Kinematic Reconstruction of Higgs Mass at the ILC.

Higgs hadronic decays at $\sqrt{s} = 350, 500\,GeV$

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DESY

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Overview

Motivation

- Precise Determination of the Higgs Mass
- Previous Study
- Analysis Plan

Analysis

- Kinematic Reconstruction of the Higgs Mass
- Jet Energy Uncertainty

Precise Determination of the Higgs Mass

- Higgs mass is an important parameter in the Standard Model
- m_H is a crucial input parameter for studying the Higgs physics
- Branching ratios like $H \to ZZ^*, WW^*$ are very sensitive to m_h
- Uncertainties on the m_H translates to uncertainties on couplings extracted from these decay modes

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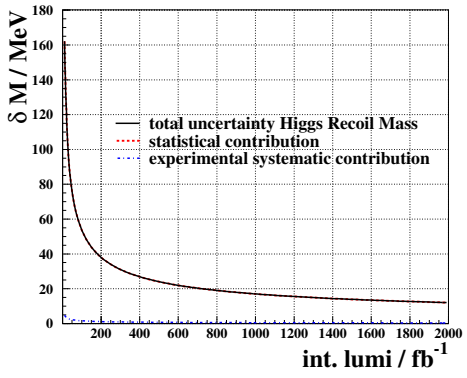
- At the ILC, dominant Higgsstrahlung process at $\sqrt{s} = 250 GeV$ enables model-independent measurement
- m_H can be determined with an accuracy of $\delta m_H = 25 MeV$ from leptonic recoil
- Requires huge luminosity at $\sqrt{s} = 250 GeV$
- Is there an alternative?



Luminosity scaling of the Higgs recoil mass measurement at $\sqrt{s} = 250 GeV$ [arXiv:1506.07830]

Previous Study

arXiv:hep-ex/0505096

Measurement of the Higgs Boson Mass with a Linear e^+e^- Collider *P. Garcia-Abia, W. Lohmann, A. Raspereza*

- Studied the potential of a linear e^+e^- collider operated at $\sqrt{s} = 350$ for the measurement of the Higgs mass
- Integrated luminosity of $500 fb^{-1}$ assumed
- Higgs masses of 120, 150 and $180 GeV$
- Uncertainty on the Higgs mass measurement is estimated to be 40, 65 and $70 MeV$

Decay Mode	Δm_H in MeV 120	150	180
$ZH \to l^+l^- q\bar{q}$	85	100	-
$ZH \to q\bar{q}q'\bar{q}'$	45	170	-
$ZH \to l^+l^- WW$	-	90	80
$ZH \to q\bar{q}WW$	-	100	150
Combined	40	65	70

Uncertainties on the determination of m_h

Analysis Plan

- Redo the analysis of $ZH \rightarrow q\bar{q}q'\bar{q}'$ using modern simulation for two center-of-mass energies:
  - $\sqrt{s} = 350\,GeV$
  - $\sqrt{s} = 500\,GeV$
- Try to assess systematics of the measurement

Analysis

- Isolated Lepton Tagging
  - CutOnTheISOElectronMVA: 0.5
  - CutOnTheISOMuonMVA: 0.7
- Fast Jet Finder
  - Algorithm: kt algorithm 1.5
  - Clustering Mode: ExclusiveNJets 6
- Satoru Jet Finder
  - Algorithm: DurhamNjet
  - Number of jets requested: 4
- Kinematic fittting
  - Opal Fitter
  - Excluding ISR photons

Kinematic Fit at $\sqrt{s} = 350\,GeV$

- MC sample generated and reconstructed for the DBD
- Plots are for fixed number of events (20,000 events)
- Fixed constraints:
  - Center-of-Mass energy
  - Momenta
- Fitted using both hard and soft constraint on m_Z

