Imperial College London

VBF Higgs to Invisible Trigger Efficiencies

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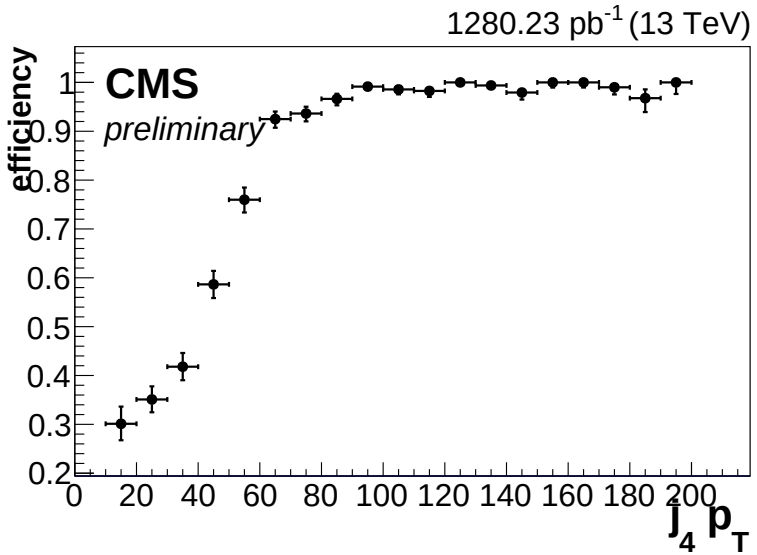
Reminder and outline

