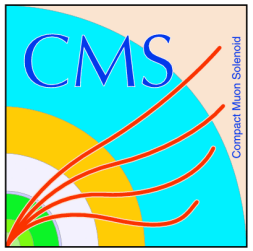
Anomalous creation and decay of top quarks

Satoshi HASEGAWA (Nagoya University)
on behalf of the ATLAS and CMS collaborations.
hasegawa@hepl.phys.nagoya-u.ac.jp



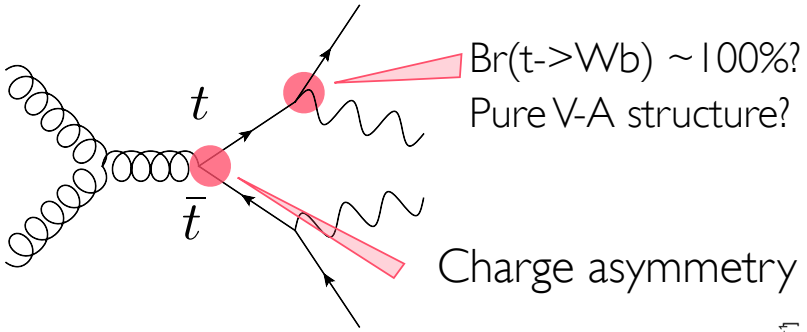
24th Rencontres de Blois, Particle Physics and Cosmology, May 30th.

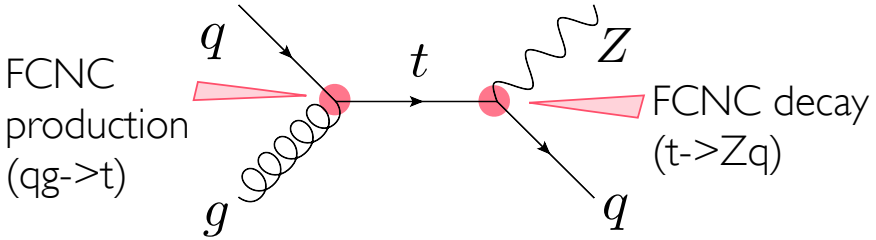
2 Why do we look into top quark?

Top quark : the heaviest elementary particle with mass of 173GeV

- The enormous mass may be related to the SSB and/or New Physics.
- Due to the high mass, new physics may appear in its production/decay.

Top quark production and decay can have information of new physics.



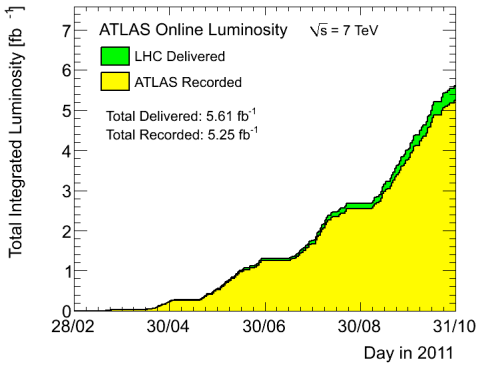


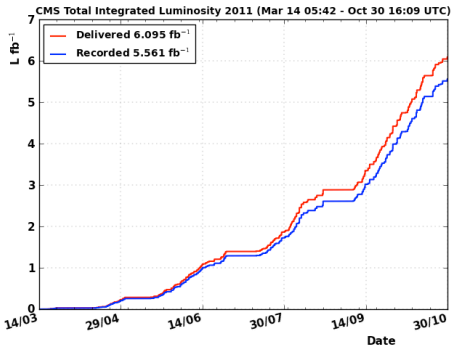
Data taking in 2011

pp collision with sqrt(s) = 7 TeV

data of ~5/fb in each experiment

= ~ 800,000 top quark pairs

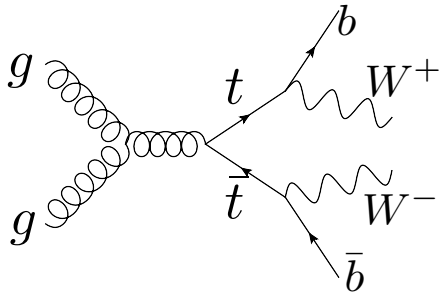




It's time for precise measurement!

