Can we separate the ZZ and WW events with 4-jets full hadronic final state ?

Performance study of the 4-jet final state event reconstruction at the CEPC Baseline

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Outline

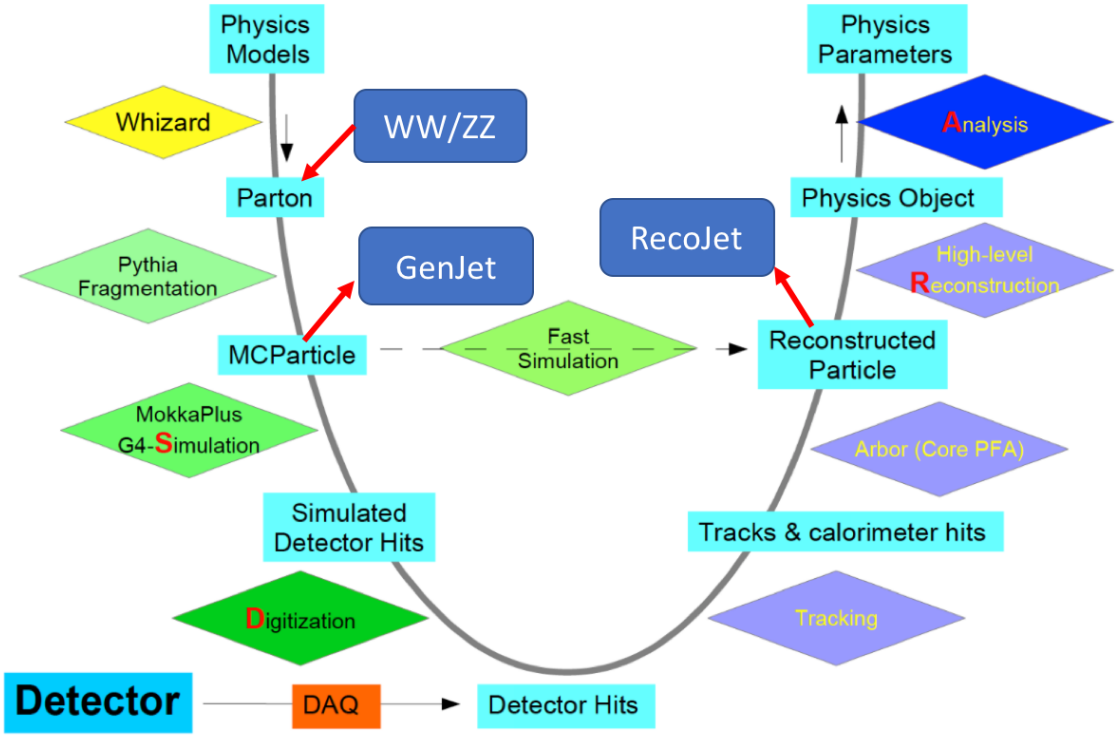
- Introduction
- Sample
- Separation performance
- Catalogue
- Impact factor
- Conclusion

Introduction

At CEPC : Jet is very important

- $W \rightarrow hadrons$: 67.41%
- $Z \rightarrow hadrons$: 69.91%
- $Higgs \rightarrow hadrons$: 69.1%
- EW(Triplet Gauge Boson Coupling), and Higgs measurements.

Sample



ee_genkt_algorithm:
R = 2, P = 1

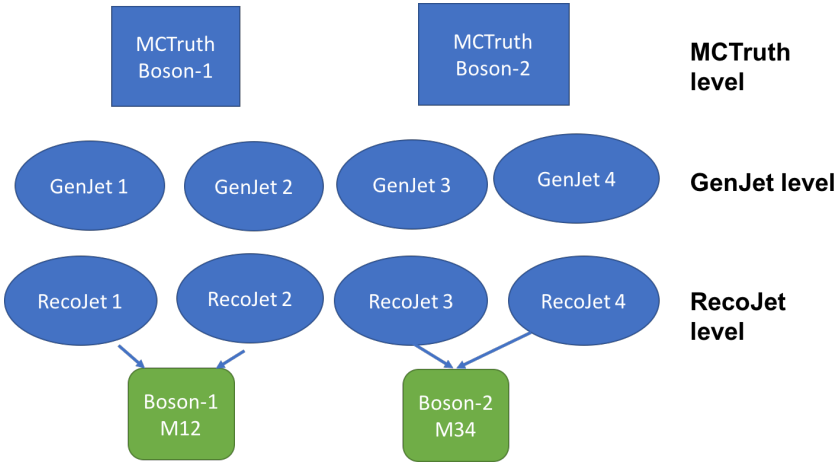
Inclusive sample :

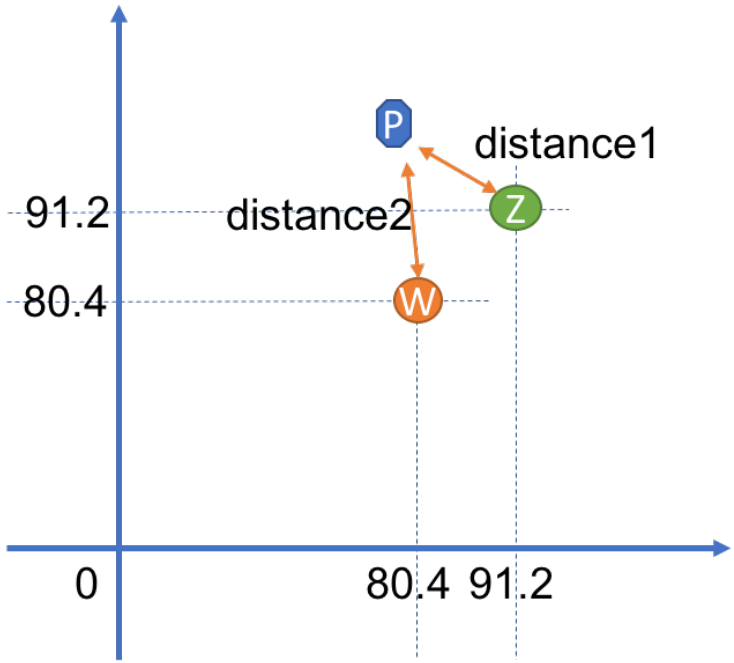
- 38k $WW \rightarrow$ 4-quarks
- 38k $ZZ \rightarrow$ 4-quarks

