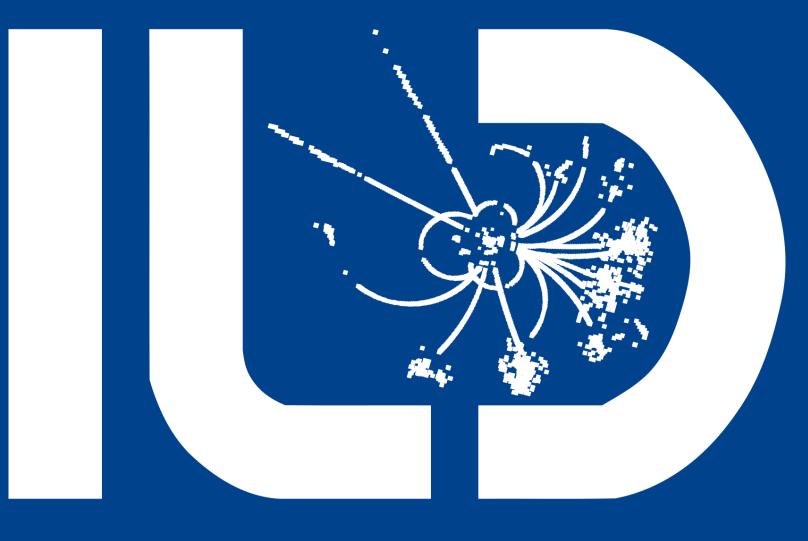


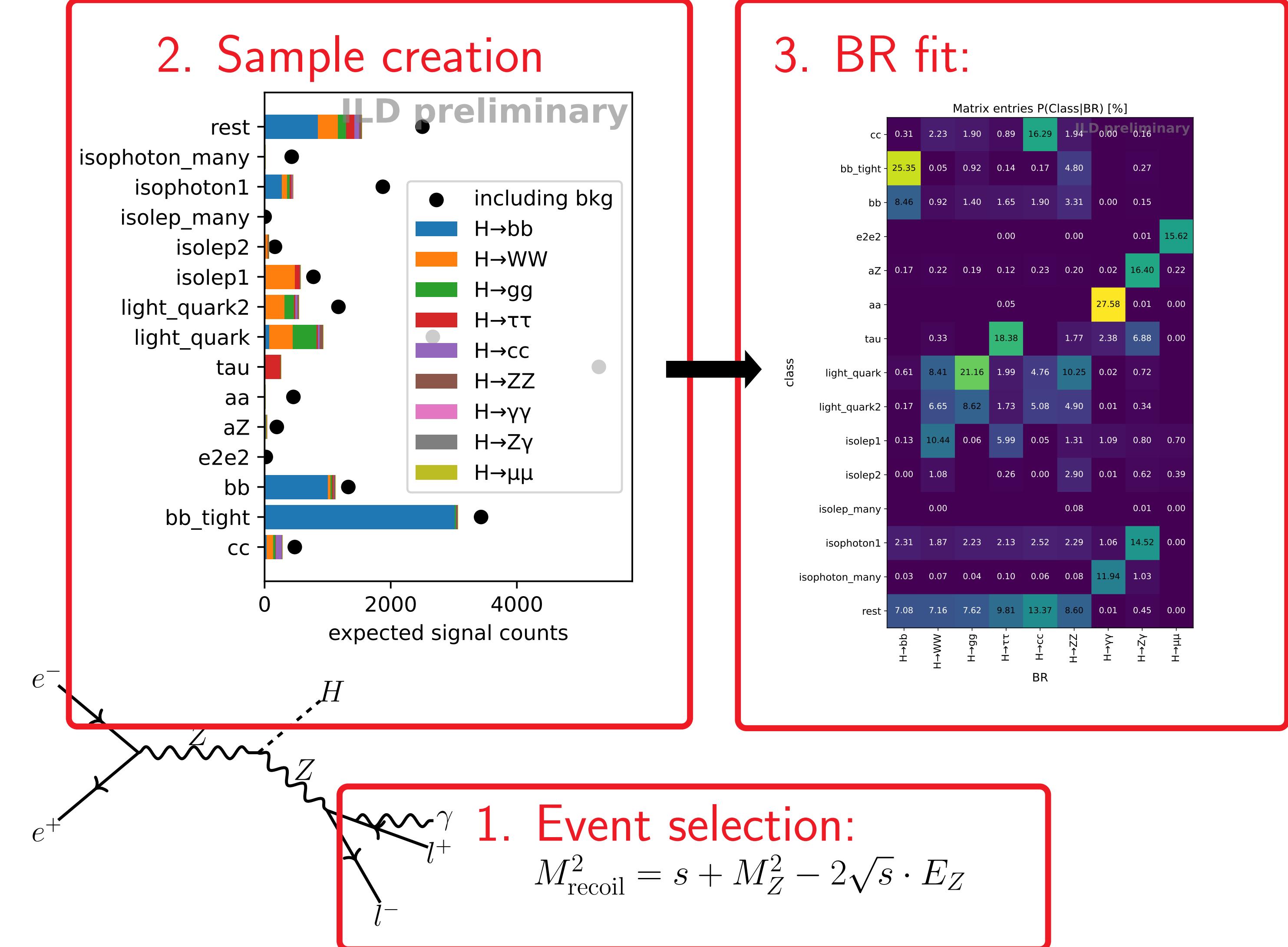
# A combined fit to the Higgs branching ratios at ILD

