Measurement of the cross section ratio $t\bar{t}$ / Z^0 in the ee and $\mu\mu$ final states at $\sqrt{s} = 7$ TeV with the CMS experiment

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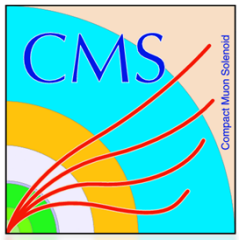
Motivation

Event selection

Results

Outlook



Motivation

$$R\left(\frac{\sigma_{t\bar{t}\to X\to l^+l^-}}{\sigma_{Z\to l^+l^-}}\right) = \frac{N_{sel}^{t\bar{t}} - N_{bg}^{t\bar{t}}}{N_{sel}^{Z} - N_{bg}^{Z}} \frac{\epsilon_Z}{\epsilon_{t\bar{t}}} \rho_{diff} \frac{\rho_{common}}{\rho_{common}} \frac{L}{L}$$

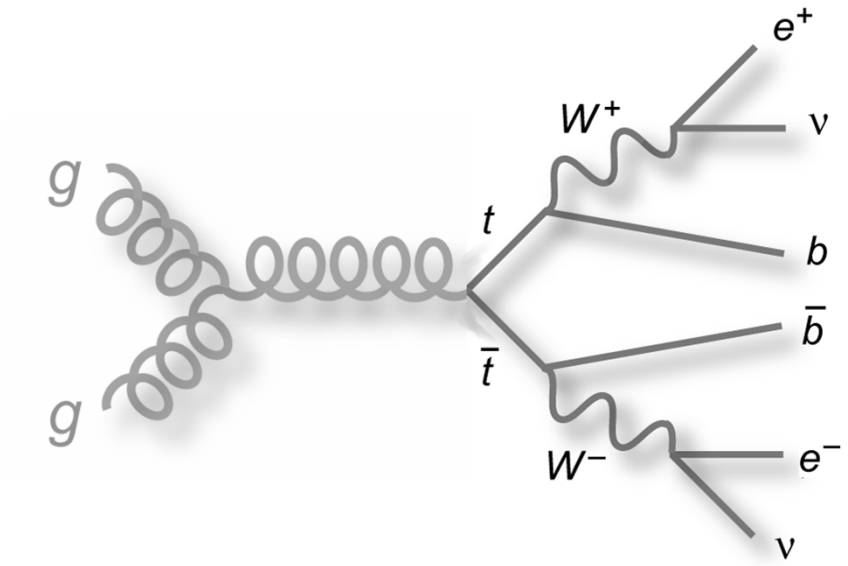
- Ingredients:
  - Selected events $N_{sel}^{t\bar{t}}$ and N_{sel}^{Z}
  - Background $N_{bg}^{t\bar{t}}$ and N_{bg}^{Z}
  - Efficiencies $\epsilon_{t\bar{t}}$ and ϵ_Z
  - Differences in efficiency correction factors ρ_{diff}
  - ~~Common correction factors~~ ρ_{common}
  - Luminosity L

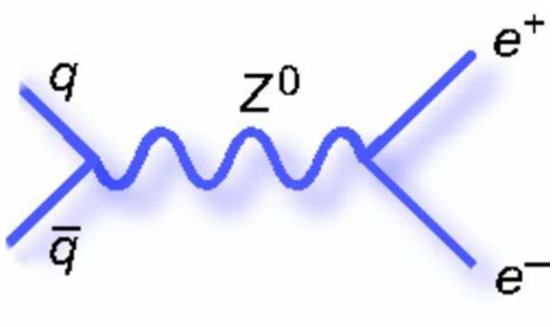
Motivation

	uncertainties:
• Same dataset / triggers	
– Luminosity	cancel
– Trigger	cancel largely
• Same lepton selection	
– Reconstruction	cancel largely
– Identification	cancel largely

- Z^0 well measured and described in theory
- Alternative luminosity estimation using measured and theory Z^0 cross section

Dileptonic $t\bar{t}$ and Z^0 decay





Leptons:

