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Hadroproduction measurements for simulations of new neutrino beams

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Precise hadroproduction data are needed to shape the primary meson production in targets for neutrino beamline calculations and tune available MonteCarlo codes. Hadroproduction data parametrizations will be described. Fast simulations of neutrino beamlines, based on such parametrizations, may be developed and will be briefly discussed.

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For the simulation of ν beams an important ingredient is the availability of good quality hadroproduction data. Parametrizations of the available hadroproduction data have been presented in the literature at low-energy ($p_{inc} \leq 30$ GeV/c), as the Sanford-Wang (SW) parametrization [1] and at high-energy, as the Atherton et al. [2], Malensek [3] and BMPT [4] parametrizations. One goal is to adopt a simple functional form appropriate for extrapolation to different center of mass energies, secondary particle momenta and targets. These parametrizations are based mainly on dedicated hadroproduction experiments, such as NA56/SPY [5], NA20 [2] and the running NA61/SHINE[7] experiment at high/medium energies or the HARP/PS214 [8] and E910 [11] experiments at low energies. They describe π/k forward production and are useful for the fast parametrizations of conventional ν beams or the future ν superbeams, such the one at JPARC [9].

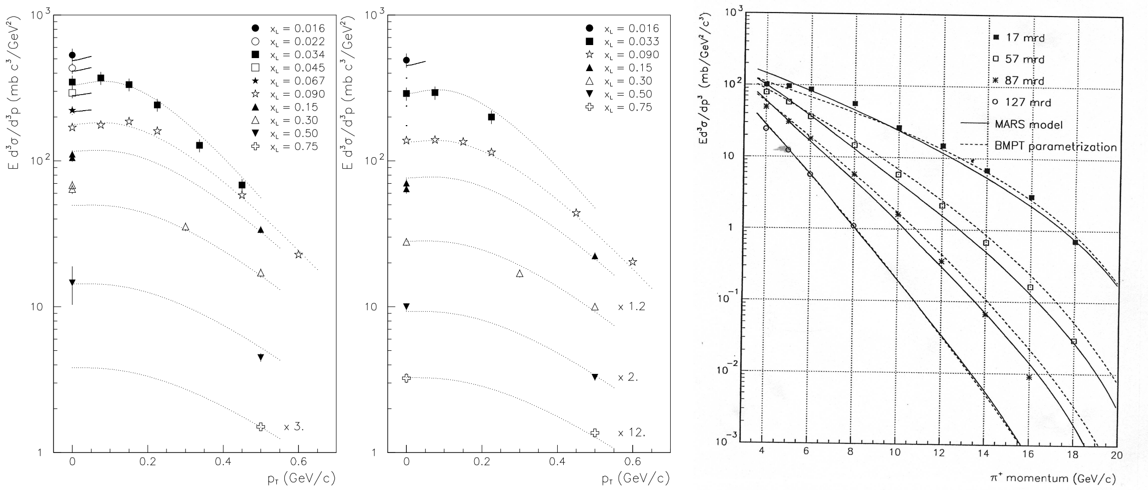

Figure 1: Left panel: BMPT parametrization, superimposed to NA56/SPY and NA20 data, for π^+ (left) and π^- (right) in p-Be interactions. Right panel: comparison of the BMT parametrization and the MARS pion production model [10] with Eichten et al. π^+ data at 24 GeV/c [12].

A comparison of the BMPT parameterization, which is fully described in reference [4], with available high energy or low energy data is shown in figure 1. The proposed empirical formulae are adequate to describe data from about 400 GeV/c down to 30 GeV/c incident beam momentum with an accuracy going from $\sim 10\%$ at high energy to $\sim 30\%$ at low energy.

At lower energies - below 30 GeV/c- the SW parametrization is commonly used [1]. The original parametrization, based on 10.9 GeV/c data, is shown in the left panel of figure 2. An example of SW parametrization, as obtained from HARP Be data and used for the study of the MiniBooNE beamline, is shown instead in the middle panel of the same figure.

The simulation of a conventional ν_μ beam is a delicate task due to complicate cascade processes involved in the neutrino production, from the meson production at the main target, and the secondary particle reinteractions along the beamline materials. Fast simulation programs parameterize ν production in terms of hadronic cross sections in the target, make a simplified description of the beamline elements and produce weighted events. In order to give a more quantitative appreciation of the accuracy that one can obtain in fast simulations of neutrino beams, the right panel of

[1]this parametrization is just an empirical description of the experimental data and is not based on a physical approach, such as the BMPT parametrization.

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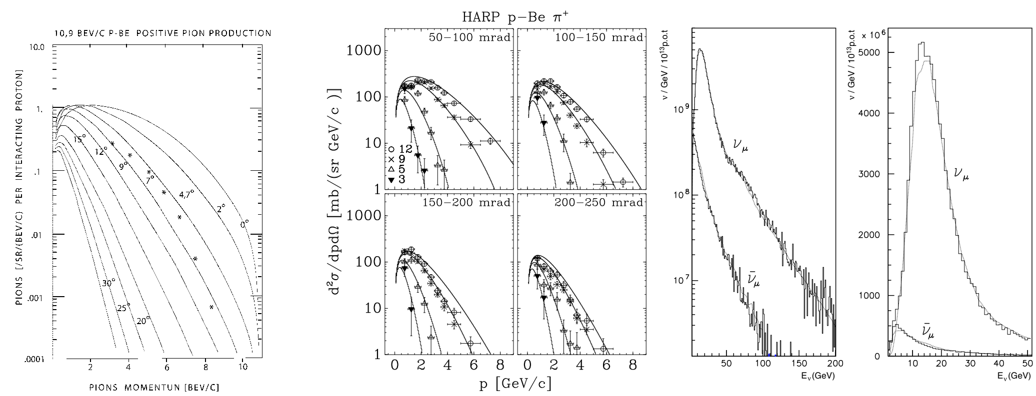

Figure 2: Left panel: original SW parametrization of π^+ production in p-Be interactions at 10.9 GeV/c. Middle panel: SW parametrizations for π^+ production in p-Be interactions at 8.9 GeV/c in the HARP experiment. Right panel: the WANF neutrino fluxes at the CHARM2 detector: the continuos lines are the experimental data from reference [13], the histogram the fast beam simulation from reference [4].

figure 2 shows the comparison between the CHARM II data and the fast simulation from reference [4]. The overall agreement is at the percent level, with at most 10% disagreement on a bin per bin basis. This fast simulation has found application in the study of long baseline ν beams, such as the optimization of the CNGS and NuMI [14] beams, where the limited MonteCarlo statistics may be a limit, due to the small solid angle subtended by the far detectors.

As a conclusion, fast simulation programs may be of limited use for a full appreciation of all neutrino beam systematics, due to the approximations involved, but are extremely helpful in their optimization phase. For these studies hadroproduction data and their parametrizations are an essential ingredient.

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