Identification of multi-jet events at the CEPC (240 GeV)

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IHEP

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Discrimination variables (Event-shape):

- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

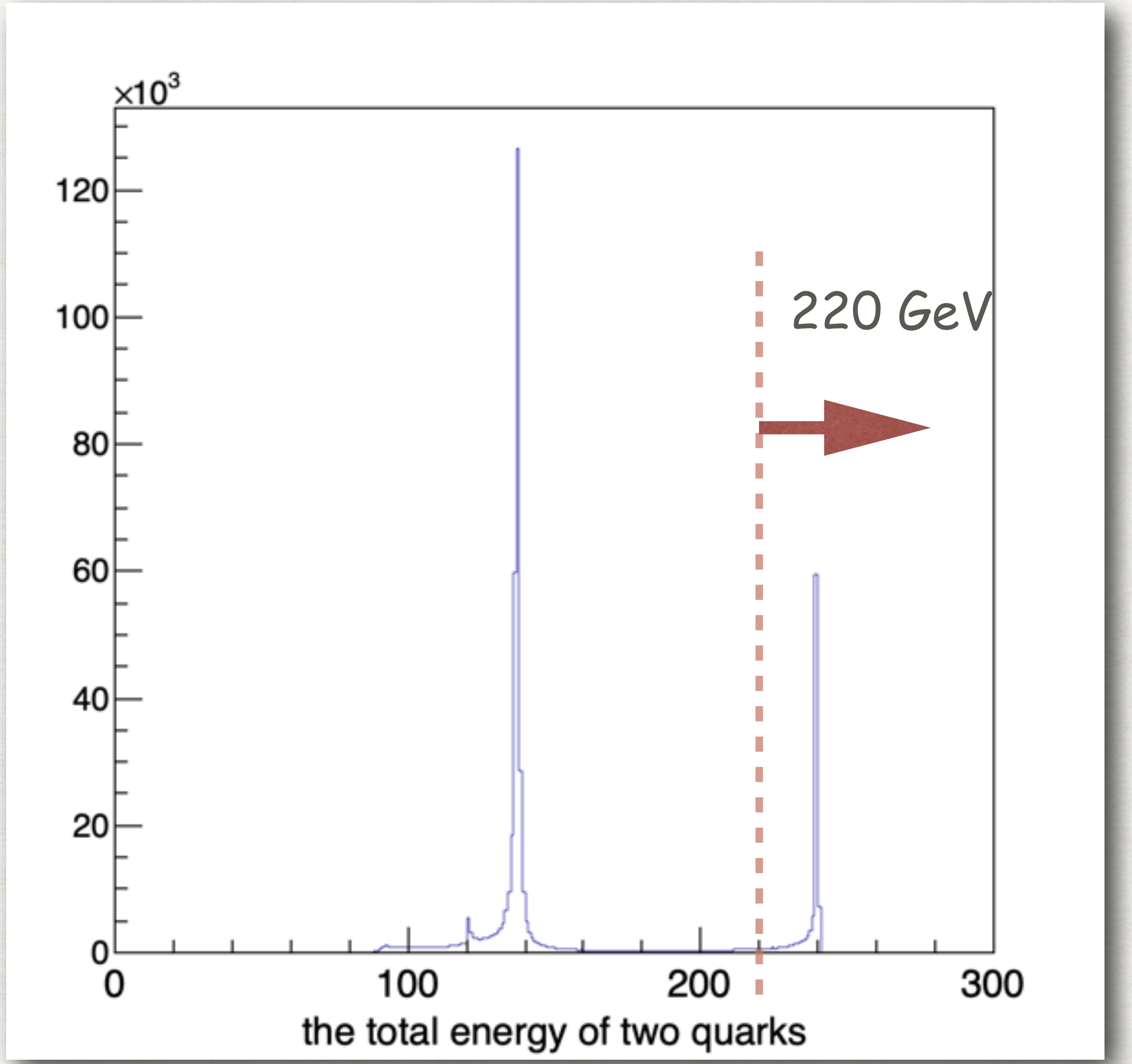
Main result: separation power

Summary

Motivation

final state	process	cross section (fb) / number		analysis
2 jets	$e^+e^- \to q\bar{q}$	54106.86	$3.0*10^8$	α_s measurement (on going)
4 jets	$e^+e^- \to WW \to 4quarks$ $e^+e^- \to ZZ \to 4quarks$ $e^+e^- \to ZH \to 4quarks$	4436.77	$2.5*10^7$	WW/ZZ separation (finished) ZH/WW(ZZ) separation (on going)
6 jets	$e^+e^- \to ZH$ $Z \to q\bar{q}, H \to WW^*(ZZ^*) \to 4quarks$	15.13	$8.5*10^4$	Br(H->WW) + Br(H->ZZ) measurement at full hadronic event

for two jets process : $e^+e^- \rightarrow q\bar{q}$



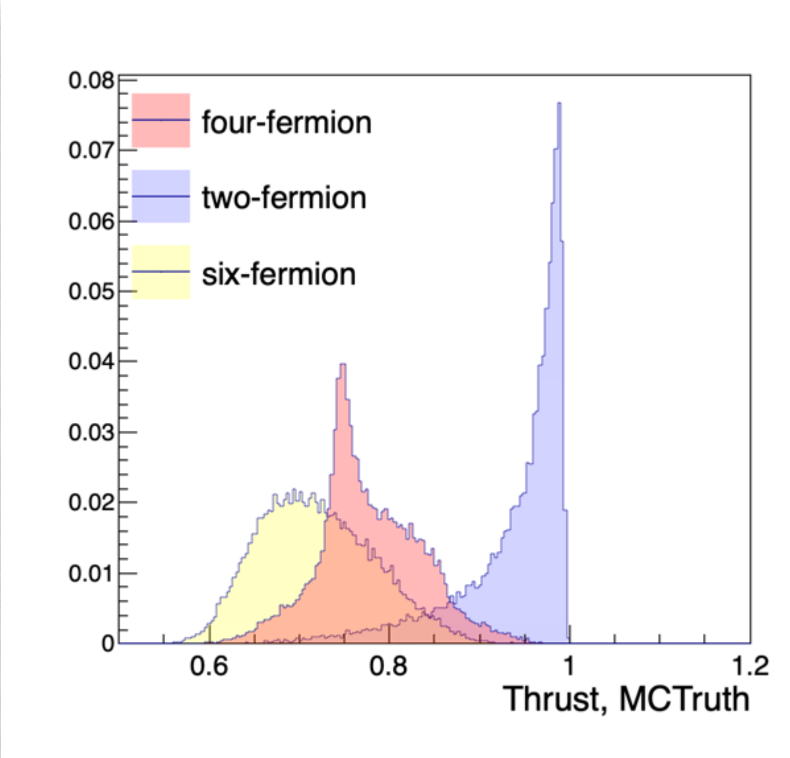
We only consider full hadronic final state events, 22% samples left.

all above analysis based on separating these multi-jet final state

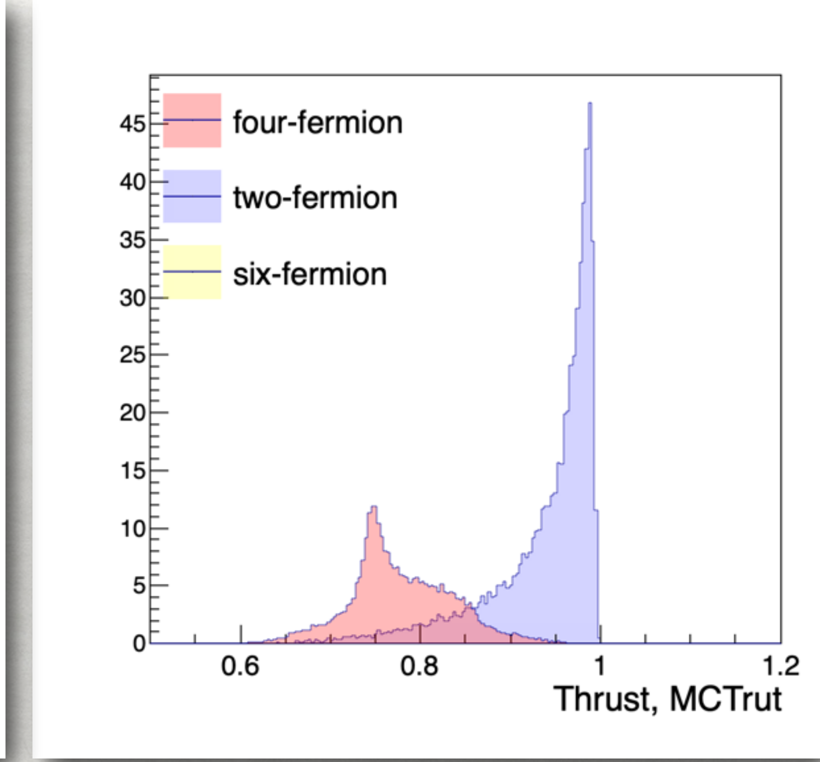
the separation methods : event shape variables

the separation power : maximum efficiency × purity.

for example :



normalized to unit one



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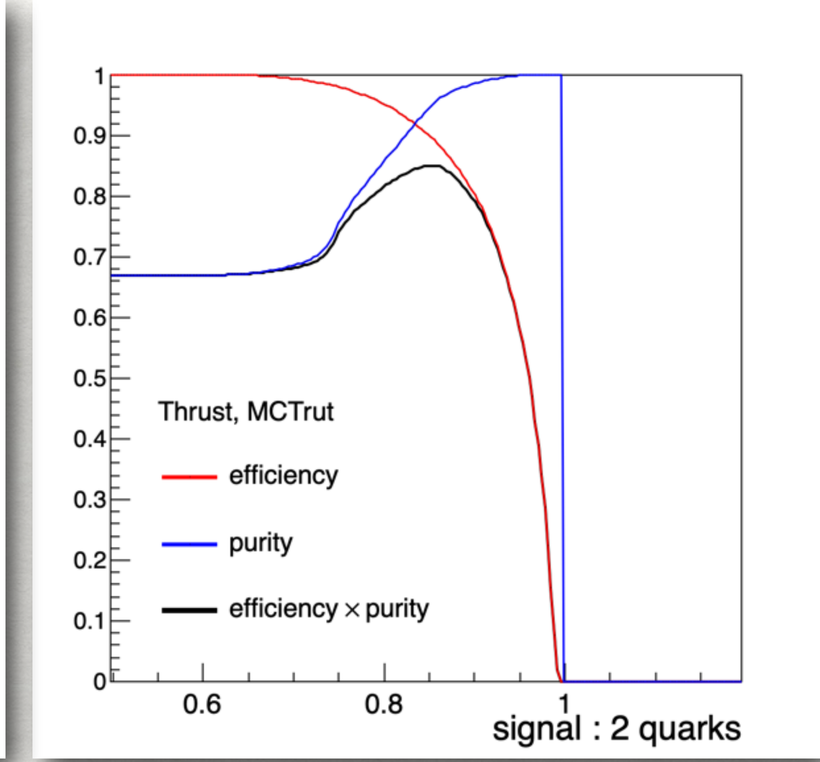