- 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

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

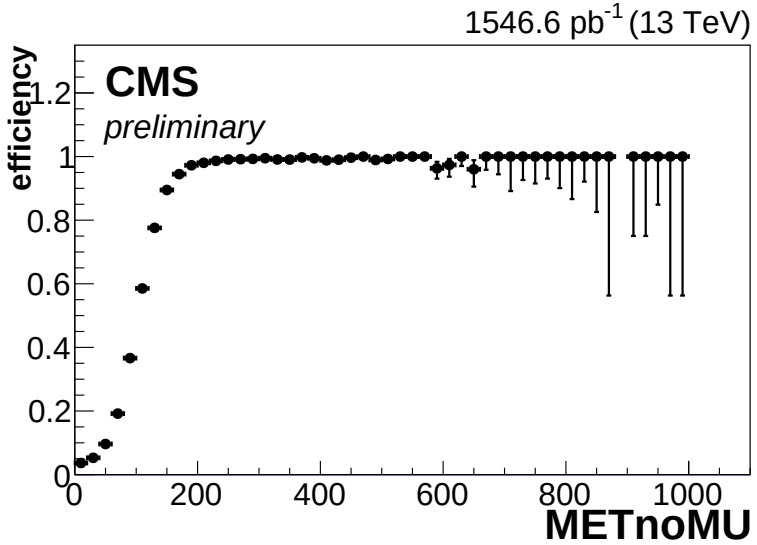


Implications for our trigger

- 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

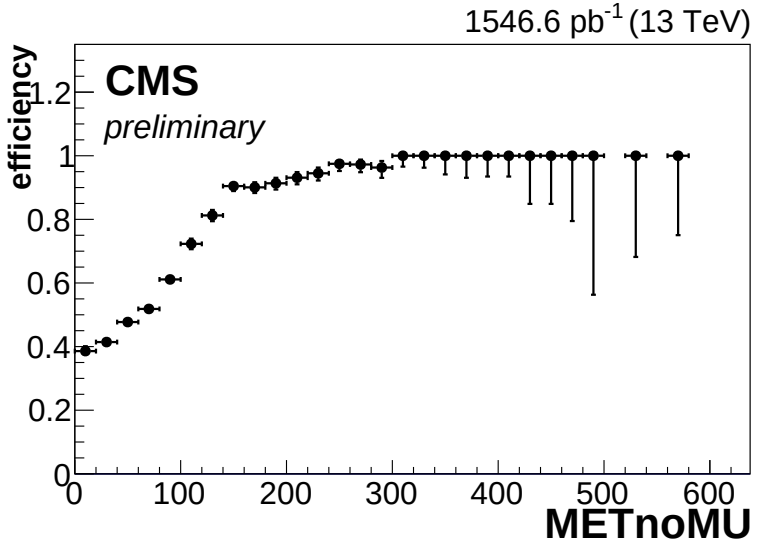
L1ETM60 Efficiency: Inclusive

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



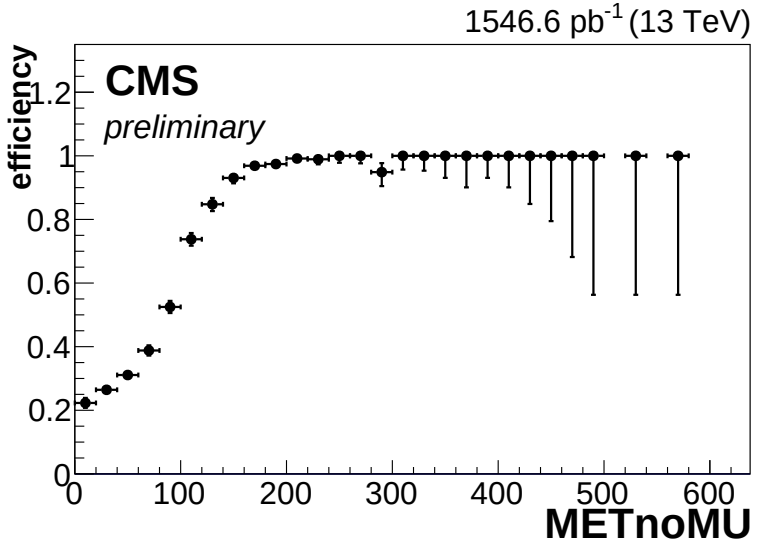
L1ETM60 Efficiency: VBF phase space

- 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



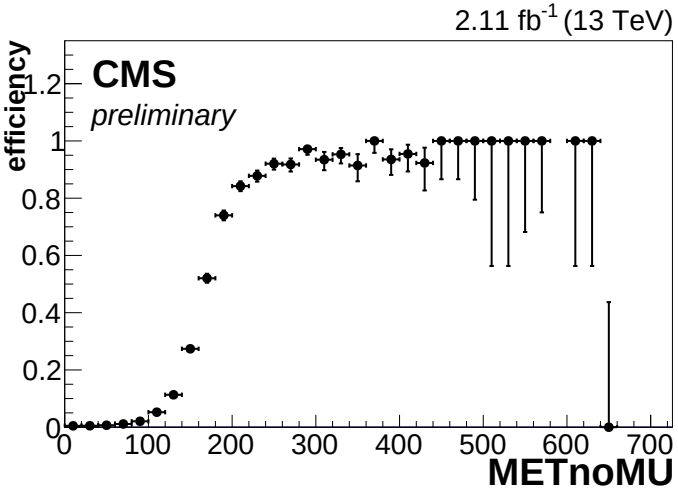
L1ETM60 Efficiency: VBF phase space

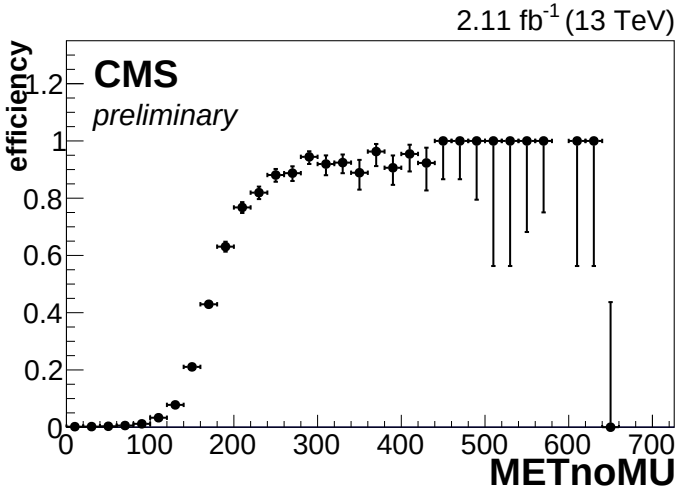
- L1 MET only sums up to $|\eta|$ =3, shelf seen on previous slide could be due to jets in the HF
- Add requirement that both jets have $|\eta| < 3$ to the denominator
- Good turn on recovered so shelf is due to events with jets in the HF



