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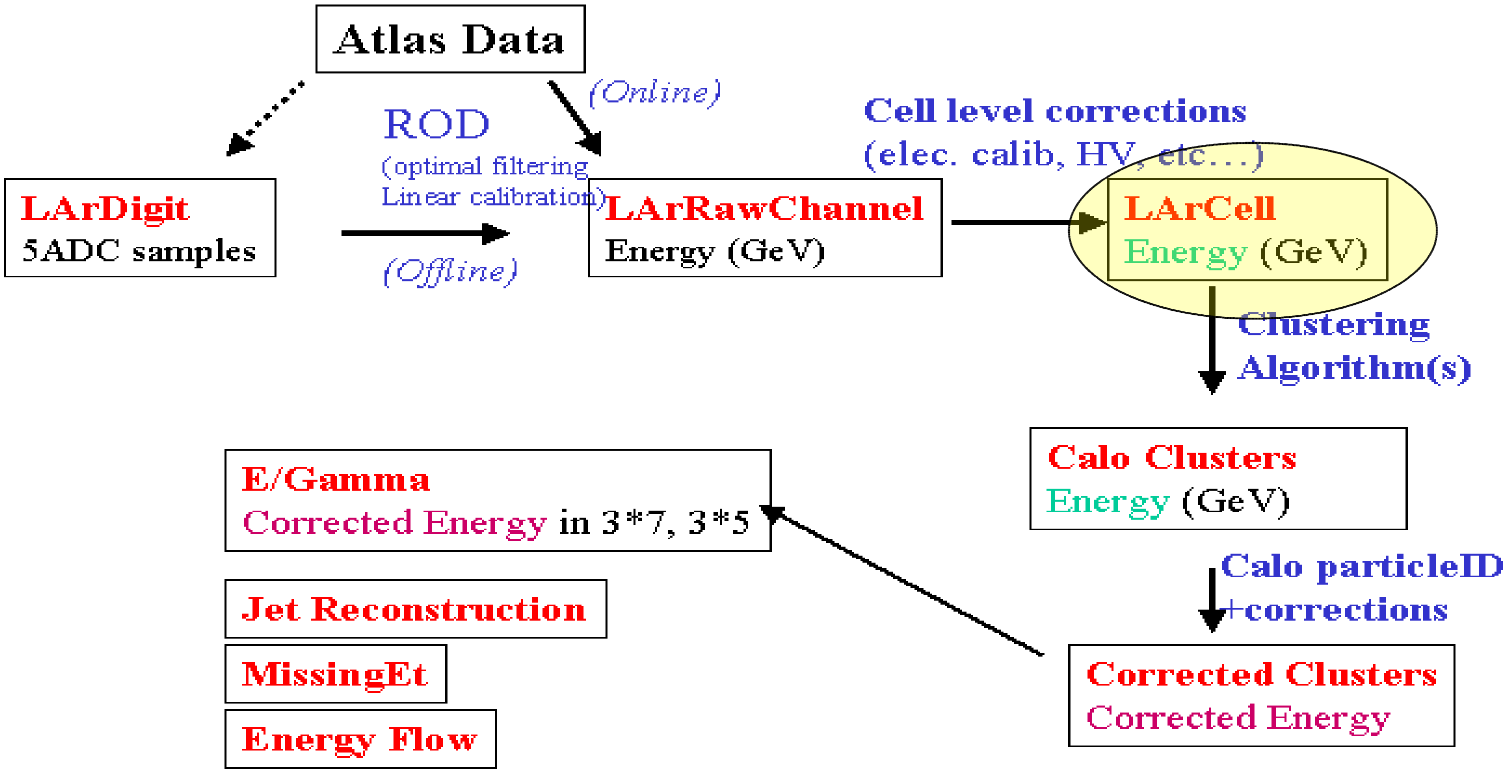
EM scale calibration for LAr EM calorimeter

- Overview: from ADC counts to cells to e/gamma clusters
- Sampling fractions & $\mu A \rightarrow MeV$
- HV corrections at cell level
- Uniformity & In situ calibration
- e/gamma specific corrections

