W mass and TGC measurement via single-W process

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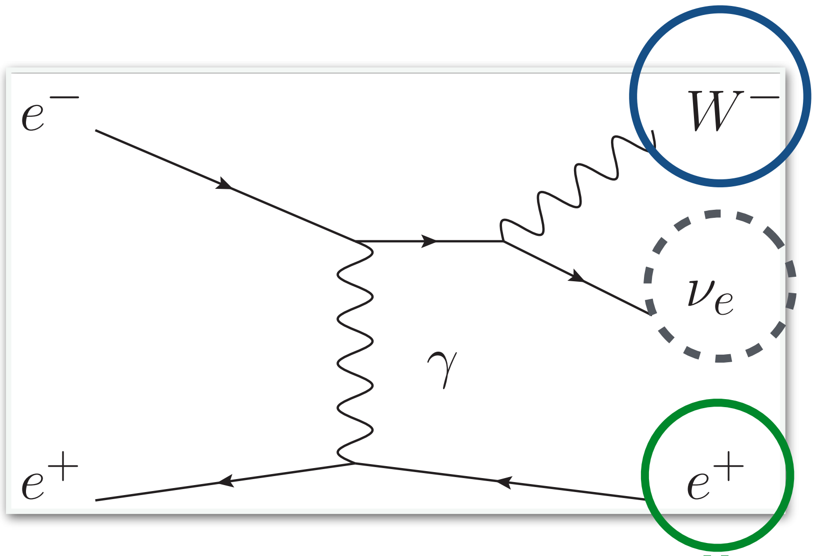
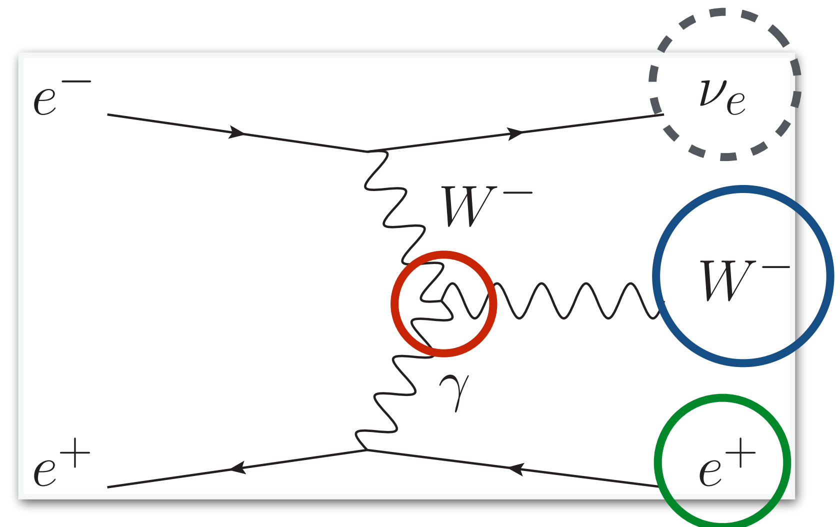
21st January, 2015 : ILD Analysis/Software Meeting
—> Introduction & current status of my study

Single W process

single-W process comes mainly from t-channel diagrams



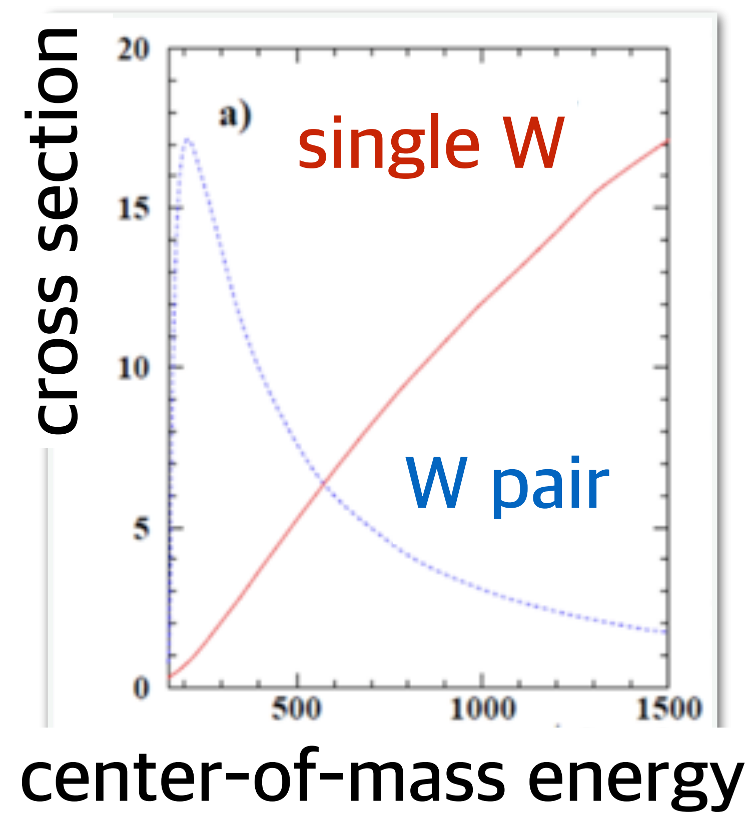
electron scatters in small angle



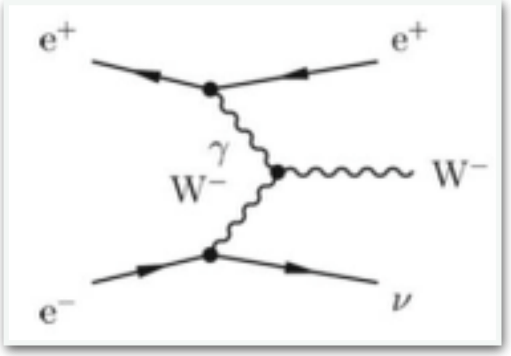
provides direct TGC measurement of γWW vertex

event signature sorely consists of the decay products of W

- W pair production is dominant around √s ~ 250GeV
- But the cross section of single W process increases as larger center-of-mass energy
  - single W process is dominant around √s ~ 1TeV



Physics interest in single W

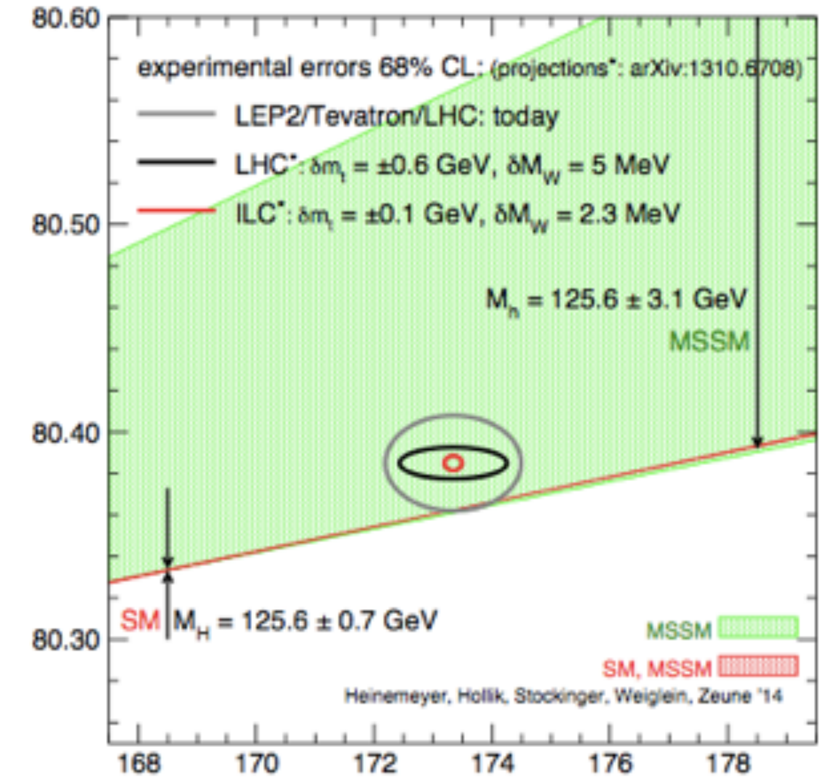


- There are 2 interesting physics motivations :
- Direct W mass measurement via hadron channel
  - this needs challenging requirements on jet energy resolution and calibration
    - good for detector optimization
    - and is a stress test for PFA performance w/o jet clustering effect
- Study of anomalous Triple Gauge boson Coupling
  - for γWW & ZWW vertices

Direct m_W measurement

In the point of view of model parameter space

- the result of precise m_W measurement can test the consistency of SM

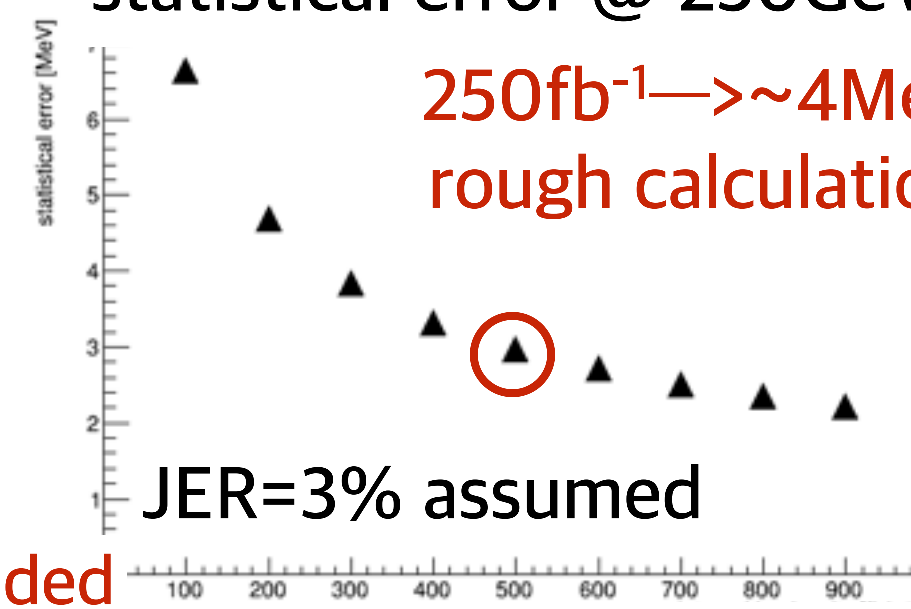


@ ILC

For the detector optimization

- evW events (W—>qq—>2-jet) are very sensitive because there is no ambiguity from jet clustering, therefore it is good for studying pure detector effects

statistical error @ 250GeV



250fb^{-1}—>~4MeV
rough calculation

JER=3% assumed

integrated luminosity

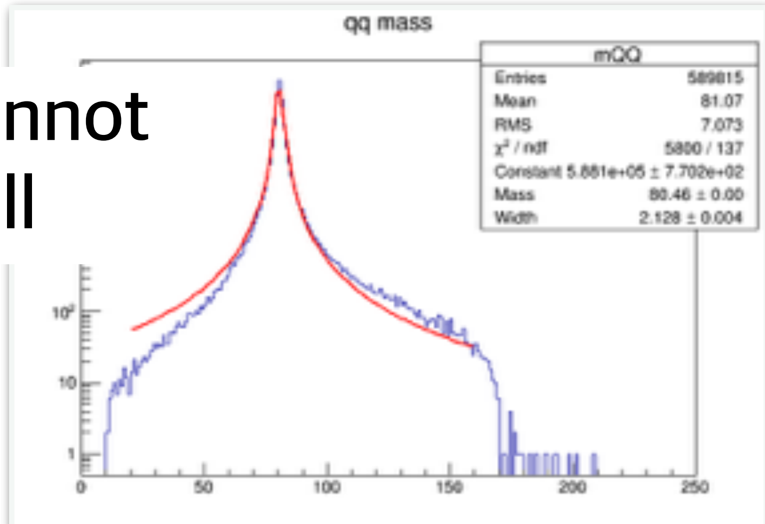
a few MeV statistical error will be provided even only @250GeV

