



Study of $Z/\gamma^* \rightarrow \tau\tau \rightarrow \mu\mu$ as a standard candle for $H \rightarrow \tau\tau \rightarrow \mu\mu$ Analysis using RUN-II data

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Goal

- $Z/\gamma^* \rightarrow \tau\tau \rightarrow \mu\mu$ is large and irreducible background for SM $H \rightarrow \tau\tau \rightarrow \mu\mu$ process, hence it can be used as standard candle to study the efficiency to reconstruct the pair of tau leptons
- Measurement of the cross section of $Z/\gamma^* \rightarrow \tau\tau$ process with small statistical and systematic uncertainties will be the important cross check to validate the new analysis techniques and method



Data Set and MC Samples

- **Run period:** Run2015D $\sqrt{s} = 13\text{TeV}$, $\int \mathcal{L} dt = 2.24\text{fb}^{-1}$, with 25ns bunch crossing,
- **Data run:** Cert_13TeV_16Dec2015ReReco_Collisions15_25ns_JSON.json
- **MC Samples:**
 - Signal sample
 - DYToJetsTautau_ForcedMudecay_M-50_amcatnlo(forced decay $Z \rightarrow \tau\tau \rightarrow \mu\mu$)
 - Background Samples
 - DYJetsToLL_M-10to50_amcatnlo, DYJetsToLL_M-50_amcatnlo, ($z \rightarrow \mu\mu$)
 - WZ, WW, ZZ, Wjets, TT, ST
 - QCD: Use Data-driven method: shape is taken from the same-sign dimuon sample and extrapolation factor OS/SS of 2, determined with QCD muon-enriched MC
- **CMSSW_76X:** Official PileUp Correction + Lepton scale factors + Met Recoil Correction + TopPtRewighting are applied



Uncertainty model

➤ The current uncertainty model includes only normalization altering uncertainties and bin-by-bin MC statistical uncertainties:

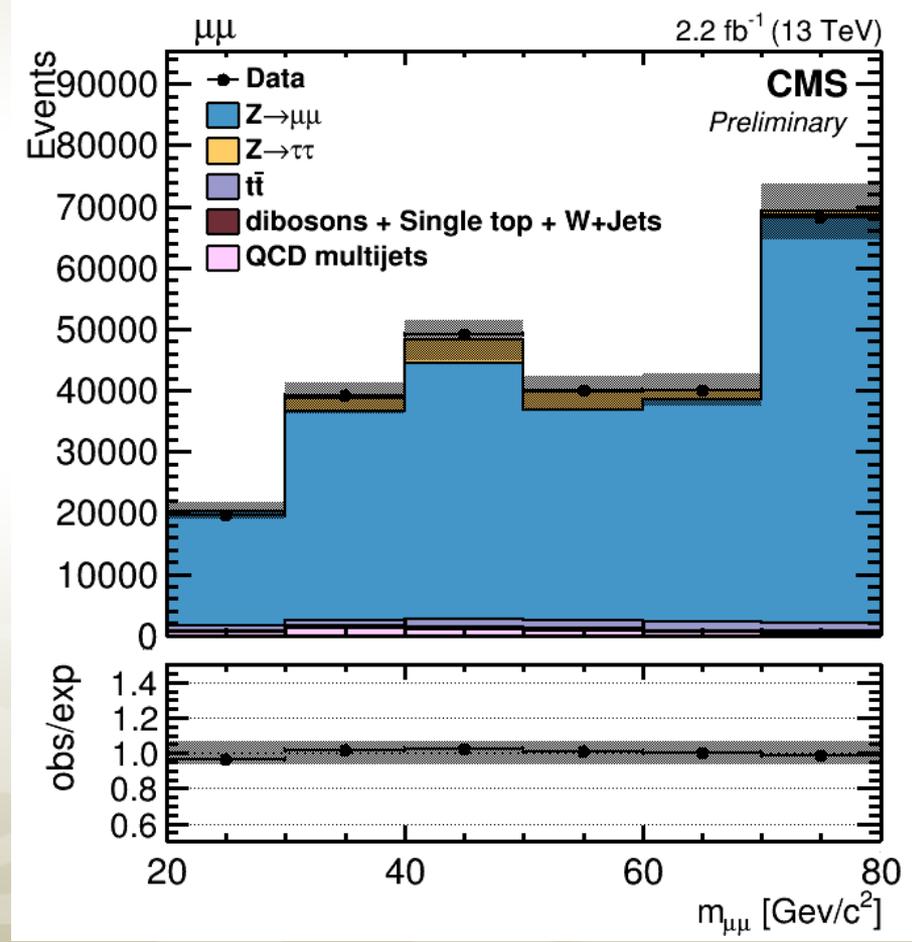
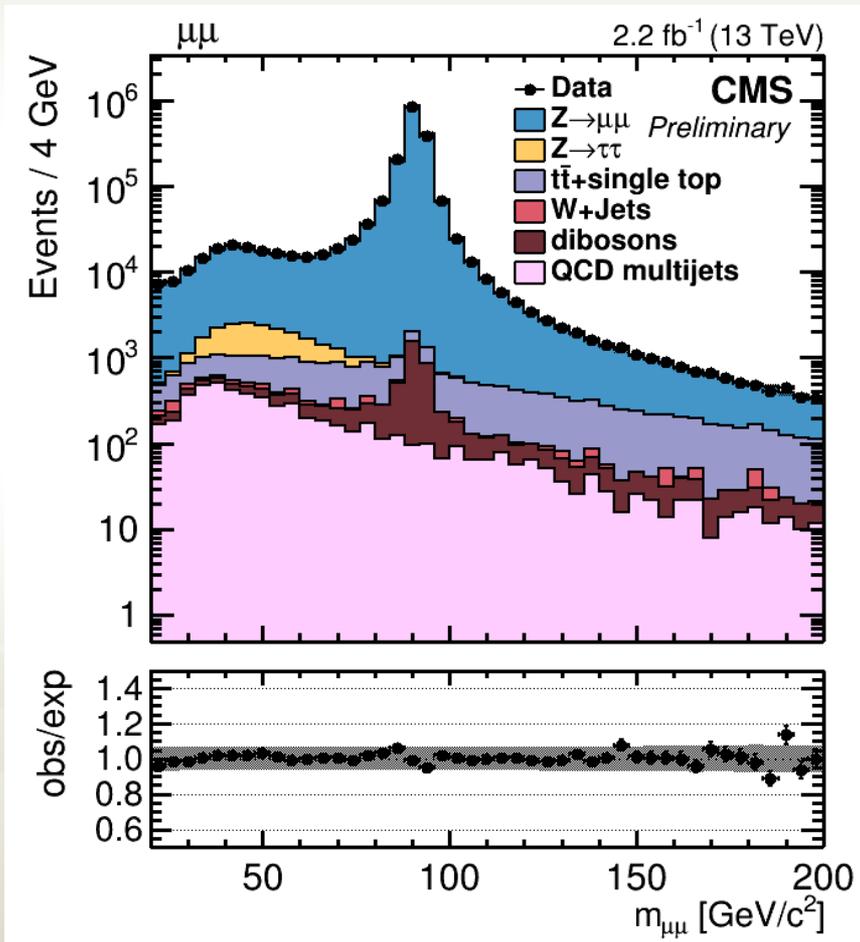
- luminosity : 2.7%
- muon Id/Iso and trigger efficiency : $3+3 = 6\%$
- uncertainty in TTBar and single-top norm : 10%
- uncertainty in electroweak bkgd norm : 15%
- uncertainty in QCD bkgd norm : 20%
- uncertainty in Z norm : 3%
- bin-by-bin MC statistical uncertainties
- uncertainty in muon momentum scale: 0.5%
- Uncertainty related to BDT: 3.3%



