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Jet Uncertainties: physics, detector and in-situ tests

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Introduction

- Usually uncertainty means how sure you are about the measurement of a intrinsically well defined object
- However a jet is not a intrinsically well defined entity : ***a jet is what the jet algorithm says it is***
- The goal of the jet algorithm is to relate the kinematic properties of the jet to the hard scattering partons
- The hard-scattering-parton concept is our way to translate the electron-positron collision concept into the hadronic colliders
- But an hadronic collision is nothing like an electron-positron collision
  - A proton is a composite object of color-charged particles
- Thus the uncertainty concept gets into a new dimension when applied to jets
- This is the end of the abstract part of the talk, now I'll move to the pragmatic one: what has been done to deal with the issues above

Generation uncertainty

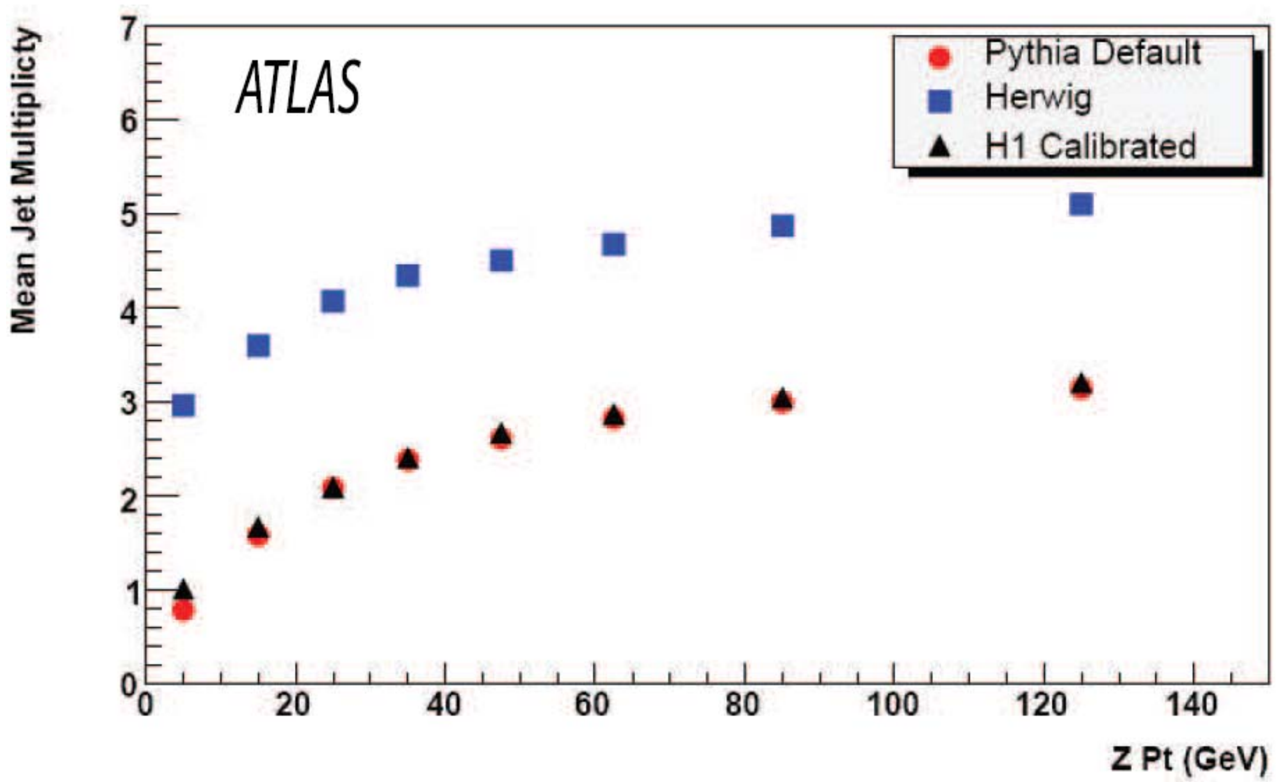
- The correct determination of the jet energy scale relies completely on the MC. Thus, the uncertainties coming from the MC modeling have an strong impact on the jet energy scale uncertainty
- At the moment Pythia is widely used as MC generator for jet studies.
- MC production with other MC generators exist but a set of systematic studies using different MC generators is not available
  - In-situ tests have been studied using Alpgen and Herwig
  - Are the different jet corrections MC independent?
    - *Pile-up corrections*
  - Are the jet properties MC independent?
    - *Jet shapes*

