Direct W mass measurement using single-W process

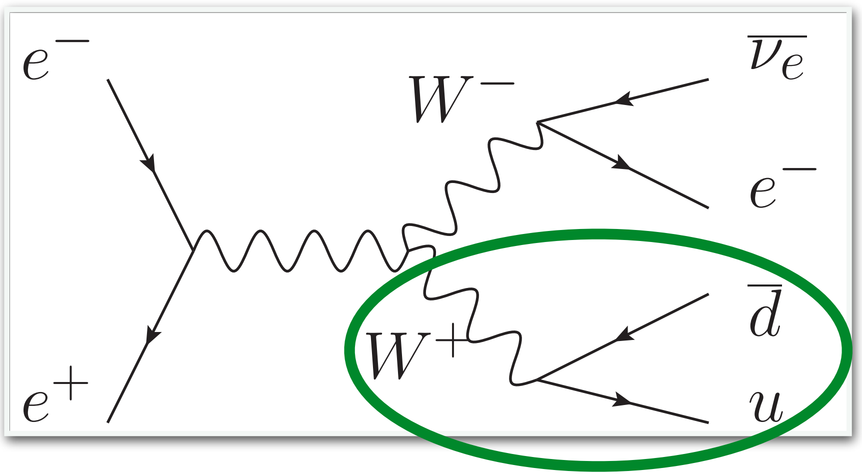
Shinshu University
K. Tsuchimoto

24th January, 2015 : The 40th General Meeting of ILC Physics
—> Progress & current status of my study

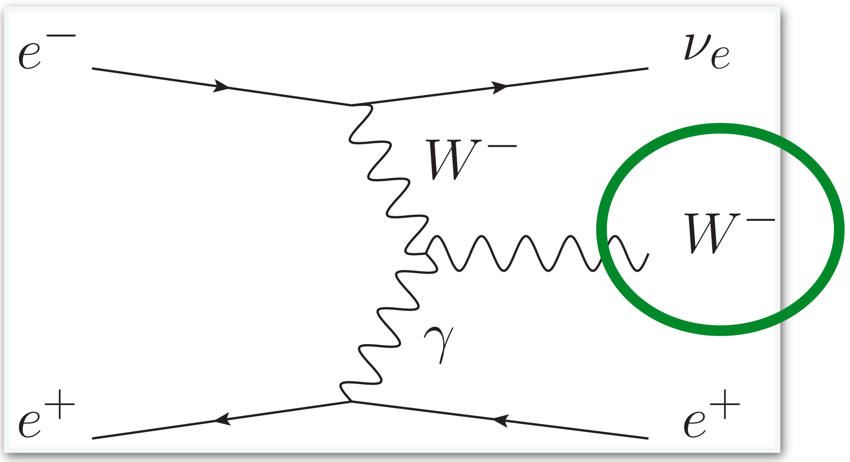
Overview - eνW

There are 2 processes which contribute to eνqq events.

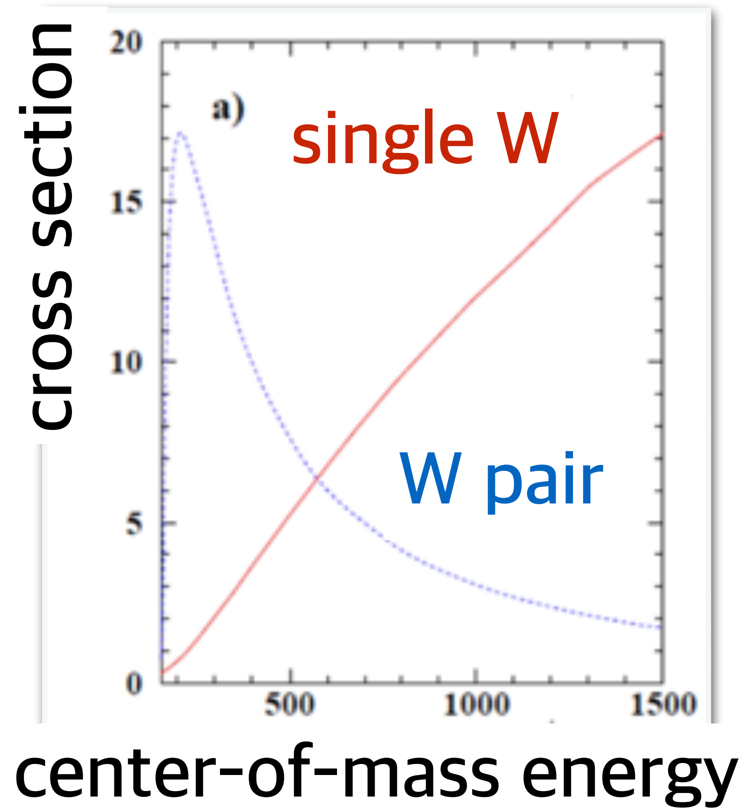
WW-pair production



single-W process



final state : eνqq



- W mass is directory measurable via hadron channel (W—>qq)
- needs challenging requirements on JER and calibration
- very sensitive and good for detector optimization because there is no ambiguity from jet clustering effect

Currently working on

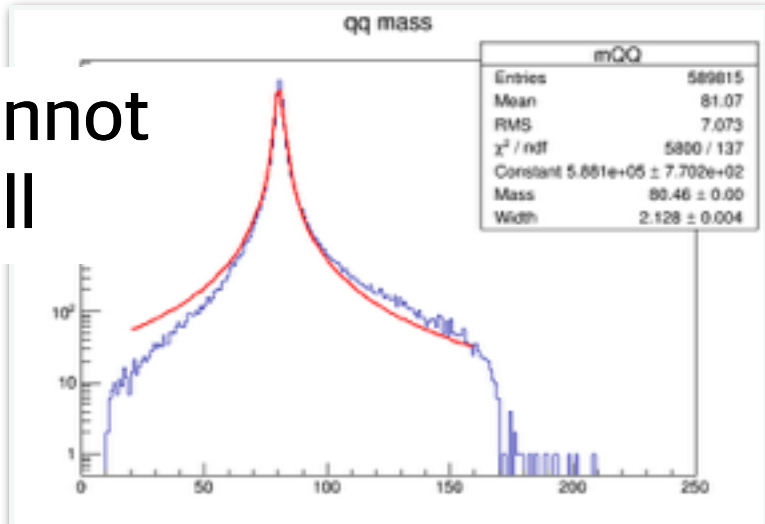
- The first step to perform direct m_W measurement is to find a proper model to describe the W invariant mass.
- DBD sample, $\sqrt{s}$ = 250 GeV for now
- There can be 3 studies to do :
    - dynamics —> fitting generator level W mass
    - kinematics —> missing neutrinos from jets
    - detector effects —> jet energy and angle resolution

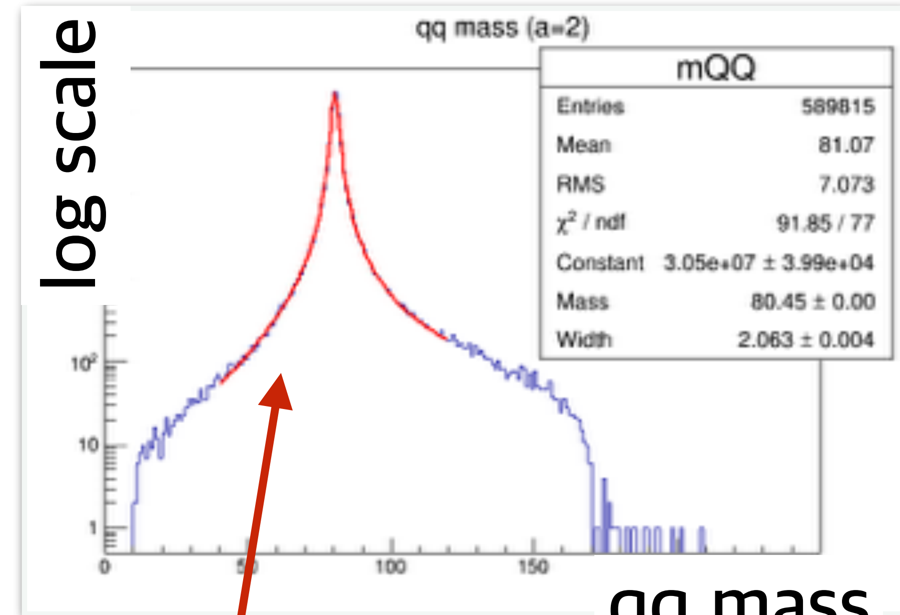
Currently working on

- The first step to perform direct m_W measurement is to find a proper model to describe the W invariant mass.
- analysis with DBD sample, $\sqrt{s}$ = 250 GeV for now
- There can be 3 studies to do :
  - dynamics —> fitting generator level W mass
  - kinematics —> missing neutrinos from jets
  - detector effects —> jet energy and angle resolution