Different cuts and Trigger info

- For this analysis we are using Single Muon trigger:
HLT_Iso Mu18
- MuonFilterName:**hltL3crIsoL1sMu16L1f0L2f10QL3f18QL3trkIsoFiltered0p09**
- For this channel, two muons have to satisfy the following conditions: (**Selection Cut**)
 - $p_T > 10$ GeV and $|\eta| < 2.4$
 - Medium PF muon identification criteria
 - Tight isolation $I_\mu < 0.15 \cdot p_T^\mu$
 - At least one muon has $p_T > 20$ GeV and matched to HLT muon object within $\Delta R < 0.5$
 - Two muon should have opposite charges

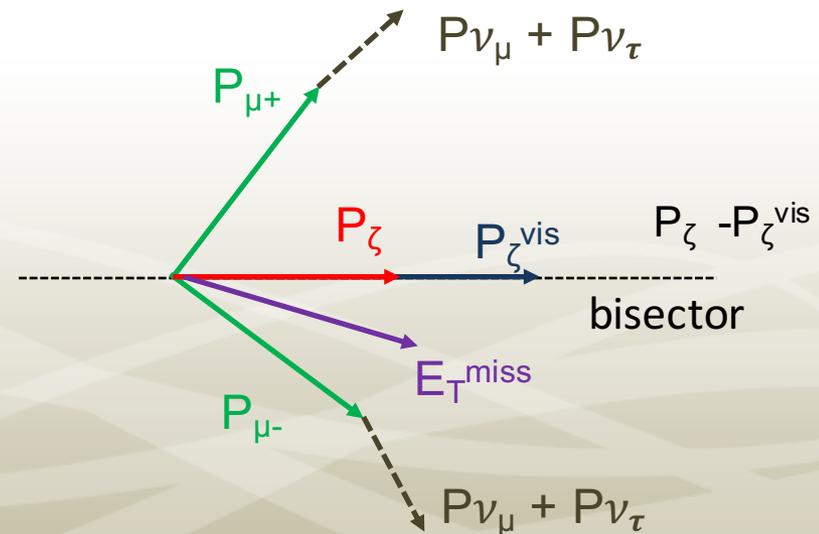
Dimuon Mass with selection cut



Multivariate (MVA) analysis using Boosted Decision Tree (BDT) method to discriminate $Z/\gamma^* \rightarrow \mu\mu$ bkg

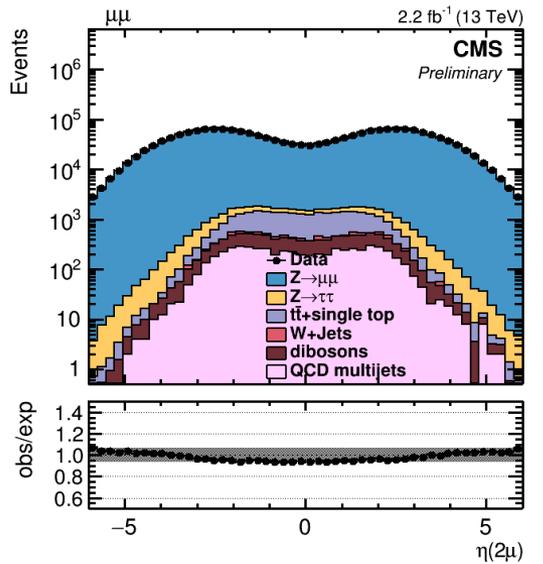
- Multivariate Analysis using Boosted Decision Tree (BDT) method is used to discriminate $Z/\gamma^* \rightarrow \tau\tau \rightarrow \mu\mu$ signal events from $Z/\gamma^* \rightarrow \mu\mu$ background
- Following discriminants used as input variables for MVA analysis

