ILD PRESENTATION 03/07

A NEW METHOD FOR MEASURING HIGGS MASS AT ILC

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Motivations & Physics

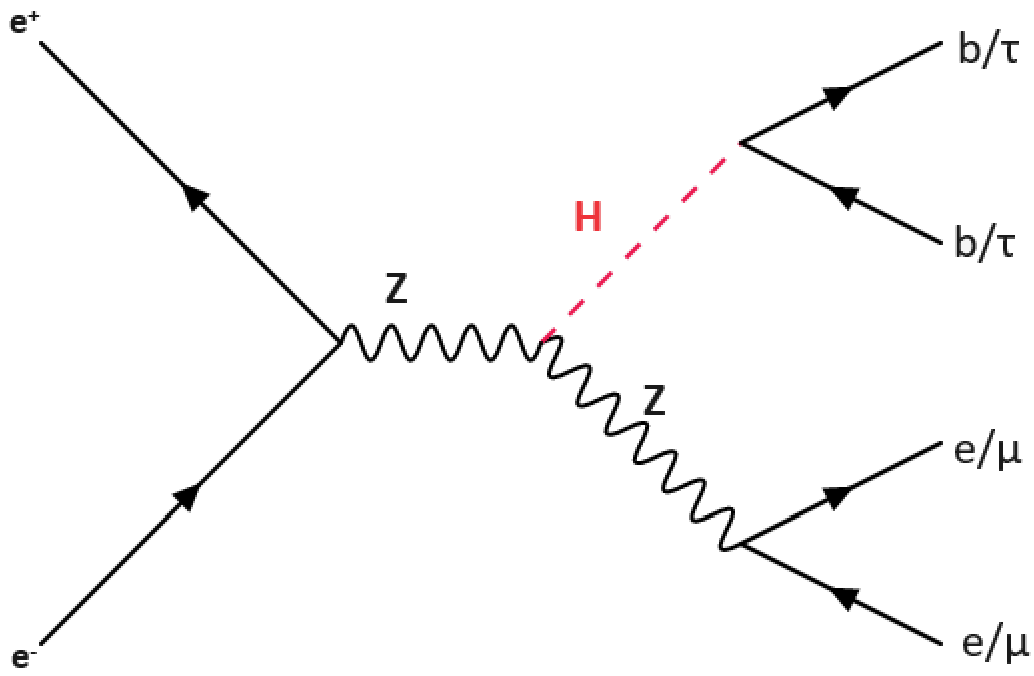
Higgs mass is a crucial input parameter in partial widths in *H→ZZ** and *H→WW** coupling

Very sensitive to m_H measurement:

$$\frac{\Delta\Gamma(H\to ZZ^*)}{\Gamma(H\to ZZ^*)} = 16 * \frac{\Delta m_H}{m_H}, \quad \frac{\Delta\Gamma(H\to WW^*)}{\Gamma(H\to WW^*)} = 14 * \frac{\Delta m_H}{m_H}$$

For a 0,1% - 0,5% precision, an uncertainty of 16-80MeV is the aim for m_H.

The New Method



Studied Processes are $e^+e^- \rightarrow ZH$, $Z \rightarrow \mu^+ \mu^-$ and $H \rightarrow \tau^+\tau^-$ compared with $H \rightarrow b\bar{b}$.

Branching Ratios:

$H \rightarrow b\bar{b}$ 58,2%

$H \rightarrow \tau^+\tau^-$ 6,3%

$Z \rightarrow \mu^+\mu/e^+e^-$ 3,36%

Electron Channel could also be added.

Provide a complimentary method to Recoil Mass to be used at ILC

Let 1,2 refer to Higgs decay products, p_x and p_y to Higgs' momentum, p_t to transverse momentum and ϕ,θ to angles.

