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Precision of electro-weak couplings of scalar leptoquarks at TESLA [1]

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Abstract

We investigate the potential to measure the electro-weak couplings of scalar leptoquarks Φ_s at TESLA for energies in the range of $\sqrt{s} \simeq 1\mathrm{TeV}$ using the pair production process $e^+e^- \rightarrow \Phi_s\overline{\Phi}_s$.

[1] Contribution to the TESLA TDR.

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Leptoquarks are hypothetical particles which combine quantum numbers of the fundamental fermions of the Standard Model and emerge as bosonic (scalar and vector) states in various extensions of the Standard Model such as unified theories and sub-structure models. In most of the scenarios the mass spectrum of these states is not predicted. In a series of models, however, one expects states in the range of several hundred GeV to a few TeV. As being colour (anti)triplets these particles are likely to be found first at TEVATRON or LHC in strong interaction processes [1]. There the corresponding cross sections are widely independent of the $SU(2)_L \otimes U(1)_Y$ gauge charges of these particles which, on the other hand, can ideally be determined via the pair production process $e^+e^- \rightarrow \Phi\overline{\Phi}$ [2] at high energy linear colliders. Since the fermionic couplings λ_{lq} of leptoquarks are found to be rather small [3] the production process is completely determined by the electroweak couplings of these particles for scalar leptoquarks [2] and additional anomalous couplings for vector leptoquarks (cf. [4] for details). Currently the mass range of $M_\Phi \lesssim 250$GeV is excluded for the 1st family leptoquark states [5], and the mass limits for 2nd and 3rd family leptoquarks are 200 and 100 GeV, respectively, [6]. Searches at TESLA will concentrate on the mass range up to $M_\Phi \lesssim 500$GeV at cms energies $\sqrt{s} \lesssim 1$TeV assuming an integrated luminosity of $\mathcal{L} = 1$ ab^{-1}. The production cross section for scalar leptoquarks is given by [2]

$$\sigma_s = \frac{\pi\alpha^2\beta^3}{2s} \sum_{a=L,R} \left| \sum_{V=\gamma,Z} Q_a^V(e) \frac{s}{s - M_V^2 + iM_V\Gamma_V} Q_\Phi^V \right|^2 \tag{1}$$

with $Q_{L,R}^\gamma = -1, Q_L^Z = (-1/2 + \sin^2(\theta_w))/\cos(\theta_w)\sin(\theta_w), Q_R^Z = \tan(\theta_w), Q_\Phi^\gamma = Q_{em}, Q_\Phi^Z = (T_3 - Q_{em}\sin^2(\theta_w))/\cos(\theta_w)\sin(\theta_w)$, where θ_w is the weak mixing angle, T_3 is z-component of the weak isospin of the leptoquark, Q_{em} its electric charge and $\beta = \sqrt{1 - 4M_\Phi^2/s}$. M_V and Γ_V denote mass and width of the gauge bosons γ and Z. The Beamstrahlung and QED initial state radiation contribution to $O(\alpha^2)$ do widely cancel against the QED and QCD final state radiation contributions, see. Ref. [7]. Therefore the Born cross section yields already a reasonable first estimate for the production cross section. Following the notation for the leptoquarks [8] the statistical precisions of the electro-weak charges $\delta Q_\Phi^{\gamma,Z}$ are summarized in table 1 considering the examples of leptoquark pair production at $\sqrt{s} = 800$TeV, $M_\Phi = 320$GeV and $\mathcal{L} = 500$ fb^{-1} (1st line) and $\sqrt{s} = 1$TeV, $M_\Phi = 400$GeV and $\mathcal{L} = 1$ ab^{-1} (2nd line). The statistical accuracies to be obtained are similar in both cases and range between ± 0.004 and ± 0.009 for Q_Φ^γ and between ± 0.008 and ± 0.04 for Q_Φ^Z.

Φ_s	Q_Φ^γ	T_3	Q_Φ^Z	#	δQ_Φ^γ	δQ_Φ^Z
S_1	1/3	0	–0.182	1419	± 0.005	$+0.035 - 0.028$
				1815	± 0.004	$+0.031 - 0.025$
$\tilde{S}_1$	4/3	0	–0.729	22706	± 0.005	± 0.032
		0		29042	± 0.004	± 0.028
S_3^u	4/3	1	1.648	36020	± 0.006	± 0.012
				45946	± 0.005	± 0.010
S_3^0	1/3	0	–0.182	1419	± 0.005	$+0.035 - 0.028$
				1815	± 0.004	$+0.031 - 0.025$
S_3^d	–2/3	–1	–2.012	24779	± 0.009	± 0.009
				31493	± 0.008	± 0.008
R_2^u	5/3	1/2	0.277	34465	± 0.005	$-0.044 + 0.041$
				44107	± 0.004	$-0.039 + 0.036$
R_2^d	2/3	–1/2	–1.552	14793	± 0.009	± 0.009
				18815	± 0.008	± 0.008
$\tilde{R}_2^u$	2/3	1/2	0.824	34465	± 0.005	± 0.042
				44107	± 0.004	± 0.038
$\tilde{R}_2^d$	–1/3	–1/2	–1.006	9005	± 0.006	± 0.012
				11486	± 0.005	± 0.010

Table 1: Statistical precision to which the electro-weak couplings Q_Φ^γ and Q_Φ^Z of scalar leptoquarks can be measured at TESLA. First lines: $\sqrt{s} = 800\text{GeV}, M_\Phi = 320\text{GeV}, \mathcal{L} = 500\text{fb}^{-1}$; Second lines: $\sqrt{s} = 1\text{TeV}, M_\Phi = 400\text{GeV}, \mathcal{L} = 1\text{ab}^{-1}$.

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