Generator level W mass

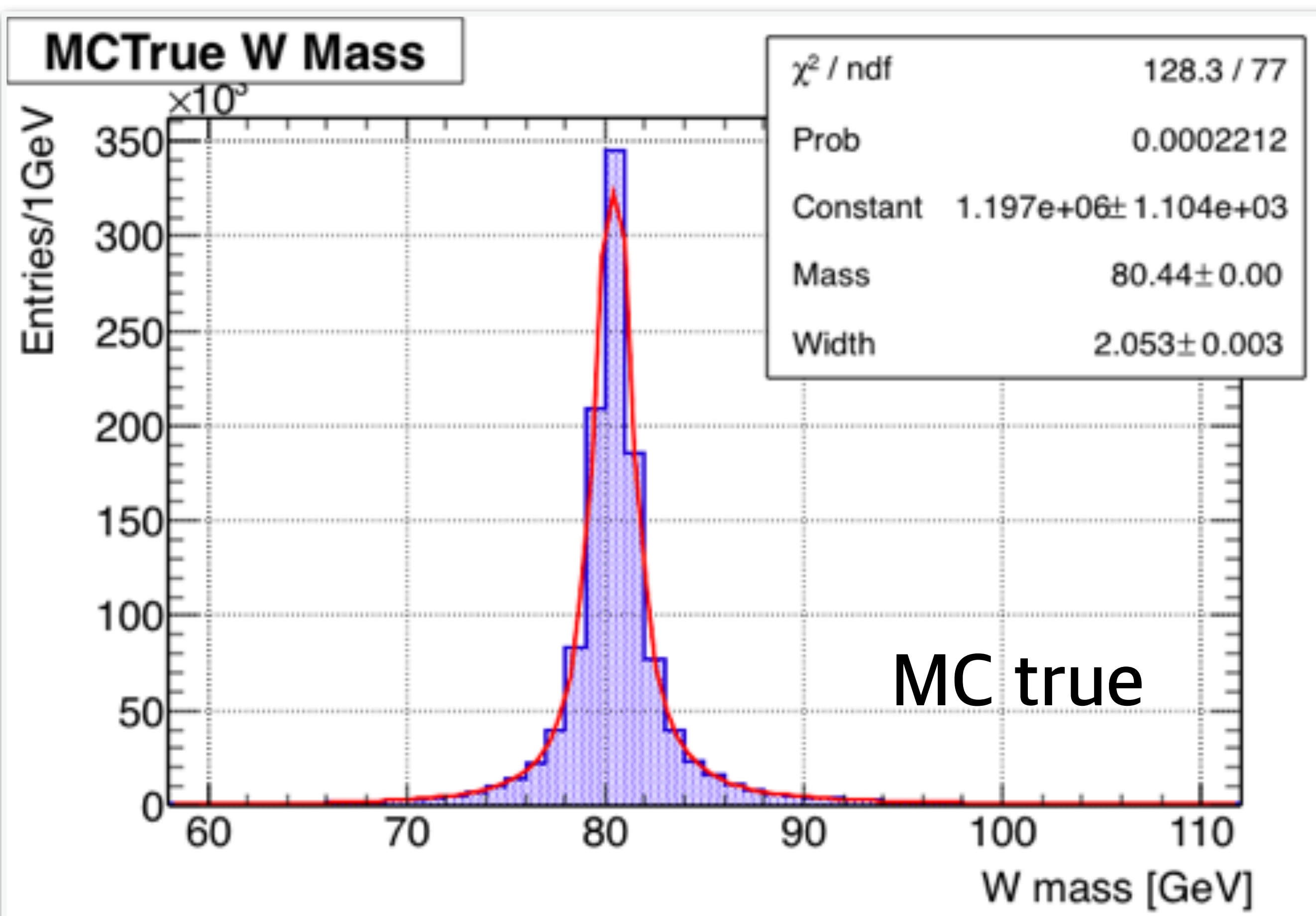
fixed width BW cannot fit the data well





log scale

qq mass



MC true

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

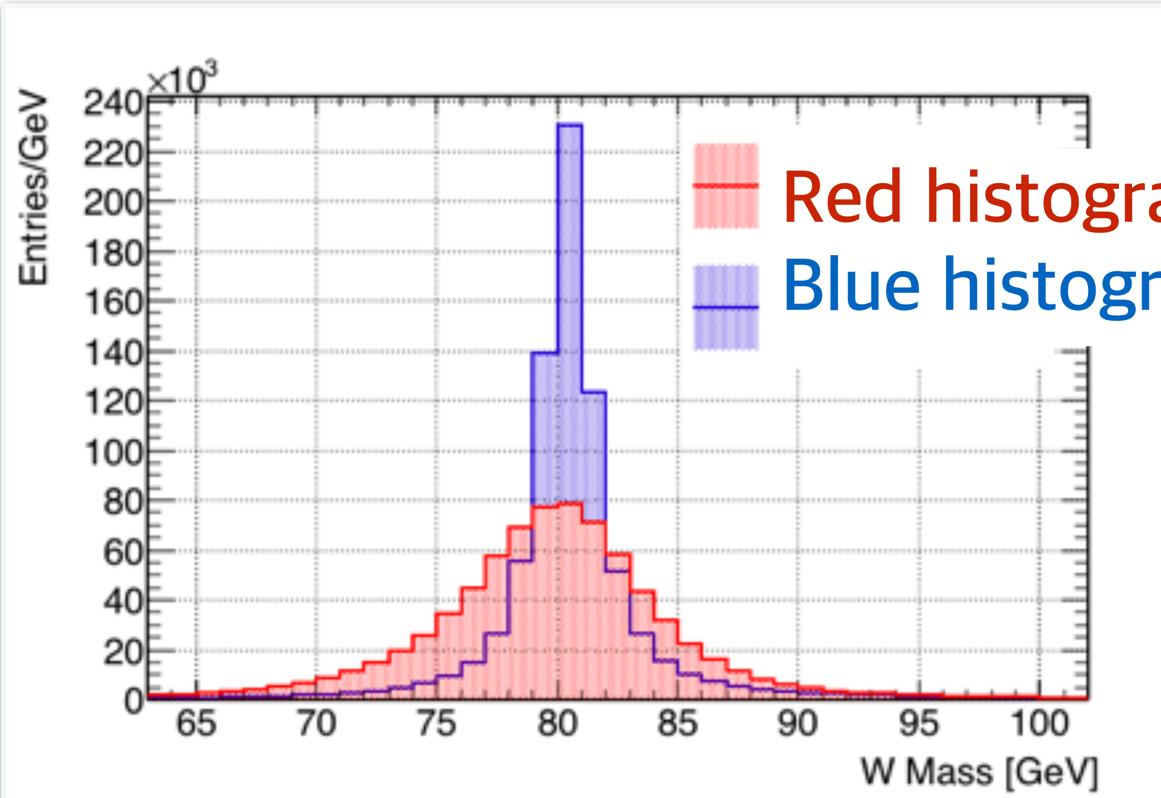
$$F(q; m_W, m\Gamma) = \frac{N m\Gamma}{\left(q^2 - m_W^2\right)^2 + (m\Gamma)^2}$$

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)

