Jet Energy Scale & Jet Energy Resolution in CEPC

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Electroweak Measurement Meeting

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Outline

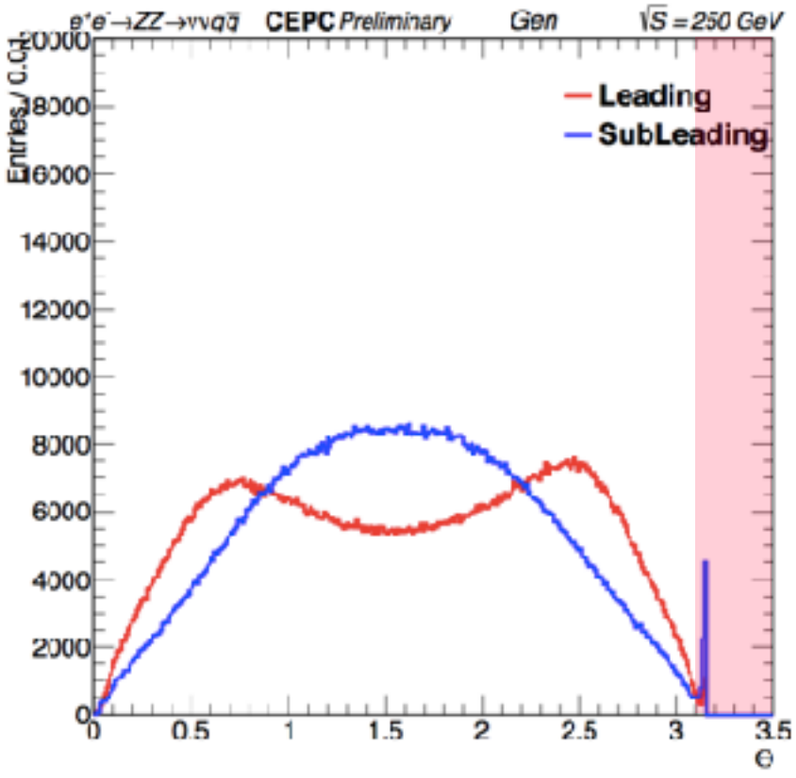
- Introduction
- Event selections
- W, Z, and Higgs boson mass distribution with dijet final state
  - Mass of dijet
  - Mass of all reconstructed final state particles
- Boson mass resolution
- Summary

Introduction

- **Mainly, I studied the dijet energy resolution with ee->ZZ->vvqq process. On the detector part, jet energy resolution is about 4% and 5% for leading jet and sub-leading jet respectively.**
- **Studied the Z, W, and Higgs boson mass resolution and performances.**
  - **Studied Z boson mass resolution by ee->ZZ->vvqq process.**
  - **Studied W boson mass resolution by ee->WW->lvqq process.**
  - **Studied H boson mass resolution by ee->ZH->vvH(->qq) process.**
- **Extracted the boson mass resolution by double-sided crystal ball function(DBCB).**

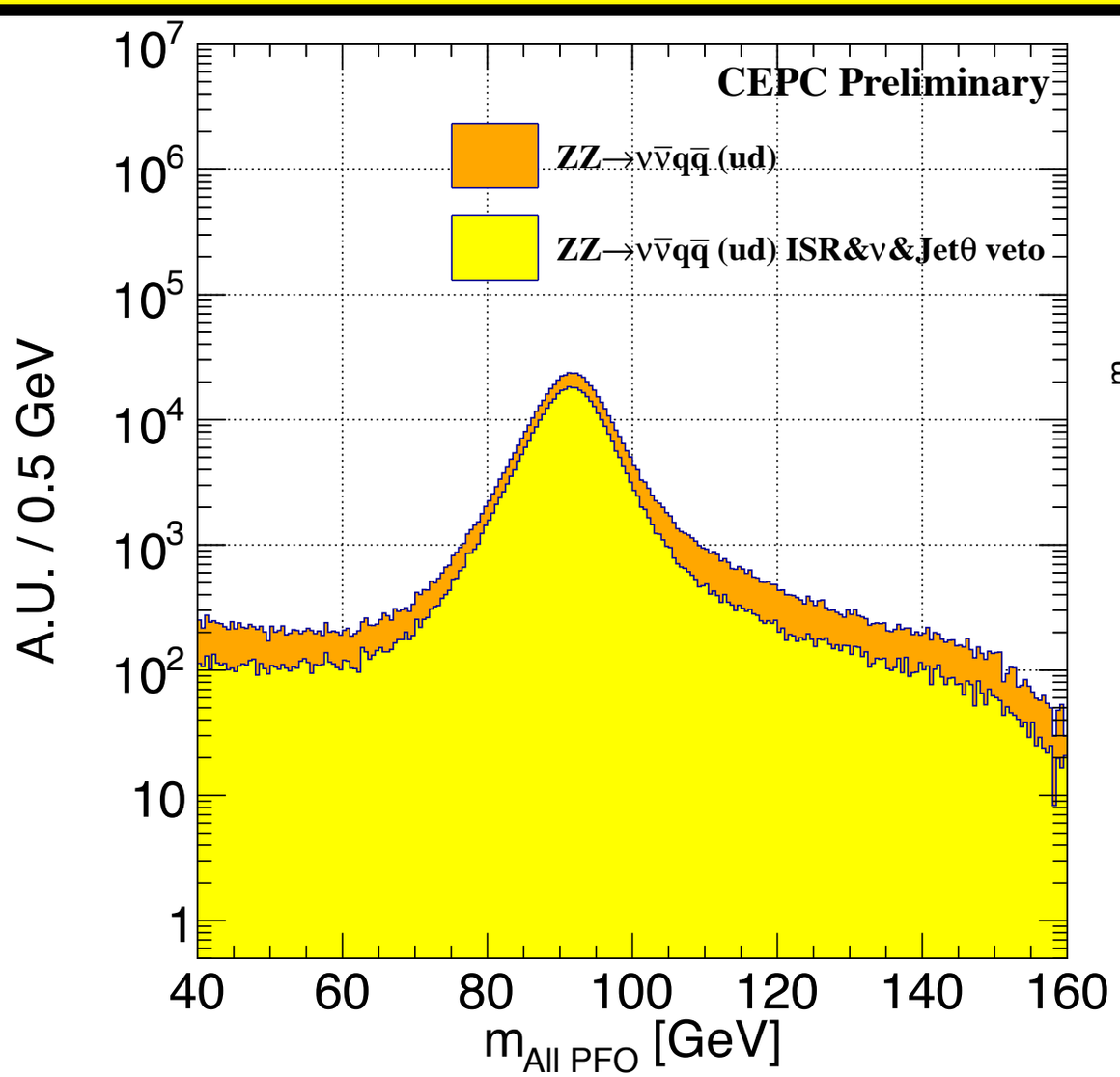
Event Selections

	ee->ZZ->vvqq	ee->WW->lvqq	ee->ZH->vvH(->qq)
Gen jet θ < 3.1	✓	✗	✗
ΔR(Reco-MCP) < 1	✓	✓	✓



- **A peak in the region Gen jet θ greater than 3.1 was caused a bug in simulation software. Thus, this region was excluded in the study.**
- **Definition of** $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$

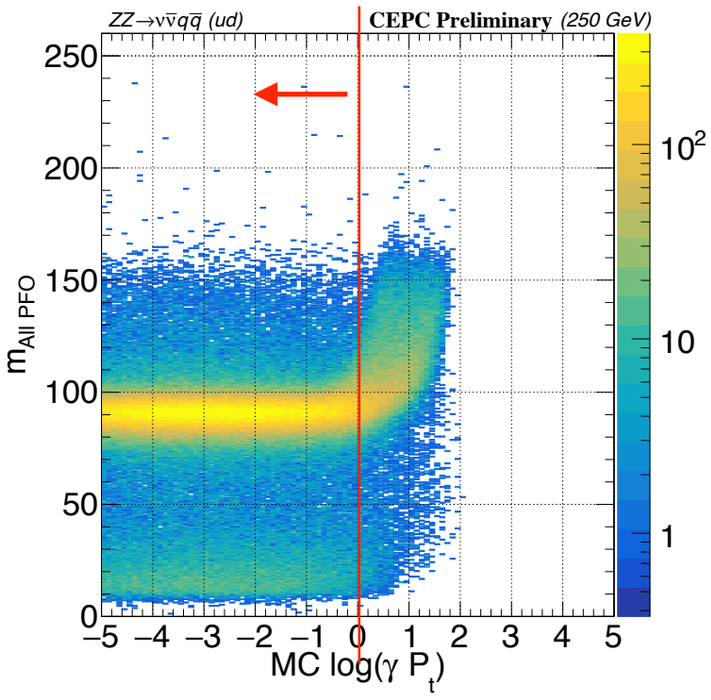
Event Selections (take ZZ for expamle)

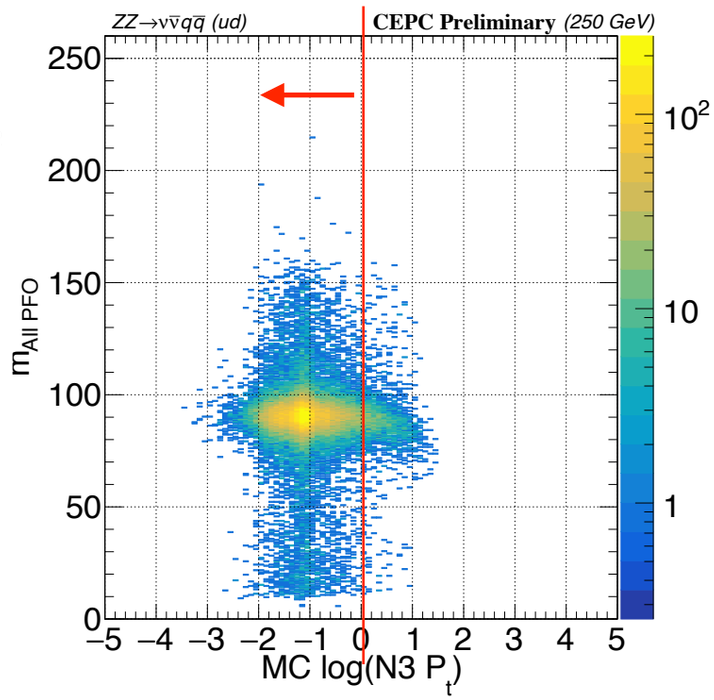


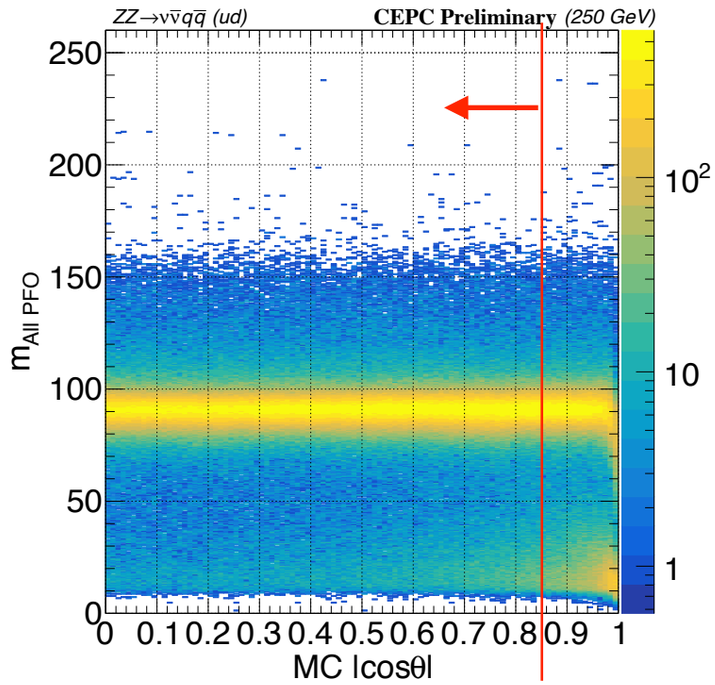
Total # of events = 1772775

Type	# of events	
All ZZ->vvqq̄ (ud)	**1324710**	
ISR Pt < 1 GeV	**1227740**	92.67%
ISR Pt <1&N3 Pt <1	**1222270**	99.55%
ISR Pt <1 &N3 Pt <1 & $\|\cos\theta\| < 0.85$	**833030**	68.15%

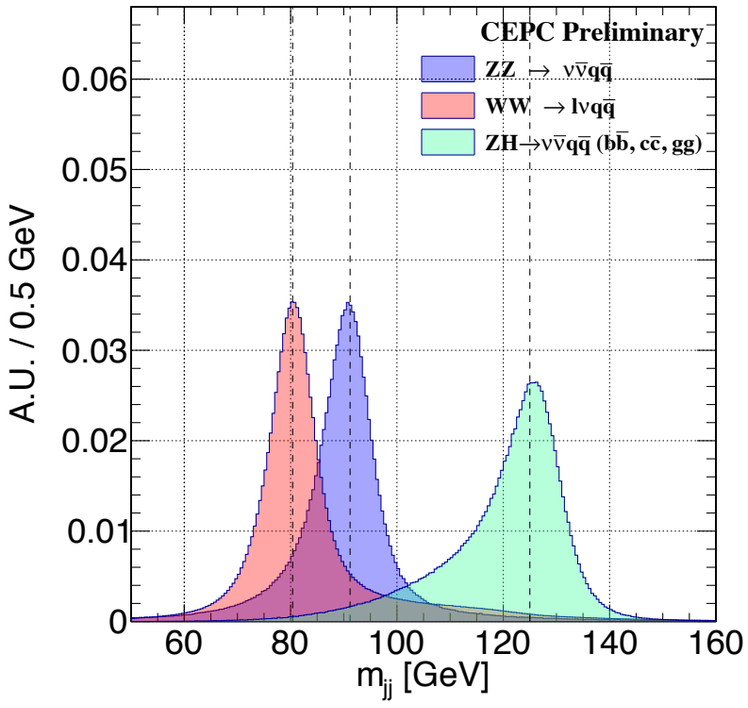
Overall = 62.88%

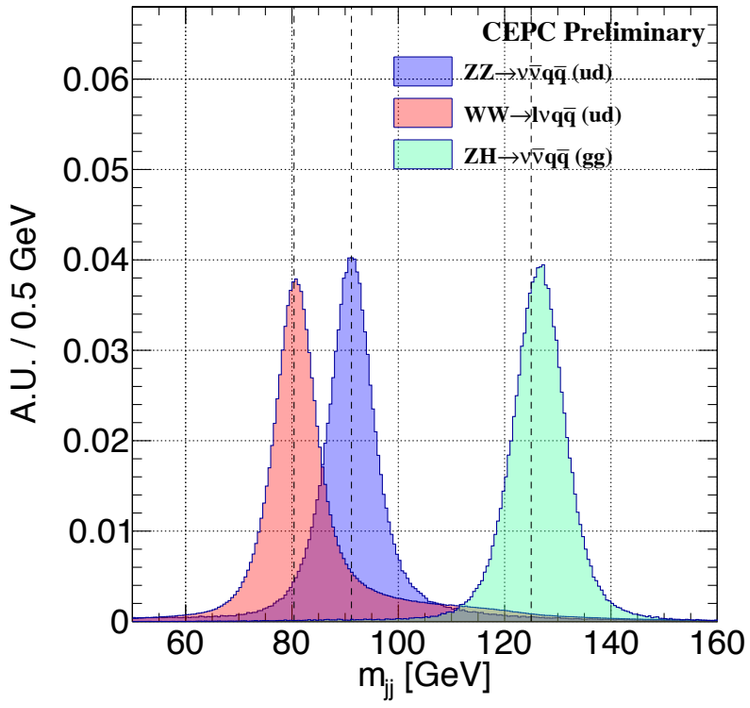


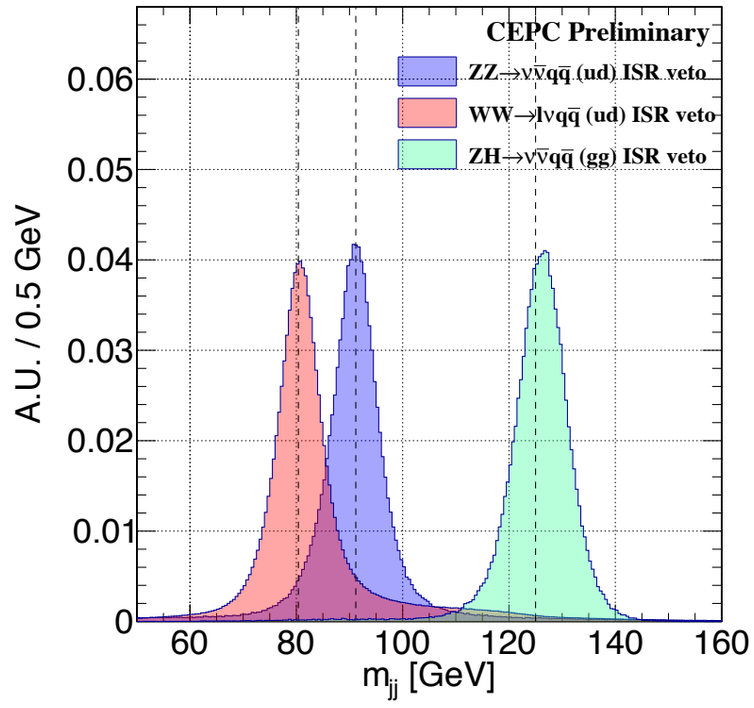


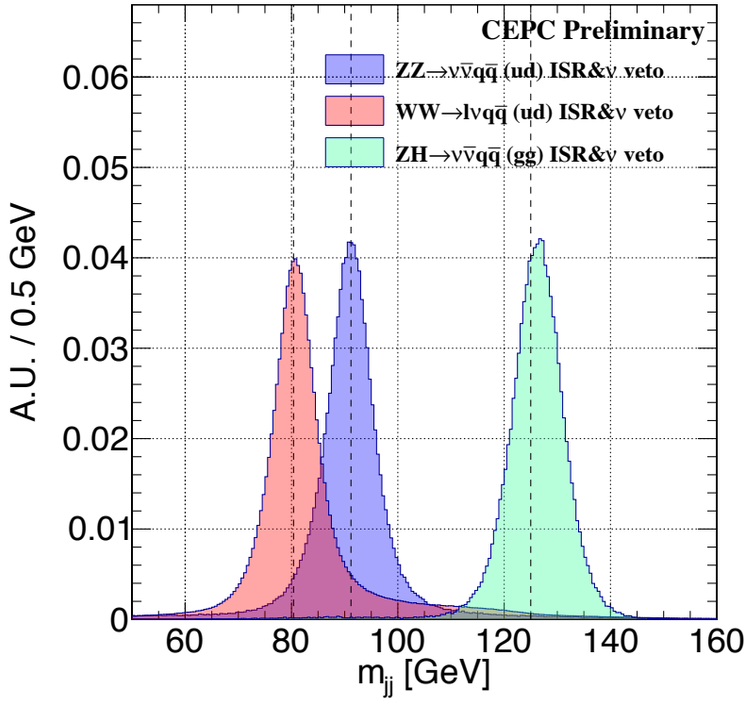


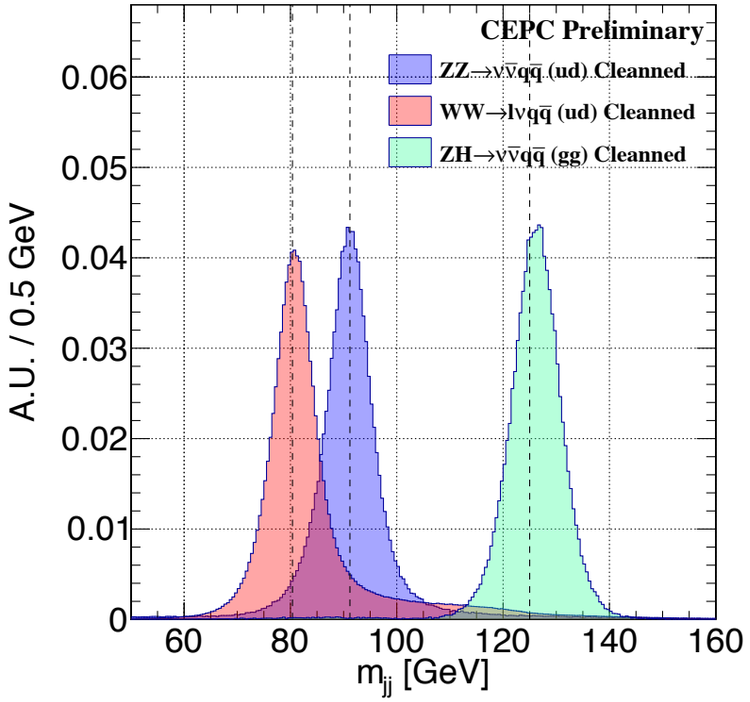
Bosons Mass Distribution(dijet)