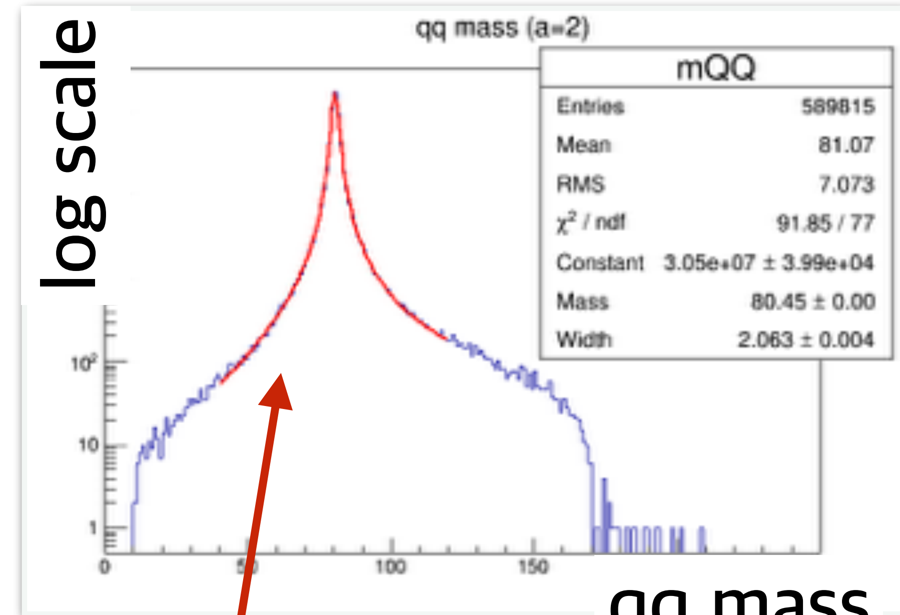
Currently working on

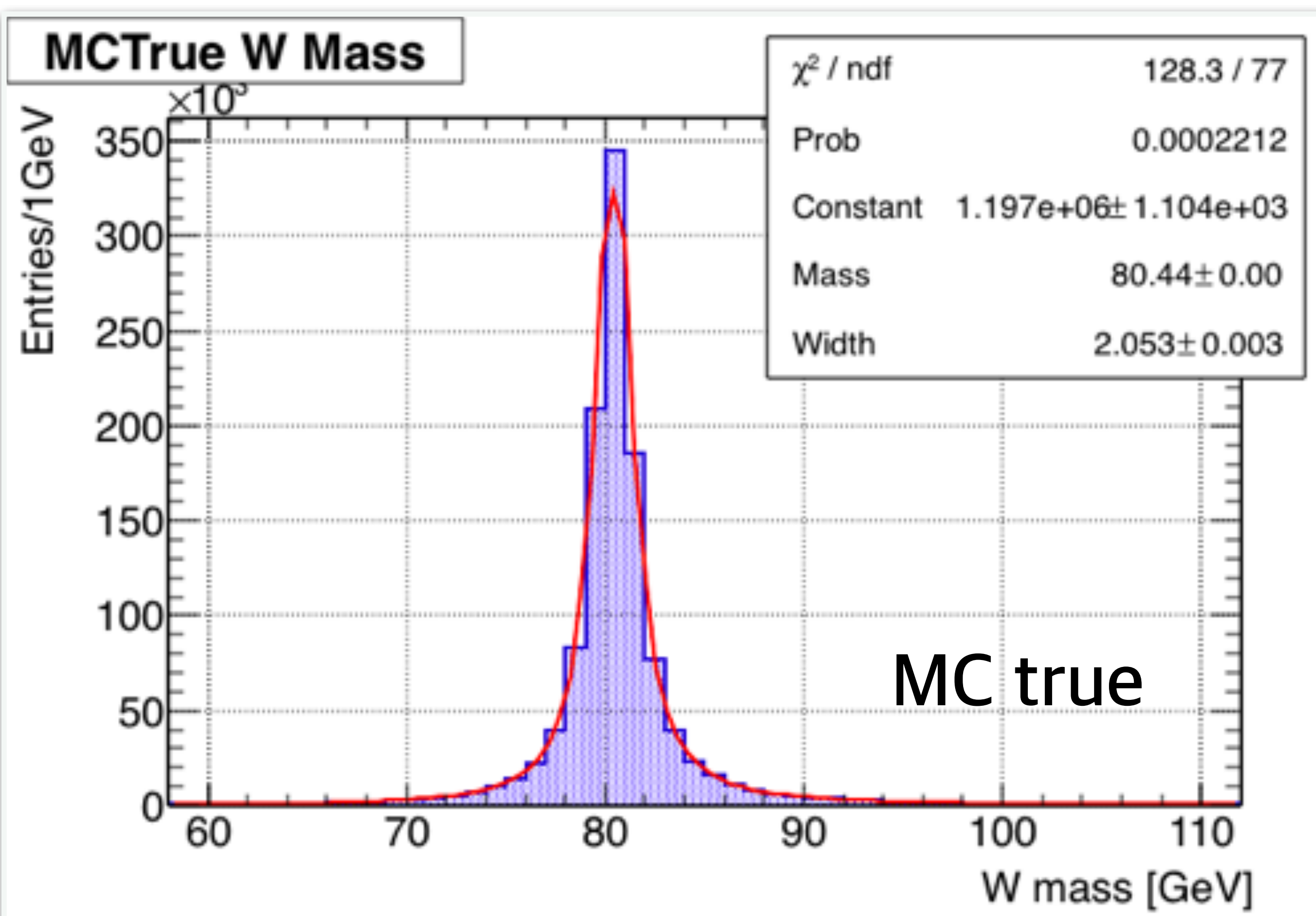
- The first step to do is to find a proper model to describe the W invariant mass.
- Note that $\sqrt{s}$ = 250 GeV now.
- There can be 3 studies to do :
  - dynamics —> running width BW function (next page)
  - kinematics —> missing neutrinos from jets
  - detector effects —> jet energy and angle resolution

Generator level W mass

fixed width BW cannot fit the data well







W mass line shape from evW is well fitted with relativistic Breit-Wigner

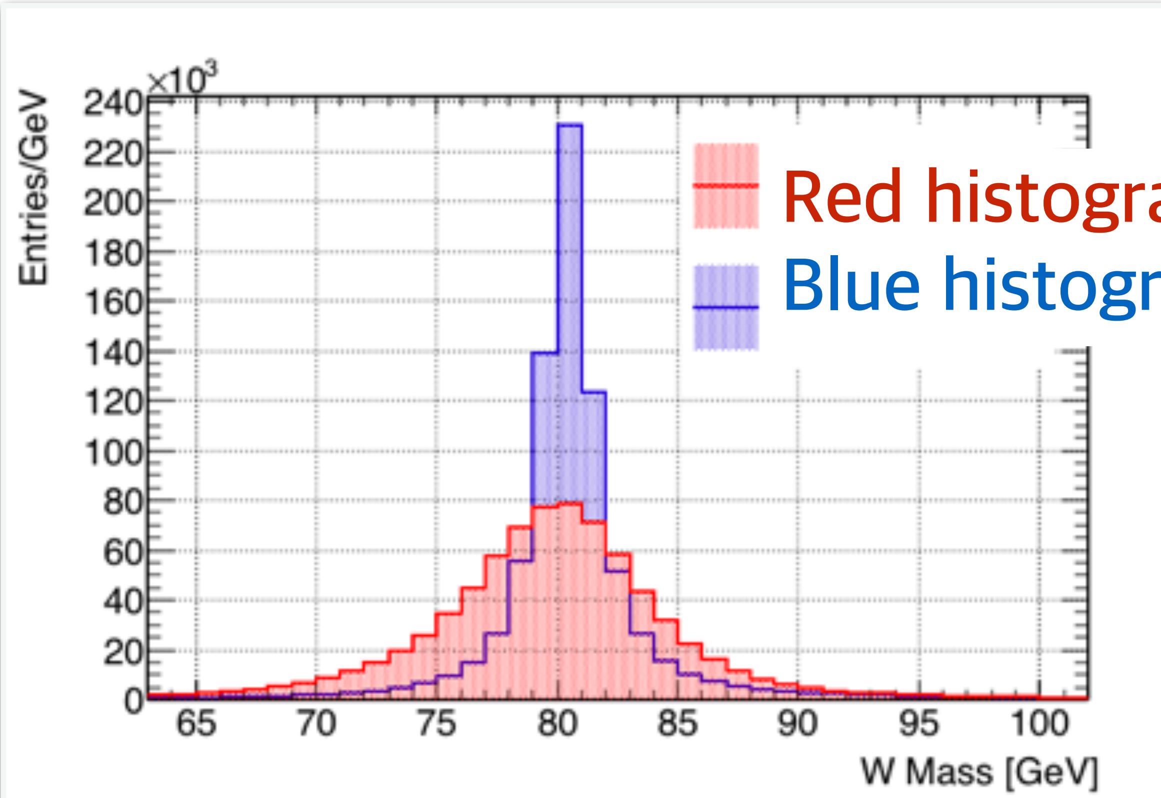
$$F(q; m_W, m\Gamma) = \frac{N m \Gamma}{\left(q^2 - m_W^2\right)^2 + (m\Gamma)^2}$$

where, $m\Gamma = m_W \Gamma_W \left(\frac{q^2}{m_W^2} \right)$

mΓ is so-called “running width”

(same convention is used for LEP2 W mass results)

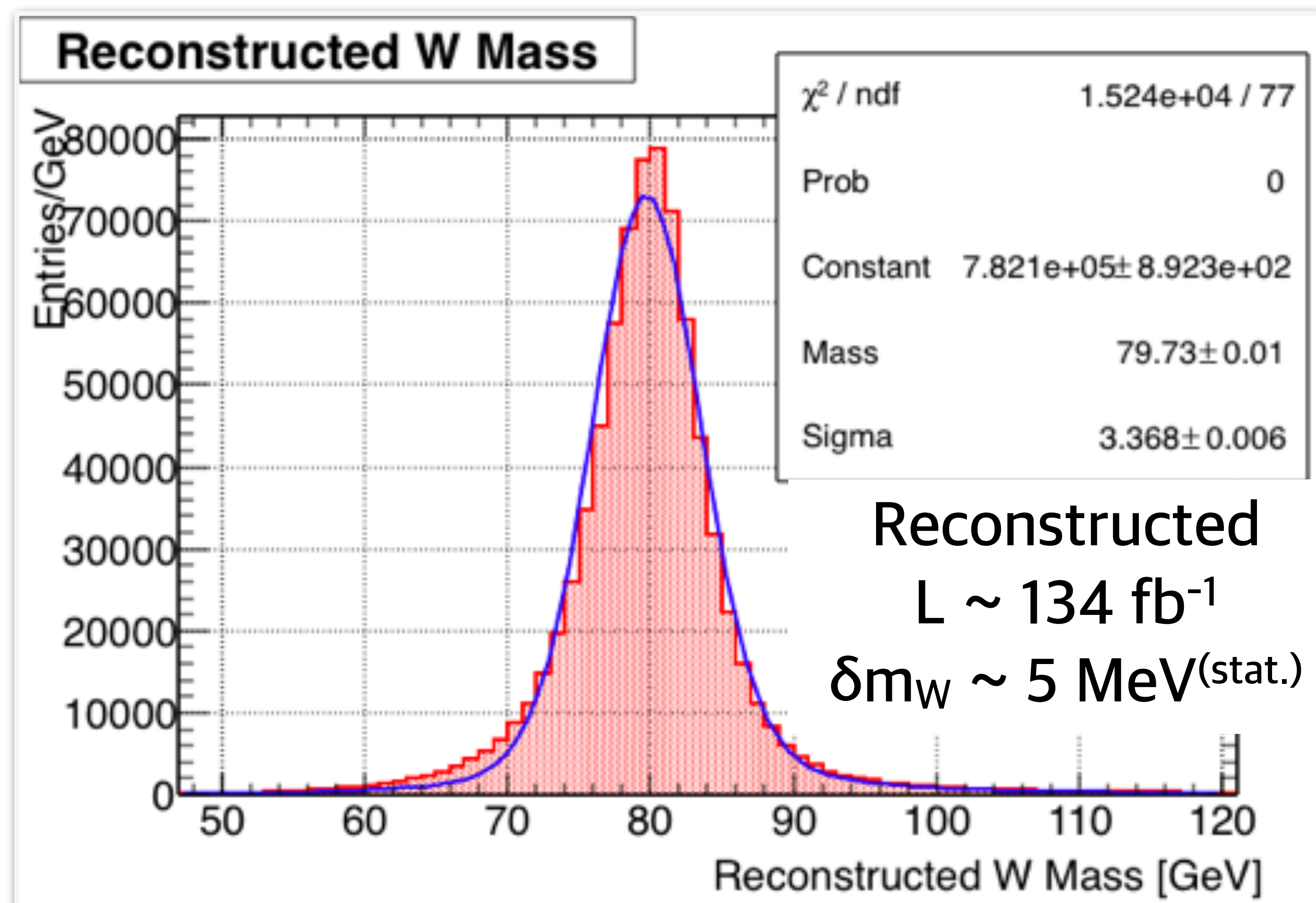
Detector level W mass



Red histogram : Reconstructed with perfect PFO

Blue histogram : Generator level qq’ mass

fitting by convoluted function :
detector effect is described as Gaussian



Reconstructed
L ~ 134 fb^{-1}
δm_W ~ 5 $MeV^{(stat.)}$

very large χ^2 (χ^2/ndf~200) came from :
- the effect of missing neutrinos
- detector effects
  —> depend on E scale and jet angles

