


# monoHiggs
# etau and mutau

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  1) Basic selections
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  4) 2017BCDE and 2017F blinded

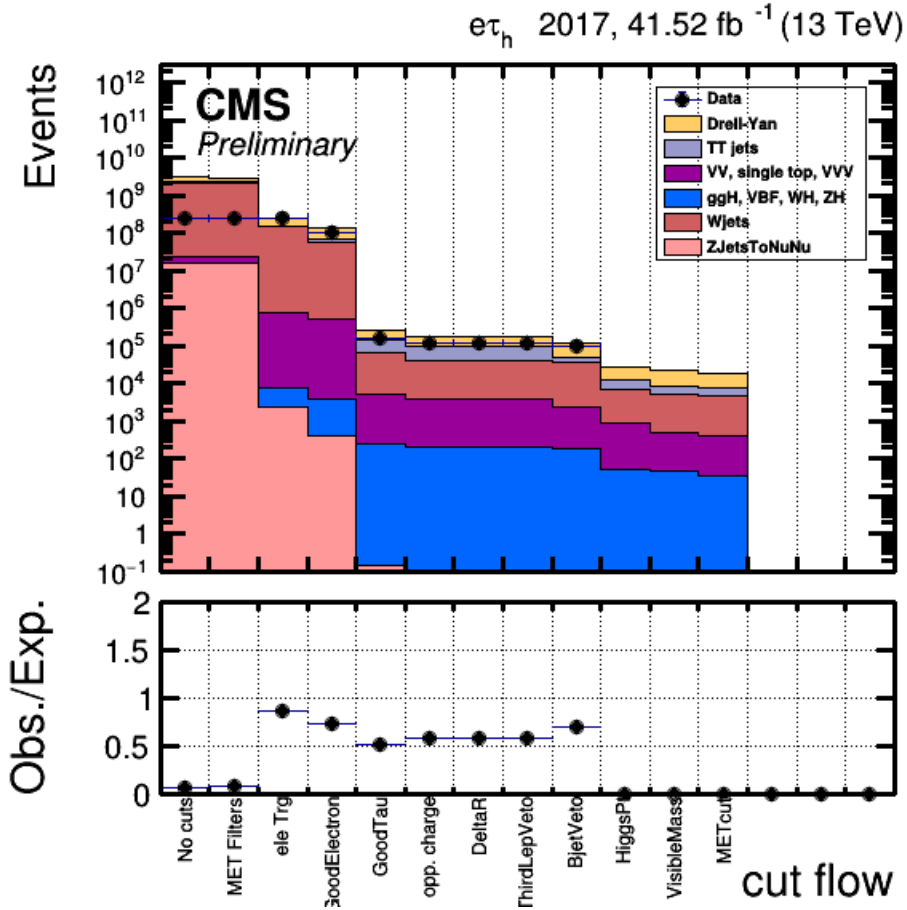
# e-tau state basic selections

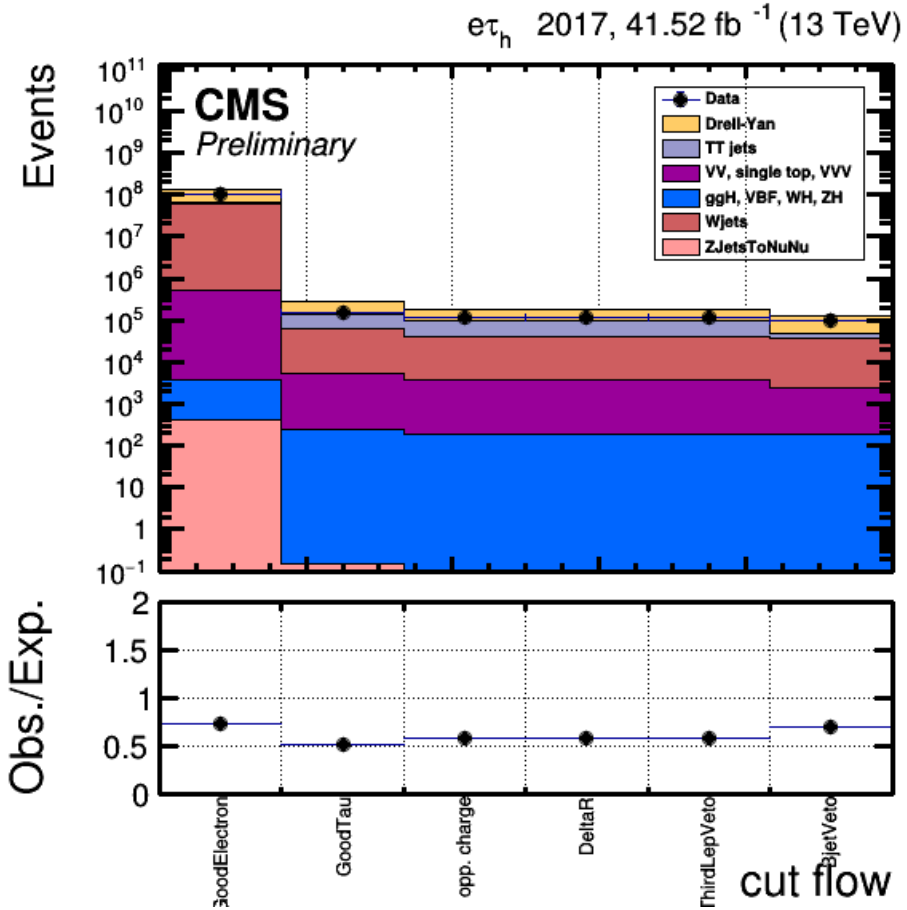
- Met filters
- Single electron trigger -> HLT_Ele35_WPTight_Gsf_v (E/gamma Trigger Recommendations )
- Good electron
  - Pt > 40 and |eta| < 2.1 (above the HLT trigger PT threshold and where efficiency is good)
  - Relative isolation < 0.1
  - Tight electron id
- Good tau
  - pt> 20 and |eta| < 2.3, (following Tau POG recommendations)
  - tau must match to the primary vertex, dZ< 0.2 cm
  - tauByMVA6TightElectronRejection and tauByLooseMuonRejection3
    -> lepton discriminators to reduce contribution from background processes where an electron or muon is misidentified as a hadronic tau
  - Tau Tight isolation (taubyTightIsolationMVArun2017v2DBoldDMwLT2017)
  - Decay modes 1 or 3
- Charge selection: opposite charge for electron and tau
- Third lepton veto
- bjetVeto

- Scale factors applied:

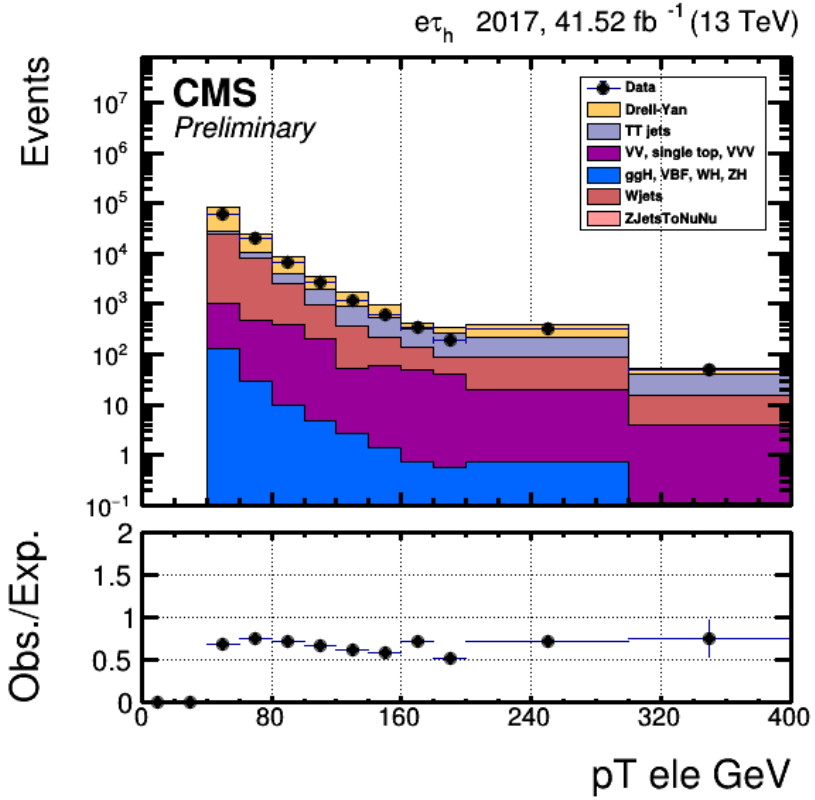
1) Tau id sf: 0.89
2) HLT Zvtx Efficiency Scale Factor : 0.991
3) Electron Reconstruction Scale Factor (Run2017BCDEF ) (depends on pt and eta)
4) Efficiency ScaleFactors(Run2017BCDEF ) (depends on pt and eta)

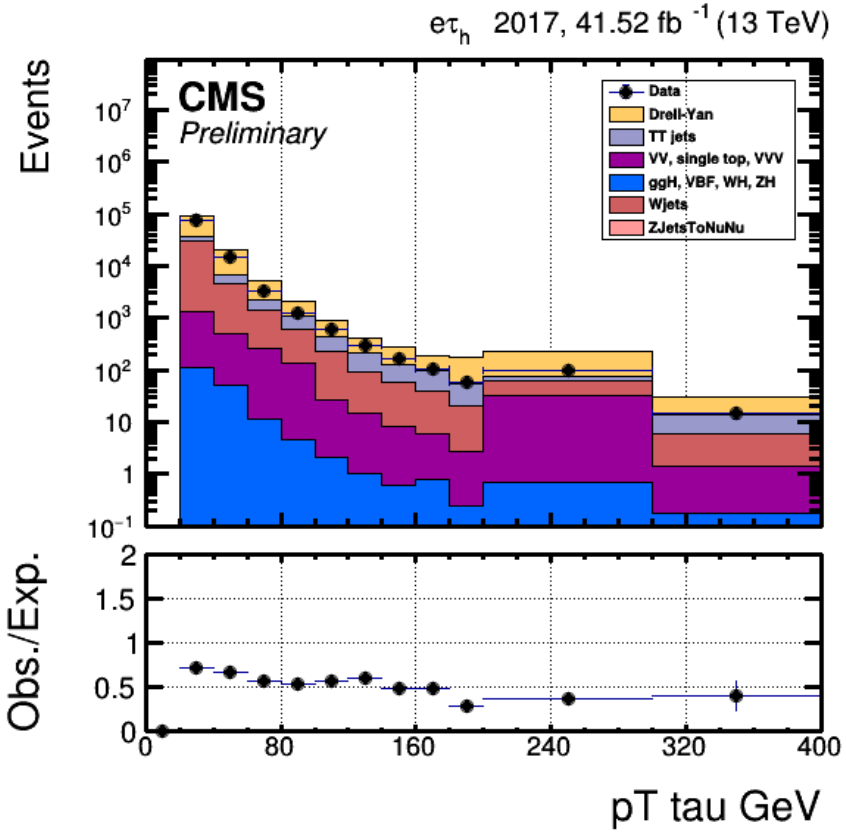
https://twiki.cern.ch/twiki/bin/viewauth/CMS/Egamma2017DataRecommendations

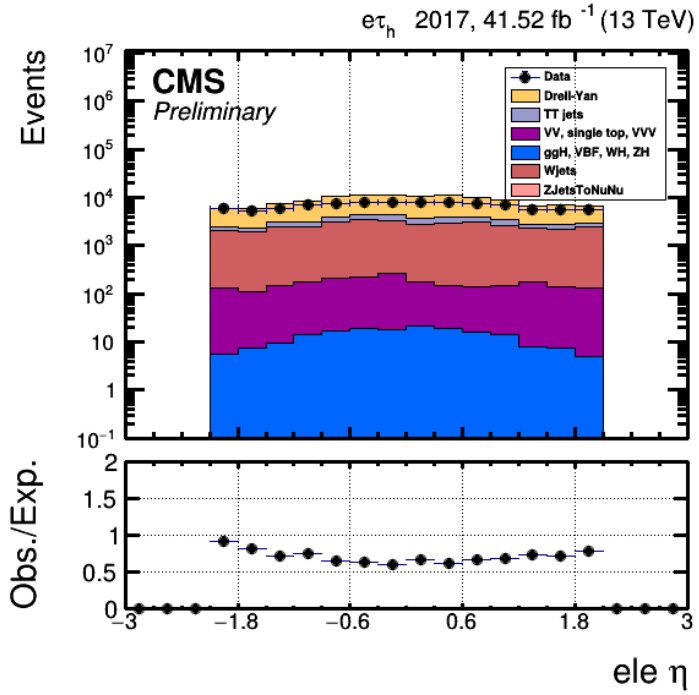

eτh 2017, 41.52 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
No cuts
MET Filters
ele Trg
GoodElectron
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
HiggsPt
VisibleMass
METcut
cut flow

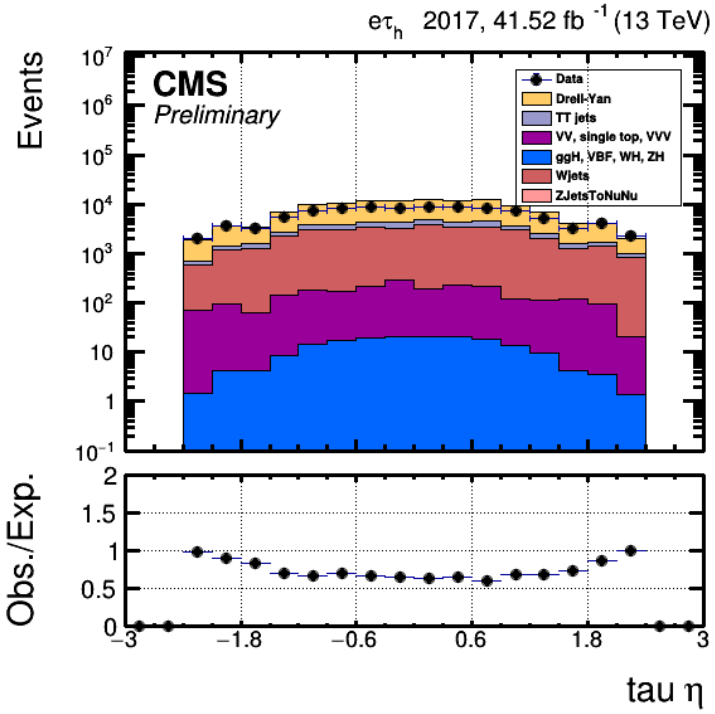

eτh 2017, 41.52 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
GoodElectron
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
cut flow

