# Combining $b$-tagging calibrations in ATLAS

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Identifying jets of particles from $b$-quarks is important for a number of the physics goals at the ATLAS experiment [1]. A number of $b$-tagging algorithms have been developed by ATLAS [2] at the LHC. The algorithms' performance is calibrated on data [3]. Calibration measures the scale factor of data performance to Monte Carlo (MC) performance. Two methods, $p_T^{rel}$ and System 8, are currently used to measure the efficiency of the $b$-tagging algorithms on $b$-jets; both use a large multi-jet sample with an associated muon collected with a range of single-jet triggers. Both methods use the relative $p_T$ of a muon in a jet as a way to measure $b$-jet purity in the calibration sample: the $p_T^{rel}$ distribution from a heavy $B$-hadron semileptonic decay is quite different than for muons from other sources. In both cases the $b$-jet scale factors are determined in $\eta$ and $p_T$ bins, as the $b$-tagging algorithms' performance is strongly dependent on these parameters.

To improve the accuracy of the scale factors, we combine the calibration results from the two methods by maximizing the following likelihood:

$$\begin{aligned}\mathcal{L} = \prod_{i=1}^{2} \mathcal{P}_i \quad = \quad & G(\kappa_1 | \hat{\kappa} \times (1 + \delta\kappa_1^{\mathrm{syst}_1} \lambda^{\mathrm{syst}_1} + \delta\kappa_1^{\mathrm{syst}_2} \lambda^{\mathrm{syst}_2}), \delta\kappa_1^{\mathrm{stat}}) \times \\ & G(\kappa_2 | \hat{\kappa} \times (1 + \delta\kappa_2^{\mathrm{syst}_1} \lambda^{\mathrm{syst}_1} + \delta\kappa_2^{\mathrm{syst}_2} \lambda^{\mathrm{syst}_2}), \delta\kappa_2^{\mathrm{stat}}) \times \\ & G(\lambda^{\mathrm{syst}_1} | 0, 1) \times G(\lambda^{\mathrm{syst}_2} | 0, 1)\end{aligned} \tag{1}$$

The function $G(x|a, w)$, as written in Eqn. 1, represents a Gaussian centered at $a$ with width $w$. $\kappa_1$ is the value of the scale factor as measured by one of the calibration analyses and $\kappa_2$ the other. $\hat{\kappa}$ is the true value of the scale factor in a given $p_T, \eta$ bin - and is what is being fit for (there is a term for each $p_T$ and $\eta$ bin). $\delta\kappa_1^{\mathrm{stat}}$ is the statistical error associated with the $\kappa_1$ measurement and is expected to be uncorrelated with all other measurements. Finally, $(1 + \delta\kappa_1^{\mathrm{syst}_1} \lambda^{\mathrm{syst}_1} + \delta\kappa_1^{\mathrm{syst}_2} \lambda^{\mathrm{syst}_2})$ are the systematic errors associated with this measurement. There is an additional Gaussian $G(\lambda^{\mathrm{syst}_1}|0, 1)$ to constrain each systematic error. The strength of the effect of each systematic error in each bin is accounted for by $\delta\kappa_i^{\mathrm{syst}_j}$. Figure 1 shows the combination results for the Secondary Vertex (SV) tagger, a tagging algorithm that reconstructs a vertex from tracks significantly displaced from the primary vertex [2].

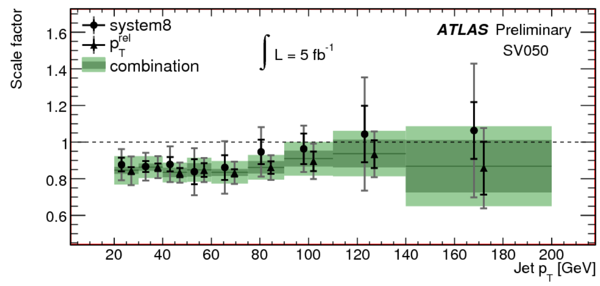


Figure 1: The results of the fit for combining scale factor results from the $p_T^{rel}$ and System 8 calibration methods. The points show the individual results and the colored bands show the results in each bin. Both statistical (dark) and statistical+systematic (light) errors are shown. Results are shown for the Secondary Vertex Tagger tuned to give 50% efficiency in a top sample (SV050). Taken from [3].

The fits are done using the RooFit library, part of ROOT. The fitting infrastructure is designed to incorporate asymmetric errors and additional calibrations in the future.

Both the $p_T^{rel}$ and System 8 methods are statistically correlated because they are based on the same jet sample. A study was done to determine the extent of the statistical correlation using a toy Monte Carlo. The numbers of events used in System 8 along with the flavor composition and the $b$-tagging efficiency were taken from data fits. The expected $p_T^{rel}$ inputs were taken by fitting data with MC templates. A toy MC is used to sample these numbers and distributions. The efficiency is re-calculated using $p_T^{rel}$ and System 8 for each sample. The correlations are then accounted for in the global fit. The method tracks the individual contributions of each systematic error to the final combination so the analyzers can properly treat common correlated errors in their analyses and the $b$-tagging calibration.

# References

[1] ATLAS Collaboration, “The ATLAS Detector”, 2008 JINST 3 S08003

[2] The ATLAS Collaboration, “Commissioning of the ATLAS high-performance $b$-tagging algorithms in the 7 TeV collision data”, ATLAS-CONF-2011-102, Preliminary Result, https://cdsweb.cern.ch/record/1369219

[3] The ATLAS Collaboration, “Measurement of the b-tag Efficiency in a Sample of Jets Containing Muons with 5 $fb^{-1}$ of Data from the ATLAS Detector”, ATLAS-CONF-2012-043, Preliminary Result, https://cdsweb.cern.ch/record/1435197