Optimal Jet Finder (OJF) in ATLAS

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OUTLINE:

- Introduction to OJF
- OJF in ATLAS: experiences, findings and results
- Some thoughts and remarks
- Conclusions and Outlook

Optimal Jet Finder (OJF)

- **Introduced and developed by:**

  F.V. Tkachov, D.Yu. Grigoriev and E. Jankowski

- **Short introduction:** Phys. Rev. Lett. 91, 061801 (2003)
- Int. Journal of Mod. Phys. A, Vol 17, No 21 (2002) 2783-2884.
- **Authors webpage (with links to source code, etc.):**

  http://www.inr.ac.ru/~ftkachov/projects/jets/welcome.html

- **Presented in *JetRec* phone meetings in January and March 2007**
- **Results in this talk are from private OJF implementation in Athena**
- **Official implementation can be expected soon (R. Seuster)**
- **Discussions with experts has started**

Optimal Jet Finder (OJF)

- **Tries to extract as much (jet) information from a HEP event as possible**
  (that is what authors call 'optimal'…)
- **OJF starts from rather ambitious, global point of view (i.e. from event view):**

HEP event: list of **particles** $p_a, \quad a = 1,2,\ldots,n_{\text{parts}}$
(partons • hadrons • calorimeter cells • towers • preclusters)

recombination matrix $\{z_{aj}\}_{n_{\text{parts}} \times n_{\text{jets}}}$

$$q_j = \sum_{a=1}^{n_{\text{parts}}} z_{aj} p_a$$

the 4-momentum q_j of the j-th jet expressed by 4-momenta p_a of the particles

result: list of **jets** $q_j, \quad j = 1,2,\ldots,n_{\text{jets}}$

Optimal Jet Finder (OJF)

- **Any allowed value of the Recombination Matrix $\{z_{aj}\}$ from previous slide describes some jet configuration**
- **'Whole trick' is to find desired optimal jet configuration by minimizing some function $\Omega(\{z_{aj}\})$**
- **Definition from Optimal Jet Finder gives (for cylindrical kinematics (pp coll.):**

$$\Omega(\{z_{aj}\})E_{Tot}^{\perp} = \frac{4}{R^2}\sum_{a=1}^{n_{part}} E_a^{\perp} \underbrace{\sum_{j=1}^{n_{jets}} z_{aj}\left(\sinh^2\frac{\eta_a-\eta_j}{2}+\sin^2\frac{\varphi_a-\varphi_j}{2}\right)}_{\text{'width' of the } j\text{-th jet}} + \underbrace{\sum_{a=1}^{n_{parts}} \bar{z}_a E_a^{\perp}}_{\text{energy outside jets}}$$

$$\eta_j \equiv \frac{\sum_{a=1}^{n_{parts}} z_{aj}E_a^{\perp}\eta_a}{\sum_{a=1}^{n_{parts}} z_{aj}E_a^{\perp}} \qquad E_a^{\perp} \equiv \sqrt{(p_a^x)^2+(p_a^y)^2} \qquad \bar{z}_a \equiv 1-\sum_{j=1}^{n_{jets}} z_{aj}$$

$$q_j \equiv (E_j, \mathbf{q}_j) \equiv \sum_{a=1}^{n_{parts}} z_{aj}p_a \qquad \frac{\mathbf{q}_j^{\perp}}{|\mathbf{q}_j^{\perp}|} \equiv (\cos\varphi_j, \sin\varphi_j) \qquad \bar{z}_a, z_{aj} \geq 0$$

E_a is the energy of the a-th particle

$R>0$ is a parameter with a similar meaning as the cone radius

OJF features

- The authors claim it is based on an optimal jet definition that solves the problem of jet definition in general
  - OJF is infrared and collinear safe
  - no issues intrinsic with seeds
  - no issues with overlapping cones: all jets are "ready to use"
- Particle energy can be shared among jets
  - Hadronization is always an effect of the interaction of at least two hard partons evolving into two jets, so some hadrons that emerge in this process can belong partially to both jets
- The association between particles and jets is obtained through the minimization of a global function
  - global variables are a bi-product of this procedure
- Particles (or part of them) are allowed to be outside all jets
  - but with a penalty in the global function to minimize

OJF running modes

- **The algorithm can be used in two modes:**

  1) Number of jets fixed

  - Parameter R (related to conventional R_{cone}) and number of initial random Z_{aj} configurations to be specified

  2) Number of jets not fixed, obtained by the algorithm

  - Parameter R, number of initial random Z_{aj} configurations and

  - Parameter ω_{cut} to be specified:

  - related to the jet resolution y_{cut} of conventional recombination algorithms

  - upper limit to the fractional transverse energy not associated to any jets

Fully hadronic t-tbar sample

- **Sample 5204 (13000 events)**

  MC@NLO fully hadronic t-tbar, full simulation, CSC12 prod.

- **AOD produced using Athena 12.0.6 and OJF private code**

  - final jet cut $E_T > 7\ GeV$

  - Jet collections using OJF:

  - no proper H1 weights available: use Cone H1 weights

  - number of jets fixed to 6, *R* **parameter set to** *0.4 or 0.7*

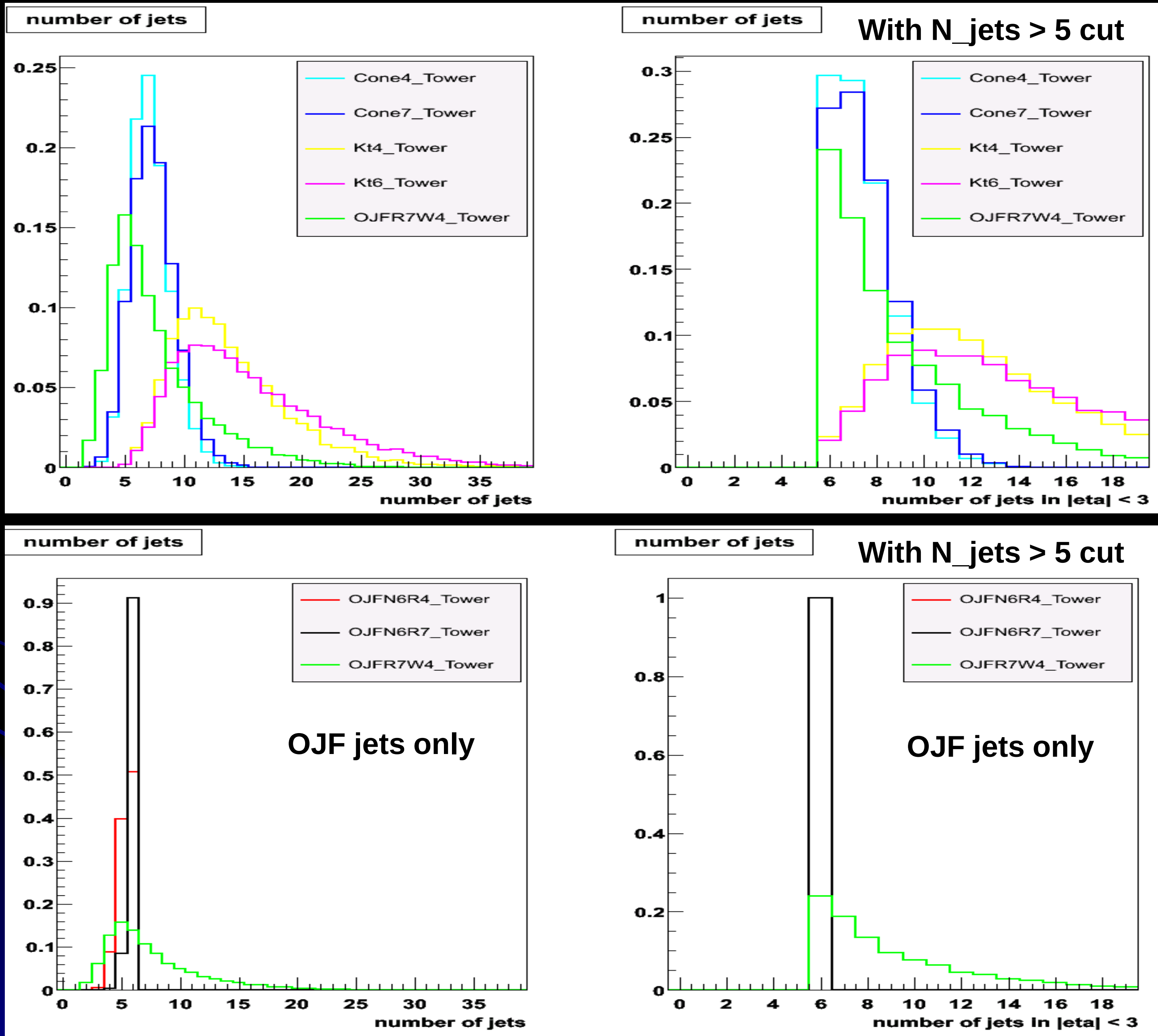
  (labels for following plots: OJFN6R4_xxx and OJFN6R7_xxx, respect.)

  - number of jets not fixed, *R* **parameter set to** *0.7* **and** ω_{cut} **set to** *0.4 (labels for following plots: OJFR7W4_xxx)*

  - jet collection from MC Truth, CaloTowers and TopoClusters

Jet multiplicity: CaloTower jets

fully hadronic t-tbar events

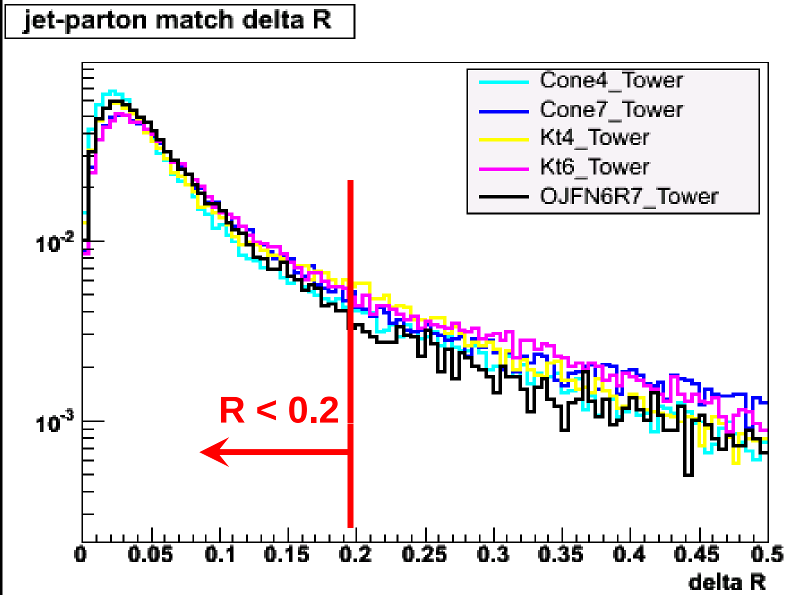


Jet-Parton matching (ttbar events)

- **Matching criteria**
  - ***For each parton, look for a matching jet***
    - **- restrict search in a region limited by $\Delta R_{max} < 0.2$**
    - **- keep the closest jet in this region**
  - ***Demand that a jet be matched only once***
    - **- matched 1 to 1**
    - **- one can then study matching efficiency**
- **Study events with “true” jet hypothesis (for ttbar events)**
  - ***Require all 6 partons to be matched 1 to 1***
    - **- this way we can study the top mass reconstruction performance for different jet algorithms**
- **For much more quantitative details on matching eff., please see extra slides!!**

Normalized distributions: CaloTower jets

matched 1 to 1 jet-parton in fully hadronic t-tbar events with at least 6 jets in |η| < 3