# e-tau final state signal region

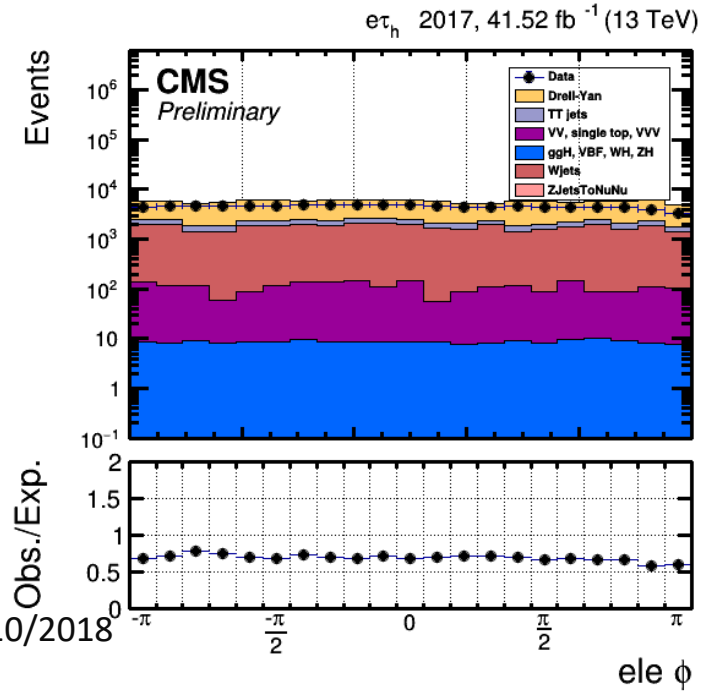


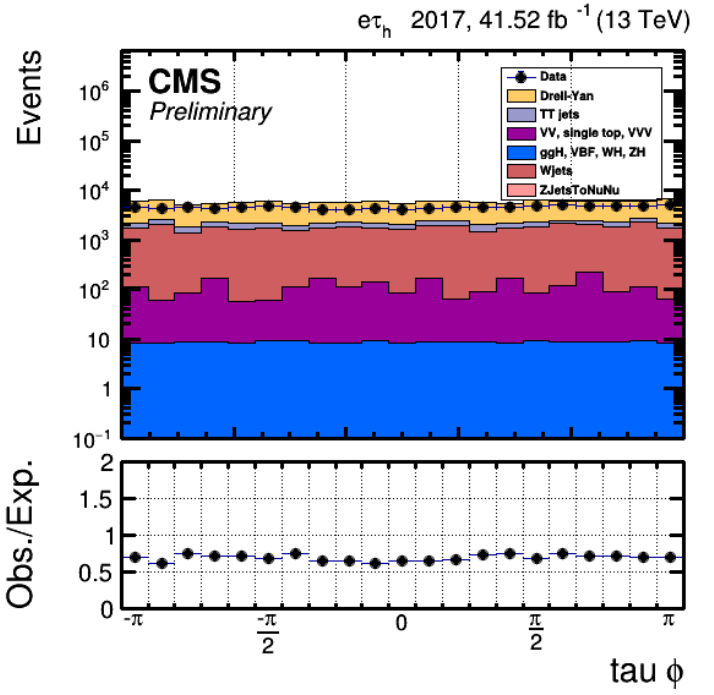






After bjet veto



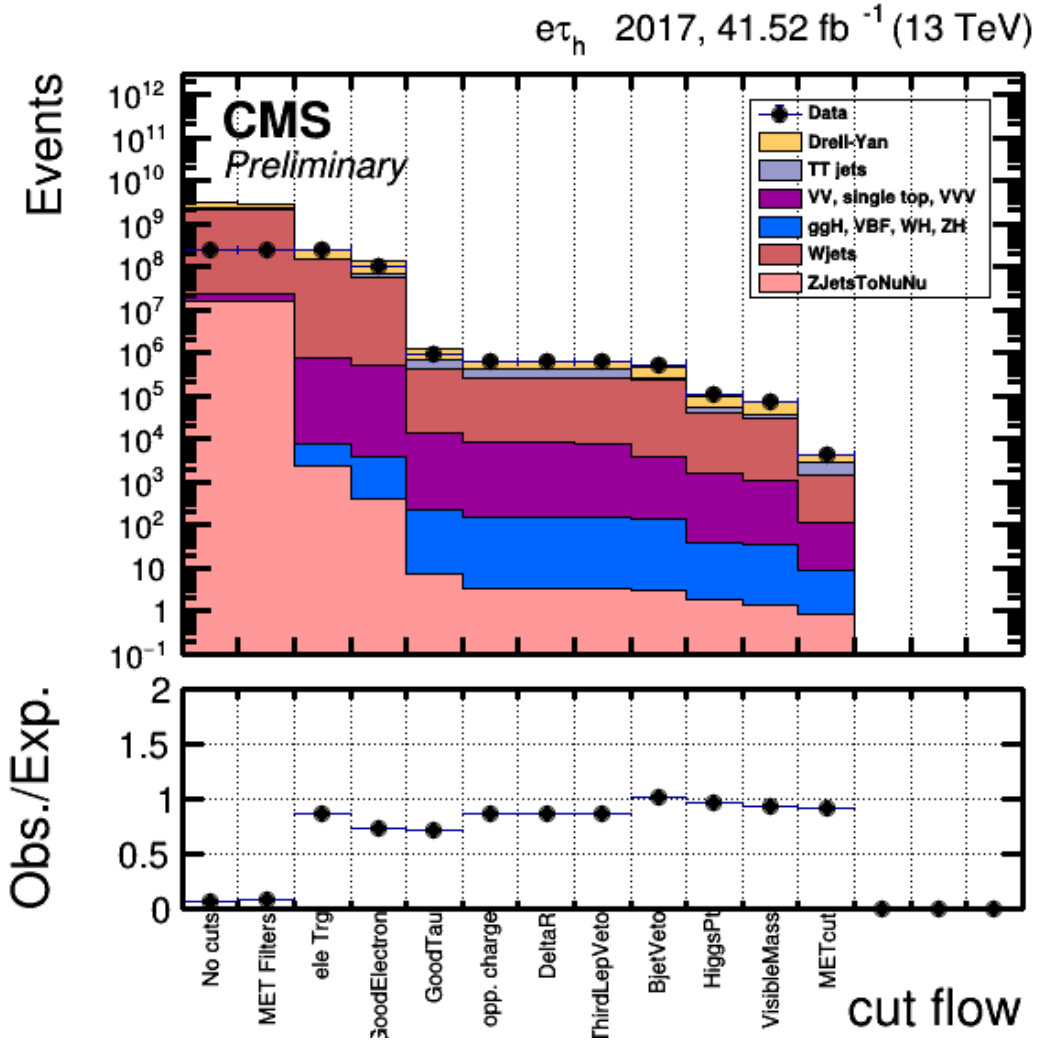
# e-tau state Wjets CR selections

- Met filters
- Single electron trigger -> HLT_Ele35_WPTight_Gsf_v (E/gamma Trigger Recommendations )
- Good electron
  - Pt > 40 and |eta| < 2.1 (above the HLT trigger PT threshold and where efficiency is good)
  - Relative isolation < 0.1
  - Tight electron id
- Good tau
  - pt> 20 and |eta| < 2.3, (following Tau POG recommendations)
  - tau must match to the primary vertex, dZ< 0.2 cm
  - tauByMVA6TightElectronRejection and tauByLooseMuonRejection3
    -> lepton discriminators to reduce contribution from background processes where an electron or muon is misidentified as a hadronic tau
  - Tau very loose isolation and not tight isolation
  - Decay modes >0
- Charge selection: opposite charge for electron and tau
- Third lepton veto
- bjetVeto
- Higgs pt > 65 and visible mass < 125

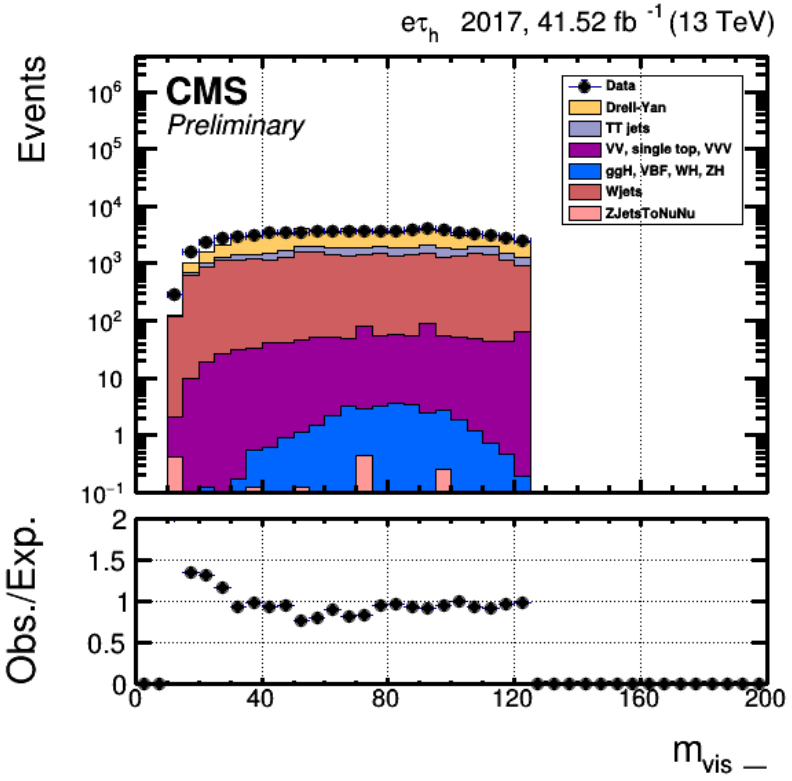
- Scale factors applied:

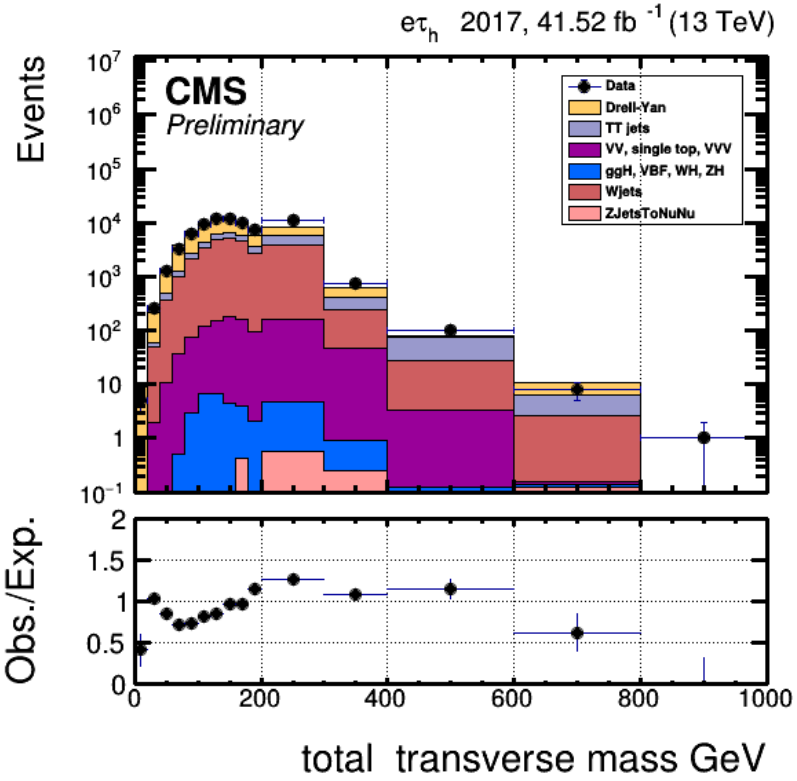
1) Tau id sf: 0.89
2) HLT Zvtx Efficiency Scale Factor : 0.991
3) Electron Reconstruction Scale Factor (Run2017BCDEF ) (depends on pt and eta)
4) Efficiency ScaleFactors(Run2017BCDEF ) (depends on pt and eta)

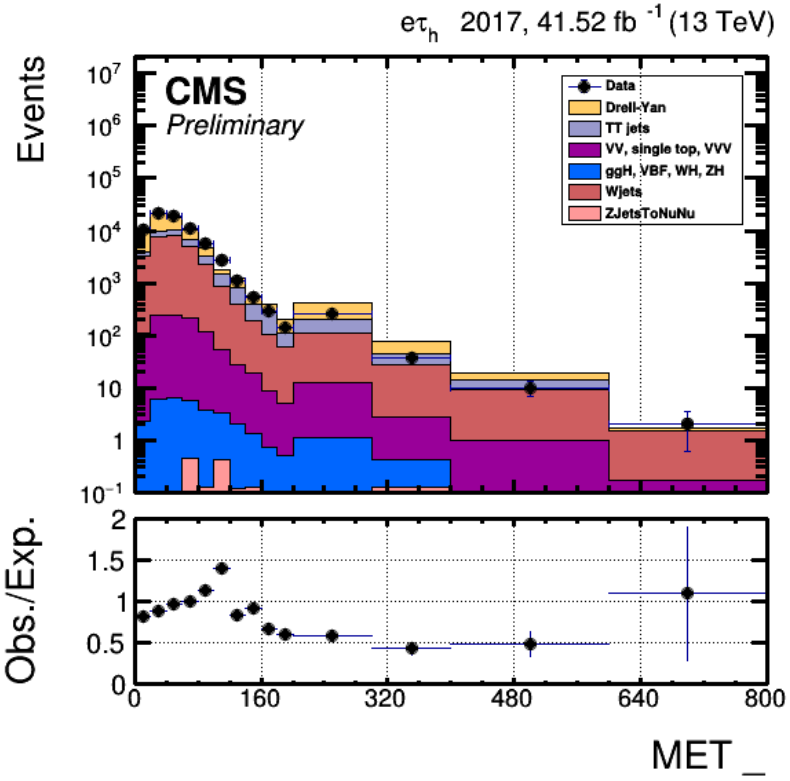
https://twiki.cern.ch/twiki/bin/viewauth/CMS/Egamma2017DataRecommendations


eτh 2017, 41.52 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
No cuts
MET Filters
ele Trg
GoodElectron
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
HiggsPt
VisibleMass
METcut
cut flow

# e-tau final state, Wjets control region

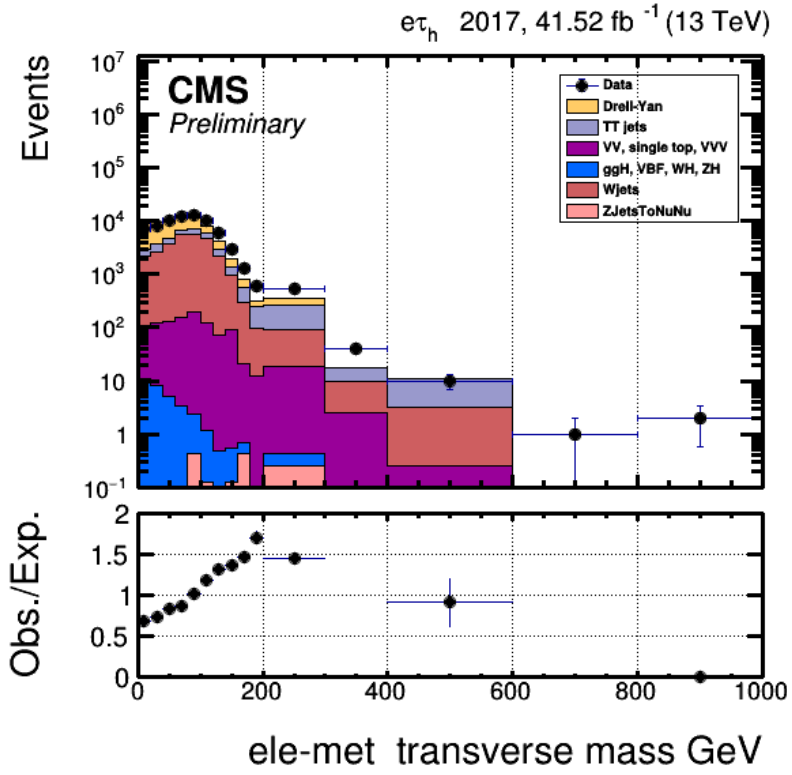


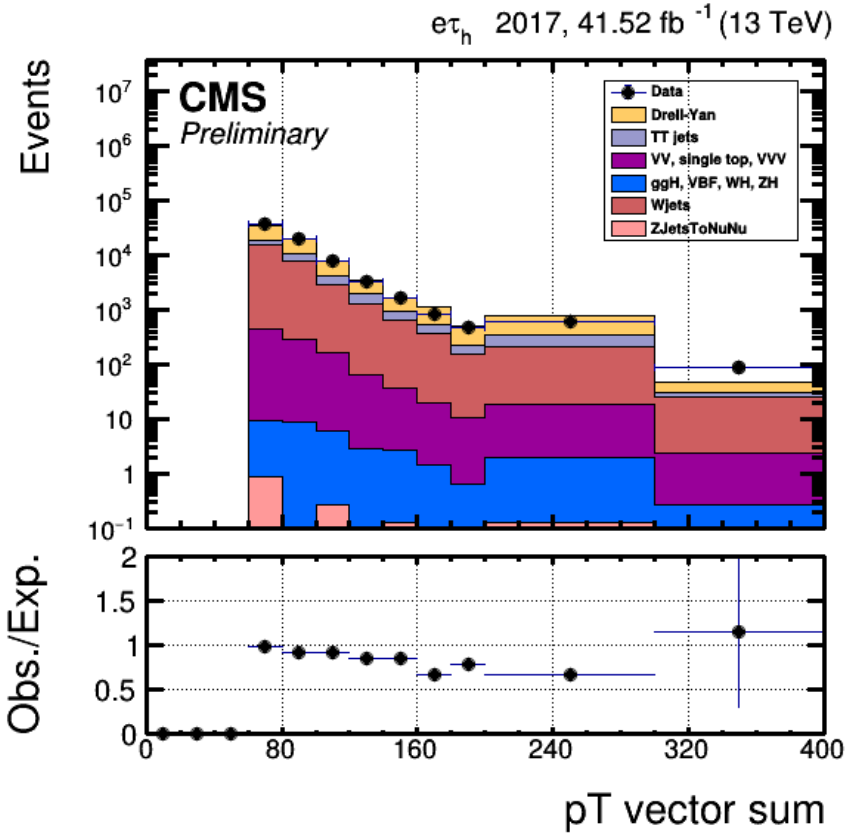




After visible mass cut

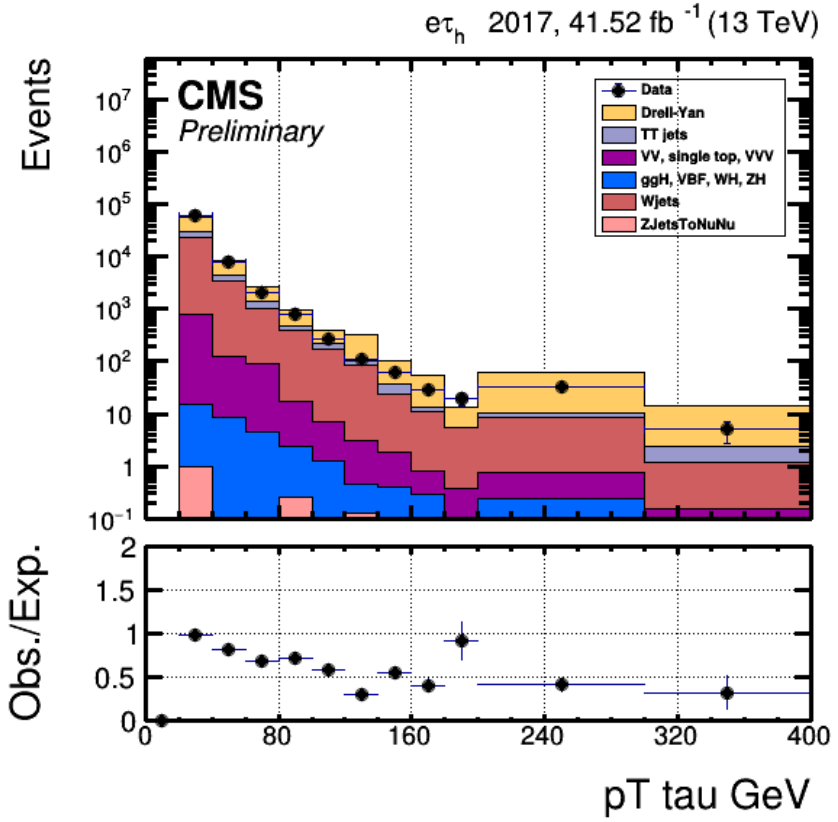
# e-tau final state, Wjets control region

