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The RICH Detector of the SELEX Experiment

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Abstract

A RICH detector was used during the 1996/7 Fixed Target run at Fermilab in experiment E781 – SELEX. The detector utilizes a matrix of 2848 phototubes for the photocathode. The Figure of Merit, N_0, has been measured to be in excess of $100\,\mathrm{cm}^{-1}$. The ring radius resolution for multitrack events has been measured to be 1.8 mm, which gives K/π separation on a $2\,\sigma$ level up to a momentum of 165 GeV/c, and p/π separation up to 320 GeV/c. We will describe the design of the detector, discuss the stability during operation, and report on achieved results.

1 Introduction

Experiment E781 [1] was designed to perform high statistics studies of production mechanisms and decay physics of charmed baryons such as Σ_c, Ξ_c, Ω_c and Λ_c. One must be able to separate π, K and p over a wide momentum range when looking for charmed baryon decays like $\Lambda_c^+ \to pK^-\pi^+$. A RICH [2] detector with a 2848 phototube photocathode array has been constructed [3] to

1 Presenters of talk and poster
2 Now at Instituto de Física, Universidad Autónoma de San Luis Potosí, Mexico
3 deceased
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do this. First results from this detector are reported in [4], and a more detailed description can be found in [5].

2 Detector

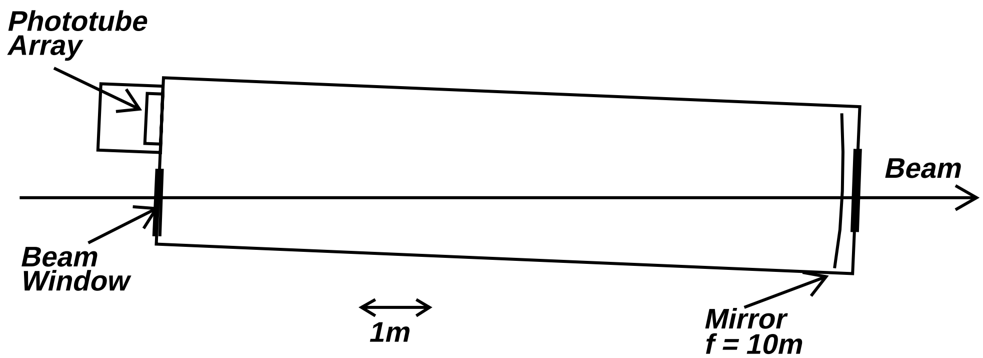

Fig. 1. Vessel Layout.

- **Vessel and Gas System** The radiator is 10 m long and 2.4 m in diameter, filled with neon at 1.05 atm.
- **Mirrors** The spherical mirror system consists of 16 hexagon-shaped glass mirrors, 40 cm across and 1 cm thick. They have an average radius of curvature of 20 m with an RMS spread less than 5 cm [6].
- **Photon Detection** The photon detection system consists of 3 parts:
  - **The holder plate** supports the phototubes arranged in an hexagonally close-packed matrix of 89×32 tubes, provides a gas seal via 2848 individually glued quartz windows and holds aluminized mylar Winston cones for each phototube, resulting in essentially 100 % coverage for detecting photons.
  - **The phototubes,** of which two different types of 15 mm diameter, 10 mm bi-alkali photocathode tubes are used. The first is a commercially available tube from Hamamatsu (R760) which has a quartz window and thus response down to 170 nm. The second is a Russian tube (FEU60) which was coated with PTP wavelength shifter to reach the same wavelength range (the quartz entrance window of the holder plate provides the 170 nm cutoff). In the central part of the phototube holder plate the R760 and the FEU60 tubes were installed in alternating columns; 19 columns are equipped with R760 tubes. In the outer parts, only FEU60 tubes were installed.
  - **Readout** consists of hybrid chips which combine an amplifier, discriminator and a differential ECL line driver. The digital output from the chips is stored in latches [7].
- **Stability** The detector performed very stably during the run which lasted more than a year, during which time the oxygen level rose by only (20 ±

12) ppm. The Figure of Merit [8], N_0, varied by less than 6 %. For the central region of the phototube array we obtained $N_0 = 104\,\mathrm{cm}^{-1}$, corresponding to 13.6 detected photons on a $\beta = 1$ ring. The index of refraction of the gas $(n-1)$ was essentially constant during the entire run, as the central value of a $\beta = 1$ ring radius distribution varied by less than $\pm 0.1\,\sigma_r$.

