Prospects for Single Top Cross Section Measurements at ATLAS with Early Data

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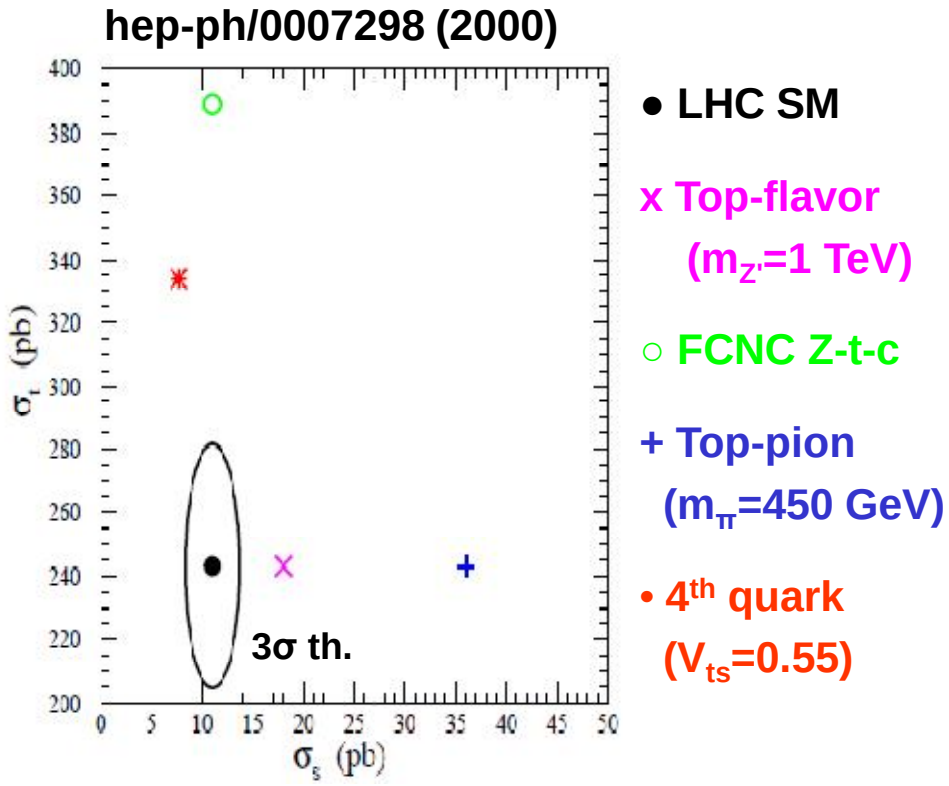
Why Study Single Top at LHC ?

- **Window to new physics**
  - Electroweak top production
  - Cross section directly proportional to $|V_{tb}|^2$
  - → Sensitive to any new additional non standard particles that may modify the top's weak coupling



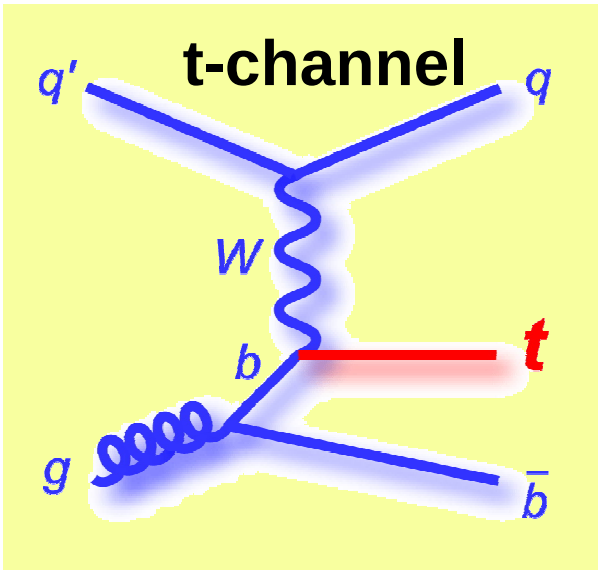
- **But also**
  - Evidence of Single top at Tevatron but yet to be observed
  - Wt-channel can only be observed at LHC
  - Background to top analyses
    - Single top cross section is large at LHC: ~320 pb

