Imperial College London

VBF Higgs to Invisible Trigger Efficiencies

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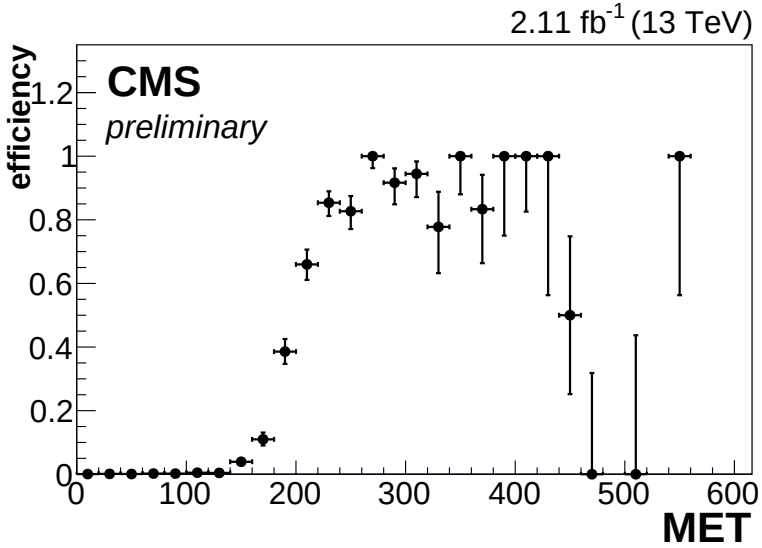
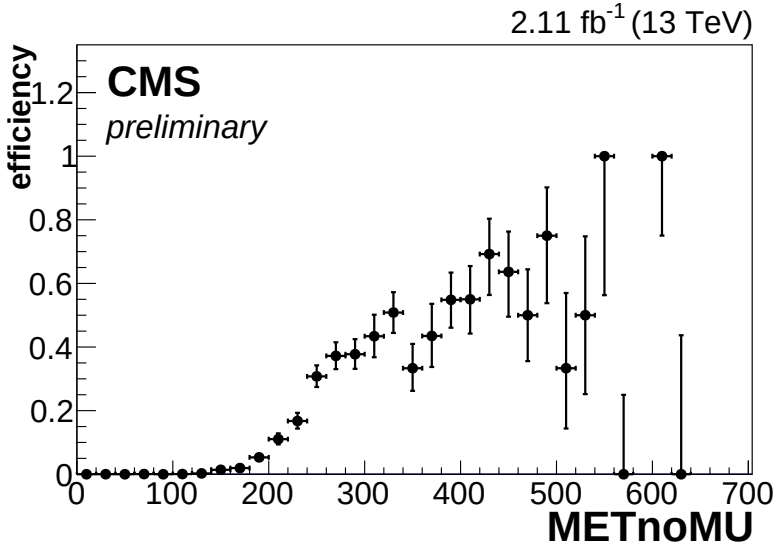
Outline

- Start by showing lowest unprescaled MET trigger efficiency
- Then show efficiency for VBF Higgs to invisible trigger
- Some inefficiencies seen which we understand and can reweight for in the analysis
  - Details shown yesterday at H-exo and in backup
  - Not for approval today but we believe we know how to fix this for next year

MET only trigger - For Approval

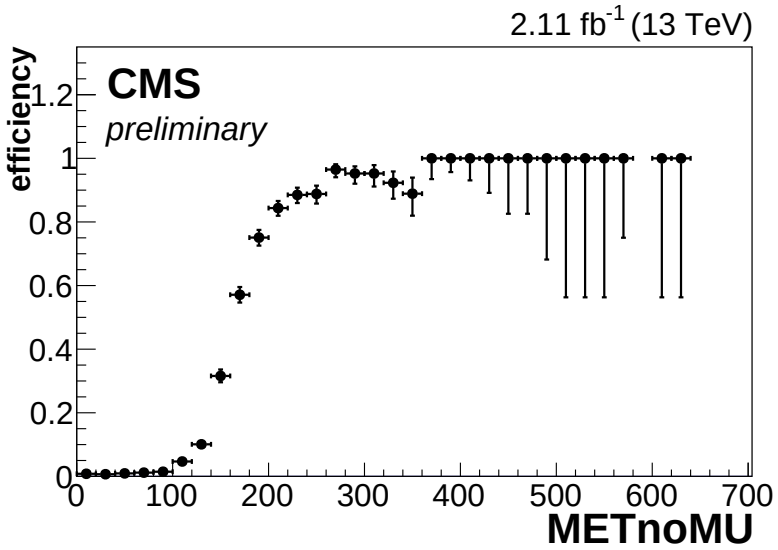
- PF MET$>$ 170 GeV is the lowest unprescaled MET trigger
- Check efficiency in VBF region: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$
- Efficiency for MET (left) looks good
- Efficiency for METnoMuons (right) is not so good:
  - Would significantly reduce statistics in our control regions
- We have a specific trigger for this analysis which solves this issue

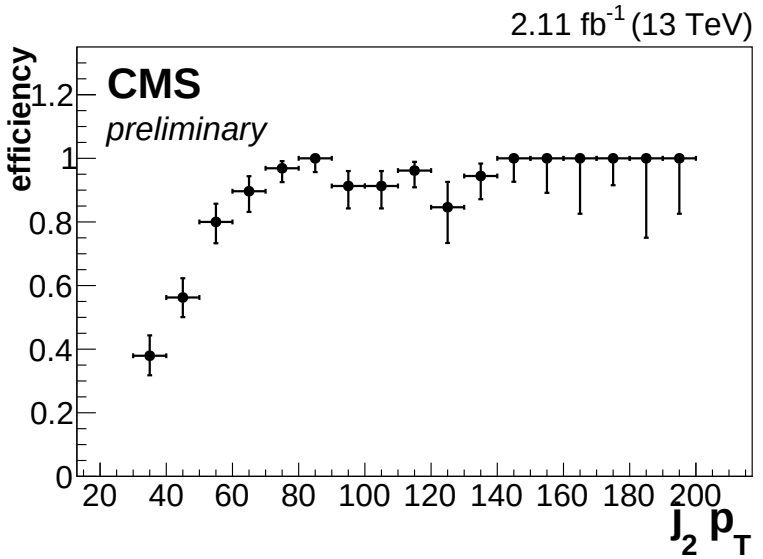




VBF Higgs to invisible trigger - For Approval

- Dataset: Full 2015D data with latest JECv6
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet pt$>$ 80, $METnoMU > 300$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$