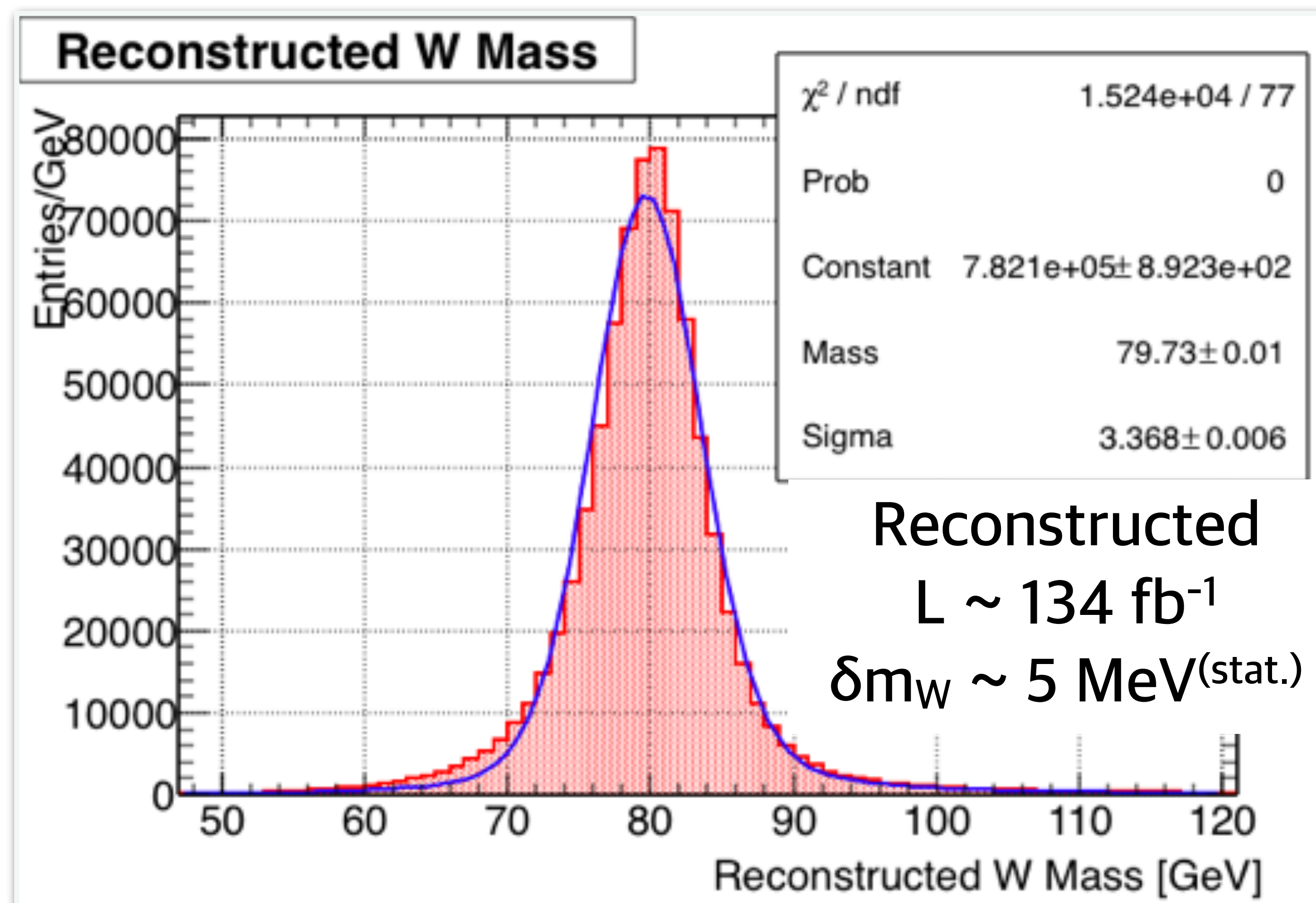
Detector level W mass



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

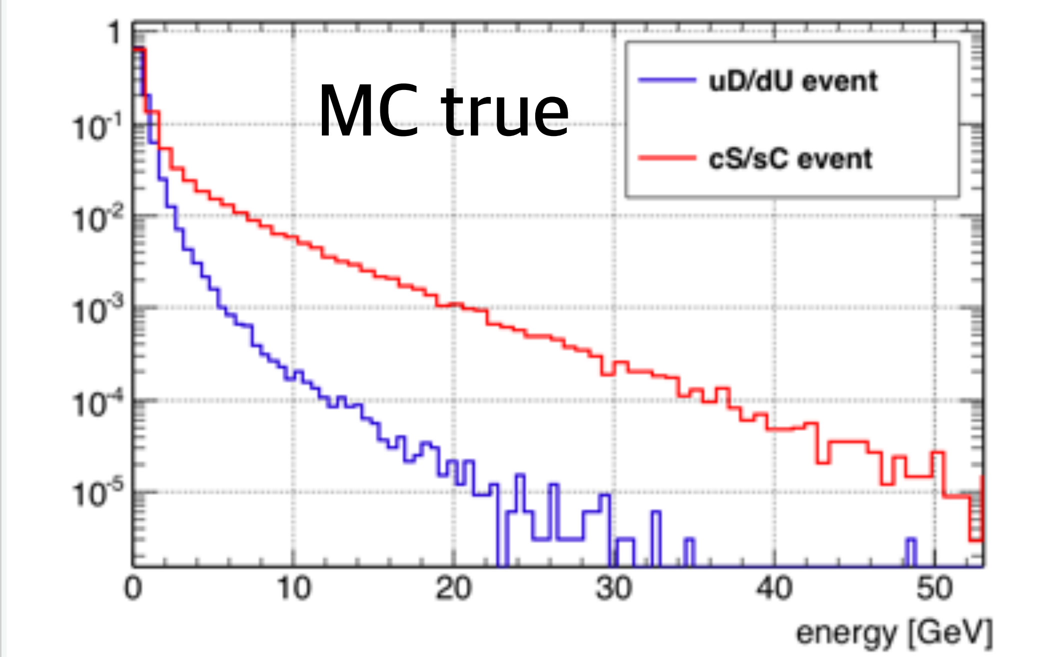
need to study these effects

Currently working on

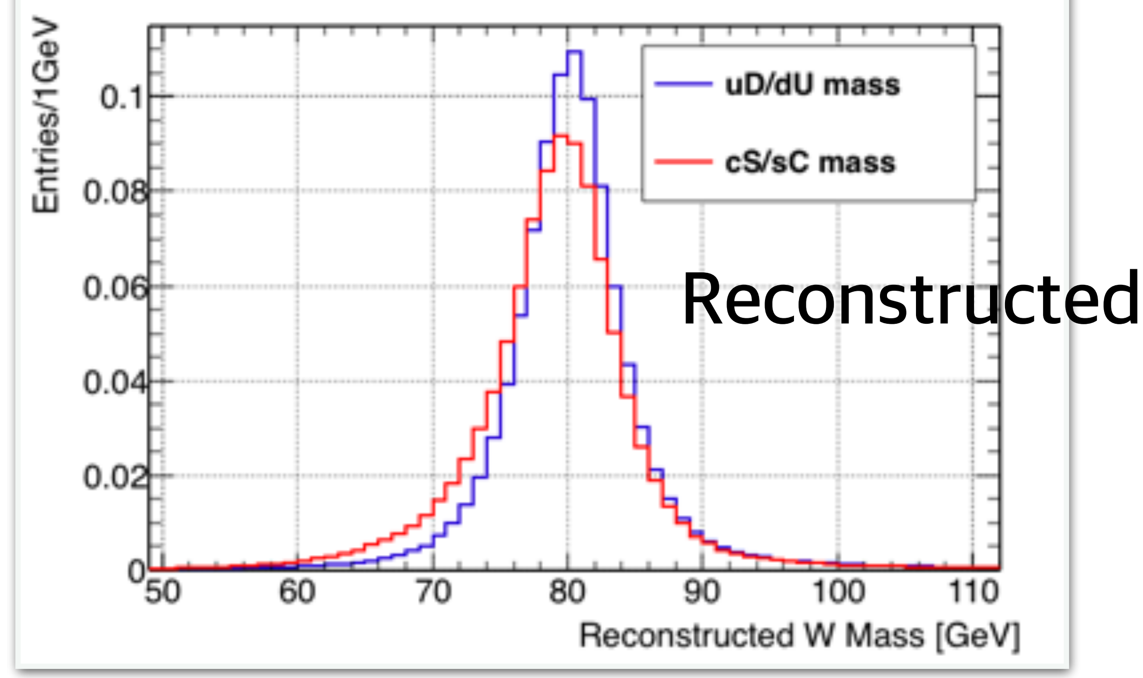
- The first step to perform direct m_W measurement is to find a proper model to describe the W invariant mass.
- analysis with DBD sample, $\sqrt{s}$ = 250 GeV for now
- There can be 3 studies to do :
    - dynamics —> fitting generator level W mass (done)
    - kinematics —> missing neutrinos from jets
    - detector effects —> jet energy and angle resolution

