PUB-81-092-E
E-456

7/16/81

FERMILAB-PUB-81-092-E

E456 TO BE SUBMITTED TO PRL
ON 7/1/81

DIRECT COMPARISON OF THE FORM FACTORS FOR NEGATIVE PIONS AND KAONS

E. B. Dally[a], J. M. Hauptman[b], J. Kubic, D. H. Stork, and A. B. Watson

Physics Department, University of California, Los Angeles, California 90024

and

Z. Guzik, T. S. Nigmanov, V. D. Riabtsov, E. N. Tsyganov, and A. S. Vodopianov

Joint Institute for Nuclear Research, Dubna, U.S.S.R.

and

A. Beretvas[c], A. Grigorian[d], J. C. Tompkins[e], T. E. Toohig,

and A. A. Wehmann

Fermi National Accelerator Laboratory, Batavia, Illinois 60510

and

J. A. Poirier, C. A. Rey[f], and J. T. Volk[g]

Physics Department, University of Notre Dame, Notre Dame, Indiana 46556

and

P. D. Rapp[h], and P. F. Shepard

Physics Department, University of Pittsburgh, Pittsburgh, Pennsylvania 15620

ABSTRACT

Simultaneous measurement of the elastic scattering from electrons of 250 GeV/c negative kaons and pions has provided a determination of the ratio of their form factors which is largely independent of normalization errors. An analysis of this ratio over the four-momentum interval $0.037 < q^2 < 0.094\ (\mathrm{GeV}/c)^2$ gives

$$\langle r_\pi^2 \rangle - \langle r_K^2 \rangle = 0.16 \pm 0.06 F^2$$

A direct experimental comparison of the negative kaon and pion form factors has been carried out by means of a simultaneous measurement of the elastic scattering of 250 GeV/c pions and kaons on electrons over a momentum transfer range $0.037<q^2<0.094$ $(GeV/c)^2$. Beam particles in this Fermilab experiment were distinguished as pions (98%) or kaons (2%) by means of a differential Cerenkov counter. The absolute cross section determination and subsequent evaluation of the separate form factors for kaons[1] and for pions[2] is described elsewhere.

Our purpose here is to describe the direct determination, in the same experiment, of the ratio of kaon and pion elastic scattering cross sections and therefore the ratio of form factors, in a manner largely independent of possible unknown systematic errors which might affect the separate determinations. Aside from particle identification, the pion and kaon triggers and event analyses were treated in identical fashion with the following exceptions: (1) the pion beam was prescaled down by a factor of four and (2) a two particle scintillation counter hodoscope signal was required for the pion trigger but not for the kaons. A total of 1934 kaon and 13945 pion elastic scatters in the range $0.037<q^2<0.094$ $(GeV/c)^2$ were thus found. The elastic scattering kinematics are similar for pions and kaons over the q^2 range studied (opening angle ranges from 5.3 to 2.9 mr for kaon-electron and 5.8 to 4.1 mr for pion-electron scattering) and systematic effects that depend upon kinematics should largely cancel in the kaon-pion ratio.

Major corrections to the separate scattering cross sections include beam attenuation (3.3% for pions, 2.9% for kaons), bremsstrahlung photons above 12 GeV (12.7% to 18.2% for pions, 13.9 to 19.6% for kaons). These corrections largely cancel in the kaon to pion cross section ratio--in any case the target and spectrometer material is the same. Radiative corrections range from 4.1% to 8.1% for pions and from 4.1% to 7.5% for kaons as determined by Monte Carlo calculations. Again these corrections should largely cancel in the ratio. Track finding inefficiency is only weakly dependent upon the scattering kinematics and is largely eliminated in the ratio. Several very small corrections for trigger inefficiencies are independent of particle type and also cancel in the ratio.