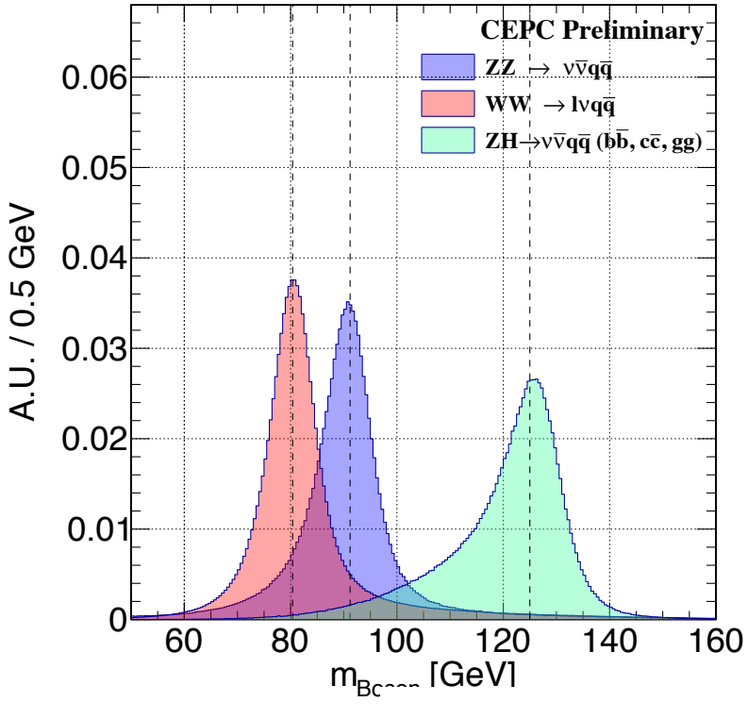


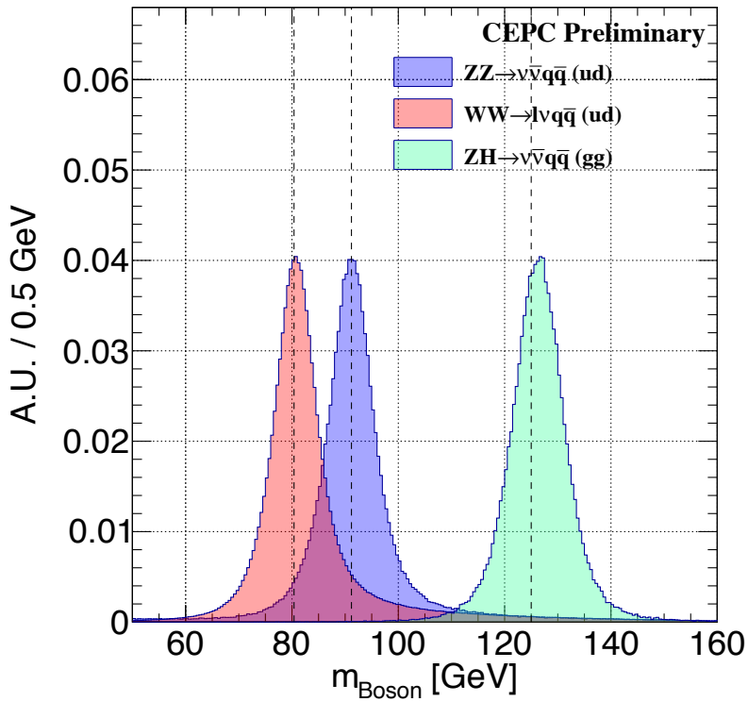


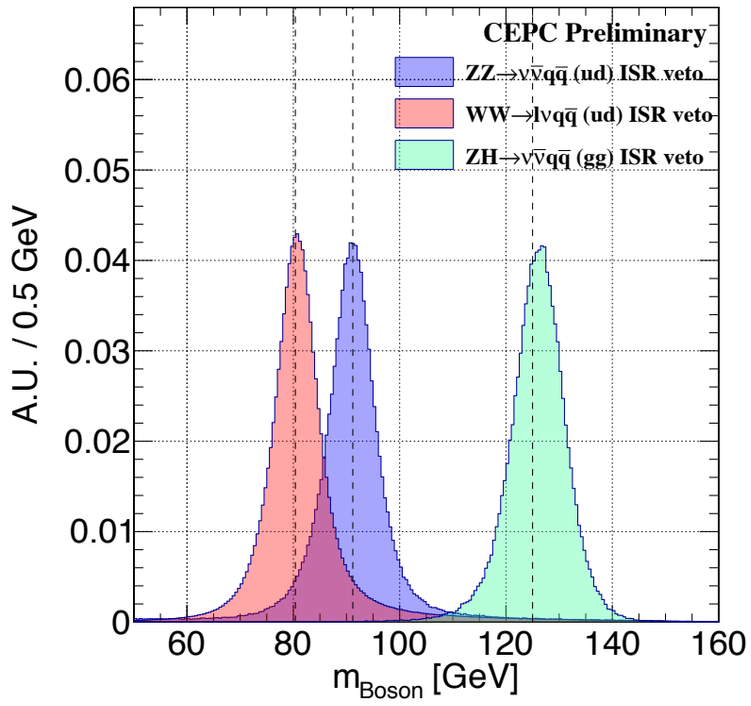


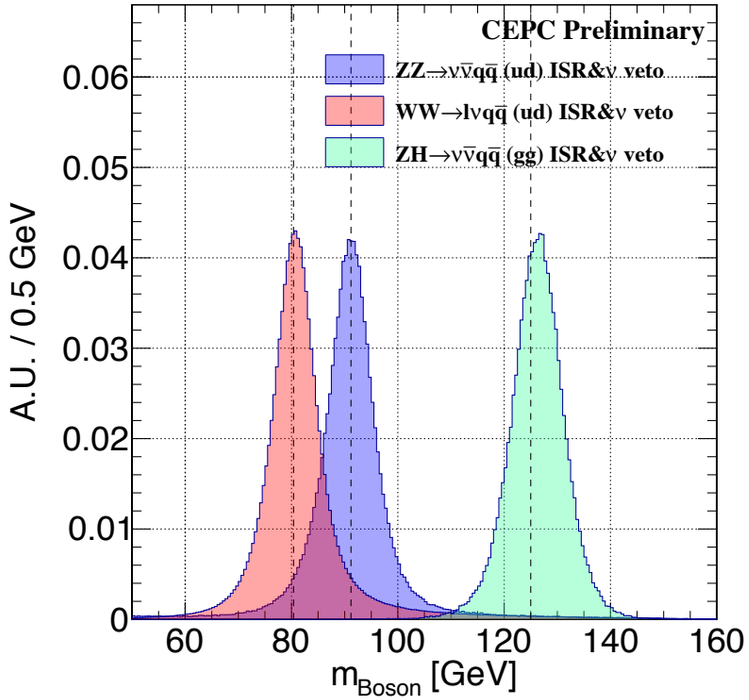
- **W, Z, and Higgs bosons mass scale are calibrated by W boson. (Multiplied W_{true}/W_{dijet})**
- **The W, Z, and Higgs bosons reconstructed by dijet (reco jet) can be well separated in CEPC.**

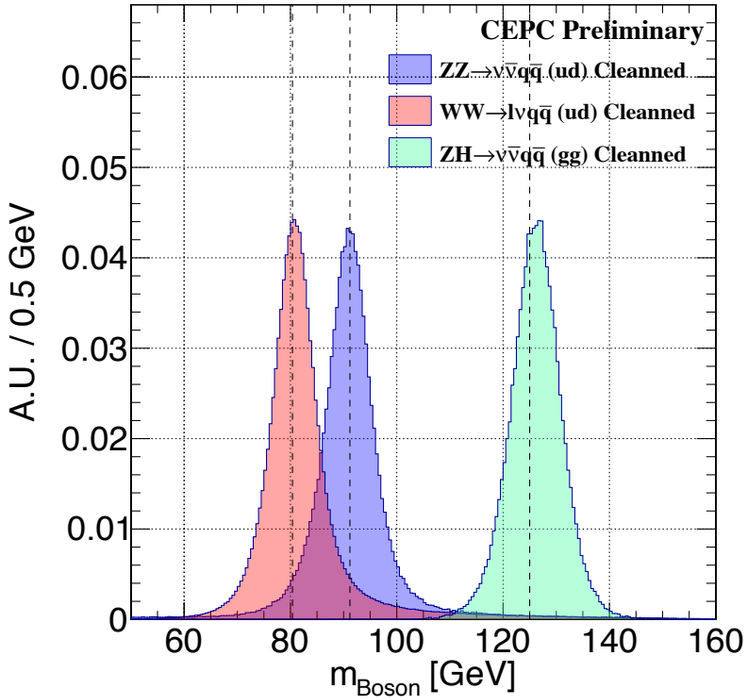
Bosons Mass Distribution(All reconstructed particles)





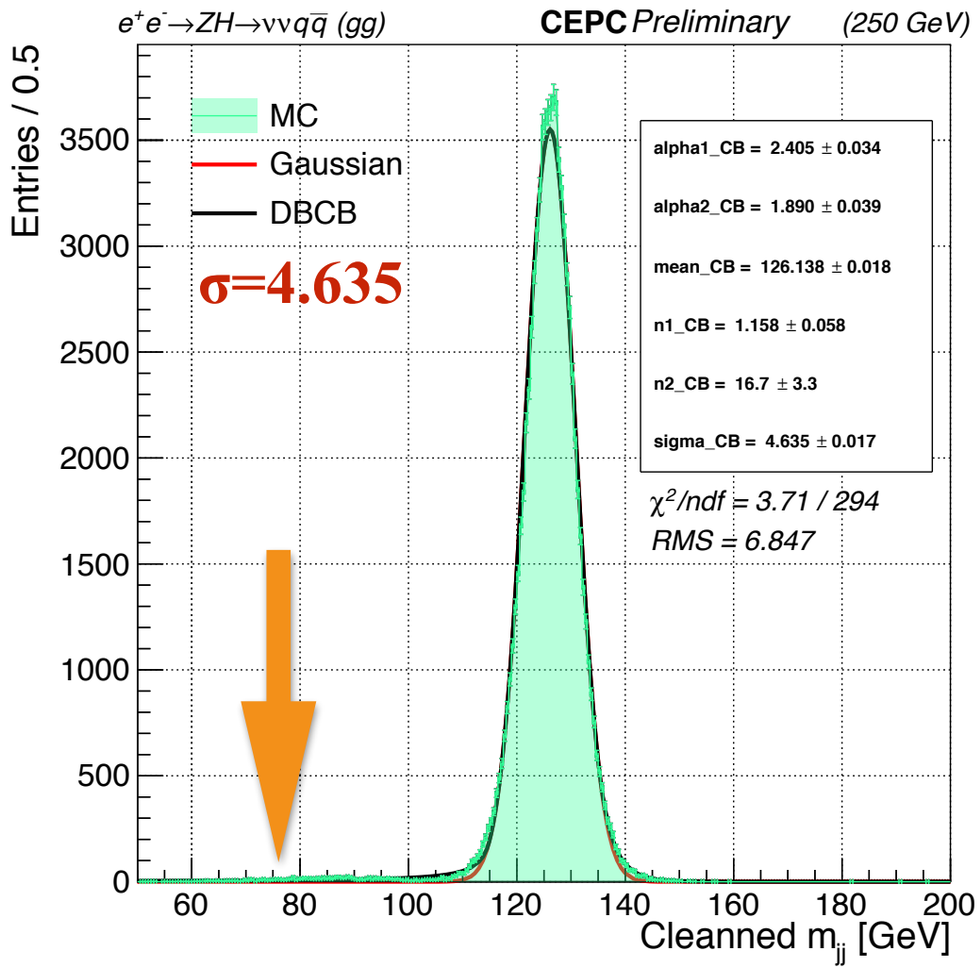


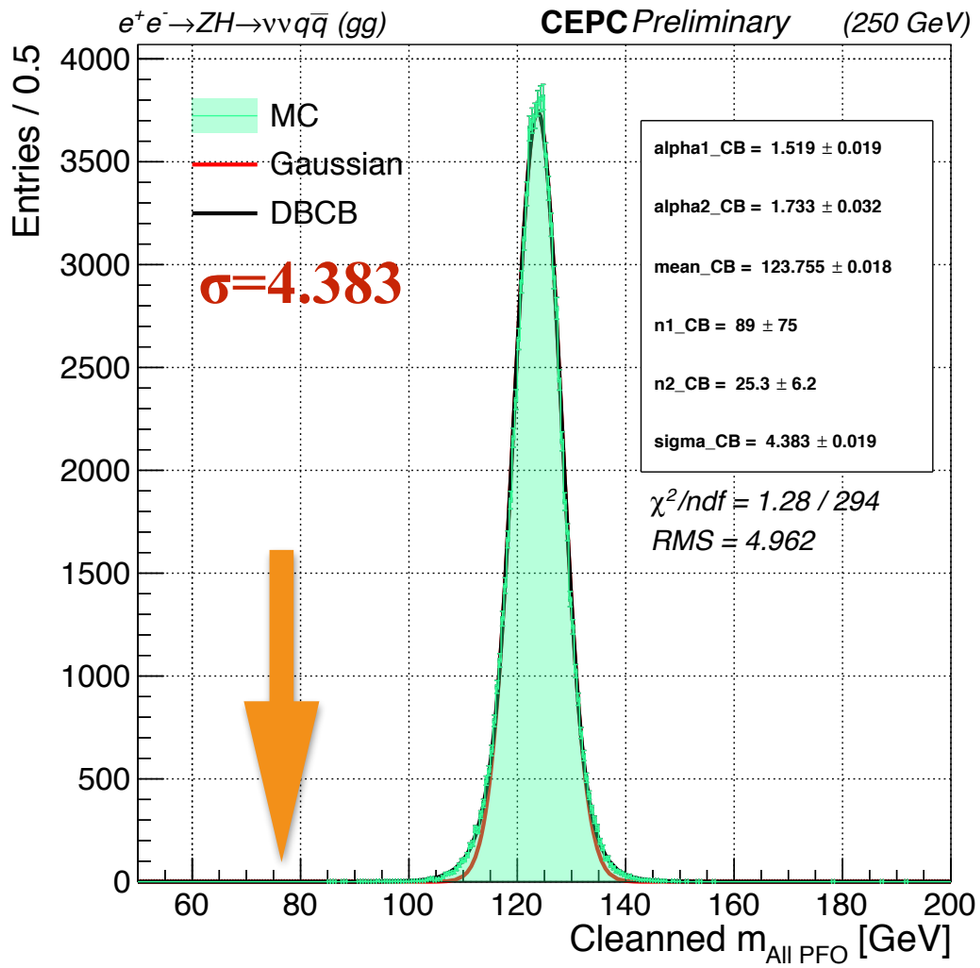




- **W, Z, and Higgs bosons mass scale are calibrated by W boson. (Multiplied W_{true}/W_{dijet})**
- **By reconstructed all final state particles, it teaches us what the perfect jet clustering should be and the pure detector performance impacts on boson mass resolution.**

Compare Two Ways of Reconstruction(take H for example)

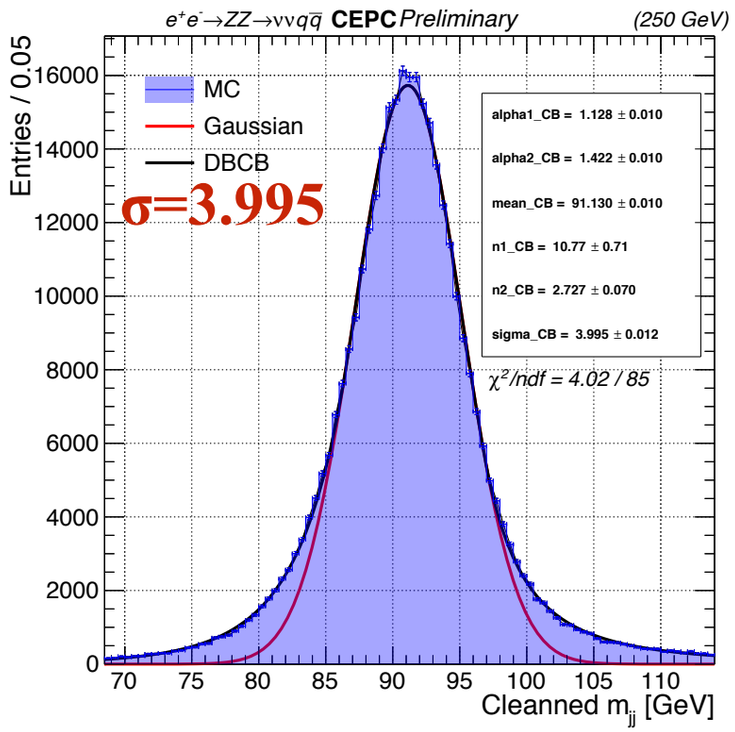


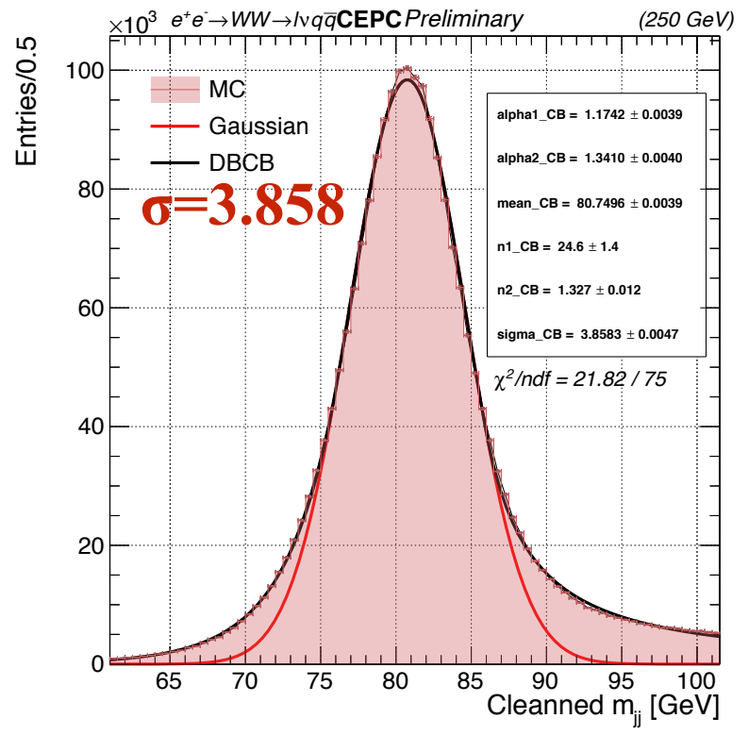


- **Reconstruct all final state particles can avoid losing particles by construction. It brings the less low energy tail and RMS.**

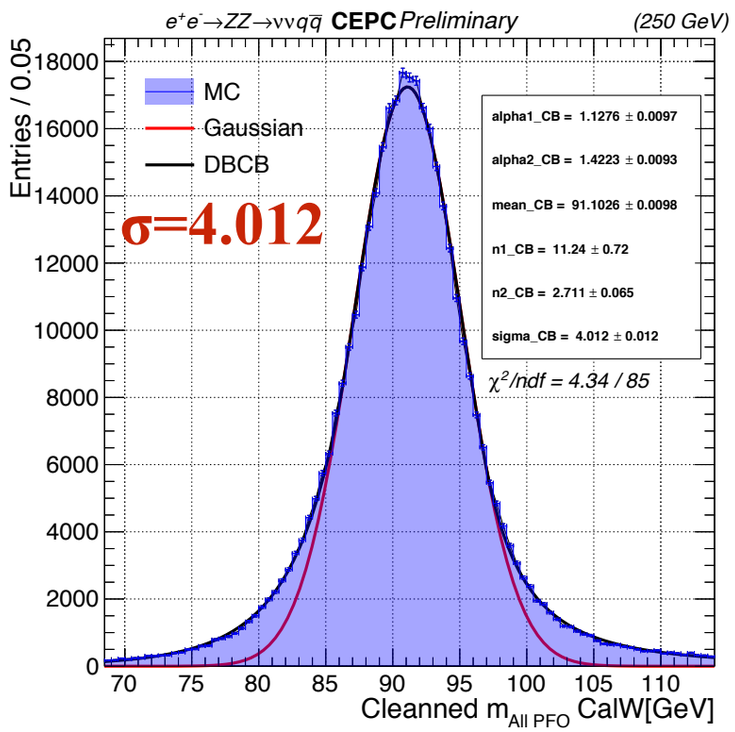
Compare Two Ways of Reconstruction

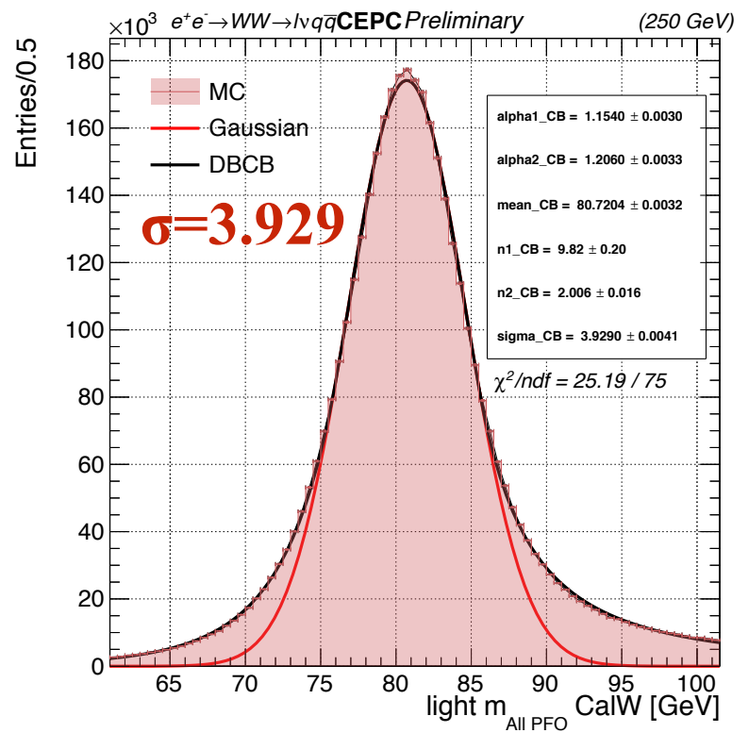
dijet





All PFO





Z **W**

Summary

- **The W, Z, and Higgs bosons reconstructed by dijet (reco jet) can be well separated in CEPC.**
- **By reconstructing two dijet, W boson mass resolution is about 4, Z boson is about 3.8, and Higgs boson is about 4.6.**

To do:

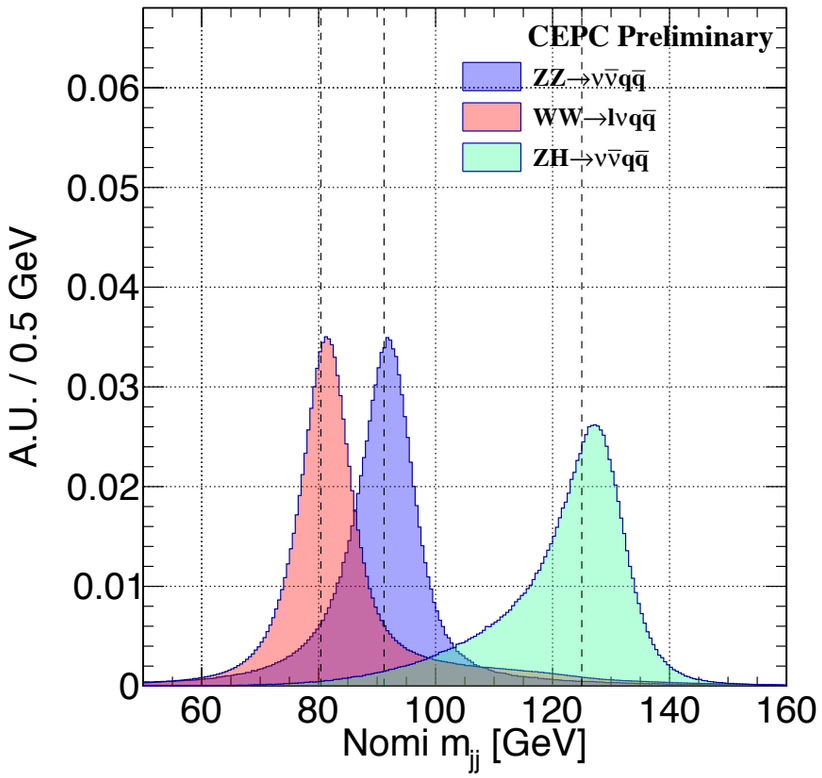
- **Quantify the W, Z, and Higgs boson mass separation.**
- **We interested in what kinds of particle will usually be excluded in jet clustering(->study the jet algorithm).**
- **A data driven calibration**