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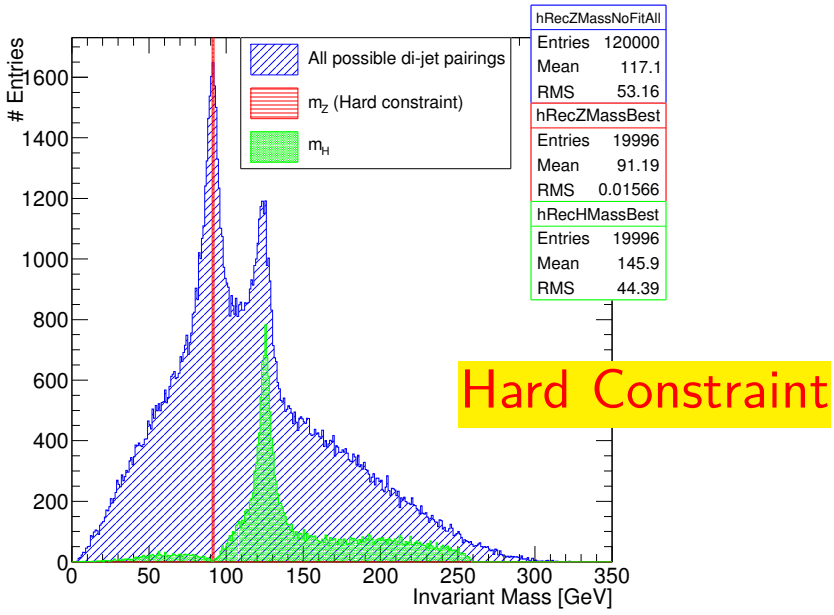
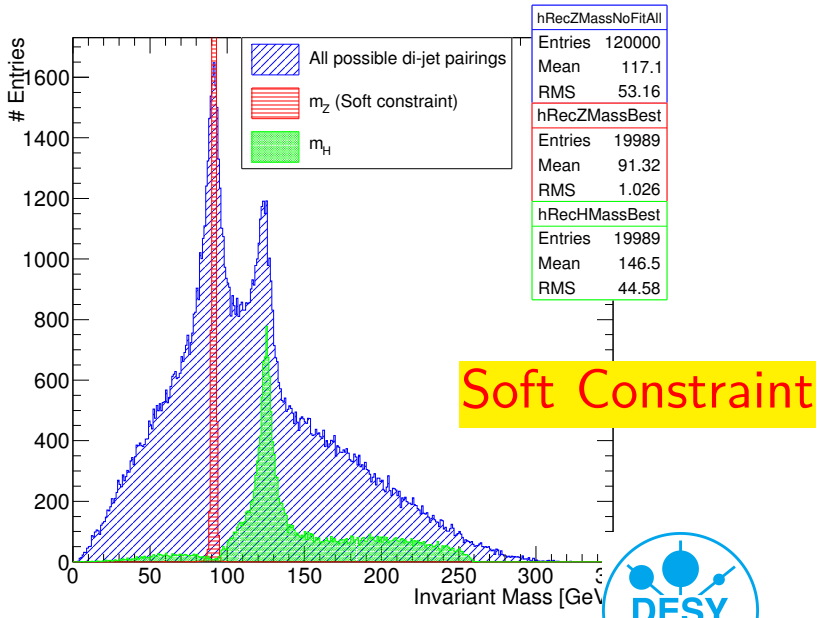
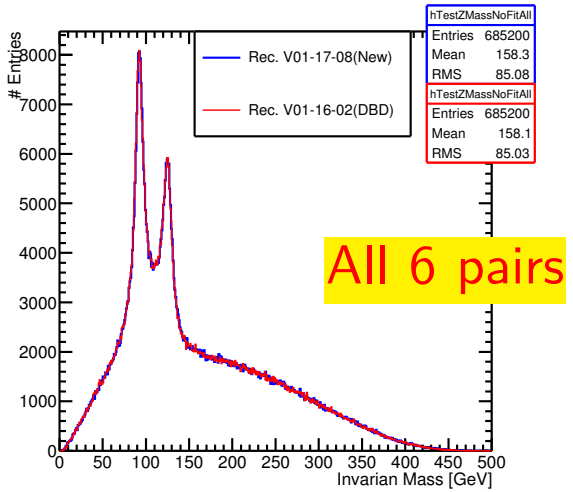


