Measuring W Mass in 1.4TeV CLIC_ILD

CLIC meeting

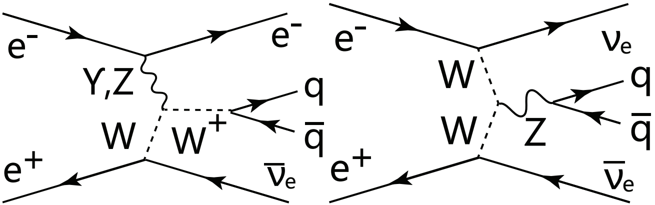
Boruo Xu (Univeristy of Cambridge)

11.6.2014

Outline

Introduction

- m_Z is measured to 2MeV. We would like to measure m_W to few MeV level.
- Currently m_W is accurate to 15MeV level.
- At high energy (TeV), single W and Z production has high cross section.
- Any bias in m_W from single W production could be corrected by m_Z measurement from single Z production.



Setup

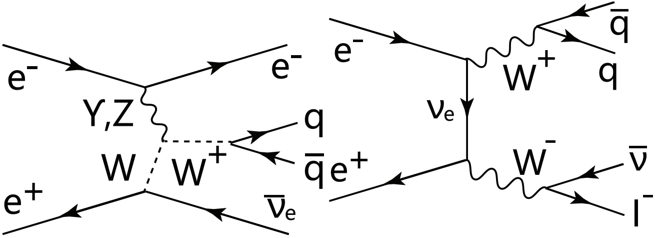
- DST Samples, CLIC_ILD, $\sqrt{s}$=1.4TeV

Type	ID	Event num	σ/fb	m_h/TeV
ee -> qqll	2645	226500	2726.7	12
ee -> qqll	3246	2104400	2725.8	12.6
ee -> qq$\nu\nu$	2199	439000	788.0	12.6
ee -> qq$\nu\nu$	3243	577200	787.7	12
ee -> qqlν	3249	2043200	4309.7	12

- All graphs are normalised to 1.5ab^{-1}

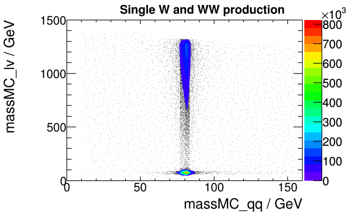
Single W selection

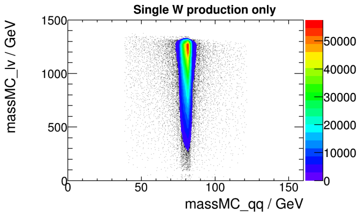
- Aim: Idenfity single W production in ee -> qqlν samples.
- Two main processes contributing are single W and W pair production
- Typical Feynman diagrams for single W and W pair production are shown below



Single W selection
MC level

- We would like to idenfity single W production at MC level first.
- $q^2 < 400 GeV^2$ [q^2 is change in four momentum of outgoing electron]
- $40 < m_{qq} < 120 GeV$
- $m_{recoil} < 60$ or $m_{recoil} > 120 GeV$
- $e_{qq} < 0.48\sqrt{s}$ or $e_{qq} > 0.52\sqrt{s}$

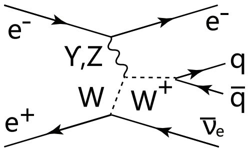




Single W selection

Reconstructed level

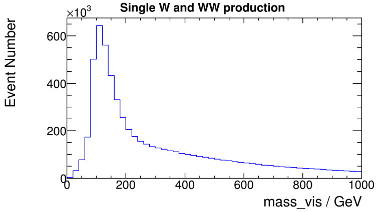
- Having identified single W production at MC level, we would like to do the same thing at reconstructed level.
- Most of time, electrons go down beam pipe. If reconsturcted $l^{\pm}$ with $E > 100 GeV$, it will be selected.
- Rest of PFO force into 2 jets, with fast jet algorthm(kt R=1.5).
- Recoil four momentum is calculated by $\sqrt{s}$ minus four momenta of dijets, taken account into samll beam crossing angle(10mrad).
- Mass of W is calculated from qq jets.

