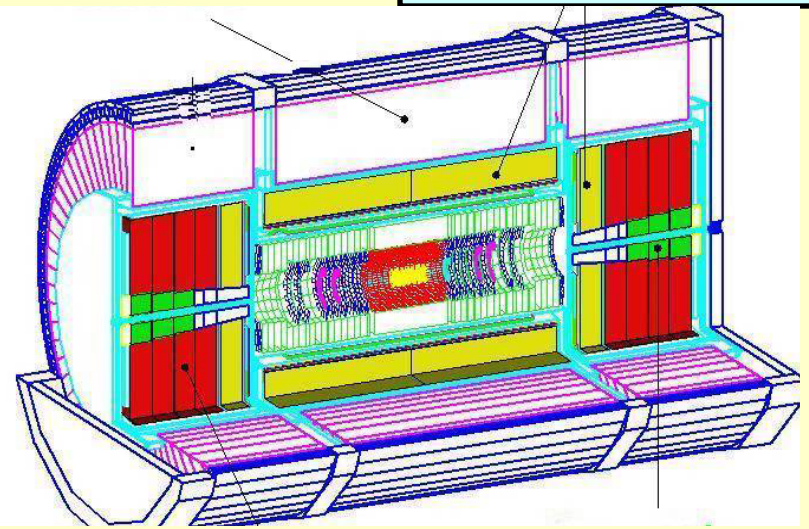
Chicago/ATLAS Work on Calibration and Analysis



ANL/Chicagp/Fermi

January 23, 2009

Frank Merritt

The Chicago Group

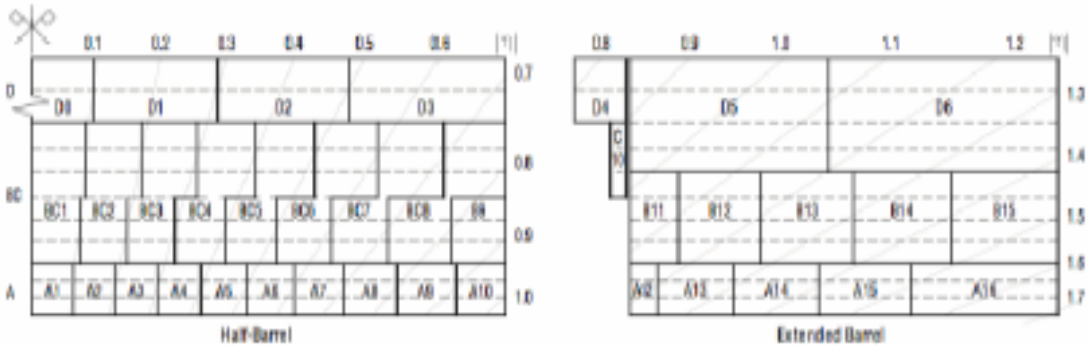
- **The Chicago group at CERN**
  - Jim Pilcher
  - Monica Dunford
  - Giulio Usai
  - Martina Hurwitz (→Chicago)
  - Imai Jen-La Plante
  - Eric Feng
  - Tudor Costin
- **The group at Chicago**
  - Kelby Anderson
  - Florencia Canelli (new!)
  - FSM
  - Mark Oreglia
  - Mel Shochet
  - Ambreesh Gupta
  - Rob Gardner

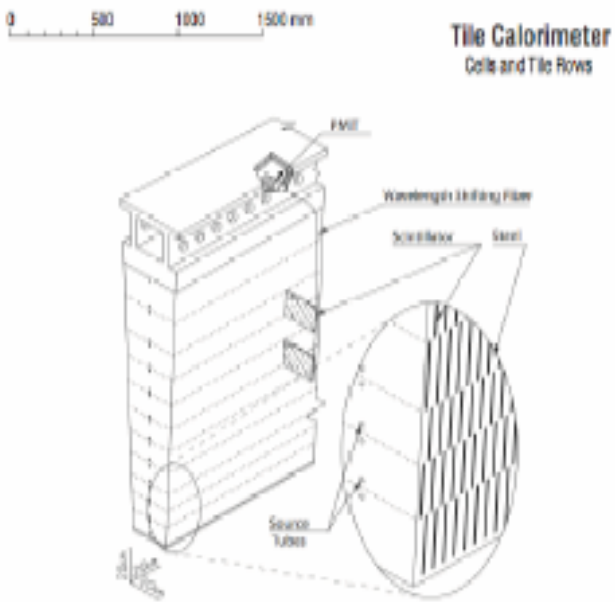
Areas of software/analysis work

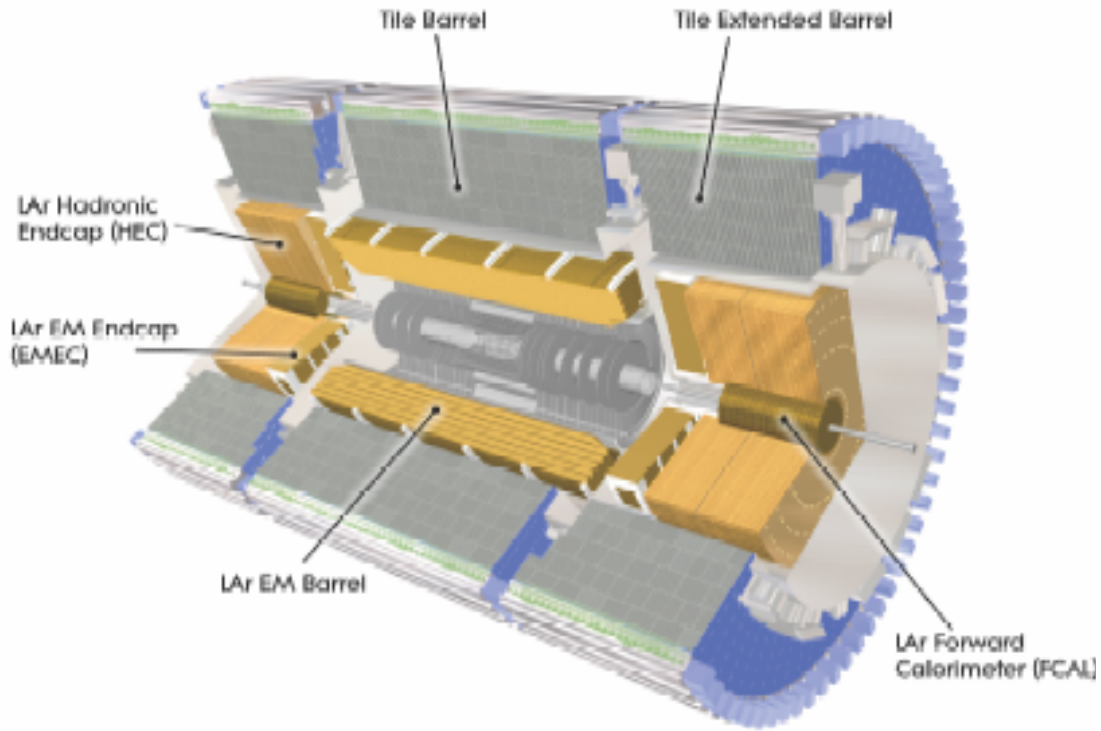
- **Calorimetry Overview**
  - Monte-Carlo Calibration
  - Z+jet, gamma+jet
  - Optimal filtering
  - Online reconstruction
  - Calorimeter monitoring
- **FTK (Mel Shochet)**

- **A few specific topics:**
- Ambreesh Gupta: Calibration and jet algorithm development, corrections, inversion method.
- Belen Salvachua (ANL): Extensive jet calibration work.
- Martina Hurwitz:
- Imai LaPlante: Studies of different algorithms, W+jets

The Calorimeters







Jet Algorithms In Athena

Iterative cone

$$\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$$

	ΔR	$E_T$seed	ΔS
ATLAS	0.7/0.4	2 GeV	50%

Split and merge procedure when ΔS of jet overlaps.

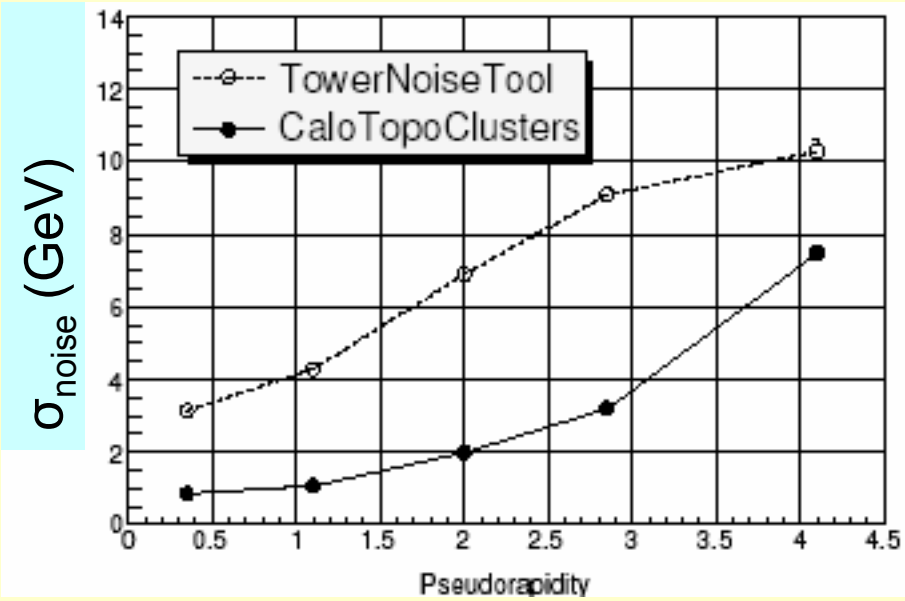
E Recombination scheme: 4 vector sum of object components to obtain jet kinematics – other schemes implemented and usable from jobOption

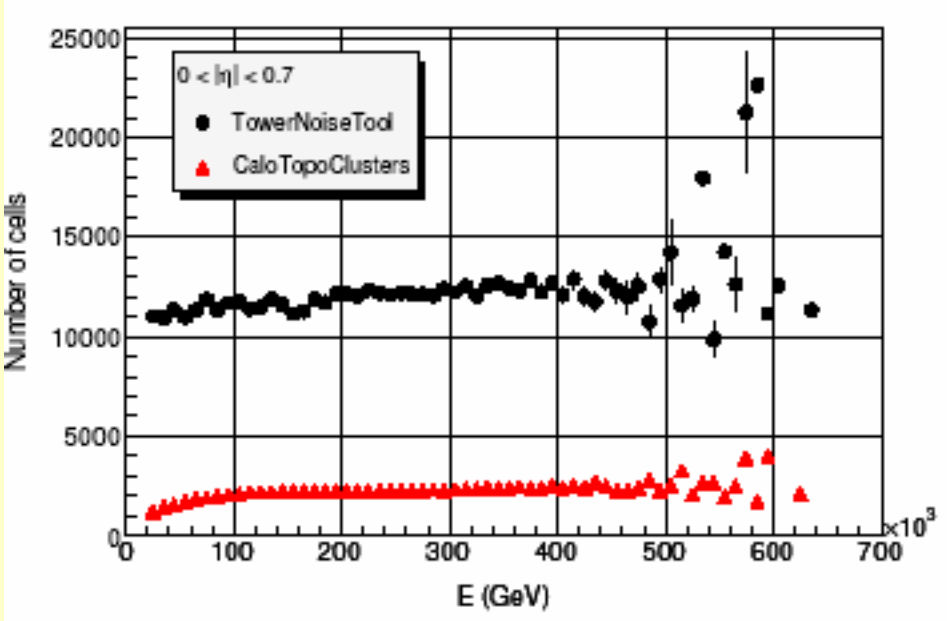
Cone algorithm is the most widely used for physics analysis in ATLAS up to recently: cone 0.4 for top physics and cone 0.7 for all other analysis.

