The HyperCP Hadronic Calorimeter

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Abstract

Preliminary results are presented from the 1996-1997 Fermilab fixed target run on the operational aspects of the HyperCP iron-scintillator hadronic calorimeter. The calorimeter was designed to trigger on the proton (anti-proton) from the Λ ($\overline{\Lambda}$) decay, suppressing triggers from secondary interactions and background muons. It used wavelength shifter fibers embedded in scintillating sheets.

1 Introduction

The primary goal of HyperCP is to look for direct CP violation in non-leptonic decays of the Ξ and Λ hyperons. CP violation should manifest itself as a difference in the angular distributions of the daughter baryons between parent hyperon and anti-hyperon. We expect to achieve a sensitivity of 2×10^{-4} in the difference of the slopes of the Λ ($\overline{\Lambda}$) decay angular distributions. This is a sensitivity two orders of magnitude better than the current limit published by PS185 [1]. A simple, fast, yet selective first-level trigger was employed to trigger on $\Lambda \rightarrow p\pi^-$ and $\overline{\Lambda} \rightarrow \overline{p}\pi^+$ decays. A high-rate hadron calorimeter was used to require a minimum energy for the protons and anti-protons.

2 E871 Spectrometer

A charged hyperon secondary beam of 150 GeV/c momentum with a 19.5 mrad angle to the horizontal was defined by a target assembly immediately followed by a collimator with a 4.88 μsr solid angle acceptance embedded in a 6 m long dipole magnet. Following a vacuum decay region was the spectrometer which consisted of 8 high-rate, narrow-pitch wire chambers (4 upstream of the analysis magnet, 4 downstream of the analysis magnet), an analysis magnet with a 1.43 GeV/c p_t kick, hodoscopes on either side of the spectrometer, a hadronic calorimeter, and a muon system used for rare and forbidden hyperon decay physics. Elevation and plan views of the spectrometer are shown in Fig. 1.

3 Hadronic Calorimeter

The addition of the hadronic calorimeter to the main triggers was designed to reduce the trigger rate due to secondary interaction particles and to provide a muon-blind component to the hyperon and kaon triggers by requiring a minimum energy for the protons and anti-protons. In order for this to work the calorimeter had to be fast since fluxes of greater than 75 kHz were encountered. The calorimeter had to have a large dynamic range since it had to detect muons (for calibrations purposes), and it had to contain hadronic showers in order to avoid trigger biases. Good position resolution was not necessary.

The calorimeter contained 64 layers of 2.41 cm Fe and 0.5 cm PS scintillator. Its total length was 238.92 cm, and its transverse size was 99.0×98.0 cm^2. It was split into 8 cells, four longitudinal and two lateral, each cell containing 256 fibers. This division into 8 cells was designed for the simplicity of readout purposes. The total interaction length was $9.6\lambda_I$, and the corresponding radiation length was $88.5X_\circ$. It had a sampling fraction of 3.54%. A side view of the calorimeter is shown in Fig. 2 where the particles are incident perpendicular to the absorber plates.

3.1 Scintillators and Fibers

The calorimeter incorporated a combination of scintillator and fiber, where the scintillator was the active medium. The scintillator, chosen for its speed, light output, and cost, was Kuraray SCSN-38 [2]. Bicron BCF-92 [3] (G2) wavelength shifting fibers embedded in keyhole shaped grooves were used to carry light to acrylic light guide mixers. The fibers were 2 mm in diameter and 2 m long. There was a total of 32 fibers in each plane of scintillator.

The fibers were read out at one end with the other end polished and sputtered with aluminum. The sputtered fibers were tested for reflectivity. Since this was a destructive procedure, only 8-10 fibers were tested from each sputtered batch of 500 fibers. Average reflectivities were 0.85 ± 0.05, and attenuation lengths (long component) of 3.48 ± 0.34 m were measured. This corresponded to a difference in light output of 6% from top to bottom, well within specifications.

