Towards a $t\bar{t}$ Cross Section Measurement in the Dilepton Channel with CMS

Results in the $\mu\mu$ Channel

Maria Aldaya, Wolf Behrenhoff, Dirk Dammann, Achim Geiser, Markus Marienfeld

2010-12-01

Introduction

- Goal: $t\bar{t}$ production cross section from 2010 CMS data ($\sim$ 35 pb^{-1})
- my analysis uses the dimuon channel
- $e\mu$ channel also studied at DESY

- results shown here are my privat results to be used for my thesis
- all plots and numbers shown in this talk are work in progress

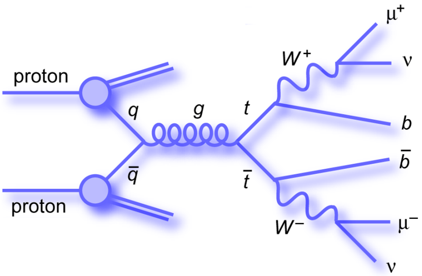
Contents

- Event Selection
- Trigger Efficiency from Data
- Estimation of QCD and Drell-Yan Background
- My preliminary Result and published Result
- Outlook

Event Selection

signal channel is $t\bar{t} \rightarrow b\bar{b}\ W^+W^- \rightarrow b\bar{b}\ \ell^+\nu\ \ell^-\bar{\nu}$

- low branching ratio of $\sim 1.6\%$ for $\mu\mu$ and ee
- twice as high for $e\mu$
- clear signature:
  - 2 oppositely charged leptons
  - 2 b-jets
  - missing transverse Energy ($\not{E}$)



Backgrounds for $\mu\mu$: everything with at least 1 muon

- other top events
- Drell-Yan
- W production
- 2 Vector-Bosons
- QCD (Mu $p_t > 15$ GeV)

Dimuon Event Selection

2 global muons with:

- $p_t > 20$ GeV
- $|\eta| < 2.4$
- $\chi^2_{norm} < 10$
- $|d_0| < 0.02\,\text{cm}$
- $n_{trk.hits} > 10$
- $n_{\mu-hits} > 1$

- $\frac{I_{Ecal}+I_{Hcal}+I_{Trk}}{p_t} < 0.15$ in $\Delta r = 0.3$ (isolation)

2 Anti-Kt5 PF jets with:

- $p_t > 30$ GeV
- $|\eta| < 2.5$
- jet id cuts
- cleaning against tight isolated muons and electrons

MET:

- PF MET > 30 GeV

2 Muons with opposite charge:

- veto on Z^0-mass: ($76\,\text{GeV} < m_{\mu\mu} < 106\,\text{GeV}$)
- veto on $m_{\mu\mu} < 12$ GeV

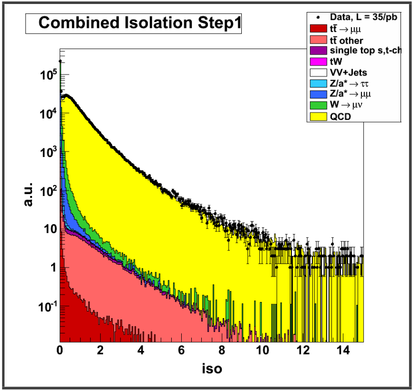
Dimuon Event Selection

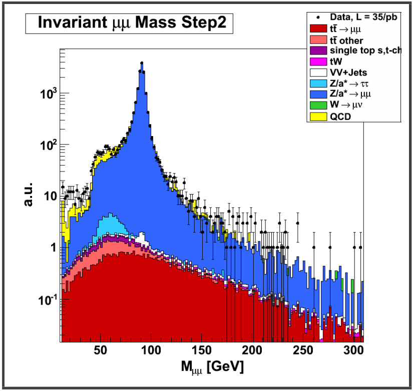
Selection applied in the following steps (used in plot titles):

- Step 0 trigger selection
- Step 1 require 1 good muon (all cuts except isolation)
- Step 2 require 2 good muons, $m_{\mu\mu} > 12$ GeV, separate events with oppositely and equally charged muons
- Step 3 require 2 isolated muons
- Step 4 split into inside and outside Z window
- Step 5 selection of one jet
- Step 6 second jet
- Step 7 MET cut

