Top LHC France

b-Jet energy scale calibration using $t\bar{t}$ lepton+jets events in ATLAS

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https://indico.in2p3.fr/event/23801/overview

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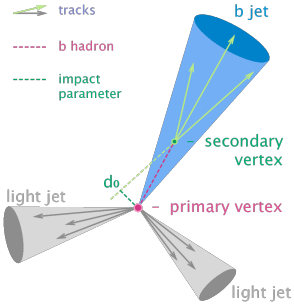
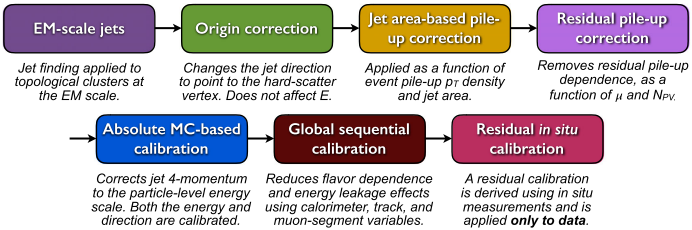
bJES = b-Jet Energy Scale = Correction of b-jet energy applied after data acquisition to compensate the imperfect calibration of the ATLAS detector and jet calibration procedure

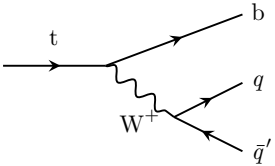




arXiv:1703.09665

b-jets play a leading role in many analyses
for instance main decay of the Higgs is $\mathrm{H} \rightarrow b\bar{b}$
$\Rightarrow$ Need for a dedicated calibration of b-jet energy

➢ **Energy scale factor (α)**: $E'_b = (1+\alpha)E_b, \quad p'_{Tb} = (1+\alpha)p_{Tb}$



Compare reconstructed m_{qqb} invariant mass distributions
$t \to Wb \to qq'b$ in Data and MC simulation to determine α

➢ Compute m_{qqb} distribution for Data

➢ Create MC templates m_{qqb} distribution shifting b-jet energy by:

$(1+\alpha_i) \to$ one m_{qqb} distribution per value α_i

$$E'^{\mathrm{MC}}_b(\alpha_i) = (1+\alpha_i)E^{\mathrm{MC}}_b, \qquad p'^{\mathrm{MC}}_{Tb}(\alpha_i) = (1+\alpha_i)p^{\mathrm{MC}}_{Tb}$$

➢ Compute $\chi^2(\alpha_i)$ between MC template and (Pseudo-)Data using m_{qqb} distributions

$\to$ find minimum $\alpha_{\min}$ of $\chi^2(\alpha)$ curve

➢ Determine statistical and systematic uncertainties: $\delta\alpha^{\mathrm{stat}}$ & $\delta\alpha^{\mathrm{syst}}$

NB: Shift of b-jet energy is performed in MC samples
but the final correction will be applied in Data

$$E_b^{\text{Data corrected}} = E_b^{\mathrm{Data}}/(1+\alpha_{\min}), \quad p_{Tb}^{\text{Data corrected}} = p_{Tb}^{\mathrm{Data}}/(1+\alpha_{\min})$$

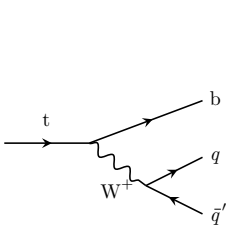
NEW METHOD: bJES measurement using $t\bar{t}$ lepton+jets was never performed in ATLAS
$\Rightarrow$ Test procedure using Pseudo-Data then use Data

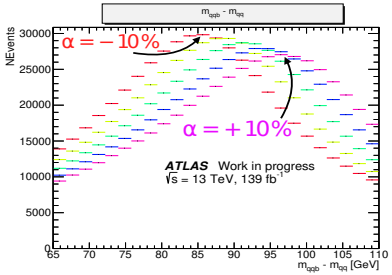
Previously: light jet calibration was used to calibrate b-jets
and uncertainties related to bJES were estimated from MC simulations

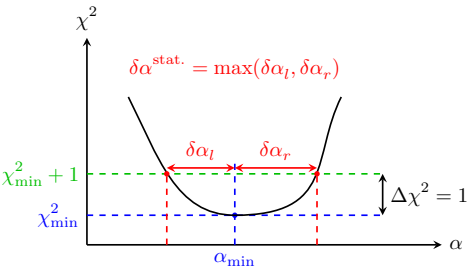
MC templates for $m_{qqb} - m_{qq}$ distribution & Statistical error determination $\delta\alpha^{\text{stat}}$

Use $\boldsymbol{m_{qqb} - m_{qq}}$ instead of $\boldsymbol{m_{qqb}}$ to reduce sensitivity to light jet calibration

