Auxiliary information for paper SUSY-2016-08 by the ATLAS Collaboration:

Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector

Parameterized selection efficiencies

To allow those who are not members of the ATLAS Collaboration to reinterpret our results for any model predicting displaced vertices, parameterized efficiencies are provided that allows anyone to calculate expected event yields. The efficiencies can be applied to vertices and events that pass certain particle-level acceptance requirements using the final-state particles in the Monte Carlo truth record.

Definition of acceptances

Model independent selection efficiencies are provided for events passing the event-level acceptance $\mathcal{A}_{\text{event}}$ defined using particle-level requirements on $E_{\text{T,true}}^{\text{miss}}$, jets, and a DV. Events are required to satisfy the following conditions:

- $E_{\text{T,true}}^{\text{miss}} > 200$ GeV, where $E_{\text{T,true}}^{\text{miss}}$ is defined as the magnitude of the transverse component of the vector sum of the momenta of the stable weakly-interacting particles in the final state.
- In order to satisfy the requirements of the post-trigger filters used in the dedicated data processing in the analysis, 75% of the integrated luminosity must require the existence of either
  - one truth jet (with $p_{\text{T}} > 70$ GeV) for which the scalar sum of the charged particle p_{T} does not exceed 5 GeV for those particles with small impact parameter with respect to the PV; or
  - two jets (with $p_{\text{T}} > 25$ GeV) satisfying the same requirement.

  The jets are defined at the stable-particle level, clustered with the anti-k_t clustering algorithm with $R = 0.4$. Note that because of changing filter setups during the data-taking period, 25% of the luminosity need not satisfy these jet requirements, retaining acceptance for signals without large amounts of displaced high-p_{T} jet activity.
- Events must contain at least one DV passing the vertex-level acceptance requirements described below.

The vertex-level acceptance $\mathcal{A}_{\text{vertex}}$ requires displaced decays of massive particles to have the following properties:

- The transverse distance between the IP and the decay position must be greater than 4 mm.
- The decay position must lie within the fiducial volume of $R_{\text{decay}} < 300$ mm and $|z| < 300$ mm.
- The number of *selected decay products* (described below) must be at least 5.

- The invariant mass of the *truth vertex* must be larger than 10 GeV. The *truth vertex* is constructed using the momenta of the *selected decay products* with a charged pion mass assumption to simulate the assumptions in the DV reconstruction used in the analysis.

The *selected decay products* used in the above *truth vertex* construction are those decay products of a given massive particle decay that satisfy the following conditions:

- The particle is charged and stable for timescales required to traverse the tracking volume.
- The particle has a transverse momentum $p_{\mathrm{T}}(|q| = 1) > 1$ GeV. For particles with electric charge $|q| \neq 1$, this requirement should use p_{T} calculated assuming a charge of $|q| = 1$.
- The particle has an approximate transverse impact parameter $d_0 \equiv R_{\mathrm{decay}} \times \sin \Delta\phi > 2$ mm, where R_{decay} is the transverse distance between the interaction point and the massive particle decay and $\Delta\phi$ is the azimuthal angle between the particle momentum at its creation and the vector from the primary vertex to the position of the displaced decay.

Efficiencies

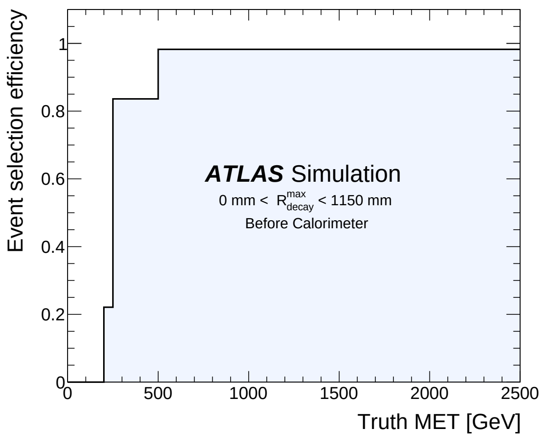
Parameterized efficiencies are provided at the event level and vertex level. Because of the inability of the ATLAS detector to fully measure the energy of jets that are produced within or beyond the calorimeter system, the event selection efficiency $\varepsilon_{\mathrm{event}}$ is provided as a function of the truth $E_{\mathrm{T}}^{\mathrm{miss}}$ described above as well as the transverse distance of the furthest heavy particle decay. These efficiencies can be found in Figure 20.