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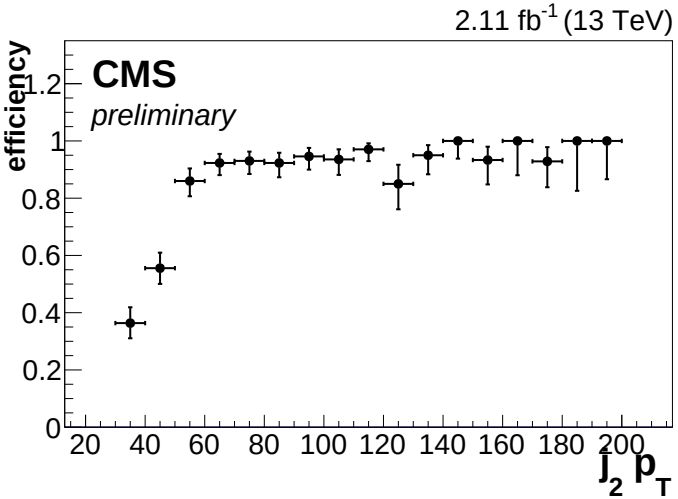
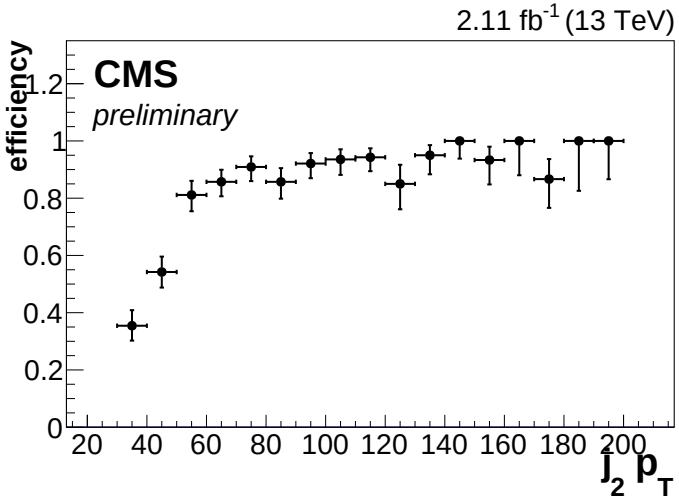
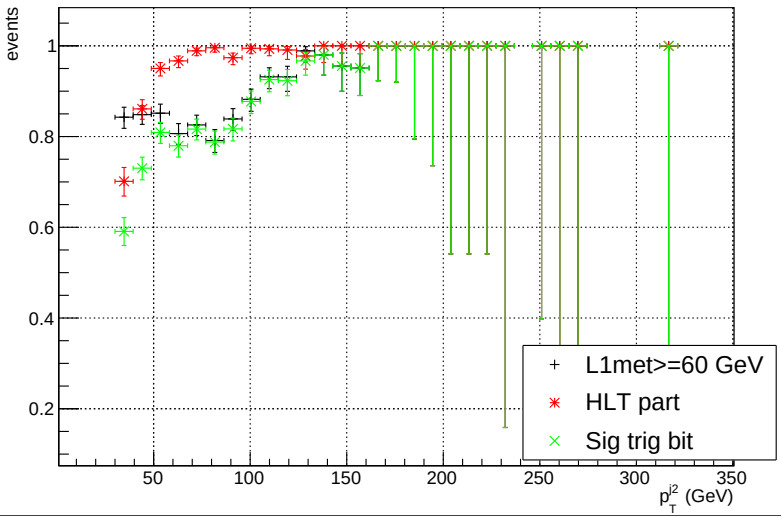
- Dataset: Full 2015D data with latest JECv6
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet pt> 80, $METnoMU > 300$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only and L1ETM60
  - MET cut very high due to slow MET turn on
- HLT only efficiency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

