Measurement of Top Quark Pair Differential Cross-Sections

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CMS and LHC top Production

The LHC is now operating in an energy and luminosity regime that allows sufficiently high production of top-antitop pairs (~1 Hz!) that precision measurements of top quark quantities can be performed. These studies allow for the verification of top quark production mechanisms at a new energy scale and further test the standard model in the scope of perturbative quantum chromodynamics.

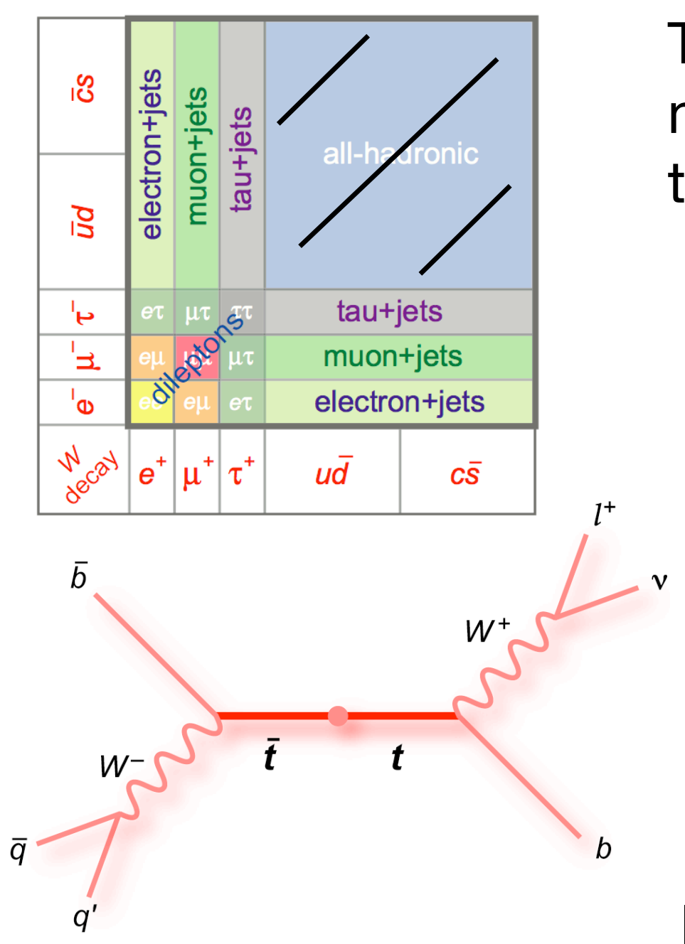
Precision top quark measurements will also provide the basis of searching for new production mechanisms and aid in the search for new physics.

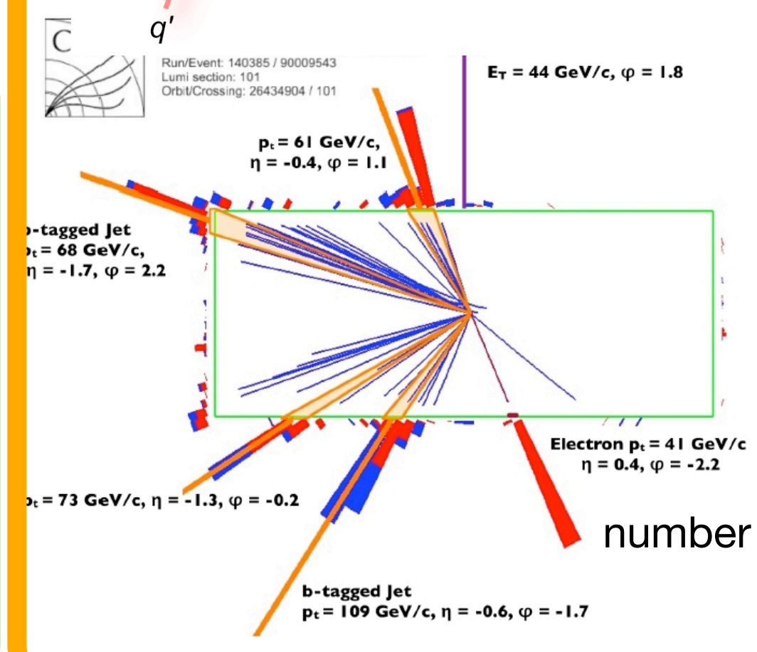
Visible phase space

The differential cross-section is normalized to unity by dividing by the cross-section measured in the visible phase space:

