Studies for Top-Mass Measurements @ ATLAS

T. Barillari, N. Ghodbane, P. Giovannini, T. Göttfert, R. Härtel, A. Jantsch,
S. Menke, R. Nisius, A. Pithis, G. Pospelov, E. Rauter, P. Schacht

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für Physik
(Werner-Heisenberg-Institut)

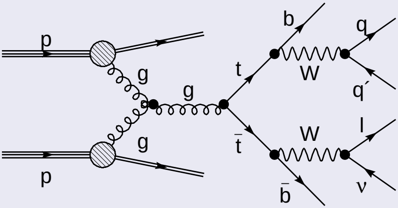
LHC-D Top Meeting 2008
Bad Honnef

Outline

Introduction

$t\bar{t}$ events

- ⇒ $t\bar{t}$ production dominated by gluon fusion ($\sim$ 90%)
- ⇒ “big“ cross section (NLO) $\sigma_{pp \to t\bar{t}} = (0.833 \pm 100)\,\text{pb}$
- ⇒ top mass reconstruction on hadronic side
  - impact of Jet Algorithms
  - control of Jet Energy Scale



Ongoing Studies (MPI Top Physics Group)

- ⇒ Jet Energy Calibration
- ⇒ Jet Algorithm Studies
- ⇒ Top Mass Reconstruction

Jet Reconstruction using TopoClusters

Cells

$\Rightarrow$ smallest ATLAS reco objects: 187652 calorimeter cells

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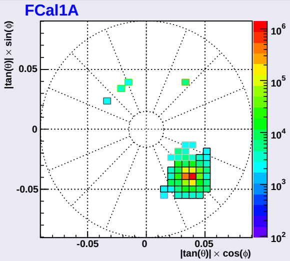
TopoCluster Algorithm (4/2/0)

(S. Menke)

⇒ seed cells: $|E_{seed}| > 4\sigma$



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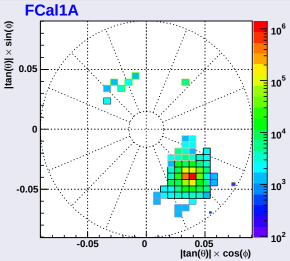

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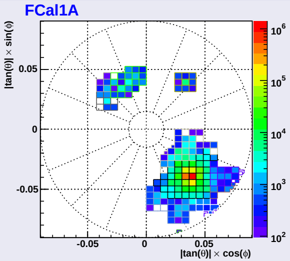
⇒ include perimeter cells: $|E_{cell}| > 0\sigma$



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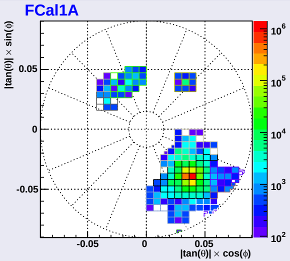
- ⇒ merge clusters sharing a neighbor cell
- ⇒ split cluster around local maxima



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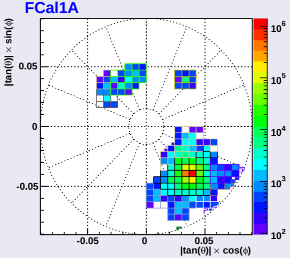

Jet Algorithm

⇒ reconstruction of jets using *Cone*- and k_T-based Jet Algorithms

Jet Energy Calibration

Global H1 Calibration

$\Rightarrow$ match a truth particle jet with each reco jet and fit cell weights

Jet Energy Calibration

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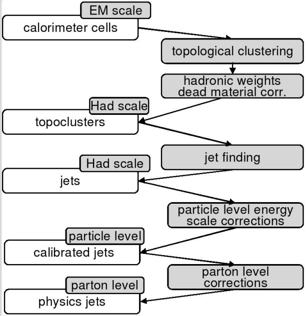
Local Hadron Calibration (S. Menke, G. Pospelov)

