levels are highly sensitive to the nuclear structure details and the measurement of the muonic X-ray transitions serves as a sensitive probe of nuclear properties such as the charge radius. In 2016, an intermediate measurement was performed with isotopically pure $^{185,187}\mathrm{Re}$ being the last stable element with a non-measured charge radius. The analysis of the $5g \to 4f$ hyperfine transitions in $^{185,187}\mathrm{Re}$ led to the extraction of their spectroscopic quadrupole moments [1]. Work in $^{185,187}\mathrm{Re}$ on extracting its charge radius based on the $2p \to 1s$ hyperfine transitions is ongoing. Due to regulations imposing the usage of only microgram quantities of $^{226}\mathrm{Ra}$ and $^{248}\mathrm{Cm}$ in the experimental area of PSI, direct stopping of muons in the radioactive targets is impossible. A technique to transfer muons to microgram quantities of target material has been developed by the muX collaboration employing muon transfer reactions in a high-pressure $\mathrm{D}_2/\mathrm{H}_2$ gas mixture. Measurements with $^{226}\mathrm{Ra}$ and $^{248}\mathrm{Cm}$ were performed in 2019 and are currently being analyzed. Although there is no obvious observation of the $^{226}\mathrm{Ra}$ muonic transitions, we are close to determining the absolute charge radius in $^{248}\mathrm{Cm}$, making it the heaviest element measured by means of muonic atom spectroscopy. The status of the muX experiment and the future plans are presented in this contribution.

[1] A. Antognini *et al.*, Phys. Rev. C 101, 054313 (2020).

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The Neutron Lifetime puzzle and the Latest Results of the UCN-tau Experiment

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The rate of neutron decay can be precisely calculated, using the theory of electroweak interactions, with an uncertainty on the order of 1e-4. Recent measurements using bottled neutrons have achieved uncertainties below 1 s (0.1 %), but other measurements observing neutron decay in flight disagree by 10 s. Attempts to resolve this discrepancy have spawned much experimental effort as well as exotic theoretical conjectures, thus far without a clear conclusion. In this talk, I will discuss the challenges of precision measurement of the neutron lifetime, illustrating the UCNtau experiment. It eliminates the dominant loss mechanisms present in previous bottle experiments by levitating polarized ultracold neutrons above the surface of a large magnetic trap. Using this approach, a new result, 877.75 ± 0.28 (stat) +0.22/-0.16 (sys) s [PRL 127, 162501 (2021)], is the most precise measurement of the lifetime. This result, together with improved measurements of the axial coupling constant, will provide a determination of the CKM matrix element Vud, independent of nuclear decays, and address the recent tension in the test of CKM unitarity.

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The neutron decay problems and new physics

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Different methods of measuring the neutron lifetime lead to discrepant results at about 4.5 sigma. These anomalies are maybe related to yet unfixed systematics but they also can be an indication to new physics beyond the Standard Model. In particular, they can be explained by a neutron transformations in dark matter particles, or they could indicate to new non-standard interactions which modify the neutron beta-decay asymmetries. I overview different scenarios which can explain the existing anomalies and which are consistent with the present experimental and astrophysical bounds, and discuss in which type of new experiments these scenarios could be tested.

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Neutron EDM Searches

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New measurements of the neutron electric dipole moment (nEDM) will place even tighter constraints on theories involving new sources of CP violation beyond the standard model. It is believed these are required in order to explain the predominance of matter over antimatter (baryon asymmetry) in the universe. The nEDM constrains new physics scenarios at the TeV scale and beyond which do not conserve CP. A new measurement also could impact a longstanding mystery in the standard model, involving the apparent lack of CP violation arising from the strong sector. A discovery of a nonzero nEDM would be a major discovery, because it would shed light on a broad range of theories.

The most precise experiments involve new intense sources of ultracold neutrons (UCN). UCN are slow moving neutrons that can be stored in material, magnetic, and gravitational bottles. The ability to trap the UCN makes them ideal for nEDM measurements. The most precise experiment to date was conducted at PSI and determined an upper bound on the nEDM of $|d_n| < 1.8 \times 10^{-26}$ $e$cm (90% c.l.). The next generation of neutron EDM experiments aim to improve the uncertainty to the 1×10^{-27} $e$cm level. In this presentation, I will review the current status of nEDM experiments worldwide, with a focus on recent experimental progress made by each project. This will include some discussion of the TUCAN EDM experiment at TRIUMF, which I am involved in.

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The Fermilab Muon g-2 Experiment: Status and Outlook

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The Fermilab Muon g-2 (E989) collaboration has published the most precise measurement of the muon anomalous magnetic moment a_μ with an uncertainty of 460 ppb in 2021 based on the Run 1 (2018) dataset. The new experimental world average of a_μ deviates by 4.2 standard deviations from the Standard Model prediction provided by the Muon g-2 Theory Initiative.
Following Run 1, experiment upgrades have improved the stability of the detector and storage ring systems and refined the characteristics of the stored muon beam. Together with the significantly larger statistics, specialized measurement campaigns, analysis improvements, and simulation efforts, these aim to reduce the combined uncertainties toward the ultimate precision goal of 140 ppb.
Following the Run 1 publication, the analysis of Run 2 and 3 data is in progress. Meanwhile, the experiment reached with the recently completed Run 5 almost the required number of observed muon decays to achieve the ultimate precision goal.

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The MEGII experiment and exotic searches

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The MEG experiment searches for the μ+ → e+ γ decay and has recently set the most stringent upper limit on its branching ratio B(μ+ → e+ γ) < 4.2 10-13 at 90% C.L., based on the full data sample acquired during 2009-2013 years. It is a factor 30 improvement over the previous limit set by the MEGA experiment (B(μ+ → e+ γ)< 1.2 10-11 at 90% C.L.) and also the strongest bound on any forbidden particle decay.
The compelling physics motivation to further explore the μ+ → e+ γ decay has led the collaboration to decide upon an upgrade of the experiment, with the aim to improve the sensitivity by at least one order of magnitude. The MEG upgrade (MEGII) has been approved at PSI and by the institutions of the international collaboration, and is now underway with the first full engineering run scheduled and accomplished for the 2020-21. MEGII started its data taking period on 2021 and is expected to continue for the following years until the full statistics is achieved. More exotics searches are also considered to be carried out with the MEG apparatus.
The current status of the experiment and the future possible searches will be discussed.

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Overview of EDM experiments

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Precision measurements of the fine structure constant

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Novel approaches to GW detection (atom interferometry)

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Ultra-light FIPs: the FIP Physics Centre approach

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Measurement of multiple scattering of positrons for the Muon Electric Dipole Moment Experiment

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The current limit on the muon electric dipole moment (muEDM) of $d_\mu < 1.8{\times}10^{-19}\,e\mathrm{cm}\ (95\%\ \mathrm{C.L.})$[1] could be improved by $\sim 10^3$ with a dedicated muEDM Experiment at PSI.
An EDM signal would be clear evidence of CP violation, while its absence at current sensitivity would constrain Beyond Standard Model theories.
The proposed muEDM Experiment [2] will employ the frozen-spin technique [3] in a compact storage ring, necessitating the placement of high voltage electrodes proximate to the design orbit of the muon.
Within the magnetic field of the storage ring, the decay positrons will intersect repeatedly with the electrodes and internal tracking detectors used to reconstruct their trajectories.
Simulations must incorporate the effects of multiple Coulomb scattering in these materials.
Ongoing simulation studies are central to informing design choices and predicting the systematic uncertainties of the measurement.
It is therefore important that the underlying models of multiple Coulomb scattering at the relevant momenta and material thicknesses are experimentally verified.
Multiple scattering of positrons and muons in graphite, Pokalon, silicon and Mylar was measured for momenta $50\,\mathrm{MeV}/c - 140\,\mathrm{MeV}/c$ on the πE1 beamline at PSI, using a beam telescope composed of three upstream and two downstream MuPix10 [4] silicon pixel sensors.
Preliminary results validating these models will be presented and the implications for the positron reconstruction efficiency discussed.
[1] G.W. Bennett et al., Phys. Rev. D, 80, 052008 (2009).
[2] A. Adelmann et al. arXiv:2102.08838 (2021).
[3] F.J.M. Farley et al., Phys. Rev. Lett., 93, 052001 (2004).
[4] H. Augustin et al., Nucl. Instrum. Methods A, 979, 164441. (2020).
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Development of a novel comagnetometer for high-precision measurement of the electron's electric dipole moment using laser-cooled Fr atoms

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In this presentation, the current status of a comagnetometer which is dedicated to search for the permanent electric dipole moment of the electron (eEDM) using francium atoms is discussed. The designed comagnetometer consists of laser-cooled Rb-87 and Cs-133 atoms trapped simultaneously in an optical lattice in order to observe the effects of Zeeman shift and vector light shift independently. This is expected to inclease the measurement precision of the eEDM, consequently allows to search for the CP violation with high precision.

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Characterisation of the simultaneous spin analyser developed for the n2EDM experiment at the Paul Scherrer Institute

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on behalf of the nEDM collaboration

In the n2EDM experiment, the measurement of the neutrons spin state is required. Neutrons are first fully polarised in a super conducting magnet and then subjected to a magnetic field of 1 µT and a strong electric field (around 15 kV/cm). The goal is to measure the neutrons precession frequency and to assess the possible frequency shift induced by the interaction between the electric field and the neutron EDM. For such a purpose, the Ramsey's oscillating fields method is used: it requires the counting of the spin up and the spin down UCN. To do so, a U-shaped Simultaneous Spin Analyser (USSA) was built at the Laboratoire de Physique Corpusculaire (LPC Caen). It is composed of two arms which separately analyse one of the two spin components. Each arm contains a Spin Flipper (SF), an analysing foil and a neutron counter (GADGET). The first tests of the USSA were carried out in July 2022 at the ultracold neutron source of the Paul Sherrer Institute (PSI Switzerland). A preliminary characterization of the USSA is presented in this poster.

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The precision magnetic field in the Muon g-2 Experiment at Fermilab

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The Muon g-2 collaboration has published the most precise measurement of the muon anomalous magnetic moment a with an uncertainty of 460 ppb in 2021. The new experimental world average of a deviates by 4.2 standard deviations from the Standard Model prediction provided by the Muon g-2 Theory Initiative. The emerging results from ab-initio lattice QCD calculations allow scrutiny of this tantalizing hint for physics beyond the Standard Model for the first time in a three way comparison. To extract the value of a at Muon g-2, a clock comparison experiment is performed with spin-polarized muons confined vertically with electric fields in a superbly controlled magnetic field environment. The anomalous spin precession frequency, defined as the deviation of the spin precession frequency from the cyclotron frequency, is determined while a high-precision measurement of the magnetic field is performed using nuclear magnetic resonance techniques. This contribution will present the multi-step measurement and analysis of the high-precision magnetic field in the muon storage volume. This work is supported by the Cluster of Excellence “Precision Physics, Fundamental Interactions, and Structure of Matter” (PRISMA+ EXC 2118/1) funded by the German Research Foundation (DFG) within the German Excellence Strategy (Project ID 39083149) and the EU Horizon 2020 Research and Innovation Programme under the Marie Sklodowska-Curie Grant Agreement No. 101006726.

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NOPTREX: A Neutron Optics Time-Reversal Violation Experiment

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**The forward neutron-nucleus scattering amplitude has a T-odd, P-odd component proportional to $\sigma_n \cdot I \times k_n$. Thus the double spin-dependent neutron absorption cross section is a suitable observable in which to search for a new source of CP-violation needed to explain the baryon asymmetry of the universe. Unlike other complementary observables such as the electric dipole moment of fundamental particles, this effect can be amplified by up to a factor of 10^6 by the interference of closely-lying mixed parity states in heavy nuclei such as ^{139}La, ^{131}Xe, ^{81}Br, and ^{117}Sn. The goal of the NOPTREX collaboration is to prepare a search for time-reversal invariance violation(TRIV) in neutron scattering by performing precision measurements of hadronic parity violation (HPV) and of $\kappa(J)$, which relates the sensitivity of TRIV to that of HPV. I will present an overview of the international effort coordinated across four neutron sources, towards building the NOPTREX experiment.

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Characterization of the new Ultracold Neutron beamline at the LANL UCN facility

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The neutron electric dipole moment (nEDM) experiment that is currently being developed at Los Alamos National Laboratory (LANL) will use ultracold neutrons (UCNs) and Ramsey's method of separated oscillatory fields to search for a nEDM. We present measurements of UCN storage and UCN transport during the commissioning of a new beamline at the LANL UCN source and demonstrate a sufficient number of stored polarized UCNs to achieve a statistical uncertainty of $\delta d_n = 2 \times 10^{-27}$ $e \cdot$ cm. We also present an analytical model describing data that provides a simple parameterization of the input UCN energy spectrum on the new beamline.

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The 2s-1s transition in muonic atoms and atomic parity violation

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Due to the large overlap between the muon and nuclear wave function, muonic atoms are an exceptionally sensitive system to study short range muon-nuclear/nucleon interactions and probe various nuclear moments. With a physics program focusing on Atomic Parity Violation (APV), the muX collaboration is performing a series of muonic X-ray measurements in medium- and high-Z nuclei, exploiting the coverage and high multiplicity of a germanium detector array and the high-quality negative muon beams at the Paul Scherrer Institute.
Here I will present the first results of a measurement program explores the possibility of observing APV directly in muonic atoms. APV arises from the mixing of the opposite parity 2p and 2s atomic states, leading to parity violation in the 2s-1s transition. We focus on Z=30 nuclei, where a measurable branching ratio of the single photon 2s-1s transition is expected.

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Measurements of the UCN energy spectra and their time evolution in a large storage volume

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The energy spectrum of ultracold neutrons (UCN) is an important factor in determining the systematic effects in precision measurements utilizing UCNs. We performed UCN energy spectrum measurements in a large storage tank filled by the PSI UCN source and studied its time evolution using OTUS - an oscillating spectrometer [1]. The obtained results will be compared to the TOF method and a detailed Monte Carlo simulation [2]. In this contribution, the current status of the OTUS project will be reported including the evolution of the energy spectrum for different UCNs storage times.

References:
[1] D. Rozpedzik, et al., EPJ Web of Conf. 219, 10007 (2019).
[2] G. Bison, et al., EPJ A 58, 103 (2022).

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Storage and Guide Tests at SUN2 for PanEDM

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Neutron Electric Dipole Moment searches typically compare spin precession of trapped ultra-cold neutrons (UCN) with a stable clock, in an applied high electric field. One approach to limit systematic uncertainties in this type of experiment employs two storage chambers, allowing for simultaneous differential measurements with two electric field orientations. In PanEDM [1] this approach is supported by exceptional low-frequency magnetic shielding [2], advanced optical magnetometry systems [3], and a high-density superthermal UCN source – SuperSUN [4].

The PanEDM experiment is currently under commissioning at the Institut Laue-Langevin, and characterisations of individual systems continues in parallel with preparations for first UCN production at SuperSUN. We present a short overview of the current status of the PanEDM experiment and report on measurements carried out at SUN2, the predecessor of SuperSUN, to investigate solutions for UCN transport and storage in PanEDM.

References

1. D. Wurm et al., EPJ Web of Conferences 219, 02006 (2019)
2. I. Altarev et al., J. Appl. Phys., vol 117, 183903 (2015)
3. M. Rosner et al,. Appl. Phys. Lett. 120, 161102 (2022)
4. O. Zimmer and R. Golub, Phys. Rev. C, vol. 92, 015501 (2015)

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Neutron Pendellösung interferometry to search for exotic interactions

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Co-authors: Albert Young [2]; Hirohiko Shimizu [1]; Masaaki Kitaguchi [1]; Michael Huber [3]; Takeda Masahiro [4]; Yutaka Yamagata [5]

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The standard model of particle physics cannot explain the origin of the accelerating expansion of the universe or the hierarchy problem of gravity. Theories beyond the standard model of physics created to solve these problems often also predict the existence of a fifth fundamental force. We search for the existence of a fifth force using neutron pendellösung interference, where the neutron intensity diffracted from a nearly-perfect crystal oscillates as a function of neutron wavelength, crystal thickness, and neutron material structure factors. Recent experiments have produced precise measurements of the neutron structure factors for the (111), (220), and (400) Bragg reflections in silicon. These data update the limits on the strength of a fifth force on the atomic length scale and include new measurements of the neutron mean square charge radius and silicon Debye-Waller factor. Extension of this experiment to germanium or other crystals will measure the material-specific Debye-Waller factors and increase our sensitivity to the neutron charge radius and fifth forces. In this talk, I report the experiment result using silicon crystal and the current status of the neutron structure factor measurements using germanium.

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Charged Lepton Flavour Violation in the Symmetry-Protected Type-I Seesaw

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The type-I seesaw model is probably the most straightforward and best studied extension of the Standard Model that can account for the neutrino masses determined from neutrino oscillation data. We study the symmetry-protected type-I seesaw, in which the Wilson coefficient of the Weinberg operator is set zero such that sizeable neutrino Yukawas are permissible that can lead to relevant effects in charged lepton flavour violating observables. We correlate $\ell \to \ell'\gamma$, $\ell \to 3\ell'$, $Z \to \ell\ell'$ and $\mu \to e$ conversion in nuclei, taking into account the constraints from electroweak precision observables and tests of lepton flavour universality and confront our predictions with current and future bounds on lepton flavour-violating processes.

