Jet Calibration Issues in ATLAS at LHC

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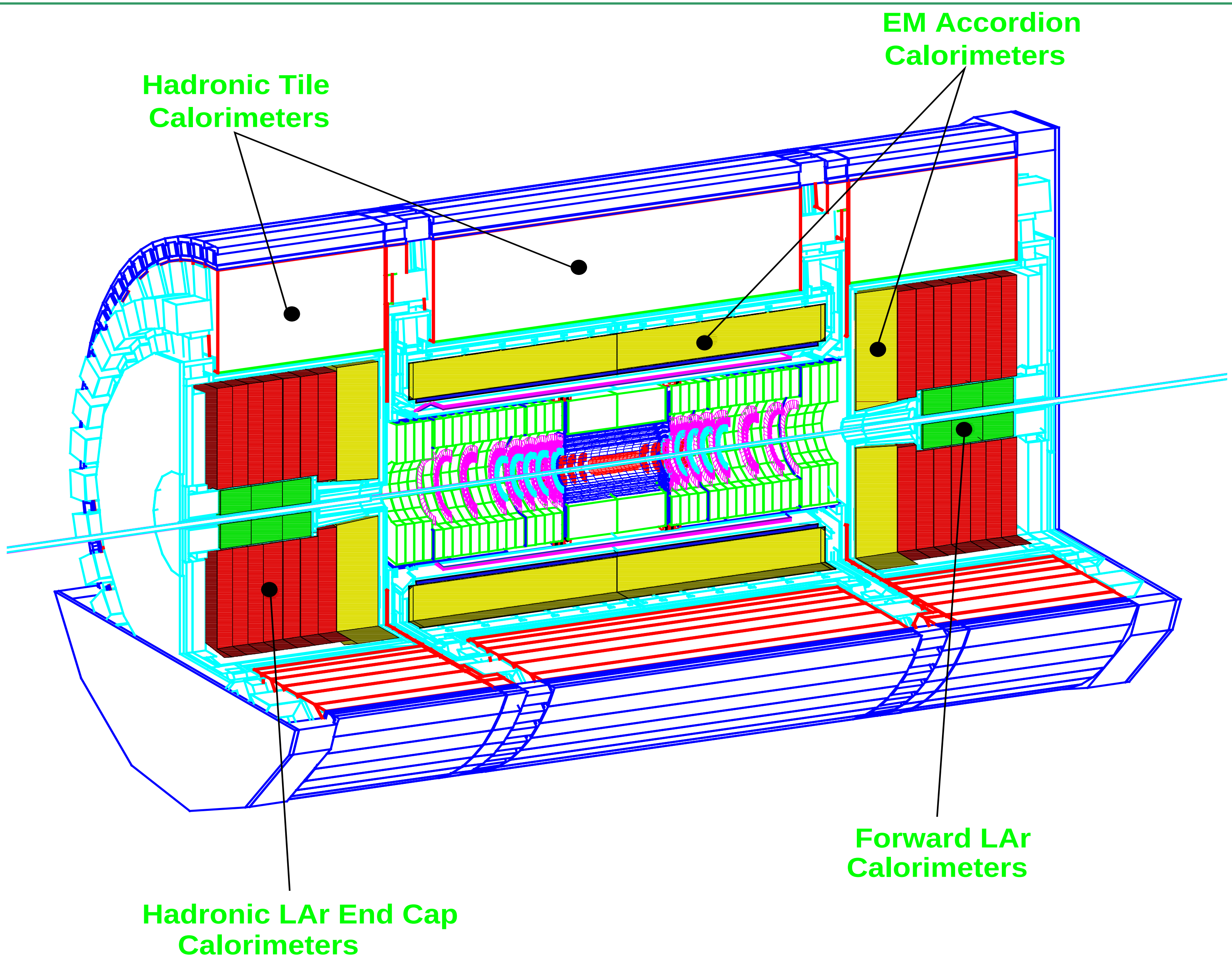
- Introduction
- Calibration Strategy
- Jet reconstruction
- In situ methods
    - Z+jets and W $\rightarrow$ jj samples
- Conclusions

Considerations

- **Physics systematics**
  - fragmentation
  - ISR
  - FSR
  - underlying and MinBias
- **Detector Systematics**
  - response diff to charged and neutral hadrons
  - non linearities
  - B-field
  - dead material
  - long. shower leakage
  - lateral shower size
  - granularity
  - electronics noise
- **Physics cases**
  - mass reconstruction
  - # jets and total E in SUSY searches
  - jet veto down to 15 GeV
  - QCD studies
- **Requirements**
  - Knowledge of E scale for jets should be ~1%

Layout of ATLAS calorimeters



Calibration Strategy

Before LHC….

