$t\bar{t}$ cross section measurement in ATLAS

. . . and my interest in W + jets

Martijn Gosselink

MCnet meeting

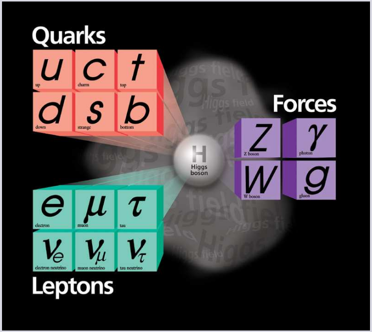
15^{th} of January 2009

Overview

- Introduction
- Cross section measurement
- Jet multiplicity
- Towards data
- Summary

The top quark

Standard Model



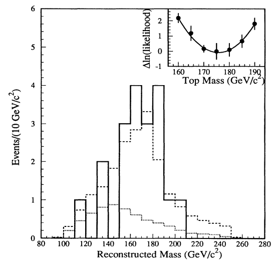
2008 results

$\sigma_{nlo}(p\bar{p} \rightarrow t\bar{t})$	7.6-7.9 pb
CDF	7.8 ± 0.9 pb
DØ	7.0 ± 0.6 pb

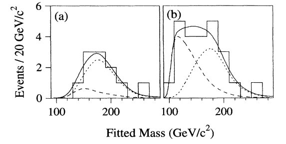
$M_{top} = 172.4 \pm 1.2$ GeV/c^2

Discovery in 1995 at Tevatron:

CDF



DØ



Why study $t\bar{t}$ events?

Many reasons

$t\bar{t}$ as signal:

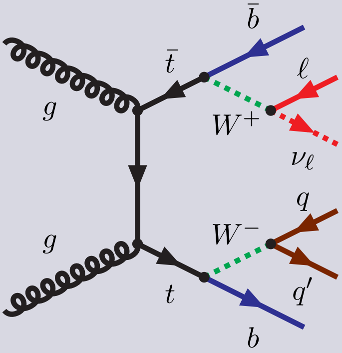
- cross section
- properties: mass, width, spin, charge, W helicity
- couplings:
  - $\mathcal{B}r(t \to Wb)$ (V_{tb})
  - $\mathcal{B}r(t \to Hq)$
  - $\mathcal{B}r(t \to Zq)$ (FCNC)

$t\bar{t}$ as background:

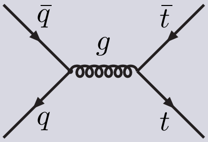
- single top, WH
- $t\bar{t}H$ *(1,000× smaller!)* ← my PhD funding
- SUSY ($\tilde{t}\bar{\tilde{t}}$)
- Heavy resonances ($Z' \to t\bar{t}$)
- ...

$t\bar{t}$ production at the LHC

$gg \to t\bar{t} \sim 90\%$



$q\bar{q} \to t\bar{t} \sim 10\%$

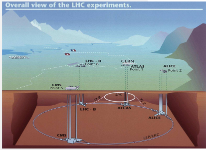


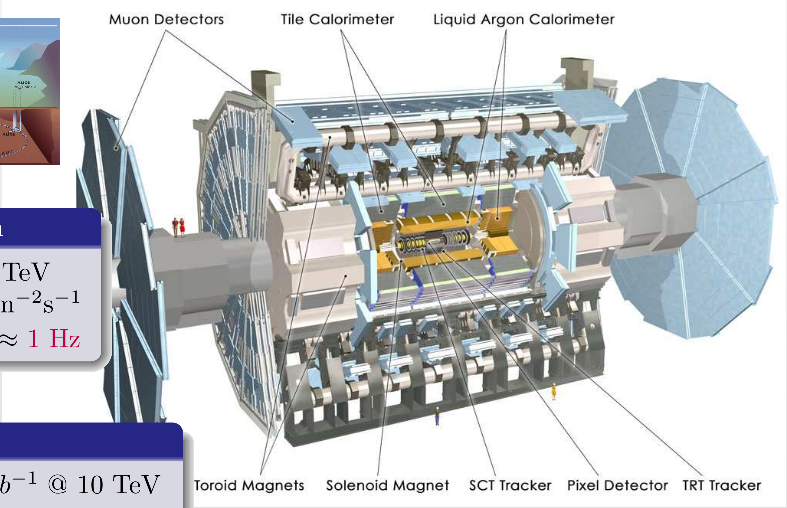
$$\mathcal{B}r(t \to Wb) \approx 1$$
$$\mathcal{B}r(W \to qq') \approx 2/3$$
$$\mathcal{B}r(W \to \ell\nu_\ell) \approx 1/3$$

$$\sigma_{nlo}(14\ \text{TeV}) = 908\ \text{pb}$$
$$\sigma_{nlo}(10\ \text{TeV}) = 425\ \text{pb}$$

Where to study $t\bar{t}$ events?

