Current result of $\mathrm{WW\ fusion}, H \rightarrow bb$ Cross-section measurement

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Outline

- Sample Generation
- Cut Chain
- Extraction of the WW fusion cross section by fit
- Kinematic fit
  - Jet energy & direction resolution for *b* jets
- The result

Sample Generation for both pdf and fake data

- 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
- SM sample:
  - 5ab^-1 2fermions + 4fermions

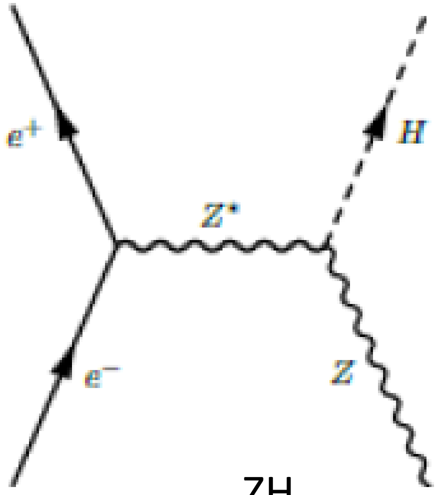
Cut Chain

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

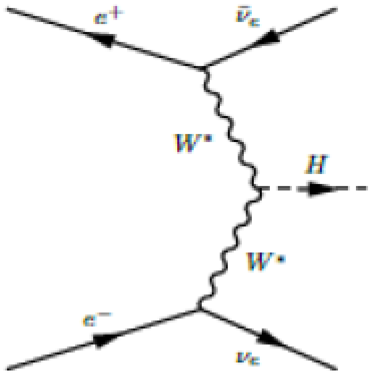
	WW fusion, H->bb	ZH, H->bb	qqbar	sw-sl	sznu-sl	ww-sl	zz-sl
Cut chain	52.8%	64.9%	25630	124	5745	3230	9764
Fit window with kinematic fit	51.2%(~10k @5ab^-1)	63.8%(~79k @5ab^-1)	22980	112	4018	2187	6503

Recoil mass

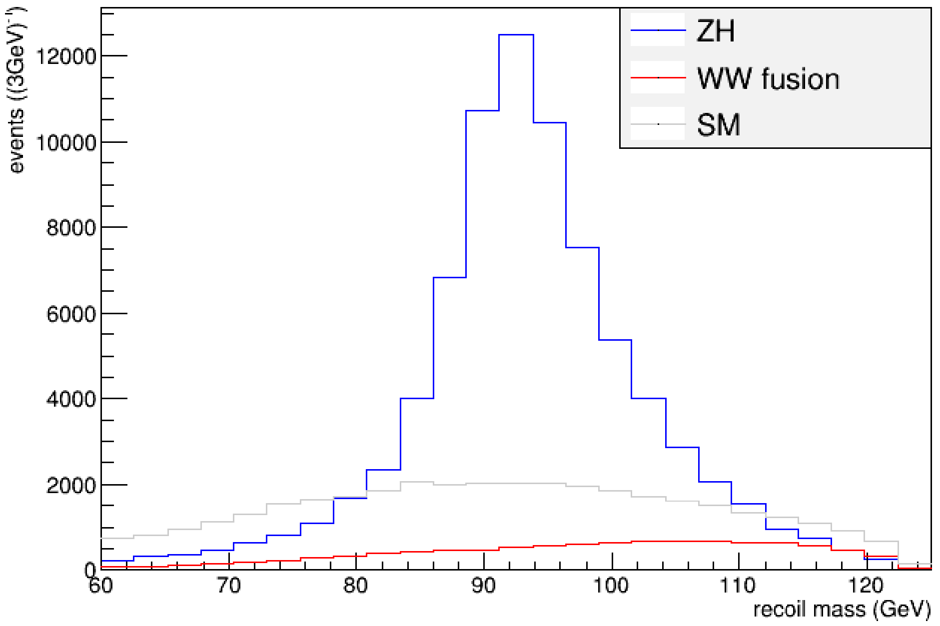
- We can extract the WW fusion events number by fitting the recoil mass or recoil angle



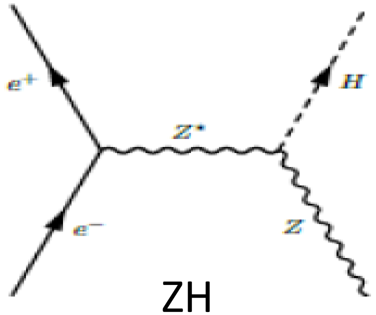
ZH



WW fusion



Kinematic fit(1)



