

VBF Higgs to Invisible Trigger Efficiencies

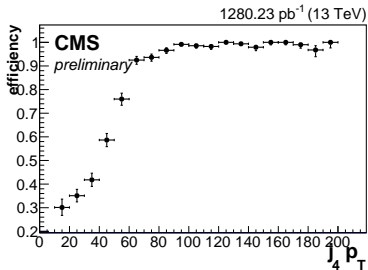
P. Dunne A. Magnan for $H \rightarrow \text{inv.}$ group

Reminder and outline

- ▶ We have previously seen slow trigger turn ons in met (300 GeV 95% efficiency) and jet 2 pt (80 GeV 95% efficiency)
- ▶ We have looked at jet pt turn on in a separate trigger path:
HLT_PFHT750_4JetPt50
- ▶ Behaviour seen there motivates studies of L1 MET turn on and calo jet prefilter
- ▶ Will go through studies then show again plots to be presented for DPS approval at Higgs tomorrow

Turn on in jet only trigger

- ▶ Have pass/fail information for HLT_PFHT750_4JetPt50
- ▶ Denominator: SingleMuon events with $HT > 1200$ GeV
 - 1200 is the 90% efficiency point
- ▶ Curve looks good, over 90% efficient by 60 GeV

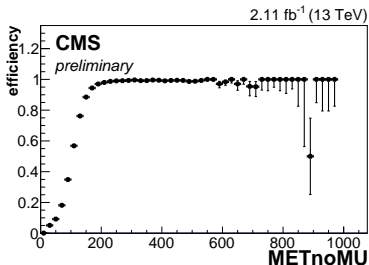


Implications for our trigger

- ▶ As 4JetPt50 trigger behaves well examine differences from our trigger:
- ▶ 4JetPt50 has no L1ETM requirement:
 - Study L1ETM turn on
 - Shown in next few slides
- ▶ 4JetPt50 has no calo jet pt prefilter:
 - According to [these slides](#) wrong JEC was used in HLT during Run2015
 - We only have trigger jet information in events that pass the trigger
 - Study HLT Calo vs offline PF jet response
 - Shown later

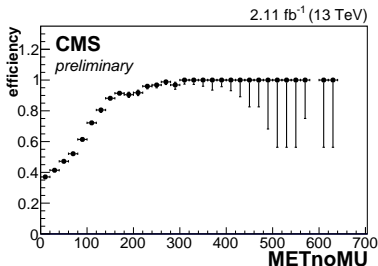
L1ETM60 Efficiency: Inclusive

- ▶ Measure L1 ETM turn on
- ▶ Trigger: L1ETM60
- ▶ Denominator: SingleMuon events passing HLT_IsoMu20
- ▶ 95% efficient by 200 GeV



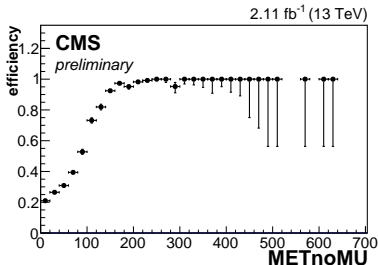
L1ETM60 Efficiency: VBF phase space

- ▶ Measure L1 ETM turn on when there is a VBF-like dijet
- ▶ Trigger: L1ETM60
- ▶ Denominator: SingleMuon events passing HLT_IsoMu20 and dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$
- ▶ Good turn on to 150 GeV then shelf



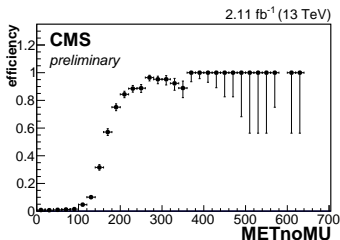
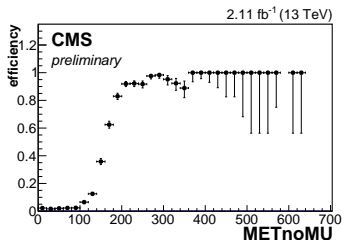
L1ETM60 Efficiency: VBF phase space

- ▶ L1 MET only sums up to $|\eta| = 3$, shelf seen on previous slide could be due to jets in the HF
- ▶ Add requirement that both jets have $|\eta| < 3$ to the denominator
- ▶ Good turn on recovered so shelf is due to events with jets in the HF



