Jet Energy Scale in ATLAS

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Introduction

- Brief intro to atlas calorimeter
- Key difficulties concerning jets in Atlas and LHC
- Atlas hadronic calibration
- Review of Jet Energy Scale estimation in Atlas

Jet energy scale and resolution : objectives in Atlas

Atlas collaboration has ambitious physics goals
Some of them require excellent jet reconstruction

- EW precision measurements (Mass of the W)
- Top physics

We want to achieve good results on resolution and JES

Resolution

TDR objective $$\frac{\sigma(E_T)}{E_T} = \frac{0.5}{\sqrt{E_T}} + 0.03$$

Jet Energy Scale

Some studies presented here show 1% is achievable in top studies
Can we do as well in general ?

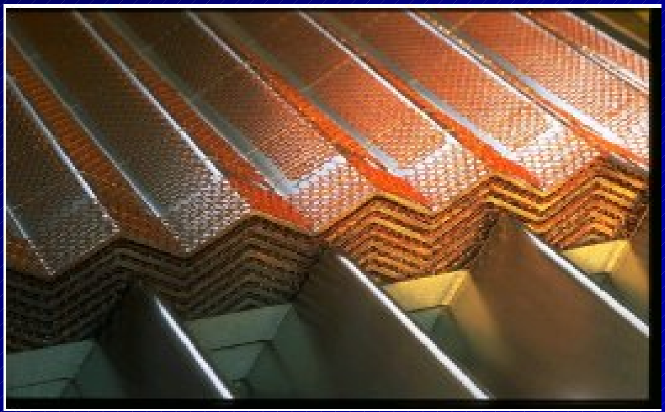
Atlas calorimeters

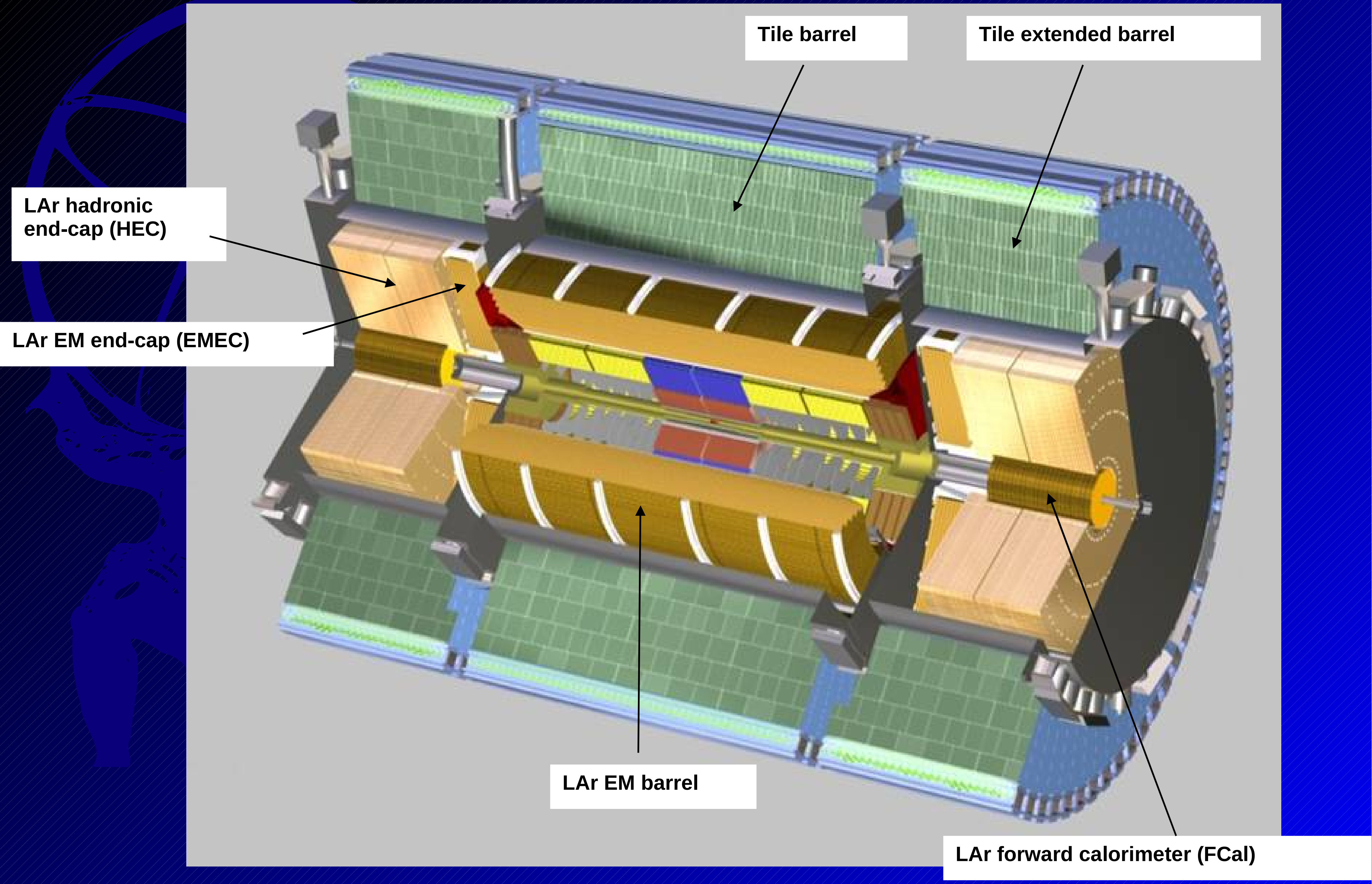
EM Calorimeter
- Liq. Ar and Lead
- Accordeon shape
- $|\eta|<2.5$

Hadronic EndCap
- Liq. Ar and Copper
- $1.5 < |\eta| < 3.2$

FCAL :
- Liq. Ar and Copper/tungsten
- $3.2 < |\eta| < 4.9$

Tile Hadronic Calorimeter :
- Scintillators and Iron
- $|\eta| < 1.7$





Tile barrel
Tile extended barrel
LAr hadronic end-cap (HEC)
LAr EM end-cap (EMEC)
LAr EM barrel
LAr forward calorimeter (FCal)

