Top quark mass and property measurements at ATLAS experiment

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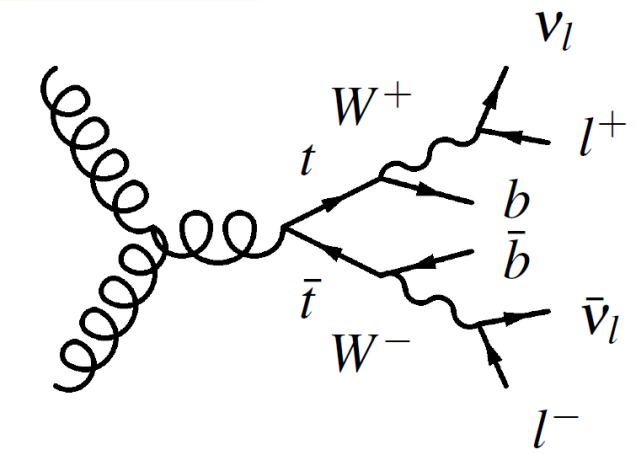
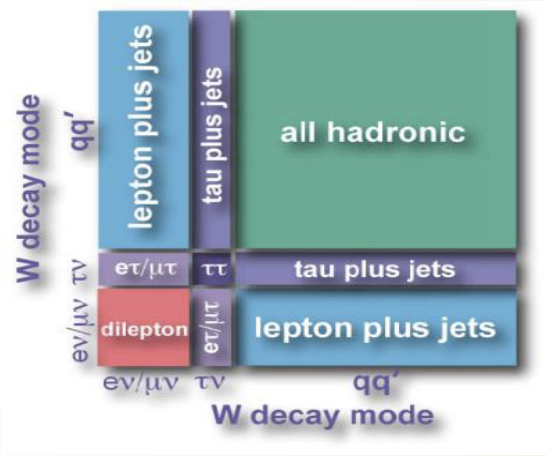
On behalf of ATLAS collabration

- 6M $t\bar{t}$ evt @ 8 TeV & 25 fb-1
- Decay before hadronization (probe quasi-bare quark), Access to properties through decay products
- Sensitive to new physics: spin, Charge, FCNC…

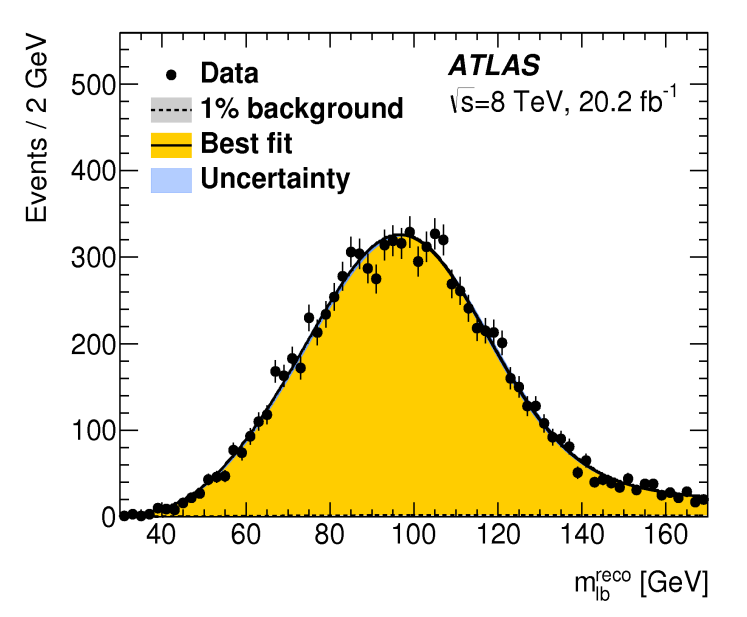


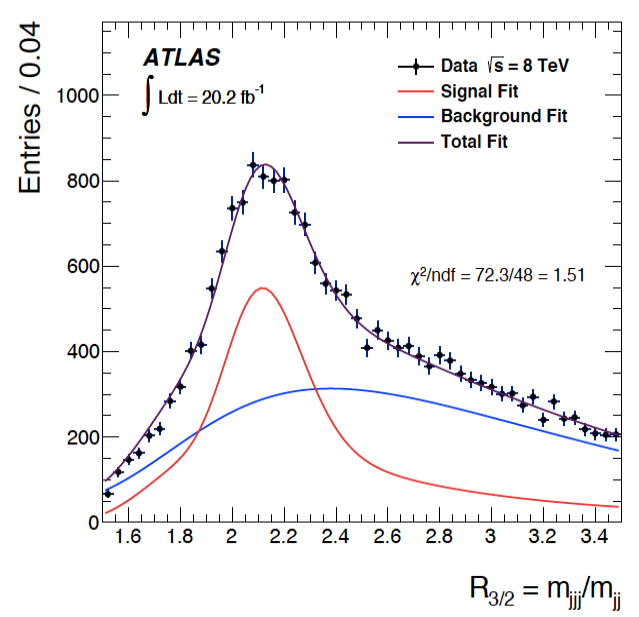


According to the decay mode of the W-boson, the tt chanel are clarified into di-lepton, single-lepton and fully-hardronic.