Missing neutrinos in jets

missing energy by ν_l in qq jets

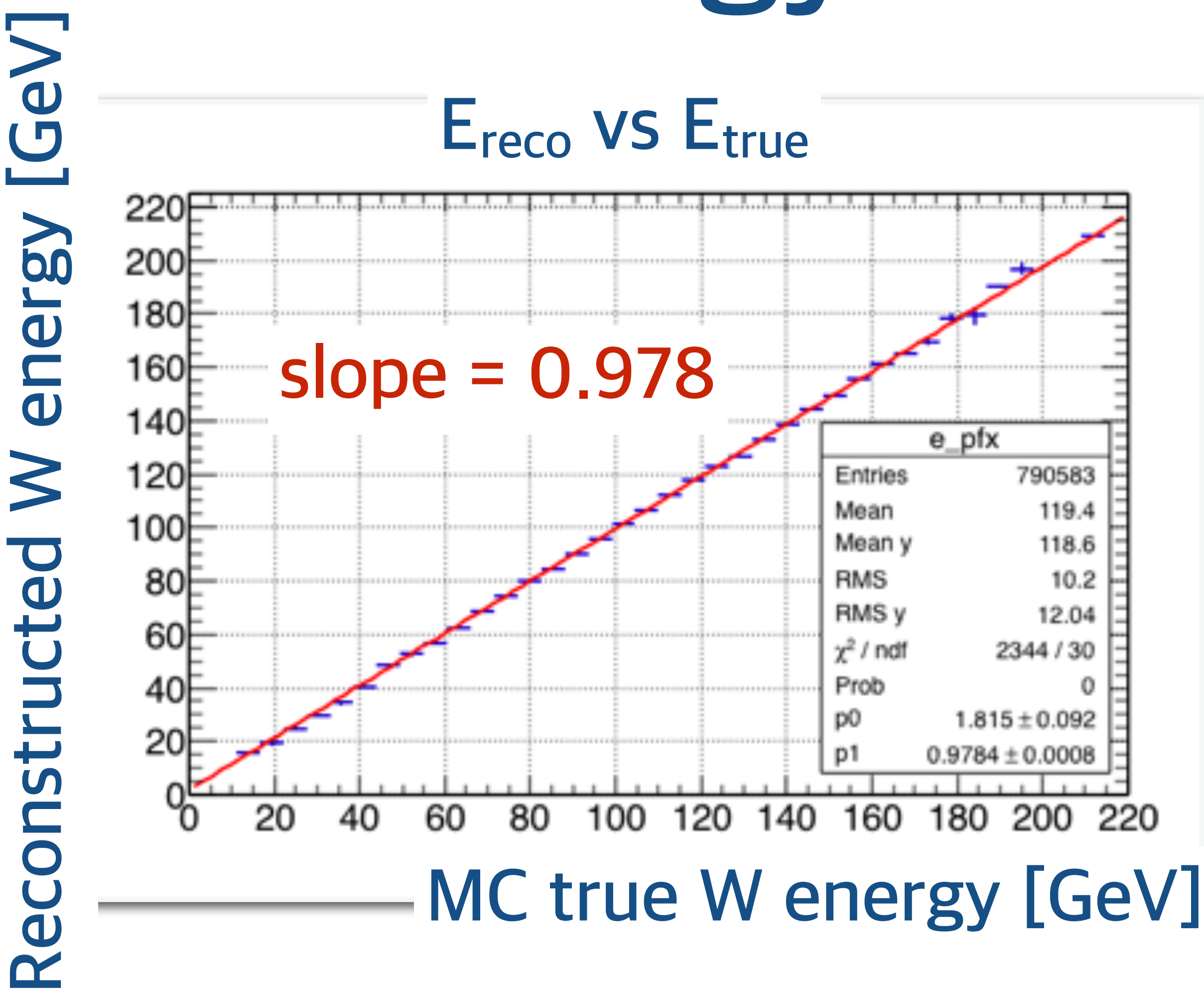


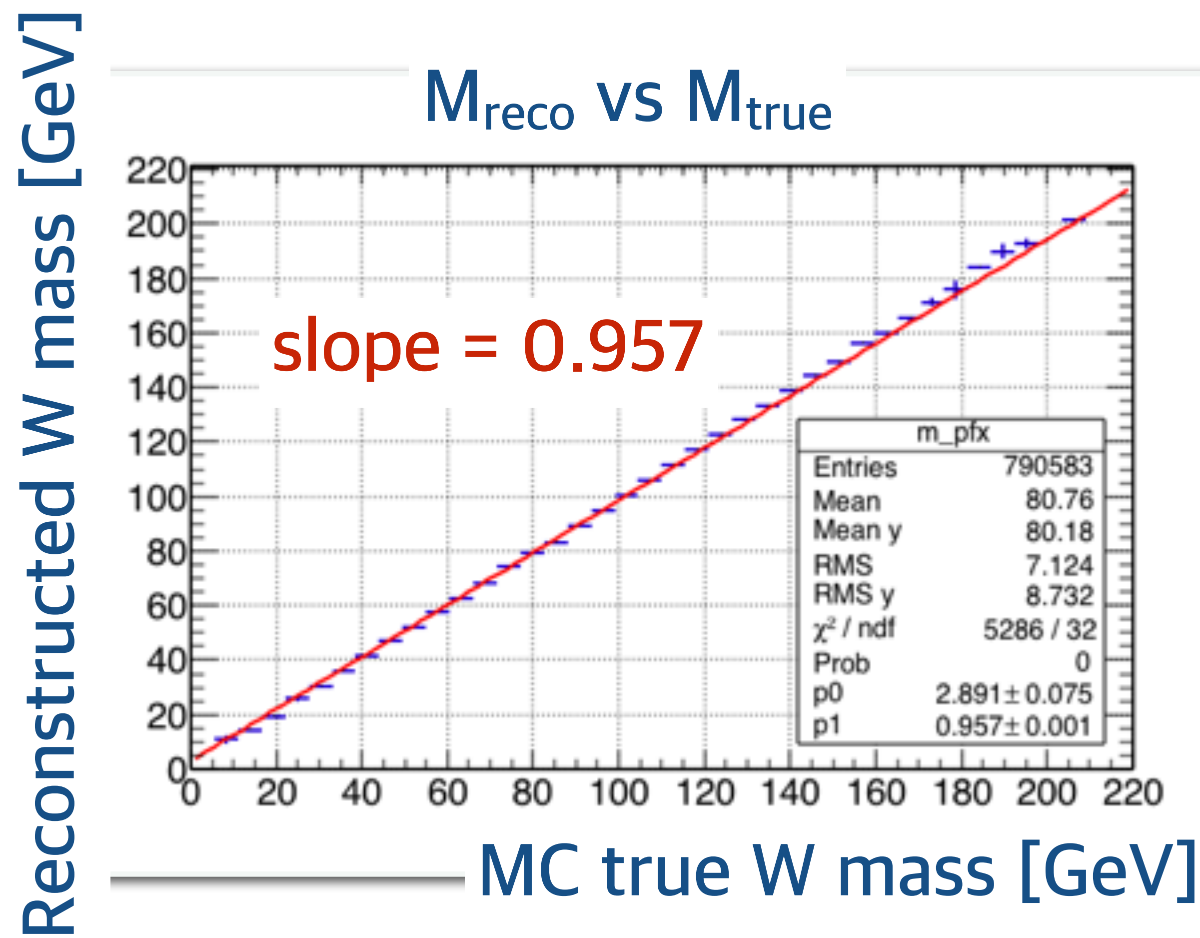
qq mass distribution



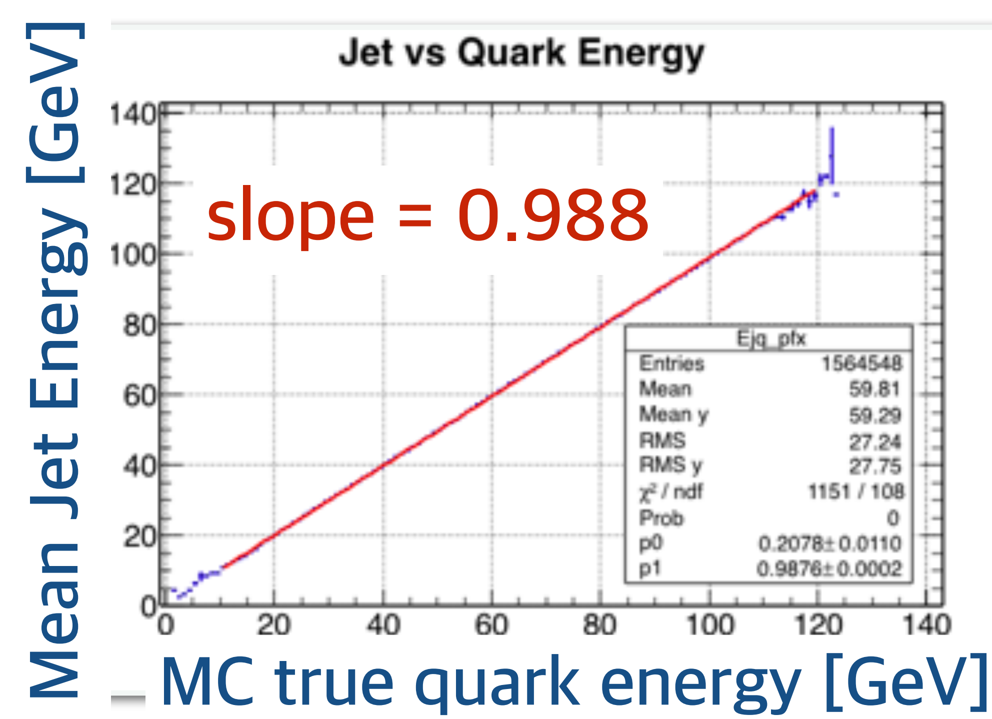
- There can be missing neutrinos in quark jets
  - like as; c—>sW—>slν (—>uWlν—>ulνlν)
  - existence of these neutrinos reduce the measurable jet energy
- This can be main reason that pulls measured W mass peak to lower value
- this effect changes the shape of W mass distribution —> large χ^2 in fitting

W energy and mass scale shifts





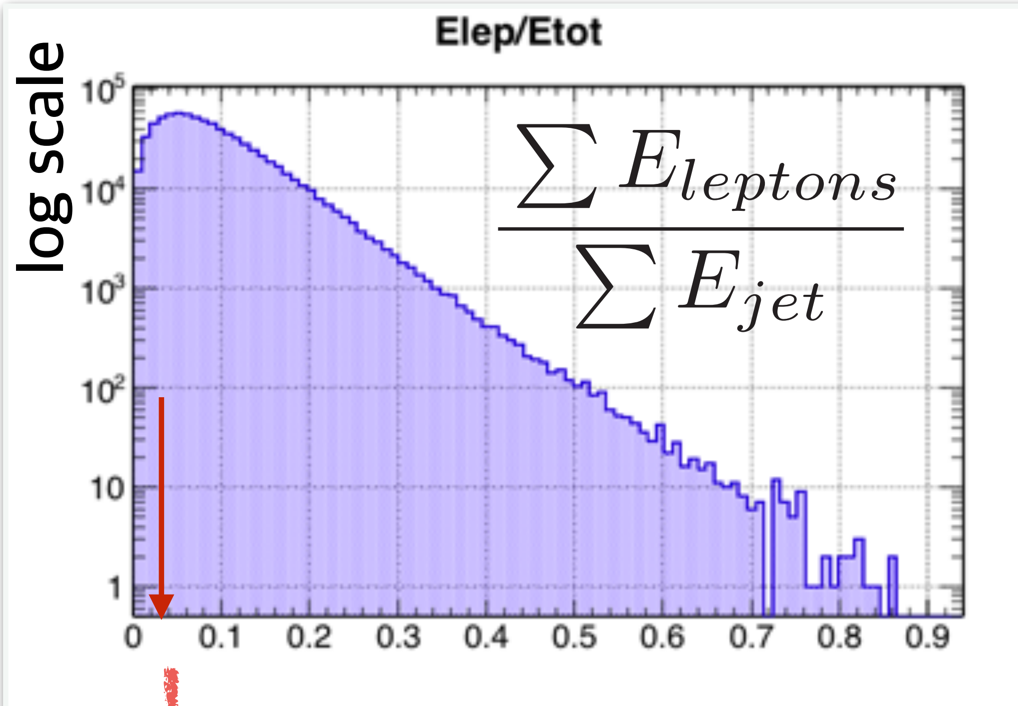
- due to the effect of missing neutrinos in jet (and also the systematic from PFA?)
  - shifted 1-2% for each quark jet E
  - shifted 2-3% for W energy scale
  - shifted 4-5% for W mass scale



