

VBF Higgs to Invisible Trigger Efficiencies

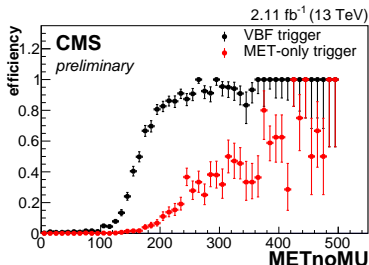
P. Dunne A. Magnan for $H \rightarrow \text{inv.}$ group

Outline

- ▶ Presenting trigger efficiency curves in data from VBF Higgs to invisible for approval
- ▶ Possible improvements to L1 part of trigger for next year will also be shown
 - Not for approval today, but study ready if wanted by the collaboration

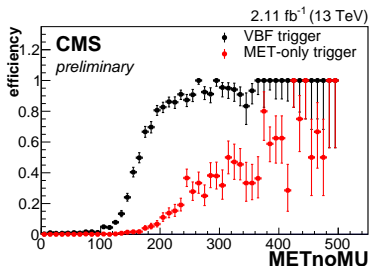
VBF Higgs to invisible trigger efficiency: Plot for Approval

- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140 (black)
HLT_PFMET170 (red)
- ▶ Denominator selection: SingleMuon events with dijet $pt > 80$, $METnoMU > 300$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$
- ▶ MET only trigger clearly inefficient for single muon events:
 - This would lead to loss of events which we use for control regions
 - Our trigger uses METnoMU and has much better efficiency



VBF Higgs to invisible trigger efficiency: For approval

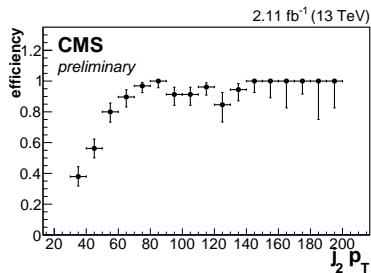
- Caption: Efficiency of VBF Higgs to invisible trigger and MET only trigger in single muon data as a function of MET ignoring muons (METnoMU). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj}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



VBF Higgs to invisible trigger: Plot and caption for approval

- ▶ We also measured the efficiency for the other variables in the trigger
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: SingleMuon events with leading jet $p_T > 80$, $MET_{noMU} > 300$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$

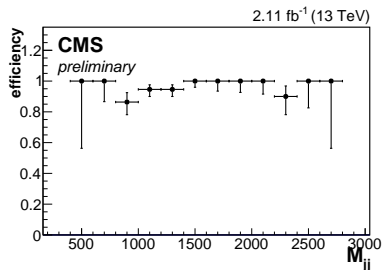
- ▶ Caption: Efficiency of VBF Higgs to invisible trigger in single muon data as a function of sub-leading jet p_T . The denominator of the efficiency is the number of events passing a single muon trigger which have a leading jet with $p_t > 80$ GeV, $MET_{noMU} > 300$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.



VBF Higgs to invisible trigger: Plot and caption for approval

- ▶ We also measured the efficiency for the other variables in the trigger
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: SingleMuon events with two or more jets $p_T > 80$, $MET_{noMU} > 300$, $\Delta\eta_{jj} > 3.6$

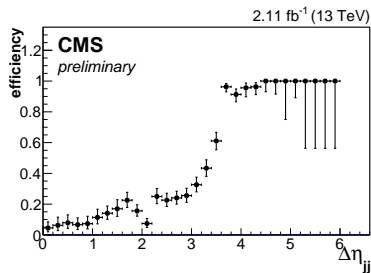
- ▶ Caption: Efficiency of VBF Higgs to invisible trigger in single muon data as a function of dijet mass (M_{jj}). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $MET_{noMU} > 300$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.



VBF Higgs to invisible trigger: Plot and caption for approval

- ▶ We also measured the efficiency for the other variables in the trigger
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: SingleMuon events with two or more jets $p_T > 80$, $MET_{noMU} > 300$, $M_{jj} > 600$

- ▶ Caption: Efficiency of VBF Higgs to invisible trigger in single muon 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.

