Branching Ratio for $\Lambda \rightarrow p\mu\nu$ †

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We have observed nine examples of the decay $\Lambda \rightarrow p\mu\nu$ in a hydrogen bubble chamber. The branching ratio is $(2.4 \pm 0.8) \times 10^{-4}$.

Among the leptonic decays of hyperons, the decay $\Lambda^0 \rightarrow \mu^- p\nu$ is quite rare and one of the hardest to identify. For this reason a good determination of the branching ratio $(\Lambda^0 \rightarrow \mu^- p\nu)/(\Lambda^0 \rightarrow \text{all modes})$ has been impossible so far. The value quoted by the Particle Data Group[1] for this ratio is $(1.35 \pm 0.60) \times 10^{-4}$ and is based on six contributions of which four could only give limits on its value. The two best values for the branching ratio[2,3] are based, respectively, on three and two events. We report here a determination of the branching ratio based on the observation of nine events.

Large samples of Λ^0 hyperons can be obtained by stopping K^- mesons in hydrogen. In 34% of all K^- absorption at rest on free protons a Λ^0 is produced, either directly or via Σ^0 production followed by electromagnetic decay into Λ^0.

A fraction of a 550 000-picture exposure of the Brookhaven National Laboratory–Columbia University 30-in. hydrogen bubble chamber was used in the search for Λ^0 muonic decays. The chamber was exposed to the low-energy separated K^- beam at the Brookhaven alternating-gradient synchrotron. 300 000 frames were scanned, corresponding to an effective sample of 1.14×10^6 Λ^0 produced.

The appearance in the chamber of a negative track, transforming at its low-energy end into a spiraling electron, allows unique identification of the track as being a μ^- at its end. Muons can appear in Λ^0 decay either directly or via the chain $\Lambda^0 \rightarrow \pi^- p$, followed by the decay in flight of the pion into $\mu^-\nu$, this last being approximately 150 times more probable than the three-body muonic decay of interest. A good fraction of the $\pi \rightarrow \mu$ decays in flight can be rejected by carefully searching the presumed muon track for sudden changes in direction ("kinks") and ionization which signal the π-μ decay, as well as by comparison of the values of the momentum of the negative track computed from its range and its curvature in the chamber magnetic field. This procedure leaves approximately 2% of the background events. To improve the background rejection further one has to use kinematics to distinguish the two processes. We notice here that in our case the Λ^0 muonic decay is not constrained kinematically because we do not know the magnitude of the Λ^0 momentum, while the decay chain $\Lambda^0 \rightarrow \pi^- \rightarrow \mu^-$ is ideally once overdetermined. We can thus select events satisfying this assumption and exclude them from our sample. We prefer, instead, to find those regions of phase space which are most populated by the background events and reject all events falling in these regions. This procedure is well known to be less dependent on an absolute knowledge of measurement errors than kinematical fitting. In practice we select a variable which can be calculated for each event and reject all events within certain boundaries.

From the study of a large sample of Monte Carlo–generated events of the type $\Lambda \rightarrow \pi \rightarrow \mu$, we concluded that the most sensitive variable which can be used to reject background events is the transverse-momentum unbalance at the Λ^0 decay vertex. This variable is of course related to the neutrino momentum both in the three-body leptonic decays and in the $\pi \rightarrow \mu\nu$ decay for the background events. However, because the Q value in two-body Λ^0 decay is much larger than the Q value in $\pi \rightarrow \mu\nu$ decay, the neutrino for the background events is usually in the opposite hemisphere from the proton. A simple way to take all this into account is to compute the quantity $t = |p_\mu{}^t| - |p_{\text{proton}}{}^t|$. p^t is the transverse momentum of the appropriate particle at the Λ^0-decay vertex with respect to the Λ^0 direction, projected onto the plane of the front window. t is usually negative for the background events and rarely becomes more positive than 15 MeV/c. In addition, the negative track momentum, properly simulated, is strongly peaked around 130 MeV/c for $\Lambda \rightarrow \pi \rightarrow \mu$ events, with few events below 90 MeV/c.