max efficiency × purity

MC: 0.853088

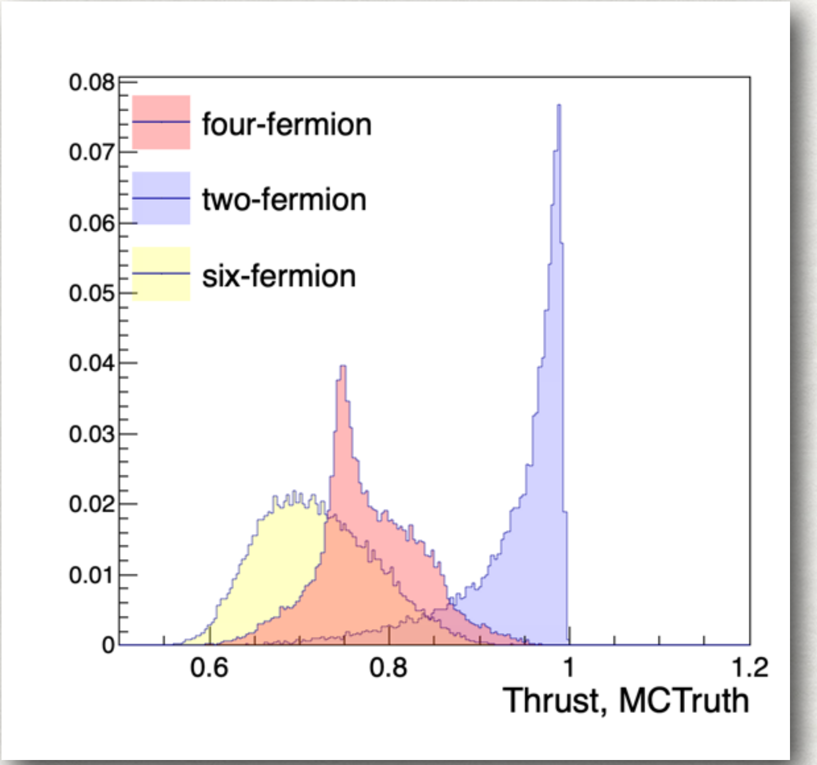
Reco: 0.851713

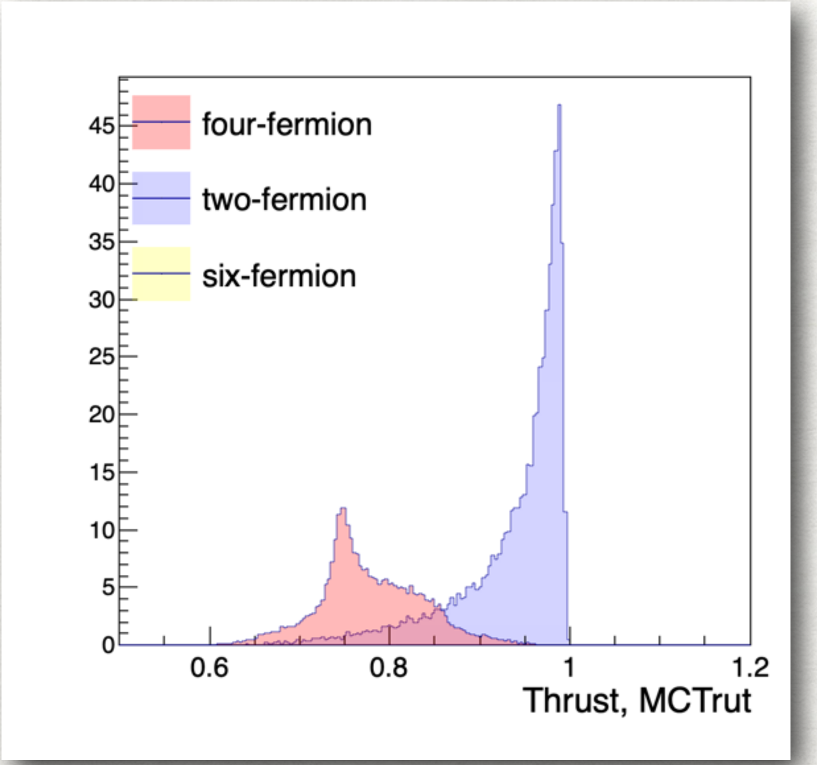
event shape variables:

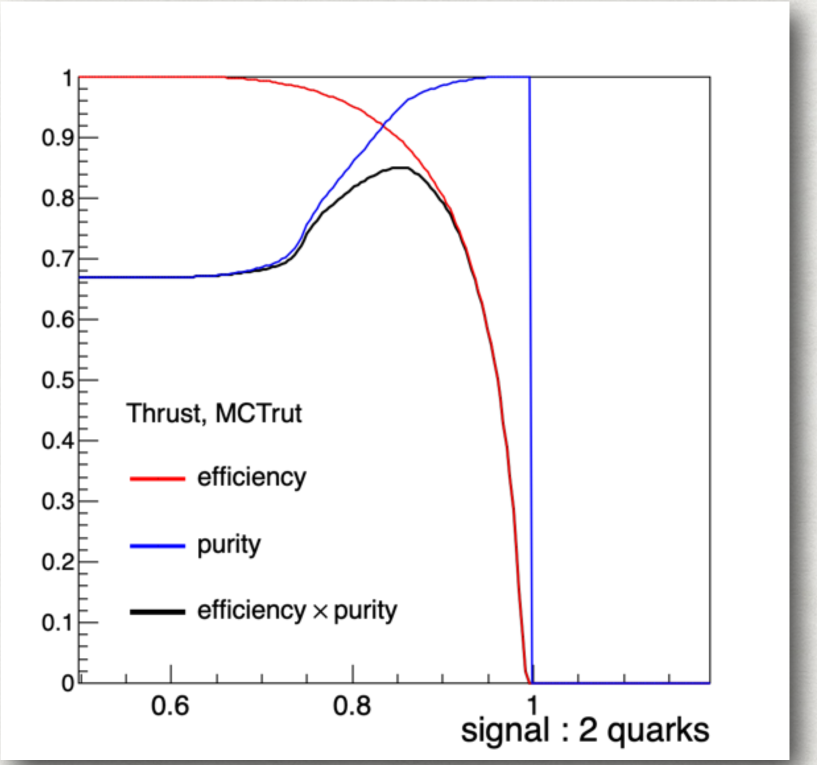
- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

thrust:

$$T = max_{n_T}\left(\frac{1}{\sum_{j=1}^{N_{particles}} |P_j|} \sum_{i=1}^{N_{particles}} |P_i \cdot n_T|\right)$$







normalized to unit one

normalized to X-section

max efficiency × purity

MC: 0.853088

Reco: 0.851713

event shape variables:

- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

hemisphere masses:

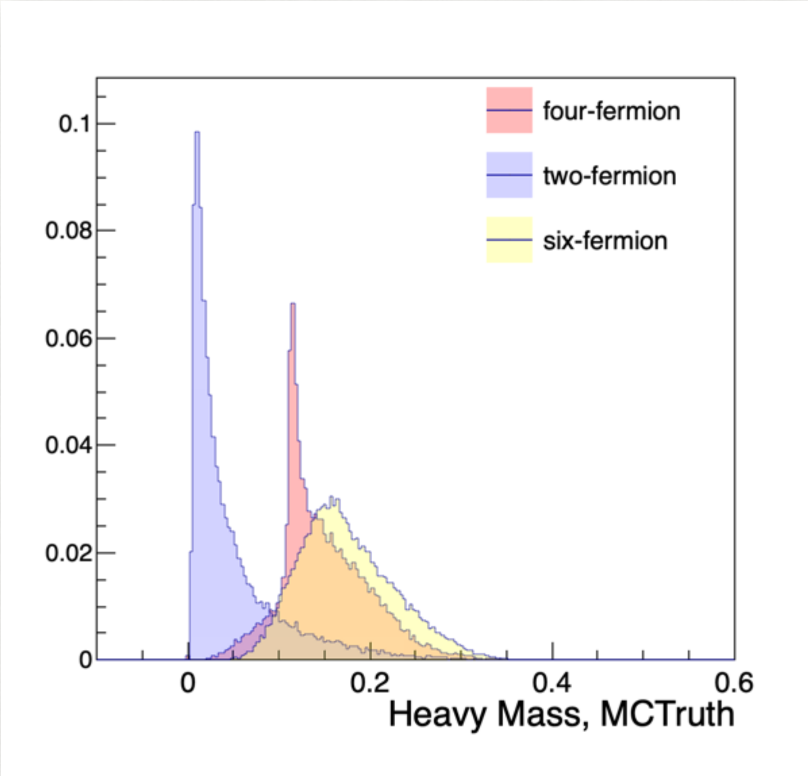
$$M_1^2/s = \frac{1}{E_{vis}^2}\left(\sum_{i=1, P_i\cdot n_T>0}^{N_{particles}} P_i\right)^2$$

$$M_2^2/s = \frac{1}{E_{vis}^2}\left(\sum_{i=1, P_i\cdot n_T<0}^{N_{particles}} P_i\right)^2$$

E_{vis} : total energy of final state particles

P_i : 4-momentum

heavy jet mass : $M_h^2/s = \max(M_1^2/s, M_2^2/s)$



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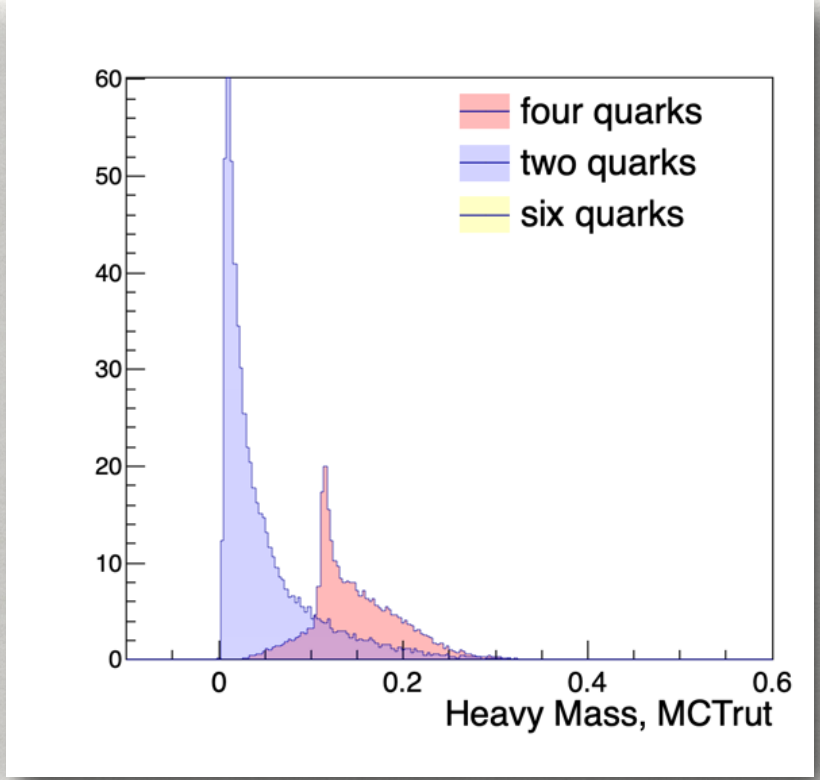
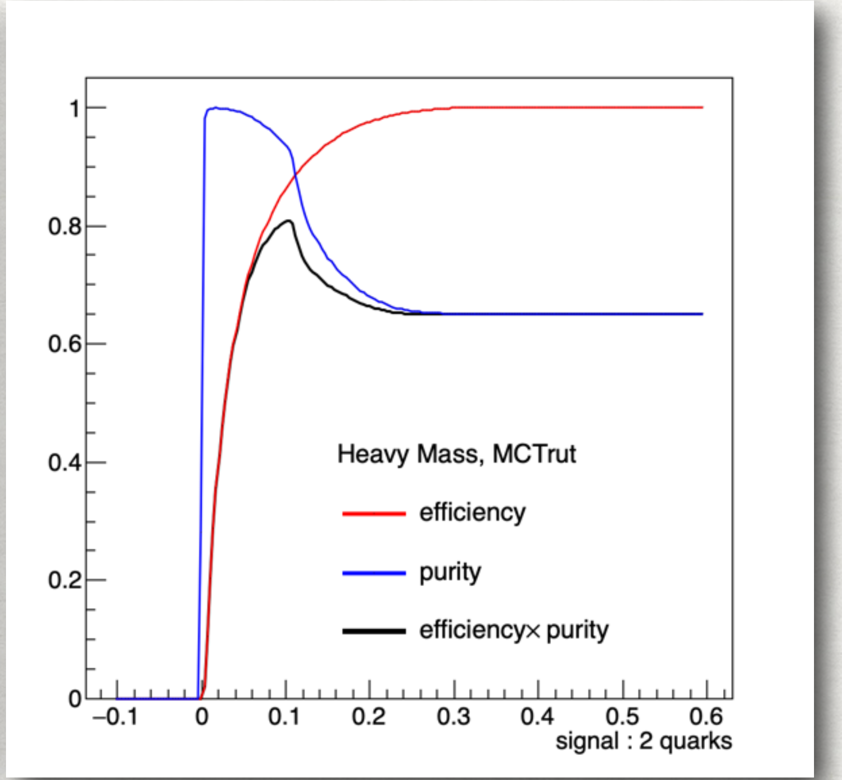


normalized to X-section



max efficiency × purity

MC: 0.815345

Reco: 0.812466

event shape variables:

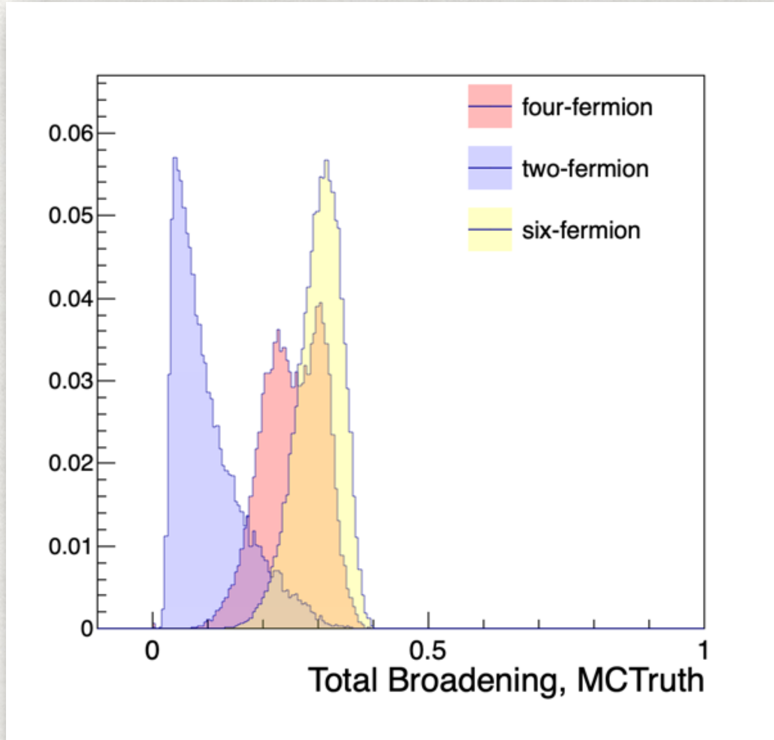
- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

jet broadening:

$$B_1 = \frac{1}{2\sum_{j=1}^{N_{particles}} |P_j|} \sum_{i=1, P_i \cdot n_T > 0}^{N_{particles}} |P_i \times n_T|$$

$$B_2 = \frac{1}{2\sum_{j=1}^{N_{particles}} |P_j|} \sum_{i=1, P_i \cdot n_T < 0}^{N_{particles}} |P_i \times n_T|$$

$$B_T = B_1 + B_2$$



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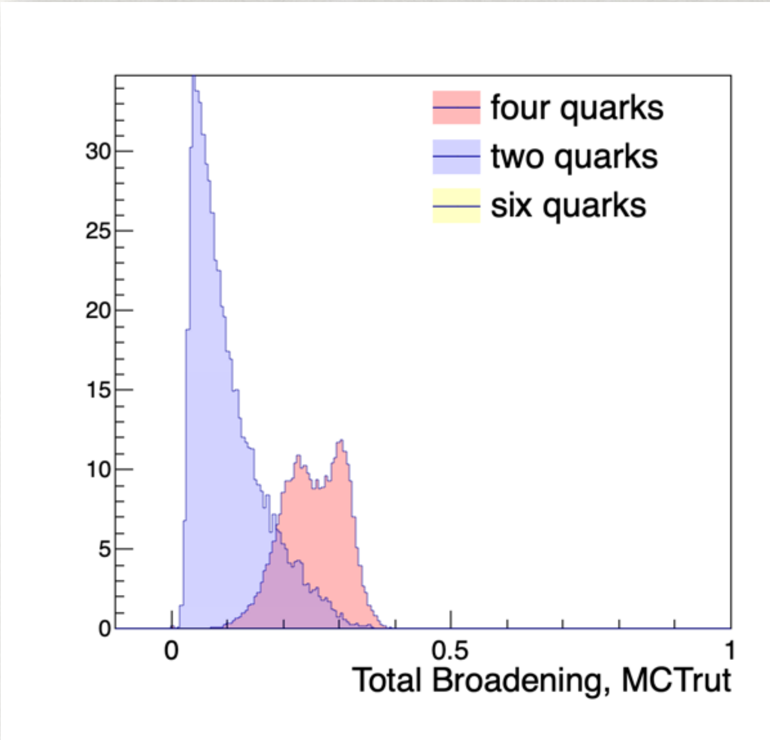

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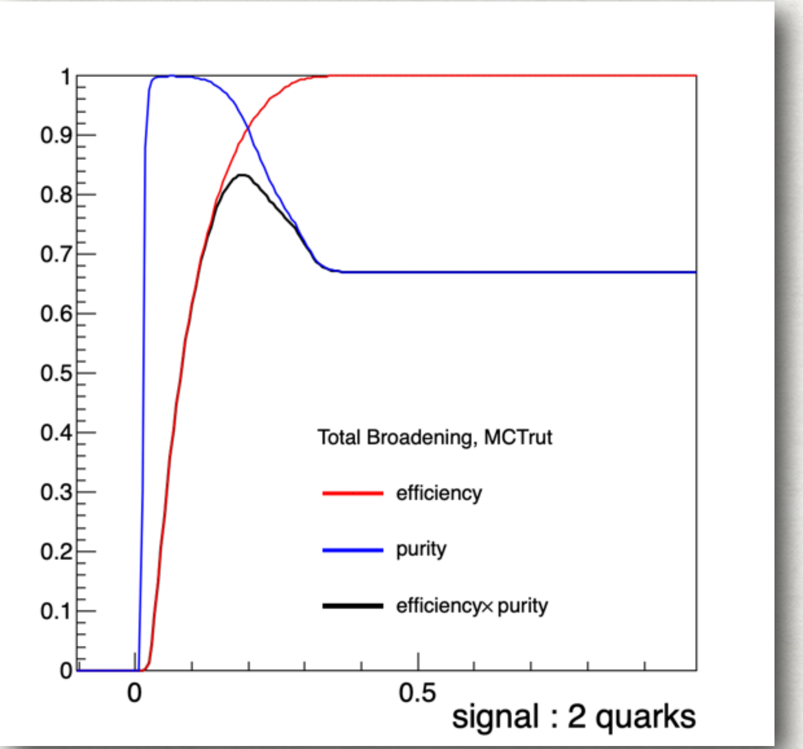
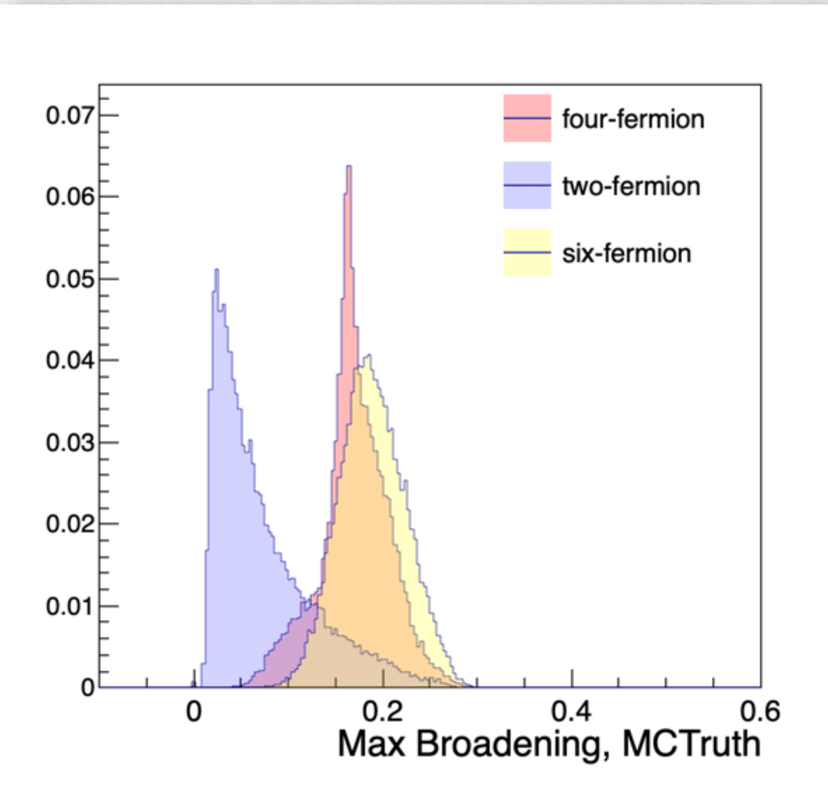


