

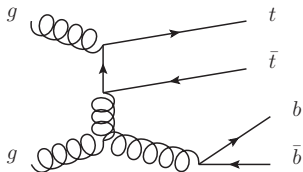
Differential $t\bar{t}+b(\bar{b})$ Cross Section Measurement at 13 TeV in the Dileptonic Channel

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DESY

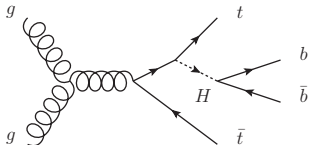
March 19, 2017





Motivation for $t\bar{t}+b\bar{b}$ Measurement

- Important BG for SM and BSM searches
 - Irreducible background for $t\bar{t}H(b\bar{b})$
 - Dominant uncertainty in $t\bar{t}H(b\bar{b})$
- Input for NLO calculations



Goals

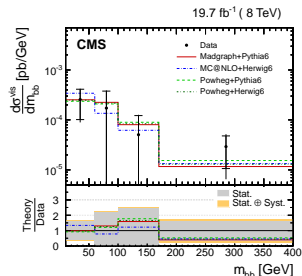
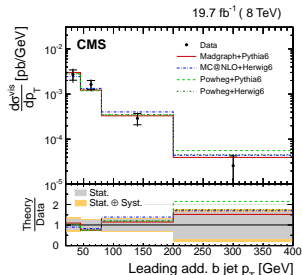
- Differential cross sections at 13 TeV
- Comparison to several theoretical predictions

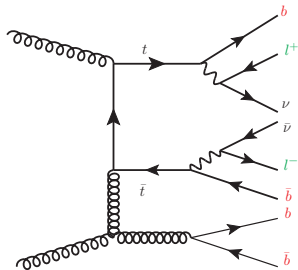
- Work in progress!

[arXiv:1510.03072] (8 TeV)

Measurement of differential cross sections

- Goal: Differential XS of "additional" jets
 - 1st, 2nd additional jet p_T , $|\eta|$
 - $\Delta R_{b\bar{b}}$, $m_{b\bar{b}}$
- First: Identify b-jets from $t\bar{t}$ pair
- Sort remaining (additional) b-jets by p_T
- Compare data to particle level predictions
 - Unfold data
 - Remove background contribution





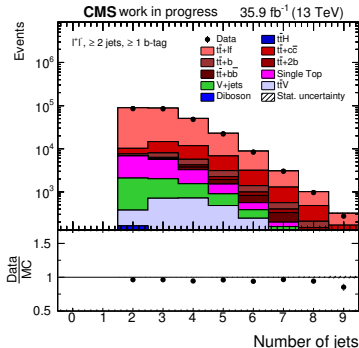
➤ Single- and dilepton triggers

➤ Leptons:

- Two opposite sign leptons
- m_{ll} : veto low mass resonances
- Same flavour: veto Z mass window
- Require large MET

➤ Jets:

- Two jets $p_T > 30$ GeV, additional jets $p_T > 20$ GeV
- ≥ 3 b tagged jets



➤ $t\bar{t}$, $t\bar{t}H$: Powheg+Pythia8

➤ V+j, $t\bar{t}V$: MG5aMC@NLO+Pythia8

➤ VV: Pythia8

Estimation of $t\bar{t}$ +HF Contribution

➤ Motivation:

- Data-MC agreement for unfolding
- Background estimation

➤ Fit b-tag multiplicity

➤ Producing templates for:

- **$t\bar{t}$ +HF**: $t\bar{t}+b\bar{b}$, $t\bar{t}+b$, $t\bar{t}+2b$
- **$t\bar{t}$ +Other**: $t\bar{t}+c\bar{c}$, $t\bar{t}+LF$
- **Other backgrounds**
 - V+Jets, VV, $t\bar{t}V$, $t\bar{t}H$

ttbb

●● or more b jets

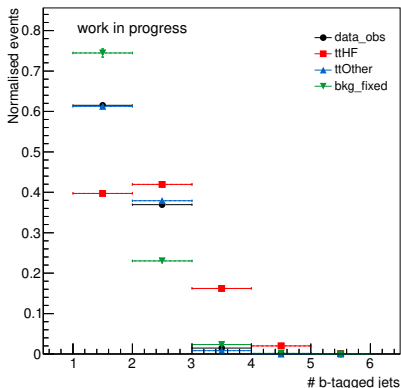
ttb

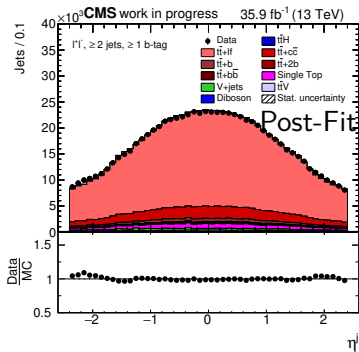
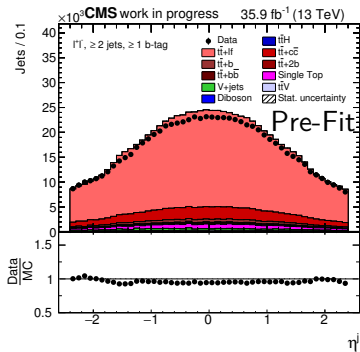
●○ not in acceptance

tt2b

●● overlapping

B-tagged jet multiplicity





- Data/MC agreement improves with HF scale factor
- Agreement before corrections is already reasonable
- Changes are small



Identification of Jets Originating from $t\bar{t}$ (RECO)

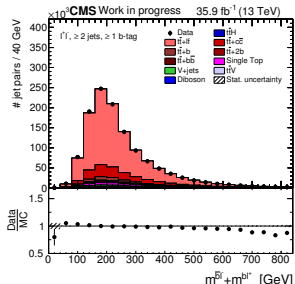
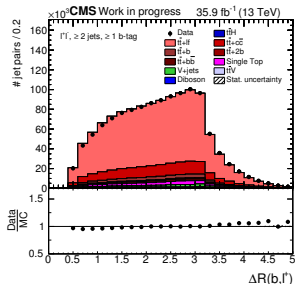
➤ Use jet charge to distinguish b and \bar{b}

$$c_{rel} = \frac{\sum_{i=1}^n c_i (\vec{p}_{jet} \cdot \vec{p}_i)^x}{\sum_{i=1}^n (\vec{p}_{jet} \cdot \vec{p}_i)^x}$$

➤ Use BDT to find jets from top quark decay

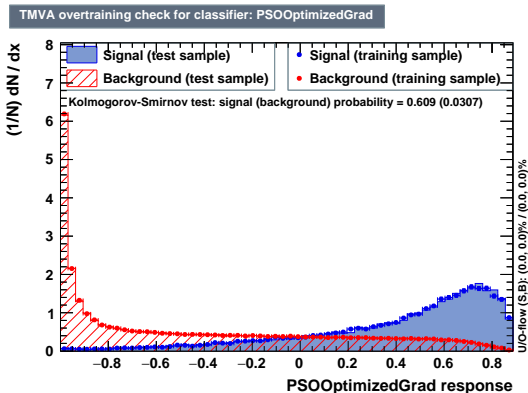
➤ BDT input variables:

- $c_{rel}^b - c_{rel}^{\bar{b}}$ jet charge
- $\Delta R^{b,l^+}, \Delta R^{\bar{b},l^-}$
- $|\Delta\phi^{bl^+}, \bar{b}l^-|$
- $p_T^{b,l^+}, p_T^{\bar{b},l^-}$
- $m^{b,l^+} + m^{\bar{b},l^-}$
- $m^{b,l^+} - m^{\bar{b},l^-}$
- $m^{b\bar{b}l^+l^-} - m^{b\bar{b}}$
- $\frac{1}{2}(m_t^{bE_t^{miss}} + m_t^{\bar{b}E_t^{miss}})$

