Top Pair Cross Section Measurement in the Semileptonic Channels in ATLAS

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Outline

- Introduction to $t\bar{t}$ cross section measurement with ATLAS
- Method of the cross section mesurement in l+jets channels
- Recent work and progress
  - Trigger efficiency measurement using top events
  - BTagging efficiency measurement using top events

*Part*1. Introduction: $t\bar{t}$ cross section measurement

- In p-p collision, top pairs are produced through gluon-gluon and quark-antiquark scattering

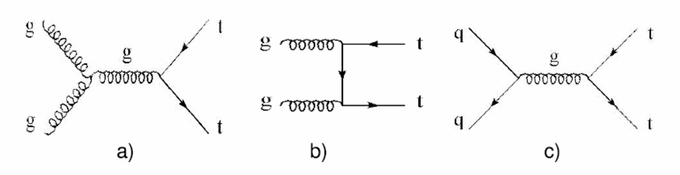
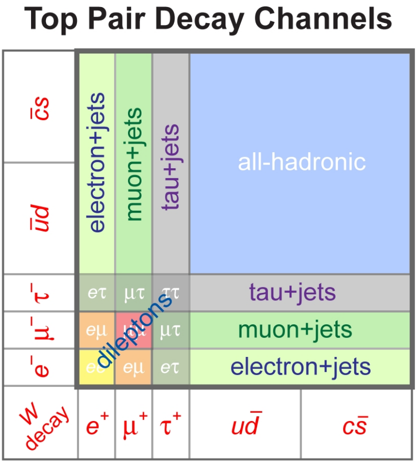


Figure: Lowest order: gluon-gluon scattering (a) & (b), quark-quark scattering (c)

- $t \rightarrow Wb$ is close to 100%, $W \rightarrow l + \nu \sim \frac{1}{3}$ and $W \rightarrow q\bar{q} \sim \frac{2}{3}$

Top pair branching fraction



Semi-leptonic channels $\sim \frac{4}{9}$

Di - leptonic channels $\sim \frac{1}{9}$

Full-hadronic channels $\sim \frac{4}{9}$

- semi-leptonic: high branching ratio
  $\Rightarrow$ best precision
- di-leptonic: very clean, low background
  $\Rightarrow$ used as a tool

expect	7 TeV	10 TeV	14 TeV
$\sigma_{t\bar{t}}$ (pb)	160.79	402.53	886.28

$\Leftarrow$ Assuming top mass 172.5 GeV, at NNLO precision

- chance to measure $t\bar{t}$ cross section at different energies

Tevatron results

- Tevatron Run II, 1fb^{-1} $p\bar{p}$ collision, $\sqrt{s} = 1.96$ TeV
- Theory: 6.8±0.6 pb at NLO + threshold resummation, m_t at 175 GeV
- 7.3±0.5(stat) ±0.6(sys)±0.4(lum) pb for CDF
- 7.4±0.5(stat)±0.6(sys)±0.4(lum) pb for D0

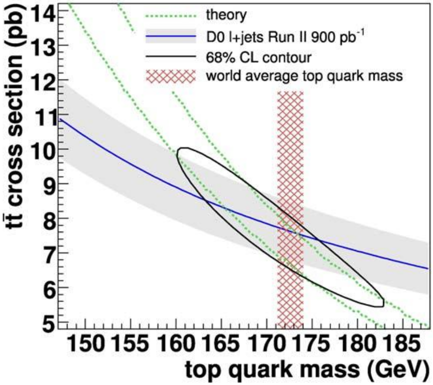


Figure : $t\bar{t}$ cross section changes in the function of top mass

⇒ check for top mass measurement on ATLAS

Measuring $t\bar{t}$ cross section

- Counting method, determination of the cross section:

$$\sigma = \frac{N_{sig}}{\mathscr{L}\times\epsilon} = \frac{N_{obs}-N_{bkg}}{\mathscr{L}\times\epsilon}$$

- To do this, we need to understand:
  - The integrated luminosity of data
  - Acceptance of the detectors
  - Objects (electron, muon, jet) identification efficiency
  - Trigger efficiency for electron and muon
  - Event selection efficiency
  - B jet tagging efficiency
  - Level of backgrounds