Overview of calibration flow



Energy= GeV on nominal EM scale

Corrected energy=corrected for leakage, upstream matter, crack, impact point variation

One set of cells on the e.m “nominal” scale to be used by all reconstruction algorithms: No specific dead matter correction
Emphasis of this talk

$E(cell) = (Corr).(\mu A \rightarrow MeV).(ADC \rightarrow \mu A).\Sigma a_i(ADC_i - Ped)$

- a_i (OFC coefficients), Ped and ADC→μA computed from electronic calibration (not discussed here)
  - Main difficulty: Knowledge of the physics pulse shape. Can be derived from electronic calibration only (+possibly electrical measurements done on the calorimeter), but requires also comparison/validation with data
- μA→MeV: to go from the measured current in the LAr to the total deposited energy in the calorimeter (LAr+Absorbers+Electrodes) by e.m showers for the “nominal” calorimeter working point
  - Can be in principle factorized as fsampl * nA/MeV
  - Eta dependent
- Corr: corrections for imperfections
  - For instance non-nominal HV settings

- Most of computations above done online in the ROD
  - *Important to get good energy for LVL2 trigger*
- Some corrections can be refined offline
  - For instance better fit of ADC→μA (using higher order non linear polynomial), etc..

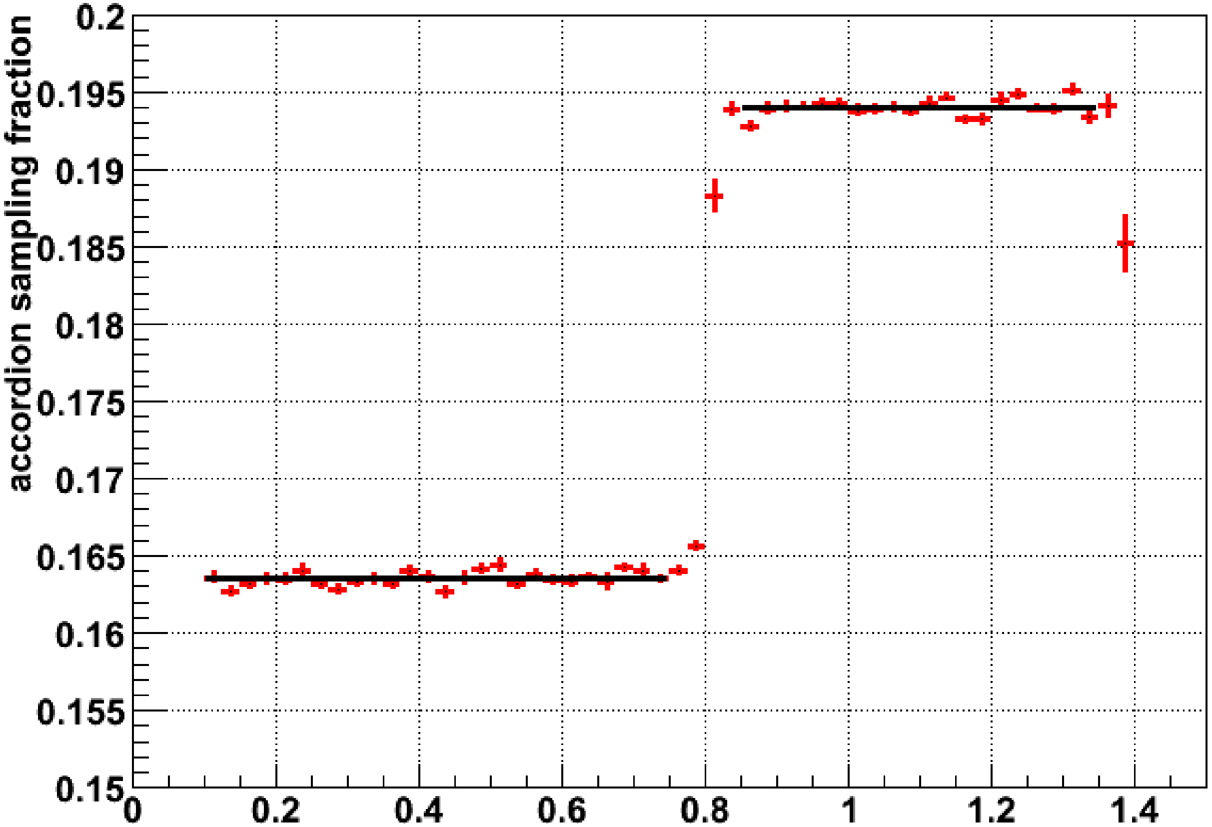
Sampling fractions and μA→MeV

- (μA→MeV)_total = (μA→MeV)_LAr / fSampl
  - (μA→MeV)_LAr = Current seen per MeV deposited in LAr
    - For barrel: convention to normalize it to the straight section of the accordion with ~constant Efield and gap
  - fSampl = E(LAr)/E(LAr+Abs+Electrodes)