In last year a lot of activity has started on other jet algorithms and in finding the best parameters for various physics studies.

Noise Suppression

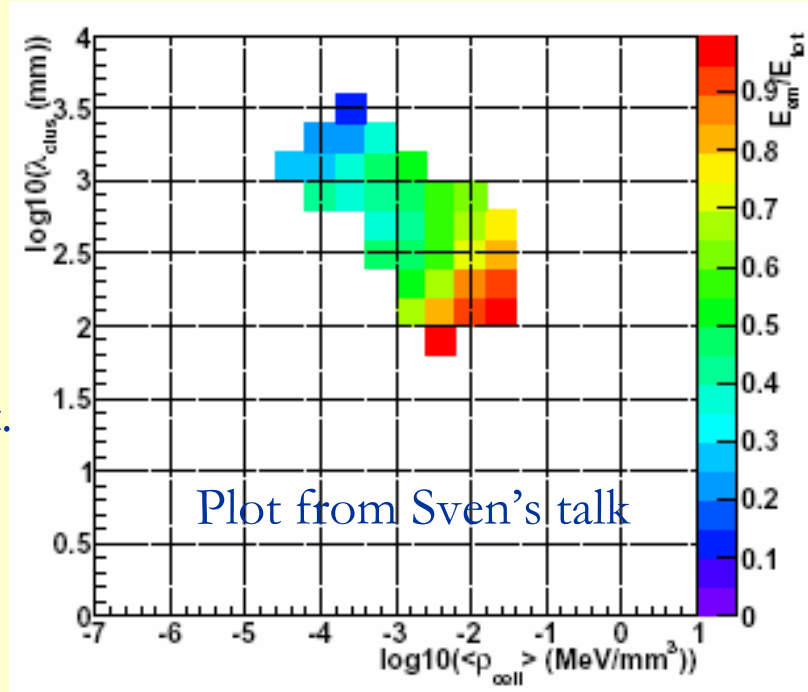
- Large number CaloCell (about 10000, mostly EM) in a jet
  - Important to have good noise suppression algorithm
- CaloTopoCluster naturally suppress noise
  - Random noisy regions do not form clusters.
- Noise sigma in jet reflect the number of CaloCell in a jet
  - Also should estimate total signal selected by noise suppression algorithm.



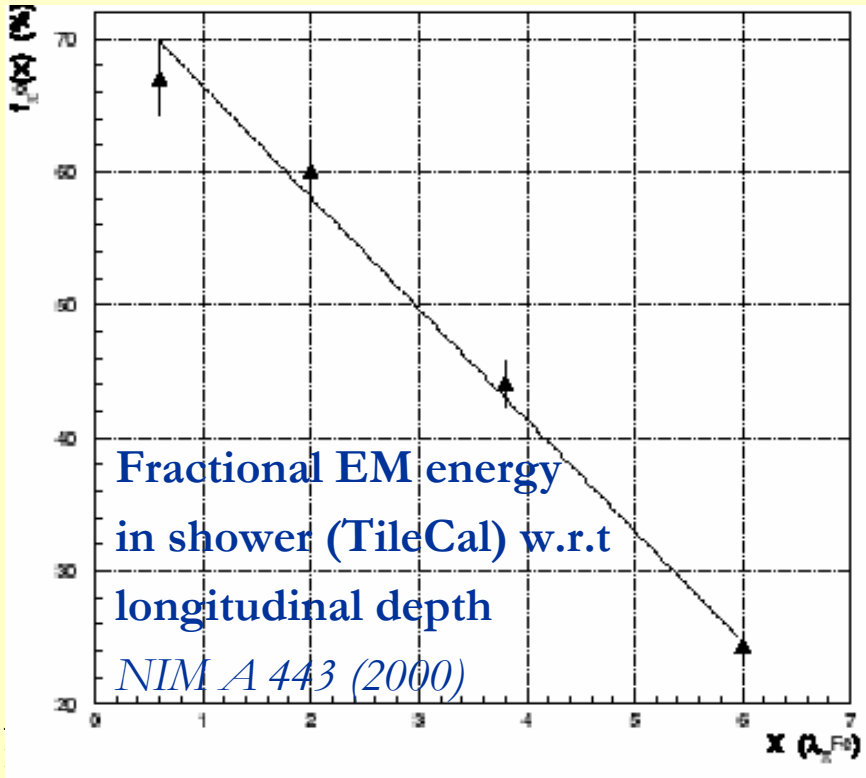


Jet Energy Correction

- Response to EM and HAD particle different
  - Calorimeter calibrated at EM scale.
  - Different jet energy correction schemes find variables correlated to hadronic energy deposit.
  - Two such variables:
    1. Energy density 2. Longitudinal depth



Large energy density
=> EM energy

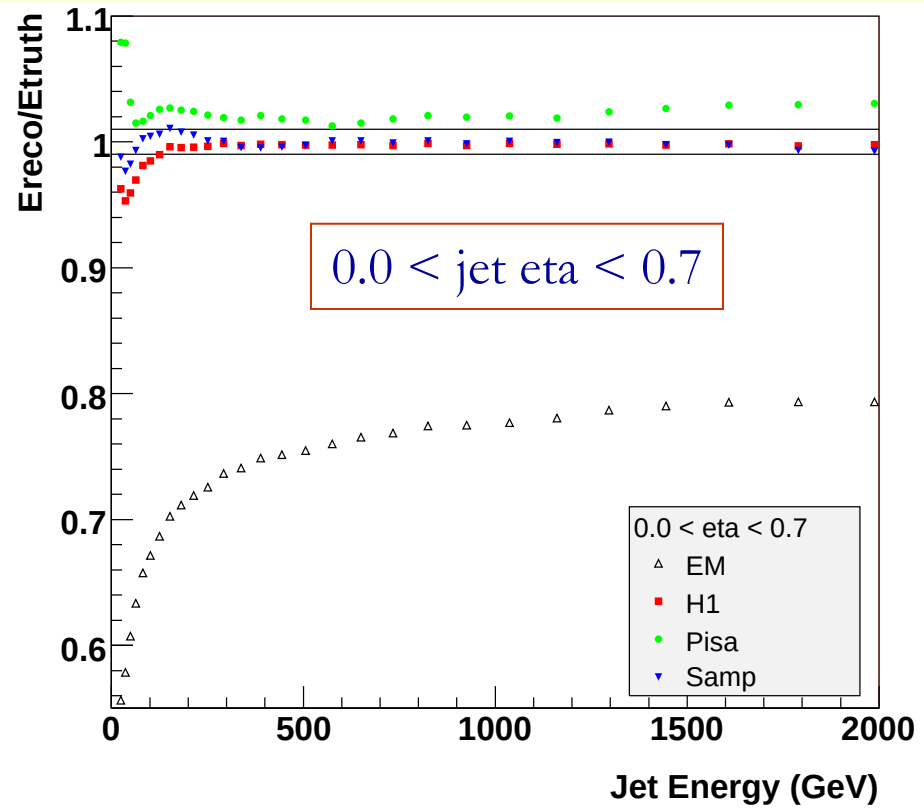


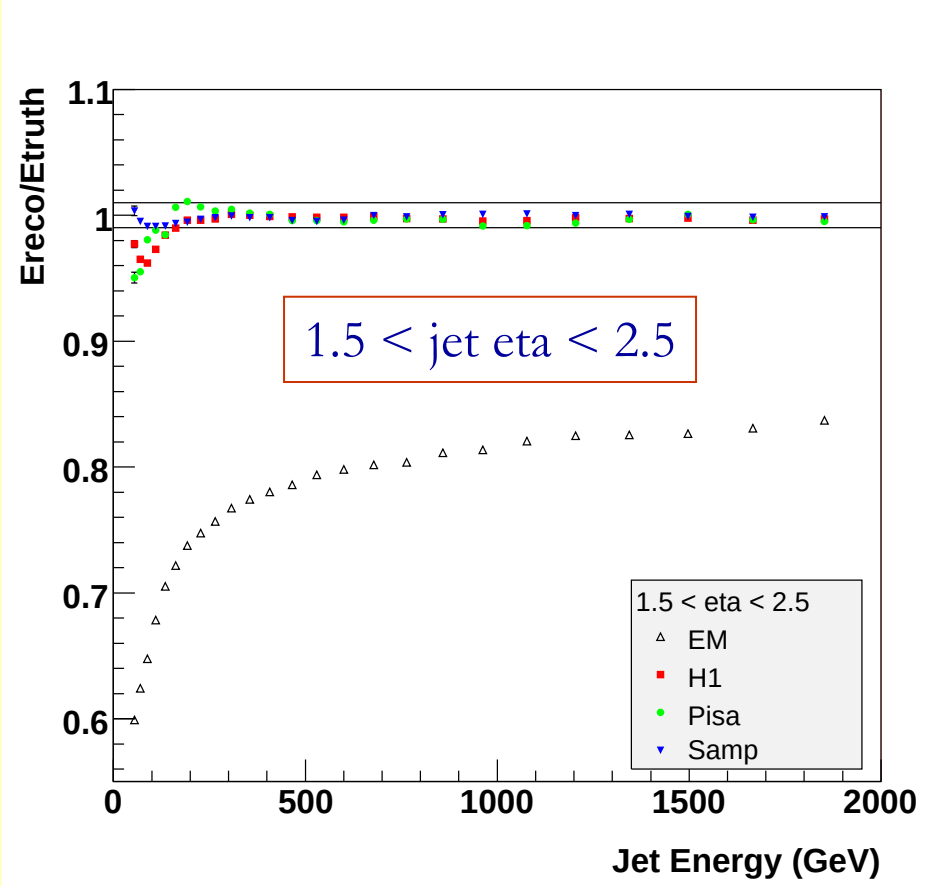
Early part shower EM
Later part shower non-EM

- Both these variables used for Jet Energy correction - weighting schemes.

Jet Linearity in energy

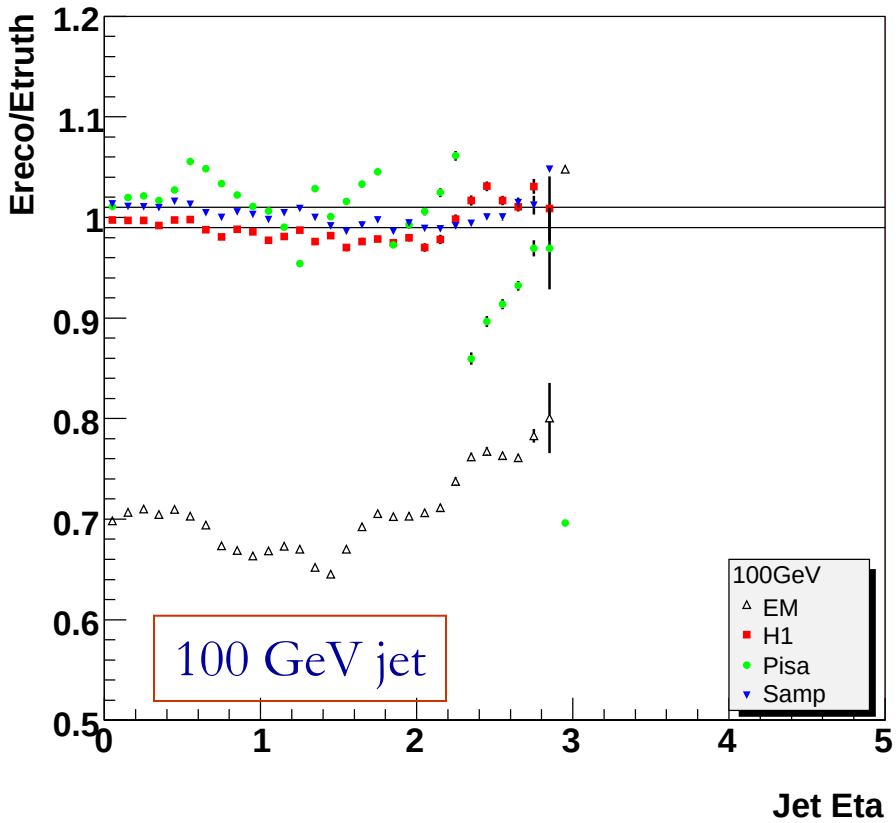
- Different calibration schemes are compared in a common setup.
- We have considered isolated jets to disentagle effects of clustering from calibration.
  - In energy range 2 GeV - 2000 GeV, linearity recovered to 1% by H1 and Sampling.
  - Some deviation beyond 1% for Pisa.

