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WEAK INTERACTION EXPERIMENTS AT THE BERKELEY SYNCHROCYCLOTRON

Roy P. Haddock
Radiation Laboratory
University of California
Berkeley, California

ABSTRACT

High intensity external meson beams have been available at the Berkeley cyclotron since October, 1957. These beams are produced by the internal proton beam striking a moveable target. Mesons leaving the target are momentum analyzed by the cyclotron's fringing field and then they are focussed by a strong-focussing quadrupole pair before passing through an eight-foot moveable collimator and on into the meson cave. A typical set-up is shown in Fig. 1. In the meson cave two bending magnets and a strong-focussing quadrupole set establish a magnetic channel and a four-foot concrete wall provides additional shielding.

The moveable production target yields beams with energies from 20 Mev up. We use a 210 ± 12 Mev/c beam which with all collimators wide open gives 10^6 π^+/min. stopped in a reasonable volume of material located 16 feet from the target. By reversing all magnetic fields we obtain a π^- beam of greater than twice the π^+ intensity. The accompanying μ^+ beam due to decay in flight of π^+'s yields about 10^5 μ^+/min. in the same stopper.

The μ^+ beam polarization and the energy dependence of the asymmetry of positrons stopped in Li, C, and $CHBr_3$ have been measured using a magnetic spectrometer. The technique is different from those previously employed. It involves using a Helmholtz coil to produce a depolarizing field of 55 ± 10 gauss in the μ-stopper. This provides an unpolarized μ-decay spectrum with the same μ-beam and geometry as the polarized μ-decay spectrum. Fig. 2 is a plot of Δ, the asymmetrical part of the spectrum,

$$\frac{\Delta}{\cos\theta} = \left[1 - \frac{Y(0)}{Y(H)} \right] / \cos\theta$$

versus positron energy. The quantities $Y(0)$, and $Y(H)$ are the yields through the spectrometer from the polarized and unpolarized μ-decay spectra respectively, and θ is the angle between positron momentum and μ^+ spin direction.

The data presented is corrected for background, ionization loss, and radiation straggling in the targets and counters as well as for virtual photon processes and inner bremsstrahlung. The solid line drawn in Fig. 2 represents the polarization expected on the basis of the two-component neutrino theory for a value of $R\xi = 0.89$ where ξ is the usual polarization parameter and R is a measure of the degree of depolarization in the stopping material and of the beam polarization.

Work on a determination of the helicity for both the electron and positron[2] from μ-decay has been completed. The reversal of the sense of polarization of positron and electron is of interest both

experimental and theoretical points of view. Experimentally some of the systematic errors that will be eliminated by measuring both polarizations and theoretically a reversal of polarization clearly demonstrates the failure of the invariance of the β-decay under charge conjugation.

The technique used to determine the polarization of high-energy β particles depends on two phenomena: (a) the bremsstrahlung radiation from a longitudinally polarized β ray is circularly polarized, and (b) the Compton transmission of circularly polarized γ rays through magnetized iron. Measurement of the photon circular polarization is made by registering the transmission through the iron when the magnetic field points toward the [illegible] converter (up) and opposite to it (down). The variable Δ used to interpret the result is derived from the transmission by the formula

$$\Delta_i = N_i(\uparrow) - N_i(\downarrow) \,/\, \tfrac{1}{2}\left[N_i(\uparrow) + N_i(\downarrow)\right]$$

where the $N_i(\uparrow)$ and $N_i(\downarrow)$ are the net transmissions for the ith energy channel with field up and down, respectively. Figure 2 shows a plot of Δ versus γ energy. The data have been corrected for instrumental asymmetry, which was independently measured, to be less than 1.5%.

We have estimated the expected asymmetries as follows: (1) assume 100% polarized betas and use McVoy and Dyson's[3] cross sections and (3) assume good geometry and use the transmission results of Gunst and Page.[4] The result of the calculation is shown in Fig. 2.

