LHCC Poster Session - CERN, 21 March 2012

Top Properties
Charge Asymmetry and Electric Charge

Introduction

The top quark is the heaviest elementary particle observed so far. As its mass is close to the electroweak scale, measurements of top quark properties, such as its electric charge and the charge asymmetry in the production of top quark pairs, might provide hints of new physics beyond the Standard Model. It is therefore interesting to measure them as precisely as possible.

Background Modeling

W+jets: shapes estimated from simulation, normalization extracted from data+MC using W charge asymmetry method.
The method is based on the imbalance between W^+ and W^- production rate in proton-proton collisions. Because this asymmetry is theoretically well understood, it can be exploited to measure the total W+jets yield for a given selection.

$$N_W = (N_{W^+} + N_{W^-}) = \frac{r_{MC}+1}{r_{MC}-1} \cdot (D^+ - D^-)$$

r_{MC} = W^+/W^- ratio from MC
$D^{+(-)}$ = # of selected positive(negative) lepton events in data

The number of W+jets events passing the selection with at least one *b*-tagged jets is estimated as

$$W_{tagged} = W_{pretag} \cdot f_{tagged}$$

where f_{tagged} is the selection efficiency of the *b*-tagging requirement, extracted from MC.

QCD background: estimates for shapes and normalization extracted from data using a matrix method. A background enriched sample is defined by applying a looser lepton selection. The QCD yield in the signal region is therefore estimated by solving the following system of equations:

$$N^{loose} = N^{loose}_{real} + N^{loose}_{fake}$$

$$N^{loose} = \varepsilon_{real} \cdot N^{loose}_{real} + \varepsilon_{fake} \cdot N^{loose}_{fake}$$

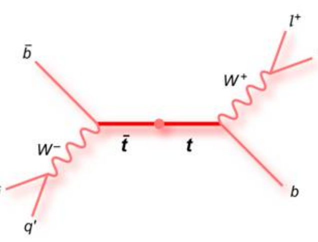
- N^{tight} = # of events with 1 lepton satisfying final selection
- N^{loose} = # of events with 1 lepton satisfying loose selection
- ε_{real} = efficiency of tight selection on real loose leptons
- ε_{real} = efficiency of tight selection on real loose leptons

other backgrounds: Z+jets, di-bosons and single-top estimated from MC

Event Selection

Both measurements have been performed in the **lepton+jets channel**, whose signature is selected with the following requirements:

- single lepton trigger
- one isolated lepton (electron, E_T>25 GeV, or muon, p_T>20 GeV), matching the corresponding high level trigger object.
- at least 4 jets with p_T>25 GeV
- at least 1 *b*-tagged jet with p_T>25 GeV



lepton+jets channel: one W decays to lepton+neutrino and the other one to a pair of quarks

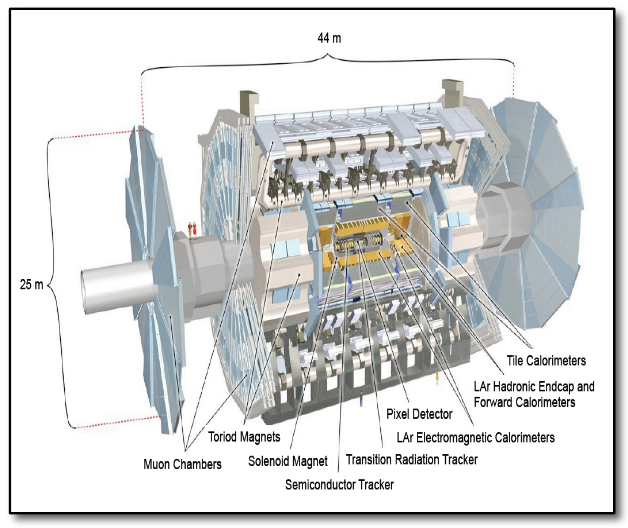
Kinematic Reconstruction

The top-antitop pair system is fully reconstructed using a kinematic likelihood method.

