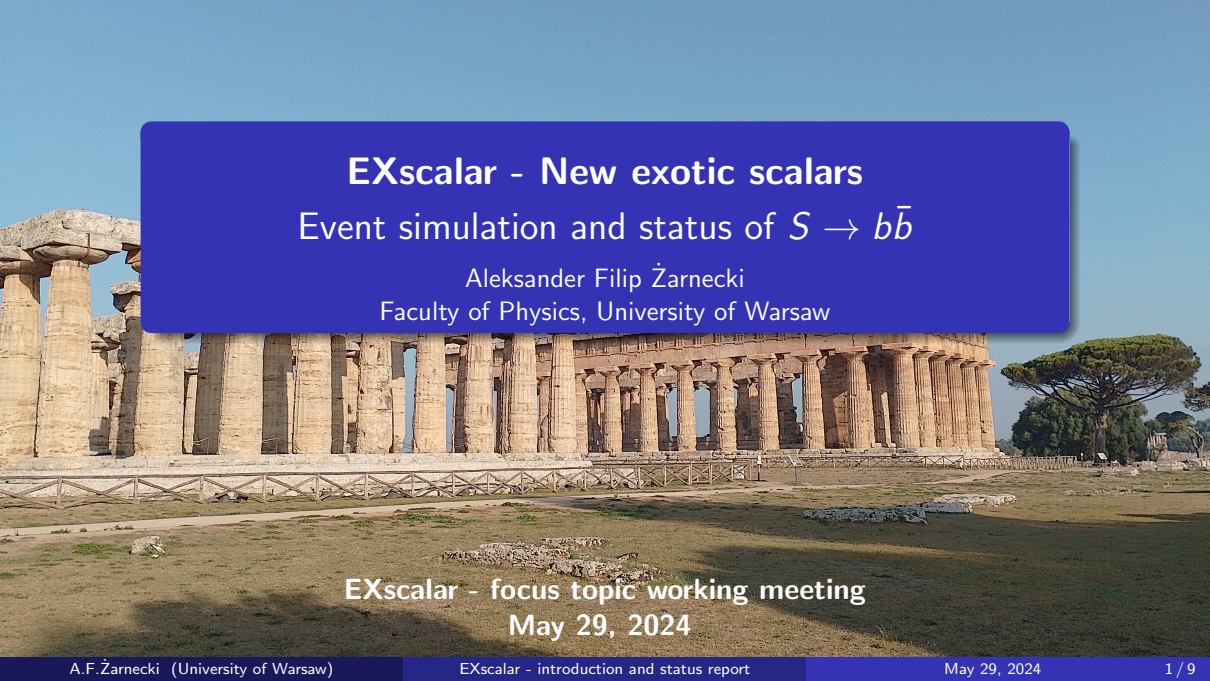

EXscalar - New exotic scalars

Event simulation and status of $S \to b\bar{b}$

Aleksander Filip Żarnecki
Faculty of Physics, University of Warsaw

EXscalar - focus topic working meeting
May 29, 2024

Event simulation

EXscalar - new exotic scalars

Primary theoretical and phenomenological target: $e^+e^- \to Z\ S$

Event simulation for $Z \to l^+l^-$ and $S \to b\bar{b}$ as an example

Possible options: from the perspective of WHIZARD user

- process $e^+e^- \to Z\ S$ plus two decays
  This is not a good choice: Z width is large and should not be neglected...
- process $e^+e^- \to (l^+l^-)_Z\ S$ followed by S decay of choice This is our choice!
  Narrow width approximation: neglect scalar width and possible interference effects

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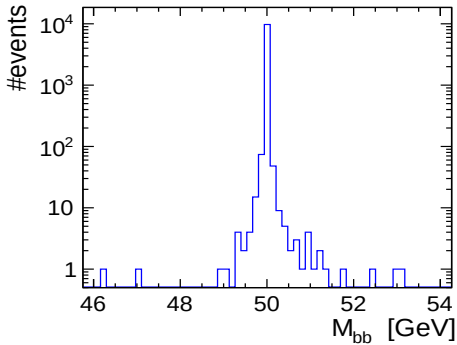
  Narrow width approximation: neglect scalar width and possible interference effects
- process $e^+e^- \to (l^+l^-)_Z\ (b\bar{b})_S$
  Takes scalar width properly into account. Does it make any difference?
- process $e^+e^- \to l^+\ l^-\ b\ \bar{b}$
  including contribution from SM-like Higgs and other SM channels (+ interference)

The first three approaches can be used with the SM (or SM_CKM) model.
The fourth one requires selecting particular model for the study...

