Top Quark Pair Production Cross Section with the ATLAS Detector

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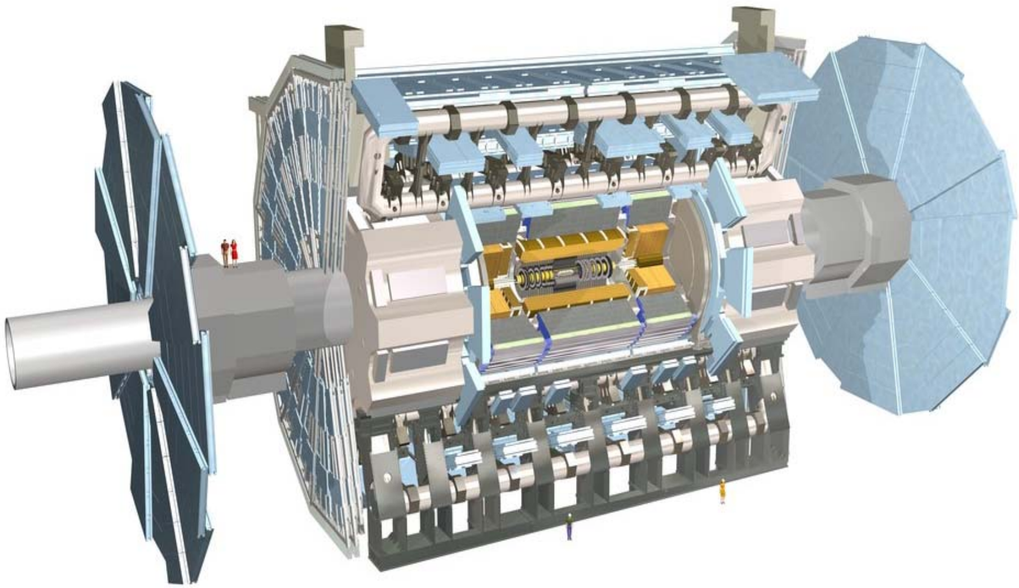
Max-Planck-Institut
für Physik
(Werner-Heisenberg-Institut)

Introduction

- Measurement of pair production cross section
- In the semileptonic channel
- Using first 100 pb^{-1} of data from ATLAS in 2008

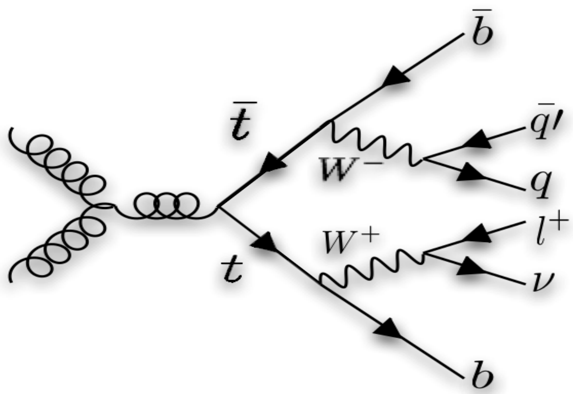


- Overview
- Event selection
- Selection efficiencies
- W+N jets
- QCD multijets
- Summary

Cross Section Measurement

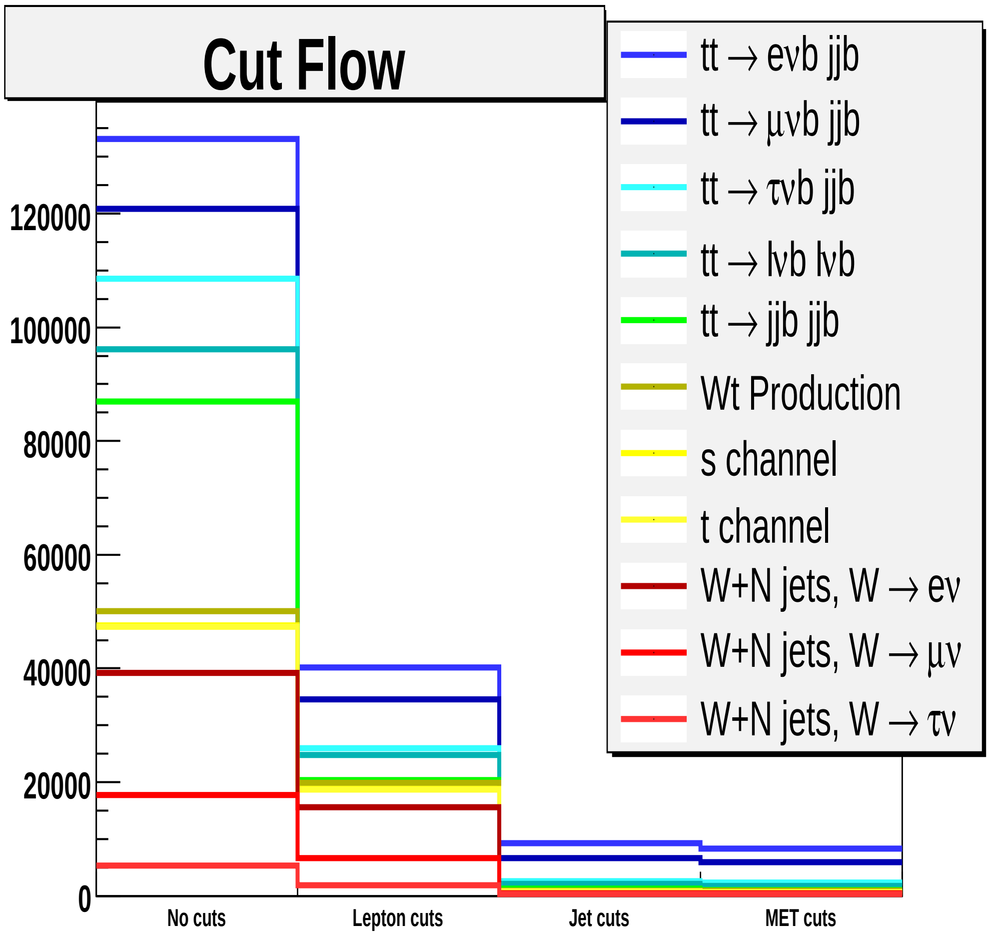
$$\sigma = \frac{N_{data} - N_{BG}}{\epsilon_{t\bar{t}} \int \mathcal{L} dt}$$

- **Estimate background rates**
  - QCD multijets
  - Electroweak W+N jet production
  - Single top production.
- **Estimate ε_{tt}**
  - Using Monte Carlo samples.
- **Luminosity:**
  - Relative luminosity measured by LUCID.
    - Absolute calibration from LHC machine parameters.
    - Relative uncertainty δL ~ 20% to 30% expected during initial data-taking.

