Pion Production in Wroclaw Neutrino Event Generator and its Comparison with Other Generators

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The problem of pion neutrinoproduction off nuclear targets and its implementation in modern Monte Carlo generators is discussed. Basics of physical models used in NuWro, GENIE, GiBUU and NEUT are outlined. Some of the most important uncertainties behind the pion production process are reviewed. experimental uncertainties connected to pion production are discussed.

KEYWORDS: Neutrino, nucleus, pion, Monte Carlo

1. Introduction

From the point of view of accelerator neutrino oscillation experiments, such as MiniBooNE, MINERvA, T2K, Nova, Hyper-Kamiokande or LBNF, pion production process is very important. It comprises about 30% of the total ν_μ charged-current (CC) scattering cross section off an atomic nucleus for beam energy around ~1 GeV.

Pion production process gives rise to backgrounds for other exclusive reaction channel measurements if the pion remains undetected. This may happen both due to detector limitations as well as the pion absorption inside atomic nuclei. One example is the neutral current (NC) π^0 production with subsequent decay of pion into two photons, which can be misidentified with ν_eCC interaction. Another commonly met problem arising due to undetected pions is the background of charged current quasielastic (CCQE) scattering measurements. In all of these cases one needs to rely upon the Monte Carlo (MC) tools in order to separate and control effects related to pions.

From the four generators mentioned in the abstract only GENIE [1] and NEUT [2] are used in the official experimental analysis. The remaining two, NuWro [3] and GiBUU [4], are tools both for development as well as testing of new physical models in MC generators.

Pions can be produced both in initial neutrino scattering vertex and during inelastic re-scattering of outgoing hadrons (through final state interactions- FSI). In MC nomenclature one applies a simplified classification of interaction processes and the exact definition of underlying physics may vary from generator to generator. Starting from the lowest energy transfer pions can be produced through the CC and NC coherent neutrino-nucleus scattering (abbreviated by COH), where the target nucleus remains in its ground state absorbing only a little momentum transfer. An increase in tranferred energy may lead to the resonant process (abbreviated by RES), where a series of nucleon resonances (starting from $\Delta(1232)$) is excited. They decay then into meson and baryon systems. Finally one reaches the region of deep inelastic scattering (DIS), which includes all processes more inelastic from RES, part of them contributing to pion production.

For most of the mentioned interaction channels there is no unique theoretical description. Here the RES process is chosen to be the main example. In MC generators resonant pion production is either based upon the Rein-Sehgal paper [5] (continuation of the earlier quark Feynman-Kislinger-Ravndal model [6]) or on a variety of isobar models (see *e. g.* [7]). Another group of more sophisticated models