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

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Outline

- Sample Generation
- Cut Chain
- How to extract the WW fusion cross section by fit on the recoil mass
- Kinematic fit
    - Jet energy & direction resolution for *b* jets
- The result

Sample Generation for both pdf and fake data

- Signal: WW fusion, H->bb
- Higgs sample:
  - ~WW fusion(signal) and ZH (background), H->anything events re100k
  - Sample for interference between ZH and WW fusion can't be generated
- SM sample:
  - 2fermions + 4fermions

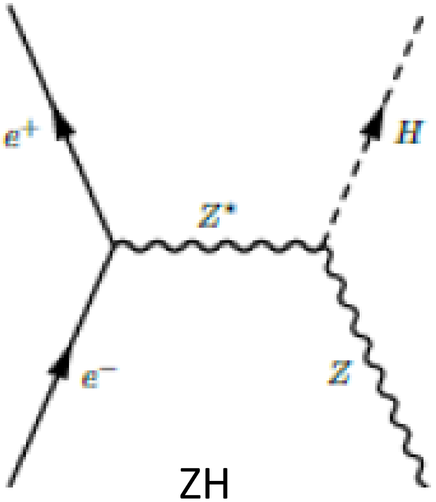
Cut Chain

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

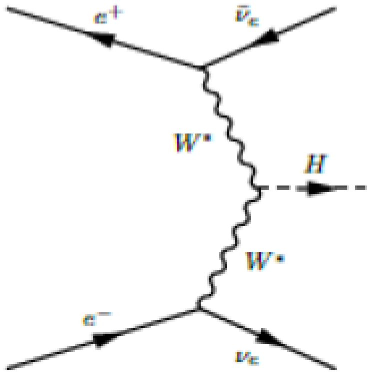
	WW fusion, H->bb	ZH, H->bb	qqbar	sw-sl	sznu-sl	ww-sl	zz-sl
Cut chain	52.8%	64.9%	25630	124	5745	3230	9764
Fit window with kinematic fit	51.2%(~10k @5ab^-1)	63.8%(~79k @5ab^-1)	22980	112	4018	2187	6503

Recoil mass

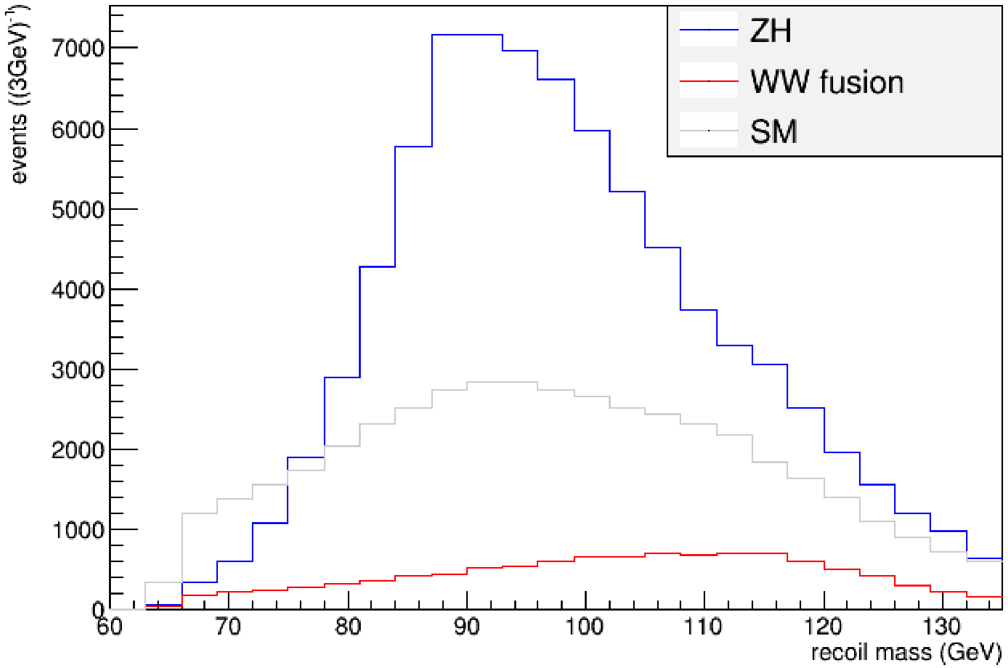
- We can extract the WW fusion events number by fitting the recoil mass or recoil angle



