Top Activities in Karlsruhe

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Outline

1. $t\bar{t}$ Cross Section Measurement in the Lepton+Jets Channel
   private work
2. Search for Single Top in the t-channel
   based on public CMS results with $\sqrt{s} = 10\text{TeV}$ simulation from 2009
3. Search for High-Mass Resonances Decaying to $t\bar{t}$
   private work

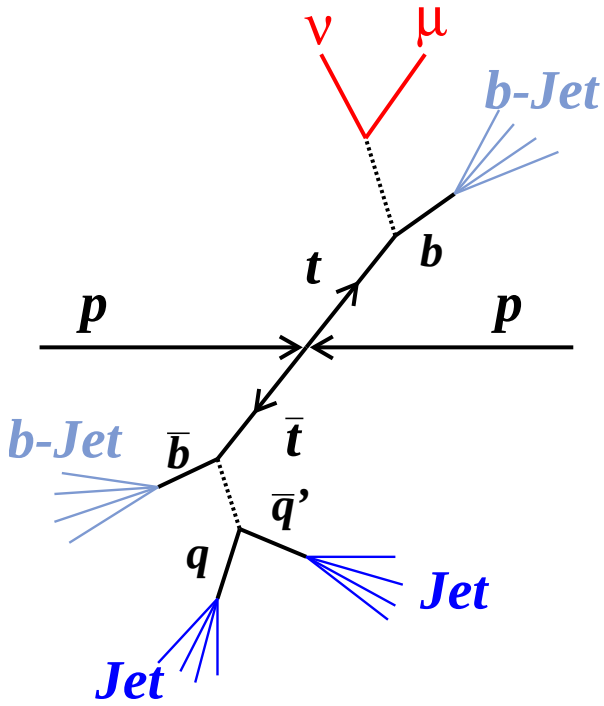
Disclaimer: most things I show today are based on work done in our group in Karlsruhe and are not (yet) official CMS results.

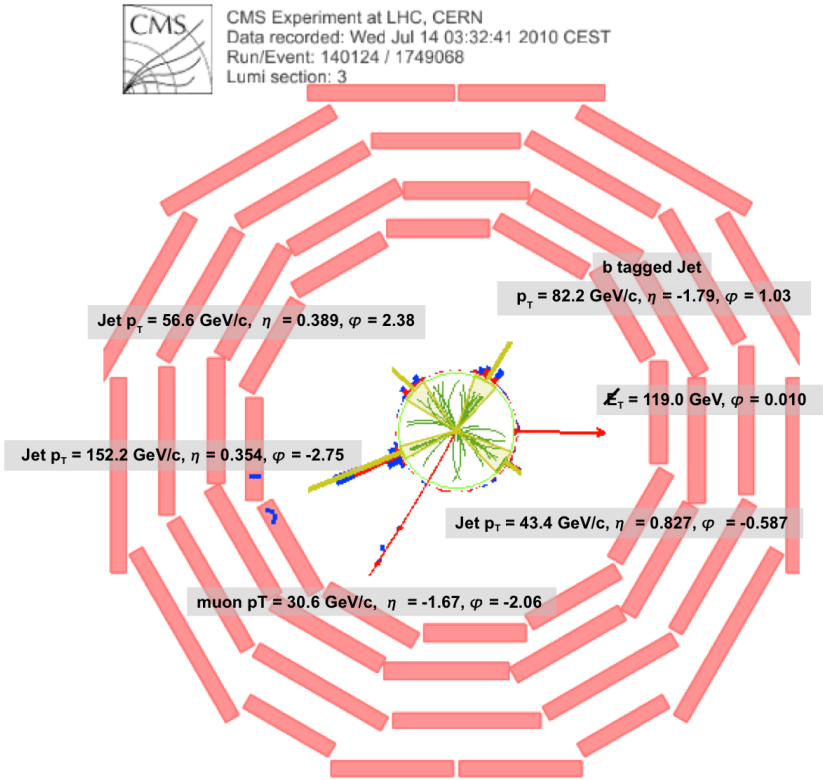
1 $t\bar{t}$ Cross Section Measurement in the Lepton+Jets Channel

2 Search for Single Top in the t-channel ($\sqrt{s} = 10$ TeV)

3 Search for High-Mass Resonances

Introduction





4 jets (2b-jets), 1 isolated high-energy lepton (e/μ), $E_{\mathrm{T}}^{\mathrm{miss}}$

- important background for many BSM physics searches
- many interesting property measurements possible of this quasi-free quark

Event Selection: for lepton+jets channel

For the muon+jets channel:

- muon trigger
- one well reconstructed muon consistent with the beam spot with $|\eta| < 2.1$, $p_T > 20\text{GeV}/c$ and relative isolation $I_{\text{rel}} < 0.05$.

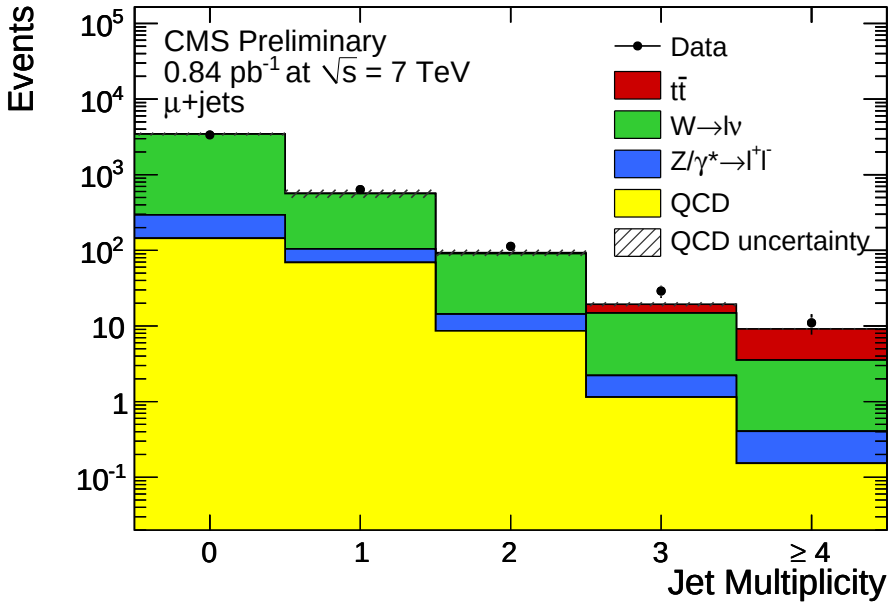
$$I_{\text{rel}} = \frac{\sum_{\text{tracks}\Delta R<0.3} p_T + \sum_{\text{calorimeter}\Delta R<0.3} E_T}{p_T^{\mu}}$$