Dilepton:	e/μ + Jets:
lepton: $p_T(l) > 20$ GeV, $\|\eta(l)\|<2.4$	lepton: $p_T(l) > 30$ GeV, $\|\eta(l)\|<2.1$
parton: $p_T(q) > 20$ GeV, $\|\eta(q)\|<2.4$	parton: $p_T(q) > 30$ GeV, $\|\eta(q)\|<2.4$

Event selection and background determination

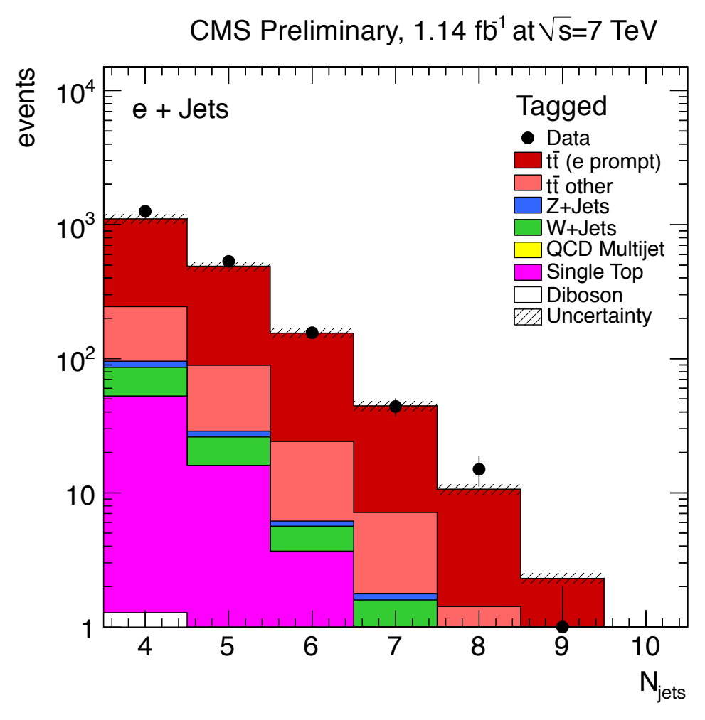




To eliminate the large backgrounds from non-top standard model processes at least one top is required to decay leptonically. Two further subchannels are defined:

e/μ + Jets:
- MET > 30
- |η|<2.4
- Exactly one lepton
- Four or more jets
- two b-tagged jets

Dilepton (ee/eμ/μμ):
- MET > 30 (not for eμ)
- |η|<2.4
- 2 oppositely charged leptons
- at least two jets
- at least one b-tag
- 76GeV< m_{ll}< 106GeV (not eμ)

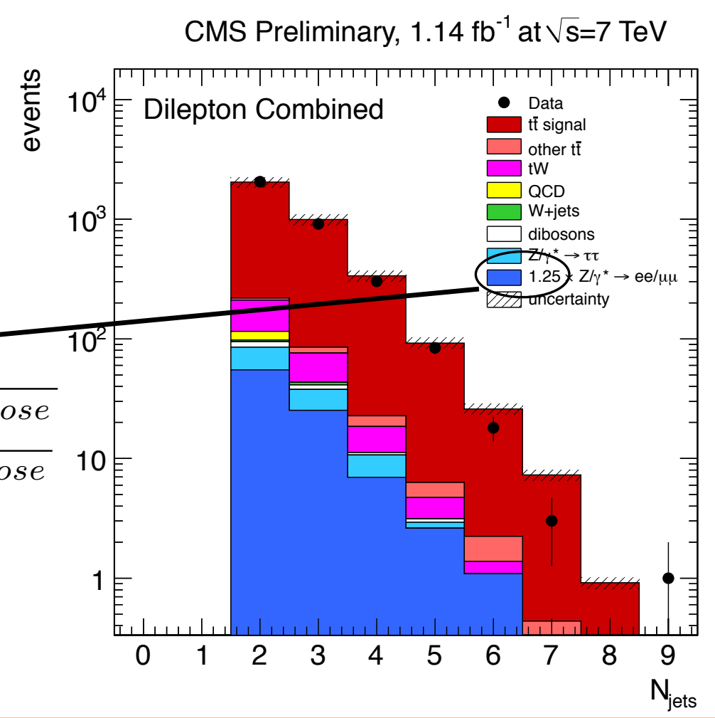


Data-driven background model:

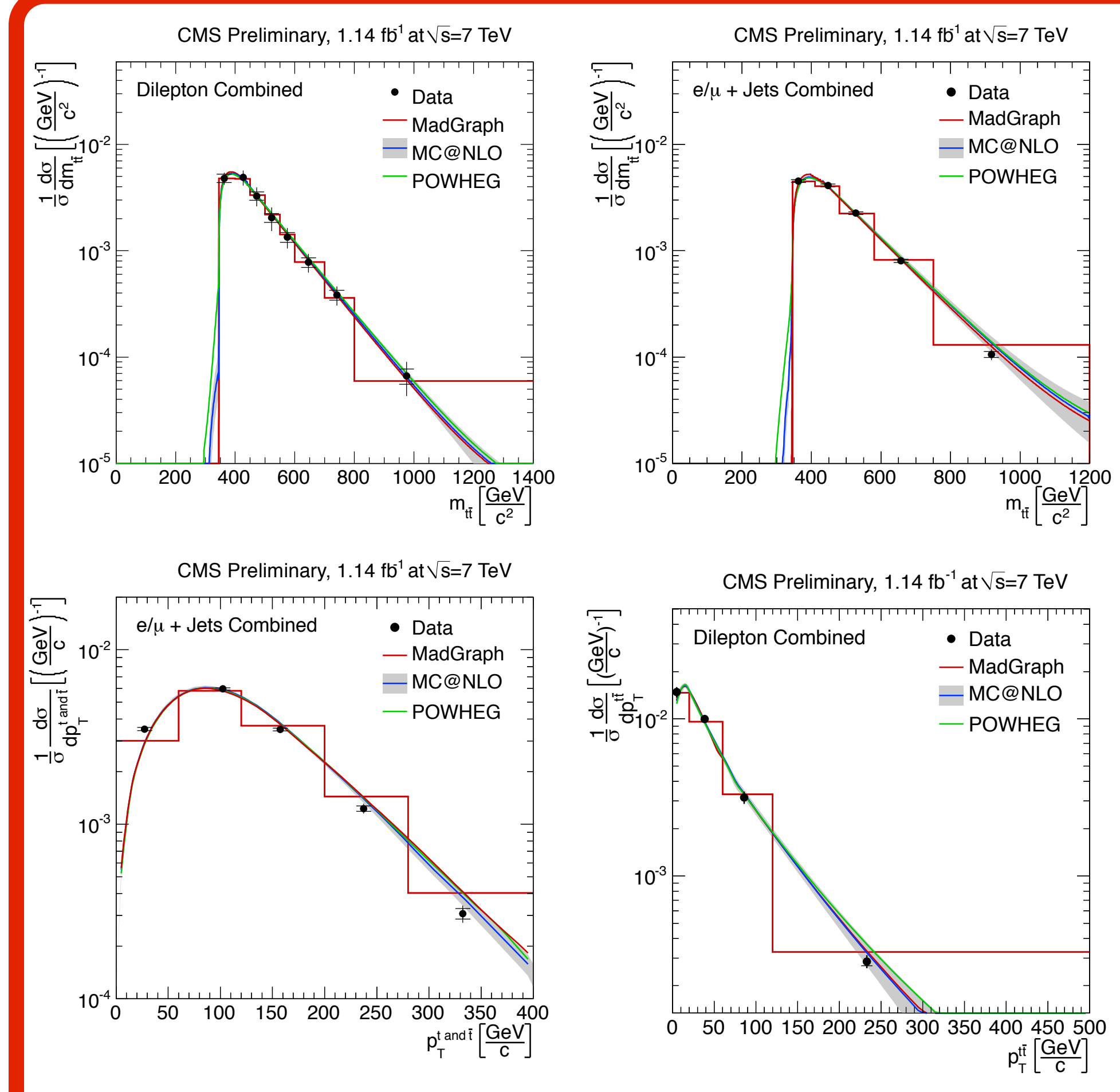
In the dilepton channel, the main source of background in the ee/μμ channels is expected to be from Drell-Yan pairs. We use a data driven approach to estimate the background outside the Z-mass veto region(76GeV< m_{ll} < 106GeV) from the data inside.

