Study of W background to top pair production cross-section in ATLAS at the LHC

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Outline

- Introduction:
  - Motivations for top quark studies at LHC
  - Cross section of top quark pair production
- How we can select top quark pair events:
  - Background contamination
- Data-driven estimation of W+jets background:
  - Description of the method
  - Main sources of uncertainty
  - Results on background estimation
- Conclusion

Why is top quark so interesting?

- **Properties:**
  - Large mass: interact heavily with the Higgs sector
    => higgs boson can be produced in association with a top quark pair
  - Short lifetime: top quark decays before hadronisation
    => study the properties of a « bare » quark (top quark mass)
- **Shopping list:**
  - Explore properties: consistency test of the Standard Model
    - **cross section**
    - mass
    - charge
    - decay modes
    - top&W polarisations
  - Search for new physics: top is a BKG for New Physics searches, need to be understood
- **In addition at LHC:** top quark is a tool for detector commissioning

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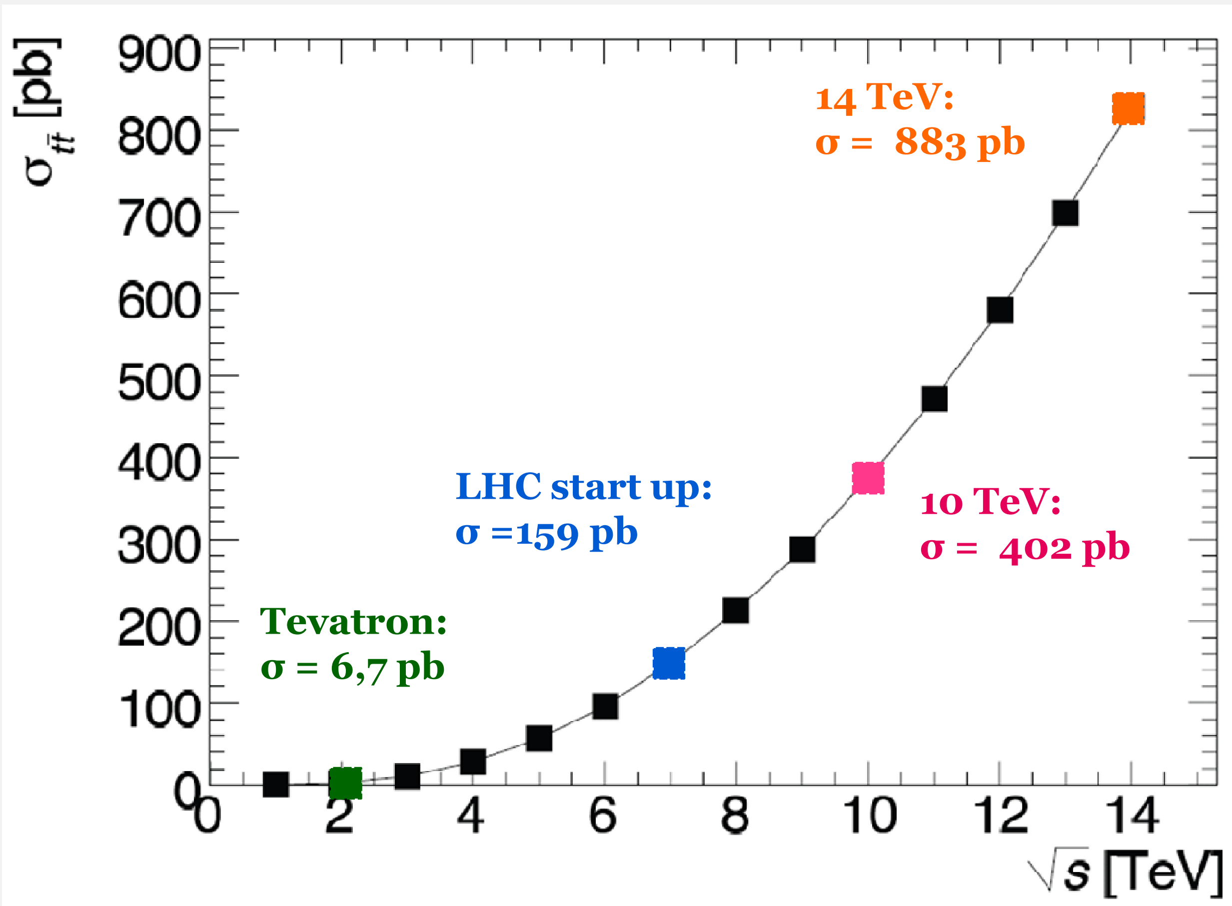
In this talk I'll focus on top quark pair production cross section measurement

