THE ρ-VALUE FOR THE β-DECAY OF THE NEGATIVE MUON

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The Duke Helium Chamber,[1] $8'' \times 5'' \times 4''$, operated in a magnetic field of 14 kilogauss, was exposed to a K^- beam at the Bevatron, and a large number of μ^- decays were found as background. A portion of these decays was examined to determine a value for the Michel parameter ρ.[2] About 50,000 pictures were scanned for μ^- decays, and 4300 of the decays found were measured.

The momentum of the electron was determined by measuring radii with templates and constructing corresponding points in three stereoscopic views. The measured momentum of the electron, which corresponds to the momentum at the mid-point of the track, was corrected for mean ionization energy loss (0.29 MeV/cm in liquid helium) and bremsstrahlung loss (the radiation length used was 765.5 cm) to obtain the momentum at the point of decay.

In order to eliminate from this sample those events which were poorly measured and to be free as much as possible of the effects of scanning inefficiency, the following selection criteria were adopted :

(a) The decay vertex had to be at least 1 cm from the chamber walls.

(b) The dip angle of the electron had to be less than 45°.

(c) The projected " potential length " of the electron had to be greater than 4 cm. The potential length is defined as that length the electron would have traversed in the chamber were there no magnetic field.

These criteria were satisfied by 2279 events.

Checks were made to ascertain the internal consistency of the data of the three laboratories in order to determine whether any selection bias existed.

Since the radius of the electron track was measured in each of the three stereoscopic views, we were able to compare the *a priori* error assignments with the errors calculated on the basis of internal consistency. This check indicated that our error assignments in measurements were realistic.

Table I lists the possible sources of systematic errors, $\Delta p/p$, in the momentum scale. The systematic errors in the reconstruction of an event may be attributed almost completely to the error in our knowledge of the distance between the fiducial marks on the chamber windows, which introduces a systematic error in the measured radii. The error in the correction for energy loss is primarily due to the fact that the density of liquid helium is known only to about 5%. In addition, a small correction was introduced to take into account possible unknown selection biases. These errors, taken in quadrature, lead to a systematic uncertainty of 0.21%.

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Table I.

Source of error	$\Delta p/p(\%)$
1. Calibration of magnetic field	0.10
2. Geometric reconstruction . .	0.06
3. Corrections for energy loss .	0.13
4. Mass of the μ^-	0.06
5. Selection bias	0.10
Total . . .	0.21%

In order to compare our experimental data with theory, we modified the ideal one parameter spectrum calculated by Michel taking into account (1) corrections for radiative effects at emission[3,4], (2) the fact that the μ^- is bound in a Bohr orbit of the helium nucleus,[5] (3) the fluctuations in the mean correction for ionization (Landau effect[6]) and bremsstrahlung losses, and (4) the resolution in momentum due to both errors in measurement and in multiple scattering.

Our experimental momentum distribution is shown in Fig. 1, plotted in units of the maximum available electron momentum. The expected theoretical spectra corresponding to ρ-values of 0.65, 0.75, and 0.85 are also shown in Fig. 1.

The best value of ρ was obtained by comparing our experimental distribution with theoretical spectra corresponding to different values of ρ, using the method of minimum χ^2. In Fig. 2, χ^2 is plotted as a function