- **Dilepton channel**: Template of m_{lb} (mass lepton and b-jet, top mass are not able to constructed due to neutrino exit in top decay) are produced from MC, Maximum likelihood method used to extract the top mass and JES, bJES. s/B division simultaneously

- **All hardronic channel:** The $R_{3/2}$ (ratio of reconstructed top mass to w mass) defined as the observable. Fitted by template distribution with generalized least square method (considering bin to bin correlations).

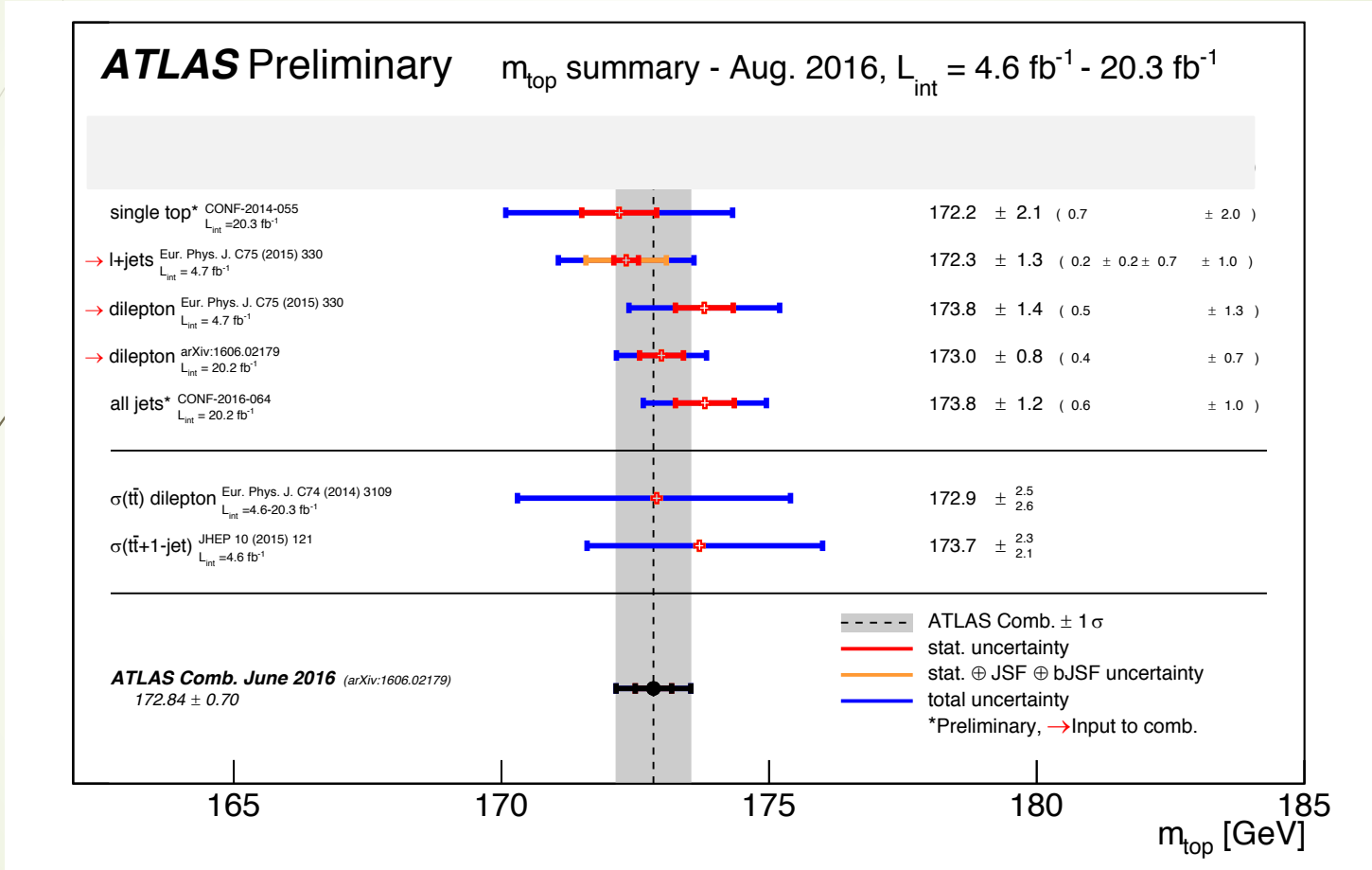




The main systematic comes from JES and bJES

[arXiv:1702.07546v1] [Physics Letters B 761 (2016) 350 – 371]

