Wtb Anomalous Top Couplings

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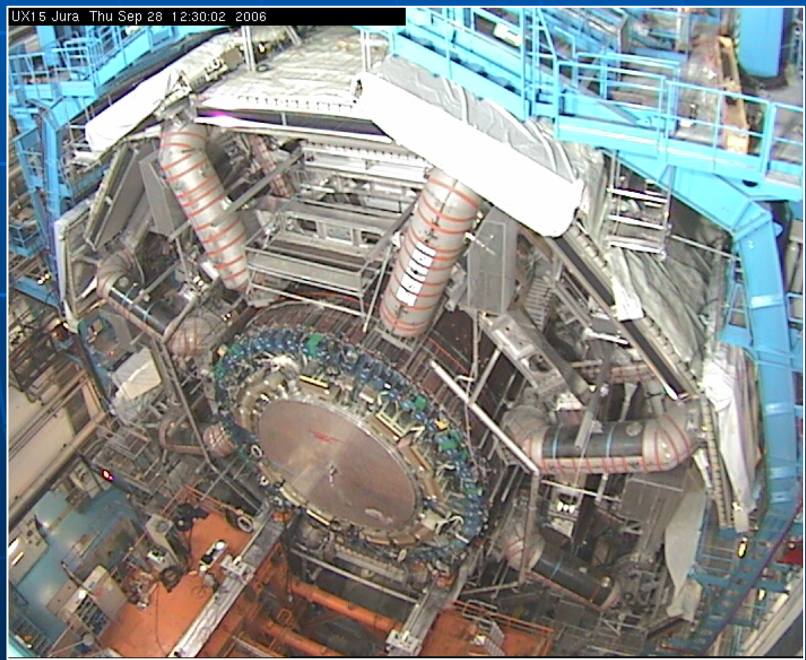
ATLAS Collaboration



Flavour in the Era of the LHC, 9th-11th October, CERN

Outline

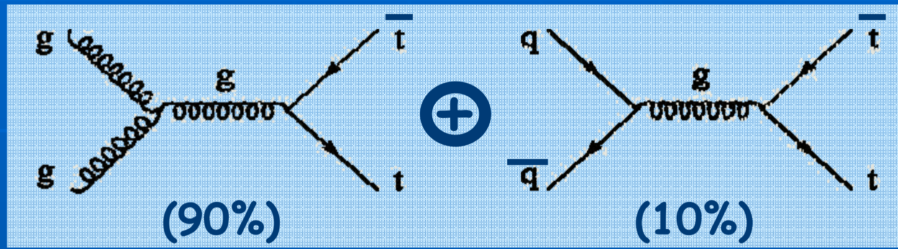
- ☑ Introduction
- ☑ Probing the Wtb vertex
- ☑ New Observables
- ☑ Analysis & Systematic Errors
- ☑ New Combination of Observables
- ☑ Conclusions

☑ Introduction

Studying the Wtb Vertex with $t\bar{t}$ events @ LHC

Production X-section:

$\sigma \sim$ 833pb @ 14TeV



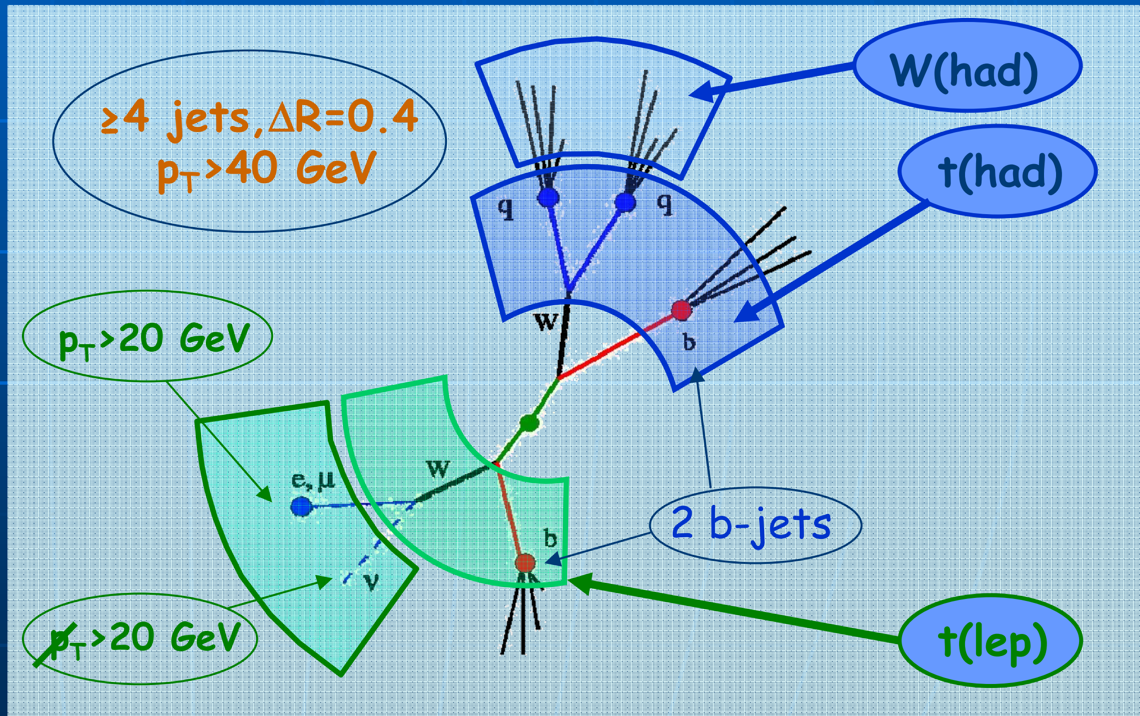
Semileptonic Topology:

Golden Channel

Clean Topology:

$t\bar{t}$ back to back

Used for several studies



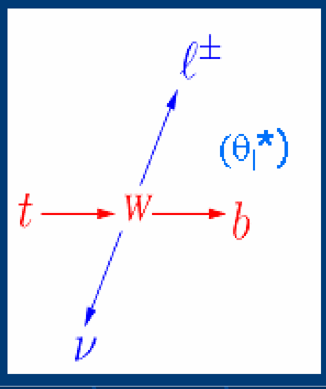
☑ Introduction

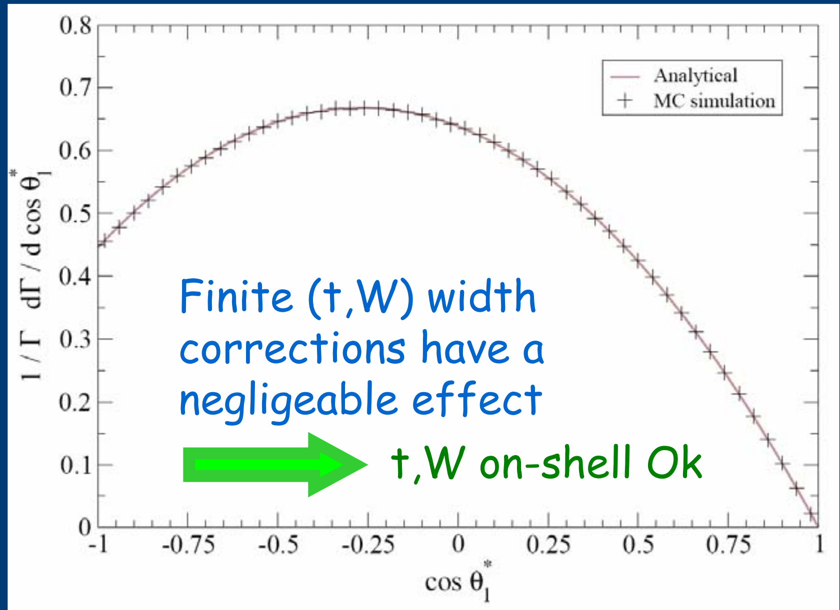
Studying the Wtb Vertex with $t\bar{t}$ events @ LHC

Measure W polarization (F_0, F_L, F_R) through:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta^*_\ell} = \frac{3}{8}(1+\cos\theta^*_\ell)^2\,F_R + \frac{3}{8}(1-\cos\theta^*_\ell)^2\,F_L + \frac{3}{4}\sin^2\theta^*_\ell\,F_0$$