Missing E_ν estimation

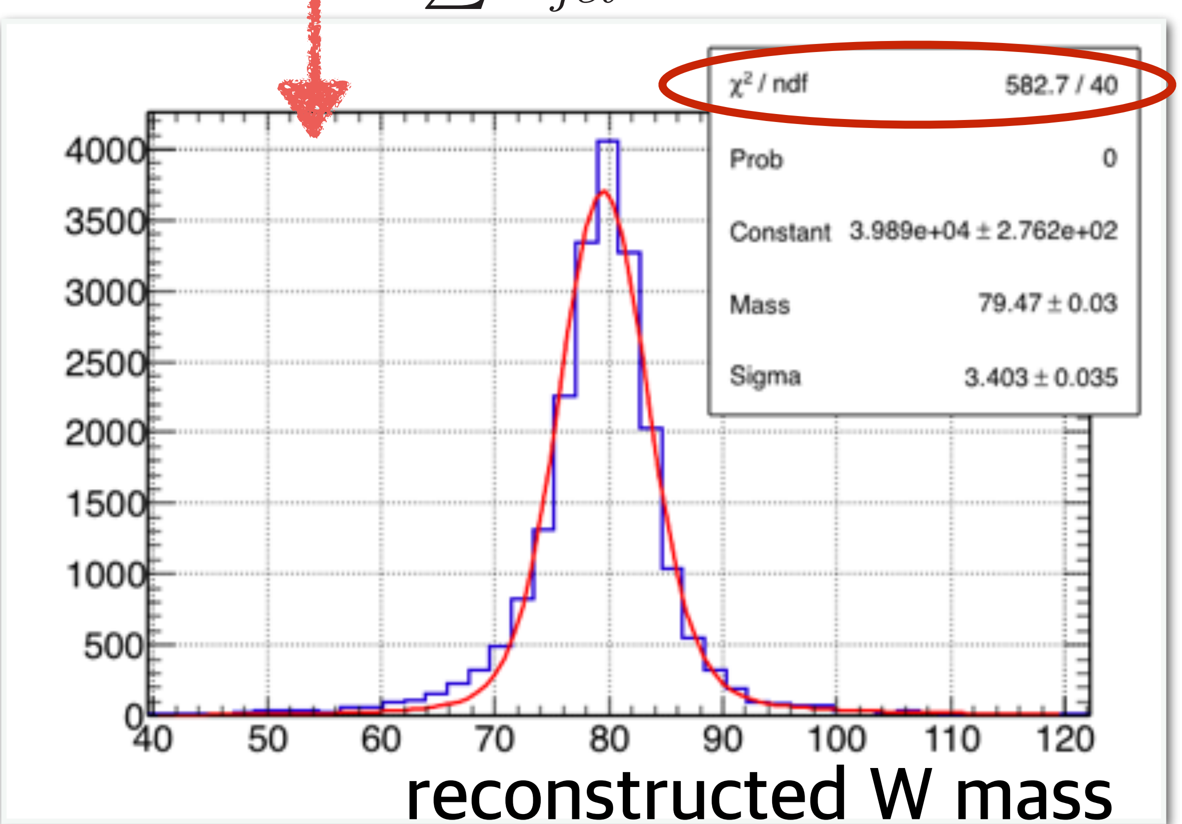
- The existence of a lepton in a quark jet can give a indication that the jet actually contains a semi-leptonic decay
  - lepton and neutrino are pair, e.g. c —> s l ν
- Can I estimate the missing neutrino energy by looking leptons from each jet ?
  - if there is any strong correlation between E_{lepton} and $E_{missing}$ …
  - this is under investigation

Leptons in composition of jet



if there is some correlation between ΣE_{lepton} and ΣE_{miss} , the W mass fitting result will be improved when the fraction of ΣE_{lepton} w.r.t. ΣE_{jet} is small

$\frac{\sum E_{leptons}}{\sum E_{jet}} < 0.01$: cut to reduce the influence of missing ν_l energy



χ^2/ndf value improved : ~200 —> ~15

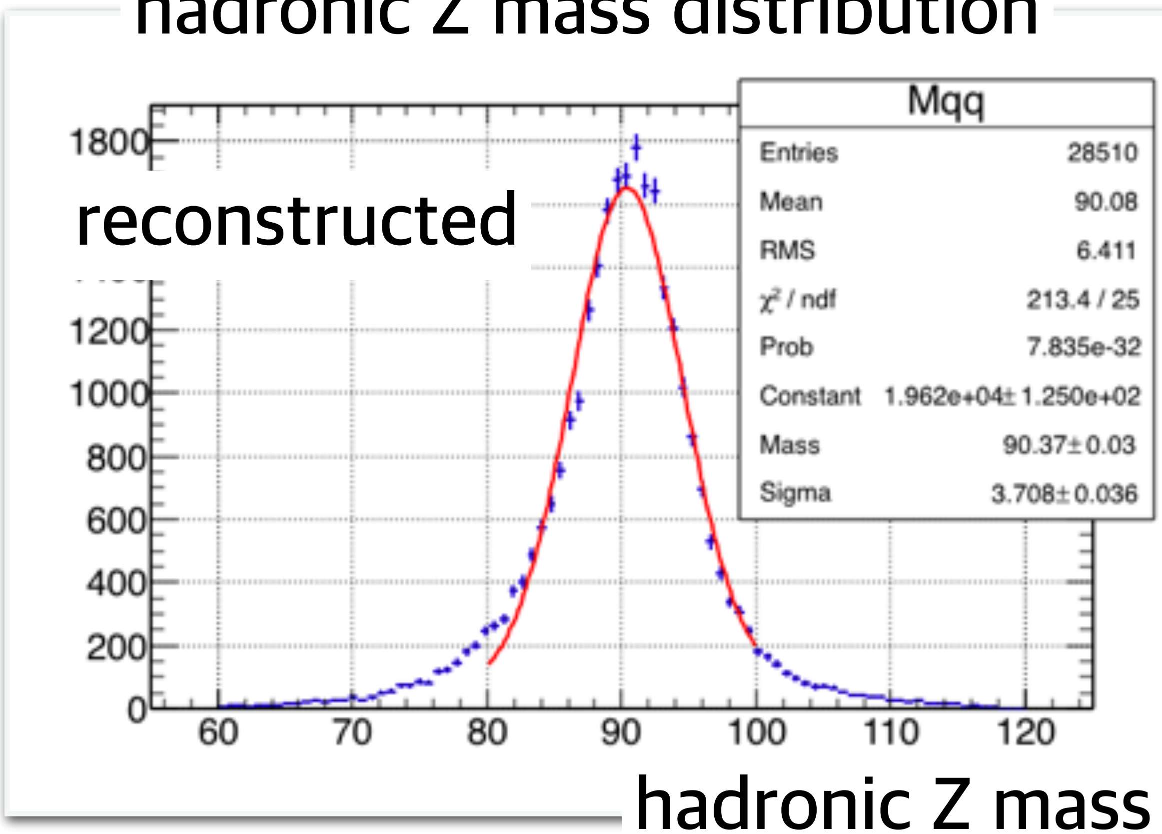
- but still large χ^2/ndf
- there may be remained some systematics from detector effects

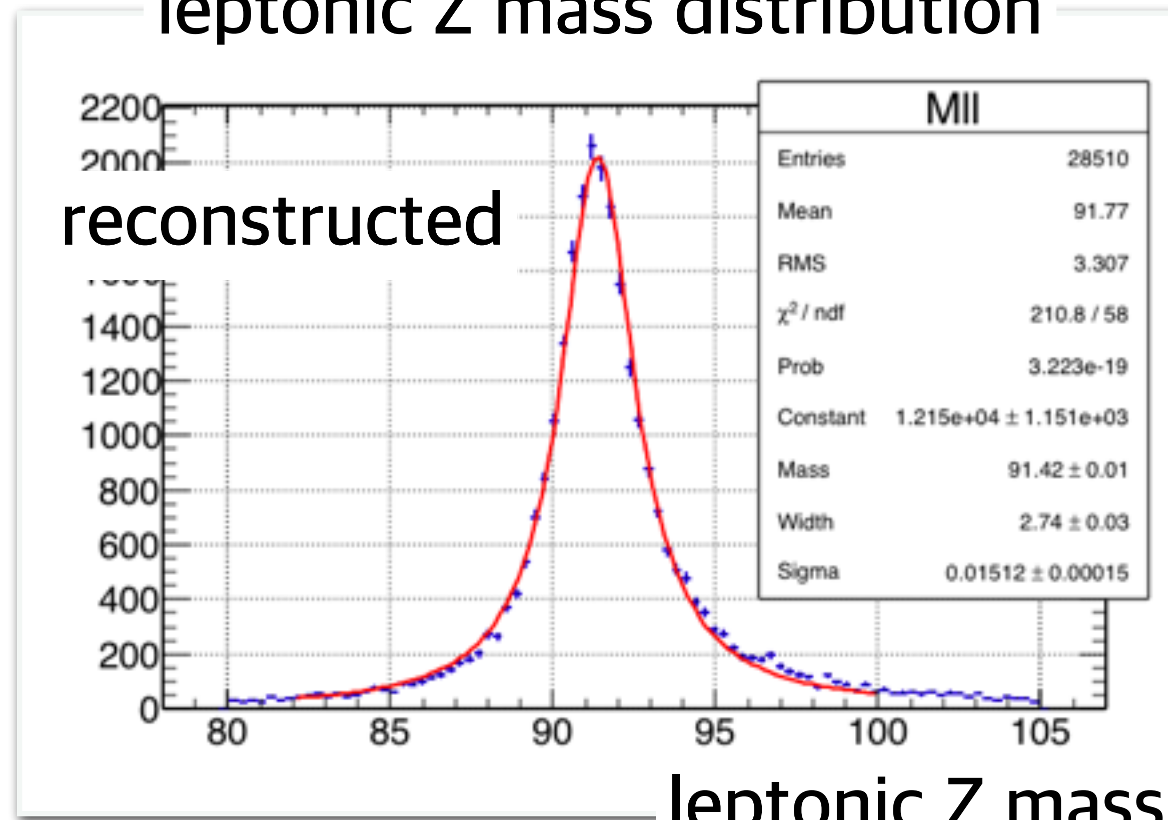
Currently working on

- The first step to perform direct m_W measurement is to find a proper model to describe the W invariant mass.
- analysis with DBD sample, $\sqrt{s}$ = 250 GeV for now
- There can be 3 studies to do :
    - dynamics —> fitting generator level W mass (done)
    - kinematics —> missing neutrinos from jets (in progress)
    - detector effects —> jet energy and angle resolution