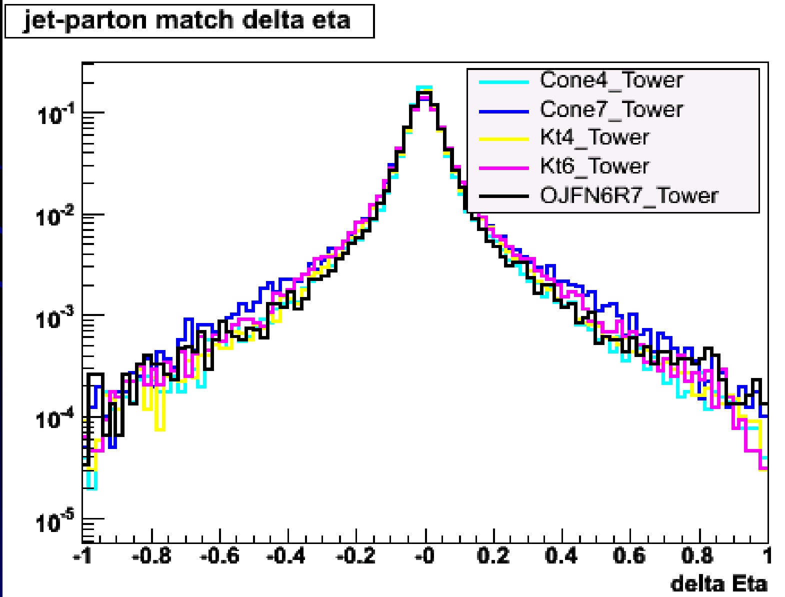


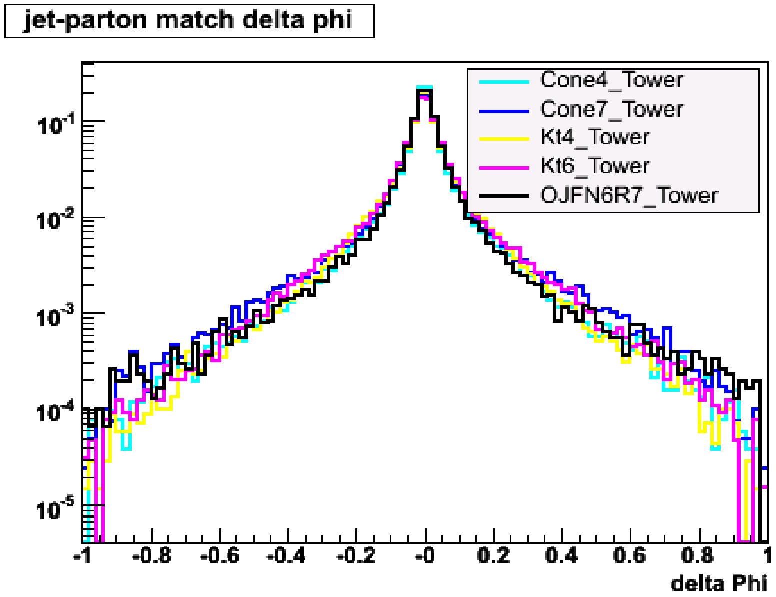
Jet – Parton

All 1 to 1 matched jets in events with at least 6 jets in |eta| < 3

OJF with R = 0.7 is between Cone4 and 7

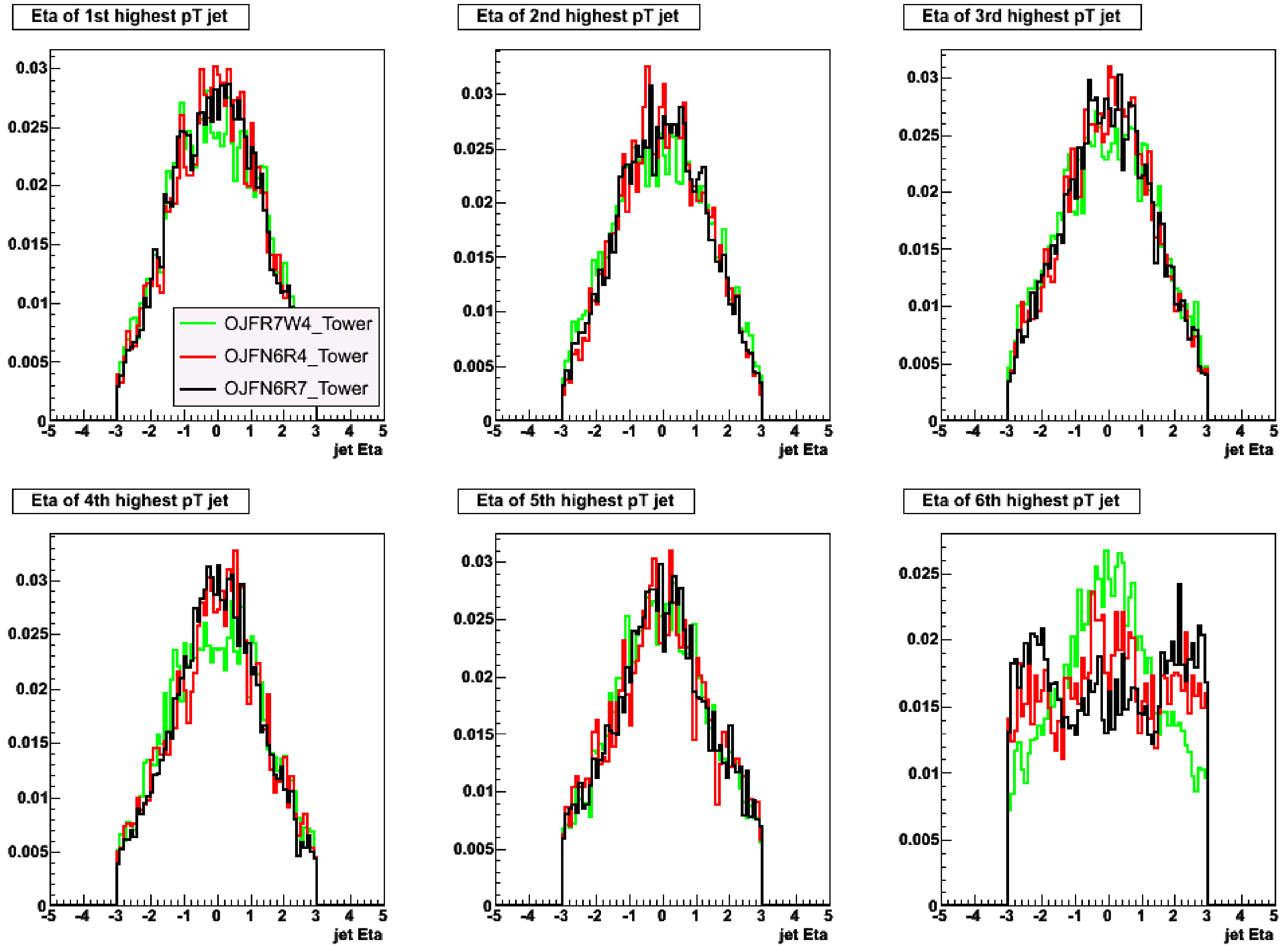
Similar results for topoJets and truthJets (extra slides)





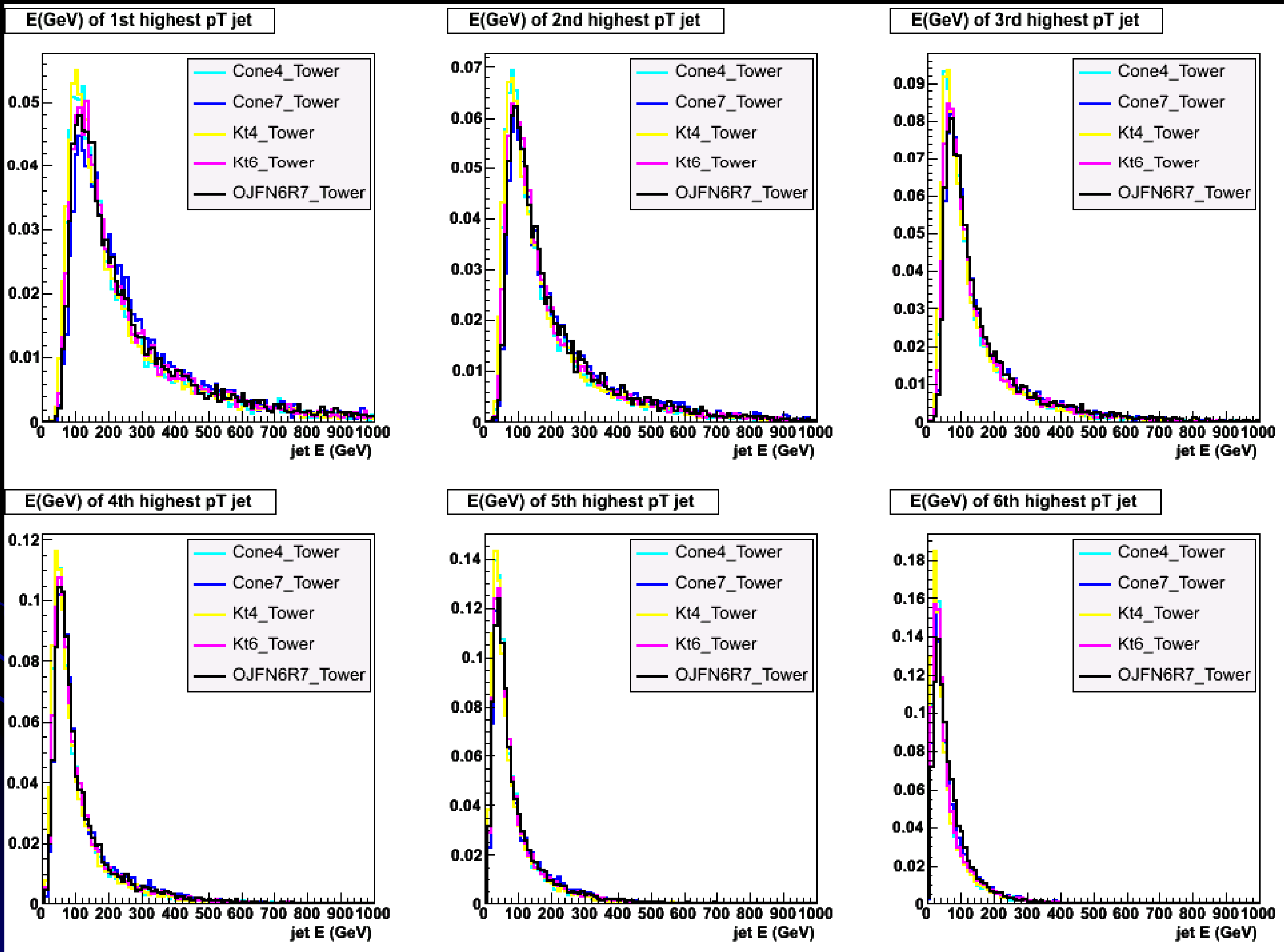
Normalized η distributions: OJF towerJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



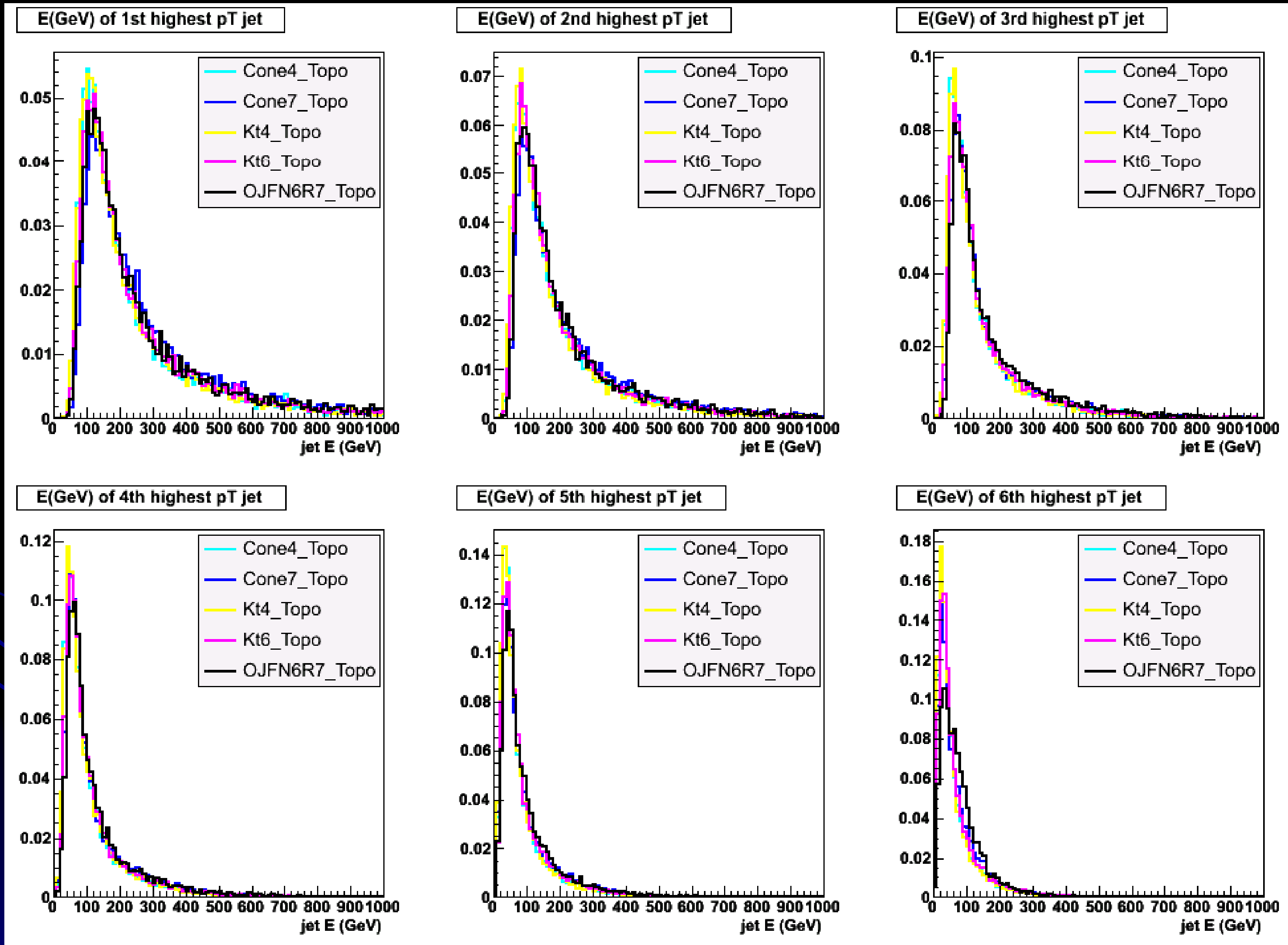
Normalized E distributions: towerJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