- Calibration with single particles at testbeam
- transfer of calibration constants to all modules

LHC start !

- intercalibration with single particles at LHC
- in situ samples
  - W $\rightarrow$ jet jet
  - Z+jet balance
- for E regions not reached before? MC...

Jet Energy Reconstruction

… before using the in situ…

fixed-cone algorithm

Cones $\Delta R=0.4$ and 0.7
Seed 2 GeV, Ecell>2σ noise
Etower (0.1x0.1) > 0.2 GeV

Jet ?

- **"Benchmark"** $E= \alpha_1 E_1+\alpha_2 E_2+\alpha_3 E_3+\alpha_4 E_4$
- **"a la H1"** $E=E_1+\sum\alpha_2(\varepsilon_{2,j})\times\varepsilon_{2,j}+\sum\alpha_3(\varepsilon_{3,j})\times\varepsilon_{3,j}+\alpha_4 E_4$

where *1…4* are PS,EM,HAD,cryostat correction terms
and *j*'s refer to cells

and $E_4=\sqrt{E_{em3}\cdot E_{had1}}$

α **'s are function parametrisations wrt to parton energy**

Jet E ?

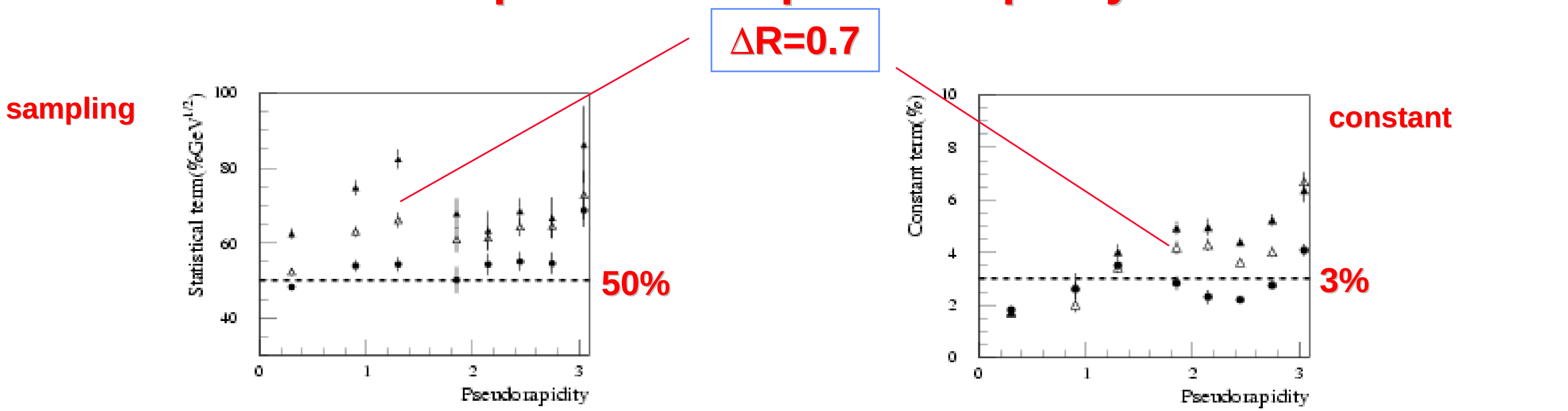
Preserves linearity (calo effects) and resolution but absolute E?

