ILD Top/HF group meeting

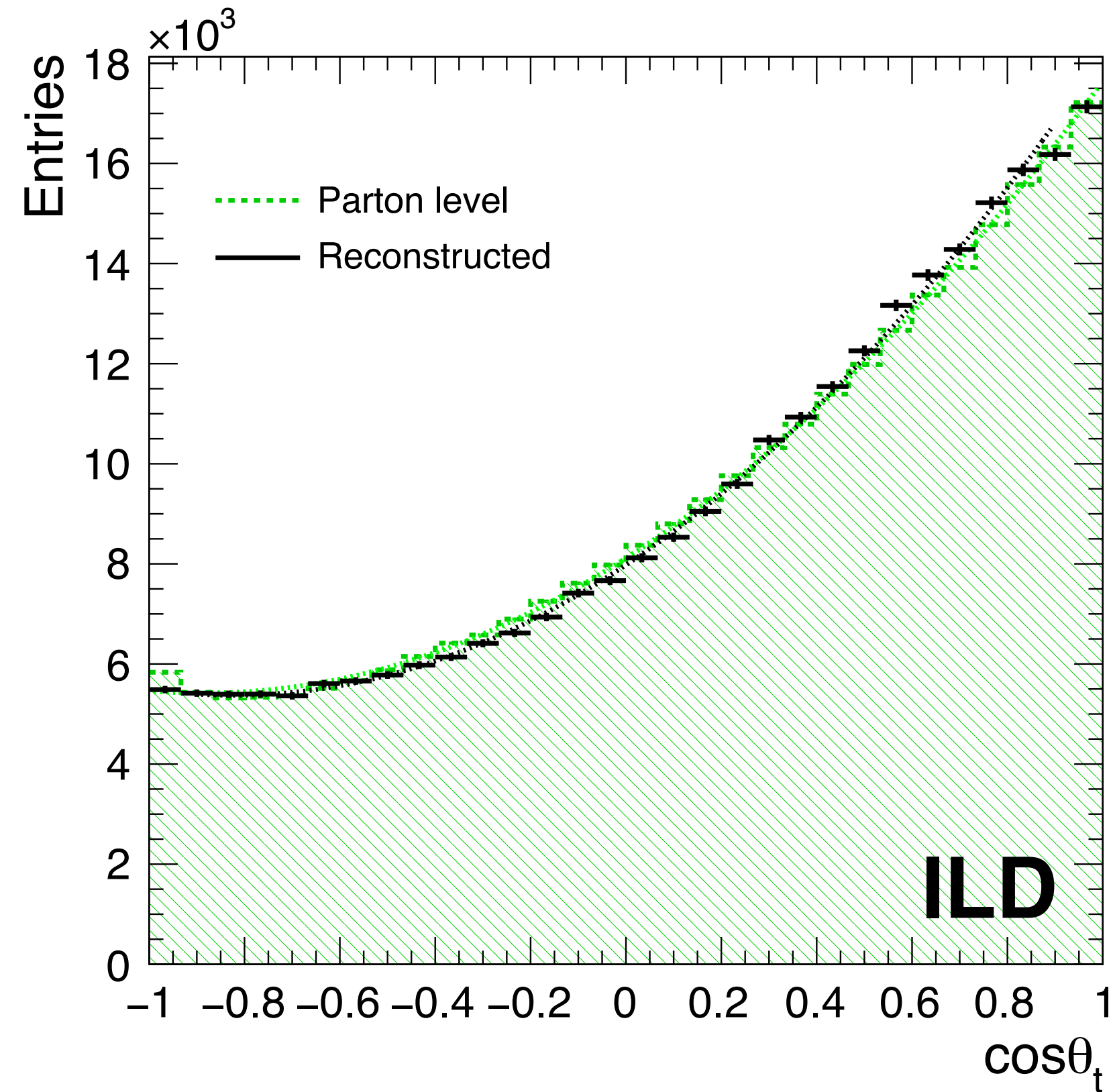**Reconstruction bias on polar angle spectrum in tt production**
12/02/20

Yuichi Okugawa, Roman Pöschl, Hitoshi Yamamoto
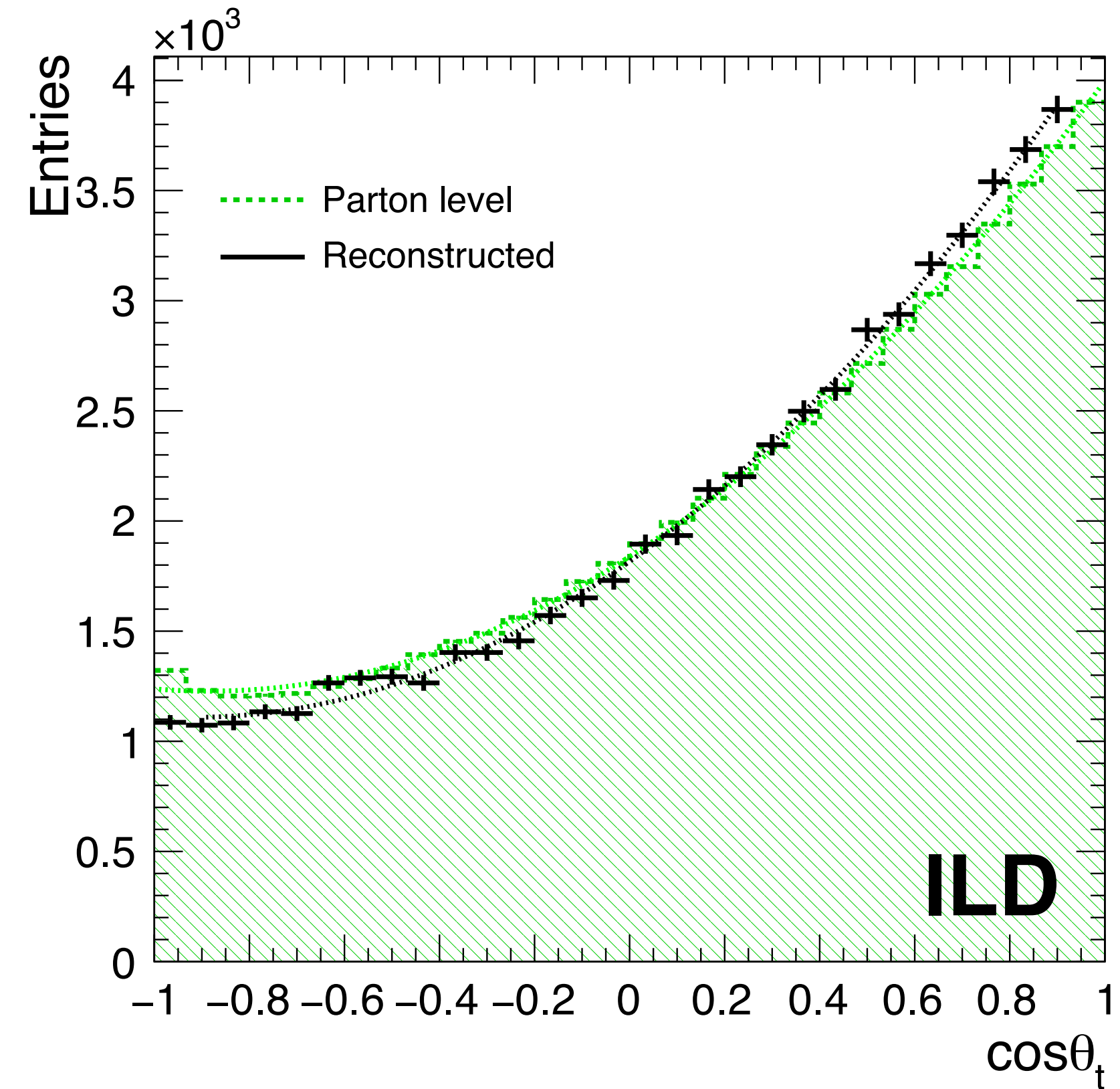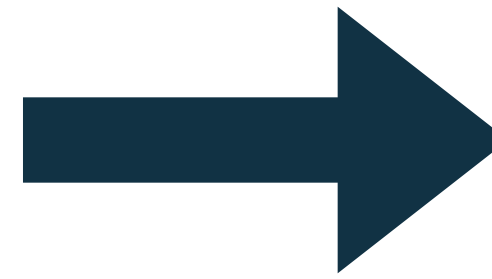
0. Outline

- ‣ Polar angle distribution of top quark for all reconstructed events

- ‣ Polar angle distribution of top quark only using vtx x vtx comparison.

Background?

- Mis-combination of b and W?
- Single Top Background?
- Reconstruction bias
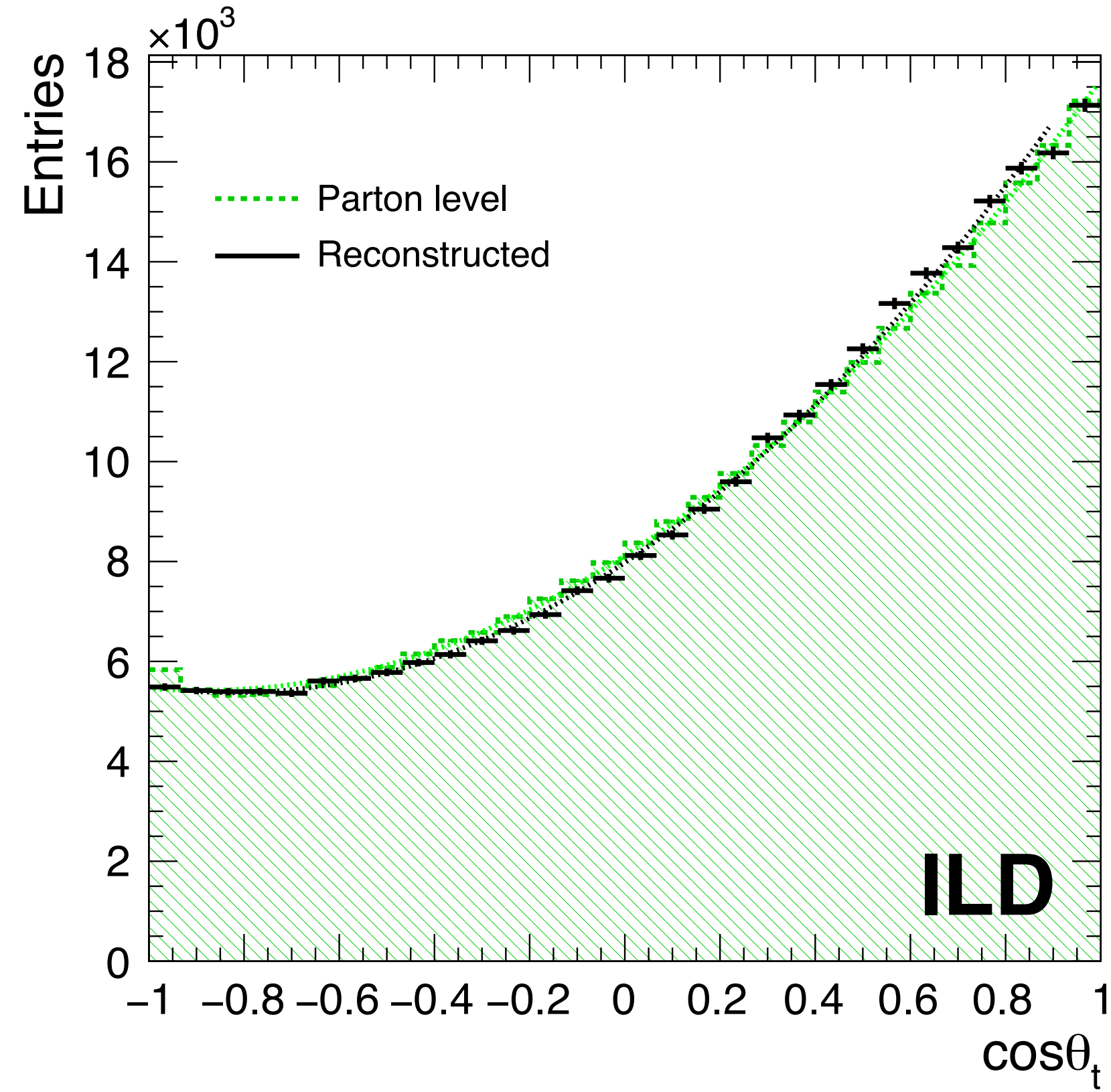
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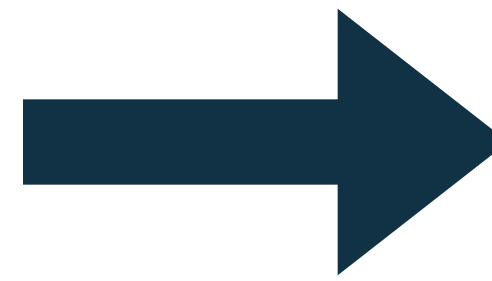
Background?

- ~~Mis-combination of b and W?~~
- Single Top Background?
- Reconstruction bias

Source of systemic error
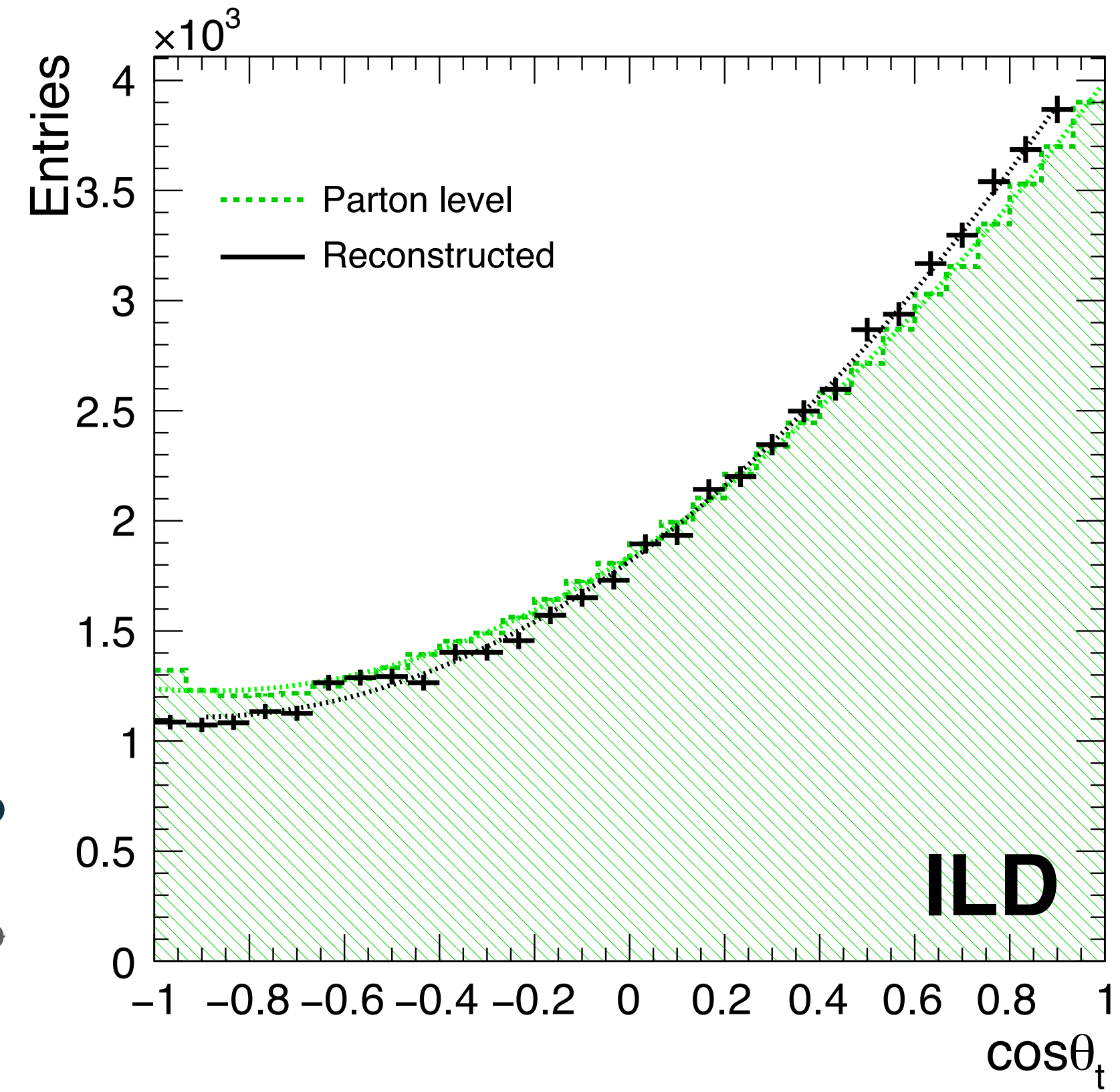
‣ Polar angle distribution of top quark for all reconstructed events

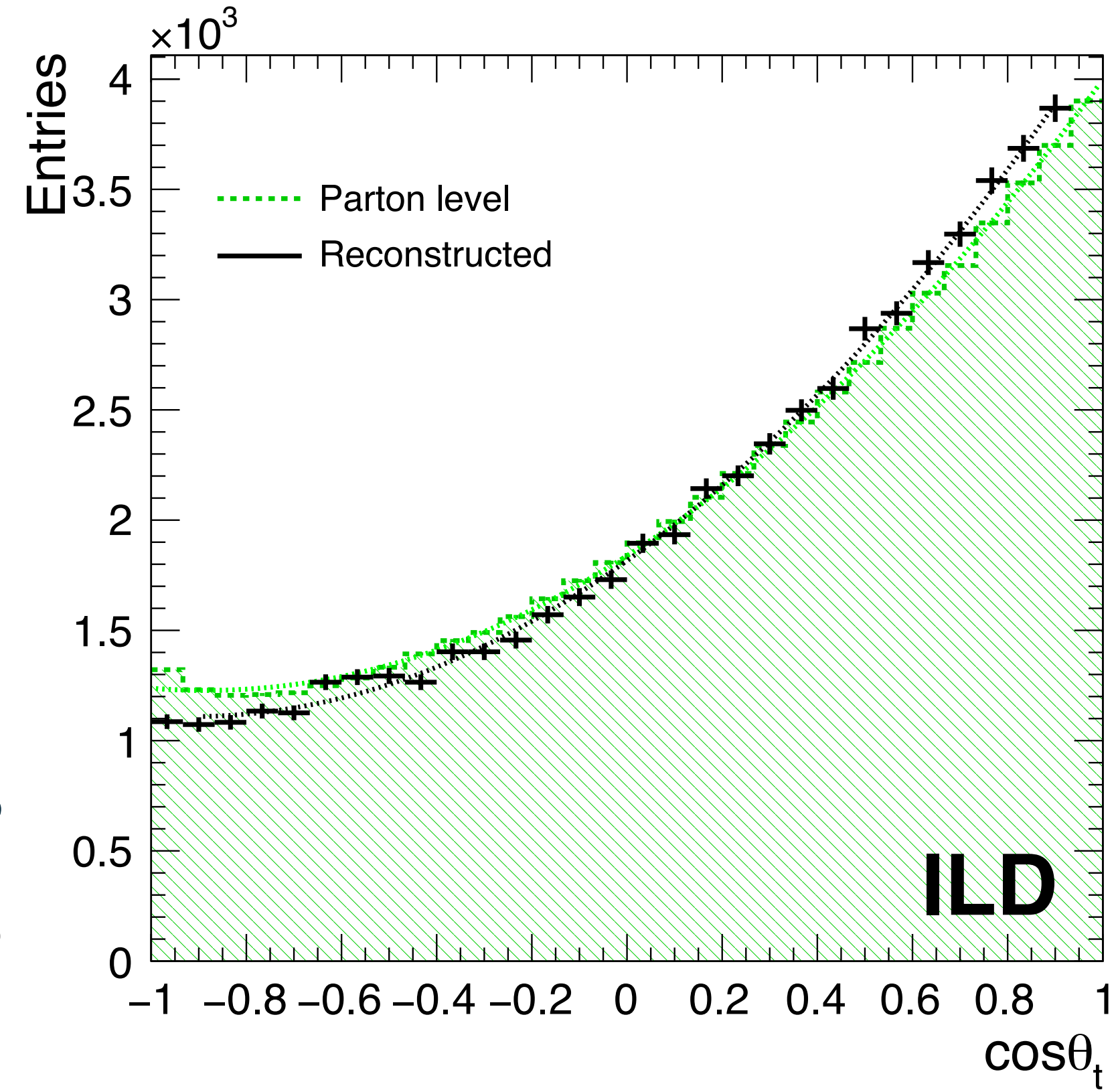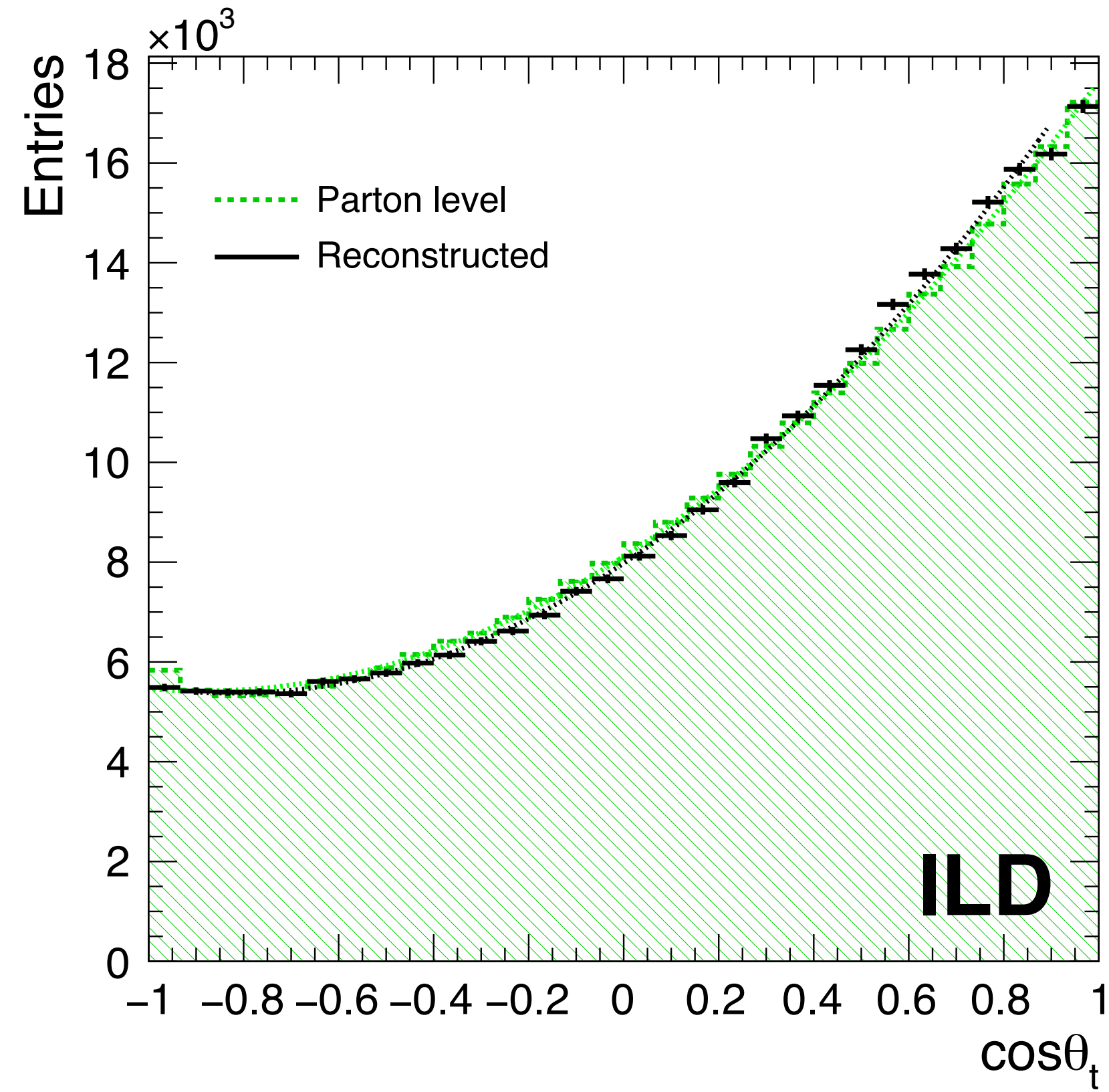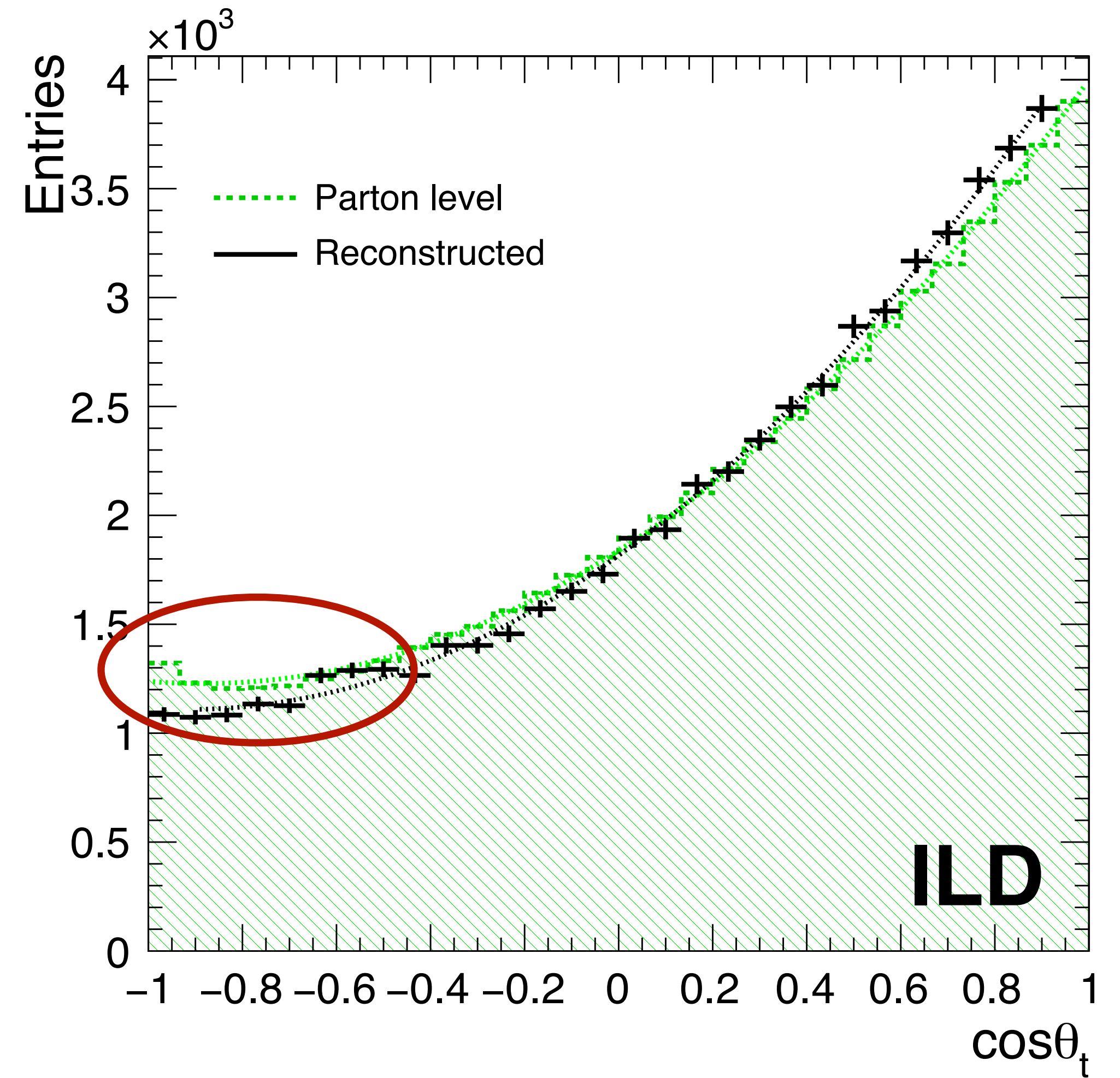‣ Polar angle distribution of top quark only using vtx x vtx comparison.