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muCool: A novel low-energy muon beam for precision experiments

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High precision experiments using muons (μ+) and muonium atoms (μ+e−) offer promising opportunities to test theoretical predictions of the Standard Model in a second-generation, fully-leptonic environment. Such experiments including the measurement of the muon g-2, muonium spectroscopy and muonium gravity would benefit from intense high-quality and low-energy muon beams.

At the Paul Scherrer Institute, a novel device (muCool) [1] is being developed to reduce the phase space of a standard μ+ beam by a factor of 109 with 10−4 efficiency, for a 105 boost in brightness. The muon beam is stopped in cryogenic helium gas and using complex electric and magnetic fields in combination with a gas density gradient the muons are steered to a mm-size spot, where they have an eV energy spread. From here, they are extracted through a small orifice into a vacuum and into a magnetic field free region. The entire process takes less than 10 μs, which is crucial given the short 2.2 μs muon lifetime.

The presented poster will outline the working principle, the present status and future prospects of the muCool experiment with a special focus on the extraction stage from the orifice into vacuum.

This work is supported by SNF grant 200441_172639

[1] Belosevic, I., Antognini, A., Bao, Y. et al. muCool: a next step towards efficient muon beam compression. Eur. Phys. J. C 79, 430 (2019). https://doi.org/10.1140/epjc/s10052-019-6932-z

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Low-energy effective field theory below the electroweak scale: one-loop renormalization in the 't Hooft-Veltman scheme

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We perform the one-loop renormalization of the low-energy effective field theory (LEFT) in the 't Hooft-Veltman (HV) scheme for γ_5. We extend the LEFT operator basis by the required set of evanescent operators. Instead of using a pure $\overline{\text{MS}}$ procedure, we renormalize physical operators such that they absorb the finite effects from insertions of evanescent operators as well as finite chiral-symmetry-breaking terms. Our results can be applied to one-loop LEFT calculations in the HV scheme: using our renormalization scheme instead of pure $\overline{\text{MS}}$ leads to results that are manifestly free of spurious chiral-symmetry-breaking terms.

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Next Generation Active Magnetic Shielding for n2EDM experiment at PSI.

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The n2EDM experiment, which is currently under construction at the Paul Scherrer Institute (PSI), is designed to improve the sensitivity of the neutron electric dipole moment by an order of magnitude.

In order to achieve this goal, it is crucial to stabilize the magnetic fields inside the precession chamber, where neutrons are stored and Ramsey measurements are performed.

For this purpose, an active magnetic shielding (AMS), which compensates the surrounding field and the occurring field changes, was designed, constructed and commissioned.

It is placed around the passive six layer mu-metal shield, on a dedicated grid spanning a volume of about 10m x 10m x 10m.

The system consists out of 55km of cables that form eight independent coils so that the three homogeneous components as well as all five linear gradients of the magnetic field can be produced.

A set of fluxgate sensors is employed to measure the magnetic field and their readings are used in a closed-loop algorithm to drive the coil currents.

In this contribution we will present the AMS system and its first performance measurements.

This project has been supported by the SNSF grants 172639, 200441, 186179 and 201473.

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Current Status for the search of time-reversal symmetry violation using compound nuclear reactions

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The large enhancement of parity-violation of the weak interaction was found in nuclear reactions for several nuclei [1]. The enhancement is explained as the mixing of parity-unfavored partial amplitudes in the entrance channel of the compound sates, s-p mixing [2]. It is proposed that the time-reversal symmetry violation is also enhanced in compound nuclei by the same mechanism [3]. We are preparing the time-reversal violation search based on this new approach.
The time-reversal violation can be obtained by measuring the neutron spin behavior in compound nuclei using polarized neutron beam and polarized nuclear target. In parallel with the development of these instruments, we conduct precise measurements of compound nuclear reactions in J-PARC MLF. The enhancement factor of time-reversal violation can be estimated by measuring the angular correlation terms of (n,γ) reactions according to the s-p mixing theory. We have measured the several correlation terms for several nuclei, such as ^{139}La, ^{117}Sn, and ^{131}Xe, which are candidates of the target nuclei in the time-reversal violation search. Furthermore, we have already started the experiments with the polarized neutron beam and the polarized target. In this presentation, we will introduce the current status of the preparation for the search of time-reversal violation.

[1] G. E. Mitchell et al., Phys. Rep. 354, 157 (2001).
[2] V. P. Gudkov, Phys. Rep. 212, 77 (1992).
[3] V. V. Flambaum and O. P. Sushkov, Nucl. Phys. A 435, 352 (1985).

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Microcalorimetric high-resolution spectroscopy of muonic lithium

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Metallic magnetic microcalorimeters (MMCs) represent a promising detection method for broad-band high-resolution x-ray spectroscopy. These systems are particularly suitable for the detection of low-energy x-rays, as found in the spectroscopy of low-Z muonic atoms. Such high-resolution spectra would enable precision measurements of charge radii of light nuclei and could thus provide important benchmarks for modern nuclear theory. In this context, plans are presented for the spectroscopy of muonic lithium using MMCs as part of an upcoming experiment at the Paul Scherrer Institute.

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Pseudoscalar pole contributions to the muon g-2 from lattice QCD

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Pseudoscalar pole diagrams are the numerically dominant component of the HLbL contribution to the muon $g-2$. We report on our computation of the pion and eta pole contributions from twisted mass lattice QCD at physical quark masses. Pion and eta transition form factors to two photons are the key intermediate quantity required to derive these contributions; on the lattice, we have access to a broad range of photon momenta and therefore produce form factor data complementary to the experimentally accessible singly virtual kinematics. This intermediate result can also be compared directly against such values where they are measured by current and past experiments, such as BES-III, CLEO, CELLO, Belle, and BaBar, and serves as a prediction in kinematic regimes that have not yet been reported. For the pion, the resulting value of $a_\mu^{\pi-\mathrm{pole}}$ is comparable with previous lattice and data-driven determinations, with combined uncertainties achieving sub-10% precision. For the subleading eta-pole contribution, we present a first ab initio determination, with a relative precision below 40%.

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Cs magnetometer based current source for permanent neutron electric dipole moment measurement

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Cs magnetometer based current source for permanent neutron electric dipole moment measurement

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(on behalf of the nEDM collaboration)

A non-zero permanent Electric Dipole Moment (EDM) in elementary A non-zero permanent Electric Dipole Moment (EDM) in elementary particles is a direct evidence for CP violation at subatomic level, which could be helpful for explaining the observed matter and anti-matter asymmetry of the Universe. In addition, the limit on any EDM of a fundamental particle or system provides a critical constraint for theoretical models. Due to this, EDM searches are being conducted on various scales from nuclei to neutron, electron and muon around the world. Among these, the neutron EDM (nEDM) and Hg EDM provide a stringent limit on θQCD, which rises the existence of an axion boson, a candidate of light dark matter. After 70 years' efforts, the limit of nEDM currently reaches the 10^{-26} e.cm [1] level measured at PSI. The goal of the new apparatus n2EDM, is in the baseline setup to reach the 10^{-27} level [2] that will test as example the theoretical prediction from left-right symmetric models [3].

To achieve this sensitivity, apart from increasing statistics, however, many technical challenges still exist which have to be overcome/optimized in order to achieve the 10-27 level. One of these challenges is the non-stability of the magnetic field over time. In order to solve this problem, a CsM based electric current source was developed at KU Leuven with $5*10^{-9}$ stability at 20 mA for 70 min, which could be used either to provide a feedback-stabilized current or for monitoring the evolution of the B-field and then performing an offline correction [4,5].

Here we present the latest performance of the CsM based electric current source and the possible schedule of its coupling with the n2EDM spectrometer at PSI. In addition, the upgrade of the magnetometry laboratory at Leuven and the planned endeavor of enhancing the sensitivity of the CsM based current source through adjusting its geometric configuration will be introduced.

[1] C. Abel et al., PHYSICAL REVIEW LETTERS 124, 081803 (2020)
[2] N.J. Ayres et al., EUR. PHYS. J. C, (2021) 81:512
[3] X. G. He et al., PHYSICAL REVIEW LETTERS 61, 1267 (1988)
[4] P.A. Koss et al., IEEE MAGNETICS LETTERS, 8 (2017) 1306205
[5] P.A. Koss et al., PHYS. REV. APPLIED 16, 014011 (2021)

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The mercury co-magnetometer in the n2EDM experiment

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The n2EDM experiment at PSI's Ultracold Neutron source aims at searching for the permanent neutron electric dipole moment with a sensitivity of about 1×10^{-27} ecm with the baseline setup. In order to correct for first order magnetic field drifts and gradients when using Ramsey's method of separated oscillating field with ultracold neutrons, this experiment requires a precise knowledge of the magnetic field. Therefore, a laser-based mercury co-magnetometer has been developed to measure the magnetic field in the two precession chambers where the UCN precess together with the Hg atoms. By taking the ratio of the mercury to neutron spin precession frequencies we will correct for systematic uncertainties related to the magnetic field.
To spin-polarize the mercury atoms, a UV laser beam will be directed to the mercury polarization chamber. The volume-averaged magnetic field can be measured by analyzing the mercury precession signal probed by another UV beam traversing the precession chambers. The stabilization of the laser light is essential for this measurement, including frequency, position, and power stabilization. The poster will present the research on frequency locking techniques of the laser source, the more than 10 meter long transport line from a laser lab to the main experimental setup, and a discussion of mercury-related systematic uncertainties.

Support by SNF Project #204118 is gratefully acknowledged.

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Precision Cross-Calibration of the NMR calibration probes for the J-PARC Muon g-2/EDM, J-PARC MuSEUM, and FNAL Muon g-2 experiments at the ANL 4T Magnet Facility

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The measurement of the muon anomalous magnetic moment a_μ is a precision test of the Standard Model and an indirect search for New Physics. The Muon g-2 (E989) collaboration has published the most precise measurement of the muon anomalous magnetic moment with an uncertainty of 460 ppb in 2021, leading to a world average that deviates by 4.2 standard deviations from the Standard Model prediction provided by the Muon g-2 Theory Initiative. The complementary Muon g–2/EDM experiment (E34) at Japan Proton Accelerator Research Complex (J-PARC) is under construction.
Both experiments, as well as the Muonium Spectroscopy Experiment Using Microwave (MuSEUM), rely on the precision measurement of the magnetic field experienced by muons and muonium respectively. All three experiments use nuclear magnetic resonance (NMR) probes to measure of the magnetic field in terms of the precession frequency of the protons.
However, materials in the probes themselves perturb the local field resulting in small correction terms. In order to cross check these correction terms the different NMR probes that use different techniques, continuous wave (cw) versus pulsed NMR, are cross-calibrated in the Argonne National Laboratory (ANL) 4T Magnet Facility. The goal is to cross check the different probes on a 35 ppb level.

This poster gives an overview of the ANL 4T Magnet Facility, presents the status of the cross-calibration at 1.45T and 1.7T, and provides an outlook for calibrations at 3T.

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Cryogenic muonium beam for the LEMING experiment

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The LEMING experiment aims to measure the free fall of muonium (M $= \mu^+ + e^-$) and thereby testing for the first time the weak equivalence principle using a purely leptonic, second-generation antimatter dominated system. Such a direct measurement requires a high-intensity, low-emittance M beam. We have demonstrated the working principle of this novel M beam by stopping accelerator muons in a thin layer of superfluid helium and by the subsequent observation of M emission from the helium target. The experimental setup including cryogenic scintillation detectors operating at $<$ 0.2 K temperatures will be described. Further, an initial characterization of the novel M source will be presented, showing the non-thermal behaviour of the M beam required for the LEMING experiment.

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Recovery of Photon Detection Efficiency of SiPMs in the liquid xenon detector by annealing

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The MEG II experiment searches for the charged lepton flavor violation process, $\mu \to e^+ + \gamma$, with the target sensitivity of branching ratio : O(10^{-14}).
Gamma-rays are detected by the liquid xenon detector to reconstruct their energy, timing, and position. In the liquid xenon detector, 4092 VUV-sensitive MPPCs produced by Hamamatsu photonics are used. Decrease of photon detection efficiency (PDE) of MPPCs during beam time was a problem and we found the PDE recovers by annealing (heating). In the beginning of 2022, annealing of almost all MPPCs was conducted. In this poster, the result of this annealing will be presented.

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Interferometry setup for the LEMING experiment

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The LEMING experiment aims to test the equivalence principle for second-generation matter, using a cold muonium beam (bound μ+e−), where the inertial mass is dominated by the muon.
The feasibility of such a measurement relies on measuring the gravitational deflection of a lifetime-limited atomic beam. In this poster, the feasibility of an atomic interferometer is discussed, which could potentially provide a percent-level measurement of g of muonium.

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Spin precession in BaF: Towards a limit on the electron's electric dipole moment

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Limiting the value of the permanent electric dipole moment on the electron (eEDM) provides a sensitive probe of the Standard Model of particle physics and its extensions. The current best limit on the eEDM is $|d_e| < 1.1 \times 10^{-29}\ e\,\mathrm{cm}$ [1] using ThO, while experiments have been performed using a number of different atoms and molecules. In our experiment a supersonic source of BaF molecules with velocities of ~600 m/s pass through well-known E- and B-fields (10 kV/cm, 10 nT resp.) [2] in which a sensitive spin precession measurement is performed.
The spin precession takes place for a superposition state of the $|F = 1, m_F = |1| >$ magnetic substates in the $X^2\Sigma^+(v = 0,\ N = 0)$ ground state, which is created and read out solely by pulsed laser field interactions. The eEDM is extracted from the final population distribution within the $|F = 1 >$ hyperfine level. Systematic biases from parameters such as laser frequency, polarisation and power are vital to control and measure. This talk will discuss the experimental techniques employed to extract an eEDM limit and quantify possible systematic effects.

[1] ACME Collaboration, Nature 562, 355–360 (2018).
[2] The NL-eEDM collaboration, Eur. Phys. J. D 72, 197 (2018)

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A muon entrance detector for the muEDM experiment at PSI

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The muEDM experiment at PSI aims to search for the muon electric dipole moment with unprecedented sensitivity. The muon is first injected into a solenoid storage ring, and then a pulsed magnetic field is used to kick the muon onto a stable orbit. To this end, a fast signal is required to trigger the magnetic field, and this is provided by a muon entrance detector consisting of an ultra-thin entrance plastic scintillator and four wall scintillators. A robust trigger can be made by constructing an anti-coincidence between the wall scintillators and the entrance scintillator. This poster presents the design and simulation study of the muon entrance detector. The expected detector performance and the effect on the phase space of the injected muon beam will also be discussed.

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The DAQ of the Mu3e Integration Runs

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The Mu3e experiment at the Paul Scherrer Institute (PSI) searches for the charged lepton flavour violating decay $\mu^+ \rightarrow e^+e^+e^-$.
The experiment aims for an ultimate sensitivity of one in 10^{16} μ decays.
The first phase of the experiment, currently under construction, will reach a branching ratio sensitivity of $2 \cdot 10^{-15}$ by observing 10^8 μ decays per second over a year of data taking.
The highly granular detector based on thin high-voltage monolithic active pixel sensors (HV-MAPS) and scintillating timing detectors will produce about 80 GB/s of data at these particle rates.

The Field Programmable Gate Array based Mu3e Data Acquisition System (DAQ) will read out the different detector parts.
The trigger-less online readout system is used to sort, time align and analyze the data while running.
A farm of PCs equipped with powerful graphics processing units (GPUs) will perform the data reduction and the identification of interesting events.

The poster presents the ongoing integration of the sub detectors into the DAQ, in particular focusing on the time aligning and the data flow inside the FPGAs of the filter farm.
It will show the DAQ system used in the Mu3e Integration Runs performed in spring 2021 and 2022.

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Multi-Objective Genetic Optimization for the High-Intensity Muon Beams at PSI

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The High-Intensity Muon Beams (HIMB) project aims to increase the rate of the intensity muon beamlines at Paul Scherrer Institute (PSI) by two orders of magnitude up to 10^10 μ+/s, with a significant impact on low-energy, high-precision muon-based experiments. This is done by improving the surface muon yield with a new target geometry and by increasing capture and transmission with solenoid-based beamlines.

Even though the project focuses on surface muons, the increased capture and transmission affect all the particle species produced at target. The beamlines will be able to deliver muons, electrons and pions, and it is essential to evaluate the deliverable beam characteristics of all the particle species in the full momentum range accepted by the dipoles, up to 80 MeV/c.

To evaluate the performances of the beamlines, we rely on particle tracking simulations in high-fidelity field maps, which are computationally intensive and time-expensive to optimize. The optimization of the relevant beam parameters is performed with Multi-Objective Genetic Algorithms (MOGA), as they have been proved efficient in solving high-dimensional global optimization problems.