    - For barrel: also includes ~7% reduction from region with lower Electric field in the accordion folds

- "First principle" computation for the EM barrel
  - (nA/MeV)_LAr : **Predict (nA/MeV)_LAr = 14.2 nA/MeV**
  - fSampl: From Geant simulation (+ 7% reduction from detailed current maps) => see plot next page

- Data EM barrel (from 2002 test-beam, T.Carli):
  - Only sensitive to product of the two
  - Taking fSampl from MC Geant 4.7, obtains **(nA/MeV)_LAr = 16 nA/MeV**
  - **Taking fSampl from MC Geant 4.8, nA/MeV agrees much better with first principle computation** (fSampl higher by ~10%)
- We are currently using in athena (μA→MeV)_total = 375 for eta<0.8 and 320 for eta>0.8 for the barrel

Barrel “fSampl” from Geant 4.7 (in atlas simulation 11.5.0)
For electron showers starting at the beginning of the calorimeter active region



What has to be done for barrel ?

- Rederive nA/MeV from combined test beam 2004 and compare using latest Geant4 and LAr simulation
- Be careful about temperature value when extrapolating to Atlas (~ 1.7%(vd)+0.5%(Ar density) per K)
- Need two values: eta<0.8 and eta>0.8 (different lead thickness)

What about Presampler ?

- (nA/MeV)_LAr can be extrapolated from measured value in accordion (need to have used the correct fSampl from Geant !!)
- Extrapolation is only a small difference in gap
- Will probably use only one value averaging over the small gap differences between presampler modules (this effect is included in the simulation)
- fSampl(Presampler) is not well defined: At the cell level use (by convention) 5% for the barrel and 1.667% for the End-Cap

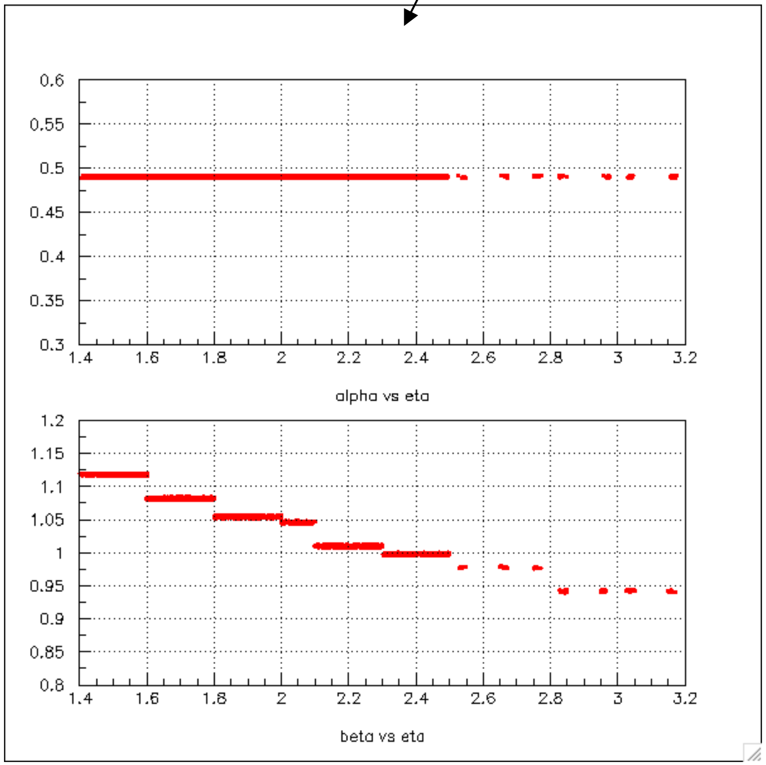
Situation in EMEC more complicated:

- LAr gap = f(eta) (from ~2.7 to 0.9mm in OW)
- Different HV per eta regions (7+2 regions for OW+IW)
- fSampl and (nA/MeV)_LAr are f(eta)
  - HV values chosen to make overall $\mu A \rightarrow MeV$ ~ flat
- Overall $\mu A \rightarrow MeV \propto \beta/(1 + \alpha\,(\eta - \eta center))$ in each region

∀ α,β parameters derived from test-beam of production modules
  - Values provided by P.Pralavorio to put in database for Atlas
  - Cf note Larg-2004-015 from F.Hubaut and C.Serfon

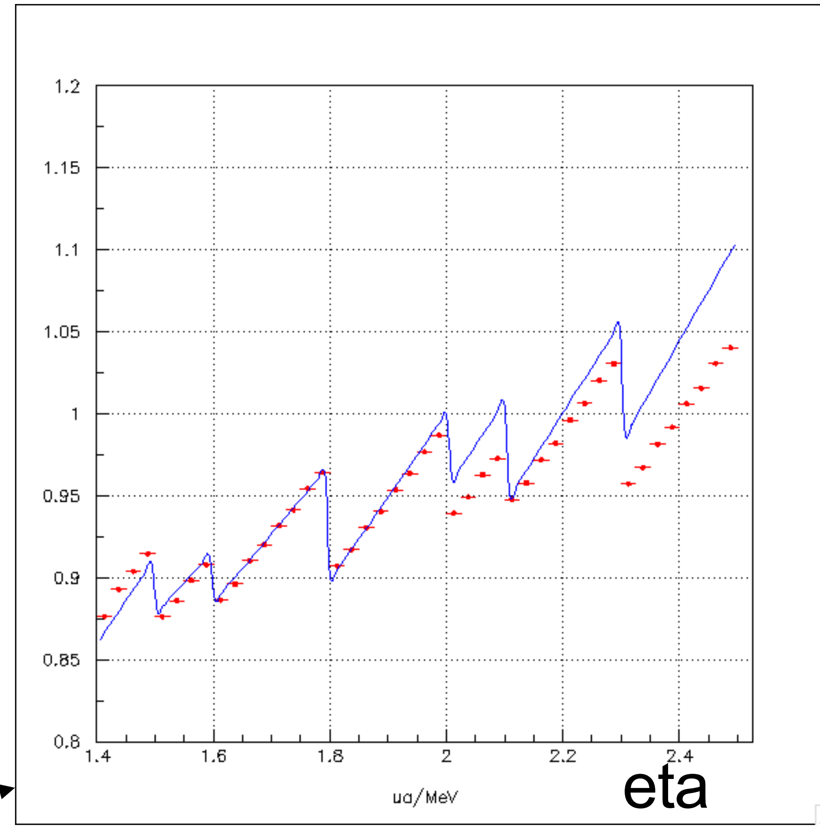
- Need proper implementation and use in athena $\mu A \rightarrow MeV$ computation
- Same comment as barrel for T(LAr) extrapolation
- Need in-situ validation and cross-checks with Z
  - This assumes that Tdrift vs eta, ofc, electronic calibration etc.. are understood well enough
  - Can start to get meaningful results with ~ 10-100 pb^{-1}
  - Crack region (1.375<eta<1.5) maybe more difficult …

α,β from test-beam vs eta



Overall μA/MeV in OW (arbitray norm.)
α,β from TB vs Atlas 11.5.0 Simulation(normalized at eta=1.9)