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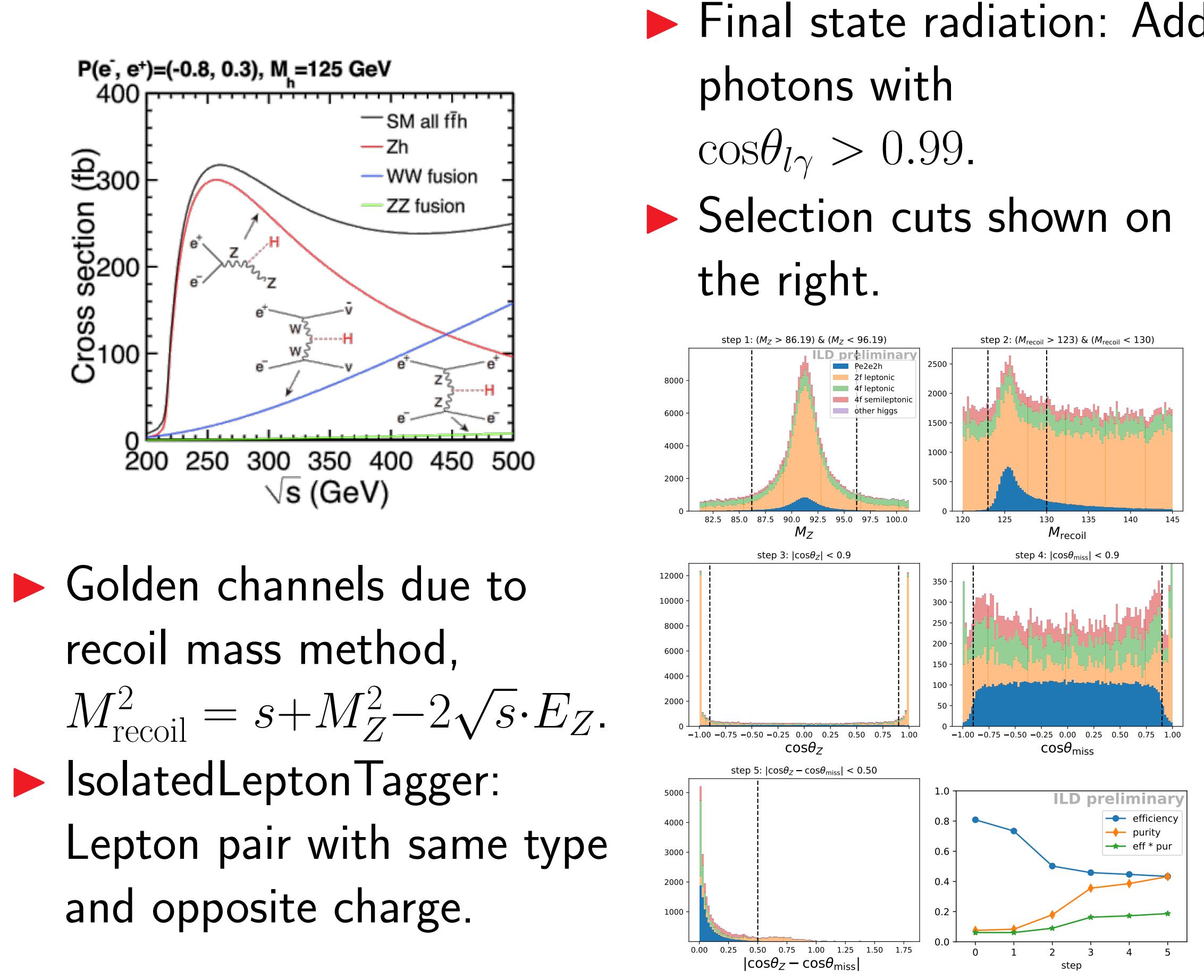