4 Calorimeter Readout

Each cell of $16 \times 16 = 256$ fibers was potted in opaque epoxy which was attached to an acrylic light guide that mixed the light before reaching the green extended R329 Hamamatsu [4] PMT's. A high-rate transistor base was designed to provide good gain stability with rate, where 300 μA was its maximum stable operating rate [5]. The signals from the calorimeter were sent to the fast electronics room via RG-8 cabling where they were split. The summed output of the signals was discriminated and used in the trigger threshold cut.

The other portion of the signals from the calorimeter was sent to ADC's. These were 14-bit flash ADC's, with 1 μs conversion times, specially designed and fabricated to digitize the calorimeter signals for the data acquisition system.

The calibration of the calorimeter was performed by using particles of well measured energy impacting it, such as the protons from Λ decays. Cell-to-cell gains were adjusted during the run using muons which produced 1.6 photoelectrons per plane of scintillator. A light pulser system using a Nitrogen laser and PIN diodes was also used to monitor the time dependence of the calibration.

5 Calorimeter Trigger Performance

Figure 3 shows how the calorimeter performed. The minimum proton momentum from a Λ decay was around 70 GeV/c. The trigger threshold was set to a conservative value of about 50 GeV. The left plot is the trigger acceptance as a function of energy for charged particles entering the calorimeter. Typical efficiencies were greater than 99%. The right plot is the uncalibrated sum of the ADC's for a momentum cut between 100 GeV/c and 120 GeV/c. The preliminary (uncalibrated) estimate of the calorimeter resolution is $\sigma/E \simeq 80\%/\sqrt{E} \oplus 2.5\%$.

6 Acknowledgements

We thank the Fermilab staff for their contributions to this experiment and for the use of their machinery in the keyhole shaped grooves in the scintillators and in the fiber polishing and sputtering processes. This work was supported in part by the U.S. Department of Energy and the National Science Foundation.

7 References

1. P.D. Barnes et al., Phys. Rev. **C54** (1996) 1877.
2. Kuraray International Corp., 30th Floor, PanAm Building, 200 Park Avenue, NY 10166.
3. Bicron, 12345 Kinsman Rd., Newbury, OH 44065.
4. Hamamatsu Corp., 360 Foothill Rd., Bridgewater, NJ 08807-0910.

5. D. Rajaram,"Design and Performance of a High-Rate Photomultiplier Base," Master's Thesis, (1996) pg. 51.

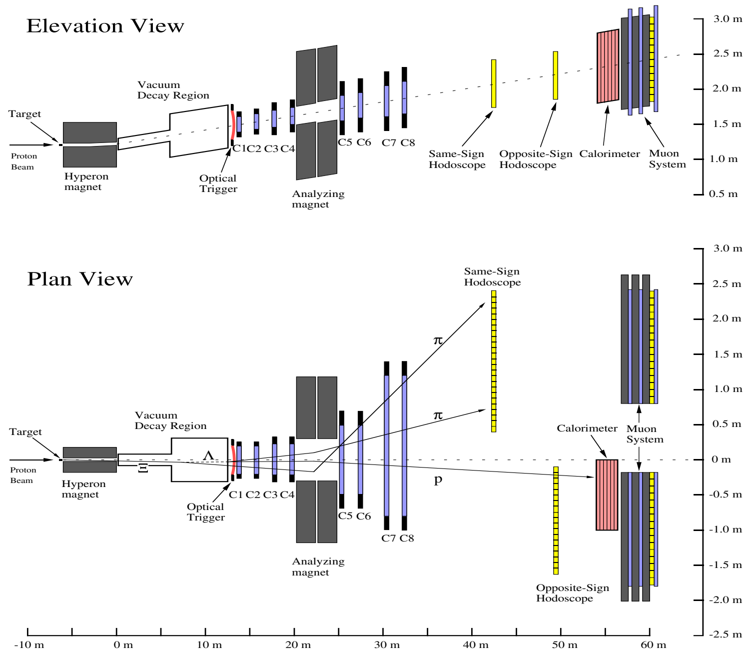

Figure 1: Elevation and plan views of the HyperCP spectrometer.