As part of the event-level efficiency, events entering the SR are required to have at least one selected DV. For each massive particle decay, an efficiency for reconstructing a DV is provided as a function of truth vertex mass, particle multiplicity, and radial detector position. These efficiencies can be found in Figures 21 and 22. The effects of the material and disabled pixel module vetoes are encapsulated in the radial binning of these efficiencies.

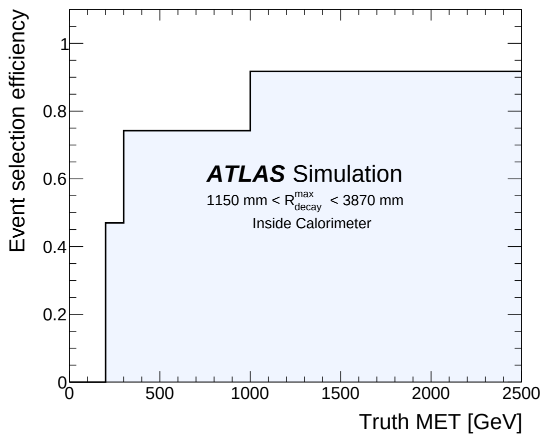
Overall, the probability that a particular event will fall into the SR is given symbolically by

$$P = \mathcal{A}_{\mathrm{event}}\, \varepsilon_{\mathrm{event}} \times \left(1 - \prod_{\mathrm{Vertices}} (1 - \mathcal{A}_{\mathrm{vertex}}\, \varepsilon_{\mathrm{vertex}})\right). \tag{1}$$

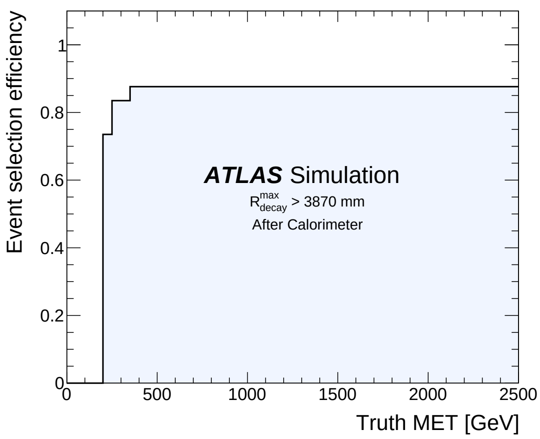
Across the signal models considered in this search, this procedure gives yields that agree with the proper analysis to roughly 10% level or less.



(a)

