Measurement of the $t\bar{t}$ production cross section in the dilepton channel in pp collisions at $\sqrt{s} = 8$TeV

GROUP A

Standard Model at the LHC

CLASHEP 2015

Ibarra-Ecuador

Motivation

Top quark measurements are of central importance to the LHC physics program.

Top quark pair production is an important source of background in many searches for NP.

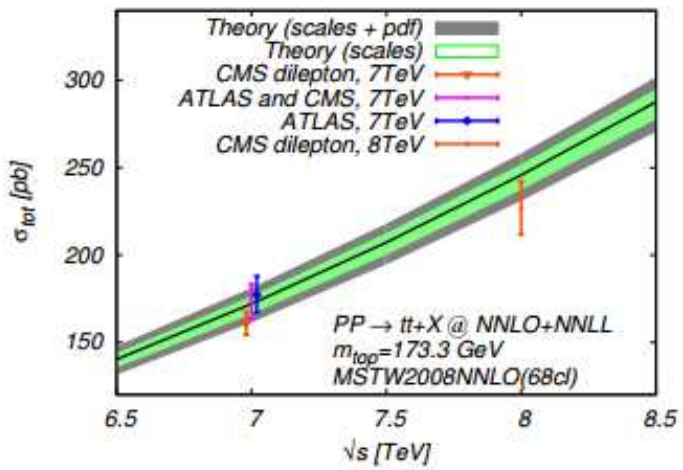
Measurement of $\sigma_{t\bar{t}}$

- Test QCD at NNLO level.
- Allows an estimation of $\alpha_s(M_Z)$ and m_t^{pole}.

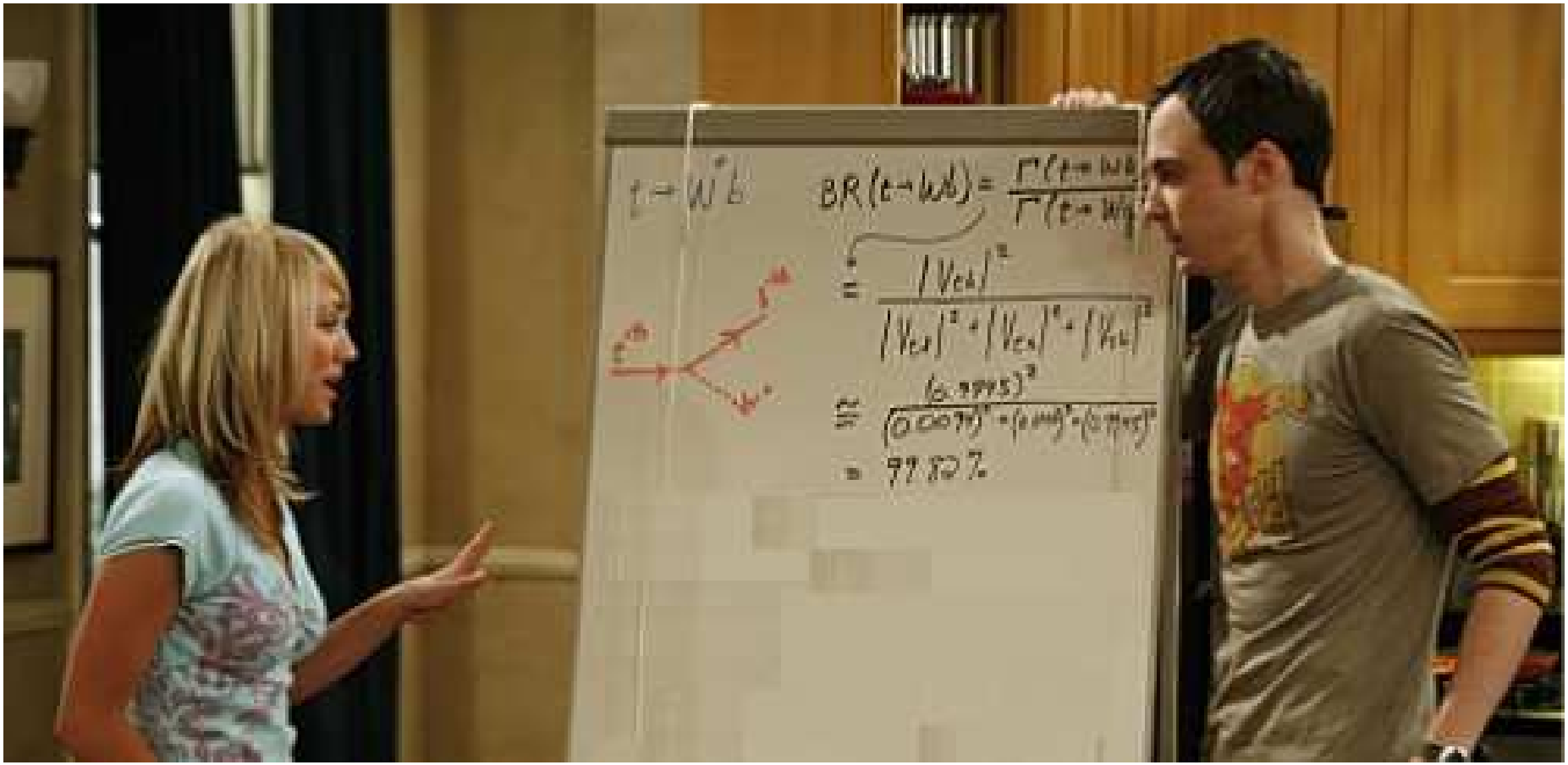
Theoretical $\sigma_{t\bar{t}}$ estimation at 8TeV ($m_t = 172.5$ GeV):

