Improving the jet energy reconstruction for Higgs precision measurement at the ILC

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Overview

Aim

- To improve b jet energy reconstruction at the ILC

Analyzing process

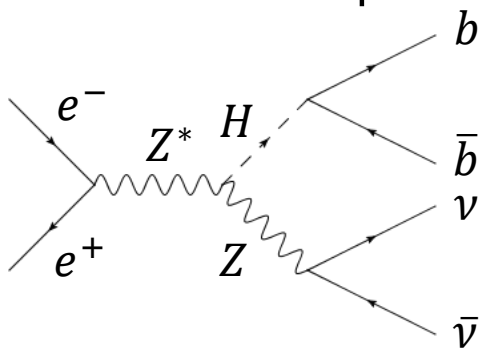
ee→ZH→νvbb

Background

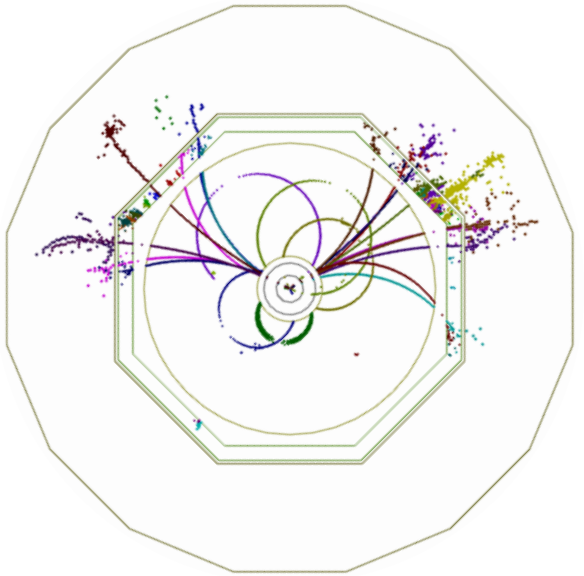
- Higgs boson decays mainly into a pair of b quarks.
- B quark jet often emits neutrinos, which makes the resolution worse.

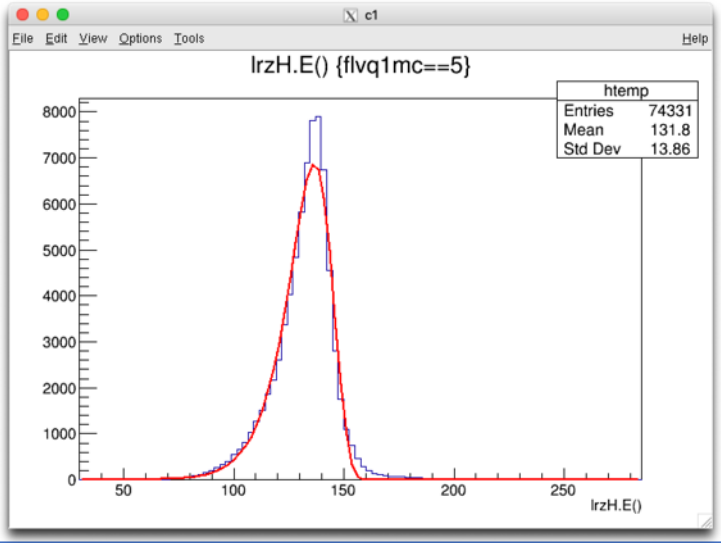
Idea

1. recover missing neutrinos 4-momentum in b jet
2. apply kinematic fit to correct parameters