PYTHIA : on-shell leading order matrix elements, high order using ISR/FSR using DGLAP evolution. Lund string fragmentation produce final state hadrons

HERWIG : parton shower approach for ISR/FSR + cluster fragmentation model. It is used with JIMMY as underlying event generator

ALPGEN : Multiparton MC generator, used with HERWIG (parton showering) and JIMMY (underlaying events) with an special matching to avoid double counting

Generation uncertainty (II)



Number of jets obtained in Z + jets events with 2 different generators

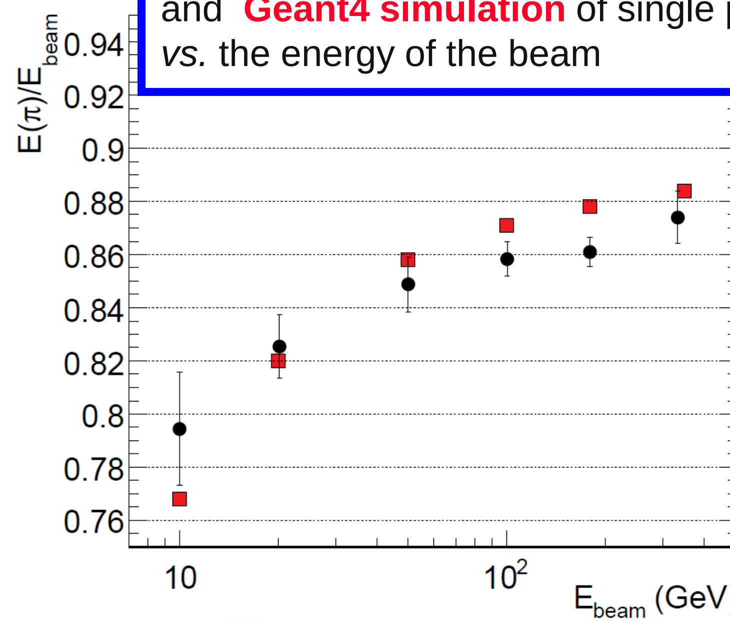
The number of jets is highly dependent of the MC generator

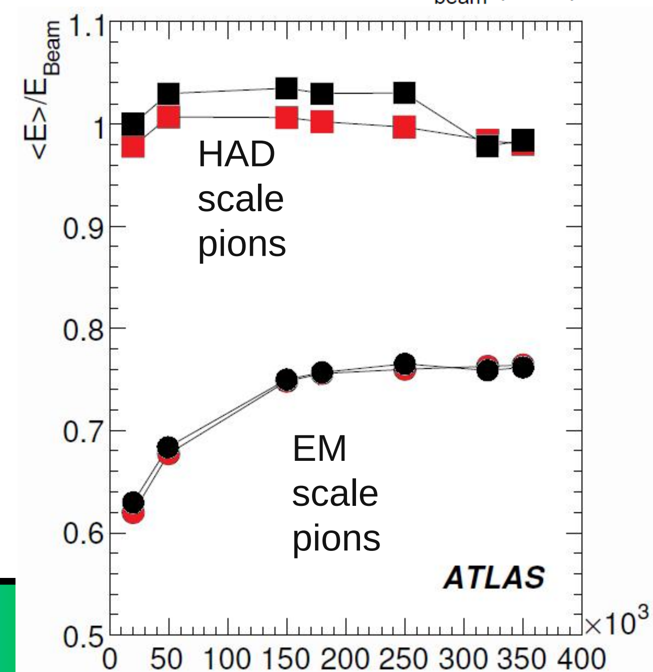
And Pythia and Herwig are both LO generators

Simulation uncertainty

- Our calorimeter is non compensated and thus non-linear.
- All the offline methods to correct the calorimeter non compensation are based in the Geant4 simulation of particles going through the detector.
- The hadronic shower is simulated using QGSP and Bertini cascade models. Also QGSP and EMV has been used.
- To what extend the uncertainty of the hadronic cascade (*physics list*) affects the weights to correct the calorimeter non compensation?

