Top Production and Decay into Tau

September 26th 2013

Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

- Measure $\sigma_{t\bar{t}}$

$\propto \# t\bar{t}$

Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

- Measure $\sigma_{t\bar{t}}$

$$\propto \#\, t\bar{t}$$

- Measure $BR(top \to \tau\nu b)$

$$\frac{\#\, t \to \tau \nu b}{\#\, t \to \text{anything}}$$

The Standard Model

- Describes fundamental particles and their interactions, except from gravity
- Explains well experimental data, but it's thought to be the low energy limit of a more fundamental theory

The Top Quark

- Observed for the first time in 1995 at Tevatron

The Top Quark

- Observed for the first time in 1995 at Tevatron
- Completes the family structure of the SM

The Top Quark

- Observed for the first time in 1995 at Tevatron
- Completes the family structure of the SM

Features

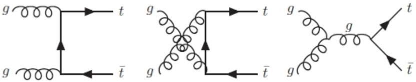
$$m_{top} \approx 173 \text{ GeV}/c^2$$
$$\tau_{top} \approx 5 \times 10^{-25} \text{ s}$$
$$\text{spin} = \frac{1}{2}$$
$$\frac{Q}{e} = \frac{2}{3}$$

Production of $t\bar{t}$

- Through strong interaction
- Two posible processes:

Production of $t\bar{t}$

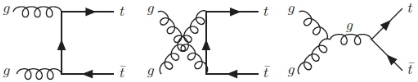
- Through strong interaction
- Two posible processes:



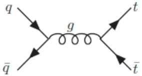
Gluon-gluon fusion
15% at Tevatron

Production of $t\bar{t}$

- Through strong interaction
- Two posible processes:



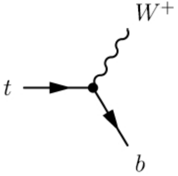
Gluon-gluon fusion 15% at Tevatron



$q\bar{q}$ annihilation 85% at Tevatron

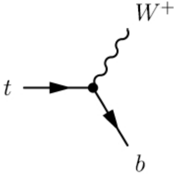
Top Quark Decay

- In the Standard Model 100%: $t \to W^+ b$, $\bar{t} \to W^- \bar{b}$

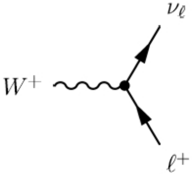


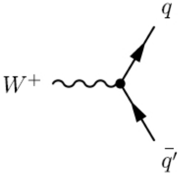
Top Quark Decay

- In the Standard Model 100%: $t \to W^+ b$, $\bar{t} \to W^- \bar{b}$



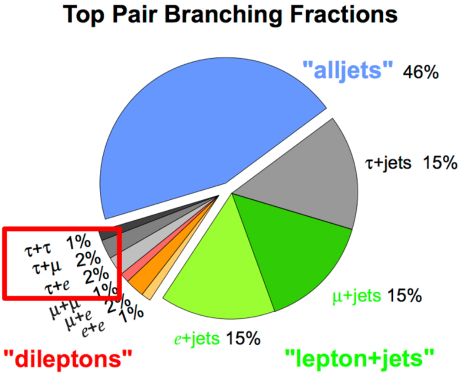
- W decays into $W \to l\nu$ or $W \to qq'$





Top Quark Decay

- $t\bar{t}$ decay channels are classified based on the the W decays



Tau Lepton

- Heaviest lepton ($m_\tau = 1.777$) GeV
- Decays with lifetime = 2.9 $\times 10^{-13}$ s
- Difficult to distinguish τ leptonic decays from isolated e or μ

τ^- decay mode	BR (%)
(leptonic)	
$\mu^- \nu_\tau \bar{\nu}_\mu$	17.4%
$e^- \nu_\tau \bar{\nu}_e$	17.9%
("one-prong" hadronic)	
$h^- \nu_\tau (\geq 0 \text{ neutrals})$	49.5%
$h^- \nu_\tau (> 0 \text{ neutrals})$	37.1%
("three-prong" hadronic)	
$h^- h^+ h^- \nu_\tau (\geq 0 \text{ neutrals})$	15.2%

Two Higgs Doublet Model

- In the Minimal SM particles acquire mass through the interaction with the Higgs field (complex doublet)
- Extensions with more Higgs doublets

Two Higgs Doublet Model

- In the Minimal SM particles acquire mass through the interaction with the Higgs field (complex doublet)
- Extensions with more Higgs doublets
- 2HDM: two complex SU(2) doublets of scalar fields
- If $m_t > m_{H^\pm} + m_b$ the decay $top \to H^+ b$ is allowed
- H^+ couples preferentially to the τ
- This would enhance $top \to \tau\nu b$

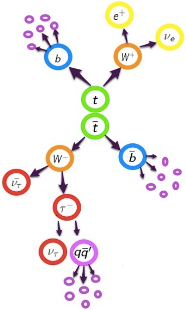
Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

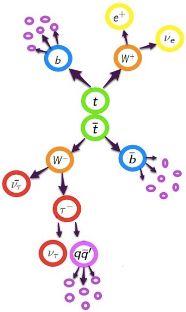
$$t\bar{t} \to b\bar{\tau}\nu\,\bar{b}e\bar{\nu}$$

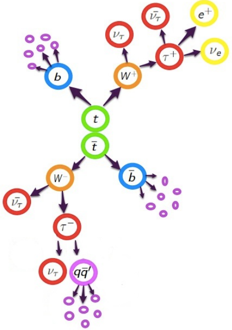


Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

$t\bar{t} \to b\bar{\tau}\nu\,\bar{b}e\bar{\nu}$ $t\bar{t} \to b\bar{\tau}\nu\,\bar{b}\tau\bar{\nu}$