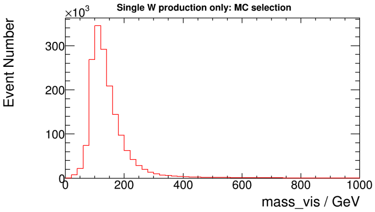


Single W selection

Reconstructed level

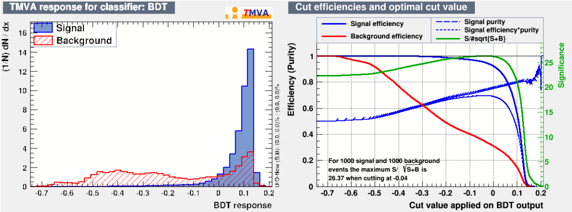
- First we tried simple "rectangular cuts"
- $m_{vis} < 300 GeV$
- Veto events with leptons





Single W selection
MVA

- Besides simple cuts, also tried MVA BDT.
- Singal: Single W; Background: Other qqlν. Variables:
- m_{recoil}
- e_{vis}
- $acolinearity_{lepton,missing}$
- $acolinearity_{qq}$
- $cos_{high\ \ energy\ \ jet}$
- cos_{qq}



Single W selection

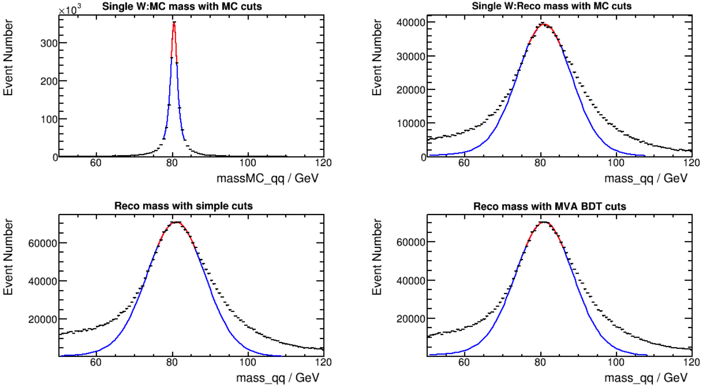
m_W

- To extract m_W after cuts, we used a simple fit.
- Fit function: Breit-Wigner convolved with gaussian
- $\frac{prefactor}{(m-m_{fit})^2+m_{fit}{}^2\Gamma_W{}^2} \otimes \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(m-m_{fit})^2}{2\sigma^2}}$
- where m_{fit} is the fitted m_W
- Γ_W is set to decay width of W boson
- σ is the fitted resolution.
- Fitted range : bins above 80% of hightest peak

Single W selection

m_W

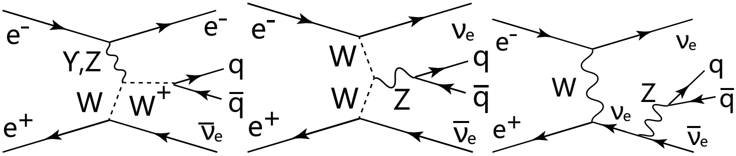
- Fitted m_W. Red is fit. Blue is extrapolation
- Top row left to right, $m_{fit} = 80.42$ and 81.05.
- Bottom row left to right, $m_{fit} = 81.03$ and 81.05



Single W selection

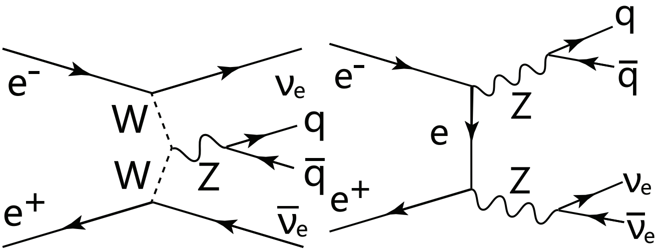
Bias

- Bias: $m_{fit} \neq m_W$. Out by few hundred MeV.
- We can calibrate the bias by measuring m_Z, as m_Z is known to 2MeV.
- Assuming simliar process like single Z production would have same bias.