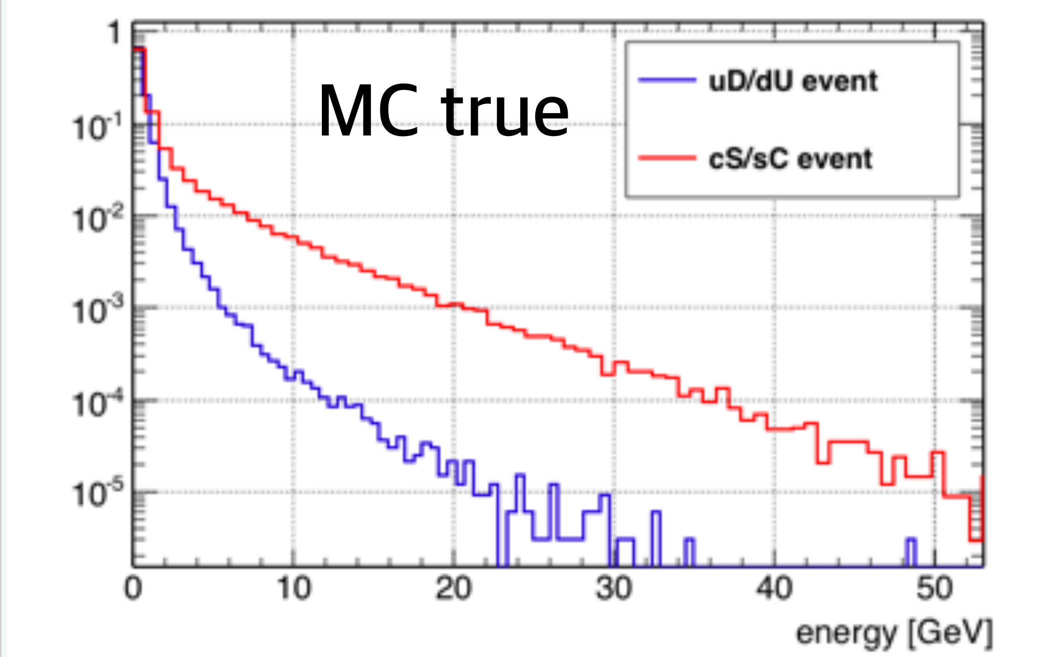
need to study these effects

Currently working on

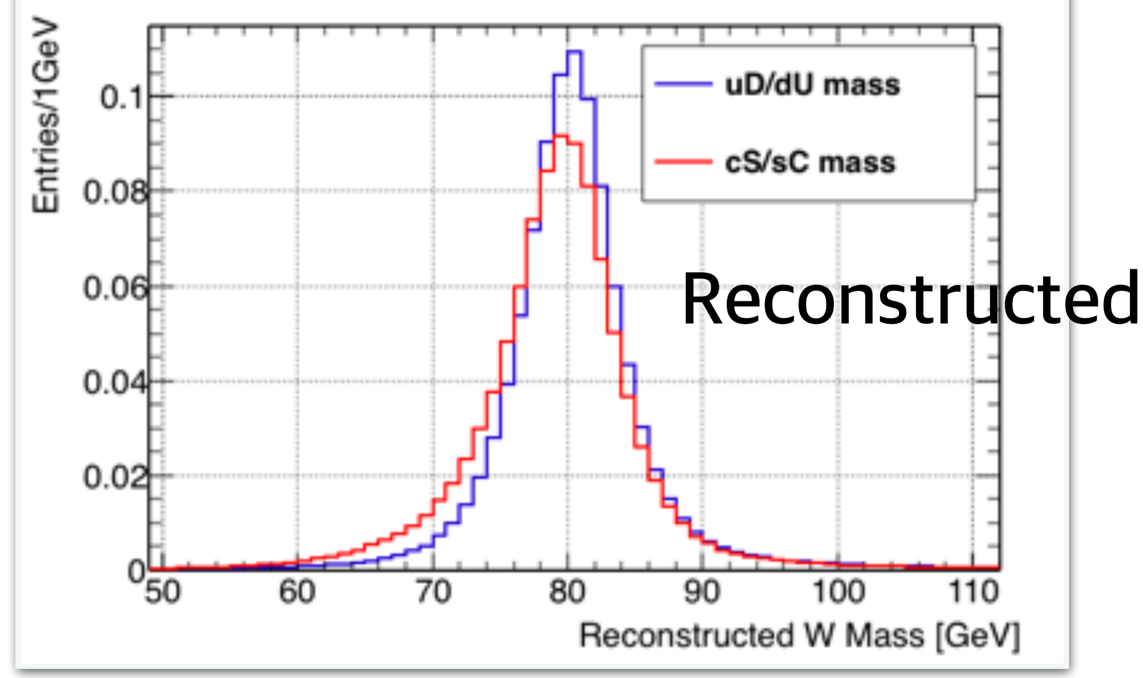
- The first step to do is to find a proper model to describe the W invariant mass.
- Note that $\sqrt{s}$ = 250 GeV now.
- There can be about 3 studies to do :
    - dynamics —> running width BW function (done)
    - kinematics —> missing neutrinos from jets (next page)
    - detector effects —> jet energy and angle resolution

