WW fusion, $H \rightarrow bb$ Cross-section Measurement

Hao Liang

25.5 2018

Outline

- Motivation
- Sample Generation
- Cut Chain
- Extraction of the WW fusion cross section by fit
- The result

Motivation

The Higgs decay width is natrually of interest to physicists. The cross-section of $WW-\text{fusion}H \to b\bar{b}$ is essential for one of two approaches to measure the higgs width at CEPC. In the approach related to $WW-\text{fusion}H \to b\bar{b}$, this Higgs mass will be calculated from four cross-sections

$$\sigma_{ZH} = F_1 \cdot g_Z^2$$

$$\text{Br}(H \to b\bar{b}) = F_2 \cdot g_b^2/\Gamma$$

$$\text{Br}(H \to W^- W^+) = F_3 \cdot g_W^2/\Gamma$$

$$\sigma_{WW-\text{fusion},H\to b\bar{b}} = F_4 \cdot g_W^2 g_b^2/\Gamma$$

Where F_i, $i = 1...4$ are constant factors, which can be calculated in theory. The Higgs width, Γ, can sovled from above four equations:

$$\Gamma = \frac{\sigma_{WW-\text{fusion},H\to b\bar{b}}}{\text{Br}(H \to W^- W^+)\text{Br}(H \to b\bar{b})} \cdot \frac{F_2 F_3}{F_4} = \frac{\boldsymbol{\sigma}_{WW-\text{fusion},H\to b\bar{b}}\boldsymbol{\sigma}_{ZH}^2}{\boldsymbol{\sigma}_{ZH,H\to b\bar{b}}\boldsymbol{\sigma}_{ZH,H\to W^-W^+}} \cdot \frac{F_2 F_3}{F_4} \quad (1)$$

Four cross sections in bold in Eq. 1 can be measured indepently to the Higgs decay model. Thus the higgs decay with will be also indepent to the Higgs decay model.

Sample Generation

- Center of mass energy: 250GeV
- Higgs sample:
  - 100k WW fusion(signal) , H->anything
  - 100k ZH (background), H->anything events
  - Sample for interference between ZH and WW fusion can’t be generated
  - Assign weights corresponding to $5\mathrm{ab}^{-1}$
- SM sample (pre-cut applied):

  $5\mathrm{ab}^{-1}$ 2fermions + 4fermions

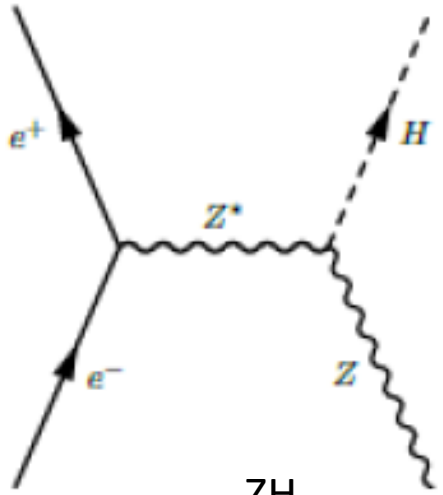
Cut Chain

- Defintion:
  - $N_{PFO} > 20$
  - $105 < E_{vis} < 155$ && $P_t > 13$
  - $Isolep\ veto$
  - $100 < M < 135$ && $65 < M_{recoil} < 135$
  - $y_{12} > 0.15$ && $y_{23} < 0.06$ &&$y34 < 0.01$
  - $-0.98 < \theta_{2jets} < -0.4$
  - $bb - likeness > 0.4$ $(bb - likeness = bb/(bb + (1-b)(1-b)))$

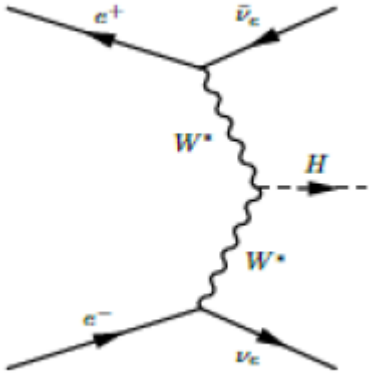
	WW fusion, H->bb	ZH, H->bb	qqbar	sw-sl	sznu-sl	ww-sl	zz-sl
Cut chain	52.8%	64.9%	25630	124	5745	3230	9764
Fit window	51.2%(~10k @5ab^-1)	63.8%(~79k @5ab^-1)	22980	112	4018	2187	6503

Recoil mass

- We can extract the WW fusion events number by fitting the recoil mass and recoil angle
- Approach1: The recoil mass is calculated by
  - $m_{recoil} = \sqrt{(\sqrt{s} - E_H)^2 - p_H^2}$
- Approach2: Where the E_H is replaced with $E_H = \sqrt{p_H^2 + m_H^2}$
  - Where $m_H = 125\text{GeV}$ is substituted.