ZH

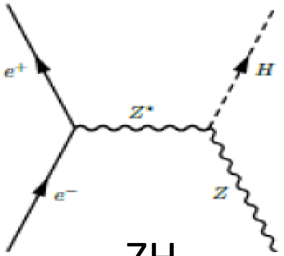


WW fusion

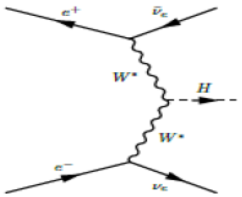


Kinematic fit(1)

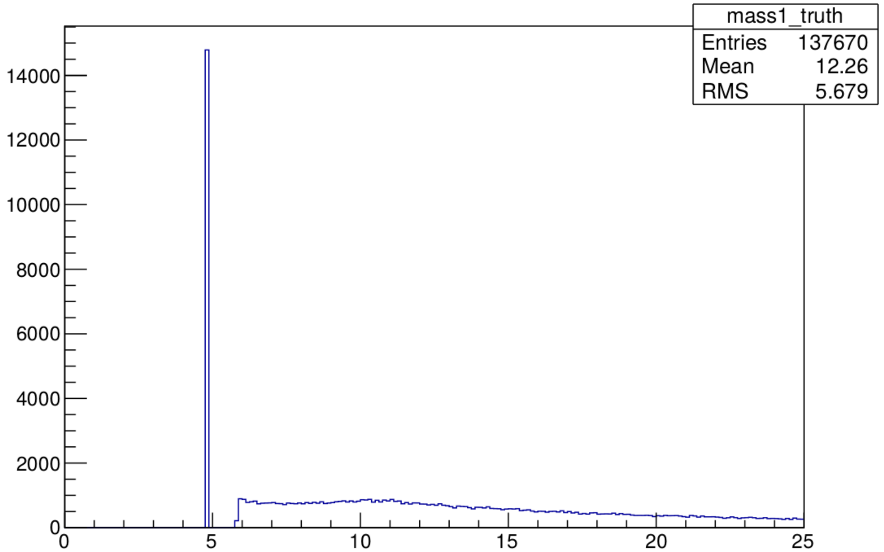
- Constraints:
  - $M_{2jets,fit} = m_H = 125\mathrm{GeV}$
  - Use a rude approximation that:
    - $M_{each\ jet,fit} = M_{each\ jet,raw}$ for each jet

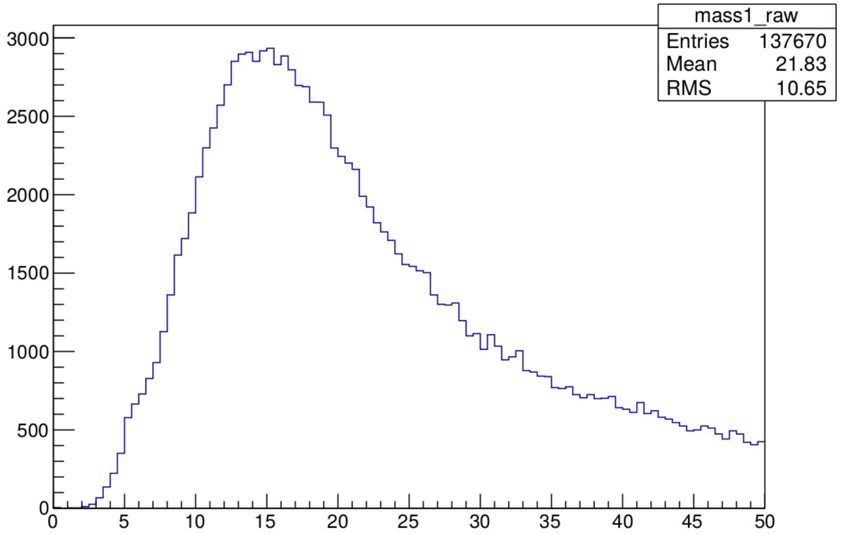


ZH



WW fusion



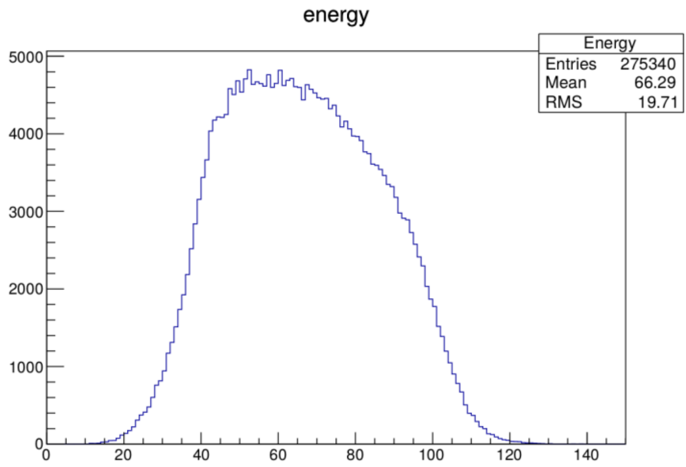


Kinematic fit(2)