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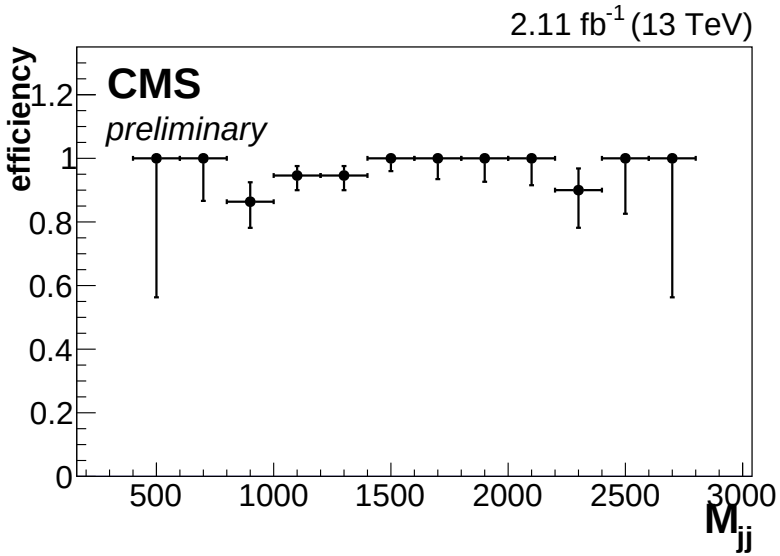
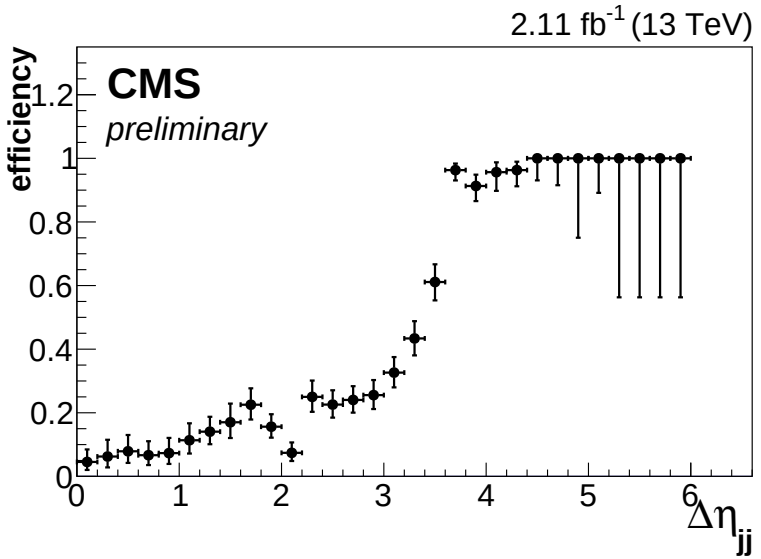


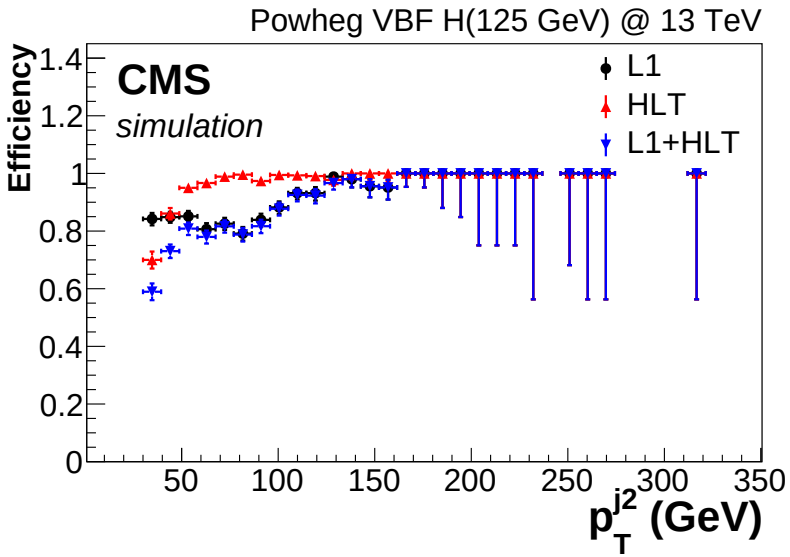


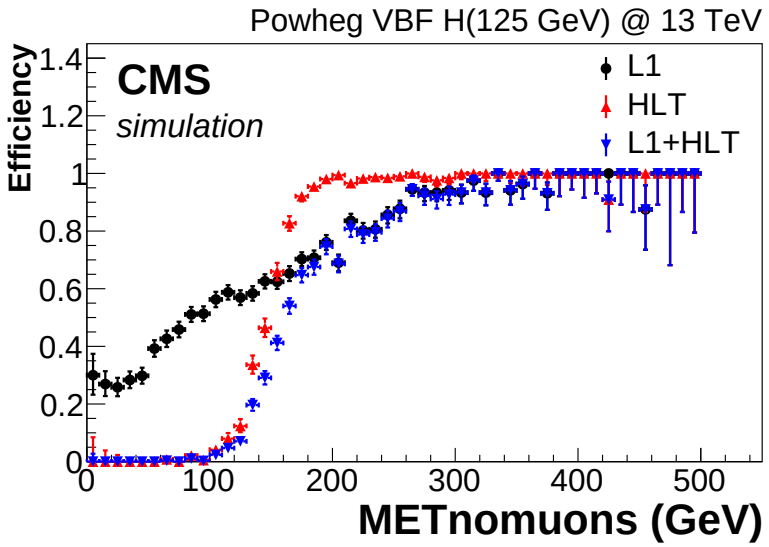
VBF Higgs to invisible trigger conclusions

- Efficiency of our trigger is significantly better than MET only 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 - For Approval

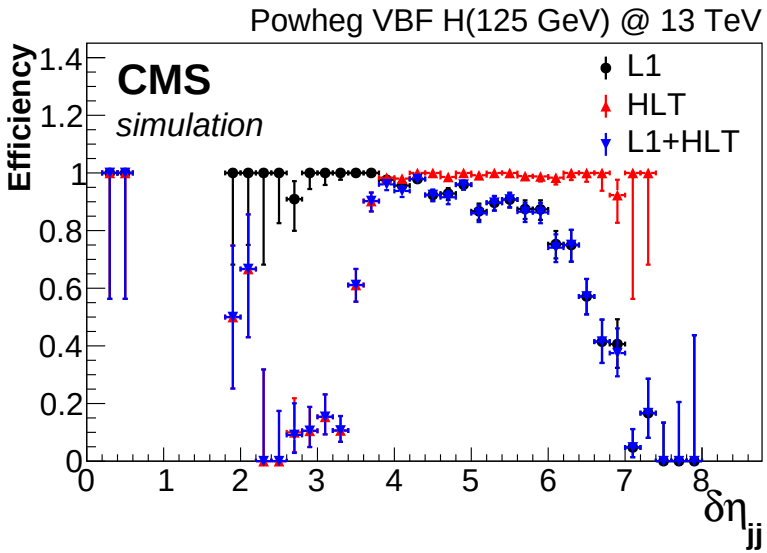
- Check efficiencies in MC of HLT (red), L1 (black) and L1+HLT (green)
- MC sample: VBF_HToInvisible_M125_13TeV_powheg_pythia8
- Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, METnoMU$>$ 200 GeV
- Turn on driven by L1, HLT turn on looks very nice

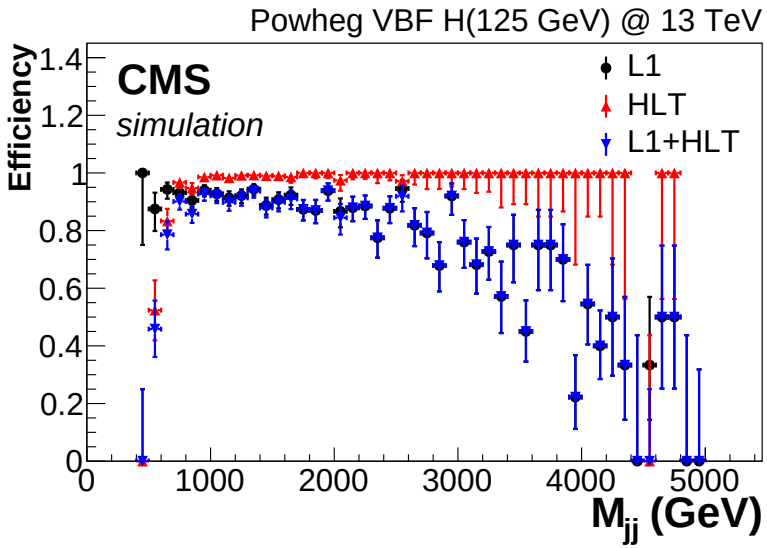




Impact of turn on on signal - For Approval

- Same again for $\Delta\eta_{jj}$ and M_{jj}
- Inefficiency for jets in the HF can be clearly seen in the left plot
  - Confirmed by other studies in backup
  - Adding additional L1 MET sum with HF would resolve this



