# Cross section studies for $t\bar{t}$ +N jets final states

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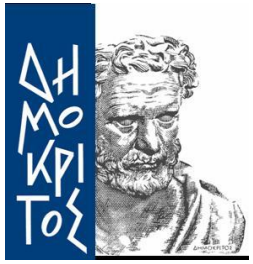
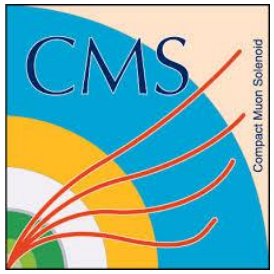




In collaboration with G. Anagnostou, G. Daskalakis, E. Elmalis

# Motivations & goals

- The process $pp \to t\bar{t} + jj$ is quite important SM process for testing QCD
- At the same time is an important background for new Physics searches.
- Our target is to measure its cross section with CMS data collected during 2012 (19.5 $fb^{-1}$) and compare the measurement with theoretical predictions.

# Theoretical Review of the study

**The** $pp \to t\bar{t} + jj$ process became very attractive for lot of theory groups to calculate it at one-loop level, since it is a background to the Higgs discovery process $pp \to t\bar{t}H \to t\bar{t} + b\bar{b}$

Fairly moderate corrections O(15%-30%) have been found.

**Bredenstein *et al.*** NLO QCD corrections to $t\bar{t}b\bar{b}$ production at the LHC:

1. quark-antiquark annihilation JHEP08 **108** (2008) **hep-ph/ 0807.1248**
2. gluon-gluon annihilation **hep-ph/ 0905.0110 (1001.4727,1001.4006)**

**G. Bevilacqua et al**. **hep-ph/0907.4723, 1002.4009, 1108.2851**

**T.Diakonidis, Bas Tausk** The case of $gg \to t\bar{t} + gg$

# Theoretical Review of the study

To give somebody an idea of the feynman diagrams that needed to be calculated at one loop level accuracy:

e.g. for the case of $pp \to \bar{t}t + jj$

TABLE I. *Partonic subprocesses contributing to the leading order process* $pp(p\bar{p}) \to t\bar{t}jj$ *at* $\mathcal{O}(\alpha_s^4)$. *The number of Feynman diagrams corresponding to these subprocesses is also shown.*

| Partonic Subprocess | Number Of Feynman Diagrams |
|---|---|
| $gg \to t\bar{t}gg$ | 123 |
| $gg \to t\bar{t}q\bar{q}$ | 36 |
| $q\bar{q} \to t\bar{t}gg$ | 36 |
| $gq \to t\bar{t}qg$ | 36 |
| $qg \to t\bar{t}qg$ | 36 |
| $qq' \to t\bar{t}qq'$ | 7 |
| $q\bar{q} \to t\bar{t}q'\bar{q}'$ | 7 |
| $q\bar{q} \to t\bar{t}q\bar{q}$ | 14 |

TABLE II. *The number of one-loop Feynman diagrams for the* $pp(p\bar{p}) \to t\bar{t}jj$ *process at* $\mathcal{O}(\alpha_s^5)$.

| Partonic Subprocess | Number Of Feynman Diagrams |
|---|---|
| $gg \to t\bar{t}gg$ | 4510 |
| $gg \to t\bar{t}q\bar{q}$ | 1100 |
| $q\bar{q} \to t\bar{t}gg$ | 1100 |
| $gq \to t\bar{t}qg$ | 1100 |
| $qg \to t\bar{t}qg$ | 1100 |
| $qq' \to t\bar{t}qq'$ | 205 |
| $q\bar{q} \to t\bar{t}q'\bar{q}'$ | 205 |
| $q\bar{q} \to t\bar{t}q\bar{q}$ | 410 |

# Theoretical Review of the study

Representative sets of Feynman diagrams for tree and one loop level for the case of $pp \to \bar{t}t + jj$