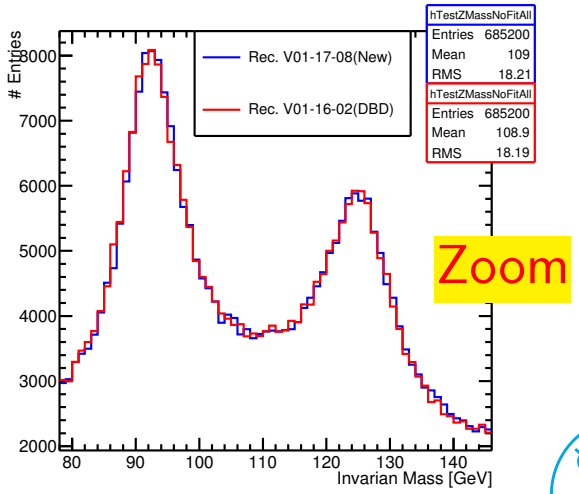


Comparison of Reconstruction Software Versions

- MC sample generated for the DBD, but not reconstructed
- Reconstructed a sample of 100k events using ILCSoft
  - DBD version (v01-16-02)
  - Latest version (v01-17-08)
- No effect is observed
- Fit on the Higgs peak:

Software Version	Mean [GeV]	Error [GeV]
v01-16-02	124.67	0.0763
v01-17-08	124.70	0.0768





Kinematic Fit at $\sqrt{s} = 500\,GeV$

- Sample reconstructed using latest ILCSoft
- Fixed constraints:
  - Center-of-Mass energy
  - Momenta
  - Hard constraint on m_Z
- Plots are for fixed number of events (100,000 events)