⇒ calibration to hadronic scale on **TopoCluster level**



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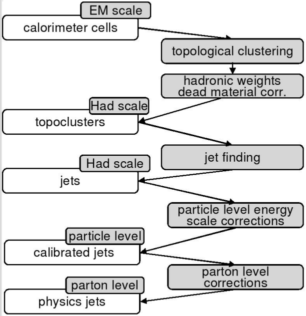
- ⇒ classify clusters into **EM**, **Hadronic** and **Unknown**



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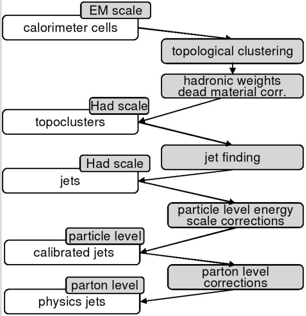
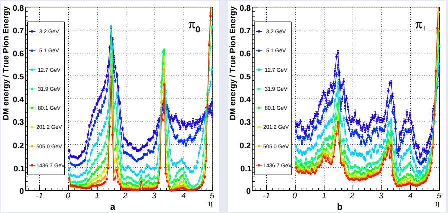
- ⇒ apply **weights to "Hadronic" clusters**
- ⇒ apply **Out-Of-Cluster (OOC)** and **Dead Material (DM)** corrections

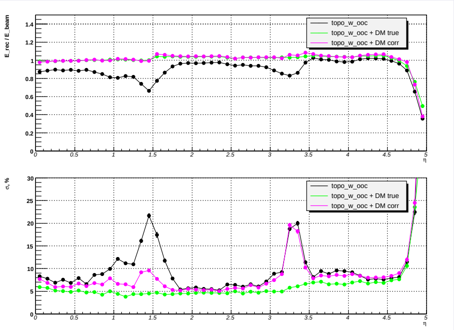


Jet Energy Calibration

Dead Material Corrections (G. Pospelov)

- ⇒ cluster level corrections for energy deposit in inactive material
- ⇒ Dead Material:
  - Inner Detector, magnetic coil
  - cryostat walls, crack regions between calorimeter modules
  - material behind calorimeter system (leakage)
- ⇒ ATLAS MC single pion simulation with DM in Calibration Hits
- ⇒ cluster cell weights calculated and applied



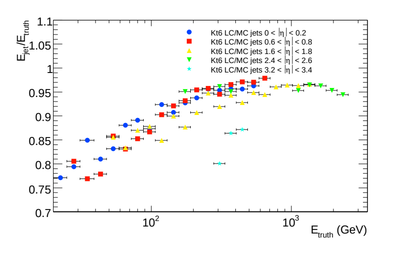


Jet Energy Scale

Comparison with Truth MC

(P. Giovannini, K. Lohwasser, S. Menke, A. J.)

- $\Rightarrow$ check of Jet Energy Scale
  - di-jet sample
  - matching: $\Delta R < 0.2$
- $\Rightarrow$ good agreement
- $\Rightarrow$ offset of mean $\sim 8\,\%$



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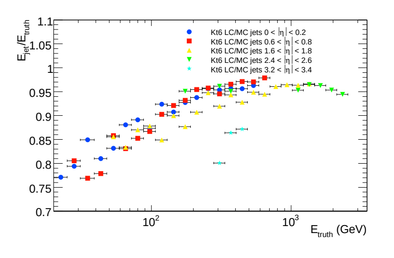
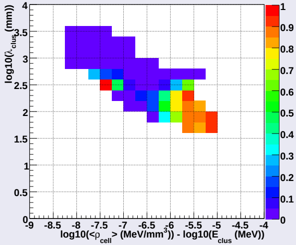
- $\Rightarrow$ known reasons:
  1. misclassification at low energies $< 5\,\mathrm{GeV}$ (em vs. hadronic cluster)
  2. low energetic particles (don't reach calorimeters)
  3. out-of-jet corrections (magnetic bending)
- $\Rightarrow$ correction only at jet level





