Energy Flow and Jet Calibration

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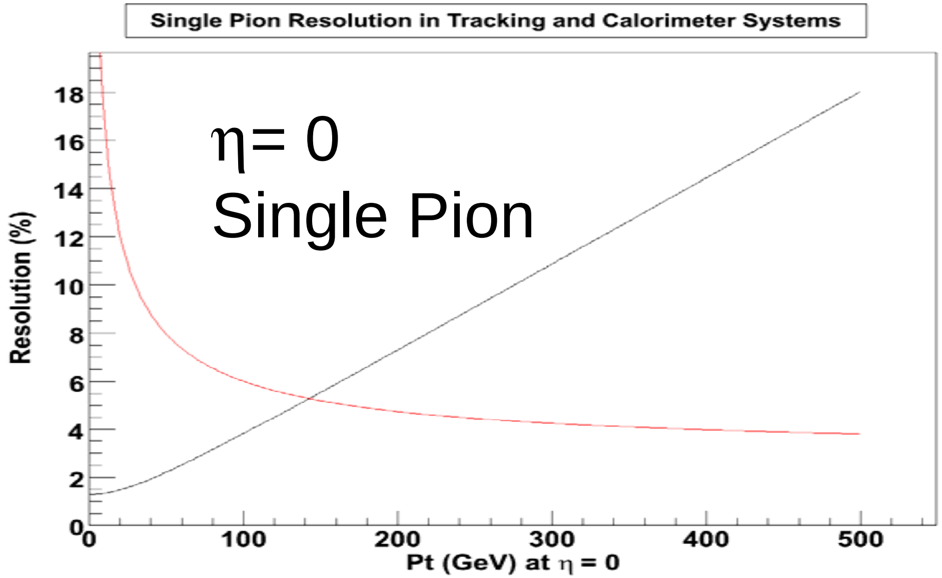
Contains work by R.Duxfield,P.Hodgson,
M.Hodgkinson,D.Tovey

Contents

- Energy Flow for Jets (M.Hodgkinson,R.Duxfield,D.Tovey)
- Jet Calibration using Probe Jet Method (P.Hodgson,R.Duxfield)
- Conclusions

Introduction

- At low energy tracking has better resolution

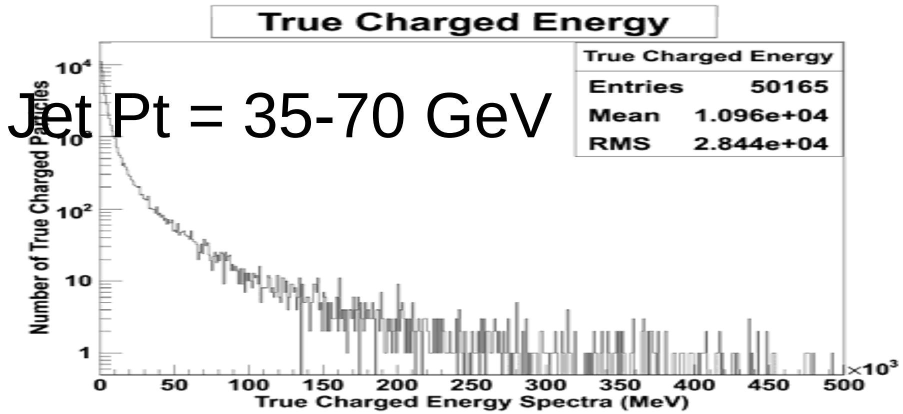


Tracking: $\sigma p_T/p_T \approx 0.036\% p_T \oplus 1.3\%$

Calo: $\sigma E/E \approx 50\%/\sqrt{E} \oplus 3\%$

(numbers from Atlas TDR for single pions in central region)

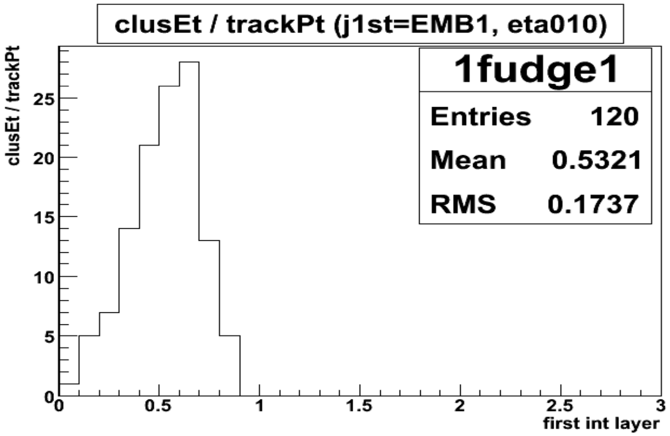
- Tracking can be used in principle to improve jet resolution

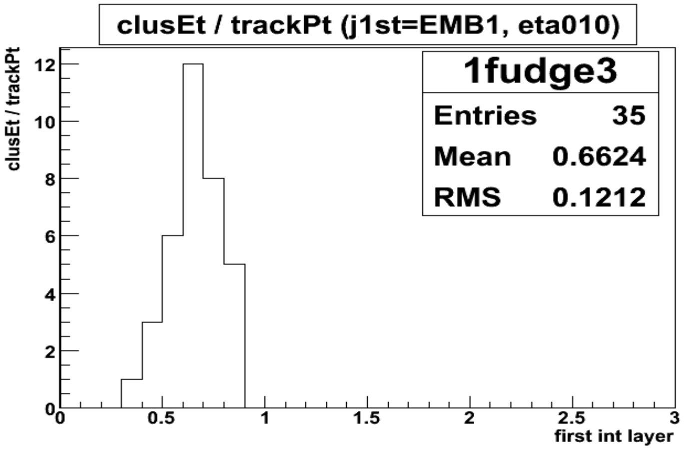


- Have to deal with fact many showers overlap in jets in ATLAS
- Must avoid double counting affects which make resolution worse
- e.g tracks not matching clusters, hadronic showers spanning multiple clusters etc