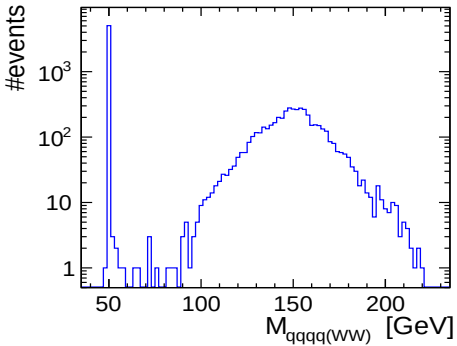
Event simulation

Narrow width approximation justified only for scalar decays to light states!

$e^+e^- \to (l^+l^-)_Z\,(b\bar{b})_S$ for $M_S = 500$ GeV



$e^+e^- \to (l^+l^-)_Z\,((d\bar{u})_{W^-}(c\bar{s})_{W^+})_S$



Significant contribution from virtual S!

Event simulation

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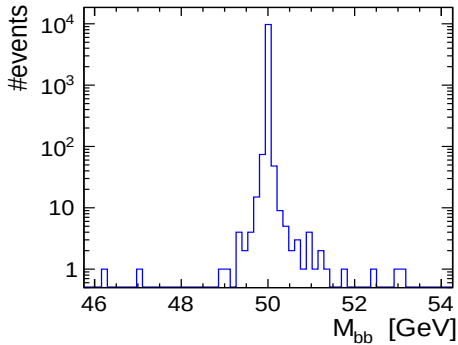

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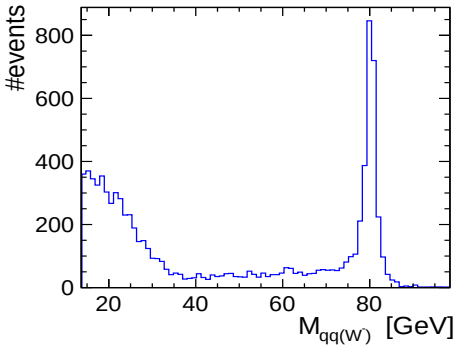


Corresponding to real W production...

Event samples

used for presented fast simulation studies

Signal and background samples generated with WHIZARD 3.1.2 using built-in SM_CKM model.

Signal samples generated by varying H mass in the model and forcing its decay to $b\bar{b}$ or $\tau^+\tau^-$.

All relevant four-fermion final states considered as background.
SM-like Higgs boson contribution included in the background simulation.

ISR and luminosity spectra for ILC running at 250 GeV taken into account

Signal samples generated for selected masses for scalar decays to $b\bar{b}$ and $\tau^+\tau^-$,
as well as for invisible scalar decays (!)

Fast detector simulation with Delphes ILCgen model.

Files available for those interested at **CERNbox**

Event samples

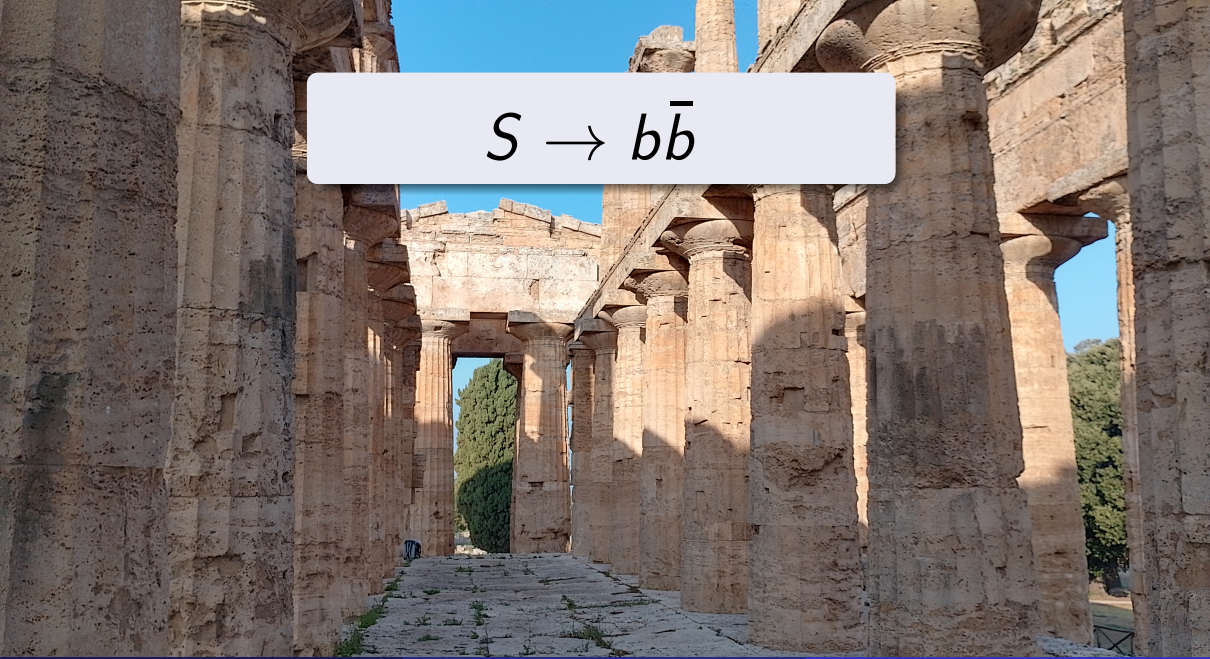
H-20 running scenario for ILC assumed running with four polarisation combinations, $\pm 80\% / \pm 30\%$ polarisation for e^-/e^+ beams...