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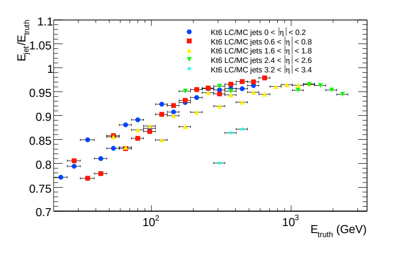
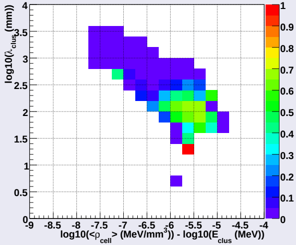
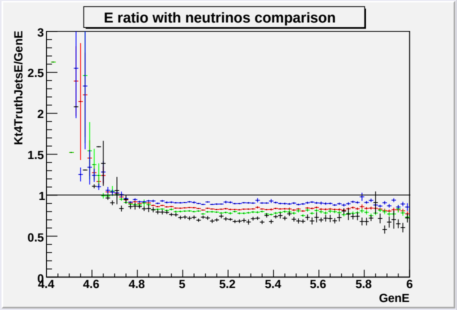




Jet Energy Scale

Truth MC Studies of *b*-Jet Energy Scale (A. Pithis)

- ⇒ impact of neutrinos on the *b*-jet energy
- ⇒ semileptonic $t\bar{t}$ decays
- ⇒ comparing energy of truth *b*-jets with generated *b*-quark energy:
  - $+$ at least one ν (100.00 %)
  - $+$ ν coming from the *b*-quark (43.50 %)
  - $+$ ν coming from a cascade *c*-quark (46.27 %)
  - $+$ more than one ν (10.23 %)
- ⇒ gluon radiation effects @ low energies



Jet Energy Scale

In-situ Calibration (T. Barillari)

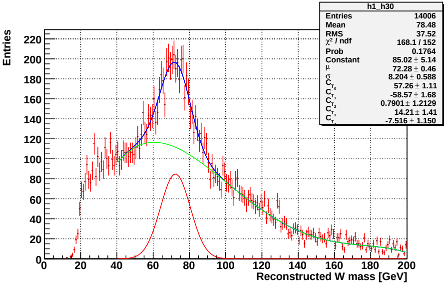
⇒ m_W reconstruction:

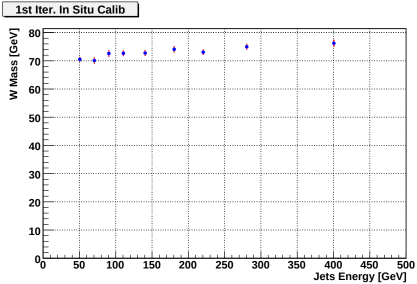
- semileptonic $t\bar{t}$ events
- Kt4 Topo(LHC) jets
- b-matching used

⇒ in-situ calibration:

- fill m_W in histogram with respect to its parton jet energies
- gaussian mean μ for m_W for each jet energy bin
- apply weights $(\mu/m_W^{PDG})^{-1}$ to jets

⇒ next iteration

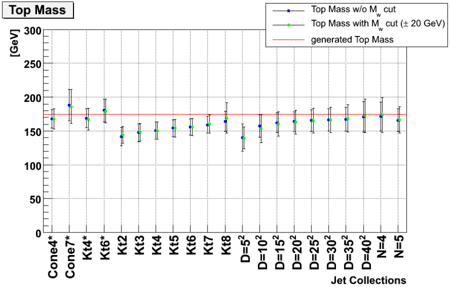


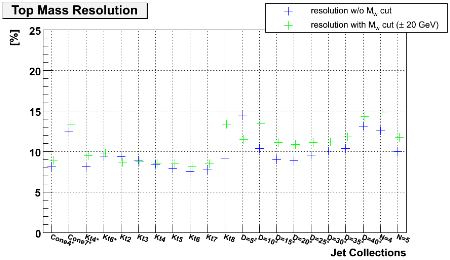


Jet Algorithm Studies

k_T Parameter Studies (R. Härtel)

