Ideas for in-situ calibration for the EMC

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input from+discussions with

T.Carli, F.Djama, G.Unal, D.Zerwas, M.Boonekamp, N.Kerschen, L.Carminati, I.Winterger, M.Aleksa, K.Cranmer, W.Lampl, and many more

ATLAS Calibration Workshop, Dec-3-2004

Some References

- Atlas LAr Group, NIM A500 (2003) 202, NIM A500 (2003) 178.
- Atlas LAr Group, Linearity and Uniformity LAr EMC Test-Beams (in preparation)
- G.Graziani, ATL-LARG-2004-001
- W. Lampl talk at Slovakia Workshop (Dec/2004)
- N.Kerschen, "New Results from e/γ", Freiburg ATLAS Overview Week Oct-5-04
- F.Djama, ATL-LARG-2004-008
- D.Fournier, M.Kado, L.Serin (talks in LAr weeks)
- ATL-COM-CAL-2004-002
- M.Boonekamp: talks in Physics Week
- Our note (ATL-COM-LARG-2004-016 Nov/04)
- M.Schaefer, PhD Thesis (Sept. 2004).

Calibration issues

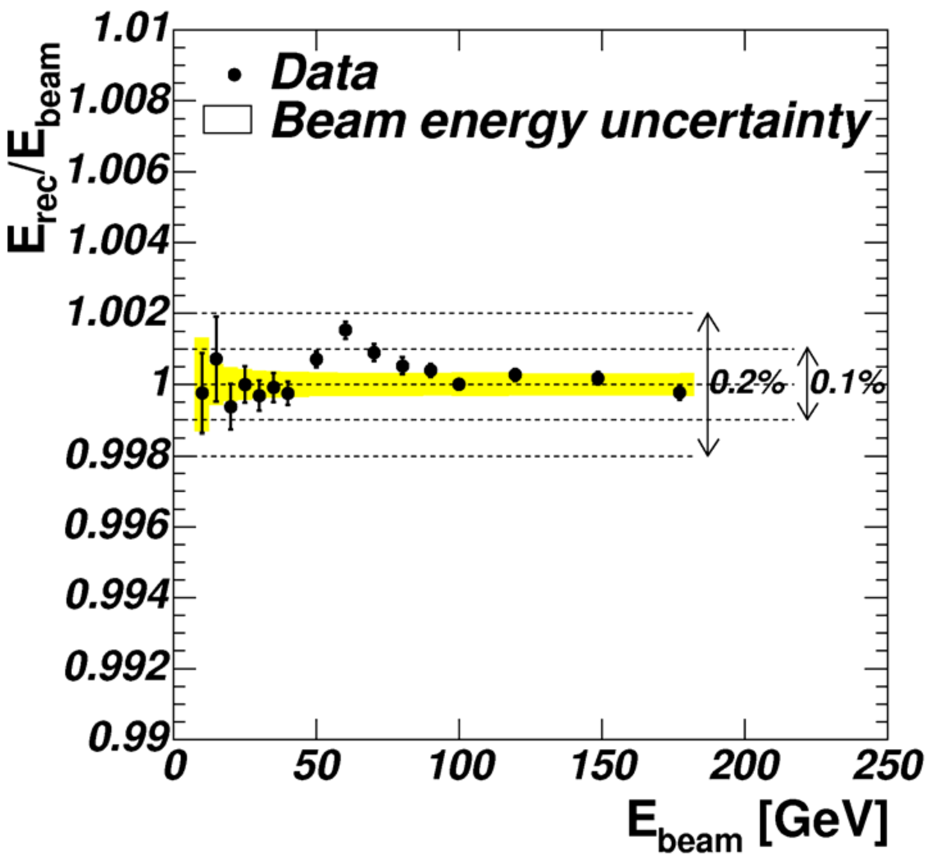
- Material corrections (different for e/γ)
  - Corrections for losses in material upstream of the EMC
- Intercalibration
  - To achieve uniform response for the 448 regions of the EMC
- Energy Scale (different for e/γ)
  - Overall correction to get to the true particle energy