Summary of the measurements



8TeV $\int Ldt$=20.2fb^{-1}

A comprehensive observables related to top spin are measured with dilepton channel in one go, considering 3 orthogonal polarization directions of top quarks

In the formula below the direction (a/b) representing 3 possible direction

1. k: top quark flying direction,
2. n: perpendicular to k and beam,
3. r: the third direction

$$\frac{1}{\sigma}\frac{\mathrm{d}^2\sigma}{\mathrm{d}\cos\theta_+^a\,\mathrm{d}\cos\theta_-^b} = \frac{1}{4}(1 + B_+^a\cos\theta_+^a + B_-^b\cos\theta_-^b - C(a,b)\cos\theta_+^a\cos\theta_-^b)$$

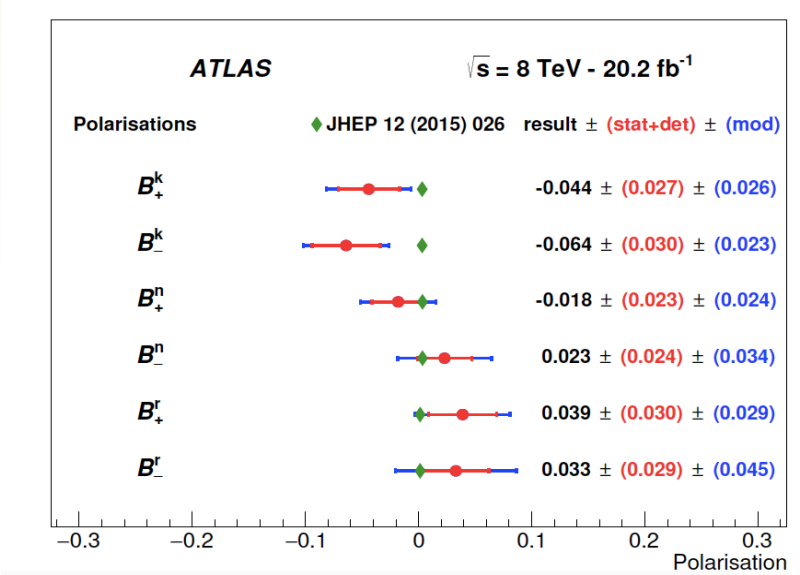
Totally 15 observables are measured, 3 for top polarization, 3 for anti-top polarization, 9 for spin correlations.

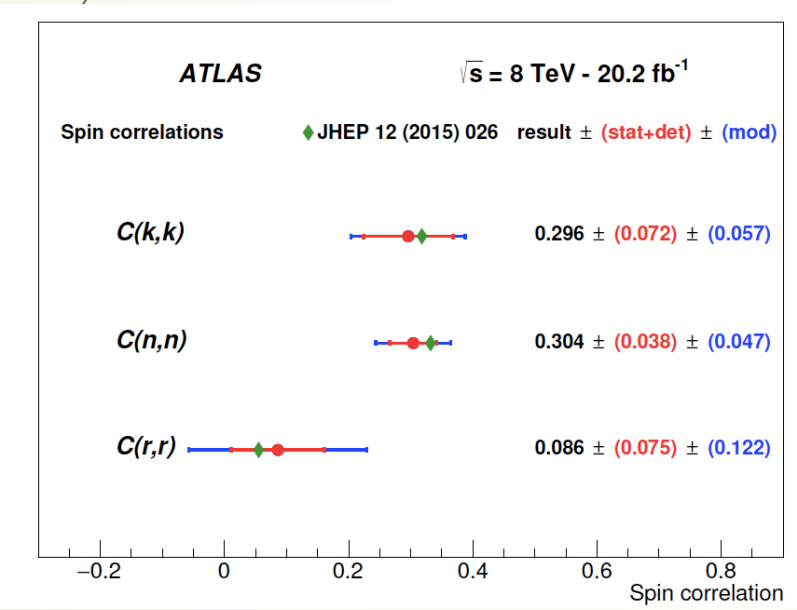
[JHEP03(2017)113]

