

Anomalous Couplings in single top production in ATLAS

V CPAN Days
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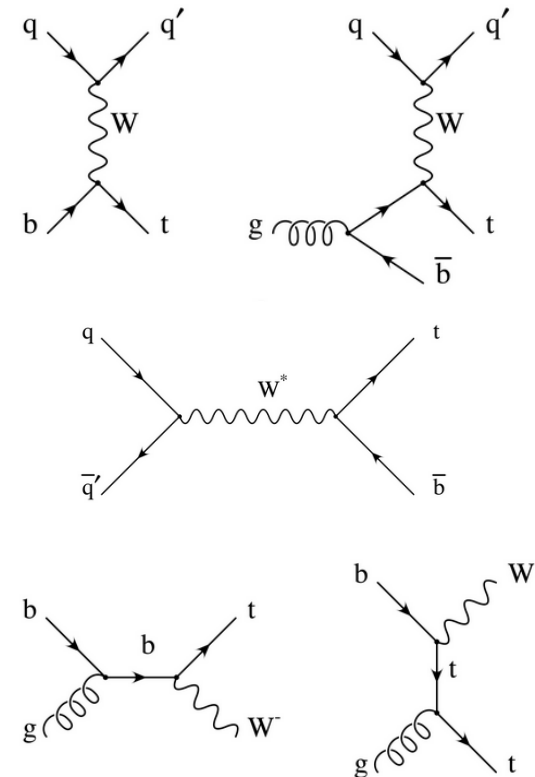


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- Physics introduction:
 - Top production
 - Wtb vertex
 - Anomalous couplings
- Analysis:
 - Event selection and background
 - Control plots
 - Asymmetry measurements
 - Limits and results

Top production in LHC

- Production of top quarks:
 - produced mainly in pairs via strong interaction: **147.4 pb**
 - Alternative production: Weak interaction involving Wtb vertex \rightarrow **single top** quark production
- Single top production at 7 TeV:
 - **t-channel (virtual W boson): 64.6 pb**
 - s-channel (virtual W boson): 15.7 pb
 - Wt channel (on-shell W boson): 4.63 pb



Cross sections at NNLO

Wtb vertex

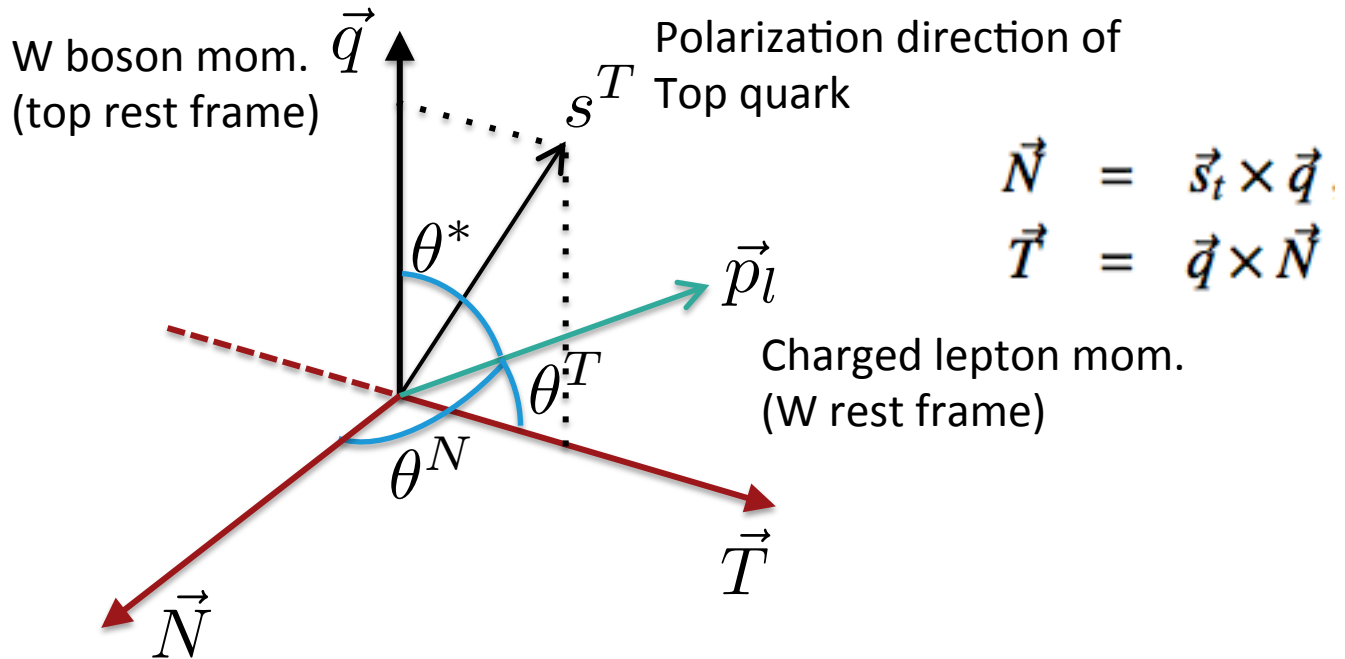
- Top quarks almost decay exclusively to W boson and a b-quark → Good to probe the couplings of the vertex **Wtb**
- The Wtb vertex can be written:

$$\begin{aligned}\mathcal{L}_{Wtb} = & -\frac{g}{\sqrt{2}}\bar{b}\gamma^\mu(V_L P_L + V_R P_R)tW_\mu^- \\ & -\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_\nu}{M_W}(g_L P_L + g_R P_R)tW_\mu^- + \text{h.c.}\end{aligned}$$

- g : weak coupling constant
- m_W : mass of W boson
- q, b, t, W : 4-mom of the particles
- $V_{L,R}$: vector couplings
- $g_{L,R}$: tensor couplings
- $P_{L,R}$: Projection operators, $(1\pm\gamma^5)/2$
- In the Standard Model V_L is close to one and V_R, g_L and g_R are zero.

Probe of anomalous couplings

- Single top quark t-channel highly polarized along the spectator quark direction ($P \sim 0.9$)



- Asymmetries derived with θ^* are not sensitive to all anomalous couplings:
 - Define θ^N and θ^T angles

Asymmetries

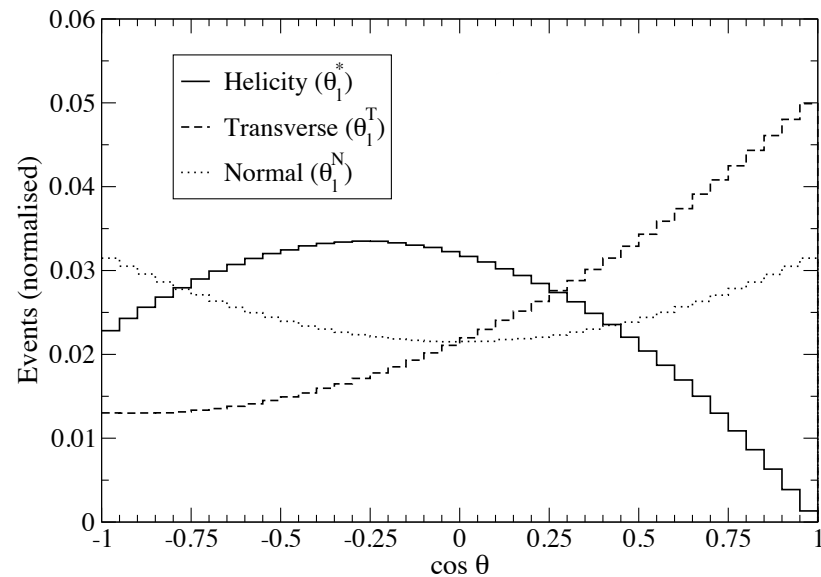
- The asymmetry backward-forward is defined as:

$$A_{FB} \equiv \frac{N_{\text{evt}}(\cos \theta > 0) - N_{\text{evt}}(\cos \theta < 0)}{N_{\text{evt}}(\cos \theta > 0) + N_{\text{evt}}(\cos \theta < 0)}$$

- θ : angle under study
- N_{evt} : number of events

- We focus on:

- Angle $\theta_N \rightarrow A_{FB}^N$
- Angle $\theta_T \rightarrow A_{FB}^T$



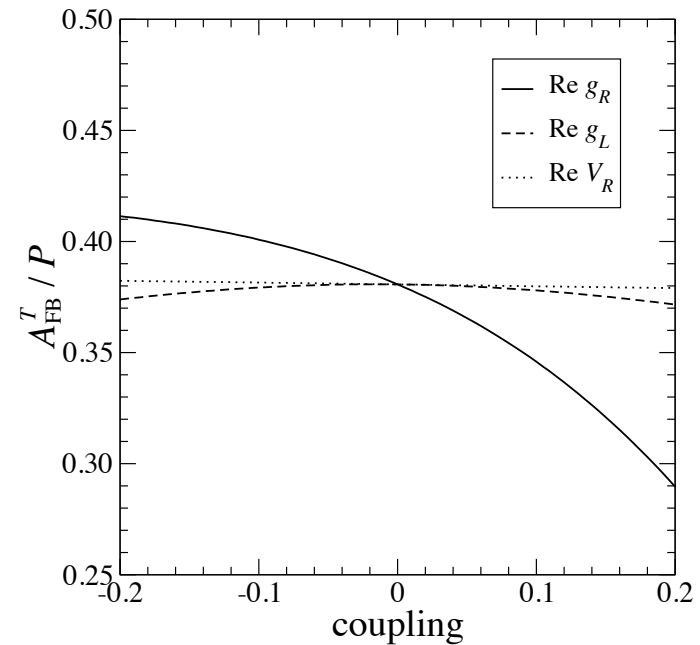
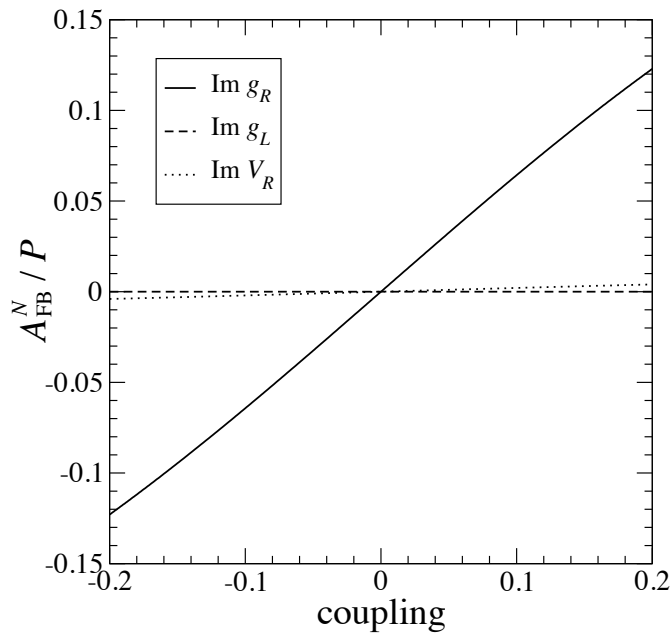
W polarisation beyond helicity fractions in top quark decays, *J.A. Aguilar-Saavedra, J. Bernabeu*

AFBN and AFBT

- A_{FB}^N and A_{FB}^T related to g_R with the approximations (assuming $V_L = 1$ and $V_R = g_L = 0$):

$$A_{FB}^T \approx 0.38P - 0.26P \operatorname{Re}(g_R)$$

$$A_{FB}^N \approx 0.64P \operatorname{Im}(g_R)$$



Wtb Analyses

- AFBN at 7 TeV:
 - AFBN very sensitive to $\text{Im}(g_R)$:
 - If $\text{Im}(g_R) \neq 0 \rightarrow$ CP-violation in top decays
 - First experimental limit to $\text{Im}(g_R)$
 - Conf. note: [ATLAS-CONF-2013-032](#) (Maria Moreno Thesis)
- AFBT at 7 TeV:
 - Work in progress.
- Anomalous couplings at 8 TeV
- We will focus in 7TeV AFBN and AFBT

Event Selection

Pre-Selection:

- Single lepton triggers
- Exactly one e^\pm or μ^\pm with $p_T > 25 \text{ GeV}$, $|\eta| < 2.5$
- Exactly 2 jets with $p_T > 30 \text{ GeV}$, $|\eta| < 4.5$
 - $p_T > 35 \text{ GeV}$ for $2.75 < |\eta| < 3.5$
 - Exactly 1 b-tag jet (JetFitterCOMBNNc @ 55% eff.), $|\eta| < 2.5$
- QCD background rejection
 - $E_T^{\text{miss}} > 30 \text{ GeV}$
 - $m_T(W) > 30 \text{ GeV}$
 - $p_T(\text{lepton}) > 40 \mp 40/(\pi-1) \cdot (\Delta\phi(\text{leading-jet,lepton}) \pm \pi)$

Selection:

$$|\eta_{\text{light-jet}}| > 2.0$$

$$H_T > 210 \text{ GeV} \quad (H_T = p_T(\text{lepton}) + p_T(\text{light-jet}) + p_T(\text{b-jet}) + E_t^{\text{miss}})$$

$$150 < m_{\text{Top}} < 190 \text{ GeV}$$

$$|\Delta\eta(\text{b-jet, light-jet})| > 1.0$$

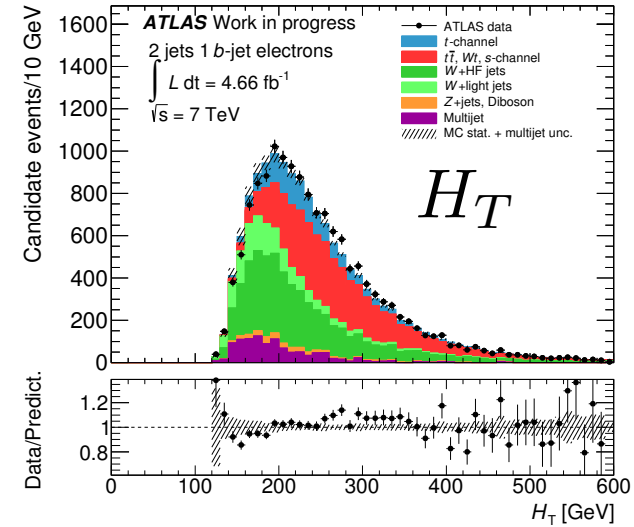
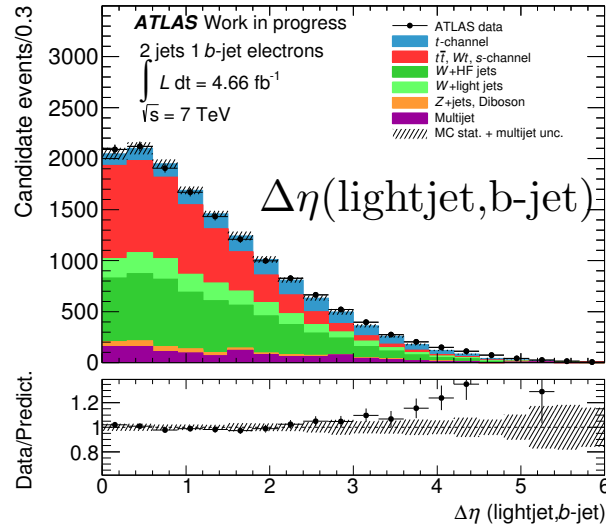
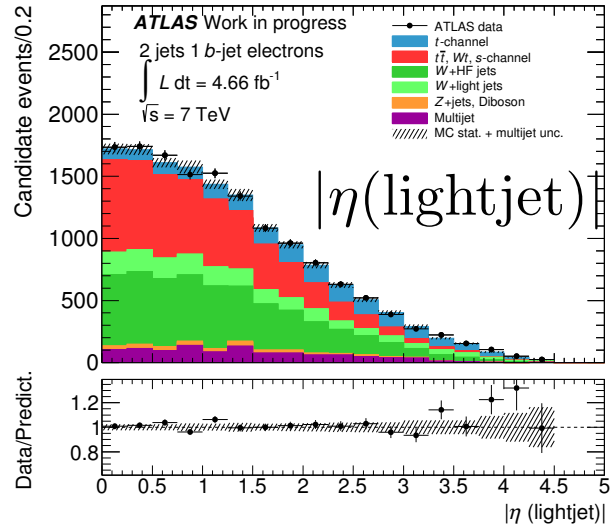
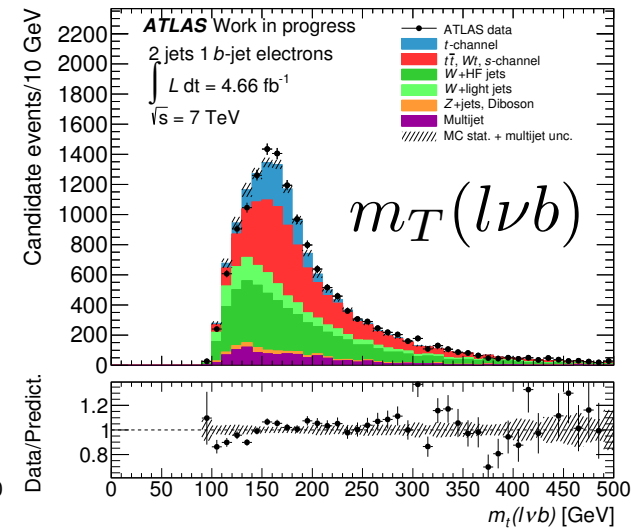
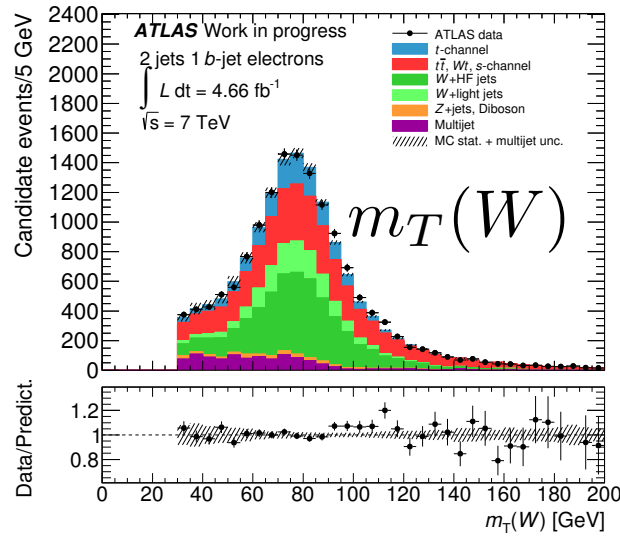
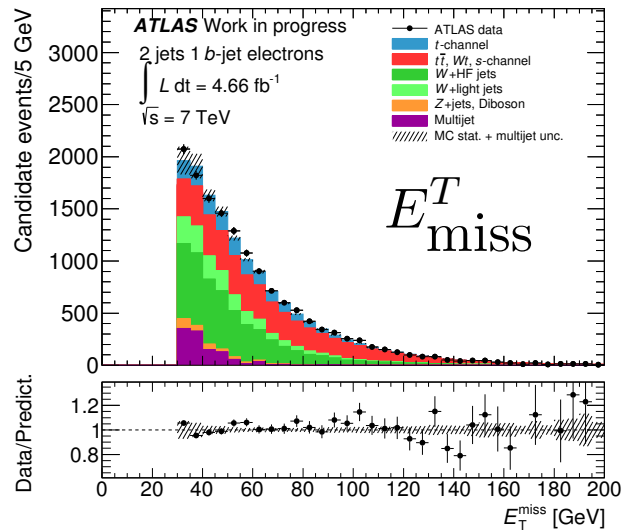
Backgrounds and samples