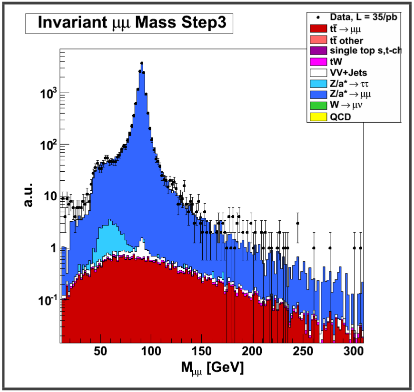
Dimuon Event Selection
Some Control Distributions

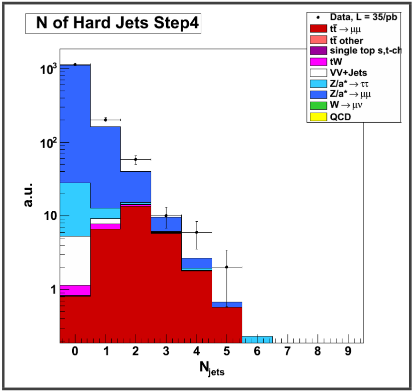
- after selection of one good muon QCD and W dominated
- with second good lepton Drell-Yan becomes most important





- with isolation requirement QCD can be neglected (at least in MC)
- also after Z mass veto Drell-Yan remains most important Background





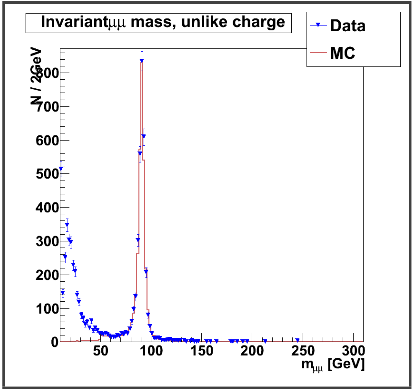
Trigger Efficiency in Data

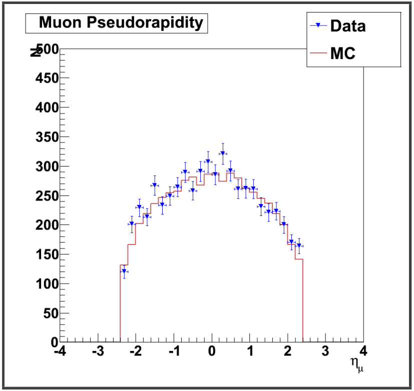
- different triggers used in data
- trigger shown here is HLT_Mu9
- requires one muon with $p_t > 9$ GeVon highest trigger level
- use Tag-and-Probe at Z^0 peak (81 GeV$< M_{\mu\mu} <$ 101 GeV):
  - dimuon events where at least one muon has fired the trigger (tag)
  - check if second muon also has fired (probe)
- match trigger muons to reconstructed analysis muons
  - $p_t > 20$ GeV
  - $|\eta| < 2.1$ (trigger acceptance)
  - analysis cuts for id, quality and isolation

Trigger Efficiency in Data

Control plots:

- normalized to luminosity
- very good agreement



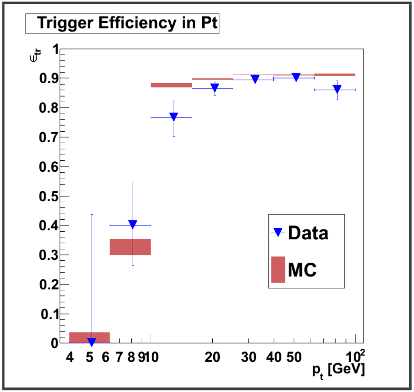


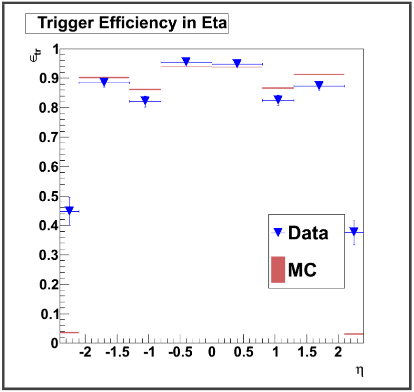
Trigger Efficiency in Data

efficiency in p_t and η

total efficiency for $p_t > 20$ GeV, $|\eta| < 2.1$:

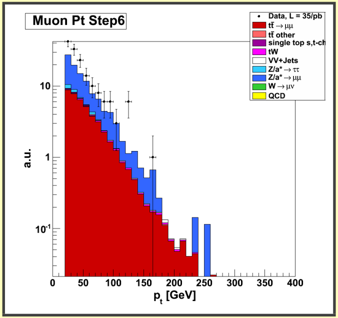
- 89.67 ± 0.51 % in data
- 91.10 ± 0.07 % in MC