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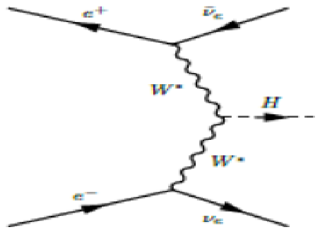
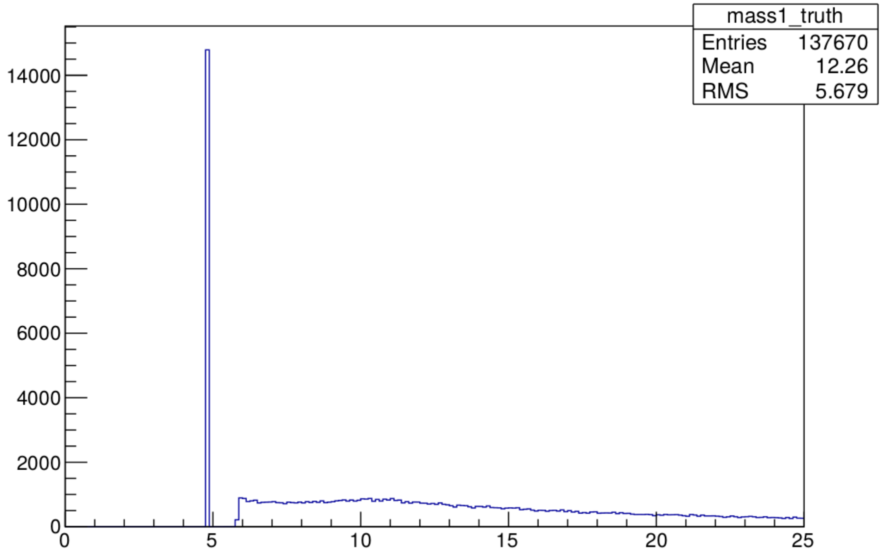
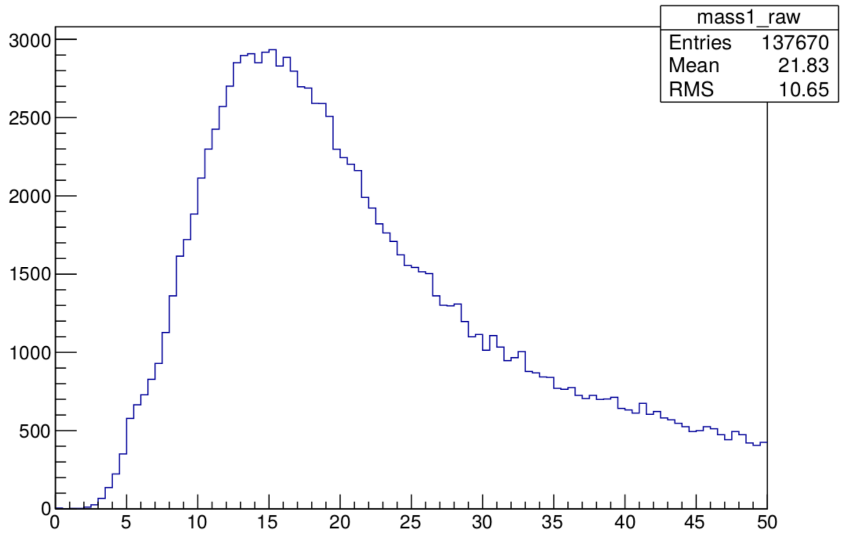


WW fusion

- Constraints:
  - $M_{2jets,fit} = m_H = 125\text{GeV}$
  - Use a rude approximation that:
    - $M_{each\ jet,fit} = M_{each\ jet,raw}$ for each jet