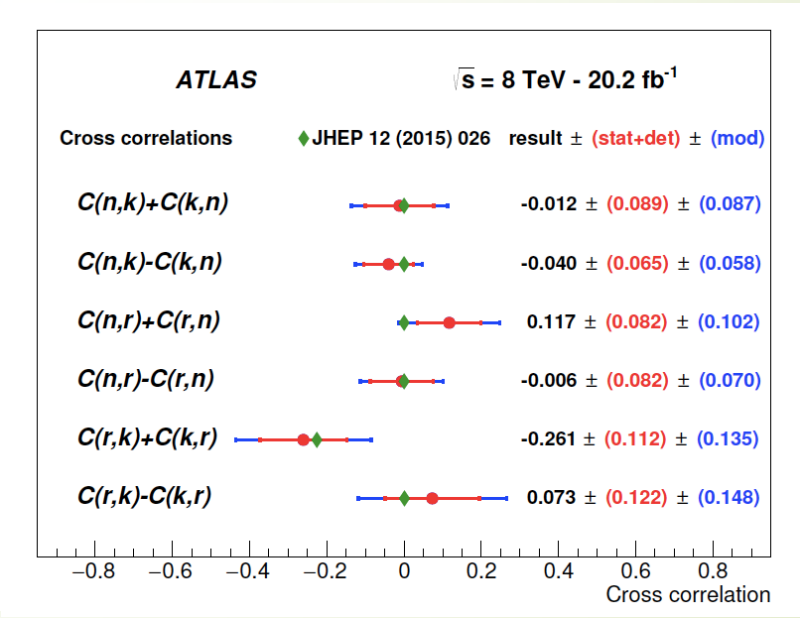
Top Polarizaiotn and Spin correlations

8TeV $\int Ldt$=20.2fb^{-1}

All the measurements are consistent with SM prediction (diamond in plots)





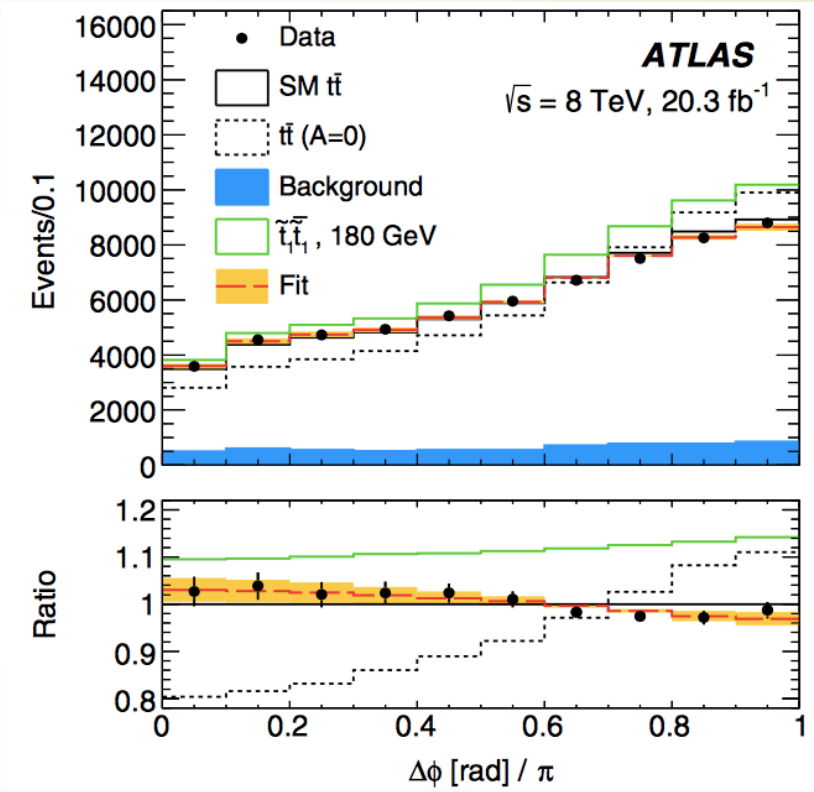


[JHEP03(2017)113]

8TeV $\int Ldt$=20.2fb^{-1}

The azimuthal opening angle, between the momentum directions of the top quark pair decay products in the laboratory frame $\Delta\phi$.

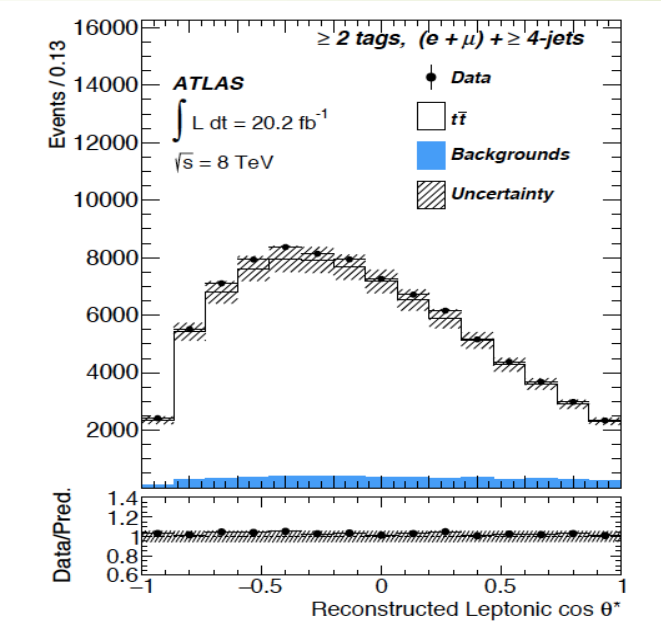
$f_{SM} = 1.20 \pm 0.05(\text{Stat}) \pm 0.13(\text{Syst})$