Light sample :

- 40k $WW \rightarrow$ uusd
- 40k$ZZ \rightarrow$uuuu

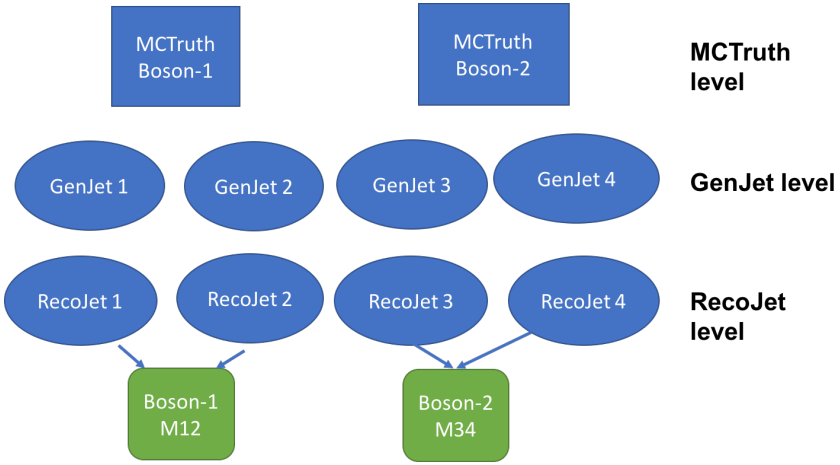
Pairing 4 jets

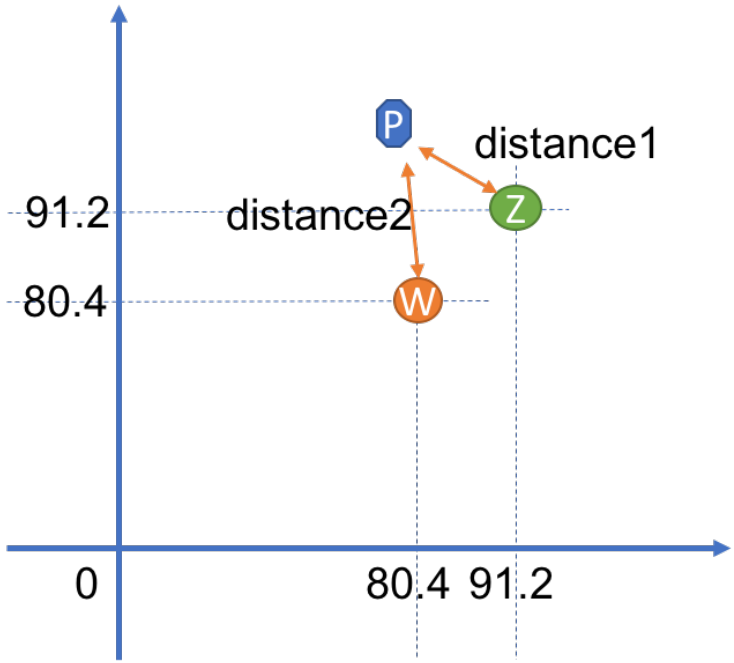




M12, M34, M13, M24, M14 and M23

Pairing 4 jets



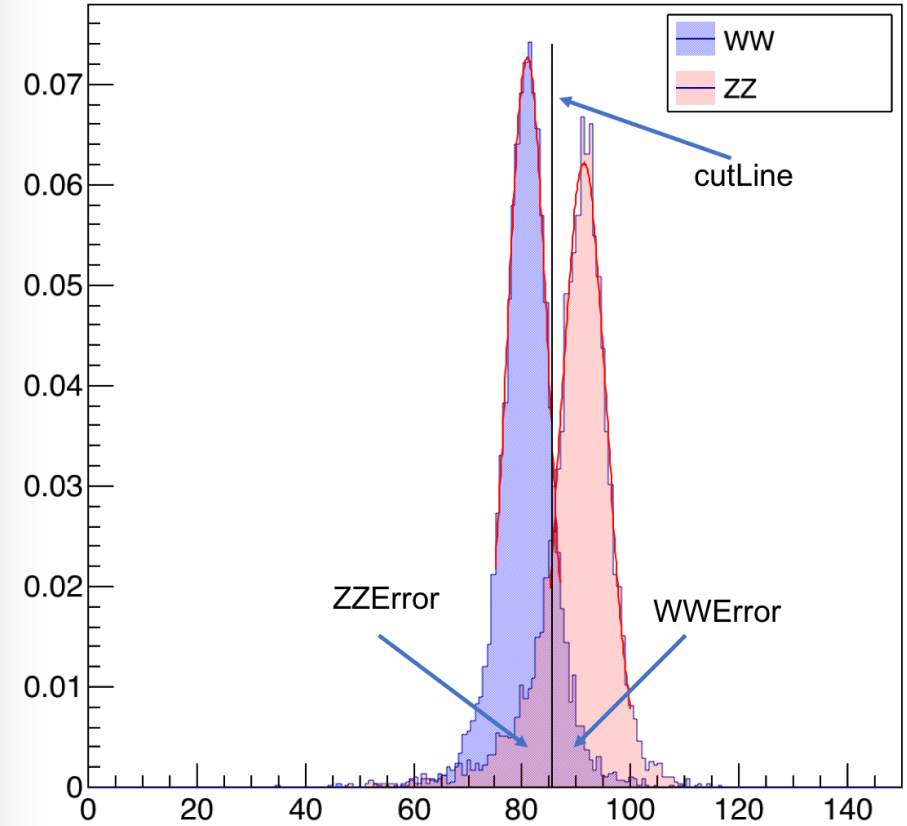


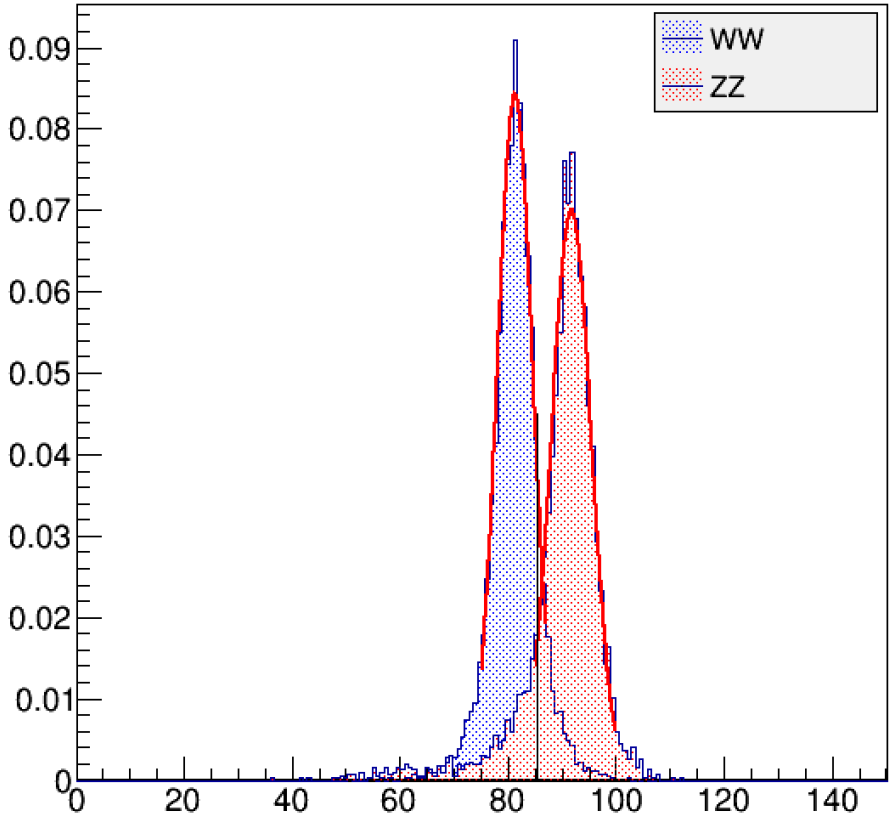
M12, M34, M13, M24, M14 and M23

$$\begin{cases} distance\_Z1 = (M12 - mass_Z)^2 + (M34 - mass_Z)^2 \\ distance\_Z2 = (M13 - mass_Z)^2 + (M24 - mass_Z)^2 \\ distance\_Z3 = (M14 - mass_Z)^2 + (M23 - mass_Z)^2 \\ \ldots \end{cases}$$