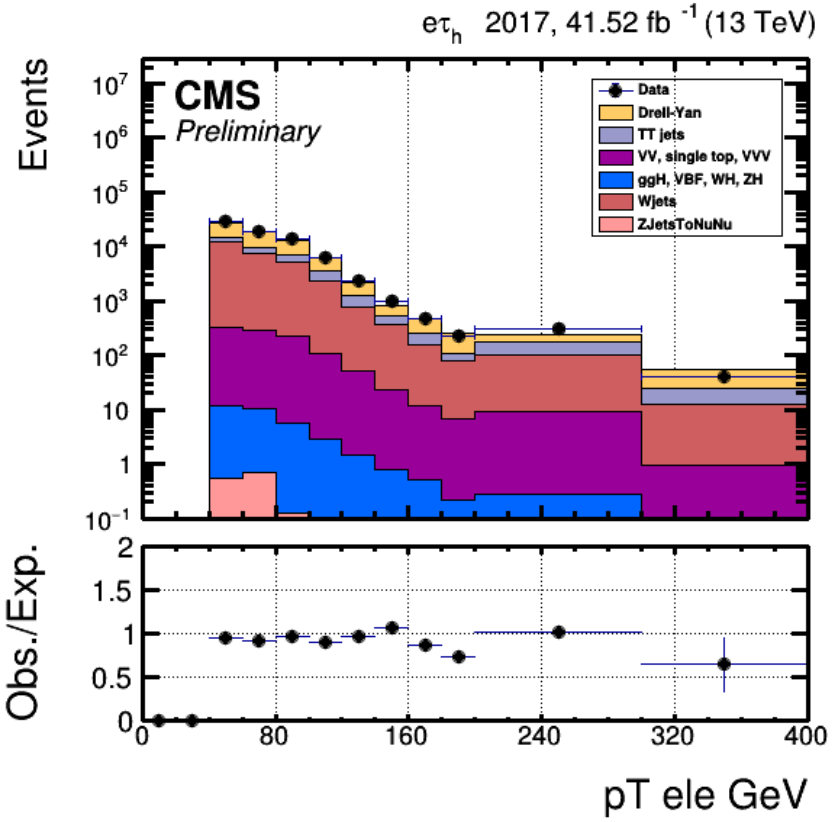



After visible mass cut

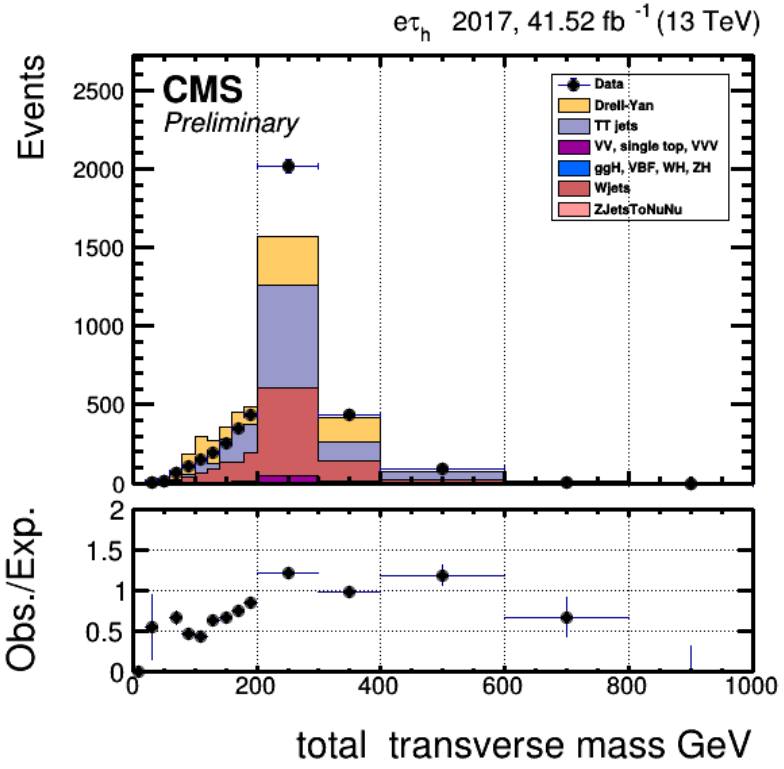
# e-tau final state, Wjets control region

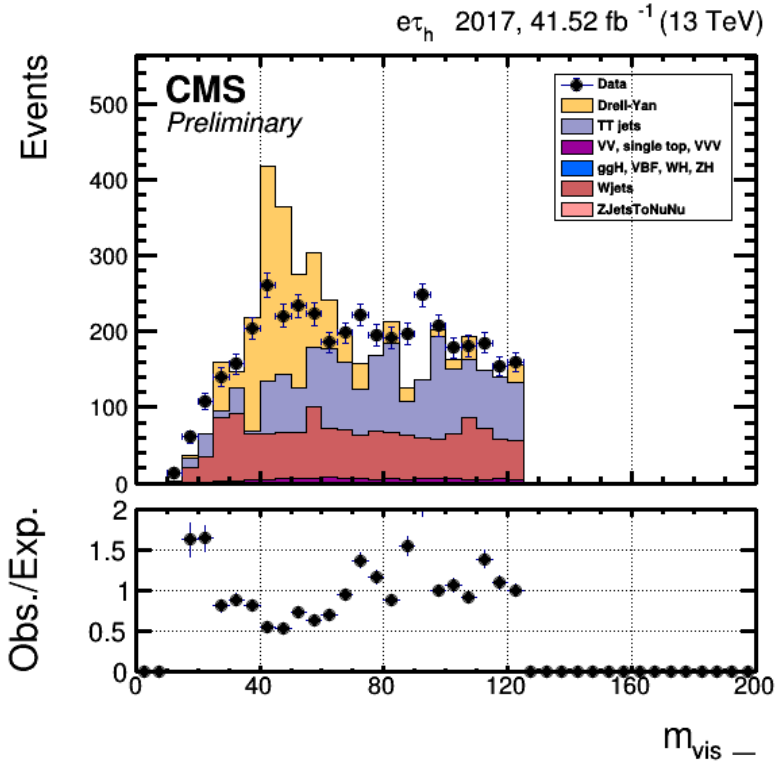


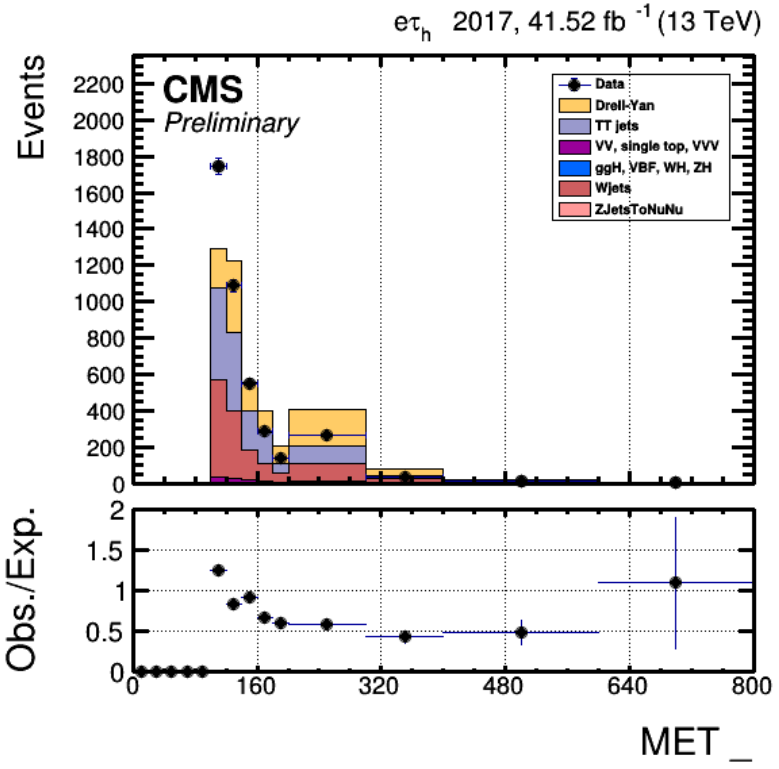




After visible mass cut

# Wjets CR with met > 106



# e-tau final state

Signal region

After b-jet veto

DY events = 75033.07
TT events = 9653.29
WJets events = 35170.64
VV events = 2154.94
ggH125 events = 182.28
ZJetsToNuNu events = 0.0
Total bkg = 122194.22
Data events = 94821.0

Wjets control region

After b-jet veto

DY events = 207374.70
TT events = 24799.54
WJets events = 228372.55
VV events = 3714.43
ggH125 events = 134.71
ZJetsToNuNu events = 2.97
Total bkg = 464398.9
Data events = 516615.0

Wjets CR

After visible mass cut

DY events = 31976.9785156
TT events = 8902.49902344
WJets events = 27158.5625
VV events = 1013.91998291
ggH125 events = 32.1661987305
ZJetsToNuNu events = 1.37051093578
Total bkg = 69085.4967316
Data events = 72012.0

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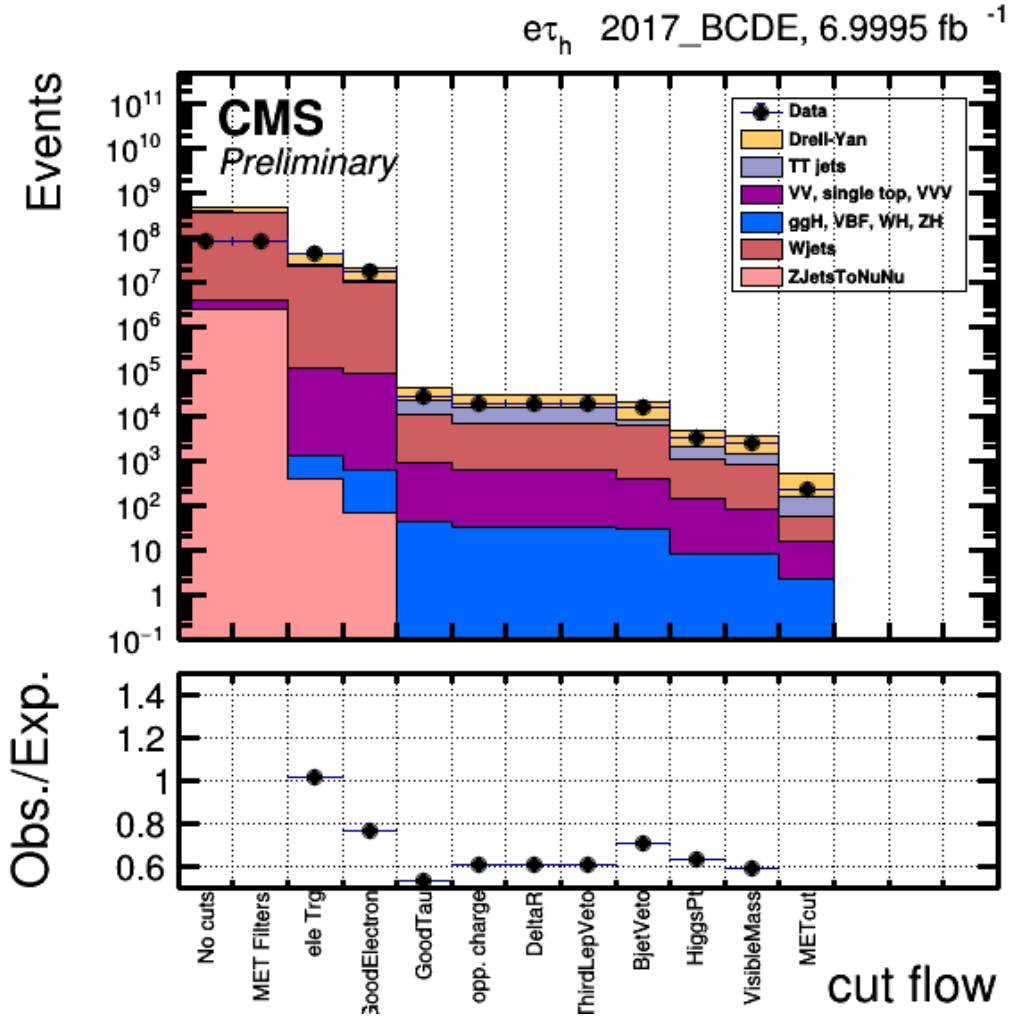
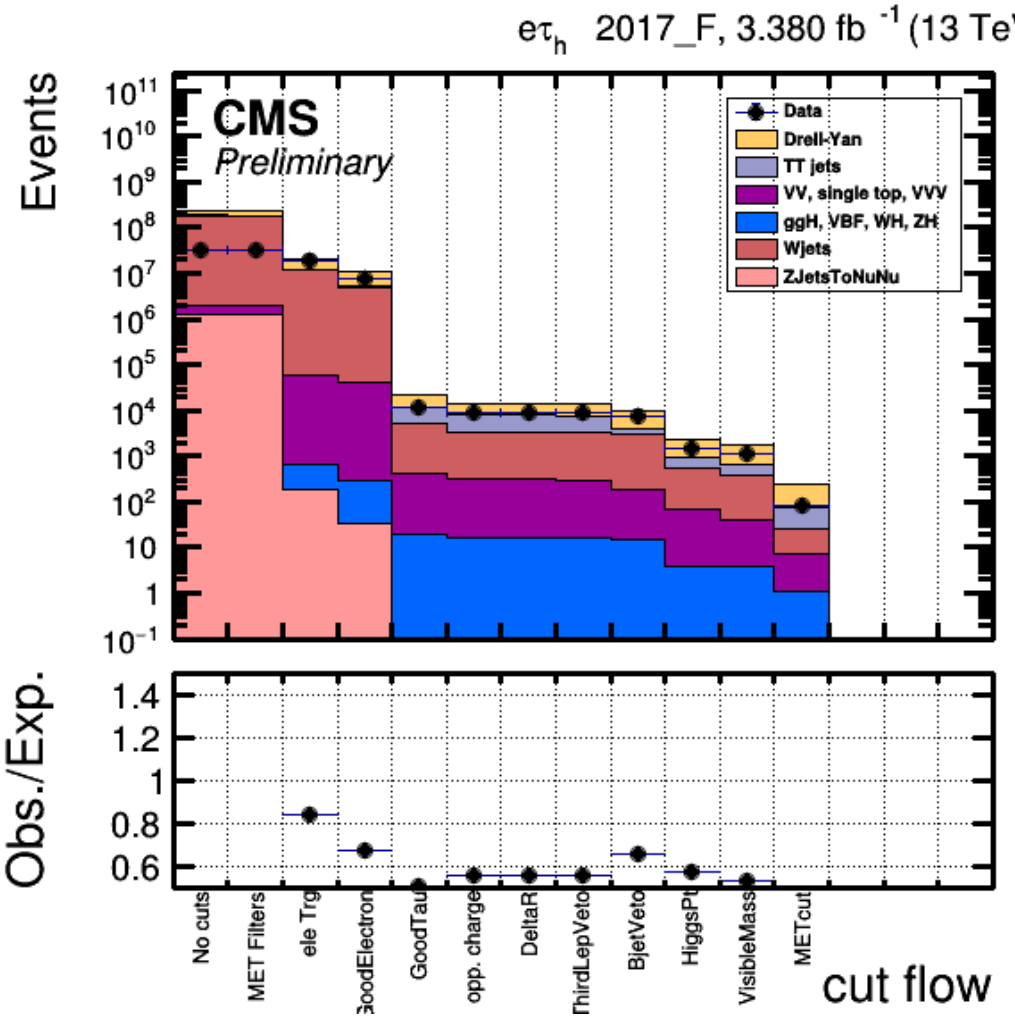
After met cut

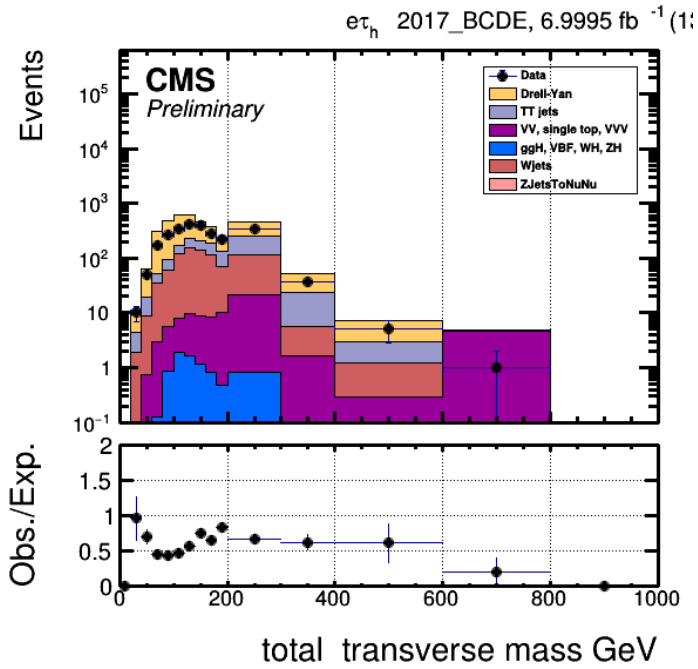
DY events = 1223.73254395
TT events = 1496.36669922
WJets events = 1349.6315918
VV events = 105.085235596
ggH125 events = 7.96253967285
ZJetsToNuNu events = 0.796658635139
Total bkg = 4183.57526886
Data events = 4126.0

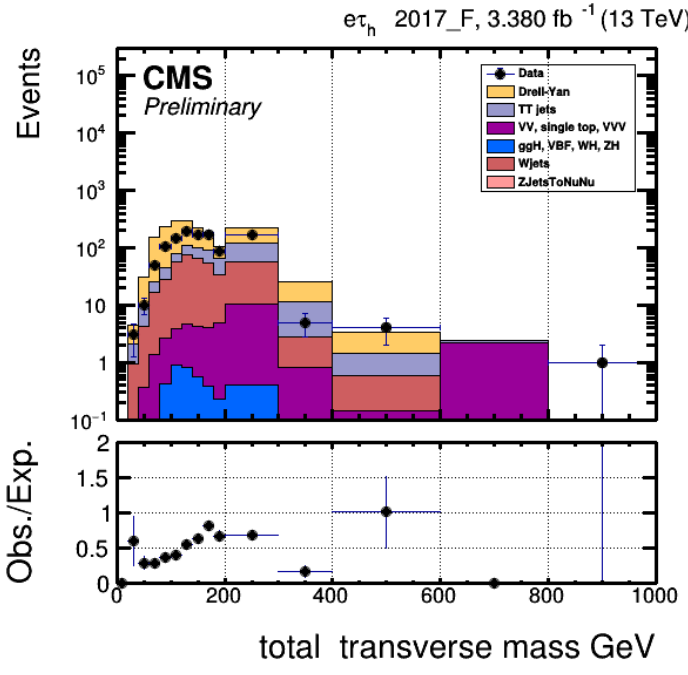
- Blinding policy
  - Selected  every 4$^{th}$ event.
  - All basic selections are same
  - Additional selections
    - Higgs pt >65
    - Visible mass < 125
    - Met > 105
- done separately for 2017BCDE data and 2017F data


eτh 2017_BCDE, 6.9995 fb -1 (13
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
No cuts
MET Filters
ele Trg
GoodElectron
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
HiggsPt
VisibleMass
METcut
cut flow


eτh 2017_F, 3.380 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
No cuts
MET Filters
ele Trg
GoodElectron
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
HiggsPt
VisibleMass
METcut
cut flow