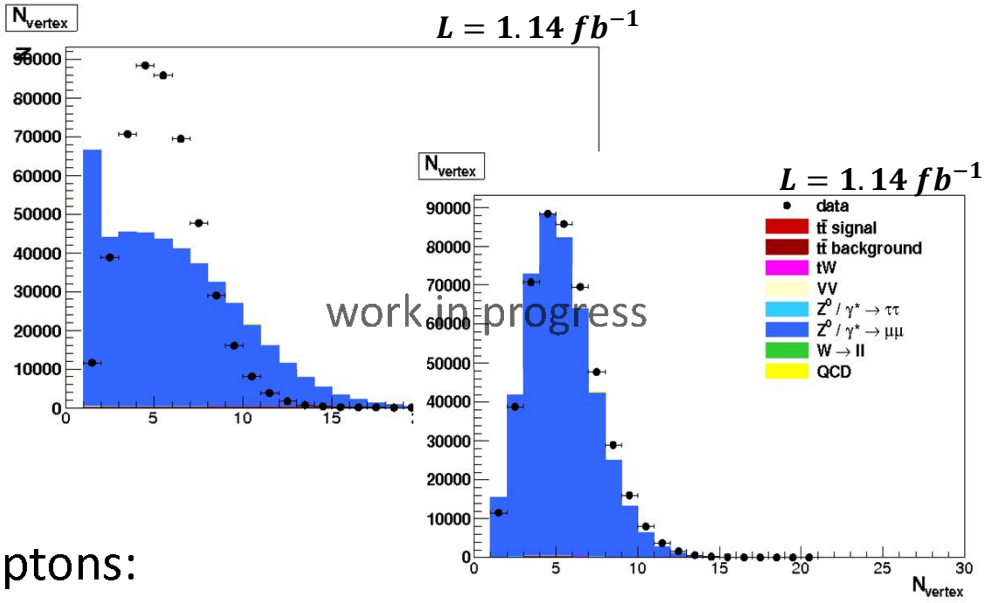
- 2 opposite sign high-p_t leptons (of same type)
- Isolated
- Central detector region

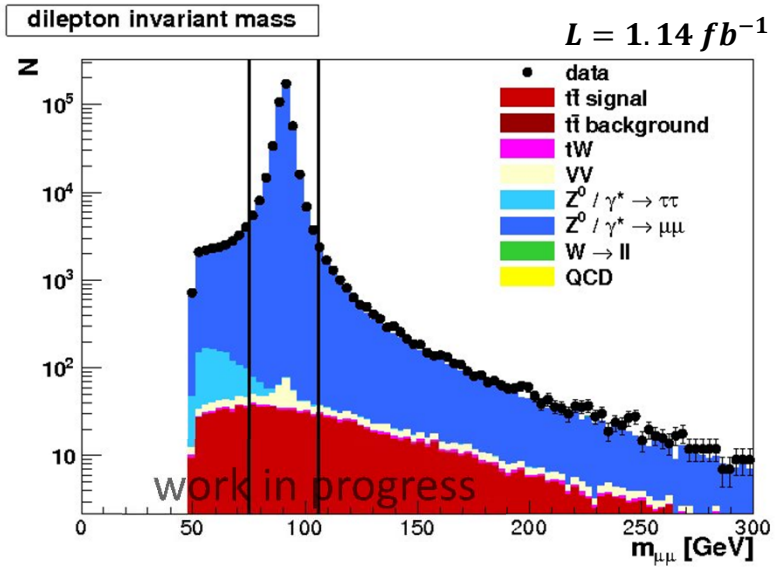
→ very similar signature

→ In ee and $\mu\mu$ channel Z^0 dominant background to $t\bar{t}$ and vice versa.

Event selection (common)

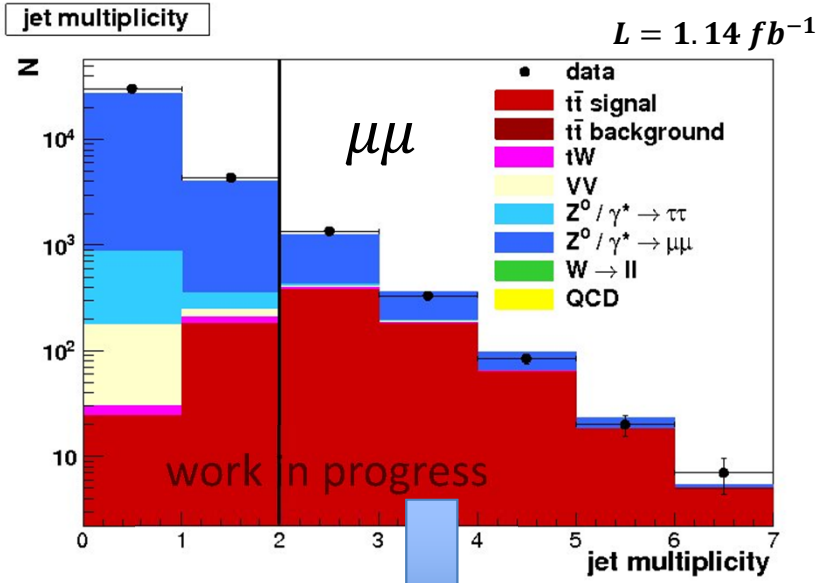
- Dataset corresponding to $L = 1.14\ fb^{-1}$
- Pile-Up reweighting
  - reweight vertex multiplicity
- Trigger:
  - dimuon, dielectron, ($e\mu$ trigger)



