A New Method For Measuring Higgs Mass

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Motivation & Method

- A new method using only transverse momentum conservation without full momentum or energy is less impacted by beam spectrum and energy uncertainties such as ISR and Beamstrahlung. The equations are as follow with 1,2 referring to Higgs decay products and p_x,p_y for Higss' momentum:

$$p_1 \sin\theta_1 \cos\phi_1 + p_2 \sin\theta_2 \cos\phi_2 = p_x \qquad p_1 \sin\theta_1 \sin\phi_1 + p_2 \sin\theta_2 \sin\phi_2 = p_y$$

$$\begin{pmatrix} p_1 \\ p_2 \end{pmatrix} = \frac{p_t}{\sin\phi_{12}} \begin{pmatrix} \frac{\sin(\phi_2-\phi)}{\sin\phi_2} \\ \frac{\sin(\phi_1-\phi)}{\sin\theta_1 \sin\theta_2} \end{pmatrix}$$

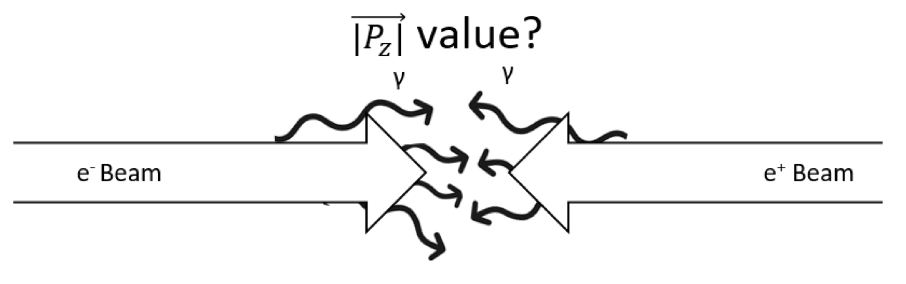
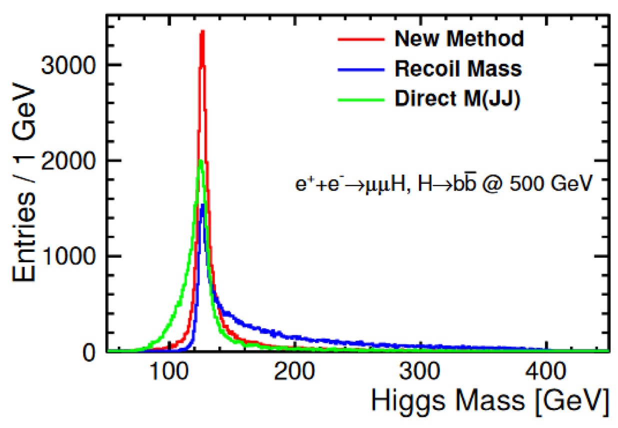


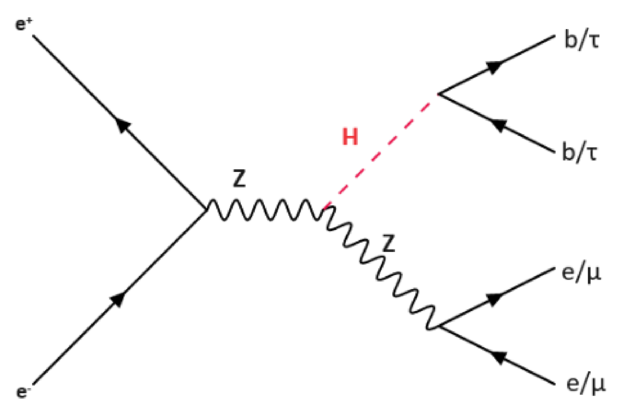
Fig 1: Sources of uncertainty in the longitudinal direction for beam calibration : Beamstrahlung and ISR

