

Light exotic scalar search analysis

first look at di-tau signature at 250 GeV

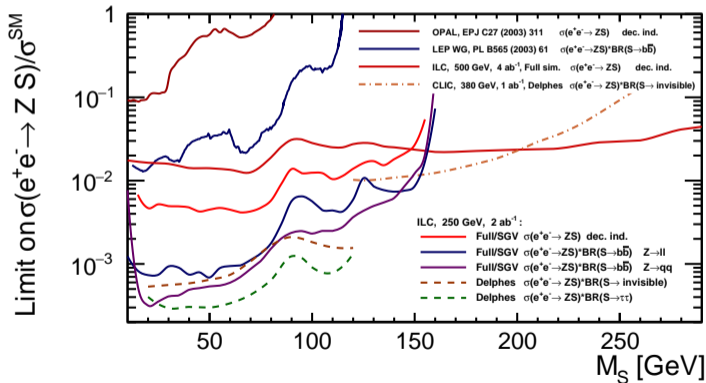
Bartłomiej Brudnowski, Weronika Sobień,
Aleksander Filip Żarnecki

Faculty of Physics, University of Warsaw

ILD Software and Analysis meeting
June 17, 2026

Introduction

Updated ECFA report plot (LC only)

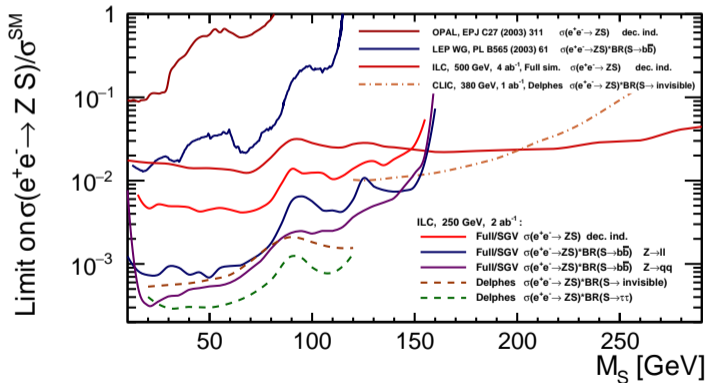


Studied in full simulation/SGV

- decay-mode indep. @ 250 GeV
- decay-mode indep. @ 550 GeV
- $b\bar{b}l\bar{l}$ / $b\bar{b}q\bar{q}$ @ 250 GeV
- $b\bar{b}l\bar{l}$ / $b\bar{b}q\bar{q}$ @ 550 GeV

Introduction

Updated ECFA report plot (LC only)



Studied in full simulation/SGV

- decay-mode indep. @ 250 GeV
- decay-mode indep. @ 550 GeV
- $b\bar{b}l\bar{l}$ / $b\bar{b}q\bar{q}$ @ 250 GeV
- $b\bar{b}l\bar{l}$ / $b\bar{b}q\bar{q}$ @ 550 GeV

We are work to include

- $\tau\tau q\bar{q}$ @ 250 GeV and 550 GeV

Recent MC request

New SGV samples were generated for exotic scalar search analysis in dedicated channels:

- $S \rightarrow \tau^+ \tau^-$ at 250 GeV
- $S \rightarrow b\bar{b}$ and $S \rightarrow \tau^+ \tau^-$ at 550 GeV

Generation completed in February 2026

First results for $S \rightarrow \tau\tau$ at 550 GeV presented by Weronika Sobień on April 15, 2026

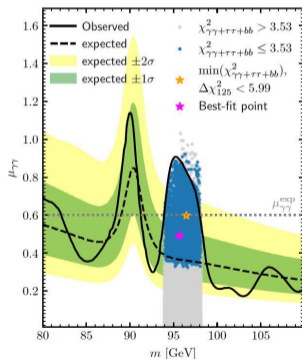
Same approach was now applied to 250 GeV signal (and background) samples...

Why $S \rightarrow \tau\tau$?

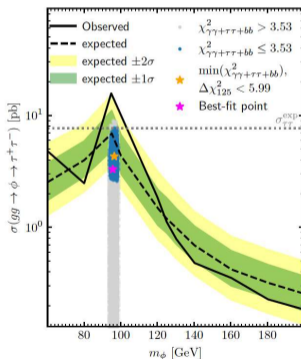
T. Biekötter, S.Heinemeyer, G. Weiglein arxiv:2203.13180

Some discrepancies point to new scalar with mass of ~ 95 GeV and **dominant decay to $\tau\tau$** ...

