TESTS OF μ-e UNIVERSALITY FOR WEAK NEUTRAL CURRENTS AT PEP

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ABSTRACT

Two techniques are proposed to test the universality of the μ-e weak neutral current interaction at large Q^2. Both techniques require large statistics and some degree of longitudinal e^+,e^- polarization but are otherwise feasible at PEP.

Two techniques are proposed to test μ-e universality at PEP. Both require large statistics experiments and some longitudinal beam polarization. The simplest method to understand consists of comparing the reactions

$$e^+e^- \to \mu^+\mu^- \tag{1}$$

and

$$e^+e^- \to e^+e^- \tag{2}$$

under special conditions of the beam. Measurement of the forward backward asymmetry of reaction (1) gives the weak coupling constants

$$g_A^e g_A^\mu / e^2 m_z^2$$

where g_A^e refers to the axial coupling constant for the electron. Considerable discussion has already been given for the experimental details of this measurement at the summer study. In order to test μ-e universality it is necessary to extract a different combination of $g_A^\ell g_A^\ell$ either $(g_A^\mu)^2$ or $(g_A^e)^2$. The former requires the study of $\mu^+\mu^- \to \mu^+\mu^-$ and is impossible. The latter can be possibly accomplished through the study of $e^+e^- \to e + e^-$ if weak interaction effects can be uniquely extracted. Budny has outlined a method in the first week of the summer study which may work using the effects of oppositely longitudinally polarized electron beams. The expected cross section when both beams are longitudinally polarized in opposite directions (we assume $P_L = 1$ for simplicity) gives

$$\frac{d\sigma}{d\Omega}\left(\frac{\alpha}{4s}\right)^{-1} = \frac{16}{(1 - z)^2} + \frac{16s(g_A^e)^2}{e^2m_z^2(1 - z)} + \frac{16s(g_V^e)^2}{e^2m_z^2(1 - z)}$$

where $z = \cos\theta$, θ is the angle between the incident and outgoing e^-. For unpolarized beams the expression is

$$\frac{d\sigma}{d\Omega}\left(\frac{\alpha}{4s}\right)^{-1} = \frac{(3 + z^2)^2}{(1 - 2)^2} + \frac{s(g_A^e)^2}{e^2m_z^2}\left\{\frac{(1 + z)(-5 + 8z + z^2)}{1 - z}\right\}$$

$$+ \frac{s(g_V^e)^2}{e^2m_z^2}\left\{\frac{3(1 + z)(3 + z^2)}{1 - z}\right\}$$

The difference in cross section for polarized and unpolarized beam configurations gives a measurement of a mixture of $(g_A^e)^2$ and $(g_V^e)^2$. For example, at $z = -1$ the difference in cross sections divided by the sum (Δ) gives

$$\Delta \simeq -s((g_A^e)^2 + (g_V^e)^2)/e^2m_z^2$$

and near $z \sim 0$ the $(g_A^e)^2$ term dominates Δ. Thus the first test of μ-e universality consists in measuring Δ in the region where $(g_A^e)^2$ terms dominate and comparing the resulting value of $(g_A^e)^2$ with the value of $g_A^e g_A^\mu$ obtained from the measurements of reaction (1). Figure 1 shows the estimated values of Δ given by Budny scaled up to PEP energy for $\sin^2\theta_w \sim 0.25$. Other values of $\sin^2\theta_w$ give Δ values that are smaller by a factor of two or less.

The second test of μ-e universality follows a suggestion of Paschos and of Mikaelean. We follow here the calculations of Mikaelean. The basic idea is that the μ angular distribution in reaction (1) is sensitive to the separate combination of $g_A^e g_V^\mu$ and $g_A^\mu g_V^e$ and a difference between these products gives rise to a new component in the angular distribution when the incident $e^\pm$ beam is longitudinally polarized on an unpolarized $e^\mp$ target. The difference between the unpolarized and polarized beam cross sections is given by (for an e^- helicity of λ^-)

$$D(\lambda^-, \theta) = \frac{-R\lambda^-}{1 + z^2}[b(1 + z)^2 + 2dz]$$

where

$$R = \frac{g_V^e g_V^\mu}{e^2 \left(1 - \frac{M_Z^2}{s}\right)}$$

$$b \simeq -[g_A^e/g_V^e] \text{ and } d = (g_A^e/g_V^e - g_A^\mu/g_V^\mu)$$

for PEP energies. The behavior of D for the case d = 0 (μ-e universality) is given in Fig. 2 (taken from Mikaelean preprint for $\sin^2\theta_W \sim 0.4$). A maximal reasonable violation of μ-e universality would be given by d/b ≃ ±2 and results in a modified value of $D(\lambda^-, \theta)$ also shown in Fig. 2 (for d/b ∿ ±1). Note that in the absence of μ-e universality breakdown $D(\lambda^-, \theta) \to 0$ for $z \to -1$ and any deviation from 0 at $z \to -1$ would be evidence for μ-e universality break down.