Energy Flow

- Use TrackToCalo to match tracks to clusters
- If matched subtract expected energy deposit (known from single particle MC - binned in E, eta and layer of first interaction - use E = 6,10,20,50 GeV samples) from cluster
- Layer of first interaction - build 2D Gaussian around track axis in calorimeter of width moliere radius. Measure longitudinal energy density profile and largest change in gradient between layers defines first interaction layer
- Subtract energy using cell removal (must have if wish to use cell weights) or simply adjust energy of cluster

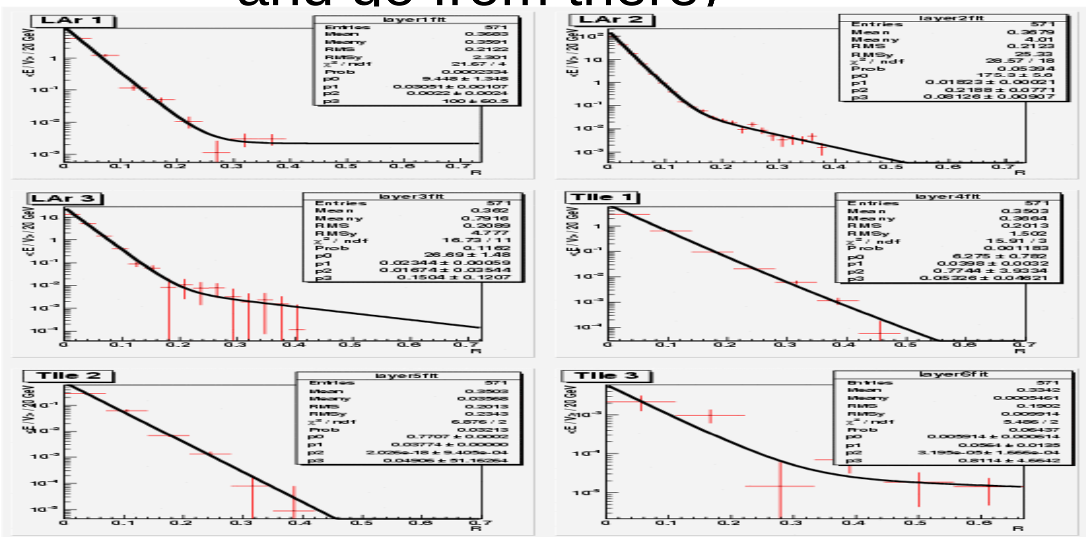




- Measure E/p from topocluster matched to tracks (left) - then require cluster has >95% energy in 0.4 cone around track (right)

Cell Based Subtraction

- Hadronic showers fluctuate a lot - try to avoid this problem as much as we can.
- Use cell ordering, not mean shower shapes
- For each calo layer bin cells in ΔR relative to track eta,phi (each bin in a layer is a “ring” of cells)
- Order all rings in all layers in order of energy density - i.e. radial energy density profiles for each layer
- Remove rings of cells in descending energy density order (i.e. should start from first em interaction/core of shower and go from there)



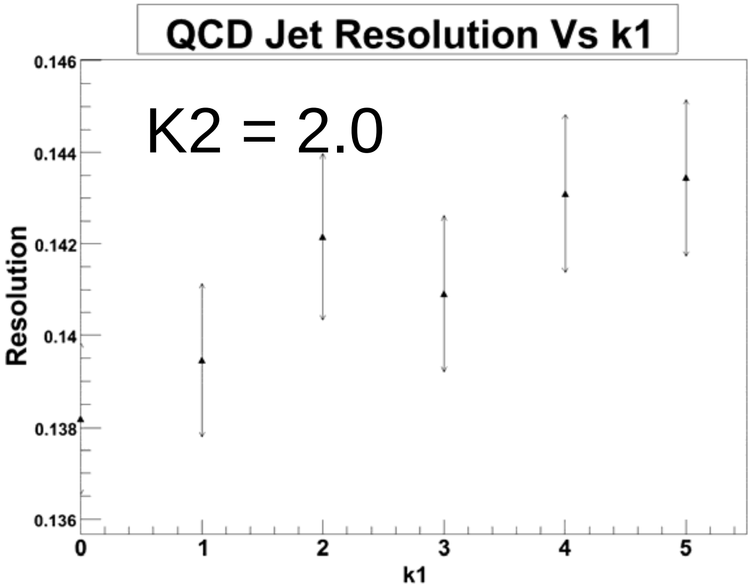
- Radial energy densities for 20 GeV pion (LAr)
- Parameterise as double exponential
- Store coeff in python files - load into eflowRec