- Dimuon eta (2μ)
- D_ζ Variable : $D_\zeta = P_\zeta - \alpha P_\zeta^{\text{vis}}$
(where, ζ is axis bisecting the angle between transverse momenta of muons decaying from tau pair)
- Missing Transverse Energy (MVA E_T^{miss})
- $\Delta\Phi(\mu^+, E_T^{\text{miss}})$

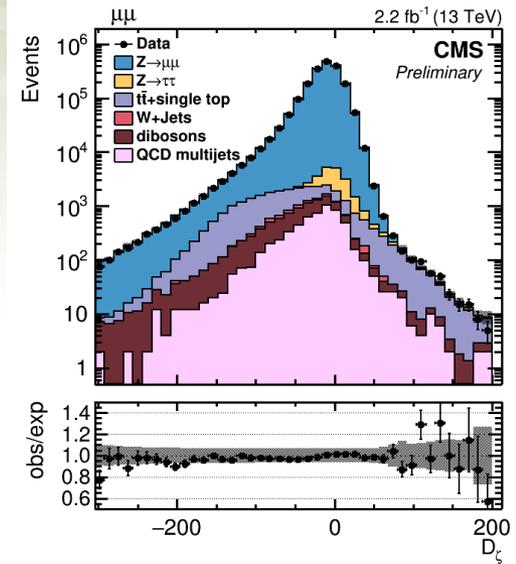


BDT discriminates

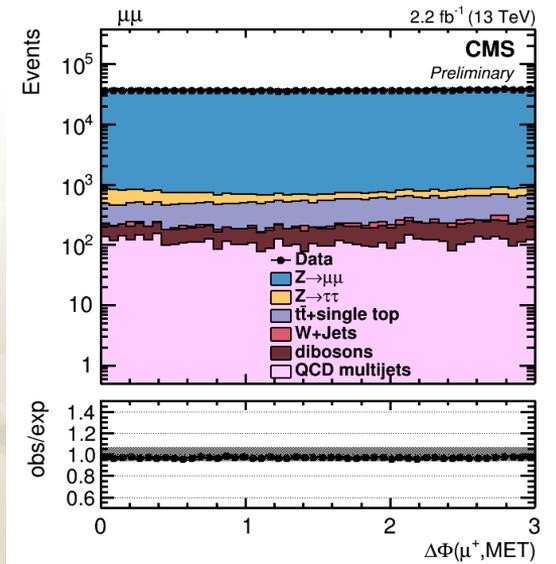
$\eta(2\mu)$



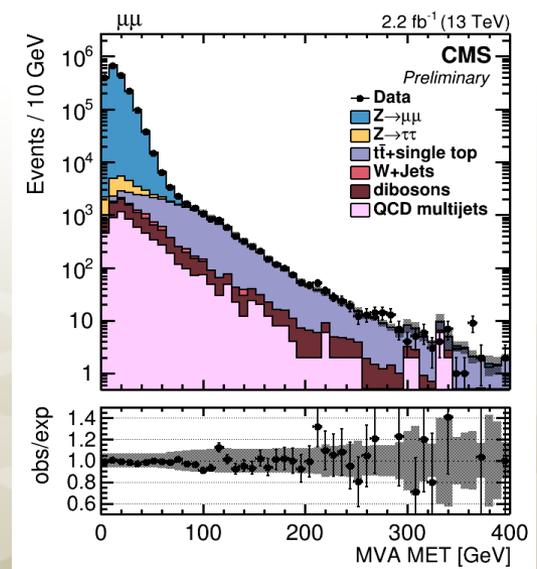
D_c



$\Delta\Phi(\mu^+, E_t^{miss})$

