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Rejecting $g \rightarrow b\bar{b}$ Jets in the ATLAS b-jet Trigger

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The ATLAS b-jet trigger system is crucial as it is important to be able to efficiently select events containing b-jet at the trigger level for analyses that involve many b-quarks in the final states, such as the search for $HH \rightarrow 4b$ production. However, in Run-2 the ATLAS b-tagger did not distinguish between jets containing a single b-hadron (b-jets) and jets containing 2 b-hadrons (bb-jet). Collision events involving small-angle $g \rightarrow b\bar{b}$ splitting, resulting in bb-jet are common in the LHC. Rejecting them in real-time would significantly reduce the readout rates of multi-b-jet triggers and ensure efficient signal extraction, which is particularly important for analyses that use multi-b-jet trigger chains. The proposed poster shows an approach to reject bb-jets in the ATLAS online b-taggers, the proposed implementation and the implications for the ATLAS Run-3 physics programme.

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This proceeding presents a study on rejecting bb-jets arising from $g \to b\bar{b}$ splitting using the flavour-tagging algorithms for the High Level b-jet trigger at ATLAS. The current baseline algorithm GN1 [1] used in the b-jet trigger is found to identify single-b-jets (signals to be kept) and bb-jets (background to be rejected) inclusively. This is evident in the overlapping distributions in the b-jet discriminant score between the two jet flavours in Figure 1.

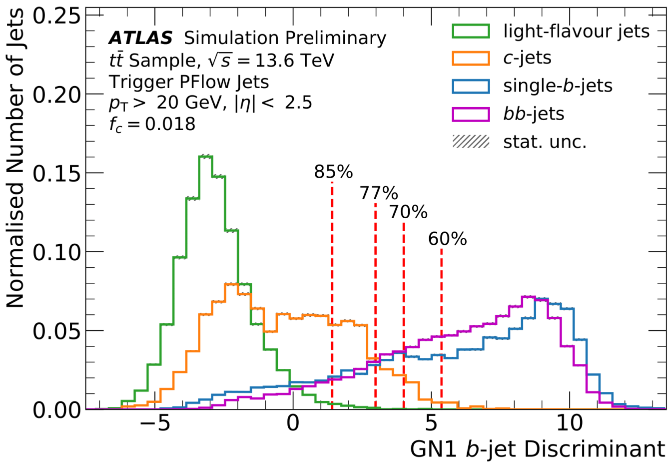

Figure 1: Distributions of the HLT b-jet discriminant score for the GN1 algorithm, for b-jets, c-jets, light-flavour jets and bb-jets. The algorithm was evaluated on HLT Particle Flow jets from a $t\bar{t}$ sample. Red vertical lines indicate the 85%, 77%, 70% and 60% b-jet efficiency working points.

A deep neural network algorithm DL1dbb, based on the DL1 architecture [2] is trained to further separate single-b-jets from bb-jets, by exploiting the same input features as GN1 but between these two jet flavours only. The b-jet discriminant score of DL1dbb shows improved separation between them, shown in Figure 2. DL1dbb is applied to jets that are tagged at the 85% b-jet efficiency working point of GN1 to form a combined tagging scheme. Compared to GN1 alone, the bb-jet rejection achieved with this combined tagging scheme is roughly a factor of three at the 77% b-jet efficiency, shown in Figure 3.

The combined tagging scheme is implemented in the ATLAS b-jet trigger in a multi-b-jet chain. The rejection of QCD multijet events with fewer than 3 single-b-jets (background) as a function of the efficiency of non-resonant $HH \to 4b$ events with at least 4 single-b-jets (signal) are estimated. It is evaluated while requiring 4 Particle Flow jets, with jet p_T thresholds of 80 GeV, 55 GeV, 28 GeV, 20 GeV, at least three of which are required to be above the b-tagging threshold. The background rejections achieved by the combined tagging scheme of GN1 and DL1dbb algorithms at lower b-jet efficiencies (70%, 75%, 77%) are found to be higher than GN1 alone, shown in Figure 4.

In conclusion, a dedicated algorithm is trained to further separate single-b-jets from bb-jets in jets tagged by the baseline b-tagging algorithm GN1 in the ATLAS b-jet trigger. In conjunction with the 85% b-jet efficiency working point of GN1, a factor of 3 in bb-jet rejection is achieved, and higher rejections of the QCD multijet background events are achieved while maintaining the same $HH \to 4b$ signal efficiencies at lower HLT b-jet efficiency working points.