Hadronic energy response in Atlas

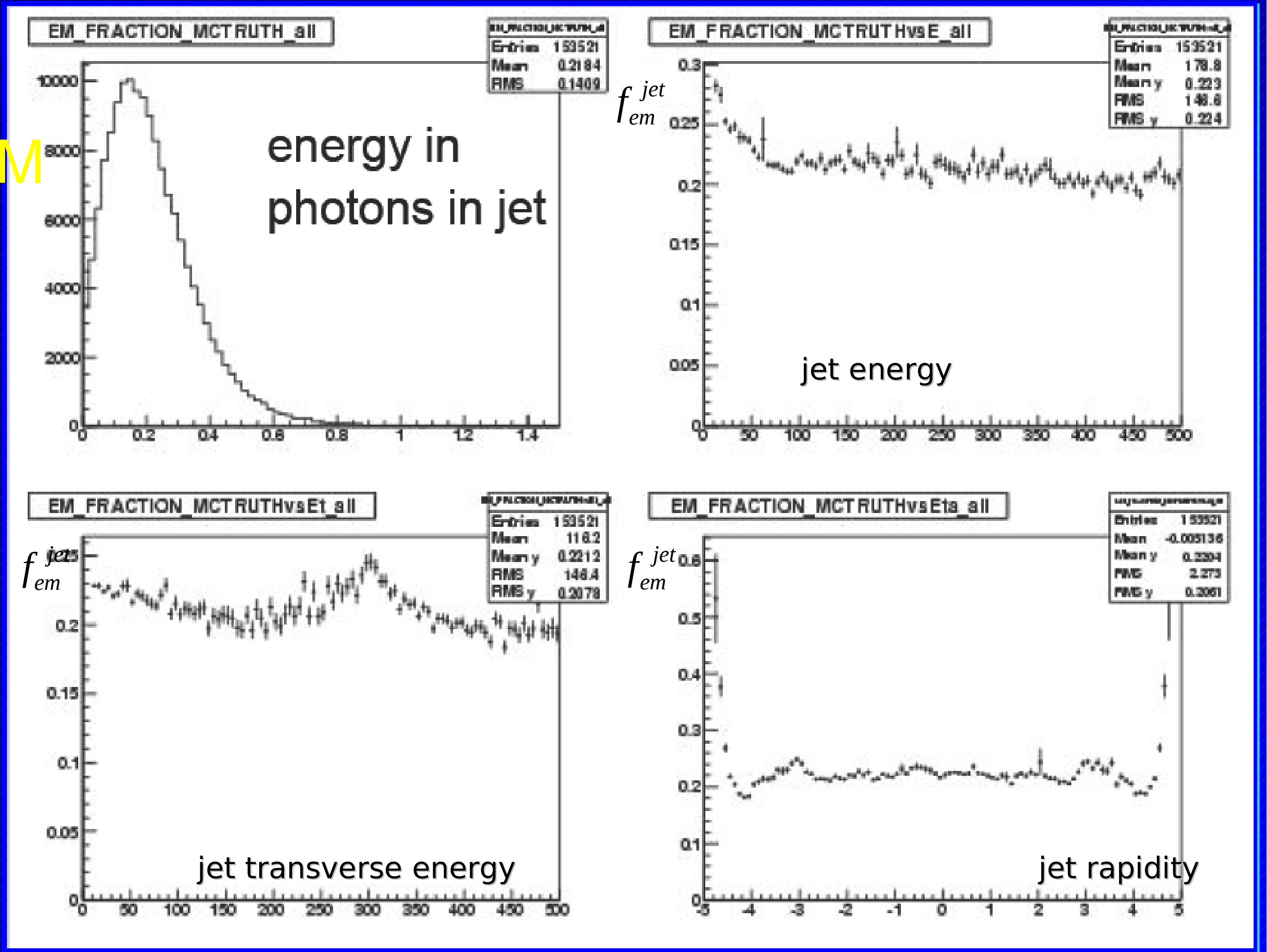
Non-compensating Calorimeter :
e/h ~ 1.3-1.6

Jets contain important EM contribution

This is the first effect to correct

Lots on effort on this topic

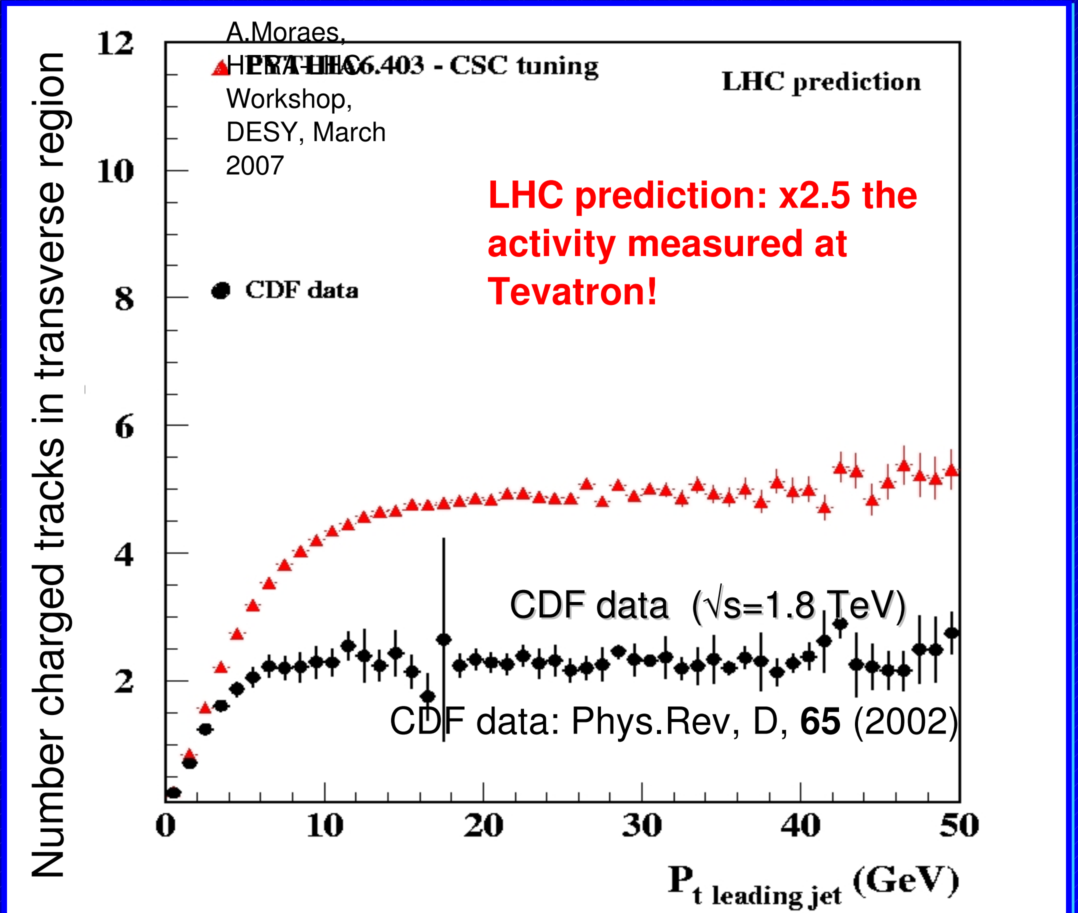
Photon energy in jets at LHC (Pythia 6.2)



LHC environement

Physics environment different from Tevatron

- Increased underlying event activity (more phase space)