3 Detector response

Figure 2 is a single event display which demonstrates the low noise of the detector (average 6 hits for beam off events), it's high efficiency, and its clear multi-track capability. A maximum likelihood analysis [9] is performed for

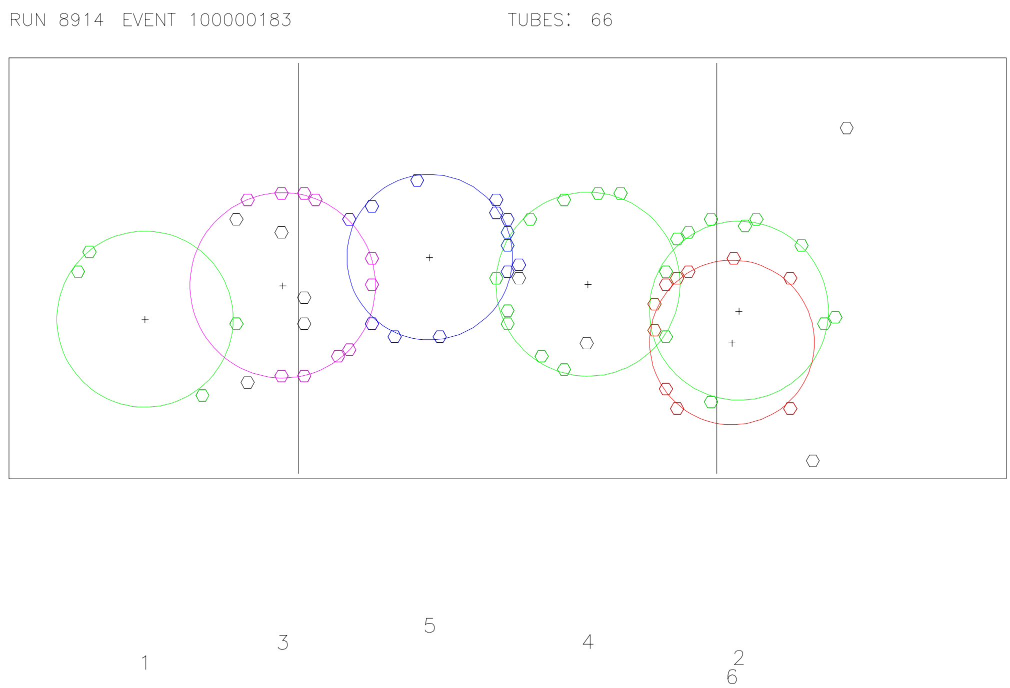

Fig. 2. Single event display.

each track in the event. The algorithm uses tracking information for the ring centers and then examines hypotheses for several different particle types for each track. For example, track 5, with momentum of 180 GeV/c, has been identified as a proton with likelihood more than 100 times that for being a pion, kaon or heavier mass particle.

Figure 3 demonstrates the power of good particle identification, showing the invariant mass for the two kaons in the reaction $\Sigma^- + A \rightarrow A + \Sigma^- K^+ K^-$. The event has exactly two negative and one positive outgoing tracks, and the energy of the outgoing particles is equal to the beam energy. A clear ϕ