Event selection

- Selection in $t\bar{t} \to e\nu b\ \mu\nu b,\ \mu\mu,\ ee$
  1. Exactly 2 isolated leptons $p_{\mathrm{T}} > 20\ \ \mathrm{GeV}$ (e or μ)
  2. Two leptons have opposite charge
  3. $|M_{ll} - M_Z| > 5\ \ \mathrm{GeV}$ ($\mu\mu$, ee channels)
  4. $E_{\mathrm{T}}^{\mathrm{miss}} > 20\ \ \mathrm{GeV}$ ($e\mu$), $E_{\mathrm{T}}^{\mathrm{miss}} > 35\ \ \mathrm{GeV}$ ($\mu\mu$, ee)
  5. At least 2 jets with $p_{\mathrm{T}} > 20\ \ \mathrm{GeV}$
- Selection in $t\bar{t} \to e\nu b\ qqb$, $t\bar{t} \to \mu\nu b\ qqb$
  1. Exactly 1 isolated lepton $p_{\mathrm{T}} > 20\ \ \mathrm{GeV}$ (e or μ)
  2. $E_{\mathrm{T}}^{\mathrm{miss}} > 20\ \ \mathrm{GeV}$
  3. At least 4 jets with $p_{\mathrm{T}} > 20\ \ \mathrm{GeV}$
  4. At least 3 jets with $p_{\mathrm{T}} > 40\ \ \mathrm{GeV}$

*Part*2. Trigger efficiency measurement

- Usually $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$ are used, but it needs an interpretation into $t\bar{t}$ events
- We measure the trigger efficiencies (e10 and mu10) using top events
  - ▷ Efficiencies in $t\bar{t} \to e(\mu)\nu b\ qqb$ are to be estimated
  - ▷ Efficiencies in the dileptonic channels are the measured
  - ▷ Trigger efficiencies for identified isolated electrons or muons
- In $t\bar{t} \to e\nu b\ \mu\nu b$, mu10 (e10) trigger is passed ⇒
  directly measure e10 (mu10) trigger efficiency ⇒
  Triggered not only by leptons from top, but also possibly from b jets
- In $t\bar{t} \to e\nu b\ e\nu b$ and $t\bar{t} \to \mu\nu b\ \mu\nu b$, tag and probe method is used ⇒
  Here we measure really the efficiency for one object
- 10 TeV, MC@NLO + Herwig, about 7.7 fb^{-1}

Trigger efficiency in $t\bar{t} \to e(\mu)\nu b\ qqb$

Channel	# Events(100 pb^{-1})	TrigEff_e10, mu10
$t\bar{t} \to e\nu b\ qqb$	594.3±2.8	*99.8*±0.1%
$t\bar{t} \to \mu\nu b\ qqb$	719.0±3.1	*88.1*±0.2%

Table: Electron and muon trigger efficiency in $t\bar{t} \to e(\mu)\nu b\ qqb$

- e10 trigger efficiency is very high $\Leftarrow$ cut electron p_{T} at 20 GeV
- About *7.7* fb^{-1} $t\bar{t}$ events $\Rightarrow$ statistical uncertainty
- mu10 trigger efficiency in $t\bar{t} \to e\nu b\ qqb$, $t\bar{t} \to e\nu b\ e\nu b \sim 10\%$
- e10 trigger efficiency in $t\bar{t} \to \mu\nu b\ qqb$, $t\bar{t} \to \mu\nu b\ \mu\nu b \sim 3\%$

mu10 efficiency with $e\mu$ method

Channel	# Evt (100 pb^{-1})	TrigEff_mu10
$t\bar{t} \rightarrow e\nu b\ \mu\nu b$	277.2±1.9	*88.2*±0.2%
$t\bar{t}$ other	41.0±0.8	88.3±2.0%
single top	11.2±0.9	93.6±2.0%
Z + jets	12.9±1.1	89.1±1.8%
W + jets	1.7±0.5	≥72.7% @68%cl
diboson	9.7±0.3	89.1±1.1%
total bkg	75.8±2.5	*89.7*±0.5%

Work in Progress !