- Minimize χ^2 to determine the fitted 4-momenta
  - $\chi^2 = \sum_{j=1}^{2} \left(P_{j,fit} - P_{j,raw}\right)^T U_j^{-1} (P_{j,fit} - P_{j,raw})$
  - U_j is the covariance matrix of 4-momentum of each jet. We can σ_θ, $\sigma_\phi$and $\sigma_E$as input to calculate this matrix.
- Implement KF
  - *KinFit* produce almost same result as self-written code, if both code did the fit successfully. But *KinFit* is more robust
  - Currectly, the fit was done by my own code
  - Plan to use *KinFit* in the future (more robust)

Jet energy & direction resolution(1)

- Sample
  - **~100k, vvH, H->bb**
  - independent to the sample used in main analysis
- Reconstructed jet energy distribution
  - The energy was dived into several bins based on right Figure
  - Number of events in each bin are of same order of magnitude.

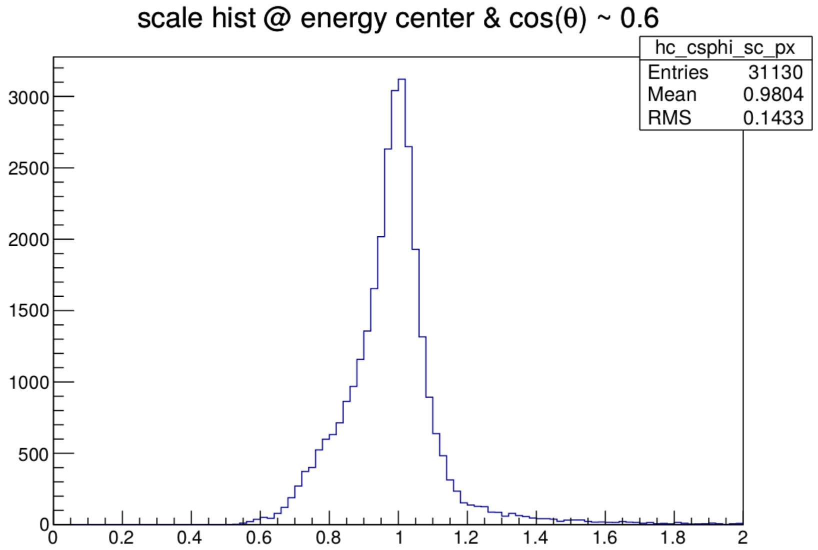


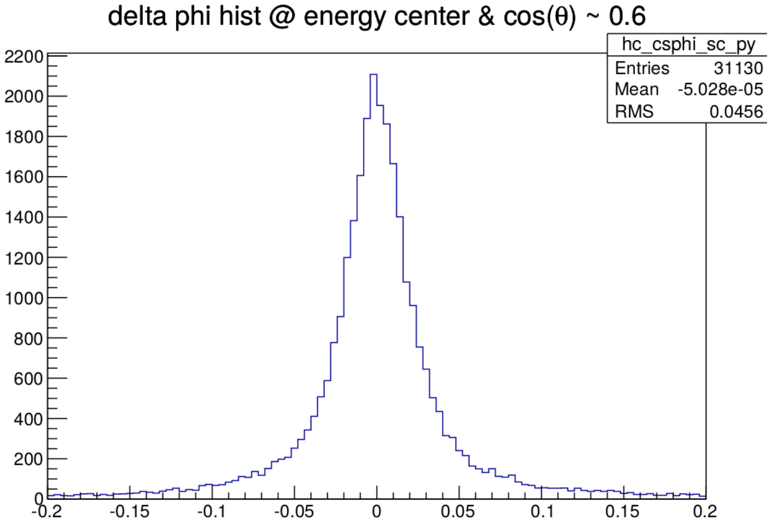
Jet energy & direction resolution(2)