Jet Energy Reconstruction

Jet Energy Resolution terms

	Sampling (% GeV$^{1/2}$)	*Constant* (%)
Barrel	52.3 ± 1.1	1.7 ± 0.1
Endcap	64.2 ± 2.4	3.6 ± 0.2

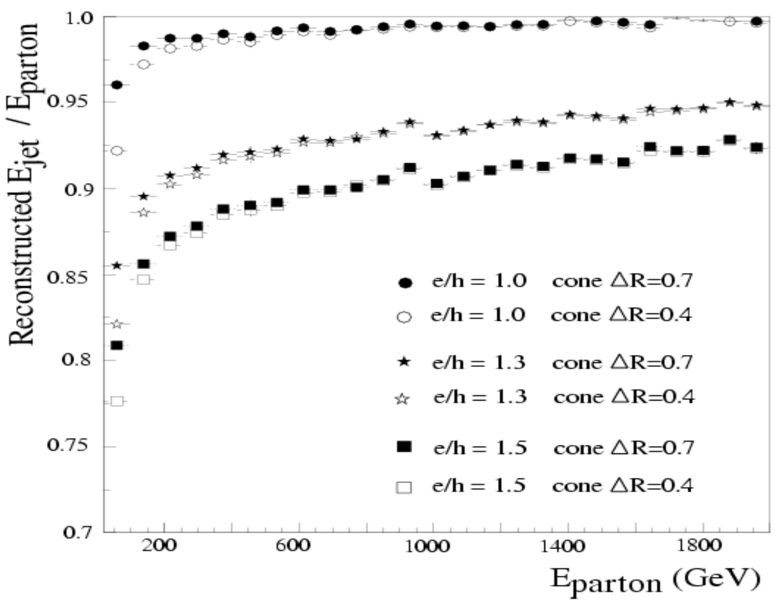
And dependece on pseudorapidity

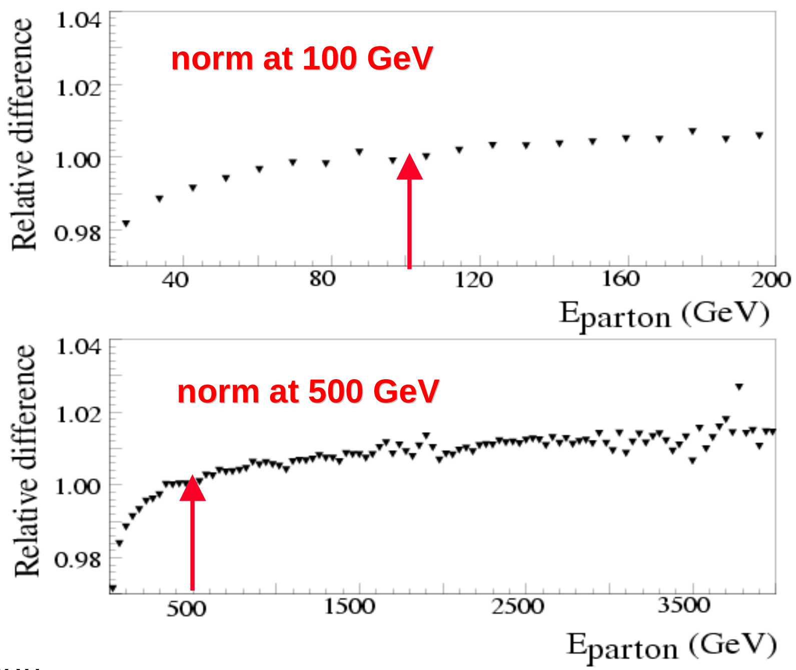


Extrapolation to high E

And after calibrating…..
What if wrong extrapolation to energies not reached before?

Example: Use of a Monte-Carlo not reproducing well the e/h





In situ samples

Need: Absolute for verification
Wish: Statistics should be adequate above bcg
Trigger available
Wide Energy coverage

Choices: Mass reconstruction of the W

- **only light q jets**
- **limited E and η reach**

Balance of p_T between Z and leading jet

- **wider E and η reach**
- **b-jet content**
- **good to transfer calibration across calorimeters?**

In situ samples

Simulated using PYTHIA 5.7

Fast simulation

- **smearing with calorimeter resolution**
- **jet finding from deposited energy in towers**

Full simulation

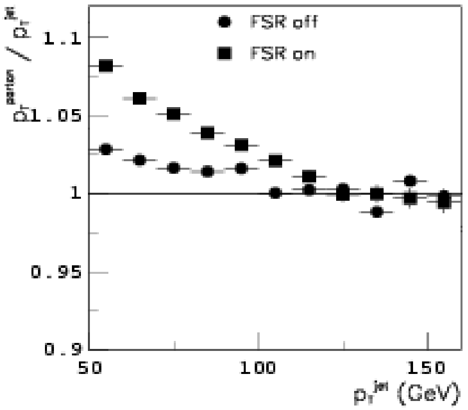
- **using GEANT 3.21**
- **G-Calor calorimeter response model**
- **addition of pile-up events and electronics noise**
- **digital filtering for cell energy reconstruction**

