1 Supplemental Material Allowed by Journal to Accompany Online Version of Paper

1.1 Detailed trigger description

Multiple triggers were used to record the data and can broadly be classified into three categories. The first category of triggers selects a set of minimum-bias events through a L1 trigger that requires a signal in at least one MBTS counter, and a second trigger that requires at least one reconstructed track with $p_{\mathrm{T}} > 0.2$ GeV at the HLT. The second category is a set of high-multiplicity triggers that apply a L1 requirement on either the transverse energy (E_{T}) in the calorimeters or a hit in at least one MBTS counter on each side, and an HLT requirement on the multiplicity of HLT-reconstructed tracks with $p_{\mathrm{T}} > 0.4$ GeV that is associated with the reconstructed vertex with the highest multiplicity in the event. The third is a set of triggers that enhance the rate of jets. These include a set of triggers that require a jet at L1 and at the HLT, and another set of triggers that require a minimum threshold on the total E_{T} in the calorimeter at L1.

1.2 Detailed track selection criteria

The criteria used to select tracks include the requirements of $p_{\mathrm{T}} > 0.4$ GeV and $|\eta| < 2.5$, a hit in the IBL or a hit in the pixel layer next to the IBL, and a minimum of six hits in the SCT. Additionally, the transverse impact parameter of the track relative to the average beam position, and the longitudinal impact parameter of the track relative to the vertex are both required to be less than 1.5 mm. To remove tracks with mis-measured p_{T} due to interactions with the material or other effects, the track-fit χ^2 probability is required to be larger than 0.01 for tracks having $p_{\mathrm{T}} > 10$ GeV.

1.3 Multiplicity distributions

Figure 1 shows the distribution of $N_{\mathrm{ch}}^{\mathrm{rec,corr}}$ for the events in the *h*-*h*, $h^{UE}-h^{UE}(AllEvents)$, $h^{UE}-h^{UE}(NoJets)$, $h^{UE}-h^{UE}(WithJets)$, and $h^{UE}-h^{J}$ cases. The default peripheral reference in the template-fits is constructed using the events in the 10–30 multiplicity interval. The average minimum-bias multiplicity of reconstructed charged-particle tracks in 13 TeV pp collisions in ATLAS is ~ 20, and the default range for the peripheral reference is taken to be a ± 10 window around this mean value. Alternative peripheral references built from the 10–40 and 20–40 multiplicity intervals are used to evaluate systematic uncertainties, where the lower and upper multiplicity ranges are increased by 10 from the default interval. The 0–10 multiplicity interval, is excluded from the peripheral references as 1) the $h^{UE}-h^{UE}(WithJets)$ and $h^{UE}-h^{J}$ cases have very few events at these low multiplicities, and 2) such low multiplicity are likely to contain a significant contribution from diffractive events.

1.4 Pythia 8 Embedding

This section motivates the choice of the 4 GeV requirement used in Eq. 2 of the Letter to remove the bias from the UE modulation on the jet selection. The effect of UE modulation on the jet selection is estimated by a toy Pythia 8 embedding study. The Pythia 8 events are simulated using the Monash 2013 tune with multi-parton interaction off and initial-state radiation on. Jet reconstruction is performed on these

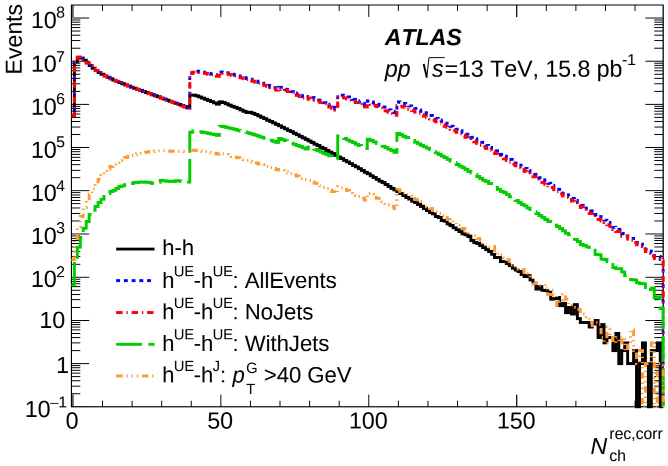

Figure 1: The distribution of $N_{\mathrm{ch}}^{\mathrm{rec,corr}}$ for the $\sqrt{s}$ = 13 TeV pp data used in this analysis. The different lines denote the *h-h*, $h^{UE} - h^{UE}(AllEvents)$, $h^{UE} - h^{UE}(NoJets)$, $h^{UE} - h^{UE}(WithJets)$, and $h^{UE} - h^{J}$ cases. The discontinuities in the distributions correspond to different high-multiplicity trigger thresholds.