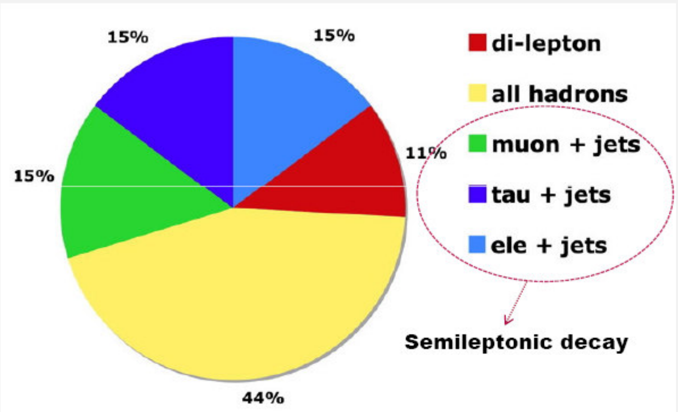
Top quark pair production: from rare to common

Top quark pair production cross-section

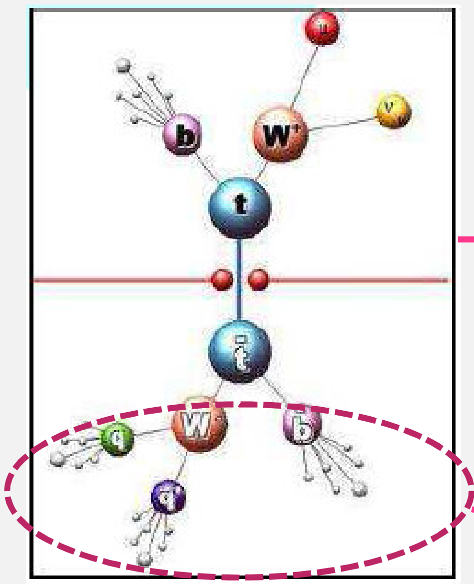


In the following slides I will present some results for 200 pb^{-1} at 10 TeV.

Top quark pair decay modes



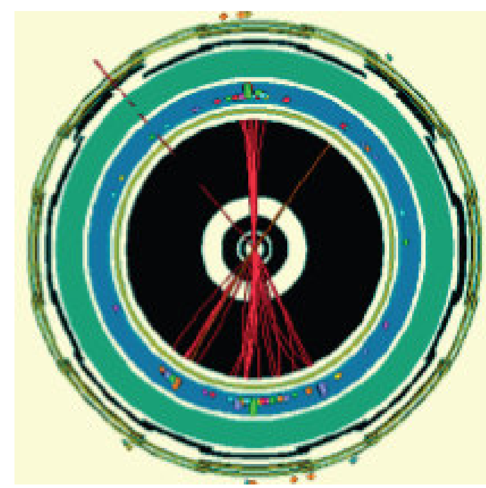
Semileptonic decay is the most studied because of :
- ○ good BR
- ○ possibility of top quark mass reconstruction
- ○ clear signature



Top quark pair semileptonic decays are characterized by the presence of:
- ❑ one energetic lepton
- ❑ at least 4 energetic jets
- ❑ missing energy

Invariant mass of these 3 jets = top quark mass

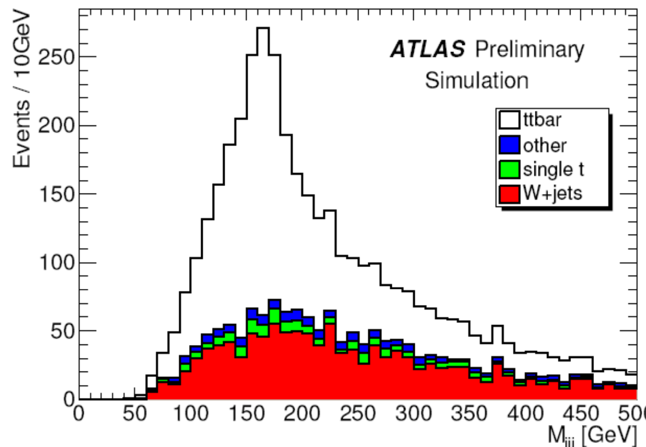
Detector view of top quark pair semileptonic decay