- Plots after Higgs pt and visible mass selection


eτh 2017_BCDE, 6.9995 fb -1 (13
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
total transverse mass GeV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CMS
Preliminary
Data
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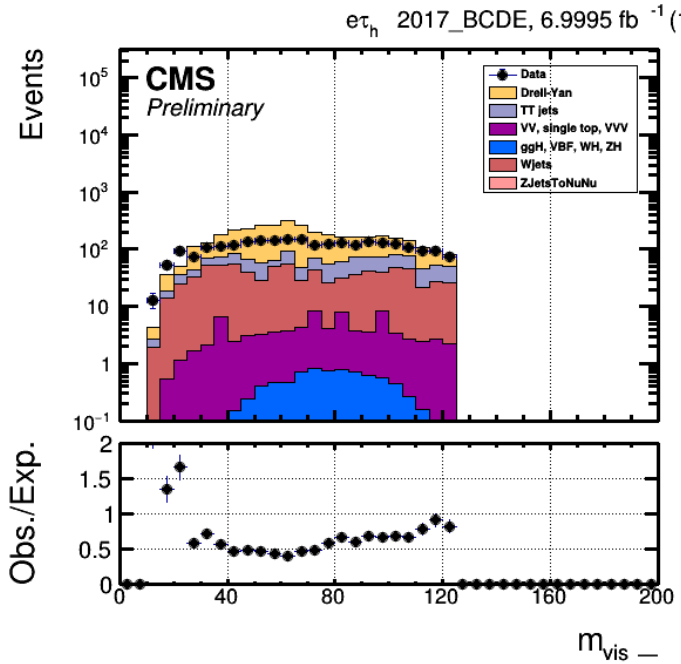
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
total transverse mass GeV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CMS
Preliminary
Data
Drell-Yan
TT jets
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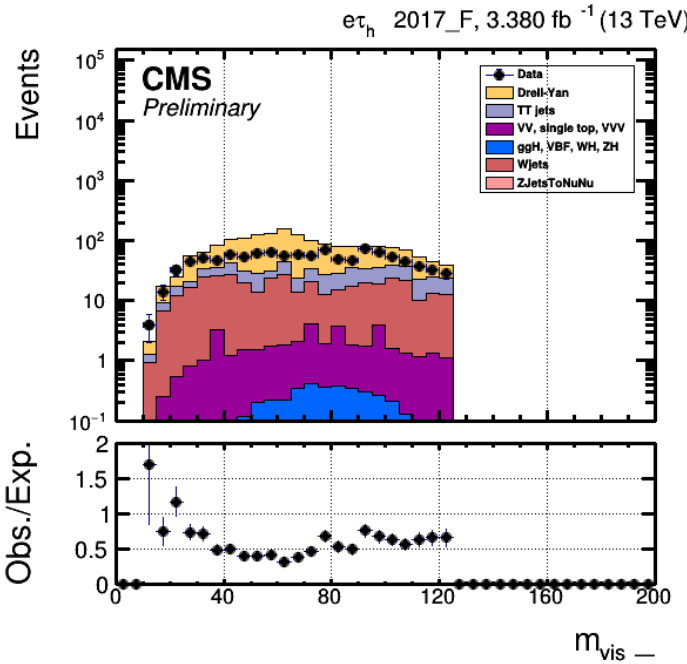
ZJetsToNuNu
Events
Obs./Exp.
mvis —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CMS
Preliminary
Data
Drell-Yan
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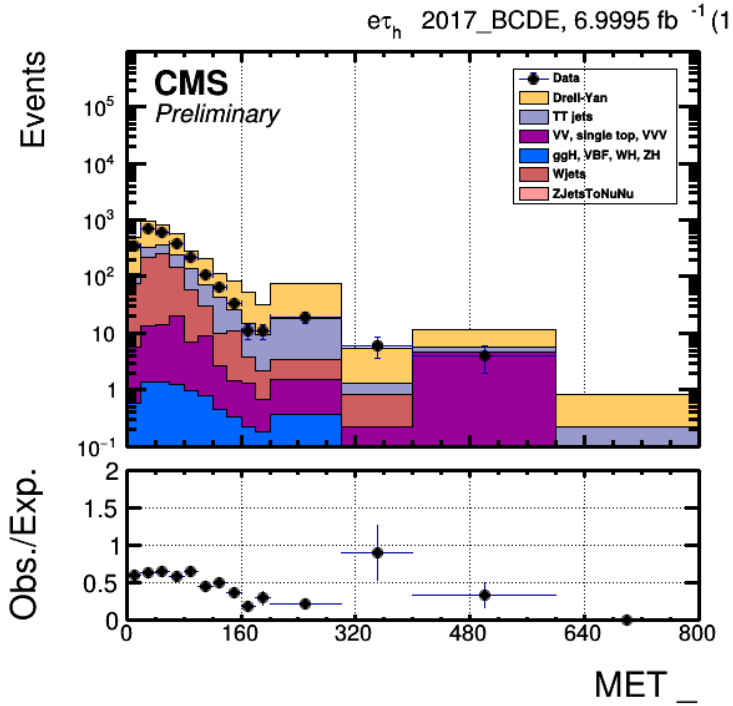
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mvis —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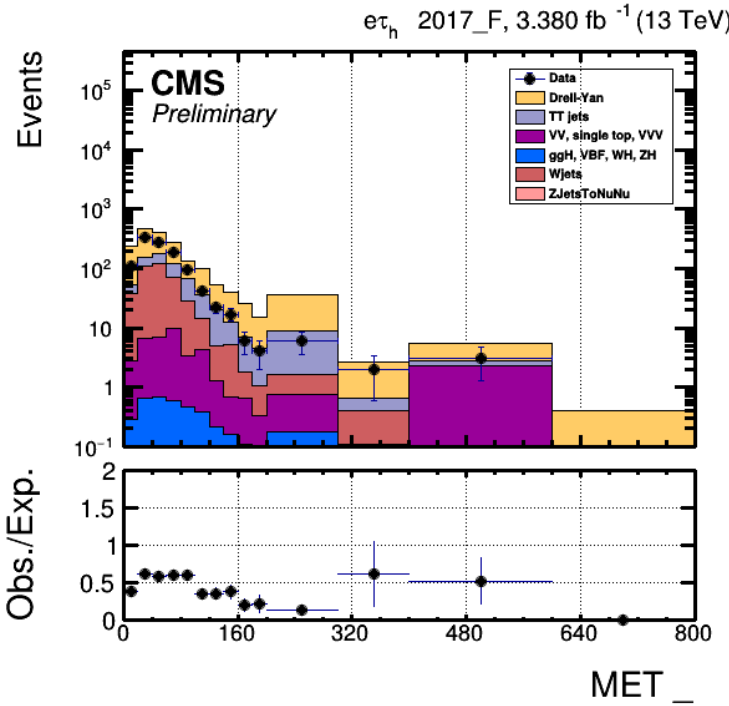
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _


eτh 2017_F, 3.380 fb -1 (13 TeV)
CMS
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TT jets
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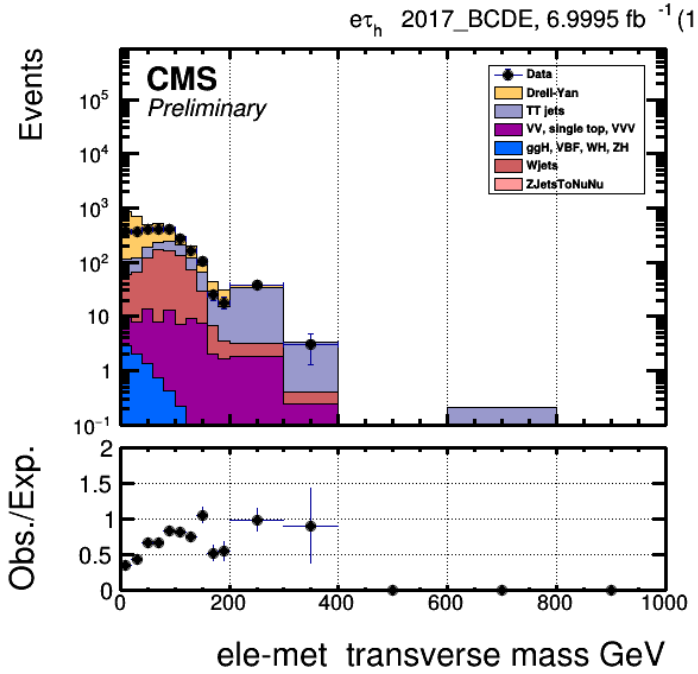
MET _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CMS
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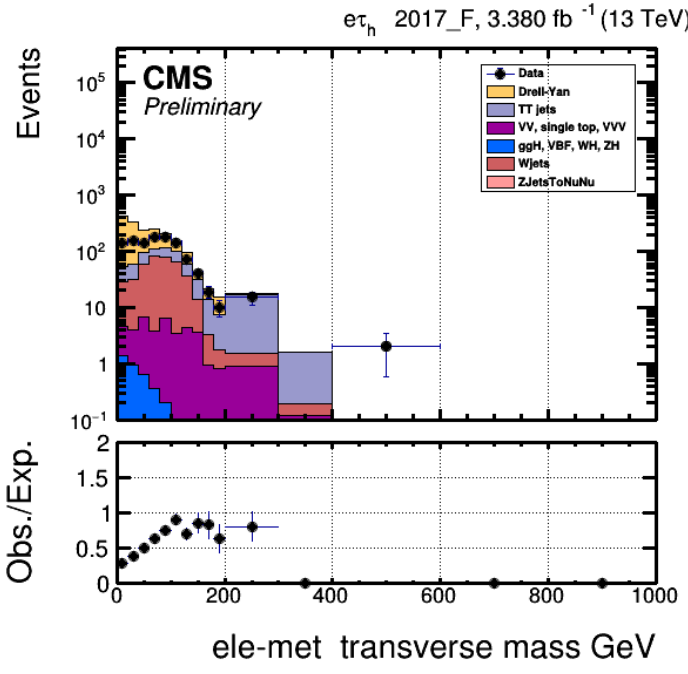
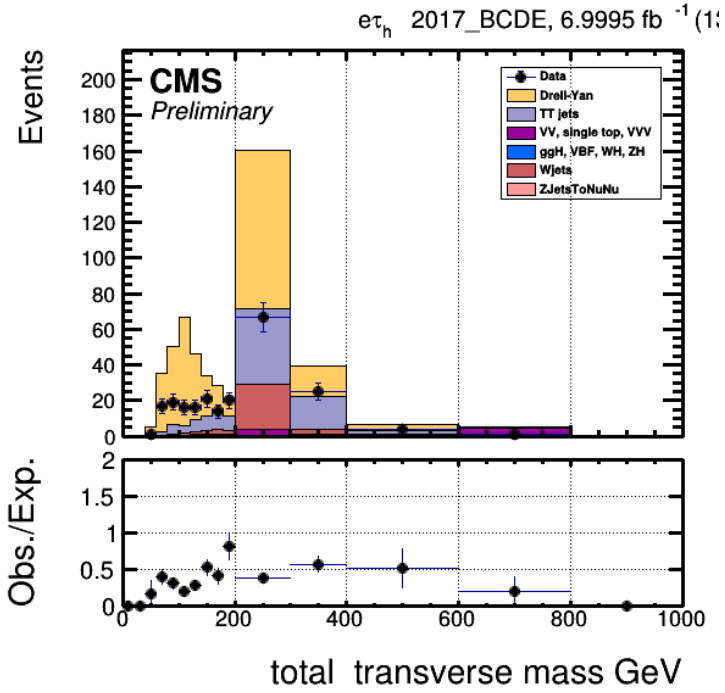
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
ele-met transverse mass GeV


eτh 2017_F, 3.380 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
ele-met transverse mass GeV