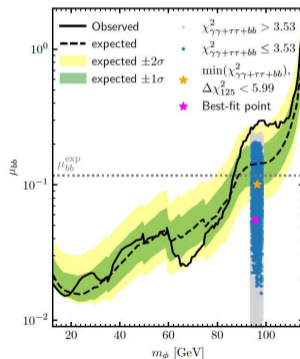
$$pp \rightarrow h_{95} \rightarrow \gamma\gamma$$



$$gg \rightarrow h_{95} \rightarrow \tau^+\tau^-$$



$$e^+e^- \rightarrow Zh_{95} \rightarrow Zb\bar{b}$$



Sven Heinemeyer @ First ECFA WS on e^+e^- Higgs/EW/top factories, October 2022

ILCsoft algorithms are run on 'PandoraPFOs' collection:

- **IsolatedPhotonTagging**
- **IsolatedLeptonTagging**
- **TaJetClustering**
- **FastJetProcessor**
ee_kt_algorithm (Durham) algorithm run in exclusive 4 jet mode
run on all PFOs, including leptons and tau candidates
(only isolated photons removed)
- **EXscalarTreeWriter4jet**
Dedicated processor to write reconstruction results to file
For each Durham jet, PID flag is set for identified leptons and tau jets

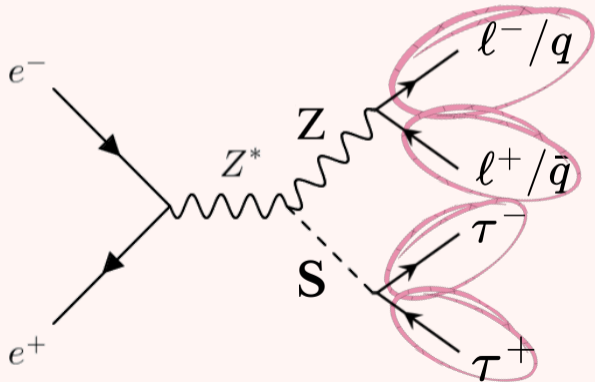
In every channel's analysis we are always looking for **four** jets.

STEP 1

STEP 2

STEP 3

STEP 4



STEP 1

qqS

Reconstructs the Z and Scalar from a forced 4-jet final state.

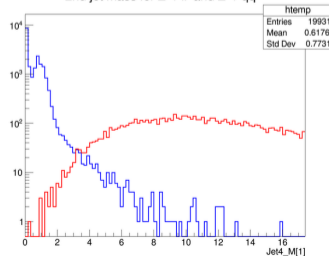
STEP 2

- Assigns the two heaviest jets to the Z boson (~ 91 GeV), and the two remaining, lighter jets to the Scalar S.
- Enforces a strict physical mass limit: the invariant mass of the Scalar jets must be < 3.0 GeV.

STEP 3

STEP 4

llS

2nd jet mass for $Z \rightarrow ll$ and $Z \rightarrow qq$ 

STEP 1

STEP 2

STEP 3

STEP 4

qqS

- Searches for two jets containing isolated leptons that strictly conserve flavor and charge.
- If multiple lepton pairs exist, selects the pair with an invariant mass closest to the nominal Z mass.
- The two remaining jets are automatically assigned to the S.
- The invariant mass of the S candidate jets must be < 3.0 GeV to guarantee they are true, narrow tau jets.

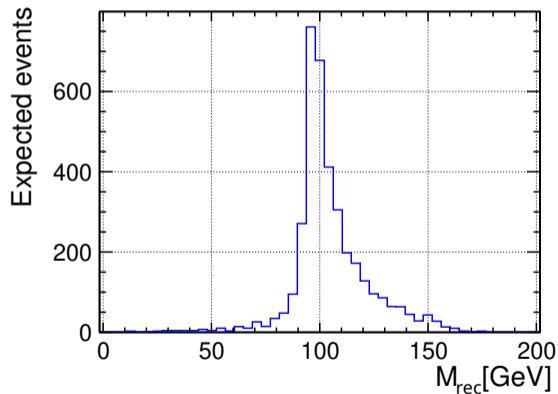
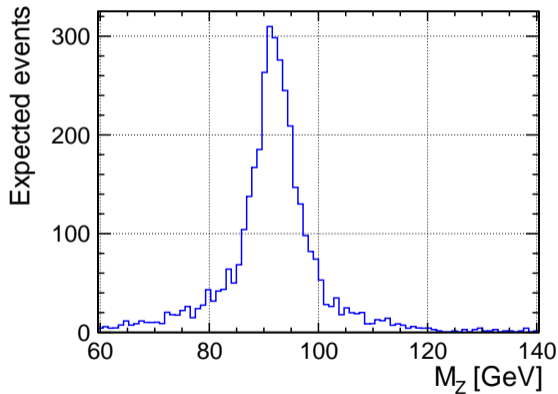
llS

$$\begin{matrix} e^- & e^+ \\ \mu^- & \mu^+ \end{matrix}$$

Reconstructs the Z and Scalar from a 4-jet final state containing exactly two primary leptons (electrons or muons).