The ATLAS detector





LHC: design

pp @ $\sqrt{s}$=14 TeV
$\mathcal{L}_{pp} \sim 10^{33}$ cm^{-2}s^{-1}
$\dot{N}_{t\bar{t}} = \mathcal{L} \cdot \sigma_{t\bar{t}} \approx 1$ Hz

LHC: 2009

$\int \mathcal{L} dt \approx 100 pb^{-1}$ @ 10 TeV
$N_{t\bar{t}} \approx 40,000$

How to analyse $t\bar{t}$ events?

The Atlas computing model

Data locations

Tier-0	1 x	:	CERN
Tier-1	10 x	:	NL,UK,ES,DE,IT,FR,TW,CA,BNL,NDGFT1
Tier-2/3	∞ x	:	within a cloud, eg. NL

Main principle  *Jobs to data*

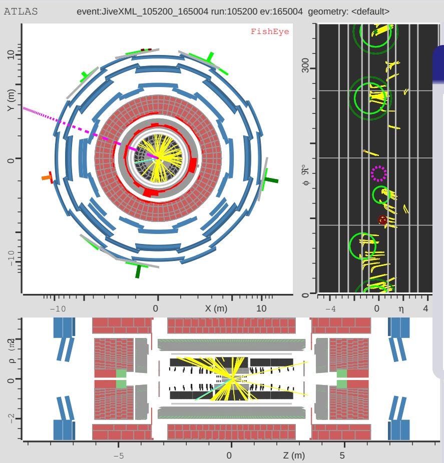
Where to run?

- LCG grid
- Nikhef cluster: STOOMBOOT (SARA)
- Local desktop

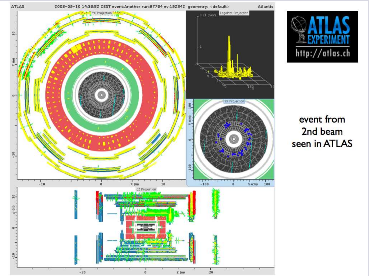
A typical $t\bar{t}$ event

Atlantis event display

Simulation...



...real beam!



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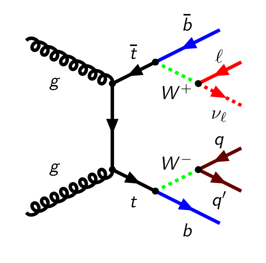
Commissioning analysis (100 pb^{-1})

Monte Carlo exercise

Event selection

- pass trigger: e / μ
- 1 isolated lepton: e / μ
- $\not{E}_T > 20$ GeV
- 3x jet $p_T > 40$ GeV/c
  1x jet $p_T > 20$ GeV/c

NB: no b-tagging used



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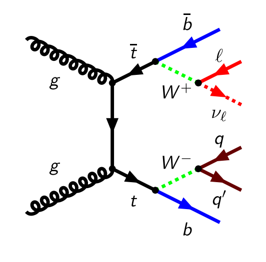
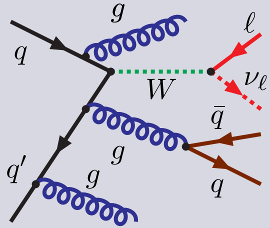
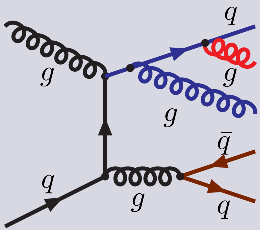


W+jets



QCD multi-jet



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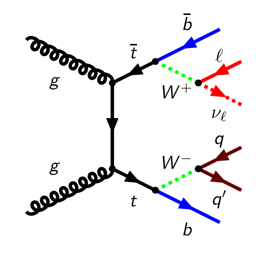

NB: no b-tagging used

Reconstructing hadronic top

- take 3-jet combination with highest p_T
- require 2-jet combination $\Delta(M_{jj} - M_W) < 10$ GeV/c^2
- $\sigma(t\bar{t}) = \dfrac{N_{gauss}(sig)}{\mathcal{L} \cdot \epsilon_{peak}}$

Commissioning analysis (100 pb^{-1})