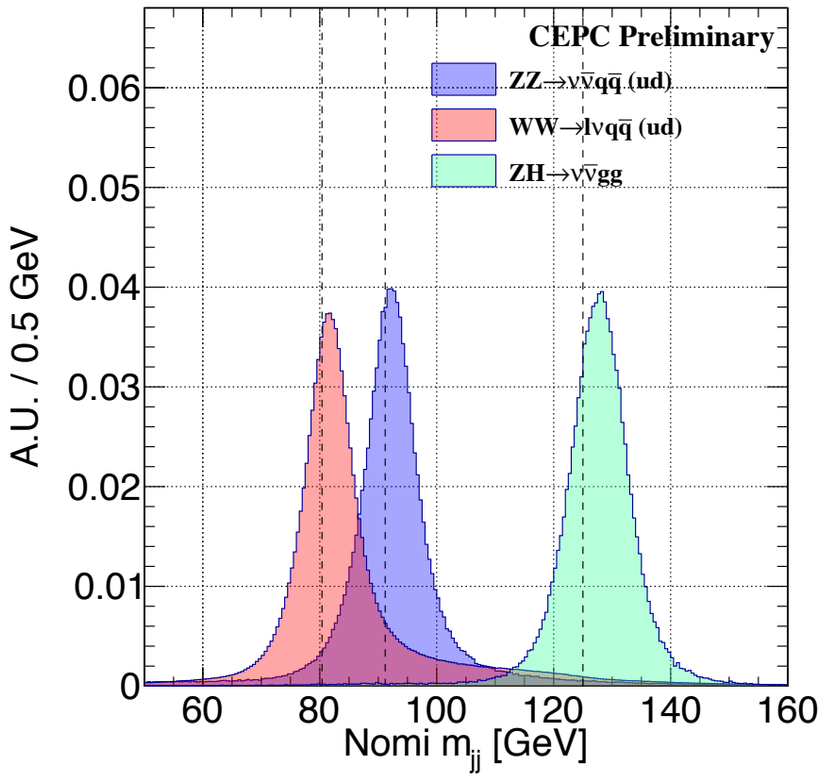
Thank for your attention

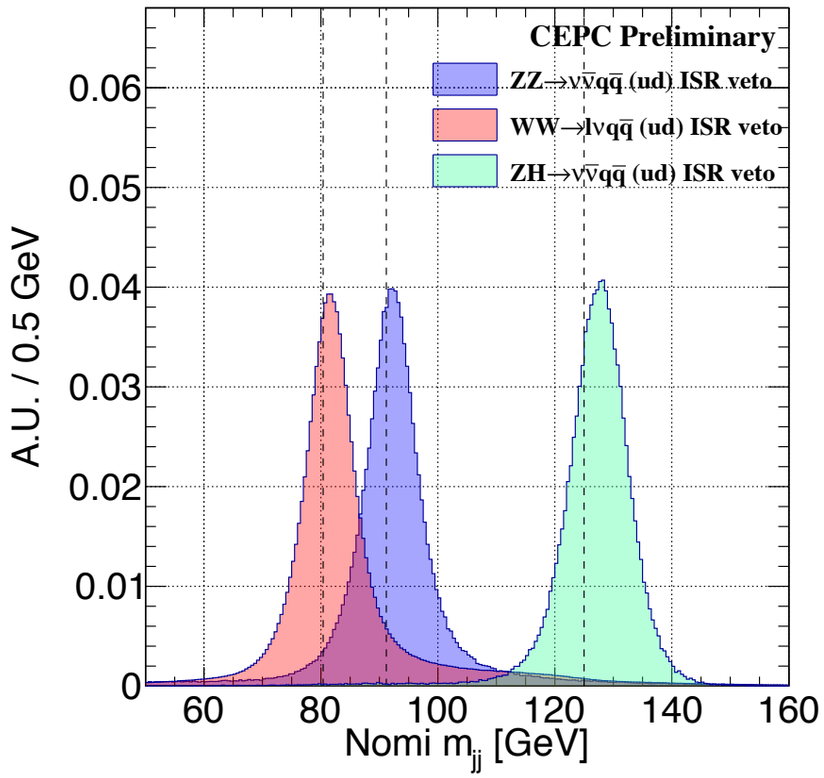
Back up

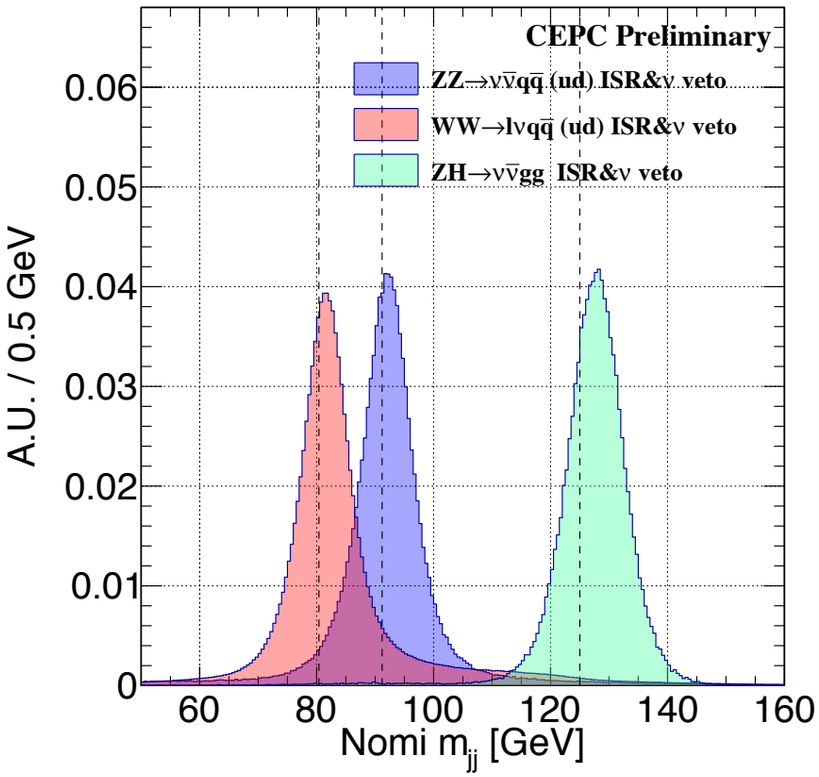
- **Nominal dijet mass distribution**
- **After flavor and energy depend calibration dijet mass distribution**
- **Flavor and energy dependence of JER and JES**
- **$m_{\text{All PFO}}$ VS. $m_{\text{All Visible MC particles}}$**
- **The detail of selection**
- **ΔR selection efficiency in ee->ZZ->vvqq**
- **ΔR as the function of the relative difference**
- **JER and JES**

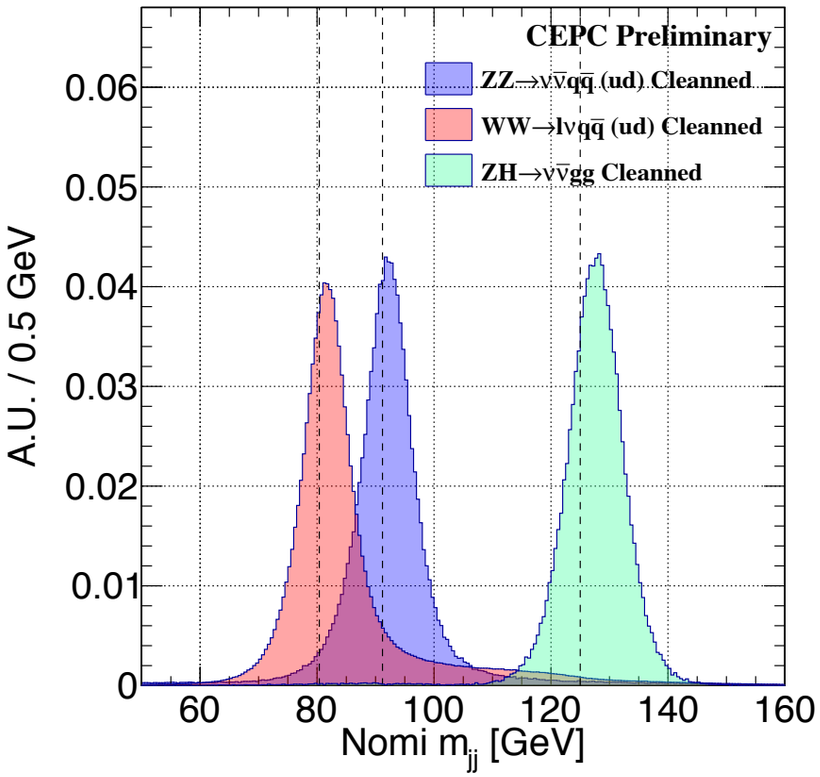
Bosons Mass Distribution



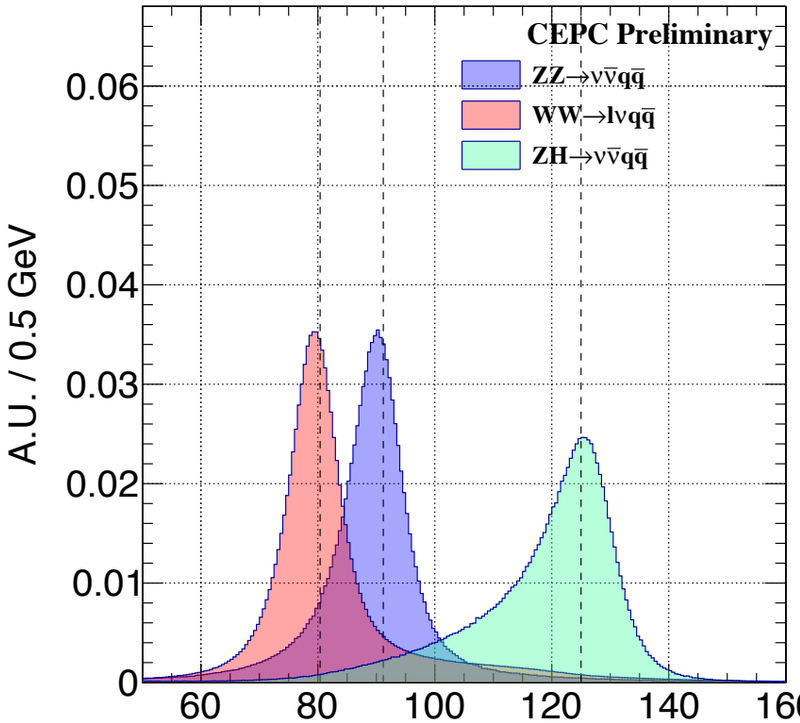


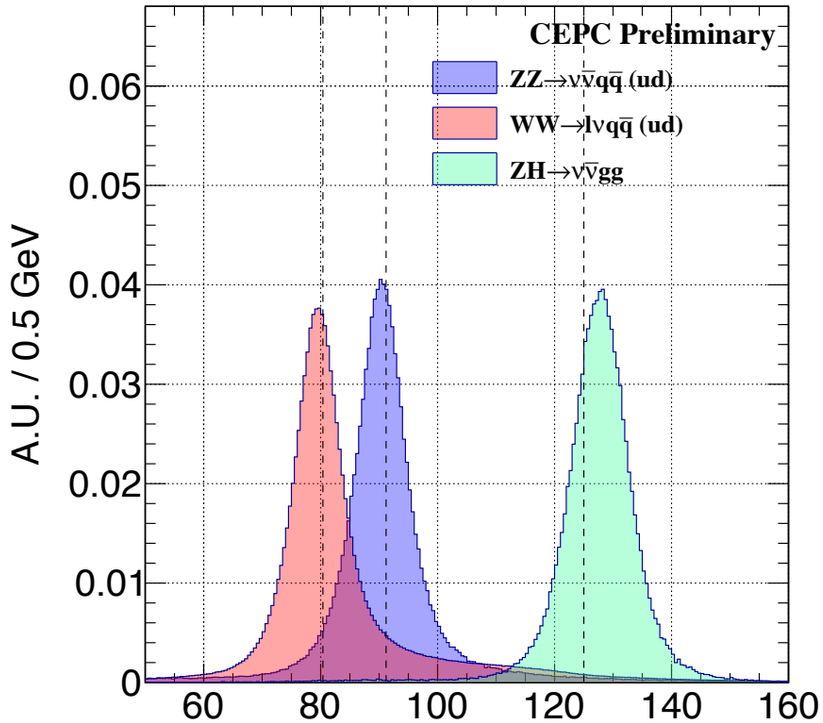


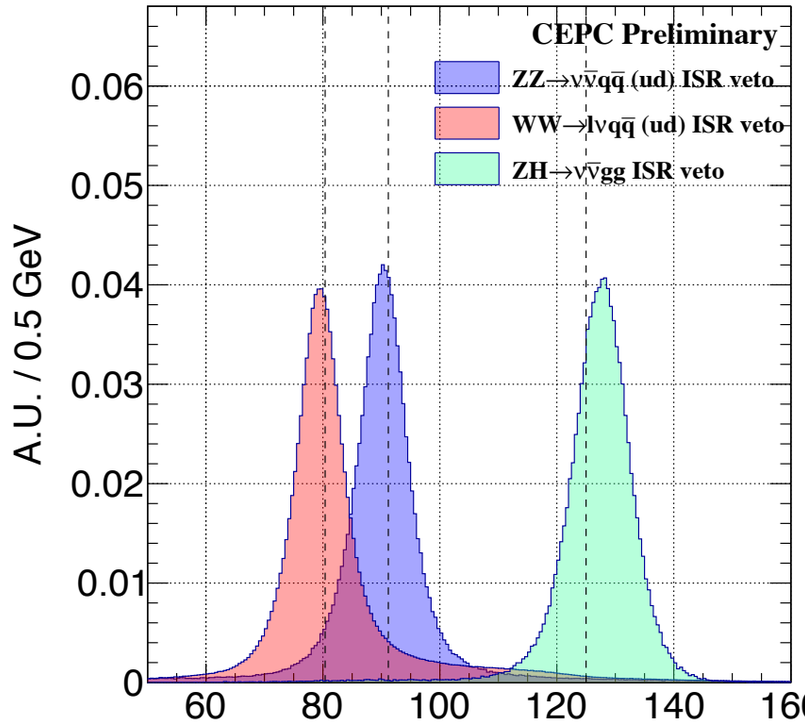


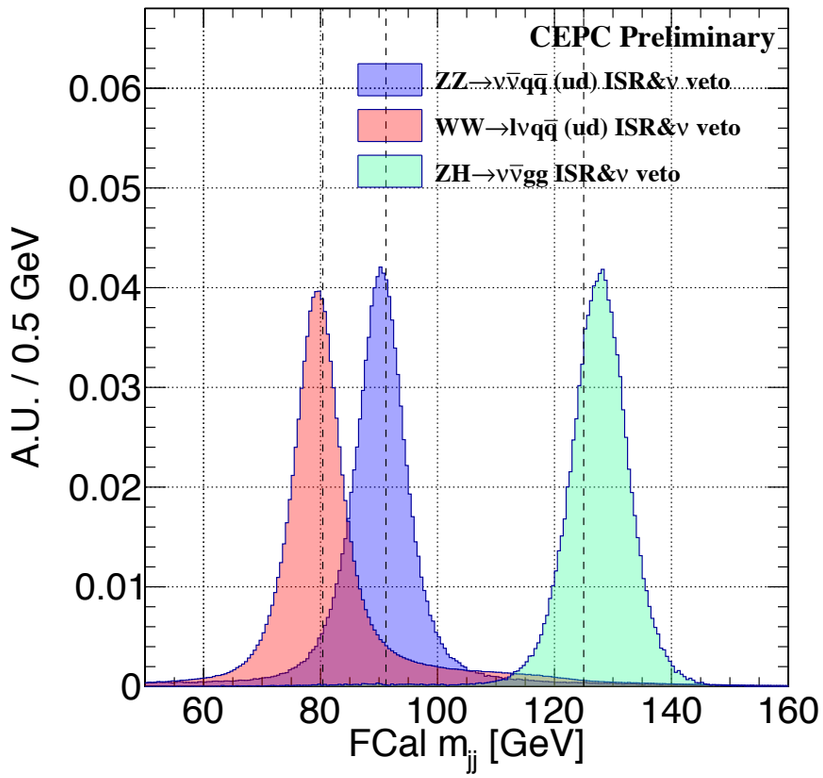


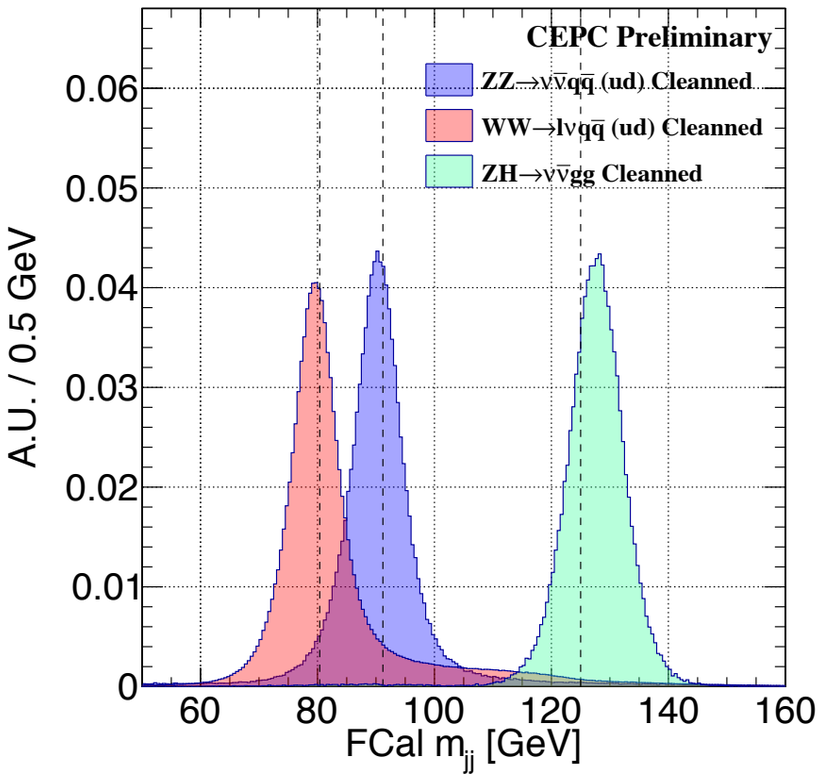
Bosons Mass Distribution



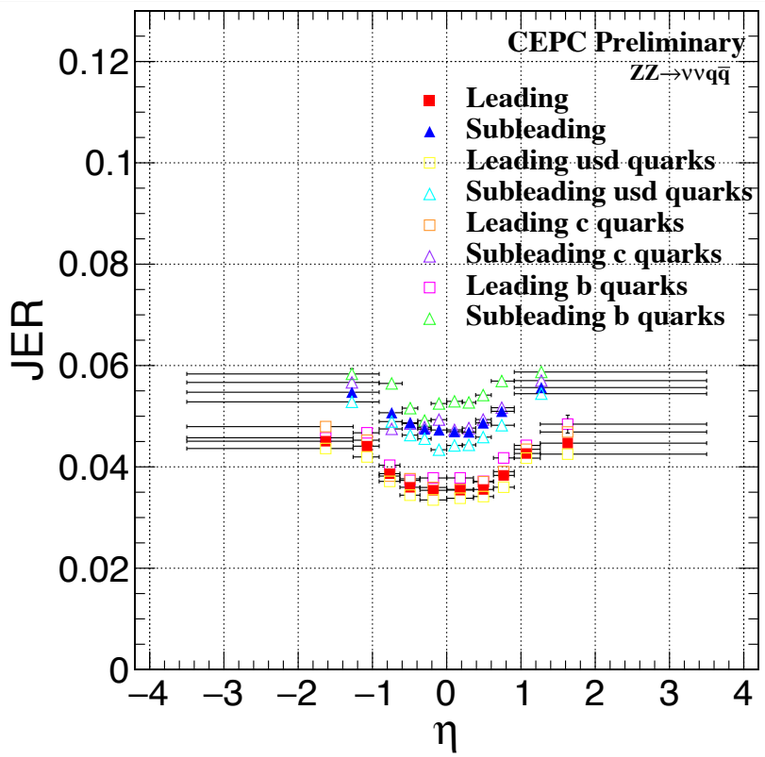


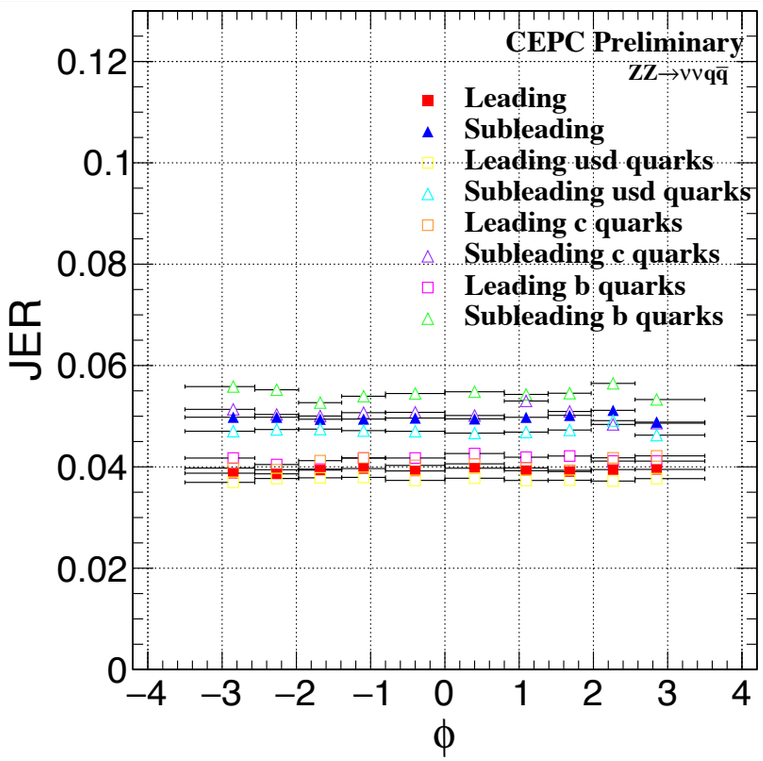


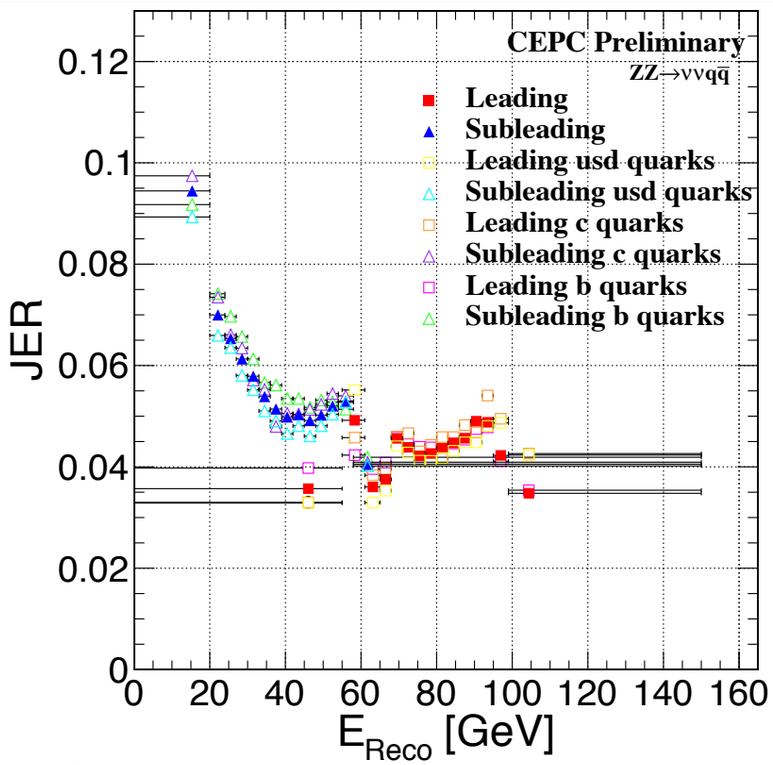


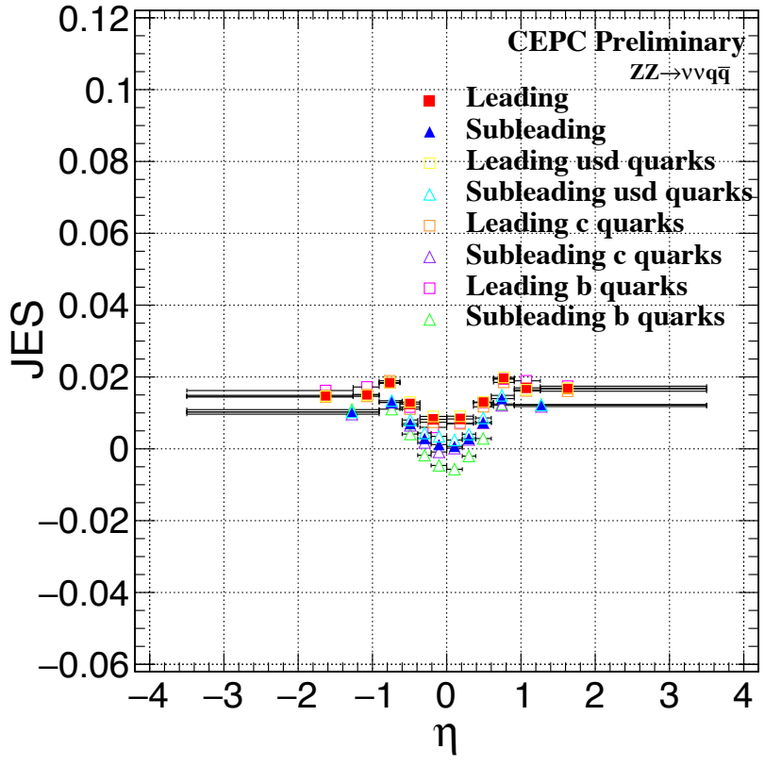


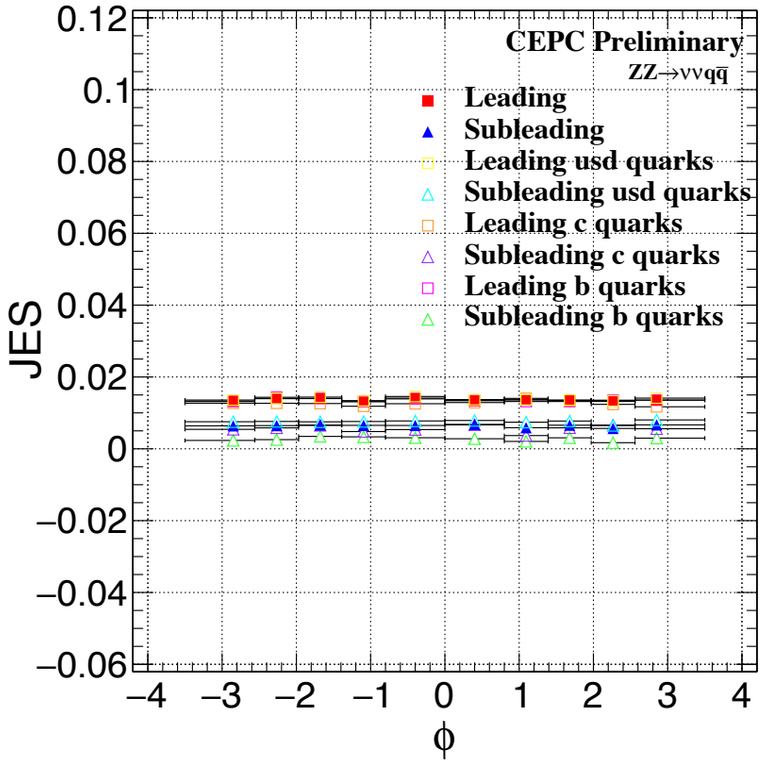
JER & JES(Reco-Gen)