- Plots after applying met selection too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Preliminary
Data
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VV, single top, VVV
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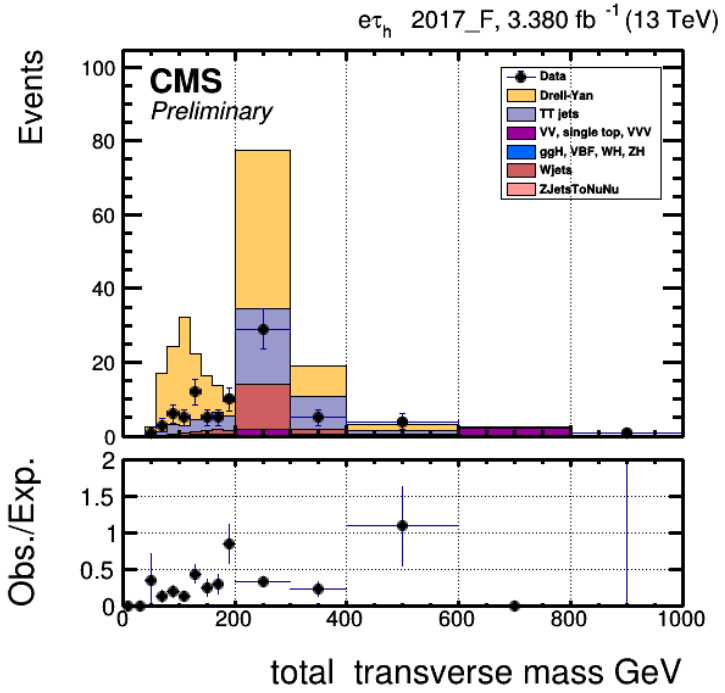
Events
Obs./Exp.
total transverse mass GeV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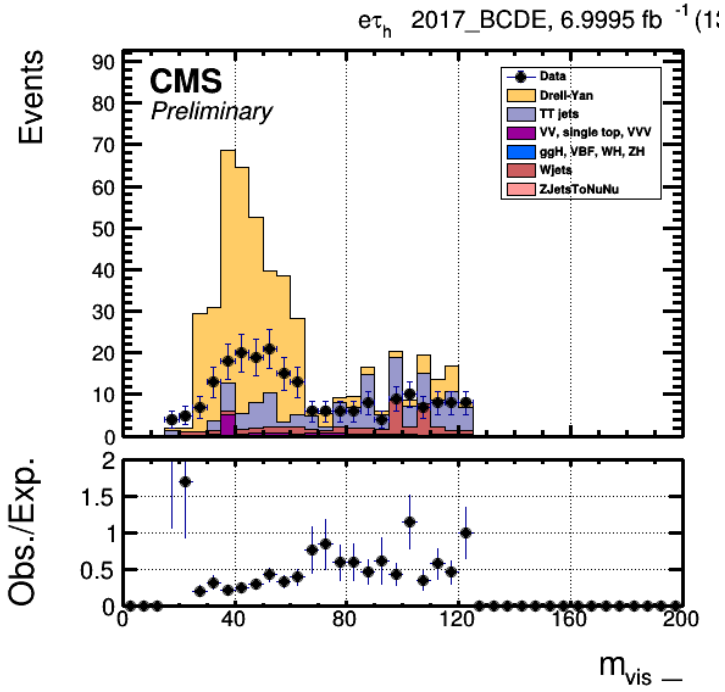
total transverse mass GeV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CMS
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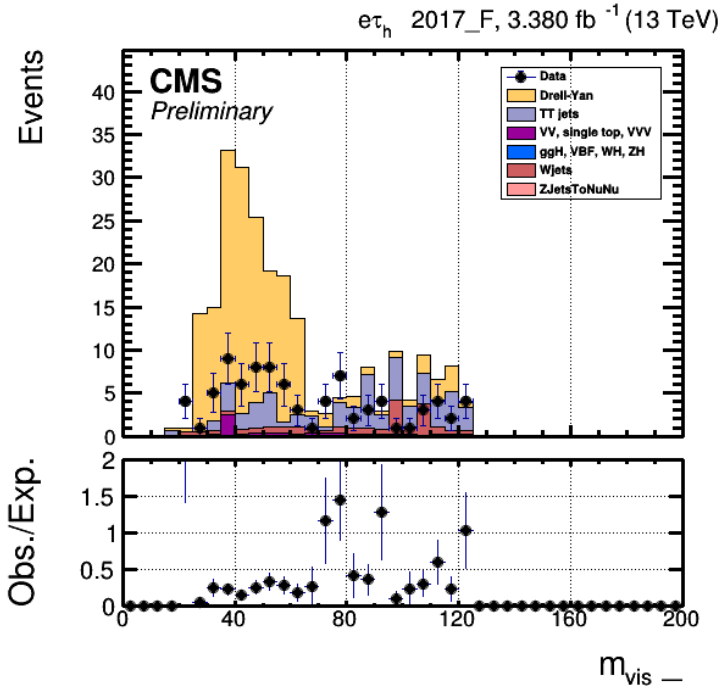
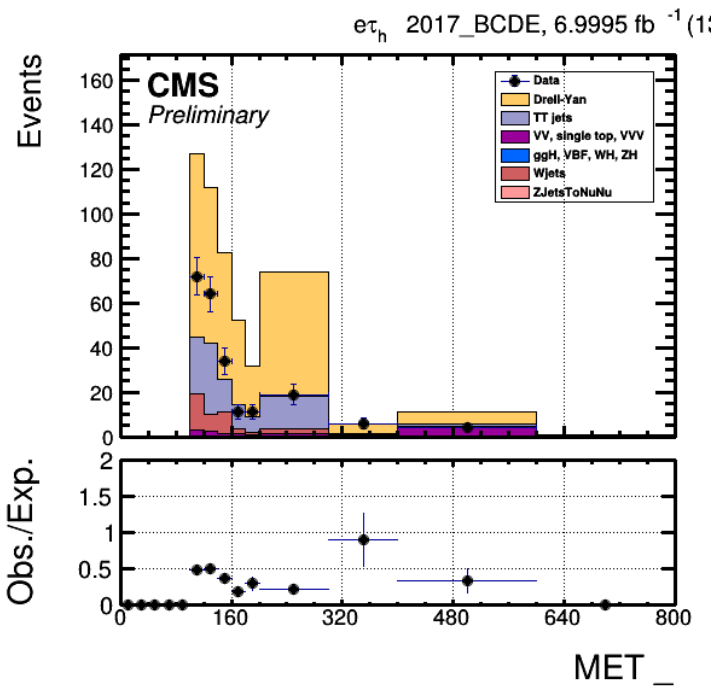
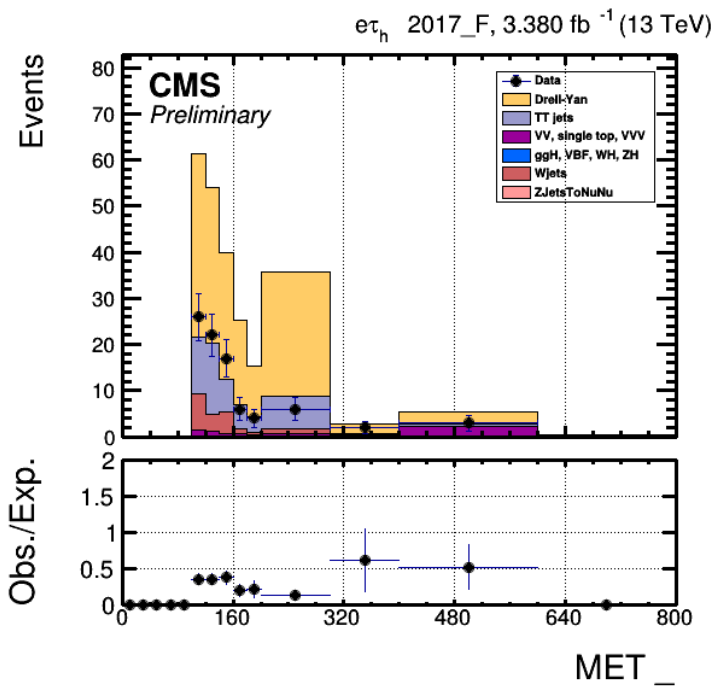
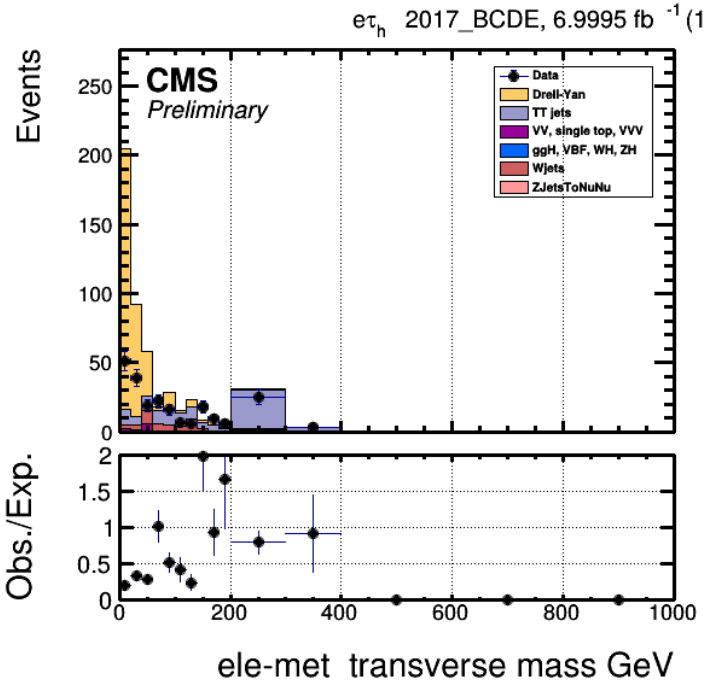
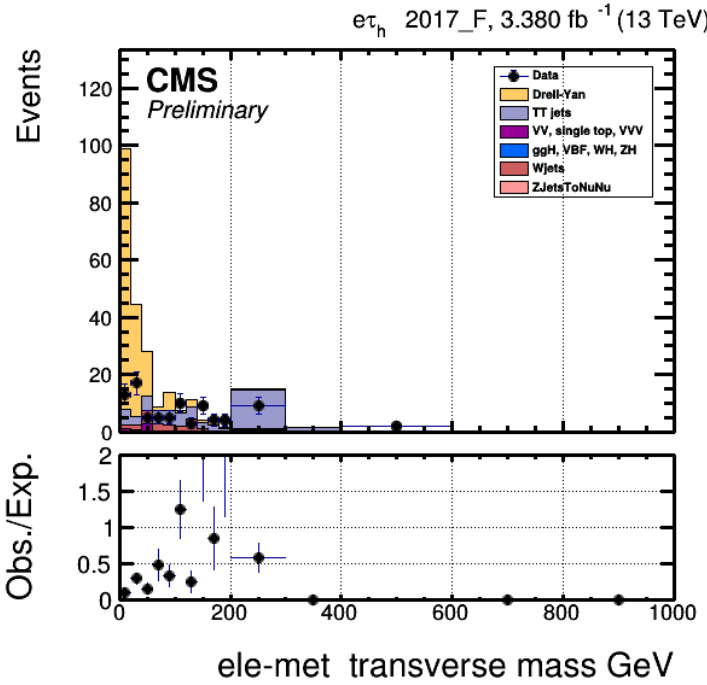
ZJetsToNuNu
Events
Obs./Exp.
mvis —


eτh 2017_F, 3.380 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mvis —


eτh 2017_BCDE, 6.9995 fb -1 (1
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _


eτh 2017_F, 3.380 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _


eτh 2017_BCDE, 6.9995 fb -1 (1
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
ele-met transverse mass GeV


eτh 2017_F, 3.380 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
ele-met transverse mass GeV



2017 BCDE blinded

After visible mass cut

DY events = 2330.08105469
TT events = 547.501647949
WJets events = 743.397827148
VV events = 74.3634719849
ggH125 events = 7.92978191376
ZJetsToNuNu events = 0.0
Total bkg = 3703.27378368
Data events = 2525.0

**********

After met cut

DY events = 334.625976562
TT events = 106.829154968
WJets events = 39.7792129517
VV events = 13.177520752
ggH125 events = 2.20200610161
ZJetsToNuNu events = 0.0
Total bkg = 496.613871336
Data events = 221.0

2017 F blinded

After visible mass cut

DY events = 1125.4263916
TT events = 264.442626953
WJets events = 359.060272217
VV events = 35.91746521
ggH125 events = 3.83007454872
ZJetsToNuNu events = 0.0
Total bkg = 1788.67683053
Data events = 1099.0

**********

After met cut

DY events = 161.623931885
TT events = 51.5983505249
WJets events = 19.213312149
VV events = 6.36472606659
ggH125 events = 1.0635663271
ZJetsToNuNu events = 0.0
Total bkg = 239.863886952
Data events = 86.0


# mutau final state

# mu-tau state basic selections

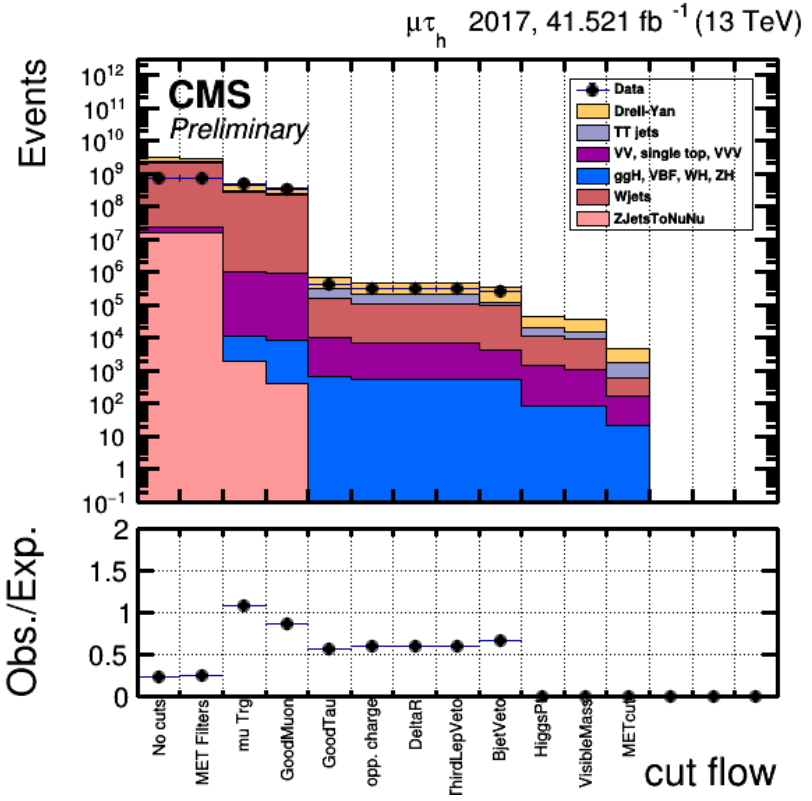
- Met filters
- Single muon trigger ->  HLT_IsoMu24_v
- Good muon
  - Pt > 30 and |eta| < 2.4  (above the HLT trigger PT threshold and where efficiency is good)
  - Relative isolation < 0.15
  - Tight muon id
  - Muon track must match primary vertex satisfying dZ < 0.2 cm and d0 < 0.45 cm
- Good tau
  - pt>  20 and |eta| < 2.3, (following Tau POG recommendations)
  - tau must match to the primary vertex, dZ< 0.2 cm
  - tauByMVA6TightMuonRejection3 and tauByVLooseElectronRejection
    -> lepton discriminators to reduce contribution from background processes where an electron or muon is misidentified as a hadronic tau
  - Tau Tight isolation (taubyTightIsolationMVArun2017v2DBoldDMwLT2017)
  - Decay modes 1 or 3
- Charge selection: opposite charge for electron and tau
- Third lepton veto
- bjetVeto

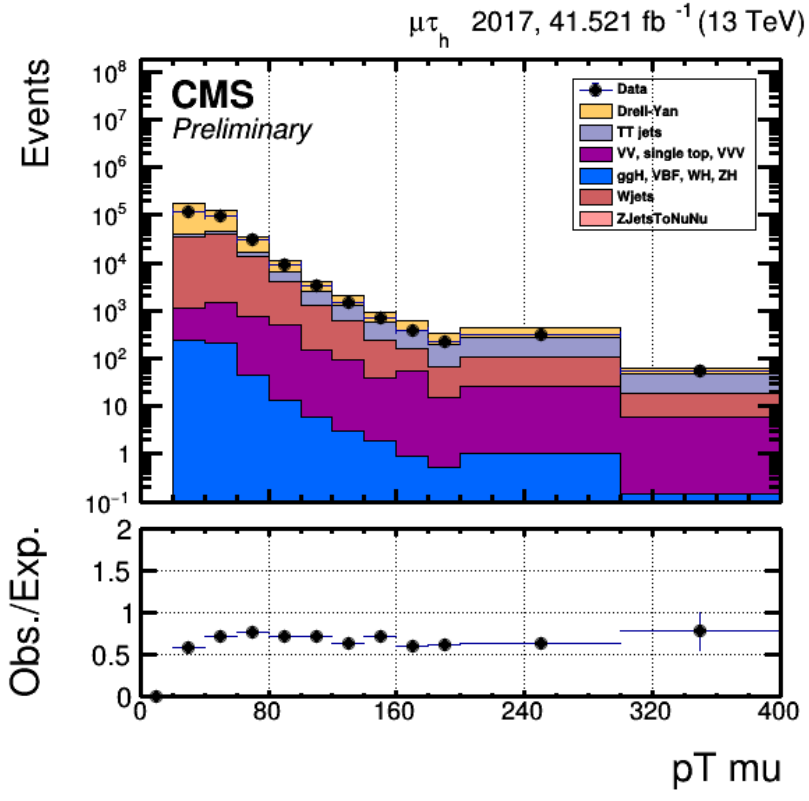
- Scale factors applied:

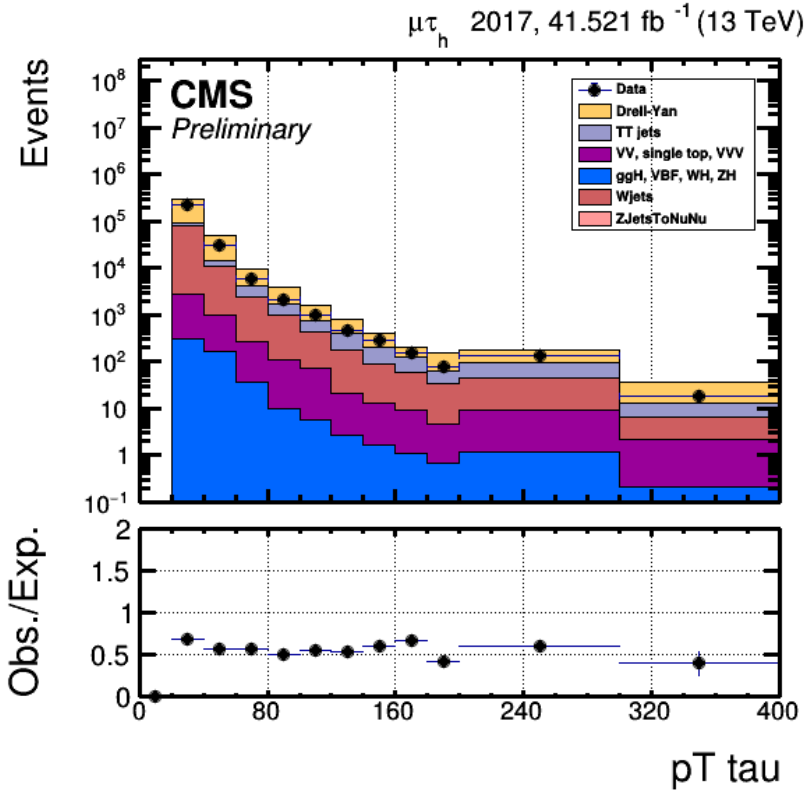
1) Tau id sf: 0.89
2) Single lepton trigger
3) Lepton ID scale factor
4) Lepton iso scale factor