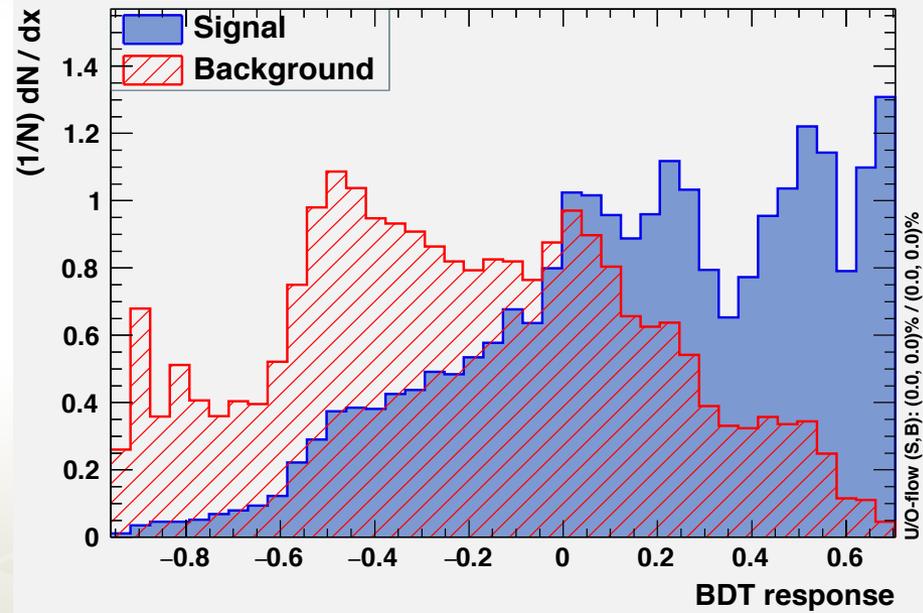


E_T^{miss}

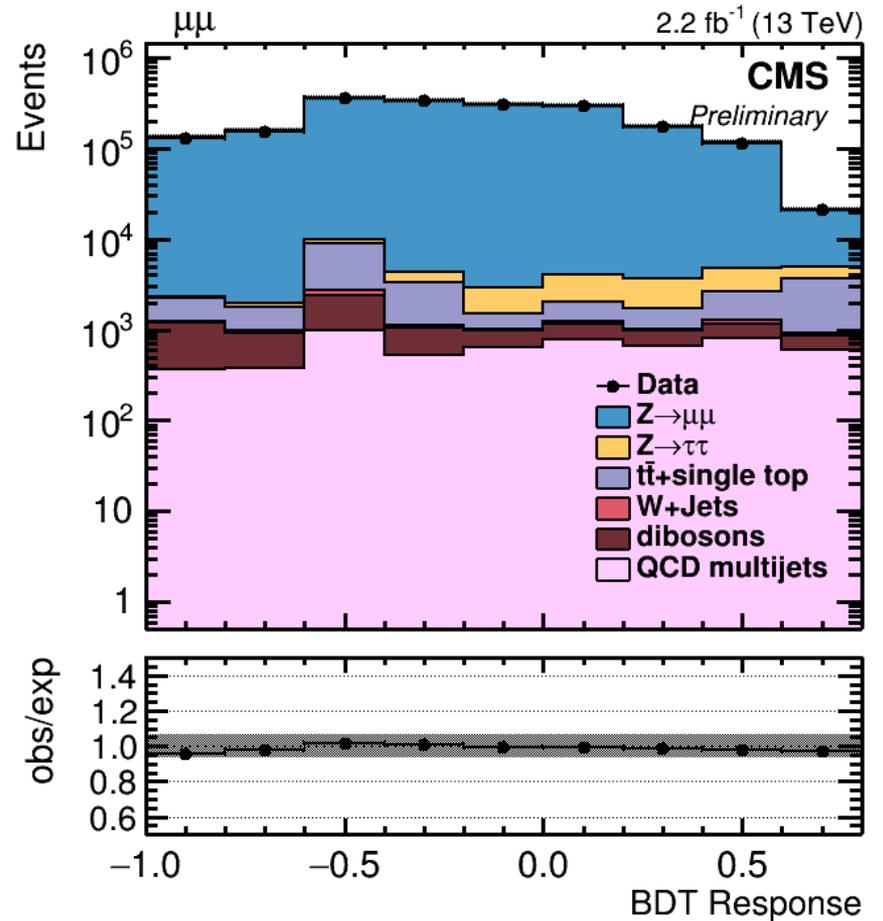


BDT Response

TMVA response for classifier: BDT

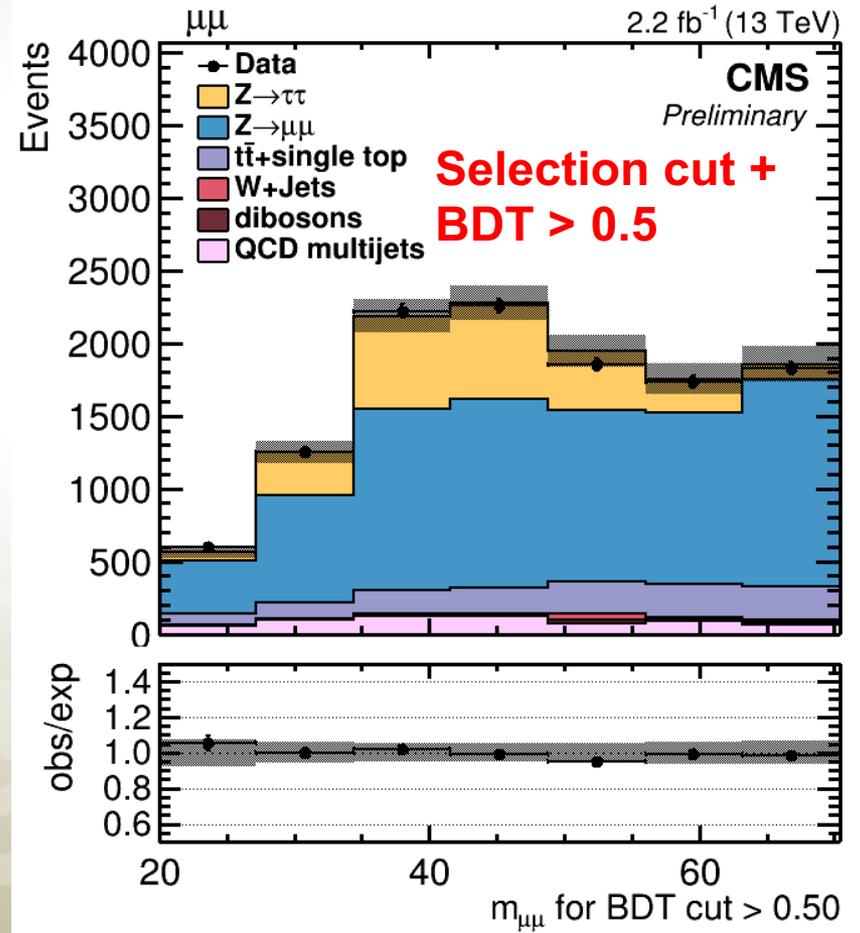
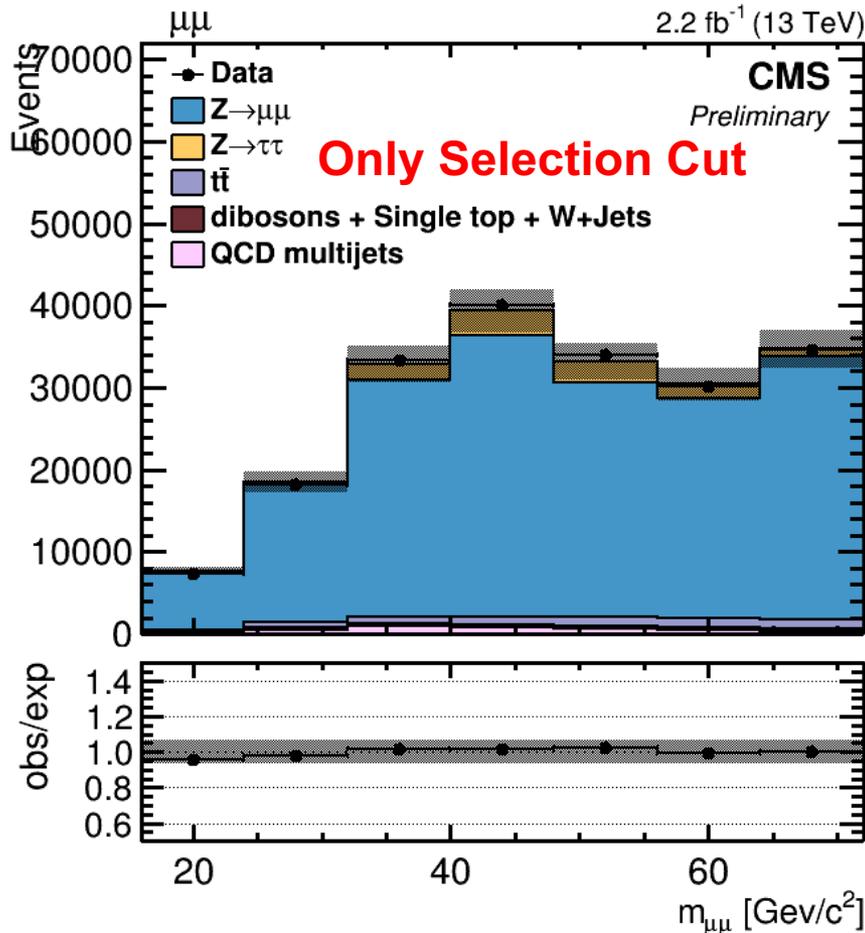


