

Measurement of the Cross section ratio $\sigma_{t\bar{t}b\bar{b}}/\sigma_{t\bar{t}jj}$ in pp collisions at $\sqrt{s} = 8$ TeV

Javier Brochero
Chonbuk National University



Introduction

One of the most promising channels for a direct measurement of the top quark Yukawa coupling is the one where the newly observed scalar boson is produced in association with a $t\bar{t}$ pair. In the standard model, the new boson decays mostly to $b\bar{b}$ leading to a $t\bar{t}b\bar{b}$ final state which has an irreducible non-resonant QCD background of $t\bar{t}b\bar{b}$. Measuring the cross section ratio allows us to cancel many experimental uncertainties. This measurement can also provide an important test of NLO QCD calculations.

Visible phase space at generator level

- Two leptons (e, μ) from W boson including leptonic tau decay.

$$p_T^\ell > 20 \text{ GeV}, |\eta_\ell| < 2.4$$

- At least four jets: anti-kt and distance parameter 0.5.

$$p_T^{\text{jet}} > 20 \text{ GeV}, |\eta_{\text{jet}}| < 2.5$$

- At least two b-jets identified seeking B-hadrons among their ancestors.

Event selection

- At least one pair of two opposite sign isolated leptons

$$p_T^\ell > 20 \text{ GeV}, |\eta_\ell| < 2.4 \text{ and } M_{\ell\ell} > 12 \text{ GeV}$$

- Invariant mass $M_{\ell\ell} \notin [76, 106] \text{ GeV}$ and missing transverse energy $E_T^{\text{miss}} > 30 \text{ GeV}$ ($\mu^+\mu^-, e^+e^-$)

- At least four jets where at least two have been tagged as b jets

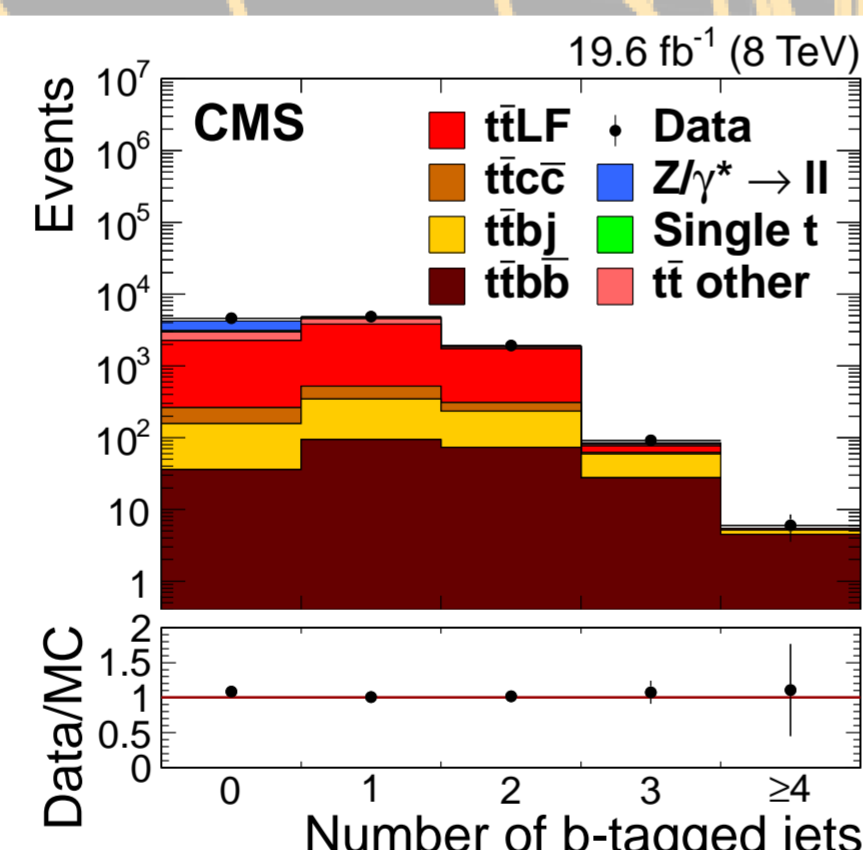
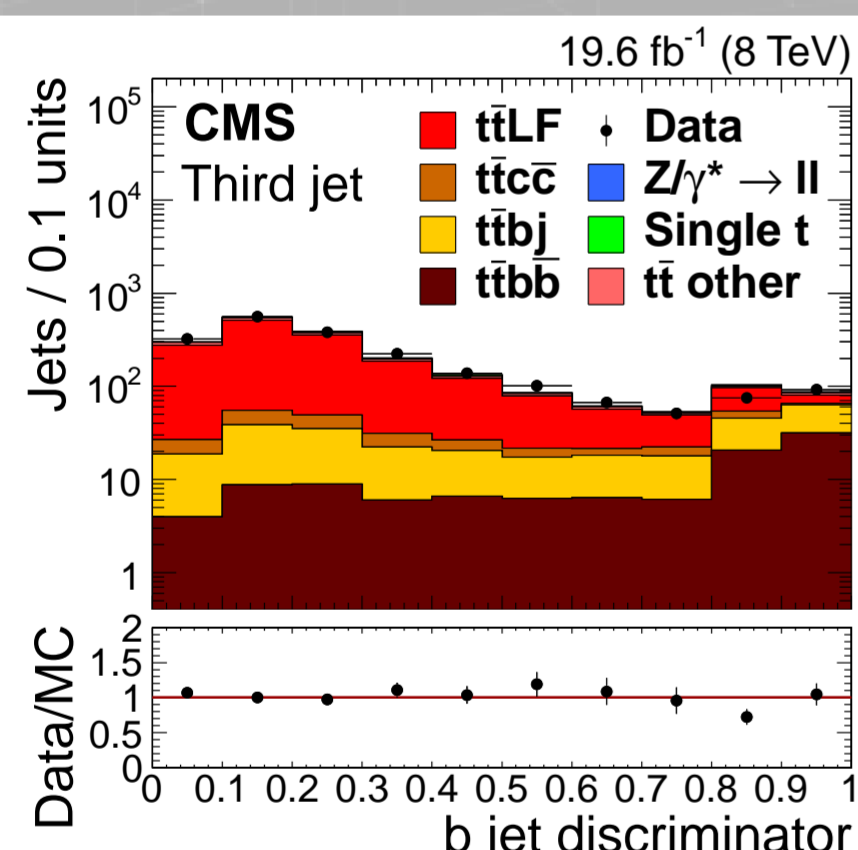
$$p_T^{\text{jet}} > 30 \text{ GeV}, |\eta_{\text{jet}}| < 2.5$$

