PROCEEDINGS OF SCIENCE

PoS(LHCP2020)240

ATL-PHYS-PROC-2020-070
06 October 2020

Measurement of the combined online and offline b-jet identification efficiency with $t\bar{t}$ events using a likelihood method in the ATLAS detector

Giovanni Bartolini, on behalf of the ATLAS Collaboration

Aix Marseille University, CNRS/IN2P3, Centre de Physique des Particules de Marseille, 163, avenue de Luminy - Case 902, 13288 Marseille cedex 09, France

E-mail: bartolini@cppm.in2p3.fr

The identification of jets coming from the hadronization of b-quarks (b-tagging) is instrumental for many physics analyses performed at the Large Hadron Collider (LHC). ATLAS has b-tagging capability starting at High-Level Trigger stage, where b-tagging algorithms can process reconstructed tracks. Physics processes with b-jets in the final state, but no lepton or missing transverse energy, can benefit from using b-tagging at trigger level to maximise the signal efficiency. In Run 2, the b-jet trigger efficiency is measured using a likelihood-based method applied to data enriched in $t\bar{t}$ di-leptonic events. The b-tagging efficiency, for trigger algorithms as well as for the combination between trigger and offline algorithms, is extracted for jets in a transverse momentum range from 35 to 600 GeV, and data-to-simulation scale factors are derived.

The Eighth Annual Conference on Large Hadron Collider Physics-LHCP2020
25-30 May, 2020
online

https://pos.sissa.it/

1. *b*-tagging at trigger level with the ATLAS detector

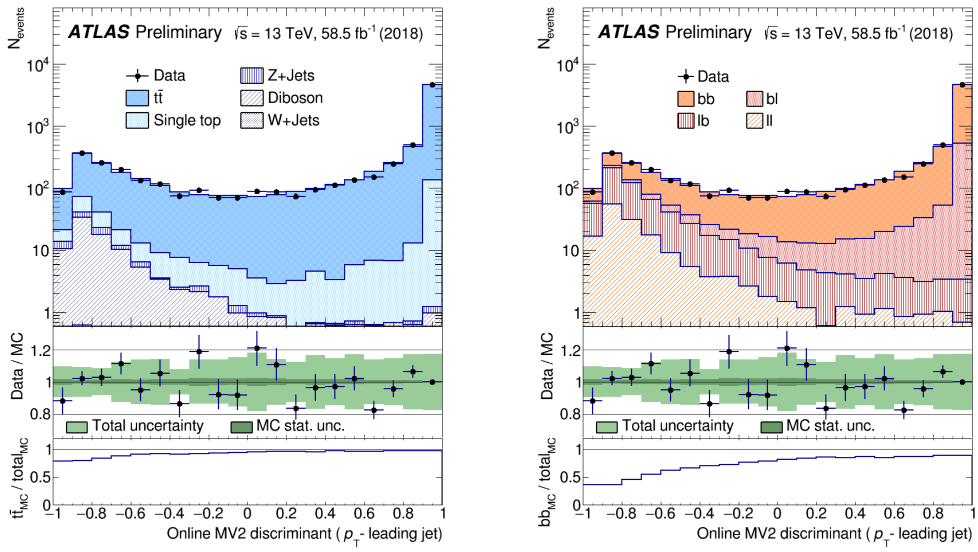
At the LHC, signal of physics beyond the Standard Model (SM) can be accessed via precision measurements of the SM, like Higgs boson properties, or direct searches of new signal. Triggering efficiently on the presence of *b*-jets allows to analyse physics processes with *b*-quarks but without other conventional signatures to trigger on, i.e. VBF $H(H \rightarrow b\bar{b})$ or fully hadronic top signatures.

