Measurement of Distributions of Event Level Variables in Top Pair Events at 7 and 8 TeV

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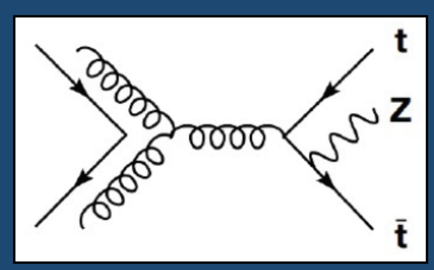
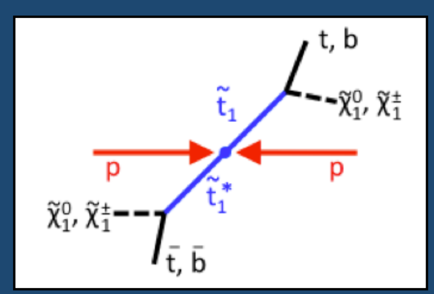
Measurements of differential top-quark pair production cross sections with respect to the global variables missing transverse energy (E_T^{miss}), jet transverse momentum sum (H_T), total observed transverse momentum sum (S_T), W-boson transverse mass (M_T^W) and W-boson transverse momentum (p_T^W) are presented, using 5.0 fb^{-1} of data from CMS at √s = 7 TeV and 19.7 fb^{-1} of data at √s = 8TeV. The semi-leptonic channel is investigated, where the leptonically decaying W-boson decays to a muon or an electron.

Motivation

- Top pair events are a background for new physics and so need to be well understood. It is also important for understanding QCD and event generators.
- Deviations in the distributions of the variables under investigation could shed light on:
- Anomalous production of rare Standard Model processes like $t\bar{t}$ + W → lν or $t\bar{t}$ + Z → νν which would show up in the E_T^{miss} distribution tail





- $t\bar{t}$ + X (where X is massive and visible) would show up in the H_T/S_T distributions
- New physics with undetectable new particles such as stop pair production → lightest supersymmetric particles (possible dark matter candidate)

Selection

- Electron channel: one electron p_T > 30 GeV/c, |η| < 2.5
- Muon channel: one muon pT > 26 GeV/c, |η| < 2.1
- ≥ 4 jets of p_T > 30 GeV/c
- ≥ 2 b-tagged jets for high purity signal sample
- Veto additional leptons

Background Estimation

There are four major backgrounds to $t\bar{t}$ production:

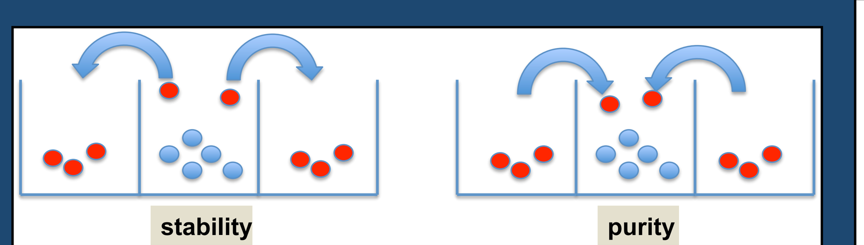
- W + jets events
- Z + jets events
- Single top events
- QCD

The first three are taken from Monte Carlo, while QCD is modelled using data-driven techniques:

- Electron channel: conversion region
- Muon channel: inverted isolation region (>0.3)

Binning Choice

- Analysis for each variable is carried out in bins
- Boundaries chosen to minimise migration of events between bins during reconstruction
- Achieved by defining purity (p^k) and stability (s^k)



$$p^k = \frac{N^k_{rec\&gen}}{N^k_{rec}} \qquad s^k = \frac{N^k_{rec\&gen}}{N^k_{gen}}$$

- Higher values mean purer, more stable bins
- We require p^k and s^k to be above 0.5

Analysis Process (I)

- After selection, produce three templates of the lepton |η| for each bin of each variable:
  - Signal ($t\bar{t}$ + single top)
  - V + jets (W + jets and Z + jets)
  - QCD
- In each bin, log likelihood fit of the three templates to data is carried out