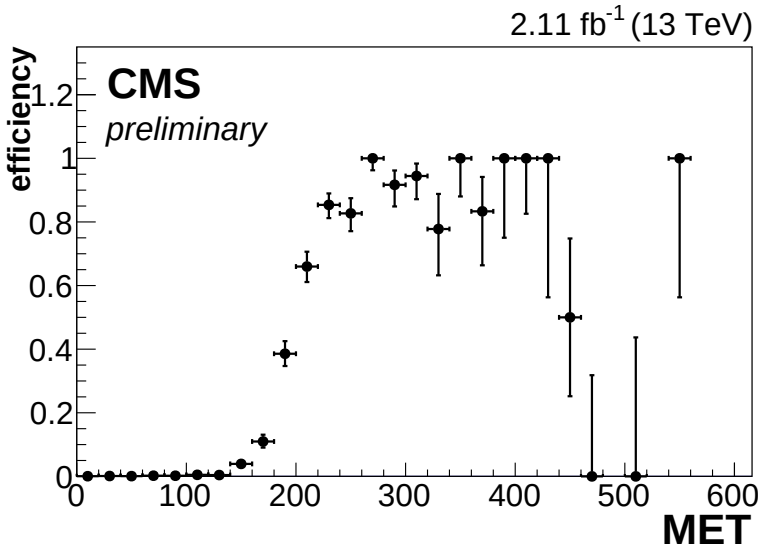


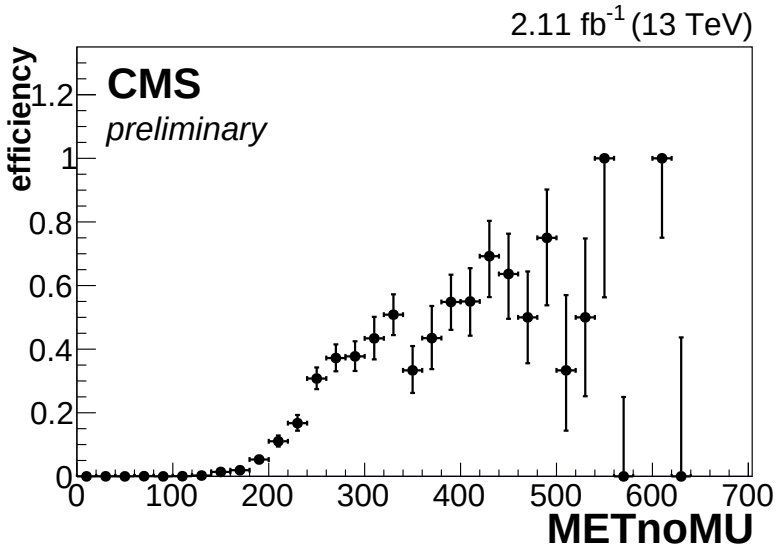
Summary

- 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 above plots for the December jamboree
  - Captions to be approve are listed in the next few slides

Plots for Approval

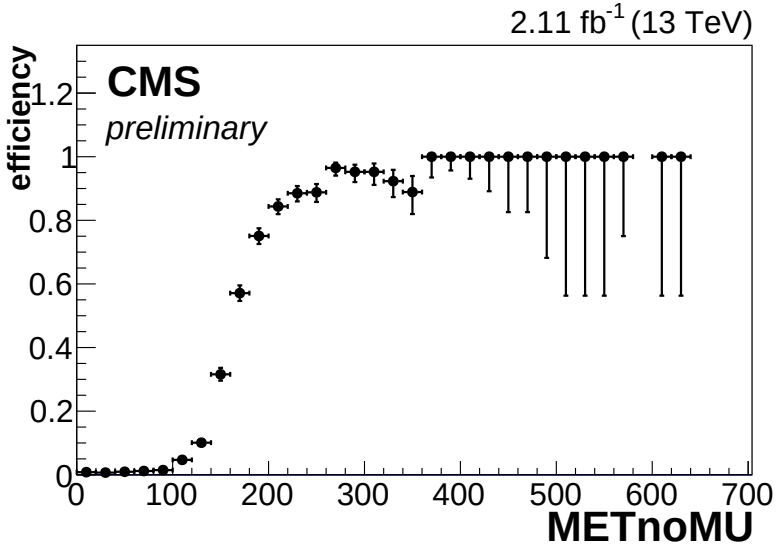
- Caption: Efficiency of MET only trigger in data as a function of MET (left) and MET ignoring muons (METnoMU) (right). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 50$ GeV, $M_{jj} > 800$ GeV and $\Delta\eta_{jj} > 3.6$ GeV. It can be seen from the left plot that the trigger is performing well, however from the right plot we can see that this trigger is not appropriate to use for our control regions using METnoMU.

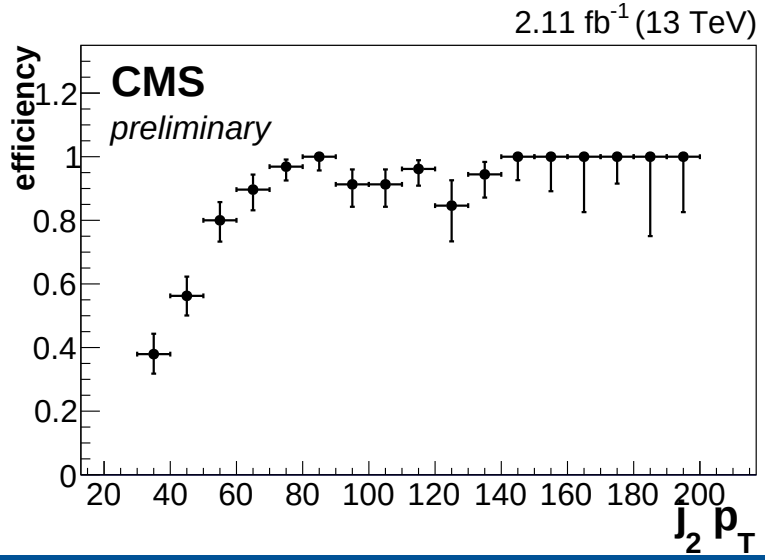




Plots for Approval

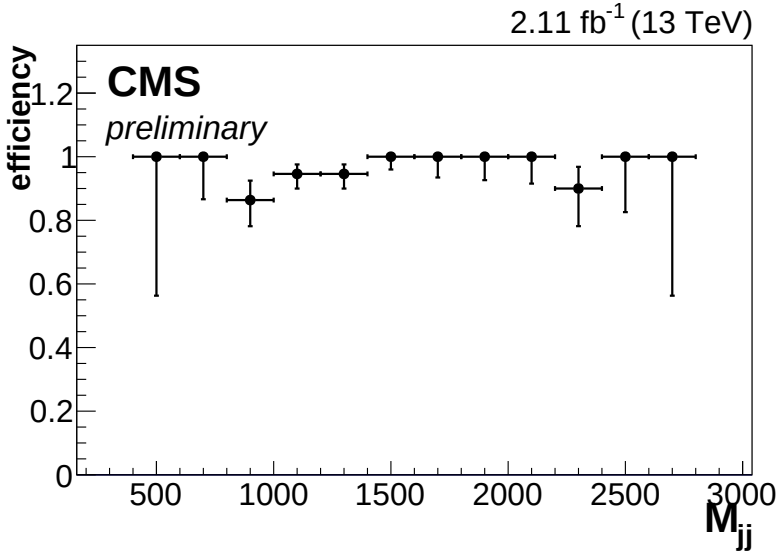
- Left caption: Efficiency of VBF Higgs to invisible trigger in data as a function of MET ignoring muons (METnoMU). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $M_{jj} > 600$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.
- Right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