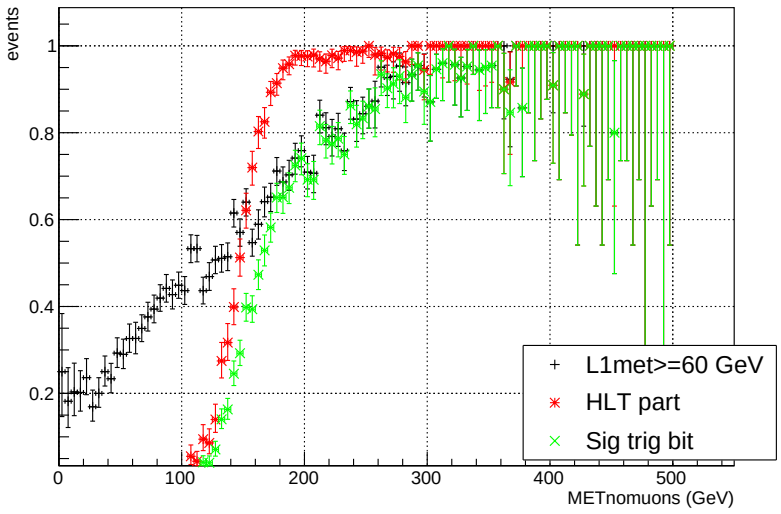




Impact of L1MET inefficiencies on signal

- 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, $\Delta\eta_{jj} > 3.6$, METnoMU$>$ 200 GeV
- We lose a lot of signal due to L1 inefficiency





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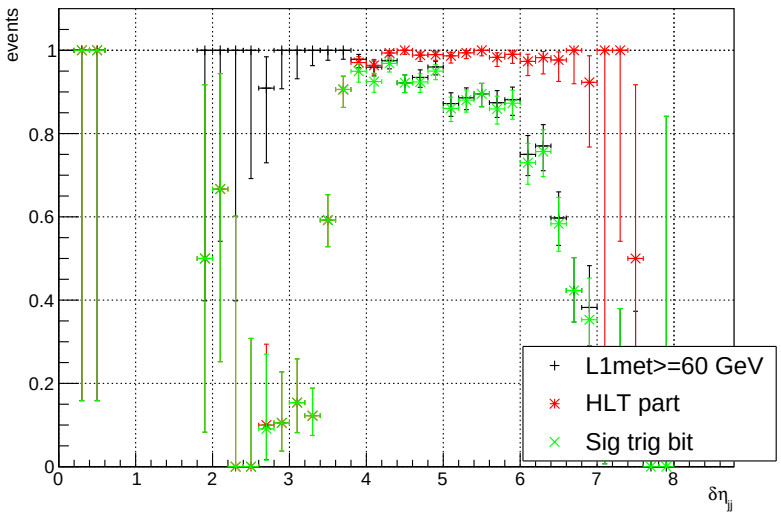
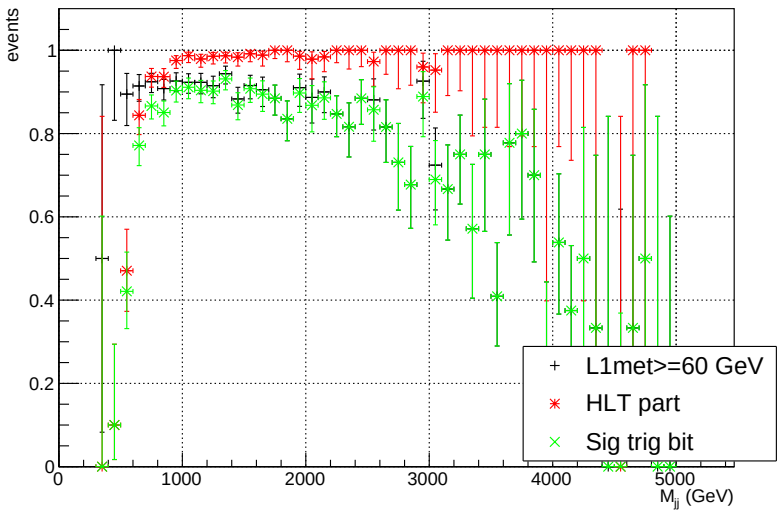
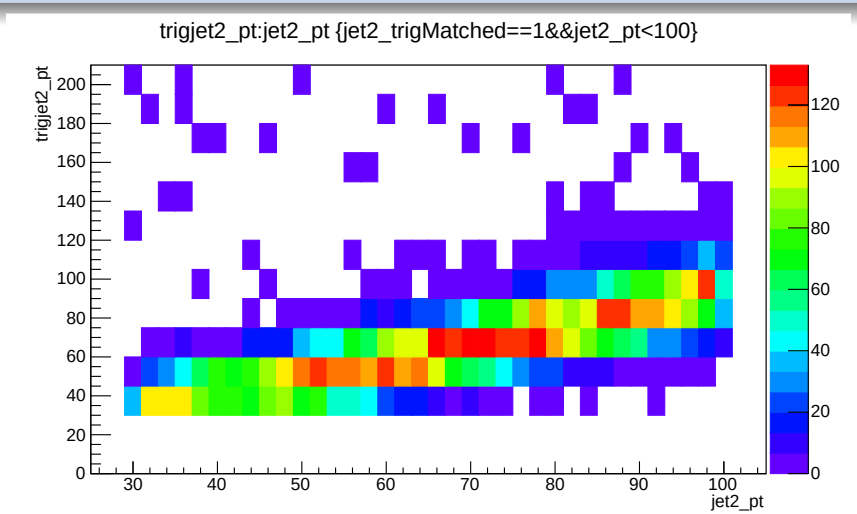
- Denominator: dijet $p_T > 50$ GeV, $M_{jj} > 800$ GeV, $\Delta\eta_{jj} > 3.6$, METnoMU$>$ 200 GeV
- Inefficiency for jets in the HF can be clearly seen in the left plot