Monte Carlo exercise

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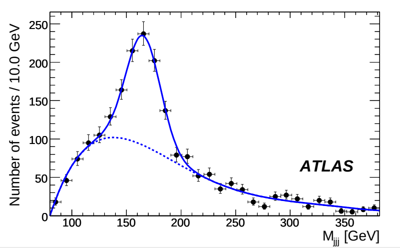

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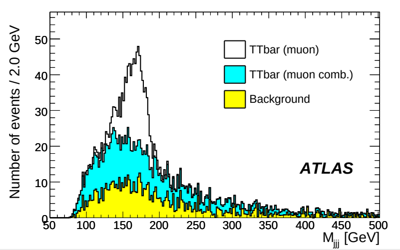
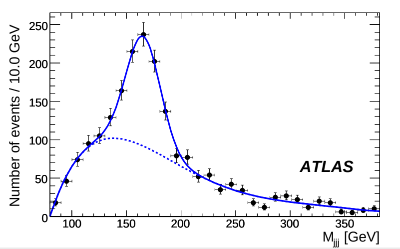
Results (for 100 pb^{-1})

Reconstructing hadronic top mass





	electron	muon
$t\bar{t}$	1,262	1,606
background	374	495
N_{peak}	327	508

background: W+jets, Z+jets, single top, $Wb\bar{b}$+jets, WW, WZ, ZZ

Systematic uncertainties

Results for 100 pb^{-1}

Source	Likelihood fit Electron (%)	Likelihood fit Muon (%)
Statistical	10.5	8.0
Lepton ID efficiency	1.0	1.0
Lepton trigger efficiency	1.0	1.0
50% more W+jets	1.0	0.6
20% more W+jets	0.3	0.3
Jet Energy Scale (5%)	2.3	0.9
PDFs	2.5	2.2
ISR/FSR	8.9	8.9
Shape of fit function	14.0	10.4

Likelihood method: $\Delta\sigma/\sigma = (7(\text{stat}) \pm 15(\text{syst}) \pm 3(\text{pdf}) \pm 5(\text{lumi}))\%$

Counting method: $\Delta\sigma/\sigma = (3(\text{stat}) \pm 16(\text{syst}) \pm 3(\text{pdf}) \pm 5(\text{lumi}))\%$

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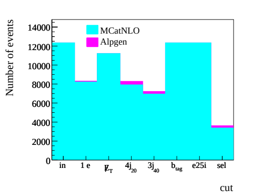
Why is jet multiplicity important?

Effects on cross section measurement

$$\epsilon_{peak} = \epsilon_{sel} \cdot \epsilon_{reco}$$

- selection efficiency



- reconstruction efficiency

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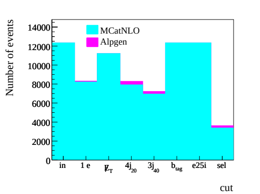

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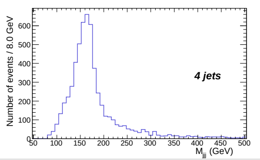
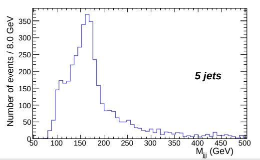
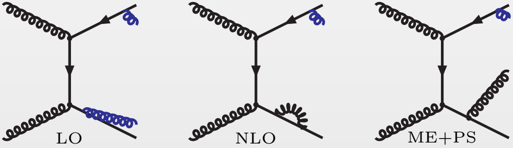




Estimating jet multiplicity

Uncertainties Monte Carlo

- Accuracy technique



- Parton shower
- ISR/FSR parameters

Estimating jet multiplicity

Uncertainties Monte Carlo

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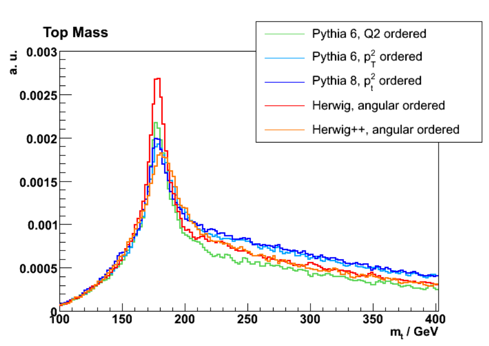