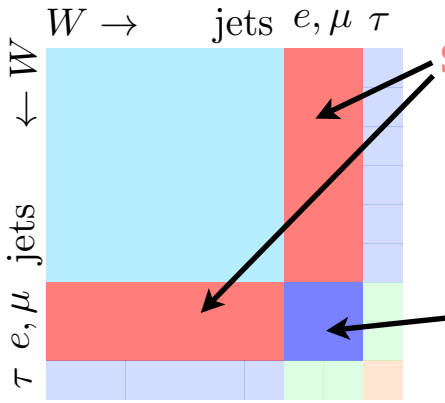
3 Top physics study at ATLAS & CMS

Typical channels in the top quark analyses



At least two jets from b-quark
+
two W boson decays

$$\sigma_{\mathrm{theory}}(pp \to t\bar{t}) = 165^{+11}_{-16}\mathrm{pb}^{(*)}$$



Single lepton channel
- two more jets
- one lepton
- missing ET

Di-lepton channel
- two leptons
- missing ET

Leptons

- are signature to achieve high S/N.
- play key role to look top quark properties.

Topics from ATLAS and CMS

- Cross section
- Property (charge, mass, ...)
- Search for resonances
- **Anomalous production and decay**

Charge asymmetry
1/fb , 4.7/fb

Same-sign top-quark production
1/fb, 4.7/fb

Top quark decay branching ratio(Vtb)
2.2/fb

W boson polarization
1/fb, 2.2/fb

FCNC production and decay
2/fb(tqg), 0.7/fb(tZq), 4.6/fb (tZq)

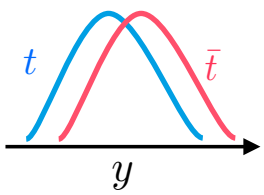
from ATLAS and CMS

(*) Nucl. Phys. Proc. Suppl. 183 (2008) 75–80, arXiv:0907.2527 [hep-ph].

4 Charge asymmetry

It has been a hot topic since the Tevatron experiments reported tensions.

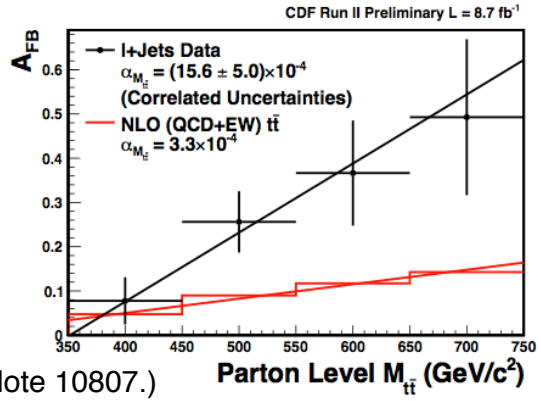
$\mathrm{Tevatron}(p\bar{p})$ → seen as F/B asymmetry.



$$\Delta y = y_t - y_{\bar{t}} \qquad A_{\mathrm{FB}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

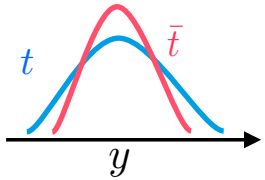
CDF : $A_{\mathrm{FB}} = 0.162 \pm 0.047(\mathrm{stat.} + \mathrm{syst.})$

Expectation : $A_{\mathrm{FB}} = 0.066$ (POWHEG) $A_{\mathrm{FB}} = 0.067$ (MC@NLO)



(CDF : Conf. Note 10807.)

$\mathrm{LHC}(pp)$ → Central/Forward asymmetry.

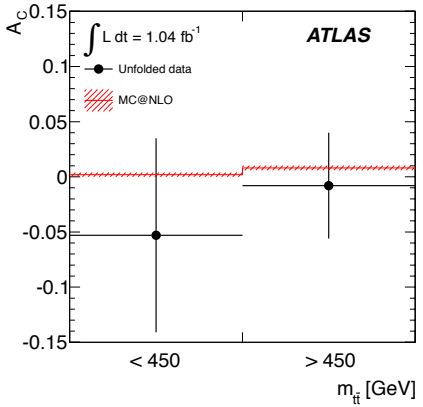


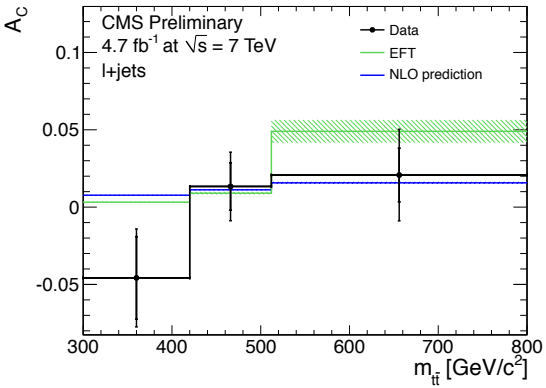
$$\Delta y = |y_t| - |y_{\bar{t}}|$$

ATLAS(SingleLepton channel)

