Study of the Decay $\Omega^- \to \Xi^- \pi^+ \pi^-$ in the HyperCP Experiment

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Abstract. The HyperCP (E871) experiment collected $\sim 10^{10}$ hyperon decays, including $\sim 10^7$ Omega decays. A signal of 134 events has been observed in the rare decay mode $\Omega^- \to \Xi^- \pi^+ \pi^-$. We present preliminary results on the contribution of $\Omega^- \to \Xi^{*0}_{1530} \pi^-$ to this process.

Keywords: Omega hyperon, Rare nonleptonic decay, HyperCP experiment
PACS: 13.30.Eg, 14.20.Jn

The rare hyperon nonleptonic 2-body decay

$$\Omega^- \to \Xi^{*0}_{1530} \pi^- \tag{1}$$

has attracted the attention of theorists due to its relative simplicity. A standard QCD-inspired description was examined in [1]. Recently, an attempt to estimate the branching ratio with the effective weak Hamiltonian and the SU(3) Skyrme model was made [2]. Since the Ξ^{*0}_{1530} is a resonance, it decays promptly: $\Xi^{*0}_{1530} \to \Xi^- \pi^+$. The same final state can be reached directly through the 3-body decay channel:

$$\Omega^- \to \Xi^- \pi^+ \pi^- . \tag{2}$$

These modes were previously studied in [4]; however, that experiment could not distinguish between these two mechanisms. Thus, the same four events were used to calculate the branching ratio for each process. The current Particle Data Group (PDG) [3] resonance-channel branching ratio was deduced using a branching ratio of $2/3$ for $\Xi^{*0}_{1530} \to \Xi^- \pi^+$, and assuming that the four events were $\Omega^- \to \Xi^{*0}_{1530} \pi^-$.

The HyperCP experiment (E871) at Fermilab collected data during 1997 and 1999. The primary goal of the experiment was to search for exotic sources of CP violation in the hyperon decay chain $\Xi \to \Lambda\pi$, $\Lambda \to p\pi$. The HyperCP spectrometer is described elsewhere [5]; a plan view is shown in Fig. 1. From the Fermilab computer-"farm" processing with loose track-finding and invariant-mass selection criteria, a total of $\sim 14 \cdot 10^6$ $\Omega \to \Lambda K \to p\pi K$ events were reconstructed for the negative-polarity mode and $\sim 5 \cdot 10^6$ for the positive (antiparticle) mode. This, the world's largest sample of Omega hyperons, is ideal for searching for rare Omega decays.

We performed a search for decays (1) and (2) with identical reconstruction and selection procedures. Events were required to have five charged tracks with three tracks on the same-sign side and two on the opposite-sign side (see Fig. 1). Reconstructed decay vertices were required to be inside the decay volume and to be consistent with the decay topology. Reconstructed invariant particle masses were restricted to be within ± 3 standard deviations (σ) of their nominal masses. The reconstructed Ω^- trajectory

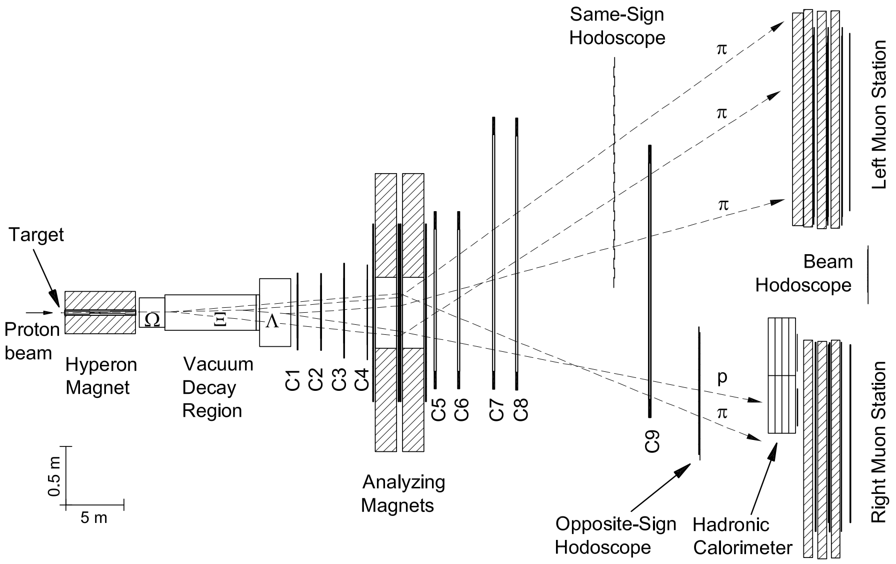

FIGURE 1. Plan view of the HyperCP spectrometer.

was traced back through the hyperon magnet and required to be inside the aperture of the hyperon channel entrance. The resonance-mode acceptance is 2.3 times higher than that for the 3-body decay mode, based on Monte Carlo (MC) simulations assuming a uniform-phase-space decay distribution. We have found 134 events within $\pm 3\sigma$ of m_Ω with little background [6].