- **ATLAS 2011 data @ 7 TeV, $4.66 \pm 0.08 \text{ fb}^{-1}$**
- **Multijet background**
 - Electron channel: Jet-Electron model
 - Shape: events with similar kinematics to the signal selection but with a jet used in place of the electron (MC sample).
 - Normalizations: binned likelihood fit on the measured MET distribution
 - Muon channel: Matrix Method
 - The contribution from QCD multijet background in the muon channel comes from non-isolated muons passing muon isolation.
 - **W + jets background**
 - Shape from MC
 - Normalization from data: global scale factor and flavour fractions
 - Define a W+jets control region (1 or 2 jets, PreSelection cuts & top mass veto)
 - Overall SF: data/MC ratio estimated in pretag sample for each jet bin
 - Flavour fractions (W+bb, W+cc, W+c & W+light) are derived using 1-jet & 2-jets events in the pretag and tagged sample. A numerical fit is performed to obtain them.
- **Signal and remaining backgrounds** (single top, top, dibosons and Z +jets): using simulated samples and theoretical cross-sections.

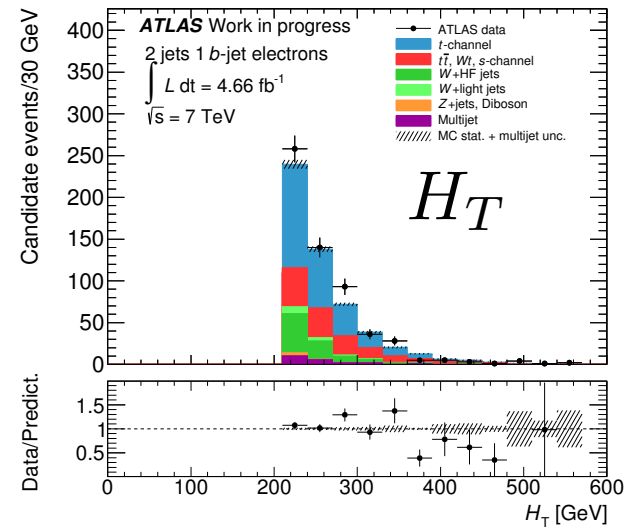
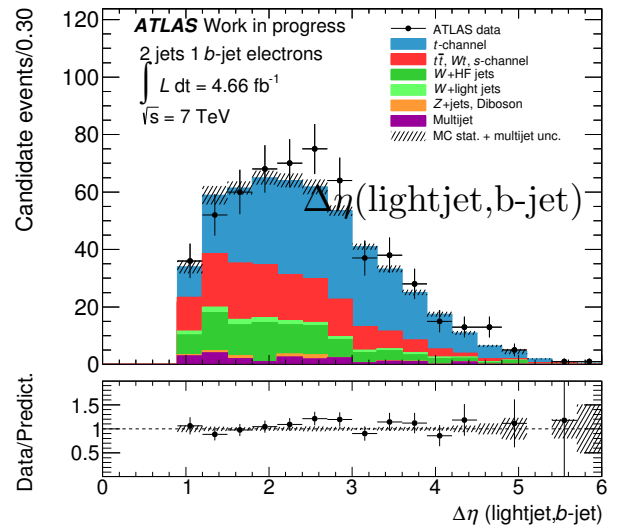
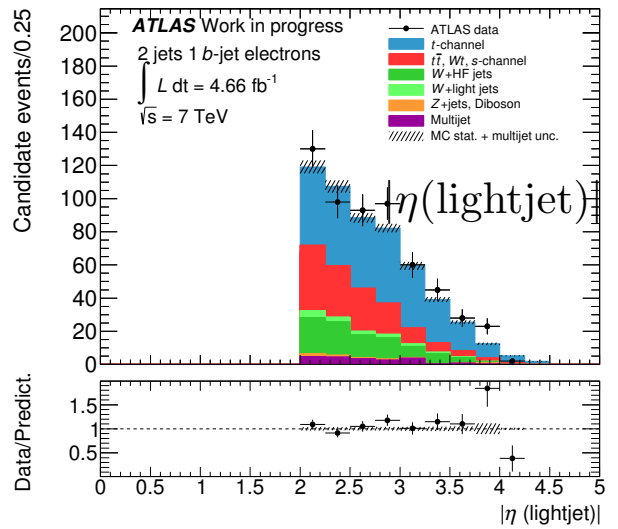
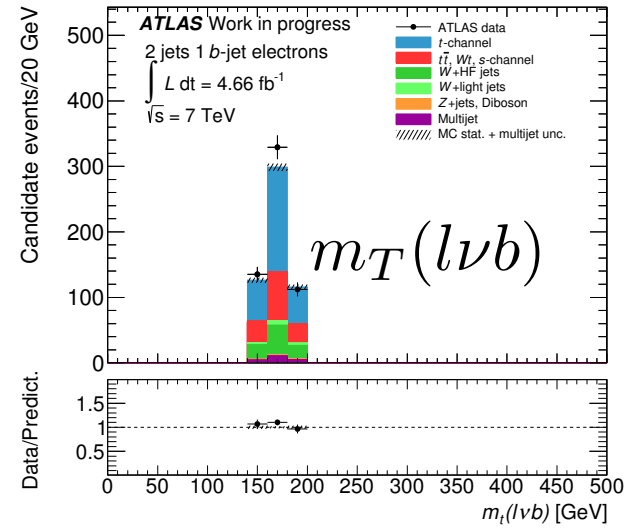
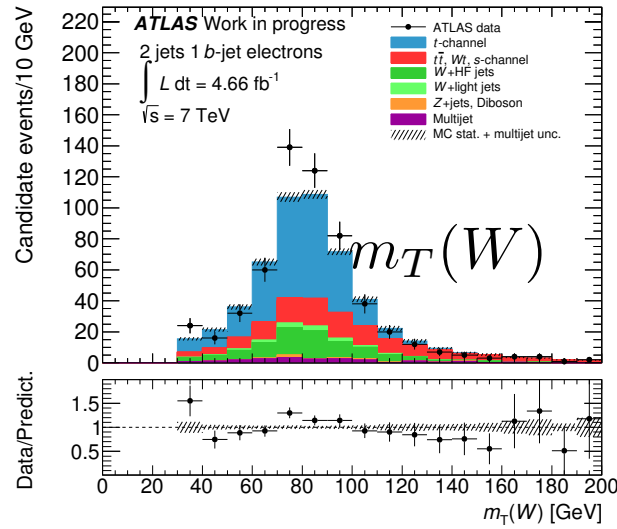
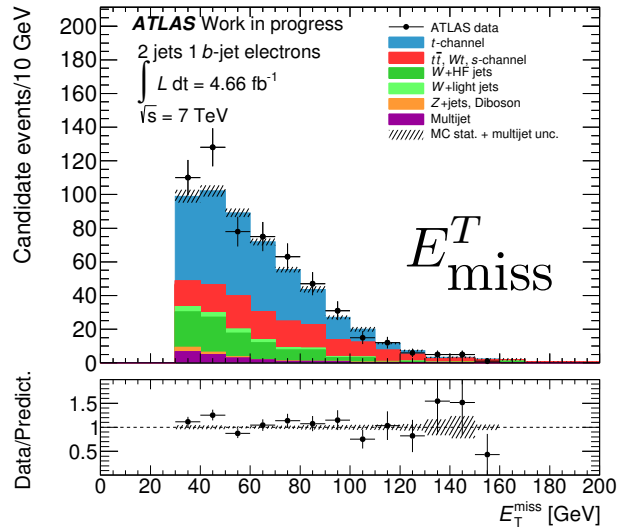
MC Generators

