Supplemental Material

ATLAS Collaboration

1 BDT input variable distributions

Two BDTs are trained to separate the VBF signal from ggF background ($\mathrm{BDT}_{\mathrm{VBF/ggF}}$) and continuum background ($\mathrm{BDT}_{\mathrm{VBF/Continuum}}$), respectively. Both BDTs use the same input variables, whose distributions are shown in Figures 1 and 2.

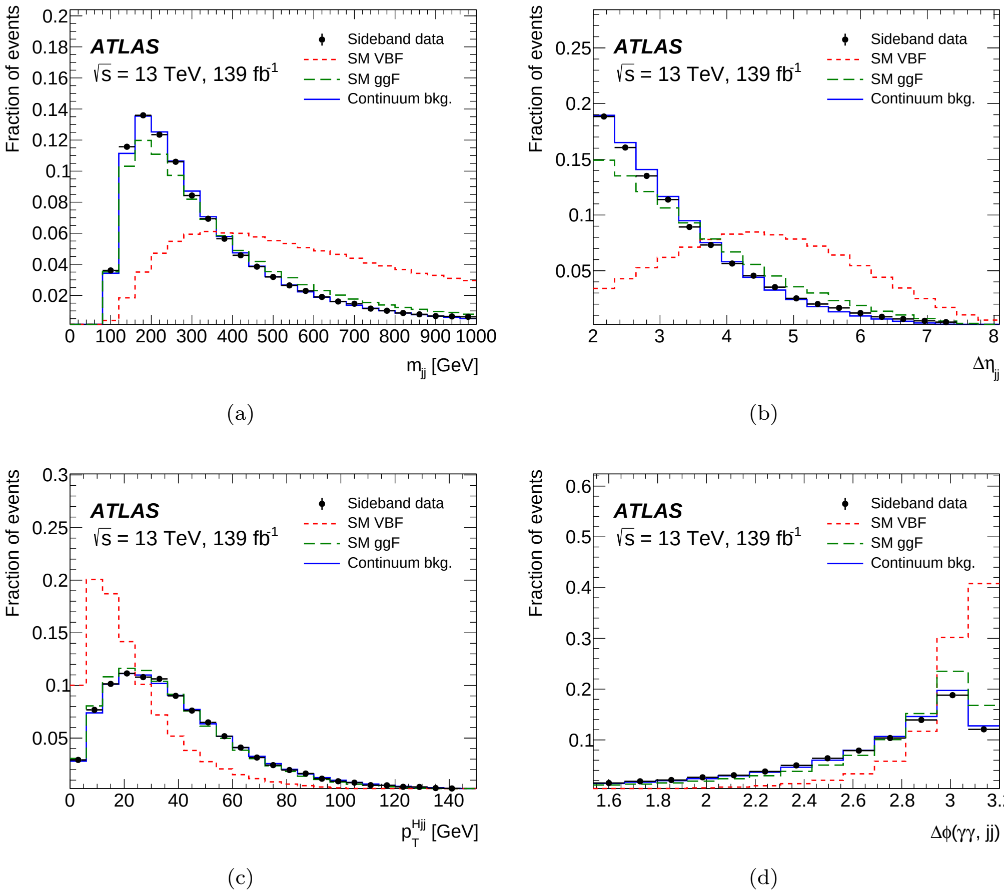
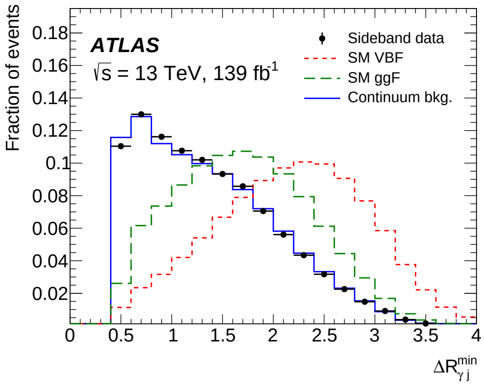
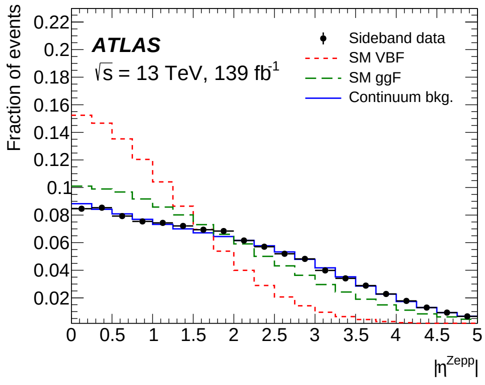