Both experimental techniques discussed here require

1. One or both longitudinally polarized beams.
2. Comparison of the rates for polarized and unpolarized configurations.
3. Observation of the charge of the leptons ($e^\pm$ or $\mu^\pm$).

4. Involve few per cent integrated effects.

The extreme importance of μ-e universality tests of weak neutral currents makes it important to provide for rotating the polarization. However, even in an optimistic situation the largest effects that can be expected at PEP will likely require very large statistic experiments (> 10^5 events) and care must be taken to minimize systematic errors (perhaps by comparing the rates for polarized and unpolarized bunches simultaneously).

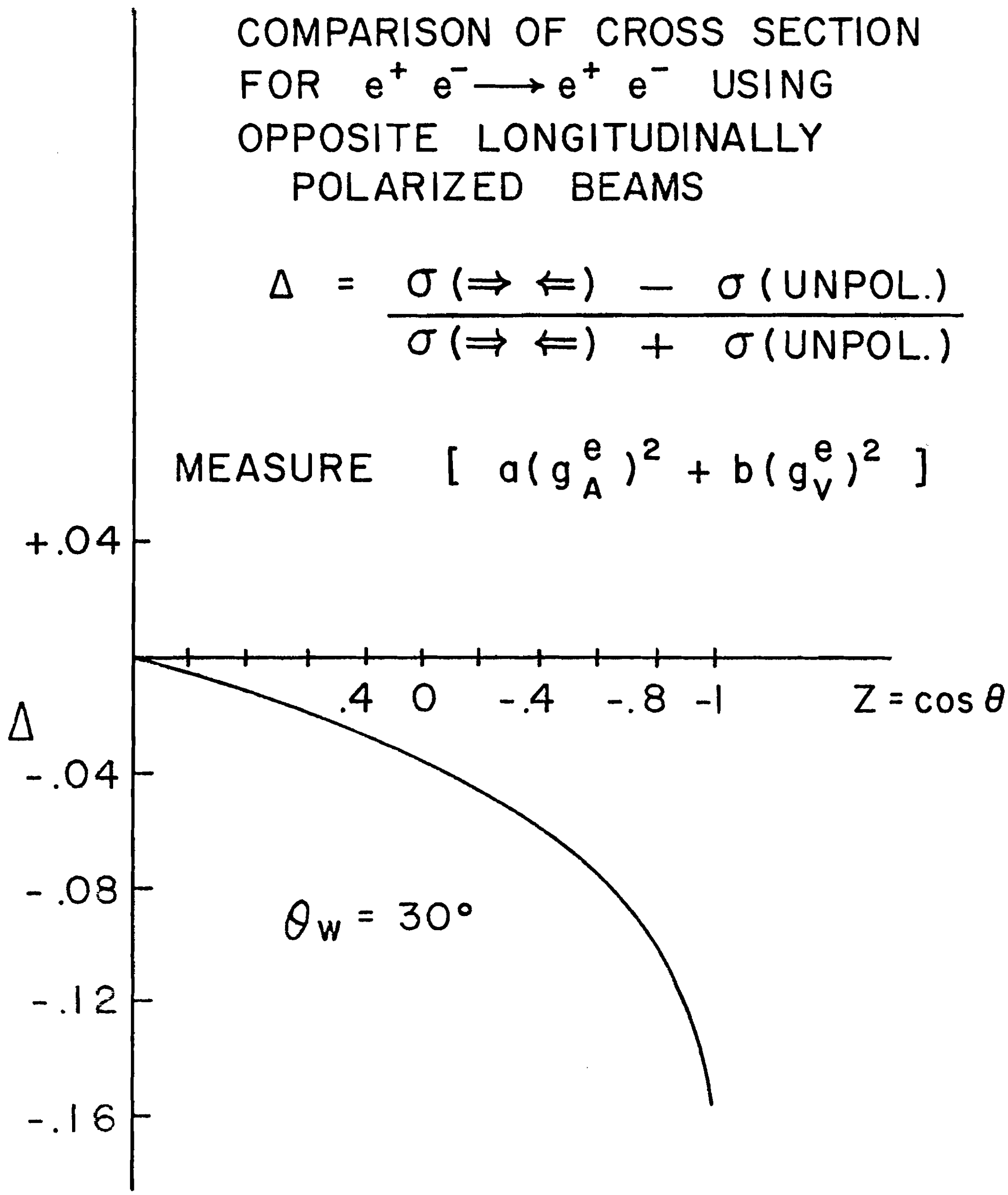
COMPARISON OF CROSS SECTION
FOR $e^+ e^- \longrightarrow e^+ e^-$ USING
OPPOSITE LONGITUDINALLY
POLARIZED BEAMS
$\Delta = \frac{\sigma(\Rightarrow \Leftarrow) - \sigma(\text{UNPOL.})}{\sigma(\Rightarrow \Leftarrow) + \sigma(\text{UNPOL.})}$
MEASURE $[\, a(g^e_A)^2 + b(g^e_V)^2 \,]$
+.04
-.04
-.08
-.12
-.16
Δ
.4
0
-.4
-.8
-1
$Z = \cos\theta$
$\theta_W = 30°$

