Report on ECFA Study Focus Topics:
EXscalar - New exotic scalars
LLPs - Long Lived Particles

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Theoretical and phenomenological targets

1. Light exotic scalar production in the process:

$$e^+e^- \to Z\,\phi$$

   Different scalar decay channels possible e.g. $b\bar{b}$, $W^{+(*)}W^{-(*)}$, $\tau^+\tau^-$ or invisible
   Non-standard decays channels of the new scalar should also be looked for.
   For maximum sensitivity, feasibility of including hadronic Z decays should be explored.

2. Light scalar pair-production in 125 GeV Higgs boson decays is proposed:

$$e^+e^- \to Z\,H \to Z\,\phi\,\phi$$

   Here again, different decay channels should be considered, both SM-like and exotic.
   While new scalar states could in general be long-lived, only scenarios with prompt decays
   are included in this focus topic (while a dedicated topic focuses on LLPs).

Decay-independent search in scalar-strahlung process   arXiv:1902.06118   arXiv:2005.06265
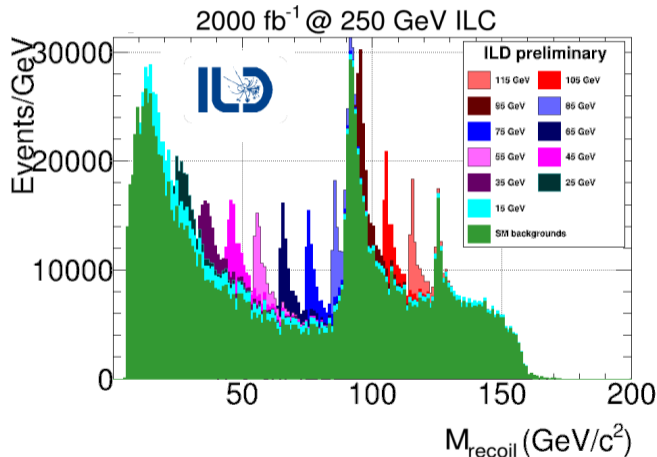
Plan to resume full simulation study, using the most up-to-date samples and new tools
(Mikael, Teresa)

Based on recoil mass $\Rightarrow$ independent on the scalar decay:

Event samples

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

H-20 running scenario for ILC assumed with $\pm 80\%/\pm 30\%$ polarisation for e^-/e^+ beams.
    "pure" initial states ($\pm 100\%$ polarisation) generated and mixed accordingly
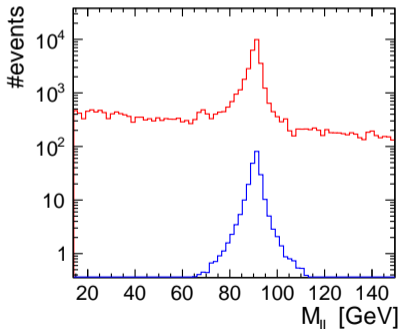 $\Rightarrow$ only two combinations (LR and RL) relevant for most processes

Fast detector simulation with Delphes ILCgen model.

## 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.
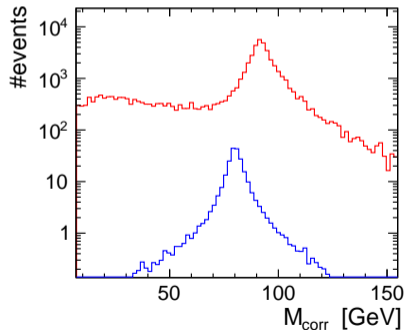
ILD-PHYS-PUB-2019-001

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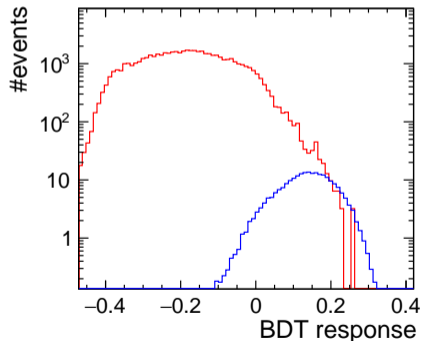di-lepton invariant mass:
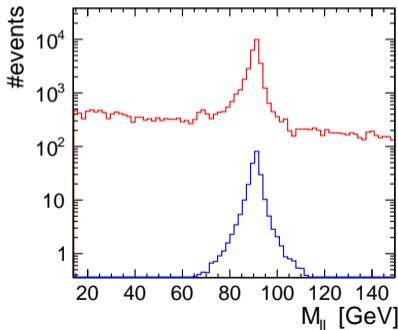
di-jet mass after jet energy correction:

for signal and background events

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   Expect to present first limit estimates in 4 weeks (for LCWS'2024?)

The plan is to "reproduce", on the fast simulation level, results of the old LEP projection
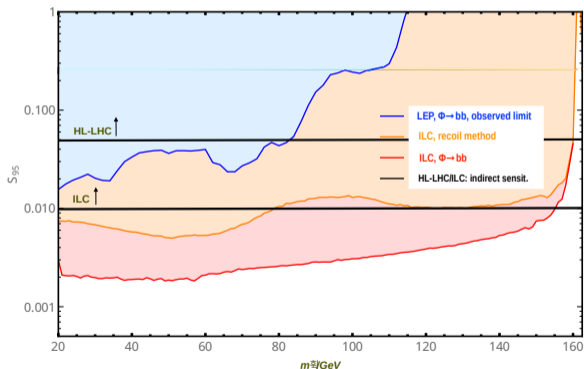
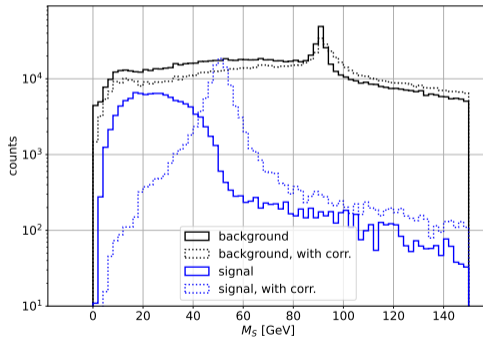Expected 95% C.L. limits on the scalar production cross section σ/σ_{SM} assuming standard BRs   arXiv:1801.09662

