mono Higgs to bb(bar) analysis

Updates

Shivani Lomte

UW Madison

Jan 6, 2023

Object Selections

AK8jet:
PFJets with Puppi and JECs applied
p_T >200GeV, $|\eta|$ <2.5, tightId,
btagDDBvLV2>0.86 (not applied for dilepCR), 70< $M_{softdrop}$ <150GeV,
ΔR (AK8jet, obj)>0.8, where obj=loose electron/muon.
AK4jet:
PFJets CHS with JECs applied
p_T >30GeV, $|\eta|$ <2.5, tightId,
ΔR (AK4jet, obj)>0.4, where obj=loose electron/muon.
btagDeepB>0.1241 (loose), btagDeepB>0.4184 (tight) for era=2018
(*btag not applied for dilepCR to gain statistics, see slide ?)
In boosted category, ΔR (AK8j[0], ak4j)>0.8
Hadronic Recoil (U):
$\vec{U} = \vec{p_T^{miss}} + \vec{p_T^{l,ll}}$
where $p_T^{l,ll}$ is single or double lepton p_T.

Object Selections

Muon:
$|\eta|$ <2.4, isPFcand,
loose: p_T >10, pfRelIso04_all<0.25, looseId
tight: p_T >30, pfRelIso04_all<0.15, tightId
Electron:
$|\eta|$ <2.5, EtaGap
loose: p_T >10, looseId
tight: p_T >40, tightId
Tau (veto):
p_T >20, $|\eta|$ <2.3,
idDecayModeOldDMs, idAntiEleDeadECal≥2, idAntiMu≥1,
idDeepTau2017v2p1VSe≥8, idDeepTau2017v2p1VSmu≥2,
idDeepTau2017v2p1VSjet≥8
Photon (veto):
p_T >20, $|\eta|$ <2.5, looseId
ΔR (photon, obj)>0.4, where obj=loose electron/muon and select AK4jet.

Datasets: MC

$t\bar{t}$, $Z(\nu\bar{\nu})$+Jets, $W(l\nu)$+Jets, DY+Jets, VV, QCD
RunIISummer20UL18NanoAODv9

Dataset name	Cross section (pb)
TTToSemiLeptonic_TuneCP5_13TeV-powheg-pythia8	365.34
TTToHadronic_TuneCP5_13TeV-powheg-pythia8	377.96
TTTo2L2Nu_TuneCP5_13TeV-powheg-pythia8	88.29
Z1JetsToNuNu_M-50_LHEFilterPtZ-50To150_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	598.9
Z1JetsToNuNu_M-50_LHEFilterPtZ-150To250_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	18.04
Z1JetsToNuNu_M-50_LHEFilterPtZ-250To400_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	2.051
Z1JetsToNuNu_M-50_LHEFilterPtZ-490ToInf_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	0.2251
Z2JetsToNuNu_M-50_LHEFilterPtZ-50To150_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	326.3
Z2JetsToNuNu_M-50_LHEFilterPtZ-150To250_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	29.6
Z2JetsToNuNu_M-50_LHEFilterPtZ-250To400_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	5.174
Z2JetsToNuNu_M-50_LHEFilterPtZ-400ToInf_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	0.8472
WJetsToLNu_Pt-50To100_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	3570.0
WJetsToLNu_Pt-100To250_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	779.1
WJetsToLNu_Pt-250To400_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	27.98
WJetsToLNu_Pt-400To600_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	3.604
WJetsToLNu_Pt-600ToInf_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia8	0.5545

Datasets: MC

Dataset name	Cross section (pb)
DYJetsToLL_LHEFilterPtZ-0To50_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia	1485.0
DYJetsToLL_LHEFilterPtZ-50To100_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia	397.4
DYJetsToLL_LHEFilterPtZ-100To250_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia	97.2
DYJetsToLL_LHEFilterPtZ-250To400_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia	3.701
DYJetsToLL_LHEFilterPtZ-400To650_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia	0.5086
DYJetsToLL_LHEFilterPtZ-650ToInf_MatchEWPDG20_TuneCP5_13TeV-amcatnloFXFX-pythia	0.04728
WZTo1L1Nu2Q_4f_TuneCP5_13TeV-amcatnloFXFX-pythia8	10.74
WZTo2Q2L_mllmin4p0_TuneCP5_13TeV-amcatnloFXFX-pythia8	5.60
WZTo3LNu_TuneCP5_13TeV-amcatnloFXFX-pythia8	4.43
ZZTo2L2Nu_TuneCP5_13TeV_powheg_pythia8	0.56
ZZTo2Q2L_mllmin4p0_TuneCP5_13TeV-amcatnloFXFX-pythia8	3.22
ZZTo2Q2Nu_TuneCP5_13TeV-amcatnloFXFX-pythia8	4.73
ZZTo4L_TuneCP5_13TeV_powheg_pythia8	1.25
WWTo2L2Nu_TuneCP5_13TeV-powheg-pythia8	12.18
WWTo1L1Nu2Q_4f_TuneCP5_13TeV-amcatnloFXFX-pythia8	50.00
QCD_HT200to300_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	111700.0
QCD_HT300to500_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	27960.0
QCD_HT500to700_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	3078.0
QCD_HT700to1000_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	721.8
QCD_HT1000to1500_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	138.2
QCD_HT1500to2000_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	13.61
QCD_HT2000toInf_BGenFilter_TuneCP5_13TeV-madgraph-pythia8	2.92