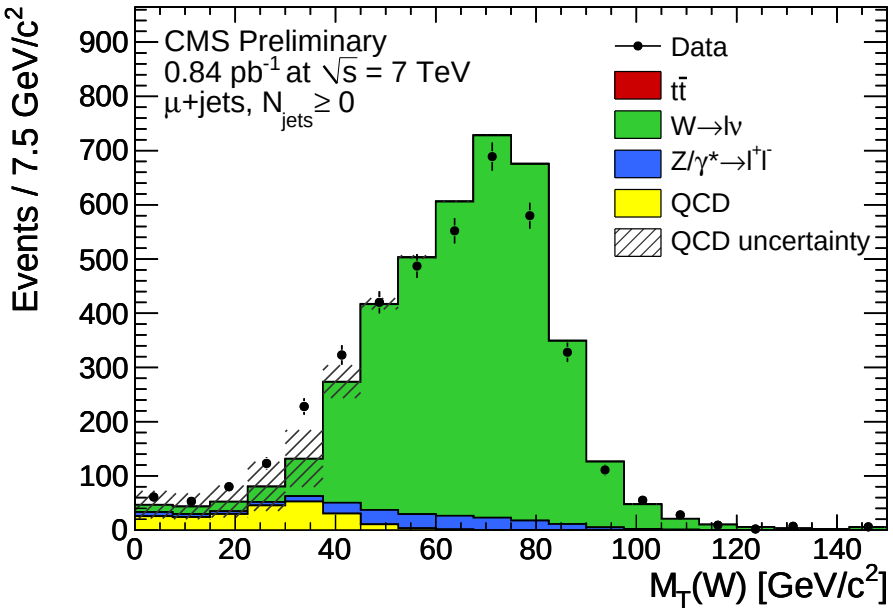
- veto on events with additional isolated muons or electrons
- $N_{\text{jet}} \geq 3, 4$ where jets are reconstructed from calorimeter and tracker information (particle flow) with the anti-k_T algorithm with $R = 0.5$.

Electron+jets selection is very similar, but uses electrons with $|\eta| < 2.5$, $E_T > 30\text{GeV}$ and $I_{\text{rel}} < 0.1$.
No b-tagging or cut on E_T^{miss} is used to minimise dependence on these quite complex quantities.

Latest CMS public results

Latest official CMS results are for $0.84 \pm 0.09 \text{pb}^{-1}$, where we had 11 events for $N_{\text{jet}} \geq 4$:





Event Selection

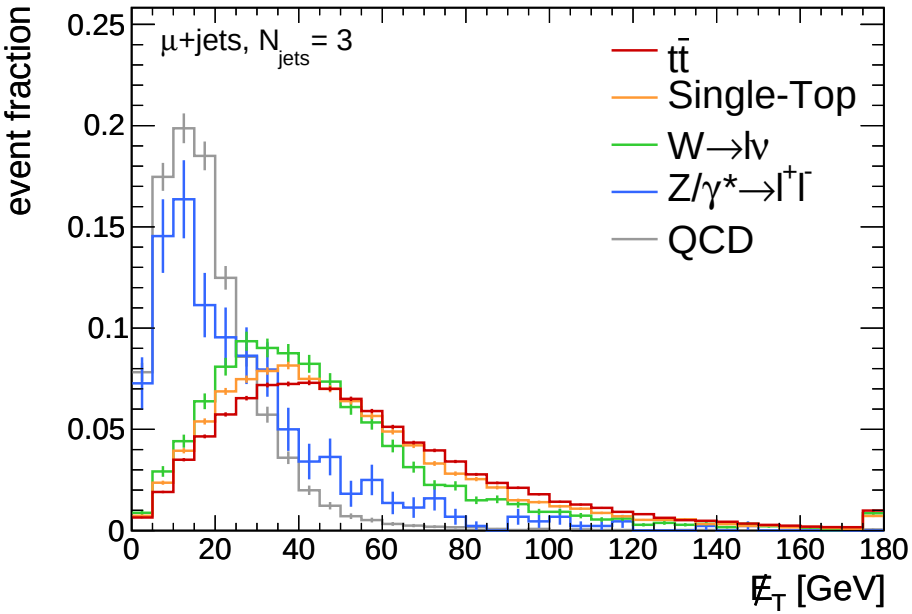
Event yields for $N_{\text{jet}} \geq 4$ for 34pb^{-1}:

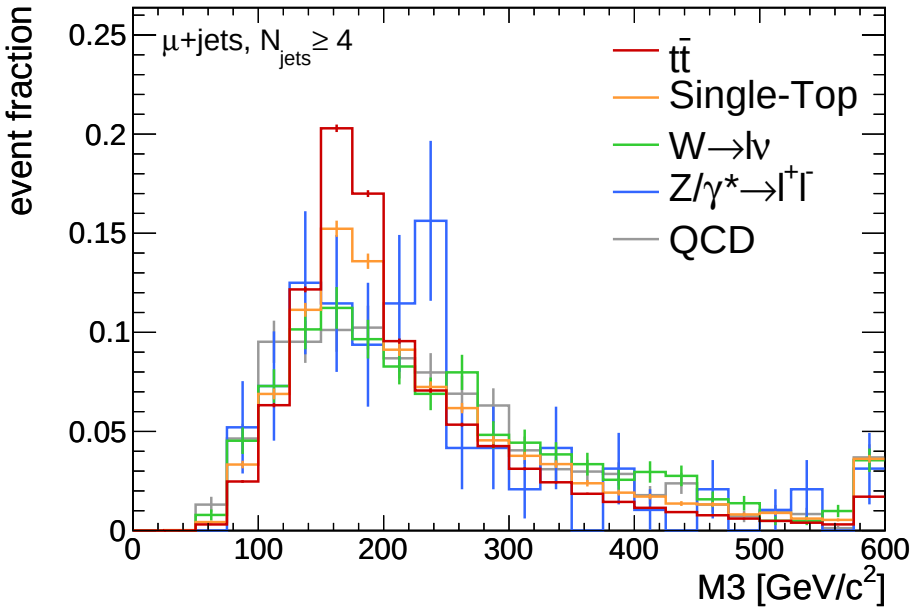
Process	e+jets	μ+jets
W+jets	91 ± 11	107 ± 13
Z+jets	14 ± 2	9.2 ± 1.4
single top	7.4 ± 0.9	9.5 ± 0.8
QCD	47 ± 9	5.0 ± 1.8
$t\bar{t}$	181 ± 34	206 ± 38
Sum MC	341 ± 37	336 ± 41
data	377	387

Uncertainties include lumi and cross section uncertainties.

Measurement Strategy

- make a binned likelihood fit to M3 for $N_{\text{jet}} \geq 4$, by varying fractions of W+jets, Z+jets, $t\bar{t}$, single top and QCD
- simultaneously, fit $E_{\text{T}}^{\text{miss}}$ in $N_{\text{jet}} = 3$ to extract background fraction