[PRL 114, 142001 (2015)]

8TeV $\int Ldt$=20.2fb^{-1}

Single lepton channel: the angle between the W decay product and the b-jet in the W boson rest frame are measured

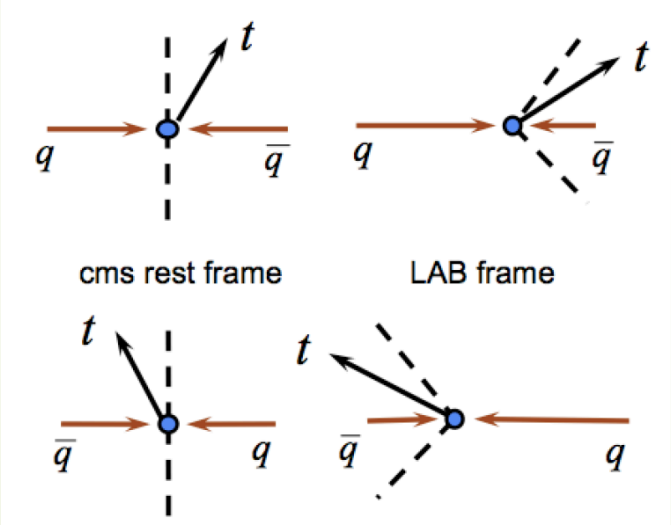


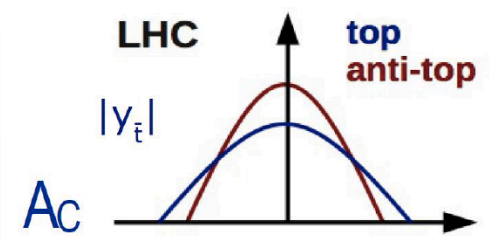
$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta^*} = \frac{3}{4}\left(1-\cos^2\theta^*\right)F_0 + \frac{3}{8}(1-\cos\theta^*)^2 F_L + \frac{3}{8}(1+\cos\theta^*)^2 F_R$$

The most precise measurement up to date is F_0 = 0.709±0.019, F_L = 0.299±0.015 and F_R =-0.008±0.014, consistent with SM predictions

[Eur. Phys. J. C (2016) 76: 432]

- top quarks pair production at NLO give non zero charge asymmetry from interferences between diagrams or enhanced by other models
- t quark is more forward than anti t quark