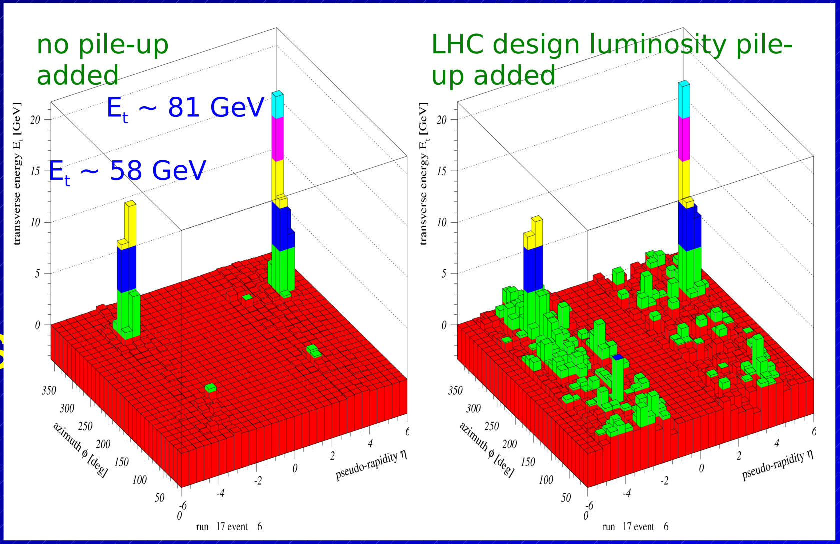


- Pile-up

LHC environement

Pile-up :

- 23 interactions per bunch crossing
  lots of additional particles per bunch crossing :
  370 particle/ rapidity units
  1800 charged tracks



- Calorimeter slow
  in Lar : full response time ~500 ns
  bunch-crossing every 25ns

Atlas hadronic calibration strategies

(from P. Loch, 2007)

- **CaloCells** (em scale)
- ↓ Tower Building ($\Delta\eta\times\Delta\varphi=0.1\times0.1$, non-discriminant)
- **CaloTowers** (em scale)
- ↓ Tower Noise Suppression (cancel E<0 towers by re-summation)
- **ProtoJets** (E>0,em scale)
- ↓ Jet Finding (cone R=0.7,0.4; k_t)
- **Calorimeter Jets** (em scale)
- ↓ Jet Based Hadronic Calibration ("H1-style" cell weighting in jets etc.)
- **Calorimeter Jets** (fully calibrated had scale)
- ↓ Jet Energy Scale Corrections (noise, pile-up, algorithm effects, etc.)
- **Physics Jets** (calibrated to particle level)
- → In-situ Calibration (underlying event, physics environment, etc.)
- **Refined Physics Jet** (calibrated to interaction level)

The global calibration scheme

Conceptually simple :

- Start from basic EM signal
- Build protojets (towers, clusters)
- Find jets
- Calibrate Jets

Calibration :

- At jet level
- based on cell weighting

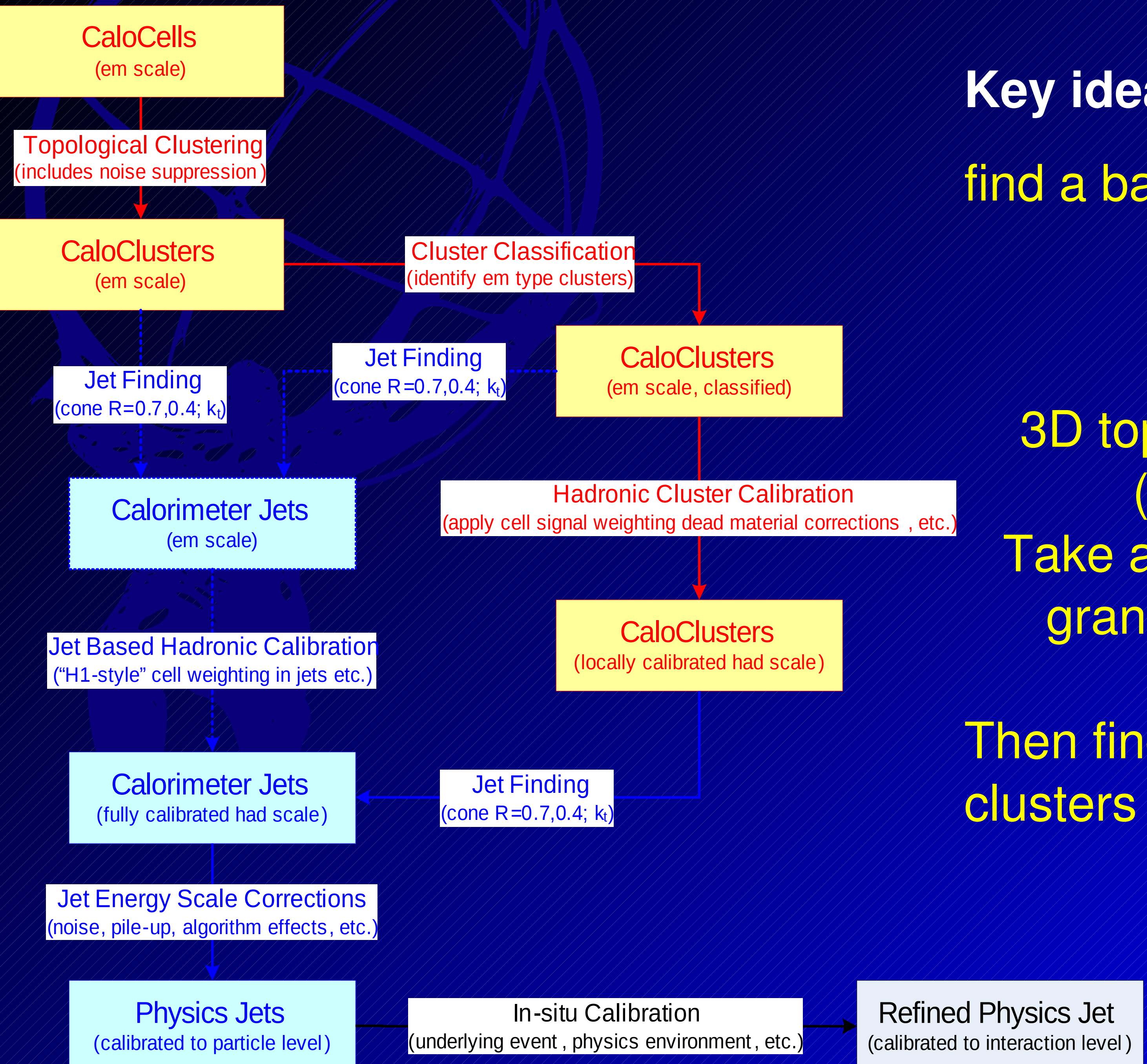
by default 'H1-like' (depends on energy density)

Has some disadvantages:

in non-compensating calos

Try to correct lots of effect with few numbers

Atlas hadronic calibration strategies II



Key idea :

find a basic hadronic signal in calorimeter

3D topological clustering (4/2/0 scheme)
Take advantage of the fine granularity of the calo !