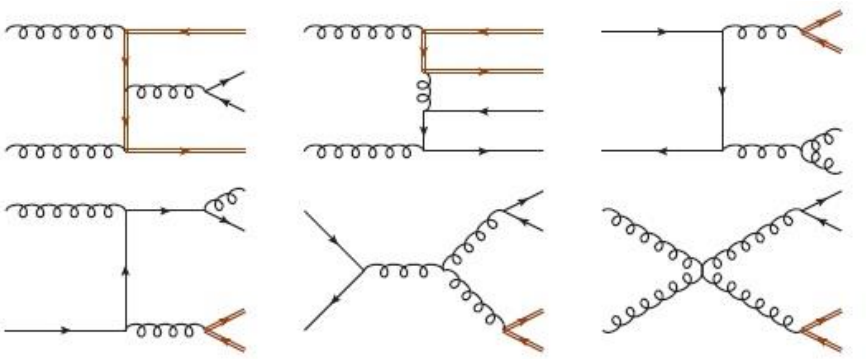


FIG. 1. *A representative set of Feynman diagrams contributing to the LO hadronic $t\bar{t}jj$ production at $\mathcal{O}(\alpha_s^4)$. Double brown lines correspond to top quarks, single lines to light quarks and wiggly ones to gluons.*

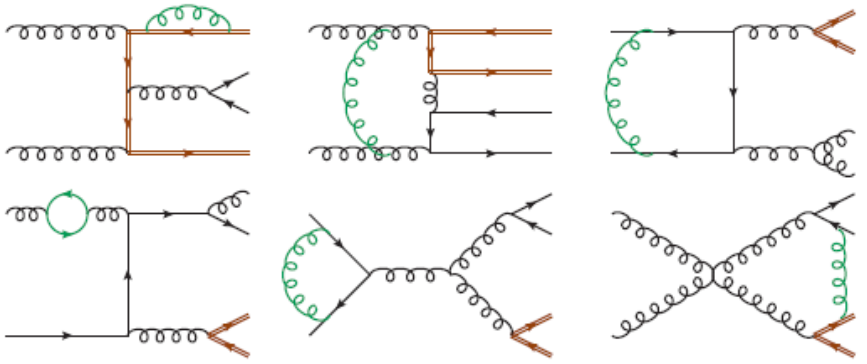


FIG. 2. *A representative set of Feynman diagrams contributing to the virtual corrections to hadronic $t\bar{t}jj$ production at $\mathcal{O}(\alpha_s^5)$. Double brown lines correspond to top quarks, single lines to light quarks and wiggly ones to gluons.*

# Theoretical Review of the study

The absolute cross sections and corresponding theoretical errors at one loop order for the CMS at 8 TeV for the most relevant to study processes:

$$\sigma^{NLO}_{t\bar{t}b\bar{b}} = (LHC_{8TeV}, M_t = 173,5GeV, CT10) = 229.3^{+40.7}_{-55.7}\,[fb]$$