Single Z selection

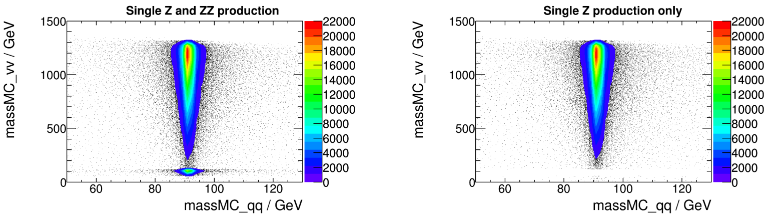
- Single Z production occurs in ee -> qq$\nu\nu$ and ee -> qqll samples.
- However, single Z production has a small cross section in ee -> qqll sample.
- We chose ee -> qq$\nu\nu$ samples. Main processes are single Z and Z pair production



Single Z selection

MC selection

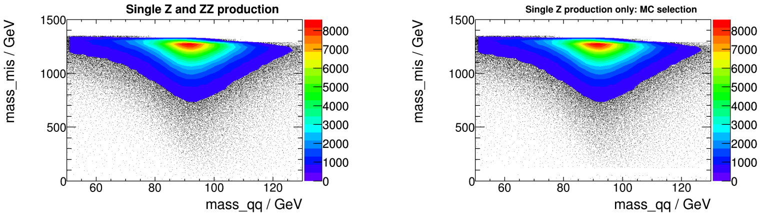
- As before, we would like to identify single Z production at MC level.
- $50 < m_{qq} < 130 GeV$
- $m_{recoil} < 50 GeV$ or $m_{recoil} > 130 GeV$



Single Z selection

Reconstructed level

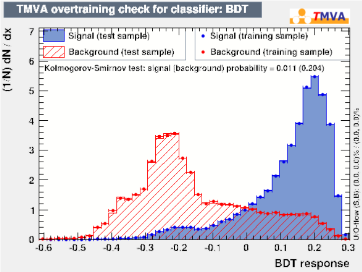
- Similarly, use simple "rectangular cuts"
- $40 < m_{qq} < 130 GeV$
- $m_{recoil} < 50 GeV$ or $m_{recoil} > 130 GeV$

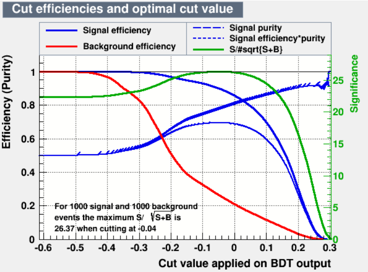


Single Z selection

MVA BDT cuts

- We also used MVA BDT to select signal-single Z production from background-ZZ production, with
- m_{qq}
- m_{recoil}
- $acolineraity_{qq}$

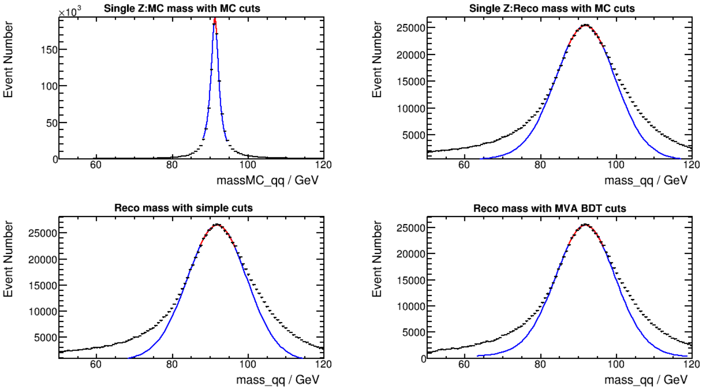




Single Z selection

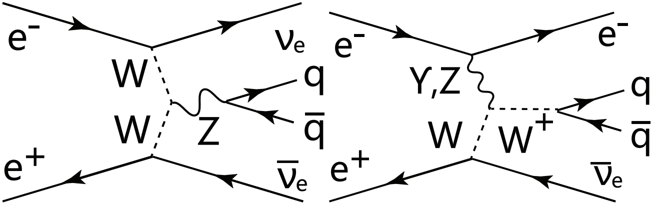
m_Z

- Using as simple fitting function as before. Fitted m_Z.
- Top row left to right, $m_{fit} = 91.21$ and 91.91
- Bottom row left to right, $m_{fit} = 91.90$ and 91.91



