state must be $\frac{1}{2}(K^0\bar{K}^0+\bar{K}^0K^0)-\frac{1}{2}(K^+K^-+K^-K^+)=\frac{1}{2}(K_1K_1+K_2K_2)-\frac{1}{2}(K^+K^-+K^-K^+)$ [see, for example, M. Goldhaber, T. D. Lee, and C. N. Yang, Phys. Rev. 112, 1796 (1958)].

[14]Using the path length given in Table I for $p_\pi > 1.95$ BeV/c, and correcting for the 10% electron and muon beam contamination, we estimate the contribution to the cross section to be 0.1 μb per event.

BINDING ENERGY OF Λ^0 HYPERONS IN HEAVY HYPERNUCLEI ($60 < A < 100$)*

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It has been shown by Jones et al.[1] that the short-range (<5 μ) hyperfragments resulting from 800-MeV/c K^--meson interactions in emulsion are, in fact, the spallation products of silver and bromine nuclei and possess mass values in the range from $A = 60$ to $A = 100$. From a study of the total visible energy release in the nonmesonic decays of these hypernuclei, an upper limit of about 35 MeV has been placed on the value of their B_Λ. From the observation of five π-mesonic decays which are attributed to hyperfragments of the same order of mass, a more precise estimation of this upper limit has been made, namely, about 25 MeV.

Two Ilford K5 emulsion stacks were exposed to the 800-MeV/c K^--meson beam at the Berkeley Bevatron. They were area scanned for beam stars. In a total of 17 000 stars, ~900 hyperfragments were found. For this work, 470 nonmesonic disintegrations of "spallation hyperfragments" were measured, among those where all prongs from the decay star could be well distinguished from those originating from the production star. The visible energy release in a decay was computed as the sum of kinetic and binding (taken as 8 MeV per particle) energies of each of the charged emitted particles, assumed to be protons. The resulting total visible energy release histogram is given in Fig. 1(a), Fig. 1(b) showing an enlarged view of the upper part of the spectrum. The available energy in these decays is $M_\Lambda - M_N - B_\Lambda + B_N \cong (184 - B_\Lambda)$ MeV. Thus the observation of a cutoff for total energy releases close to 150 MeV allows us to put an upper limit of about 35 MeV on B_Λ for this class of hypernuclei.[2]

The details of five π-mesonic decays which are attributed to the same type of hypernuclei are set out in Table I. These have been collected from stacks exposed to stopping K^- and 800-MeV/c K^- beams at the Berkeley Bevatron and to the 1.5-BeV/c K^- beam at the CERN proton synchrotron. In each of these events the total visible energy release is much smaller than that usually associ-

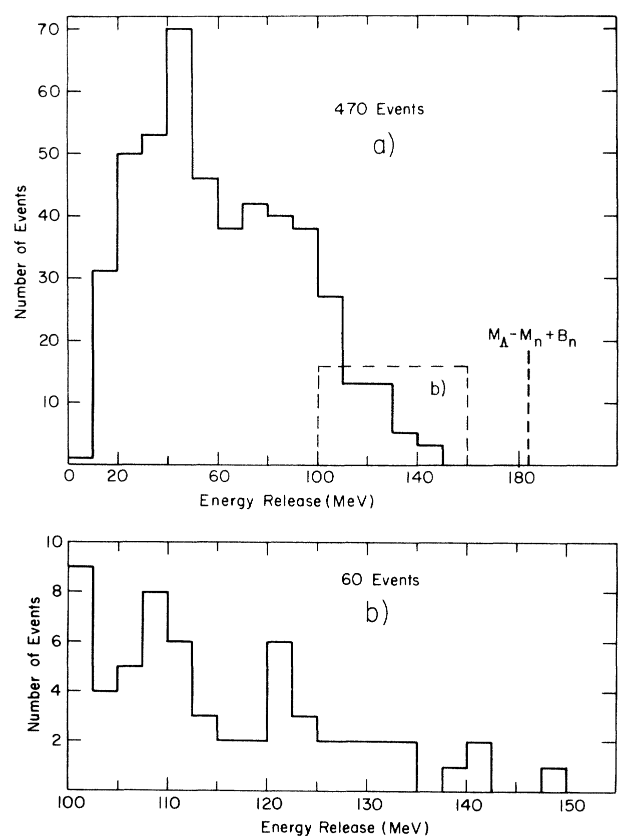

FIG. 1. Total visible energy release distribution for nonmesonic "spallation hyperfragment" disintegrations.