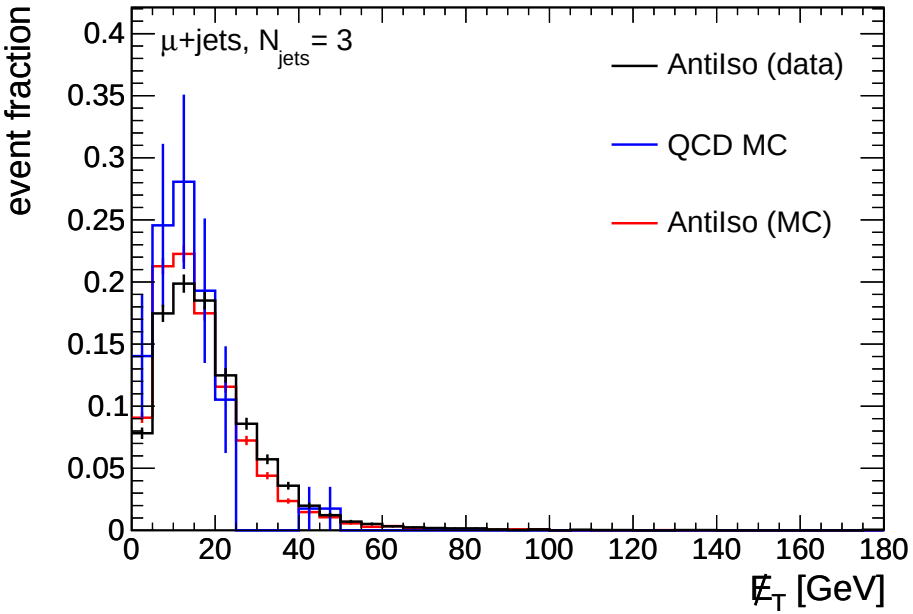


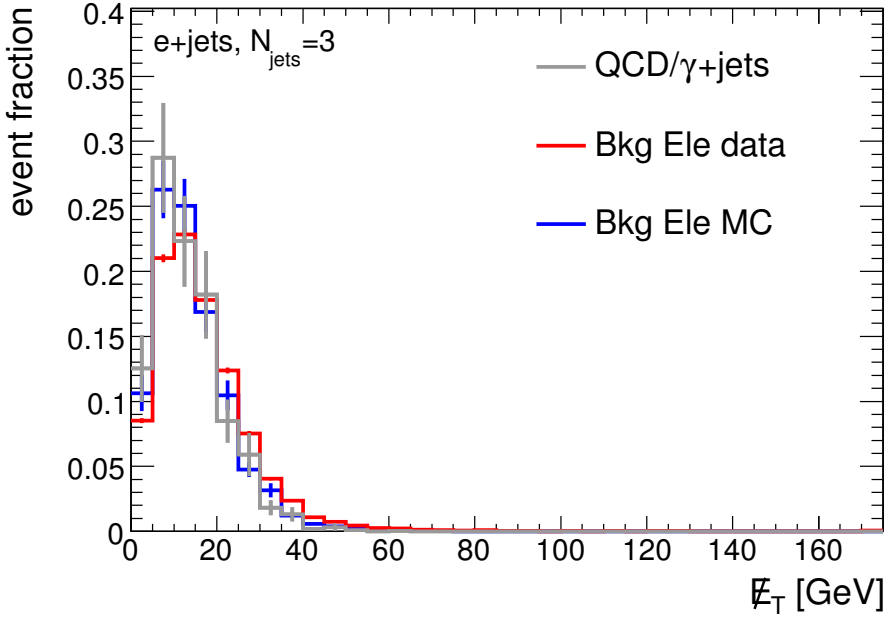


M3 is the invariant mass of the three jets with largest vectorial p_{T} sum.

QCD modeling

Build the QCD template for E_T^{miss} and M3 by using data sidebands.
For the μ+jets channel, the sideband is defined via I_{rel}.
In the electron+jets channel, some electron ID cuts are inverted.





Systematic Uncertainties

Systematic uncertainties include

- Q^2 scale for hard interaction
- matrix element/parton shower matching parameters
- amount of initial and final state radiation
- jet energy scale
- jet energy resolution
- parton distribution functions
- lepton trigger and reconstruction efficiency
- luminosity

To incorporate these, alternative templates for M3 and $E_{\mathrm{T}}^{\mathrm{miss}}$ are derived by repeating the event selection on samples affected by these uncertainties.

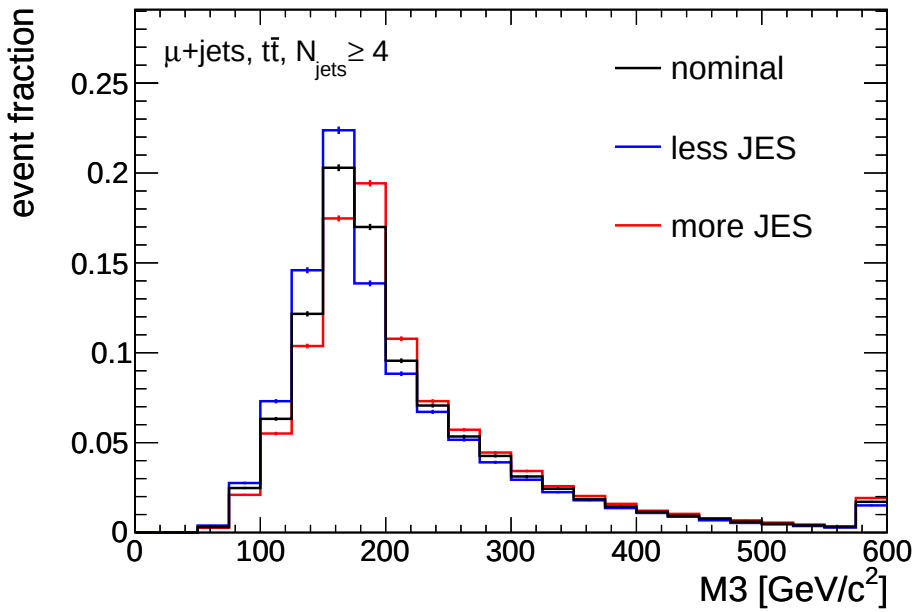
Example Uncertainty: jet energy scale

Varying jet energy scale by $\pm 1\sigma$ uncertainty, acceptance and templates change.

Relative acceptance changes:

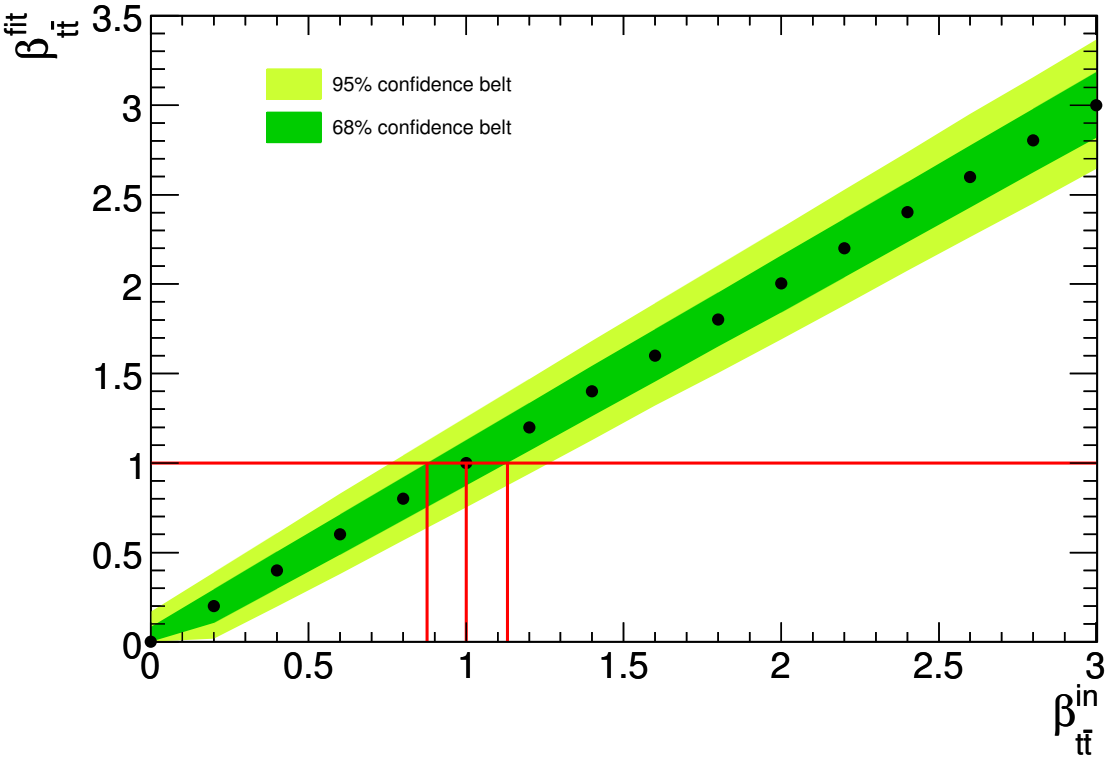
	less JES		more JES	
process	$N_{\text{jet}} = 3$	$N_{\text{jet}} \geq 4$	$N_{\text{jet}} = 3$	$N_{\text{jet}} \geq 4$
$t\bar{t}$	+1.5%	-8.6%	-2.1%	+8.0%
single top	-6.8%	-12.2%	+5.9%	+12.2%
Z+jets	-12.1%	-12.5%	+13.4%	+14.5%
W+jets	-10.9%	-15.6%	+13.5%	+13.6%

