Overview of EM Calibration Strategy for ATLAS

Stathes Paganis
(Univ. of Wisconsin, Madison)

ATLAS Physics Workshop
Rome, 9-June-2005

Introduction

- General:
  - Goal: optimum Linearity/Uniformity and Resolution
  - Today: we are very close to optimum linearity using energy independent calibration weights but resolution is far from optimum, in particular at eta regions of increased upstream material.
  - However: we must be cautious not to put linearity into trouble while trying to fine-tune resolution by imposing very complex E-dependent EM corrections.
- To refine calibration we need to separate the different effects and understand their eta and energy dependence.
- We need different calibrations for electrons and photons (material effect)
- How can topological clustering be used for EM (S.Menke talk)
  - Can we have an energy independent EM TopoCluster?
- TestBeam 2004: a test-bench for improving calibration and testing clustering (electrons/photons).
- Intercalibration: to make uniform the response of different regions of the calorimeter.

Calibration Workshop 2004 Action Items

Calibration Stages (from Slovakia Workshop)

D. Froidevaux (overview panel for calo calibration workshop, Slovakia 2004)

- Each stage in the reconstruction sequence gathers additional knowledge and provides more refined estimates of the energy ⇑ fine-tuning of calibration as reconstruction progresses (sometimes even undoing what was done at previous stage)

- One must understand calibration at each stage:
  1) Calibration at Level-1 (separate RODs, different problems but less critical)
  2) Calibration at ROD-level (very critical for EM!)
  3) Level-2/Event Filter calibration issues
  4) Offline Cell level reconstruction (CaloCell @ EM Scale)
     Very important ongoing work for hadronic calorimetry
  5) → Calibration/Corrections at Clustering stage (CaloCluster)
  6) Combined reconstruction (e-gamma, jets, …)
  7) → Identified particles (electrons, photons, b-jets, …)

List of Cluster Corrections (e/γ)

G.Unal 9/May/05

- **Fixed Cluster Status in 10.0.1 (default « Rome » option)**
  - Corrections applied: Dependence / SIZE (approx)

Corrections applied	Dependence	SIZE (approx)
S shape in eta, middle	*f(eta,Energy)*	
Phi offset	*f(eta,Energy)*	
S shape in eta, strips	*f(eta,Energy)*	
E vs phi local modulation	*f(eta,Energy)*	0.5%
E vs eta local modulation	*f(Energy)*	0.2%
Gap correction	*f(eta)*	
Longitudinal weights (« lwc904gap »)	*f(eta)*	3-10%

  - Everything derived from G4 single electron samples (Scott+Stathes)
  - Longitudinal Weights:

    E(corr) = Scale(eta)*(Offset(eta)+W0(eta)*EPS+E1+E2+W3(eta)*E3)
  - Latest iteration of longitudinal weights using 9.0.4 single electrons. Out-of-cone corrections aborbed in Scale(eta)
  - Some corrections different for 5x5, 3x5 3x7
- **Topological Cluster Status in 10.0.1** (N.Kerschen, M.Boonekamp)
  - S-shape in eta, Phi offset, E vs phi modulation corrections implemented but not applied yet (6/3/3 cuts).

EM Cluster Corrections: Action Items

(overview panel for calorimeter calibration workshop, Slovakia 2004)

A12: Establish a clear strategy on which corrections should be applied at what stage (Cluster, e-gamma, electron, photon, …)

A13: Establish the order in which the corrections should be applied.

A14: Establish the corrections that need to be applied at Level-2

A15: Derive the complete set of corrections for Sliding Window (high priority)

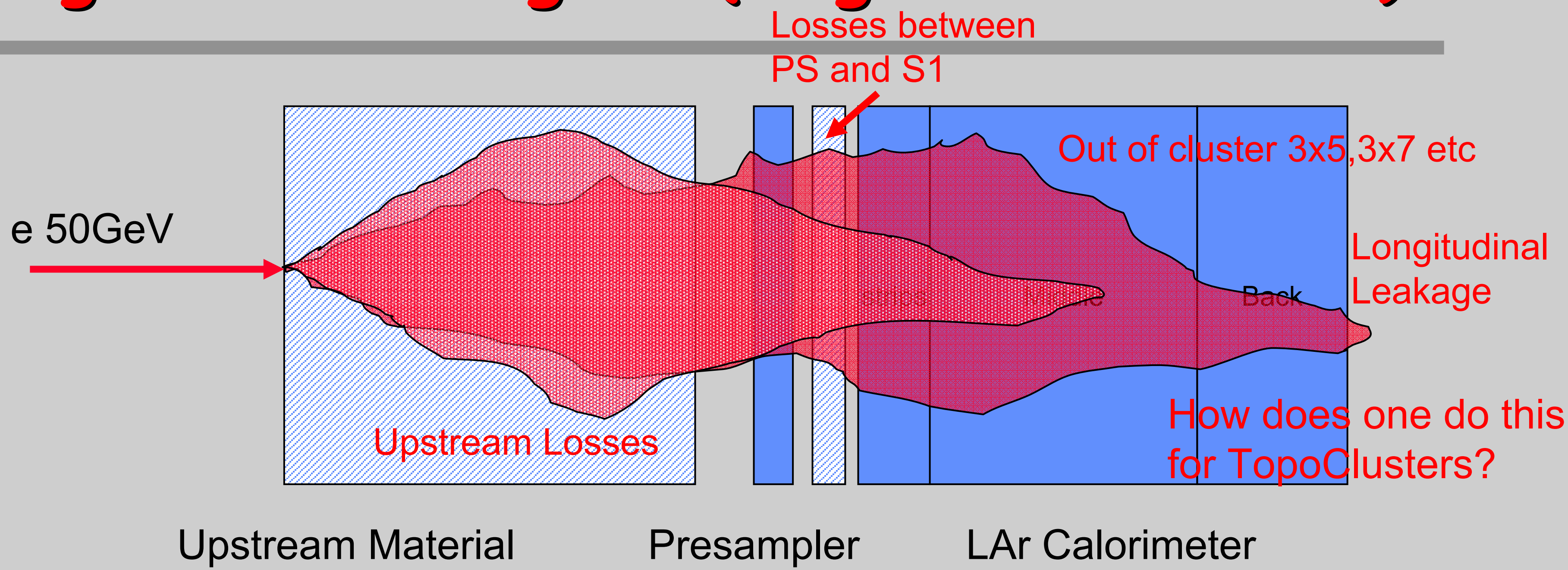
A16: Work on corrections for Topological Clustering may continue, but at low priority … **need to complete Sliding Window for Rome studies**.

A17: Investigate the integration of the more sophisticated weighting scheme developed for 2002 (T. Carli et. al.) in Athena:

- Comparison between CTB and TB simulation
- Comparison between TB and ATLAS Simulation to understand transport of calibration to ATLAS (see also talk by L. Serin)

A18: Define required Calibration Streams + Monitoring

Longitudinal Weights (largest correction)



Best Performance: Erec independent of Eloss (function of shower depth)

- ATLAS Longitudinal weights (only eta dependent) calculated today using 10-100GeV electrons and the parametrization:

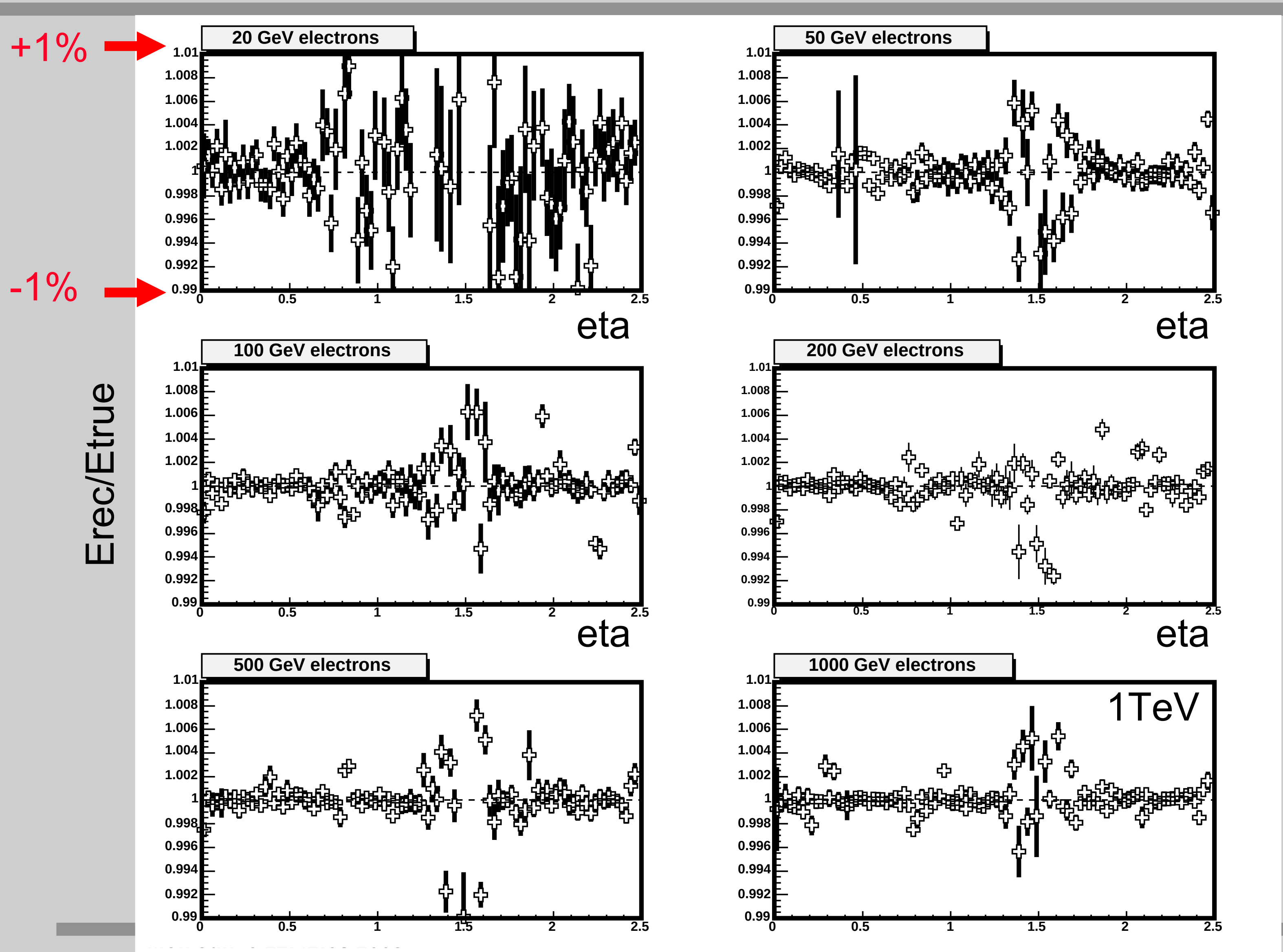
$$E_{rec} = \lambda\left(b + W_0 E_{pres} + E_1 + E_2 + W_3 E_3\right)$$

TDR + offset (introduced from careful TBeam Analysis, talk by L.Serin)

