L-R asymmetries and signals for new bosons [*]

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Abstract

Several left-right parity violating asymmetries in lepton-lepton scattering in fixed target and collider experiments are considered as signals for doubly charged vector bosons (bileptons).

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The left-right asymmetry when only one of the lepton is polarized is defined as follows [1]

$$A_{RL}(ll \to ll) = \frac{d\sigma_R - d\sigma_L}{d\sigma_R + d\sigma_L}, \tag{1}$$

where $d\sigma_{R(L)}$ is the differential cross section for one right (left)-handed lepton l scattering on an unpolarized lepton l. That is

$$A_{RL}(ll \to ll) = \frac{(d\sigma_{RR} + d\sigma_{RL}) - (d\sigma_{LL} + d\sigma_{LR})}{(d\sigma_{RR} + d\sigma_{RL}) + (d\sigma_{LL} + d\sigma_{LR})}, \tag{2}$$

where $d\sigma_{ij}$ denotes the cross section for incoming leptons with helicity i and j, respectively, and they are given by

$$d\sigma_{ij} \propto \sum_{kl} |M_{ij;kl}|^2, \quad i, j; k, l = L, R. \tag{3}$$

Another interesting possibility is the case when both leptons are polarized. We can define an asymmetry $A_{R;RL}$ in which one beam is always in the same polarization state, say right-handed, and the other is either right- or left-handed polarized (similarly we can define $A_{L;LR}$):

$$A_{R;RL} = \frac{d\sigma_{RR} - d\sigma_{RL}}{d\sigma_{RR} + d\sigma_{RL}}, \qquad A_{L;RL} = \frac{d\sigma_{LR} - d\sigma_{LL}}{d\sigma_{LL} + d\sigma_{LR}}. \tag{4}$$

We can define also an asymmetry when one incident particle is right- handed and the other is left-handed and the final states are right- and left or left- and right-handed:

$$A_{RL;RL,LR} = \frac{d\sigma_{RL;RL} - d\sigma_{RL;LR}}{d\sigma_{RL;RL} + d\sigma_{RL;LR}} \tag{5}$$

or similarly, $A_{LR;RL,LR}$. These asymmetries, in Eqs.(4) and (5), are dominated by QED contributions. However, this will not be the case if a bilepton resonance does exist at typical energies of the NLC. To show this fact is the goal of this paper. These asymmetries can be calculated for both fixed target (FT) and collider (CO) experiments.

We can integrate in the scattering angle and define the asymmetry $\overline{A}_{RL}$ as

$$\overline{A}_{RL}(ll \to ll) = \frac{(\int d\sigma_{RR} + \int d\sigma_{RL}) - (\int d\sigma_{LL} + \int d\sigma_{LR})}{(\int d\sigma_{RR} + \int d\sigma_{RL}) + (\int d\sigma_{LL} + \int d\sigma_{LR})}, \tag{6}$$

where $\int d\sigma_{ij} \equiv \int_{5^o}^{175^o} d\sigma_{ij}$. All these asymmetries can be studied in future accelerators [2,3].

The importance of these sort of parity breaking asymmetries in fixed target experiments in lepton-lepton scattering was first pointed out in Ref. [1]. For the case of electron-electron scattering the mass of the electrons can be neglected. For an energy of $E = 50$ GeV and for a scattering angle (in the center of mass frame) of $\theta = 90^o$ the left-right asymmetry, defined in Eq. (1) has a value $\approx -3 \times 10^{-7}$ in the standard model. Radiative corrections reduce this value about $40 \pm 3\,\%$ [4]. It is expected that fixed target experiments like those at SLAC [5] can measure this asymmetry [4]. For the muon-muon elastic scattering this asymmetry is $\approx 5.4 \times 10^{-5}$ [6]. We have studied also the non-diagonal elastic scattering $e\mu \to e\mu$. In the last case we obtain a value of -5.9×10^{-8} for a muon energy of 50 GeV and -2.9×10^{-7} for muon energy of 190 GeV. At these energies the muon mass cannot be neglected [7]. This type of asymmetry can be measured using the high-energy muon beam M2 of the CERN SPS as in the NA47 experiment [8].

The relevance of these asymmetries in collider experiments was first pointed out in Refs. [6,9]. In fixed target experiments the cross sections are large ($\sim$ mb) and the asymmetries small ($\sim 10^{-7}$). On the other hand, in collider experiments the cross sections are small ($\sim 10^{-3}$nb) but the asymmetries large (~ 0.1 for the muon-muon case). Explicitly we have that at energies $\sqrt{s} = 300$ GeV and $\theta \approx 90^o$ the asymmetry is

$$A_{RL}^{\text{CO,ESM}}(ee \to ee) \approx -0.05, \tag{7}$$

for the electron-electron case and

$$A_{LR}^{\text{CO,ESM}}(\mu\mu \to \mu\mu) \approx -0.1436, \tag{8}$$

for the muon-muon case. Future colliders with polarized lepton-lepton scattering can have the appropriate luminosity to measure these parameters.

If a muon-electron collider is constructed in the future, it would be possible to measure the $A_{RL}^{CO;ESM}(\mu e) = -0.024$ for $E_\mu = 190$ GeV ($\sqrt{s} \sim 380$ GeV) and $\theta = 90^o$. At high energies the mass effects are not important.