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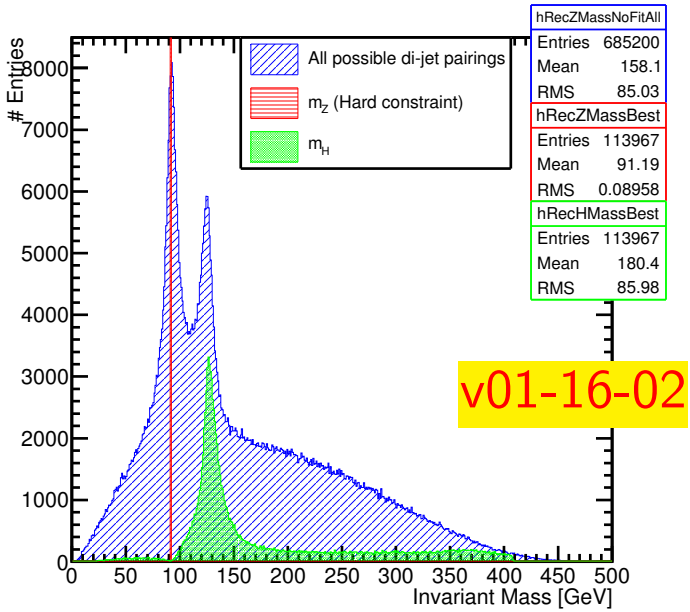
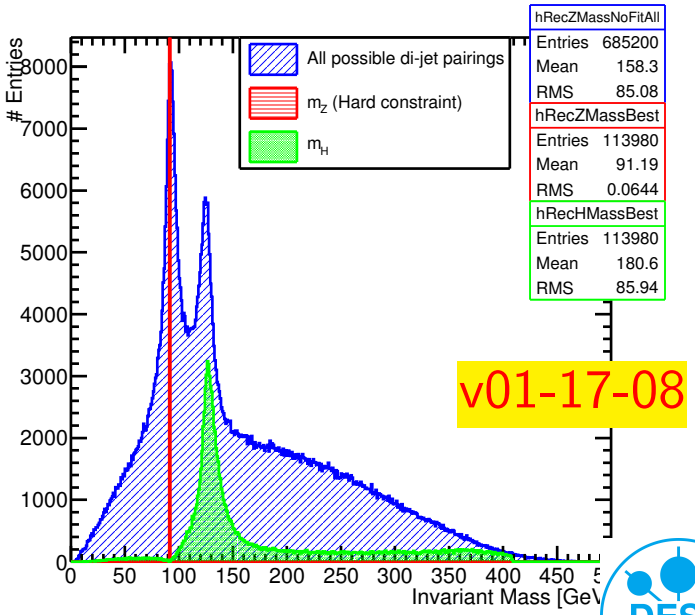
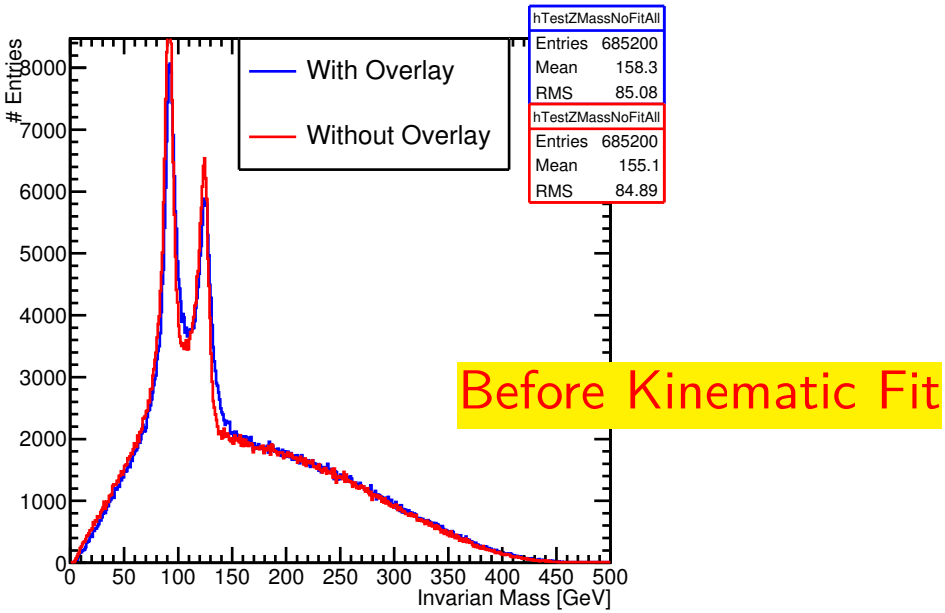


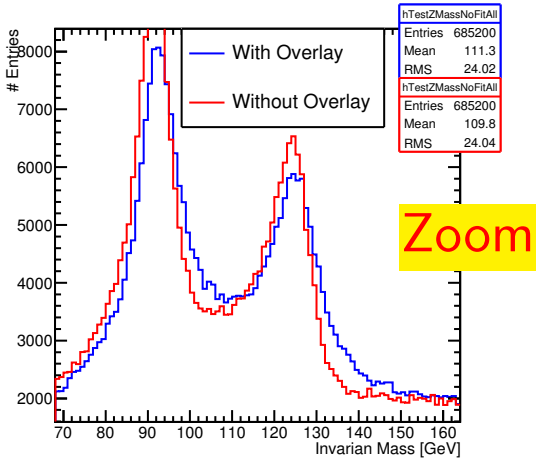


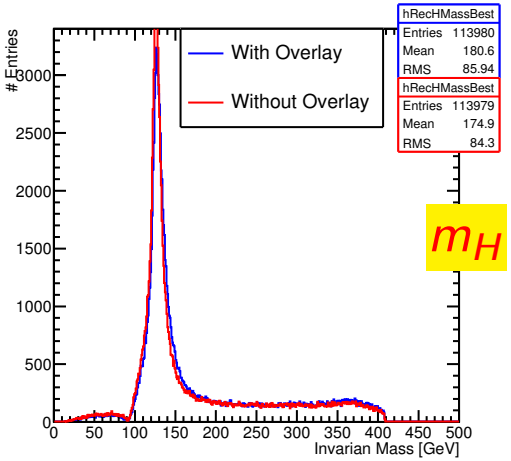
Effect of $\gamma - \gamma$ Background Overlay