W+jets background

Invariant mass of the 3 jets coming from hadronic top quark decay

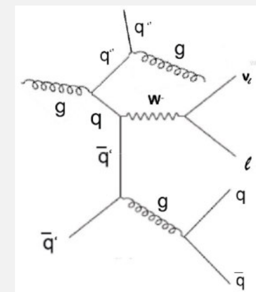
200 pb^{-1}, 10 TeV, electron channel



! Moving from 10 TeV to 7 TeV: $\sigma_{t\bar{t}}$ decreases by a factor **~2.5**, σ_{W+jets} of a factor **~1.5**.

Sample	Events (200 pb^{-1})	
	Electron ch.	Muon ch.
$t\bar{t}$	2600	3144
W+jets	1305	1766
Other backg.	409	433

Main background: W+jets

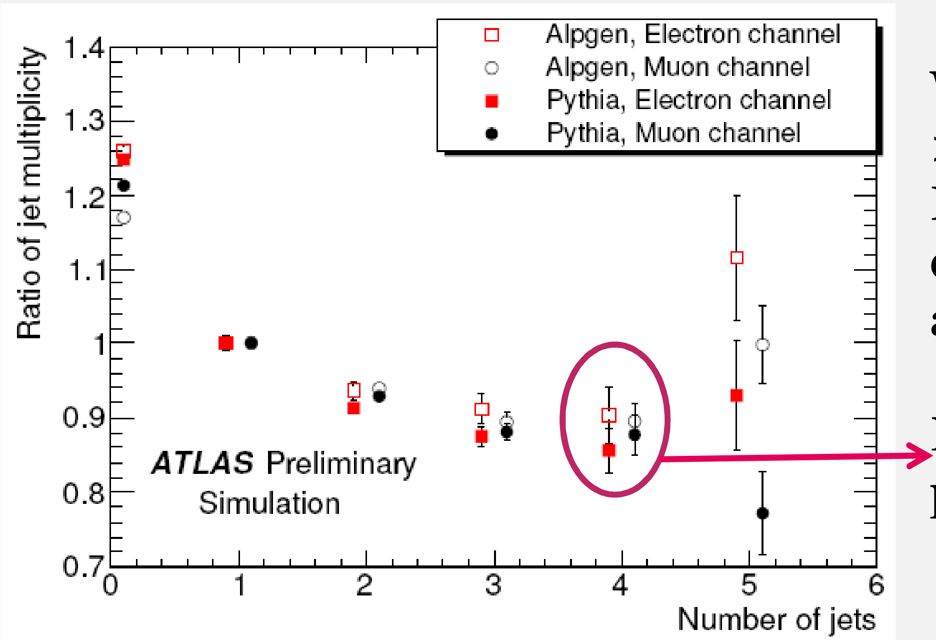


- W+jets can have the same experimental signature ($\sigma_{W+4jets}$ is non negligible)
- W+jets cross section has a big uncertainty : ~100% for W+4jets
  - No exact calculation for this process
  - Monte Carlo prediction are based on parameters estimated for energy one order of magnitude lower than LHC one.
  - It' s difficult to measure it directly from data because of big top quark contamination.

Uncertainty on σ_{W+jets}	Error on $\sigma_{top\ quark\ pair}$
20%	10%
50%	25%

Method for W+jets background estimation I

- W/Z ratio is predicted with much smaller uncertainty [1-2]



W /Z ratio as a function of Njet (jet p_T > 20GeV) normalized at σ_{W+1jet} / σ_{Z+1jet}. Results are shown for muon and electron channel, using both Alpgen and Pythia samples.

Difference between Alpgen and Pythia predictions is **~10%** (<< 100%!)