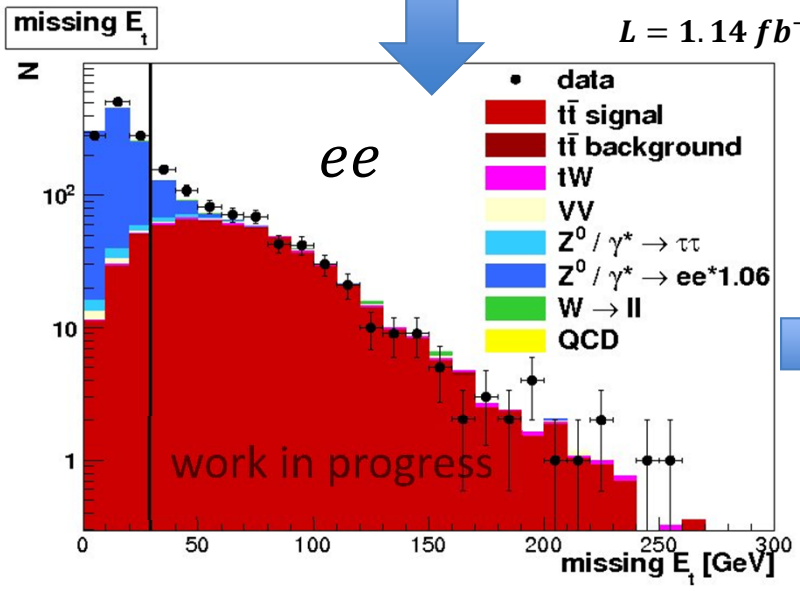


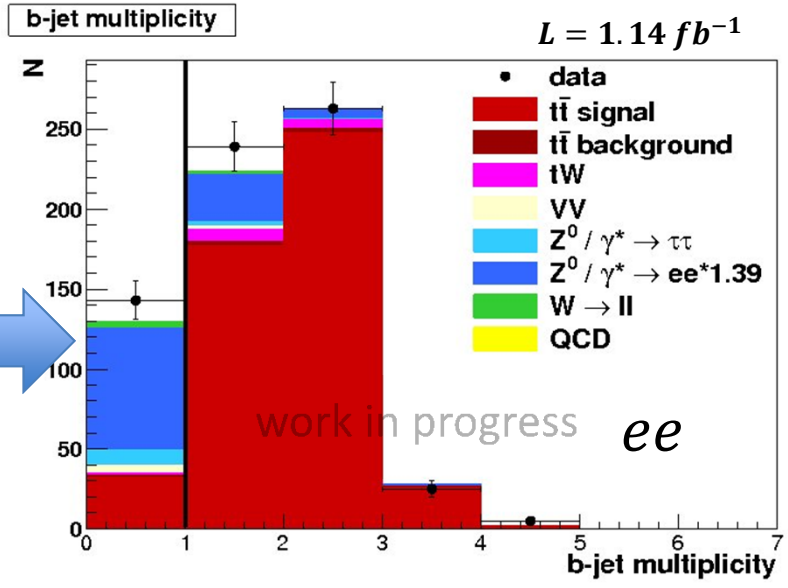
- Leptons:
  - p_t > 20 GeV, $|\eta|$ < 2.4, identification
  - Isolation(PF) < 0.17 (electrons) or 0.2 (muons)
  - Highest p_t opposite sign pair
  - Invariant mass m_{ll} > 50GeV
  - For Z^0:
    - 76 GeV < m_{ll} < 106 GeV
  - For $t\bar{t}$:
    - m_{ll} < 76 GeV or 106 GeV < m_{ll}

Event selection ($t\bar{t}$)



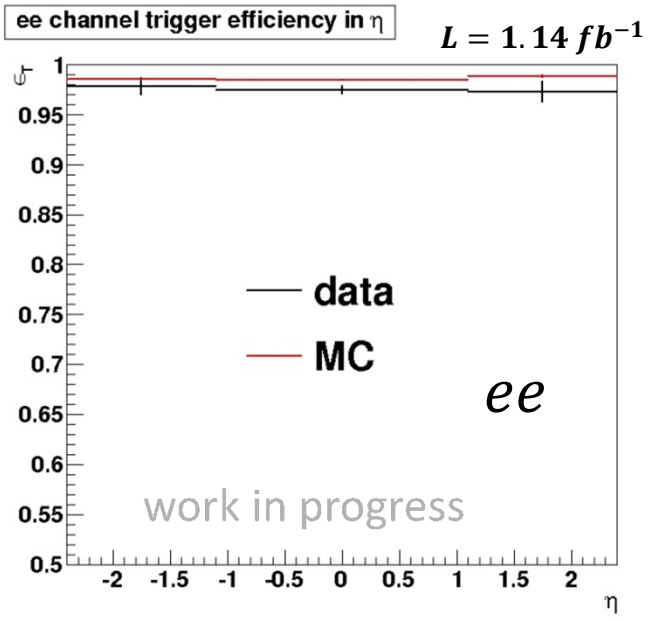
- $\geq$ 2 jets:
  - p_t > 30 GeV
  - $|\eta|$ < 2.4
- Missing E_T
  - $E_{T,miss}$ > 30 GeV
- $\geq$1 b-tagged jet
  - compromise between efficiency, background and systematics

