Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter
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Mainz Institute for Theoretical Physics

Bridging the Standard Model to New Physics with the Parity Violation Program at MESA

Organized by Jens Erler (UNAM), Mikhail Gorshteyn (JGU Mainz) and Hubert Spiesberger (JGU Mainz).

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The main objective of the two-week program was to review the physics opportunities which ultra-high precision polarization experiments at MESA may present within the Standard Model (SM) and beyond. It involved 28 longer (45 to 60 minutes) talks and three shorter ones (about 15 minutes) on topics ranging from searches for physics beyond the SM and their necessary radiative corrections to recent developments in neutrino scattering to neutron skins and hadronic parity violation (HPV). There were ample and lively discussions following the presentations which were continued in four dedicated discussion sessions. In the following, a summary of the issues is given. It refers to new ideas and to the progress made in their understanding.

In his opening talk, Bill Marciano introduced the idea of adding the option of a polarized positron beam to MESA operations. The radiative corrections to e^+p scattering result in a smaller asymmetry compared to the e^-p case increasing the new physics sensitivity and providing complementarity. The challenges involved in the production of a high intensity e^+ beam with sufficient polarization would be enormous, but may deserve a closer look.

There are searches for physics beyond the SM in parity violating electron scattering (PVES) in Mainz and at Jefferson Lab. No conclusive evidence for new physics has been reported so far. Drell-Yan cross section and forward-backward asymmetry measurements in dilepton final states contribute to precision determinations of the weak mixing angle (talk by Siqi Yang) and cut into the available new physics parameter space. In the absence of new light and very weakly coupled particles, the new physics may be described model-independently by an effective field theory.

Vincenzo Cirigliano and Adam Falkowski reviewed the charged and neutral current sectors, and Paul Souder raised the question to what extent the highest energy bins at the LHC with sensitivity to the (non-interfering) square of dimension-6 amplitudes provide strong constraints on sums of positive terms without cancellations. This would be of greater concern for the new physics motivation for PVDIS at SoLID than for elastic scattering at MOLLER (talk by Krishna Kumar), Qweak (David Armstrong) or P2 (Frank Maas). The loopholes to his argument include new gauge bosons that are leptophobic or have large invisible widths, very light degrees of freedom, and possibly four-quark or diquark-diboson operators. It is important to quantify them and to revisit the complementarity between the approaches at the high-energy and high-intensity frontiers (Michael Ramsey-Musolf). Moreover, novel approaches like the CONUS coherent neutrino

scattering experiment, presented by Manfred Lindner, may contribute with complementary results in the long run.

Low-energy SM tests have reached a precision where previously ignored radiative corrections (RC) become important. Ayres Freitas, Aleks Aleksejevs, Rodolfo Ferro reported on recent progress regarding higher order corrections; Konstantin Ottnad and Jonas Wilhelm presented results from lattice QCD on non-perturbative corrections.

A vivid discussion concerned the ways to present the running of $\sin^2\theta_W$. A more radical suggestion was made by Hiren Patel in the context of a two-loop RC to Møller scattering, namely to use SM EFT with heavy bosons and quarks integrated out. It would operate with only four-fermion operators and the respective Wilson coefficients (say, C_1's and C_2's) and all RC would be purely QED and QCD. While it would allow to treat all large logarithms on the same footing (which is a valid point for 2-loop RC), it would lead to giving up the renormalizability of the SM and various other problems which the follow-up discussion could not solve.

As for super-allowed $0^+ \to 0^+$ β-decays, the γ-W box contributions (Chien Yeah Seng) need to be re-evaluated already at the level of free neutron decay. But the effects due to the nuclear environment must also be scrutinized. The issue is analogous to γ-Z box diagrams (Peter Blunden) in the neutral current sector. Data from β-decays and neutron lifetime measurements provide the information required for a determination of V_{ud}. The status of experiments in this area was reviewed by Werner Heil and John Hardy. Bill Marciano pointed out that using g_A as obtained via post-2002 asymmetry measurements, plus V_{ud} from superallowed decays, would lead to the conclusion that the neutron lifetime obtained from bottle experiments is preferred over that from beam experiments. Alejandro Garcia reported on the progress in assessing new tensor inter-actions with a high-precision measurement of the a and b correlation coefficients in ^{6}He decay.

Barry Holstein and Jordy de Vries reported on a new paradigm according to which HPV may be organized with respect to NC enhancements and $\sin^2\theta_W$ suppressions. To test it, more experimental data are needed. Beyond the recently completed NPDγ experiment at ORNL, Mike Snow reported on the status of spin rotation in polarized n-^{4}He scattering. Discussions pointed out a possible input from the future MESA program. Along the nucleon anapole moment, which is an important part of the P2 program, an energy-upgrade to 200 MeV MESA+ will allow to probe the PV π^+ production at threshold which would mainly be sensitive to the PV coupling h_1^π. A feasibility study for the latter measurement was proposed.

Dionysis Antypas reviewed recent progress on PNC effects in Dy and Yb atoms, subject to an active experimental program in the local group of Dima Budker. Yevgeny Stadnik

presented an overview of atomic theory required to extract information from these and future atomic PNC experiments, discussed sensitivity of atomic experiments to Dark Matter effects (e.g. axions), and proposed new neutrino-mediated long-range PV forces which may become testable on the experiment in the near future.

PVES experiments such as PREX and CREX (Krishna Kumar) or the ancillary aluminum measurement at Qweak (Wouter Deconinck) may be used to understand neutron skins in nuclei (Concettina Sfienti) and neutron stars (Chuck Horowitz). An important question is which nuclei precision measurement at MESA would optimize the physics output. Xavier Roca Maza proposed to use charge radii of mirror nuclei as an additional observable beyond the symmetry energy and electric dipole polarizability to constrain nuclear models that are then used to obtain information on the equation of state of neutron-rich matter via neutron skin measurements. In beta decay, mirror nuclei are important systems for the V_{ud} extraction. Thus a joint analysis of the two reactions should be advantageous.

The beam normal spin asymmetries on nuclei may help testing our understanding of the Coulomb distortion corrections which are an important ingredient for extracting the neutron skin from PV asymmetry measurements. Coherent pi-0 production on nuclei at low momentum transfer, previously proposed as an alternative method to access the neutron skin, requires further theoretical work to remove a systematic uncertainty due to strong interaction effects connecting the measured cross sections to the neutron skin.