NNLO in pQCD, including soft gluon resummation at NNLL order.

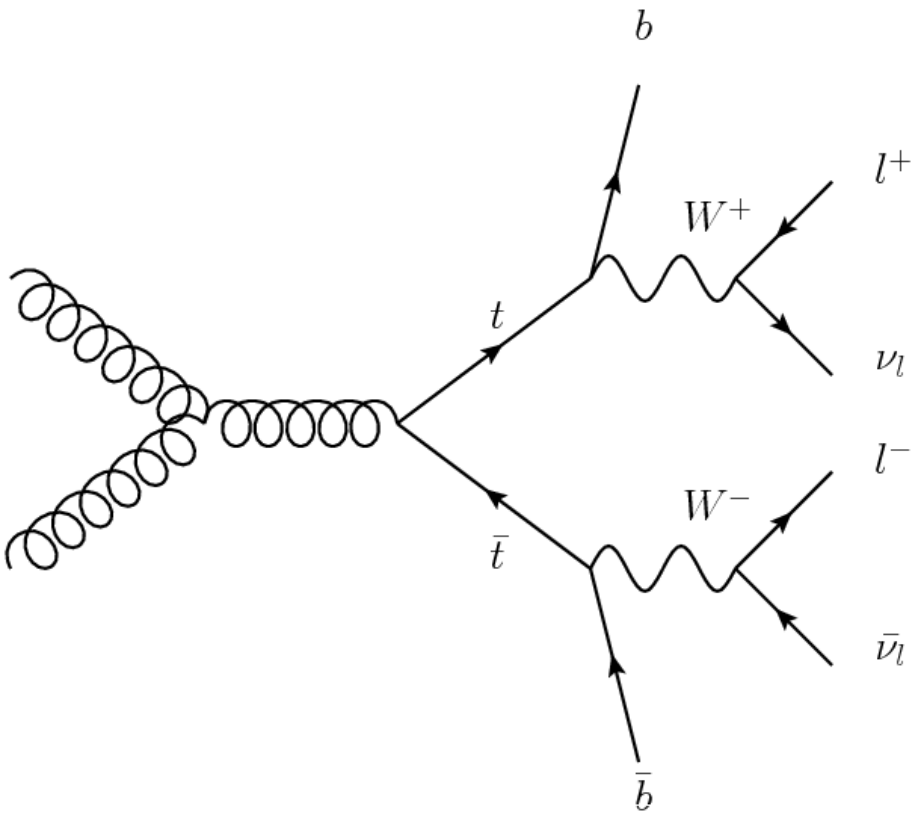
$$\sigma_{t\bar{t}} = 252.9^{+6.4}_{-8.6}(scale) \pm 11.7(PDF + \alpha_s)\text{pb}$$