- ⇒ systematic study of Jet Algorithm parameter dependence of the top mass
- ⇒ standard cuts applied on semileptonic $t\bar{t}$ MC
- ⇒ $m_{top} = $ 3-jet combination with max p_T
- ⇒ with & w/o W cut (within 80.4 ± 20.0 GeV)
- ⇒ C4, C7, Kt4, Kt6 (Topo & H1)
- ⇒ Kt incl. (Topo & LHC)
- ⇒ Kt excl. (Topo & LHC)

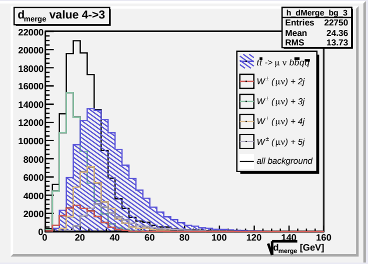


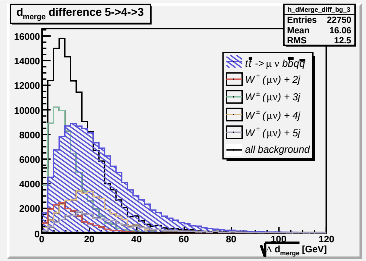


Jet Algorithm Studies

d_{Merge} from excl. k_T algorithm as event shape variable (T. Göttfert)

- $\Rightarrow$ quality study of d_{Merge} distributions
- $\Rightarrow$ d_{Merge} as discrimination variable for background
- $\Rightarrow$ $d_{Merge}(4 \rightarrow 3) \equiv$ minimal distance of all protojet pairs in the event with only 4 jets left
- $\Rightarrow$ each entry in histogram is $d_{Merge}(n+1 \rightarrow n)$ for one event
- $\Rightarrow$ only $W(\rightarrow \mu\nu) + jets$ so far
- $\Rightarrow$ electron removal not yet available (to be done on cluster level)





Top Mass Reconstruction in semileptonic Channel

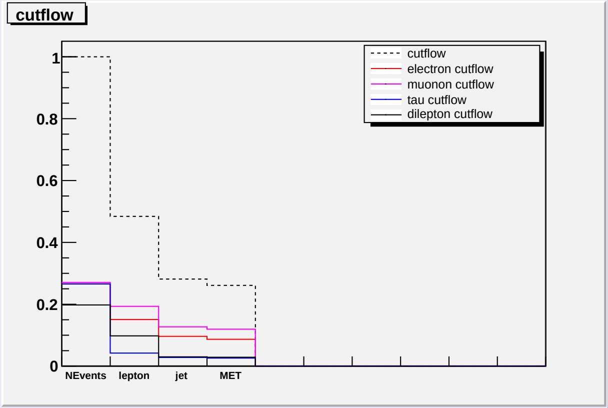
Sample

$\Rightarrow$ leptonic $t\bar{t}$ MC (Jimmy & Mc@NLO) (5200) (Athena 13.0.30)

Preselection

(E. Rauter)

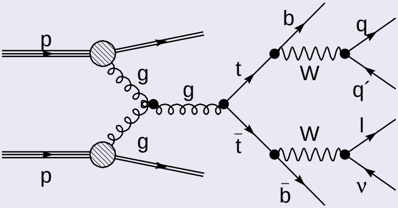
- $\Rightarrow$ exactly 1 lepton with $E_T > 20\,\text{GeV}$ and $|\eta| < 2.5$
- $\Rightarrow$ at least 4 jets with $E_T > 20\,\text{GeV}$, $|\eta| < 2.5$, not overlapping with a loose electron:
  - $\Delta R < 0.1$
  - $E_{jet}/2 < E_{e^-}$
- $\Rightarrow$ $MET > 20 GeV$



Top Mass Reconstruction in semileptonic Channel

Top Reconstruction using p_T balance method (E. Rauter)

- ⇒ taking only 4 leading jets in p_T
- ⇒ assuming 2 leading jets in p_T as *b*-jets
- ⇒ next 2 as jets from partons of hadronic *W* decay
- ⇒ isolated lepton and *MET* from leptonic *W* decay
- ⇒ 2 different $t\bar{t}$ combinations



