resonant frequency of the μ meson to that of the proton in water in the same magnetic field. The results for copper and aluminum are corrected by a rough calculation of the Knight shift[6] and then agree with that for $CHBr_3$ in which there should be no diamagnetic shift to the accuracy quoted. It should be noted that our result for aluminum disagrees with that of the Chicago group[4,7] to about twice their stated error.

Using our result for $CHBr_3$ and the value for the μ-meson mass given by Crowe,[8] the g-factor is found to be $2(1.0020 \pm 0.0005)$ as compared to $2(1.00116)$ as predicted by theory. Of even greater interest is the lower limit for the μ-meson mass given by Crowe from a determination of μ-mesonic x-rays[9] of $(206.77 \pm 0.04)\,m_e$. This yields $g > 2(1.00154 \pm 0.00022)$ which is also in disagreement with theory. It should be noted that the error arises mostly from the measurement of the mass which stems from uncertainty in the calculation of the vacuum polarization correction.

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NEUTRAL CASCADE HYPERON EVENT*

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The existence of a neutral cascade hyperon Ξ^0 has been predicted theoretically,[1] on the basis of the strangeness theory of Gell-Mann and Nishijima, as the neutral counterpart of the negative cascade hyperon,[2] Ξ^-, which decays by $\Xi^- \to \pi^- + \Lambda$.

In an attempt to establish the existence of this particle the Lawrence Radiation Laboratory 15-inch hydrogen bubble chamber was operated in a separated beam of (1.15 ± 0.02)-Bev/c K^- mesons produced by the Bevatron. Two Cork-Wenzel-Lambertson parallel-plate spectrometers[3] were used to remove pions from the beam. Typical operating conditions gave $\approx 1.5\ K^-$, $\approx 0.2\ \pi^-$, and ≈ 4.5 beam μ^- mesons per picture.[4] The total number of K^- mesons through the chamber was about 10^5.

A large number of K^- interactions in hydrogen were observed; among them were some 500 single V^0 events, resulting from the reactions

$$K^- + p \to \bar{K}^0 + n, \qquad (1a)$$

$$K^- + p \to \Lambda + \pi^0, \qquad (1b)$$

$$K^- + p \to \Sigma^0 + \pi^0. \qquad (1c)$$

In any of these, additional π^0 mesons may also have been produced.

On the other hand, only seven double V^0 events were observed. Since the reactions (1) lead only to single V^0's, whereas associated production by π^- mesons leads to double V^0's in about 20% of the interactions, the strikingly small ratio of double V^0 events to single V^0 events again shows that we are dealing principally with K^- interactions.

Six of the double V^0's were clear cases of associated production by π^-, five being

$$\pi^- + p \to \Lambda + K^0, \qquad (2a)$$

and one

$$\pi^- + p \to \Sigma^0 + K^0, \quad \Sigma^0 \to \Lambda + \gamma. \qquad (2b)$$

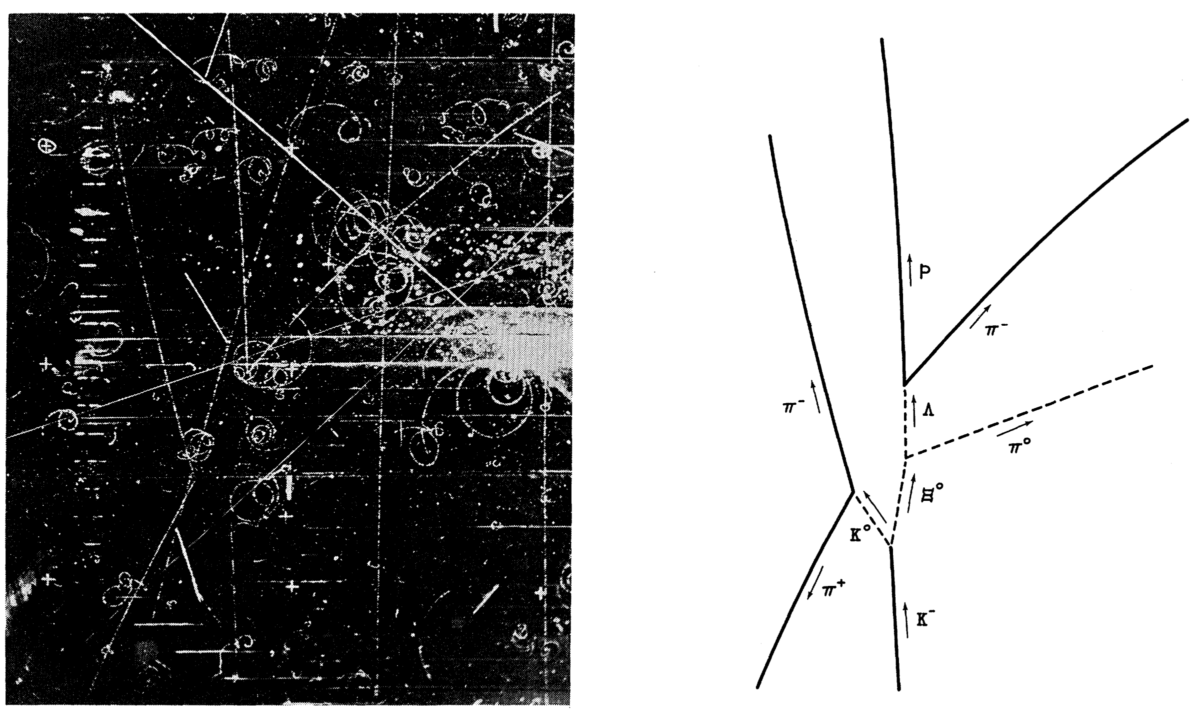
Most of these were produced by pions of some-what less than the K^--beam momentum.

