Searching for New Particles Beyond the Standard Model by Proton Bremsstrahlung

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1. Theoretical Motivation

Many proposals for new physics beyond the Standard Model (BSM) predict novel, weakly interacting, light scalar or vector particles. Classical examples of such particles include Majorons, axions, Kaluza- Klein modes in the Randall-Sundrum scenarios with extra dimensions and many others. As discussed over the years, novel light particles could be responsible, among other things, for solving the strong CP problem in QCD, giving neutrino its mass, or even explaining the origin of Dark Energy. These new particles can be produced by proton bremsstrahlung and detected by particle decay or scatter in the center of neutrino detectors, assuming that the proton beam is on-axis.

2. Estimated Signal Rates

The model of Nelson and Walsh (Ann E. Nelson and Jonathan Walsh, arXiv:0711.1363) is used to demonstrate the sensitivity of neutrino detectors to new light gauge vector bosons. Nelson and Walsh introduce a new light gauge vector boson ("paraphoton") that is consistent with existing experiments. The paraphoton has a mass of ~ 10 keV, a lifetime of ~ 2.5 ns, and a coupling strength of $g^2/e^2 \sim 10^{-9}$. Such a paraphoton would be produced in the target in the forward direction (< 5 mrad) by hadronic bremsstrahlung of the incident proton beam ($\sim 1\% \times 10^{-9}$) followed by the electromagnetic conversion of the paraphoton in the neutrino detector (total number of radiation lengths, N, times 10^{-9}). Note that the paraphoton would experience hardly any attenuation due to either decay or conversion over the travel distance to the detector. Assuming a reconstruction efficiency of 50%, the number of paraphoton events in the forward direction ($\cos\theta > 0.99$) per 10^{21} POT is approximately equal to

$$(10^{21})(1\%)(10^{-9})(N)(10^{-9})(50\%).$$

Therefore, neutrino detectors should be able to confirm or rule out the model of Nelson and Walsh. Also, new weakly interacting particles could decay in the neutrino detector or contribute to the elastic scattering cross section off electrons. These reactions are also characterized by very forward reconstructed recoil electrons or gammas with $\cos\theta > 0.99$.