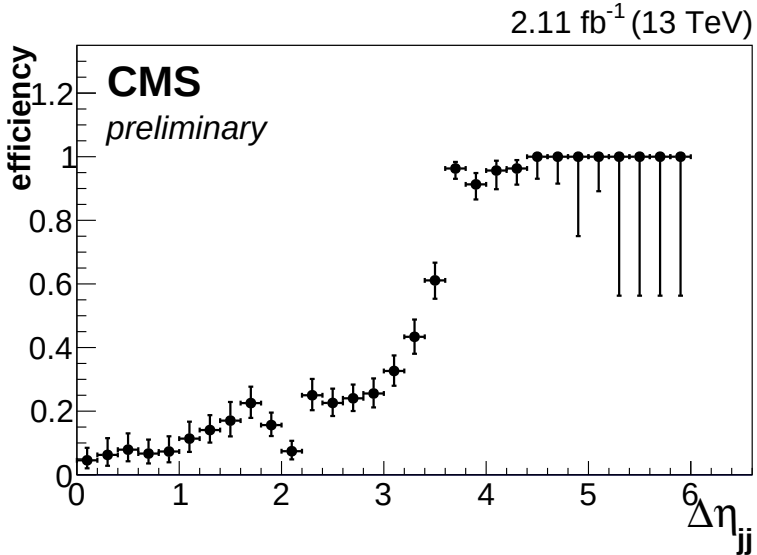




Plots for Approval

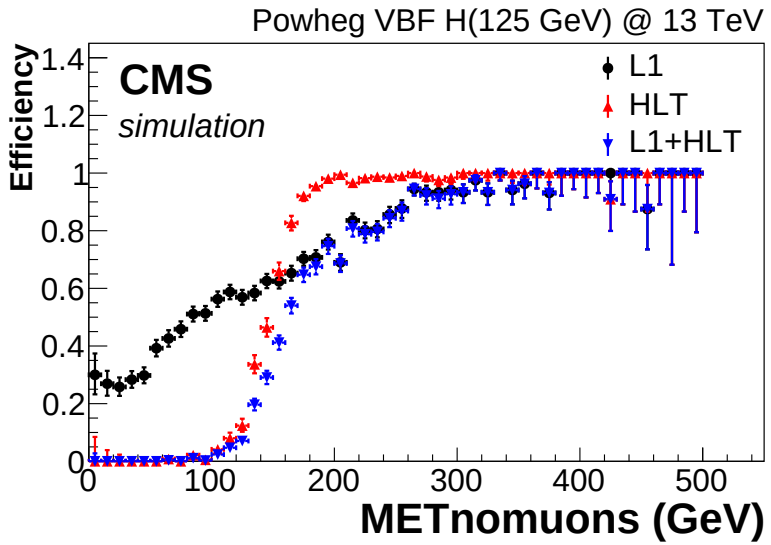
- Left caption: Efficiency of VBF Higgs to invisible trigger in data as a function of dijet mass (M_{jj}). The denominator of the efficiency is the number of events passing a single muon trigger which have two jets with $p_T > 80$ GeV, $METnoMU > 300$ GeV and $\Delta\eta_{jj} > 3.6$ GeV.
- Right caption: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





Plots for Approval

- 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. The slow L1 turn on is understood to be due to the HF not being included in the L1 MET sum.



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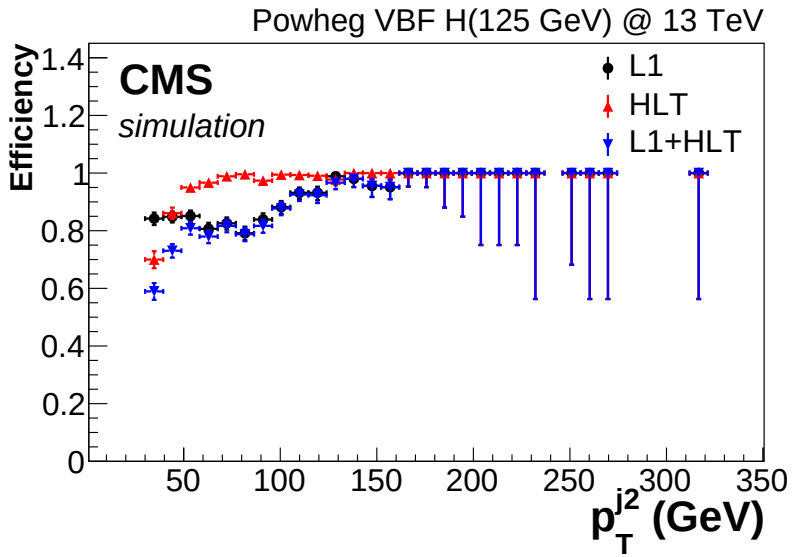

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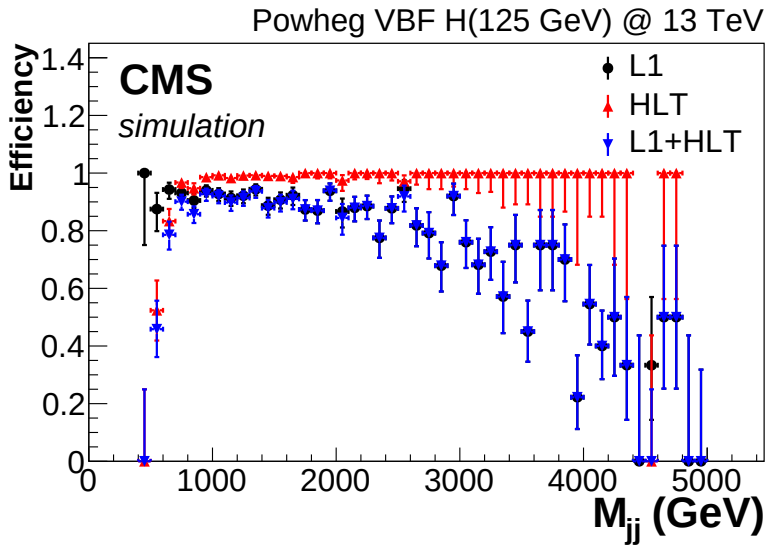