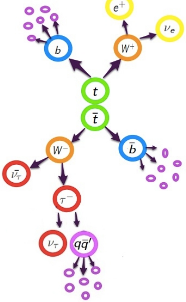




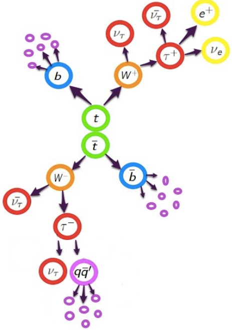
Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

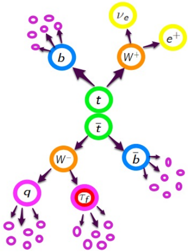
$t\bar{t} \to b\bar{\tau}\nu\, \bar{b}e\bar{\nu}$



$t\bar{t} \to b\bar{\tau}\nu\, \bar{b}\tau\bar{\nu}$



$t\bar{t} \to b\bar{\tau}\nu\, \bar{b}qq'$

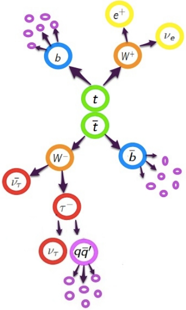


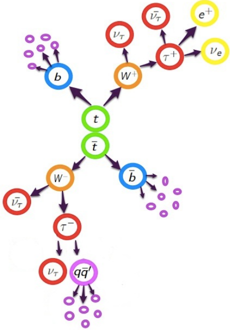
Aim of the Analysis

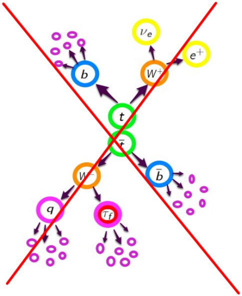
Measurement of top pair production with one hadronic tau decay

First part of the Analysis:

$t\bar{t} \to b\bar{\tau}\nu\,\bar{b}\ell\bar{\nu}$ $t\bar{t} \to b\bar{\tau}\nu\,\bar{b}\tau\bar{\nu}$ $t\bar{t} \to b\bar{\tau}\nu\,\bar{b}qq'$





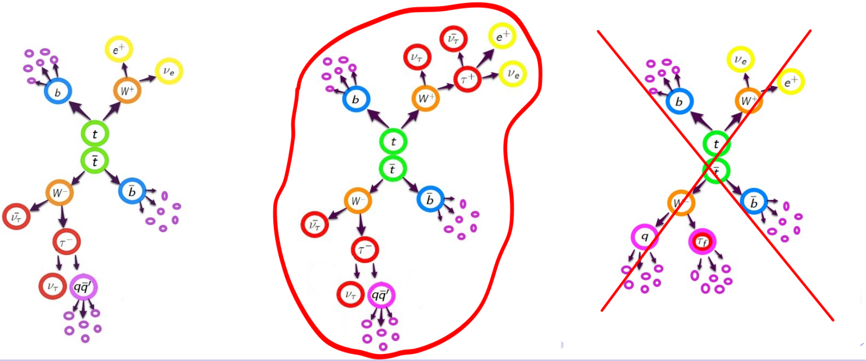


Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

Second part of the Analysis:

$t\bar{t} \to b\bar{\tau}\nu\,\bar{b}\ell\bar{\nu}$ $t\bar{t} \to b\bar{\tau}\nu\,\bar{b}\tau\bar{\nu}$ $t\bar{t} \to b\bar{\tau}\nu\,\bar{b}qq'$

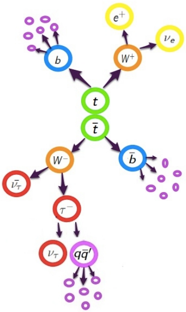


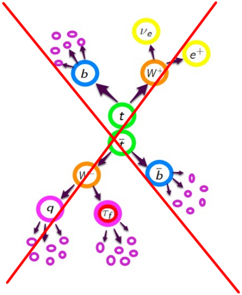
Aim of the Analysis

Measurement of top pair production with one hadronic tau decay

Second part of the Analysis:

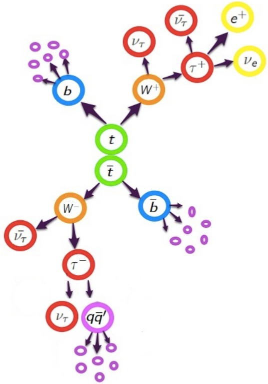
$t\bar{t} \to b\bar{\tau}\nu\,\bar{b}\ell\bar{\nu}$ Only 3rd generation $t\bar{t} \to b\bar{\tau}\nu\,\bar{b}qq'$





Aim of the Analysis

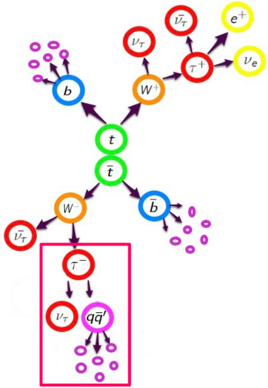
Measurement of top pair production with one hadronic tau decay



- One hadronic τ candidate
- One e or μ candidate
- Opposite electrc charge for lepton and τ
- Two or more jets
- At least one b-jet
- $E_T^{miss} > 10$ GeV

Aim of the Analysis

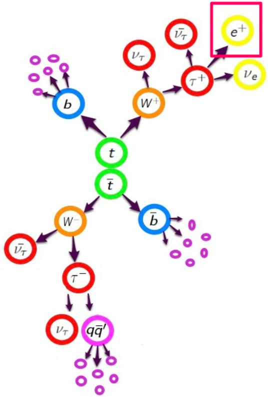
Measurement of top pair production with one hadronic tau decay