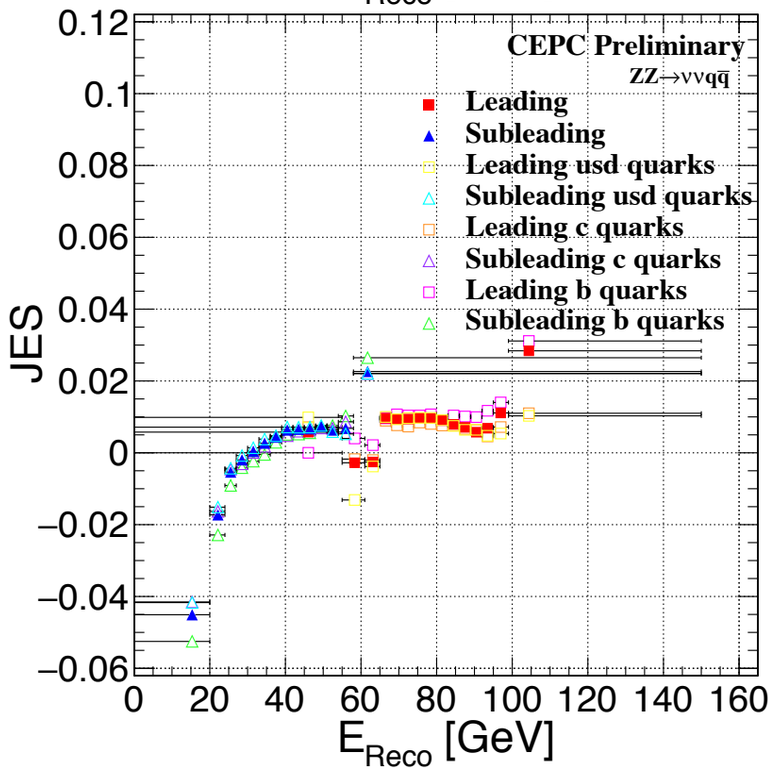






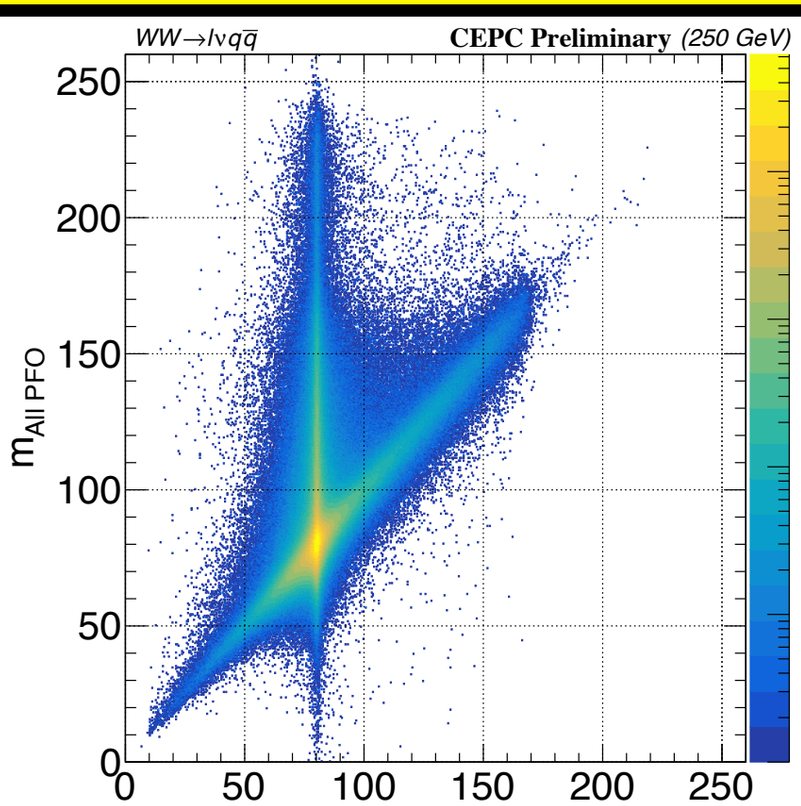


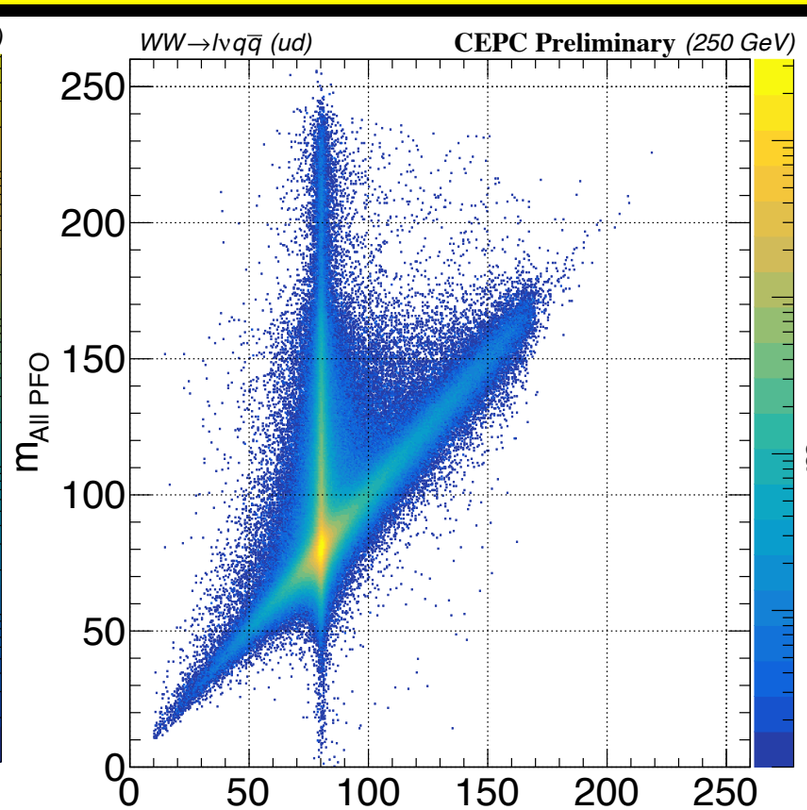


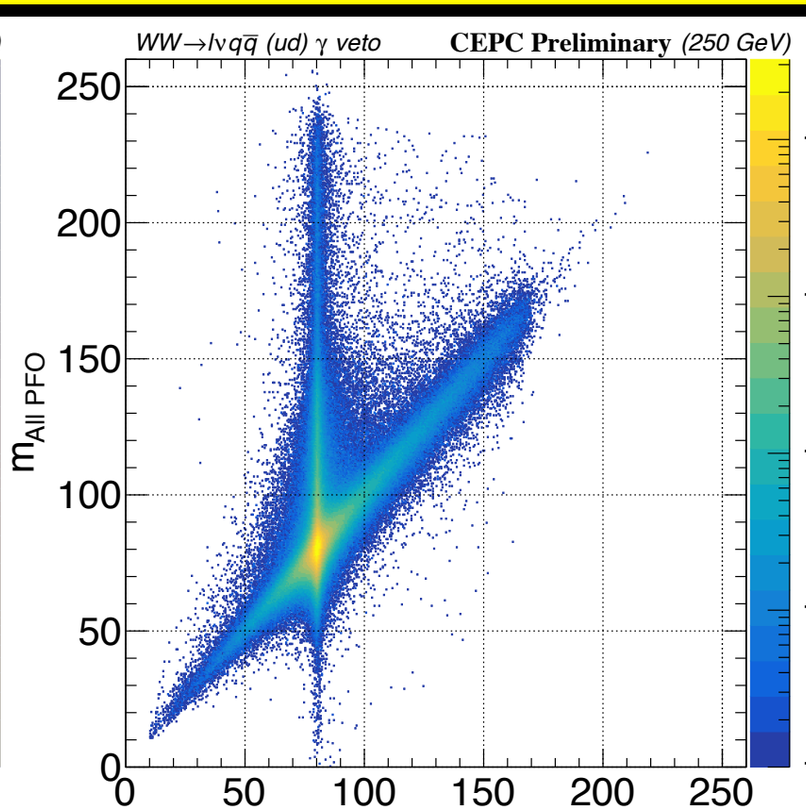


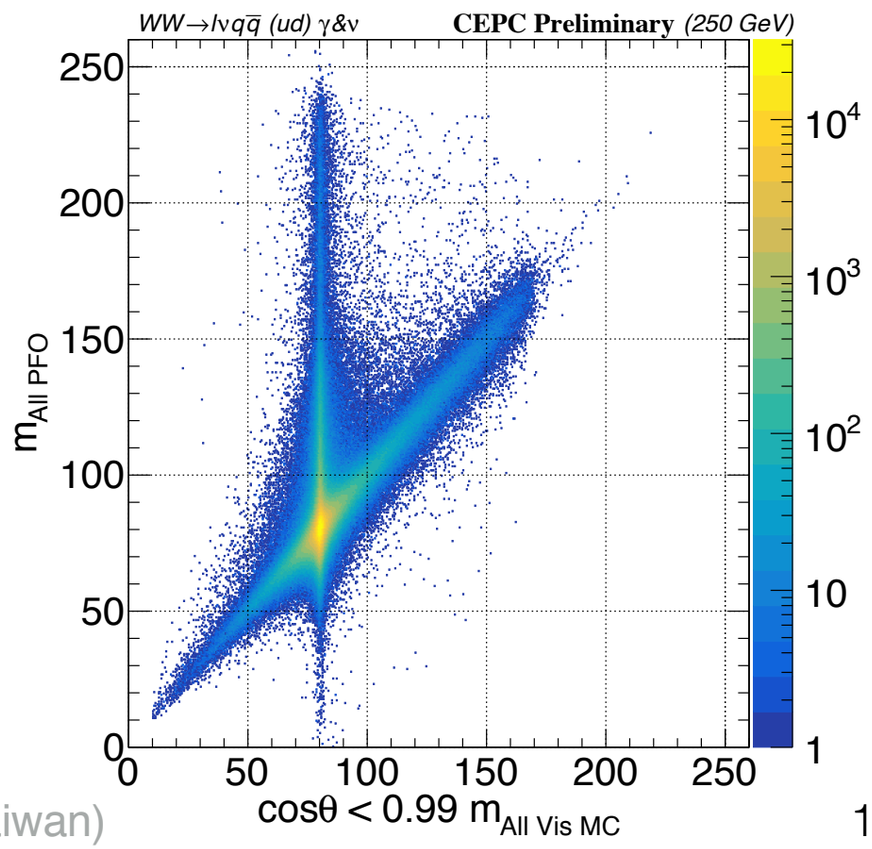
- **JER/JES of heavy flavor quark are worse than light flavor one about 0.5%.**

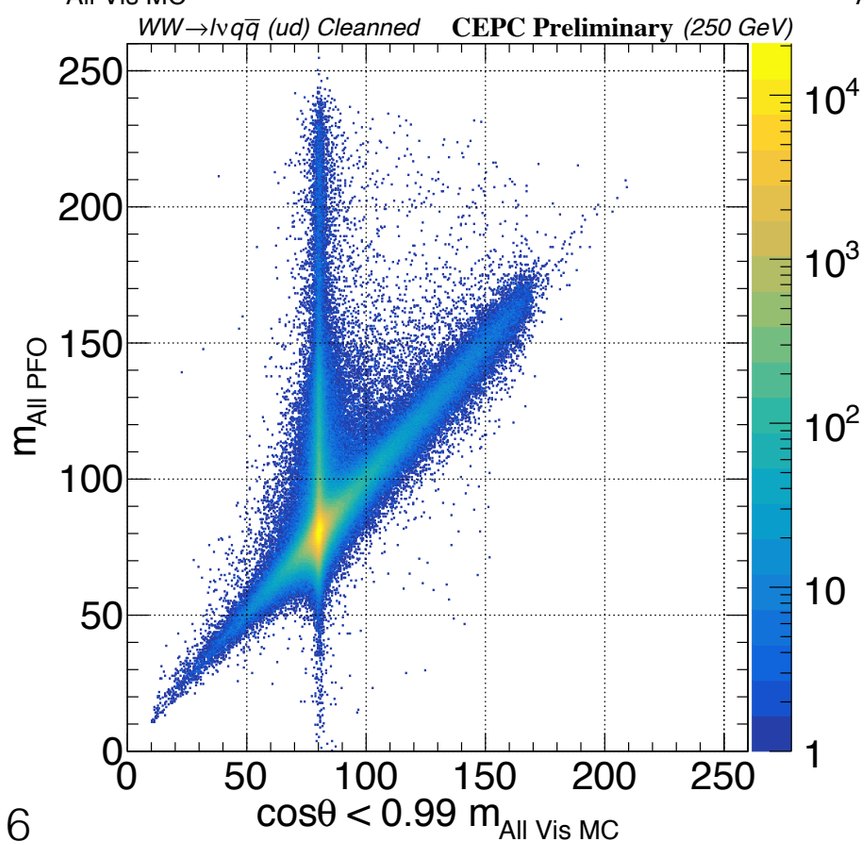
$m_{\text{All PFO}}$ VS. $\cos\theta < 0.99$ $m_{\text{All Vis MC}}$



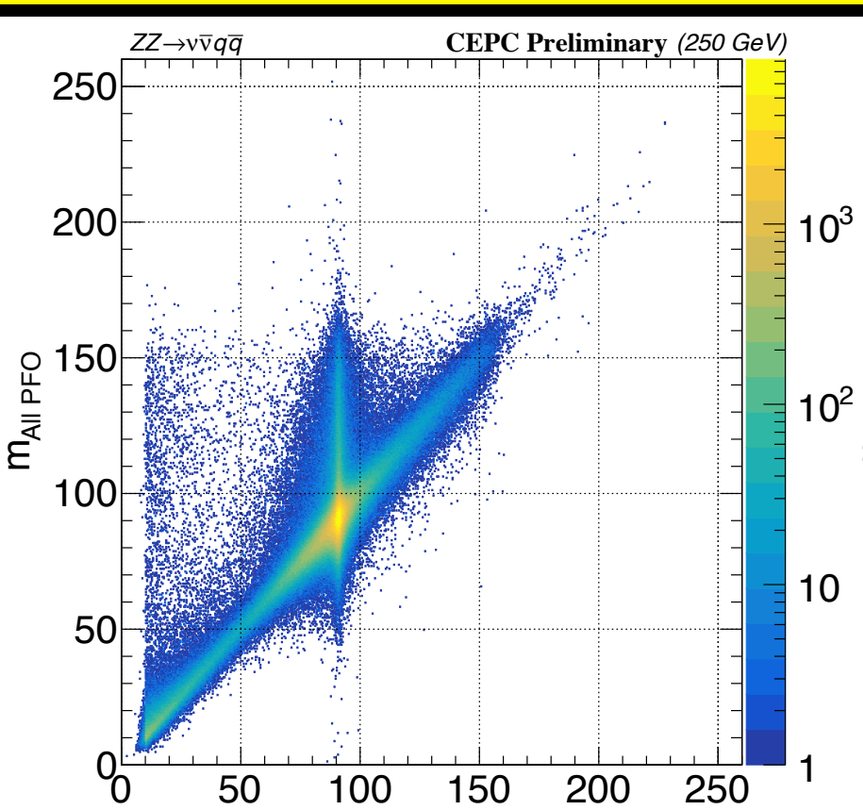


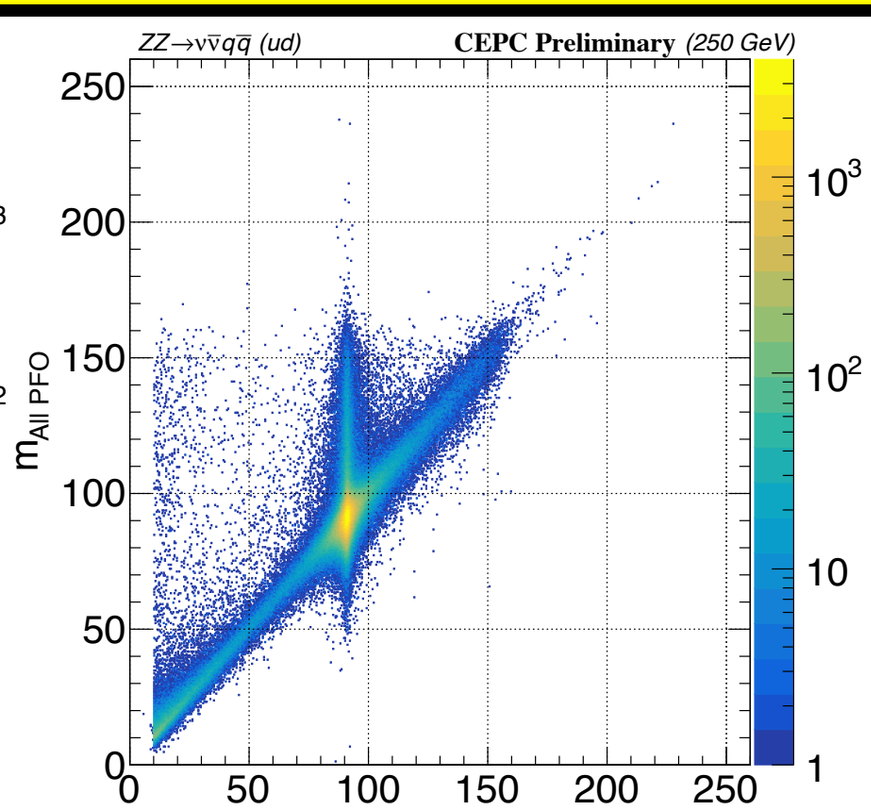


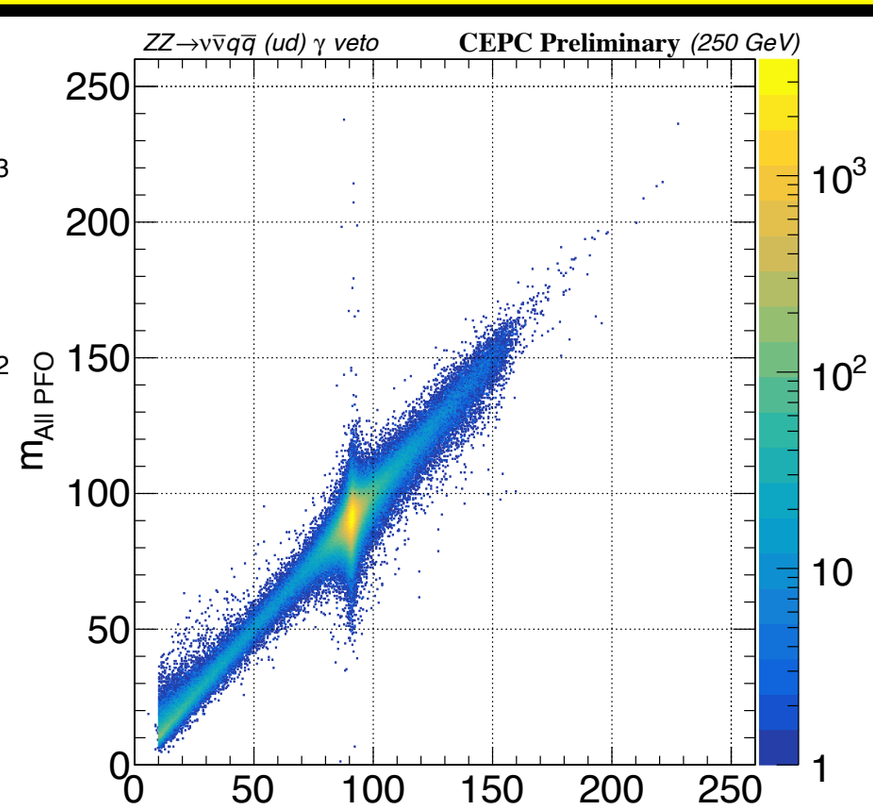


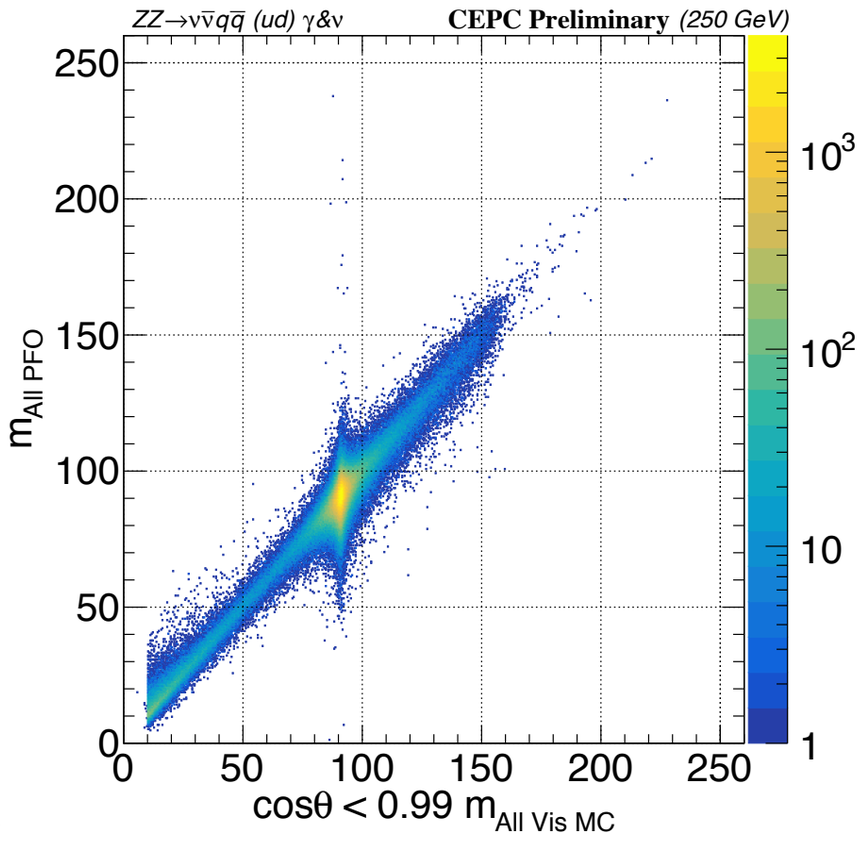


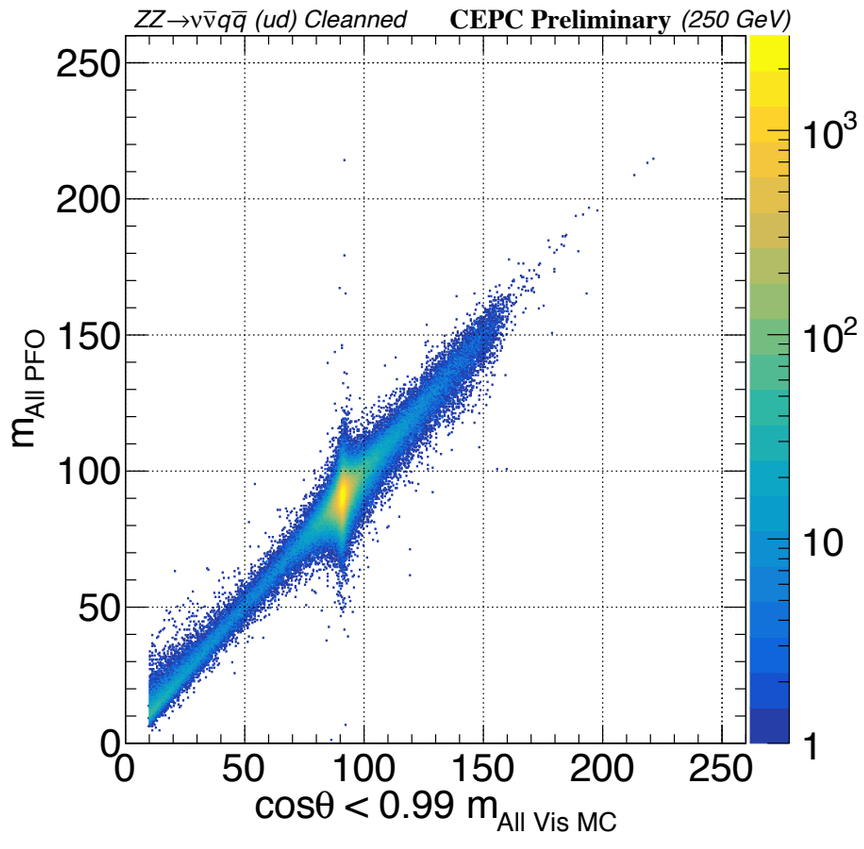
$m_{\text{All PFO}}$ VS. $\cos\theta < 0.99$ $m_{\text{All Vis MC}}$