## Schematic overview



## 1. Event selection

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



- Golden channels due to recoil mass method,  
 $M_{\text{recoil}}^2 = s + M_Z^2 - 2\sqrt{s} \cdot E_Z$ .
- IsolatedLeptonTagger:  
Lepton pair with same type and opposite charge.

## 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 ( $S = \text{data} - \text{bkg}$ ).
- $M$ : 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

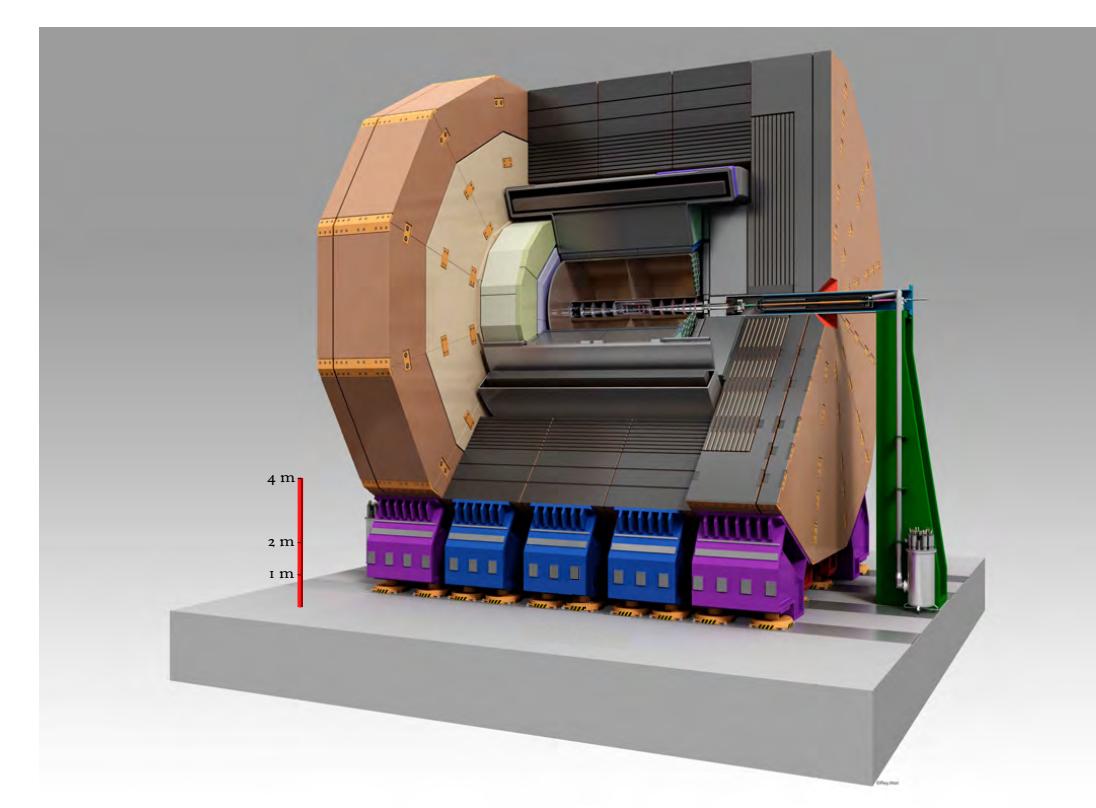
- The International Linear Collider: Technical Design Report (2013).
- The International Large Detector: Interim Design Report: arXiv:2003.01116.