A number of corrections are uncorrelated and are not eliminated in the cross section ratio. Corrections for beam decay within the spectrometer were 0.1% for pions and 1.4% for kaons; secondary decay of pions contributed 0.1 to 0.3%, kaons 1.4 to 1.7%. Use of the differential Cerenkov counter for kaon and pion identification produced different beam conditions: the off-momentum beam cut was 1.5% for pions, 0.5% for kaons and beam contamination was 0.4% for pions and 0.1% for kaons. The largest independent correction was that of geometric inefficiency. The geometric loss was less than 5% for more than half the momentum transfer region studied. However, at the lowest momentum transfer, 11% of the pions were lost by clipping on the vertical jaws of the magnet whereas 5% of the kaons were lost. Since the jaw profiles were cleanly observed in the data, the correction was straightforward. At the highest momentum transfer, 27% of the pions were lost by the two-particle scintillation counter hodoscope geometry whereas no kaons were lost. Since the hodoscope was not a requirement in the kaon trigger, its efficiency and geometry were continuously monitored throughout the experiment through the use of the kaon events. In the final pion analysis the geometric correction was tested by varying the cut away from the scintillation counter edges. After correction, no effect was observed on the pion form factor. In summary, our estimate of the overall systematic uncertainty which remains in the cross section ratios is less than 1%. The errors are dominated by the statistical errors in the kaon data.

The ratio of the square of the kaon and pion form factor is given in Figure 1. We have for either a pole form or a dipole form, to first order

$$|F_K|^2/|F_\pi|^2 = 1 + 1/3q^2(\langle r_\pi^2\rangle - \langle r_K^2\rangle)$$

The result of a least squared fit is $\langle r_\pi^2\rangle - \langle r_K^2\rangle = 0.15 \pm 0.06F^2$ with chi-square value 3.5 for 6 degrees of freedom. An expansion of the pole form to next order gives

$$|F_K|^2/|F_\pi|^2 = 1 + 1/3q^2(\langle r_\pi^2\rangle - \langle r_K^2\rangle)(1 + 1/12q^2(\langle r_\pi^2\rangle - 3\langle r_K^2\rangle))$$

If we use the values of $\langle r_\pi^2\rangle = 0.439F^2$ and $\langle r_K^2\rangle = 0.28F^2$ obtained in this experiment[1,2] to fix the term $\langle r_\pi^2\rangle - 3\langle r_K^2\rangle = -0.401F^2$, we obtain $\langle r_\pi^2\rangle - \langle r_K^2\rangle = 0.16 \pm 0.06F^2$ for a chi-squared of 3.5 for 6 degrees of freedom.

The result that $\langle r_\pi^2\rangle - \langle r_K^2\rangle = 0.16 \pm 0.06F^2$, is of particular importance for the charged kaon, as pion data exists over the q^2 range -10 to +10 $(\mathrm{GeV}/c)^2$. A pion fit by Heyn and Lang[3] over this q^2 range gives $\langle r_\pi^2\rangle = 0.47 \pm 0.02F^2$. This would imply that $\langle r_K^2\rangle = 0.31 \pm 0.06$. If the electroproduction data is excluded they get $\langle r_\pi^2\rangle = 0.43F^2$, which yields

$\langle r_K^2 \rangle = 0.27 \pm 0.06F^2$ If the best fit of all the direct pion scattering data[2], $\langle r_\pi^2 \rangle = .403F^2$, is used, the corresponding radius squared is $\langle r^2_K \rangle = 0.24 \pm 0.06F^2$.

We wish to acknowledge the support of Professor R. R. Wilson and the essential assistance of many of the Fermilab staff. This work was supported in part by the U. S. Department of Energy and by the U. S. National Science Foundation.

FOOTNOTES

[a] Now at Varian Associates, Hansen Way, Palo Alto, CA 94306.

[b] Now at Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720.

[c] Now at Rutgers University, Piscataway, NY 08854.

[d] Now at Hughes Aircraft Co., Culver City, CA 90230.

[e] High Energy Physics Laboratory, Stanford University, Stanford, CA 94305.

[f] Now at Intersonics, Inc., Northbrook, IL 60062.

[g] Now at Ohio State University, Columbus, OH 43210.

[h] Now at Fermi National Accelerator Laboratory, Batavia, IL 60510.