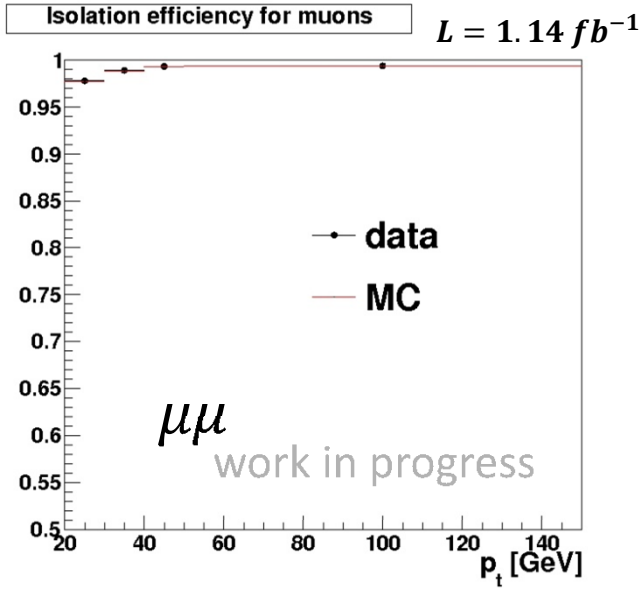




Measured efficiencies, correction factors

- **Trigger efficiencies with independent triggers:**
  - Choose dataset triggered by independent $E_{T,miss}$ triggers
  - Apply full lepton selection (without m_{ll} and charge requirements)
  - Ask for fired dilepton trigger
  - $\epsilon_T^{data} = \frac{N_{fired}^{data}}{N_{sel}^{data}} \Rightarrow \rho_T(p_t, \eta) = \frac{\epsilon_T^{data}}{\epsilon_T^{MC}}$