## Implementation

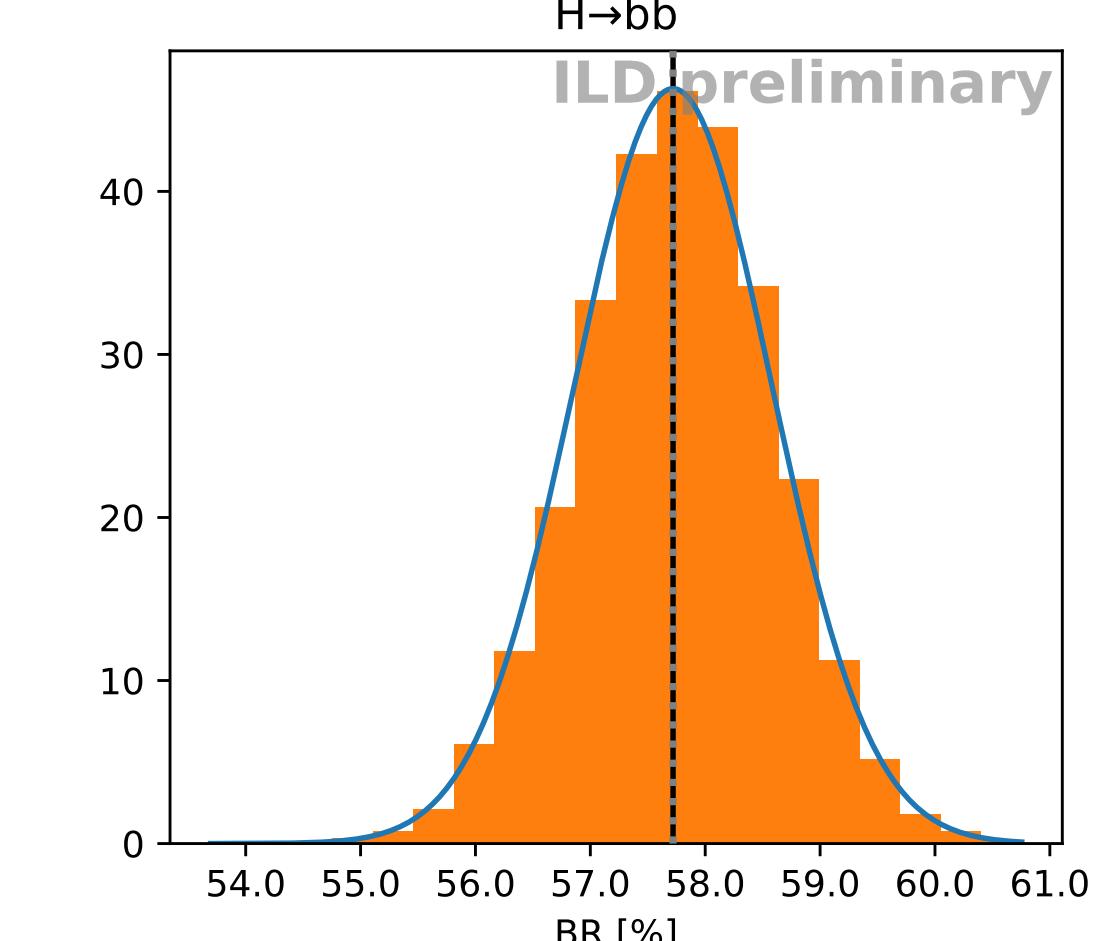
Full simulation study at  $\sqrt{s} = 250$  GeV

(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.
- $\geq 400k$  simulated events/SM Higgs decay mode.
- Polarized initial beams: 80% left (30% right) polarized electron (positron) beam.
- $2000 \text{ fb}^{-1}$  integrated luminosity.