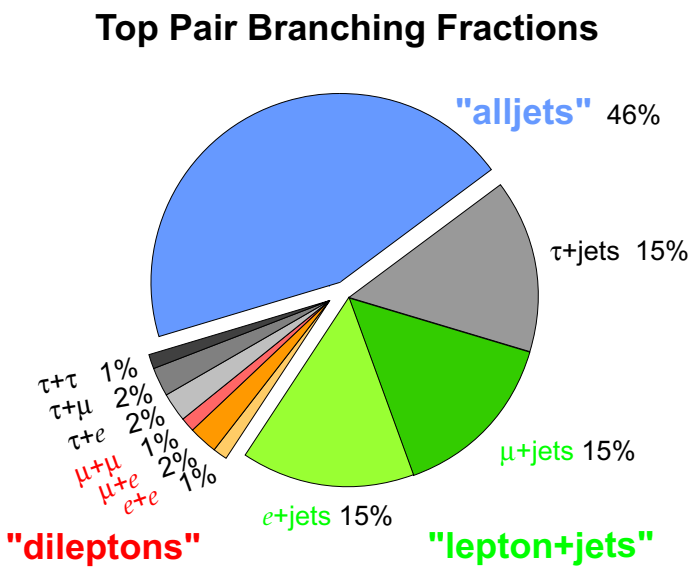
Top quark pair production

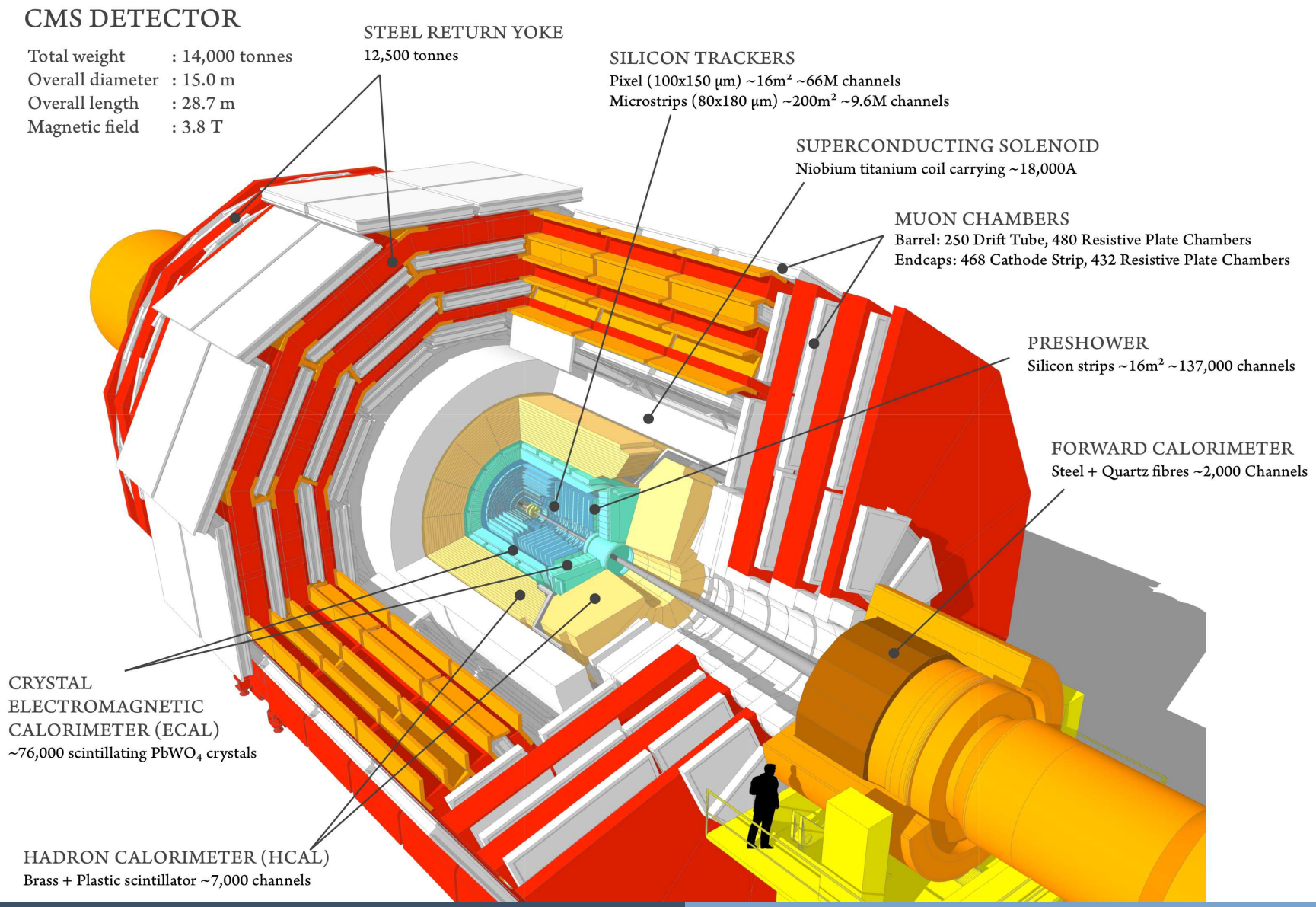


Top quark pair production



Top quark pair production via strong interaction: Gluon production (dominant at LHC)




CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO4 crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

Event selection

TRIGGER LEVEL

$2e, 2\mu, e+\mu;\ P_{T_1} > 17\text{GeV}\ P_{T_2} > 8\text{GeV}$

↓

CMS PARTICLE-FLOW ALGORITHM

Two high P_T isolated opposite charge leptons

Both $P_T > 20\text{GeV}$, $|\eta_e| < 2.5$, $|\eta_\mu| < 2.1$