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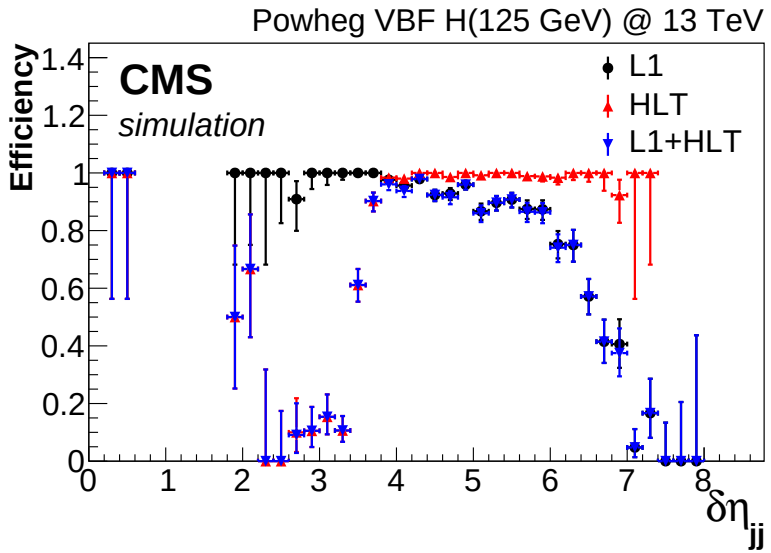
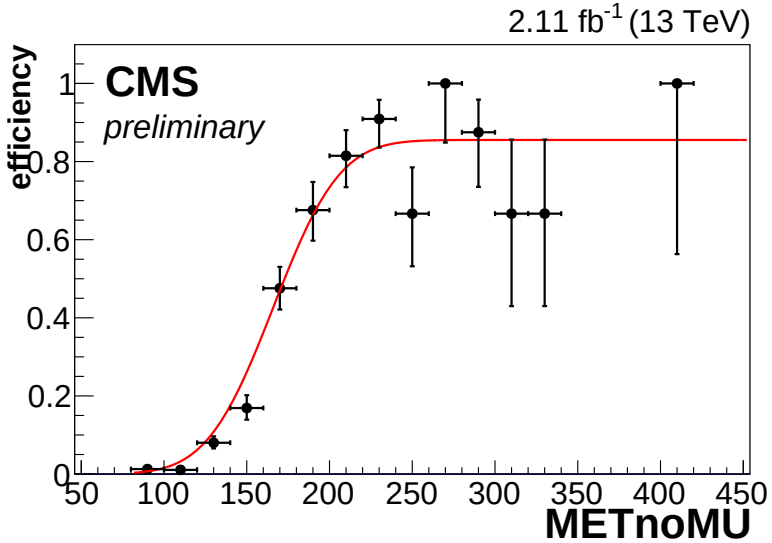


Backup

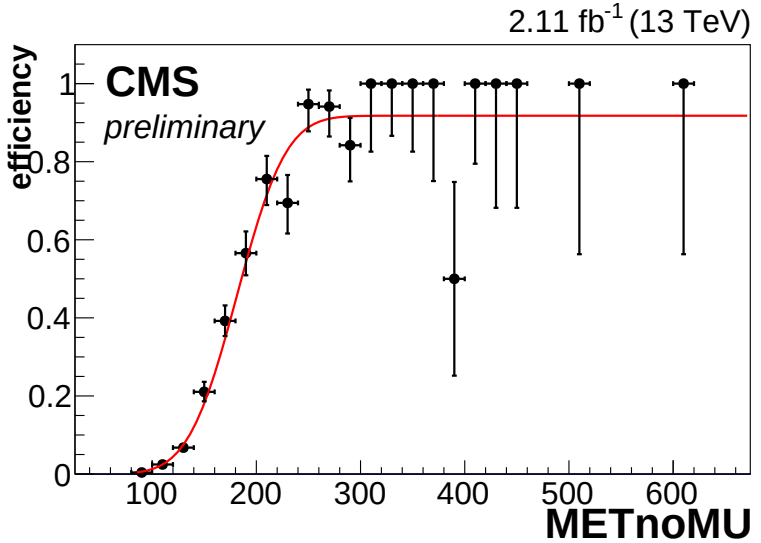
Binned trigger efficiencies for first analysis

- 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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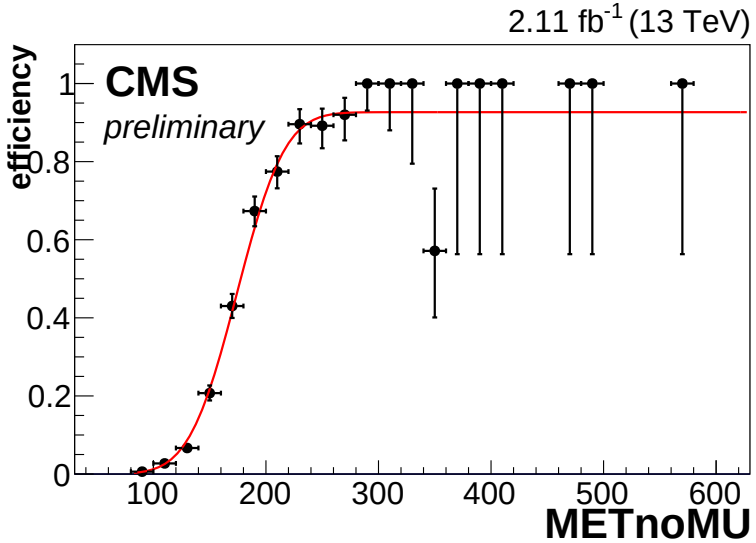
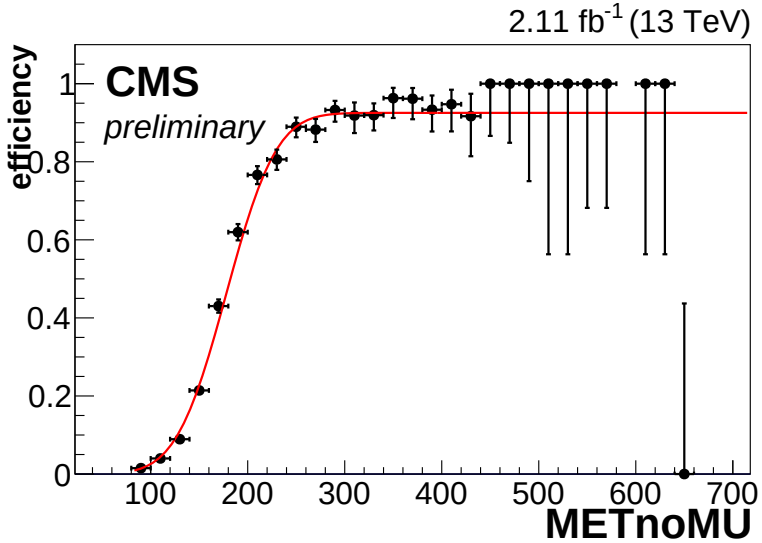
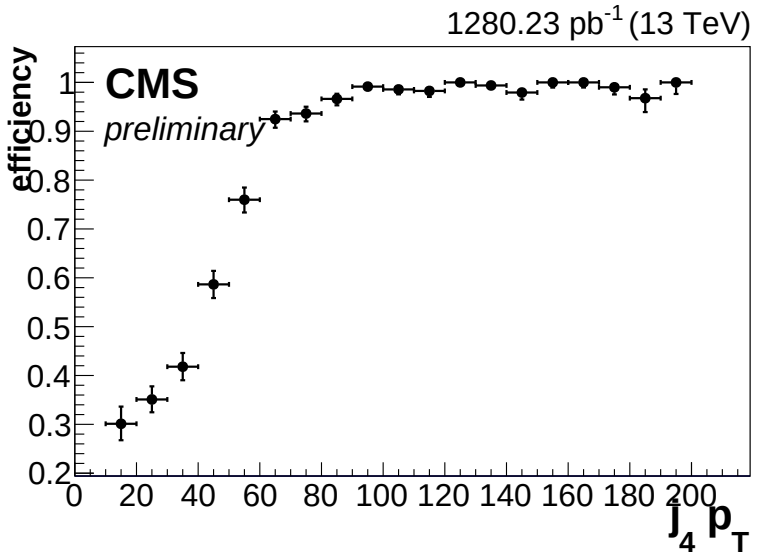


