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SELEX RICH Performance and Physics Results [1]

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Abstract

SELEX took data in the 1996/7 Fixed Target Run at Fermilab. The excellent performance parameters of the SELEX RICH Detector had direct influence on the quality of the obtained physics results.

Key words: RICH detector, Phototubes, Charmed baryons
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1 Introduction

The Fermilab experiment E781 (SELEX): A Segmented Large x_F Baryon Spectrometer [1,2], which took data in the 1996/97 fixed target run at Fermilab, is designed to perform high statistics studies of production mechanisms and decay physics of charmed and charmed-strange baryons such as Σ_c, Ξ_c, Ω_c and Λ_c. The physics goals of the experiment require good charged particle identification to look for the different baryon decay modes. One must be able to separate π, K and p over a wide momentum range when looking for charmed baryon decays like $\Lambda_c^+ \to p\,K^-\pi^+$.

A RICH detector with a 2848 phototube photocathode array has been constructed [3,4] to do this. The detector begins about 16 m down-

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stream of the charm production target, with two analysis magnets with 800 MeV/c p_t-kick each in-between, and is surrounded by multi-wire proportional and drift chambers which provide particle tracking. The average number of tracks reaching the RICH is about 5 per event. First results from this detector can be found in [5]. A detailed description of the detector itself is given in [6,7].

In this article we first describe shortly the main parts of the detector (vessel, mirrors, photon detector), after this we will review its stability during the run and performance for physics analyses. Finally we report about physics results obtained with the help of the RICH up to now.

2 Description of the detector

A detailed description can be found in [6]. Here we will repeat the main features only. The SELEX RICH detector consists of a 10.22 m long vessel with 93 in. diameter, filled with pure Neon at atmospheric pressure. After initial filling to a slight (1 psi) overpressure, the vessel was perfectly tight for a period of more than 15 months.

At the end of the vessel an array of 16 hexagonal spherical mirrors is mounted on a low-mass hexpanel with 3-point mounts to form a sphere of 19.8 m radius. Each mirror is 10 mm thick, made out of low-expansion class, and has a reflectivity $> 85\,\%$ at 160 nm. Before evaporating, the quality of every mirror was measured [8].

The phototube matrix at the focal plane consists of 2848 1/2 in. photomultipliers in a hexagonal closed packed matrix of 89 columns in 32 rows. One column of 32 phototubes is connected to one common high voltage. In the center part, alternating columns of Hamamatsu R760 and FEU60 tubes are employed, and in the outer part only FEU60 tubes are used. Every phototube is connected to a preamplifier-discriminator-ECL driver hybrid chip, and the readout of the signals is performed with a standard wire-chamber electronics [9] with 170 nsec integration time.

The whole vessel is tilted by 2.4° so particles are not passing through the phototubes.

3 Performance of detector

The detector performance over the 15 month running period was very stable.

In the central region (mixed R760 and FEU60) we observed on average 13.6 photons for a $\beta = 1$ particle, corresponding to a figure of merit [10] $N_0 = 104\,\mathrm{cm}^{-1}$, and in the outside (only FEU60) we obtained $N_0 = 70\,\mathrm{cm}^{-1}$.

The refractive index, measured in several different ways, was stable to better than 0.6 %, which would change the ring radius at $\beta = 1$ by less than 10 % of its resolution.

The single photon resolution was estimated to be 5.5 mm, with the biggest contribution coming from the size of the phototubes. The ring radius resolution for the typical multitrack environment was measured at 1.56 mm. In fig. 1 we show the distribution of ring radii for single track

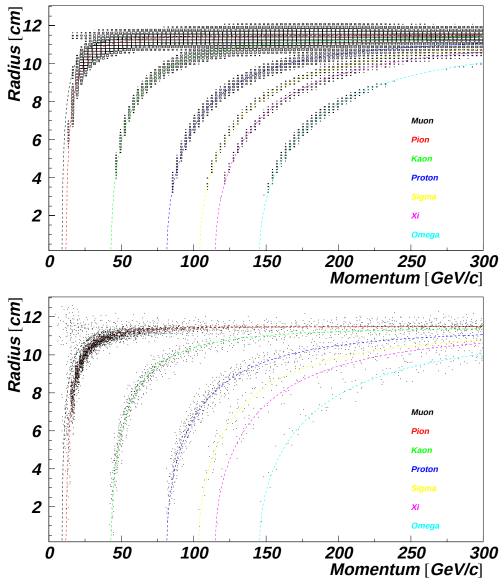

Fig. 1. Distribution of ring radii and momentum for single track events. Top: $53 \cdot 10^6$ negative tracks. Bottom: 180000 positive tracks. The lines show the expected for ring radii for $\mu^\pm$, $\pi^\pm$, $K^\pm$, $p^\pm$, $\Sigma^\pm$, $\Xi^\pm$, and $\Omega^\pm$.