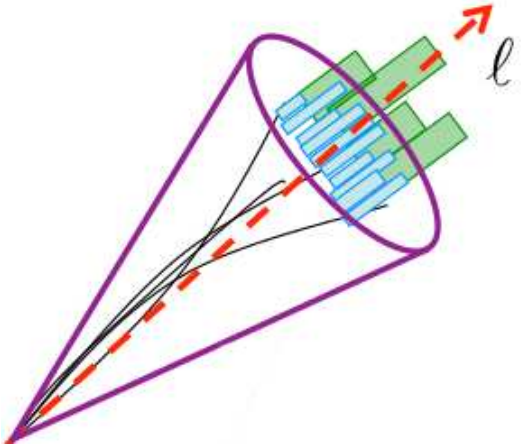
↓

The pair of leptons with the highest

P_T is selected.

Dilepton candidates

- Isolation cone: $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2} < 0.3$
- Relative isolation:
  $$I_{rel} = \frac{\sum P_T(\text{particles reconstructed})}{P_T(\text{lepton candidate})} < 0.15$$
- Remove dilepton candidate events with an invariant mass $M_{\ell\ell} < 20\text{GeV}$ and $|M_{\ell\ell} - M_Z| < 15\text{GeV}$.



$\not{E}_T$

Missing transverse energy $\not{E}_T > 40\text{GeV}$ for e^-e^+ and $\mu^-\mu^+$. No required $\not{E}_T$ for $e^\mp\mu^\pm$.