Background estimation

- Contributions from Drell-Yan are estimated from Z candidates in data using the ratio of outside and inside Z mass window in simulation.
- QCD is estimated from data using like-sign lepton pairs.

Data and MC comparison

$t\bar{t}b\bar{b} = 105$ events



Systematic uncertainties

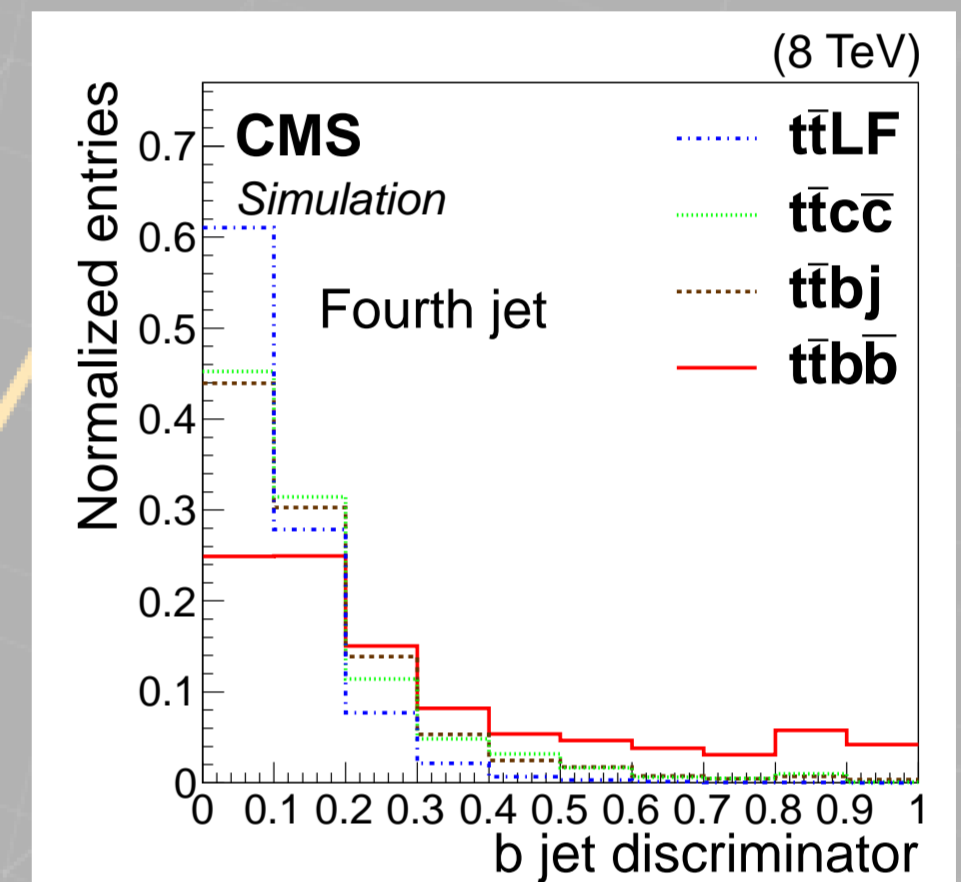
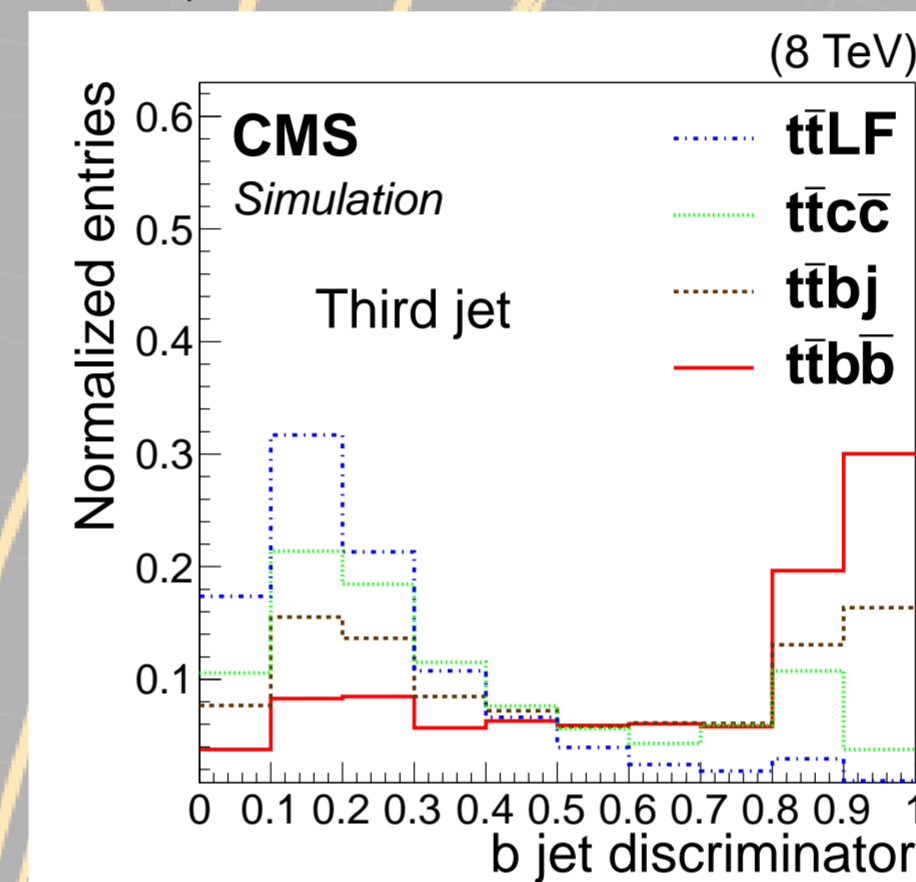
Source	$\sigma_{t\bar{t}b\bar{b}}$ [%]	$\sigma_{t\bar{t}jj}$ [%]	$\frac{\sigma_{t\bar{t}b\bar{b}}}{\sigma_{t\bar{t}jj}}$ [%]
Pileup	1.0	1.0	1.0
JES & JER	11	8.0	5.0
b tag (b quark flavour)	15	<0.1	15
b tag (c quark flavour)	4.0	<0.1	4.0
b tag (light flavour)	7.0	<0.1	7.0
Ratio of $t\bar{t}b\bar{b}$ and $t\bar{t}bj$	9.0	<0.1	9.0
Bkgnd modelling	1.0	1.0	1.0
$t\bar{t}c\bar{c}$ fraction in the fit	4.2	0.2	4.0
Lepton identification	4.0	4.0	—
MC generator	3.0	3.0	3.0
