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An Updated Simulation of the Booster Neutrino Beam

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The Booster Neutrino Beam

The Booster Neutrino Beam (BNB) supplies neutrinos to many experiments at FNAL, including the Short Baseline Neutrino (SBN) program. The neutrino flux predictions for the BNB were originally calculated for MiniBooNE [1], and subsequent experiments have rescaled these original predictions. For the SBN program, a new simulation of the BNB (G4BNB) has been created. This poster gives an overview of the status of this new simulation.

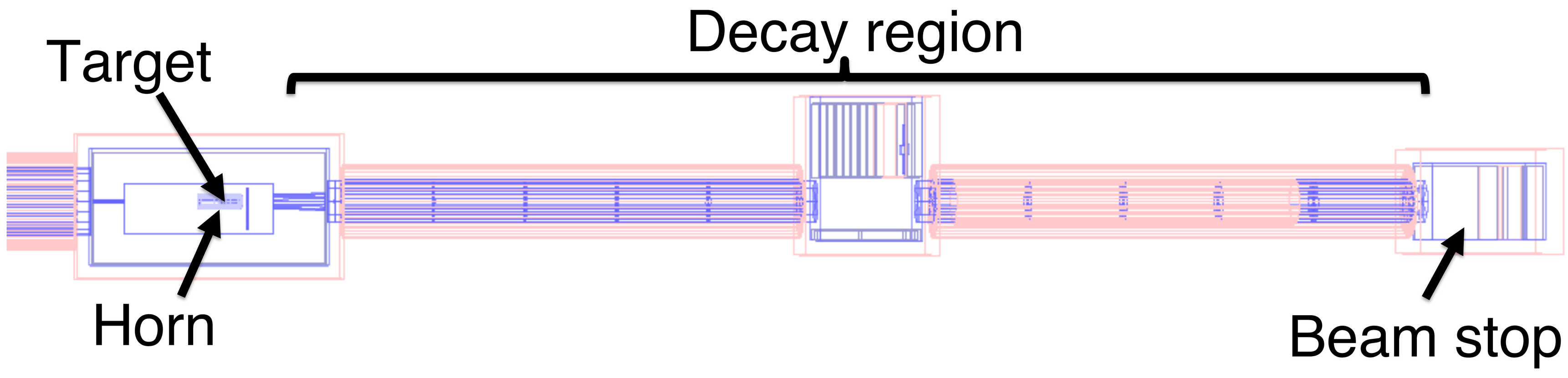

Fig. 1: The geometry in the G4BNB simulation

The geometry of the G4BNB simulation was imported from the original MiniBooNE simulation, and includes a Beryllium target, focusing horn, decay region and beam stop. In order to ensure the accuracy of this modelling, a survey of the BNB site is planned for the 2024-25 beam shut down.

Physics Simulation

The BNB is supplied with 8 GeV protons from the Booster accelerator. The products of the initial pBe scatter are created using the same model as the MiniBooNE simulation, and their energy spectra can be seen below.