Separation performance

$0.5\times(M12 + M34)$

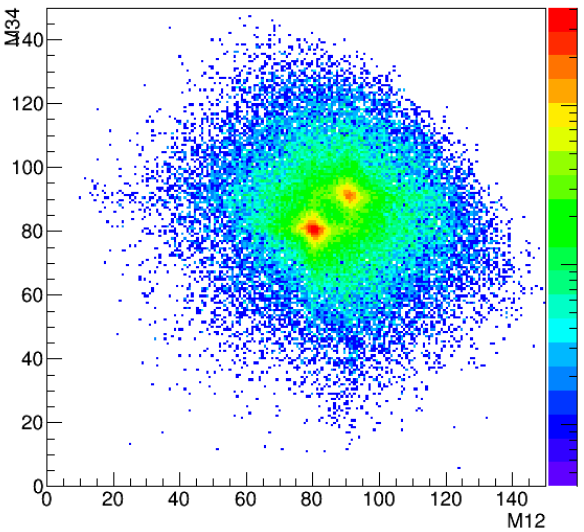


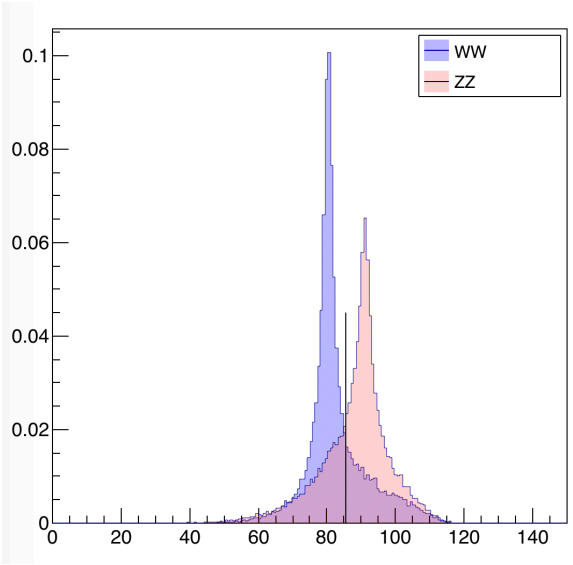


overlaping ratio :
ZZError + WWError

peaking distance :
$$\frac{\Delta M}{(\sigma_1+\sigma_2)\times 0.5}$$

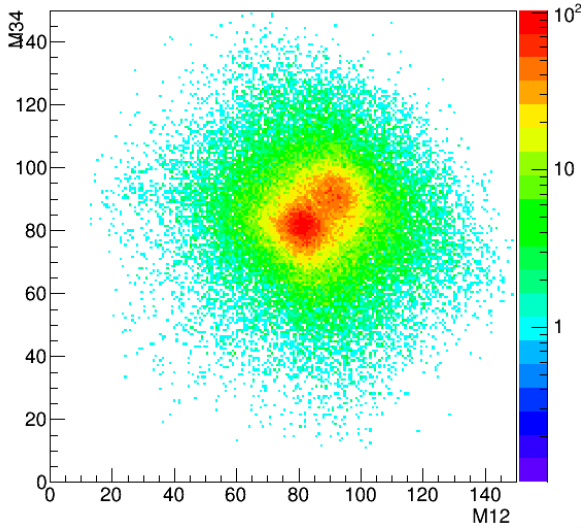
Separation performance

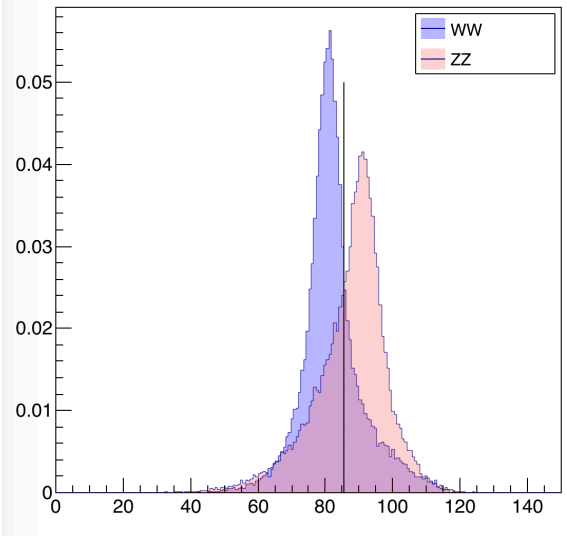




ee_genkt_algorithm :
R = 2, P = 1

GenJet
overlaping ratio :
57.24%

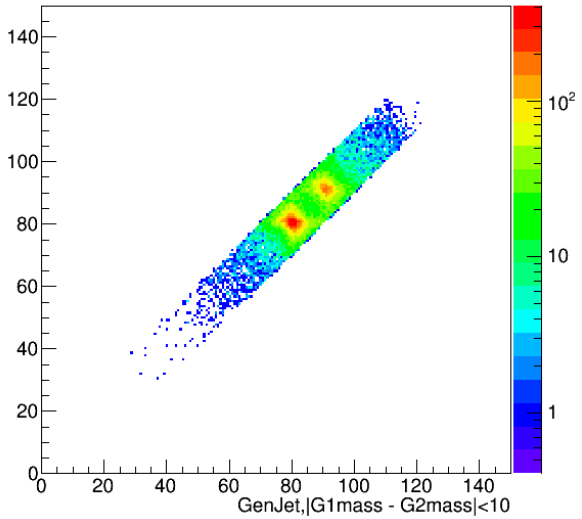


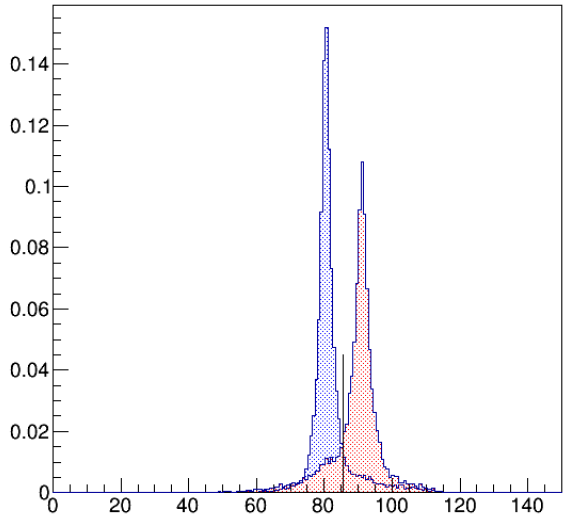


RecoJet
overlaping ratio :
62.71%

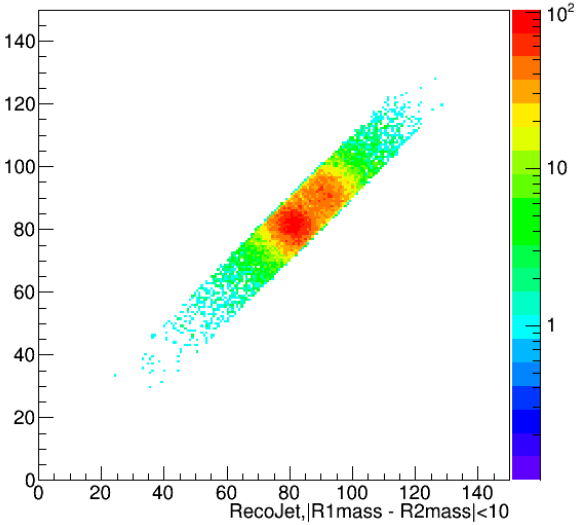
Separation performance

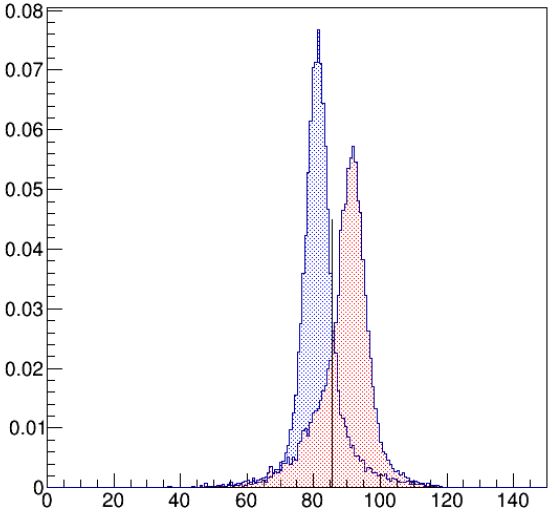
cut : $|M12 - M34| < 10$





GenJet
overlaping ratio :
32.37%
WW selection ratio : 59.07%
ZZ selection ratio : 47.10%

