4C Fits in $e^+e^- \rightarrow WW/ZZ \rightarrow qqqq$ at $E_{cm}=1$ TeV

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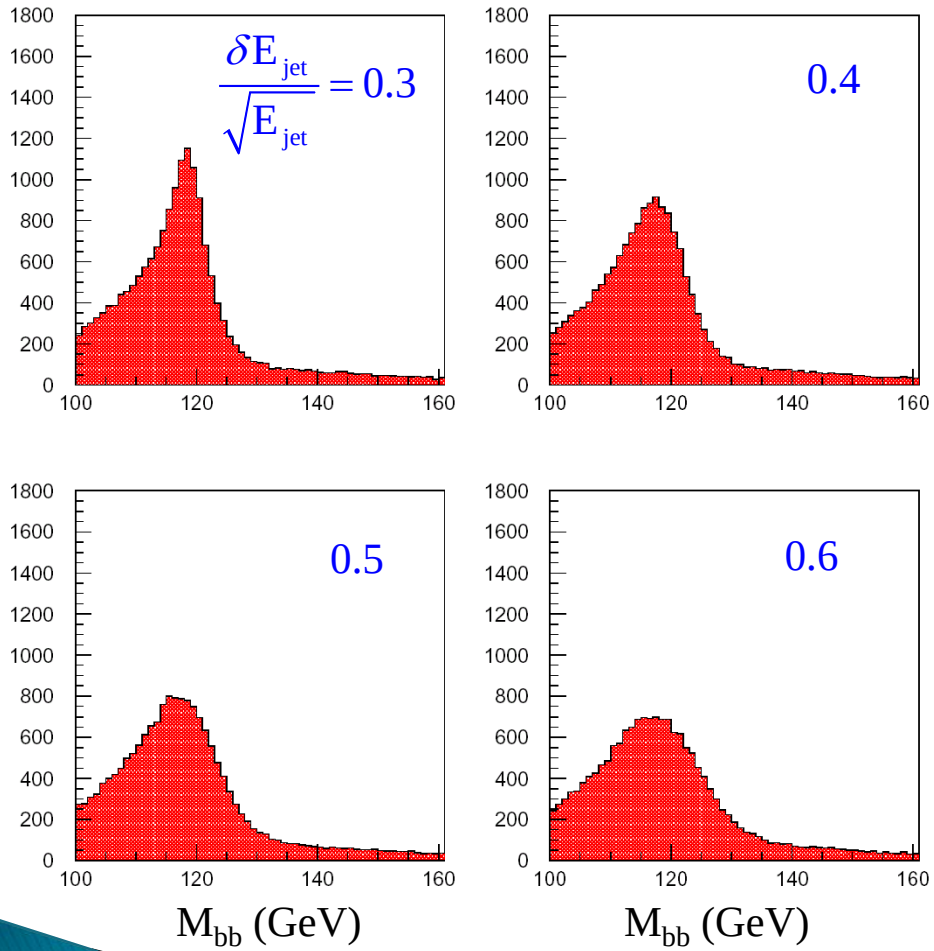
Procedure

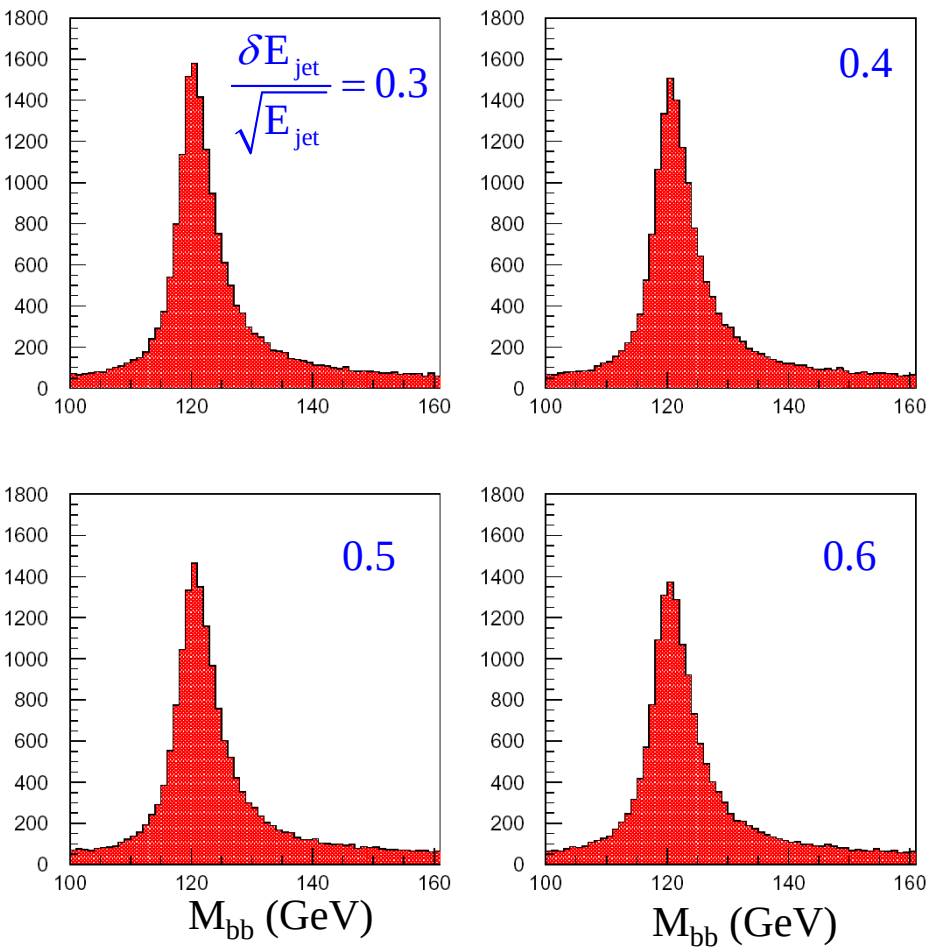
- Start with 200,000 e+e- → uddu events at E_{cm}=1 TeV processed through sim+reco using the sidloi3 detector
- Use truth information to remove events with ISR
- Match reco jets with true jets
- Use the matched jets to find the errors in the 16 variables. (E,β,Θ,ϕ for each jet)
- Constrain ΣE = 1000, ΣPx = ΣPy = ΣPz = 0.
- Motivation: Fast MC study of ZH at 350 GeV

$$e^+e^- \to ZH \to qqb\bar{b}$$

Reconstructed M_{bb}



4C Fitted M_{bb}



“Perfect” reconstruction used to define true jets

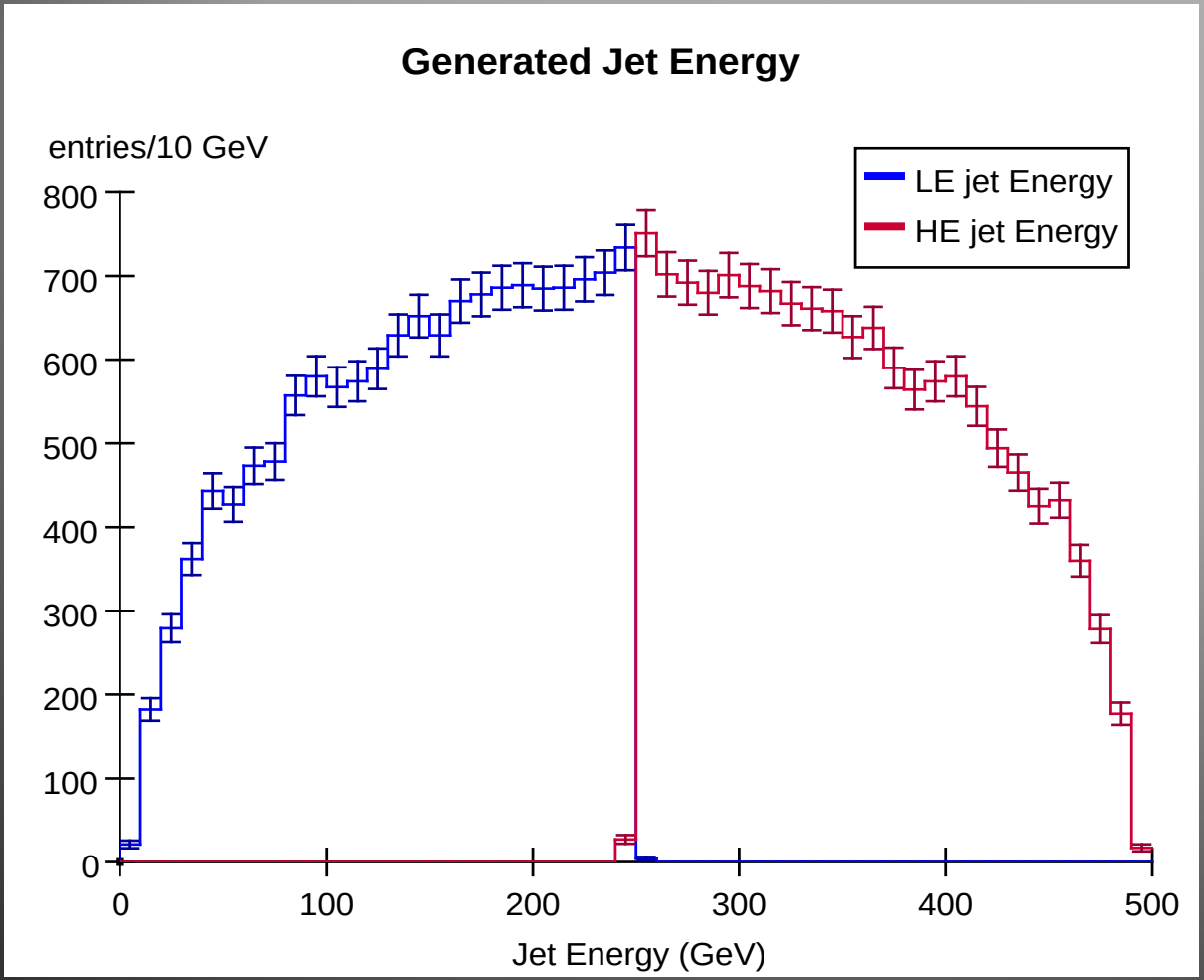
- Find pdg94 particles. If n != 2, fail.
- Find parent quarks. If n != 2, only use quarks with 1 daughter. If n still != 2, fail.
- Trace generator final state particles to pdg94.
- Boost quarks and fs particles to pdg94 system, then attach fs particles to nearest q.
- Jet 0 is max E jet in dijet with max cos(Θ), jet 1 partner, jet 2 maxE in other dijet, jet 3 partner
- Should be no difference in jet 0,2 distributions or jet 1,3 distributions

Jet clustering from PFOs

- Hemisphere cut: Use thrust axis, separate particles by dot product >< 0.
- For each hemisphere: Boost to cm, find thrust axis, separate into hemisphere.
- If # particles in any of the 4 jets < 2, fail.
- Match to “perfect” with chisq.