The remaining event is the one being reported here. A photograph and a diagram giving our interpretation of the event are shown in Fig. 1. The angles and momenta of the left-hand V^0 are consistent with $K_1{}^0$ decay, and are inconsistent with Λ decay. The K^0 momentum and angle of emission are consistent with the reaction $\pi^- + p \rightarrow \Sigma^0 + K^0$ of a beam-momentum pion.

The two charged tracks of the right-hand V^0 are consistent with Λ decay, giving $Q = 37.2 \pm 2.7$ Mev (accepted value 37.4 Mev). However, the decay is noncoplanar; i.e., the line connecting the end of the beam track and the vertex of the Λ fails by $7.0 \pm 0.7°$ (see Fig. 2) to lie in the Λ decay plane. This line also fails to lie in the production plane defined by the K^0 path and the beam track by $2.5 \pm 0.7°$. The latter discrepancy could be explained easily if the process were (2b), but to explain the lack of coplanarity of the Λ decay, using only well-established processes, we must invoke either (a) reaction (2b) followed by a β decay of the Λ, or (b) a scattering of the Λ in the hydrogen, or (c) an accidental coincidence of a K^0-meson production event with an unassociated Λ from the bubble chamber wall.[5]

Possibility (a) may be ruled out on kinematic grounds alone. Because of the large unbalance of transverse momentum, the electron and neutrino need more energy than would be available to them. The decay[6] $\Lambda \rightarrow p + e^- + \nu$, for the most favorable Λ momentum, fails to balance energetically by 48 Mev, or 3.7 standard deviations; the error is mostly in angle measurements. For such large discrepancies, angle errors do not have Gaussian distributions, and this large a discrepancy is not possible. A decay via $\Lambda \rightarrow p + \mu^- + \nu$ fits even less well; radiative decay, $\Lambda \rightarrow p + \pi^- + \gamma$,[7] may also be ruled out by similar arguments.

The second possibility, a Λ scattering, is likewise unsatisfactory. Choosing that initial Λ direction of motion for which the scattering angle would be smallest, one asks what the proton recoil range would be to account for the observed Λ. This turns out to be 4 mm, which would be clearly visible. To have a proton range small enough that there would be some doubt, namely



(a) (b)

FIG. 1. Photograph and sketch of Ξ^0 event.

