In–Situ Jet Energy Scale Calibration of Large–Radius Jets

Matthew Epland

Duke University

Nov. 3, 2016

US LUA, LBNL
Why Calibrate Large–Radius Jets?

- Heavy objects decaying to multiple quarks are conveniently reconstructed as large–radius jets
  - Substructure tagging opens a window on processes like $X \rightarrow t\bar{t}$, $VV$, $HH$
- Without a calibrated Jet Energy Scale (JES) discoverable features would be smeared and measurements would be off

- Begin by calibrating JES from Monte Carlo (MC) simulations:
  
  $$\text{MC Calibration} = \left\langle \frac{p_T^{\text{MC, Reco}}}{p_T^{\text{MC, Truth}}} \right\rangle$$

![Large–Radius Jets Diagram]
In–Situ Calibration Methods

After initial MC calibration, derive additional in–situ calibrations from data

\[ \gamma + \text{Jet} \]
\[ t\bar{t} \text{ (Forward–Folding)} \]

\[ p_T \text{ [GeV]} \]

\[ \sim 2\% \text{ uncertainty} \]

\[ \sim 2\% \text{ uncertainty} \]

Valid on 200–350 GeV

\[ \sim 2.1\% \text{ uncertainty} \]
\( B = \frac{p_T^J}{p_T^{\text{ref}}} \)

\( R(p_T^J) = \langle B_{\text{Data}} / B_{\text{MC}} \rangle \)

\( p_T^\gamma \approx p_T \cos(\Delta \phi) \mid \)

**Large–radius jet:** anti–\( k_t \) \( R = 1.0 \), trimmed

**Extra radiation:** anti–\( k_t \) \( R = 0.4 \)**

Extra Radiation, **Veto!**
\(\gamma + \text{Jet Balance}\)

**ATLAS Work in Progress**

\[ \sqrt{s} = 13 \text{ TeV}, \int \mathcal{L} \, dt = 3.2 \text{ fb}^{-1} \]

\(\gamma\)-jet Events, |\(\eta^{\text{lead jet}}\)| < 0.8
anti-\(k_t\), R = 1.0, LC Trimmed

\[\langle p_T^{\text{jet}} / p_T^{\text{ref}} \rangle\]

- Data15
- Pythia8
- Stat. ⊕ Syst.

\(\frac{\text{Data15}}{\text{MC}}\)

\(\mu = 0.955 \pm 0.006\)
\(\mu_{\text{Pythia8}} = 0.980 \pm 0.002\)

\(350 < p_T^{\text{jet}} [\text{GeV}] < 400\)

Data15
Pythia8

**ATLAS Work in Progress**

Matthew Epland

In–Situ JES of Large–Radius Jets

Nov. 3, 2016 5 / 7
\( \gamma + \text{Jet Systematics} \)

\[ \sqrt{s} = 13 \, \text{TeV}, \int L \, dt = 3.2 \, \text{fb}^{-1} \]

\( \gamma\text{-jet Events, } |\eta^{\text{lead jet}}| < 0.8 \)

anti-\( k_t \) \( R = 1.0 \), LC Trimmed

\( \rho_{\text{ref}} \) [GeV] vs. Fractional Variation

- Stat. + Syst.
- Statistical
- MC Modeling
- \( \Delta \phi \) Selection
- Event Topology Selection
- \( \gamma \) Purity
- \( \gamma \) Energy Scale and Res.
Summary

- Uncertainty in the JES calibration is a major systematic for many large-radius jet analyses, such as diboson resonance searches.
- Combining the in-situ methods should produce a calibration with $\sim 2\%$ uncertainty.
- The new in-situ calibration will be approximately a factor of two improvement over the current calibration.
Backup
\( \gamma + \text{Jet Event Selection} \)

- **Photons**
  - \( p_T^\gamma > 180 \text{ GeV} \)
  - \( |\eta^\gamma| < 1.37 \)
  - Tight identification and isolation \( (E_T^{40} < 0.022p_T + 2.45 \text{ GeV}) \)

- **Large–Radius Jets \((J_1)\)**
  - \( p_T^{J_1} > 20 \text{ GeV} \)
  - \( |\eta^{J_1}| < 0.8 \)
  - Overlap removal: \( \Delta R_{\gamma, J_1} > 0.2 \)

- **Small–Radius Jets \((j_2)\)**
  - Cleaned + JVT \( \geq 0.59 \)
  - Overlap removal: \( \Delta R_{\gamma, j_2} > 0.4, \Delta R_{J_1, j_2} > 1.0 \)

- **Topological Selections**
  - \( \Delta \phi > 2.8 \)
  - \( p_T^{j_2} < \max \left( 15 \text{ GeV}, 0.1 \ p_T^{\text{ref}} \right) \)
$\gamma + \text{Jet} \ B \ vs \ p_T^{\text{ref}}$

$\sqrt{s} = 13 \text{ TeV}, \int L \ dt = 3.2 \text{ fb}^{-1}$

$\gamma$-jet Events, $|\eta^{\text{lead jet}}| < 0.8$

anti-$k_t \ R = 1.0$, LC Trimmed

$\text{Data15}$
Small–Radius In–Situ JES

\begin{align*}
\text{anti-}k_t \ R=0.4, \ EM+\text{JES} \\
\text{Data 2015}
\end{align*}

\text{ATLAS} \ Preliminary \\
\sqrt{s} = 13 \text{ TeV, 3.2 fb}^{-1} \\
|\eta|<0.8

\begin{align*}
\frac{\text{Response}}{\text{Response MC}} \\
\text{Data}
\end{align*}

\begin{align*}
\gamma+\text{jet} \\
\text{Z+jet} \\
\text{Multijet}
\end{align*}

\text{Total uncertainty} \\
\text{Statistical component}
http://cds.cern.ch/record/2206137.