LA-3780-MS

MASTER

324
12-18-67

LOS ALAMOS SCIENTIFIC LABORATORY
of the
University of California
LOS ALAMOS • NEW MEXICO

Experimental Determinations of Half-Lives
or Mean Lives of Free Pions and Muons:
A Literature Search

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in the United States of America. Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151

Price: Printed Copy \$3.00; Microfiche \$0.65

LOS ALAMOS SCIENTIFIC LABORATORY
of the
University of California
LOS ALAMOS • NEW MEXICO

Report written: July 26, 1967

Report distributed: November 27, 1967

**Experimental Determinations of Half-Lives
or Mean Lives of Free Pions and Muons:
A Literature Search**

Compiled by

Jean Furnish

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

EXPERIMENTAL DETERMINATIONS OF HALF-LIVES OR MEAN LIVES OF FREE PIONS AND MUONS: A LITERATURE SEARCH

INTRODUCTION

NUCLEAR SCIENCE ABSTRACTS, vol. 5 (1951) through vol. 21 no. 12 (June 30, 1967) was searched for abstracts relating to experimental determinations of half-lives or mean lives of free pi-mesons and mu-mesons. The abstracts are arranged in rough chronological order by year with the most recent given first.

1.

5353 MEAN LIFE OF THE π^0 MESON. Stamer, P.; Taylor, S.; Koller, E. L.; Huetter, T.; Grauman, J.; Pandoulas, D. (Stevens Inst. of Tech., Hoboken, N. J.). Phys. Rev., 151: 1108-16 (Nov. 25, 1966).

An estimate of the π^0 mean lifetime was obtained from a sample of 232 $K^+ \rightarrow \pi^+ + \pi^0$ decays at rest. The π^0 's were detected by the Dalitz mode ($\pi^0 \rightarrow e^+ + e^- + \gamma$), and the decay distances from the K^+ ending to the π^0 decay points were measured. These events were found in an area scanning of an emulsion stack of 600- μ m Ilford G5 emulsion pellicles exposed to a 400 MeV/c separated K^+ beam. The observed mean π^0 lifetime is $(1.0 \pm 0.5) \times 10^{-16}$ sec. (auth)

2.

11748 INSTRUMENTATION FOR STUDYING π^+ -MESON PHOTOPRODUCTION. Aleksandrov, Yu. M.; Grushin, V. F.; Zapevalov, V. A.; Leikin, E. M. Tr. Fiz. Inst., Akad. Nauk SSSR, 34: 213-19(1966). (In Russian).

In investigating the reaction $\gamma + p \rightarrow \pi^+ + n$ with 230 MeV gamma quanta, there is a kinematic relation between the energy of the gamma quantum and the angle of emission of the π -meson. The problem can be resolved by counting only the π^+ -mesons emitted at a given angle with a definite energy. A scintillation counter with a small inlet aperture can be used for counting the π^+ -mesons. Magnetic analysis and measuring the range in a substance can be used to determine the energy of the π^+ -mesons. The π^+ -mesons can also be identified from the $\pi \rightarrow \mu$ -transition, which takes place with a characteristic time $\tau_\pi = 2.55 \times 10^{-8}$ sec. The pulse from the π^+ meson and the pulse from the μ^+ meson are counted in coincidence to detect the π^+ mesons. About 10^3 positrons per π^+ meson are present as background after passing the beam through a magnet. An anticoincidence scheme eliminated most of the positron interference because of the difference in ranges of the positrons and π^+ mesons. A triple coincidence scheme was used to detect the $\pi^+ \rightarrow \mu$ -decay. A diagram of the electronic arrangement is presented. The lifetime of the π^+ meson was determined from a plot of N_μ as a function of the time shift in the gate pulse. (TTT)

3.

18892 MEAN LIFE OF THE π^0 MESON. Stamer, Peter Eric. Hoboken, N. J., Stevens Inst. of Tech., 1966. 42p. Thesis.

An estimate of the π^0 mean lifetime was obtained from a sample of 232 $K^+ \rightarrow \pi^+ + \pi^0$ decays at rest. The π^0 's were detected by the Dalitz mode ($\pi^0 \rightarrow e^+ + e^- + \gamma$), and the decay distances from the K^+ ending to the π^0 decay points were measured. These events were found in an area scanning of an emulsion stack of 600- μ m Ilford G5 emulsion pellicles exposed to a 300 MeV/c separated K^+ beam. The observed mean π^0 lifetime is $(1.0 \pm 0.5) \times 10^{-16}$ sec. (Dissertation Abstr.)

4.

2714 A NEW MEASUREMENT OF THE LIFETIME OF THE POSITIVE PION. Eckhause, M.; Harris, R. J. Jr.; Shuler, W. B.; Siegel, R. T.; Welsh, R. E. (College of William and Mary, Williamsburg, Va.). Phys. Lett., 19: 348-50(Nov. 1, 1965).

The lifetime of the positive meson (π) was measured by a digital timing technique for mesons (π) stopped in a plastic scintillation counter. This method permits improvement in precision by more than an order of magnitude over previous measurements. The counter arrangement is shown. Mesons (π) were brought to rest in a counter at the rate of 250/sec. A second scintillation counter for counting mesons (μ) was optically separated from the π counter by a thin sheet of aluminized plastic. A large fraction of mesons (μ) from the mesons (π) decaying in the π counter penetrated into the μ counter. Thus the meson (π) stop signal and the meson (μ) decay signal occurred in different counters, permitting measurement of the time interval for each decay event by means of a 100 Mc digital time analyzer. About 2.5×10^6 events with time intervals between 40 and 250 nsec after the meson (π) stop signal were used in the analysis. The weighted mean of 15 runs yielded a value of 26.1 ± 0.02 nsec for the mean lifetime of the positive meson (π). (J.F.P.)

5.

7806 WEAK INTERACTIONS. Lee, T. D.; Wu, C. S. (Columbia Univ., New York). *Ann. Rev. Nucl. Sci.*, 15: 381-476(1965).

A critical and comprehensive survey of the theoretical aspects of weak interactions is presented in general discussions on exact symmetry properties, the effective lagrangian and its selection rules, and the possible existence of the intermediate boson. Experiments and phenomenological analysis dealing with leptonic reactions in beta decay, muon decay, muon capture, and pion decays are discussed. (L.B.S.)

6.

9732 PRIMAKOFF EFFECT AND π^0 LIFETIME. Bellettini, G. (Univ., Pisa); Bemporad, C.; Braccini, P. L.; Foa, L. *Nuovo Cimento* (10), 40A: 1139-70(Dec. 21, 1965).

The results of an experiment to measure the π^0 lifetime via the inverse decay process (Primakoff effect) are presented. The coherent photoproduction of neutral pions in the reaction $\gamma + \text{Pb} \rightarrow \pi^0 + \text{Pb}$ was measured with very high angular resolution with a π^0 detector containing 10 independent counting channels, at the two mean energies 950 and 1000 Mev, using the bremsstrahlung beam of the Frascati electron synchrotron. The angular distributions show a characteristic bumping around the forward direction, giving conclusive evidence for the existence of the Primakoff effect. The results are interpreted in terms of two amplitudes—the electromagnetic and the nuclear one—adding up coherently to give the over-all coherent cross section. Such a cross section is expressed in terms of four unknown parameters: the lifetime τ , the phase δ between the electromagnetic and nuclear amplitude, the strength C of the nuclear amplitude, and the nuclear radius R_0 . Neutral-pion reabsorption inside nuclear matter is taken into account, and a χ^2 analysis of the data is done in terms of τ , δ , C , and R . The best fit τ value is $(0.73 \pm 0.105) \cdot 10^{-16}$ sec. Systematic errors, as well as the sensitivity of the results to the model used to interpret the data, are extensively discussed and conservatively taken into account. (auth)

7.

17346 (JINH-P-2534) IZMERENIE VREMENI ZHIZNI π^+ -MEZONA. (Measurement of π^+ Meson Lifetime). Dunaitsev, A. F.; Pikhtev, R. N.; Prokoshkin, Yu. D.; Simonov, Yu. N. (Joint Inst. for Nuclear Research, Dubna (USSR). Lab. of Nuclear Problems). 1965. 12p. Dep. mn.

The mean lifetime of the π^+ meson is measured by the method which is not affected by the background due to the accompanying $\mu^+ \rightarrow e^+$ decay. The stoppings and decay of π^+ mesons were detected by a system of scintillation counters. The pulses from all the counters were displayed on the screen of a high-speed five-ray oscilloscope. A time and height pulse analysis of about 17 thousand oscillograms gave the mean value for the π^+ lifetime to be $\tau_{\pi^+} = (25.85 \pm 0.35)\text{ns}$. The main difference of this method from those applied earlier is that it employed a "trap" for positrons appearing in $\mu^+ \rightarrow e^+$ decay, what allowed to decrease this background by more than two orders of magnitude. (auth)

8.

19451 (UR-875-126, Paper 3) A MEASUREMENT OF THE LIFETIME OF THE POSITIVE PION. Kinsey, K. F.; Lobkowicz, L.; Nordberg, M. E. Jr. (Rochester Univ., N. Y. Dept. of Physics and Astronomy). 11p.

The decay of about 10^8 positive pions was measured. Diagrams are given showing the counter array and electronic apparatus used in the measurement. The mean of the best values obtained was 26.41 sec. (M.O.W.)

9.

21665 MEASUREMENT OF THE LIFETIME OF THE POSITIVE PION. Kinsey, K. F.; Lobkowicz, F.; Nordberg, M. E. Jr. (Univ. of Rochester, N. Y.). Contract AT(30-1)-875. *Phys. Rev.*, 144: 1132-7(Apr. 29, 1966). (UR-875-112).

Using fast electronic techniques, the π^0 decay sequence for about 10^8 stopped positive π -mesons was observed. The exponential decay of the π can be followed for 8 mean lives, and yields a value of $\tau_{\pi^+} = 26.40 \pm 0.08$ nsec. This value disagrees with previously reported values. (auth)

10.

24052 COMPARISON OF PION AND ANTIPION LIFETIMES. Bardon, M.; Dore, U.; Dorf, D.; Krieger, M.; Lederman, L.; Schwarz, E. (Columbia Univ., New York). *Phys. Rev. Lett.*, 16: 775-9(Apr. 25, 1966).

Measurements of the ratio of π^+ to π^- lifetimes are presented. The method is based upon the detection of π - μ decays in flight for pion beams of ~ 120 Mev/c. (B.G.D.)

11.

27925 EXPERIMENTAL EVIDENCE FOR THE EXISTENCE OF THE PRIMAKOFF EFFECT AND A NEW MEASUREMENT OF THE π^0 LIFETIME. Bellettini, G. (Univ., Pisa); Bemporad, C.; Braccini, P. L.; Foa, L. pp 217-22 of Proceedings of the International Symposium on Electron and Photon Interactions at High Energies. Vol. II. Hamburg, Deutsche Physikalische Gesellschaft e. V., 1966.

The coherent photoproduction of mesons (π^0) on lead around the forward direction was investigated. Evidence for the existence of the Primakoff effect was obtained, and a value for the lifetime of the meson (π^0) was determined from the magnitude of the effect. (D.C.W.)

12.

34217 MESON MASSES AND DECAYS. Yellin, Joel (Univ. of Chicago). *Phys. Rev.*, 147: 1080-93 (July 29, 1966). (COO-264-278; EFINS-65-79).

