PRODUCTION AND DETECTION OF A CHARGED HEAVY LEPTON AT A Z^o FACTORY

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We discuss the possibility of observing a hypothetical new member, $L^{\pm}$, of the lepton series:

$$\begin{pmatrix} e^{\pm} \\ \nu_e \end{pmatrix} \begin{pmatrix} \mu^{\pm} \\ \nu_\mu \end{pmatrix} \begin{pmatrix} \tau^{\pm} \\ \nu_\tau \end{pmatrix} \begin{pmatrix} L^{\pm} \\ \nu_L \end{pmatrix} \quad \cdots$$

which could be produced in pairs through the process,

$$(e^+e^-) \rightarrow \gamma, Z^o \rightarrow (L^+, L^-) \ .$$

Experiments at PETRA have searched for L^+L^- through their leptonic decays,

$$L^{\pm} \rightarrow \nu_L \ell^{\pm} \nu_\ell \qquad (\ell = e, \mu, \tau)$$

and placed a lower bound $M_L \geqslant 15$ GeV/c^2 to the heavy lepton's mass.

If $2M_L$ does not exceed the Z^o mass ($M_{Z^o} \approx$ 90 GeV/c^2), the production of (L^+L^-) pairs at the Z^o pole should be abundant. We discuss a heavy lepton in the mass range $15 \leq M_L \leq 45$ GeV/c^2 and use the value $M_L = 30$ GeV/c^2 for numerical estimates. We assume also the mass of the associated neutrino ν_L to be 0.

An e^+e^- collider with a luminosity of $2 \times 10^{31} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$ would produce in a year of running (2×10^7 sec) about 10^7 Z^o's.

The branching ratio into L^+L^- is taken to be:

$$BR(Z^o \rightarrow L^+L^-) = \beta \cdot BR(Z^o \rightarrow \mu^+\mu^-) = 0.74 \times 0.03 = 0.02 \ ,$$

yielding 2×10^5 L^+L^- pairs per year.

The heavy lepton decays into leptonic channels:

$$L \rightarrow \nu_L \ell \nu_\ell \qquad (\ell = e. \mu, \tau)$$

and into hadronic channels:

$$L \rightarrow \nu_L (q\bar{q}') \ ,$$

where $(q\bar{q}')$ stands for $(u\bar{d})$, $(c\bar{s})$, and, possibly for $(t\bar{b})$, depending on the mass of the $(t\bar{b})$ pair. The branching ratio for leptonic decays is:

$$BR(L \rightarrow \nu_L \ell \nu_\ell) = 1/(3+3n_q) \ ,$$

where n_q is the number of $(q\bar{q}')$ paris energetically accessible. For $n_q = 2(3)$, one obtains $BR(L \rightarrow \nu_L \ell \nu_\ell) = 0.11 (0.08)$. For the rate estimations, we use 0.10.

The cleanest signal of an L^+L^- pair seems to be when both L's decay into leptonic channels: one into a μ, the other into an e. The signature is then a μe pair of opposite sign.

Using the above branching ratios, one would expect

4000 $L^+L^- \rightarrow \mu e$ events/year

and

116 $L^+L^- \rightarrow \tau^+\tau^- \rightarrow \mu e$ events/year .

(For $BR(\tau \rightarrow \ell \nu\nu)$ we used 0.17.)

Hadronic decays of L^+L^- are 100 times more abundant; hadronic jets have, however, an average charged-track multiplicity of ≈ 20 and are rejected by requiring a single charged track per hemisphere. We also anticipate a detector with good e-μ-π discrimination (cfr. e.g., OPAL proposal for LEP) which would allow an unambiguous e-μ-π identification for $P_{e,\mu} \geqslant$ 3 GeV/c.

The main background comes from $Z^o \rightarrow \tau^+\tau^-$ followed by $\tau^+\tau^- \rightarrow \mu e$. One anticipates 17340 such events per year; 4 times the L^+L^- signal.

This background can, however, be reduced by kinematical considerations. Due to the larger Lorentz-factor ($\gamma_\tau \approx 25$, whereas $\gamma_L \approx 1.5$), the background $(e\mu)$ pairs are highly collinear compared to $(e\mu)$ pairs from L^+L^-.

The figure indicates the maximal deviation from collinearity, α_{max}, for both $\tau^+\tau^-$ and L^+L^-, plotted against the total energy $E_\mu + E_e$ of the lepton pair. (P_μ and P_e was assumed > 3 GeV/c.) A cut along the kinematic limit would eliminate most of the background for a relatively low loss in the signal.

To determine the mass M_L of the heavy lepton, one has to analyze the energy spectrum of the electrons and muons. Comparing the observed laboratory spectra to the c.m.s. spectra predicted under the assumption of e-μ-τ-L universality, one obtains the Lorentz factor γ_L of the heavy lepton in $Z^o \rightarrow L^+L^-$ decay.

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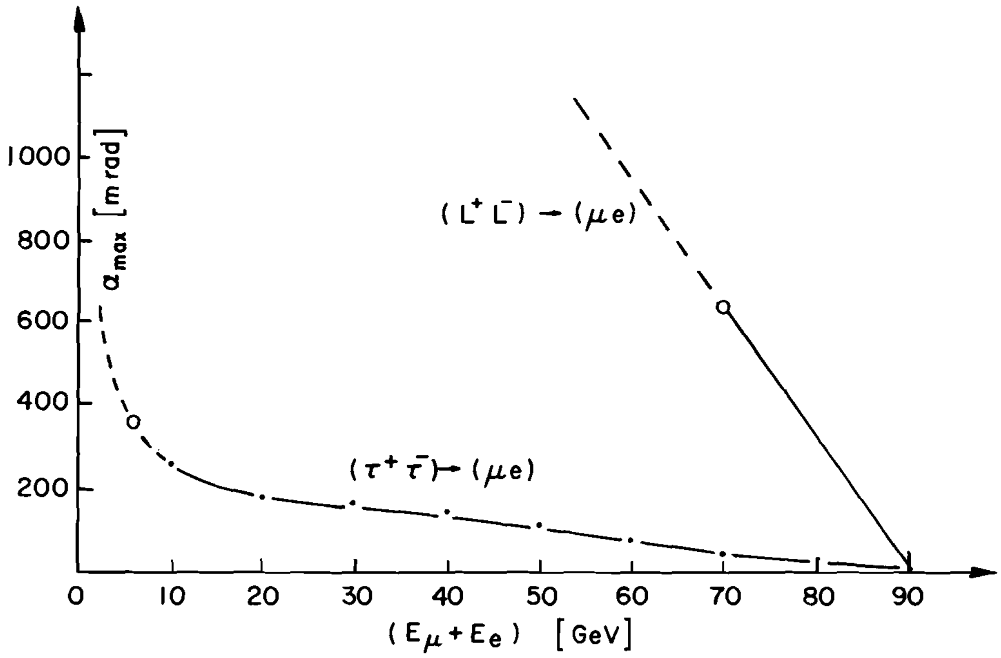

Figure 1: MAXIMAL DEVIATION FROM COLLINEARITY FOR L^+L^- AND $\tau^+\tau^-$ VS THE TOTAL ENERGY OF THE LEPTON PAIR.