SUSY Mu+VBF Trigger Performance with 2017 Data

CMS Collaboration

Abstract

SUSY Mu+VBF trigger performance results for 13 TeV from CMS are presented. The results are based on the 36.7 fb\(^{-1}\) of data obtained in 2017 and include the efficiencies as a function of various variables reconstructed with the offline version of the CMS software. The inclusive trigger efficiency is 98.3% for events containing a muon and two jets that pass the VBF selection criteria, with the leading (sub-leading) jet \(p_T > 120\) (60) GeV, \(\eta < 5.0\), and missing transverse momentum \(E_T^{\text{miss}} > 150\) GeV.
Mu+VBF Trigger Performance with 2017 Data

CMS Collaboration

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Overall caption

The following slides present the efficiency of a trigger targeting events with a soft muon ($\mu$), two forward jets with a large invariant mass and moderate missing transverse momentum (MET or $E_T^{\text{miss}}$). This trigger is used in the context of search for supersymmetric particles produced through vector boson fusion (VBF) processes. The dataset analyzed corresponds to 36.7 fb$^{-1}$ of proton–proton collisions at $\sqrt{s} = 13$ TeV recorded in 2017.

The Level 1 condition of the trigger requires two jets with transverse momentum ($p_T$) typically greater than 100 and 35 GeV, and a pair of jets with $p_T > 35$ GeV and an invariant mass ($M_{jj}$) greater than 620 GeV (L1_DoubleJet_100_35_DoubleJet35_Mass_Min620). The High Level Trigger condition requires the presence of two jets with $p_T$ greater than 40 GeV, a pseudorapidity difference ($\Delta \eta_{jj}$) greater than 3.5, and an invariant mass greater than 750 GeV. It also requires the scalar sum of the $p_T$ of all the jets, $H_T$ to be greater than 300 GeV and at least 60 GeV of missing transverse energy when muons are omitted in the energy sum.

In the following plots, the efficiency is computed as a function of various variables reconstructed with the offline version of the CMS software. Events are selected from a sample collected with a single muon trigger (HLT_IsoMu27). The offline muon passes the tight identification and working point for Particle–Flow isolation [1]. The offline reconstructed jets are not matched to the jets on trigger level. A common selection (summarized in the table below) is applied for all events entering the denominator. For each plot, only the cut on the variable under study is dropped, except in Fig. 5.

Finally the figures also indicate the inclusive efficiency of 98.3% for the full set of cuts in the table below.

# Offline selection

<table>
<thead>
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<th>Central Selections</th>
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<tr>
<td><strong>Trigger</strong></td>
<td>SingleMu</td>
</tr>
<tr>
<td><strong>Mu</strong></td>
<td></td>
</tr>
<tr>
<td>$p_T$</td>
<td>$&gt; 30$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\eta</td>
</tr>
<tr>
<td>Identification and Isolation</td>
<td>Tight (0.15)</td>
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<tr>
<td>$N(\mu)$</td>
<td>$\geq 1$</td>
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<tr>
<td><strong>Jets</strong></td>
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<tr>
<td>$p_T$ (leading jet)</td>
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</tr>
<tr>
<td>$p_T$ (sub-leading jet)</td>
<td>$&gt; 60$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\eta</td>
</tr>
<tr>
<td>$N_{Jets}$</td>
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</tr>
<tr>
<td>$H_T$ ($p_T &gt; 30$ GeV, $</td>
<td>\eta</td>
</tr>
<tr>
<td><strong>MET</strong></td>
<td>$E_T^{\text{miss}}$ (no $\mu$) $&gt; 150$ GeV</td>
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<table>
<thead>
<tr>
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<th>VBF Selections</th>
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<tr>
<td>$\eta_{\text{jet1}} \cdot \eta_{\text{jet2}}$</td>
<td>$&lt; 0$</td>
</tr>
<tr>
<td>$\Delta \eta_{jj}$</td>
<td>$&gt; 3.6$</td>
</tr>
<tr>
<td>$M_{jj}$</td>
<td>$&gt; 1000$ GeV</td>
</tr>
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</table>
Figure 1 caption

Trigger efficiency of VBF-tagged jets with a soft muon (p_T(μ) > 8 GeV) in single muon data as a function of the offline missing transverse energy ignoring muons. Both offline and online jets are reconstructed with the Particle-Flow algorithm, where a jet is clustered with the anti-k_T algorithm with distance parameter R = \sqrt{\eta^2 + \phi^2} of 0.4. Online and offline jets are not matched. The efficiency measured here is only the hadronic part of the VBF+μ trigger.