What are we interested?

- Key parameters

  - **b-jet Energy**

    ‣ $-0.9 < \cos\theta_t < -0.6$

    ‣ Single Top Tag (based on Gen info)

    ‣ Usage of vtx x vtx
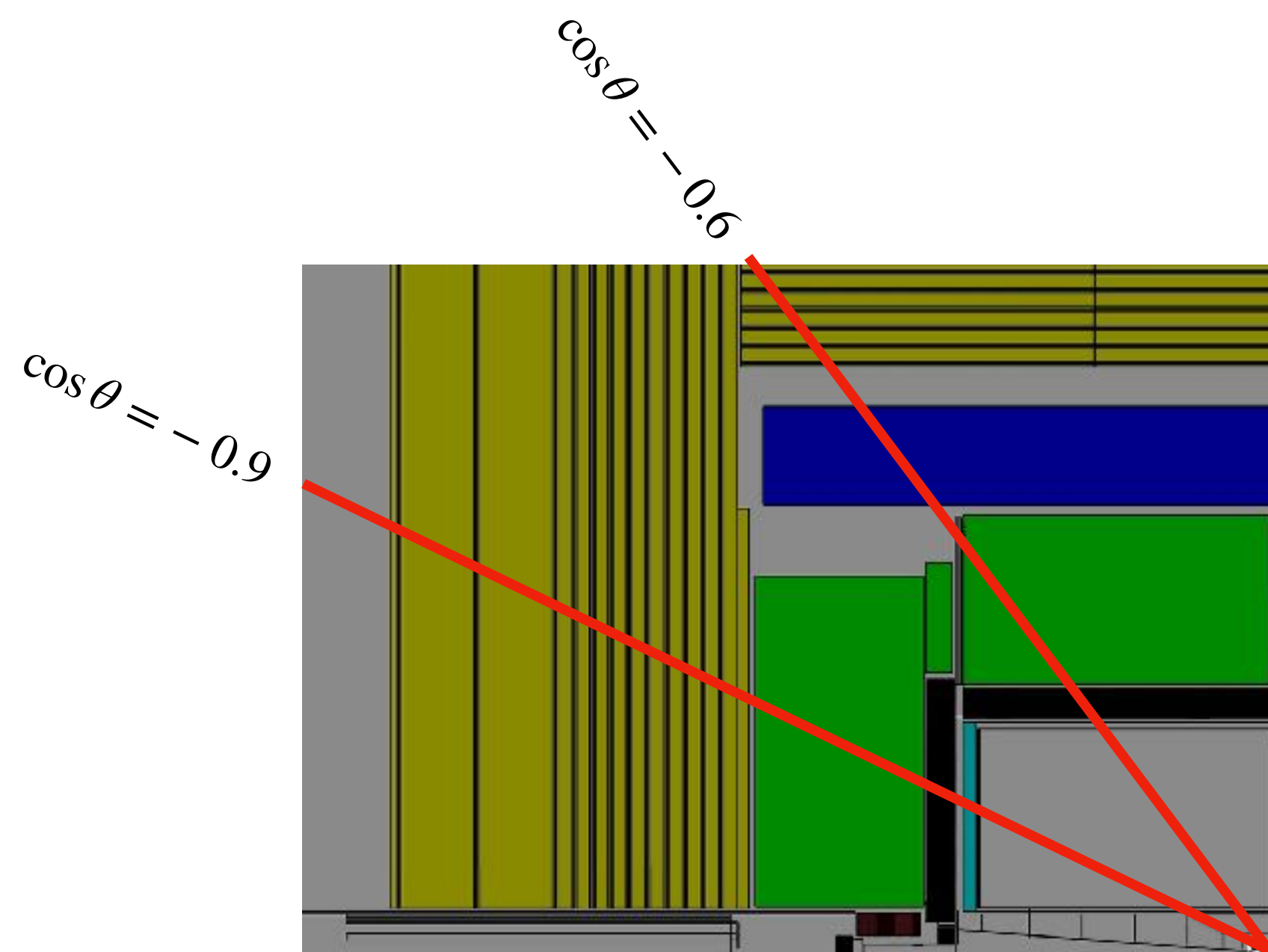
2. Possible Sources of Systematic Errors

$t\bar{t}$ Production

Single Top Production

T-channel

S-channel
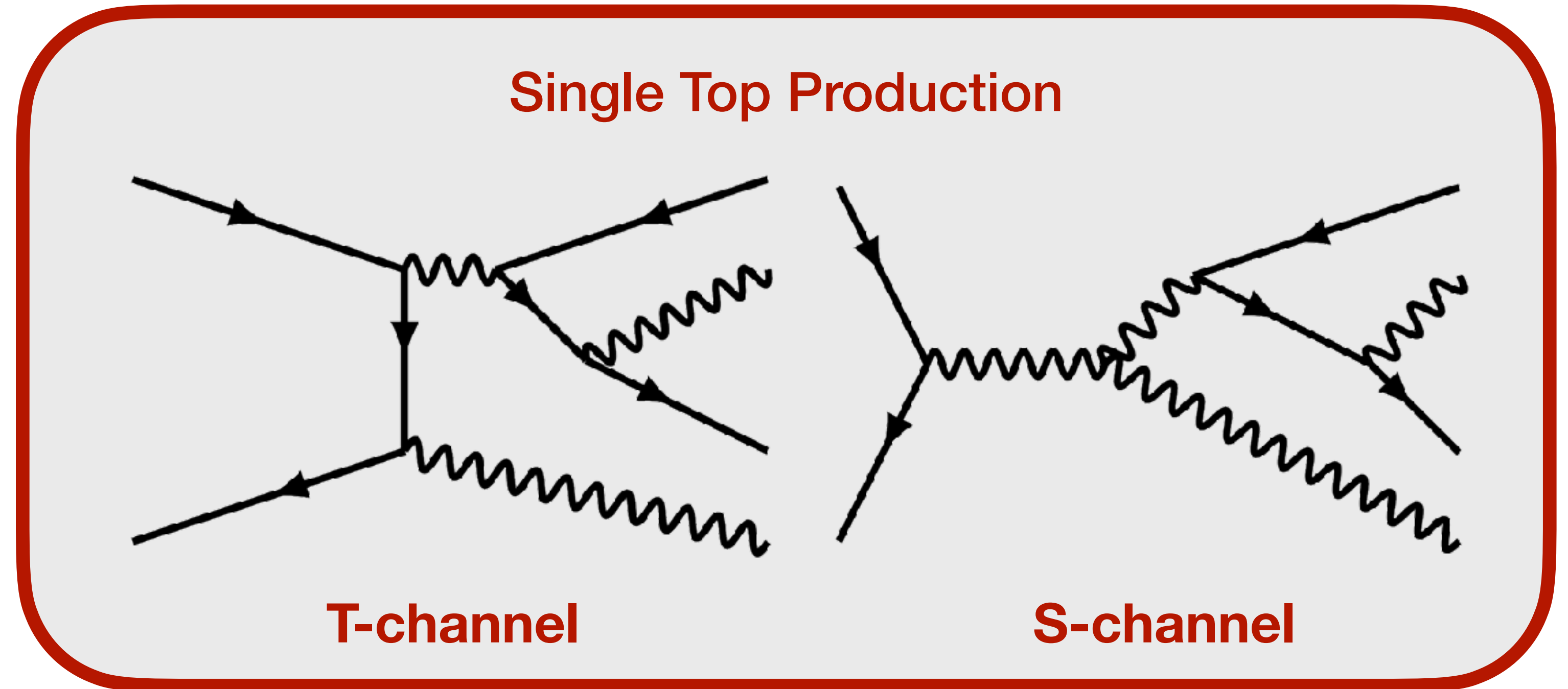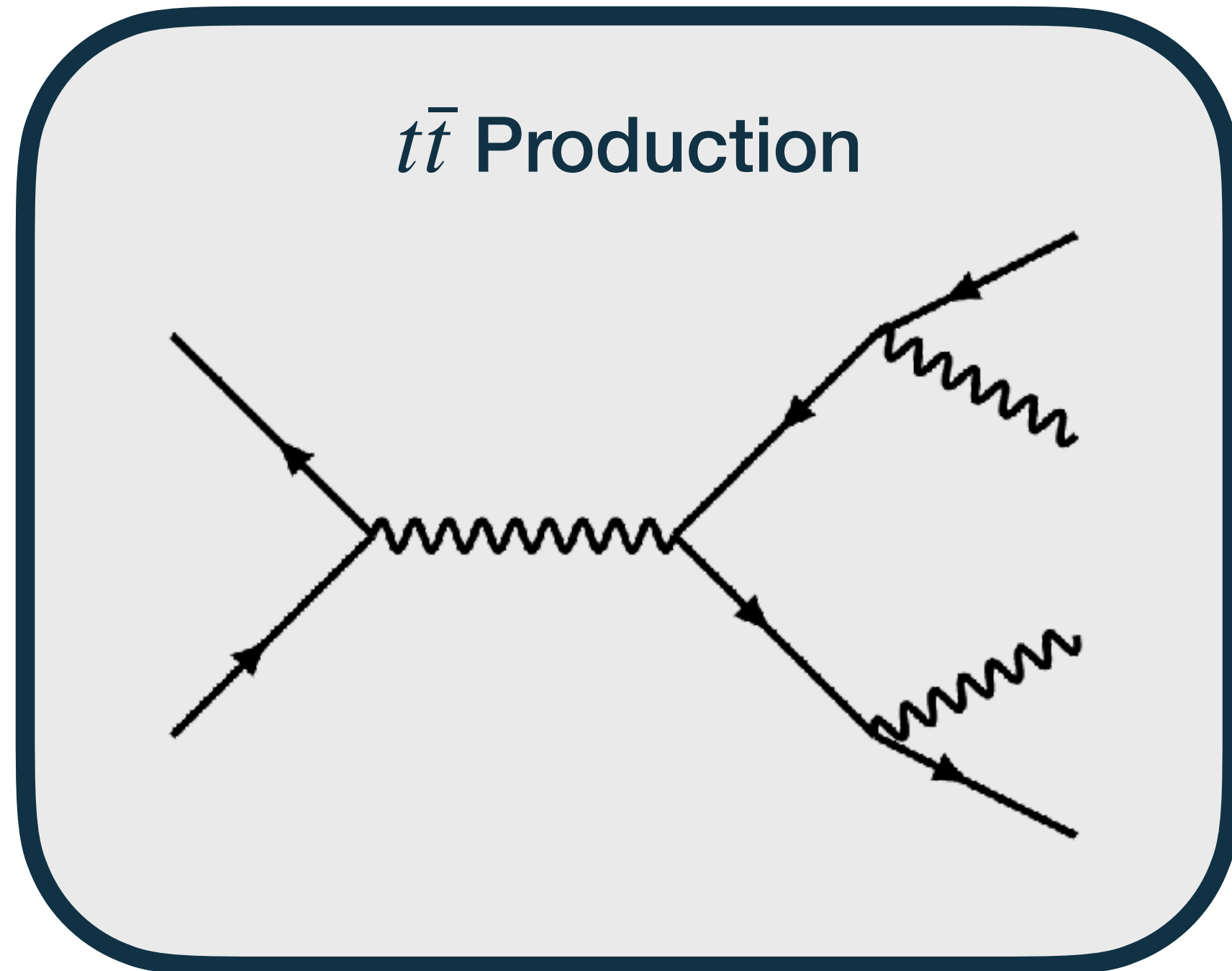
- Two processes are difficult to be distinguished.

  ‣ Share the same final states. ($b\bar{b}q\bar{q}'\ell\bar{\nu}$)

  ‣ Events are mixed in the parton level.

Combination

‣ Charge comparison is necessary to distinguish t and $\bar{t}$.

‣ **VTX x VTX**

One of the ways to compare charges. It compares charges associated to secondary vertices.

- This analysis considered events to correspond to top quark pair production when the following criteria is satisfied for both of W and *b* pairs.

$$|m_{Wb} - m_t^{MC}| < 15 \text{ GeV}$$

If only one of these pair meet this criterium, the events are labeled as single top quark event.

Fuster, J 2015, arXiv:1411.2355 [hep-ex]

b-jet Energy Distribution
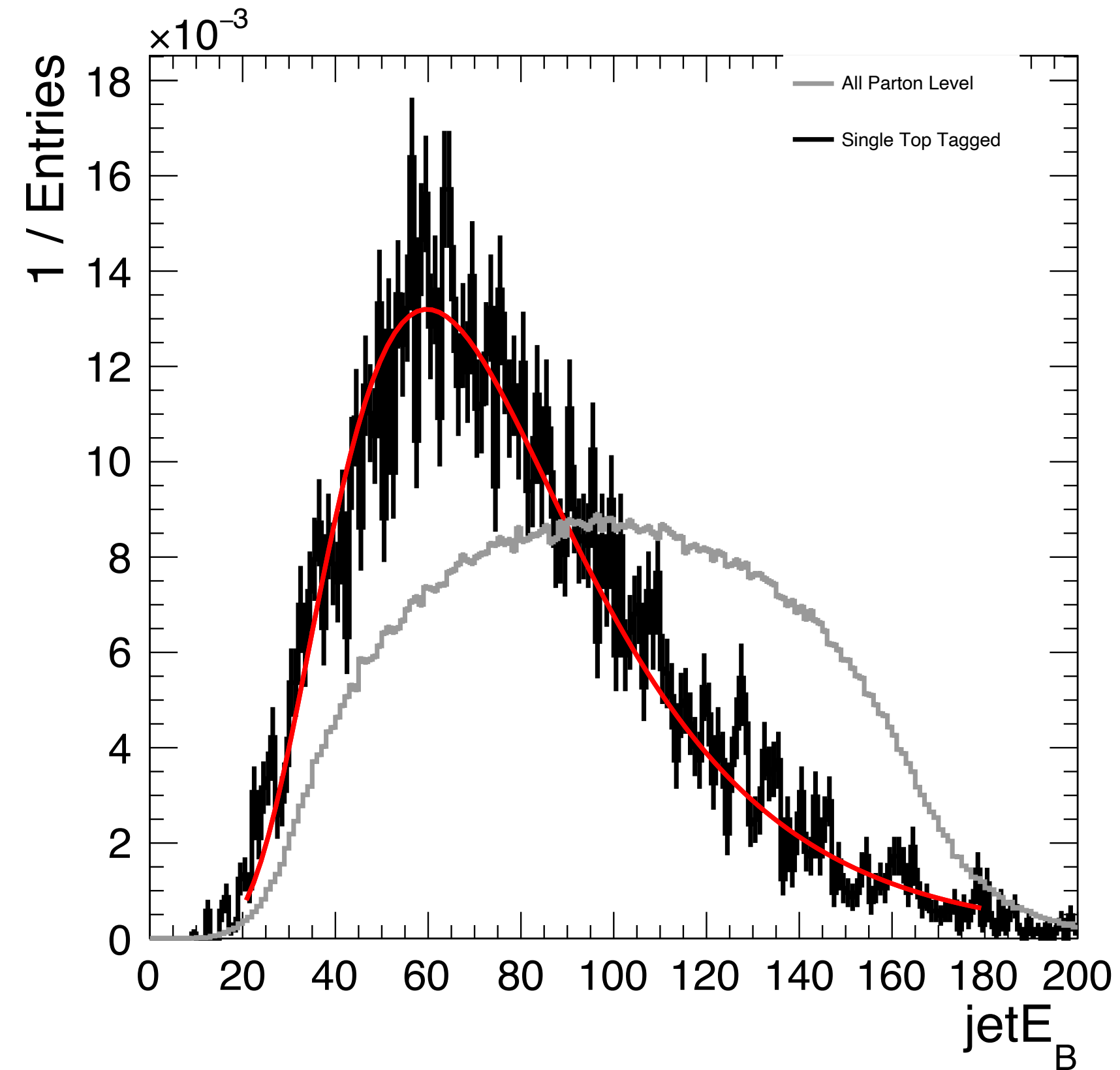
- ‣ b-jet energy distribution of hadronic top for all reconstructed events.
- ‣ black: $\cos\theta < -0.9$ && singleTop tag

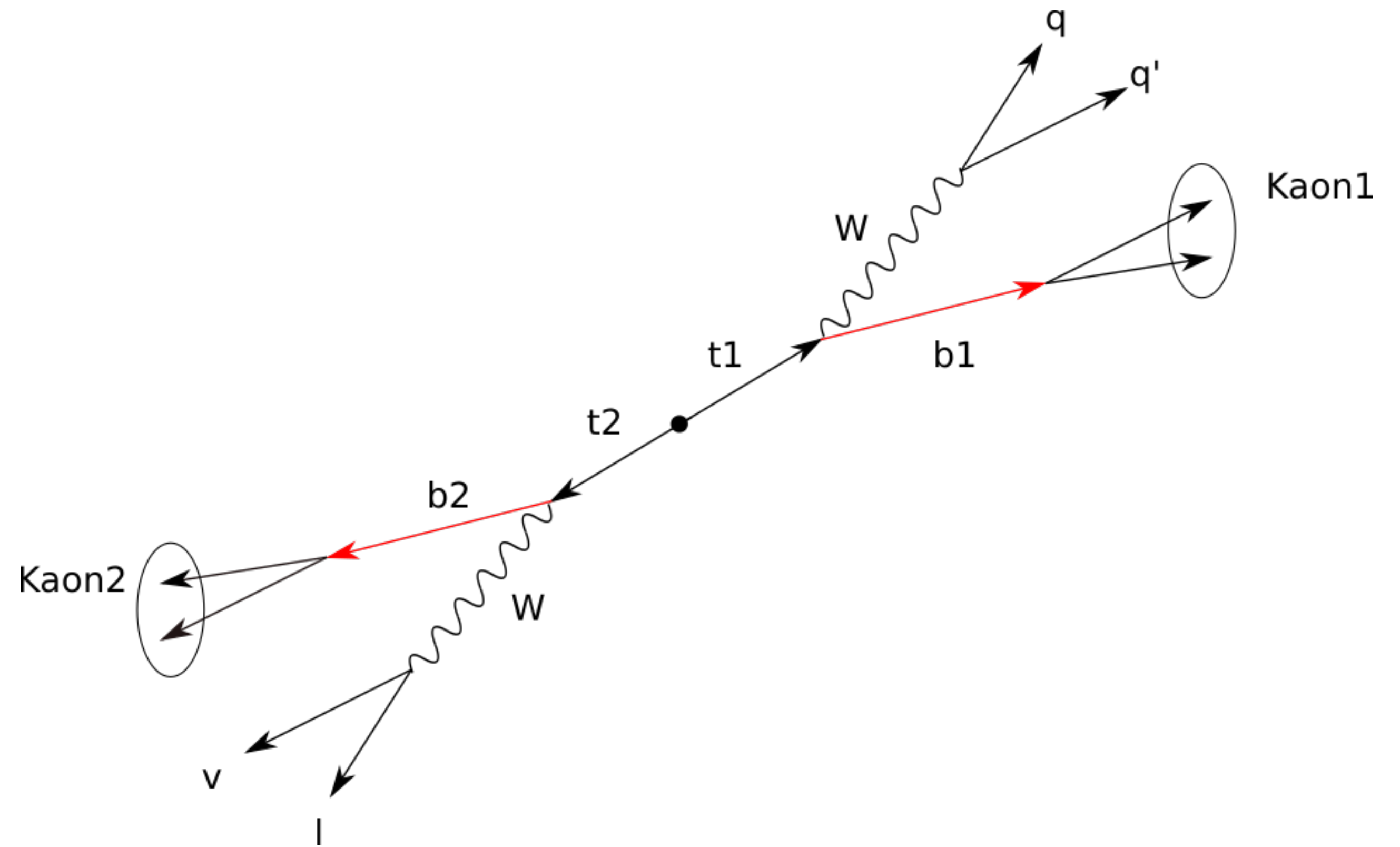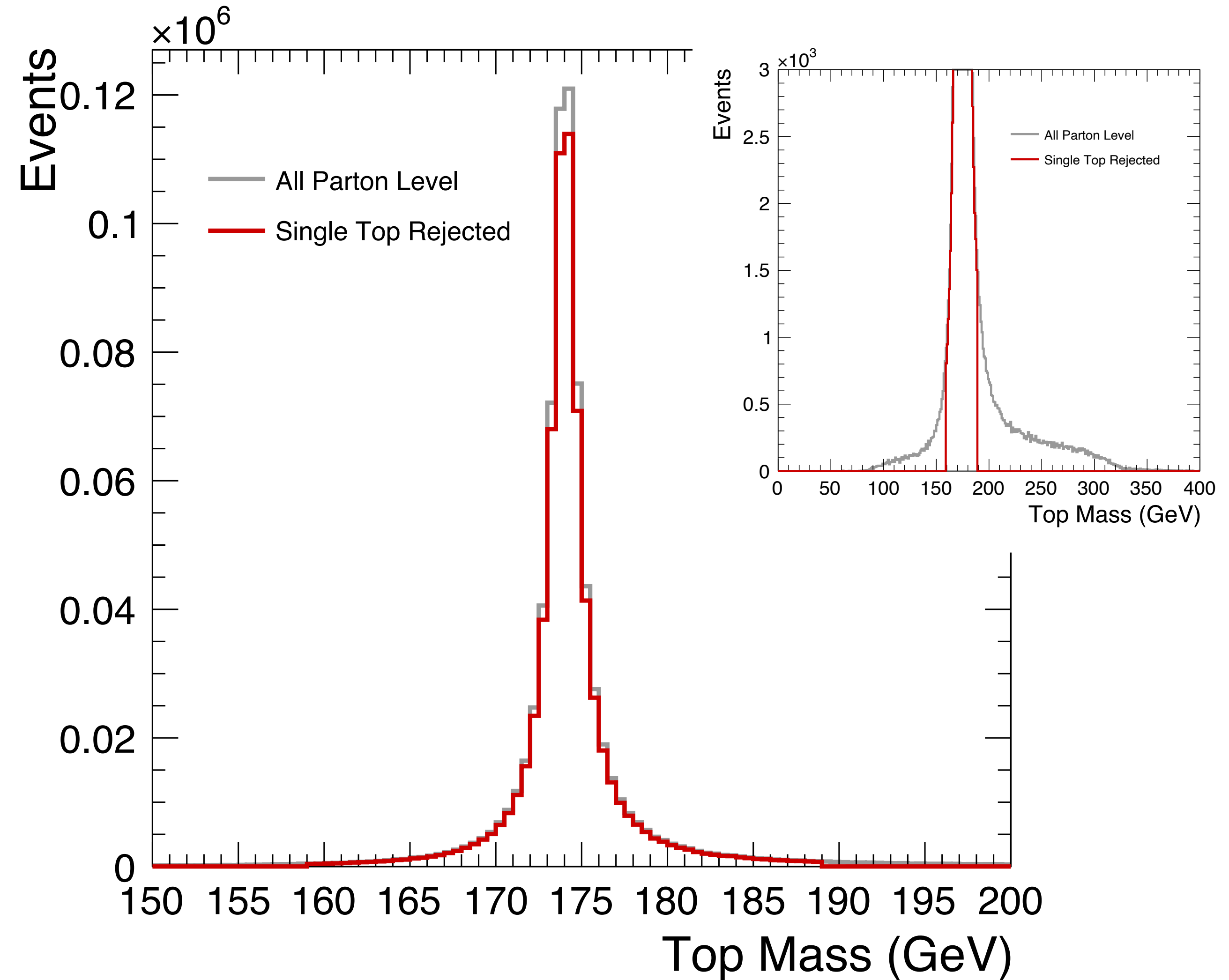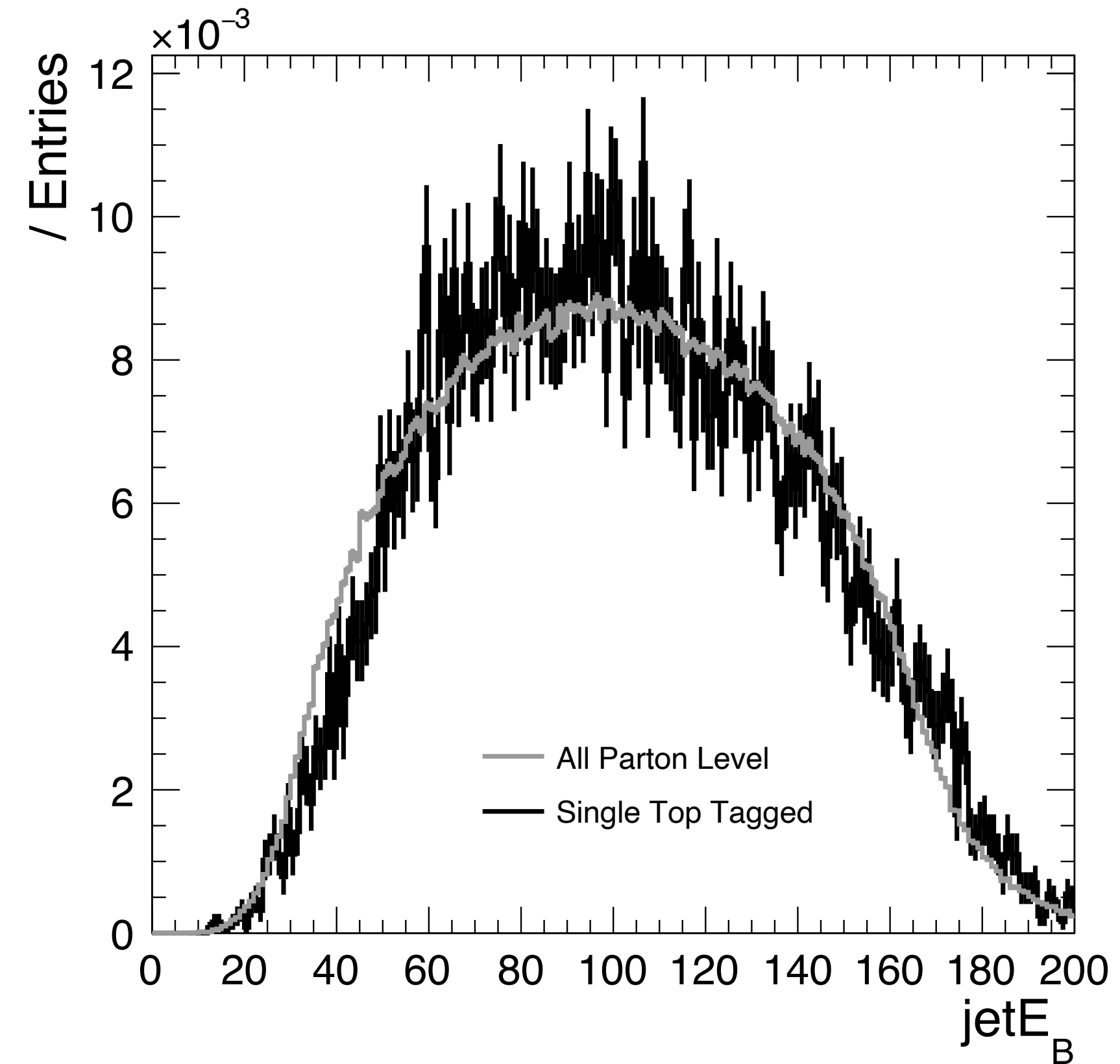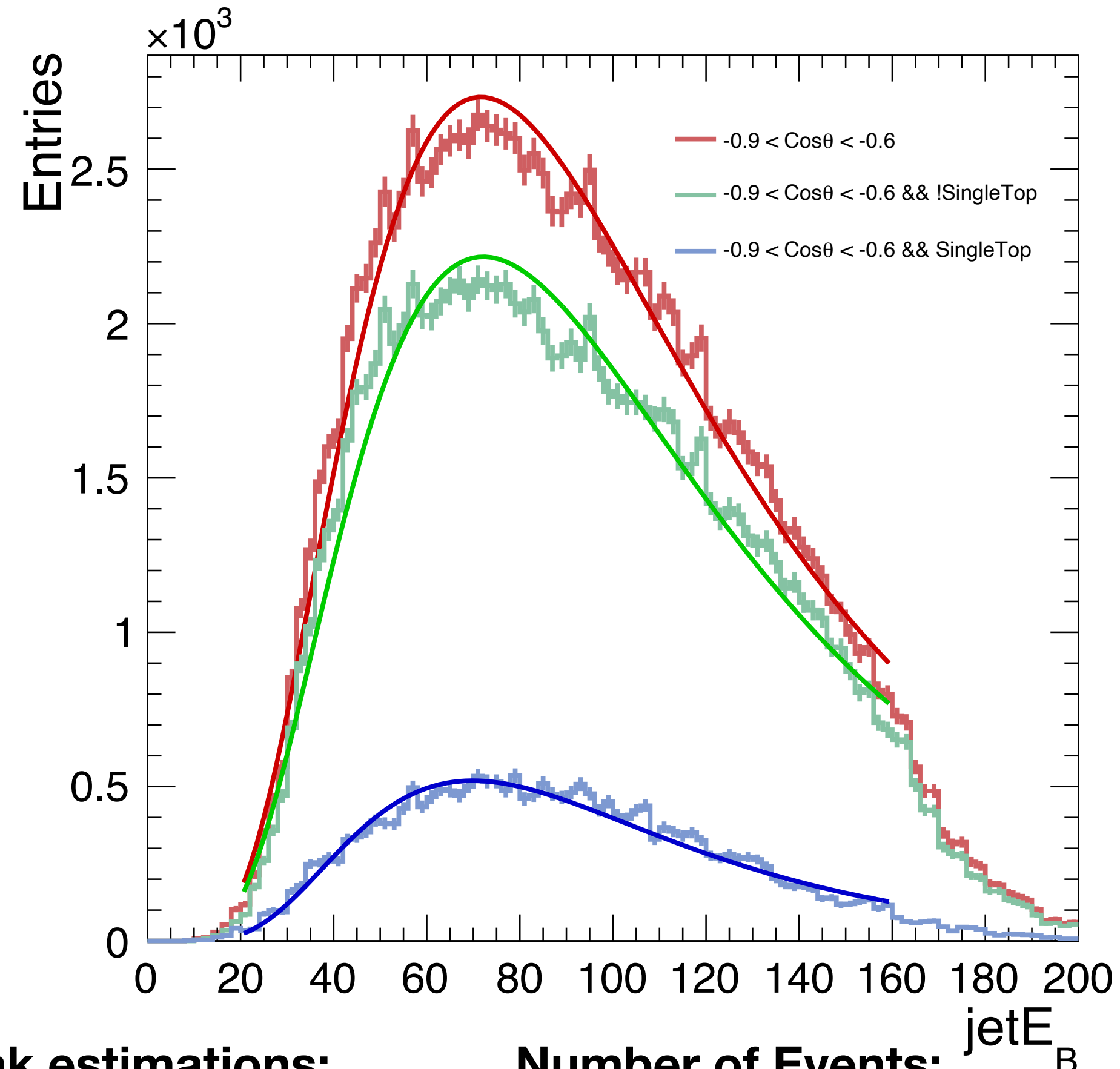- ‣ b-jet energy distribution of hadronic top only using vtx x vtx comparison.
- ‣ black: vtx x vtx && singleTop tag