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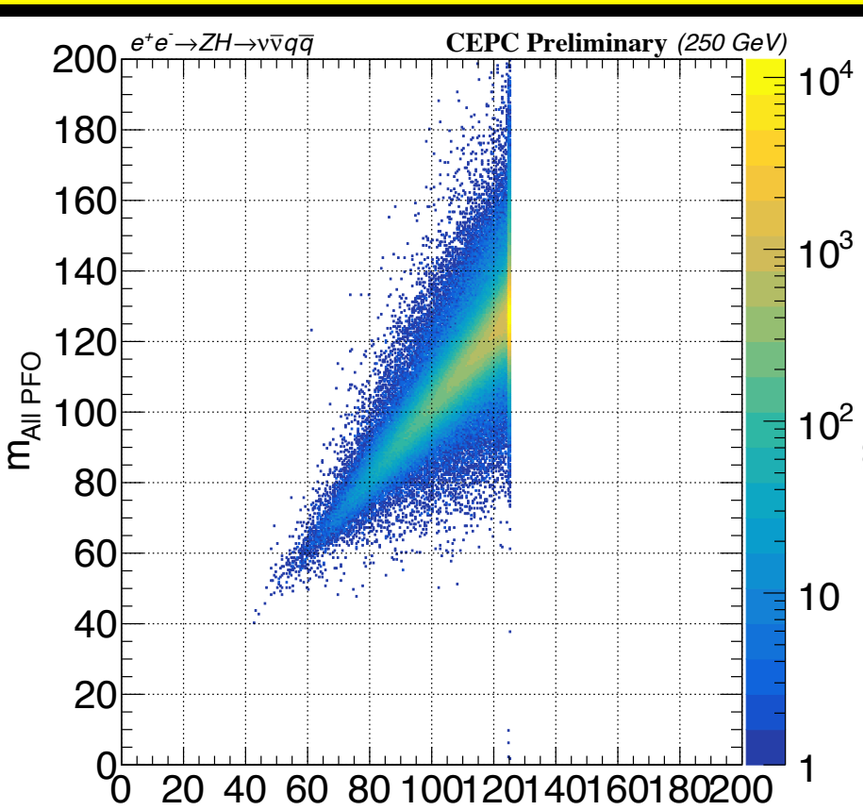
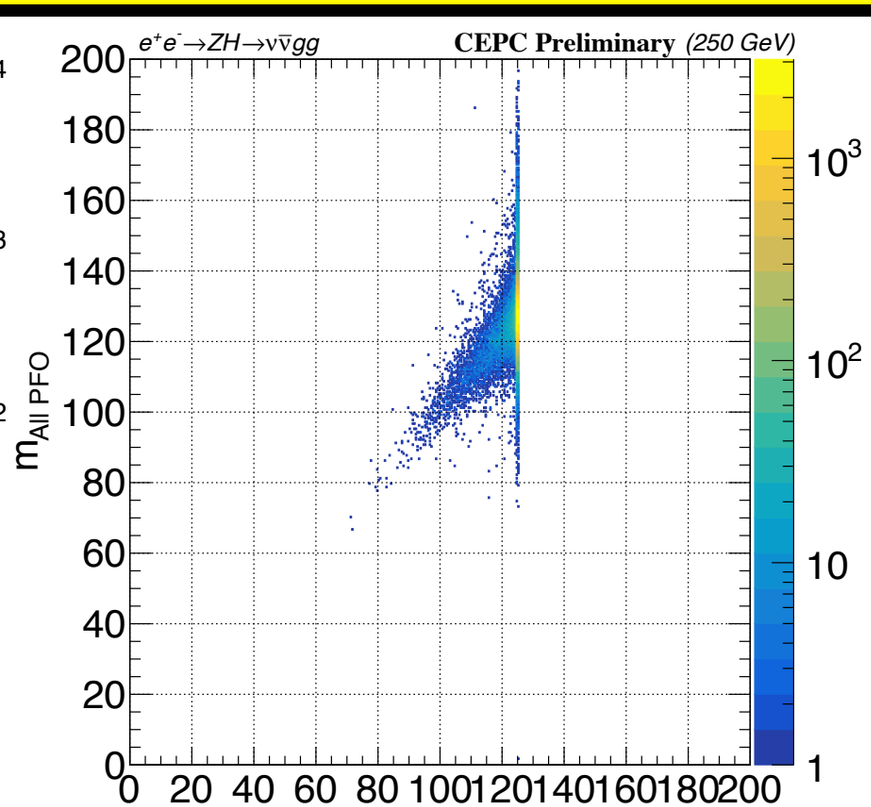
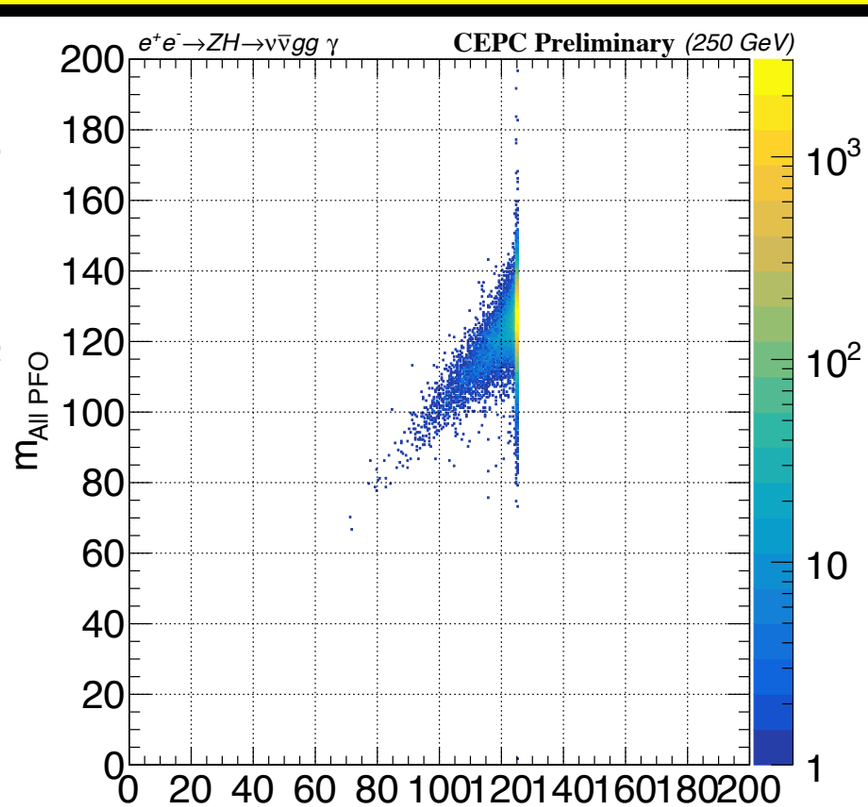
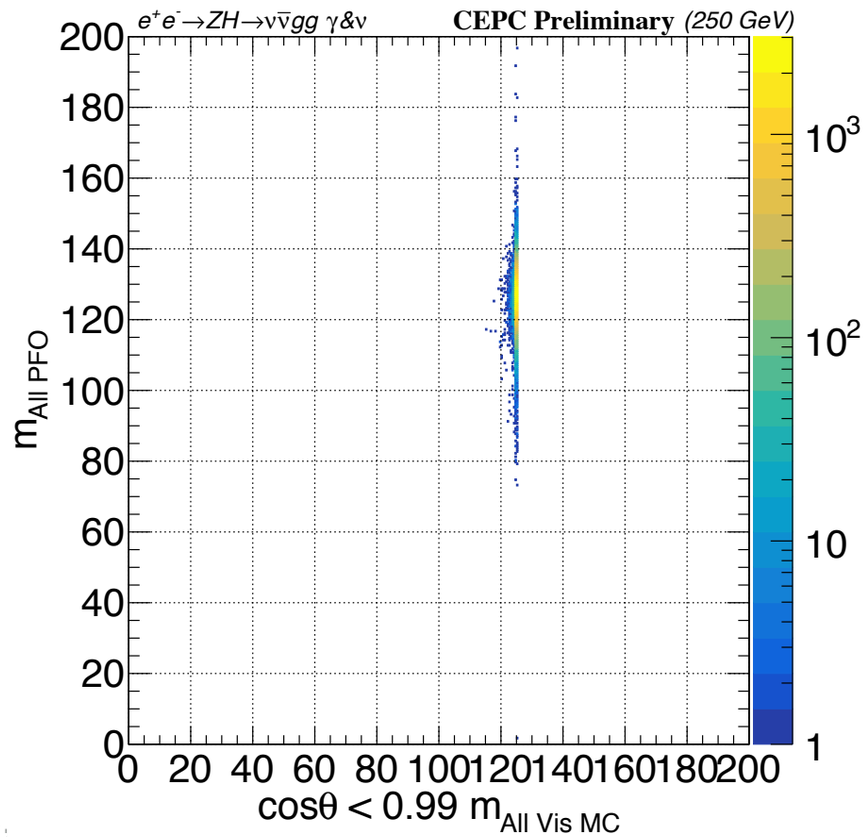
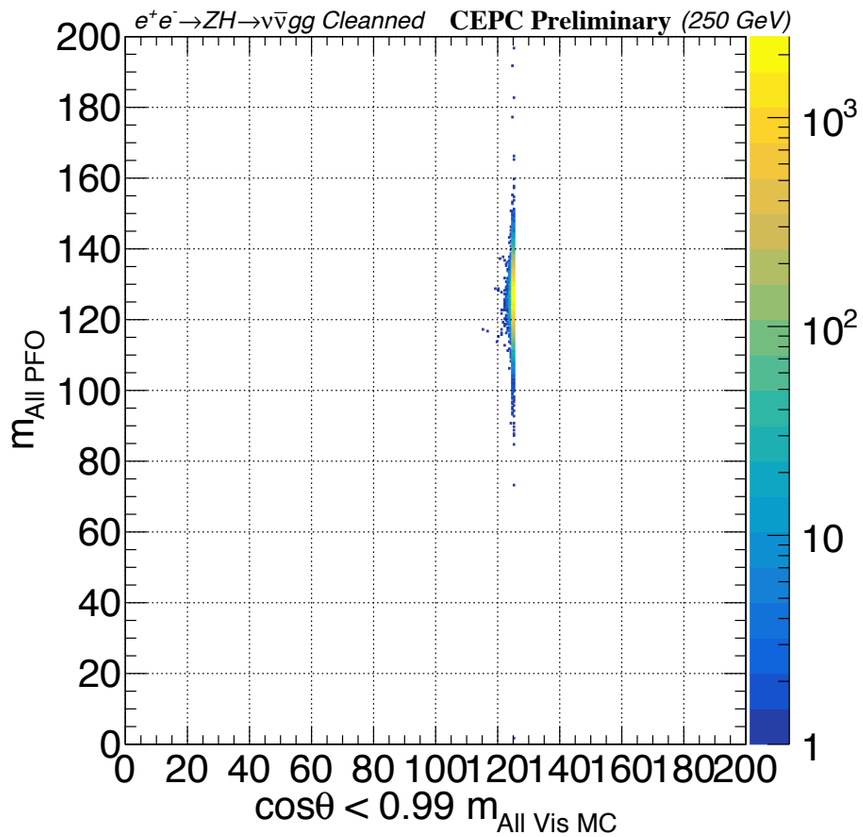


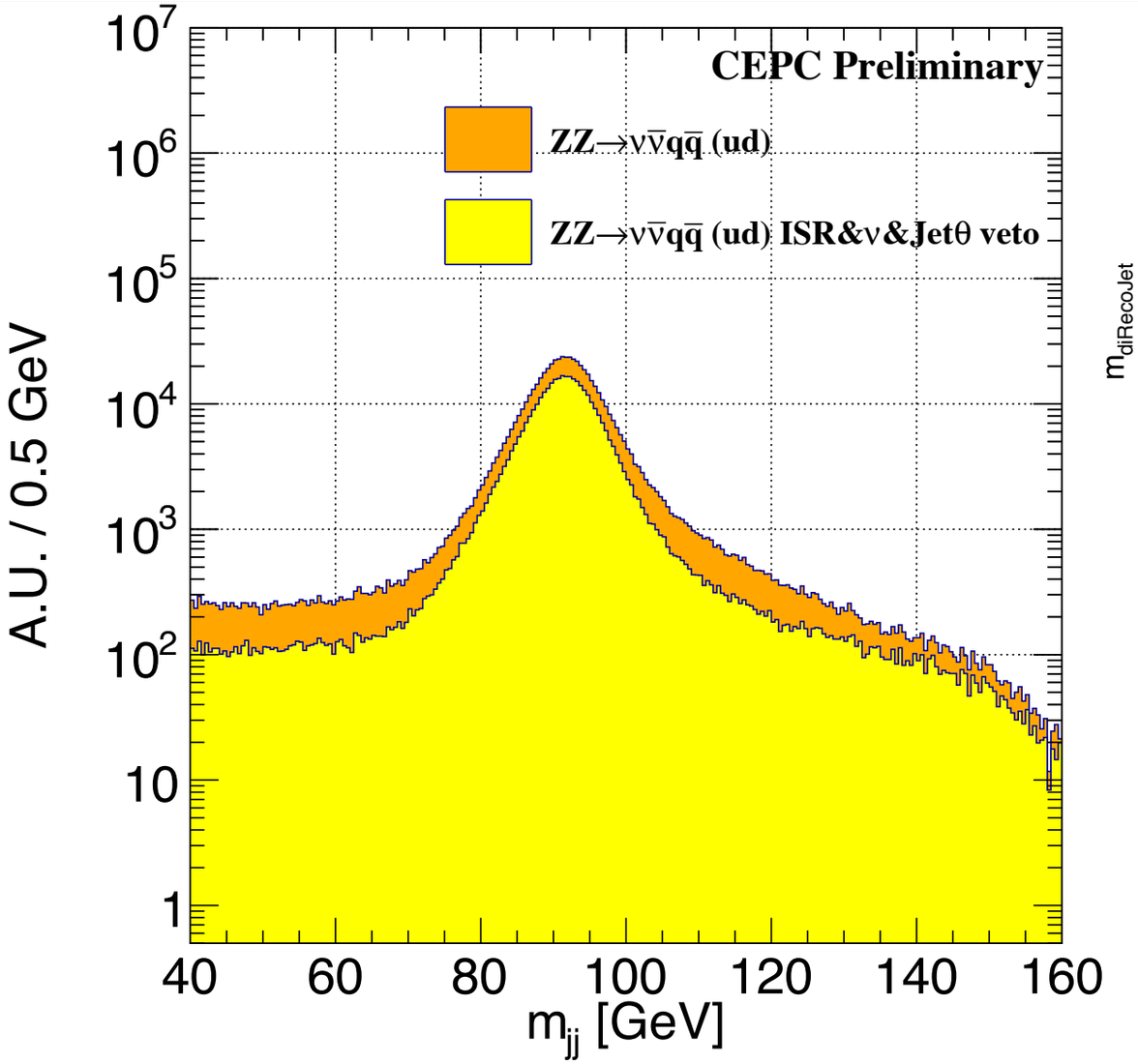








Jets @ ZZ, Z->dijet



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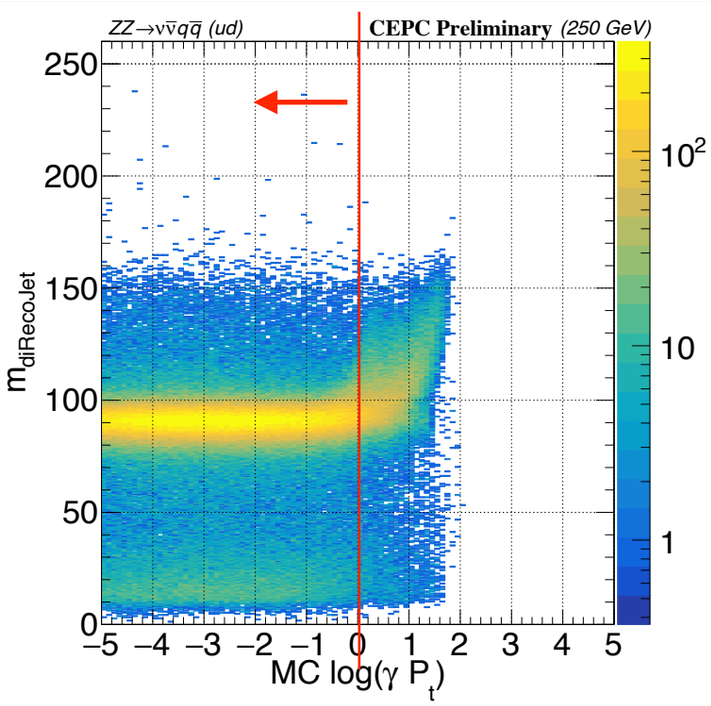
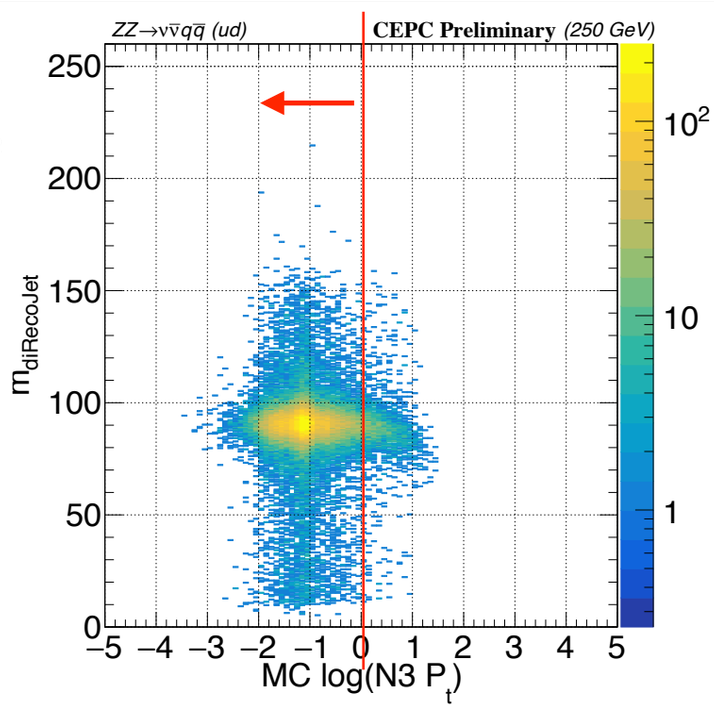
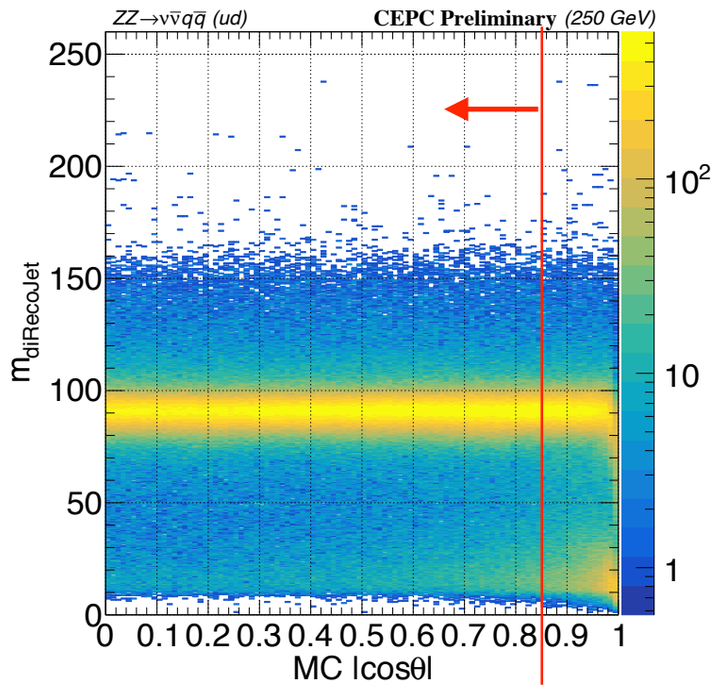
ISR Pt <1 &N3 Pt <1 & |cosθ| < 0.85	**833030**	68.15%