Using lepton angular distribution (with respect to top direction) in W cm system:





SM(LO): F_0=0.703 , F_L=0.297 , F_R=3.6x10^{-4}

(NLO): F_0=0.695 , F_L=0.304 , F_R=0.001

☑ Probing the Wtb vertex

- Anomalous Couplings in the t→bW decay:

$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\,\gamma^{\mu}\left(V_L P_L + V_R P_R\right) t\, W_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\,\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(g_L P_L + g_R P_R\right) t\, W_{\mu}^{-} + \text{h.c.}$$

PRD45 (1992) 124:

$$f_1^R \equiv V_R$$
$$f_2^L \equiv -g_L$$
$$f_2^R \equiv -g_R$$

PRD67 (2003) 014009 ($m_b \neq 0$)

- How to test these new couplings ?

They affect the F_0,F_L and F_R and the angular distribution

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☑ Probing the Wtb vertex

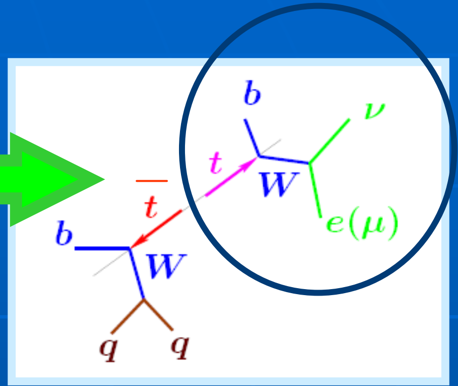
- Sensitivity limited by systematic errors
  - » Related theoretical observables are affected differently by systematic errors (experimental point of view)

- Several methods were used to test the ATLAS sensitivity:
  - » Extract limits from measured F_0,F_L and F_R ;
  - » Fit the angular distr. with new observables $\rho_R=F_R/F_0$ and $\rho_L=F_L/F_0$;
  - » Fit with the known dependence with V_R, g_L and g_R;
  - » Use new Asymmetries and study their dependence with V_R, g_L and g_R.

☑ New Observables

Anomalous Couplings in the $t \to bW$ decay

☒ Use $t \to bW$ decay in Semileptonic $t\bar{t}$ Events



☒ New observables $\rho_R = F_R/F_0$ and $\rho_L = F_L/F_0$

SM(LO): $\rho_L = 0.423$, $\rho_R = 0.0005$ ($m_b \neq 0$)

(NLO): $\rho_L = 0.438$ $\rho_R = 0.002$

☒ New Angular Asymmetries: A_{FB}, A_+ and A_-

$$A_t = \frac{N(x>t) - N(x<t)}{N(x>t) + N(x<t)}$$

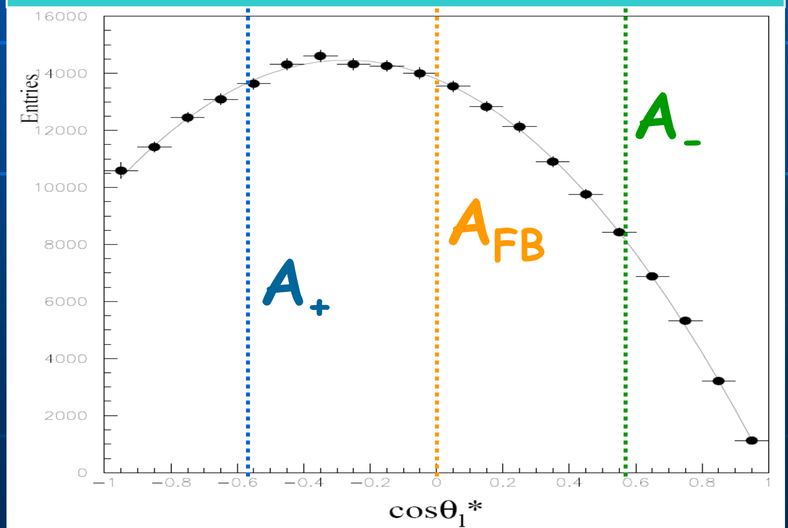
$$\begin{aligned} A_{\rm FB} &= \frac{3}{4}\left[F_R - F_L\right], \\ A_+ &= 3\beta\left[F_0 + (1+\beta)F_R\right], \\ A_- &= -3\beta\left[F_0 + (1+\beta)F_L\right], \end{aligned}$$