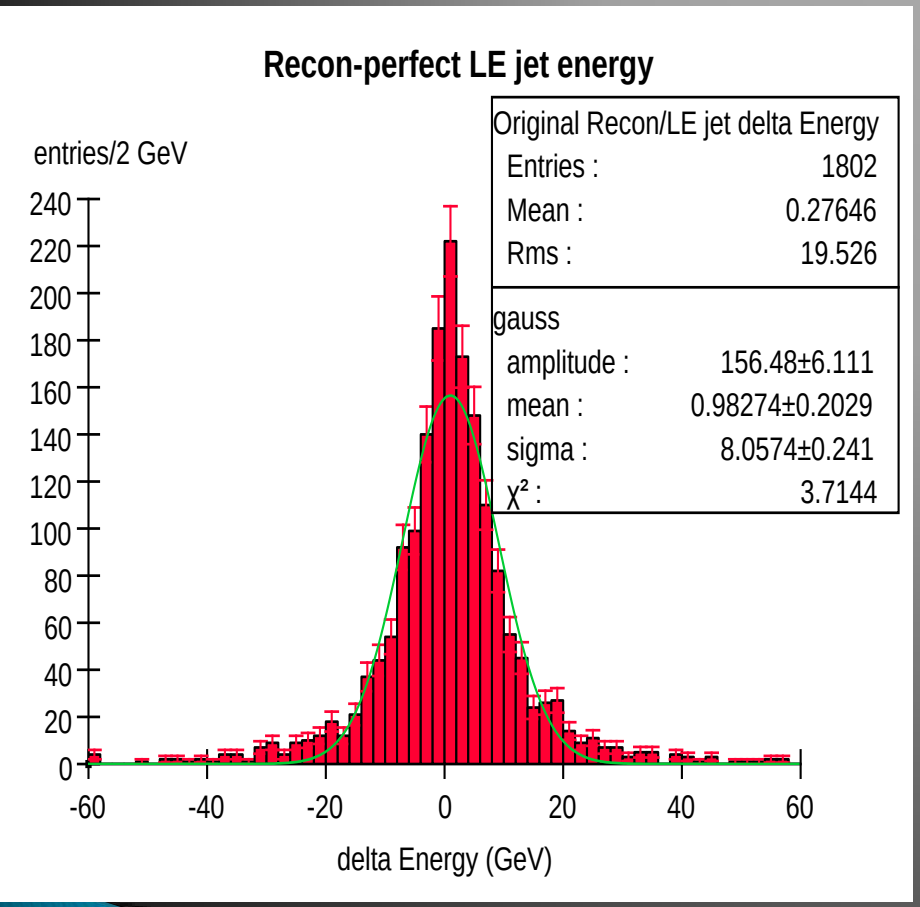
5

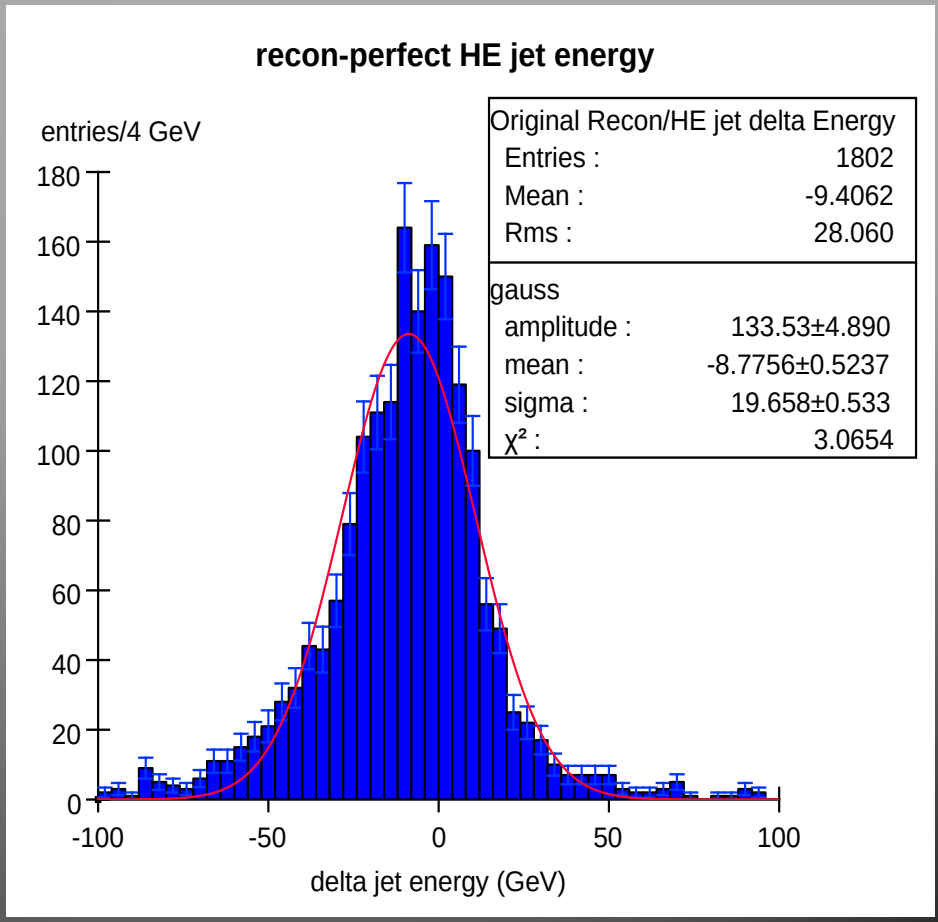
Full E WW events



6

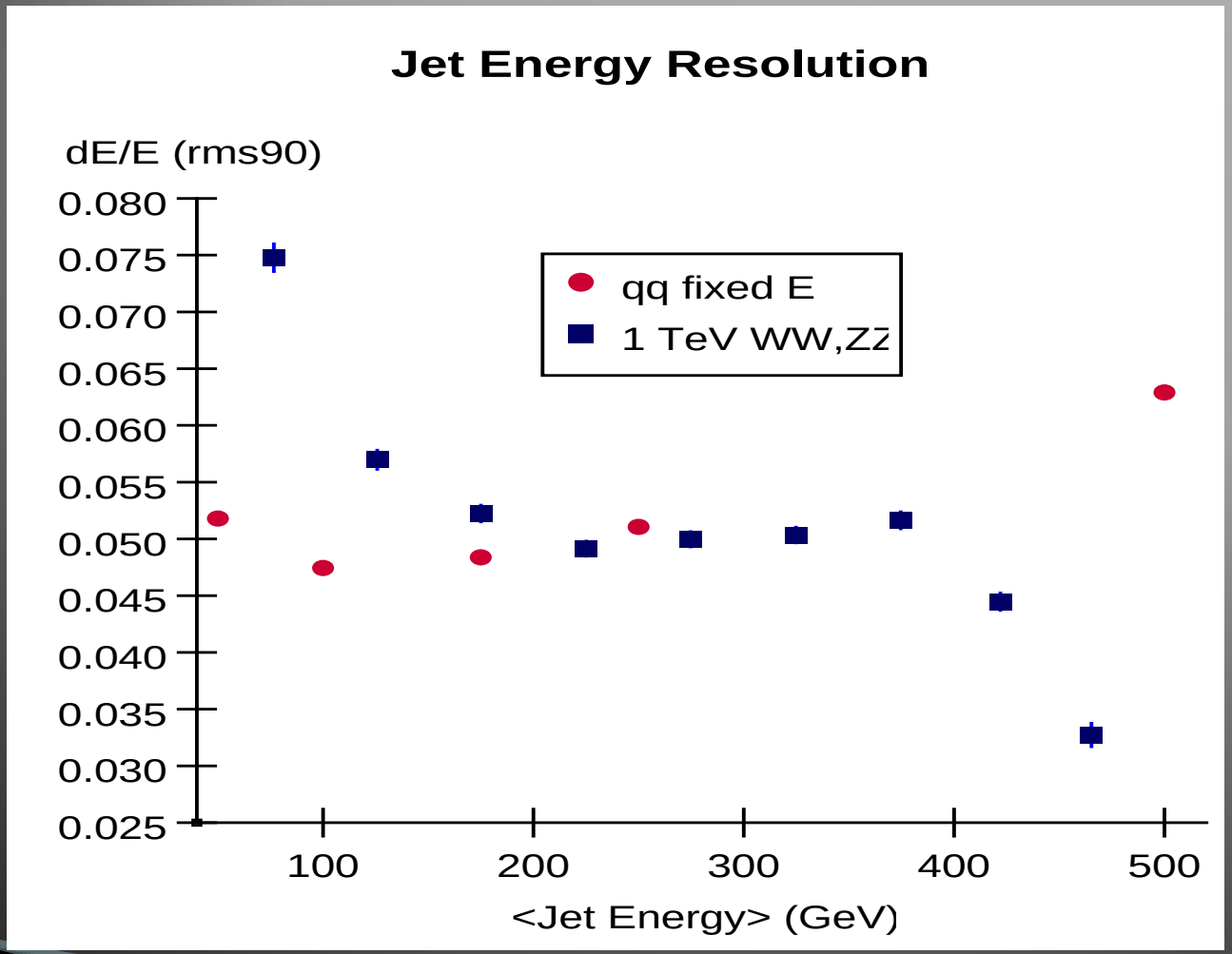
Prefit results: Energy





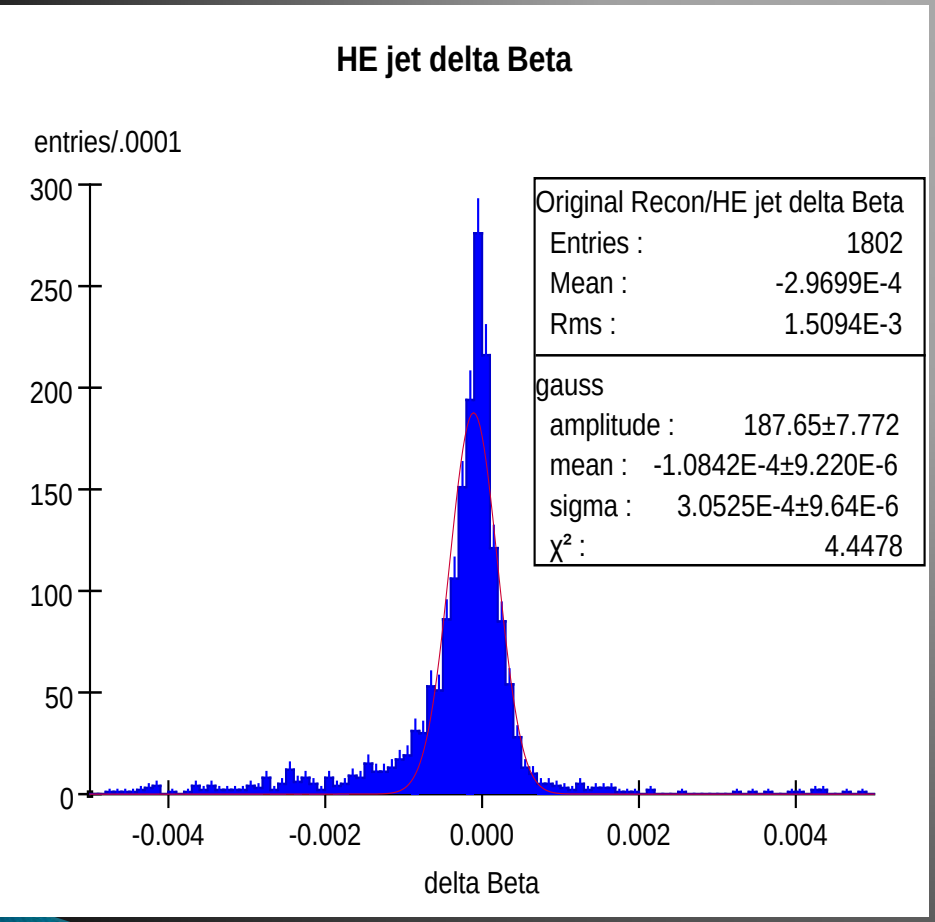
7

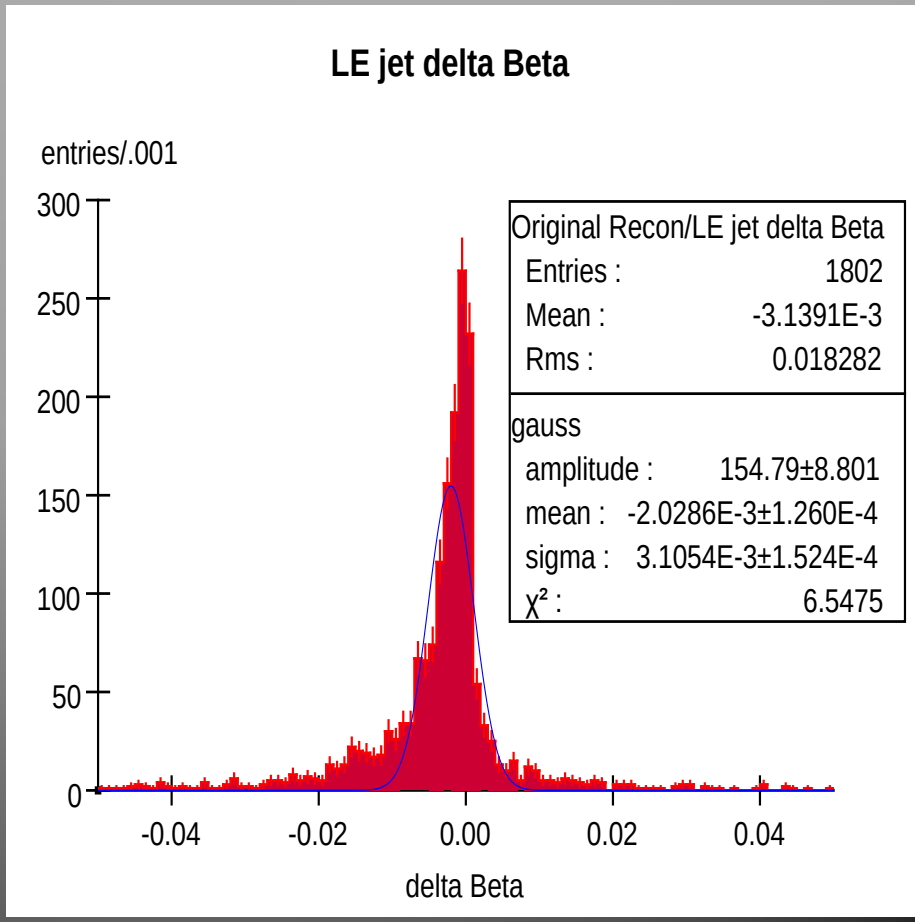
Jet Energy comparison



8

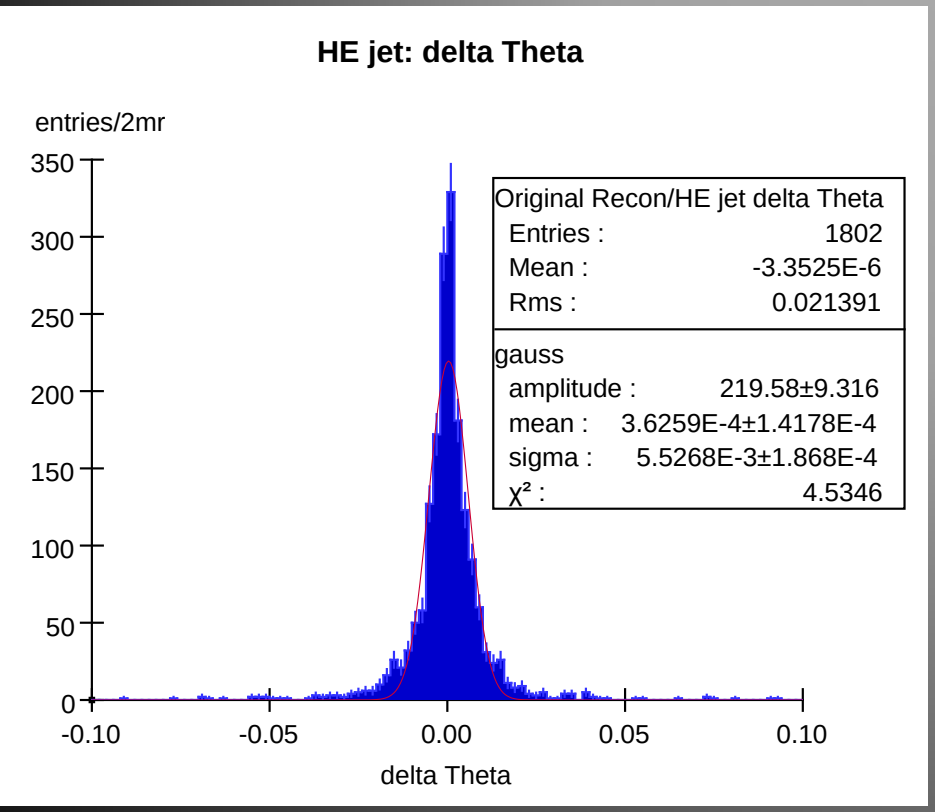
Prefit results: Beta

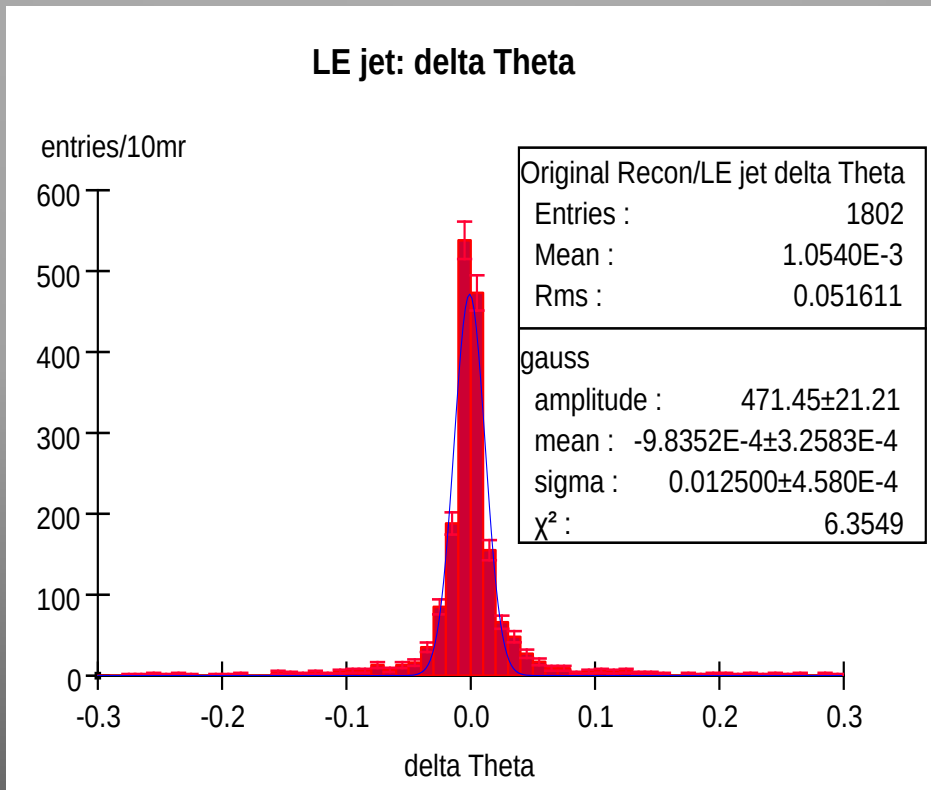




9

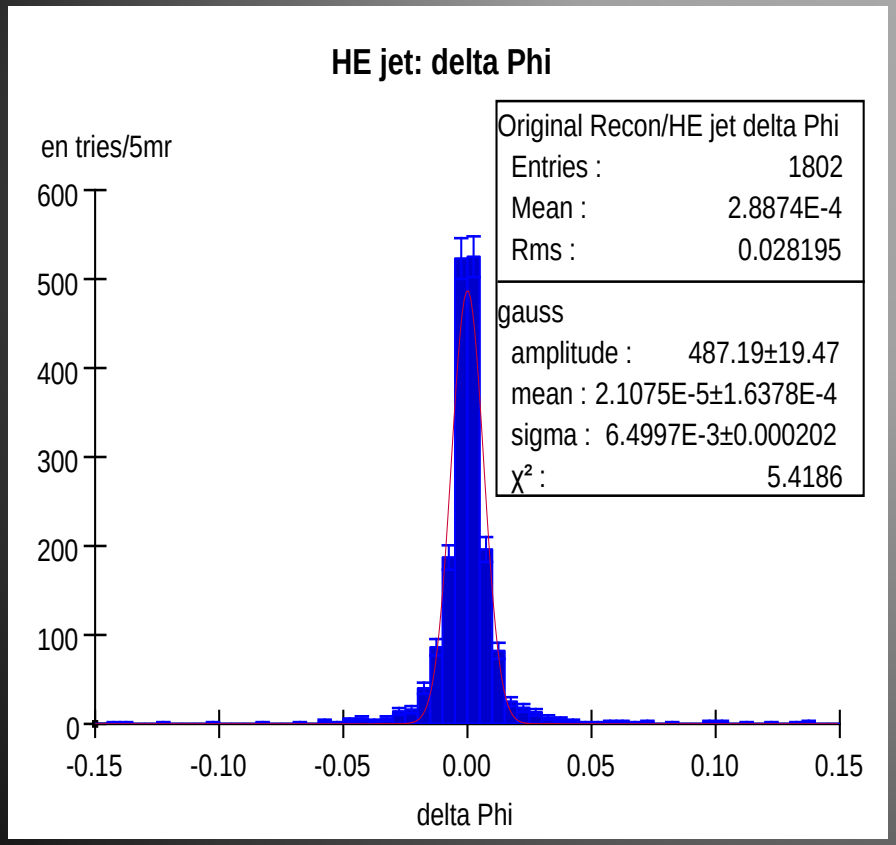
Prefit results: Theta

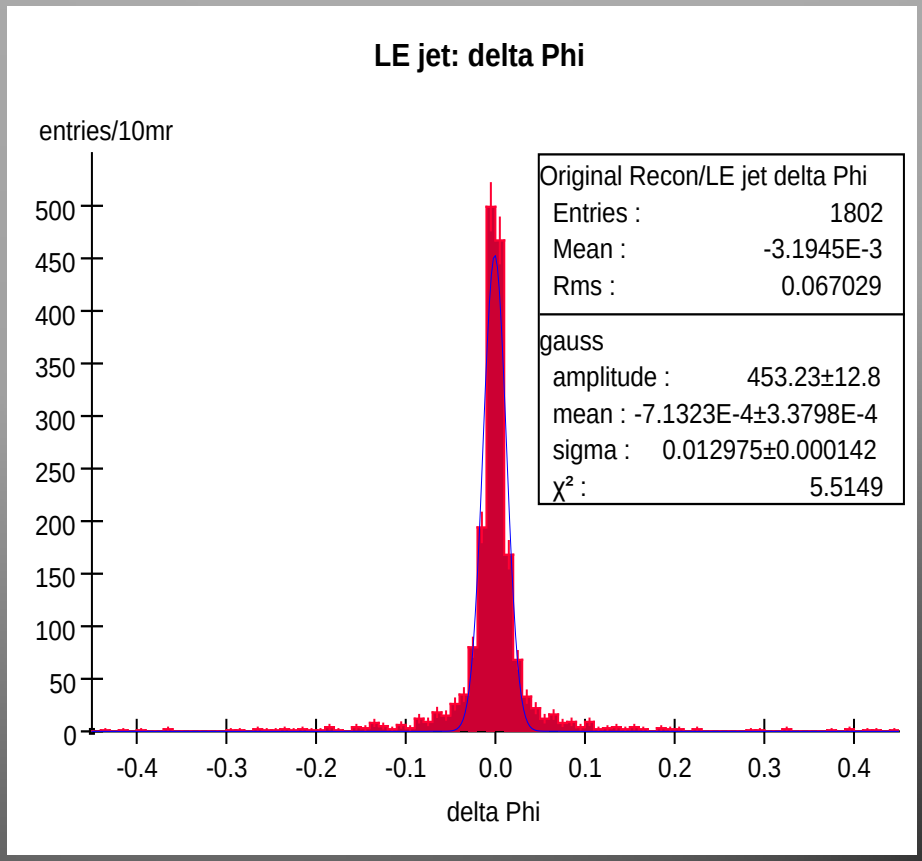




10

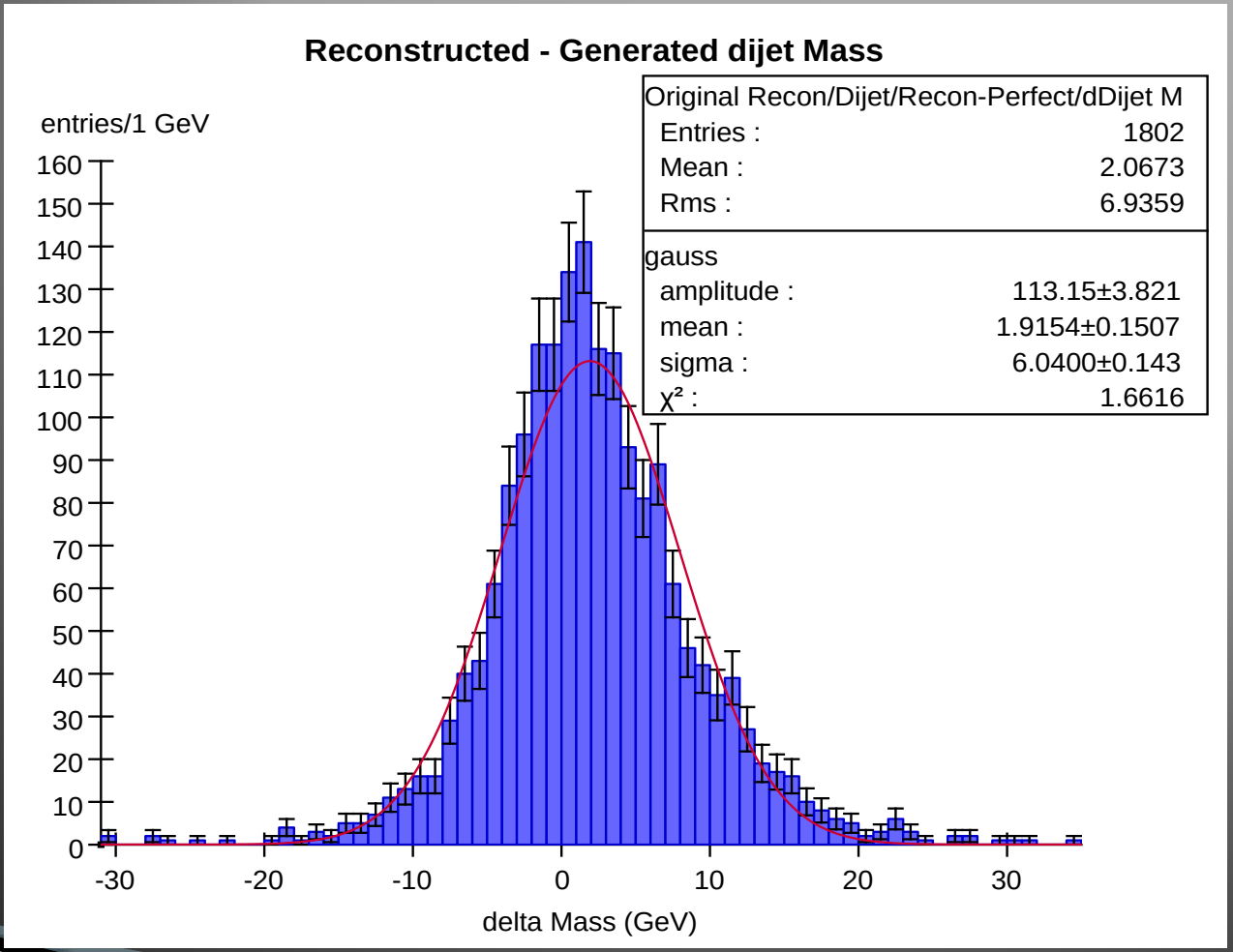
Prefit results: Phi





11

Prefit results: Mass

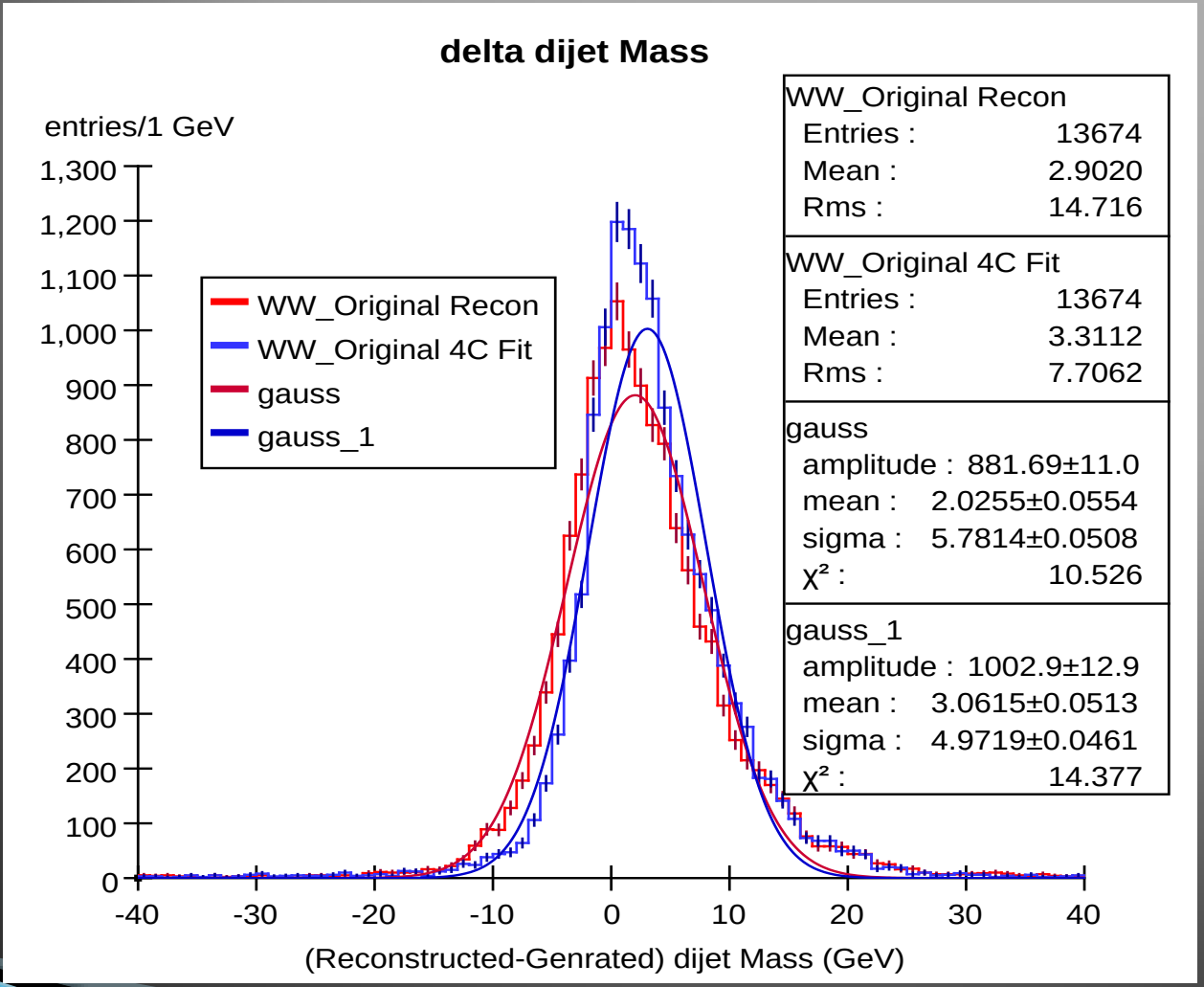


12

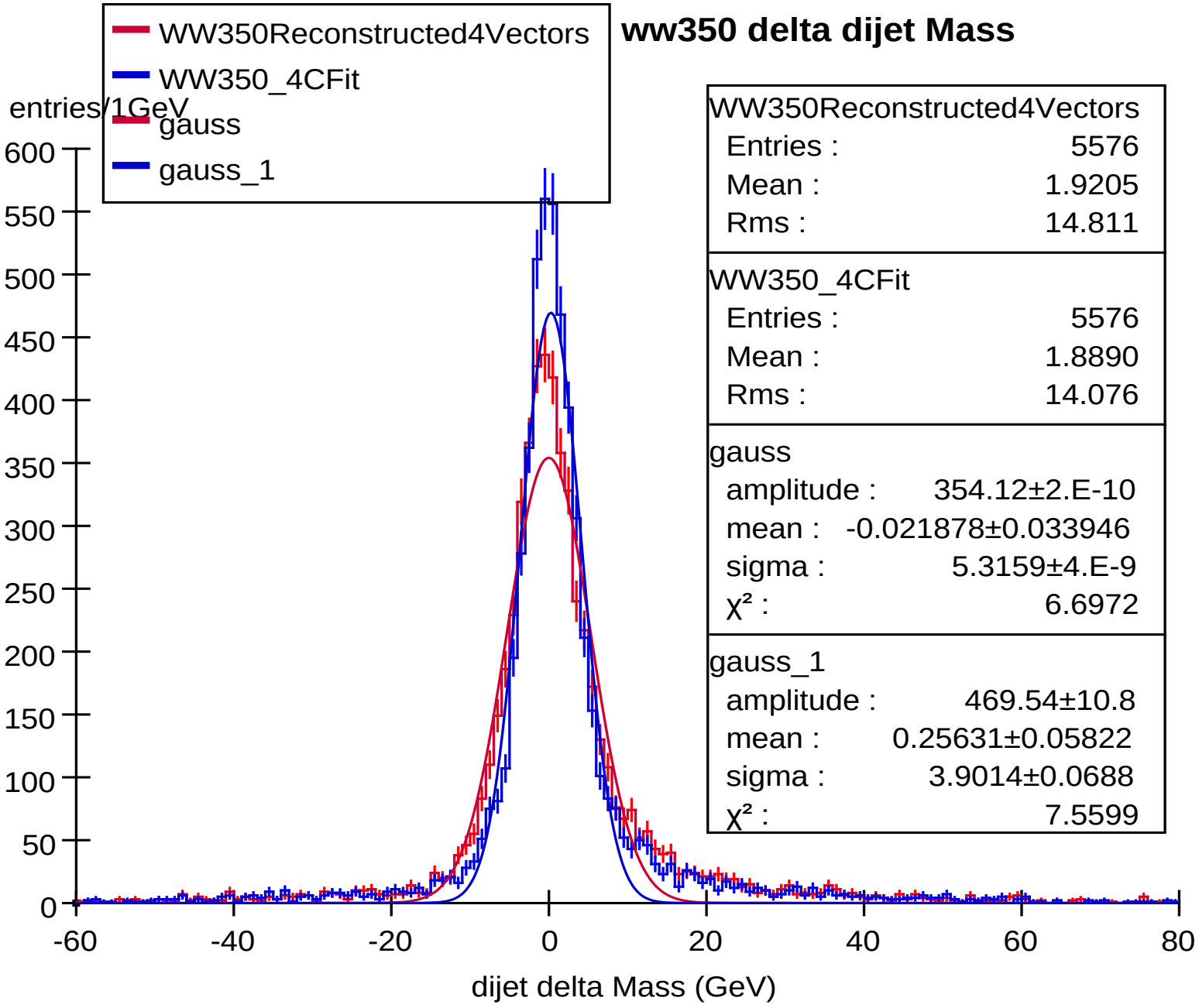
Observations

- Offset in Energy expected.