- One hadronic τ candidate
- One e or μ candidate
- Opposite electrc charge for lepton and τ
- Two or more jets
- At least one b-jet
- $E_T^{miss} > 10$ GeV

Aim of the Analysis

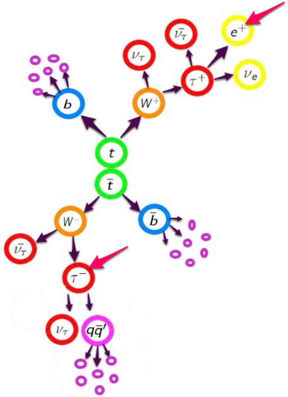
Measurement of top pair production with one hadronic tau decay



- One hadronic τ candidate
- One e or μ candidate
- Opposite electrc charge for lepton and τ
- Two or more jets
- At least one b-jet
- $E_T^{miss} > 10$ GeV

Aim of the Analysis

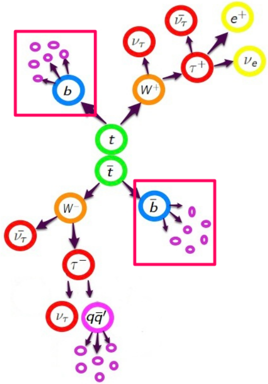
Measurement of top pair production with one hadronic tau decay



- One hadronic τ candidate
- One e or μ candidate
- Opposite electrc charge for lepton and τ
- Two or more jets
- At least one b-jet
- $E_T^{miss} > 10$ GeV

Aim of the Analysis

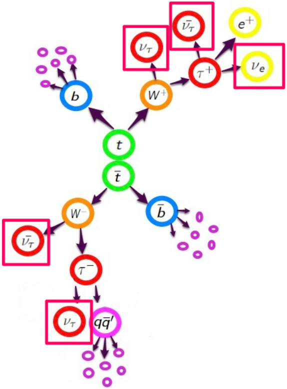
Measurement of top pair production with one hadronic tau decay



- One hadronic τ candidate
- One e or μ candidate
- Opposite electrc charge for lepton and τ
- Two or more jets
- At least one b-jet
- $E_T^{miss} > 10$ GeV

Aim of the Analysis

Measurement of top pair production with one hadronic tau decay



- One hadronic τ candidate
- One e or μ candidate
- Opposite electrc charge for lepton and τ
- Two or more jets
- At least one b-jet
- $E_T^{miss} > 10$ GeV

Aim of the Analysis

- Reject events with $M_{inv}(\ell, \tau)$ close to M_Z
- $H_T = E_T^{miss} + E_T^{tau} + \sum E_T^{jets} > 150$ GeV
- Likelihood1 > 0 (E_T^{miss}, $M_T(\ell, E_T^{miss})$, E_T^{3rdjet}) to distinguish between misidentified and genuine τ
- Use the distribution of Likelihood2 ($M_T(\ell, E_T^{miss})$, E_T^{ℓ}, $\Delta\phi(\ell, E_T^{miss})$) used to discriminate between lepton+tau and di-tau decays

Aim of the Analysis

- Reject events with $M_{inv}(\ell, \tau)$ close to M_Z
- $H_T = E_T^{miss} + E_T^{tau} + \sum E_T^{jets} > 150$ GeV
- Likelihood1 > 0 (E_T^{miss}, $M_T(\ell, E_T^{miss})$, E_T^{3rdjet}) to distinguish between misidentified and genuine τ
- Use the distribution of Likelihood2 ($M_T(\ell, E_T^{miss})$, E_T^{ℓ}, $\Delta\phi(\ell, E_T^{miss})$) used to discriminate between lepton+tau and di-tau decays

Aim of the Analysis

- Reject events with $M_{inv}(\ell, \tau)$ close to M_Z
- $H_T = E_T^{miss} + E_T^{tau} + \sum E_T^{jets} > 150$ GeV

- Likelihood1 > 0 (E_T^{miss}, $M_T(\ell, E_T^{miss})$, E_T^{3rdjet}) to distinguish between misidentified and genuine τ

- Use the distribution of Likelihood2 ($M_T(\ell, E_T^{miss})$, E_T^{ℓ}, $\Delta\phi(\ell, E_T^{miss})$) used to discriminate between lepton+tau and di-tau decays

Overview of the Improvements

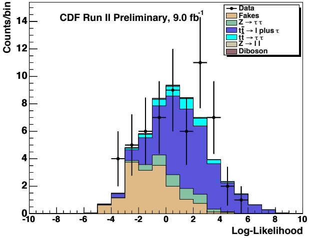
- Analysis already blessed on June 28th 2012
- Two corrections:
  - Heavy-flavor correction for Drell-Yan processes with $b\bar{b}$
  - Inclusion of the feedback from the variation of $BR(top \to \tau\nu b)$ in $BR(top \to l\nu b)$ and $\sigma_{t\bar{t}}$

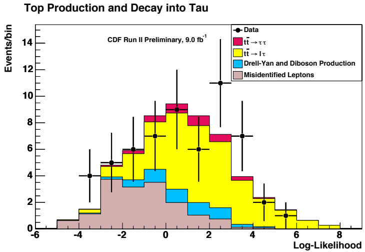
Heavy-flavor Correction Factor

- Drell-Yan + heavy flavour underestimated in MC by 80%
- Heavy flavour is a small but significant contribution in Drell-Yan processes due to b-tagging

Heavy-flavor Correction Factor

- Drell-Yan + heavy flavour underestimated in MC by 80%
- Heavy flavour is a small but significant contribution in Drell-Yan processes due to b-tagging
- After the correction, no big changes in the distributions, e.g. for Likelihood1:





Heavy-flavor Correction Factor

- Change in the number of selected events after L1 > 0

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^* \to \tau\tau$	$1.12 \pm 0.07 \pm 0.25$	$1.41 \pm 0.08 \pm 0.29$	$2.53 \pm 0.11 \pm 0.53$
$Z/\gamma^* \to ll$	$0.10 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.13 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.7 \pm 0.3^{+1.6}_{-1.7}$	$18.8 \pm 0.6^{+2.1}_{-2.1}$	$33.6 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^* \to \tau\tau$	$1.25 \pm 0.08 \pm 0.25$	$1.53 \pm 0.08 \pm 0.29$	$2.78 \pm 0.11 \pm 0.53$
$Z/\gamma^* \to ll$	$0.14 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.17 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.9 \pm 0.3^{+1.6}_{-1.7}$	$18.9 \pm 0.6^{+2.1}_{-2.1}$	$33.9 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Heavy-flavor Correction Factor

- Change in the number of selected events after L1 > 0

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^* \to \tau\tau$	$1.12 \pm 0.07 \pm 0.25$	$1.41 \pm 0.08 \pm 0.29$	$2.53 \pm 0.11 \pm 0.53$
$Z/\gamma^* \to ll$	$0.10 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.13 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.7 \pm 0.3^{+1.6}_{-1.7}$	$18.8 \pm 0.6^{+2.1}_{-2.1}$	$33.6 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^* \to \tau\tau$	$1.25 \pm 0.08 \pm 0.25$	$1.53 \pm 0.08 \pm 0.29$	$2.78 \pm 0.11 \pm 0.53$
$Z/\gamma^* \to ll$	$0.14 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.17 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.9 \pm 0.3^{+1.6}_{-1.7}$	$18.9 \pm 0.6^{+2.1}_{-2.1}$	$33.9 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Heavy-flavor Correction Factor

- Change in the number of selected events after L1 > 0

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^{*} \to \tau\tau$	$1.12 \pm 0.07 \pm 0.25$	$1.41 \pm 0.08 \pm 0.29$	$2.53 \pm 0.11 \pm 0.53$
$Z/\gamma^{*} \to ll$	$0.10 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.13 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.7 \pm 0.3^{+1.6}_{-1.7}$	$18.8 \pm 0.6^{+2.1}_{-2.1}$	$33.6 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^{*} \to \tau\tau$	$1.25 \pm 0.08 \pm 0.25$	$1.53 \pm 0.08 \pm 0.29$	$2.78 \pm 0.11 \pm 0.53$
$Z/\gamma^{*} \to ll$	$0.14 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.17 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.9 \pm 0.3^{+1.6}_{-1.7}$	$18.9 \pm 0.6^{+2.1}_{-2.1}$	$33.9 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Heavy-flavor Correction Factor

- Change in the number of selected events after L1 > 0

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^* \to \tau\tau$	$1.12 \pm 0.07 \pm 0.25$	$1.41 \pm 0.08 \pm 0.29$	$2.53 \pm 0.11 \pm 0.53$
$Z/\gamma^* \to ll$	$0.10 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.13 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.7 \pm 0.3^{+1.6}_{-1.7}$	$18.8 \pm 0.6^{+2.1}_{-2.1}$	$33.6 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Process	Muon Sample	Electron Sample	Total
Fakes	$1.80 \pm 0.31^{+0.13}_{-0.31}$	$2.20 \pm 0.64^{+0.18}_{-0.48}$	$4.01 \pm 0.71^{+0.31}_{-0.80}$
$Z/\gamma^* \to \tau\tau$	$1.25 \pm 0.08 \pm 0.25$	$1.53 \pm 0.08 \pm 0.29$	$2.78 \pm 0.11 \pm 0.53$
$Z/\gamma^* \to ll$	$0.14 \pm 0.03 \pm 0.03$	$0.03 \pm 0.01 \pm 0.01$	$0.17 \pm 0.03 \pm 0.04$
Diboson	$0.09 \pm 0.02 \pm 0.03$	$0.09 \pm 0.02 \pm 0.03$	$0.17 \pm 0.03 \pm 0.05$
$t\bar{t} \to \tau l + X$	$10.56 \pm 0.08 \pm 1.34$	$13.73 \pm 0.10 \pm 1.75$	$24.29 \pm 0.13 \pm 3.09$
$t\bar{t} \to \tau\tau + X$	$1.07 \pm 0.03 \pm 0.14$	$1.37 \pm 0.03 \pm 0.18$	$2.44 \pm 0.04 \pm 0.32$
Total Expected	$14.9 \pm 0.3^{+1.6}_{-1.7}$	$18.9 \pm 0.6^{+2.1}_{-2.1}$	$33.9 \pm 0.6^{+3.7}_{-3.8}$
Observed	12	24	36

Cross section

- The correction for the Drell-Yan + heavy flavor scale factor changes the number of expected events by about 0.7%
- This has an impact on the measured $t\bar{t}$ cross section

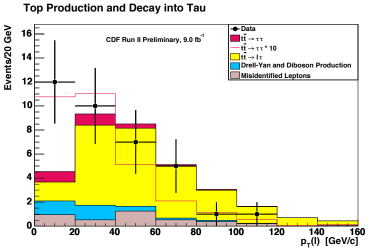
Cross section

- The correction for the Drell-Yan + heavy flavor scale factor changes the number of expected events by about 0.7%
- This has an impact on the measured $t\bar{t}$ cross section
- $\sigma_{t\bar{t}} = \frac{N_{sel} - N_{bg}}{\sum[(BR_{l\tau}\epsilon_{l\tau} + BR_{\tau\tau}\epsilon_{\tau\tau}) \int \mathcal{L} dt]}$
- $\sigma_{t\bar{t}} = 8.1 \pm 1.7(stat)^{+1.2}_{-1.1}(syst) \pm 0.5(lum)$ pb