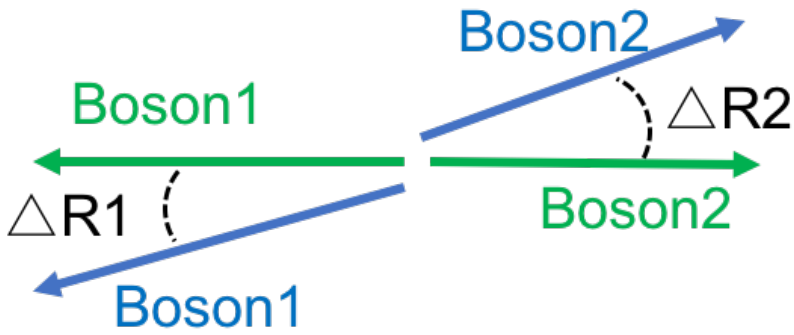




RecoJet
overlaping ratio :
45.48%
WW selection ratio : 54.01%
ZZ selection ratio : 43.8%

ΔR

- MCTruth level ($Boson_{tru}$)
- GenJet level ($Boson_{gen}$)
- RecoJet level ($Boson_{reco}$)

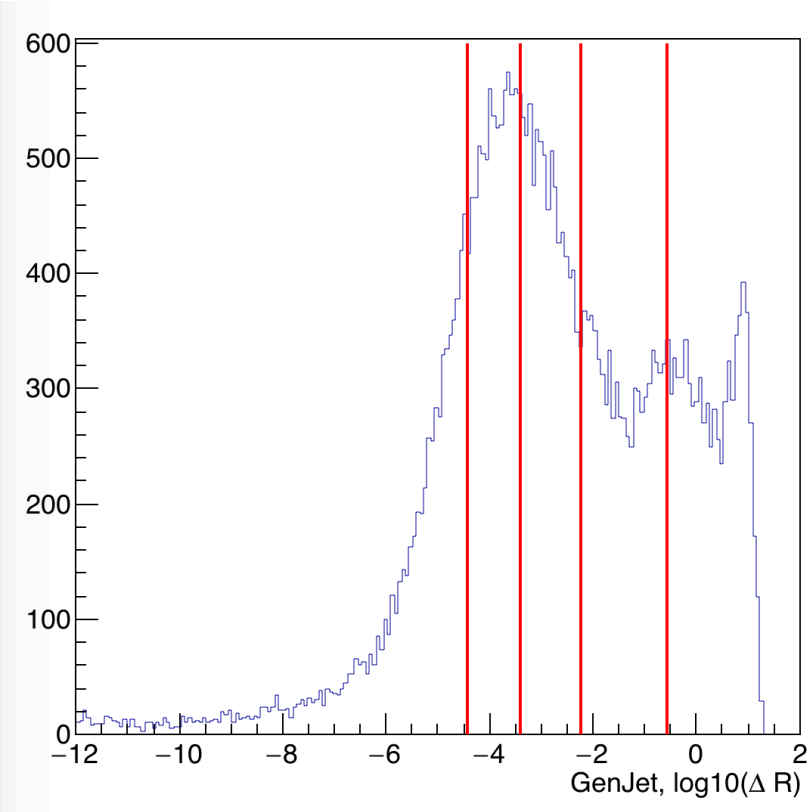


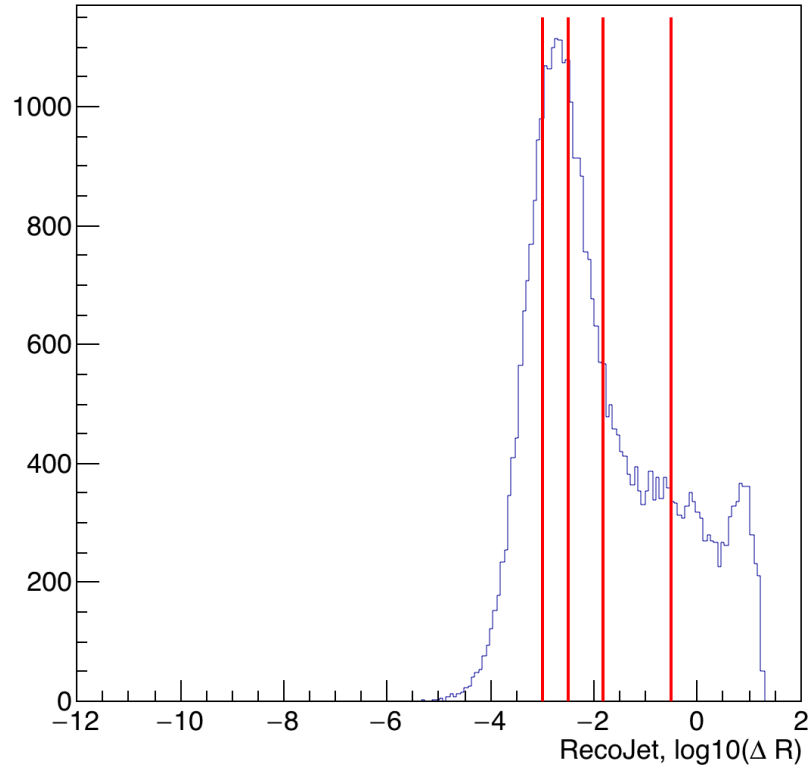
$$\Delta R = \Delta R_1 \times \Delta R_2$$

$$\Delta R_1 = \sqrt{(\theta_{boson1_{tru}} - \theta_{boson1_{reco/gen}})^2 + (\phi_{boson1_{tru}} - \phi_{boson1_{reco/gen}})^2}$$

$$\Delta R_2 = \sqrt{(\theta_{boson2_{tru}} - \theta_{boson2_{reco/gen}})^2 + (\phi_{boson2_{tru}} - \phi_{boson2_{reco/gen}})^2}$$