Jet p_T: 80+, M_{jj}: 1000+



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

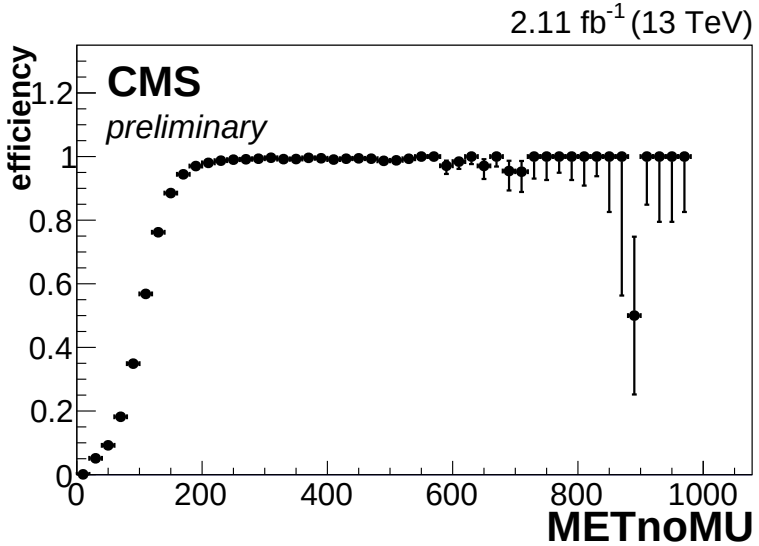


Implications for our trigger

- 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

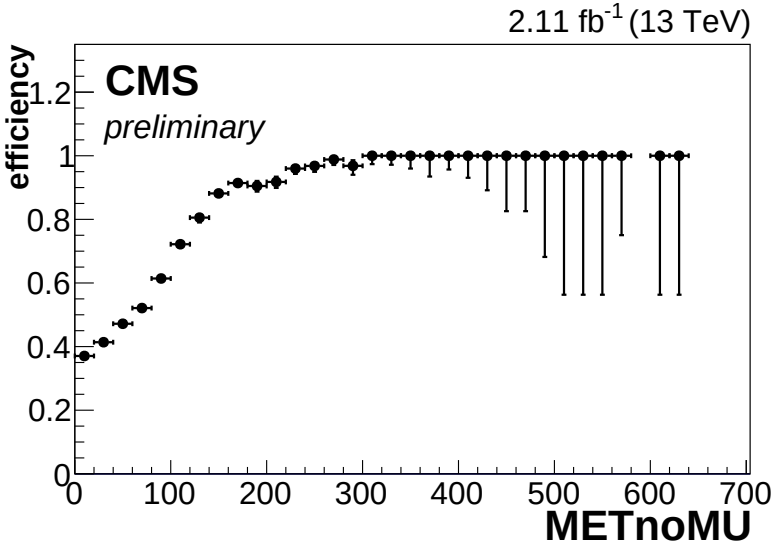
L1ETM60 Efficiency: Inclusive

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



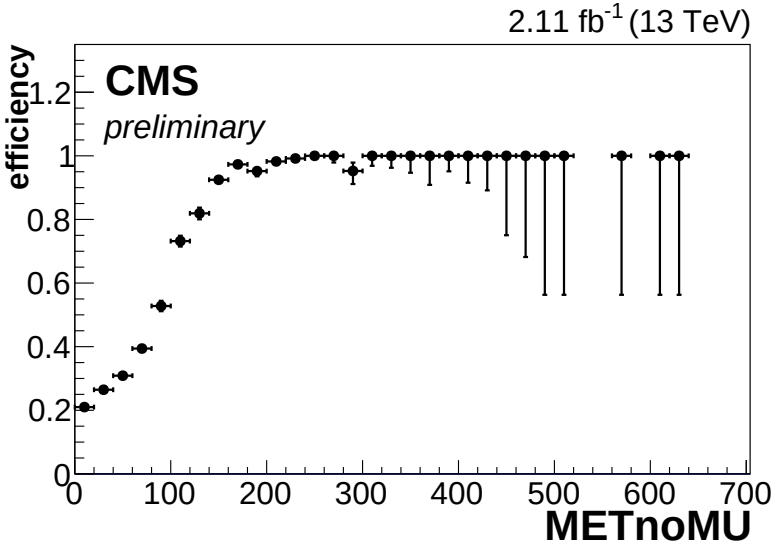
L1ETM60 Efficiency: VBF phase space

- 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



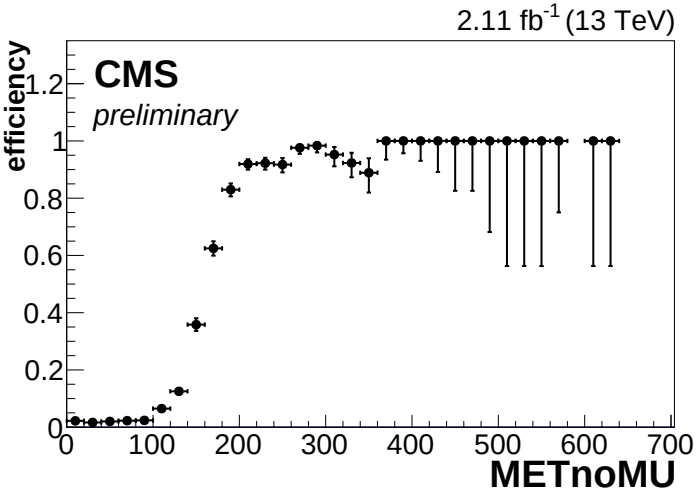
L1ETM60 Efficiency: VBF phase space

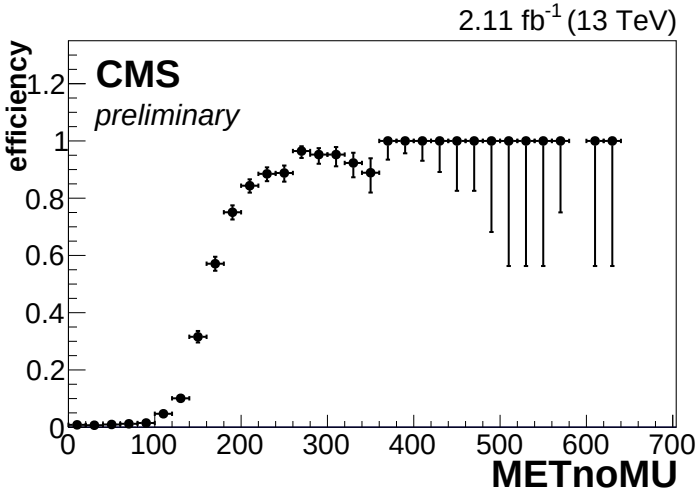
- L1 MET only sums up to $|\eta|$ =3, shelf seen on previous slide could be due to jets in the HF
- Add requirement that both jets have $|\eta| < 3$ to the denominator
- Good turn on recovered so shelf is due to events with jets in the HF



Signal trigger turn on: MET

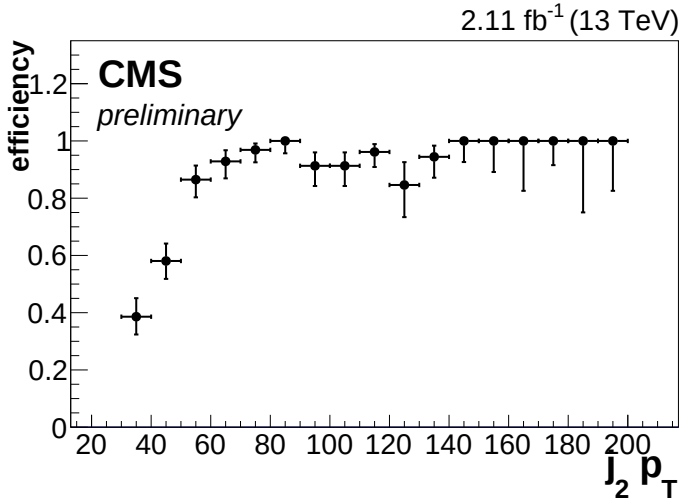
- Measure HLT efficiency (left) and L1+HLT efficiency (right)
- Dataset: Full 2015D data with latest JECv6
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60
  - Jet pt cut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