Sample	Generator
Single top t-channel	AcerMC + Pythia (tune Perugia 2011c)
Multijet	JetElectron(multijet MC & data) / Matrix Method(data)
W + jets	Alpgen + Herwig
Z + jets	Alpgen + Herwig
Dibosons	Herwig
Top Pairs	Powheg + Pythia (tune Perugia 2011c)
Single top Wt and s-channel	Powheg + Pythia (tune Perugia 2011c)

Control plots at Preselection – electrons



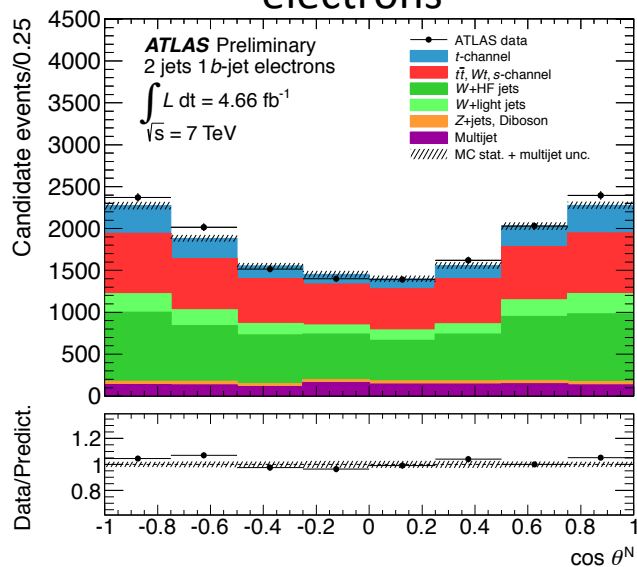
Control plots at Selection – electrons



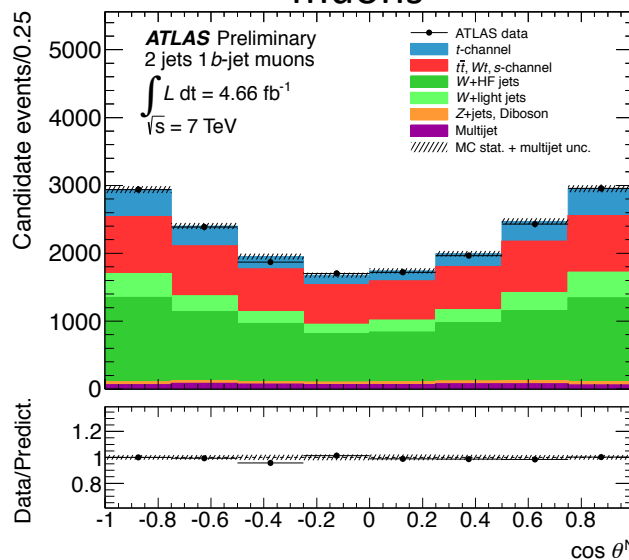
ASYMMETRY MEASUREMENTS

$\cos(\theta_N)$ and $\cos(\theta_T)$ at PreSelection

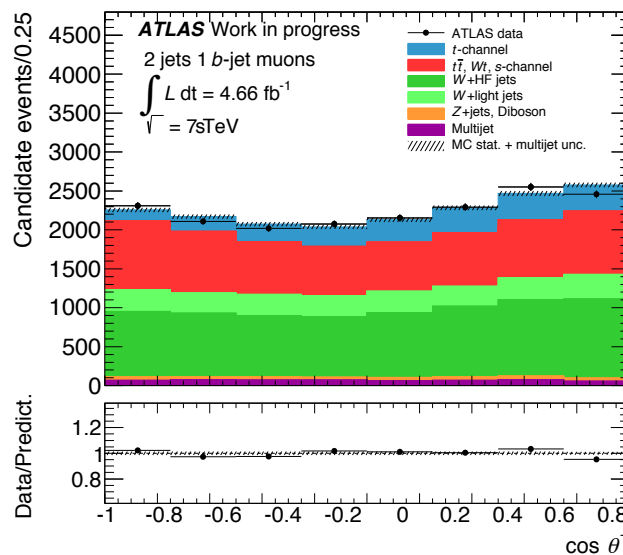
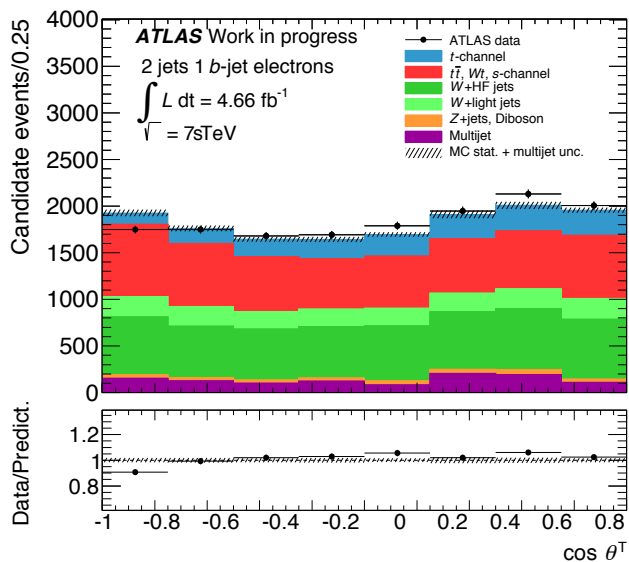
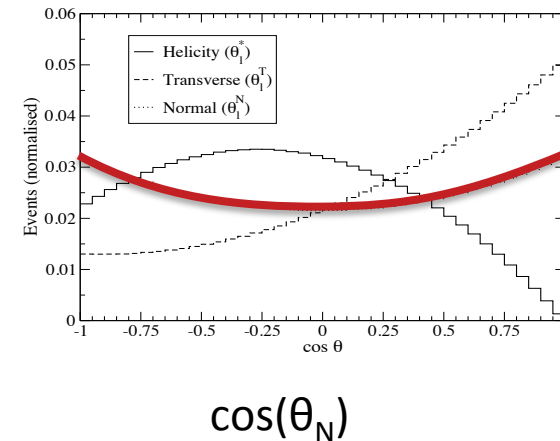
electrons