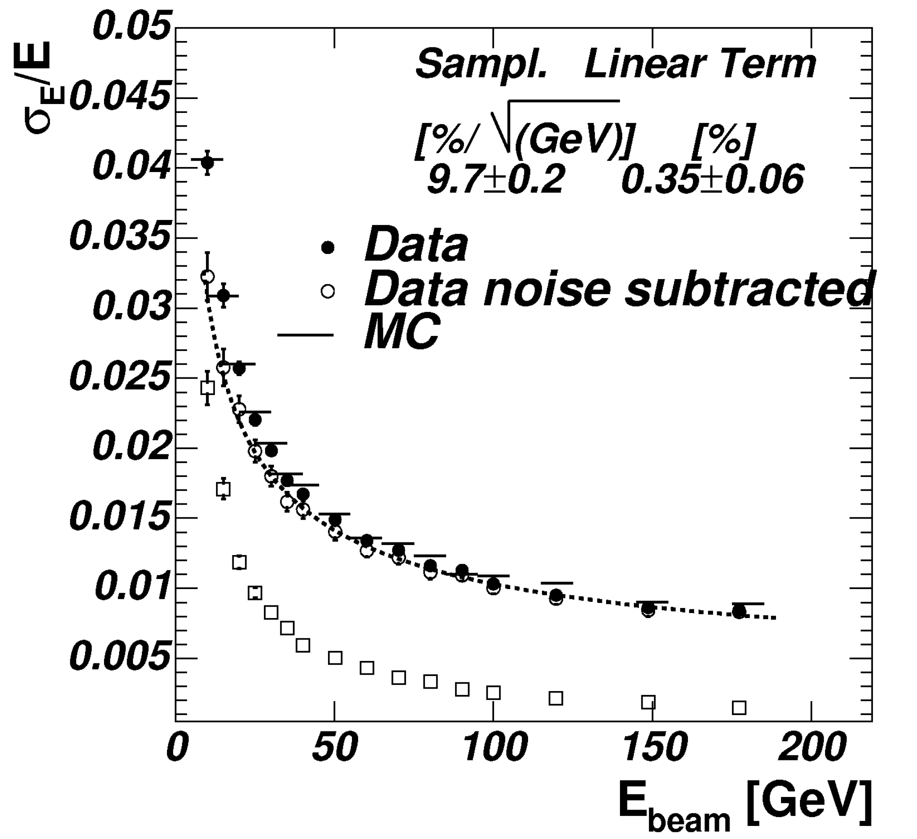
Material Corrections: Facts about Longitudinal Weights

~Final Results from TestBeam02

- Linearity <0.2% from 10GeV to 180GeV
- Resolution 9.7%/sqrt(E) + 0.35%
- Weights are Energy Dependent!
- Questions:
  - Can we port the new parametrizations in ATLAS?
    - In 2002 we have ~1.1X0 upstream, ATLAS is at least double
    - CTB2004 material scan analyses will help
  - How do we extract/monitor these weights in-situ?
    - Must decouple from Intercalibration issues
  - Can we use our best ATLAS weights from MC in real data taking?

Linearity & Resolution TB02 (W.Lampl talk)