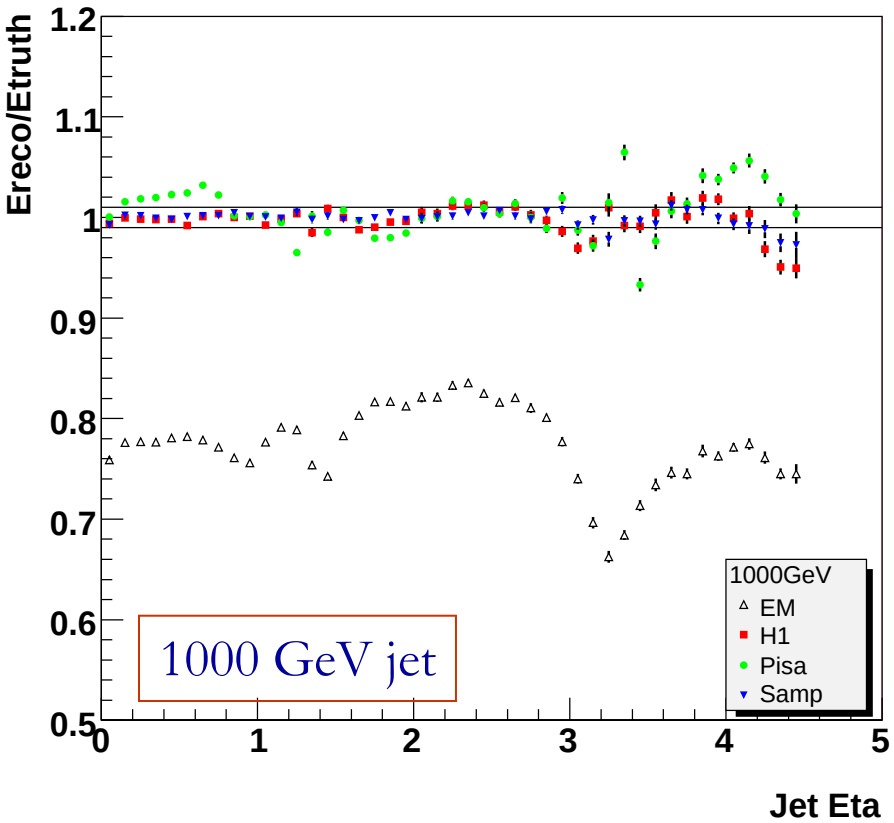




Jet Linearity in eta

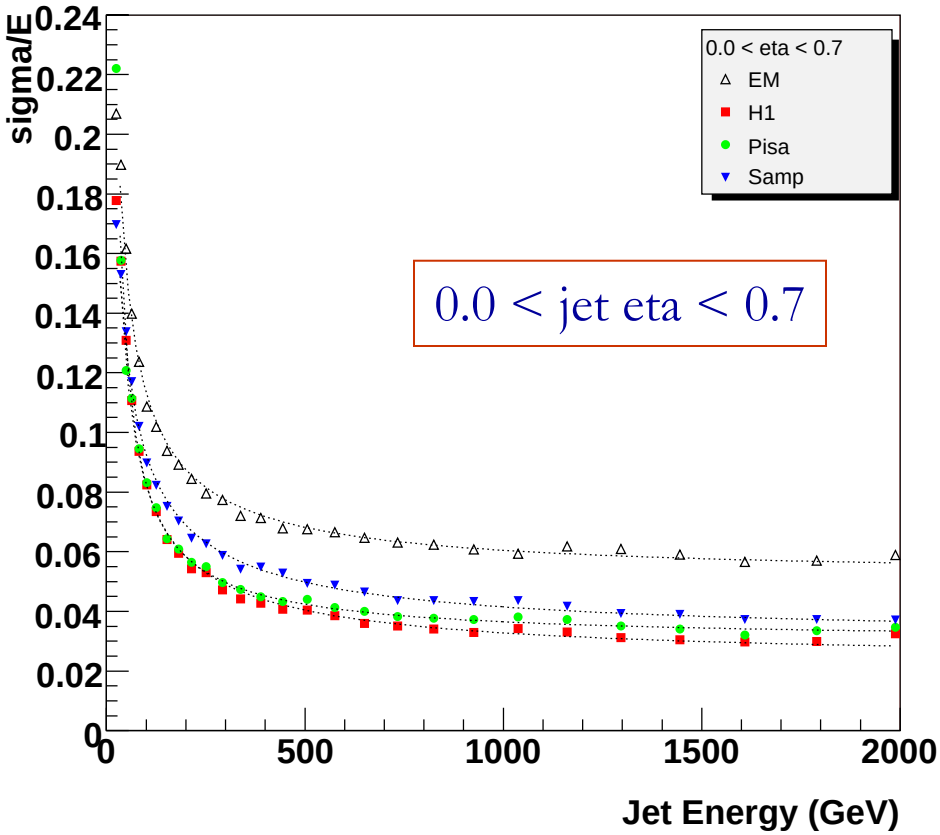
- Jet linearity in eta is complicated by the changing material and detector regions.
  - H1 and sampling recover linearity close to 1%
  - Pisa has larger fluctuations at low energies (no fudge factor applied). The deviation at eta>2.2 is due to sw problem.

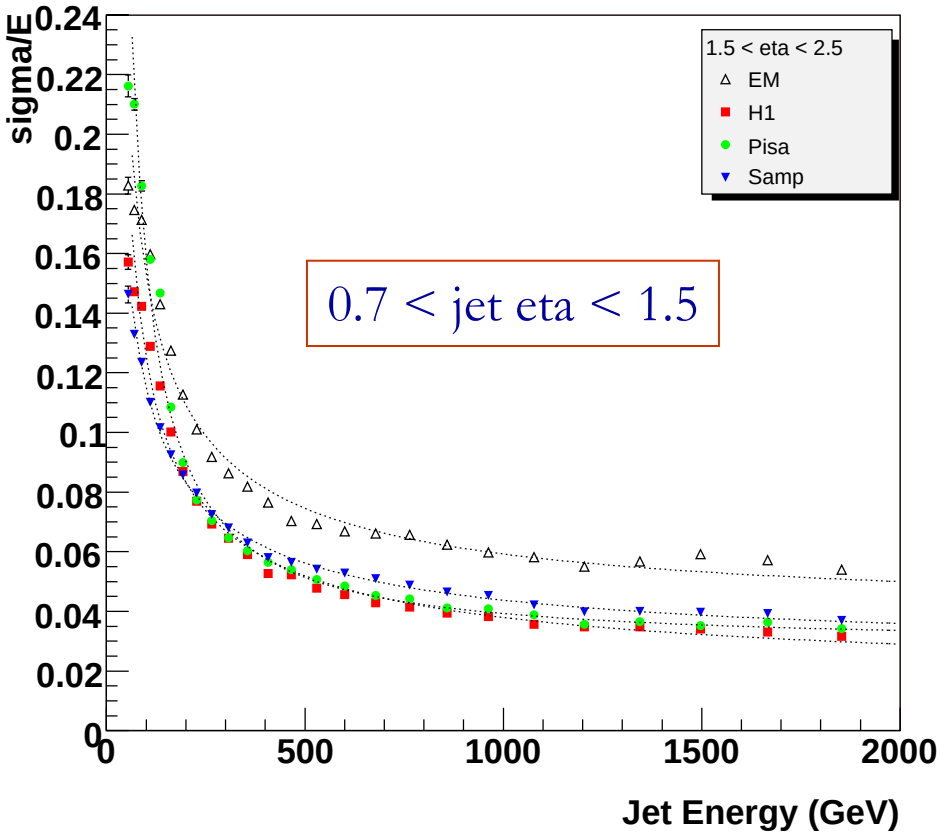




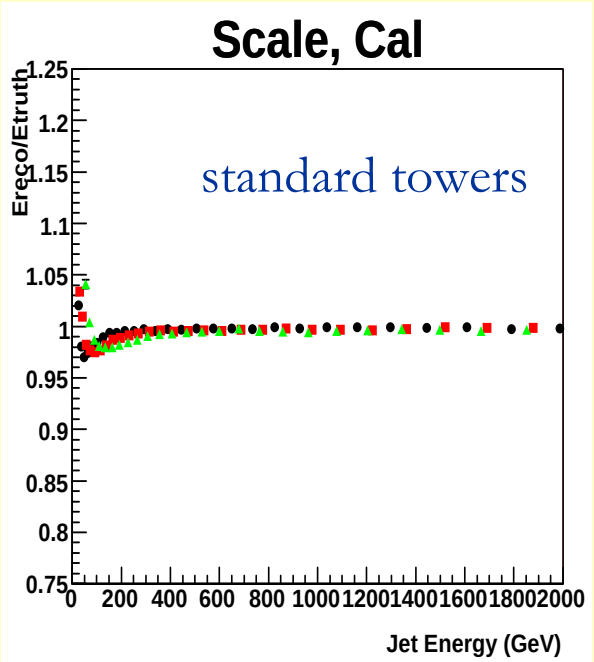
Jet Resolution

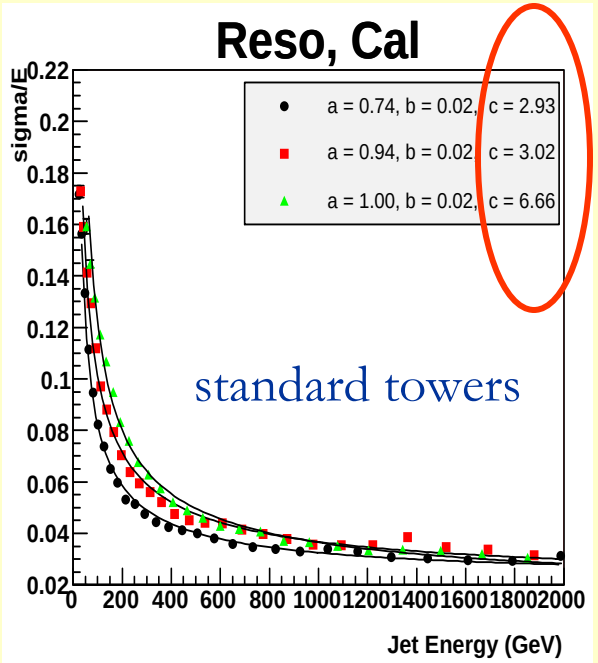
- The energy density calibration methods have better resolution compared to sampling method at higher energies.
  - the difference decreases at higher eta.