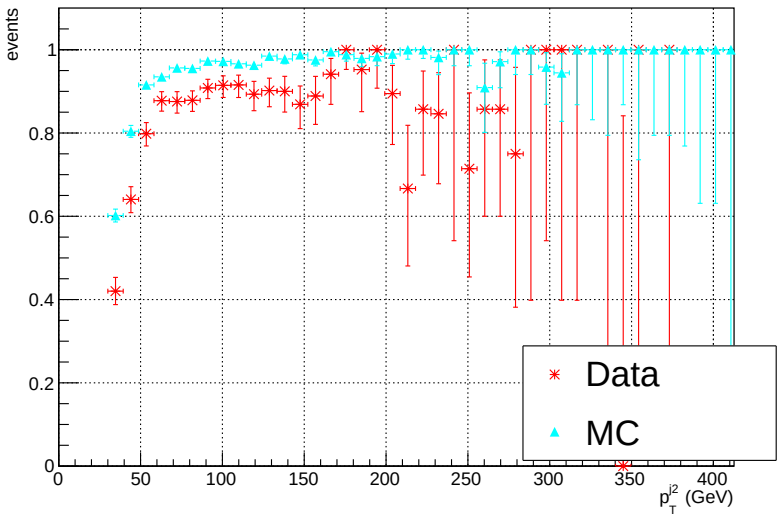
Calo jet prefilter

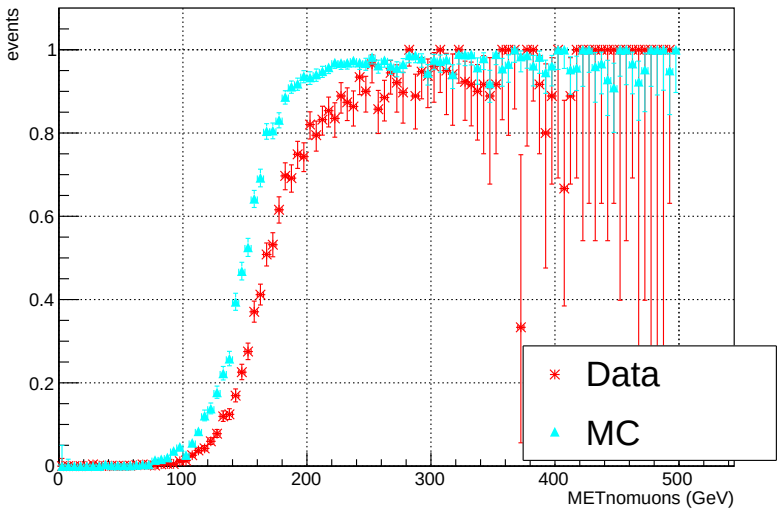
- Even after factoring out L1 effect jet pt is less efficient than in run 1
- According to these slides wrong JEC was used in HLT during Run2015
  - We have a calo prefilter at 30 GeV
  - Calo JEC are large so wrong JEC could cause the remaining jet pt issues
- Plot offline jet pt (x axis) against trigger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