$$N^{ll}_{out} = R^{ll}_{out/in}\left(N^{ll}_{in} - 0.5N^{e\mu}_{in}k_{ll}\right) \qquad k_{\mu\mu} = \sqrt{\frac{N^{\mu\mu,loose}}{N^{ee,loose}}}$$

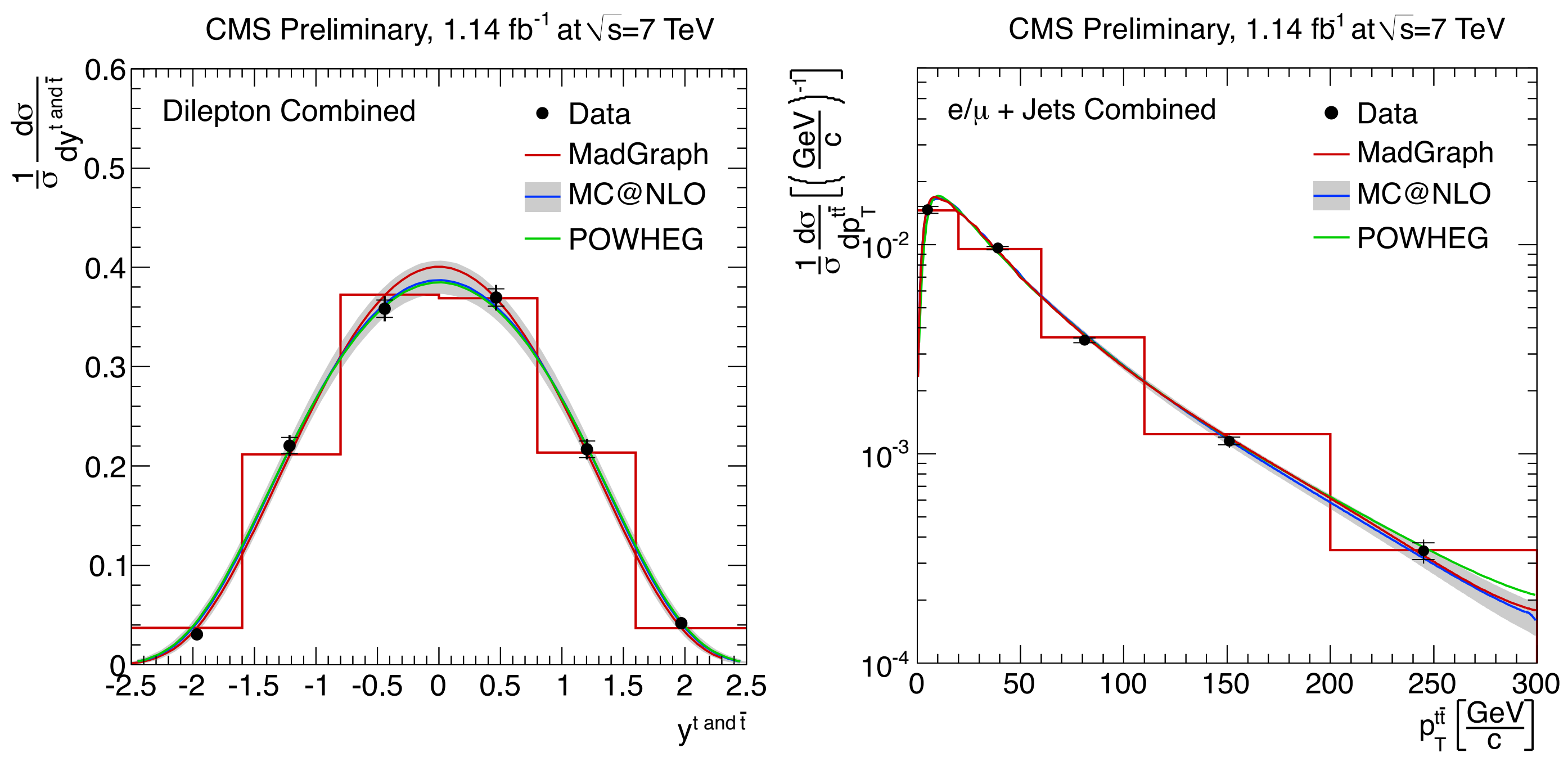
number expected bg events expected
Number inside
Reconstruction efficiency
Ratio inside and out (from MC)
Number inside in eμ