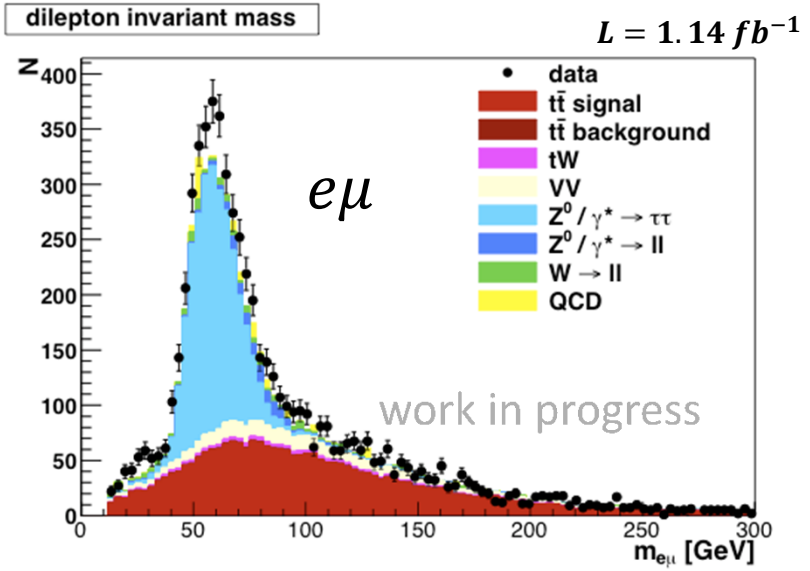


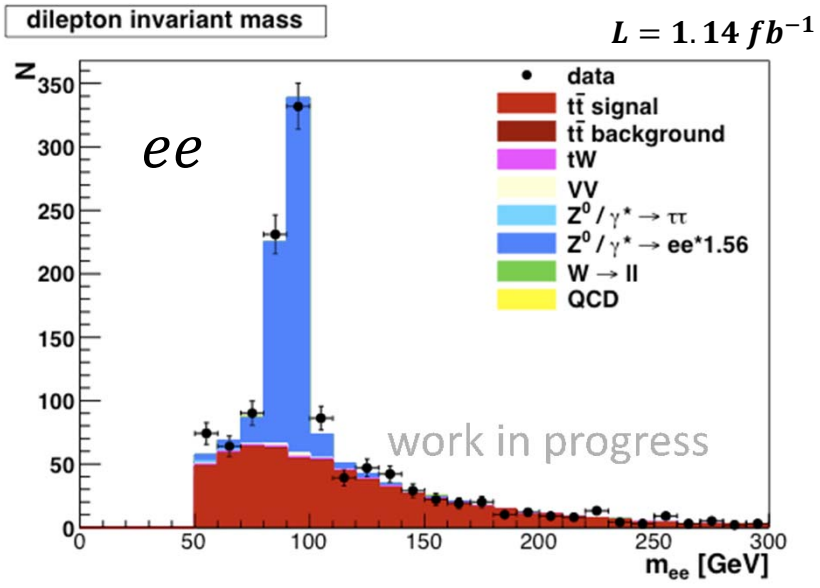
- **Isolation efficiencies on Z^0 peak:**
  - Apply full lepton selection without isolation
  - Select highest p_t lepton as probe
  - Search for highest p_t opposite sign isolated lepton
  - Select Z^0 m_{ll} region
  - Ask for isolation of probe lepton
  - $\rho_{Iso} \approx 1$

$t\bar{t}$ and Z^0 background using $e\mu$ channel

Background to Z^0 signal from data:

- Do same Z^0 selection for $e^{\pm}\mu^{\mp}$
- Correct for degrees of freedom and lepton efficiencies
- $N^Z_{bg,\mu\mu} = \frac{1}{2} N^Z_{e\mu} \frac{\epsilon^Z_\mu}{\epsilon^Z_e} = \frac{1}{2} N^Z_{e\mu} \sqrt{\frac{N^Z_{\mu\mu}}{N^Z_{ee}}}$





Rescale Z^0/γ^* background to $t\bar{t}$ signal

- Select Z^0 peak region
- Apply $t\bar{t}$ selection (inverted Z^0 Veto)
- Determine non Z^0/γ^* contribution N^Z_{bg} from data
- Scale Z^0/γ^* MC to fit $N^Z_{data} - N^Z_{bg}$
- Apply factor in whole m_{ll} region

cutflow

	dilepton	Z^0 selection	Z^0 veto	one jet	two jets	missing E_T	b-tag
$t\bar{t}$ *signal*	1050	287	764	744	575	486	445
$t\bar{t}$ *background*	14	4	10	10	8	7	6
tW	65	17	48	42	18	16	13
VV	525	337	188	57	14	7	2
$Z^0 / \gamma* \rightarrow \tau\tau$	796	60	737	115	26	13	3
$Z^0 / \gamma* \rightarrow ee$	360478	332577	27902	4577	981	114	41
$W \rightarrow ll$	148	36	112	36	10	6	2
QCD	438	261	176	0	0	0	0
MC sum	363516	333579	29937	5581	1633	648	513
Data	391230±625	358523±599	32707±181	5784±76	1740±42	675±26	532±23

TABLE 1. Cutflow for *ee* channel including all corrections and scaling factors

	dilepton	Z^0 selection	Z^0 veto	one jet	two jets	missing E_T	b-tag
$t\bar{t}$ *signal*	1184	327	858	834	653	554	509
$t\bar{t}$ *background*	4	2	2	2	2	1	1
tW	73	19	54	48	21	18	15
VV	351	155	196	51	10	8	2
$Z^0 / \gamma* \rightarrow \tau\tau$	890	67	824	125	24	12	3
$Z^0 / \gamma* \rightarrow \mu\mu$	429744	398555	31189	5048	1060	132	50
$W \rightarrow ll$	6	1	5	2	0	0	0
QCD	0	0	0	0	0	0	0
MC sum	432252	399124	33128	6110	1769	726	581
Data	458931±677	422458±650	36473±191	6168±79	1807±43	671±26	541±23

TABLE 1. Cutflow for $\mu\mu$ channel including all corrections and scaling factors

Full Z^0 selection

Full $t\bar{t}$ selection

Main systematic uncertainties (ratio)

- Theory uncertainties (scale, matching, topmass) $\approx 6\%$
  - Dominated by $t\bar{t}$
  - PDF not yet accounted for (anti-correlation?)
- Detector modeling (JES,JER,PU) $\approx 3\%$
  - Dominated by $t\bar{t}$
  - PU cancels partially
- Scale factors (Trigger, Isolation, Id, reconstruction) $\approx 0.3\%$
  - Common cancel almost
  - Id, reconstruction assumed to cancel completely
- $t\bar{t}$ scale factors (b-tag , Isolation difference) $\approx 4.2\%$
- Background $\approx 5\%$
  - Dominated by $t\bar{t}$