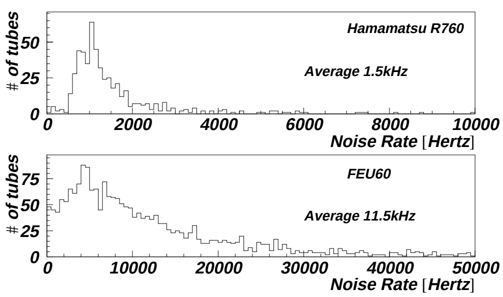

Fig. 2. Distribution of noise rates (conservative estimate) for the two types of phototubes used in the detector.

events, where one can identify eight particles and eight anti-particles, demonstrating the huge dynamic range of this detector. With the same dataset we measured the noise of the detector, by counting the number of hits not assigned to a ring, taking into account the integration time of the readout electronics. The result is shown in fig. 2, for the two different types of phototubes used. For beam-

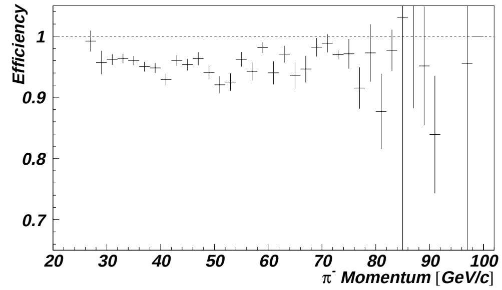

Fig. 3. Identification efficiency for π^- as function of momentum.

off events we observed on average 6 hits.

For particle identification, we calculate likelihoods for different particle hypotheses [11], using information from the tracking system. With the help of kinematically reconstructed signals we measure the identification efficiency for different cuts. For protons (using $\Lambda \to p\pi^-$ decays) in the momentum range $100\,\mathrm{GeV}/c < p_p < 200\,\mathrm{GeV}/c$, the identification efficiency is around 98 %, and even below proton threshold ($\approx 90\,\mathrm{GeV}/c$), the efficiency is above 90 % [6], with a misidentification rate of a few percent, which can be attributed to tracking errors. The same is true for kaons [6].

Pions from charm decays have usually lower momenta than other decay products; for that reason in SELEX we accept as pions in charm analysis also tracks which do not reach the RICH. Should the track be within the RICH acceptance, we require the ratio of the likelihood of that track to be a pion to all other particles to be ≥ 0.1. In fig. 3 we show that the identification efficiency is above 90 % without a sharp turn-on.

4 Physics Results

SELEX submitted first publications in 1999, after first reports at conferences in 1998. To date SELEX has published seven papers and two more are submitted. Some papers on mesons and hyperons do not use the RICH in their analyses [12–15], but for charm physics the RICH proved to be essential in the analysis, reducing the background significantly but still having high efficiency.

SELEX published measurements of the Λ_c^+ [16] and $D_s^\pm$ [17] lifetimes, where the RICH was essential in suppressing reflection below the mass peak stemming from mis-identified daughter particles.

The measurement of production properties of $\Lambda_c^\pm$ [18] with 4 different beam particles (Σ^-, π^-, p, π^+) also benefitted largely from the RICH. More hadroproduction results for D^0, $D^\pm$, and $D_s^\pm$ are in preparation [19].

SELEX also observed for the first time a Cabbibo suppressed decay mode of a charmed strange baryon, the $\Xi_c^+ \to pK^-\pi^+$ [20].

Just recently, SELEX reported on the first observation of doubly-charmed baryons [21].

5 Summary and Outlook

The RICH detector is an essential part of the physics analysis in SELEX, due to its high efficiency and large dynamic range. It fulfilled all the design criteria.

With seven papers already published plus two submitted, the collaboration is preparing at this moment several more publications to be submitted in the near future. After a first pass over all data taken ($15 \cdot 10^9$ interactions, 10^9 events on tape) in 1998/9, from which all of the publications to date were obtained, we finished a second pass with improved reconstruction software in 2001. The analysis of these data is just starting and many more results are expected.

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