250 GeV
ee→ZH→νvbb

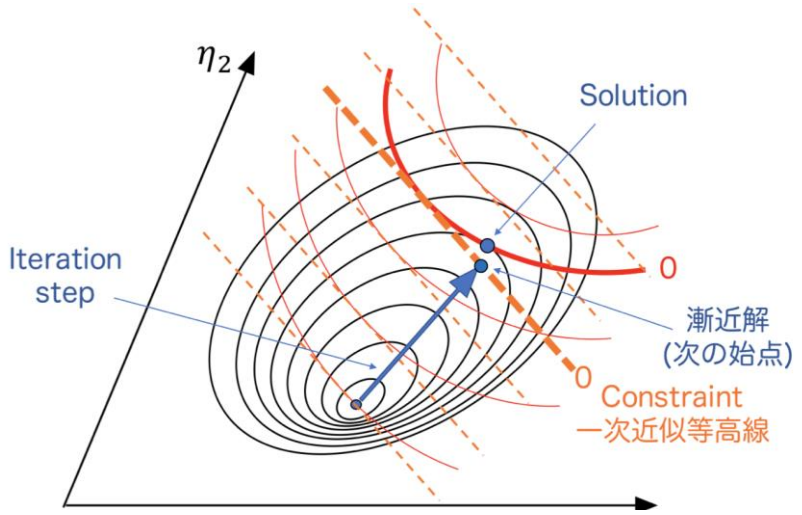




Kinematic Fit

- a means of improving resolution
- impose kinematic constraint and

detector resolution by Lagrange multiplier



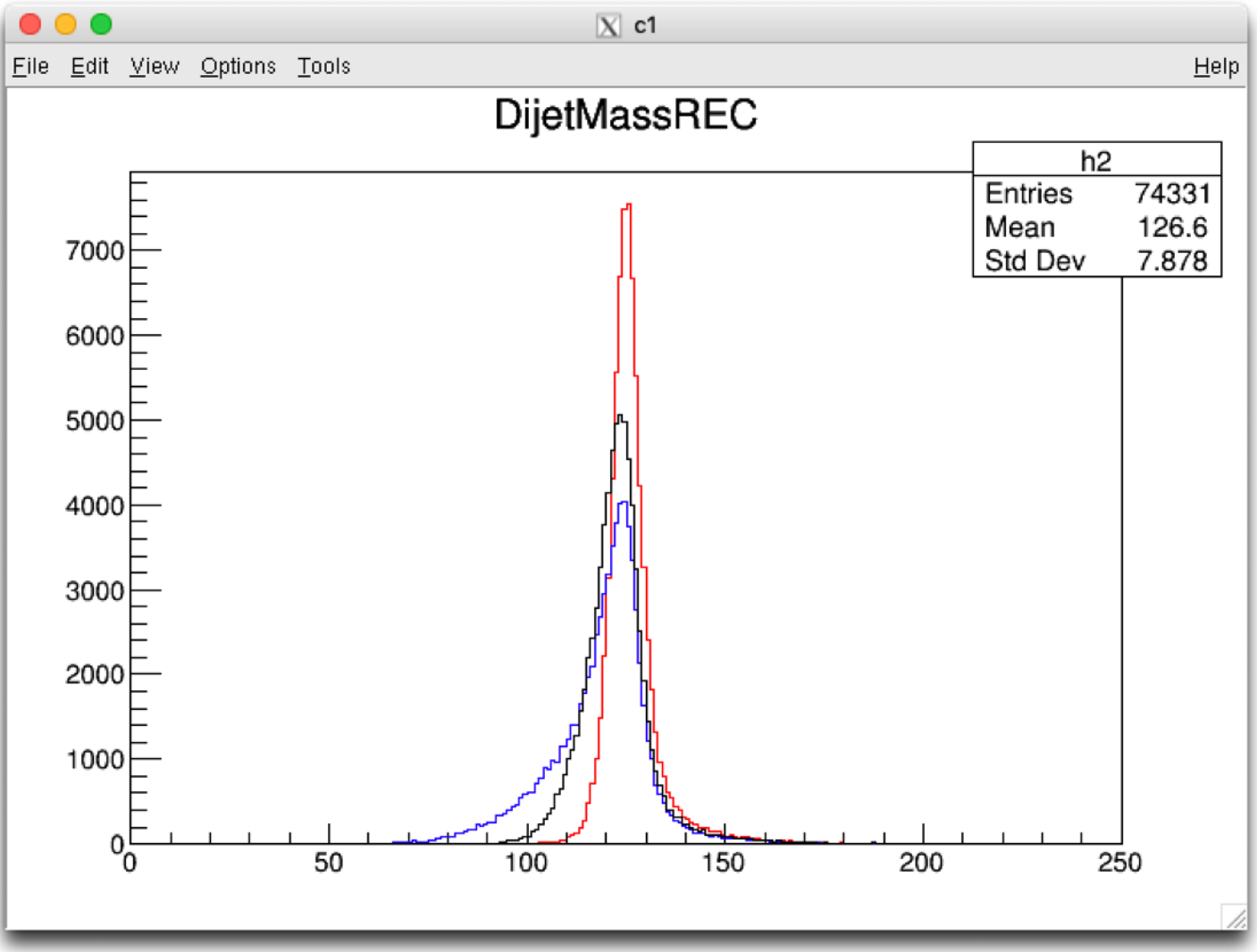
$\vec{y}$:measured values, $\vec{\eta}$:parameters , V:covariance matrix, $\vec{\xi}$:constants

$$\chi^2 = (\vec{y}-\vec{\eta})^T V^{-1}(\vec{y}-\vec{\eta}) + 2\sum_{k=1}^{K}\lambda_k\, g_k(\vec{\eta},\vec{\xi}) + \sum_{l=1}^{L}\left(\frac{h_l(\vec{\eta},\vec{\xi})}{\sigma_{h_l}}\right)^2$$

