FITTED: **FIT**s **t**o **E**lectroweak and Nuclear Precision **D**ata

Jens Erler and Mikhail Gorchtein (JGU Mainz)

1. Research objectives

During the first runs at the LHC the long-awaited Higgs boson was discovered, but no signs for physics beyond the Standard Model (BSM) turned up. As a result, there is increasing emphasis on indirect BSM searches, where one looks for small deviations from the Standard Model (SM). This strategy can only be successful if the SM is over-constrained, which means a maximal set of precision observables needs to be identified for which experimental and theoretical uncertainties can be controlled simultaneously. The precision in this endeavor has become very high, and in order to move forward a reevaluation of all sources of uncertainties and correlations, including those of theoretical origin, is called for. At the same time, the very high precision also brings previously disjoint physics communities together, all but guaranteeing novel synergetic effects.

In this proposal we wish to address the aforementioned requirements by performing global fits to electroweak precision data including those obtained at typical hadronic energy scales and below, paying particular attention to the assessment and inclusion of theoretical uncertainties and their possible correlations between otherwise independent observables. The most notorious source of theory uncertainty originates from the strong interaction and enters via form factors, parton distribution functions, hadronic and nuclear corrections etc.

Specifically, we propose to reassess these for the parity-violating electron scattering (PVES) program P2 commencing soon at the Mainz Energy-Recovering Superconducting Accelerator (MESA) which will provide high-precision measurements of the so-called weak charges of the proton, ^{12}C, and heavier nuclei, as well as the electron (the latter by MOLLER at JLab). Weak charges can also be extracted in atomic parity violation experiments. Difficult to calculate electroweak radiative corrections, e.g. the γZ box, may contribute non-negligibly and must be reliably estimated.

The interpretation of PVES experiments within the systematic framework of the SM effective field theory (SMEFT) will connect them with measurements at the high-energy frontier, such as mass measurements and Drell-Yan processes at the LHC. Thus, we also propose a global analysis of all relevant electroweak data in this context, linking nuclear, high-energy and atomic physics communities.

Another electroweak test attracting renewed interest is the unitarity of the quark-mixing (CKM) matrix, especially regarding light quarks (its first row). The most precisely known element is $|V_{ud}|$ extracted from superallowed nuclear beta decays. However, justifying and improving the current nominal precision of about 3×10^{-4} (dominated by nuclear structure effects) demands precisely knowing charge radii across the superallowed nuclear isotriplet assuming isospin symmetry and quantifying breaking thereof. Measurements at GSI/FAIR, PSI, ISOLDE, FRIB, TRIUMF and other facilities will be in a position to provide this information. Another uncertainty is introduced by the γW box contribution related to the γZ box by isospin symmetry, showcasing subtle correlations amongst a priori unrelated electroweak measurements. MESA will furthermore allow one to access the neutron radii of stable superallowed daughter nuclei. Joined with the charge radii, will allow a test of our understanding of isospin symmetry breaking on a quantitative level.

1. Connection to Transnational Access infrastructures (TAs) and / or Virtual Access projects (VAs)

While this is a theory (phenomenology) proposal, this project will be crucial to provide a rigorous framework for the interpretation of experimental data (both within the SM and beyond) of the currently planned measurements, but will also help shape the future physics programs at facilities such as GSI/FAIR and LHC@CERN, as well as in particular P2@MESA and MOLLER@JLab.

3. Estimated budget request

245,000 € for a Ph. D. student for a time period of 4 years at 75% of 81,600 € annually (according to the DFG personnel rates table for 2025).

Travel budget: 5,000 € per year for a total of **20,000 €**.

4. Participating and partner institutions

JGU Mainz, Germany

University of Freiburg, Germany

ETH Zürich, Switzerland

Paul Scherrer Institute, Switzerland

University of Pittsburgh, PA, USA

University of Tennessee at Knoxville, TN, USA

University of Alberta, AB, Canada