

CFSTI PRICE(S) \$	_____	N66-18306	
		(ACCESSION NUMBER)	(THRU)
Hard copy (HC)	<u>1.00</u>	<u>6</u>	<u>1</u>
		(PAGES)	(CODE)
Microfiche (MF)	<u>.50</u>	<u>CR 70754</u>	<u>24</u>
		(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

853 July 65

A New Measurement of the Lifetime of the Positive Pion*

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* Supported in part by the National Aeronautics and Space Administration.

The lifetime of the positive pion has been measured by a digital timing technique for pions stopped in a plastic scintillation counter. Use of this method has permitted improvement in precision by more than an order of magnitude over previous measurements.¹

The counter arrangement is shown in Fig. 1. Pions from the Carnegie Tech cyclotron were brought to rest in counter " π " at the rate of 250/sec. A second scintillation counter (" μ ") was optically separated from " π " by a thin (0.0005") sheet of aluminized plastic. A sizable fraction of the muons from pions decaying in counter " π " (thickness 0.032 in.) penetrated into counter " μ ". Thus the pion stop signal and the muon decay signal occurred in different counters, permitting measurement of the time interval for each decay event by means of a 100 Mc/sec digital time analyzer.²

Fast coincidence logic (10 nsec resolution) provided a pion-stop signal $12\pi\bar{5}$ which opened the gate of the digital timer, and the gate-closing signal was then the decay muon signature $\mu\bar{5}$. Counter 5 was placed as close as possible to counter " μ ", and served to suppress

507-37067-K

background due to beam particles, and positrons from the decay of stopping muons. Counter 5 also suppressed background arising from π - μ -e decays in which the stopping pion opened the timing gate and the positron closed it.

A total of approximately 10^7 π - μ decays were recorded. Of these, about 2.5×10^6 events with time intervals between 40 and 250 nsec after the pion stop signal were used in the analysis. The decay spectrum of π - μ events with lifetimes less than 40 nsec displayed anomalies related to the finite resolving time of the circuitry, and was not included in the analysis.

The digital timer included protective circuits which prevented storage of events in which two pions stopped within the maximum period of analysis (4 μ sec), as well as circuits to insure that uncorrelated background presented a zero slope at all input rates. Possible non-uniformity of channel widths was investigated in tests with uncorrelated start and stop signals, confirming channel uniformity to better than one part in 1000. Analysis also indicated zero slope for the random signals.

Fifteen separate runs comprised the experiment reported here. The total pion amplitude in the first 10 nsec-side channel analyzed was about 10^6 counts. After fifty channels the amplitude was 5×10^3 , of which about 90% was a 2.2 μ sec lifetime component, the remainder being "flat" background. The 2.2 μ sec background was produced by positrons of the π - μ -e decay chain, and corresponded to events for which the muons failed to register in the counter " μ ", but the positrons did.

Correction for the background was made according to the following considerations. At the instant of the pion stop signal ($t=0$), the only source of background positrons is muons stopping with the pion beam as beam contamination. After $t = 0$, positrons from the π - μ - e decay should increase with time for a few pion mean lives. In order to measure these effects, and thus ascertain the time distribution for the background, two "growth" runs were taken. For these runs, counters " μ " and 5 in coincidence closed the timing gate, while the same $12\pi\bar{5}$ opened the gate. The time spectrum then took the form characteristic of a parent-to-radioactive daughter decay. These "growth" runs were then used to predict the shape of the μ - e background under the π - μ decay curves, after subtracting linear background from each. The resulting π - μ curves could then be fitted by least squares analysis to a function of the form $Ae^{-t/\tau}$ to obtain τ , the lifetime of the pion. Each of the 15 π - μ runs was analyzed separately. Good statistical agreement among runs was obtained, and the chi-square value for each run was as expected, when the analysis of decay events started at 40 nsec or more after the pion stop signal. The weighted mean of the 15 runs yields the following value for the mean lifetime of the positive pion:

$$\tau_{\pi^+} = 26.01 \pm 0.02 \text{ nsec}$$

The uncertainty quoted is one statistical standard deviation. This result differs by two standard deviations from that quoted in reference 1, but is consistent with earlier measurements quoted therein.

In addition to ascertaining statistical consistency among runs and goodness of functional fit (acceptable χ^2) for each run, an important

test of the data was to confirm that the mean lifetime obtained was insensitive to the choice of time intervals used in the analysis. Fig. 2 is a plot of pion lifetime against early channel cut-off varied from 30 nsec to 140 nsec, with late channel cut-off at 250 nsec in all cases. The data show no non-statistical fluctuation of lifetime over this range.