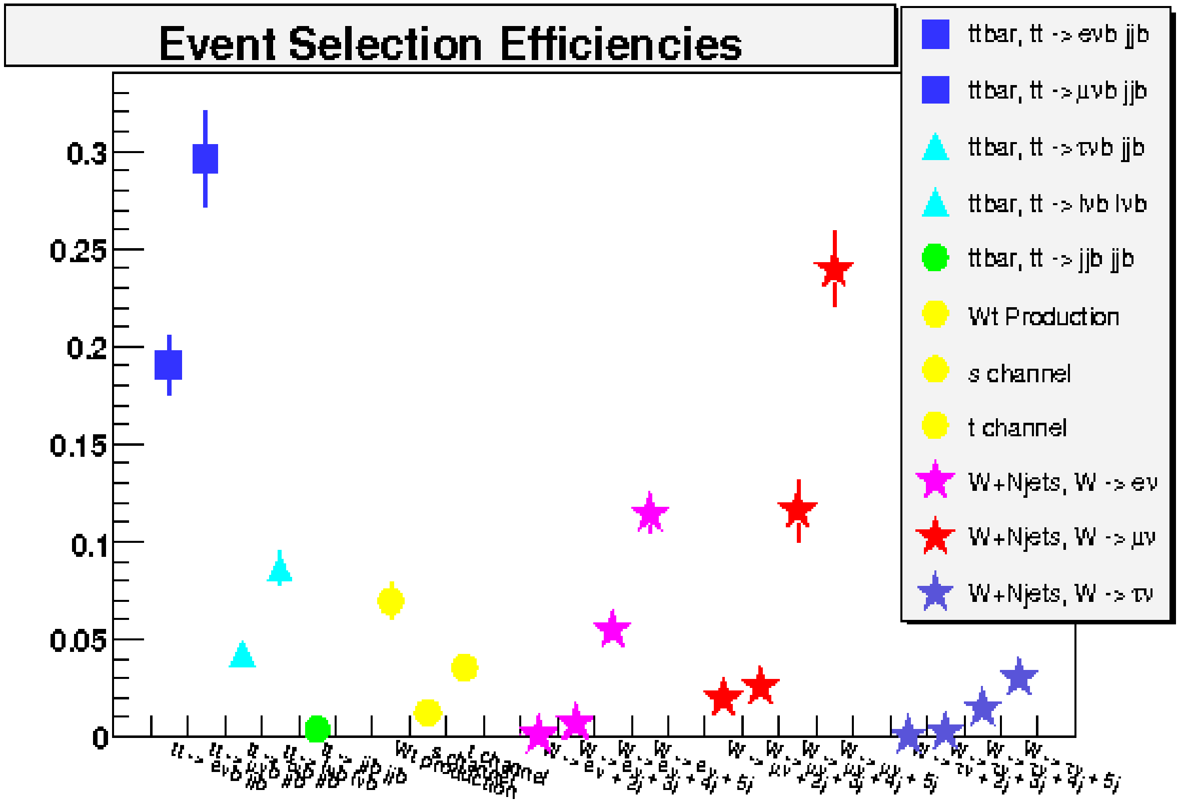


Event Selection

- Commissioning Analysis Cuts.
  - **Exactly one e or μ.**
    - Central
    - Isolated
    - Highly energetic.
  - **At least four jets.**
    - Central
    - Highly energetic.
  - No b-tagging.
  - **MET > 20 GeV.**
- **Before cuts S/B = 0.16**
- **After cuts S/B = 1.56**

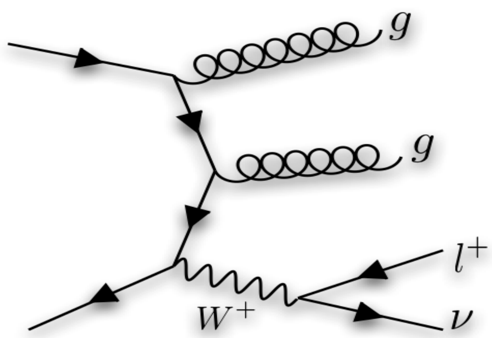


Selection Efficiencies



- **Small selection efficiencies:**
  - **dileptonic ttbar**
  - **hadronic ttbar**
  - **single top**
  - **W→τν** plus partons
- **Large selection efficiencies:**
  - **W→eν** plus 5 partons
  - **W→μν** plus 4 or 5 partons

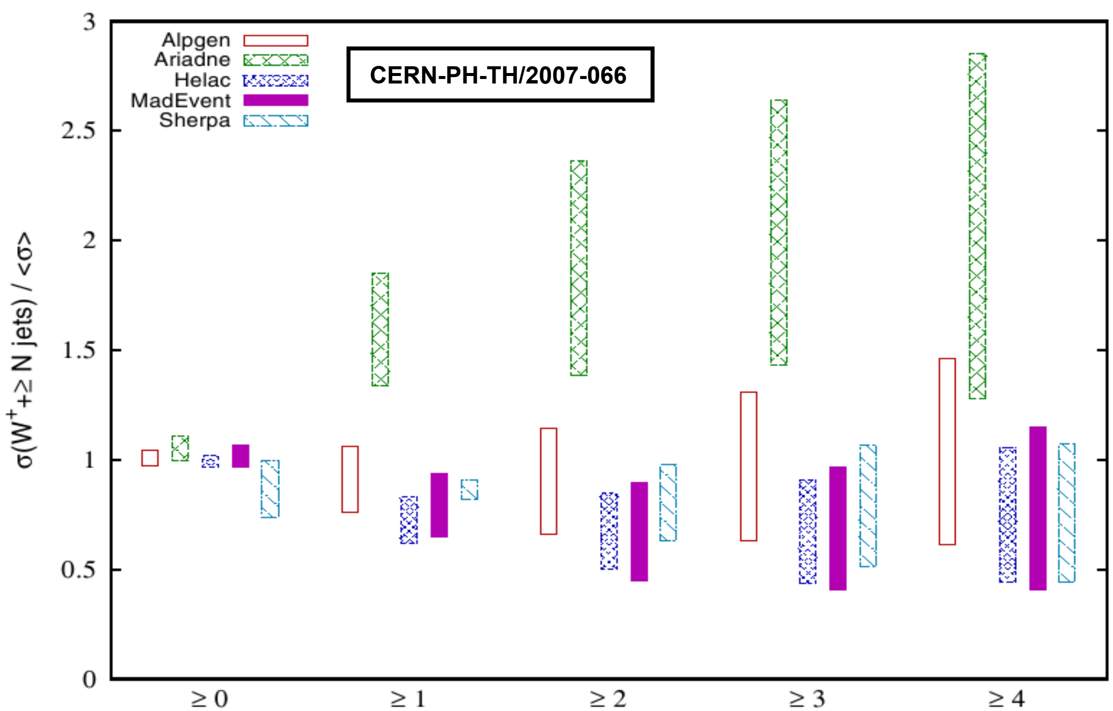
- Statistical uncertainty on ε is quite small.
- A first estimate of δε due to uncertainty on Jet Energy Scale was performed by varying cuts on jet p_T by 5%.