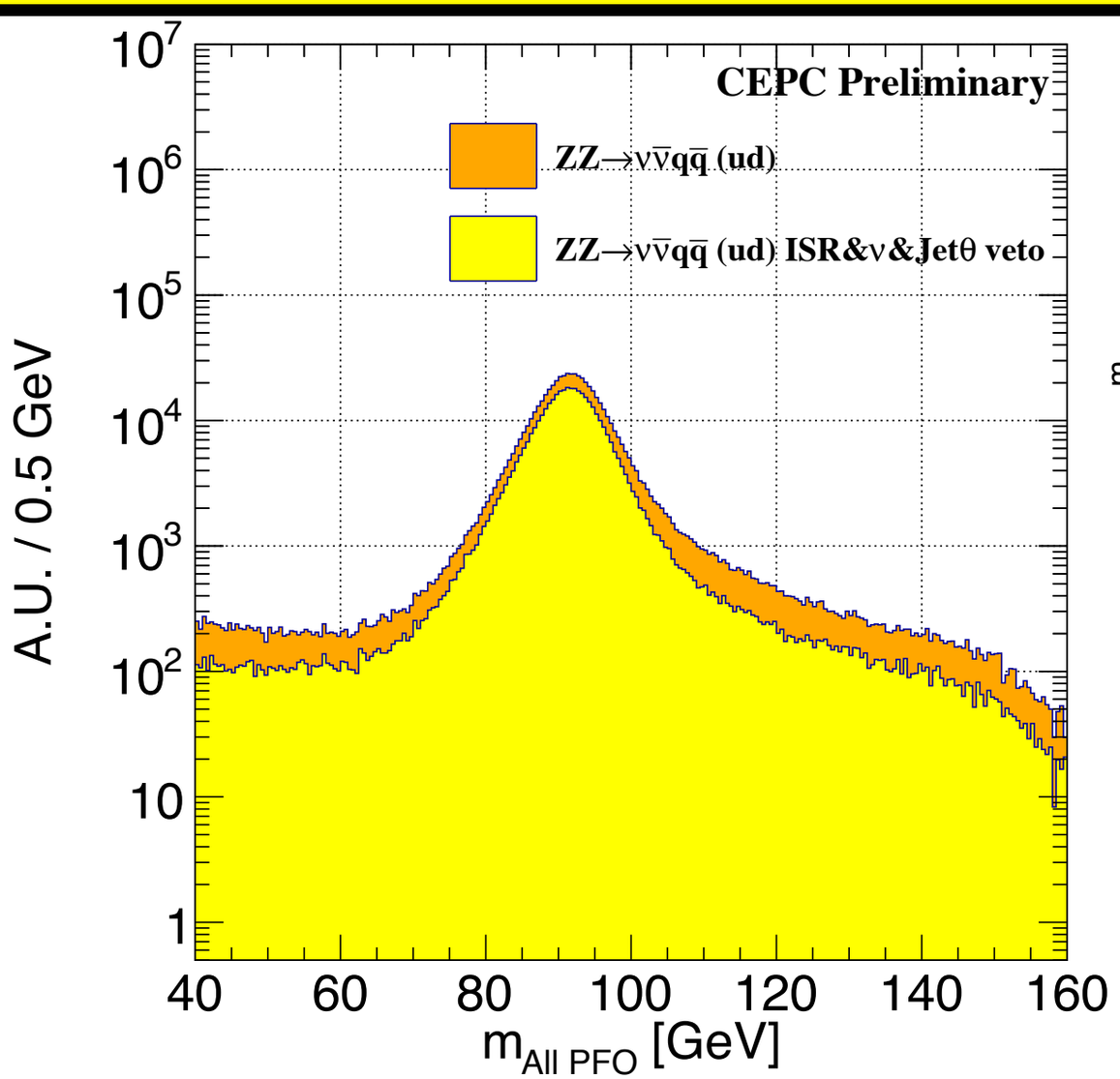
Overall = 62.88%







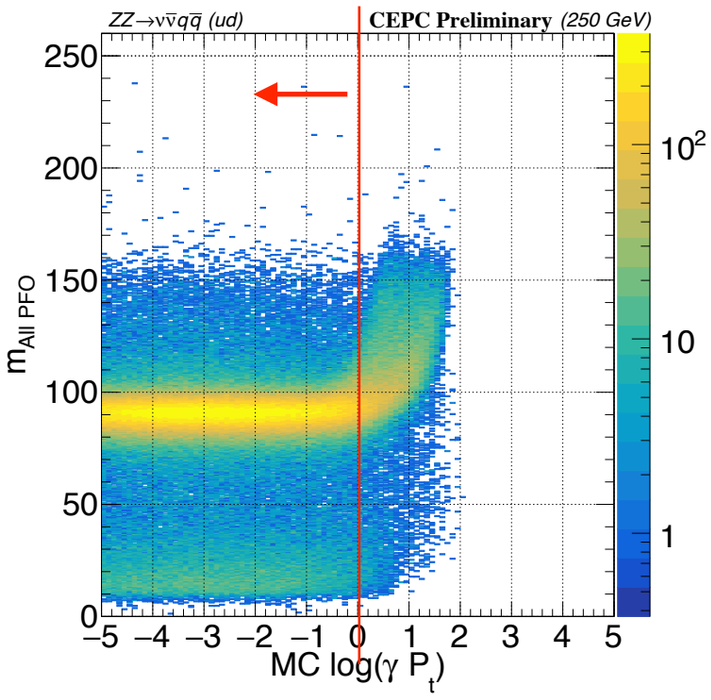
All PFO @ ZZ, Z->dijet

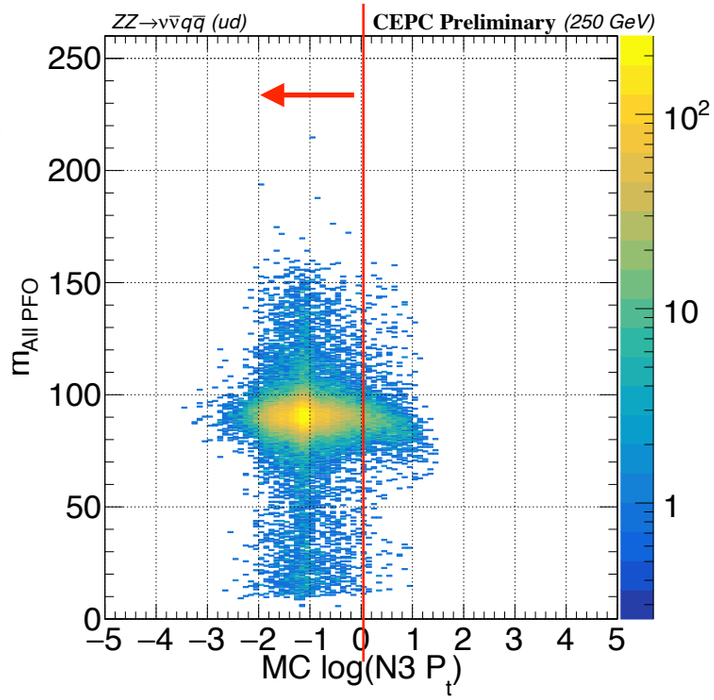


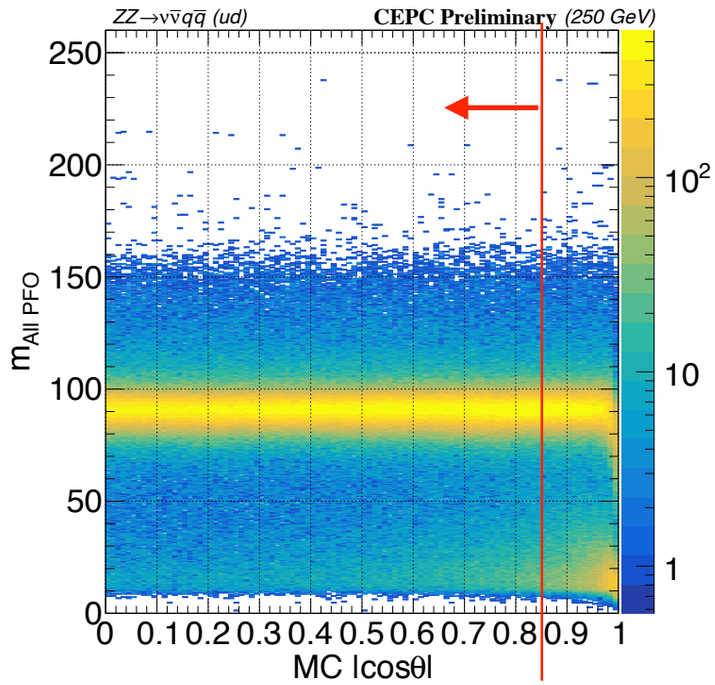
Total # of events = 1772775

Type	# of events	
All ZZ->vvqq̄ (ud)	**1324710**	
ISR Pt < 1 GeV	**1227740**	92.67%
ISR Pt <1&N3 Pt <1	**1222270**	99.55%
ISR Pt <1 &N3 Pt <1 & $\|\cos\theta\| < 0.85$	**833030**	68.15%

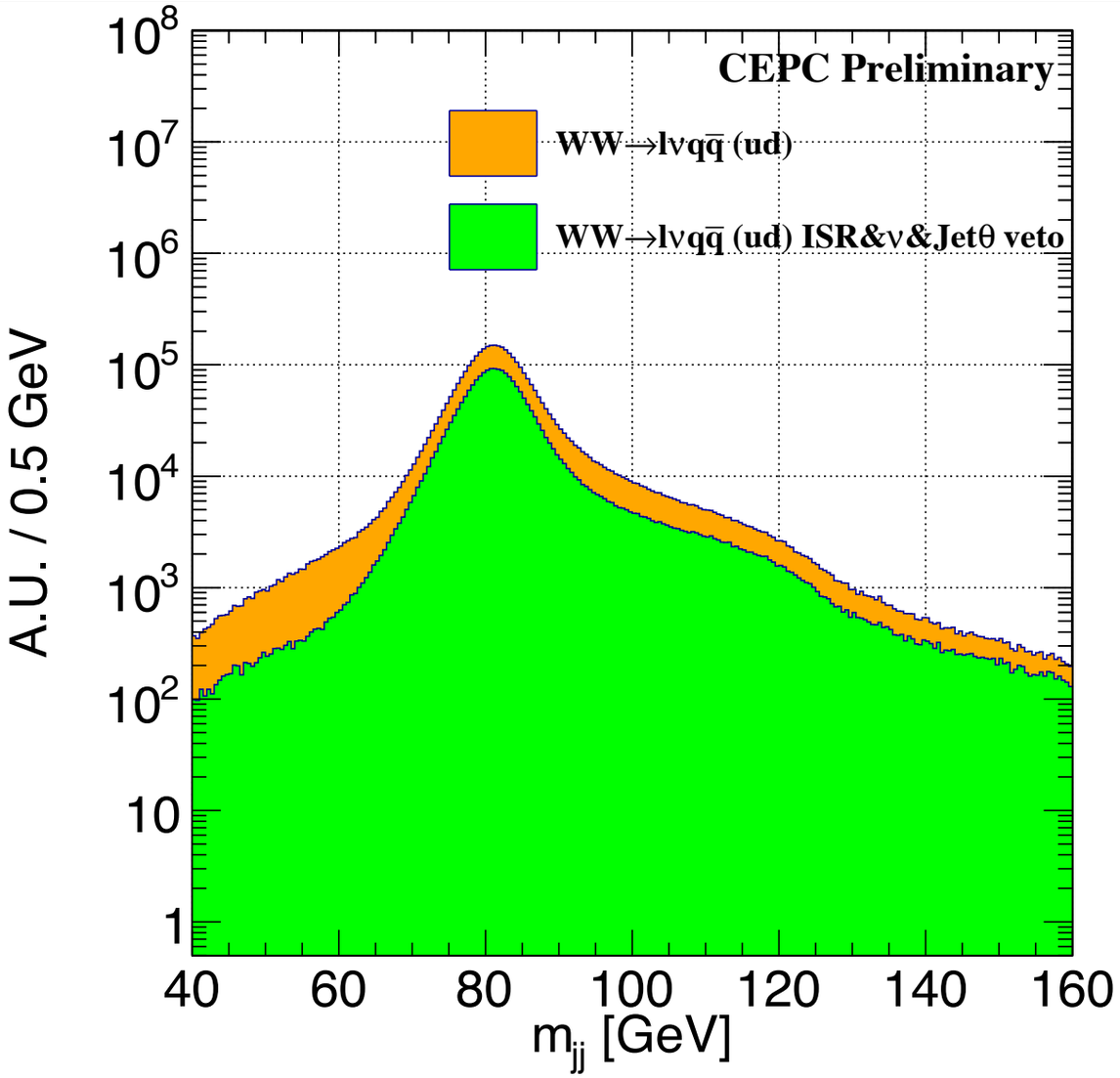
Overall = 62.88%







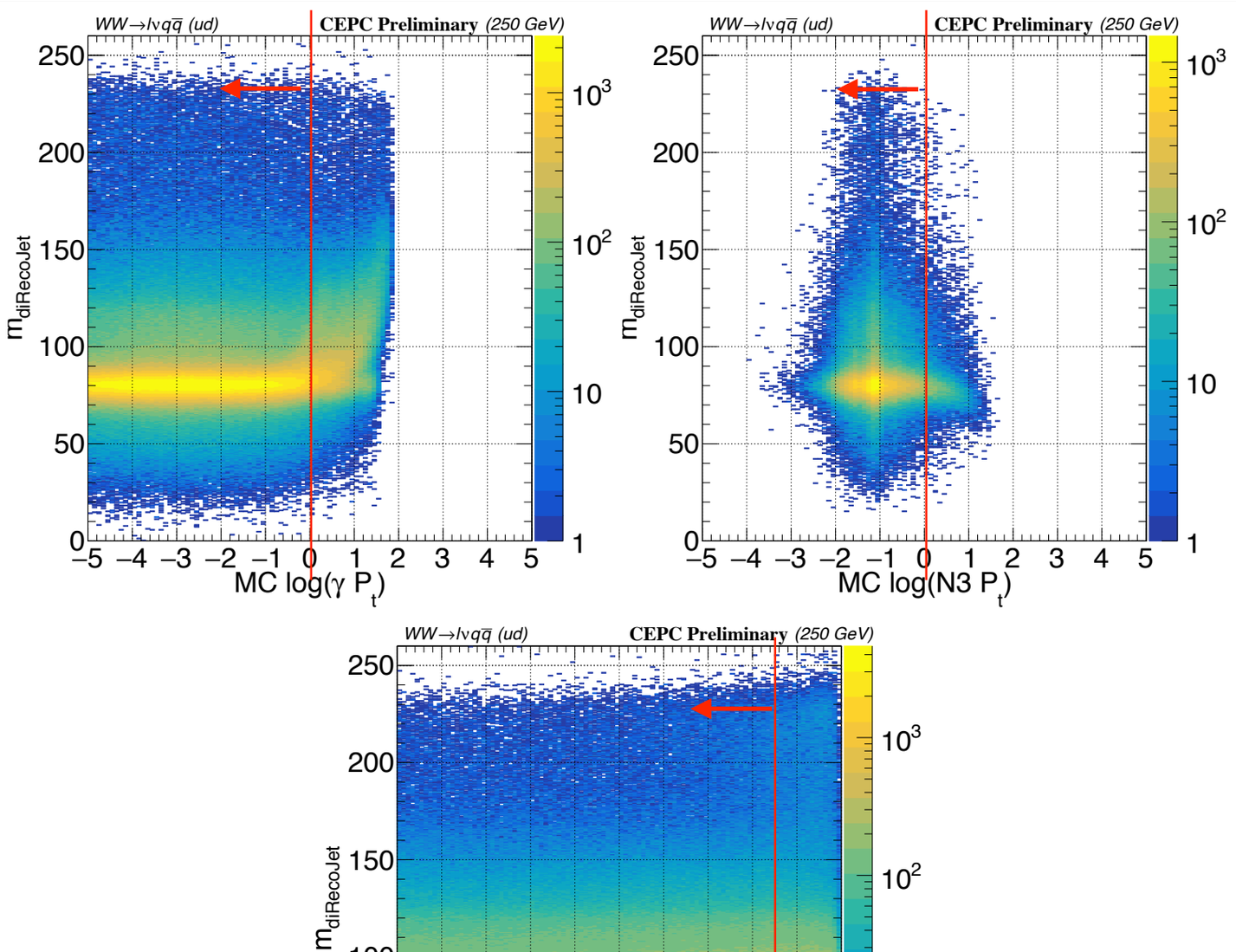
Jets @ WW, W->dijet



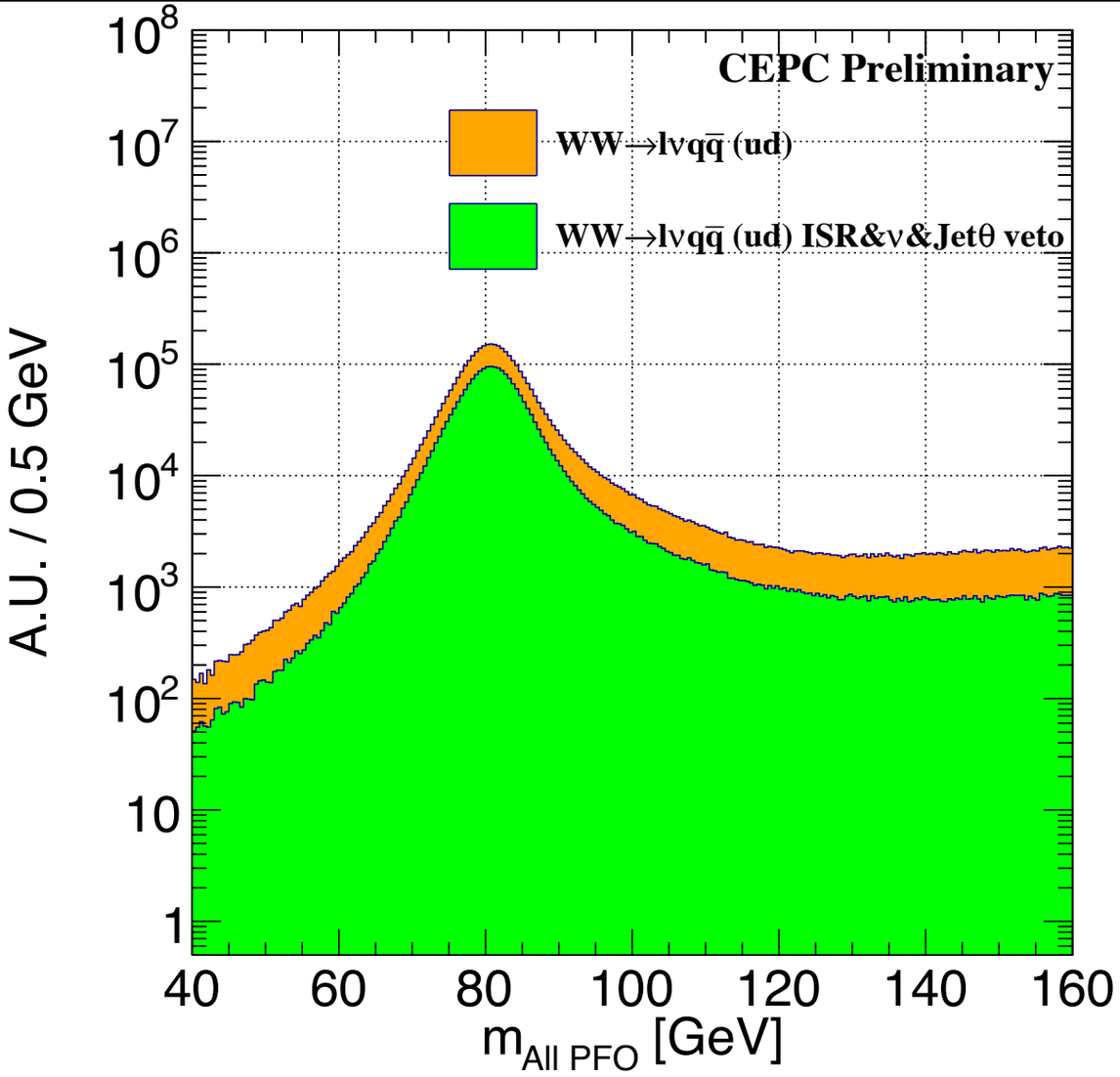
Total # of events = 11176194

Type	# of events	
All WW->vvqq̄	**8815200**	
ISR Pt < 1 GeV	**8111780**	92.02%
ISR Pt <1&N3 Pt <1	**8078460**	99.58%
ISR Pt <1 &N3 Pt <1 & $\|\cos\theta\| < 0.85$	**4941960**	61.17%

Overall = 56.06%



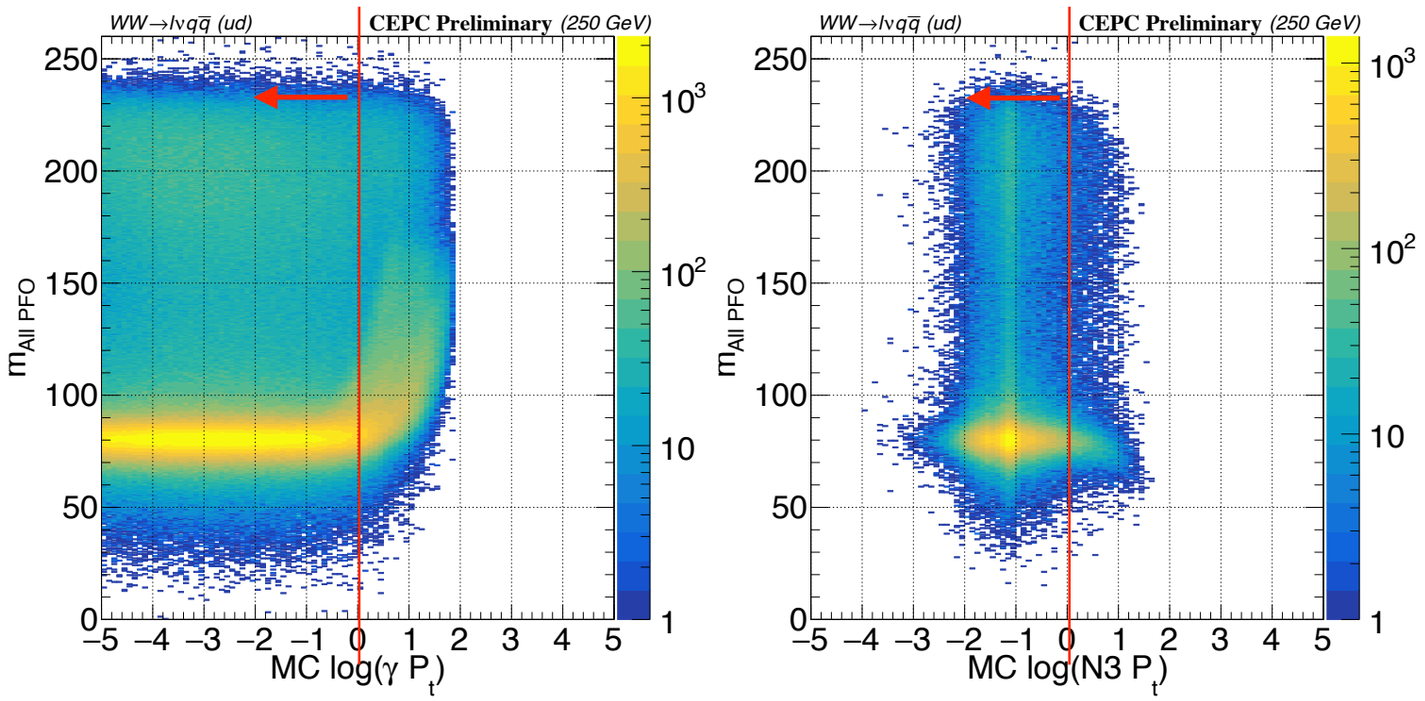
All PFO @ WW, W->dijet

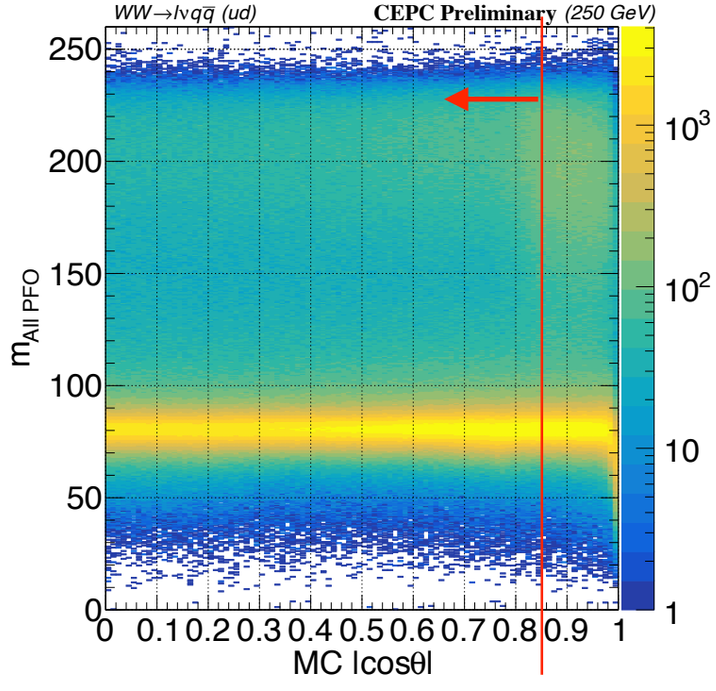


Total # of events = 11176194

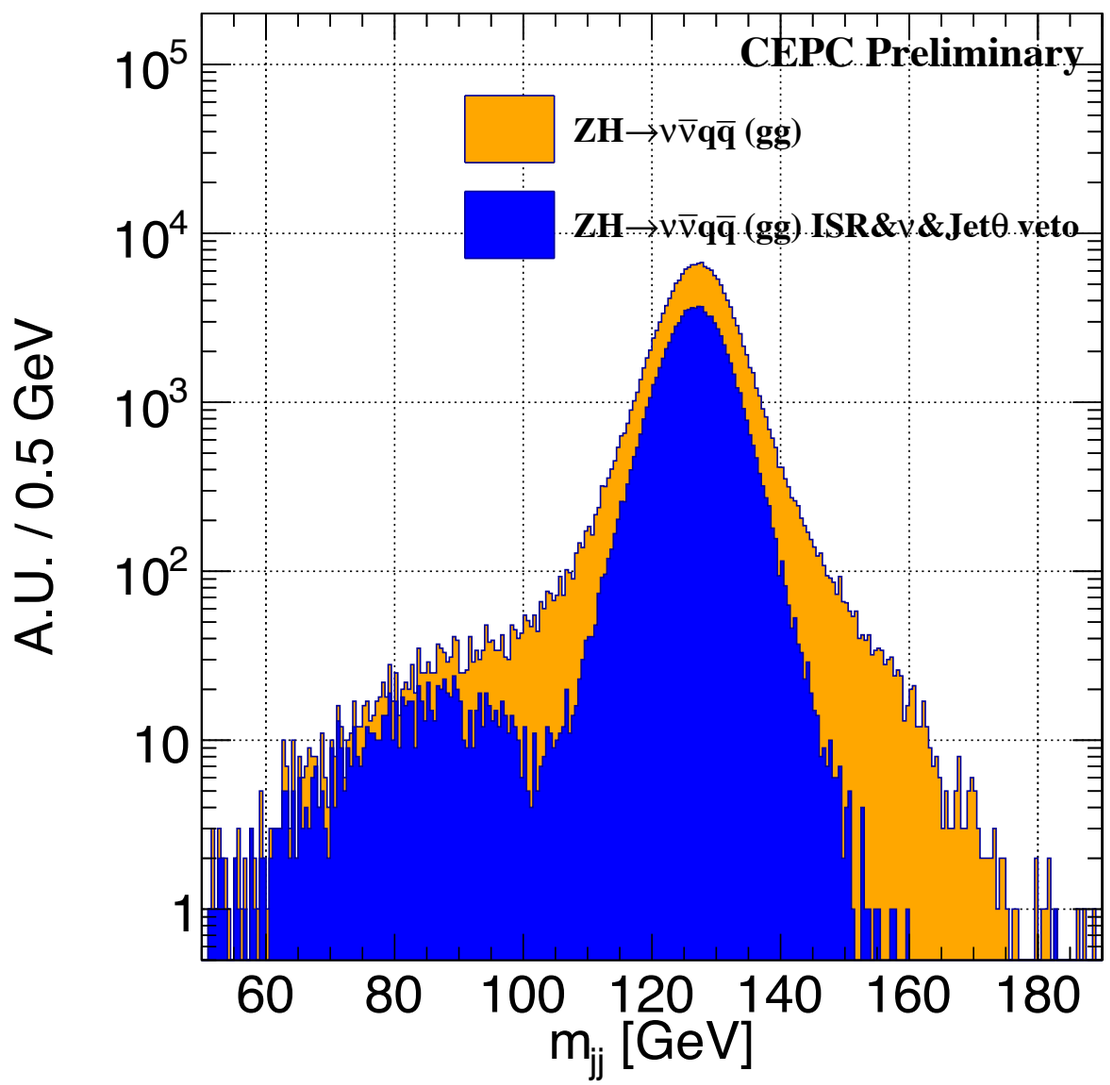
Type	# of events	
All WW->vvqq̄	**8815200**	
ISR Pt < 1 GeV	**8111780**	92.02%
ISR Pt <1&N3 Pt <1	**8078460**	99.58%
ISR Pt <1 &N3 Pt <1 & $\|\cos\theta\| < 0.85$	**4941960**	61.17%

