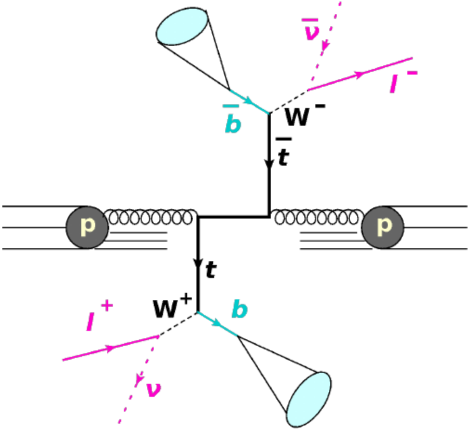
# Measurement of differential top-quark pair production cross sections in $pp$ colisions at $\sqrt{s} = 7$ TeV




**Dilepton channel: $3$ possible final states:**

- $e^{\pm}e^{\mp}$ + 2 $b$-jets + 2 neutrinos
- $\mu^{\pm}\mu^{\mp}$ + 2 $b$-jets + 2 neutrinos
- $e^{\pm}\mu^{\mp}$ + 2 $b$-jets + 2 neutrinos

$\Rightarrow$ selecting events with two leptons, two jets, also expect missing transverse energy (MET)

$t$ and $\bar{t}$ are then reconstructed from measured final state particles and assumptions on $m_W$, $m_t$

## Data samples:

- $e^{\pm}e^{\mp}$: '`DoubleElectron`'
- $\mu^{\pm}\mu^{\mp}$: '`DoubleMu`'
- $e^{\pm}\mu^{\mp}$: '`MuEG`'

# Event selection

## Primary vertex:

- dof $> 4$
- impact parameter $< 2$ cm in transverse plane and $< 24$ cm in z

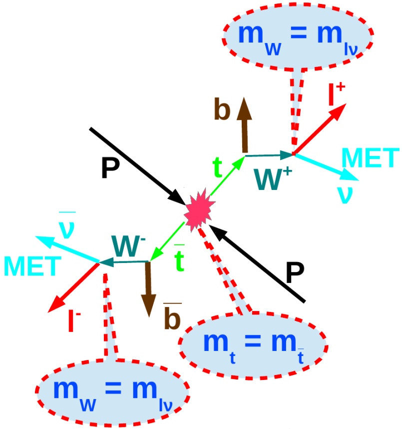
## Leptons: two leading $p_T$ opposite signed $p_T > 20$ GeV, $|\eta| < 2.4$

- Electrons ('`gsfElectrons`')
  - isolated with $I_{\mathrm{rel}}^{\Delta R<0.3} < 0.17$ ($\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$)
  - no missing hits in the silicon tracker
- Muons ('`muons`')
  - isolated with $I_{\mathrm{rel}}^{\Delta R<0.3} < 0.20$
  - required to be global muons
  - at least 10 valid tracker hits and 2 pixel hits
  - global track fit $\chi^2$/dof $< 10$
  - impact parameter to PV $< 0.02$ cm in transverse plane and $< 0.5$ cm in z
- $M(ll) > 12$ GeV
- in $ee$ and $\mu\mu$ channels exclude $16 < M(ll) < 106$ GeV
- in $ee$ and $\mu\mu$ channels require MET $> 30$ GeV

## Jets ('`ak5PFJets`'): at least two with $p_T > 30$ GeV, $|\eta| < 2.4$

- anti-$k_T$ with clustering parameter $0.5$
- Jet energy correction: '`ak5PFL1FastL2L3Residual`'
- at least one $b$-tagged using CSVL (discriminant $> 0.244$)
- CSV information stored only for '`ak5CaloJets`': perform matching choosing closest jet in $\Delta R$

**Goal:** obtain $\vec{p}_t$ and $\vec{p}_{\bar{t}}$




Efficiency determined in signal MC:
$\approx 70\%$ vs $90\%$ in the paper

- Measured input: $2$ leptons, $2$ jets, MET
- Unknowns: $\bar{p}_\nu$, $\bar{p}_{\bar{\nu}}$ (6)
- Constraints:
  - $m_t$, $m_{\bar{t}}$ (2)
  - $m_{W+}$, $m_{W-}$ (2)
  - $(\bar{p}_\nu + \bar{p}_{\bar{\nu}})_T = \mathrm{MET}$ (2)
- For each pair of jets, solve this using the method from [Phys. Rev. D73 (2006) 054015]
- If there are several solutions in event (either because of many jet combinations, or several solutions for one configuration), prefer:
  - with 2 $b$-tagged jets
  - with 1 $b$-tagged jets
  - with highest weight, weight is determined according to the MC neutrino energy spectrum
- Difference from the paper: no $m_t$ scan $\Rightarrow$ worse efficiency due to detector effects

[DESY-THESIS-2012-037]

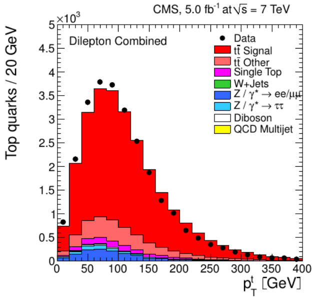
**Signal:**

- MadGraph + Pythia6, 55M

**Background:**

- $t\bar{t}$ 'other', mainly via $\tau$ decays (MadGraph + Pythia6)
- single top (POWHEG + Pythia6), 1.5M
- Drell-Yan (DY) (MadGraph + Pythia6), 44M
- $W$ + jets (MadGraph + Pythia6), 55M
- Diboson and QCD multijet considered in the paper, but contribute negligibly: not used