ΔR

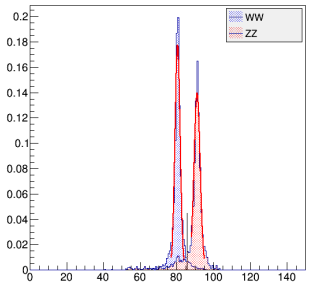


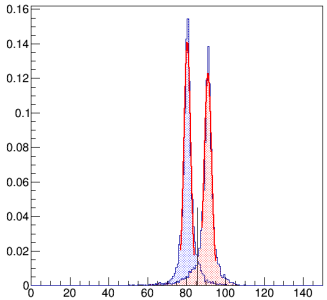
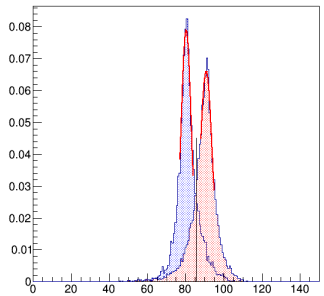
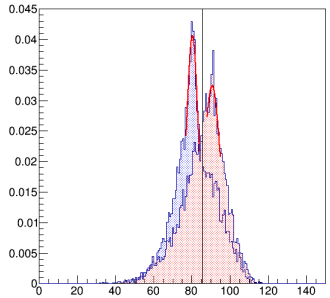
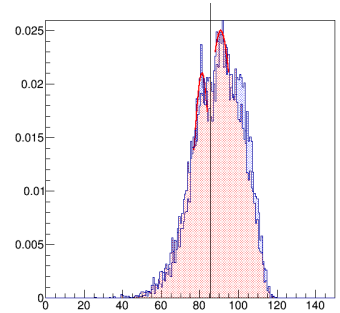


Characterize jet clustering performance into five sub-categories according to ΔR. Each category contains 20% events.

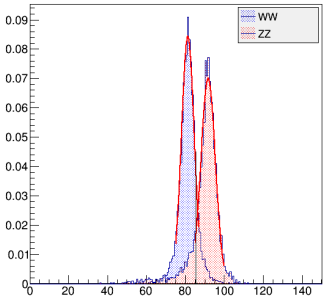
Category

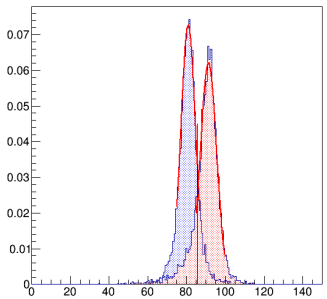
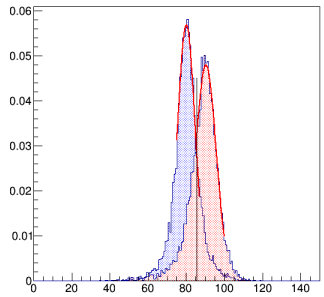
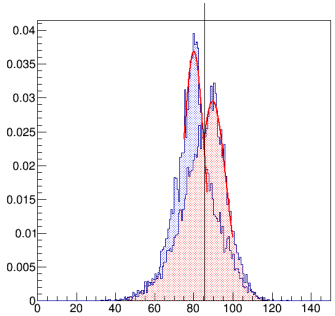
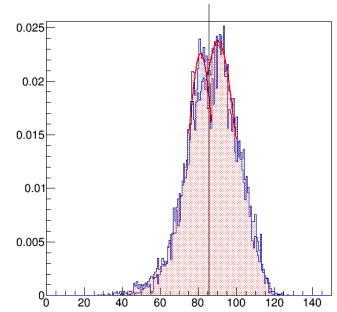
At GenJet level :



At RecoJet level :



