SYMD 1: Symposium SMuK Dissertation Prize 2022

Time: Monday 14:00–15:40 Location: Audimax

Invited Talk SYMD 1.1 Mon 14:00 Audimax

Timeless Quantum Mechanics and the Early Universe — •Leonardo Chataigner — Department of Physics and Astronomy, University of Bologna — Institut für Theoretische Physik, Universität zu Köln

Candidate theories of quantum gravity must answer the questions: how can the dynamics of quantum states of matter and geometry be defined in a diffeomorphism-invariant way? How are the quantum states related to probabilities in the absence of a preferred time? To address these issues, we discuss the construction and interpretation of relational observables in quantum theories with worldline diffeomorphism invariance, which serve as toy models of quantum gravity. In this context, we present a method of construction of quantum relational observables which is analogous to the construction of gauge-invariant extensions of noninvariant quantities in usual gauge (Yang-Mills) theories. Furthermore, we discuss how the notion of a physical propagator may be used to define a unitary evolution in the quantum theory, which is to be understood in terms of a generalized clock, as is the classical theory. We also discuss under which circumstances this formalism can be related to the use of conditional probabilities in a generalization of the Page-Wootters approach. Finally, we also examine how our formalism can be adapted to calculations of quantum-gravitational effects in the early Universe.

Invited Talk SYMD 1.2 Mon 14:25 Audimax

First tritium β-decay spectrum recorded with Cyclotron Radiation Emission Spectroscopy (CRES) — •Christine Claessens — Center for Experimental Nuclear Physics and Astrophysics, University of Washington, WA, USA

The observation of neutrino flavor oscillation proved that neutrinos have mass, thereby requiring us to extend the Standard Model of particle physics. Until now, laboratory experiments could only set upper limits on the electron-weighted neutrino mass $m_\beta < 0.8\,\mathrm{eV/c^2}$. The Project 8 collaboration aims to determine the absolute neutrino mass scale from the distortion of the tritium beta decay spectrum near the endpoint. To this end, the collaboration has successfully established CRES, a frequency-based approach to detect electrons and measure their kinetic energy. In this work, an event detection system consisting of real-time triggering and offline event reconstruction has been developed. Since the neutrino mass is determined from the shape distortion it induces in the tritium spectrum, it is essential to quantify any dependence of the electron detection efficiency on energy or, equivalently, frequency. This work demonstrates the importance of including the detection efficiency in the analysis of the first tritium spectrum recorded with CRES for an accurate endpoint measurement and the extraction of the electron-weighted antineutrino mass. In addition, a requirement for the precision of detection efficiency measurements for a future CRES experiment with a $40\,\mathrm{meV/c^2}$ target sensitivity has been determined.

Invited Talk SYMD 1.3 Mon 14:50 Audimax

Watching the top quark mass run - for the first time! — •Matteo M. Defranchis[1], Katerina Lipka[2], and Sven-Olaf Moch[3] — [1]CERN, Geneva, Switzerland — [2]DESY, Hamburg, Germany — [3]UHH, Hamburg, Germany

In the Standard Model of particle physics, the masses of elementary particles are understood as the fundamental couplings to the Higgs field. A special role is played by the mass of the top quark, the most massive elementary particle currently known, whose value affects conclusions about the stability of the vacuum state of our universe. The interaction between quarks and gluons is described by a sector of the Standard Model known as Quantum Chromodynamics, with the strength of the interaction depending on a quantity called strong coupling constant. According to Quantum Chromodynamics, the strong coupling constant rapidly decreases at higher energy scales. The effect is known as the "running of the coupling constant". The same is also true for the masses of the quarks, and the experimental verification of this effect is an essential test of the validity of the Standard Model. Furthermore, the presence of physics beyond the Standard Model can lead to modifications of the mass running by means of the effect of virtual particles. In this work, the running of the top quark mass is measured using high-energy proton-proton collision data collected by the CMS experiment at the CERN Large Hadron Collider. In this way, the fundamental quantum effect of the mass running is investigated for the first time for the most massive elementary particle known.

Invited Talk SYMD 1.4 Mon 15:15 Audimax

Towards beam-quality-preserving plasma accelerators: On the precision tuning of the wakefield — •Sarah Schröder — Deutsches Elektronen-Synchrotron (DESY), Hamburg

Plasma wakefields enable record-setting GeV/m-level acceleration gradients, making them a promising avenue for reducing the size and associated costs of future particle accelerators - with potentially revolutionary implications for basic research and a wealth of industrial and medical applications. The control and optimisation of the acceleration process in the plasma is fundamentally linked to the ability to fine-tune the μm-scale wakefield structure, calling for diagnostics with femtosecond resolution. In this contribution, a novel methodology that allows measurement [1] and tuning [2] of the plasma wakefields at the femtosecond level in a simple way is presented. These novel capabilities allowed the detailed structure of a GV/m-level wakefield acting on the electron bunch throughout the acceleration process to be directly measured for the first time [1] and ultimately fine-tuned such that the energy spread and charge of the bunch were preserved while achieving an energy-transfer efficiency of 42% [3]. These results mark a crucial step towards quality-preserving and efficient high-gradient acceleration - a necessary development to meet the continuous demand for ever-higher beam energies in high-energy particle physics.

[1] S. Schröder, et al. Nat. Commun. 11, 5984 (2020)
[2] S. Schröder et al., J. Phys.: Conf. Ser. 1596 012002 (2020)
[3] C.A. Lindstrøm, J.M. Garland, S. Schröder et al., Phys. Rev. Lett. 126, 014801 (2021)