$t\bar{t}$ template changes:



Statistical Method

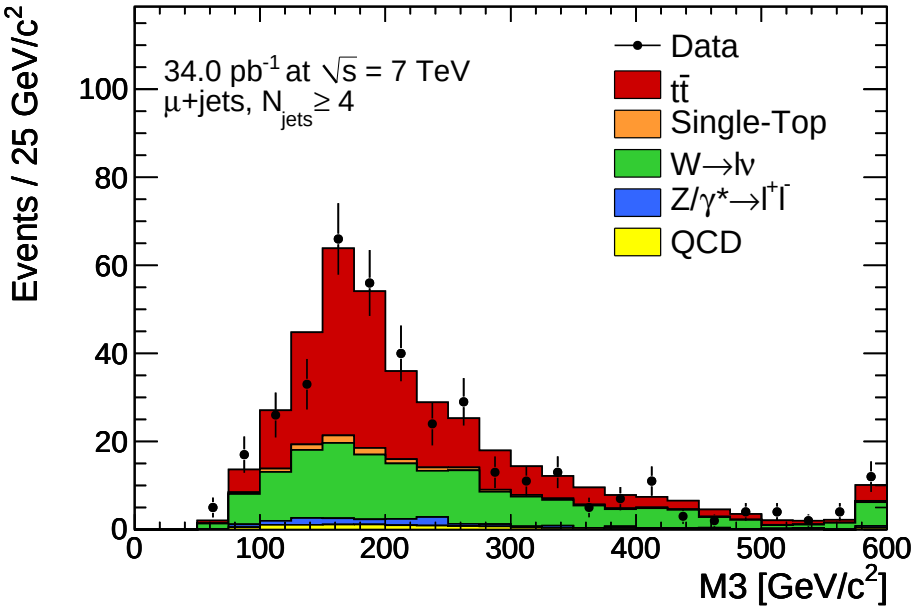
Use a Neyman construction with $\sigma_{t\bar{t}}^{fit}$ as test statistic by constructing the band of the central 68% $\sigma_{t\bar{t}}^{fit}$ as function of $\sigma_{t\bar{t}}^{in}$, using toy experiments:

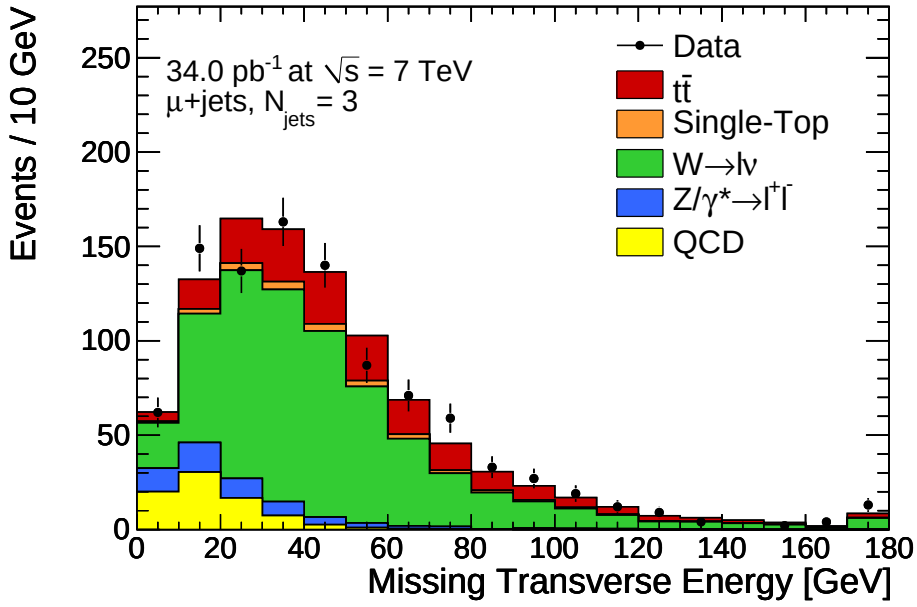


Systematic uncertainties are included in the stage of toy experiments by drawing toy data from templates affected by systematic uncertainties.

Results, Outlook

Scaled to fit result:





The expected relative uncertainty on the $t\bar{t}$ cross section is $\mathcal{O}(0.1)$ statistical and a total uncertainty of $\mathcal{O}(0.2)$.

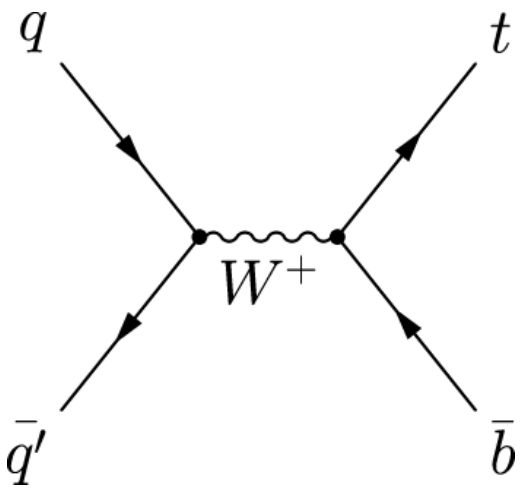
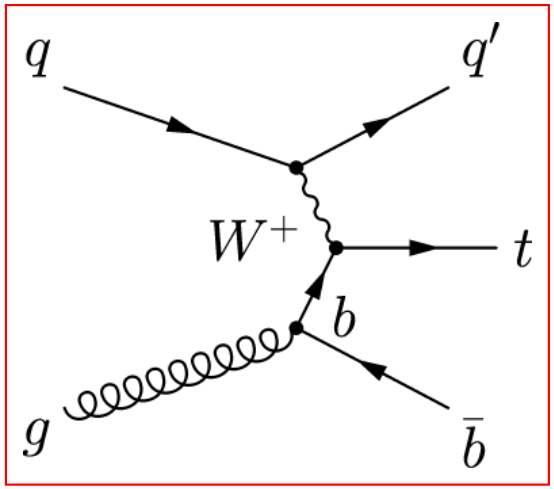
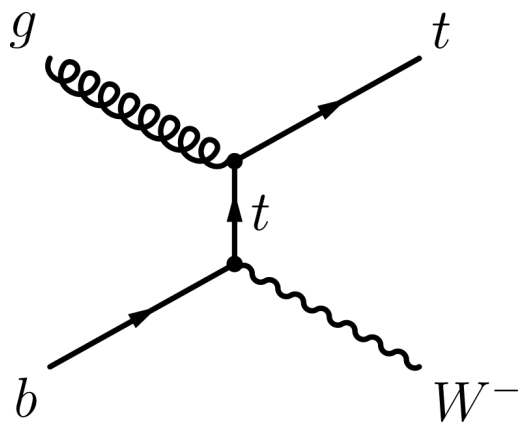
Strive for publication until Moriond (March 2011).

