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

An estimate of the \( \pi^0 \) mean lifetime was obtained from a sample of 232 \( K^+ \) (\( K^+ \rightarrow \pi^+ + \pi^0 \)) decays at rest. The \( \pi^0 \)'s were detected by the Dalitz mode (\( e^+ + e^- + \gamma \)), and the decay distances from the \( K^+ \) ending to the \( \pi^0 \) decay points were measured. These events were found in an area scanning of an emulsion stack of 600-\( \mu \)m Ilford G5 emulsion pellets exposed to a 400 MeV/c separated \( K^+ \) beam. The observed mean \( \pi^0 \) lifetime is \( (1.0 \pm 0.5) \times 10^{-18} \) sec. (auth)

2.

In investigating the reaction \( \gamma + p \rightarrow \pi^+ + n \) with 320 MeV gamma quanta, there is a kinematic relation between the energy of the gamma quantum and the angle of emission of the \( \pi^+ \)-meson. The problem can be resolved by counting only the \( \pi^+ \)-mesons emitted at a given angle with a definite energy. A scintillation counter with a small inlet aperture can be used for counting the \( \pi^+ \)-mesons. Magnetic analysis and measuring the range in a substance can be used to determine the energy of the \( \pi^+ \)-mesons. The \( \pi^+ \)-mesons can also be identified from the \( \pi^+ \) - \( \mu \)-transition, which takes place with a characteristic time \( \tau \approx 2.55 \times 10^{-8} \) sec. The pulse from the \( \pi^+ \)-meson and the pulse from the \( \mu \)-meson are counted in coincidence to detect the \( \pi^+ \) - \( \mu \)-decay. A diagram of the electronic arrangement is presented. The lifetime of the \( \pi^+ \)-meson was determined from a plot of \( N_\mu \) as a function of the time shift in the gate pulse. (TTT)

3.

An estimate of the \( \pi^0 \) mean lifetime was obtained from a sample of 232 \( K^+ \) (\( K^+ \rightarrow \pi^+ + \pi^0 \)) decays at rest. The \( \pi^0 \)'s were detected by the Dalitz mode (\( e^+ + e^- + \gamma \)), and the decay distances from the \( K^+ \) ending to the \( \pi^0 \) decay points were measured. These events were found in an area scanning of an emulsion stack of 600-\( \mu \)m Ilford G5 emulsion pellets exposed to a 300 MeV/c separated \( K^+ \) beam. The observed mean \( \pi^0 \) lifetime is \( (1.0 \pm 0.5) \times 10^{-18} \) sec. (Dissertation Abstr.)

4.

The lifetime of the positive pion (\( \pi^+ \)) was measured by a digital timing technique for mesons (\( \pi \)) 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 (\( \pi \)) were brought to rest in a counter at the rate of 250/sec. A second scintillation counter for counting mesons (\( \pi \)) was optically separated from the \( \pi \) counter by a thin sheet of aluminized plastic. A large fraction of mesons (\( \pi \)) from the \( \pi \) mesons (\( \pi \)) decaying in the \( \pi \) counter penetrated into the \( \mu \) counter. Thus the \( \pi \) meson (\( \pi \)) stop signal and the meson (\( \pi \)) decay signal occurred in different counters, permitting measurement of the time interval for each decay event by means of a 100 Me digital time analyzer. About 2.5 \times 10^5 events with time intervals between 40 and 250 nsec after the meson (\( \pi \)) stop signal were used in the analysis. The weighted mean of 15 runs yielded a value of 26.1 \pm 0.02 nsec for the mean lifetime of the positive meson (\( \pi \)). (J.F.P.)

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

6. **PRIMAKOFF EFFECT AND $\pi^+$ LIFETIME.**


The results of an experiment to measure the $\pi^+$ lifetime via the inverse decay process (Primakoff effect) are presented. The coherent photoproduction of neutral pions in the reaction $\gamma + Pb \rightarrow \pi^0 + Pb$ was measured with very high angular resolution with a $\pi^0$ 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 $\tau$, the phase difference $\phi$ between the electromagnetic and nuclear amplitude, the strength $C$ of the nuclear amplitude, and the nuclear radius $R_n$. Neutral-pion reabsorption inside nuclear matter is taken into account, and a $\chi^2$ analysis of the data is done in terms of $\tau$, $\delta$, $C$, and $R$. The best fit $\tau$ value is $(0.73 \pm 0.105) \times 10^{-16}$ 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. **IZMERENIE VREMENI ZHIZNII $\pi^+$-MEZONA.**