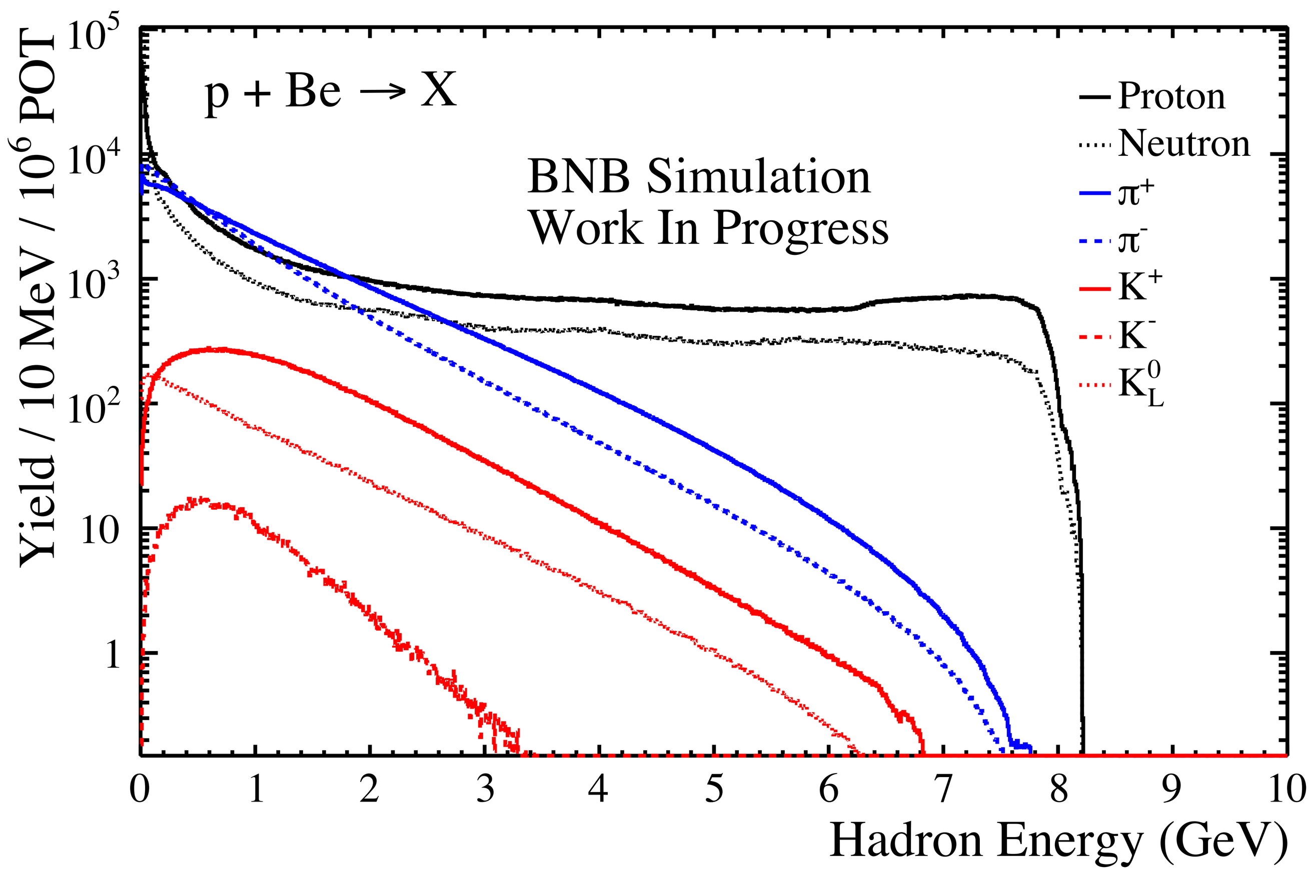

Fig. 2: Energy spectra of the initial products of the pBe scatter

The GEANT4 version used to propagate these particles has been updated from v4.8.1 to v4.10.4. This allows G4BNB to be run on current machines, where the original simulation is no longer supported, so can be used to validate systematic uncertainties on the flux prediction. Updated kaon decay parameters from SciBooNE [2,3] are also included. Additionally, the ability to save the entire hadron ancestry of neutrinos has been added, improving studies of systematics and BSM processes.

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Predicted Flux

The predicted flux of G4BNB at SBND is presented below. In order to compare to the previous simulation, the MiniBooNE flux predictions were rescaled to the size and distance of SBND. The updated kaon decay parameters [2,3] have also been added as weightings to both.