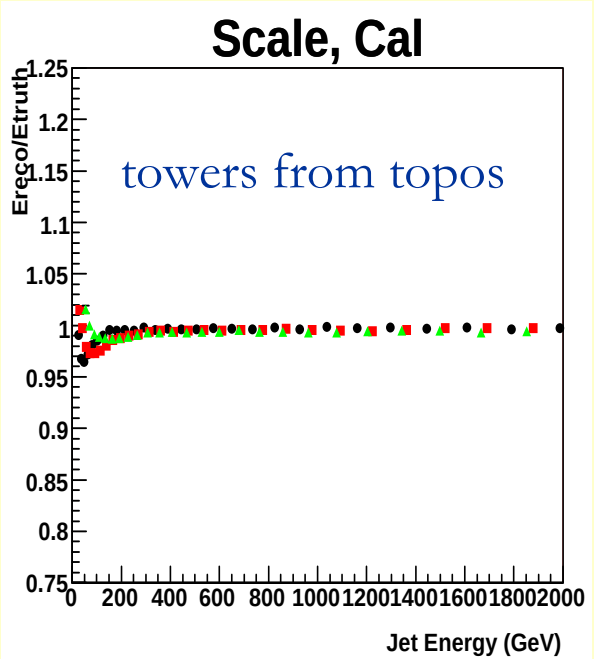


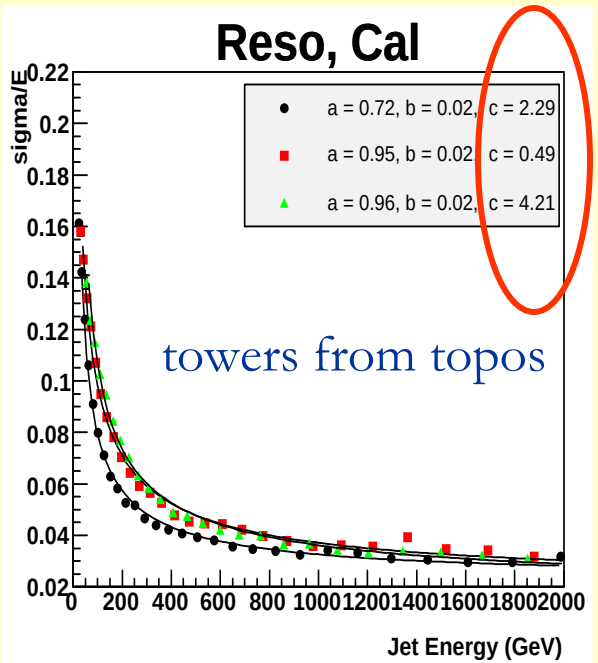


Jet Resolution









- Multi-jet event
  - Cone 0.7
  - Use towers that include only those cells that belong to topoclusters
  - H1 weights.

Un calibrated (barrel region)

$$\frac{\sigma(E)}{E} = \frac{0.94}{\sqrt{E(GeV)}} \oplus 0.05 \oplus \frac{0.0}{E(GeV)}$$

Calibrated (standard towers)

$$\frac{\sigma(E)}{E} = \frac{0.74}{\sqrt{E(GeV)}} \oplus 0.02 \oplus \frac{2.9}{E(GeV)}$$

Calibrated (towers from topos)

$$\frac{\sigma(E)}{E} = \frac{0.72}{\sqrt{E(GeV)}} \oplus 0.02 \oplus \frac{2.3}{E(GeV)}$$

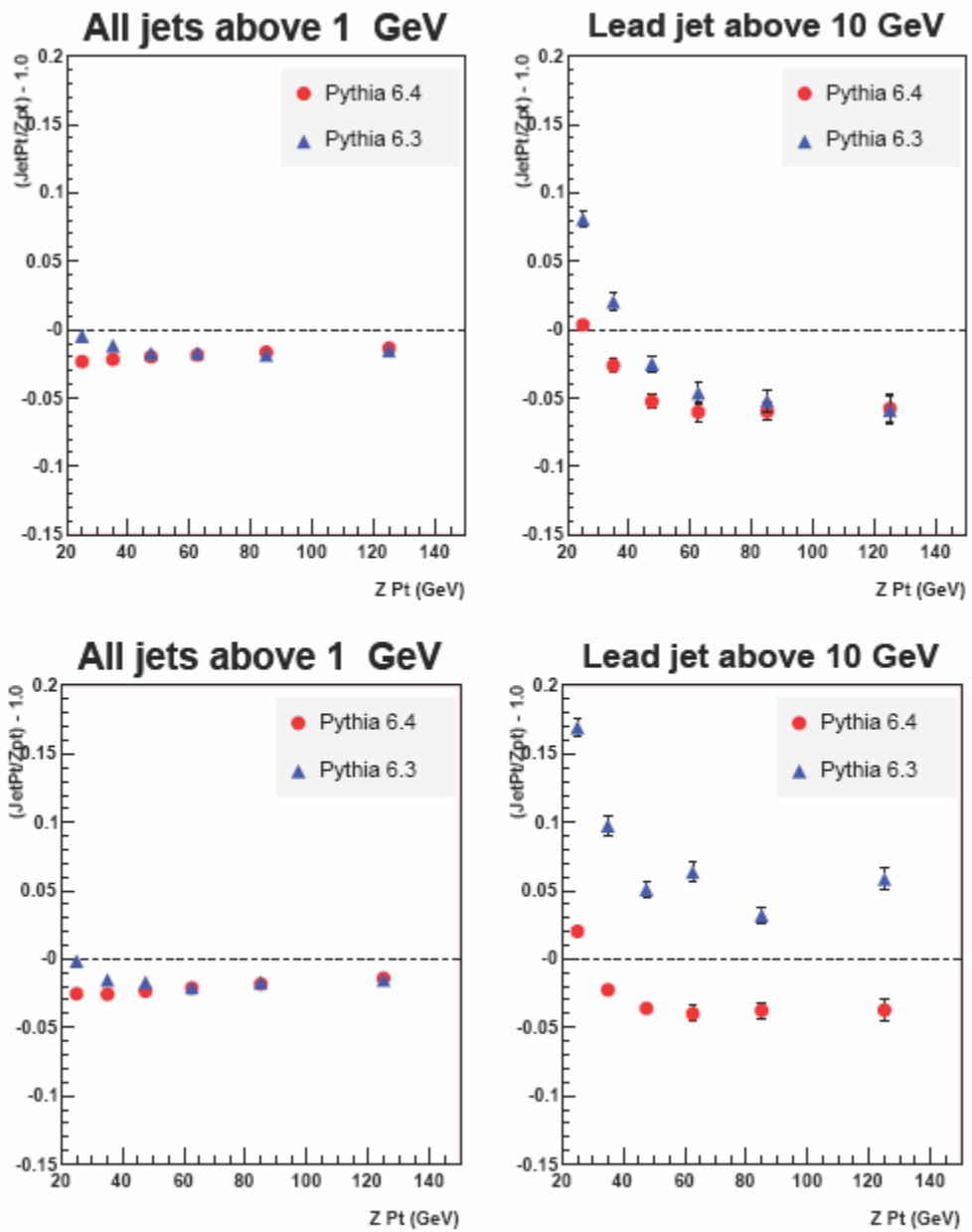
Summary & Conclusion

- We have started to define a set of measurement to assess jet reconstruction and calibration performance (concerning constituents and weighting schemes).
- **CaloTopoCluster significantly reduces noise**
- Studies to understand the performance of jet reconstruction with topocluster
  1. There are indications that topoclusters should be limited in size to be effectively used as input to jet clustering alg's.
  2. Efficiency using 2 GeV seed is higher for topoclusters.
  3. Decreasing the seed to 1 GeV for towers almost recovers the efficiency (w.r.t. topoclusters) without affecting the fake rate.
  4. Loss of efficiency at high energy is mainly due to splitting (it needs more investigation to be completely understood)
- **Comparison studies between different jet energy correction schemes performed.**
  1. **H1 and Sampling are linear to 1% at high energy (low energy a few %).**
  2. **Methods using cell energy density give better resolution at high energies.**

In Situ calibration

- So far, calibration is based on Monte-Carlo studies of jets, and calibration constants are fitted to give closest agreement between "truth" (generator) and reconstruction.
- When ATLAS turns on, the first critical job in calorimetry will be to study well-understood events to determine the jet energy scale, and to adjust calibration constants.
- Best candidates for this are $Z \rightarrow ee$ for electromagnetic calibration and Z+Jet or γ+Jet events for hadronic calorimetery. But balancing the leading jet against the Z/γ -- which worked well at the Tevatron – gives significant biases at LHC energies.
- Have investigated this at the generator level:

Pt balance in Z+jet events



Drell-Yan production

qg+qq+gg

(Y-axis is JetPt/ZPt-1)

Figure 8: *PtBalance* for the sum of all jets with $P_T > 1$ GeV, and the lead jet with $P_T > 10$ Ge for Pythia ISUB=1 (*upper*) and ISUB=15+30 (*lower*) for Z → ee.

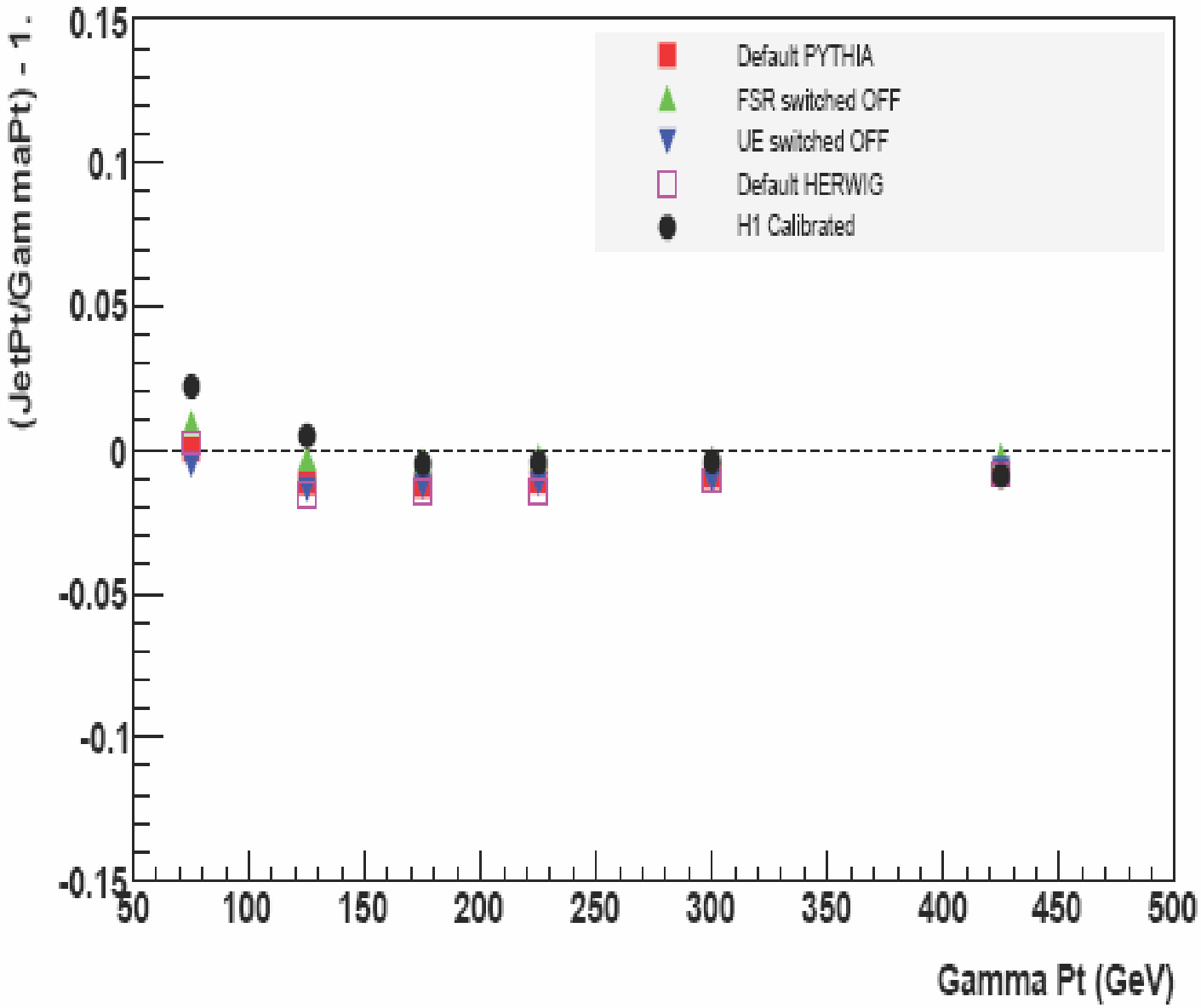


Figure 24: Average Pt balance of all jets above 1 GeV w.r.t the γ in γ+jet events. Except for the Full Simulation, the points are from truth jets.