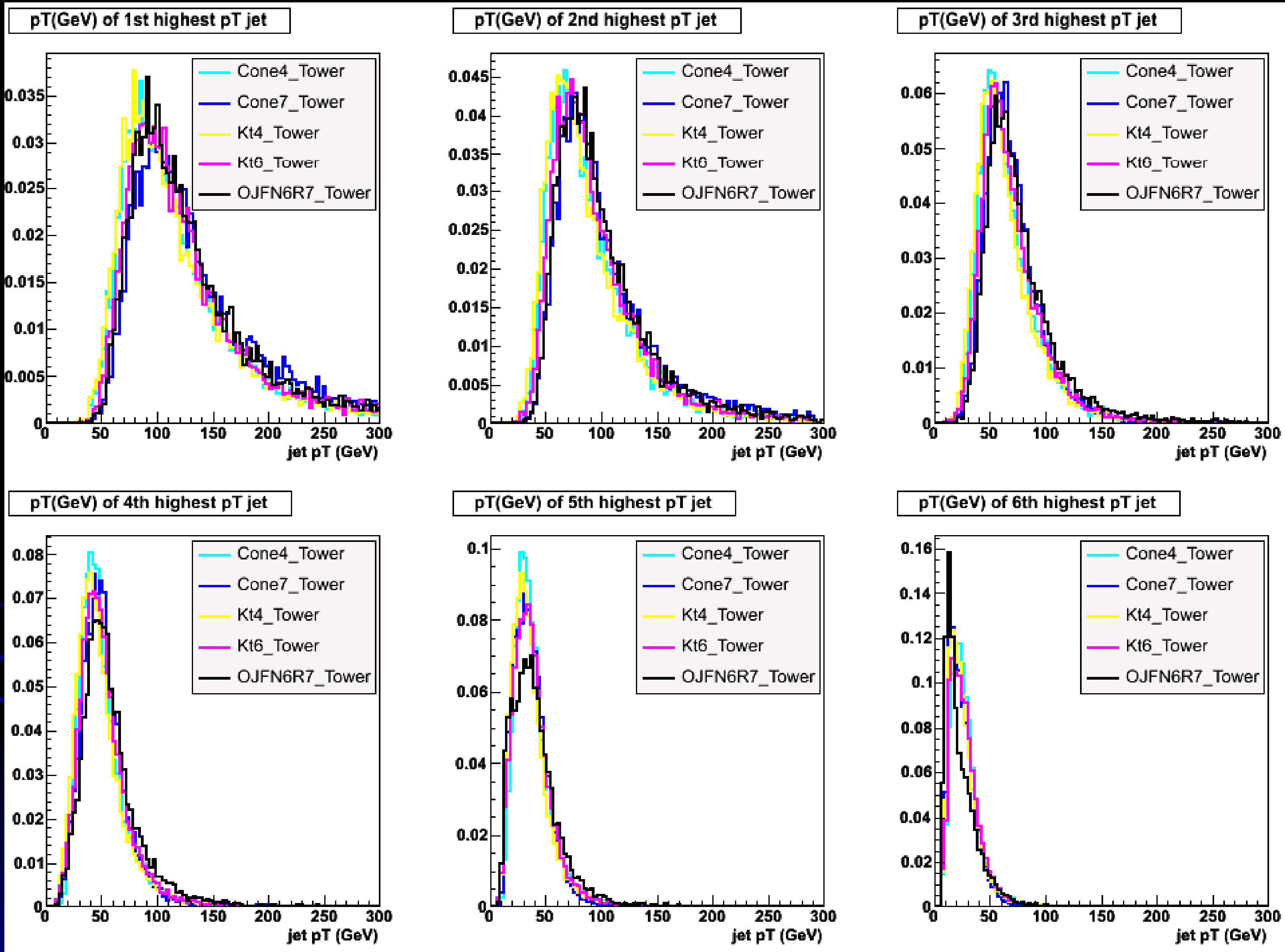
Normalized E distributions: topoJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



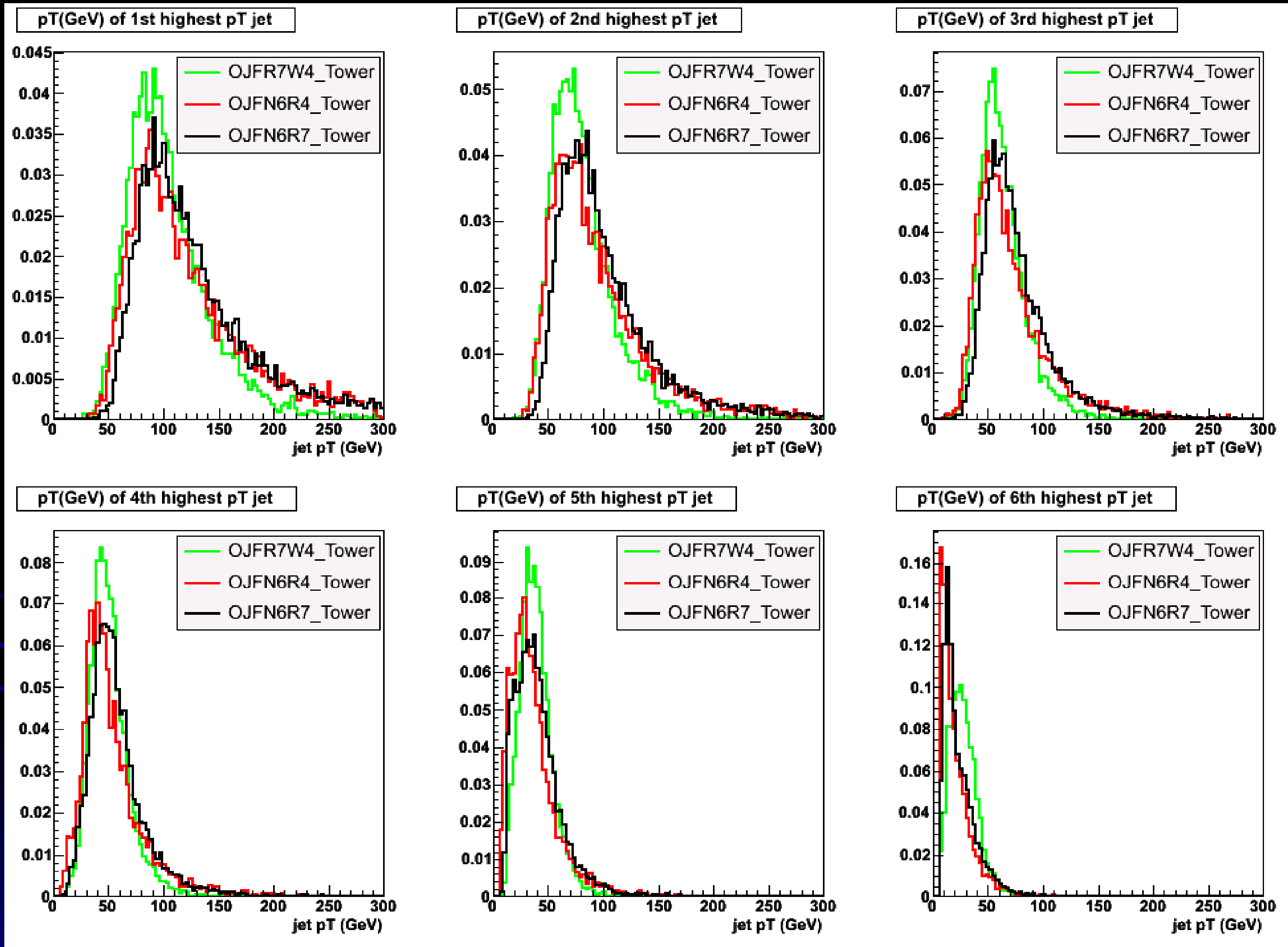
Normalized p_T distributions: towerJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



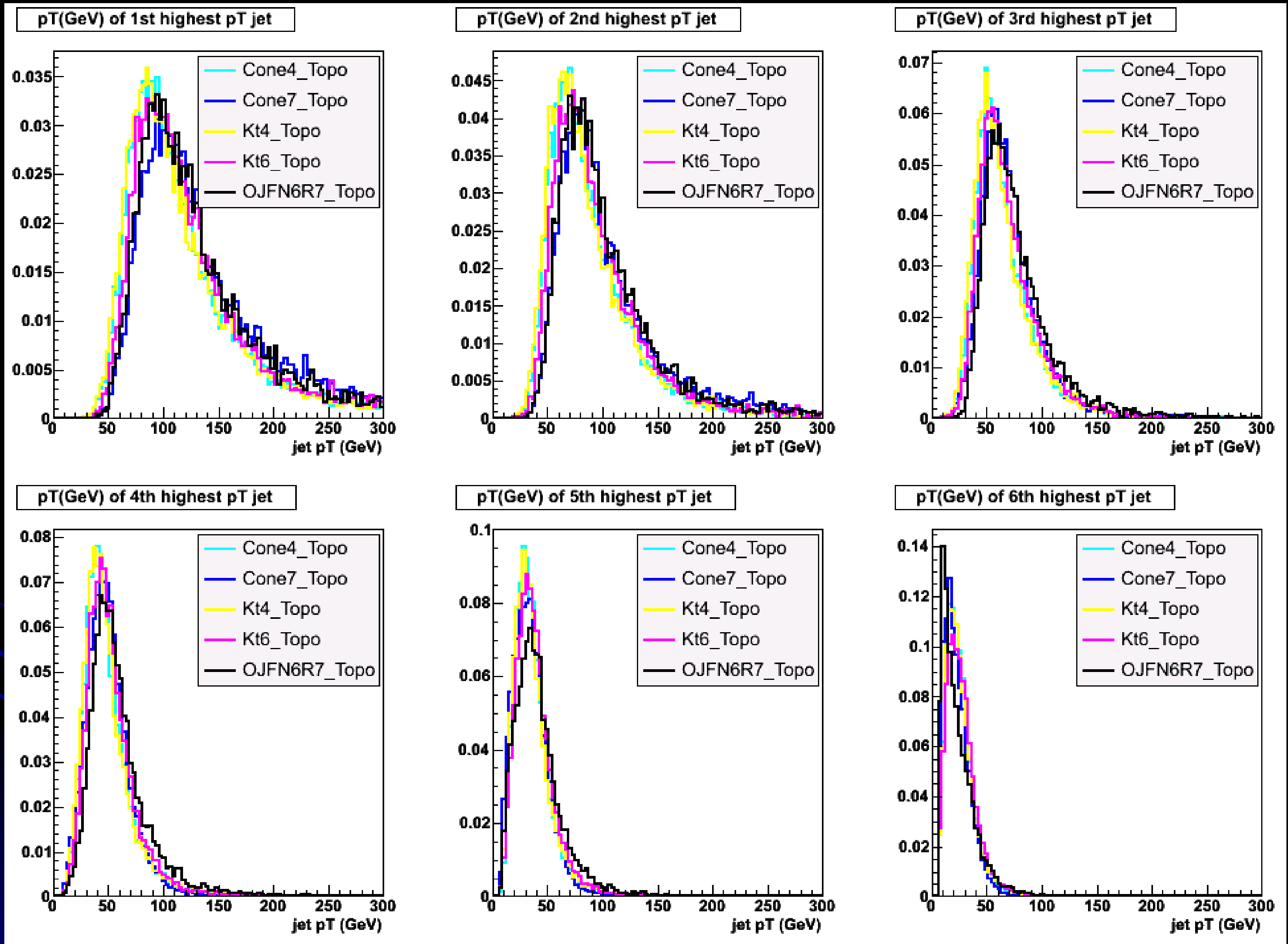
Normalized p_T distributions: OJF towerJets