- Offset in Beta unexpected.
- Offset in Mass opposite to what we expected.

WW evts: Dijet Mass resolution



14


WW350Reconstructed4Vectors
WW350_4CFit
gauss
gauss_1
ww350 delta dijet Mass
entries/1GeV
600
550
500
450
400
350
300
250
200
150
100
50
0
-60
-40
-20
0
20
40
60
80
dijet delta Mass (GeV)
WW350Reconstructed4Vectors
Entries : 5576
Mean : 1.9205
Rms : 14.811
WW350_4CFit
Entries : 5576
Mean : 1.8890
Rms : 14.076
gauss
amplitude : 354.12±2.E-10
mean : -0.021878±0.033946
sigma : 5.3159±4.E-9
χ² : 6.6972
gauss_1
amplitude : 469.54±10.8
mean : 0.25631±0.05822
sigma : 3.9014±0.0688
χ² : 7.5599

The approximate expression for the two-jet mass M is

$$M^2 \approx 2E_1E_2(1-\cos\theta)$$

$$\frac{\Delta M}{M} \approx \frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right]$$

but the full expression is

$$M^2 = m_1^2 + m_2^2 + 2E_1E_2(1-\beta_1\beta_2\cos\theta) \quad , \quad \beta_j = \left(1-\frac{m_j^2}{E_j^2}\right)^{\frac{1}{2}}$$

$$\frac{\Delta M}{M} \approx \frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2} \oplus \frac{\theta\sin\theta}{1-\cos\theta}\frac{\Delta\theta}{\theta} \oplus \frac{1+r^{-1}\cos\theta}{1-\cos\theta}\frac{m_1^2}{E_1E_2}\frac{\Delta m_1}{m_1} \oplus \frac{1+r\cos\theta}{1-\cos\theta}\frac{m_2^2}{E_1E_2}\frac{\Delta m_2}{m_2}\right]$$

$$r = \frac{E_1}{E_2}$$

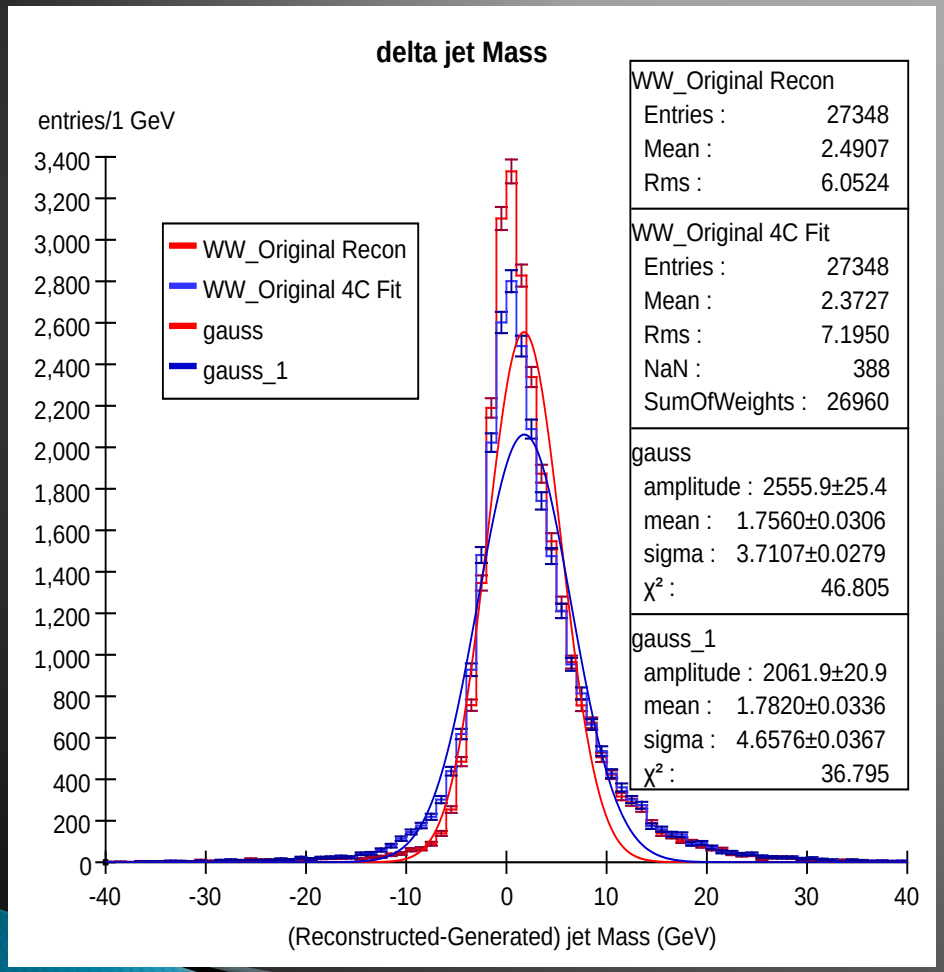
Using the variable β_1 and β_2 in place of m_1 and m_2 the full expression is

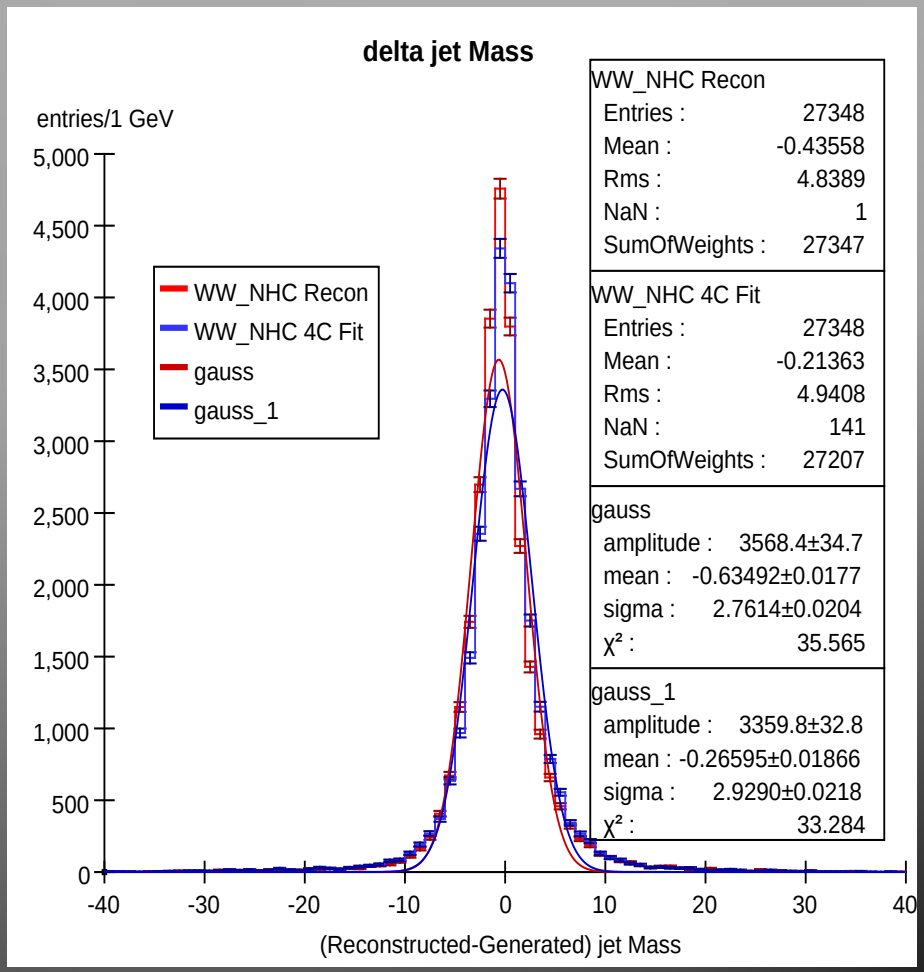
$$\frac{\Delta M}{M} \approx \frac{1}{2}\left[\left(1+(1-\beta_1^2)^2\left(\frac{r+\cos\theta}{1-\cos\theta}\right)^2\right)^{1/2}\frac{\Delta E_1}{E_1} \oplus \left(1+(1-\beta_2^2)^2\left(\frac{r^{-1}+\cos\theta}{1-\cos\theta}\right)^2\right)^{1/2}\frac{\Delta E_2}{E_2}\right.$$
$$\left. \oplus \frac{\theta\sin\theta}{1-\cos\theta}\frac{\Delta\theta}{\theta} \oplus \frac{r+\cos\theta}{1-\cos\theta}\beta_1\Delta\beta_1 \oplus \frac{r^{-1}+\cos\theta}{1-\cos\theta}\beta_2\Delta\beta_2\right]$$

For $1-\beta_j \ll \theta \ll 1$ this becomes

$$\frac{\Delta M}{M} \approx \frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2} \oplus 2\frac{\Delta\theta}{\theta} \oplus \frac{2(r+1)}{\theta^2}\Delta\beta_1 \oplus \frac{2(r^{-1}+1)}{\theta^2}\Delta\beta_2\right]$$