Second Likelihood

Used for the fit to discriminate between single-tau and di-tau

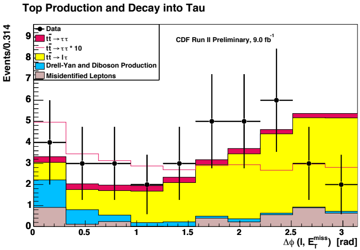
- P_T^{lepton}
- $\Delta\phi(lepton, E_T^{miss})$
- $M_T(lepton, E_T^{miss})$



Second Likelihood

Used for the fit to discriminate between single-tau and di-tau

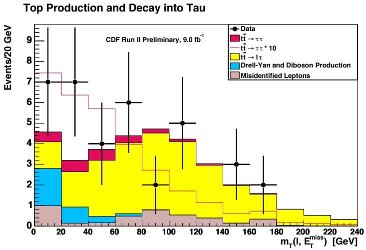
- P_T^{lepton}
- $\Delta\phi(lepton, E_T^{miss})$
- $M_T(lepton, E_T^{miss})$



Second Likelihood

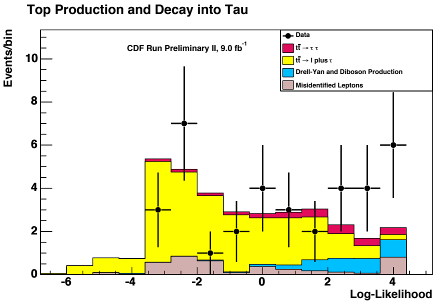
Used for the fit to discriminate between single-tau and di-tau

- P_T^{lepton}
- $\Delta\phi(lepton, E_T^{miss})$
- $M_T(lepton, E_T^{miss})$



Second Likelihood

Used for the fit to discriminate between single-tau and di-tau



Fit to measure $BR(top \to \tau\nu b)$

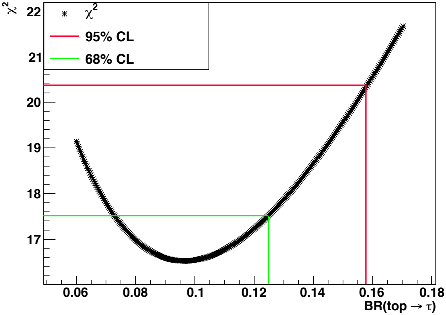
- Using the MCLimit package
- Compare the expected distribution of the variable Likelihood2 with the distribution of the data
- Fit $BR(top \to \tau\nu b)$, i.e. amount of single-tau and di-tau signal to best match data (varying background/systematics within uncertainties)

Improvements to the Fit

- Correction to the formula for the fit
- In the Blessed Analysis $\sum BR(top \to anything)$ was not constrained to be one
- $BR(top \to e\nu b)$, $BR(top \to \mu\nu b)$, $BR(top \to had)$ decrease as $BR(top \to \tau\nu b)$ increase and vice-versa

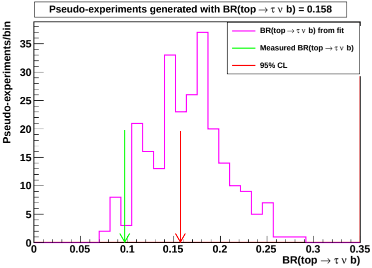
$BR(top \to \tau\nu b)$ from the Fit

- Best value of $BR(top \to \tau\nu b)$: 0.096 $\pm$ 0.028
- $BR(top \to \tau\nu b) < 0.158$ at 95% CL



Check of the 95% CL coverage

- Generate pseudo-experiments with $BR(top \to \tau\nu b) = 0.158$
- Fit them to find the best BR
- Count the number of times BR from fit $<$ measured value
- The 95% coverage was confirmed



$BR(top \to H^+ b)$

Assumptions:

- $BR(top \to W^+ b) + BR(top \to H^+ b) = 1$
- $BR(H^\pm \to \tau\nu) = 1$

$$BR(top \to H^+ b) = \frac{BR(top \to \bar{\tau}\nu b) - BR(W^+ \to \bar{\tau}\nu)}{1 - BR(W^+ \to \bar{\tau}\nu)}$$

$BR(top \to H^+b)$

Assumptions:

- $BR(top \to W^+b) + BR(top \to H^+b) = 1$
- $BR(H^\pm \to \tau\nu) = 1$

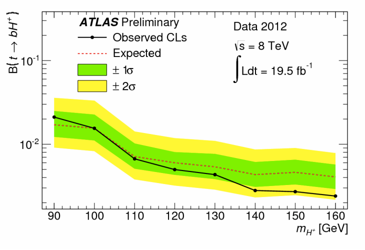
$$BR(top \to H^+b) = \frac{BR(top \to \bar{\tau}\nu b) - BR(W^+ \to \bar{\tau}\nu)}{1 - BR(W^+ \to \bar{\tau}\nu)}$$

- Measured $BR(top \to \tau\nu b)$ below Standard Model
- Feldman-Cousins method to find 95% CL
- $BR(top \to H^+b) < 0.061$ at 95% CL

Limits on $BR(top \to H^+ b)$ set by LHC

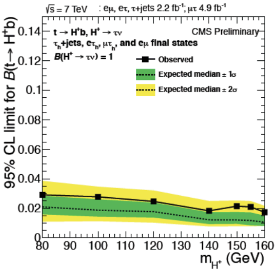
ATLAS

- $19.5\ \text{fb}^-1,\ \sqrt{s} = 8$ TeV



CMS

- $4.9\ \text{fb}^-1,\ \sqrt{s} = 7$ TeV



Conclusions

- In this analysis dileptonic top pair decays with one hadronic τ are selected
- We improved the analysis correcting it for the heavy flavour scale factor in Drell-Yan processes and inserting the constrain $\sum BR(top \to anything) = 1$
- $\sigma_{t\bar{t}} = 8.1 \pm 1.7(stat)^{+1.2}_{-1.1}(syst) \pm 0.5(lum)$ pb
- $BR(top \to \tau\nu b)$: 0.096 ± 0.028
- $BR(top \to \tau\nu b) < 0.158$ at 95% CL
- $BR(top \to H^+ b) < 0.06$ at 95% CL

