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Search for light exotic scalar production at the ILC

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Summarized in this contribution is the study of the International Large Detector (ILD) sensitivity to the new exotic light scalar production in the scalar-strahlung process, $e^+e^- \to Z\,S$, at the International Linear Collider running at 250 GeV. Presented are the expected 95% C.L. limits on the ratio of the production cross section times branching fraction to the SM Higgs boson production cross section at given mass. New scalar decay channel considered is $S \to b\bar{b}$ while the leptonic decay channels are assumed for the associated Z boson, $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$. Boosted Decision Tree classifiers were trained for signal-background separation and their response distributions were used to calculate the limits.

This work was carried out in the framework of the ILD Concept Group

1 Monte Carlo samples

The Monte Carlo samples used for the analysis were generated with WHIZARD v.2.8.5[1]. The processes considered in the analysis are the ones containing either 2 or 4 fermions in the final state. For the background, processes with Z and W production were used, as well as Higgs production with all subsequent decays. For signal, 31 data samples were generated for scalar particle mass from 10 GeV to 160 GeV. For each considered process separate samples were generated for each electron-positron polarisation combination assuming 100% polarization and then properly reweighted to reflect the assumed H-20 running scenario. The detector response for the background samples was simulated using the full simulation (GEANT4) while for the signal SGV fast simulation framework [2] was used.

2 Event selection and classification

All data samples were processed using the a modular MARLIN[3]framework, a part of ILCSOFT package[4], designed for efficient data analysis and based on LCIO data model. Dedicated processors were used to select isolated leptons while jet clustering and flavour tagging were performed within LCFIPLUS package. At the pre-selection stage, selected were events with exactly two isolated leptons and two reconstructed jets, consistent with the expected event kinematics. Variables describing both the scalar decay and the Z decay products, including object 4-momenta, numbers of particles and jet flavor tagging results, were used for event classification. Invariant mass of the scalar particle reconstructed using the recoil mass technique was also included.

Event classification was done with Boosted Decision Trees (BDTs) trained separately for each beam polarization setting and each scalar particle mass, resulting in 124 trained classifiers. Considered for each mass point were BDT response distributions for beam each polarisation combination as well as a combined distribution resulting from combination of the four distributions for polarized beams. An example of the combined BDT response distribution is shown in Figure 1.

3 Results

Expected 95% C.L. limits on the scalar production cross section were calculated from the template fit to the BDT response distributions. For each scalar mass considered, limits were calculated for each beam polarization setting as well as for the combined data (from the combined BDT response distribution). The resulting limits are shown in Figure 2. Limits obtained for LL and RR polarization running are an order of magnitude weaker than for LR and RL. This is the result of much smaller luminosity for these beam polarisation

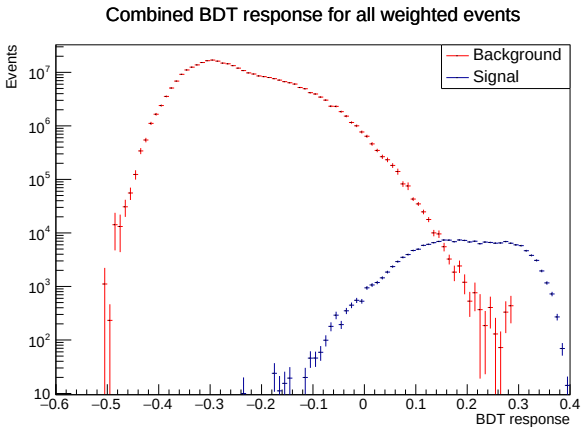

Figure 1: Combined distribution of the BDT response for the expected Standard Model backgrounds and signal of scalar particle production with mass of 50 GeV. Scalar production cross section is normalized to 1% of the SM cross section for this mass.

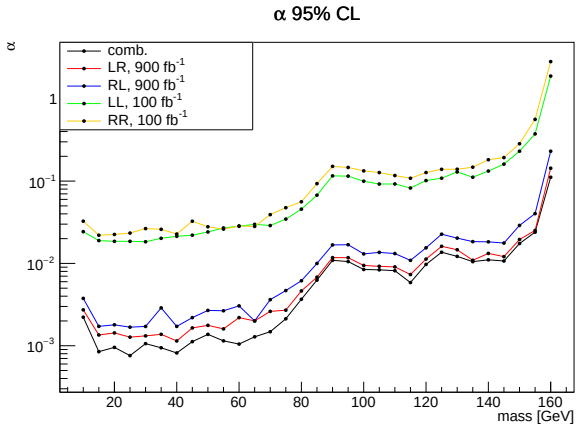

Figure 2: Expected limits on the ratio α of the new scalar production cross section to the SM Higgs boson production cross section at given mass, assuming 100% branching ratio to $b\bar{b}$. Presented are limits obtained for different beam polarization settings and for the combined data sample.

settings. For all polarisations the limits at 80 GeV start to become weaker due to electroweak bosons now becoming more difficult to separate from the scalar particle. At 125 GeV one can see a peak caused by the Higgs boson having very similar signature to the new scalar particle at that mass. The limits weaken sharply for mass approaching the kinematic limit of $\sqrt{s} - M_Z$.

4 Conclusion

Considered in this study was the sensitivity of the ILD detector operating at the 250 GeV ILC for discovering new exotic scalar particles produced in the scalar-strhlung process, $e^+e^- \to Z\,S$, assuming scalar decays to $b\bar{b}$. To avoid huge background from hadronic $W^+\,W^-$ events, only leptonic decays of the Z boson produced in association with the new scalar were considered. The expected 95% C.L. limits on the scalar production cross section times the $b\,\bar{b}$ branching ratio, relative to the SM production cross section, were calculated in the mass range between 10 and 160 GeV. Results correspond to about order of magnitude increase in sensitivity with respect to the model independent study [5], assuming decays of the new scalar to $b\bar{b}$ dominate.

References

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