$\uparrow$

no $\cos\theta < -0.9$

Phase-space region with enrichment of single top events

jetE$_b$ for $-0.9 < \cos\theta_t < -0.6$

Peak estimations: **Number of Events:**

maxRed   = 71.6 GeV   Red Events: 132855

maxGreen = 72.2 GeV   Green Events: 109538

maxBlue   = 69.8 GeV   Blue Events: 23317
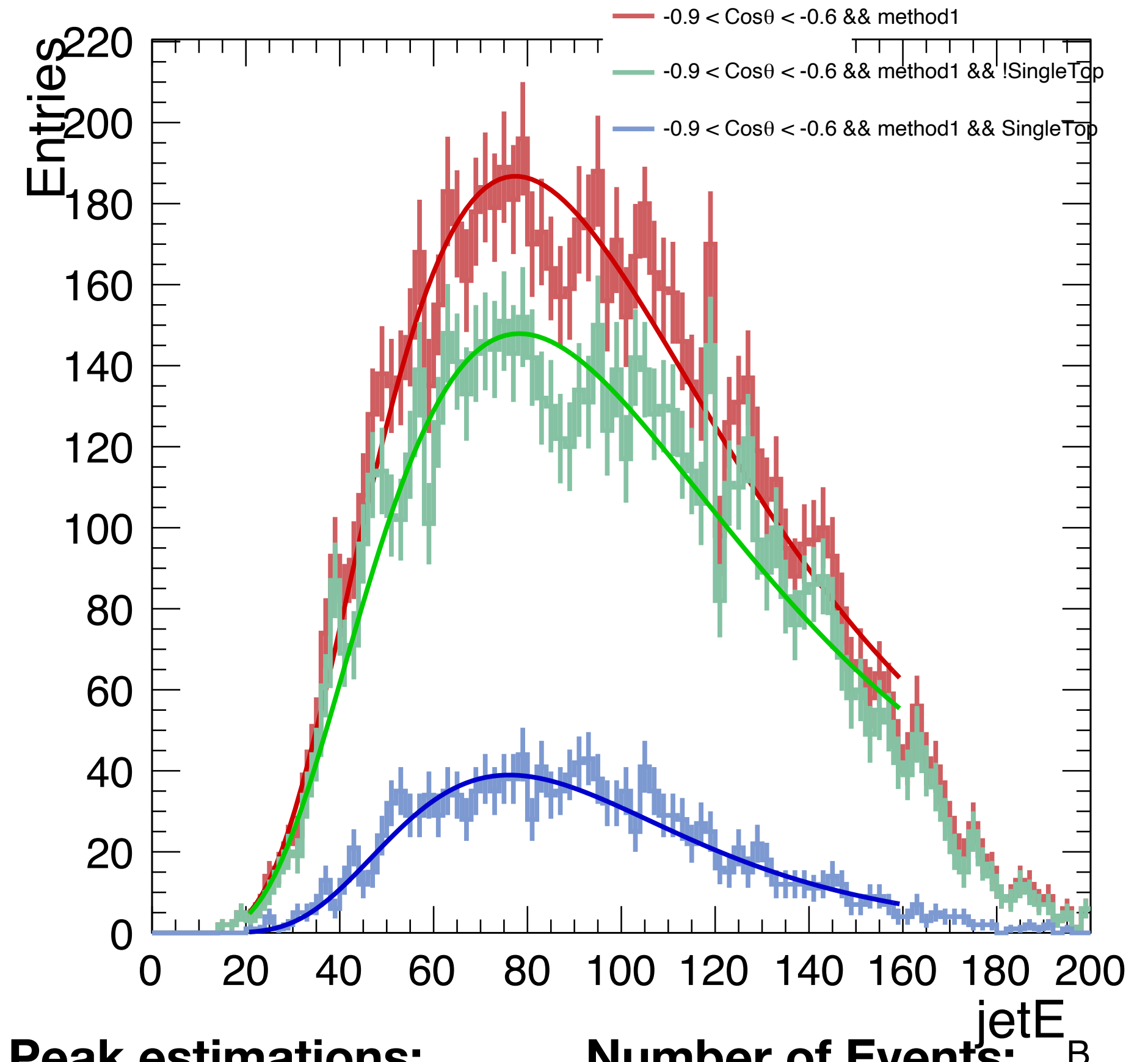
Peak estimations: **Number of Events:**

maxRed   = 77.4 GeV   Red Events: 8918

maxGreen = 78.3 GeV   Green Events: 7319

maxBlue   = 76.1 GeV   Blue Events: 1599

Phase-space region with enrichment of single top events

jetE$_b$ for $-0.9 < \cos\theta_t < -0.6$
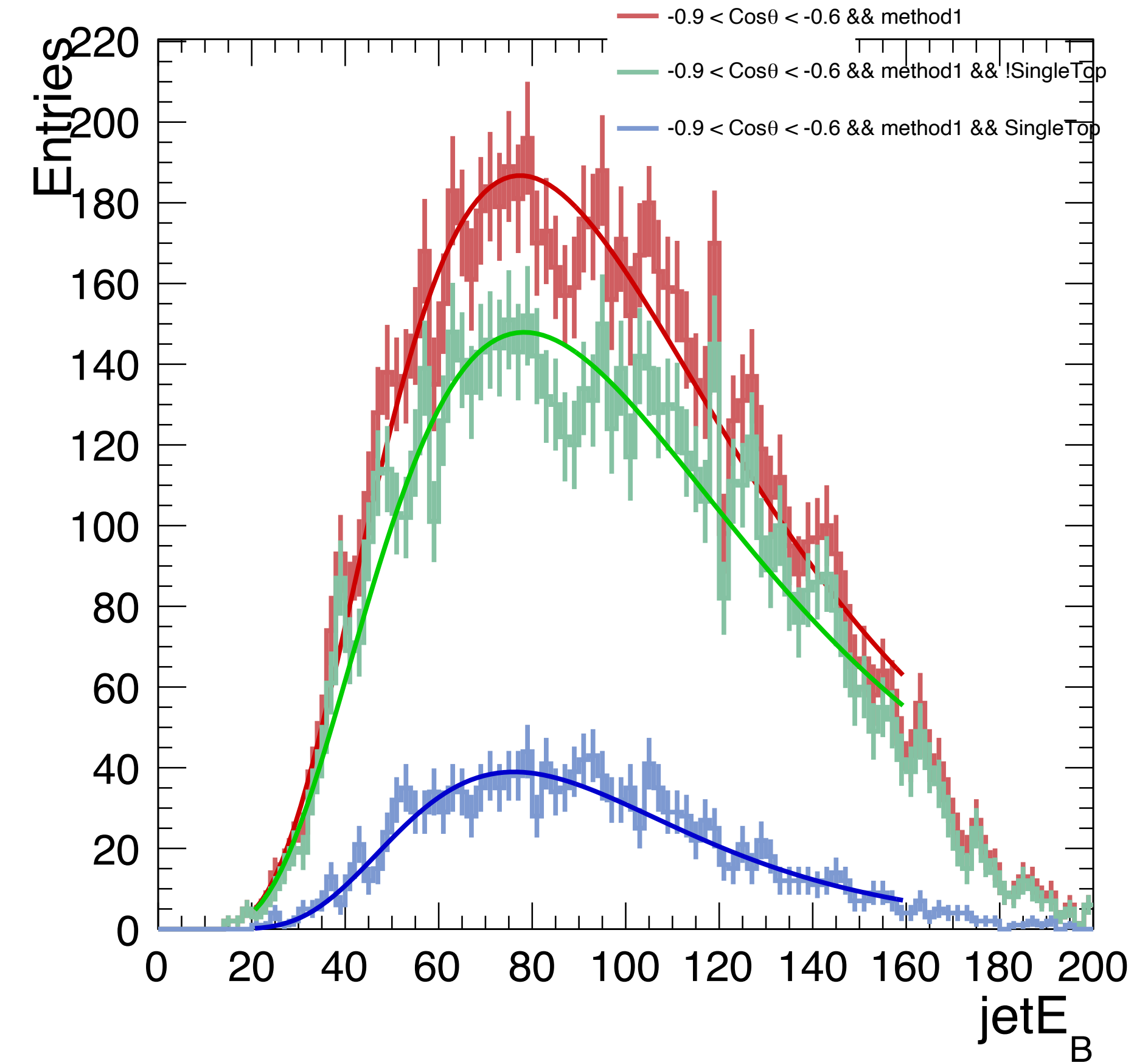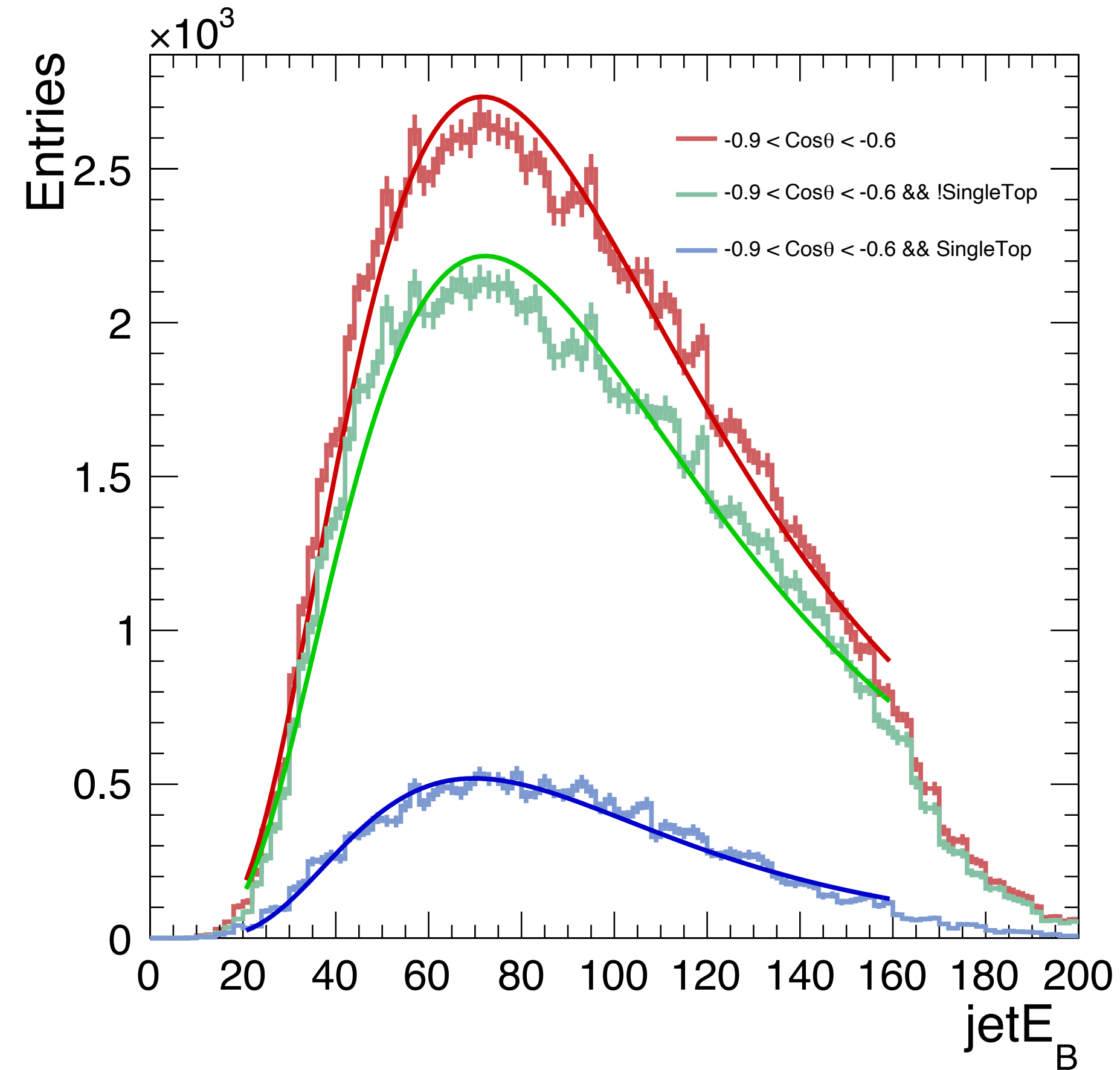
This phase-space region is characterized by the low energetic b-jets. From the distribution, however, there's no obvious difference between single-top and regular tt events. VTX x VTX doesn't suppress much single top events.
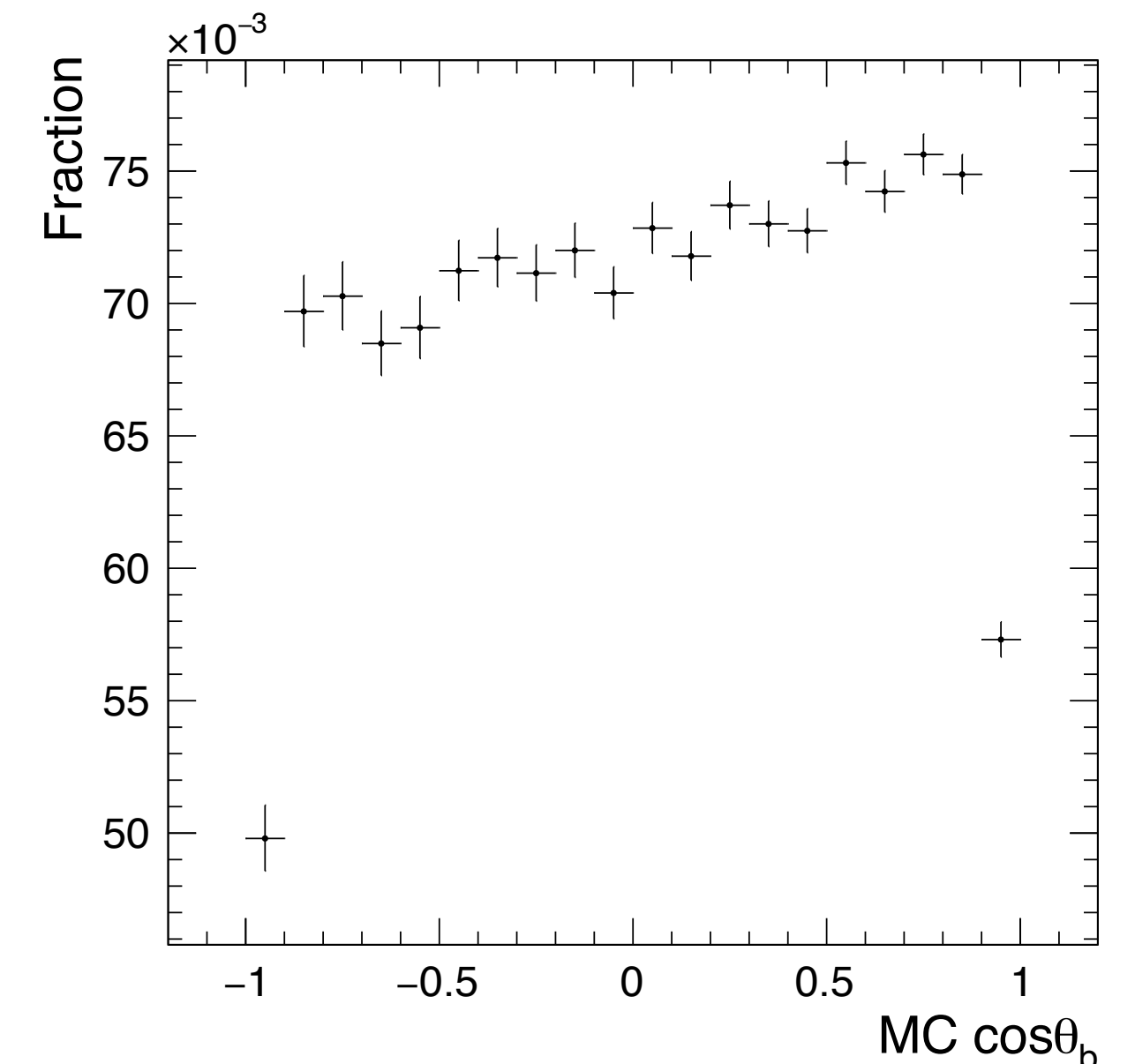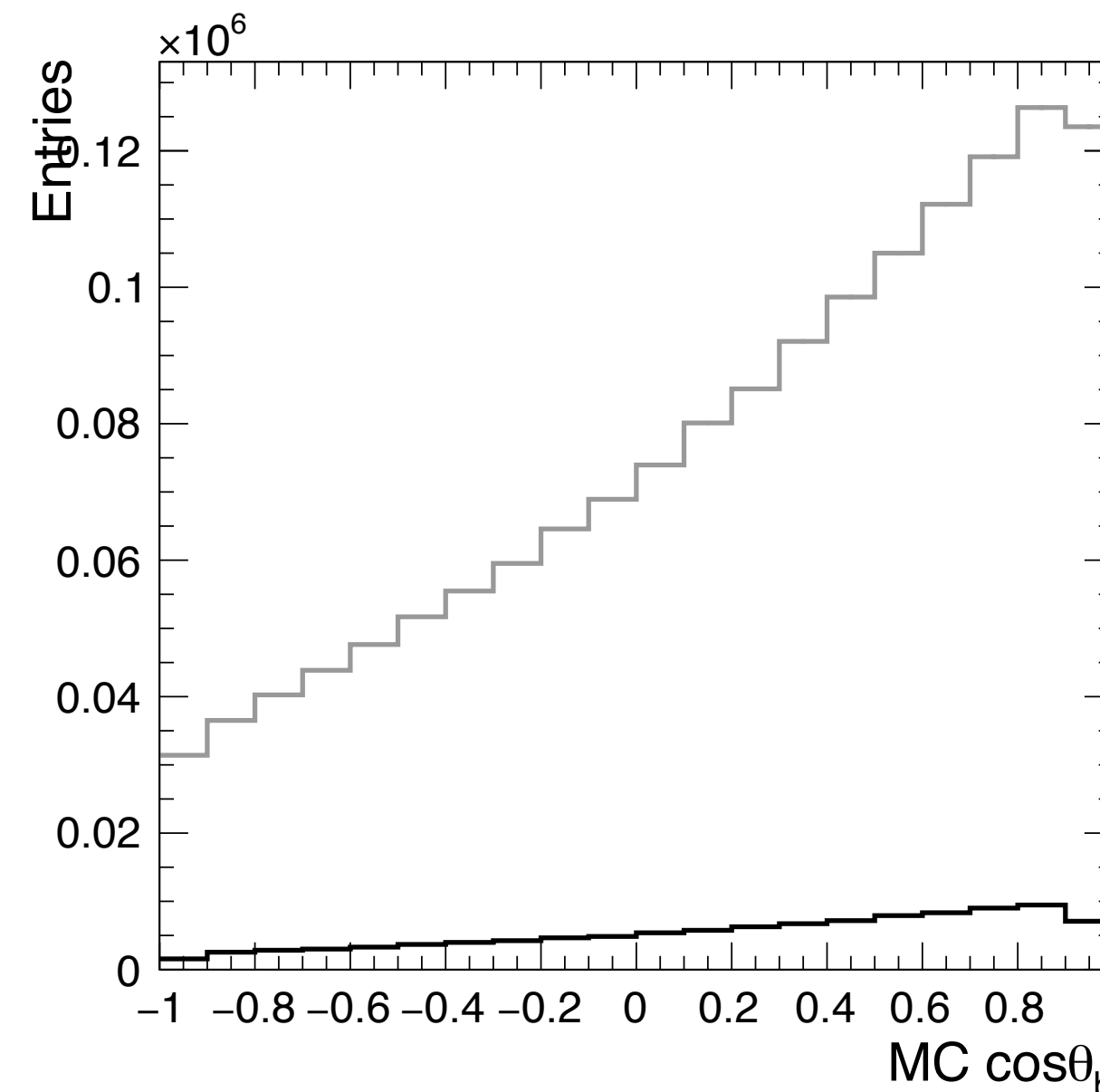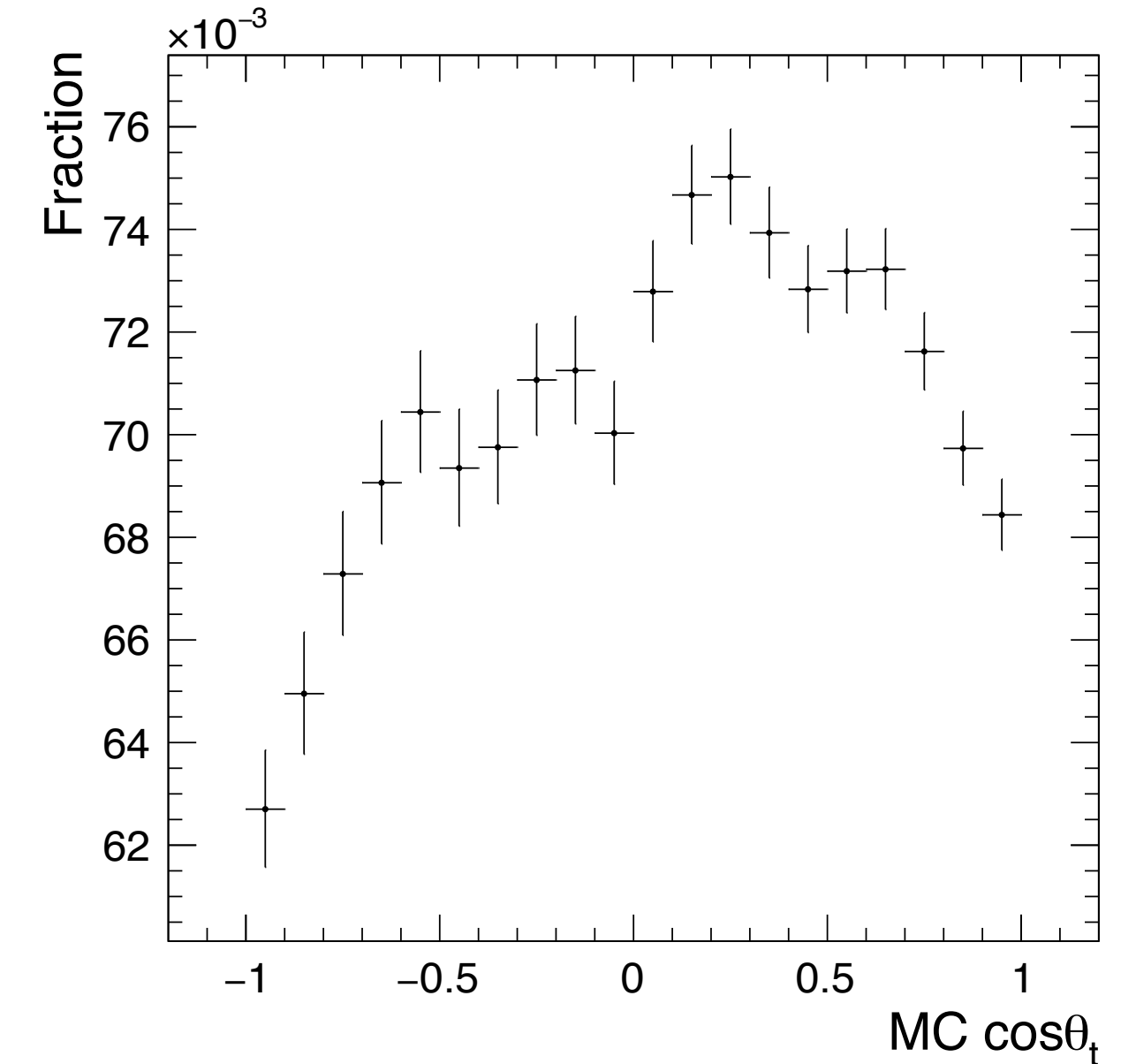
Efficiency Calculation

