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Probing Subatomic Matter with Polarized Electrons: MeV to TeV Physics

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The study of weak neutral current (WNC) interactions, mediated by the Z^0 boson, plays a central role in tests of the electroweak and strong interactions. In fixed target electron scattering, the WNC amplitude can be isolated by measuring the fractional difference in the scattering rate for incident right- and left-handed longitudinally polarized relativistic electrons on unpolarized nuclear targets. A non-zero asymmetry, a signature of violation of parity symmetry, is dominated by the ratio of the WNC amplitude to the electromagnetic amplitude. Depending on the length scale being probed in specific reactions, asymmetries range from 100 parts per million (ppm) to as small as 0.1 ppm. Over the past 3 decades, the technology for measuring such small asymmetries has steadily improved, making it feasible to address a variety of fundamental questions in nuclear and particle physics. With judicious choice of kinematics and targets, various experiments have been designed to probe the role of virtual strange quarks in the nucleons's charge and magnetization distributions, to obtain a measure of the ground-state neutron distribution of a heavy, spinless nucleus and to test the gauge structure of the WNC interaction itself, in a manner complementary to high energy collider experiments. After a brief historical overview, new results in parity-violating electron scattering from experiments at the Stanford Linear Accelerator Center and the Thomas Jefferson National Accelerator Facility and their implications will be presented. The potential impact of ongoing experiments will be reviewed and new ideas for future accelerator facilities will be discussed.