By TMVA



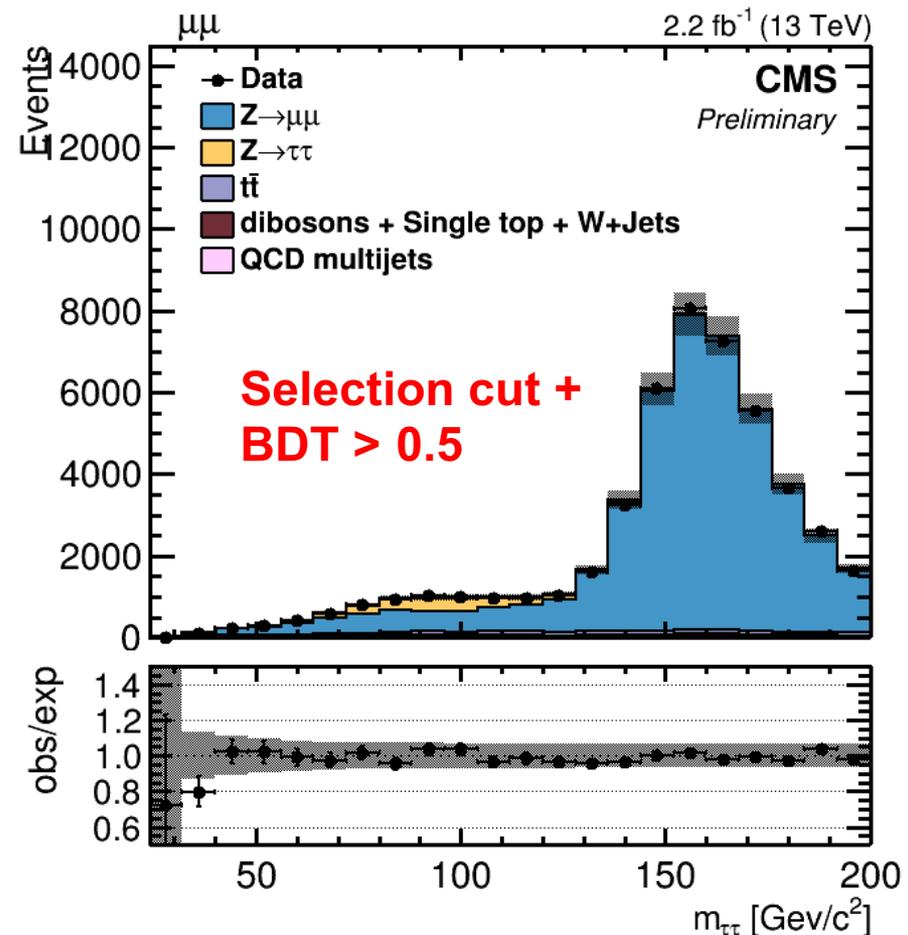
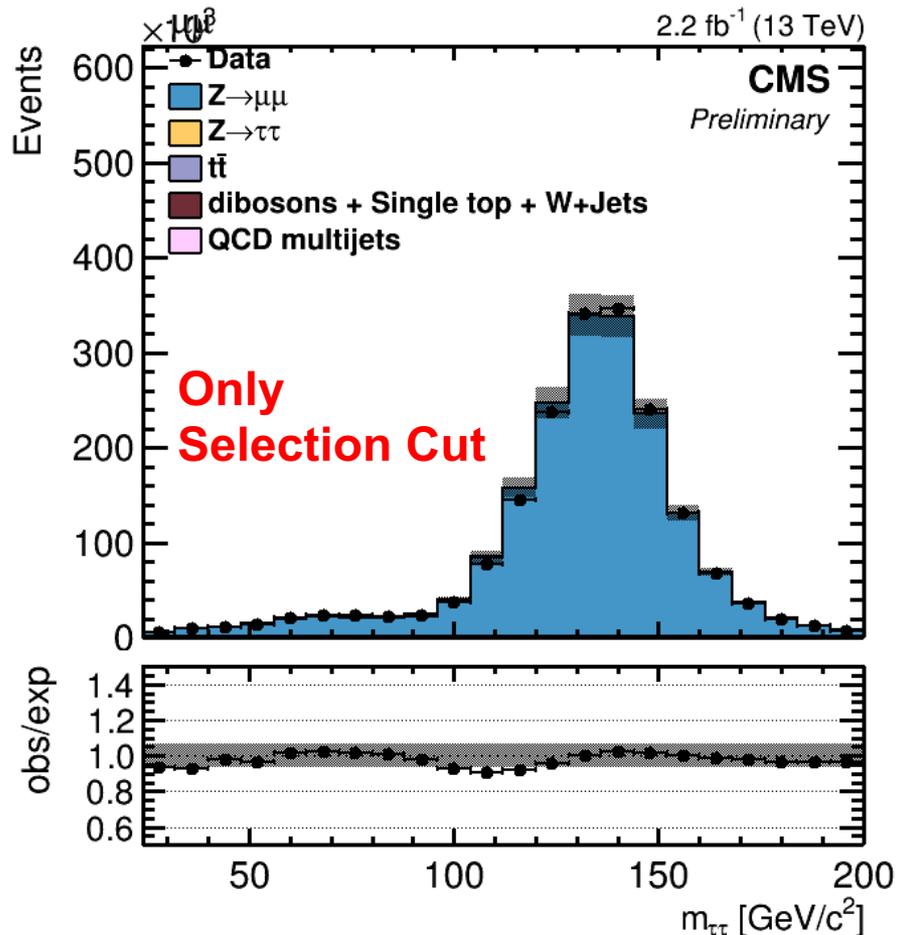
dimuon mass

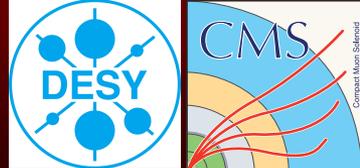
After optimizing the BDT cut, we applied tight cut $BDT > 0.5$ to reduce $Z/\gamma^* \rightarrow \mu\mu$ bkg and to increase the yield of $Z/\gamma^* \rightarrow \tau\tau \rightarrow \mu\mu$



Secondary Vertex (SV) Fit di-tau mass

- SV fit algorithm is used to reconstruct the invariant mass of the pair of tau leptons. This method best on the maximization of the likelihood function





