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In Memoriam Engin Arık and Her Colleagues

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Early Top Physics in ATLAS

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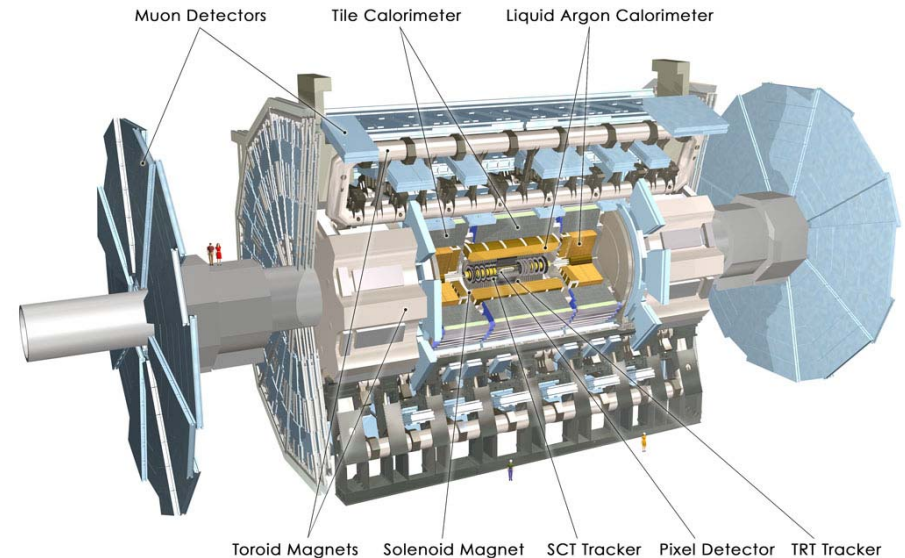
Outline

- LHC and the ATLAS-Experiment
- Top Physics at the LHC
- Top quark production cross-section
 - top pair production
 - single top production
- Conclusion



LHC and the ATLAS Experiment

- first collision data summer 2009
- \sqrt{s} between 10-14 TeV (under discussion)
- Luminosity up to $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
 - expected integrated Luminosity $\sim 100 \text{ pb}^{-1}$ to 1 fb^{-1}
- ATLAS currently commissioned with tracks from cosmic showers





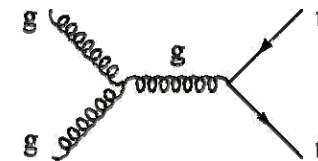
Top Physics at LHC

- top production:
 - pair production cross section:
 - $\sigma_{tt} \sim 7 \text{ pb}$ (Tevatron)
 - $\sigma_{tt} \sim 400 \text{ pb}$ (10 TeV)
 - $\sigma_{tt} \sim 900 \text{ pb}$ (14 TeV)
 - $\sim 1 \text{ tt-event/s}$ at $10^{33} \text{ cm}^{-2}\text{s}^{-1}$
 - single top production
 - $\sigma_t \sim 320 \text{ pb}$ (14 TeV)

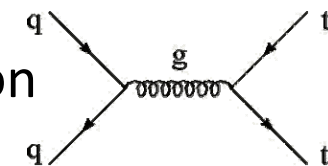
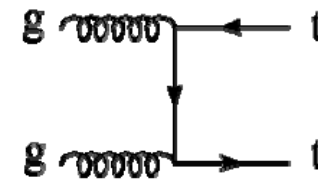
- top-quark decay

- top decays always in $W+b$ -quark with the W -boson
 - $W \rightarrow qq \sim 2/3$
 - $W \rightarrow l\nu \sim 1/3$

top pair production:



$\sim 90\%$



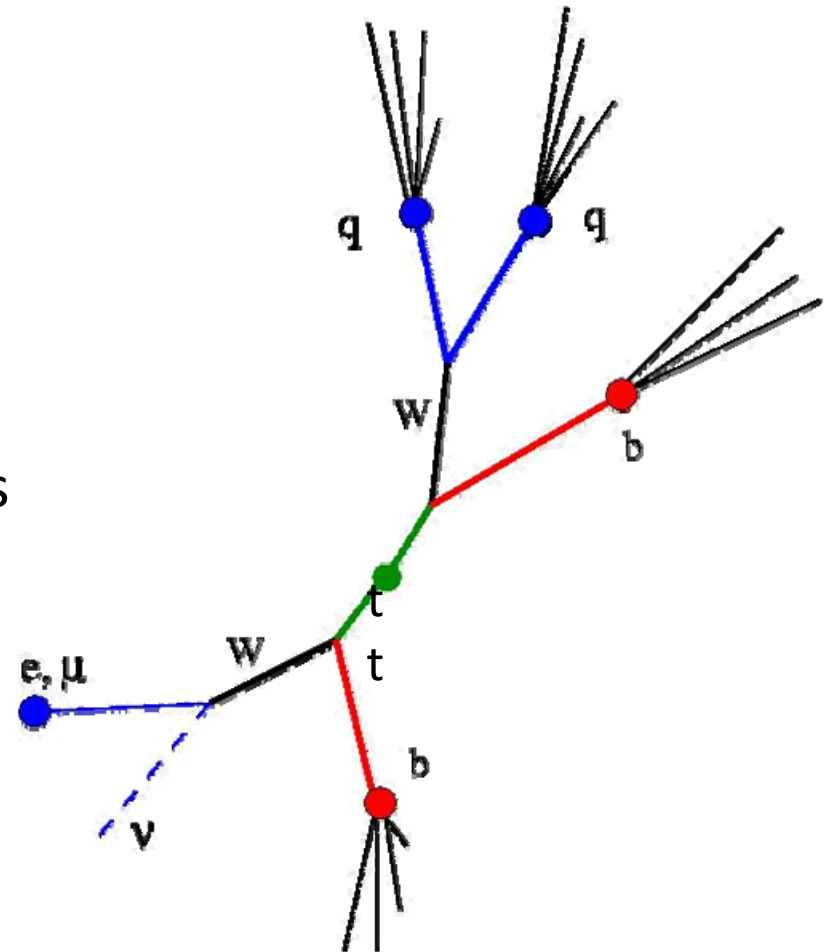
$\sim 10\%$

all results presented assume $\sqrt{s} = 14 \text{ TeV}$



Identifying Top Pair Events

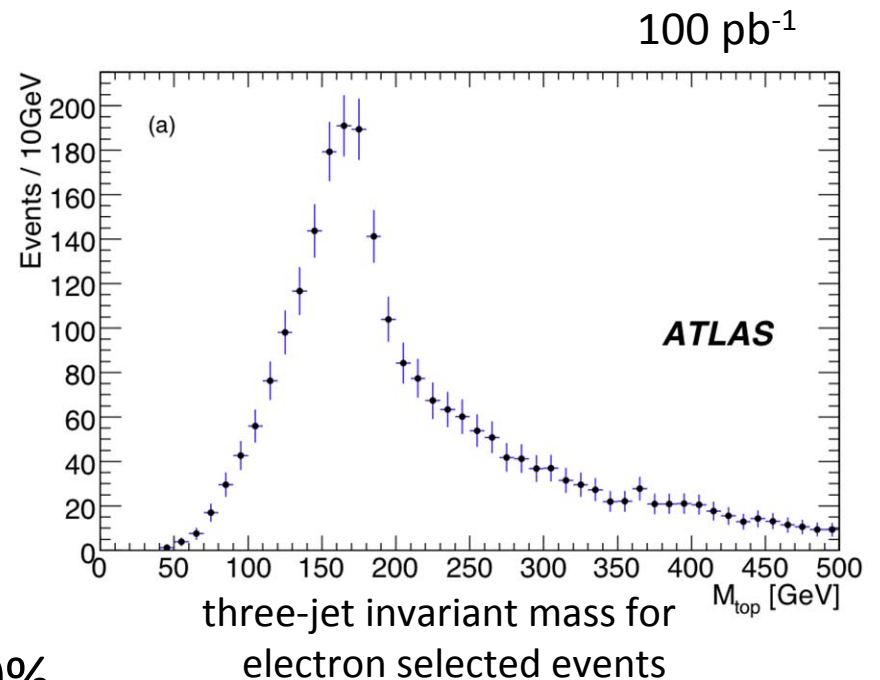
- “golden decay channel”:
semi-leptonic decay
- main background
 - W +multijet events
 - QCD events with fake leptons
- expect $100 \text{ pb}^{-1} \sim$ first months of LHC data taking