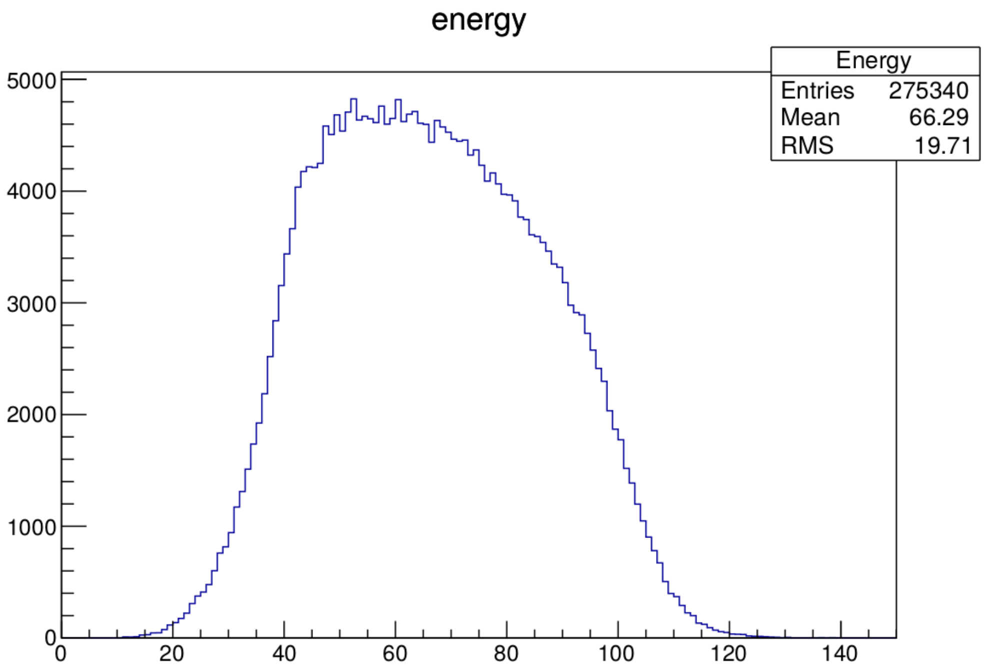
Kinematic fit (2)

- Minimize χ^2 to determine the fitted 4-momenta

$$\chi^2 = \sum_{i=1,2} \left(\frac{\theta_i - \theta_i'}{\sigma_{\theta,i}}\right)^2 + \left(\frac{\phi_i - \phi_i'}{\sigma_{\phi,i}}\right)^2 + \left(\frac{E_i - E_i'}{\sigma_{E,i}}\right)^2$$

Estimation of Jet energy & direction resolution (1)

- Sample
  - Alternative ~130k events, vvH, H->bb
  - 6 energy bins: 0GeV, 50GeV, 60GeV, 70GeV, 80GeV, 95GeV and 250GeV
  - 10 equal cos(polar angle) bins