SM(LO):

$$A_{\rm FB} = -0.2225, \; A_+ = 0.5482, \; A_- = -0.8397$$

(NLO): $A_{FB} = -0.2269$, $A_+ = 0.5429$, $A_- = -0.8402$

A_{FB} [t=0] $A_\pm$ [t= ∓($2^{2/3}$-1)]

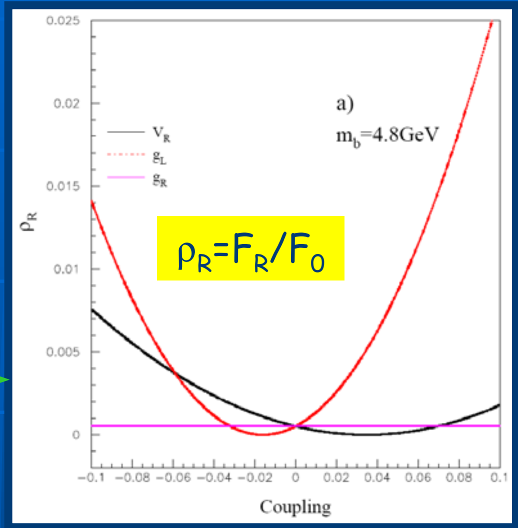


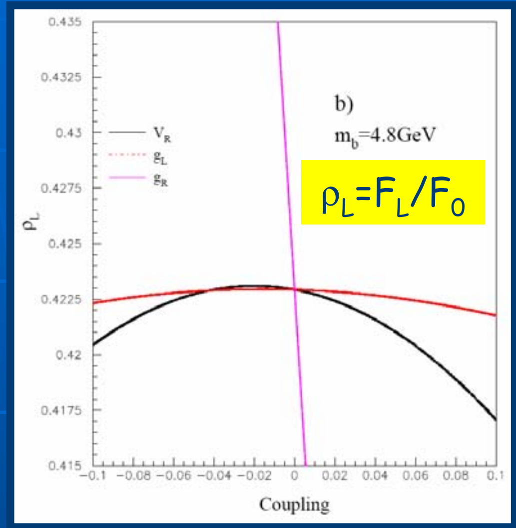
☑ New Observables

Anomalous Couplings in the $t \to bW$ decay

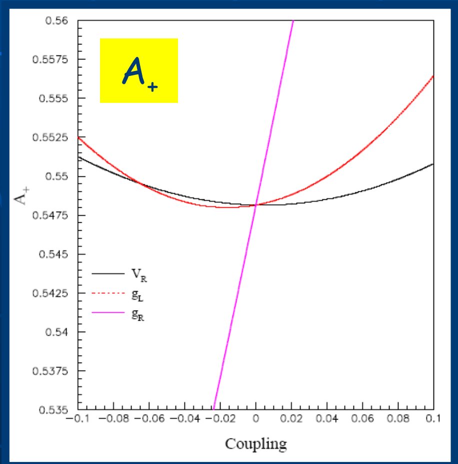
☒ Dependence of $\rho_R = F_R/F_0$ and $\rho_L = F_L/F_0$ with new couplings:

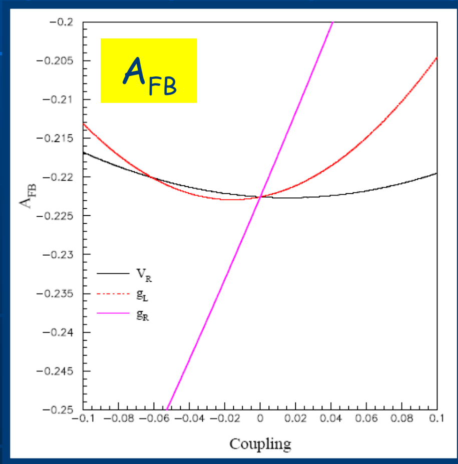
($m_b \neq 0$)