- In order to seek the parameter dependency of vtx x vtx selection, the efficiency was calculated as following:

$$\text{Fraction} = \frac{\text{\# of events passed vtx x vtx}}{\text{The entire \# of Reconstructed events}}$$

- b polar angle distribution has drop in efficiency at forward and back end of the detector due to acceptance.

- vtx x vtx selection induces non-uniform efficiencies for the regions in which we expect good acceptance.
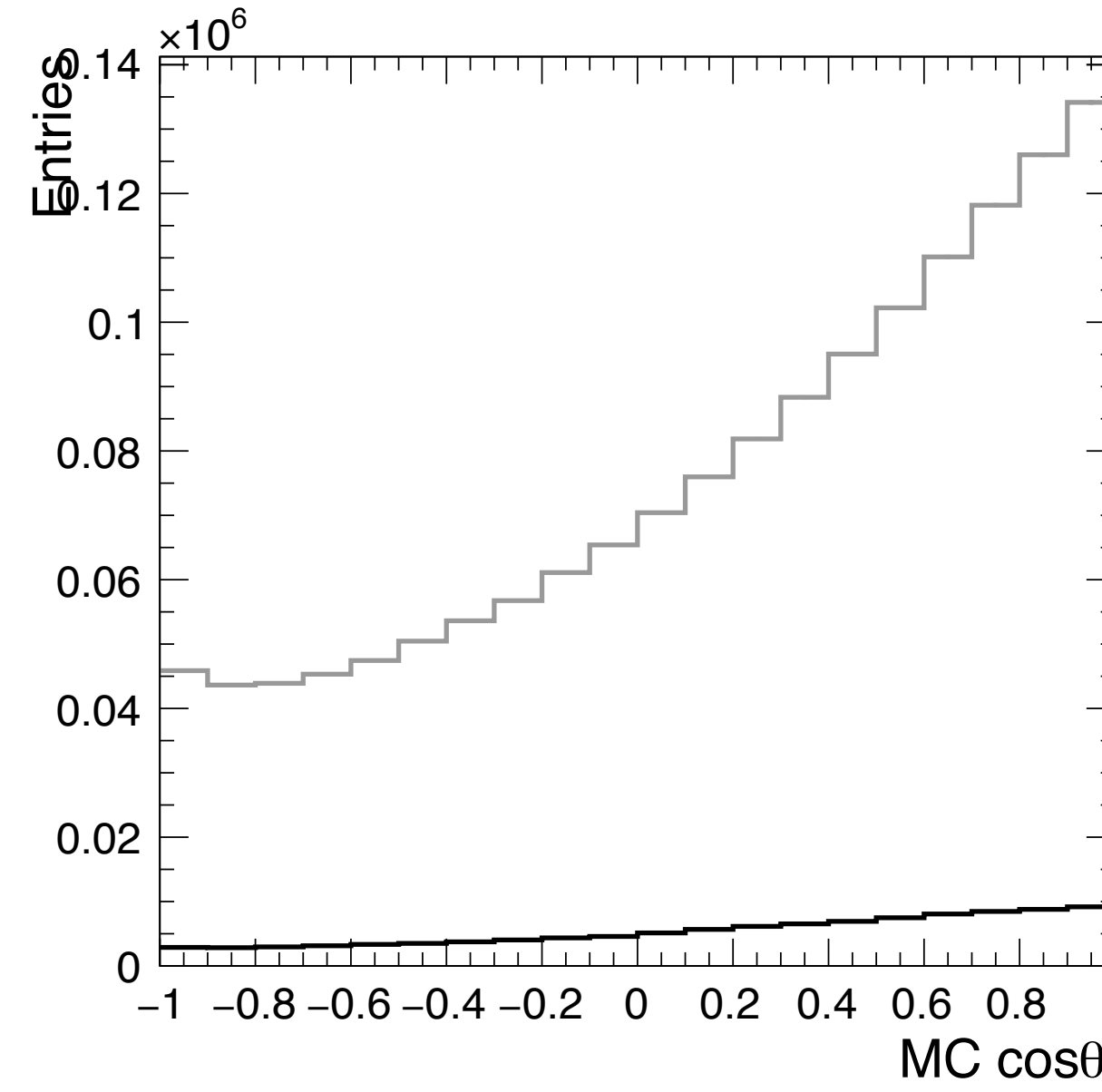
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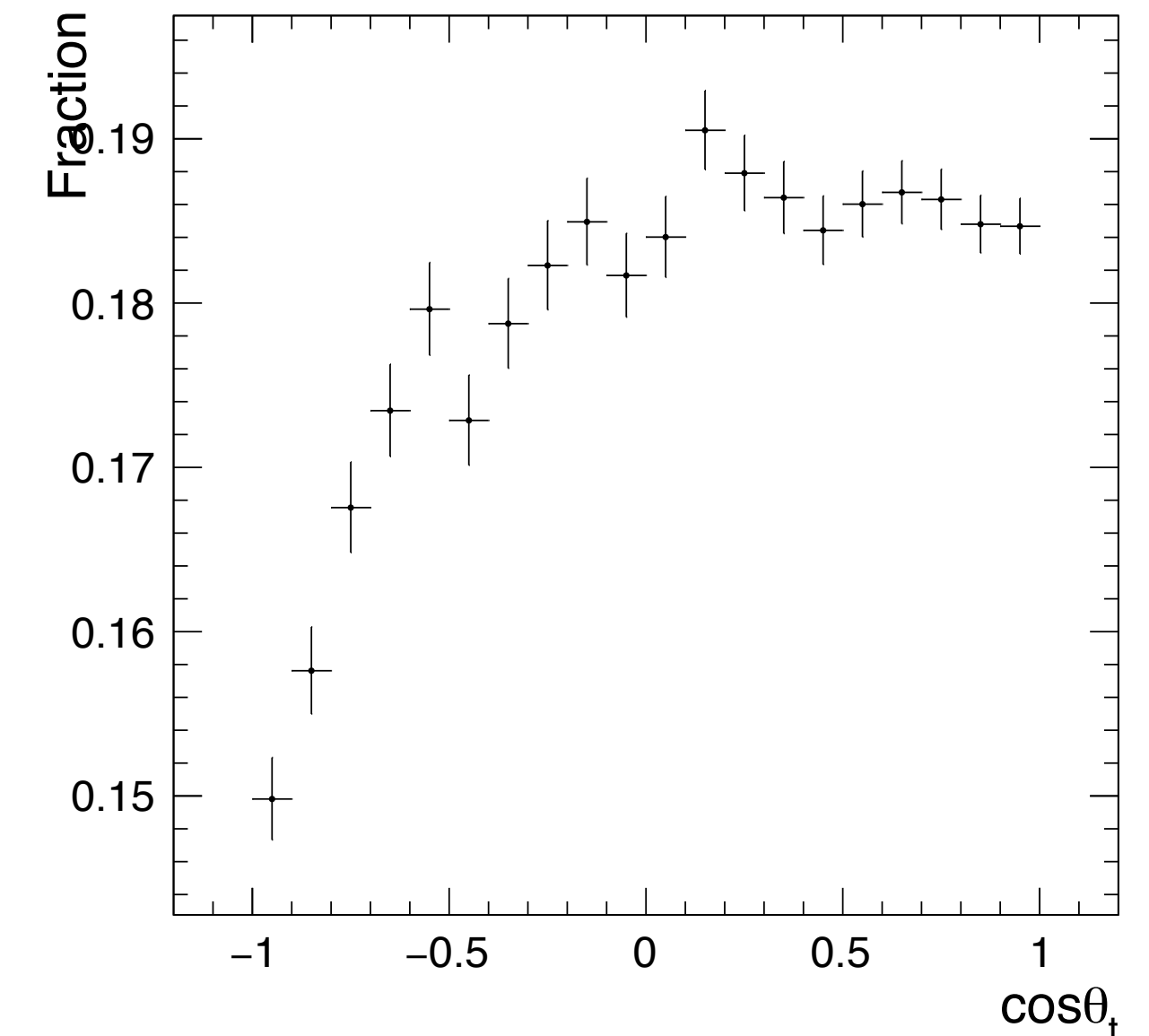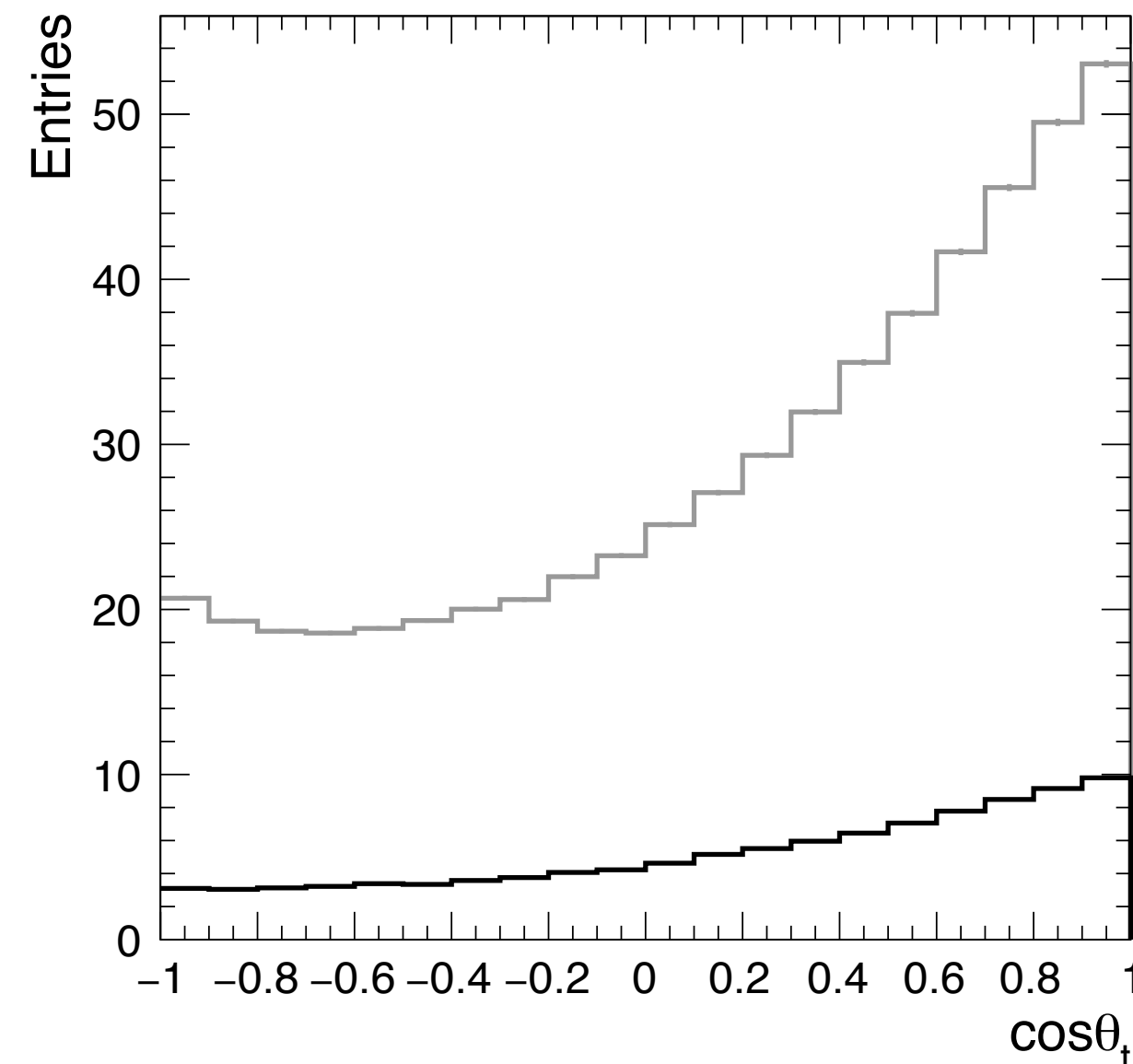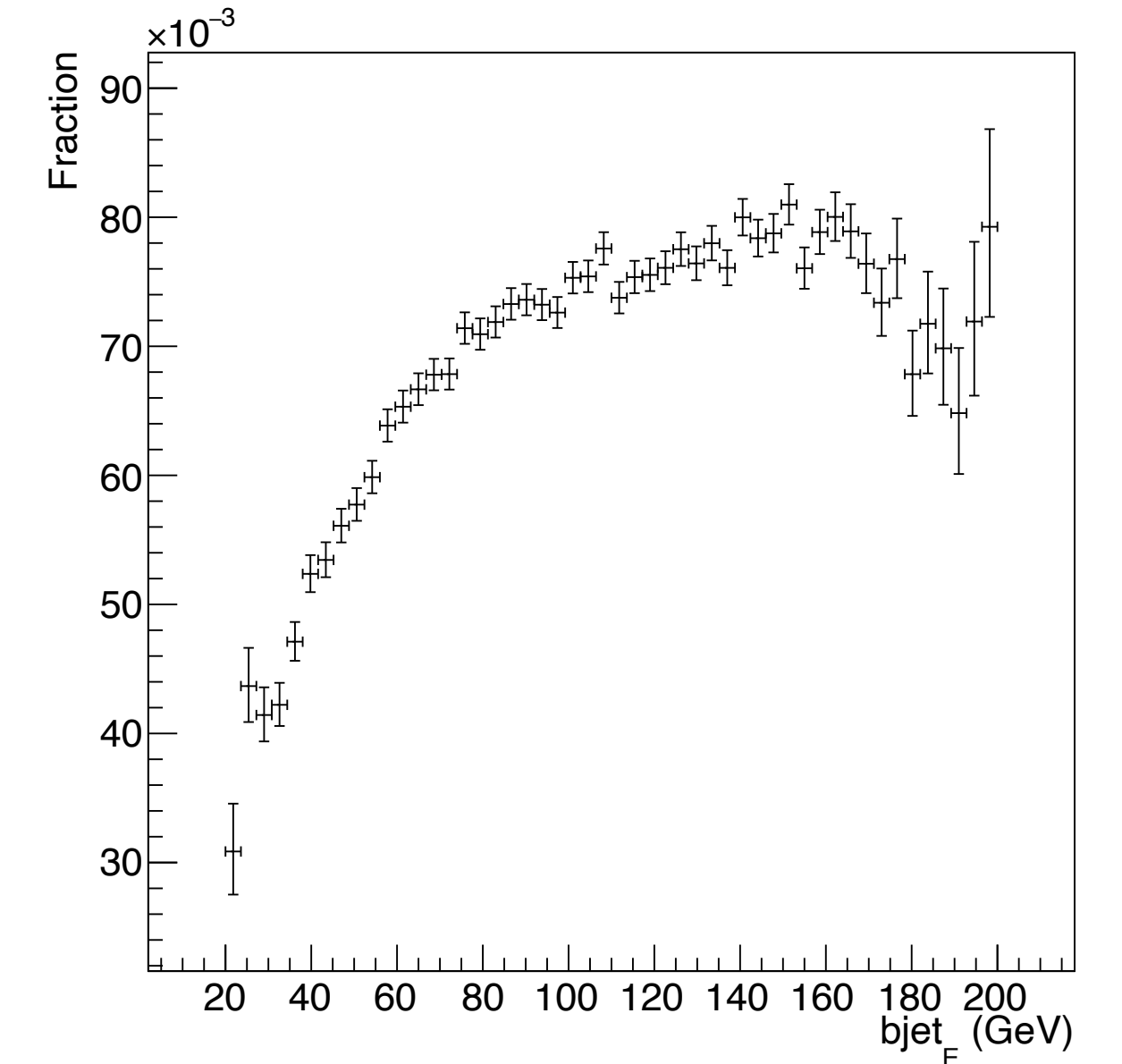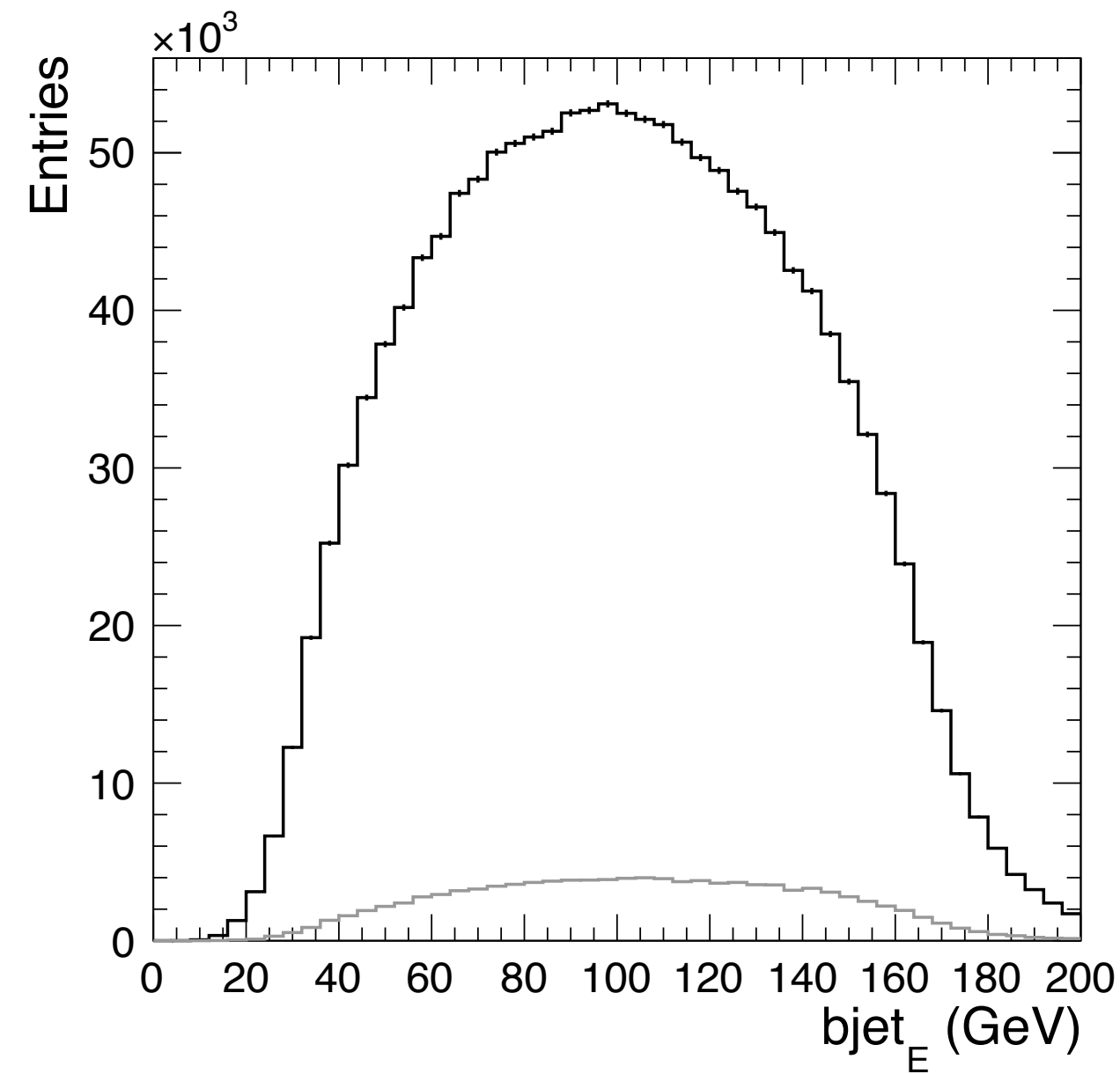
Single Top && -0.9 < cosθ < -0.6