Summary and Future work

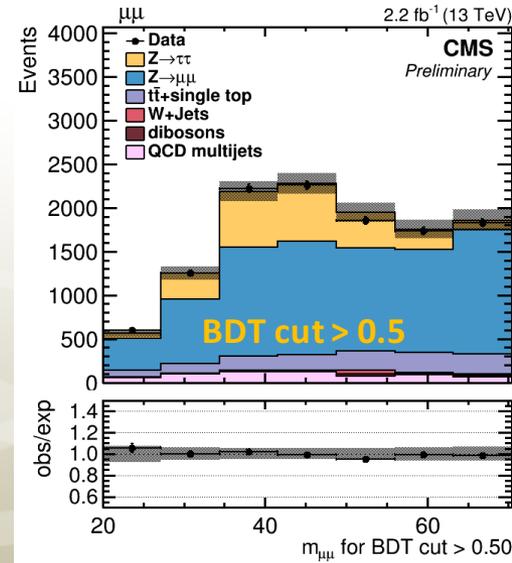
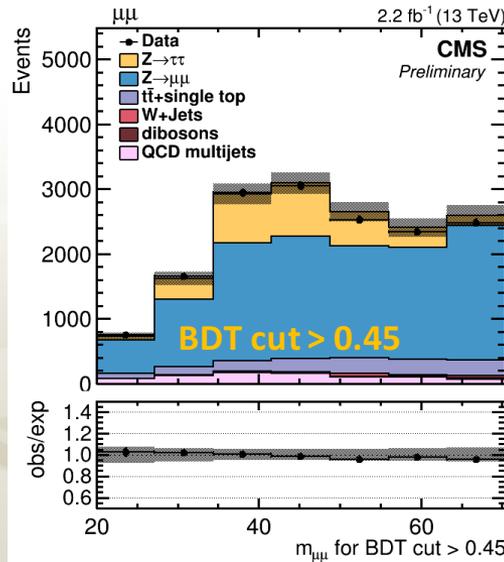
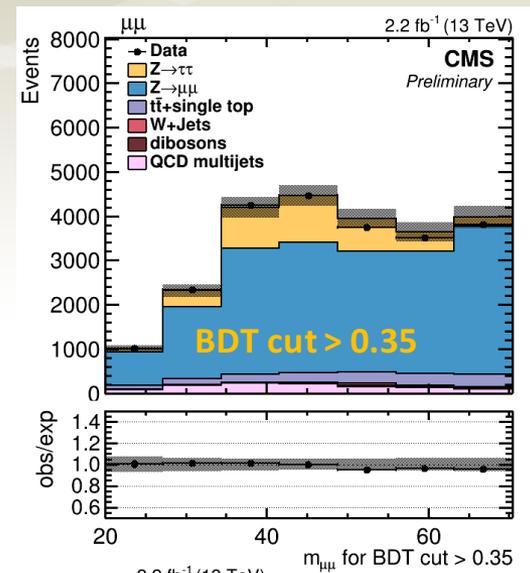
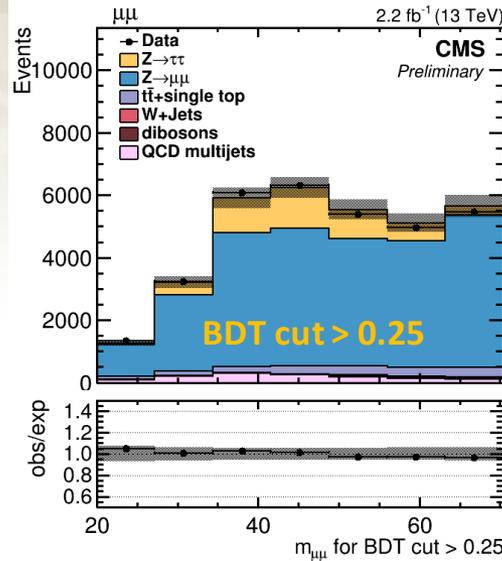
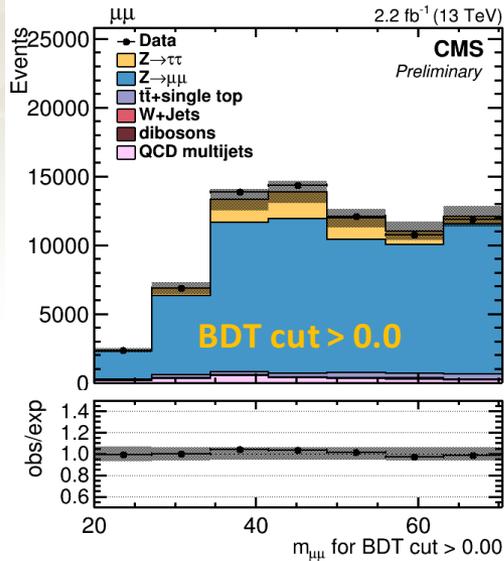
- Using MVA BDT, we manage to reduce $Z/\gamma^* \rightarrow \mu\mu$ bkg and increase the purity of the signal sample
- Finalized the $Z/\gamma^* \rightarrow \tau\tau \rightarrow \mu\mu$ results to combine with other channels to calculate the cross section of the $Z/\gamma^* \rightarrow \tau\tau$ process
- **Future Work**
 - Update analysis to study SM $H \rightarrow \tau\tau \rightarrow \mu\mu$ process
 - For Higgs analysis, in addition to above discriminants, visible dimuon mass and reconstructed tau pair mass will be used to discriminate the $H \rightarrow \tau\tau \rightarrow \mu\mu$ events from $Z/\gamma^* \rightarrow \tau\tau \rightarrow \mu\mu$
 - Along with Single muon trigger, use double muon trigger to see the overall improvement in the analysis