Thanks

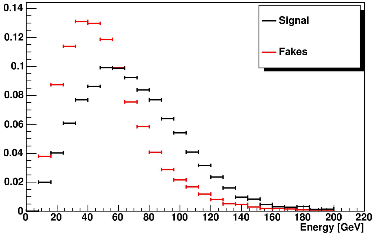
To Stephan, Aurore and Matteo

And to the organizers of the Summer Student Program!

Backup

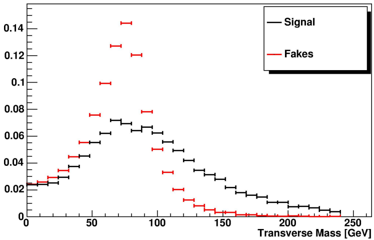
First Likelihood

- E_T^{miss}
- $M_T(l, E_T^{miss})$
- E_T^{3rdjet}



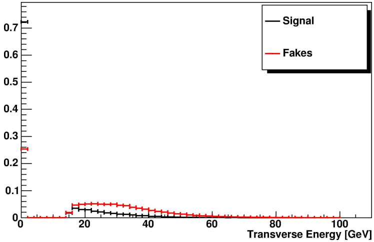
First Likelihood

- E_T^{miss}
- $M_T(l, E_T^{miss})$
- E_T^{3rdjet}



First Likelihood

- E_T^{miss}
- $M_T(l, E_T^{miss})$
- E_T^{3rdjet}



Improvements to the fit

$$N = N^{l\tau} + N\tau\tau + N^{bg} =$$
$$N^{bg} + \sum \epsilon A \left[BR(top \to l\nu b) + BR^{(fit)}(top \to \tau nub) + BR^{MC}(top \to \tau nub) \right]$$
$$\times 2BR^{(fit)}(top \to \tau nub) BR^{PDG}(\tau \to \nu jets) \sigma_{t\bar{t}} \int \mathcal{L}\, dt$$

Improvements to the fit

$$N = N^{l\tau} + N\tau\tau + N^{bg} =$$
$$N^{bg} + \sum \epsilon A \left[BR(top \to l\nu b) + BR^{(fit)}(top \to \tau nub) + BR^{MC}(top \to \tau nub)\right]$$
$$\times 2BR^{(fit)}(top \to \tau nub) BR^{PDG}(\tau \to \nu jets) \sigma_{t\bar{t}} \int \mathcal{L}\, dt$$

- $BR(top \to l\nu b) = BR^{SM}(top \to l\nu b)\left[1 + \frac{BR^{(MC)}(top \to \tau, nu, b) - BR^{(fit)}(top \to \tau \nu b}{1 - BR^{SM}(top \to l\nu b)}\right]$
- $\sigma_{t\bar{t}} = \sigma^{lep}_{t\bar{t}} \frac{BR^{MC}(top \to l\nu b)}{BR(top \to l\nu b)}$

Scaling

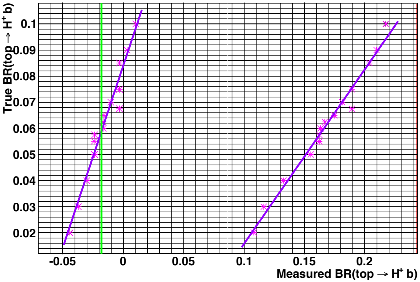
- $N^{\tau\tau} = N^{\tau\tau(MC)} \frac{BR^{(fit)\,2}(top \to \tau \nu b)}{BR^{(MC)\,2}(top \to \tau \nu b)\left[1 + \frac{BR^{(MC)}(top \to \tau, nu, b) - BR^{(fit)}(top \to \tau \nu b}{1 - BR^{SM}(top \to l \nu b)}\right]}$
- $N^{\tau l} = N^{\tau l(MC)} \frac{BR^{(fit)}(top \to \tau \nu b)}{BR^{(MC)}(top \to \tau \nu b)}$

Scaling

- $N^{\tau\tau} = N^{\tau\tau(MC)} \frac{BR^{(\textbf{fit})\,\textbf{2}}(top{\to}\tau\nu b)}{BR^{(\textbf{MC})\,\textbf{2}}(top{\to}\tau\nu b)\left[1{-}BR^{(\textbf{fit})}(top{\to}\tau\nu b){+}BR^{(\textbf{MC})}(top{\to}\tau\nu)\right]}$
- $N^{\tau l} = N^{\tau l(MC)} \frac{BR^{(\textbf{fit})}(top{\to}\tau\nu b)}{BR^{(\textbf{MC})}(top{\to}\tau\nu b)}$

95% CL limit for $BR(top \to H^+ b)$

- $BR(top \to H^+ b)$ is negative (0.017)
- Feldman-Cousins method to find 95% CL
- $BR(top \to H^+ b) <$ 0.061 at 95% CL



Electron Identification Selection

Standard CDF requirements for electron identification selection

Variable	Requirement
Region	CEM
Fiducial	SMX Fiducial
E_T	≥ 10 GeV
Track p_T	≥ 8 GeV$/c$
Track z_0	≤ 60 cm
COT AxSL	≥ 3
COT StSL	≥ 2
Conversion	veto
E_{HAD}/E_{EM}	$\leq (0.055 + 0.00045 \times E)$
Isolation	≤ 0.1
$Lshr$	≤ 0.2
E/P	≤ 4.0 or $p_T \geq 50$ GeV$/c$
CES ΔZ	≤ 3.0 cm
CES $q\Delta X$	$-3.0 \leq q\Delta X \leq 1.5$ cm
CES Strip χ^2	≤ 10.0