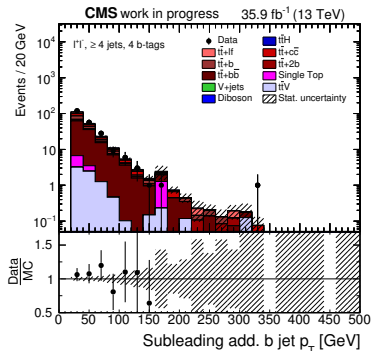
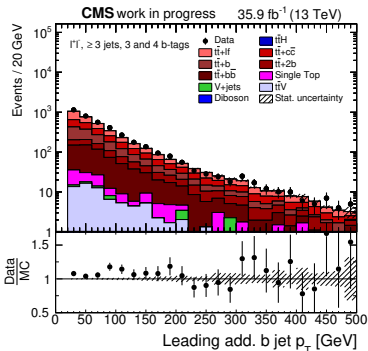


MVA: Training and Evaluation

- ▶ Training:
 - Powheg+Pythia8 $t\bar{t}$ +jets events
 - Train on ≥ 3 jets, 3 b-tags, and 4 jets, 4 b-tags events
 - Signal(Background): Correct(Wrong) assignment of b jets from $t\bar{t}$ decay
- ▶ Optimization
 - Hyperparameter, sets of variables
 - Criteria: Good separation power, no overtraining



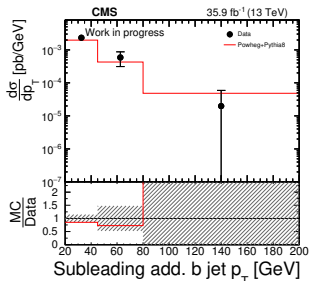
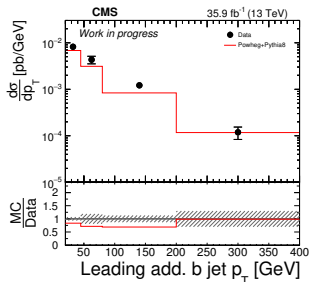
- Behavior of additional jets of key interest from theory community
- Additional jets as defined by MVA



- Simple distributions are well described

Absolute Differential Cross Sections

- Calculation of differential XS:
$$\frac{d\sigma}{dx_i} = \frac{\sum_j A_{ij}^{-1} (N_j^{data} - N_j^{bkg})}{\Delta x_i \cdot L}$$



- Absolute XS: Powheg+Pythia8 scaled to NNLO XS
- ≈ 25% deviation between data and Powheg+Pythia8
- As seen in the fit
 - Consistent with other ongoing measurements



Summary

- $t\bar{t}+b\bar{b}$ is important for SM and BSM physics
- Improved stat. uncertainty wrt. 8 TeV analysis by factor of 2.1
- Monte Carlo shows good agreement with 2016 Data

Next Steps

- Study of systematic uncertainties ongoing
- Differential cross sections:
 - Compare to NLO calculations: Sherpa, PowHel, Herwig 7
 - Close collaboration with Maria Vittoria Garzelli (PowHel) to provide 13TeV $t\bar{t}+b\bar{b}$ predictions
- Rivet routine
 - Explore kinematic reconstruction for $t\bar{t}+b\bar{b}$

Thank you very much
for your attention!



BACKUP

Datasets

➤ Data: $L = 35.867 \pm 0.9 \text{ fb}^{-1}$, 2016

- Signal: Powheg+Pythia8
- Background:
 - Single Top: Powheg+Pythia8
 - Diboson: Pythia8
 - V+Jets, $t\bar{t}+V$: MG5aMC@NLO+Pythia8
- Additional simulations for comparison with unfolded results:
 - Powheg+Herwig++
 - Production/Evaluation of other samples ongoing

➤ Applied Scale Factors

- Lepton ID/Iso
- b-tag
- PU reweighting
- JER and JES