Missing neutrinos in jets

missing energy by ν_l in qq jets

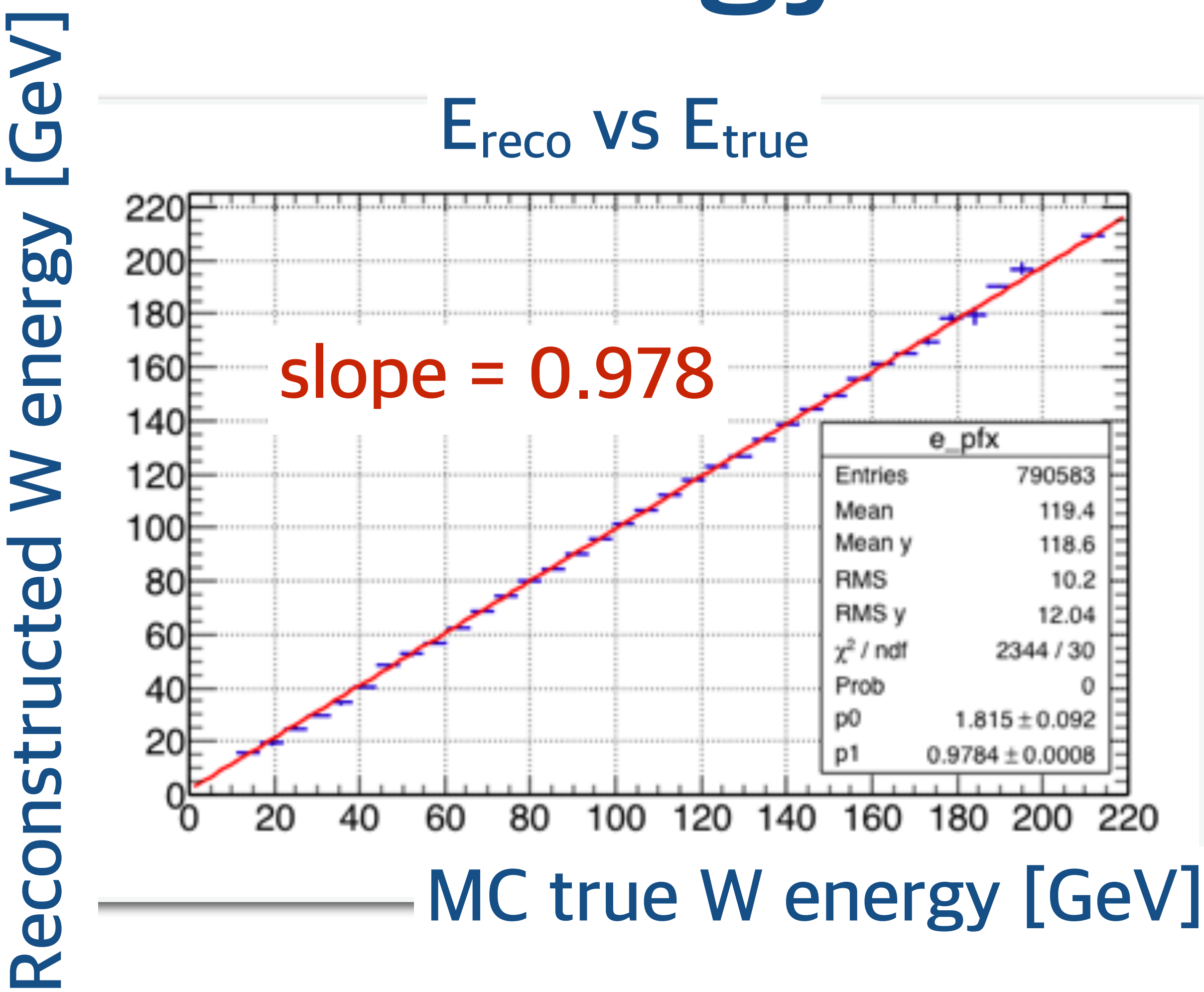


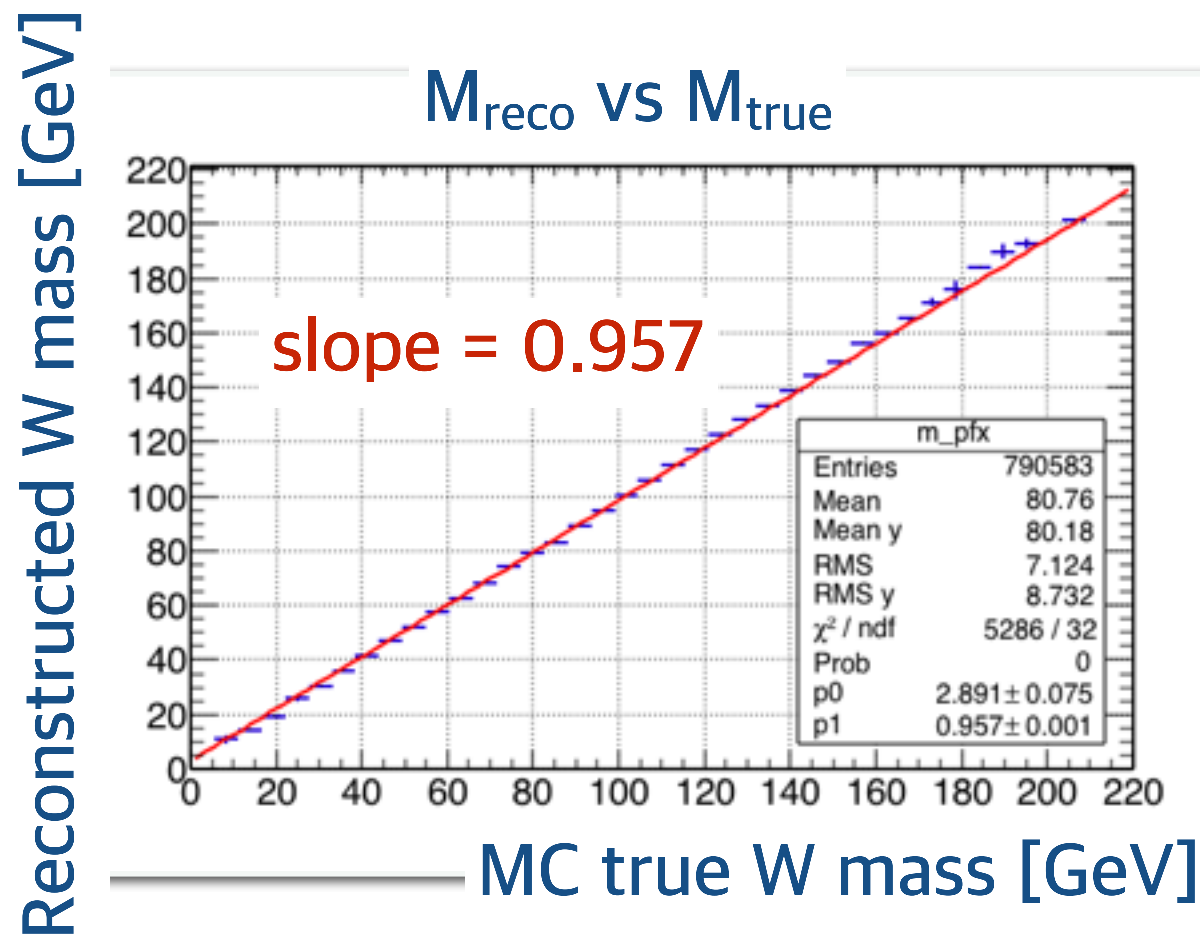
qq mass distribution



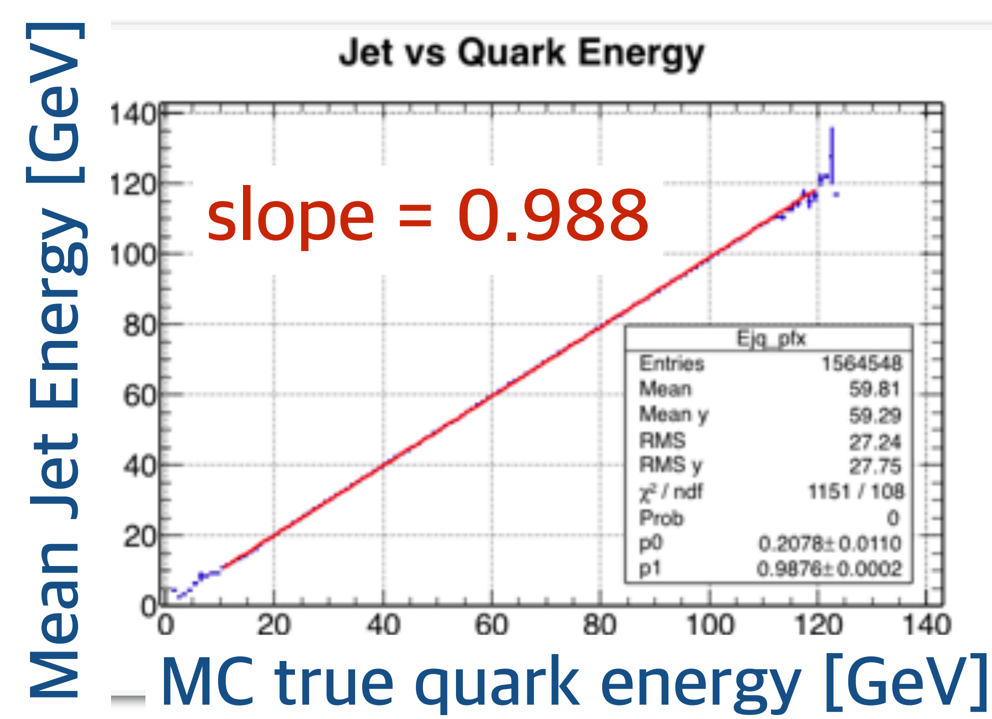
- There can be missing neutrinos in quark jets
    - like as; c—>sW—>slν (—>uWlν—>ulνlν)
    - missing energy distributions are not same by different W decay modes (i.e. different final state quarks)
- This can be main reason that causes large χ^2 in fitting and pulls measured W mass peak to lower value
    - this effect changes the shape of W mass distribution

W energy and mass scale shifts





- due to the effect of missing neutrinos in jet (and also the systematic from PFA?)
  - shifted 1-2% for each quark jet E
  - shifted 2-3% for W energy scale
  - shifted 4-5% for W mass scale

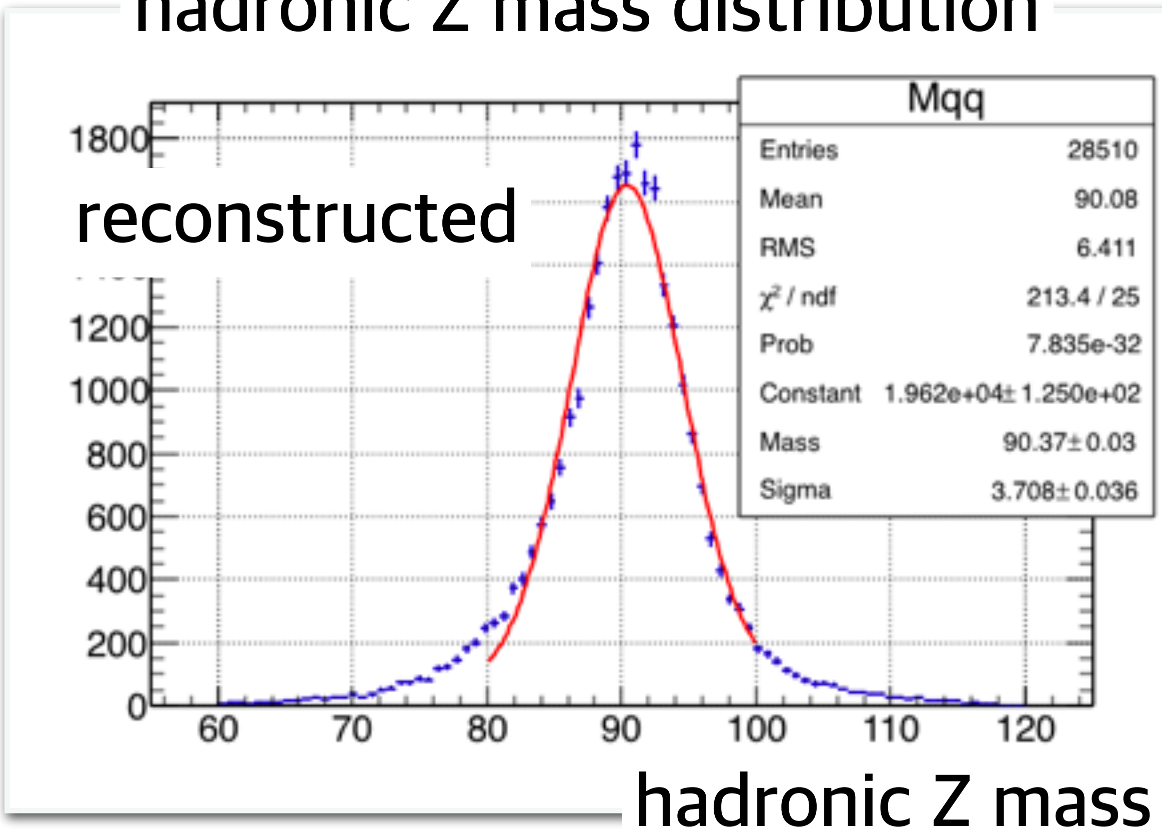


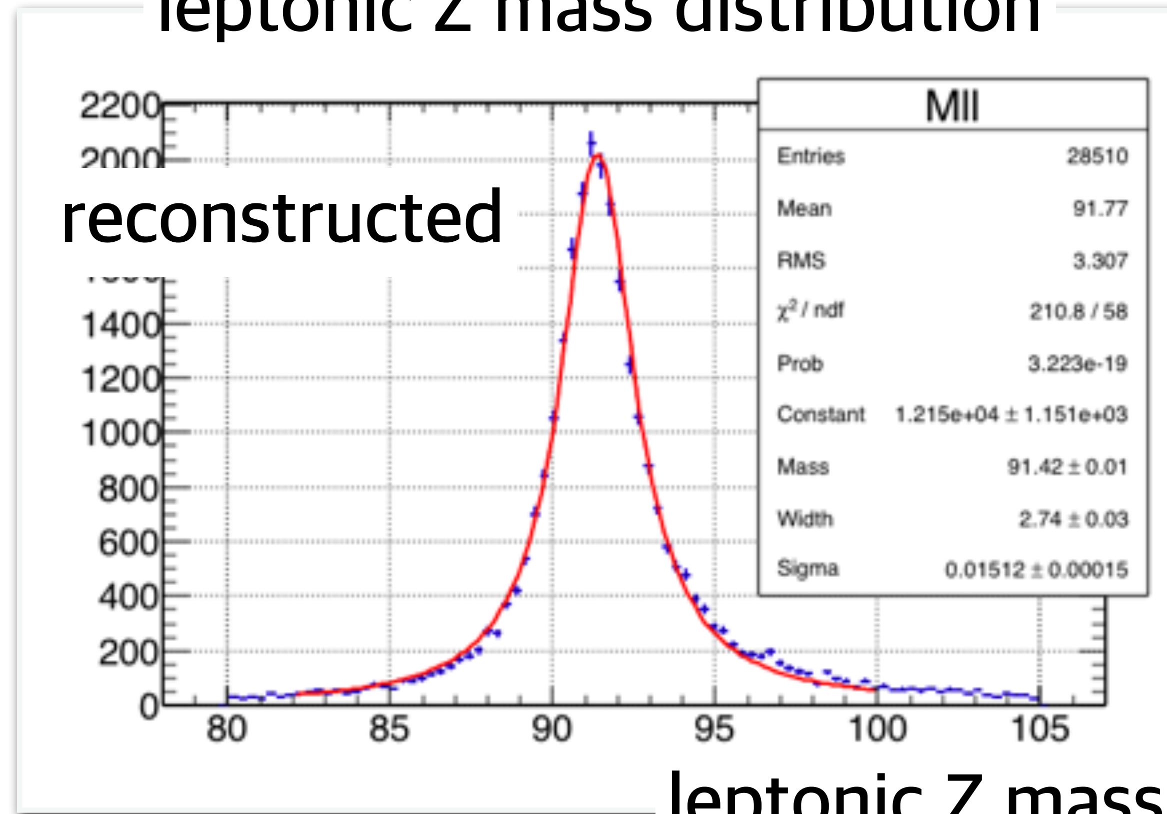
Currently working on

- The first step to do is to find a proper model to describe the W invariant mass.
- Note that $\sqrt{s}$ = 250 GeV now.
- There can be about 3 studies to do :
    - dynamics —> running width BW function (done)
    - kinematics —> missing neutrinos from jets
        - correction have not been done yet
    - detector effects —> jet energy and angle resolution (work-in-progress)

- To calibrate the jet energy scale and understand similar detector effects, try to use Z mass reconstruction via ZZ—>qqll event
- procedure;
  1. reconstruct Z—>di-muon(leptonic) and Z—>di-jet(hadronic)
  2. calibrate jet energy scale by using that precisely known value of $m_Z^{hadronic}$ = 91.1876±0.0021 (PDG)
  3. also use Z mass distribution to understand other detector effects

Z mass plots





large χ^2 mainly came from missing neutrinos momenta

large χ^2 came from BG treatment; nothing considered so far

- leptonic mass is not affected by missing neutrinos
    - relativistic BW convoluted with Gaussian would be able to fit the data very well if reasonable BG treatment can be met
- to fit the hadronic mass, more proper function is necessary

Summary

- Single W process is potentially useful for physics at ILC
    - for direct W mass measurement
    - for triple gauge boson coupling study via γWW & ZWW
- We are now trying to do direct measurement of W mass via hadronic system (W—>qq')
    - first on $\sqrt{s}$ = 250 GeV
    - jet energy scale calibration and detector effect study in progress
    - we have not found the proper model function to fit the W invariant mass distribution

Next

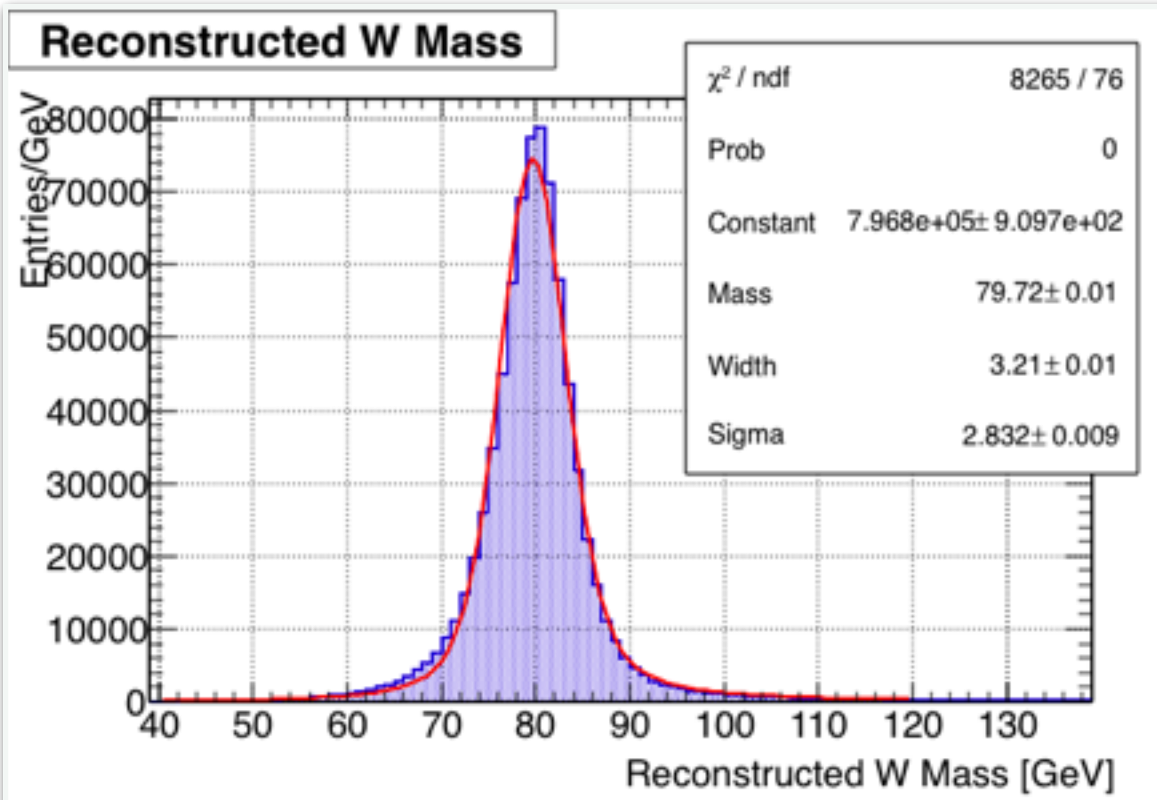
- after we obtained proper model to describe W mass . . .
- then we can change some detector simulation conditions to study systematic uncertainties
    - jet energy scale uncertainty
    - impact of different tune of PFA
    - parton shower and hadronization model
- others to improve result
    - track energy correction (pi0 fitting?)
    - kinematic fitting (missing energy from final state neutrino)