- To calibrate the jet energy scale and understand similar detector effects, try to use Z mass reconstruction via ZZ—>qqll event
- strategy;
    1. reconstruct Z—>di-jet(hadronic)
    2. calibrate jet energy scale by using that precisely known value of $m_Z^{hadronic}$
    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 less affected by missing neutrinos than hadronic one
    - 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 Z mass, more proper function or reduction of systematics is necessary

Summary

- We are now trying to do direct measurement of W mass via hadronic system (W—>qq')
  - using eνW samples (single-W process included)
  - first on $\sqrt{s}$ = 250 GeV
  - influence of missing energy from neutrinos in jet is now under investigation
  - jet energy scale calibration and detector effect study in progress

Next

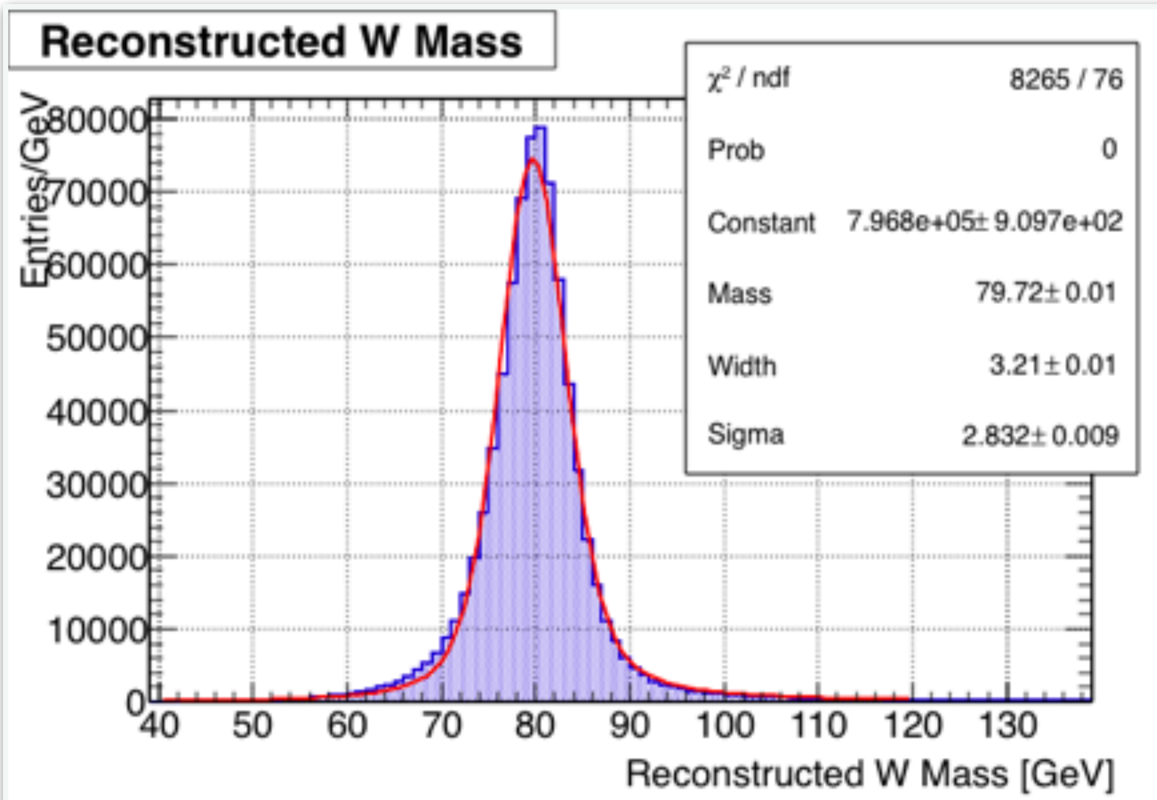
- after we obtained proper model to describe W mass and good jet energy calibration,
- then we can change some detector simulation conditions to study systematic uncertainties
  - jet energy scale uncertainty
  - impact of different tune of PFA
  - parton shower and hadronization model
- others to improve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

