# Measurement of the Jet Energy Resolution in ATLAS using Data-Driven Techniques

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# In-situ measurement of jet energy resolution

## Motivation

- A precise reconstruction of the jet energy and its resolution are fundamental ingredients of many physics analysis and searches
- In MC events, the jet energy resolution due to detector effects can be estimated straightforwardly by matching particle-level jets and calorimeter-jets in $\eta - \phi$ space and looking at the width of the jet response distributions. Nevertheless, this approach can of course not be implemented in a data-taking scenario.
- We present two different data-driven techniques, which allow the jet energy resolution to be estimated from calorimeter observables
  1. Dijet Balance Method (DØ collaboration)
  2. Bisector Method (CDF collaboration)
- Jet energy resolution has three main contributions:
  - *Noise term*: Electronic noise, which dominates in the low energy regime
  - *Stochastic response*: Poissonian event-to-event fluctuations
  - *Constant term*: Effects proportional to the jet energy (e.g. dead material, etc.)

### Jet Momentum Resolution

$$\frac{\sigma_{p_T}}{p_T} = \frac{N}{p_T} \oplus \frac{S}{\sqrt{p_T}} \oplus C$$

# In-situ measurement of jet energy resolution

## Dijet Balance Method, Anti-$k_T$ 0.6 Topo-jets

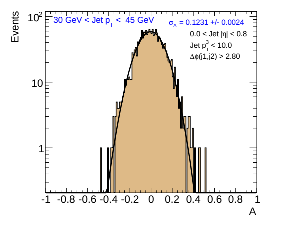
- The determination of the jet $p_T$ resolution in the Dijet Balance technique is based on momentum conservation in the transverse plane. It assumes there are only two jets on the event which have the same particle $p_T$. The asymmetry distribution of the two jets $A(p_{T,1}, p_{T,2})$ is defined as:

$$A \equiv \frac{p_{T,1} - p_{T,2}}{p_{T,1} + p_{T,2}}$$

- For a dijet event, transverse momentum balance implies $\langle p_{T,1} \rangle = \langle p_{T,2} \rangle \equiv p_T$. Furthermore, since both jets are required to be in the same $\eta$ region, it follows $\sigma_{p_{T,1}} = \sigma_{p_{T,2}} = \sigma_{p_T}$, yielding to the central relation of this method:

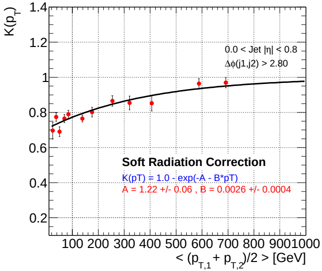
$$\frac{\sigma_{p_T}}{p_T} = \sqrt{2}\,\sigma_A$$

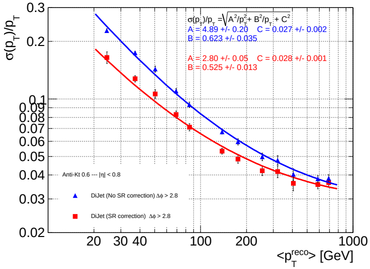
  - Two back to back leading jets, satisfying at least $\Delta\phi > 2.8$ btw them.
  - Both jet in $|\eta| < 0.8$
  - Other jets are required to have $p_T < 10$ GeV
  - Events including b-jets and jets with muons are vetoed.
  - 12 $\langle p_T \rangle$ regions, from 20 GeV up to 1 TeV



# Dijet Balance Method: Soft Radiation Correction

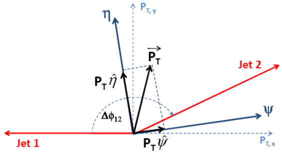
- Events with soft radiation prevent the two leading jets from balancing in the transverse plane. One could attempt stricter cuts or event require no third calorimiter jet in the event. However, this would not preclude the presence of additional soft particle jets not found at calorimeter level due to reconstruction inefficiencies at low $p_T$
- $A \equiv \frac{p_{T,1}-p_{T,2}}{p_{T,1}+p_{T,2}}$ is measured for a series of $p_{T,3}$ threshold values. For each $p_T$ bin, the set of resolutions obtained from the different $p_{T,3}$ threshols are fitted and extrapolated to $p_{T,3} \rightarrow 0$.
- A soft radiation correction factor is applied to the biased raw resolution extracted from the di-jet imbalance asymmetry. The correction attains 30% at low $p_T$