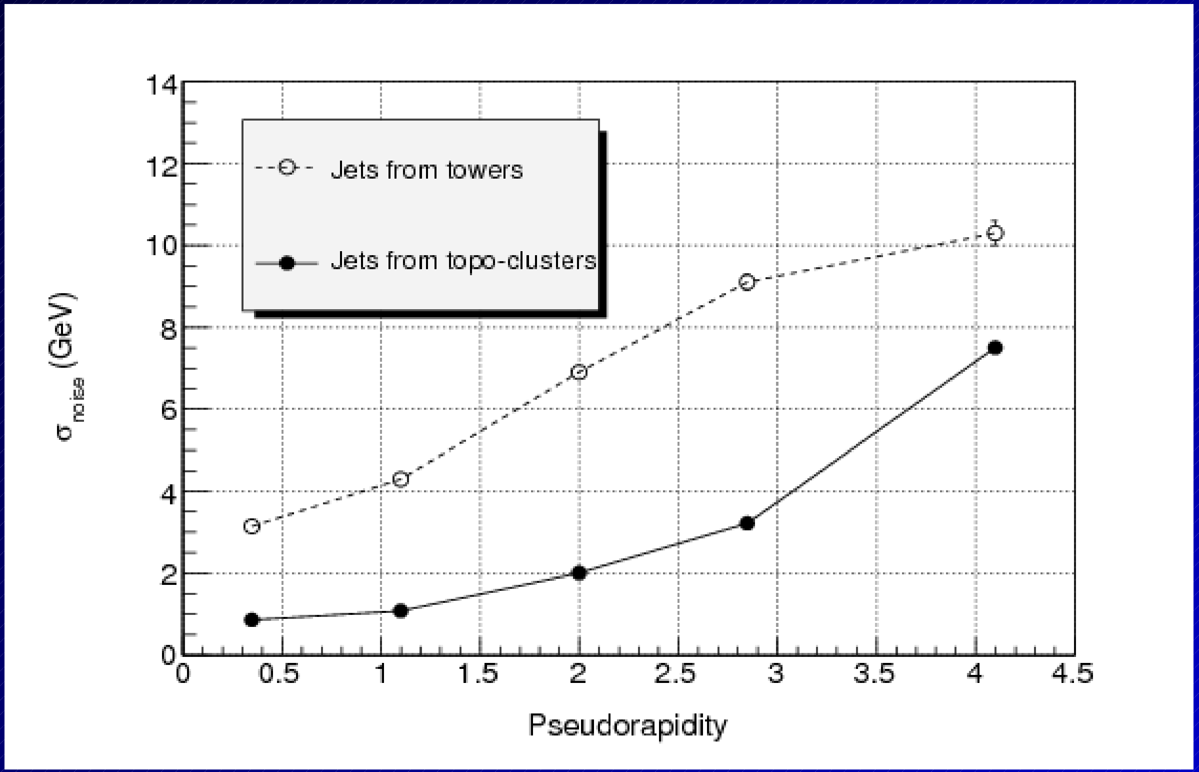
Then find jets on calibrated clusters

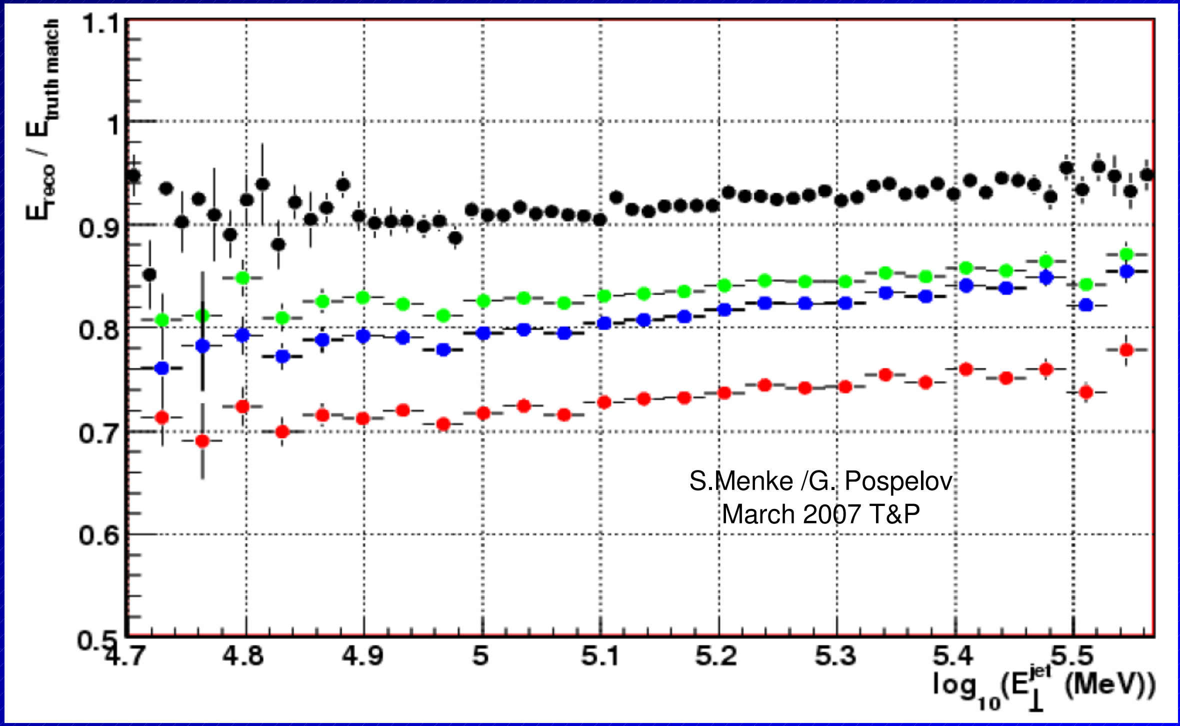
Advantages :

- Much better noise suppression

- Factorized corrections
    - Hadronic
    - Dead material
    - Out-of-cluster energy

- Calibrated input:
    - physical interpretation
    - ~ massless pseudo-particles