Objective of This Talk

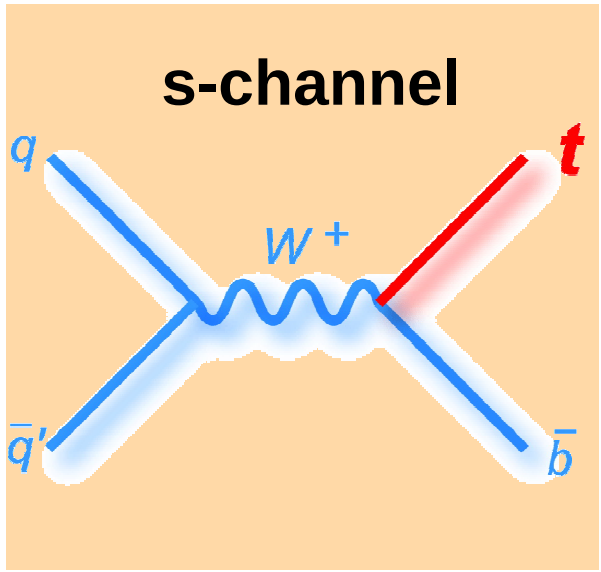
- **Determine sensitivity for single top cross section measurement**
  - For **all** three single top channels
  - With **simple** techniques: cut based analyses
  - and with more sophisticated tools: **MVA**
  - For **early data** (1-10 fb^{-1}) but not first data
- **With our current knowledge of**
  - **Expected systematic** uncertainties
  - **Theoretical** cross sections
  - Detector full **simulation**
  - Trigger and reconstruction algorithm **efficiencies**

Single Top Quark Production at LHC

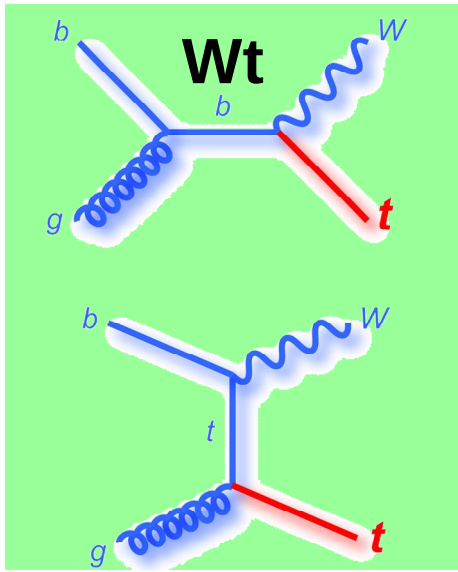
- **Top quark pair production**
  - LHC: pp→ gluon → ttbar (833 pb) dominant mode
- **Single top production**
  - Weak production mechanism: Wtb vertex
  - Signature: 1 central high-p_t b-jet, W leptonic decay, 1-2 extra jets



σ_{NLO} = 246 ± 12 pb

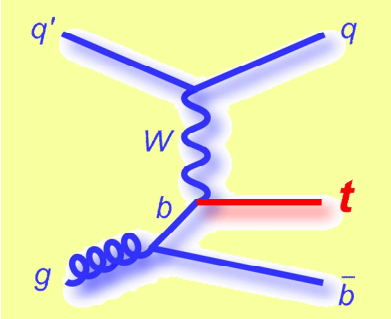


σ_{NLO} = 11 ± 1 pb



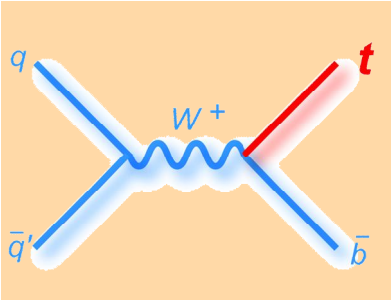
σ_{NLO} = 66 ± 2 pb

Single Top Signatures



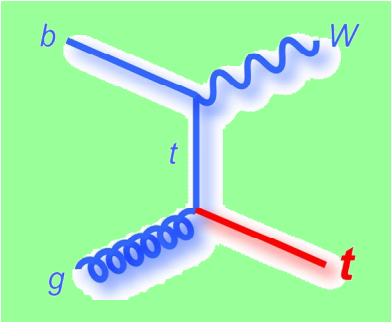
t-channel single top

- 1 or 2 extra forward jet (b-jet often very forward)
- leptonic decay of W only: 1 high-p_T e or μ + missing E_T



s-channel single top

- 1 second central b-jet
- leptonic decay of W only : high-p_T e or μ + missing E_T