Overall = 56.06%





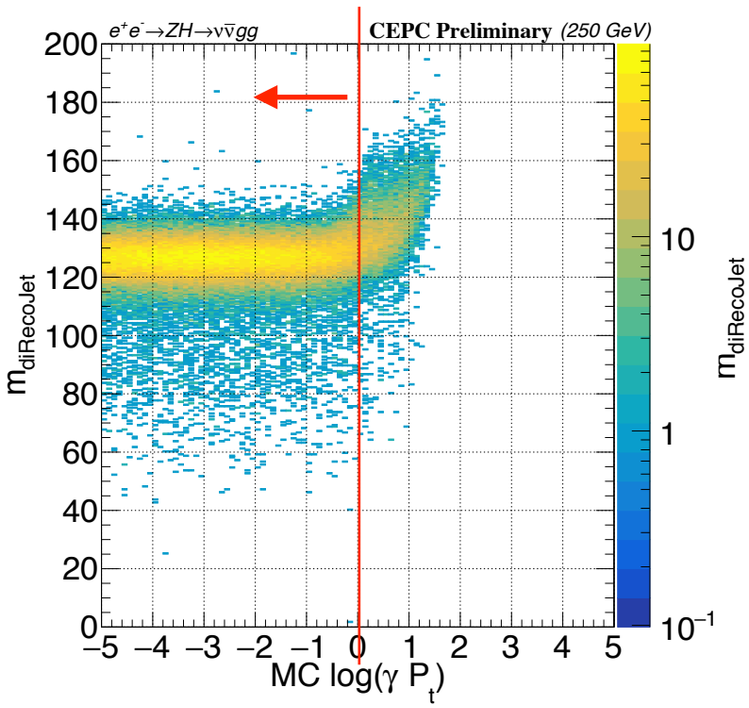
Jets @ vvH, H->gluons

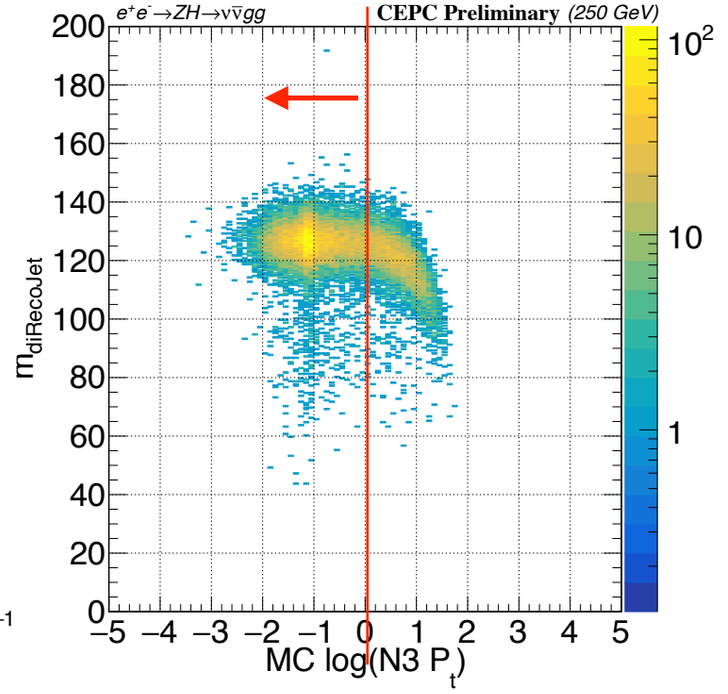


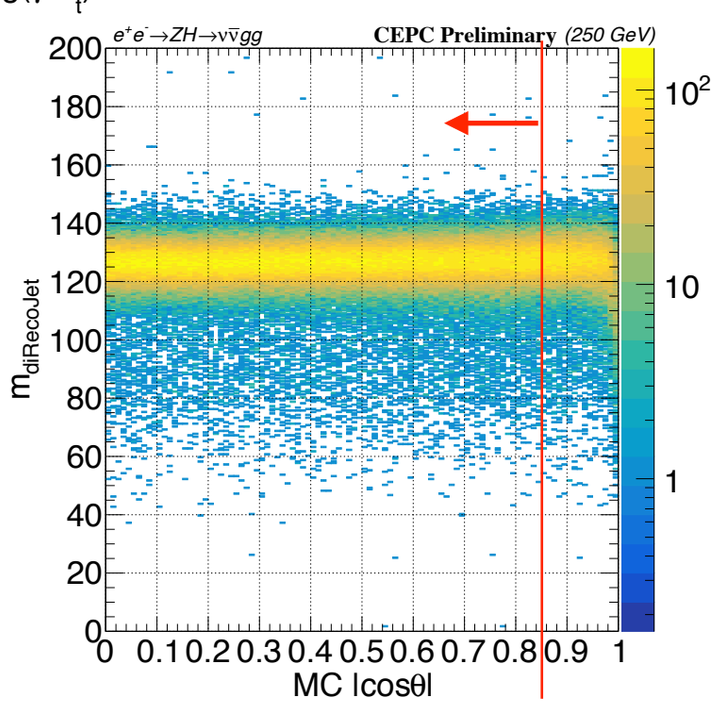
Total # of events = 238394

Type	# of events	
All vvH->vvgg	**289976**	
ISR Pt < 1 GeV	**273796**	94.42%
ISR Pt <1&N3 Pt <1	**258572**	94.43%
ISR Pt <1 &N3 Pt <1 & $\|\cos\theta\| < 0.85$	**196710**	76.07%

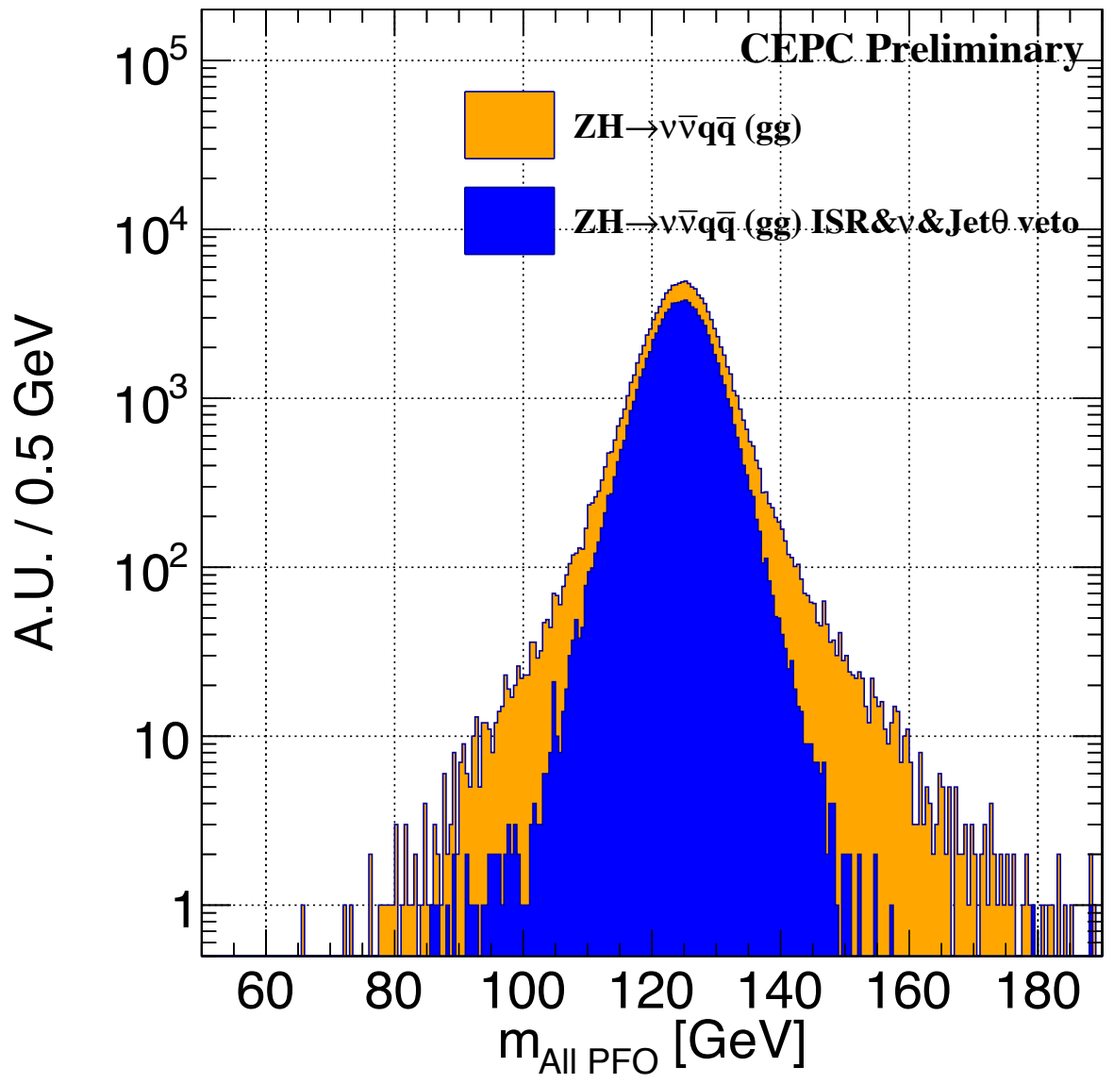
Overall = 67.83%







All PFO @ vvH, H->gluons



Total # of events = 238394

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ISR Pt < 1 GeV	**273796**	94.42%
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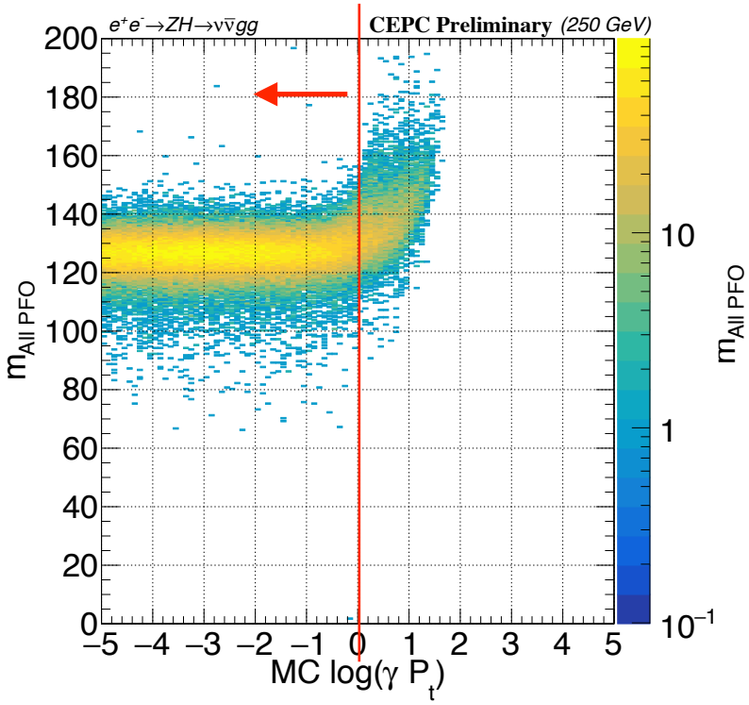
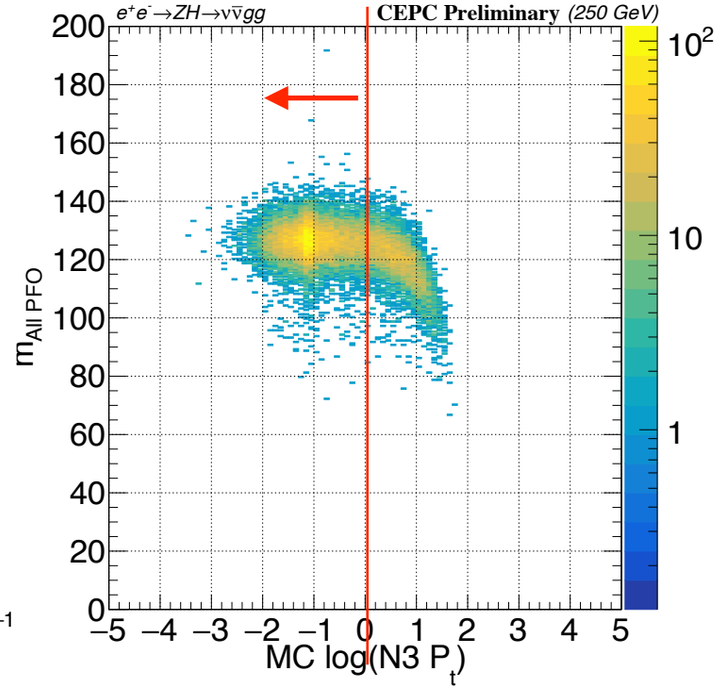
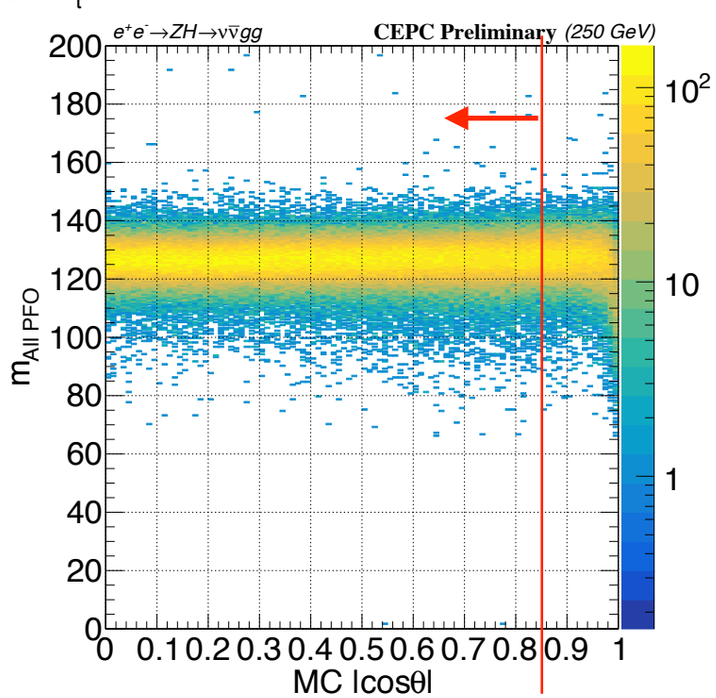
ISR Pt <1 &N3 Pt <1 & $\|\cos\theta\| < 0.85$	**196710**	76.07%

Overall = 67.83%

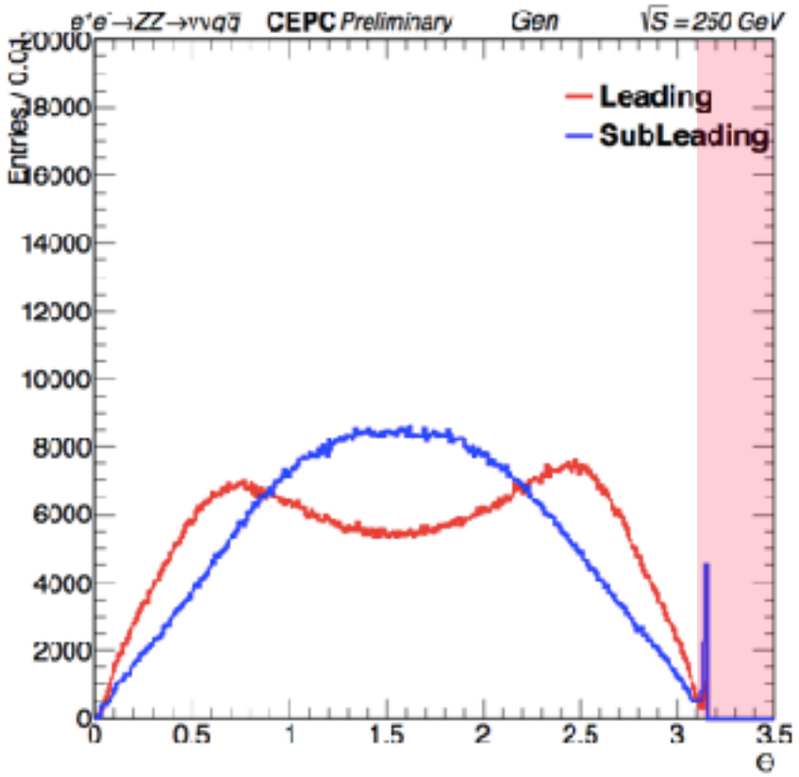


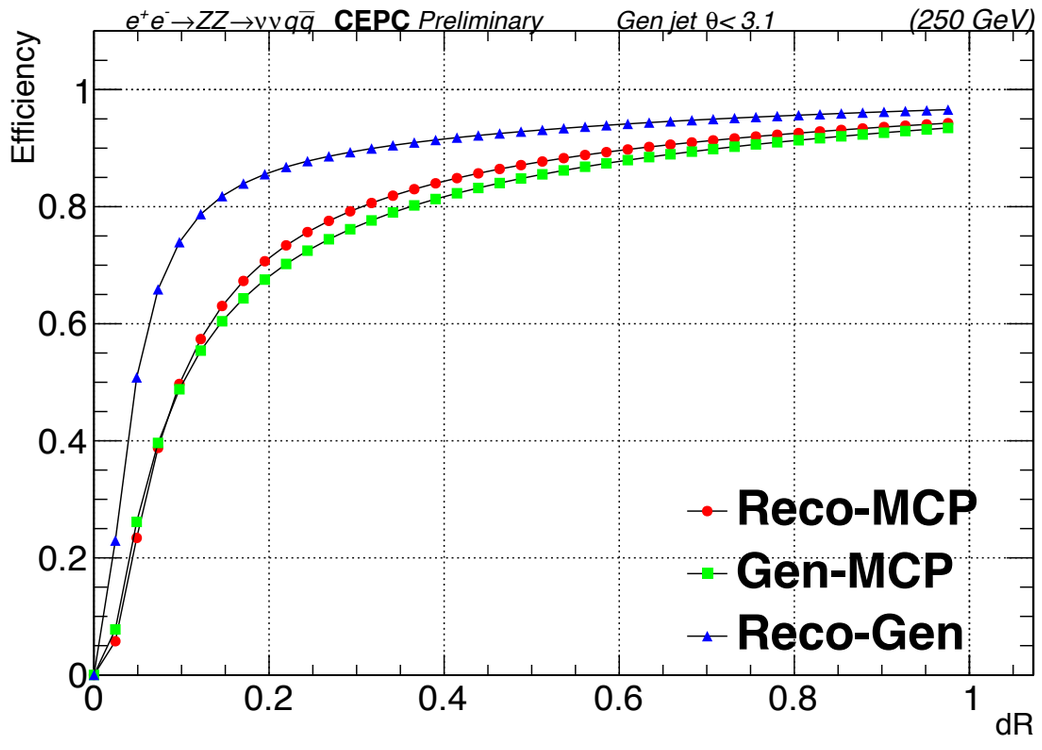




Event Selection

Items	JER/JES(Reco-Gen)	JER/JES(Gen-MCP)
Gen jet theta < 3.1	✓	✓
ΔR(Reco-MCP) < 0.1	✓	✗





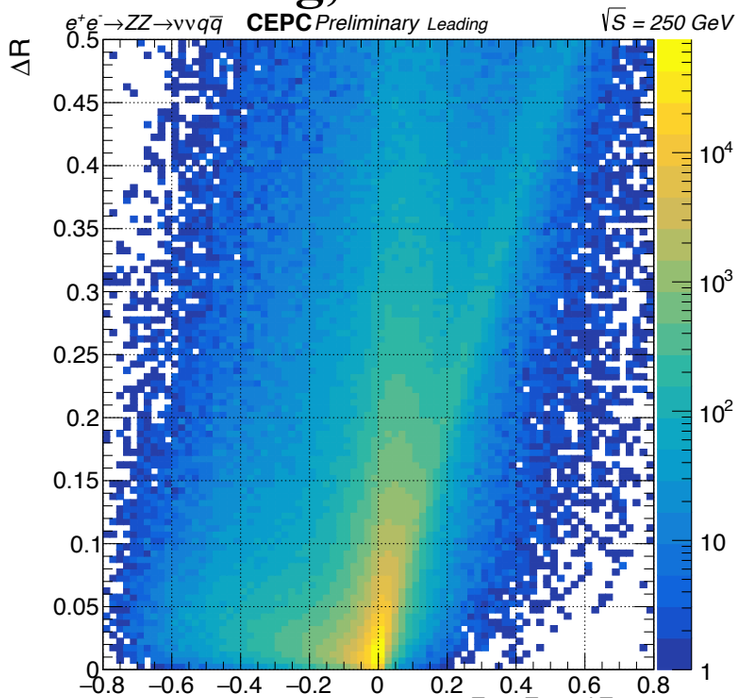
Efficiency=

$$\frac{\text{\# of leftover event}}{\text{\# of total event}}$$

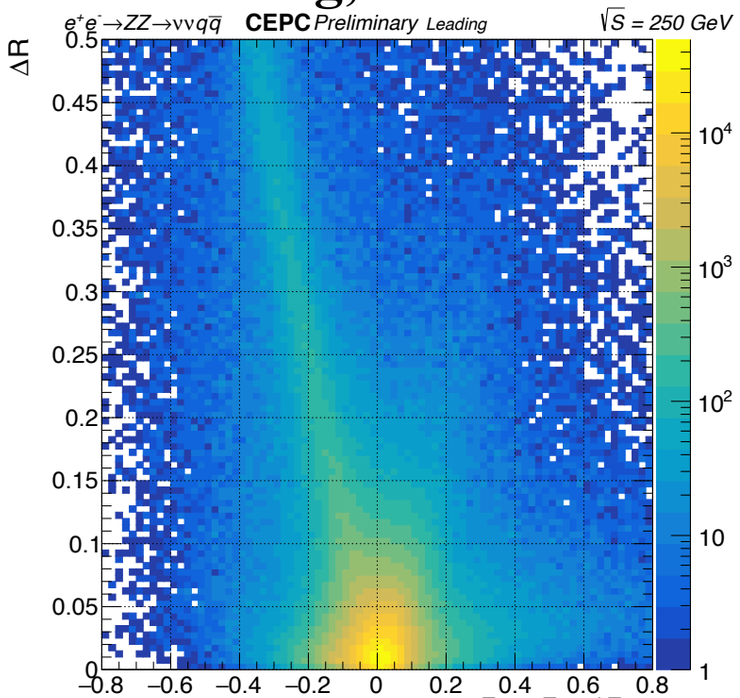
$$\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$$