- Other $t\bar{t}$ leptonic channels (eg. $t\bar{t} \rightarrow e\nu b\ \tau\nu b$) are taken as backgrounds here
- Backgrounds are not biasing the measurement

mu10 efficiency with $\mu\mu$ method

Channel	# Evt (100 pb^{-1})	TrigEff_mu10
$t\bar{t} \rightarrow \mu\nu b\ \mu\nu b$	149.7±1.4	*86.9*±0.2%
$t\bar{t}$ other	24.3±0.6	87.8±0.7%
single top	6.3±0.7	86.6±2.7%
Z + jets	17.9±1.1	86.4±1.8%
W + jets	0.6±0.2	72.2±9.1%
diboson	5.3±0.3	85.8±1.2%
total bkg	54.4±2.0	*86.9*±0.6%

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- We expect $\epsilon\ (t\bar{t} \rightarrow \mu\nu b\ qqb)$ = 86.9%+(1-86.9%)×10% = *88.2*%

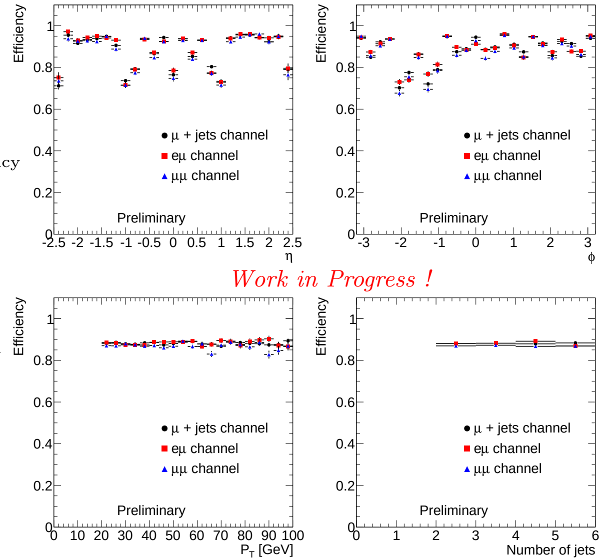
(1-86.9%): not selected μ but trigger event

10%: efficiency of mu10 from $t\bar{t} \rightarrow e\nu b\ qqb$

mu10 efficiency as a function of η, ϕ, p_T and nJet

- On the η plot transitional part has lower efficiency

- On the ϕ plot ATLAS feet and 8 toroid coils are seen



- In the function of pT and nJet: flat $\Rightarrow$ fine

Summary for trigger efficiency measurement

- Using $t\bar{t}$ dileptonic channels, we can measure trigger efficiency
- With 10 TeV 100 pb^{-1} data, the estimated statistical error:

Method	$e\mu$	ee / $\mu\mu$
e10	0.3%	0.5%
mu10	2.0%	2.6%

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- Need a large statistics (fb^{-1}) to measure efficiencies as a function of η, ϕ, p_{T} and nJet

*Part*3. BTagging efficiency measurement: method

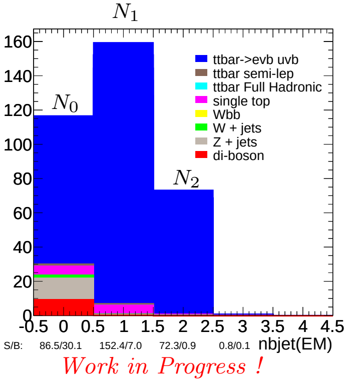


Figure: Number of b tagged jets $t\bar{t} \rightarrow e\nu b\ \mu\nu b$

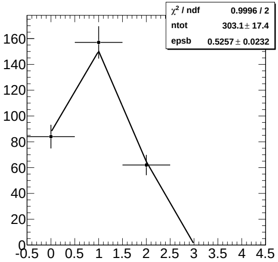
- Selection as trigger measurement
- $t\bar{t} \rightarrow$ other di-leptons $(\tau + \tau \ldots)$ are considered as signal
- The number of events with n btag jets N_i depends on ϵ_b, ϵ_{nonb} and F_{ij}
- We fit ϵ_b and N_{tot}, ϵ_{nonb} and F_{ij} fixed