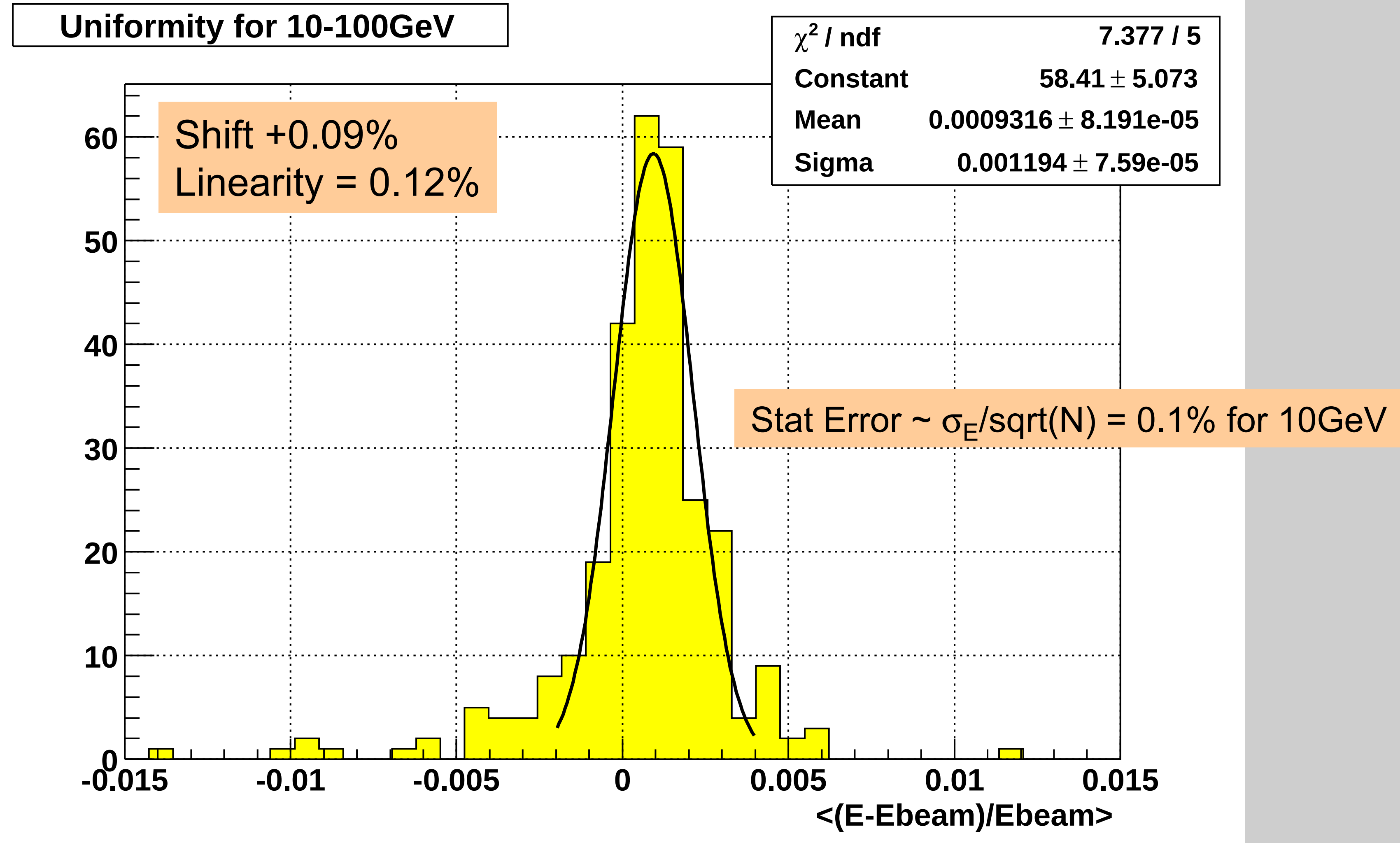
ATLAS: Linearity and Resolution

- Import TBeam parametrizations to ATLAS
  - We started for simplicity with

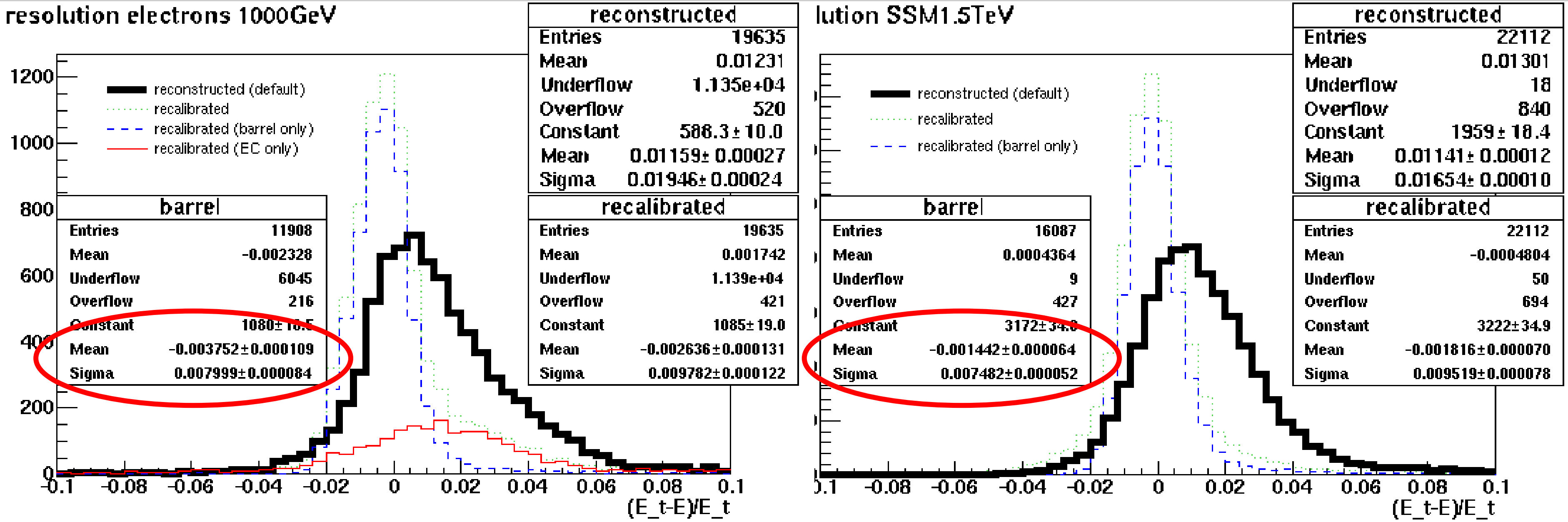
$$E_{rec} = \lambda\left(b + W_0 E_{pres} + E_1 + E_2 + W_3 E_3\right)$$

