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MASTER

MEASUREMENT OF THE UP-DOWN ASYMMETRIES IN THE BETA DECAY OF POLARIZED LAMBDAS*

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DISCLAIMER

We have performed an experiment on the beta decay of the lambda hyperon at the Argonne National Laboratory Zero Gradient Synchrotron using spark chamber and counter techniques. The objective of the experiment is to study the form of the weak interaction in this decay by measuring the up-down asymmetries of neutrinos, electrons and protons with respect to the lambda spin.

Polarized lambdas were produced in the reaction $\pi^- p \rightarrow \Lambda K^0$ below Σ threshold with a beam of momentum 1025±3 Mev/c incident on a liquid hydrogen target.[1] The momenta of electrons and protons from the beta decay were measured with a magnetic spectrometer consisting of optical spark chambers and counters (Fig. 1). The electrons were detected by scintillation counters and a threshold gas Cherenkov counter.[2] Scintillation counters and a water Cherenkov counter in anticoincidence detected the protons. The times-of-flight measured for both particles, when combined with momenta, aid identification of the beta decay. To achieve a practical event rate we made no attempt to detect the K^0. We determine the plane of production from the lambda decay vertex and the beam pion. This enables us to measure the up-down asymmetries in the laboratory system and reconstruct the lambda center of mass.

The events were photographed in 90° stereo by two 35 mm cameras[3] and the time-of-flight information, displayed on two four-gun CRT's, was recorded by a third camera. Each roll of film contains 3500 frames taken with a lambda beta trigger and 500 frames with the gas Cherenkov counter not required in the trigger logic. This assures us of an event ratio $\Lambda p\pi/\Lambda\beta > 10$. We collected an average of 1500 frames per lambda beta event. The frames were scanned for vees having topologies required by the trigger with vertices in the fiducial volume; 20% of the frames satisfied this criterion. To eliminate a possible source of background, we made the fiducial volume for decay free of spark chamber plates.

Most of the vees are electron-positron pairs, and we reject 95% of the pairs without digitizing the spark chamber pictures. The time-of-flight provides a rejection factor ≈ 8 by eliminating events with fast positive particles $(v \approx c)$ (Fig. 2a). In addition, we exclude events with positive momenta < 250 Mev/c, which is well below the low momentum cut-off for protons. The remaining ≈ 40 candidates per event are digitized, reconstructed in space and fit for momentum. Subsequent analysis shows that the composition of a typical sample of candidates per one lambda beta event is: 15 pairs, 12 vees with vertices outside the fiducial volume or with non-intersecting tracks, 12 $\Lambda p\pi$ events, and less than one K^{o}_{e3}. We impose a cut based on electron-positron invariant mass (Fig. 2b) combined with a more precise velocity determination to reduce the pairs to $< .01$ at a loss of $< .02$ lambda beta events. Knowing the electron trajectory we use aperture, focussing and timing properties of the electron

Cherenkov counter to reduce the $\Lambda p\pi$ events to $<$ 0.8 . Kinematic analysis with a $\Lambda p\pi$ hypothesis provides additional rejection based on invariant lambda mass, missing kaon mass, transverse momentum (Fig. 3a, b) and π^- time-of-flight (Fig. 2c). As a result, the $\Lambda p\pi$ background is reduced to $<$ 0.1 at a loss of $<$ .05 lambda beta events. The difference between π^+ and proton time-of-flight reduces the K^o_{e3} background to $<$ 0.01. We searched for other sources of background by lowering the beam momentum below the threshold for lambda production. No simulated events have been found in sufficient data to yield sixteen lambda beta events at nominal beam momentum. We conclude that our present sample of 110 events contains less than: 10 $\Lambda p\pi$, two electron-positron pairs and one K^o_{e3}.

The lambda beta events are subjected to further analysis. We compute the momentum components of neutrino, electron and proton along the normal to the production plane and form up-down correlations with the lambda spin. In addition, we transform the events to the lambda center of mass. This transformation has two acceptable solutions for one-third of our data. Among the quantities derived from the center of mass reconstruction are the proper lifetime and beta spectrum shown in Fig. 3c, d. We use the triggered $\Lambda p\pi$'s to verify the accuracy of our event reconstruction and obtain rms errors of 5 Mev/c^2 in lambda mass, 9 Mev/c^2 in missing kaon mass and 13 Mev/c in transverse momentum. The same events measure the lambda polarization P = 0.87 ± 0.08 and the branching ratio R = $0.79^{+0.17}_{-0.09} \times 10^{-3}$.[5]

In this type of experiment it is essential to know the inherent up-down symmetry of the apparatus. Our apparatus is designed to be symmetric with respect to the midplane. We use pairs to verify this symmetry for electron detection and πp scattering events for proton detection. This test shows that the asymmetry for particle detection is $< .03$. The two-body lambda decays provide another check of symmetry from the comparison of events with spin projection up or down relative to the midplane. We find that $(\alpha P)_{up} = 0.56 \pm 0.10$ and $(\alpha P)_{down} = 0.55 \pm 0.06$. The lambda beta asymmetries also show no bias with respect to spin orientation.

