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τSPECT- towards a new measurement of the free neutron lifetime in a full-3D magnetic trap

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Neutron physics can provide cornerstone ingredients for a high-precision test of the Cabibbo-Kobayashi-Maskawa (CKM) matrix unitarity without nuclear structure corrections. The matrix element Vud is extracted from the combination of a high-accuracy determination of λ, the ratio of axial-vector and vector coupling strength of the weak interaction, a commensurate theoretical description of neutron beta decay, and a high accuracy determination of τn. In a first step, τSPECT aims to determine τn with an uncertainty of < 0.3 s to illuminate the neutron lifetime puzzle, a significant disagreement of τn measurements using complementary methods. The τSPECT experiment confines ultracold neutrons (UCNs) in a full 3D magnetic gradient field trap. We have operated the instrument at the UCN source of the Paul Scherrer Institute since 2023. After filling and holding UCNs for hundreds of seconds in the trap, τSPECT counts the surviving UCNs and extracts τn from the storage curve. Quasi-trapped
UCNs could leave the trap on the timescale of τn, and a strict control of these marginally trapped UCNs is required to avoid a bias towards a low value of τn. In 2023, τSPECT was transferred from JGU Mainz to PSI and reassembled. In 2024, τSPECT has performed a first blinded science data run with an anticipated statistical precision of 1 s on τn. The most important systematic bias effects could be investigated for the first time with high statistics, and dedicated background studies were performed. We will present the current instrument's performance, selected aspects of the ongoing data analysis, and near-term performance upgrade opportunities. The τSPECT setup provides an indispensable test bed for future full-magnetic trap setups featuring larger volume and deeper trapping potential.

Author: Prof. FERTL, Martin (Johannes Gutenberg University Mainz)

Presenter: Prof. FERTL, Martin (Johannes Gutenberg University Mainz)

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