Wtb anomalous couplings (ATLAS)

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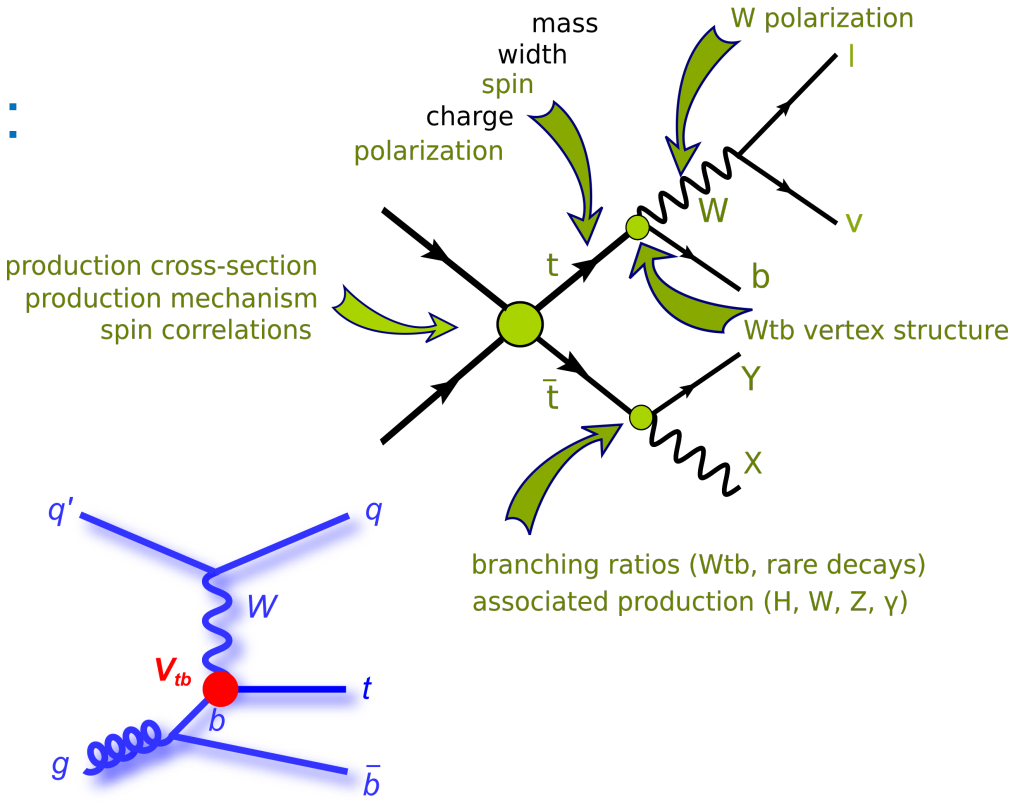
CERN/FP/123619/2011
CERN/FIS-NUC/0051/2015

Goal: measure top quark couplings in *Wtb*
☞ understand stresses with SM

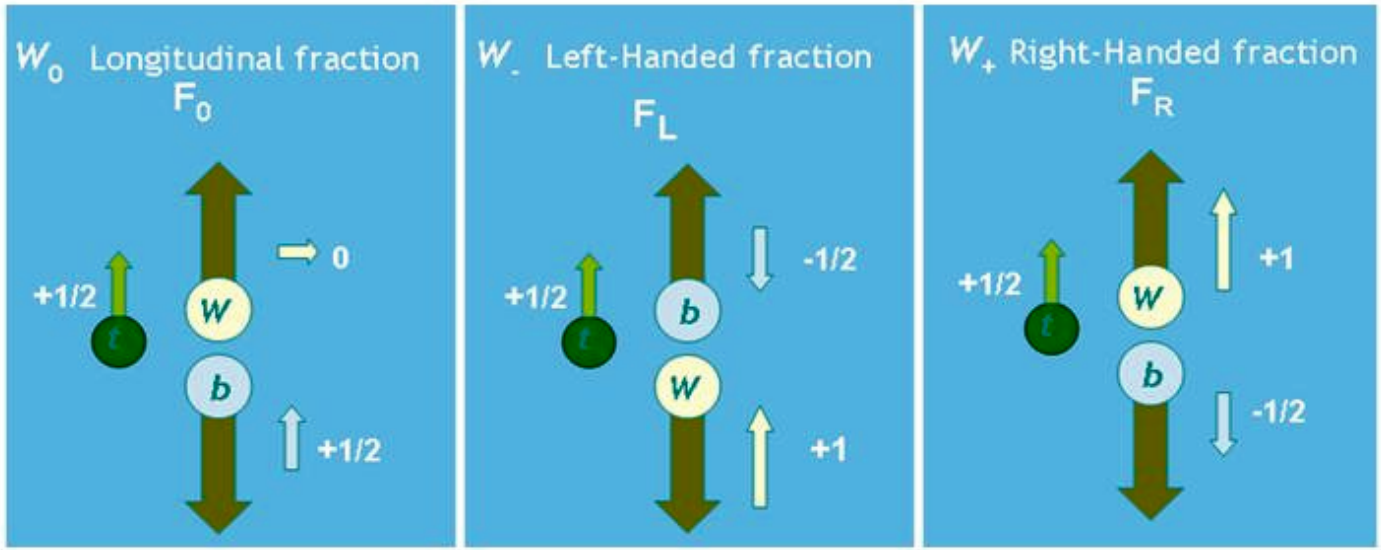
Already Explored by ATLAS:

- The *Wtb* vertex structure in $t\bar{t}$ events
- Single top quark physics
- Anomalous couplings (EFT parameters) at the *Wtb* vertex and fit of ATLAS observables



Angular distributions allow studying the vertex:

[Few observables=$F_{0,L,R}$, A_{+-0}, $\rho_{L,R}$]

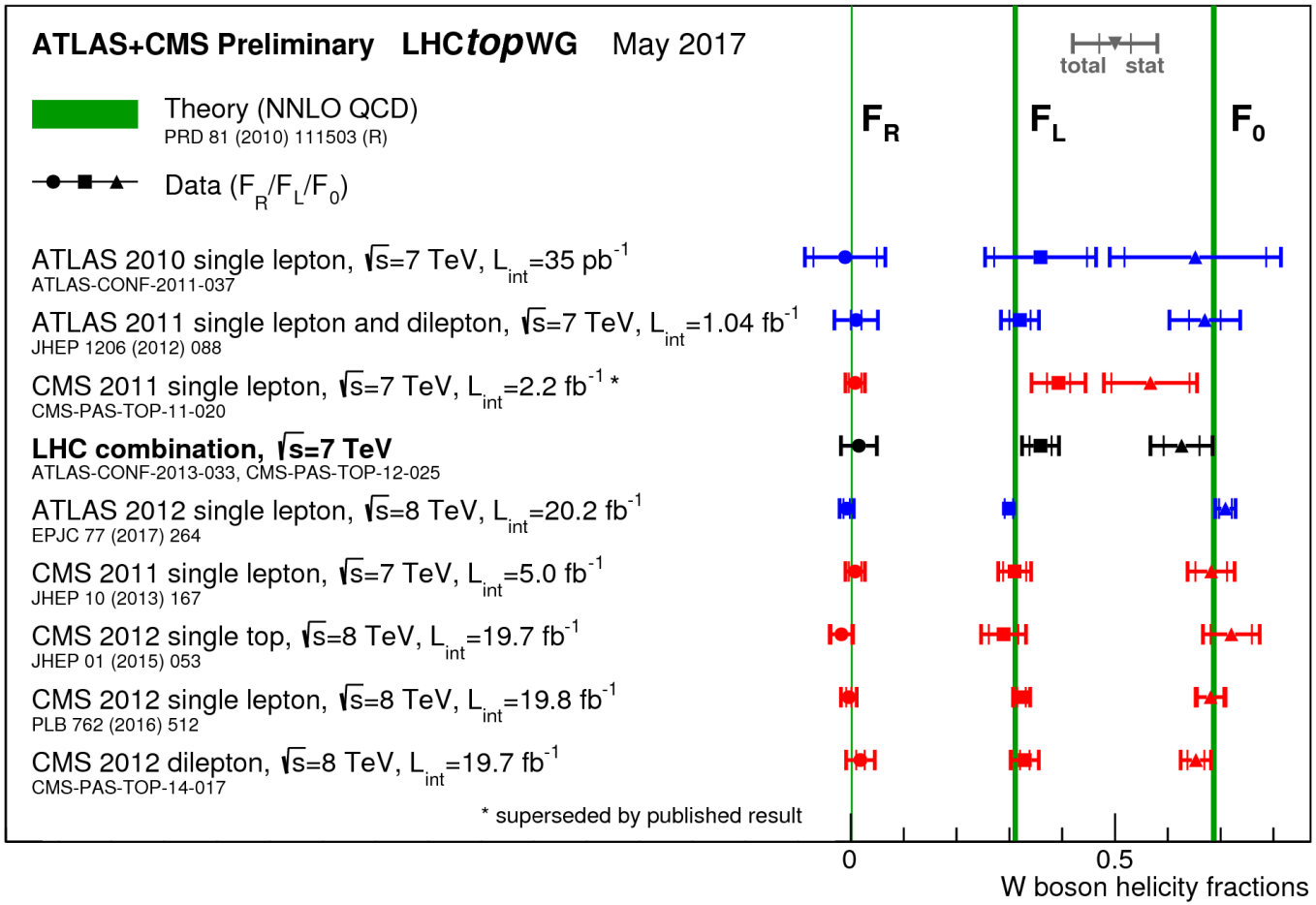


W bosons produced with different helicities:

$$F_0^{\mathrm{SM}} = 0.687 \pm 0.005 \quad F_{\mathrm{L}}^{\mathrm{SM}} = 0.311 \pm 0.005 \quad F_{\mathrm{R}}^{\mathrm{SM}} = 0.0017 \pm 0.0001,$$
$$(F_0 + F_{\mathrm{L}} + F_{\mathrm{R}} = 1)$$

@ NNLO QCD calculation, Phys. Rev. **D81** (2010) 111503

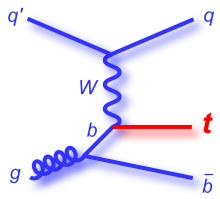
Summary of *W*-boson helicity meas. @ LHC



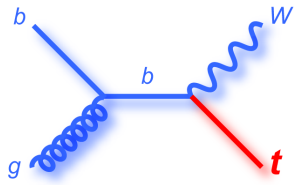
$\Delta F_0/F_0$=3%, $\Delta F_L/F_L$=5% F_R=-0.008$\pm$0.014

Single top quark physics

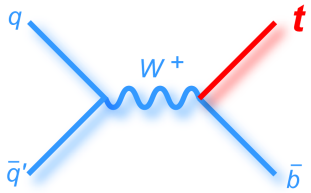
- All single top quark production cross sections used @ LHC:



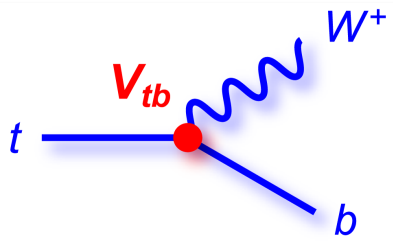
t-channel



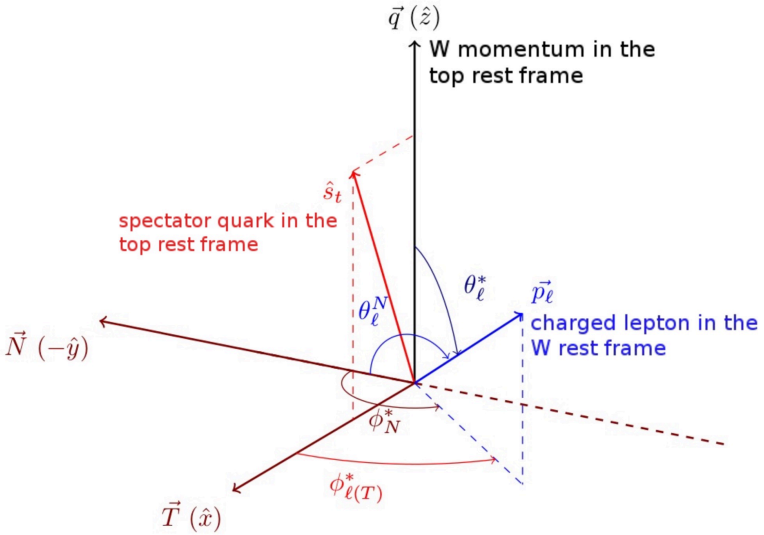
(*Wt*-prod.)



(*s*-channel)



- Angular distributions in *t*-channel exploited helicity formalism, PRD **93** (2016) 011301
  ☞ full spin-density matrix for *W* helicity fractions



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Asymmetry	Angular observable	Polarisation observable	SM prediction
$A_{\rm FB}^{\ell}$	$\cos\theta_\ell$	$\frac{1}{2}\alpha_\ell P$	0.45
$A_{\rm FB}^{tW}$	$\cos\theta_W \cos\theta^*_\ell$	$\frac{3}{8}P\,(F_{\rm R}+F_{\rm L})$	0.10
$A_{\rm FB}$	$\cos\theta^*_\ell$	$\frac{3}{4}\langle S_3\rangle = \frac{3}{4}\,(F_{\rm R}-F_{\rm L})$	−0.23
$A_{\rm EC}$	$\cos\theta^*_\ell$	$\frac{3}{8}\sqrt{\frac{3}{2}}\langle T_0\rangle = \frac{3}{16}\,(1-3F_0)$	−0.20
$A_{\rm FB}^{T}$	$\cos\theta^T_\ell$	$\frac{3}{4}\langle S_1\rangle$	0.34
$A_{\rm FB}^{N}$	$\cos\theta^N_\ell$	$-\frac{3}{4}\langle S_2\rangle$	0
$A_{\rm FB}^{T,\phi}$	$\cos\theta^*_\ell \cos\phi^*_T$	$-\frac{2}{\pi}\langle A_1\rangle$	−0.14
$A_{\rm FB}^{N,\phi}$	$\cos\theta^*_\ell \cos\phi^*_N$	$\frac{2}{\pi}\langle A_2\rangle$	0