In the following studies

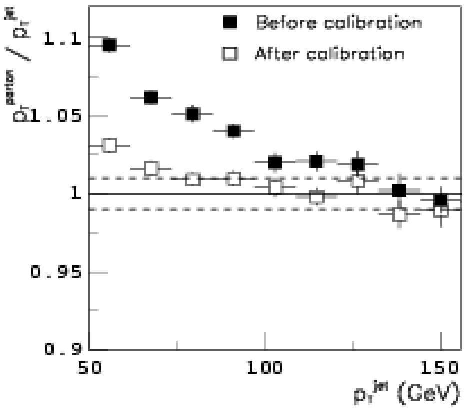
- **Fixed cone algorithm used for jet reconstruction**
- **Benchmark/Sampling method for jet E calculation**

In situ W ➔ jj

W's are abundant in the top sample
At low L 1500 lνjjbb final states/day
No bcg problem tagging the isolated lepton and two b-jets out of the the four



p_T^{parton}/p_T^{jet}



<u>After calibrating:</u>

~50 GeV out of cone losses

>200 GeV jet overlap pbms
(add cut of ΔR>0.8)

>70 GeV 1% is achievable

~50 GeV 3% looks fair

In situ W→jet jet

- High statistics W → jj decay in tt events should provide the wished 1% absolute scale precision from 50 to few hundred GeV.
- Lower end of spectrum:
  - interplay between FSR and out of cone losses for specific reconstruction algorithms
- Higher end
  - residual effects due to overlap are significant and statistics start to be a problem after cuts for well-separated jets

In situ Z+jet

Direct Z production, events with Z+jets where Z→ee or Z→$\mu\mu$
Method: p_T balance between Z (leptonic/precisely measured) and highest p_T jet
Large cross section, no statistics problem

… but balance is not perfect

- **fractional imbalance between Z and jet :**

$$\mathrm{FrI} = \frac{p_T^Z - p_T^{jet}}{p_T^Z}$$

p_T imbalance wrt to processes

HP	+UE	+FSR	+ISR	
0.026	0.005	0.050	0.097	$20<p_T<60$ GeV jets
0.015	0.002	0.034	0.071	$60<p_T<120$ GeV jets

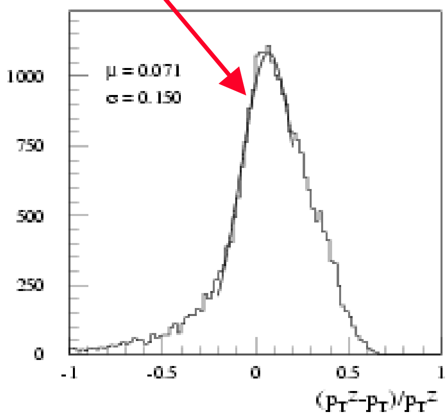
In situ Z+jet

Selections to favour topologies with back-to-back Z and jet

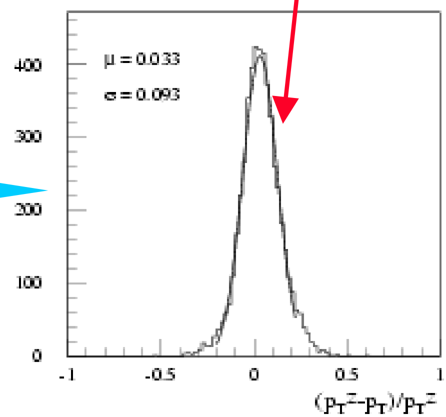
- **azimutal angle between Z and leading jet > 3.06 rad**
- **loose jet veto: no other jet p_T>40 GeV and $|\eta|$<3.2 (**possible at high L**)**
- **tight jet veto: no other jet p_T>15 GeV and $|\eta|$<4.9**

p_T imbalance wrt to selection cuts

1 jet p_T>20 GeV η<3.2	$\Delta\phi$>3.06 rad	$\Delta\phi$>3.06 rad Loose jet veto	$\Delta\phi$>3.06 rad Tight jet veto	
0.097	0.050	0.049	0.044	20<p_T<60 GeV
0.071	0.042	0.041	0.033	60<p_T<120 GeV