Conclusions

- Good progress on Monte-Carlo analysis and calibration tools.
- Much better understanding of Z+jet and γ+jet events.
  - Should be able to extract jet energy scale, and to verify calibration and resolution.
- Still much to do:
    - How to handle dead or problem cells.
    - Need monitoring/calibration at cell level using data.
    - Better understanding of MC systematics.

Jet Scale with Numerical Inversion

JetEtMiss Meeting, 16 January 2009

Ambreesh Gupta

Outline:

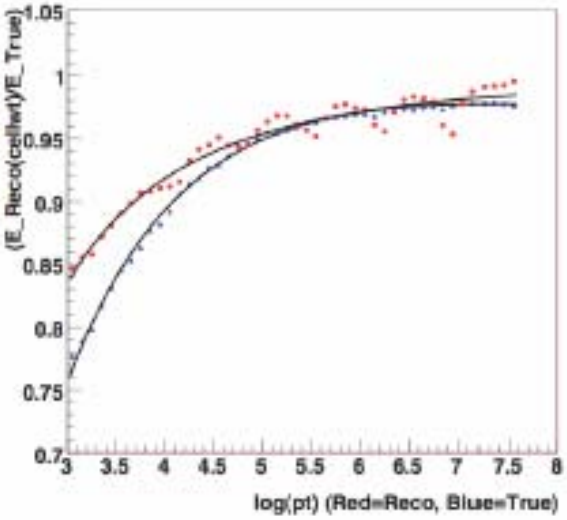
- Why use Numerical Inversion?
- Description of Numerical Inversion
- Results
- Plans/Conclusion

Why Numerical Inversion?

- Jet energy corrections are derived w.r.t a standard scale - truth jet in MC, gamma/Z etc., in in-situ methods. But jet energy correction has to be applied to reconstructed jets without reference to truth.

- In H1-style correction, first CellWt is applied as a function cell energy density. Next, JetScale is derived from the profile - E_reco(CellWt)/E_true vs. log(Et_reco(CellWt)).

- With larger statistics it was discovered that this profile has dips of order few % due to J0-J7 sample boundaries.
- Also, the above JetScale correction is sensitive to input jet spectrum and finite detector resolution.



- Numerical inversion can be used to derive JetScale as a function of reconstructed jet energy that also resolves above issues.

JetScale with Numerical-Inversion

- The following conditional probability relation can be used to estimate corrected jet energy.

$$P(E^T \mid E^R) = P(E^R \mid E^T) * P(E^T) / (\text{Normalization})$$

E^R is reconstructed jet energy. E^T is true jet energy. $P(E^T)$ is input jet spectrum.

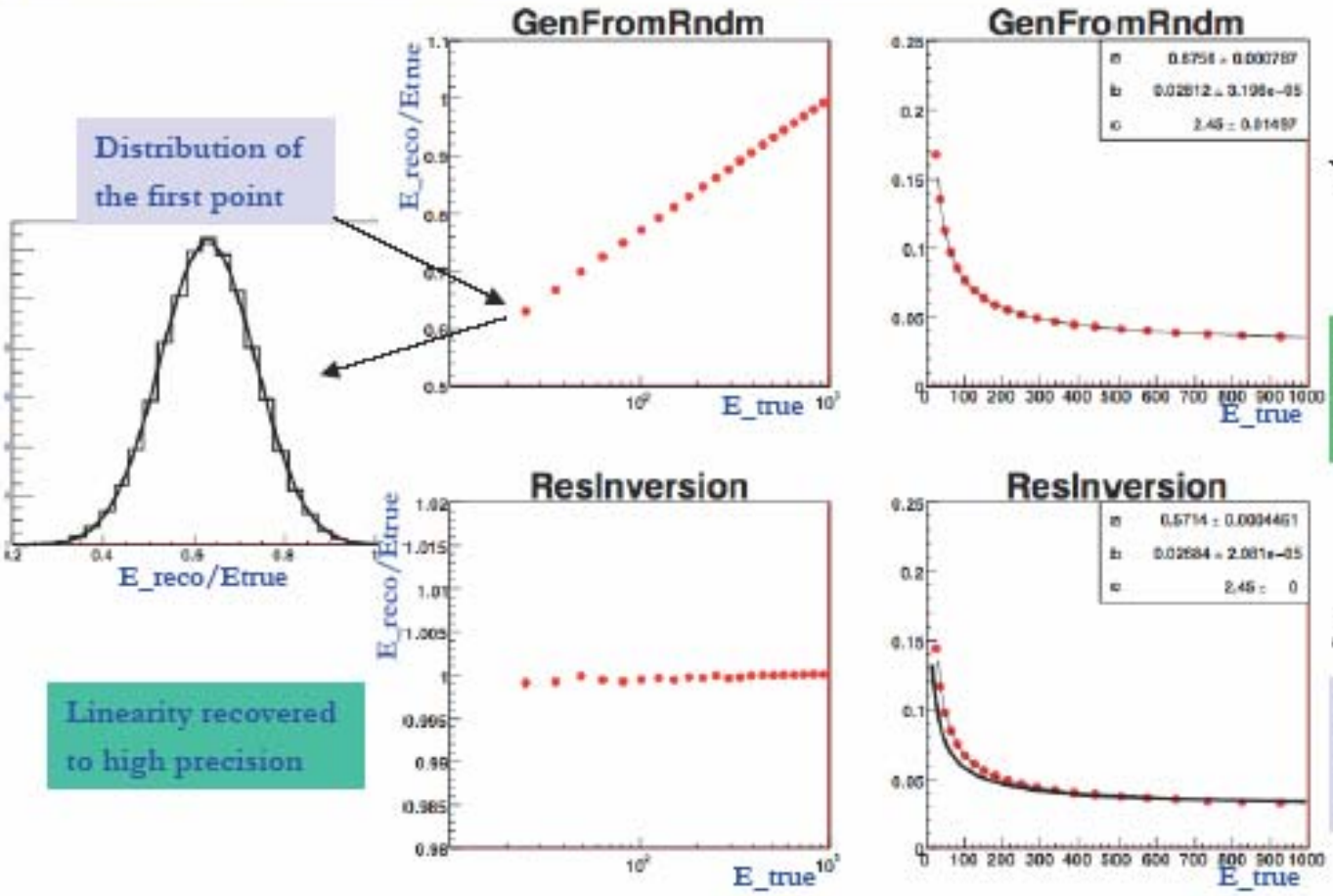
- $P(E^R \mid E^T)$ is the response of the detector to a truth jet of certain energy and eta - Response Function. This is the crucial ingredient to be validated/built with data.

- $P(E^T)$ is the input jet spectrum. Since we are interested here in performance w.r.t true jet energy, this can be set to a constant value.

- For range of E^T we calculate $P(E^T \mid E^R)$ and build a distribution. The mean of this this distribution is taken to be the corrected jet energy: $E^C = \langle P(E^T \mid E^R) \rangle$

Testing Inversion on ToyMC

For a random E_true (1-1000 GeV) generate -
E_reco = Gaussian smear(E_true) + Logarithmic offset(E_true);



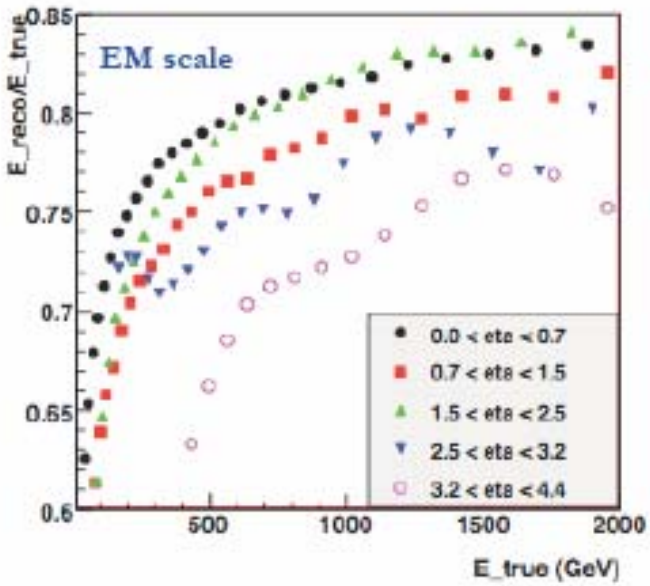
Distribution of the first point

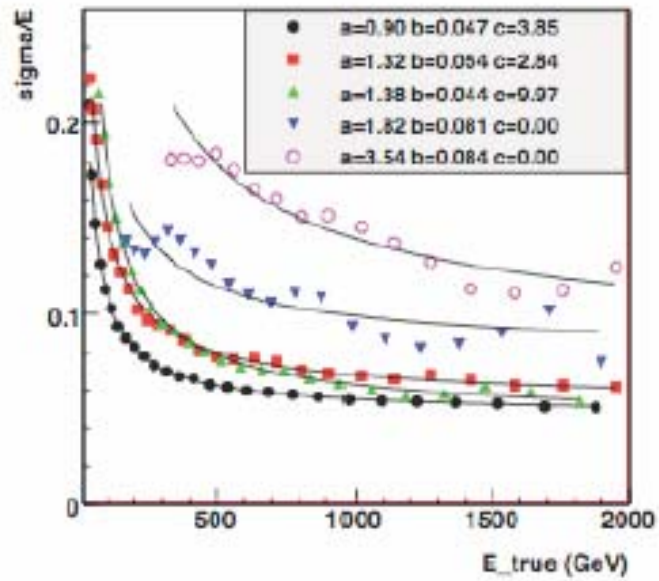
Numerical Inversion using Gaussian Response Function

Linearity recovered to high precision

Generated resolution: 50%/sqrt(E)+3% (solid black line)