FIG. 1

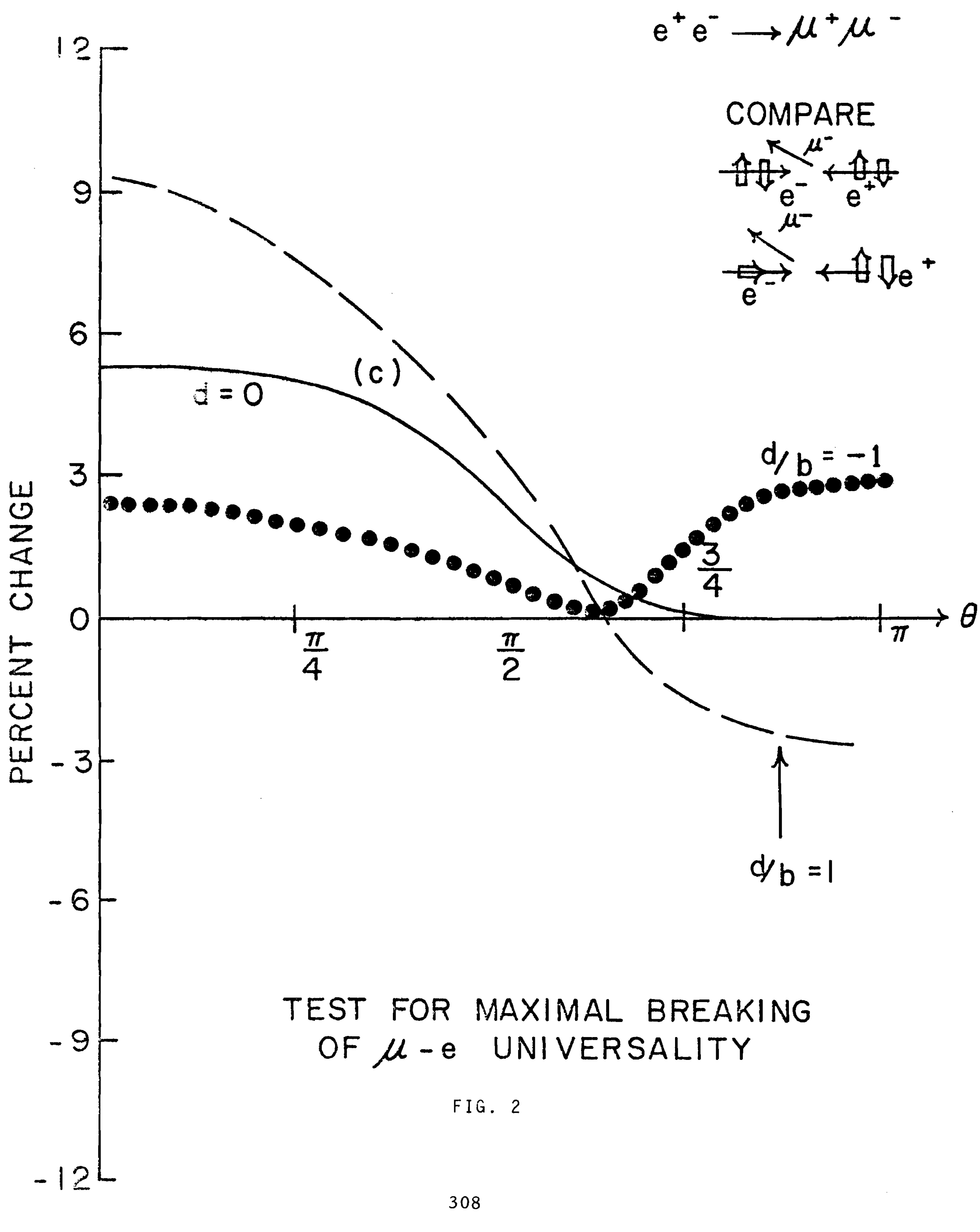
e⁺ e⁻ ⟶ μ⁺ μ⁻
COMPARE
μ⁻
e⁻
e⁺
μ⁻
e⁻
e⁺
12
9
6
3
0
- 3
- 6
- 9
-12
PERCENT CHANGE
(c)
d = 0
d/b = -1
3/4
π/4
π/2
π
θ
d/b = 1
TEST FOR MAXIMAL BREAKING
OF μ - e UNIVERSALITY

FIG. 2