generated events, using the anti-k_{T} clustering algorithm with a radius parameter of 0.4. The jets thus produced are called *generated-jets* hereafter. The generated events are filtered by requiring the events to have a generated-jet with p_{T} greater than 15 GeV and a balanced generated-jet with $p_{\mathrm{T}} > 10$ GeV and $|\Delta\phi| > 5\pi/6$ relative to the first jet. The generated (stable[1]) particles are embedded onto minimum bias data events. After the embedding, jets are reconstructed using the embedded particles and the original particle flow objects [1] present in the data-event, using the anti-k_{T} clustering algorithm with a radius parameter of 0.4. These jets are called *embedded-jets* hereafter. Similar jet clustering is also done using only the particle flow objects in the minimum-bias data used in the embedding study. These jets are called *data-jets* hereafter.

The embedded-jets are required to match a generated-jet with $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.1$. The embedded-jets are also required to be separated from data-jets by $\Delta R > 0.8$. The p_{T} of the embedded-jets is always larger than the p_{T} of the matched generated-jet as the particle flow objects in the data always push up the p_{T}. The issue of concern for this analysis is that this increase in the p_{T} is dependent on the azimuthal angle that the jet makes with the second-order event-plane, due to the modulation in the UE. To visualize the bias from the UE modulation, the difference between the azimuthal angle of the embedded-jet, ϕ^{jet}, and the second-order event plane angle, Ψ_2^{Data}, is plotted in Figure 2. The Ψ_2 angle is calculated using particles from the data events only, excluding particles within one unit in η around any data-jets with p_{T} greater than 15 GeV. Since Pythia 8 events are uncorrelated with the data event onto which they are embedded, the distribution of $\phi^{\mathrm{jet}} - \Psi_2^{\mathrm{Data}}$ is, by construction, constant for the generated-jets. However, for the embedded-jets the corresponding distribution is modulated, as shown in Figure 2.

Since the modulation effects are dominated by low p_{T} particles, grooming the jets to remove soft particles can remove the UE bias. A groomed jet p_{T} definition is proposed here, by summing the p_{T} of jet constituents with p_{T} greater than a particular threshold X:

$$p_{\mathrm{T}}^{\mathrm{G}} = \left|\sum \boldsymbol{p}_{\mathrm{T}}^{>\,\mathrm{X\,GeV}}\right|, \quad (1)$$

[1] The generated particles that are not decayed further by Pythia 8 are called stable here.

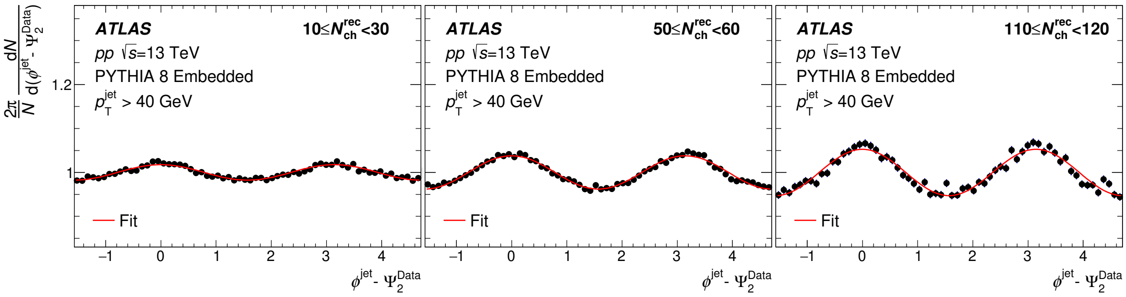

Figure 2: The distribution of $\phi^{\text{jet}} - \Psi_2^{\text{Data}}$ for the embedded jets. The continuous line indicates a Fourier fit to the distribution that includes a 2$^{\text{nd}}$ order modulation. The different panels correspond to different multiplicity intervals.

