STUDY OF DARK PHOTONS IN PROTON-NUCLEUS SCATTERING

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New investigations in the study of dark photons emitted in the process of scattering of protons on nuclei will be reported in the talk. Dark photons — hypothetical gauge bosons associated with a hidden U(1) symmetry — represent one of the most actively discussed candidates for mediators of dark matter interactions with the Standard Model sector. Their experimental detection remains a fundamental challenge of modern nuclear and particle physics, motivating the development of new theoretical frameworks capable of predicting observable cross sections and angular distributions. According to the theoretical model proposed in Ref. [1], it is supposed that such photons can be emitted via an intermediate channel of production of charged pions in proton-nucleus reactions. These pions subsequently undergo decay with the emission of dark photons, providing a potentially measurable signal in a kinematic region that is experimentally accessible at existing and planned accelerator facilities. The coupling constant of dark photons to ordinary photons (kinetic mixing parameter ε) governs the production rate and is constrained by existing data from beam-dump and collider experiments. To investigate this phenomenon, a new microscopic model has been developed, which is based on previous investigations and the formalism established in Refs. [2, 3]. The model incorporates a quantum-mechanical description of the proton-nucleus scattering process, a realistic treatment of pion production within the nuclear medium, and a subsequent calculation of the dark photon yield from pion decay. Special attention is paid to the role of nuclear structure effects and Coulomb distortions in the entrance channel, both of which can significantly modify the predicted spectra. The theoretical formalism adopted in the present work treats the proton-nucleus interaction within the optical model framework, employing a complex optical potential that accounts for both elastic and inelastic channels. Pion production is described using an effective Lagrangian approach that captures the dominant Δ(1232)-resonance mechanism, which is known to be the primary source of pion yield at beam energies in the range of several hundred MeV to a few GeV. The subsequent dark photon yield from charged pion decay ($\pi^\pm \to e^\pm \nu_e A$) is evaluated by integrating over the pion phase space weighted by the appropriate branching ratio as a function of the kinetic mixing parameter ε. The resulting dark photon differential spectra are obtained as a function of energy and emission angle, providing direct input for the design of detection strategies at existing fixed-target facilities.

The approach developed here is conceptually related to, yet methodologically distinct from, existing calculations of ordinary bremsstrahlung emission in proton-nucleus collisions studied in Refs. [2, 3], where the electromagnetic field of the decelerating proton directly produces photons in the nuclear Coulomb field. The present pion-mediated channel offers a sensitivity to the dark sector that is complementary to direct bremsstrahlung searches, since it probes a different kinematic region and is governed by a distinct production mechanism with its own set of nuclear-structure dependencies. Estimates of the expected signal rates suggest that, for values of the mixing parameter ε in the range 10^{-4}–10^{-3}, the dark photon yield per proton-on-target at beam energies of 1–2 GeV is potentially large enough to be distinguished from the Standard Model background with modest detector requirements, making this channel practically accessible at proton accelerators operated for nuclear physics research purposes.

In the report, a short review of the current status of this topic will be presented, including a discussion of the most relevant experimental constraints and theoretical predictions available in the literature. The model for study of this phenomenon will be described in detail, with numerical estimations of the dark photon production cross sections and their dependence on beam energy and nuclear target. Comparisons with existing bremsstrahlung calculations and prospects for experimental verification at future facilities will also be discussed. The results indicate that proton-nucleus scattering may provide a competitive complementary channel for dark photon searches at intermediate energies.

1. D. Curtin, Y. Kahn, R. Nguyen. Phys. Rev. D 108 (2023) 095039.
2. S.P. Maydanyuk et al. Microscopic study of nuclei synthesis in pycnonuclear reaction $^{12}C+^{12}C$ in neutron stars 2025. arXiv: 2510.05726 [nucl-th].
3. S.P. Maydanyuk, V.S. Vasilevsky. Systematic study of bremsstrahlung emission in reactions with light nuclei in cluster models 2023. arXiv: 2304.04082. Phys. Rev. C 108 (2023) 064001.