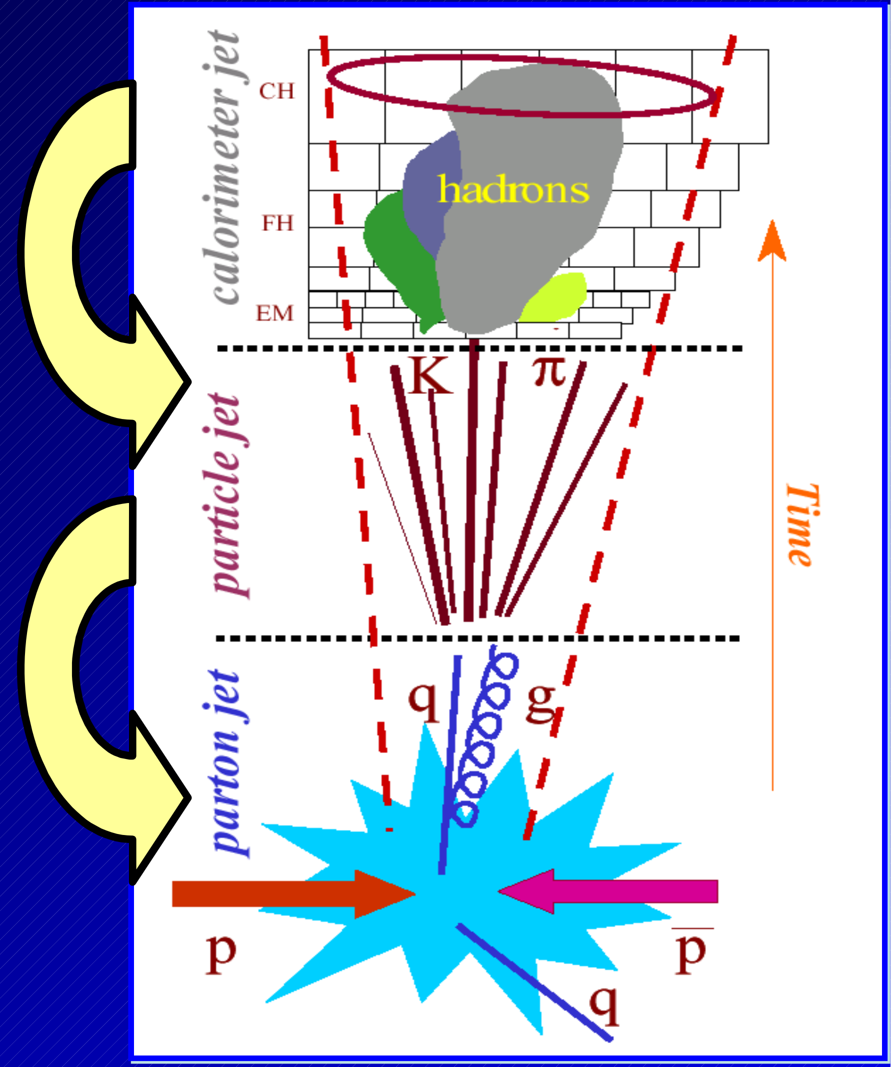




Finding Jet Energy Scale

Hadronic calibration

Jet energy scale/
In situ calibration



Several studies done in ATLAS

- Z+jets, gamma+jets
- E/Pt in tau samples
- Di-jets balance
- In-situ calib through W mass in ttbar samples

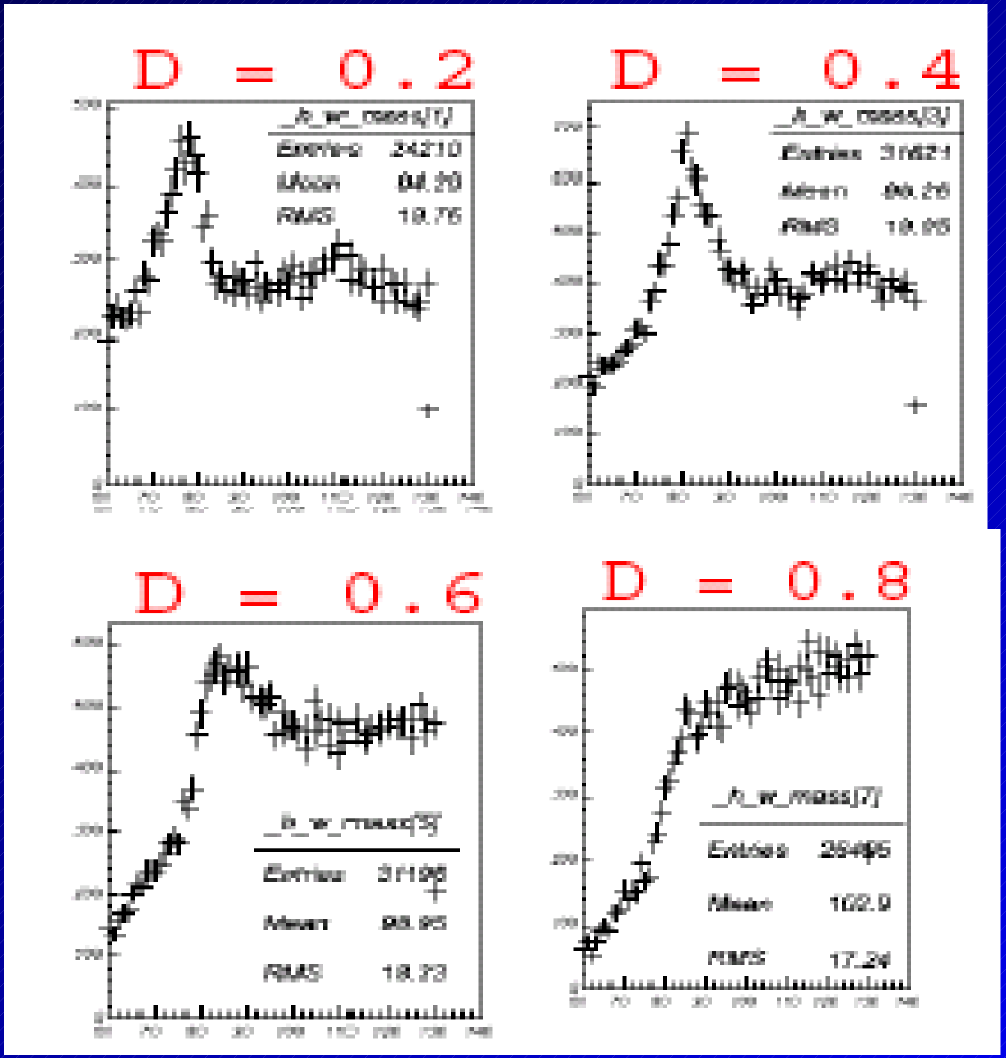
Jet Algorithm

First order effect is
Jet Algorithm and their
main parameter

Jet Algorithms behaves
differently under
different analysis

Jet Algorithm are differently
affected by
Pile-up

N.Godbhane, JetRec June 2006



top quark mass distrib for different
value of the D parmater of Kt Algo

Energy Scale from Z+jets, gamma+jets

Principle :