We wish to express appreciation for the hospitality shown by Dr. R. B. Sutton and the staff of the Carnegie Tech Nuclear Research Center; to express thanks to Mr. S. Hummel for construction of the counters, to Mr. D. Makowiecki for assistance with the electronics, and to Dr. R. Carrigan for valuable suggestions.

References

1. J. Ashkin, et. al, Nuovo Cimento 16 (1960) 490.
2. M. Eckhause, R. T. Siegel, and R. E. Welsh, (to be published).

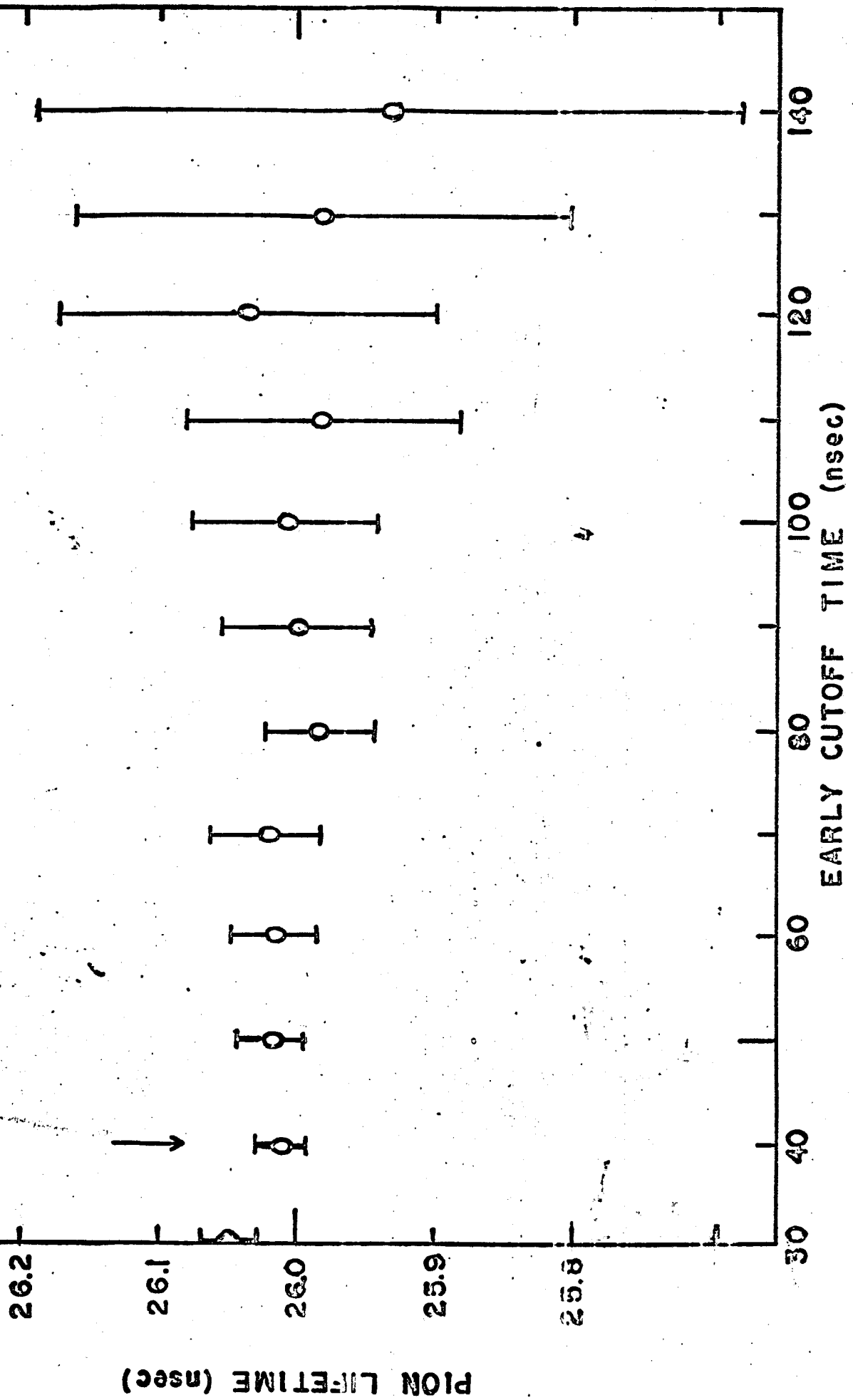


Fig. 2. Pion lifetime vs. early cut-off time.