Top Quark Mass Reconstruction using High Pt Top in the Lepton + Jets Channel

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- ❑ Topology of Lepton + Jets
- ❑ High Pt top basic idea
- ❑ 3 methods for jets selection
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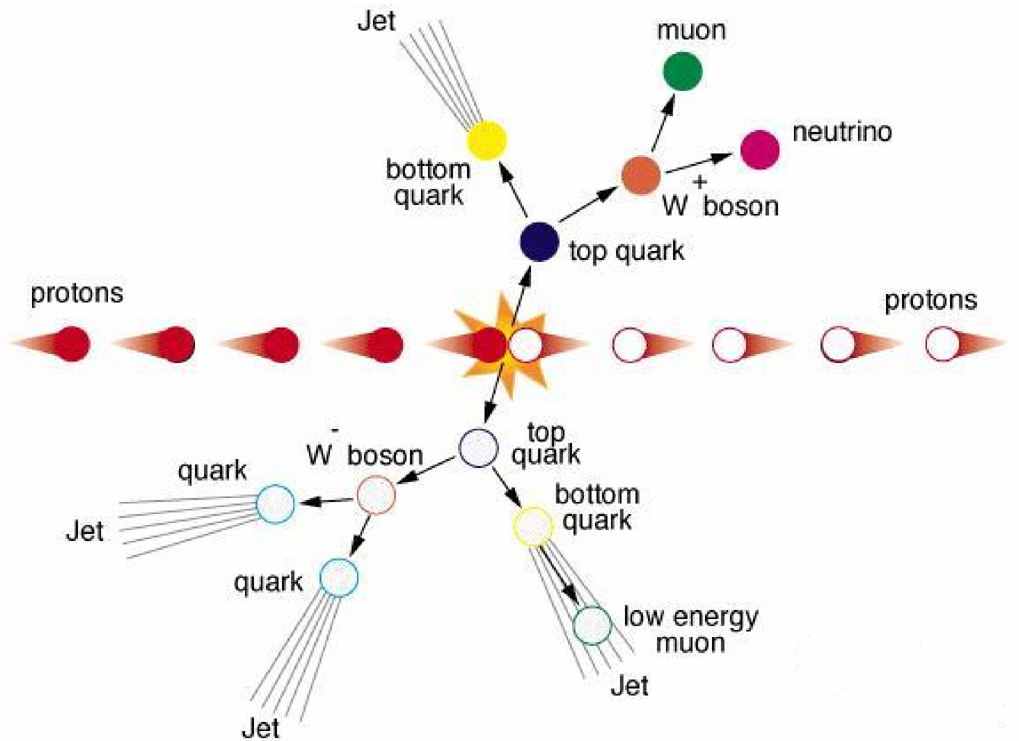
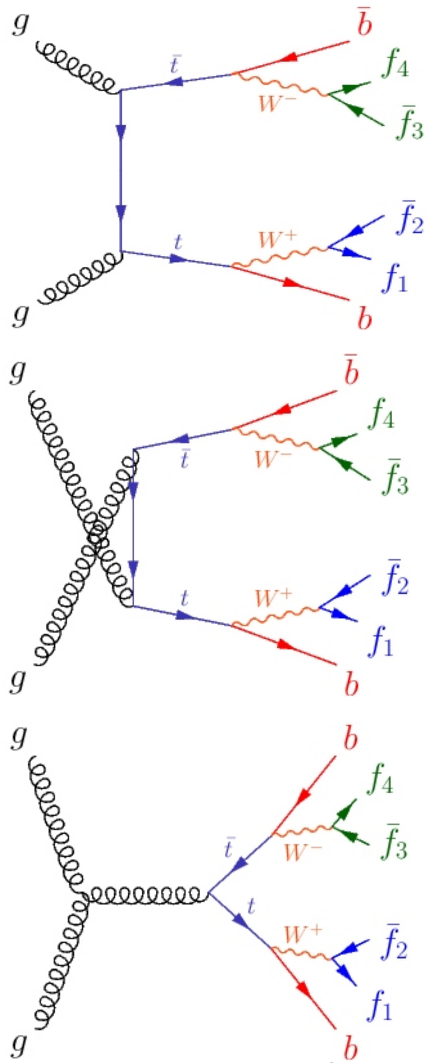
- ❑ Clusters invariant masses $\mathbf{M^{top}_{clus}}$
- ❑ Underlying Event (UE_{clus}) estimation and subtraction
- ❑ Calibration from high Pt W_{clus}
- ❑ Summary

Topology of Lepton + Jets channel at LHC

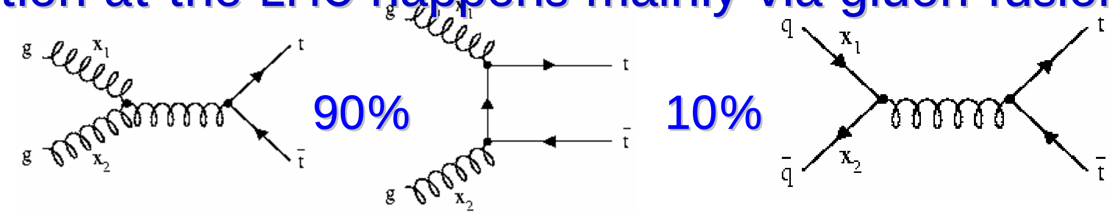
- NLO Cross-section for tt~ production at LHC is σ(tt)~830 ± 100 pb-1(LO about ½ of this at the same scale)



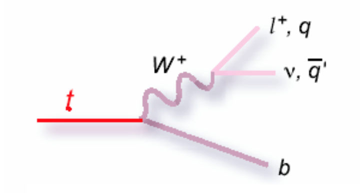


Top production and decay at the LHC

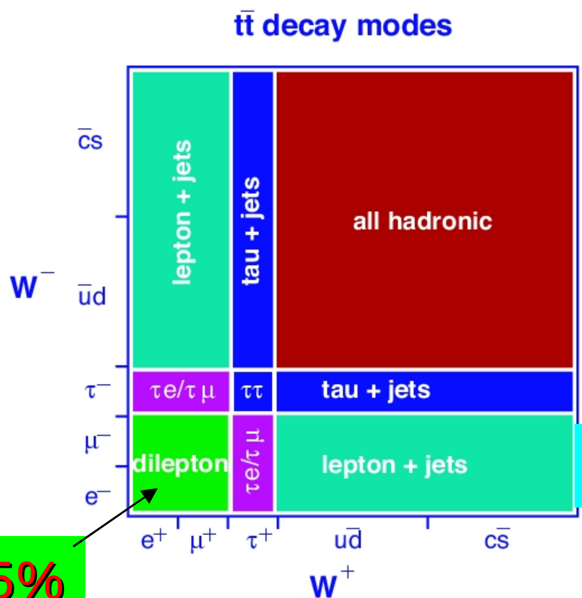
Top production at the LHC happens mainly via gluon fusion:



The top in the SM decays into W+b, leading to different signatures



~100%



~46%

~29%

~4.5%

☞ need to reconstruct and identify

- electrons
- muons
- b-jets
- light jets
- missing E_T

High P_t top basic idea

- ✓ Highly boosted top quark decay back-back, making two hemispheres
- ✓ When the top has a higher boost, one expect the opening angle between W and b (from top decay) to be smaller.
- ✓ High pt tops have decay angles close to the top flight direction and therefore the mass of the objects in a large cone around the top direction is correlated with real top mass.
- ✓ The idea why we take high pt tops is to get the three jets from the top decay close to each other and that they can be collected in one cone with a large opening angle.
- ✓ One could calculate the mass of the objets which are in larger cone around the top quark direction of flight. For this the top quark needs to have a larger pt > 200GeV.

Generator level cuts

$$t\bar{t} \to bW^{+}bW^{-} \to bq\bar{q}bl\nu(l=\mu)$$

- $P_t^{top} > 200$ GeV, $|\eta| < 3.0$
- $P_t^{anti\text{-}top} > 200$ GeV, $|\eta| < 3.0$
- $P_t^{\mu} > 20$ GeV, $|\eta| < 2.0$
- $P_t^{q} > 20$ GeV, $|\eta| < 2.5$

FAMOS_1_4_0 samples

165 Top mass point = 20K events

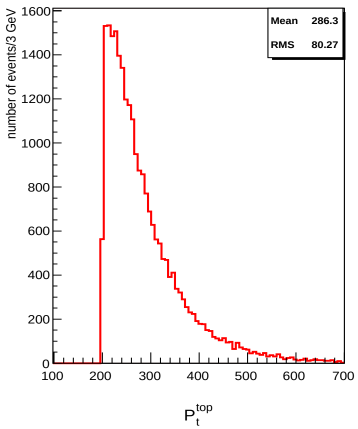
175 Top mass point = 50K events

185 Top mass point = 20K events

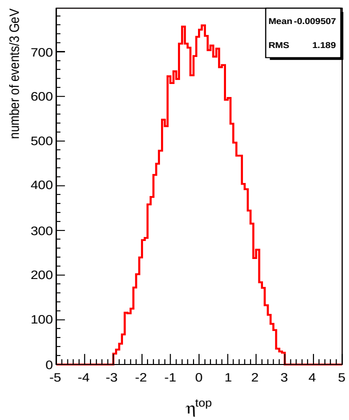
X-section more than 1% of the total tT cross-section

	no of events With pile-up	Int luminosity fb^{-1}	X-section pb
$t\bar{t} \to bW^{+}bW^{-} \to bq\bar{q}bl\nu(l=\mu)$	**49535**	**7.23**	**6.85**

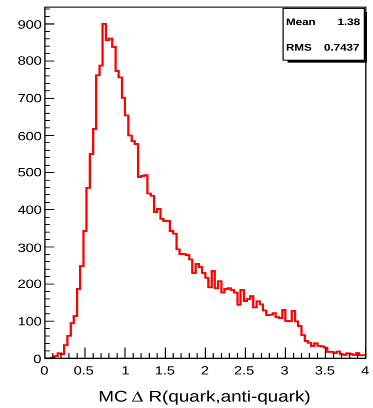
Partonic Level Distributions



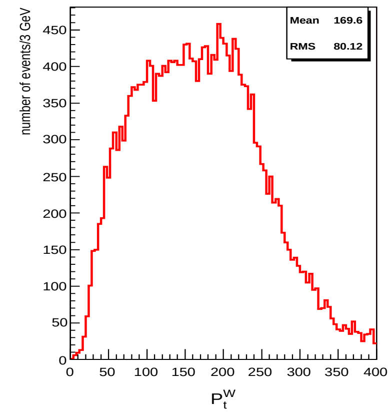
P_t^{top}



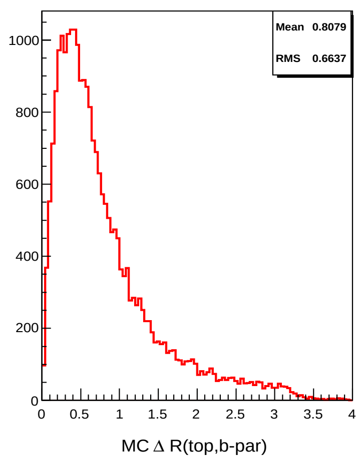
MC η^{top}



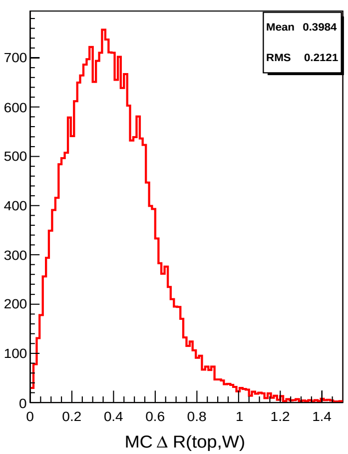
ΔR(q,qbar)