Jet criteria

- JETS reconstructed with ANTI-k_T CLUSTERING ALGORITHM.
- At least 2 reconstructed jets $\Rightarrow$ $P_T > 30\text{GeV}$, $|\eta| < 2.5$
- There must be a b-jet in the event.

Background Estimation

- Drell-Yan:

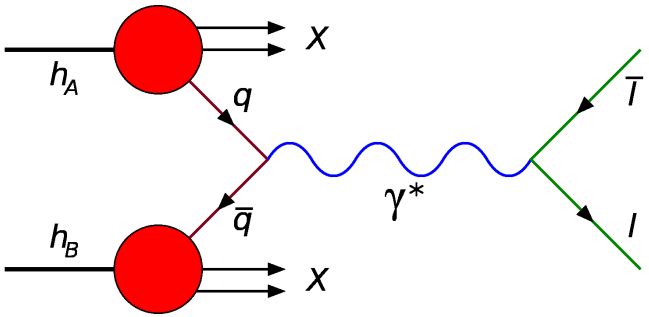
  DY-MC normalization given by data inside Z mass window.

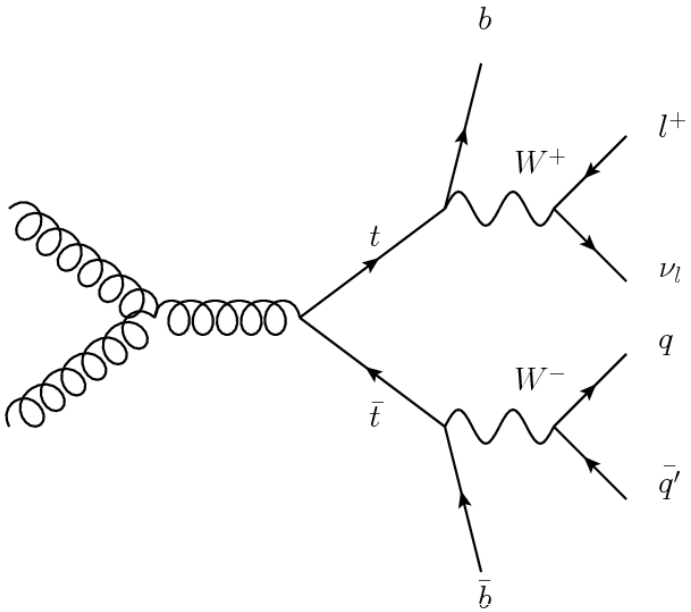
- Single-Top-Quark and VV Events:

  MC simulated

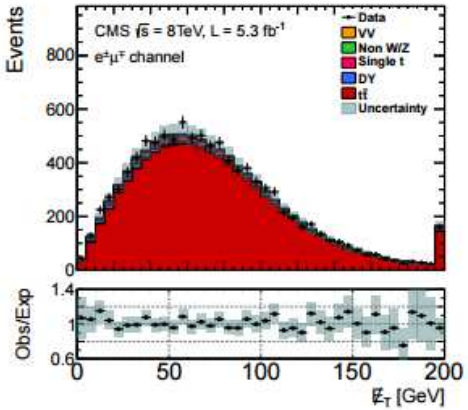
- Non-W/Z Leptons

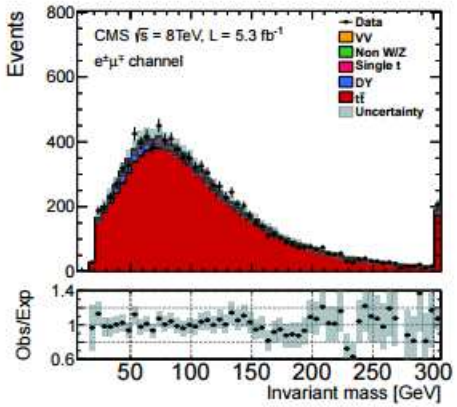
  - ⋆ $t\bar{t}$ lepton+jet
  - ⋆ Non-prompt leptons: can arise from decays of mesons or heavy-quark decays