Approximately one-fifth of our data has been analyzed. The up-down asymmetries[6] from the present sample of lambda beta events are neutrino asymmetry $A_{\nu} = 0.75 \pm 0.22$ electron asymmetry $A_e = 0.17 \pm 0.22$ and proton asymmetry $A_p = -0.42 \pm 0.22$. Interpreting these asymmetries in the framework of a V, A interaction generalized to strange particle decays by Cabibbo[7], we find that $g_1/f_1 = 0.35 {}^{+.27}_{-.14}$ in some disagreement with the SU(3) prediction of $g_1/f_1 = .74$[9] and with the world average $g_1/f_1 = .83 \pm .18$.[4] The magnitude of the world average g_1/f_1 is determined by the electron-neutrino correlation obtained from unpolarized lambda decays;[10] the sign, by the asymmetry of electrons from decays of polarized lambdas[11]. The electron asymmetry in our experiment agrees with these measurements. The electron-neutrino correlation obtained by reconstructing our events in the center of mass is $A_{e\nu} = -0.3 \pm 0.3$, also in agreement with existing data. The lower value of g_1/f_1 in our experiment is attributable to the neutrino up-down asymmetry.[12] The agreement between our results and a V - A description of strange particle decays can be improved by introducing large induced terms into the interaction.[13]

FIGURE CAPTIONS

Fig. 1. Plan view of Experimental Apparatus.

Event trigger = neutral production · electron · proton,

neutral production = $\overline{C1} \cdot 1 \cdot 2 \cdot 3 \cdot \bar{4} \cdot \bar{T}$,

electron = E(only one) · C2,

proton = P1 · P2 · P3 · $\overline{C3}$

Fig. 2. (a) Proton-pion time-of-flight difference.

(b) Electron-positron invariant mass.

(c) Electron-pion time-of-flight difference.

Fig. 3. (a) Scatter plot of invariant lambda mass vs. missing kaon mass ($\Lambda p \pi$ hypothesis) for lambda beta events. The one and two standard deviation contours for analyzed $\Lambda p \pi$ events are indicated.

(b) Spectrum of transverse neutrino momentum for lambda events. The missing transverse momentum for analyzed $\Lambda p \pi$ events is also shown.

(c) Distribution of proper lifetime for lambda beta events. The neutral production requirement suppresses short-lived lambdas.

(d) The electron spectrum in the lambda center of mass.

REFERENCES AND FOOTNOTES

1. J.A. Anderson, F.S. Crawford, B.B. Crawford, R.L. Golden, L.J. Lloyd, G.W. Meisner, and L.R. Price, Proceedings of the 1962 Annual International Conference on High Energy Physics at CERN (CERN, Geneva, 1962) p. 271; and J. Keren, Phys. Rev. 133, B457 (1964).

2. H. Hinterberger, L. Lavoie, B. Nelson, R.L. Sumner, J.M. Watson, R. Winston, and D. M. Wolfe, Rev. Sci. Instr. 41, 413 (1970).

3. T.A. Romanowski, E.R. Hayes, J. Terandy, and K. Reibel, Nuclear Instr. and Meth. 73, 117 (1969).

4. We use $\alpha = .645 \pm .016$. "Review of Particle Properties," Particle Data Group, Rev. Mod. Phys. 42, 87 (1970).

5. $R = .85 \pm .07 \times 10^{-3}$. Ibid.

6. These asymmetries are not statistically independent. Our analysis uses the three independent up-down asymmetries obtained by categorizing each event in one of the six possible combinations of pairs of momenta along and against the spin.

7. N. Cabibbo, Phys. Rev. Letters 10, 531 (1963).

8. Our asymmetries indicate $f_2/f_1 = 0.8 \pm 1.8$ provided weak magnetism is the only relevant induced term. The sign of g_1/f_1 is opposite to that for the non-relativistic g_A/g_V; e.g., $g_1/f_1 = 1.25$ for neutron beta decay. The decay interaction in this notation is given, for example, in J.M. Watson and R. Winston, Phys. Rev. 181, 1907 (1969); D.R. Harrington, Phys. Rev. 120, 1482 (1960); P.S. Desai, Phys. Rev. 179, 1327 (1969).

9. H. Filthuth, Topical Conference on Weak Interactions, CERN, Geneva, 1969.

References and Footnotes (continued)

10. C. Baglin, V. Brisson, A. Rousset, J. Six, H.H. Bingham, M. Mikolic, K. Schultze, C. Henderson, D.J. Miller, F.R. Stannard, R.T. Elliot, L. K. Rangan, A. Haatuft, and K. Myklebost, Nuovo Cimento 35, 977 (1965); R.P. Ely, G. Gidal, G.E. Kalmus, W.M. Powell, W.J. Singleton, C. Henderson, D.J. Miller, F.R. Stannard, Phys. Rev. 137, B1302 (1965); J.E. Maloney and B. Sechi-Zorn, Phys. Rev. Letters 23, 425 (1969); and R. Loveless, J. Canter, J.A. Cole, J. Lee-Franzini, and P. Franzini, Bull. Am. Phys. Soc. 14, 519 (1969).

11. V. G. Lind, T.O. Binford, M.L. Good, and D. Stern, Phys. Rev. 135, B1483 (1964); J. Barlow, I.M. Blair, G. Conforto, M.I. Ferrero, C. Rubbia, J.C. Sens, P.J. Duke, and A.K. Mann, Physics Letters 18, 64 (1965); and K.H. Althoff, T. Andersson, R.M. Brown, D. Freytag, K.S. Heard, J. Heintze, R. Mundhenke, H. Rieseberg, V. Soergel, H. Stelzer, and A. Wagner, (unpublished).