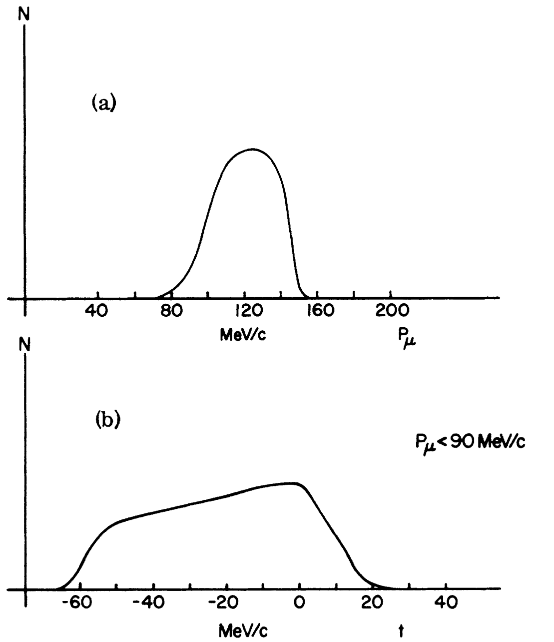

FIG. 1. (a) Muon momentum distribution for the simulated $\Lambda \to \pi \to \mu$ events. (b) t distribution from the simulated $\Lambda \to \pi \to \mu$ events where $t = |p_\mu{}^t| - |p_{\text{proton}}{}^t|$.

As a result of our Monte Carlo calculation we showed that if one chooses events with $p_\mu < 90$ MeV/c, and $t > 15$ MeV/c, the remaining sample contains less than 0.06% of the original $\Lambda \to \pi \to \mu$ background. This is illustrated partly in Figs. 1(a) and 1(b) which give, respectively, the p_μ and t distributions from the $\Lambda \to \pi \to \mu$ events.

Data.—Scanners were instructed to search for V's, with an obvious electron decay at the end of the negative track. All candidates found were examined by physicists. 337 events were retained with no visible kinks or changes in ionization in the negative track. The events were required to be consistent with the decay of a Λ^0 produced by a K^- stopping nearby in the chamber. The positive track had to be black and stop in the visible region of the chamber. Each candidate was very carefully and accurately measured on film-plane digitizing machines and reconstructed with the TVGP program. Two different measurements of the negative track, one all the way to its last point and one up to about 10 cm from the V vertex, were used to obtain accurate values of momentum from range and curvature. All events with a difference between the two values greater than three standard deviations were rejected. 182 events remained and were subjected to the restrictions described above: (a) $p_\mu < 90$ MeV/c; (b) $t > 15$ MeV/c; and in addition we required

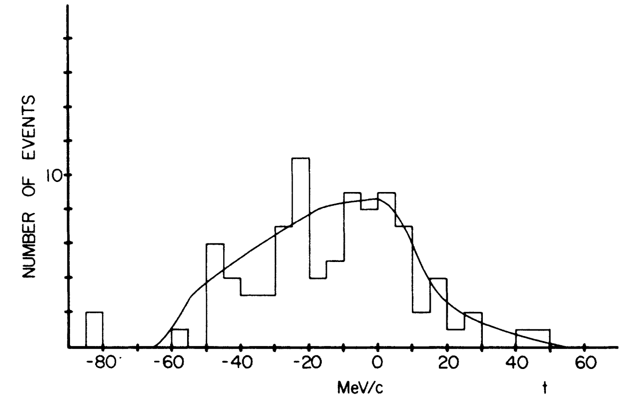

FIG. 2. The t distribution for the 92 events (see text). The continuous line is the computed contribution of the $\Lambda \to \pi \to \mu$ background events plus the true three-body decays.