Q^2 scale	8.0	3.0	6.0
PS matching	12	5.0	3.0
PDF	4.0	4.0	<0.1
Eff. ($t\bar{t}c\bar{c}$ fraction)	—	1.6	1.6
Luminosity	2.6	2.6	—
Total uncertainty	28	12	22

Measurement

- Jets are ranked in decreasing order of the b-tagging discriminant.
- A simultaneous fit is performed to the b-tagging discriminant distributions of the 3rd and 4th jet.

$$f(k, R) = k \cdot N_{\text{bkg}}^{\text{MC}} + N_{\text{bkg}}^{\text{data-driven}} + k \cdot N_{t\bar{t}jj} \cdot \left[R \cdot N_{t\bar{t}b\bar{b}}^{\text{norm}} + R' \cdot N_{t\bar{t}bj}^{\text{norm}} + (1 - R - R') \cdot N_{t\bar{t}LF+t\bar{t}cc}^{\text{norm}} \right]$$

- R is the ratio of $t\bar{t}b\bar{b}$ over $t\bar{t}jj$ at the reconstruction level.
- R' is the ratio of $t\bar{t}bj$ over $t\bar{t}jj$, when constraining the ratio $t\bar{t}b\bar{b}/t\bar{t}bj$ to the MC prediction.