W+N Jets Background

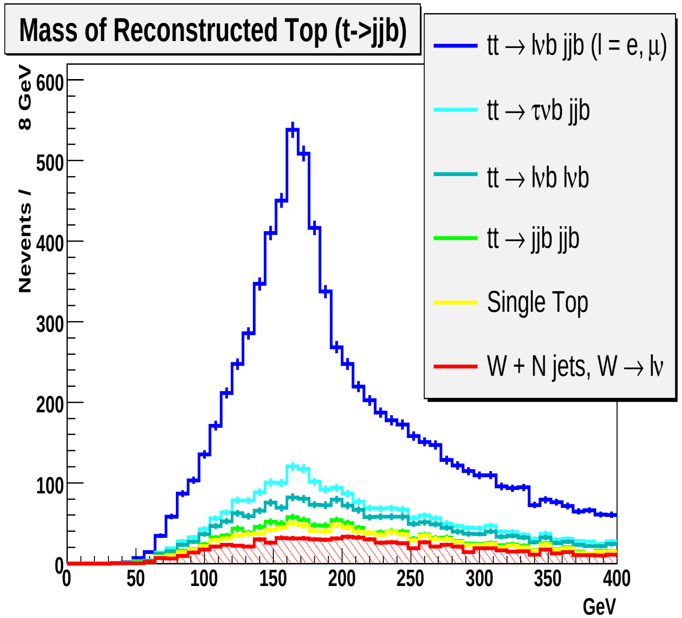
- Most dangerous background.
- $N_{expected} = \sigma_{W+Njets}\, \varepsilon_{W+Njets} \int L\, dt$

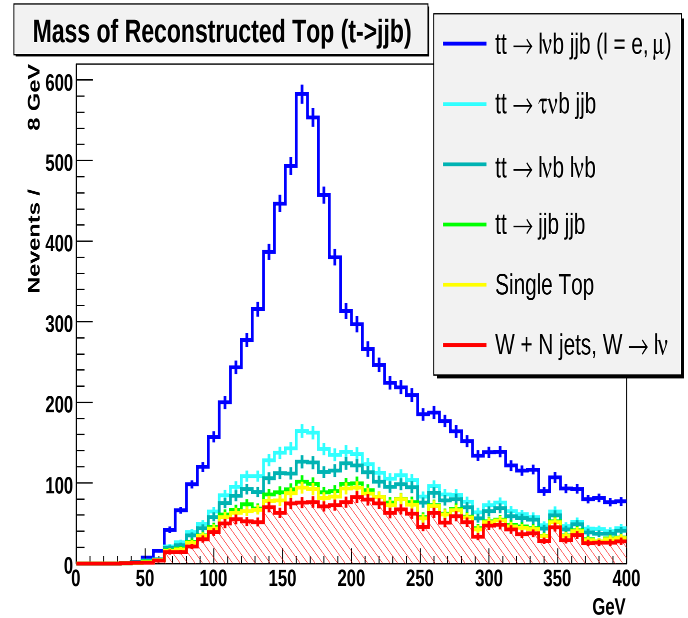
- Selection efficiencies for events with 4 or 5 partons are large.
- Uncertainty on $\sigma_{W+Njets}$ is large.
- Uncertainty on $N_{expected}$ will be large.
- Effective cuts are needed to reduce background rate.



Systematic Uncertainty on $\sigma_{(W^+)+Njets}$

W+N Jets





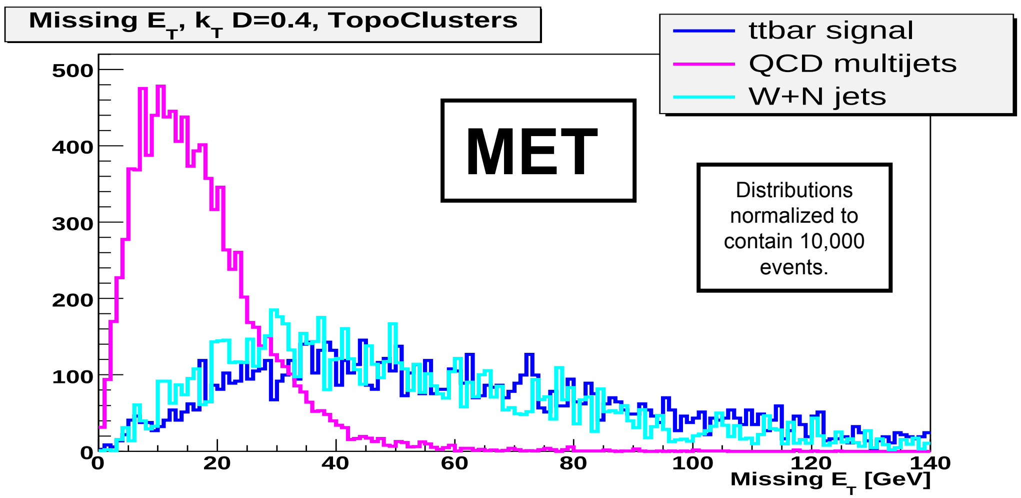
Low and high estimates of W+N jets contribution in $\int L\,dt = 100\ pb^{-1}$.

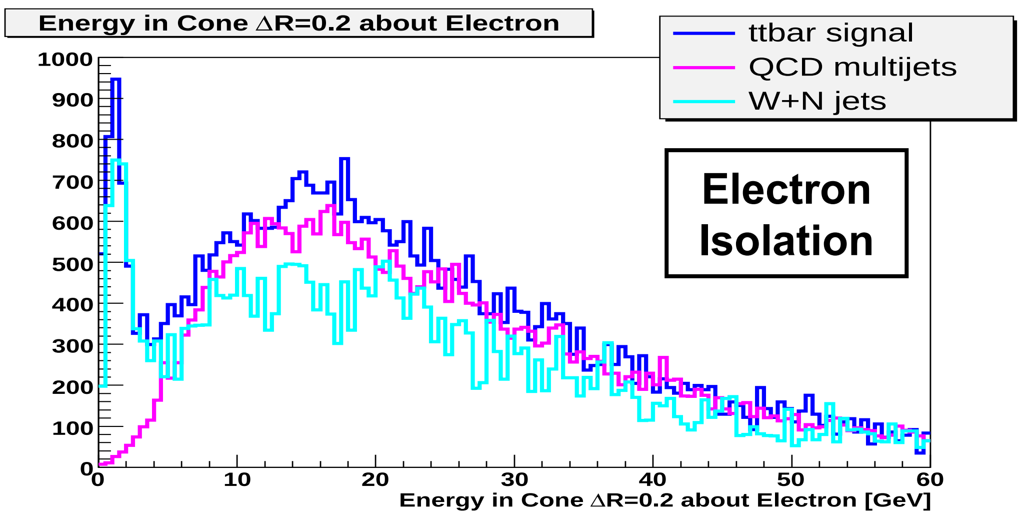
Process	Alpgen cross section [pb]	Relative uncertainty assigned to σ	N_{exp}, low estimate	N_{exp}, central value	N_{exp}, high estimate
W+2 partons	2032	20%	42	53	63
W+3 partons	771	30%	190	271	352
W+4 partons	273	40%	465	775	1085
W+5 partons	91	50%	400	800	1200

Number of selected W + N jet events expected in $\int L\,dt = 100\ pb^{-1}$.

