Trigger Effect on Jet η-Intercalibration at the ATLAS detector

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Outline

- The LHC and the ATLAS detector
- Introduction to jet calibration
- Trigger bias
- Trigger effect extraction (TEE)
- Conclusions

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The Large Hadron Collider (LHC)

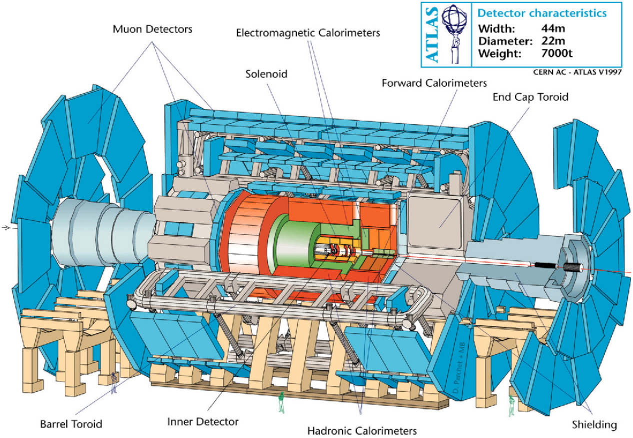
LHC is currently the world's largest particle accelerator situated at CERN near Geneva, at the border between Switzerland and France

The LHC ring is 27 km long (it was built in the old LEP tunnel).

The LHC accelerates protons in both directions until they collide at four intersection points with a central mass system energy of up to 14 TeV (7 TeV in 2010).

The four large experiments located at the intersection points are: ATLAS, CMS, ALICE and LHCb

The ATLAS detector



ATLAS is a general purpose particle detector designed to measure energies and momenta of *electrons*, *photons*, *hadronic jets* and *muons* which are created in collision events, and also the *missing transverse energy* (undetectable particles like neutrinos or new particles: gravitons, SUSY particles, etc.)

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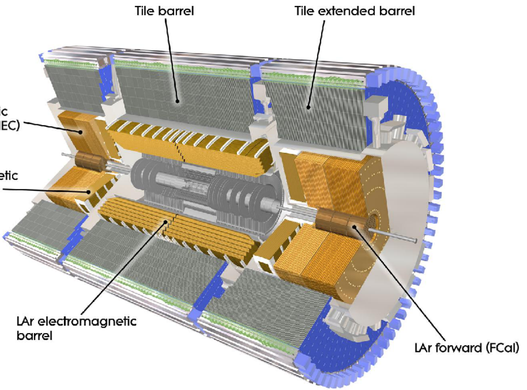
The ATLAS calorimeter



- The electro-magnetic barrel, both endcaps and FCALs are sampling calorimeters utilizing liquid argon as the active material and different high density metals as absorbers (lead, copper, tungsten): hadronic endcap and hadronic FCAL are *non-compensating*
- The hadronic barrel (TILE) is a *non-compensating* sampling calorimeter with plastic scintillators as the active material and steel as absorber

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Jet calibration - motivation

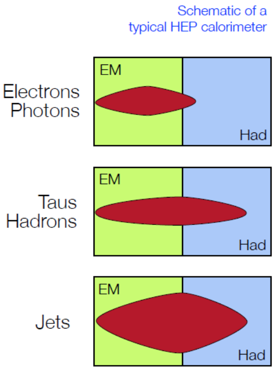
The response of the calorimeter is usually **different** for *electromagnetic* particles (e, γ, $\pi_0 \to \gamma\gamma$) and *hadronic* particles ($\pi^{\pm}$, p, n, etc.)

$\Rightarrow$ If an electromagnetic and a hadronic particle have the *same energy*, the ratio of measured energies is always $e/h > 1$

Unless the calorimeter is *hardware-compensating* (due to inclusion of radioactive elements such as *U* in the calorimeter structure), one needs to correct for this ratio on the *software level*, because a hadronic jet usually contains particles of both sorts

Also, different calorimeter layers and regions may have different response

$\Rightarrow$ **Jet calibration**



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Jet calibration - howto

1. *Pre-calibration* with test beams in the lab before beginnning of operation in the actual experiment
2. *Detector simulation* (with **GEANT**) using simulated data from *Monte Carlo generators*
3. *In-situ calibration*, i.e. calibration with taken data

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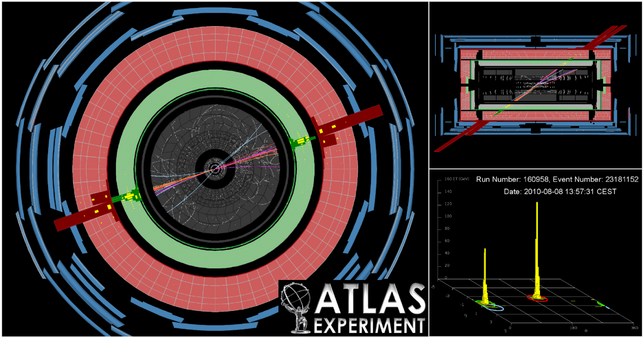
In-situ jet intercalibration