The mean lifetime of the $\pi^+$ meson is measured by the method which is not affected by the background due to the accompanying $\mu^- - e^+$ decay. The stoppings and decay of $\pi^+$ 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 $\pi^+$ lifetime to be $\tau_{\pi^+} = (25.85 \pm 0.35)\mu$s. The main difference of this method from those applied earlier is that it employed a "trap" for positrons appearing in $\mu^- - e^+$ decay, which allowed to decrease this background by more than two orders of magnitude. (auth)


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

9. **MEASUREMENT OF THE LIFETIME OF THE POSITIVE PION.**


Using fast electronic techniques, the $\mu^- - e^+$ decay sequence for about $10^8$ stopped positive $\pi$-mesons was observed. The exponential decay of the $\pi$ can be followed for 8 mean lives, and yields a value of $\tau_{\pi^+} = 26.60 \pm 0.98$ nsec. This value disagrees with previously reported values. (auth)

10. **COMPARISON OF PION AND ANTIPION LIFETIMES.**


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

11. **EXPERIMENTAL EVIDENCE FOR THE EXISTENCE OF THE PRIMAKOFF EFFECT AND A NEW MEASUREMENT OF THE $\pi^+$ LIFETIME.**


The coherent photoproduction of mesons ($\pi^+$) 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 ($\pi^+$) was determined from the magnitude of the effect. (D.C.W.)
The masses, decay rates, and decay spectra of the octet of \(\pi\) mesons, the nonet of \(\Lambda\) 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 26 states, combining an SU(61) with an SU(6)3. Further, the strength of the couplings of the SU(3) octets in the 26 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 \(\pi\) mesons and \((M, M, J)\). 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)

The lifetime ratio of \(\pi^+\) and \(\pi^-\) 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 \(|(\tau(\pi^+)/\tau(\pi^-))| = 0.98 \pm 0.08. (\pi-\pi)

The mean lifetime of the meson \(\pi^+\) was measured by a method in which the influence of the background due to the accompanying \(\pi^-\) and \(\pi^\circ\) decay is excluded. The measured lifetime is equal to 25.85 \pm 0.35 nsec. (auth)


An experiment to measure the ratio \(\tau(K^+)/\tau(K^-)\) is described. An analysis of the effects of the experimental procedure the lifetime ratio of the \(\pi\) mesons was also measured. (B.G.D.)


An experiment for measuring the total lifetime of positive and negative mesons \(\tau\) and the ratio of these lifetimes is described. The lifetime measurement for the negative mesons \(\tau\) in flight is performed, and the positive \(\tau\) lifetimes are determined by measuring the attenuation due to decay as a function of distance of nearly identical beams of mesons \(\tau^+\) and \(\tau^-\). The results are \(26.0 \pm 0.08\) nsec for mesons \(\tau^+\) and \(25.80 \pm 0.21\) for mesons \(\tau^-\) lifetimes. (J.F.P.)


A stack of Ilford L4 emulsions was exposed to a stopping \(K^+\) beam at Berkeley. The \(K_L\), decay of the \(K^+\), \(K_L\), \(\pi^+\) was used to estimate the lifetime of the \(\pi^+\). A final sample of 38 events was measured, errors were estimated, and the flight distance of the \(\pi^+\) was calculated. The final result was a lifetime of about \(1.5\) x 10^-14 sec. This result is in agreement with other experiments. (A.G.W.)


The \(\pi^0\) mean life is measured using a method that utilizes the relativistic flight-path dilation produced by a high pion velocity. A \(\pi^0\) 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 \(\pi^0 \rightarrow e^-\pi^+\pi^-\pi^+\) in a study of 3600 such stars. The primary path lengths could be accurately measured and were automatically calculated by specially developed equipment. The \(\pi^0\) 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 the charged secondary pions at all angles is \(274 \pm 10\) Mev/c. The mean longitudinal momentum 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 \(\tau(\pi^0)\) of the \(\pi^0\). 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 \((1.7 \pm 0.5)\) x 10^-14 sec. (auth)
20.


After a summary of the electromagnetic properties and lifetime of the meson(a), calculations and measurements of the hfs intervals for hydrogen, muonium, and positronium, and of the fine structure intervals of the 2p 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.