Using only Transverse Momentum Conservation with p_1 and p_2:

$$\begin{pmatrix} p_1 \\ p_2 \end{pmatrix} = \frac{p_t}{\sin \phi_{12}} \begin{pmatrix} \frac{\sin(\phi - \phi_2)}{\sin(\theta_1)} \\ \frac{\sin(\phi_1 - \phi)}{\sin(\theta_2)} \end{pmatrix}, \quad \begin{array}{l} p_1 \sin\theta_1 \cos\phi_1 + p_2 \sin\theta_2 \cos\phi_2 = p_x \\ p_1 \sin\theta_1 \sin\phi_1 + p_2 \sin\theta_2 \sin\phi_2 = p_y \end{array}$$

Advantages:

-No energy in the resulting mass formula, only direction needed

-Less uncertainty from Beam calibration, especially at higher energies

-Complementary method with the Recoil Mass

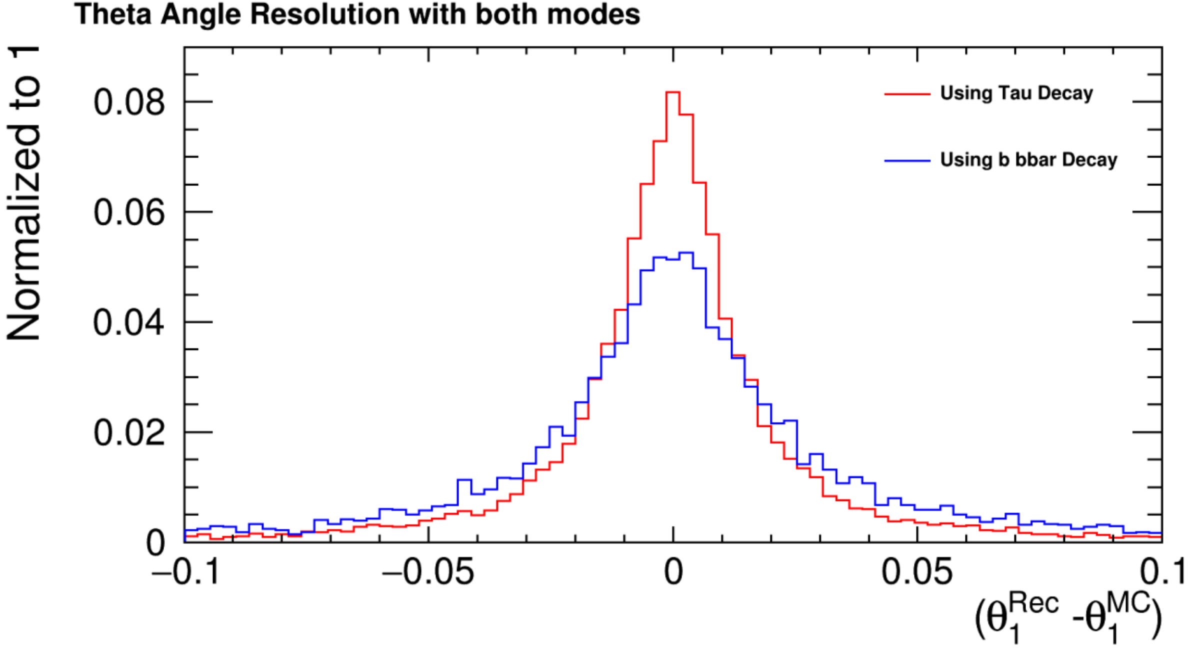
Simulations

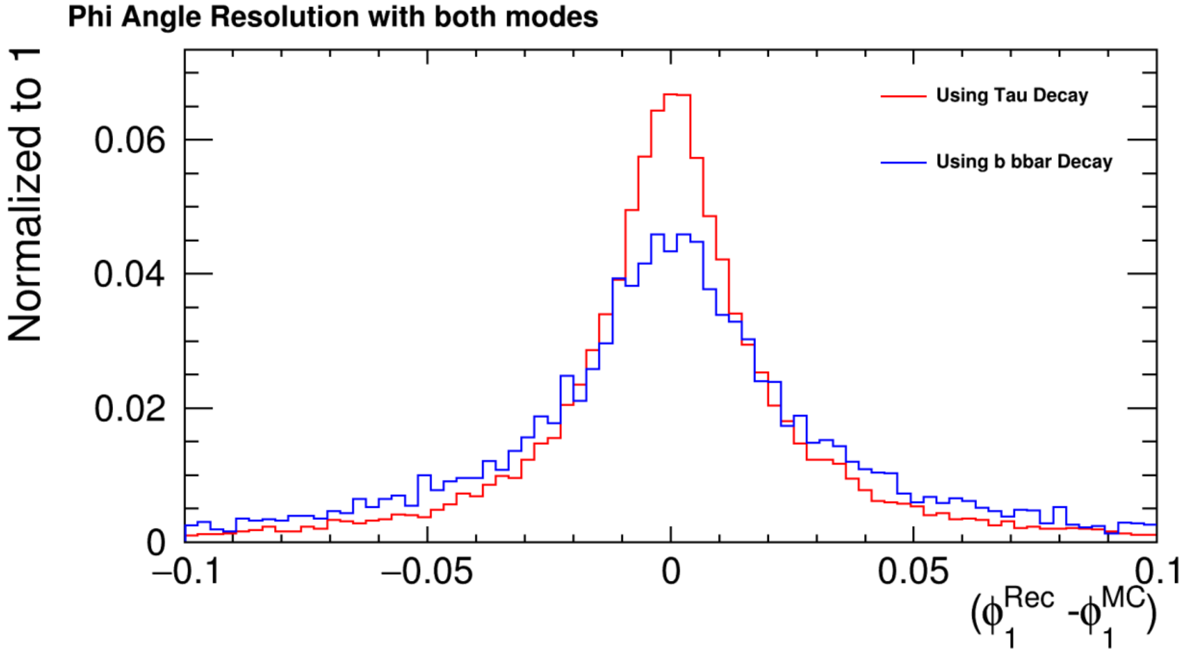
Whizard: Event Generator with ISR, Beamstrahlung and Parton showers and hadronization by with Pythia ➔ Monte Carlo events or Truth events

GEANT4: Simulates the detectors and the detection of Truth events

PandoraPFA and LCFIPlus: Full event reconstruction with digitization, particle flow analysis, jet clustering…

Physics Analysis with ROOT

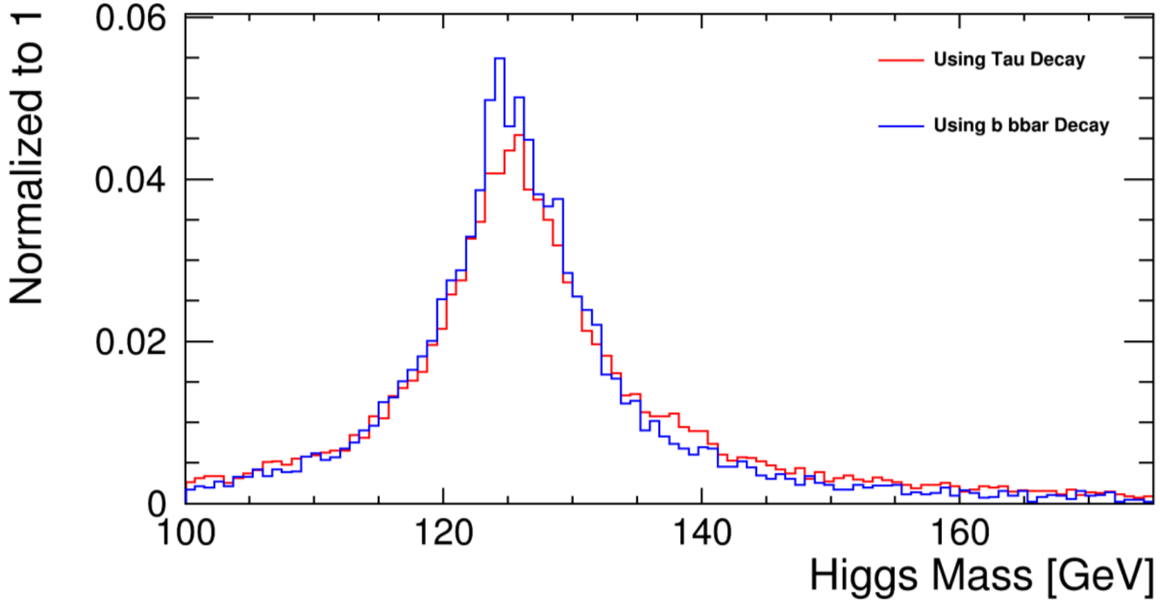




All data is computed for both of the H decay products and shown for either $\tau\tau$ or bb.