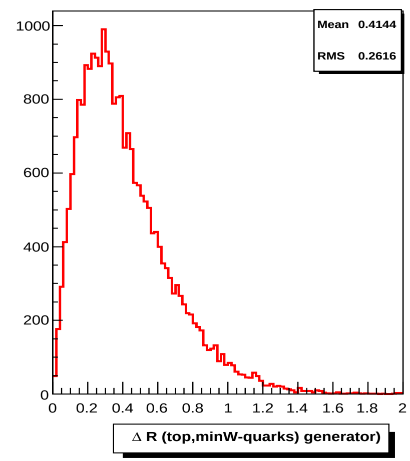
P_t^W



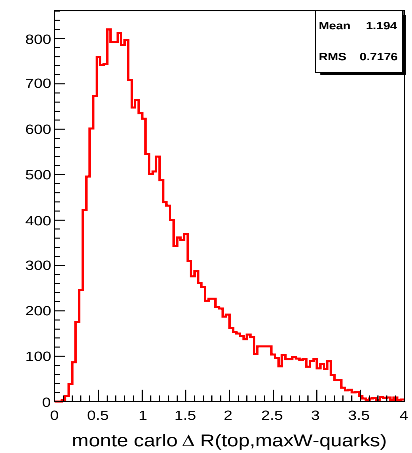
ΔR(top,b-par)



ΔR(top,W)

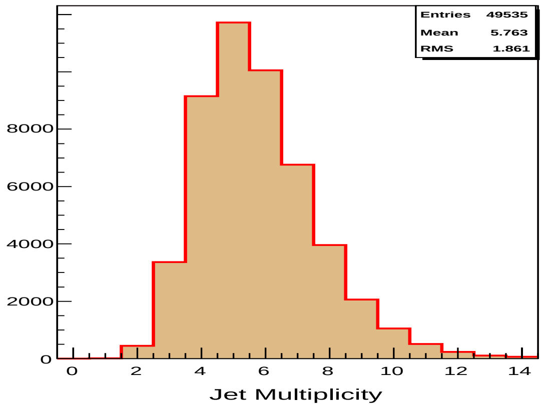


ΔR(top, min W-quarks)

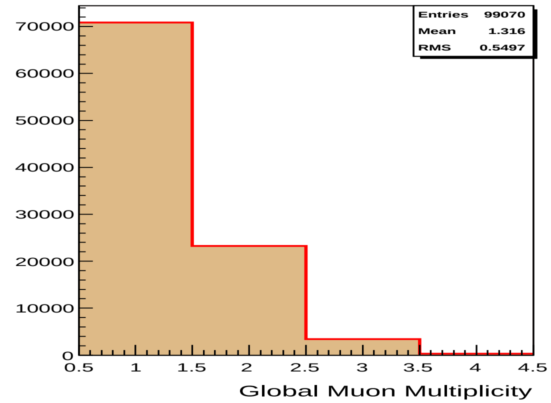


ΔR(top, max W-quarks)

Jet Multiplicity distribution



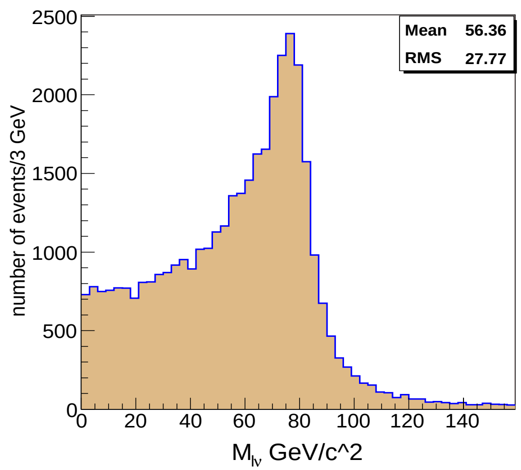
Global muon multiplicity dist.



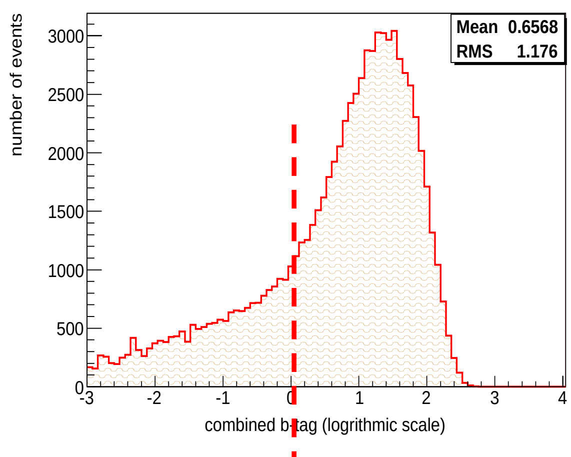
- METMC → MET from particles
- MET > 30 GeV
- At least 1 iso good muon, P_t>20 GeV, $|\eta|$<2.0

combined b-tag disc. > 1.0

(60% b-tag efficiency)



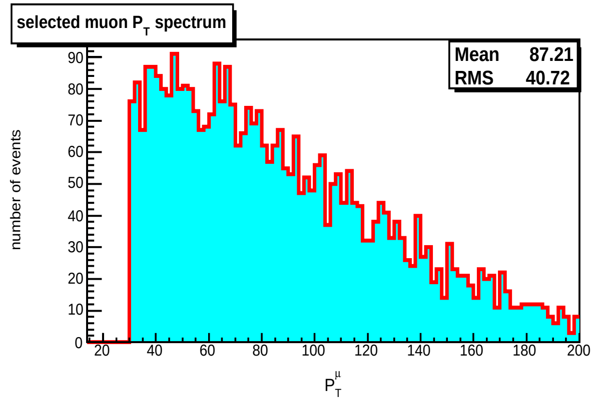
leptonic W reco mass

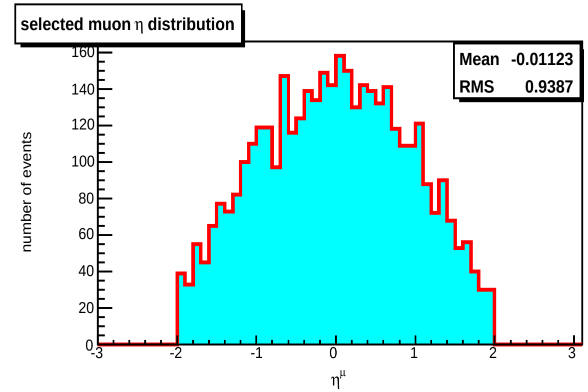


combined b-tag discriminator

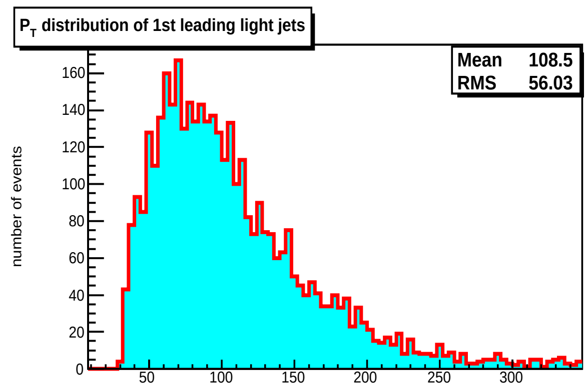
Leading jets and muons P_t distributions

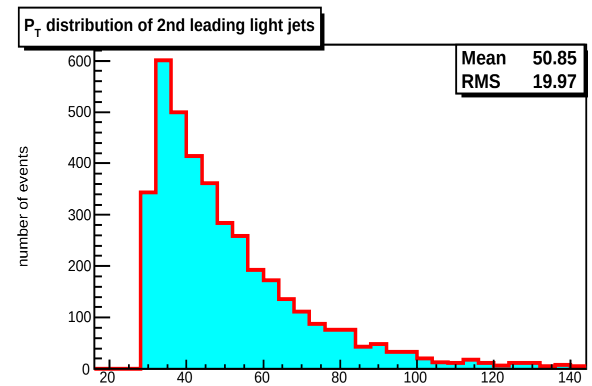
Isolated muon
$\Sigma Pt_{trks}/Pt_{\mu}$) < 5%
(ΔR=0.01-0.2)
Efficiency > 92%