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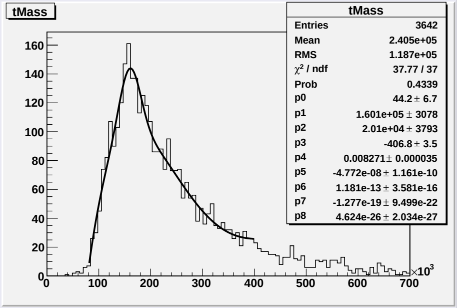
- $\Rightarrow$ isolated lepton and *MET* from leptonic W decay
- $\Rightarrow$ 2 different $t\bar{t}$ combinations
- $\Rightarrow$ take $t\bar{t}$ pair with best p_T balance



Top Mass Reconstruction in all hadronic Channel

Sample

⇒ all hadronic $t\bar{t}$ MC (Herwig & MC@NLO) (5204) (Athena 13.0.30)

Preselection

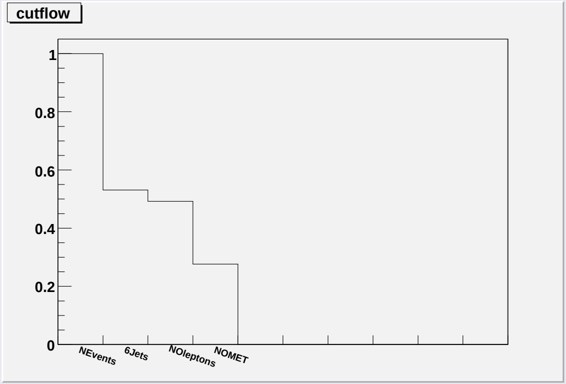
(P. Giovannini)

⇒ at least 6 jets with $p_T > 20\,\text{GeV}$, $|\eta| < 2.5$, not overlapping with a loose electron:

- $\Delta R < 0.2$
- $E_{jet}/2 < E_{e^-}$

⇒ no lepton with $p_T > 20\,\text{GeV}$ and $|\eta| < 2.5$

⇒ $MET < 20 GeV$

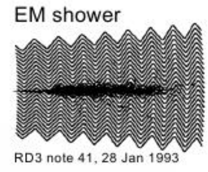


Conclusion

- ⇒ TopoCluster and Local Hadron Calibration in good agreement with MC
- ⇒ correction on jet-level calibration in progress
- ⇒ studies of jet reconstruction algorithms ongoing
- ⇒ in-situ calibration using m_W reconstruction
- ⇒ top mass analysis in semileptonic and hadronic channels started

Backup slides

Particle Shower



Electromagnetic Shower

- $e^{\pm}$, γ
- pair production, bremsstrahlung

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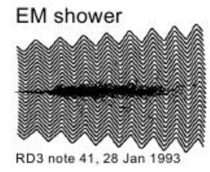

