Contribution ID: **126** Type: **Oral**

Uniform beam simulation technique for NuMI beam scans and ML studies at Fermilab

Tuesday 22 August 2023 14:40 (20 minutes)

Fermilab's neutrino facilities, including NuMI and the upcoming LBNF, use proton beams to produce positively and negatively charged pions and kaons. Detailed simulations are necessary to study particle interactions and beam propagation. To efficiently analyze beam scan effects, we propose a method for generating multiple simulation samples with high statistics. By simulating a single sample with a uniform distribution for each beam parameter, simulation time and computing resources can be significantly reduced. We calculate Gaussian weights and apply them to post-processing measurements. The alignment of the primary proton beam, target, and focusing horn has a significant impact on the neutrino energy spectrum, and changes in beam parameters can be estimated by scanning the proton beam across the target. Muon monitors detect and respond to these changes, and comparing beam scan data with simulations establishes a correlation between the two. This combined approach also offers valuable beam diagnostics. Our simulation technique allows users to generate as many random beam simulations as needed for beam scan studies and can be applied to a wide range of machine learning algorithms.

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Session Classification: parallel (room#103)

Track Classification: WG3: Accelerator Physics