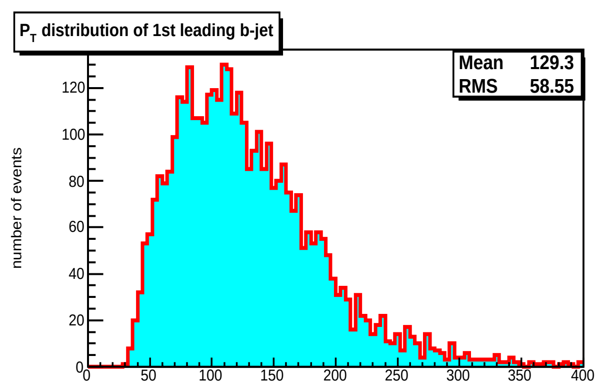


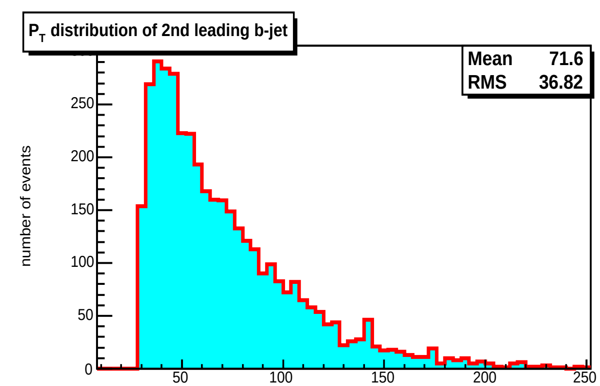
Leading light jets P_t





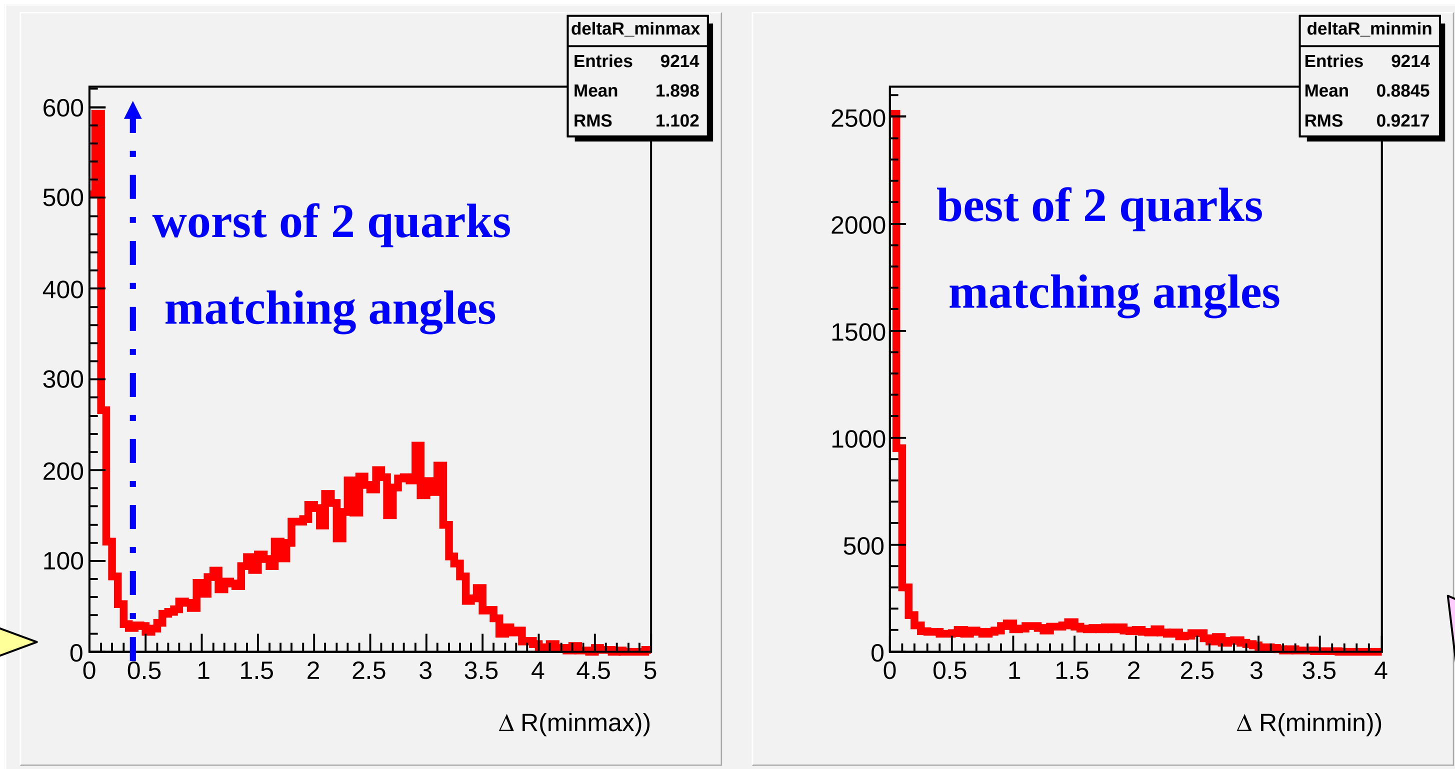
Leading b-jets P_t





Jet-Parton Matching (JPM)

- 2 light jets + 2 quarks from W
  - 4 possible jet combinations → take best combination



Correctly matched if $\Delta R < 0.4$

Maximum of two minimas

Introducing 3 approaches

- Three approaches to select events
  + jet combination (for top direction)

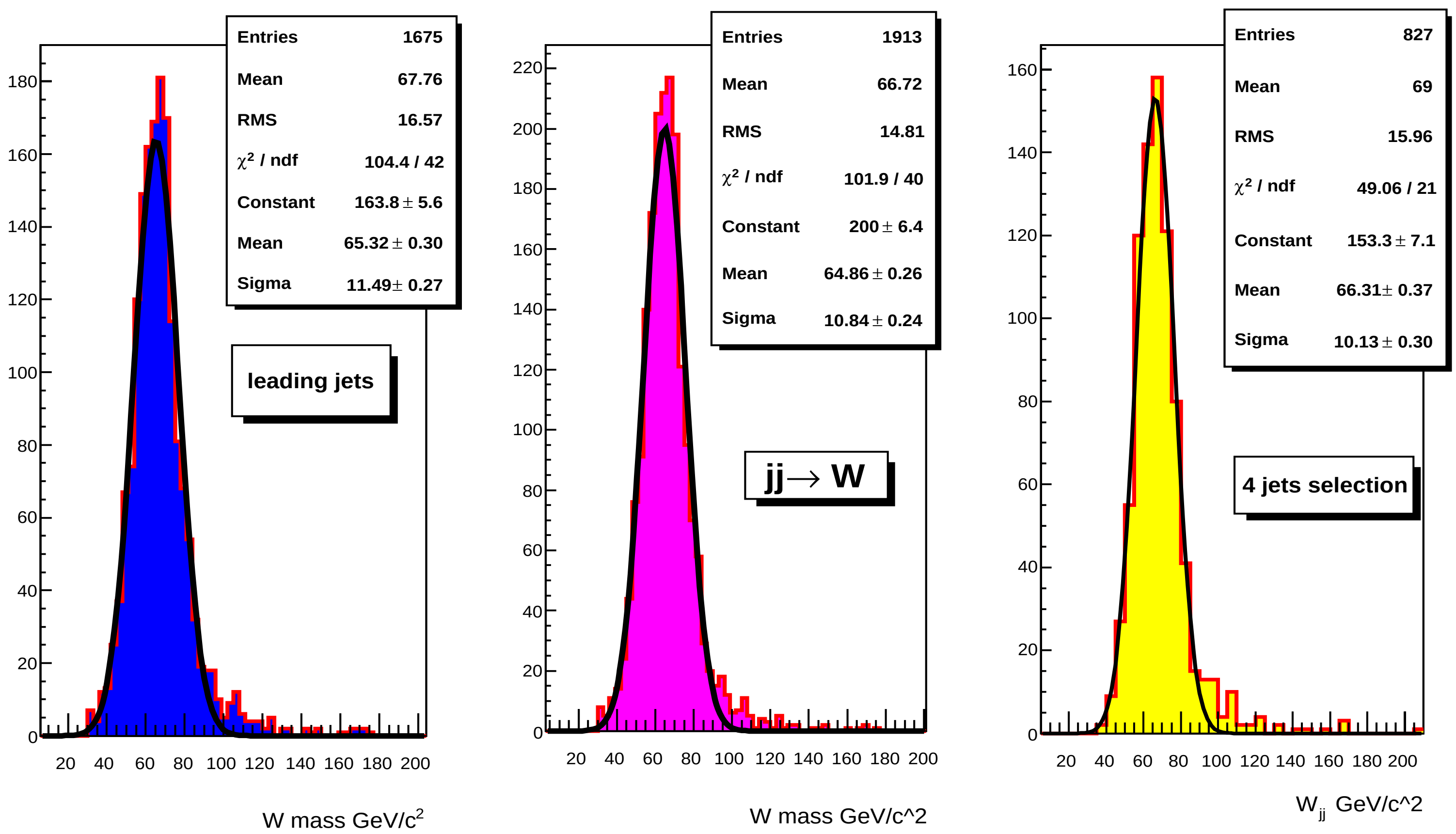
- Leading jets ≥ 2 b-tagged jets, ≥ 2 non b-tagged jets
- Exactly 4 leading jets, =2 b-tagged jets, = 2 non b-tagged jets
- >2 leading b-jets, 2 light jets with m_{jj} closest to W mass

Top quark selection from leading jets

Kinematical cuts	Selection efficiency %	No of events
Before selection	100	49535
no of iso muons	93.6	46370
$\geq$ 1 iso muon $P_t > 30$ GeV	92.7	45920
$\geq$ 1 reco light jets $P_t > 20$ GeV	91.1	45117
$\geq$ 2 reco light jets $\|\eta\| < 2.5$	73.6	36484
$\geq$ 1 b-jet $P_t > 20$ GeV	55.6	27543
$\geq$ 2 b-jets $\|\eta\| < 2.5$	18.6	9214
$\|m_{jj} - m_W^{nom}\| < 20$ GeV	8.5	4235

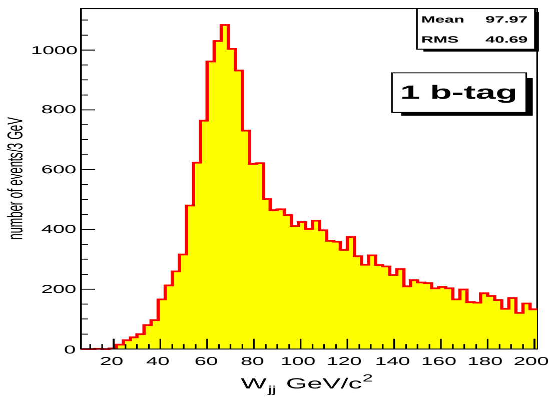
m_W^{nom} = 65.24 (gaussian fitted correctly matched)

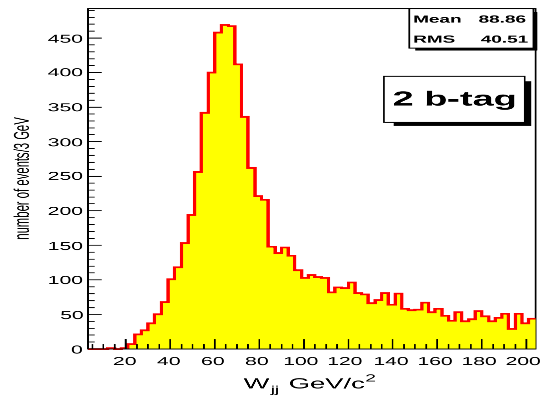
Nominal mass—fitted mass ~ 65 GeV



Same $m_W^{nominal}$ used in all selections

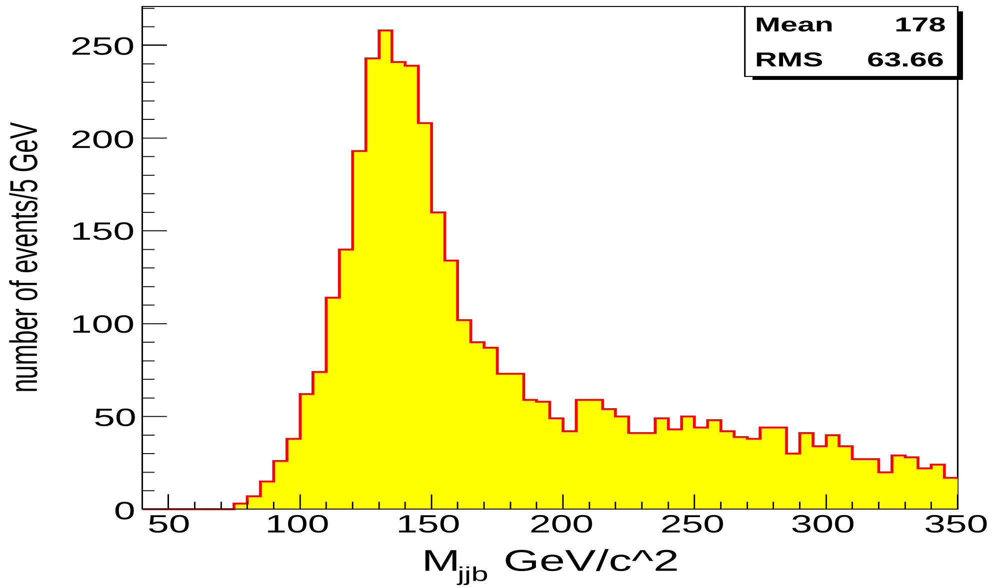
Top quark mass measurment from leading jets