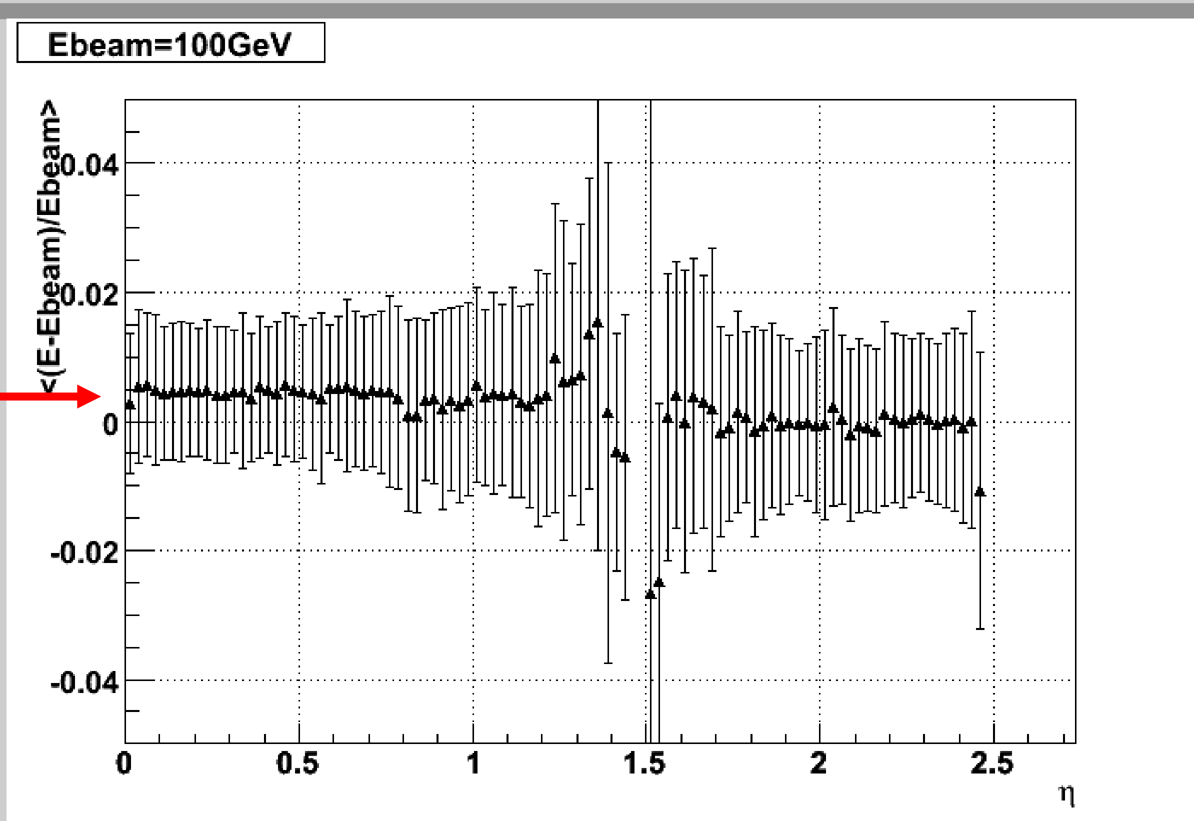
electrons

Linearity Performance DC2 layout (10.0.1)

S. Snyder



Linearity for Rome layout (10.0.1)



+0.4%

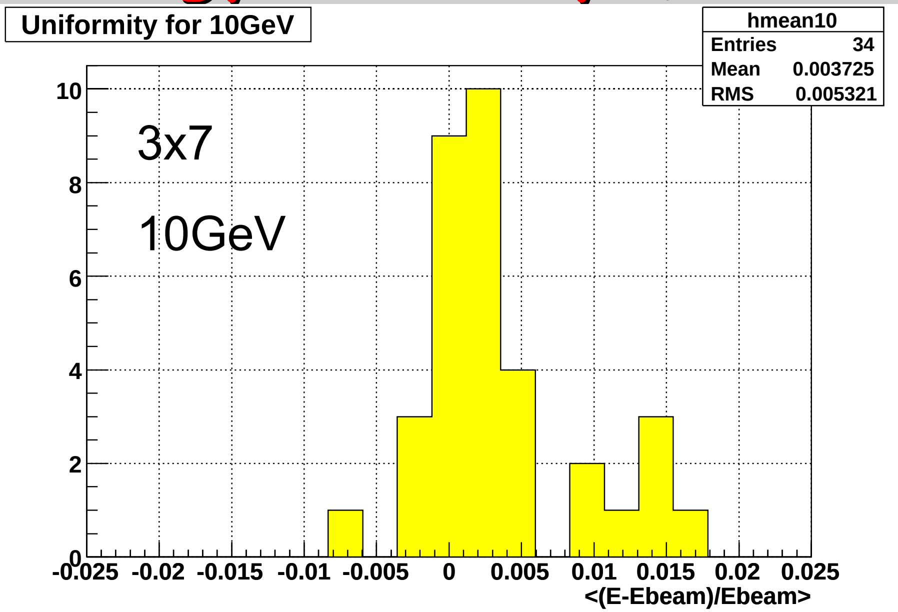
For Rome layout we have an overcorrection by ~0.4% in the barrel

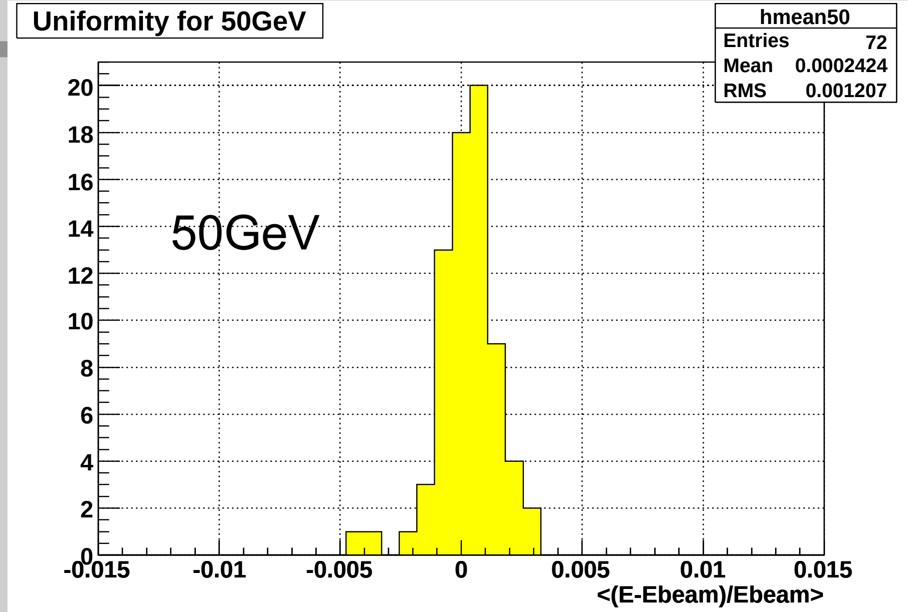
<u>Reason:</u>

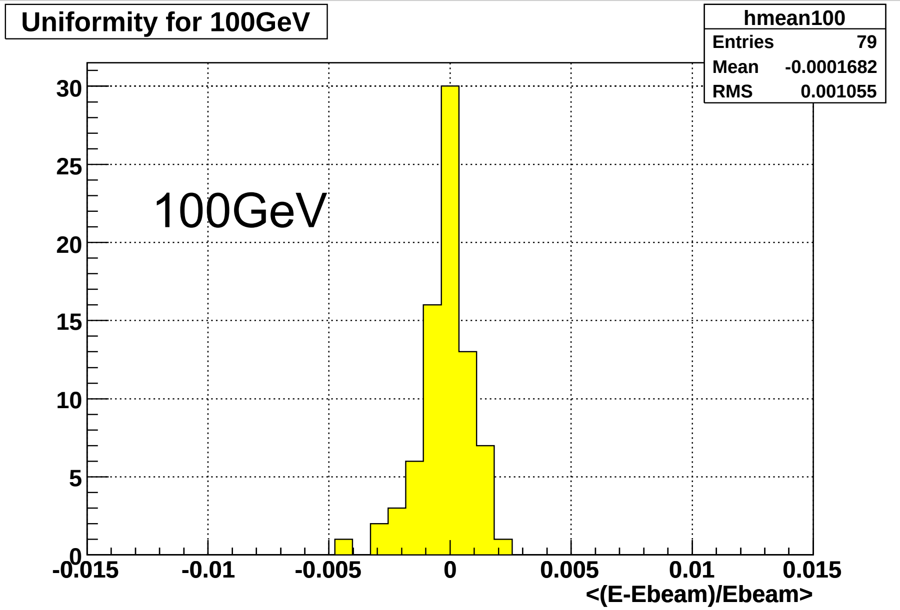
Rome Barrel Sampling Fraction decreased by ~0.4% in simulation after samples were produced. Fix: scale long. weight λ can absorb this known factor.

Energy Linearity (10.0.1) 10-100GeV 3x7

SP







(mean reconstructed energies – truth) for all eta and Energy bins

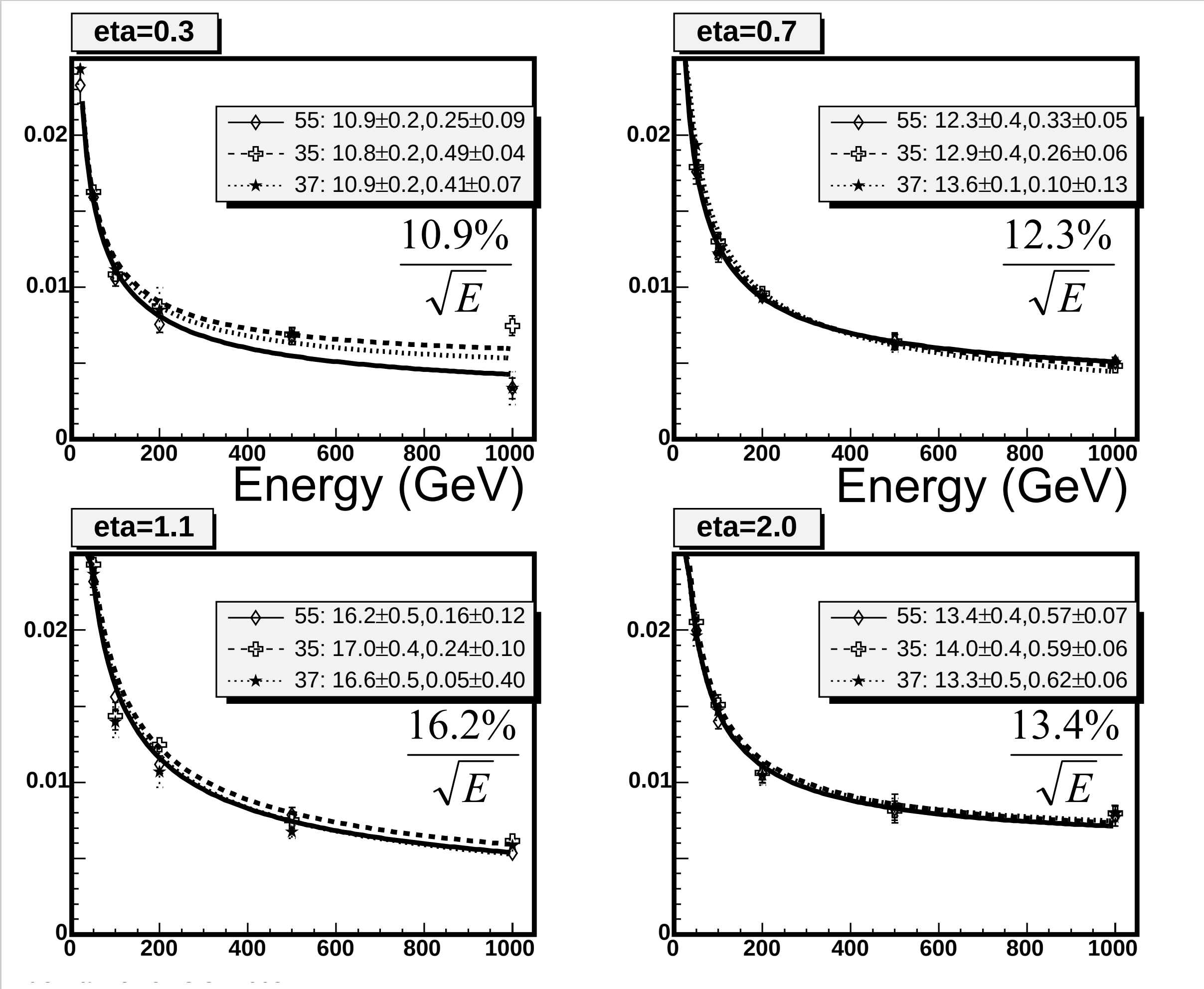
0.1%-0.2% spread

Comments:

Gap region excluded.