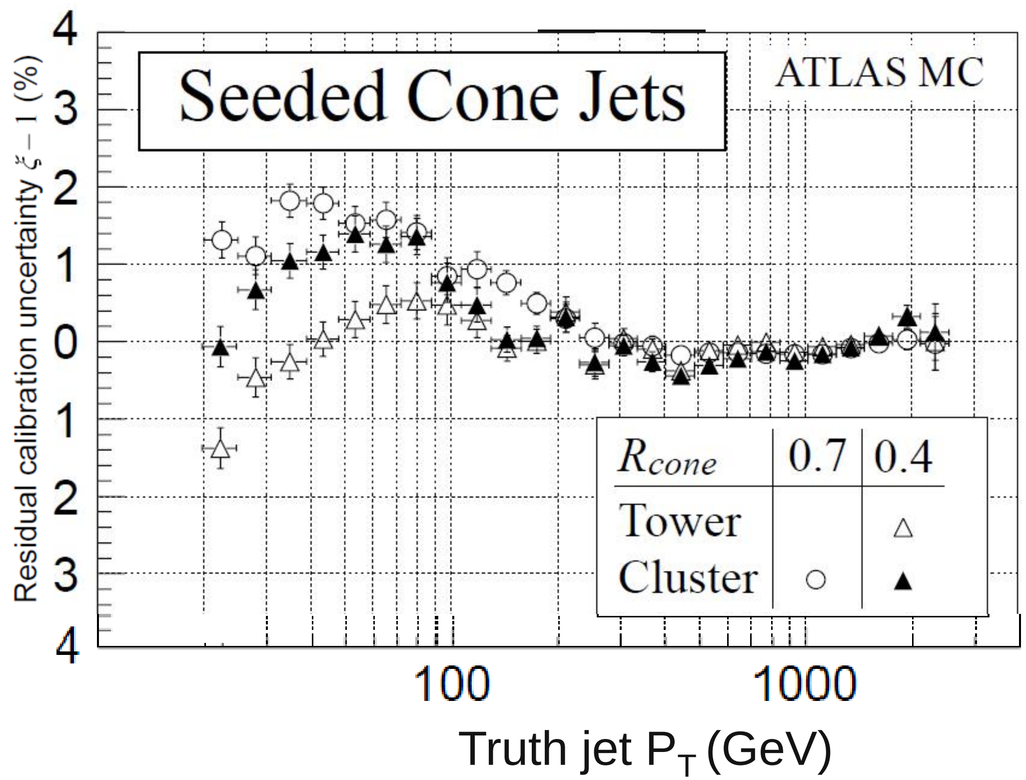
Calorimeter response: **tesbeam data** and **Geant4 simulation** of single pions *vs.* the energy of the beam





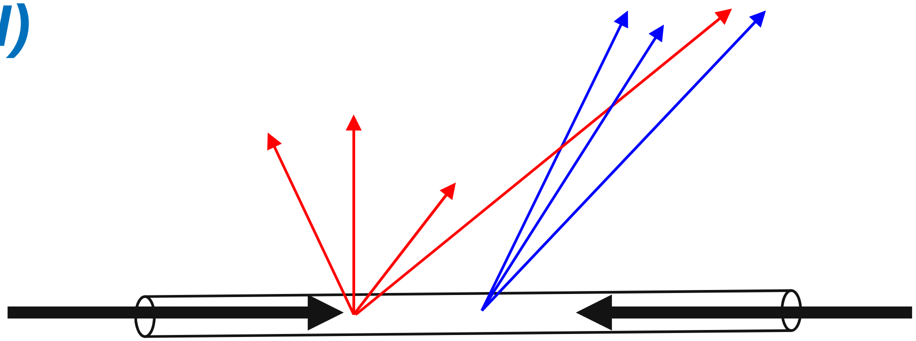
Reconstruction uncertainty (I)