from CTEQ/MCnet summerschool talk: Alex Flossdorf

Estimating jet multiplicity

Uncertainties Monte Carlo

- Accuracy technique
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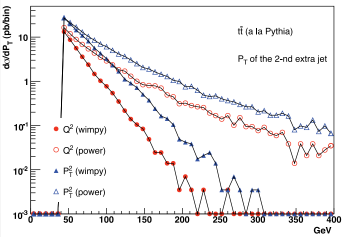
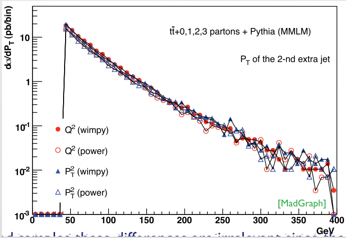
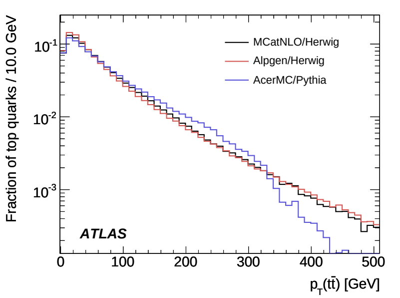


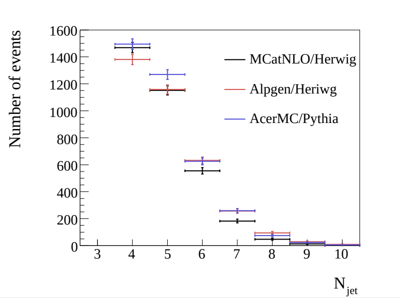
from Fabio Maltoni



Estimating Monte Carlo uncertainty

Comparison





$t\bar{t}(\mu)$	ϵ_{sel}		ϵ_{reco}		ϵ_{comb}	
MC@NLO	27.72	± 0.40	19.30	± 0.67	5.35	± 0.20
AlpGen	28.87	± 0.41	19.39	± 0.66	5.60	± 0.21
AcerMC	30.40	± 0.41	17.49	± 0.62	5.32	± 0.20

Estimating Monte Carlo uncertainty

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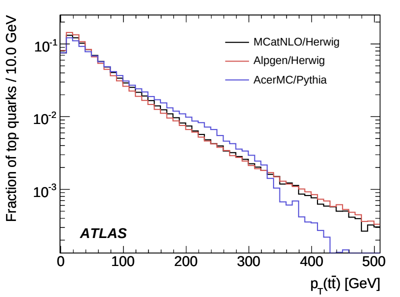

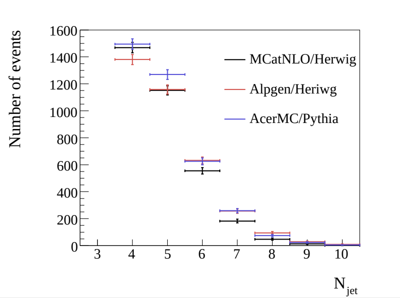

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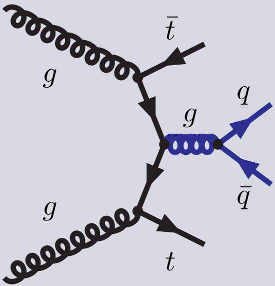
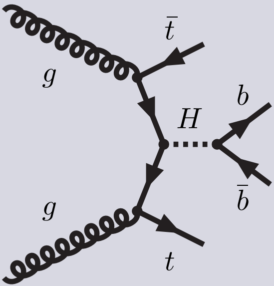
Implications for $t\bar{t}H$

Looking a bit further

$\sigma(pp \to t\bar{t}) \approx 900$ pb



$\sigma(pp \to t\bar{t}H_{120}) \approx 700$ fb



sample	**commissioning**	**b-tagging**
$t\bar{t}(\mu)$	3,677	950
$t\bar{t}H$	**4**	**2**

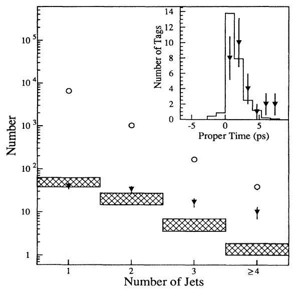
First data

Plans for 2009

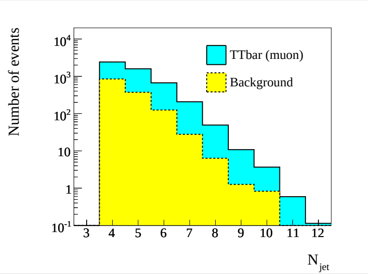
Measure jet rates in events with:

- isolated μ
- $\not{E}_T$
- (many) jets

CDF 1995



ATLAS ...?