Likelihood input:
- 4-momenta of four jets
- 4-momentum of the lepton
- missing transverse momentum, E_T^{miss}

Constraints:
- top mass and width: m_t=172.5 GeV, Γ_t=1.5 GeV
- W mass and width: m_W=80.4 GeV, Γ_W=2.1 GeV

The Atlas Detector

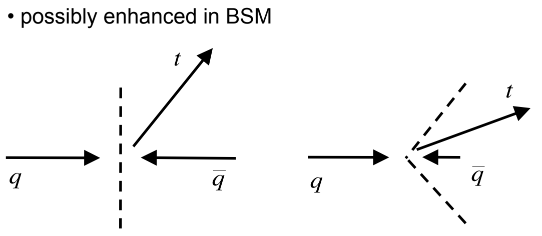


- Inner detector: tracking for charged particles, primary and secondary vertex reconstruction
- Calorimeter system: measurement of electron and jet energy, fundamental for E_T^{miss} reconstruction
- Muon chambers: muon identification and reconstruction

Top Quark Charge Asymmetry

Asymmetry @ LHC

The asymmetry is only present in $q\bar{q} \to t\bar{t}$ process, where the produced (anti)top quark is preferentially produced along the direction of the incoming (anti)quark.
- small in Standard Model: NLO contribution
- possibly enhanced in BSM

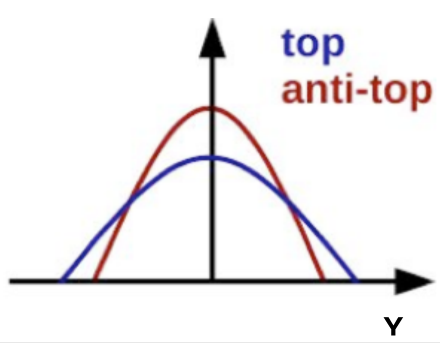


In p-p collisions, the direction of the incoming quark is not known. However, quarks are more likely to be valence quarks, while only sea anti-quarks are available. This causes a momentum imbalance, reflected in the rapidity distribution being broader for top quarks than for antitops.

Observable used to measure the asymmetry:

$$A_C = \frac{N(\Delta|Y|>0) - N(\Delta|Y|<0)}{N(\Delta|Y|>0) + N(\Delta|Y|<0)}$$

with $\Delta|Y| = |Y_{top}| - |Y_{antitop}|$



Event Yield

The measurement has been performed with the first portion of 2011 data, corresponding to an integrated luminosity of **1.04 fb⁻¹**.

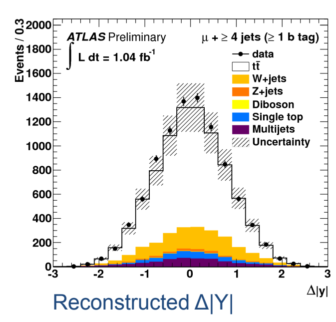
W+jets is the main background in both electron and muon channel.

Channel	μ + jets pretag	μ + jets tagged	e + jets pretag	e + jets tagged
$t\bar{t}$	7000 ± 600	6000 ± 500	5000 ± 400	4300 ± 350
Single top	458 ± 40	366 ± 32	320 ± 28	256 ± 22
W+jets	8600 ± 1200	1400 ± 310	5400 ± 700	870 ± 180
Z+jets	940 ± 330	134 ± 47	760 ± 270	105 ± 37
Diboson	134 ± 7	22 ± 2	80 ± 5	13 ± 1
multijets	1500 ± 800	500 ± 500	900 ± 500	250 ± 250
Total background	12000 ± 1400	2400 ± 600	8000 ± 900	1500 ± 320
Signal + background	19000 ± 1600	9000 ± 800	12000 ± 1000	6000 ± 500
Observed	19639	9124	12096	5829

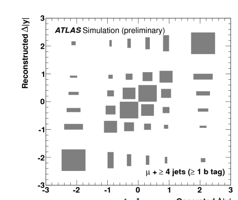
Unfolding Procedure

MC SIMULATION
1. Acceptance and reconstruction distort truth distribution T_j into reconstructed S_i via response matrix R_{ij}: $S_i = \sum_j R_{ij} T_j$
2. The response matrix is inverted by applying iteratively Bayes' theorem (T_j being the initial prior).