# Bisector Technique

- The imbalance transverse momentum vector $\vec{P}_T = \vec{P}_T^{jet,1} + \vec{P}_T^{jet,2}$ is defined, and the method considers its projections along an orthogonal coordinate system in the transverse plane $(\psi, \eta)$, where $\eta$ is chosen in the direction that bisects $\Delta\phi_{12} = \phi_1 - \phi_2$, the angle formed by $\vec{P}_T^{jet,1}$ and $\vec{P}_T^{jet,2}$




- Many sources give rise to fluctuations adn thus to non-zero variances of its $\psi$ and $\eta$ components, denoted:

$$\sigma_\psi^2 \equiv Var(P_{T,\psi}) \qquad \text{and} \qquad \sigma_\eta^2 \equiv Var(P_{T,\eta})$$

- The basic assumption of the Bisector method is that the $\psi$ and $\eta$ variances are equal at particle level (More details: See extra info):

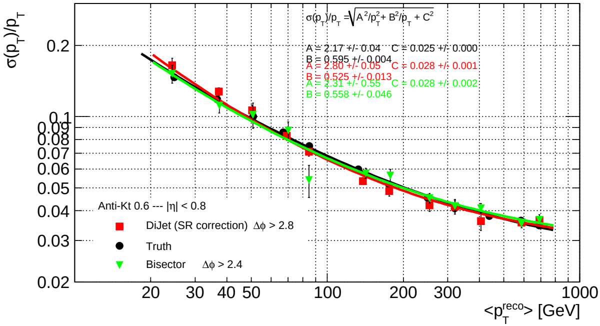
$$\sigma_\psi^{2\ part} \equiv Var(P^{part}_{T,1\ \psi} + P^{part}_{T,2\ \psi}) = Var(P^{part}_{T,1\ \eta} + P^{part}_{T,2\ \eta}) \equiv \sigma_\eta^{2\ part}$$

- Wherefrom it follows the calorimeter resolution can be measured as below. Thus, soft radiation effects are removed by subtracting in quadrature $\sigma_\eta$ from $\sigma_\psi$.

$$\frac{\sigma(P_T)}{P_T} = \frac{\sqrt{Var(P_T^{calo} - P_T^{part})}}{\langle P_T \rangle} = \frac{\sqrt{\sigma_\psi^{2\ calo} - \sigma_\eta^{2\ calo}}}{\sqrt{2}\,\langle P_T \rangle}$$

## **Performance:** $0 < |\eta| < 0.8$**, Anti-**$k_T$ **0.6 Topo jets**

- The outcome of the two methods has been compared. At the same time we have tested the results against the true MC resolutions, where calorimeter jets in each event are matched to particle jets in $\eta - \phi$ space, and associated if $\Delta R < 0.3$. The level of agreement between the 3 sets of points in excellent within errors ($\approx 1\%$). The respective fits are also included
- From the Bisector technique side, it has been found it is essential to investigate the validity of $\sigma^{part}\eta = \sigma^{part}_{\psi}$. When tighting the $\Delta\phi$ cut, the equality does not hold at low $p_T$, which would bias (enlarge) the measured resolution. A tight cut limi the degree of fluctuation along the $\eta$ axis, while leaving the $\psi$ unaffected ($\Delta\phi > 2.4$).



## Summary, Conclusions and Future Prospects

- The studies were performed with jets reconstructed with Anti-$k_T$ 0.6 algorithm from topoclusters and cell energy density weighting calibrated (H1-style)
- The aim has been to study the feasibility of data-driven methods to measure resolutions
- We have found that both methods reproduce the straight resolutions with a precision of better than 1%. Furthermore, since both methods are not affected by the same systematics, their agreement to each other provides a crosscheck of the results.

- We should still investigate, however, if both methods agree with each other and with the true resolutions for:
- Narrower jets, as anti-$k_T$ 0.4 are being already investigated
- Jets made from other algorithms
- Photon + Jets events.

## Extra Information

# Extra Info

## Documentation and Some Other Talks

- ATLAS internal report
- http://indico.cern.ch/contributionDisplay.py?contribId=1&confId=40714
- http://indico.cern.ch/contributionDisplay.py?contribId=0&confId=23237