We present here the optimization strategy of the HIMB beamlines based on MOGA and its results.

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Hunting for axion-like particles with the nEDM and n2EDM experiments at PSI

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Ultralight Axions and axion-like particles are important dark matter candidates. If they are responsible for a significant proportion of dark matter, and are thus present in a large number density, they can be viewed as a galactic-scale classical field oscillating at a frequency proportional to their mass m_a. Interactions of a coherently oscillating axion dark matter field with gluons could then induce an oscillation in the neutron EDM. By using data from the nEDM experiment at the Paul Scherrer Institut this allows us to set laboratory constraints on the axion-gluon coupling.

We present a refined analysis of the data from the nEDM experiment at PSI which improves the limits on the oscillation amplitude, and thus coupling strength, by a factor of two for mass ranges between 10^{-24} eV ≤ m_a ≤ 10^{-17} eV (corresponding to frequencies between $2{\cdot}10^{-8}$ Hz - $5{\cdot}10^{-5}$ Hz) compared to our previously published results. Furthermore, we give predictions on the exclusion limits that will be achieveable with the data from the n2EDM experiment at PSI, which is expected to start data-taking in 2023.

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Operation of Liquid Xenon Gamma-Ray Detector for MEG II Experiment Physics Run in 2022

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The MEG II experiment searches for $\mu \to e\gamma$ decay which is one of the charged lepton flavor violation decays. The discovery of this decay will be clear evidence of new physics beyond the Standard Model. The liquid xenon (LXe) gamma-ray detector is one of the subdetectors in the MEG II experiment. It measures the energy, position and timing of the gamma-ray from $\mu \to e\gamma$. The LXe scintillation light is read out by 4092 VUV-sensitive SiPMs and 668 PMTs.
This poster will report on the operation of the LXe detector in the 2022 physics run. Parameters such as a gain and a photon detection efficiency of the photosensors need to be monitored continuously as they fluctuate over the beamtime. The current status and the outlook of the LXe detector will be reported.
Fluctuations of the gain of the photon sensors due to the opening and closing a beam blocker have been observed. The sensors can be calibrated more accurately by taking this fluctuation into account. The current status of the calibration that takes into account the sensor response variation caused by the opening and closing of the beam blocker will be also reported.

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Beamline Final Foci Optimisations for High Intensity Muon Beams at PSI

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The High Intensity Muon Beams (HIMB) project at the Paul Scherrer Institute (PSI) will provide an unprecedented rate of 1e10 muons/sec to next-generation intensity frontier particle physics and material science experiments. As part of our work on the beamline design optimisation for the HIMB, we used differential-algebraic transfer maps with system knobs computed using the code *COSY INFINITY* to minimise the beam spot sizes at the final foci. Levenberg-Marquardt and simulated annealing optimisers were used in the final foci optimisations.

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Proton Structure through the Two-Photon Exchange

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In this poster presentation, I will discuss the two-photon exchange (TPE) as a crucial higher-order contribution to lepton-proton scattering and the theory of light muonic atoms. In particular, I will focus on the proton polarizability contribution as the dominant uncertainty in the theory prediction of the Lamb shift and the hyperfine splitting (HFS) in muonic hydrogen (μH). It is important to provide the best possible theoretical estimate for the TPE correction to guide the upcoming high-precision measurements of the μH ground-state HFS.

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Overview of SuperSUN : A superthermal UCN source

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A new source of ultracold neutrons (UCNs), developed at the Institut Laue-Langevin (ILL) and named SuperSUN, is currently being commissioned. The source converts the cold neutrons, delivered by ILL's existing beam H523, to UCNs in a vessel filled with isotopically pure superfluid helium-4, wherein the inelastic scattering process transfers the neutron's energy and momentum to phonons in the superfluid. The inverse Boltzmann-suppressed process is negligible at temperatures below 0.6 K, enabling long storage times and high in-situ UCN densities. The SuperSUN conversion volume is illuminated by a primary beam with a white cold spectrum. Its cylindrical wall is composed of an m=3 supermirror which guides the cold neutrons inside the volume, and of a layer of Cytop which displays a large time constant for UCN storage. Using the full beam provides not only higher intensity around the wavelength 0.89 nm, where the dominant single-phonon process for UCN production takes place, but also a contribution to UCN production by multi-phonon processes. The beam stop at the end of the line was successfully tested, absorbing the radiation of the direct primary beam. Cryogenic tests have demonstrated the reachability of a temperature of 0.6 K of the conversion medium with an additional heat load of 100 mW, simulating the potential heat load from the neutron beam. A neutron characterization of the source will be performed to determine among others, the neutron density and spectrum that it can deliver to its first user, PanEDM.

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Development of a Talbot-Lau interferometer for the measurement of the neutron electric charge

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Neutron grating interferometers can be employed as powerful tools to perform high-precision measurements of deflection angles and scattering. A novel concept of a symmetric Talbot-Lau interferometer using absorption gratings is under development at the University of Bern. The ultimate goal of this project will be a sensitive measurement of the neutron electric charge. Currently, a proof-of-principle apparatus is being investigated at the cold neutron beamline BOA at the Paul Scherrer Institute. On the proposed poster, a description of the experiment, first experimental results concerning the setup, and the achievable sensitivities will be presented.

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The MONUMENT Experiment; Ordinary Muon Capture as a benchmark for 0nßß-decay nuclear structure calculations

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Extracting particle physics properties from neutrinoless double-beta (0nßß) decay requires a detailed understanding of the involved nuclear structures. Still, modern calculations of the corresponding nuclear matrix elements (NMEs) differ by factors 2-3.

The high momentum transfer of Ordinary Muon Capture (OMC) provides insight into highly excited states similar to those that contribute virtually to 0nßß transitions.
The precise study of the gamma particles following the OMC process makes this a promising tool to validate NME calculations, and test the quenching of the axial vector coupling g_A.

The MONUMENT collaboration is performing a series of explorative OMC measurements involving typical ßß decay daughter isotopes such as Se-76 and Ba-136, as well as other benchmark isotopes. In this presentation the experiment carried out at the Paul Scherrer Institute and first results from the beam-time in 2021 will be presented.

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The Holmes ion implanter commissioning runs

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The HOLMES experiment aims to measure directly the neutrino mass with a calorimet- ric approach studying the end point of the 163Ho electron-capture decay spectrum. This isotope is produced via neutron capture by 162Er and its very low Q-value (2.8 keV) makes it a very good choice but introduces two critical aspects. The first one is the need to embed the isotope inside the cryogenic microcalorimeters so that the energy released in the decay process is entirely contained within the detectors, except for the fraction taken away by the neutrino. The second one is the rejection of 166mHo radioactive isotope, created from impurities during the neutron irradiation, that could produce false signal in the region of interest. So a dedicated implanter with a sputter ion source, an acceleration section (up to 50 keV) and a magnetic dipole (for ion selection and beam focusing) has been designed and developed. Different targets for the implanter ion source have been also developed in collaboration with Genoa Chemistry Department and PSI (Paul Scherrer Institute). This work will show the status of the machine development and the results on the different target solutions.

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A Boosted Decision Tree Model for the Positron Acceptance in the Muon g-2 Experiment

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A high-fidelity simulation is crucial in the study of systematic errors arising from beam dynamics and detector acceptance in the Muon g-2 experiment at Fermilab. Gm2ringsim, our current Geant4-based simulation package is computationally expensive and has limited the amount of dataset that can be produced for various systematic studies. We propose a "divide and conquer" approach, where the typical Geant4 simulation is divided into beam and spin dynamics, muon decay, and positron detection. The last part which involves positron tracking in the storage ring and electromagnetic shower development in the calorimeter was modeled using time-efficient machine learning algorithms. We trained Adaptive Boosted Decision Tree (BDT) models to classify positron events according to their initial position and momentum. Our models have a higher Area Under the Receiver Operation Characteristic curve (AUROC) compared to the heuristic cut approach. Our benchmark also showed that the BDT-based simulation is two orders of magnitude faster in computational time. This demonstrates the potential of machine learning models for fast simulations in precision frontier experiments.

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Neutron lifetime experiment using a pulsed neutron source at J-PARC

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A free neutron decays into a proton, an electron, and an antineutrino in a lifetime of about 880 s. The lifetime is an important parameter for particle physics and astrophysics. For example, the abundance ratio of light elements in the early universe in the Big Bang nucleosynthesis is determined using the neutron lifetime, and the lifetime also determines the Vud term of the Cabibbo-Kobayashi-Maskawa mixing matrix. Although the neutron lifetime is important in modern physics, there is a 9.5 s (4.6σ) discrepancy between the results of two typical measurement methods: the beam method and the storage method. The beam method measures the decay products and the neutron flux, and the storage method counts the number of neutrons remaining after some storage time. The discrepancy is called the neutron lifetime puzzle and it is not yet settled.

To solve the problem, a neutron lifetime experiment using a new method is in progress at J-PARC MLF BL05 (NOP). In our method, the neutron decays and the helium capture reactions which correspond to neutron flux are measured simultaneously by a Time Projection Chamber (TPC) filled with working gas and ^{3}He. To reduce the background events, the neutron beam is shaped into bunches of about 40 cm by Spin Flip Chopper (SFC) and injected into the TPC. The systematic uncertainties are different from the previous beam experiments since our experiment measures decay electrons and the flux by the same detector. We aim to measure the neutron lifetime with an accuracy of 1 s (0.1%) and this experiment published the first result with acquired data during 2014-2016 as 898 +/-10 (stat.) +15/-18 (sys.) s. Towards an accuracy of 1 s, we have improved the measurement system and analysis methods.

To increase beam flux, new larger flipper coils and magnetic super mirrors have been introduced. The new SFC increases the flux by 3 times, and statistical accuracy of 1 s can be achieved within 180 days of measurements, whereas over 300-day data acquisition was needed in the previous optics. We have continued physical measurements until 2022 using the new neutron optics.

The dominant systematic uncertainty in the first result is due to the difference in the amount of gas-scattered background between the experimental and calculated values and corresponds to a systematical error of +2/-14 s. Since there could be gamma-ray background events that were not considered, we have performed measurements of low-energy gamma-ray induced by neutrons by irradiating the ^{6}LiF plate with neutrons. To reduce the gas-induced background, measurements also have been performed with the TPC operating gas pressure of 50 kPa instead of the conventional 100 kPa, and all acquired data corresponds to a statistical accuracy of about 2 s.

In this presentation, we give an overview of the neutron lifetime measurements, details of the upgrades, and the latest results of the analysis.

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Improved Search for CP Violation in Ortho-Positronium Decay

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Symmetry under the combined charge and parity (CP) transformations is only known to be viola tedthrough mixing matrices in the Standard Model. This leads to vanishingly small effects in many low energy processes. Positronium (Ps) is a purely leptonic bound state that decays to photons. Any observation of CP violation in Ps would indicate beyond Standard Model physics. We are designing an apparatus to search for CP violation in Ps decay to three photons, to be run at the Facility for Rare Isotope Beams. Positronium is formed by surrounding a positron emitting source with low density powder. The apparatus consists of three rings of photon detectors with the Ps source at the center. The entire apparatus sits inside the warm bore of a superconducting solenoid to induce a tensor polarization in the Ps system. With this we can measure a 5-fold correlation between the photon momenta and the Ps spin. Here we present progress on detector design and testing, Ps formation, and simulations of the detector apparatus. With our design we expect to reach our target sensitivity of 10-4 with 35 days of continuous running – a 10 x improvement over existing limits.
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qBounce: first measurement of the neutron's electric charge with a Ramsey-type GRS experiment

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The qBounce collaboration successfully commissioned a new Ramsey-type gravitational resonance spectroscopy (GRS) setup at the Institute Laue-Langevin (Grenoble). This increases the achievable sensitivity significantly with respect to previous implementations. In 2018, we measured the gravitational state transitions with the new setup. This Ramsey-type implementation is not only sensitive to a range of hypothetical variations of Newtonian potential at the micrometer scale, but also enables to test the electric charge neutrality of the neutron. We present the results of the first neutron charge measurements and give an outlook on future developments.

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The Mu3e Cosmic Run 2022

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The Mu3e experiment will search for the lepton flavour violating decay $\mu^+ \rightarrow e^+e^-e^+$ and is aiming for a sensitivity of one in 10^{16} muon decays. Since this decay is highly suppressed in the Standard Model to a branching ratio of below $\mathcal{O}(10^{-54})$, an observation would be a clear sign for new physics.

In the Mu3e detector, four layers of silicon pixel sensors will be used to track electrons and positrons and a time resolution of $\mathcal{O}(100ps)$ will be provided by scintillating tile and fibre detectors. The overall detector is expected to produce a data rate from 80 Gbit/s (Phase I) to 1 Tbit/s (Phase II), which will be processed in a three-layer, triggerless DAQ system using FPGAs and a GPU filter farm for online event selection.

A prototype of the detector was operated in summer 2022 in the Mu3e cosmic run with the intent to test and validate a variety of systems and identify possible problems. The operated prototype included two layers of pixel sensors, a scintillating fibre module and a vertical slice of the final data acquisition (DAQ) system. The run was also used for commissioning and validation of the DAQ and first tests of the data analysis and track reconstruction with real detector data.

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Precise theory prediction for di-lepton production

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Using the McMule framework, we present fully differential predictions for the process $e^+e^- \to \mu^+\mu^-, \tau^+\tau^-$ with polarised initial states, including the dominant QED corrections at NNLO. Weak corrections are included at NLO in an effective field theory approach. This calculation is important for a wide range of experiments measuring the R ratio (e.g. Daphne, VEPP, …) or tau properties (e.g. Belle II). The latter is particularly interesting in the light of a recent proposal to measure the tau's anomalous magnetic moment using production asymmetry.

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Sympathetic cooling of highly charged ions in a Penning trap using a self-cooled electron plasma

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The amazing evolution of precision in recent Penning-trap experiments is driving the need for ever-improving cooling techniques. In this talk, the prospect of a new sympathetic cooling technique using an electron-plasma coupled to a single highly charged ion is presented. Utilizing the synchrotron-radiation of electrons in a strong magnetic field enables cooling to very low motional quantum numbers, almost to their ground state. Using a common-resonator, the motion of this self-cooled electron plasma can be coupled to a single ion stored in a spatially separated Penning trap, allowing sympathetic cooling of all modes of the ion. The extremely low expected temperatures in the milllikelvin range open up an exciting new frontier of measurements in Penning traps.

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Measurements of np - 2s transitions in the hydrogen atom

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Precision experiments in the hydrogen atom have a long tradition and extensive studies of transitions between low lying $n \leq 12$ states were carried out [1−6]. These measurements can be used to determine values of the Rydberg constant and the proton charge radius. We present a new experimental approach to perform measurements of transition frequencies between the metastable 2s $^2\mathrm{S}_{1/2}(F = 0, 1)$ state of H and highly excited np-Rydberg states with principal quantum number $n \geq 23$.
We generate the hydrogen atoms by dissociating H_2 in a dielectric barrier discharge located at the orifice of a pulsed cryogenic valve [7]. The hydrogen atoms are entrained in the supersonic expansion of H_2. The atoms are photoexcited to a specific hyperfine level of the metastable 2s $^2\mathrm{S}_{1/2}$ state by a home-built frequency-tripled Fourier-transform-limited pulsed titanium-sapphire laser (pulse length 40 ns). They enter a magnetically shielded region in which transitions to highly excited np or Rydberg Stark states are induced by a narrow-band frequency-doubled continuous-wave titanium-sapphire laser, which is phase locked to an optically stabilized frequency comb and referenced over a fiber network to a SI traceable primary frequency standard [8]. The highly excited Rydberg states are detected by pulsed-field ionization. We will report progress on our efforts to minimize uncertainties from stray electric fields and Doppler shifts and to obtain spectral lines with a FWHM below 10 MHz.
This work is supported by the Swiss National Science Foundation through the Sinergia-Program (Grant No. CRSII5-183579) and Grant No. 200020B-200478.

[1] J. C. Garreau *et al.*, J. Phys. France **51**, 2293 (1990).
[2] C. G. Parthey *et al.*, Phys. Rev. Lett. **107**, 203001 (2011).
[3] A. Beyer *et al.*, Science **358**, 79 (2017).
[4] H. Fleurbaey *et al.*, Phys. Rev. Lett. **120**, 183001 (2018).
[5] N. Bezginov *et al.*, Science **365**, 1007 (2019).
[6] A. Grinin *et al.*, Science **370**, 1061 (2020).
[7] S. Scheidegger *et al.*, J.Phys. B **55**, 155002 (2022)
[8] D. Husmann *et al.*, Optics Express **29**,24592 (2021).