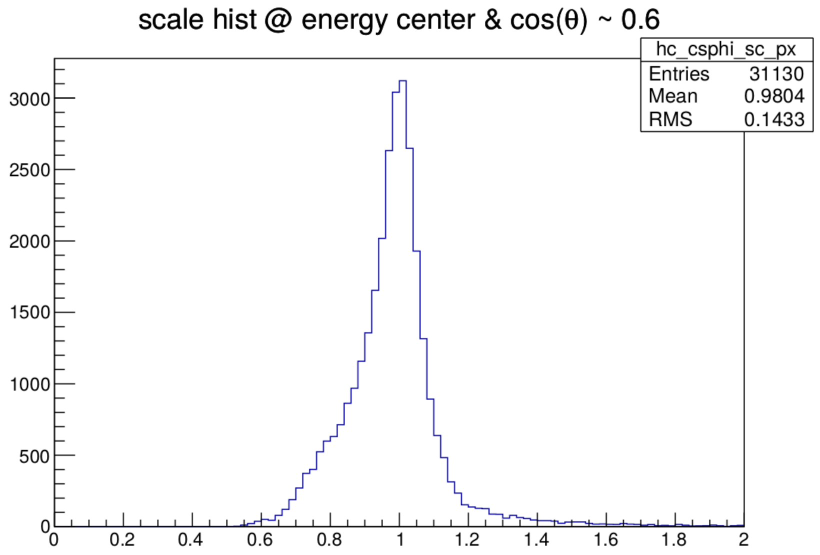


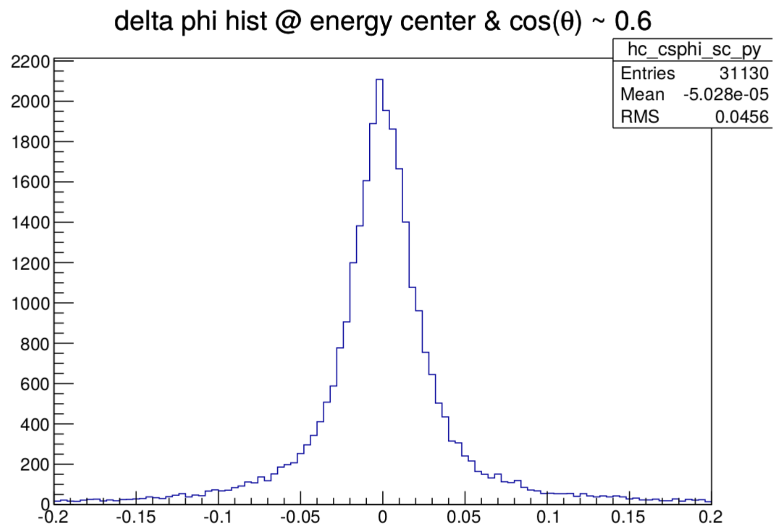
Estimation of Jet energy & direction resolution(2)

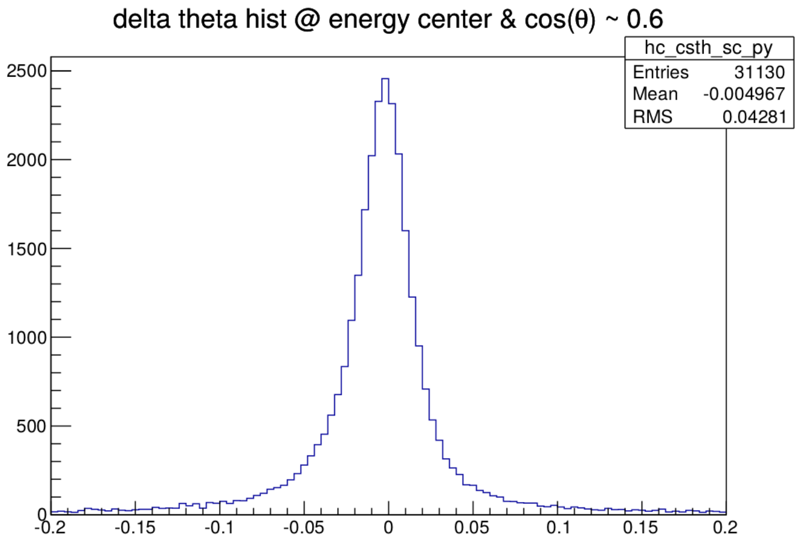
- Match quark and reconstructed jet
  - 1st approach: Minimize a χ^2
    - $\chi^2 = \sum_{j=1}^{2} \left(\boldsymbol{p}_{j,jet} - \boldsymbol{p}_{j,quark}\right)^2$
  - 2nd approach: Find the root of every particles in a jets using MC truth and link information (See Gang Li's FSClasser)
  - The results from these two approaches seem same. But the latter approach was used finally.

Jet energy & direction resolution(3)

- Resolution
  - Energy scale: E_{jet}/E_{quark}
  - $\Delta\phi$: $\phi_{jet} - \phi_{quark}$
  - $\Delta\theta$: $\theta_{jet} - \theta_{quark}$
  - The resolution can be described by a covariance matrix
    - E.g The $\sigma^2(scale) = cov(scale, scale) = \overline{\left(scale - \overline{scale}\right)^2}$ etc.



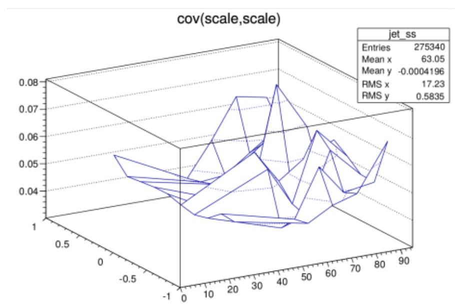


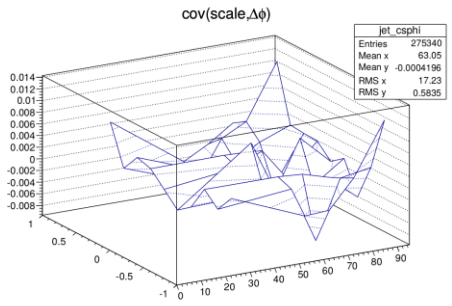


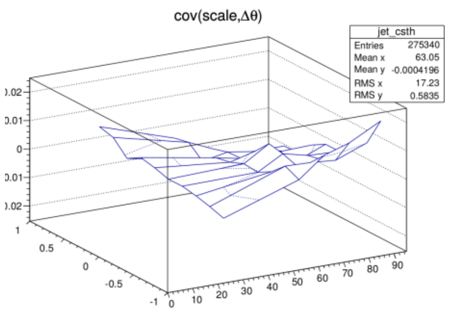
Covariance matrix as a function of jet energy and polar angle