Single Z selection
Bias

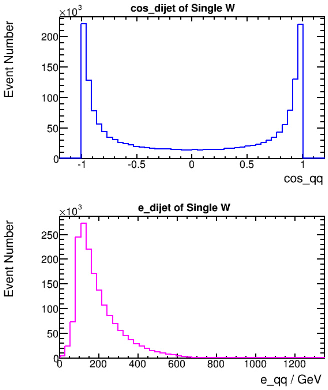
- Bias: $m_{fit} \neq m_Z$.
- However, it has similar bias as single W production
- We can calibrate the bias by measuring m_Z, as m_Z is known to 2MeV.



Comparison

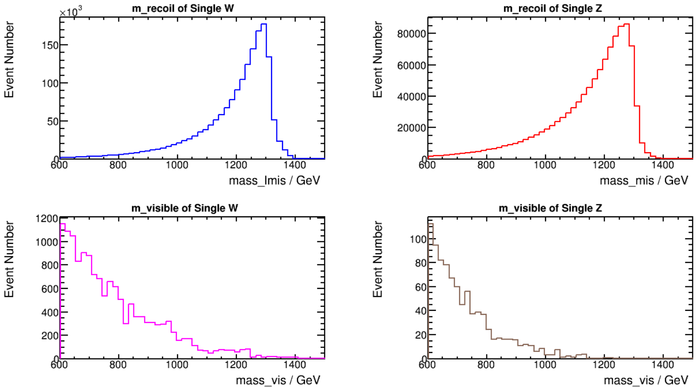
Single W and Z

- To justify that single W and single Z production may have same bias, we compared some parameters of two.
- Reconstructed quantites after MC selection.



Comparison
Single W and Z

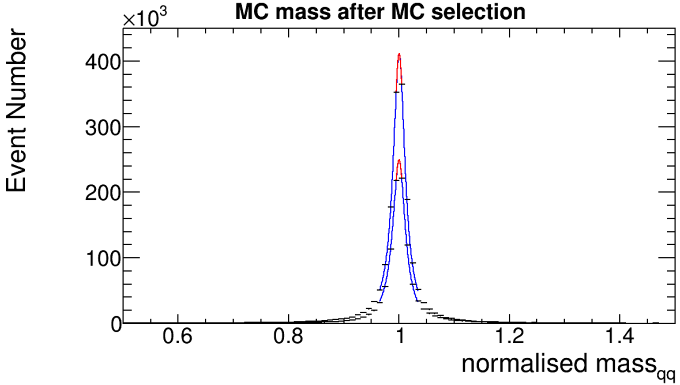
- Some more parameters for comparisions of single W and single Z production
- Reconstructed quantites after MC selection.



Results

MC m_{fit} after MC cuts

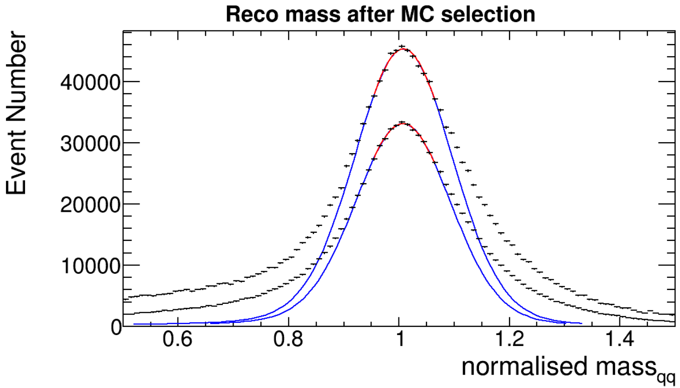
- To compare m_{fit} from single W and single Z production, we normalised m_{fit} to m_W or m_Z.
- MC m_{fit} after MC cut is shown.
- Single W production has a higher peak.