QCD Multijet Background

- **Reducible BG.**
- **MET** is due to
  - b→Wc→lνc
  - Mismeasurement
- **Leptons** are
  - Non-prompt
  - 'Fake'
- **Fake Rate**
  - $R \sim 10^{-5}$ (ATLAS TDR)
  - $R = R(p_T, \eta)$
- **Difficult to model QCD multijet background adequately using Monte Carlo samples, detector simulation.**
- **Contribution will be measured from data.**





Hard cuts placed only on jet quantities. No cuts on lepton quantities.

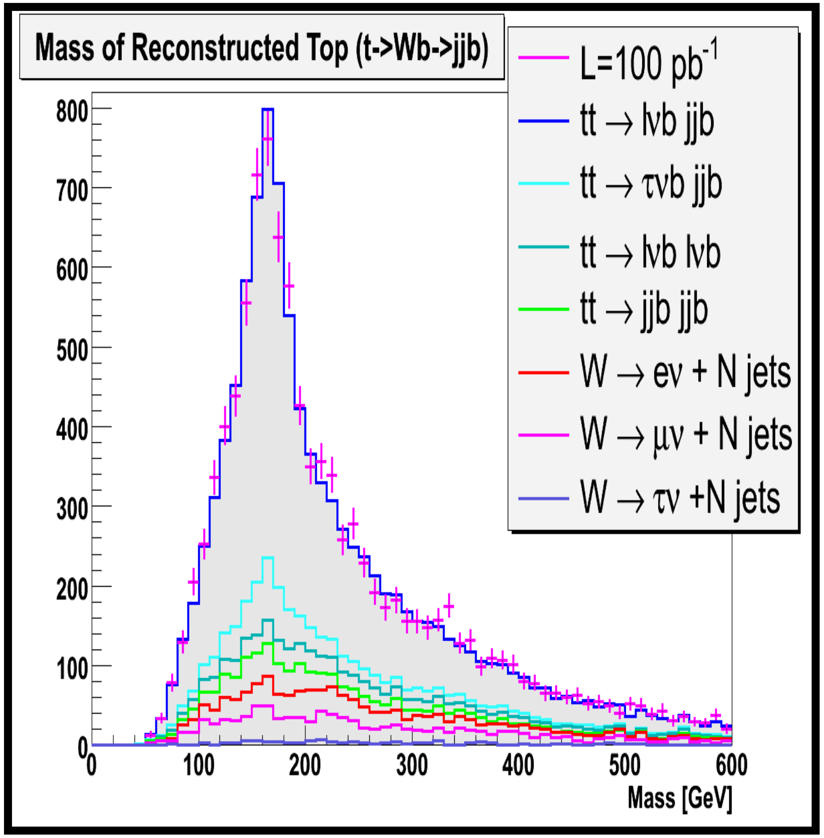
Summary and Outlook

- **Measurement of σ_{tt}**
  - **In semileptonic channel**
  - **Using 100 pb^{-1} of first data.**

  - **Selection efficiencies**
  - **Background rates**

- **We are looking forward to the day the LHC comes online.**

Invariant Mass of t→Wb→jjb



Backup Slides

Measuring Absolute Luminosity

- **Measure rate of process with large, well-known cross section.**
  - $R = L\,\sigma$
  - More easily applicable to e^+e^- colliders than to hadron colliders.
  - Example: QED Babha scattering.
- Calculate luminosity using **beam parameters**.
  - $L = F\,f\,\Sigma N_1 N_2\ /\ 4\pi\sigma_x^*\sigma_y^*$
    - Beam revolution frequency is f = 11 kHz.
    - F = 0.9 accounts for nonzero crossing angle.
    - N_1 and N_2 are the number of protons in colliding bunches.
      - Caveat: bunch currents will not be very uniform.
    - σ_x^* and σ_y^* are transverse bunch widths at interaction point.
      - Caveat: beam profile measurements are necessary.
  - Typical precision is 5% - 10%.
- Use the **optical theorem**.
  - Measure total rate of pp interactions R_{total}.
  - Measure rate of forward elastic scattering $dR_{elastic}/dt\,|_{t=0}$.
  - $L\,dR_{elastic}/dt\,|_{t=0} = R_{total}^2(1 + \rho^2)\ /\ 16\,\pi$
    - Protons scatter with very small momentum transfer t.
    - ρ is ratio of real to imaginary part of elastic forward amplitude.
  - Typical precision is 5% - 10%

