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Modeling the Neutron Whispering Gallery to Search for New Short Range Forces

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New short-range forces (SRF) are predicted in many theories beyond the Standard Model of particle physics in the form of weakly interacting scalar or pseudo-scalar bosons. For example, dark matter could be explained by the existence of a weakly interacting boson, and some theories with extra spatial dimensions predict such a particle. Neutrons are useful tools in searches for these SRFs due to their neutrality and small electric polarizability. These properties minimize false effects in experimental searches for new interactions. Precision studies of the neutron whispering gallery effect, or the confinement of neutron matter waves along a smooth curved surface, is a particularly promising method to search for these new forces.

By sending a cold neutron beam with a grazing incidence angle into a cylindrical cut of a MgF2 single crystal, intricate interference patterns have been observed during recent experiments at the Institut Laue Langevin. If new SRFs exist and interact with the neutrons in the whispering gallery through the nuclei in the crystal, these interference patterns will be perturbed. To look for those perturbations in the latest measurements, and to constrain SRF models, a theoretical model was developed to describe the observed interference patterns as a superposition of quasi-stationary states in a finite potential well. The potential well is formed by the optical potential of the crystal and the centrifugal force experienced while propagating along the surface of the cylinder. To incorporate the effects of the roughness of the mirror and the SRFs on the quasi-stationary states and their energies, logarithmic perturbation theory was used. A description of this model will be presented as well as the first analysis of the most recent experimental campaign.

Primary author: PIOQUINTO, Jason (University of Virginia; Institut Max von Laue Paul Langevin)

Co-authors: Prof. BAESSLER, Stefan (University of Virginia); Dr CLADÉ, Pierre (Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Université, Collège de France); Prof. NESVIZHEVSKY, Valery (Institut Laue Langevin); Prof. REYNAUD, Serge (Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Université, Collège de France); Ms SCHREINER, Katharina (Institut Max von Laue - Paul Langevin; Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Université, Collège de France, Paris; University of Vienna, Vienna Doctoral School in Physics); Mr SHI, Mingyu (Institute for Quantum Electronics, Eidgenössische Technische Hochschule (ETH) Zürich); Dr VORONIN, Alexei (P.N. Lebedev Physical Institute); Mr ZHAO, Anran (University of Virginia)

Presenter: PIOQUINTO, Jason (University of Virginia; Institut Max von Laue Paul Langevin)

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