fully hadronic t-tbar events
with at least 6 jets in $|\eta| < 3$



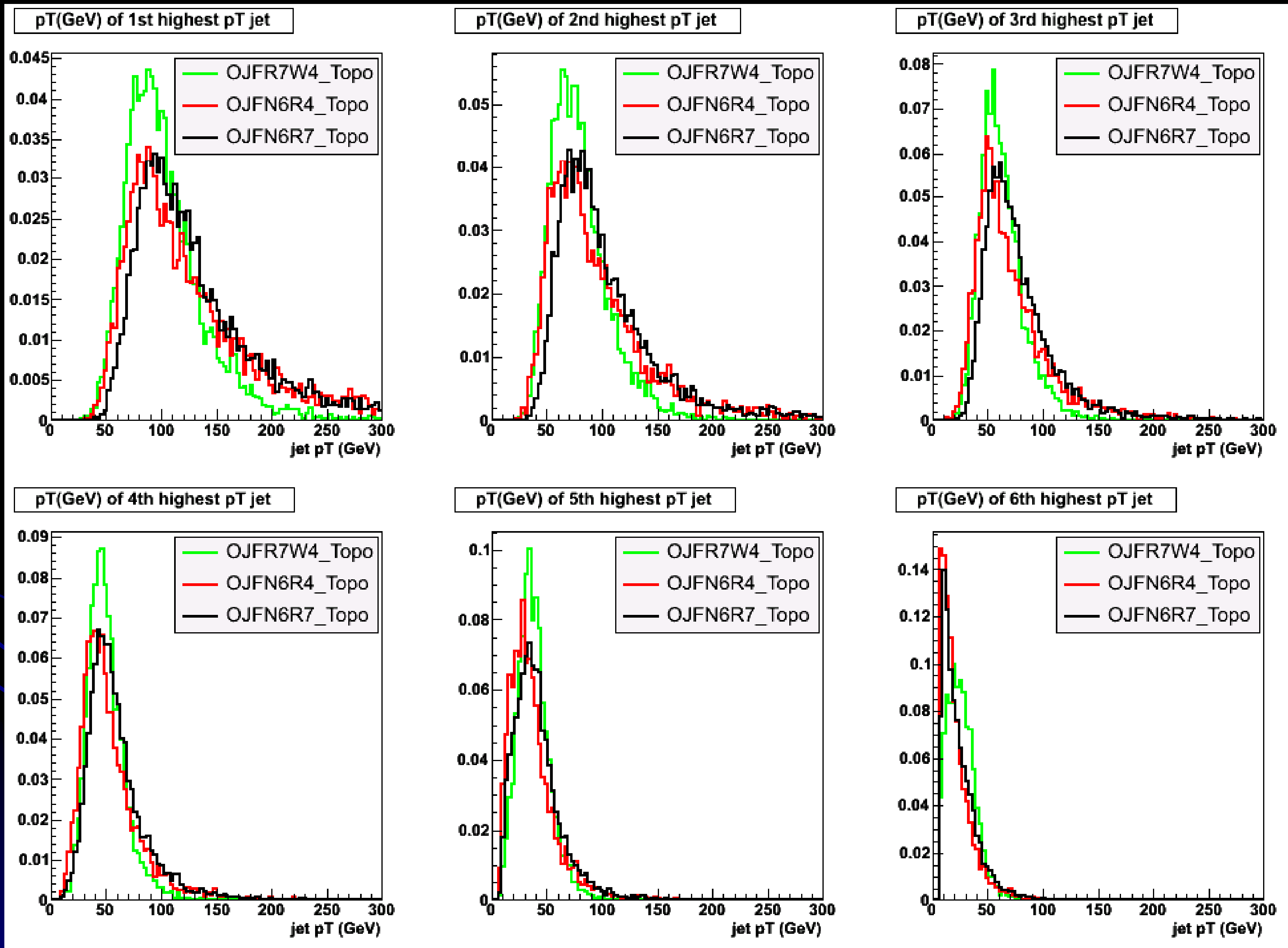
Normalized p_T distributions: topoJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



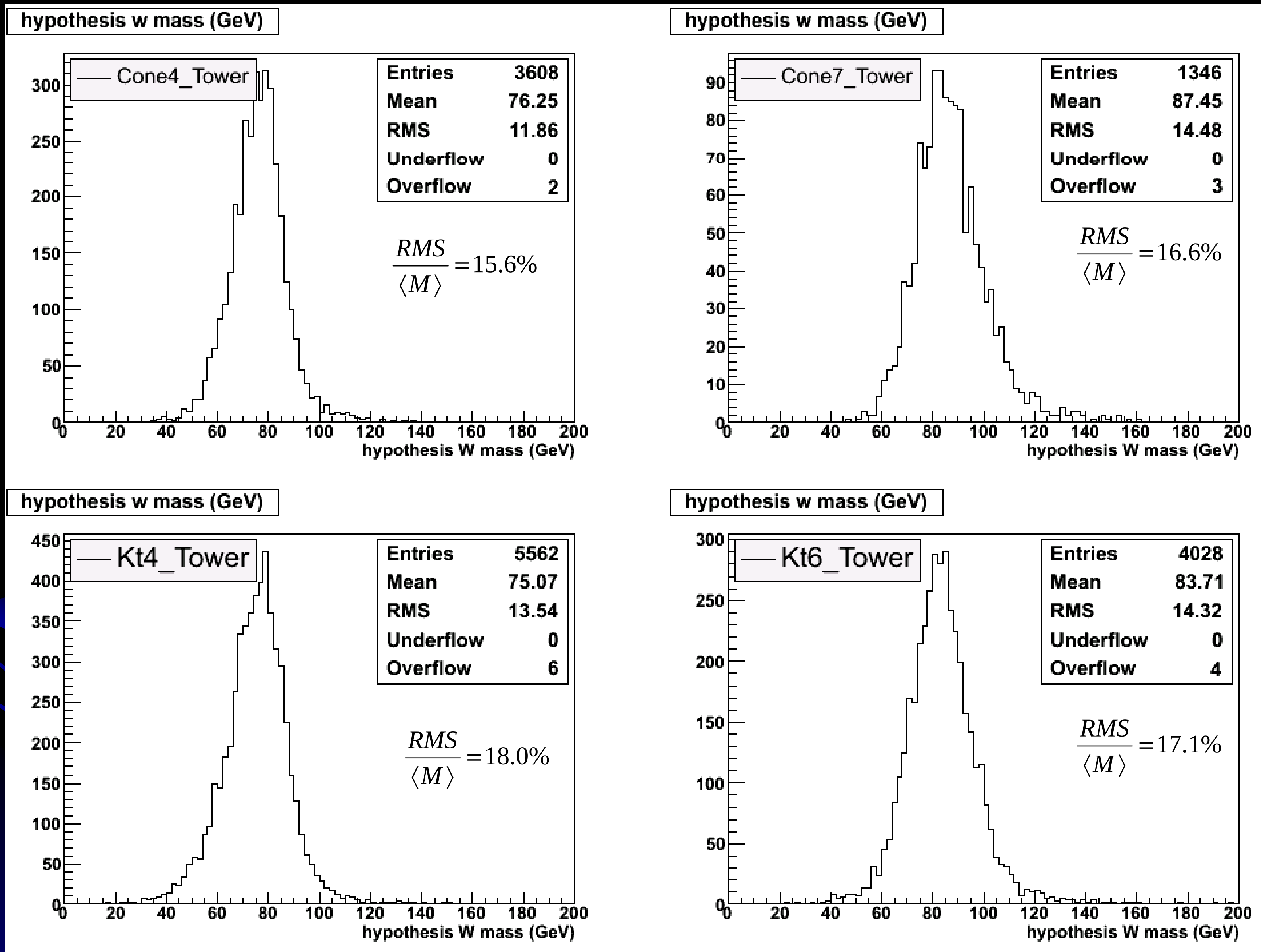
Normalized p_T distributions: OJF topoJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



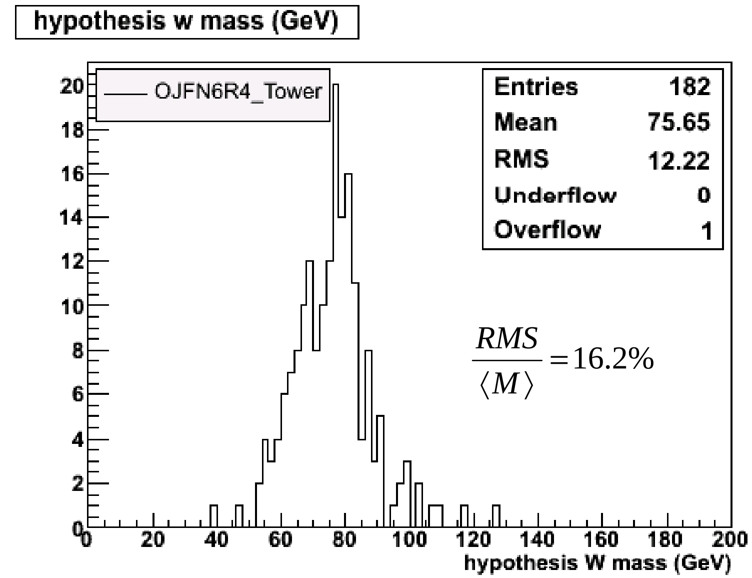
W mass plots: TowerJets

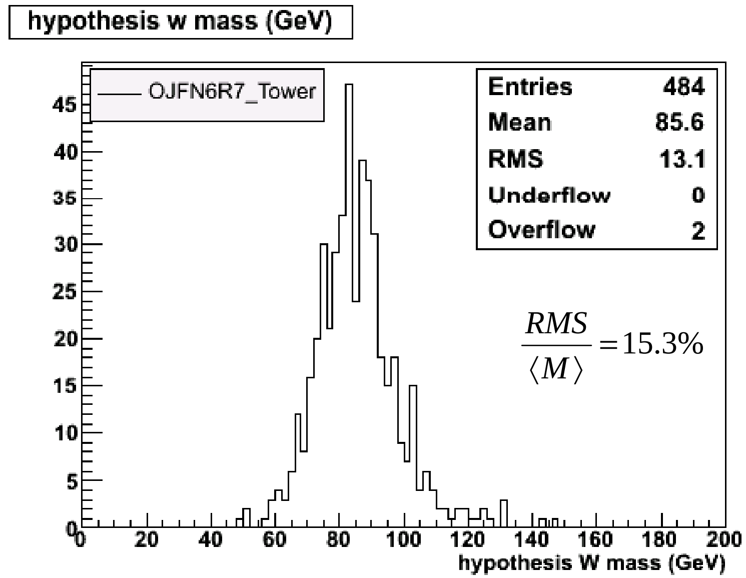
fully hadronic t-tbar events with at least 6 jets in |η| < 3 with all partons matched 1 to 1

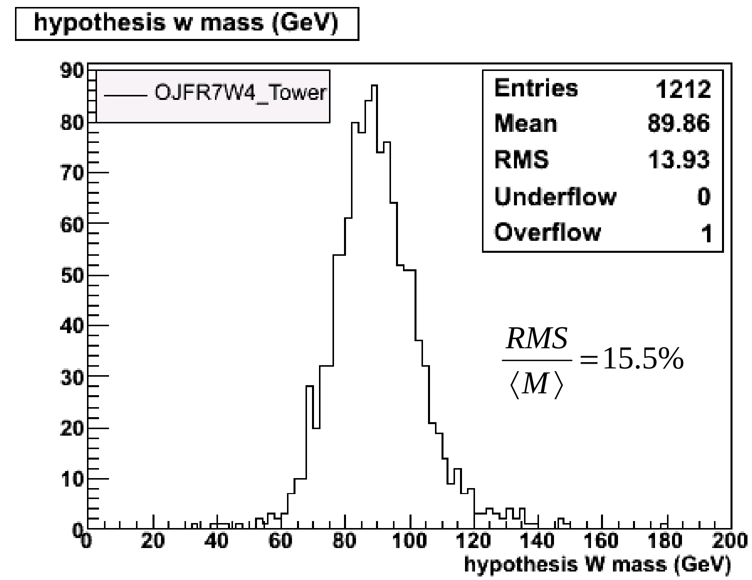


W mass plots: OJF TowerJets

fully hadronic t-tbar events with at least 6 jets
in |η| < 3 with all partons matched 1 to 1