1 $t\bar{t}$ Cross Section Measurement in the Lepton+Jets Channel

2 Search for Single Top in the t-channel ($\sqrt{s} = 10$ TeV)

3 Search for High-Mass Resonances

Introduction

s-channel	t-channel	associated production
		

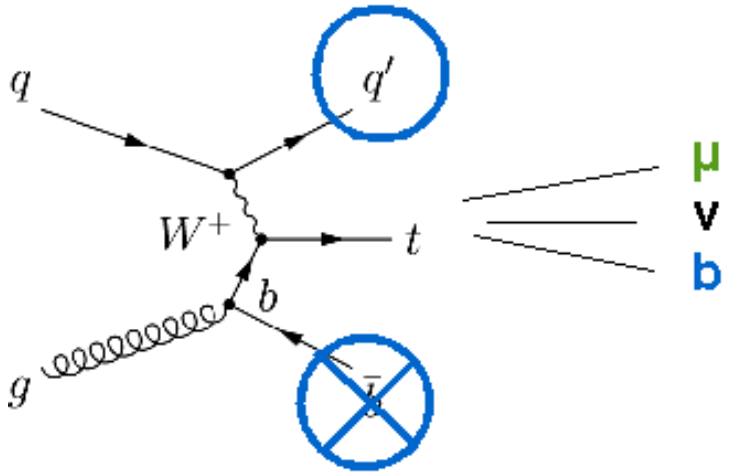
cross sections for $\sqrt{s} = 7$TeV, in pb:

4.6	64.6	10.6

The most promising production channel is the t-channel.

Here: use μ decay channel.

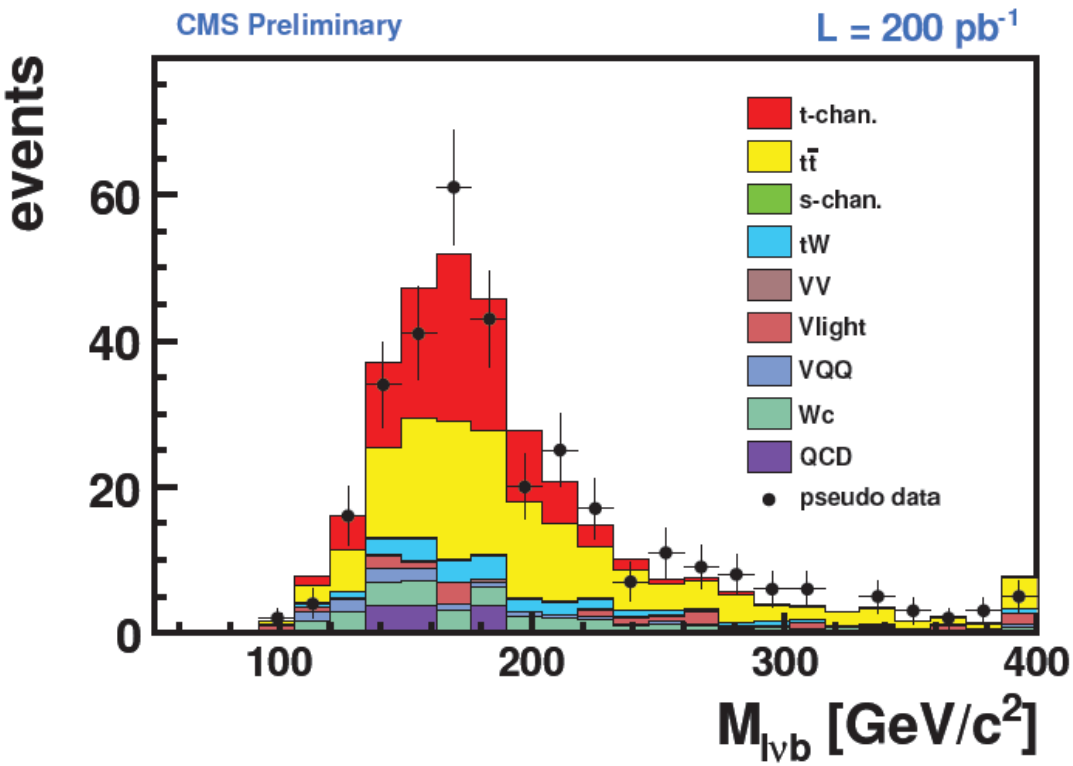
Event Selection



1. muon trigger and one isolated muon with $|\eta| < 2.1$, $p_T > 20\text{GeV}/c$
2. veto on events with additional isolated muons or electrons
3. exactly two jets with $|\eta| < 5.0$, $p_T > 30\text{GeV}/c$
4. one b-tagged jet
5. veto on additional b-tagged jets (to reduce $t\bar{t}$ background)

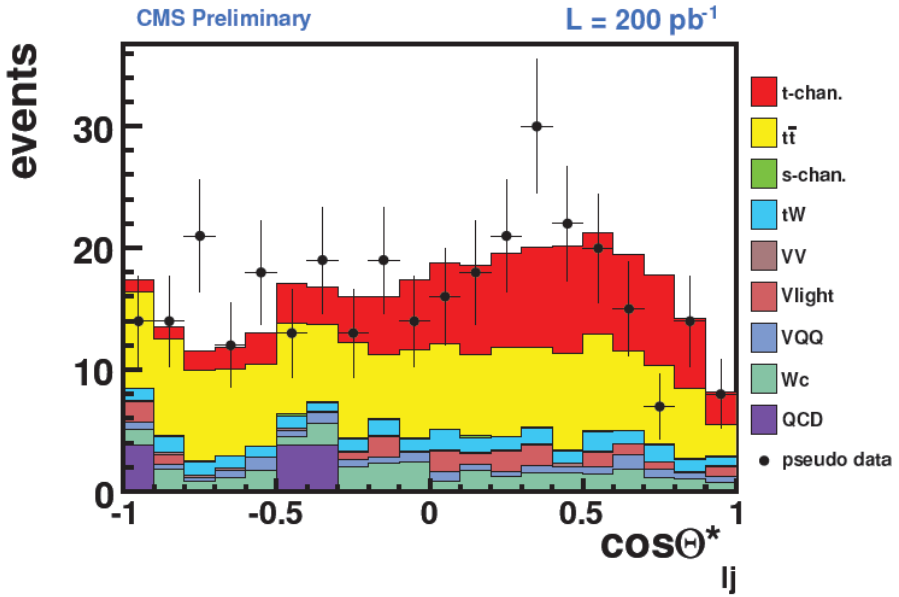
Top-quark four-momentum reconstruction

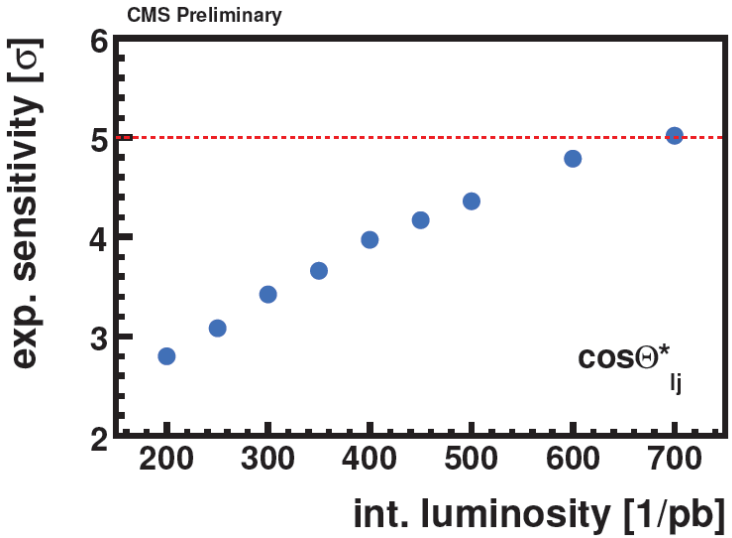
Use $E_{\mathrm{T}}^{\mathrm{miss}}$, μ momentum, and m_W constraint to reconstruct the four-vector of the W-boson from the top decay.
Adding the momentum of the b-tagged jet yields an estimate for the top-quark four vector.



