Update on $t\bar{t}t\bar{t}$ Searches in Single Lepton/OS Dilepton Channel Using 2016 Data

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Current Status

- Aiming at re-preapproval, all documentations are in place.
- We are requesting for the production of two new $t\bar{t}$ samples with 9M events each for the two channel(semi-lep and OS dilep), with dedicated cuts at generator level to increase MC stats by a factor of $\backsim$ 10 in high multiplicity/discriminant tails. Details on slide 18
- We are studying the effects of possible background from QCD multi jets with mis-identified leptons.

Data, MC and Objects

Data and MC

- Run2016 B-H, $35.9 pb^{-1}$
- Summer 16 MiniAOD MC for Morond 17
  - signal sample: $t\bar{t}t\bar{t}$ amc@NLO
  - background samples: $t\bar{t}$(backup, mass, width, magdraph), single $t(\bar{t})$, DY, W+jets, $t\bar{t} + Z/H/W/dibossons$

Objects

Single Lepton

- μ : tight ID, $p_T > 26$ GeV, $|\eta| < 2.1$, $Iso < 0.15$
- e : tight ID, $p_T > 35$ GeV, $|\eta| < 1.4442$ or $1.566 < |\eta| < 2.1$
- *jet* : loose ID, $p_T > 30$ GeV, $|\eta| < 2.1$, $\Delta R > 0.4$

OS Dilepton

- μ : loose ID, leading(subleading) lep $p_T > 25(20)$ GeV, $|\eta| < 2.4$, $Iso < 0.15$
- e : loose ID, leading(subleading) lep $p_T > 25(20)$ GeV, $|\eta| < 1.4442$ or $1.566 < |\eta| < 2.4$
- *jet* : loose ID, $p_T > 30$ GeV(25 GeV if tagged as b), $|\eta| < 2.4$, $\Delta R > 0.4$

Event Selection and MC Re-weighting

Event selection

Single Lepton

- N_l^{tight}=1
- $N_\mu^{loose} = 0, N_e^{veto} = 0$
- $N_j \geq 8(7)$ in $e(\mu)$ channel of which $N_{tags}^M \geq 2$
- $\not{E}_T > 50$ GeV
- $HT \geq 500$ GeV

OS Dilepton

- Exactly 2 OS leptons
- $M_{ll} \geq 106$ GeV or $76 \geq M_{ll} \geq 20$ GeV
- $N_j \geq 4$ of which $N_{tags}^M \geq 2$
- $HT \geq 500$ GeV

MC Re-weighting

- Trigger eff.
- Lepton scales
- Pileup Reweight
- JER/JEC
- b-tagging eff.
- top p_T *reweight*

