A combined fit to the Higgs branching ratios at ILD

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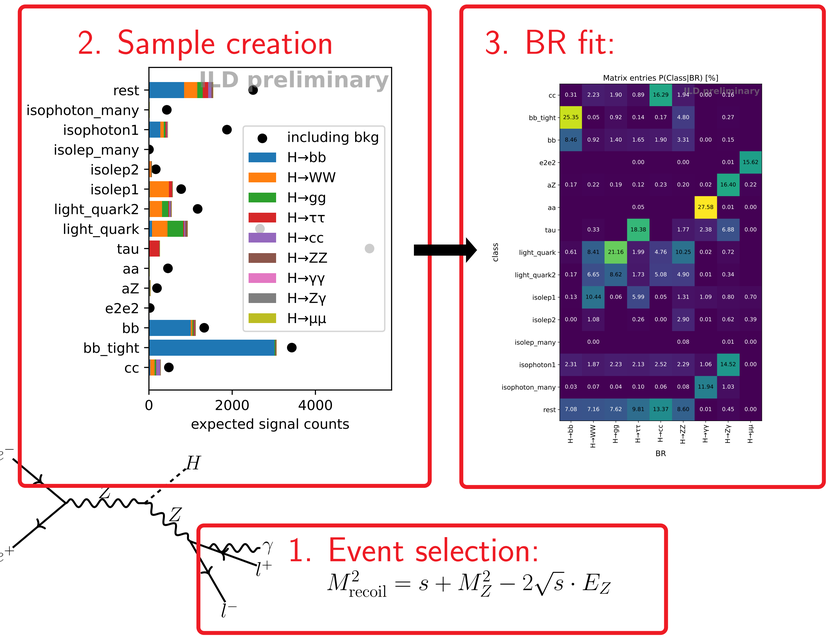
Schematic overview

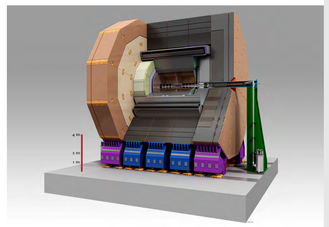


1. Event selection:
$M^2_{\text{recoil}} = s + M^2_Z - 2\sqrt{s} \cdot E_Z$

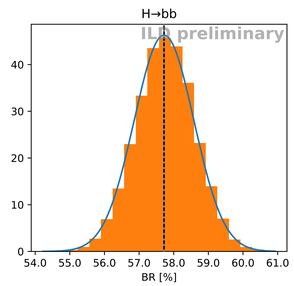
Implementation

Full simulation study at $\sqrt{s} = 250$ GeV (MC2020 ILD mass production).

- $\sqrt{s} = 250$ GeV ideal for the Higgsstrahlung process.
- Considered backgrounds: Standard Model (SM) processes with 2 or 4 fermions in the final state.
- ≥ 400k simulated events/SM Higgs decay mode.
- Polarized initial beams: 80% left (30% right) polarized electron (positron) beam.
- 2000 fb^{-1} integrated luminosity.



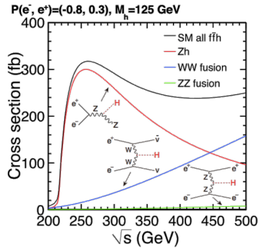
Toy validation



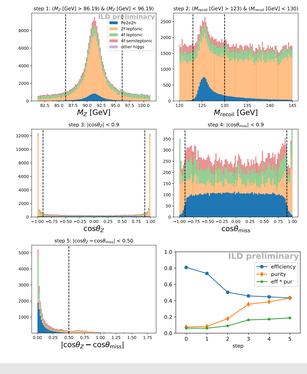
Draw toys from Multinomial (N_{data} fixed).
The histogram stores the $H \to b\bar{b}$ branching ratio at the fit minimum. The distribution can be described by a Gaussian with mean and varaince obtained from the fit on the expected event counts.

1. Event selection

Solely information from recoiling Z boson is used:
Independent of Higgs decay.
Currently only with $Z \to \mu^+\mu^-$, $Z \to e^+e^-$
Higgsstrahlung events as signal channels.



- Golden channels due to recoil mass method, $M^2_{\text{recoil}} = s + M^2_Z - 2\sqrt{s} \cdot E_Z$.
- IsolatedLeptonTagger: Lepton pair with same type and opposite charge.
- Final state radiation: Add photons with $\cos\theta_{l\gamma} > 0.99$.
- Selection cuts shown on the right.



2. Sample creation

- Events without the part identified as from the recoiling Z boson.
- Create bins inspired by the expected decays, with established tools.
- E.g. `bb_tight`: No Isolated leptons or photons in event. Require `LCFIPlus` btag1 > 0.8 for event clustered into two jets.

3. Branching ratio (BR) fit

BRs from minimization of $\vec{S} = M \cdot \vec{B} = \vec{f}(\vec{B})$ through `MINUIT`/iminuit.

- $\vec{S}$: The signal counts per category ($S = data - bkg$).
- M: The probability matrix from simulations per bkg and decay mode.
- $\vec{B}$: The target: branching ratios. Use e.g. the SM BRs as fit starting values.
- Cost function: Multinomial log-likelihood. $-\ln\mathcal{L} = -N_{\text{data}} \sum_i S_i \ln\left(\sum_j M_{ij} B_j\right)$.

References

- The International Linear Collider: Technical Design Report (2013).
- The International Large Detector: Interim Design Report: arXiv:2003.01116.

Results

- Extraction of major branching ratios from single analysis. → Full statistical correlation matrix.
- Independent of σ_{ZH} and $\sigma_{\text{VV-fusion}}$.
- Can automatically adapt to BR scenarios drastically different from SM.

	SM BR	σ_{stat}
$H \to bb$	57.72	0.86
$H \to WW$	21.76	1.34
$H \to gg$	8.55	1.25
$H \to \tau\tau$	6.20	1.30
$H \to cc$	2.72	0.55
$H \to ZZ$	2.62	1.93
$H \to \gamma\gamma$	0.24	0.17
$H \to Z\gamma$	0.17	0.35
$H \to \mu\mu$	0.03	0.14

Table 1: Fit on the expected event counts. In percent. ILD preliminary.

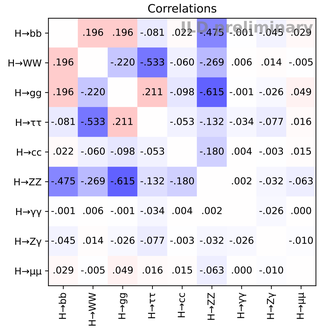


Figure 1: Statistical correlations from NLL minimization.

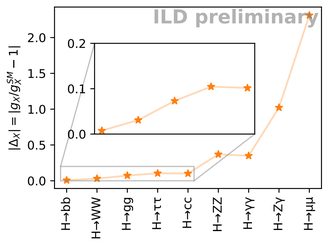


Figure 2: Relative BR uncertainty.

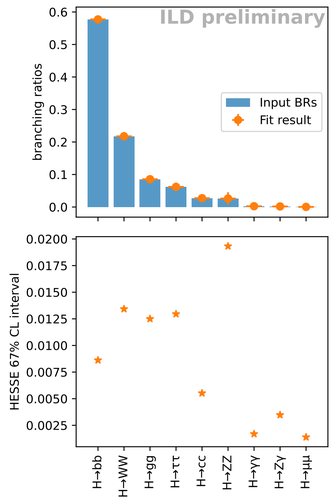


Figure 3: Higgs branching ratios and their uncertainty (assuming expected/SM values).