- Linearity from 10GeV to 1TeV to better than 0.4%
  - Must be verified with new electron samples
  - We also have more realistic noise now
- Resolution consistent with TBeam extrapolations
  - From 10GeV to 1TeV
  - Using 3x7 (DC1) and 5x5 (post 8.x) clusters (TBeam02 uses 3x3)
- Intercalibration: is decoupled from the material problem at the moment (users could induce factors by hand and study their recovery)

Linearity for 10-100GeV electrons in ATLAS for |η|<2.5 except crack (new result: 8.x.x)



Linearity at the TeV scale (old result: 7.x)



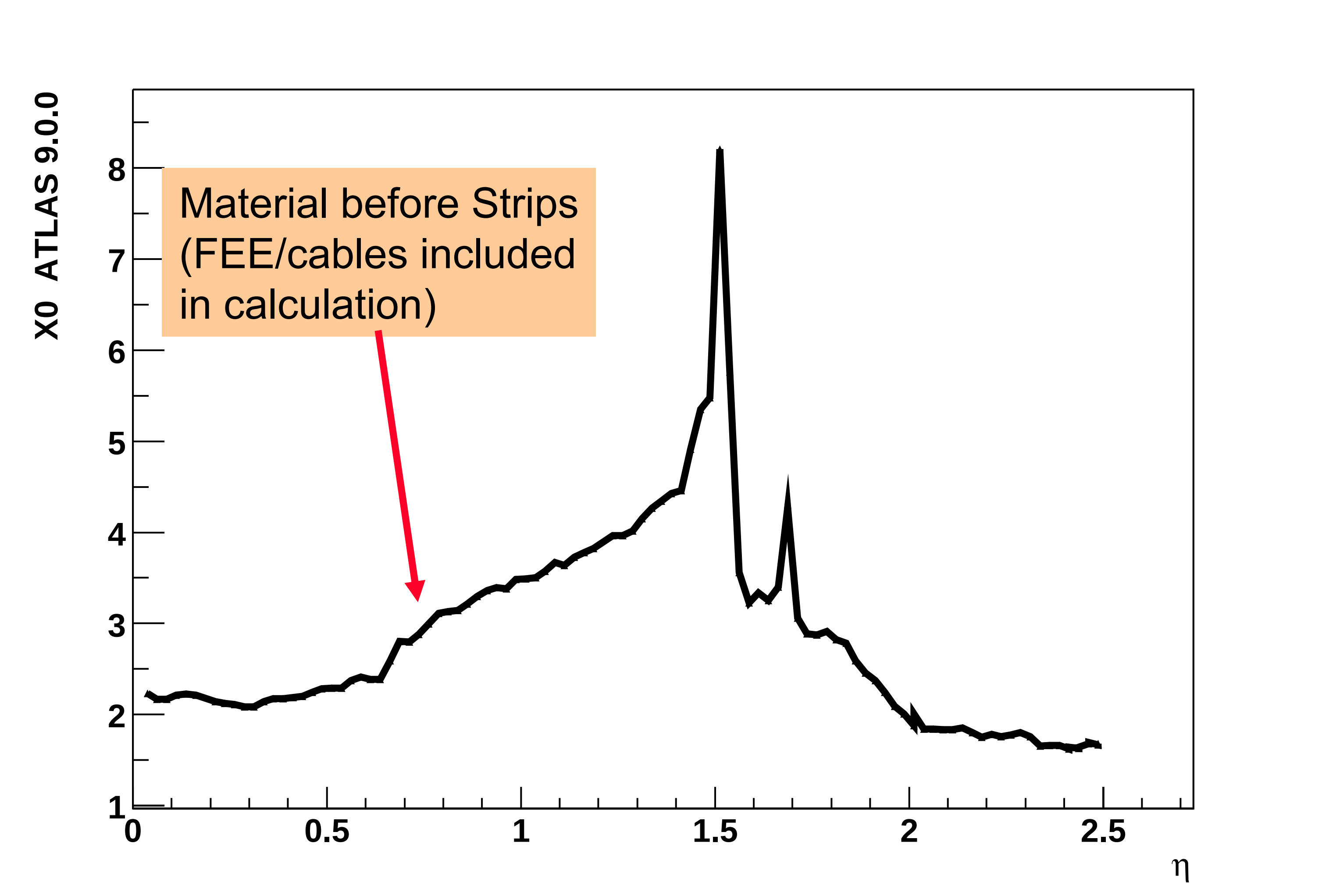
From M.Schaefer Ph.D thesis, Grenoble, Sept/2004