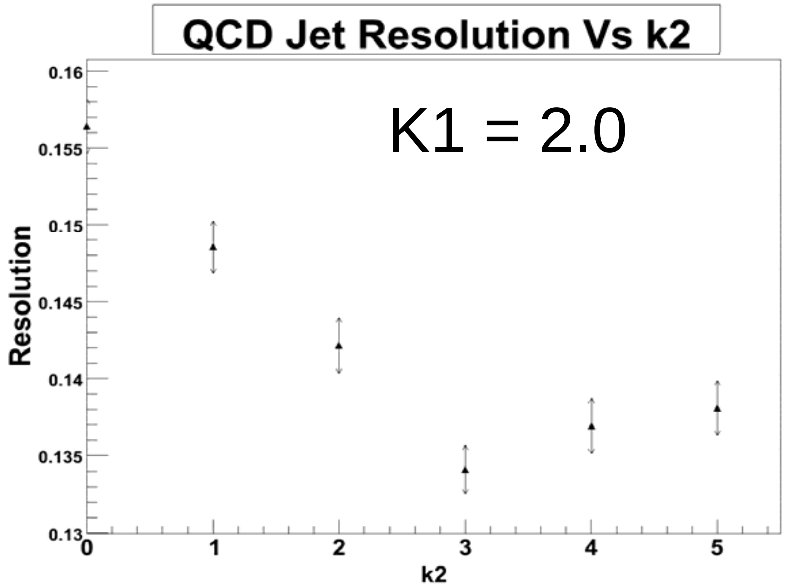
Additional Energy Flow Logic

- First remove expected energy deposits from clusters (globally or remove cells until expected E is removed)
- If $E_{Clus}^{LeftOver} < K_1 \times \sigma_{\exp ected\_energy\_depos}$ then discard cluster
- If $E_{Cluster} < E_{\exp ected} - k_2 \times \sigma_{\exp ected}$ use cluster energy and NOT track energy (suspicion is hadronic showers spanning multiple clusters, but has not been studied yet!)
- Else keep cluster with adjusted E, eta,phi
- Therefore energy flow objects could be tracks, clusters or track-cluster pairs (multiple tracks can map to one cluster)
- They inherit from INavigable4Momentum and hence it is easy to run jet finding on them (jet finding is designed for these generic objects, not calo specific objects)

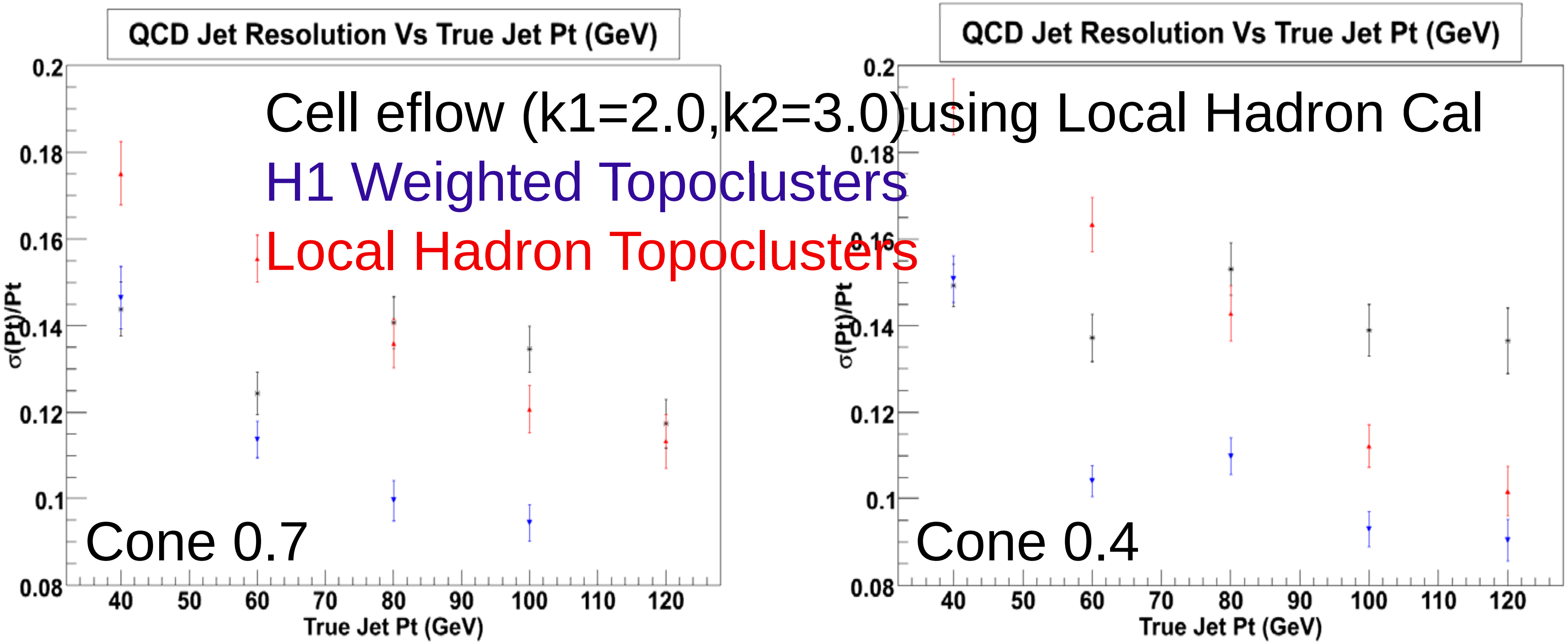
Results (QCD Jets)