S mass reconstruction

study by Kamil Zembaczyński

Assumption of high τ boost and their collinearity to jets for reconstructing S mass. From transverse momentum balance:

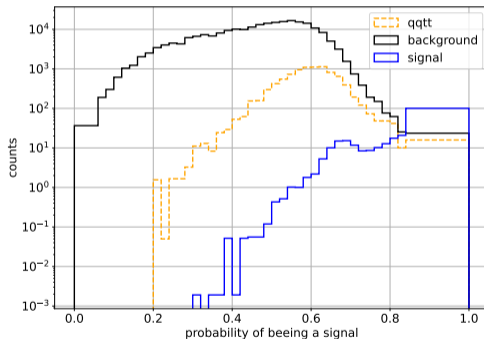$$\overline{\not{p}_T} = E_{\nu_1} \cdot \overline{n}_1 + E_{\nu_2} \cdot \overline{n}_2$$

Example for $e_L^- e_R^+$ polarisation and tight event selection.

BDT

study by Kamil Zembaczyński

Separate BDT for each polarisation and event category
(hadronic, semi-leptonic or leptonic)

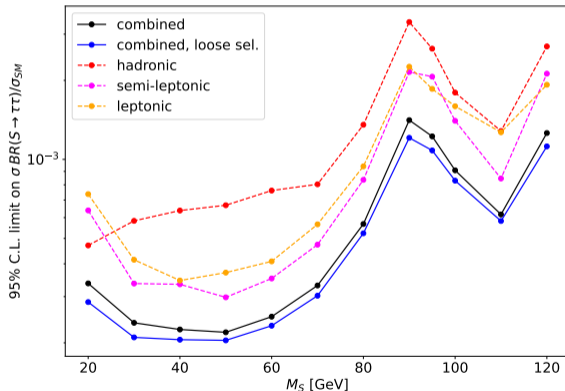

Example for $e_L^- e_R^+$ polarisation and tight hadronic event selection.
Signal for scalar mass of 50 GeV normalized to 1% of SM cross section.

95% C.L. limits on the production cross section

dedicated presentation planned in two weeks

in units of the SM cross section for Higgs-strahlung process
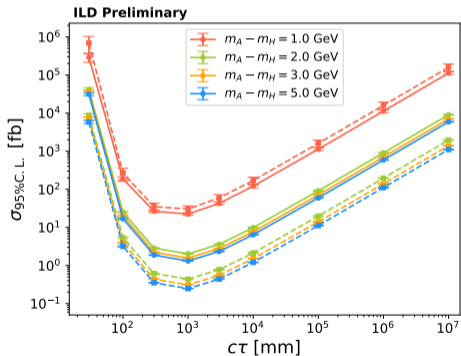(with given scalar mass)
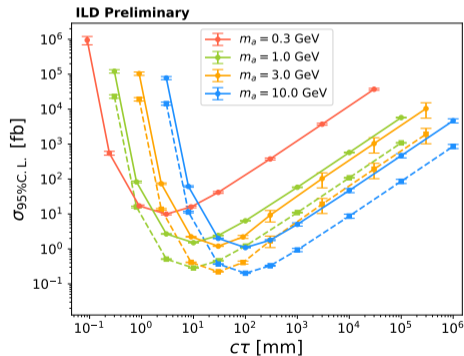

ILC H-20 running scenario at 250 GeV

LLPs - Long Lived Particles

Study by Jan Klamka   (paper in internal review)

Expected cross section limits for processes with single displaced vertex

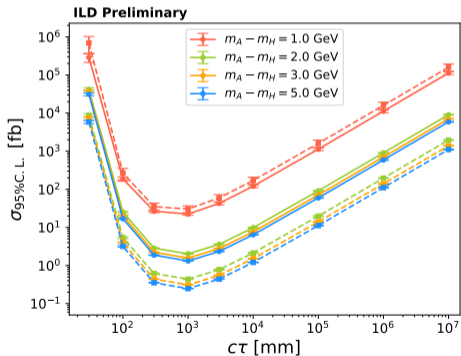Heavy scalars (IDM)   Light pseudoscalar (ALP)

Last reported at S&A meeting, Feb. 14, 2024

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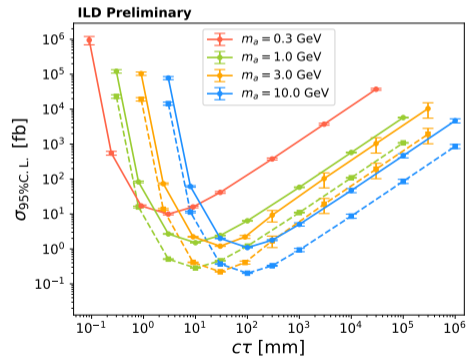

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Study by Jan Klamka

Still on the "To Do" list: beyond the paper being processed now

- Casting signature limits to different BSM models.
- Study expected performance of pixel-TPC
- Performance comparison with all-silicon tracking design (reiterate)