Total # Events: 366718

Selected # Events: 4571

Single Top && -0.9 < cosθ < -0.6 && Method1

Jet Energy
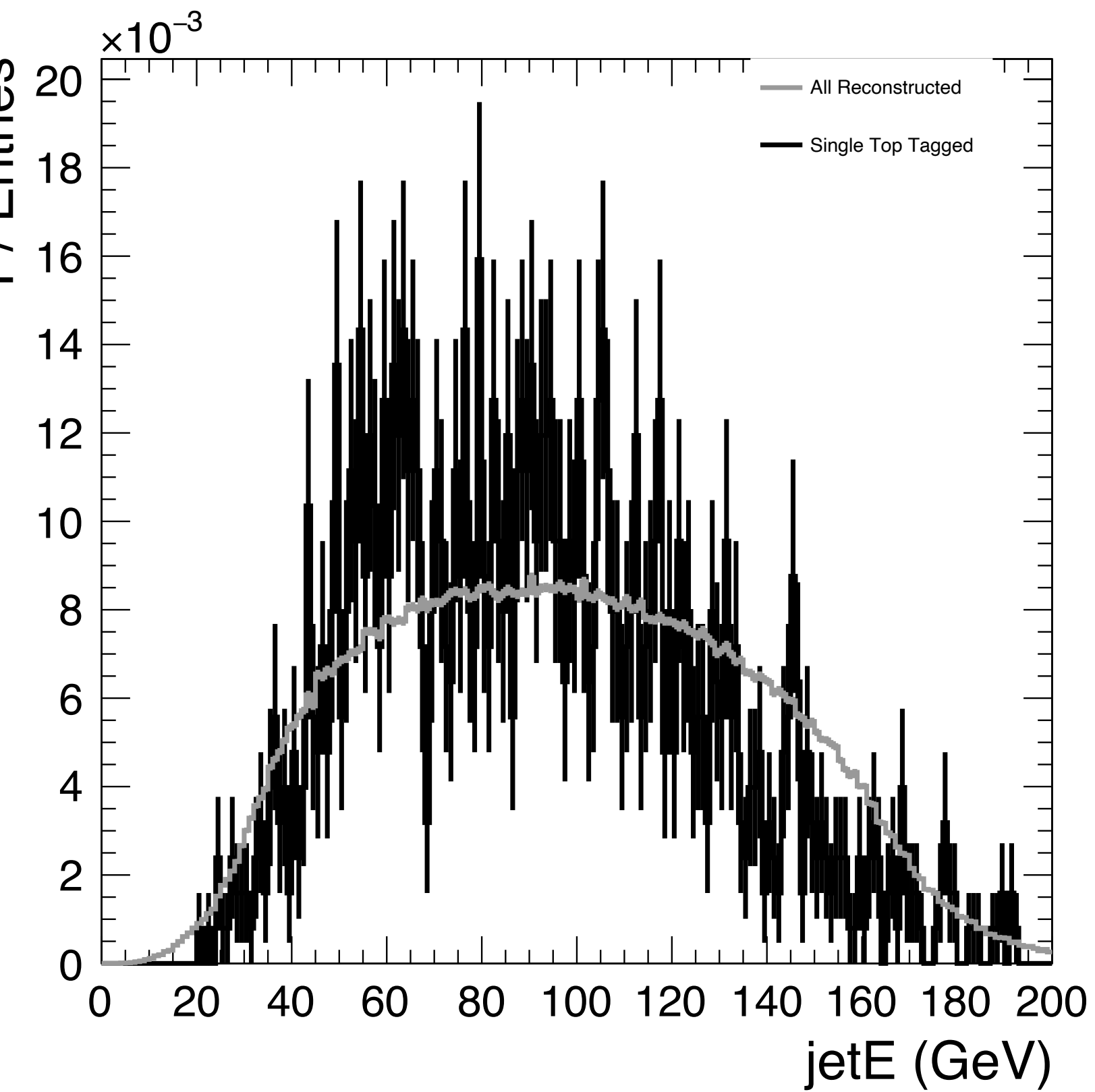
Track Energy
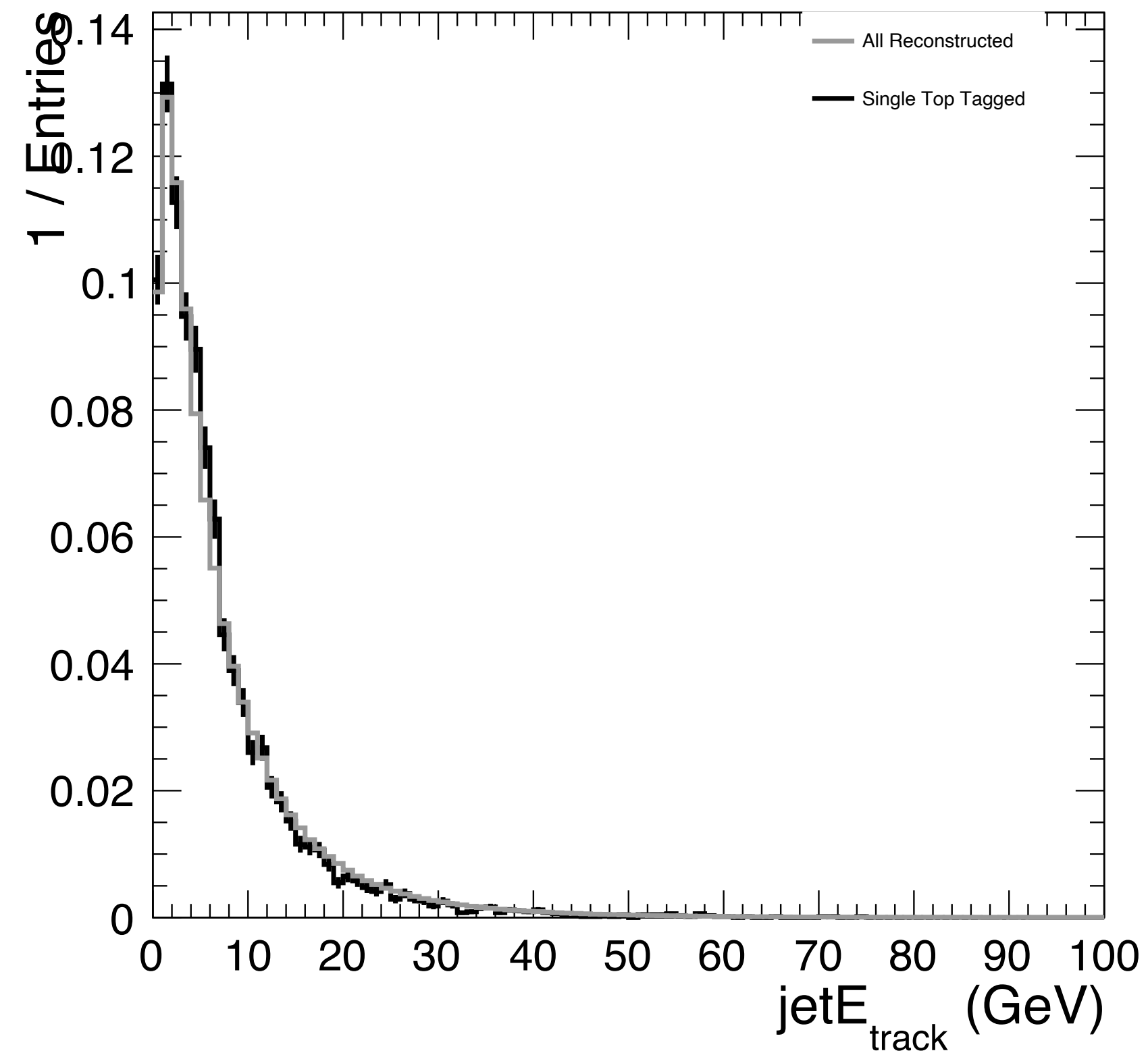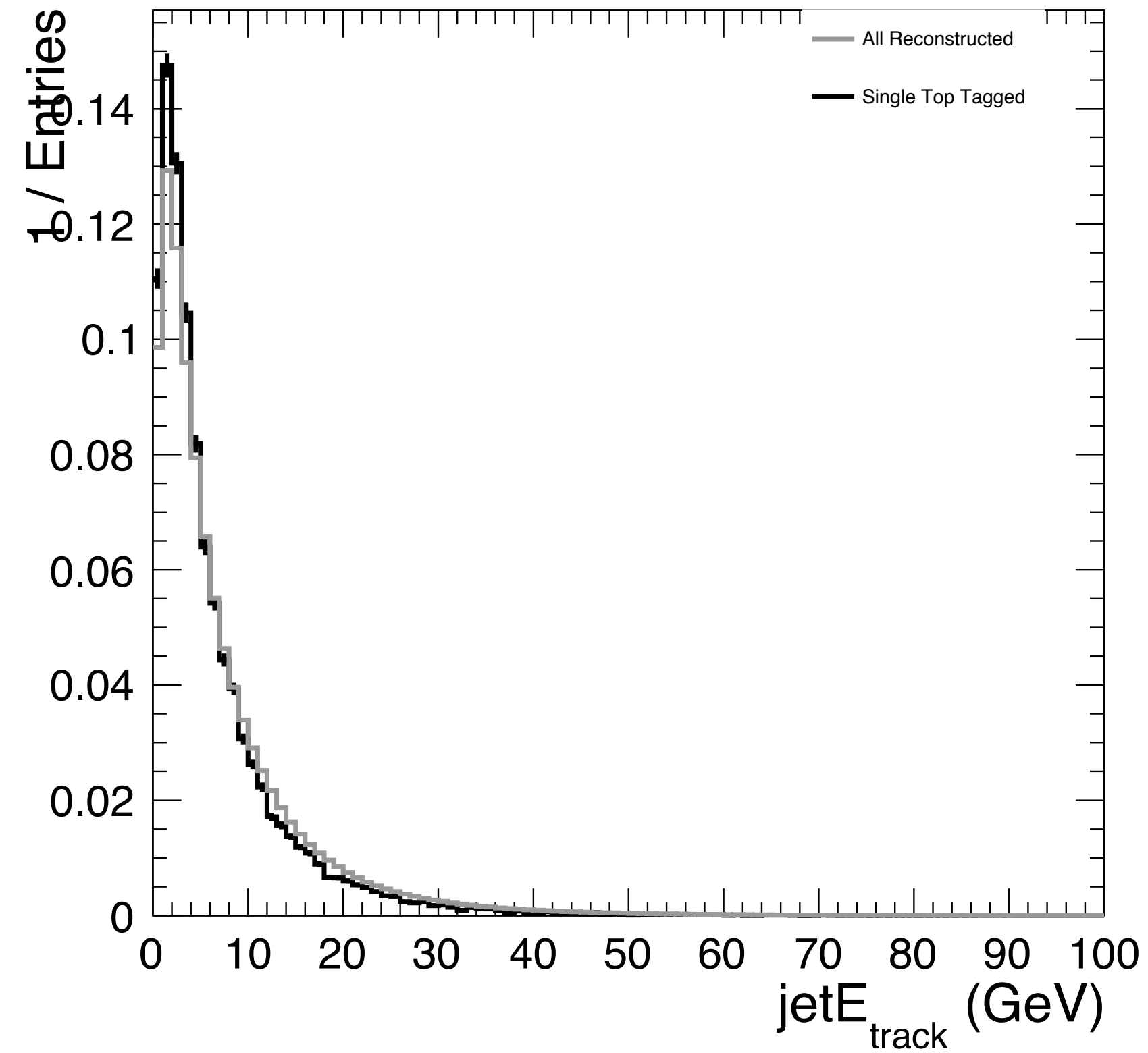
Track Momentum

Total # Events: 366718

Selected # Events: 628

Single Top && -0.9 < cosθ < -0.6 && NOT Method1
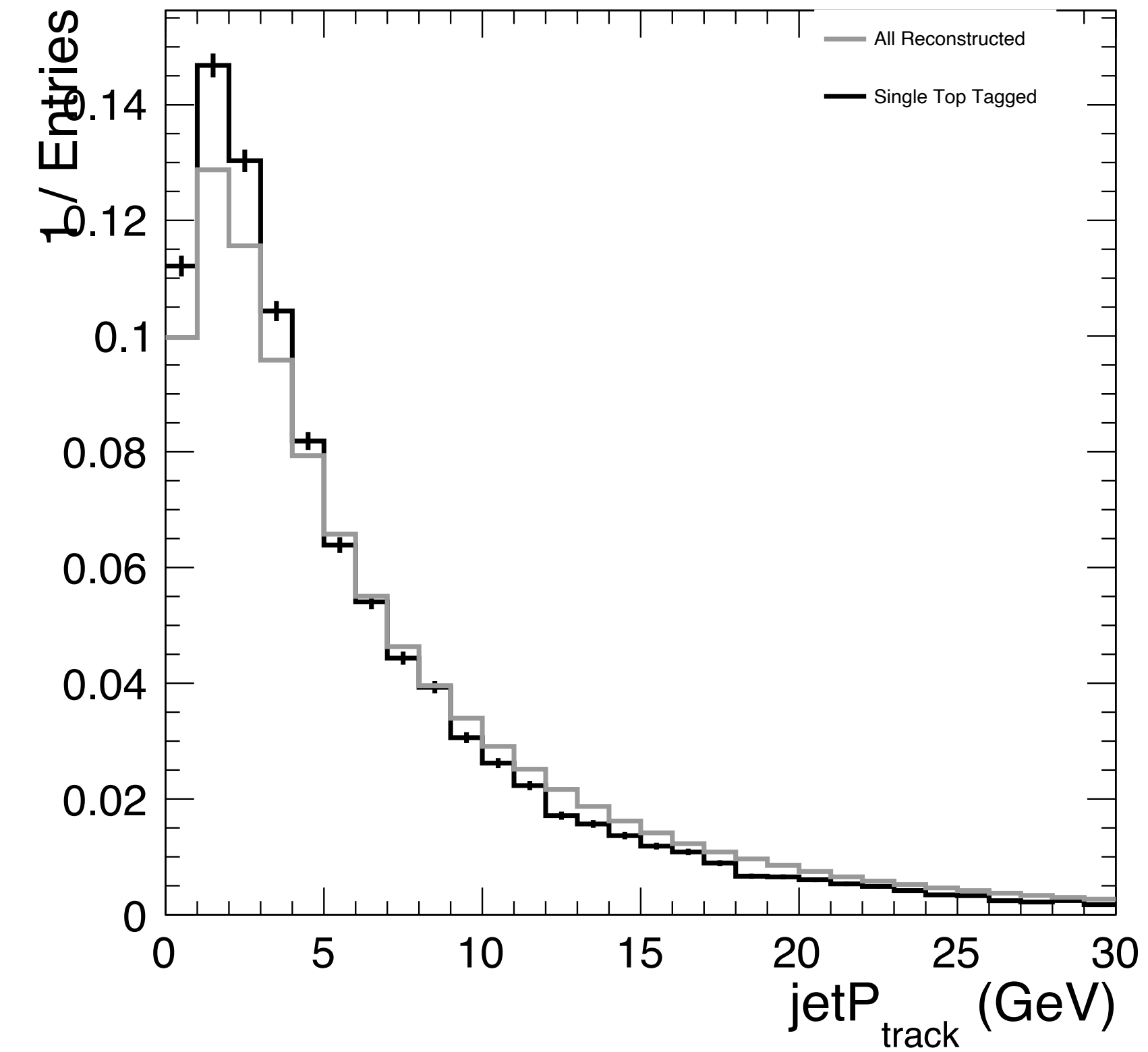
Total # Events: 366718

Selected # Events: 3943

5. Conclusion

- Reconstructed spectrum for the polar angle distribution of top was tilted when **vtx x vtx** method was applied.

- In the $t\bar{t}$ analysis, this inefficiencies may have been compensated by the other methods (e.g. kaon x kaon, isolated lepton chg, etc…)

- Detector optimization is required to avoid inefficiencies come with vtx x vtx selection.

  ‣ We need to clearly define the goals for the optimization.

  ‣ Revisit vertex restorer and apply a correction with the help of the MC.

1. Single Top Contributions

   - The distribution tends to accumulate at the lower end of polar angle. ($-0.9 < \cos\theta_t < -0.6$ region was investigated)

2. Reconstruction bias from **vtx x vtx**

   - vtx x vtx comparison method fails to reconstruct the events with soft b-jets. (in particular, b-jets with low track energy and momentum)

   - The bias also serve as filter against single top events yet the contribution is very weak.

5. Conclusion

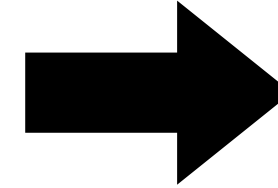- Reconstructed spectrum for the polar angle distribution of top was tilted when **vtx x vtx** method was applied.

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Backup

4. Single Top Analysis

- **Generated Lep/Had Top Mass**
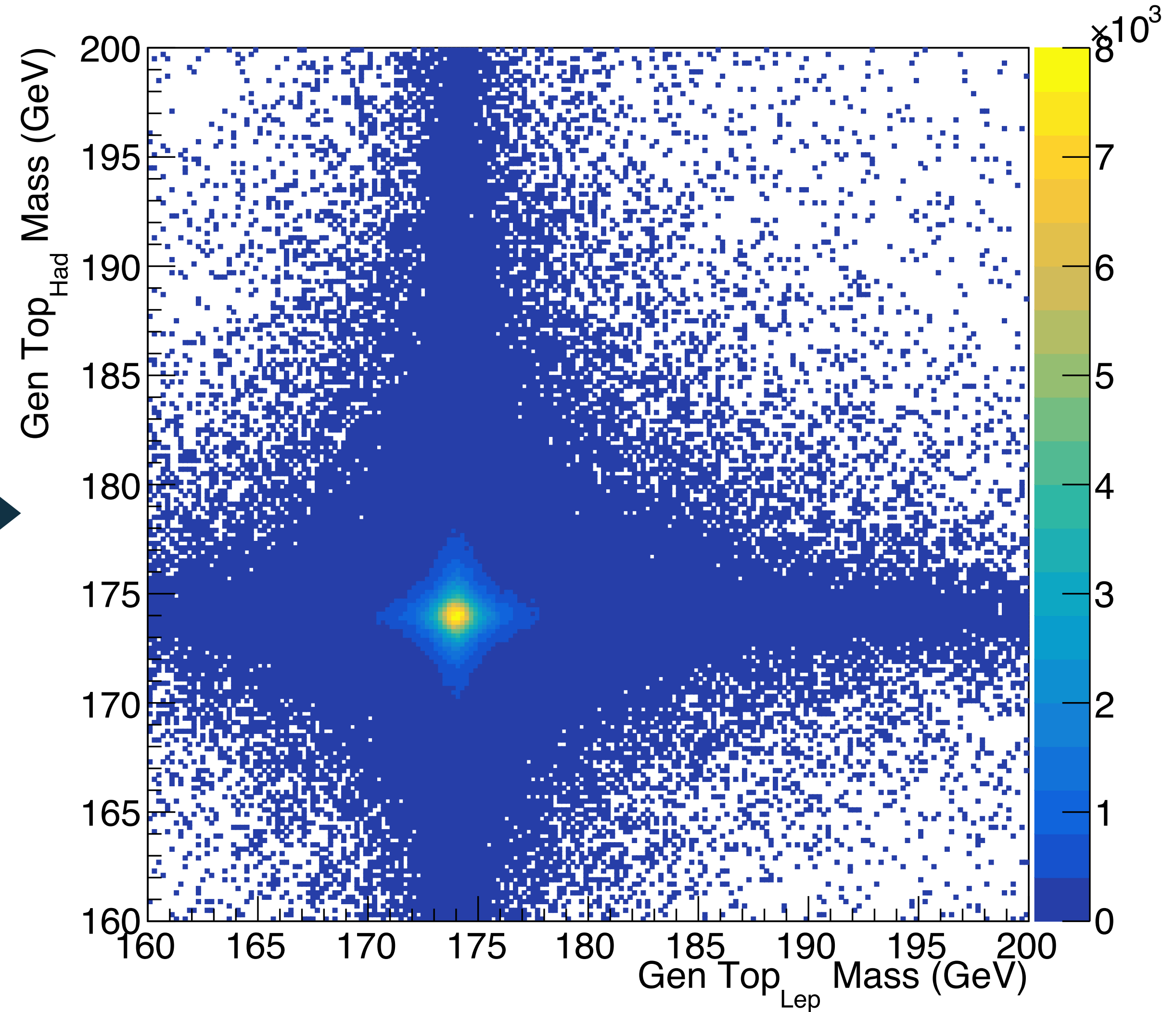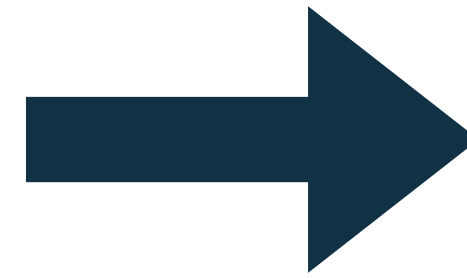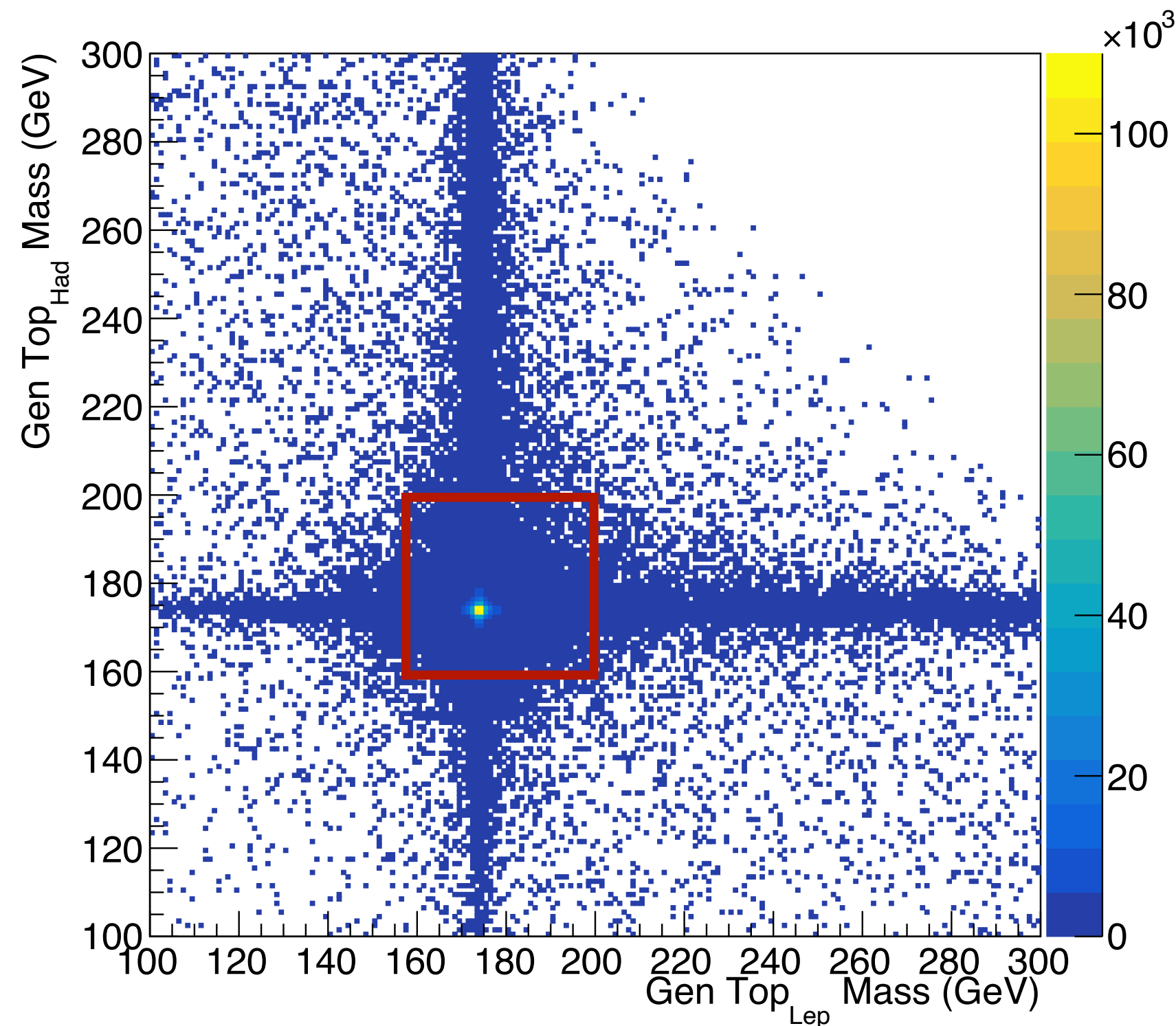
▸ Events clusters around 174 GeV region yet still huge amount of off-shell events.