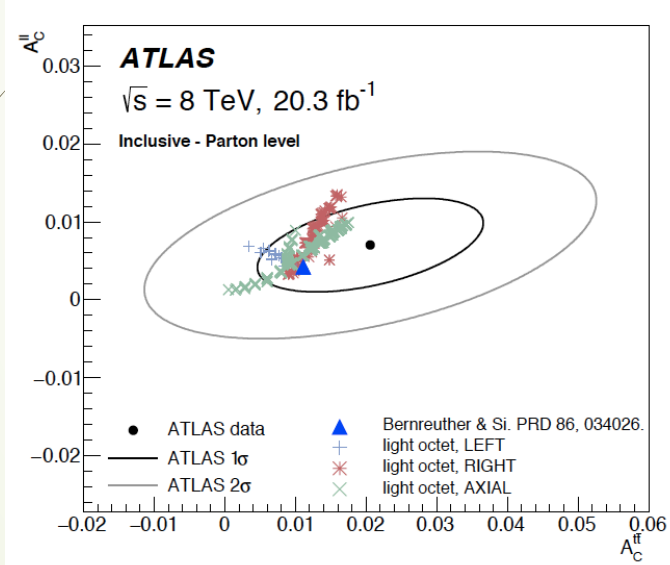


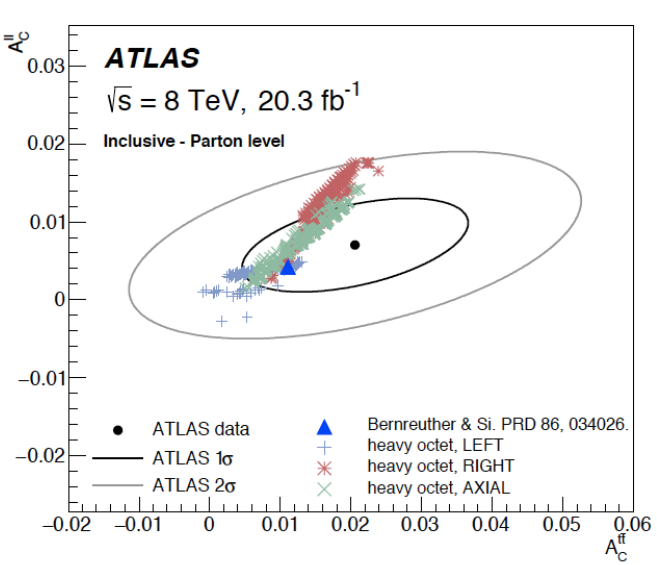


Dilepton channel

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

$$A_C^{t\bar{t}} = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$



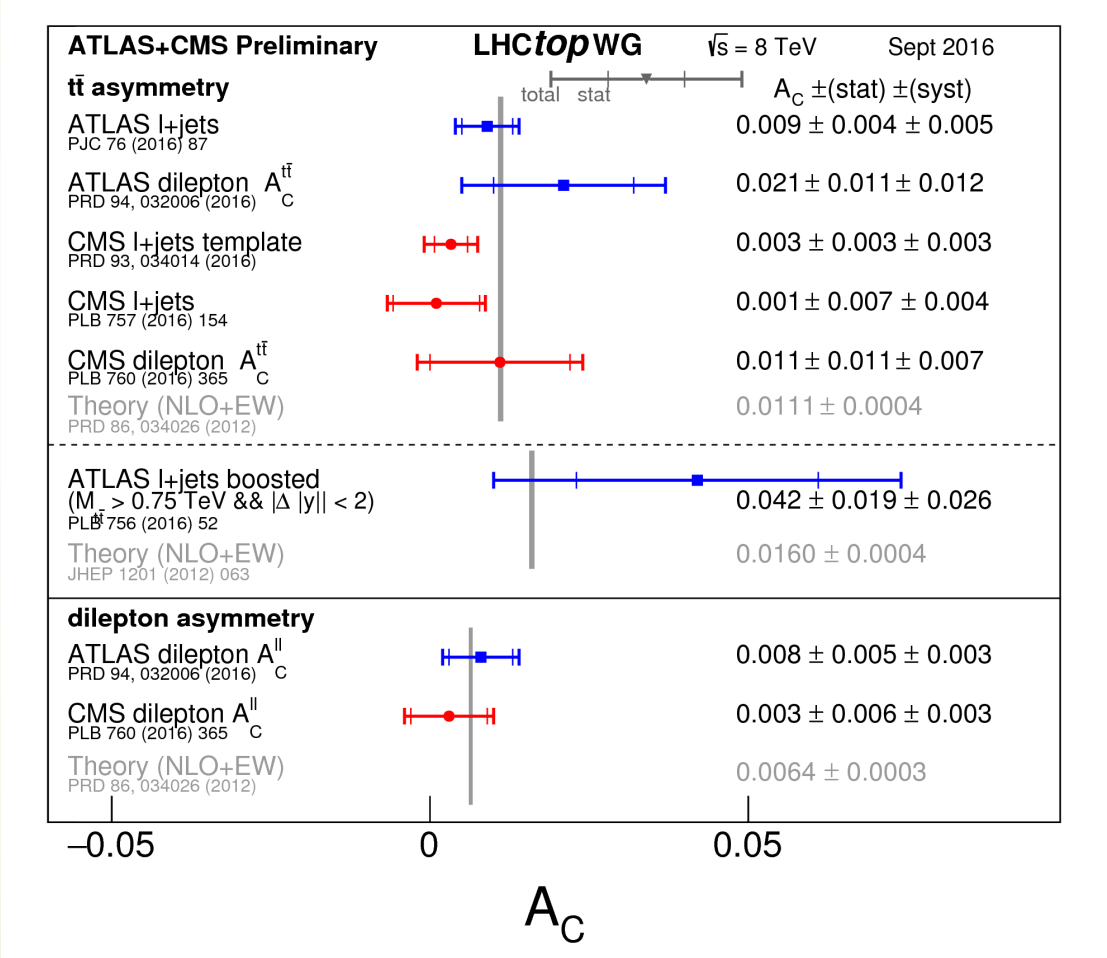


$$A_C^{\ell\ell} = 0.008 \pm 0.006$$

$$A_C^{t\bar{t}} = 0.021 \pm 0.016.$$

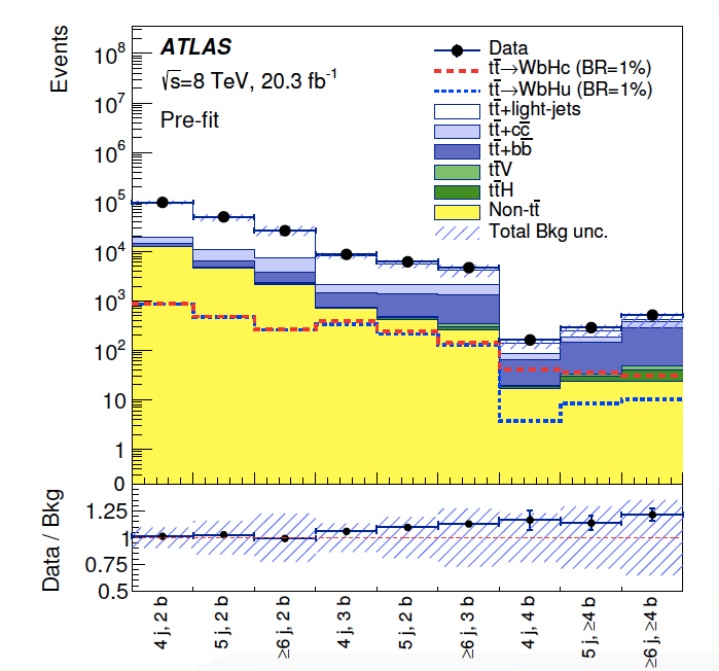
[PHYSICAL REVIEW D 94, 032006 (2016)