12. Recent results from the CERN-Heidelberg group are: $A_e = 0.10 \pm 0.10$, $A_p = -0.56 \pm 0.10$, (private communication).

13. Indications that large induced terms may be required, are discussed by R. Oehme, R. Winston and A. Garcia, EFI Report 70-31 (unpublished).

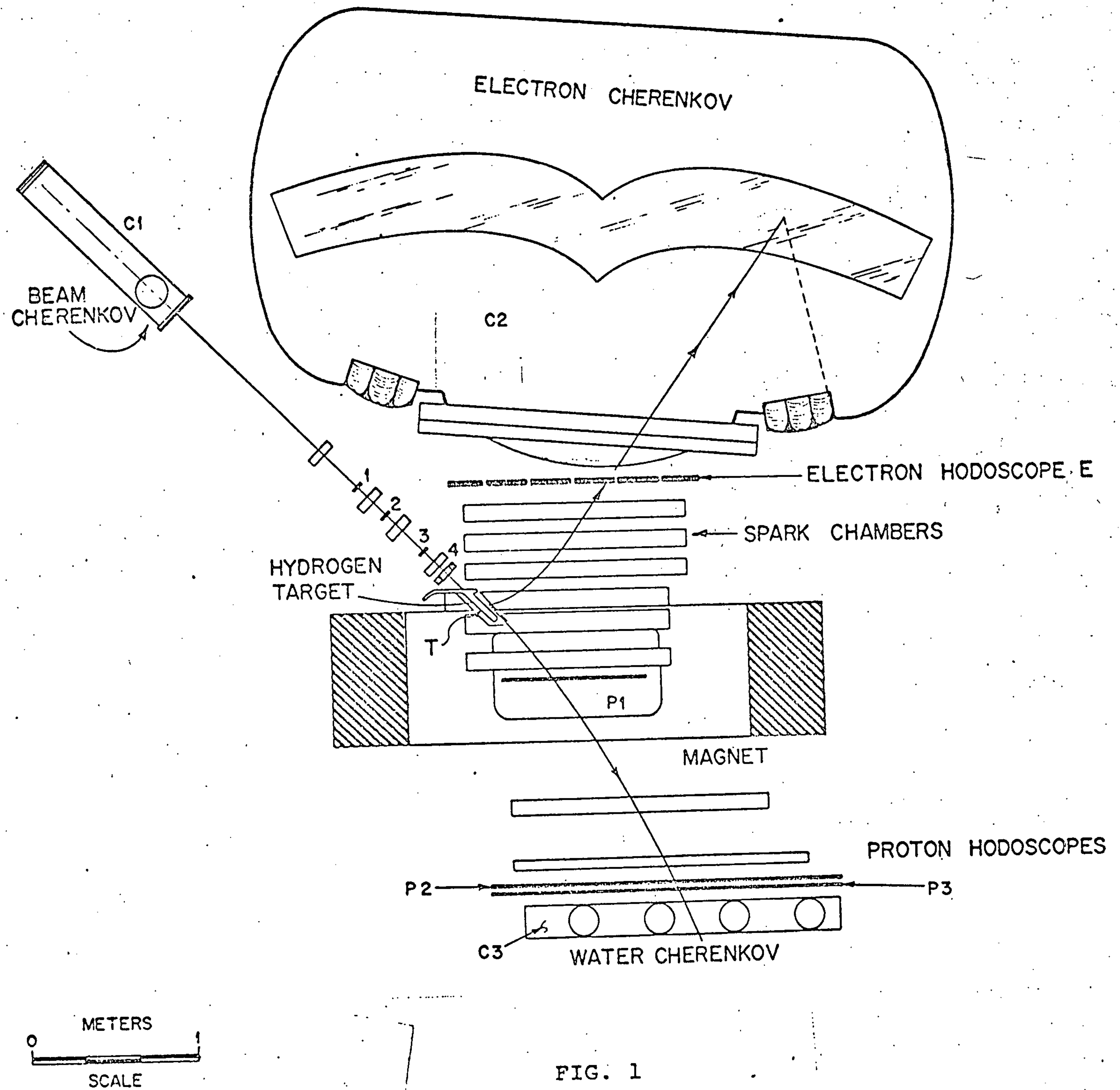

ELECTRON CHERENKOV
C1
BEAM
CHERENKOV
C2
ELECTRON HODOSCOPE E
1
2
3
4
SPARK CHAMBERS
HYDROGEN
TARGET
T
P1
MAGNET
PROTON HODOSCOPES
P 2
P3
C3
WATER CHERENKOV
METERS
0
1
SCALE