3. Single Top Analysis

MC Top mass

$|M_{bW} - M_{top}| < 15$ GeV

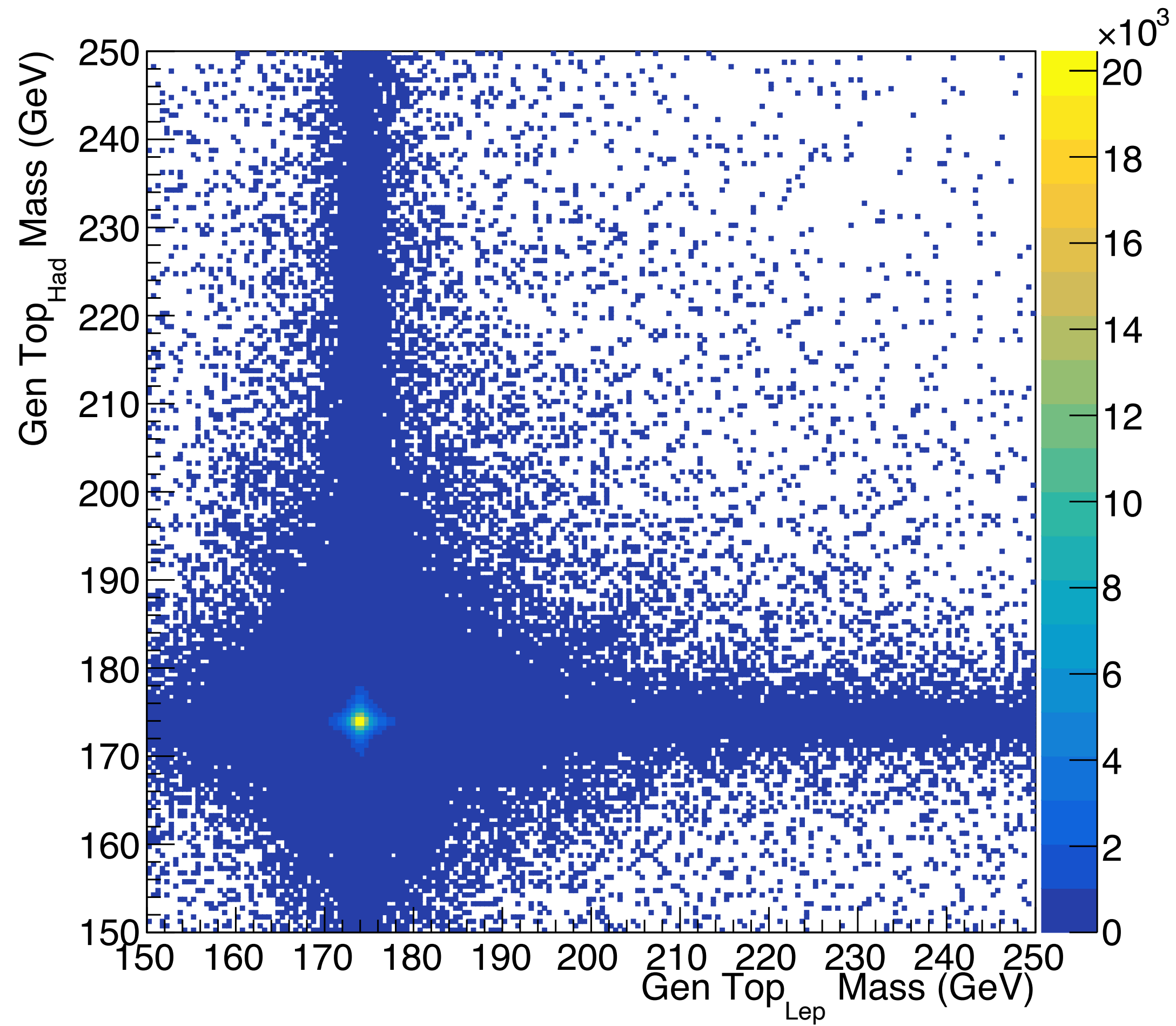‣ Gen Top mass for the entire events

‣ Gen Top mass after single Top ID

3. Single Top Analysis

Reco Top mass

‣ Reco Top mass for the entire events (Top1=Had, Top2=Lep)

‣ Reco Top mass after single Top ID

3. Single Top Analysis

Reco Top mass (zoomed)
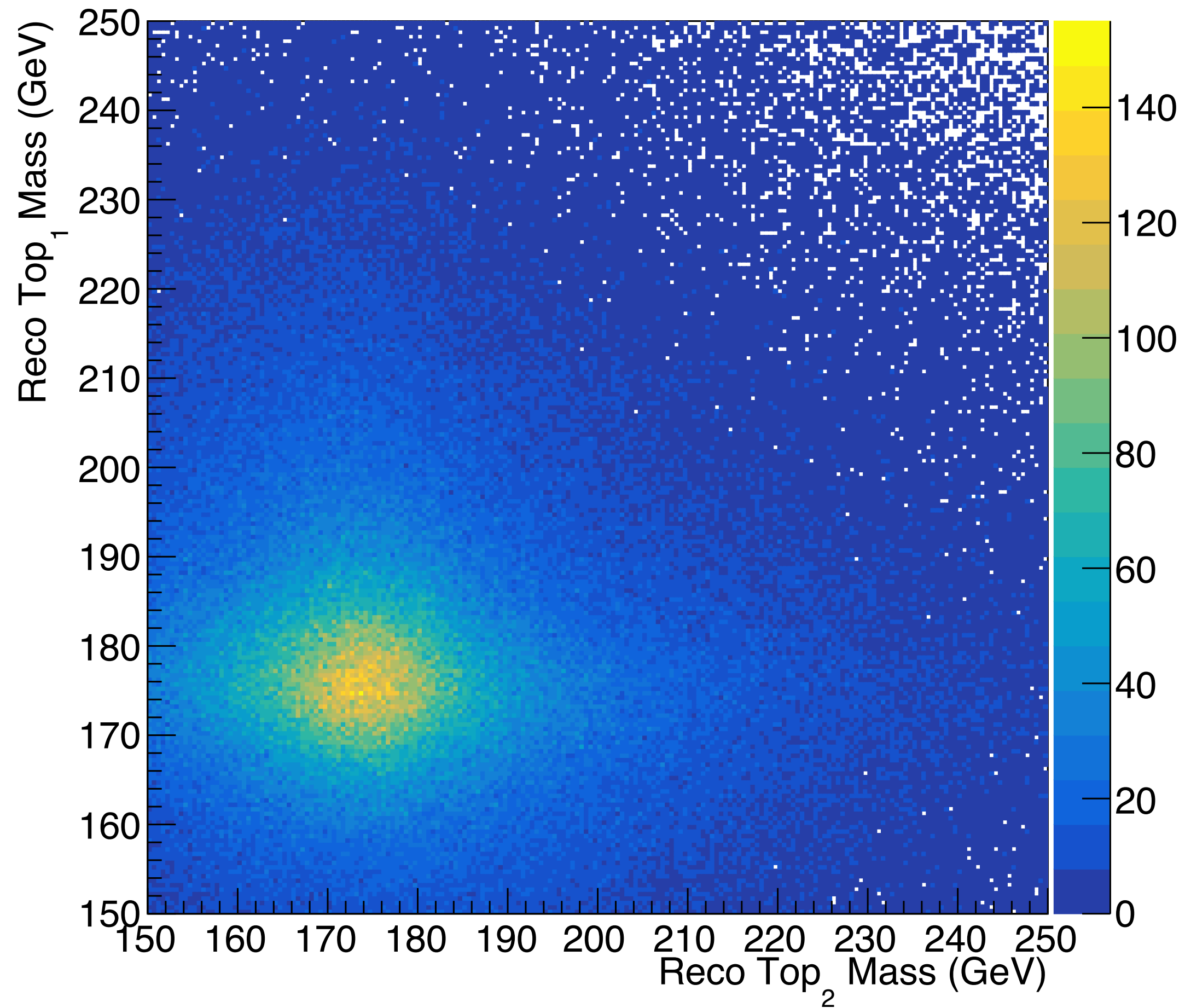
▸ Reco Top mass for the entire events (Top1=Had, Top2=Lep)
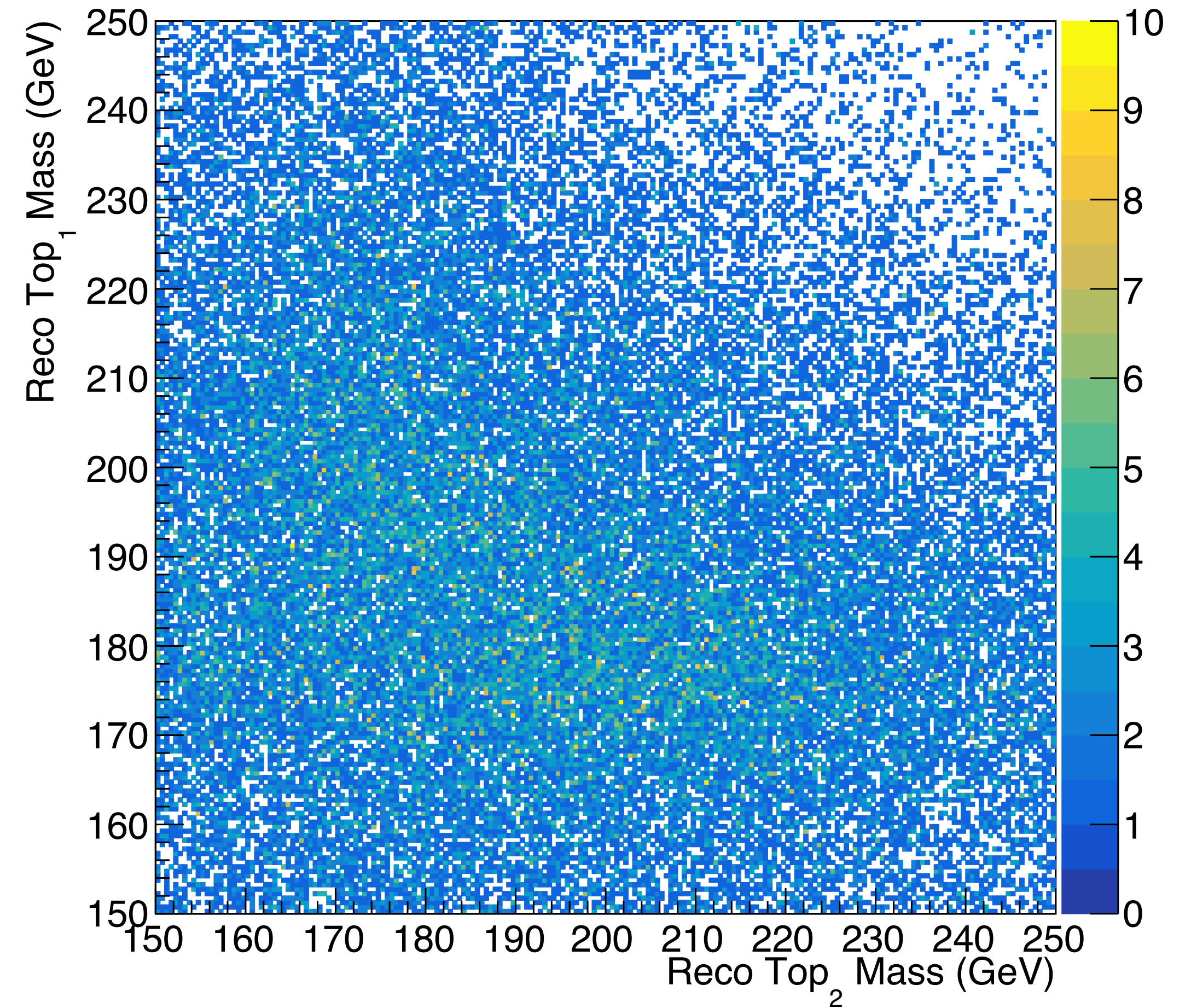
▸ Reco Top mass after single Top ID

4. Selection

SingleTop && Cos0.9 && Method1
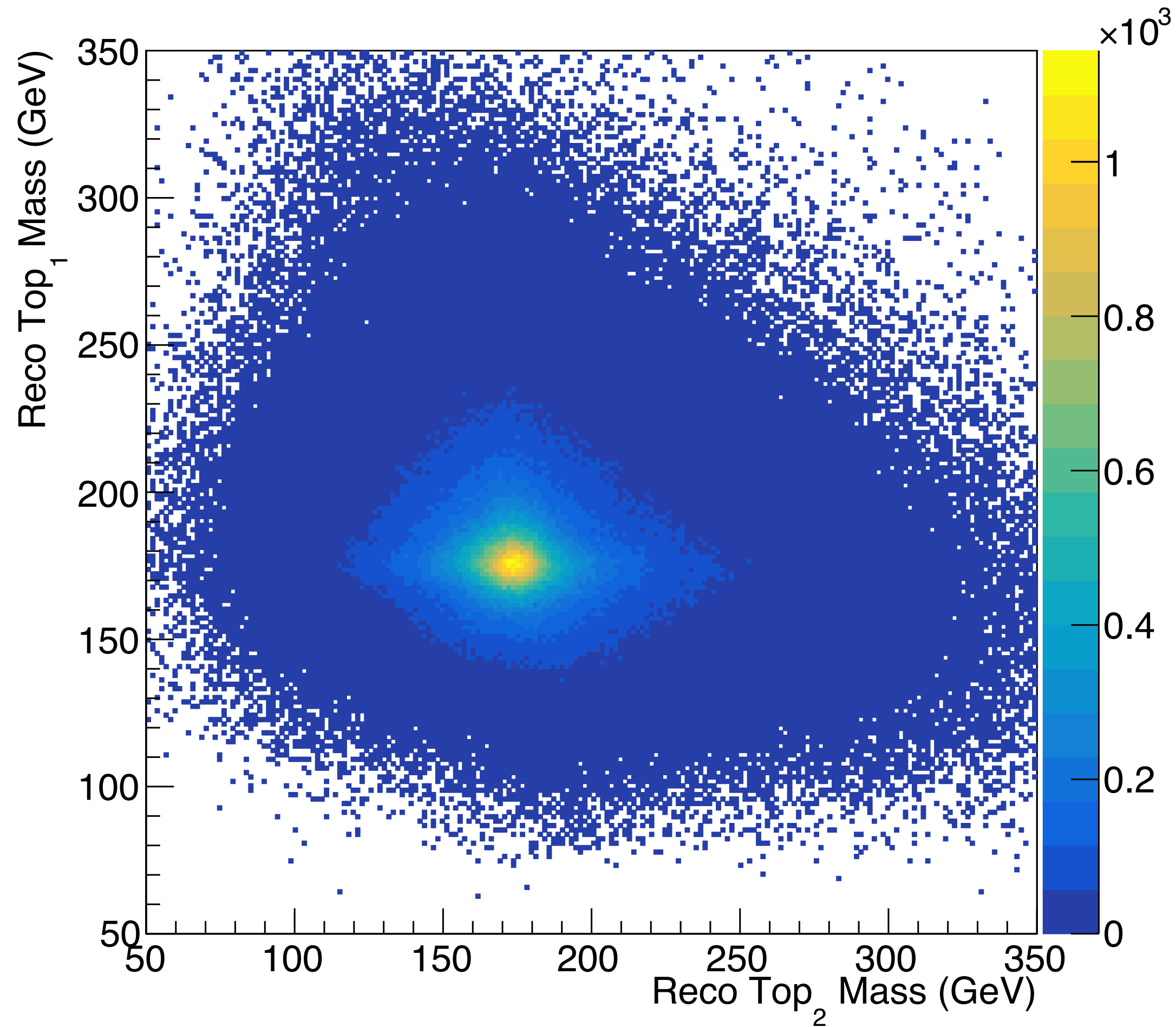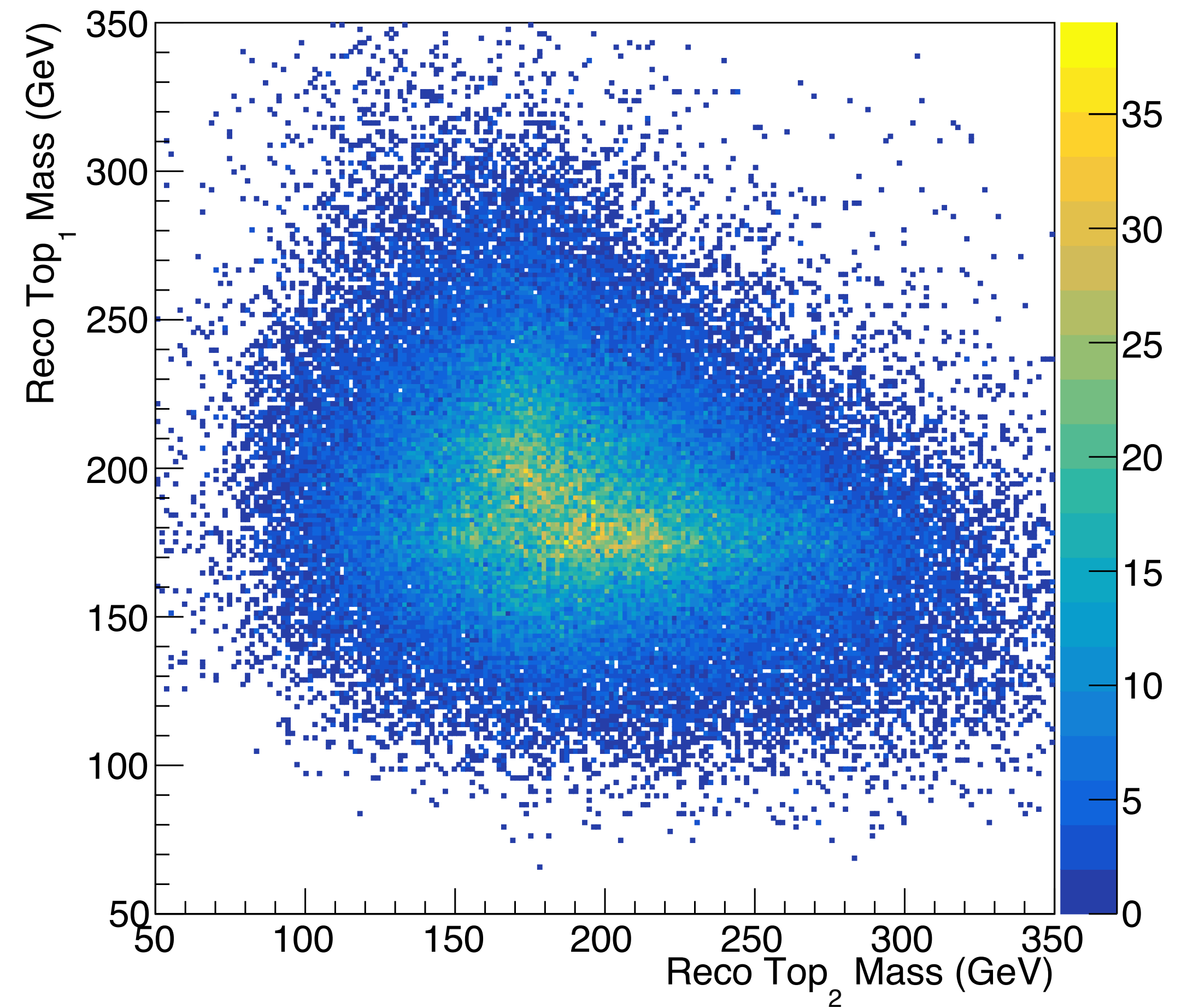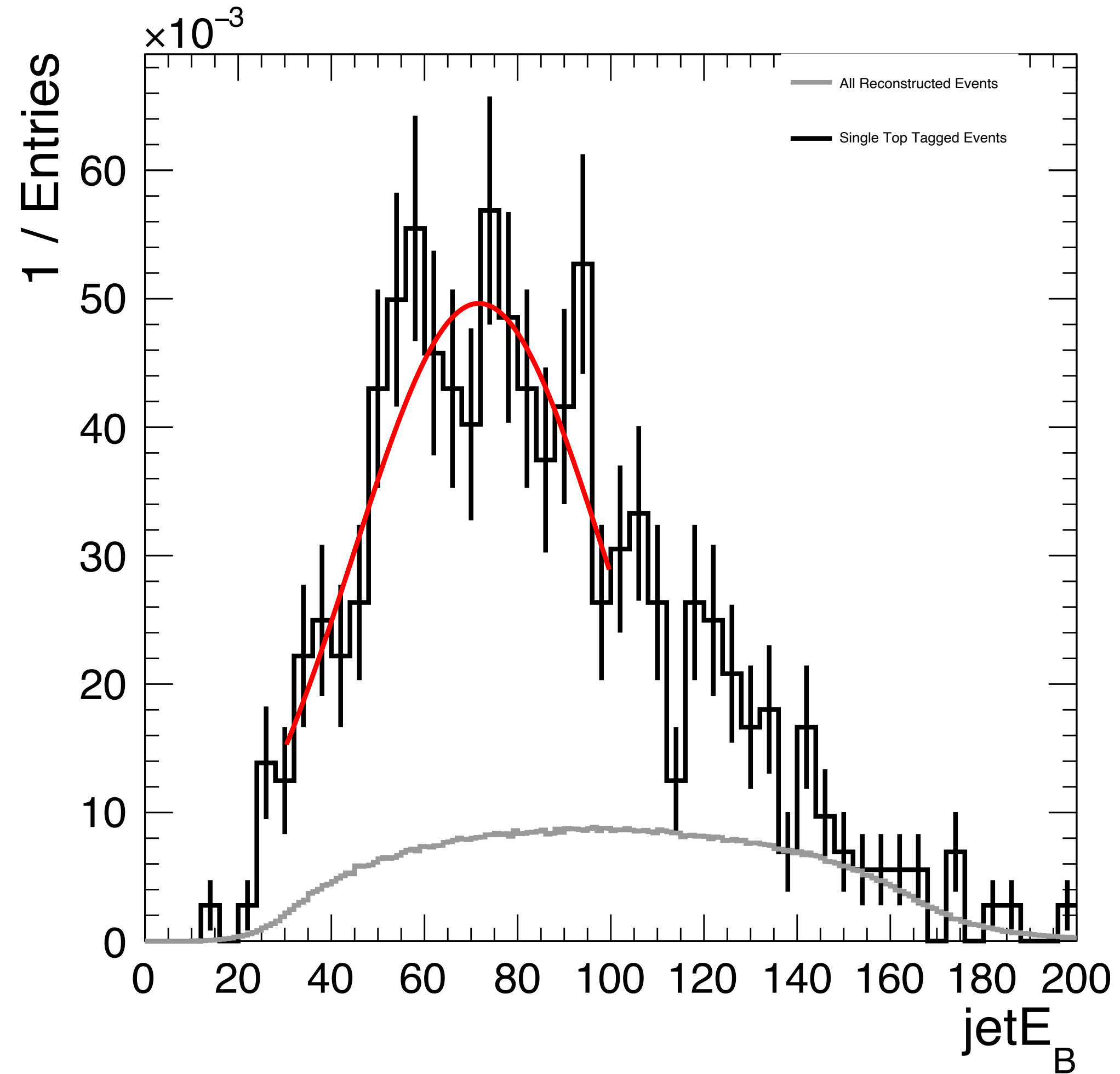

Fit Parameters (Crystalball)

NAME	VALUE	ERROR
Constant	4.96431E-02	2.25619E-03
Mean	7.16641E+01	1.76326E+00
Sigma	2.6926E+01	1.62229E+00
Alpha	1.54754E+00	7.3487E-01
N	-1.12659E+05	4.24264E-01

Total Events: 1.51585e+06
Selected: 721

4. Selection

SingleTop && Cos0.9
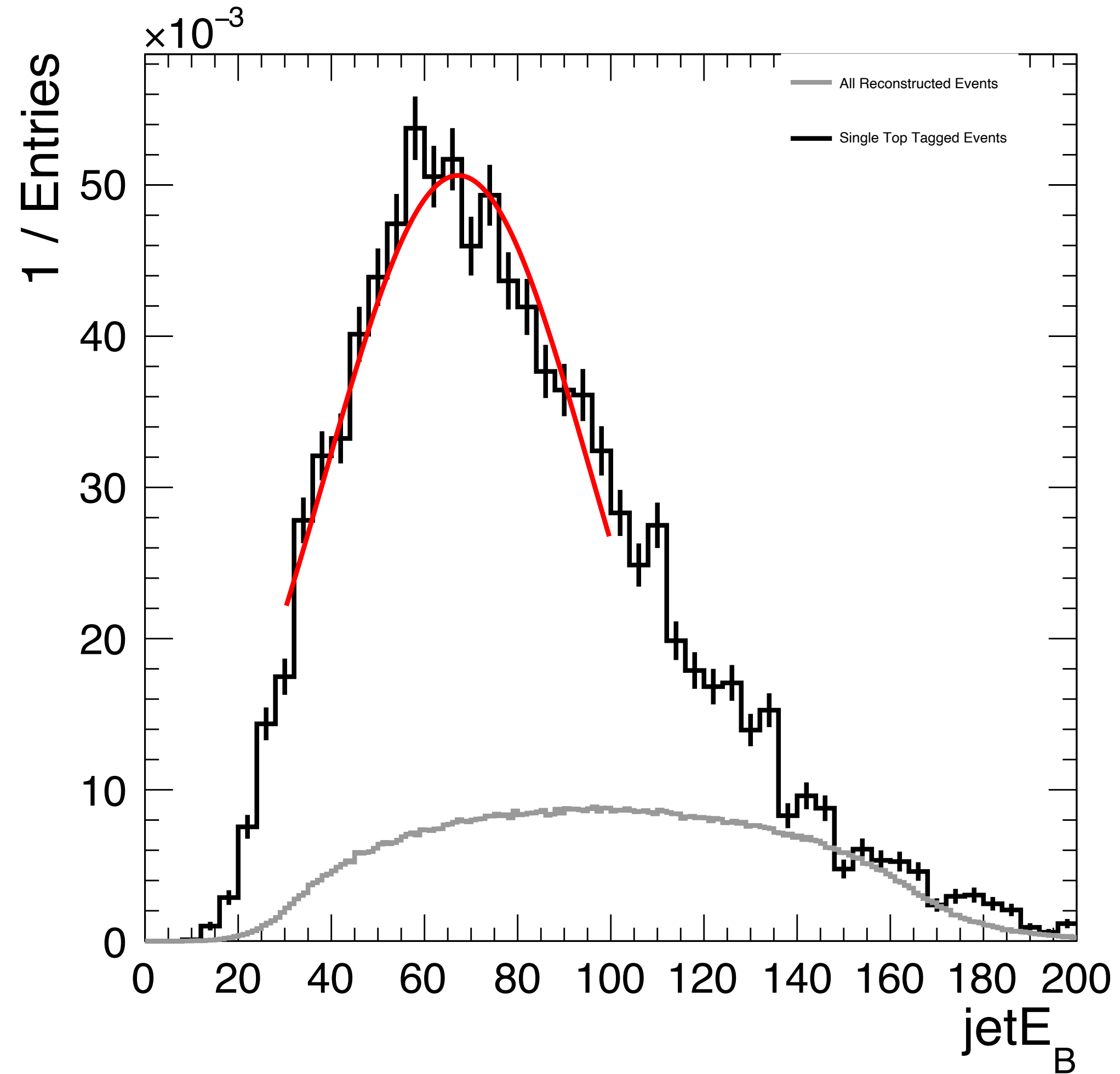
Fit Parameters (Crystalball)

NAME	VALUE	ERROR
Constant	5.06353E-02	5.50782E-04
Mean	6.7238E+01	5.53692E-01
Sigma	2.87102E+01	5.70428E-01
Alpha	1.51941E+00	3.31116E-03
N	1.53473E+00	4.24264E-01