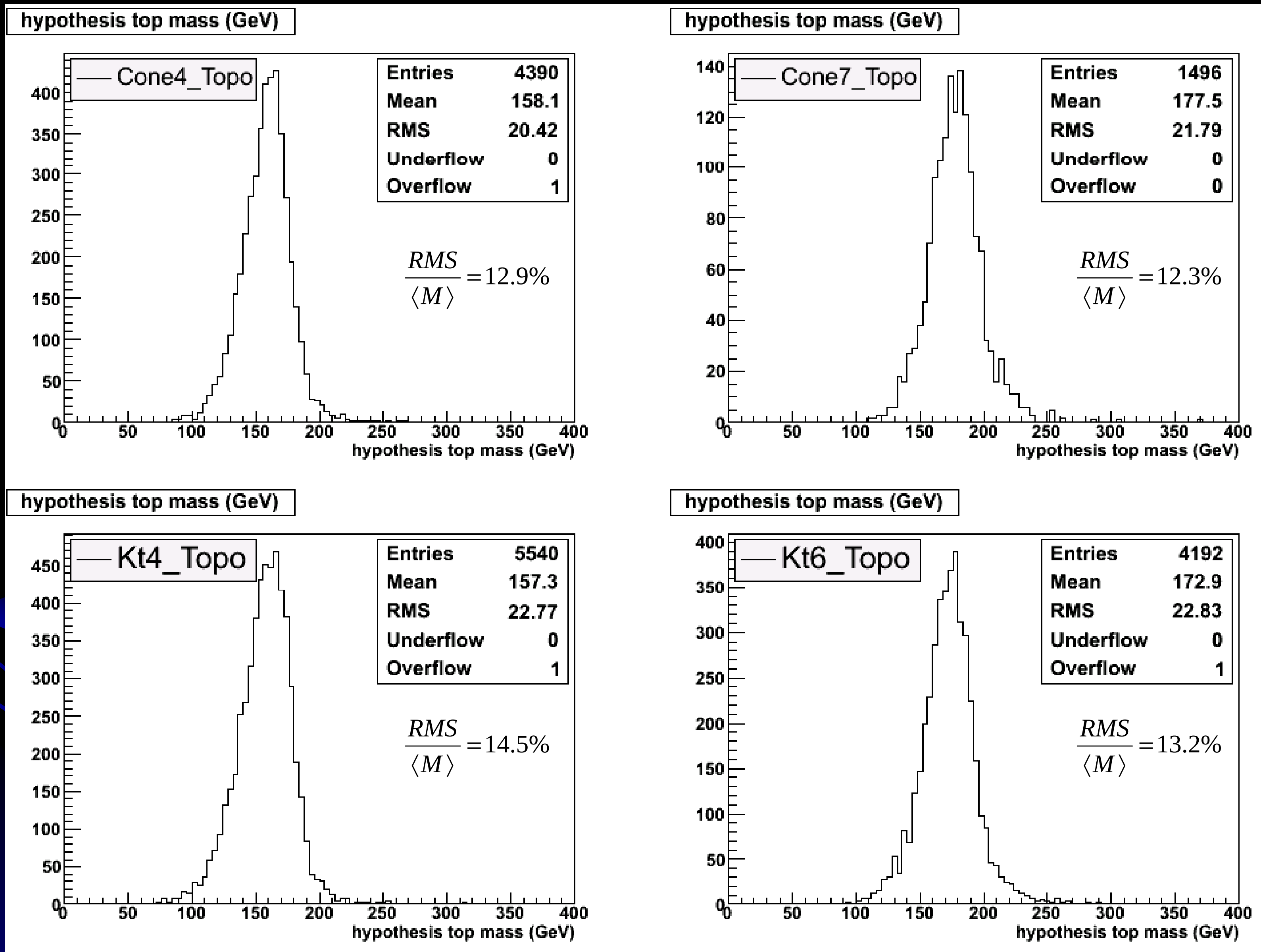






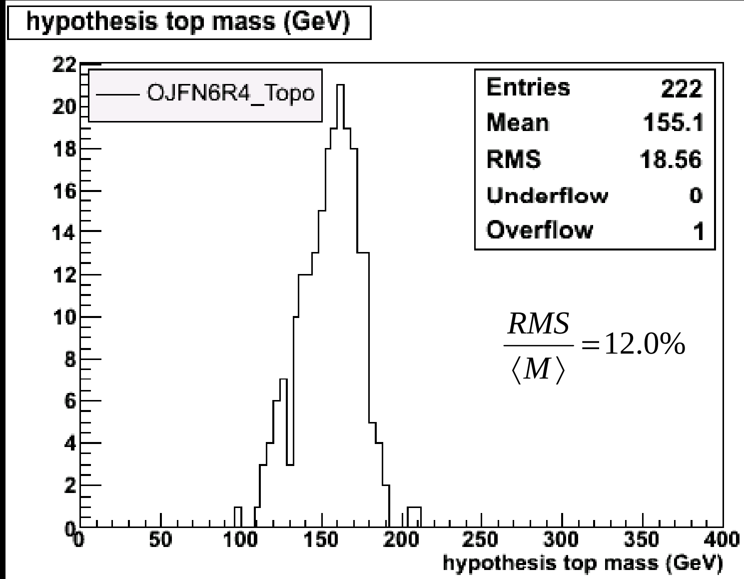
top mass plots: TopoJets

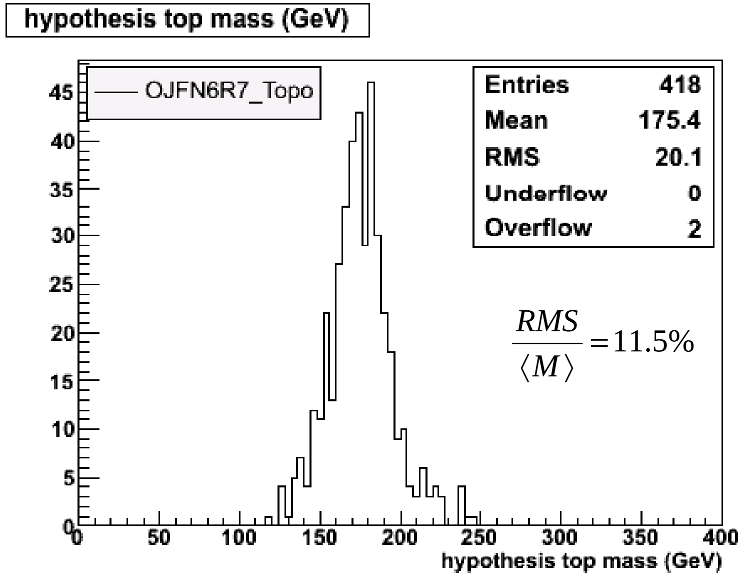
fully hadronic t-tbar events with at least 6 jets in |η| < 3 with all partons matched 1 to 1

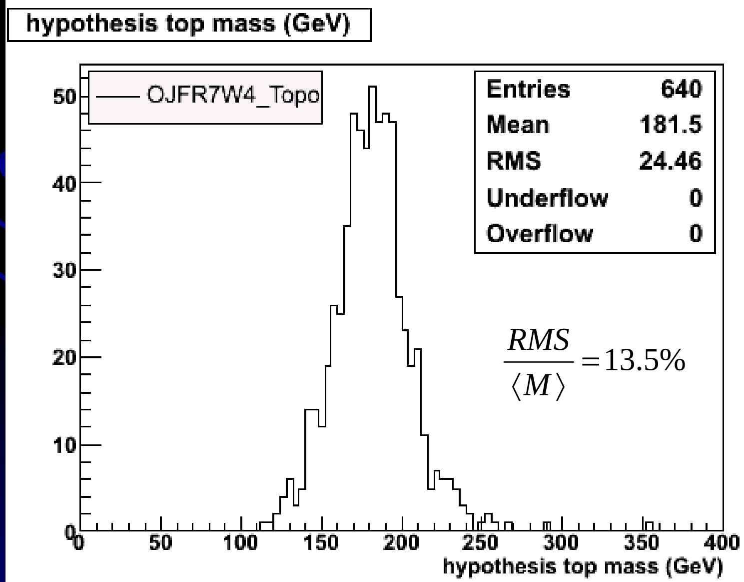


top mass plots: OJF TopoJets

fully hadronic t-tbar events with at least 6 jets
in |η| < 3 with all partons matched 1 to 1







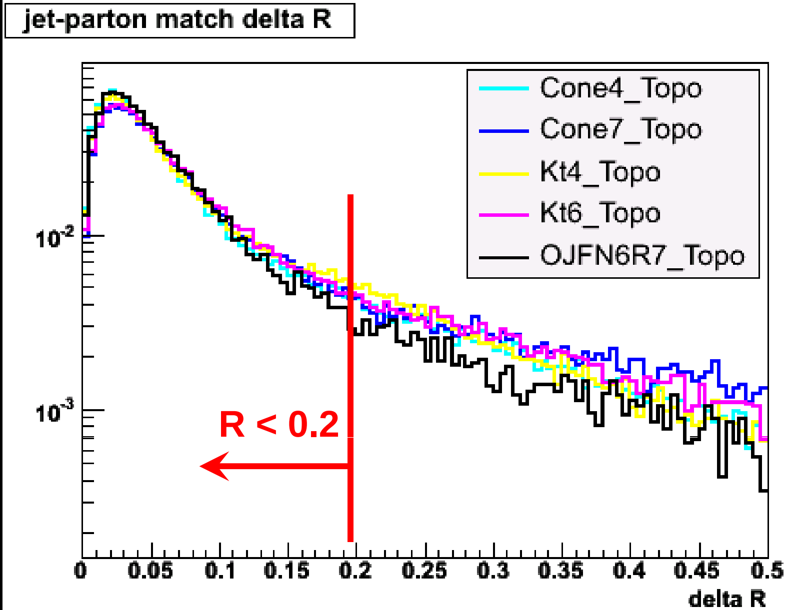
Conclusions and Outlook

- There is additional jet finder on the market, Optimal Jet Finder (OJF)
- The authors claim it is based on an optimal jet definition that solves the problem of jet definition in general. OJF is based on global event properties
- It is infra-red and collinear safe and there are no seed-related problems nor overlapping jets. It could provide more event info than standard jet algorithms
- Official implementation in Athena is very much in progress
- First tests with OJF in the ATLAS environment are quite encouraging. Agreement with Kt and Cone is good, but we would like to do better ☺
- More systematic tests in progress:
  - fine tuning of OJF parameter space
  - studies with different physical samples
- Years of testing for Cone and Kt, OJF deserves a bit of attention as well
- Hopefully, this is just a beginning of long and interesting journey…

Extra Slides

Normalized distributions: Topo jets

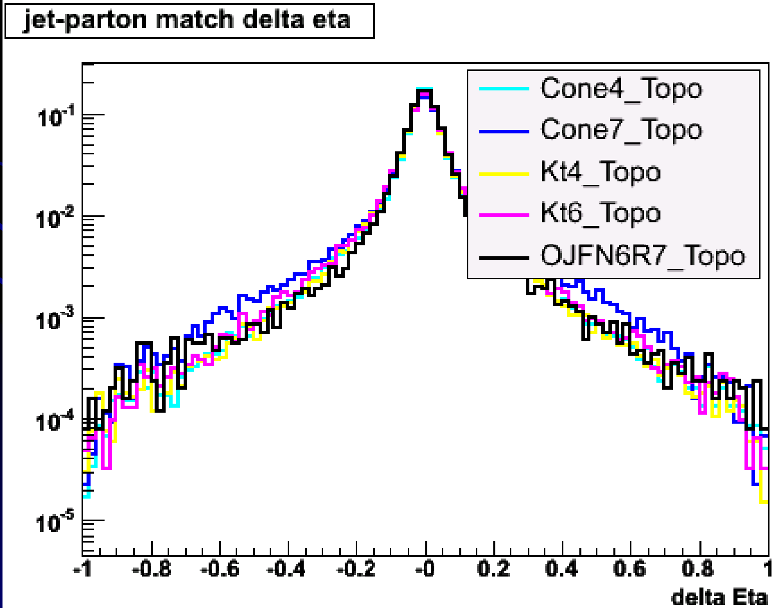
matched 1 to 1 jet-parton in fully hadronic t-tbar events with at least 6 jets in $|\eta| < 3$