FIG. 1

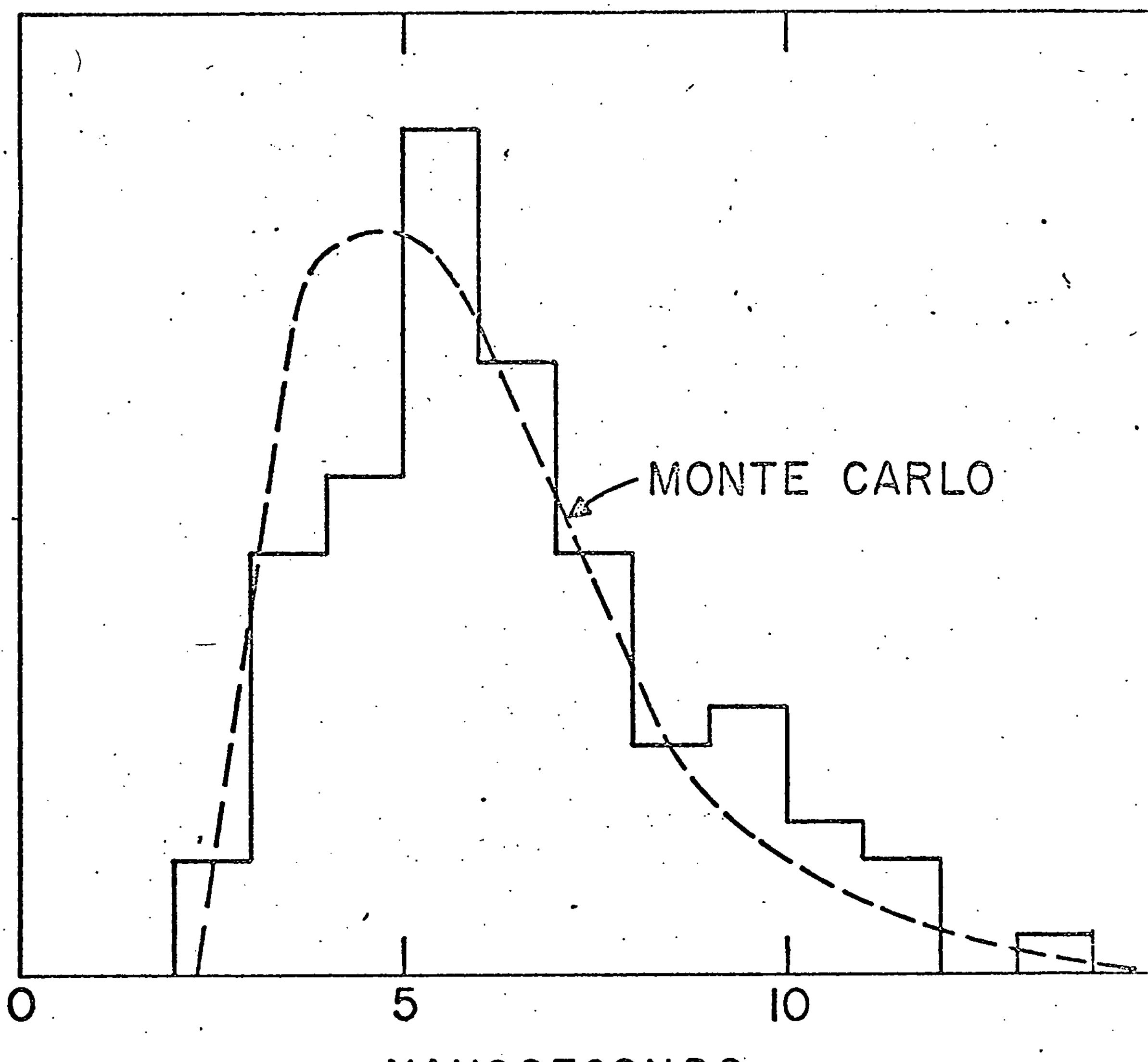


FIG. 2 (a)
p-π^+ TIME-OF-FLIGHT DIFFERENCE

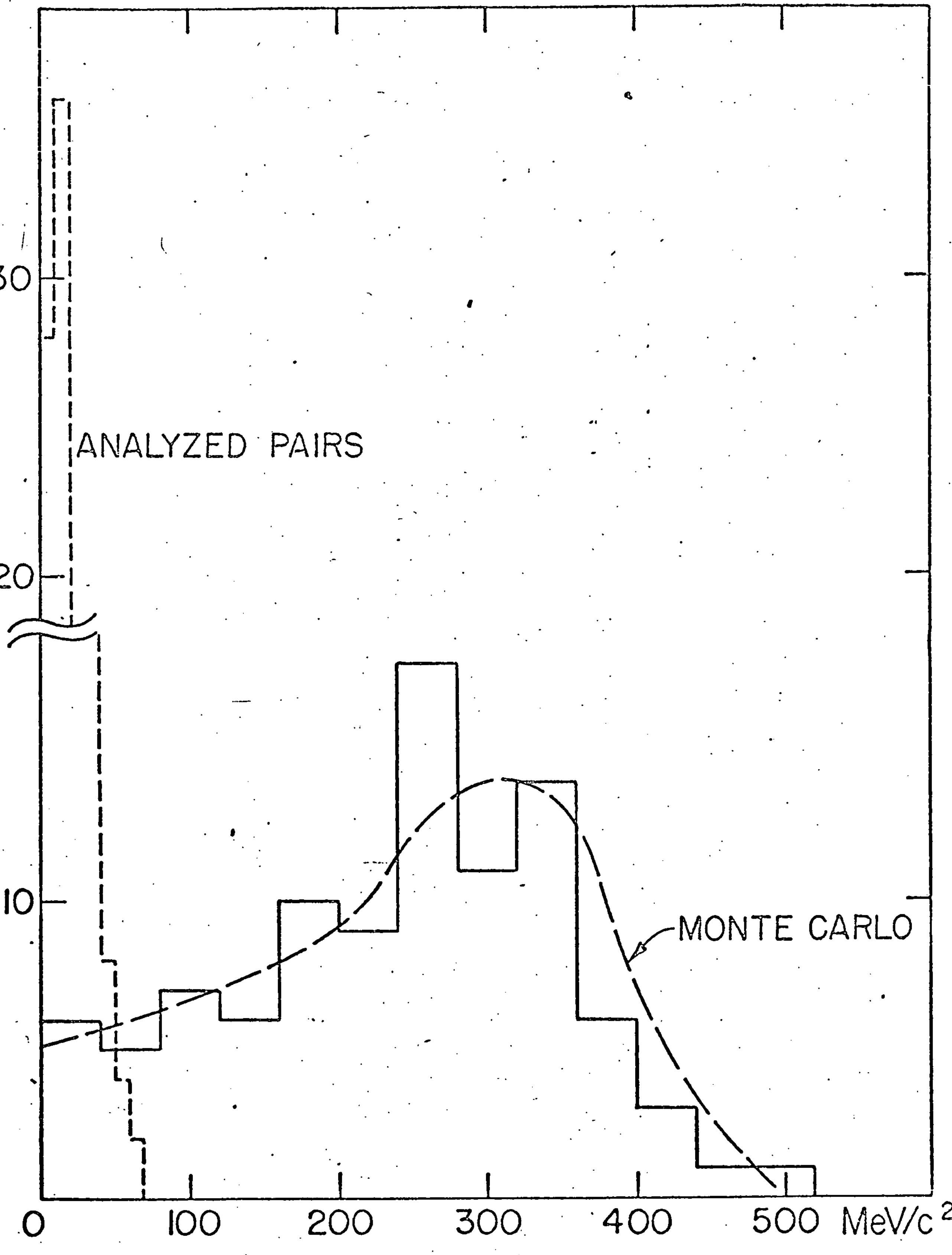