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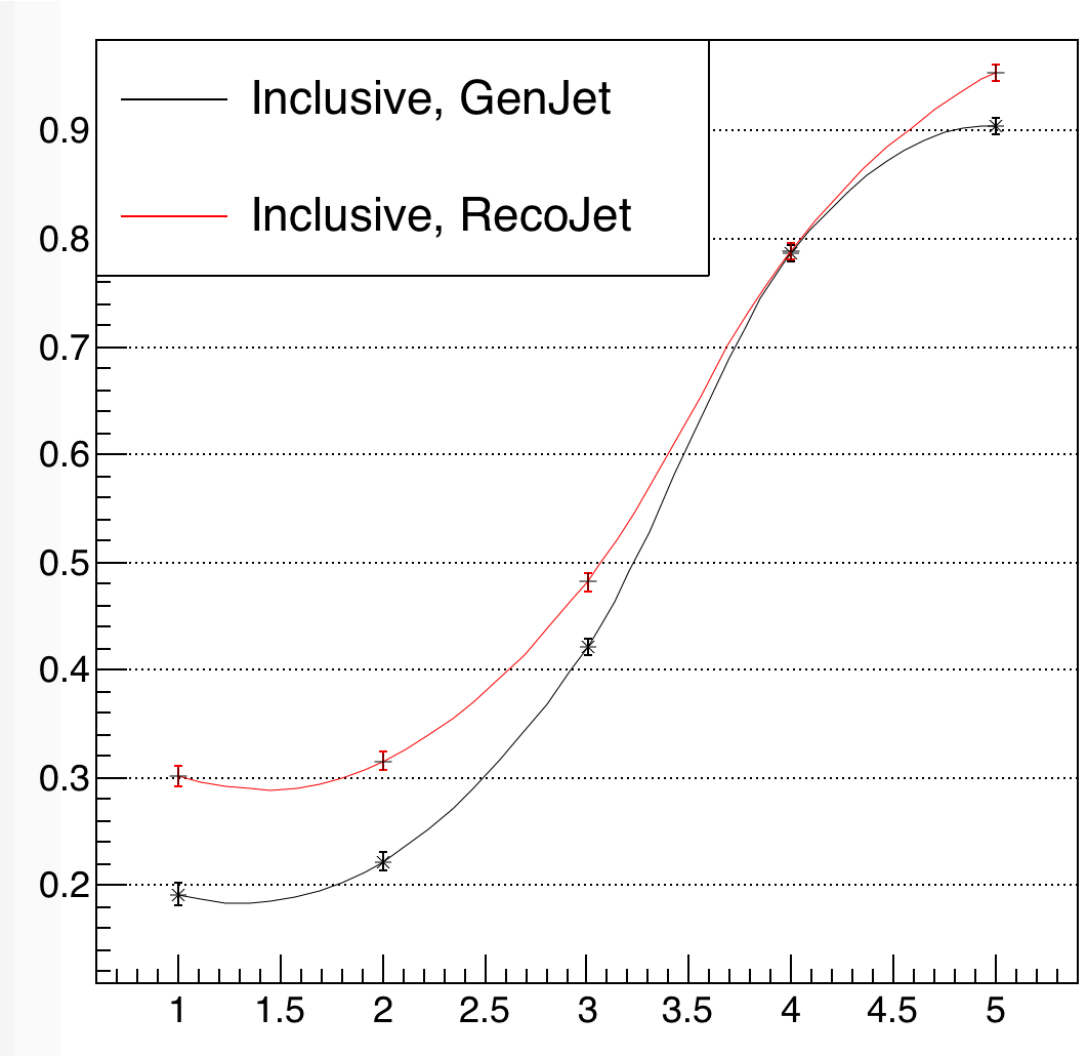
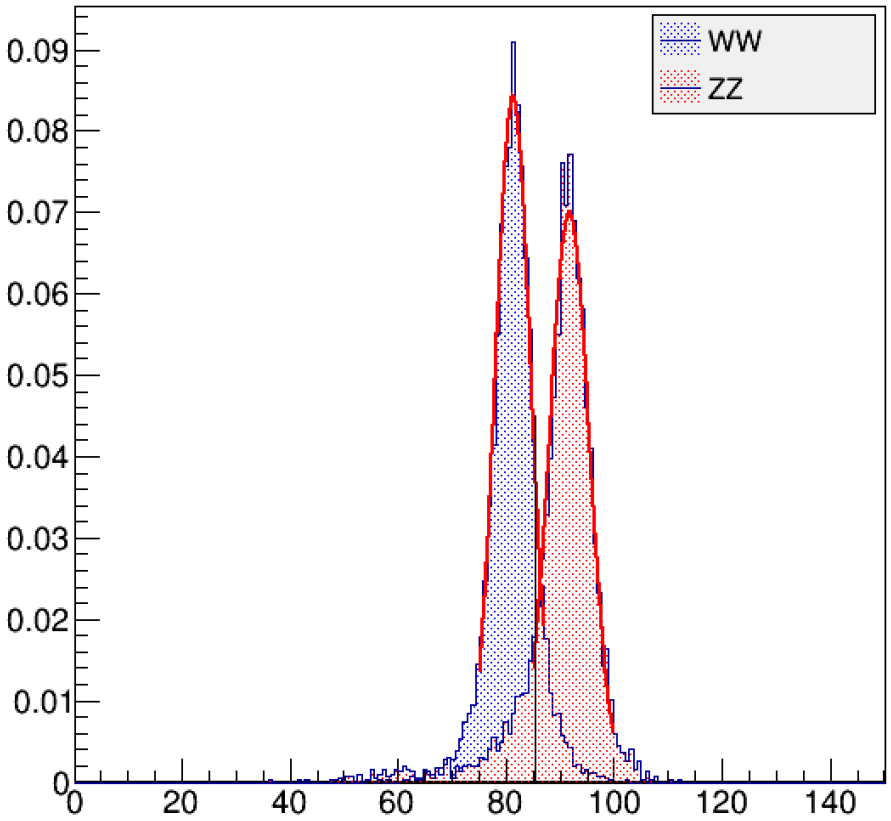