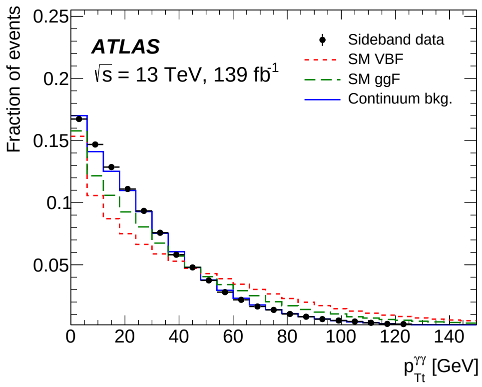
Figure 1: Distributions of the BDT input variables: (a) invariant mass of the dijet system formed by the two leading jets (m_{jj}), (b) pseudorapidity separation of the dijet system ($\Delta\eta_{jj}$), (c) p_{T} of the Higgs boson and the leading two jets (p_{T}^{Hjj}), and (d) azimuthal angle between the diphoton and dijet systems ($\Delta\phi(\gamma\gamma, jj)$). The red dashed line presents the VBF signal. The green long dashed line presents the ggF background. The blue solid line presents the continuum background. The black dots present the data in the $m_{\gamma\gamma}$ sideband ($m_{\gamma\gamma} \in [105, 118]$ GeV or $[132, 160]$ GeV).



(a)



(b)



(c)

Figure 2: Distributions of the BDT input variables: (a) minimum angular separation between the photons and the two leading jets ($\Delta R_{\gamma j}^{\rm min}$), (b) $\eta^{\rm Zepp}$ and (c) perpendicular projection of the diphoton $p_{\rm T}$ onto the diphoton thrust axis ($p_{\rm Tt}^{\gamma\gamma}$). The red dashed line presents the VBF signal. The green long dashed line presents the ggF background. The blue solid line presents the continuum background. The black dots present the data in the $m_{\gamma\gamma}$ sideband ($m_{\gamma\gamma} \in [105, 118]$ GeV or $[132, 160]$ GeV).

2 BDT selections for categorization

The output of the $\rm BDT_{VBF/ggF}$ and $\rm BDT_{VBF/Continuum}$ are used to enrich the VBF signal purity. Figure 3 shows the distributions of the BDT output, as well as the requirements for the event categorization. The left panel shows the two-dimensional distributions of $\rm BDT_{VBF/continuum}$ v.s. $\rm BDT_{VBF/ggF}$ for both data in the $m_{\gamma\gamma}$ sideband and VBF signal which are normalized to unity. The vertical line at 0.15 indicates the requirement on $\rm BDT_{VBF/ggF}$ to separate the tight and loose regions. The ratio of VBF signal over ggF background is improved by a factor of ten in the tight region. The horizontal line at 0.32 (0.09) indicates the requirement on $\rm BDT_{VBF/Continuum}$ in the $\rm BDT_{VBF/ggF}$ tight (loose) region, in order to maximize the combined significance for the VBF signal. The events are finally categorized into four regions: TT, TL, LT, and LL. The right panel shows the $\rm BDT_{VBF/continuum}$ distributions in the $\rm BDT_{VBF/ggF}$ tight and loose regions.