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So far all the results were obtained in the standard model. In certain kind of models there are doubly charged scalars (H^{--}) or/and vector (U^{--}) bileptons [10]. As expect the asymmetry is larger in the U-pole. For instance,

$$A_{RL}^{\text{CO,ESM+U}}(ee \rightarrow ee) = -0.099, \tag{9}$$

and

$$A_{RL}^{\text{CO,ESM+U}}(\mu\mu \rightarrow \mu\mu) = -0.1801, \tag{10}$$

when we add to the standard model asymmetry the contributions due to the the bilepton U for $M_U = 300$ GeV and $\Gamma_U = 36$ MeV. In Fig. 1 we show the behaviour of the asymmetry $A_{RL}^{\text{CO,ESM+U}}$ as a function of the mass of the boson U^{--}.

For the electron-electron case we can define the quantity

$$\delta \overline{A}_{RL}(ee \rightarrow ee) \equiv (\overline{A}_{RL}^{\text{CO,ESM+U}} - \overline{A}_{RL}^{\text{CO,ESM}})/\overline{A}_{RL}^{\text{CO,ESM}}, \tag{11}$$

where $\bar{A}$'s are define in Eq. (6). Although $\delta \overline{A}_{RL}$ is large (near 50 for $\sqrt{s} = 300$) at the U-resonance we would like to stress that it remains appreciably large even far from the U-peak. That particular behavior suggests that this quantity could be the one to be considered in the search for new physics, like the bilepton U^{--}, in future colliders. On the other hand, the asymmetry is insensitive to the contributions of the doubly charged scalars.

We have used also the asymmetries defined in Eq. (4). In this case it is interesting to note that

$$A_{R;RL}^{\text{CO,ESM+U}}(ee \rightarrow ee) \approx -A_{R;RL}^{\text{CO,ESM}}(ee \rightarrow ee), \tag{12}$$

and we see that such a difference on sign is a good signature for the discovery of the vector bilepton.

The contributions of an extra neutral vector boson Z' has also been considered for the case $A_{RL}(\mu e)$. In this case the asymmetry is considerably enhanced and it will be appropriate in searching for extra neutral vector bosons with mass up to 1 TeV. Since in the 331 model

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the Z' couplings with the leptons are flavor conserving we do not have additional suppression factors coming from mixing [10]. Hence, the μe elastic scattering can be very helpful, even with the present experimental capabilities, for looking for non-standard physics effects.

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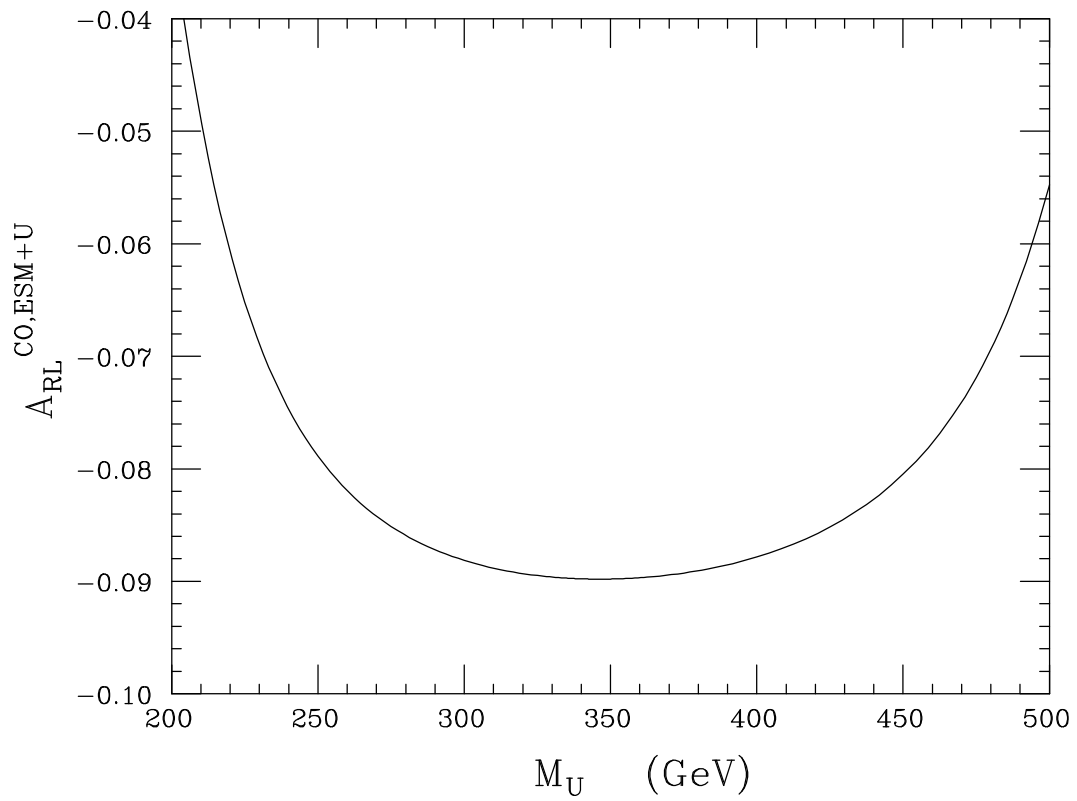[10] F. Pisano and V. Pleitez, *Phys. Rev. D* **46**, 410 (1992).

Fig. 1

FIG. 1. $L - R$ asymmetry as a function of the M_U mass for $\theta = \pi/2$, $\sqrt{s} = 300$ GeV and $\Gamma_U = 36$ MeV.