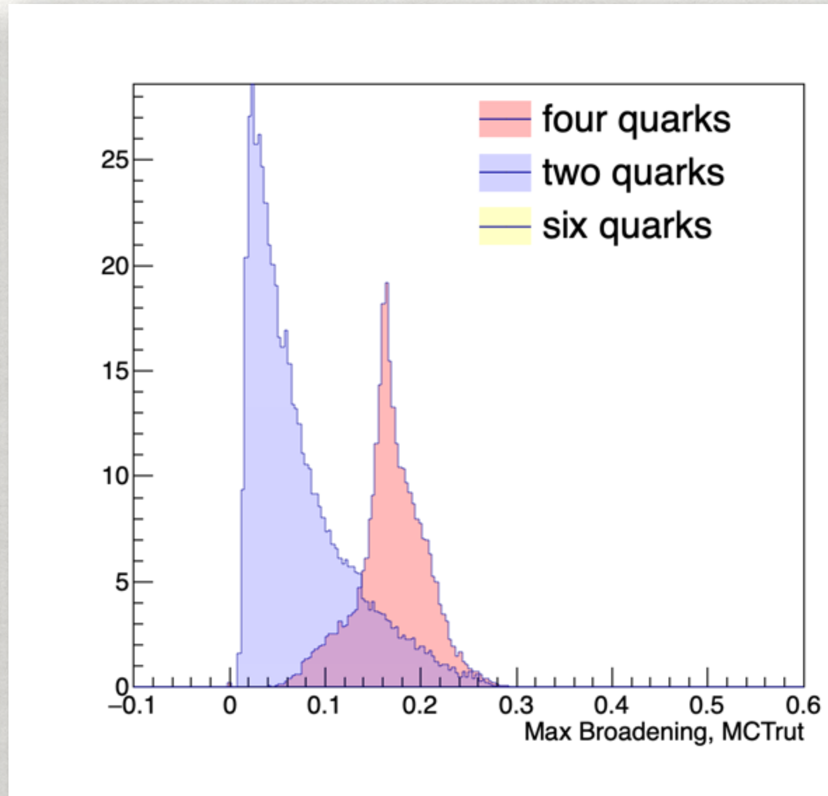
max efficiency × purity

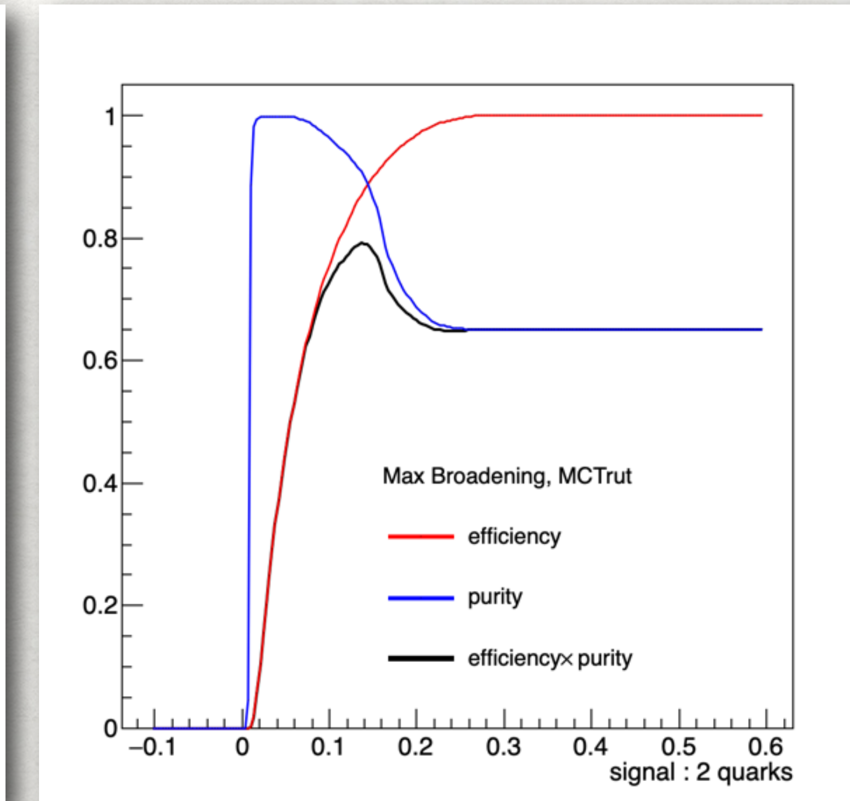
MC: 0.836156

Reco: 0.834205

$$B_W = max(B_1, B_2)$$







normalized to unit one

normalized to X-section

max efficiency × purity

MC: 0.80235

Reco: 0.800644

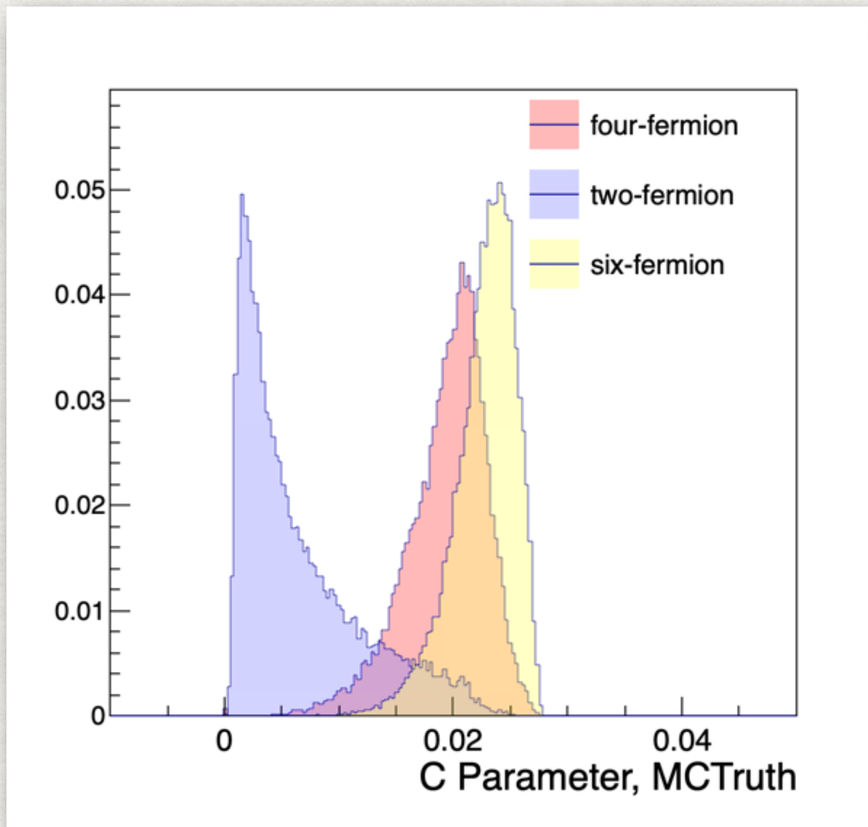
event shape variables:

- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

C and D parameter:

$$L^{ab} = \frac{1}{\sum_{j=1}^{N_{particles}} |P_j|} \sum_{i=1}^{N_{particles}} \frac{P_i^a P_i^b}{|P_i|}$$

C parameter : $C = 3(\lambda_1\lambda_2 + \lambda_1\lambda_3 + \lambda_2\lambda_3)$ λ is the eigenvalue of L^{ab}



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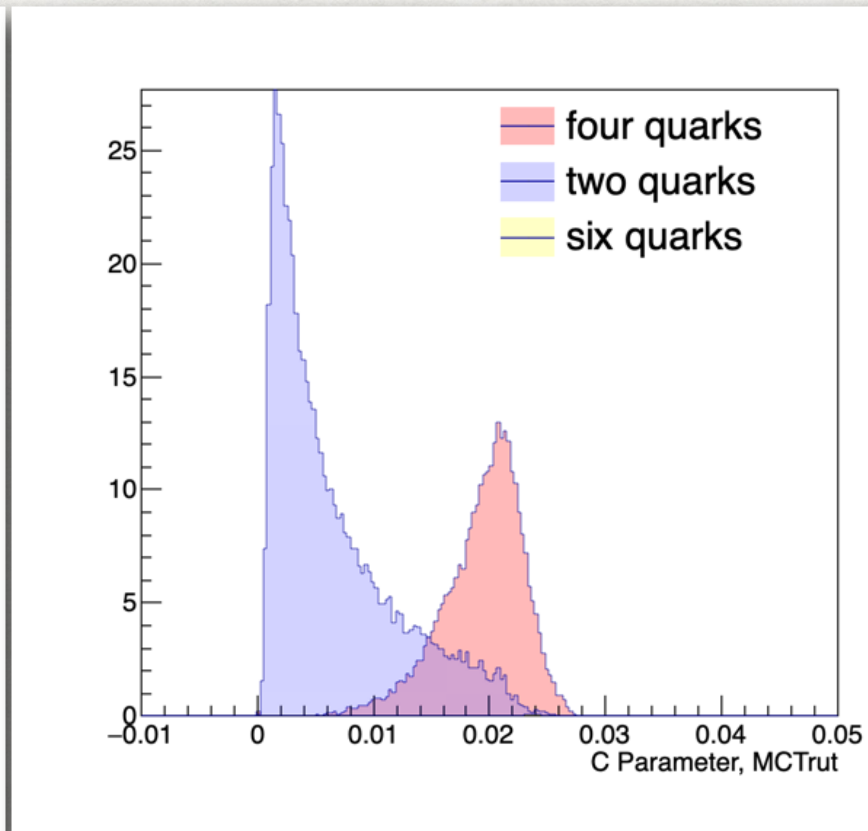

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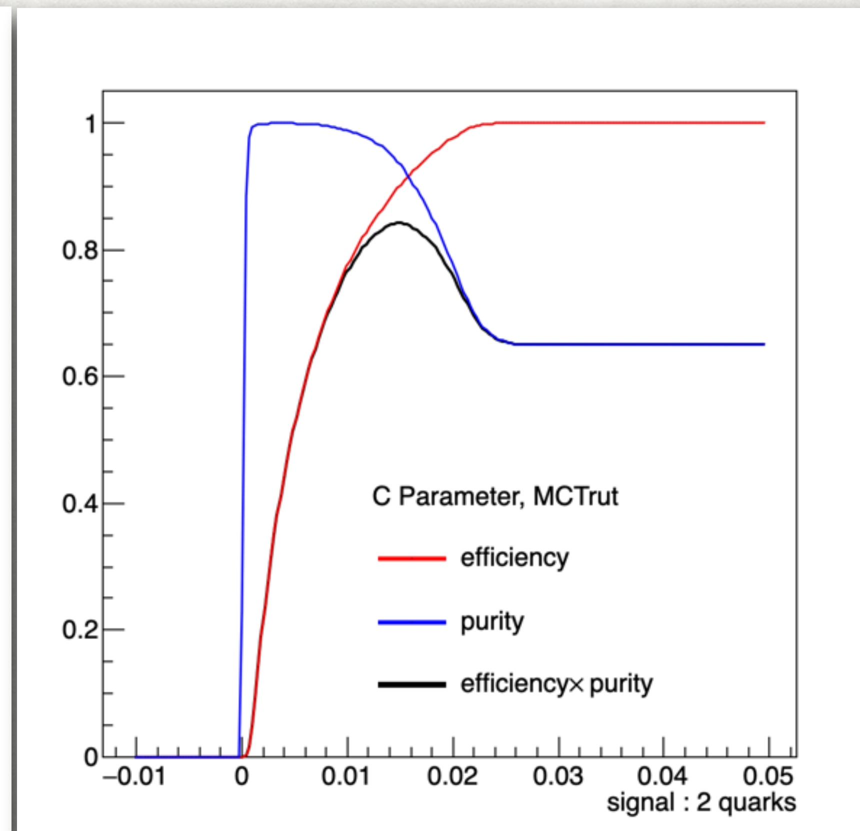
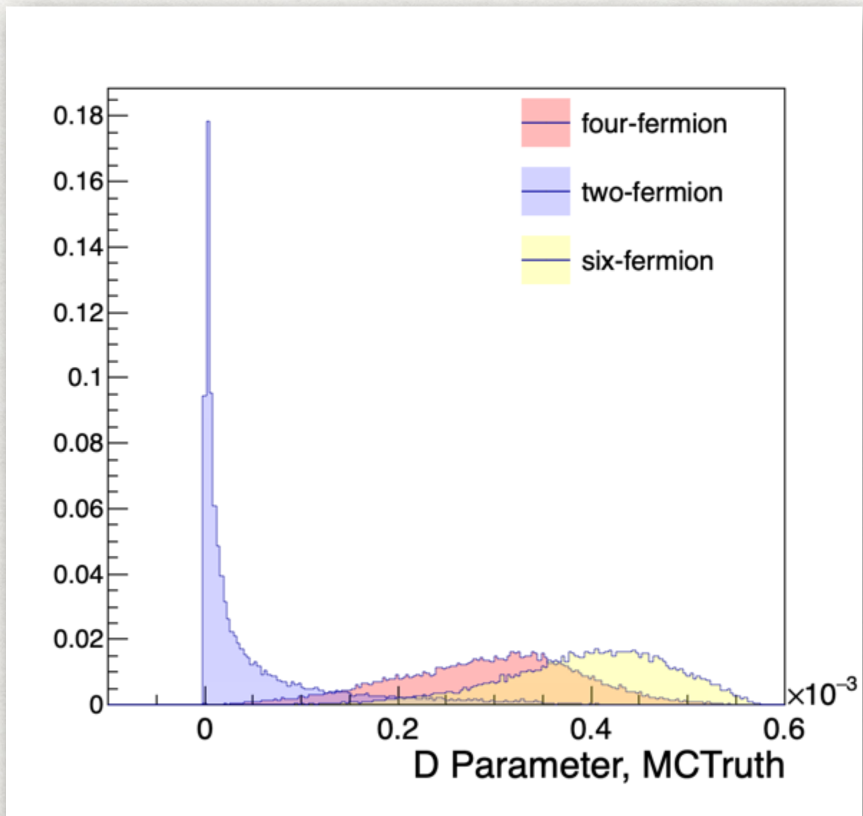