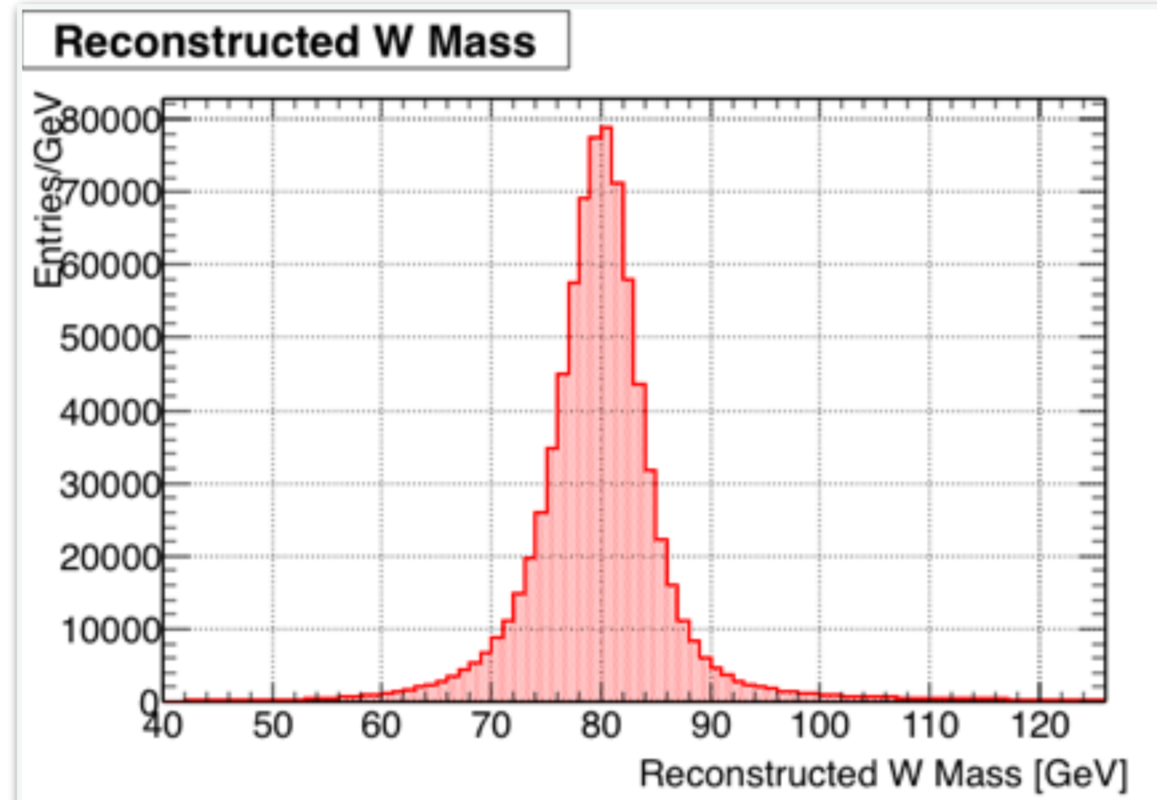
Back up

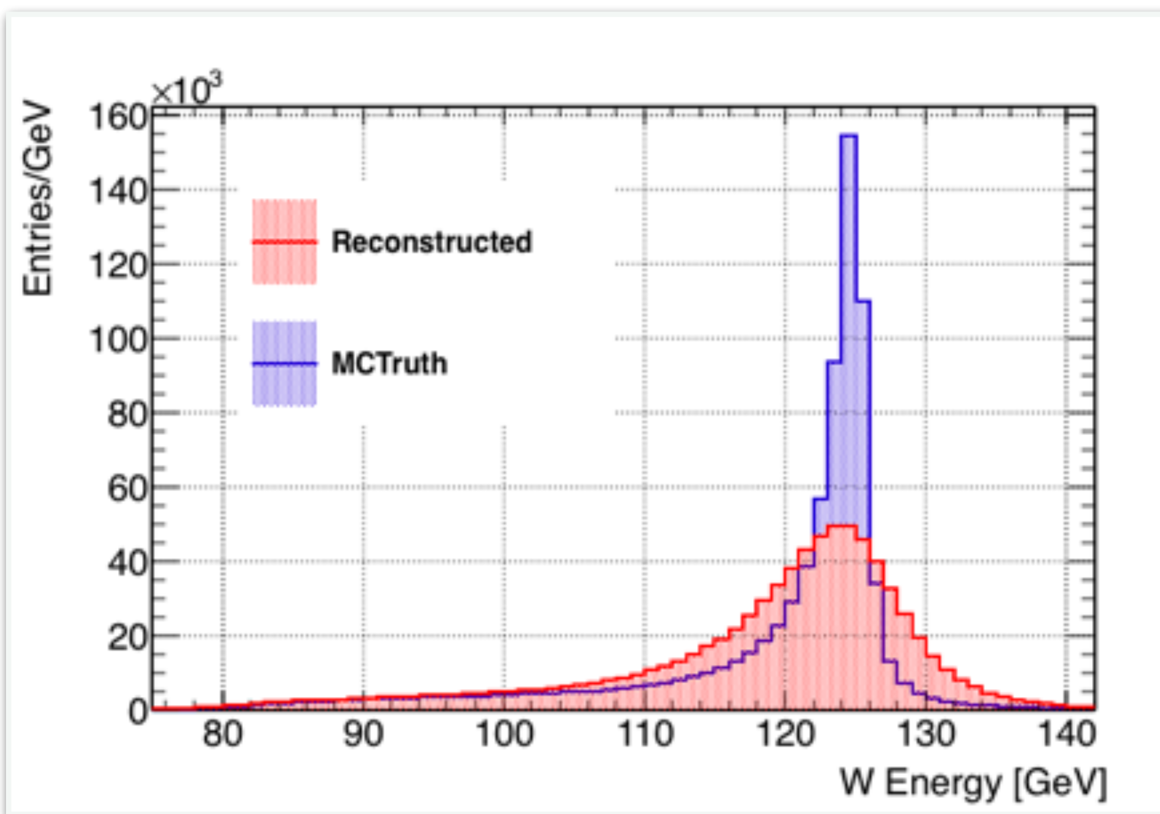
Simulation conditions

- First at $\sqrt{s}$ = 250 GeV, polarization eLpR
- 4 fermion DBD samples (sw_sl0qq) are used
  - evqq final state events include both single-W and WW-pair diagrams
  - note that WW processes are dominant at $\sqrt{s}$ = 250 GeV
  - with no backgrounds so far
- Detector model : ILD_o1_05
- ILC soft version : v01-17-05