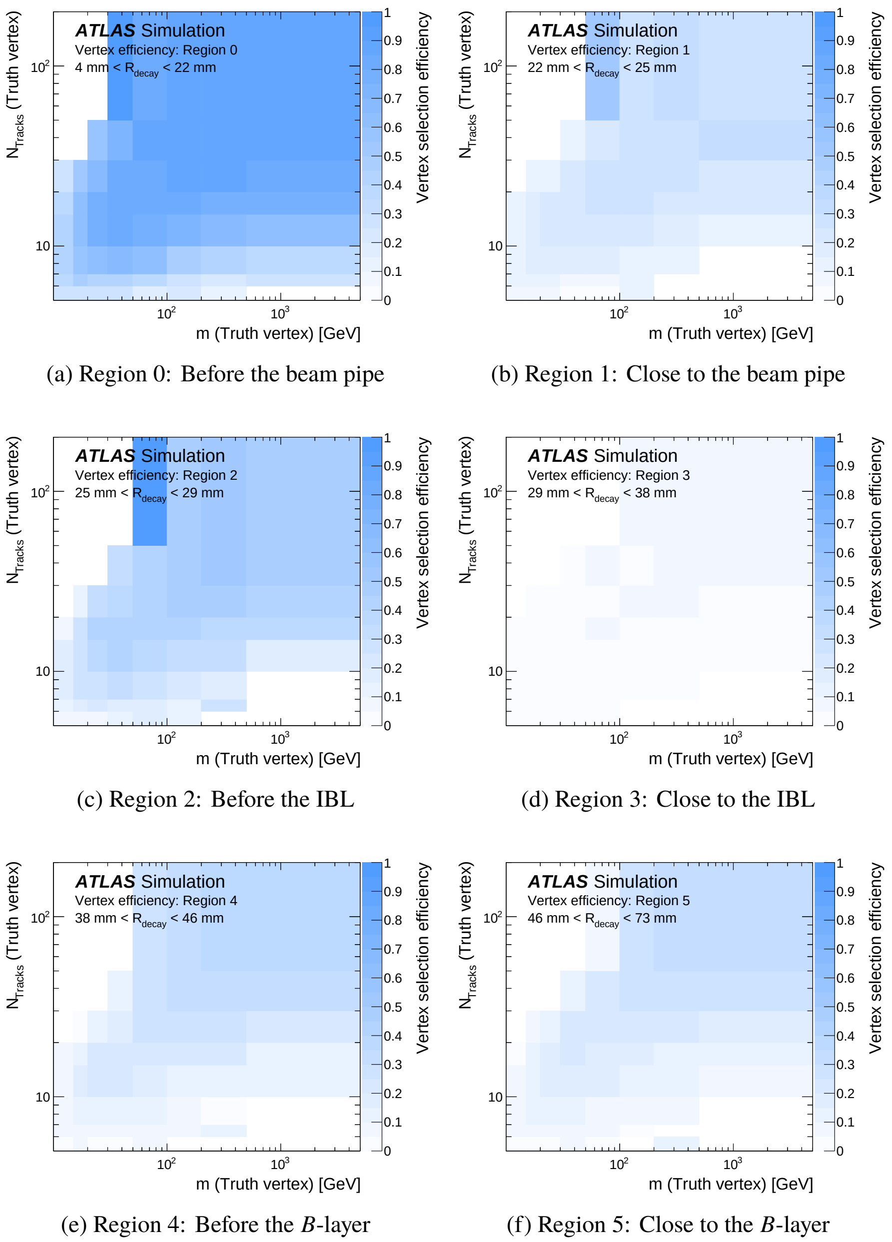


(b)



(c)

Figure 20: Parameterized event selection efficiencies are shown as a function of truth $E_{\mathrm{T}}^{\mathrm{miss}}$ as defined above. Event-level efficiencies are evaluated for events that have truth $E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV, pass a trackless jet requirement as described in the text, and have at least one displaced truth decay within the fiducial volume. To satisfy the event-level efficiency, events must then pass the *full event selection*, as defined in Section 4. The event efficiencies are evaluated separately for events which have all truth decay vertices occurring before the start of the ATLAS calorimeter, the furthest truth decay occurring inside the calorimeter, and the furthest decay occurring after the end of the ATLAS calorimeter.