- The denominator (dashed) is the number of events passing the single muon trigger (IsoMu27) which have at least one muon with p_T > 30 GeV and |\eta| < 2.4, and jets with the leading (sub-leading) p_T > 120 (60) GeV, |\eta| < 5.0, \eta_{jet1} \cdot \eta_{jet2} < 0, Δ\eta_{jj} > 3.6, M_{jj} > 1000 GeV, and H_T(|\eta|<5.0) > 450 GeV. Here, H_T is the scalar sum of the jet p_T greater than 30 GeV. The numerator (filled) is the number of events passing all selections above and the VBF+μ trigger (Mu8_TrkIsoVVL_DiPFJet40_DEta3p5_Mjj750_HTT300_PFMETNoMu60)

- Efficiency (dots) = Numerator / Denominator
VBF Trigger Efficiency (|\eta(j)|<5.0)

Fig.1

\[ \varepsilon(\text{E}_{\text{T}}^{\text{miss}} > 150 \text{ GeV}) = 98.3^{+0.1}_{-0.1} \% \]

36.7 fb\(^{-1}\) (13 TeV, 2017)
Figure 2 caption

Trigger efficiency of VBF-tagged jets with a soft muon ($p_T(\mu) > 8$ GeV) in single muon data as a function of the offline $H_T$ defined by the scalar sum of the $p_T$ of the jets with $p_T > 30$ GeV and $|\eta| < 5.0$. Both offline and online jets are reconstructed with the Particle-Flow algorithm, where a jet is clustered with the anti-$k_T$ algorithm with distance parameter $R = \sqrt{\eta^2 + \phi^2}$ of 0.4. Online and offline jets are not matched. The efficiency measured here is only the hadronic part of the VBF+$\mu$ trigger.

- The denominator (dashed) is the number of events passing the single muon trigger (IsoMu27) which have at least one muon with $p_T > 30$ GeV and $|\eta| < 2.4$, and jets with the leading (sub-leading) $p_T > 120$ (60) GeV, $|\eta| < 5.0$, $\eta_{jet1} \cdot \eta_{jet2} < 0$, $\Delta \eta_{jj} > 3.6$, $M_{jj} > 1000$ GeV, and $E_T^{miss} > 150$ GeV. The numerator (filled) is the number of events passing all selections above and the VBF+$\mu$ trigger (Mu8_TrkIsoVVL_DiPFJet40_DEta3p5_Mjj750_HTT300_PFMETNoMu60)

- Efficiency (dots) = Numerator / Denominator
VBF Trigger Efficiency ($|\eta(j)|<5.0$)

**Fig. 2**

**CMS Preliminary**

$\varepsilon(H_T > 450 \text{ GeV}) = 98.3^{+0.1}_{-0.1}$% 

36.7 fb$^{-1}$ (13 TeV, 2017)
Figure 3 caption

Trigger efficiency of VBF-tagged jets with a soft muon ($p_T(\mu) > 8$ GeV) in single muon data as a function of the invariant mass of two jets. Both offline and online jets are reconstructed with the Particle-Flow algorithm, where a jet is clustered with the anti-$k_T$ algorithm with distance parameter $R = \sqrt{\eta^2 + \phi^2}$ of 0.4. Online and offline jets are not matched. The efficiency measured here is only the hadronic part of the VBF+$\mu$ trigger.

