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Absolute determination of Λ_c and D_s branching ratios

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Abstract

In this paper we focus on two aspects of charm production in neutrino interactions: low-multiplicity processes such as the diffractive D_s and the quasi-elastic charmed-baryon production. We shall show that these processes allow a clear identification of the charmed hadron, and therefore a very good estimate of absolute decay branching ratios. Together with low systematic errors, these measurements can provide, for instance, a precise measurement of f_{D_s}.

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Keywords: Neutrino; Charm production; Absolute branching ratios

1. Introduction

As it has been pointed out elsewhere (see Ref. [1] and references therein), the ν-Factory can be seen as a charm factory. Here we focus on two aspects of charm production in neutrino interactions: low-multiplicity processes such as the diffractive D_s and the quasi-elastic charmed-baryon production.

In the following, we consider nuclear emulsions both as neutrino target and tracking device. It is worth stressing that the use of nuclear emulsions is limited by the overlapping of interactions. A density of interactions of about $20/\text{cm}^3$ is reasonable. On the other hand, $10^7 \nu_\mu$ interactions are needed for the measurements we will discuss in the following. Such a statistics could be obtained by running the machine at low luminosity and taking data for a few years (months) whether the experiment is located far from ($\mathcal{O}$(1 km)) or close to ($\mathcal{O}$(100 m)) the neutrino source.

2. Direct evaluation of the Λ_c^+ branching ratios

2.1. Model-independent extraction of $BR(\Lambda_c^+ \to pK^-\pi^+)$

So far, only model-dependent extractions of Λ_c^+ branching ratios have been obtained, see Ref. [2]. They rely on different theoretical assumptions on B physics, namely the B branching ratios to Λ_c, and give results that are not in quite a good agreement. A method, based on the neutrino quasi-elastic charm production, for a model-independent determination of most of the Λ_c^+ branching ratios has been proposed in Ref. [3]. A model-independent determination of Λ_c^+ branching ratios would provide a better theoretical understanding of the baryonic b-decays. For a detailed discussion of this method, see Ref. [3].

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Table 1
Statistical and systematic accuracy achievable in the determination of the Λ_c^+ absolute branching ratios, assuming a collected statistics of $10^7 \nu_\mu$ CC events, as a function of the relative error on $\mathcal{R}$. The central values are taken from Ref. [2]

Channel	PDG BR [2] (%)	ΔBR (%) ($\frac{\Delta\mathcal{R}}{\mathcal{R}} = 10\%$)	ΔBR (%) ($\frac{\Delta\mathcal{R}}{\mathcal{R}} = 100\%$)	ΔBR (%) ($\frac{\Delta\mathcal{R}}{\mathcal{R}} = 500\%$)
$\Lambda_c^+ \to pK^-\pi^+$	(5.0 ± 1.3)	$(\pm 0.09 \pm 0.04)$	$(\pm 0.09 \pm 0.09)$	$(\pm 0.09 \pm 0.4)$
$\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$	(2.0 ± 0.7)	$(\pm 0.06 \pm 0.01)$	$(\pm 0.06 \pm 0.04)$	$(\pm 0.06 \pm 0.1)$
$\Lambda_c^+ \to \Lambda e^+\nu_e$	(2.1 ± 0.7)	$(\pm 0.06 \pm 0.01)$	$(\pm 0.06 \pm 0.04)$	$(\pm 0.06 \pm 0.1)$

2.2. Measurement accuracy

The expected accuracy on the determination of the Λ_c^+ branching ratios as a function of the relative error on $\mathcal{R}$, the quasi-elastic charm production cross-section relative to the deep-inelastic one, is shown in Table 1.

3. Direct evaluation of D_s branching ratios and f_{D_s} measurement

The experimental knowledge on leptonic D_s decays is very little. Currently, the branching ratios for $D_s \to l\nu$ decays have been estimated by the PDG [2] to be $BR(D_s \to \mu\nu) = (4.6 \pm 1.9) \times 10^{-3}$ and $BR(D_s \to \tau\nu) = (7 \pm 4) \times 10^{-2}$. Being the leptonic branching ratios proportional to the decay constant [5], these large uncertainties translate into a large uncertainty on the extraction of the decay constant f_{D_s}.

A method that would allow at the ν-Factory the extraction of most of the D_s branching ratios, and consequently of f_{D_s}, by means of purely leptonic decays, has been proposed in Ref. [4]; the expected accuracy would be better than 5%. Once f_{D_s} will be measured with such an accuracy, one will feel more confident about extrapolating to the decay constants in the B system, f_B and f_{B_s}, which are crucial quantities for the quantitative understanding of $B^0_{(s)}$–$\bar{B}^0_{(s)}$ oscillations and the extraction of V_{td} (V_{ts}) from them.

For a detailed discussion of this method, see Ref. [4].

Table 2
Statistical and systematic accuracy achievable in the determination of the D_s absolute branching ratios, assuming a collected statistics of $10^7 \bar{\nu}_\mu$ CC events. The central values are taken from Ref. [2]

Channel	PDG BR [2]	New method
$D_s \to \mu\nu$	$(4.6 \pm 1.9) \times 10^{-3}$	$(\pm 0.55 \pm 0.15) \times 10^{-3}$
$D_s \to \tau\nu$	$(7 \pm 4)\%$	$(\pm 0.17 \pm 0.23)\%$
$D_s \to l\nu$	$(2.0 \pm 0.5)\%$	$(\pm 0.08 \pm 0.07)\%$

3.1. Measurement accuracy at a neutrino factory

The expected accuracy on the determination of the D_s branching ratios is shown in Table 2 for a few channels, together with the current status. To compute the expected number of events in each decay channel we have used the central values (shown in Table 2 together with their errors) given by the Particle Data Group [2].

Therefore, by using the measured branching ratios given in Table 2: $f_{D_s} = 288 \pm 4(\text{stat}) \pm 5(\text{syst})$ MeV.

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