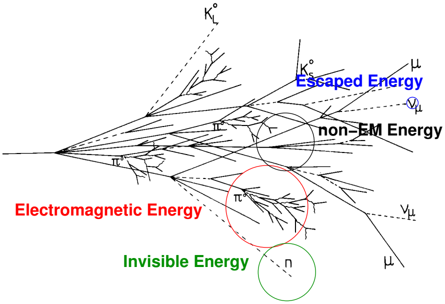

Electromagnetic Shower

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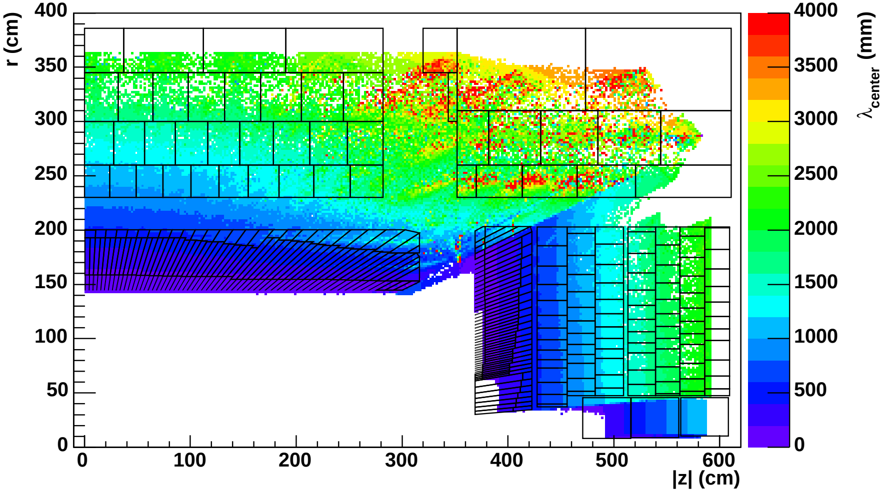
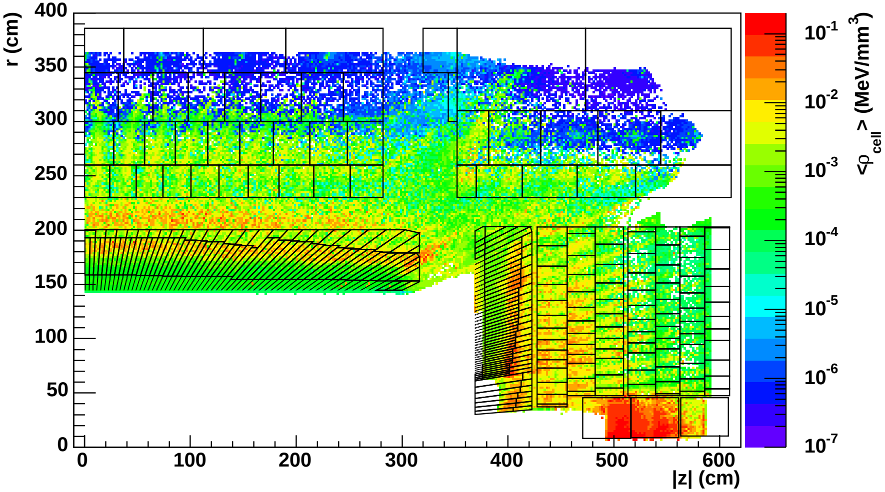
Hadronic Shower

- hadrons ($\pi^{\pm}$, K, p, n, hadronic τ-decays, ...)
- nuclear interactions
- em sub-shower π^0
- invisible/escaped energy
- high fluctuations in shape

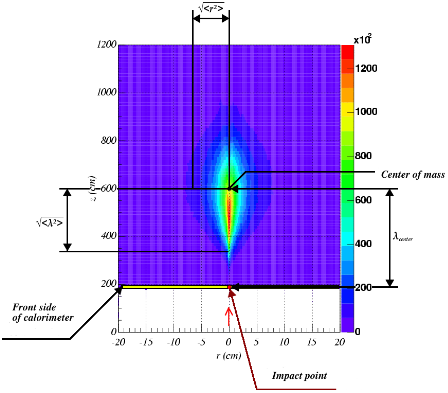
λ_{center}

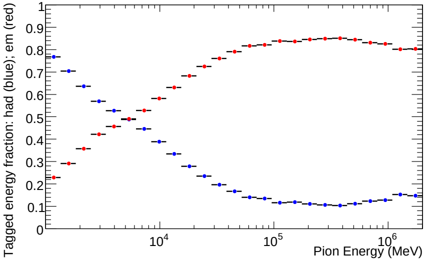


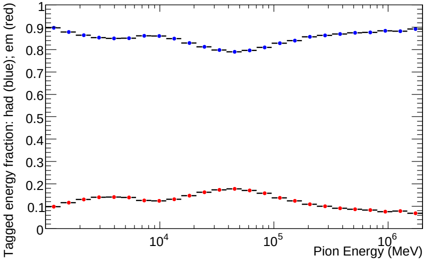
$\langle \rho_{cell} \rangle$



Additional Information Sven







k_T exclusive mode

The k_T exclusive mode:

1. take a list of protojets and define distances:

ΔR distance scheme

$$d_i = p_{Ti}^2$$
$$d_{ij} = min\left(p_{Ti}^2, p_{Tj}^2\right) \Delta R_{ij}^2 \qquad \text{with } \Delta R_{ij}^2 = \Delta\phi^2 + \Delta\eta^2$$

2. find d_{min}, the smallest of all d_i, d_{ij}
3. if d_{min} is a d_i, declare protojet as “beam jet”,
   if it’s a d_{ij}, merge the two jets i and j according to

E recombination scheme

$$p_{ij}^\mu = p_i^\mu + p_j^\mu$$

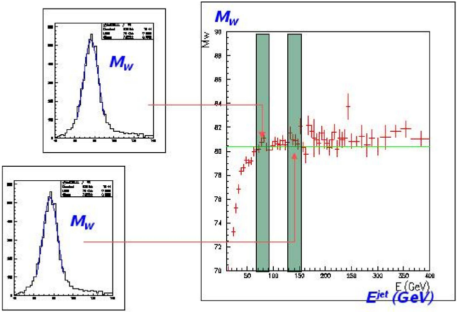
4. iterate until all $d_i, d_{ij} > d_{cut}$

Jet Algorithm Studies: Cuts (R. Härtel)

- ⇒ at least 1 lepton with $p_T > 20\,\text{GeV}$ and $|\eta| < 2.5$
- ⇒ at least 4 jets with $p_T > 40\,\text{GeV}$, $|\eta| < 2.5$, not overlapping with an loose electron within $\Delta R < 0.4$
- ⇒ electron isolation: $< 8\,\text{GeV}$ within a $\Delta R = 0.45$ Cone
- ⇒ muon isolation: $< 2\,\text{GeV}$ within a $\Delta R = 0.2$ Cone
- ⇒ $MET > 20 GeV$

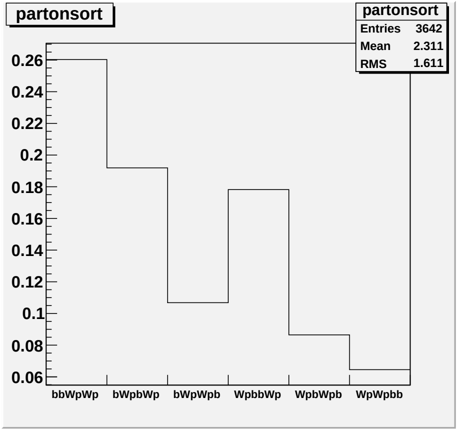
In-situ Calibration (D. Pallin)

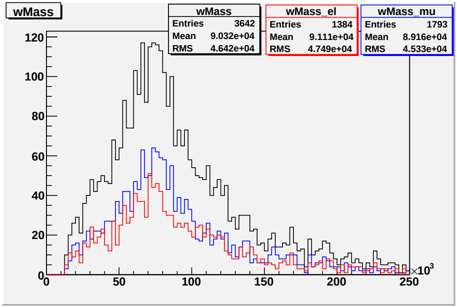
- reconstruct m_W
- define jet energy bins
- for both W parton jets(!) fill m_W in a histogram with respect to the jet energy
- fit with gaussian and plot μ/m_W^{PDG}
- apply weights $1/(\mu/m_W^{PDG})$ to jets and start second iteration

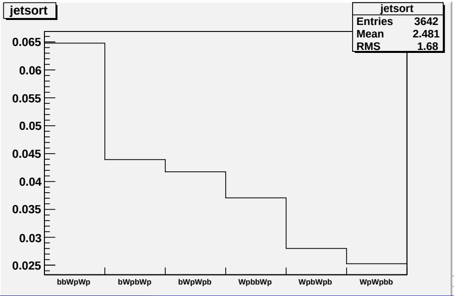


Additional information Emanuel

- Container: *Kt4H1TopoParticleJets*, *StacoMuonCollection*, *MET_LocHadTopoObj*







MET Paola

- Container: *Kt4H1TopoParticleJets*, *StacoMuonCollection*, *ElectronAODCollection*, *MET_RefFinal*