Relative Resolution for m_H and Absolute Resolution for angles are fitted with Gaussians with ROOT to get the errors of each channel

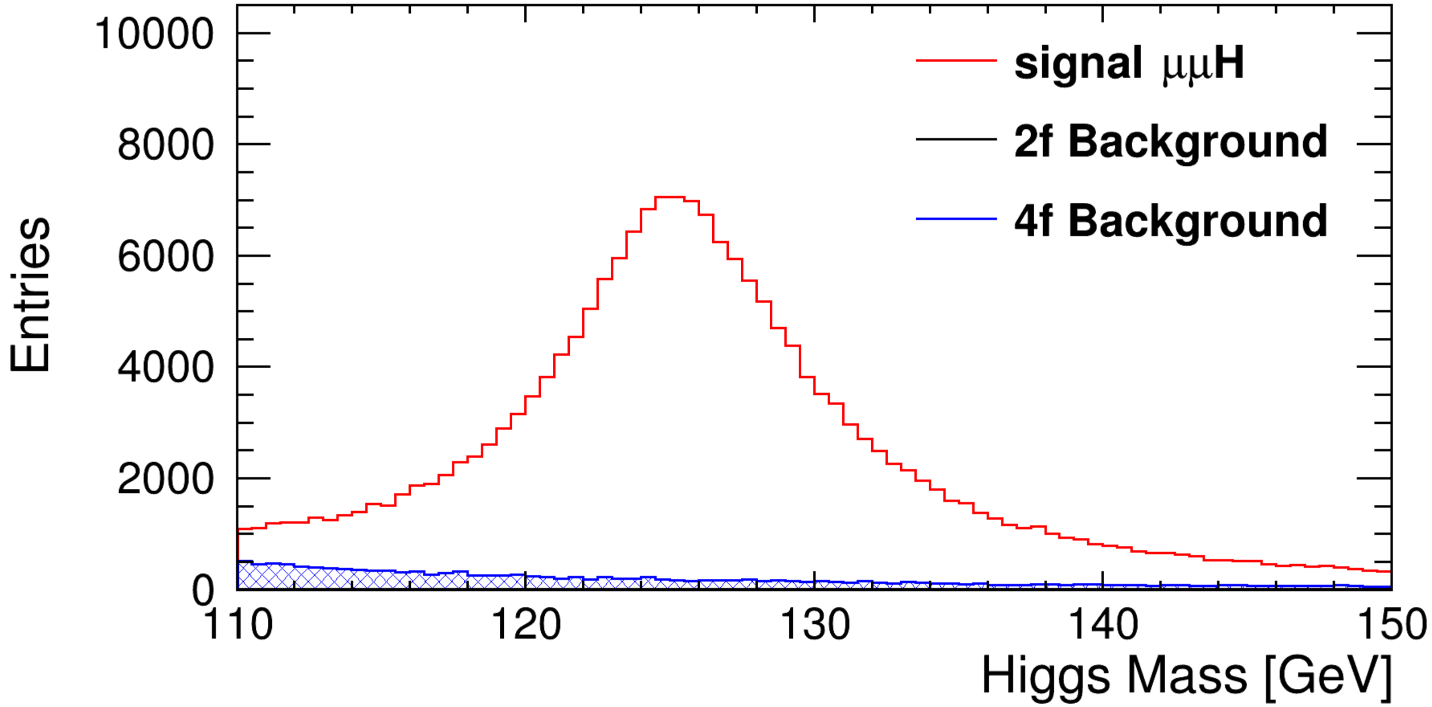
The distributions are similar in each cases for $b\bar{b}$ and $\tau\tau$ with the $b\bar{b}$ more peaked.



Resolution	θ_1 [degree]	ϕ_1 [degree]	Δm_H [GeV]
Using $b\bar{b}$	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

With a 2000fb^{-1} Luminosity, 100% efficiency and the $\mu\mu$ channel for Z decay,

The error $\partial m_H = \frac{\Delta m_H}{\sqrt{N}}$ is then ~20MeV for $b\bar{b}$ and ~100 MeV for $\tau^+\tau^-$