scale | Direction angle | Polar angle

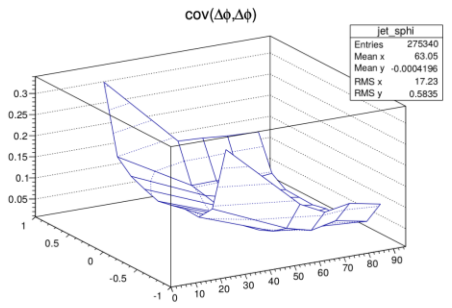
scale

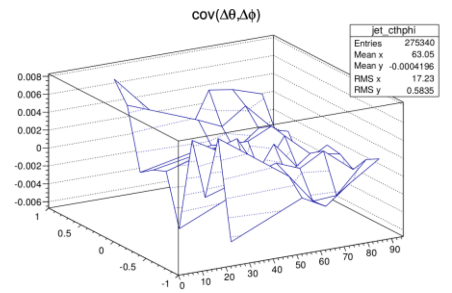




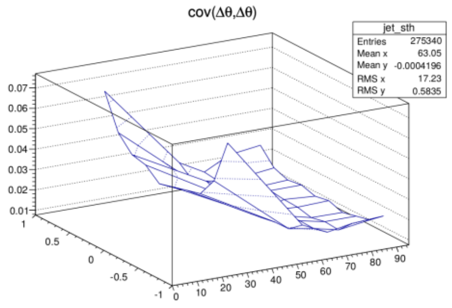


Direction angle

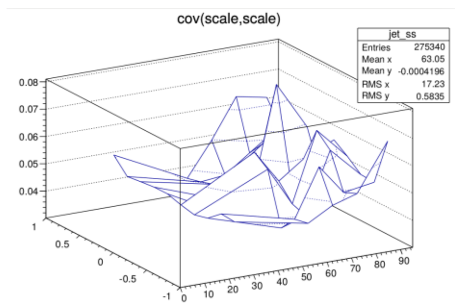
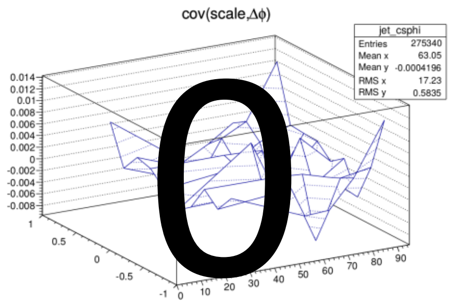
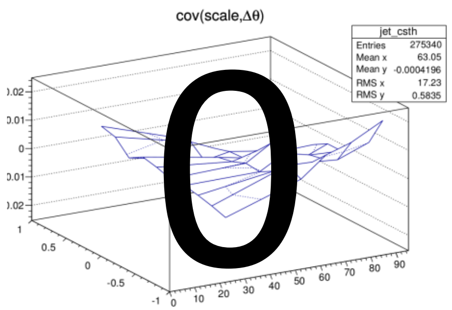
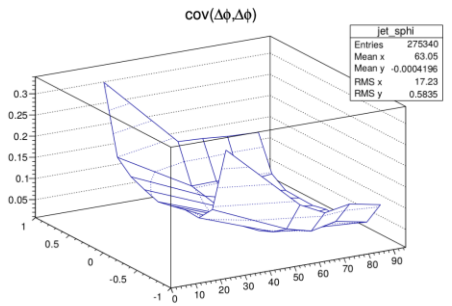
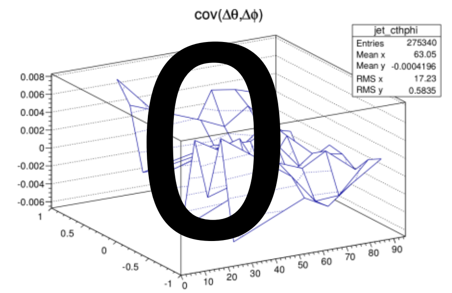
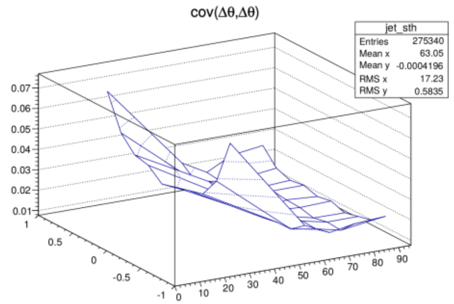