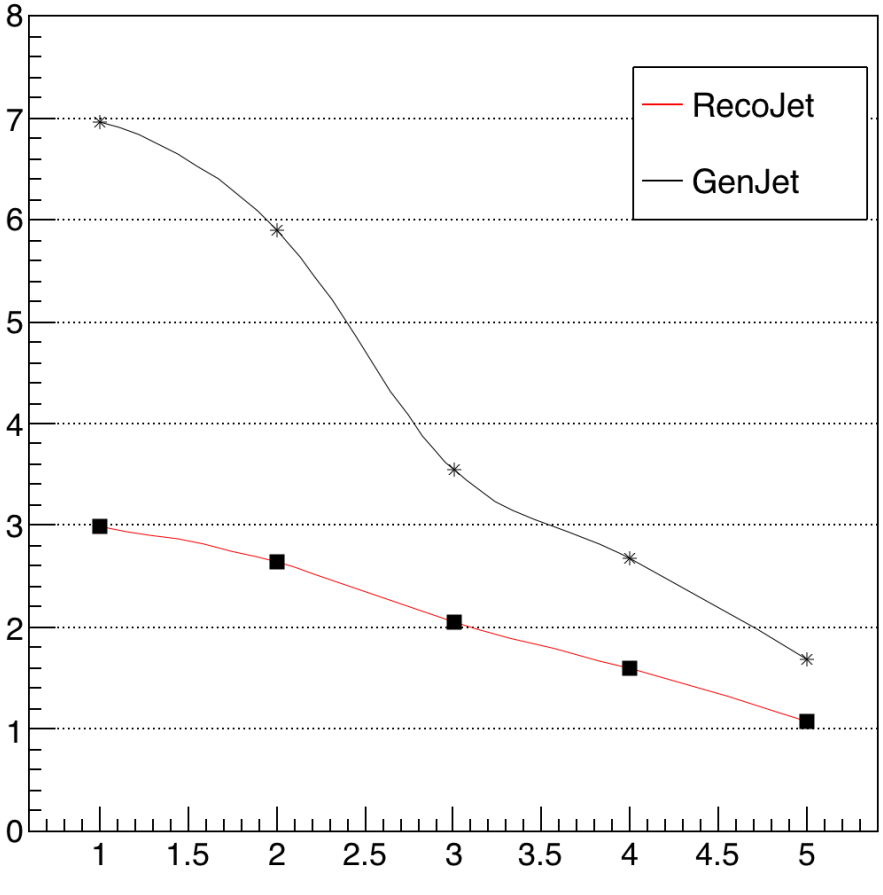


The overlaping ratio variates with the jet clustering performance.