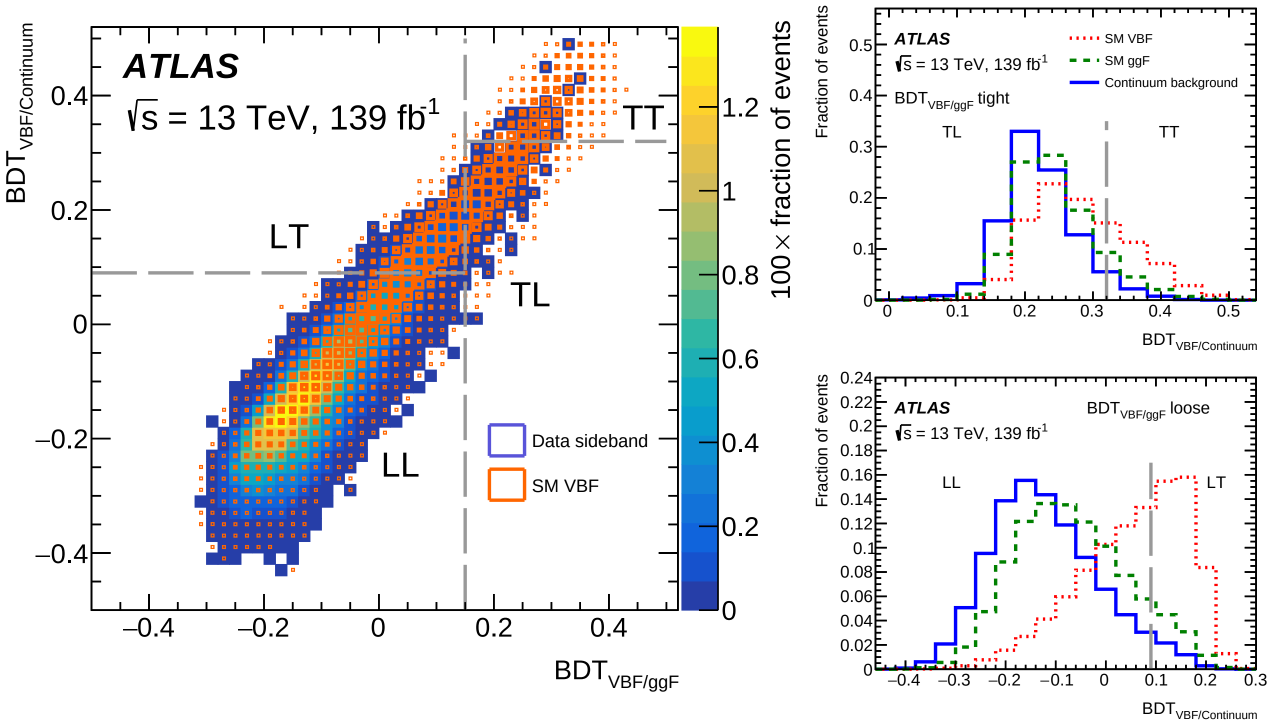


Figure 3: Left: Normalized two-dimensional distributions of $\mathrm{BDT}_{\mathrm{VBF/continuum}}$ v.s. $\mathrm{BDT}_{\mathrm{VBF/ggF}}$ for both data in the $m_{\gamma\gamma}$ sideband and VBF signal. The vertical line indicates the requirement on $\mathrm{BDT}_{\mathrm{VBF/ggF}}$ to separate the tight and loose regions, while the horizontal lines indicate the requirements on $\mathrm{BDT}_{\mathrm{VBF/continuum}}$. The events are categorized into four regions: TT, TL, LT, and LL. Right: $\mathrm{BDT}_{\mathrm{VBF/continuum}}$ distributions in the $\mathrm{BDT}_{\mathrm{VBF/ggF}}$ tight and loose regions. The vertical lines indicate the requirements on $\mathrm{BDT}_{\mathrm{VBF/continuum}}$.