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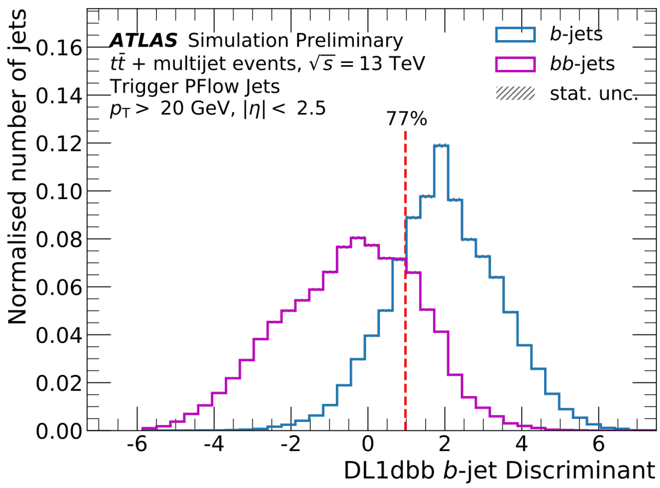

Figure 2: Distributions of the HLT b-jet discriminant score for the DL1dbb algorithm, for b-jets and bb-jets. The algorithm was evaluated on HLT Particle Flow jets from $t\bar{t}$ and QCD multi-jet samples. The red vertical line indicates the 77% b-jet efficiency working point.

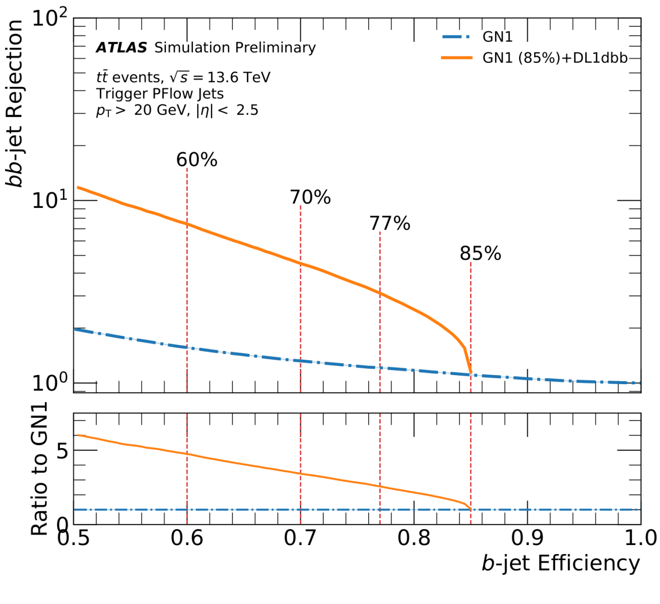

Figure 3: bb-jet rejection as a function of the HLT b-jet efficiency of the combined GN1 and DL1dbb algorithms, in comparison to GN1 alone. The rejection is evaluated on a $t\bar{t}$ sample. The 85%, 77%, 70% and 65% b-jet efficiencies are indicated by red vertical lines.

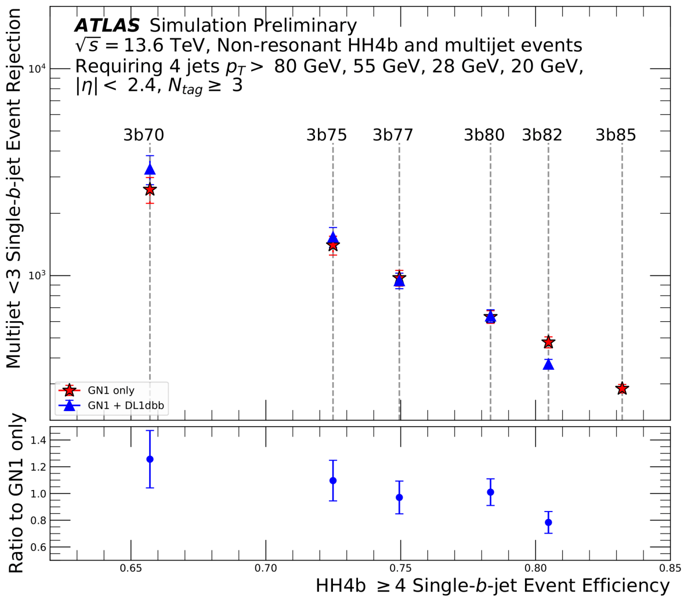

Figure 4: Rejection of QCD multijet events with fewer than three single-b-jets as a function of efficiency of non-resonant $HH \to 4b$ events with at least 4 single-b-jets, evaluated while requiring 4 Particle Flow jets, with jet p_T thresholds of 80 GeV, 55 GeV, 28 GeV, 20 GeV, at least three of which are required to be above the b-tagging threshold. The background rejections of GN1 only at a range of b-jet efficiency working points are indicated by stars, ad the rejections of GN1 and DL1dbb combined are indicated by triangles.

References

[1] The ATLAS Collaboration, *Graph Neural Network Jet Flavour Tagging with the ATLAS Detector*, ATL-PHYS-PUB-2022-027, (June 2022)

[2] The 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) 970, (Jan 2020)