Datasets: Data

Dataset: MET
UL2018_MiniAODv2_NanoAODv9-v2
Run2018[A-D]
Integrated luminosity of $58.899 fb^{-1}$ (2018)

MET Triggers and Filters

Triggers
HLT_PFMETNoMu120_PFMHTNoMu120_IDTight_PFHT60
HLT_PFMETNoMu120_PFMHTNoMu120_IDTight
HLT_PFMETNoMu140_PFMHTNoMu140_IDTight

Filters
Flag_goodVertices
Flag_globalSuperTightHalo2016Filter
Flag_HBHENoiseFilter
Flag_HBHENoiseIsoFilter
Flag_eeBadScFilter
Flag_EcalDeadCellTriggerPrimitiveFilter
Flag_BadPFMuonFilter
Flag_BadPFMuonDzFilter
Flag_hfNoisyHitsFilter
Flag_BadChargedCandidateFilter
Flag_ecalBadCalibFilter

Analysis Strategy

Boosted and Resolved Category to reconstruct Higgs recoiling against dark matter particles.

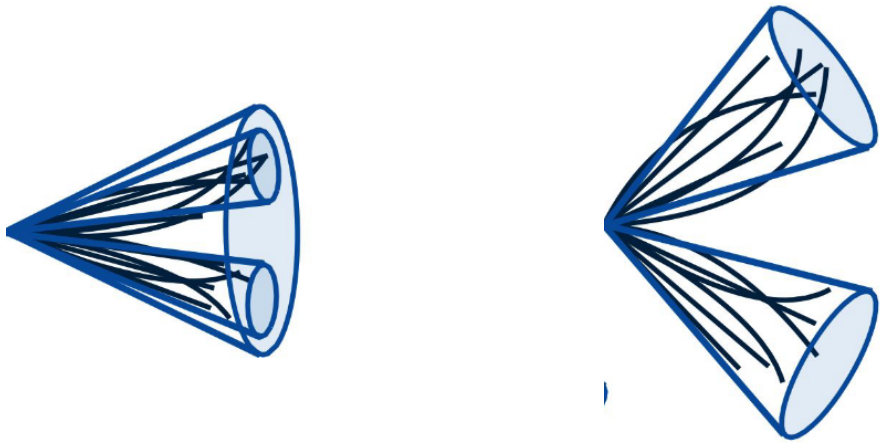


Figure: Large radius jet 'FatJet' (left) and small radius 'Resolved' jets (right)

Event Selections

Variable	Selections		
	SR	dilepton control region	tt control region
Recoil(U)	-	250 GeV	250 GeV
p_T^{miss}	250 GeV	-	>50 GeV
N_{AK8jet}	1 (p_T >200, $70 < m_{SD} < 150$, DDBvL >0.86)	1 (p_T >200, $70 < m_{SD} < 150$, DDBvL not applied)	1 (p_T >200, $70 < m_{SD} < 150$, DDBvL >0.86)
N_{bj}	0	0	1
N_{aj}	<= 2	<= 2	<= 2
N_l	0	2	1
m_{ll}	-	[60-120]	-
anti QCD $\Delta\phi(p_T^{miss}$, AK4jet)	>0.4	-	-
$N_{a\gamma}$	0	0	0
N_{atau}	0	0	0

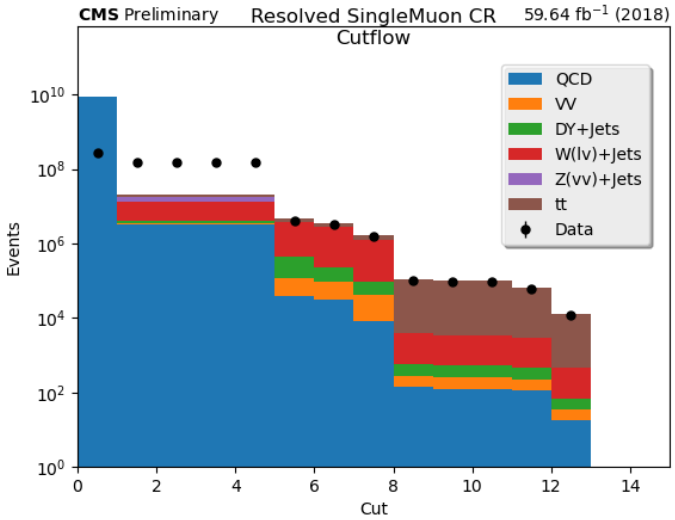
Table 15: Signal and Control region selections applied in the boosted category. Here "a" is for "additional", l is for lepton and j is for ak4jet

Variable	signal region	dilepton control region	tt control region
Recoil	-	200 GeV	200 GeV
p_T^{miss}	200 GeV	<100 GeV	>50 GeV
p_T^{j1}	50 GeV	50 GeV	50 GeV
p_T^{j2}	30 GeV	30 GeV	30 GeV
m_{jj}	[100-150]	[100-150]	[100-150]
p_T^{jj}	>100	>100	>100
$N_{a\gamma}$	0	0	0
N_{aTau}	0	0	0
anti QCD $\Delta\phi(p_T^{miss}$, jet)	>0.4	-	-
N_{aj}	<=2	<=2	>1
N_{al}	0	2	1
m_{ll}	-	[60-120]	-

Table 16: Selection cuts applied in the resolved category. Here "a" is for "additional", l is for lepton and j is for ak4jet