- Use J1,2,3 samples (17-140 GeV Pt)
- Only use highest pt jet in event
- Jet |eta| < 1.8 and deltaR between eflow jet and calo (H1,Local Had) < 0.1
- Use Particle in Cone truth definition
- Use eflowRec-00-01-66-CSCJetTag-05 - NOT in release 12.0.6.x (eflowRec-00-01-66 is)
- Cell based energy flow + local hadron calibration



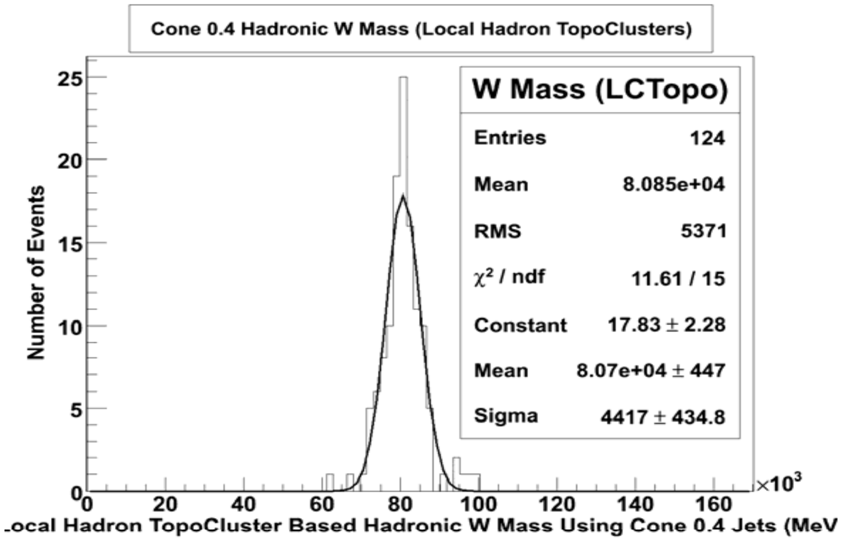


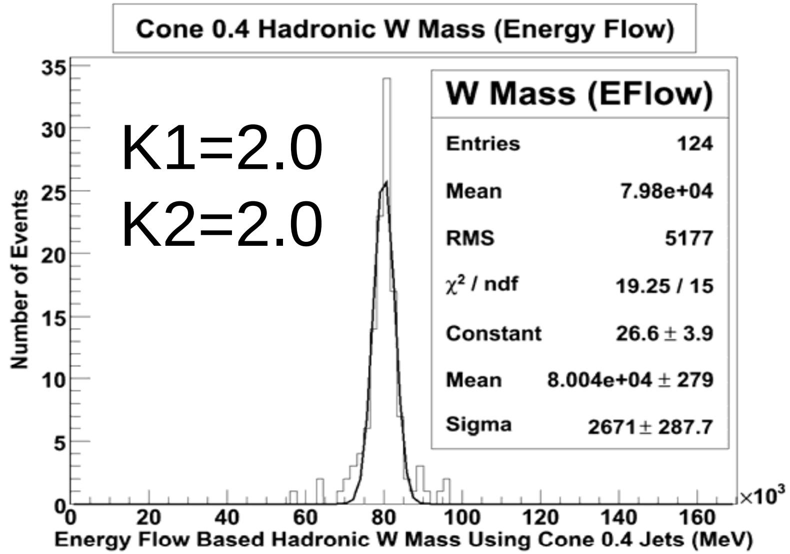
Results (QCD jets)



- Bins of 50-70,70-90 GeV etc
- Eflow + local hadron resolution better than just calo local hadron for jets < ~70 GeV Pt
- H1 weighted calo jets better resolution than calo local hadron jets for all jet pt - but eflow should be compared to calo jets using same calibration scheme

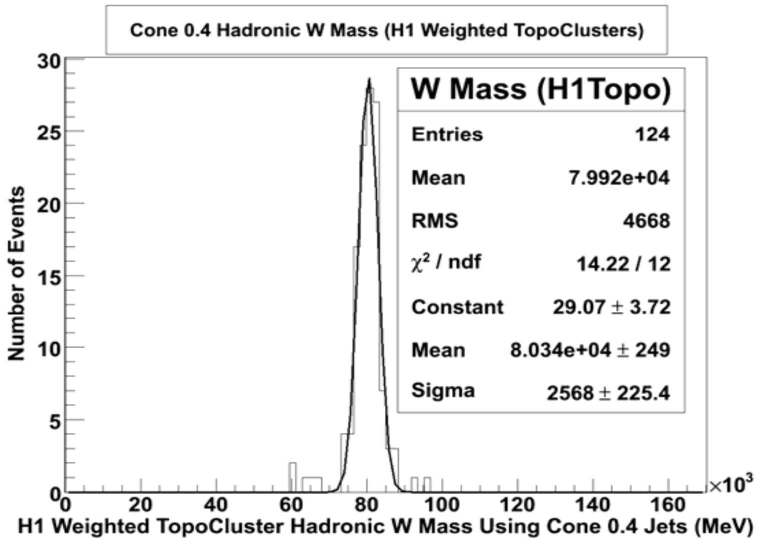
W->qq in Top Quark Events





- Use some typical top analysis cuts (sample 5200)
- Four highest pt H1 TopoClus jets have pt > 40 GeV + MET > 40 GeV
- Find smallest value of below eqn and plot W mass

$$\sqrt{\left(\frac{m_{top} - m_{PDGTop}}{\sigma_{PDGTop}}\right)^2 + \left(\frac{m_W - m_{PDGW}}{\sigma_{PDGW}}\right)^2}$$