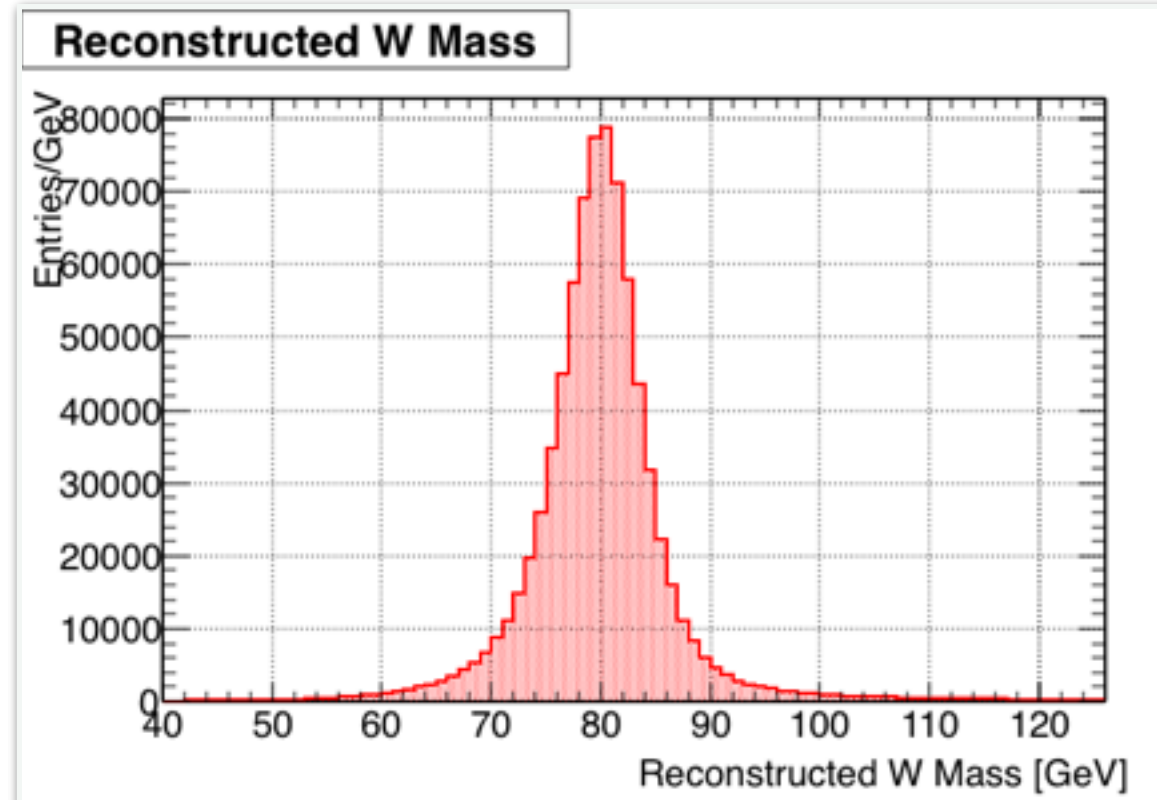
Back up

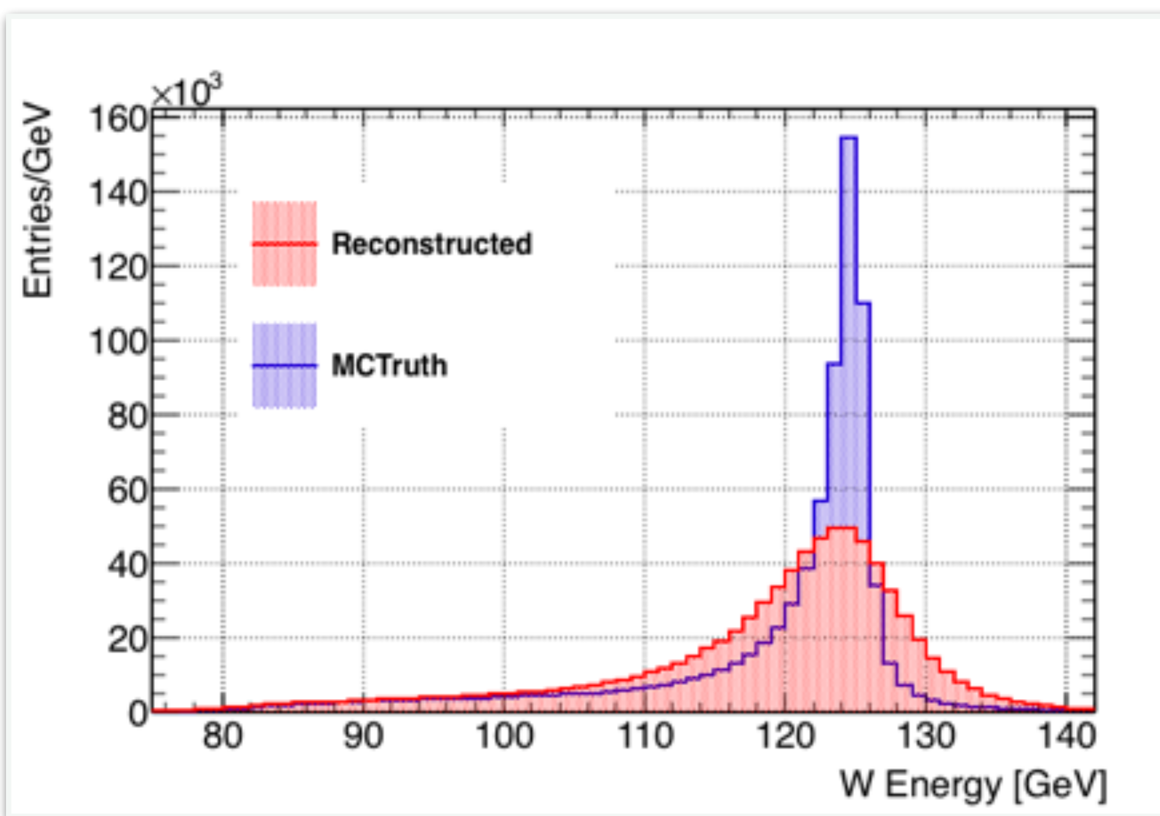
Simulation conditions

- 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



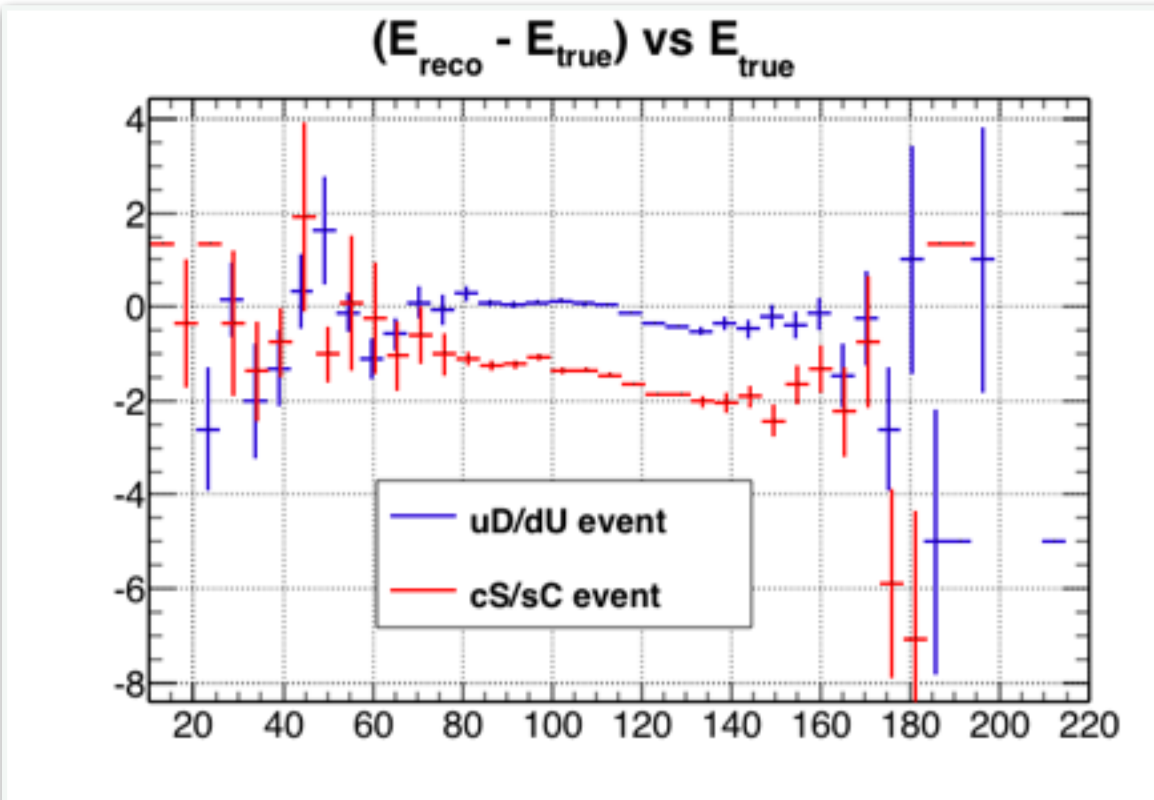


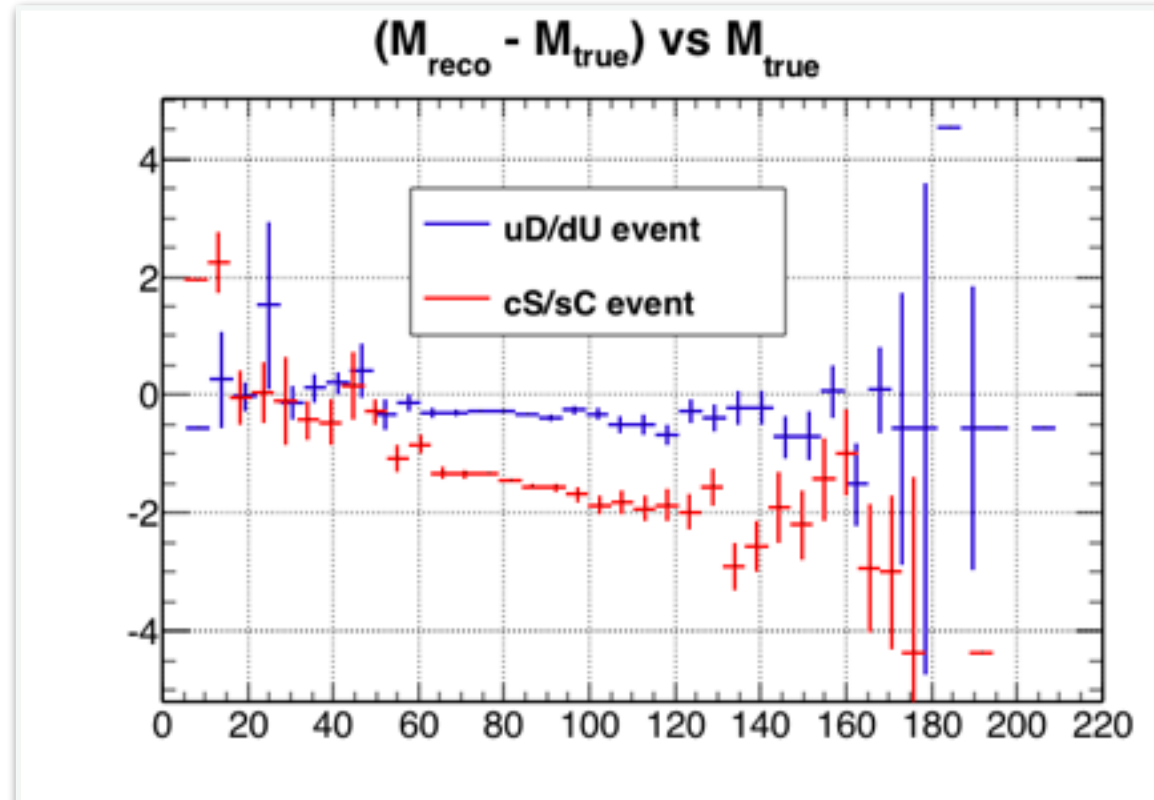


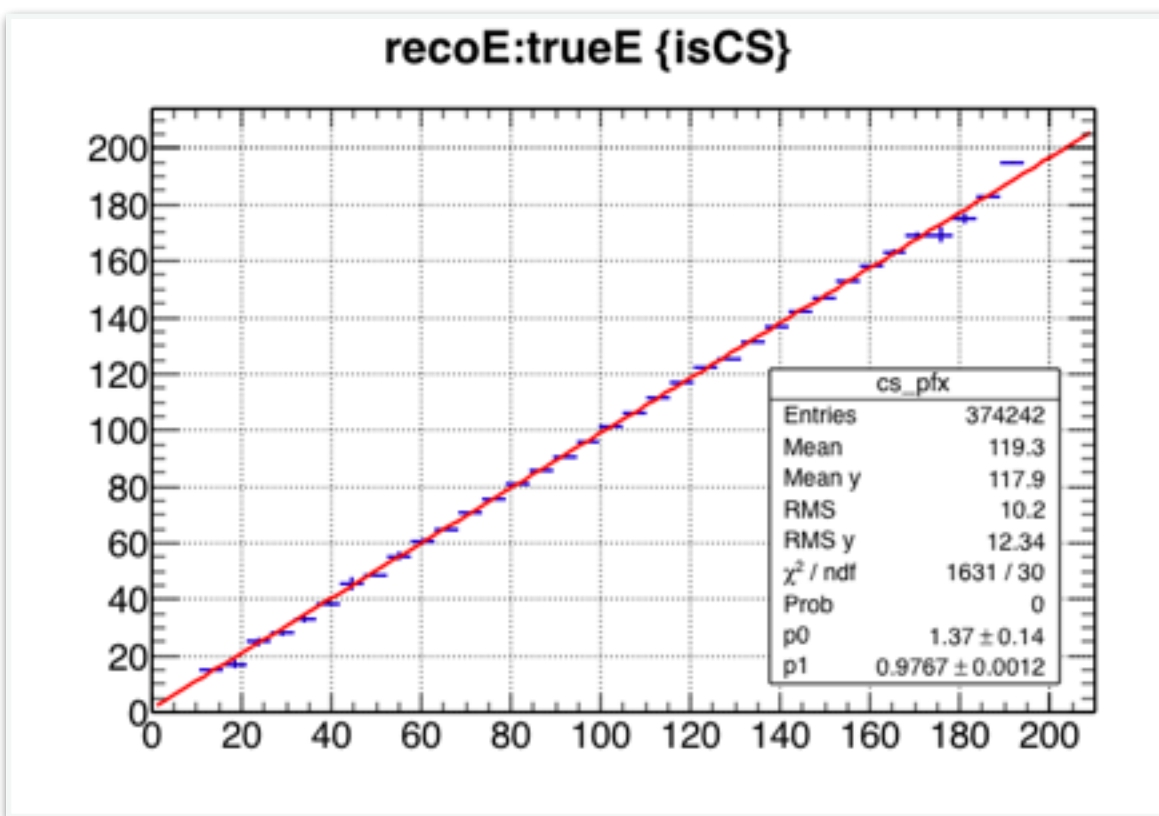
PFOs which came from ISRs, final state leptons(e and ν) and overlays(beam backgrounds) have already removed before jet clustering