Barrel Sampling Fraction adjusted (Rome Barrel SF increased by ~0.4% in simulation after samples were produced)

Resolution for electrons at different η (10.0.1)



Scott Snyder

Noise included

Energy Resolution Comparison with TDR

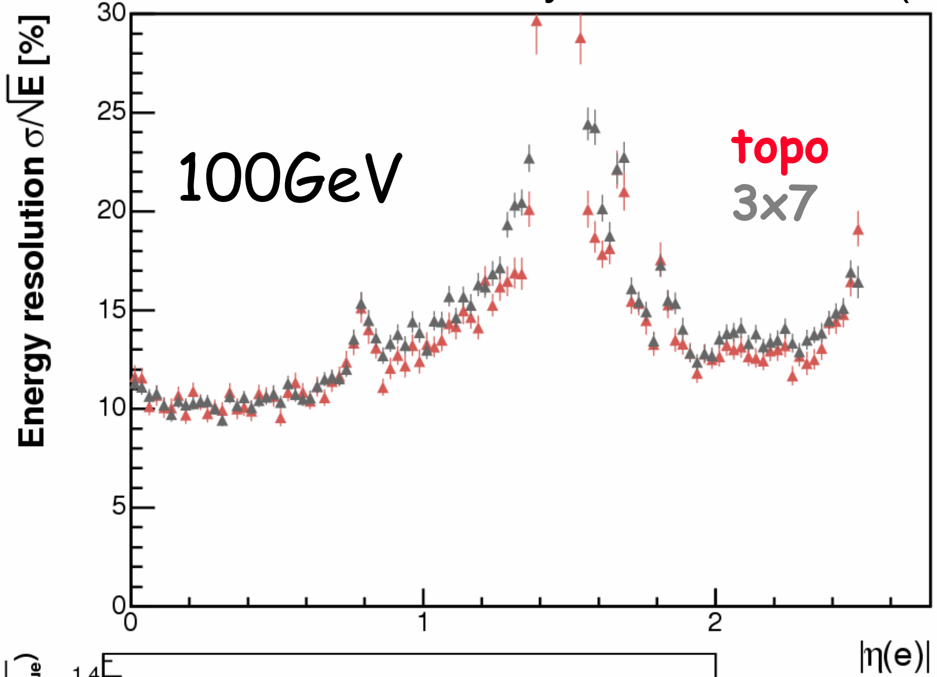
G.Unal

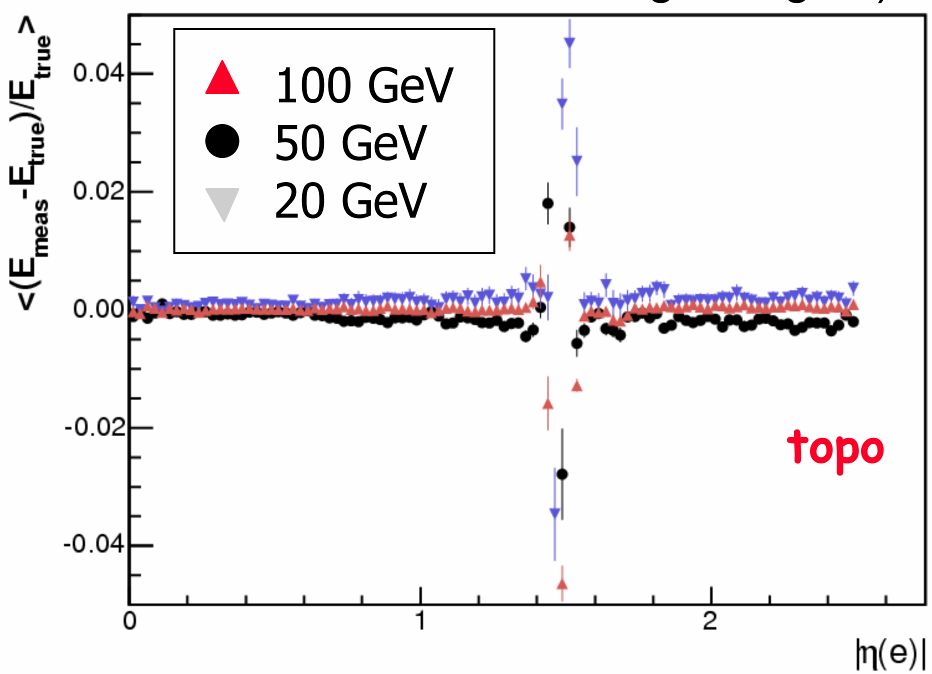
Eta	10.0.1 Samp. Term	TDR Samp.Term
0.0625	9.9%	
0.3	**10.9% (inc. noise)**	**8.54%**
0.6125	11.0%	
1.0875	**16.0%**	**12.5%**
1.2625	18.2%	
2.0125	11.8%	

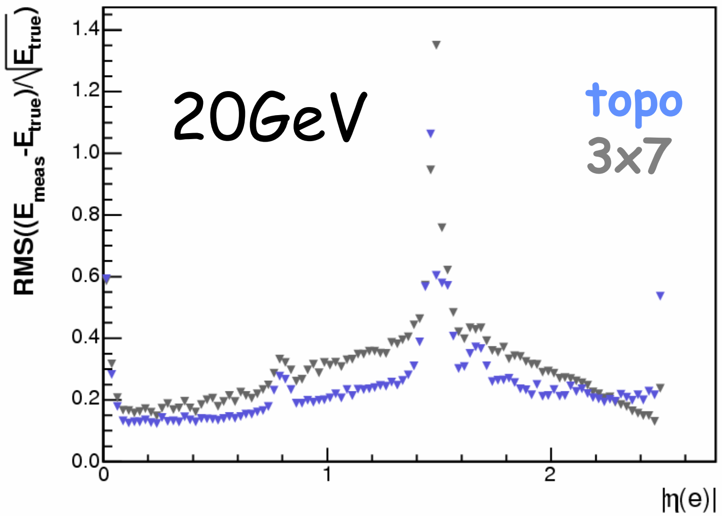
EM Resolution is up to 25% worse than in the TDR

10.0.1 TopoCluster(630) vs 3x7

Flores,Mellado,Quayle,Sau Lan Wu (topo and 3x7 recalculation of Long. Weights)



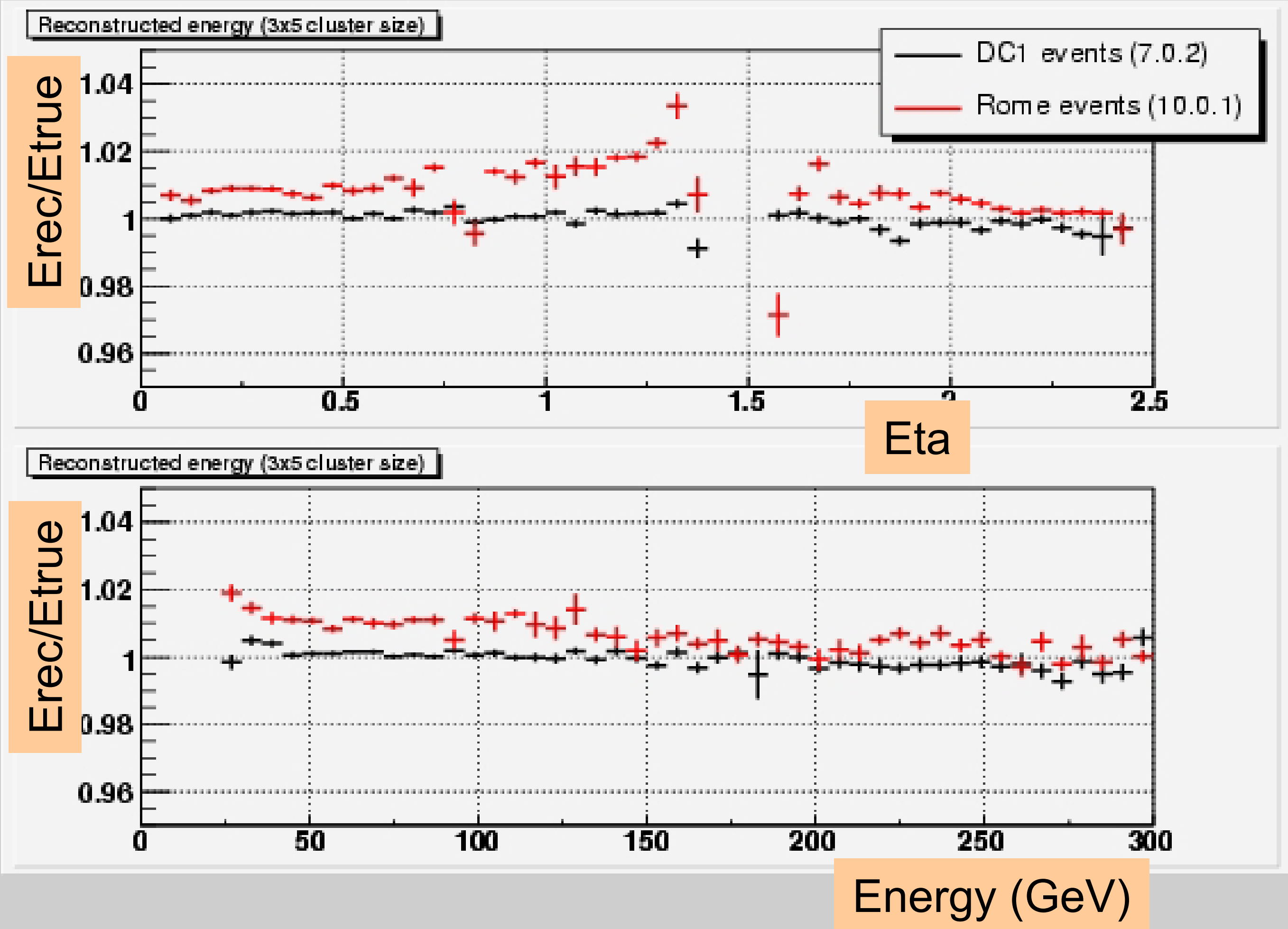




- <u>Resolution σ:</u> similar to 3x7
- <u>Linearity:</u> systematic shift: ~0.4%, maybe more over larger energy range. Needs to be understood.
- <u>RMS:</u> improved with TopoCluster. Expected since outliers more likely to be caught by TopoCluster. Needs to be evaluated in realistic environment.

photons

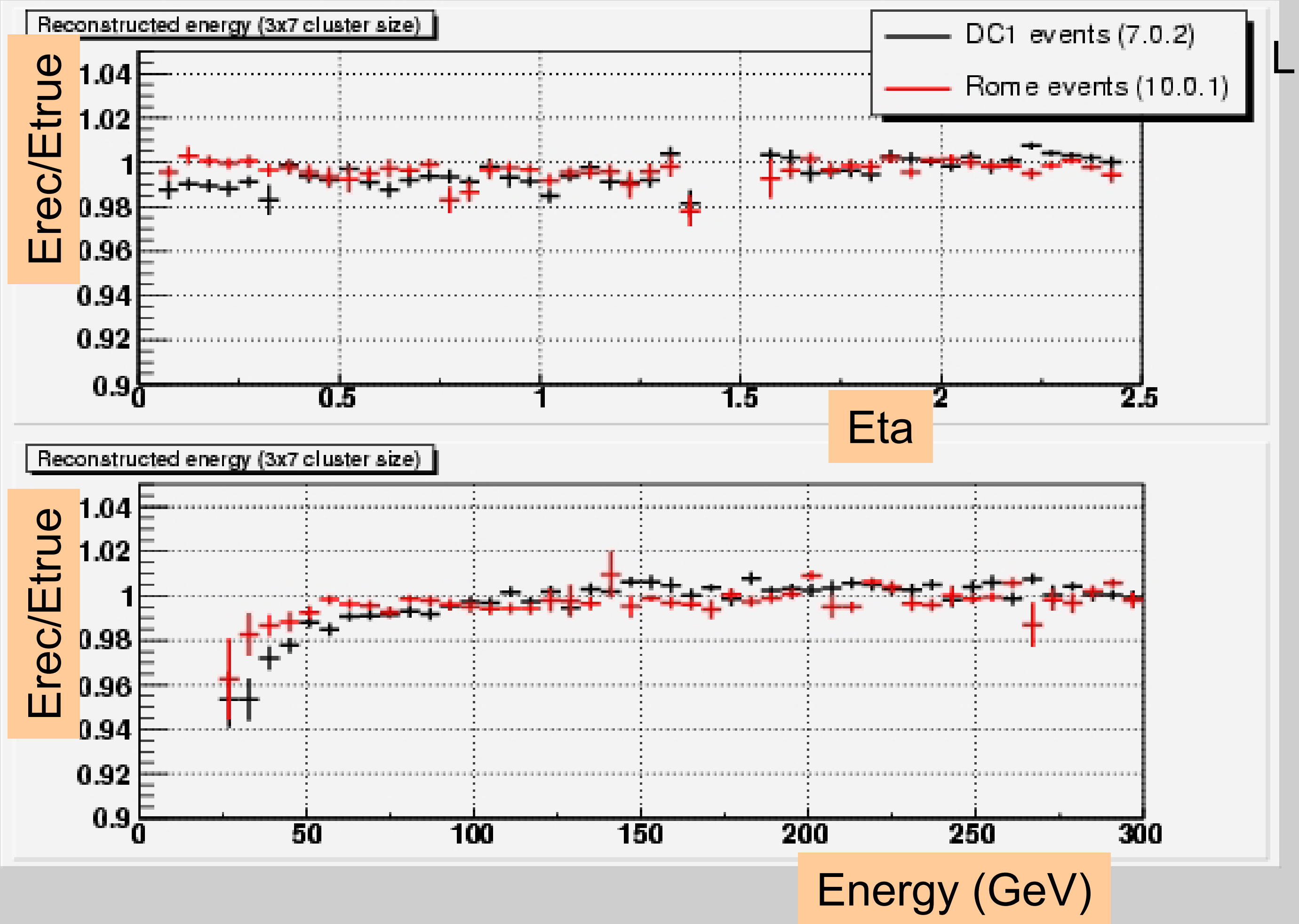
Linearity for non-converted Photons (3x5)