m_W reconstruction with perfect PFOs



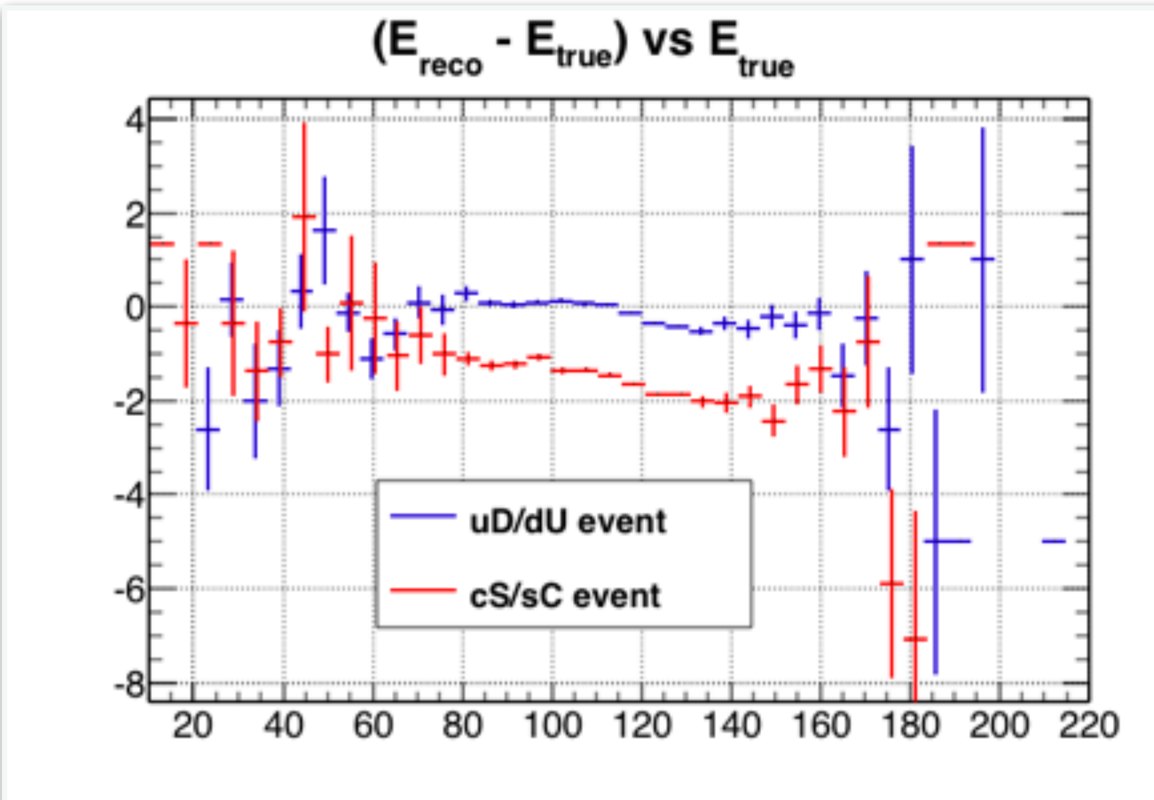


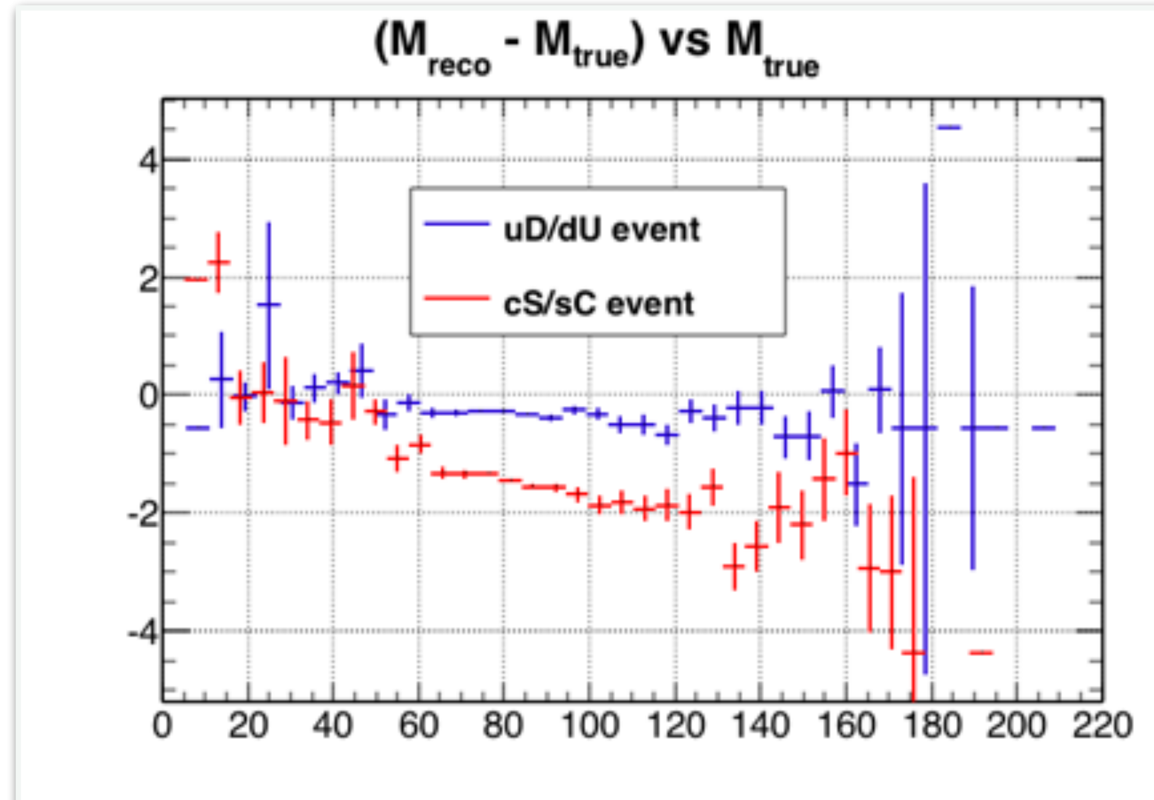


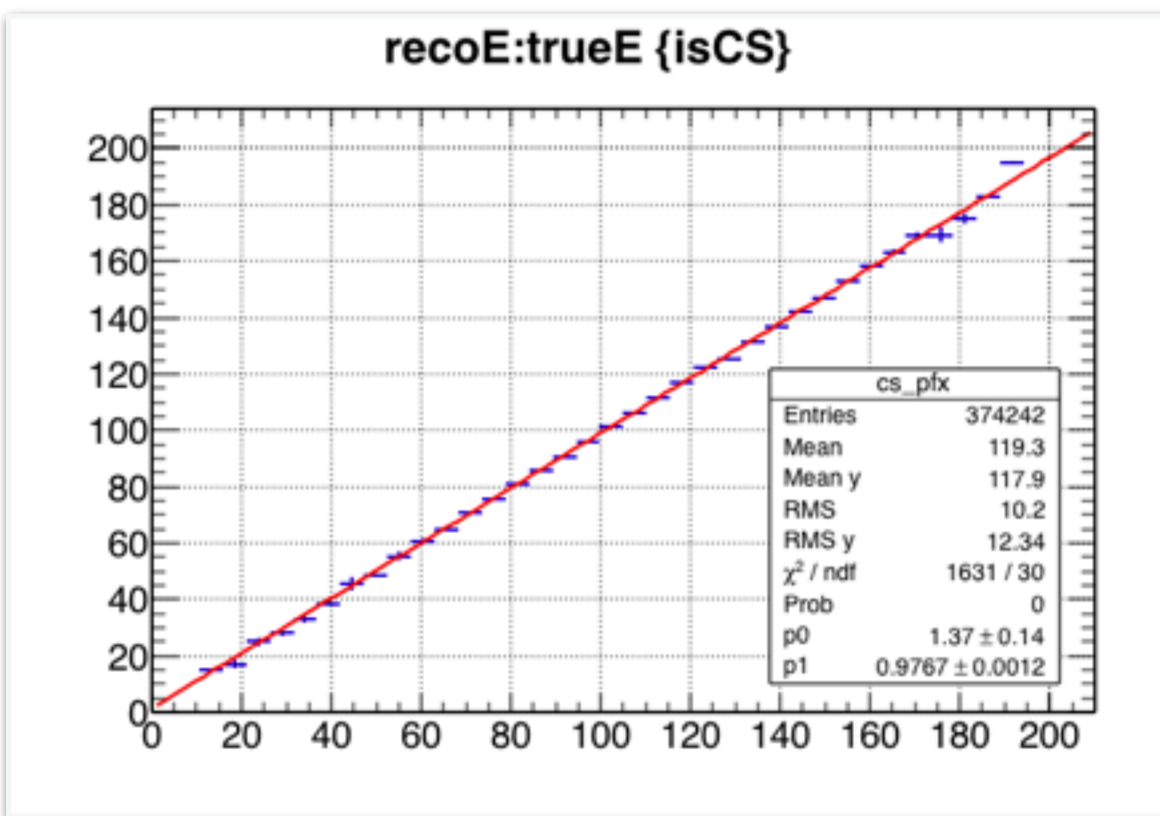
PFOs which came from ISRs, final state leptons(e and ν) and overlays(beam backgrounds) have already removed before jet clustering

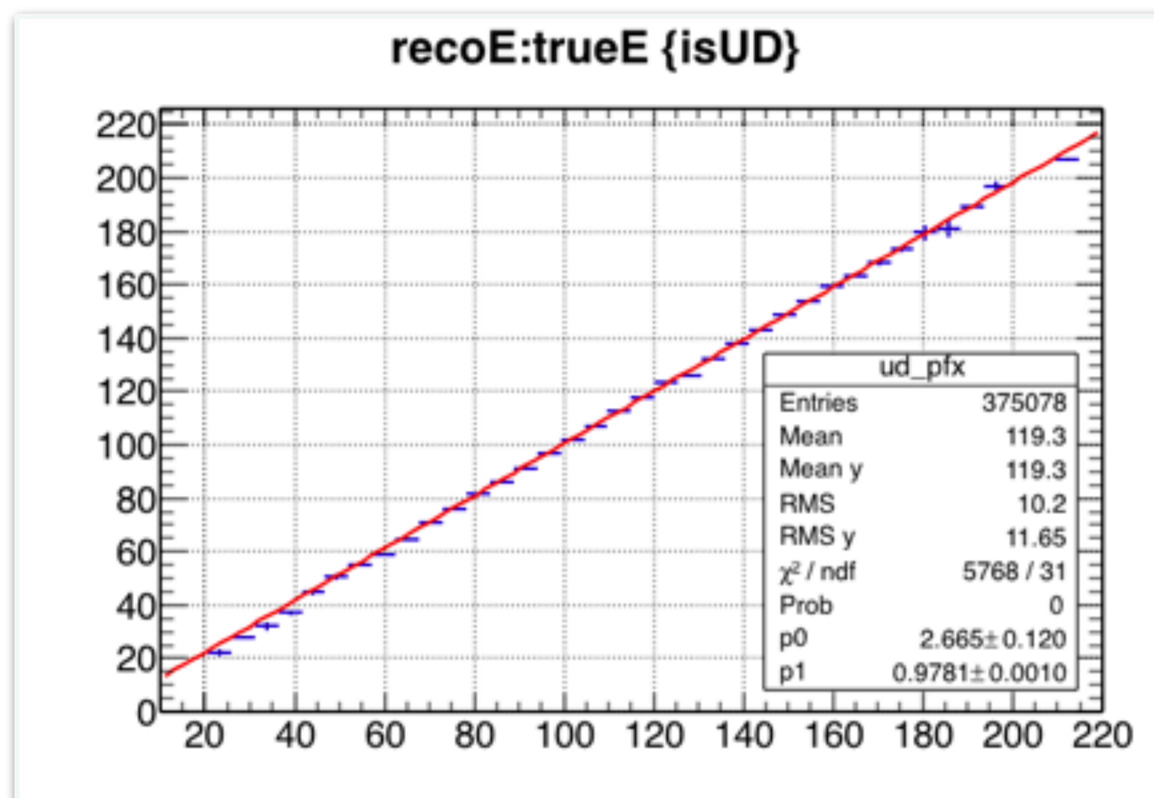
jet clustering is performed by Durham algorithm