Top Pair Cross-Section

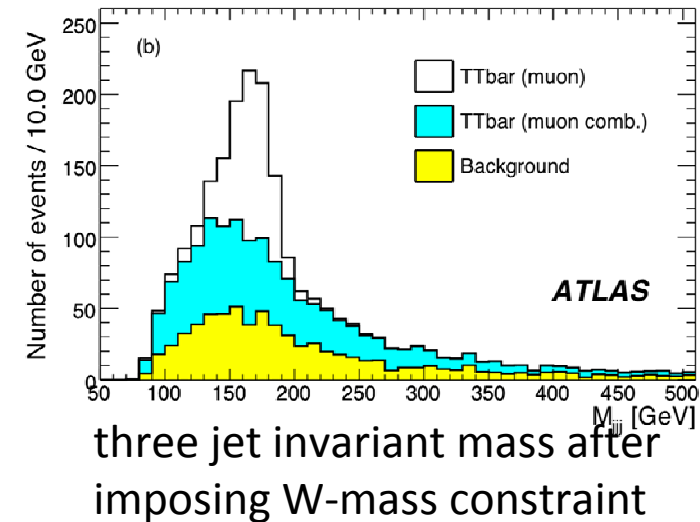
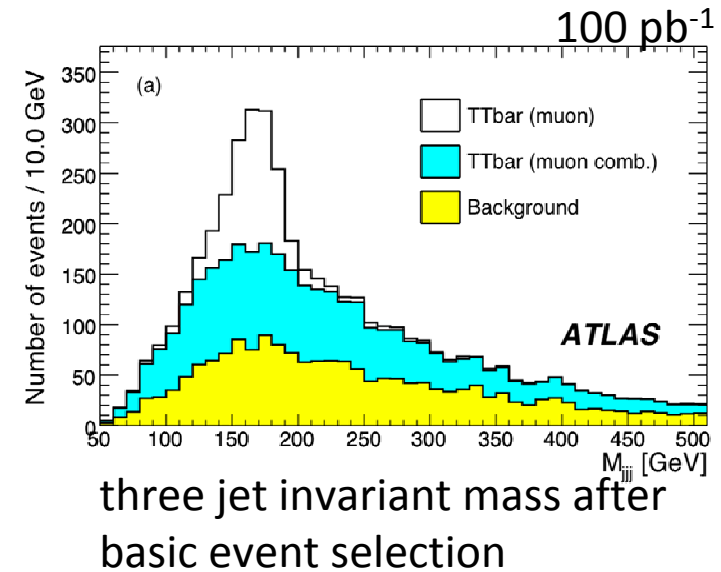
- event selection
Semileptonic channel:
 - one lepton with $p_T > 20$ GeV
 - missing $E_T > 20$ GeV
 - at least three jets with $p_T > 40$ GeV
 - additional 4th jet with $p_T > 20$ GeV
 - event selection efficiency $\sim 20\%$
- select three-jet combination with highest p_T
- commissioning selection without b-tag applied





Top Pair Cross Section

- Background evaluation:
 - require two jets to be compatible with a W-boson
 - one out of three di-jet combinations within 10 GeV of nominal W-mass (W-mass constraint)
 - ~50% efficiency
- window around expected top mass $141 < m_t < 189$ GeV
- S/B: 5.3 (μ) / 5.8 (e)





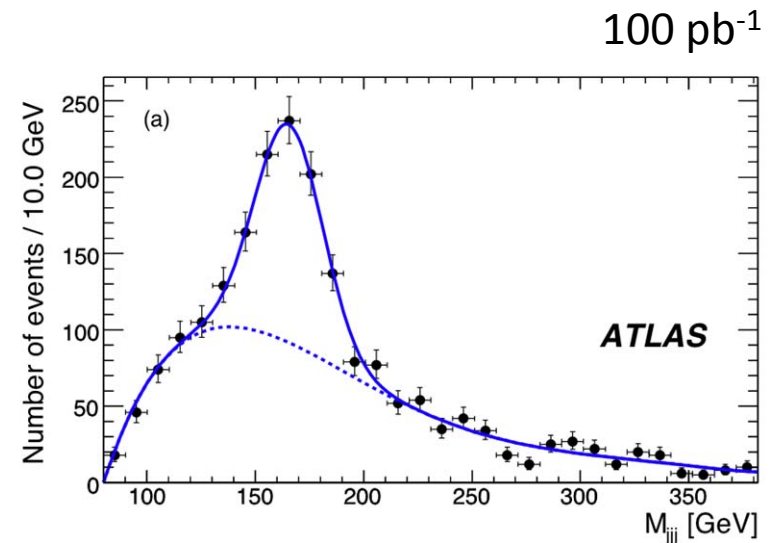
Top Pair Cross Section

- cut and count method:

$$\sigma = \frac{N_{\text{Observed}} - N_{\text{background}}}{L \cdot \varepsilon}$$

or

- estimate background with likelihood fit to 3-jet invariant mass distribution



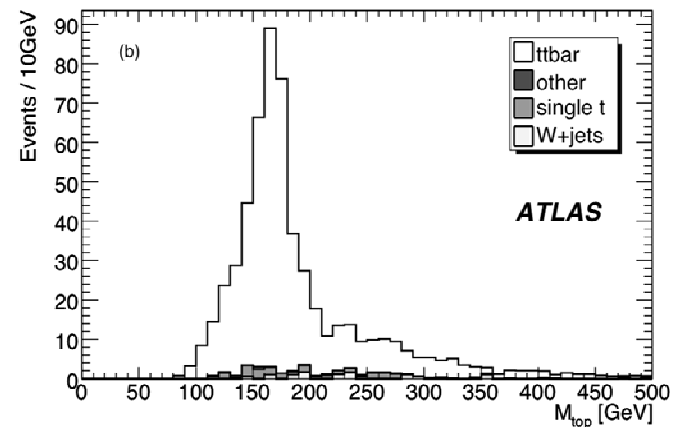
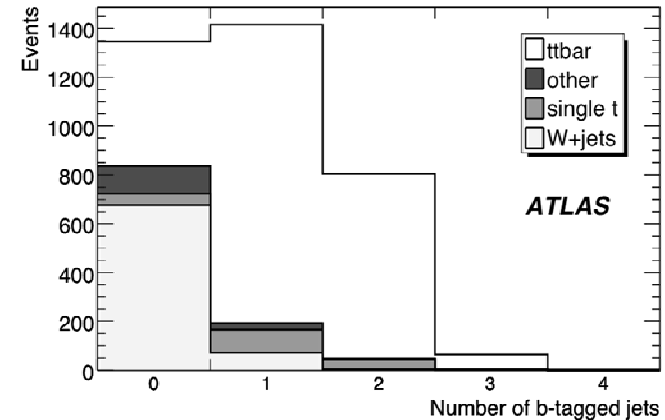
fit to the top signal

$\Delta\sigma/\sigma$	stat	syst	pdf	lumi
Counting	3%	16%	3%	5%
Likelihood	7%	15%	3%	5%



b-Tag in Semileptonic tt-Events

- require two b-tags in the event
 - reduce W+jets and combinatorial background
 - S/B: 20.1 (μ) / 21.6 (e)
 - slightly increased statistical uncertainty, decreased systematic uncertainty, but additional error due to b-tagging efficiency
- use top-pair events to calibrate b-tagging
 - talk by Mike Flowerdew



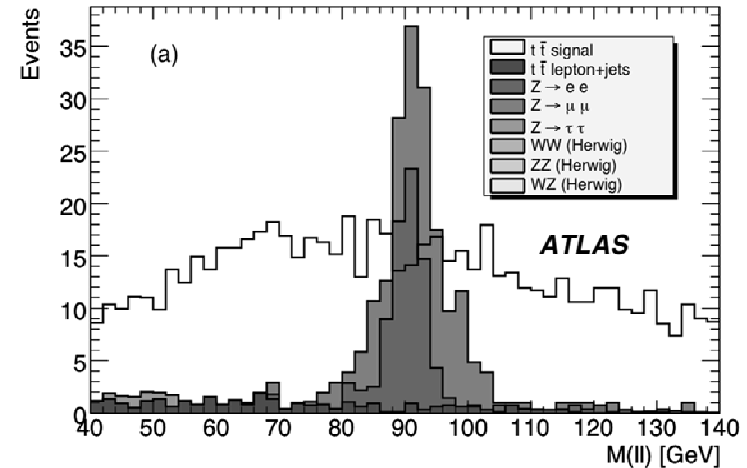
m_{top} requiring one or two jets coming from a b-quark