https://twiki.cern.ch/twiki/bin/viewauth/CMS/MuonReferenceEffs2017

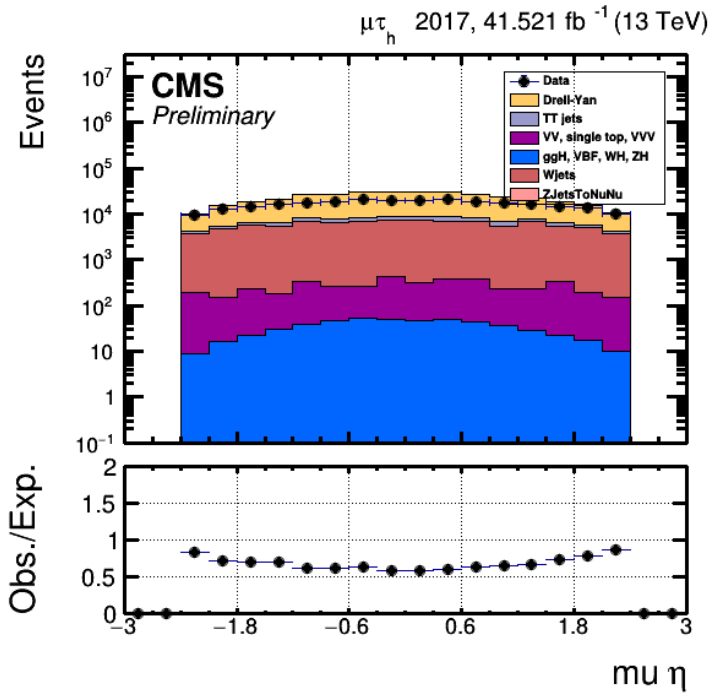
# mu-tau final state signal region

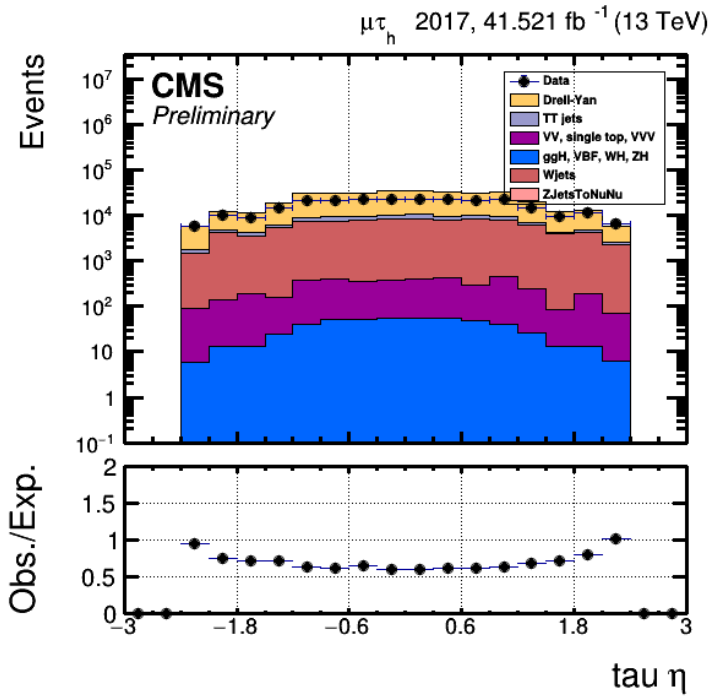


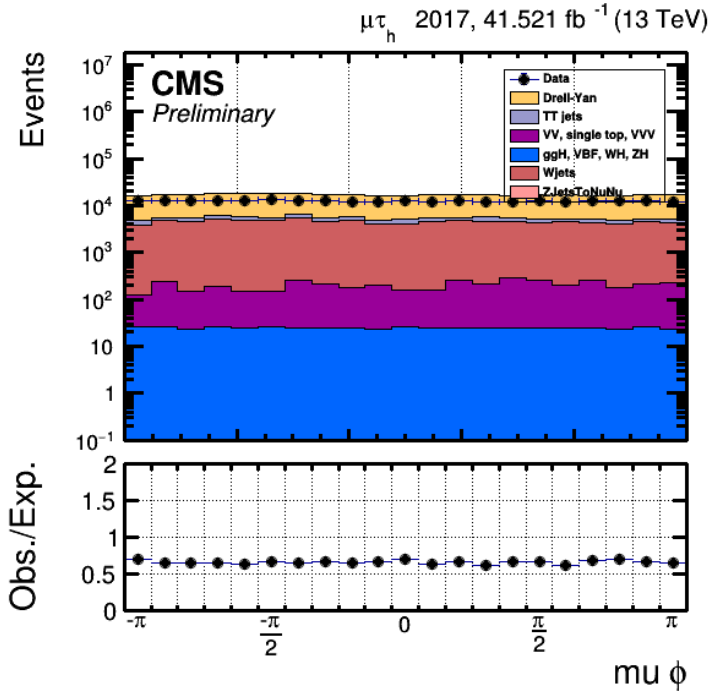



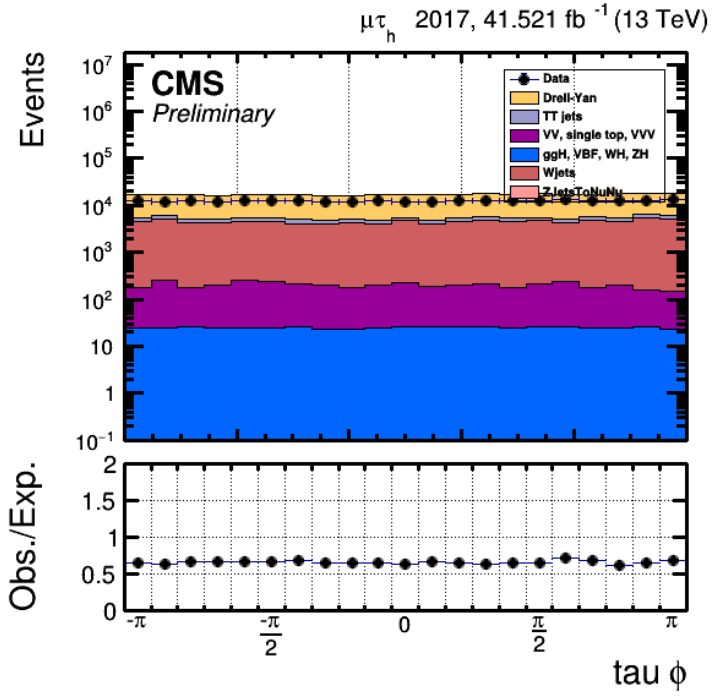

After bjet veto




After bjet veto



# mu-tau state Wjets CR selections

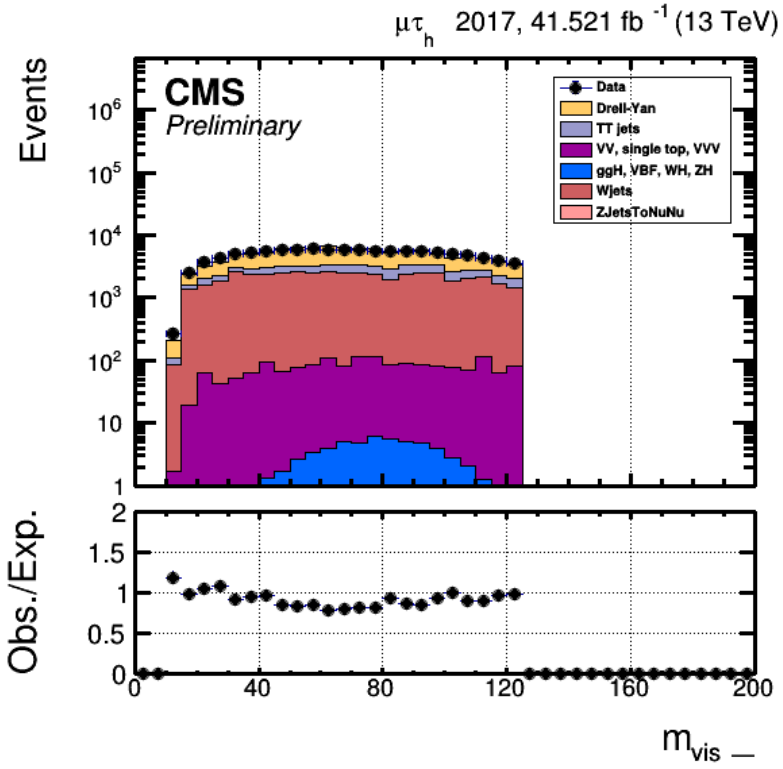
- Met filters
- Single muon trigger ->  HLT_IsoMu24_v
- Good muon
  - Pt > 30 and |eta| < 2.4  (above the HLT trigger PT threshold and where efficiency is good)
  - Relative isolation < 0.15
  - Tight muon id
  - Muon track must match primary vertex satisfying dZ < 0.2 cm and d0 < 0.45 cm
- Good tau
  - pt>  20 and |eta| < 2.3, (following Tau POG recommendations)
  - tau must match to the primary vertex, dZ< 0.2 cm
  - tauByMVA6TightMuonRejection3 and tauByVLooseElectronRejection
    -> lepton discriminators to reduce contribution from background processes where an electron or muon is misidentified as a hadronic tau
  - Tau loose isolation and not tight isolation
  - Decay modes >0
- Charge selection: opposite charge for electron and tau
- Third lepton veto
- bjetVeto

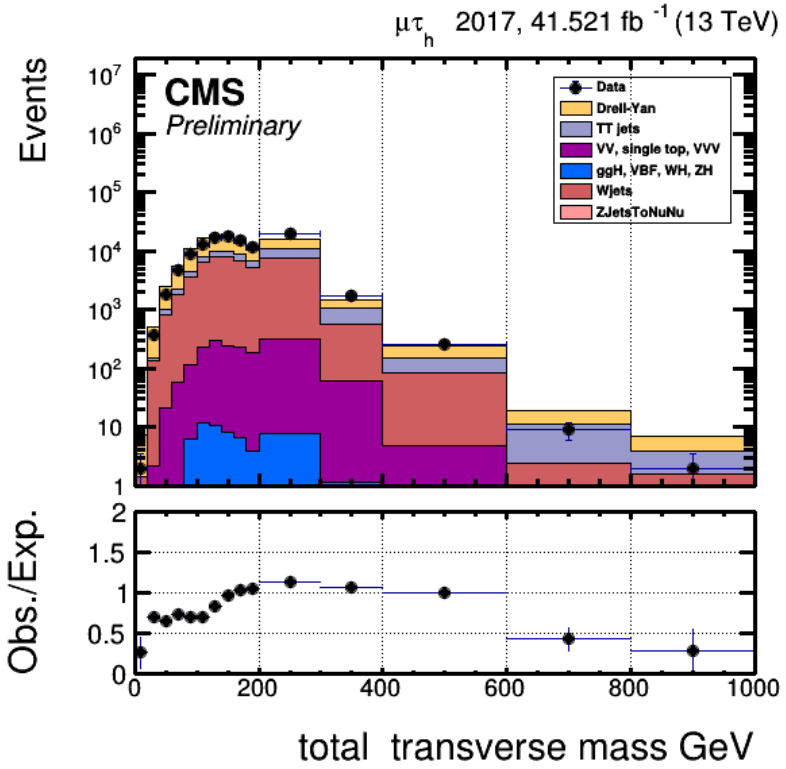
- Scale factors applied:

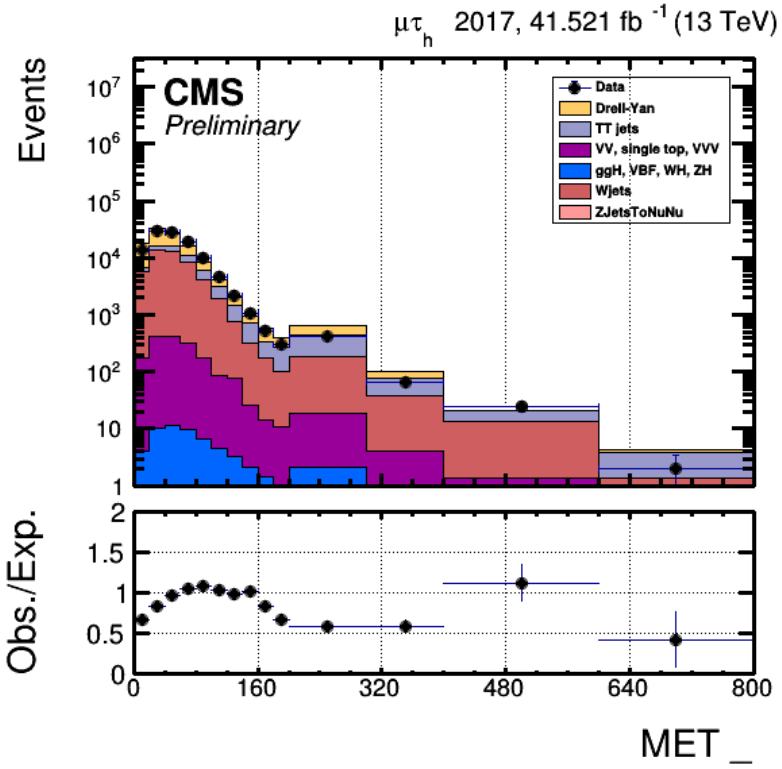
1) Tau id sf: 0.89
2) Single lepton trigger
3) Lepton ID scale factor
4) Lepton iso scale factor

https://twiki.cern.ch/twiki/bin/viewauth/CMS/MuonReferenceEffs2017

# mu-tau final state, Wjets control region

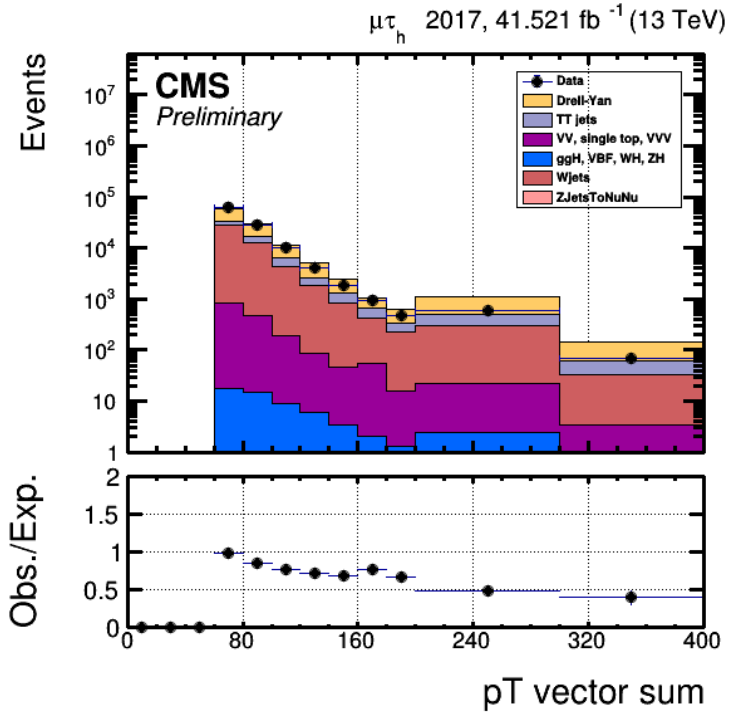


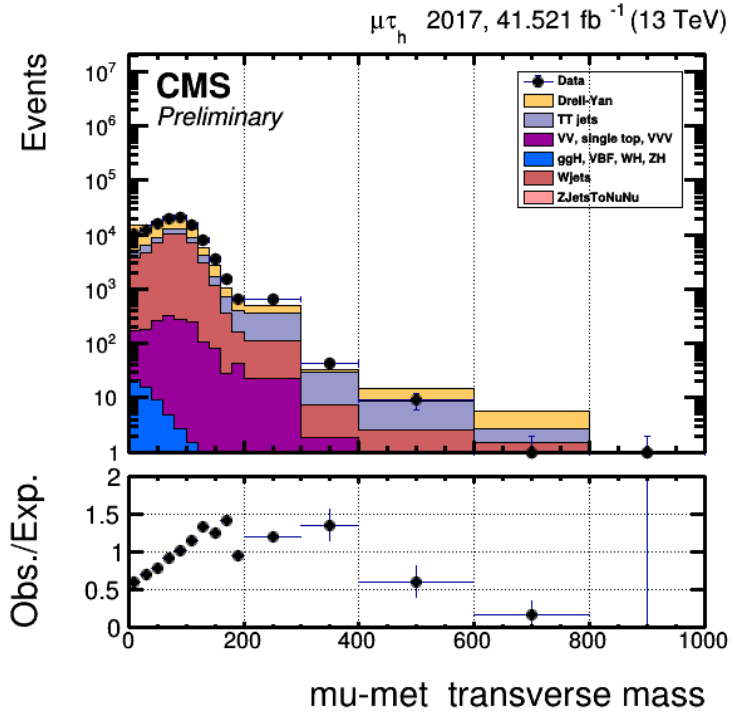




After visible mass cut

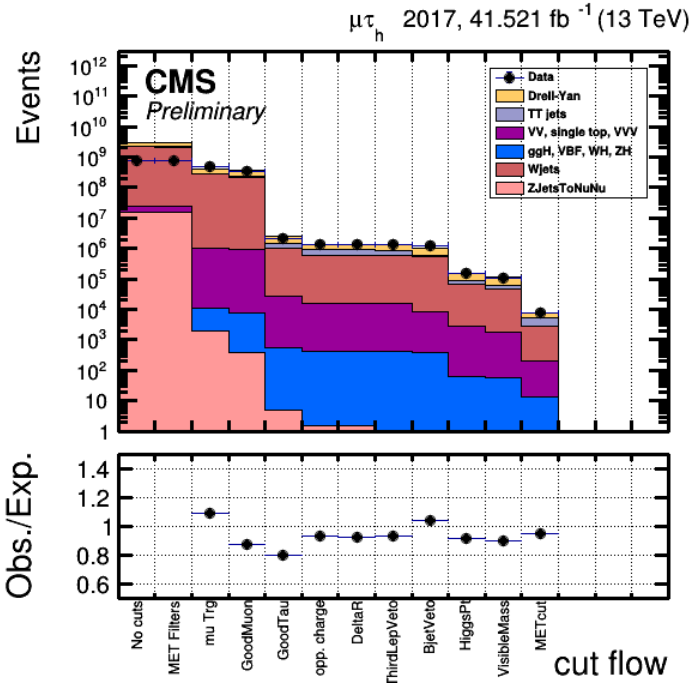
# mu-tau final state, Wjets control region

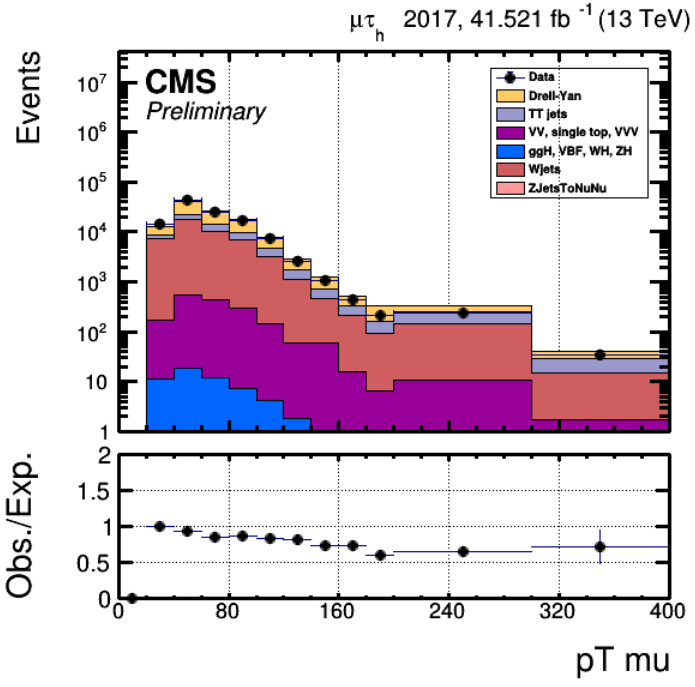


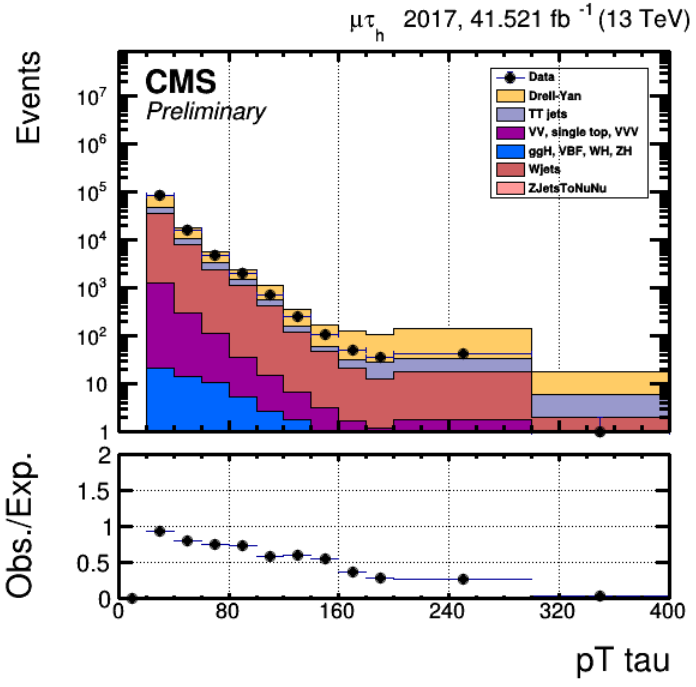




After visible mass cut

# mu-tau final state, Wjets control region




After visible mass cut

# Mu-tau final state

Signal region

After b-jet veto

DY events = 244740.015625
TT events = 18116.8671875
WJets events = 90889.09375
VV events = 3733.87548828
ggH125 events = 518.398986816
ZJetsToNuNu events = 0.0
Total bkg = 357998.251038
Data events = 260112.0