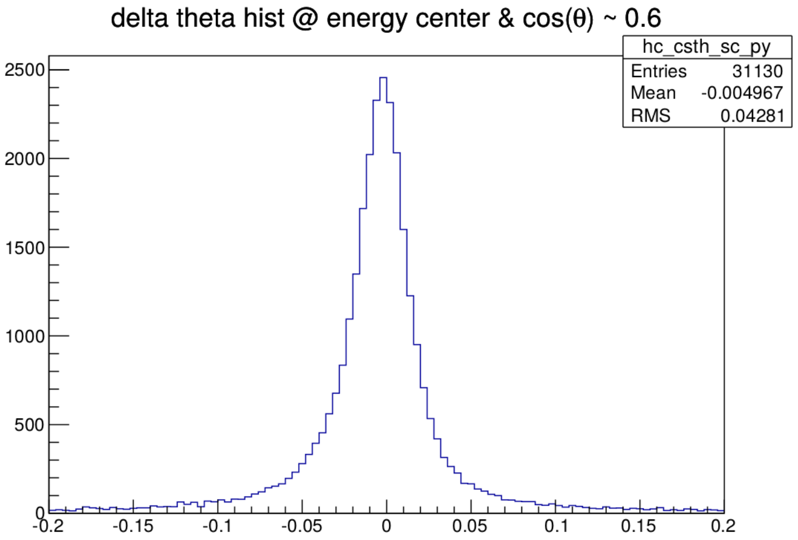
- Match quark and reconstructed jet
  - 1st approach: Minimize a χ^2
    - $\chi^2 = \sum_{j=1}^{2}\left(\boldsymbol{p}_{i,jet} - \boldsymbol{p}_{j,quark}^{2}\right)^2$
  - 2nd approach: Find the root of every particles in a jets using MC truth and link information (See Gang Li's FSClasser)
  - The results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