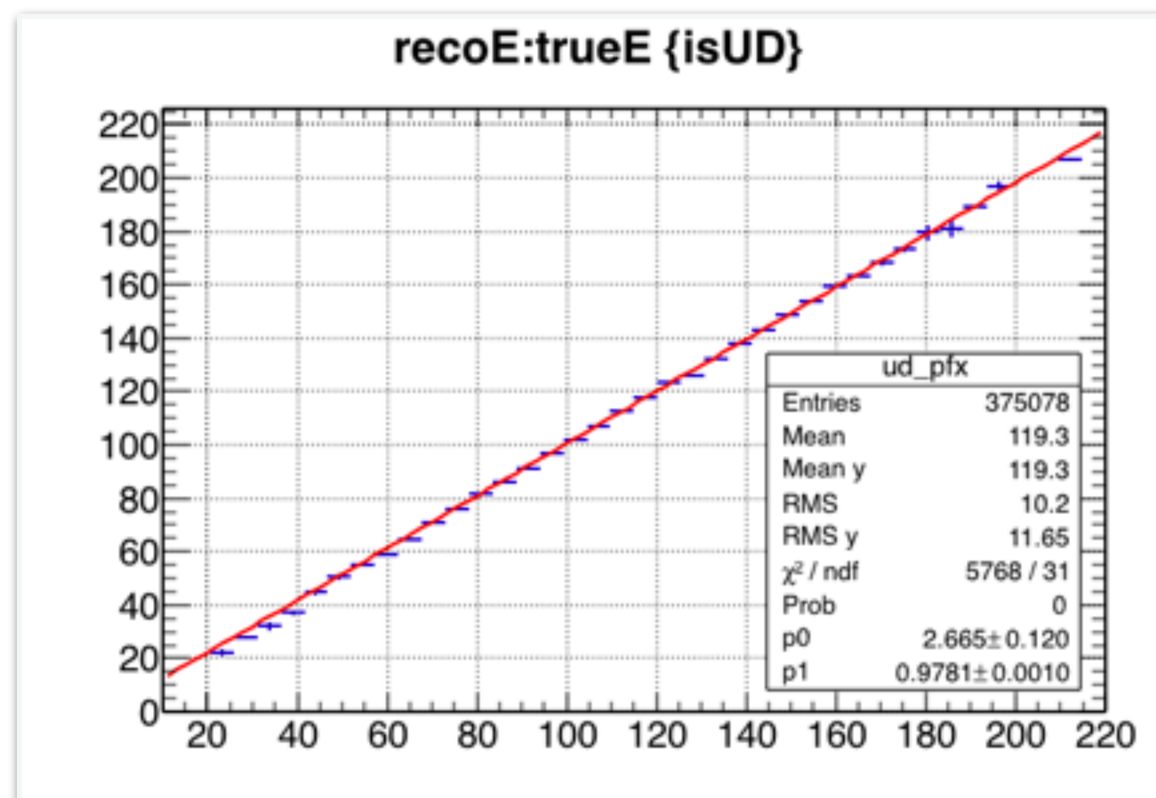
jet clustering is performed by Durham algorithm

missing neutrino plots







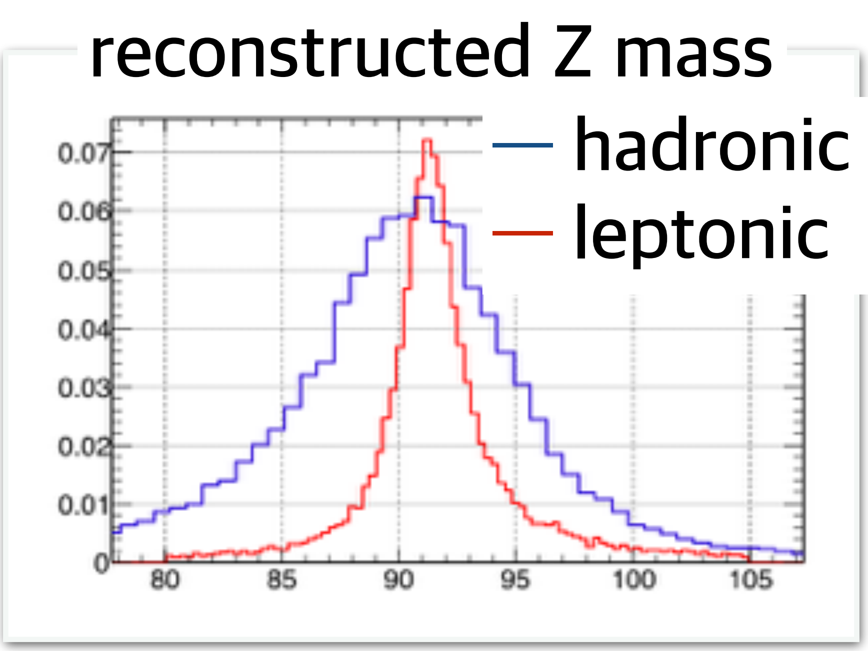


particle identification

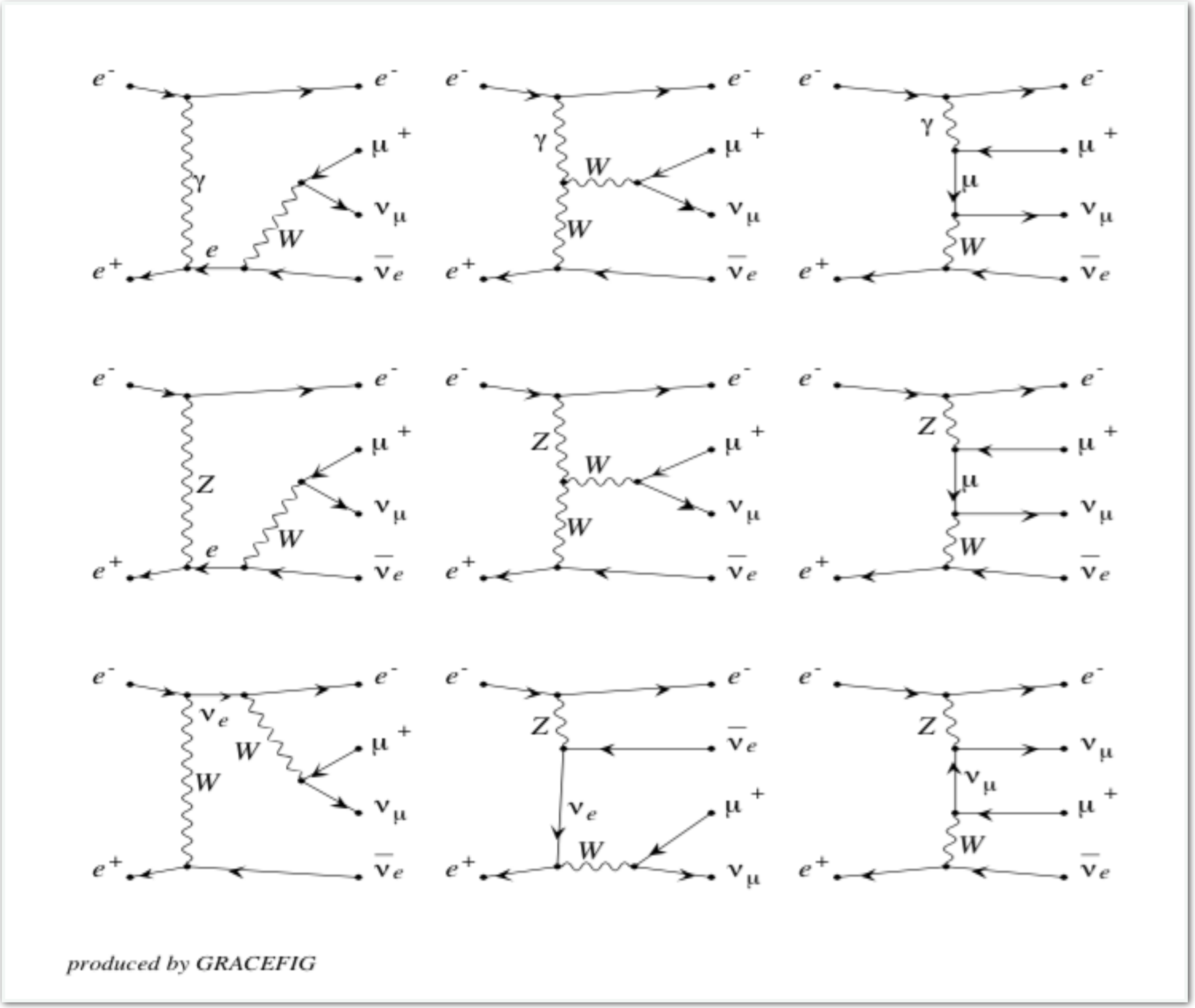
- electrons
  - charge != 0
  - $0.7 < (E_{ECAL} + E_{HCAL}) / |p| < 1.4$
  - $0.9 < E_{ECAL} / (E_{ECAL} + E_{HCAL}) < 1.0$
- muons
  - charge != 0
  - $0.0 < (E_{ECAL} + E_{HCAL}) / |p| < 0.3$
  - $0.0 < E_{ECAL} / (E_{ECAL} + E_{HCAL}) < 0.4$
- photons
  - charge == 0
  - $0.7 < (E_{ECAL} + E_{HCAL}) / |p| < 1.3$
  - $E_{ECAL} / (E_{ECAL} + E_{HCAL}) > 0.9$

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