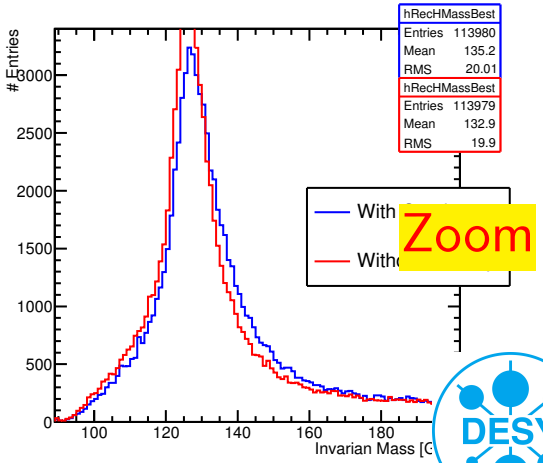
- Reconstructed using ILCSoft v01-17-08 with and without $\gamma - \gamma$ background overlay
- Overlay removal can be further optimized?

Kinematic Fit	$\gamma - \gamma$	**Mean [GeV]**	**Error [GeV]**
Before	w	124.701	0.0768
Before	w/o	123.835	0.0662
After	w	127.213	0.0806
After	w/o	126.261	0.0472









Kinematic Fit Uncertainties

JetFitObject

JetFitObject j1 (E, θ, ϕ, σ_E, σ_θ, σ_ϕ, m);

For the previous plots fixed uncertainties which give good results are used:

- $\sigma_\theta = 100 mrad$
- $\sigma_\phi = 100 mrad$
- $\sigma_E = 1.2/\sqrt{E}$

What if we compute σ_E per jet based on its content?

Jet Energy Resolution Results

Sum up energy uncertainties for all PFOs in a jet:

- If PFO is charged: use its covariance matrix
- If PFO is a photon: use ECAL energy resolution $\frac{\sigma_E}{E} = \frac{16\%}{\sqrt{E}} \oplus 2\%$
- If neutral hadron: use HCAL energy resolution $\frac{\sigma_E}{E} = \frac{50\%}{\sqrt{E}} \oplus 1\%$

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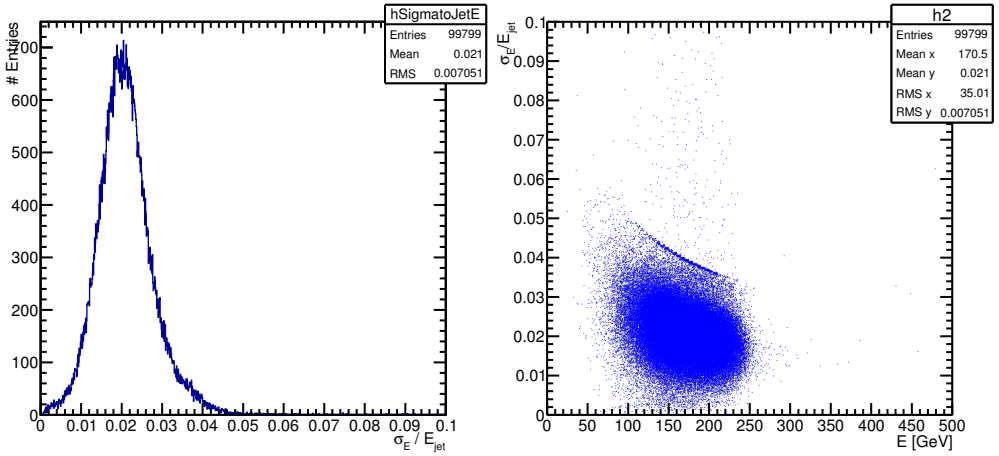