Total Events: 1.51585e+06
Selected: 12185

4. Selection

SingleTop
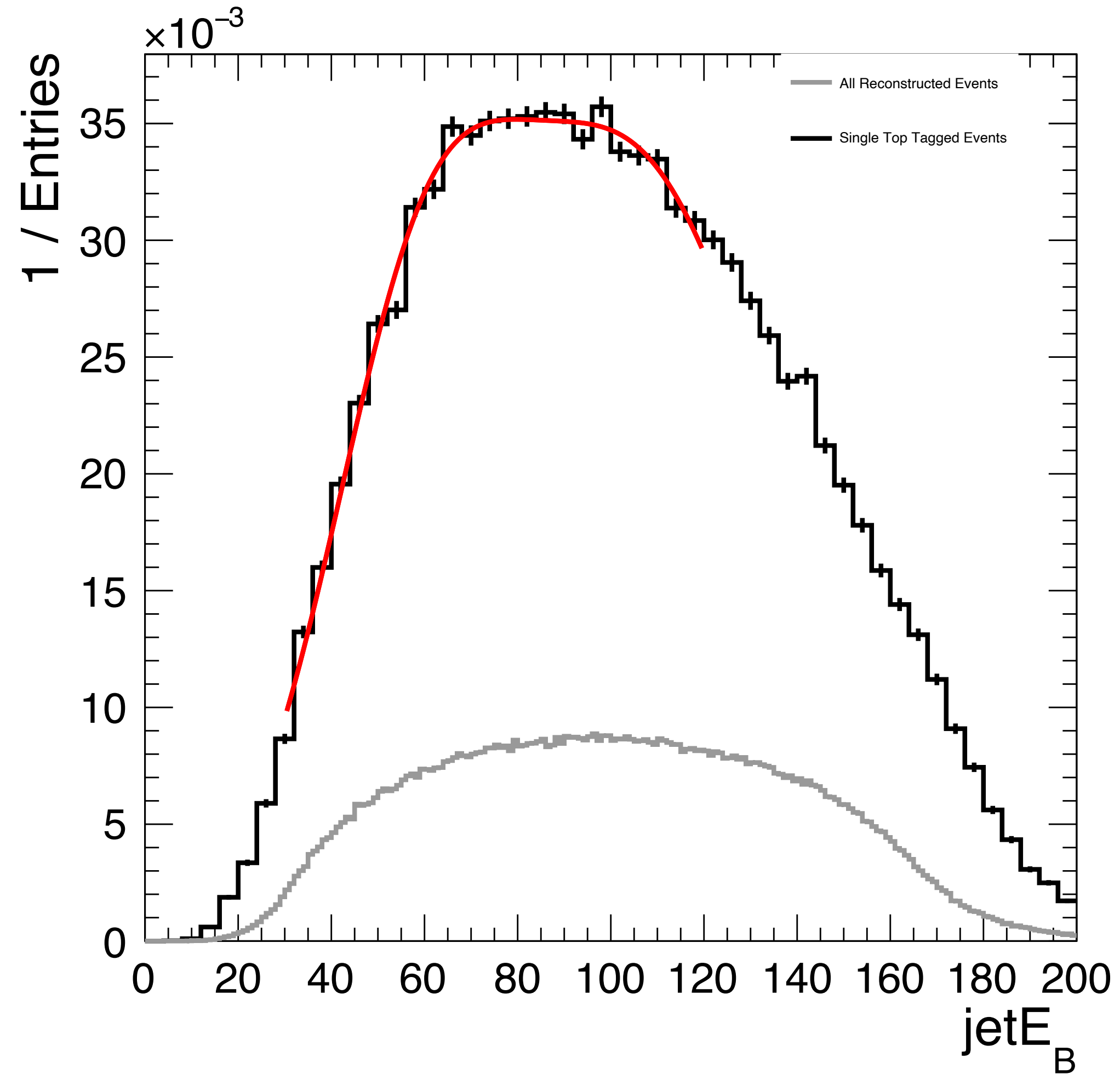
Fit Parameters (Double Gaus)

NAME	VALUE	ERROR
Const1	3.30635E-02	6.16687E-04
Mean1	1.0408E+02	1.98225E+00
Sigma1	3.24949E+01	2.1929E+00
Const2	1.89943E-02	2.70058E-03
Mean2	5.7729E+01	8.85771E-01
Sigma2	1.97371E+01	8.33313E-01

Total Events: 1.51585e+06
Selected: 183956

Cos0.9
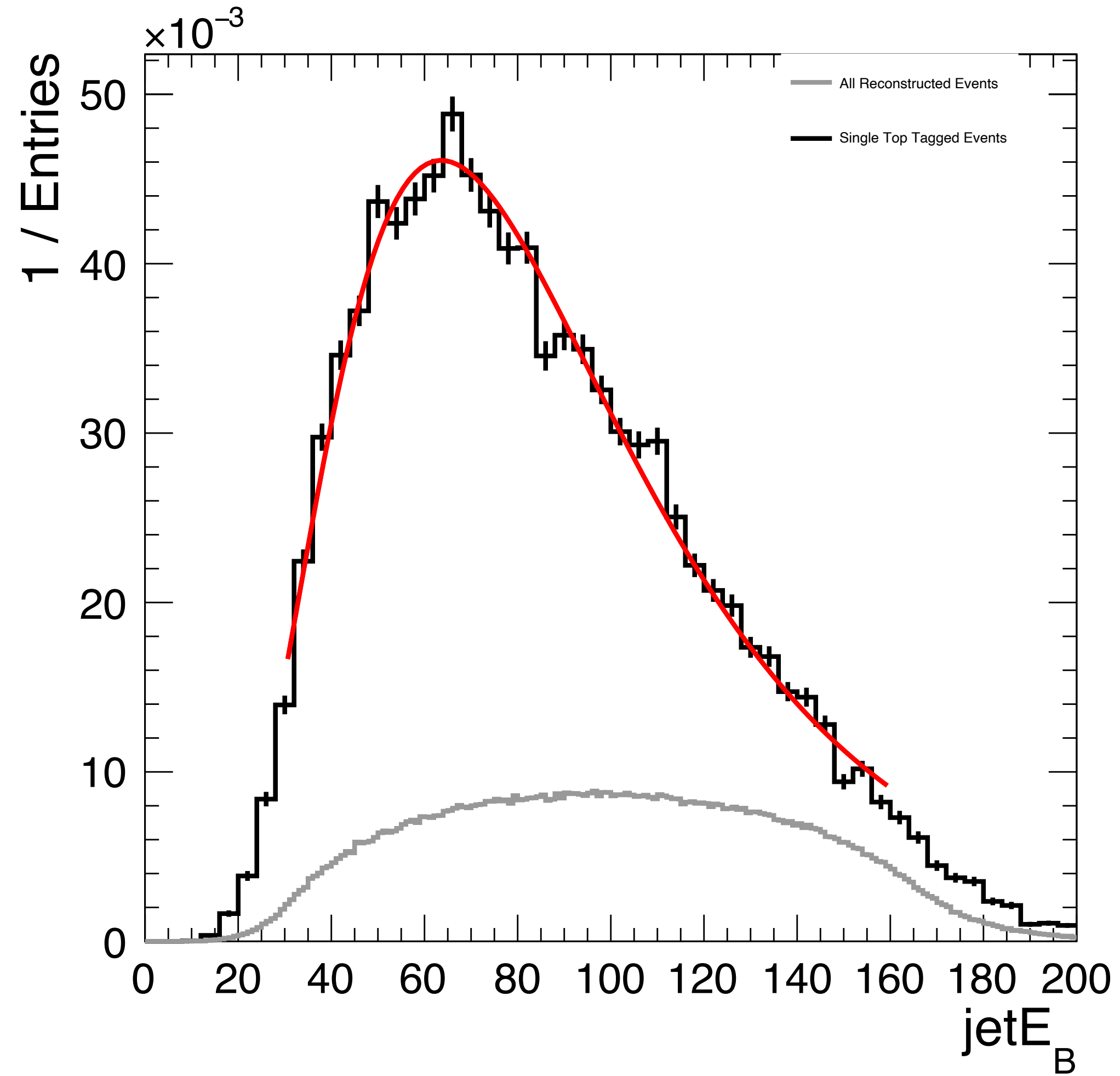
Fit Parameters (Log Normal)

NAME	VALUE	ERROR
p0	4.132E+00	6.76613E-02
p1	8.08274E+01	8.50019E-01
p2	1.65201E+00	1.15857E-02

Total Events: 1.51585e+06
Selected: 45868

Max = 62.823 GeV

Method1
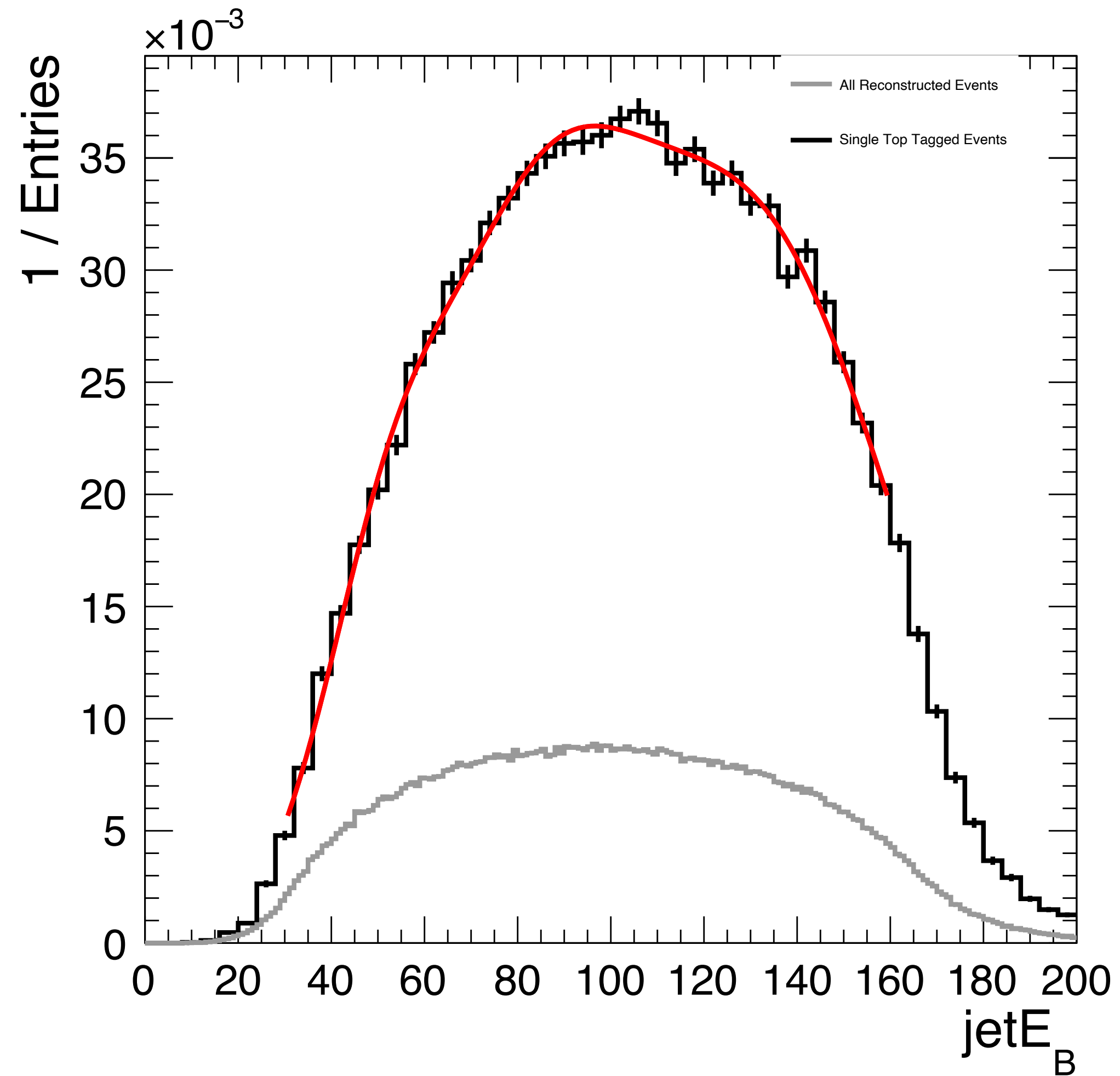
Fit Parameters (Triple Gaus)

NAME	VALUE	ERROR
Const1	1.01315E-02	2.57171E-03
Mean1	5.08603E+01	1.94586E+00
Sigma1	1.37695E+01	1.40127E+00
Const2	2.56534E-02	5.36272E-03
Mean2	8.14914E+01	5.19481E+00
Sigma2	2.27535E+01	1.87701E+00
Const3	3.08501E-02	2.37975E-03
Mean3	1.31256E+02	5.68089E+00
Sigma3	2.99661E+01	4.16266E+00

Total Events: 1.51585e+06
Selected: 107715

Max = 96.5769 GeV

All
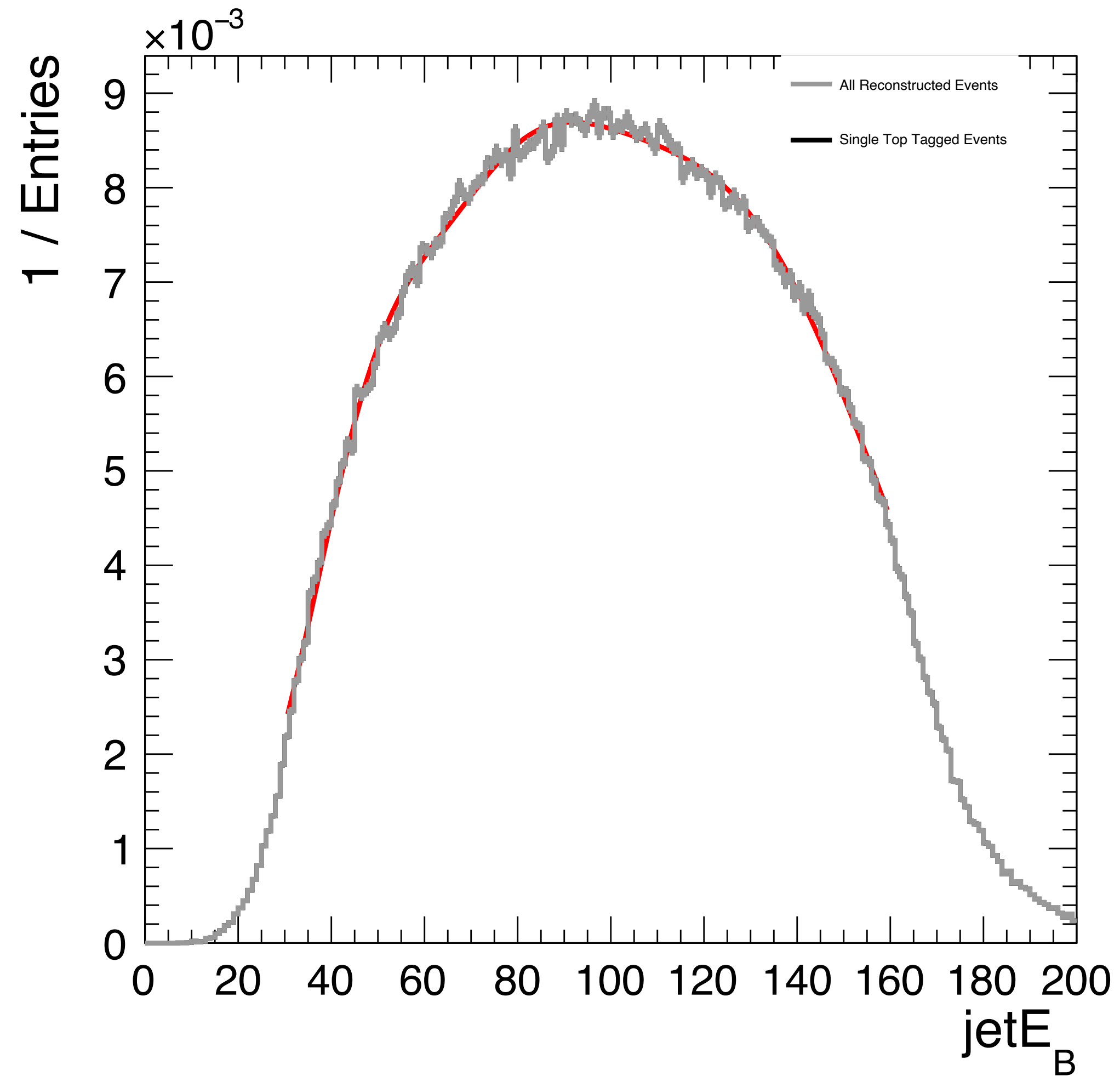
Fit Parameters (Triple Gaus)

NAME	VALUE	ERROR
Const1	2.32525E-03	2.55238E-04
Mean1	4.6308E+01	4.37737E-01
Sigma1	1.31458E+01	6.46767E-01
Const2	5.20107E-03	3.89298E-04
Mean2	7.28125E+01	1.6434E+00
Sigma2	2.36618E+01	6.96797E-01
Const3	7.52981E-03	1.56847E-04
Mean3	1.24267E+02	1.85224E+00
Sigma3	3.5185E+01	1.28613E+00

Total Events: 1.51585e+06
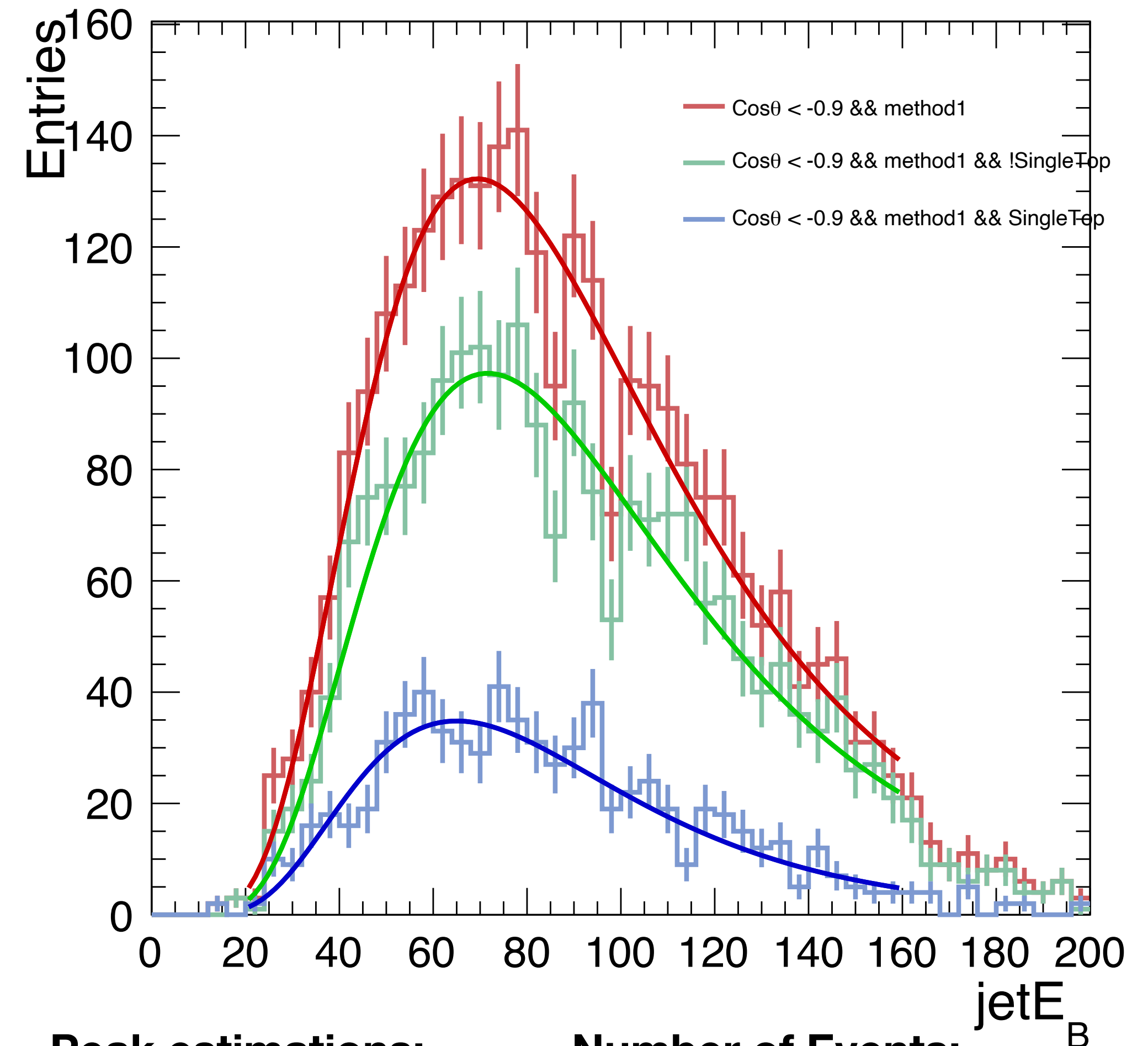
Max = 91.6638 GeV

b-jet Energy vs MC $\cos\theta_b$

Fit func: LogNormal
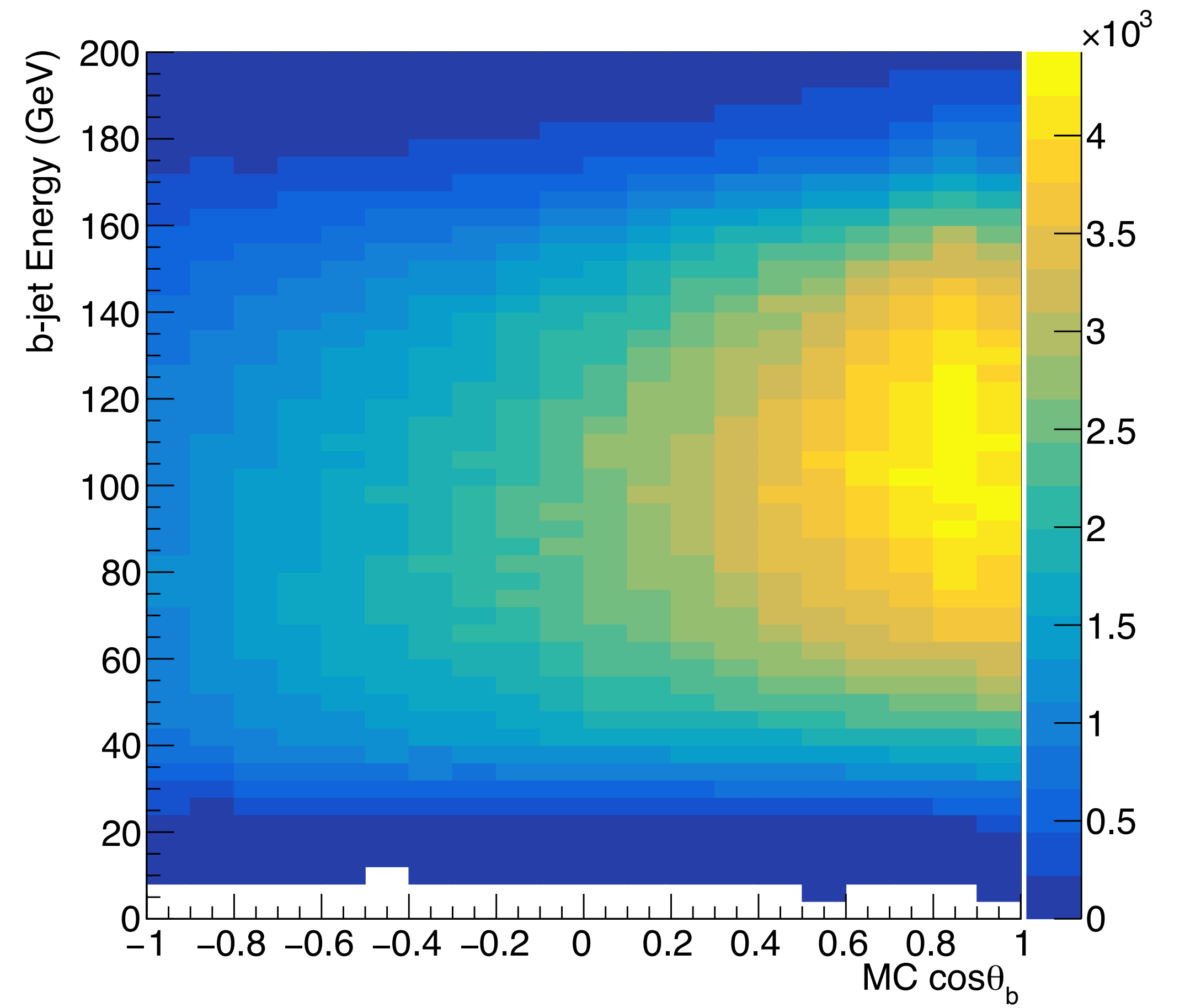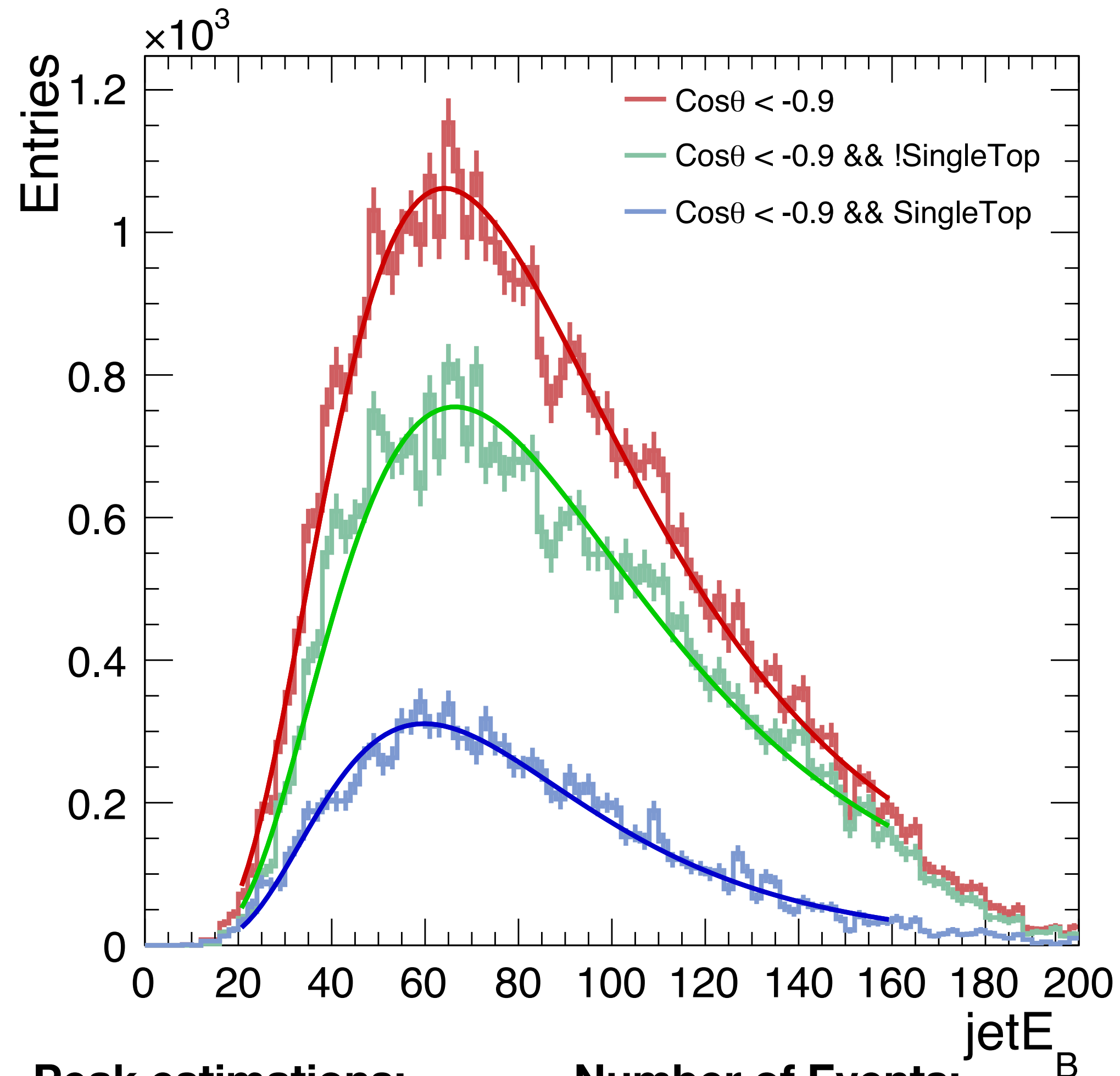
Peak estimations: **Number of Events:**

