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# Measurement of the W boson helicity using top pair events at $\sqrt{s} = 8$ TeV with the CMS detector

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This document gives an overview over the recent results on helicity measurement of W boson originated from top pair events. The results are obtained using data collected by the CMS detector at a center-of-mass energy of 8 TeV. The helicity measurements are confronted with the most precise theoretical predictions of the standard model.

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# 1 Introduction

Top quarks decay almost exclusively into a b quark and a W boson via the electroweak interaction. In particular, the measurement of the W boson polarization in the top quark decays allows to probe the tWb structure and to search for possible extensions of the standard model (SM).

In general, W bosons in the top quark decays can be produced in three states of left-handed, right-handed, and longitudinal helicity. Since the W boson couples to a b quark of left-handed chirality which translates into left-handed helicity in the massless limit of the b quark, right-handed W bosons are not expected to be produced in the top quark decays. Defining  $\Gamma_{L,0,R}$  as the partial width of the top quark decaying into left-handed, right-handed, and longitudinal W boson helicities, the helicity fractions are given by  $F_{L,0,R} = \frac{\Gamma_{L,0,R}}{\Gamma_{total}}$ .

The W boson polarization affects several kinematic variables in which can be used to measure the helicity components. Among all relevant kinematic observables which are sensitive to the W boson helicity fractions, the widely used one is the angular distributions of the top quark decay products. All following measurements employs this observable to extract the helicity fractions.

## 2 Measurement of the W boson helicity using $t\bar{t}$ events in the dilepton final state at $\sqrt{s} = 8$ TeV

The first analysis presented uses  $t\bar{t}$  events with two leptons, electrons and/or muons, in the final state [2]. The analysed data sample corresponds to an integrated luminosity of  $19.7 \text{ fb}^{-1}$  at a center of mass energy of 8 TeV, collected by the CMS detector [1]. Events are required to contain two charged leptons with opposite sign, missing transverse energy, and two b tagged jets. Background originating from Drell-Yan (DY) events is suppressed by requiring large missing energy in the  $e^+e^-$  and  $\mu^+\mu^-$  channels. In addition, dimuon or dielectron events in the region around the Z boson mass peak are also rejected. The contribution of DY+jets events in dimuon and dielectron is estimated from a Z boson mass window control region, and is used to normalize the simulation in the signal region. A analytical Matrix Weighting Technique (AMWT) [3] is used to reconstruct best top pair candidates. The  $\cos(\theta^*)$  distribution, which is used to perform the measurement, is presented in Figure 1.

In order to extract the W boson helicity fractions, a reweighting technique as explained in [4] is used. In this method, the reweighted signal distribution of  $\cos(\theta^*)$  in simulation is fitted to the observed distribution. The W boson helicity fractions, obtained from a fit to the reconstructed distributions of  $\cos(\theta^*)$ , are  $F_L = 0.329 \pm 0.029$ ,  $F_0 = 0.653 \pm 0.026$ , and  $F_R = 0.018 \pm 0.027$ .

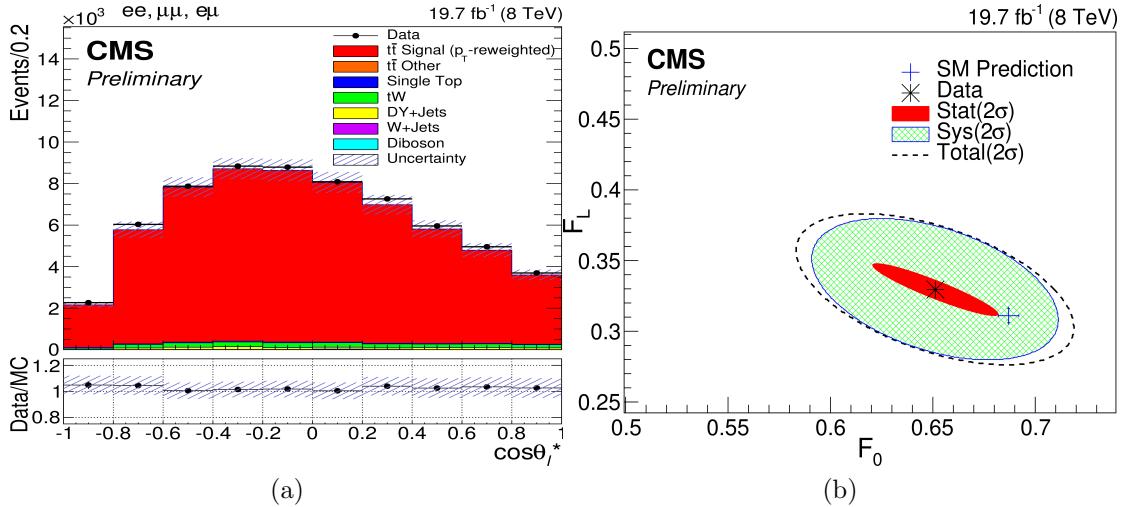


Figure 1: (a) Distribution of the  $\cos(\theta^*)$  for the three dilepton channels considered together. (b) The 95% region in the  $(F_0, F_L)$  plane obtained from the fit to data. The measured and theoretical values of the W boson helicity fractions are shown as well [2].