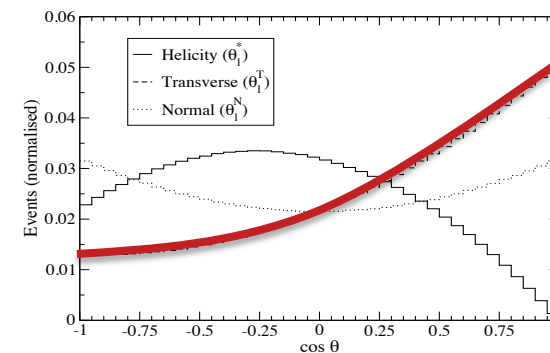
muons



Theoretical shape

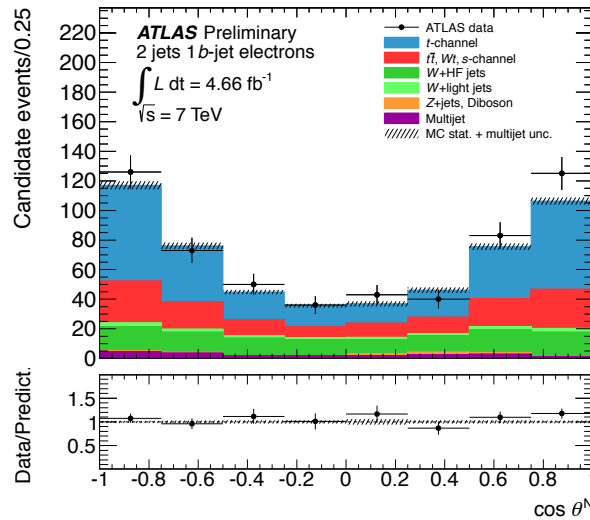


$\cos(\theta_T)$

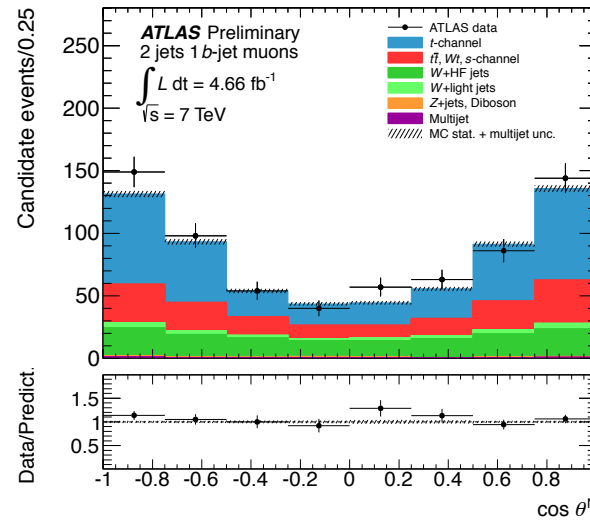


$\cos(\theta_N)$ and $\cos(\theta_T)$ at Selection

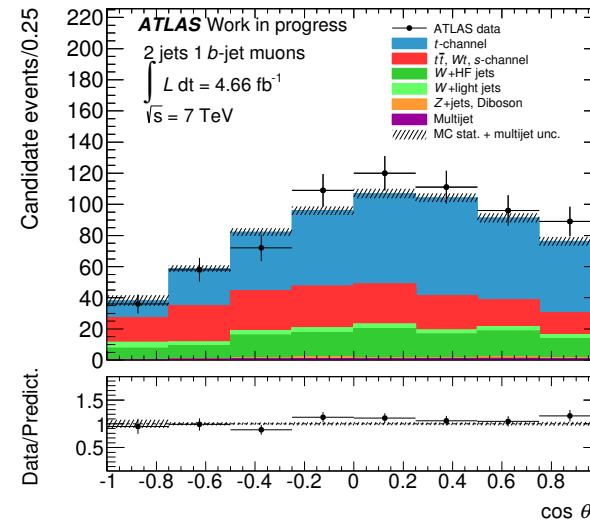
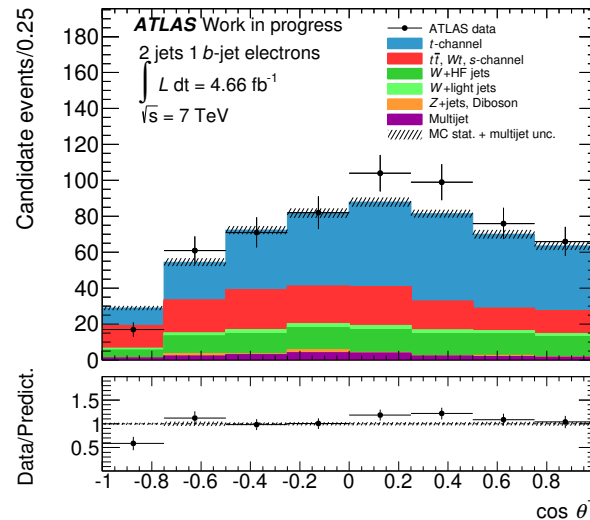
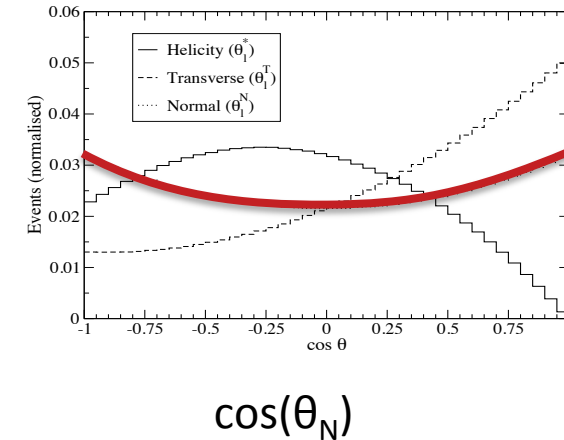
electrons



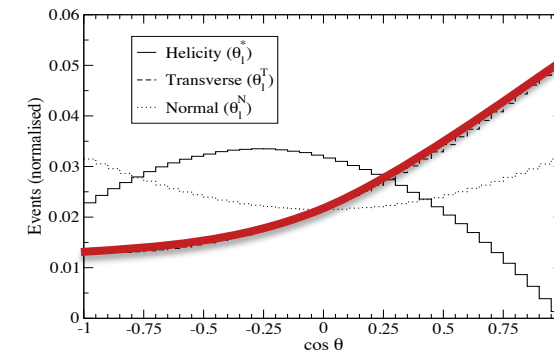
muons



Theoretical shape



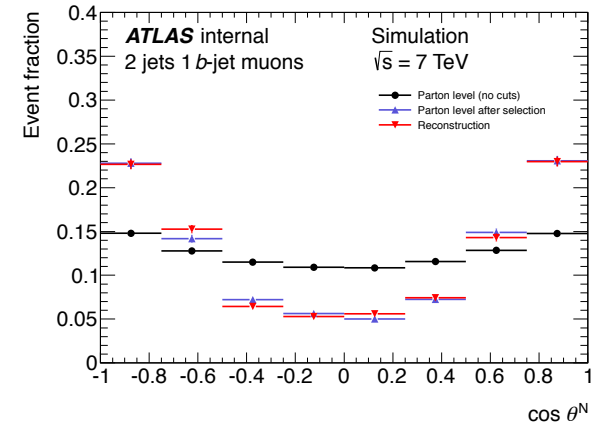
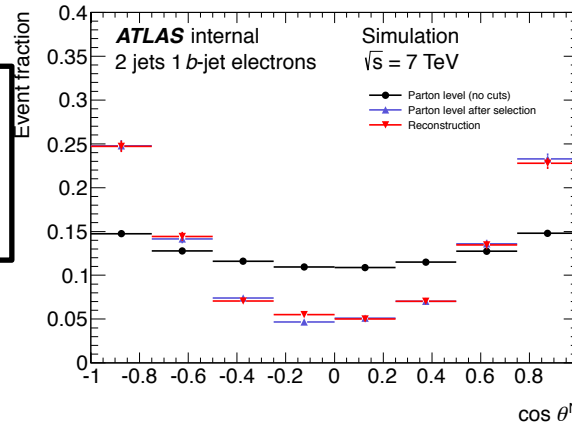
$\cos(\theta_T)$



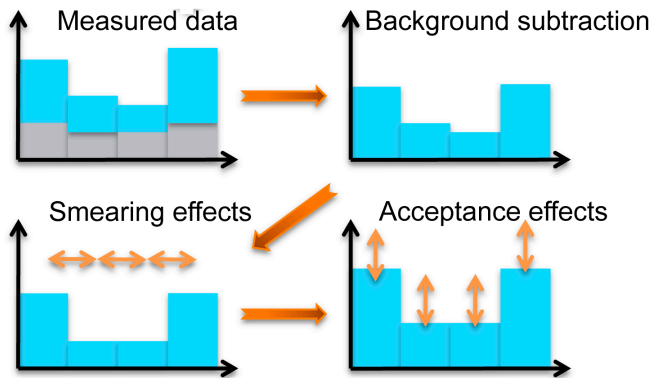
Unfolding to parton level

- From the cosine distributions, we extract the forward-backward asymmetries. The reconstructed distributions are distorted by the detector response and the event selection.