L.Carminati

Data Challenge 1: photons were used for calibration
Rome: electrons were used for calibration

Linearity for Converted Photons (3x7)



L.Carminati

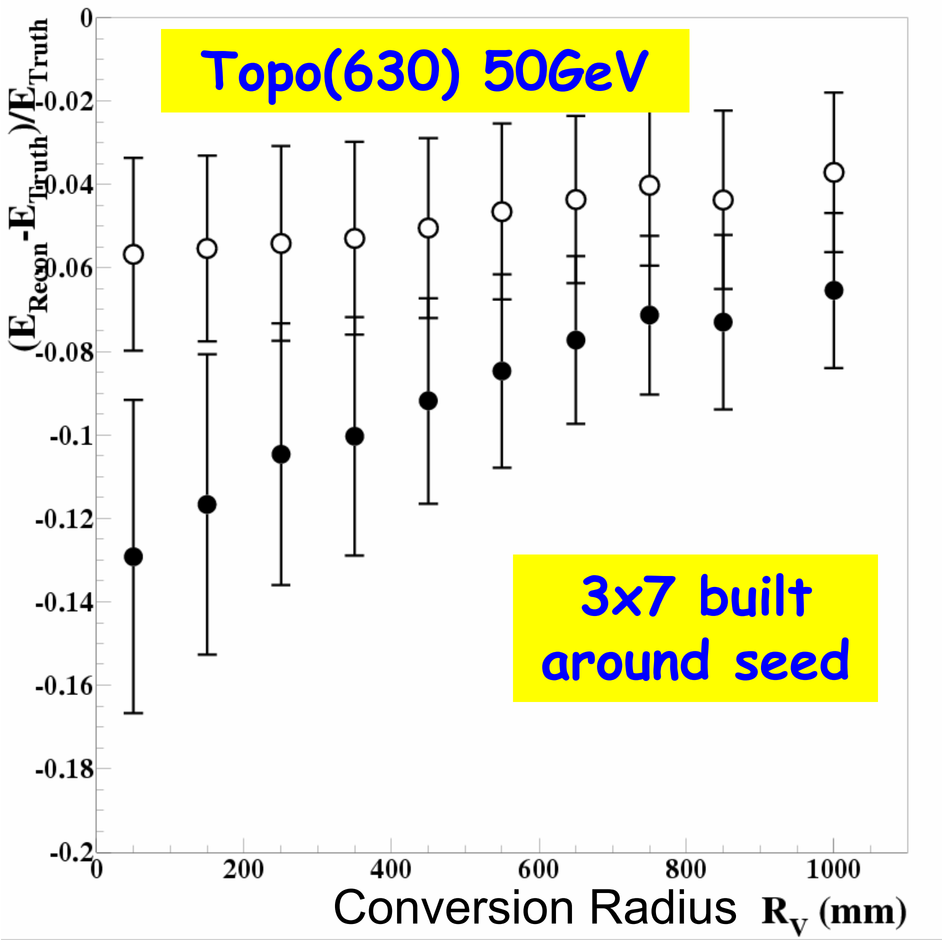
Converted photons: electron calibration (Rome events) works well above 40-50GeV. At low energies, early conversions spoil linearity

Fixed Cluster Photon Summary

- For photons today we use electron calibration
  - It works for converted photons (3x7).
  - It doesn't work for non-converted photons (3x5) since the presampler weight is lower by ~10% due to later showering of the photon.
  - This is a 1% effect at midrapidity increasing with the material up to 2-2.5%.
- At low pt and converted photons we have loss of linearity

Converted photon energy can be recovered with TopoClusters

Fang, Flores, Mellado, Sau Lan Wu



Comments

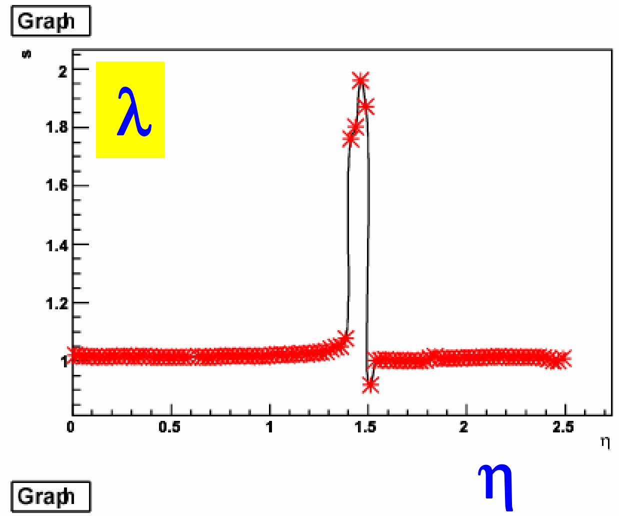
- Reconstruction in the presence of other particles not done in detail
- Incorporate use of the inner detector
- Modified 3x7 (currently built around the seed)
- **3x7 built from a TopoCluster which identifies conversions**
- CTB photon studies with TopoClusters and fixed size clusters (see talk by T.Koffas)
- CTB TopoCluster studies with electrons (N.Kerschen)

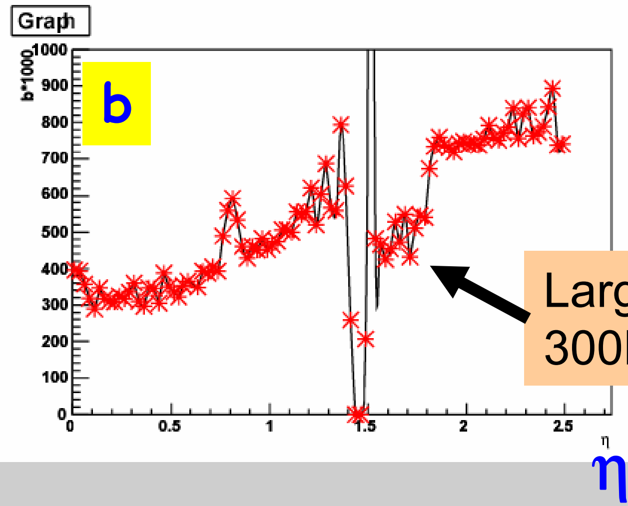
For early conversions, 3x7 energy is lost out of the cluster.
TopoCluster could improve linearity.

TopoClusters for (non)converted photons

Fang, Flores, Mellado, Sau Lan Wu (Recalculation of Weights)

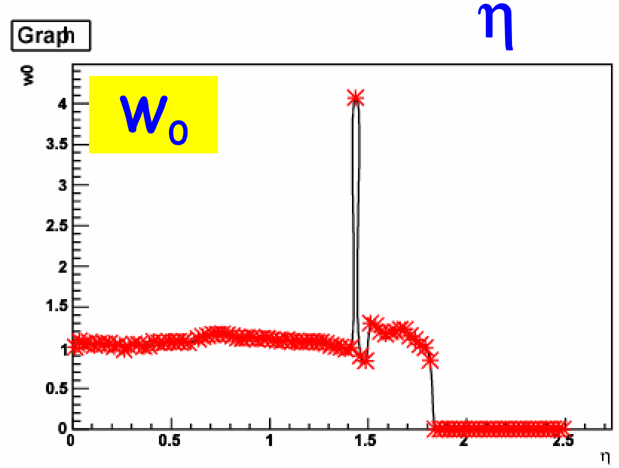
10.0.1
Rome





630
Topo

Large Offsets
300MeV, eta=0.3



Sampling Term: %/sqrt(E)

	η=1.1 unconv. γ	η=1.1 conv. γ	η=2.0
TDR	9.5±0.2	12.5±0.4	10.7±0.3
Here	10.1±0.2	14.0±0.5	10.2±0.3

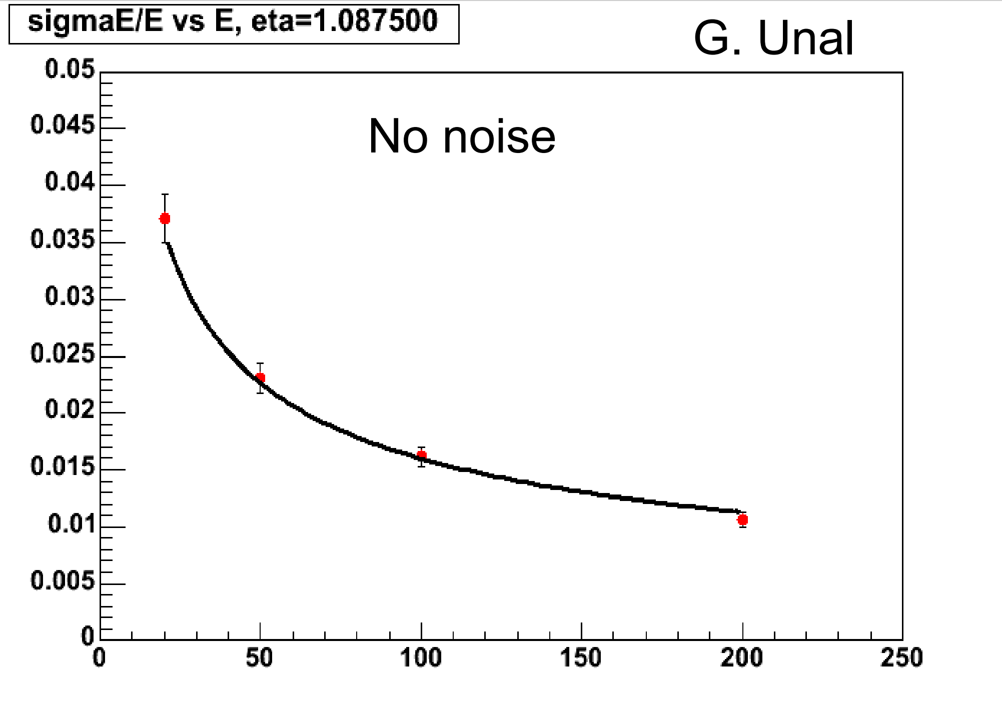
$$E_{rec} = \lambda\left(b + W_0 E_{pres} + E_1 + E_2 + W_3 E_3\right)$$

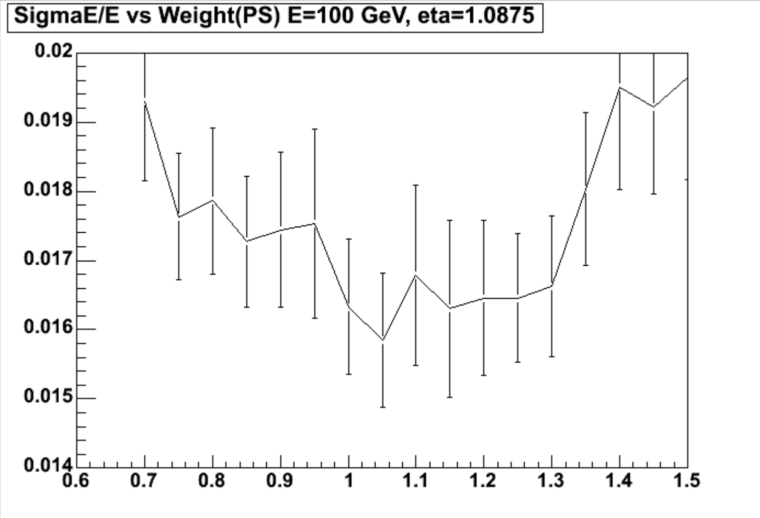
Comments on clustering

- **Fixed cluster size EM reconstruction (no noise cuts):**
  - Corrections have been studied in detail in TestBeams and ATLAS.
  - Fixed clusters provide excellent linearity/uniformity over a wide energy range (to 0.1-0.2%) and used for egamma variables
- **Topological Clustering (incl. noise cuts):**
  - Corrections are being studied
  - Collects energy efficiently (not limited by the fixed window)
  - Evident intrinsic (clustering) non-linearities are seen in TestBeams and ATLAS MC and must be understood. The large unphysical offsets partially compensate for the non-linearities.
  - Resolution only slightly better than the one with fixed clusters.