Samples

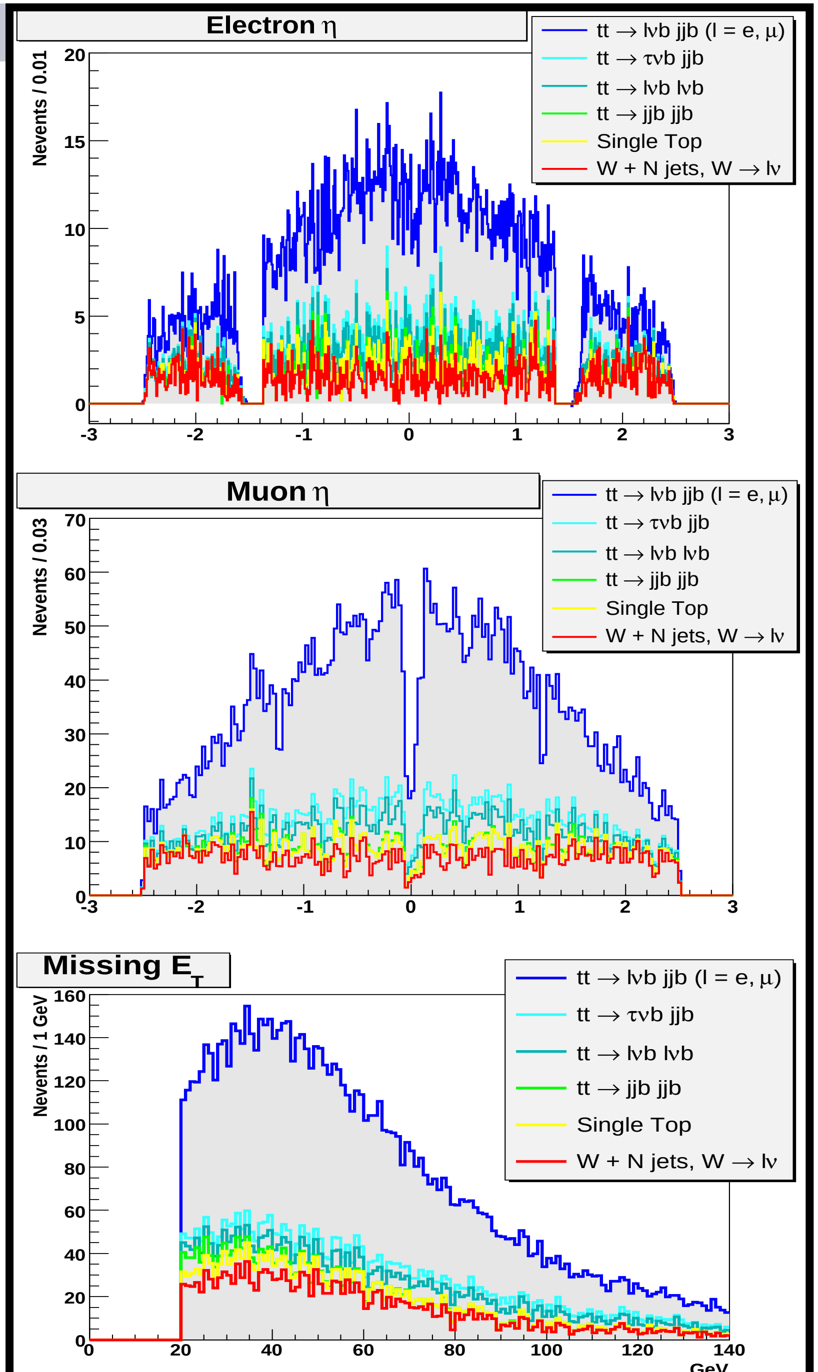
- **Semileptonic and dileptonic ttbar events:**
  - MC@NLO and Herwig.
  - Sample 5200, TID 8037.
  - no 1mm bug; bug in e isolation.
  - Filter requires prompt lepton, σ*f = 461 pb.
- **Hadronic ttbar events:**
  - MC@NLO and Herwig.
  - Sample 5204, TID 6015.
  - 1mm bug.
  - Filter forbids prompt lepton, σ*f = 369 pb.
- **Single top samples:**
  - AcerMC and Pythia.
  - **Wt Production:** sample 5500, TID 6958.
    - σ*f = 25.5 pb, W→lv plus W→jj
  - **s channel:** sample 5501, TID 6959.
    - σ*f = 2.3 pb, filter requires W→lv.
  - **t channel:** sample 5502, TID 6960.
    - σ*f = 81.5 pb, filter requires W→lv.
  - 1 mm bug.

Samples

- **W+Njets events**
  - Alpgen and Herwig.
  - Samples 8240-8250, TID 14769-14784.
  - No 1 mm bug.
  - TruthJetFilter requires 3 jets with p_T>30 GeV, |eta|<5.
- **QCD multijet events**
  - Alpgen and Herwig.
  - Samples 5061, 5062, 5063, 5064.
  - σ*f=21188 pb, σ*f=53283 pb, σ*f=9904 pb, σ*f=6436 pb.
  - Generated in 11.0.42, reconstructed in 12.0.6.
  - Filter requires 4 jets with $|\eta|<6$.
    - Lead jet must have $p_T(j_1)$>80 GeV.
    - 3 subsequent jets must have p_T>40 GeV.

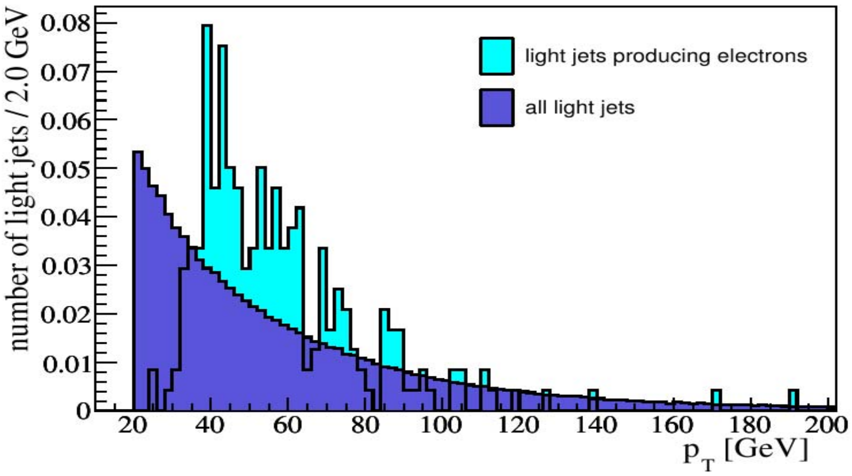
Selection Cuts

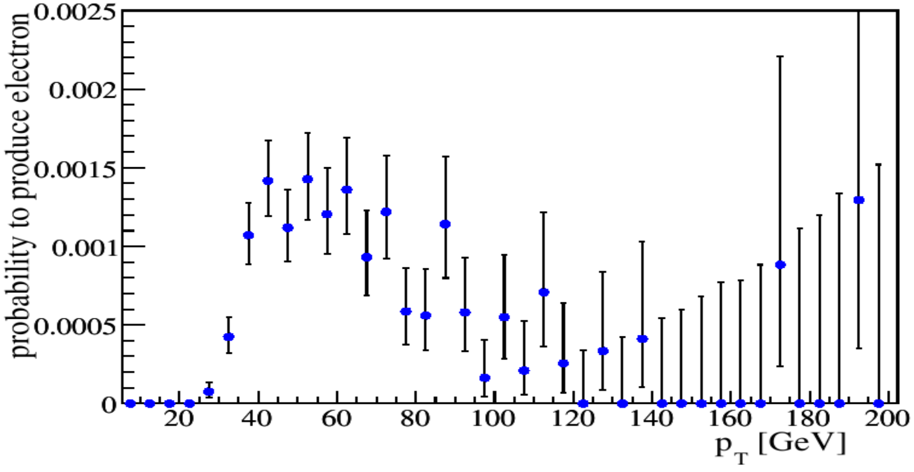
- **Inclusive k_T algorithm, E scheme, D=0.4.**
- **Hard Jet Cuts**
  - No cuts are applied to lepton quantities.
  - Require at least four jets:
    - $|\eta| < 5.0$.
    - Lead jet must have $p_T(j_1)>80$ GeV.
    - Three subsequent jets must have $p_T(j)>40$ GeV.
- **Commissioning Analysis Cuts**
  - Exactly one isolated, high-p_T electron or muon.
    - $E_{\Delta R=0.20} < 6$ GeV.
    - $p_T(l) > 20$ GeV, $|\eta| < 2.5$.
    - Muons are reconstructed by Staco.
    - Electron candidates must:
      - Be reconstructed by eGamma.
      - Fulfill (isEM==0).
      - Exclude crack region $1.37<|\eta|<1.52$.
  - At least four jets.
    - $|\eta| < 2.5$
    - First three jets have $p_T(j) > 40$ GeV.
    - Fourth jet has $p_T(j_4) > 20$ GeV.
    - Jets are removed if $\Delta R(j,e)<0.4$.
  - Missing Transverse Energy: MET > 20 GeV.