The goal of jet intercalibration is to achieve the same (software corrected) *relative* response for jets having same transverse momentum (p_t) in **all calorimeter regions** by utilizing p_t conservation in **dijet events**:



Ultimately one can perform "absolute" calibration with γ + jet or Z + jet events (with $Z \to ee$ or $\mu\mu$)

Here, only η-intercalibration ($\eta := -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$) is considered, not ϕ-intercalibration

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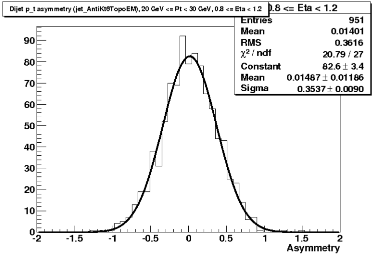
Jet η-intercalibration

Standard η-intercalibration strategy

1. Choose a **reference** region in η (e.g, in this talk, $|\eta| < 0.8$)
2. Consider dijet events with one jet in the reference region (**reference jet**), and the other in some other η bin (**probe jet**)
3. Fill *dijet asymmetry* $A := \frac{p_{t,\text{probe}} - p_{t,\text{ref}}}{\frac{1}{2}\left(p_{t,\text{probe}} + p_{t,\text{ref}}\right)}$ value in the asymmetry histogram for this bin



Asymmetry histogram built using the whole ATLAS dataset from 2010

4. Fit all histograms and calculate the calibration constants $c := \frac{2+\langle A\rangle}{2-\langle A\rangle}$

This is done for all p_t bins (diagonal binning, i.e. binning w.r.t. $\frac{1}{2}\left(p_{t,\text{probe}} + p_{t,\text{ref}}\right)$) to finally obtain the calibration factor as a function $c = c\left(p_t, \eta\right)$

Problem: Jet trigger!

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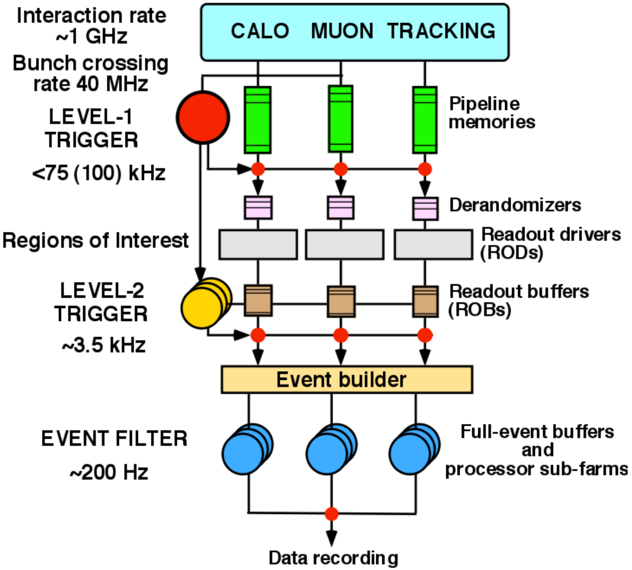
ATLAS trigger system



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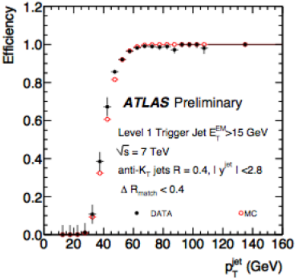
ATLAS level 1 jet triggers

Based on level 1 calorimeter trigger (L1Calo) are, in particular, jet triggers who select events with jets that pass a certain p_t threshold

For example, the L1_J15 trigger selects all jets, whose $p_t > 15$ GeV

However, since p_t is measured "on the fly" with low precision, the trigger efficiency is not a step function, but rather a slowly increasing value, reaching $\approx 100\%$ only at $\approx p_t = 70$ GeV (see figure on the right)

To avoid bias from trigger selection, in the standard method, one only considers p_t bins above the full efficiency point of the trigger that selected the data sample (for $p_t \lesssim 50$ GeV, the *minimum bias trigger* is used)



Trigger efficiency of L1_J15

This reduces the available statistics considerably, especially because of *trigger prescaling*: *prescale factor* of *N* means, only 1 event of *N* triggered events will be selected for final data recording (or next level trigger)

The lower the trigger threshold, the higher the prescaling factor!