Polar angle



Covariance matrix as a function of jet energy and polar angle

	scale	Direction angle	Polar angle
scale		0 	0 
Direction angle			0 
Polar angle			

Values used in the kinematic fit

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

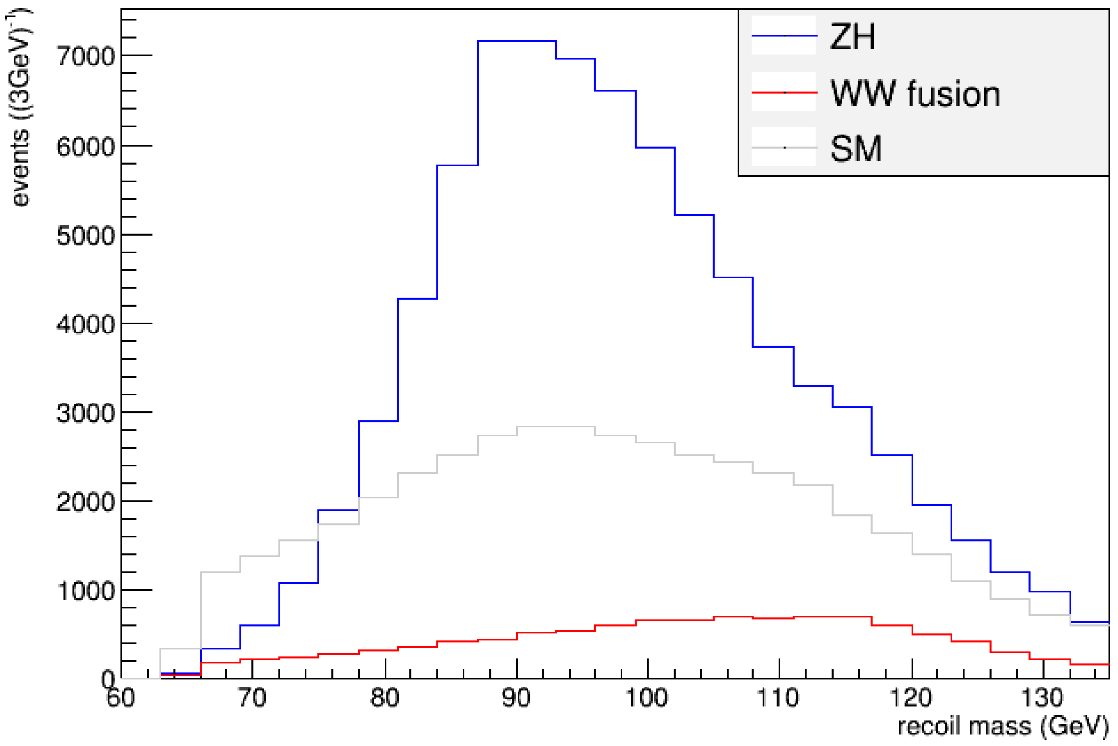
- Backgrounds (except ZH, Z->vv, H->bb) can be determined very well in theory and experiments. The signal stress of those were fixed to be 1.
- The expected number of ZH, Z->vv,H->bb would be measured via eeH, $\mu\mu$H and qqH channels:
  - The uncertainties of coupling constants concerns only electroweak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