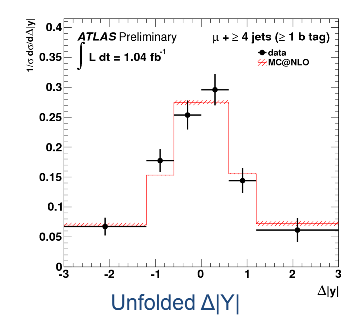
3. The observed Δ|Y| distribution is unfolded to truth level, after subtracting background.



Reconstructed Δ|Y|



response matrix



Unfolded Δ|Y|

Results

The asymmetry has been measured to be:

A_C= -0.047 ± 0.045(stat.) ± 0.028(syst.) (e+jets)
A_C= -0.002 ± 0.036(stat.) ± 0.023(syst.) (μ+jets)

and the combined result:

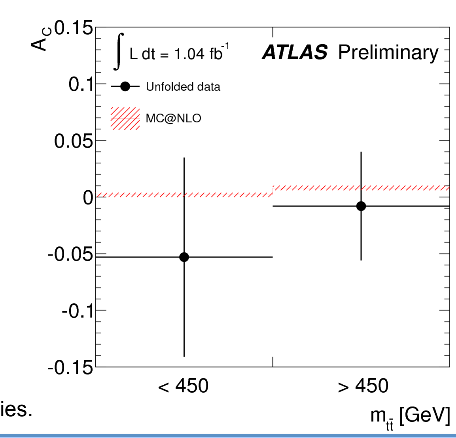
A_C= -0.018 ± 0.028(stat.) ± 0.023(syst.)

compatible with the MC@NLO prediction: A_C= 0.006±0.002

The measurement as a function of the top pair mass led to:

A_C= -0.053 ± 0.070(stat.) ± 0.054(syst.) (m_{tt}<450 GeV)
A_C= -0.008 ± 0.035(stat.) ± 0.032(syst.) (m_{tt}>450 GeV)

Signal modeling and Jet Energy Scale are dominant sources of uncertainties.



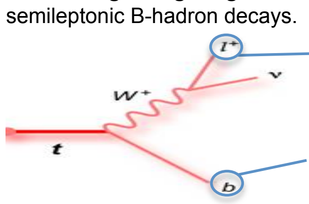
Top Quark Electric Charge

ATLAS-CONF-2011-141

Top Quark Charge Determination (0.70 fb⁻¹)

- Standard Model Top Quark:
  $t^{(+2/3)} \to b^{(-1/3)} + W^{(+1)}$, $W^+ \to \ell^+ + \nu_\ell$
- Exotic Quark:
  $t^{(-4/3)} \to b^{(-1/3)} + W^{(-1)}$, $W^- \to \ell^- + \bar{\nu}_\ell$

- Charge of W boson is determined via its leptonic decay.
- Charge of *b*-jet is estimated with two alternative methods: **track charge weighting** or from the sign of **soft muons** in semileptonic B-hadron decays.



Track Charge Weighting - Selection
- the presence of a second *b*-tagged jet is required.
- Each of the two b-jets has to contain at least two well reconstructed charged particles with p_T> 1 GeV

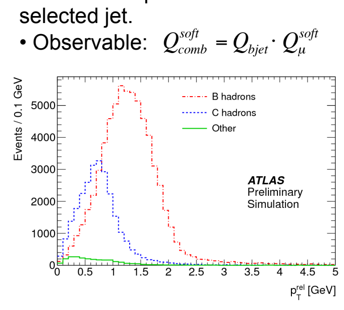
Soft Muon - Selection
- a muon with p_T>4 GeV has to be found inside a ΔR=0.4 within the jet axis.