Cutflow: Resolved Category

Single Muon CR: One tight muon

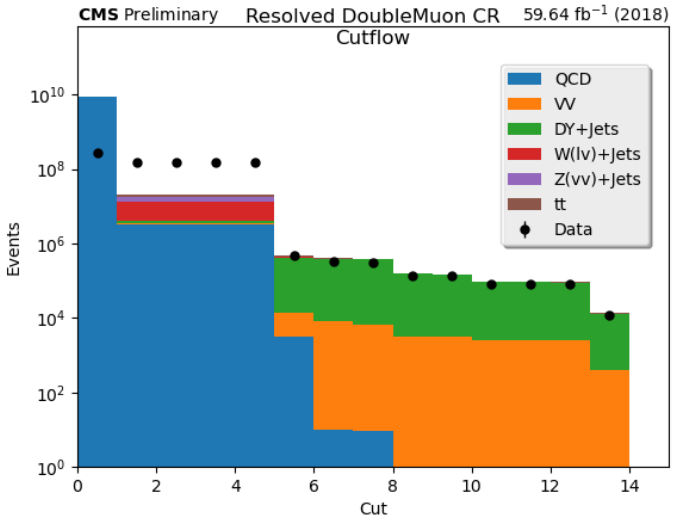


Bin	Selection	NEvents(Data)	NEvents(MC)	Ratio (Data/MC)
0	no cut	2.72E08	8.71E09	0.031
1	MET Trigger	1.49E08	2.01E07	7.413
2	MET Filters	1.49E08	2.01E07	7.413
3	$N_\tau = 0$	1.49E08	2.01E07	7.413
4	$N_\gamma = 0$	1.48E08	2.00E07	7.428
5	iso tight $N_\mu = 1$	4.15E06	4.65E06	0.893
6	$p_T^{miss} > 50GeV$	3.27E06	3.60E06	0.909
7	$U > 200GeV$	1.58E06	1.62E06	0.976
8	$N_{additionaljet} >= 1$	1.02E05	1.09E05	0.942
9	$p_T(b_1) > 50GeV$	9.76E04	1.04E05	0.942
10	$p_T(b_2) > 30GeV$	9.76E04	1.04E05	0.942
11	$p_T(b_1 b_2) > 100GeV$	6.13E04	6.30E04	0.972
12	$100 < M(b_1 b_2) < 150GeV$	1.24E04	1.33E04	0.930

'*additionaljet*' means select AK4jet with ΔR>0.4 from b_1 & b_2 jets.

Cutflow: Resolved Category

Double Muon CR: Two loose muons, atleast one tight muon



Bin	Selection	NEvents(Data)	NEvents(MC)	Ratio (Data/MC)
0	no cut	2.72E08	8.71E09	0.031
1	MET Trigger	1.49E08	2.02E07	7.413
2	MET Filters	1.49E08	2.02E07	7.413
3	$N_\tau = 0$	1.49E08	2.02E07	7.413
4	$N_\gamma = 0$	1.48E08	2.00E07	7.428
5	iso loose $N_\mu = 2$, tight $N_\mu \geq 1$	4.64E05	4.84E05	0.958
6	$60 < M(\mu\mu) < 120GeV$	3.29E05	4.16E05	0.791
7	$p_T^{miss} < 100GeV$	3.09E05	3.97E05	0.779
8	$U > 200GeV$	1.39E05	1.55E05	0.897
9	$N_{additionaljet} <= 2$	1.35E05	1.52E05	0.888
10	$p_T(J_1) > 50GeV$	8.04E04	9.30E04	0.865
11	$p_T(J_2) > 30GeV$	8.04E04	9.30E04	0.865
12	$p_T(J_1J_2) > 100GeV$	7.91E04	9.17E04	0.862
13	$100 < M(J_1J_2) < 150GeV$	1.17E04	1.34E04	0.868

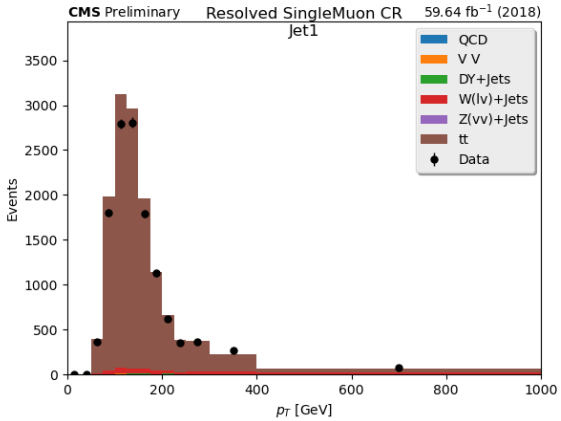
'*additionaljet*' means select AK4jet with ΔR>0.4 from J_1 & J_2 jets. (non btagged AK4jets, only p_T and η cut.)
Here, dijet has no btag requirement to gain statistics.

