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# Hadron Production Measurements for Long-Baseline Neutrino Experiments with NA61/SHINE

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A precise prediction of the neutrino flux is a key ingredient for achieving the physics goals of long-baseline neutrino experiments. In modern accelerator-based neutrino experiments, neutrino beams are created from the decays of secondary hadrons produced in hadron-nucleus interactions. Hadron production is the leading systematic uncertainty source on the neutrino flux prediction; therefore, its precise measurement is essential.

The NA61/SPS Heavy Ion and Neutrino Experiment (NA61/SHINE) is a fixed-target experiment at the CERN Super Proton Synchrotron, which studies hadron production in hadron-nucleus and nucleus-nucleus collisions for various physics goals. For neutrino physics, light hadron beams (protons, pions, and kaons) are collided with a light nuclear target (carbon, aluminum, and beryllium) and spectra of outgoing hadrons are measured.

This talk will review the recent results and ongoing hadron production measurements in NA61/SHINE for the precise neutrino flux predictions in the T2K and Fermilab long-baseline neutrino experiments. For the T2K experiment, the interactions of 31 GeV/$c$ proton beams on a thin carbon or a replica of the T2K 90 cm-long carbon target were measured and these measurements have significantly reduced T2K's neutrino flux uncertainty. For the Fermilab long-baseline neutrino beamlines (NuMI and LBNF), measurements are currently ongoing for 60–120 GeV proton, pion, and kaon beams on various nuclear targets. This talk will also discuss the prospects for future hadron production measurements with NA61/SHINE beyond 2020, after the Long Shutdown 2 of the accelerator complex at CERN.

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