Results

Reco m_{fit} after MC cuts

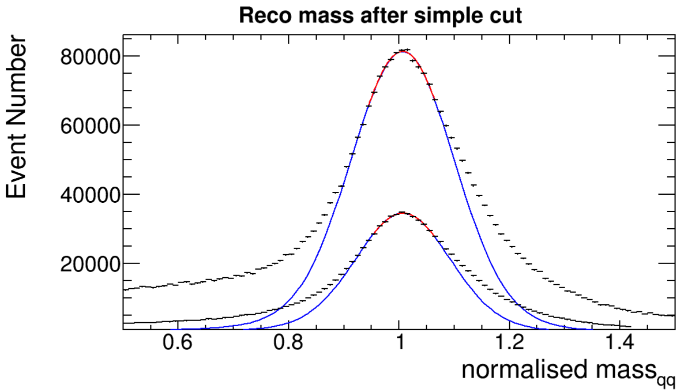
- Compare normalised reconstructed m_{fit} after MC cuts.
- Single W production has a higher peak.



Results

Reco m_{fit} after rectangular cuts

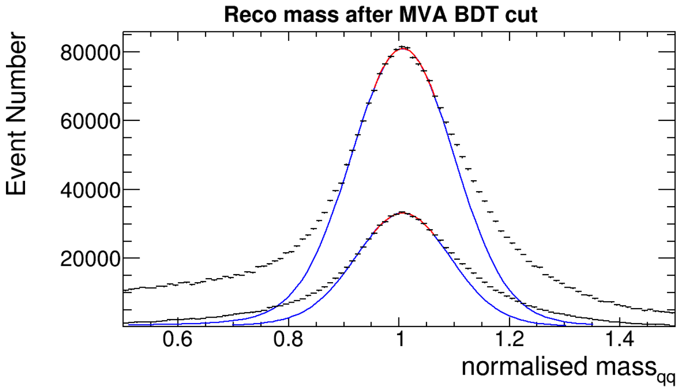
- Compare normalised reconstructed m_{fit} after simple "rectangular cuts".
- Single W production has a higher peak.



Results

Reco m_{fit} after MVA BDT cuts

- Compare normalised reconstructed m_{fit} after MVA BDT cuts.
- Single W production has a higher peak.



Summary

m_{fit}

- Errors are noted in brackets

Cuts	M_W / GeV	M_Z / GeV
MC afterMC cuts	80.4216±0.0017	91.2109±0.0042
Reco after MC cuts	81.0583±0.0295	91.9157±0.0396
"Rectangular"	81.0321±0.0204	91.9045±0.0387
MVA BDT	81.0473±0.0202	91.9057±0.0394
Best	80.385±0.015	91.1876±0.0021

Cuts	Effieiency	Purity
W "Rectangular" Cuts	96%	46%
W MVA BDT > -0.04 Cuts	95%	49%
Z "Rectangular" Cuts	95%	94%
Z MVA BDT > -0.05 Cuts	90%	97%

Summary

- Difference in MeV is estimated by $(M_{W,fit}/M_{Z,fit} - 1) \times M_{W,best}$

Cuts	Norm M_W	Norm M_Z	Diff
MC: MC cuts	1.00034±0.00002	1.00019±0.00003	12±3
Reco: MC cuts	1.00921±0.00033	1.00840±0.00037	65±40
"Rectangular"	1.00780±0.00025	1.00831±0.00036	41±35
MVA BDT	1.00799±0.00028	1.00832±0.00037	26±37
Best	1±0.00019	1±0.00002	0±15

Conclusion

- Single W and Z measurements have similar bias.
- On its own, single W and Z measurements have simliar biases of few hundred MeV.
- If we assume that m_Z is known to 2MeV, m_W can be calibrated to tens of MeV.
- Normalised m_W and m_Z are consistent within errors.
- Precision is limited by sample size. A larger sample would decrease errors and improve measurements.

Thank you!

Boruo Xu
xu@hep.phy.cam.ac.uk