Shift of b-jet energy $\Rightarrow$ shift on the reconstructed $m_{qqb} - m_{qq}$





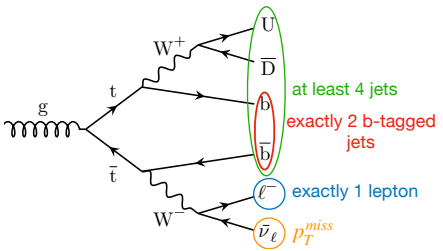


$\chi^2 \rightarrow$ compare shifted MC template and (Pseudo-)Data

$$\chi^2(\alpha_i) = \sum_k \frac{(O_k - E_k(\alpha_i))^2}{O_k} = \sum_k \frac{(N_k^{\text{Data}} - N_k^{\text{MC}}(\alpha_i))^2}{N_k^{\text{Data}}}$$

$$\chi^2_{\text{min}} := \chi^2(\alpha_{\text{min}})$$

To increase precision on $\alpha_{\text{min}} \pm \delta\alpha^{\text{stat}}$ use penalized spline ($\approx$ mix between fit and interpolation) with smoothing parameter λ



$t\bar{t} \to$ lepton+jets events
$\ell = \mathrm{e}, \mu$, U = u, c and D = d, s

- $\sigma(t\bar{t} \to X) = 832$ pb
- BR($t\bar{t} \to$ lepton+jets) = 44%
- $\boldsymbol{N_{t\bar{t}\to\text{lepton+jets}} = \mathrm{BR} \times \mathcal{L} \times \sigma \approx 51\text{M events}}$
- Good rejection of QCD hadronic background
- $m_{\mathrm{W}} = 80.4$ GeV
- $m_t = 172.5$ GeV

Selection criteria

- $p_T^{\text{lepton}} \geq 40$ GeV
- $p_T^{\text{miss}} \geq 30$ GeV
- $m_T^{\mathrm{W}} + p_T^{\text{miss}} \geq 60$ GeV

- Exactly 4 jets:
  - **Exactly two light jets:** q_1 and q_2
  - **Exactly 2 *b*-tagged jets:** among the 2 b-tagged jets, select the b-jet such that the invariant mass $m_{q_1 q_2 b,\text{min}}$ is the closest to the top quark mass:

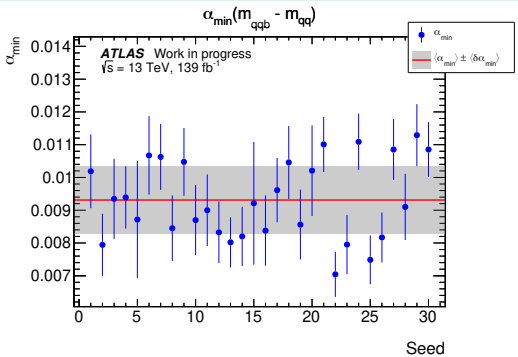
$$\left|m_t - m_{q_1 q_2 b_{\text{min}}}\right| = \min_{b_k, k=1,2} \left|m_t - m_{q_1 q_2 b_k}\right|$$

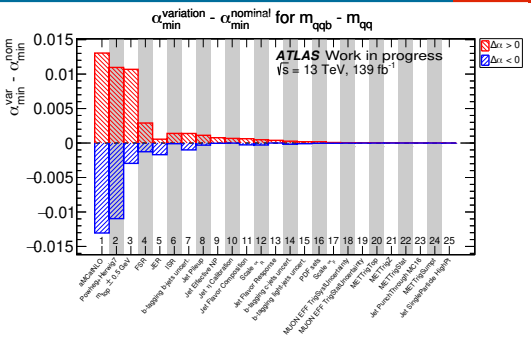
- **Additionally require:**

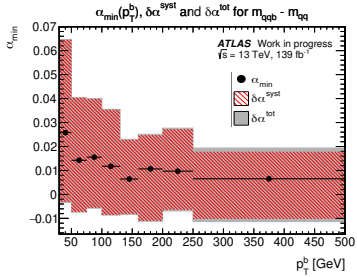
$$\left|m_{\mathrm{W}} - m_{q_1 q_2}\right| \leq 50 \text{ GeV} \qquad \text{and} \qquad 130 \text{ GeV} \leq m_{q_1 q_2 b_{\text{min}}} \leq 210 \text{ GeV}$$

Inclusive & Differential measurement in Data

Inclusive: $\alpha_{\min} \pm \delta\alpha^{\text{stat}} \pm \delta\alpha^{\text{syst}} = 0.94\% \pm 0.10\% \pm^{+2.10\%}_{-1.81\%}$







- Main systematic uncertainties are related to modelling and top mass uncertainties
- Inclusive and differential measurement are in agreement
- Good precision on the energy scale factor
- First time in situ b-jet energy scale factor is measured in Data