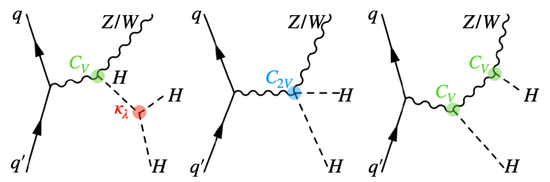
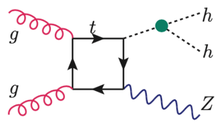
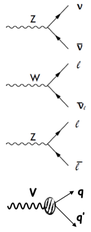
Search for Higgs boson pair production in $b\bar{b}b\bar{b}$ final state in association with a vector boson with the CMS detector

Motivation







MET (Znn)

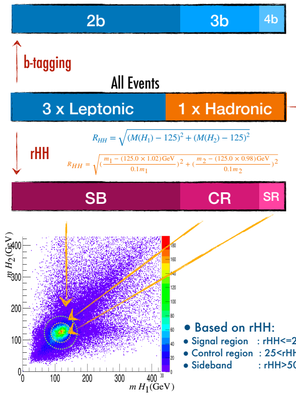
Semi-Lep (Wln)

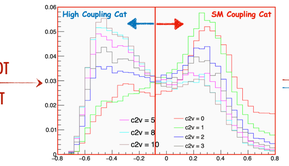
Di-Lep (Zll)

All-Hadronic (Had)

- CV, C2V, Kl couplings are involved.
- Leptonic decay of vector boson can tell the difference between Z & W.
- Cross sections are enhanced by the constructive interference.

Categorization

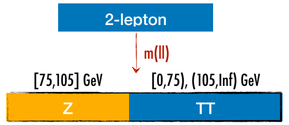




C2V BDT

Kl BDT

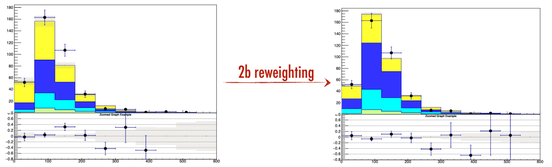
Analysis...



- SR and 3/4 b-tagged is selected as signal

Background

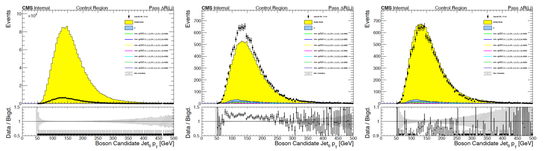
ZLL



Background modeled by 3-btagged events

Background modeled by 2-btagged events

Had



(a) No weight (b) JCM only (c) JCM + FvT

QCD background modeled with 3-btagged events with different weights calculated

Selection

Leptonic Channel

- GoodMuons: (2 Muons for Z)
  - |Muon_eta| < 2.4
  - Muon_pt > 20
  - Muon_pfRelIso04_all < max_rel_iso [0.25]
- GoodElectrons: (2 Electrons for Z)
  - |Electron_eta| < 2.5
  - Electron_pt > 20
  - Electron_pfRelIso03_all < max_rel_iso[0.15]

- GoodMuon: (1 Muon for W)
  - |Muon_eta| < 2.4
  - Muon_pt > 25
  - Muon_pfRelIso04_all < max_rel_iso [0.06]
- GoodElectron: (1 Electron for W)
  - |Electron_eta| < 2.5
  - Electron_pt > 25
  - Electron_pfRelIso03_all < max_rel_iso[0.06]

- MET
  - PassMetFilters
  - MET_pt > 150
  - No jet (pt >30GeV and eta <10) with dPhi_Jet_MET < 0.5 (suppress QCD)

Hadronic Channel

- >= 4 b-tagged jets with DeepJet>0.6
- >= 6 jets with pT > 20 GeV and |eta|<2.4
- Higgs Candidate Jets: (4 leading DeepJet score jets)
- Form 2 di-jets satisfying 45GeV < m_jj < 190GeV