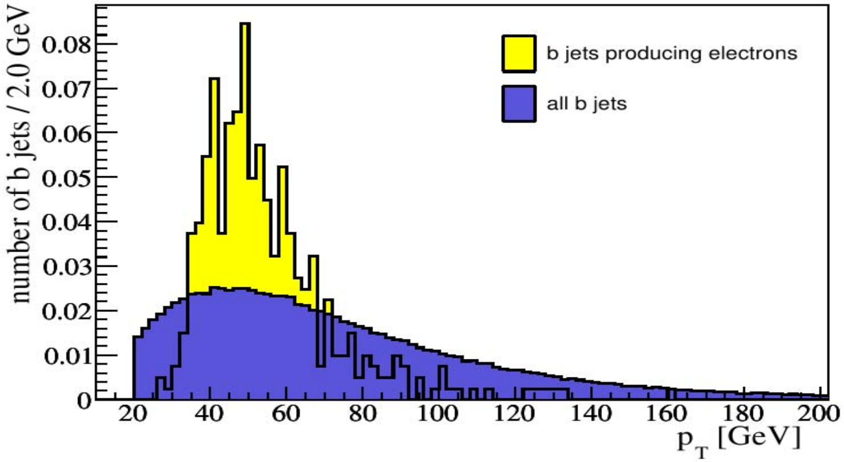


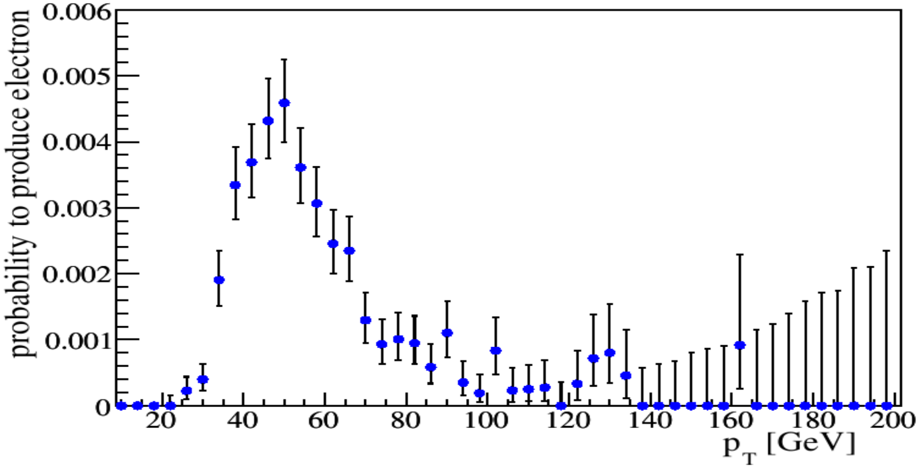
Lepton Fake Rate $R(p_T)$

A. Doxiadis, M. Kayl, Nikhef, ATL-COM-PHYS-2008-04





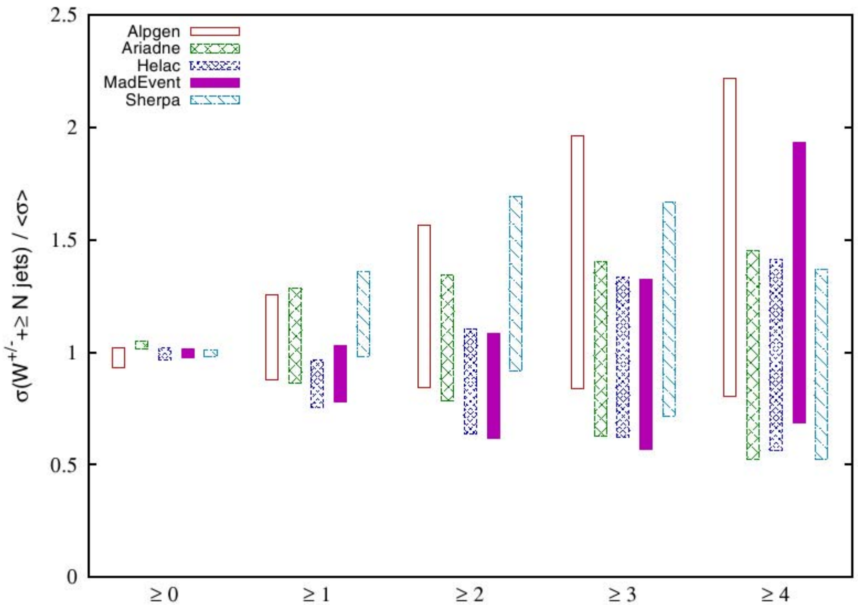




Uncertainty on $\sigma_{W+Njets}$

- "Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions"
- CERN-PH-TH/2007-066