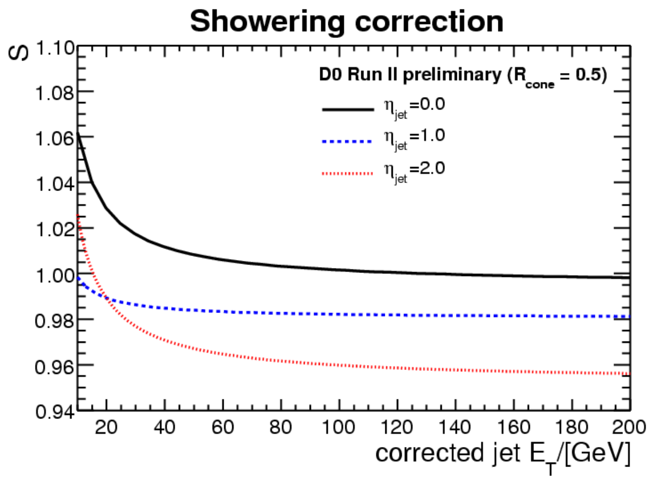
- As I said a jet is defined by the jet algorithm, thus it should not be any jet-uncertainty related with the jet reconstruction
- However you want to compare reconstructed jets *vs.* truth jets
  - Truth jets are very well defined
  - Reconstructed jets are not (even when the algorithm is)
    - What input should I use? Towers, topoclusters, topotowers
    - Is the calibration of these objects going to affect my jet reconstruction?



Reconstruction uncertainty (II)

- Often lots of undesired objects are included in the jet reconstruction
  - In time Pile-Up effects
- In addition due to showering effects some energy depositions in the detector are not clusterized by the jet algorithm
  - Ouf of cone (or showering) corrections
- The bunch crossing is much shorter that the calorimeter signal, is the impact of out-of-time pile-up in the jet reconstruction?





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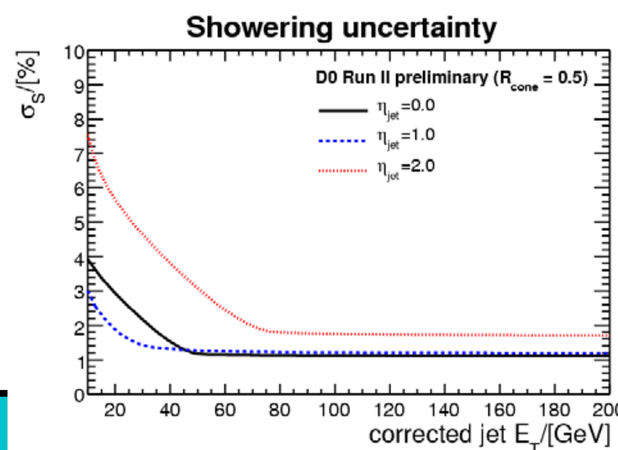

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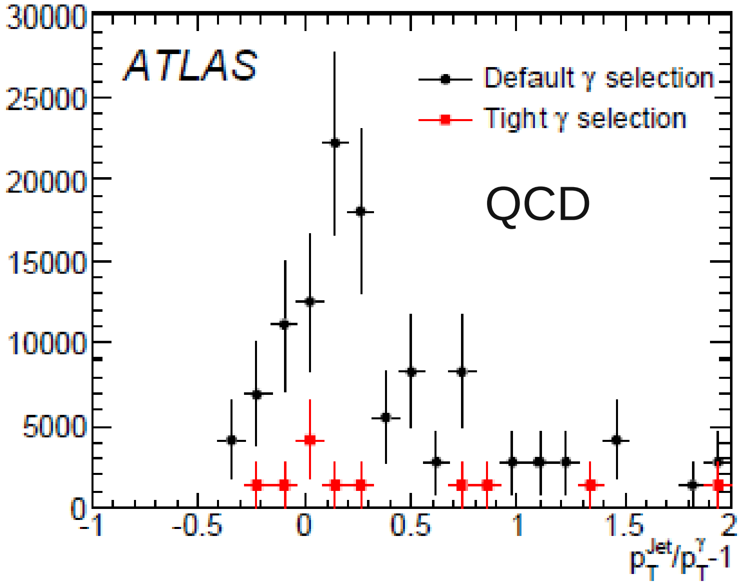
Jet uncertainty : in situ tests