- Pt conservation
- Z or gamma are well calibrated objects

Extract information on JES of the jets recoilling against these objects

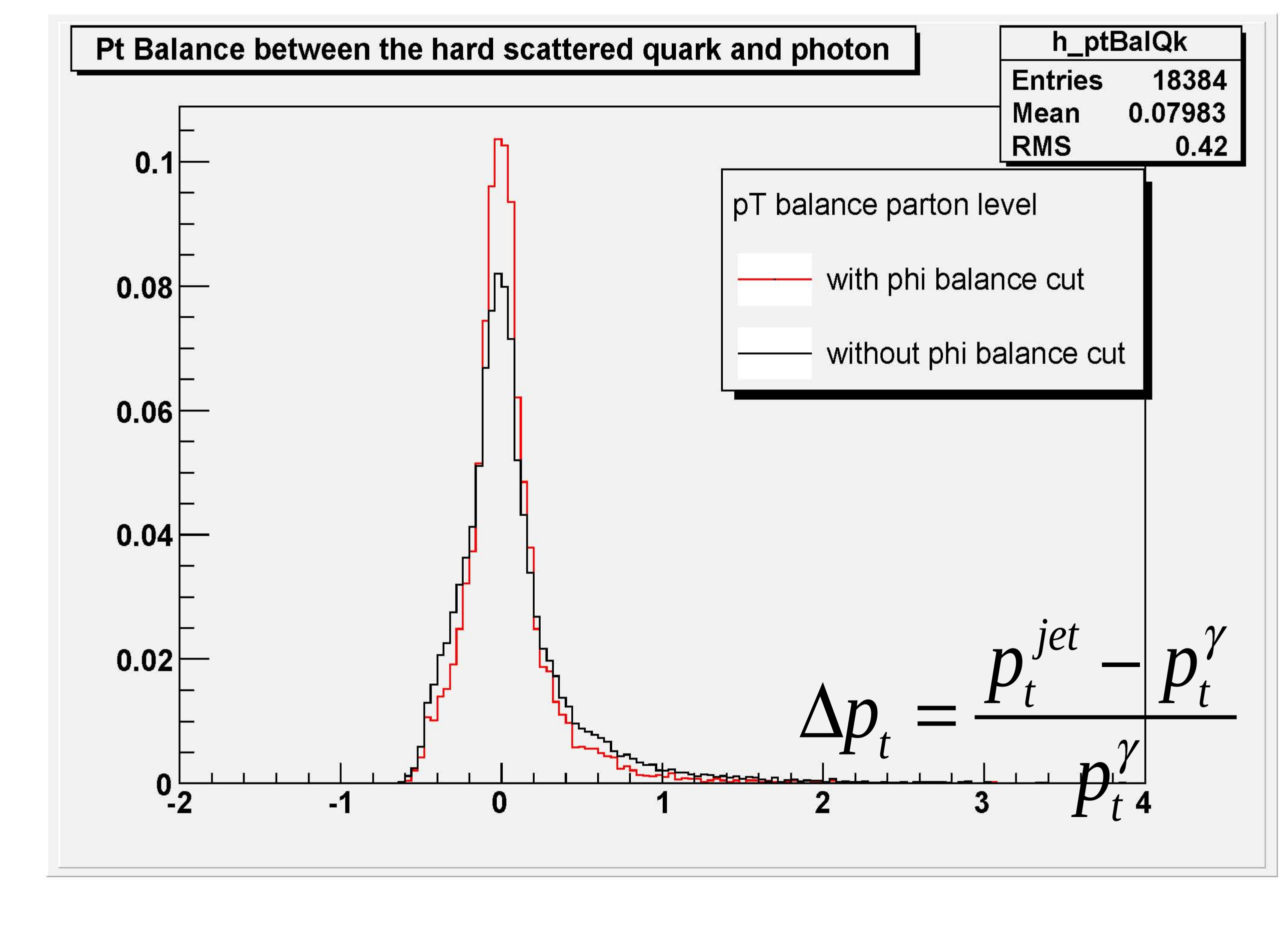
- Balancing against
  - gamma : large statistic, larger QCD backgrounds
  - Z : clear signal, lower statistics

- Accessible Pt tange ~[40GeV, 400GeV]
- Need to control biais (Trigger, selection procedure...)

- 2 ways of using this events : **Pt balance** & **Missing Et projection**

Z/gam+jets : Pt balance

Basic procedure :
- select isolated gamma
  +Ptcut >30GeV
- select highest Pt Jet
- phi back-to-back cut



Compare
parton, particle, reco jets

Extract JES

Several studies have been performed :
- gamma+jets
- Z+jets
- Recoil against 1 or several jets

Uncertainties :
- kinematic cuts
- physics effects

→ Uncertainties around 3%

Z/gam+jets :Missing Et Projection

Principle :

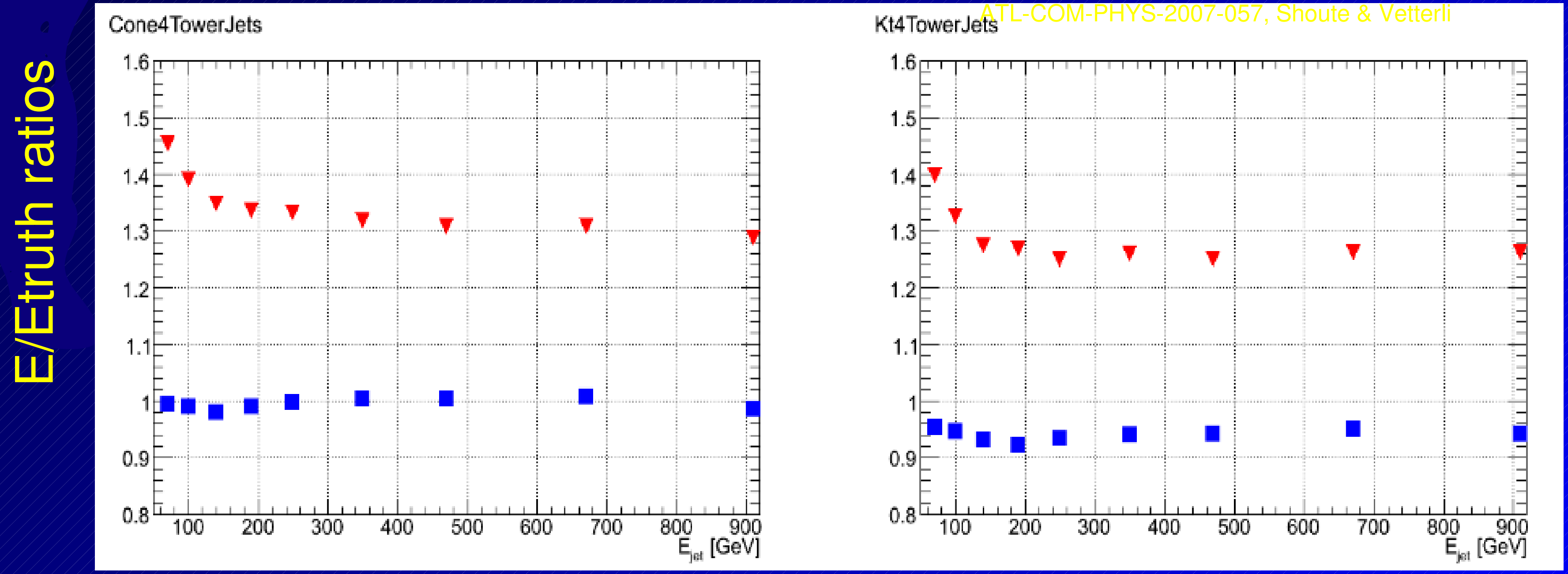
Do not use Jets to estimate the response