(c) a dip of all tracks <60°. We find that 92 events are left after (c) and (a) combined, and 9 events remain after (b). On the basis of our Monte Carlo calculation we estimate that less than 0.82 background event is contained in the final sample. The t distribution for the 92 events is shown in Fig. 2, together with the distribution for the $\Lambda \to \pi \to \mu$ background plus the Λ three-body decays. The agreement between data and calculation shows that the background is fairly well understood. It is worth noting that for all the selected events, momentum from range and momentum from curvature for the negative track differ by less than one standard deviation.

The effect of this selection criterion on the true muonic events is calculated by integrating the decay distribution over the corresponding region. The result is that 3.55% of all events survive the procedure described. The scanning efficiency was determined, from a double scan of two-thirds of the film used, to be 85%. The effective number of Λ^0 was obtained by a double scanning of 20% of the exposure, scattered throughout the portion of film used. The efficiency for this scan was 90%. Using the branching ratio $(\Lambda \to \pi^- p)/(\Lambda \to \text{all}) = 0.653$,[1] we obtain 1.14×10^6 for the effective number of Λ^0 produced. Thus the Λ^0 muonic branching ratio is given by

$$\frac{\Lambda^0 \to \mu^- p \nu}{\Lambda^0 \to \text{all}} = \frac{9 - 0.82}{1.14 \times 10^6} \, \frac{1}{0.0355} \, \frac{1}{0.85}$$

$$= (2.4 \pm 0.8) \times 10^{-4},$$

where the error is purely statistical.

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Determination of the $\omega \to \pi^+\pi^-$ Decay Amplitude from Photoproduction*

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Interference between ρ^0 and ω photoproduced from carbon, aluminum, and lead has been studied in the 2π decay mode. The branching ratio $(\omega \to 2\pi)/(\omega \to 3\pi)$ is $2.8 \pm 0.6\%$. The phase difference between the decay amplitudes $\omega \to 2\pi$ and $\rho^0 \to 2\pi$ is $63° \pm 16°$.

The existence of the G-parity–nonconserving decay $\omega \to \pi^+\pi^-$ is by now well established.[1-4] However, the value of the branching ratio and the phase of the decay amplitude are poorly known. Most information to date comes from studies of interference between ω and ρ^0 decaying through the $\pi^+\pi^-$ channel. To get quantitative results from such studies, it is necessary to understand the mechanisms that produce the ρ^0 and ω. In particular, one must know the relative magnitude, relative phase, and degree of coherence of the production amplitudes. If the ρ^0 and ω are produced in hadronic interactions, such information is invariably lacking. On the other hand, the mechanisms for photoproduction of ρ^0 and ω mesons from complex nuclei are much better understood[5-6] and are favorable for interference experiments because the degree of coherence is high. e^+e^- colliding-beam studies[7] share these advantages, but so far have been limited by poor statistics.

We have studied the process $\gamma A \to \pi^+\pi^- A$ (where A is for carbon, aluminum, and lead), and observed ρ^0-ω interference. The experimental setup is shown in Fig. 1. A 9.4-GeV bremsstrahlung beam passes through a target, located in the center of a small magnet (normally off), and then buries itself in a tungsten and lead plug. Pion pairs produced in the target are deflected by the second, large magnet and then pass through a system of trigger counters F, M, and B and the wire spark chambers $S1$-$S6$. The particle trajectory after the magnet, along with the pointlike target volume, suffice to determine the particle's vector momentum and hence the invariant mass of the $\pi\pi$ pair.

If the counters indicate that a pair of particles has passed through the system, the chambers are fired, read (via magnetostrictive readouts) into an IBM 1800 computer, and written onto magnetic tape. Also read in is the magnetic field in the large magnet. Various checks are made on line, but the track reconstruction and subsequent analysis are performed off line.

The absolute mass scale was determined to $\pm 0.25\%$ by floating-wire measurements. The geometric detection efficiency was determined by Monte Carlo calculations. To extend the mass range covered, a small amount of data was taken with larger trigger counters and reduced magnetic fields. The mass resolution was determined by Monte Carlo calculations, adjusted slightly on the basis of the electron transverse-momentum distribution; the rms widths were ± 5.50