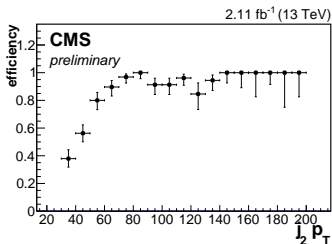
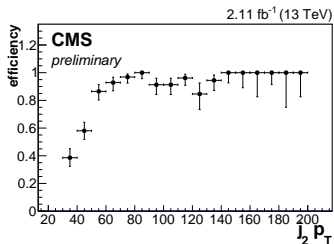
Signal trigger turn on: MET

- ▶ Measure HLT efficiency (left) and L1+HLT efficiency (right)
- ▶ Dataset: Full 2015D data with latest JECv6
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60
 - Jet pt cut very high due to slow jet pt turn on
- ▶ HLT only efficiency slightly better



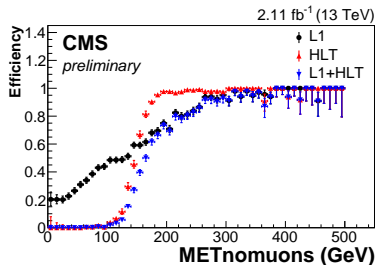
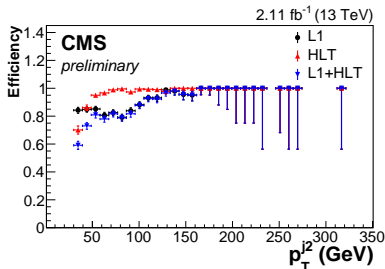
Signal trigger turn on: jet pt

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- ▶ Denominator: SingleMuon events with dijet $p_T > 80$, $MET_{noMU} > 300$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only and L1ETM60
 - MET cut very high due to slow MET turn on
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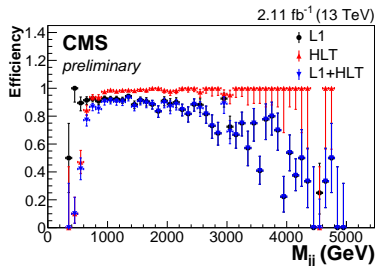
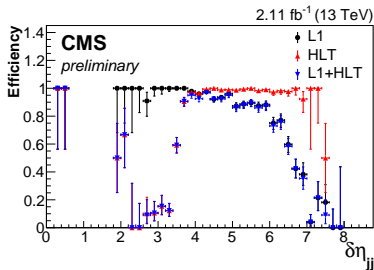
Impact of L1MET inefficiencies on signal

- ▶ Signal $\Delta\eta_{jj}$ higher than background so may be more affected by L1 inefficiency
- ▶ Check efficiencies in MC of HLT (red), L1 (black) and L1+HLT (green)
- ▶ MC sample: VBF_HToInvisible_M125_13TeV_powheg_pythia8
- ▶ Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, $MET_{noMU} > 200$ GeV
- ▶ We lose a lot of signal due to L1 inefficiency



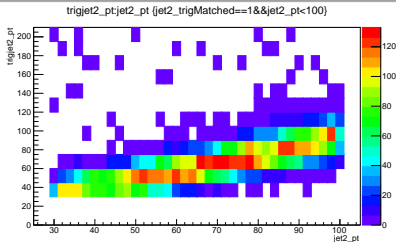
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- ▶ Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, METnoMU > 200 GeV
- ▶ Inefficiency for jets in the HF can be clearly seen in the left plot



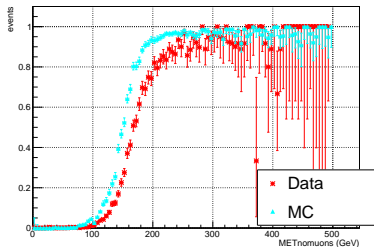
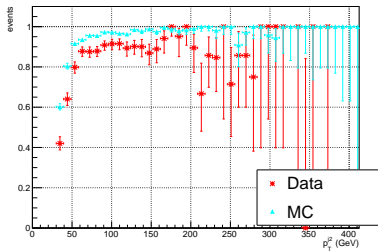
Calo jet prefilter