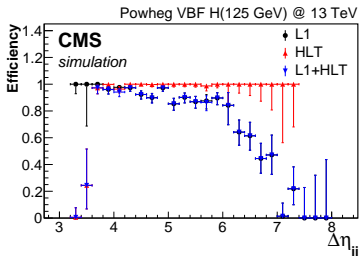
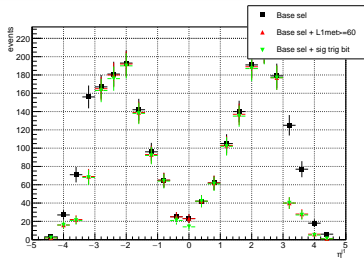


VBF Higgs to invisible trigger conclusions

- ▶ Efficiency of our trigger is significantly better than the MET only trigger for METnoMU
- ▶ The METnoMU and jet p_T turn ons become fully efficient at 300 and 80 GeV respectively
 - We can use the region in the turn on by reweighting MC events to account for inefficiency
- ▶ Our trigger turn ons in $\Delta\eta_{jj}$ and M_{jj} look good

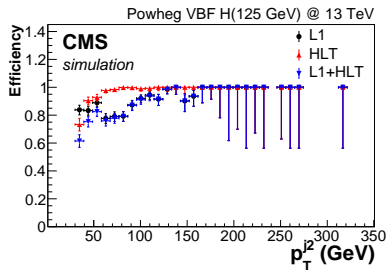
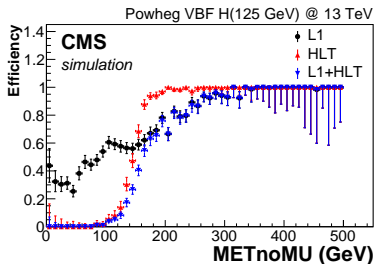
Impact of turn on on signal

- ▶ Not for approval today but ready if wanted by the collaboration
- ▶ Check efficiencies in signal MC of HLT (red), L1 (black) and L1+HLT (blue)
- ▶ Denominator selection: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, METnoMU > 200 GeV
- ▶ L1 inefficiency for jets in the HF can clearly be seen
 - Adding additional L1 MET sum with HF would resolve this
- ▶ HLT turn on looks very nice



Impact of turn on on signal

- ▶ Not for approval today but ready if wanted by the collaboration
- ▶ Same again for METnoMU and jet 2 p_T
- ▶ Inefficiency again coming from L1
- ▶ HLT turn on looks good



Summary

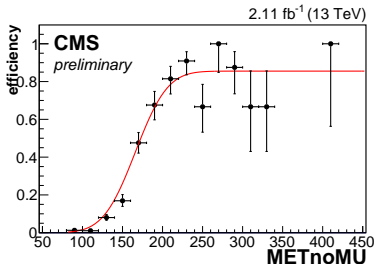
- ▶ We have a good understanding of our trigger turn ons
- ▶ Things generally are behaving as they should
- ▶ We see some inefficiencies due to L1 MET η restriction
 - Reweighting of MC will allow us to still use these regions for the analysis
 - Adding an additional L1 MET sum with HF would resolve this
- ▶ We ask for approval of the plots marked “for approval” to be shown at the December jamboree

Backup

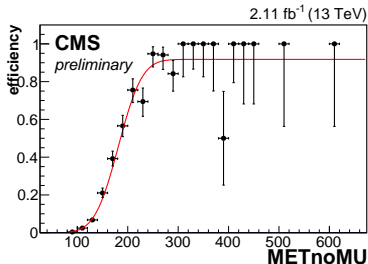
Binned trigger efficiencies for first analysis

- ▶ Measure L1+HLT MetNoMu efficiency of signal trigger in bins of jet p_T and M_{jj}
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: 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