Background Corrections

MC not perfectly tuned to the data, e.g. Drell-Yan contribution for higher jet multilplicity underestimated



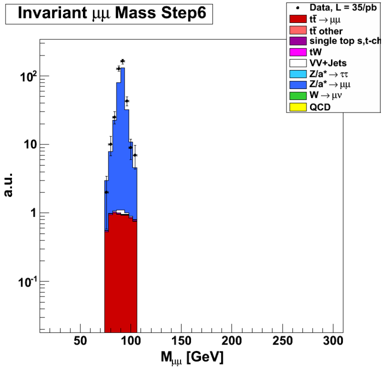
⇒ derive Background from data where possible

⇒ select also events in BG dominated regions

- Drell-Yan (DY) event from Z-peak region
- QCD and Fake-Leptons from events with 2 equally charged muons

DY$\rightarrow \mu\mu$ BG estimation:

- subtract non DY MC contributions from data
- renormalize $Z \rightarrow \mu\mu$ contribution in Z veto region to data
- applied in all selection steps separately

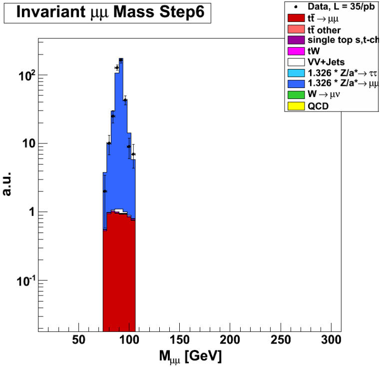


Correction factors:

- in first selection steps few percent
- for higher jet multiplicities not negligible

DY$\rightarrow \mu\mu$ BG estimation:

- subtract non DY MC contributions from data
- renormalize $Z \rightarrow \mu\mu$ contribution in Z veto region to data
- applied in all selection steps separately



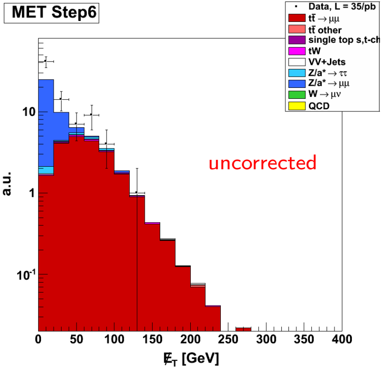
Correction factors:

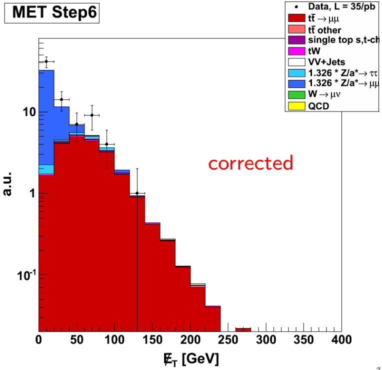
- in first selection steps few percent
- for higher jet multiplicities not negligible

Background Corrections

Drell-Yan $\longrightarrow \tau\tau$

- apply same correction to DY$\rightarrow \tau\tau$
- for Step 7 correction factor of Step 6 is applied for $\tau\tau$ because Z$\rightarrow \tau\tau \rightarrow \mu\mu$ has real physics $\not{E}$
- below: example plot for $\not{E}$ before cut





Wrong charge method (private work):

- idea: for processes with fake muons charge between muons is (almost) uncorrelated
  $\Rightarrow$ estimate contribution of QCD/fake $\mu^+\mu^-$ events from number of events with equally charged muons (wrong charge)
- ratio between right-charge and wrong-charge from muon enriched MC as upper limit
  double fake not simulated but ratio should be lower than in MC ($\mathrm{R}^{\mathrm{MC}}_{r/w} \approx 1$)
- number of selected wrong-charge events is zero in data
  $\Rightarrow$ estimate upper limit of fake contribution
- estimate efficiency of jet and $\not{E}$ cuts from sample with loose selection

- 3 different selections on data:

tight	normal analysis selection
loose	only p_t, η, Tracker Muon, n_{Hits} and isolation requirements for muons
very loose	without n_{Hits}, iso < 0.3

- assumption: efficiency is not correlated to (fake)muon properties (for very loose selection it probably is)

wrong-charge data	tight	loose	very loose
2 good muons	264	1223	1352
2 iso muons	1	5	18
Z veto	1	3	13
1 Jet	1	2	12
2 Jets	0	0	8
MET	0	0	0