ATLAS [1] is a general purpose particle physics experiment based at the LHC. In Run 2 ATLAS collected proton–proton collisions at $\sqrt{s}$ = 13 TeV with an instantaneous luminosity of $\sim 10^{34}$ cm^{-2}s^{-1}, correspondig to ∼ 40 million collisions per second. The number of events is progressively reduced by a trigger system, up to a rate processable by the acquisition system, ∼1000 events/s. The Run 2 ATLAS trigger was divided into two levels. The Level 1 (L1), hardware-based, uses calorimeters and muon detectors with reduced granularity to identify Regions of Interest (RoI) and to apply a first trigger decision based on coarsely reconstructed physics objects. The High Level Trigger (HLT), software-based, analyses the L1 RoIs using the full detector. It further reduces the trigger rate thanks to object reconstruction algorithms close to offline levels (leptons, missing energy, tracks, jets, *b*-jets).

The lifetime of *b*-hadrons, of the order of 1.5 ps, allows them to travel a few millimetres before decaying. Jets from those decays have tracks originating from a vertex displaced by a measurable length from the interaction point. Starting from 2016, the ATLAS trigger system used the Boosted Decision Tree (BDT) based MV2 tagger at HLT, which lead to bringing online *b*-tagging performance close to the offline one. MV2 combines the output of three different low-level *b*-tagging algorithms: IP2D/IP3D, based on impact parameter 2D (d_0) or 3D (d_0,z_0) distributions, SV1, based on the reconstructed secondary vertex properties, and JetFitter, which is based on the topology of the *B*-meson decay chains within the calorimeter jet.

2. *b*-jet trigger calibration using $t\bar{t}$ events

To achieve a high *b*-jet purity sample, necessary for the efficiency calibration, a sample enriched with dileptonic $t\bar{t}$ events is isolated. Events are selected with specialized *performance* triggers which require the presence of a lepton and at least two calorimeter jets where the online *b*-tagging algorithms are applied without taking a decision. This allows the possibility of storing online *b*-tagging discriminant into the data. For the offline selection, events are required to have exactly two leptons with opposite charge and different flavor ($e\mu$) to minimize contributions from non-$t\bar{t}$ processes, and exactly two offline particle flow jets, to minimize the contribution of radiation. Both offline jets need to be matched to HLT jets with a geometrical requirement $\Delta R < 0.2$, necessary step to associate the online *b*-tagging discriminant to the offline jets used for the calibration. An additional kinematic cut based on a pseudo-top reconstruction involving the invariant mass of lepton+jet pairs is applied to reduce light-jet content [2]. The distribution of the online *b*-tagging discriminant for jets in events passing the selection requirement is shown in Figure 1a, where jets are shown according to the physics process they have been generated from, while in Figure 1b the same is shown after jets are categorized according to their flavor. It has to be noticed how most jets are produced in $t\bar{t}$ events and that, contrary to light jets, *b*-jets accumulate to values of MV2 close to one.



(a) **(b)**

Figure 1: *Discriminant output of the online MV2 algorithm for the p_T-leading jet in events passing the selection applied for the online b-jet identification efficiency measurement. Simulated events are classified according to (a) the physics process and (b) the flavor composition of the two jets. The lower panels show the data-to-simulation ratio as well as the fraction of (a) $t\bar{t}$ events and (b) bb events among the simulated events. [3]*

For the efficiency estimation, selected events are classified according to jet p_T and b-tagging discriminant, the b-jet identification efficiency is then extracted using a likelihood-based method [2]. For online only b-tagging, the efficiency is defined as:

$$\epsilon_b^{\text{trig}} = \frac{N_{\text{jets}}(\text{pass online } b\text{-tag})}{N_{\text{jets}}(\text{total})}.$$