scale hist @ energy center & cos(θ) ~ 0.6


delta phi hist @ energy center & cos(θ) ~ 0.6


delta theta hist @ energy center & cos(θ) ~ 0.6

Covariance matrix as a function of jet energy and polar angle

scale

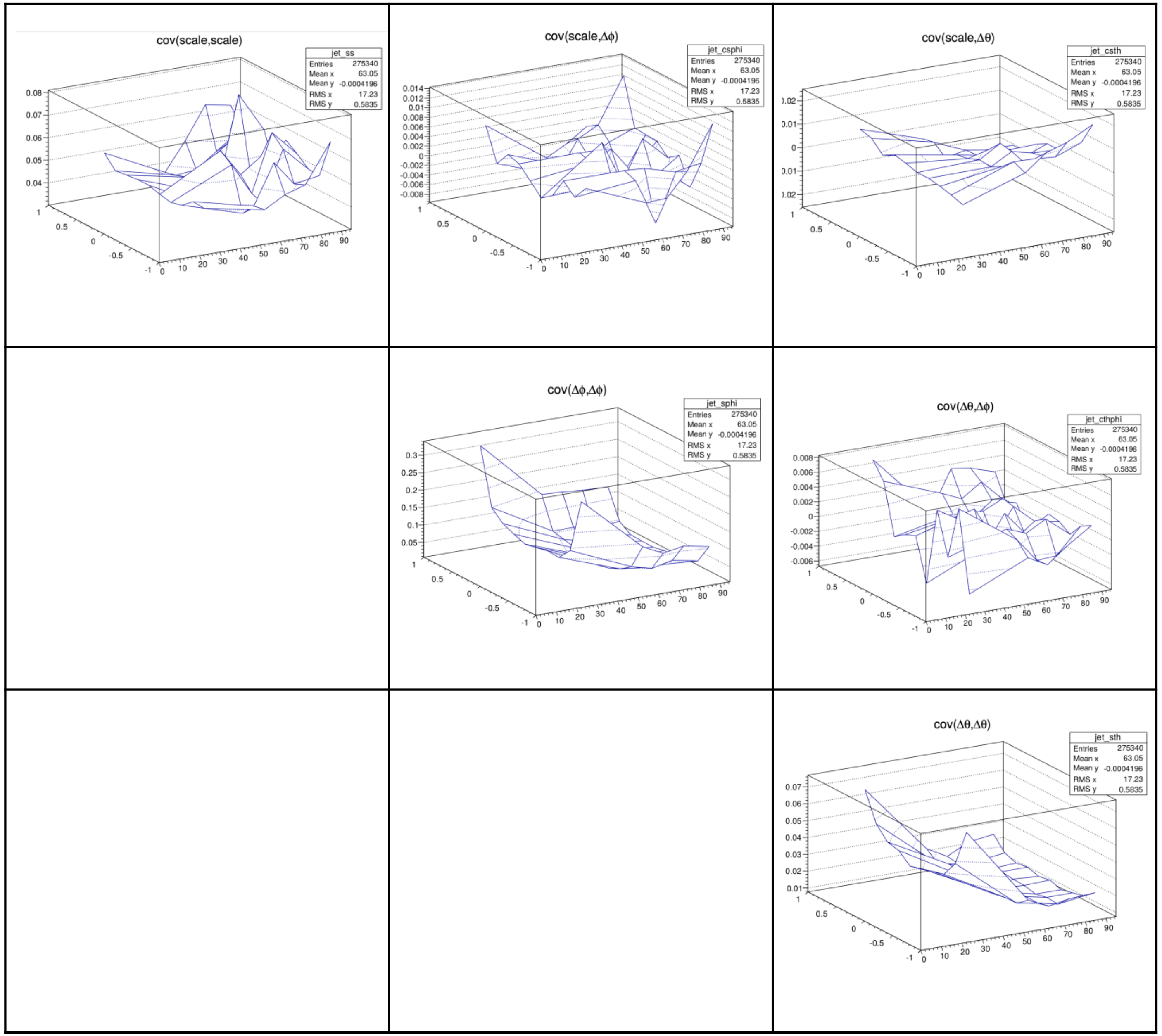
Direction angle

Polar angle

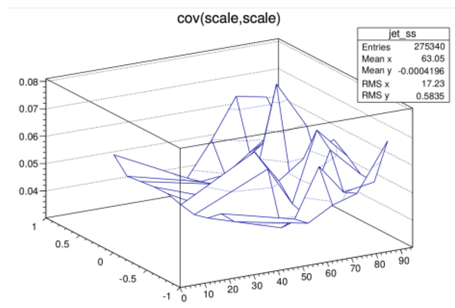
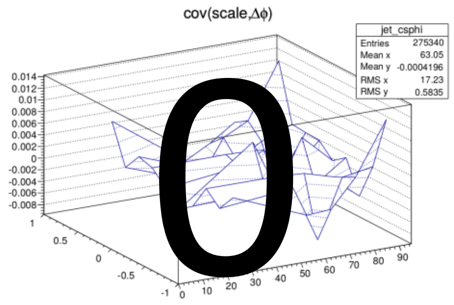
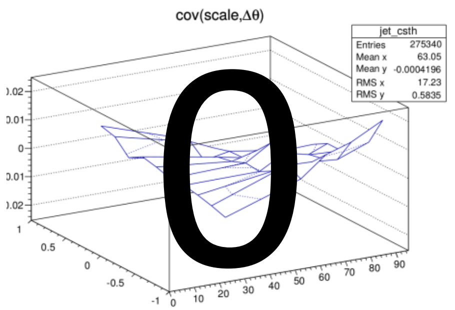
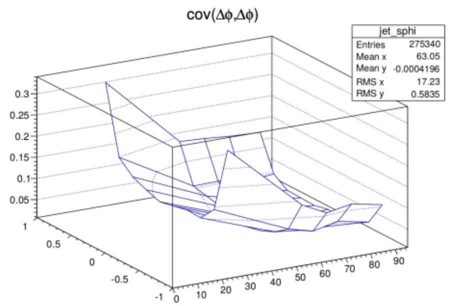
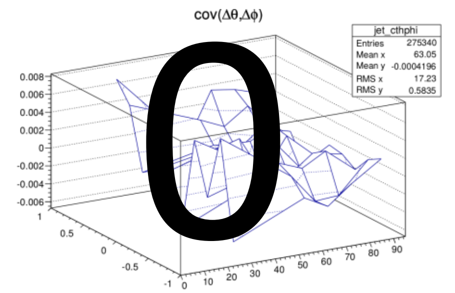
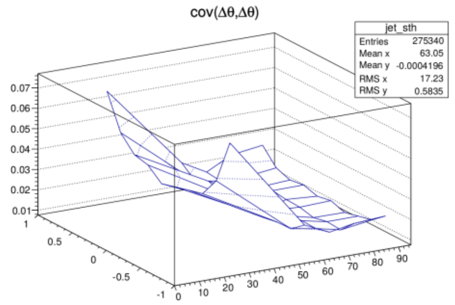
scale

