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Wave-Packet Treatment for Detection of Accelerator Neutrinos

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Neutrinos are treated as point particles in Monte Carlo simulations for predicting detector counting rate. In this talk, a theoretical study on possible conflict between point-particle and wave-packet pictures in accelerator neutrino experiments will be presented. It is a quantum-mechanical phenomenon that neutrino wave packets spread as they propagate in space. The effect of longitudinal spreading on neutrino oscillation probabilities has been studied in various theoretical frameworks. However, comparatively less attention has been paid to the implication of transverse spreading of neutrino wave packets. In accelerator neutrino experiments, Lorentz boost restricts neutrinos from spreading in the forward direction, while the transverse spreading tends to "defocus" neutrinos from their classical paths. As a consequence, the transverse spreading smears the kinematic distribution of neutrinos from pion decay and could distort the measured neutrino energy spectrum. Our approach treats neutrinos as wave packets, for which the detector counting rate is derived using simple quantum-mechanical treatment. Considering the geometric setup and beam profile similar to the MINOS and NOvA experiments, we demonstrate that the transverse spreading of neutrino wave packets would result in a shifted energy spectrum from that predicted in point particle scenario if the wave packet acquires an initial transverse width less than approximately 10 fm from pion decay. Absence of such spectral shift in current or future near detector data could in turn constrain the initial transverse width of a neutrino wave packet from pion decay.

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