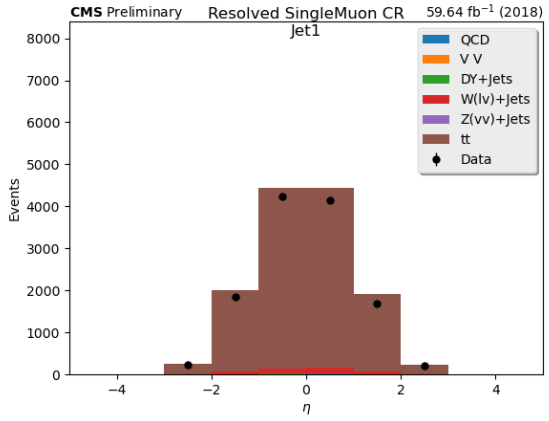
Updates: Jan 19

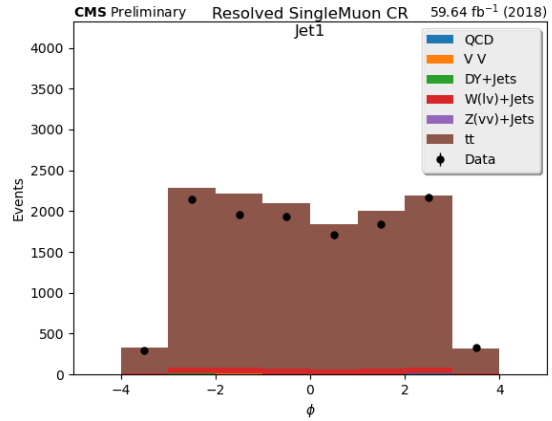
- Resolved Category Plots in Single and Double Muon Control Region after applying Event Selections.

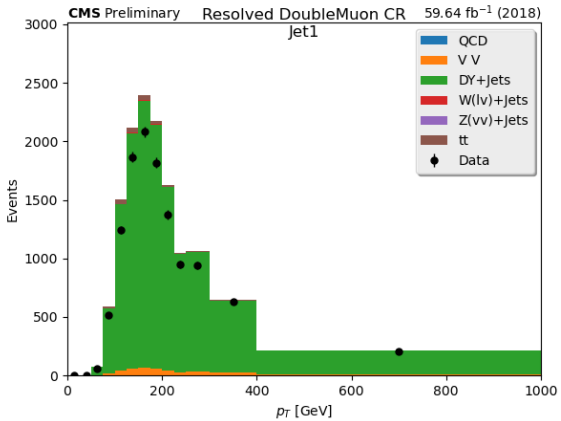
Jet Kinematics: leading jet pT, Eta, Phi

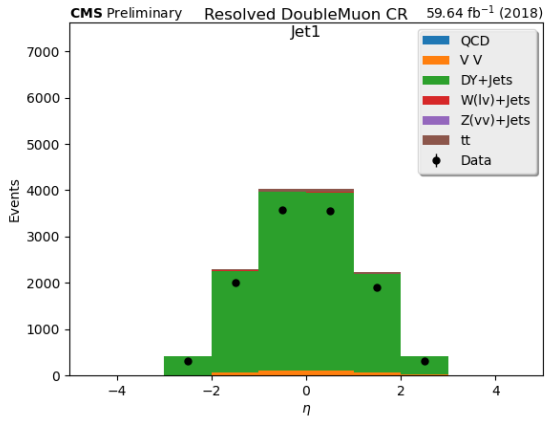
SingleMuon CR has b-tagged jets, DoubleMuon CR no b-tag requirement.