Muon Identification Selection

Standard CDF requirements for electron identification selection

Variable	Requirement
p_T	$>$ 10 GeV
$\|z_0\|$	$>$ 60 cm
$\|d_0^{corr}\|$	$<$ 0.2 cm
E_{rel}^{iso}	$<$ 0.1 (if $p_T \geq 20.$)
E_T^{iso}	$<$ 2.0 GeV (if $p_T \leq 20.$)
COT AxSL	≥ 3
COT StSL	≥ 2
ρ_{COT}	$>$ 140 cm

Requirements for electron identification selection

Variable	Requirement, $p_T > 20$ GeV	Requirement, $p_T < 20$ GeV
E_{EM}	$< 2 + max(0,\ 0.0115 * (p - 100))$ GeV	2 GeV
E_{HAD}	$6 + max(0,\ 0.028 * (p - 100))$ GeV	$3.5 + (p_T/8.0)$ GeV
$\|\Delta_{CMU}\|$ (CMUP muon)	$<$ 3 cm	$<$ 3 cm or $\chi^2_{CMU} < 9.0$
$\|\Delta_{CMP}\|$ (CMUP muon)	$<$ 7 cm	$<$ 7 cm or $\chi^2_{CMP} < 9.0$
$\|\Delta_{CMX}\|$ (CMX muon)	$<$ 6 cm	$<$ 6 cm or $\chi^2_{CMX} < 9.0$

Minimum Ionizing Particles Identification Selection

Requirements MIP identification selection

Variable	Requirement, $p_T > 20$ GeV	Requirement, $p_T < 20$ GeV
E_{EM}	$< 2 + max(0,\ 0.0115 * (p - 100))$ GeV	< 2 GeV
E_{HAD}	$< 6 + max(0,\ 0.028 * (p - 100))$ GeV	$< 3.5 + (p_T/8.0)$ GeV
$\sum p_T^{iso}$	< 4 GeV	< 4 GeV
E_{rel}^{iso}	< 0.2	–
E_T^{iso}	–	< 4.0 GeV

Tau Identification Selection

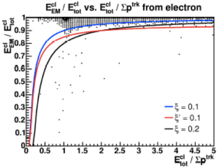
Tau Identification Requirements

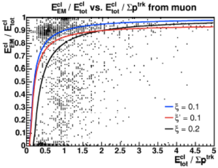
Variable	Requirement
$E_T^{SeedTwr}$	≥ 6.0 GeV
$p_T^{SeedTrk}$	≥ 6.0 geV or ≥ 8.0 GeV when selecting muon candidates
$E_T^{Cluster}$	≥ 10.0 GeV for 1 prong taus or ≥ 15.0 GeV for 3 prong taus
p_T^{Vis}	≥ 15.0 GeV$/c$ for 1 prong taus or ≥ 20.0 GeV$/c$ for 3 prong taus
$\mid Z_{CES} \mid$	$9 \leq \mid Z_{CES} \mid \leq 230$ cm
Σp_T^{iso}	≤ 2.0 GeV
$\Sigma E_T^{\pi^0 iso}$	≤ 1.0 GeV
p_T^{iso}	≤ 1.5 GeV
COT Ax. Seg.	≥ 3
COT St. Seg.	≥ 2
E_T^{shtwr}	≥ 1.0 GeV
N^{twr}	≤ 6
θ_{sig}	$min(0.17, \frac{5.0}{E^{Cluster}[GeV]})$rad
ξ'	≤ 0.1
E_{tot}/p	≥ 0.4
M^{vis}	≤ 1.8 GeV
$N^{\pi^0 iso}$	≤ 0
N^{trk}	$= 1,3$
Charge	± 1
$d_0^{seedtrk}$	0.2 cm

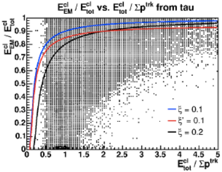
Tau Identification Selection

$$\xi' = \frac{E_{tot}}{\Sigma \mid \vec{p}_i \mid}\left(0.95 - \frac{E_{EM}}{E_{tot}}\right)$$

$$\xi = \frac{E_{had}}{\Sigma \mid \vec{p}_i \mid} = \frac{E_{tot}}{\Sigma \mid \vec{p} \mid}\left(1 - \frac{E_{EM}}{E_{tot}}\right)$$