Di-Lepton Channel

100 pb⁻¹

- select two isolated opposite signed leptons
 - main background: $Z \rightarrow l^+l^-$ events
- cut and count:
 - events with missing E_T
 - reject events with M_{ll} consistent with M_Z
- similar precision with different methods

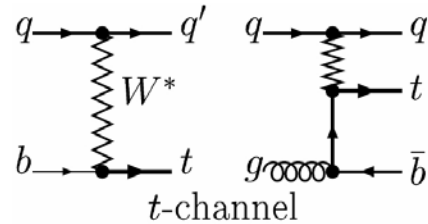


	stat	syst	pdf	lumi
counting	4%	+5 -2%	2%	5%
template	3%	4%	2%	5%
likelihood	5%	+8 -5%	2%	5%

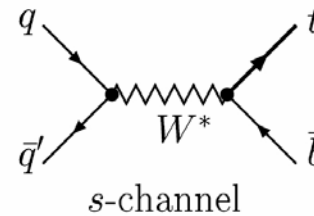


Single Top Decays

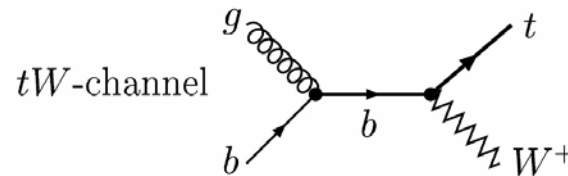
t-channel:
 $\sigma_t=240 \text{ pb}$



s-channel:
 $\sigma_t=10 \text{ pb}$



tW-channel:
 $\sigma_t=60 \text{ pb}$



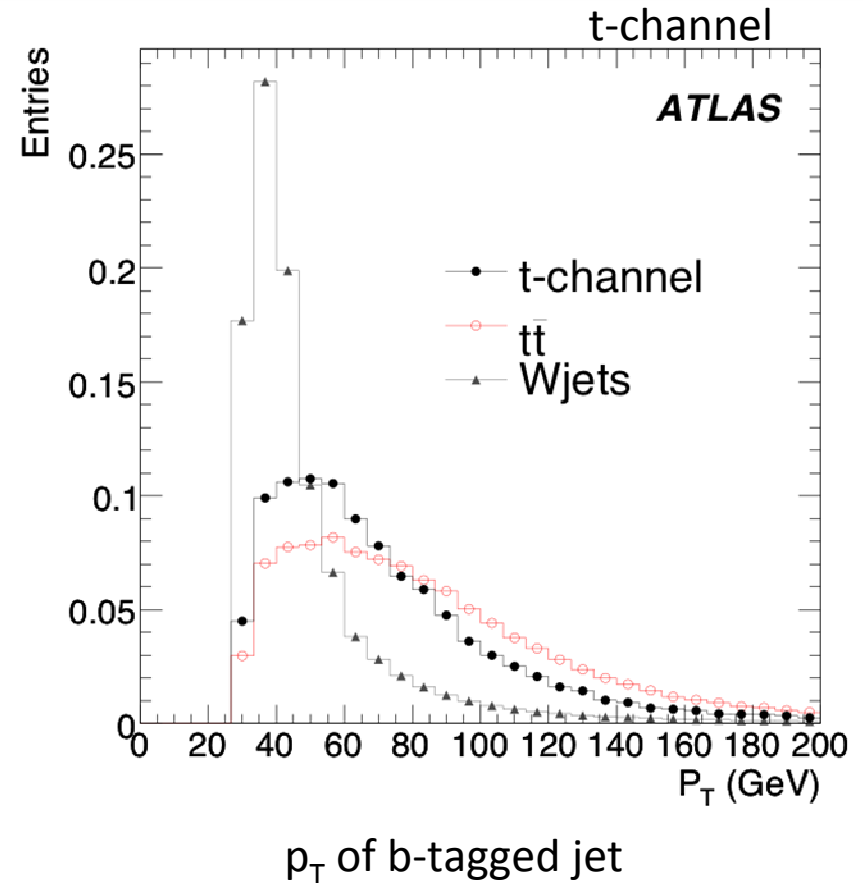
tt-cross section:
 $\sigma_t=900 \text{ pb}$

- electroweak single top quark production
 - extract V_{tb}
- sensitive to new particles and FCNC
- large background from top-pairs, W +jets and QCD events