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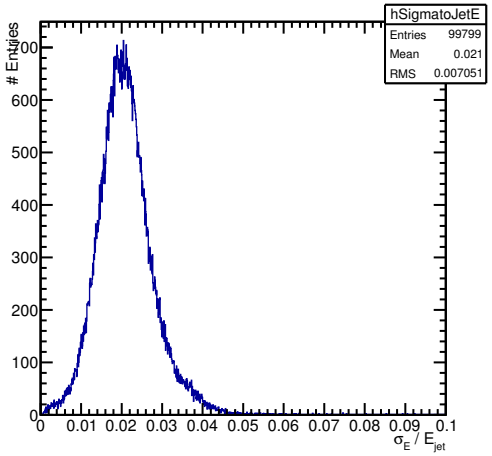

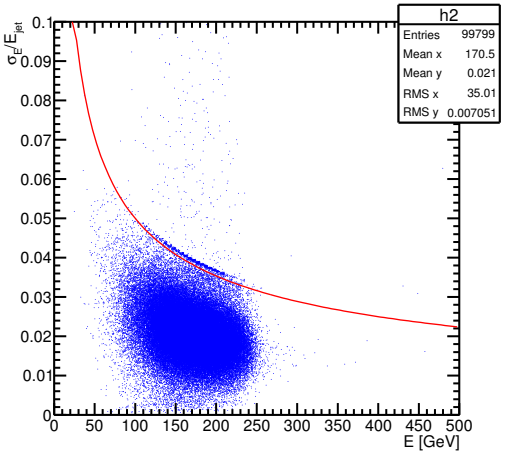

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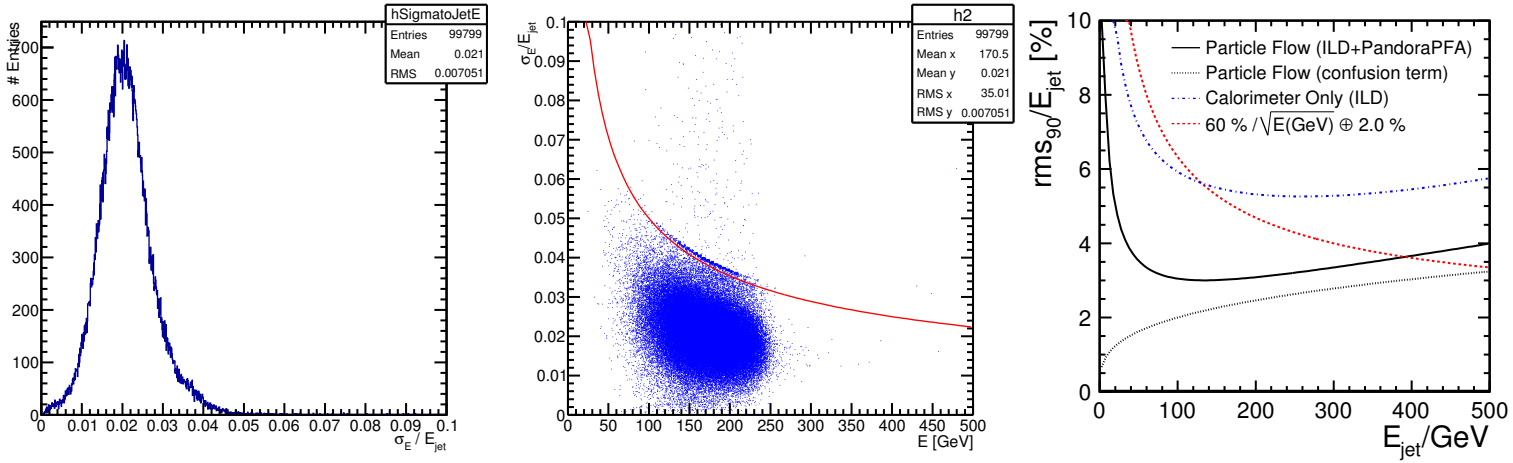
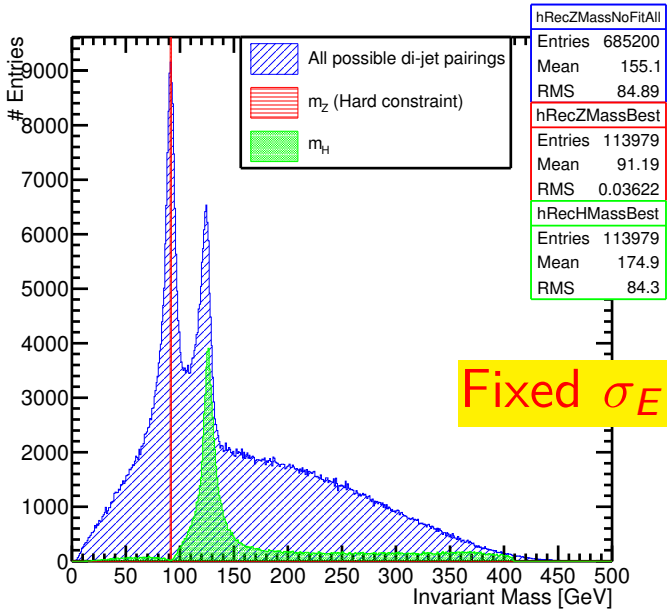
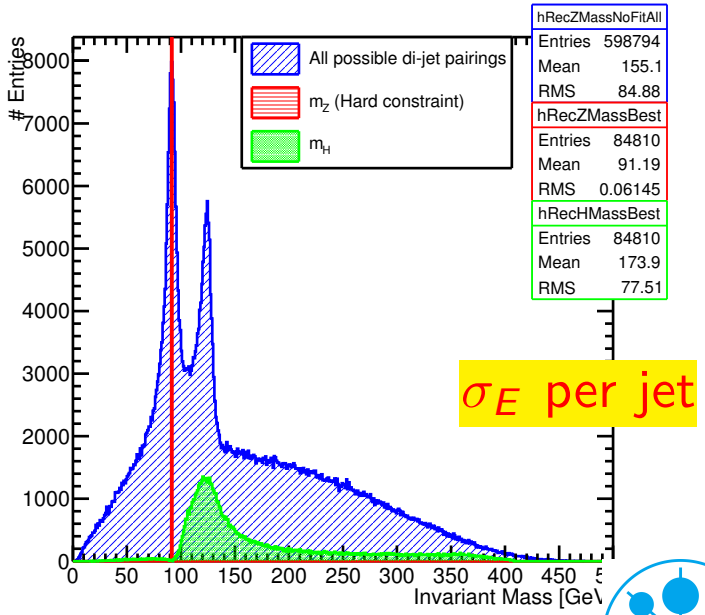