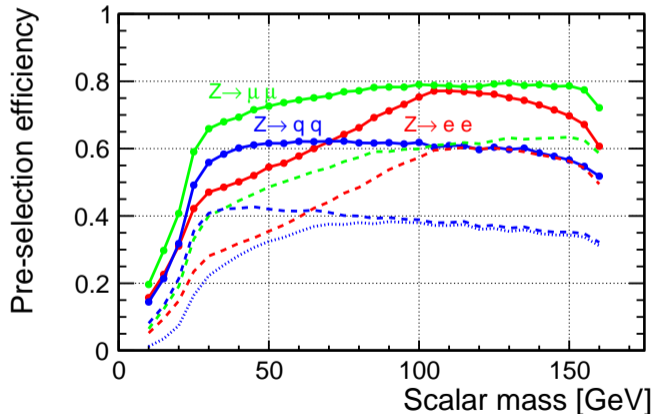
Event reconstruction

Example: hadronic Z decay channel, $M_S = 95 \text{ GeV}$



Preselection efficiency at 250 GeV

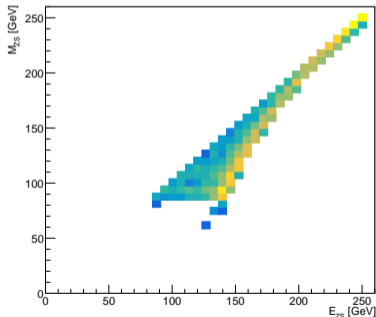
All the tau decay channels combined: (dashed: tight selection)



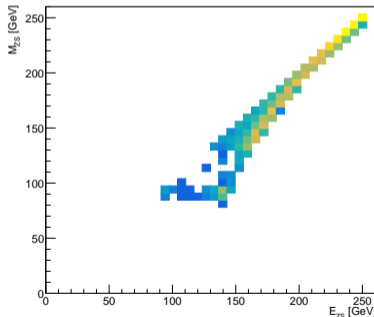
Low mass scalars

For very light scalars significant contribution from “radiative return” events !!!

$M_S = 10$ GeV



$M_S = 40$ GeV

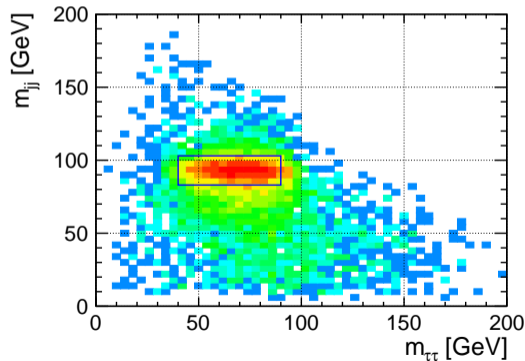


⇒ reduced selection efficiency, additional selection path for merged tau jets

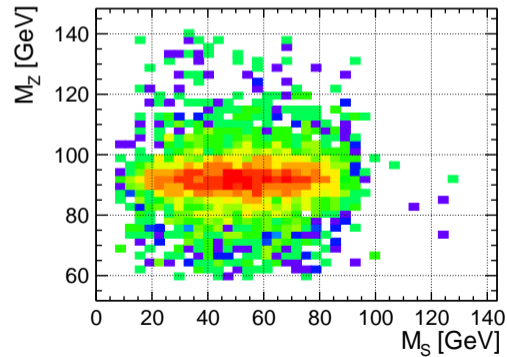
Comparison with Delphes

After event reconstruction and pre-selection cuts

Delphes results (LCWS'2023)



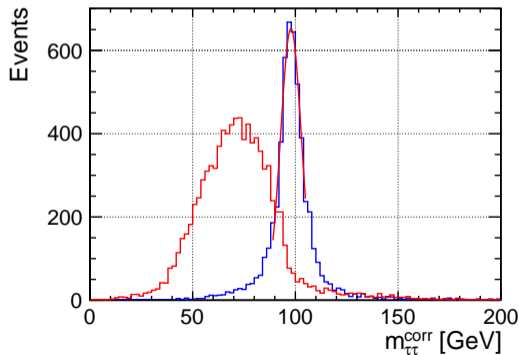
New SGV samples



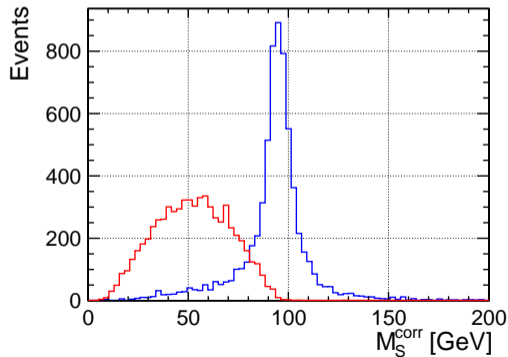
Comparison with Delphes

Scalar mass reconstruction based on collinear approximation

Delphes results (LCWS'2023)