The distribution of $\Xi^-\pi^+$ mass[1] vs. $\pi^+\pi^-$ mass is shown as large dots in the Dalitz plots of Fig. 2. It is compared with the distribution of resonance-channel MC events (small dots) in Fig. 2a, where the Ξ^{*0}_{1530} mass was simulated with a Breit–Wigner probability density function, and of 3-body MC events in Fig. 2b. Both decays were generated uniformly in phase space in the rest frame of the Ω^-. The reconstructed $\Xi^-\pi^+$ mass distribution (Dalitz plot projection on the "$\Xi^-\pi^+$ mass" axis) for the resonance mode MC and the 3-body decay mode MC appear in Fig. 3. Qualitatively our data are more consistent with the 3-body decay than with the resonance mode. But the data do not agree well with either model (note the encircled region in Fig. 2b, where the MC predicts an accumulation of events not apparent in the data).

At large $\Xi^-\pi^+$ mass, the data are seen in Fig. 3 to fall substantially *below* the continuum (uniform-phase-space 3-body decay) MC simulation. This could mean that the resonant and continuum channels interfere destructively. However, before such an interpretation can be confirmed, the possibility must first be ruled out that the observed event deficit reflects some subtle systematic effect not as yet included in our MC simulation. Further study will be performed to test these possibilities.

In conclusion, with a 34-fold increase in $\Omega^- \to \Xi^-\pi^+\pi^-$ event sample compared to the previous experiment, we can estimate the contribution of the resonance decay channel $\Omega^- \to \Xi^{*0}_{1530}\pi^-$ to this process. Our preliminary inference is that, contrary

[1] For brevity, we refer to the reconstructed $p\pi^-\pi^-\pi^+$ mass as "$\Xi^-\pi^+$ mass."

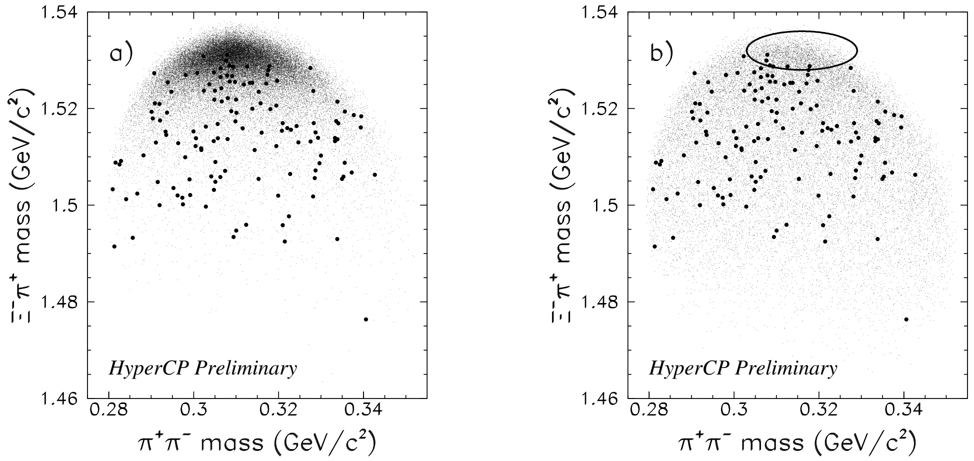

FIGURE 2. Reconstructed $\Xi^-\pi^+$ mass vs. $\pi^+\pi^-$ mass for the (a) resonance-channel MC, and (b) 3-body MC. The large dots represent the data. The encircled region in (b) is where the MC predicts an accumulation of events not apparent in the data.

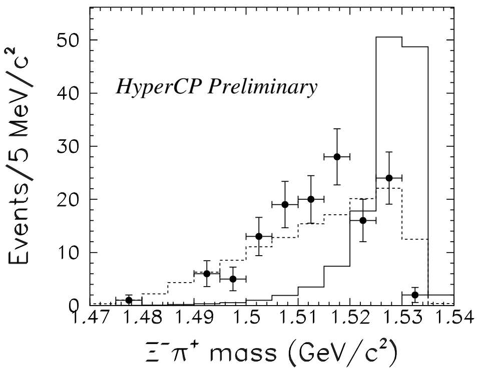

FIGURE 3. Reconstructed $\Xi^-\pi^+$ mass distribution. Dots with error bars — data (134 events); solid line — resonance-channel MC; dashed line — 3-body MC. Both MCs are normalized to 134 events.

to previous assumption, the decay is dominantly continuum (2) and not resonant (1). Further work is needed to study the dependence of the result on the assumed decay model and asymmetry parameters as well as other systematics.

We thank the conference organizers for a fruitful meeting. We are indebted to the Fermilab staff for their important contributions.

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