The masses, decay rates, and decay spectra of the octet of 0^- mesons, the nonet of 1^- mesons, the $X(960)$ resonance, and a proposed $\eta^*(1620)$ resonance having the quantum numbers of $\eta(550)$ are considered. Spin-unitary-spin symmetry and nonet symmetry are used so that the mesons fall into 36 states, combining an $SU(6)_1$ with an $SU(6)_{35}$. Further, the strength of the couplings of the $SU(3)$ octets in the 36 with respect to the $SU(3)$ singlets is fixed by assuming that the form of the coupling remains unchanged when the singlet states are included. After making a particular choice of Hamiltonian the masses and the decay rates are predicted, using as input the masses of the octet of 0^- mesons and (M_ρ, M_ω) . These predictions are in reasonable agreement with presently existing experimental data. Related meson decays using the above scheme to eliminate the arbitrariness in the relative coupling strength of the singlet states are also discussed. The model of Gell-Mann, Sharp, and Wagner was used and invariant-mass spectra for the three-body decays are given. (auth)

13.

39760 (JINR-P-2802) IZMERENIE OTNOSHENIYA VREMEN ZHIZNI π^+ -I π^- -MEZONOV. (Measurements of Half-Life Ratio of π^+ and π^- Mesons). Komarov, V. I.; Petrukhin, V. I.; Savchenko, O. V. (Joint Inst. for Nuclear Research, Dubna (USSR). Lab. of Nuclear Problems). 1966. 12p. Dep. mn.

The lifetime ratio of π^+ and π^- mesons was measured in order to determine CPT invariance of the weak interaction responsible for pion decay. An isotropic discharge helium or neon chamber was used for recording 15 Mev pion decay. The results of the first series of photographs showed the magnitude $[t(\pi^+)/t(\pi^-)] = 0.98 \pm 0.08$. (tr-auth)

14.

39821 MEASUREMENT OF π^+ -MESON LIFETIME. Dunaitsev, A. F.; Pikhtev, R. N.; Prokoshkin, Yu. D.; Simonov, Yu. N. (Joint Inst. for Nuclear Research, Dubna, USSR). *Yadern. Fiz.*, 4: 105-9 (July 1966). (In Russian).

The mean lifetime of the meson (π^+) was measured by a method in which the influence of the background due to the accompanying $\mu^+ \rightarrow e^+$ decay is excluded. The measured lifetime is equal to 25.85 ± 0.35 nsec. (auth)

15.

41884 PRECISE MEASUREMENTS OF THE K^+/K^- AND π^+/π^- LIFETIME RATIOS. Lobkowitz, F. (Univ. of Rochester, N. Y.); Melissinos, A. C.; Nagashima, Y.; Tewksbury, S.; von Briesen, H. Jr.; Fox, J. D. *Phys. Rev. Lett.*, 17: 548-52 (Sept. 5, 1966). (UR-875-152).

An experiment to measure the ratio $\tau(K^+)/\tau(K^-)$ is described. As a check on the experimental procedure the lifetime ratio of the π mesons was also measured. (B.G.D.)

16.

41891 COMPARISON OF THE LIFETIMES OF POSITIVE AND NEGATIVE PIONS. Ayres, David S. (Univ. of California, Berkeley); Eandi, Richard D.; Greenberg, Arthur S.; Kenney, Robert W.; Kurz, Richard J.; MacDonald, Burns; Caldwell, David O.; Stearns, Brenton F. pp 419-25 of *Proceedings of the Williamsburg Conference on Intermediate Energy Physics*. Vol. I. Williamsburg, Va., College of William and Mary, 1966.

An experiment for measuring the total lifetime of positive and negative mesons (π) and the ratio of these lifetimes is described. The lifetime measurement for the negative mesons (π^-) in flight is performed, and the positive (π^+) lifetimes are determined by measuring the attenuation due to decay as a function of distance of nearly identical beams of mesons (π^+) and (π^-). The results are 26.26 ± 0.08 nsec for mesons (π^+) and 25.80 ± 0.21 for mesons (π^-) lifetimes. (J.F.P.)

17.

1382 ON THE LIFETIME OF THE NEUTRAL π^- -MESON. D. A. Evans and J. H. Mulvey (Oxford Univ.). p.477-81 of "Proceedings of the Sienna International Conference on Elementary Particles. Vol. I." Bologna, Societa Italiana di Fisica, 1963.

A stack of Ilford L4 emulsions was exposed to a stopping K^+ beam at Berkeley. The K_{s1} decay of the K^+ , $K_{s1} \rightarrow \pi^+ + \pi^0$, was used to estimate the lifetime of the π^0 . A final sample of 58 events was measured, errors were estimated, and the flight distance of the π^0 was calculated. The final result was a lifetime of about 1.5×10^{-16} sec. This result is in agreement with other experiments. (A.G.W.)

18.

6555 MEAN LIFE OF THE NEUTRAL π MESON. Hla Shwe, Frances M. Smith, and Walter H. Barkas (Univ. of California, Berkeley). *Phys. Rev.*, 136: B1839-47 (Dec. 21, 1964).

The π^0 mean life is measured using a method that utilizes the relativistic flight-path dilation produced by a high pion velocity. A π^- beam of 3.5 Bev/c made interactions in Ilford K5 emulsion. Some 103 secondary neutral pions were observed to decay by the Dalitz mode ($\pi^0 \rightarrow e^+ + e^- + \gamma$) in a study of 3600 such stars. The π^0 path lengths could be accurately measured and were automatically calculated by specially developed equipment. The π^0 momentum spectrum is assumed to be the same as that of the secondary charged pions found by multiple-scattering measurements. The mean transverse momentum of secondary charged pions at all angles is 274 ± 10 Mev/c. The opening-angle distribution of the electron pairs was measured and compared with extensive calculations of the expected laboratory-system distribution in order to evaluate the number of unobserved events. A statistical approach is used to evaluate the mean life (τ_{π^0}) of the π^0 . To evaluate the complex effects of electron scattering, the finite grain size, and the random grain spacing, pairs of electron tracks were generated artificially by a Monte Carlo program and the results compared with the observations. The neutral-pion mean life is estimated as $(1.7 \pm 0.5) \times 10^{-16}$ sec. (auth)

19.

12248 THE LIFETIME OF THE MUON AND THE EXPERIMENTAL LIMITATION OF THE μ -e SYMMETRY. Leau-fu Lo (Inner Mongolian Univ., [China]); Tan Lu, and Kuo-shen Yang. Wu Li Hsueh Pao, 20: 1101-13(Nov. 1964). (In Chinese)

The μ -e symmetry is destroyed by the anomalous interaction. The influence of the anomalous interaction on the weak-processes is discussed, and the relation between the renormalization of the weak-interaction constant and such properties of the anomalous interaction as the charge independence and the γ_5 -transformation are analyzed. The renormalized constants are shown to be $G_V = G$, $G_A = \epsilon G$, $\epsilon = 1 + \delta$. This result is used to solve the difficulty which occurs when one uses the universal V-A Fermi weak-interaction theory and the conserved vector current hypothesis to explain the lifetime of the muon. Comparing the theory with various experiments, the result $\delta = 0.04$ is found, which may be interpreted as the experimental limitation of the μ -e symmetry. (auth)

20.

29011 PRECISION MEASUREMENTS ON THE MUON, MUONIUM, POSITRONIUM, AND HELIUM AS RELATED TO FUNDAMENTAL ATOMIC CONSTANTS. J. M. Bailey and V. W. Hughes (Yale Univ., New Haven). p.130-8 of "Nuclidic Masses." Vienna-New York, Springer-Verlag, 1964.

After a summary of the electromagnetic properties and lifetime of the meson(μ), calculations and measurements of the hfs intervals for hydrogen, muonium, and positronium and of the fine structure intervals of the 2^3P levels of helium are reviewed, together with a determination of the fine structure constant α from the hfs interval of muonium. (D.C.W.)

21.

41404 MEAN LIFETIME OF THE π^0 MESON. Evans, D. A. (Oxford Univ.). Phys. Rev., 139: B982-91(Aug. 23, 1965).

An experiment is described to measure the mean life of the π^0 meson using nuclear emulsions. The basic method was employed previously, viz., the determination of the flight distances of π^0 mesons produced at a unique velocity in the $K_{\pi 2}$ decay mode of the K^+ meson and decaying through the mode $\pi^0 \rightarrow \gamma e^+ e^-$. The coordinates of the grains composing the tracks in 67 such events were measured, and the flight distances of the π^0 s determined by geometrical reconstruction of the events. It was considered that an accurate estimation of the various errors involved was essential to the correct computation of the lifetimes, and such estimations were attempted. The effect of the presence of a certain type of spurious event upon the final results is demonstrated. The value for the mean lifetime obtained is $\tau_{\pi^0} = (1.6_{-0.5}^{+0.6}) \times 10^{-16}$ sec. (auth)

22.

45360 A MEASUREMENT OF THE π LIFETIME VIA THE INVERSE DECAY PROCESS. Bellettini, G. (Istituto Nazionale di Fisica Nucleare, Pisa, Italy; Università, Pisa, Italy); Bemporad, C.; Braccini, P. L.; Foa, L. Phys. Letters, 18: 333-8(Sept. 1, 1965).

The lifetime of the neutral meson (π) was measured by studying meson (π^0) photoproduction on a heavy nucleus. The basic principle is that around the forward direction the coherent photoproduction is more predominant than the incoherent production and that the amplitude for the coherent process contains together with a nuclear part, an electromagnetic part which describes neutral meson (π) photoproduction in the interaction of the incident photon with a virtual photon associated with the Coulomb field of the target nucleus. This process can be considered the inverse of the meson (π^0) disintegration into two photons, and the resulting cross section is inversely proportional to the meson (π^0) lifetime. The coherent photoproduction of neutral mesons (π) on lead around the forward direction was measured with an angular resolution of the order of $\pm 0.5^\circ$ using a meson (π^0) detector containing 10 independent counting channels. The lifetime obtained is $\tau^0 = (0.74 \pm 0.105) 10^{-16}$ sec. (J.F.P.)

23.

906 THE MEAN LIFE OF THE NEUTRAL π -MESON. Maung Hla Shwe. Thesis, Berkeley, Calif. Univ. of California, 1963. 71p.

The proper mean life of the neutral pion was measured by a new method, which utilizes a large relativistic time dilation. Negative pions of 3.5 Bev/c were allowed to make interactions in Ilford K5 nuclear research emulsions. From a total of 3600 interactions, 103 neutral pions were found, which decayed by the Dalitz mode $\pi^0 \rightarrow (e^+ + e^-) + \gamma$. The π^0 path lengths were accurately measurable and were automatically calculated by specially developed microscope equipment. The neutral-pion momentum spectrum was assumed to be the same as that of the secondary charged pions (which was found to be multiple scattering measurements). The mean transverse momentum of secondary charged pions at all angles is 274 ± 10 Mev/c. The opening angle distribution of the electron pairs was measured and compared with extensive calculations of the expected laboratory distribution in order to evaluate the number of unobserved events. A statistical approach was used to evaluate the mean life, τ_{π^0} , of the neutral pion. The maximum likelihood estimate is $\tau_{\pi^0} = 2.0_{-0.3}^{+0.4} \times 10^{-16}$ sec. Systematic errors were carefully eliminated, and their residual effect is thought to be small. The significance of the measured π^0 mean life for various theories is reviewed. (Dissertation Abstr.)

