Degenerate BESS model at future colliders

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A brief overview of the sensitivity of future colliders to new vector particles from strongly interacting Higgs is presented. In particular the capability of detecting almost degenerate resonances is reviewed.

1. Introduction

Alternative realizations of the electroweak symmetry breaking can be formulated by means of effective lagrangians which are built on the basis of the known symmetry properties and which can a priori contain no resonance or new resonances like scalar and vector particles. The good SM fit to the electroweak precision data does not necessarily exclude possible extensions along this direction which in general assume a large Higgs mass. One can compensate the effect of the large Higgs mass by some new high order operator or some new particle [1]. A recent critical review of this option can be found in [2]. These new operators or the presence of new particles can give a signature at new accelerators like LHC and future linear colliders. For instance the parameters α_4 and α_5 appearing in the effective lagrangian to order p^4 can be detected by studying WW scattering at future colliders with the sensitivity shown in [3]; the possibility of detecting new vectors from strong WW interaction at CLIC [4] and at VLHC [5] has been also recently investigated. I will present here a brief overview of the phenomenology of new vector resonances from the degenerate BESS model.

2. The degenerate BESS model

The degenerate BESS model (D-BESS) [6] is a realization of dynamical electroweak symmetry breaking which predicts the existence of two new triplets of gauge bosons almost degenerate in mass ($L^\pm$, L_3), ($R^\pm$, R_3). The extra parameters are a new gauge coupling constant g'' and a mass parameter M, related to the scale of the underlying symmetry breaking sector. In the charged sector the $R^\pm$ fields are unmixed and $M_{R^\pm} = M$, while $M_{L^\pm} \simeq M(1+x^2)$ where $x = g/g''$ with g the usual $SU(2)_W$ gauge coupling constant. The L_3, R_3 masses are given by $M_{L_3} \simeq M\,(1+x^2)\,,\ \ M_{R_3} \simeq M\,(1+x^2\tan^2\theta)$ where $\tan\theta = s_\theta/c_\theta = g'/g$ and g' is the usual $U(1)_Y$ gauge coupling constant. These resonances are narrow and almost degenerate in mass with $\Gamma_{L_3}/M \simeq 0.068\ x^2$ and $\Gamma_{R_3}/M \simeq 0.01\ x^2$, while the neutral mass splitting is: $\Delta M/M = (M_{L_3} - M_{R_3})/M \simeq (1-\tan^2\theta)\,x^2 \simeq 0.70\ x^2$. This model respects the existing stringent bounds from electroweak precision data since the S, T, U (or $\varepsilon_1, \varepsilon_2, \varepsilon_3$) parameters vanish at the leading order due to an additional custodial symmetry. Therefore the precision electroweak data only set loose bounds on the parameter space of the model.

Future hadron colliders may be able to discover these new resonances by their production through quark annihilation and decay in the lepton channel: $q\bar{q}' \to L^\pm, W^\pm \to (e\nu_e)\mu\nu_\mu$ and $q\bar{q} \to L_3, R_3, Z, \gamma \to (e^+e^-)\mu^+\mu^-$. The relevant observables are the di-lepton transverse and invariant masses. The main backgrounds, left to these channels after the lepton isolation cuts, are the Drell-Yan processes with SM gauge bosons exchange in the electron and muon channel. A study has been performed using Pythia and CMSJET, which performs a simulation of the energy smearing of CMS detector,[7]. Results are given in Table I for the sum of the electron and muon channels

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Table I Sensitivity to L_3 and R_3 production at the LHC and CLIC for L =100(500) fb^{-1} with M =1,2(3) TeV at LHC and L =1000 fb^{-1} at CLIC.

g/g''	M (GeV)	Γ_{L_3} (GeV)	Γ_{R_3} (GeV)	$\frac{S}{\sqrt{S+B}}$ LHC $(e+\mu)$	$S/\sqrt{S+B}$ CLIC (hadrons)	ΔM CLIC
0.1	1000	0.7	0.1	17.3		
0.2	1000	2.8	0.4	44.7		
0.1	2000	1.4	0.2	3.7		
0.2	2000	5.6	0.8	8.8		
0.1	3000	2.0	0.3	(3.4)	62	23.20 ± .06
0.2	3000	8.2	1.2	(6.6)	152	83.50 ± .02

for L = 100 fb^{-1}. For the case M =3 TeV the results are given for an integrated luminosity of 500 fb^{-1}.