Reco W-boson purity with 2 quarks matched = 18.17%

Reco W-boson purity with 1 quark matched = 42.7%



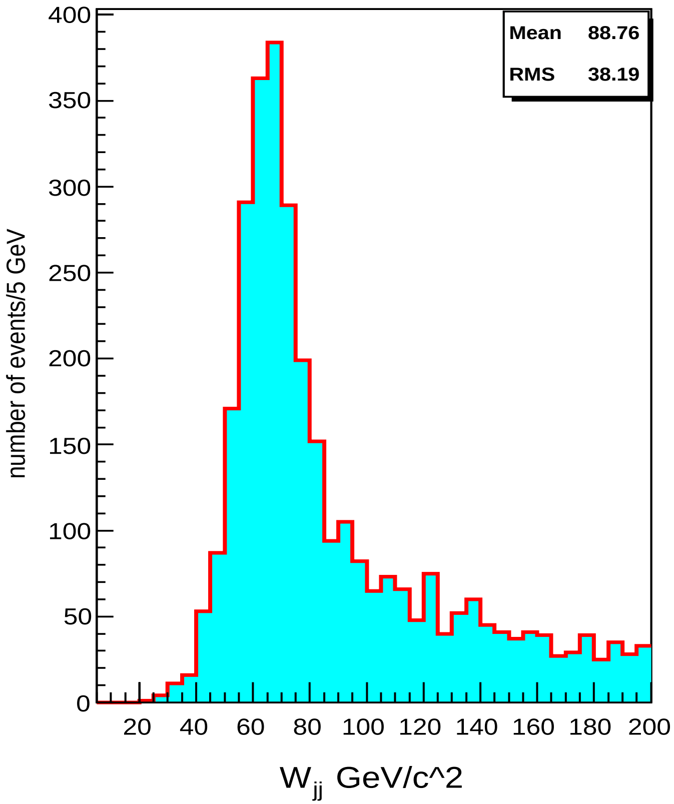
b-jet with furthest (max ΔR) wr.t muon

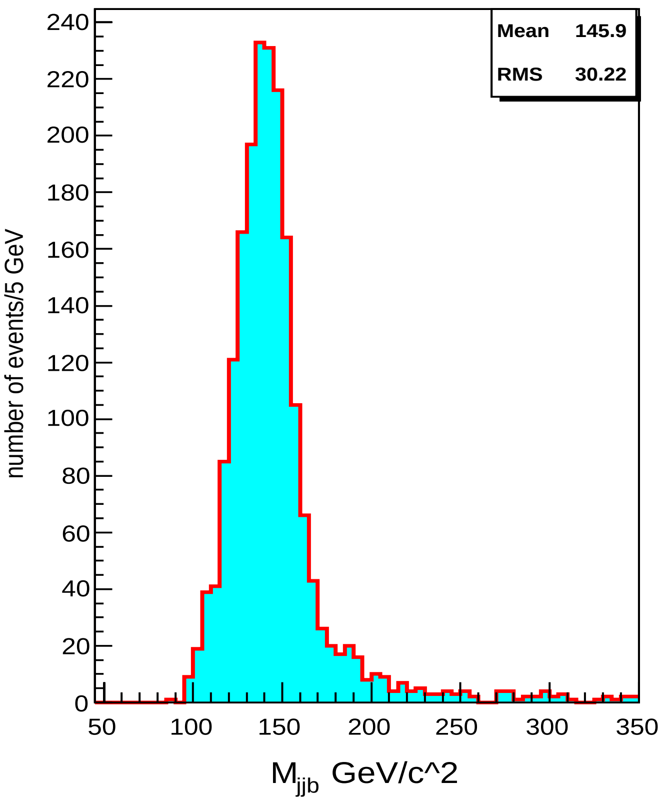
Top quark selection from four jets topology

Kinematical cuts	Selection efficiency %	no of events
Before selection	100	49535
no of iso muons	93.6	46370
$\geq$ 1 iso muon P_t > 30 GeV	92.7	45916
$\geq$ 1 reco light jets P_t > 20 GeV	92.7	45915
Exectly 4 jets $\lvert\eta\rvert < 2.5$	21.3	10551
Exectly 2 light jets	8.0	3941
Exectly 2 b-jets	8.0	3941
$\lvert m_{jj} - m_W\rvert < 20$ GeV	3.9	1937

Reco W-boson purity with 2 quarks matched = 20.98%

Reco W-boson purity with 1 quark matched = 43.26%





Di-jet invariant mass dist from four jets selection

Di-jet with associated b-jet invariant mass dist. from four jets selection

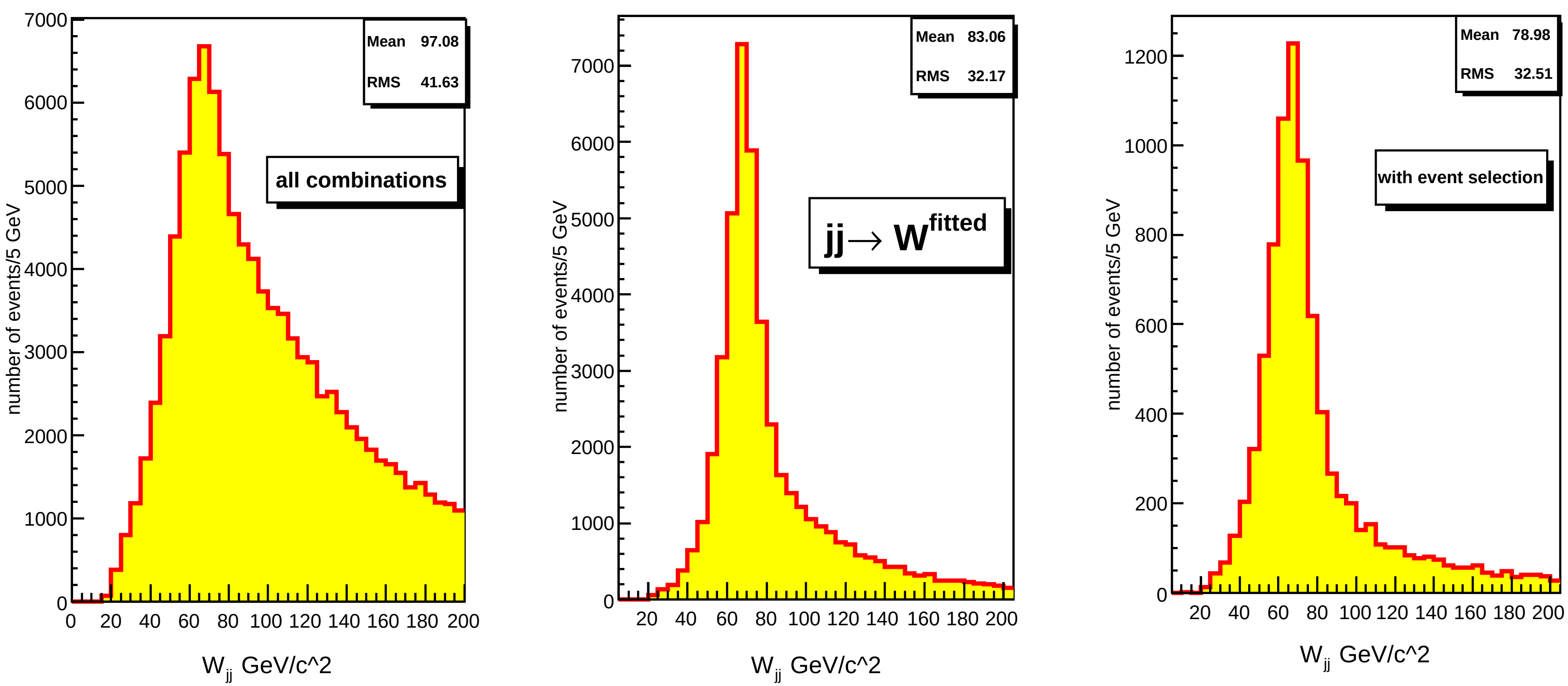
Top quark selection from $jj \rightarrow W$

Kinematical cuts	Selection efficiency %	no of events
Before selection	100	49535
no of iso muons, $P_t > 30$ GeV, $\lvert\eta\rvert < 2.0$	92.7	45920
2 $jj \rightarrow W$, $P_t > 20$ GeV, $\lvert\eta\rvert < 2.5$	73.6	36484
≥ 2 b-jets $P_t > 20$ GeV, $\lvert\eta\rvert < 2.5$	18.6	9214
$\lvert m_{jj} - m_W \rvert < 20$ GeV	11.9	5917