Resolution Studies

Resolution Study: we are close to optimum with the current weighting procedure

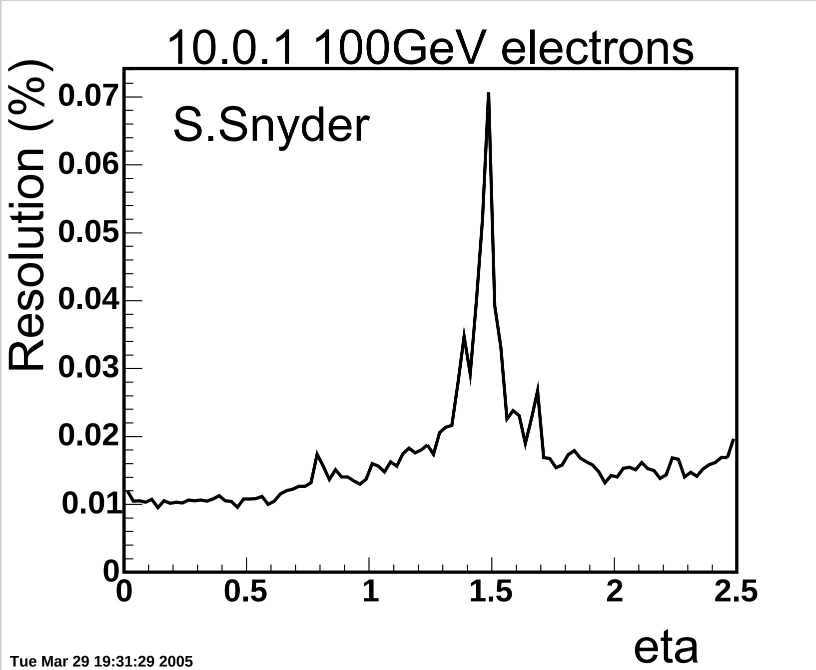


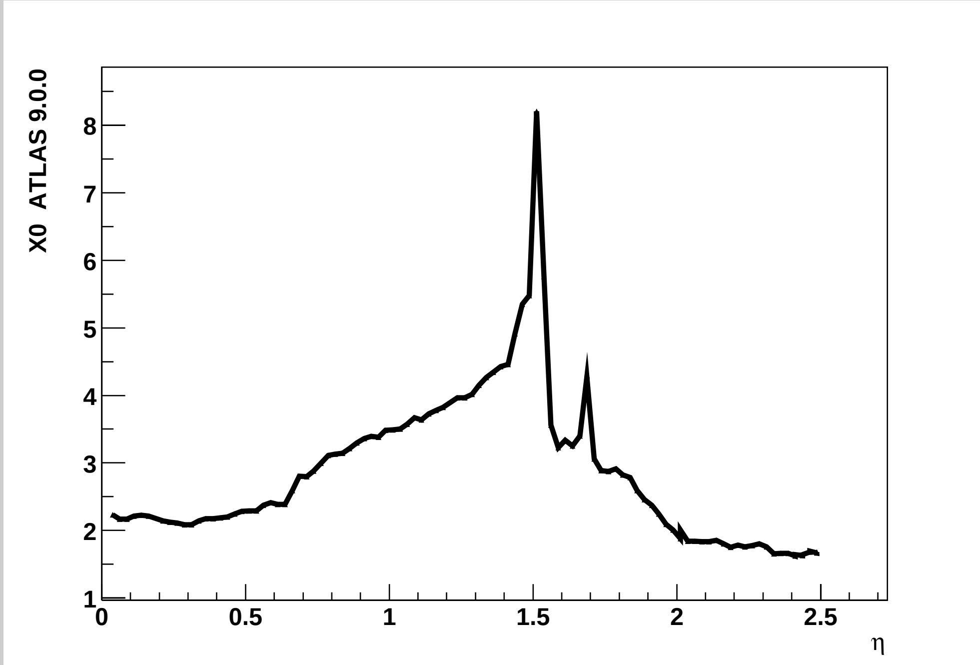


Switch off layer weight and look at resolution vs PS weight (a 5% sampling fraction is applied at the cell level)
Weight used in 10.0.1 is 0.96 which is very close to minimum.
Conclusion: cannot really improve resolution with this correction procedure

For Barrel eta>1 results are ~15-25% worse than values quoted in the TDR (for instance 12.5% at 1.1)
At smaller eta, results are closer to TDR (but still slightly worse)

Resolution correlates with the material upstream of the Calorimeter





X0 map of material in front of strips

The dependence on longitudinal shower fluctuations increases for:

- E loss out of cluster
- E loss after the PS and before the Strips
- E leaking from the back
- Accordion Sampling Fraction

Refined Calibration: Factorize the different effects

$$E_{rec} = \lambda\left(b + W_0 E_{PS} + \frac{1}{SF_{acc}}\left(E_1 + E_2 + W_3 E_3\right)\right)$$

$$W_0 = \frac{E_{loss}^{upstreamPS} + E_{loss}^{betweenPS-S1} + E_{PS}^{act} + E_{PS}^{passive}}{E_{PS}^{act}} = \frac{E_{loss}^{beforeS1}}{E_{PS}^{act}}$$

ATLAS 10.0.1 parametrization: Parameters (like W0) absorb different effects. This is the source of loss of resolution.

Example of refined parametrization (can be exactly checked by simulation)

$$E_{rec} = E_{outcone} + b + \underbrace{\left\langle \frac{E_{Loss}^{uptoPS}}{E_{PS}^{act}} \right\rangle E_{PS} + \left\langle \frac{E_{PS}^{act} + E_{PS}^{pas}}{E_{PS}^{act}} \right\rangle E_{PS}} + E_{Loss}^{PS-S1} + \left\langle \frac{1}{SF_{acc}} \right\rangle \left(E_{acc}\right) + E_{Leak}$$

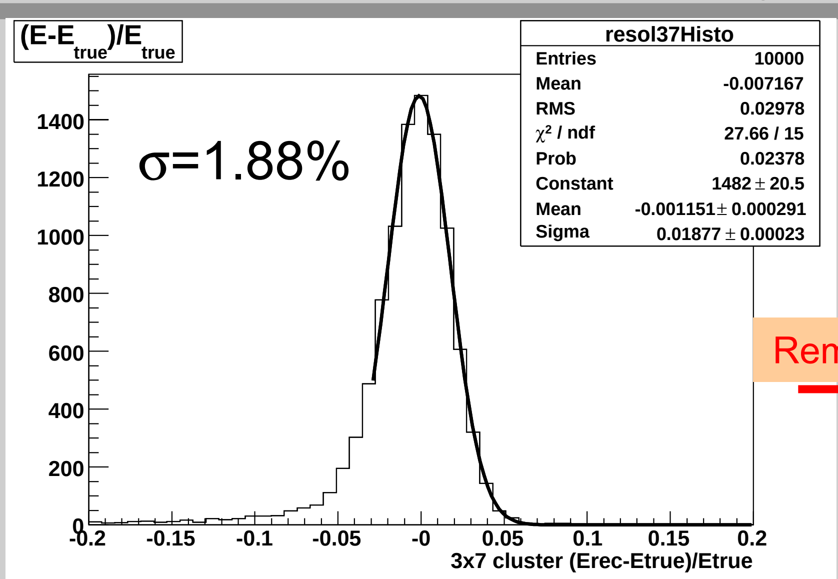
Presampler Linearity valid up to 3-4X0

Use Calibration Hits in full simulation (true deposited energy):

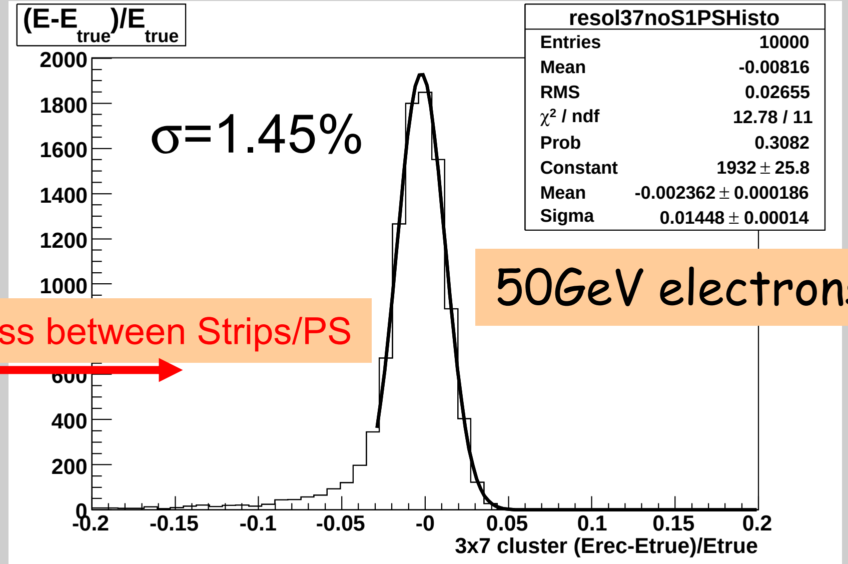
- **Energy in LAr = ‘active energy’**
- **Energy in Passive material (i.e. Lead) = ‘inactive energy’**
- **Energy in Cryostat, cables etc = ‘dead energy’**

Summary of EM Resolution Loss at eta=1.2125

3x7 10.0.2 50GeV Banfi, Carminati, Paganis



Remove Eloss between Strips/PS



50GeV electrons

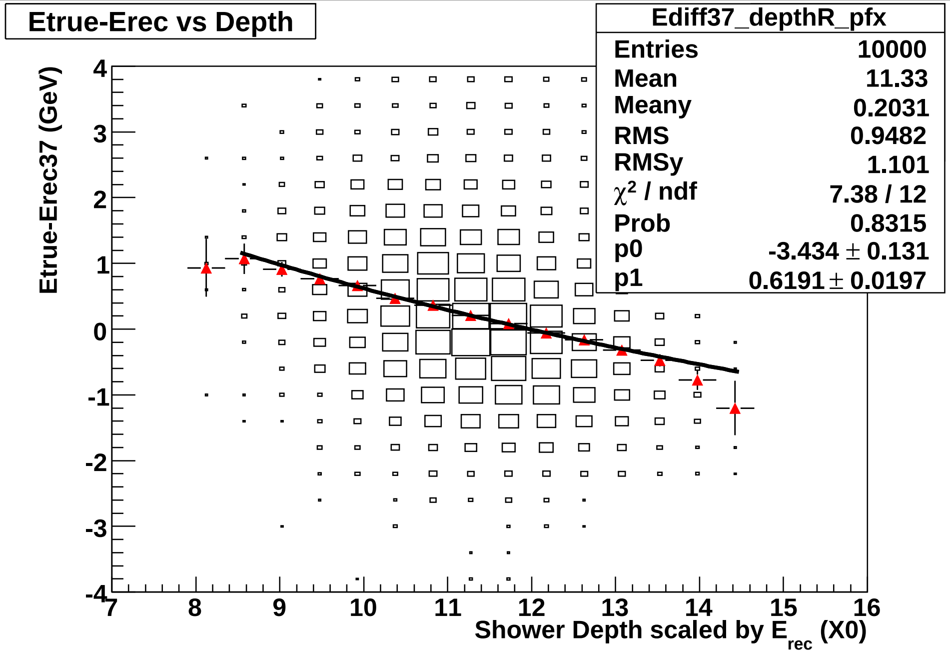
Electron Energy	20GeV	50GeV
3x7 EM Resolution	2.88%	1.88%
3x7 EM Resolution no losses between PS and S1	2.23%	1.45%
Approx. Optimum EM Resolution (*)	2.12%	1.32%
Loss due to Eloss between S1 and PS	-23%	-23%
Loss due to out-of-cluster fluctuations	-5%	-9%

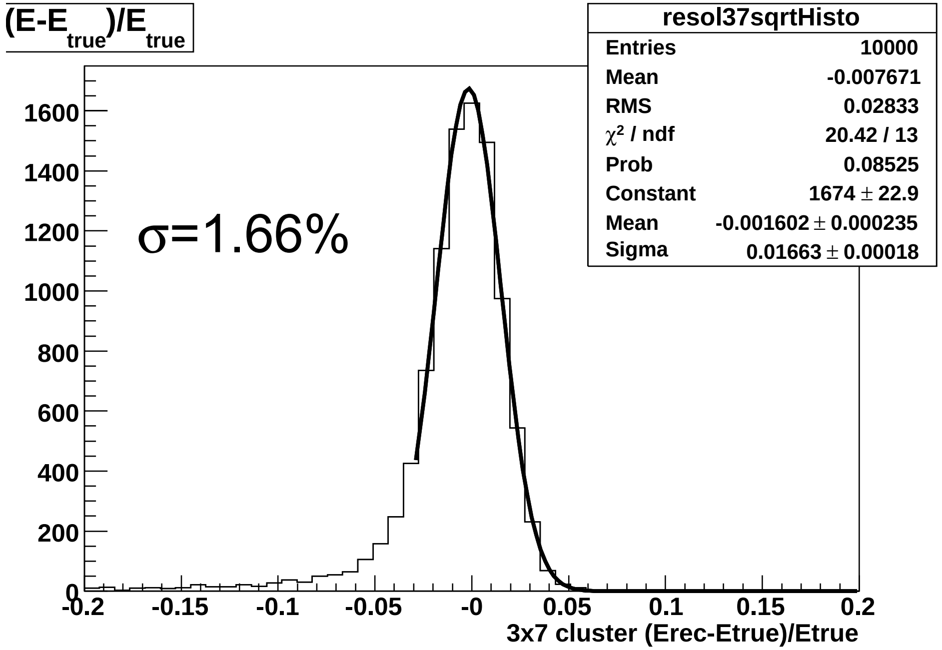
→ ~9.5%/sqrt(E)

(*) Only dE/dx, i.e. no noise, no pile-up, no charge effects etc.