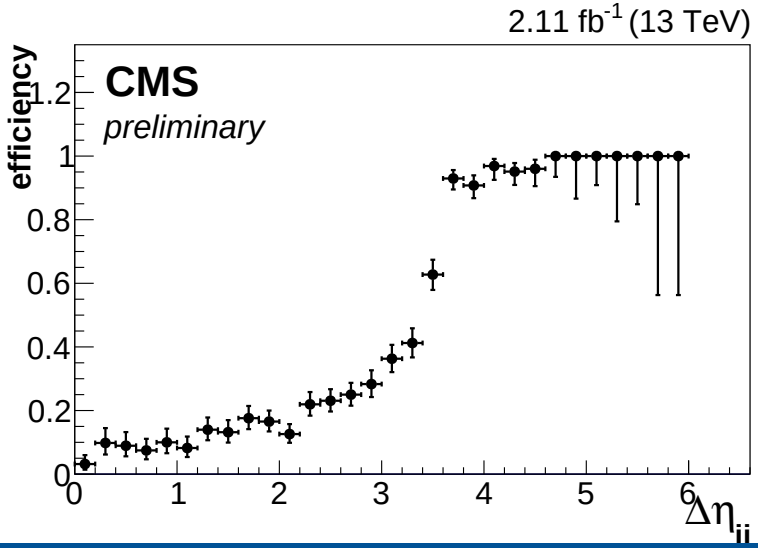
Summary

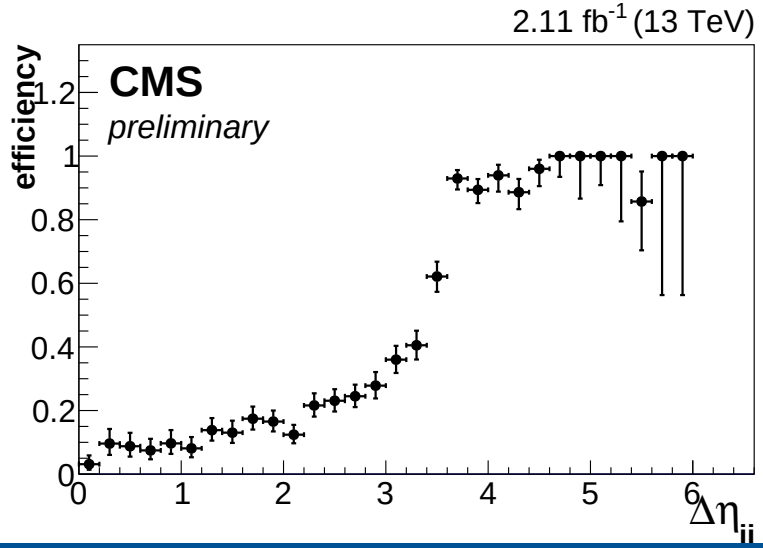
- L1ETM60 is inefficient in the VBF phase space due to it ignoring the HF
  - We lose a lot of signal from this L1 inefficiency
  - Correlation between variables forces cuts used making data turn ons to be very high, situation even worse for softer events
  - Even after factoring out L1 effect still 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
  - We see 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
- Needs more investigation: We currently only have trigger jet information for events that pass the trigger
  - Reemulating trigger on raw data so we can check if events failing trigger fail calo filter or pf filter