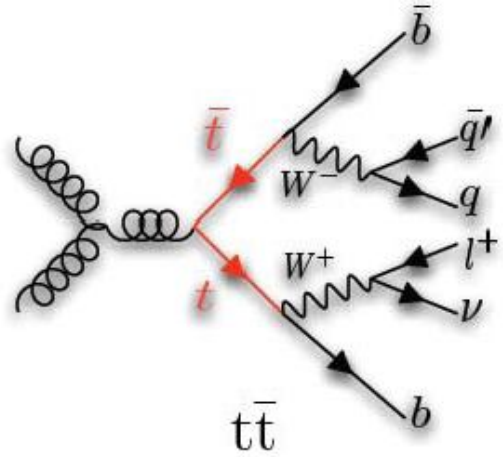


Associated Wt production

- 1 second W boson
- lepton + jet channel: 2 jets,1 lepton, missing E_T
- di-lepton channel: 2 leptons, some missing E_T, no extra jet
  - (not considered in this talk)

- **Generator used to simulate these processes: AcerMC + Pythia**

Main Backgrounds



Top pairs (σ≈800pb) → Dominant background to all analyses

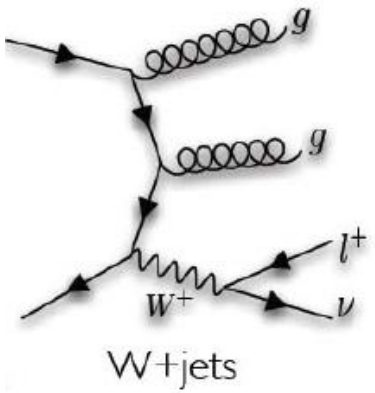
- Can be reduced by requiring 1 b-tag veto, cut on forward jet
- **Generators**: MC@NLO+Herwig (NLO), AcerMC + Pythia (ISR/FSR)

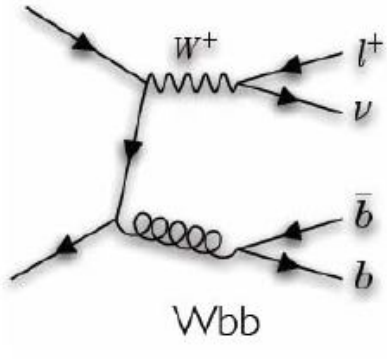
W+jets

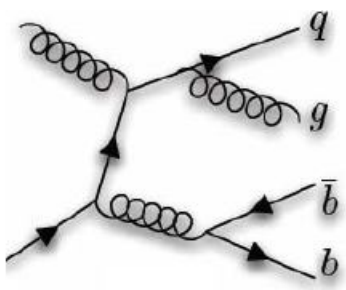
W+light jets(σ≈O(100) nb)

W+bb+jets (σ≈O(0.1) nb)

- hard b-jet pt cut helps reduce this BG
- **Generators**: Alpgen + Pythia (+K fact)







Multijet events with a fake lepton

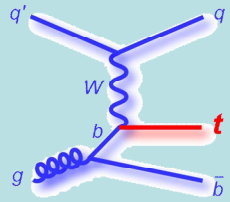
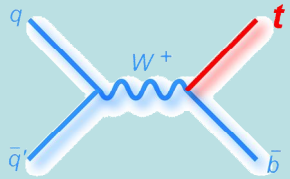
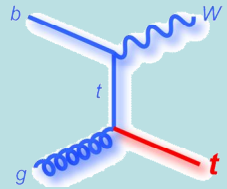
- Triangular cut in ME_T vs $\Delta\varphi$(Lepton, ME_T) plane could help reduce this BG
- **Generator**: Pythia dijet

Event Selection

- **Common pre-selection**
  - Inclusive lepton trigger (80% efficiency)
  - 1 isolated electron or muon, p_T>30 GeV, |η|<2.5
  - Missing E_T > 20 GeV
  - 1 b-tagged jet, p_T > 30 GeV, |η|<2.5
    - b-tag eff ~60%, rej ~ 100
  - 1 extra jet, p_T > 30 GeV
  - 2 to 4 jets with p_T>15 GeV