The discovery limit at LHC with L = 100 fb^{-1} is $M \sim 2$ TeV with $g/g'' = 0.1$. Beyond discovery, the possibility to disentangle the double peak structure depends strongly on g/g'' and smoothly on the mass [7]. A lower energy LC can also probe this multi-TeV region through the virtual effects in the cross-sections for $e^+e^- \to L_3, R_3, Z, \gamma \to f\bar{f}$. Due to the presence of new spin-one resonances the annihilation channel in $f\bar{f}$ and W^+W^- is more efficient than the fusion channel. In the case of D-BESS, the L_3 and R_3 states are not strongly coupled to WW making the $f\bar{f}$ final states the most favourite channel for discovery. The analysis at $\sqrt{s}$ = 500 GeV and $\sqrt{s}$ = 800 GeV is based on the following observables: σ^μ, σ^h, $A_{FB}^{e^+e^-\to\mu^+\mu^-}$, $A_{FB}^{e^+e^-\to\bar{b}b}$, $A_{LR}^{e^+e^-\to\mu^+\mu^-}$, $A_{LR}^{e^+e^-\to\bar{b}b}$, $A_{LR}^{e^+e^-\to had}$. For σ^h and σ^μ a systematic uncertainty of 2% and 1.3% has been also assumed. The sensitivity contours obtained for L = 1000 fb^{-1} and $P(e^-)$ = 80% are shown in Figure 1. The allowed regions are below the curves.

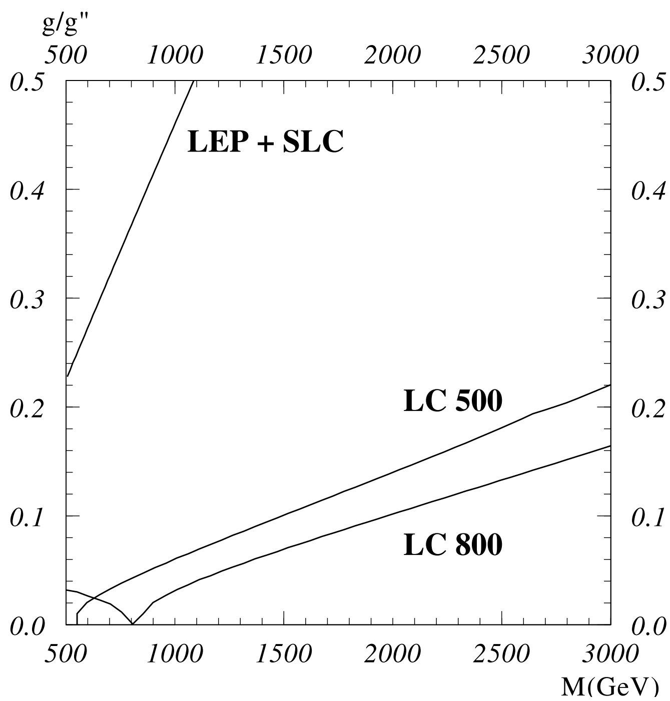

Figure 1: 95% CL contour in the plane $(M,\ g/g'')$ from e^+e^- linear colliders with $\sqrt{s}$ = 500(800) GeV. Also shown are the present bounds from LEP and SLC. The allowed regions are below the lines.

The LC indirect reach for $\sqrt{s}$ <M is lower or comparable to that of the LHC. However, the QCD background rejection essential for the LHC sensitivity still needs to be validated using full detector simulation and pile-up effects.