- ▶ Even after factoring out L1 effect jet pt is less efficient than in run 1
- ▶ According to [these slides](#) wrong JEC was used in HLT during Run2015
 - We have a calo prefilter at 30 GeV
 - Calo JEC are large so wrong JEC could cause the remaining jet pt issues
- ▶ Plot offline jet pt (x axis) against trigger calo jet pt (y axis)
- ▶ Large differences seen between calo jet pt and offline jet pt



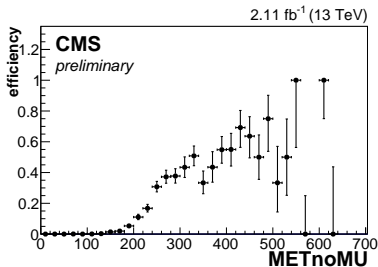
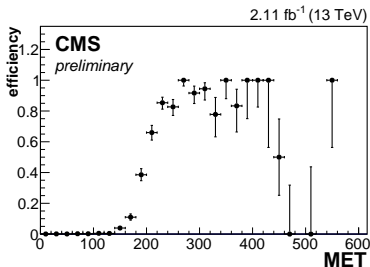
Calo jet prefilter

- ▶ Further check, compare HLT efficiency in data (with wrong JEC) to that in MC (with correct JEC)
- ▶ MC sample: WJetsToLNu-mg and all the HT-binned samples
- ▶ Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, $MET_{noMU} > 200$ GeV
- ▶ MC efficiency quite a bit better: more evidence wrong JEC could be to blame



Comparison with MET only trigger

- ▶ PF MET > 170 GeV is the lowest unprescaled MET trigger
- ▶ Check efficiency in VBF region: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$
- ▶ Efficiency for MET (left) looks good
- ▶ Efficiency for METnoMuons (right) is not so good:
 - Would significantly reduce control region statistics, currently the dominant error
- ▶ Our signal trigger is therefore important for maintaining analysis sensitivity

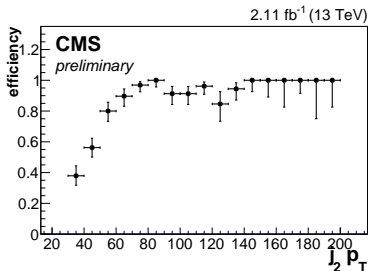
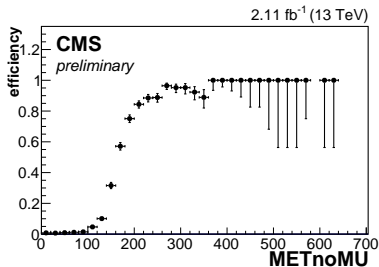


Summary of Studies

- ▶ L1ETM60 is inefficient in the VBF phase space due to it ignoring the HF
 - We lose signal from this L1 inefficiency
 - Variable correlation makes denominator cuts high, looks worse for softer events
 - Even after factoring out L1 effect still less efficient than in run 1, especially jet p_T
- ▶ Incorrect JEC was used in HLT during Run2015
 - Calo jet JEC are large so this could cause problems
 - Calo jets with 30 GeV p_T frequently have offline p_T above pf trigger threshold
 - HLT efficiency is better in MC than data
 - Suggests wrong JEC could be to blame
 - Reemulating trigger on raw data so we can check if events failing trigger fail calo filter or pf filter
- ▶ Signal trigger still provides much better efficiency for control regions than MET only trigger
- ▶ Efficiency next year expected to be much improved by better JEC and possible L1MET including HF

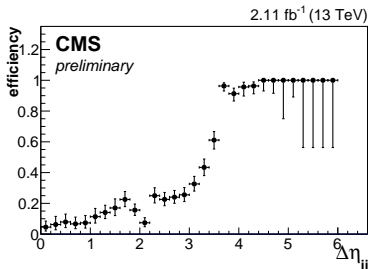
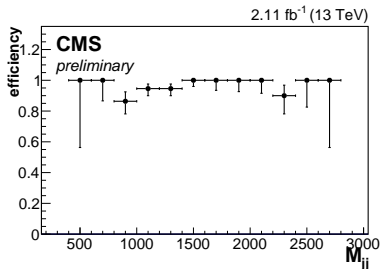
Plots for Approval Tomorrow

- ▶ Left caption: Efficiency of VBF Higgs to invisible trigger in data as a function of MET ignoring muons (METnoMU). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.
- ▶ Right caption: Efficiency of VBF Higgs to invisible trigger in data as a function of sub-leading jet p_T . The denominator of the efficiency is the number of events passing a single muon trigger which have a leading jet with $p_t > 80$ GeV, $METnoMU > 300$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.