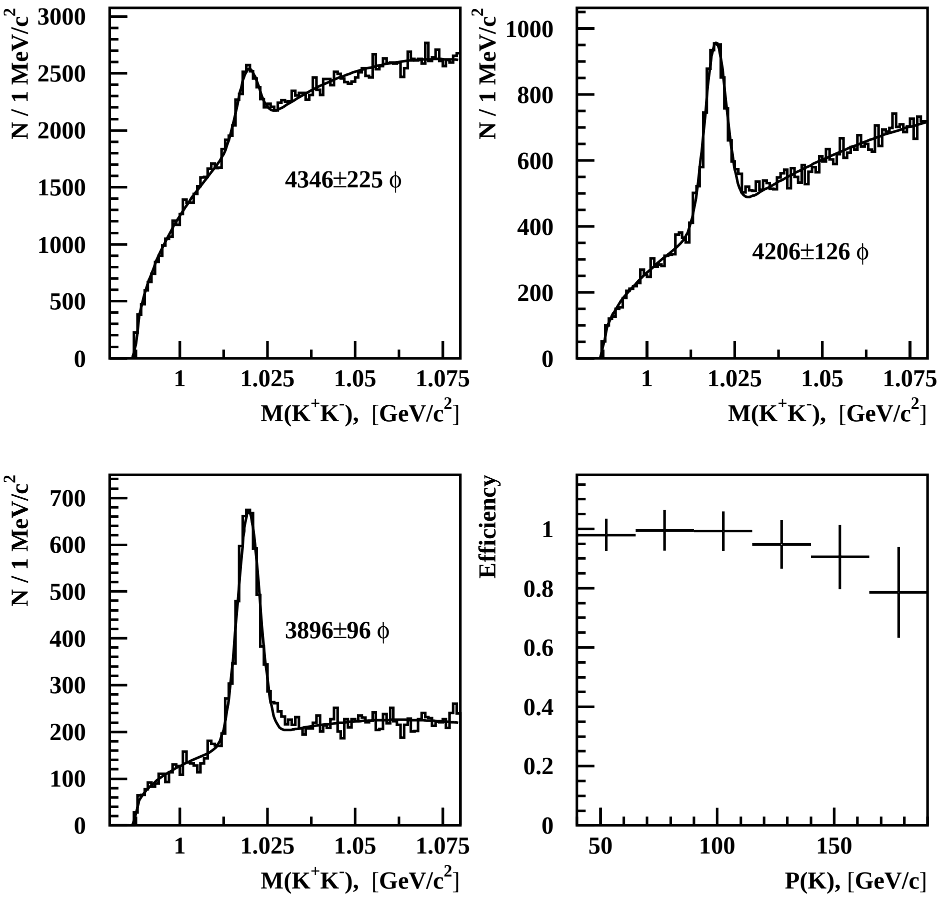

Fig. 3. Invariant mass of K^+K^-. Top left: No identification of the kaons. Top right: One kaon is identified. Bottom left: Both kaons identified. Bottom right: Efficiency for the RICH to identify a kaon as a function of its momentum. For identification, the likelihood of the track to be a kaon is required to be at least as big as the likelihood of it to be a pion.

peak can be seen, demonstrating that the RICH has a very high efficiency for identifying the kaons.

To determine the single-track ring radius resolution, we can use single-track events or isolated tracks from interaction data. For isolated tracks, the distribution of fitted ring radii is shown in fig. 4. The resulting peak has a width of $\sigma_r = 1.56\,\mathrm{mm}$, which is consistent with the expectation calculated from the single hit resolution and the number of observed hits.

Figure 5 shows the efficiency of identifying protons in multitrack events. This plot was obtained using $\Lambda \to p\pi^-$ decays, asking how often the likelihood of the positive track to be a proton was as least as big as the likelihood of it

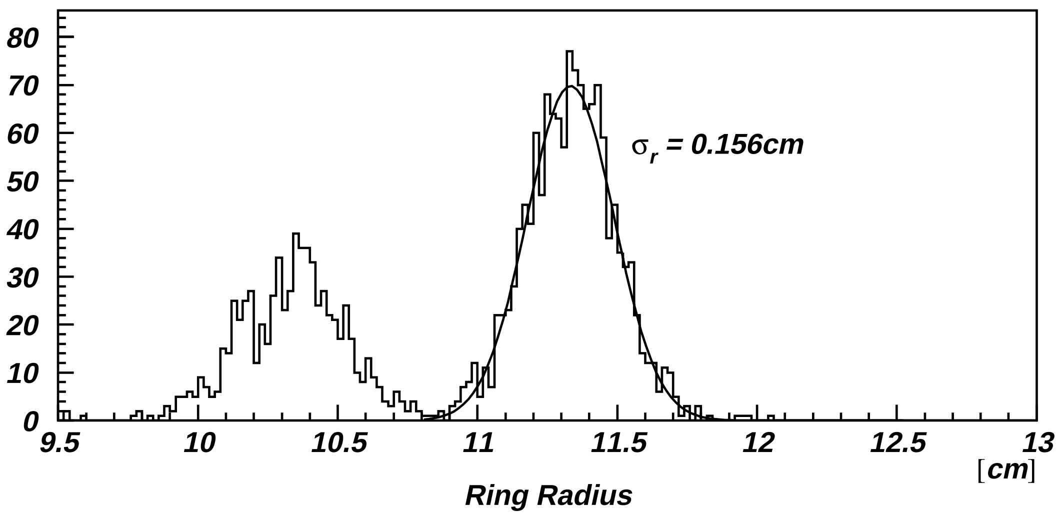

Fig. 4. Ring radius distribution for interaction data for tracks with $95-105\,\mathrm{GeV/c}$ momentum. Very well separated peaks corresponding to pions (right) and kaons (left) can be seen.