FIG. 2 (b) PAIR MASS

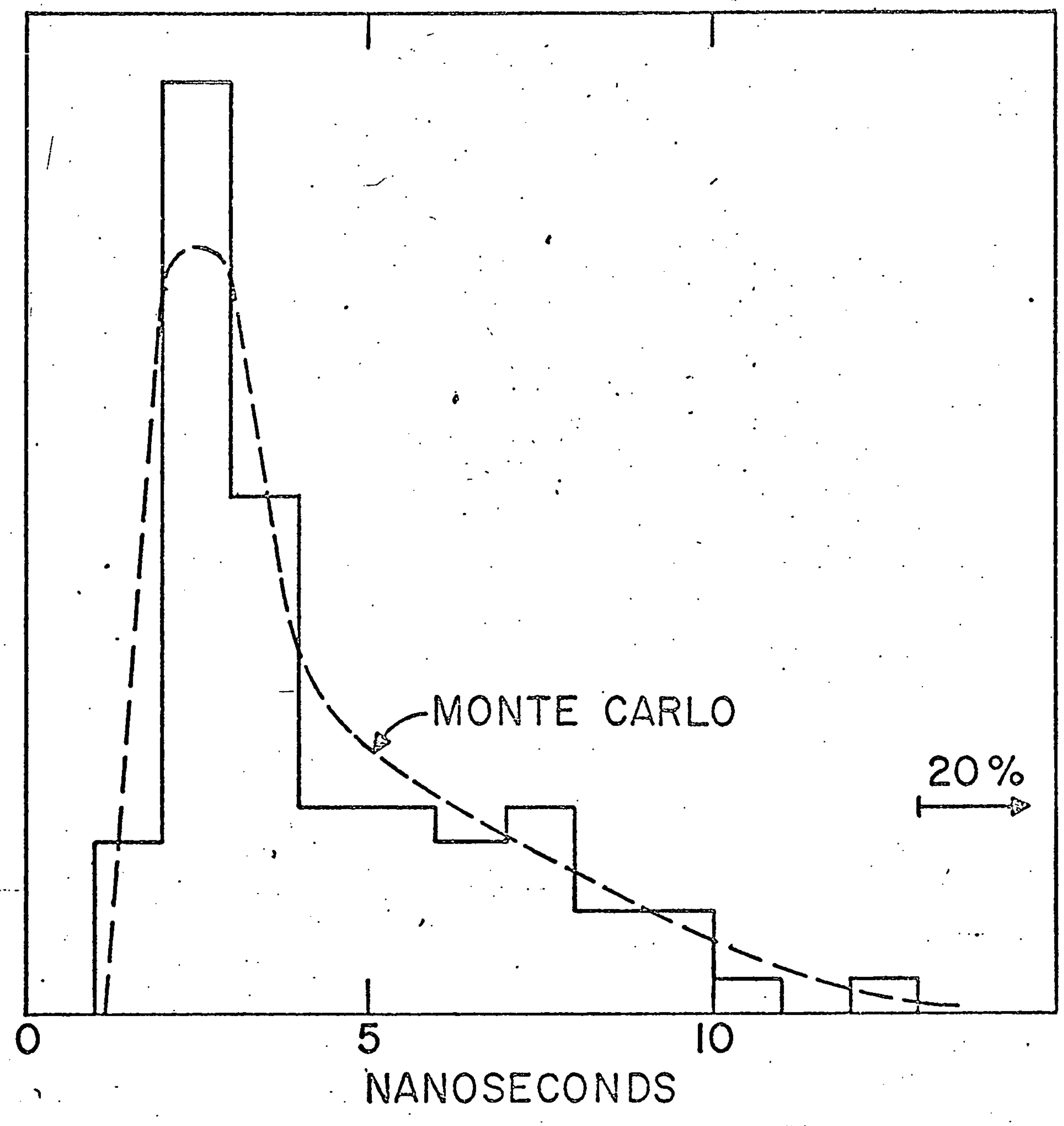
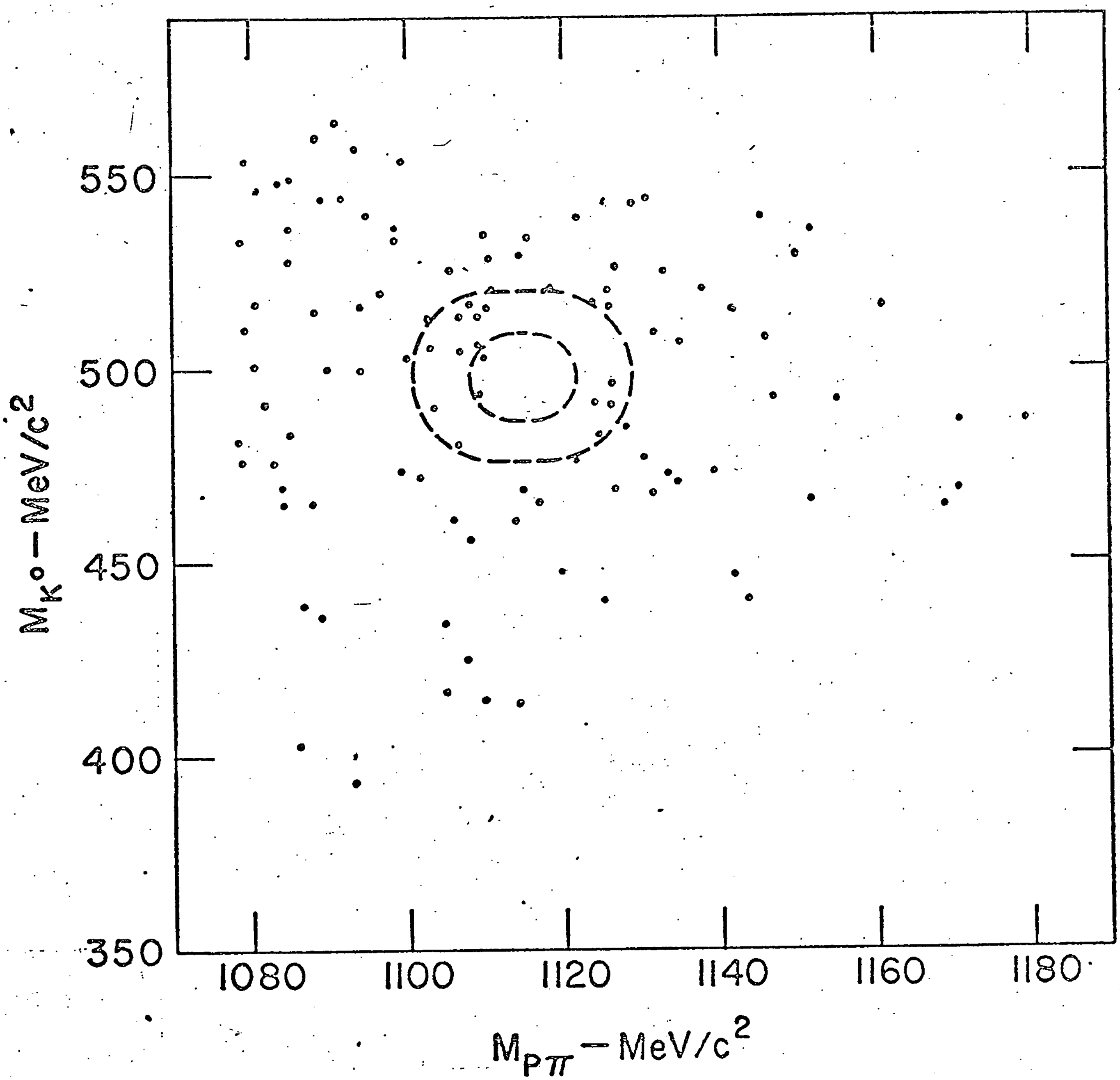


FIG. 2(c)

e - π⁻ TIME-OF-FLIGHT DIFFERENCE



550
500
450
400
350
1080
1100
1120
1140
1160
1180
M_{K^o} — MeV/c²
$M_{P\pi}$ — MeV/c²

FIG. 3 (a)