- Z can be selected with higher purity than W even at high jet multiplicity

[1] Phys. Lett B224 (1989) 237.
[2] Phys. Rev. D68 (2003) 033014

Method for W+jets background estimation II

Thus we predict W+jets as:

$$W^{SR} = C_{MC} * Z^{SR} * (W^{CR}/Z^{CR})$$ → **measured from data**

Estimated from MC: $C_{MC} = (W^{SR}/W^{CR})_{MC} * (Z^{CR}/Z^{SR})_{MC}$

- C_{MC} = coef < 1 because of mass difference for W and Z
- SR = signal region: tt_{bar} commissioning analysis cuts (4 jets p_T>20 GeV, 3 of them p_T>40 GeV)
- CR = control region (exactly one jet of p_T > 20 GeV)

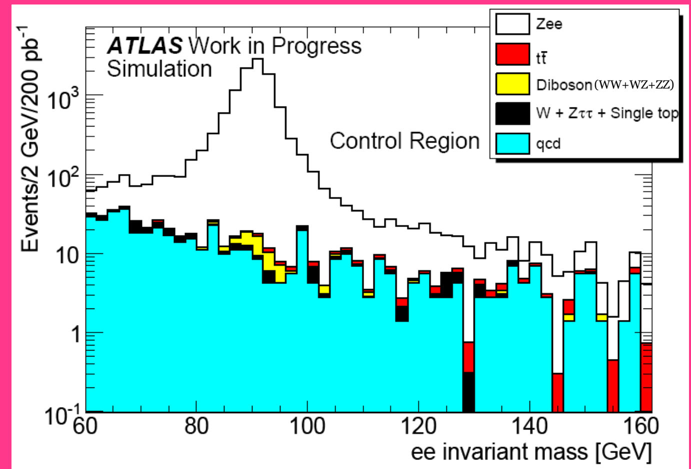
Main sources of uncertainty:

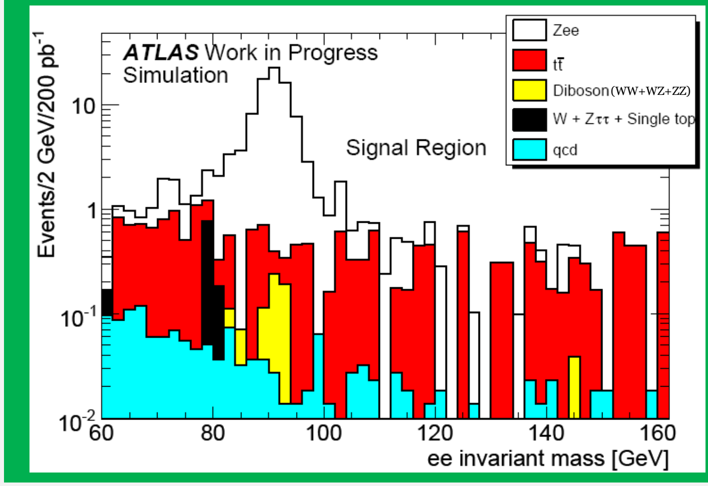
- uncertainty on Monte Carlo predictions on C_{MC}
- statistical limitation at 200 pb^{-1}
- uncertainty on purity of control samples

$Z \rightarrow ee$ control sample: control and signal like region

Process	Control region (200 pb^{-1})	Signal region (200 pb^{-1})
Z (ee)	10210	82
Z (μμ)	0.0	0.0
Z(ττ)	0.1	0.1
W	6.0	0.0
$t\bar{t}$	8.4	2.8
Single top	2.9	0.0
Wbb	0.0	0.0
WW+WZ+ZZ	24.9	0.5
QCD	110	0.4