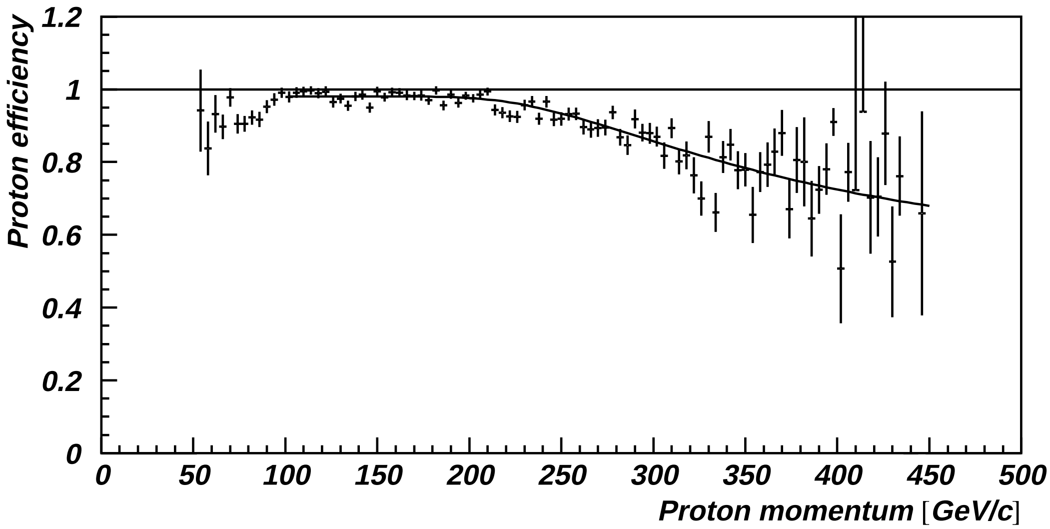

Fig. 5. Proton identification efficiency as a function of the proton momentum.

to be a pion. The efficiency is well above 95 %, although at higher momenta the proton and pion interpretations for the track become indistinguishable. A fit (line in fig. 5) gives a ring radius resolution of 1.8 mm, which includes all effects such as ring overlap, tracking errors etc, and because of these effects the ring radius resolution for multitrack events is larger than the ring radius resolution determined from single-track events or from isolated tracks. With this observed resolution we can separate (on a $2\,\sigma$ level) kaons and pions up to $165\,\mathrm{GeV/c}$ and protons and pions up to $320\,\mathrm{GeV/c}$. These numbers are expected to improve with ongoing work on the analysis code.

4 Conclusion

Within the SELEX experiment we used a RICH detector which utilized a matrix of 2848 photomultipliers as photon detectors. The operation of the detector was very stable over more than one year. For the center of the detector we obtained $N_0 = 104\,\mathrm{cm}^{-1}$, corresponding to 13.6 detected photons on a $\beta = 1$ ring. The ring radius resolution achieved is 1.56 mm for isolated tracks and 1.8 mm for interaction data. The efficiency for particle identification is more than 90 % over the entire momentum range of interest to the experiment.

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[1] SELEX Collaboration: Carnegie-Mellon University, Fermilab, University of Iowa, University of Rochester, University of Hawaii, University of Michigan-Flint, Ball State, Petersburg Nuclear Physics Institute, ITEP (Moscow), IHEP (Protvino), Moscow State University, University of São Paulo, Centro Brasileiro de Pesquisas Fisicas (Rio de Janeiro), Universidade Federal da Paraiba, IHEP (Beijing), University of Bristol, Tel Aviv University, Max-Planck-Institut für Kernphysik (Heidelberg), University of Trieste, University of Rome “La Sapienza”, INFN, Universidad Autónoma de San Luis Potosí, Bogazici University.

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