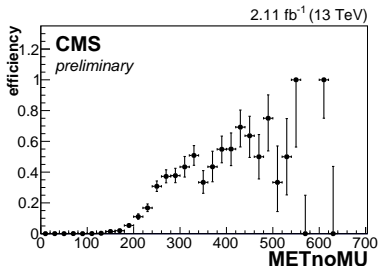
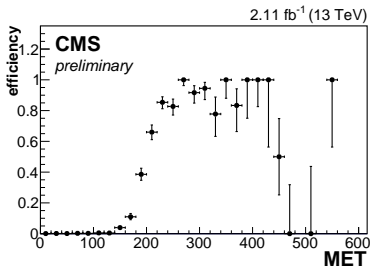
Plots for Approval Tomorrow

- ▶ Left caption: Efficiency of VBF Higgs to invisible trigger in data as a function of dijet mass (M_{jj}). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $MET_{noMU} > 300$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.
- ▶ Right caption: Efficiency of VBF Higgs to invisible trigger in data as a function of dijet $\Delta\eta$. The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $MET_{noMU} > 300$ GeV and $M_{jj} > 600$ GeV.



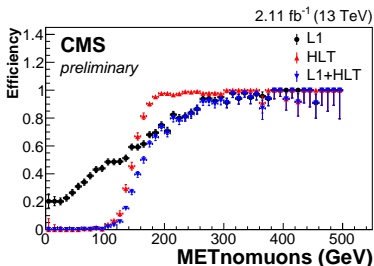
Plots for Approval Tomorrow

- ▶ Left caption: Efficiency of MET only trigger in data as a function of MET. The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 50$ GeV, $M_{jj} > 800$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.
- ▶ Right caption: Efficiency of MET only trigger in data as a function of MET ignoring muons (METnoMU). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 50$ GeV, $M_{jj} > 800$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.



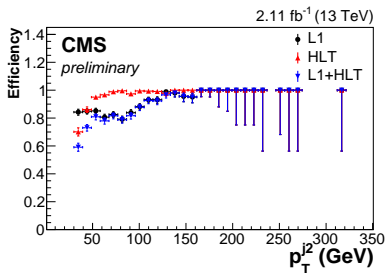
Plots for Approval Tomorrow

- Caption: The Level 1 (black), HLT (red) and total (blue) efficiency of the VBF Higgs to invisible trigger in MC as a function of MET ignoring muons (METnoMU). The denominator of the efficiency is the number of events in a signal MC sample which have two jets with $p_T > 80$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.



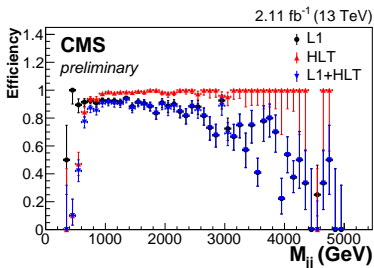
Plots for Approval Tomorrow

- Caption: The Level 1 (black), HLT (red) and total (blue) efficiency of the VBF Higgs to invisible trigger in MC as a function of sub-leading jet p_T . The denominator of the efficiency is the number of events passing in a signal MC sample which have a leading jet with $p_T > 80$ GeV, $MET_{noMU} > 300$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.



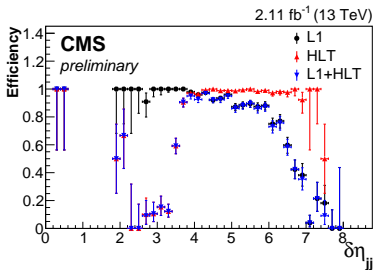
Plots for Approval Tomorrow

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Plots for Approval Tomorrow

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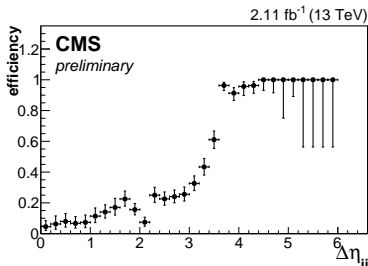
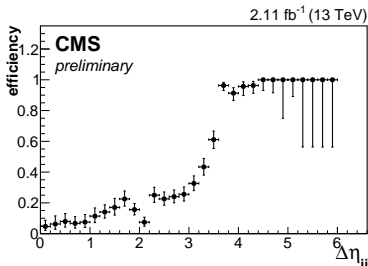
Summary