Analysis Process (II)

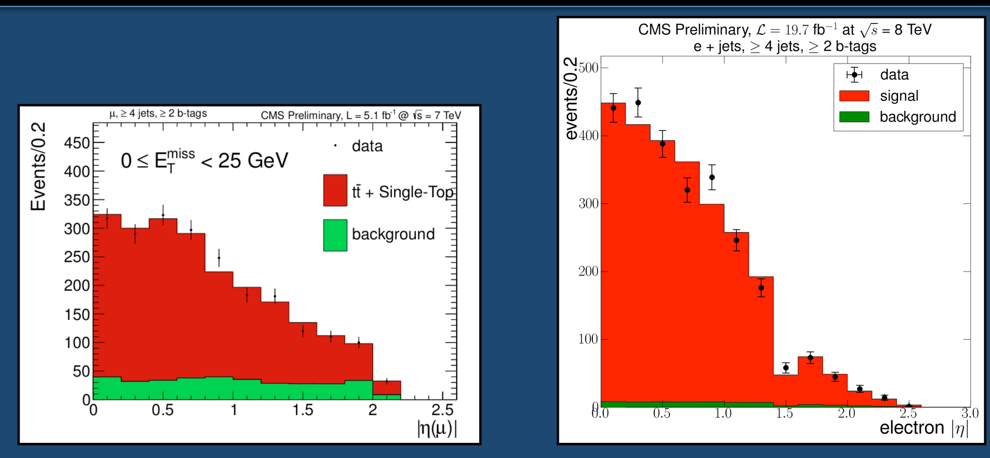


Figure 1: Distribution of lepton |η| after fitting in the muon channel in lowest E_T^{miss} bin (l) and in the electron channel in the highest E_T^{miss} bin (r)

- Subtract single top contribution from the fitted "signal" template to obtain number of $t\bar{t}$ events
- For each variable, the number of $t\bar{t}$ events in all bins is unfolded (see below)

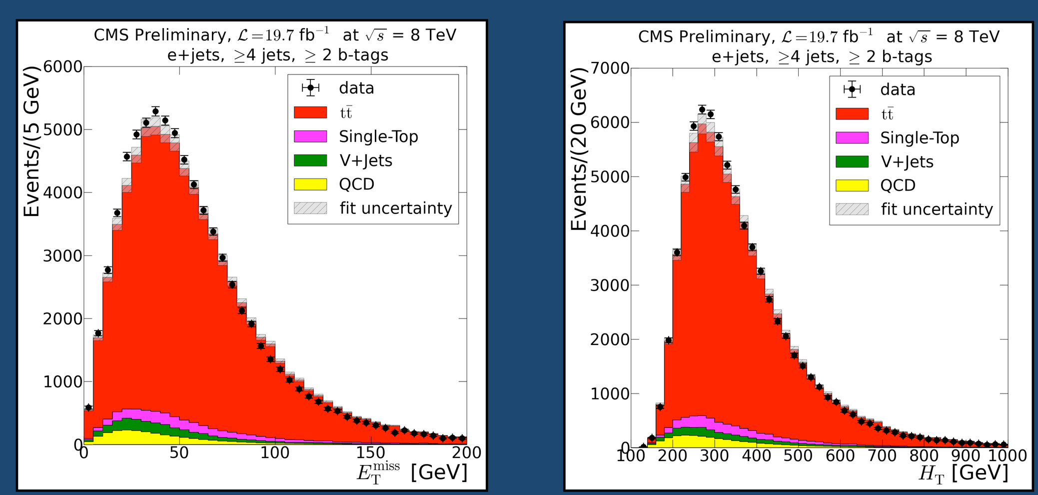


Figure 2: Distributions of E_T^{miss} and H_T after fitting in electron channel

- Unfolded number of $t\bar{t}$ events is used to calculate the normalised differential cross section
- Divide by branching ratio and luminosity for partial cross-section in a bin

$$\Delta\sigma^i_{t\bar{t}} = \frac{N^i_{t\bar{t}}}{\mathrm{BR}\times\epsilon\times\mathcal{L}}$$