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Mapping of the magnetic field in the n2EDM experiment

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The uniformity of the magnetic field inside the inner part of the n2EDM experiment is a crucial condition to achieve the desired sensitivity of $10^{-28} e\ cm$ for the neutron electric dipole moment (EDM). The magnetic-field mapper is a dedicated nonmagnetic robot designed to measure the magnetic field at any point of a large cylindrical volume ($0 \leq \rho \leq 780\ mm$, $0 \leq \phi \leq 360°$, $-410 \leq z \leq 410\ mm$). It was installed in the n2EDM setup in 2021 and has been playing a key role in the n2EDM experiment preparation. Its purpose during the first mapping campaign is to characterize and qualify the inner parts of n2EDM: the remanent field inside the MSR, the production of the $1 \mu T$ neutron holding field, the magnetic purity of the octagonal vacuum tank.

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Search for a permanent muon electric dipole moment at the Fermilab Muon g-2 experiment

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A permanent electric dipole moment (EDM) in any elementary particle implies CP symmetry violation and thus could help explain the baryon asymmetry in the universe. Within the Standard Model (SM), the muon EDM is extremely small (~10^{-42} e cm) and therefore any detected signal is a strong hint of new physics beyond the SM. In the Muon g-2 experiment at Fermilab, we aim to perform a more sensitive search of the muon EDM using both tracker-based and calorimeter-based approaches. In the calorimeter-based approach, the muon EDM signal can be searched using the relationship between the muon g-2 phase and the vertical hit position of positrons on the calorimeter. In this poster, we will present a preliminary result of the calorimeter-based analysis using Run-2/3 data.

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Demonstration of a multilayer-type neutron interferometer with pulsed source and nuclear scattering length measurement

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A neutron interferometer is a device that splits the wavefunction of a single neutron into two paths, superimposes them, and detects the potential difference between the two paths as a phase difference. Neutron interferometers were practically used in the 1970s, and have contributed greatly to the development of quantum mechanics, such as the verification of spinors and the phase shift of matter waves due to gravity. Until now, neutron interferometers have been cut out of Si ingots, which could only use mono-energetic neutrons and were limited in size.
We have developed a multilayer interferometer as an alternative to the Si interferometer and successfully demonstrated it with a pulsed neutron beam at J-PARC. The multilayer-type interferometer consists of half- and total-reflection neutron mirrors deposited on an optical device called a beam-splitting etalon with a precisely defined gap. In use of a pulsed neutron beam, the phase of neutron interference appears in the neutron time of flight for each pulse. The availability of white neutrons significantly increases the number of available neutrons and use of the pulsed neutron suppresses the time-dependent systematic uncertainty. We achieved a high visibility of 70% with the beam width of 100 μm and the beam gap of 400 μm, allowing complete separation of the beam paths.
Currently, we are working on precise measurements of neutron scattering lengths of nuclei which are fundamental parameters in neutron scattering experiments. We have measured Si, Al, Ti, and V as the first trial. The obtained scattering lengths were consistent with literature values [1] except V, whose scattering length was about 50% larger than that.
In this talk, we report the status of the neutron interferometer and the results of the nuclear scattering length, and future development plans for the multilayer-type interferometer.

[1] V. F. Sears, "Neutron scattering lengths and cross sections", Neutron news 3.3 (1992), 26-37.

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The (Z,A) Dependence of Muon-to-Electron Conversion

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Should muon-to-electron conversion in the field of a nucleus be found in the current generation of experiments, the measurement of the atomic number dependence of the process will become an important experimental goal. We present a new treatment of the (Z,A) dependence of muon-to-electron conversion. Our approach differs from earlier work in that it combines nuclear charge distribution determinations from both electron scattering and muonic atoms, takes into account the effect of permanent quadrupole deformations, and employs a Hartree-Bogliubov model for the neutron distributions. The results are compared with earlier calculations.

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Measuring the free neutron lifetime with τSPECT

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The τSPECT experiment aims at measuring the free neutron lifetime, which is a key ingredient for high-precision tests of the Standard Model of Particle Physics and is also fundamental for understanding the production of light elements during the Big Bang Nucleosynthesis.

Neutrons with energies in the range of tens of nano electronvolts are loaded by spin flipping into the tSPECT neutron storage volume, where they are confinded by magnetic field gradients only. With the τSPECT experiment, the free neutron lifetime can be extracted by counting the surviving neutrons in the storage volume after different storage times. Fully-magnetic storage of neutrons eliminates systematic uncertainties related to neutron-wall interactions present in earlier experiments.

This poster gives an overview of the motivation, the components, the measurement process, and the current status of the τSPECT experiment, which is located at the TRIGA reactor in Mainz, Germany.

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Search for axion-like particles in muon decays

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The search for charged Lepton Flavour Violation in muon decays is a key tool to test the Standard Model at the intensity frontier. The MEG II and Mu3e experiments at PSI are respectively designed to detect $\mu \to e\gamma$ and $\mu \to eee$ with an unprecedented accuracy. Moreover, both experiments are competitive in searching for muon decays involving an invisible axion-like particle X. In this regard, a viable channel is the two-body decay $\mu \to eX$, whose signature is a monochromatic signal close to kinematic endpoint of the $\mu \to e\nu\bar{\nu}$ background. The hunt for such an elusive signal requires extremely accurate theoretical predictions for event generation and data analysis.

In this contribution, we present a new state-of-the-art computation of $\mu \to eX$ and $\mu \to e\nu\bar{\nu}$, both implemented in the McMule framework. Assuming the nominal performances of the MEG II and Mu3e detectors, we employ the new predictions to estimate the expected sensitivity on $\mu \to eX$ for different X masses and couplings. The study evaluates with particular attention the impact of the theoretical error on the experimental analysis. Furthermore, we consider an hypothetical forward detector, conceived to increase the sensitivity for right-handed signals.

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New Magnetically Shielded Room for ^{3}He/^{129}Xe co-magnetometer experiments

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The ^{3}He/^{129}Xe co-magnetometer is a high precision experiment that can address a variety of fundamental questions including the measurement of the \textit{CP}-violating permanent electric dipole moment (EDM) of the ^{129}Xe atom, looking for a violation of Lorentz Invariance, and searching for a spin-dependent \textit{P}- and \textit{CP}-violating nucleon-nucleon interaction mediated by Axions or axion-like particles. Next level ^{3}He/^{129}Xe co-magnetometer experiments require improved magnetic conditions. Here, we report on the performance of a new Magnetically Shielded Room (MSR) consisting of three layers of Mu-metal with a thickness of 3~mm each, and one additional highly conductive copper-coated aluminum layer with a thickness of 10~mm. The MSR has a cubical shape with an accessible interior volume with an edge length of 2560~mm. An optimized degaussing (magnetic equilibration) procedure, and shielding factor and residual magnetic field measurements will be presented.

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Parallel plate force metrology as a tool to probe the dark sector

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Ever since the discovery of accelerated expansion, the cosmological standard model Lambda-CDM has been our best description of the universe on large scales. In recent years, however, significant tensions have appeared that cast doubt on the validity of dark matter being a cold non-interacting fluid, and the cosmological constant being a global parameter. Moreover, searches for weakly interacting massive particles at accelerators have so-far not been successful. Therefore, light particles, such as the QCD axion have moved into the spotlight. While there is a vast theoretical landscape of effective models at low energies, there exist general frameworks to classify them. The Wilczek-Moody formalism classifies all possible tree-level interactions between fermions, while Kostelecky's standard model extension provides a comprehensive framework for terms breaking the Lorentz invariance.
Using these frameworks, precision force metrology at low energies can be used to search for the manifestations of hypothetical fifth forces. While traditional torsion balances have long set the standards in this area, the Casimir And Non-Newtonian force EXperiment CANNEX is the world's only force metrology setup operating in the geometry of macroscopic plane parallel plates. In this talk, I will review the technique, status, and prospects of this unique setup in the context of dark matter and dark energy detection.

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Precision flavour and tau physics at FCC-ee

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The abundant production of beauty and charm hadrons in the $5 \cdot 10^{12}$ Z boson decays expected at FCC-ee offers outstanding opportunities in flavour physics that exceed those available at Belle II by a factor of 20, and are complementary to the LHC heavy-flavour programme. A wide range of measurements will be possible in heavy-flavour spectroscopy, rare decays of heavy-flavoured particles and CP-violation studies, which will benefit from the low-background experimental environment, the high Lorentz boost, and the availability of the full spectrum of hadron species. The huge data samples of the Tera-Z phase opens also the possibility of much improved determinations of tau-lepton properties – lifetime, leptonic and hadronic widths, and mass – allowing for important tests of lepton universality. In addition, via the measurement of the tau polarisation, FCC-ee can access a precise determination of the neutral-current couplings of electrons and taus. These measurements present strong experimental challenges to match as far as possible statistical uncertainties, $O(10^{-5})$, raising strict detector requirements. This contribution will present an overview of the broad potential of the FCC-ee flavor physics program and also some preliminary results from recent analyses.

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Precision measurements in the beta decay of 6He

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Precision measurements in nuclear beta decay have proven in the past years their capability to search for new physics beyond the standard model (SM), by looking for deviations of certain sensitive observables away from their SM predictions. The study of the full beta energy spectrum offers a great medium for probing these observables and thus searching for new physics.
The long-term goal of this work is to perform the most precise measurement of the beta-energy spectrum in 6He decay in order to extract the Fierz interference term b, which depends linearly on the tensor coupling constants, allowing us to search for or to constrain the presence of exotic tensor interactions in the nuclear beta decay. For this purpose, we are performing two experiments at the Grand Accélérateur National d'Ions Lourds (GANIL) with slow (25 keV) and fast (300 MeV) beams of 6He. The two measurements give the possibility to study carefully the systematic effects accompanying each of them.
The experiment with the low energy beam was already performed in 2021. The setup of this experiment allows not only the Fierz term extraction, but also a high precision measurement of the 6He half-life. The spectrum shape analysis is still in progress; however, the half-life analysis is completed resulting with the world's most precise value of 6He half-life.
This contribution will introduce the general context of the project, cover the low energy experiment's setup and data analysis up to the measurement of the 6He half-life and the extraction of the Fierz term later on.

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First result of pLGAD sensor, and channeling in silicon sensors

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The advent of silicon detectors with an internal gain mechanism has opened new avenues in the field of low-energy precision physics. However, these sensors need to be modified before they can be used in the field of precision low-energy physics. One sensor, with such modifications, is the so-called pLGAD (proton Low Gain Avalanche Detector) [1]. The sensor stems from the iLGAD (inverse Low Gain Avalanche Diode) technology and takes it a few steps further by optimizing it for use in low-energy physics experiments. The sensor provides a high SNR (Signal to Noise Ratio) with positional resolution, and ease of operation at a fraction of cost of its competitors for low penetrating particles (particles which penetrate <100μm in silicon).

In this talk, first characterization results from the proof of principle run of the pLGAD sensor will be presented. Furthermore, the previously unaccounted effect of proton channeling of will be discussed [2]. The discussion will focus on how channeling introduces the systematic effects, in particular how it can cause changes in the overall backscattering rate, the profile of deposited energy, and depth of the impinging particle within the active sensor area. Consequently, its influence on the efficiency of the pLGAD sensor in the special case of NoMoS (Neutron decay products Momentum Spectrometer) will be demonstrated and the corresponding systematic uncertainty for the detection of low-energy protons (~15keV) will be estimated.

[1] W. Khalid, M. Valentan, A. Doblas, D. Flores, S. Hidalgo, G. Konrad, J. Marton, N. Moffat, D. Moser, S. Onder, G. Pellegrini, J. Villegas, First results for the pLGAD sensor for low-penetrating particles, Nucl. Instr. Meth. A 1040 (2022). DOI: 10.1016/j.nima.2022.167220

[2] W. Khalid, S. Baeßler, G. Hobler, J. Marton, D. Moser, M. Valentan, G. Konrad, The effects of channeling on proton backscattering in neutron beta decay experiments, Nucl. Instr. Meth. A, In preparation.

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Spectral characterization of the SUN-2 ultracold neutron source by vertical time-of-flight

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The SUN-2 source [1] at the Institut Laue-Langevin (ILL) is a prototype source of ultracold neutrons (UCN) that converts cold neutrons into UCN via downscattering in superfluid helium. UCN, which have kinetic energies on the order of hundreds of nanoelectronvolts, can be trapped in material-walled storage vessels and used, for example, in experimental searches for the neutron electric dipole moment. Continued improvements to the statistical sensitivity of such measurements can be achieved at new high-flux sources, such as those planned at the ILL [2] and the European Spallation Source [3].

The spectral characterization of these sources will be instrumental to the determination of critical design factors of experiments installed there. This characterization is often pursued by measuring neutron time-of-flight (TOF) through horizontal guides. Unforunately, this technique prohibits spectroscopy of UCN with energies below the optical potential of the detector entrance window, resulting in a design blindspot for experiments that aim to maximize their statistical reach.

This difficulty is overcome by the vertical TOF technique, in which falling UCN are accelerated to velocities sufficient to enter the detection volume. Using this method, measurements were made of the full UCN energy distribution of SUN-2 in its most recent configuration, with its internal production volume coated by a top layer of the fluoropolymer CYTOP [4]. Results are presented for both continuous and accumulation operation modes of the source. To our knowledge, this work consitutes the first measurement of the low energy tail of the UCN spectra produced at a superfluid helium based UCN source.

References

[1] A. Steyerl, Ultracold Neutrons (pp. 70–76), World Scientific (2020).
[2] O. Zimmer and R. Golub, Phys. Rev. C, vol. 92, 015501 (2015).
[3] E. Klinkby et al., Adv. High Energy Phys., vol. 2014, Article ID 241639 (2014).
[4] T. Neulinger et al., Eur. Phys. J. A, vol. 58, Article 141 (2022).

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Update on the UCN source at PSI

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In the Paul Scherrer Institute, we operate a solid deuterium moderated Ultracold Neutron (UCN) source. UCNs are storable for several minutes, which makes them suitable for measuring neutron properties.

The UCN source will be used in the n2EDM experiment, which will measure the neutron electric dipole moment. This is CP violating and could help explain the Baryon Asymmetry of the Universe.

To improve experimental statistics, we work to understand and increase UCN output. For example by improving the quality of the deuterium crystal and optimising UCN transport. This talk will explain the source and give an overview of our improvements.

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Acceleration Effect in Quantum Mechanics and Neutron Optics

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ACCELERATION EFFECT IN QUANTUM MECHANICS AND NEUTRON OPTICS

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The report is devoted to the problem of interaction of neutrons with accelerating objects. As was recently shown [1], the previously known Accelerating Matter Effect (AME) [2], is only a special case of a more general effect, consisting in the fact that the result of the interaction of a wave with any object moving with acceleration is a change in its frequency. With some reservations, this Acceleration Effect (AE) can be interpreted as a differential Doppler effect, in which the absorption and emission of a wave are separated by a time interval during which the velocity of the object changes.
The most important question is whether the AE is valid in quantum mechanics, when the process of interaction of a particle or quanta with an object, although it has a finite duration, cannot be divided into the absorption and emission phases. Substantial arguments in favor of such an assumption were obtained in [3]. Assuming that the AE is valid in quantum mechanics, we must conclude that the conclusion about the change in the frequency and energy of the neutron should also be valid in the case of neutron scattering on an atomic nucleus moving with acceleration. This means that neutron scattering by the nuclei of accelerating matter is inelastic and not isotropic.
Since it is the elasticity and isotropy of scattering that form the basis of the theory of dispersion of neutron waves in matter, it can be expected that at high accelerations of matter, completely new neutron-optical effects can be expected to appear. The report discusses a possible experiment to observe this kind of effect.

References
1.Frank A. I. Physics-Uspekhi, 63, 500 (2020)
2.Frank A. I, Geltenbort P., Jentschel M et al. Phys. of Atomic Nuclei 71 1656 (2008)
3. Zakharov M.A., Kulin G.V. and Frank A.I. Eur. Phys. J. D 75, 47 (2021).

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Minimizing Magnetic Dipole Contamination in the n2EDM Experiment

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The n2EDM experiment searching for the neutron electric dipole moment is currently being commissioned at PSI. Essential for a tenfold sensitivity improvement relative to the current best result is a uniform magnetic field ($\sigma(B_z) < 170$pT). Any localized magnetic contamination of the apparatus may result in a systematic error of the measurement.
Parts in the direct vicinity of the neutron precession chambers need to be non-magnetic at a level of a few pT at 5cm distance from the surface. Therefore, the collaboration has built a new high-sensitivity gradiometer using laser-pumped caesium magnetometers to qualify all parts installed in the experiment. The poster will present the new device and first measurements.

Support by Swiss National Science Foundation Project #188700 is gratefully acknowledged.

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Diffusion of μp in the hyperfine-splitting experiment at PSI

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Due to the close bond between orbiting muon and nucleus, the energy levels of muonic atoms are highly sensitive to effects of the nuclear structure. In order to study the magnetic structure of the proton, we are preparing a measurement of the ground-state hyperfine splitting in muonic hydrogen (μp) at Paul Scherrer Institute (PSI). In this experiment, μp atoms diffuse through a hydrogen gas cell in order to be excited with an infrared laser. To constrain experimental parameters and predict signal rates for the measurement, we use Monte Carlo simulations of the diffusion process. For this, we have implemented custom physics processes in Geant4 based on differential rates for molecular collisions. This poster provides an introduction to the detection scheme of the hyperfine-splitting experiment and reviews our simulations of μp diffusion in the target.