W mass reconstruction jj---W

Reco W-boson purity with 2 quarks matched = 20.76 %

Reco W-boson purity with 1 quark matched = 40.6 %

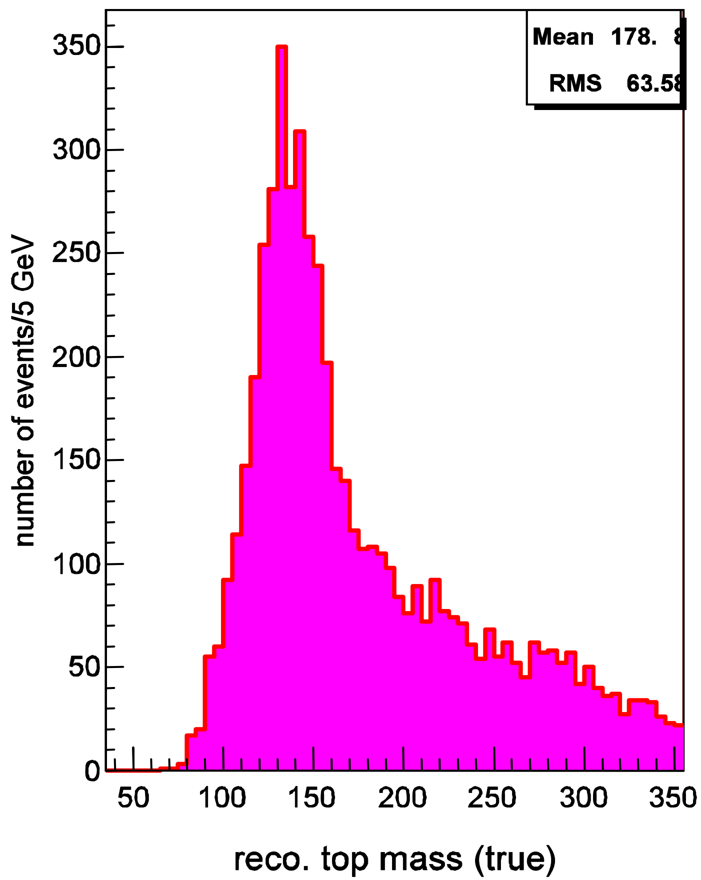


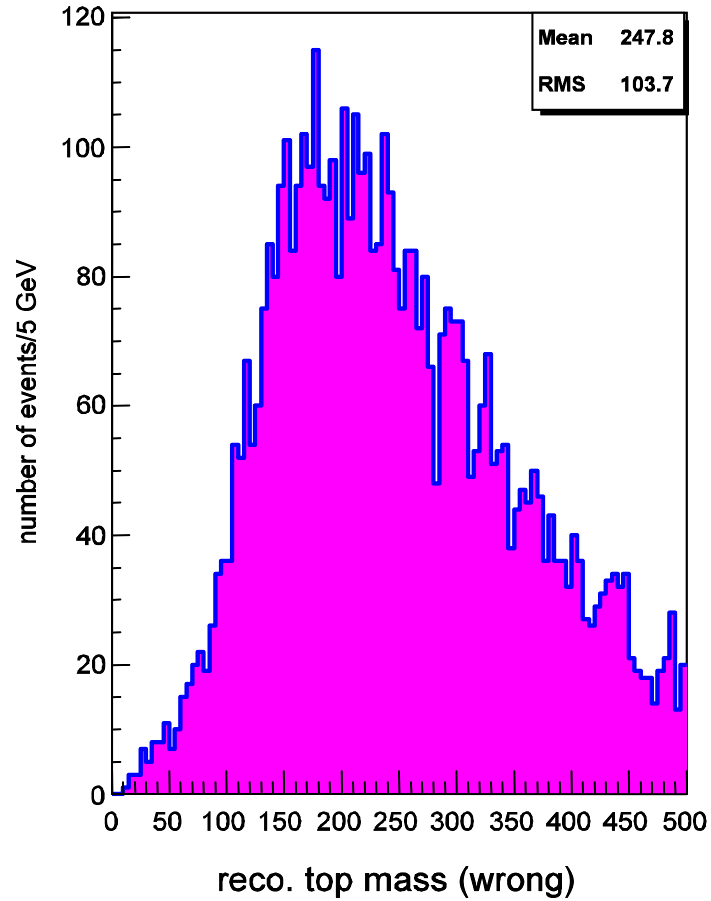
All jets combinations

Before b-jet selection

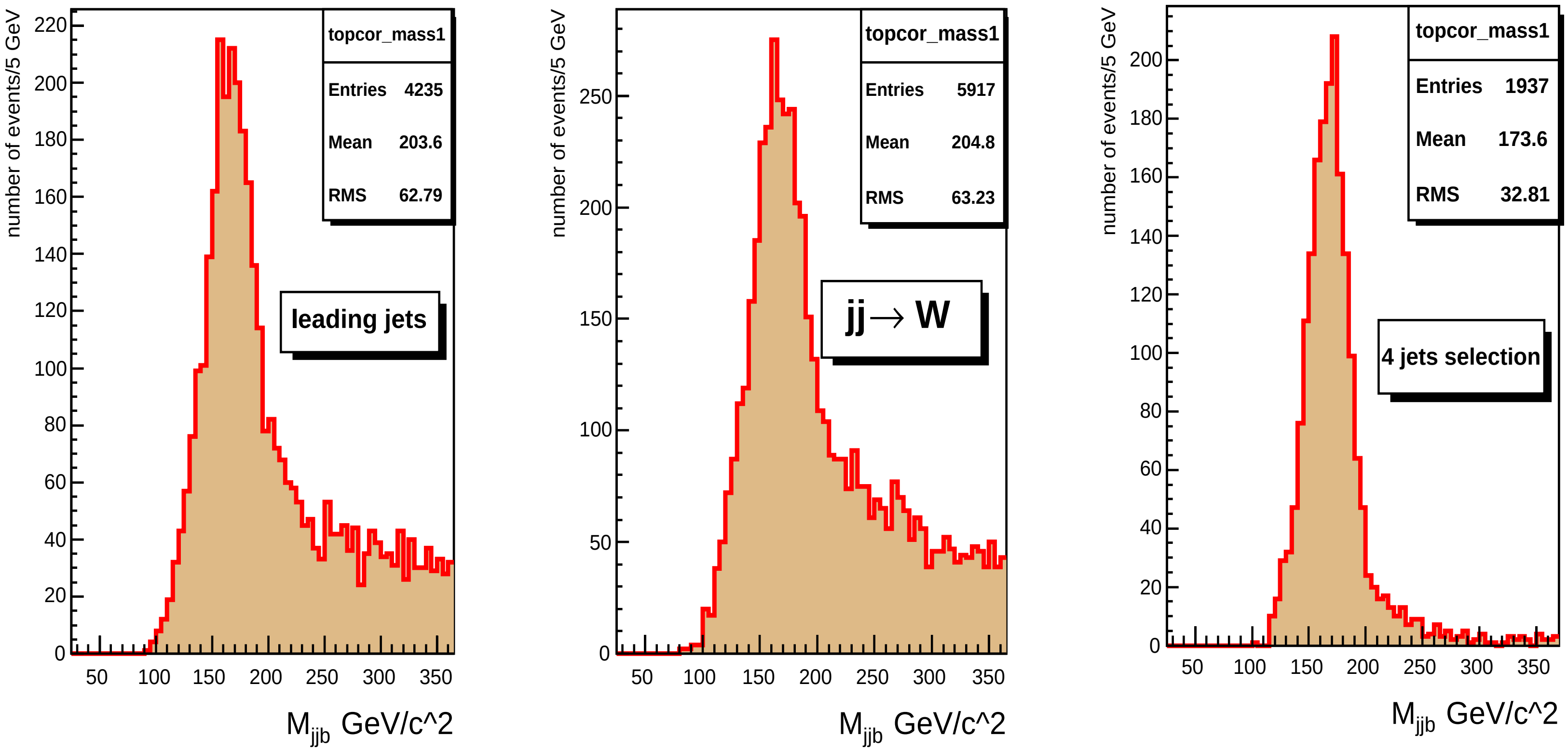
After full selection

Top quark mass reconstruction from jj→W





M_{jjb} plots for all selections after calibration



Comments on m_{jjb}

- Study based on shape of distributions for top direction determination
- Explored three types of selection criteria for hadronic top mass reconstruction
- Four jets selection results low efficiency with higher W purity
- Jets with inv mass close to W have higher efficiency with intermediate purity of W

Cluster Method (special Algorithem)

- Once top direction determined,and $P_t(jjb)$= 200 GeV
- Invariant mass of all calorimeters clusters

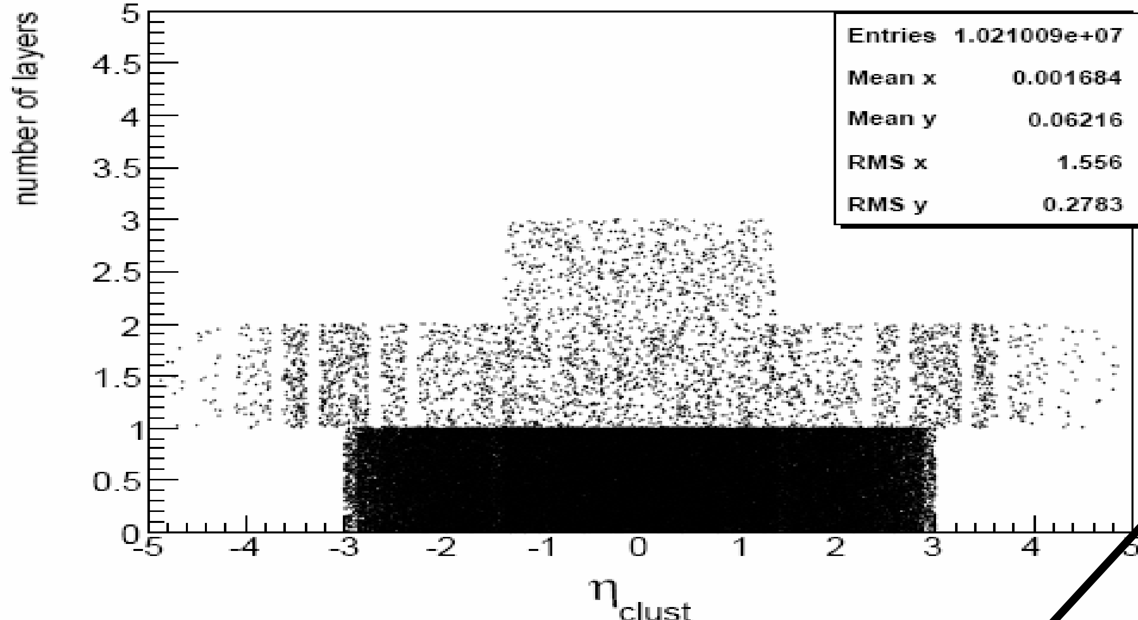
$\Delta\eta \times \Delta\varphi$ around top direction

$$m^2_{clusters}(\Delta R) = (E^2 - P^2) = \Big(\sum_{i=0.7}^{n\Delta R} E_i\Big)^2 - \Big(\sum_{i=0.7}^{n\Delta R} \overline{P}_i\Big)^2$$

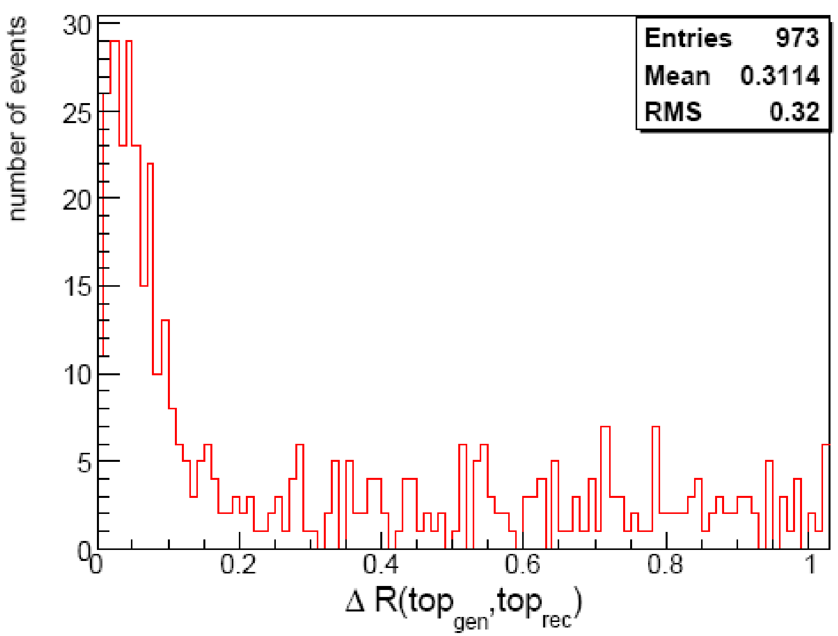
- ✓ E_i represents total energy of the ith cluster
- ✓nDR runs over all clusters within selected cone size
- ✓P_i its 3-momenta vector

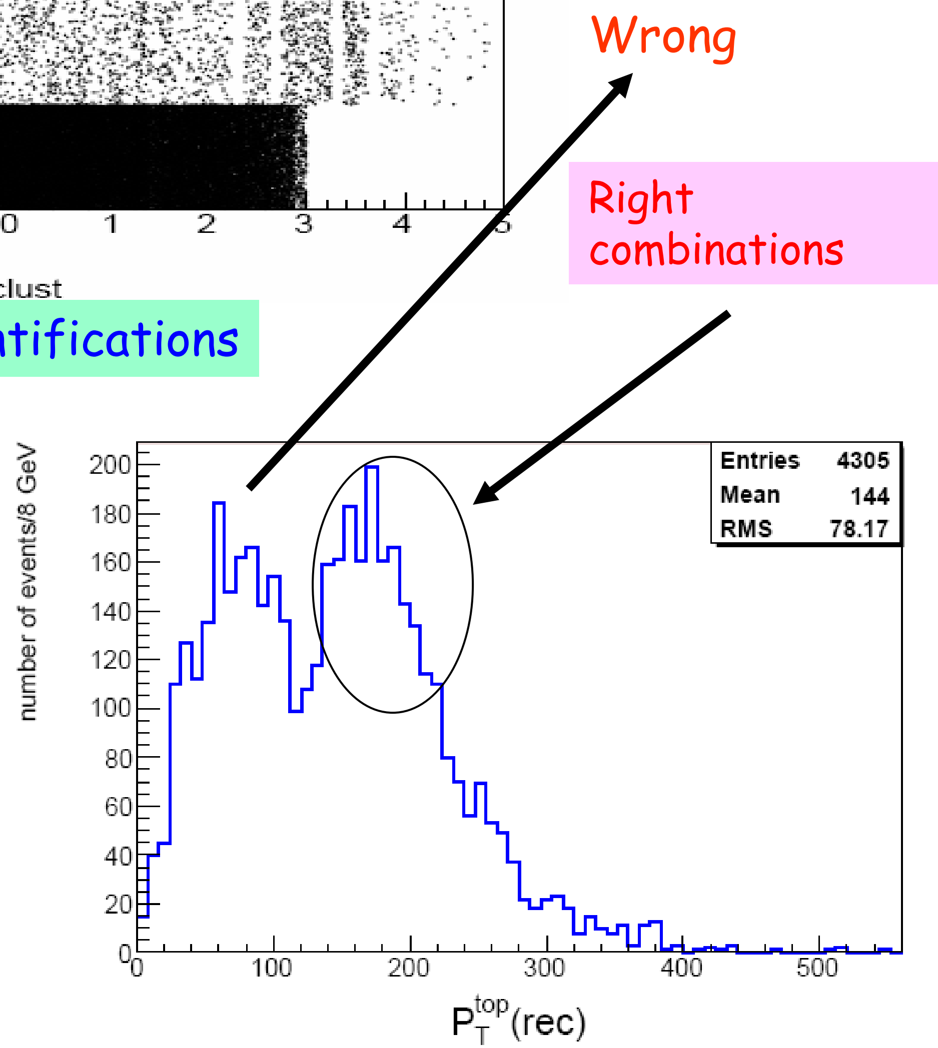
We know only E, η, φ about clusters
Assumptions:
considering particles masseless