Detailed systematics in backup

Results

$$R\left(\frac{\sigma_{t\bar{t}\to X\to\mu\mu}}{\sigma_{Z\to\mu\mu}}\right) = \left(2.60 \pm 0.12\ (stat) \pm^{0.27}_{0.22}\ (syst)\right)\ 10^{-3}$$

$$R\left(\frac{\sigma_{t\bar{t}\to X\to ee}}{\sigma_{Z\to ee}}\right) = \left(2.97 \pm 0.13\ (stat) \pm^{0.25}_{0.33}\ (syst)\right)\ 10^{-3}$$

Include theory value for Z cross section (NNLO) *:

$\sigma_{Z\to ll} = (972 \pm 42) pb$

Include BR for total cross section (PDG):

$BR(t\bar{t} \to X \to ll) = (1.616 \pm\ 0.023)\%$

$$\sigma_{t\bar{t}\to X\to\mu\mu} = 156.6 \pm 7.4\ (stat) \pm^{16.3}_{13.2}\ (syst)\ \pm 3.4\ (theo)\ \ (pb)$$

$$\sigma_{t\bar{t}\to X\to ee} = 177.6 \pm 8.0\ (stat) \pm^{14.7}_{19.9}\ (syst) \pm 3.5\ (theo)\ \ (pb)$$

In agreement with CMS measurement PAS TOP-11-005 (dilepton 3 channels):

$$\sigma_{t\bar{t}\to X\to ll} = 169.9 \pm 3.9\ (stat) \pm 16.3\ (syst) \pm 7.6\ (lumi)\ \ (pb)$$

* https://twiki.cern.ch/twiki/pub/CMS/GeneratorMain/ShortXsec.pdf

Summary / Outlook

Cross section ratio of $t\bar{t} \to X \to l^+l^-$ and $Z^0 \to l^+l^-$ using data corresponding to a luminosity of $1.14\ fb^{-1}$ at $\sqrt{s} = 7$ TeV taken by CMS:

$$R\left(\frac{\sigma_{t\bar{t}\to X\to\mu\mu}}{\sigma_{Z\to\mu\mu}}\right) = \left(2.60 \pm 0.12\ (stat) \pm^{0.27}_{0.22}\ (syst)\right) 10^{-3}$$

$$R\left(\frac{\sigma_{t\bar{t}\to X\to ee}}{\sigma_{Z\to ee}}\right) = \left(2.97 \pm 0.13\ (stat) \pm^{0.25}_{0.33}\ (syst)\right) 10^{-3}$$

- Uncertainties dominated by $t\bar{t}$ cross section measurement
- Will become larger due to PDF uncertainties
- Resulting cross section consistent with CMS public result (PAS TOP-11-005)

- **Outlook:**
  - Implement lepton identification measurement from data (impact should be small)
  - Investigate PDF uncertainties (due to anti correlation impact can be large)
  - Simultaneous fit of PDF parameters?
  - Combine channels

