Cross section limits for $e^+e^- \to Z\,S$ in $S \to bb$ channel for ILC at 550 GeV

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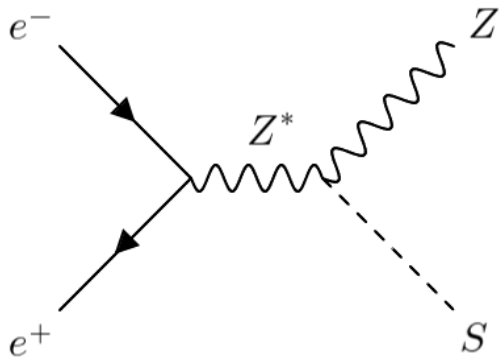
Introduction

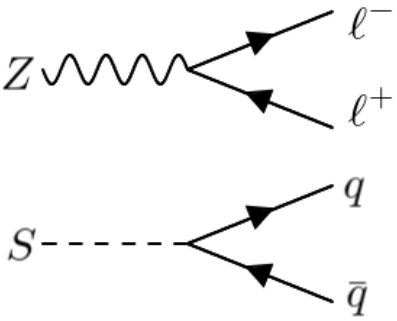
There are many models containing a second scalar particle that is not currently excluded by the measurements. ILC at 550 GeV can search for new scalar production up to masses of about 460 GeV.



The general goal is to estimate 95% C.L. limits on the cross section ratio of the new extra scalar particle production to the SM Higgs production cross section at given mass:

$$\alpha_0 = \sigma\left(e^+e^- \to ZS\right)/\sigma_{SM}$$

Decay channels



Considered in the presented study is decay

$$S \to b\bar{b}$$

which is expected to be a dominant decay channel in many models (for light scalars).

So the limits obtained assuming 100% BR in this channel refer to

$$\alpha = \mathcal{B}(S \to b\bar{b}) \times \sigma\left(e^+e^- \to ZS\right)/\sigma_{SM}$$

Full simulation/SGV study

Background samples:

- 550 GeV center-of-mass energy,
- generated with Whizard v.2.8.5 or 3.1.4/5,
- simulated with SGV,
- total integrated luminosity $4\,\mathrm{ab}^{-1}$.

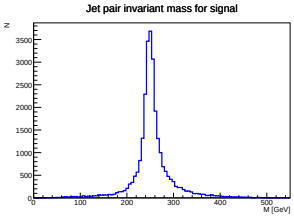
Signal samples:

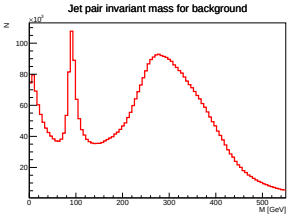
- 550 GeV center-of-mass energy,
- generated with Whizard v.3.1.5,
- detector simulation done by SGV.

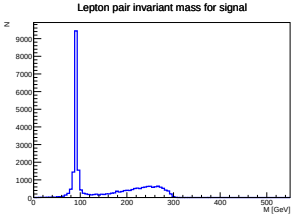
Full simulation/SGV study
$Z \to ll$ **analysis**

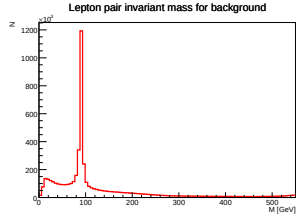
- Only events with a reconstructed electron or muon pair taken into account
- N=2 exclusive jet clustering and b-tagging with LCFI+
- event classification with root TMVA
  classification considered separately for each beam polarization

Reconstructed invariant mass





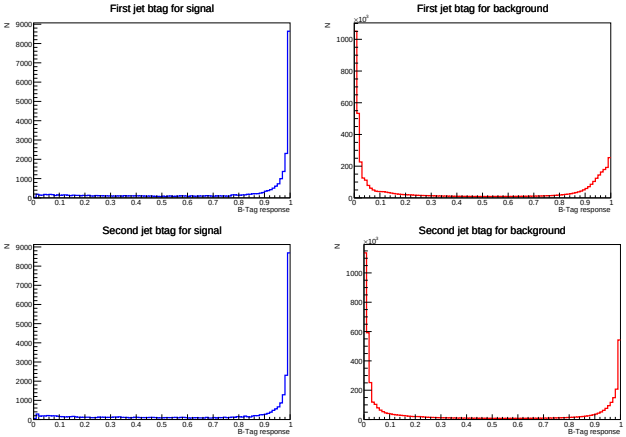




- Invariant mass of the jet pair.
- Invariant mass of the lepton pair.