An experiment is described to measure the mean life of the π0 meson using nuclear emulsions. The basic method was employed previously, viz., the determination of the flight distances of π0 mesons produced at a unique velocity in the K_2 decay mode of the K^{+} meson and decaying through the mode π^{0} → γ + e^{+}e^{-}. The coordinates of the grains composing the tracks in 67 such events were measured, and the flight distances of the π0'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 \( \tau_{π0} = (1.6±0.5\times10^{-11}) \times 10^{-11} \) sec. (auth)

22.


The lifetime of the neutral meson (\( \pi \)) was measured by studying meson (\( \pi^0 \)) 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 (\( \pi \)) 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 (\( \pi^0 \)) disintegration into two photons, and the resulting cross section is inversely proportional to the meson (\( \pi^0 \)) lifetime. The coherent photoproduction of neutral mesons (\( \pi \)) on lead around the forward direction was measured with an angular resolution of the order of 0.5° using a meson (\( \pi^0 \)) detector containing 10 independent counting channels. The lifetime obtained is \( \tau_{π} = 0.74±0.16 \times 10^{-11} \) sec. (J.F.P.)

23.


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 130 and K.5 nuclear research emulsions. From a total of 3600 interactions, 103 neutral pions were found, which decayed by the Dalitz mode \( π^0 → (π^0 + \gamma) + γ \). 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 \( τ_{π^0} = 2.5±0.1 \times 10^{-11} \) 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.)

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


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


The lowest order electromagnetic corrections to \(\beta\) and \(\mu\) decay have been calculated in an intermediate vector-boson theory. Assuming universal coupling, the \(\mu\) 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)


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


An experiment to measure the \(\pi^0\) mean life, using a new method that utilizes the relativistic flight-path dilatation produced by a high pion velocity is reported. A negative pion meson beam of 3.5 Bev/c interacts in Ilford K.5 emulsion. Some 163 secondary \(\pi^0\) are observed to decay by the Dalitz mode \(\pi^0 \rightarrow e^+ e^- \gamma\) in a study of 3600 such stars. The \(\pi^0\) path lengths can be accurately measured and are automatically calculated by specially developed equipment. The \(\pi^0\) 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 in 274 \(\times\) 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 \(\tau\) of the \(\pi^0\). 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,325-371)) The determination of the lifetime of the \(\pi^0\) meson. H. Heckman (California. Univ., Berkeley. Lawrence Radiation Lab.). Measurements and techniques for a nuclear emulsion experiment to determine the meson \(\pi^0\) lifetime are discussed. (C.E.S.)

32. 19106  Mean life-time of the neutral pion. E. L. Koller, S. Taylor, and T. Huettler (Stevens Inst. of Tech., Hoboken, N.J.). Nuovo Cimento (10), 27: 1405-9 (Mar. 16, 1963). (In English) The mean lifetime of the \(\pi^0\) meson is measured. The decay distance of \(\pi^0\) mesons produced by \(K^+\) decay at rest \((K^+ - \pi^+ + \pi^0)\) and subsequent decay by the Dalitz mode \((\pi^0 - e^+ + e^- + \gamma)\) is measured. Using Ilford G-5 emulsions, exposed in a 300 Mev/c separated \(K^0\) beam, 88 of the above events are found. The observed mean \(\pi^0\) lifetime is \((2.8 \pm 0.8) \times 10^{-16}\) sec. (auth)

33. 19122  Mean life of the neutral pion. G. Van Dardel, D. Dekkers, R. Mermid, J. 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(\(\pi^0\)) 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 \(\pi^0\), which is effective in producing 5-Bev/c positrons, is obtained by weighting the \(\pi^0\) spectrum with the probability that a positron from a \(\pi^0\) has a momentum of 5-Bev/c. The momentum spectra of \(\pi^0\) and \(\pi^+\) are assumed to be of equal shape and the latter was measured. This effective \(\pi^0\) 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 \((1.05 \pm 0.18) \times 10^{-18}\) sec. (C.E.S.)