24.

2585 (ISS-63/37) RELAZIONE SULL'ATTIVITÀ DEI REPARTI 1° E 2° DEI LABORATORI DI FISICA (SOTTOSEZIONE "SANITA" ASSOCIATA ALL'INFN) NEL 1962-63. (Progress Report of the Sanità Subsection of the INFN During the Period 1962-63). (Italy. Istituto Superiore di Sanità, Rome). June 18, 1963. 27p.

Research dealt with meson(π^0) photoproduction, the lifetime of mesons (π^+) in flight, neutron spectra following meson(π^-) absorption at rest in nuclei, fluorescence yield and coherent scattering in the interaction of 662-kev gamma rays with bound electrons, and the interaction of positrons at rest with matter. Technological development included techniques for high precision measurements of radioactivity, an acoustic spark chamber, and equipment for nuclear physics and for track chamber scanning. Numerical tables of the kinematics of multiple meson photoproduction were calculated, and programs were prepared for the IBM 7040 computer. (D.C.W.)

25.

4428 (BNL-809) MUON BIBLIOGRAPHY. Marjorie Comstock, comp. (Brookhaven National Lab., Upton, N. Y.). Apr. 1963. Contract AT-30-2-GEN-16. 22p.

References relating to μ mesons are presented for 1958 to April 1963 and are arranged according to year. Sources for the 625 references are Nuclear Science Abstracts, Science Abstracts, Series A, Physics, and the Brookhaven Research Library. Subjects included are static properties, electromagnetic interactions, mesic atoms and molecules, weak interactions, μ -meson structure and anomalous interactions, cosmic rays, and μ -meson beams. (R.E.U.)

26.

24390 (JINR-P-1624) O SVOISTVAKH π^0 -MEZONOV, OBRAZUYUSHCHIKHSYA V π^0 -N I π^- -C VZAIMODEISTVIYAKH PRI ENERGII 7.5 Gev. (On Properties of π^0 Mesons Produced in π^- -N and π^- -C Interactions at 7.5 Gev). V. B. Lyubimov, Mu Chun, and V. N. Streltsov (Joint Inst. for Nuclear Research, Dubna, U.S.S.R. Lab. of High Energy). 1964. 9p.

The properties of π^0 mesons detected in the propane chamber by the two absorbed γ quanta were studied. (auth)

27.

42383 Mu MESON LIFETIME. Am. J. Phys., 32: XV(Oct. 1964).

An experimental method to determine the lifetime of the meson (μ) is outlined. (C.E.S.)

28.

760 RADIATIVE CORRECTIONS TO DECAY PROCESSES MEDIATED BY VECTOR BOSONS. R. A. Shaffer (Johns Hopkins Univ., Baltimore). Phys. Rev., 128: 1452-7(Nov. 1, 1962).

The lowest order electromagnetic corrections to β and μ decay have been calculated in an intermediate vector-boson theory. Assuming universal coupling, the μ lifetime agrees with the experimental value if the boson's mass is chosen to be that of a K meson. The results are relatively insensitive to the value chosen for the cutoff. (auth)

29.

9389 COMPARISON OF THE LIFETIMES OF POSITIVE AND NEGATIVE MUONS IN LIQUID HYDROGEN. E. W. Anderson, E. Bleser, S. Meyer, J. Rosen, J. Rothberg, and I. T. Wang (Columbia Univ., New York). p.417-18 of "1962 International Conference on High-Energy Physics at CERN." Geneva, European Organization for Nuclear Research, 1962.

Measurement of μ^+ and μ^- lifetimes in very pure hydrogen gave a result of $\tau^+/\tau^- = 1.000$ with an uncertainty of 0.2%. (A.G.W.)

30.

11500 (UCRL-10118(Rev.)) THE MEAN LIFE OF THE NEUTRAL PI MESON. Hla Shwe, Frances M. Smith, and Walter H. Barkas (California Univ., Berkeley. Lawrence Radiation Lab.). May 28, 1962. Contract W-7405-eng-48. 42p.

An experiment to measure the π^0 mean life, using a new method that utilizes the relativistic flight-path dilation produced by a high pion velocity is reported. A negative pi meson beam of 3.5 Bev/c interacts in Ilford K.5 emulsion. Some 103 secondary π^0 are observed to decay by the Dalitz mode ($\pi^0 \rightarrow e^+ + e^- + \gamma$) in a study of 3600 such stars. The π^0 path lengths can be accurately measured and are automatically calculated by specially developed equipment. The π^0 momentum spectrum is assumed to be the same as that of the secondary charged pions found by multiple scattering measurements. The mean transverse momentum of secondary charged pions at all angles is 274 ± 10 Mev/c. The opening-angle distribution of the electron pairs is measured and compared with extensive calculations of the expected laboratory-system distribution in order to evaluate the number of unobserved events. A statistical approach is used to evaluate the mean life (τ_{π^0}) of the π^0 . The maximum-likelihood estimate is $\tau_{\pi^0} = 2.0 \times 10^{-16}$ sec. The residual effect of systematic errors is thought to be small. The observed Dalitz pairs are listed. 32 references. (auth)

31.

18531 (CERN-63-3(p.325-37)) THE DETERMINATION OF THE LIFETIME OF THE π^0 MESON. H. Heckman (California Univ., Berkeley. Lawrence Radiation Lab.).

Measurements and techniques for a nuclear emulsion experiment to determine the meson (π^0) lifetime are discussed. (C.E.S.)

32.

19104 MEAN LIFE-TIME OF THE NEUTRAL PION. E. L. Koller, S. Taylor, and T. Huetter (Stevens Inst. of Tech., Hoboken, N. J.). Nuovo Cimento (10), 27: 1405-9 (Mar. 16, 1963). (In English)

The mean lifetime of the π^0 meson is measured. The decay distance of π^0 mesons produced by $K_{\pi 2}$ decay at rest ($K^+ \rightarrow \pi^+ + \pi^0$) and subsequent decay by the Dalitz mode ($\pi^0 \rightarrow e^+ + e^- + \gamma$) is measured. Using Ilford G-5 emulsions, exposed in a 300 Mev/c separated K^+ beam, 88 of the above events are found. The observed mean π^0 lifetime is $(2.8 \pm 0.9) \times 10^{-16}$ sec. (auth)

33.

19122 MEAN LIFE OF THE NEUTRAL PION. G. Von Dardel, D. Dekkers, R. Mermod, J. D. Van Putten, M. Vivargent, G. Weber, and K. Winter (CERN, Geneva). Phys. Letters, 4: 51-4 (Mar. 1, 1963). (In English)

High energy neutral mesons (π) were produced in platinum foils of 3-60 micron thickness exposed to the 18-Bev internal proton beam of the CERN proton synchrotron, and the production of positrons relative to all heavier particles was measured in a secondary beam of 5-Bev/c. The momentum spectrum of π^0 , which is effective in producing 5-Bev/c positrons, is obtained by weighting the π^0 spectrum with the probability that a positron from a π^0 has a momentum of 5-Bev/c. The momentum spectra of π^0 and π^+ are assumed to be of equal shape and the latter was measured. This effective π^0 spectrum is narrow and is characterized by an average momentum of 7.12-Bev/c and a rms momentum of 7.26-Bev/c. The mean life was determined to be $(1.05 \pm 0.18) \times 10^{-16}$ sec. (C.E.S.)

34.

22418 (ISS-62/7) RELAZIONI PRESENTATE AL CONGRESSINO DEI LABORATORI NAZIONALE DE FRASCATI, (7-9 FEBBRAIO 1962). Papers Presented at the Congress of the National Laboratories in Frascati (February 7-9, 1962). (Italy. Istituto Superiore di Sanità, Rome). Mar. 1, 1962. 67p.

Summaries of the papers presented by the Physics Laboratory of the Istituto Superiore di Sanità at the High Energy Physics Congress held in Frascati in February 1962 are compiled. The subjects discussed are measurements of single π^0 meson photoproduction and Compton effect on protons, heavy neutral meson photoproduction, π^- meson capture in complex nuclei, measurement of the lifetime of π^+ mesons on curved and straight paths, and preliminary results on the study and utilization of the "synchrotron light." (J.S.R.)

35.

29497 (NEVIS-114) PRECISION LIFETIME MEASUREMENT ON POSITIVE AND NEGATIVE MUONS. S. L. Meyer, E. W. Anderson, E. J. Bleser, L. M. Lederman, J. L. Rosen, J. E. Rothberg, and I. T. Wang (Columbia Univ., Irvington-on-Hudson, N. Y. Nevis Labs.). May 1963. Contract Nonr-266(72) 26p. (R-366; Cu-220)

An experiment to measure and compare the free decay rates of positive and negative muons is described. Muons from the Nevis Synchrocyclotron were stopped in a liquid hydrogen target containing less than 1 ppm D_2 and less than 1 part in 10^8 of other impurities. In this situation, the rate of μ^- capture in H_2 was the only significant correction to the free decay rate of μ^- and was measured in a separate experiment. The lifetimes were monitored by measuring the time intervals between muon stops and decay electrons using a transistorized digitron of 30 nsec channel width. Electronic circuitry of the "interference remover" type was employed to eliminate time-dependent background. μ^- and μ^+ lifetimes were measured with the same apparatus and under essentially the same conditions of rate and geometry. The ratio of the lifetimes is expected to be particularly insensitive to any systematic errors. The results are: $\tau_{\mu^-} = 2.198 \pm 0.002 \mu\text{sec}$ (hydrogen correction made); $\tau_{\mu^+} = 2.197 \pm 0.002 \mu\text{sec}$; and $R = \tau_{\mu^-}/\tau_{\mu^+} = 1.000 \pm 0.001$. (auth)

36.

10875 DECAY OF NEUTRON PIONS. Hla Shwe, Frances M. Smith, and Walter H. Barkas (Univ. of California, Berkeley). Phys. Rev., 125: 1024-7 (Feb. 1, 1962).

The proper mean life of the neutral pion is measured utilizing a large relativistic time dilation. Negative pions of 3.5 Bev were permitted to interact in K-5 nuclear emulsions. High-energy neutral pions from some 2000 interaction stars were observed when they decayed by the Dalitz mode. The distances from the star centers at which they decayed were accurately measurable. The momentum spectrum of the neutral pions was assumed to be the same as that of the charged pions produced in the same interactions. Angular distributions of the secondary charged and neutral pions are presented separately. The mean transverse momentum of the charged pions was measured and found to be 250 ± 10 Mev/c. The neutral pion mean life is $(1.9^{+1.3}_{-0.6}) \times 10^{-16}$ sec. (auth)

37.

10945 (AD-260039) MEAN LIFE OF THE NEGATIVE MUON IN CARBON (thesis). Robert Albert Butterfield (Utah. Univ., Salt Lake City). June 1961. 34p.

Positive and negative muons are stopped and their decay observed. The composite mean life of these muons is calculated and the negative mean life in carbon is computed from the composite data. Results of calculations show a composite mean life in carbon of $(2.087 \pm 0.037) \times 10^{-6}$ sec, and the negative muon mean life in carbon is $(1.94 \pm 0.09) \times 10^{-6}$ sec. (J.R.D.)