Project Etmiss against Z direction

$$R = 1 + \frac{E_T^{miss} \cdot \hat{n}_T^Z}{P_T^Z}$$

Measure R in different energy bin

Extract JES by fitting the mean values in bins as fct of E



Estimated uncertainty : 2-3 %

In-situ calibration in ttbar studies

Principle :

Use W hadronic decays

Constraint JES thanks to the well know W mass

Precision on jets angle good enough :

$$M(W)_{PDG} = \sqrt{\alpha(E_1)\alpha(E_2)}\, M(W)_{j_1 j_2}$$

Restrictions :

Light jets

Pt range : 40 – 400 GeV

Eta range <2.5

3 Methods in Atlas

Chi-squared fit

Templates

Iterative method

W-> jj : Chi-squared method

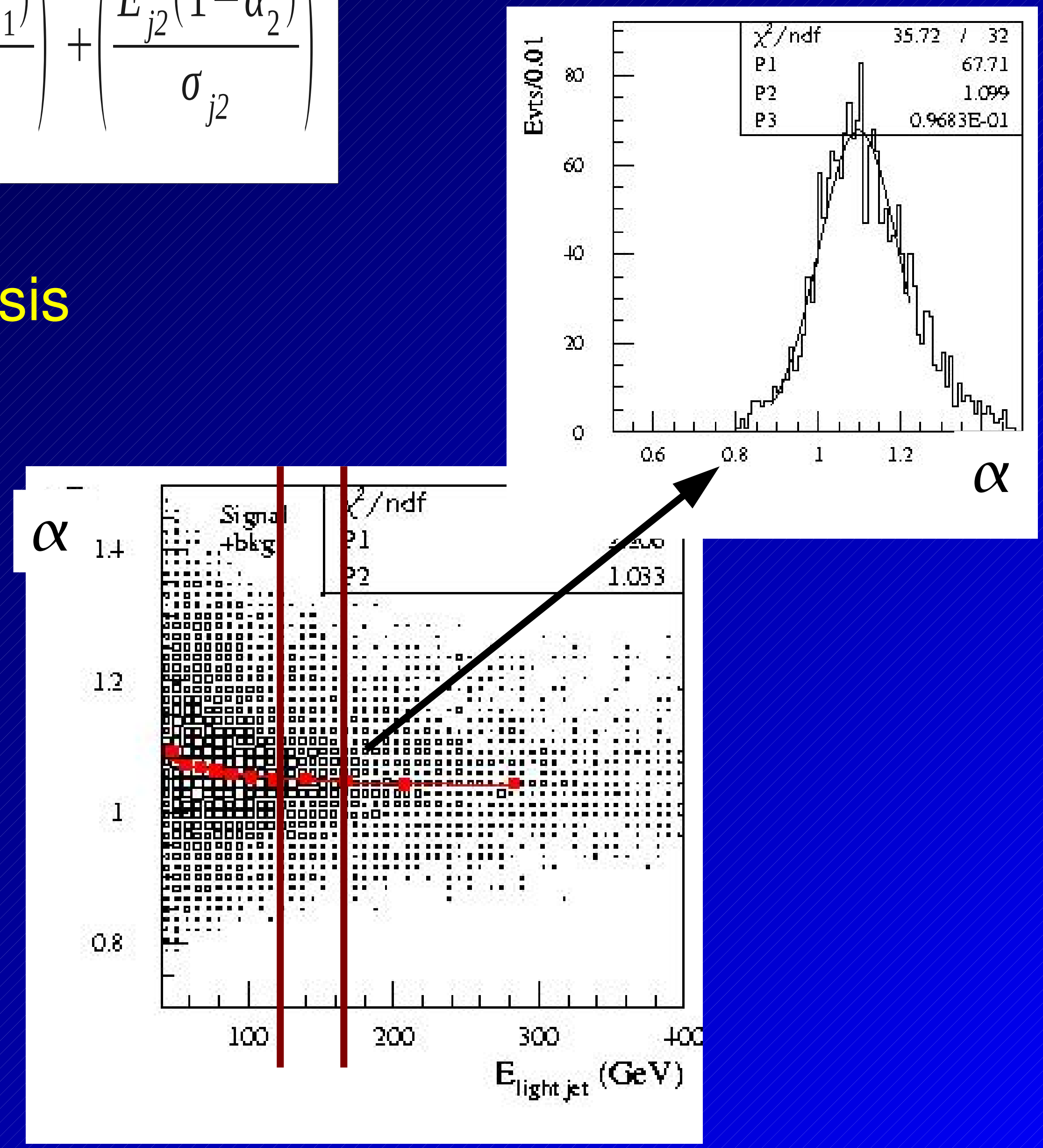
$$\chi^2 = \frac{\left(M_{jj}(\alpha_1, \alpha 2) - M_W\right)^2}{\Gamma_W^2} + \left(\frac{E_{j1}(1-\alpha_1)}{\sigma_{j1}}\right)^2 + \left(\frac{E_{j2}(1-\alpha_2)}{\sigma_{j2}}\right)^2$$

SN-ATLAS-2004-040

Minimize on event-by-event basis

Fit alpha distributions in E bins
→ extract JES

JES depends on E only



W-> jj : templates method

1. Start from MC ttbar events

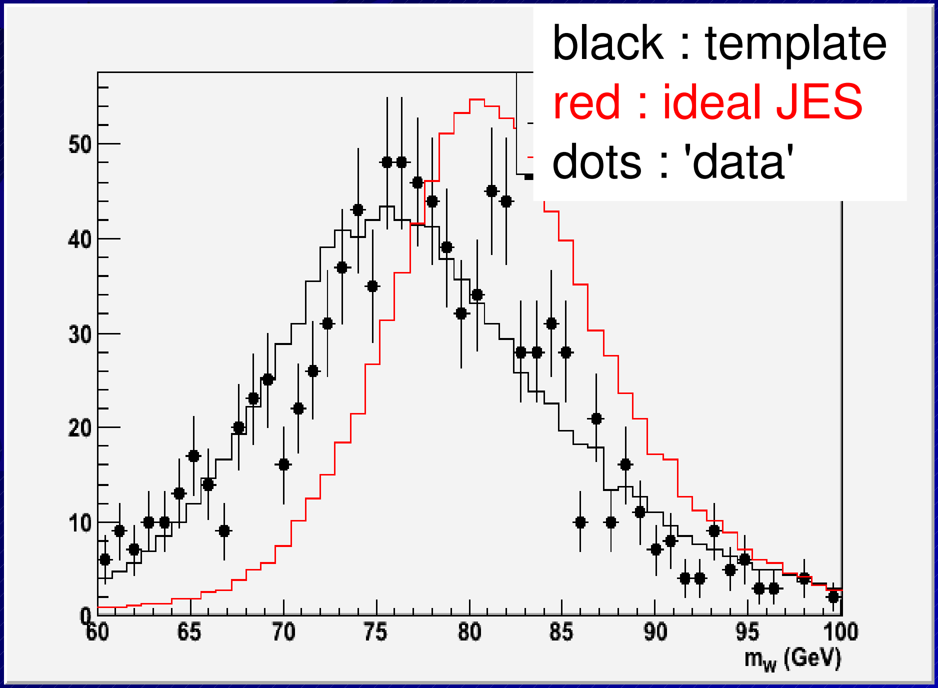
(N. Besson, J schwindling et al)