These results indicate that μ^+ is right-handed and μ^- is left-handed. For the two-component theory, μ^+ is left-handed, and μ^- is right-handed. The results are in agreement with the assumption of (a) the two-component theory with left-handed neutrinos, (b) conservation of leptons, (c) universal β-decay theory with V and A interactions, (d) complete polarization of both μ^+ and μ^-.

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REFERENCES

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2. Pierre C. Marq, Kenneth M. Crowe, and Roy T. Haddock, UCRL-2263, 1958.

3. K. M. McVoy and F. J. Dyson, Phys. Rev. 106, 1360 (1957); K. W. McVoy, Phys. Rev. 106, 828 (1957).

4. S. L. Quist and L. A. Page, Phys. Rev. 92, 970 (1957).

LEGENDS

Fig. 1. Plan view of the 184-inch cyclotron meson-beam facility. Beams of π^- mesons are obtained by reversing the cyclotron field and the beam-forming magnets.

Fig. 2. Results for the asymmetry measurement for various targets. In order that these data might appear on a similar scale, each point was corrected for radiation straggling before being plotted. Shown is the simplest two-component theory for $R\xi = 0.89$.

Fig. 3. Asymmetry measurements obtained for β's from μ^+ and μ^- decay. The data have been corrected for a measured shift in the zero line due to the influence of analyzer magnetic field on the γ counter. The curves are calculated asymmetries; δ_I would be expected for 100% polarized photons, δ_{II} is calculated by assuming 100% polarized electrons make bremstrahlung in the lead radiator but by neglecting multiplicative shower effects. The top curves are for right-handed particles and the bottom curves for left-handed ones. To change the assignment of the left- and right-handedness it would be necessary to reflect both expected curves above the zero line.

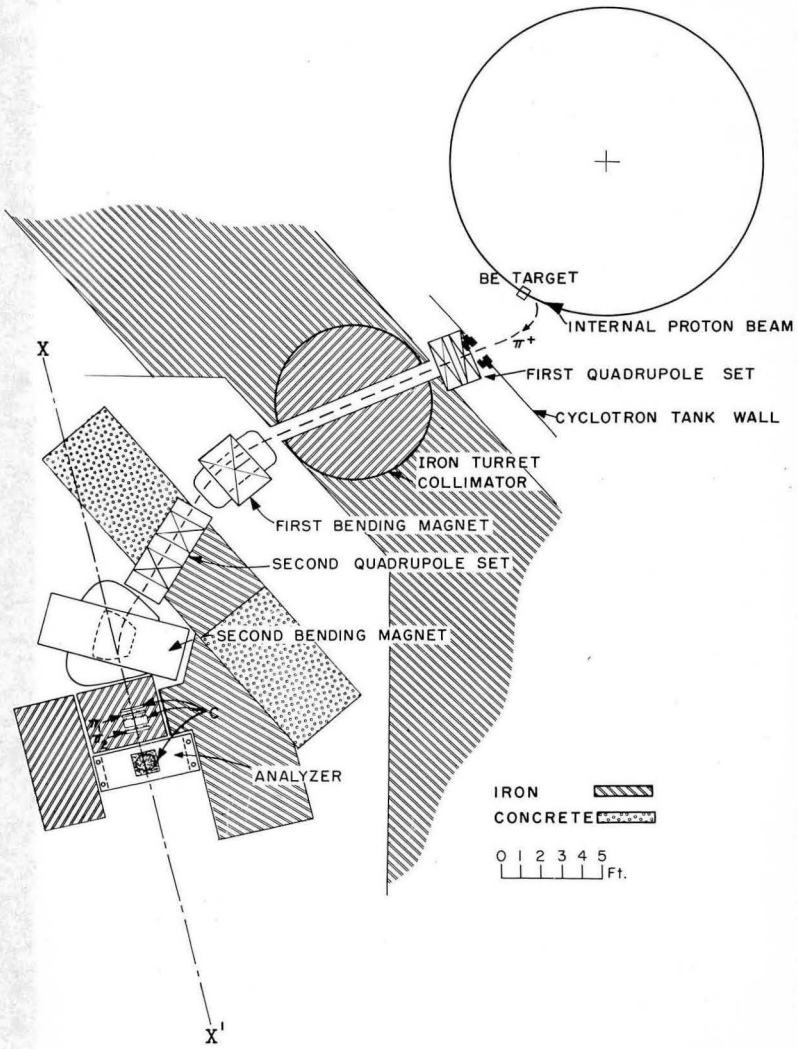
BE TARGET
INTERNAL PROTON BEAM
π^+
FIRST QUADRUPOLE SET
CYCLOTRON TANK WALL
IRON TURRET
COLLIMATOR
FIRST BENDING MAGNET
SECOND QUADRUPOLE SET
SECOND BENDING MAGNET
C
ANALYZER
X
X'
IRON
CONCRETE
0 1 2 3 4 5
Ft.