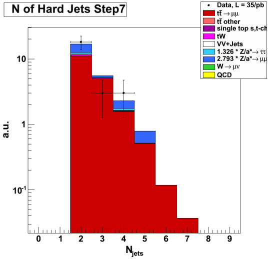
- 0 events with 2 jets
  $\Rightarrow$ upper limit for zero count is 1.148 (Poisson)
- loose cuts increase statistics by a factor $R_{tight \to loose} \approx 5$ but still no events with 2 Jets
  $\Rightarrow$ upper limit goes down by factor 5
- Ratio between right-charge and wrong-charge events $\mathrm{R}_{r/w}^{MC} \approx 2$ is taken from MC

Calculate upper limit for QCD and fake:

$$\mathrm{N} < 1.148 \times \frac{R_{r/w}^{MC}}{R_{tight \to loose}} \approx 0.5$$

- cut on $\not{E}$ not even considered because of correlation with muon iso
- including it would reduce upper limit by another order of magnitude to $\lesssim 0.05$
- apt for cross checks with methods used in official CMS analysis

Preliminary Result



preliminary cross section result:

- 24 candidate events
- efficiency from MC is 19.6%

some systematics not yet considered
most important:

- luminosity
- jet energy scale
- lepton reconstruction and isolation efficiency
- pile-up (gives bias in $\not{E}$ distribution)

Preliminary result:

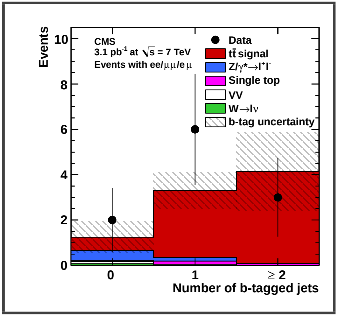
Process	N_{evts}
tW	0.579
VV	0.266
DY$\rightarrow \tau\tau$	1.071
DY$\rightarrow \mu\mu$	5.254
(other	$<$ 0.59)
sum	7.170

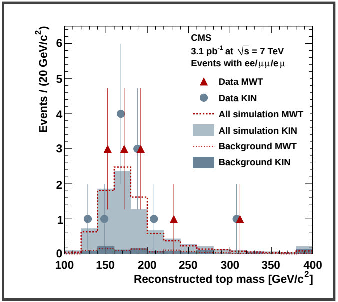
$\sigma = (157.5 \pm 46 \text{ (stat)})$ pb

systematic error from wrong-charge BG: $^{+0.0}_{-5.5}$ pb

CMS Published Result

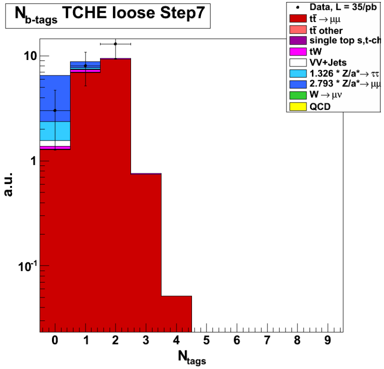
- Result using all decay channels ($\mu\mu$, $e\mu$, ee) just published
- arXiv:1010.5994v1
- first 3.1 pb^{-1} of data used
- 11 candidates ($3\mu\mu$, $5e\mu$, $3ee$)

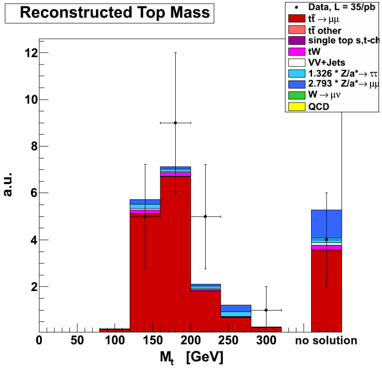




- most backgrounds estimated from data
- b-tagging only used for validation
- 2 mass reconstruction methods to check top-like event topology
- (194 ± 72 (stat) $\pm$ 24 (syst)$\pm$ 21 (lumi)) pb^{-1}

Outlook





Techniques to reject further BG:

- use either b-tagging
- or kinematic event solution to verify top-like event topology

Outlook

Other dilepton channels: $e\mu$, ee

- usually analyzed simultaneously
- $e\mu$ also already studied at DESY
- also want to establish ee channel