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Search for new gravity-like short range interactions in the submicron range by means of neutron-nanoparticle scattering

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In modern physics, four fundamental interactions—electromagnetic, strong, weak, and gravitational—are being studied under a unified framework known as the Theory of Everything. Among them, gravity is significantly weaker than the others, which has been known as the hierarchy problem. One proposed solution is the Large Extra Dimension (LED) model, which suggests that additional spatial dimensions exist beyond our familiar three. Graviton can propagate through these extra dimensions, but in our observable 3D space, it manifests itself as a Yukawa-type interaction. This leads to possible deviations from Newtonian gravity at short distances, which can be experimentally probed. To search for such deviations, experiments have been carried out at the laboratory level using torsion balances and cantilevers, or limits on the unknown force have been obtained by reanalyzing the results of existing experiments, such as the Casimir force measurement experiment. In our study, we focus on small-angle neutron scattering (SANS) as a tool for investigating deviations in the submicron scale. SANS measures the momentum transfer distribution, which is the Fourier transform of the scattering potential. When a Yukawa potential is added to the nuclear potential, a characteristic momentum transfer distribution emerges. Since the Yukawa interaction of the present interest is a gravity-like one, its strength is proportional to the target mass. In addition, the scattering intensity is enhanced in the case of coherent scattering by many particles contained in a volume corresponding to the momentum transfer in the scattering. Since this enhancement is useful to improve the sensitivity of the measurement, we conducted SANS experiments using nanoparticles, whose sizes are well-suited to probe interactions in submicron scales. In the case of coherent scattering, the background due to nuclear scattering is also enhanced. To suppress nuclear scattering, the nanoparticle target had to be made with an element with small coherent scattering length such as vanadium. Recently, we have succeeded in producing real nanopowder made of vanadium for the first time, and using it as the target, a SANS measurement was carried out at the J-PARC spallation neutron facility. In addition, we are working on the development of hydrogenabsorbing vanadium nanoparticles to further reduce nuclear force scattering. This presentation will explain the theoretical background, experimental methods, target development, and results of our neutron scattering experiments, as well as discuss future directions for probing short-range modifications to gravity.

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