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Producing high brilliance gamma rays via Compton scattering in flying focus regime

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Some of the highest-energy photon beams produced experimentally rely on a fundamental quantum electrodynamics process: nonlinear Compton scattering between laser photons and ultra-relativistic electrons. We discuss how the energy lost by electrons and the yield of emitted photons in this process can be substantially increased by replacing a stationary-focus laser pulse with an equal-energy flying-focus pulse. The moving focal point of a flying focus forms an intensity peak that can travel at any velocity, independent of the laser group velocity, over distances much longer than a Rayleigh range [1]. This enables co-propagation of ultra-relativistic particles with the laser focus, so that they stay in the region of peak field intensity for prolonged interaction times [2,3]. The advantages of the flying focus are a result of operating in the quantum regime of the interaction, where the energy loss and photon yield scale more favorably with the interaction time than the laser intensity. Analytic estimates and simulations show that GeV-scale electrons colliding with 1-10 J laser pulses can increase up to five times the yield of 1-20 MeV photons using a flying focus pulse, laying the foundation for producing the brightest laboratory gamma source in this energy range [4].

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[4] M. S. Formanek, J.P. Palastro, D. Ramsey, A. Di Piazza, arXiv:2501.08183

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