38.

13894 PRECISION MEASUREMENT OF THE μ^+ LIFETIME. Richard A. Lundy (Univ. of Chicago). *Phys. Rev.*, **125**: 1688-96 (Mar. 1, 1962).

A precision measurement of the mean lifetime of the positive muon, $\tau(\mu^+)$, is described. On the basis of 12 internally consistent, independent determinations performed under a variety of experimental conditions $\tau(\mu^+)$ is found to be $(2.203 \pm 0.004) \mu\text{sec}$. These determinations are performed by means of a digital electronic time interval measuring device embodying a continuous wave oscillator. The experimental conditions, in particular concerning the percentage of background events, are described. Attention is paid to sources of systematic error, such as time dependence of background events and rate dependence of the overall measuring process. All sources of background are localized, their effects quantitatively exhibited and, in general, suppressed electronically during actual lifetime determinations. The prediction of the conserved vector-current theory, using $f_0(\text{O}^{14}) = (3069 \pm 13) \text{ sec}$ and $m_\mu = 206.76 m_e$, is (including radiative corrections) $\tau(\mu^+) = 2.298 \pm 0.05 \mu\text{sec}$, and thus in disagreement with the experimental value. A discussion of the logical operation of the digital device is presented. A general formalism is given that establishes the connection between arbitrary interval distributions presented at the input of such devices and their corresponding output interval distributions. (auth)

39.

21272 RECENT ADVANCES IN PION AND MUON PHYSICS. [PART] I. A. W. Merrison (Univ. of Liverpool). *Advances in Phys.*, **11**: 1-37 (Jan. 1962).

Muon and pion data are presented. Decay parity violation, masses, lifetimes, and rare decay modes of muons and pions are discussed. Muon magnetic and electric dipole moments are given. (L.N.N.)

40.

25901 (LNF-62/37(p.118-38)) MISURE DI VITA MEDIA DI MESONI π SU TRAIETTORIA RETTILINEA E CIRCOLARE. (Measurement of the Mean Life of π Mesons on Rectilinear and Circular Trajectories). M. Ageno, G. Matthiae (Italy. Istituto Superiore di Sanità, Rome), E. Amaldi (Rome. Università. Istituto di Fisica), B. Rispoli (Italy. Comitato Nazionale per l'Energia Nucleare. Centro di Studi Nucleari, Casaccia), and G. Sanna (Italy. Comitato Nazionale per l'Energia Nucleare. Laboratori Nazionali, Frascati).

The problems to be solved in the measurement of the mean life of π mesons are reviewed in some detail as an introduction to the discussion of the principles of the experimental apparatus. The effective conditions for the measurements were derived and corrections that must be made because of impurities in the pion beam are given. The present state of the experiment is tabulated. (J.S.R.)

41.

29691 MEAN LIFETIME OF THE π^0 MESON. J. Tietge and W. Poeschel (Max-Planck-Institut für Physik und Astrophysik, Munich). *Phys. Rev.*, **127**: 1324-7 (Aug. 15, 1962).

An estimate of the π^0 mean lifetime has been obtained by a method first attempted by Harris, Orear, and Taylor in 1957. The decay distances of monoenergetic π^0 mesons, produced by the $K_{\pi 2}$ decay at rest ($K^+ \rightarrow \pi^+ + \pi^0$) and decaying via the Dalitz mode ($\pi^0 \rightarrow e^+ + e^- + \gamma$), were measured. In two stacks of nuclear emulsion (Ilford K5), exposed to the 700-Mev/c K^+ beam at the Berkeley Bevatron, 45 events of this type were found. For the π^0 mean lifetime a value of $\tau = (2.3_{-1.1}^{+1.4}) \times 10^{-16} \text{ sec}$ has been obtained. (auth)

42.

875 ESTIMATE OF THE NEUTRAL π -MESON LIFETIME. R. F. Blackie, A. Engler, and J. H. Mulvey (Univ. of Oxford). *Phys. Rev. Letters*, **5**, 384-5 (1960) Oct. 15.

The lifetime of π^0 was determined by analyzing K^+ decays at rest in emulsions. Events were selected in which the $K_{\pi 2}$ mode, $K^+ \rightarrow \pi^+ + \pi^0$, was followed by the decay of the π^0 meson to give an electron pair. Both the velocity and direction of flight of the π^0 were determined by the kinematics of the K^+ decay, and the presence of the electron pair allowed the point of decay of the π^0 to be found. The results of 26 pair events were analyzed. The value obtained for the mean lifetime is $(3.2 \pm 1) \times 10^{-16} \text{ sec}$. (M.C.G.)

43.

3349 SEARCH FOR A SECOND π^0 . W. Selove and M. Gettner (Univ. of Pennsylvania, Philadelphia). *Phys. Rev.*, **120**, 593-8 (1960) Oct. 15.

The energy distribution of neutrons from the charge exchange reaction $\pi^- + p \rightarrow \pi^0 + n$ was studied, for π^- mesons stopped in liquid hydrogen, to investigate the possible existence of a second π^0 with mass within a few Mev of the mass of the "ordinary" π^0 . No neutron group corresponding to such a second π^0 was seen. The sensitivity of the measurement was such that a second group of relative intensity above 10 to 20% would have been seen for any second π^0 with a mass in the range between about $\frac{3}{4}$ Mev and 2 Mev away from the mass of the ordinary π^0 . The data give a lower limit to the π^0 lifetime: $\tau > \sim 5 \times 10^{-21} \text{ sec}$. (auth)

44.

9714 LIFETIME OF THE NEUTRAL PION. V. Glaser (European Organization for Nuclear Research, Geneva) and R. A. Ferrell. Phys. Rev., 121: 886-92 (Feb. 1, 1961).

As Primakoff noted, the phenomenological coupling constant of the neutral pion with the electromagnetic field can be investigated by considering the photoproduction of neutral pions in an external Coulomb field. This is the inverse of the usual two-photon decay (one of the photons being provided by the external field). The relationship between the cross section and the free lifetime of the π^0 was derived. Although the total cross section was small, it was found at high energy that the differential cross section was strongly peaked near the forward direction. The peak cross section was proportional to the fourth power of the photon energy. It was this feature that made possible an experimental determination of the lifetime by the photoproduction method to an accuracy of about 10%. A minimum photon energy of 1 Bev was required to avoid uncertainties in the nuclear form factor. A higher photon energy would be necessary only if the π^0 mean life was greater than 5×10^{-17} sec. The backgrounds to be expected from nuclear photoproduction were estimated and found to be sufficiently small. In particular, the interference between the coherent nuclear π^0 photoproduction and the Primakoff process was not excessive. (auth)

45.

9778 AN EXPERIMENT TO DETERMINE THE π^0 LIFETIME. A. V. Tollestrup, S. Berman, R. Gomez, and H. Ruderman (California Inst. of Tech., Pasadena). p. 27-30 of "Proceedings of the 1960 Annual International Conference on High Energy Physics at Rochester, The University of Rochester, Rochester, N. Y., August 25-September 1, 1960."

An attempt was made to determine the lifetime of the meson (π^0) by observation of the photoproduction process in the Coulomb field. The cross sections were measured for a lead target. The lifetime was not determined from the data. However, calculations indicate that, if all the counts at 0° can be attributed to the lifetime effect, the lifetime is $\geq 5 \times 10^{-17}$ sec. (M.C.G.)

46.

9779 THE LIFETIME OF THE NEUTRAL PION. R. G. Glasser, N. Seeman, and B. Stiller (Naval Research Lab., Washington, D. C.). p. 30-1 of "Proceedings of the 1960 Annual International Conference on High Energy Physics at Rochester, The University of Rochester, Rochester, N. Y., August 25-September 1, 1960."

Preliminary results gave a lifetime of $2.3 \pm 0.8 \times 10^{-16}$ sec for the neutral pion. Mesons (K^+) were stopped in an emulsion and the emulsion scanned for K_{s1} decays accompanied by a Dalitz pair. The weighted average of the events gave 0.122 ± 0.045 for the mean decay distance. This led to the lifetime value given. (M.C.G.)

47.

9889 A DETERMINATION OF THE LIFETIME OF THE μ^+ MESON. A. Astbury, P. M. Hattersley, M. Hussein, A. Kemp, and H. Muirhead (Univ. of Liverpool, England). p. 542-4 of "Proceedings of the 1960 Annual International Conference on High Energy Physics at Rochester, The University of Rochester, Rochester, N. Y., August 25-September 1, 1960."

The lifetime of μ^+ mesons was measured by stopping positive pions in a sulfur target and detecting the electrons from the decay sequence $\pi^+ \rightarrow \mu^+ \rightarrow e$. A value of 2.23 ± 0.006 μ sec was obtained for the lifetime. (M.C.G.)

48.

11948 PROTON COMPTON EFFECT. G. Bernardini (Univ. of Illinois, Urbana and CERN, Geneva), A. O. Hanson, A. C. Odian, T. Yamagata, L. B. Auerbach, and I. Filosofo. Nuovo cimento (10), 18: 1203-36 (Dec. 16, 1960). (In English)

The elastic scattering of photons by protons was measured for 100- to 290-Mev photons at 90 and 139° c.m.s. scattering angles. The expected large increase in cross section is observed at energies approaching that of ($3/2, 1/2$) pion-nucleon resonance. The scattering can be qualitatively explained by the ordinary Thomson amplitude combined with that of the ($3/2, 1/2$) resonance. A more detailed examination of the cross section in the region just above the photo-meson threshold has shown that it is sensitive to the π^0 photon coupling. From the experimental data, a conclusion may be made that the π^0 mean life should be between 10^{-16} and 10^{-18} sec. (auth)

49.

14945 (NYO-9279) PRECISE MEASUREMENTS OF THE MEAN LIVES OF μ^+ AND μ^- MESONS IN CARBON (thesis). Richard A. Reiter (Carnegie Inst. of Tech., Pittsburgh). Aug. 1960. Contract AT(30-1)-883. 64p.

The lifetimes of approx 6 million positive mu mesons were measured, using a crystal controlled oscillator as a clock. The resulting decay curve was analyzed on a digital computer and gave a mean life of 2.211 ± 0.003 μ sec. The mean life of negative mu mesons in carbon was measured and found to be 2.043 ± 0.003 μ sec. The resulting nuclear capture rate is $(0.373 \pm 0.011) \times 10^6$ /sec, assuming that the decay rate of a negative mu meson bound in carbon is equal to the decay rate of the positive mu meson. (auth)

50.

16329 COULOMB PHOTOPRODUCTION OF π^0 AT HIGH ENERGY AND π^0 LIFETIME. C. Chiuderi (Università, Florence) and G. Morpurgo. *Nuovo cimento* (10), 19: 497-511 (Feb. 1, 1961). (In English)

The possibility is suggested of determining the lifetime of the π^0 meson using π^0 photoproduction in a Coulomb field. Competition with coherent nuclear production necessitates a rather high photon energy. Even at 1 Bev, the Coulomb photoproduction dominates over the coherent nuclear one only in a very narrow cone around the forward direction. It must be shown further that the incoherent production is not dominant in this cone. Though the incoherent production is certainly smaller than the coherent nuclear one by a factor of A (= mass number), the incoherent cross section does not have the factor $\sin^2 \theta$ which affects both the Coulomb and the nuclear coherent cross sections. A calculation of the incoherent photoproduction of π^0 at small angles is therefore made using a multipole expansion and sum rules. It is shown that, for lead, the incoherent cross section at small angles is at most of the same order of magnitude of the nuclear coherent one so that it does not dominate the picture. For light nuclei the competition between incoherent and coherent nuclear production at small angles is more unfavorable and depends rather critically on the properties of the individual nucleus chosen. It is concluded that heavy nuclei are the most suited for this experiment and that, at 1 Bev, only lifetimes shorter than $\sim 10^{-16}$ may be measured by this method. (auth)

51.