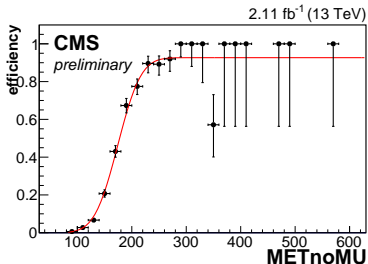
Jet p_T : 70-80, M_{jj} : 1000+



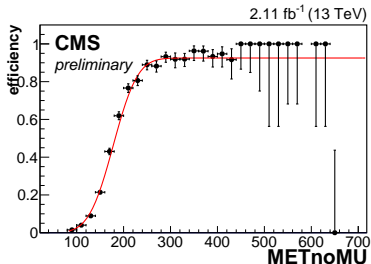
Binned trigger efficiencies for first analysis

- ▶ Measure L1+HLT MetNoMu efficiency of signal trigger in bins of jet p_T and M_{jj}
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: 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 : 80+, M_{jj} : 800-1000

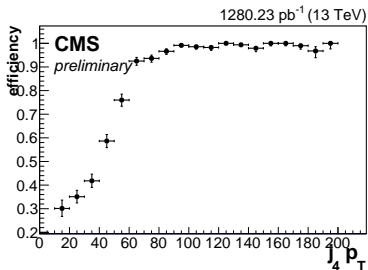


Jet p_T : 80+, M_{jj} : 1000+



Turn on in jet only trigger

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

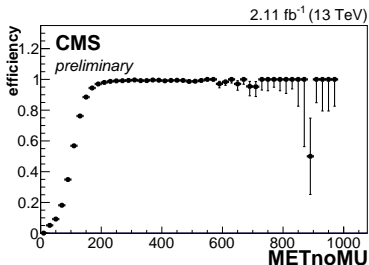


Implications for our trigger

- ▶ 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

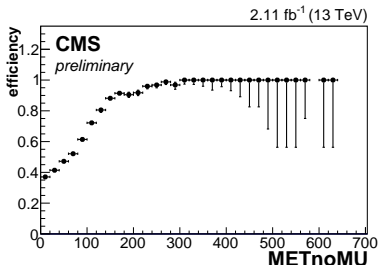
L1ETM60 Efficiency: Inclusive

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



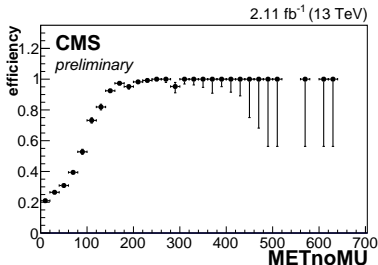
L1ETM60 Efficiency: VBF phase space

- ▶ Measure L1 ETM turn on when there is a VBF-like dijet
- ▶ Trigger: L1ETM60
- ▶ Denominator selection: 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



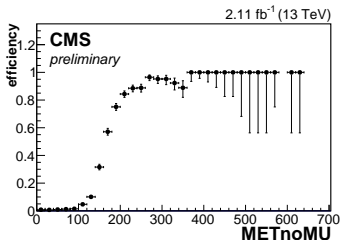
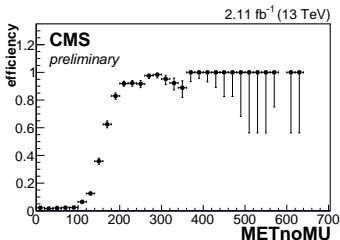
L1ETM60 Efficiency: VBF phase space

- ▶ 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



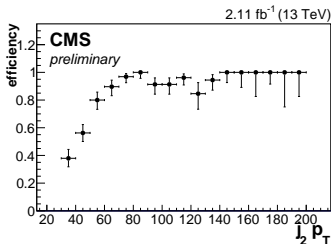
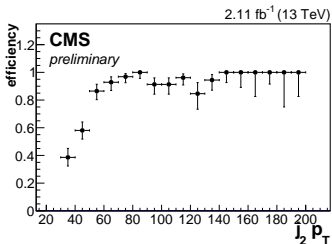
Signal trigger turn on: MET