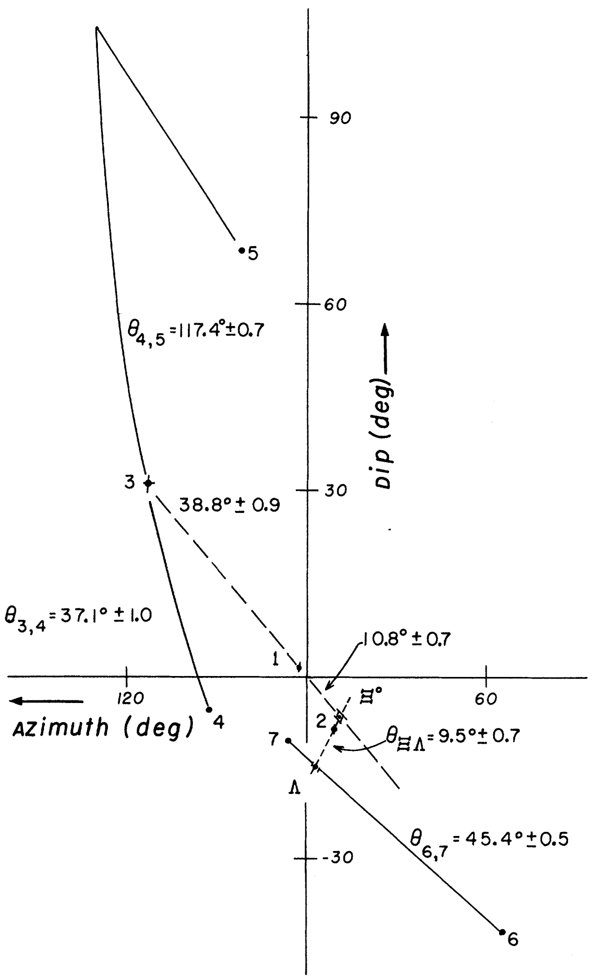


FIG. 2. Stereographic projection (Wulff plot) of the event. Observed tracks: 1, beam K^-; 2, line connecting end of beam track to vertex of Λ; 3, line connecting end of beam track to vertex of K^0; 4, π^-; 5, π^+; 6, π^-; 7, p. Inferred "tracks": Λ, obtained by balancing transverse momentum of Tracks 6 and 7; Ξ^0, obtained by intersection of production plane (containing Tracks 1 and 3) with the plane containing Track 2 and the Λ.

0.5 mm, requires stretching the errors by more than 5 standard deviations. Inelastic scatterings, for instance, $\Lambda+p\rightarrow\Sigma^0+p$, would also always give a visible recoil. Double scatterings, scatterings on deuterium, or neutron reactions on deuterium that might look like Λ events are exceedingly unlikely; for instance, the probability that we have in the entire experiment a double V^0 with a Λ scattering on deuterium that resembles a Ξ^0 event is $\leq 10^{-6}$.

The third possibility, a chance coincidence, can be shown to be most improbable on statistical grounds. Since the argument hinges on how well the event fits the production and decay of a Ξ^0 hyperon, let us now turn to this hypothesis. If we assume the K^0 meson to be produced in association with a heavy unstable particle, the incident particle being a beam K^- meson, then the extra energy available in the center of mass in the K^-+p system (compared with the π^-+p system) requires the heavy particle to be much heavier than a Σ^0. If this particle travels a distance of 3.7 cm and decays into a Λ and a π^0, then the presence of an associated Λ can be explained, as well as its apparent noncoplanarity.

The mass of the particle may then be deduced in two ways, i.e., from its production and from its decay. First, if we take the production process to be a two-body reaction, the heavy particle must lie in the plane formed by the beam track and the line of flight of the K^0 meson. Further, the direction of the heavy particle in this plane is fixed by the requirement that its path intersect that of the Λ. Then, using the production angles and the measured K^0 momentum, we can calculate the heavy-particle mass as well as the momentum of the incident K^- meson. The calculated momentum of the incident K^- is 1.13 $\pm$0.06 Bev/c, which agrees well with the nominal beam momentum. (This serves as a first check on our hypothesis.) The heavy-particle mass is 1303$\pm$28 Mev.

Second, if the heavy-particle velocity as determined in the above calculation is taken in conjunction with the observed Λ momentum and angle, a second mass determination is possible. The heavy-particle mass resulting from this calculation, based on the assumption of decay into a π^0 and a Λ, is 1349$\pm$30 Mev. This value is insensitive to the heavy-particle velocity, and therefore the two determinations are nearly independent.

Combining the two mass determinations,[8] we obtain

$$M=1326\pm20 \text{ Mev}.$$

The closeness of this result to the accepted Ξ^- mass of 1321$\pm$35 Mev[9] is remarkable.

One might put the arguments the other way and ask to what extent the agreement (within errors) with the Ξ^- mass restricts the position, momentum, and angle of the decay Λ. In order for the Ξ^0 mass, as determined by its production, to vary by 30 Mev, the Λ need be moved (transversely) only 0.4 mm. Similarly, in order for the Ξ^0 mass, as determined by its decay, to vary by 30 Mev, the Λ momentum must be changed by 50 Mev/c (at fixed angle), or the angle by 2° (at fixed momentum).

These restrictions form a strong argument against the possibility of accidental coincidence. A careful estimate shows that the probability of getting one such accidental event in the entire experiment is of the order of 10^{-5}. We have not been able to think of any more likely possibilities. Therefore, we believe that this event represents the production and decay of a Ξ^0, i.e. a hyperon of strangeness-2 and mass comparable to that of the Ξ^-.[10]

The measured dynamical variables of the event are:

K^0: Momentum, 277.5 ± 5.0 Mev/c; production angle (laboratory system), $38.8 \pm 0.9°$.