Result





Con4Topo

EM scale jets

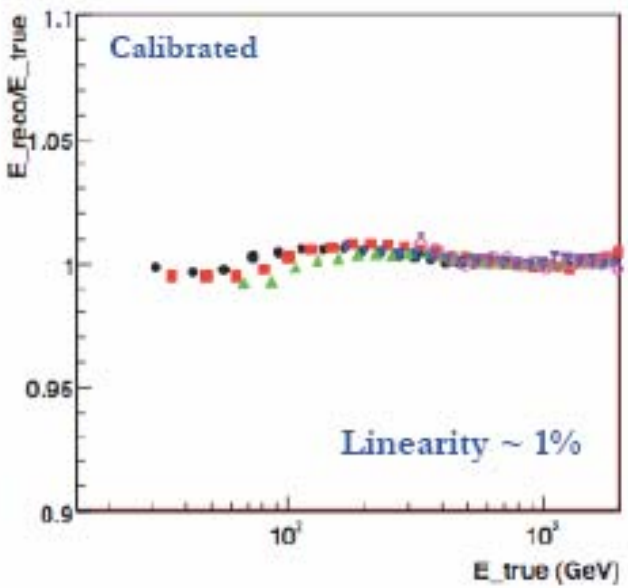
↓

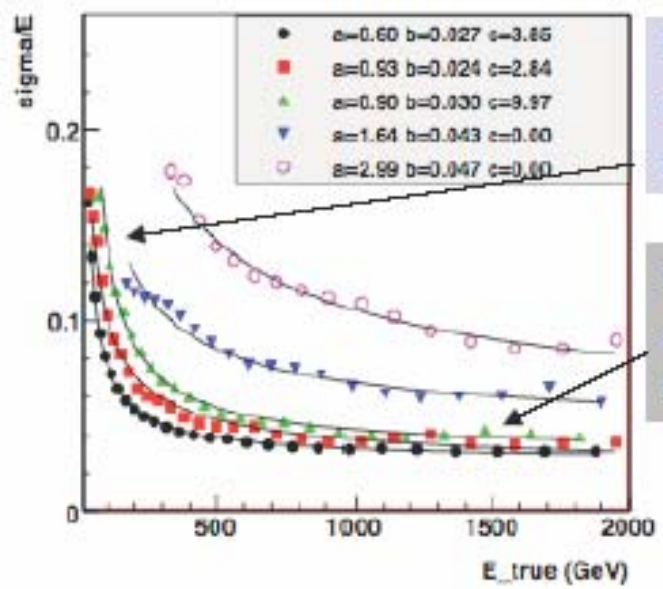
H1CellWt jets

→ Inversion

↓

Calibrated Jets

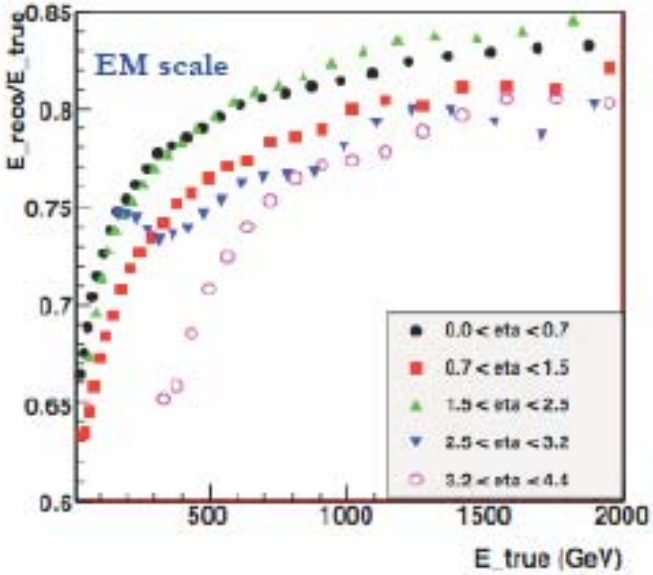


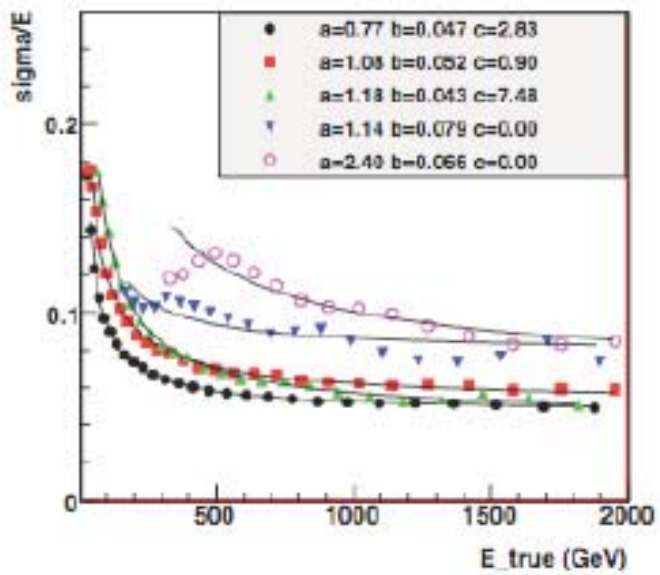


Resolution at lower energies improves by recovering linearity

Resolution at higher energies improves from E/V cell weight

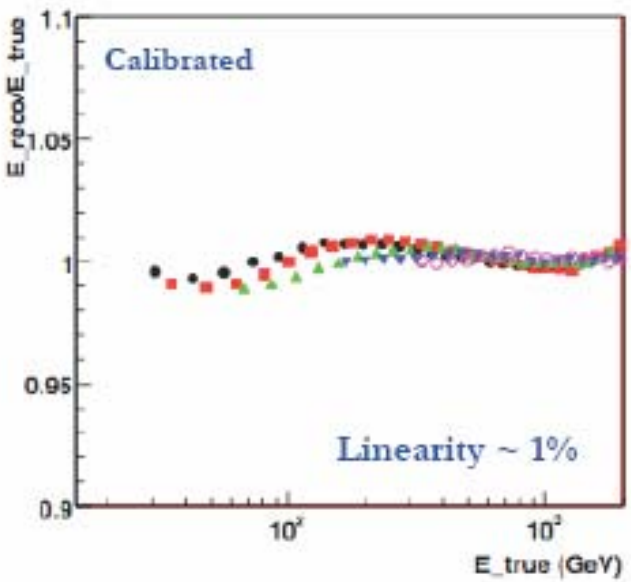
Result

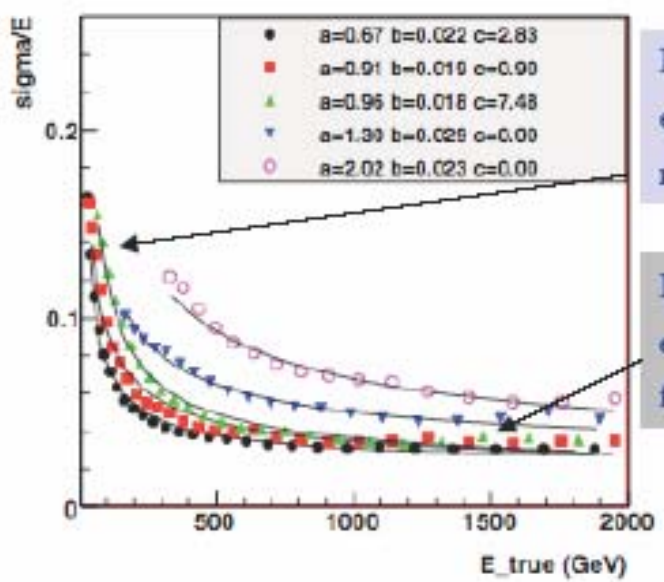




Cone7Tower

EM scale jets
↓
H1CellWt jets
↓
Inversion
↓
Calibrated Jets

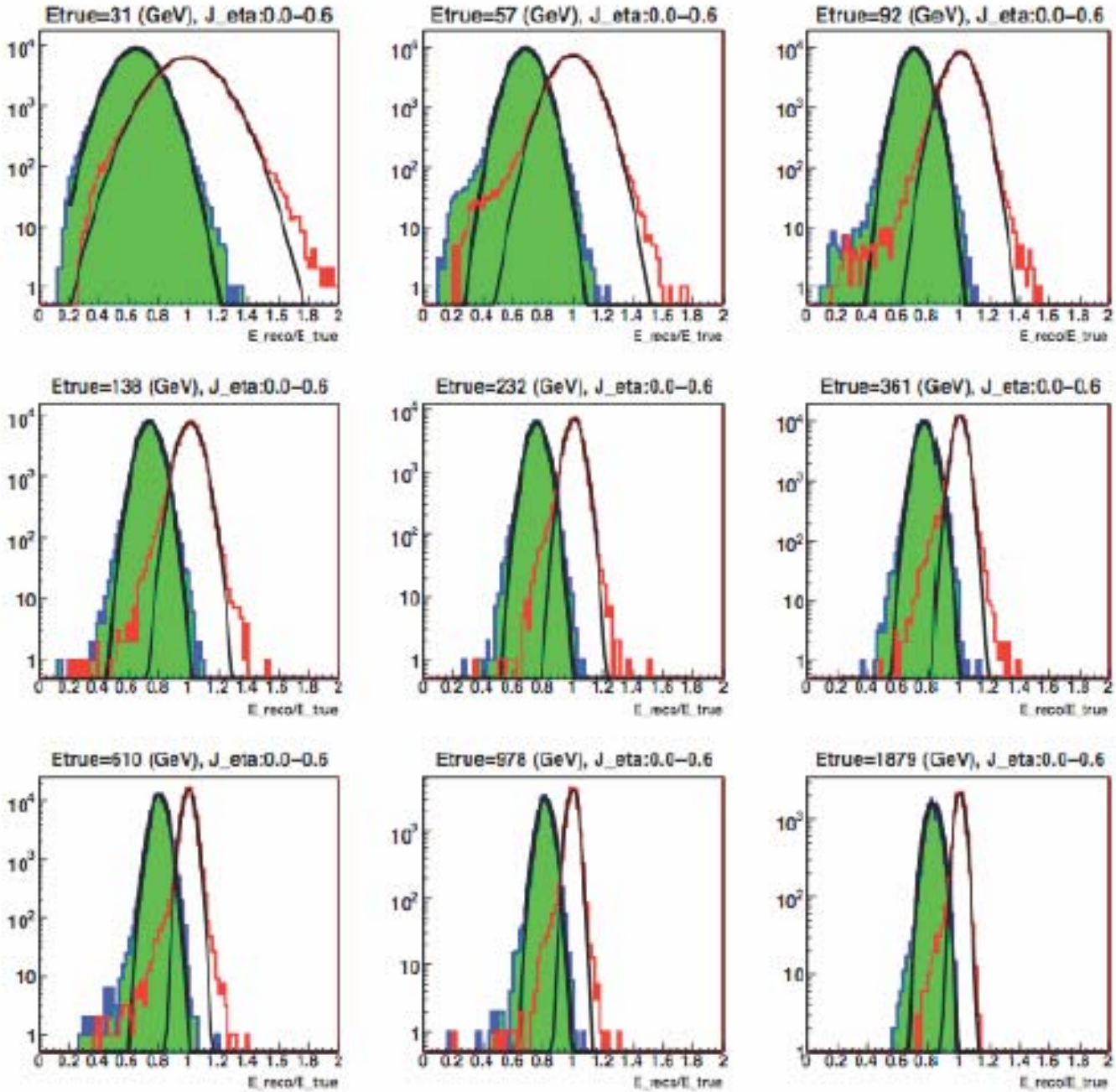




Resolution at lower energies improves by recovering linearity

Resolution at higher energies improves from E/V cell weight

Tails NTJ



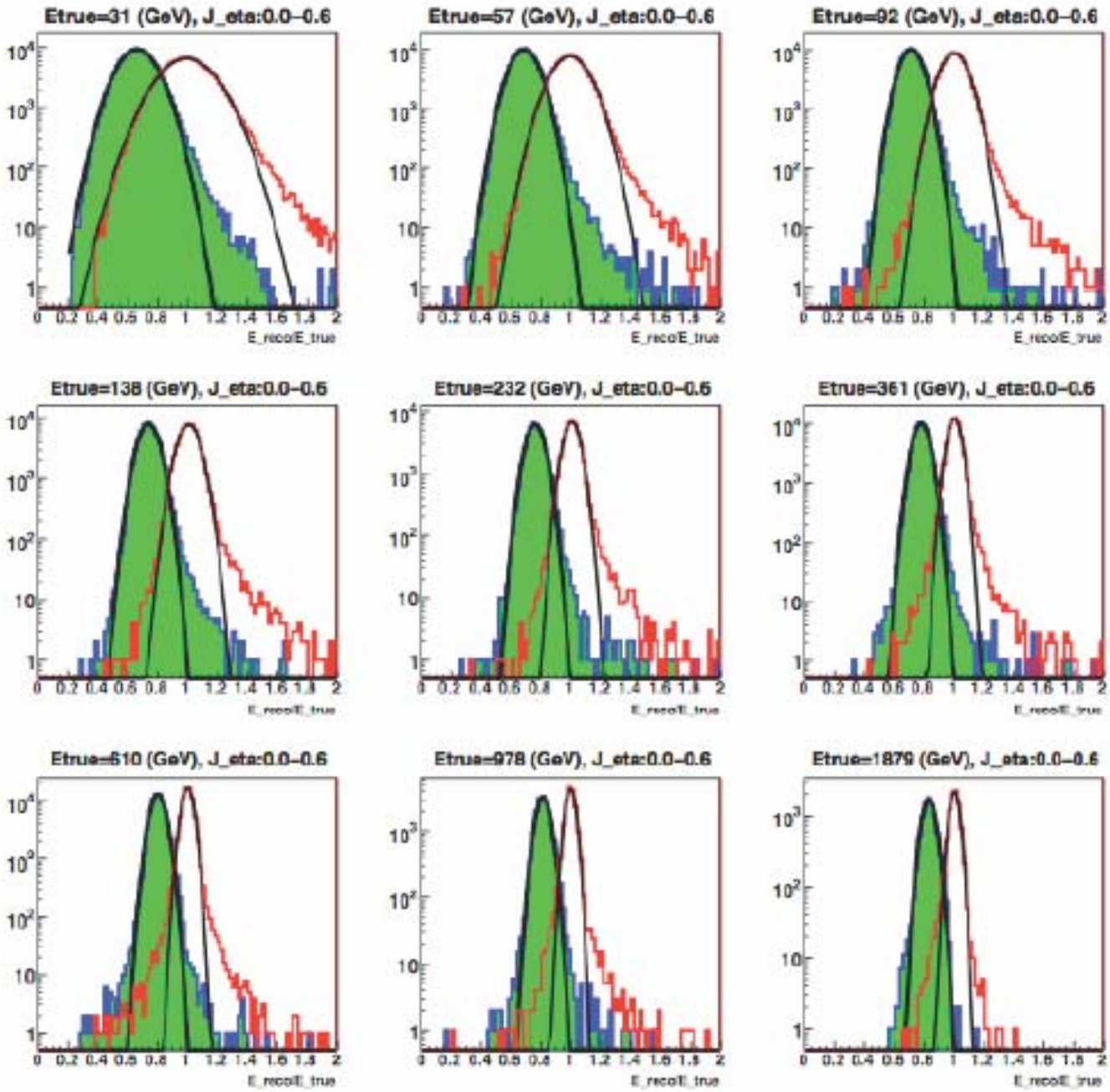
Truth jet is Nearest-Truth-Jet

dr1 < 0.2
dr2 > 1.0

dr1 is angular distance between reco and nearest truth jet.

dr2 is angular distance between reco jet and second nearest truth jet.

Tails PIC



Truth jet is Particles-In-Cone

Same dr1, dr2 cuts also applied here.

dr1 < 0.2

dr2 > 1.0

dr1 is angular distance between reco and nearest truth jet.

dr2 is angular distance between reco jet and second nearest truth jet.

Current work on photon+jet

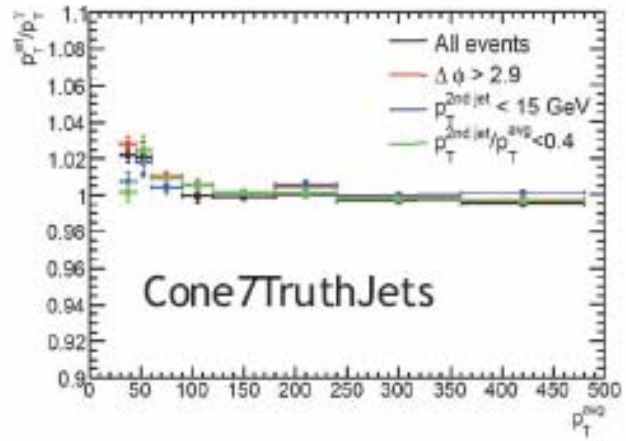
Martina Hurwitz

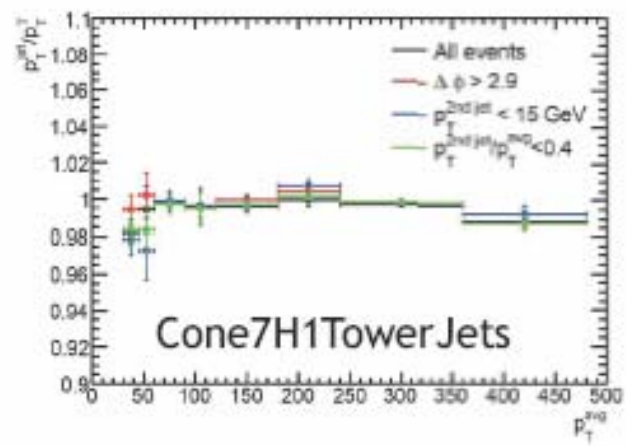
Chicago group meeting

November 24, 2008

Balance vs p_T

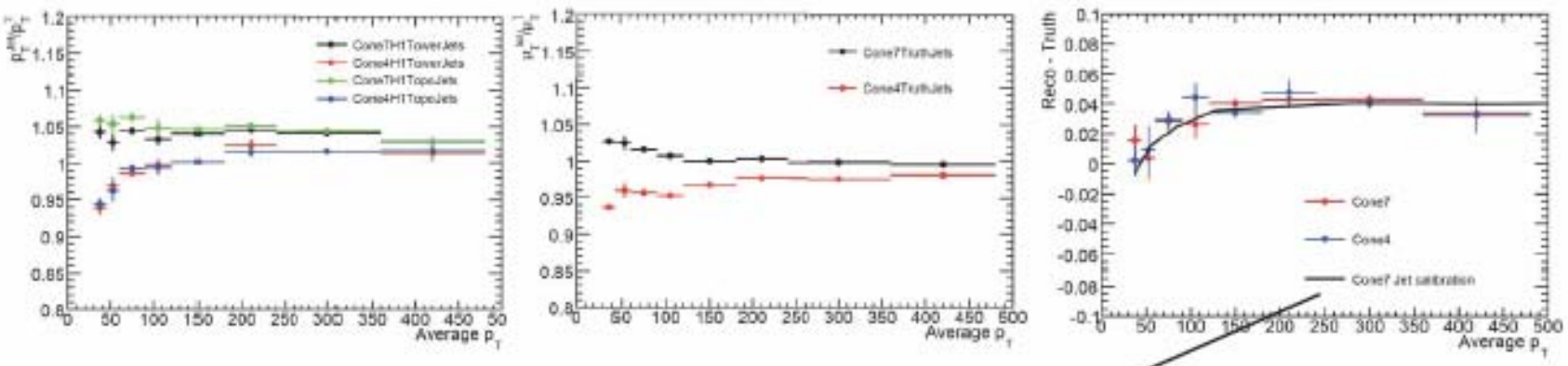
- 14.2.20 datasets