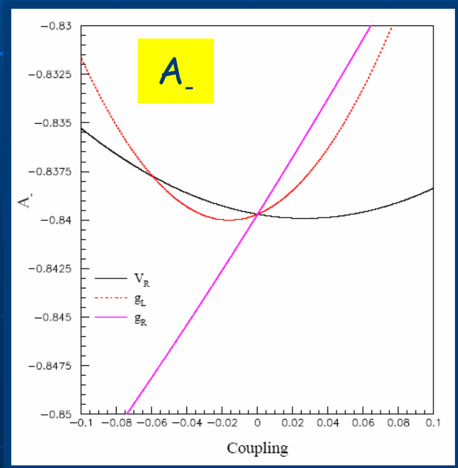




☒ Dependence of New asym A_+ and A_- with new couplings:





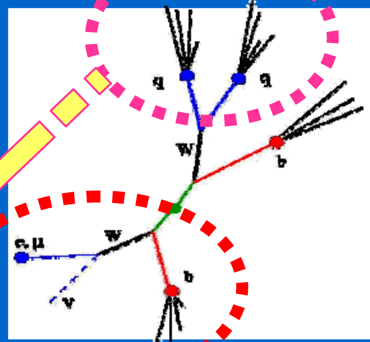


☑ Analysis & Systematic Errors

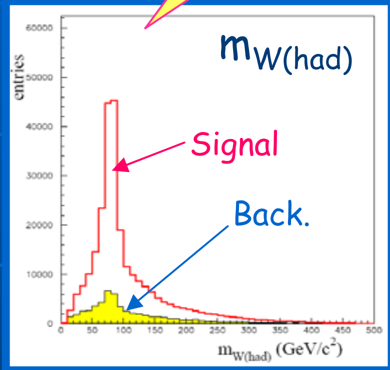
New Discriminant Analysis for Semileptonic Channel:

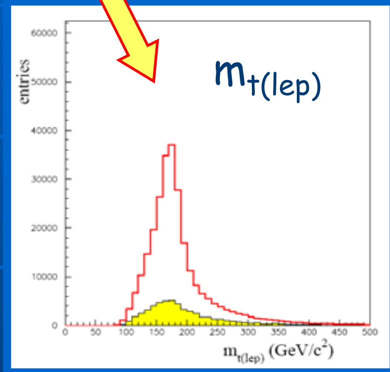
(already presented in the previous meetings)

- Preselection: 1 lepton (p_T>25GeV, $|\eta|$<2.5)
  ≥4 jets (p_T>20GeV, $|\eta|$<2.5)
  2 b-jets and $\not{p}_T$>20GeV



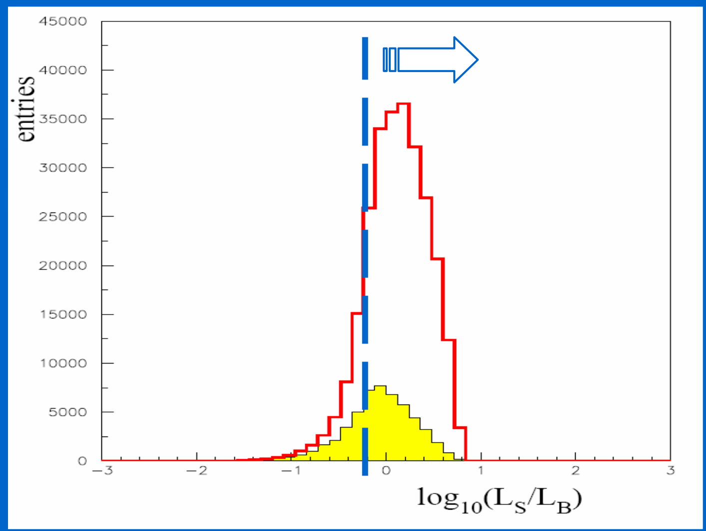
- Discriminant Variables:
  $m_W, m_{t(had)}, m_{t(lep)}, p_{T\text{-jets}}$





$$\mathcal{L}_S = \Pi_{i=1}^{n} \mathcal{P}_i^{signal} \quad \mathcal{L}_B = \Pi_{i=1}^{n} \mathcal{P}_i^{back.}$$