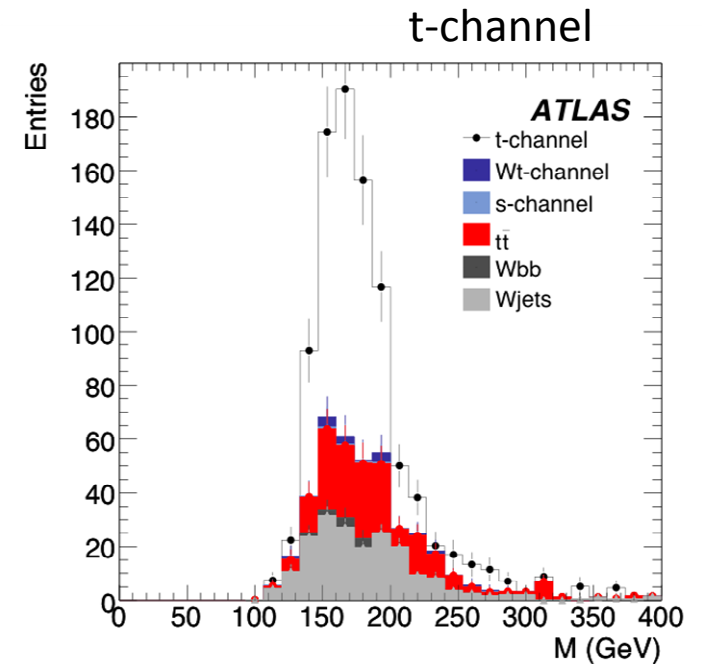
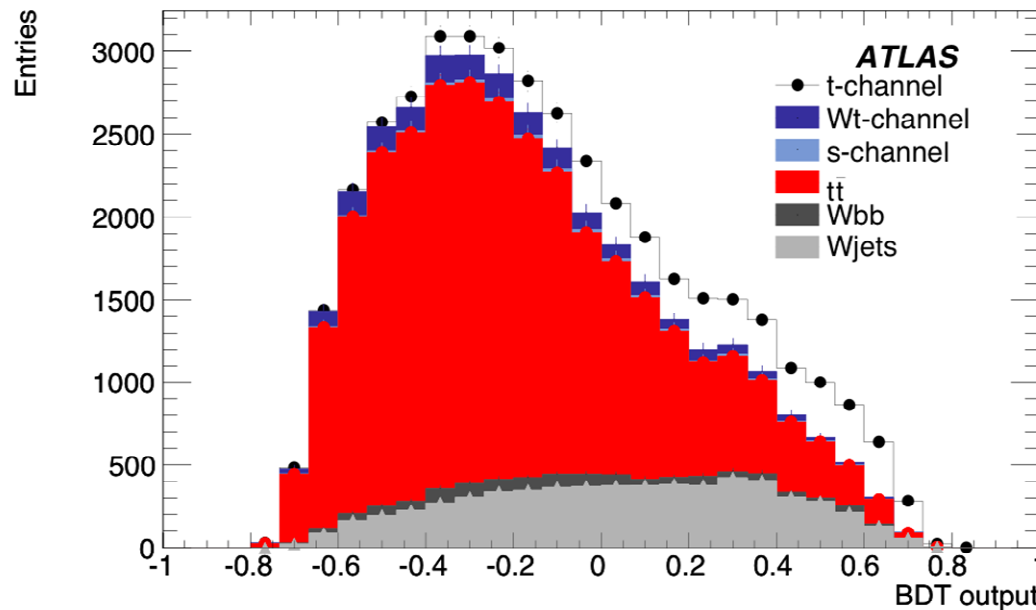
Single Top Cross Section

- selection:
 - isolated high p_T lepton
 - two jets with high p_T
 - one jet at least with b-tag
 - missing E_T
- multivariate analysis method