Jet Energy Scale Calibration

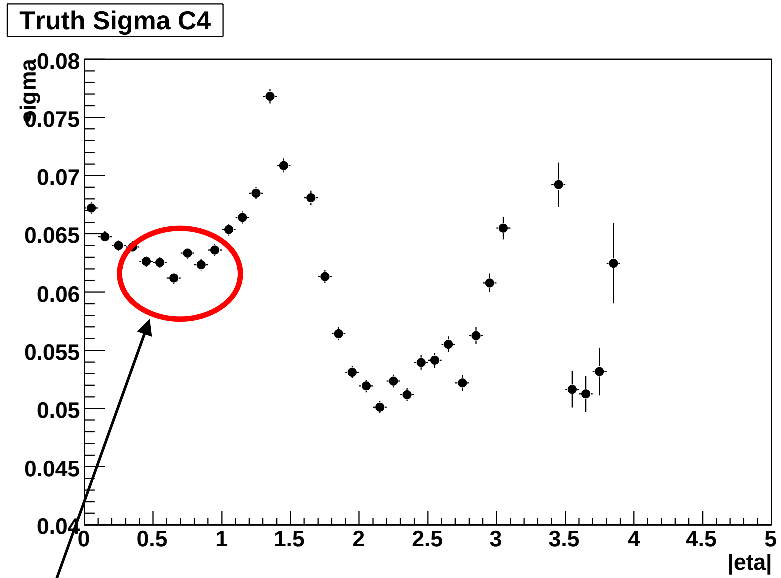
R Duxfield, P Hodgson

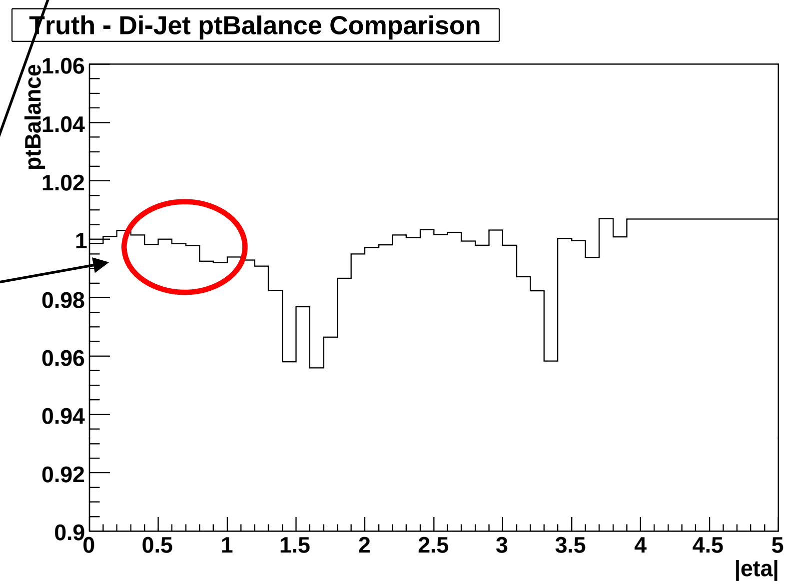
Outline of Method

- Analysis in two parts.
- Match truth jets to reconstructed jets and identify a uniform region in eta.
  - N truth jets >= 2, N reco jets >= 2
  - Matched if $\Delta R < 0.1$
  - pT balance = pT reco / pT truth
  - Fit adaptive Gaussian and plot mean and sigma in eta bins