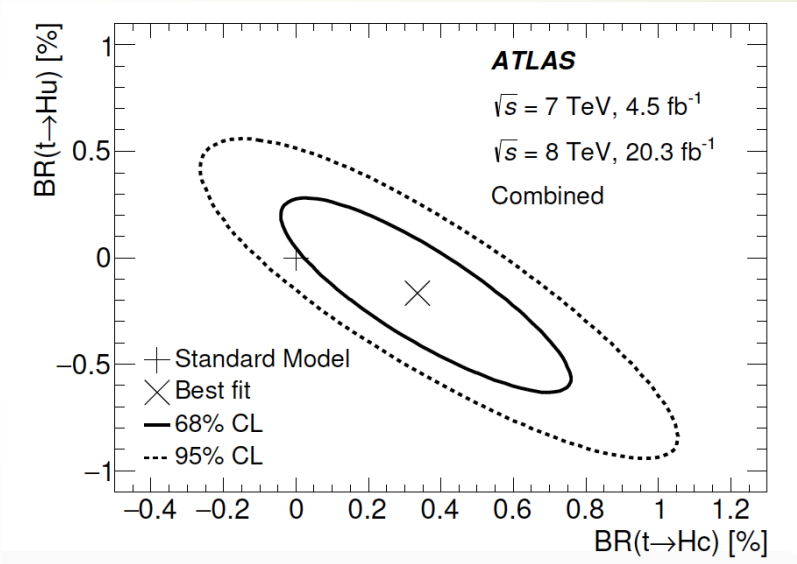
Summary of the measurement and with CMS results added



$t\bar{t} \rightarrow Wb(W \rightarrow l\nu)Hq(H \rightarrow bb)$ are defined as signals

Likelihood discriminator utilizing the kinematic info from resonance distribution (Lepontic top mass, hadronic top mass and Higgs mass) is defined to separate the signal and background





Combine the result of analysis of H→WW*,$\gamma\gamma, \tau\tau$, the 95% CL upper limits on the t→Hc and t→Hu branching ratios are 0.46% and 0.45% respectively.

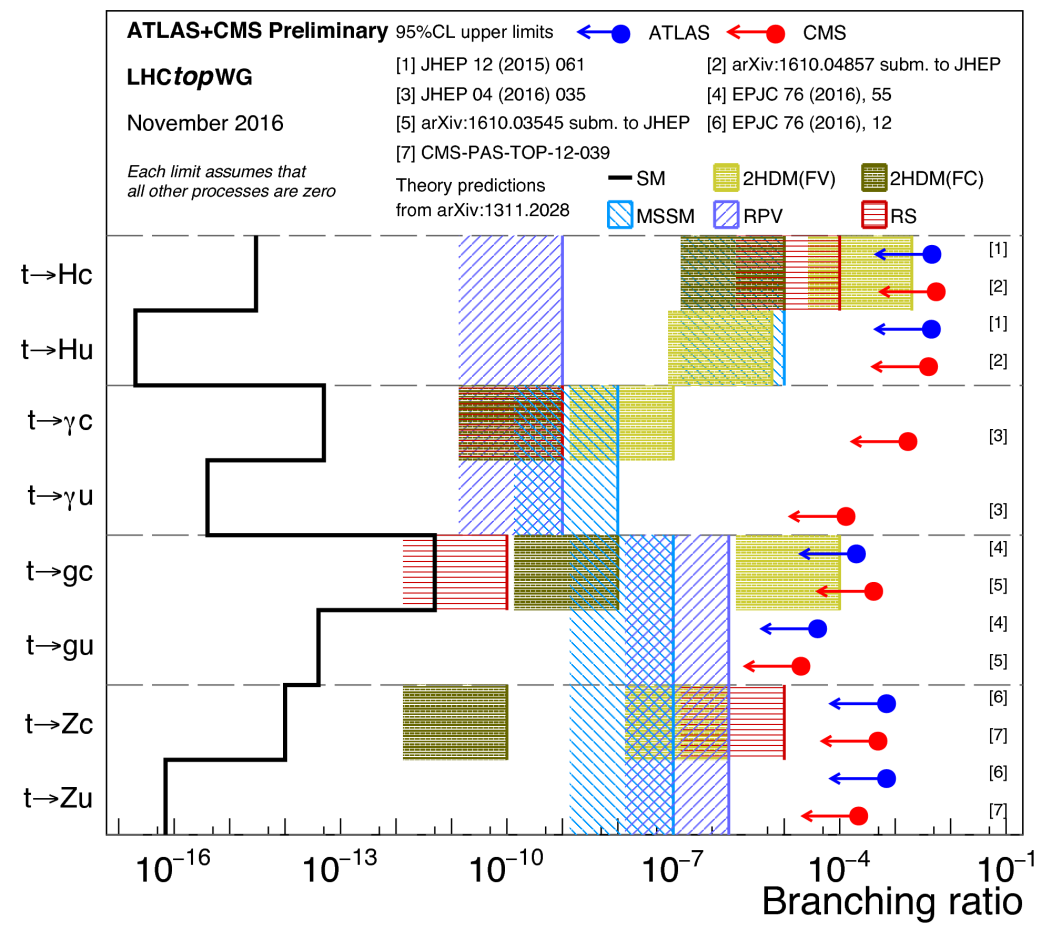
[arXiv:1509.06047v2]