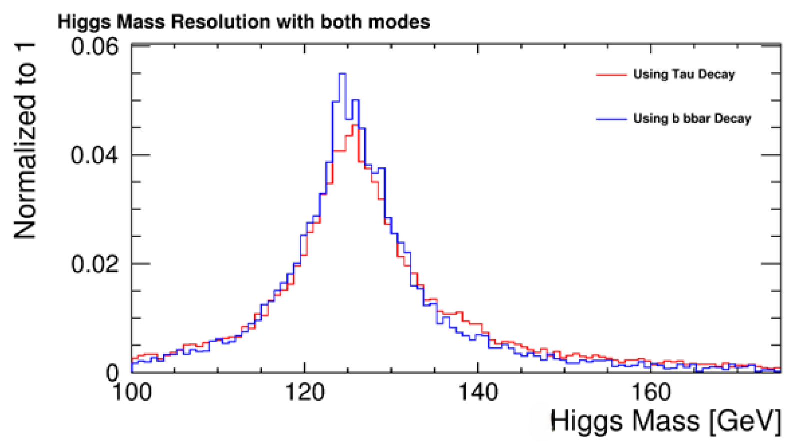


- This is a Complementary method to the Recoil Mass method which can be used at ILC especially at higher energies.

Signal Study

- First simulations done only with signal $H \to b\bar{b}$ (BR=58.2%) and $H \to \tau^+\tau^-$ (BR=6.3%). Z decay is used to tag events and pre-selection.





- For each decay mode, resolutions for θ and ϕ angles and m_H have been fitted with gaussians. $b\bar{b}$ mode has lower systematic error for Higgs mass than $\tau\tau$: $\partial m_H^{bb} = \frac{\Delta m_H^{bb}}{\sqrt{N^{bb}}} = 20MeV$ when $\partial m_H^{\tau\tau} = 100MeV$ with $2000fb^{-1}$ luminosity at ILC.

Resolution	θ_1 [degree]	ϕ_1 [degree]	Δm_H [GeV]
Using bb	0.80 ± 0.03	0.92 ± 0.02	4.17 ± 0.16
Using $\tau^+\tau^-$	0.67 ± 0.01	0.73 ± 0.01	4.51 ± 0.14

Decay Vertex Reconstruction

- To improve the method, the decay vertices can be used to obtain the direction of Higgs decay products directly. The Recoil Mass method is still better when $\sqrt{s} = 250$ GeV but at 500 GeV this tendency could change.
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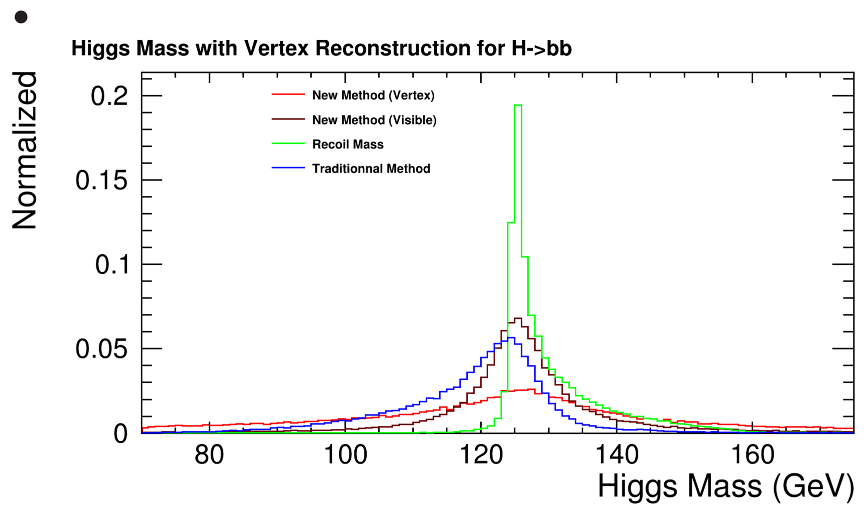
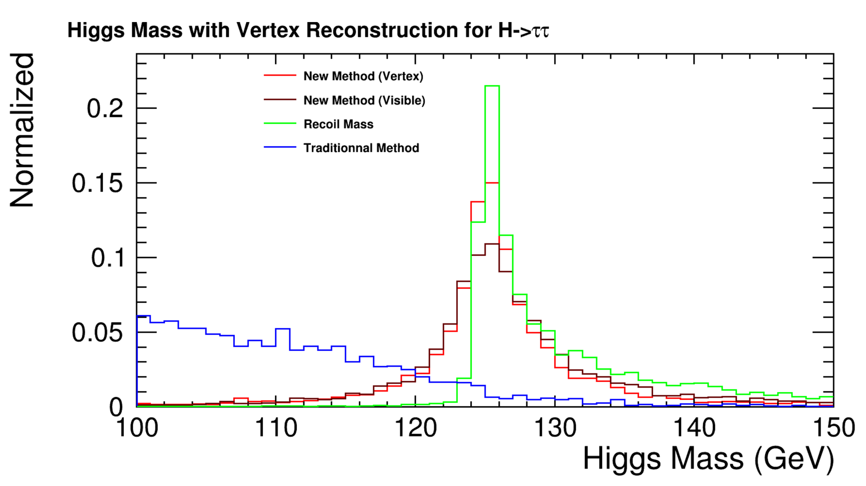