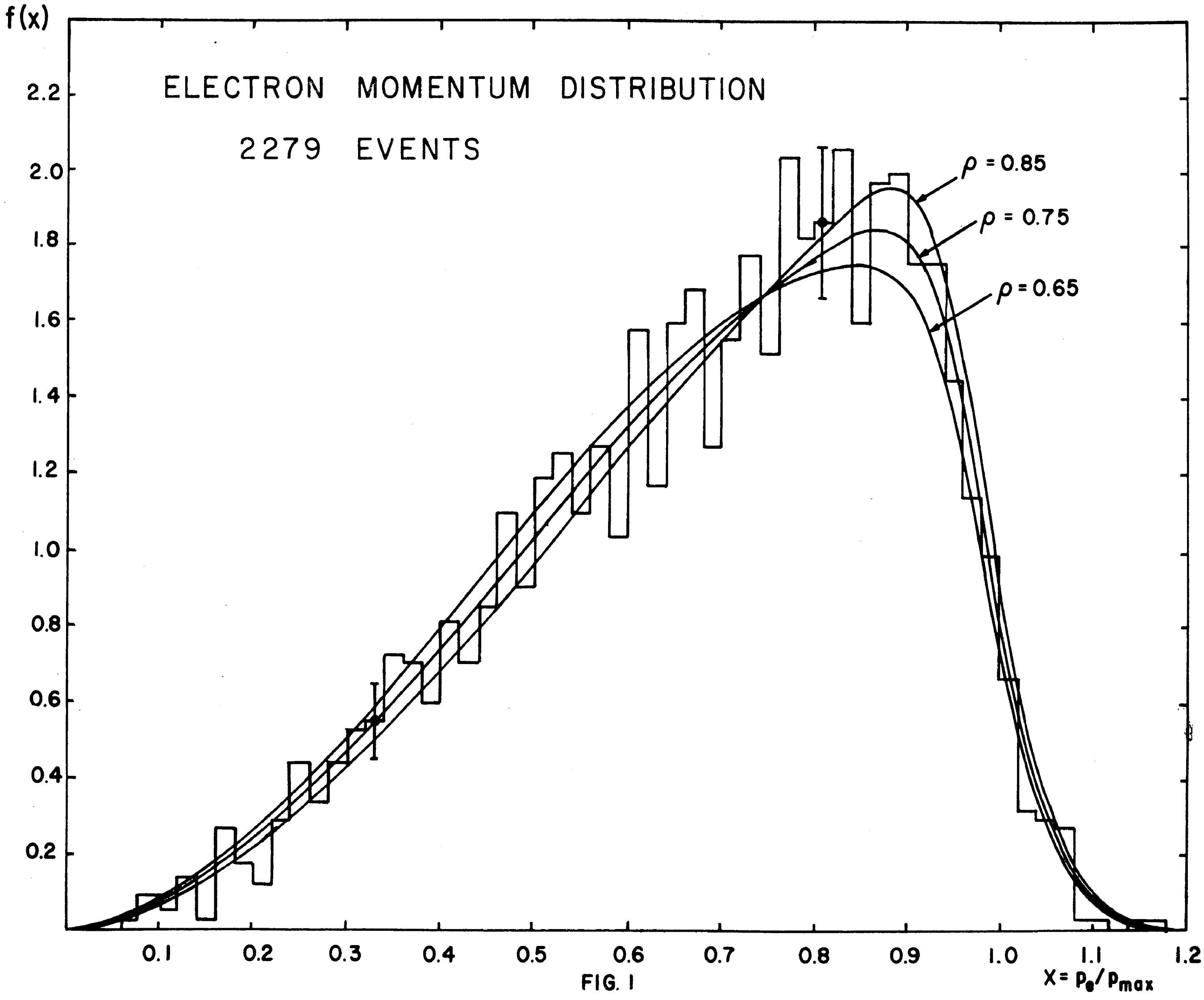

Fig. 1 Experimental momentum distribution of electrons from μ^- in He.

of ρ (the solid curve). The minimum value of χ^2 was 80, in good agreement with the expected value of 82 ± 12.

To check our calculations, we decided to test our resolution function and momentum scale. By varying the width of the resolution function for a fixed ρ-value (namely, $\rho = 0.764$), we found from the χ^2 curve, shown in Fig. 3, that our width is $3\pm7\%$ larger than our estimated value. To detect any systematic error in our momentum scale, the momentum scale in the spectrum was stretched by varying amounts, again keeping ρ fixed at our best value. The results are shown in Fig. 4. The best fit stretching factor was found to be 1.003 ± 0.004, which corresponds to

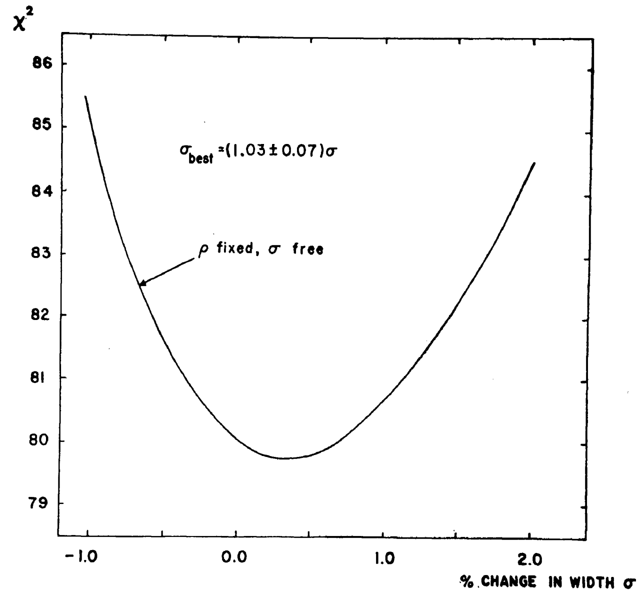

Fig. 3 Dependence of χ^2 on the width of the resolution function.