missing neutrino plots

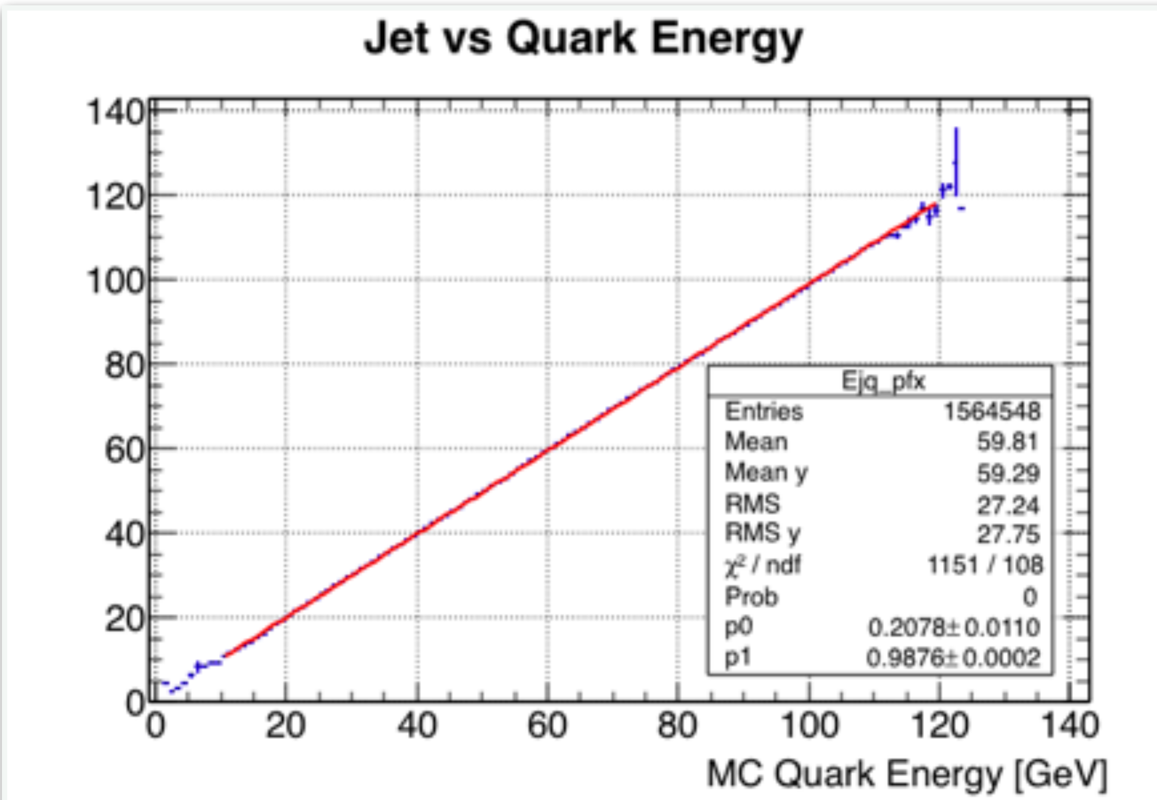


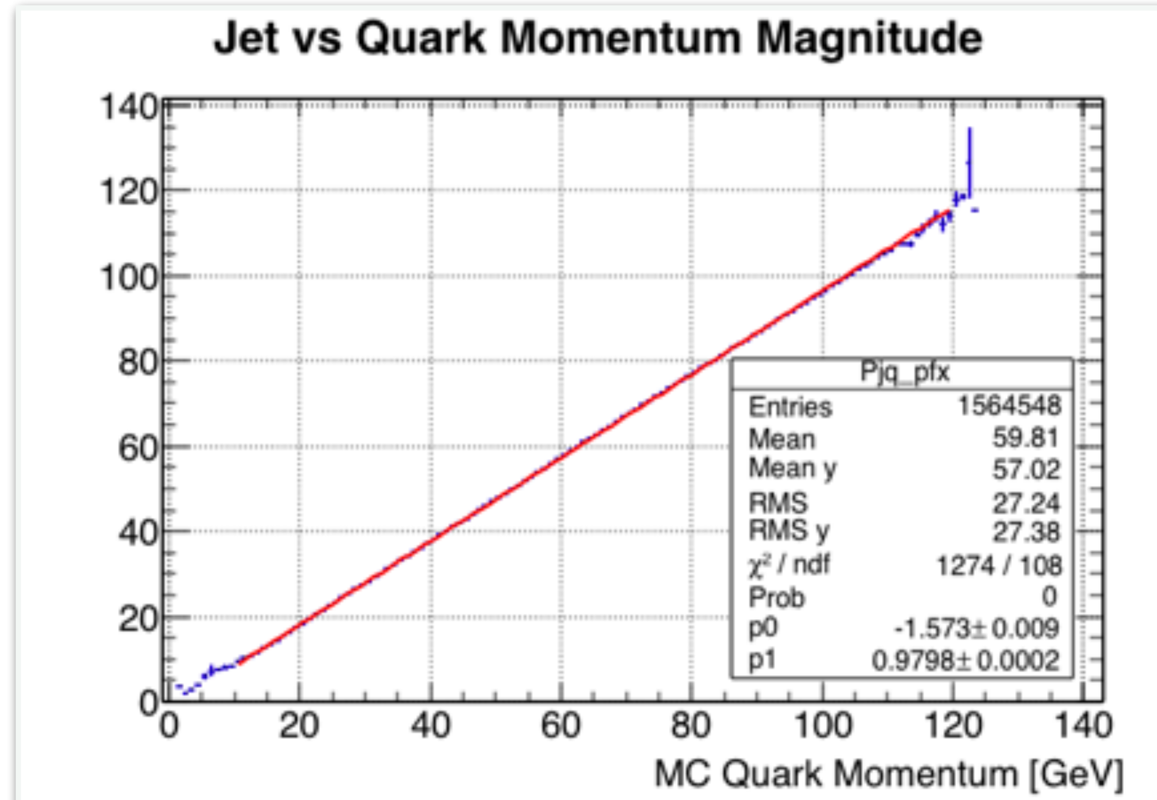


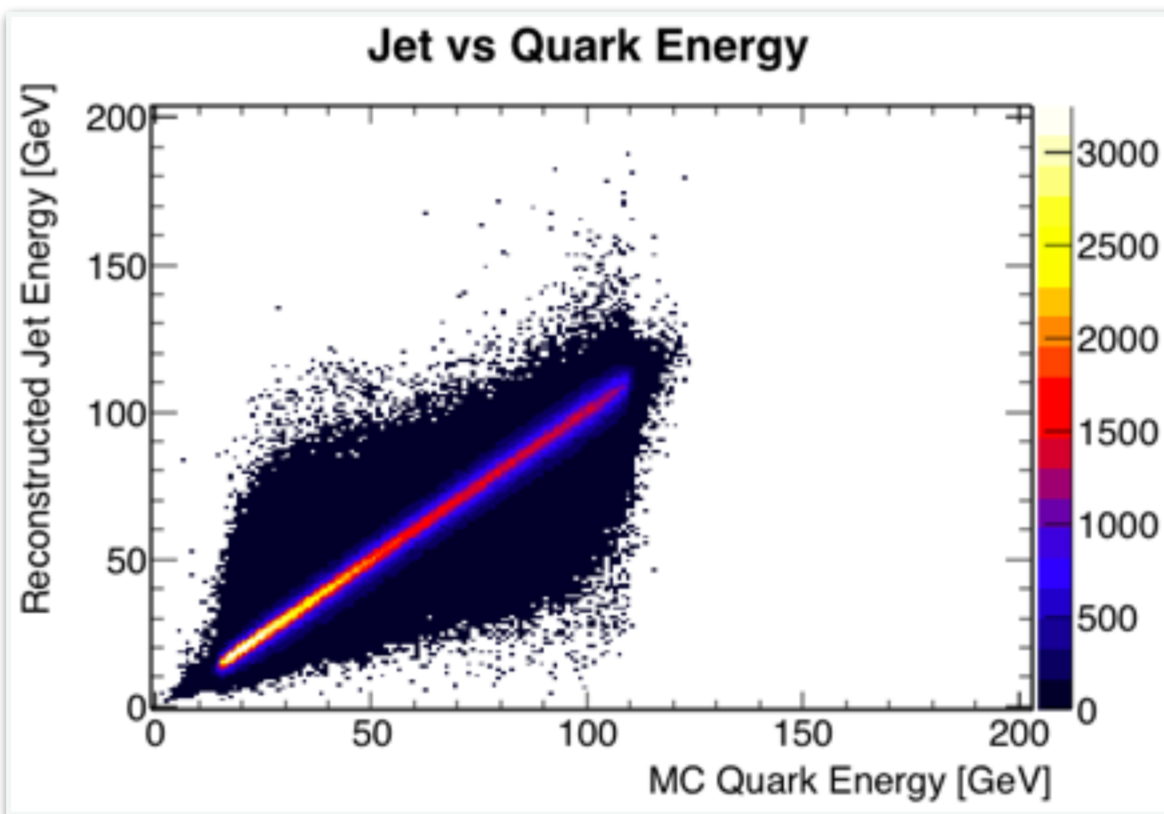


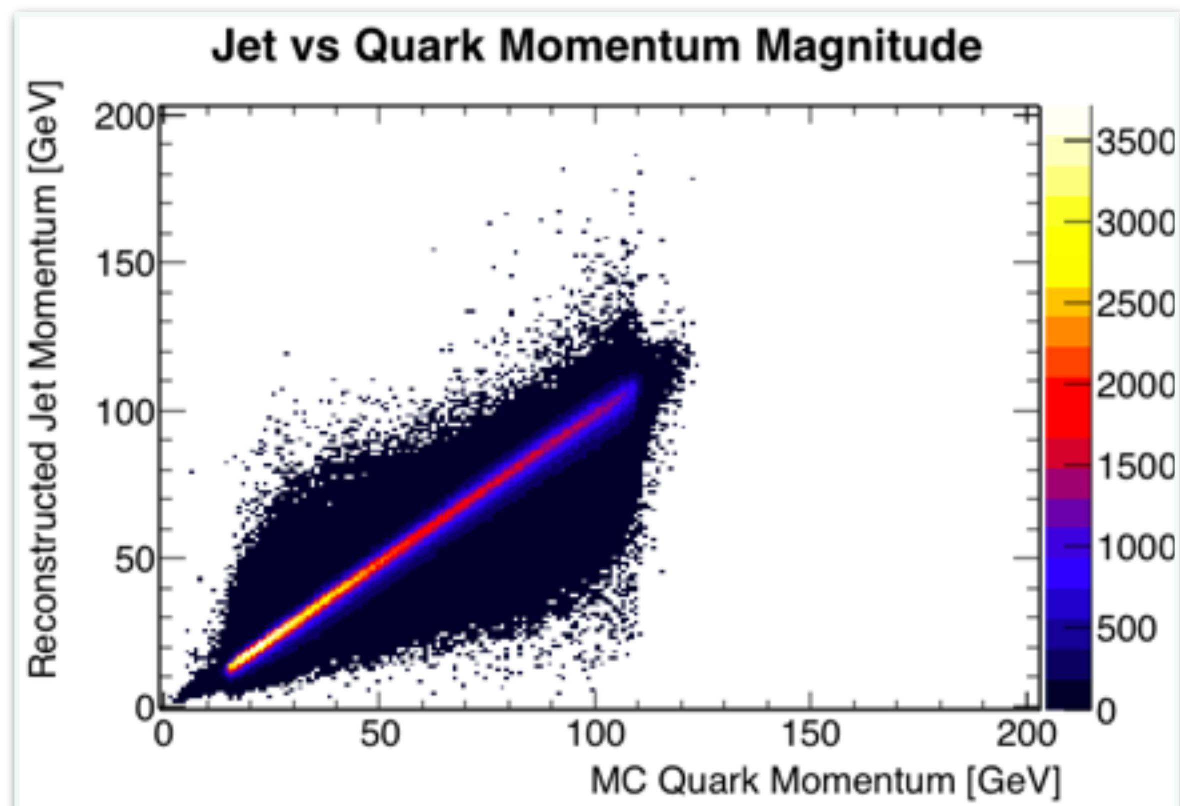


each quark jet from W

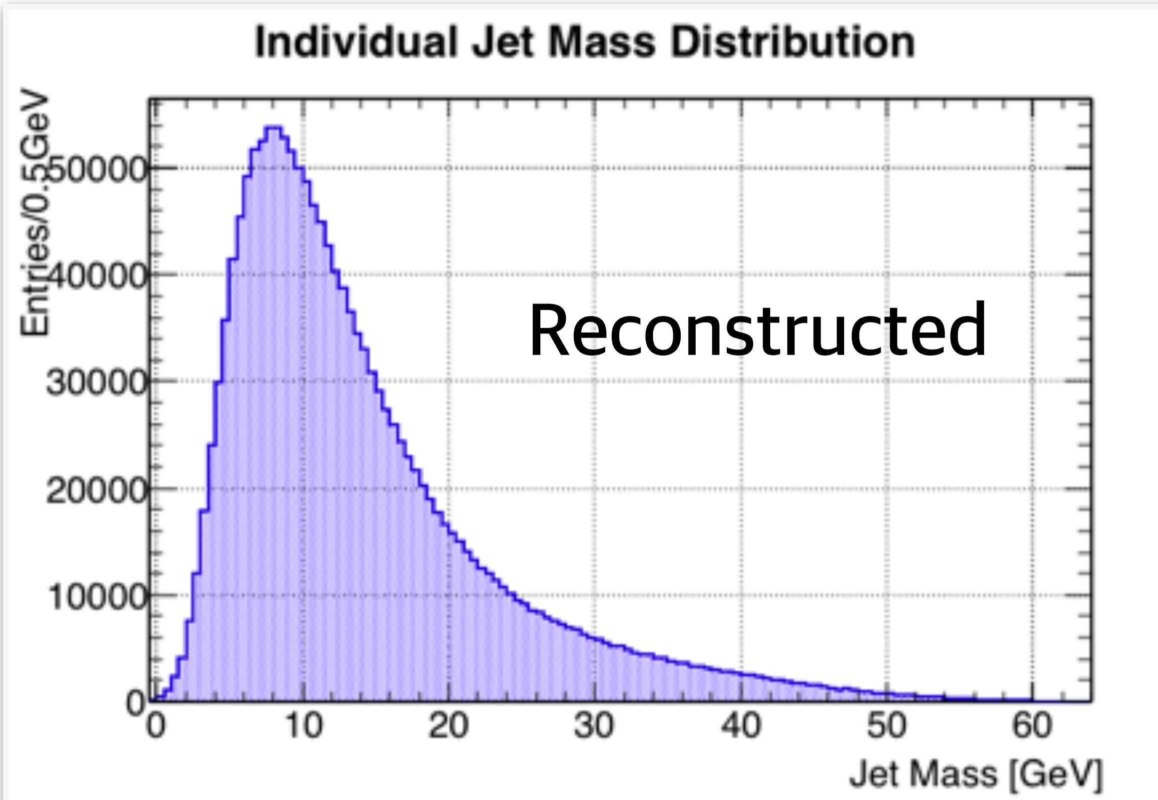


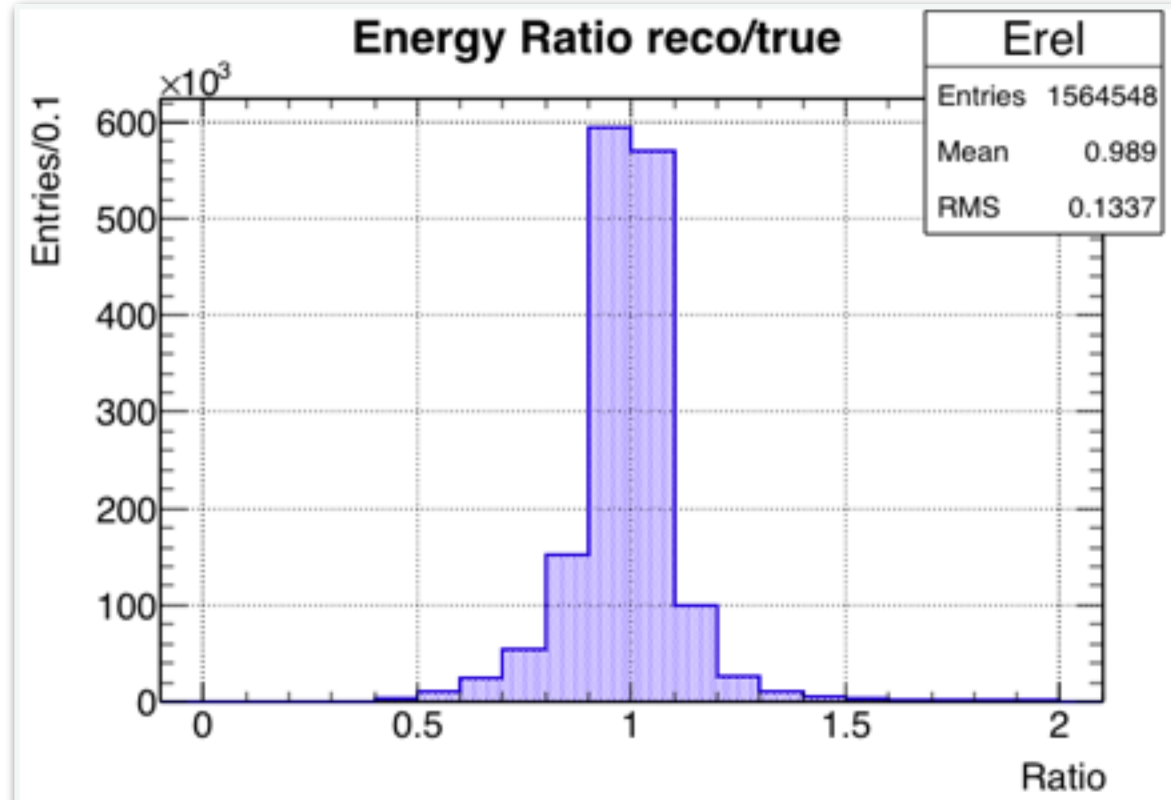


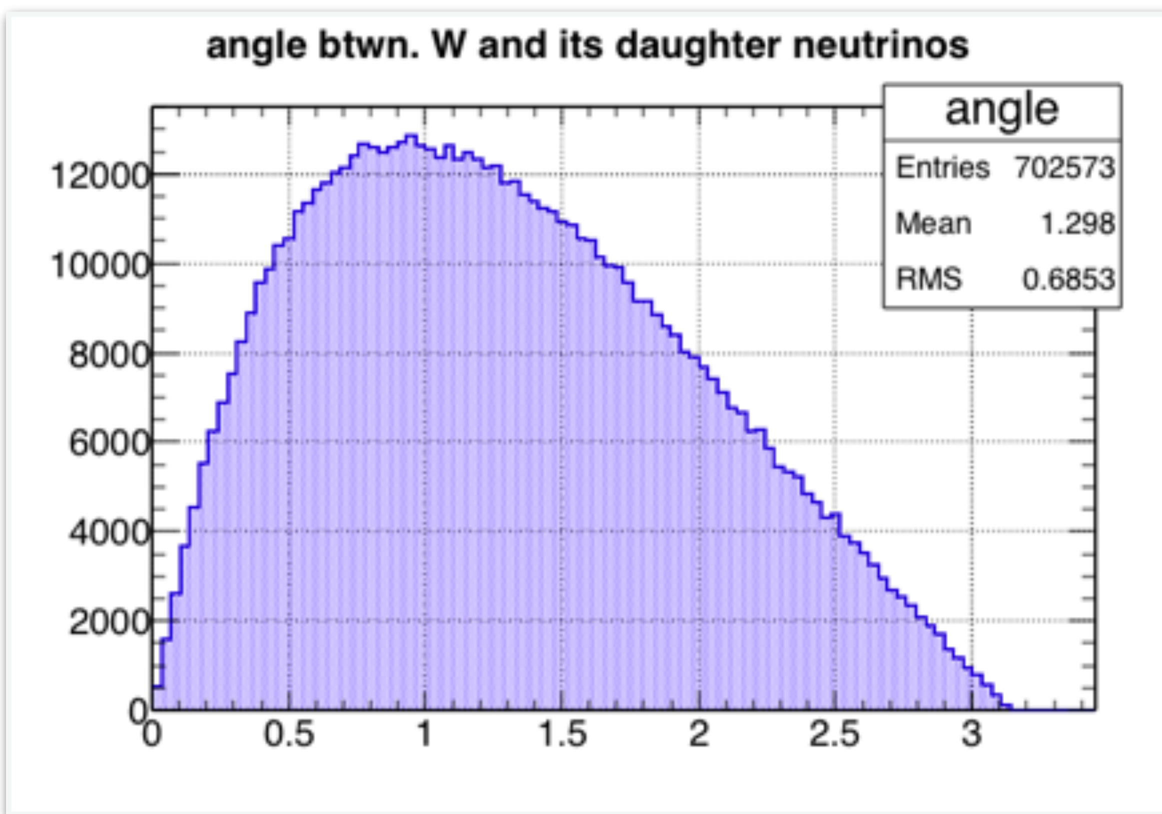


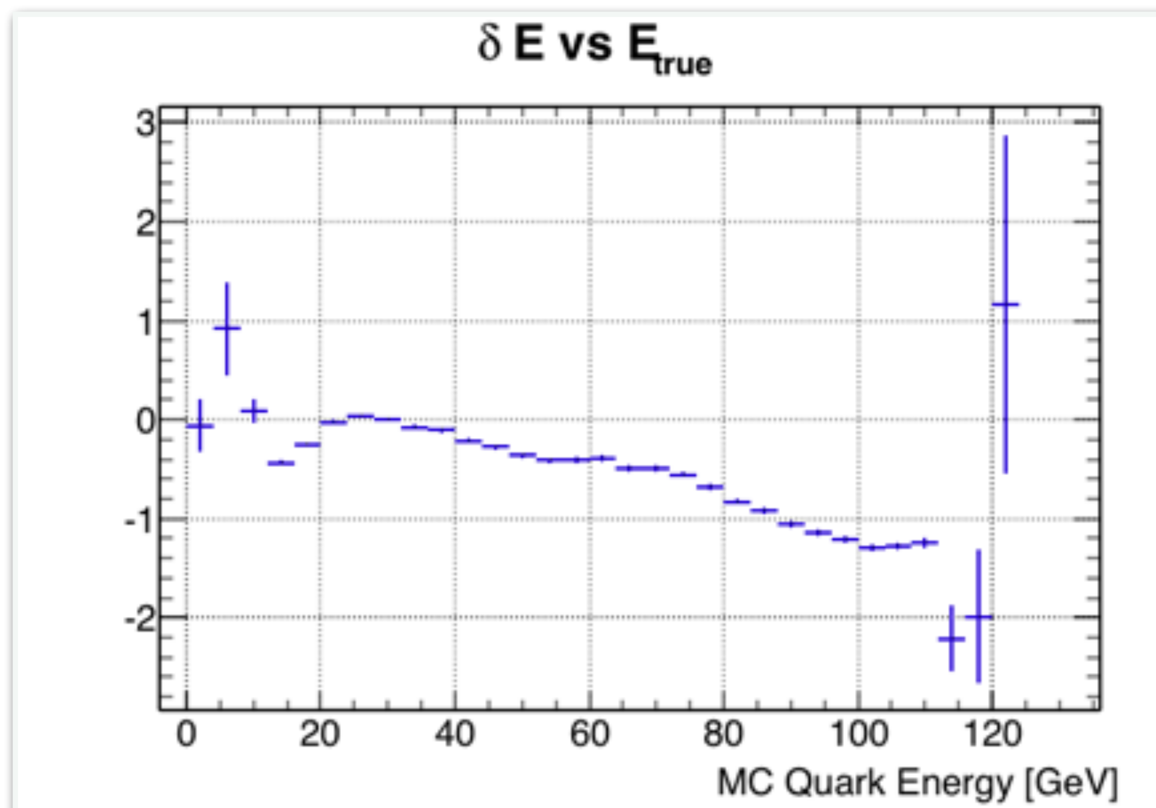


each quark jet from W



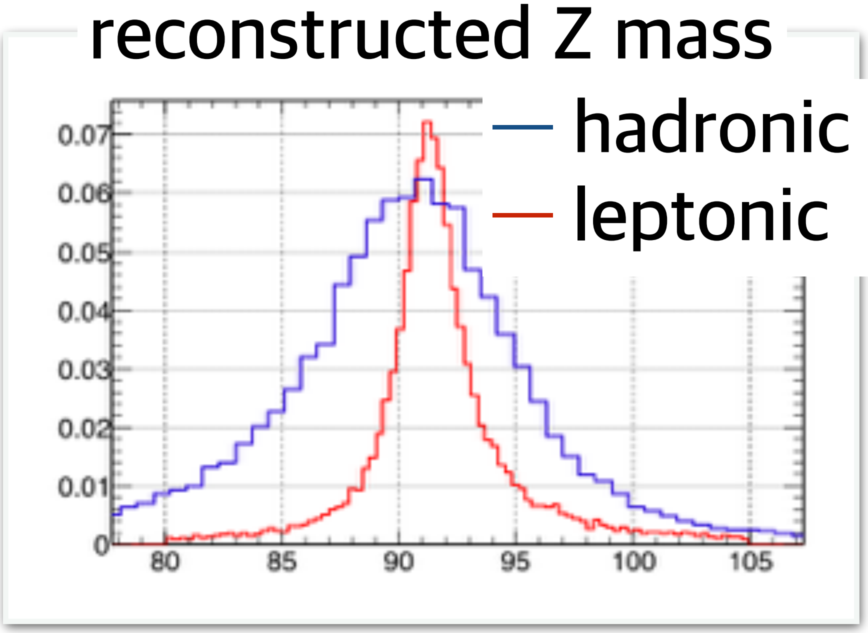