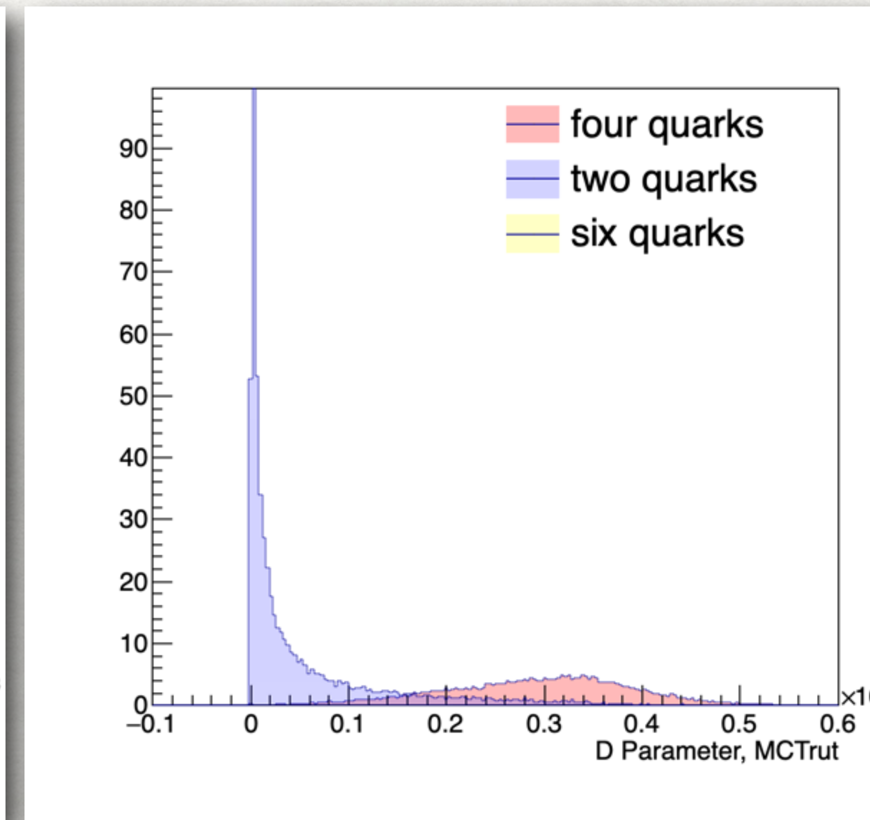
max efficiency × purity

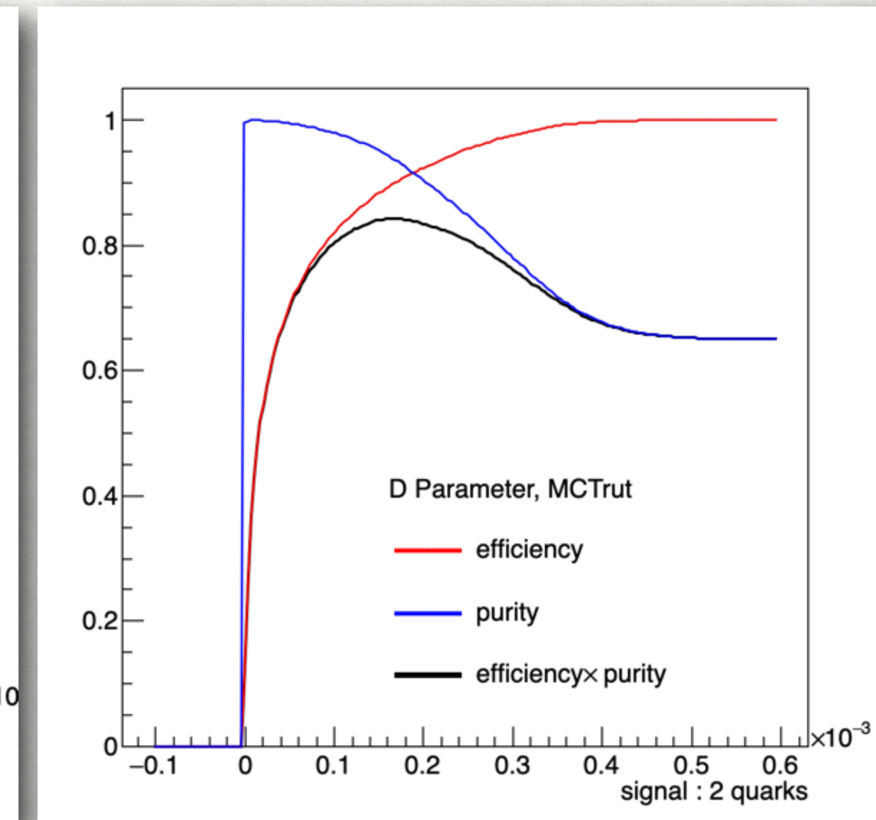
MC: 0.848953

Reco: 0.847589

D parameter : D = $27 \times \lambda_1 \times \lambda_2 \times \lambda_3$







normalized to unit one

normalized to X-section

max efficiency × purity

MC: 0.849227

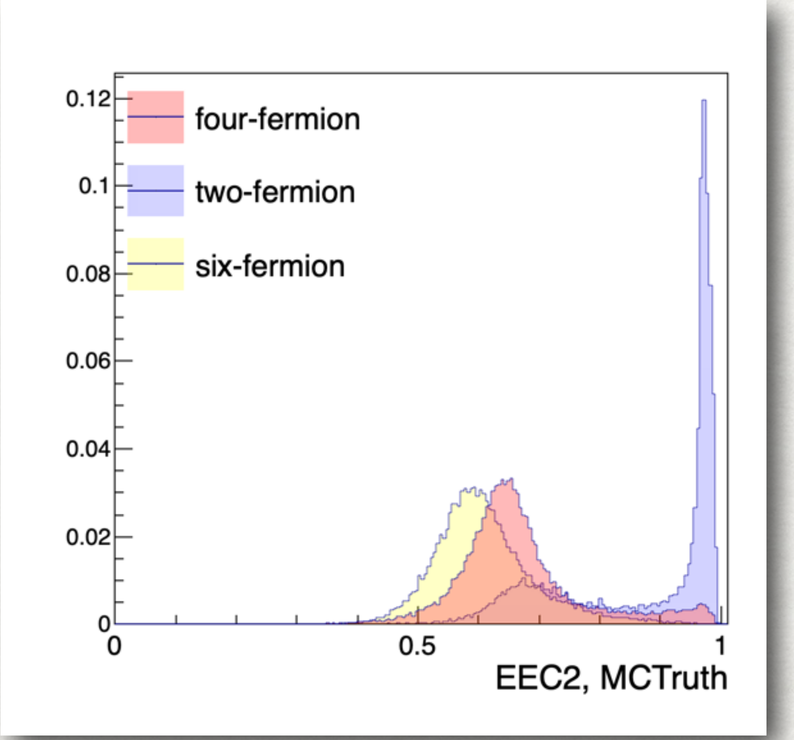
Reco: 0.848108

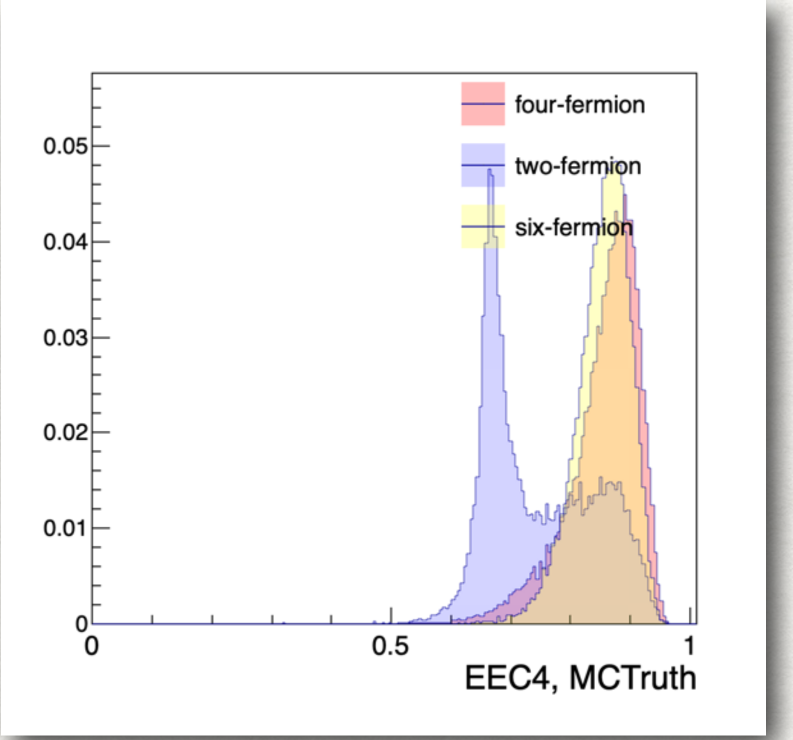
event shape variables:

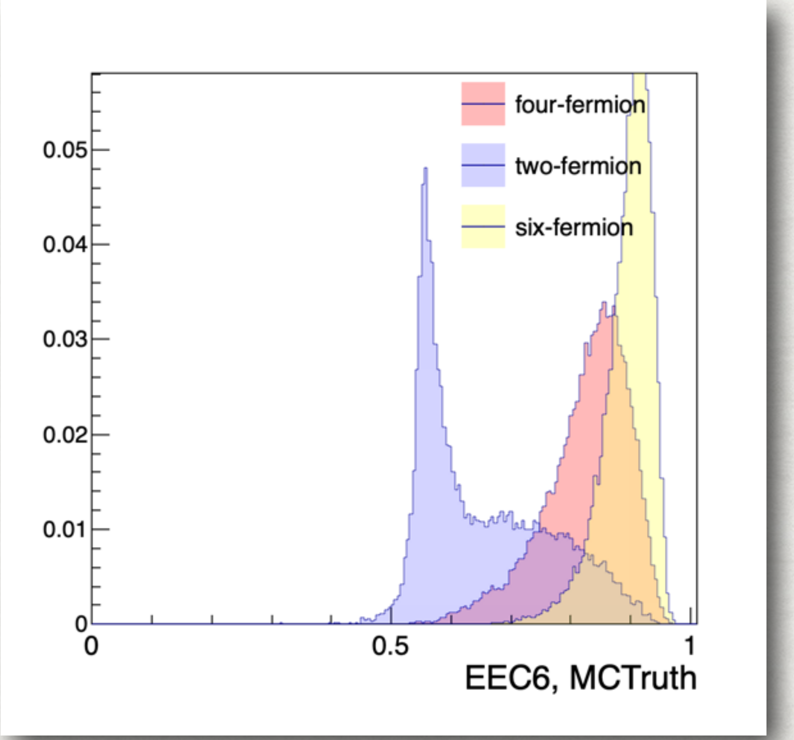
- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

energy-energy correlation (EEC)

$$EEC = \frac{1}{\sigma_{tot}} \sum_{ij} \int d\sigma \frac{E_i E_j}{Q^2} \delta(cos\chi - cos\theta_{ij})$$







max efficiency*purity	normalized to Xsection	
	MC	Reco
EEC2	0.744905	0.742189
EEC4	0.691678	0.696338