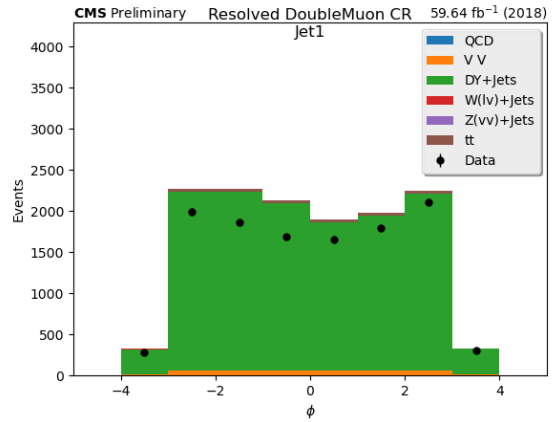




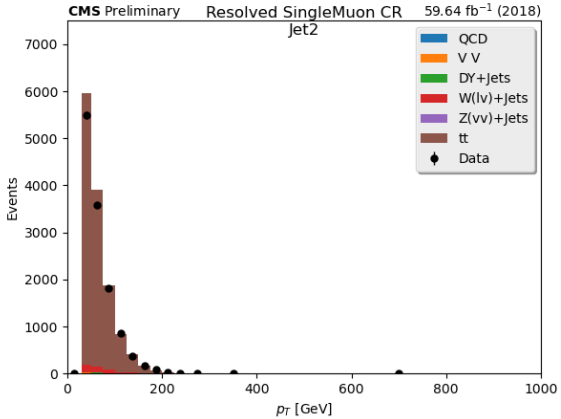


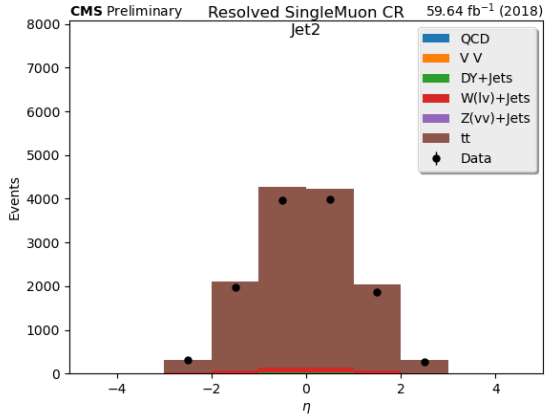


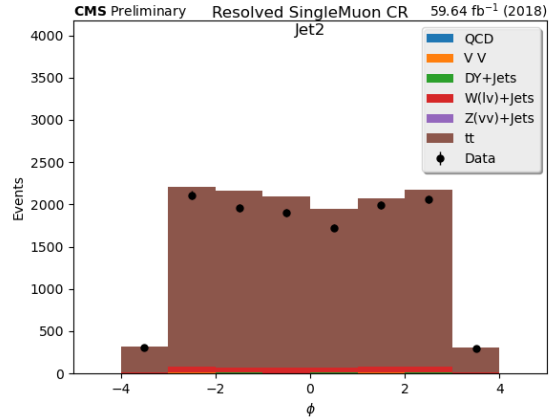


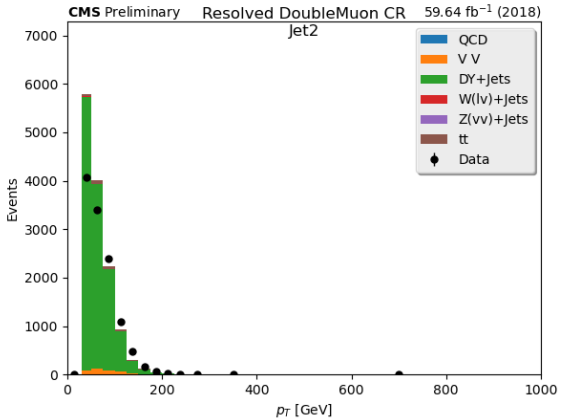


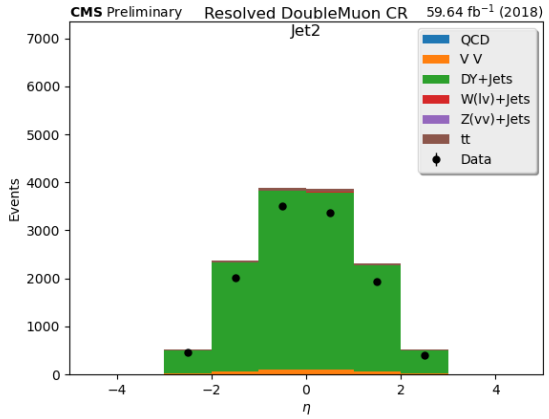
Jet Kinematics: subleading jet pT, Eta, Phi