- Reminder: 10-120 GeV electrons were used + no Longitudinal leakage correction.
- So, we have evidence that the longitudinal weights are energy independent
- We must check with 9.x.x high energy electrons
- Don't understand yet: the energy dependence seen in the TBeam

What we know: Material Description + Geant4

- We know to some accuracy the ATLAS material distribution.
- We have a reliable simulation, G4.
  - Notice: differences in the absolute scale (from data Z->ee)
- This knowledge allows us to extract the longitudinal weights with reasonable accuracy.
  - Caution: up to an overall scale
  - Accuracy of extracted weights: CTB2004 should check!
- Such an extraction is decoupled from Intercalibration.

X0 map for ATLAS 9.0.0



Examples of Ideas for in-situ Calibrations

Assumption common to all scenarios

- Initial intercalibration will be done with cosmic and halo muons.
- Talks by F.Gianotti, L.Serin (recent commissioning and LAr meetings).
- What level can we reach?
  - I always assume that better than 1% level is possible

Matter vs InterCalibration: One Scenario

- material with MC,
- intercalibration with Z->ee

- For Upstream material effects:
  - How well we know the material distribution?
  - How much we trust our G4 MC?
- For Intercalibration:
  - It has been shown with Z->ee (F.Djama, TDR, more?)

- Personally: this is good for the beginning.

Matter vs InterCalibration: 2nd Scenario

- material with MC,
- intercalibration with W->eν in ϕ (Boonekamp et al)
- intercalibration+Scale with Z->ee in η (Boonekamp)

- This is work in progress

Matter vs InterCalib: 3rd Scenario

- Combined Method: Material+InterCalib.
- Absorb InterCalibration in scale weight λ.
- Calibration with Z->ee

- Has NOT been tried with pp->Z+X
- Requires statistics (roughly 800 bins)
- Has only been tried with electron beams

Extending the method to include Intercalibration

Combined Intercalibration and Longitudinal Weight Extraction for the ATLAS Liquid-Argon EM Calorimeter

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Abstract

Two major problems for most physics analyses in ATLAS are: (i) the equalization of response of different physical regions of the electromagnetic (EM) Calorimeter (intercalibration), and (ii) the correction of upstream material effects in energy reconstruction through extraction of the EM longitudinal weights. A possible solution to these problems consists of the in-situ calibration of the calorimeter using electrons from $W^{\pm}$ or Z^{0}-boson decays. When electrons are used, intercalibration depends on longitudinal weights and vice versa, making it very hard to decouple the two effects in-situ. In this note we report on the development of a combined minimisation method that provides simultaneous intercalibration and longitudinal weight extraction and can be used during the ATLAS data taking. It is shown that an intercalibration at the ≃2ppm level, including upstream material effects and excluding the crack region, can be achieved under realistic conditions. A small degradation of the energy resolution is seen. One advantage of the combined method is the use of a single data sample. In this study event samples from the Data Challenge 2 (DC2) production were used to test the applicability of the method.