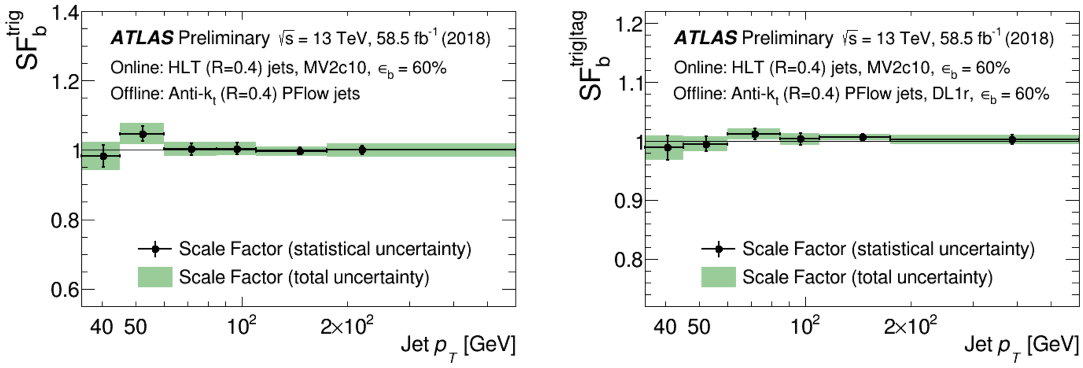
The same method is also used to measure the conditional b-jet identification efficiency, defined as:

$$\epsilon_b^{\text{trig|tag}} = \frac{N_{\text{jets}}(\text{pass online and offline } b\text{-tag})}{N_{\text{jets}}(\text{pass offline } b\text{-tag})}.$$

For this, all combinations of six online and four offline working points are calibrated. These measured efficiencies are used to correct possible deviations in the simulation by evaluating data-to-simulation scale factors (SF):

$$SF_b = \frac{\epsilon_b^{\text{data}}}{\epsilon_b^{\text{MC}}}$$

The conditional SFs are intended for analysis that use both online and offline b-tagging in combination. Figures 2a and 2b show the obtained SFs for the 60% single-cut working point of the online MV2 for respectively the online only efficiency measurement and the conditional efficiency measurement after applying the 60% single-cut working point on the DL1r offline tagger. The modeling uncertainties on $t\bar{t}$, shown in Figure 3, were computed based on the difference between the nominal MC sample and other samples generated with alternative parton shower and hadronization model,



(a) **(b)**

Figure 2: *Scale factors (data/MC) for (a) online b-jet identification efficiency (SF_b^{trig}) measurement and (b) for the conditional online b-jet identification efficiency ($SF_b^{trig|tag}$) measurement after applying the 60% single-cut working point on the DL1r offline tagger, for the 60% single-cut working point of the online MV2 tagger as a function of offline jet p_T. [3]*

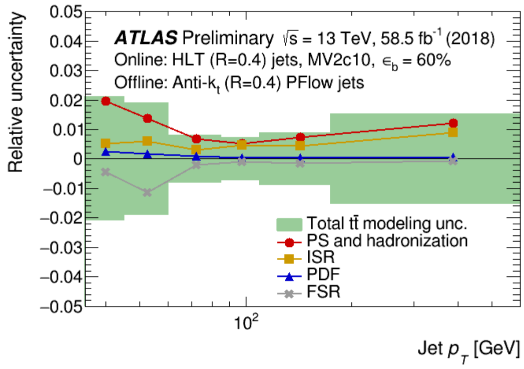


Figure 3: *Decomposition of the $t\bar{t}$ relative modeling uncertainty on the online b-jet identification efficiency measurement of the online MV2 tagger for the 60% single-cut working point as a function of jet p_T. The total $t\bar{t}$ modeling uncertainty is shown as a green band while the various components are shown as points. [3]*

additional initial-state radiation (ISR), final-state radiation (FSR), and alternative parton density function (PDF).

References

[1] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, 2008 JINST 3 S08003

[2] ATLAS Collaboration, *ATLAS b-jet identification performance and efficiency measurement with $t\bar{t}$ events in pp collisions at $\sqrt{s}$ = 13 TeV*, Eur.Phys.J.C 79 (2019) 11, 970, arXiv:1907.05120 [hep-ex]

[3] ATLAS public, *ATLAS b-jet Trigger Public Results*, BJetTriggerPublicResults twiki: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BJetTriggerPublicResults