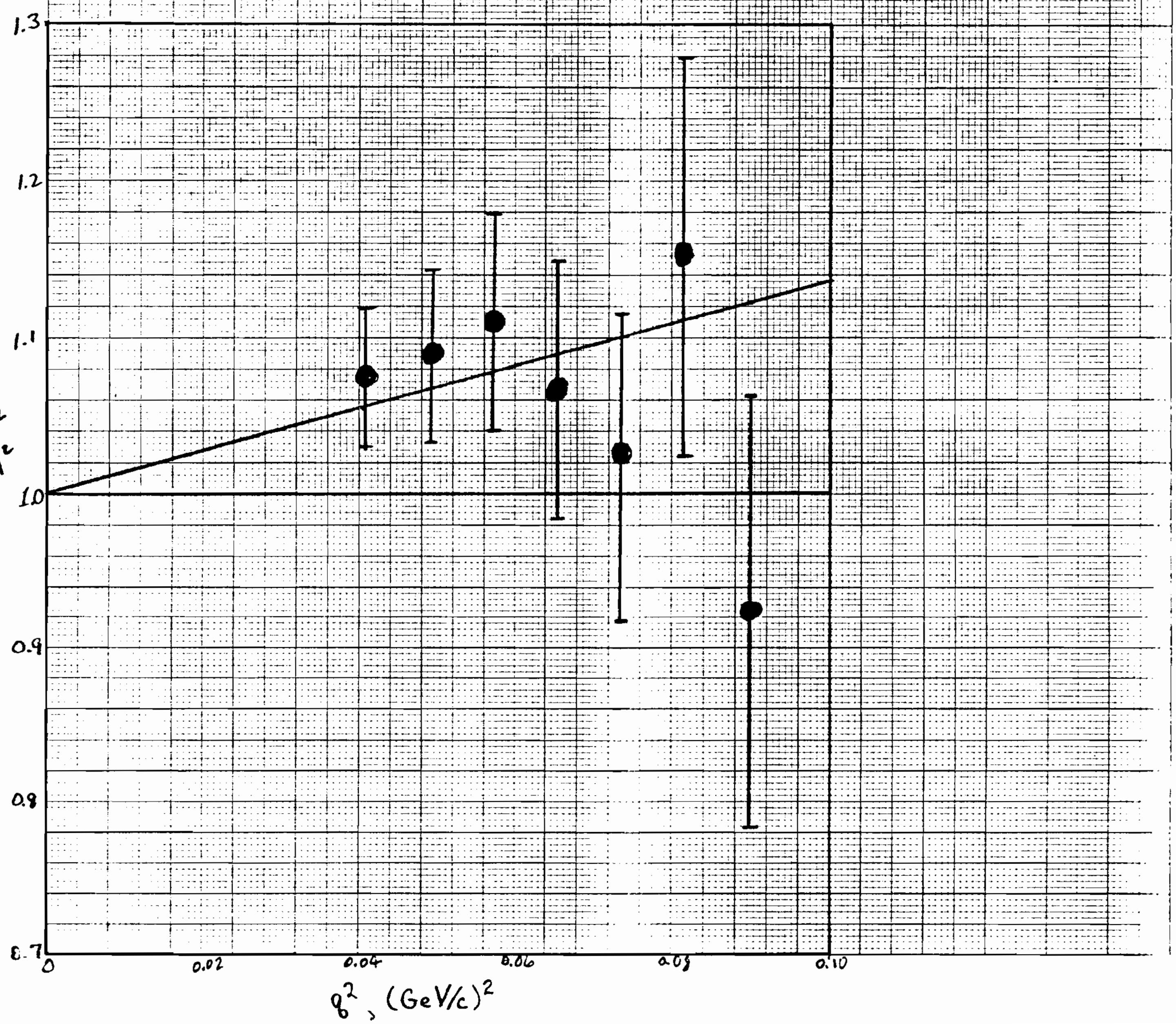
REFERENCES

1. E. B. Dally, et al., Phys. Rev. Lett. 45, 232 (1980).
2. E. B. Dally, et al., accompanying letter.
3. M. P. Heyn and C. B. Lan, UNIGRAZ-UTP 06/80, May 1980.

FIGURE CAPTIONS

Figure 1: Ratios of the squares of the kaon and pion form factors versus q^2. The line is a second order fit to the pole form for the form factors (as described in the text) with

$$\langle r_\pi^2 \rangle - \langle r_K^2 \rangle = 0.16 \pm 0.06 F^2.$$



461510

10 X 10 TO THE CENTIMETER
KEUFFEL & ESSER CO. MADE IN U.S.A.