COM-LARG-2004-16

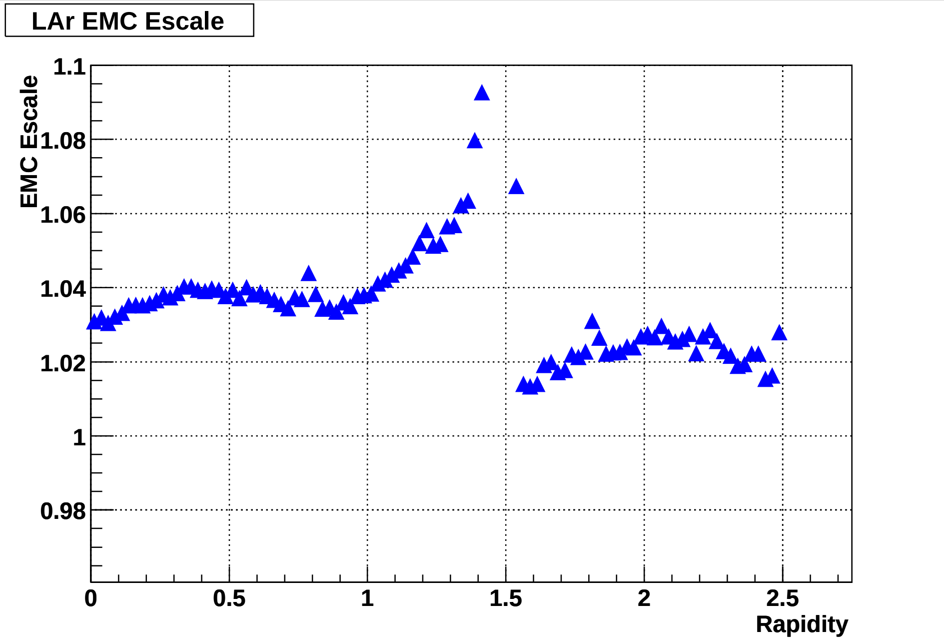
Intercalibration is the process of making the response of 448 physically distinct regions of the EM Calorimeter uniform.

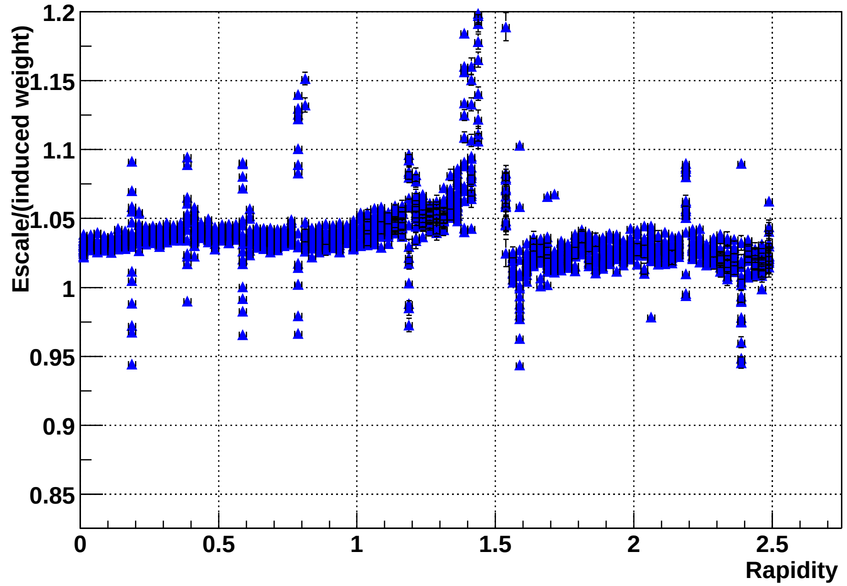
Initial intercalibration will be done with cosmic muons but its in-situ monitoring will be done with … pp->Z+X->ee+X

But for the longitudinal weights we also plan to use pp->Z+X->ee+X :

The two problems are coupled!

Scale λ: how it absorbs the intercalibration factors α





Material effects only

Scale / (induced IC weights α)
Material + Intercalibration (±5%)

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

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

Discussion on Tools for Data Monitoring

Tools for Monitoring and need for data samples

- What tools do we need?
  - Example: monitor of linearity for electrons
- At what level? (AOD, ESD)
- Saclay group started thinking/working along this direction.