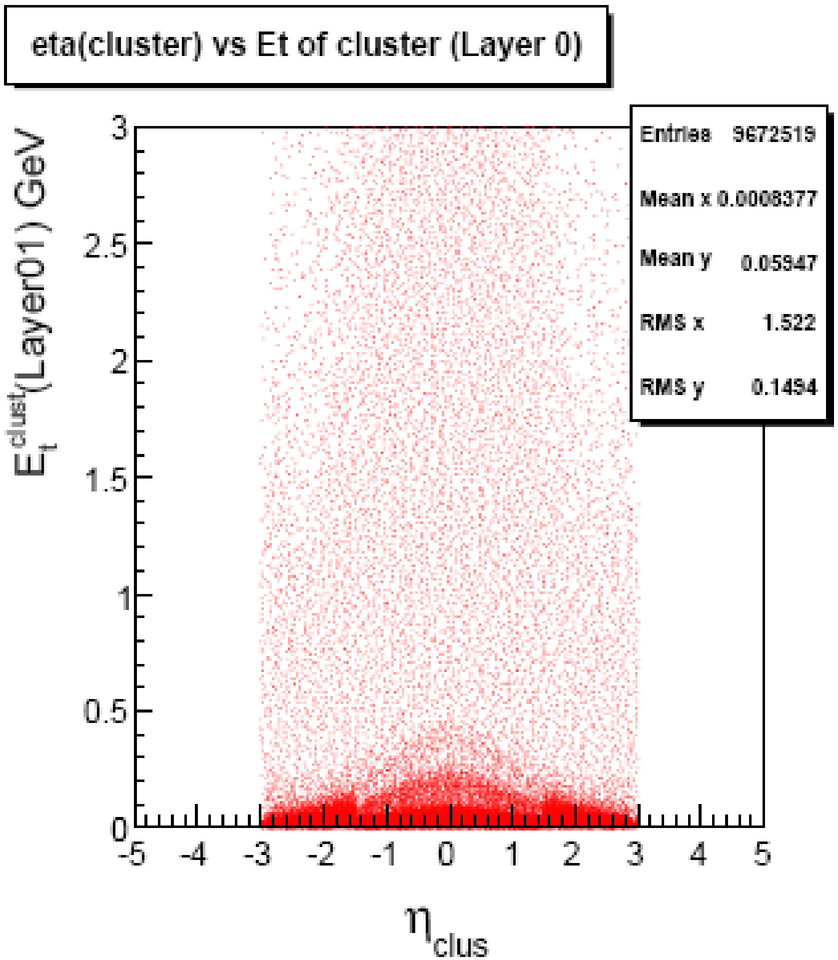
$$m \approx 0 \Rightarrow E^2 \equiv P^2$$
$$P_x = E \sin\vartheta \cos\varphi$$
$$P_y = E \sin\vartheta \sin\varphi$$
$$P_z = E \cos\vartheta$$

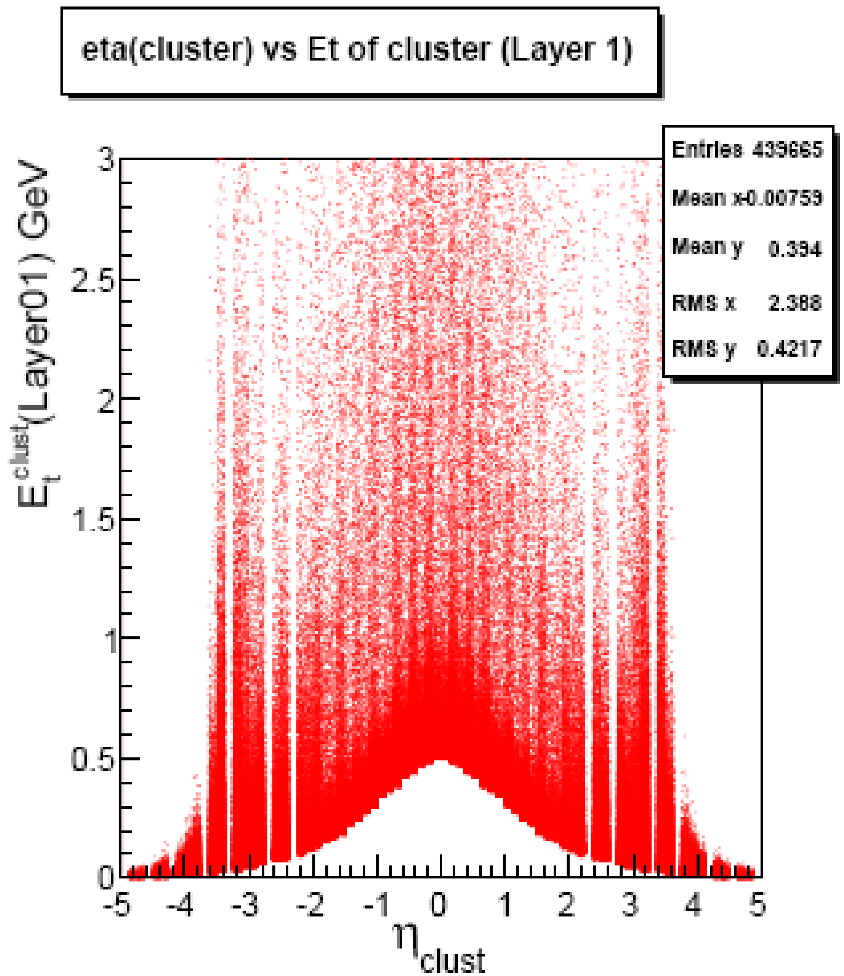


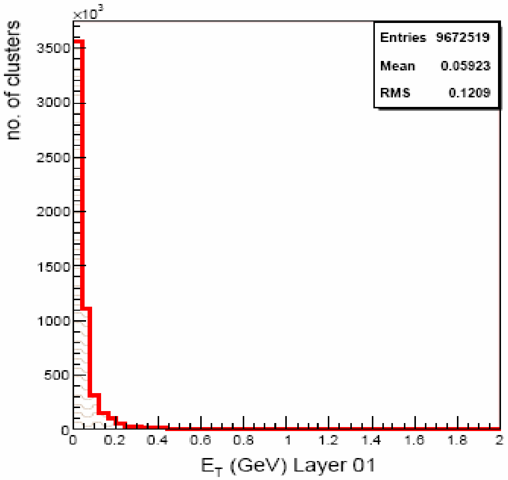
Calorimeters identifications

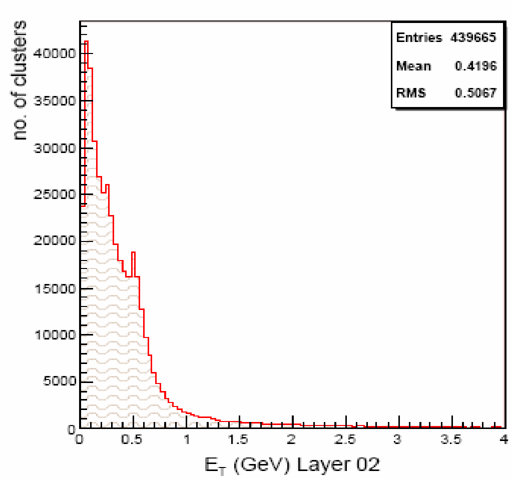


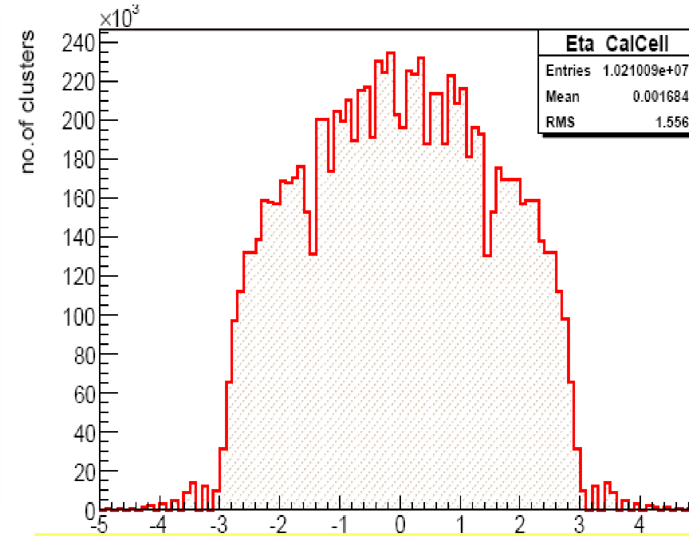



eta(cluster) vs Et of cluster (Layer 0)
Entries 9672519
Mean x 0.0008377
Mean y 0.05947
RMS x 1.522
RMS y 0.1494
E_t^clust(Layer01) GeV
η_clus
-5 -4 -3 -2 -1 0 1 2 3 4 5
0 0.5 1 1.5 2 2.5 3


eta(cluster) vs Et of cluster (Layer 1)
Entries 439665
Mean x 0.00759
Mean y 0.394
RMS x 2.388
RMS y 0.4217
E_t^clust(Layer01) GeV
η_clust
-5 -4 -3 -2 -1 0 1 2 3 4 5
0 0.5 1 1.5 2 2.5 3

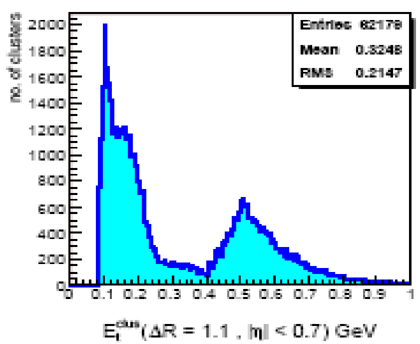


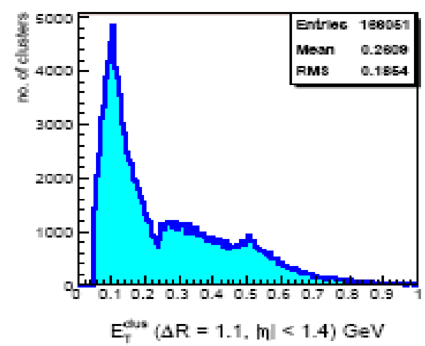


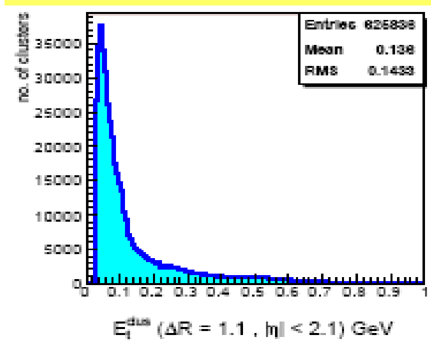


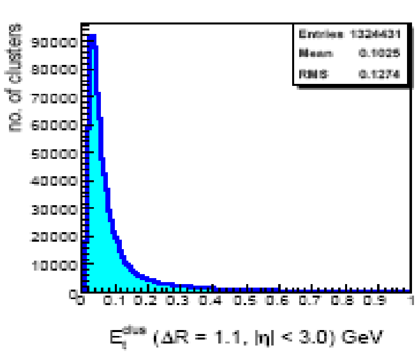
E_t(ECAL) << E_t(HCAL)