Measurement Strategy, Outlook

- use a binned likelihood fit to $M_{l\nu b}$ to extract signal fraction
- alternatively, use a fit to the helicity angle θ^* which exploits the $V - A$ structure of the weak interaction and is more robust against many systematic uncertainties
- studies suggest that several 100 pb^{-1} are required for a 3σ evidence. $\rightsquigarrow$ study the use of multivariate techniques





1 $t\bar{t}$ Cross Section Measurement in the Lepton+Jets Channel

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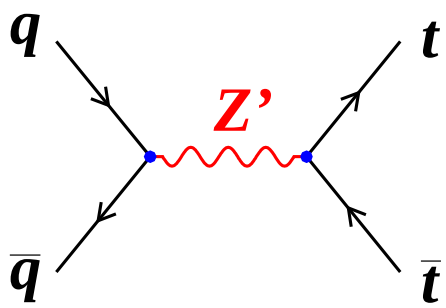
3 Search for High-Mass Resonances

Introduction

Search for a heavy resonance decaying to $t\bar{t}$ in the muon+jets channel.

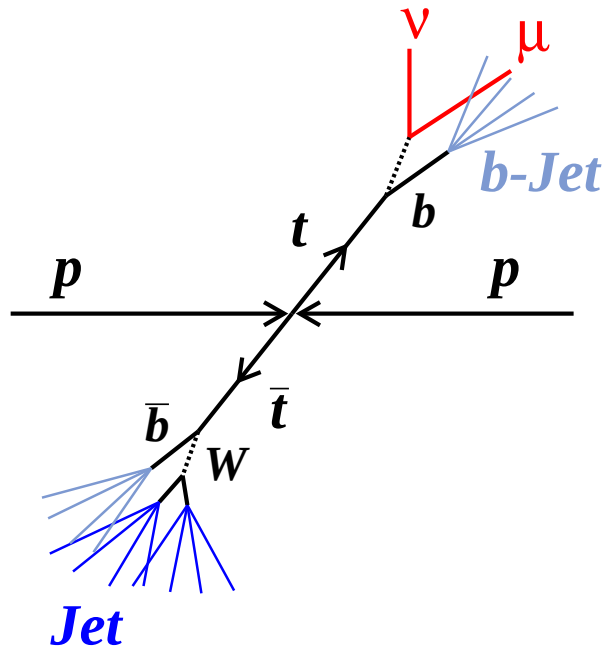


Could be axigluons, Kaluza-Klein states, topcolor Z', ...

$\rightsquigarrow$ try to be model-independent by searching bumps in $M_{t\bar{t}}$

- jets might merge
- lepton might not be well isolated

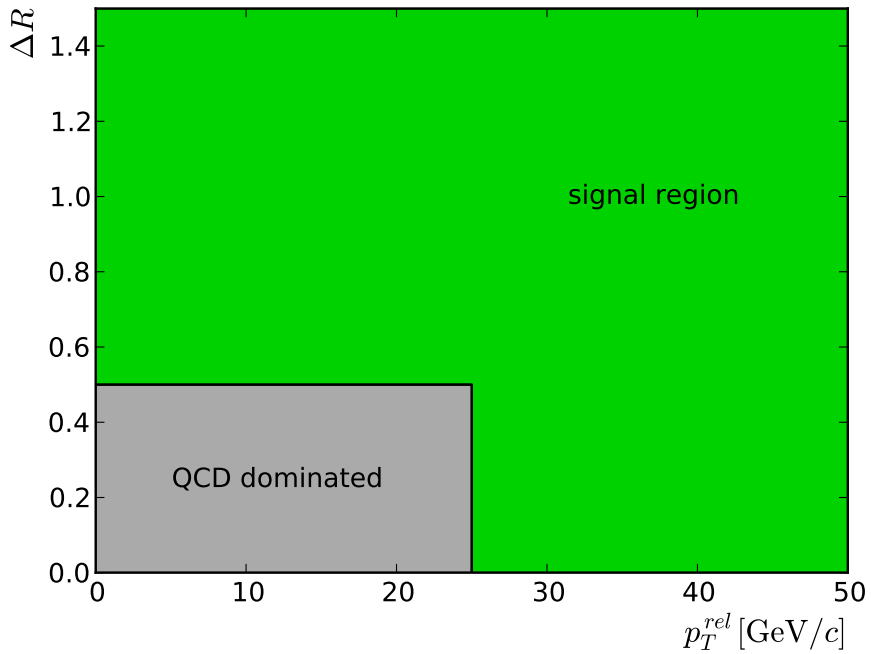
$\rightsquigarrow$ adapt event selection



Event Selection

1. muon trigger and one well reconstructed muon with $|\eta| < 2.1$, $p_T > 20\text{GeV}/c$. Instead of an isolation cut, search the nearest jet (in ΔR) with $p_T > 25\text{GeV}/c$ and calculate the relative transverse momentum of the muon w.r.t. the jet axis, p_T^{rel}.
2. $N_{\text{jets}} \geq 2$ with $p_T > 50\text{GeV}/c$, $|\eta| < 2.4$ constructed from calorimeter and tracker information (particle flow).
3. $H_{T,\text{lep}} > 150\text{GeV}$

Muon 2D-cut:



Reconstruction

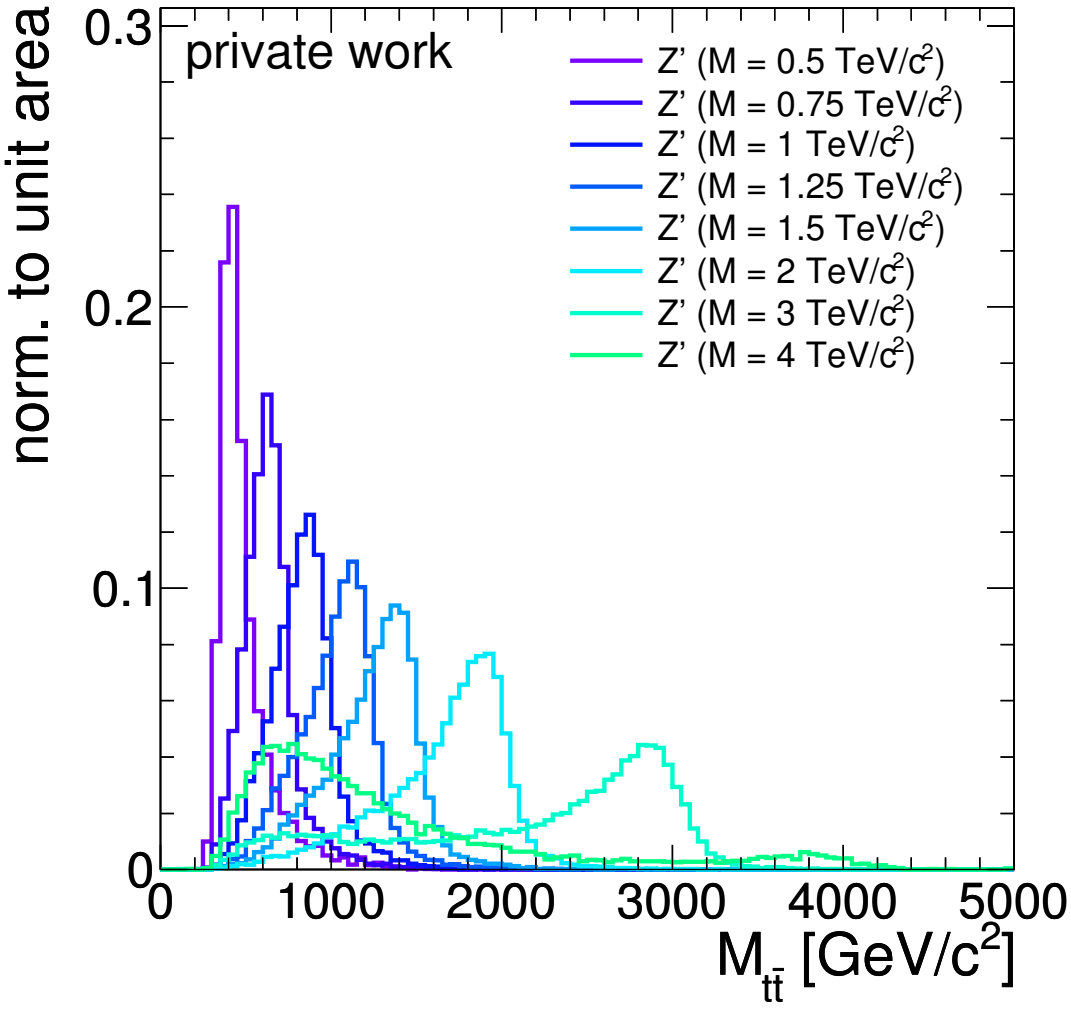
Use $E_{\mathrm{T}}^{\mathrm{miss}}$, μ momentum, and m_W contraint to reconstruct the four-vector of the W-boson from the top decay.
Make a list of hypotheses, assigning jets to either the leptonically decaying top quark t_{lep}, the hadronically decaying top quark t_{had}, or none of them.
The top momenta are the sum of all assigned jets and leptons.
Decay products are expected to be close in ΔR for high-energy top.
$\rightsquigarrow$ choose the hypothsesis with minimal

$$\Delta R_{\mathrm{sum}} := \Delta R(t_{\mathrm{lep}}, \mu) + \Delta R(t_{\mathrm{lep}}, \nu) + \Delta R(t_{\mathrm{lep}}, b).$$

If there is more than one with the same value, choose the one with maximal $\Delta R_{t\bar{t}}$.

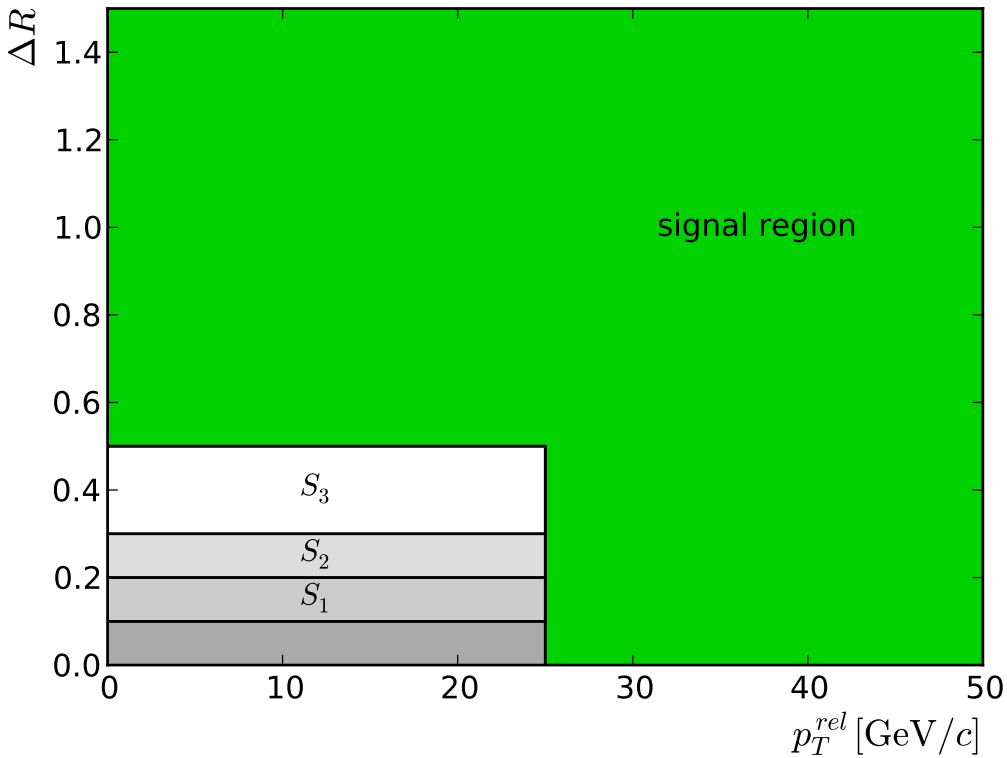
Reconstruction Performance

Relative $M_{t\bar{t}}$ resolution is about 9–12% for $M_{Z'} > 1\text{TeV}/c^2$.