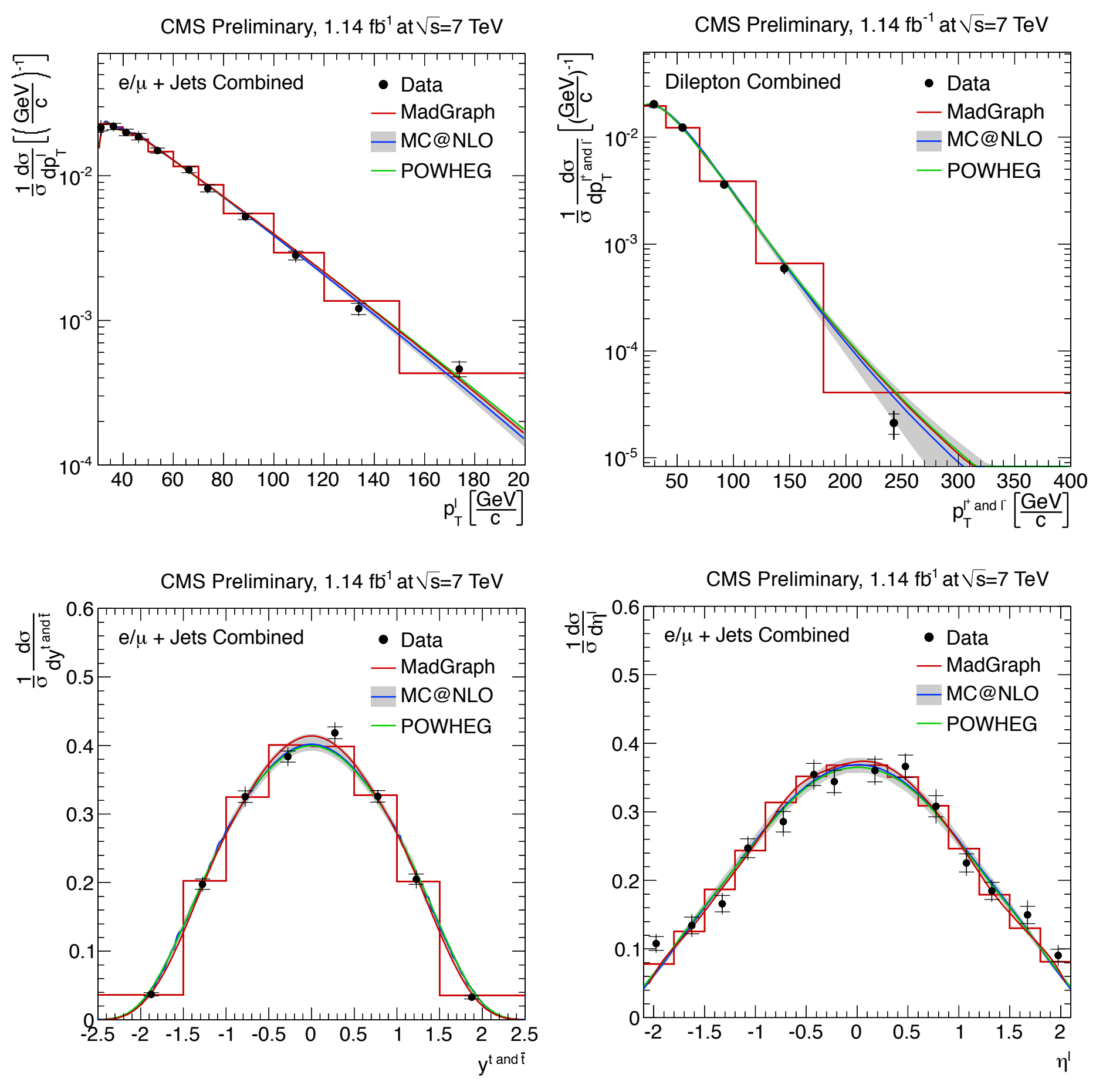


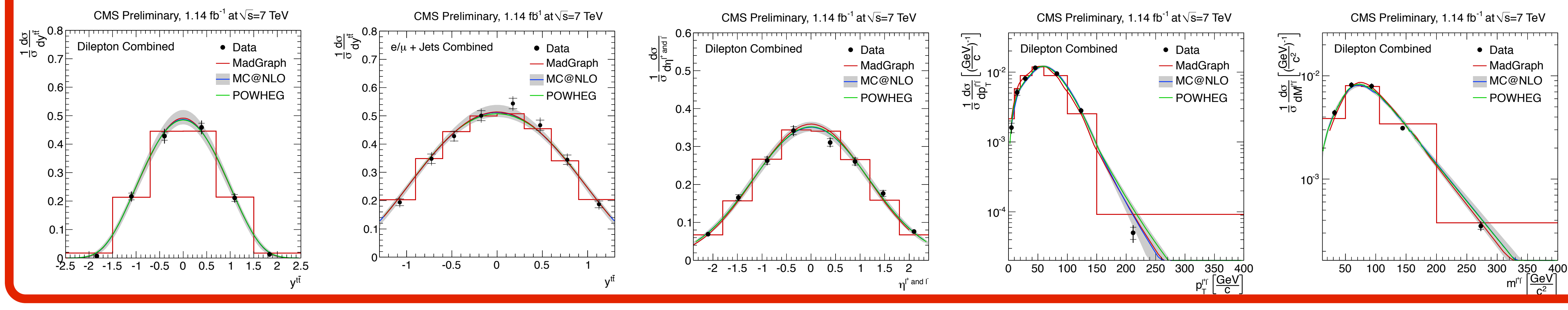
Results of the measurement



For the first time at the LHC, normalized differential cross-sections are measured as functions of transverse momentum, (pseudo-)rapidity, and the invariant mass of the final state leptons, the top quarks, and the top-antitop system in the visible phase space. The dataset corresponds to 1.14 fb^{-1}