Fig. 1

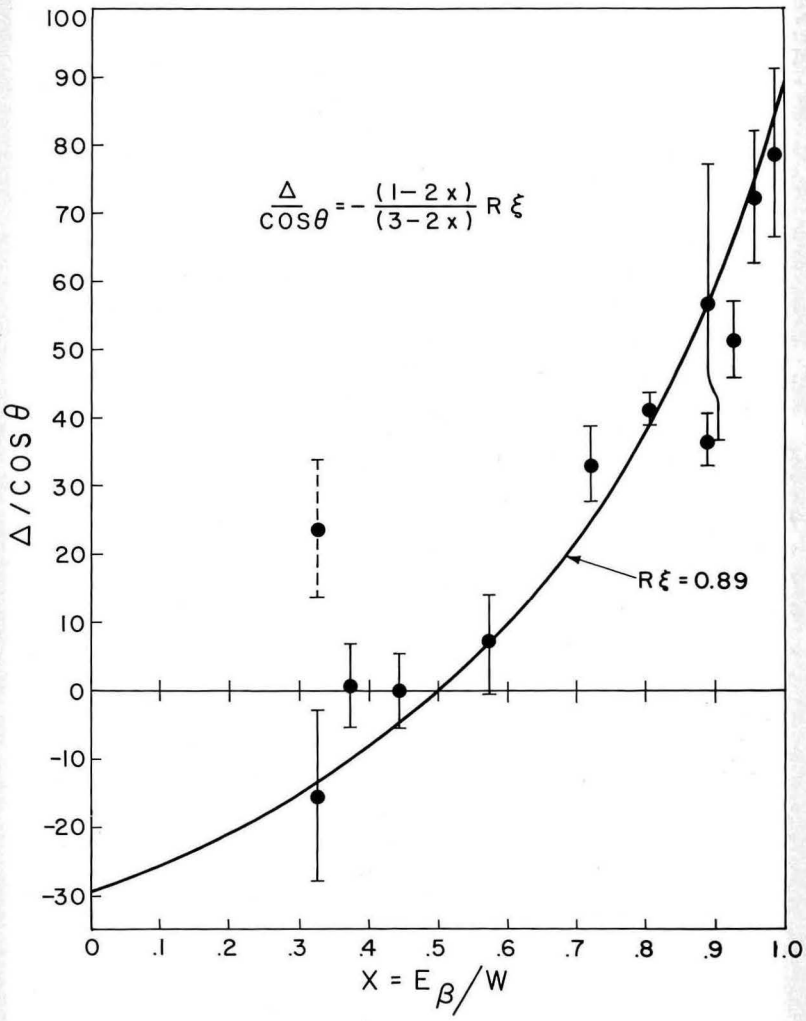
$\frac{\Delta}{\cos\theta} = -\frac{(1-2x)}{(3-2x)} R\xi$
$R\xi = 0.89$
$\Delta / \cos\theta$
$X = E_\beta / W$
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