To reduce the number of samples, "pure" initial states ($\pm 100\%$ polarisation) generated

$\Rightarrow$ only two combinations (LR and RL) relevant for most processes

Samples need to be properly mixed in the analysis, but this can be easily done with appropriate weighting factors.

Detailed description included in **CERNbox**

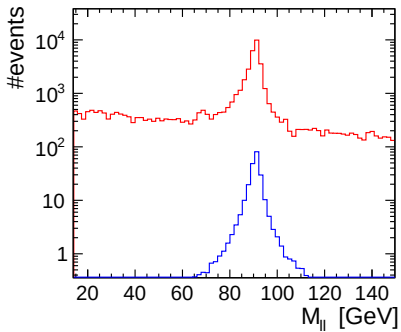

$S \to b\bar{b}$

Event reconstruction

study by Bartłomiej Brudnowski

Focusing on leptonic decays, $Z \to e^+e^-/\mu^+\mu^-$; huge W^+W^- background for hadronic decays

di-lepton invariant mass:



for signal and background events

Direct reconstruction of the scalar mass much more problematic. Invariant mass of two b jets poorly reconstructed, large impact of energy losses in semi-leptonic heavy meson decays.

However, conservation of transverse momentum can be used to reconstruct jet energies from leptonic final state and jet angles.

ILD-PHYS-PUB-2019-001

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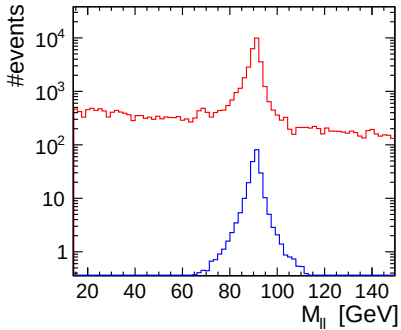
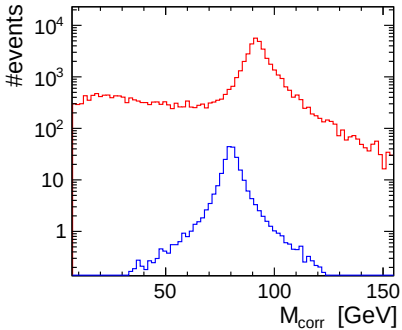


for signal and background events

di-jet mass after jet energy correction:

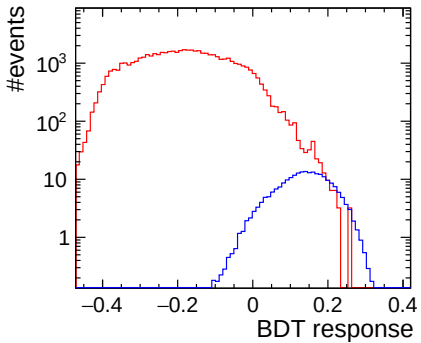


M_S=80 GeV scenario normalized to 1% of the $\sigma_{SM}(M_S)$

Event classification

study by Bartłomiej Brudnowski

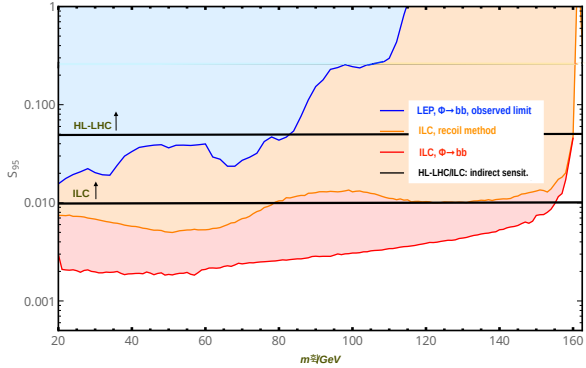
First results from the BDT classifier used on the preselected event samples, $e_R^- e_L^+$ "pure" state (two electrons or muons, two b-tagged jets)



M_S=80 GeV scenario normalized to 1% of the $\sigma_{SM}(M_S)$

Prospects

The plan is to "reproduce", on the fast simulation level, results of the old LEP projection



Expected 95% C.L. limits on the scalar production cross section σ/σ_{SM} assuming standard BRs arXiv:1801.09662