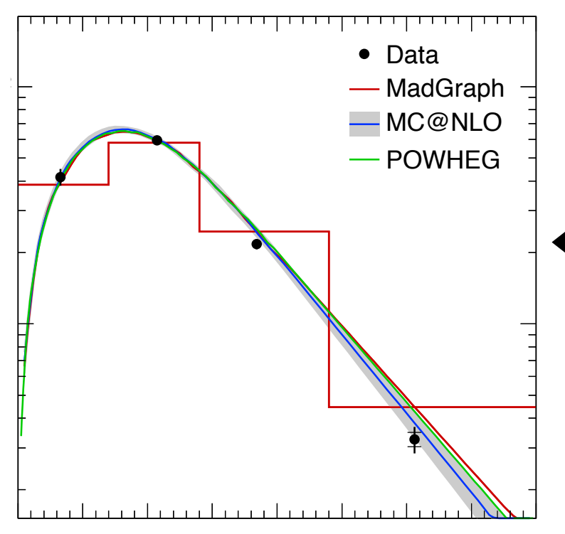




In all results, the data points have been placed at the intersection of the fit to the MadGraph simulation (the curve) and the measurement in that bin (horizontal line).

Also shown are the fits to results of the POWHEG simulation and the MC@NLO simulation. The MC@NLO has also been provided with one-sigma error bands.