- ▶ We have a good understanding of our trigger turn ons
 - We see some inefficiencies due to L1 MET η restriction and possible incorrect JEC effects
- ▶ We will ask tomorrow for approval to show the trigger turn on curves at the December jamboree

Backup

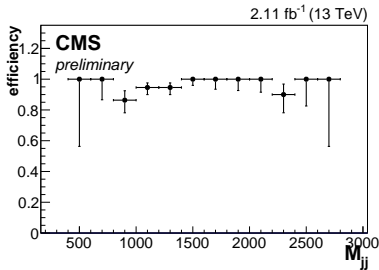
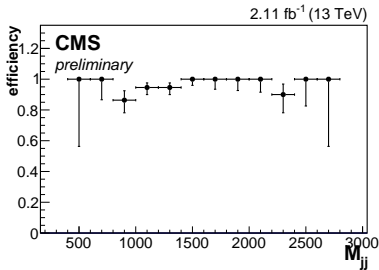
$\Delta\eta_{jj}$ data turn on

- ▶ Measure HLT efficiency (left) and L1+HLT efficiency (right)
- ▶ Dataset: Full 2015D data with latest JECv6
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60
- ▶ Possible decrease at end of L1+HLT efficiency due to HF jets



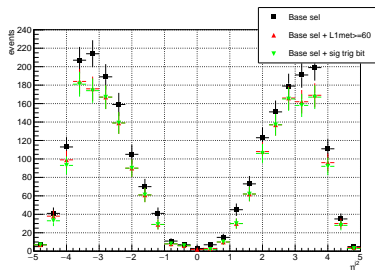
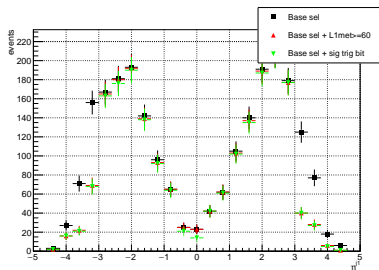
M_{jj} data turn on

- ▶ Measure HLT efficiency (left) and L1+HLT efficiency (right)
- ▶ Dataset: Full 2015D data with latest JECv6
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60



Impact of L1MET inefficiencies on signal

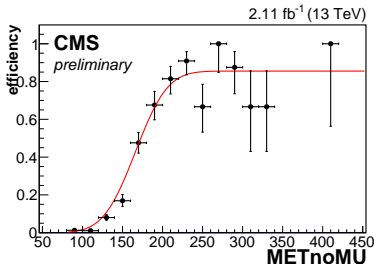
- ▶ Check effect of L1 inefficiency as a function of jet eta
- ▶ MC sample: VBF_HToInvisible_M125_13TeV_powheg_pythia8
- ▶ Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, $MET_{noMU} > 200$ GeV
- ▶ L1 inefficiency for jets in the HF can be clearly seen



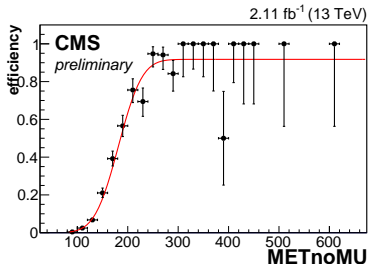
Binned trigger efficiencies for first analysis

- ▶ Measure L1+HLT MetNoMu efficiency of signal trigger in bins of jet p_T and M_{jj}
- ▶ Dataset: Full 2015D data with latest JECv6
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator: SingleMuon events with dijet $\Delta\eta_{jj} > 3.6$ plus binned cuts
- ▶ Bins: Jet p_T : 70-80, 80+, M_{jj} : 800-1000, 1000+

Jet p_T : 70-80, M_{jj} : 800-1000



Jet p_T : 70-80, M_{jj} : 1000+



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