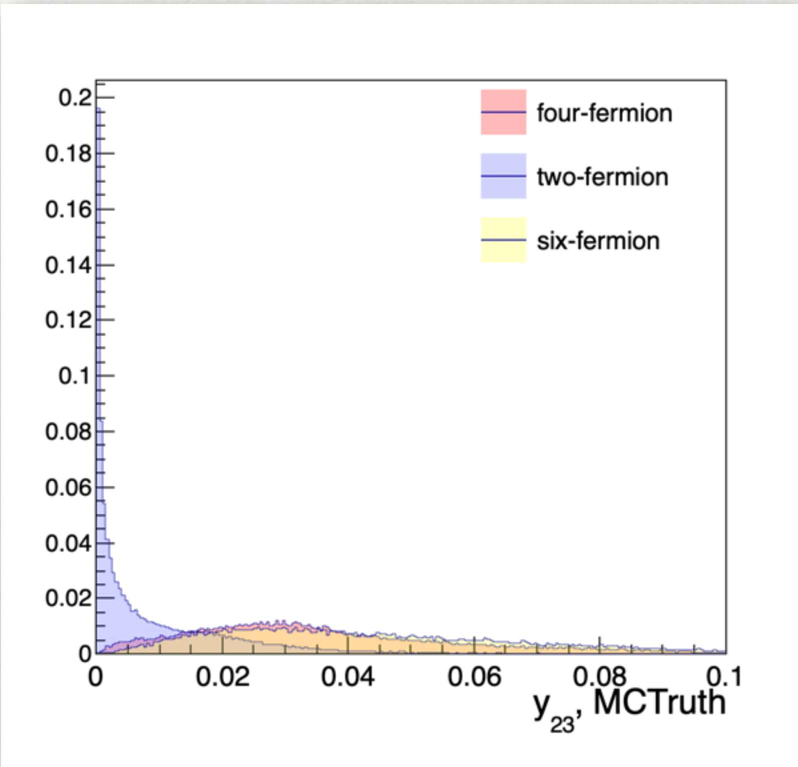
event shape variables:

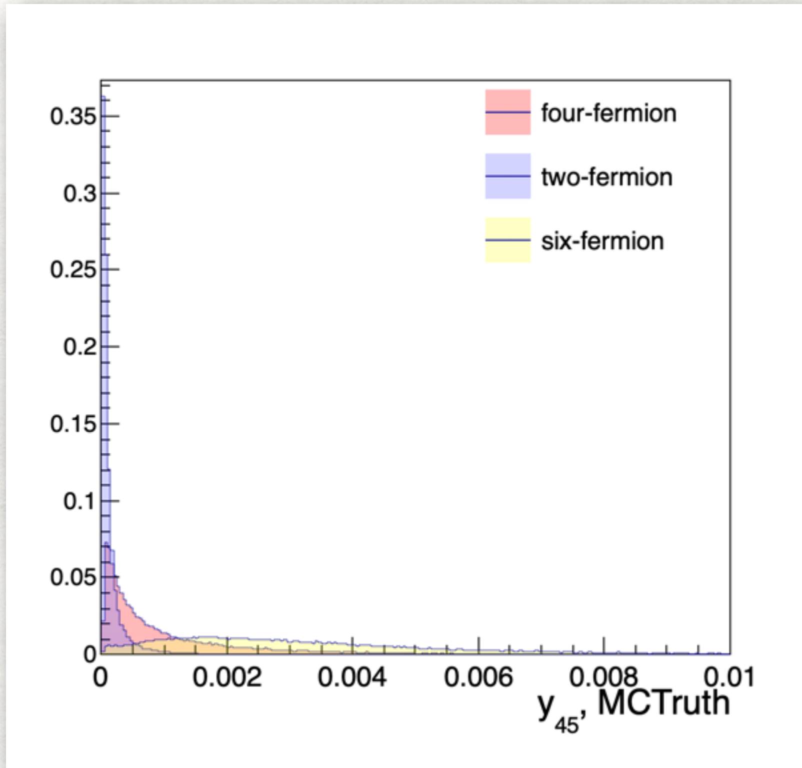
- thrust
- heavy mass
- wide and total broadening
- C and D parameter
- energy-energy correlation
- jet transition variable

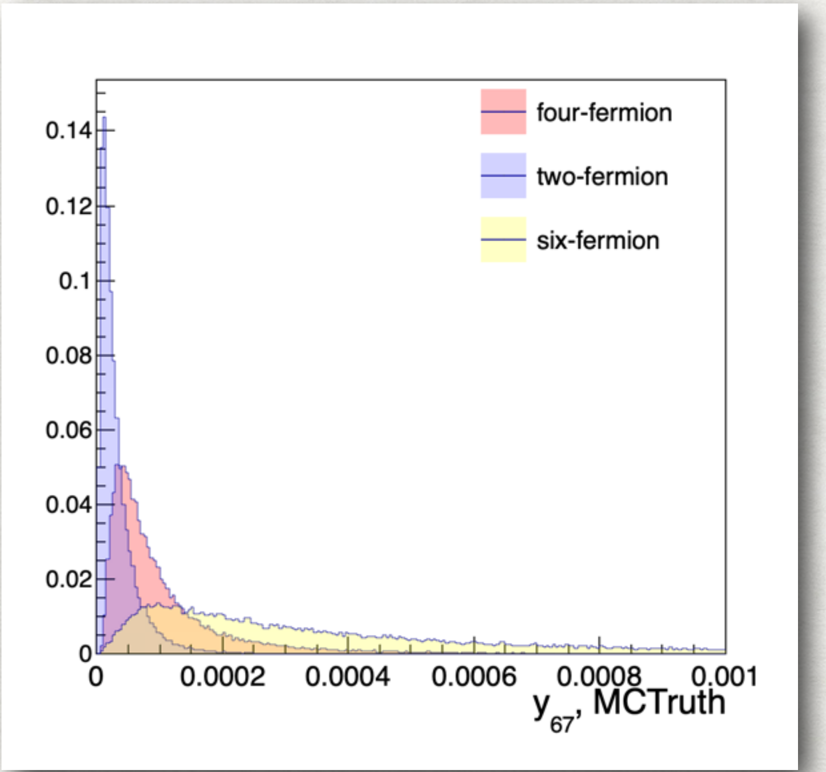
jet transition variable :

ee_kt_algorithm

$$d_{ij} = 2min(E_i^2, E_j^2)(1 - cos\theta_{ij})$$







max efficiency*purity	normalized to Xsection	
	MC	Reco
y_{23}	0.75294	0.783771
y_{45}	0.762077	0.751312

the separation performance

signal : two jets

background : four jets

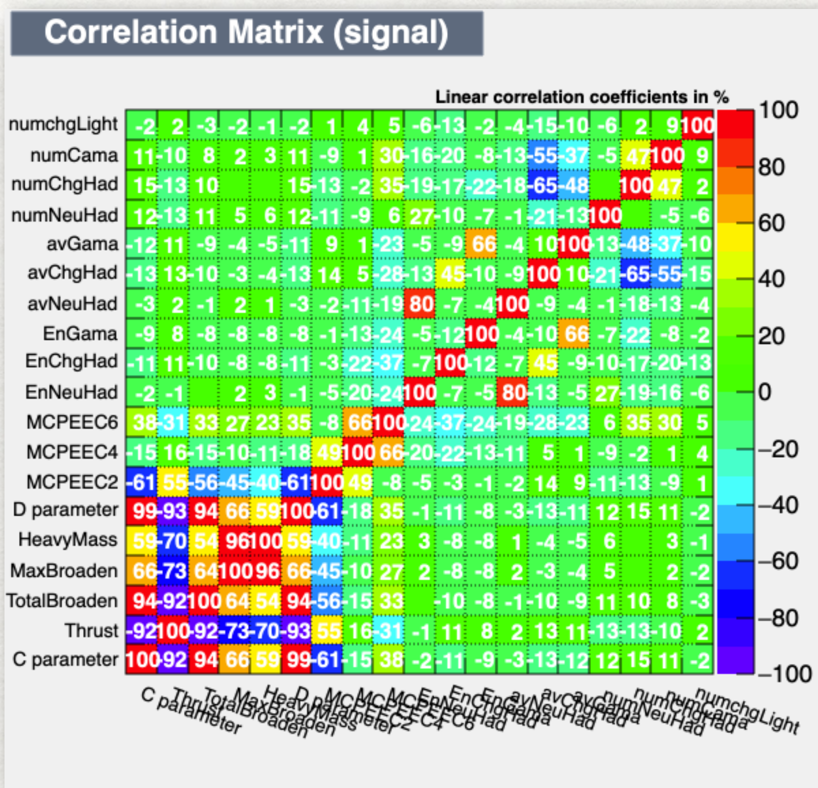
eff * purity		thrust	heavy mass	W-B	T-B	C	D	EEC2	EEC4	y_{23}	y_{45}
MC	4	0.725126	0.662227	0.626333	0.689816	0.710484	0.711881	0.518468	0.458078	0.515794	0.496913
	2	0.853088	0.815345	0.80235	0.836156	0.848953	0.849227	0.744905	0.691678	0.75294	0.762077
Reco	4	0.719017	0.656155	0.622944	0.687122	0.706065	0.706444	0.515967	0.470759	0.602634	0.460444
	2	0.851713	0.812466	0.800644	0.834205	0.847589	0.848108	0.742189	0.696338	0.783771	0.751312

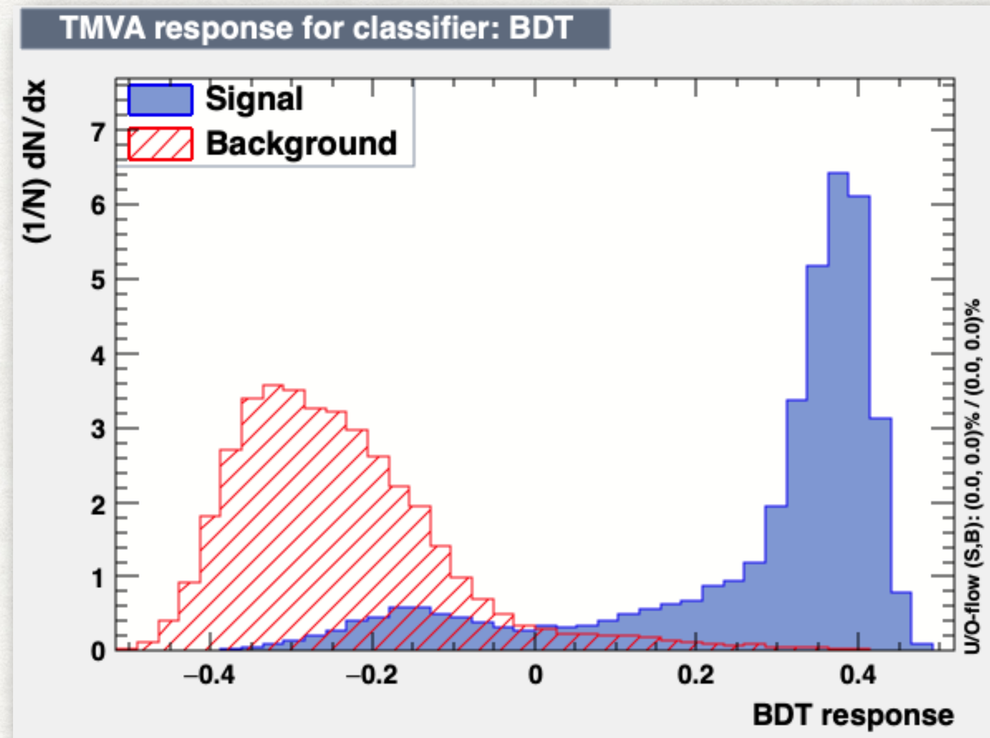
consistant result between MCTruth level and Reconstruction level