Assuming a resonant signal to be seen at the LHC or at a lower LC, the multi-TeV collider can measure its width, mass and investigate the existence of an almost degenerate structure [8]. This preliminary study has been recently validated by taking full account for the luminosity spectrum and accelerator induced backgrounds[9]. The ability in identifying the model distinctive features has been studied using the CLIC production cross section and the flavour dependent forward-backward asymmetries, for different values of g/g''. The CLIC luminosity spectrum has been obtained with a dedicated beam simulation program for the nominal parameters at $\sqrt{s} = 3$ TeV. In order to study the systematics from the knowledge of this spectrum, the modified Yokoya-Chen parameterization has been adopted. The beam energy spectrum is described in terms of N_γ, the number of photons radiated per $e^\pm$ in the bunch, the beam energy spread in the linac σ_p and the fraction $\mathcal{F}$ of events outside the 5% of the centre-of-mass energy. The resulting distributions for $M = 3$ TeV and $g/g'' = 0.15$ are shown in Figure 2 for the case of the CLIC.02 beam parameters (L=0.40$\times 10^{35}$ cm^{-2} s^{-1} and N_γ=1.2).

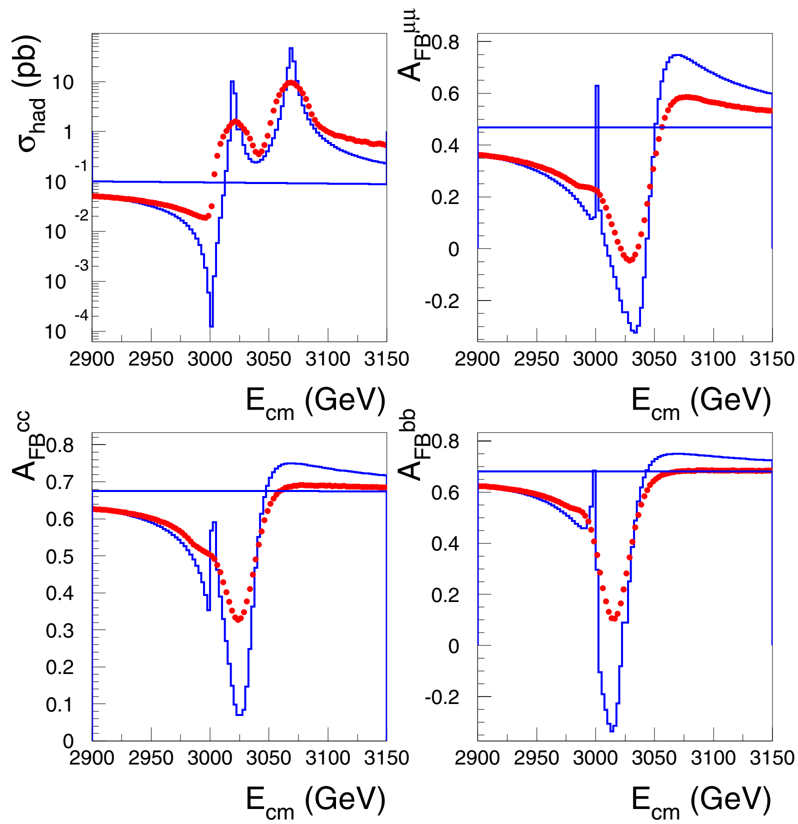

Figure 2: The hadronic cross section (upper left) and $\mu^+\mu^-$ (upper right), $b\bar{b}$ (lower left) and $c\bar{c}$ (lower right) forward-backward asymmetries at energies around 3 TeV. The continous lines represent the predictions for the D-BESS model with $M = 3$ TeV and $g/g'' = 0.15$, the flat lines the SM expectation and the dots the observable D-BESS signal after accounting for the CLIC.02 luminosity spectrum

This study has demonstrated that with 1000 fb^{-1} of data, CLIC will be able to resolve the two narrow resonances for values of the coupling ratio $g/g'' > 0.08$, corresponding to a mass splitting $\Delta M = 13$ GeV for $M = 3$ TeV, and to determine ΔM with a statistical accuracy better than 100 MeV (see Table I).

The profile of new resonances can be studied with high accuracy due to the large CLIC luminosity. Additional work has to be done to see how this accuracy can be exploited to distinguish the nature of the resonances.

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