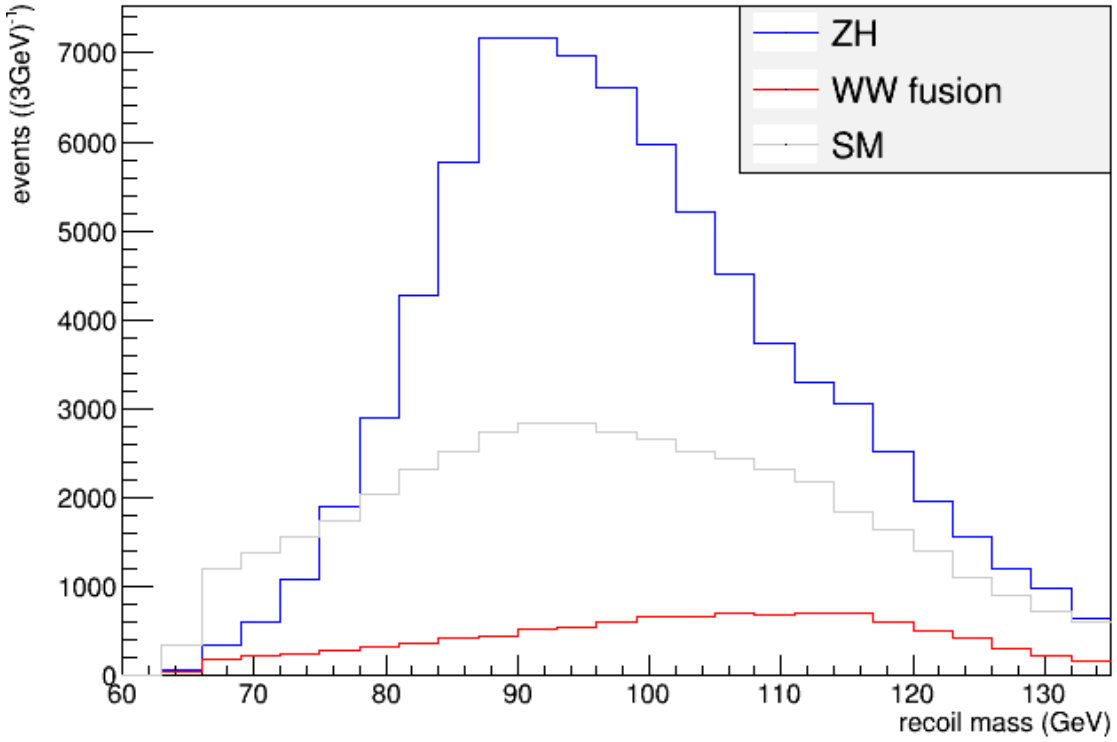


ZH

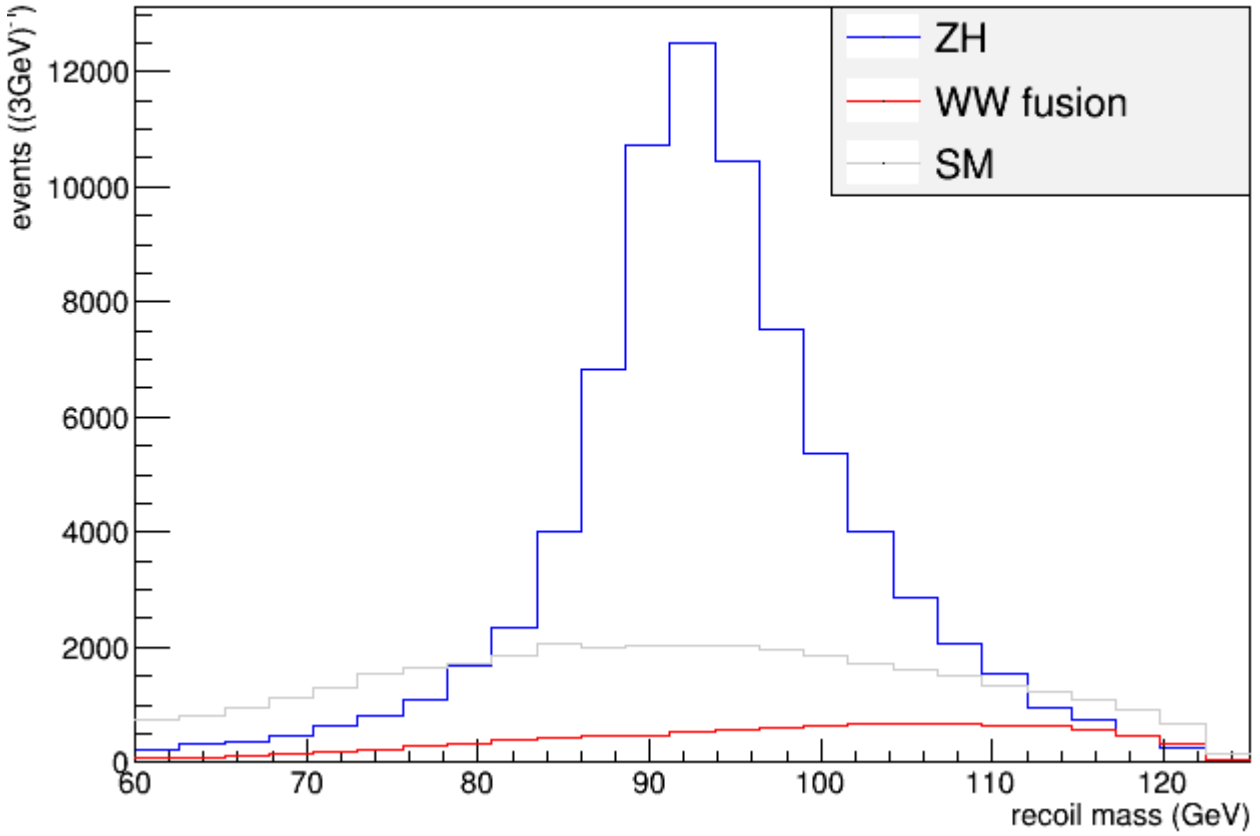


WW fusion

Recoil mass comparision



Approach 1



Approach 2

How to fit to extract the ww fusion, H->bb cross-section (1)

- Backgrounds (except ZH, Z->vv, H->bb) can be determined very well in theory and experiments. The signal stress of those were fixed to be 1.
- The expected number of ZH, Z->vv,H->bb would be measured via eeH, $\mu\mu$H and qqH channels:
  - The uncertainties of coupling constants concerns only electroweak part are assumed to be neglegible.
  - Three signal stresses are proportianal to ZH, Z->vv,H->bb at tree level
  - The uncertainty of ZH, Z->vv, H->bb $= 1/\sqrt{\frac{1}{\sigma^2_{eeH,H\to bb}} + \frac{1}{\sigma^2_{\mu\mu H,H\to bb}} + \frac{1}{\sigma^2_{qqH,H\to bb}}} =$

    $= 1/\sqrt{(\frac{1}{1.2\%})^2+(\frac{1}{1.1\%})^2+(\frac{1}{0.4\%})^2} = 0.375\%$

How to fit to extract the WW fusion, H->bb cross-section(2)

- Construct the likelihood as
  - $-\log L = 0.5\left(\frac{\mu_{\mathrm{ZH}}-1}{0.375\%}\right)^2 - \log P(data|\mu_{ZH}N_{ZH}pdf_{ZH} + \mu_{WWF}N_{WWF}pdf_{WWF} + N_{bkg}pdf_{bkg})$
  - The μ_{ZH}, μ_{WWF} are events numbers normalized by SM prediction for ZH, Z->vv, H->bb and WW fusion, H->bb respectively.
- The statistical uncertainty was determined via the hessian matrix at maximum point of the minus log likelihood.

Result

the uncertainties are shown as bellow:

5ab^{-1}	Fit recoil mass of 2 jets	Fit recoil mass and θ of 2 jets
Raw data	3.9%	3.8%
E_H replaced by $\sqrt{p_H^2 + m_H^2}$	3.2%	3.1%

0.1% improvement by combining fitting the θ

0.7% improvement by replacing E_H with $\sqrt{p_H^2 + m_H^2}$