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


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 and less than 1 part in \(10^6\) of other impurities. In this situation, the rate of \(\mu^-\) capture in H was the only significant correction to the free decay rate of \(\mu^-\) 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. \(\mu^-\) and \(\mu^+\) 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: \(\tau_{\mu^-} = 2.198 \pm 0.002\) nsec (hydrogen correction made); \(\tau_{\mu^+} = 2.197 \pm 0.002\) nsec; and \(R = \tau_{\mu^-}/\tau_{\mu^+} = 1.000 \pm 0.001\). (auth)

36. 10975  Decay of neutron pions. Hua 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 dilution. 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 \(250 \pm 10\) Mev/c. The neutral pion mean life is \((1.85 \pm 0.2) \times 10^{-18}\) sec. (auth)


Positive and negative muons are stopped and their decays 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 \((2.08 \pm 0.33) \times 10^{-4}\) sec, and the negative muon mean life in carbon is \((1.94 \pm 0.08) \times 10^{-4}\) sec. (J.R.D.)
A precision measurement of the mean lifetime of the positive muon, \( \tau(\mu^+ \rightarrow e^- + \nu_\mu + \bar{\nu}_\mu) \), 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 \( f(\pi^-) = (3069 \pm 13) \text{sec} \) and \( m_\mu = 206.76\text{MeV} \), is (including radiative corrections) \( \tau(\mu^+) = 2.208 \pm 0.05 \mu\text{sec} \), and thus in disagreement with the experimental value. A discussion of the logical operation leading to 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)

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.)

The energy distribution of neutrons from the charge exchange reaction \( \pi^+ + p \rightarrow n + n \) was studied, for \( \pi^+ \) mesons stopped in liquid hydrogen, to investigate the possible existence of a second \( \pi^+ \) with mass within a few MeV of the mass of the "ordinary" \( \pi^+ \). No neutron group corresponding to such a second \( \pi^+ \) 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 \( \pi^+ \) with a mass in the range between about 2 to 5 MeV away from the mass of the ordinary \( \pi^+ \). The data give a lower limit to the \( \pi^+ \) lifetime: \( \tau > 5 \times 10^{-11} \text{sec} \). (auth)

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 $\pi^0$ 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 15%. A minimum photon energy of 1 kev was required to avoid uncertainties in the nuclear form factor. A higher photon energy would be necessary only if the $\pi^0$ mean life was greater than $5 \times 10^{-17}$ sec. The backgrounds to be expected from nuclear photoproductions were estimated and found to be sufficiently small. In particular, the interference between the coherent nuclear $\gamma$ photoproduction and the Primakoff process was not excessive. (auth)

AN EXPERIMENT TO DETERMINE THE $\mu^0$ LIFETIME. A. V. Tollestrup, S. Berman, R. Gomes, and H. Ruderman (California Inst. of Tech., Pasadena). p. 37-30 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 muon ($\mu^0$) by observation of the photoproduction process in the Coulomb field. The cross sections were measured for a high target. The lifetime was not determined from the data. However, calculations indicate that, if all the events at 0° can be attributed to the lifetime effect, the lifetime is $\pm 5 \times 10^{-17}$ sec. (M.C.G.)


Preliminary results gave a lifetime of $2.3 \pm 0.8 \times 10^{-14}$ sec for the neutral pion. Mesons ($K^0$) were stopped in an emulsion and the emulsion scanned for $K_{\ell 4}$ decays accompanied by a Dultz pair. The weighted average of the events gave $0.122 \pm 0.045$ for the mean decay distance. This led to the lifetime value given. (M.C.G.)


The lifetime of $\mu^0$ 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 $0.123 \pm 0.006 \mu$sec was obtained for the lifetime. (M.C.G.)


The elastic scattering of photons by protons was measured for 100- to 290-Mev photons at 90 and 135° c.m. scattering angles. The expected large increase in cross section is observed at energies approaching that of $(\gamma, \pi^0)$ pion-meson resonance. The scattering can be qualitatively explained by the ordinary Thomson amplitude combined with that of the $(\gamma, \pi^0)$ 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 $\pi^0$ photon coupling. From the experimental data, a conclusion may be made that the $\pi^0$ mean life should be between $10^{-14}$ and $10^{-15}$ sec. (auth)


The lifetimes of about 5 million positive mu mesons were measured using a crystal-controlled oscillograph as a clock. The resulting decay curve was analyzed on a digital computer and gave a mean life of $2.211 \pm 0.023 \mu$sec. The mean life of negative mu mesons in carbon was measured and found to be $2.043 \pm 0.033 \mu$sec. The resulting nuclear capture rate is $0.373 \pm 0.011 \times 10^9$/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 n AT HIGH ENERGY AND n LIFETIME. C. Chiuderi (Universita, 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 n meson using n 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 (p mass number), the incoherent cross section does not have the factor sin2 θ which affects both the Coulomb and the nuclear coherent cross sections. A calculation of the incoherent photoproduction of n 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 \(10^{-18}\) may be measured by this method. (auth)

51. 