Figure 3 shows the $\phi^{\text{jet}} - \Psi_2^{\text{Data}}$ using different values of the threshold X in Eq. (1). The modulation in the distribution systematically decreases with increasing X, and is nearly gone for $X = 4$ GeV.

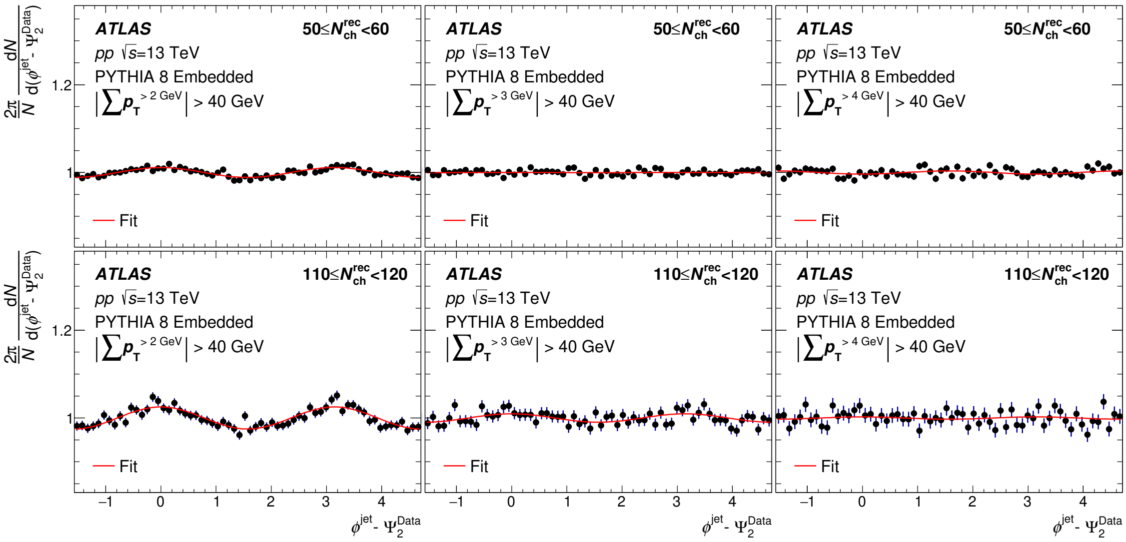

Figure 3: The distribution of $\phi^{\text{jet}} - \Psi_2^{\text{Data}}$ for the embedded jets. The continuous line indicates a Fourier fit to the distribution that includes a 2$^{\text{nd}}$ order modulation. From left to right, the three panels in each row correspond to increasing thresholds X (in Eq. (1)) of 2 GeV, 3 GeV, and 4 GeV. The top (bottom) row corresponds to the 50–60 (110–120) multiplicity interval.

1.5 Illustration of the procedure for selecting $h^{UE} - h^{UE}$ and $h^{UE} - h^{J}$ pairs

Figures 4 and 5 illustrate the procedure for selecting the $h^{UE} - h^{UE}$ and $h^{UE} - h^{J}$ pairs, respectively.

1.6 Cross checks on jet selections used in the analysis

This section discusses several checks that are made to test the sensitivity of the results on the jet selections used in the analysis.

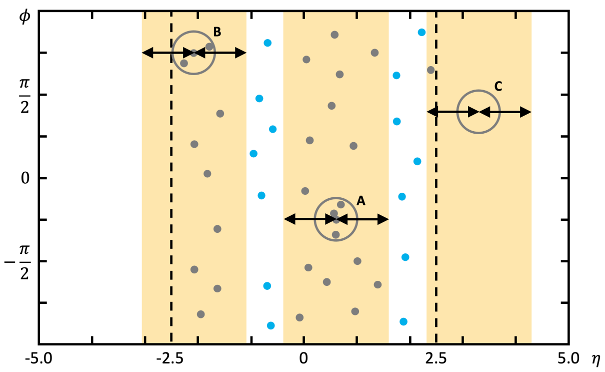

Figure 4: Conceptual depiction of the procedure to measure the $h^{UE} - h^{UE}$ correlations. The x and y-axes depict η and ϕ, respectively. The ATLAS calorimeter system extends over ± 4.9 in η, over which range the jets are reconstructed. The vertical dashed lines at $\eta = \pm 2.5$ indicate the acceptance of the ATLAS ID, over which charged-particle tracks are reconstructed. The figure shows an event with three $p_{\mathrm{T}}^{\mathrm{G}} > 15$ GeV jets (grey circles). The vertical yellow bands indicate a ± 1 η window around the jets. The reconstructed tracks within the yellow bands (grey dots) are excluded from the $h^{UE} - h^{UE}$ correlation study. The blue dots represent the tracks that are used in the $h^{UE} - h^{UE}$ correlation.