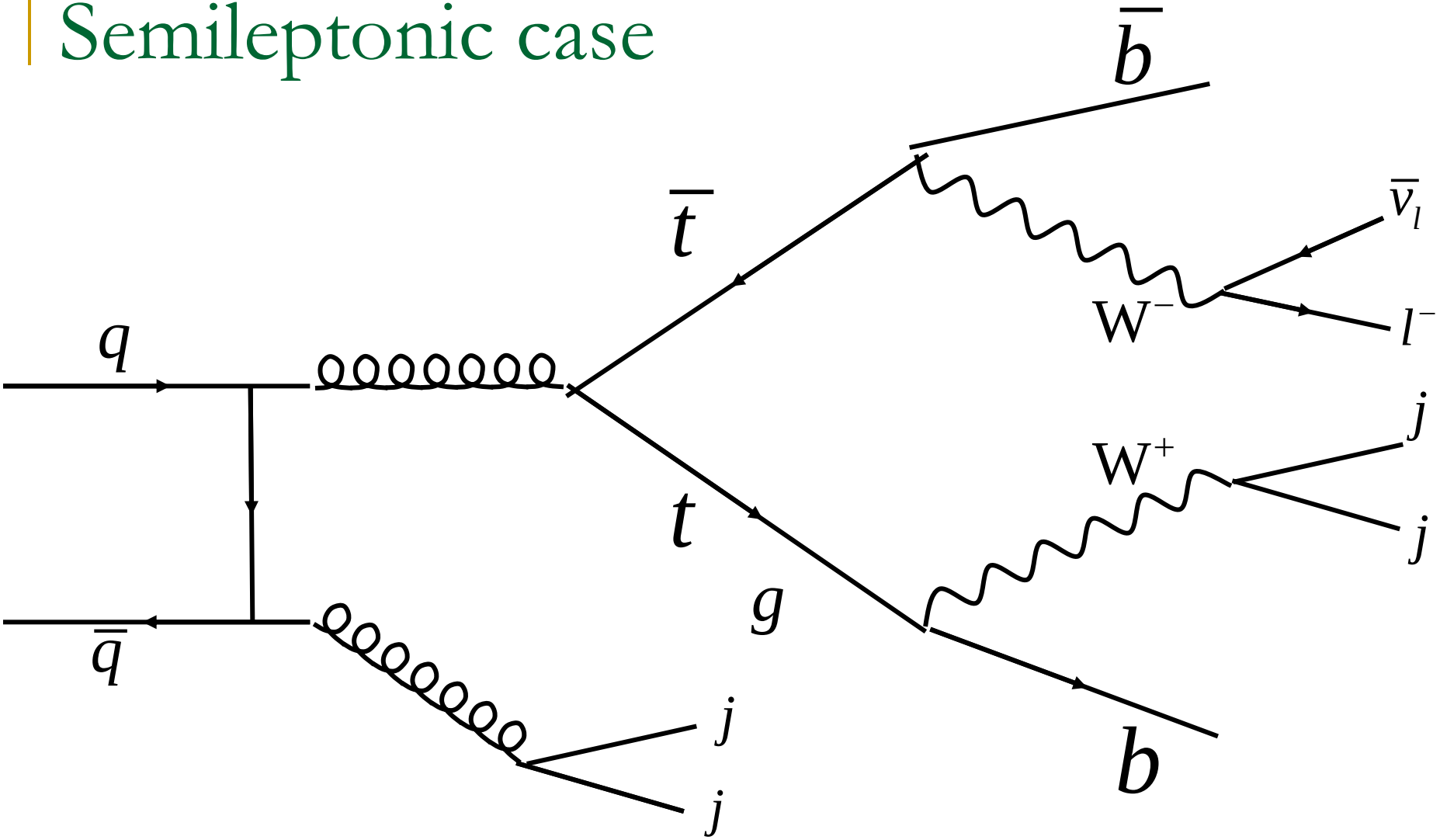
$$\sigma^{NLO}_{t\bar{t}jj} = (LHC_{8TeV}, M_t = 173,5GeV, CT10) = 20.97^{-3.25}_{-2.79}\,[pb]$$

The tables and figures and cs were taken from **G. Bevilacqua et al**. **hep/ph. 1108.2851 1403.2046**

# Our specific final state

- We are mainly interested for the **semileptonic** final state of the  system:
- So one top decays to W and b and then W decays semileptonically to electrons & muons
- The other top decays to W b and W decays to two jets.
- So our final state contains: e or μ , at least 4 jets with 2 of them identified as b-jets and MET from neutrino.
- Main background processes are : the other modes of ttbar, single top, Wjets, Zjets, VV, QCD

# Semileptonic case



# Experimental Signature

- Triggers

Single muon : HLT_IsoMu24_eta2p1_vX

It requires at least one isolated muon with $P_T$ > 24GeV on trigger object level

Single electron : HLT_Ele27_WP80_v10

Accepts an event if an electron with $E_T$ > 27GeV has been found at HLT object level