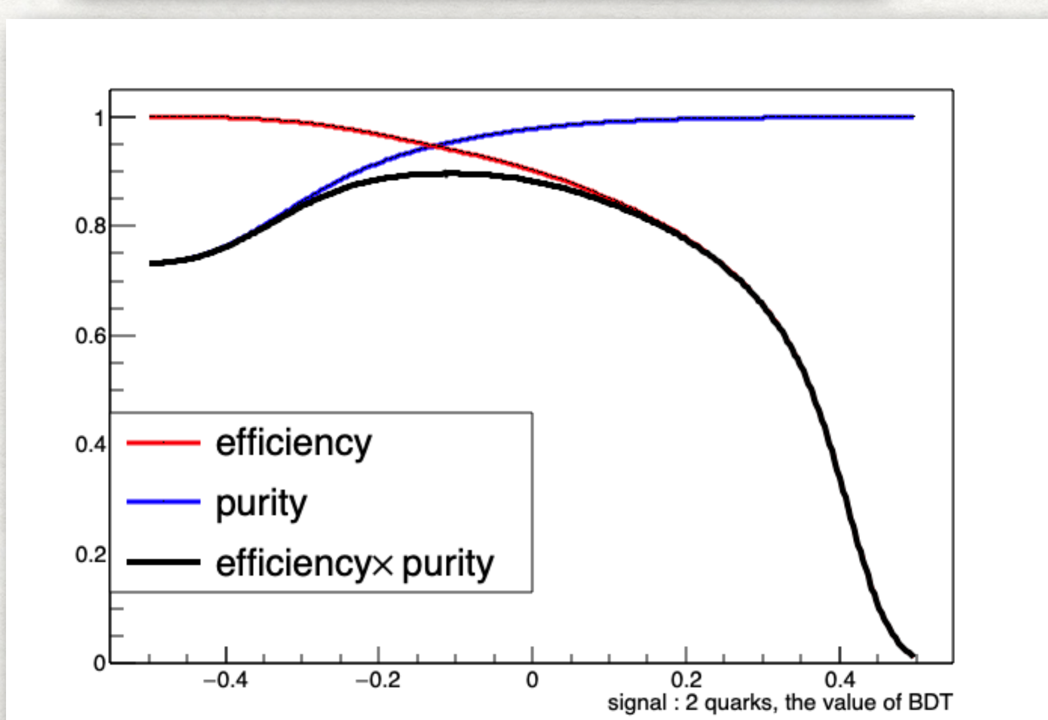
BDT Results

signal : the two-jet

background : the four-jet







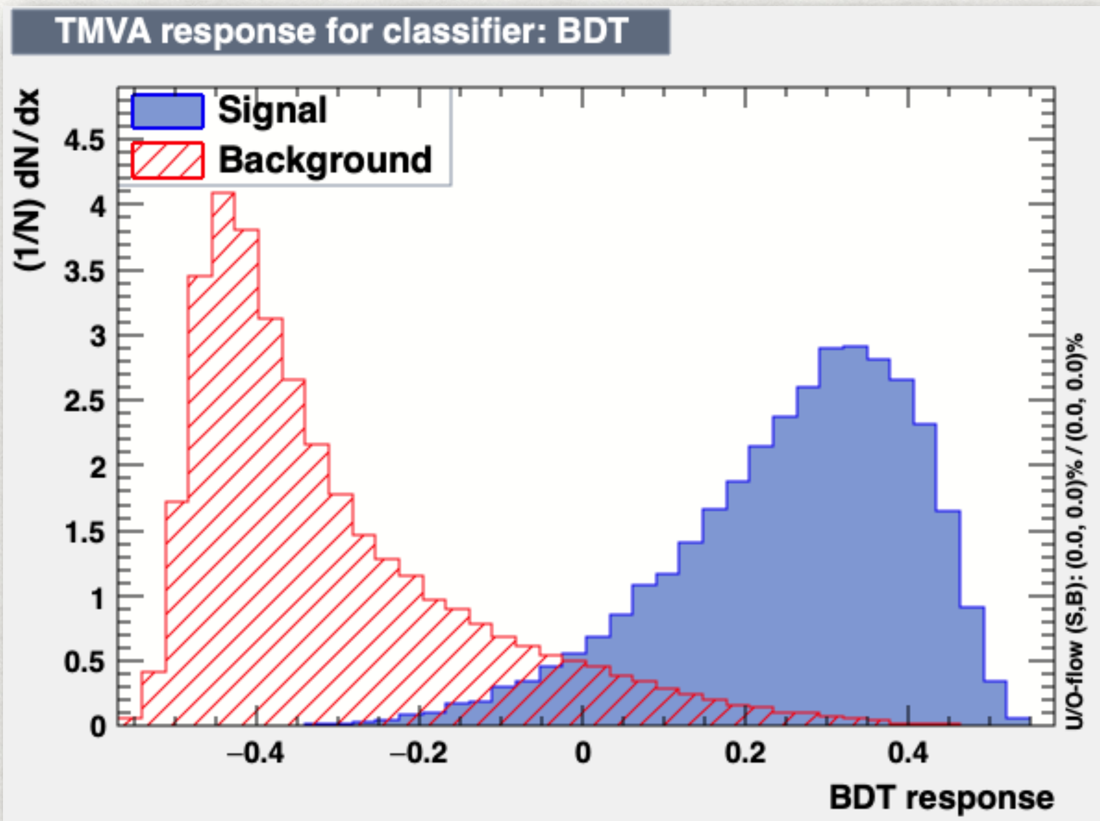
max efficiency × purity

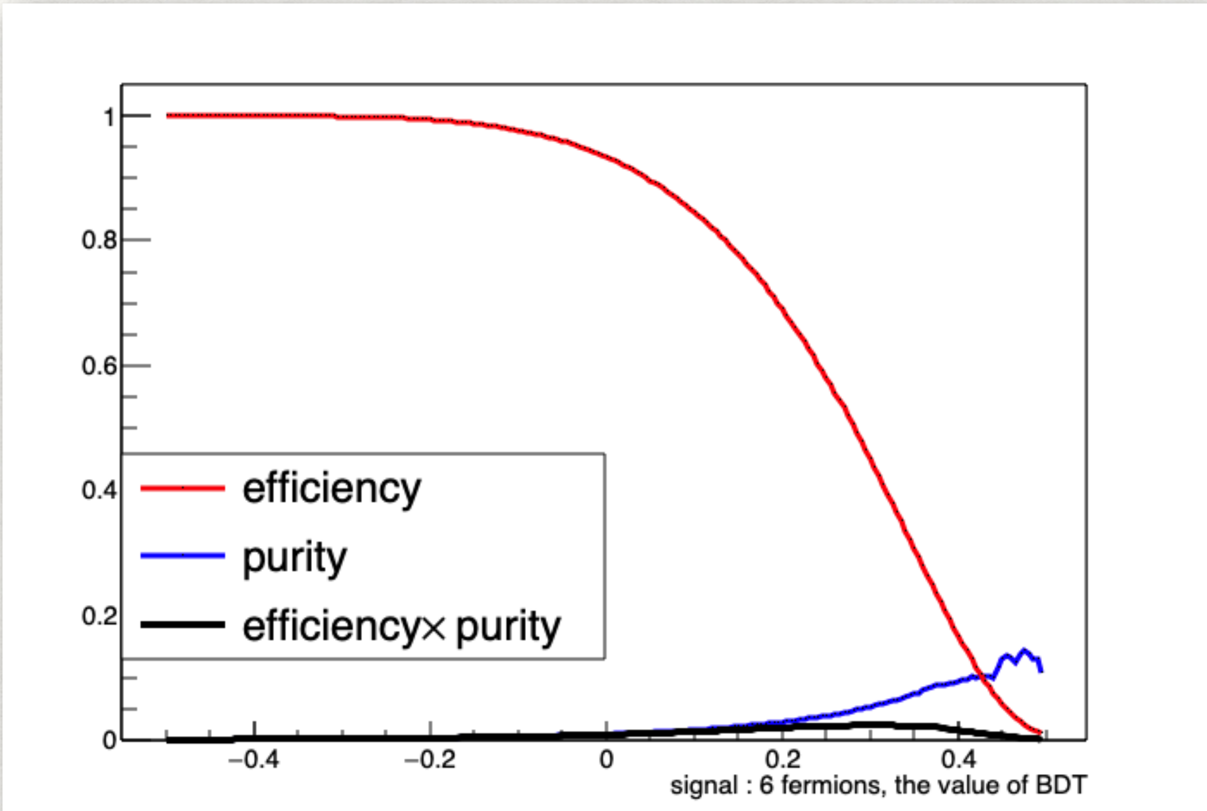
MC : 0.896342

Reco : 0.890765

signal : the six-jet

background : the two-jet and the four-jet





$$\frac{\sigma_{background}}{\sigma_{signal}} = 1080$$

Since the cross section of the six jets final state is very small compared to the two jets and the four jets, we need to find more powerful method to identify the six jets events.

Summary :

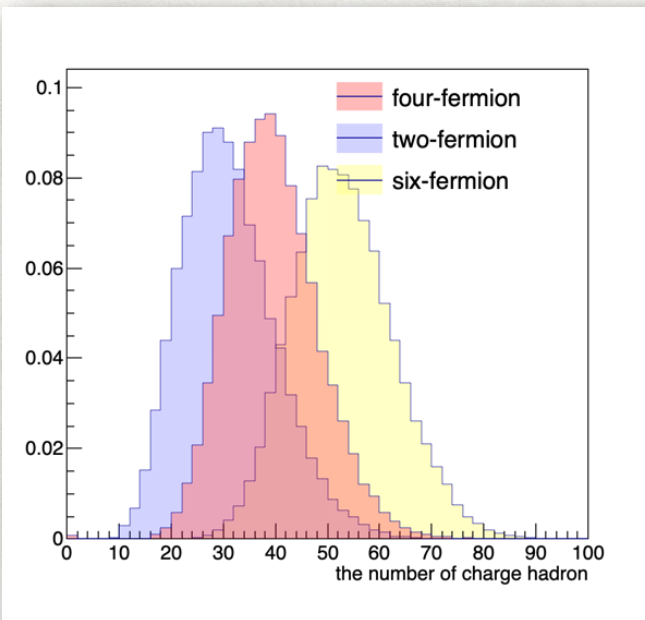
- At the CEPC, the events with multi-jet final state occupy large part and various analysis can be done with these kinds of events.
- The event shape variables can efficiently separate the two-jet from the four-jet. The separation performance is consistant for these variables.
- The event shape variables plus multiplicity variables can identify six fermions from the background of two fermions and four fermions to some extent. Then we can measure the Higgs branching ratio for these processes.

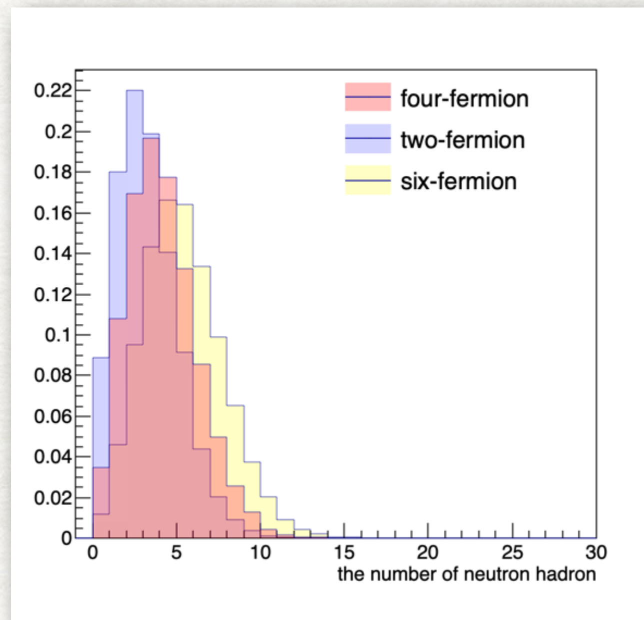
Thanks !