- Likelihood Ratio:



$L_R > -0.2$

ATLFAST

- Statistics (10fb^{-1}):
  - Δ Signal: ε=9% (220k)
  - Δ Back: 36k events

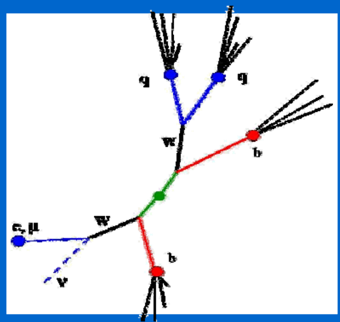
☑ Analysis & Systematic Errors

Anomalous Couplings in the $t \to bW$ decay

- Results for the different observables:

$L=10fb^{-1}$

Semileptonic Channel:



Observable	Result		
F_0	0.699	± 0.004 (stat)	± 0.020 (sys)
F_L	0.299	± 0.004 (stat)	± 0.019 (sys)
F_R	0.0021	± 0.0030 (stat)	± 0.0033 (sys)
ρ_L	0.4274	± 0.0080 (stat)	± 0.0356 (sys)
ρ_R	0.0004	± 0.0021 (stat)	± 0.0016 (sys)
A_{FB}	-0.2231	± 0.0035 (stat)	± 0.0130 (sys)
A_+	0.5472	± 0.0032 (stat)	± 0.0099 (sys)
A_-	-0.8387	± 0.0018 (stat)	± 0.0028 (sys)

- Limits on Couplings (one at a time different from zero):

	V_R ($g_L = g_R = 0$)	g_L ($V_R = g_R = 0$)	g_R ($V_R = g_L = 0$)
F_0	–	$[-0.141, 0.108]$	$[-0.0367, 0.0228]$
F_L	$[-0.204, 0.191]$	$[-0.175, 0.144]$	$[-0.0309, 0.0231]$
F_R	$[-0.0770, 0.146]$	$[-0.0666, 0.0346]$	–
ρ_L	$[-0.254, 0.206]$	–	$[-0.0275, 0.0227]$
ρ_R	$[-0.0282, 0.0987]$	$[-0.0455, 0.0129]$	–
A_{FB}	$[-0.118, 0.148]$	$[-0.0902, 0.0585]$	$[-0.0268, 0.0227]$
A_+	$[-0.140, 0.146]$	$[-0.112, 0.0819]$	$[-0.0213, 0.0164]$
A_-	$[-0.0664, 0.120]$	$[-0.0620, 0.0299]$	$[-0.0166, 0.0282]$

☑ New combination of observables

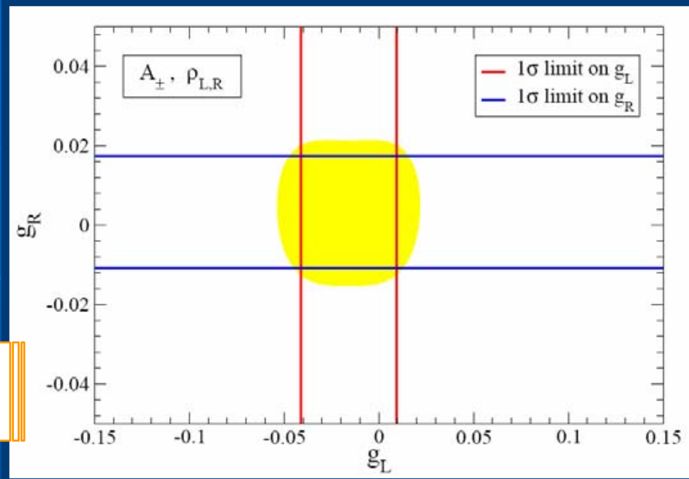
…but one can do better by combining the most sensitive measurements