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

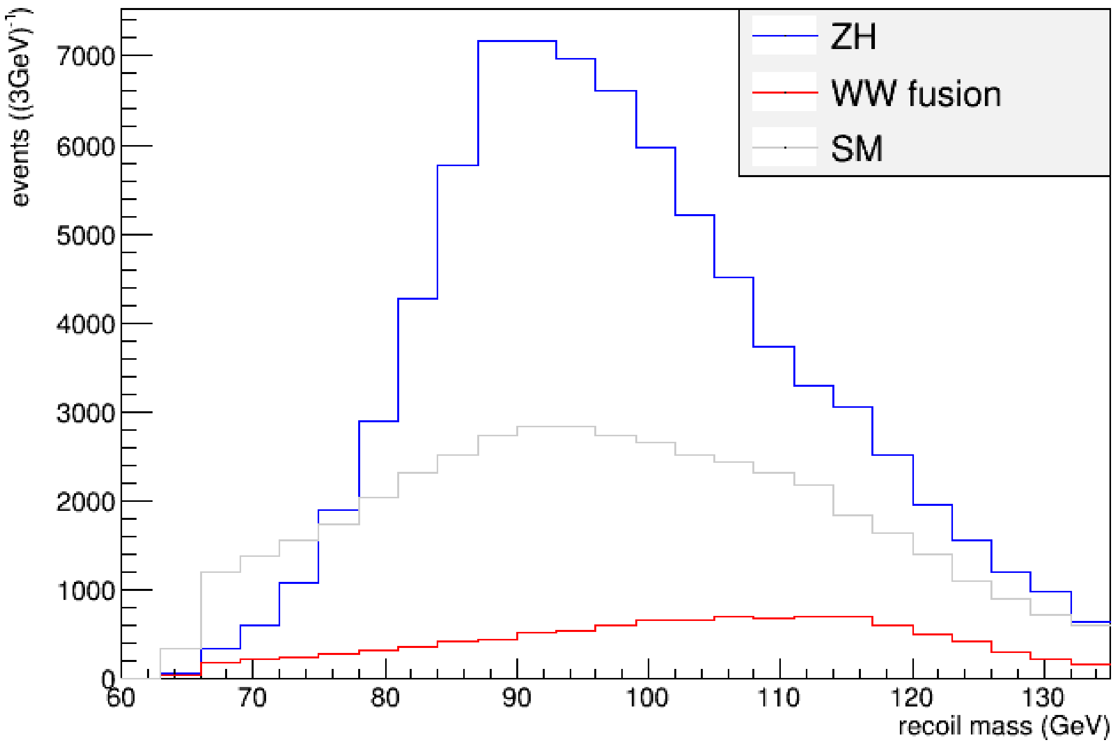
How to fit to extract the ww fusion, H->bb cross-section(1)

- I hope the expected number of SM backgrounds can be determined very well by some control region. The error could be negligible.
- The expected number of ZH, Z->vv,H->bb would be measured very well by eeH, $\mu\mu$H and qqH channels (We also assume we have known the electroweak very very well here). But the uncertainty is still not negligible.
  - The uncertainly of ZH, Z->vv, H->bb = $1/\sqrt{\frac{1}{\sigma^2_{eeH,H\rightarrow bb}}+\frac{1}{\sigma^2_{\mu\mu H,H\rightarrow bb}}+\frac{1}{\sigma^2_{qqH,H\rightarrow bb}}}$
  - $1/\sqrt{(\frac{1}{1.2\%})^2+(\frac{1}{1.1\%})^2+(\frac{1}{0.4\%})^2}= 0.375\%$