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BeamEDM – A beam experiment to search for the neutron electric dipole moment

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The neutron Electric Dipole Moment (EDM) has attracted interest as a promising channel for finding new physics for a long time. The existence of a neutron EDM would violate CP symmetry given CPT conservation. This new source of CP violation could explain the baryon asymmetry of the universe. The BeamEDM experiment aims to measure the neutron EDM using a novel technique which overcomes the previous systematic limitation of neutron beam experiments, the relativistic vxE effect. The experiment exploits the time-of-flight technique with a pulsed cold neutron beam which allows to distinguish between time dependent and time independent effects such as the EDM. A proof-of-principle apparatus has been developed to perform preliminary measurements for the future full-scale experiment intended for the European Spallation Source in Sweden. In this presentation the details of the experimental setup together with the latest results from a data taking campaign in August/September 2020 at the PF1b beamline at the Institut Laue-Langevin in France will be presented.

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Search for a muon EDM using the frozen spin technique at PSI

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The discovery of an electric dipole moment (EDM) of the muon would break time invariance and violate the combined symmetry of charge and parity (CP), shedding light on the imaginary parts of coupling constants in the muon sector of beyond standard model physics (BSM). A search for a muon EDM is an exciting test of the standard model complementary to the recently reported combined 4.2σ deviation from the SM in the anomalous magnetic dipole moment "(g-2)" and the observed tensions in B-decays at the large hadron collider. A dedicated muon EDM experiment will not only push EDM searches beyond the first generation of fundamental particles, but also probes the role of lepton flavor universality in nature.
At PSI we propose an experiment to search for the EDM of the muon based on the frozen-spin technique. We intend to exploit the high electric field,E=1GV/m, experienced in the rest frame of the muon with a momentum of p=125MeV/c when passing through a large magnetic field of B=3T. Measured muon fluxes at the muE1 beam line of PSI permit an improved search with a sensitivity of σ(dμ)≈6E-23 ecm, about three orders of magnitude more sensitive than for the current upper limit of
|dμ|≤1.8E-19 ecm [G.W. Bennett, B. Bousquet, H. N. Brown, et al., PRD 80, 052008 (2009)]. In this contribution we will discuss and illustrate the concept and design of the muon EDM apparatus being setup in two phases at PSI.

A discovery of a muon EDM at the proposed experimental sensitivity would establish the existence of physics beyond the Standard Model, while a null result would set a significantly improved upper limit on an otherwise un-constrained Wilson coefficient in an effective-field-theory description of BSM physics.

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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 EDM has become a topic of particular interest due to the tensions between theory and experiment in the magnetic anomaly of the muon and the electron as well as hints to 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 6×10^{-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.

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A novel method of searching for spin-dependent long range force

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Many theoretical models that expand boundaries of the Standard Model of elementary particles predict the existence of the hidden sector of particles, which can very weakly interact with the visible sector of Standard Model particles. The exchange of virtual particles characterizes a new type of spin-spin interactions, which are different from the well-known electromagnetic ones. The Authors of Refs [1], [2] made an attempt to construct a theoretical model for describing weak spin-spin interactions also using the gauge approach. It was predicted that invariance of Lagrangian field theory under a class of the coordinate-dependent Lorentz group of transformations requires the introduction of a massless axial vector gauge field which gives rise to a super-weak long-range spin-spin force in vacuum which is attractive for parallel spins. According to the theoretical model the axial-vector field couples to the axial-vector current of the Dirac field and to the photon field or to the neutral spin − 1 field. At that initially axial-vector field was introduced in Ref. [3] for the purpose to give stability to the classical electron and also to make quantum electrodynamics divergence free.

The search for exotic new forces and interactions generated by the spin of matter particles and electromagnetic fields has a long history [4]. Since, as predicted, the coupling constant g of new fields is very small, their detection in force interactions becomes problematic and requires the precise measurements [5] - [8]. On the other hand, such fields must be truly highly penetrating. We are guided by the idea that optical experiments can be among the most accurate. That is why we offer optical effects of axial-vector fields. It was predicted that a constant axial-vector field leads to a change in the polarization of the wave that passes through its region of action. Axial-vector gauge fields must interact with electromagnetic fields, since photons carry spin.
A system of field equations was obtained for the evolution of the vector potential of an electromagnetic wave, where the action of an uniform axial-vector field enters the source on the right side of the equation. A linearly polarized electromagnetic wave acquires an orthogonal component of the electric field strength and becomes a wave with circular polarization. The area of action of the axial-vector field plays the role of some active medium, passing through which the electromagnetic wave acquires an orthogonal component of the strength of the electric and magnetic fields, which leads to the appearance of elliptical polarization. In this case, the orthogonal component of the electric field strength is proportional to the hyperbolic sine, which is proportional to the square of the coupling constant of the axial vector and electromagnetic fields. The domain of action of the field for the wave plays the role of some anisotropic medium, which in itself is a very interesting consequence of the theory. For the optical wavelength range this effect can be detected only in the noise. If we create a closed system of propagation of an electromagnetic wave, which must experience repeated action of the axial-vector field, then the amplitude of the perpendicular component of the electric field in the wave will increase.
Since the proof of the influence of new fields on the wave amplitude as a result of predicting the smallness of the coupling constant may encounter significant difficulties, we will consider the case of the action of a wave axial-vector field. We assume that in the case of considering a wave axial-vector field, effects can be obtained that will be simpler in their experimental implementation. The case of the action of a wave axial-vector field at the frequency Ω was considered, and a new effect of modulation of the initial electromagnetic wave was predicted. It was shown that in the process of interaction of an electromagnetic wave with a new field, additional harmonics arise at frequencies $\omega \pm \Omega$. The original electromagnetic wave propagating at the frequency ω will decay into three waves, one of which also moves at the original frequency ω, and two harmonics have frequencies $\omega \pm \Omega$. Thus, we have considered the problem of the influence of a new physical field generated by the spin of an electromagnetic field on the properties of an electromagnetic wave. We

theoretically propose a new optical physics based method which can be used to search for an exotic spin-dependent interaction mediated of the axial-vector gauge bosons.

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1. P. C. Naik, T. Pradhan, Long-ray interaction between spins. Journal of Physics A: Mathematical and General, 14(10), 2795 (1981).
2. T. Pradhan, R. P. Malik, P. C. Naik, The fifth interaction: universal long range force between spins. Pramana - J. Phys. 24, 77 (1985).
3. T. Pradhan and A. Lahiri, Finite quantum electrodynamics, Phys. Rev. D. 10, 1872 (1974).
4. M. Safronova, D. Budker, D. DeMille, D. F. J. Kimball, A. Derevianko, and C. W. Clark, Search for new physics with atoms and molecules, Rev. Mod. Phys. 90(2), 025008 (2018).
5. Joerg Jaeckel and Andreas Ringwald, The Low-Energy Frontier of Particle Physics, Annu. Rev. Nucl. Part. Sci. 60:405 (2010).
6. Moody J. E., Wilczek F., New macroscopic forces? Phys. Rev. D Part. Fields 30, 130 (1984).
7. C. E. Cramer, A torsion balance search for spin-coupled forces, thesis, Univ. of Washington (2007).
8. Vasilakis G., Brown J. M., Kornack T. W., Romalis M. V., Limits on new long range nuclear spin-dependent forces set with a K-3He comagnetometer. Phys. Rev. Lett. 103, 261801 (2009).

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Silicon detector for neutron beta decay measurements with PERC

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The PERC facility is currently under construction at the FRM II in Garching, Germany. It will serve as an intense and clean source of electrons and protons from neutron beta decay for precision studies. It aims to improve the measurements of the properties of weak interaction by one order of magnitude and to search for new physics via new effective couplings.
PERC's central component is a 12 m long superconducting magnet system that has recently been delivered. It hosts an 8 m long decay region in a uniform field. An additional high-field region selects the phase space of electrons and protons, which can reach the downstream detector to minimize systematic uncertainties.
The downstream main detector and the two upstream backscattering detectors, will initially be scintillation detectors with (silicon) photomultiplier readout. In a later upgrade, the downstream detector will be replaced by a pixelated silicon detector. We present the current design status of the silicon detector prototype.

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The backscatter detector system of PERC

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The PERC (Proton Electron Radiation Channel) instrument is a neutron decay facility currently being set up at the research reactor FRM II of the Heinz Maier-Leibnitz Zentrum in Garching. Its main component is a 12-meter long superconducting magnet system, which was recently delivered to the FRM II.
We aim to measure several correlation coefficients in neutron beta decay one order of magnitude more precisely than previous experiments. From the results, we will derive the nucleon axial coupling and the CKM matrix element $_{ud}$ and search for scalar and tensor couplings.
The spectrum of electrons from neutron decay will be obtained using two detector systems: the primary detector system located downstream will be a scintillation or silicon detector or a magnetic spectrometer. The secondary detector system, used to identify and veto backscatter events, consists of two pixelated scintillation detectors read out by silicon photomultipliers.
This poster presents the current status of the design of this the secondary detector system, including results from Geant4 simulations validated by measurements with pions at the PSI.

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Improved Standard-Model Prediction for □0→□+□– and Constraints on BSM Physics

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We present the recent work on an improved Standard-Model prediction for the rare decay $\pi^0 \to {}^+e^-$, which plays a crucial role in the test of the long-distance dynamics of the strong interaction. The reduced amplitude of the decay is determined by the pion transition form factor for $\pi^0 \to \gamma^*\gamma^*$, for which we employ a dispersive representation that incorporates both time-like and space-like data as well as short-distance constraints. The resulting SM branching fraction, $\mathrm{Br}[\pi^0 \to {}^+e^-] = 6.25(3)\times 10^{-8}$, reveals a ten-fold improvement in precision over experiment and sharpens constraints on physics beyond the Standard Model.

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Clathrate Hydrates as Novel Moderators for Very Cold Neutron Sources

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Clathrate hydrates [1] are water-based solids with large unit cells that show promise as potential moderators for use in the development of new, more intense sources of very cold neutrons (VCN). Such sources have the potential to enhance existing neutron scattering techniques, and to increase the reach of particle physics experiments that employ beams of slow neutrons. These include investigations of the neutron β-decay, nEDM, $n\overline{n}$-oscillation or experiments using VCN in neutron interferometry (i.e. gravity induced phase shift).

Since their discovery in the early 19th century, clathrate hydrates have steadily gained interest in diverse fields of study. Current areas of active research, particularly in industrial chemistry, include the extraction and storage of natural gases in clathrate hydrates for energy applications. More recently, however, these materials have attracted interest as potential neutron moderators due to their low energy modes, which are a consequence of the ability of these so-called inclusion compounds to host guest molecules in cages that are formed by networks of hydrogen-bonded water molecules. Of particular interest is a binary clathrate hosting oxygen and tetrahydrofuran (THF) as guest molecules. The molecular oxygen provides an additional path for neutron slowdown exploiting the zero-field splitting of the magnetic triplet ground state of molecular oxygen [2].

Previous studies of these low energy modes have been carried out via measurements of the neutron dynamical structure factor $S(q, \omega)$ of several guest molecule-containing clathrate hydrates [3]. However, these investigations report $S(q, \omega)$ in arbitrary units, which cannot be used to generate quantitative predictions of the performance of clathrate hydrate moderators by simulation. We present here, in absolute units, measurements of the temperature-dependent dynamical structure factor of fully deuterated THF-containing clathrate hydrate, carried out at the Panther and IN5 instruments at the ILL. These measurements will serve as a baseline for respective NCrystal [4] scattering kernels, within the HighNESS project [5]. In addition, we report on time-of-flight VCN transmission measurements in THF clathrate hydrate, performed at the ILL PF2-VCN beamline. From these latter data, we extract the VCN mean free path, which is a transport parameter that is critical to the accurate simulation of potential VCN sources.

References

[1] A. K. Sum et al., Ind. Eng. Chem. Res. 48 7457 (2009).
[2] O. Zimmer, Phys. Rev. C 93, 035503 (2016).
[3] H. Conrad et al., Physica B 350, e647 (2004).
[4] X.-X. Cai, T. Kittelmann, Comput. Phys. Commun., 246, 106851 (2020)
[5] V. Santoro et al., arXiv:2204.04051v1 (2022).

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The Power Distribution System for the Mu3e Experiment

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The Mu3e experiment under construction at the Paul Scherrer Institute, Switzerland, aims to search for the lepton flavour violating decay of a muon into one electron and two positrons with an ultimate sensitivity of one in 10^{16} muon decays. The detector for the Mu3e experiment consists of High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) combined with scintillating tiles and fibres for precise timing measurements.
The entire detector and front-end electronics are located in the 1m diameter bore of a 1T superconducting magnet. A compact power distribution system based on custom DC-DC converters provide the detector ASICs and readout FPGAs with supply voltages of 1.1V to 3.3V with currents up to 30A per channel. 126 converters are placed as close as possible to the detector and provide 10kW of power in total. The final version is currently being designed and integrated into the experiment to be used during the upcoming commissioning runs.
The poster presents the results of recent prototype tests and the path to the production of the full power system.

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Measurement of Neutron Polarization and Transmission for the nEDM@SNS Experiment.

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The neutron electric dipole moment experiment at the Spallation Neutron Source (nEDM@SNS) will implement a novel method, which utilizes polarized ultra-cold neutrons (UCN) and polarized ^{3}He in a bath of superfluid ^{4}He, to place a new limit on the nEDM down to 2-3$\times 10^{-28}$ e·cm. The experiment will employ a cryogenic magnet and magnetic shielding package to provide the required magnetic field environment to achieve the proposed sensitivity. I will present the design and implementation of a ^{3}He polarimetry setup at the SNS to measure the monochromatic neutron polarization and transmission losses resulting from passage through the magnetic shielding and cryogenic windows.

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κ-deformed CPT violation and its phenomenological consequences in decays and interference

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Non-commutativity of a class of space-time, called κ-Minkowski, corresponds to curvatures of the momentum space.
In the rigorous treatment of fields on κ-Minkowski space and using the concept of antipode, one can find actions of discrete symmetries C, P, and T on fields and explicitly derive a subtle difference between Lorentz transformations of particles and antiparticles, resulting in particular in deformation of the charge conjugation operator \cite{bevilacqua}.
Antipodal mapping entails the momentum- and deformation-dependent corrections to antiparticle's momenta being typical p^2/κ where κ is expected to be the order of Planck mass.
This fact opens observational consequences that can be explored in high-energy experiments.
First, when the lifetimes of particles and antiparticles are simultaneously and precisely measured in the lab and transformed to particles' rest frames, they exhibit differences that can be used to set experimental bounds on κ, being 10^{14} GeV at LHC energy and 10^{16} GeV at future colliders \cite{arzano,bevilacqua}.
Second, in interference between two mass eigenstates, e.g. in neutral kaon pairs, antipode deformation of the antiparticle's component results in admixture of states with ill-defined CPT and the p^2/κ corrections to a time-dependent interference pattern.
This allows for the derivation of an earlier-postulated parametrization of CPT violation effects in kaon interference by using the energy-independent parameter ω (cf. Ref. \cite{bernabeu}) for which there exist experimental bounds from the KLOE experiment at low energy \cite{kloe}. Using the density matrix formalism it also naturally provides time evolution with the deformation-dependent dissipative term.

\bibitem{bevilacqua} A. Bevilacqua, J. Kowalski-Glikman and W. Wislicki, Phys. Rev. D105 (2022) 105004;
\bibitem{arzano} M. Arzano, J. Kowalski-Gikman and W. Wislicki, Phys. Lett. B794 (2019) 41;
\bibitem{bernabeu} J. Bernabeu, N. Mavromatos and J. Papavassiliou, Phys. Rev. Lett 92 (2004) 131601;
\bibitem{kloe} KLOE-2: D. Babusci et al., JHEP 04 (2022) 059;

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The Mu3e vertex detector - prototyping, cooling, and upcoming production

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The Mu3e experiment searches for the lepton flavor violating decay $\mu^+ \rightarrow e^+e^-e^+$ with an ultimate aimed sensitivity of 1 event in 10^{16} decays.
For this goal a very high momentum resolution is required.
This goal can only be achieved by reducing the material budget per tracking layer to $X/X_0 \approx 0.1\,\%$ and by using gaseous helium as coolant, a novelty for particle detectors.
The pixel detector is based on High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) which are thinned to $50\,\mu m$.

This poster presents the first successful operation of a thin pixel detector cooled with gaseous helium and thermal studies regarding the two inner tracking layers of Mu3e.
In addition, the upcoming detector production of the Mu3e vertex detector including chip and module quality control will be outlined.