Wjets CR

After b-jet veto

DY events = 452228.28125
TT events = 45709.5976562
WJets events = 548321.75
VV events = 8155.96582031
ggH125 events = 372.576721191
ZJetsToNuNu events = 0.310649216175
Total bkg = 1054788.4821
Data events = 1195328.0

**********

Wjets CR

After visible mass cut

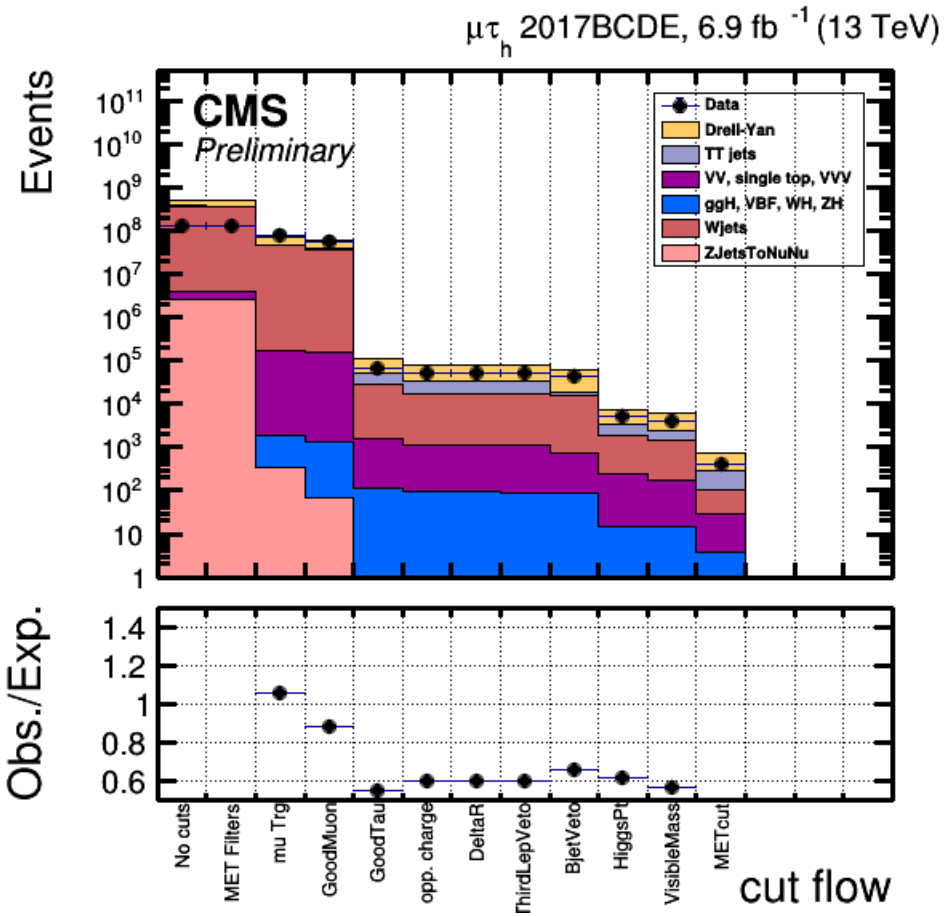
DY events = 48130.8320312
TT events = 14502.5097656
WJets events = 46818.3984375
VV events = 1690.72021484
ggH125 events = 56.7316894531
ZJetsToNuNu events = 0.0
Total bkg = 111199.192139
Data events = 110081.0

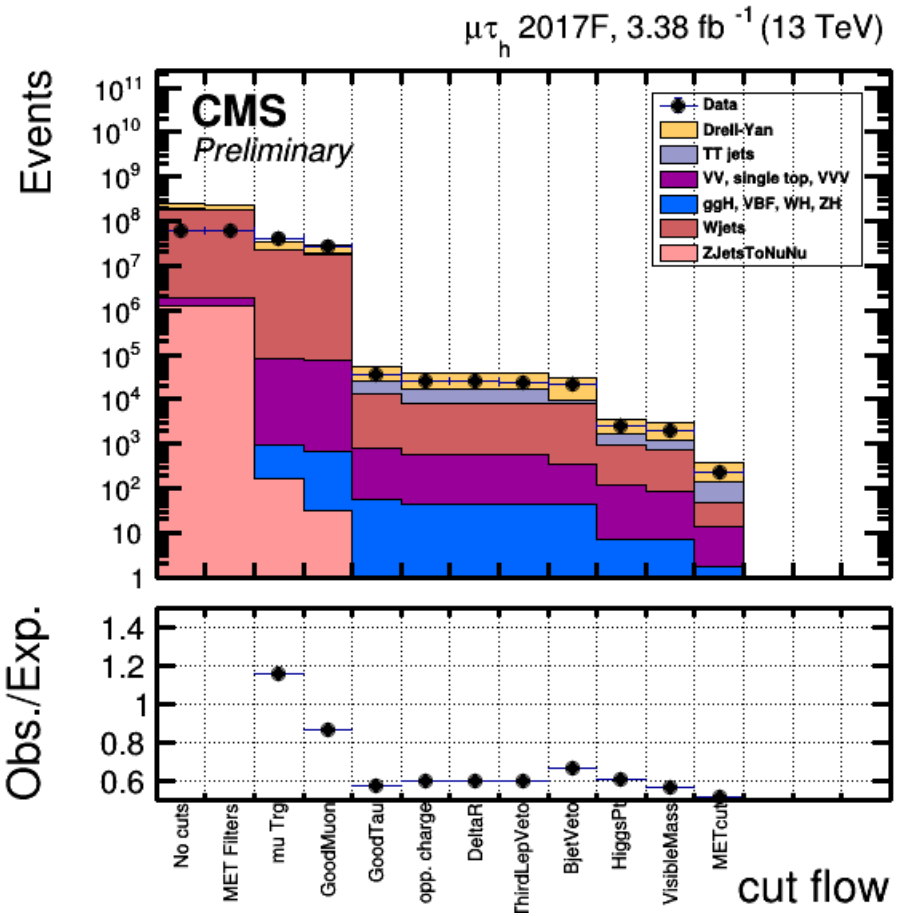
**********

After met cut

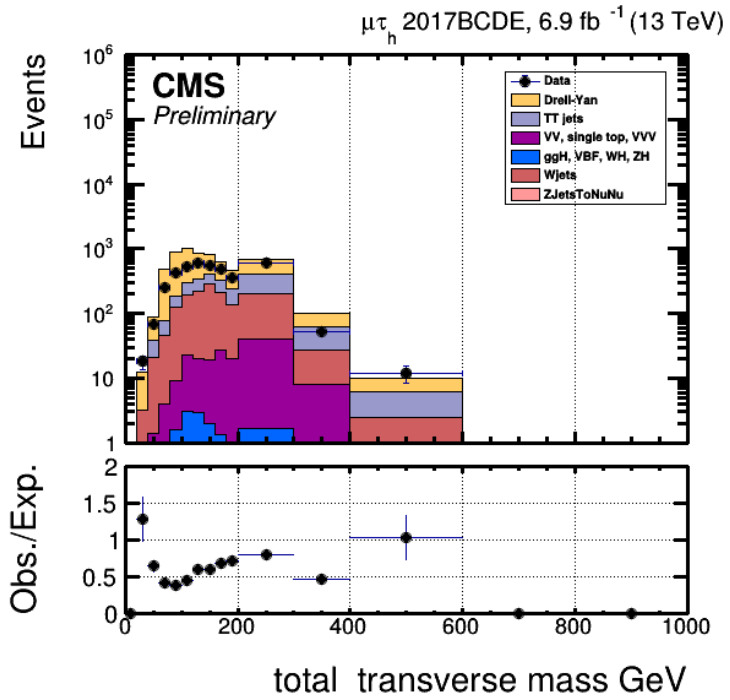
DY events = 2122.83178711
TT events = 2567.02880859
WJets events = 2579.85375977
VV events = 196.467727661
ggH125 events = 13.2802667618
ZJetsToNuNu events = 0.0
Total bkg = 7479.46234989
Data events = 7639.0

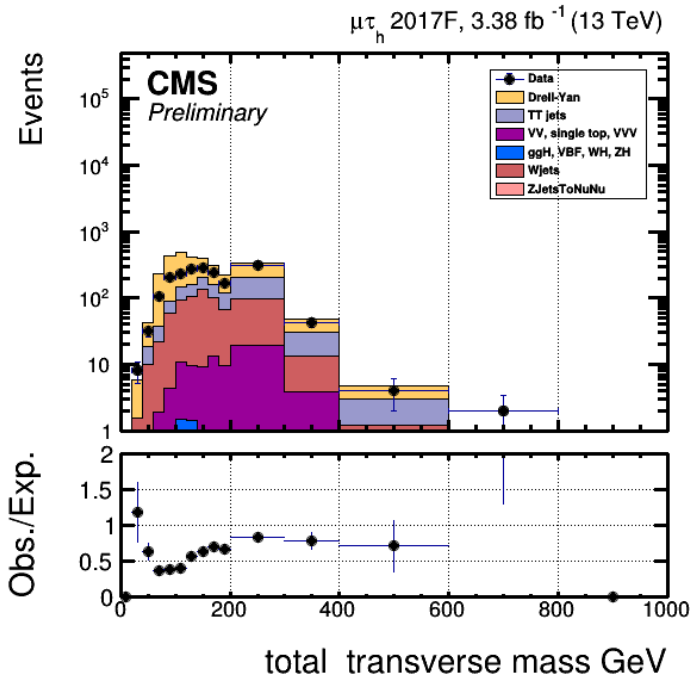
- Blinding policy
  - Selected  every 4$^{th}$ event.
  - All basic selections are same
  - Additional selections
    - Higgs pt >65
    - Visible mass < 125
    - Met > 105
- done separately for 2017BCDE data and 2017F data

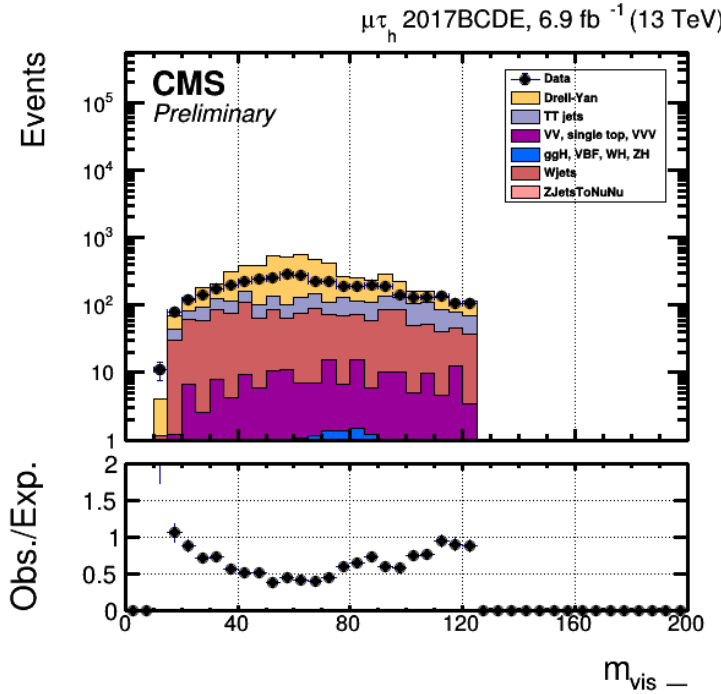

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
DrellYan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
No cuts
MET Filters
mu Trg
GoodMuon
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
HiggsPt
VisibleMass
METcut
cut flow

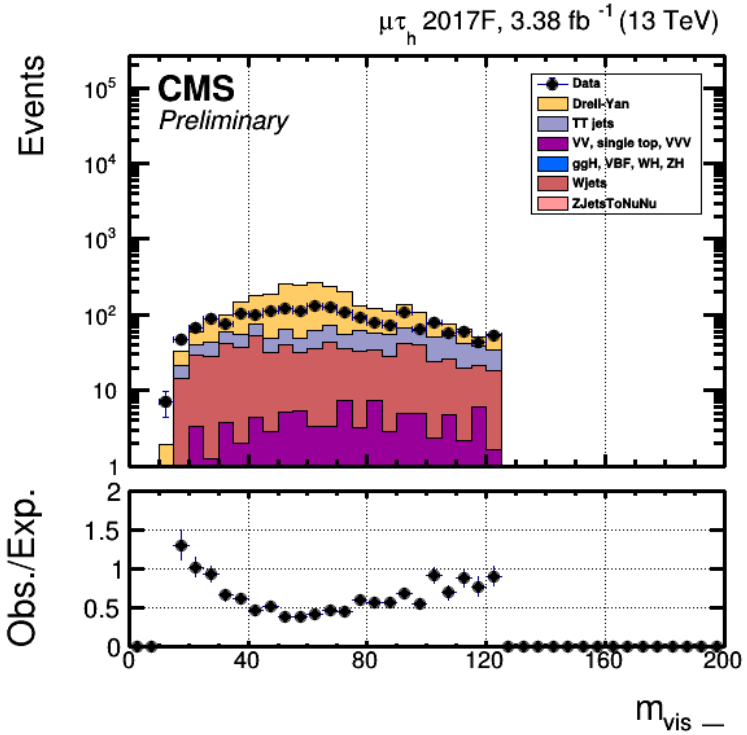

μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
DrellYan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
No cuts
MET Filters
mu Trg
GoodMuon
GoodTau
opp. charge
DeltaR
ThirdLepVeto
BjetVeto
HiggsPt
VisibleMass
METcut
cut flow

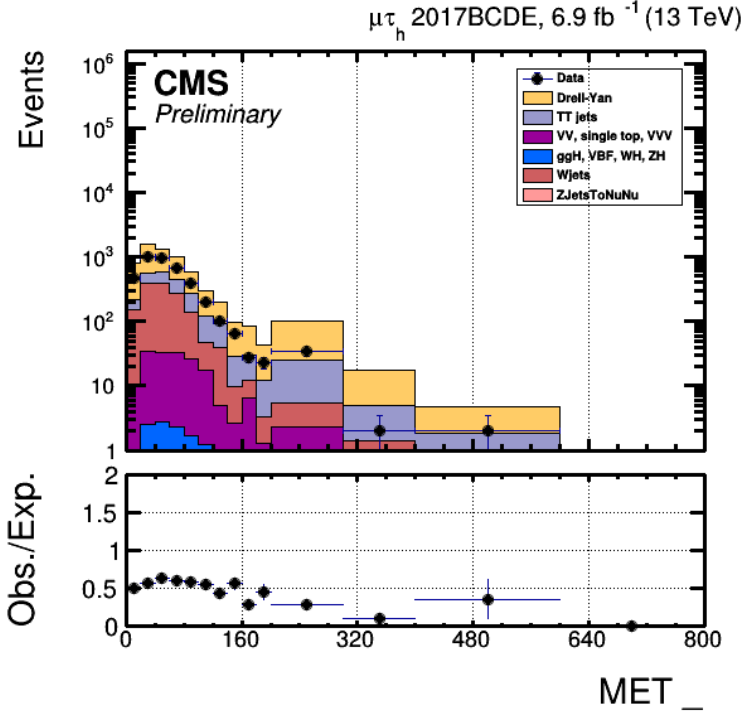
- Plots after Higgs pt and visible mass selection