  ➔ Removes most of the multijet and W+jet background
- **Then apply analysis specific selection**

Number of Selected Events: 1fb^{-1}

Process	t-channel	s-channel	Wt-channel
			
Selection	• b-jet cut p_T>50 GeV • fwd light jet cut |η|>2.5	• 2nd b-jet p_T>30 GeV • Veto extra jet p_T>15 GeV • Topological cut: H_T(jets), ΔR(b1,b2), p_T(lep)	• b-jet cut p_T>50 GeV • Veto extra b-jet, • Hadronic W mass cut
Signal	**1460**	**24.8**	**639**
Other ST	148	39.5	1418
ttbar	2816	145.1	3022
W+jets	942	66.4	3384
Total BG	**3906**	**251**	**7824**
S/B	0.37	0.1	0.08
S/√B	23.4	1.6	7.2

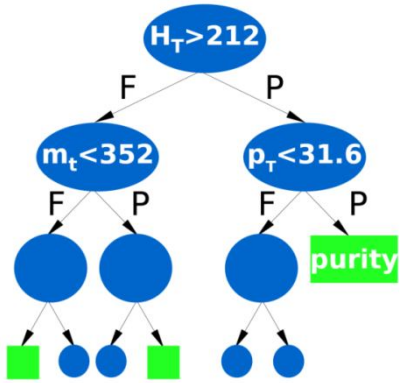
Significance ok for t-channel and Wt. But systematics not included !

Multivariate Analysis

- **Improve signal separation**
  - Combine information of several (poorly) discriminating variables
- **Boosted decision trees: t-channel and Wt**

Decision Tree : At each node find variable and cut that gives the best separation

Boosting : Average over several trees, reweight Use TMVA implementation



- **Likelihood ratio S/(S+B): s-channel**

$$L = \Pi P_{Signal}(x_i) / (\Pi P_{Signal}(x_i) + \Pi P_{Background}(x_i))$$

- **For each analysis, several discriminants are trained**
  - 1 discriminant per principal background
  - Different sets of discriminating variables
  - Split analyses in separate channels (electron/muon, jet multiplicity)
  - **Cut on discriminants chosen as to minimize total xsec error**

Cross Section Uncertainty

- **Poisson likelihood**

$$L(\sigma) = \prod_{\text{channel}\,i}^{N} \frac{e^{-(B_i+\alpha_i L_i \sigma)}.(B_i+\alpha_i L_i \sigma)^{D_i}}{D_i!}$$

- B_i : # of background events
- α_i : signal acceptance.
- L : integrated luminosity.
- D_i : expected data = $B_i + \alpha_i L \sigma_{th}$
- σ : cross section to fit

  - Use toy MC to generate D as Poisson, shift B_i, α_i, L for all sources of systematic errors

- **Main systematic effects**
  - Luminosity: 5% variation
  - Jet energy scale: 5% variation jet energy
  - B-tagging efficiency: 5% variation
  - Cross section: 10% ttbar, 20% W+jets, Wbb+jets
  - ISR/FSR: ~10% variation event yield