A survey is made of mesons (m, k), hyperons (A, Λ, Σ), 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. 

Using the scintillation counter method, measurements were made of the values, average with respect to two state of hyperfine structure, of the \(μ_0\) asymmetry coefficients of (μ - 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 \(μ_0\) 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 \(μ_0, \tau, n, and \(μ_0\) level populations in the states F = 1 and F = 0 in phosphorus as well as the \(μ_0\) and \(μ_0\) probabilities of the capture of mesons by the nucleus these states were calculated. The values found indicated that \(μ_0 > \lambda_1, (auth)\)

53. 

Discussions are presented of research carried out in the fields of: Nuclear Physics, on prompt γ rays from He^6 bombardment of O^16, mesons-\(n^0\) 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 CaF_2/Mn thermoluminescence dosimeter, and luminescence phenomena in glass. (B.O.G.)

54. 

An estimate of the mean lifetime of the \(\pi^0\) 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 \(K_L^0\) meson (\(K^+\) - \(\pi^+ + \pi^0\)) and the subsequent decay of the \(\pi^0\) via the Dalitz mode, \(\pi^0 → e^+ + e^- + γ\). In the present experiment we were able to utilize a new fine-grained emulsion (llford I.4) 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 \(\pi^0\) is \(1.9 ± 0.5 \times 10^{-16}\) sec. (auth)

55. 

The angular distribution of neutrons following the nuclear capture of polarized mesons (\(μ^0\)) in \(^{12}\)C was determined for the process: \(μ^0 + p → n + ν\). The (\(μ^0\)) lifetime in \(^{12}\)C was determined to be \(0.46 ± 0.05\) μsec. (C.J.G.)

56. 

Measurements for the determination of the apparent mean life of \(μ^−\)-mesons in Ca and Pb are reported. The values obtained are \(τ = (35.7 ± 3) \times 10^{-4}\) sec in Ca and \(τ = (7.3 ± 0.6) \times 10^{-4}\) sec in Pb. The results are in agreement with those obtained by other investigators and with theoretical estimations. (auth)
57.
14302

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

58.
19740

The mean life of the positive \( \pi^+ \) meson was determined from about 8000 \( \pi^- \mu^- \) 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 \( \pi^+ \) meson is \( \tau_\pi = 25.46 \pm 0.32 \) nsec. (auth)

59.
12049

A one inch carbon target was bombarded by 70-Mev \( \pi^0 \) mesons. The muons from \( \pi^0 \) decays were randomly polarized, thus eliminating possible modulation of the decay curve. The weighted average of 16 runs gave a mean life of \( 2.211 \pm 0.003 \) \( \mu \)sec for \( \mu^- \) mesons. The mean life of \( \mu^- \) mesons was found to be \( 2.043 \pm 0.003 \) \( \mu \)sec. (B.O.G.)

60.
24295

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 \( G_f \) for the vector \( \beta \)-decay and \( G_\mu \) for the muon decay are equal. The precision with which \( G_\mu \) is known has improved considerably due to more accurate measurements of the muon mean lifetime and mass. To determine \( G_\mu \) more accurately the \( f^+ \) value was measured for the \( 0^- \rightarrow 0^+ \) transition in \( O^{14}(2^+)N^{14}_0 \). After a total correction of +0.289\% for nuclear electromagnetic form factors, competition from \( K \) capture, and electron screening, the \( f^+ \) value is 3069 \pm 13 nsec. The corrected \( f^+ \) value yields \( G_\mu = (1.416 \pm 0.003) \times 10^{-48} \) erg cm\(^2\). If this value is adopted for \( G_\mu \), then, without radiative corrections, the calculated mean lifetime of the muon becomes 2.260 \pm 0.010 \( \mu \)sec, which is 1.8 \pm 0.5\% greater than the mean of the observed lifetime, 2.219 \pm 0.003 \( \mu \)sec. (B.O.G.)