TOP-11-013

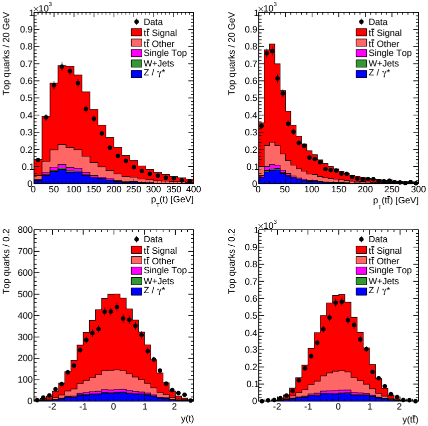



In total processed:

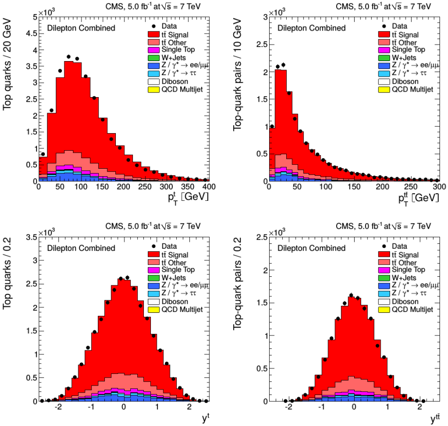
- Data: 33M ($e\mu$) + 50M ($ee$) + 40M ($\mu\mu$) $\approx$ 123M
- MC: $\approx$ 155M (processing MC took $\times 5$ more time than data: busy events, larger fraction selected)

**Overall $\sim$ 2 weeks (not CPU time!)**, running several jobs in parallel on one machine, but also gaps between running jobs. Some jobs needed to be resubmitted. Bottleneck: data network access (latent server responce?). *Any improvement here is very desirable: how will it be feasible for more complicated analyses, or 2012 data?..*

## Open Data




## TOP-11-013




- ≈ 25% less events than expected from TOP-11-013: consistent with smaller kin. reco efficiency
- Larger MC / data: consistent with missing scale factors, corrections etc.
- Slightly larger background fraction
- Shapes very similar

* $p_T(t)$, $y(t)$ vs $p_T(t), p_T(\bar{t})$ and $y(t), y(\bar{t})$ in paper

**Cross section measured at parton level in full phase space:**

$$\frac{\mathrm{d}\sigma}{\mathrm{d}Y} = \frac{N_{Sig}}{ALB\Delta Y},\ N_{Sig} = N_{DATA} - N_{MCbackgr},\ E = \frac{N_{MCreco}}{N_{MCgen}}$$

$$\sigma = \int \frac{\mathrm{d}\sigma}{\mathrm{d}Y}$$

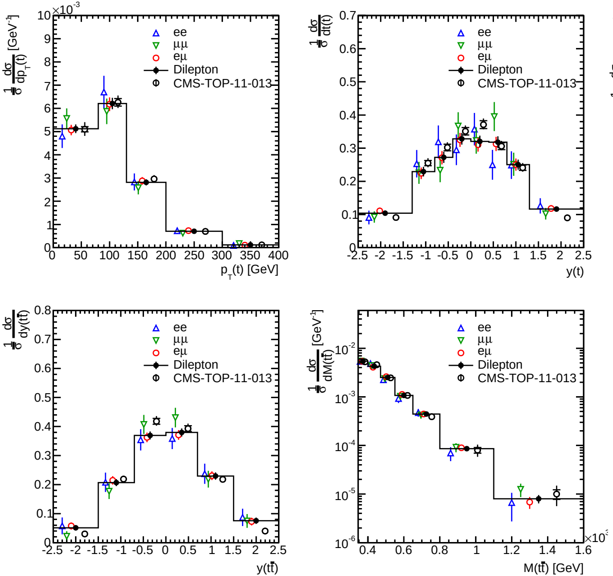
$L = 2.5\ \mathsf{fb}^{-1}$, $B = 4.6\%$

**Efficiency $E$ determined as bin-to-bin corrections: no 'unfolding'.**
This should give underestimated stat. uncertainties and might bias central values in bins with small purity/stability and poor MC description.

**Measure:**

- normalised differential x-section $\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}Y}$ (published in TOP-11-013)
- total x-section (published in TOP-13-004)

# Normalised differential cross sections




- Consistent results in all three channels
- **Consistent with the paper!** (no difference larger than 3 $\sigma$)
- Trends at large $|y(t)|$, $|y(t\bar{t})|$: unfolding might be important here

# Total cross section

How it is determined:

- Using $e\mu$ channel only (most precise)
- In this analysis obtained by integrating over differential x-section
- More sophisticated procedure in the paper

**Open data**

e.g. by integrating $p_T(t)$ diff. x-section:
$\sigma(t\bar{t}) = 163.3 \pm 4.3$ (stat) pb

additionally spread between integrations over different variables $\approx 10$ pb:
$\sigma(t\bar{t}) = 163.3 \pm 4.3$ (stat) $\pm$ 5 (syst) pb

**TOP-13-004**

$173.6 \pm 2.1$ (stat) $^{+4.5}_{-4.0}$ (sys) $\pm 3.8$ (lum) pb

- Reasonable consistency. In agreement with larger MC / data rate, missing corrections etc.
- Total x-section sensitive to (in)efficiency, scale factor issues (cancel to large extend for normalised x-section).