- $t\bar{t} \rightarrow Wb(W \rightarrow l\nu)Zq(H \rightarrow ll)$ **are defined as signals**
- Background are estimated and validated with MC and control data. No signal excess observed and the at BR<7*10-4(95%CL)

Sample	Yields
WZ	$1.3 \pm 0.2 \pm 0.6$
$t\bar{t}V$	$1.5 \pm 0.1 \pm 0.5$
tZ	$1.0 \pm 0.1 \pm 0.5$
Fake leptons	$0.7 \pm 0.3 \pm 0.4$
Other backgrounds	$0.2 \pm 0.1 \pm 0.1$
Total background	$4.7 \pm 0.4 \pm 1.0$
Data	3
Signal efficiency [$\times 10^{-4}$]	$7.8 \pm 0.1 \pm 0.8$

[arXiv:1508.05796v2]

Summary of the FCNC measurement, including the CMS results



8TeV $\int Ldt$=20.2fb^{-1}

- **Dilepton channel**
- Lepton from top decay to tag the charge of the b quark and charge of muon in b-jets used to probe the charge asymmetry

$$A^{\mathrm{ss}} = \frac{P\left(b \to \ell^{+}\right) - P\left(\bar{b} \to \ell^{-}\right)}{P\left(b \to \ell^{+}\right) + P\left(\bar{b} \to \ell^{-}\right)}, \qquad A^{\mathrm{os}} = \frac{P\left(b \to \ell^{-}\right) - P\left(\bar{b} \to \ell^{+}\right)}{P\left(b \to \ell^{-}\right) + P\left(\bar{b} \to \ell^{+}\right)},$$

- The charge asymmetry is the sum of the contributions from several CP asymmetry cases

$$A^{\mathrm{ss}} = r_b A^{b\ell}_{\mathrm{mix}} + r_c \left(A^{bc}_{\mathrm{dir}} - A^{c\ell}_{\mathrm{dir}}\right) + r_{c\bar{c}} \left(A^{bc}_{\mathrm{mix}} - A^{c\ell}_{\mathrm{dir}}\right)$$

$$A^{\mathrm{os}} = \tilde{r}_b A^{b\ell}_{\mathrm{dir}} + \tilde{r}_c \left(A^{bc}_{\mathrm{mix}} + A^{c\ell}_{\mathrm{dir}}\right) + \tilde{r}_{c\bar{c}} A^{c\ell}_{\mathrm{dir}}$$

[JHEP02(2017)071]

8TeV $\int Ldt$=20.2fb^{-1}

- The change asymmetry is measured to compatible to zero, consistent with the simulation with no CP violation embedded
- The largest uncertainty is statistical uncertainty and then from the modeling and JES

$$A^{ss} = -0.007 \pm 0.006\ (\text{stat.})\ ^{+0.002}_{-0.002}\ (\text{expt.}) \pm 0.005\ (\text{model})$$
$$A^{os} = 0.0041 \pm 0.0035\ (\text{stat.})\ ^{+0.0013}_{-0.0011}\ (\text{expt.}) \pm 0.0027\ (\text{model})$$

- The charge asymmetry are converted to the cp asymmetries, which are consistent with 0.

Summary

- The most precise top mass measurement is 172.84±0.70GeV from ATLAS, dilpton channel combination. This top mass is corresponding to the top mass used in the ttbar MC simulation.
- The top/W polarization, spin correlation, and top charge asymmetry are compatible with SM prediction at the current precision.
- FCNC process are far from discovered with now data even with the enhanced cross section according to BSM