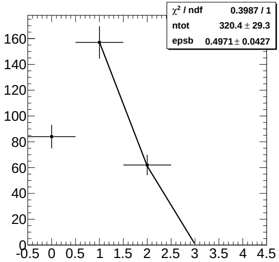
  - ◇ The expected ϵ_b is 53.2%
  - ◇ Non-b jet mistag rate : ϵ_{nonb} 0.4%
  - ◇ F_{ij} is shown blow:

i\j	0	1	2	3	4	5	6
0	-	-	0.9±0.1%	0.3±0.0%	0.1±0.0%	0.0±0.0%	0.0±0.0%
1	-	12.6±0.2%	6.5±0.1%	2.4±0.1%	0.7±0.1%	0.2±0.0%	-
2	30.9±0.3%	26.5±0.3%	12.5±0.2%	4.4±0.1%	1.1±0.1%	-	-
3	0.3±0.0%	0.3±0.0%	0.1±0.0%	0.1±0.0%	-	-	-
4	0.1±0.0%	0.1±0.0%	0.0±0.0%	-	-	-	-
5	0.0±0.0%	0.0±0.0%	-	-	-	-	-
6	0.0±0.0%	-	-	-	-	-	-

Table: F_{ij} (fraction number of events with i jets matching b quark and j jets not)

Fitted results of total number of events





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N_t (without bkgs)	Expected	fit N0 - N3	fit N1 - N3
$t\bar{t} \to e\nu b\ \mu\nu b$	317.6±2.4	312.1±14.5	307.9±20.7
$t\bar{t} \to e\nu b\ e\nu b$	96.9±1.3	98.9±12.9	103.7±18.7
$t\bar{t} \to \mu\nu b\ \mu\nu b$	176.0±1.8	172.8±13.1	176.4±25.5

N_t (with bkgs)	Expected	fit N0 - N3	fit N1 - N3
$t\bar{t} \to e\nu b\ \mu\nu b$	317.6±2.4	350.2±14.3	322.2±20.9
$t\bar{t} \to e\nu b\ e\nu b$	96.9±1.3	115.8±12.8	110.8±19.2
$t\bar{t} \to \mu\nu b\ \mu\nu b$	176.0±1.8	205.4±13.3	187.5±26.0

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Table: Results for total number of events with or without backgrounds

Fitted results of b tagging efficiency

ϵ_b (without bkgs)	Expected	fit N0 - N3	fit N1 - N3
$t\bar{t} \to e\nu b\ \mu\nu b$	53.2±0.2%	54.3±2.4%	55.2±4.7%
$t\bar{t} \to e\nu b\ e\nu b$	53.2±0.4%	53.1±5.4%	51.2±7.2%
$t\bar{t} \to \mu\nu b\ \mu\nu b$	53.4±0.3%	54.1±3.8%	53.8±7.3%

ϵ_b (with bkgs)	Expected	fit N0 - N3	fit N1 - N3
$t\bar{t} \to e\nu b\ \mu\nu b$	53.2±0.2%	49.8±2.2%	54.3±4.6%
$t\bar{t} \to e\nu b\ e\nu b$	53.2±0.4%	47.3±4.6%	50.1±7.1%
$t\bar{t} \to \mu\nu b\ \mu\nu b$	53.4±0.3%	47.1±3.1%	52.4±7.2%

Work in Progress !

Table: Results for ϵ_b with or without backgrounds

- The ϵ_b is less affected by the background events than N_t
- N_0 makes ϵ_b lower because of its high background contamination

Systematics

- Relative statistical precision (10 TeV, 100 pb^{-1}) and systematics:

Fitting:	$N_0 - N_3$	$N_1 - N_3$
ϵ_{nonb} 0 - 2%:	$^{+0.8}_{-1.6}$%	$^{+0.8}_{-2.5}$%
background ±100%:	9.6%	1.7%
b-jet label(ΔR 0.2 - 0.5):	$^{+1.6}_{-2.5}$%	$^{+1.6}_{-3.4}$%
jet energy scale ±5%:	0.2%	0.2%
b-jet energy scale ±1%:	$<$ 0.1%	$<$ 0.1%
AcerMC vs MC@NLO:	0.2%	0.1%
Total:	$^{+9.8}_{-10.1}$%	$^{+2.5}_{-4.2}$%
Statistical precision:	4.2%	6.8%