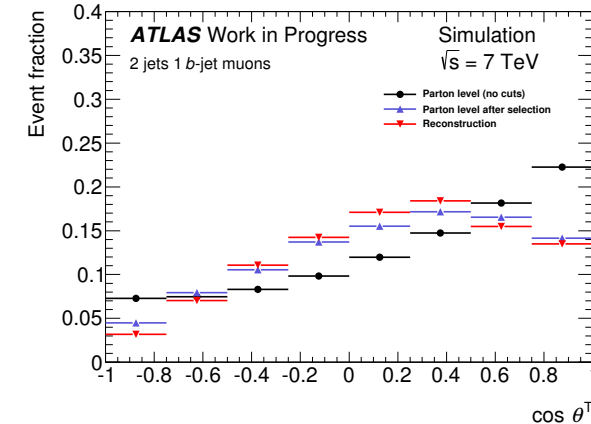
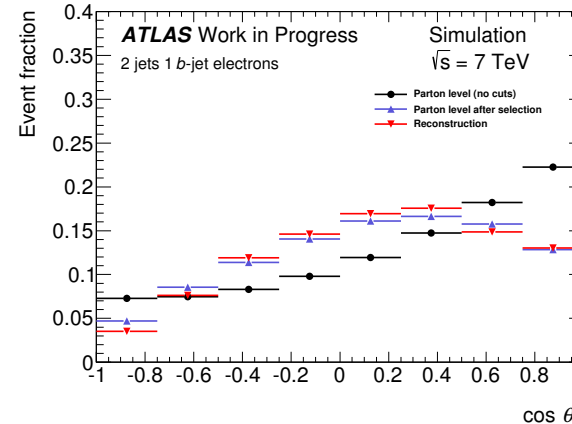
-- Parton level without cuts
 -- Parton level after selection
 -- Reconstruction after selection



$\cos(\theta_N)$



Unfolding procedure



$\cos(\theta_T)$

Systematic uncertainties

- The procedure to evaluate the systematic uncertainties is the following:
 - For each systematic uncertainty source, run 15k pseudo experiments (PEs) to evaluate the impact of that source in to the asymmetry.
 - In each pseudo-experiment, the measurement is repeated on a pseudo-data (MC signal + bkg) distribution corresponding to the integrated data luminosity. The number of events is allowed to fluctuate varying each bin according to a Poisson distribution.

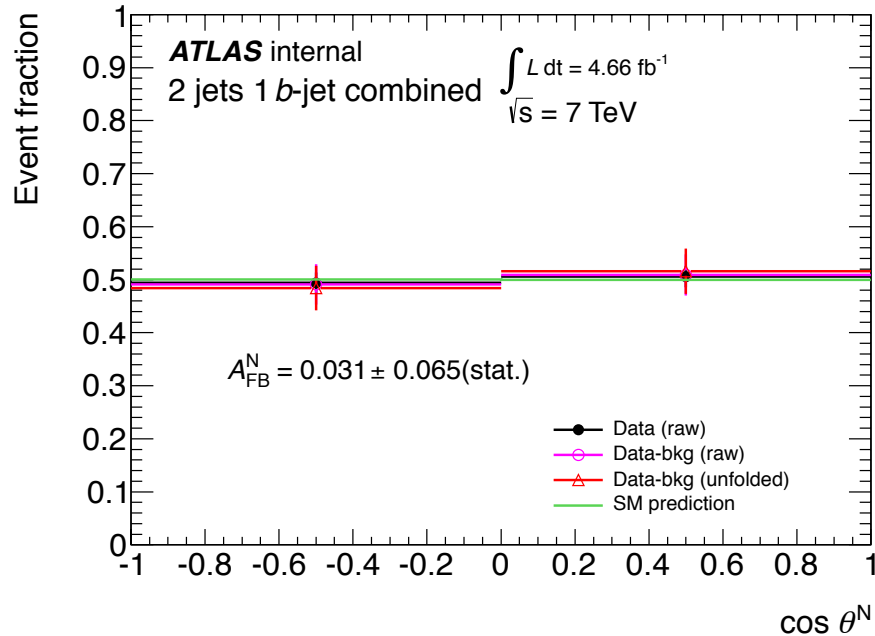
Systematic uncertainties

Systematic	ΔA_{FB}^N
Lepton reco. eff.	<0.001 / <0.001
Lepton energy reso.: no scale	0.002 / 0.006
Lepton energy reso.: ID	-0.001 / 0.001
Lepton energy reso.: MS	-0.003 / <0.001
Jet energy scale	-0.005 / 0.009
E_T^{miss} (cellout)	-0.001 / -0.001
E_T^{miss} (pileup)	0.002 / -0.004
SF b -tag	<0.001 / -0.001
SF c -tag	0.001 / <0.001
SF mistag	-0.001 / -0.001
JVF SF	<0.001 / <0.001
Jet reconstruction efficiency	0.001 / -0.001
Jet energy resolution	0.007 / -0.007
Luminosity	0.001 / 0.001
Z+jets norm.	0.002 / 0.002
$t\bar{t}$ norm.	0.001 / 0.001
s -ch. norm.	-0.001 / -0.001
Wt -ch. norm.	0.001 / <0.001
dibosons norm.	<0.001 / <0.001
W +jets shape (iqopt3)	<0.001 / <0.001
W +jets shape (ptjmin10)	0.001 / -0.001
QCD shape and norm.	0.007 / -0.007
ISR/FSR	0.001 / -0.001
t -ch. MC generator	0.024 / -0.024
$t\bar{t}$ MC gen. and PS	0.010 / -0.010
PDF	0.003 / -0.003
Unfolding	0.003 / -0.003
Total	+0.029 / -0.031

Systematic	ΔA_{FB}^T
Lepton reco. eff.	0.008 / -0.009
Lepton energy reso.: no scale	0.003 / -0.03
Lepton energy reso.: ID	0.003 / -0.005
Lepton energy reso.: MS	0.003 / -0.010
Jet energy scale	0.08 / -0.06
E_T^{miss} (cellout)	0.010 / -0.07
E_T^{miss} (pileup)	0.04 / -0.014
SF b -tag	0.015 / -0.014
SF c -tag	0.0013 / -0.003
SF mistag	0.02 / -0.002
JVF SF	0.003 / -0.005
Jet reconstruction efficiency	0.008 / -0.008
Jet energy resolution	0.04 / -0.04
Luminosity	0.024 / -0.015
Z+jets norm.	0.005 / -0.005
$t\bar{t}$ norm.	0.02 / -0.02
s -ch. norm.	<0.001 / <0.001
Wt -ch. norm.	0.002 / -0.002
dibosons norm.	<0.001 / <0.001
W +jets shape (iqopt3)	0.001 / -0.001
W +jets shape (ptjmin10)	0.001 / -0.001
QCD shape and norm.	0.02 / -0.02
ISR/FSR	<0.001 / <0.001
t -ch. MC generator	0.015 / -0.015
$t\bar{t}$ MC gen. and PS	0.003 / -0.003
PDF	0.017 / -0.017
Unfolding	0.013 / -0.013
Total	+0.11 / -0.11

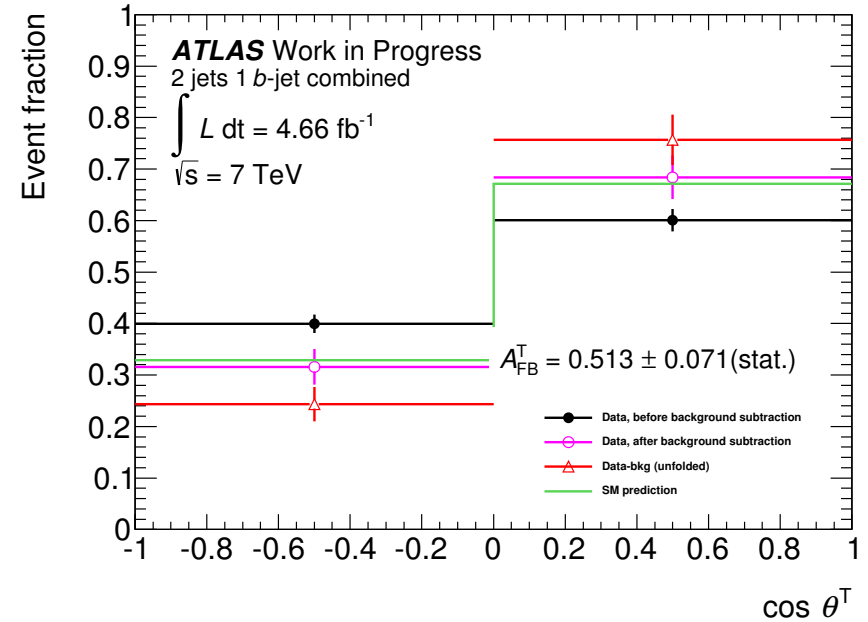
Asymmetry measurements

AFBN



combined	A_{FB}^{N}
Data (raw)	0.012 ± 0.028 (stat.)
Data (raw, bkg. subtracted)	0.018 ± 0.055 (stat.)
Data unfolded	0.031 ± 0.065 (stat.) $^{+0.029}_{-0.031}$ (syst.)