- Use this eta region as reference region for pT balance

- See region 0.4 < |eta| < 0.6 is good

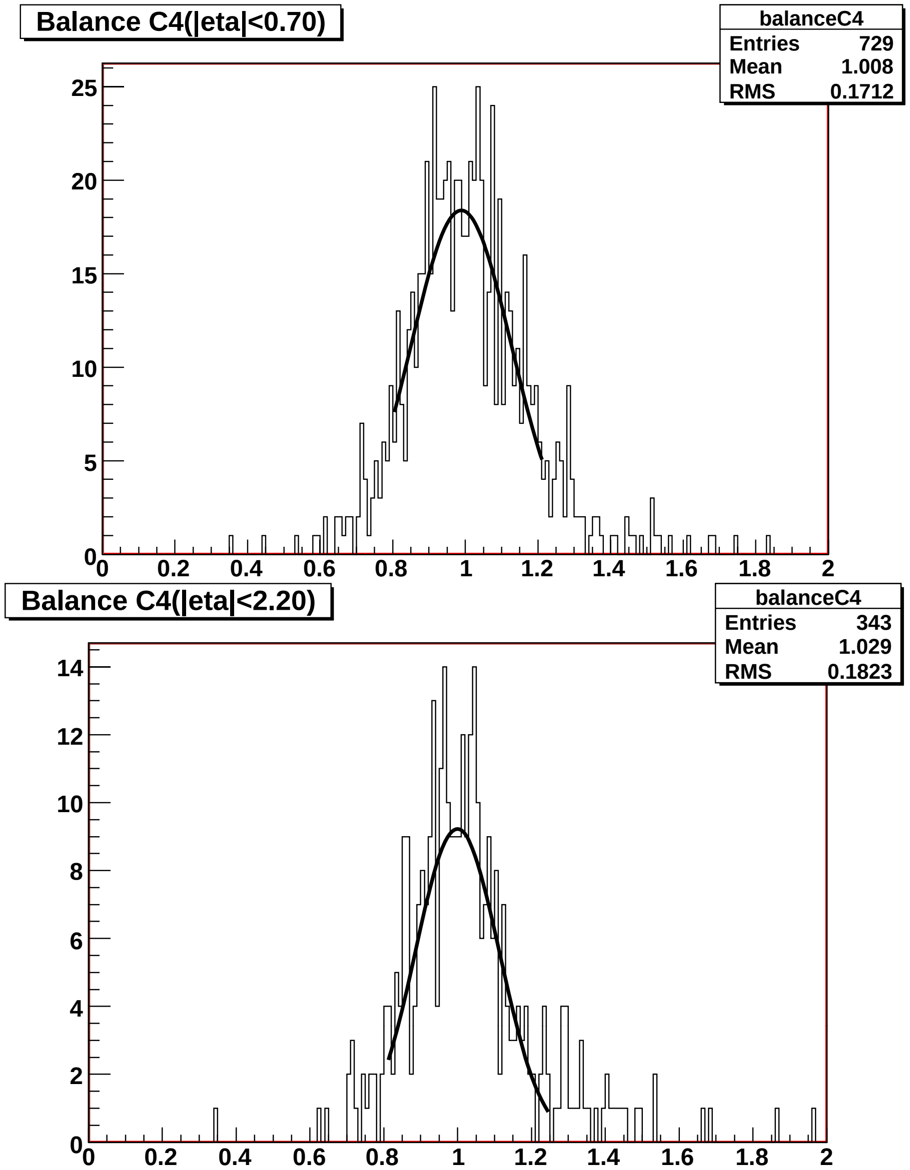


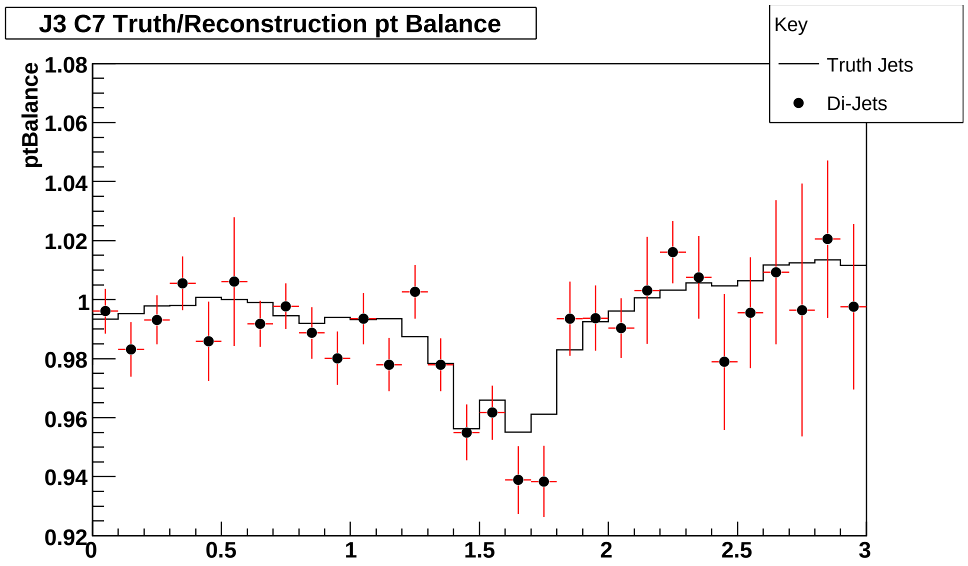


Di Jet pT Balance

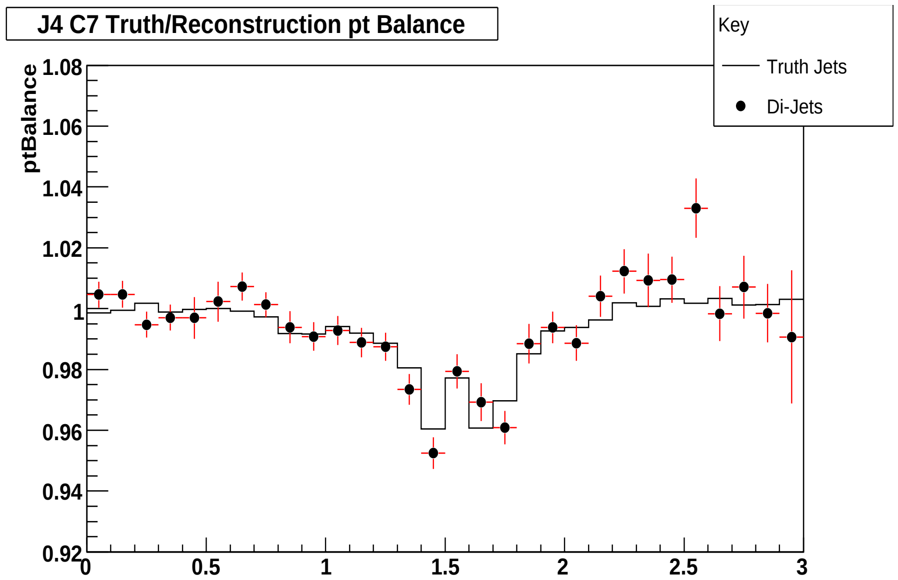
Now look at reconstructed di-jets

- N jets = 2
- Cut on pT of third jet, scan pT range to find optimum pT cut for particular J# sample
- Demand jet closest to |eta| = 0.5 has 0.4 < $|eta|_{jet}$ < 0.6
- This is the reference jet
- pTbalance = pT $_{probe}$ / pT $_{ref}$
- Fit an adaptive gaussian
- Bin fit means in |eta| probe
- This gives JES relative to scale in reference region………