(a) Region 0: Before the beam pipe

(b) Region 1: Close to the beam pipe

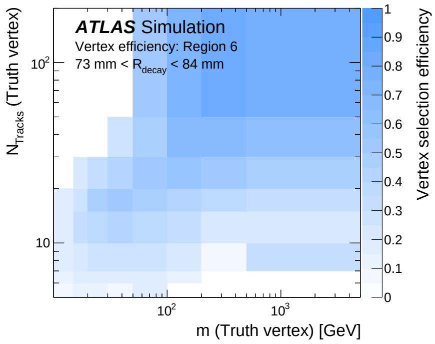
(c) Region 2: Before the IBL

(d) Region 3: Close to the IBL

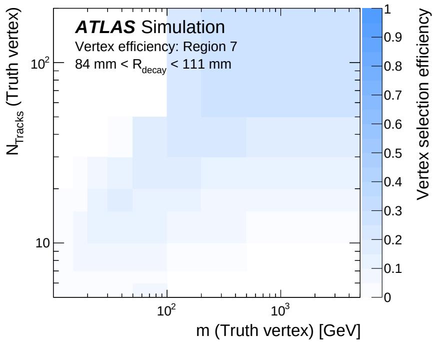
(e) Region 4: Before the B-layer

(f) Region 5: Close to the B-layer

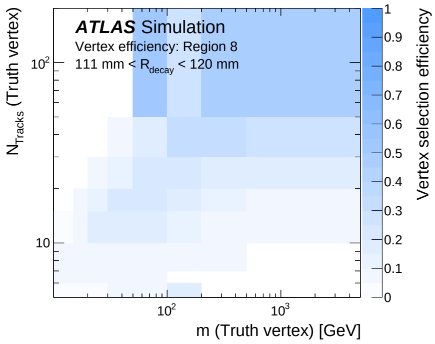
Figure 21: Parameterized vertex-level efficiencies as a function of number of particles associated to a truth decay vertex, and the vertex invariant mass. Selected particles are required to have nonzero electric charge, $p_T(|Q| = 1) > 1$ GeV, and $d_0 > 2$ mm, as described in the text. The per-vertex efficiency is evaluated only for truth vertices that have at least 5 associated tracks, an invariant mass > 10 GeV, and are in the region 4 mm < R_{decay} < 300 mm, and $|Z_{\text{decay}}| < 300$ mm. A truth vertex satisfies the vertex level efficiency if it can be matched to a reconstructed DV which passes the *final vertex selection* as defined in Section 4. Vertex-level efficiencies are given separately for each radial region.



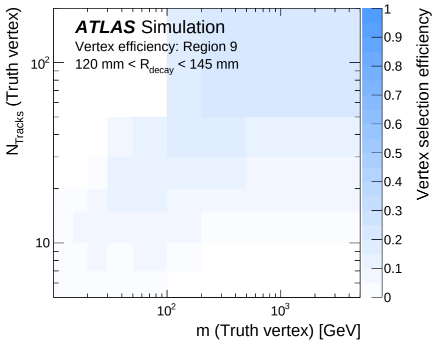
(a) Region 6: Before pixel layer 1



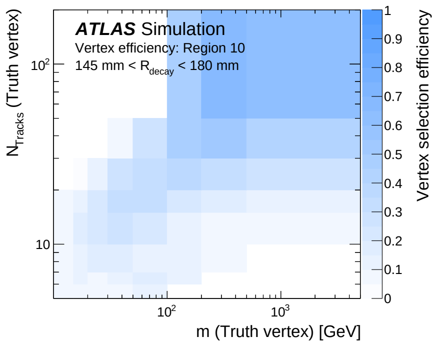
(b) Region 7: Close to pixel layer 1



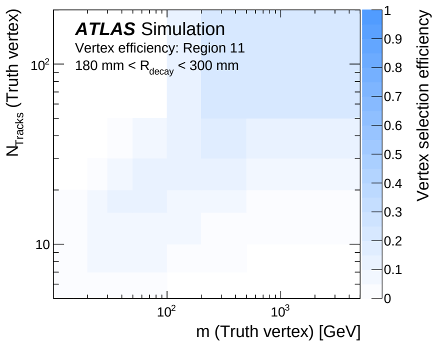
(c) Region 8: Before pixel layer 2



(d) Region 9: Close to pixel layer 2



(e) Region 10: Pixel supports



(f) Region 11: Before SCT

Figure 22: Parameterized vertex-level efficiencies as a function of number of particles associated to a truth decay vertex, and the invariant vertex mass. Selected particles are required to have nonzero electric charge, $p_{\mathrm{T}}(|Q| = 1) > 1$ GeV, and $d_0 > 2$ mm, as described in the text. The per-vertex efficiency is evaluated only for truth vertices that have at least 5 associated tracks, an invariant mass > 10 GeV, and are in the region 4 mm $< R_{\mathrm{decay}} <$ 300 mm, and $|Z_{\mathrm{decay}}| <$ 300 mm. A truth vertex satisfies the vertex level efficiency if it can be matched to a reconstructed DV which passes the *final vertex selection* as defined in Section 4. Vertex-level efficiencies are given separately for each radial region.