BACKUP

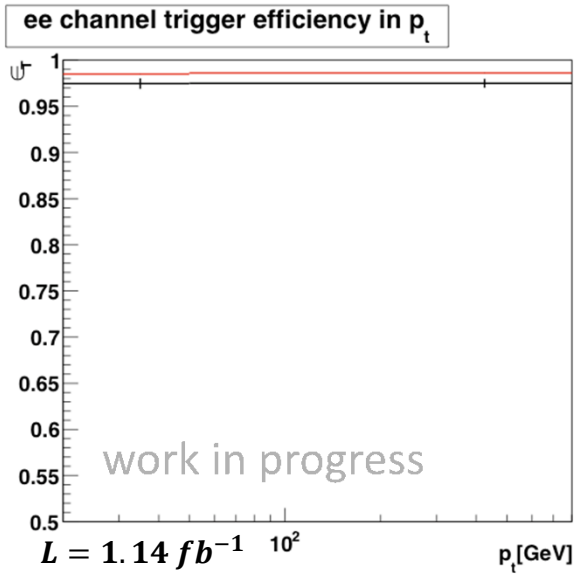
dimuon channel systematics detailed

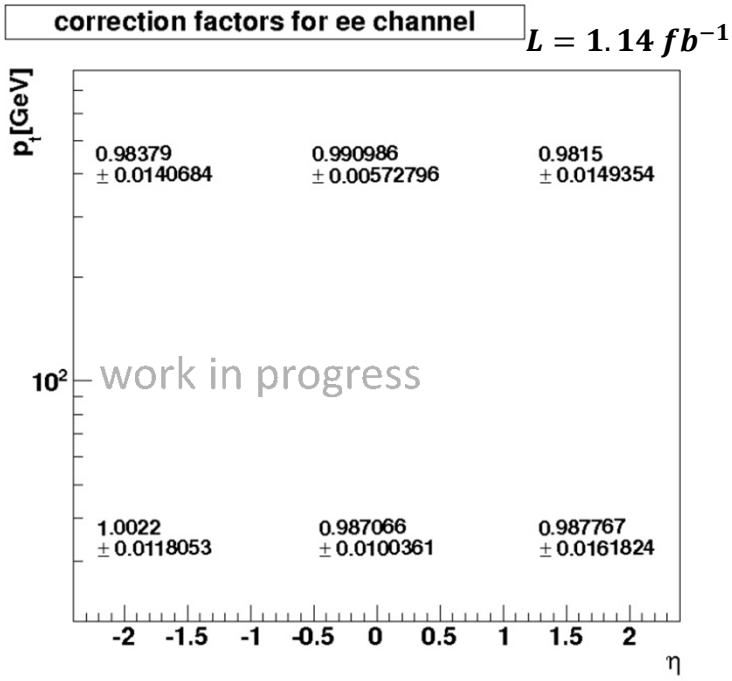
	Z	tt	ratio
Scale	-3% +1.6%	+2.2% -2.4%	+5.4% -4%
matching	-0.6% -0.7%	+3.8% - 0.4%	+4.4% +0.3%
topmass		-0.8% + 1.6%	-0.8% +1.6%
PDF			under invest.
JES		-2.2% +2.8%	-2.2% +2.8%
JER		+0.7% -0.6%	+0.7% -0.6%
PileUp	+0.6% -1.7%	0.3%	-0.3% +1.4%
Trigger	>1%	>1%	0.3%
Isolation		4%	4%
btagging		1.2%	1.2%
background	1%	5.4%	5.5%
Total (w/o PDF)			-8.4% +10.4%

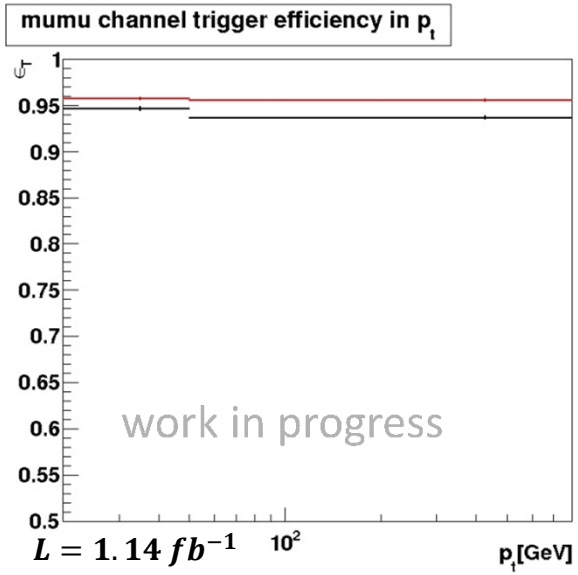
dielectron channel systematics detailed

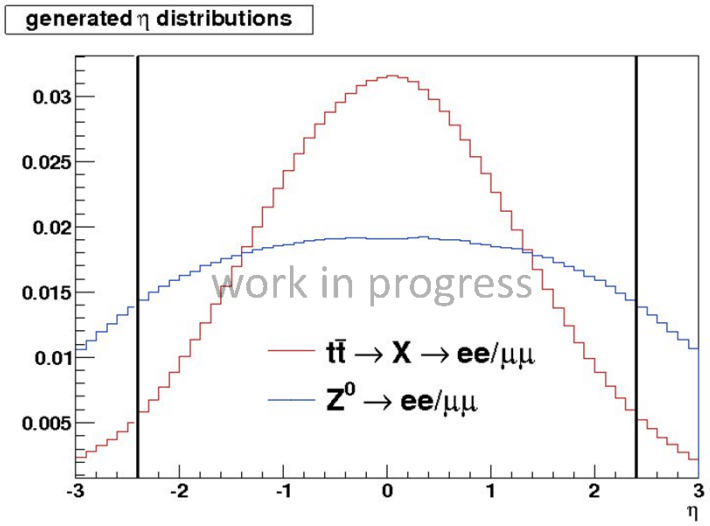
	Z	tt	ratio
Scale	-2.7% + 1.9%	-3.8% -4%	-1.2% -5.7%
matching	-1.0% - 1.3%	-2.3% -5.4%	-1.3% -4.2%
topmass		-5.6% +1.7%	-5.6% +1.7%
PDF			under invest.
JES		-1.7% +2.8%	-1.7% +2.8%
JER		+1.1% -0.6%	+1.1% -0.6%
PileUp	+0.8% -2%	0.2%	-0.7% +2%
Trigger	>1%	>1%	0.3%
Isolation		4%	4%
btagging		1.2%	1.2%
background	1%	4.4%	4.5%
Total (w/o PDF)			-11.2% +8.3%

