Title
AN EXPERIMENTAL CHECK ON THE RANGE-ENERGY CURVE OF PIONS IN PROPANE

Author
Patrick, Jack W.

Publication Date
1960-10-24

UCRL-9455

UNIVERSITY OF CALIFORNIA

Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

UCRL-9455

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

AN EXPERIMENTAL CHECK ON THE RANGE-ENERGY CURVE OF PIONS IN PROPANE

Jack W. Patrick

October 24, 1960

AN EXPERIMENTAL CHECK ON THE RANGE-ENERGY CURVE OF PIONS IN PROPANE

Jack W. Patrick

Lawrence Radiation Laboratory
University of California
Berkeley, California

October 24, 1960

ABSTRACT

The kinetic energies, T_a, of pions from τ^+ decays in propane have been determined by using the information given by the angles of the secondary particles. This method is independent of any range-energy relation. Comparison of the results with the energies T_R obtained by using the most recent theoretical range-energy curve gives $T_a/T_R = 1.06 \pm 0.03$. The theoretical curve is assumed to be correct in shape. The range interval investigated is between 4 mm and 14 cm.

AN EXPERIMENTAL CHECK ON THE RANGE-ENERGY CURVE OF PIONS IN PROPANE

Jack W. Patrick

Lawrence Radiation Laboratory
University of California
Berkeley, California

October 24, 1960

I. INTRODUCTION

For a means of checking range-energy relations it would be desirable to determine the kinetic energies T_{a_i} of charged particles in propane by a method independent of range. Such a method was made available by the use of measurements made on pion secondaries from τ^+ decays at rest in a 30-in. propane bubble chamber.[1] The conservation of energy and momentum in a τ^+ decay at rest demands that the three secondaries be coplanar. This in turn means that the following relation holds:

$$\frac{p_1 c/m_\pi c^2}{\sin \alpha_1} = \frac{p_2 c/m_\pi c^2}{\sin \alpha_2} = \frac{p_3 c/m_\pi c^2}{\sin \alpha_3} = \lambda , \quad (1)$$

where $p_i c$ is the momentum in Mev of the ith pion, and the space angles (here plane angles) are as shown in Fig. 1.

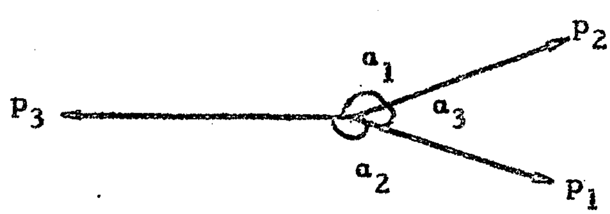


Fig. 1. Momentum diagram for decay at rest. The angles are plane angles in such a case.

Since the total energy of the pion can be written as $W_i = \left((p_i c)^2 + (m_\pi c^2)^2 \right)^{1/2}$, we find by substitution

$$W_i = m_\pi c^2 (1 + \lambda^2 \sin^2 \alpha_i)^{1/2} . \quad (2)$$

Further, the conservation of energy demands that we have

$$Q + 3\, m_\pi c^2 = m_\pi c^2 \left[\sum_{i=1}^{3} (1 + \lambda^2 \sin^2 \alpha_i)^{1/2} \right]. \tag{3}$$

From mass measurements,[2] Q is already known, while the α_i are found experimentally. One, therefore, has a function of the form

$$F(\lambda, \alpha_i) = \frac{Q + 3\, m_\pi c^2}{m_\pi c^2} = \text{constant}. \tag{4}$$

This can be solved for λ by the use of Newton's method and without any knowledge of the $p_i c$. Once λ has been found, the determination of W_i and hence T_{α_i} is trivial.

Thus, one may evaluate the kinetic energies of pions in propane independently of any range measurements.

II. EXPERIMENTAL PROCEDURE

The data were obtained using the 453-Mev/c K^+ beam from the Bevatron[3] entering the 30-in. propane bubble chamber[1] of the Powell-Birge Group. Various absorbers were used in front of the chamber.[3] The sensitive volume of the chamber was 30-1/2 in. long by 21-1/2 in. wide by 6-1/2 in. deep, operating in a magnetic field of 14,000 gauss. All events were recorded on film in the usual way by a pair of cameras, separated to give a binocular effect. This provided a permanent stereoscopic record of each event.

III. TREATMENT OF DATA

The developed film was scanned using stereo film projectors of the Powell-Birge Group.[4] The film number and other information about all K^+ decays found were then recorded on IBM cards for future reference. Those 167 K^+ decays that were of the τ^+ mode were carefully checked several times after this original scan. This checking was to identify those decays in which a τ^+ was still possibly in flight and those events in which pions left the chamber before stopping. An attempt was made to eliminate those events that were spurious τ^+ decays (scatters, etc.); there were seven such events eliminated.