Λ: Momentum, 920 ± 50 Mev/c; angle (laboratory system) between Λ and Ξ^0, $9.5 \pm 0.7°$.

Ξ^0: Production angle (laboratory system), $10.8 \pm 0.7°$.

The incident K^- momentum agrees so well with the independently determined beam momentum, 1.15 ± 0.02 Bev/c, that it is highly probable that our K^- is one of the beam K^-'s. On this basis we can determine the mass much more precisely: $M_{\Xi^0} = 1308 \pm 8$ Mev at production. This gives $\chi^2 = 0.077$ ($\langle\chi^2\rangle = 1$).

If we consider all the information given by the production, the beam momentum, and the decay (assuming $\Xi^0 \to \pi^0 + \Lambda$), we find for the most probable mass $M_{\Xi^0} = 1311 \pm 8$ Mev. For this we find $\chi^2 = 1.45$ ($\langle\chi^2\rangle = 2$). The event cannot be used for a check of the decay mode; for instance, if we assume $\Xi^0 \to \gamma + \Lambda$, we find an even better fit ($\chi^2 = 0.247$).

The cross section, based on this one event, is $\sigma_{\Xi^0 K^0} \approx 50$ μb. We have not seen any examples of $K^- + p \to \Xi^- + K^+$; this sets a diffuse upper limit, $\sigma_{\Xi^- K^+} \leq 17$ μb. (No correction for lifetime is made here. If the lifetime of either Ξ is long compared with 5×10^{-10} sec, many would escape from the chamber.) Our one Ξ^0 lived 1.5×10^{-10} sec.

It is interesting to compare the above cross sections with those for the similar reactions

$$\pi^- + p \to \Sigma^- + K^+,$$
$$\pi^- + p \to \Sigma^0 + K^0,$$

at the same outgoing c.m. momentum (190 Mev/c)[11]:

$$\sigma_{\Sigma^- K^+} \approx 200\ \mu\text{b},$$
$$\sigma_{\Sigma^0 K^0} \approx 400\ \mu\text{b}.$$

At present the search for production of cascade hyperons in the 1.15-Bev/c K^- beam is being continued in collaboration with the Lawrence Radiation Laboratory 30-inch propane bubble chamber group.

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SEARCH FOR ENHANCEMENT OF BREMSSTRAHLUNG PRODUCED BY 575-Mev ELECTRONS IN A SINGLE CRYSTAL OF SILICON*

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Dyson and Überall[1] and Purcell[2] have predicted that considerable deviation from the Bethe-Heitler formulas for high-energy bremsstrahlung and electron pair production is expected in case the target material is crystalline. The basis of this effect is the low momentum transfer $\vec{q}$ to the Coulomb field in these processes. Bremsstrahlung by a 600-Mev electron leading to a 300-Mev photon leads to a momentum transfer to the Coulomb field down to a minimum value of 500 ev/c. Hence if such a transfer $\vec{q}$ corresponds to a reciprocal lattice vector of the crystal, the screened Coulomb field of the various atoms acts coherently and the production amplitude is enhanced. Detailed calculations of this effect have been carried out by Überall[3]; this experiment was aimed at checking these predictions.

A single-crystal plate of silicon of 0.013-in. thickness was placed in the analyzed beam of the Stanford electron linear accelerator. The crystal was mounted in a double goniometer to permit rotation of the crystal about two coplanar perpendicular axes perpendicular to the beam. The zero position of the goniometer was adjusted to correspond to the (100) plane of the crystal perpendicular to the beam; this orientation was established by Laue back-reflection photographs using a standard metallographic camera.

X-rays radiated in the crystal were detected by letting them produce photopions of specified energy in a polyethylene target. The positive pions were counted in a scintillation counter after magnetic analysis via the μ-decay positrons. The counting rate was examined as a function of "scanning" the goniometer over a range of approximately ±0.04 radian about both axes in steps of approximately 0.010 radian. About 1500 counts per point were taken. No statistically significant dependence of x-ray intensity on crystal orientation was found.

This result was assessed quantitatively by folding the functions computed by Überall into the angular resolution of the experiment as defined by the multiple scattering of the primary beam in the crystal target itself. Since this scattering involves small momentum transfers also, one could expect crystal coherence effects here as well, and therefore measured rather than computed scattering angles were used in the computation of the "expected" x-ray intensity variation as a function of angle between the crystal planes and the incident electron beam angle.