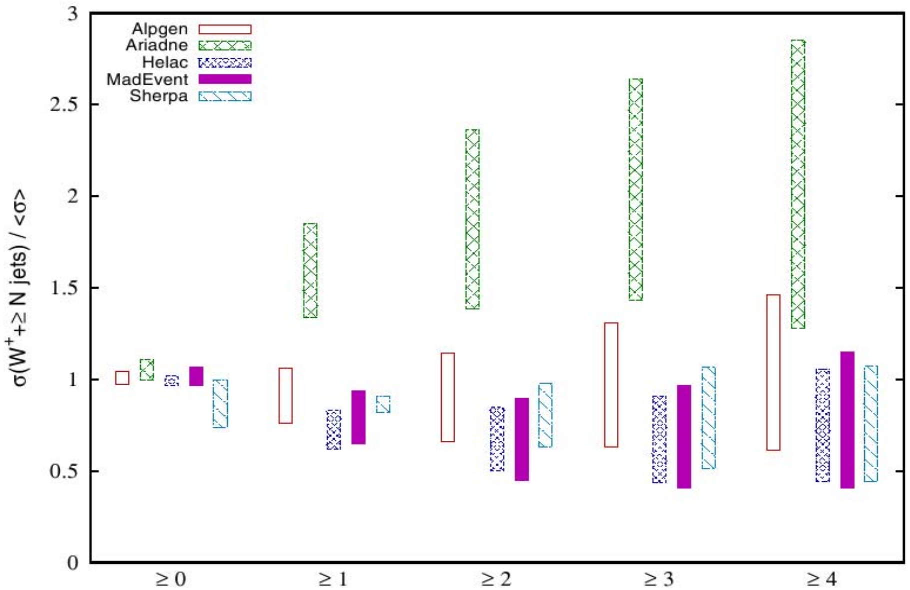
Systematic Variation at Tevatron



Proton-antiproton collisions, 1.96 TeV, $W^{\pm}$,

Cone7 jets, $E_T(j)>10$ GeV, $|\eta|<2$

Systematic Variation at LHC



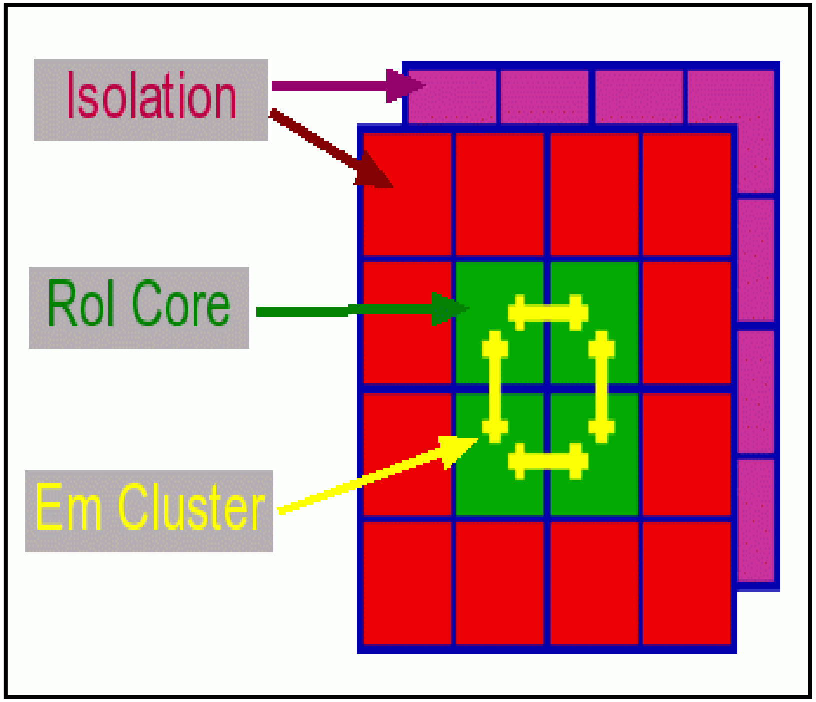
Proton-proton collisions, 14 TeV, only W^{+},

Cone4 jets, $E_T(j)>20$ GeV, $|\eta|<4.5$

Trigger

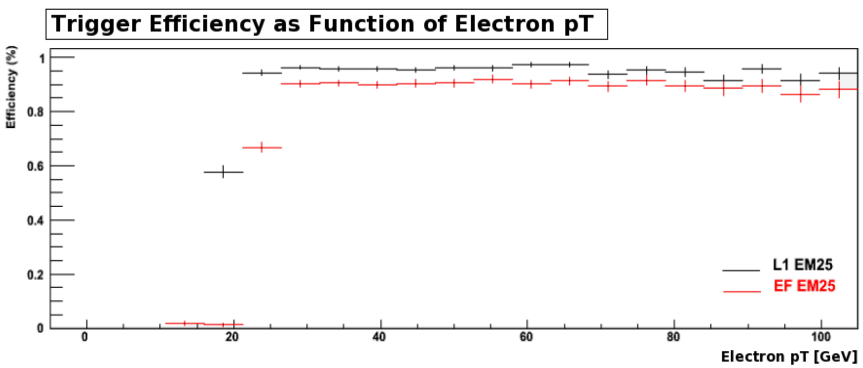
- **L1 trigger**
  - 4x4 matrix of calorimeter towers.
  - 2x2 central core is “Region of Interest”
  - 12 surrounding towers measure isolation

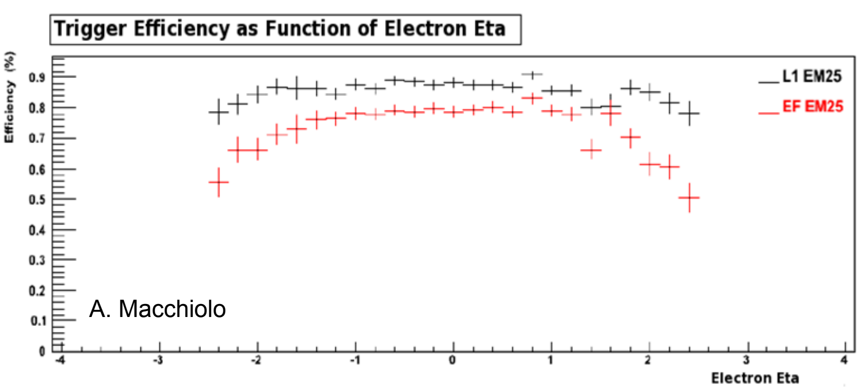
- **Electron trigger**
  - **L1_em25i** requires
    - E_T>18 GeV in ROI in EM calorimeter
    - E_T<2 GeV in ROI in hadron calorimeter
    - Isolation:
      - E_T<3 GeV in EM calorimeter
      - E_T<2 GeV in hadron calorimeter
  - **Event Filter** requires E_T>18 GeV
  - $\varepsilon_{trigger}$ = 99% for electrons with p_T>25 GeV.
- **Muon trigger**
  - **L1_mu20** requires E_T>17.5 GeV.