Find observables which correlate to the Energy loss fluctuations

Carli, Carminati, Lampl, Paganis





Strong correlation between resolution and measured shower depth

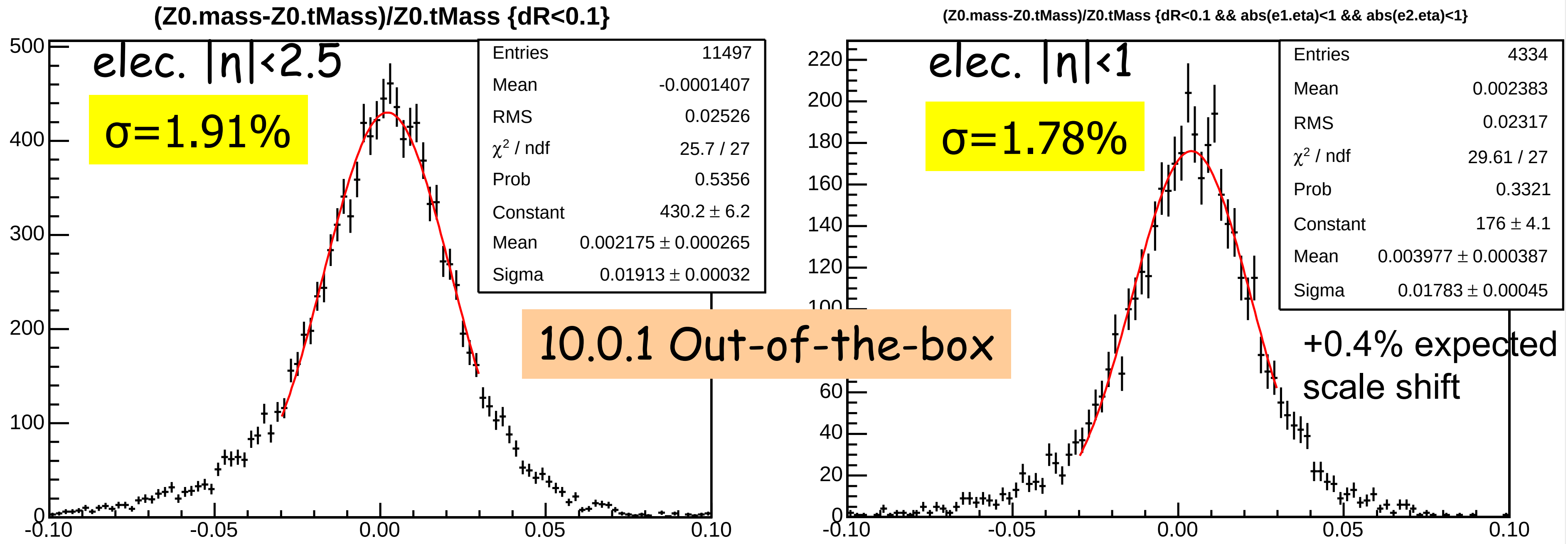
Significant (12%) improvement!

$$E_{rec} = \lambda \left(b + \left\langle \frac{E_{Loss}^{uptoPS}}{E_{PS}^{act}} \right\rangle E_{PS} + \left\langle \frac{E_{PS}^{act} + E_{PS}^{pas}}{E_{PS}^{act}} \right\rangle E_{PS} + E_{Loss}^{PS-S1} + \left\langle \frac{1}{SF_{acc}} \right\rangle (E_{acc}) \right)$$

Eloss from new TBeam parametrization: $c + W_s \frac{\sqrt{E_{PS} E_{S1}}}{E_{acc}}$

Z->ee Resolution 3x7 10.0.1 Rome

Flores,Mellado,Quayle,Sau Lan Wu



Post 10.0.1 recalibration gave similar resolutions and no shift in the Z mass

10.0.1 longitudinal weights are close to their optimum values for the present parametrization.

InterCalibration in-situ

N.Kerschen, M.Boonekamp, F.Djama

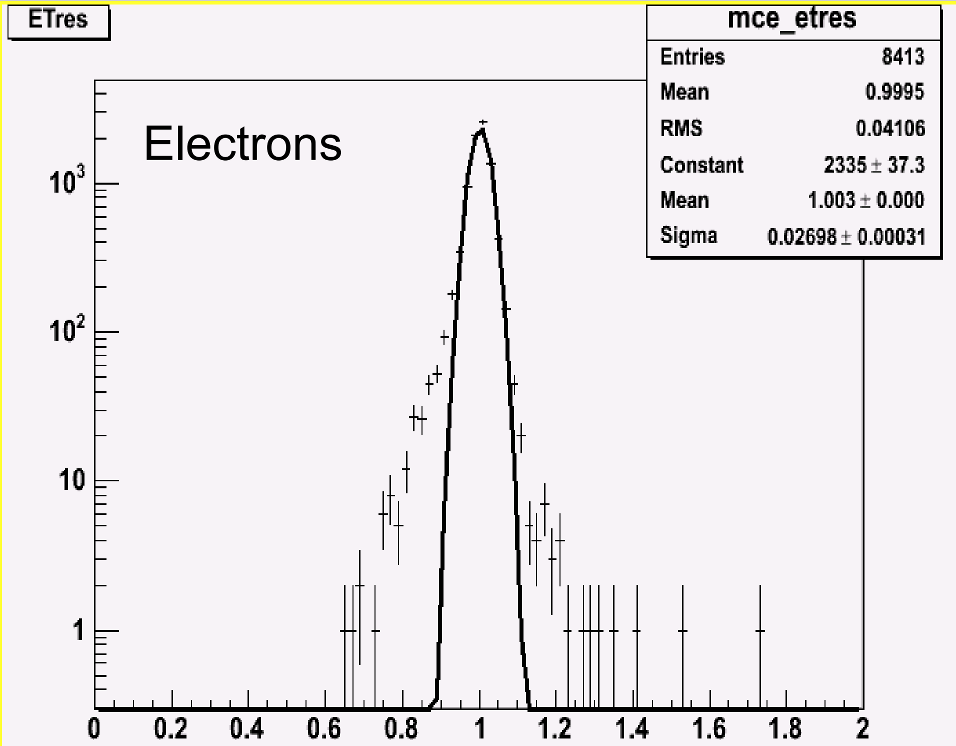
- Intercalibration of different regions of the LAr calorimeter is possible with Z->ee (TDR)
- Several Methods have been proposed
  - ATL-LARG-2004-08 (FD)
    - 0.3% Uniformity was found in DC1 for the Barrel
  - Method for independent phi/eta intercalibration (NK,MB)
    - Phi with min-bias, W->eν and γ+Jet
    - Eta with Z->ee
    - 0.2% Uniformity is found with full sim
  - Caution on material effects: ATL-LARG-2004-016 (SP)
- Monitor calorimeter linearity with Z->ee
  - Use reference Z->ee distribution which includes resolution effects (NK,MB)

Summary/Future

- Clustering methods
  - Since 10.0.1: different calibrations for 3x5,5x5,3x7 clusters
  - First efforts to use TopoClusters for e/γ in CTestBeam and ATLAS
    - Clustering non-linearities must be understood
- Electron-based fixed cluster calibration:
  - Good Linearity from 10GeV-500GeV
  - 15-25% resolution loss wrt TDR, mostly due to increased amount of material in front of EM Calo (it needs update soon).
- Ability to apply different corrections for photons in the coming software releases.
- Efforts for refined parametrizations:
  - Must separate effects that affect performance.
  - Shower longitudinal fluctuations are enhanced due to the presence of material in front of the calorimeter.
  - Work towards improving the resolution has started both in CTB04 and ATLAS/CTB simulation.
  - Impact on Physics: see talk by L.Carminati

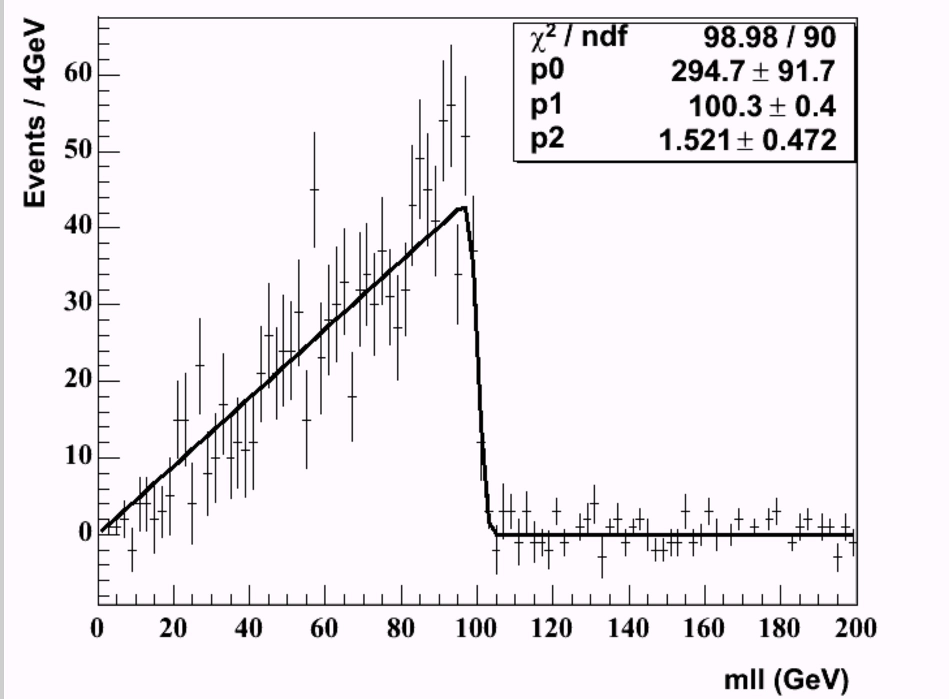
Supporting Viewgraphs

SUSY Highlight: egamma work in action



ET_{rec}/ET_{true}

Ignacio Aracena

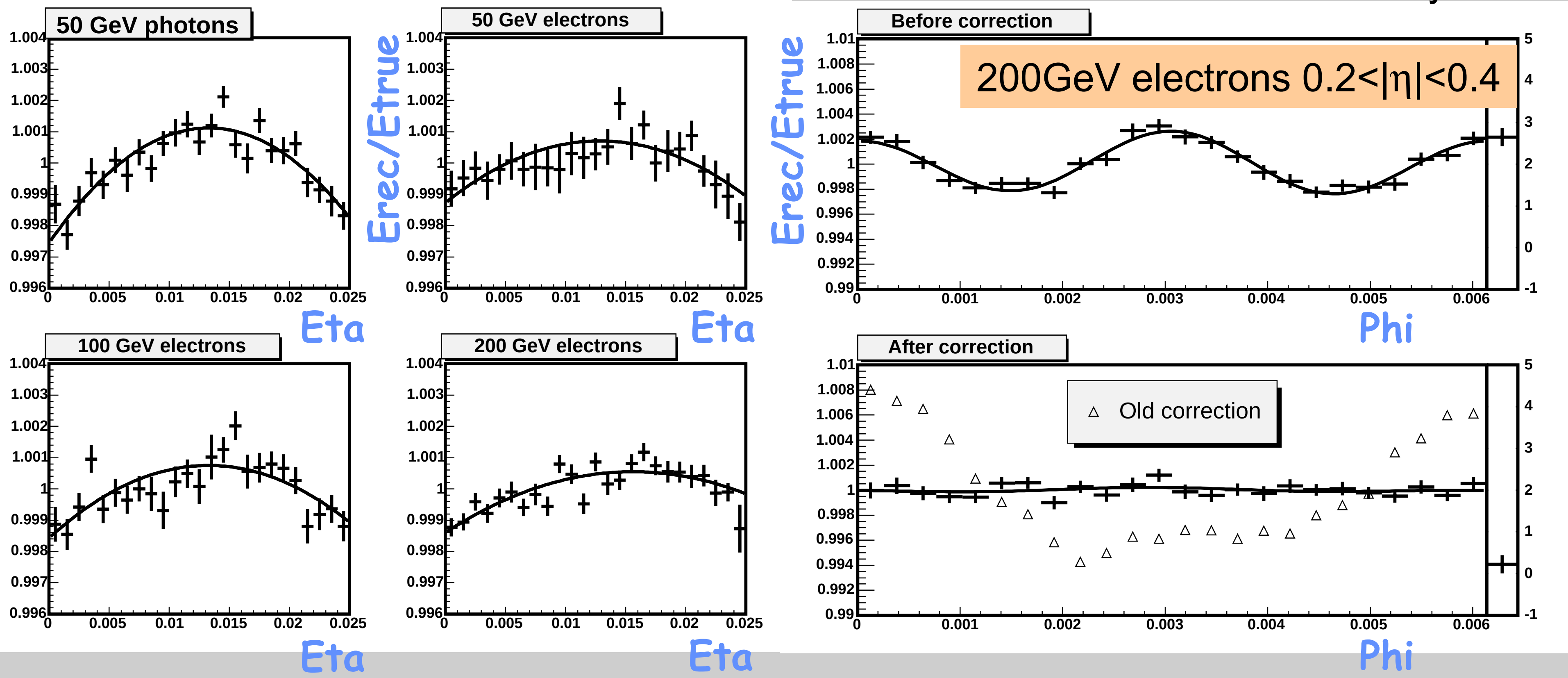


SameFlavour OppSign – OppFlavour OppSign

67000 events used in this analysis ($3.4fb^{-1}$)
2 OS/SF leptons (e,μ), PT > 10GeV