Soft Muon Method

- Determine b-jet charge based on the reconstruction of soft muon charge:

$$BR(b \to \mu + \nu + X) \approx 11\%$$

- The pairing of the b-jet and lepton coming from the top decay is done based on a kinematic reconstruction. The event is accepted if a soft muon is present inside the selected jet.
- Observable: $Q^{soft}_{comb} = Q_{bjet} \cdot Q^{soft}_{\mu}$



contamination from D-hadron decays is minimized by requiring p_T^{rel}>800 MeV for soft muons

Channel	μ + jets			e + jets		
Selection	Preselection	2 *b*-tags	soft muon	Preselection	2 *b*-tags	soft muon
$t\bar{t}$	3219	1127	895	2242	749	628
Single top	163	35	39	125	25	28
W+jets (DD)	491	39	79	315	25	49
Z+jets	41	4	13	34	3	6
Diboson	8	1	2	5	1	1
QCD (DD)	227	17	41	54	4	9
Total	4200 ± 700	1220 ± 190	1070 ± 190	2800 ± 400	810 ± 130	720 ± 120
Observed	4315	1227	1033	3001	859	844

Track Charge Weighting Method

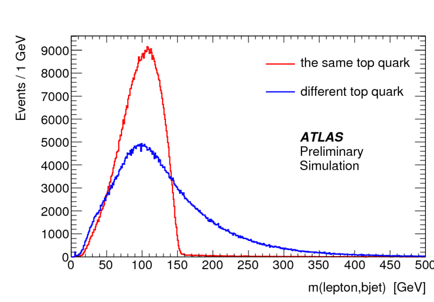
- Count charged particles inside *b*-jet and define *b*-jet charge as:

$$Q_{bjet} = \frac{\sum_i q_i |\vec{j} \cdot \vec{p}_i|^k}{\sum_i |\vec{j} \cdot \vec{p}_i|^k}$$

- q_i, p_i : charge and 3-momentum of i^{th} particle
- j : b-jet axis direction
- k=0.5 : parameter for best separation b/anti-b jets

- Condition for (b-jet,lepton) pairing is mass(b, ℓ) < top mass

- Observable: $Q_{comb} = Q_{bjet} \cdot Q_\ell$



m(b, ℓ) distribution for correct (red) and wrong pairing

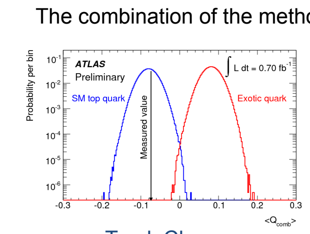
Results

The measured combined charge $Q^{(soft)}_{comb}$ shows a good agreement with the Standard Model prediction in both methods. Signal modeling and limited statistics are the dominant source of uncertainties.

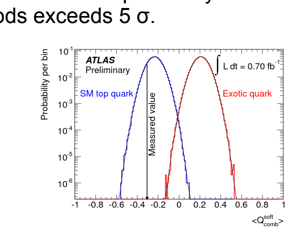
channel	$< Q_{comb} >$		
	Data	SM (MC)	SM $t\bar{t}$
e + jets	-0.088 ± 0.020 (stat) ± 0.012 (syst)	-0.084 ± 0.020	-0.086 ± 0.021
μ +jets	-0.078 ± 0.018 (stat) ± 0.010 (syst)	-0.081 ± 0.018	-0.086 ± 0.019
e/μ + jets	-0.082 ± 0.013 (stat) ± 0.011 (syst)	-0.082 ± 0.013	-0.086 ± 0.014

channel	$< Q^{soft}_{comb} >$		
	Data	SM (MC)	SM $t\bar{t}$
e + jets	-0.36 ± 0.07 (stat) ± 0.04 (syst)	-0.237 ± 0.016	-0.266 ± 0.010
μ + jets	-0.26 ± 0.07 (stat) ± 0.06 (syst)	-0.232 ± 0.015	-0.240 ± 0.009
e/μ + jets	-0.31 ± 0.05 (stat) ± 0.04 (syst)	-0.234 ± 0.011	-0.251 ± 0.007

The exotic scenario of a "top-like" quark has been excluded at more than 4.5 σ with both methods independently.
The combination of the methods exceeds 5 σ.



Track Charge Weighting Method



Soft Muon Method

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ATLAS EXPERIMENT