Figure 1 is a map of the counts obtained as a

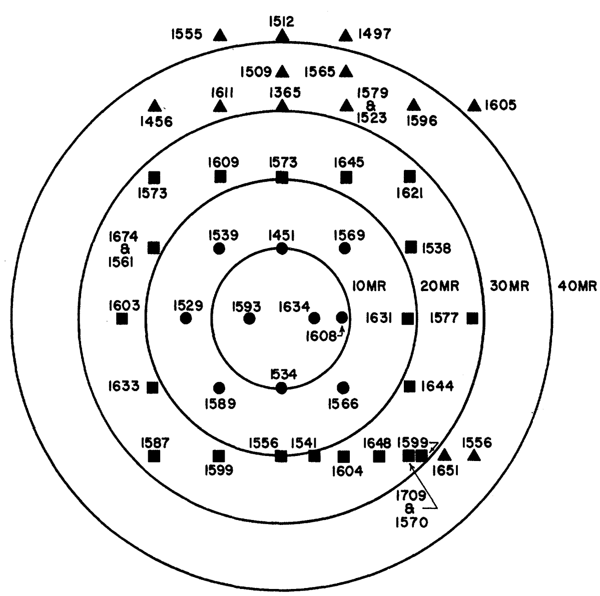
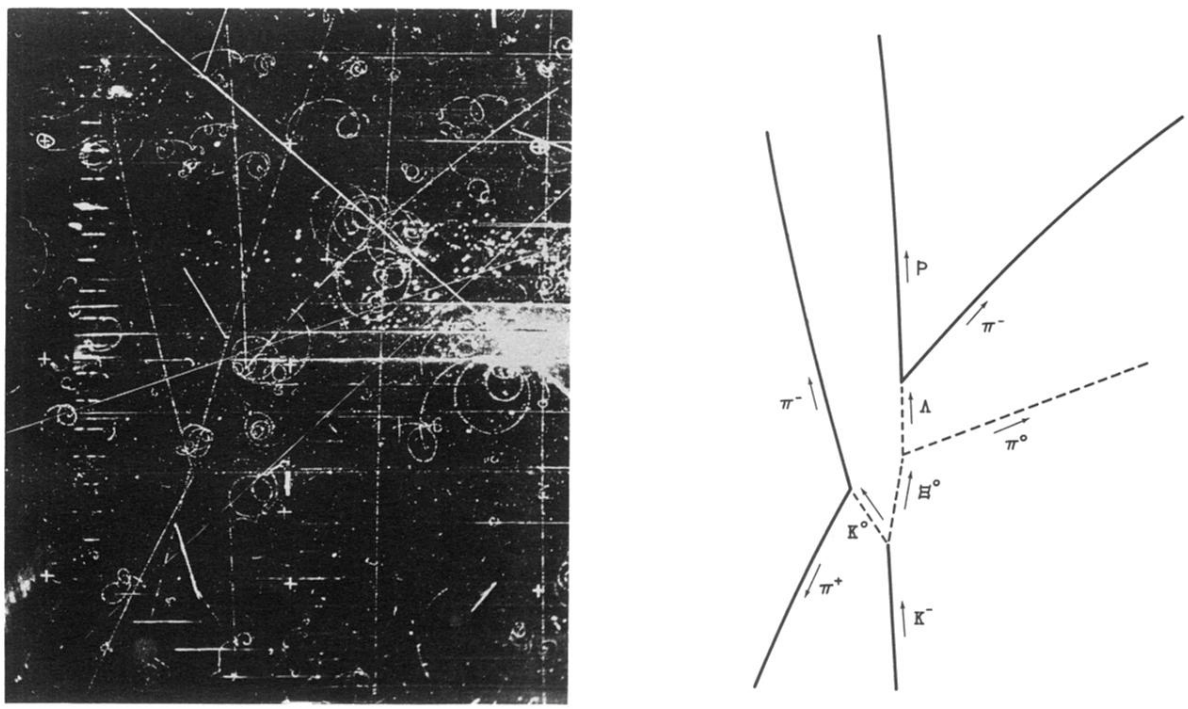


FIG. 1. The circles shown are lines of equal angle between the direction of the incident electron beam and the [100] axis of the Si crystal in which bremsstrahlung is produced. The angles are shown in milliradians (mr). Each point represents the measured intensity in counts of bremsstrahlung near an energy of 235 Mev.



(a) (b)

FIG. 1. Photograph and sketch of Ξ^0 event.