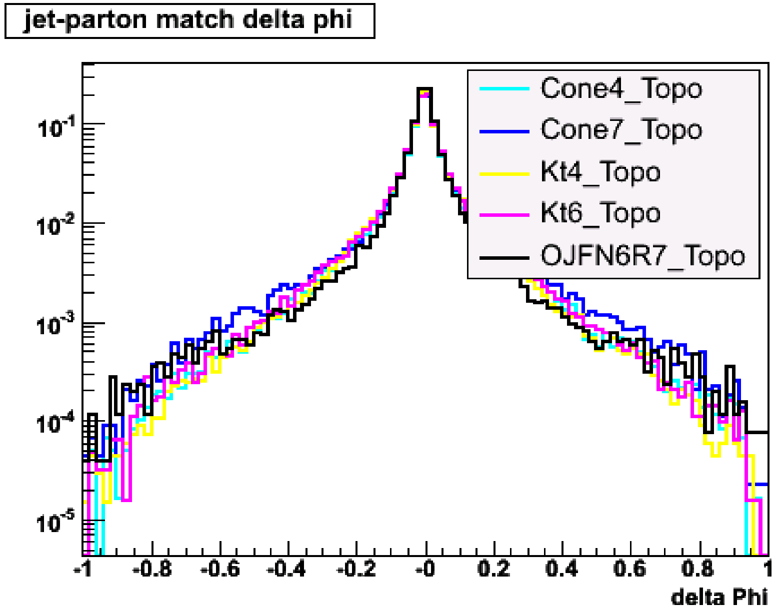


Jet – Parton

All 1 to 1 matched jets in events with at least 6 jets in |eta| < 3

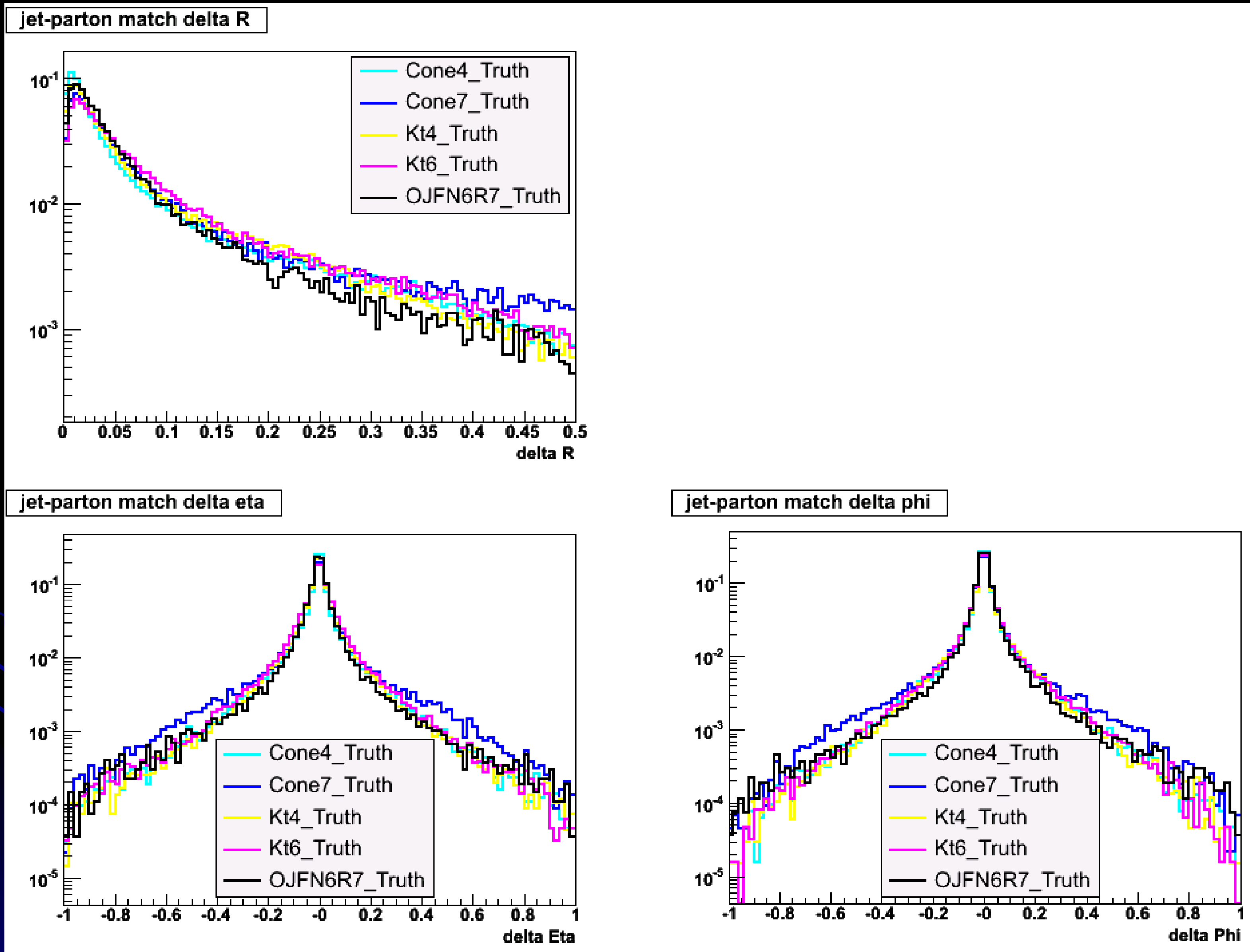
OJF with R = 0.7 is between Cone4 and Cone7





Normalized distributions: truthJets

matched 1 to 1 jet-parton in fully hadronic t-tbar events with at least 6 jets in |η| < 3



Event and Jet hypothesis selection

- **Try to compare jet matching efficiency for different jet algorithms**
  - **Fully hadronic t-tbar, choice of sample**
    - **Require at least 6 jets in $|\eta| < 3$**

      - clearly, algorithms with more than 6 jets will have a better chance at 6 jet-parton matching
    - **only consider the 6 highest pT jets**

      - algos with more than 6 jets still have a better chance at 6 jet-parton matching
    - **only consider events with exactly 6 jets**

      - perhaps a more fair way to compare 6 jet-parton matching for OJF with fixed number of jets (= 6)
  - **No jet E_T cuts applied**

Jet-Parton matching: CaloTower jets

fully hadronic t-tbar 6204 sample 12.0.X	Cone4TowerParticleJets	ConeTowerParticleJets	Kt4TowerParticleJets	Kt6TowerParticleJets	OJFTowerJets (R6 R4)	OJFTowerJets (R6 R7)	OJFTowerJets (R7 W8)
number of events	12983	12983	12983	12983	12983	12983	12983
at least 6 jets in |eta| < 3	10471	10084	12834	12863	4625	8162	7617
all matched partons 1 to 1	1804	673	2781	2014	91	242	606
matching efficiency	**17.2%**	**6.7%**	**21.7%**	**15.7%**	**2.0%**	**3.0%**	**8.0%**
selection efficiency	**13.9%**	**5.2%**	**21.4%**	**15.5%**	**0.7%**	**1.9%**	**4.7%**
at least 6 jets in |eta| < 3	10471	10084	12834	12863	4625	8162	7617
all matched partons 1 to 1	1804	673	2781	2014	91	242	606
assume 6 highest pt jets	833	379	899	796	91	242	321
matching efficiency	**17.2%**	**6.7%**	**21.7%**	**15.7%**	**2.0%**	**3.0%**	**8.0%**
selection efficiency	**6.4%**	**2.9%**	**6.9%**	**6.1%**	**0.7%**	**1.9%**	**2.5%**
at least 6 jets in |eta| < 3	10471	10084	12834	12863	4625	8162	7617
exactly 6 jets	3103	2738	297	262	4625	8162	1833
all matched partons 1 to 1	375	107	41	20	91	242	59
matching efficiency	**12.1%**	**3.9%**	**13.8%**	**7.6%**	**2.0%**	**3.0%**	**3.2%**
selection efficiency	**2.9%**	**0.8%**	**0.3%**	**0.2%**	**0.7%**	**1.9%**	**0.5%**
matching efficiencies							
u	72%	57%	73%	66%	62%	62%	64%
dbar	65%	48%	64%	56%	54%	54%	54%
b	77%	63%	74%	69%	68%	67%	71%
ubar	74%	57%	72%	72%	62%	63%	65%
d	66%	49%	67%	61%	54%	53%	57%
bbar	77%	63%	73%	70%	68%	68%	68%

It is very difficult to come up with totally fair matching-efficiency comparisons. But, even without tuning, OJF results are already comparable to Cone and Kt

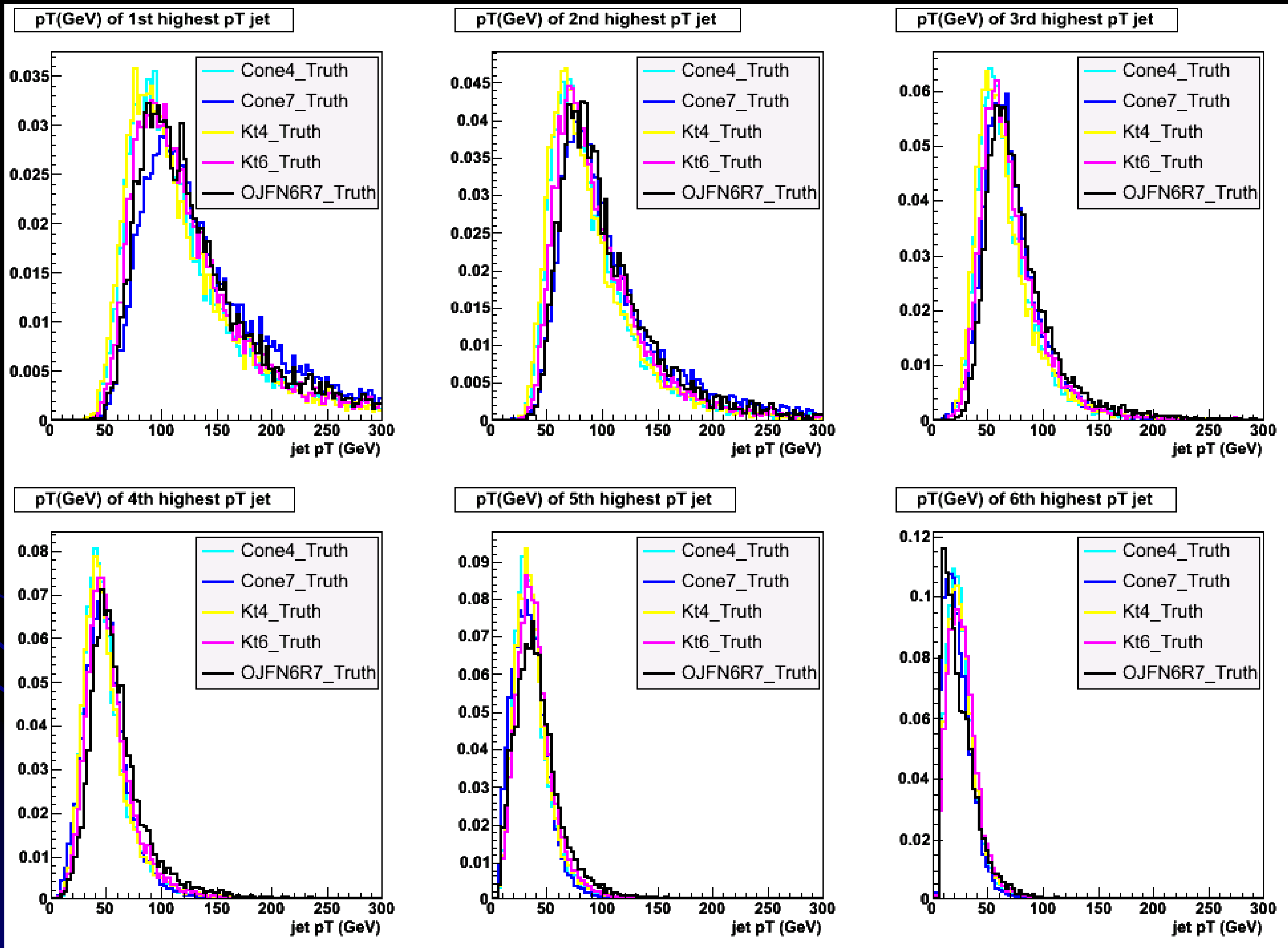
Jet-Parton matching: topoJets

fully hadronic t-tbar 5204 sample 12.0.X	Cone4TopoParticleJets	ConeTopoParticleJets	Kt4TopoParticleJets	Kt6TopoParticleJets	OJFTopoJets (N6 R4)	OJFTopoJets (N6 R7)	OJFTopoJets (R7 N4)
number of events	12983	12983	12983	12983	12983	12983	12983
at least 6 jets in |eta| < 3	11977	11244	12700	12570	4182	6856	5312
all matched partons 1 to 1	2195	748	2770	2096	111	209	320
matching efficiency	**18.3%**	**6.7%**	**21.8%**	**16.7%**	**2.7%**	**3.0%**	**6.0%**
selection efficiency	**16.9%**	**5.8%**	**21.3%**	**16.1%**	**0.9%**	**1.6%**	**2.5%**
at least 6 jets in |eta| < 3	11977	11244	12700	12570	4182	6856	5312
all matched partons 1 to 1	2195	748	2770	2096	111	209	320
assume 6 highest pt jets	910	392	939	877	111	209	186
matching efficiency	**18.3%**	**6.7%**	**21.8%**	**16.7%**	**2.7%**	**3.0%**	**6.0%**
selection efficiency	**7.0%**	**3.0%**	**7.2%**	**6.8%**	**0.9%**	**1.6%**	**1.4%**
at least 6 jets in |eta| < 3	11977	11244	12700	12570	4182	6856	5312
exactly 6 jets	1704	1908	618	805	4182	6856	1798
all matched partons 1 to 1	211	81	94	116	111	209	49
matching efficiency	**12.4%**	**4.2%**	**15.2%**	**14.4%**	**2.7%**	**3.0%**	**2.7%**
selection efficiency	**1.6%**	**0.6%**	**0.7%**	**0.9%**	**0.9%**	**1.6%**	**0.4%**
matching efficiencies							
u	74%	55%	71%	74%	63%	62%	63%
dbar	63%	47%	69%	62%	55%	55%	55%
b	77%	62%	79%	77%	68%	68%	70%
ubar	73%	55%	77%	76%	64%	62%	62%
d	66%	48%	67%	64%	54%	54%	55%
bbar	75%	61%	77%	76%	70%	69%	69%

It is very difficult to come up with totally fair matching-efficiency comparisons. But, even without tuning, OJF results are already comparable to Cone and Kt