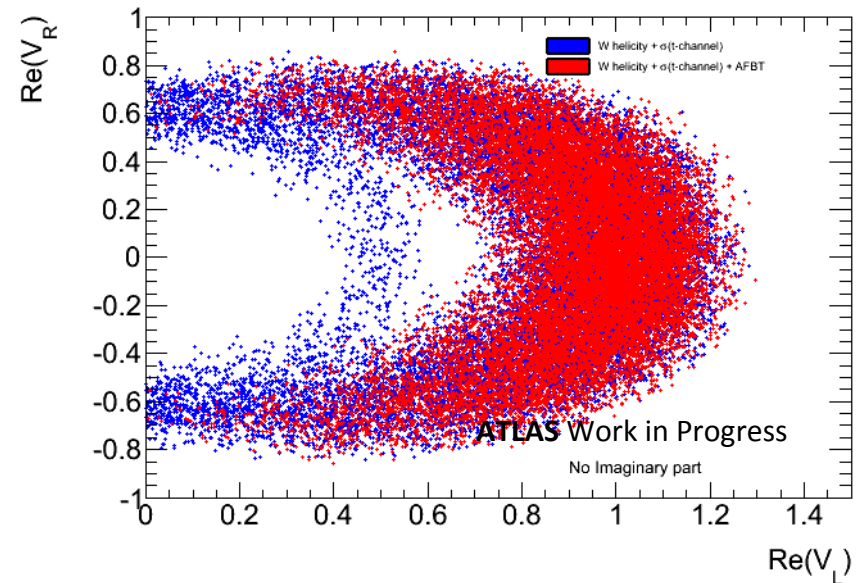
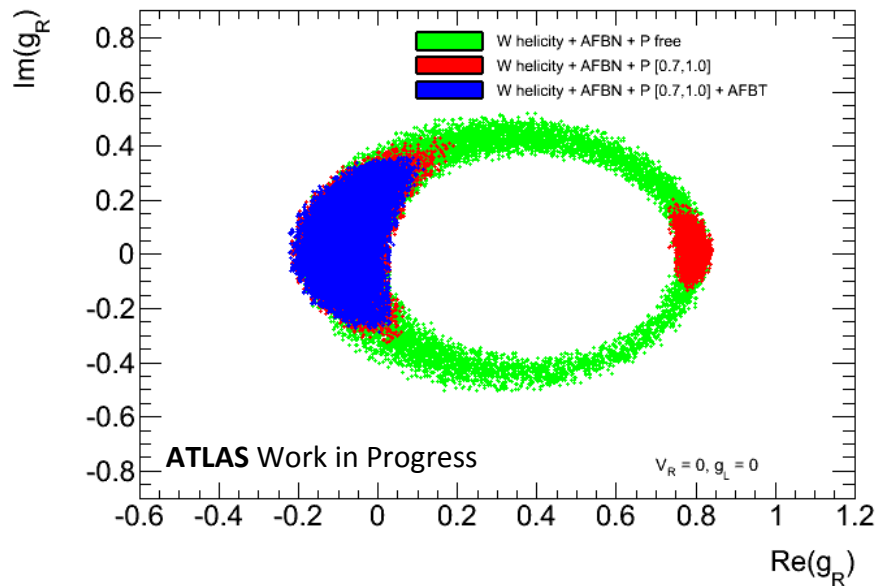
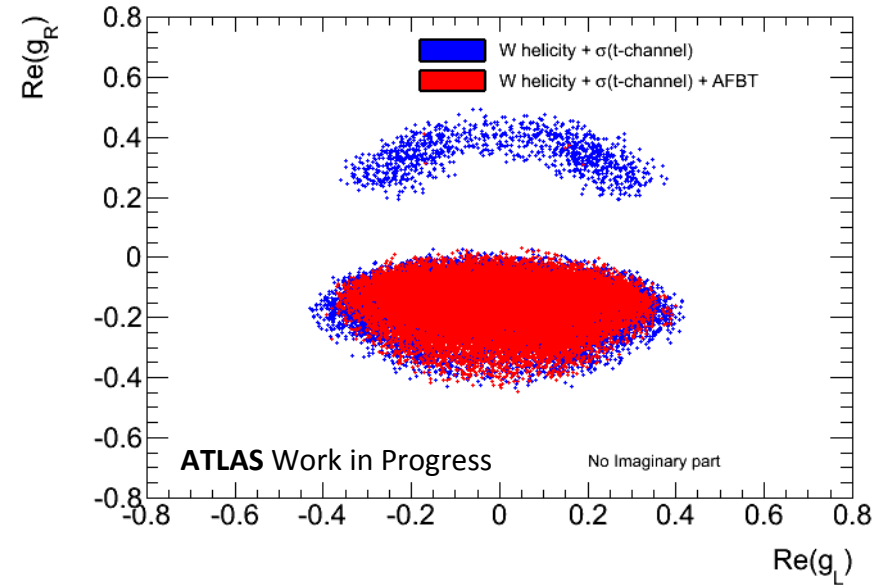
AFBT



combined	A_{FB}^{T}
Data (raw)	0.201 ± 0.028 (stat.)
Data (raw, bkg. subtracted)	0.357 ± 0.038 (stat.)
Data unfolded	0.513 ± 0.071 (stat.) ± 0.115 (syst.)

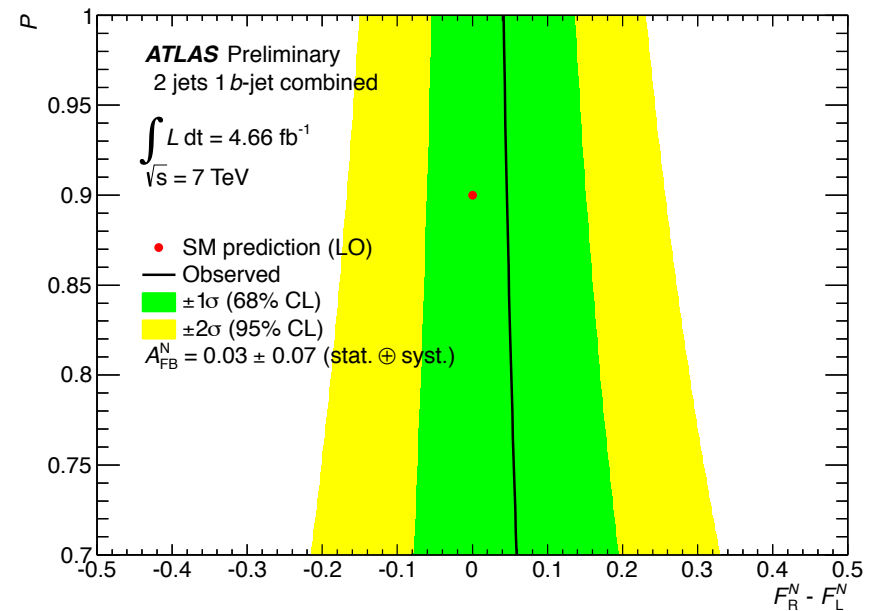
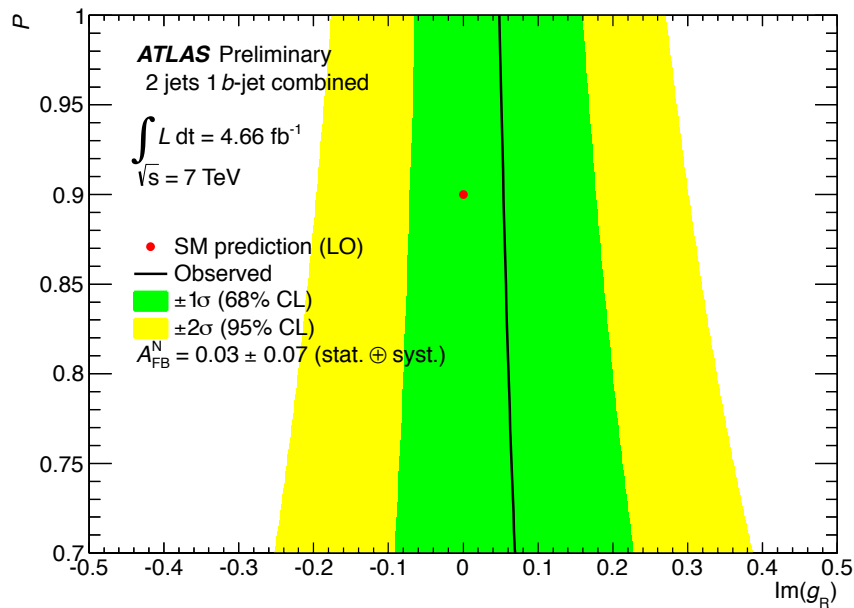
Limits to coupling constants