- The denominator (dashed) is the number of events passing the single muon trigger (IsoMu27) which have at least one muon with $p_T > 30$ GeV and $|\eta| < 2.4$, and jets with the leading (sub-leading) $p_T > 120$ (60) GeV, $|\eta| < 5.0$, $\eta_{\text{jet1}} \cdot \eta_{\text{jet2}} < 0$, $\Delta \eta_{ij} > 3.6$, $H_T(|\eta|<5.0) > 450$ GeV, and $E_T^{\text{miss}} > 150$ GeV. Here, $H_T$ is the scalar sum of the jet $p_T$ greater than 30 GeV. The numerator (filled) is the number of events passing all selections above and the VBF+$\mu$ trigger (Mu8_TrkIsoVVL_DiPFJet40_DEta3p5_Mjj750_HTT300_PFMETNoMu60)

- Efficiency (dots) = Numerator / Denominator
VBF Trigger Efficiency ($|\eta(j)|<5.0$)

Fig. 3

$\epsilon(M_{jj} > 1000 \text{ GeV}) = 98.3^{+0.1}_{-0.1} \%$

36.7 fb$^{-1}$ (13 TeV, 2017)
Figure 4 caption

Trigger efficiency of VBF-tagged jets with a soft muon \( p_T(\mu) > 8 \) GeV in single muon data as a function of the pseudorapidity difference between two jets. Both offline and online jets are reconstructed with the Particle-Flow algorithm, where a jet is clustered with the anti-\( k_T \) algorithm with distance parameter \( R = \sqrt{\eta^2 + \phi^2} \) of 0.4. Online and offline jets are not matched. The efficiency measured here is only the hadronic part of the VBF+\( \mu \) trigger.

- The denominator (dashed) is the number of events passing the single muon trigger (IsoMu27) which have at least one muon with \( p_T > 30 \) GeV and \( |\eta| < 2.4 \), and jets with the leading (sub-leading) \( p_T > 120 \) (60) GeV, \( |\eta| < 5.0 \), \( \eta_{\text{jet1}} \cdot \eta_{\text{jet2}} < 0 \), \( M_{jj} > 1000 \) GeV, \( H_T(|\eta|<5.0) > 450 \) GeV, and \( E_{T\text{miss}} > 150 \) GeV. Here, \( H_T \) is the scalar sum of the jet \( p_T \) greater than 30 GeV. The numerator (filled) is the number of events passing all selections above and the VBF+\( \mu \) trigger (Mu8_TrlIsoVL_DiPFJet40_DEta3p5_Mjj750_HTT300_PFMETNoMu60)

- Efficiency (dots) = Numerator / Denominator
VBF Trigger Efficiency ($|\eta(j)|<5.0$)

Fig. 4

$\varepsilon(\Delta\eta_{jj} > 3.6) = 98.3^{+0.1}_{-0.1} \%$

CMS Preliminary

36.7 fb$^{-1}$ (13 TeV, 2017)
Figure 5 caption

Trigger efficiency of VBF-tagged jets with a soft muon ($p_T(\mu) > 8$ GeV) in single muon data as a function of the sub-leading jet $p_T$. Both offline and online jets are reconstructed with the Particle-Flow algorithm, where a jet is clustered with the anti-$k_T$ algorithm with distance parameter $R = \sqrt{\eta^2 + \phi^2}$ of 0.4. Online and offline jets are not matched. The efficiency measured here is only the hadronic part of the VBF+$\mu$ trigger.

- The denominator (dashed) is the number of events passing the single muon trigger (IsoMu27) which have at least one muon with $p_T > 30$ GeV and $|\eta| < 2.4$, and jets with the leading (sub-leading) $p_T > 120$ (60) GeV, $|\eta| < 5.0$, $\eta_{jet1} \cdot \eta_{jet2} < 0$, $\Delta\eta_{ij} > 3.6$, $M_{jj} > 1000$ GeV, $H_T(|\eta| < 5.0) > 450$ GeV, and $E_T^{miss} > 150$ GeV. Here, $H_T$ is the scalar sum of the jet $p_T$ greater than 30 GeV. The numerator (filled) is the number of events passing all selections above and the VBF+$\mu$ trigger (Mu8_TrkIsoVVL_DiPFJet40_DEta3p5_Mjj750_HTT300_PFMETNoMu60).
- Efficiency (dots) = Numerator / Denominator
VBF Trigger Efficiency ($|\eta(j)|<5.0$)

Fig. 5

36.7 fb$^{-1}$ (13 TeV, 2017)

$\varepsilon = 98.3^{+0.1}_{-0.1}\%$

CMS Preliminary

Efficiency

Numerator

Denominator

Events/10 GeV

Sub-leading jet $p_T$ [GeV]

Efficiency