2. Smear quantities for W quarks :

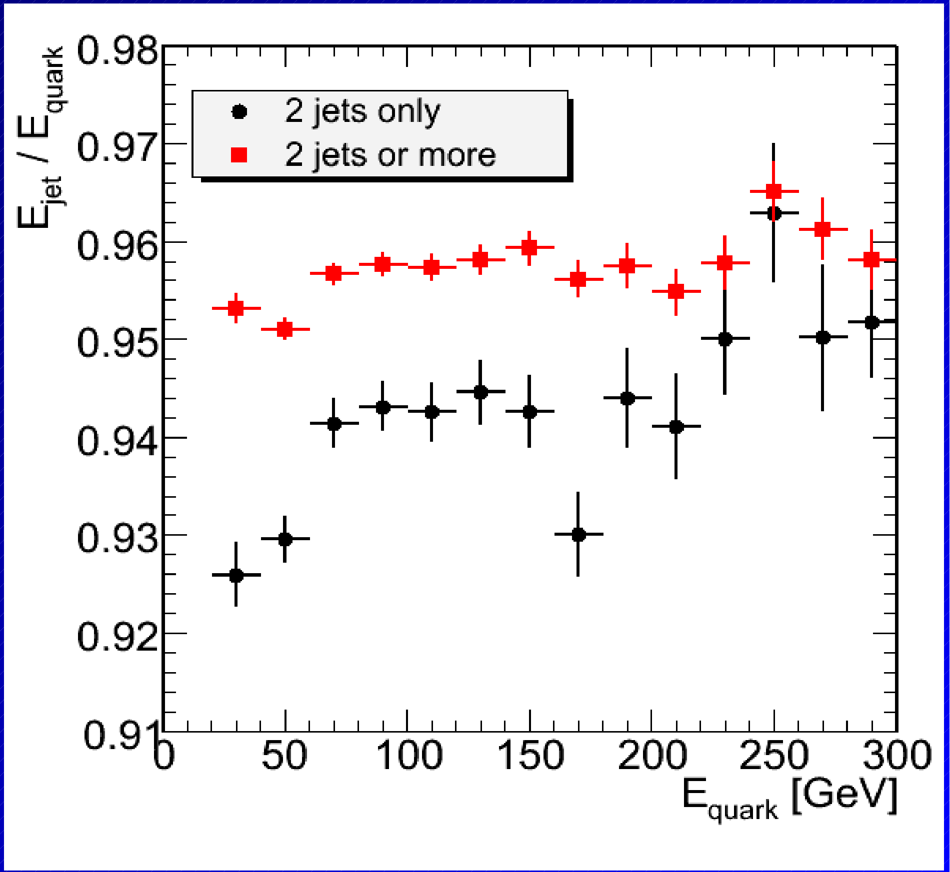
   energy scales α and relative energy resolutions β

3. Generate set of histograms for different values of quanttities

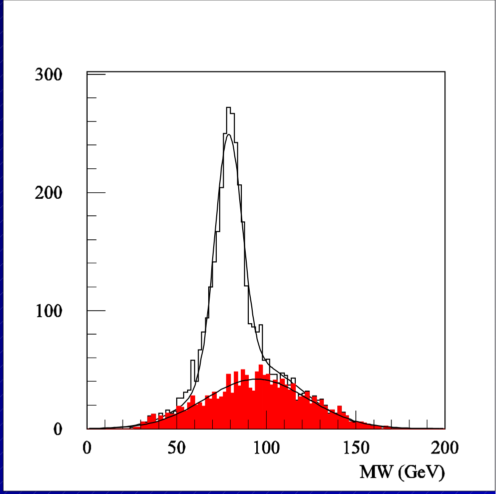
4. Fit each template histogram to m_{jj} in the « data », find best χ^2



Mass distribution



W-> jj : Iterative method



Principle :

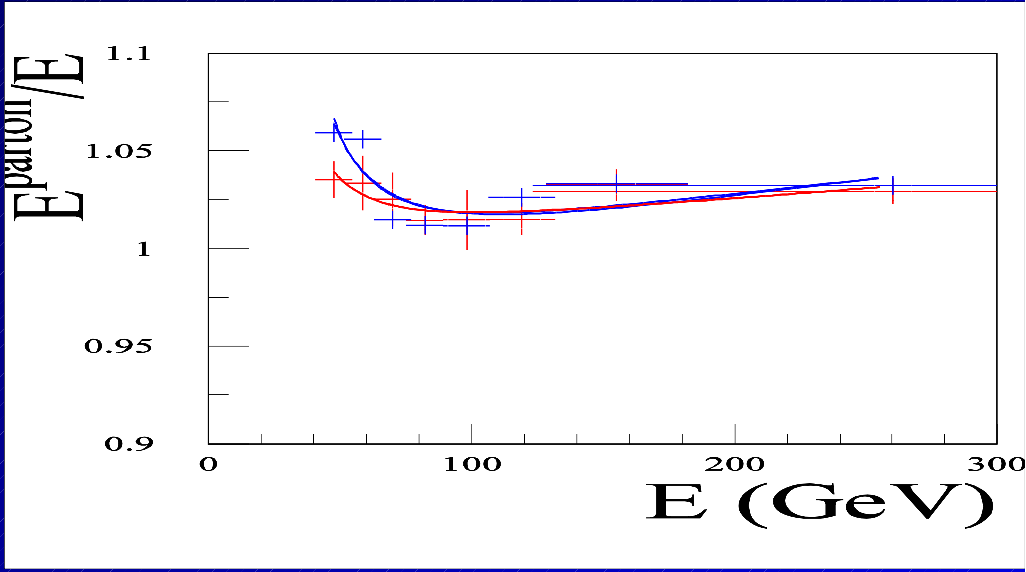
Use Mw distribution around peak, separate in E bins

$$R(E) = MW_{PDG} / M_{J1J2}(E)$$

Apply R(E) to each jet (E_1 -> $R(E_1)$xE_1)

Iterate ~3 times

$$JES(E) = \prod_{niter} R^n(E)$$



(E. Cognéras, D.Pallin)

Methods have been compared

- Similar results
- Statistical uncertainties (Iterative method) :

  750 pb^{-1} ~0.5 %
  100 pb^{-1} ~2.0%

- Systematics uncertainty estimated <1 %

Conclusions

Lots of effort have been made to build a refined calibration scheme

- provide a good hadronic signal

Several preparation studies for JES and In-situ calibration

- In top studies the show we can reach 1% uncertainty on JES
- Can we do as well in general ?

Anyway it will take time to reach this quality

- Difficult environment
- Understanding the detector

Experience from Tevatron is very welcome and certainly fruitful