Process	2f_l	2f_h	4f_l	4f_sl	4f_h	BG	llh	Signal	Signf
Cross Section (fb)	103542	695920	15807.9	19163.2	16800.5	232638	10,3083	**5,95817**	
Generated Events	1,88E+08	9,71E+08	1,12E+07	1,66E+07	9,58E+06	1,20E+09	1,00E+06	**1,00E+06**	
Cut0	1,46E+06	16048	3,27E+06	824121	270,899	5,57E+06	19429.3	**11311.2**	**4.78924**
Cut1	1,03E+06	31,778	8,20E+04	158666	0	1,28E+06	17449,4	**10168.8**	**8,96809**
Cut2	2,40E+00	23,4257	3,18689	122529	0	1,23E+05	14173,8	**9537.39**	**26,2413**
Cut3	2,40064	22,019	3,18689	122529	0	1,23E+05	14161,2	**9537.39**	**26,2425**
Cut4	0	1,36209	0,218908	290778	0	2,91E+05	9237,16	**8958,71**	**45,9345**
Cut5	0	1,36209	0	22626,9	0	2,26E+04	8415,75	**8161,5**	**46,5127**
Cut6	0	0	0	2513,97	0	2,51E+03	7281,25	**7084.71**	**72,3121**

Full simulations at 250 GeV. With all backgrounds + Cuts.

$$\sigma = \frac{N_{signal}}{\sqrt{N_{signal} + N_{Background}}}$$

60% Efficiency and 72 sigmas for the bb mode.

Gaussian Fit gives: m_H=125,28±0,019GeV

Cuts Applied to bb mode:

Cut 1: lepton pair must be muons with mass close to m_Z at 10GeV

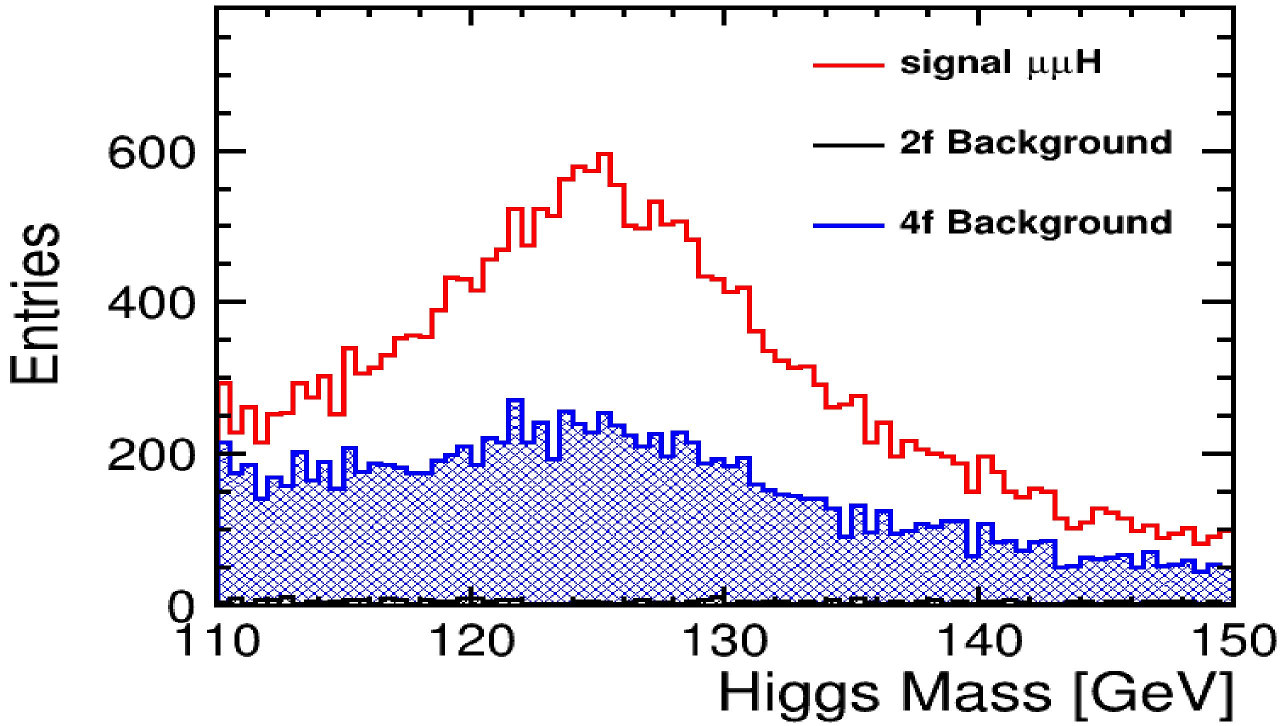
Cut 2:$n_{ChargedPFOs}$ >3 in each jet

Cut 3:E_{vis}+E_{lep} >150 GeV

Cut 4: b-likeness > 0,66

Cut 5: Lepton pair: abs(cos) < 0,9

Cut 6:Tight cut on Higgs mass: 110<m_H^{new}<150 GeV



Process	2f_l	2f_h	4f_l	4f_h	4f_sl	BG	llh	Signal	Signf
Cross Section	12928.9	231973	15807.9	19163.2	16800.5	296728	10.31	**0.66**	
Events	2.60e+07	4.64e+07	3.16e+07	3.83e+07	3.36e+07	5.93e+08	20616.5	**1313.27**	**0.846**
Cut0	1.45e+06	16048.00	3.27e+06	824121.00	270.90	5.57e+06	19429.30	**1221.13**	**0.518**
Cut1	1.03e+06	31.78	82040.60	15866.10	0	1.28e+06	17449.40	**1094.55**	**0.969**
Cut2	1.03e+06	0	81438.20	2132.72	0	1.18e+06	1604.86	**1062.67**	**1.005**
Cut3	1.03e+06	0	80885.70	2132.72	0	1.14e+06	1604.62	**1062.55**	**1.006**
Cut4	369732.00	0	35189.40	528.38	0	405451.00	1437.07	**954.75**	**1.498**
Cut5	288014.00	0	20762.60	201.28	0	49765.30	1396.04	**870.66**	**3.869**
Cut6	1699.11	0	8590.98	182.62	0	10472.80	1236.30	**832.15**	**7.826**
Cut7	954.57	0	3265.98	98.82	0	4318.88	1194.68	**803.74**	**11.230**
Cut8	46.19	0	986.32	5.94	0	4275.34	667.96	**627.46**	**15.373**

Worse significance and efficiency at 48% for tau channel and σ=15

Less events because BR(ττ)= 6% but BR(bb)=58%

Fit gives:
m_H=125,31± 0,072 GeV

For ττ:

Different Cuts and more added for leptonic background:

Cut 1: lepton pair must be muons with mass close to m_Z

Cut 2:$n_{ChargedPFOs}$ <4 in each jet because τ decays to 1-prong or 3-prong

Cut 3:$E_{vis}+E_{lep}$ >100 GeV

Cut 4:$E_{vis}+E_{lep}$<220 GeV

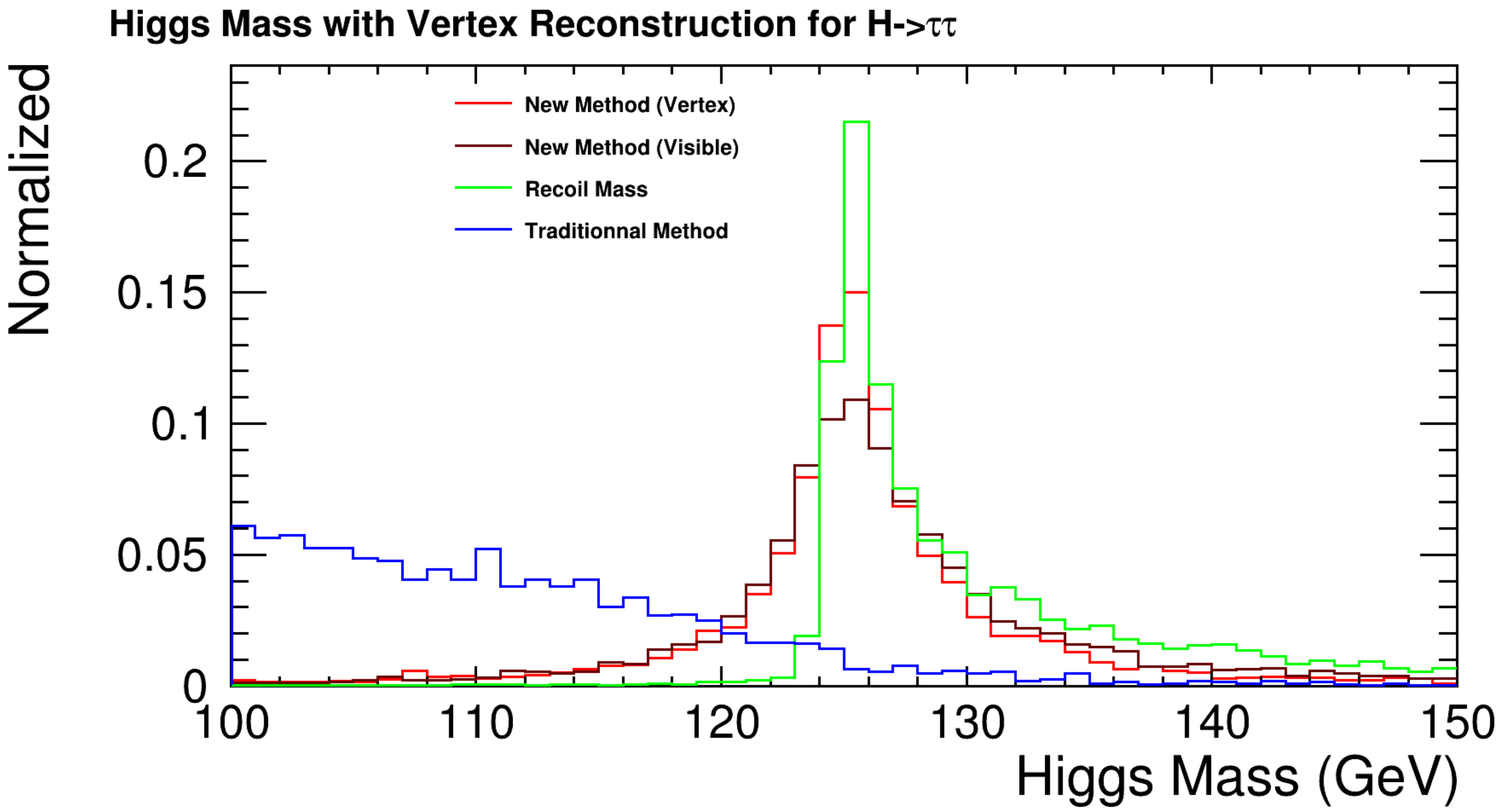
Cut 5: Lepton pair: abs(cos) < 0,9

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^{new}<150 GeV

Possible Improvements:



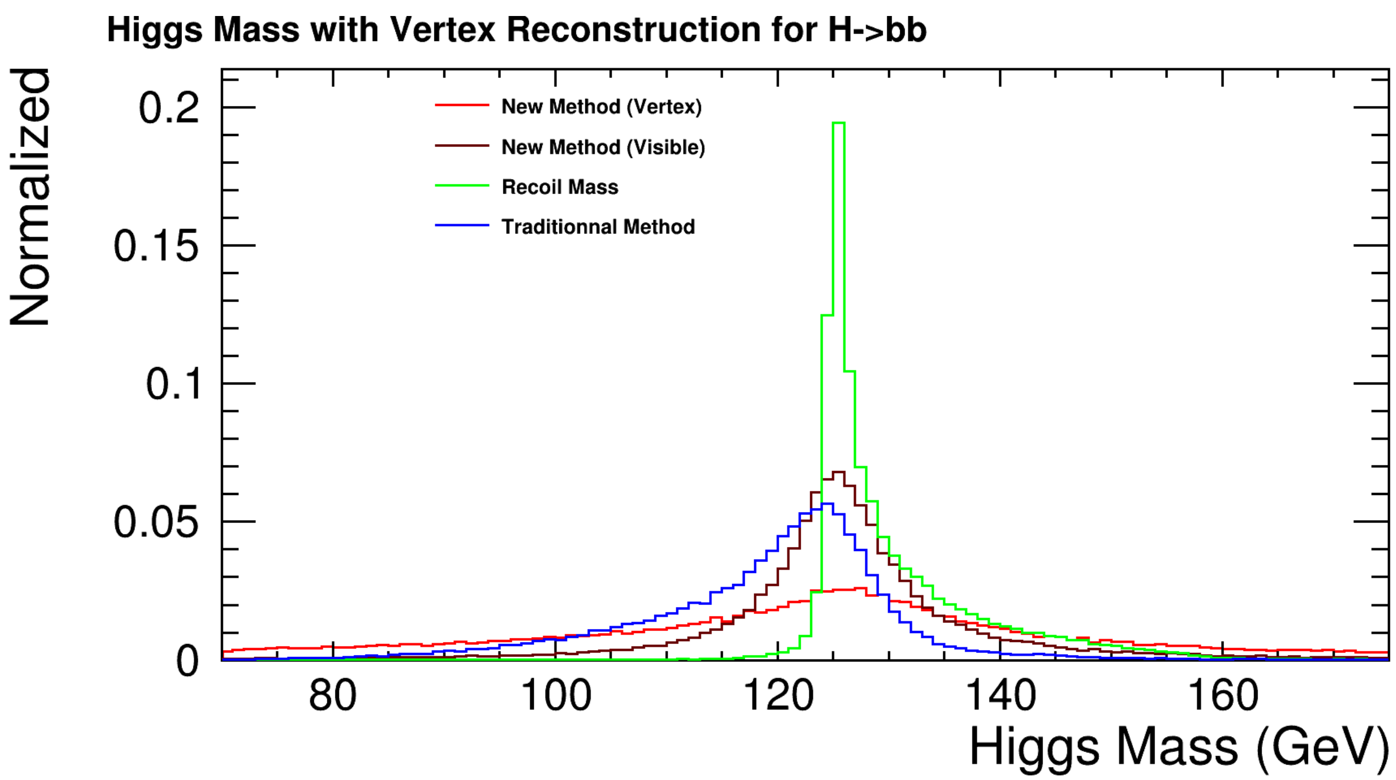
Use the 2 Decay Vertices for measuring directions of b or τ