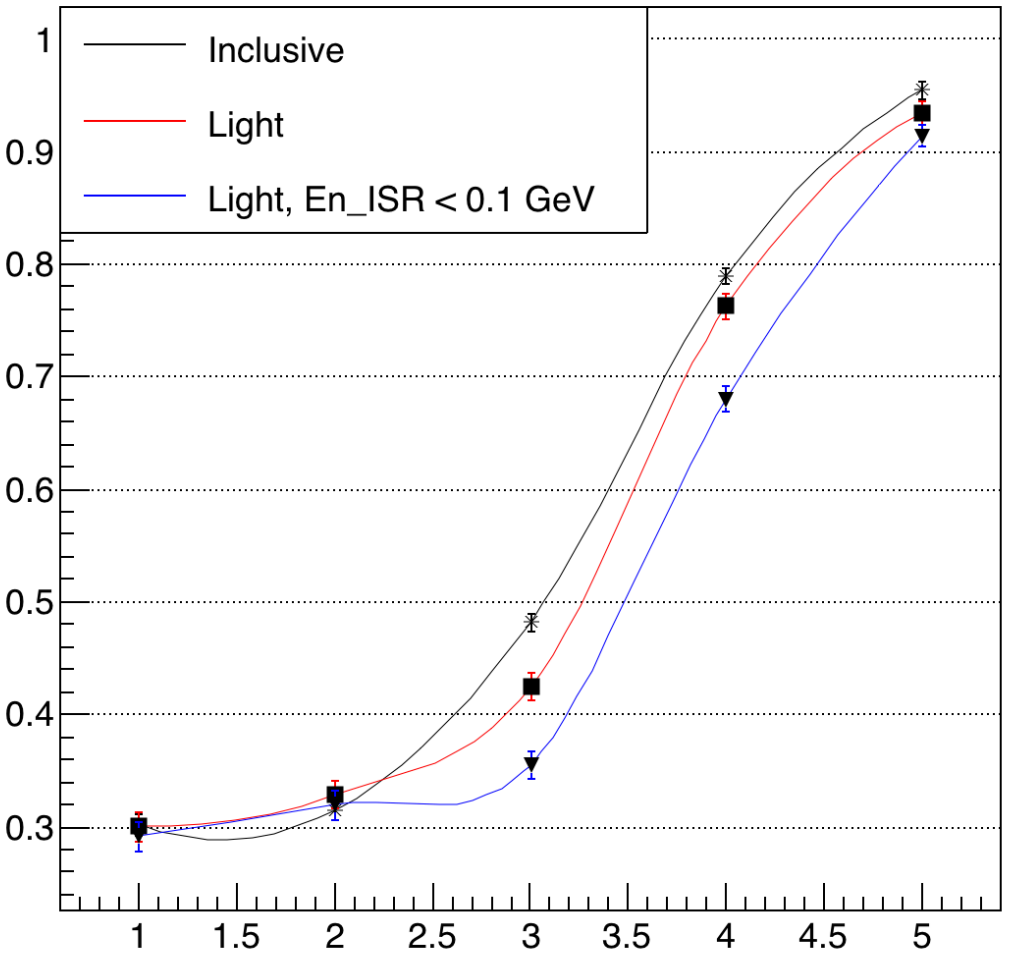
Category

$$\text{peaking distance} = \frac{\Delta M}{0.5\times(\sigma_1+\sigma_2)}$$





Impact factor



- neutrinos in heavy-flavor quarks decay
- initial state radiation (ISR)

P = ? R = ? for ee_genkt_algorithm when WW/ZZ→4 quarks

overlap ratio

	P = -1	P = 0	P = 1	P = 2	P = 3
$R = 2.5$	88.60%	84.57%	62.71%	65.04%	68.28%
$R = 2$	89.03%	84.57%	62.71%	65.04%	68.28%
$R = 1$	100.00%	96.44%	66.85%	69.24%	73.67%

Answer : R = 2, P = 1

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(vi) Neutrinos in heavy flavor quarks decay and initial state radiation have impact on separation performance.

Thanks !

Back Up

fastjet

- jet: a collimated spray of stable particles arising from the fragmentation and hadronisation of a parton after a collision
- fastjet: a tool used to do jet clustering, in other words, find the parton as accurate as possible
- two main classes of jet clustering algorithms in use: cone algorithm and sequential clustering algorithms
  - cone algorithm assume that particles in jets will show up in conical regions and thus they cluster based on $\eta - \phi$ space
  - sequential clustering algorithms assume that particles within jets will have smaller differences in transverse momenta and thus groups particles based on momentum space.

sequential clustering algorithm

$$\text{a similar method} \begin{cases} d_{ij} = min(P_{ti}^a, P_{tj}^a) \times \dfrac{R_{ij}^2}{R} \\ d_{iB} = P_{ti}^2 \end{cases}$$

- a : corresponding to a particular clustering algorithm
- $R_{ij}^2 = (\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2$ is the $(\eta - \phi)$ space distance between the two particles
- R is the radius parameter which determines the final size of the jet.
- $d_{iB} = P_{ti}^a$: the momentum space distance between the beam axis and the detected particle
- a smaller R can reduce the amount of the underlying event and pile-up captured by the jet, preventing the overestimation of the jets mass and energy
- a larger R allows the jet to capture enough of the hadronised particles

at CEPC

- pp collisions: emphasize invariance under boosts along the beam axis since, thus the natural variables are transverse momenta P_t , azimuthal angle ϕ and pseudo-rapidity $\eta = -ln(tan(\theta/2))$
- e^+e^- collision: rotational invariance, thus the natural variables are energies E and polar angles θ, ϕ

So the equation of sequential clustering algorithm:

$$\text{ee\_genkt\_algorithm} \begin{cases} d_{ij} = min(E_i^{2p}, E_j^{2p}) \times \dfrac{1 - cos\theta_{ij}}{1 - cosR} \\ d_{iB} = E_i^{2p} \end{cases}$$