WW evts: Jet Mass resolution





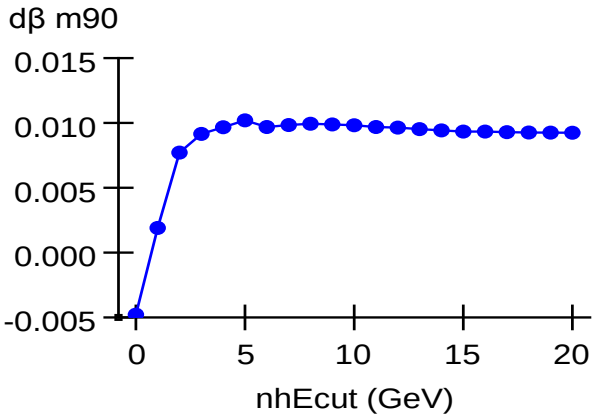
18

Neutral Hadron Cut (NHC) recon procedure

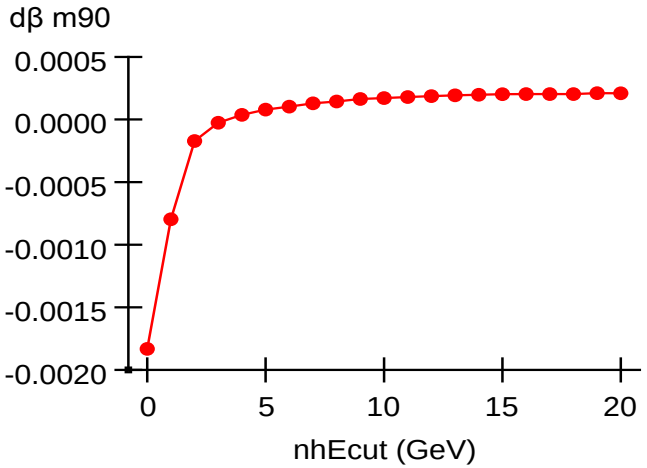
- Calculate β for each jet, ignoring neutral hadrons with E < {0,1,2,…20} GeV
- For each jetE bin, Ebin = 0,1,…9 , jetE = (25 +50*i) +- 25 GeV, histogram dβ.
- Plot dβ m90 vs nhEcut.
- Use dβ = 0 crossover as value of nhEcut for that jet Energy.
- Linearly extrapolate between data points for NHC beta value.