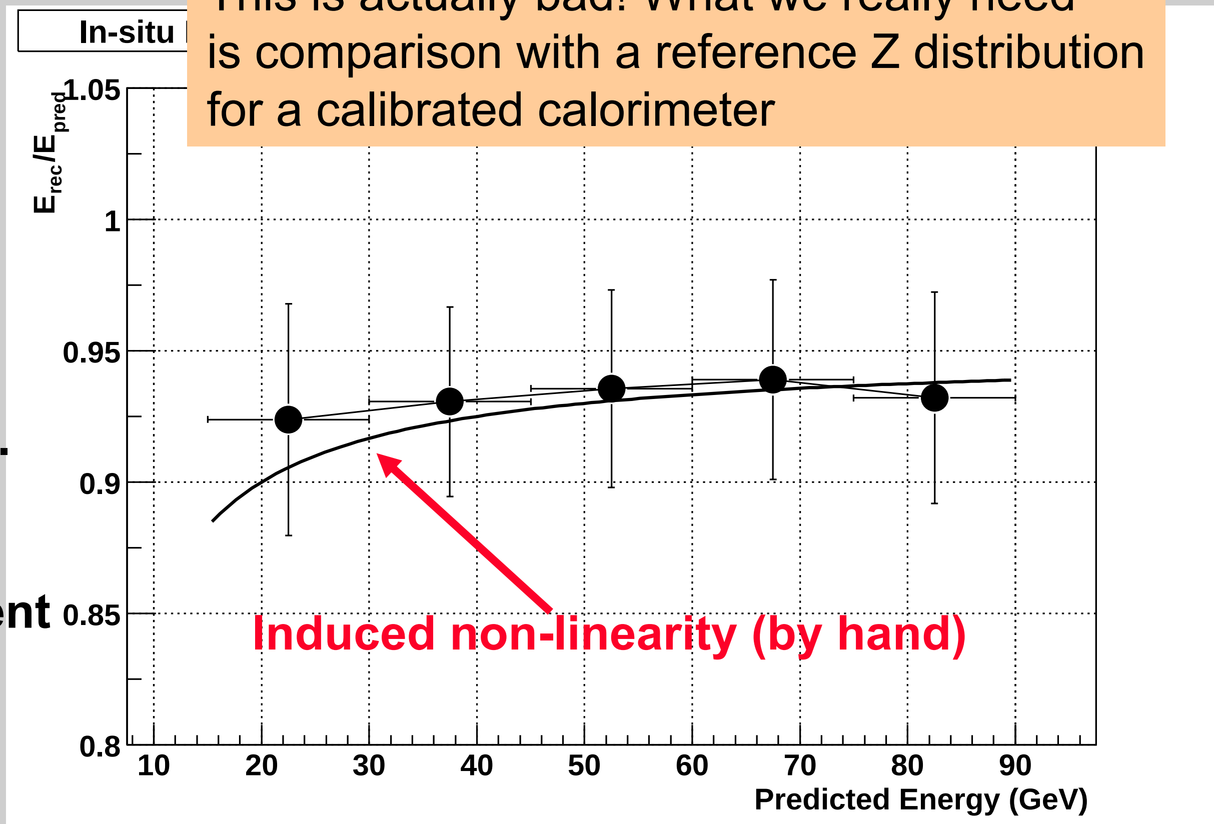
- We really need pp->Z+X,W+X samples for studies and tool development:
  - Expect: 10^6 W->ev per fb^{-1} (~1.5 month)
  - Expect: 10^5 Z->ee per fb^{-1} (~1.5 month)

In-situ linearity monitoring for the EMC

- Can we monitor the EMC uniformity during the data taking?

We use full-sim Z–>ee :
Pt1, Pt2 : Calorimeter
η, φ : inner detector
We perform a simple fit for the Pt1,Pt2 with the hypothesis that the electrons come from the Z.