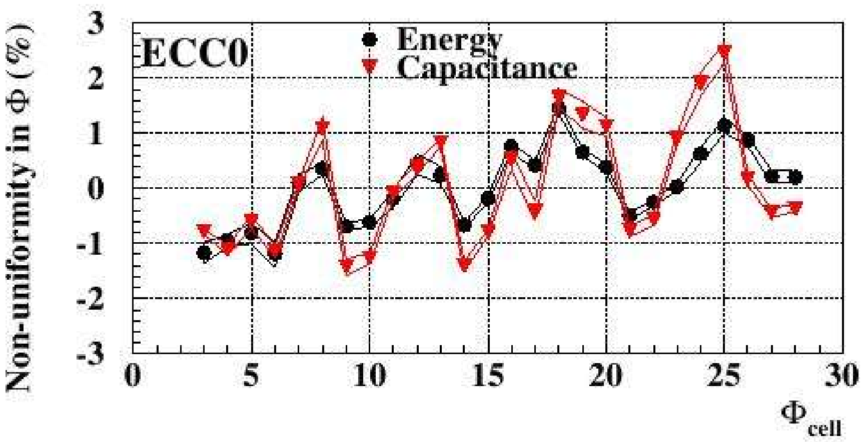
Next step: compare absolute values ?

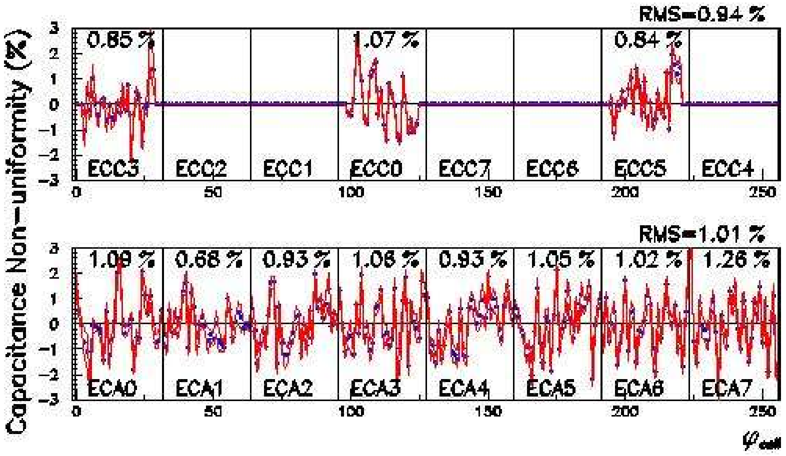


MC simulation being improved and compared with TB data
(cf dedicated presentation)

Situation in EMEC more complicated:

- In addition, some gap variations with phi in the modules lead to (smaller) phi variations of the response
  - Where to correct this ? Should probably go in μA→MeV factor (?)