$t\bar{t}t\bar{t}$ Search Method

Binned analysis fitting on event level BDT

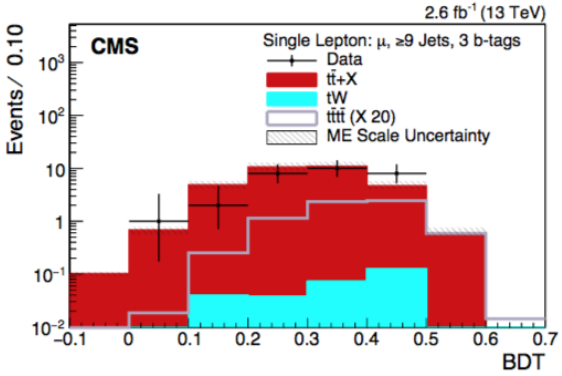


Figure: Single μ event level BDT in $\geq$9 jet 3 btag category

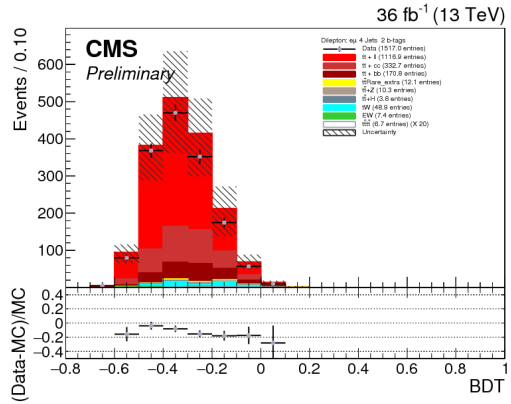


Figure: μe event level BDT in CR

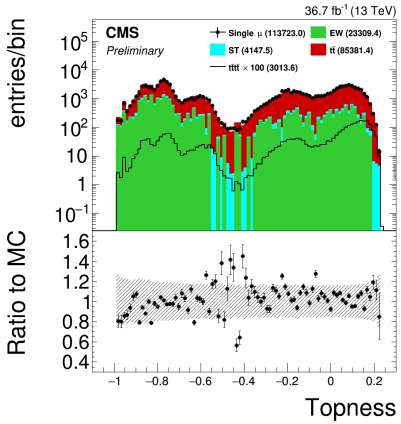
Event categorization in $N_j \otimes N_{tags}^M$ for limit fitting

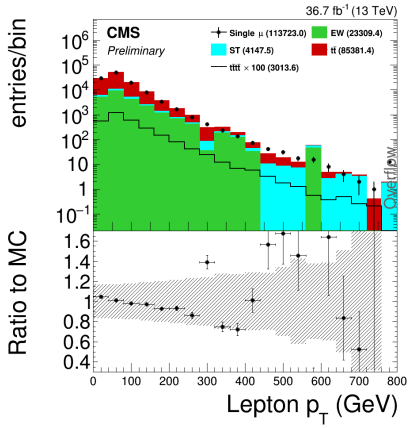
- Single lepton channel
  - μ: N_j: 7, 8, 9, 10+; N_{tags}^M: 2, 3, 4+
  - e: N_j: 8, 9, 10+; N_{tags}^M: 2, 3, 4+
- OS Dilepton channel: N_j: 4-5, 6-7, 8+; N_{tags}^M: 2, 3+

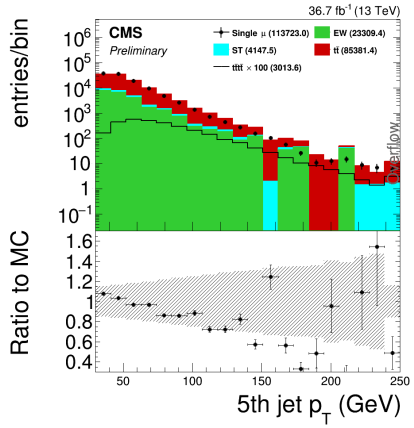
Input Variables and Some Data/MC Agreement Plots

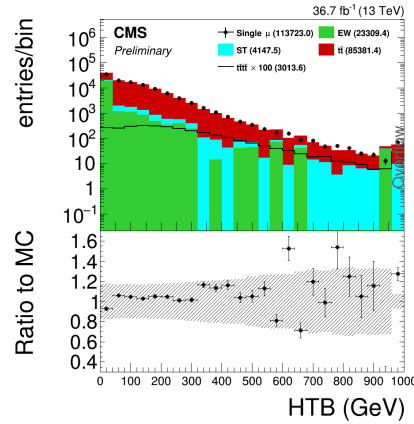
- Single lepton channel

$BDT_{trijet2}$, HTH, H_T^b, H_T^{Rat}, p_T^{5thjet}, p_T^{6thjet}, M_{RE}^H, HT_X, p_T^{lep}, CSV_3, CSV_4, CSV_{3rdjet}, CSV_{4thjet}