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Improved limits on lepton-flavor-violating decays of light pseudoscalars via spin-dependent μ→e conversion in nuclei

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Lepton-flavor-violating decays of light pseudoscalars, $P = \pi^0, \eta, \eta' \to \mu e$, are stringently suppressed in the Standard Model up to tiny contributions from neutrino oscillations, so that their observation would be a clear indication for physics beyond the Standard Model. However, in effective field theory such decays proceed via axial-vector, pseudoscalar, or gluonic operators, which are, at the same time, probed in spin-dependent $\mu \to e$ conversion in nuclei. We derive master formulae that connect both processes in a model-independent way in terms of Wilson coefficients, and study the implications of current $\mu \to e$ limits in titanium for the $P \to \mu e$ decays. We find that these indirect limits surpass direct ones by many orders of magnitude.

based on: arXiv:2204.06005 [hep-ph]

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Exact Two-Photon Exchange Contribution to Elastic Lepton-Proton Scattering: A Low-energy Effective Theoretical Approach

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We evaluate the exact two-photon exchange (TPE) correction to the unpolarized elastic lepton-proton scattering at small momentum transfer using a low energy effective field theory, heavy baryon chiral perturbation theory. The infrared divergent four- point box diagram with one heavy proton propagator is evaluated analytically via dimensional regularization. We present a numerical comparison of the finite (physical) part of our exact result with one based on the widely used soft-photon approximation. It is found that the exact contributions are around 150-200% more than the SPA contribution depending upon the beam energy and lepton mass. We estimate the charge asymmetry for both electron-proton and muon-proton scattering in the MUSE kinematic region.

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CP violation search in nuclear beta decay: The MORA experiment at JYFL, Finland

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The Matter's Origin from RadioActivity (MORA) project focuses on ion manipulation in traps and laser orientation methods for the searches for New Physics (NP) in nuclear beta decay, aimed at explaining the matter-antimatter asymmetry observed in the Universe.
Precision experiments studying nuclear ⍰ decay complement high-energy physics measurements searching for signatures of physics beyond the Standard Model. This includes precise measurements of correlations in nuclear beta decay, which are capable of probing NP at energies beyond the TeV scale, offering an interesting interplay with high energy searches undertaken at the LHC for the years ahead. Among these, the precision measurement of the D correlation, occurring in mixed Fermi and Gamow-Teller nuclear ⍰ decay transitions of spin-polarized nuclei, is arguably one of the most interesting probes. The D correlation violates Time reversal symmetry, and via the CPT theorem, is sensitive to CP violation. With a sensitivity beyond 10-4, the measurement of the D correlation would not only probe NP but would also be sensitive to weak magnetism via the Final State Interaction effects.
MORA will use an innovative in-trap laser polarization technique for the precision measurement of the D correlation in the beta decay of 23Mg. The JYFL Accelerator Laboratory, Jyvaskyla Finland, and more specifically the IGISOL facility provides an ideal environment for the initial phase of the MORA experiment. The first test experiments with a 23Mg beam have been carried out in the IGISOL facility at Jyväskylä in February and May 2022. For the initial offline optimization, a stable 23Na+ ion beam slowed down to 100 eV was efficiently tuned for trapping. Trapping efficiency of up to ~ 10% of the narrow, ⍰1µs bunches delivered by the minibuncher of the IGISOL radiofrequency (RF) cooler could be attained, for >100 ms trapping time. During the beam time, 105 ions of 23Mg per µA of the primary proton beam could be produced via a fusion-evaporation reaction. A 90⍰mW circularly polarized laser beam could be injected and aligned in the trap. Despite these achievements, large contamination of 23Na hindered the recording of β-recoil coincidences. A new online test is being scheduled to increase the purity of the beam and will be performed in November 2022.
In this contribution, I will discuss the MORA experiment as well as recent experimental advancements and ongoing studies on possible systematic effects.

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Muon flavor violation and EDM in light of muon g-2

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Recent developments in the muon $g-2$ anomaly may bring about a renaissance of μ (and τ) physics. The anomaly can be accounted for in the general two Higgs doublet model (without *ad hoc* Z_2 symmetry) via one-loop exchange of nondegenerate scalar H and pseudoscalar A bosons that have flavor changing neutral Yukawa couplings $\rho_{\tau\mu}$ and $\rho_{\mu\tau}$ at $\sim 20\lambda_\tau$, i.e. 20 times the usual τ Yukawa coupling. The complexity of $\rho_{\tau\mu}\rho_{\mu\tau}$ leads to rather large μEDM that can be detected by the PSI program. A similar diagram with $\rho_{\tau e} \simeq \rho_{e\tau} = calO(\lambda_e)$ induces $\mu \to e\gamma$, right into the sensitivity range of MEG II. The $\mu e\gamma$ dipole can be further probed by $\mu \to 3e$ and $\mu N \to eN$, where the latter may access extra diagonal quark Yukawa couplings ρ_{qq}. For the τ lepton, $\tau \to \mu\gamma$ can probe $\rho_{\tau\tau}$ down to λ_τ or lower, while $\tau \to 3\mu$ can probe $\rho_{\mu\mu}$ down to $calO(\lambda_\mu)$. The absence of $h(125) \to \tau\mu$ implies the h-H mixing angle c_γ has to be close to vanishing. While seemingly artificial, it may call for a symmetry behind the emergent "alignment" ($c_\gamma \to 0$) phenomenon. If $\rho_{\tau\mu}$ and $\rho_{\mu\tau}$ are at the more *natural* $calO(\lambda_\tau)$ so the one-loop mechanism is not behind the muon g-2 anomaly, μ and τ flavor violation remain interesting, but become a bit less rosy.

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7-order enhancement of the Stern-Gerlach effect of neutrons diffracting in a crystal

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We spatially split a non-polarized neutron beam passing through a 21.6 cm thick silicon crystal into two polarized beams with opposite spin orientations using a small magnetic field gradient of 3.1 G/cm (analogy to the Stern-Gerlach effect). To do this we used a two-crystal Laue diffraction scheme and Bragg angles close to the orthogonality. At the maximum achieved diffracting angle θB =82°, we got the splitting of 4.1 ± 0.1 cm. The amplification factor compared to that in the absence of the crystal was 1.1 × 10^7 in good agreement with the theory [1].

References

1. V.V. Voronin, S.Yu. Semenikhin, D.D. Shapiro et al, Physics Letters B **809** (2020) 135739

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^3He polarization and injection system for the nEDM@SNS SOS apparatus

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The Systematic and Operations Studies (SOS) for the neutron electric dipole moment (nEDM) experiment at the Spallation Neutron Source (SNS) will measure the trajectory correlation functions of ^3He and neutrons in order the determine the expected frequency shift from the geometric phase effect in the nEDM@SNS experiment. To this end the SOS apparatus will utilize Metastability Exchange Optical Pumping (MEOP) to polarize ^3He to 80% polarization at room temperature. The ^3He is then injected into measurement cell inside the cryovessel where the experiment is performed with concentrations of ^3He as low as 10^{-10} and a temperature of 0.4 K. We describe the polarization and injection system as well as report on results from tests of the MEOP system, simulations of ^3He injection, and our calculations of trajectory correlation functions.

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Implications of new physics in semileptonic $b \to cl\bar{\nu}_l$ transitions.

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Recently, various indications of lepton non-universality have been remarked in semileptonic B meson decay processes, both in the neutral-current ($b \to sll$) and charged-current ($b \to cl\bar{\nu}_l$) transitions. Influenced by these fascinating quotients, we examined the semileptonic decays involving the $b \to cl\nu_l$ quark level transitions. We executed it through a model independent analysis in order to survey the nature of new physics. Taking into consideration the most general effective Hamiltonian, we introduce $\Lambda_b \to \Lambda_c \tau \bar{\nu}_\tau$, $B_c^+ \to \eta_c \tau^+ \nu_\tau$, and $B \to D^{**} \tau \bar{\nu}_\tau$ (where $D^{**} = \{D_0^*, D_1^*, D_1, D_2^*\}$ are the four lightest excited charm mesons) processes, in the presence of new physics. We conducted a global fit to different sets of new coefficients, counting the measurements on R_D, R_{D^*}, $R_{J/\Psi}$, ${P_\tau}^{D^*}$, and the upper limit on Br($B_c^+ \to \tau^+ \nu_\tau$). We express the inferences of constrained new couplings on the branching ratios, forward-backward asymmetry, lepton non-universality ratios (LNU), lepton and hadron polarization asymmetry of these decay modes with respect to q^2.

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Searching for 76Ge neutrinoless double-beta decay with GERDA and beyond

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The GERmanium Detector Array (GERDA) experiment at the Laboratori Nazionali del Gran Sasso (LNGS, Italy) searched for the lepton-number-violating neutrinoless double-beta ($0\nu\beta\beta$) decay of ^{76}Ge. The potential discovery of such phenomenon would have significant implications in cosmology and particle physics, helping unrevealing the Majorana nature of neutrinos.
The main feature of the GERDA design consisted in operating an array of bare germanium diodes enriched in ^{76}Ge in an active liquid argon shield. Phase II physics run (December 2015 - November 2019) reached an unprecedentedly low background index of 5.2×10^{-4} counts/(keV kg yr) in the signal region, collecting an exposure of 103.7 kg yr while operating in a background-free regime. No signal was observed after a total exposure of 127.2 kg yr for a combined analysis of Phase I (November 2011 - September 2013) and Phase II data. A lower bound on the half-life of $0\nu\beta\beta$ decay in ^{76}Ge was set at $T_{1/2} > 1.8 \times 10^{26}$ yr (90\% C.L.), which coincides with the median expectation under the no signal hypothesis.
This contribution will review the GERDA experiment design together with its final results, also providing an overview of the next Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND) project.

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Neutron beta-decay studies at LANL

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(UCNA and UCNτ Collaboration)
Beta decay of a free neutron is the simplest form of "semi-leptonic" weak interaction and is free from nuclear structure effects. Despite the simplicity, the lifetime measurement remains one of the most challenging measurements, bearing different results depending on the technique ("bottle" or "beam") experiment [1, 2]. Another critical measurement from the decay is the correlation (Ao) between the neutron's initial spin and emitted electron's momentum. Neutron lifetime and axial neutron charge determined using Ao are inputs to determine the magnitude of the Cabibbo-Kobayashi-Maskawa (CKM) matrix element (Vud) and provide a means to study physics beyond the standard model.

Los Alamos National Laboratory hosts two experiments (UCNτ and UCNA) to measure the lifetime and beta-asymmetry parameters, exploiting the ultra-cold neutron (UCN) beam. The experiments are undergoing upgradation in terms of the design to achieve more storage of UCNs to gain higher sensitivity limits. This contribution will discuss details of the experiments and expected new results.

References:

1. Golub, R., D. Richardson, and S. K. Lamoreaux, 1991, Ultra-Cold Neutrons (Adam Hilger, Bristol, England).
2. D. J. Salvatet al., Phys. Rev. C89, 052501.

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Resonances of exotic three-body atomic systems

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In scattering quantum theory, resonances play a central role for determining the lifetime of the state of a system. By means of the Lagrange-mesh method (LMM), such resonances can be accurately studied. By combining the LMM to the complex scaling method, I present accurate computations of the resonances of the negatively charged positronium ion for low orbital momenta (L = 0, 1). In addition, by combining the LMM and the Kohn variational method, I present accurate computations of the resonances of the antiprotonic helium atom for a vast range of angular momenta (from L = 0 to 80).

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Atomic clocks, precision measurements and tests of the Standard Model

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Time and frequency are the most accurately measurable quantities in physics. Some optical atomic clocks reach a relative frequency uncertainty close to 10-18 and allow to search for deviations in the predictions of Einstein's general relativity, test modern unifying theories and to develop new sensors for gravity and navigation.
In my talk, I will introduce the concepts of optical clocks and precision spectroscopy, present the current international status and discuss recent measurements which give new boundaries on possible deviations from predictions of general relativity and the standard model.

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Recent Developments in Beam Neutron Lifetime Experiments

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Neutron decay is the prototype for nuclear beta decay and other semileptonic weak interactions. The value of the neutron lifetime and angular correlation coefficients can be used to determine the weak coupling constants G_A, G_V, and the CKM matrix element V_{ud}. Neutron decay was important in the early universe and the lifetime is needed in theoretical calculations of primordial element abundances. Two main experimental methods, the neutron beam method and the ultracold neutron storage method, unfortunately now disagree by more than 8 seconds (4 standard deviations). I will review recent and current neutron lifetime experiments using the beam method, including systematic tests using the NIST apparatus and the upcoming BL3 experiment.

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qBounce: Using GRS to investigate bouncing neutrons on mirrors

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qBounce uses Ultra-Cold Neutrons (UCNs) in a mechanical Ramsey type spectrometer to investigate gravity. The neutrons are trapped on the surface of mirrors by gravity leading to discrete quantum states. Transitions between these states are induced by mechanical oscillations of the mirrors in a Ramsey type fashion. Using this novel method called Gravity Resonance Spectroscopy (GRS) high precision measurements of the local acceleration of the neutron have been performed. The neutron has near zero charge and low polarizability when compared to atoms so the system is insensitive to many external influences.

The experiment was comissioned in 2017 at the ILL in Grenoble and in 2018 the first proof of principle of this Ramsey type GRS was published. Improvements to the experimental setup were investigated and implemented increasing stability and precision in 2018 and 2019. Precision measurements of transitions were performed in 2020 and 2021.

These results allows the investigation of Dark Matter and Dark Energy models which are predicted to interact with the neutron leading to shifts in the energies and transition frequencies observed by qBounce.

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Towards a neutron electric dipole moment measurement with an advanced ultracold neutron source at TRIUMF

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Measurements of the neutron electric dipole moment (EDM) occupy an important place in today's particle physics. A finite value of the neutron EDM would indicate time-reversal symmetry violation, and based on the CPT theorem, also CP violation. Hence, it serves as a sensitive probe for CP violation. The current best upper limit of $1.8 \times 10^{-26}\, e \cdot \mathrm{cm}$ (90% C.L.) [1] is obtained through measurements of spin precession frequencies of stored ultracold neutrons (UCNs) under electric and magnetic fields. Limited numbers of UCNs available for the experiments have statistically limited the precision of recent measurements.

The TUCAN (TRIUMF Ultra-Cold Advanced Neutron) collaboration aims to measure the neutron EDM with an improved precision by using a new high-intensity UCN source currently being constructed at TRIUMF. Our UCN production scheme based on spallation neutron production and superthermal UCN conversion with superfluid helium has been successfully demonstrated by a prototype UCN source [2]. With the new improved source, a statistical EDM sensitivity of $10^{-27}\, e \cdot \mathrm{cm}$ (68% C.L.) is expected to be attained in about 400 days of measurement.

Recently, core components of the new UCN source, such as optimized neutron moderators [3], a high-performance helium cryostat [4], and a nickel-phosphorus coated UCN production vessel have been built, tested and are being commissioned at TRIUMF. Developments of components of the neutron EDM spectrometer, such as a magnetically shielded room, atomic magnetometers, UCN polarization analyzers and an UCN precession chamber are also advancing in parallel [5].

In this presentation, an overview of the recent works by the TUCAN collaboration will be presented, and prospects for the new EDM measurement will be discussed.

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[1] C. Abel et al., Phys. Rev. Lett. **124**, 081803 (2020).
[2] S. Ahmed et al. [TUCAN Collaboration], Phys. Rev. C **99**, 025503 (2019).
[3] W. Schreyer et al., Nucl. Inst. Meth. A **959**, 163525 (2020).
[4] S. Kawasaki, T. Okamura and the TUCAN collaboration, IOP Conf. Ser.: Mater. Sci. Eng. **755**, 012140 (2020).
[5] T. Higuchi for the TUCAN collaboration, EPJ Web Conf., **262** 01015 (2022).

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Overview and new tresults H2 molecular spectroscopy

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Hadronic contributions to the anomalous magnetic moment of the muon

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Hadronic contributions to the anomalous magnetic moment of the muon

Interpretation of the recent experimental result for the anomalous magnetic moment of the muon by the Fermilab E989 experiment (and even more so of future updates with yet increased precision) depends crucially on the accuracy of the Standard-Model prediction, especially control over hadronic corrections. In the talk, I will give an overview of the current status, focusing on recent developments for hadronic vacuum polarization.

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High-precision Penning-trap experiment PENTATRAP

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High-precision Penning trap mass spectrometry is the most precise technique employed to measure masses of nuclides with half-lives as short as a few ten ms. Currently, there are about a dozen high-precision Penning-trap mass spectrometers located in North America and Europe. The majority of them are part of various Rare Ion Beam (RIB) facilities and aim at measurements of masses of short-lived nuclides with fractional uncertainties down to 1E-9. The other group encompasses four ultra-precise Penning trap mass spectrometers. Their major goal are mass-ratio measurements on long-lived and stable nuclides with fractional uncertainties of as small as a few ppt.
In this second group the PENTATRAP experiment is probably the most advanced. It is located at the Max-Planck Institute for nuclear physics and aims to perform mass-ratio measurements on a very broad range of long-lived nuclides to assist, e.g., experiments on the determination of the neutrino mass, on the search for the fifth force, on the investigation of atomic metastable states that can be suitable ion clock transitions and so on. In this talk I will (after a quite detailed introduction of Penning-trap mass spectrometry) present latest achievements and future plans with PENTATRAP.