- Efficiency correction: $\mathcal{E}_{t\bar{t}b\bar{b}} = 18.7\%$ and $\mathcal{E}_{t\bar{t}jj} = 7.2\%$

$$\frac{\sigma_{t\bar{t}b\bar{b}}}{\sigma_{t\bar{t}jj}} = \frac{\mathcal{E}_{t\bar{t}jj}}{\mathcal{E}_{t\bar{t}b\bar{b}}} \cdot R$$

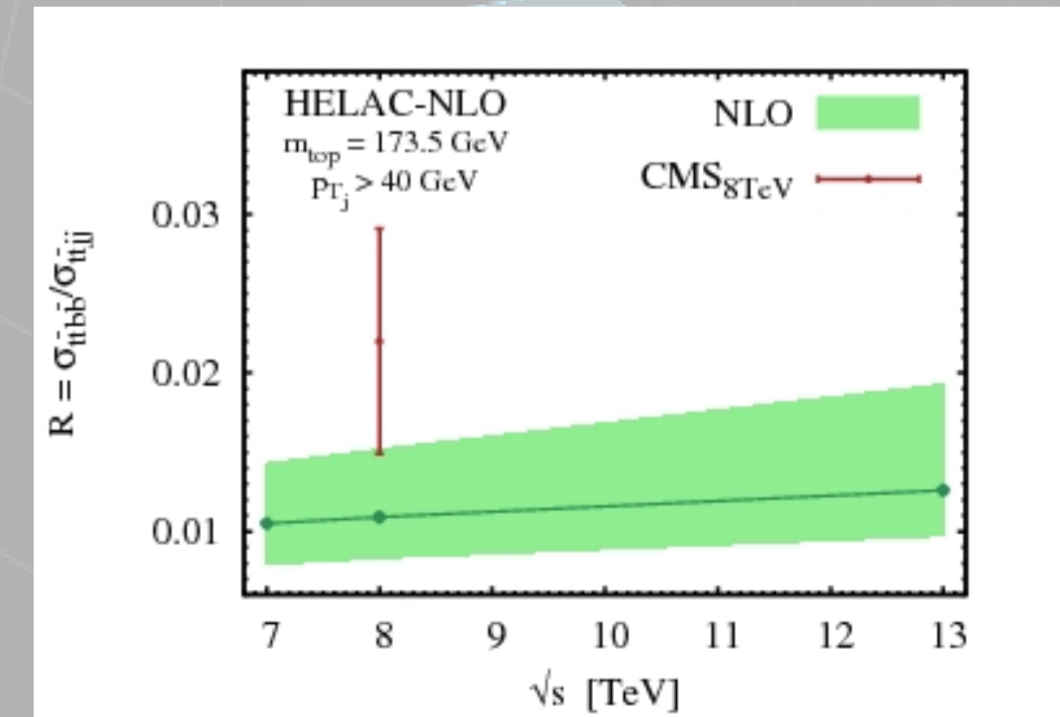
Results

- Visible phase space

$$\frac{\sigma_{t\bar{t}b\bar{b}}}{\sigma_{t\bar{t}jj}} = \begin{cases} 0.022 \pm 0.003(\text{stat.}) \pm 0.005(\text{syst.}), & p_T^j > 20 \text{ GeV} \\ 0.022 \pm 0.004(\text{stat.}) \pm 0.005(\text{syst.}), & p_T^j > 40 \text{ GeV} \end{cases}$$

- Full phase space: Top quark is treated as stable, i.e. no requirements on leptons and b jets from top quarks but on additional jets.

- CMS measurement[1] and NLO calculation[2] are compared.



Conclusion

We have measured the cross section ratio $\sigma_{t\bar{t}b\bar{b}}/\sigma_{t\bar{t}jj}$ in pp collisions at $\sqrt{s} = 8$ TeV. Data and theory predictions are compatible within their uncertainties. More precise measurements are expected with more data and will be a useful input for $t\bar{t}H$ searches.

References

- CMS Collaboration, "Measurement of the cross section ratio $\sigma_{t\bar{t}b\bar{b}}/\sigma_{t\bar{t}jj}$ in pp collisions at $\sqrt{s} = 8$ TeV", *CMS-TOP-13-010*, *CERN-PH-EP-2014-249* (2014) arXiv:1411.5621.
- G. Bevilacqua and M. Worek, "On the ratio of $t\bar{t}b\bar{b}$ and $t\bar{t}jj$ cross sections at the CERN Large Hadron Collider", *JHEP* **1407** (2014) 135, doi:10.1007/JHEP07(2014)135, arXiv:1403.2046.