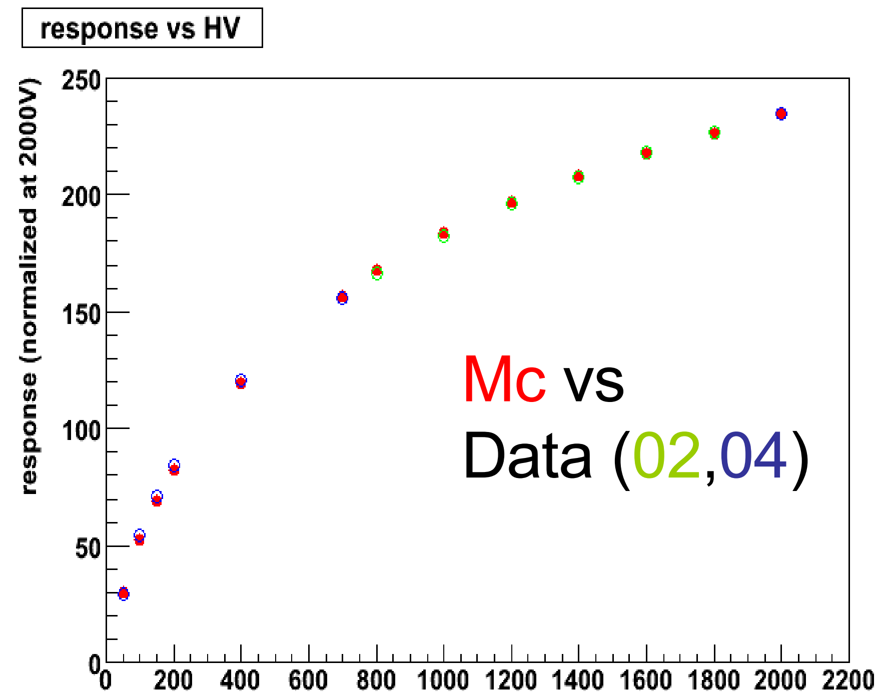




- All these problems specific to EMEC are understood and under control

Non nominal HV corrections

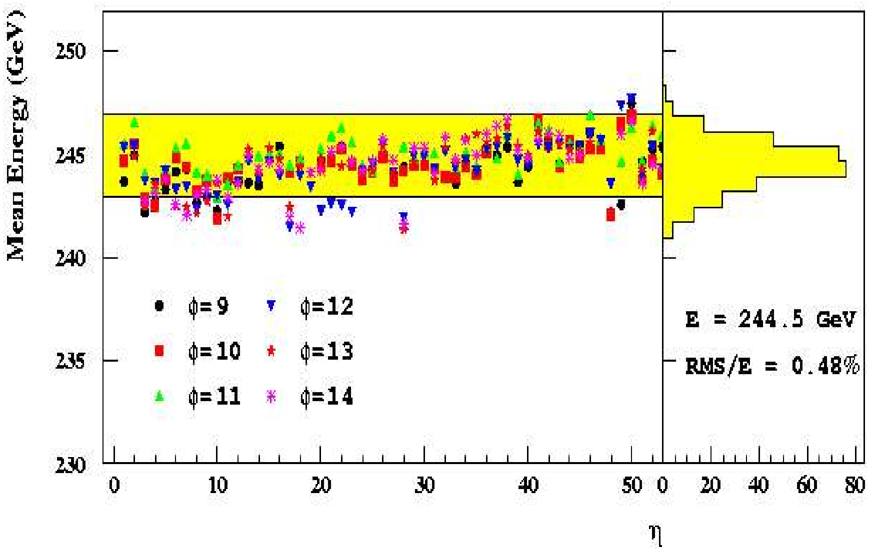
- At cell level, weight by a factor depending on HV applied to each 1/2 gap:
  - For instance factor 2 is HV=0 on all 1/2 gaps in one cell
  - Can compute weight for any HV and 1/2 gap configuration provided response vs HV is known *(cf figure for comparison between barrel test-beam and simulation)*
  - If HV >0 and HV <Nominal, should recomputed OFC to take into account different drift times
- Should do as much as possible in the ROD
- Refinements or corrections for more intermittent problems offline
- Need more refined correction at cluster level to include impact point dependence