Backup: Trigger efficiencies

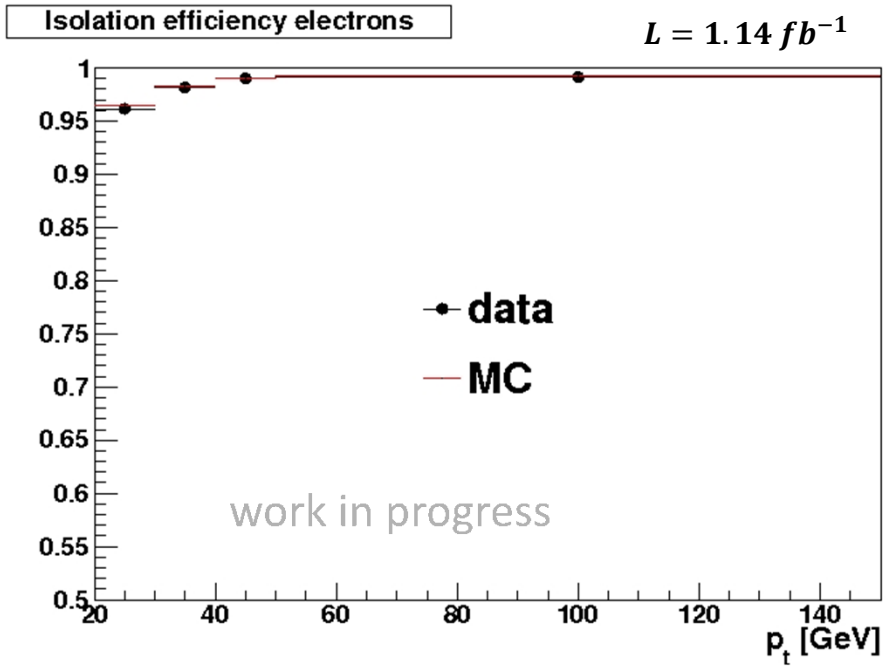


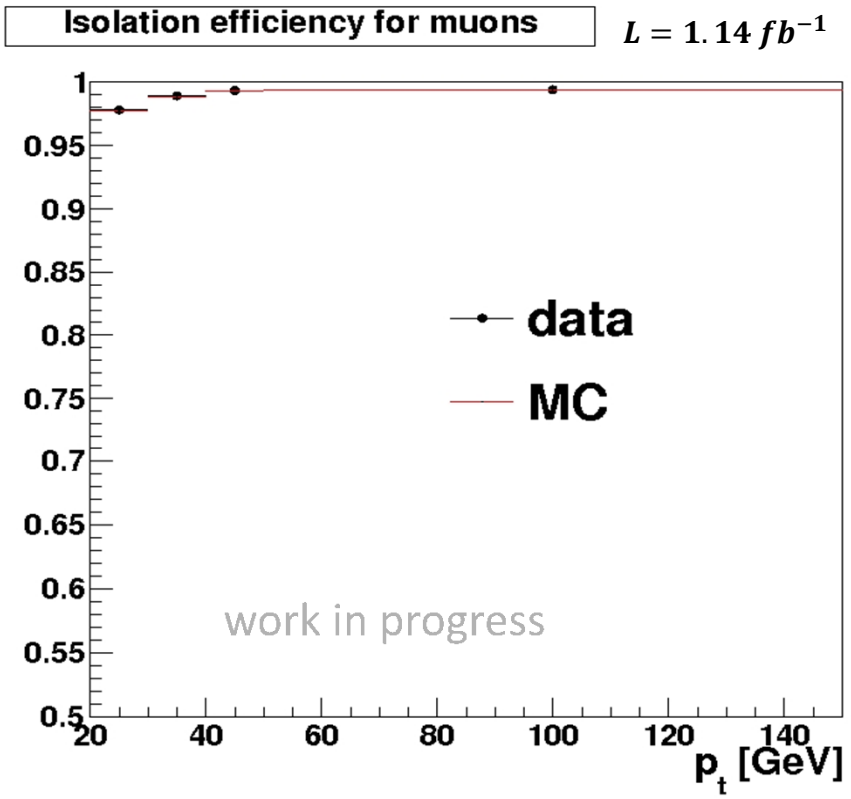






Backup: Isolation efficiencies





Backup: main contr. MC samples

Sample	Generator	Cross section $[pb^{-1}]$
$t\bar{t}$	Madgraph	169.9 *
$Z^0 \rightarrow ll,\ m_{ll} > 50$	Madgraph	3457
tW	Pythia 6	5.3
WW	Pythia 6	4.51
WZ	Pythia 6	0.61
ZZ	Pythia 6	7.4
QCD	Pythia 6	several

* PAS TOP-11-005 cross section