The Reason for ΔR Cut

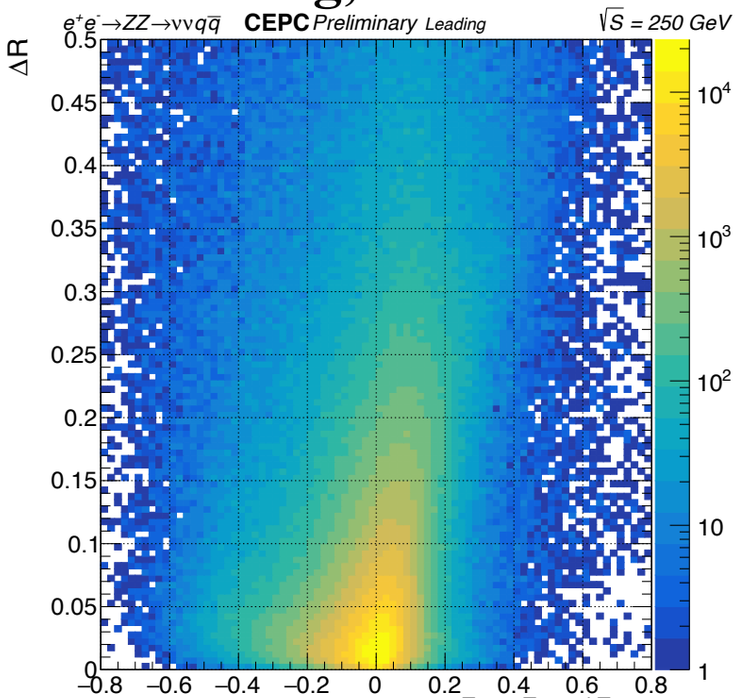
Leading, Gen-MCP



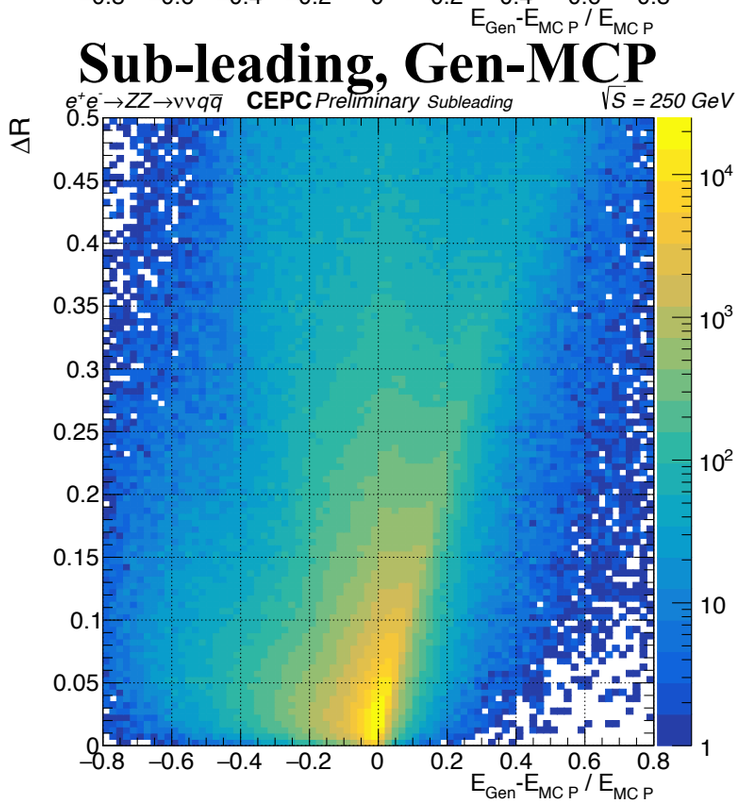
Leading, Reco-Gen



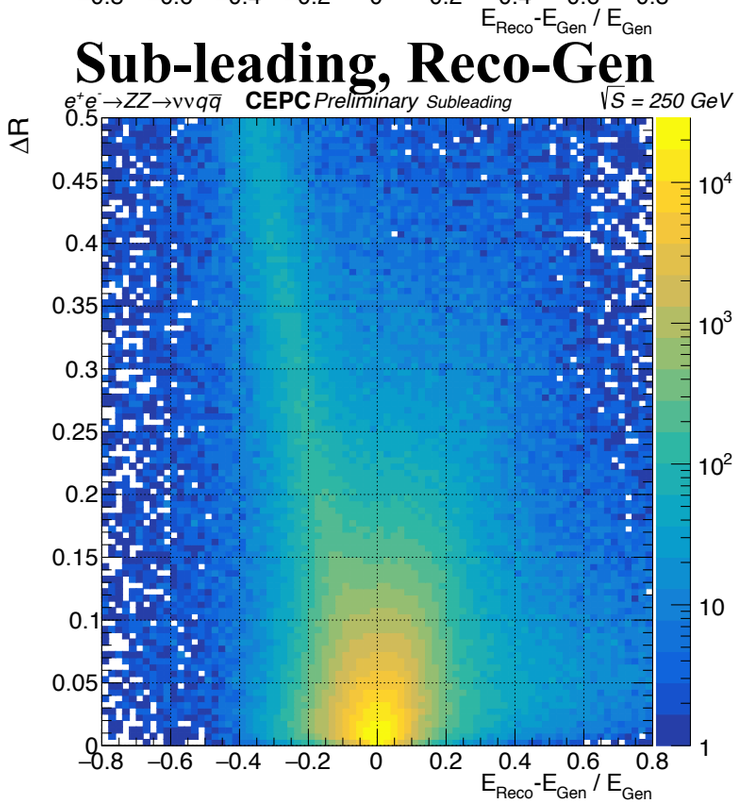
Leading, Reco-MCP



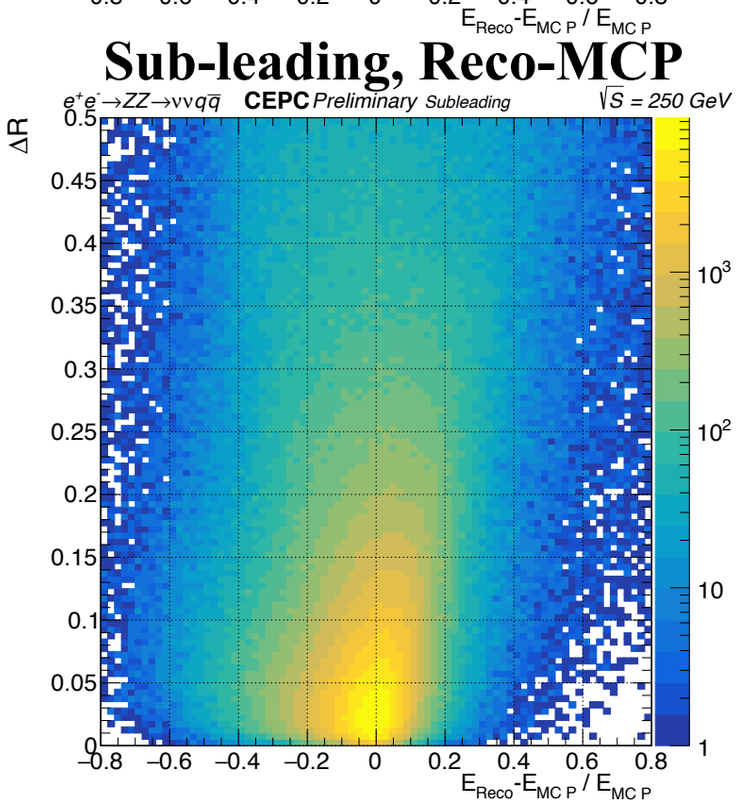
Sub-leading, Gen-MCP



Sub-leading, Reco-Gen



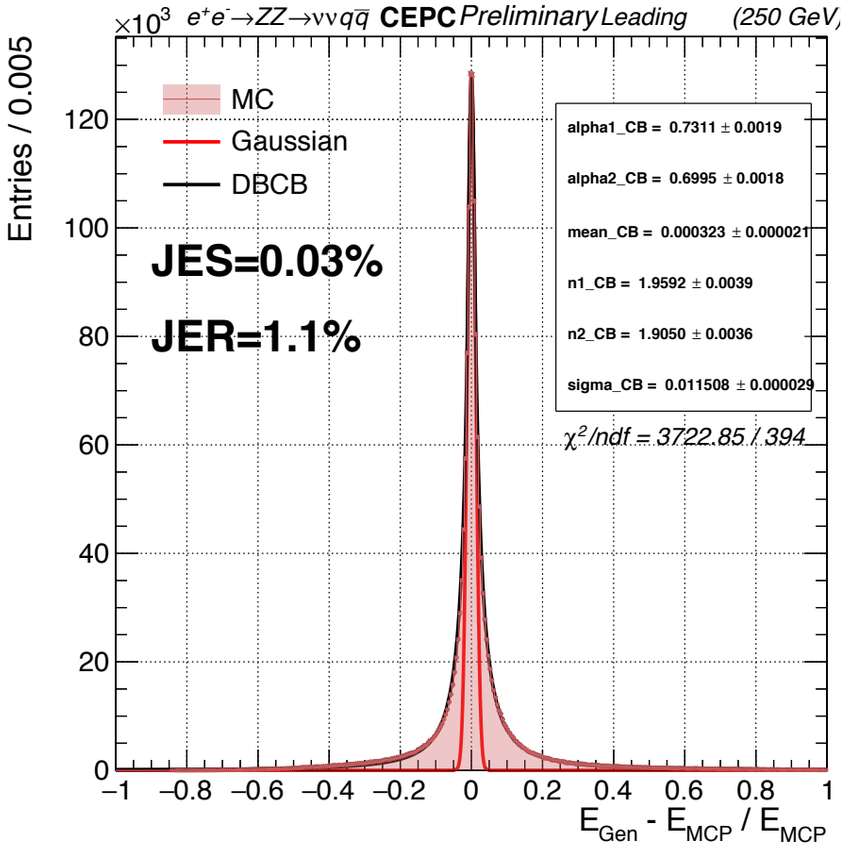
Sub-leading, Reco-MCP



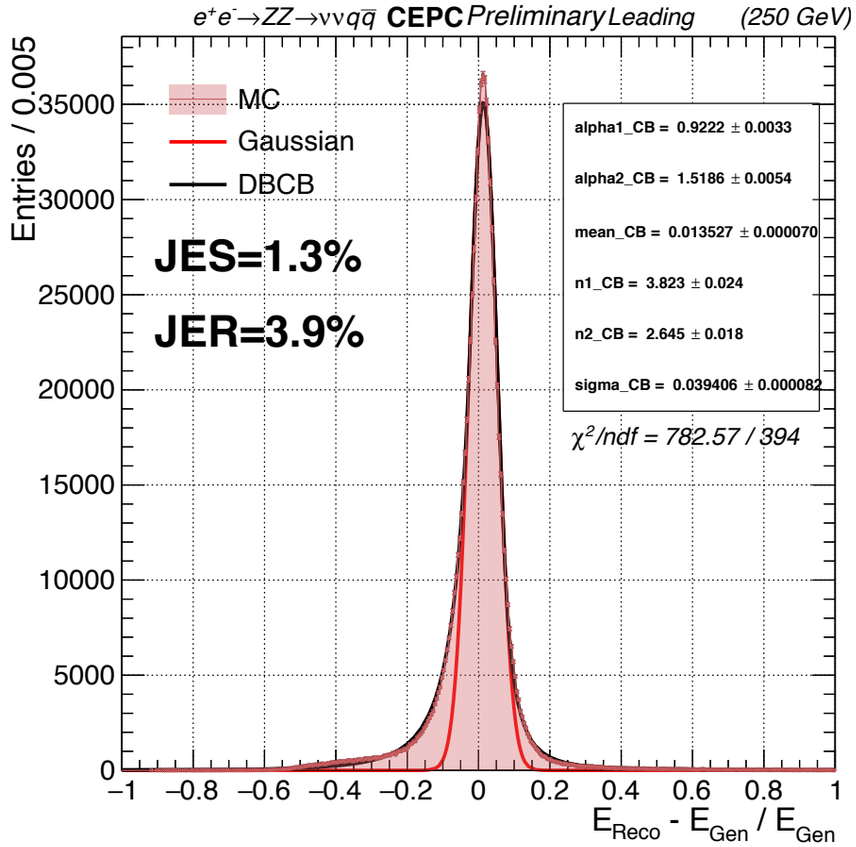
The jet clustering bring a significant uncertainty.

Leading JER & JES

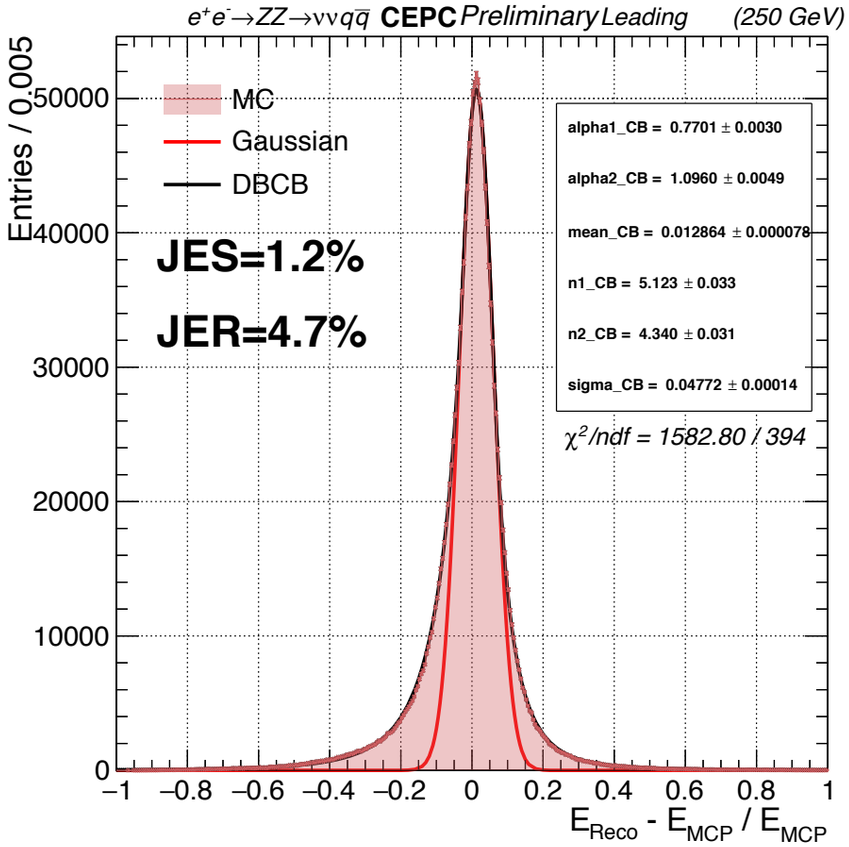
Gen-MCP



Reco-Gen

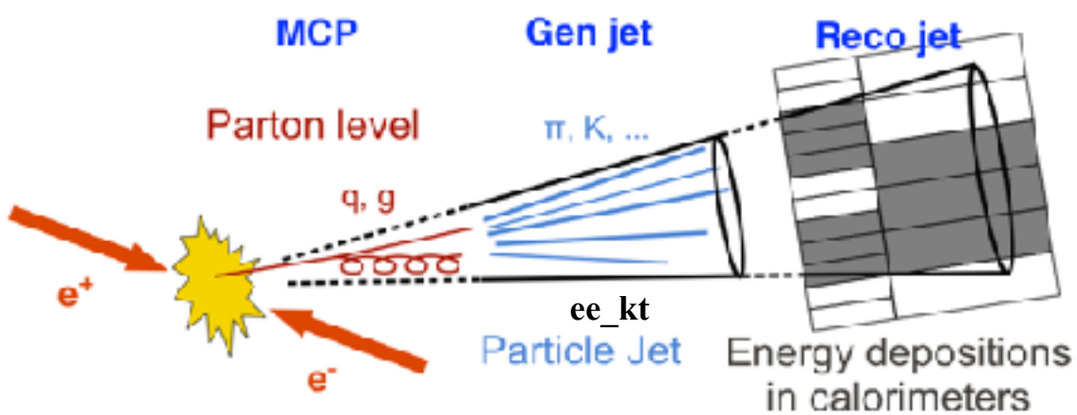


Reco-MCP



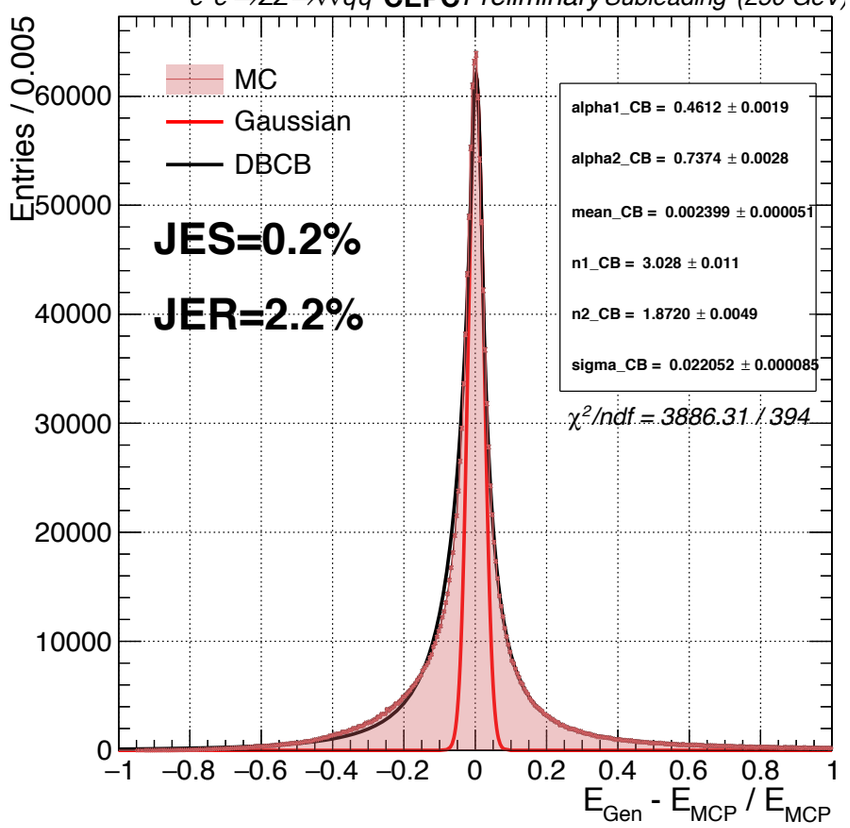
MCP → **Gen jet** → **Reco jet**

- **JER/JES between reco jet and MCP would combine the effects of two previous stages.**

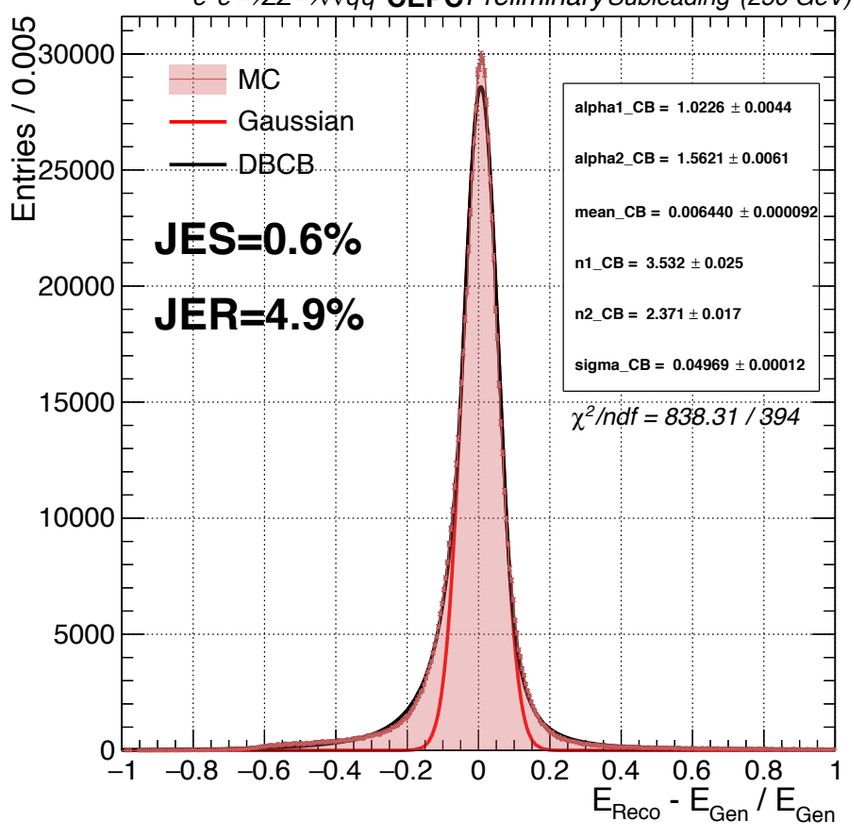


Sub-leading JER & JES

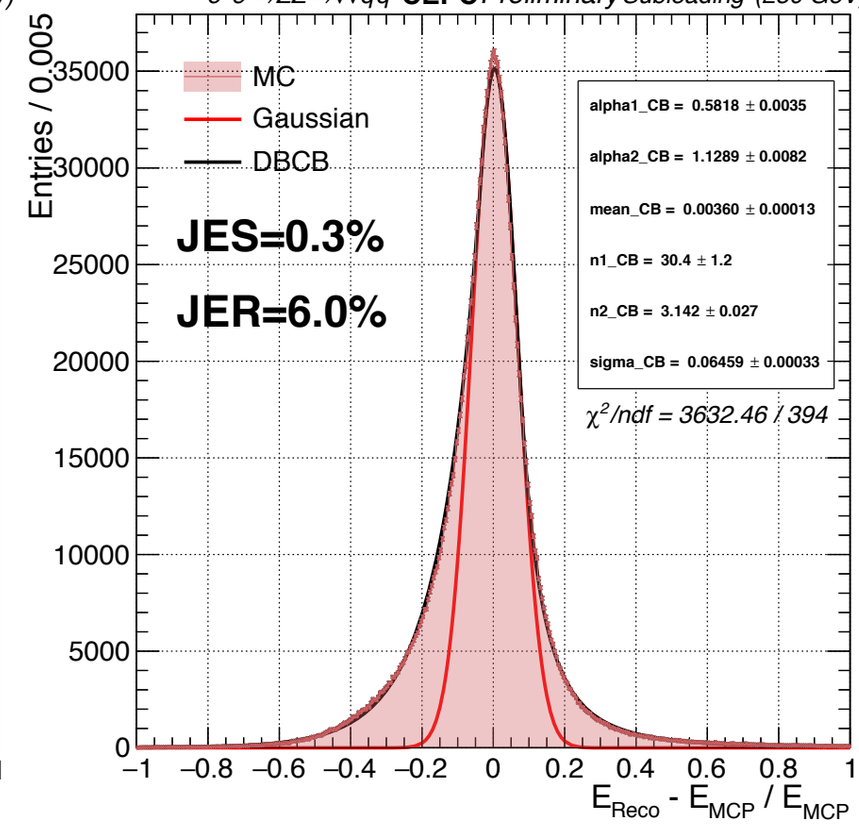
Gen-MCP



Reco-Gen



Reco-MCP



- **JER/JES between reco jet and MCP would combine the effects of two previous stages.**