Energy modulations

Scott Snyder

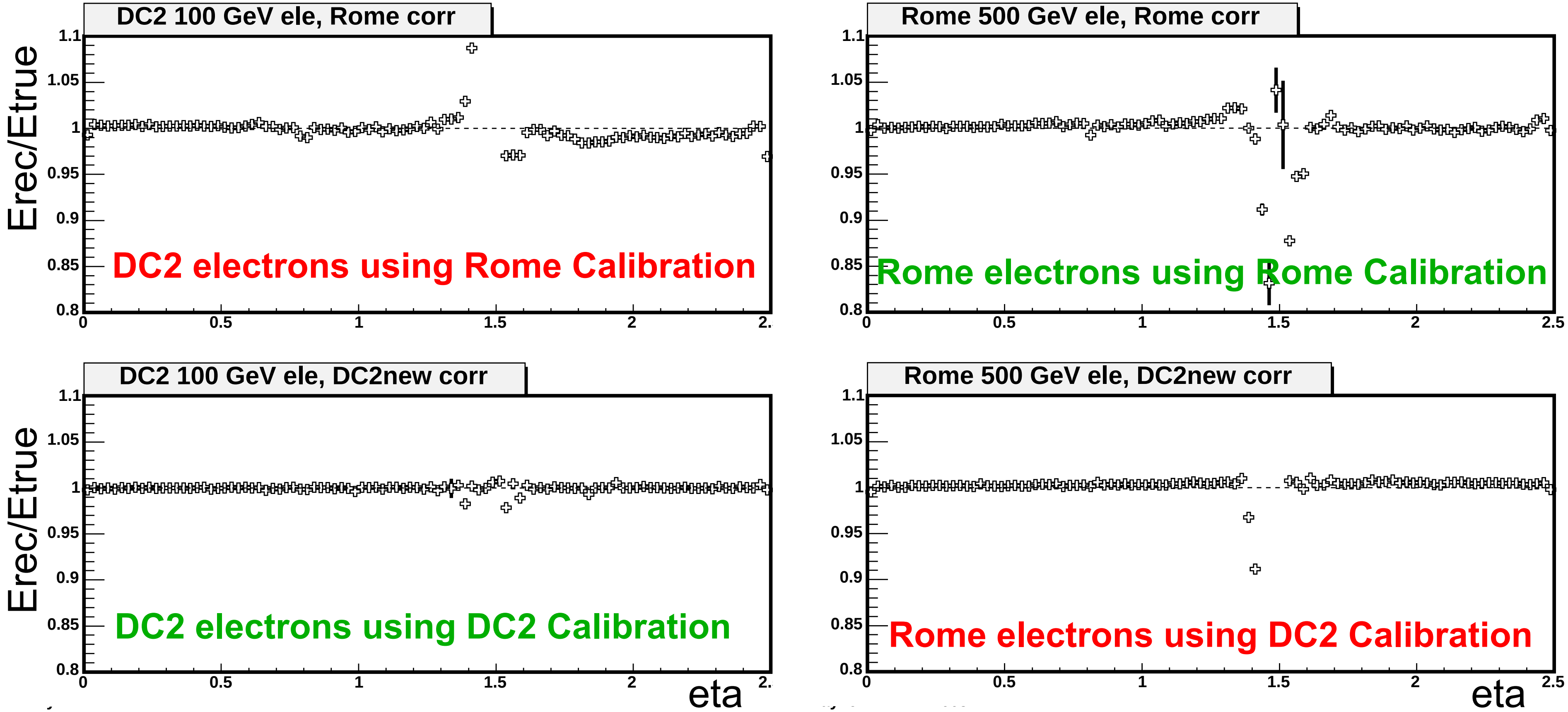


~0.2% effect, (Tbeam02: 0.8%)

~0.5% effect, (Tbeam02: 1-1.5%)

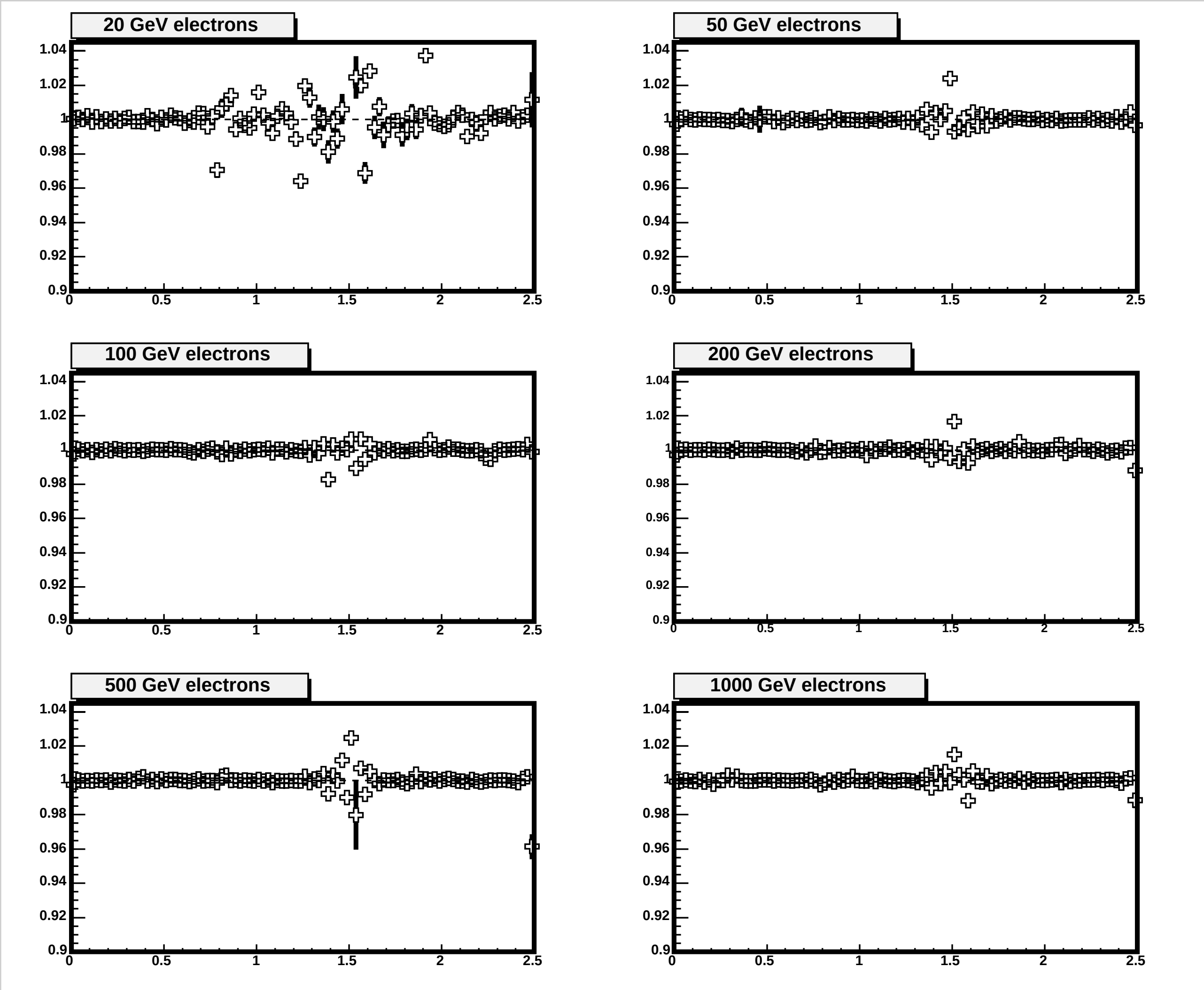
Linearity Performance (10.0.1)

Scott Snyder (+ independent checks by K.Benslama, SP)



Comment: for Rome, small shift by ~0.4% in the Barrel due to a change in the Sampling Fraction.

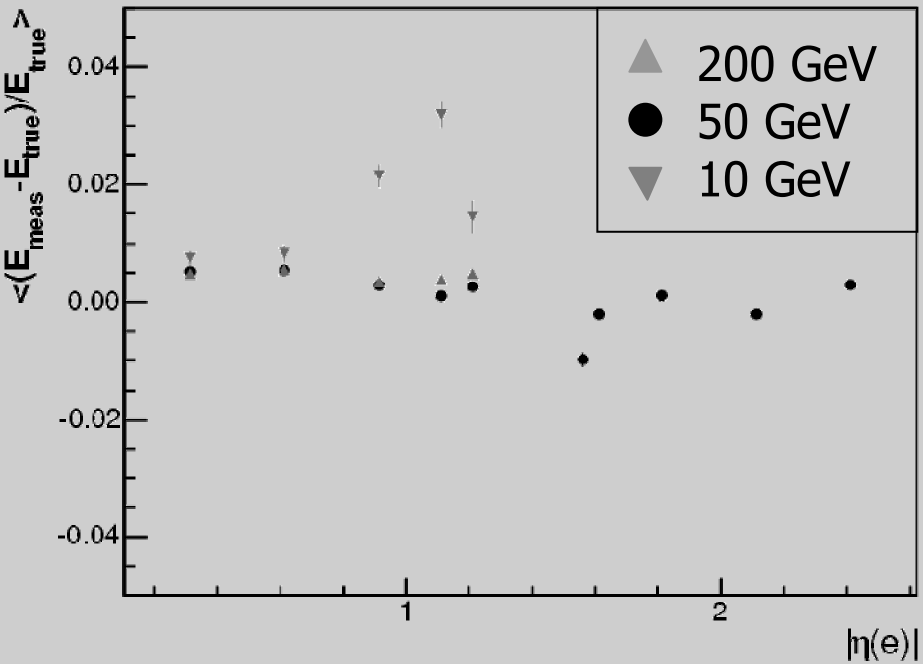
Linearity Performance (10.0.1)