Signal of 250 GeV scalar production (blue) compared with SM background (red)

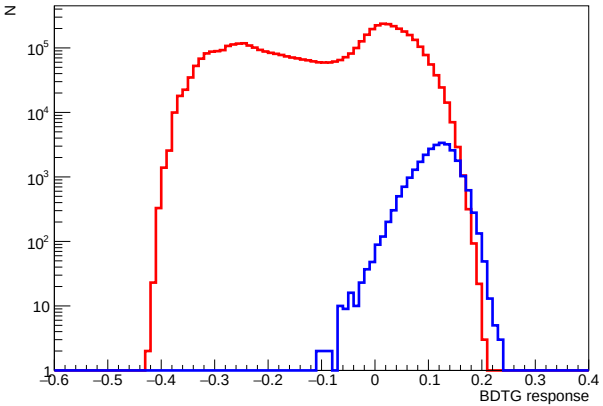
Flavor tagging



- b-tagging for both jets.

Signal of 250 GeV scalar production (blue) compared with SM background (red)

Classifier training



- A BDT classifier using BDTG algorithm (BDT with Gradient Boost) has been used to classify the events.
- Events were classified separately for each mass and each polarization.
- Example BDT distribution can be seen on the plot to the left. It show the BDT distribution for the 250 GeV LR polarization.

Signal normalized to SM Higgs production cross section for M_H=250 GeV

Limit calculation

Instead of using a single cut on BDT response, signal significance is calculated from the BDT response histograms for signal and background:

$$Z = \sqrt{\sum_i \left(\frac{s_i^2}{b_i} \right)}$$

where s_i is the expected signal in each bin (for SM cross section) and b_i is the background level. Low background bins are combined to avoid statistical fluctuations.

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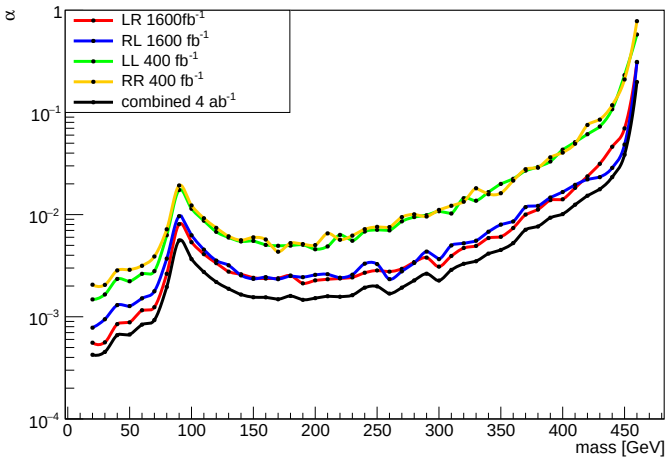
95% C.L. (2σ) limits on $\alpha = \sigma\left(e^+e^- \to ZS\right) \cdot \mathcal{B}(S \to b\bar{b})/\sigma_{SM}$ are then calculated as:

$$\alpha_{95\%CL} = \frac{2}{Z} = 2 \cdot \left(\sqrt{\sum_i \left(\frac{s_i^2}{b_i}\right)}\right)^{-1}.$$

Obtained limits



- Limits for all beam polarization settings and the combined limit.
- A peak from Z production can be seen, however no Higgs peak observed - ZH background samples required.

Conclusions

Light exotic scalars still not excluded – interesting case to be studied at future e^+e^- colliders.

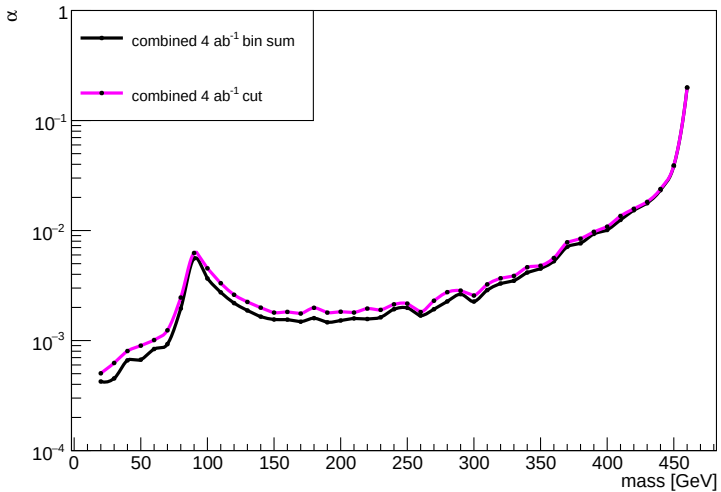
Preliminary results for the 550 GeV limits have been obtained.

More background samples need to be added for more accurate results.

Scalar production with hadronic Z decays is ongoing.

Questions?

Bin sum vs cut limit calculation comparison



Training variables

- Number of electrons, muons and photons.
- Reconstructed Z energy and transverse momentum.
- $\cos\theta$ between the jets from the reconstructed scalar in the cms frame the scalar.
- Invariant mass of the reconstructed Z and S.
- B-tag response for both jets.
- Transverse momentum of one of the jets.
- Number of b jets based on a cut value.
- Recoil mass calculated based on the lepton 4-mom.