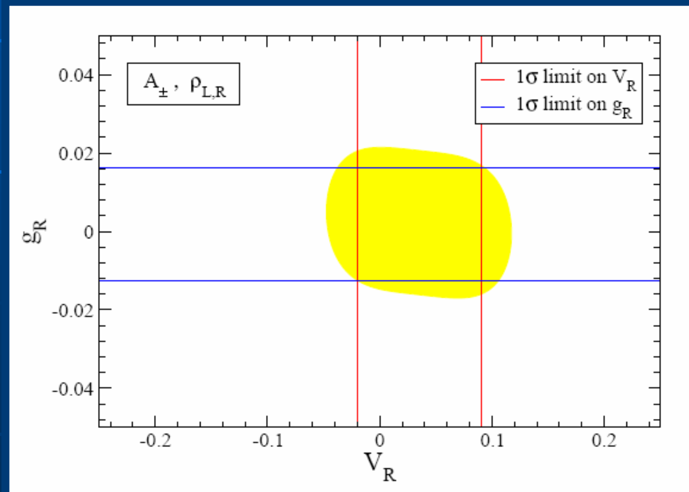
A_+, A_-, ρ_R and ρ_L

☑ New combination of observables

Anomalous Couplings in the $t \to bW$ decay

Two Dimension Regions:



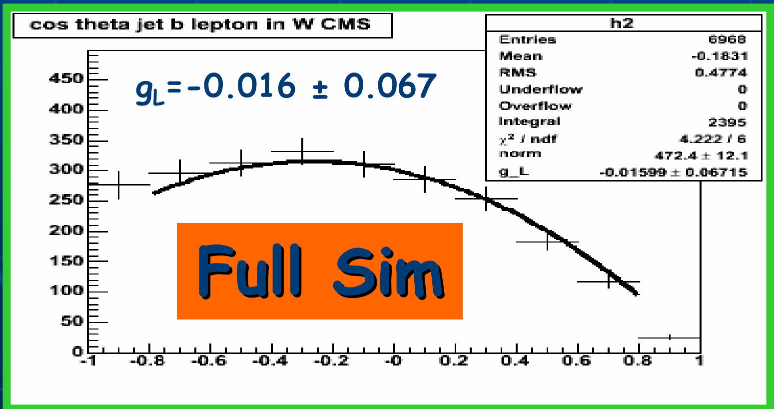


☒ Correlations Taken into Account: A_+, A_-, ρ_R and ρ_L

1σ Limits:

	V_R	g_L	g_R
$A_\pm, \rho_{R,L}$	$[-0.0195, 0.0906]$	×	×
$A_\pm, \rho_{R,L}$	×	$[-0.0409, 0.00926]$	×
$A_\pm, \rho_{R,L}$	×	×	$[-0.0112, 0.0174]$
$A_\pm, \rho_{R,L}$	×	$[-0.0412, 0.00944]$	$[-0.0108, 0.0175]$
$A_\pm, \rho_{R,L}$	$[-0.0199, 0.0903]$	×	$[-0.0126, 0.0164]$

☒ Studies with Full simulation under way (CSC):



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☑ Conclusions

- ☑ The ATLAS sensitivity to anomalous couplings at the Wtb vertex was presented for a luminosity of $10 fb^{-1}$. With this luminosity it is possible to constrain the anomalous couplings to the level of few % (taking into account the expected systematic errors)

- ☑ New observables were introduced (A_+,A_-,ρ_R and ρ_L) which have proven to be more sensitivity to new couplings

- ☑ The written contribution to the final report with all these results was sent to the contact persons

☑ Conclusions

Wtb Anomalous Couplings in Top Quark Decays

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Abstract
The sensitivity of the ATLAS experiment to Wtb anomalous couplings is studied with top quark pairs produced at the LHC which decay through the semileptonic channel, $t \to W^+ b$, $\bar{t} \to W^- \bar{b}$ with one of the W bosons decaying leptonically and the other hadronically. Several observables are discussed in order to achieve the best precision level on the measurement of the anomalous couplings. Combining the most sensitive observables, the precision achieved in the determination of Wtb anomalous couplings is of a few percent in the semileptonic channel alone.