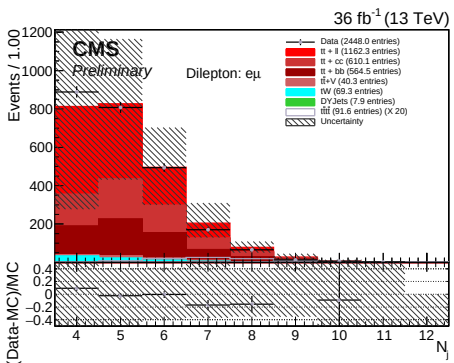


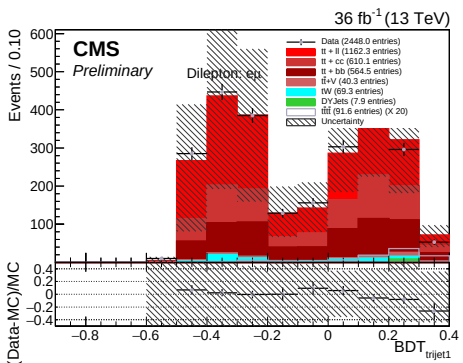


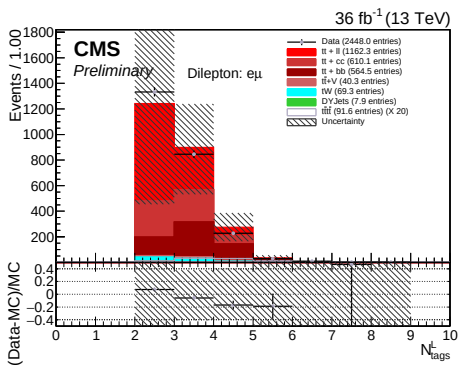


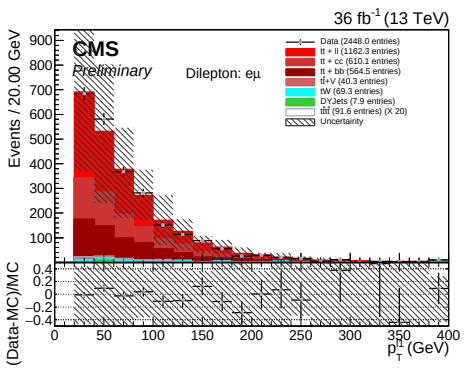
- OS Dilepton channel

N_j, $BDT_{trijet1}$, H_T^b, H_T^{2M}, HTH, S, H_T^{Rat}, p_T^{l1}, η^{l1}, ΔR_{ll}, ΔR_{bb}, N_{tags}^L, N_{tags}^M, p_T^{3rdjet}, p_T^{4thjet}









- Overall reasonable distributions agreements within uncertainties.

Sources of Systematic Uncertainties

Experimental Uncertainties

- Luminosity uncertainty
- Pileup $\pm 1\sigma$
- Lepton SFs uncertainty
- JER $\pm 1\sigma$
- JES(split)
  - SubTotalPileUp
  - SubTotalRelative
  - SubTotalPt
  - SubTotalScale
  - Jet flavor
- b-tag CSV $\pm 1\sigma$
- Heavy flavor fraction
- Top p_T reweight
- Jet normalization

Theoretical Uncertainties

- ME scale
- MC cross sections
- UE tune
- PS scale
- ME-PS matching
- PDF

Fitting Strategy

- Likelihood fit using Combine Tool
- Fit is performed on event level BDT output discriminator
- Fit is performed in different $N_j \otimes N_{tags}^M$ categories simultaneously.
- Blind highest jet/tag multiplicity categories.
  - single lepton: blind 10+ jets & 4+ tags category
  - OS dilepton: blind 8+ jets & 3+ tags category
- Combine results from single lepton channel and OS dilepton channel.

Template Fit in Single Lepton Channel

Table: Single lepton blinded fitting results

Channel	Expected limit $\times \sigma^{SM}_{t\bar{t}t\bar{t}}$	Expected xsec $\times fb$	Expected significance
e			
μ			
combined			

Nuisance Pulls of Single Leptonic Fit

Impact of Nuisance Parameters

Template Fit in OS Dilepton Channel

Table: OS dilepton blinded fitting results

Channel	Expected limit $\times \sigma^{SM}_{t\bar{t}t\bar{t}}$	Expected xsec $\times fb$	Expected significance
$\mu\mu$			
$e\mu$			
ee			
combined			

Nuisance Pulls of OS Dileptonic Fit

Impact of Nuisance Parameters

Combined Results

Table: Single lepton + OS dilepton blinded combined results

Channel	Expected limit $\times \sigma^{SM}_{t\bar{t}t\bar{t}}$	Expected xsec $\times fb$	Expected significance
l+jets			
OS ll+jets			
combined			

Backups

Event level BDT overtraining check

Genfilter Studies