Unfolding

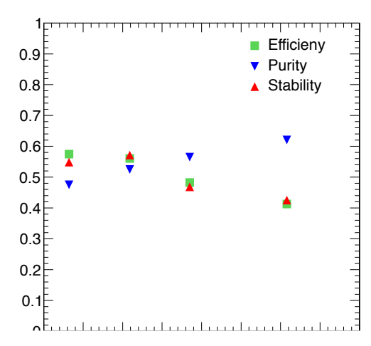


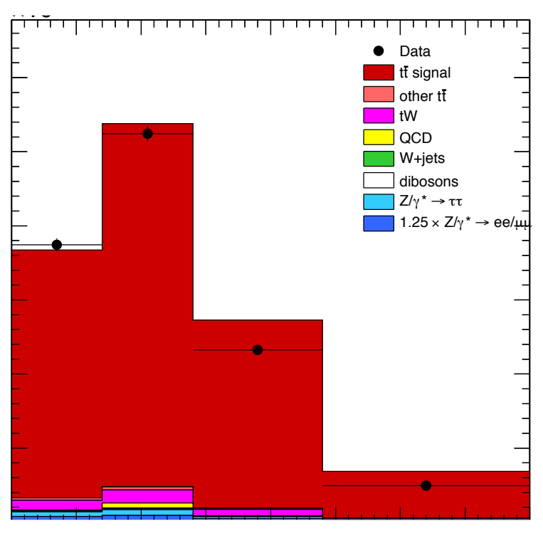
$$\frac{1}{\sigma}\frac{d\sigma^i}{dX} = \frac{1}{\sigma}\frac{N^i_{Data} - N^i_{BG}}{\Delta^i_{\chi}\epsilon^i L}$$

$$Purity^i = \frac{N^i_{rec\&gen}}{N^i_{rec}}$$

$$Stability^i = \frac{N^i_{rec\&gen}}{N^i_{gen}}$$

$$Efficiency^i = \frac{N^i_{rec}}{N^i_{allgen}}$$





In each bin of measurement, effects from the finite experimental resolution can cause migration across the bin boundaries from which the event was generated and where it was reconstructed. These migrations are studied as functions of **Purity** measures the migration into the bin, while **Stability** measures the migration out of the bin. The binning for the above plots has been chosen such that the purity and stability are both **above 50%.** To correct for these migrations, a bin-by-bin correction factor (**Efficiency**) is applied. This process is known as bin-by-bin unfolding and simultaneously takes into account signal efficiency corrections and the unfolding correction.
For the top system mass in dileptons, the unfolding is done via the Singular Value Decomposition (SVD). In this method a full covariance matrix is used to account for all correlations between bins. In a process known as regularization the non-significant components are suppressed. It has been shown that the two methods produce similar results.

Systematic Uncertainties

By normalizing the differential cross section to unity many systematics cancel out, e.g. luminosity. The remaining systematics are primarily shape-only and reduced in magnitude. The uncertainties are calculated in each bin of measurement. Statistical and systematic uncertainties are comparable in magnitude in the majority of bins

Kinematic Reconstruction

In order to access the indiviual top quantities, reconstruction algorithms are employed for the two channels.

Lepton + jets (kinematic fit):

The four vectors of the measured physics objects are assigned to decay particles of the top(i.e. the b-tagged jets are assigned to the b-quark). These quantities are varied according to their experimental resolutions under the following constraints:

- m_W = 80.4 GeV
- m_{top} =$m_{antitop}$
- MET = $p_{T,\nu}$ ($p_{z,\nu}$=0 initially)
- Only 4-5 leading jets considered

A χ^2 minimization is performed over all permutations of jet combinations to select the best fit.

Di-Lepton (kinematic solution):

The system is underconstrained due to the presence of two neutrinos. We take these four-vectors
- 2 b-tagged (or leading) jets
- 2 leptons
- MET

and the constraints:
- m_W = 80.4 GeV
- m_{top} = $m_{antitop}$ = fixed
- $p_{T,\nu 1}$ + $p_{T,\nu 2}$ = MET

To solve the underconstrained system, the neutrino energy is fit to an MC spectrum and solutions are accepted for a top masse between 100-300 GeV in 1GeV increments. Solutions are then ranked according to number of b-tags and the match to the MC spectrum.

Dilepton $m_{top\text{-}antitop}$:
The mass of the top-antitop system is calculated directly from:
2 leading jets MET(p_z(υ)=0) 2 leading leptons

The Future!

With the full 2011 dataset (4x the data!) and an estimated equivalent dataset at 8 TeV, the measurement of the differential cross-sections will test the standard model with unprecedented precision, and in a new energy regime.