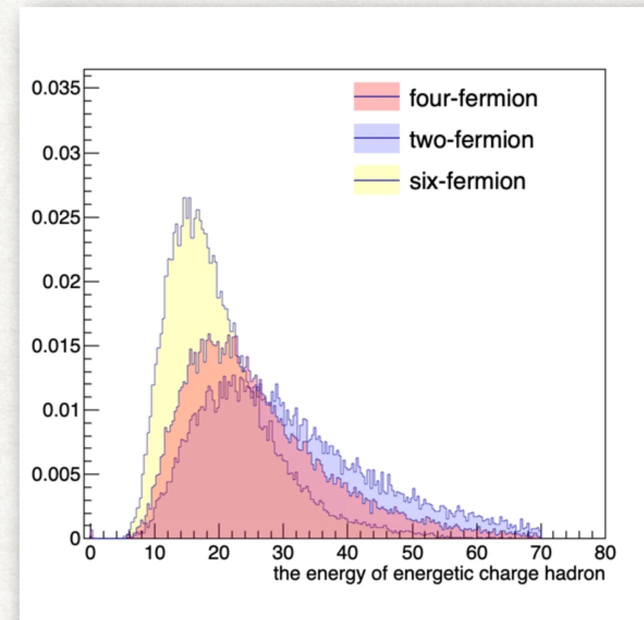
Backup

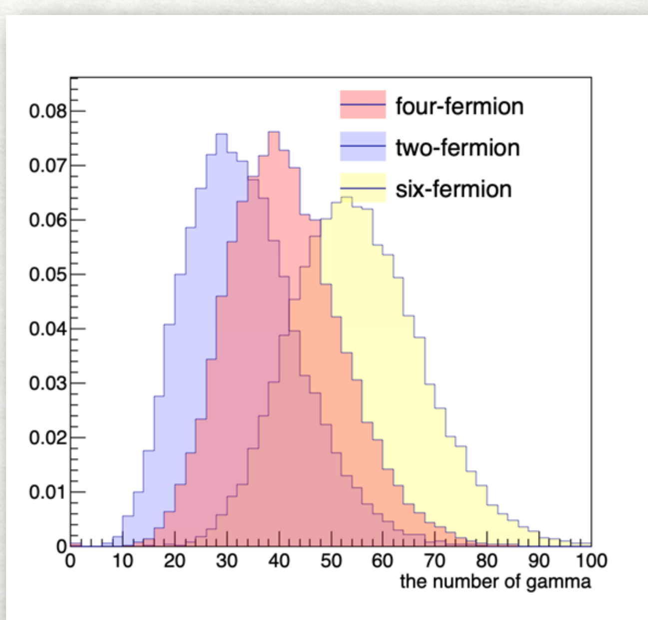
Multiplicity variables :

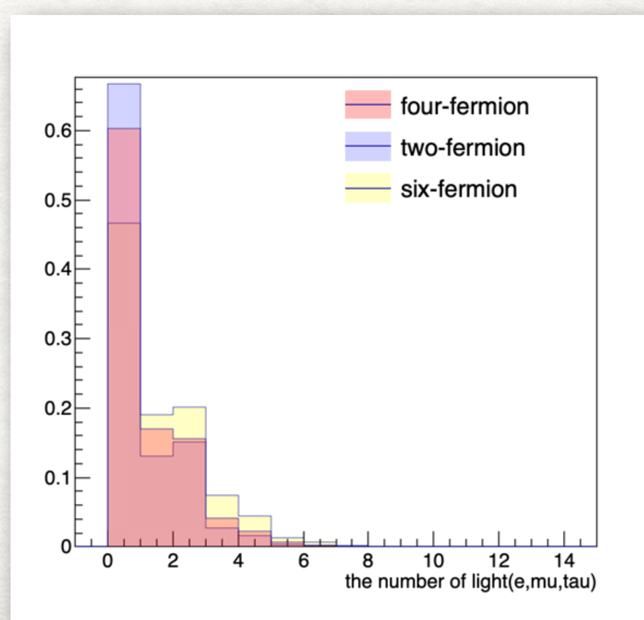
- the number of neutron hadron, charge hadron, gamma and light (e, μ)
- the energy of energetic neutron hadron, charge hadron, gamma and light (e, μ)
- the average energy of neutron hadron, charge hadron, gamma and light (e, μ)

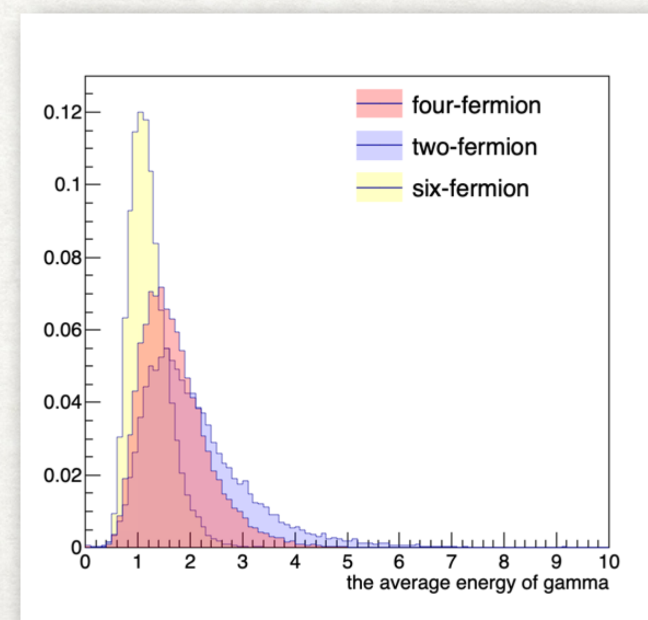


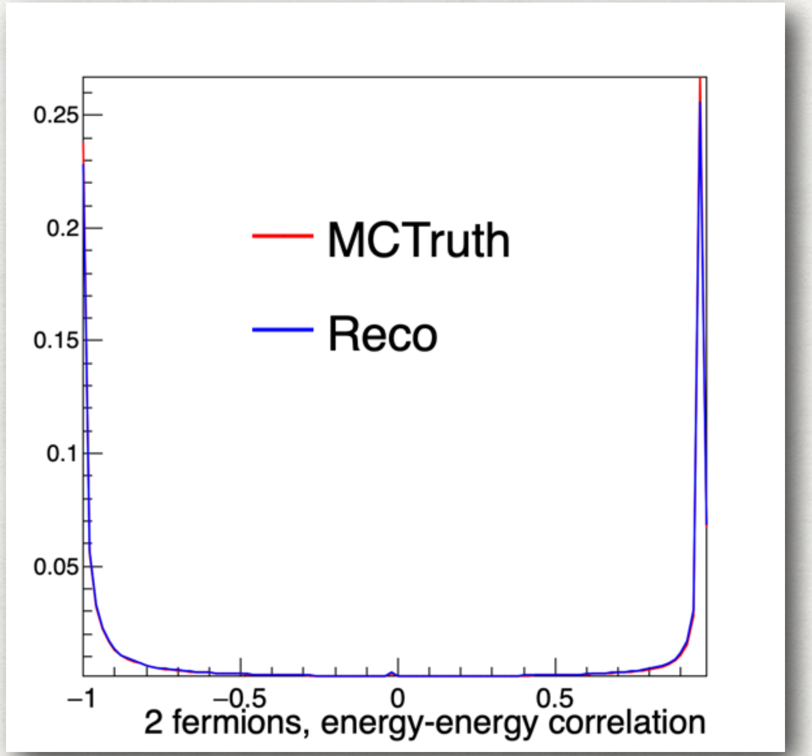


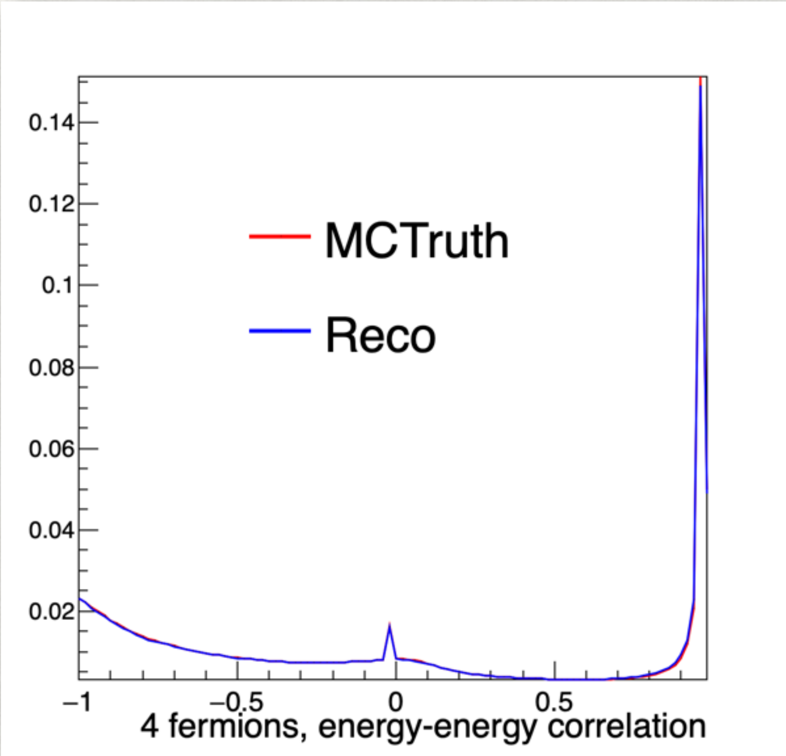


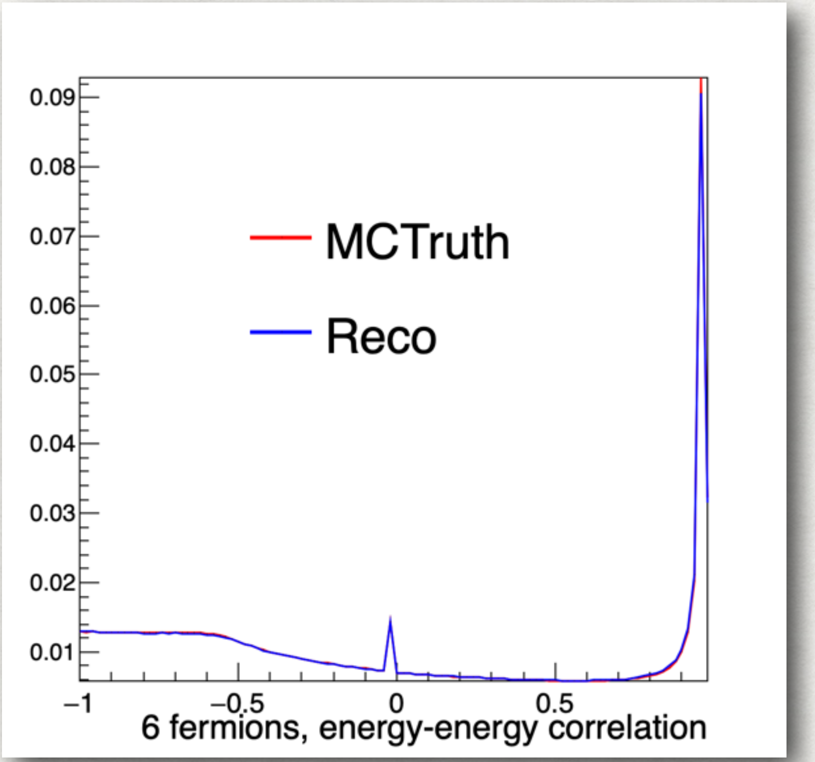












$$likelihood = \frac{\sum (P1_i) \times P2_i}{\sqrt{\sum (P1_i \times P2_i) \times \sum (P2_i \times P2_i)}}$$

$P1$: the histogram of each event

$P2$: the statistic distribution of each kinds of samples

i : i'th bin