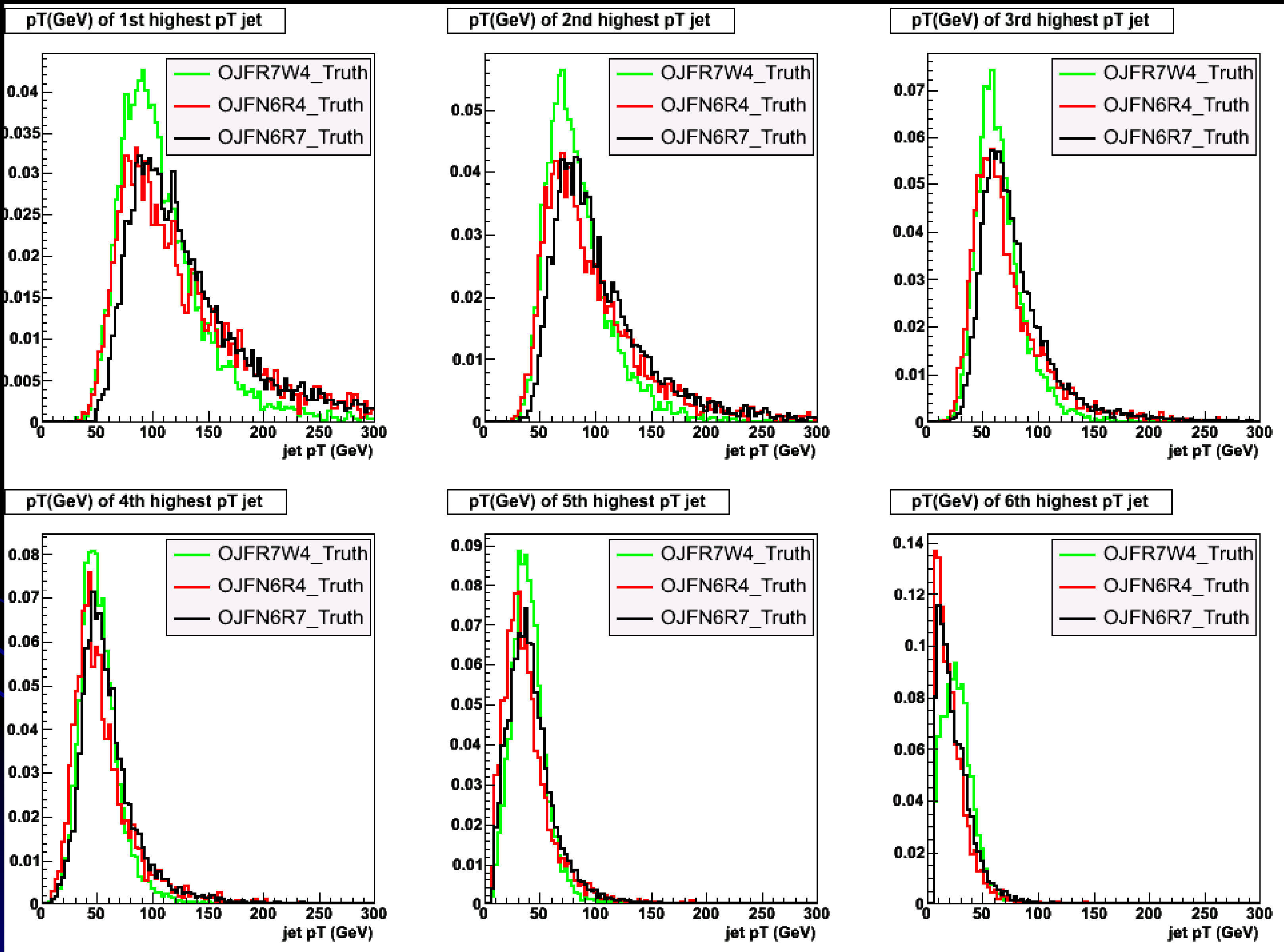
Normalized p_T distributions: truthJets

fully hadronic t-tbar events
with at least 6 jets in $|\eta| < 3$



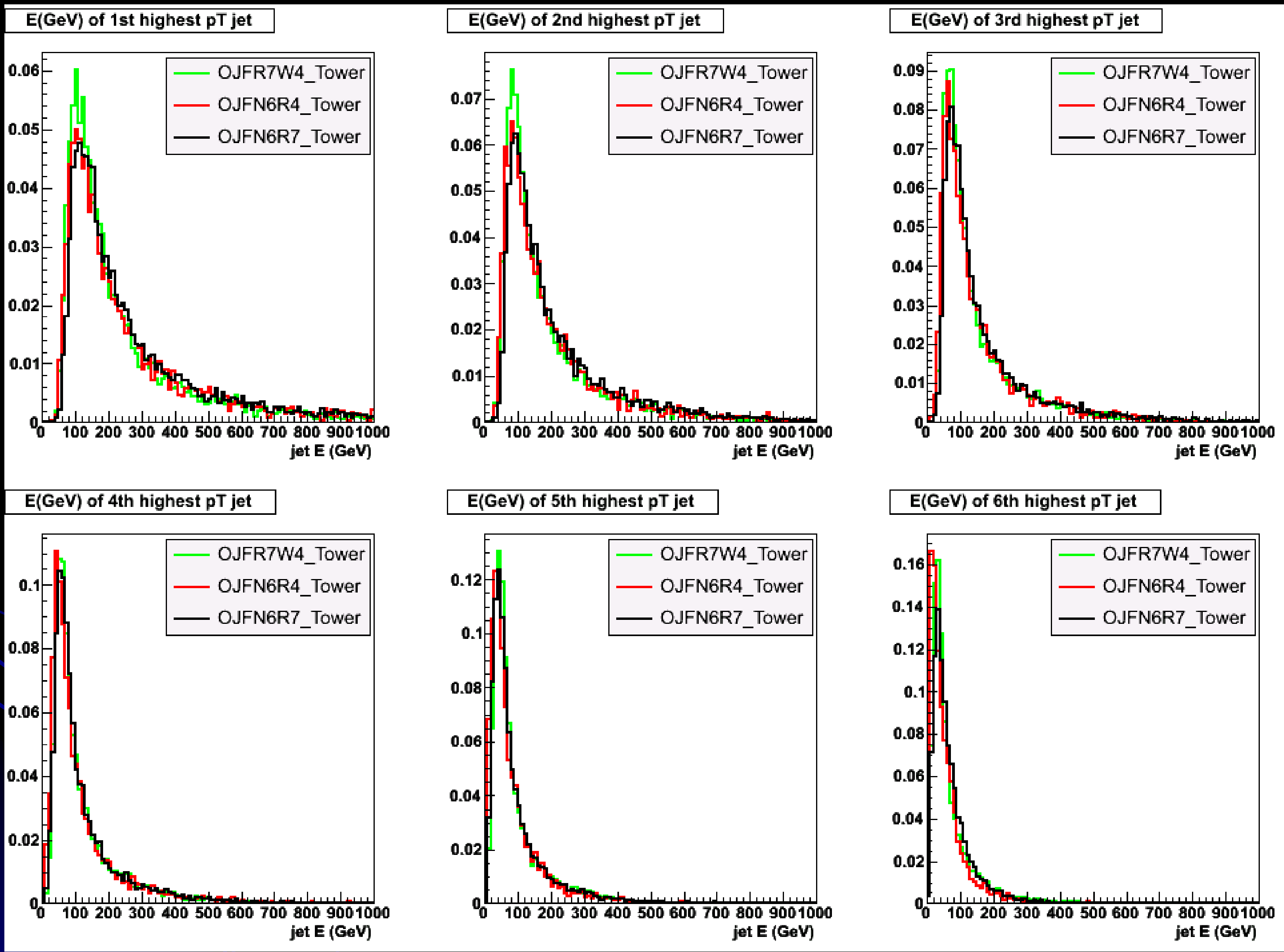
Normalized p_T distributions: OJF truthJets

fully hadronic t-tbar events with at least 6 jets in $|\eta| < 3$



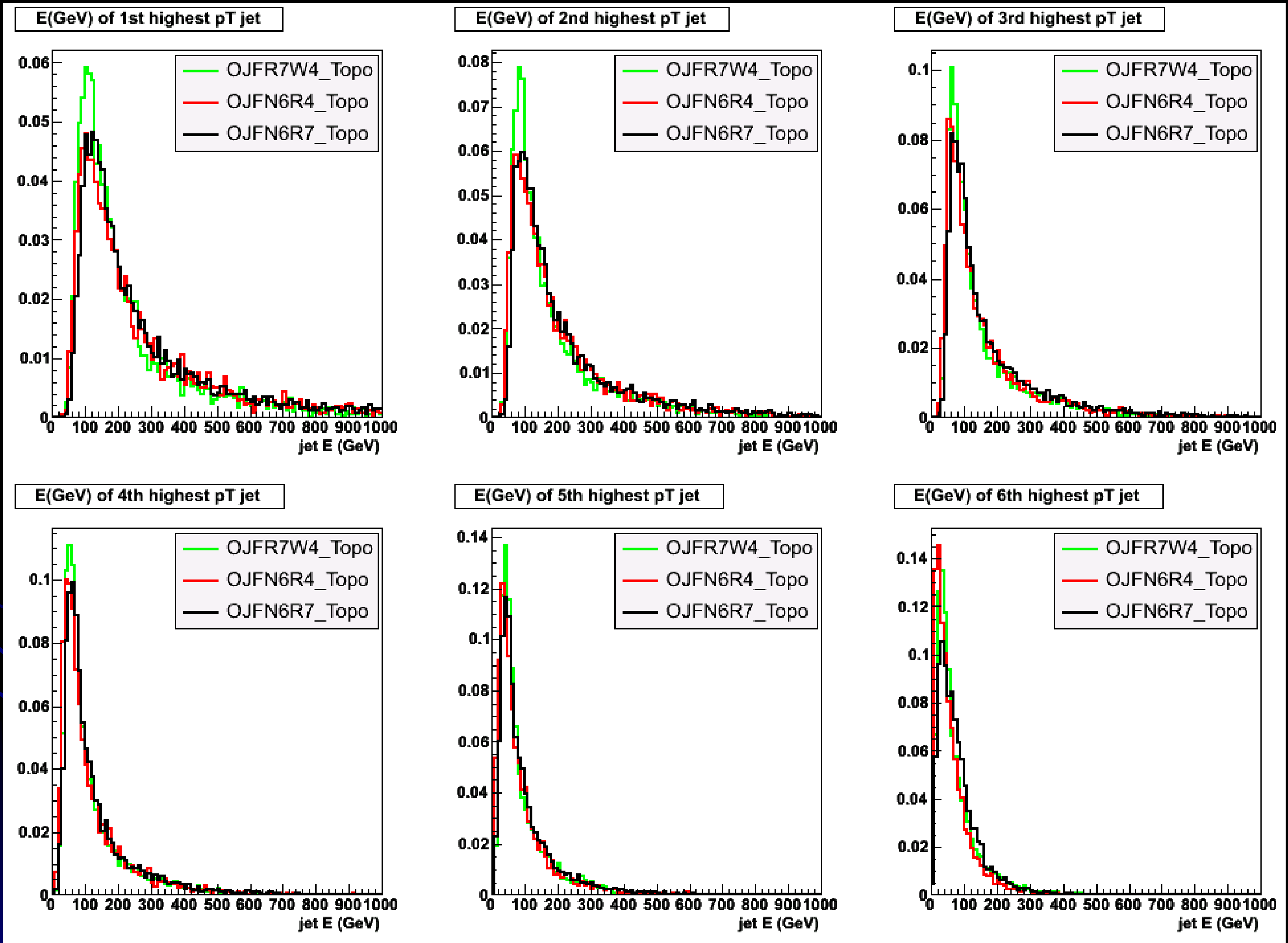
Normalized E distributions: OJF towerJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



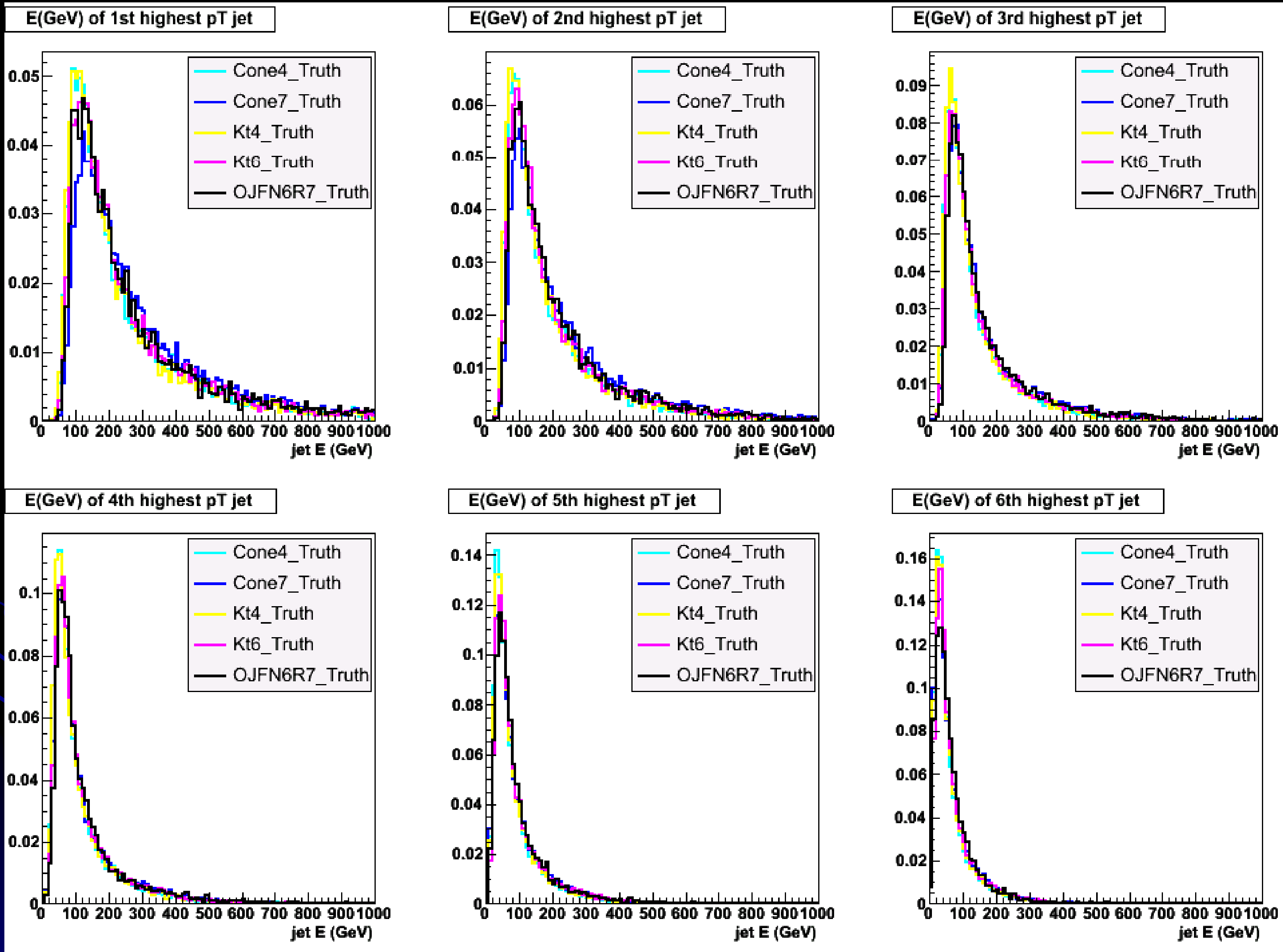
Normalized E distributions: OJF topoJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