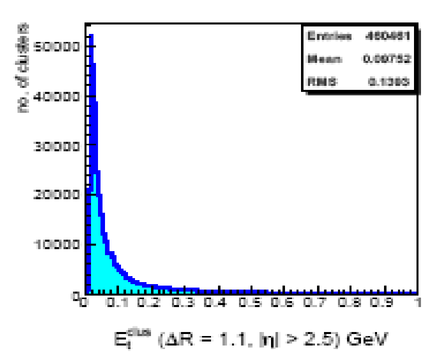
Reco clusters pseudo-rapidy

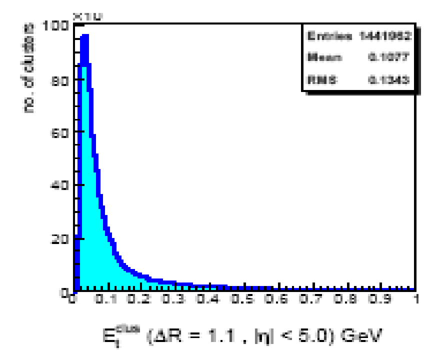






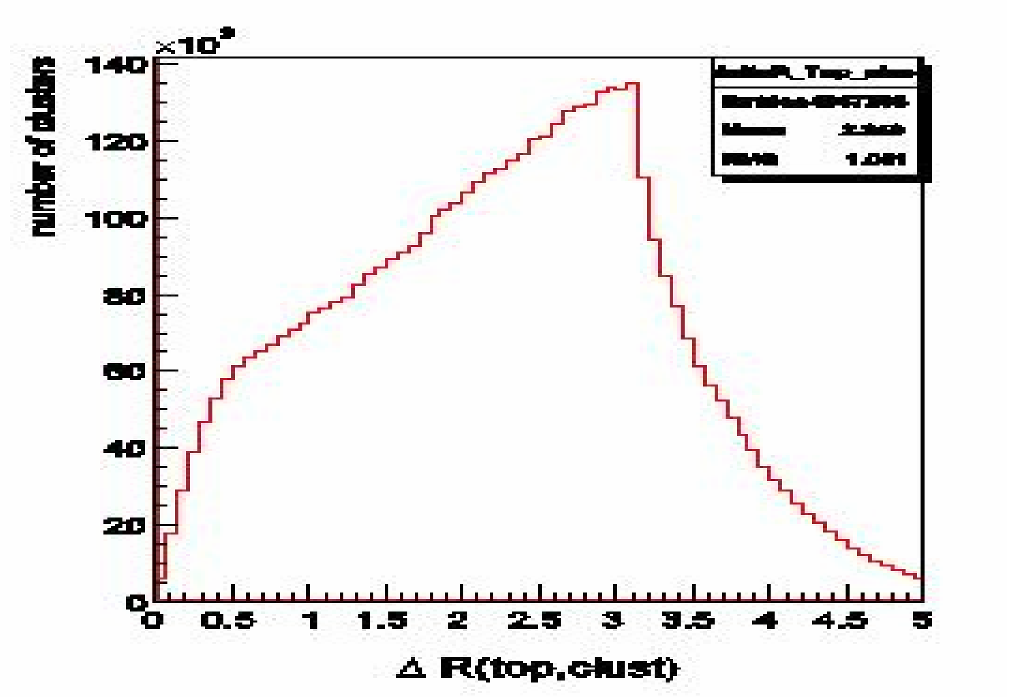






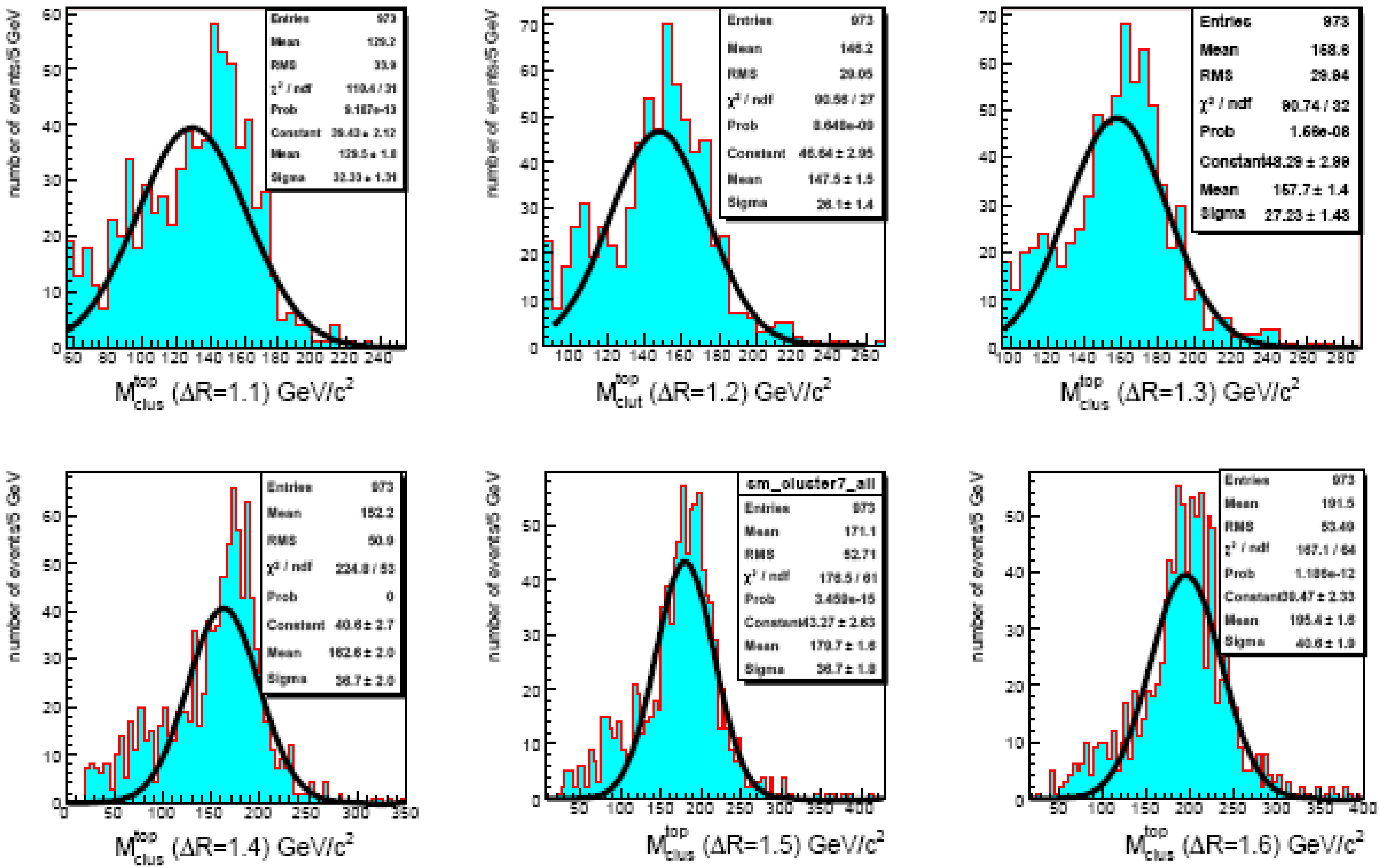
E_t behaviour on jet cone size

Opening angle b/w reco top and calo clusters

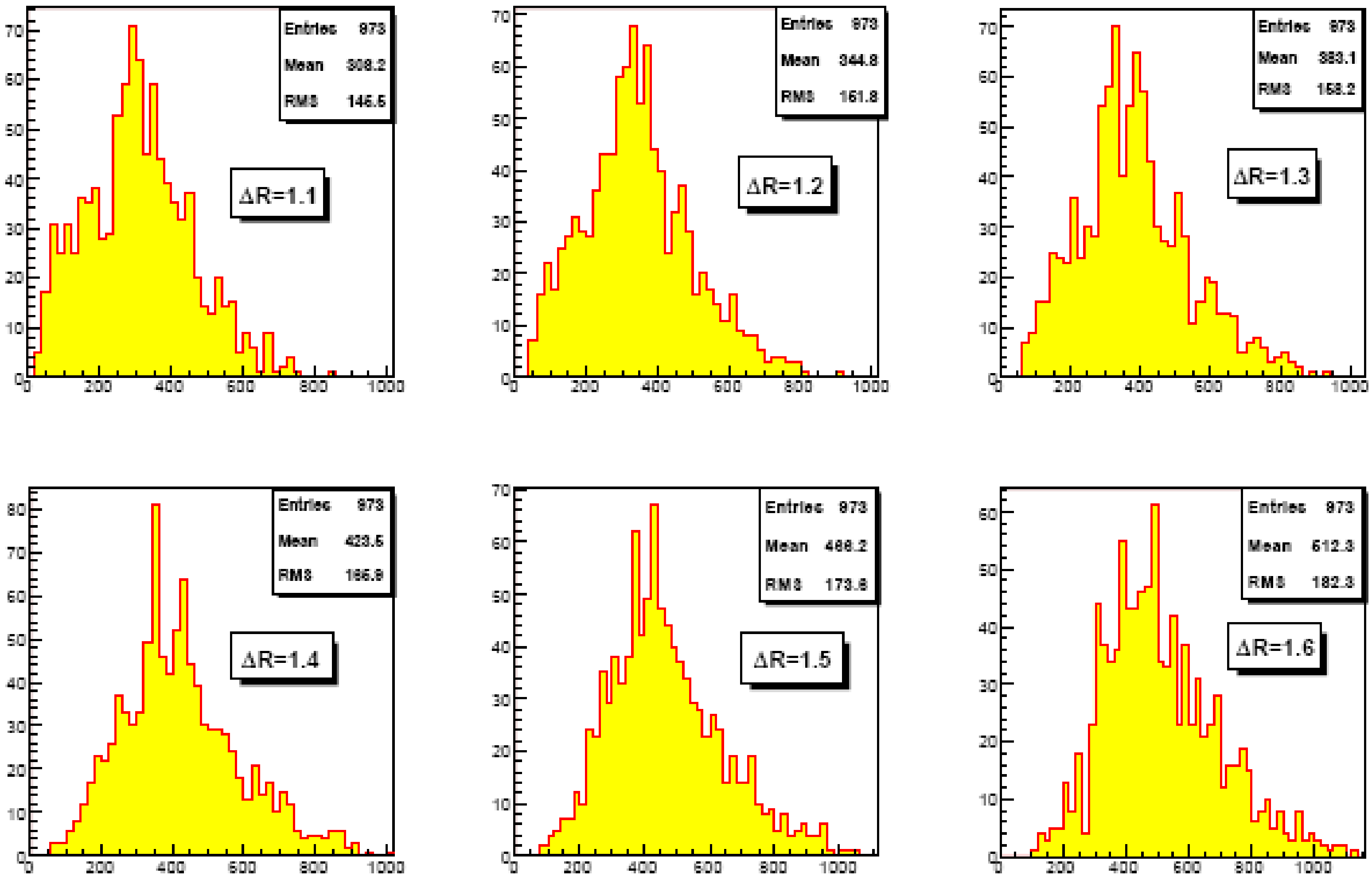


ΔR (top,clusters)