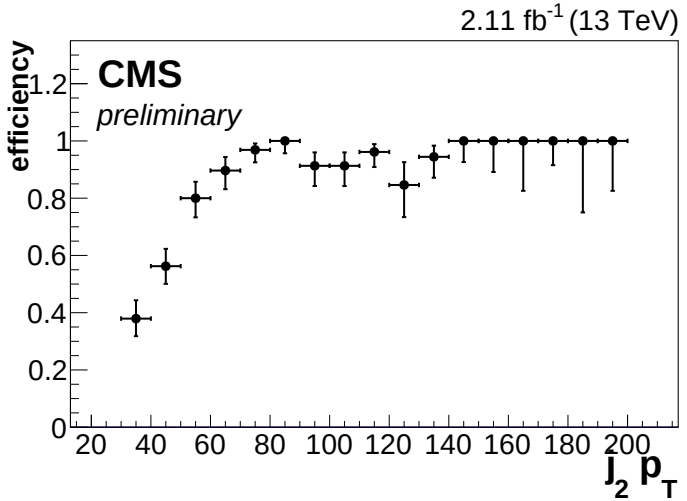




Signal trigger turn on: jet pt

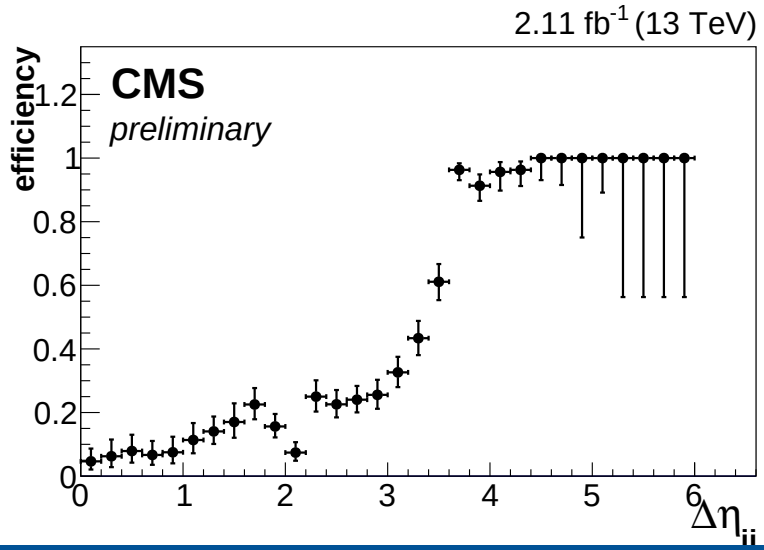
- Measure HLT efficiency (left) and L1+HLT efficiency (right)
- Dataset: Full 2015D data with latest JECv6
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet pt$>$ 80, $METnoMU > 300$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only and L1ETM60
  - MET cut very high due to slow MET turn on
- HLT only efficiency slightly better

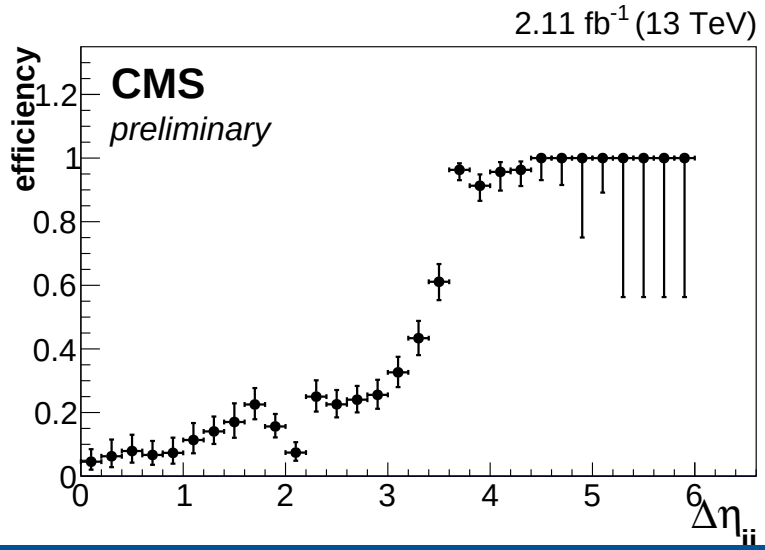




$\Delta\eta_{jj}$ data turn on

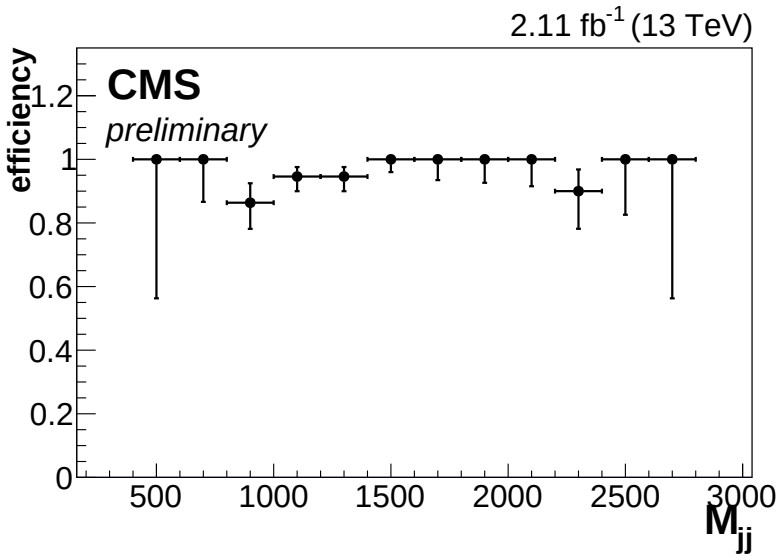
- Measure HLT efficiency (left) and L1+HLT efficiency (right)
- Dataset: Full 2015D data with latest JECv6
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60
- Possible decrease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