- $|\eta^{jet}|<2.5$
- Truth level
  - Event cleaning cuts affect balance at low p_T
  - Cone7 jets have true balance very close to 1.0 above 80 GeV
- Reco level
  - Leaving out region with hole ($-3.5<\eta<-2$, $-1.6<\varphi<0$)
  - Reco balance close to truth balance (1.0) indicates good calibration





Results, 14.2.10

- Reminder of results from last meeting: older dataset with miscalibration
- Only event cut here: $\Delta\varphi > 2.9$
- Difference between reco and truth balance corresponds to miscalibration
- Remember that this isn't full story: same generated events used at truth and reco



Black line: p_T^{reco}/p_T^{true} in dijet events

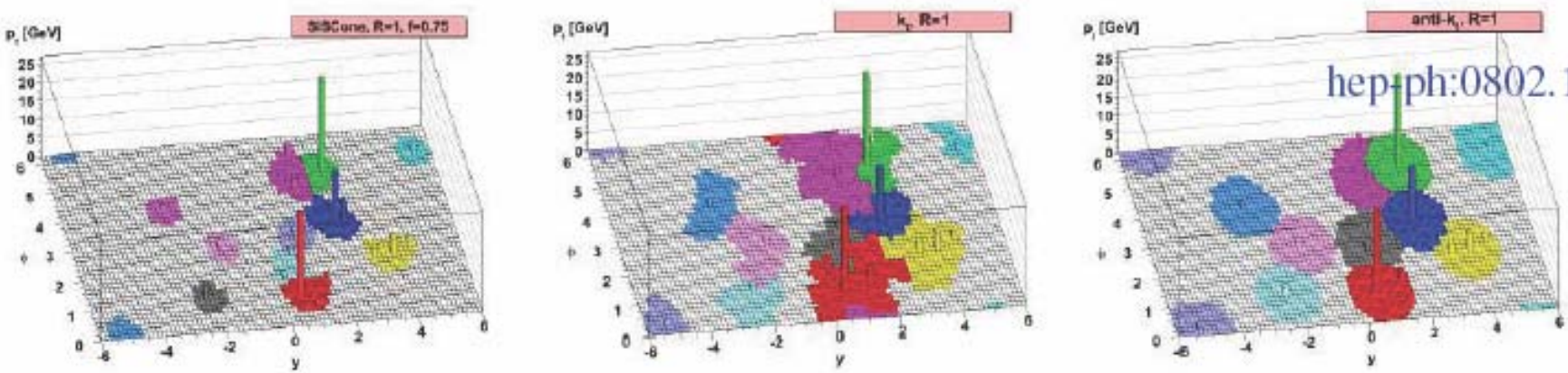
Studies of W($\rightarrow e\nu$) + Jets: Comparison of Jet Algorithms

Imai Jen-La Plante

November 24, 2008

Jet Algorithms

- ATLAS Cone jet algorithm is not favored by theorists
  - Infrared unsafe: jet multiplicity sensitive to additional soft particles
  - Problematic since effects leading to soft particles (hadronization, underlying event, pileup) are difficult to model
- Considering selected infrared and collinear safe alternatives
  - SIS Cone: seedless, considers all possible cones, split-merge
  - Inclusive k_T: sequential recombination, clustering uses distances weighted by transverse momentum, k_T, $d_{ij} = \min(k_{ti}^2, k_{tj}^2)\ \Delta R^2 / R^2$
  - Anti-k_T: as above, replacing k_T by $1 / k_T$