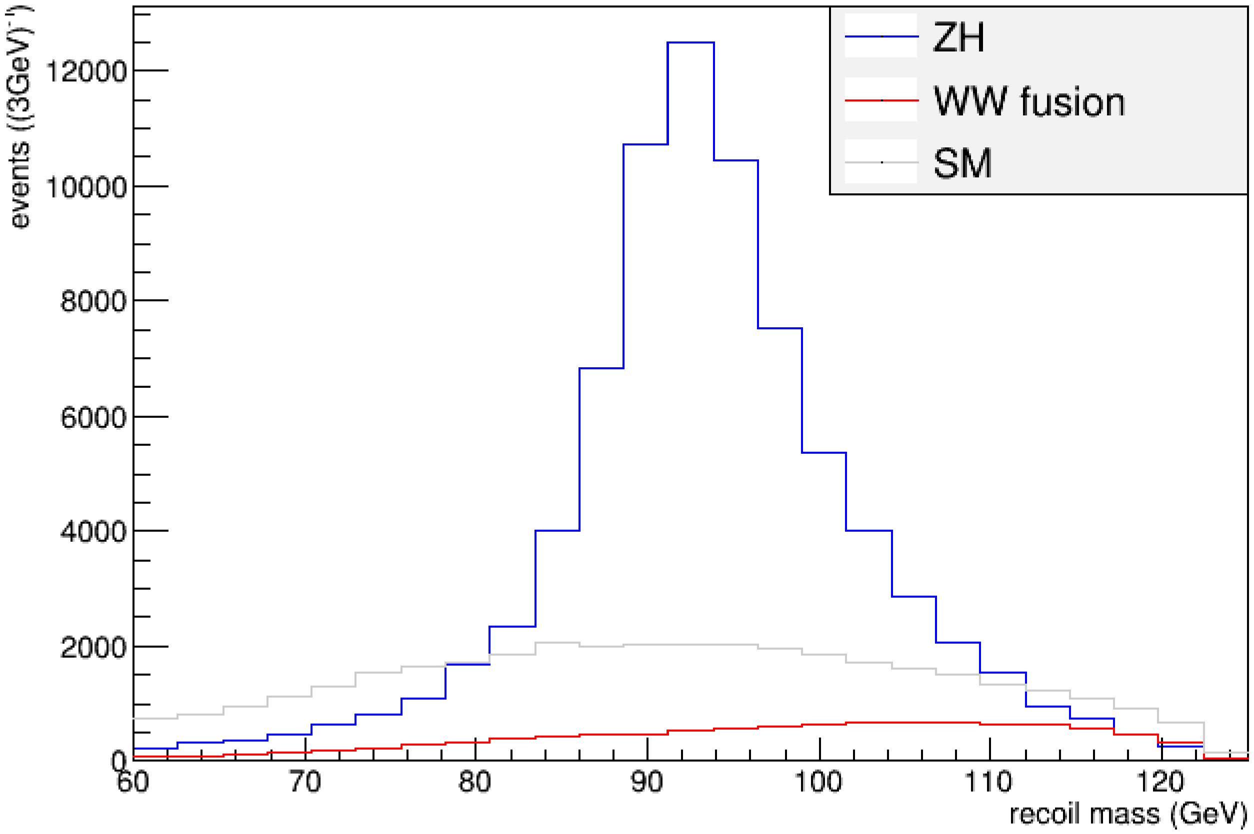
How to fit to extract the ww fusion, H->bb cross-section(2)

- Construct the likelihood as
  - $-\log L = 0.5\left(\frac{\mu_{zH}-1}{0.375\%}\right)^2 - P(data|\mu_{ZH}N_{ZH}pdf_{ZH} + \mu_{zh}N_{wwf}pdf_{wwf} + N_{SM}pdf_{SM})$
  - The μ_{zh}, μ_{wwf} is events number normalized by SM prediction for ZH and WW fusion respectively.
- The statistics uncertainty was determined by output message of *Tminuit* minimizer. In my experience, this error is quite close to the value determined by toy MC (fluctuate data and repeat fit again and again).