Those 64 τ^+ events that seemed to be decays at rest and those product pions all appeared to end inside the chamber were then set aside for a special program of analysis. This was in addition to the standard treatment given them and the other 96 τ^+ events. This standard procedure consisted of the measurement by the projection microscope of the track of each pion. All coordinates and angular information were automatically recorded on IBM cards. The data were processed by the IBM-650 program Fog III.[5] The momenta were calculated using the measured curvature of the track and the known magnetic field strength.[6]

Unfortunately, in nearly every τ^+ decay at least one, and often two, pion tracks were too short and (or) too steep to allow accurate momentum determination. The resultant errors in measurement were often greater than 100 %. Therefore, one had to rely mainly on the data obtained from those 64 events that had been set aside for special treatment. Here the calculation of momentum was from range measurements. These ranges in turn were measured by the special digitized projection scanning scope (**Frankenstein).** From the pion range and the range-momentum (range-energy) curves of Chupp et al.[7] were obtained the pion momenta. Distortion effects, optical corrections, and other factors were included in obtaining the true value of the range. The total range came from the program Fog III.

Naturally such measurements could only be valid if the pion track ended inside the chamber. More refined measurements with the projection scope showed that 19 of the 64 events were not measurable because of technical difficulties such as a steep prong, poor film condition, cross-over tracks, etc.

IV. RESULTS AND DISCUSSION

The data reduction described in the previous section provided complete information--coordinates, angles, and momenta--on 45 τ^+ decays.

By the use of the condition of coplanarity, angle measurements, and the Q value, the parameter λ was determined. From this W_i was found and, hence, T_{α_i}.

For comparison with the value T_{R_i} of the kinetic energy obtained from the theoretical range-energy curve, one may plot T_α/T_R versus the pion range. Since we expected that any skewness would more likely be present in the kinetic energies T_α rather than in those energies T_R calculated from the range-momentum (range-energy) curve, we used T_α/T_R rather than its reciprocal.

Then ratios of T_α over T_R were formed and plotted against the corresponding pion range (see Fig. 2). There were few events beyond 14 cm, so no treatment of these data was attempted. Any τ^+ in flight would mean that the condition of coplanarity need not hold, although such might not be detected experimentally. Hence the ratios for such events are in doubt. Most of these events were those whose pions had ranges greater than 14 cm.

In order to eliminate clearly inconsistent data, the ratios were arranged in descending order of magnitude. The top sixth and bottom sixth were eliminated, leaving an interval of 0.245, twice the standard deviation (2σ). Then the mean value $\langle T_\alpha/T_R \rangle = 1.10 \pm 0.03$ and the median value $(T_\alpha/T_R)_{med} = 1.06 \pm 0.03$ were obtained for the truncated column of 81 events. The standard deviation of the mean is $\sigma_n = \sigma/\sqrt{81} = 0.03$.

The median value is probably the more accurate because the expression for W_i involves $\sin \alpha$ in such a form as to cause any measurement error in α_i to be insensitive to sign in second order. Thus a systematic error in the positive direction should result.

V. ACKNOWLEDGMENTS

I wish to thank those who have had a part in the data reduction: Howard White and his staff, Charles Jinks, Sheila Boehm, Louis Smith, and Sheldon Welles.

Drs. Harry Heckman and Walter Barkas have offered guidance and helpful suggestions as the work proceeded.

Of course, the data could not have been obtained in the first place without the cooperation of the Bevatron crew and the Powell-Birge, Goldhaber, and Barkas groups.

The use of Eq. (1) in the problem of the τ^+ decay we owe to the work of Berthelot et al.[8]

This work was done under the auspices of the U. S. Atomic Energy Commission.

REFERENCES

1. W. M. Powell, W. B. Fowler, and L. O. Oswald, A 30-Inch Propane Bubble Chamber, UCRL-8277, May 1958.

2. W. Barkas and A. Rosenfeld, Data for Elementary-Particle Physics, March 1958 (masses revised July 1959).

3. W. Powell, R. Birge, G. Goldhaber, and W. Barkas, Tabulation of K^+ Momenta for Experiment 11, UCRL Engineering Note File 4310-12, RB-1, February 24, 1958.

4. F. Solmitz, Rough Measurement of Bubble Chamber Events Using Stereo Projectors, UCRL Engineering Note, January 16, 1957.