Fit Object　　Hard Constraint　　Soft Constraint

recover neutrinos for di-jet mass with MC

only H→bb

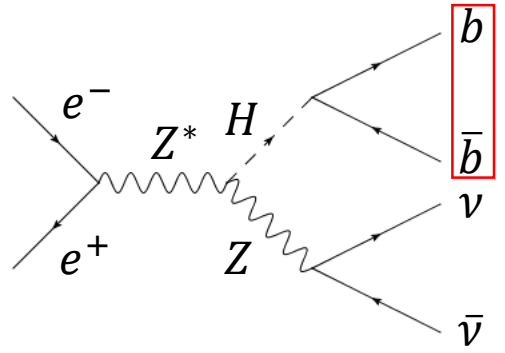


- di- b jet mass plot
- A b quark jet often emits neutrinos, which makes the resolution worse.
- recover 4-momentum of neutrinos using MC information

no neutrino recoverd

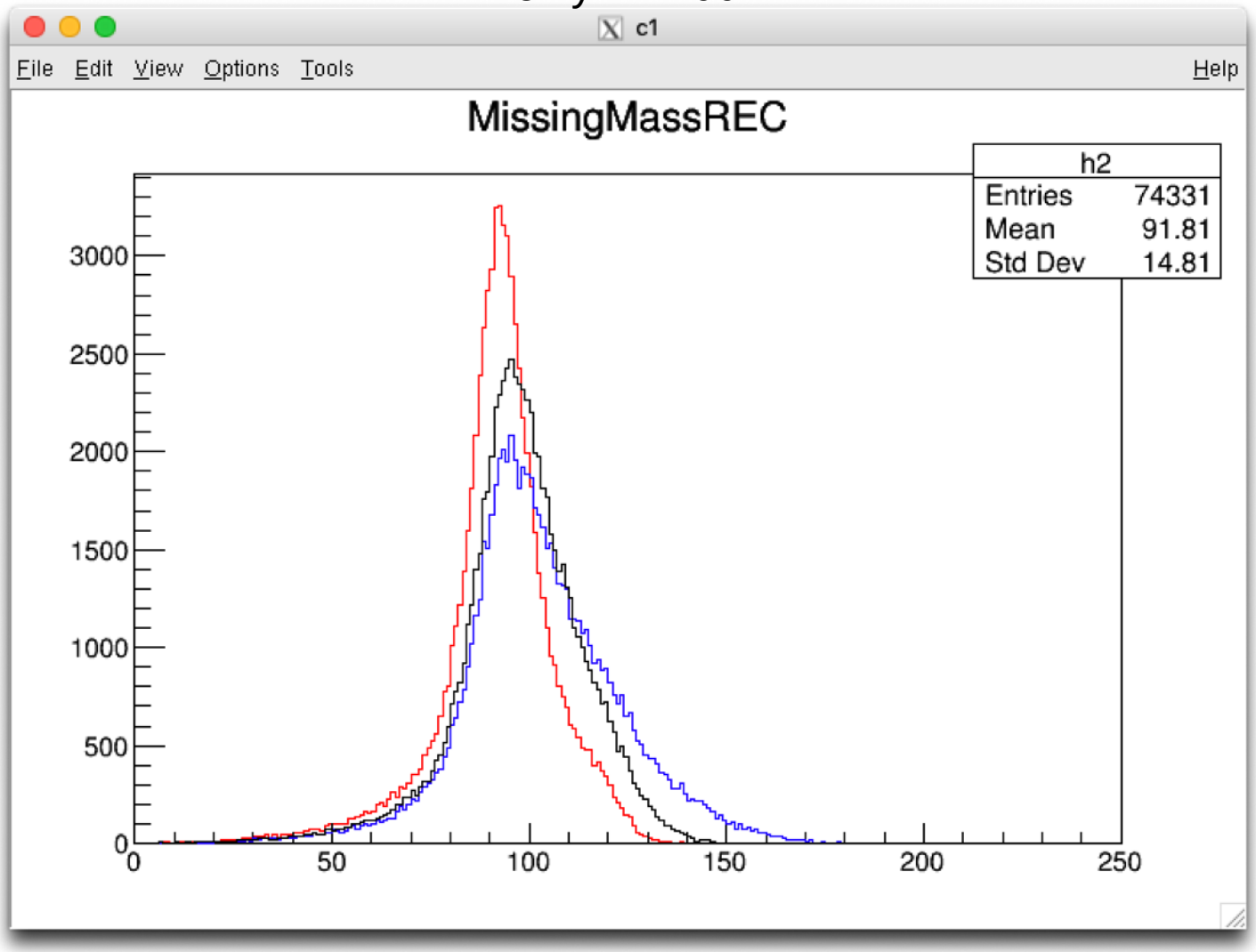
half 4-momentum of neutrinos recovered

full 4momentum of neutrinos recovered



recover neutrino energy for missing mass with MC

only H→bb

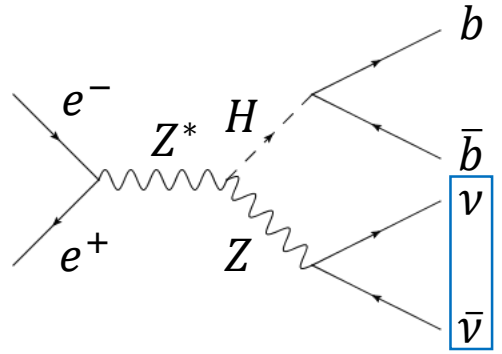


- missing mass plot
- recover 4-momentum of neutrinos using MC information