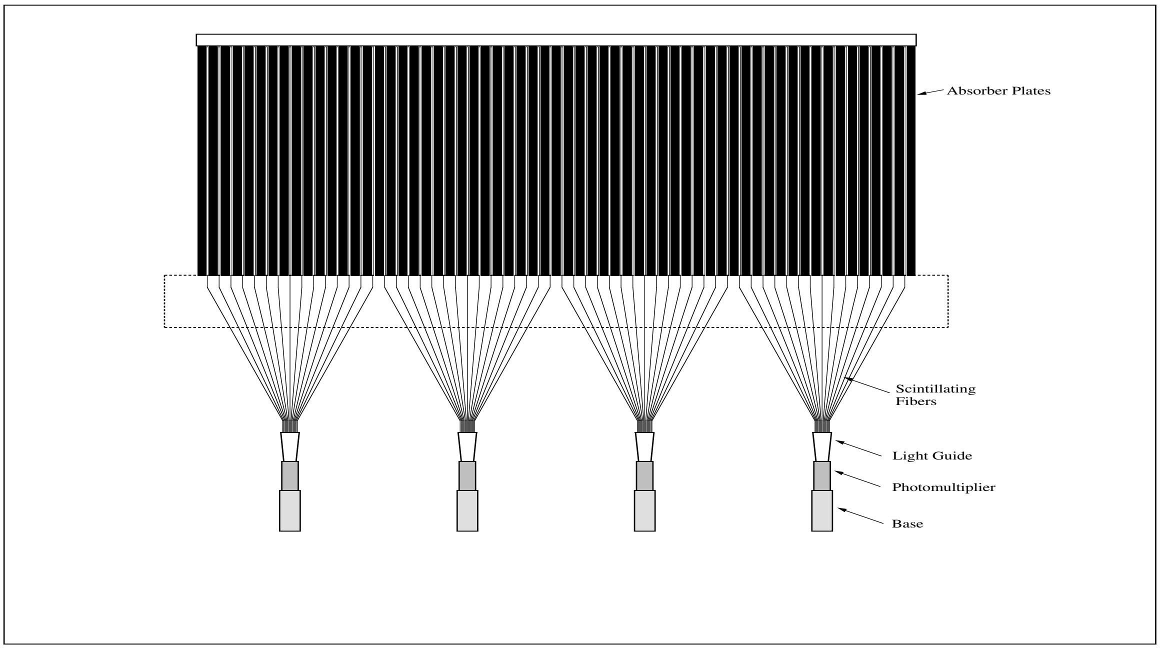

Figure 2: Side view of the hadronic calorimeter.

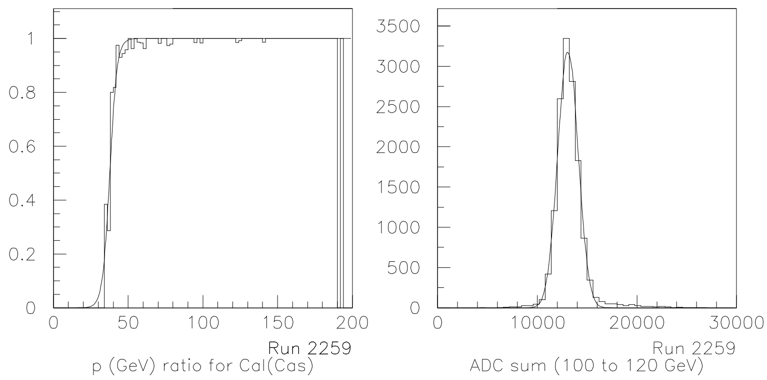

Figure 3: Calorimeter energy and resolution.