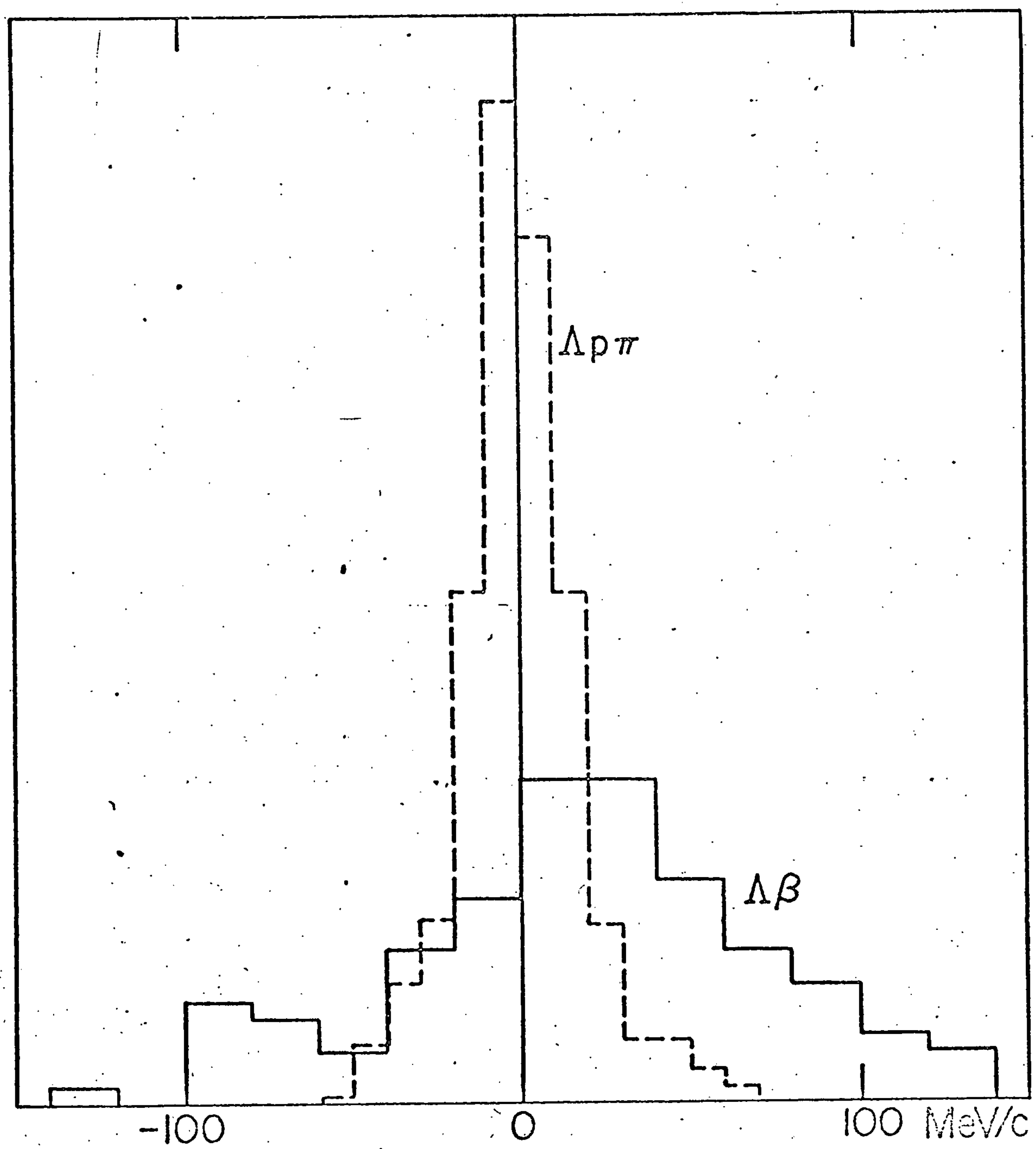
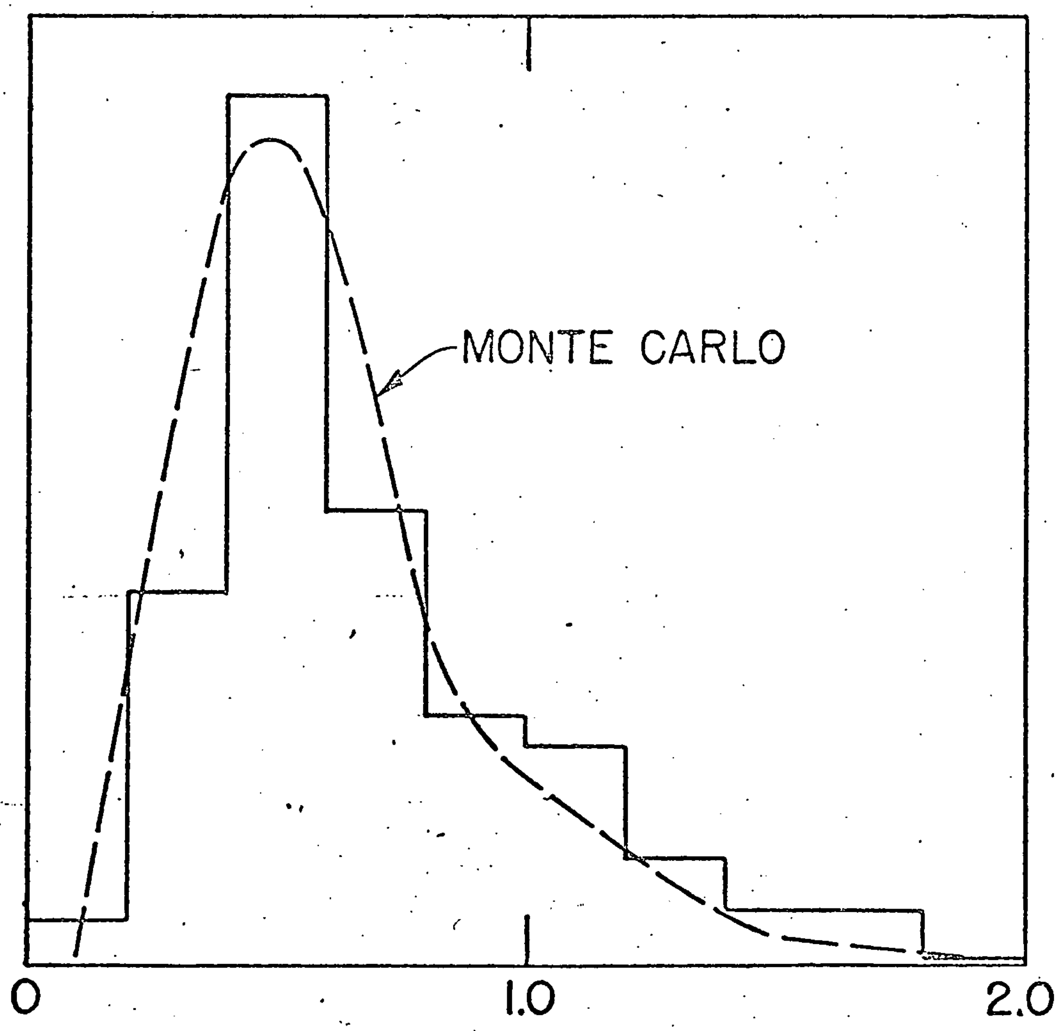