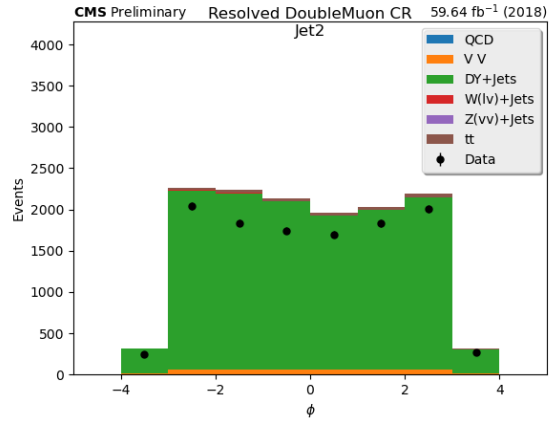




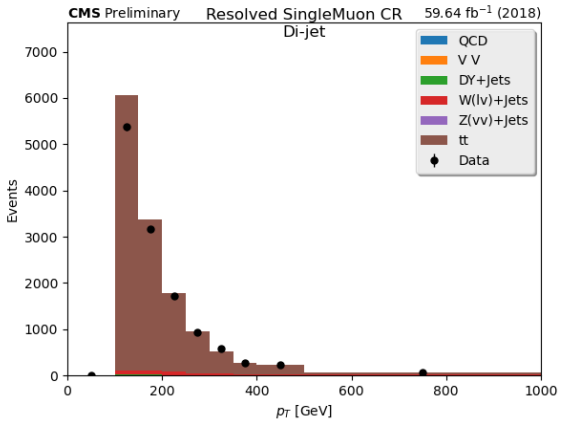


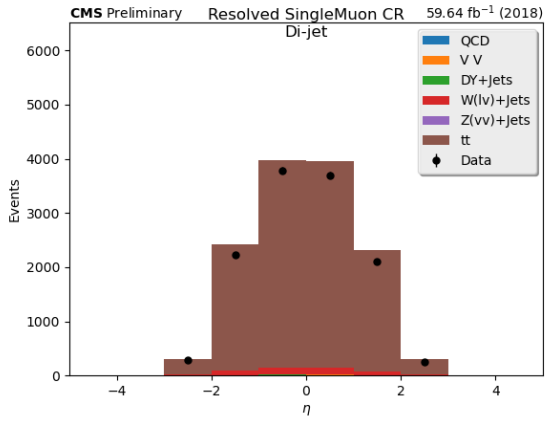


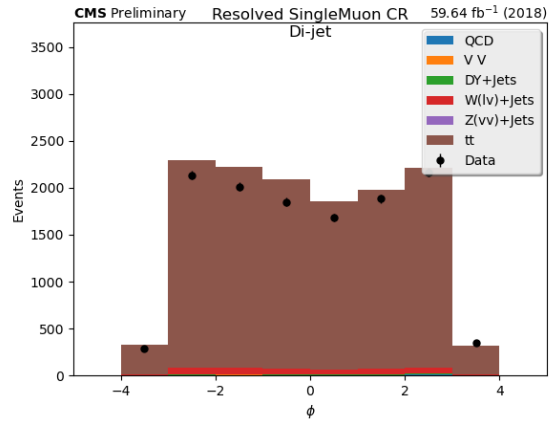


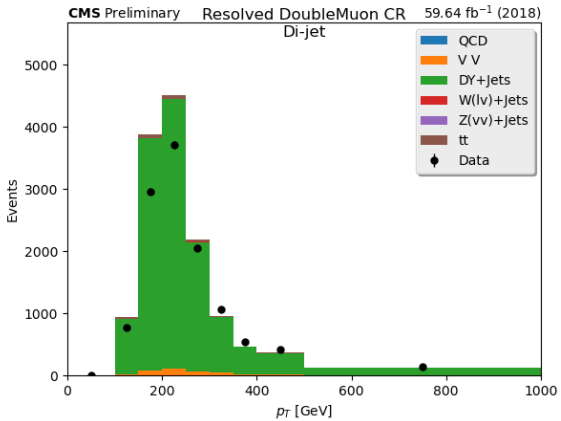


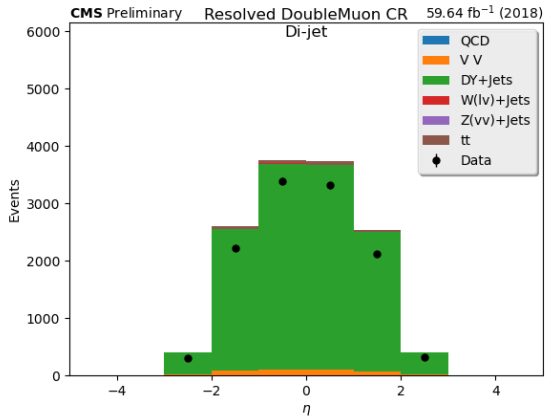
Di-jet Kinematics: pT, Eta, Phi

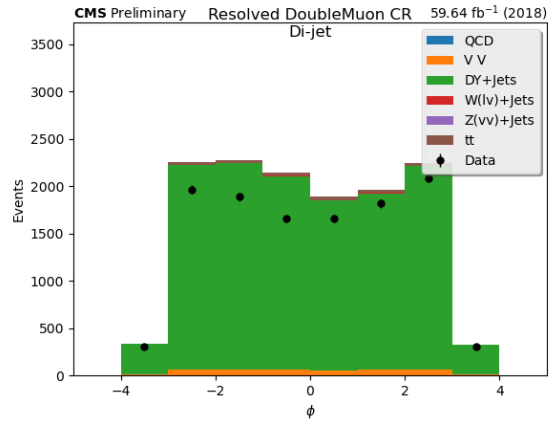




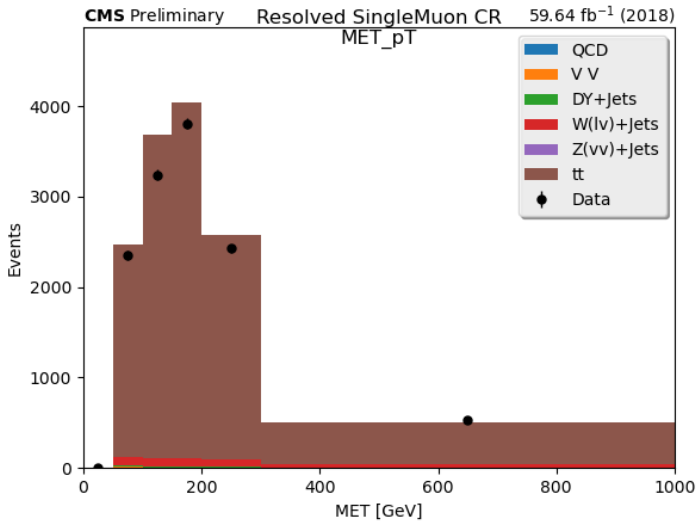


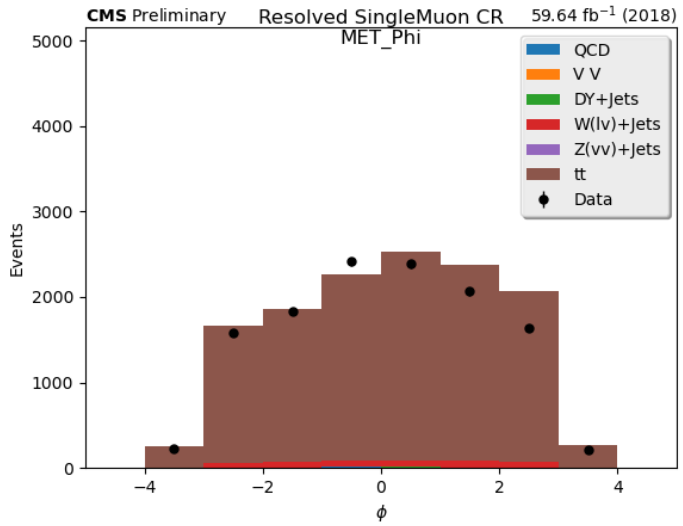


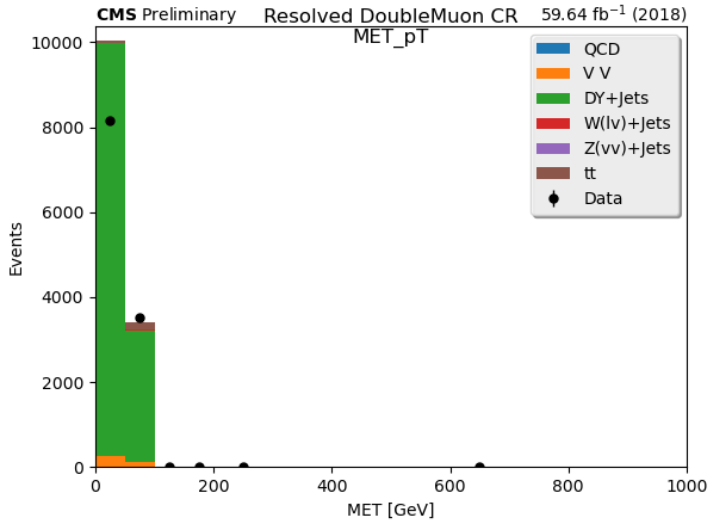


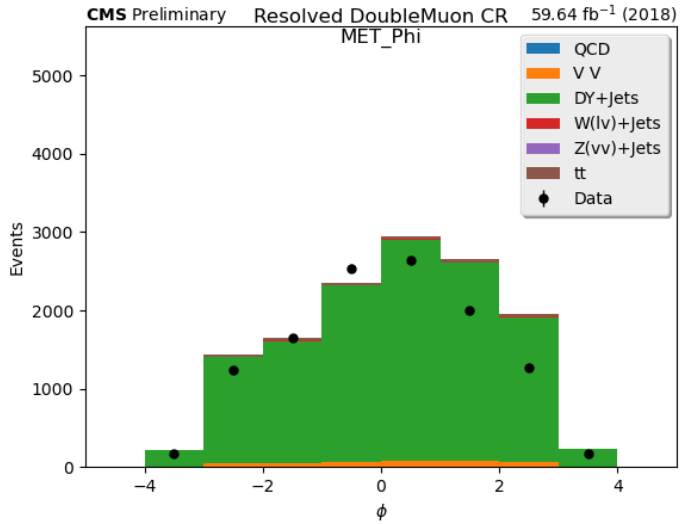


MET: pT and Phi

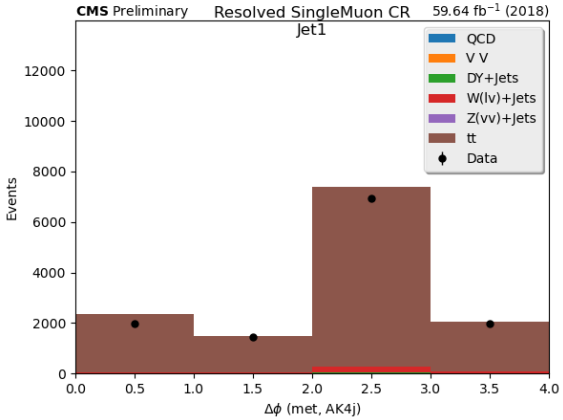


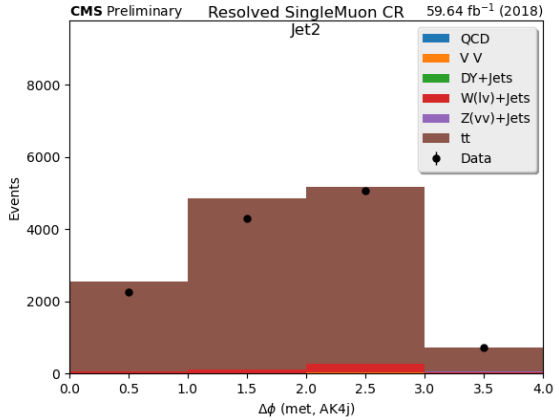


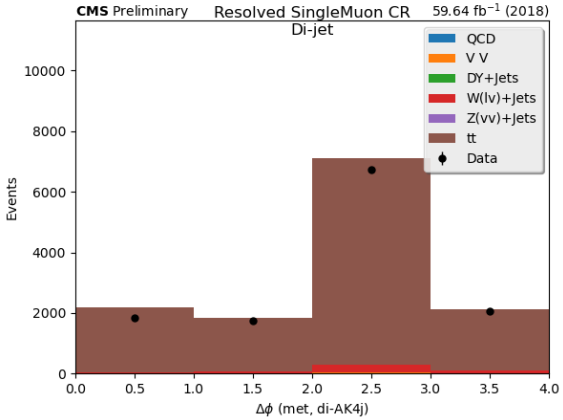


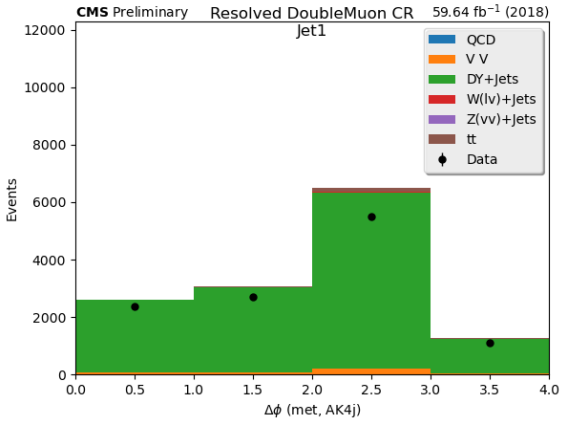


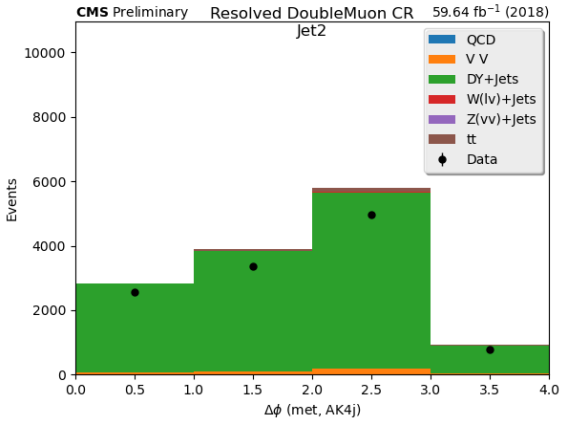