maxRed   = 64.2 GeV   Red Events: 45868

maxGreen = 66.4 GeV   Green Events: 33683

maxBlue   = 59.8 GeV   Blue Events: 12185

Peak estimations: **Number of Events:**

maxRed   = 68.9 GeV   Red Events: 2876

maxGreen = 70.8 GeV   Green Events: 2155

maxBlue   = 64.5 GeV   Blue Events: 721

bjet Energy vs top polar angle
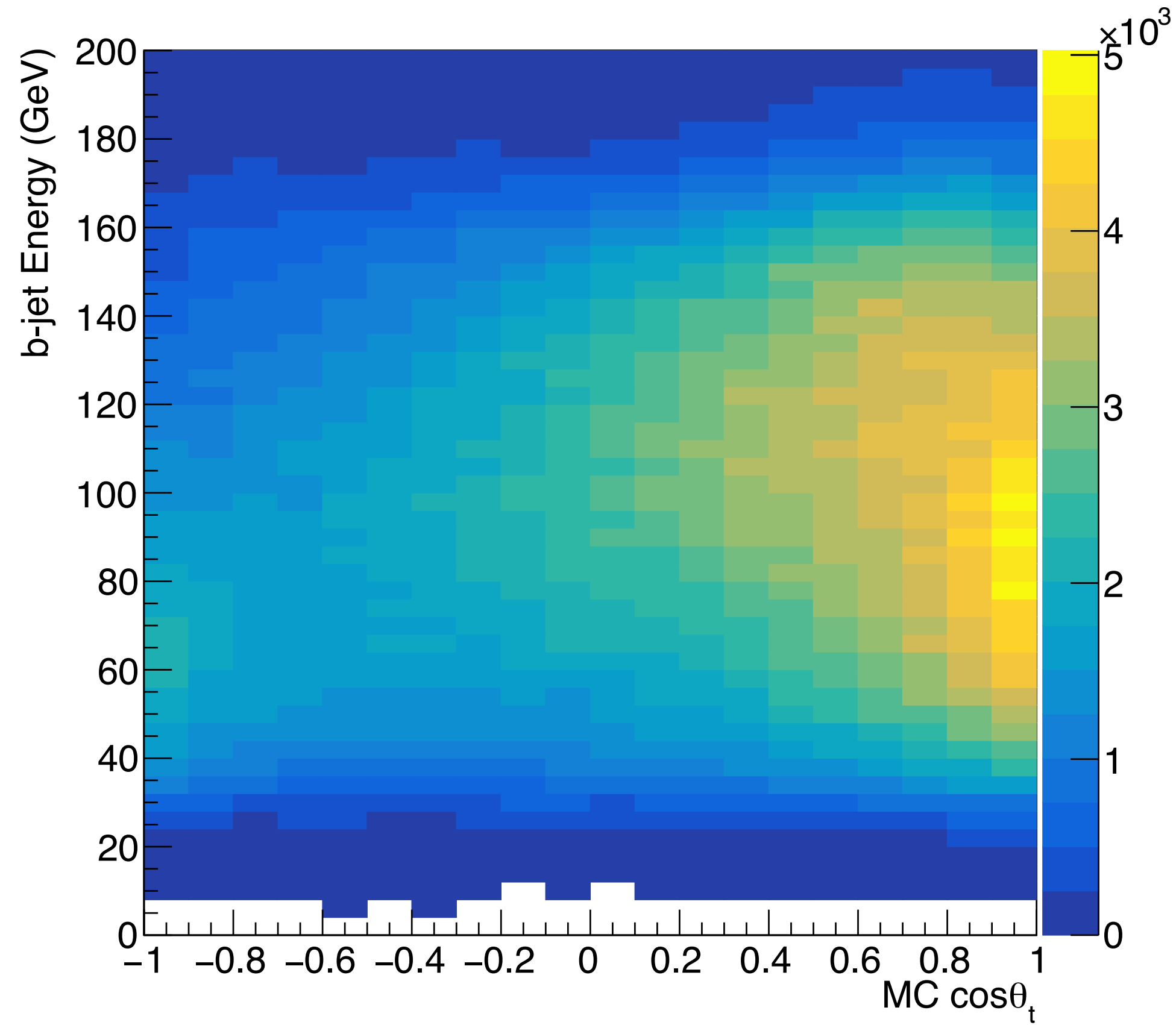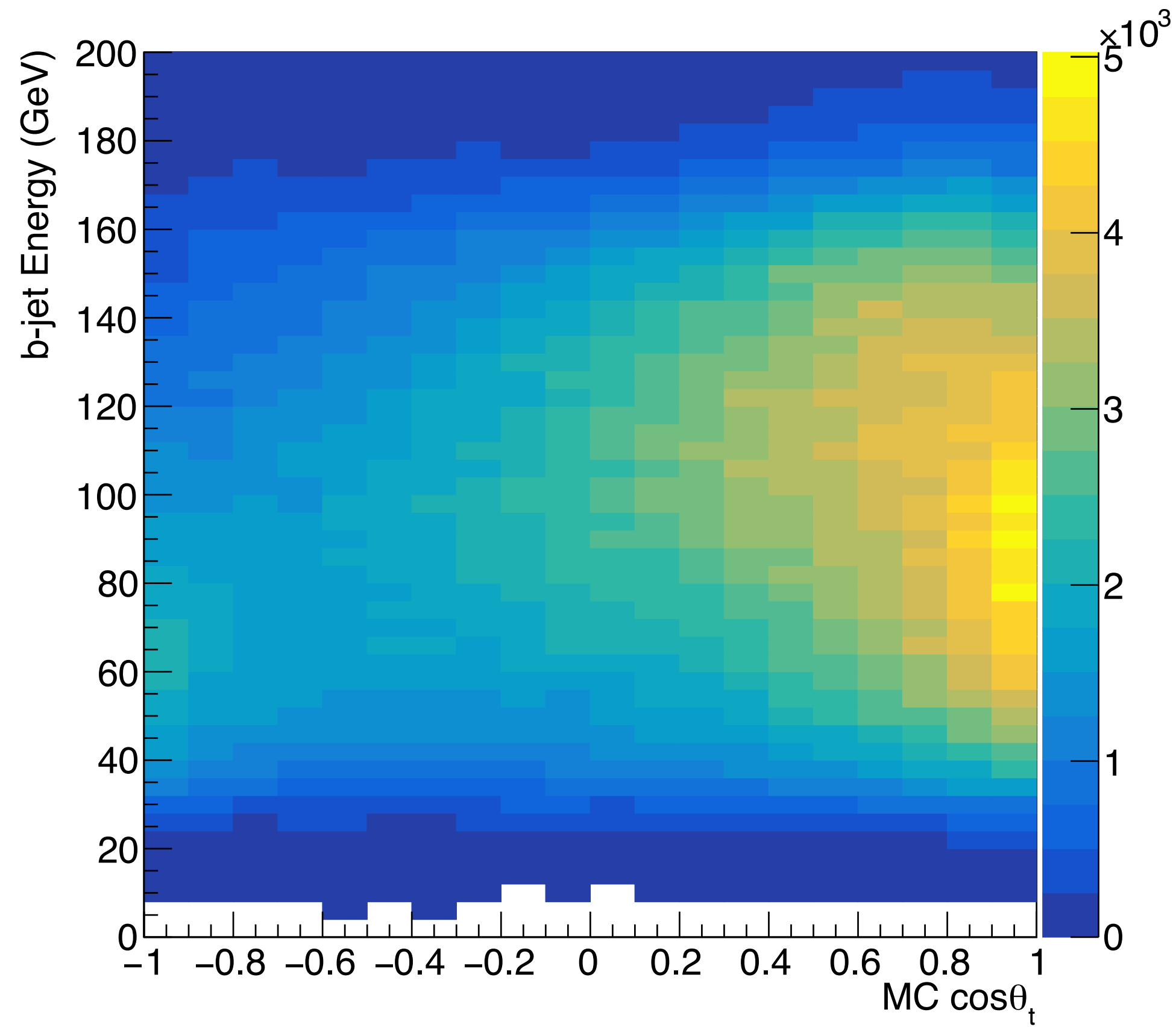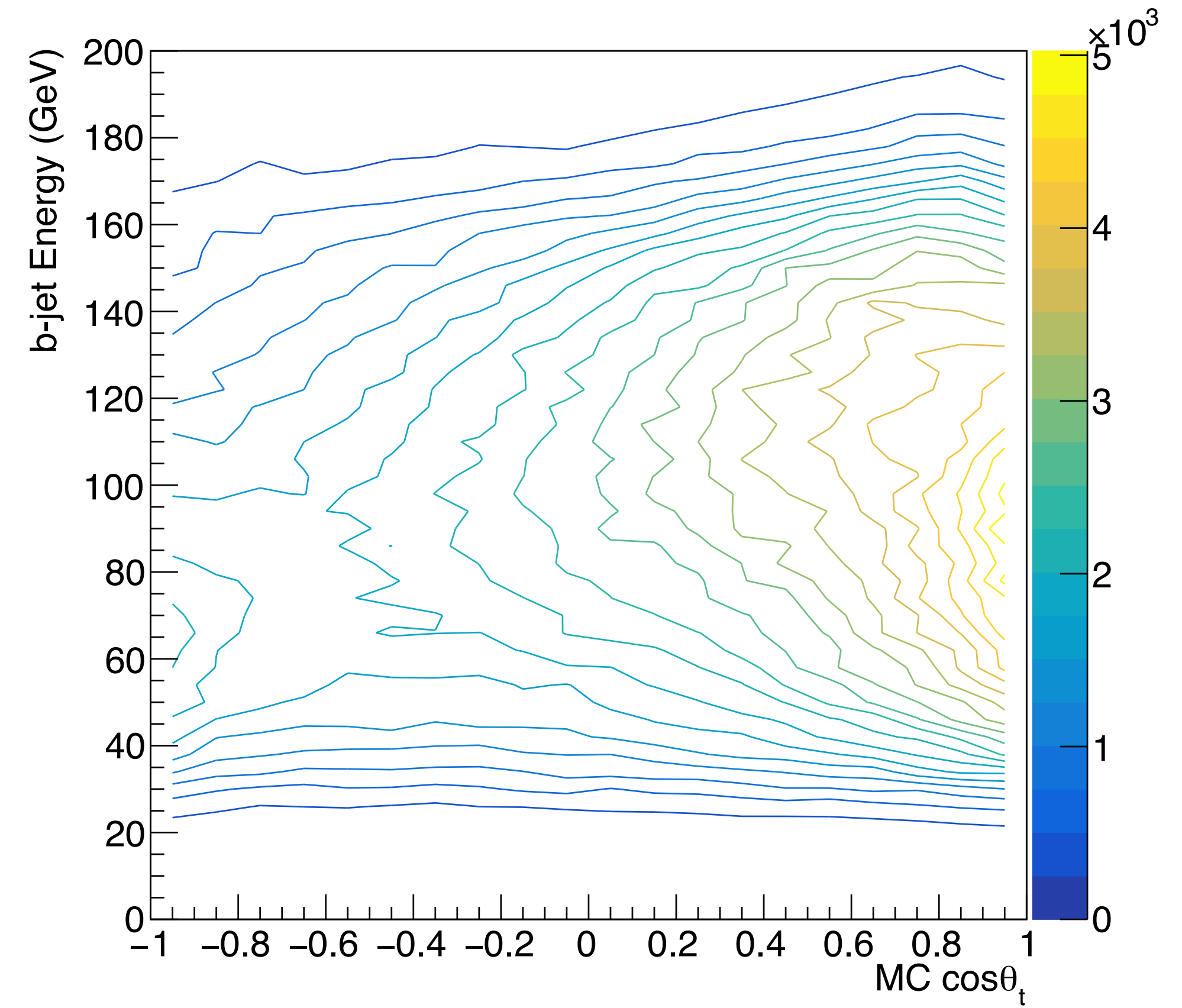

‣ 2D hist for the entire events.
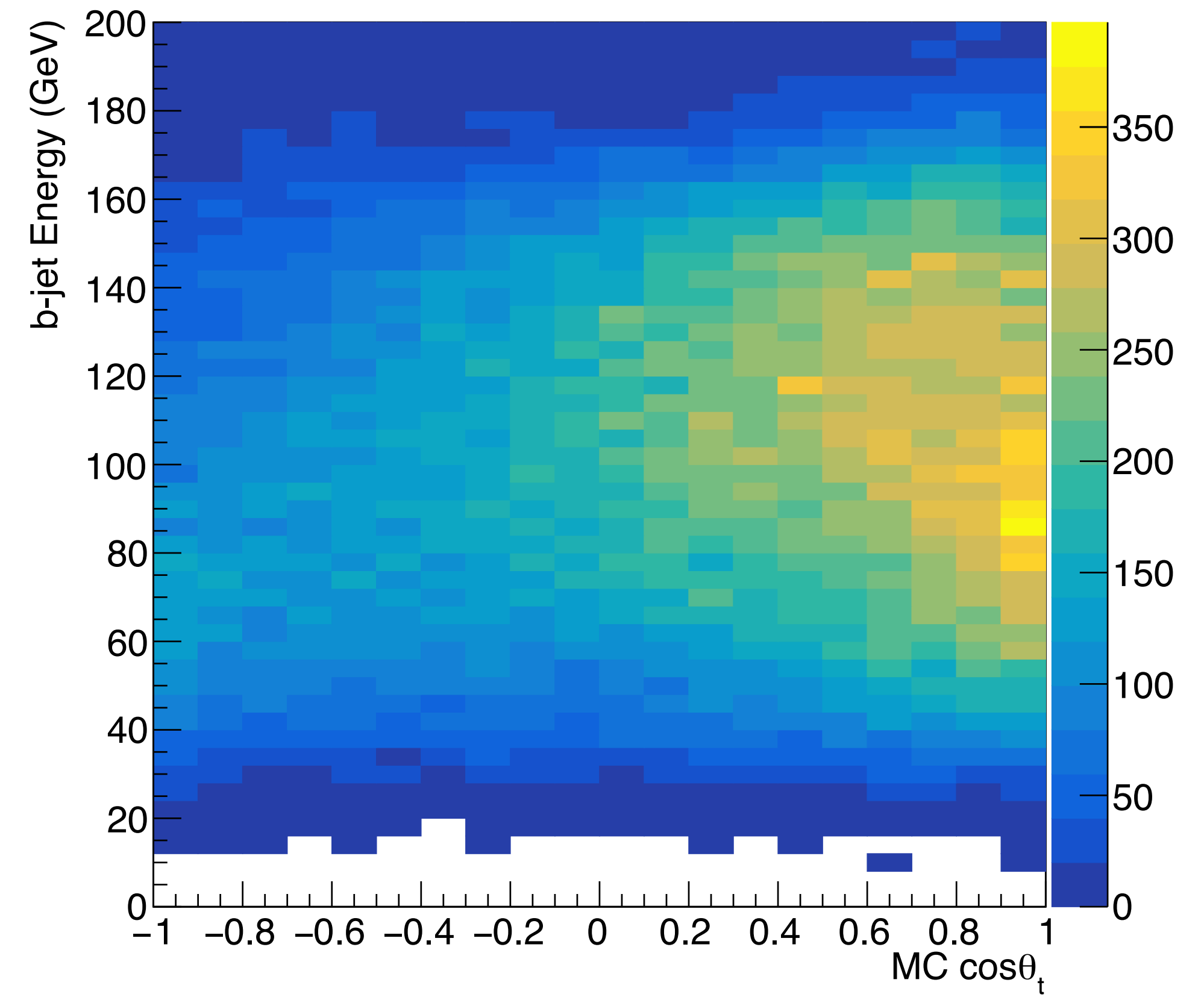
‣ 2D hist after **method1** application.
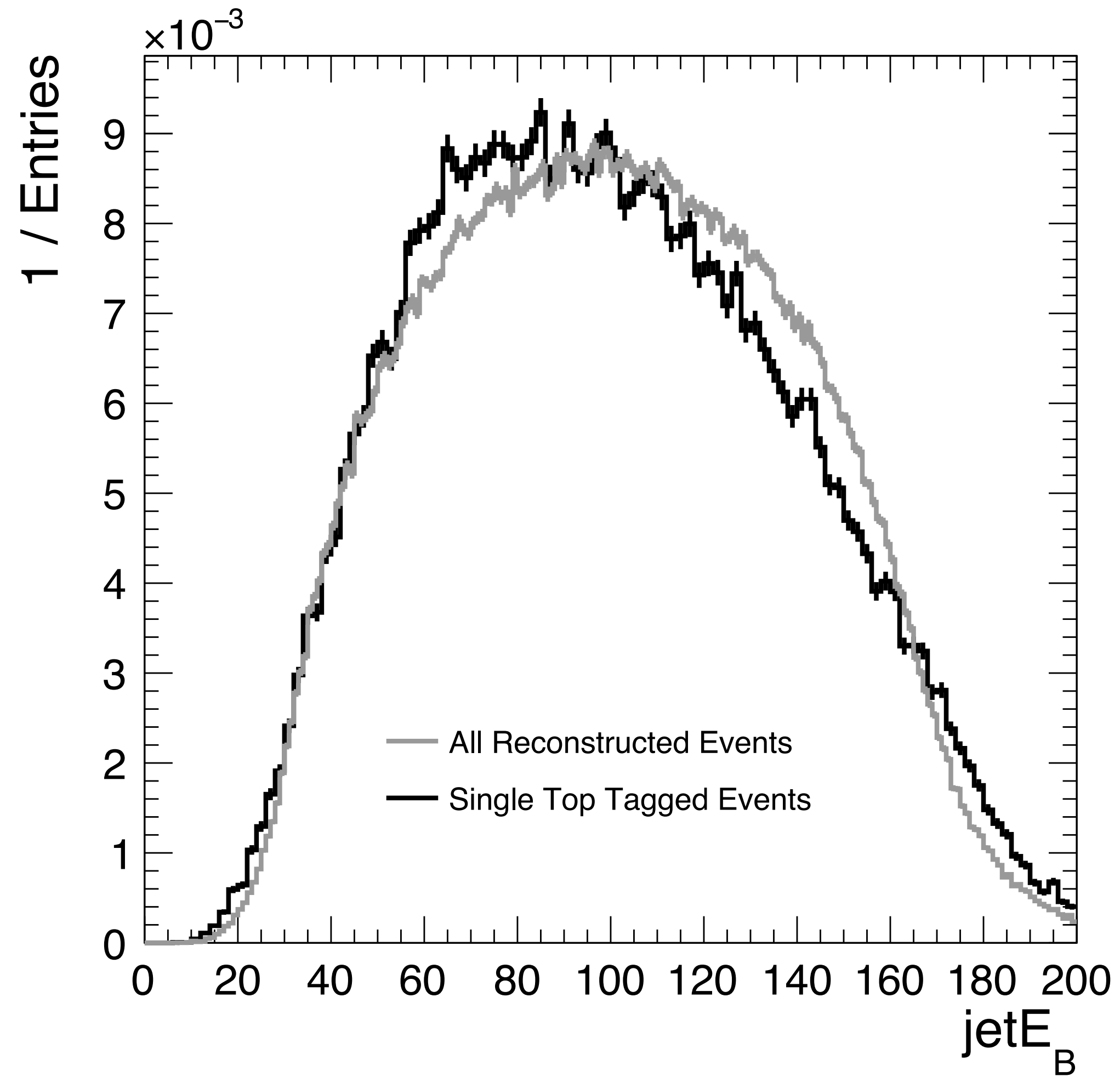
bjet Energy vs top polar angle

- ‣ 2D hist for the entire events.

- ‣ contour plot for the left distribution
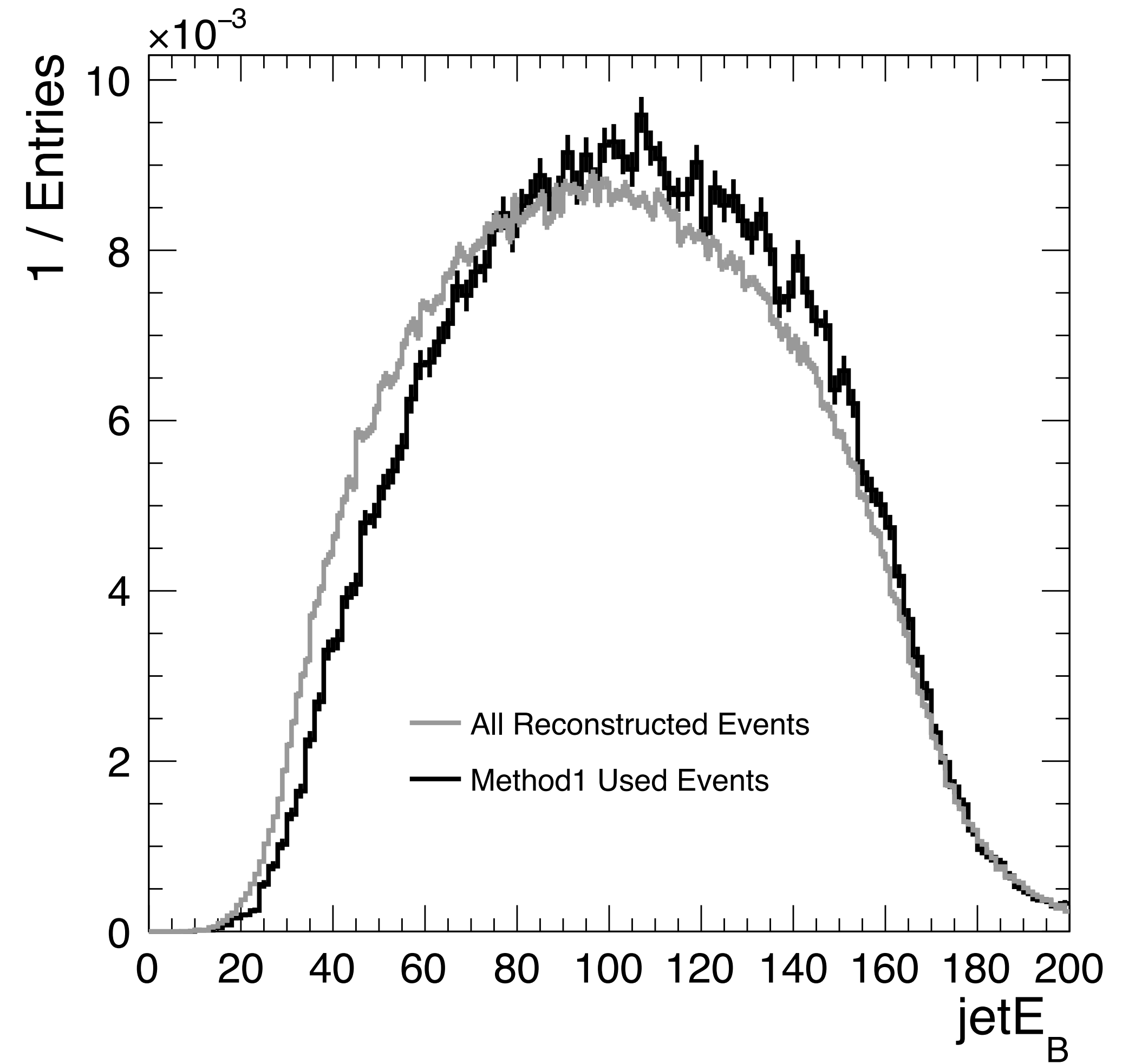
Number of Events:

All Reco Events: 1.51585e+06

Single Top Tagged Events: 183956

Number of Events:

All Reco Events: 1.51585e+06

Vtx x Vtx Used Events: 107715