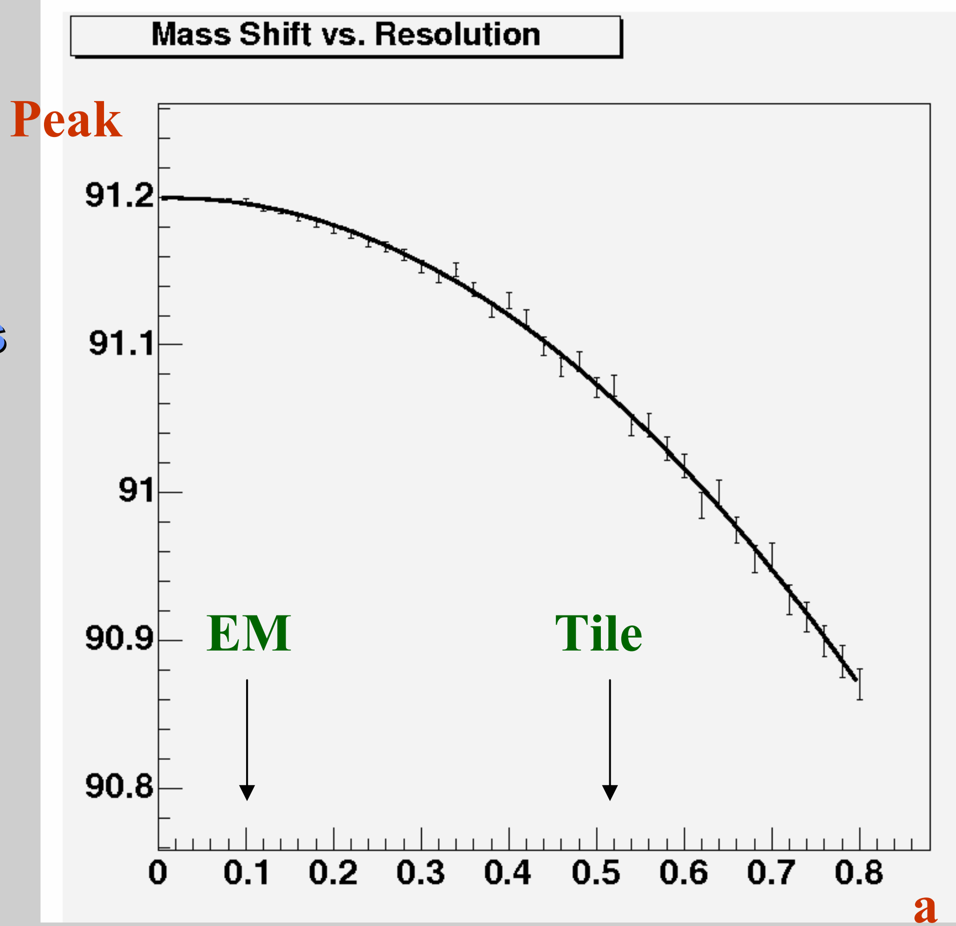
$E_{predicted}$: from fit
E_{rec} : from measurement



This is actually bad! What we really need is comparison with a reference Z distribution for a calibrated calorimeter

Energy Scale vs Resolution (M. Boonekamp)

- **Simple Calculation:**
  - Z → ff, at rest
  - E_f gaussian : $a/\sqrt{E}$
  - Variable a



- **So, there is no such thing like absolute scale since we always have error in the energy measurement!**
- **When Z is used for calibration we must include resolution effects for the reference distribution.**

Energy Scale vs Resolution (K.Cranmer)

$$E_1 = E_1^0 + e_1$$
$$E_2 = E_2^0 + e_2$$

Measurement = True Energy + Error

$$M = \sqrt{2E_1E_2(1-\cos\theta)} = \sqrt{2E_1^0E_2^0(1-\cos\theta)}\sqrt{1+\underbrace{\frac{e_1}{E_1^0}+\frac{e_2}{E_2^0}+\frac{e_1e_2}{E_1^0E_2^0}}_{R}} =$$
$$= M_0\left(1+R/2-R^2/8+\mathrm{O}\left(R^3\right)\right)$$

$$\left\langle\frac{-M_0R^2}{8}\right\rangle = \frac{-M_0}{8}\frac{1}{\sqrt{2\pi\sigma_R^2}}\int_{-\infty}^{+\infty}R^2e^{-R^2/2\sigma_R^2}dR = -\frac{M_0\sigma_R^2}{8} = -\frac{M_0\sqrt{\sigma_1^2+\sigma_2^2}}{8}$$

Small variation (5 MeV for $\sigma_{1,2}=1.5\%$)
But our goal in ATLAS is 20MeV for the W mass

Summary

- In-situ calibration/monitoring:
  - Material correction
  - Intercalibration
  - Overall Energy Scale

- Our handles to the problem:
  - Material:
    - we can use material maps and detector simulation
    - we can use data (Z->ee, W->ev, etc)
  - Intercalibration:
    - Data (cosmic/halo muons, Z->ee, W->ev, etc)
  - Overall Scale:
    - Data (Z->ee), with caution to systematics

- For Rome and later: we need pp->Z+X,W+X samples to test the several proposed ideas.