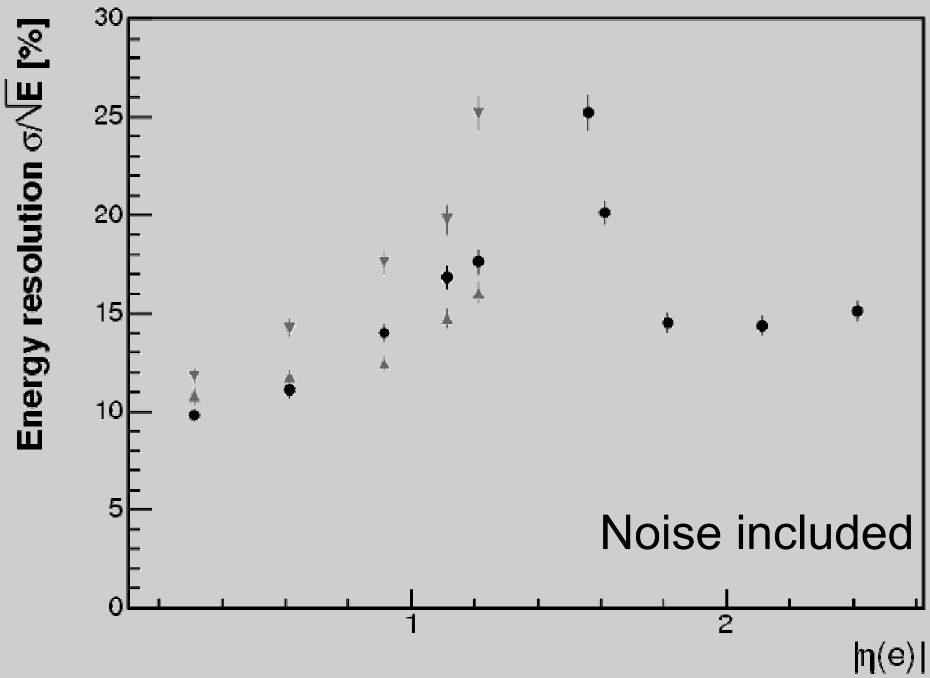


Linearity/Resolution Performance 10.0.1

3x7 Clusters

Flores, Mellado, Quayle, Sau Lan Wu 10/May/05

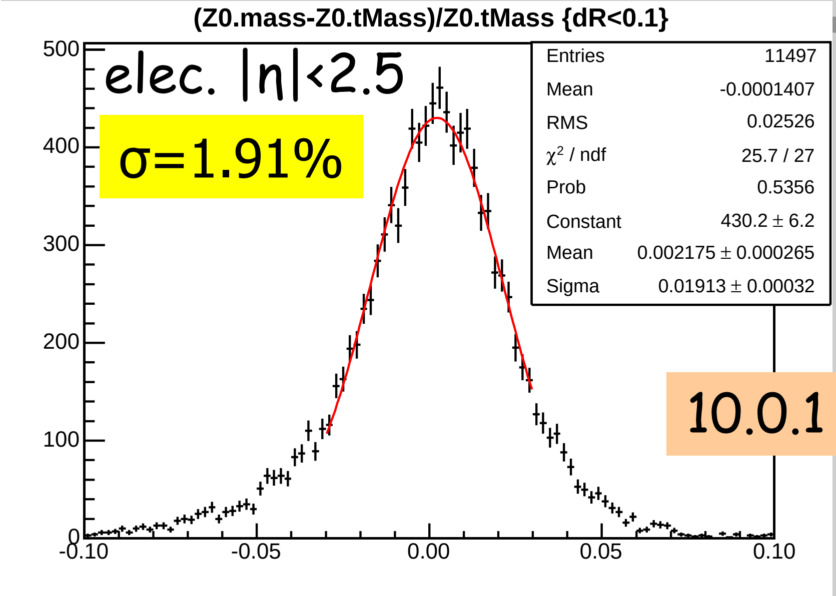


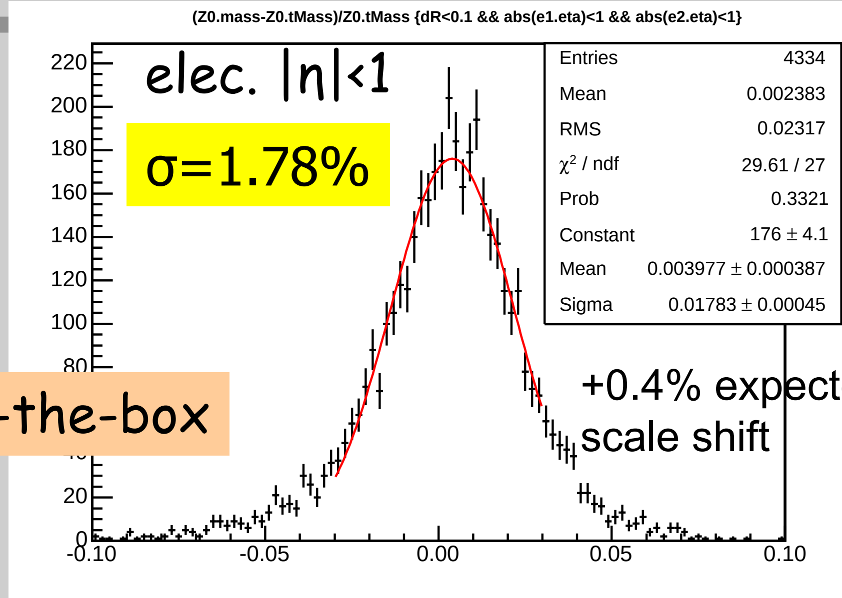


REMOVE: Comparison with TDR here!
Results in agreement with checks from other groups

Z->ee Resolution 3x7 (10.0.1)

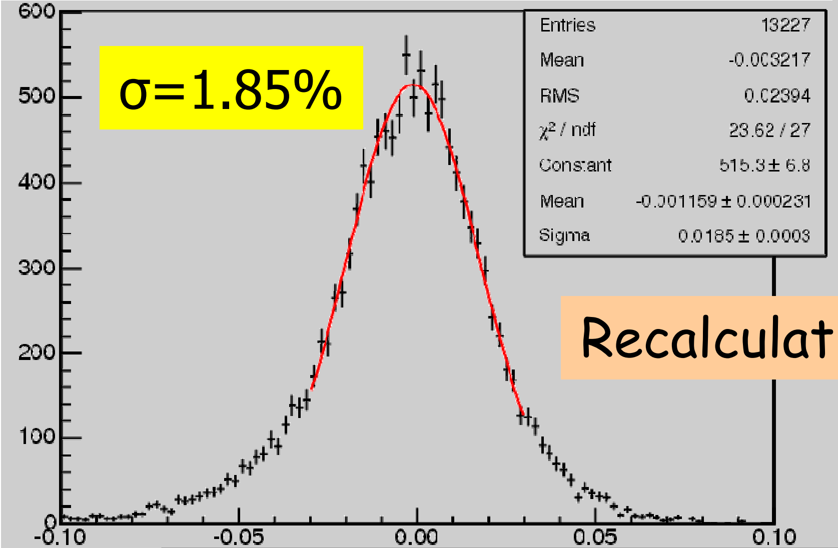
Wisconsin

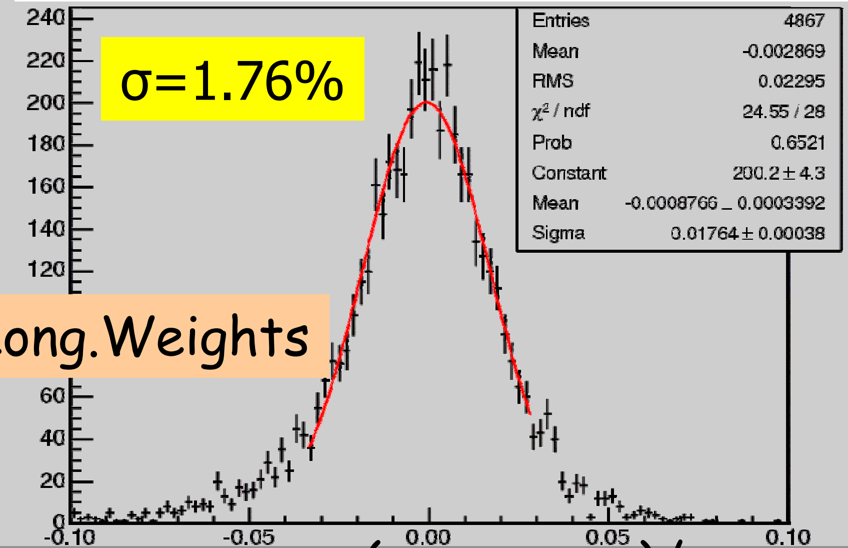




10.0.1 Out-of-the-box

+0.4% expected scale shift



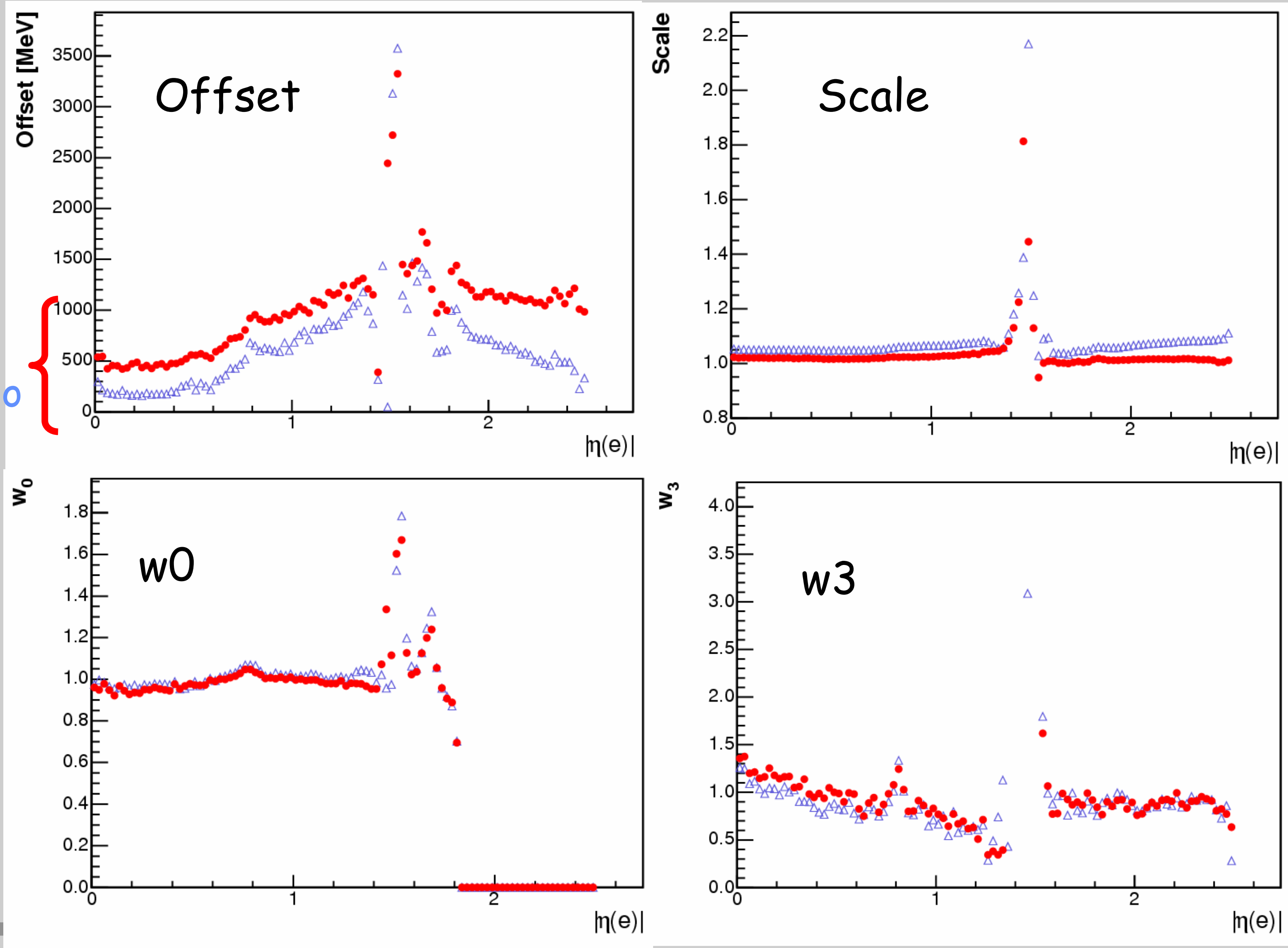


Recalculation of Long.Weights

$(m_{meas}-m_{true})/m_{true}$ $(m_{meas}-m_{true})/m_{true}$

TopoCluster vs 3x7 weights

Higher for topo



Cluster Corrections (slovakia)

- Correction at cluster level (no knowledge whether $\gamma/e^+/e^-$) :
  - Treat (not necessarily mask) noisy cells, : “a few” expected
  - Lateral leakage f(size,eta,E) ~5% for electrons
  - Gap correction (up to 40%)
  - Eta2 S-shape correction
  - Energy upstream/downstream material (layer weights, longitudinal leakage) (consistent with lateral leakage correction already applied) ? (also LVL2)
  - eta1, phi 2 position correction/offset
  - Energy modulation with impact point : phi 0.5%, eta 0.1%: (beware effect on average energy)
  - Alignment corrections if not already done
  - High Voltage Effects
- Some corrections are dependent of the particle type: electron or photon.
  - Defer corrections to e-gamma or electron-photon stage?
  - Average corrections at early stage and fine-tuning at later stage?

Presampler Linearity at eta=1.2125