Hadronic Calibration for the ATLAS Jet Trigger

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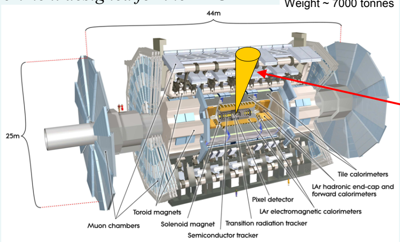
Work developed within the ATLAS High Level Trigger Jet Slice Group

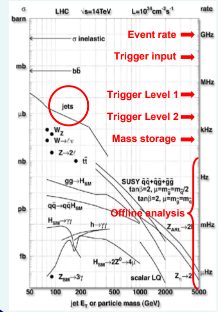
1. The ATLAS Experiment

ATLAS is a multipurpose experiment designed for the LHC

- *Center of mass energy*: 14 TeV
- *Design luminosity*: 10^{34} cm^{-2}s^{-1}
- *Bunch crossing rate*: 40 MHz
- *Collisions per crossing*: 25
- *Interaction rate*: 1GHz
- *Channels*: ~100 million



2. Data challenges



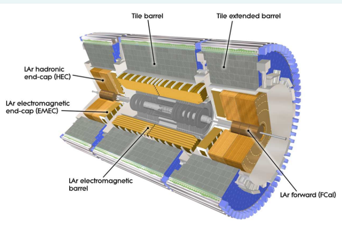
Data volume:

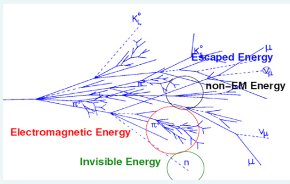
- High event rates and large event sizes
- Impossible to store full data stream
- Use trigger system to filter the events
- Store only the most interesting events

Trigger on Jets:

- Most jets result from trivial processes (QCD)
- Some interesting processes have jets signatures (top physics, SUSY, exotics)
- Main background for jets are jets
- Jets must be accurately measured
- Procedure must be fast

3. The ATLAS Calorimeter



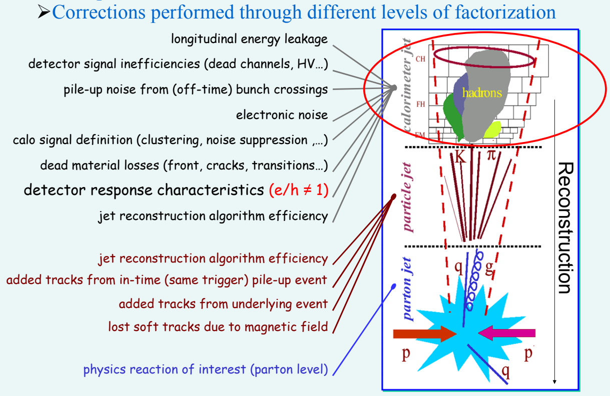


- Trigger and measure γ, e, τ, **jets**, E_T^{miss}
- energy scale precision at 1% level
- good hermeticity

- Hadronic showers have several components
- Not all energy is sampled
- Fractions vary with energy
- Response to electromagnetic and hadronic parts is different: e/h ~ 1.3 – 1.6

4. Hadronic Calibration

- Jets are reconstructed from energy depositions in calorimeter cells
- Multiple reconstruction effects need to be corrected
- Corrections performed through different levels of factorization



- Hadronic calibration corrects the energy scale of calorimeter jets
- Calibration of trigger jets uses a simple, robust and fast method

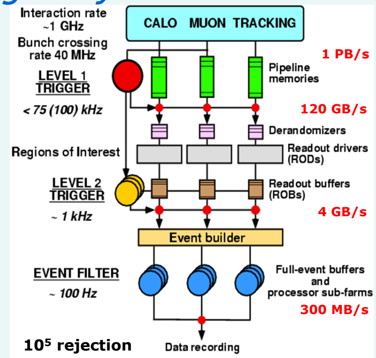
5. ATLAS Trigger System

LEVEL 1 TRIGGER (LVL1)
- Hardware-Based (FPGAs ASICs) Coarse granularity from calorimeter & muon systems
- 2 μs latency (2.5 ms pipelines)

LEVEL 2 TRIGGER (LVL2)
Regions-of-Interest (RoI) "seeds" from LVL1
- Full granularity for all subdetectors
- Request event fragments
- Fast rejection software
- O(40 ms) processing time