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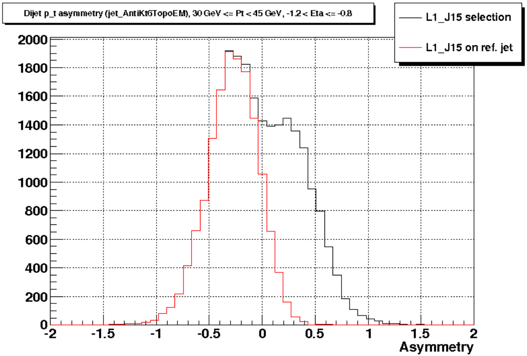
Trigger effect on jet η-intercalibration

In a sample, selected by a certain trigger (e.g. L1_J15), in the p_t region below the 100% trigger efficiency point, the trigger is more likely to fire on a jet with a higher p_t ⇒ bias in the asymmetry distribution:



Idea: Try to extract the trigger bias in-situ to obtain the true dijet asymmetry coming from calorimeter miscalibration

This way one could use higher p_t threshold jet triggers and not lose much statistics due to prescaling!

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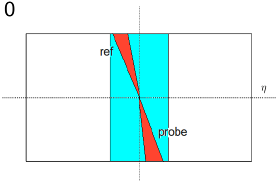
Original idea of the TEE method

Idea: Extract the trigger bias leaving only true asymmetry
Method: consider two subsamples

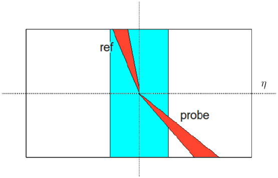
Subsample 1: **Both** jets are in **reference** region
$\Rightarrow$ if there were **no** trigger bias, dijet asymmetry would be 0

- Choose **reference** and **probe** jets randomly
- Require trigger on **reference** jet
- Calculate dijet asymmetry A_{refref}
  which comes **purely** from trigger bias



Subsample 2: **Reference** jet in the reference region,
probe jet elsewhere

- Require trigger on **reference** jet
- Calculate dijet asymmetry A_{refprobe}
  which includes miscalibration **and** trigger bias
- Calculate true asymmetry $A_{\text{true}} = A_{\text{refprobe}} - A_{\text{refref}}$



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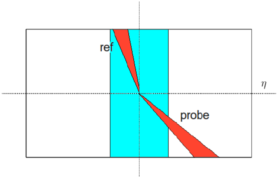
Correction to the TEE method

Subsample 2: **Reference** jet in the reference region, **probe** jet elsewhere



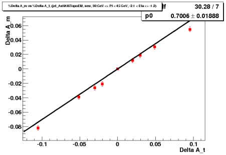
Observation: simple subtraction does **not** work, the correct way to calculate A_{true} is

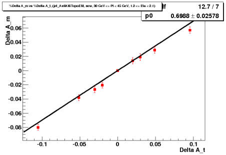
$$A_{\text{true}} = \frac{1}{s}\left(A_{\text{refprobe}} - A_{\text{refref}}\right),$$

where $s = s\left(p_t, \eta\right)$ is determined from a miscalibration simulation:

$$p_{t,\text{probe}} \to p_{t,\text{probe}}\left(1 + x\right) \Rightarrow A_{\text{true}} \to A_{\text{true}} + \left[1 - \left(\frac{A_{\text{true}}}{2}\right)^2\right] \cdot x + \mathcal{O}\left(x^2\right)$$

s is the slope of the linear fit of a $\Delta A_{\text{measured}}$ vs $\Delta A_{\text{theoretical}}$





The reason for $s < 1$ is that, due to event migration between p_t bins, events with **lower/higher** asymmetry will **enter** and events with **higher/lower** asymmetry will **leave** all p_t bins for **positive/negative** x, respectively

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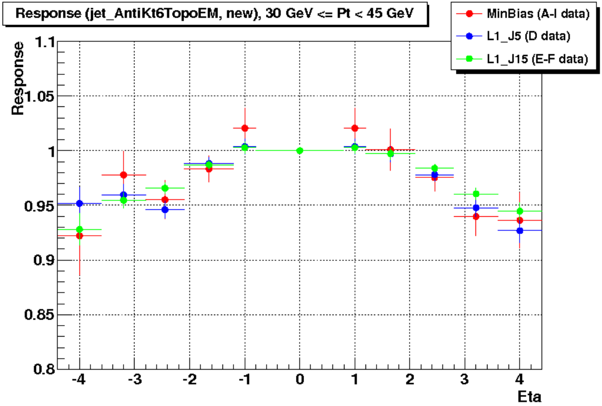
An example of a result



The letters denote periods of data taking:

- A-I: the whole 2010 dataset
- D: data taken from 2010/06/24 to 2010/07/19, integrated luminosity: $\approx$ 320 nb^{-1}
- E-F: data taken from 2010/07/19 to 2010/08/30, integrated luminosity: $\approx$3 pb^{-1}

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- A new method has been developed to perform in-situ jet η-intercalibration below the 100% efficiency point of the selecting trigger $\Rightarrow$ much more statistics due to higher prescaling of the lower triggers
- The method has been verified with a precision of $\lesssim 2\%$ using real physics data taken by the ATLAS experiment in the year 2010
- The presented results will be prepared for an upcoming ATLAS conference note on jet calibration (and hopefully published there)

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