Anomalous couplings/EFT parameters in global fits

General Wtb vertex

Eur.Phys.J. C50 (2007) 519-533

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

Vector (V_R) and Tensor like couplings (g_L, g_R) zero @ tree level in SM

- Angular distributions of the top decay products (and asymmetries) can be used to probe anomalous couplings at the *Wtb* vertex ☞ **Combination is the game!**

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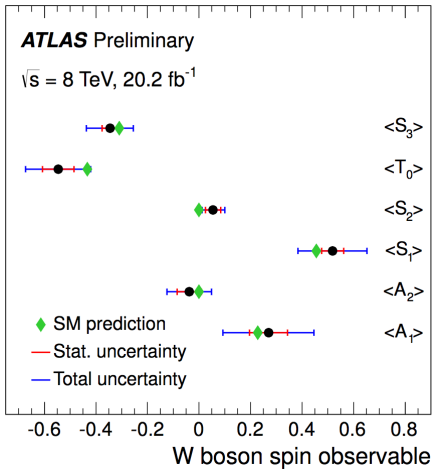
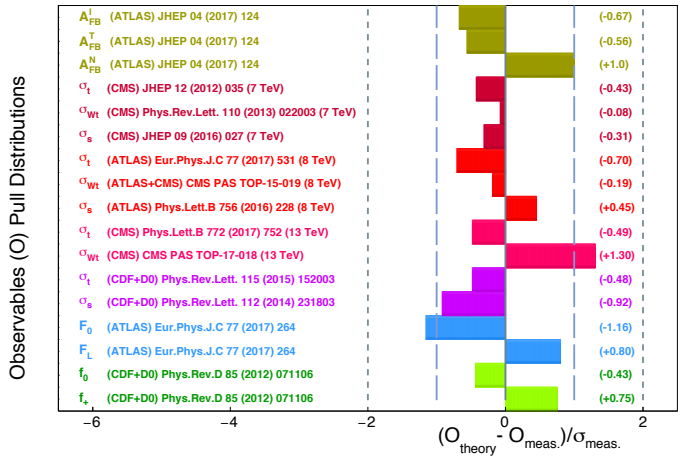
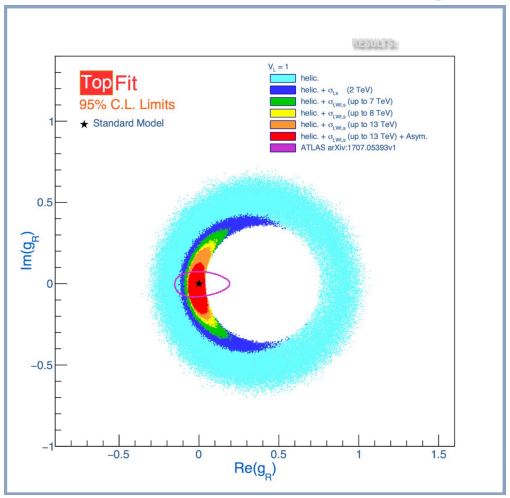


PRD 97 (2018) no.1, 013007



PRD 97 (2018) 1, 013007 (TopFit)



- **All couplings allowed to vary (Real and Imaginary parts)**

  ☞ **Still significant room for improvement?**

- **We expect to perform the same type of combination @ HL-LHC and HE-LHC**

Conclusions

- $t\bar{t}$ as well as single top quark observables expected to be studied for HL-LHC as well as HE-LHC
- **The team:** F. Déliot, M.Fiolhais, A. Onofre, R.Faria, P.Lagarelhos, C.M.Pease (HL-LHC generation and analysis) R.Martins and A.Reigoto (for HE-LHC generation, simulation)
- **The timescale:** two deadlines ahead (before December 2018) i.e.,
  June 2018, first results expected to be progressively available
  September 2018, for TOP2018
- **The deliverables:**
  Progressively understand how observables change sensitivity to anomalous/EFT parameters

Probably we need to understand what High Precision means @ HL-LHC and HE-LHC