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

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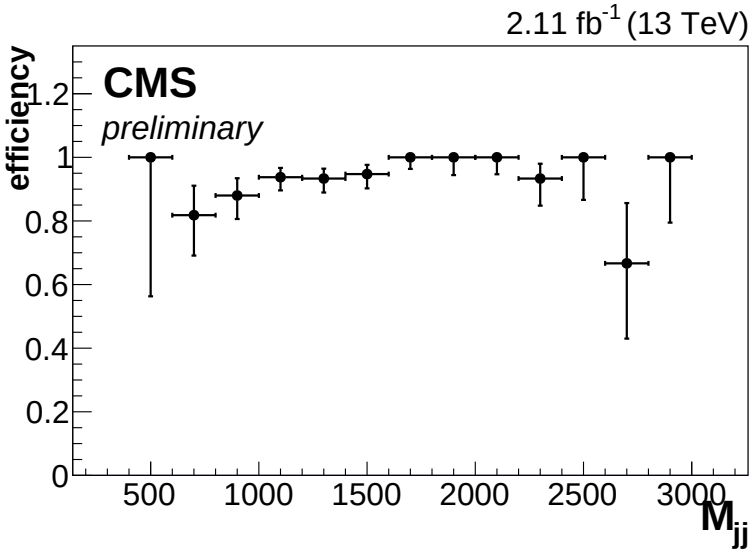
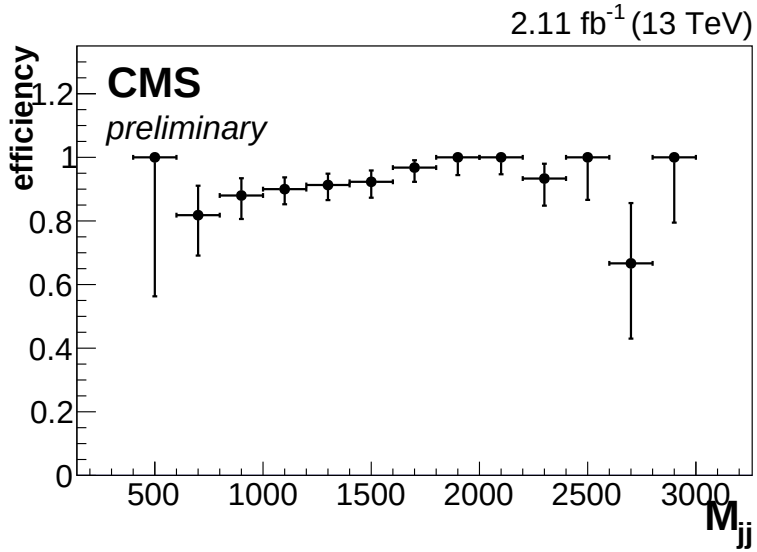
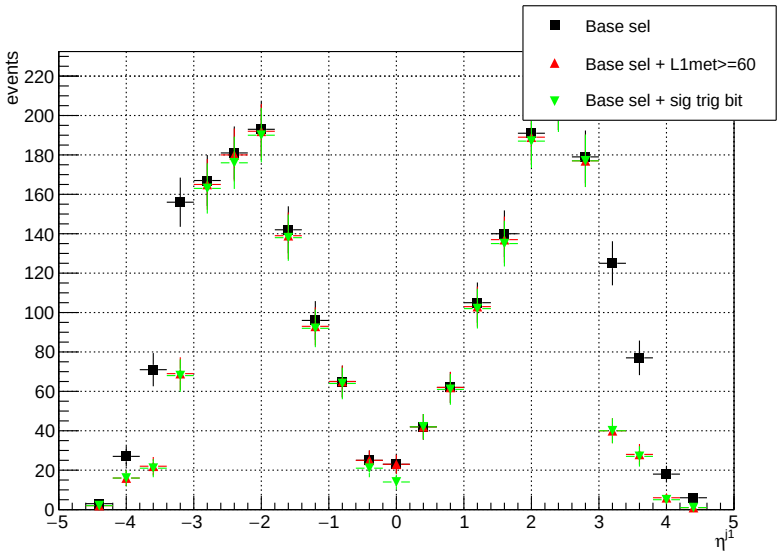
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet $p_T > 80$, $M_{jj} > 600$, $\Delta\eta_{jj} > 3.6$ plus for left plot only L1ETM60