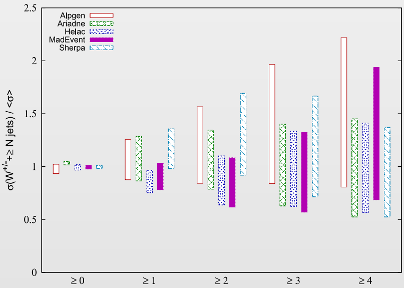


Predicting $W + jets$

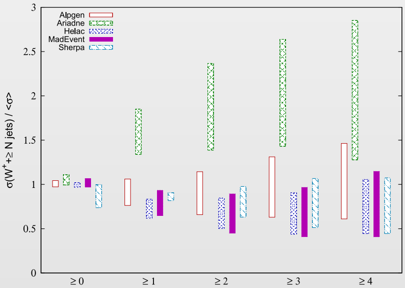
Preparing for first data

$$\frac{\sigma\,(W + \text{n-jets})}{\langle\sigma\rangle}$$

Tevatron



LHC



hep-ph/0706.2569

MCnet studentship

Plans for 4 months

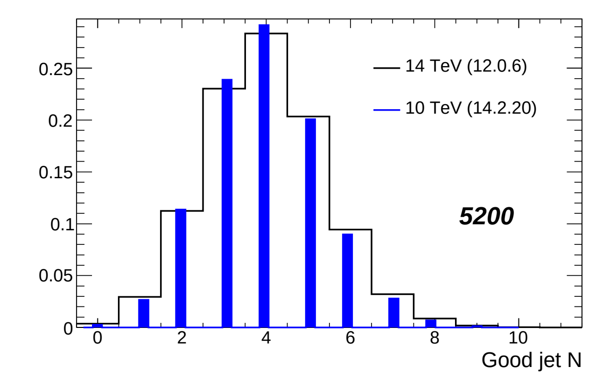
1. Get more familiar with Ariadne/CKKW-L
2. Ariadne in ATLAS framework
3. Ariadne CKKW-L in ATLAS framework
4. Study $W+$ jets in $t\bar{t}$ analysis
5. Other processes (?)
6. ...

Summary

- The Atlas experiment
- Top cross section measurement
- The effect of jet multiplicity
- Importance of good Monte Carlo prediction
- Future plans

10 vs 14 TeV

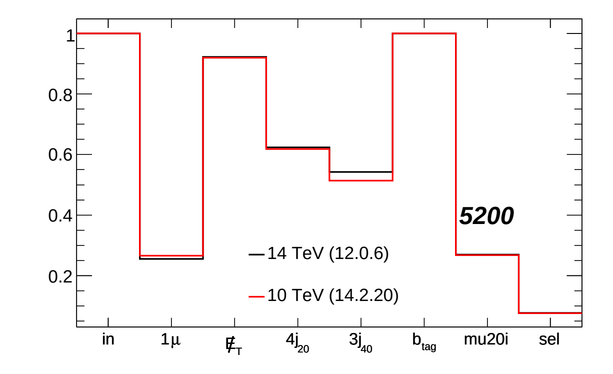
Jet multiplicity in $t\bar{t}$ events



10 vs 14 TeV

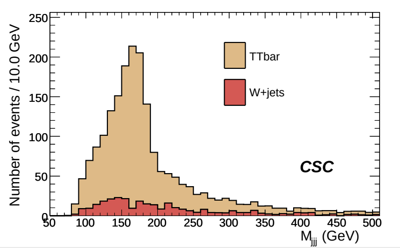
Selection Efficiencies

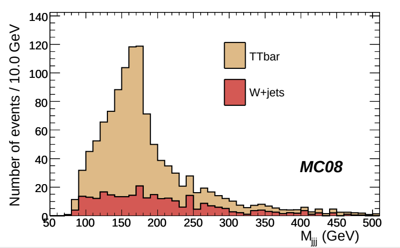
muon channel



10 vs 14 TeV

M_{jjj} with M_W constraint (muon channel)





	CSC	MC08
$t\bar{t}$	1,725	890
W+jets	318	297

Results from CSC

Counting method and likelihood fit

Source	Likelihood fit Electron (%)	Likelihood fit Muon (%)	Counting method Electron (%)
Statistical	10.5	8.0	3.5
Lepton ID efficiency	1.0	1.0	1.0
Lepton trigger efficiency	1.0	1.0	1.0
50% more W+jets	1.0	0.6	9.5
20% more W+jets	0.3	0.3	3.8
Jet Energy Scale (5%)	2.3	0.9	9.7
PDFs	2.5	2.2	2.5
ISR/FSR	8.9	8.9	8.9
Shape of fit function	14.0	10.4	-