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

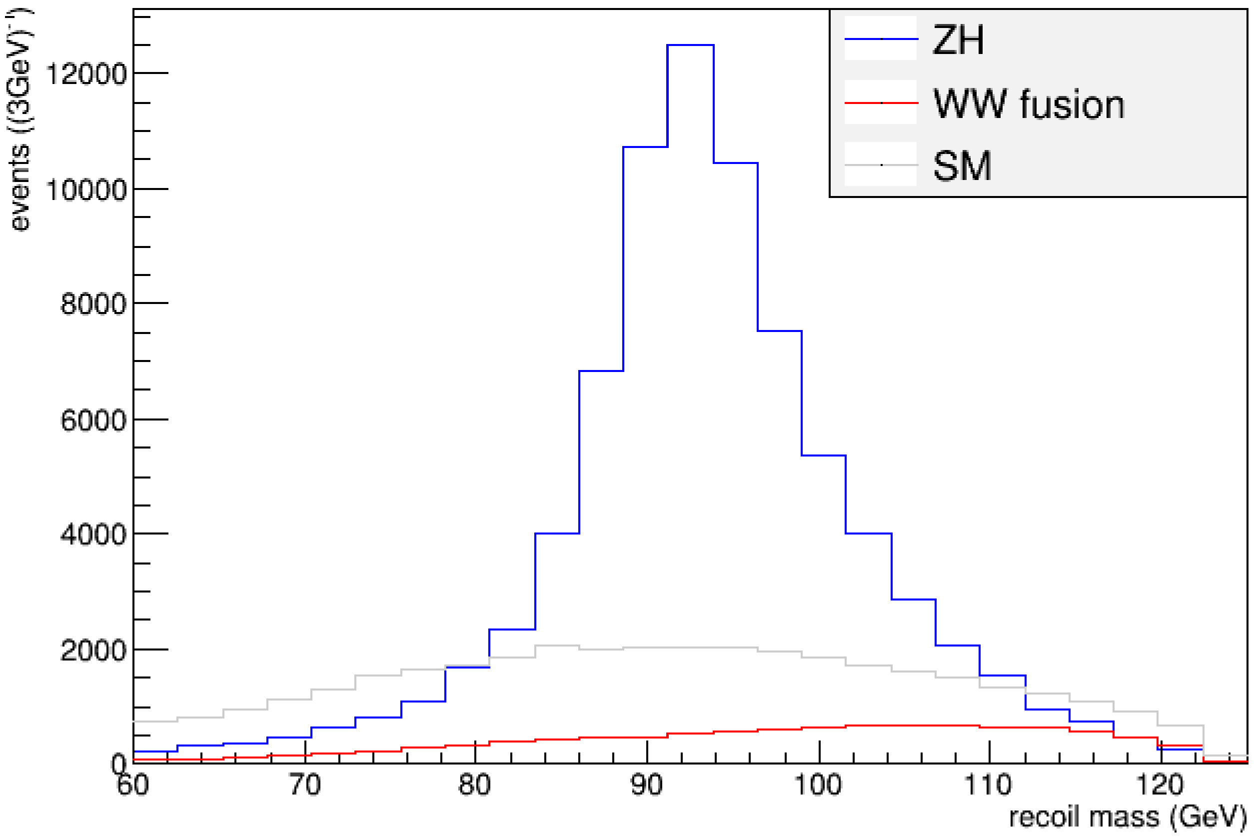
How to fit to extract the ww fusion, H->bb cross-section(2)

- Construct the likelihood as
  - $-\log L = 0.5\left(\frac{\mu_{zH}-1}{0.375\%}\right)^2 - \log P(data|\mu_{ZH} N_{ZH} pdf_{ZH} + \mu_{zh} N_{wwf} pdf_{wwf} + N_{bkg} pdf_{bkg})$
  - 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.