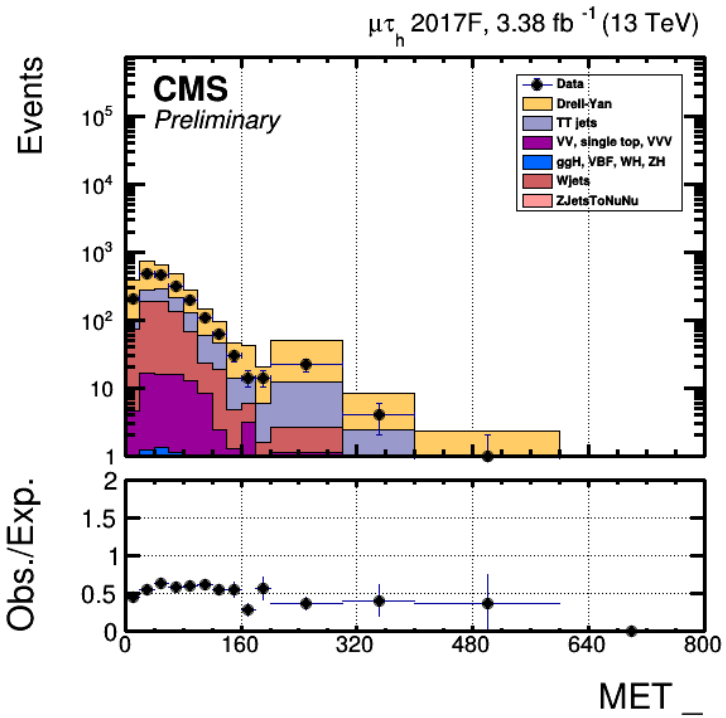

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
total transverse mass GeV

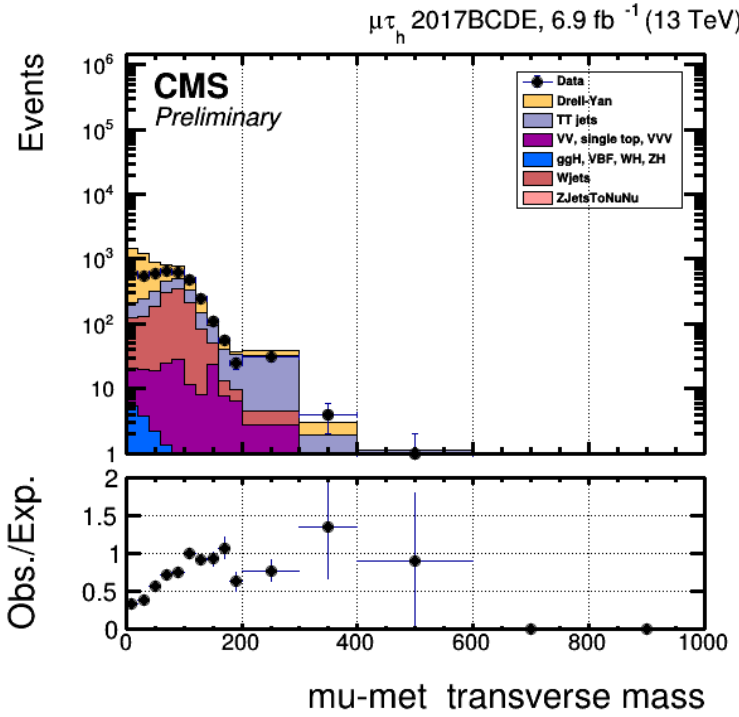

μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
total transverse mass GeV

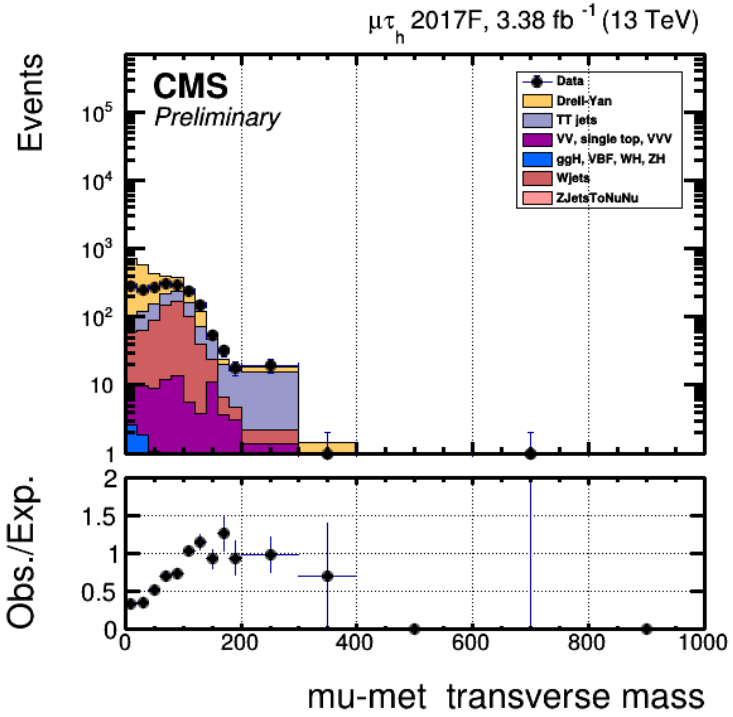

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mvis —


μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mvis —

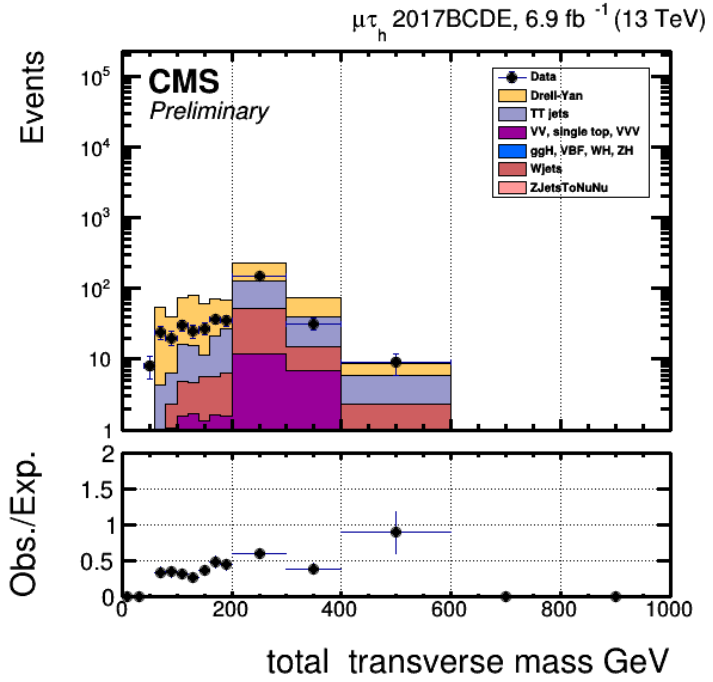

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _

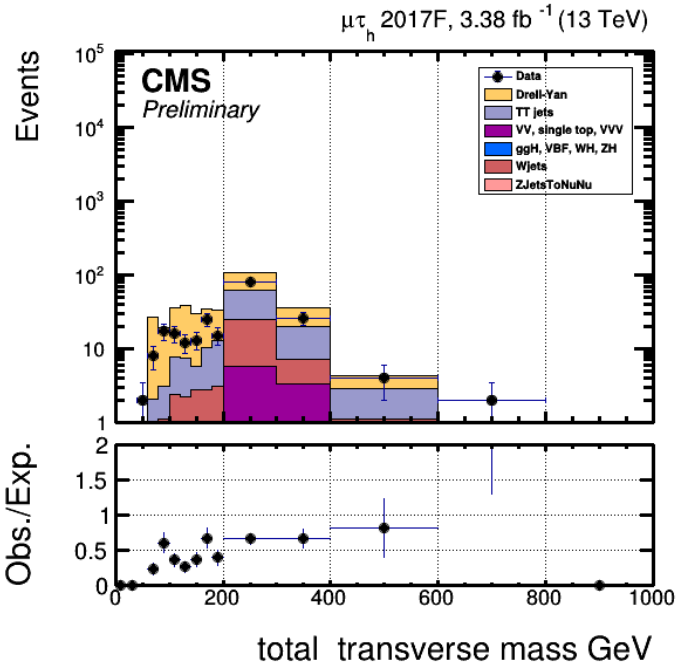

μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _

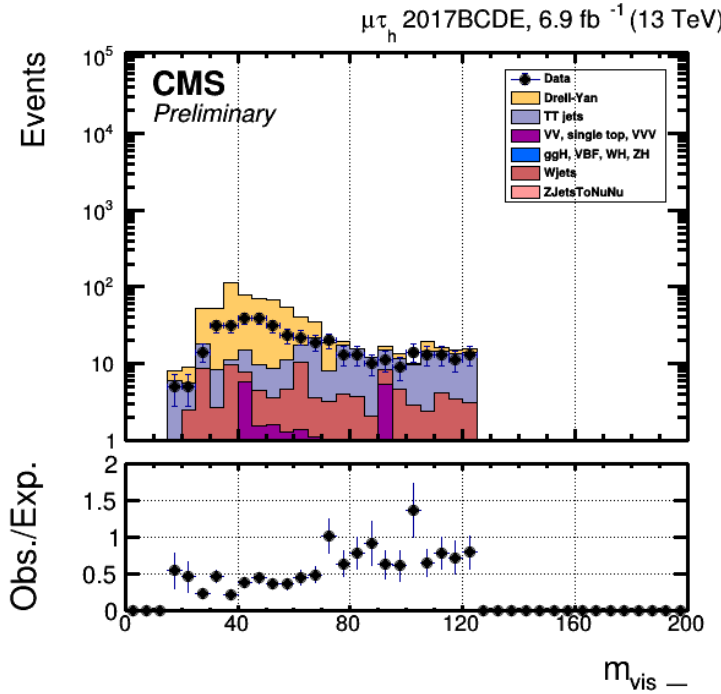

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mu-met transverse mass

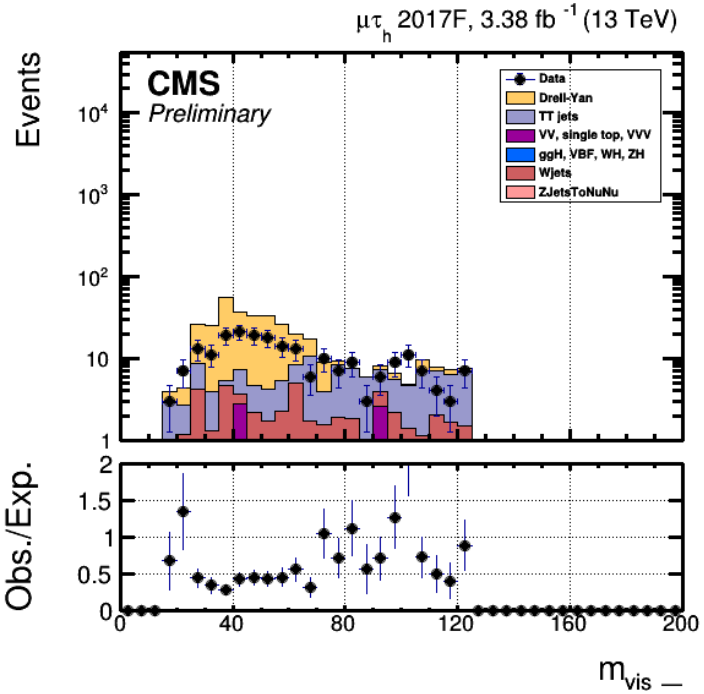

μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mu-met transverse mass

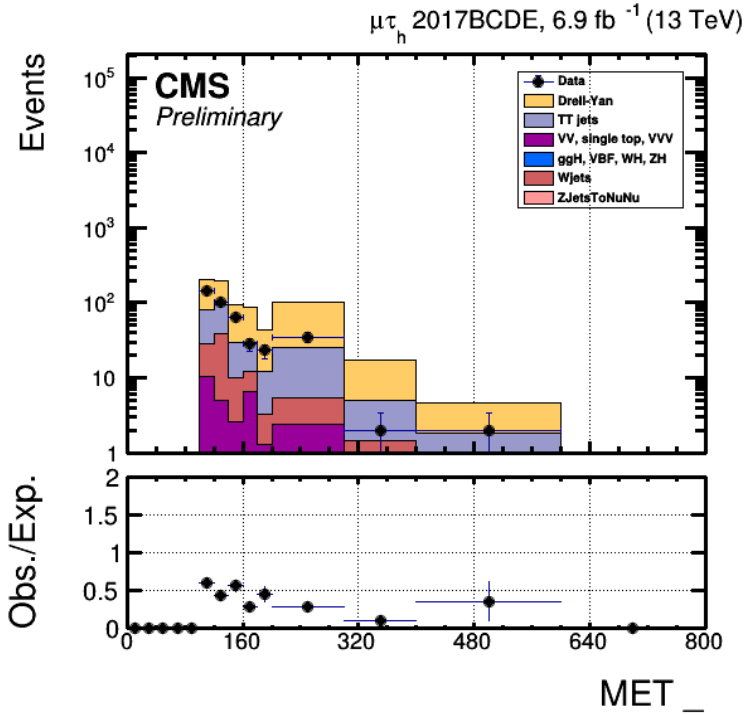
- Plots after applying met selection too

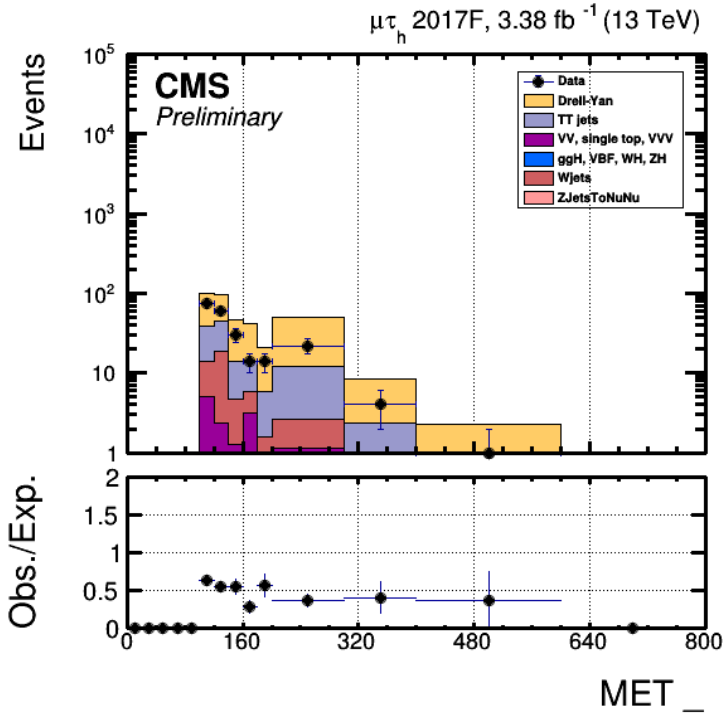

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
total transverse mass GeV

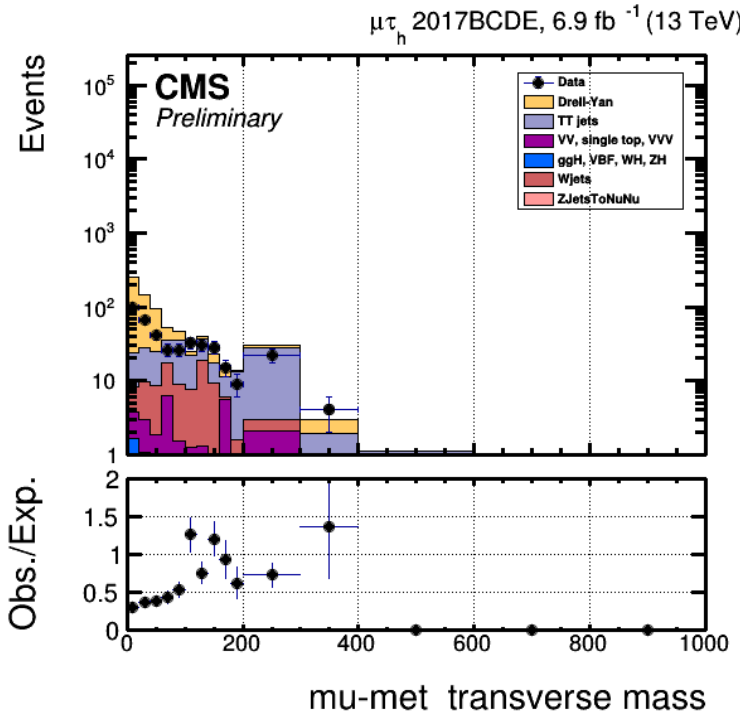

μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
total transverse mass GeV

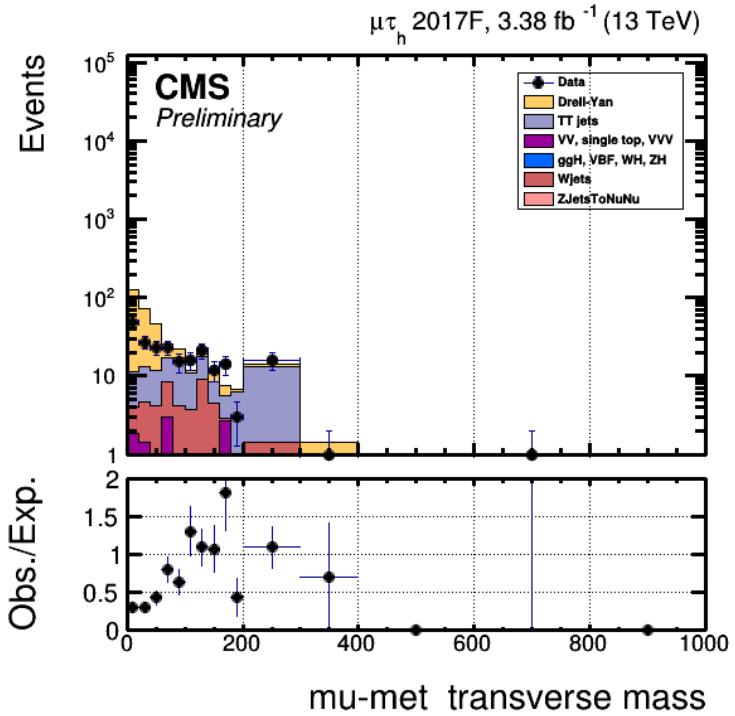

μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mvis


μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mvis


μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _


μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
MET _


μτh 2017BCDE, 6.9 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mu-met transverse mass


μτh 2017F, 3.38 fb -1 (13 TeV)
CMS
Preliminary
Data
Drell-Yan
TT jets
VV, single top, VVV
ggH, VBF, WH, ZH
Wjets
ZJetsToNuNu
Events
Obs./Exp.
mu-met transverse mass

2017 BCDE blinded

After visible mass cut

DY events = 3661.52758789
TT events = 942.064331055
WJets events = 1298.32995605
VV events = 158.505493164
ggH125 events = 14.1892490387
ZJetsToNuNu events = 0.0
Total bkg = 6074.6166172
Data events = 3963.0

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After met cut

DY events = 474.380554199
TT events = 178.203384399
WJets events = 71.5000686646
VV events = 25.1186542511
ggH125 events = 3.62206315994
ZJetsToNuNu events = 0.0
Total bkg = 752.824724674
Data events = 399.0

2017 F blinded

After visible mass cut

DY events = 1768.51318359
TT events = 455.015930176
WJets events = 627.091918945
VV events = 76.5579605103
ggH125 events = 6.85339021683
ZJetsToNuNu events = 0.0
Total bkg = 2934.03238344
Data events = 1903.0

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After met cut

DY events = 229.125228882
TT events = 86.0720214844
WJets events = 34.534450531
VV events = 12.1322803497
ggH125 events = 1.74945211411
ZJetsToNuNu events = 0.0
Total bkg = 363.613433361
Data events = 220.0