5. This program is available from the Computing Department, Lawrence Radiation Laboratory, Berkeley.

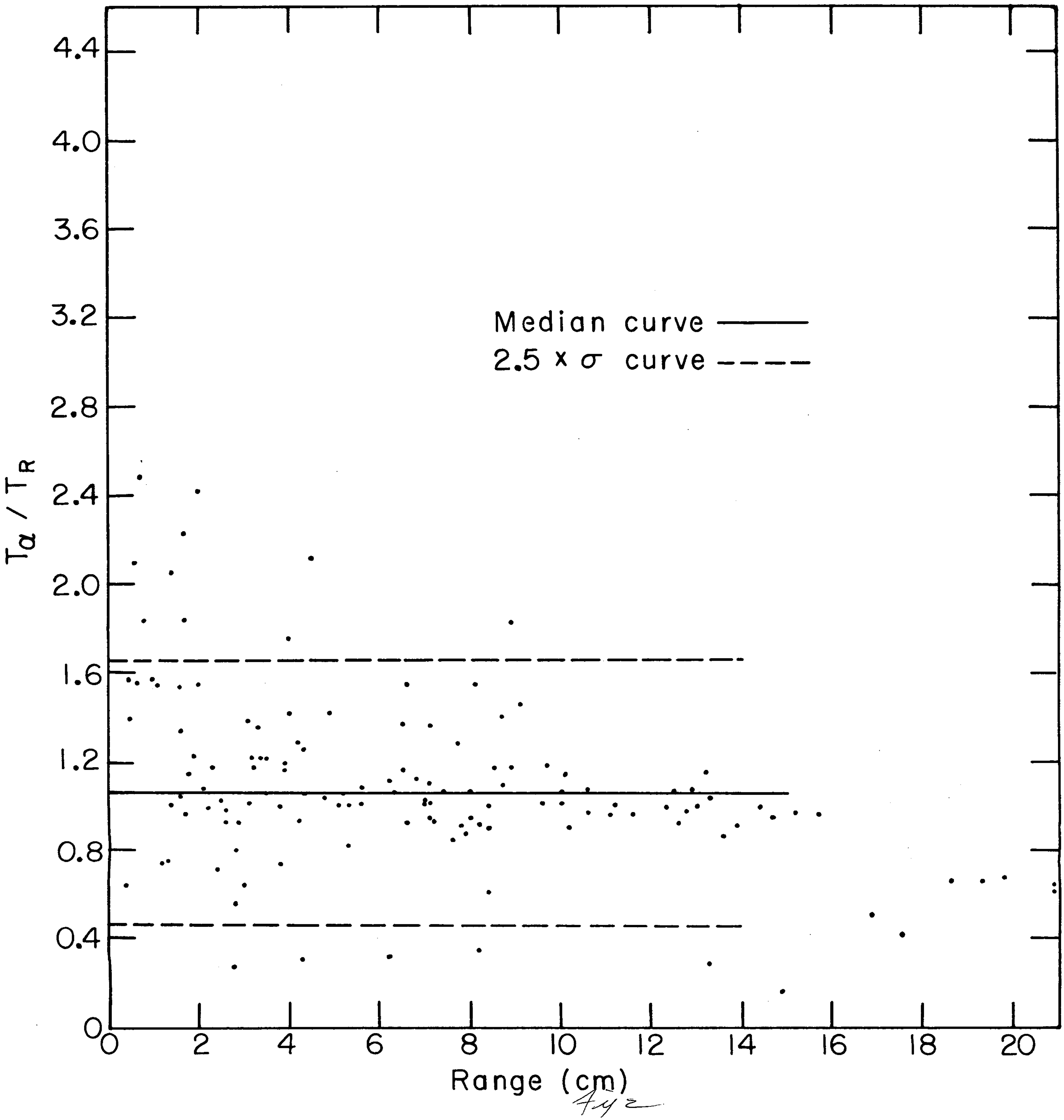
6. L. G. Ratner, Magnetic Measurements [of] Propane Chamber in Sagane Magnet UCRL Engineering Note File 4310-15 MT-4, October 27, 1958.

B. Matsen and R. Lanou, Ranges of Charged Particles in Propane UCRL Engineering Note File 4310-12 RB-2, April 14, 1958.

8. A. Berthelot, O. Goussu, D. Revel, L. Scarsi, L. Bacchella, M. Di Corato, R. Levi Setti, G. Tomasini, M. René, and G. Vanderhaeghe, Nuovo cimento **4**, 1529 (1956).

LEGENDS

Fig. 2. Plot of range *versus* the ratio of the kinetic energy determined from the angle to that determined from the range. The median value of this range is 1.06 0.03. The median curve is shown along with the curves defining an area 2.5 standard deviations from the median line.



4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
Tα / TR
Median curve
2.5 x σ curve
0
2
4
6
8
10
12
14
16
18
20
Range (cm)