- The new method when using vertices is more precise for $H \to \tau^+\tau^-$ with a sharp peak with a width of 2 GeV. This improves the previous results by a factor of 3 for this mode. For $H \to b\bar{b}$ the precision becomes worse with a 7 GeV width. Because 2 vertices must be found to measure m_H this way, the number of events drops significantly BR($\tau \to 3-prong$)= 15% so a high luminosity comparable to the LHC must be used.

Cuts Chosen for BackGround Elimination

To select which cuts to apply, 2 important quantities to maximize are the significance and efficiency:

$$\eta = \frac{N_{signal}}{\sqrt{N_{signal} + N_{Background}}}, \qquad \epsilon = \frac{N_{aftercut}}{N_{beforecut}}$$

A pre-selection is done where at least one isolated leptons pair must be found with an invariant mass close to m_Z,if more than one found, the closest one is kept. Then, after removing $\gamma\gamma \to$low-p_T hadrons events, the remaining PFOs are given to LCFIPlus for jet clustering and flavor-tagging.
After that, different cuts have been chosen for each decay mode:

- For $H \to b\bar{b}$:

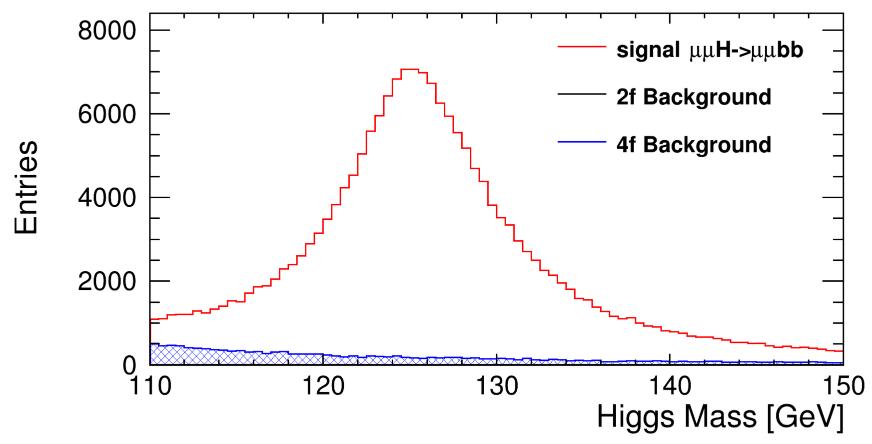
- Cut 1: lepton pair must be muons with mass close to mZ
- Cut 2: $n_{ChargedPFOs}$ >3 in each jet
- Cut 3: E_{vis}+E_{lep} >100 GeV
- Cut 4: b-likeness > 0,66
- Cut 5: Lepton pair: $|\cos Z|$ < 0,9
- Cut 6: Tight cut on Higgs mass: 110<m_H<150 GeV