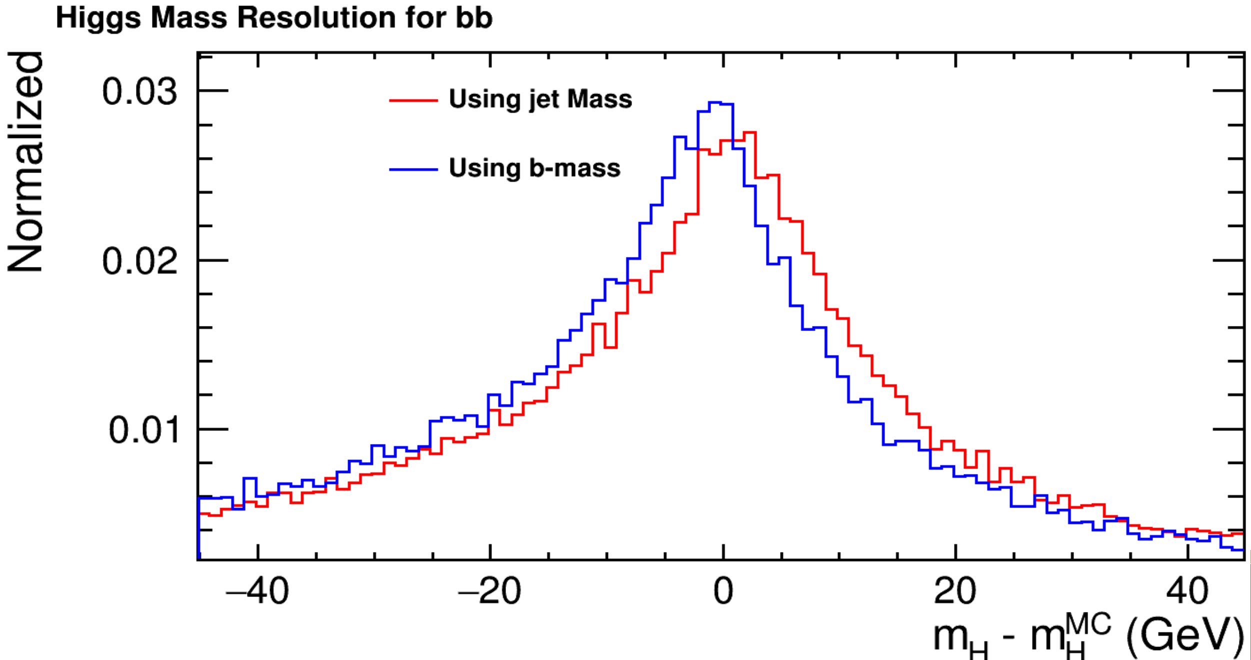
More peaked:

σ=2GeV

Δm_H=48 MeV

Small Number of events for ττ so need higher luminosity





For bb, more events where 2 vertices are found but worse performance:

σ=7,4 GeV
Δm_H=242 MeV

Shift between b-jet mass and b mass. Not centered on 0 aswell.

Thank You For Your Attention