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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 an experiment in planning at DESY, Hamburg, using the electron beam of the European XFEL. LUXE is intended to study collisions between a high-intensity optical laser pulse and 16.5 GeV electrons from the XFEL electron beam, as well as collisions between the laser pulse and high-energy secondary photons. This will elucidate quantum electrodynamics (QED) at the strong-field frontier, where the electromagnetic field of the laser is above the Schwinger limit. In this regime, QED is non-perturbative. This manifests itself in the creation of physical electron-positron pairs from the QED vacuum, similar to Hawking radiation from black holes. LUXE intends to measure the positron production rate in an unprecedented laser intensity regime. The experiment has received a stage 0 critical approvement (CD0) from the DESY management and is in the process of preparing its technical design report (TDR). An overview of the LUXE experimental setup and its challenges and progress will be given, along with a discussion of the expected physics reach in the context of testing QED in the non-perturbative regime as well as with regards to searches for light exotic particles.

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The LEMING experiment

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Despite the immense success of the Standard Model (SM), it is well known to be incomplete in describing Nature. Most obviously it is not incorporating gravity, and also falling short in explaining cosmological observations like the baryon asymmetry of the Universe, or the nature of dark matter and dark energy. Recent tensions concerning lepton universality are also persistent in the latest results of LHCb [1], or the muon g-2 experiment [2]. In this talk, we discuss exotic atomic systems like antiprotonic helium (ASACUSA experiment at CERN) and muonium (LEMING experiment at PSI) that gives us access to some of these beyond SM physics.

In our newly approved LEMING experiment at the Paul Scherrer institute we aspire to carry out next generation atomic physics and gravity experiments using muonium, which is an exotic atom consisting purely leptons, a muon and an electron ($M = \mu^+ + e^-$) [3]. The result of a M gravity measurement would be a direct test of the weak equivalence principle using elementary (anti)leptons from two families, in the absence of large binding energies from the strong interaction.

We started this challenging task by developing a novel cold atomic M beam in vacuum using muon conversion in superfluid helium. The basis of this new concept relied on the measured behavior of exotic atoms in SFHe, a recent laser spectroscopy result using antiprotonic helium at CERN [4]. Our new tantalizing measurements with the newly synthesized cold M beam production put us on a path for increased precision in 1S-2S laser spectroscopy of M, and may pave the way for a free fall experiment, that would be the first direct measurement of the gravitational interaction using (anti)leptons.

References

[1] LHCb Collaboration, Nat. Phys. 18, 277–282 (2022)
[2] Muon g–2 Collaboration, Phys. Rev. Lett. 126, 141801 (2021)
[3] A. Soter and A. Knecht, SciPost Phys. Proc. 5, 31 (2021)
[4] A. Soter et. Al Nature volume 603, pages 411–415 (2022)

Session / 204

Proton structure in and out of muonic hydrogen

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In this talk, I will discuss light muonic atoms, with a focus on the theory of two-photon-exchange corrections in muonic hydrogen and deuterium. In addition, I will give a summary of the satellite workshop "Proton structure in and out of muonic hydrogen — the ground-state hyperfine splitting".

Session / 275

Progress Towards the Development of the nEDM@SNS Experiment

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The nEDM@SNS experiment under development for the Spallation Neutron Source at Oak Ridge National Laboratory is projected to achieve a 90% C.L. limit on the neutron EDM of $< 3 \times 10^{-28}$ e-cm via the innovative technique originally proposed by R. Golub and S.K. Lamoreaux [Phys. Rept. 237, 1 (1994)]. The concept of the experiment will be briefly reviewed, followed by a status report on progress towards the development of the experiment.

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The neutron electric dipole moment experiment at Los Alamos National Laboratory

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The electric dipole moment of the neutron (nEDM) is exceedingly small in standard model of particle physics. However, beyond standard model theories allow for larger values of the nEDM, possibly within the reach of upcoming experiments. This talk will present an overview and status of the nEDM experiment under development at the Los Alamos National Laboratory (LANL) ultracold neutron source and targeting a measurement uncertainty of 3×10^{-27} e-cm. The experiment features a double-cell geometry, ^{199}Hg co-magnetometry, external optical magnetometers, precision holding field and gradient coils, and a large, state-of-the-art magnetically shielded enclosure. Some of the experimental team's findings during the present commissioning of major components of the apparatus will be described.

Session / 180

B anomalies and Lepton Flavour Universality

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Over the last decade, measurements of both b⟶sl+l- and b⟶clν decays have consistently shown tensions with Standard Model predictions. These tensions are referred to collectively as the flavour or B anomalies. Key drivers of the flavour anomalies include measurements of Lepton Flavour Universality and of the angular distributions of b⟶sl+ l-decays. This talk will give an overview of the current status of the flavour anomalies and prospects for future measurements using data collected during the LHC Run 3.

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Latest results amd precision measurements with NA62

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The NA62 experiment at CERN collected the world's largest data set of charged kaon decays in 2016-2018, leading to the first measurement of the Branching Fraction of the ultra-rare $K^+ -> \pi^+ \nu \nu$ decay. The $K^+ \to \pi^+ \nu \bar{\nu}$ decay was observed with a significance of 3.4σ, based on 20 candidate events. This measurement also sets limits on BR($K^+ \to \pi^+ X$), where X is a scalar or pseudo scalar particle. The analysis of the 2018 data sample and the future NA62 plans and prospects are reviewed.

The flavour-changing neutral current decay K^+ -> $\pi^+ \mu^+ \mu^-$ is induced at the one-loop level in the Standard Model. Preliminary results from an analysis of the $K^+ -> \pi^+ \mu^+ \mu^-$ decay are reported. The most precise determination of the $K^+ -> \pi^+ \mu^+ \mu^-$ form-factor parameters a+ and b+ made by NA62 using data collected in 2017 and 2018 is described.

In addition to the precision SM measurement, NA62 employs dedicated trigger lines to collect dilepton final states, which can be used to search for lepton flavor and lepton number violating kaon decays. The stringent upper limits on the rates of several K^+ decays violating lepton flavour and lepton number conservation, obtained with the NA62 data set, are presented.

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Searching for the permanent electric dipole moment using laser cooled francium atoms

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An experimental apparatus dedicated to search for the permanent electric dipole moment (EDM) of laser cooled francium atoms has been constructed at RIKEN Nishina Center, Japan. In this talk, the principle of the EDM measurement using francium atoms and the experimental status using the newly built apparatus will be presented.

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BRAND – search for exotic couplings in weak interactions using the transverse electron polarization in the decay of free neutrons

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Co-authors: Adam Kozela [2]; Alerbert R. Young [3]; Boguslaw Wloch [2]; Dagmara Rozpedzik [1]; Dieter Ries [4]; Ghnashyam Gupta [1]; Jacek Zejma [1]; Jinj Ha Choi [3]; Karishma Dhanmeher [2]; Krzysztof Pysz [2]; Lennert De Keukeleere [5]; Martin Engler [4]; Nathal Severijns [5]; Noah G. Yazdandoost Khosravi [4]; Torsten Soldner [6]

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Neutron and nuclear beta decay correlation coefficients are sensitive to the exotic scalar and tensor interactions that are not included in the Standard Model (SM). The experiment BRAND will measure simultaneously seven neutron correlation coefficients: *H, L, N, R, S, U* and *V* that depend on the transverse electron polarization – a quantity which vanishes in the SM. Five of these correlations: *H, L, S, U* and *V* were never attempted experimentally before. The expected impact of this experiment is comparable to that of frequently measured "traditional" correlation coefficients (*a, b, A, B, D*) but offers completely different systematics and additional sensitivity to imaginary parts of the scalar and tensor couplings. In order to demonstrate the feasibility of the challenging techniques such as the event-by-event decay kinematics reconstruction together with the electron polarimetry a test program is ongoing on the PF1B beam line at the Laue-Langevin Institute, Grenoble, France (ILL), with simplified experimental setups. The strategy of the project assumes gradual increase of sensitivity by extending the fiducial volume and angular coverage of detectors.

In the contribution, the current status of R&D and demonstration experiments will be presented.

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Why do we want to search for a muon EDM ?

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The new g-2 measurement suggests new physics in the anomalous magnetic moment of the muon. While this is related to real part of the corresponding Wilson coefficient, the imaginary part gives rise to an electric dipole moment. In this talk, I show that in models with heavy new physics (i.e. realized above the EW scale) one naturally expect a sizable muon EDM within the reach of the planned PSI experiment.

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Muon g-2 and EDM at J-PARC

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The J-PARC muon g-2/EDM experiment aims to measure g-2 and EDM of muon by using a reaccelerated thermal muon beam and a compact muon storage magnet at J-PARC MLF muon facility. A new surface muon beamline (H-line) has been partially constructed. The first beam was delivered in January, 2022. Remaining parts of construction are in progress. In this talk, status of the experimental preparation and plans will be presented.

Session / 316

MuSun: Muon Capture on the Deuteron

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The goal of MuSun is a first precise measurement of a weak process in the 2-nucleon (2N) system. These reactions include muon capture on the deuteron, $\mu + d \longrightarrow n + n + \nu$, together with two astrophysics reactions of fundamental importance, solar pp fusion and νd reactions. The above interactions involve the same, but poorly known axial-vector coupling at a four-nucleon vertex, which also enters in the construction of chiral three-nucleon forces and in other weak and strong dynamics. MuSun plans to determine the strength of this coupling with about 5 times better precision than presently known from the 2N system.
The MuSun employs a novel experimental method to measure muon capture, based on a TPC filled with ultra-pure cryogenic deuterium gas to track the stopping muons from the
piE1 beamline at PSI. After collecting the full statistics of 1.4x10^10 events, the MuSun collaboration concentrated on the analysis of this data. In my talk I will present the experiment and the analysis including the complete experimental error budget before the final unblinding step.

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Hyperfine Structure Measurements on Hydrogen and Deuterium for CPT and Lorentz Invariance tests

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The ASACUSA collaboration proposed a hyperfine structure (HFS) measurement on a beam of antihydrogen at the antiproton decelerator of CERN to test CPT invariance. Supporting matter experiments are of high relevance in antihydrogen research. They have been performed for the sigma transition (F,M_F: 1,0 $\rightarrow$ 0,0) of the hydrogen HFS at 1.42 GHz with the noteworthy precision of 2.7 ppb using ASACUSAs antihydrogen HFS spectrometer. Subsequently the setup has been improved to access the more sensitive pi transition (F,M_F: 1,1 $\rightarrow$ 0,0) and campaigns have been carried out to address so far unconstrained coefficients of the standard model extension (SME) framework. This is possible even without comparison to antimatter through alternating measurements with static magnetic guiding fields of opposing directions. In parallel a device has been designed to enable similar HFS measurements around 320 MHz on deuterium, where the proton possesses a significantly larger momentum resulting in orders of magnitude higher sensitivity to certain SME coefficients. The status of the analysis of the latest hydrogen campaign will be presented and a progress report on the deuterium experiment will be given.

Session / 313

New Searches for Neutron Oscillations at ORNL

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Two critical questions in particle physics remain unanswered–what is the particle nature of dark matter, and why is there no antimatter in the universe? Searches for neutron oscillations are an essential component of the worldwide program to understand baryon number violation and what comprises dark matter, but are underexplored experimentally. If dark matter is made up of a rich hidden sector such as "mirror matter," neutral particles such as the neutron might oscillate into their dark twin. This phenomenon was suggested as the source of the long-standing discrepancy between the cold neutron appearance ("beam") and ultracold neutron disappearance ("bottle") techniques for measuring the neutron lifetime. I will describe a new search for mirror neutron oscillations recently performed at ORNL's Spallation Neutron Source that has ruled out this explanation of the neutron lifetime puzzle. I will also discuss plans for additional searches at ORNL and the ESS, including searches for neutrons transforming into mirror neutrons and back into antineutrons. This program will inform a future high sensitivity search for neutrons transforming directly into antineutrons in the NNBAR experiment, which can improve sensitivity by three orders of magnitude over the previous direct search.

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Search for neutron disappearance into sterile states

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The origin of matter and dark matter might be explained by models invoking copies of the Standard Model, e.g. mirror matter, which are sterile under ordinary Standard Model forces. Previous experiments constrained neutron to mirror neutron (n-n') oscillations by searching for anomalous neutron losses during the storage of ultracold neutrons (UCN). However, the presence of a mirror magnetic field or a mass splitting between neutron and sterile state would suppress the oscillation probability. We installed a new experiment at the PSI UCN source to search for resonant n-n' oscillations in magnetic fields between 5 μT and 360 μT and oscillation times on the order of 100 s. We present our setup and a preliminary analysis of our first measurements.

The experiment features a large 1.47 m^3 stainless steel storage volume with a storage-time constant for UCN of 202 s and a mean time between subsequent collisions of the neutron with the vessel walls of 0.17 s. After a storage time of 180 s we detect on average 10^6 UCN. A monitoring phase after filling of the storage volume compensates drifts and fluctuations of the UCN output of the source. We achieved a statistical sensitivity on the asymmetry observable of the normalized neutron counts after storage in a vertical up and down magnetic field of 10^{-4} per measurement day.

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Neutron beta decay with pulsed cold neutron beams

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The instrument PERKEO III was used to measure most precisely the beta asymmetry in neutron decay at the cold neutron beam line PF1b of the ILL, Grenoble. From this measurement, we extract the ratio of nucleon axial-vector and vector couplings. When combined with the neutron lifetime, this provides the CKM matrix element V_{ud} with only a factor two in precision to the combined result from superallowed nuclear decays. PERKEO's successor, the PERC instrument, is currently being commissioned at the FRM II, Garching, which aims at an improved measurement of the beta asymmetry by a factor of five. Pulsed neutron beams are key to systematic control in both experiments.

A combined analysis of the beta-asymmetry and the Fierz interference term provides the currently most precise and systematically clean limit from neutron decay. Just before recent lock-downs, the PERKEO III group completed a successful campaign at the ILL to measure the beta spectrum with the aim improve these limits.

In this talk, I will discuss recent results by the PERKEO III collaboration and present the status of its successor PERC.

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Reanalysis of the of β-$\bar{\nu}_e$ angular correlation measurement aSPECT with new constraints on Fierz interference

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The aSPECT collaboration published in 2020 the most precise value on the electron-antineutrino correlation coefficient $a = -0.10407(82)$ of neutron β-decay. Meanwhile we revised some systematic errors and reanalysed our data including the Fierz interference term b. We will present our new value for a, which only marginally differs from our previous published result together with the revision of some systematic errors. Further we will discuss our Fierz term result in the context of today most precise result on b from neutron β-decay published by the Perkeo III collaboration.

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Update on the PEN experiment: A precision measurement of rare pion decays

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Historically, pion and muon decays have provided essential information regarding nature of the electroweak interactions. In modern times, pions and muons are theoretically studied to a high precision within the extremely well understood Standard Model framework. This simplicity permits pion decays to be used as sensitive probes for physics Beyond the Standard Model (BSM). The comparison of the chirally supressed $\pi \to \mathrm{e}\nu(\gamma)$ decay and the $\pi \to \mu\nu(\gamma)$ decay presents the best test for electron-muon universality, an assumed feature of the Standard Model. Violations of lepton universality may indicate BSM features such as massive neutrinos, charged higgs multiplets, leptoquarks, or several other new possibilities. Experiments have failed to reach the necessary precision by nearly an order of magnitude in order to test the theoretically predicted Standard Model values. The PEN collaboration led by the University of Virginia has performed detailed measurements at the Paul Scherrer Institute with the goal of obtaining a relative uncertainty of 5×10^{-4} for the $\pi \to \mathrm{e}\nu(\gamma)$ branching ratio. The PEN apparatus consists of a mini time projection chamber for incoming pion tracking as well as plastic scintillating beam counters and active target, for dectection of pion decays at rest. Decay products are tracked and identified using a cylindrical multi-wire proportional chamber, plastic scintillating hodoscopes, and a pure spherical CsI electromagnetic calorimeter that covers 3π sr. Key elements in the analysis include radiative decays, timings, wire chamber efficiencies, highly realistic Monte Carlo simulations, decays in flight, and the low energy tail resulting from energy leakage in the electromagnetic shower. A review of the analysis, current status, and expected systematic uncertainties will be given.

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Overview of Pienu results and the PIONEER project

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A next-generation rare pion decay experiment, PIONEER, is motivated by several inconsistencies between Standard Model predictions and data pointing towards the potential violation of lepton flavor universality. PIONEER will measure the charged-pion branching ratio to electrons vs muons (R_pi), a quantity which is very sensitive to a wide variety of new physics effects - including those at very high mass scales- and which is theoretically predicted to a precision 15 times better than current experimental results. PIONEER will use a combination of new detector technologies based an LGAD silicon tracking target, a deep calorimeter with high solid angle coverage and high-speed electronics to optimize its energy and time resolution in view of matching the theoretical precision. I'll discuss recent results from previous measurements of R_pi, in particular from the PIENU experiment at TRIUMF, and present PIONEER's experimental goals.