61.
12049
NYO-8546
ON MEASUREMENT OF THE LIFETIME OF THE \( s^3 \) MESON. K. Lande and W. Selove. Apr. 22, 1958. 4p. Contract AT(30-1)-2055. $1.80 (pb), $1.80 (mf) OTC.

Because the lifetime \( \tau \) is not infinite, the rest mass of the \( s^3 \) is defined only within an energy uncertainty \( \Delta M = \hbar/\tau \). This energy width will show up as a second spread in the Q value of the reaction \( \pi^+ + p \rightarrow s^3 + n + Q \). The kinetic energy of the neutrons produced in this reaction will show a fractional spread given by \( \Delta T/T = \Delta M/Q \), where \( \Delta M \) is the spread in mass value of the \( s^3 \). By carrying out the reaction with \( s^3 \) 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 \( s^3 \) beam intensities to measure \( \Delta T/T \) to about 1\%. This would permit determination of the lifetime if shorter than \( 10^{-10} \) to \( 10^{-12} \) 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 \( 10^{-12} \) to \( 10^{-14} \) seconds. (A.C.)

The lifetime of \( \mu^- \) 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.


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.B.R.)


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 \( \mu^- \) lifetime is described. A value of 2.261 \( \pm 0.007 \) \( \mu \) sec was found for the \( \mu^- \) mean life. (W.D.M.)


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


A detailed investigation into nuclear collisions of energy between \( 10^{12} \) to \( 10^{13} \) ev is reported. The ratio of \( \pi^- \) mesons to charged shower particles has been determined with high statistical accuracy yielding a value \( R = 0.353 \pm 0.044 \). 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 \( \pi^- \) mesons) are created in approximately equal numbers and that the interaction mean free path for such particles does not differ appreciably from that of \( \pi^- \) mesons, the values \( R \) and \( Q \) enable an estimate to be made of the fraction of shower particles which are not \( \pi^- \) 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 Dahanyake 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 \( \pi^- \) meson has been determined by a method which does not involve the
determination of the energy of the meson. The mean life obtained is \(1.25 \times 10^{-15}\) sec. (auth)

70.

6849


A new upper limit on the \(s^0\) lifetime has been obtained by using 12 \(K_{e3}^0\) endings in nuclear emulsion where the \(s^0\) decays by a direct pair, \(s^0 - (e^+ + e^-) \gamma\). The distance traveled by the \(s^0\) before decay was measured from the intersection of the \(K^+\) and \(s^0\) tracks to the intersection of the pair and \(s^0\) (collinear with \(s^0\)). The inherent accuracy of the measuring technique was found to be \(\pm 0.5\) micron per event by using \(\gamma\) secondary as mock events. With the statistics of 12 events it should be possible to detect a \(s^0\) decay length of \(\pm 0.3\) microns or greater. Our data give no indication of a displacement of pair origins from the \(K\) endings. Thus the \(s^0\) decay length is probably less than \(0.3\) microns. This corresponds to a lifetime of less than \(5 \times 10^{-14}\) sec. Information on the upper limit of the \(s^0\) lifetime is obtained from a plot of the likelihood function vs \(s^0\) lifetime. The likelihood function is down by a factor of 30 for a lifetime of \(1 \times 10^{-15}\) sec and is rapidly decreasing for longer lifetimes. (auth)

71.

9030


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 \(1.35 \pm 0.5\) s. The effect of experimental biases is discussed, and the final result is compared with that of other authors. (auth)

72.

12173


The delayed coincidence technique has been used to observe the decay of a composite beam of positive and negative \(\mu\) 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 0.8 to 4.0 \(\mu\)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 \(1.58 \pm 0.07, 2.15 \pm 0.09, 1.48 \pm 0.08\) \(\mu\)secs. in Al, C, S respectively. The mean lives of positives in Al, Pb, and S are \(2.35 \pm 0.11, 2.23 \pm 0.09, 2.15 \pm 0.14\) \(\mu\)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 \(1.93 \pm 0.24\) \(\mu\)secs. From the data obtained, the ratio of positive to negative \(\mu\) mesons has been found to be \(0.95 \pm 0.16\). 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


The composite mean life of \(\mu\) 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 \(\mu^{+}/\mu^{-}\) ratio is nearly unity, the mean life of the negative \(\mu\) mesons has been obtained to be equal to \(2.04 \pm 0.14\) (carbon), \(1.52 \pm 0.14\) (NaOH), microseconds. (auth)

74.