Single Top Cross Section

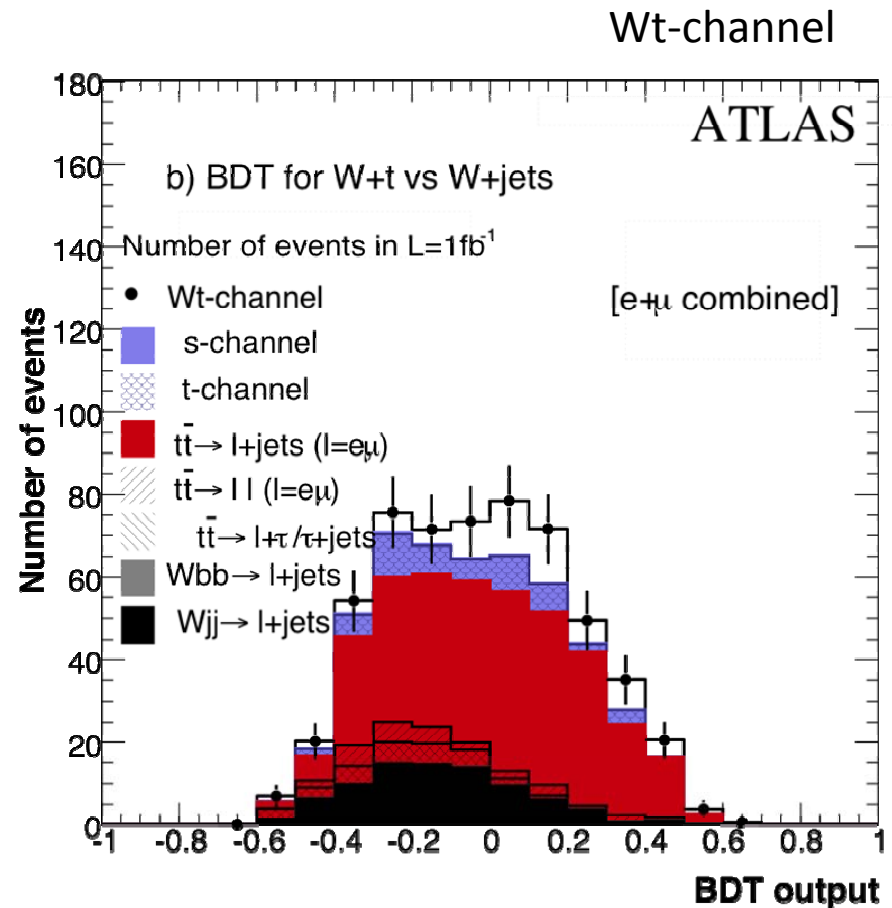


- difficult to reduce background with cut based analysis
- **Boosted Decision Tree** analysis selects ~ 500 signal events (1 fb^{-1} , S/B: 1.3)
- $\Delta |V_{tb}| / |V_{tb}| = 11\%(\text{stat.} + \text{syst}) + 4\%(\text{theo.})$



Single Top Cross Section

- multivariate analysis
- consider 2, 3 and 4 jet case
- BDT selects ~ 60 events (1 fb^{-1} , S/B 0.35)
- require $1\text{-}10 \text{ fb}^{-1}$ for convincing signal
- much more difficult than $t\bar{t}$ -cross-section
 - no 'early' physics channel





Single Top Cross Section

$\Delta\sigma/\sigma$	expected cross-section	stat. 1 fb ⁻¹ [10 fb ⁻¹]	syst. 1 fb ⁻¹ [10 fb ⁻¹]
t-channel (cut based)	240 pb	5% [2%]	45% [22%]
t-channel (BDT)	240 pb	6% [2%]	22% [10%]
Wt-channel	60 pb	21% [6.6%]	48% [19.4%]
s-channel	10 pb	64% [20%]	94% [48%]

- dominated by systematic uncertainties
- single top cross-section measurements very demanding



Other Top Analysis

- top mass measurement (1 fb^{-1})
 - select $t\bar{t}$ -pair events in the semileptonic decay channel with two b-tagged jets
 - jet energy scale dominant systematic uncertainties between 1 and 3.5 GeV
- top pair spin correlations (10 fb^{-1})
 - 5σ discovery of spin correlations expected
- rare top decays: FCNC $t \rightarrow \{Z, \gamma, g\}q$



Conclusion

- LHC is a top factory
 - $\sim 800\text{k}$ top pair events at 14 TeV and 1 fb^{-1}
- significant top pair cross section measurement possible with 100 pb^{-1}
 - $\Delta\sigma/\sigma \sim 18\%$
 - no b-tag necessary, but improves S/B ratio
- single top production suffers from large background
 - b-tag necessary to reduce background
 - $\Delta\sigma/\sigma \sim 23\%$ (1 fb^{-1})