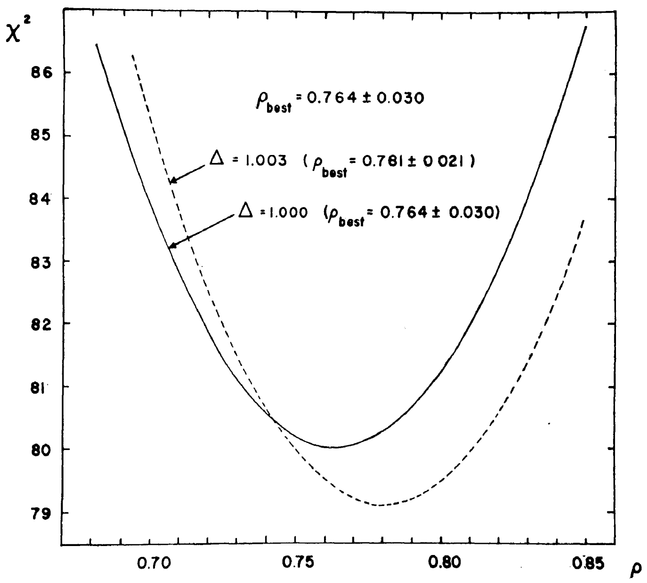

Fig. 2 χ^2 *vs* ϱ for data of Fig. 1.

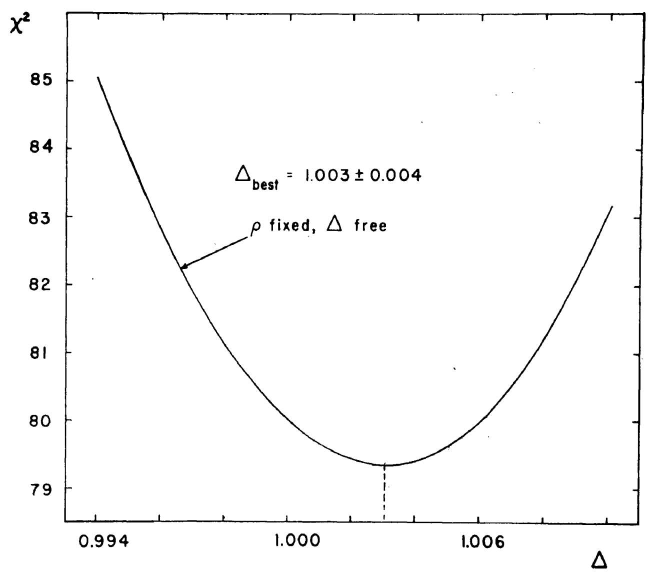

Fig. 4 Dependence of χ^2 on the width of the stretching factor, Δ

Table II.

Experimenters	Source	Method	No. of events	Charge	Quoted ϱ-value
Leighton et al (1949)	cosmic rays	expansion cloud chamber	75	$\mu^\pm$	0.075 ± 0.20
Lagarrigue and Peyrou (1951)	cosmic rays	expansion cloud chamber	150	$\mu^\pm$	$0.19\ \pm0.12$
Bramson et al (1952)	accelerator	nuclear emulsions	301	μ^+	$0.41\ \pm0.13$
Hubbard (1952)	accelerator	expansion cloud chamber	400	μ^+	$0.26\ \pm0.26$
Vilain and Williams (1954) . .	accelerator	expansion cloud chamber	280	μ^+	$0.50\ \pm0.13$
Sargent et al (1955)	accelerator	diffusion cloud chamber	415	μ^-	$0.68\ \pm0.11$
Bonetti et al (1956)	cosmic rays	nuclear emulsions	506	$\mu^\pm$	$0.57\ \pm0.14$
Crowe et al (1956)	accelerator	double focusing spectrometer	—	μ^+	$0.62\ \pm0.03$
Rosenson (1958)	accelerator	diffusion cloud chamber	1300	μ^+	$0.67\ \pm0.05$
Dudziak et al (1959)	accelerator	spiral orbit spectrometer	—	μ^+	0.741 ± 0.027
Plano (1960)	accelerator	hydrogen bubble chamber	9213	μ^+	0.785 ± 0.020
This experiment (1960) . . .	accelerator	helium bubble chamber	2279	μ^-	0.764 ± 0.032

a new ρ-value of 0.781 ± 0.024 (statistical error) as shown in Fig. 2 by the dotted curve. Since our evaluation of the systematic error (0.21%) and that calculated from a best fit procedure (0.3 ± 0.4%) were in excellent agreement, as well as our assignment of the width of the resolution function, we conclude that $\rho = 0.764 \pm 0.032$, where the error now consists of the systematic as well as the statistical error. This value is compared with that of other experimenters in Table II[7-17].

We conclude that

(a) the μ^- ρ-value agrees within the errors with the value for μ^+, and

(b) our experimental ρ-value is in excellent agreement with the two component neutrino hypothesis of Lee and Yang[18].

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