Background Estimation





	Number of events		
Source	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$
Drell–Yan	386±116	492±148	194±58
Non-W/Z leptons	25±10	114±46	185±72
Single top quark	127±28	157±34	413±88
VV	30±8	39±10	94±21
Total background	569±120	802±159	886±130
$t\bar{t}$ dilepton signal	2728±182	3630±250	9624±504
Data	3204	4180	9982

Systematic ~~Errors~~ Uncertainties

Systematic Uncertainties

Source	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$
Trigger efficiencies	4.1	3.0	3.6
Lepton efficiencies	5.8	5.6	4.0
Lepton energy scale	0.6	0.3	0.2
Jet energy scale	10.3	10.8	5.2
Jet energy resolution	3.2	4.0	3.0
b-jet tagging	1.9	1.9	1.7
Pileup	1.7	1.5	2.0
Scale (μ_F and μ_R)	5.7	5.5	5.6
Matching partons to showers	3.9	3.8	3.8
Single top quark	2.6	2.4	2.3
VV	0.7	0.7	0.5
Drell–Yan	10.8	10.3	1.5
Non-W/Z leptons	0.9	3.2	1.9
Total systematic	18.6	18.6	11.4
Integrated luminosity	6.4	6.1	6.2
Statistical	5.2	4.5	2.6

1. Experimental:
   1. Leptons reconstruction and selection efficiency (1 %−2 %) in data and simulation.
   2. Dilepton trigger efficiency: Estimated from data
   3. Jet Energy Resolution and Jet Energy Scale
   4. b-Jet tagging and Mis-tag(2 % and 10 % respectively).
   5. Pileup and integrated luminosity.
2. Theoretical: Matching partons to showers (MLM), μ_F and μ_R.

Results

- Simple counting analysis method after applying the selection criteria.

$$\sigma \cdot b_r = \frac{N_{events} - N_{bkg}}{A \cdot \epsilon \cdot L} \tag{1}$$

	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$
ϵ_{total} (%)	0.203 ± 0.012	0.270 ± 0.017	0.717 ± 0.033
$\sigma_{t\bar{t}}$ (pb)	$244.3 \pm 5.2 \pm 18.6 \pm 6.4$	$235.3 \pm 4.5 \pm 18.6 \pm 6.1$	$239.0 \pm 2.6 \pm 11.4 \pm 6.2$

Results

A combination of the 3 final states using the BLUE method yields a measured cross section of

$$\sigma_{t\bar{t}} = 239.0 \pm 2.1(stat) \pm 11.3(syst.) \pm 6.2(lum.)pb \tag{2}$$

for a top-quark mass of 172.5GeV.

$$\sigma_{t\bar{t}} = 252.9^{+6.4}_{-8.6}(scale) \pm 11.7(PDF + \alpha_s)pb \tag{3}$$

Summary and Conclusions

- Measurement of top quark pair production cross section in proton-proton collisions at $\sqrt{s} = 8$TeV for events containing a lepton pair (e^+e^-, $\mu^+\mu^-$, $e^\pm\mu^\mp$), at least two jets with at least one tagged as b-jet, and a large imbalance in transverse momentum in the final state.
- The cross-section dependence of the m_t in the range 160-185 GeV can be parametrized as:

$$\frac{\sigma_{t\bar{t}}}{\sigma_{t\bar{t}}(m_t = 172.5)} = 1.00 - 0.009 \cdot (m_t - 172.5) - 0.000168 \cdot (m_t - 172.5)^2 \quad (4)$$