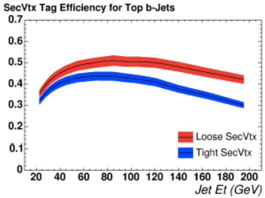


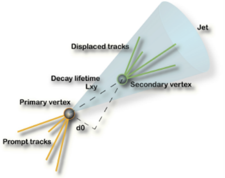




SecVtx b Quark Tagging Efficiency

b quark tagging efficiency using tight or loose SecVtx tagger





Monte Carlo Samples

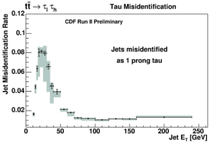
Process	Inst. Lum.	Gen.	N. Events	σ_{prod}
$Z/\gamma^* \to \tau\tau + 0\text{p}$ $M_Z = [20, 75]$ GeV	Low Lum.	Alpgen	1'236'000	224 pb^{-1}
$Z/\gamma^* \to \tau\tau + 1\text{p}$ $M_Z = [20, 75]$ GeV	Low Lum.	Alpgen	1'159'000	12 pb^{-1}
$Z/\gamma^* \to \tau\tau + (\geq 2\text{p})$ $M_Z = [20, 75]$ GeV	Low Lum.	Alpgen	2'270'000	2.5 pb^{-1}
$Z/\gamma^* \to \tau\tau + 0\text{p}$ $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	5'860'000	221 pb^{-1}
$Z/\gamma^* \to \tau\tau + 1\text{p}$ $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	5'723'000	30 pb^{-1}
$Z/\gamma^* \to \tau\tau + (\geq 2\text{p})$ $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	2'263'000	5.8 pb^{-1}
$Z/\gamma^* \to \tau\tau + 0\text{p}$ $M_Z = [20, 75]$ GeV	High Lum.	Alpgen	400'000	224 pb^{-1}
$Z/\gamma^* \to \tau\tau + 1\text{p}$ $M_Z = [20, 75]$ GeV	High Lum.	Alpgen	400'000	12 pb^{-1}
$Z/\gamma^* \to \tau\tau + (\geq 2\text{p})$ $M_Z = [20, 75]$ GeV	High Lum.	Alpgen	800'000	2.5 pb^{-1}
$Z/\gamma^* \to \tau\tau + 0\text{p}$ $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	2'401'000	221 pb^{-1}
$Z/\gamma^* \to \tau\tau + 1\text{p}$ $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	2'401'000	30 pb^{-1}
$Z/\gamma^* \to \tau\tau + (\geq 2\text{p})$ $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	953'000	5.8 pb^{-1}
WW	Low Lum.	PYTHIA	1'095'000	11.3 pb^{-1}
WZ	Low Lum.	PYTHIA	1'083'000	3.2 pb^{-1}
ZZ	Low Lum.	PYTHIA	1'090'000	3.6 pb^{-1}
WW	High Lum.	PYTHIA	1'100'000	11.3 pb^{-1}
WZ	High Lum.	PYTHIA	1'102'000	3.2 pb^{-1}
ZZ	High Lum.	PYTHIA	1'102'000	3.6 pb^{-1}

Monte Carlo Samples

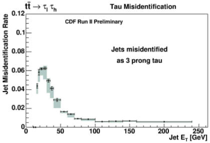
Process	Inst. Lum.	Gen.	N. Events	σ_{prod}
$Z/\gamma^* \to \mu\mu$ + 0p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	2’659’000	221 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 1p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	2’652”000	30 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 2p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	4’660’000	4.8 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 3p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	536’000	0.77 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + ($\geq$ 4p) $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	530’000	0.14 pb^{-1}
$Z/\gamma^* \to ee$ + 0p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	2’639’000	221 pb^{-1}
$Z/\gamma^* \to ee$ + 1p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	2’625’000	30 pb^{-1}
$Z/\gamma^* \to ee$ + 2p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	536’000	4.8 pb^{-1}
$Z/\gamma^* \to ee$ + 3p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	524’000	0.77 pb^{-1}
$Z/\gamma^* \to ee$ + ($\geq$ 4p) $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	525’000	0.14 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 0p $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	1’020’000	221 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 1p $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	1’021’000	30 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 2p $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	1’793’000	4.8 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + 3p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	192’000	0.77 pb^{-1}
$Z/\gamma^* \to \mu\mu$ + ($\geq$ 4p) $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	192’000	0.14 pb^{-1}
$Z/\gamma^* \to ee$ + 0p $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	1’024’000	221 pb^{-1}
$Z/\gamma^* \to ee$ + 1p $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	1’024’000	30 pb^{-1}
$Z/\gamma^* \to ee$ + 2p $M_Z = [75, 105]$ GeV	High Lum.	Alpgen	1’793’000	4.8 pb^{-1}
$Z/\gamma^* \to ee$ + 3p $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	192’000	0.77 pb^{-1}
$Z/\gamma^* \to ee$ + ($\geq$ 4p) $M_Z = [75, 105]$ GeV	Low Lum.	Alpgen	192’000	0.14 pb^{-1}

Tau Fake Rate

Variable	Tau ID
$p_T^{SeedTrk}$	≥ 6.0 geV or ≥ 8.0 GeV when selecting muon candidates
$E_T^{Cluster}$	≥ 10.0 GeV for 1 prong taus or ≥ 15.0 GeV for 3 prong ones
$\mid Z^{CES} \mid$	$9 \leq\mid Z^{CES} \mid\leq 230$ cm
E_T^{ShTwr}	≥ 1.0 GeV
N^{Twr}	≤ 6
ξ'	≤ 0.1
E/P	≥ 0.4



(a)1 prong taus



(b)3 prong taus

Systematics

Summary of the systematic uncertainties

Process	$Z/\gamma^* \to \tau\tau$	$Z/\gamma^* \to ll$	*Diboson*	$t\bar{t} \to \tau l + X$	$t\bar{t} \to \tau\tau + X$	*Fakes*
Trigger	±3%	±3%	±3%	±3%		±3%
Cross Section	±15%	±15%	±6%	–	–	–
PDF	–	–	–	±0.5%	±0.5%	–
Showering	–	–	–	±3%	±3%	–
Color Recon.	–	–	–	±4%	±4%	–
ISR/FSR	–	–	–	±9%	±9%	–
Pile Up	–	–	–	±2.5%	±3%	–
JEC	±9%	±20%	±20%	±2%	±3%	–
τ E_T *scale*	±4%	±20%	±20%	±0.5%	±1.5%	–
τ *ID scale*	±3%	–	±3%	±3%	±3%	–
SECVTX Tag	±5%	±5%	±5%	±5%	±5%	–
SECVTX Mistag	±20%	±20%	±20%	–	–	–
Fake Rate	–	–	–	–	–	$^{+7\%}_{-20\%}$

Fine Backup