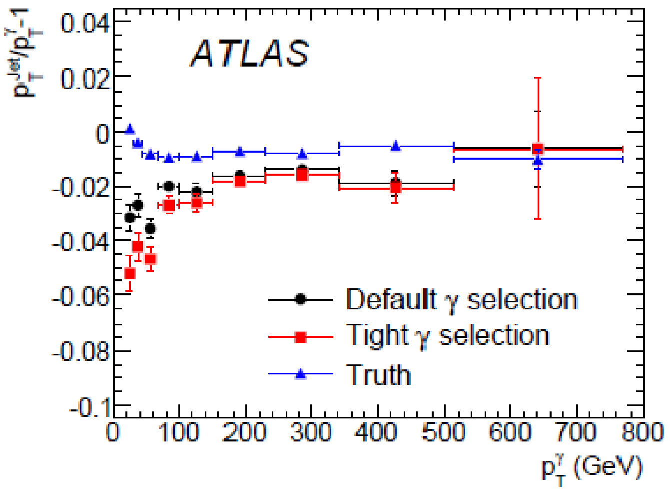
In situ validation tests

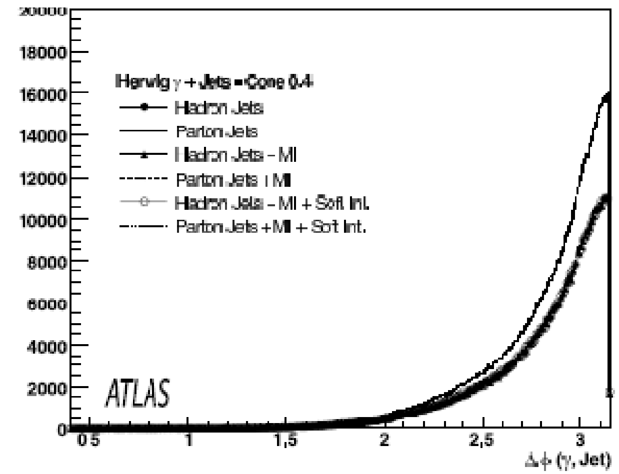
- All the uncertainties seen so far or came intrinsically from the MC of are very MC dependent
- It is thus very important to establish a set of tests to validate the jet energy scale without relaying in MC
- This tests are based in candles: well understood objects that help us to understand the jet scale
  - $\gamma + \mathrm{jet}$: the EM scale is easier to understand than the hadronic scale
  - $\mathrm{Z} + \mathrm{jet}$: The $Z \rightarrow e^{+}e^{-}$ and we are in the same case as above
    - *The dimuon channel can also be used will similar performance*
  - Dijet events : allow for calorimeter intercalibration
  - W mass

$\gamma + jet$ events

- The goal is to balance the P_T of the jet w.r.t the P_T of the photon
  - The photon decays and produces and well understood em shower in the calorimeter
- However
  - Is it only a two bodies system? NO
  - Could a jet fake a photon? YES