Recoil mass with kinematic fit



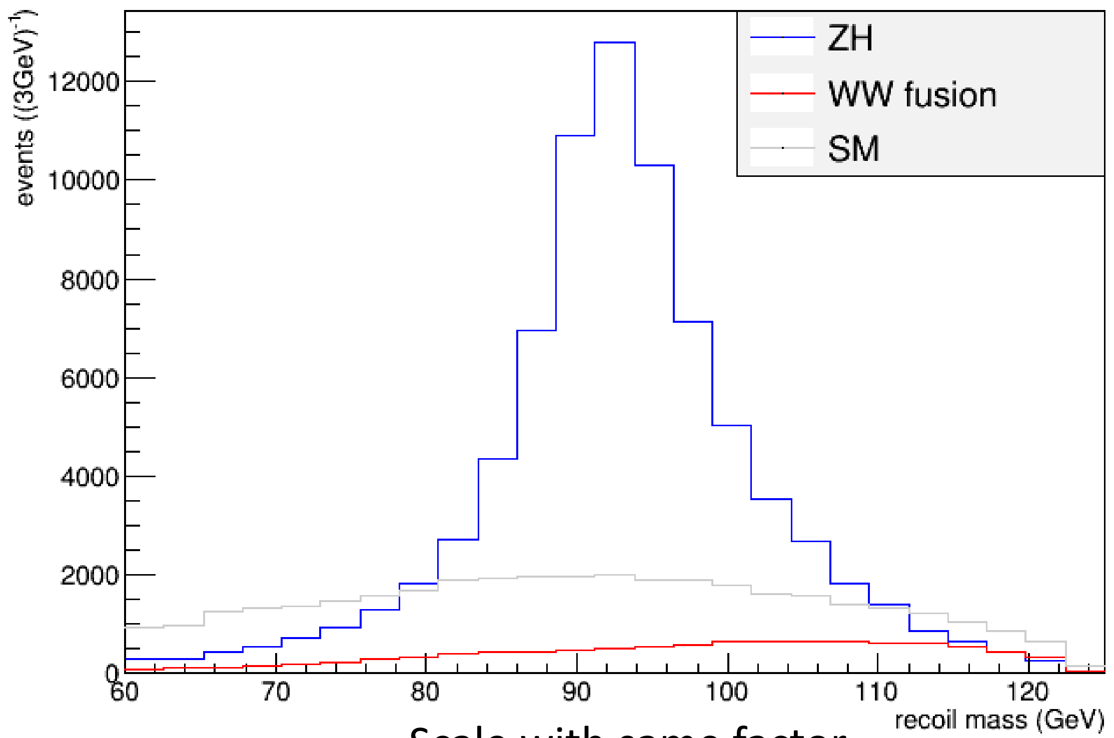
raw



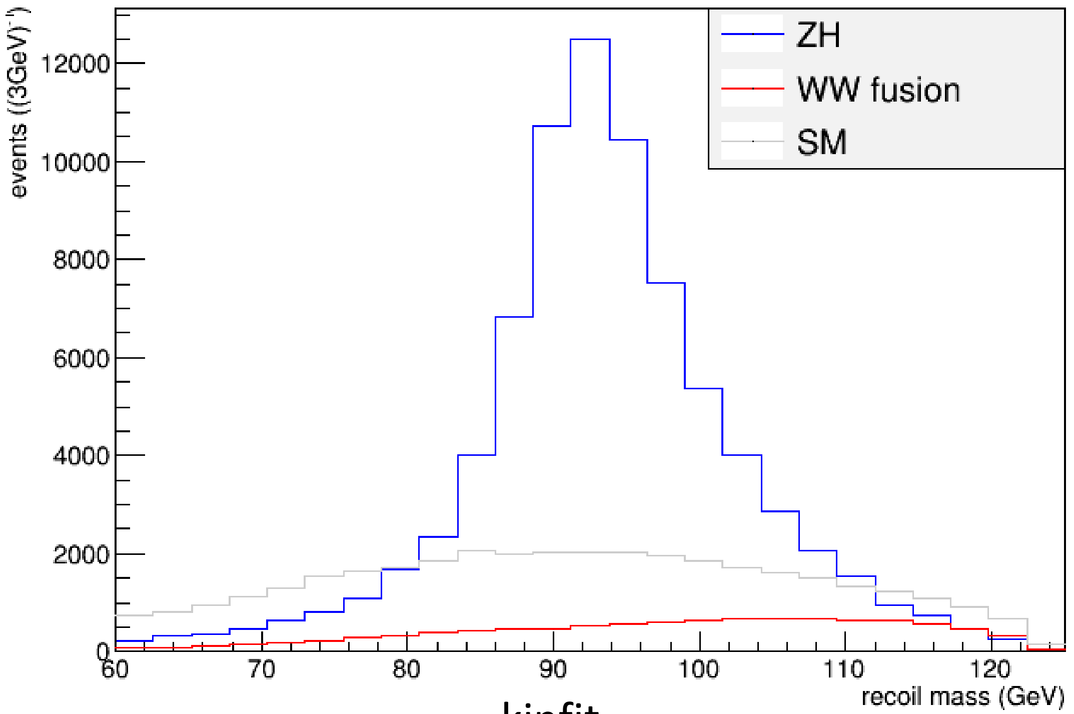
kinfit

A simple but effective approach to do kinematic fit

- Scale the momenta of di-jet with same factor such that their invariant mass is m_H



Scale with same factor



kinfit

Result

$5\mathrm{ab}^{-1}$	Fit recoil mass of 2 jets	Fit recoil mass and θ of 2 jets
Raw data	3.9%	3.8%
Kinematic fit	3.2%	3.1%
Simple Kinematic fit	3.2%	3.1%

Pre-CDR (Zhenxing based on fast simulation): 2.8%

Junping Tian's result @ ICL, 250GeV & $250\mathrm{fb}^{-1}$ is 8.1% which would be **1.8%** at integrated luminosity of $5\mathrm{ab}^{-1}$.
(Note that the beam polariation and enviroments are different.)