## Toy validation



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

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

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

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

## Results

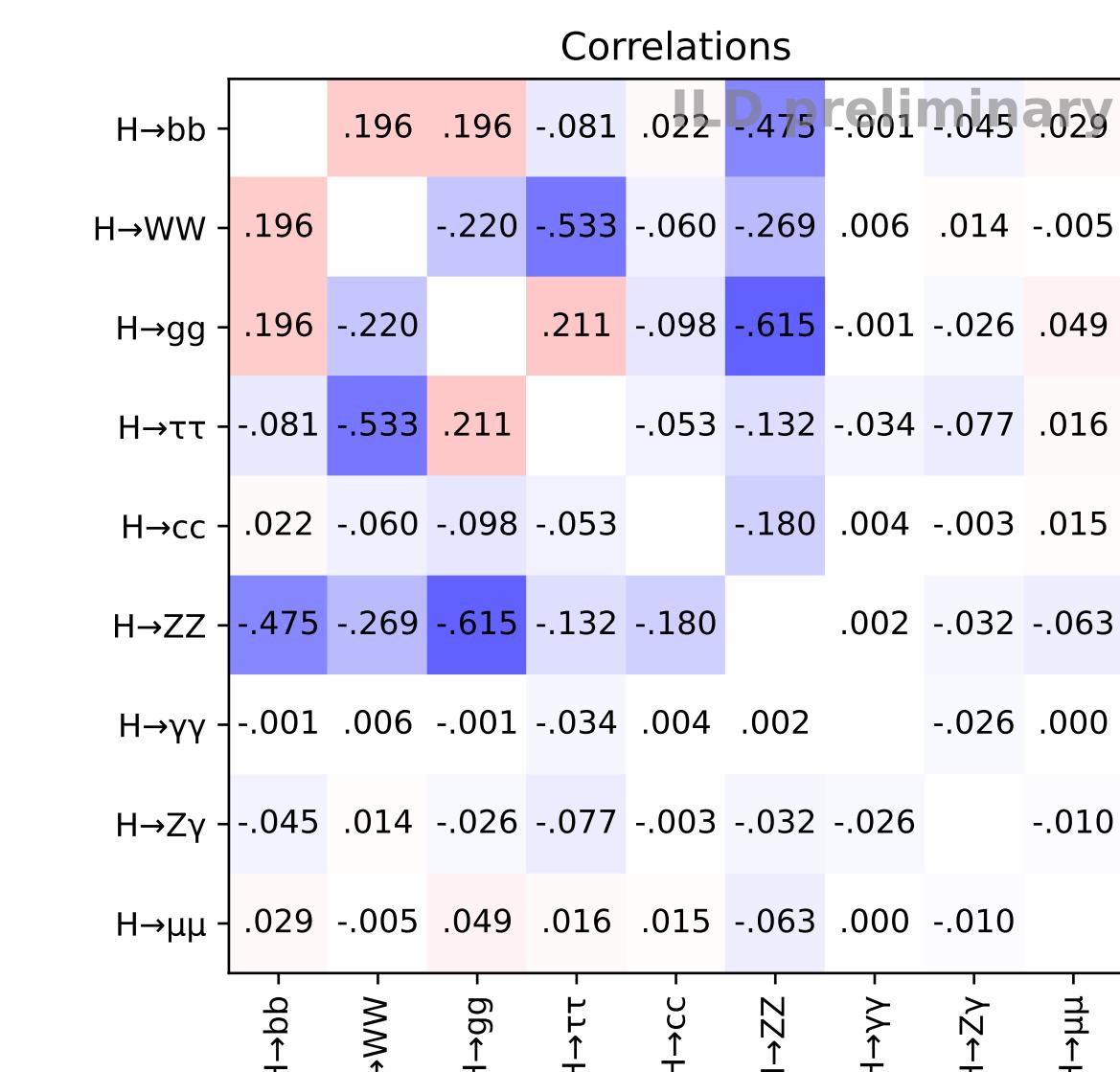


Figure 1: Statistical correlations from NLL minimization.