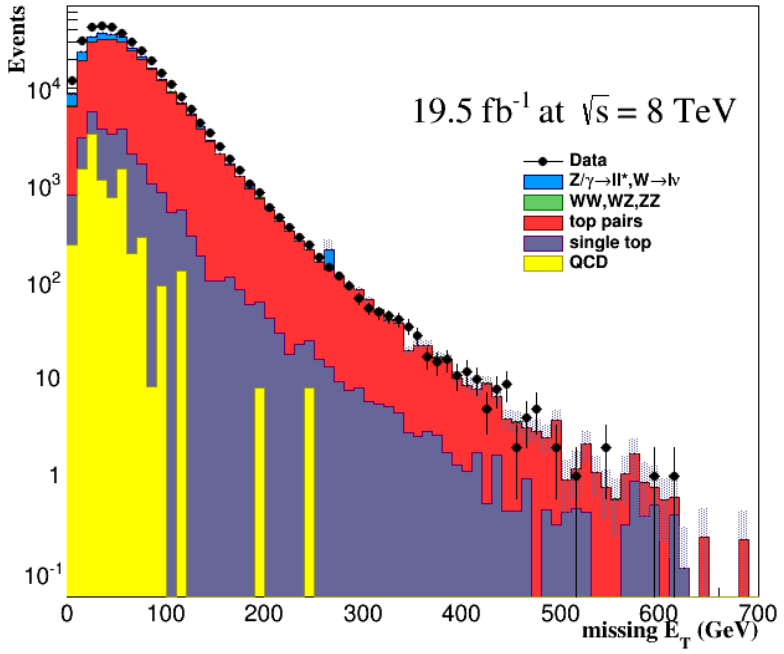
Unprescaled through the whole 2012

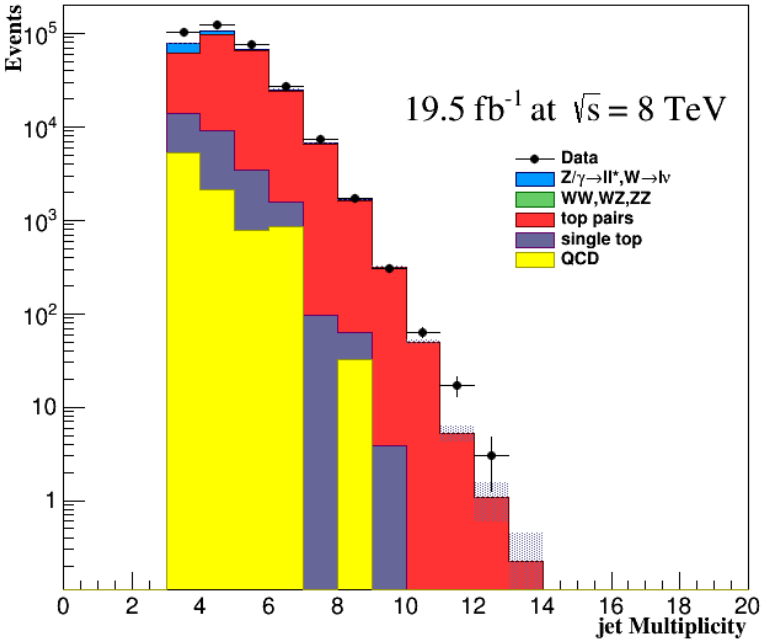
- 2 B-tagged jets (tagged with the CSV) with $P_T$ >35.0 GeV and () $|\eta|$<2.4 plus one additional jet with $P_T$ >35.0 GeV

- Most energetic lepton (tight) with $P_T$ > 30.0 GeV

and $|\eta|$<2.4

# MET & Multiplicity (first look)




All backgrounds from MC. No data-driven methods applied yet.

# Data driven Background treatment

- W+jets

Charge asymmetry is expected in W+jets (more up quarks that down)

$$N_{WJets} \sim \frac{N_D^+ - N_D^-}{A_W}$$

- QCD

Is not well reproduced by MC

The idea is to suppress it as much as possible through our selection and estimate what remains with data driven methods

# The Cross Section measurement

The total cross section to measure is given by:

$$\sigma \cdot BR = \frac{N_{data} - N_{bkg}}{L \cdot ACC \cdot EFF}$$

- $N_{data}$ the number of observed events in data.
- $N_{bkg}$ number of estimated background events.
- BR The branching ratio of the considered channel
- L the integrated luminosity (19,5 $fb^{-1}$)
- ACC the acceptance (geometric and kinematic)
- EFF the efficiency for signal events to pass the selection

# Systematic Uncertainties

**EXPERIMENTAL**

- Luminosity
- Jet Energy Scale
- Trigger and lepton selection efficiencies
- Jet energy resolution
- B-tagging (efficiencies and mistagging rates)
- Pileup

# Systematic Uncertainties

**THEORETICAL**

- The matrix Element/ Parton shower matching threshold
- Factorisation scale $Q^2$
- Effects due to uncertainties on the PDFs

# Future plans

- Control better the W+ jets and QCD background
- Apply all the data driven methods to have an even better agreement between data and MC.
- The target seems really challenging.

  A lot of work but worth doing it.

THANK YOU

# BACKUP SLIDES