304


Problems in the measurement of the extremely short lifetime 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 \(10^{-14}\) sec are considered feasible. (D.E.B.)

75.

918


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 \(\gamma\) energies in the region 1000 Mev and above. An estimate of the lifetime of \(\pi^0\) mesons yields a value of \(1.2 \times 5 \times 10^{-16}\) sec. (D.E.B.)
3216 UCRL-3314

76.
3322 CEA-482

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 mesons in the showers was found to be 2.10 ± 0.15 ms. (B.J.H.)

77.
4782

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 absorbers to be equivalent in 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 1.86 ± 0.19 microseconds. In the case of NaF (C, Al, 10.13 absorber), the experimental points have been found to represent a composite decay curve giving the mean life equal to 1.82 ± 0.09 microseconds. The Z dependence of the composite mean life has been found to fit an empirical relation, μ = 2.50 - 0.965 Z microseconds in the interval Z = 6 to Z = 16. (auth)

78.
9504

An analysis is presented of the soft component arising from a high-energy nuclear shower (~ 3 x 10^12 ev) observed is 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 (1.9 ± 0.5) x 10^{-11} 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)

79.
3956

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 x 10^{-9} sec, its lifetime is (11.0 ± 1.1) x 10^{-9} sec. No evidence for any longer-lived heavy mesons has been found. (auth)

80.
4544

The anomalous magnetic moment of the intermediate nucleons has been included in a treatment of the two-photon decay of the π\(^+\). 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)

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


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 moments 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 \( 2.3 \times 10^{-8} \) 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 Nielson. (auth)


The system used for the determination of the lifetime of the \( \mu \) meson in Pb was described previously (NYO-074). The lifetime was determined as \( 66.5 \pm 11 \) usec, after correction for the large background. This is not inconsistent with the value of \( 72 \pm 5.2 \) usec, reported by Harrison, Koufeli, Godfrey, and Reynolds (Phys. Rev. 86, 616A(1952)). (L.M.T.)


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

\[ \pi^- \rightarrow \mu^- + \nu \]

\[ \nu_{\mu} + \bar{\nu}_{\mu} + N \]

are then compared under the assumption that both reactions are governed by the same form and strength of \( \beta \) 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: \( 5 \times 10^{-10} \) sec for \( Q = 35 \) Mev and \( 2 \times 10^{-10} \) sec for \( Q = 75 \) Mev. The two \( Q \) values have been interpreted in terms of a mass doublet. (auth)


The mean lives of the \( \pi^+ \) and \( \pi^- \) 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, \( \pi^+ \rightarrow \mu^+ + \nu \), is assumed to be isotropic in the rest system of the \( \pi \) 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)

THE DISINTEGRATION OF \( \mu \) MESONS IN CARBON. A. Alberigi Quaranta and E. Pancini. Nuovo cimento (0) 9, 955-8(1952) Oct. (in English)

An experiment is described for the study of some of the properties of \( \mu \) mesons stopped in carbon. The \( \mu^+ \) and \( \mu^- \) mesons have been studied separately, and very precise apparent mean lifetimes in carbon of \( \tau^+ = 2.22 \pm 0.06 \) usec and \( \tau^- = 2.18 \pm 0.07 \) usec 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 \( \mu^+ \) and \( \mu^- \) 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)

Lifetimes of \( \mu^- \) mesons stopped in Li, Be, and C have been determined with the apparatus used for measurement of the \( \mu^- \)-meson lifetime (Phys. Rev. 84, 1243(1951)). About 50,000 decays in each element, with delays in the range 1 to 11 \( \mu \)sec, were counted. The contribution to the decay curves of the \( \mu^- \) decay was estimated by computing the relative number of \( \mu^- \) mesons stopped in the absorber, brass counter walls, and iron supports, assuming a \( \mu^- \)-meson mean life of 2.22 \( \pm \) 0.02 \( \mu \)sec, as previously determined. The \( \mu^- \)-decay curve was then determined by subtracting the \( \mu^- \) component from the measured composite (\( \mu^+ + \mu^- \)) curve. The \( \mu^- \) and \( \mu^- \) decay lifetimes are equal within the limits of experimental error. Data for each absorber lies to the fraction \( f \) of the total electron emission rate due to \( \mu^- \) mesons, the composite (\( \mu^+ + \mu^- \)) mean life, the \( \mu^- \)-meson mean life, and the nuclear capture rate for the \( \mu^- \) meson. (L.M.T.)