- Divide by bin-width for differential cross-section in each bin

$$\frac{d\sigma^i_{t\bar{t}}}{dX} = \frac{\Delta\sigma^i_{t\bar{t}}}{\Delta X} = \frac{N^i_{t\bar{t}}}{\mathrm{BR}\times\mathcal{L}\times\Delta X}$$

- Divide by total cross-section for normalised differential cross-section

$$\frac{1}{\sigma^{tot}_{t\bar{t}}}\frac{d\sigma^i_{t\bar{t}}}{dX} = \frac{1}{\sum_j \frac{d\sigma^j_{t\bar{t}}}{dX}}\frac{d\sigma^i_{t\bar{t}}}{dX}$$

Unfolding

- Singular Value Decomposition unfolding used to unfold the measured number of $t\bar{t}$ events to the true number of events
- Accounts for trigger, selection and identification efficiencies, and for finite detector resolution
- RooUnfold framework is used; requires the following Monte Carlo as input:
  - True and reconstructed variable
  - Response matrix (2D histogram) of true variable v. reconstructed variable
  - Regularisation parameter (k-value)

Results (I)

- Combination of channels is carried out by performing the calculation with the sum of the unfolded numbers of events from the muon and electron channels
- Results generally show good agreement between data and simulation when compared with generators
- Systematics measured by using central response matrix with systematically varied distribution as the reconstructed variable input
- Largest uncertainties arise from jet energy scale and W + jets background modelling

Results (II)

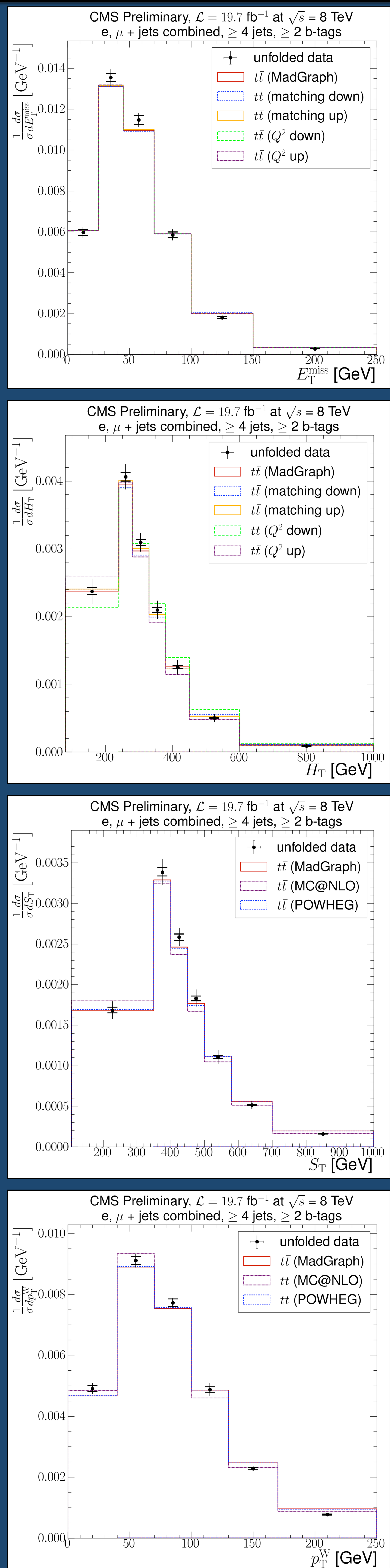


Figure 3: Combined normalised differential cross-section measurements at 8 TeV with respect to (from top to bottom) E_T^{miss} and H_T compared to theoretical systematic samples and S_T and p_T^W compared to different generators

Documentation

8 TeV: CMS-PAS-TOP-12-042, https://cds.cern.ch/record/1599734
7 TeV: CMS-PAS-TOP-12-019, http://cds.cern.ch/record/1478671

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