Sorry for the LONG talk

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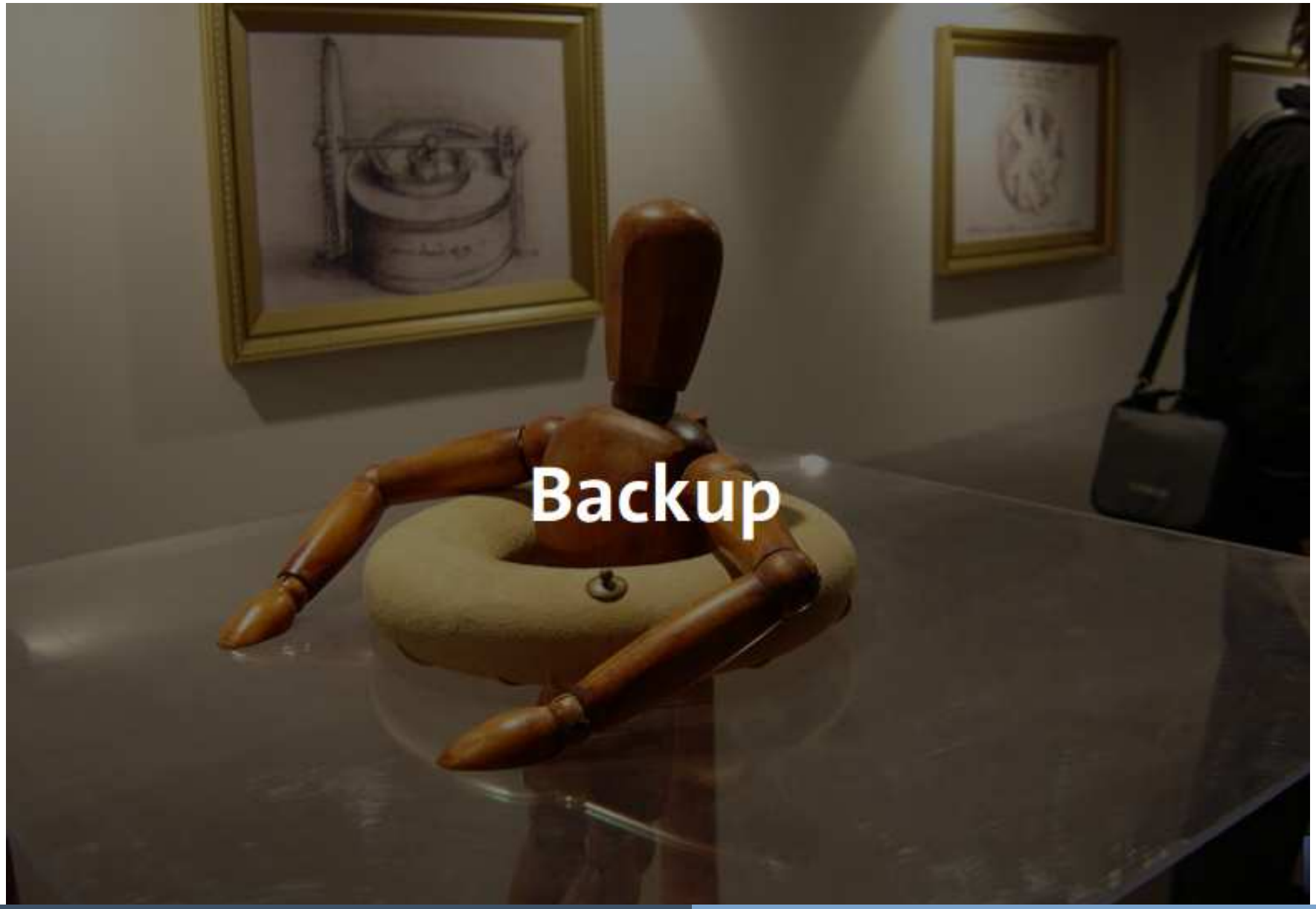
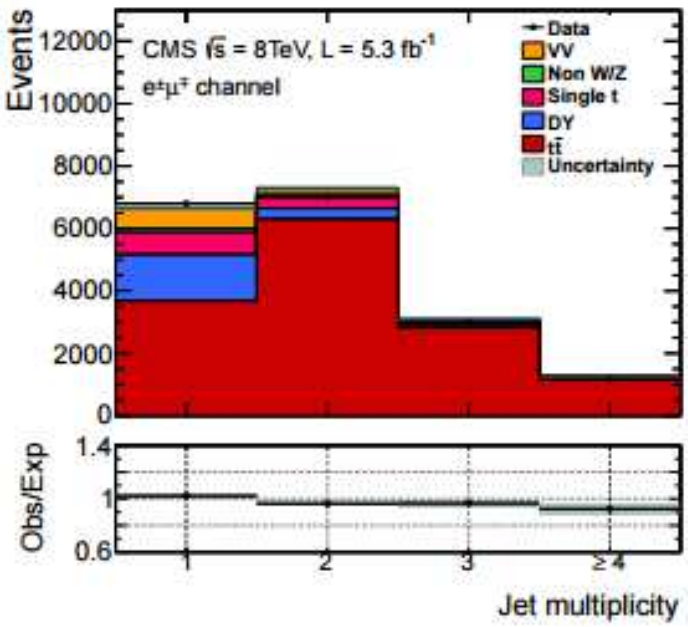
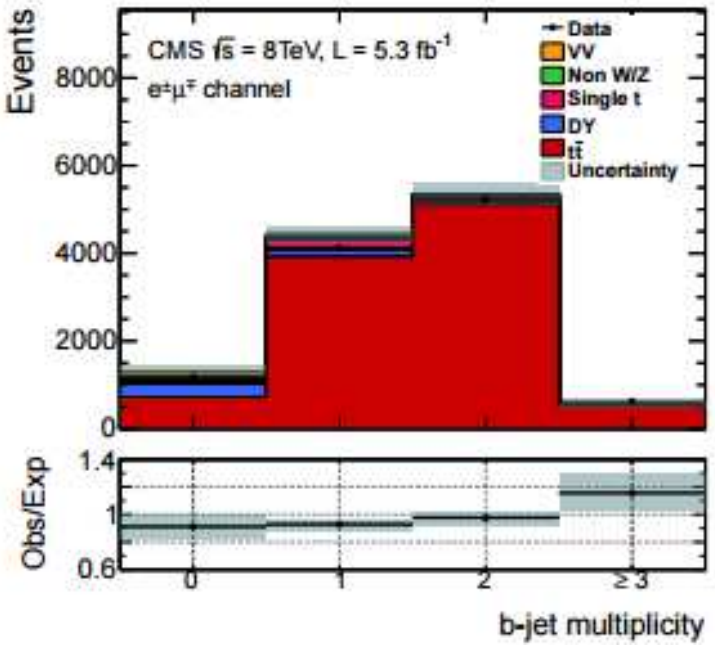

Backup

Backup Slides - Jet multiplicity





Backup Slides - DY Background Determination from data-driven method

- DY is estimated using the $R_{out/in}$ method:
  The events **outside** the Z mass window are obtained by normalising the event yield from simulation to the observed number of events inside the Z mass window.

$$N^{\ell^+\ell^-}_{out/in}(obs) = R^{\ell^+\ell^-}_{out/in}(N^{\ell^+\ell^-}_{out/in} - 0.5N^{e\mu}_{in}k_{\ell\ell}) \quad (5)$$

- $R_{out/in}$ is the ratio of the number of events outside/inside the Zveto region taken from a DY MC sample
- Data-to-simulation scale factor: 1.3 ± 0.4 for the $e^{\pm}u^{\mp}$ channel, 1.7 ± 0.5 and 1.6 ± 0.5 for the e^+e^- and $\mu^+\mu^-$ channels, respectively.

Backup Slides - m_t^{pole} and $\alpha_s(M_Z)$ estimation