Fr I

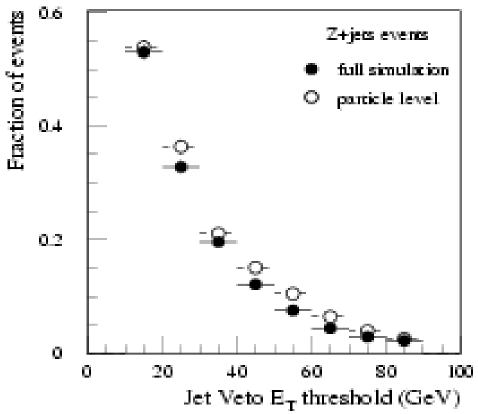


In situ Z+jet

Impact of cuts assessed also with full simulation

Example is the jet veto capability with comparison between fast and full simulation

Fraction on events with >1 jet is reconstructed wrt to the p_T threshold applied



Cone ΔR = 0.7

adjustment of p_T threshold to take into account the EM scale calibration in full sim

Good agreement between fast and full sim in jet veto efficiency!

In situ Z+jet

Number of jets after cuts for 10 fb^{-1} integrated luminosity in calorimeter and p_T regions

	20-60 GeV	60-120 GeV	>120 GeV
Barrel (… 1.7)	340K 9K	180K 4K	44K 1K
End-cap (… 3.2)	190K 5K	90K 1.5K	16K 0.5K
Forward (… 4.9)	30K	10K	1K

Nr of b-jets
90% purity

Rates after cuts are adequate for statistical sensitivity of 1% for p_T<200 GeV.

Nr of b-jets assuming 50% tagging efficiency hopefully sufficient to constrain b-jet scale to % level.

NB overall jet sample content:
28% gluon , 54% light quark, 12% c and 6% b-jets

In situ Z+jet

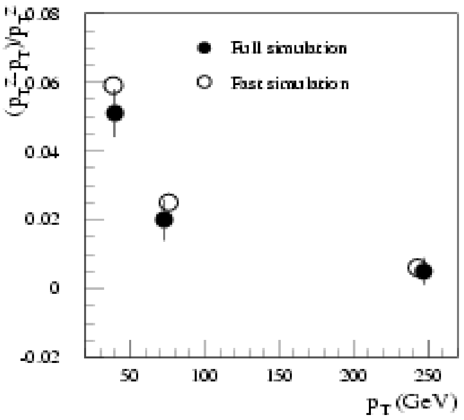
Comparison between full and fast simulation

	1 jet p_T>20 GeV η<3.2	$\Delta\phi$>3.06 rad	$\Delta\phi$>3.06 rad Loose jet veto	$\Delta\phi$>3.06 rad Tight jet veto
Fast:	0.053 0.106	0.040 0.091	0.039 0.089	0.033 0.076
Full:	0.057 0.089	0.037	0.027	0.024 0.050

all jets
b-jets

Average Fractional Imbalance in three p_T ranges

p_T>40 GeV and $|\eta|$<3.2



In situ Z+jet

Accuracy of the calibration in this sample

Reconstructed jet p_T rescaled to balance the Z p_T wrt to the original parton p_T

Fractional imbalance of the two p_T's

20-60	60-120	>120
0.049	0.015	0.004

GeV

Systematics and effect on fractional imbalance

Uncertainties in modelling ISR:
1.5 factor in $\Lambda_{QCD} \rightarrow \pm 1.5\%(0.3\%)$ at low (high) p_T

Topology uncertainties on back-to-back:
$\Delta\phi$ cut tightening by 0.06 rad $\rightarrow$ -0.7% to -0.1%

Cone enlarging to $\Delta R=0.7 \rightarrow$ 0.3%

Outlook

- The 1% jet calibration uncertainty is difficult but it seems not impossible with the current studies
- The two types of in situ samples are somewhat complementary
  - $W \to jj$
    - will provide very accurately the E-scale at intermediate energies but
    - systematics rise at the low and high end of spectrum
  - Z to jet balance
    - can reach higher energies and $|\eta|$ (even the forward)
    - systematics are very high at low energies, but above 60 GeV the 1% requirement seems possible
    - can offer separate calibration of b-jets
    - can transfer calibration across calorimeters
    - can check the linearity of calorimeter (TeV values at the endcap and forward regions)