24259 MESONS AND HYPERONS. G. A. Snow and M. M. Shapiro (Univ. of Maryland, College Park and U. S. Naval Research Lab., Washington, D. C.). *Revs. Modern Phys.*, 33: 231-8 (Apr. 1961).

A survey is made of mesons (π, K), hyperons (Λ, Σ, Ξ), and their antiparticles. The mass, mean life and decay mode, spin, and parity of each of these particles are detailed. The concept of strangeness is reviewed. (T.F.H.)

52.

25382 (JINR-D-701) SPIN DEPENDENCE OF WEAK INTERACTION IN THE PROCESS $\mu^- + p \rightarrow n + \nu$. A. E. Ignatenko, A. B. Kuptsov, Suang-ming Li, M. G. Petrasku, L. B. Yegorov, and G. V. Zhuravlev (Joint Inst. for Nuclear Research, Dubna, U.S.S.R. Lab. of Nuclear Problems). 1961. 14p.

Using the scintillation counter method, measurements were made of the values, average with respect to two states of hyperfine structure, of the $\bar{a}_0$ asymmetry coefficients of $(\mu^- e)$ -decay electrons in mesic atoms of silver and red and black phosphorus. The lifetimes τ of mesons in these modifications of phosphorus were also determined. The quantities of $\bar{a}_0$ for red and black phosphorus indicated that the time of the relaxation of meson spins in mesic atoms decreases owing to the presence of conductivity electrons. On the basis of $\bar{a}_0$ and τ , the n , and n_0 level populations in the states $F = 1$ and $F = 0$ in phosphorus as well as the λ_1 and λ_0 probabilities of the capture of mesons by the nucleus in these states were calculated. The values found indicated that $\lambda_0 > \lambda_1$. (auth)

53.

26437 (NP-9538) NRL QUARTERLY ON NUCLEAR SCIENCE AND TECHNOLOGY. Progress Report for the Period July-September 1960. (Naval Research Lab., Washington, D. C.). Oct. 1, 1960. 24p.

Discussions are presented of research carried out in the fields of: Nuclear Physics, on prompt γ rays from He^3 bombardment of O^{18} , mesons- π^0 lifetime, and a photo-proton spectrometer; High-temperature Physics, on a selective signal detector for measuring low-level radioactive airborne contamination, and a computer analysis of Brillouin flow in relativistic beams of moderate current; and Dielectrics, on the $\text{CaF}_2:\text{Mn}$ thermoluminescence dosimeter, and luminescence phenomena in glass. (B.O.G.)

54.

26875 MEAN LIFETIME OF THE NEUTRAL PION. R. G. Glasser, N. Seeman, and B. Stiller (Naval Research Lab., Washington, D. C.). *Phys. Rev.*, 123: 1014-20 (Aug. 1, 1961).

An estimate of the mean lifetime of the π^0 meson was obtained from an experiment employing a direct time-of-flight technique first attempted by Harris et al. in 1957. This method is based upon the observation in nuclear emulsion of the decay of the $K_{\pi 2}^+$ meson ($K^+ \rightarrow \pi^+ + \pi^0$) and the subsequent decay of the π^0 via the Dalitz mode, $\pi^0 \rightarrow e^+ + e^- + \gamma$. In the present experiment we were able to utilize a new fine-grained emulsion (Ilford L4) that yielded markedly improved resolution. The availability of the separated K^+ beam from the Bevatron at Berkeley permitted detection and measurement of 76 Dalitz decays. The mean lifetime of the π^0 is $(1.9 \pm 0.5) \times 10^{-16}$ sec. (auth)

55.

3947 ANGULAR DISTRIBUTION OF NEUTRONS FOLLOWING THE NUCLEAR CAPTURE OF POLARIZED MUONS. A. Astbury, I. M. Blair, M. Hussain, M. A. R. Kemp, H. Muirhead, and R. G. P. Voss (Univ. of Liverpool). *Phys. Rev. Letters* 3, 476-8 (1959) Nov. 15.

The angular distribution of neutrons following the nuclear capture of polarized mesons (μ^-) in S^{32} was determined for the process: $\mu^- + p \rightarrow n + \nu$. The (μ^-) lifetime in S^{32} was determined to be 0.46 ± 0.05 μsec . (C.J.G.)

56.

4748 ON THE DETERMINATION OF THE MEAN LIFE OF μ^- MESONS IN Ca AND Pb. A. Alberigi Quaranta, U. Dore, and F. Pieraccini (Università, Rome and Istituto Nazionale di Fisica Nucleare, Rome). *Nuovo cimento* (10) 14, 48-9 (1959) Oct. 1. (In English)

Measurements for the determination of the apparent mean life of μ^- -mesons in Ca and Pb are reported. The values obtained are $\tau = (35.7 \pm 3) \times 10^{-8}$ sec in Ca and $\tau = (7.3 \pm 0.6) \times 10^{-8}$ sec in Pb. The results are in agreement with those obtained by other investigators and with theoretical estimations. (auth)

57.
14302

NEW EXPERIMENTAL DATA ON π - AND μ -MESON DECAY. A. O. Vaisberg. Uspekhi Fiz. Nauk 70, 429-87(1960) Mar. (In Russian)

An analysis is made of experimental data developed during the last two years on the properties of "free" π and μ mesons. The mass and lifetimes of π and μ mesons, electron spectra in $\pi \rightarrow \mu \rightarrow e$ decay, spatial electron distribution asymmetry, lepton spirality and lepton charge conservation law, μ -meson magnetic moment, π -meson electron decay, radiation decay of π and μ mesons, and depolarization of μ mesons are discussed. 144 references. (R.V.J.)

58.
19740

A NEW MEASUREMENT OF THE MEAN LIFE OF THE POSITIVE PION. J. Ashkin, T. Fazzini, G. Fidecaro, Y. Goldschmidt-Clermont, N. H. Lipman, A. W. Morrison, and H. Paul (European Organization for Nuclear Research, Geneva). Nuovo cimento (10) 18, 490-504(1960) May 1. (In English)

The mean life of the positive π meson was determined from about 8000 π - μ decay events recorded by photographing pulses on an oscilloscope and analyzing the data with a fast computer. The value obtained for the mean life of the π -meson is $\tau_{\pi} = 25.46 \pm 0.32$ nsec. (auth)

59.

19750

PRECISE MEASUREMENTS OF THE MEAN LIVES OF μ^+ and μ^- MESONS IN CARBON. R. A. Reiter, T. A. Romanowski, R. B. Sutton, and B. G. Chidley (Carnegie Inst. of Tech., Pittsburgh). Phys. Rev. Letters 5, 22-3 (1960) July 1.

A one inch carbon target was bombarded by 70-Mev π^+ mesons. The muons from π^+ decays were randomly polarized, thus eliminating possible modulation of the decay curve. The weighted average of 14 runs gave a mean life of 2.211 ± 0.003 μ sec for μ^+ mesons. The mean life of μ^- mesons was found to be 2.043 ± 0.003 μ sec. (B.O.G.)

60.
26295

FT VALUE OF O^{14} AND THE UNIVERSAL FERMI INTERACTION. R. K. Bardin, C. A. Barnes, W. A. Fowler, and P. A. Seeger (California Inst. of Tech., Pasadena). Phys. Rev. Letters 5, 323-6(1960) Oct. 1.

The experimentally observed near equality of the coupling constants in beta and muon decays has suggested that all the "weak interactions" proceed by a universal Fermi interaction. It is of interest to establish the degree to which the coupling constants G_V for the vector β -decay and G_μ for the muon decay are equal. The precision with which G_μ is known has improved considerably due to more accurate measurements of the muon mean lifetime and mass. To determine G_V more accurately the ft value was measured for the $0^+ \rightarrow 0^+ \beta$ transition in $O^{14}(\beta^+ \nu)N^{14}$. After a total correction of +0.289% for nuclear electromagnetic form factors, competition from K capture, and electron screening, the ft value is 3069 ± 13 sec. The corrected ft value yields $G_V = (1.416 \pm 0.003) \times 10^{-48}$ erg cm³. If this value is adopted for G_μ , then, without radiative corrections, the calculated mean lifetime of the muon becomes 2.250 ± 0.010 μ sec, which is $1.8 \pm 0.5\%$ greater than the mean of the observed lifetime, 2.210 ± 0.003 μ sec. (B.O.G.)

61.

12049 NYO-8546

Pennsylvania. Univ., Philadelphia.
ON MEASUREMENT OF THE LIFETIME OF THE π^0 MESON. K. Lande and W. Selove. Apr. 22, 1958. 4p. Contract AT(30-1)-2055. \$1.80(ph), \$1.80(mf) OTS.

Because the lifetime τ is not infinite, the rest mass of the π^0 is defined only within an energy uncertainty $\Delta M = 1/\tau$. This energy width will show up as a second spread in the Q value of the reaction $\pi^- + p \rightarrow \pi^0 + n + Q$. The kinetic energy of the neutron produced in this reaction will show a fractional spread given by $\Delta T/T \approx \Delta M/Q$, where ΔM is the spread in mass value of the π^0 . By carrying out the reaction with π^- mesons brought to rest in hydrogen and by using a relatively simple time-of-flight method to determine the neutron energy and energy spread, it is possible with available π^- beam intensities to measure $\Delta T/T$ to about 1%. This would permit determination of the lifetime if shorter than 10^{-20} to 10^{-18} seconds. If the lifetime is longer, then the measurement would only establish this time as the lower limit to the lifetime. Reported experimental information on the lifetime gives only an upper limit, which appears to be 10^{-16} to 10^{-18} seconds. (A.C.)

62.
12086

DETERMINATION OF THE AVERAGE LIFETIME OF μ -MESONS IN IRON. Ryszard Braun. Zeszyty Nauk. Univ. Łódz., Ser II No. 3, 191-212(1957). (Translated from Referat. Zhur. Fiz. No. 9, 1958, Abstract No. 19820.)

The lifetime of μ mesons was determined to be $= 2.14 \pm 0.06$ microseconds in iron. The mesons were liberated from cosmic rays and stopped in an iron absorber. The decay electrons were observed with the aid of delayed coincidences.

63.
14740

REDETERMINATION OF THE μ^+ MEAN LIFE. R. A. Swanson, R. A. Lundy, V. L. Telegdi, and D. D. Yovanovitch (Univ. of Chicago). Phys. Rev. Letters **2**, 430-1(1959) May 15.

The muons were produced in a 2.5-g/cm^2 thick scintillator by the reaction $\pi^+ \rightarrow \mu^+ \rightarrow e^+$. The experimental set up is shown, and special equipment is discussed. A value of $2.261 \pm 0.007\text{ }\mu\text{sec}$ was found for the μ^+ mean life. (W.D.M.)