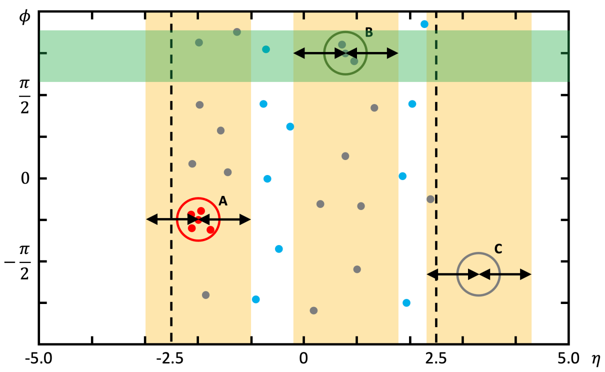

Figure 5: Conceptual depiction of the procedure to measure the $h^{UE} - h^{J}$ correlations. The x and y-axes depict η and ϕ, respectively. The ATLAS calorimeter system extends over ± 4.9 in η, over which range the jets are reconstructed. The vertical dashed lines at $\eta = \pm 2.5$ indicate the acceptance of the ATLAS ID, over which charged-particle tracks are reconstructed. The figure shows an event with two $p_{\mathrm{T}}^{\mathrm{G}} > 15$ GeV jets (grey circles, labelled as B and C), and a $p_{\mathrm{T}}^{\mathrm{G}} > 40$ GeV jet (red circle, labelled as A). The red dots represent the tracks that are considered as jet constituents (h^{J}) of the $p_{\mathrm{T}}^{\mathrm{G}} > 40$ GeV jet. The vertical yellow bands indicate a ± 1 η window around the jets. The blue dots represent the tracks that are treated as UE tracks (see Figure 4). The green band indicates the region scanned to find the balancing jet for jet-A. In this case the balancing jet is jet-B. In the absence of a balancing jet, the event is not used for the $h^{UE} - h^{J}$ correlation.

- The sensitivity of the $h^{UE} - h^{J}$ v_2 measurements to the $p_{\mathrm{T}}^{\mathrm{G}}$ selection is evaluated by varying the $p_{\mathrm{T}}^{\mathrm{G}}$ selection threshold from the nominal value of 40 GeV to 35 GeV and 50 GeV.
- The sensitivity of the v_2 to the p_{T} threshold applied on the jet constituents in Eq. (1) is checked by raising it from its default value of 4 GeV to 4.5 GeV.
- A threshold of $p_{\mathrm{T}}^{\mathrm{G}} = 15$ GeV is applied to separate the hard and soft processes in the event. This threshold is an analysis choice as there is no p_{T} value that fully separates hard and soft processes. The sensitivity of the results to the choice of the jet $p_{\mathrm{T}}^{\mathrm{G}}$ is investigated by increasing the threshold from its nominal value of 15 GeV to 20 GeV.

- As stated in the Letter as isolation requirement is imposed on the $p_{\mathrm{T}}^{\mathrm{G}} > 40$ GeV jets in the $h^{UE} - h^{J}$ correlations. This isolation requirement requires that there are no $p_{\mathrm{T}}^{\mathrm{G}} > 15$ GeV jets within $\Delta R = 1$ of the $p_{\mathrm{T}}^{\mathrm{G}} > 40$ GeV jets used in the $h^{UE} - h^{J}$ correlation analysis. As a cross-check the measurements are repeated with this isolation requirement removed.

For all these cases no significant variation is observed in the measurements, and the results with these variations are consistent with the nominal ones within the quoted systematic and statistical uncertainties.

References

[1] ATLAS Collaboration,
Jet reconstruction and performance using particle flow with the ATLAS Detector,
Eur. Phys. J. C **77** (2017) 466, arXiv: 1703.10485 [hep-ex].