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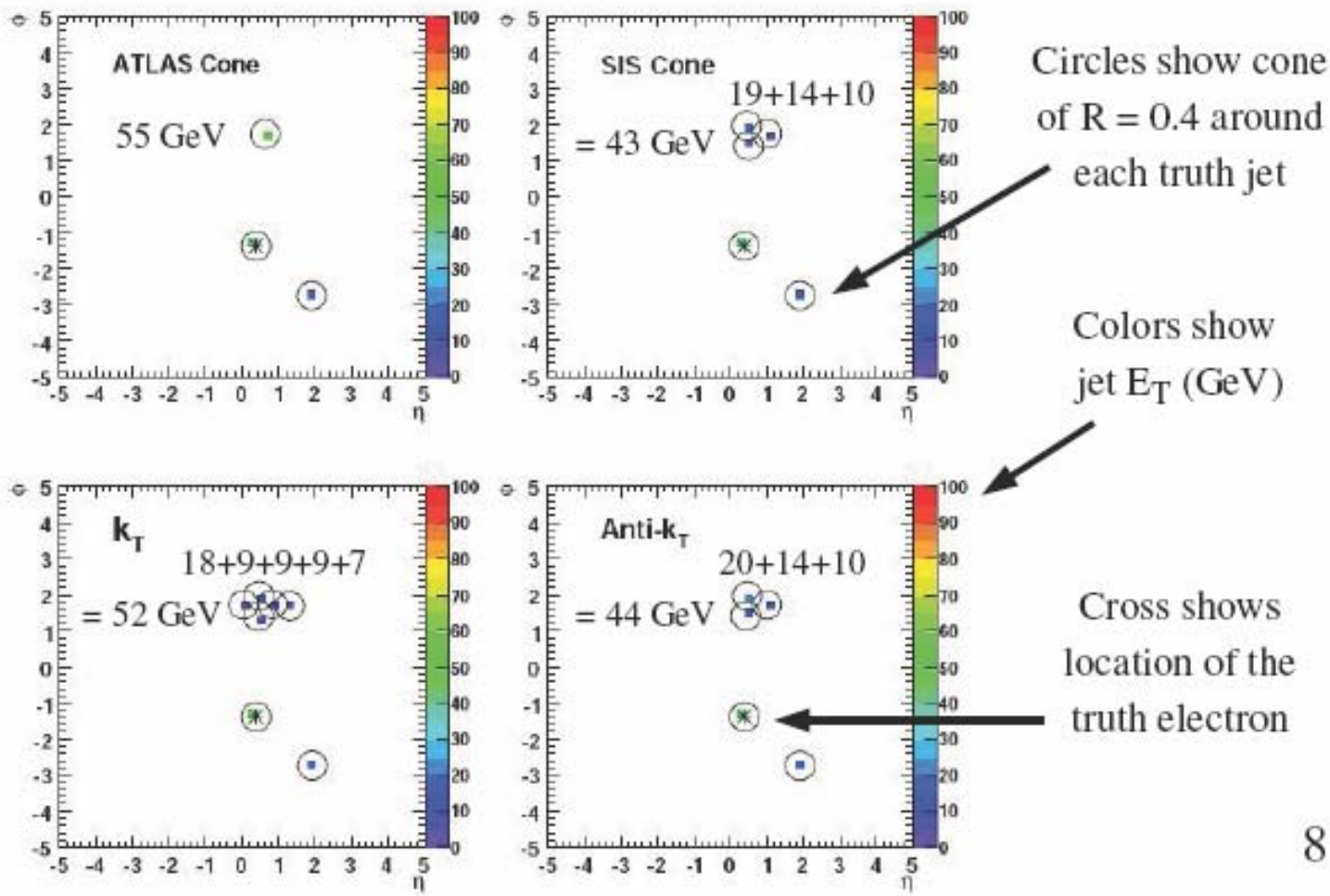
Truth Jets: First Example

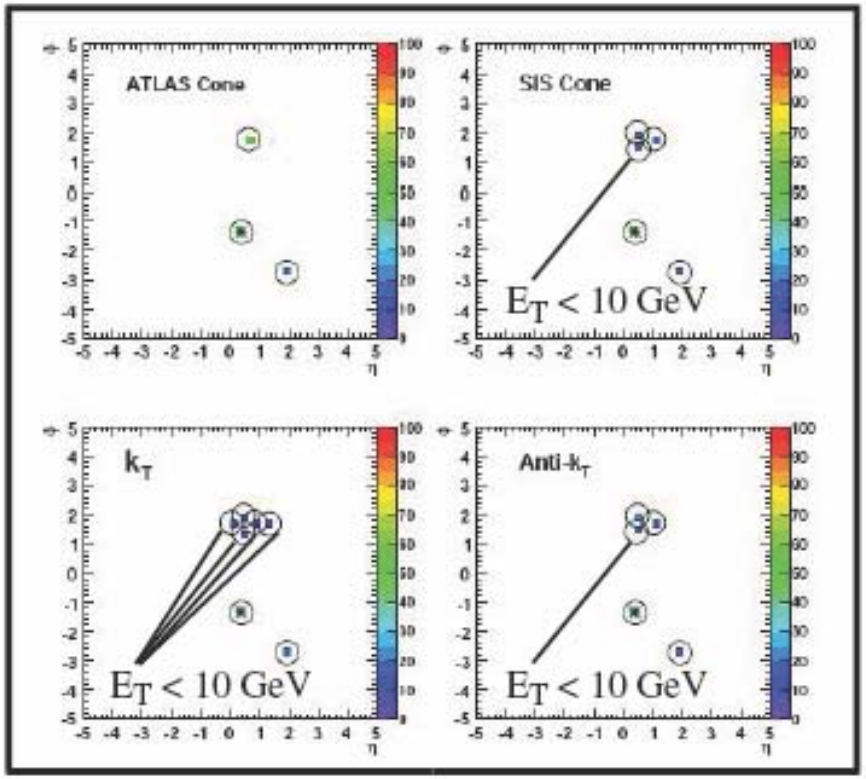
- Selected an event with large E_T differences between geometrically matched truth jets: alternative algorithms find more jets, lower E_T



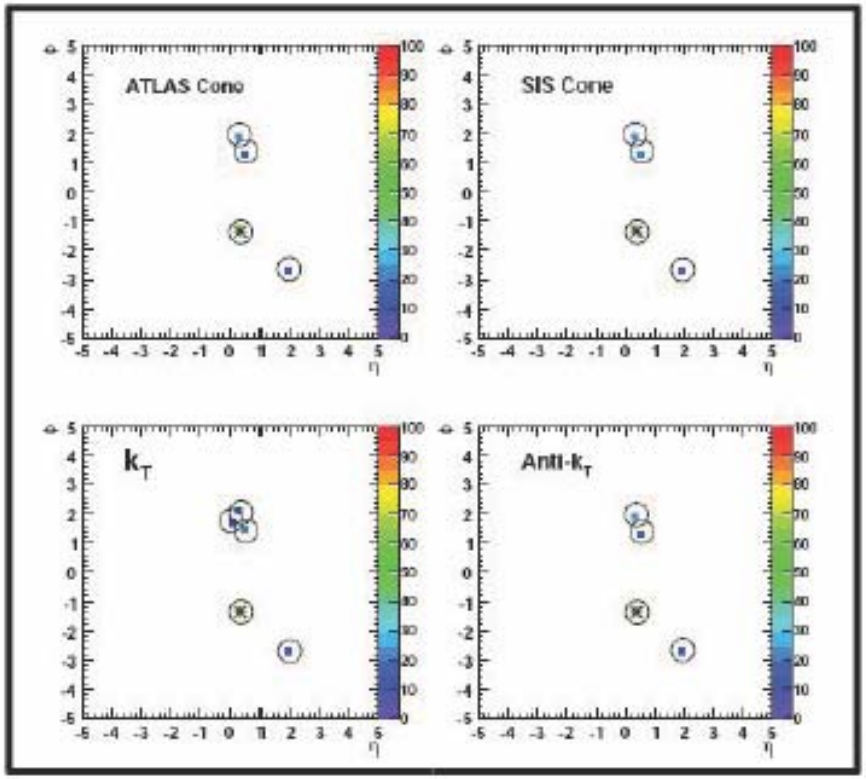
First Example Again

- Same event shown on slide 8: more truth jets found by each alternative algorithm than by ATLAS Cone
- Less difference between algorithms for reconstructed jets

Truth Jets

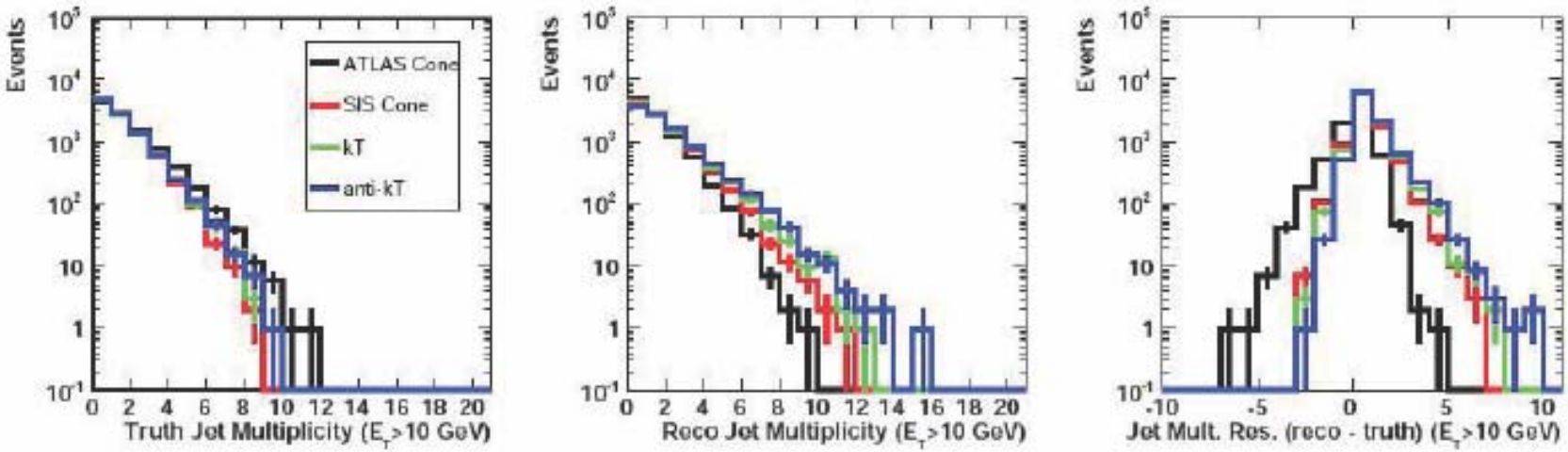


Reconstructed Jets



Jet Multiplicity (cont'd)

- Significant differences become visible when including jets with E_T between 10 and 20 GeV
  - Larger difference between truth and reco jet multiplicities for each algorithm
  - Behavior differs between ATLAS cone and other algorithms



- Jet algorithm choice becomes more important when including soft jets; for this analysis, plan to stay above 20 GeV

Update

Jet Recovery (with **Eric**)
Alpgen Validation

Georgios Choudalakis
University of Chicago

U. Chicago Monday Meeting
2008/12/15

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ATLAS NOTE

ATL-PHYS-COM-2008-xxx

December 11, 2008

Use of Tracks to Reconstruct Jets in Damaged Calorimeter Regions

currently under review

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News Summary

- **Eric** + **I** put together this note.
  - The clue of our study is that if there's *severe* damage (like 22.5° of LAr missing) then it makes some sense to use track jets. But nothing revolutionary. Reconstruction efficiency is improved, but energy resolution is better only above ~ 1 TeV.
- Out of curiosity, examined MET in cases of detector damage. (see backups)
- Working on ALPGEN QCD samples validation. Producing 10s of plots. See backups. More is to come.
- Talking with Guillaume Unal + Sven Menke + Sasha Solodkov to implement Dead Cell correction (TileCal+LAr).
- MobyDick with the hardware people.