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The Mu2e experiment

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The Mu2e experiment, currently under construction at Fermilab, will search for neutrinoless mu->e conversion in the field of an aluminum atom. A clear signature of this charged lepton flavor violating two-body process is given by the monoenergetic conversion electron of 104.97 MeV produced in the final state.

An 8 GeV/c pulsed proton beam interacting on a tungsten target will produce the pions decaying in muons; a set of superconducting magnets will drive the negative muon beam to a segmented aluminum target where the stopped muons will eventually convert to electrons; a set of detectors will be used to both identify conversion electrons and reject beam and cosmic backgrounds.

The experiment will need 3-5 years of data-taking to achieve a factor of 10^4 improvement on the current best limit on the conversion rate.

After an introduction to the physics of Mu2e, we will report on the status of the different components of the experimental apparatus. We conclude with our current estimate of the experiment's sensitivity and discovery potential.

Session / 182

Dark matter: the hunt for the unknown

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Astronomical and cosmological observations strongly suggest that most of the matter in our Universe is non-luminous and made of an unknown substance called Dark Matter. But, currently, it remains invisible and undetectable directly on Earth and makes it one of the greatest mysteries in particle physics. Even if its direct detection escapes to the scientific community in our time, dark matter remains a fundamental concept that would explain how our Universe was formed and offer a unique chance to discover physics beyond the Standard Model.
Currently, many worldwide experiments are searching for dark matter to solve this mystery and understand its properties. After presenting how we can detect it directly, I will give an overview of the numerous experimental dark matter searches and the challenge we are now facing by reaching such an unprecedented level of sensitivity that never-before-seen background signals have to be considered.

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Dark sector studies with the PADME experiment

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The evidence of dark matter so far is based only on gravitational effects observed at cosmological and astrophysical level. To explain these effects, many theoretical models suggest other non-gravitational very-weak interactions between dark matter and ordinary matter. To test this hypothesis, different experiments are trying to directly produce dark matter at particle accelerators.
The Positron Annihilation into Dark Matter Experiment (PADME), ongoing at the Laboratori Nazionali di Frascati of INFN, is looking for hidden particle signals by studying positron-electron annihilations.
The experiment was built and commissioned at the end of 2018 and beginning of 2019, and collected $\approx 5 \times 10^{12}$ positrons on target at 430 MeV in 2020.
The analysis of the missing-mass spectrum of single photon final states is the first scientific item under study, with the aim of identifying a signal of a dark photon produced in association with an ordinary photon. PADME is expected to reach a sensitivity of up to 10^{-6} on ϵ^2 (kinetic mixing parameter) representing the coupling of a low-mass dark photon (m< 21.7 MeV/c^2) with ordinary photons.
The PADME approach is sensitive to any new particle that couples to fermions: Axion-Like Particles, dark Higgs, and even a protophobic new state recently indicated by a nuclear physics experiment in Hungary ("X17 anomaly"). Since this state has been observed decaying in e^+e^- pairs, PADME has the unique opportunity to try to produce it resonantly. By lowering the energy of the beam at $\approx$ 280 MeV it would be possible to directly produce X17 and subsequently study its decay.
PADME is preparing a new data taking to study "X17 anomaly" that will start September 2022. In the talk the details of the ongoing analyses and the new data taking will be presented.

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Discovering Neutrinoless Double-Beta Decay in Ge-76 with the LEGEND Experiment

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The search for neutrinoless double beta ($0\nu\beta\beta$) decay is considered as the most promising way to prove the Majorana nature of neutrinos as well as to give indication on the mass hierarchy and on the absolute mass scale. The discovery of $0\nu\beta\beta$ decay would moreover open the way for theories predicting the observed matter anti-matter asymmetry of the Universe being a consequence of lepton number violation through leptogenesis.

Building upon the success of GERDA and MAJORANA experiments, the LEGEND (Large Enriched Germanium Detector for Neutrinoless bb Decay) Collaboration aims at building a ^{76}Ge-based $0\nu\beta\beta$ experiment with a sensitivity on the half-life beyond 10^{28} years, to fully span the inverted neutrino mass ordering region. The LEGEND project will proceed in two steps: in the first phase, 200 kg of enriched germanium detectors will be deployed in the existing GERDA facility at LNGS. With an exposure of 1 t·yr and a BI of 0.5 cts/(FWHM·t·yr), LEGEND-200 will be able to reach a sensitivity of about 10^{27} yr at 90% C.L. In the second phase, the enriched germanium mass will be increased up to 1000 kg. With a background index of 0.025 cts/(FWHM·t·yr) and with an exposure of 10 t·yr, LEGEND-1000 will be able to reach a 3σ half-life discovery sensitivity of 1.3×10^{28} yr.
In this talk an overview of the LEGEND project will be presented together with the status of LEGEND-200, currently in the commissioning phase at LNGS.

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Search for Neutrinoless Double Beta Decay of 130Te: latest results from the CUORE experiment

Author: Stefano Ghislandi[None]

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The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for 0νββ decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its 3rd result of the search for 0νββ, corresponding to a tonne-year of TeO2 exposure. This is the largest amount of data ever acquired with a solid state detector and the most sensitive measurement of 0νββ decay in 130Te ever conducted, with a median exclusion sensitivity of 2.8×10^25 yr. We find no evidence of 0νββ decay and set a lower bound of 2.2 ×10^25 yr at a 90% credibility interval on the 130Te half-life for this process. In this talk, we present the current status of CUORE search for 0νββ with the updated statistics of one tonne-yr. We finally give an update of the CUORE background model and the measurement of the 130Te 2νββ decay half-life, study performed using an exposure of 300.7 kg·yr.

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Physics program at MESA in Mainz

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At the institute of nuclear physics in Mainz, the Mainz Energy-Recovery Superconducting Accelerator MESA is currently under construction. The talk will discuss the physics program of this new high-intensity facility. The polarized extracted beam will be used for parity-violation experiments with the P2 setup, in particular a precision measurement of the weak mixing angle $\sin^2\theta_W$ in scattering off hydrogen, standard model tests in scattering off carbon and a measurement of the neutron skin in scattering off lead. Even higher intensities are available in energy-recovery mode, where the MAGIX spectrometer setup with an internal gas jet target will be used for e.g. form factor measurements and studies of reactions of interest for nuclear astrophysics. The DarkMESA experiment finally will be placed behind the P2 beam dump to search for potential dark matter particles.

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New Limit on Axion-Like Dark Matter using Cold Neutrons

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The current best estimate for the universe's matter content consists of 84% dark matter, and the search for its composition remains of great interest. One possible candidate is a so-far undetected ultra-low-mass axion. Various astronomical observations and laboratory experiments constrain the axion mass and its interaction strength in the allowed phase space. In this talk, we report on a search for dark matter axion-like particles (ALPs) using a Ramsey-type apparatus for cold neutrons. A hypothetical ALP-gluon-coupling would manifest in a neutron electric dipole moment signal oscillating in time. Twenty-four hours of data have been analyzed in a frequency range from 23 μHz to 1 kHz, and no significant oscillating signal has been found. The usage of present dark-matter models allows constraining the coupling of ALPs to gluons. Details of the analysis and results will be presented.

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The Search for Neutron - Anti-Neutron Oscillations at the European Spallation Source

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With the Standard Model (SM) of particle physics undisputedly established and well-tested nevertheless a number of major open questions in modern physics remain. These include the observed asymmetric abundances of matter and antimatter in our known universe after baryogenesis. The NNBAR experiment [1] was proposed to search for baryon number violation (BNV) due to conversion of a neutron (n) into an anti-neutron (¯n). A process that could explain the aforementioned asymmetry. The BNV process may occur as free neutrons propagate via ballistic motion to a detector, where anti-neutrons will annihilate and be detected via their multi-pion decay signature.
(A schematic of the setup of the planned experiment is given in Fig.1 in the attachment)
The general aim for the planned experimental campaign at the ESS is to reach an increase in sensitivity of three orders of magnitude over the current limit, obtained at a previous experiment at the ILL [2]. For this advantage of the expected unique high intensities of cold neutrons from the second, lower moderator system at ESS will be taken. Development, design and optimization of the various components comprising the experiment are currently explored in course of the HighNESS project [3]. This comprises the design of the moderator for cold neutrons, the transport of the neutrons to the detector region and the detector itself.
An overview is given on the present state of the work on the NNBAR experiment with special focus on the optics and the detector system.

References

[1] Addazi, A., et al. "New high-sensitivity searches for neutrons converting into antineutrons and/or sterile neutrons at the HIBEAM/NNBAR experiment at the European Spallation Source." Journal of Physics G: Nuclear and Particle Physics 48.7 (2021): 070501.
[2] Baldo-Ceolin, Massimilla, et al. "A new experimental limit on neutron-antineutron oscillations." Zeitschrift für Physik C Particles and Fields 63.3 (1994): 409-416.
[3] Santoro, V., et al. "Development of a High Intensity Neutron Source at the European Spallation Source: The HighNESS project." arXiv preprint arXiv:2204.04051 (2022)

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Direct neutrino mass measurements

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While neutrino oscillations disprove massless neutrinos, decay kinematics give access to their absolute mass value. Using high-precision tritium beta-decay spectroscopy, the KATRIN experiment places the current best limit on the effective electron anti-neutrino mass at 0.8 eV (90% CL). New operational conditions for an improved signal-to-background ratio, the reduction of systematic uncertainties and a substantial increase in statistics allow to expand this reach. This talk will focus on the latest results of the KATRIN experiment, as well as promising projects for direct neutrino mass exploration in the near future.

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Cyclotron radiation emission spectroscopy for neutrino mass measurement and exotic interaction searches

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Cyclotron radiation emission spectroscopy (CRES) is a new avenue towards high-precision measurements of nuclear -decay spectra. High energy resolution and intrinsic low background have been demonstrated for CRES. As frequency-based technology CRES has an independent set of systematic uncertainty contributions in comparison to most classical electron spectroscopy techniques. Combined with an ultra cold atomic tritium source, CRES promises a technology to surpass the intrinsic neutrino mass sensitivity limit related to the molecular final state population in state-of-the-art experiments. We will report on the first CRES-based tritium endpoint spectrum measurement and the extracted neutrino mass limit. Applied to MeV-scale electron spectra emitted from 6He and 19Ne, searches for chirality-flipping exotic interactions are currently prepared. First CRES signals form MeV electrons and positrons will be presented. This work is supported by the Cluster of Excellence "Precision Physics, Fundamental Interactions, and Structure of Matter"
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Studies of Exotic Physics with Antiprotons and Protons

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The Standard Model of particle physics is incredibly successful and glaringly incomplete. Among the questions left open is the striking imbalance of matter and antimatter in our universe, which inspires experiments to compare the fundamental properties of matter/antimatter conjugates with high precision. The BASE collaboration at the antiproton decelerator of CERN is performing such high-precision comparisons with protons and antiprotons. Using advanced cryogenic Penning traps, we have recently performed the most precise measurement of the proton-to-antiproton charge-to-mass ratio with a fractional uncertainty of 16 parts in a trillion [1]. In another measurement, we have invented a novel spectroscopy method, that allowed for the first direct measurement of the antiproton magnetic moment with a fractional precision of 1.5 parts in a billion [2]. Together with our last measurement of the proton magnetic moment [3] this improves the precision of previous magnetic moment based tests of the fundamental CPT invariance by more than a factor of 3000. A time series analysis of the sampled magnetic moment resonance furthermore enabled us to set first direct constraints on the interaction of antiprotons with axion-like particles (ALPs) [4], and most recently, we have used our ultra-sensitive single particle detection systems to derive constraints on the conversion of ALPs into photons [5]. In parallel we are working on the implementation of new measurement technology to sympathetically cool antiprotons [6] and to apply quantum logic inspired spectroscopy techniques [7]. I will review the recent results produced by BASE, with particular focus on the recent 16 p.p.t. comparison of the antiproton-to-proton charge-to-mass ratio. I will also outline strategies to further improve our high-precision studies of matter-antimatter symmetry, which will include the implementation of the transportable antiproton trap BASE-STEP.
[1] M. J. Borchert et al., Nature 601, 35 (2022).
[2] C. Smorra et al., Nature 550, 371 (2017).
[3] G. Schneider et al., Science 358, 1081 (2017).
[4] C. Smorra et al., Nature 575, 310 (2019).
[5] J. A. Devlin et al., Phys. Rev. Lett. 126, 041321 (2021).
[6] M. A. Bohman et al. Nature 596, 514 (2021)
[7] J. M Conrejo et al., New J. Phys. 23 073045

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Spectroscopic and Gravitational studies of antimatter: the ALPHA antihydrogen experiment at CERN

At CERN, we have recently become able to study atoms of antihydrogen - the antimatter equivalent of hydrogen. The question to be addressed is fundamental and profound: "Do matter and antimatter obey the same laws of physics?" The Standard Model requires that hydrogen and antihydrogen have the same spectrum. The possibility of applying the precision measurement techniques of atomic physics to an antimatter atom makes antihydrogen a very compelling testbed for fundamental symmetries such as CPT. I will discuss the latest developments in antihydrogen physics: observation of the first laser-driven transition (1S-2S) [1,2] observation of the antihydrogen hyperfine structure [3], observation of the Lyman-alpha transition [4], and laser cooling of trapped antihydrogen [5]. To study antihydrogen, it must first be produced, trapped [6], and then held for long enough [7] to observe a transition - using very few anti-atoms. I will illustrate the techniques necessary to achieve the latest milestones, and then consider the future of optical spectroscopy, as well as gravitational studies [8] with the brand-new ALPHA-g experiment.

[1] Observation of the 1s-2s Transition in Trapped Antihydrogen, M Ahmadi et al., (ALPHA Collaboration) Nature 541, 506–510 (2017).
[2] Characterization of the 1S-2S transition in antihydrogen, M Ahmadi et al., (ALPHA Collaboration), Nature 557, 71–75 (2018).
[3] Observation of the hyperfine spectrum of antihydrogen, M Ahmadi et al., (ALPHA Collaboration) Nature 548, 66–69 (2017).
[4] Observation of the 1S−2P Lyman-α transition in antihydrogen, M Ahmadi et al., (ALPHA Collaboration), Nature 561, 211–215 (2018).
[5] Laser cooling of antihydrogen atoms, (ALPHA Collaboration), Nature 592, 35–42 (2021).
6. Andresen, G.B. et al., Trapped Antihydrogen, Nature, 468, 673 (2010).
[7] Andresen, G. B. et al. Confinement of antihydrogen for 1,000 seconds. Nature Physics 7, 558 (2011).
[8] Amole, C. et al., Description and first application of a new technique to measure the gravitational mass of antihydrogen, Nature Communications DOI: 10.1038/ncomms2787 (2013).

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Farewell

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LEMING

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Precision measurements in hydrogen and helium

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Few-electron atoms and molecules are attractive systems for precision spectroscopy because their properties can be calculated with high accuracy from first principles. The measurements serve to test theoretical predictions, ideally at the level where their accuracy iσ limited by the uncertainties of the fundamental constants or by unrecognized physical effects. I will report on precision measurements of energy intervals in cold samples of H, He and H_2. We focus on the measurements of accurate transition frequencies to high Rydberg states, which we then use to determine ionization energies by Rydberg-series extrapolation. These ionization energies can then be compared to values calculated from first principles. In the case of He, for instance, the first complete calculation of the α^7m Lamb shift for several triplet states has recently been carried out and the ionization energy of the 2^3S_1 metastable state was reported to be 1 152 842 742.231(52) MHz [1], which differs from the experimental value of 1 152 842 742.640(32) MHz [2] by almost 8σ. In the case of H_2, HD and D_2, the results agree within the combined uncertainties of about 1 MHz, see, e.g., [3-5]. The talk will give an overview of the sources of uncertainties that limit our measurements and present our strategy to improve the precision and accuracy of the experimental results. This strategy includes the development of (a) improved sources of cold samples of H, He and H_2 (see, e.g., [6]), the use of an improved frequency calibration through a stabilized fiber network with ring topology providing a SI-traceable frequency standard from the Swiss Federal Institute of Metrology METAS [7], and the use of improved methods to reduce systematic uncertainties arising from stray electric fields [8].
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1. V. Patkóš, V. A. Yerokhin, and K. Pachucki, Phys. Rev. A 103, 042809 (2021).
2. G. Clausen, P. Jansen, S. Scheidegger, J. A. Agner, H. Schmutz and F. Merkt, Phys. Rev. Lett. 127, 093001 (2021).
3. M. Puchalski, J. Komasa, P. Czachorowski, and K. Pachucki, Phys. Rev. Lett. 122, 103003 (2019).
4. N. Hölsch, et al, Phys. Rev. Lett. 122, 103002 (2019).
5. J. Hussels, et al., Phys. Rev. A 105, 022820 (2022).
6. S. Scheidegger, D. Schlander, J. A. Agner, H. Schmutz, P. Jansen and F. Merkt, J. Phys. B 55, 155002 (2022)
7. D. Husmann, et al., Opt. Express 29, 24592 (2021)
8. N. Hölsch, I. Doran, M. Beyer and F. Merkt, J. Mol. Spectrosc. 97, 111648 (2022).