FIG. 3(b) NEUTRINO TRANSVERSE MOMENTUM



NANOSECONDS

FIG. 3(c) LAMBA LIFETIME

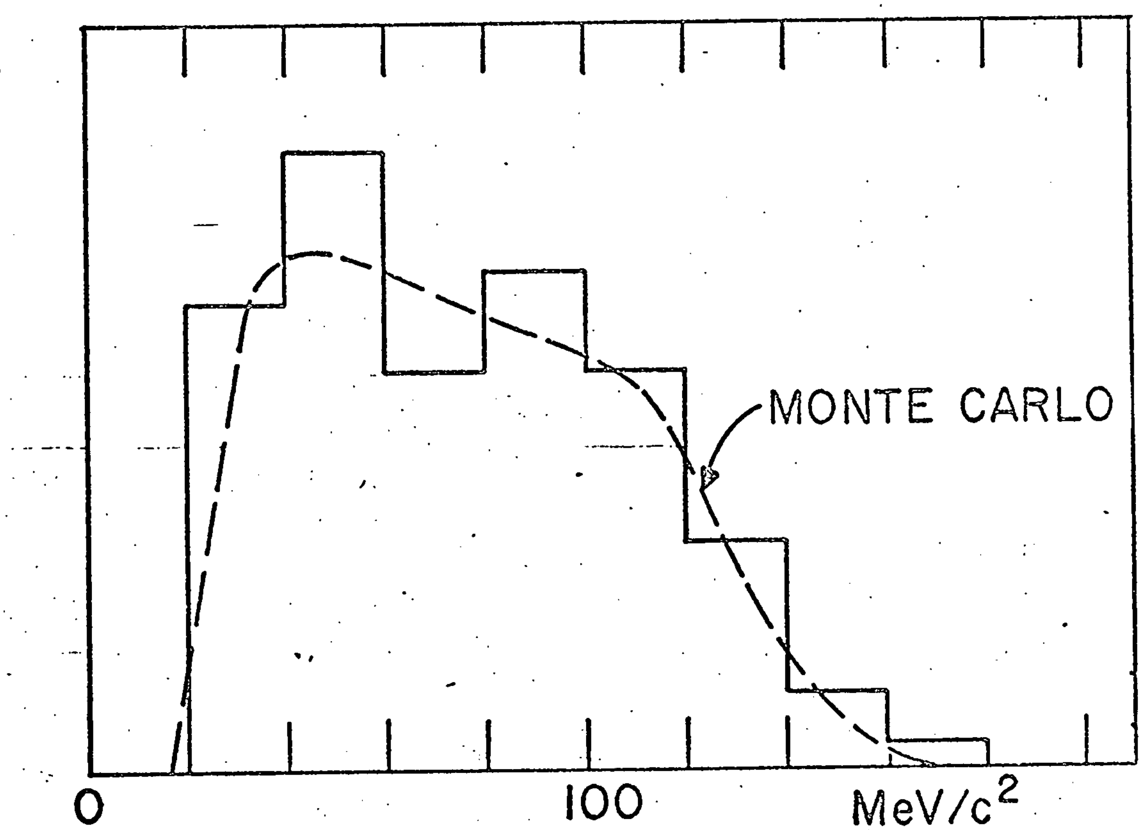


FIG. 3 (d)

ELECTRON ENERGY (c.m.)

Form AEC–427
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