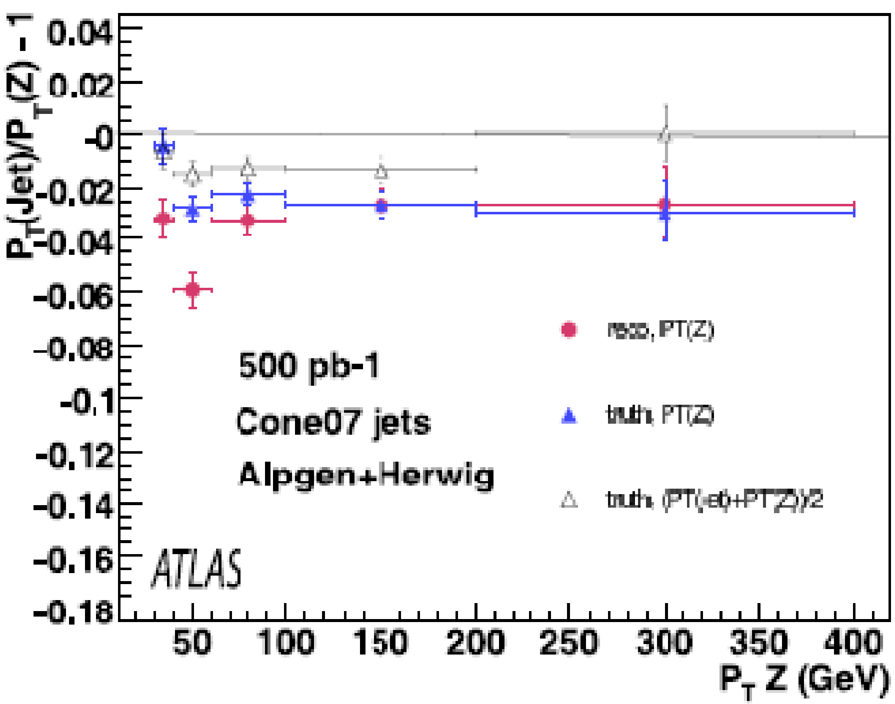


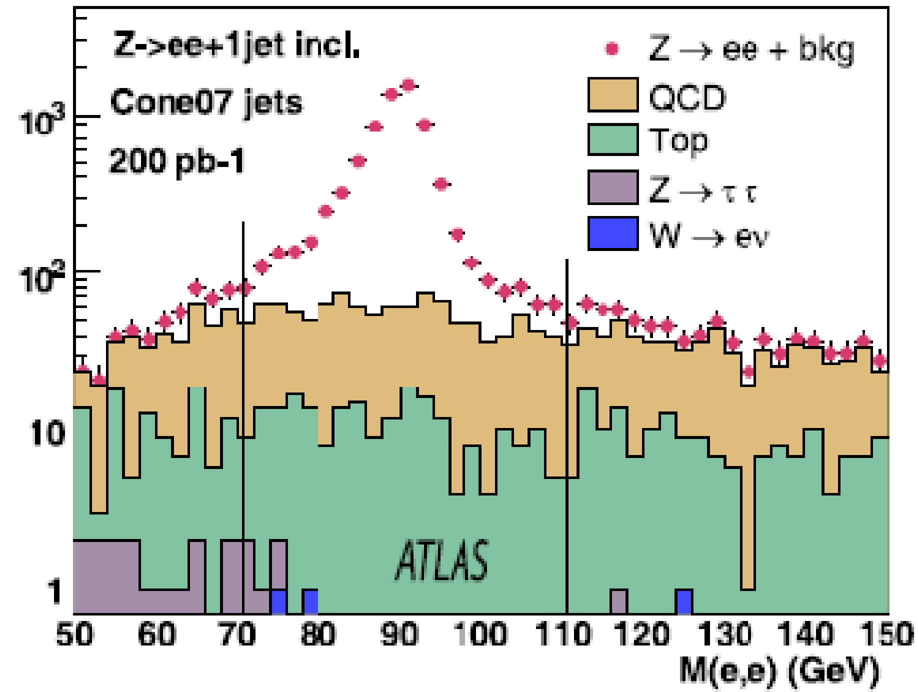


p_T interval	γ+jet σ (pb)	Dijet σ (pb)	σ ratio (Dijet / γ+jet)
$17 < p_T < 35$ GeV	2.61×10^5	1.38×10^9	5.29×10^3
$35 < p_T < 70$ GeV	2.76×10^4	9.33×10^7	3.38×10^3
$70 < p_T < 140$ GeV	2.59×10^3	5.88×10^6	2.27×10^3
$140 < p_T < 280$ GeV	1.99×10^2	3.08×10^5	1.55×10^3
$280 < p_T < 560$ GeV	1.17×10^1	1.25×10^4	1.07×10^3
$560 < p_T < 1120$ GeV	4.90×10^{-1}	3.60×10^2	7.35×10^2

Z + jet events

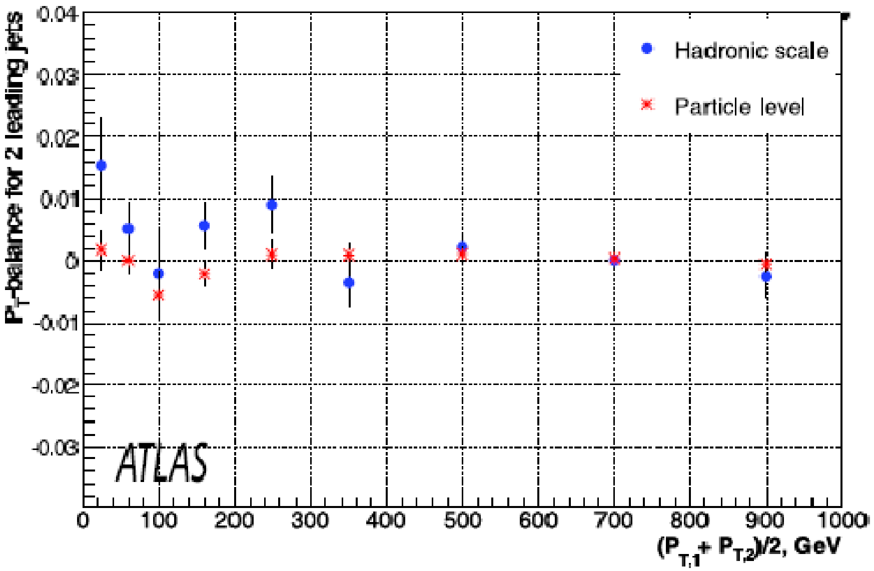
- Here we balance the jet w.r.t. the Z system
- The Z system is reconstructed via the lepton channel (*e* or muon)
- Less background than in the photon case
- Also less statistics and less P_T range