Kinematic fit using propagated errors at $\sqrt{s} = 500\,GeV$

- MC sample generated for the DBD, not reconstructed
- Reconstructed a sample of 100k events using ILCSoft v01-17-08
- Constraints on Center-of-Mass energy, momenta and hard constraint on m_Z





Summary

- Kinematic fit processor for $ZH \rightarrow q\bar{q}q'\bar{q}'$ process is developed
- First kinematic fit is performed for $\sqrt{s} = 350 GeV$
- MC sample dataset generated for the DBD is reconstructed using DBD and latest versiions of the ILC soft
- First kinematic fit is performed for $\sqrt{s} = 500 GeV$ using $\sigma_E = \frac{120\%}{\sqrt{E}}$
- σ_E computed per jet based on the jet contents
- New σ_E is used to perform kinematic fit.
- Confudion term to be included in per jet σ_E
- Systematics assessment to be performed after error propagation study is done

Backup

Kinematic Fitting

- Energies and momenta of reconstructed particle are measured with uncertainties which is limited by detector resolution, hadronisation, etc.
- Each event is bound to some constraints like energy and momentum conservation
- Kinematic fit uses this information to fit the data
- To fit the data kinematic fit needs to have underlying hypothesis and to know which objects are to be fitted
  - $e^+e^- \rightarrow ZH \rightarrow q\bar{q}q'\bar{q}'$: 4 jets
- Each object is characterized by fixed or measured parameters
  - Measured: E, θ, ϕ
  - Fixed: Mass