no neutrino recovered

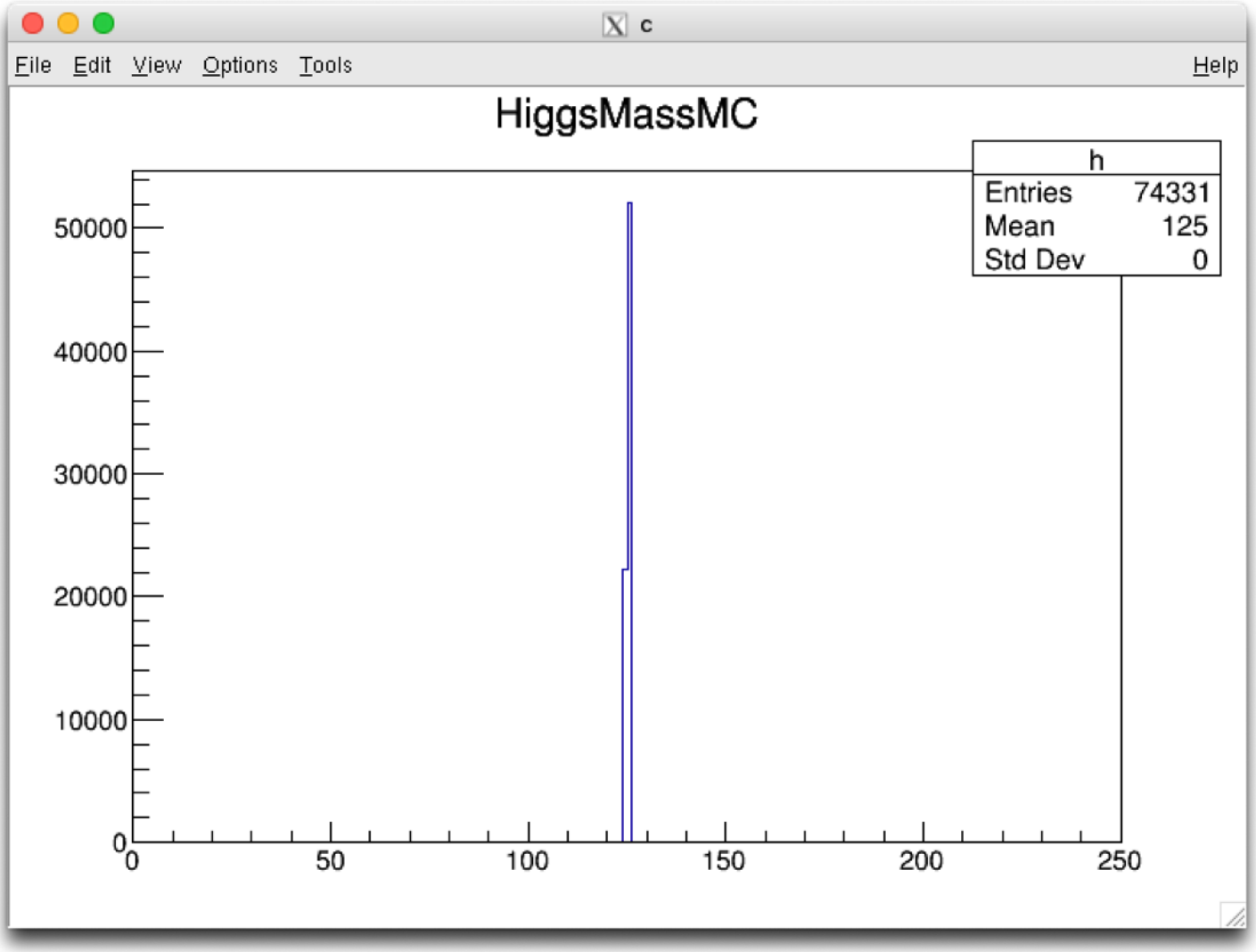
half 4-momentum of neutrinos recovered

full 4momentum of neutrinos recovered



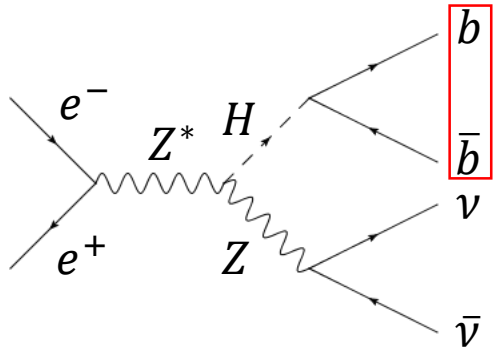
constraint for Higgs mass

only H→bb



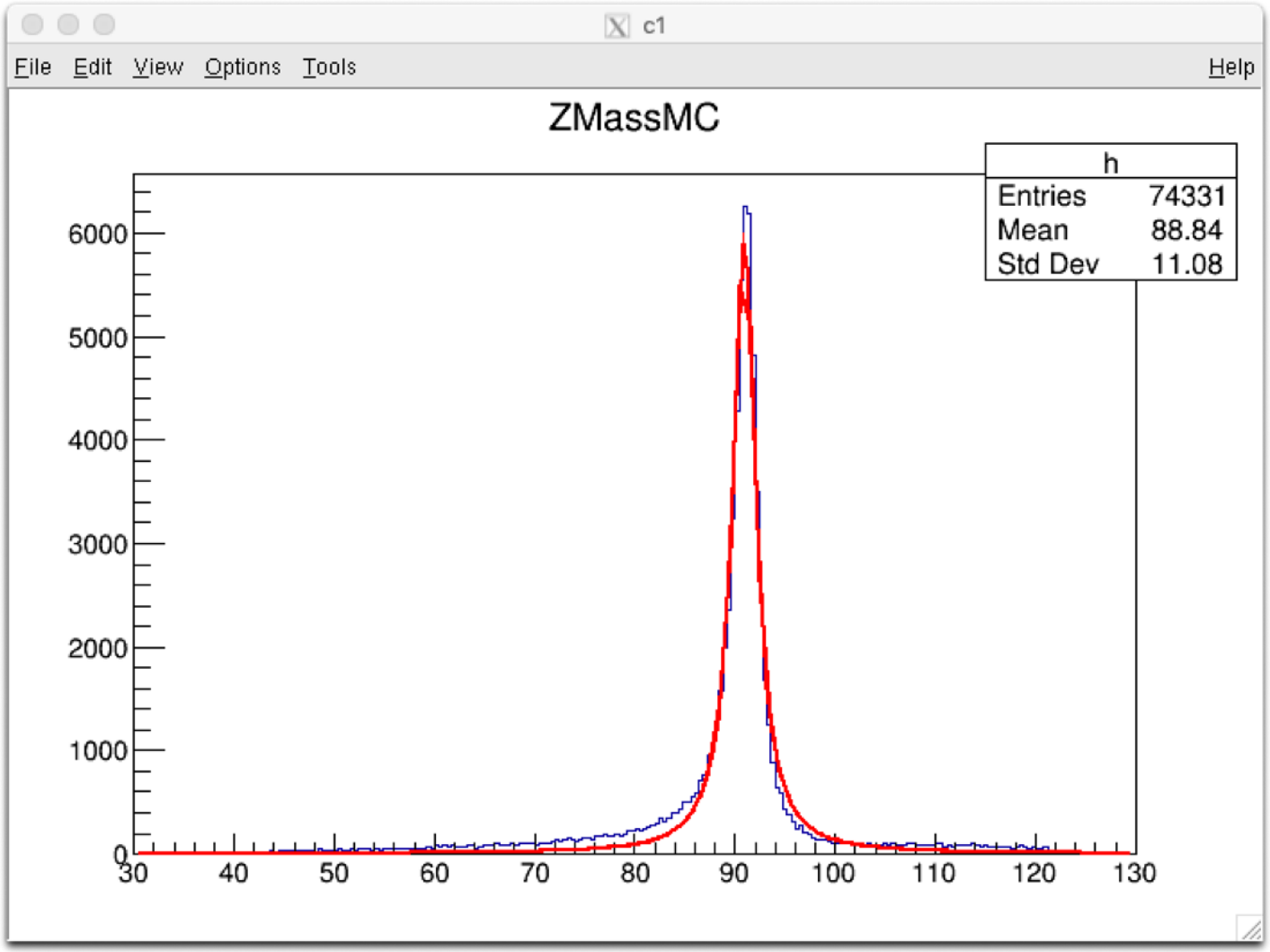
total width of a Higgs boson<0.013[GeV](PDG2019)