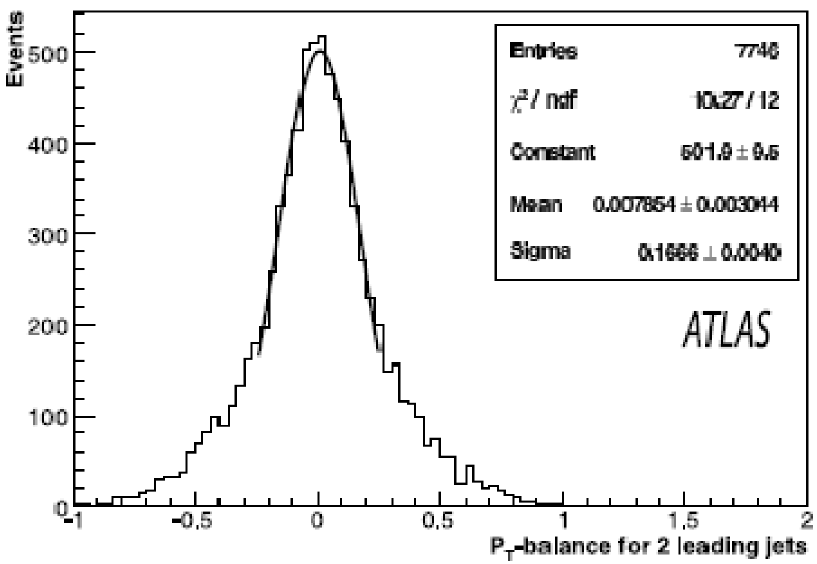




QCD events

- They can only be used for calorimeter intercalibration not for JES validation
- As many statistics as needed
- However cuts are needed for pure dijets events
- Multijet events can be used for high P_T calibration





Back-UP

Ouf of cone correction

The main goal of the showering correction is to correct for energy leaking outside (inside) the jet cone coming from particles inside (outside) the jet cone. As already pointed out, this correction intends to correct for "detector showering" only (i.e. instrumental effects such as shower development in the calorimeter, magnetic field bending, etc), and not for physics showering resulting for large-angle gluon radiation.

This correction is evaluated separately in data and Monte Carlo using photon+1jet candidate events, and requiring exactly one primary vertex reconstructed (to reduce the impact of multiple interactions). For a given bin of estimated jet energy and pseudorapidity, the first step is compute the jet energy density profile from calorimeter towers as a function of radial distance (in rapidity-phi space) to the jet-axis. After baseline-subtraction (contributed to by the underlying event, noise and pileup), the Monte Carlo ratio of energy within the jet cone radius to the total energy up to a larger radius (referred to as "jet limit") is defined as the "detector+physics" showering correction (i.e. including both detector and physics showering). The same procedure is repeated in Monte Carlo at the particle level (i.e. without detector effects), yielding the "physics-only" showering correction. Finally, the ratio of "detector+physics" and "physics-only" corrections yields the final showering correction.

Fig. 14 (15) illustrates the showering correction for Rcone=0.7 (0.5) jets in data as a function of corrected (up to absolute response) jet transverse energy for different pseudorapidity values.

The dominant systematic uncertainties (see Figs. 16 and 17) are associated with the baseline subtraction procedure and the choice of the "jet limit" radius, and are estimated in the simulation. Also sizable is the statistical uncertainty related to high jet transverse energy extrapolation, particularly in the forward region, due to the limited available statistics.

γ + jet balance : purity