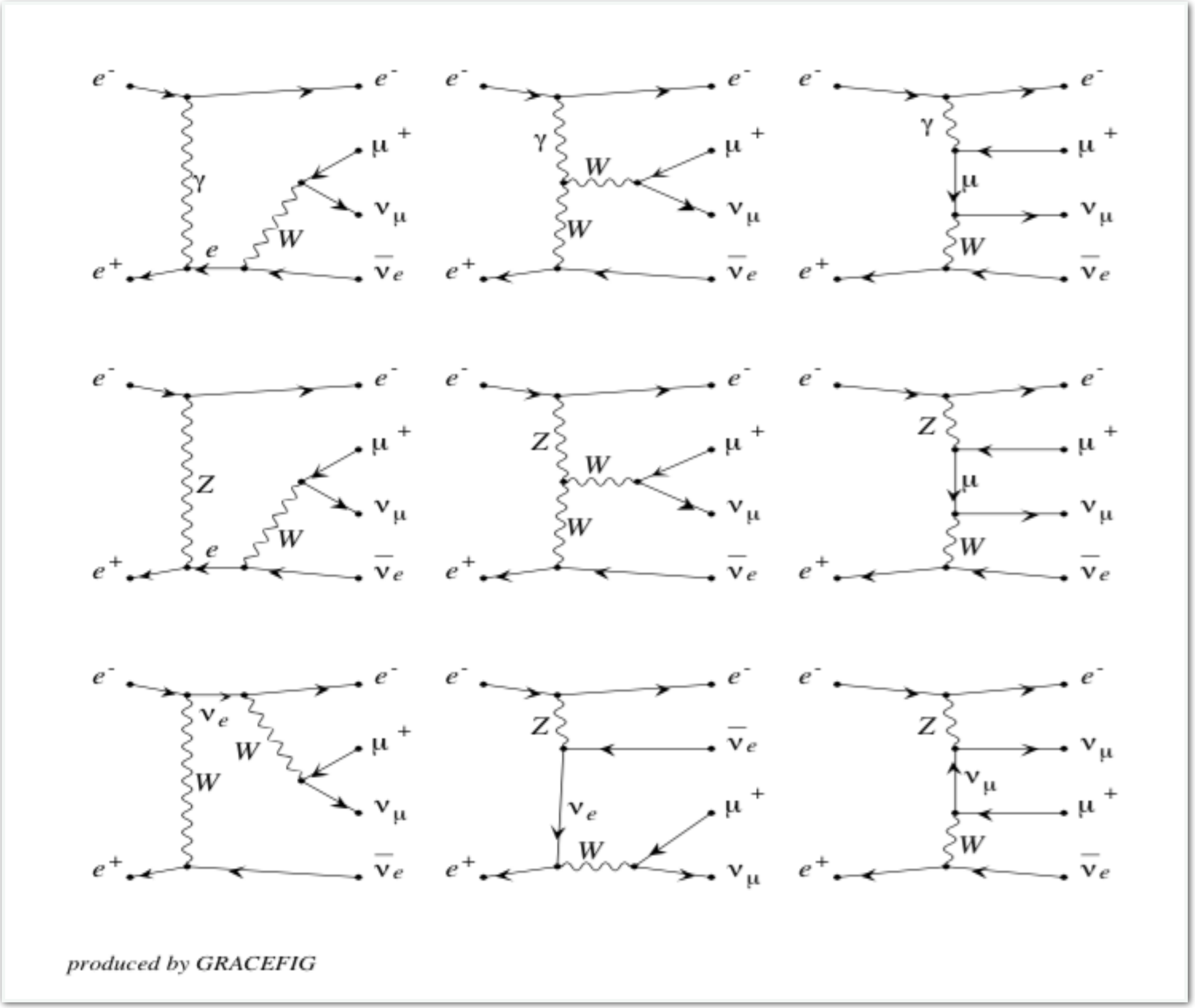


semileptonic Z reconstruction

- ZZ—>qqll (background: Zγ—>qqll, γγ—>qqll)
- Cuts (not optimized, performed with perfect PFA)
    - Number of isolated μ < 2
    - M_{ll}^{reco} < 80 GeV, 105 GeV < M_{ll}^{reco}
    - E_{ll}^{reco} < 115 GeV, 135 GeV < E_{ll}^{reco}
    - M_{qq}^{reco} < 60 GeV, 120 GeV < M_{qq}^{reco}
    - E_{qq}^{reco} < 100 GeV, 140 GeV < E_{qq}^{reco}



single W diagrams (eνμν)



eνW diagrams