Table I. Details of five π^--mesonic "spallation hyperfragment" decays.

Event No.	Origin[a]	Hyperfragment range (μ)	HF Decay Products Ident.	R (μ)	Kinetic Energy (MeV)	Assumed decay mode	Upper limit of B_Λ (MeV)
EFINS 1	K^- absorbed at rest (1)	~1	π^- (p)	1068 187	6.4 5.2	$\pi-p-r$	26.0
EFINS 2	K^- absorbed at rest (0)	~1	π^-	1270	7.1	$\pi-r$	38.5
EFINS 3	800-MeV/c K^--meson interaction (6)	2	π^- (p)	39 130	0.9 4.1	$\pi-p-r$	32.6
BX 1	1.5-BeV/c K^--meson interaction (11)	4.4	π^-	5664	16.6	$\pi-r$	29.0
BX 2	1.5-BeV/c K^--meson interaction (6)	2.6	π (p)	1271 342	7.1 7.4	$\pi-p-r$	23.1

[a]The numbers in parentheses indicate the number of nucleonic charged particles emitted in the primary disintegration.

ated with the mesonic decays of light hyperfragments ($A \leq 14$). Furthermore, in no case is a charged stable particle of short range (<30 μ) emitted in the decay. This is as one would expect from Coulomb barrier effects if these hyperfragments indeed have charge $30 \lesssim Z \lesssim 40$. For the two events which were produced in the absorptions of K^- mesons at rest, an Auger electron, usually taken to indicate capture by a heavy nucleus, was present at the K^--meson star in each case. Finally, the three other events which have ranges shorter than 5 μ are interpreted as spallation hyperfragments using the same considerations,[1] assumed to be valid for the nonmesonic decays. The estimates of B_Λ are upper limits, since the emission of a neutron in the decay process or the excitation of the residual nucleus will pass undetected. It is seen that from these events the upper limit of B_Λ may be set at about 25 MeV.[3]

Figure 2 shows the B_Λ versus $A_{\text{core}}^{-2/3}$ plot. The low-mass points are from the results of Ammar et al.[4] Masses of the spallation hyperfragments have been roughly estimated from the number of charged particles emitted in the primary K^--meson interaction, bearing in mind that no distinction can be made between interactions occurring on silver ($A = 108$) or bromine ($A = 80$) nuclei. Since B_Λ is rather insensitive to A in this region, this large uncertainty does not seriously affect any reasonable extrapolation to infinite A on this plot. It is seen that the value thus obtained for the Λ-nucleus potential well depth, D_Λ, cannot much exceed 30 MeV. In fact, our results fit very well with the value 26.0 ± 2.5 MeV estimated by Dalitz[5] for D_Λ from the known B_Λ of ${}_\Lambda C^{13}$.

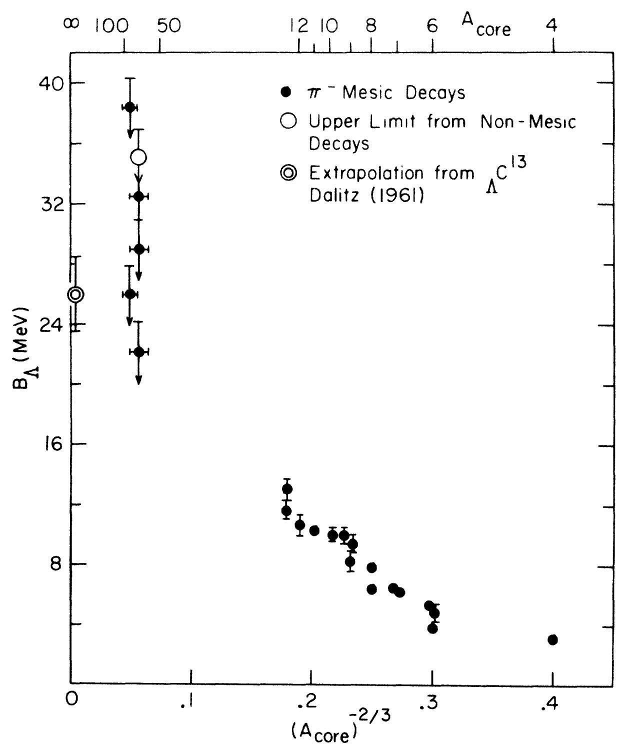

FIG. 2. Plot of B_Λ versus $A_{\text{core}}^{-2/3}$.