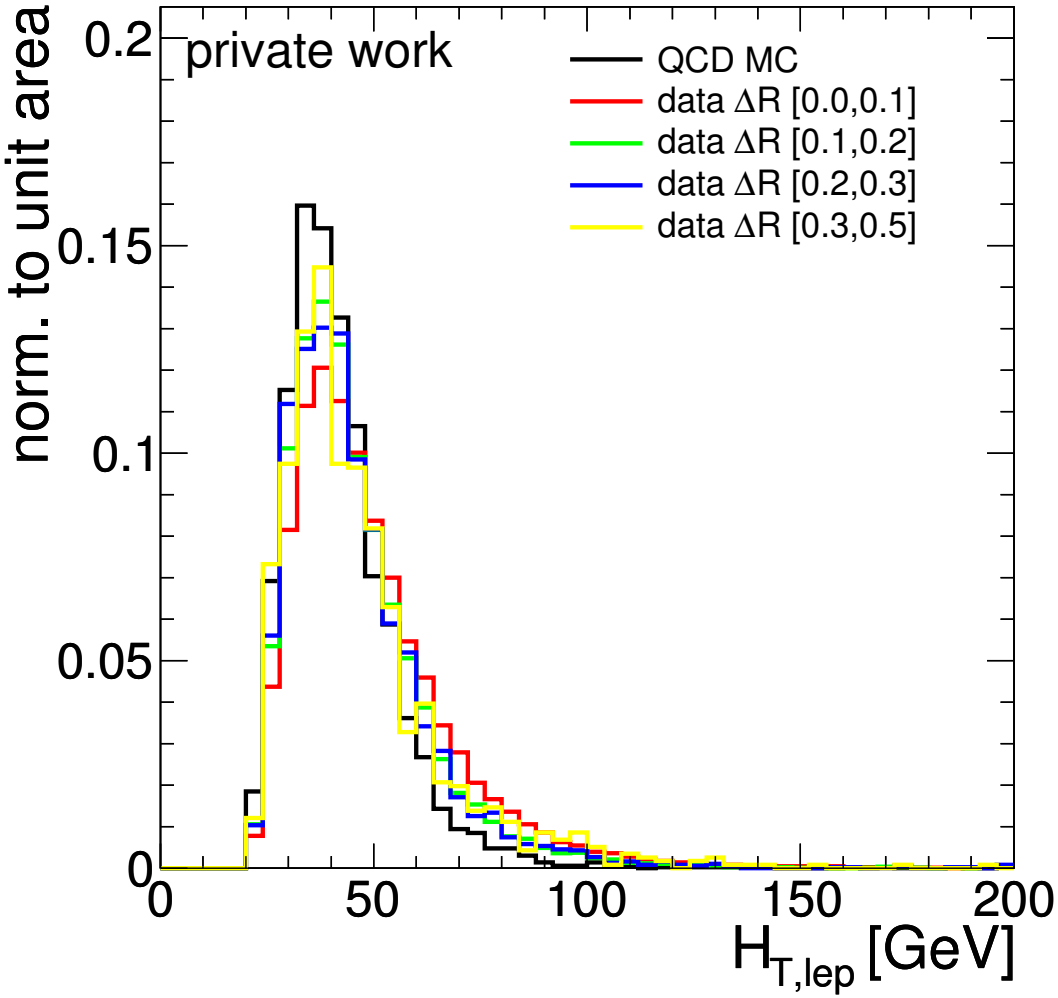
Measurement Strategy

- make a template fit to $M_{t\bar{t}}$ to extract Z' signal cross section / limit
- simultaneously, fit $H_{\mathrm{T,lep}}$ in the region $H_{\mathrm{T,lep}} < 150\mathrm{GeV}$
- use templates from Monte-Carlo except for QCD which is taken from 2D-cut sidebands



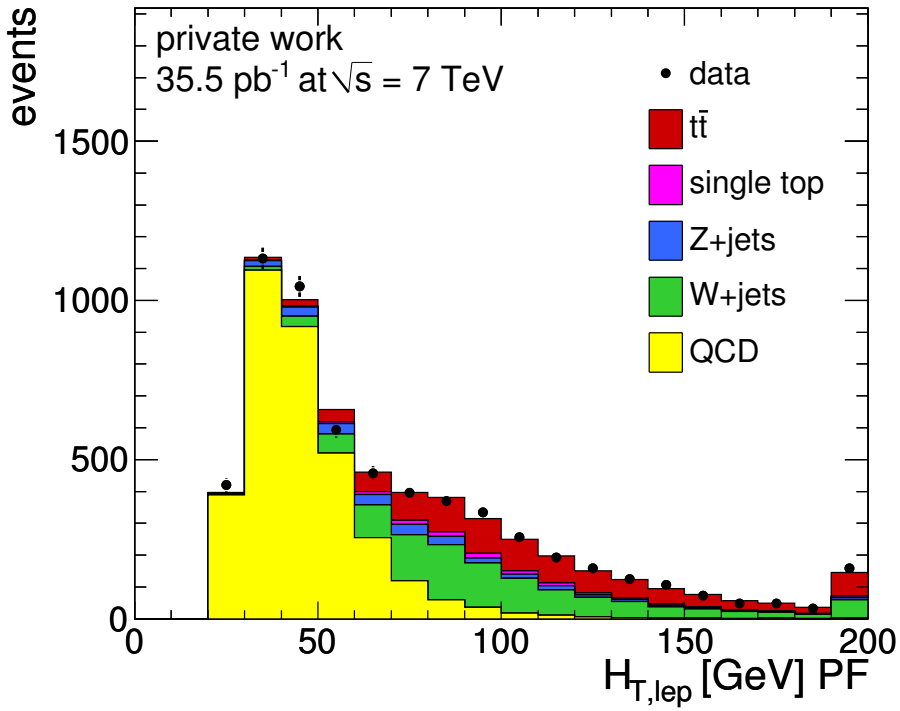
QCD modeling: cross checks

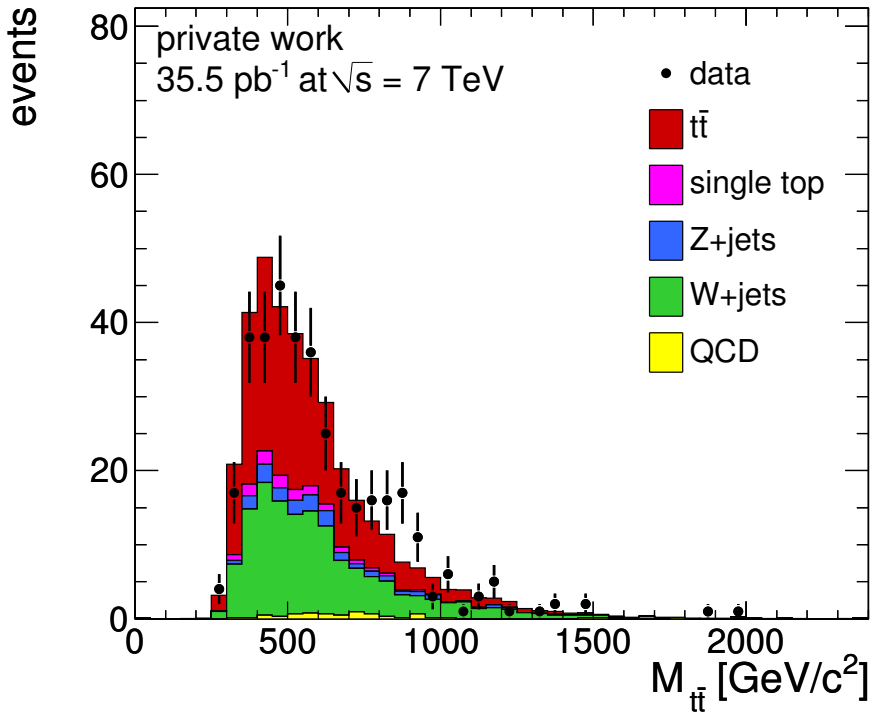
QCD model from data slightly different from Monte-Carlo, but consistent between different sidebands.



Plots

Backgrounds normalized to fitted fraction of $t\bar{t}$, W/Z+jets and QCD. the QCD model is from data sideband.





Outlook

- include electron+jets channel
- more studies using top-tagging for the hadronic side
- aim for public result early next year

After cross section measurement is established, focus on top quark properties. Studies concerning b-tagging, $t\bar{t}$ event reconstruction, and differential measurements (charge asymmetry) are ongoing and will be intensified.

References

- CMS-PAS-TOP-09-003: Prospects for the first Measurement of the $t\bar{t}$ Cross Section in the Muon-plus-Jets Channel at $\sqrt{s} = 10$ TeV with the CMS Detector
- CMS-PAS-TOP-09-004: Plans for an early measurement of the $t\bar{t}$ cross section in the electron+jets channel at $\sqrt{s} = 10$ TeV
- CMS-PAS-TOP-09-005: Prospects for the measurement of the single-top t-channel cross section in the muon channel with 200 pb^{-1} of CMS data at 10 TeV
- CMS-PAS-EXO-09-008: Search for heavy narrow $t\bar{t}$ resonances in muon-plus-jets final states with the CMS detector
- CMS-PAS-TOP-10-004: Selection of Top-Like Events in the Dilepton and Lepton-plus-Jets Channels in Early 7 TeV Data