- Limits using the measured constraints:
 - W helicity
 - t-channel cross-section
 - AFBN
 - AFBT
 - Polarization



Results

Limits to $\text{Im}(g_R)$ depending on the polarization

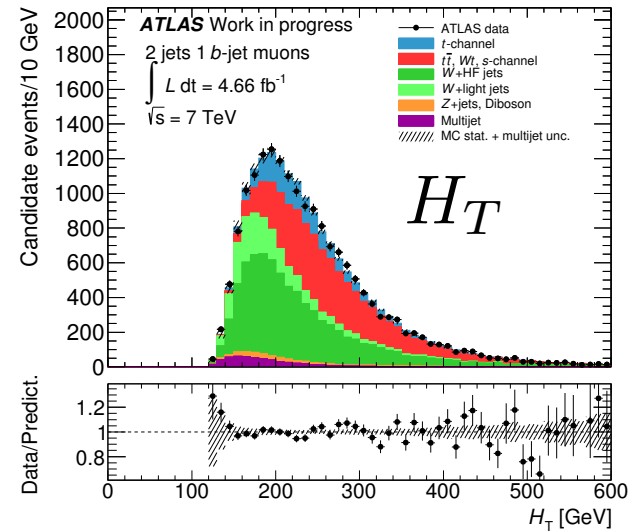
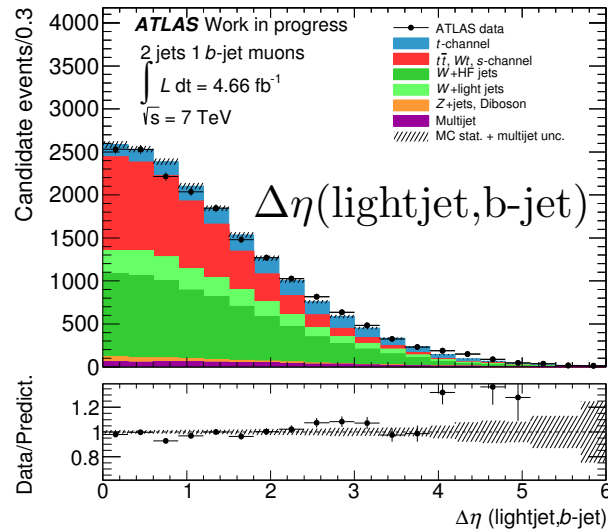
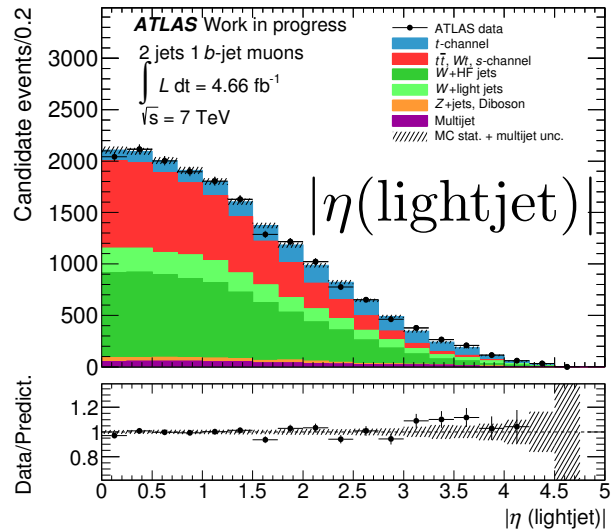
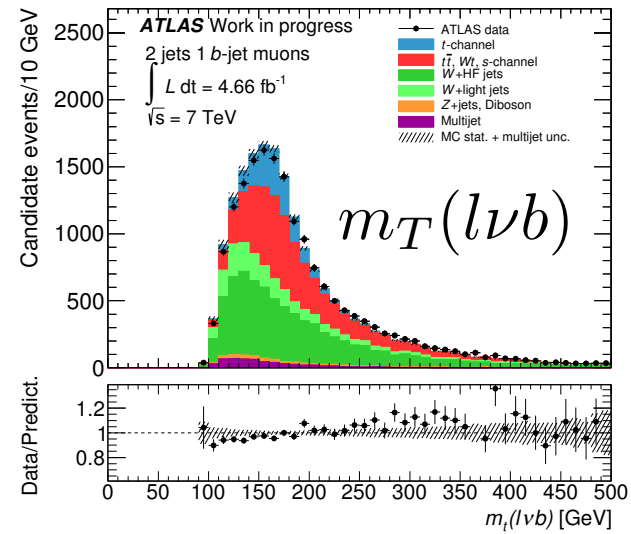
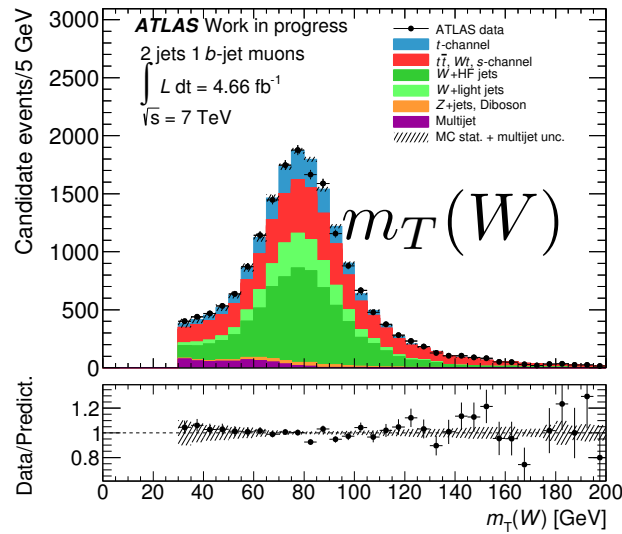
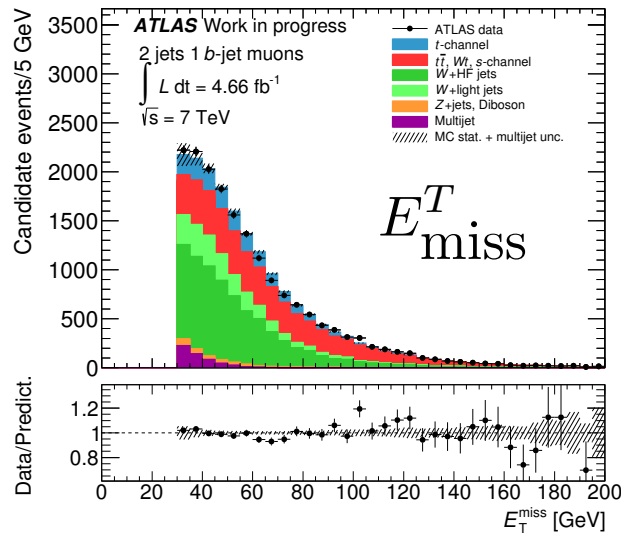


Summary

- The Wtb vertex in the single top quark has been studied:
 - AFBT and AFBN at 7 TeV:
 - AFBN already approved
 - AFBT work in progress
 - Analysis at 8 TeV ongoing
- Results:
 - Measurement of the coupling constants compatible with the Standard Model predictions.

BACKUP SLIDES

Control plots at PreSelection – muons



Control plots at Selection – muons