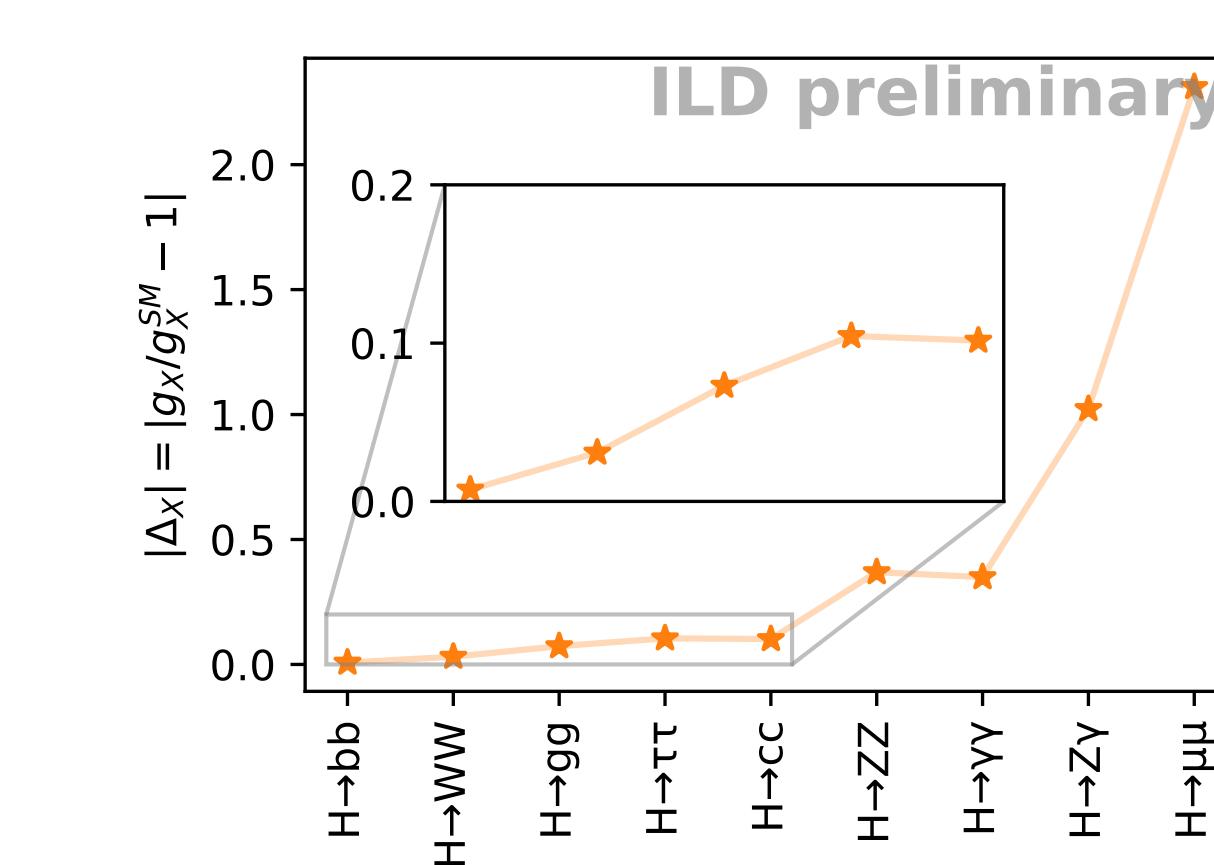


Figure 2: Relative BR uncertainty.