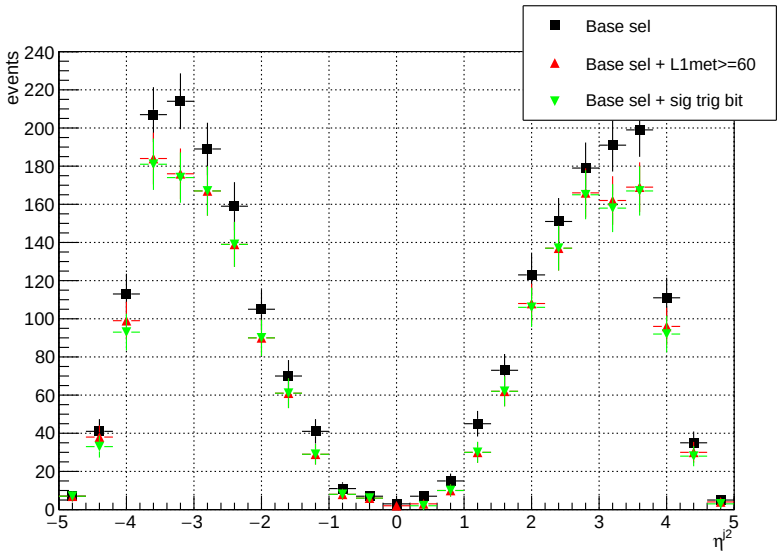




Impact of L1MET inefficiencies on signal

- 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





Binned trigger efficiencies for first analysis

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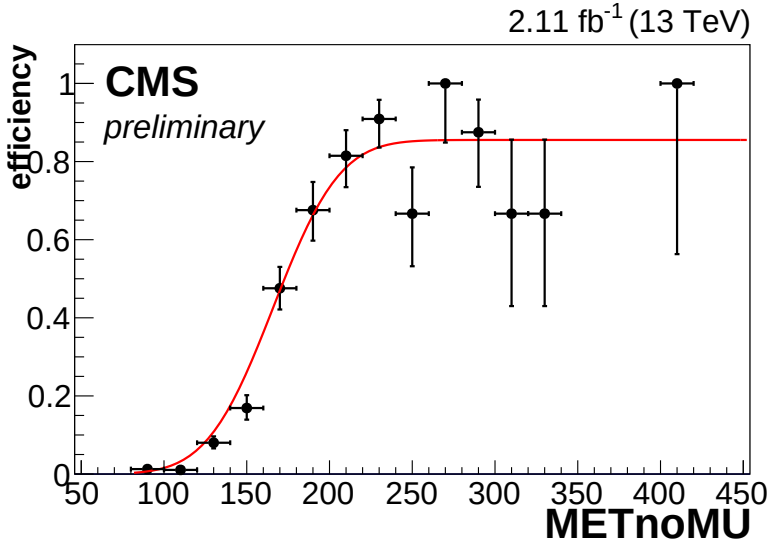
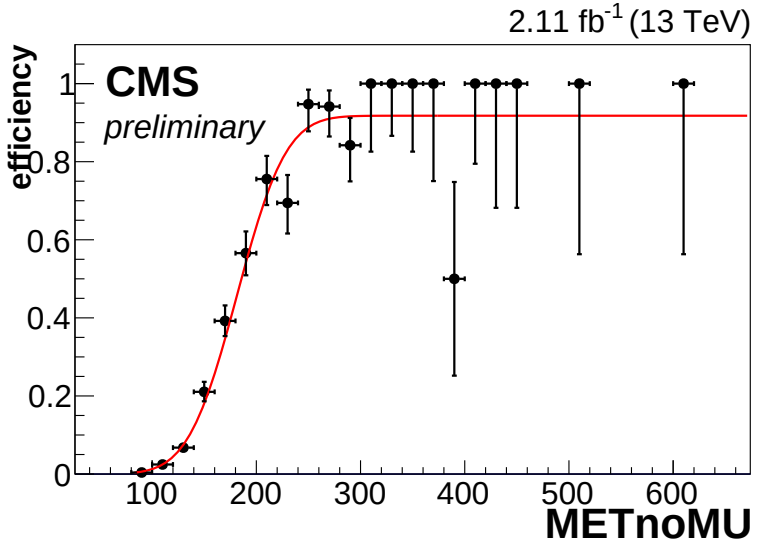
- Trigger: HLT_DiPFJet40_DEta3p5_MJJ600_PFMETNoMu140
- Denominator: SingleMuon events with dijet $\Delta\eta_{jj} > 3.6$ plus binned cuts
- Bins: Jet p_T: 70-80, 80+, M_{jj}: 800-1000, 1000+

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



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



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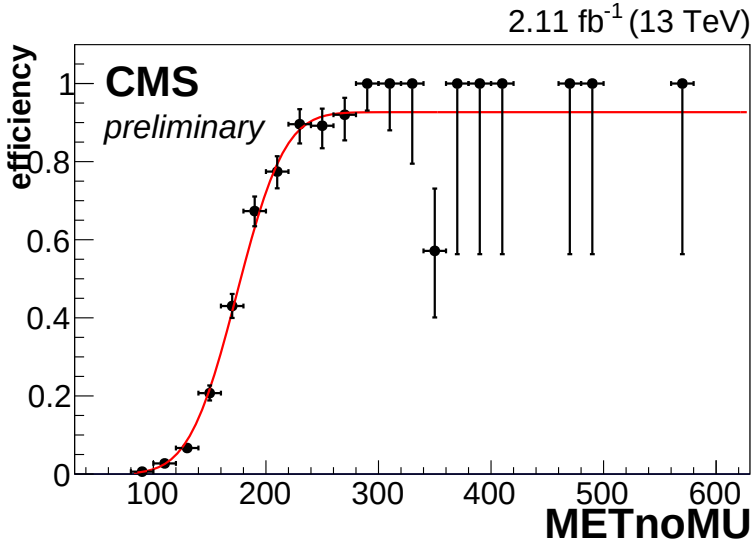

Jet p_T: 80+, M_{jj}: 1000+