Within the sample of spallation hyperfragments produced by the interaction of both 800-MeV/c and 1.5-BeV/c K^- mesons, the three examples of mesonic decay in Table I were accompanied by ~1100 nonmesonic disintegrations. This may not be inconsistent with a nonmesonic/mesonic ratio of order 100 as given recently in a preliminary estimate[6] for a hypernucleus of mass $A \approx 100$.

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[1]B. D. Jones, B. Sanjeevaiah, J. Zakrzewski, M. Csejthey-Barth, J. P. Lagnaux, J. Sacton, M. J. Beniston, E. H. S. Burhop, and D. H. Davis, Proceedings of the Aix-en-Provence Conference on Elementary Particles, 1961 (C. E. N. Saclay, France, 1961); Phys. Rev. 127, 236 (1962).

[2]By a similar approach, Kenyon has recently obtained $B_\Lambda < \sim 57$ MeV for a comparable selection of hypernuclei [I. R. Kenyon (to be published)].

[3]Both upper limits on B_Λ obtained above could be, in fact, underestimated owing to the following effects: (a) the presence of spallation hypernuclei off the nuclear stability line, having separation energy B_N or $B_P \neq 8$ MeV, contrary to what was assumed, and (b) the possibility that such hypernuclei were produced in excited states and that they did not reach the ground state before undergoing mesonic or nonmesonic disintegration. These uncertainties are assumed to involve an error of $\sim\pm 2$ MeV in the quoted B_Λ values.

[4]R. G. Ammar, L. Choy, W. Dunn, M. Holland, J. H. Roberts, E. N. Shipley, N. Crayton, D. H. Davis, R. Levi Setti, M. Raymund, O. Skjeggestad, and G. Tomasini (to be published).

[5]R. H. Dalitz, Proceedings of the Rutherford Jubilee International Conference, Manchester, 1961 (Heywood & Co., London, 1961), p. 103.

[6]R. H. Dalitz and G. Rajasekharan (private communication).

TOTAL CROSS SECTIONS OF NEGATIVE PIONS IN THE MOMENTUM RANGE 2 TO 5 BeV/c†

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Few accurate data are presently available on the total π^--p cross section in the momentum range 2 to 4.5 BeV/c. We present here the results of measurements in this range using counter techniques. In addition, cross sections in good geometry for π^--carbon scattering were measured at 3 and 4 BeV/c in order to investigate a discrepancy between the π^+-C cross sections previously measured by the authors[1] and the π^--C cross sections of Wikner.[2]

The experimental arrangement is shown in Fig. 1. The pion beam was used simultaneously by the University of Michigan spark chamber group to measure π^--p differential cross sections. After passing through their 18-in.-long hydrogen target, the beam was refocused by Q_2 and used for our measurements. The π^--p cross sections were measured by using a CH_2-C subtraction with carefully matched polyethylene and graphite targets, the former containing 2.9 g/cm^2 of hydrogen. Incident pions were counted by measuring $M_1M_2CM_3M_4$ coincidences. The numbers of transmitted pions were measured with three different geometries simultaneously by means of counters

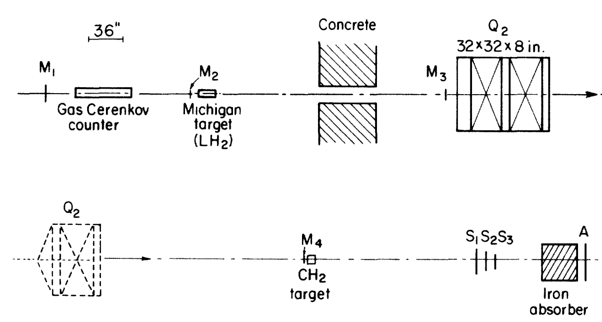

FIG. 1. Experimental arrangement. The π^- beam was taken off at 0 degrees from a target in the Bevatron. The first quadrupole and bending magnet are not shown. The vertical scale is exaggerated twofold for clarity.