Contribution ID: **486** Type: **Parallel**

Hadron Production Measurements for Neutrino Oscillation Experiments with NA61/SHINE

Friday, 6 July 2018 09:30 (15 minutes)

The uncertainty in the flux of neutrino beams is dominated by our understanding of both the primary interactions of protons and the secondary interactions of protons, kaons and pions with target and beamline material. Hadron production measurements from a comprehensive set of interactions will allow modern neutrino experiments to make more precise neutrino cross section and oscillation measurements. Measurements of charged hadron spectra and total cross sections have recently been obtained by NA61/SHINE, a fixed target experiment at the CERN SPS, for a variety of beam particles, beam momenta and target materials. From the 2010 dataset of 31 GeV/c protons interacting with a T2K replica target, multiplicities of π^+, π^-, K^+, K^- and protons have been obtained. These measurements supplement the results from the 2009 thin target measurements, which have been used to constrain the T2K neutrino flux prediction. The application of the replica target results is ongoing and is expected to further reduce the uncertainties in the flux prediction. Starting in 2015 and continuing through 2018, NA61/SHINE has been recording interactions relevant to the neutrino beams at NuMI and LBNF located at FNAL. These beams are used by the ongoing experiments NOνA and MINERνA and the future experiment DUNE. In 2015, total inelastic and production cross section measurements have been obtained from interactions of K^+ at 60 GeV/c and π^+ at 31 and 60 GeV/c with carbon and aluminum targets. In 2016 and 2017, NA61/SHINE recorded interactions of π^+, π^- and protons with momenta ranging from 31 to 120 GeV/c with carbon, aluminum and beryllium targets. The first of these interactions to be analyzed is 60 GeV/c π^+ with thin carbon and beryllium targets, where multiplicities of π^+, π^-, K^+, K^- and protons are being measured. In the summer of 2018, NA61/SHINE will resume data taking including interactions of 60 GeV/c K^+ with carbon and 120 GeV/c protons on a NOνA replica target.

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Session Classification: Neutrino Physics

Track Classification: Neutrino Physics