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- By fitting $N_0 - N_3$, if backgrounds are better known, systematic would be lower

*Part*3.2 Measurement at 7 TeV, 10 pb^{-1}

Channels	Events	0-tag	1-tag	2-tags
$t\bar{t} \rightarrow e\nu b\ \mu\nu b$	12.9±0.3	5	6	2
$t\bar{t} \rightarrow e\nu b\ e\nu b$	3.8±0.2	1.5	1.8	0.5
$t\bar{t} \rightarrow \mu\nu b\ \mu\nu b$	6.6±0.2	2.3	3.3	1
Total	23.3±0.4	8.8	11.1	3.5

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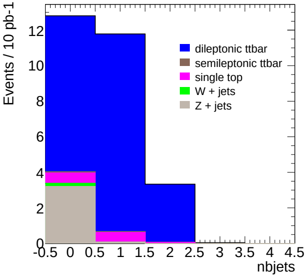
- With this statistics, we cannot separate the 3 channels ⇒ fit the sum of the N_{tag} histograms



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Channels	0-tag	1-tag	2-tags
signal	8.8	11.1	3.5
$t\bar{t} \rightarrow l\nu b \quad qqb$	0.07	0.04	0.01
sigle top	0.58	0.54	0.05
Z + jets	3.20	0.07	0.00
W + jets	0.18	0.00	0.00
Total Bkg	4.03	0.65	0.06
S/B	2.2	17	55

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- No diboson background included yet, may be important

Results with backgrounds

		Without Background		With Background	
	Expected	N_0 - N_2	N_1 - N_2	N_0 - N_2	N_1 - N_2
ϵ_b	45.4%	43.7±8.0%	46.3±15.9%	37.8±7.5%	45.0±15.4%
N_{tot}	23.3	23.5±5.0	24.0±10.0	28.0±5.6	25.5±10.5

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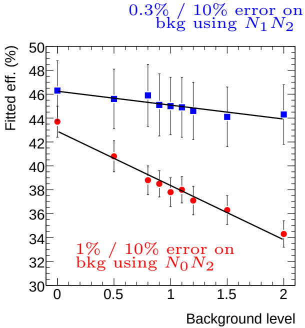
- Error bars = statistical error for 10 pb^{-1}
- Without background:
  - Average values in agreement with expected ones
  - Statistical error of factor 2 worse when using only N_1 - N_2 (expect lower sensitivity to bkg)
- Systematics due to background a factor 3 worse using N_0 N_2



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*Part*3.3 Measurement using semileptonic channels

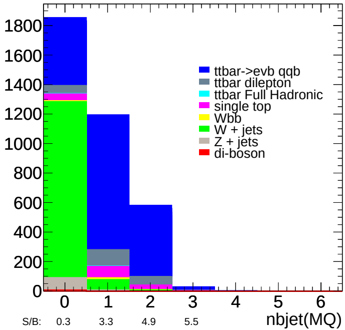

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Figure: Number of b tagged jets $t\bar{t} \to \mu\nu b\ qqb$

- Backgrounds greater than in dileptonic
- 10 TeV, 100 pb^{-1} sample
- Fit N_{tot}, ϵ_b and ϵ_c
- A limit is set on ϵ_c: $[0\%, 40\%]$
- The light jet mistagging rate is 0.166%

◇ S/B much smaller than in dileptonic
◇ Uncertainty: RMS for 100 pb^{-1}
◇ Fitted results, see below:

$t\bar{t} \to \mu\nu b\ \mu\nu b$	Expected	no bkg	with bkg
N_{tot}	1889.8±5.8	1886.5±48.7	2356.0±57.7
ϵ_b (%)	54.4±0.1	55.9±4.7	52.6±1.8
ϵ_c (%)	9.1±0.1	8.2±3.2	8.1±2.7

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Summary and to do list

- In order to measure $t\bar{t}$ cross section, we try to look with MC the trigger and b-tagging efficiency measurement
- We are eager to apply the measurement on data, but with 0.15 pb^{-1} data, 0.024 $t\bar{t}$ is expected. So keep patient
- Finish the work on b-tagging efficiency measurement
- Get prepared for cross section measurement


THANK
YOU