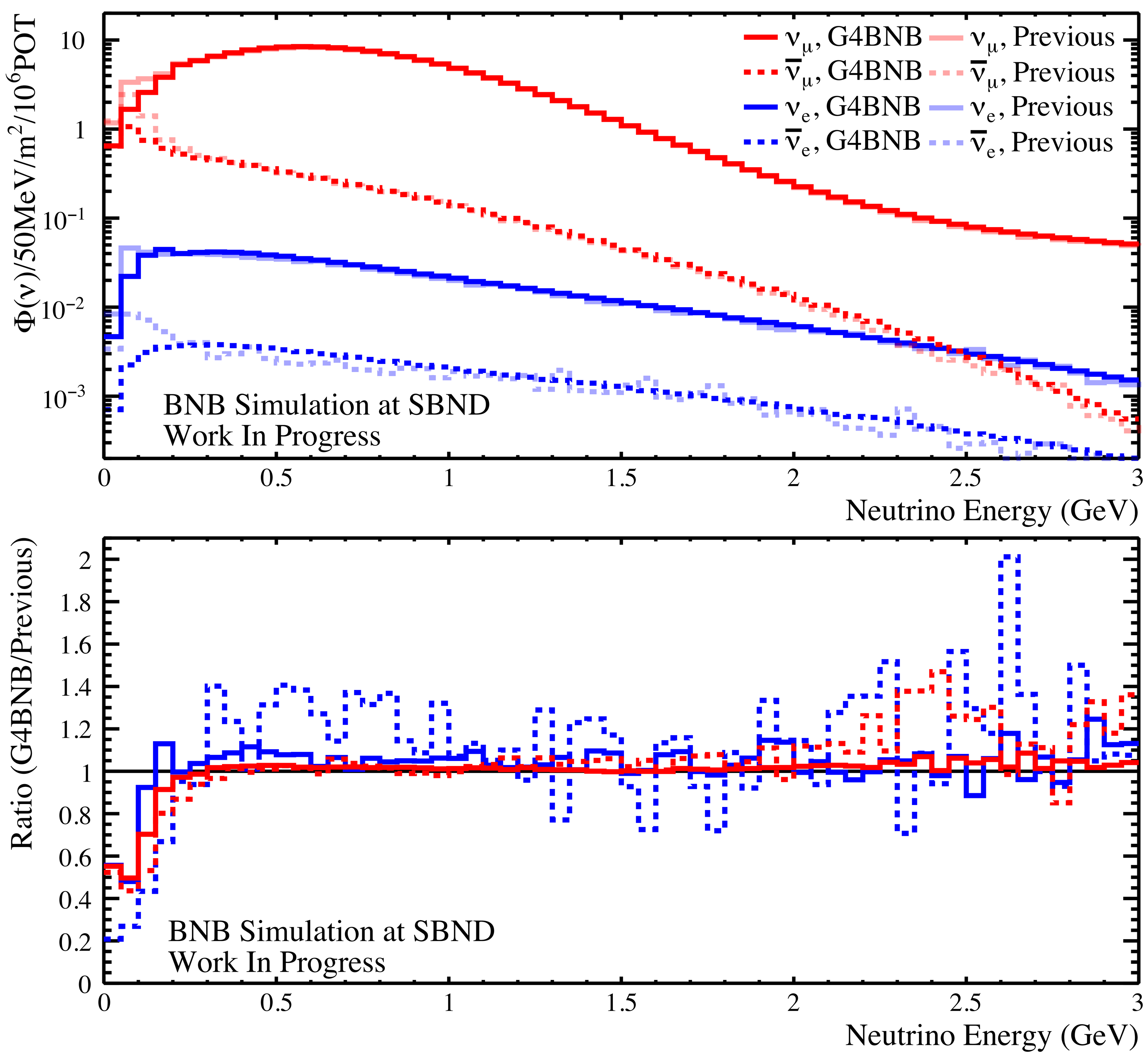

Fig. 3: Comparison of the G4BNB simulation flux predictions at SBND to a rescaled version of the original MiniBooNE simulation (including the updated kaon parameters).

It can be seen for energies > 0.3 GeV, the predictions match well for each neutrino type. For $\bar{\nu}_e$, the differences between the predictions are dominated by the statistical uncertainties of the original simulation. However, at energies < 0.2 GeV, there is a notable deficit in the G4BNB predicted flux for all neutrino types. The original simulation had large uncertainties in this range, but the systematic methods will be revisited for G4BNB. This prediction will be important for studies at SBND which plans to probe into low energies but does not affect the published low energy result from MiniBooNE [4], which presents energies > 0.2 GeV.

Further work on G4BNB is planned before publication of a final flux prediction. This includes finalization of GEANT4 version based on comparison to available scattering data, the use of dedicated, extant data from EMPHATIC to constrain the flux, investigation of systematic uncertainties, and addition of neutral mesons for BSM studies.

[1] A. A. Aguilar-Arevalo *et al.* (MiniBooNE Collaboration), Neutrino flux prediction at MiniBooNE, Phys. Rev. D **79**, 072002 (2009)

[2] C. Mariani, G. Cheng, J. M. Conrad, and M. H. Shaevitz, Improved parametrization of K^+ production in p–Be collisions at low energy using Feynman scaling, Phys. Rev. D **84**, 114021 (2011)

[3] G. Cheng et al. (SciBooNE Collaboration), Measurement of K^+ production cross section by 8 GeV protons using high-energy neutrino interactions in the SciBooNE detector, Phys. Rev. D **84**, 012009 (2011)

[4] A. A. et al. (MiniBooNE Collaboration), Significant Excess of Electronlike Events in the MiniBooNE Short-Baseline Neutrino Experiment, Phys. Rev. Lett. **121**, 221801 (2018)