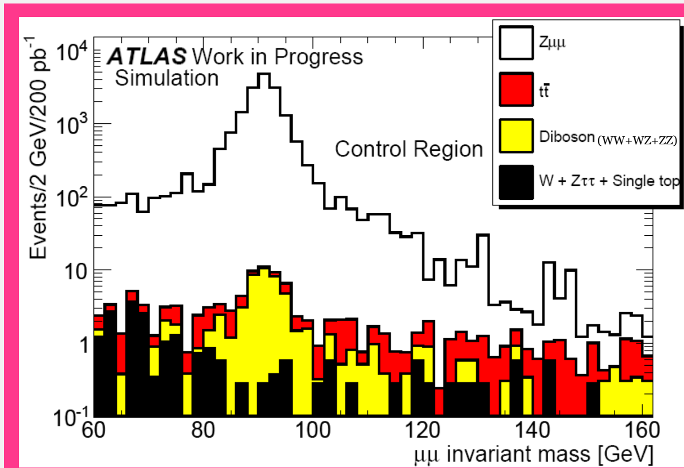
- **Statistical uncertainty** is negligible for CR (~ 1%), but is important for SR **(~ 11%)**
- Z events can be selected with **high purity**:
  - ~1% in 1 jet region
  - <4% in signal like region

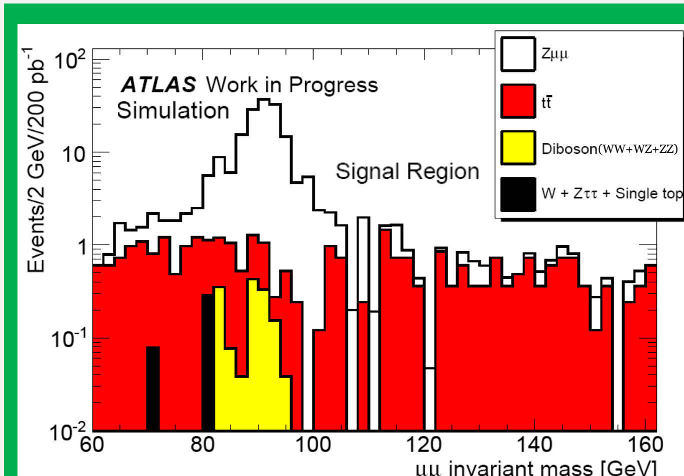




Z→μμ control sample: control and signal like region

Pocess	Control region (200 pb⁻¹)	Signal region (200 pb⁻¹)
Z (μμ)	15750	150
Z (ee)	0.0	0.0
Z(ττ)	0.9	0.0
W	0.0	0.0
$t\bar{t}$	10.5	5.0
Single top	2.3	0.0
Wbb	0.0	0.0
WW+WZ+ZZ	40.0	1.0
QCD	≤50.0	≤0.5





- **Statistical uncertainty** is negligible for CR (<1%), but is important for SR **(~ 8%)**
- Z events can be selected with **high purity**:
  - ~0.1% in 1 jet region
  - <4% in signal like region

W control region

Process	Electron Analysis (200 pb^{-1})	Muon Analysis (200 pb^{-1})
W(eν)	**148700**	0.0
W(μν)	43	**190300**
W(τν)	5570	6820
Z(ee)	1197	0.0
Z (μμ)	1.0	8066
Z(ττ)	879	1130
$t\bar{t}$	203	241
Single top	272	308
Wbb	97	119
WW+WZ+ZZ	427	557
QCD	42000	31000

- **Statistical error is negligible** both in electron and muon channel (< 1%)
- Not negligible QCD contamination both in electron and muon chan.

↓ 50% uncertainty on QCD

Error from background:

- **~17%** electron chan.
- **~11%** muon chan.

Uncertainty on C_{MC}

Values of C_{MC} obtained for Alpgen and Pythia samples. The error depends on available Monte Carlo statistic

	Electron Analysis	**Muon analysis**	**Combined**
Alpgen	1.00±0.04	0.92±0.04	0.96±0.03
Pythia	0.80±0.06	0.89±0.05	0.85±0.04

→ **Systematic uncertainty of 12%.**

This systematic could improve using first data: possibility of tuning Monte Carlo generators.

Conclusion

Final uncertainties:

Source of uncertainty	Electron Analysis	Muon analysis
Statistical for 200 pb-1	11.3 %	8.3%
Purity of control region W sample	17.0%	12.7%
Monte Carlo correction factor	12.1%	12.1%
Total uncertainty	**23.7%**	**19.3%**

W+jets background can be estimated from Z+jets with a total uncertainty of **~20%** → **~ 10%** uncertainty on top quark pair cross section.