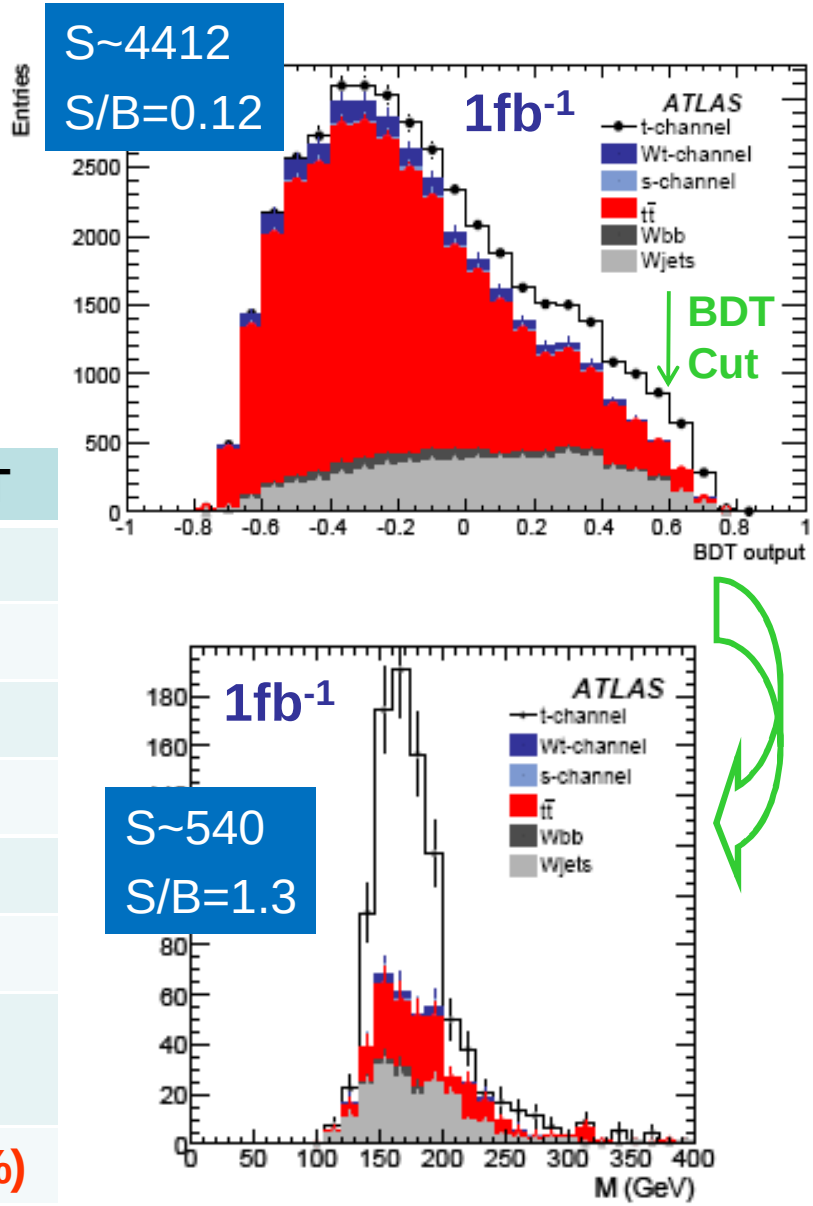
t-channel Analysis

Event Selection

- harder b-jet cut: p_T>50 GeV
- forward light jet cut |η|>2.5 (cut based analysis only)

1 BDT discriminant vs top pairs

Source	δσ/σ cut-based	δσ/σ BDT
Stat. error	5.0%	5.7%
MC stat.	6.5%	7.9%
Luminosity	**18.3%**	8.8%
B-tag efficiency	**18.1%**	6.6%
Jet energy scale	**21.6%**	**9.9%**
Lepton ID, trigger	2.3%	1.8%
Theory (xs, PDF, ISR/FSR…)	**28.1%**	**13.5%**
Total 1(10) fb^{-1}	**45% (22%)**	**22% (10%)**