Fig. 2

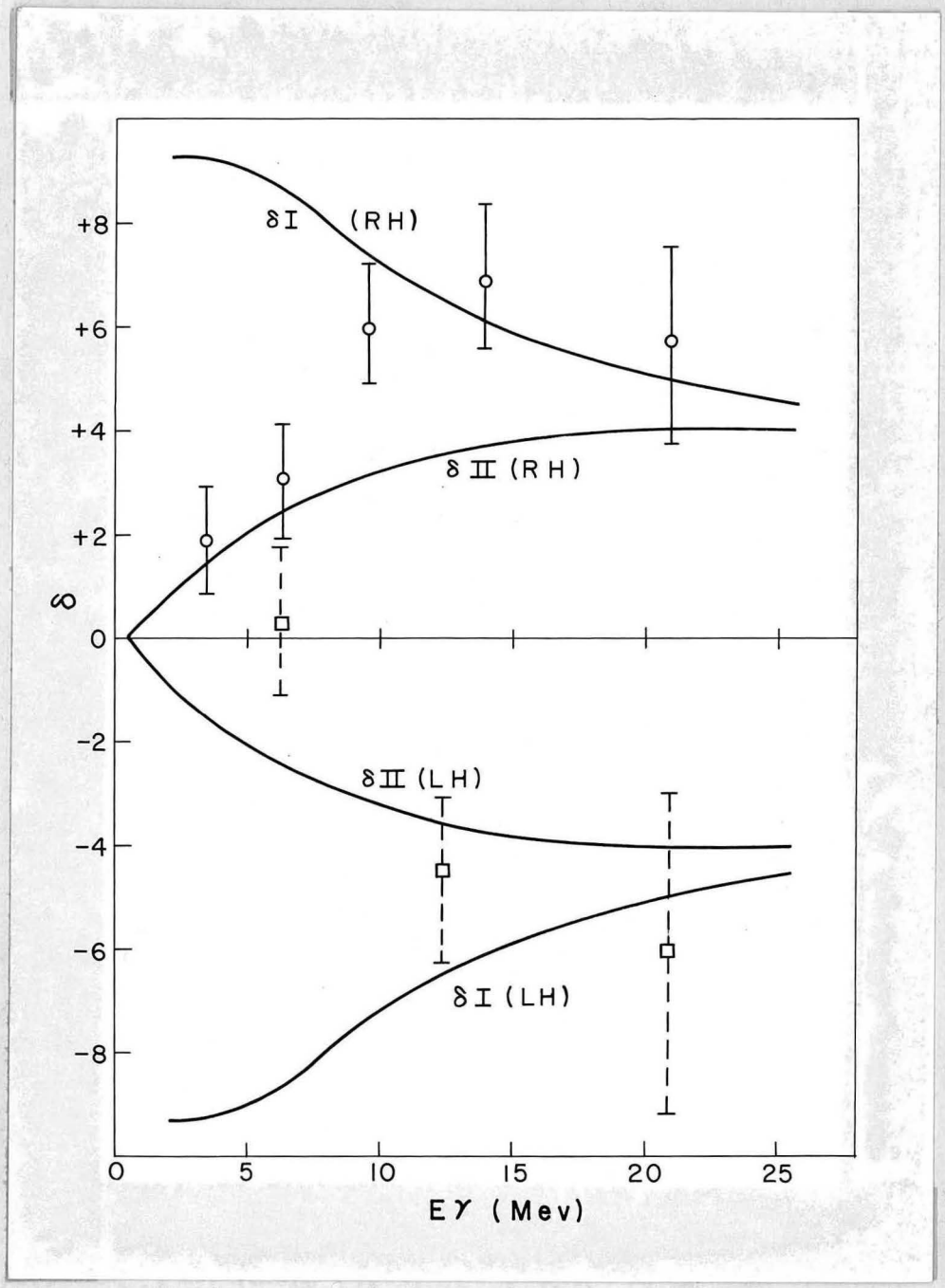

Fig. 3