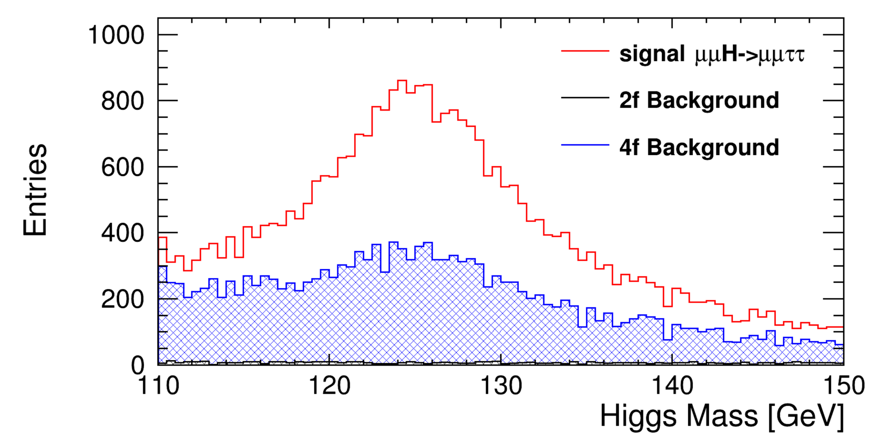
- For $H \to \tau^+\tau^-$:

- Cut 1: lepton pair must be muons with mass close to mZ
- Cut 2: $n_{ChargedPFOs}$ <4 in each
- Cut 3: 220 GeV >E_{vis}+E_{lep} >100 GeV
- Cut 4: E_{vis}+E_{lep} <220 GeV
- Cut 5: Lepton pair: $|\cos Z|$ < 0,9
- Cut 6: At least 1 charged PFO in a jet: $n_{ChargedPFOs}$ >0
- Cut 7: Cut on System's Recoil Mass: 110<m_{Recoil}<150 GeV
- Cut 8: Tight cut on Higgs mass: 110<m_H<150 GeV

Results For Full Simulations

In the $b\bar{b}$ mode, the background is dominated by 4-fermions semi-leptonic processes. A MVA analysis could improve more this choice of cuts but it hasn't been done here yet. For $\tau\tau$, both 2-fermions and 4-fermions leptonic processes are dominant and cuts 3, 6 and 7 were added to filter them.





Thus, we obtain for each mode:

$$\frac{\Delta\sigma_{\mu\mu H} BR(H \to b\bar{b})}{\sigma_{\mu\mu H} BR(H \to b\bar{b})} = \frac{1}{\eta} = \frac{1}{74} = 1.35\% \quad \Delta m_H^{b\bar{b}} = 20MeV$$

$$\frac{\Delta\sigma_{\mu\mu H} BR(H \to \tau^+\tau^-)}{\sigma_{\mu\mu H} BR(H \to \tau^+\tau^-)} = \frac{1}{\eta} = \frac{1}{15} = 6.67\% \quad \Delta m_H^{\tau\tau} = 73MeV$$

The analysis is done with the new method without using decay vertices and full background simulations. The $H \to b\bar{b}$ mode has better significance at $\eta = 74$ and $\epsilon = 0.60$ while $H \to \tau^+\tau^-$ is at $\eta = 15$ and $\epsilon = 0.48$.
With a Gaussian fit, the uncertainty is 20 MeV for $H \to b\bar{b}$ and 73 MeV for $H \to \tau^+\tau^-$. The analysis using decay vertices hasn't been done yet and could yield better results for the τ mode. Also, the electron channel $Z \to e^+e^-$ can be used to have more statistics.

References

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Partners & Aknowledgements