19

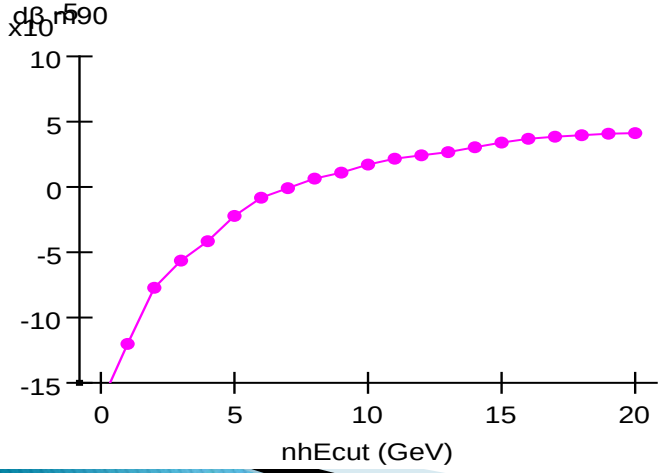
Ebin 0



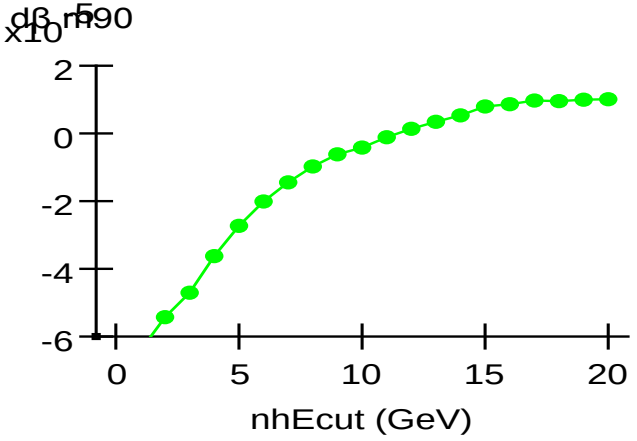
Ebin 3



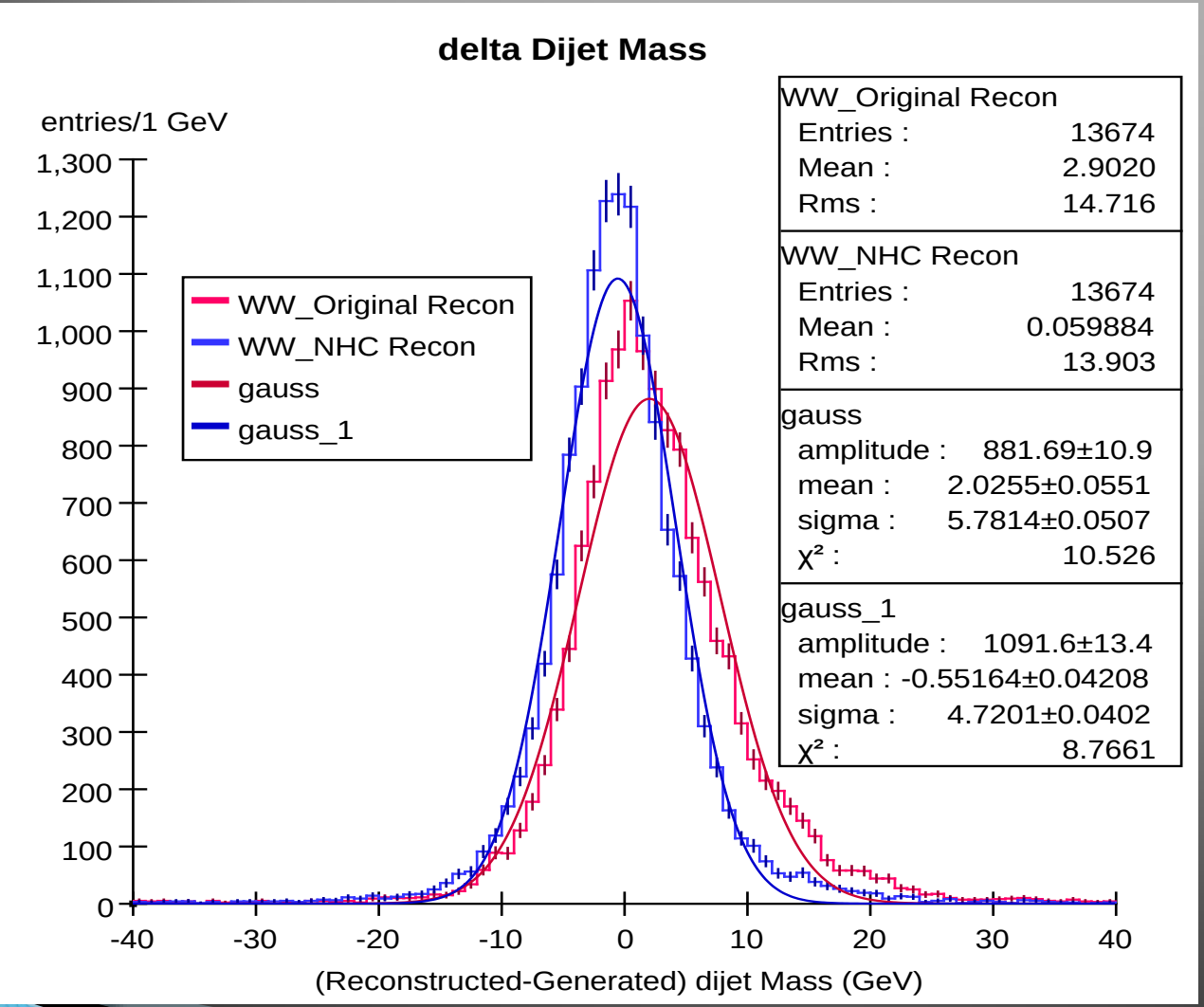
Ebin 6



Ebin 8

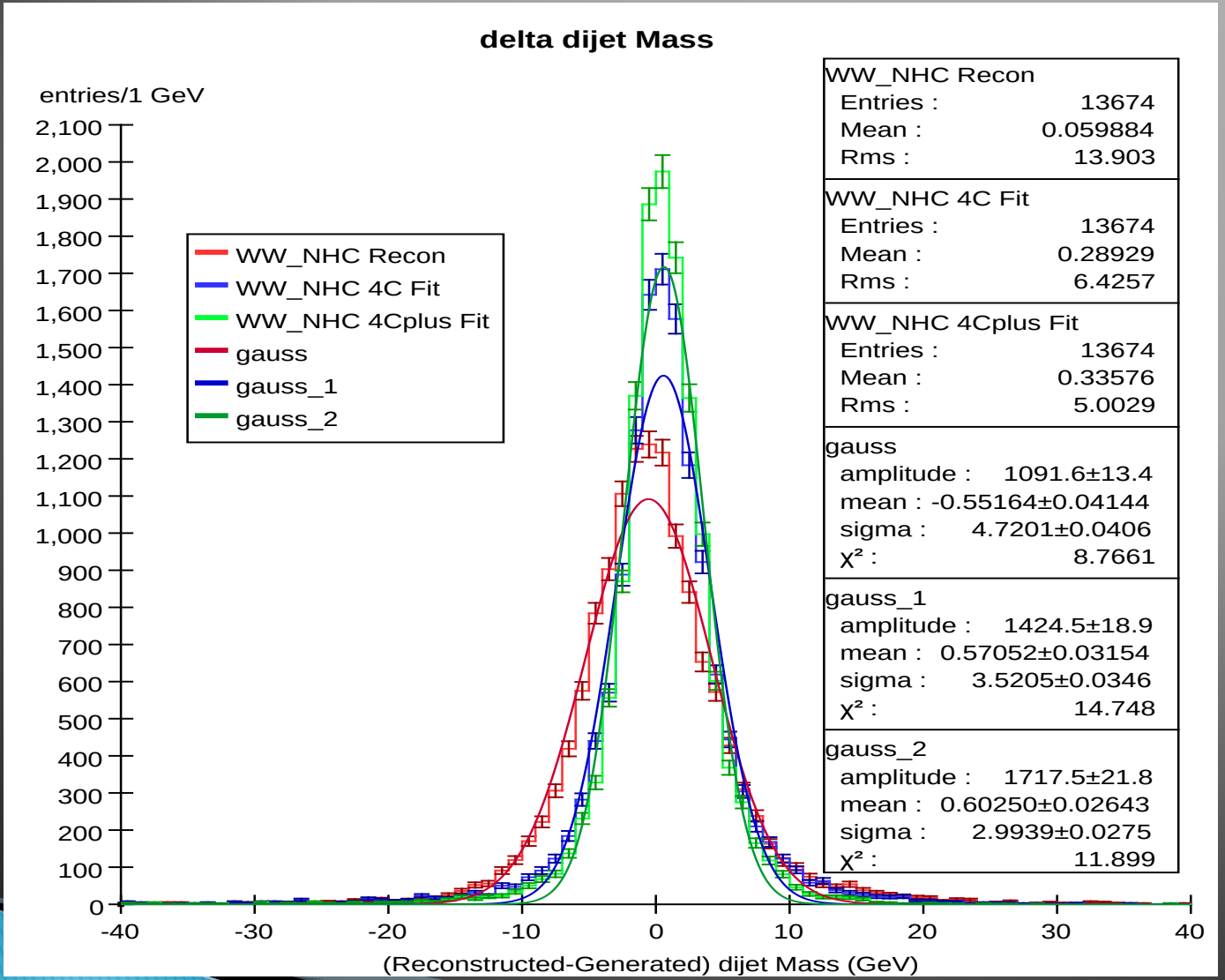


WW evts: Dijet Mass resolution



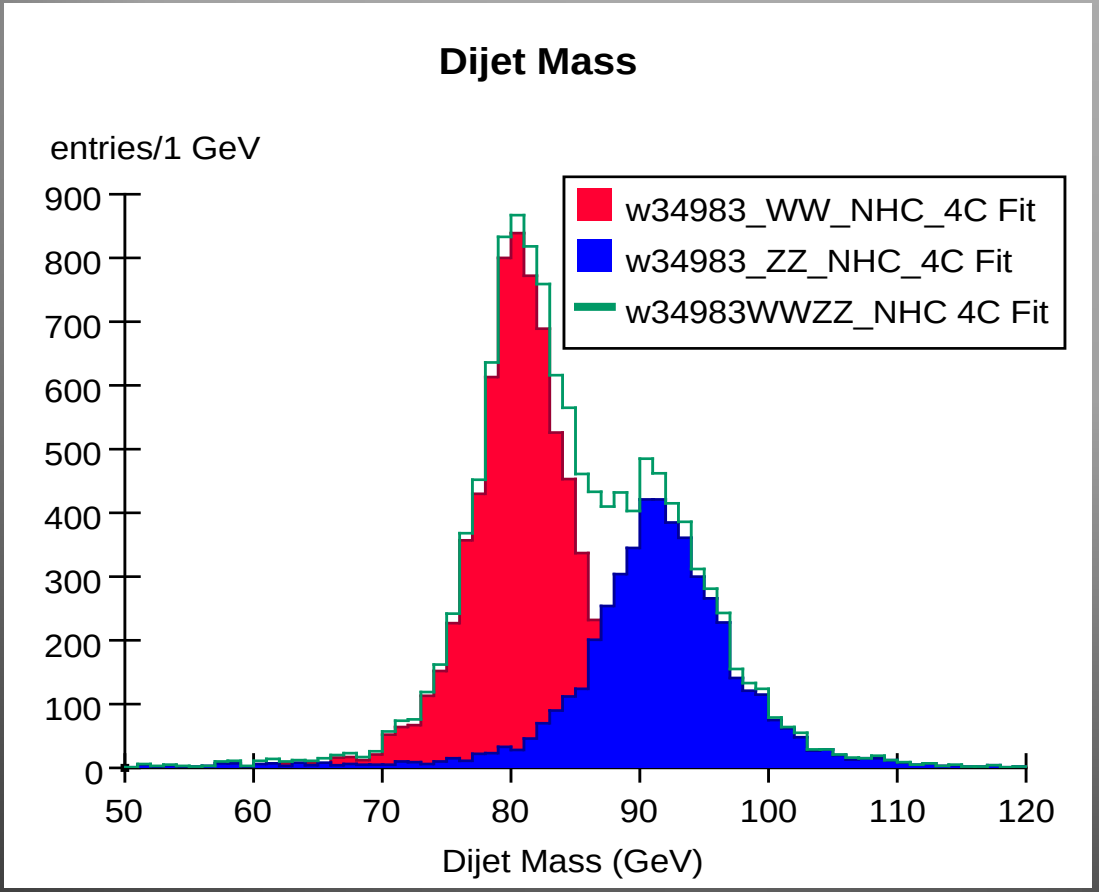
21

WW evts: Dijet Mass resolution



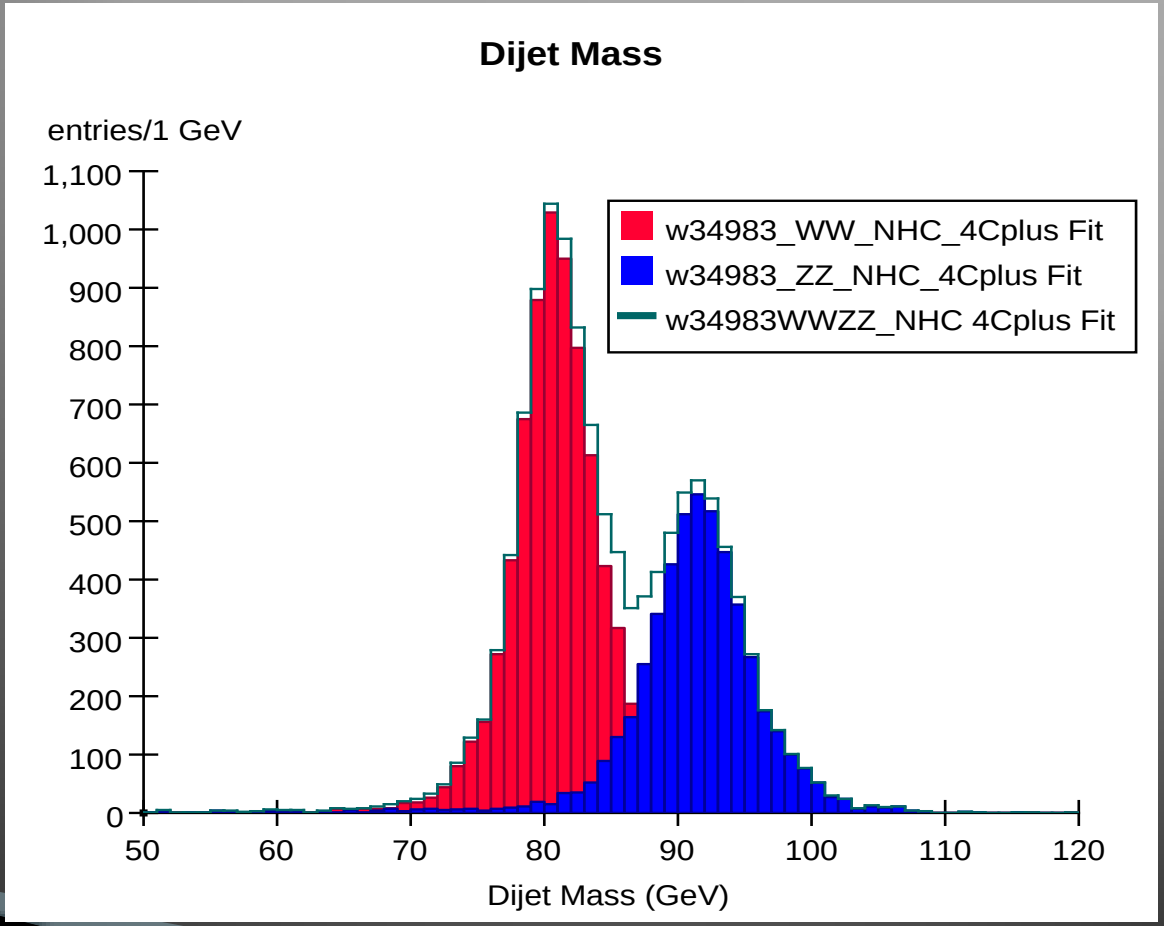
22

100% e-(R) WZ separation



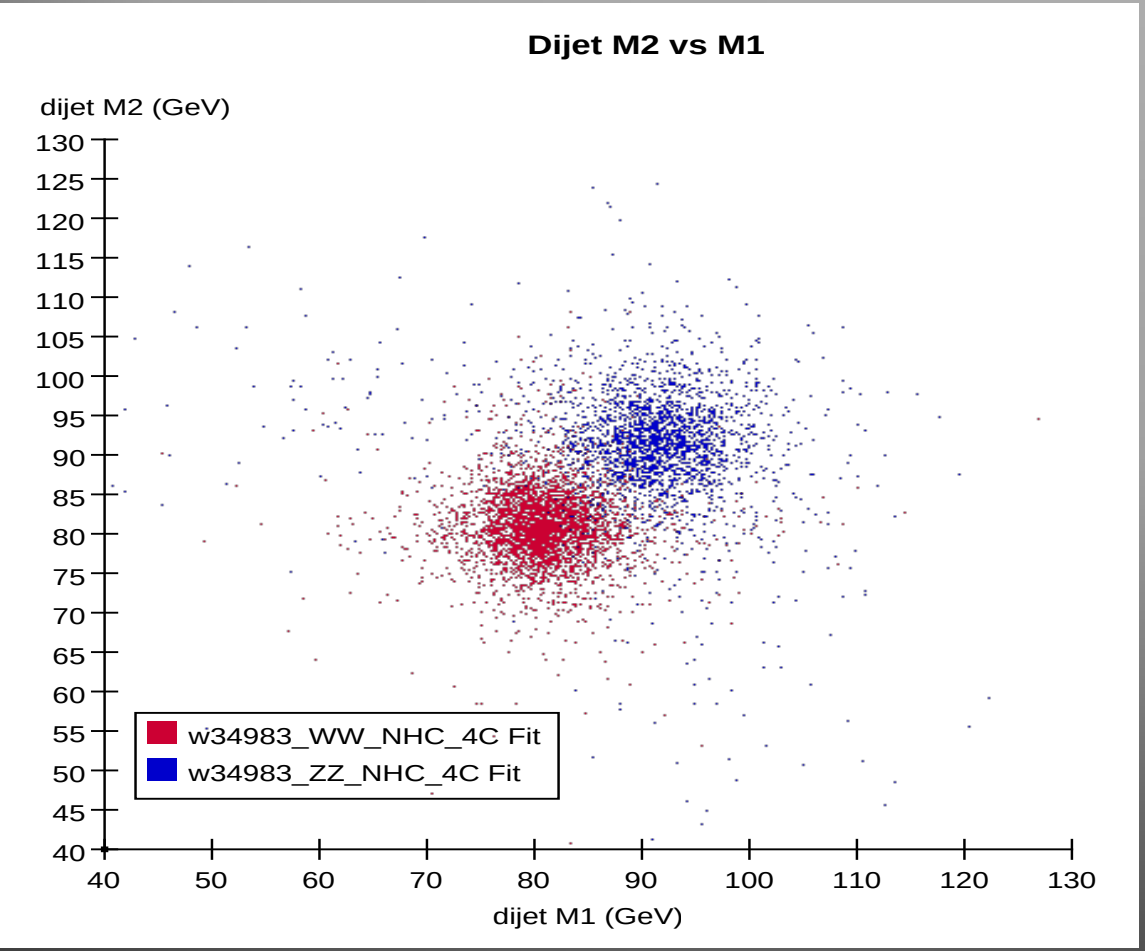
23

100% e-(R) WZ separation – This time add term to chi-square that constrains individual W energies to be within true ΔE