### 3 Measurement of the W boson helicity using $t\bar{t}$ events in the semi-leptonic final state at $\sqrt{s} = 8$ TeV

The CMS collaboration also reports the study of the W-boson helicity fractions in top-quark decays using a sample of  $t\bar{t}$  events where one of the top quarks decays semileptonically and the other decays hadronically [5]. The analysis is done using the collected data in 2012 with the CMS detector at the LHC, corresponding to an integrated luminosity of  $19.8 \text{ fb}^{-1}$ . The event selection requires either one muon or one electron, along with four jets in the final state in which two of them must be identified as originating from b quarks. Events with an additional soft muon or and additional soft electron are vetoed in order to reject backgrounds from dileptonic  $t\bar{t}$  and DrellYan events. To reduce the QCD multijet background, the transverse mass of the leptonically decaying W boson, is required to be greater than 30 GeV/c.

A kinematic fit is used to determine the best combination of b jets, other jets, and lepton candidates to the top quark and antiquark decay hypotheses. The reconstructed helicity angle distributions are then fitted to measure the W-boson helicity fractions and to derive possible anomalous tWb couplings.

Figure 2(a) shows the distribution for the  $\cos(\theta^*)$  of the helicity angle from the

leptonic  $\mu$ +jets branch. The measured W boson helicity fractions are found to be  $F_0 = 0.681 \pm 0.012$  (stat.)  $\pm 0.023$  (syst.),  $F_L = 0.323 \pm 0.008$  (stat.)  $\pm 0.014$  (syst.), and  $F_R = -0.004 \pm 0.005$  (stat.)  $\pm 0.014$  (syst.), which are consistent with the SM expectations. Figure 2(b) shows the measured W boson helicity fractions in the  $(F_0, F_L)$  plane with the allowed two-dimensional 68% and 95% CL regions.

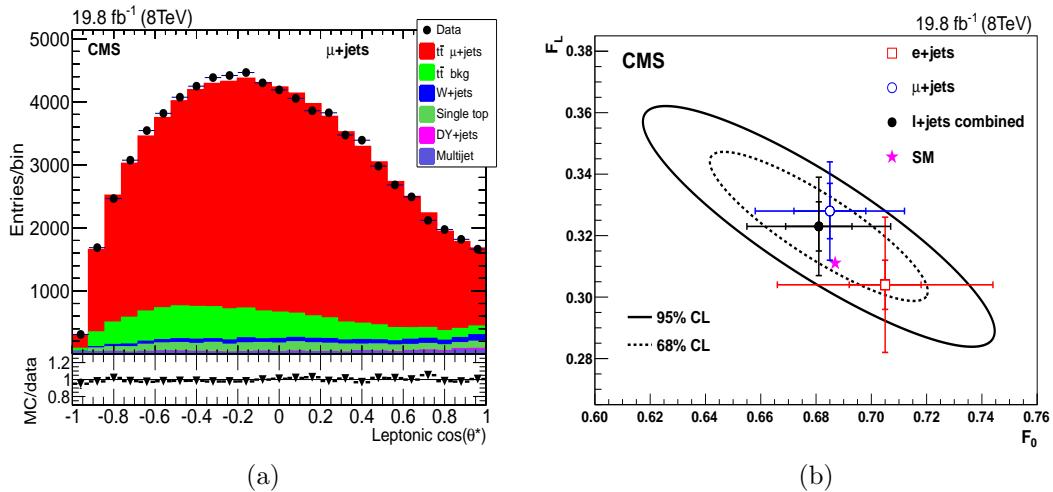


Figure 2: (a) Distribution of the  $\cos(\theta^*)$  in the leptonic branch. (b) The measured W boson helicity fractions in the  $(F_0, F_L)$  plane obtained from the fit to data [5].

## References

- [1] S. Chatrchyan *et al.* [CMS Collaboration], JINST **3**, S08004 (2008). doi:10.1088/1748-0221/3/08/S08004
- [2] M. Khakzad *et al.* [CMS Collaboration], CERN CMS-PAS-TOP-14-017, (2015) [<http://cds.cern.ch/record/2035390>].
- [3] B. Abbott *et al.* [D0 Collaboration], Phys. Rev. Lett. **80**, 2063 (1998) doi:10.1103/PhysRevLett.80.2063 [hep-ex/9706014].
- [4] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1310**, 167 (2013) doi:10.1007/JHEP10(2013)167 [arXiv:1308.3879 [hep-ex]].
- [5] V. Khachatryan *et al.* [CMS Collaboration], Phys. Lett. B **762**, 512 (2016) doi:10.1016/j.physletb.2016.10.007 [arXiv:1605.09047 [hep-ex]].