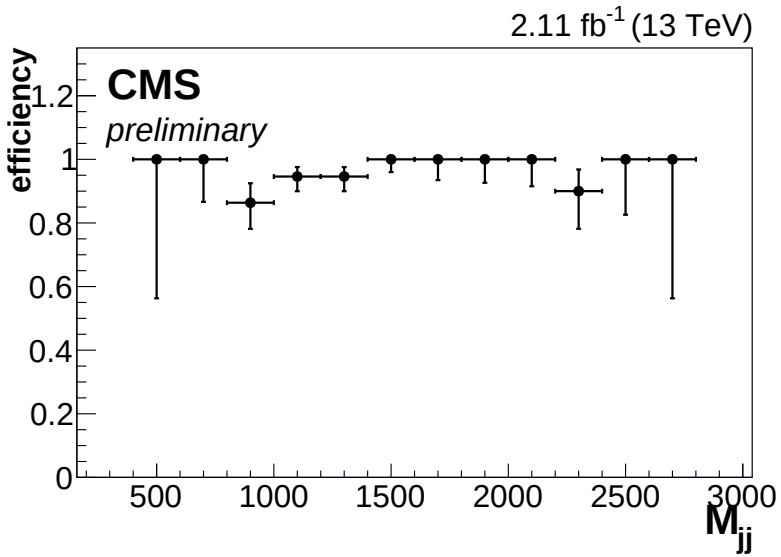




M_{jj} data turn on

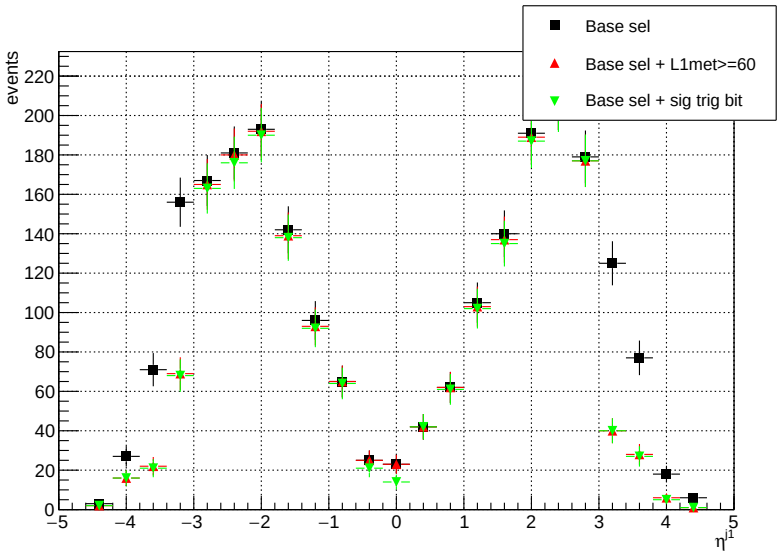
- Measure HLT efficiency (left) and L1+HLT efficiency (right)
- Dataset: Full 2015D data with latest JECv6
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60

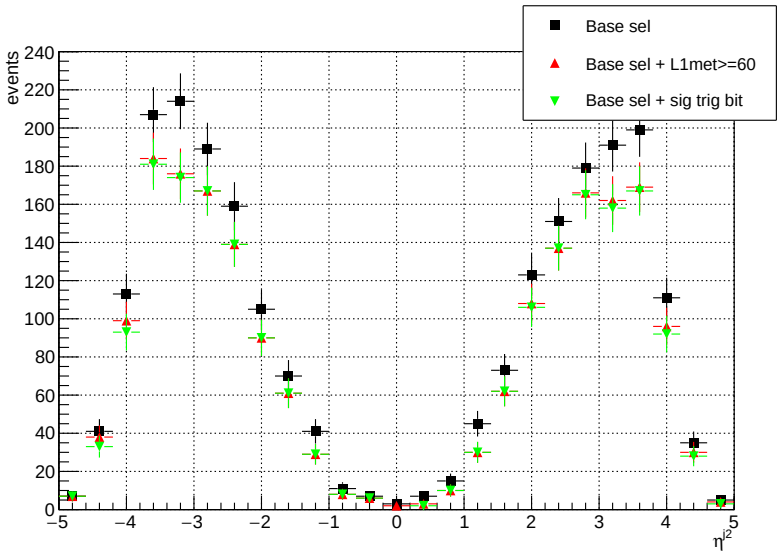




Impact of L1MET inefficiencies on signal

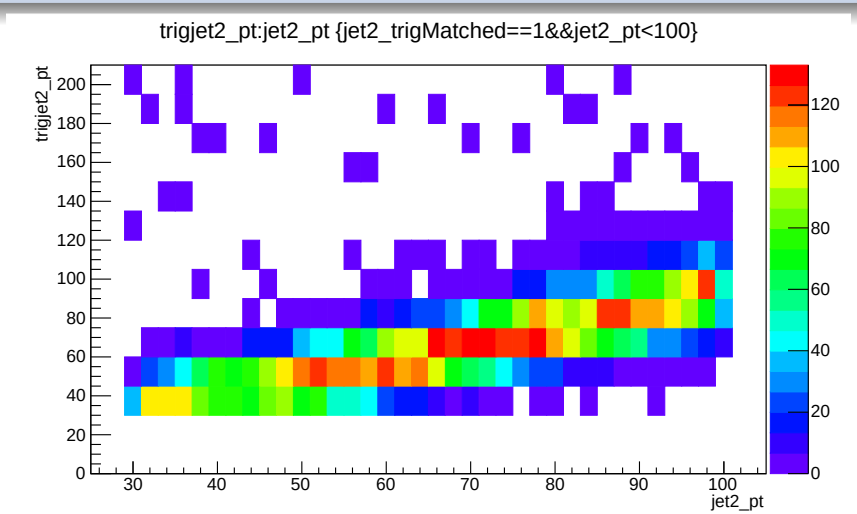
- Check effect of L1 inefficiency as a function of jet eta
- MC sample: VBF_HToInvisible_M125_13TeV_powheg_pythia8
- Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, METnoMU$>$ 200 GeV
- L1 inefficiency for jets in the HF can be clearly seen





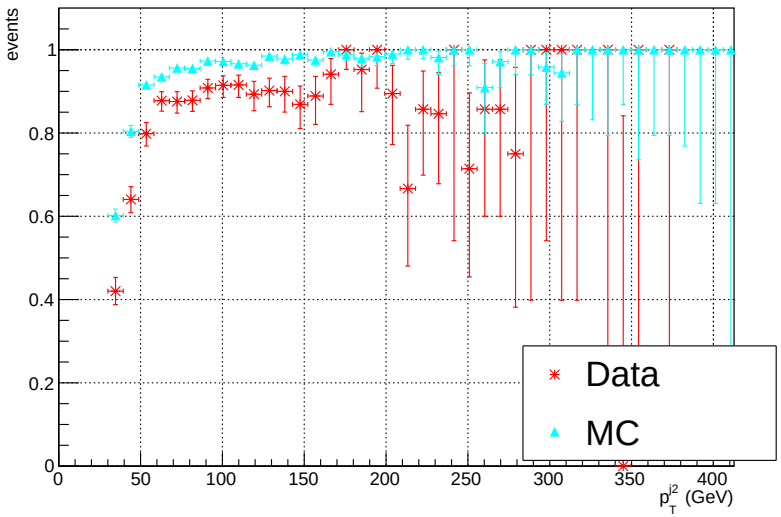
Calo jet prefilter

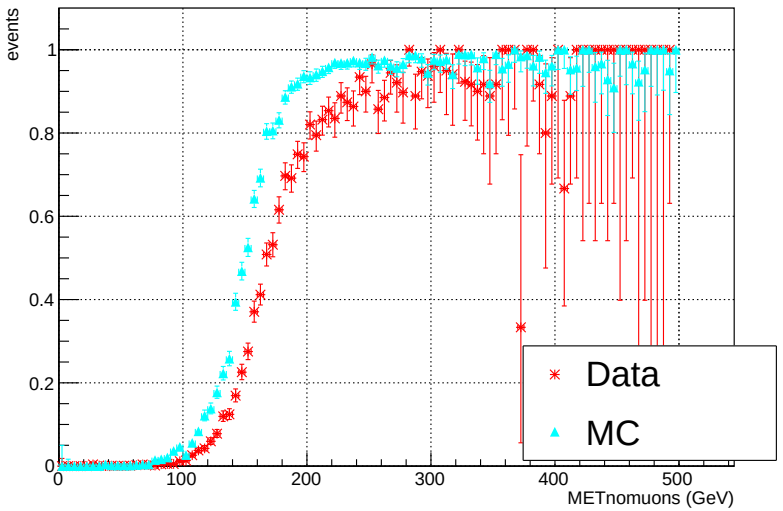
- Even after factoring out L1 effect jet pt is less efficient than in run 1
- According to these slides wrong JEC was used in HLT during Run2015
  - We have a calo prefilter at 30 GeV
  - Calo JEC are large so wrong JEC could cause the remaining jet pt issues
- Plot offline jet pt (x axis) against trigger calo jet pt (y axis)
- Large differences seen between calo jet pt and offline 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, $Delta\eta_{jj} > 3.6$, METnoMU$>$ 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 pt
- 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