→Hard Constraint



constraint for Z mass

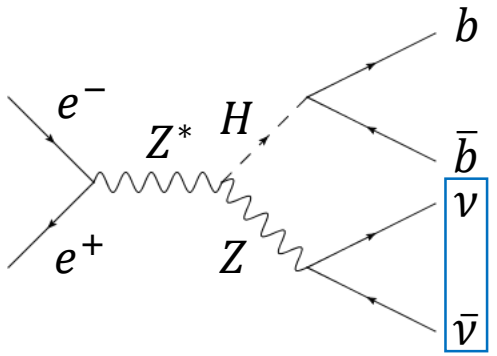
only H→bb



total width of a Z boson ~ 2.5 [GeV](PDG2019)

Breit-Wigner distribution is fit well to Z Mass plot.

→Breit-Wigner Soft Constraint



Next Step

1. recover missing neutrinos 4-momentum in b jet

   to find neutrino in b jets by detecting and correcting for semileptonic decay

2. include kinematic fit to correct parameters

   by imposing hard constraint for di-jet mass

   and soft BW constraint for missing mass

MarlinKinfit

- a library for kinematic fitting
- uses Newton's method for chi-square minimization
- Both hard constraint and soft constraint are available.

$\vec{y}$:measured values, $\vec{\eta}$:parameters , V:covariance matrix, $\vec{\xi}$:constants

$$\chi^2 = (\vec{y}-\vec{\eta})^T V^{-1}(\vec{y}-\vec{\eta}) + 2\sum_{k=1}^{K}\lambda_k\, g_k(\vec{\eta},\vec{\xi}) + \sum_{l=1}^{L}\left(\frac{h_l(\vec{\eta},\vec{\xi})}{\sigma_{h_l}}\right)^2$$

Fit Object　　Hard Constraint　　Soft Constraint

improve MarlinKinfit

- MarlinKinfit is developed that measured values follow a Gaussian distribution.

$$\chi^2 = (\vec{y} - \vec{\eta})^T V^{-1} (\vec{y} - \vec{\eta}) + 2 \sum_{k=1}^{K} \lambda_k \, g_k(\vec{\eta}, \vec{\xi}) + \sum_{l=1}^{L} \left(\frac{h_l(\vec{\eta}, \vec{\xi})}{\sigma_{h_l}} \right)^2$$

- try to redefine chi-square (f, h_l' are p.d.f.) so that it works measured values follow non Gaussian distribution as log-likelihood

$$L(\vec{\eta}) = f(\vec{y}; \vec{\eta}) \prod_{k=1}^{K} \delta(g_k(\vec{\eta}, \vec{\xi})) \prod_{l=1}^{L} h_l'(\vec{\eta}; \vec{\xi})$$

$$\chi^2 = -2 \ln f(\vec{y}; \vec{\eta}) + 2 \sum_{k=1}^{K} \lambda_k \, g_k(\vec{\eta}, \vec{\xi}) - 2 \sum_{l=1}^{L} \ln h_l'(\vec{\eta}; \vec{\xi})$$

forward task

- improve MarlinKinfit to assume Breit-Wigner soft constraint for Z mass
- improve MarlinKinfit to non gaussian fit object
- update ee→ZH→vvbb SN ratio