64.
16413

THE PROPERTIES OF LIGHT AND HEAVY MESONS. W. Gentner (CERN, Geneva). Naturwissenschaften **46**, 283-9(1959). (In German)

A brief review is given of the properties of light and heavy mesons. Detection methods, production, life time and decay schemes, mass, interactions, mesonic atom, fusion, and heavy mesons are considered. (J.S.R.)

65.

22817

MEASUREMENT OF μ^+ LIFETIME. J. Fischer, B. Leontic, A. Lundby, R. Meunier, and J. P. Stroot (CERN, Geneva). Phys. Rev. Letters **3**, 349-50(1959) Oct. 1.

The remarkable agreement of the experimental with the theoretical value for the lifetime of the muon is the strongest indication that the vector current is conserved and the strengths of axial and polar vector currents are equal when strong interactions are not present. An experiment to remeasure the μ^+ lifetime is described. A value of $2.20 \pm 0.015\text{ }\mu\text{sec}$ was obtained. (W.D.M.)

66.
4351

ON THE MEAN LIFE OF μ^- -MESONS IN ELEMENTS OF MEDIUM AND HIGH ATOMIC NUMBER. A. Alberigi-Quaranta, F. Pieraccini, and D. Broadbent. Nuovo cimento (10) **6**, 1084-1101(1957) Nov.

The mean life of μ mesons stopped in iron has been investigated by means of a new apparatus. The experimental arrangement for the determination of the mean life of μ^- in elements of mean and high atomic number is described.

67.
4939

MU-MESON PHYSICS. J. Rainwater (Columbia Univ., New York). Ann. Rev. Nuclear Sci. **7**, 1-30(1957).

68.

521 NP-6135

California. Univ., Los Angeles.

FINAL REPORT. PART I. PROPERTIES OF NEGATIVE K-MESONS. Stanley C. Freden. PART II. NEGATIVE MUON CAPTURE IN INTERMEDIATE Z ELEMENTS. Joleroy Gauger. [1956]. Included reprint: FAST TIMING OF SCINTILLATION PULSES. Harold K. Ticho and Joleroy Gauger. Rev. Sci. Instr. **27**, 354-9(1956). 96p. DA Project No. 599-01-004. Contract DA-04-495-Ord-318.

The exposure of nuclear emulsions and scanning and identification of K particles are described, and the mass was found. The K-meson capture phenomena were studied. The equipment used to avoid recording useless data, the twelve-channel differential chronotron, when studying negative meson capture in intermediate Z elements was constructed and is described. The mean life values in V, Cr, and Mn were derived. Using a modified chronotron, time interval distributions due to two liquid scintillation counters were studied under various experimental conditions. (F.S.)

69.
696

ON THE NATURE OF PARTICLES PRODUCED IN EXTREMELY ENERGETIC NUCLEAR COLLISIONS. F. A. Brisbout, C. Dahanayake, A. Engler, Y. Fujimoto, and D. H. Perkins (Univ. of Bristol, England). Phil. Mag. (8) **1**, 605-21(1956) July.

A detailed investigation into nuclear collisions of energy between 10^{12} to 10^{13} ev is reported. The ratio of π^0 mesons to charged shower particles has been determined with high statistical accuracy yielding a value $R = 0.393 \pm 0.044$. The central cores of the 'jets' have been carefully scanned to detect secondary interactions produced by the shower particles and the ratio, Q, of the number of interactions produced by neutral to the number produced by charged shower particles has been obtained. $Q = 0.25 \pm 0.09$. If it is assumed that in nuclear collisions of very high energy, neutral and charged particles (other than π mesons) are created in approximately equal numbers and that the interaction mean free path for such particles does not differ appreciably from that of π mesons, the values R and Q enable an estimate to be made of the fraction of shower particles which are not π mesons. The results indicate that $\sim 25\%$ of the shower particles must be heavy mesons, hyperons, nucleon-antinucleon pairs, and ejected nucleons. In order to estimate the contribution to the above fraction from heavy mesons, a detailed analysis of the products of secondary disintegrations has been carried out. The results, although preliminary, are compared with those of Dahanayake et al. (1955) and are consistent with the assumption that most of these unidentified shower particles in the core are heavy unstable particles. The lifetime of the π^0 meson has been determined by a method which does not involve the

determination of the energy of the meson. The mean life obtained is $1.8^{+0.1}_{-0.1} \times 10^{-10}$ sec. (auth)

70.

6849

LIFETIME OF THE NEUTRAL PION. G. Harris, J. Orear, and S. Taylor (Columbia Univ., New York). Phys. Rev. **106**, 327-9(1957) Apr. 15.

A new upper limit on the π^0 lifetime has been obtained by using 12 $K^+ \pi^+$ endings in nuclear emulsion where the π^0 decays by a direct pair, $\pi^0 \rightarrow (e^+ + e^-) + \gamma$. The distance traveled by the π^0 before decay was measured from the intersection of the K^+ and π^+ tracks to the intersection of the pair and π^0 (colinear with π^+). The inherent accuracy of the measuring technique was found to be ~ 0.5 micron per event by using π^+ secondaries as mock events. With the statistics of 12 events it should be possible to detect a π^0 decay length of ~ 0.3 micron or greater. Our data give no indication of a displacement of pair origins from the K endings. Thus the π^0 decay length is probably less than ~ 0.3 microns. This corresponds to a lifetime of less than 5×10^{-16} sec. Information on the upper limit of the π^0 lifetime is obtained from a plot of the likelihood function vs π^0 lifetime. The likelihood function is down by a factor of 30 for a lifetime of 1×10^{-16} sec and is rapidly decreasing for longer lifetimes. (auth)

71.

9030

THE LIFETIME OF POSITIVE HEAVY MESONS. B. Bhowmik, D. Evans, S. Nilsson, and D. J. Prowse (Univ. of Bristol), F. Anderson, D. Keefe, and A. Kennan (Univ. Coll., Dublin), N. N. Biswas, M. Ceccarelli, and P. Waloschek (Max-Planck-Institut für Physik, Göttingen), J. E. Honner, M. Grilli, and L. Guerriero. Nuovo cimento (10) **5**, 994-1003(1957) Apr.

Over two hundred examples of the decay in flight of positive heavy mesons produced at the Bevatron have been observed in the photographic emulsions, and from these the lifetime of the particles has been estimated. The lifetime averaged over all modes of decay is found to be $1.35^{+0.10}_{-0.08}$ s. The effect of experimental biases is discussed, and the final result is compared with that of other authors. (auth)

72.

12173

THE VARIATION OF THE MEAN LIFE OF MUONS WITH THE ATOMIC NUMBER OF ABSORBER. N. N. Biswas and M. S. Sinha. Trans. Bose Research Inst. Calcutta **19**, 49-69 (1953-55).

The delayed coincidence technique has been used to observe the decay of a composite beam of positive and negative μ mesons at sea-level in Al, C, Pb and S absorbers. In cases of Al and S the points on a semi-logarithmic scale for the time intervals 0.6 to 4.0 μ secs. fit two straight lines, one yielding the life time of the composite beam and the other that of the positives alone. The composite mean lives

are found to be 1.58 ± 0.07 , 2.15 ± 0.09 , 1.48 ± 0.08 μ secs. in Al, C, S respectively. The mean lives of positives in Al, Pb, and S are 2.35 ± 0.11 , 2.23 ± 0.09 and 2.15 ± 0.14 μ secs. respectively. It has been concluded that the composite mean lives are dependent on Z, and decreases with increase of Z. The mean life of the negatives in C is determined to be 1.93 ± 0.24 μ secs. From the data obtained, the ratio of positive to negative mu mesons has been found to be 0.95 ± 0.16 . This does not agree with the view of 20% excess of positive mesons and it is argued that the simple theory of meson production by the collision of a primary beam of protons with the air nuclei is not sufficient to account for the observed ratio. (auth)

73.

12176

MEAN LIFE OF μ MESONS IN ELEMENTS AND COMPOUNDS. N. N. Biswas. Trans. Bose Research Inst. Calcutta **19**, 79-87(1953-55).

The composite mean life of μ mesons stopped in elements (C, Mg) and the compound (NaOH) of low atomic numbers has been determined using a four-channel delay discriminator circuit. Assuming that the μ^+/μ^- ratio is nearly unity, the mean life of the negative μ mesons has been obtained to be equal to 2.04 ± 0.14 (carbon), 1.52 ± 0.14 (NaOH), microseconds. (auth)

74.

304

ON THE MEASUREMENT OF THE MEAN LIFE TIME OF STRANGE PARTICLES. E. Amaldi (Univ. of Rome). Nuovo cimento (10) **2**, Suppl. 1, 253-62(1955).

Problems in the measurement of the extremely short life time of some particles are reviewed. The cloud chamber technique of Bartlett is presented, and methods for extending this technique for emulsion use are suggested. Lifetimes, measurements of 10^{-10} sec are considered feasible. (D.E.B.)

75.

918

IONIZATION AT THE ORIGIN OF ELECTRON PAIRS, AND THE LIFETIME OF THE NEUTRAL PION. D. H. Perkins (Univ. of Bristol, England). Phil. Mag. (7) **46**, 1146-8 (1955) Oct.

Measurements of ionization along the paths of energetic pairs indicate a reduction in ionization near the origin of the pair. This reduction is attributed to the behavior of the pair as an electric dipole near the origin and as two monopoles further along the path. Determination of this effect is believed to be of value in estimating γ energies in the region 1000 Bev and above. An estimate of the lifetime of π^0 mesons yields a value of 1.2 to 5×10^{-15} sec. (D.E.B.)

76.

3216 UCRL-3314

California. Univ., Berkeley. Radiation Lab.
SIMPLE CONSIDERATIONS RELATING STRANGE-PARTICLE LIFETIMES, Arthur H. Rosenfeld and M. Lynn Stevenson. Feb. 20, 1956. 4p. Contract W-7405-eng-48. \$1.80(ph OTS); \$1.80(mf OTS).

77.

4782 CEA-482

France. Commissariat à l'Énergie Atomique, Paris.
SUR LA DETERMINATION DE QUELQUES CARACTERISTIQUES FONDAMENTALES DE COMPTEURS DE GEIGER-MULLER. APPLICATIONS A L'ETUDE DES PARTICULES RETARDEES DES GERBES ATMOSPHERIQUES DU RAYONNEMENT COSMIQUE. (theses). (On the Determination of Some Fundamental Characteristics of Geiger-Mueller Counters. Applications to the Study of Delayed Particles in Atmospheric Cosmic Ray Showers (thesis)). E. Picard. 1955. 67p.

The operating principles of Geiger counters are reviewed, and the discharge mechanism of a self-quenching counter is discussed. The motion of primary electrons in the counters is also discussed, and expressions are derived for the latent induction time for the counter. The use of G-M counters in coincidence circuits is briefly surveyed. The movement of positive ions in the counter is reviewed in some detail, and expressions are included for counter dead time. The delayed particles in cosmic ray showers in air were studied by G-M counters in coincidence. The mean life of μ mesons in the showers was found to be $2.10 \pm 0.15 \mu\text{s}$. (B.J.H.)

78.

9504

THE DEPENDENCE OF THE COMPOSITE MEAN LIFE OF MU-MESONS ON THE ATOMIC NUMBER OF THE ABSORBER. N. N. Biswas (Bose Inst., Calcutta). *Indian J. Phys.* 29, 527-33(1955) Nov.