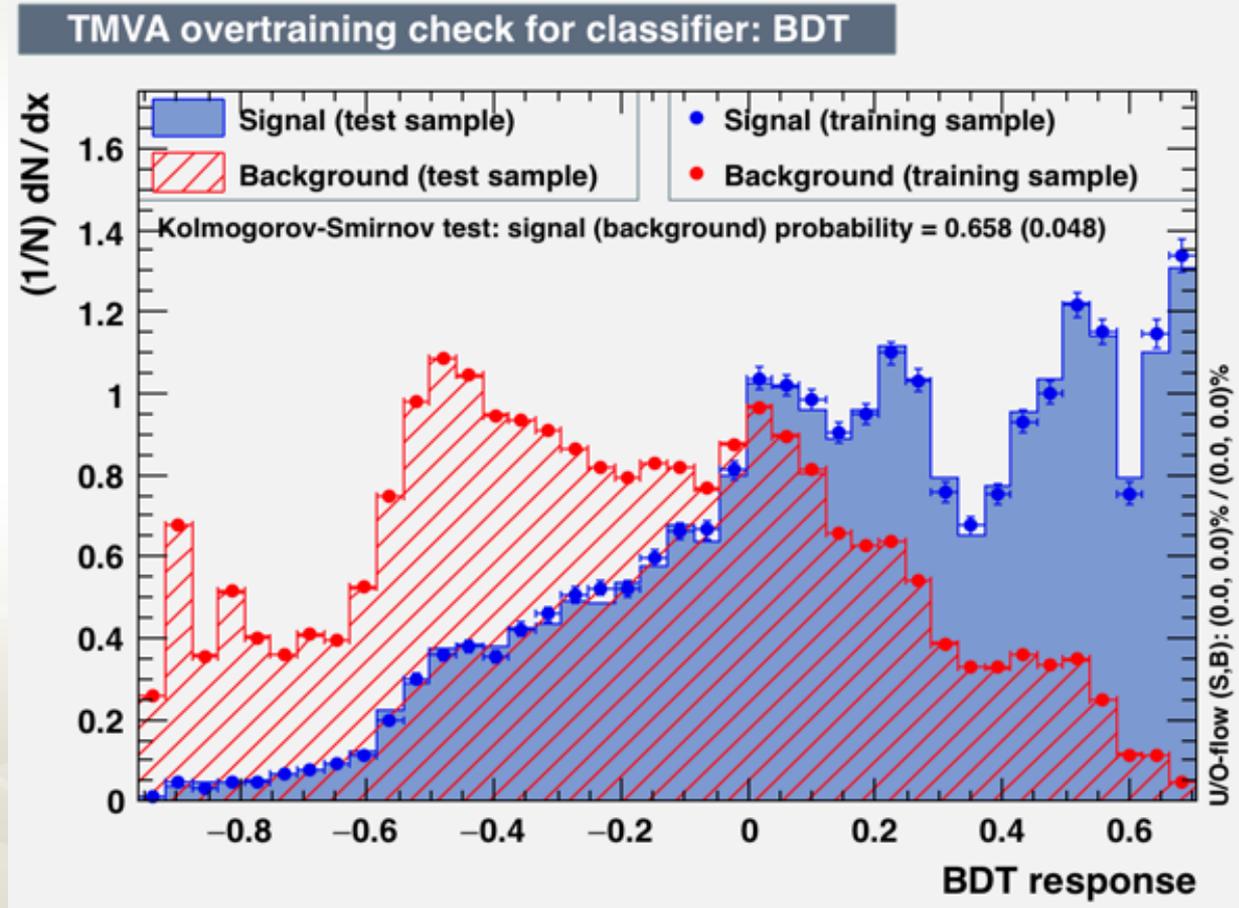
Thank you!



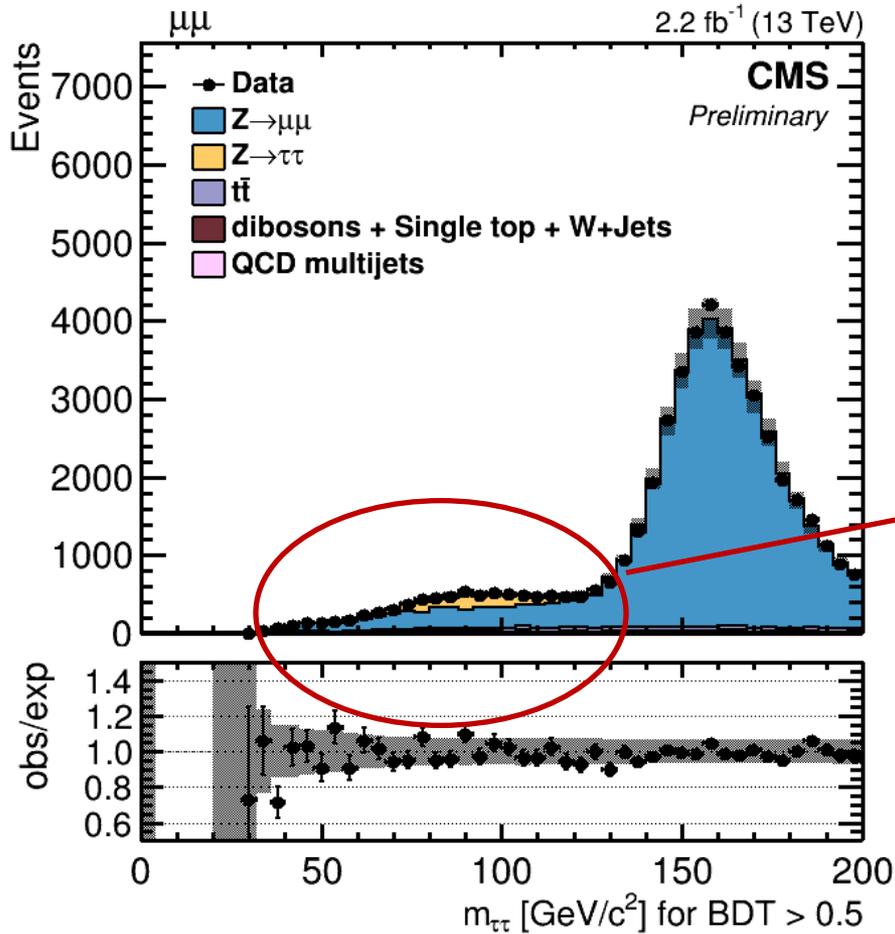
Backup



TMVA BDT overtraining check



With BDT > 0.5



Zoom Plot

