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A Quantum Computational Determination of the Weak Mixing Angle in the Standard Model

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The weak mixing angle s_W is a fundamental constant in the Standard Model (SM) and measured at the Z boson mass to be $\widehat{s}^2_W(m_Z) = 0.23129 \pm 0.00004$ in the $\overline{\text{MS}}$ renormalization scheme, where $m_Z = 91.2$ GeV. On the other hand, non-stabilizerness - the magic - characterizes the computational advantage of a quantum system over classical computers. We consider the production of magic from stabilizer initial states, which carry zero magic, in the 2-to-2 scattering of charged leptons in the SM at the tree level, which is mediated by the photon and the Z boson. Using the second order stabilizer Rényi entropy, and averaging over all 60 initial stabilizer states and the scattering angle, we compute and minimize the magic production as a function of s^2_W in the Møller scattering $e^-e^- \to e^-e^-$, which is free of kinematic thresholds. At the centre-of-mass energy $\sqrt{s} = m_Z$, there is a unique minimum in magic production at $\mathbf{s}^2_W(m_Z) = 0.2317$, which agrees with the measured $\widehat{s}^2_W(m_Z)$ at the sub-percent level. At higher energies, the magic-minimizing $\mathbf{s}^2_W$ continues to agree with the empirical value at the percent level or better, up to 10 TeV. The finding suggests the electroweak sector of the SM tends to generate minimal quantum resources from the computational viewpoint.

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