- ▶ Measure HLT efficiency (left) and L1+HLT efficiency (right)
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: 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



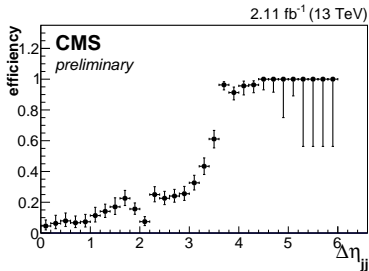
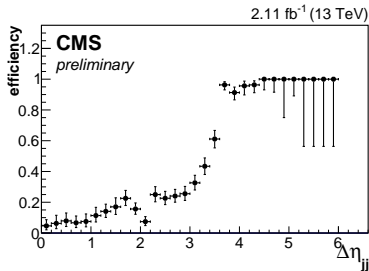
Signal trigger turn on: jet p_T

- ▶ Measure HLT efficiency (left) and L1+HLT efficiency (right)
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: 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
- ▶ HLT only efficiency slightly better



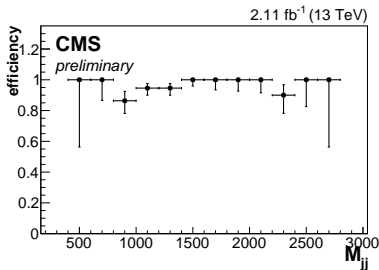
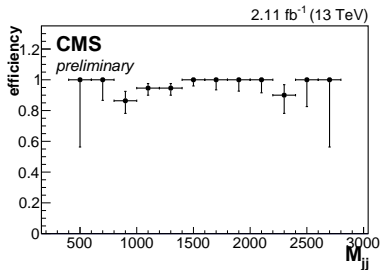
$\Delta\eta_{jj}$ data turn on

- ▶ Measure HLT efficiency (left) and L1+HLT efficiency (right)
- ▶ Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- ▶ Denominator selection: 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



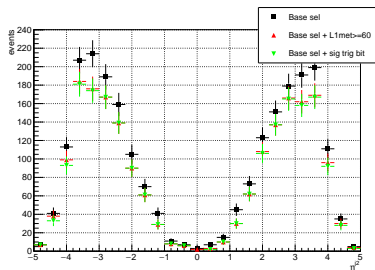
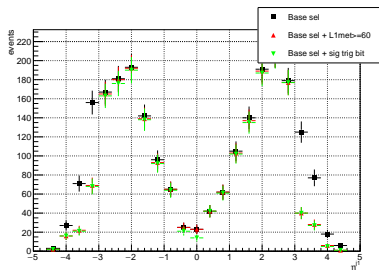
M_{jj} data turn on

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



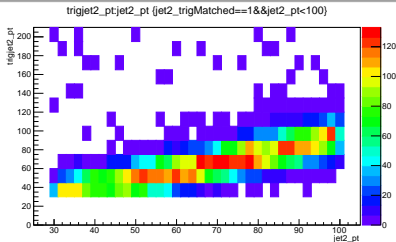
Impact of L1MET inefficiencies on signal

- ▶ Check effect of L1 inefficiency as a function of jet eta
- ▶ MC sample: VBF_HToInvisible_M125_13TeV_powheg_pythia8
- ▶ Denominator selection: 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



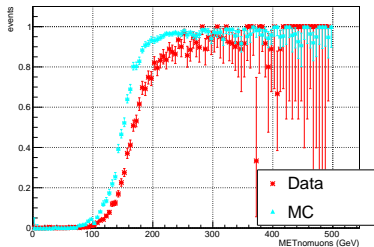
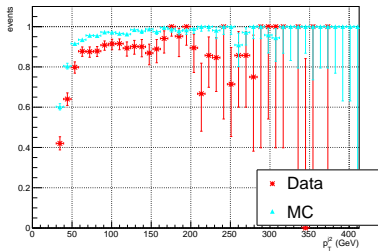
Calo jet prefilter

- ▶ 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 selection: 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



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