$360/m_{4j} - 0.5 < \Delta R(Leading\ S_T\ dijets) < max(1.5, 650/m_{4j} + 0.5)$

$235/m_{4j} < \Delta R(Sub\ leading\ S_T\ dijets) < max(1.5, 650/m_{4j} + 0.7)$

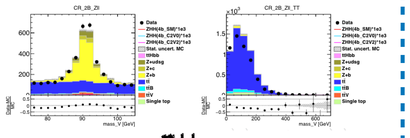
- Vector Boson Candidate Jets:
- Pairing all candidates and find 65GeV < m_{jj} < 105GeV

- GoodJets: [AK4]
  - Jet_puId>6 or Jet_Pt>50
  - Jet_lepFilter > 0
  - Jet_jetId > 4
  - Jet_PtReg > 20
  - |Jet_eta|<=2.5

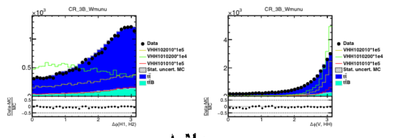
DeepJet for AK4 jets and ParticleNet for AK8 jets

- 2 leading PN score AK8 jets [Boosted]
  - |Jet_eta|<=2.5
  - Jet_Pt > 150GeV
  - Same WP used in VBF

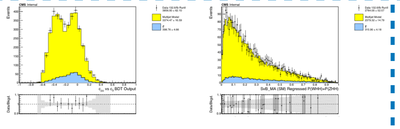
Background



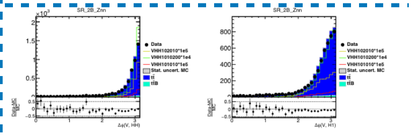
ZLL



WLn



Had



MET

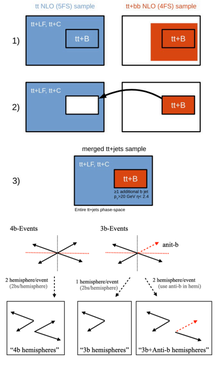
- ttbar: MC

$t\bar{t}b\bar{b}$ in Powheg NLO $t\bar{t}$ 5FS sample is from parton shower which will bring large uncertainties.
Replace $tt+B$ events in tt(5FS) with ttbb(4FS).

- V+Jet: MC

DY+Jets will be reweighted to NLO as a function of Z pT.

Lacking MC events in signal region will bring statistic uncertainties.
Use 2 b-tagged events to be reweighted to 3/4 b-tagged events(signal).



- Multi-jet background: reweighted three-tag data (>= 4jets, exactly 3 b-tagged)
  - Jet Combinatoric Model (JCM): A weight only based on jet multiplicity
  - FvT Classifier: A weight mostly based on kinematic, derived by a neural network which has the same architecture with the SvB classifier.

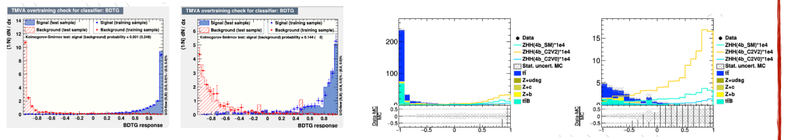
$$P_{4b,multijet} = P_{4b,data} - P_{4b,t\bar{t}}$$

- ttbar: MC

Observable

Leptonic Channel

3 Leptonic Channels X 2 Cats



6 SvB BDTs: Output will be used as the observable

Hadronic Channel

1 Hadronic Channel X 2 Cats

- Hierarchical Combinatoric ResNet(Residual Neural Network)

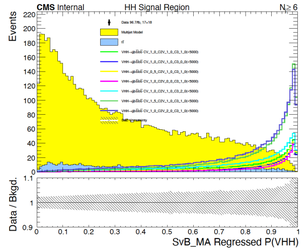
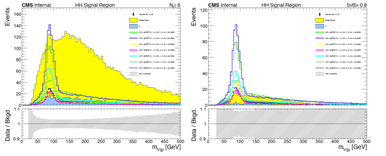


Figure: SvB Classifier Output

$m_{V_{jj}}$ after SvB Cut



(a) Before SvB cut (b) After SvB cut

J. Alison[3] A. Chayanit[4] Y. Lai[2] C. Liu[3] C. Palmer[2] X. Sun[1] L. Wang[2] L. Zhang[1]

1. Peking University (CN)
2. University of Maryland (US)
3. Carnegie-Mellon University (US)
4. Chulalongkorn University (THI)

lisheng.zhang@cern.ch