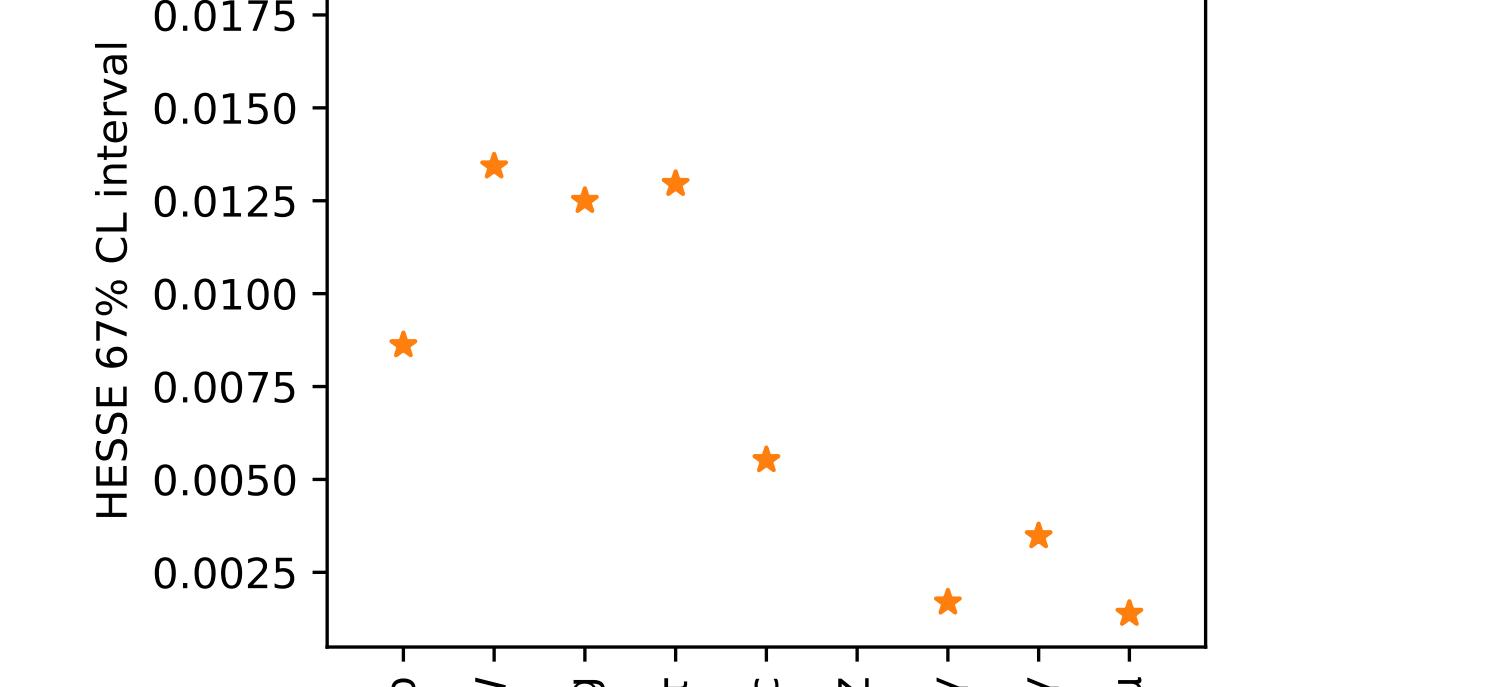
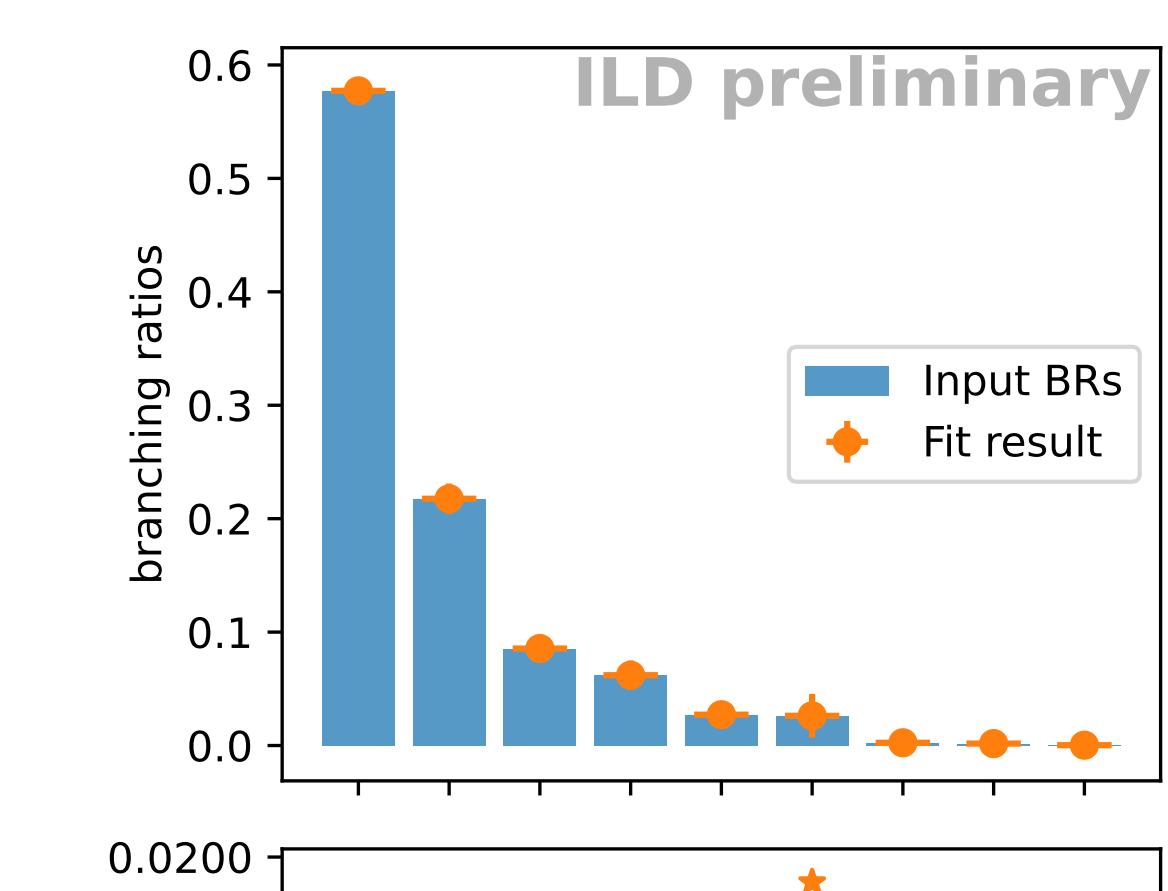


Figure 3: Higgs branching ratios and their uncertainty (assuming expected/SM values).