New SGV samples



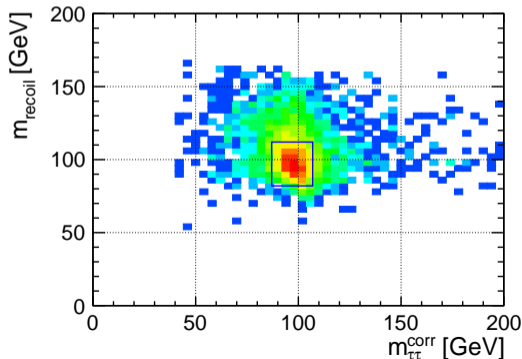
Comparison with Delphes

Scalar mass distribution (recoil vs corrected)

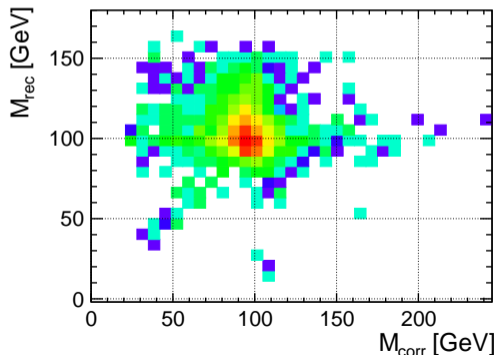
After box cut in M_Z vs M_{raw} plane

Signal for $M_S = 95$ GeV

Delphes results (LCWS'2023)



New SGV samples



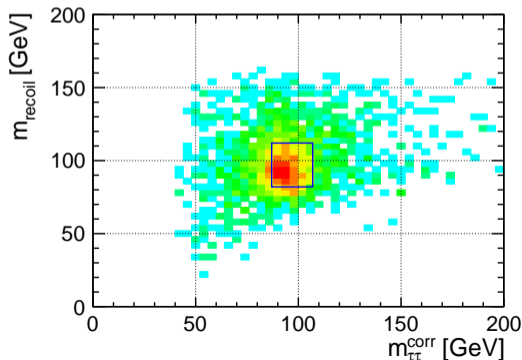
Comparison with Delphes

Scalar mass distribution (recoil vs corrected)

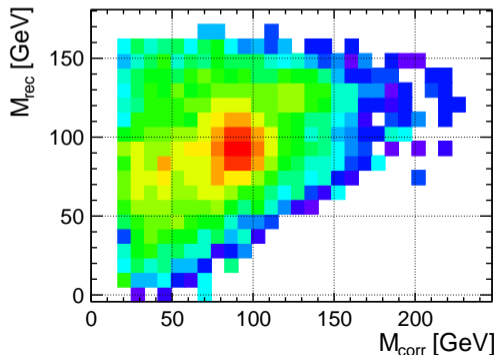
After box cut in M_Z vs M_{raw} plane

SM background

Delphes $qq\tau\tau$ (LCWS'2023)



SM full sim. (all combined)



Delphes results from cut-based analysis 900 fb^{-1} ($-80\% / +30\%$)

Hadronic tau decay selection

Sample	Events expected after			Final eff.
	Presel.	Z + raw mass	corr + rec	
Signal	1234.69	711.957	423.921	3.179
$qqqq$	38636	4980.42	603.688	0.004
$qq\nu$	4793.66	104.21	0	0
$qq\tau\nu$	98069.7	296.134	0	0
$qqll$	929.392	29.5045	0	0
$qq\tau\tau$	10283.6	4360.07	2107.54	1.41
$qq\nu\nu$	1426.37	0	0	0
h_2	1889.55	486.201	22.1	0.02
Total	156028	10256.5	2733.33	
Significance	7.54			

SGV/full sim. results from cut-based analysis 900 fb^{-1} ($-80\% / +30\%$)

Hadronic tau decay selection (tight)

Sample	Events expected after			Final eff.
	Presel.	Z + raw mass	corr + rec	
Signal	6471	2516	1173	8.04%
4f had	9194	1352	0.8	
4f sl	38643	11179	1610	
4f lep	3936	642	27.5	
2f	9472	782	4.7	
h_{SM}	2930	871	5.4	
Total	64177	14826	1648	
Significance	22.1			

Preselection very different from the one used with Delphes!...

Conclusions

Reconstruction procedure developed for 550 GeV adopted to 250 GeV

All signal and (large part of) background samples processed

First results look promising

Just starting to look into details...