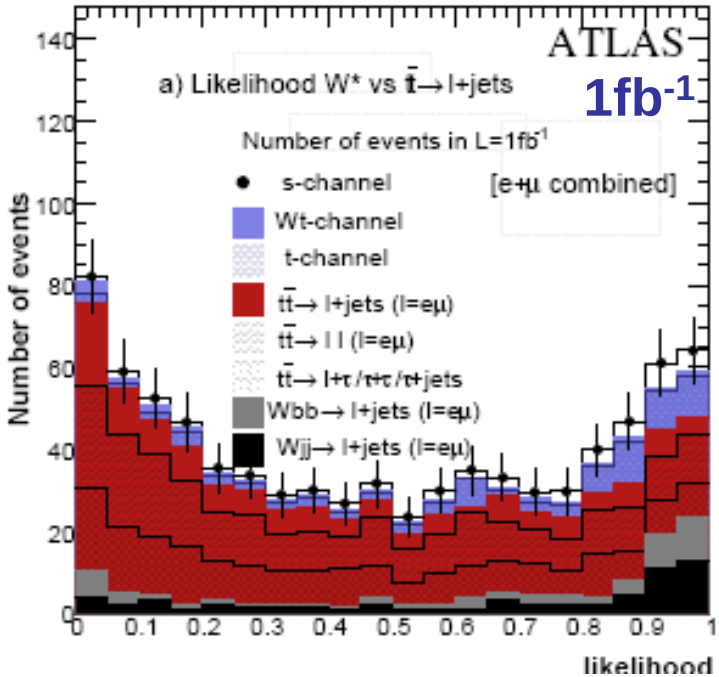
s-channel Analysis

Event Selection

- 2 b-tagged jets p_T>30 GeV
- Veto of extra jet p_T>15 GeV

5 Likelihood functions

- vs tt→l+jets, tt→ll, tt→l+τ/ττ
- vs W→l+jets, ST t-channel



S~15, S/B~20% (1fb^{-1})

Source	δσ/σ Likelihood
Stat. error	**64%**
MC stat.	29%
Luminosity	31%
B-tag efficiency	**44%**
Jet energy scale	25%
Lepton ID, trigger	6%
Theory (xs, PDF, ISR/FSR…)	**74%**
Total 1(10) fb^{-1}	**95% (48%)**

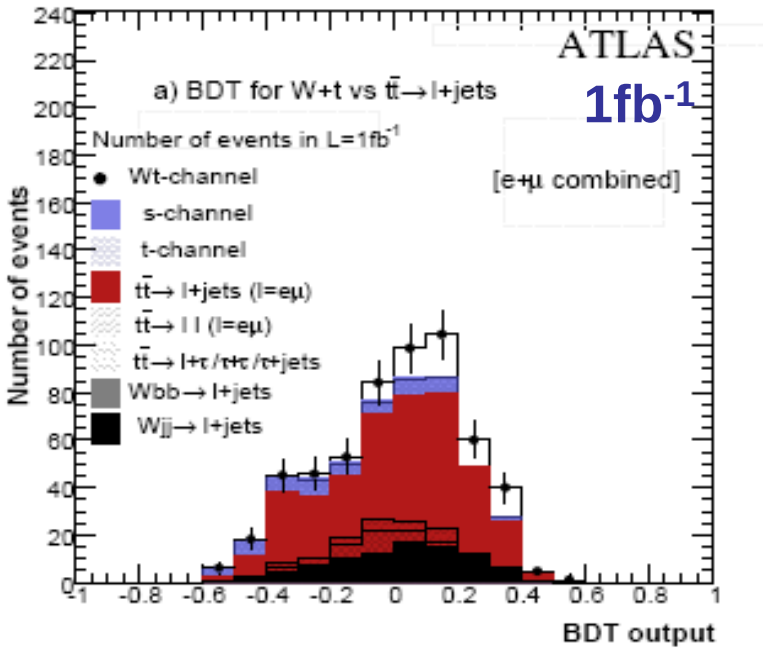
Wt-channel

Event Selection

- harder b-jet cut: p_T>50 GeV
- Veto extra b-jet

12 Boosted Decision Trees

- vs tt→l+jets, tt→dilepton, W→l+jets, t-channel
- BDT for 2/3/4 jet multiplicity



S~80, S/B~40% (1fb^{-1})

Source	δσ/σ BDT
Stat. error	**20.6%**
MC stat.	15.6%
Luminosity	**20%**
B-tag efficiency	16%
Jet energy scale	11%
Lepton ID, trigger	3.2%
Theory (xs, PDF, ISR/FSR…)	**35%**
Total 1(10) fb^{-1}	**48%(19%)**

Summary

- **Prospects for single top cross section measurements**
  - Early data (≤10 fb^{-1})
  - Simple (cut based) and more complex analysis (MVA)
  - Realistic systematics, detector simulation …
- **Results**
  - t-channel: observation may be possible for ~1fb^{-1}
  - → measurement of |Vtb| with Δ|Vtb|/|Vtb|~12%
  - Wt channel: possible observation for ~10fb^{-1}
  - s-channel: require more stat. > 30fb^{-1}
- **Prospects: once ST signal is established**
  - Study top properties (polarization)
  - New physics searches (non-SM cross section, modified kinematics): charged Higgs, W' …