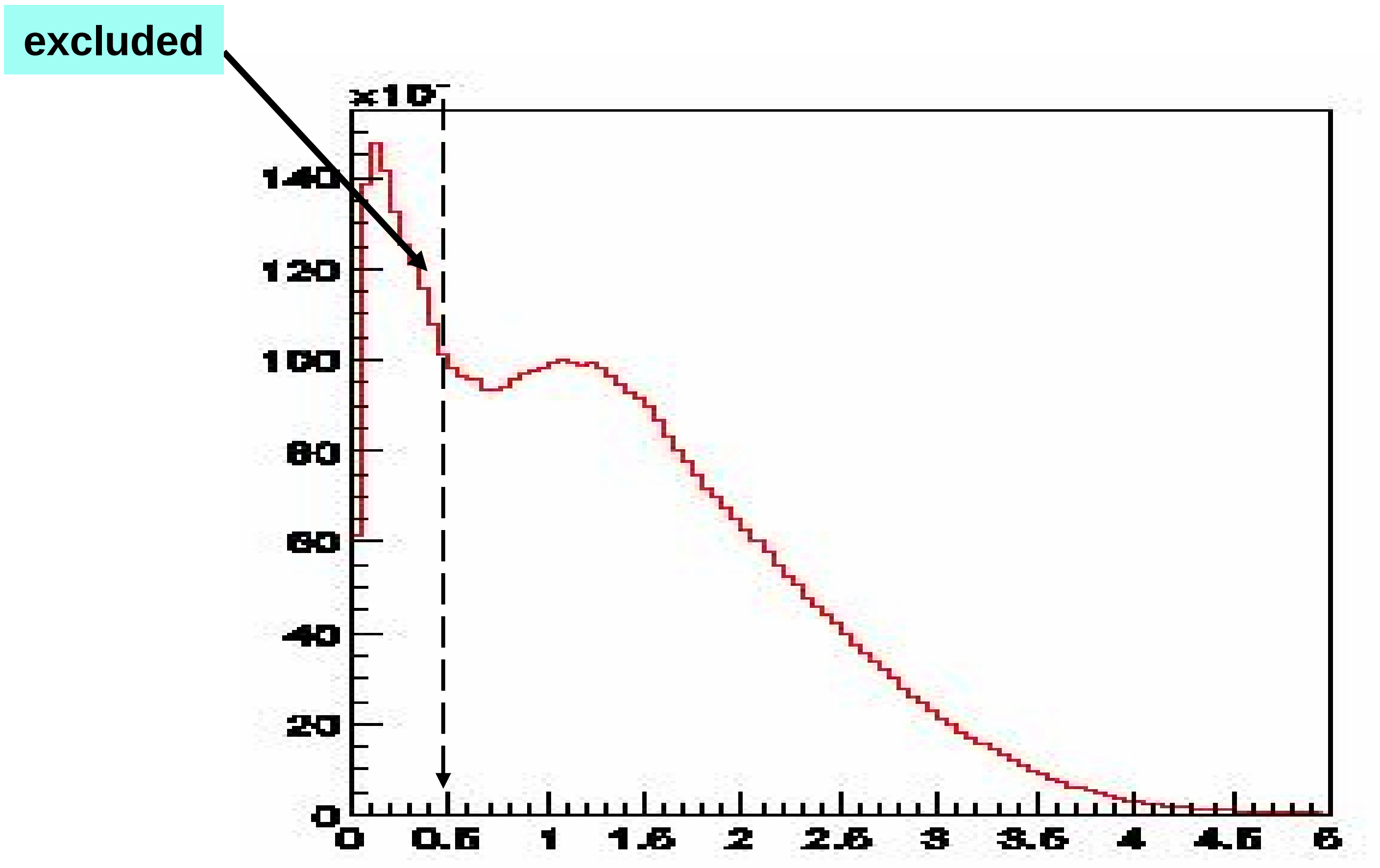
Top mass reconstruction from calorimeter clusters



Calorimeter(ECAL+HCAL) clusters distribution



Variable for underlying event measurement



min ΔR (all jets, clust)

UE Estimation Method

From average cells energy outside jets

LAYER # 01 (ECAL)

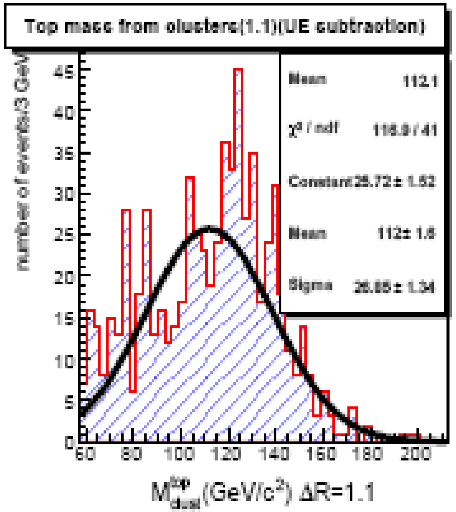
Jet Isolation cut	$\langle E_t \rangle$ / cluster (MeV) < no of clusters > / high P_t event					
	$\lvert\eta\rvert < 0.7$	$\lvert\eta\rvert < 1.4$	$\lvert\eta\rvert < 2.1$	$\lvert\eta\rvert < 3.0$	$\lvert\eta\rvert > 3.0$	$\lvert\eta\rvert < 5.0$
$\Delta R = 0.7$	47.6 779	41.2 1686	43.8 2673	43.8 2673	36.5 479	41.6 3757
$\Delta R = 0.8$	47.3 690	40.9 690	43.7 690	43.7 690	36.5 469	41.3 3317
$\Delta R = 0.9$	47.2 603	40.6 1365	43.6 2268	43.6 2268	36.5 469	41.3 3317
$\Delta R = 1.1$	47.3 436	39.9 1053	43.5 1858	43.5 1858	36.5 454	41.0 2860
$\Delta R = 1.5$	46.6 175	38.4 523	43.5 1106	40.4 1975	36.8 410	40.4 1975

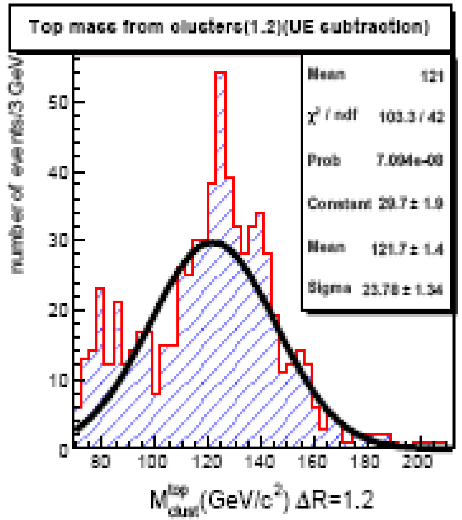
UE Estimation Method

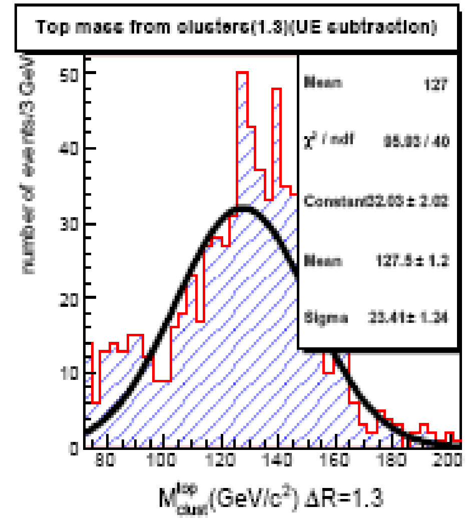
LAYER # 02 (HCAL)

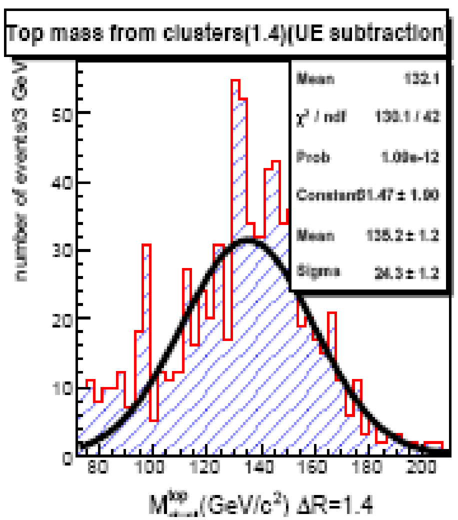
Jet Isolation cut	$\langle E_t \rangle$ / cluster (MeV) < no of clusters > / high P_t event					
	$\|\eta\| < 0.7$	$\|\eta\| < 1.4$	$\|\eta\| < 2.1$	$\|\eta\| < 3.0$	$\|\eta\| > 3.0$	$\|\eta\| < 5.0$
$\Delta R = 0.7$	632.5 38	512.6 88	449.5 135	364.9 227	225.4 178	324.2 347
$\Delta R = 0.8$	630.0 34	507.3 81	443.7 125	358.4 217	225.3 177	318.6 34
$\Delta R = 0.9$	626.7 30	501.0 73	437.2 116	351.3 206	225.2 176	312.6 325
$\Delta R = 1.1$	623.7 22	487.8 22	424.0 22	336.7 22	225.2 176	300.6 22
$\Delta R = 1.5$	606.1 9	456.2 29	394.1 56	307.4 134	225.7 165	278.0 247

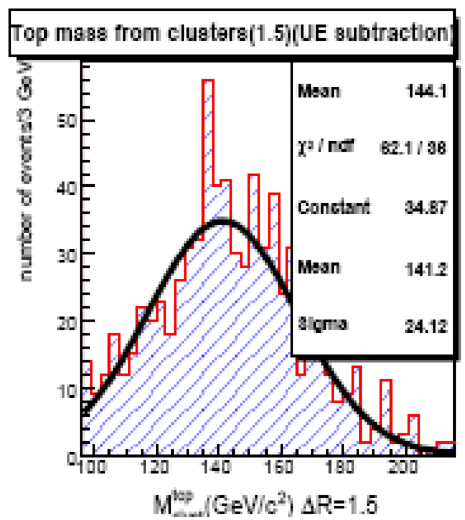
Top mass with UE subtraction

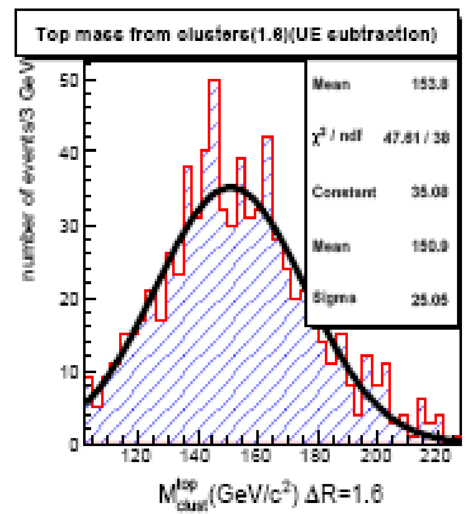












Clusters invariant masses

	$\langle M_{clust}^{top}$(fitted)$\rangle$ (GeV) no UE subtraction	$\langle M_{clust}^{top}$(fitted)$\rangle$ (GeV) UE subtraction
ΔR=1.1	130	112
ΔR=1.2	148	121
ΔR=1.3	158	127
ΔR=1.4	163	135
ΔR=1.5	180	141
ΔR=1.6	195	150

Top Mass Scale Calibration using Hight P_T W sample

Calibration Coefficient Formula

$$C_{Top} = \frac{1}{N_{\Delta R}} \sum_{\Delta R=1}^{N \Delta R} \frac{M^{W}}{m_{clus}^{W}(\Delta R)}$$

Top Mass determination

$$m_{top} = \frac{1}{N\Delta R} \sum_{\Delta R=1}^{N\Delta R} m_{clus}^{top}(\Delta R) \times C_{top}$$

Summary

- Study based on Fast simulation
- Compared different jets selections (CMS Internal Note)
- Finalize UE subtraction
- Top mass from clusters (fit ?) (CMS Internal Note…….. ?)
- Look at leanrity vs true top mass
- Systematics specific to this method
- Calibration is tuned.
- Full Simulations results are expected soon