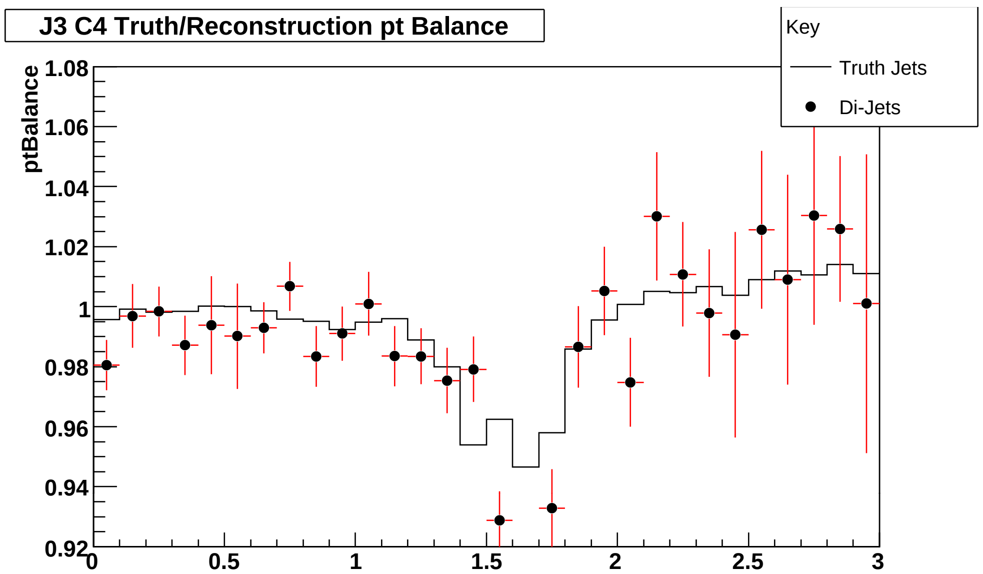




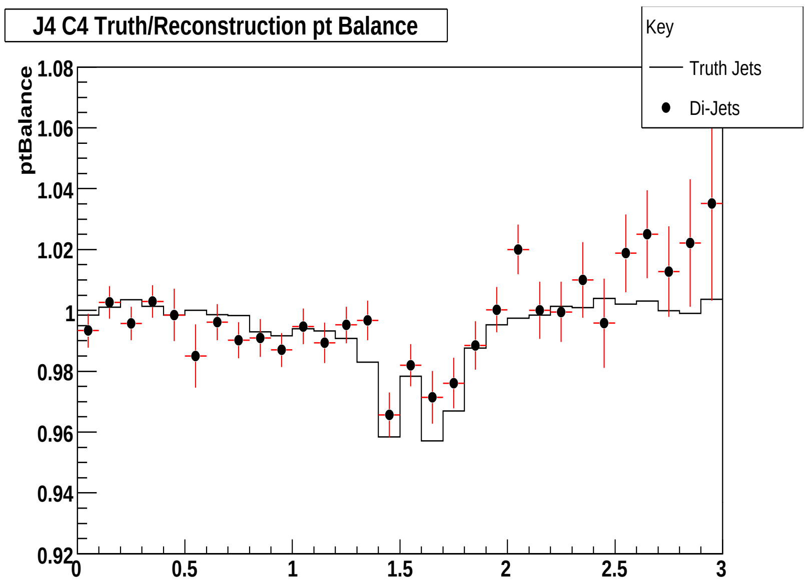
pt: 15 GeV, eta: 0.5



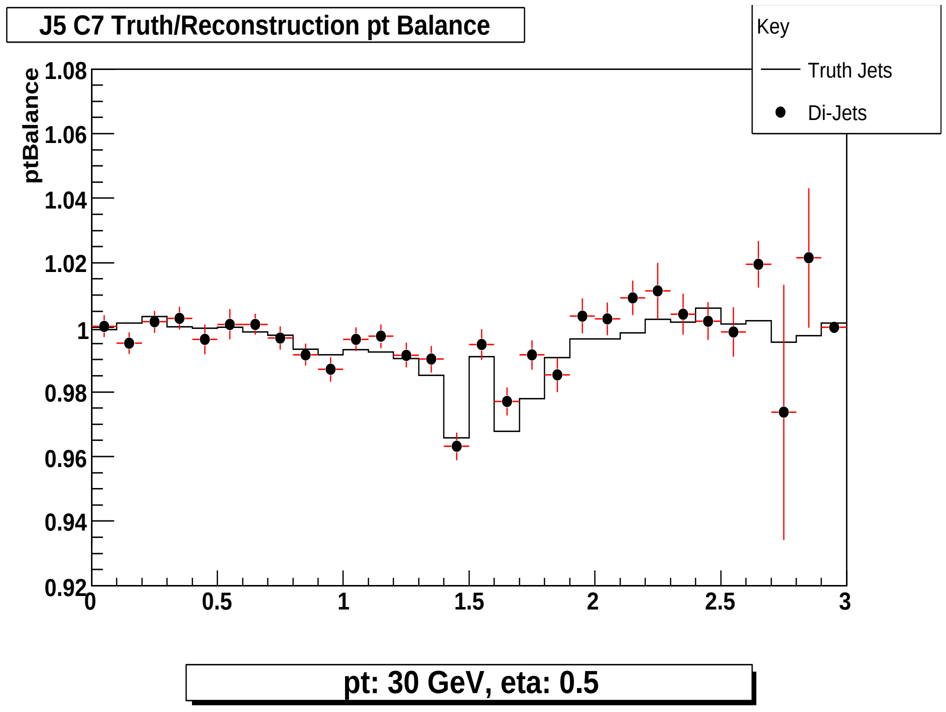
pt: 25 GeV, eta: 0.5

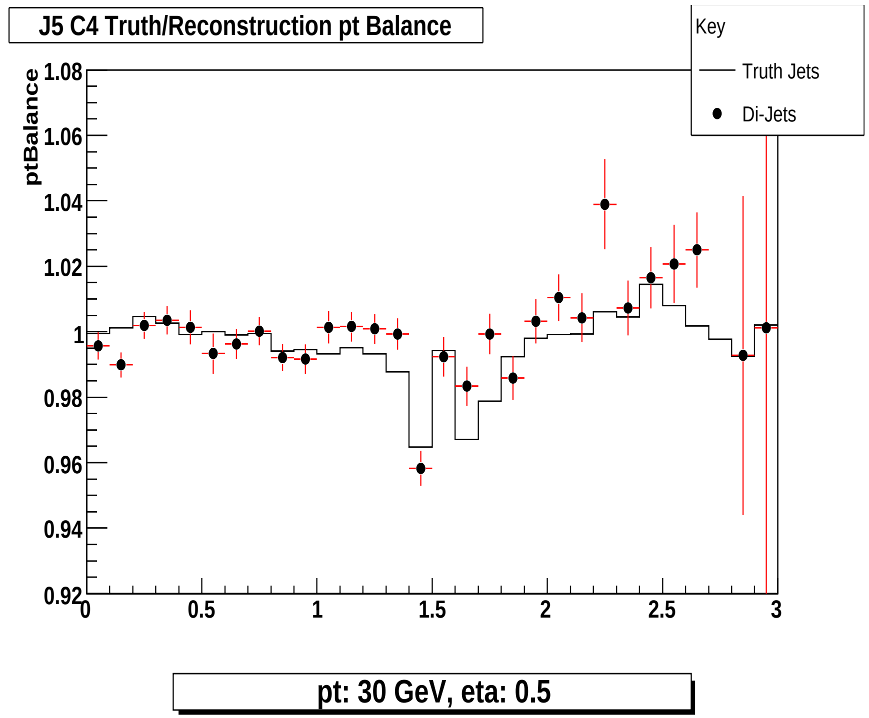


pt: 15 GeV, eta: 0.5

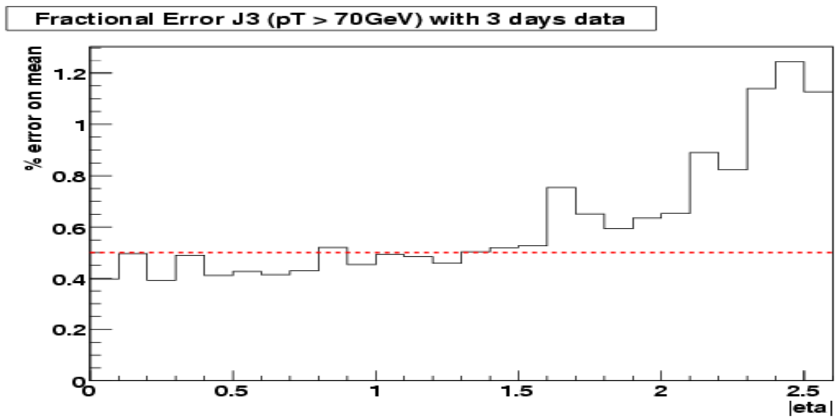


pt: 25 GeV, eta: 0.5





- Relative Jet Energy Scale can be determined to < 1% with 3 days of data (assuming nominal jet prescales, J70 prescale is 5, do not change)



- Statistics runs out at high eta
- Try to use CSC Forward jet samples

Conclusions

- CSC support note on energy flow performance written (some jet plots intended for CSC Jet overview note - CSC Jet 5)
- Energy flow technique using local hadron calibration improves low pt (< 70 GeV) jet resolution (compared to local hadron calo jets) and improves W mass resolution
- Working on:
- H1 weights for energy flow (had reasonable results in 12.0.x, but not quite as good as H1 calo jets)
- Comparison of jet efficiency (vs pt, eta) for eflow jets compared to calo jets - jet veto etc
- Finding events where eflow jet is in tail of jet resolution, calo jet is not (already used this technique to find major improvement to logic)
- Repeating CSC plots in release 13 (eflow uses additional out of cluster corrections now) - use these studies to feed further improvements into14.0.x
- Nominally quick look in 13.0.20 I see jet resolutions look better (local hadron calo jets and eflow with local hadronc) in J1,2,3 samples.

Conclusions

- Used probe jet method to measure relative Jet Energy Scale using J3,4,5 samples
- Nominal jet prescales leads to conclusion that relative JES statistical error can be controlled to < 1% with 3 days data (in central part of detector)
- See if Forward Jet samples can be used to study relative JES in forward regions (not enough events in Jx samples)
- Contribution for CSC note on track