dPhi between MET and Jet1, Jet2, Di-jet

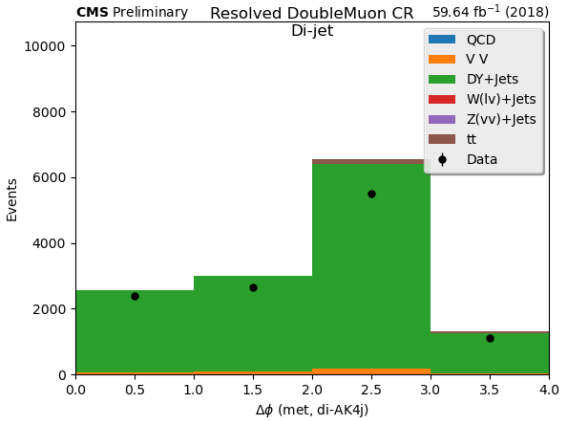










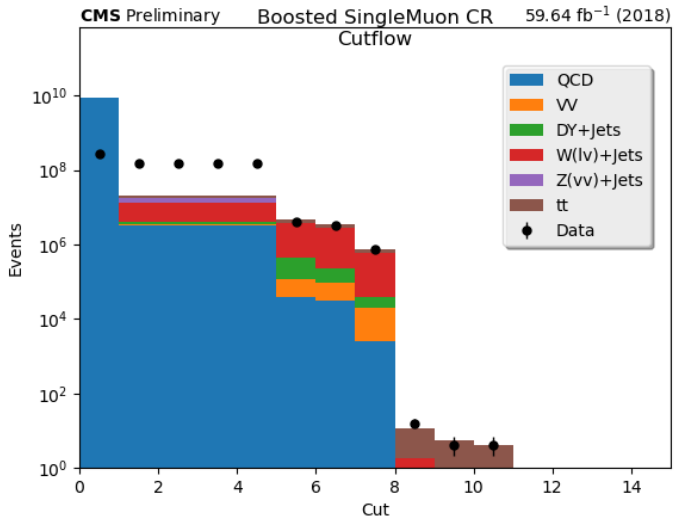


Updates: Jan 19

- Boosted Category needs work. How to improve?

Cutflow: Boosted Category

Single Muon CR: One tight muon

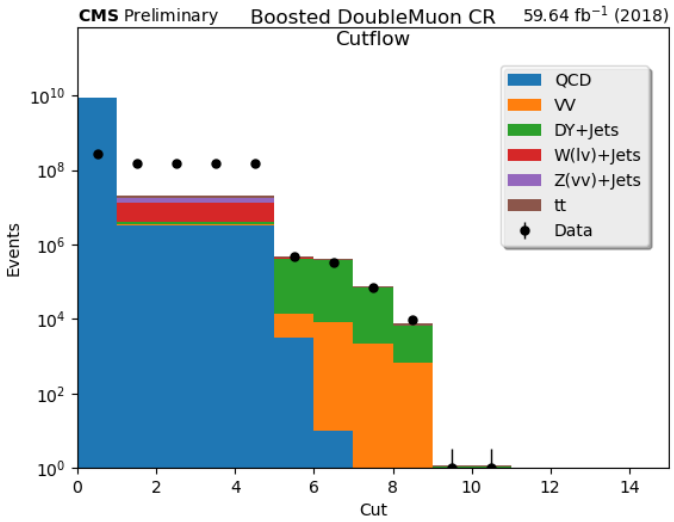


Bin	Selection	NEvents(Data)	NEvents(MC)	Ratio (Data/MC)
0	no cut	2.72E08	8.71E09	0.031
1	MET Trigger	1.49E08	2.02E07	7.413
2	MET Filters	1.49E08	2.02E07	7.413
3	$N_\tau = 0$	1.49E08	2.02E07	7.413
4	$N_\gamma = 0$	1.49E08	2.00E07	7.428
5	iso tight $N_\mu = 1$	4.15E06	4.65E06	0.893
6	$p_T^{miss} > 50GeV$	3.27E06	3.60E06	0.909
7	$U > 250GeV$	7.19E05	7.35E05	0.978
8	$NFJ(bb) = 1$	1.60E01	1.18E01	1.353
9	loose $N_{bj} = 1$	4.00	5.51	0.726
10	$N_{additionaljet} <= 2$	4.00	4.17	0.960

*unsure about cut 9

Cutflow: Boosted Category

Double Muon CR: Two loose muons, atleast one tight muon



Bin	Selection	NEvents(Data)	NEvents(MC)	Ratio (Data/MC)
0	no cut	2.72E08	8.71E09	0.031
1	MET Trigger	1.49E08	2.02E07	7.413
2	MET Filters	1.49E08	2.02E07	7.413
3	$N_\tau = 0$	1.49E08	2.02E07	7.413
4	$N_\gamma = 0$	1.48E08	2.00E07	7.428
5	iso loose $N_\mu = 2$, tight $N_\mu \geq 1$	4.64E05	4.84E05	0.958
6	$60 < M(\mu\mu) < 120GeV$	3.29E05	4.16E05	0.790
7	$U > 250GeV$	6.90E04	7.32E04	0.942
8	$NFJ = 1$	9.33E03	7.47E03	1.249
9	loose $N_{bj} = 0$	1.00	1.22	0.822
10	$N_{additionaljet} <= 2$	1.00	1.18	0.846

Here, FatJet has no btag requirement to gain statistics.
*unsure about cut 9