Recoil mass with kinematic fit



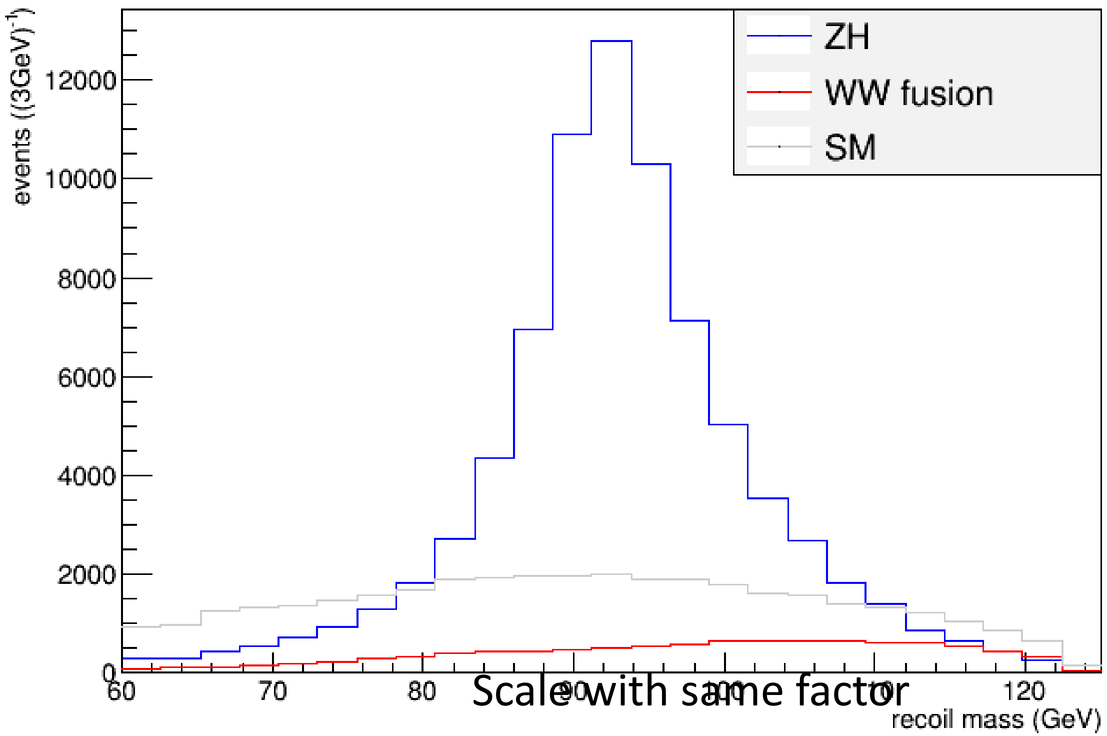
raw



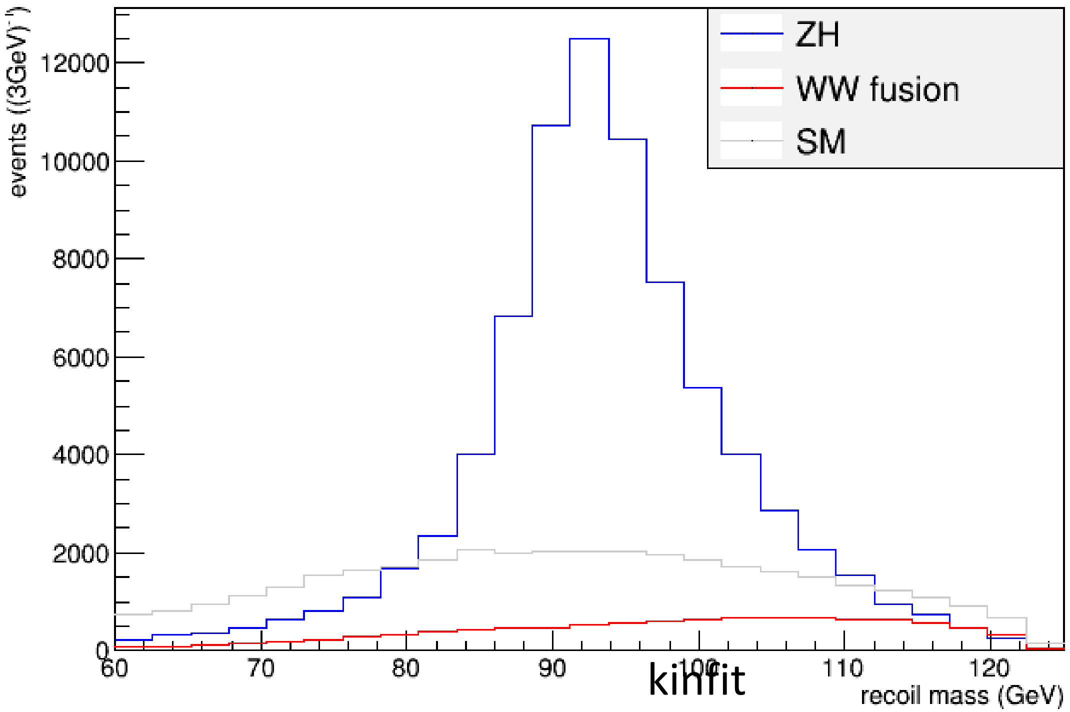
kinfit

A simple but effective approach to do kinematic fit

- Scale the two jets moment with same factor such that their invariant mass ~ 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 & $250\mathrm{fb}^{-1}$: 8.1% which would be **1.8%** at integrated luminosity of 5ab^01