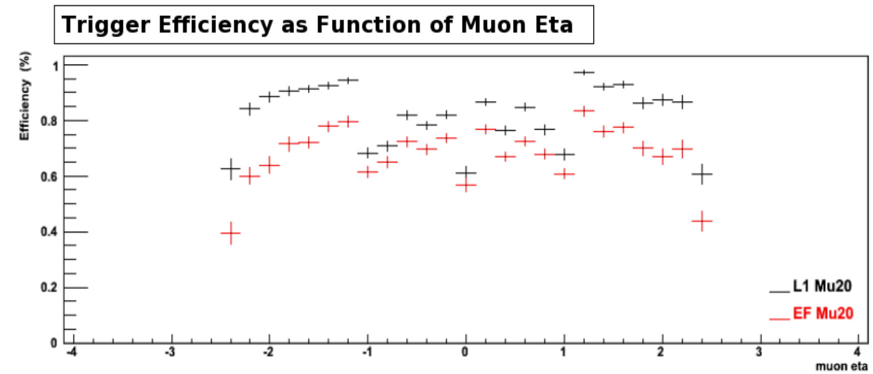


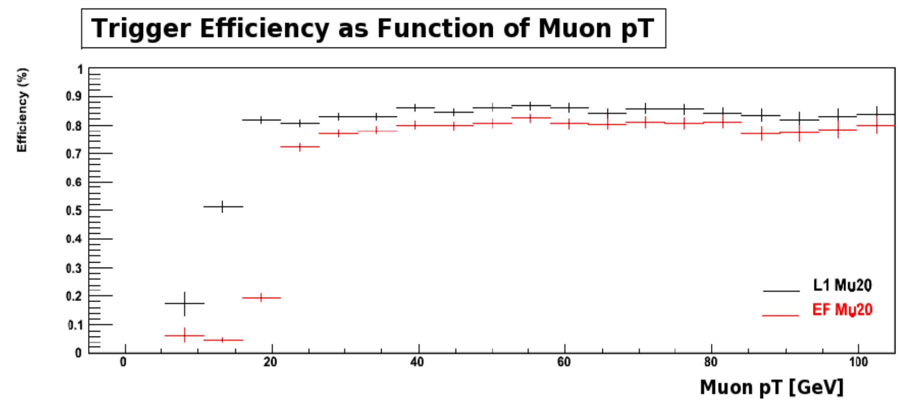
Trigger

- e25i and mu20
- Plots contain
  - ttbar events (sample 5200)
  - Analysis cuts (see backup slides)
  - $p_T(l)>10$ GeV
- L1 Trigger, Event Filter (EF)









- Efficiency for e25i to observe an electron in tt→eνbjjb is **84%.**
- Efficiency for mu20 to observe a muon in tt→μνbjjb is **78%.**

Top Samples

Process		sample	Cross section [pb]	Theoretical uncertainty on σ [pb]	ε_{filter}	σ*f [pb]	L [pb^{-1}]	Weight (100 pb^{-1})	Initial events	Final events	Efficiency [%]	stat. uncertainty	Wtd final events
ttbar	$tt \rightarrow (e\nu b)(jjb)$	5200	833	100	0.54	461	770.7	0.130	94304	17932	19.02	0.13	2327
	$tt \rightarrow (\mu\nu b)(jjb)$								94489	27975	29.61	0.15	3630
	$tt \rightarrow (\tau\nu b)(jjb)$								95292	4049	4.25	0.07	525
	$tt \rightarrow (l\nu b)(l\nu b)$								70324	6072	8.63	0.11	788
	$tt \rightarrow (jjb)(jjb)$	5204	833	100	0.46	369	190.6	0.525	65742	237	0.36	0.02	3186
Single top	Wt production	5500				25.5	421.6	0.237	10750	744	6.92	0.24	176
	s channel	5501				2.3	5652	0.018	13000	159	1.22	0.10	3
	t channel	4402				81.5	152	0.657	12400	437	3.52	0.17	287

W+N Jets

Process		Cross section [pb]	Relative uncertainty on σ	MLM match rate	ε_{filter}	σ*f [pb]	L [pb^{-1}]	Weight (100 pb^{-1})	Initial events	Final events	Efficiency [%]	stat. uncertainty	Wtd final events
W→eν	2 partons	2032	0.20	0.402	0.262	214	593.0	0.1686	126916	102	0.08037	0.00008	17
	3 partons	771	0.30	0.301	0.534	124	556.8	0.1796	69006	479	0.694	0.032	86
	4 partons	273	0.40	0.252	0.78	53.7	232.3	0.4306	12463	680	5.456	0.203	293
	5 partons	91	0.50	0.264	0.929	22.3	165.8	0.6032	3700	423	11.432	0.523	255
W→μν	2 partons	2032	0.20	0.402	0.020	16.3	260.1	0.3844	4250	82	1.929	0.211	32
	3 partons	771	0.30	0.304	0.276	64.7	185.5	0.5391	12000	304	0.253	0.143	164
	4 partons	273	0.40	0.229	0.576	36.0	446.4	0.2240	16073	1859	11.566	0.252	416
	5 partons	91	0.50	0.264	0.84	20.2	173.4	0.5766	3500	837	23.914	0.721	483
W→τν	2 partons	2032	0.20	0.415	0.104	87.7	233.2	0.4289	20450	9	0.044	0.015	4
	3 partons	771	0.30	0.303	0.373	87.1	149.2	0.6703	13000	32	0.246	0.043	21
	4 partons	273	0.40	0.245	0.686	45.9	119.9	0.8342	5500	79	1.436	0.160	66
	5 partons	91	0.50	0.264	0.866	20.8	525.4	0.1903	10930	328	3.001	0.163	62

Selection Efficiencies

Process		Efficiency $p_T(j) > 42$ GeV $p_T(j_4) > 21$ GeV	Efficiency $p_T(j) > 40$ GeV $p_T(j_4) > 20$ GeV	Efficiency $p_T(j) > 38$ GeV $p_T(j_4) > 19$ GeV	Uncertainty due to Δp_T	Relative uncertainty due to Δp_T
ttbar	tt→(eνb)(jjb)	0.175	0.190	0.206	0.015	0.081
	tt→(μνb)(jjb)	0.272	0.296	0.321	0.025	0.084
	tt→(τνb)(jjb)	0.0388	0.0425	0.0461	0.0036	0.085
	tt→(lνb)(lνb)	0.0772	0.0863	0.0950	0.009	0.103
	tt→(jjb)(jjb)	0.0034	0.0036	0.0038	0.0002	0.061
Single top	Wt production	0.0603	0.0692	0.0799	0.01	0.14
	s channel	0.0101	0.0122	0.0142	0.002	0.17
	t channel	0.0321	0.0352	0.0396	0.004	0.11
W→eν	2 partons	0.00059	0.00080	0.00105	0.0002	0.28
	3 partons	0.000549	0.00694	0.00903	0.002	0.25
	4 partons	0.0468	0.0546	0.0627	0.008	0.14
	5 partons	0.104	0.114	0.125	0.01	0.09
W→μν	2 partons	0.0136	0.0193	0.0264	0.007	0.33
	3 partons	0.0208	0.0253	0.0323	0.007	0.23
	4 partons	0.0996	0.1157	0.1318	0.016	0.14
	5 partons	0.219	0.239	0.258	0.019	0.08
W→τν	2 partons	0.00034	0.00044	0.00049	0.0001	0.17
	3 partons	0.0022	0.0025	0.0033	0.0008	0.22
	4 partons	0.0124	0.0143	0.0173	0.003	0.17
	5 partons	0.0275	0.0300	0.0325	0.002	0.08