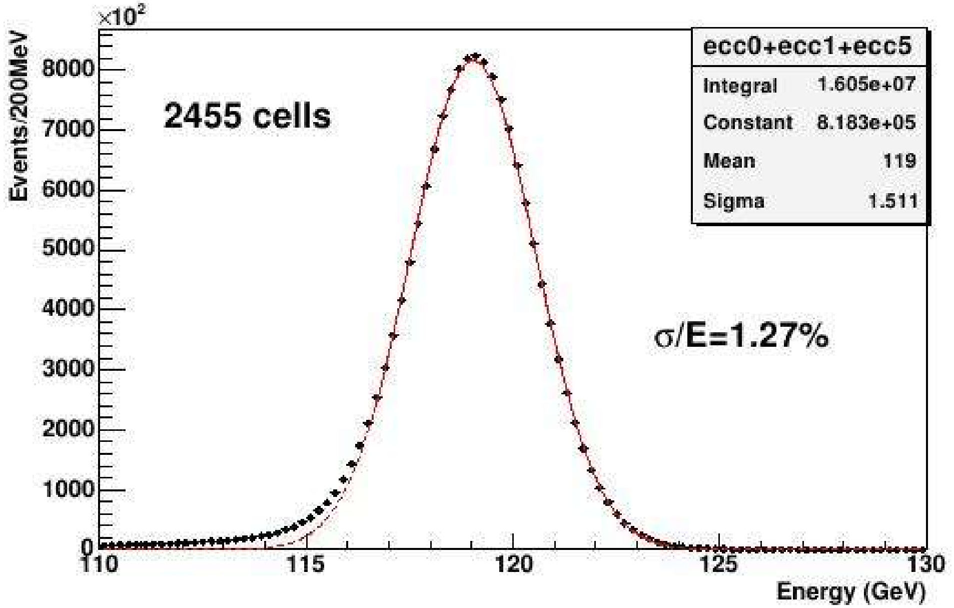


Other small corrections that could be applied: response vs Temperature, etc..

Uniformity and in-situ calibration

- From electronics calibration + calorimeter construction, uniformity inside 0.2x0.4 eta-phi regions should be at the ~0.45% level
- Verified with test-beam of production modules
  - Still quite good over larger area *(->plot next slide)*
- Intercalibration of 0.2x0.4 regions can be checked/done with Z->ee (as well as setting of overall scale)
  - Expected accuracy ~0.4% for ~100pb^{-1}
  - Will absorb imperfections in calibrations described earlier (will need to iterate when these calibrations are changed…)
  - This assumes that corrections for upstream matter are under control (*cf next slide*)
  - Result of this intercalibration can be in principle propagated to the cell level calibration (so that it is also available for jets and Etmiss)
    - If systematics understood
    - Probably a small effect on the jet resolution anyway





Preliminary uniformity from 1 barrel production module beam-tested : 0.48% over ~300 cells.

(M.Kado, LAr week november 05)

Energy resolution at 120 GeV for 3 beam-tested EMEC modules (2455 cells ~ 3 m^2 of detector).

Global constant term <0.7%

E/gamma specific corrections

- Not applied at the cell-level, only for EM clusters
- Corrections for position and energy measurements
- Most complicated correction: correction for upstream energy loss
  - Use PS and strips energy to derive correction
    - Several formula being investigated now (has to balance robustness vs refinement and accuracy)
    - Revisit what to do in EMEC at eta>1.8 (no presampler) ?
  - Not discussed in details here (specific to electrons and photons)
  - Main difficulty: Should disentangle in-situ non-uniformity effects and uncertainties in upstream matter
    - Need more quantitative studies
    - Also need to understand better uncertainties in extrapolation from electrons to photons
  - Will be a challenge for ultimate non-linearity of EM calorimeter (W mass)

Conclusions

- 2 key ingredients to get "correct" e.m. scale calibration
  - Electronic calibration (OFC,ramps, etc…)
  - Energy to current conversion from TB
- Should be careful to have everything done consistently to extrapolate from TB to Atlas
  - We have most of the ingredients in hand, need to go through all this before next year
- Also be careful about "small" changes in some conditions (like temperature) which can gives few % effect on the scale
- Commissioning will bring more informations about electronic calibration + some checks/measurements with cosmics muons
- In situ cross-check with Z can start already with "low" luminosity (~100 pb^{-1} or even less) *Need to disentangle several effects*
- *Can we gain by using also more inclusive electron samples with E/p for the calibration ?*
- Reaching the "ultimate" accuracy for e/gamma will require understanding many difficult systematics
  - But the "ultimate" accuracy for e/gamma is not critical for hadronic calibration

Backups

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  - fSampl = E(LAr)/E(LAr+Abs+Electrodes)
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- "First principle" computation for the EM barrel
  - (nA/MeV)_LAr = q . Vd.E/V
    - Q = 1MeV/W(LAr) *f(recombination)**e*
      - W =23.6 eV
      - f(recombination) ~ 0.965 at our electric field (few % uncertainty)
    - Vd = drift velocity (=Vd(Temperature))
      - Known within few % from measurements *(cf Larg-99-008)*
    - E/V = 1/gap in the straight section (<gap> = 2.1 mm)
    - **Predict (nA/MeV)_LAr = 14.2 nA/MeV**
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