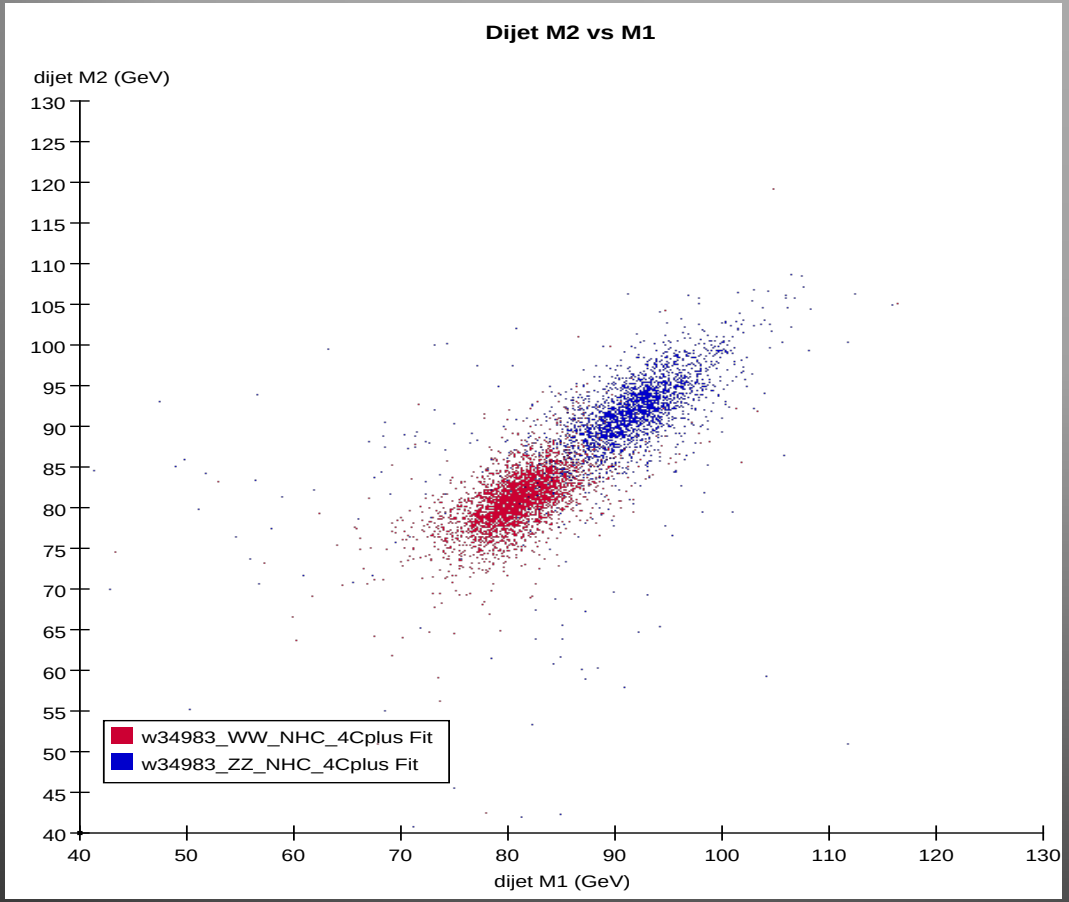
24

100% e-(R) WZ separation



25

100% e-(R) WZ separation – This time add term to chi-square that constrains individual W energies to be within true ΔE



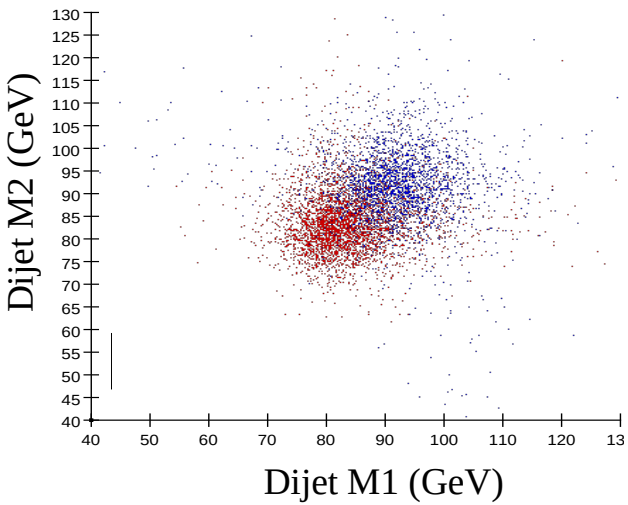
26

$e^+e^- \rightarrow uddu$ at $\sqrt{s} = 1$ TeV

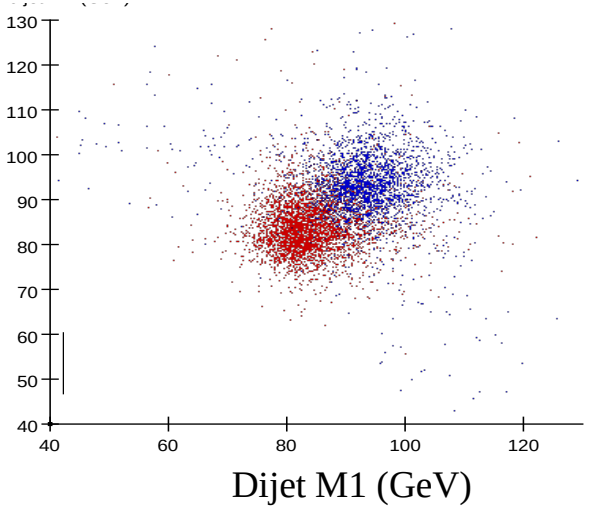
Full energy W^+W^- / ZZ (no ISR)

W^+W^- ZZ

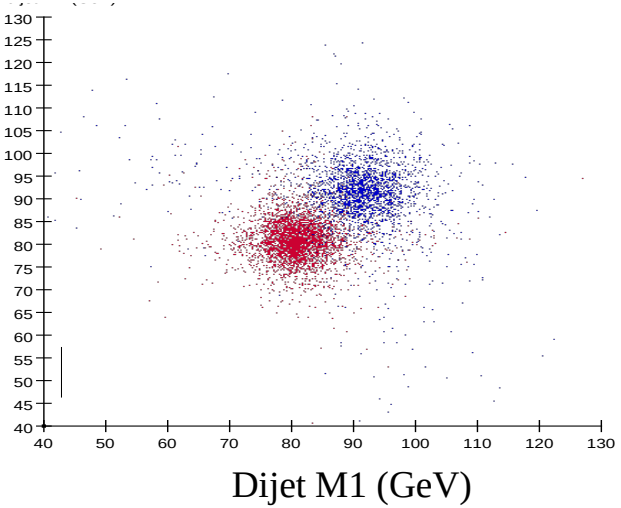
Original Reconstruction



4C Fit Only



4C Fit + Neutral Hadron E Cut

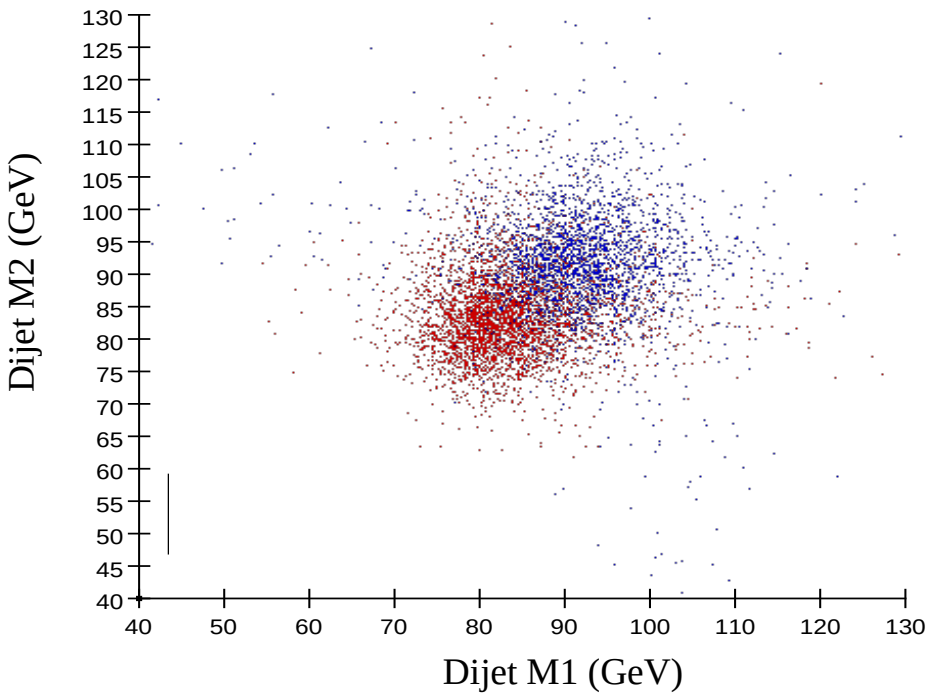


$e^+e^- \rightarrow uddu$ at $\sqrt{s} = 1$ TeV

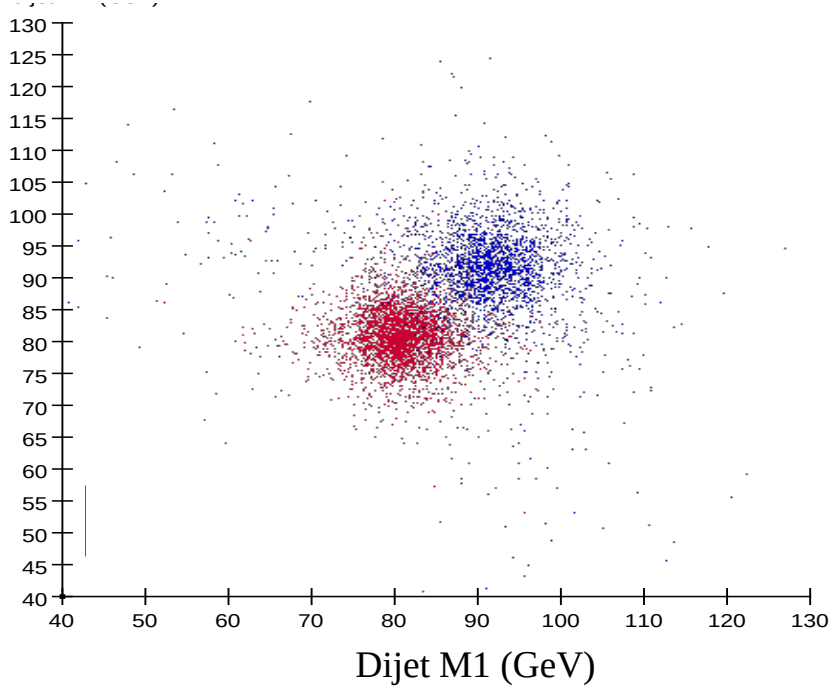
Full energy W^+W^- / ZZ (no ISR)

W^+W^- ZZ

Original Reconstruction



4C Fit + Neutral Hadron E Cut



Summary

- Looked at W/Z mass separation using 200,000 e+e- → uddu events at E_{cm}=1 TeV processed through sim+reco using the sidloi3 detector
- Initial results with 4C Energy-Momentum constraints were disappointing
- Problem was traced to large overestimate of the jet mass from PFO's originating from hadron shower fragments
- An improvement in jet mass resolution was obtained by removing low energy neutral hadron PFO's
- Using the improved jet mass estimate and beam energy-momentum constraints we now get a reasonable W/Z mass separation at E_{cm}=1 TeV

29