The measurements of the mean life of the composite beam of μ -mesons (both positive and negative) at sea level in absorbers of C, Al, S and Pb have been reported previously. The same experiment has been conducted with water and NaF absorbers. In water (only oxygen is effective, since a hydrogen atom rarely captures a μ -meson), the composite mean life is found to be 1.95 ± 0.08 micro-seconds. Choosing the thickness of water absorber to be equivalent to the sulfur absorber with respect to the stopping power of the μ -mesons, the decay curve of the positives in S has been taken to represent the same in water and hence by subtraction, the mean life of the negative μ -mesons in water has been determined to be equal to 1.80 ± 0.19 micro-seconds. In the case of NaF ($Z_{\text{eff}} = 10.1$) absorber, the experimental points have been found to represent a composite decay curve giving the mean life equal to 1.82 ± 0.09 micro-seconds. The Z dependence of the composite mean life has been found to fit an empirical relation, $\tau = 2.50 - 0.065 Z$ microseconds in the interval $Z = 6$ to $Z = 16$. (auth)

79.

332

RADIATION CORRECTION IN THE LIFE OF π^0 MESONS. A. D. Galanin and V. G. Solov'ev. *Zhur. Eksptl. i Teoret. Fiz.* 27, 112-15(1954) July. (In Russian).

80.

1927

ANALYSIS OF A HIGH-ENERGY COSMIC-RAY SHOWER.

I. SOFT COMPONENT AND TRIDENT PROCESS. M.

Koshiba and M. F. Kaplon (Univ. of Rochester, N. Y.).

Phys. Rev. 97, 193-200(1955) Jan. 1.

An analysis is presented of the soft component arising from a high-energy nuclear shower ($\sim 3 \times 10^{13}$ ev) observed in stripped emulsion. The chief results obtained are: (1) the production ratio of neutral π mesons to charged shower particles is 0.50 ± 0.11 ; (2) the lifetime of the neutral π meson is found to be $(1.0 \pm 0.1) \times 10^{-14}$ sec; (3) the mean free path for direct electron pair production by high-energy electrons is found to be 4.4 and 1.1 radiation units for electrons in the energy intervals 1 to 10 Bev and 10 to 100 Bev, respectively. (auth)

81.

3956

MEASUREMENTS OF THE LIFETIMES OF CHARGED HEAVY UNSTABLE PARTICLES. P. R. Barker, D. M. Binnie, B. D. Hyams, and R. J. Rout (Univ. of Manchester). *Phil. Mag.* (7) 46, 307-10(1955) Mar.

A new counter method for measuring the lifetime of unstable mesons is described. Lifetime measurements on 13 charged heavy mesons are reported. It is concluded that if there exists only one heavy meson giving fast decay products, with a lifetime greater than 5×10^{-9} sec, its lifetime is $(11.0 \pm 1.5) \times 10^{-9}$ sec. No evidence for any longer-lived heavy mesons has been found. (auth)

82.

4544

EFFECT OF THE ANOMALOUS NUCLEON MAGNETIC MOMENT ON THE π^0 LIFETIME. Stanley Cohen (Institute for Nuclear Studies, Chicago). *Phys. Rev.* 98, 749-50(1955) May 1.

The anomalous magnetic moment of the intermediate nucleons has been included in a treatment of the two-photon decay of the π^0 . It is found that this inclusion leads to a shorter, rather than a longer, lifetime, thereby failing to reduce the discrepancy between the experimental and previous theoretical values. (auth)

83.

4691

MEAN LIVES OF POSITIVE AND NEGATIVE μ MESONS.

N. N. Biswas and M. S. Sinha (Bose Institute, Calcutta, India). *Phys. Rev.* **94**, 1400-01(1954) June 1.

Integral decay curves for composite beams of $\mu^\pm$ mesons in Al, S, C, and Pb were obtained by the delayed-coincidence technique. (auth)

84.

7101

A DETERMINATION OF μ -MESOTRON REST LIFETIME AND A VERIFICATION OF THE RELATIVISTIC EXPRESSION FOR VARIATION OF LIFETIME WITH MOMENTUM.

D. W. Seymour and W. F. G. Swann (Bartol Research Foundation, Swarthmore, Penna.). *J. Franklin Inst.* **258**, 277-86(1954) Oct.

Measurements of cosmic ray intensity have been made simultaneously with counter telescopes at altitudes differing by about 3000 ft and in locations which were the same within a distance of about 8 miles. Data were obtained for various thicknesses of lead absorber and with an additional thickness of absorbing material in the upper telescopes to compensate for absorption in the air column between the two sets of telescopes. From the foregoing data the rest mean life values have been calculated on the basis of the relativistic variation of mean life with momentum for various ranges of momenta of the rays concerned. The theory of the calculation allows for the continual change of mean life resulting from loss of momentum of the mesotrons as they pass through the air. The value of the rest mean life obtained is 2.3×10^{-8} sec and is constant over the ranges of momenta concerned, within the limits of accuracy of the data, thus confirming to this extent the relativistic expression. The results are in close agreement with those of Rossi et al, but differ from the results obtained by Nielsen. (auth)

85.

271

Johns Hopkins Univ.

LIFETIMES OF THE μ -MESON IN HEAVY ELEMENTS, by L. Zernow and L. Madansky, p.37-8 of ANNUAL REPORT ON STUDIES OF NUCLEAR GAMMA RAYS, by L. Madansky and F. Rasetti. Sept. 1, 1952. 2p. (NYO-3901(p.37-8))

The system used for the determination of the lifetime of the μ^- meson in Pb was described previously (NYO-674). The lifetime was determined as 66.5 ± 11 μ sec, after correction for the large background. This is not inconsistent with the value of 72 ± 5.2 μ sec, reported by Harrison, Keuffel, Godfrey, and Reynolds (*Phys. Rev.* **86**, 616A(1952)). (L.M.T.)

86.

276

THE V-PARTICLE AND THE COMPOSITE PION. R. J.

Finkelstein. *Phys. Rev.* **88**, 555-8(1952) Nov. 1.

It is assumed that the V particle is described by a spinor wave function, and that the pion may be treated as a nucleon-antinucleon pair. The rates of the following reactions

$$\left. \begin{array}{l} \pi \rightarrow \mu + \nu \\ V^0 \rightarrow \pi + p \end{array} \right\}, \text{ now written as } \left\{ \begin{array}{l} (P + \bar{N}) \rightarrow \mu + \nu \\ V^0 \rightarrow \bar{P} + N \end{array} \right\} + P'$$

are then compared under the assumption that both reactions are governed by the same form and strength of β interaction. The ratio of the two lifetimes is independent of all numerical details of the pion structure. Putting in the observed lifetime of the pion, one finds for the lifetime of the V: 5×10^{-10} sec for $Q = 35$ Mev and 2×10^{-10} sec for $Q = 75$ Mev. The two Q values have been interpreted in terms of a mass doublet. (auth)

87.

281

THE LIFETIMES OF THE π^+ AND π^- MESONS. R. P.

Durbin, H. H. Loar, and W. W. Havens, Jr. *Phys. Rev.* **88**, 179-83(1952) Oct. 15.

The mean lives of the π^+ and π^- mesons are determined by measurements of the attenuation in flight of a 73-Mev meson beam, using a scintillation counter telescope of variable length. The decay scheme, $\pi^\pm \rightarrow \mu^\pm + \nu$, is assumed to be isotropic in the rest system of the π meson. The data, when the Lorentz time dilation is taken into account, give for the mean lives at rest, $\tau_- = 2.55 \pm 0.19 \times 10^{-8}$ sec, and $\tau_+ = 2.44 \pm 0.18 \times 10^{-8}$ sec. (auth)

88.

644

THE DISINTEGRATION OF μ MESONS IN CARBON. A.

Alberigi Quaranta and E. Pancini. *Nuovo cimento* (9) **9**, 959-68(1952) Oct. (In English)

An experiment is described for the study of some of the properties of μ mesons stopped in carbon. The μ^+ and μ^- mesons have been studied separately, and very precise apparent mean lifetimes in carbon of $\tau^+ = 2.22 \pm 0.06$ μ sec and $\tau^- = 2.18 \pm 0.07$ μ sec have been found. The data obtained from these measurements are discussed and compared with those of other experimenters to see if there is a possible difference in the behavior of the positive and the negative mesons. It is concluded that there are no indications for believing that there is a real difference between the natural mean lives of the μ^+ and μ^- mesons, although the eventual possibility of a divergence cannot be excluded. It is further demonstrated that there are no indications for believing the energy spectra of the disintegration electrons to be greatly different for the plus and minus mesons. (auth)

89.

1203

LIFETIMES OF THE μ^- -MESON STOPPED IN LI, Be, AND C. W. E. Bell and E. P. Hincks. *Phys. Rev.* **88**, 1424-5 (1952) Dec. 15.

Lifetimes of μ^- mesons stopped in Li, Be, and C have been determined with the apparatus used for measurement of the μ^+ -meson lifetime (*Phys. Rev.* **84**, 1243(1951)). About 30,000 decays in each element, with delays in the range 1 to 11 μ sec, were counted. The contribution to the decay curves of the μ^+ decay was estimated by computing the relative number of μ^+ mesons stopped in the absorber, brass counter walls, and iron supports, assuming a μ^+ -meson mean life of 2.22 ± 0.02 μ sec, as previously determined. The μ^- -decay curve was then determined by subtracting the μ^+ component from the measured composite ($\mu^+ + \mu^-$) curve. The μ^+ and μ^- decay lifetimes are equal within the limits of experimental error. Data for each absorber include the fraction f of the total electron emission rate due to μ^- mesons, the composite ($\mu^+ + \mu^-$) mean life, the μ^- -meson mean life, and the nuclear capture rate for the μ^- meson. (L.M.T.)

90.

2379

LIFE-TIME OF μ -MESONS. B. V. Sreekantan. *Proc. Indian Acad. Sci.* **36**, 289-98(1952) Oct.

The disintegration curves of μ^+ mesons at rest in two absorbers, Pb and paraffin, have been determined experimentally by an oscilloscopic method using cosmic-ray mesons at sea level as the source of μ -mesons. The mean life time for μ^+ mesons in Pb is 2.24 ± 0.17 μ sec and in paraffin 2.24 ± 0.15 μ sec. A description of the equipment built for this experiment is given. (auth)

91.

4218

Rochester Univ.

HIGH ENERGY NUCLEAR PHYSICS: PROCEEDINGS OF THE THIRD ANNUAL ROCHESTER CONFERENCE [HELD AT THE UNIVERSITY OF ROCHESTER ON] DECEMBER 18-20, 1952. H. P. Noyes, M. Camac, and W. D. Walker, comps. and eds. 115p. (NP-4585)

The report summarizes the discussions on the latest experimental and theoretical activities in high-energy nuclear physics which were presented at this conference attended by well over 100 physicists representing about 50 American and foreign universities and research laboratories. The discussions at the various sessions were centered around the following subjects: (1) charge independence and the saturation of nuclear forces; (2) pion production and pion-nucleon scattering; (3) V^0 particles; (4) superheavy mesons and theoretical approaches to the pion problem; (5) pion-nucleon phase shifts—megalomorphs; (6) theoretical calculations of pion-nucleon scattering; and (7) experimental methods for mesic x rays, new particles, μ -meson production in stars, π^0 -meson lifetime and electron pairs, and the general problem of nuclear interactions. (L.M.T.)