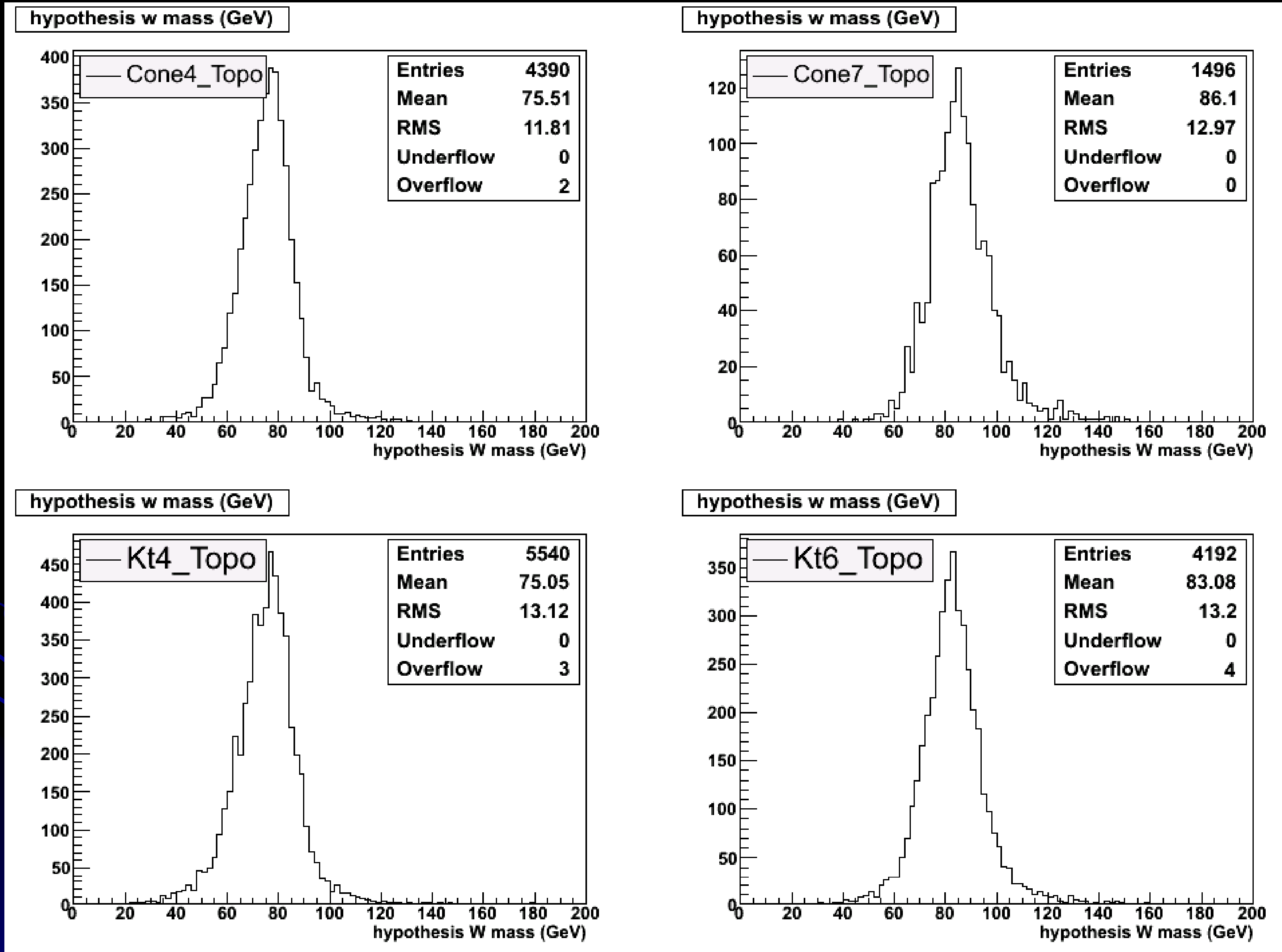
Normalized E distributions: truthJets

fully hadronic t-tbar events
with at least 6 jets in |η| < 3



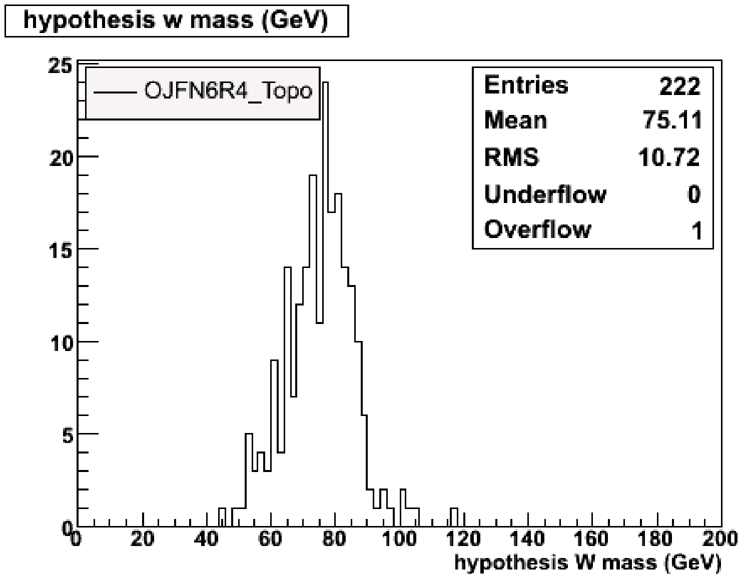
W mass plots: TopoJets

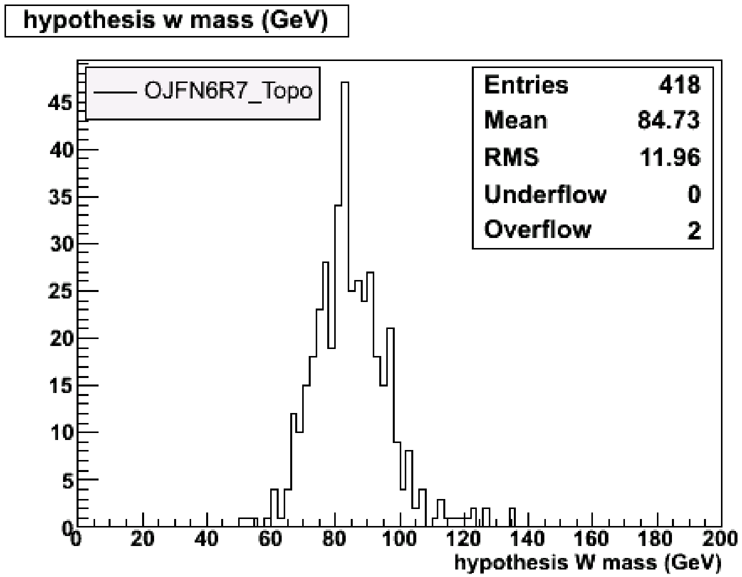
fully hadronic t-tbar events with at least 6 jets in $|\eta| < 3$ with all partons matched 1 to 1

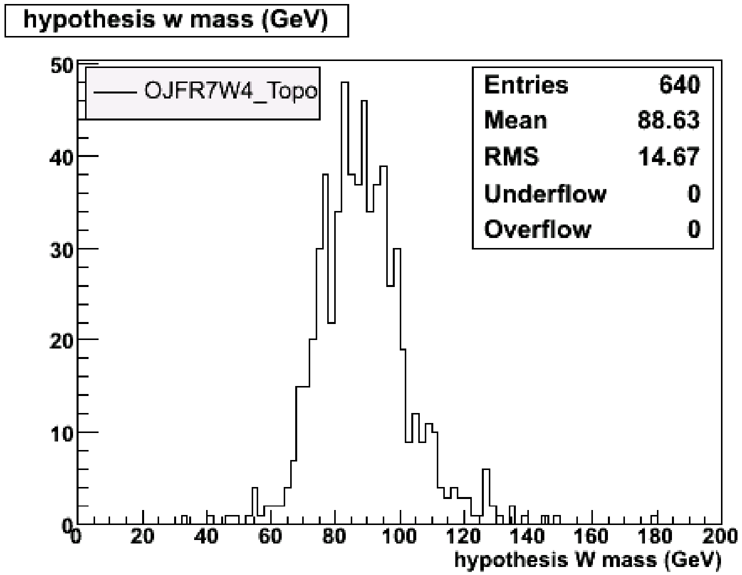


W mass plots: OJF TopoJets

fully hadronic t-tbar events with at least 6 jets in $|\eta| < 3$ with all partons matched 1 to 1

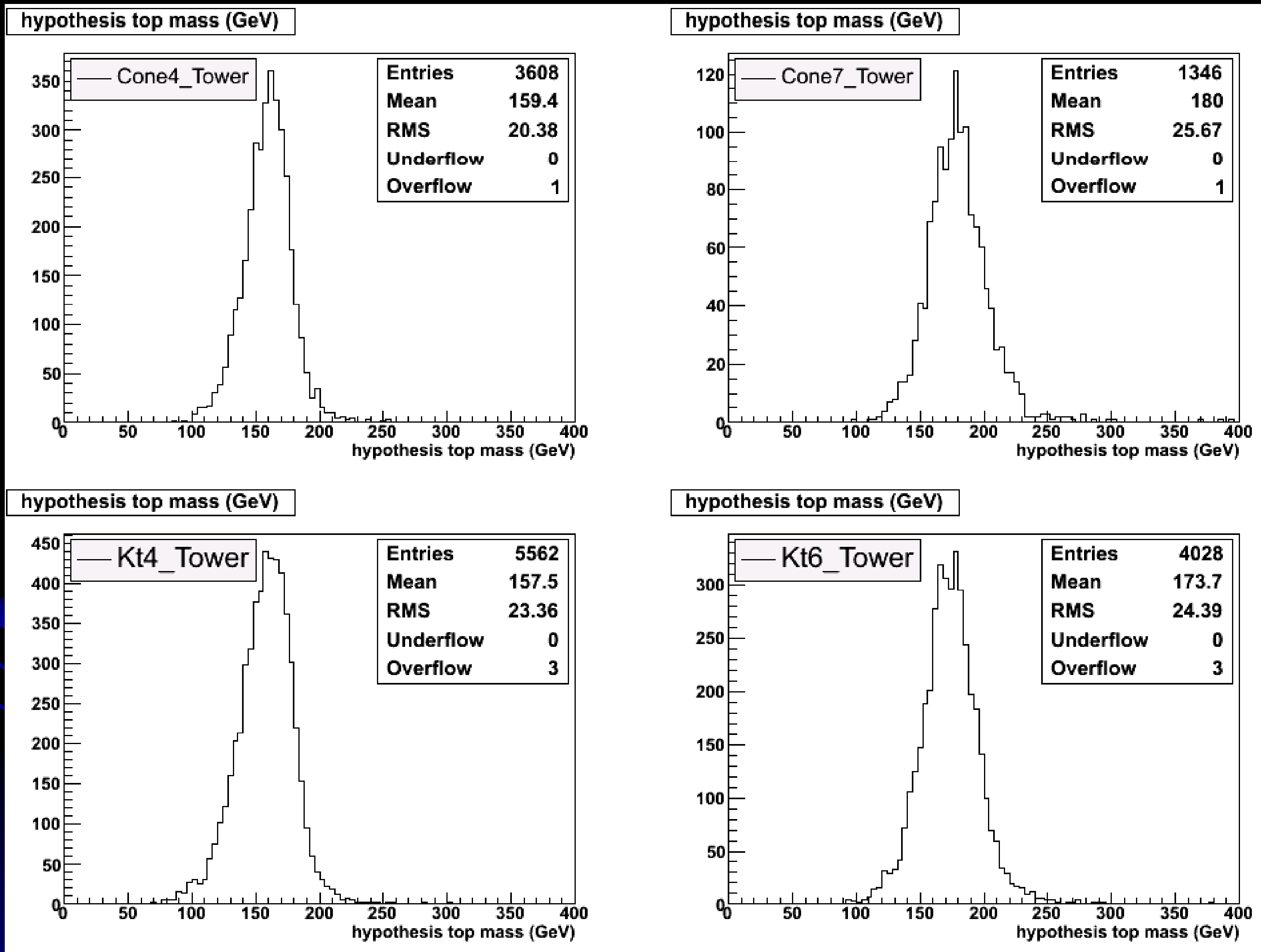






top mass plots: TowerJets

fully hadronic t-tbar events with at least 6 jets
in $|\eta| < 3$ with all partons matched 1 to 1



top mass plots: OJF TowerJets

fully hadronic t-tbar events with at least 6 jets in $|\eta| < 3$ with all partons matched 1 to 1