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Radial tail resolution in the SELEX RICH

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Abstract

We use a seven million event data sample of 600 GeV/c single-track pion events, where the pion track is reconstructed upstream and downstream of the SELEX RICH. We build the RICH ring radius histogram distribution and count the tail events that fall outside 5σ, giving a fraction of 4×10^{-5} events outside the Gaussian tails. This control of events establishes the ability of using the RICH as a velocity spectrometer for high-precision searches of the $K^+\rightarrow\pi^+\nu\bar{\nu}$ decay like it is planned in the CKM experiment.

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1. Introduction

Two RICH velocity spectrometers have been proposed by the CKM collaboration [1–3]. The CKM goal is a 5% measurement on the V_{td} element of the CKM matrix. CKM requires the detection of 100 $K^+\rightarrow\pi^+\nu\bar{\nu}$ decay events to reach its goal.

On top of the signal there is a much more copious $K^+\rightarrow\pi^+\pi^0$ decay. To separate the signal region a level of 3×10^{-5} in the fraction of RICH ring radius tail events is required.

SELEX RICH single-track data have been used to quantify the radius distribution tails. The present work is an improved version of a previously reported result in the CKM proposal [1], where a level of 7.9×10^{-5} fractional events was reached using only the existence of the track upstream of the RICH detector.

2. SELEX

Fig. 1 shows the relevant SELEX detectors used in this study. Each event was triggered by beam scintillators located upstream of the scattering targets. The particle is tracked by a magnetic

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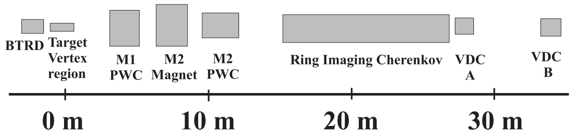

Fig. 1. SELEX spectrometer schematic.

spectrometer located upstream of the RICH. The magnet is surrounded by wire chambers and silicon strip detectors. In order to remove unwanted decays we selected events where only one track is fit all the way from the beam region to the wire chambers. To remove multiple-track events we selected events with a single segment found in the wire chambers. In order to guarantee the track existence downstream of the RICH we used a set of position detectors named Vector Drift Chambers (VDC A and B). We extrapolated the upstream track to determine the existence of hits in the VDC chambers and then fit a straight line to them. We joint the upstream and downstream segments to form a single track when the opening angle is less than 0.2 mrad.

We make use of the SELEX Total Cross Section Measurement data [4]. The data consist of 600 GeV/c single-particle events. The data are approximately half π^- and half Σ^-, with a contamination of K^- and Ξ^- at the 1% level. We make use of the Beam Transition Radiation Detector (BTRD), to select only pions as the $\beta = 1$ particle crossing the entire $\approx$ 60 m length of the SELEX spectrometer.

3. SELEX RICH

The RICH configuration, parameters, and properties have been previously reported [5,6]. The general features are described in the following lines.

The RICH detector consists of a 10.22 m long vessel filled with Ne gas. Cherenkov light was reflected on a 2.4 m × 1.2 m spherical mirror of 19.8 m radius and 10 mm thickness. The mirror was built from 16 hexagonal pieces, each one 40 cm across. The photon detector located at the focal plane consists of 2848 $\frac{1}{2}$ in phototubes. The phototubes were arranged in a matrix of 89 columns by 32 rows. Two different brands of phototubes were used Hamamatsu R760 and FEU60. The central part of the matrix had alternated columns of each brand of tubes; the outer part had only FEU60 tubes.

SELEX uses upstream track information to locate the ring center on the photon detector. A likelihood algorithm assigns the ring radius and locates phototubes on the ring for different charged lepton, meson and hyperon hypothesis.

The measured single-hit resolution is 5.5 mm. The contributions come from: matrix pixel size, 4.04 mm; upstream PWC resolution, 3.0 mm; mirror alignment, 2.06 mm; and dispersion in neon, 1.2 mm. The ring radius resolution measured for the case of single tracks is 1.5 mm, while for the multitrack case it is 1.8 mm.

In the SELEX RICH all particle species at 600 GeV/c are considered to have the same radius within the above-measured resolution. At this momentum the Ω^- differs by 3.4 mm from the $\beta = 1$ ring radius, while the electron, μ and π ring radius overlap at 11.5 cm.

4. Radius distributions and tails

Candidate phototubes are selected from a circular band of ± 1.27 cm centered on the circle found by the SELEX likelihood method. Using the ring center and radius as free parameters a fit with error handling is performed on the candidate phototubes [7,8]. This algorithm reduces the single-hit resolution to 0.47 cm by removing the upstream PWC contribution.

We build the radius distribution and apply a multi-Gaussian fit to it. Three common parameters are used to describe each Gaussian: number of entries under the curve (p_1); average radius (p_2); and single-hit resolution (p_3). The fitting multi-Gaussian function is

$$g = p_1 \sum_i f_i \frac{1}{\sqrt{2\pi s_i^2}} \mathrm{e}^{-(1/2)(\frac{x-p_2}{s_i})^2}, \quad s_i = \frac{p_3}{\sqrt{i-3}},$$

where i is the number of phototubes on the ring; f_i weights each Gaussian by the number of events corresponding to each i.