BACKUP

Single Top at LHC vs Tevatron

- **Larger cross sections at LHC**

Process	Tevatron	LHC
t-channel	2 pb	240 pb (x120)
s-channel	0.9 pb	11 pb (x11)
Wt	0.1 pb	66 pb (x660)
Top pair	7 pb	833 pb (x120)
W+jets	~2 nb	~20 nb (x10)

- **S/B ratio**
  - t-channel: similar
  - s-channel: worse by a factor 10 …
  - Wt: improved by a factor of 6

  → But higher statistics

Single Top Triggers

- **Trigger turn-on curves**

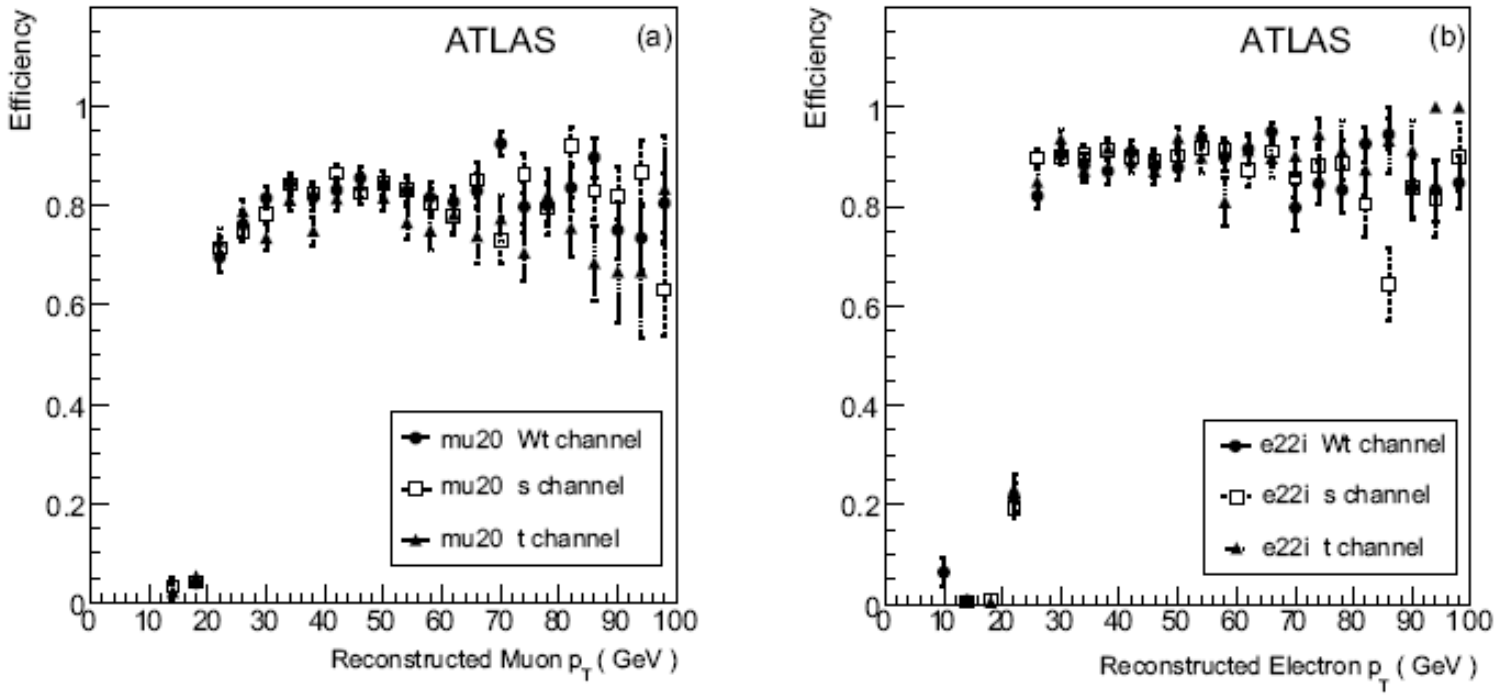


Figure 6: Turn-on curves are shown for the mu20i (a) and the e25i (b) trigger. In both plots, the circles represent Wt-channel single-top, the squares represent s-channel single-top, and the triangles represent t-channel single-top events.