92.

5605

THE MEAN LIFE OF NEGATIVE μ MESONS STOPPED IN IRON. A. H. Benade. *Phys. Rev.* **91**, 971-2(1953) Aug. 15.

The mean life of negative cosmic-ray μ mesons stopping in an Fe absorber has been found experimentally to be 0.21 ± 0.06 μ sec. The upper limit to the mean number of neutrons produced is very roughly one per meson captured by an Fe nucleus. (auth)

93.

1297

DETERMINATION OF THE MEAN LIFE-TIME OF μ -MESONS. J. Pernegr. *Nature* **168**, 1004(1951) Dec. 8.

The photographic-emulsion method has been applied to the determination of the mean lifetime of μ mesons from their anomalous absorption. A batch of Ilford C2 plates was exposed without absorber to cosmic radiation at an altitude of 1780 m. A second batch was exposed at 2640 m under a Pb absorber corresponding in stopping power to the layer of air between the two stations. The rest mass m_0 of the μ meson was determined by grain-counting and Coulomb-scattering methods as $m_0 = 110$ Mev/c². The mean lifetime τ_0 was calculated as $\tau_0 = 2.3 \pm 0.3 \times 10^{-6}$ sec from the formula $\tau_0 = \frac{m_0}{p} L$, where p = effective momentum and

L = mean range before decay; L is a function of differences in height and number of mesons at the two altitudes. These measurements show that ρ mesons are almost exclusively μ mesons.

94.

2163

THE LIFETIME OF THE μ^+ -MESON. W. E. Bell and E. P. Hincks. *Phys. Rev.* **84**, 1243(1951) Dec. 15.

The μ^+ -meson lifetime has been determined by stopping the mesons in Fe. Trays of G-M counters in coincidence recorded the distribution of delays between mesons stopping in 3.8 cm of Fe and decay electrons. A least-squares fit to the data gives a mean life $\tau = 2.22 \pm 0.02$ μ sec for the μ^+ meson. The corresponding half life is 1.54 μ sec.

95.

3387

Bartol Research Foundation, Franklin Inst.

FIRST ANNUAL REPORT OF THE WORK OF THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE. Sept. 30, 1951. 313p. (NP-3729)

A review is given of the work completed or in progress from Oct. 1, 1950 to Sept. 30, 1951. The review consists of articles on (1) cosmic rays—investigation at very high altitudes, observations of the latitudes effect at high altitudes, experiments with photographic plates, and redetermination of mean life of the mesotron as a function of momentum; (2) nuclear physics—instruments and some nuclear reactions relating to the Van de Graaff Generator, radioactivity, development conversion counters, and the large Van de Graaff generator; and (3) linear accelerator. All work described is or will be published in suitable form in various scientific journals. Reprints of published reports or copies of reports to be submitted for publication are included in the report.

96.

4167

MEAN LIFE OF THE POSITIVE π -MESON. William L. Kraushaar. *Phys. Rev.* 86, 513-17(1952) May 15.

Photoproduced π^+ mesons stopped and decayed in a xylene-terphenyl liquid scintillation counter. The pulses from the counter were amplified and displayed on two oscilloscopes. The entire sequence $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ could be observed, and from the measurement of 670 π - μ decay times, a value of $2.53 \pm 0.10 \times 10^{-8}$ sec was obtained for the π^+ mean life. (auth)

97.

5173

NUCLEAR INTERACTIONS OF GREAT ENERGY. PART I. EVIDENCE FOR THE CREATION OF HEAVY MESONS. R. R. Daniel, J. H. Davies, H. Mulvey, and D. H. Perkins. *Phil. Mag.* (7) 43, 753-74(1952) July.

The masses of charged mesons produced among the "shower" particles in the nuclear interactions of protons of great energy have been determined by scattering and grain-density measurements. For energies greater than 50 bev heavy mesons of mean mass $\sim 1300 m_e$, provisionally identified as κ mesons, are produced with a frequency comparable with that of the π mesons. Evidence for the creation of such heavy mesons is also provided by an observed decrease in the ratio of neutral π mesons to shower particles at very high energies. A method is described for measuring the lifetime of the neutral π meson, which takes advantage of the existence of an alternative mode of decay: $\pi^0 \rightarrow \gamma + \beta^+ + \beta^-$. It is shown that the proportion of π mesons which decay in this second mode is not greater than 4%. The preliminary observations suggest that the mean lifetime is about 10^{-14} sec. (auth)

98.

5174

HALF LIVES OF μ^+ AND μ^- MESONS. N. Dallaporta. *Nuovo cimento* (9) 9, 449-52(1952) May. (In Italian)

Published data on the half life of μ mesons in various absorbers are collected and discussed. Half lives of $2.215 \pm 0.006 \times 10^{-8}$ sec for μ^+ and $\sim 2.5 \times 10^{-8}$ for μ^- are obtained by extrapolating adjusted values to zero absorber. Methods for improving these values are suggested. 19 references.

99.

5452

Laboratory for Nuclear Science and Engineering, Mass. Inst. of Tech.

SYNCHROTRON GROUP and THEORETICAL GROUP, p.208-22 of PROGRESS REPORT [FOR PERIOD JUNE 1, 1951 TO MAY 31, 1952]. May 31, 1952. 15p. (AECU-2128(p.208-22))

Operation and maintenance of the synchrotron are briefly described. Experimental results obtained with a Be target are given on the mean life of the π^- meson and the ratio π^-/π^+ at angles of 90 and 135° to the synchrotron beam. μ^+ meson detection with the short γ -ray pulse is discussed. The report of the Theoretical Group consists of brief statements of current investigations concerning meson dynamics, nuclear theory, theory of nuclear reactions and scattering, etc.

100.

5453

New York Univ.

I. ON THE MEAN LIFETIME OF μ -MESONS. II. THE VARIATIONS OF THE POSITIVE/NEGATIVE RATIO OF COSMIC RAY μ -MESONS WITH MOMENTUM AND ALTITUDE, by H. A. Morewitz and M. H. Shamos. June 26, 1952. 15p. (NYO-3347)

I. The mean lifetime of μ -mesons in C and S has been measured by the delayed-coincidence technique. The lifetime of the μ^+ meson in S is $\tau_s^+ = 2.09 \pm 0.05 \mu\text{sec}$. This compares favorably with values found in materials of low atomic number, but there is a statistically significant difference between it and a recent measurement in Fe. The lifetime of the μ^- meson in C is $\tau_c^- = 1.92 \pm 0.03 \mu\text{sec}$, a value compatible with Wheeler's theory and other lifetimes determined in materials of higher Z. II. The μ^+/μ^- ratio at a momentum of $\sim 325 \text{ Mev/c}$ at sea level obtained from the time distribution of the delayed coincidences in C and S is $\mu^+/\mu^- = 1.06 \pm 0.03$. When this ratio is compared with other "selected" experiments performed at various altitudes by plotting all ratios as a function of momentum from the top of the atmosphere, then the best fit to the experimental points is given by: $P = P_0 \exp[(\mu^+/\mu^-)/0.38]$, where $P < 4 \text{ bev/c}$ and $P_0 \approx 0.165 \text{ bev/c} = 35 \text{ mb}$. It is concluded that there is no appreciable meson production in the atmosphere above ~ 35 millibars and below ~ 590 millibars. (auth)

101.

1083

University of California Radiation Laboratory
MEASUREMENT OF THE POSITIVE π -MESON LIFETIME.
Clyde E. Wiegand. Oct. 16, 1950. 28p. (UCRL-952)

The use of electronic detectors to determine the lifetime of the π mesons produced in a polyethylene target by the 322-Mev x-ray beam of the Berkeley synchrotron has been investigated. The detectors consisted of two crystals of transstilbene arranged to form a counter telescope at right angles to the beam, the phosphorescent radiation caused by an ionizing particle in either crystal being detected by multiplier phototubes. Pulses were recorded in both differential and integral fashion. The following results for the mean lifetime and half life of positive π mesons are given: $\tau = (2.62 \pm 0.13) \times 10^{-8}$ sec, $T_{1/2} = (1.82 \pm 0.09) \times 10^{-8}$ sec from differential data; $\tau = (2.58 \pm 0.14) \times 10^{-8}$ sec, $T_{1/2} = (1.79 \pm 0.10) \times 10^{-8}$ sec from integral data.

102.

1583

M.I.T. Laboratory for Nuclear Science and Engineering
COSMIC RAY GROUP, p.11-22 of [SEVENTEENTH]
PROGRESS REPORT; [JULY 1, 1949, TO JULY 1, 1950].
Bruno Rossi and G. E. Valley. July 1, 1950. 12p.
(NP-1777)

Work during the past year on shower production by penetrating particles; observations with the large square, the high-pressure, and the 12-in. cloud chambers; balloon-borne experiments; air showers; specific ionization; scintillation counters; short-pulse detection of synchrotron mesons; and π^+ meson lifetime is summarized.

103.

4509

Atomic Energy Research Establishment, Harwell, Berks.
(England)

EXPERIMENTS ON THE CAPTURE OF NEGATIVE μ
MESONS. R. Batchelor. Apr. 4, 1951. 20p. (AERE-
N R-682)

Experiments have been carried out to measure the mean
lives of negative μ mesons in materials of low atomic num-
ber by detecting any neutrons emitted after capture. No
conclusions could, however, be made on this capture proc-
ess since the bremsstrahlung produced by the decay elec-
trons in their passage through the absorber gave a larger
counting rate than the neutron rate looked for. The results,
however, have been used to add weight to the conclusions of
Hinks and Pontecorvo that the μ meson decays by the proc-
ess $\mu \rightarrow e + 2\nu$. (auth.)

104.

6354

ON THE LIFETIME OF THE NEGATIVE π -MESON.

L. M. Lederman, E. T. Booth, H. Byfield, and J. Kessler.
Phys. Rev. **83**, 685-6(1951) Aug. 1. (Letter to the editor)

The negative π -meson lifetime has been redetermined,
using the external meson beam of the Nevis cyclotron. The
decays were observed in the course of the flight of π mesons
through a 16-in. magnet cloud chamber. The μ^- meson
mass obtained from momentum and mass analyses of the
cloud-chamber data is $209.8 \pm 1.3 m_e$, and the lifetime is
 $2.92 \pm 0.32 \times 10^{-8}$ sec.

105.

6355

CAPTURE OF μ -MESONS IN HEAVY ELEMENTS. F. B.
Harrison, J. W. Keuffel, and G. T. Reynolds. Phys. Rev.
83, 680-1(1951) Aug. 1. (Letter to the editor)

Mean-life measurements of negative μ mesons in Cu and
Sb have been made. Large liquid scintillation counters
recorded the delayed γ rays and neutrons of a few Mev
produced by meson capture in the absorber. Integral delay
distributions for Cu and Sb are shown, and mean lives of
 0.122 ± 0.014 and $0.050 \pm 0.006 \mu\text{sec}$, respectively, were
computed. Another graph shows the capture probability vs.
effective atomic number Z_{eff} as calculated by Wheeler
(Revs. Modern Phys. **21**, 133(1949)). Good agreement with
the Z_{eff}^2 law was found.