The disintegration curves of \( \mu^- \) 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 \( \mu^- \) mesons. The mean life time for \( \mu^- \) mesons in Pb is 2.24 \( \pm \) 0.17 \( \mu \)sec and in paraffin 2.24 \( \pm \) 0.15 \( \mu \)sec. A description of the equipment built for this experiment is given. (auth)


The \( \mu^- \)-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 lifetime \( \tau = 2.22 \pm 0.02 \mu \)sec for the \( \mu^- \) meson. The corresponding half life is 1.54 \( \mu \)sec.
96.


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 π⁺ → μ⁺ → e⁺ could be observed, and from the measurement of 670 π⁺-decay times, a value of 2.53 ± 0.10 × 10⁻⁴ sec was obtained for the π⁺ mean life. (auth)

97.


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 ~1300 me, provisionally identified as π mesons, are produced with a frequency comparable with that of the 7 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: π⁻ → γ + β⁺ + β⁻. It is shown that the proportion of π mesons which decay in this second mode is not greater than 1%. The preliminary observations suggest that the mean lifetime is about 10⁻¹⁴ sec. (auth)

98.


Published data on the half life of μ mesons in various absorbers are collected and discussed. Half lives of 2.215 ± 0.006 × 10⁻⁴ sec for μ⁺ and ~2.5 × 10⁻⁴ sec for μ⁻ are obtained by extrapolating adjusted values to zero absorber. Methods for improving these values are suggested. 10 references.

99.


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 r/3₄ 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.


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 C is r⁺ = 2.09 ± 0.05 μsec. 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 r⁻ = 1.92 ± 0.03 μsec, 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 ~325 Mev/c at sea level obtained from the time distribution of the delayed coincidences in C and S is μ⁺/μ⁻ = 1.06 ± 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 = P₀ ≥ [μ⁺/μ⁻]/0.38, where P < 4 bev/c and P₀ = 0.185 bev/c = 35 mb. It is concluded that there is no appreciable meson production in the atmosphere above ~55 millibars and below ~800 millibars. (auth)

101.


The use of electronic detectors to determine the lifetime of the π mesons produced in a polychethylene target by the 322-Mev x-ray beam of the Berkeley synchrotron has been investigated. The detectors consisted of two crystals of tristibene arranged to form a counter telescope at right angles to the beam, the phosphorescent radiation 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: r⁺ = (2.62 ± 0.13) × 10⁻⁴ sec, T₁/₂⁺ = (1.82 ± 0.09) × 10⁻⁴ sec from differential data; r⁺ = (2.58 ± 0.14) × 10⁻⁴ sec, T₁/₂⁺ = (1.79 ± 0.10) × 10⁻⁴ sec from integral data.

102.


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

**EXPERIMENTS ON THE CAPTURE OF NEGATIVE \( \mu \)**

MESONS. R. Batchelor. Apr. 4, 1951. 20p. (AERRN-882)

Experiments have been carried out to measure the mean lives of negative \( \mu \) mesons in materials of low atomic number by detecting any neutrons emitted after capture. No conclusions could, however, be made on this capture process since the bremsstrahlung produced by the decay electrons 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 Blanks and Pontecorvo that the \( \mu \) meson decays by the process \( \mu \rightarrow e + 2\nu \). (auth)

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**ON THE LIFETIME OF THE NEGATIVE PI-MESON.**


The negative \( \pi \)-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 \( \pi \) mesons through a 16-in. magnet cloud chamber. The \( \mu^- \) meson mass obtained from momentum and mass analyses of the cloud-chamber data is 209.8 ± 1.3 m\(_e\), and the lifetime is 2.42 ± 0.32 \times 10^{-6} \text{sec}.

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**CAPTURE OF \( \mu^- \)MESONS IN HEAVY ELEMENTS.**


Mean-life measurements of negative \( \mu \) mesons in Cu and Sb have been made. Large liquid scintillation counters recorded the delayed \( \gamma \) 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 ± 0.006 \text{\mu sec}, respectively, were computed. Another graph shows the capture probability \( \text{e} \) vs. effective atomic number \( Z_{\text{eff}} \) as calculated by Wheeler (Rev. Modern Phys. 21, 133(1949)). Good agreement with the \( Z_{\text{eff}} \) law was found.