EVENT FILTER
- "Seeded" by LVL2 result
- Potential full event access
- Offline-like Algorithms
- O(4 s) processing time

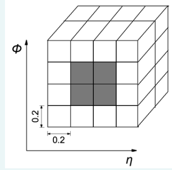
High Level Trigger (HLT)



6. Jet Trigger & Calibration

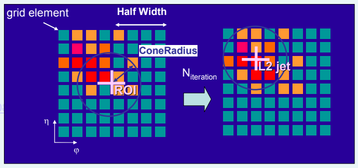
LVL1:

- Custom designed processors
- Sliding window (0.8×0.8 in η,ϕ) with 0.4×0.4 central cluster
- Searches for a local transverse energy maximum
- Provides starting point (seed) for LVL2 trigger



LVL2:

- Data preparation: access data in a RoI around LVL1 seed.
- Create grid of detector elements, by default each corresponding to a calorimeter cell.
- Iterative cone algorithm (typically 3 iterat.)
- Calculate energy-weighted η,ϕ positions
- Apply calibration:



- $E_{jet}=\sum_i(\omega_{EM}\times E_{EM}+\omega_{HAD}\times E_{HAD})_i$
- Two sets of weights, one for the electromagnetic energy and one for the hadronic energy
- Weights depend on E_{jet} logarithmically: $\omega_i = a_i + b_i\times\log(E_{jet})$
- Index i runs over 44 bins of 0.1 units in η ⇒ $\omega = \omega(E_{jet},\eta)$
- Weights calculated by minimizing the energy difference w.r.t. Monte Carlo (MC) samples:

$$\chi^2 = \sum_{m=1}^{N_{jets}} \left[\frac{(E_m^{truth} - E_m^{rec})}{\sigma_m}\right]$$

Event Filter:

- Offline-like jet reconstruction algorithms
- Reconstruction in a RoI around LVL2 seed
- Offline calibration available

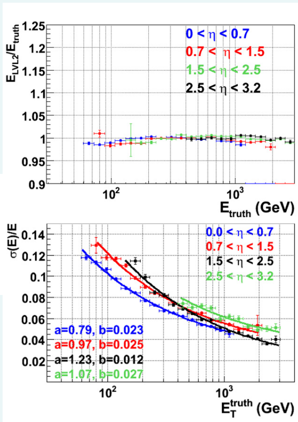
7. Jet Energy Scale

Very important to discriminate transverse energy thresholds ⇒ the jet energy scale has to be well measured for a large range of energies, from 20 to 400 GeV:

- With current calibration procedure, the energy scale is correct within 2% for all energies and all η regions
- Small improvement in the resolution when using the calibration
- Resolutions fit to: $\frac{\sigma(E)}{E} = \frac{A(GeV^{1/2})}{\sqrt{E}} \oplus B$

η region	Before calibration		After calibration	
	A	B	A	B
(0.0,0.7)	1.03 ± 0.03	0.059 ± 0.001	0.96 ± 0.02	0.039 ± 0.001
(0.7,1.5)	1.28 ± 0.03	0.064 ± 0.001	1.18 ± 0.03	0.041 ± 0.001
(1.5,2.5)	1.53 ± 0.04	0.046 ± 0.001	1.37 ± 0.03	0.025 ± 0.002
(2.5,3.2)	1.86 ± 0.13	0.063 ± 0.003	1.46 ± 0.08	0.040 ± 0.003

- Improvements in data unpacking speed: use coarse granularity Front-End Board energy sums as grid elements for the e.m. calorimeter, with similar performance.
- Possible improvement in resolution: introduce a dependency of the weights with the fraction of electromagnetic energy, $\omega = \omega(E_{jet},\eta, f_{EM})$



9. Summary & conclusions

- The ATLAS LVL2 Trigger uses a fast iterative cone algorithm to reconstruct jets in a RoI around the LVL1 seeds, followed by a simple jet energy calibration algorithm.
- The calibration weights depend on the jet energy and η, and are calculated using Monte Carlo samples.
- After calibration, the jet energy scale for the LVL2 jets is correct within 2% for all energies.
- Improvements in speed are possible using coarser granularity with the same performance.
- In-situ calibration with data should be used to test the MC based calibration

8. Commissioning with First Data

- In-situ calibration with real data:
  - At LHC energies Monte Carlo models have large uncertainties
  - MC based hadronic calibration must be verified with data
  - Use energy balance in real data events to perform the calibration
  - Example: Z + jets
  - Callenge: apply this procedure within the constraints of the trigger