$$A_C = -0.018 \pm 0.028(\mathrm{stat.}) \pm 0.023(\mathrm{syst.})$$

$A_{C,\mathrm{expect}} = 0.006 \pm 0.002$ MC@NLO generator





CMS (SingleLepton channel)

$$A_C = 0.004 \pm 0.010(\mathrm{stat.}) \pm 0.012(\mathrm{syst.})$$

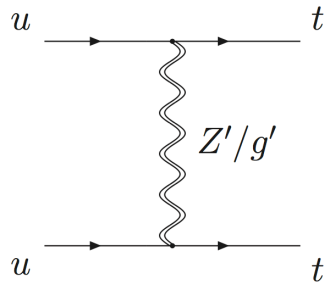
$A_{C,\mathrm{expect}} = 0.0115 \pm 0.0006$ SM expectation (*)

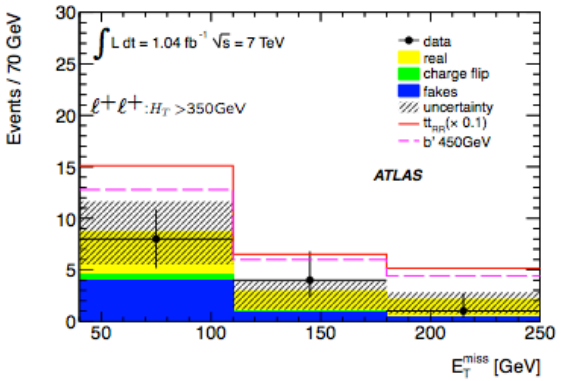
Neither inclusive excess nor mass dependence were seen.

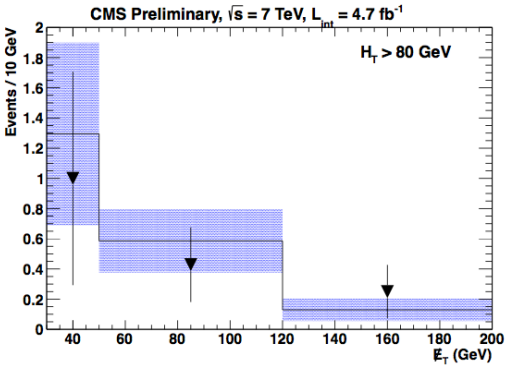
(*)arXiv:1109:6830

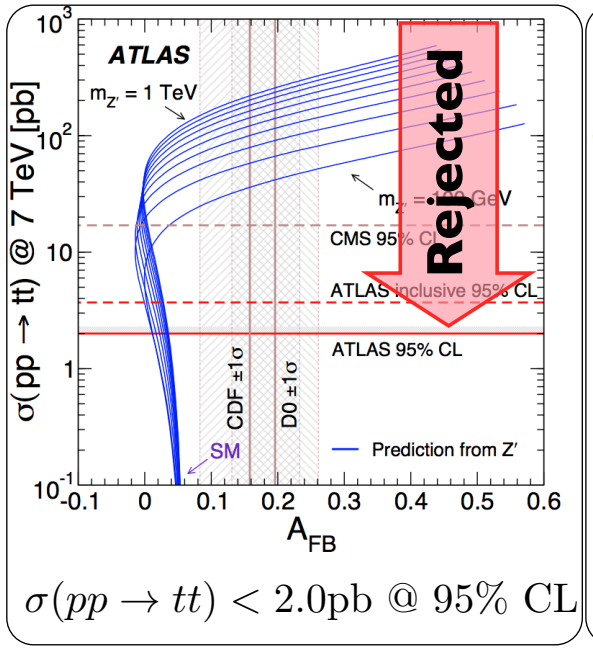
5 Same sign top-quark production

It is interesting especially for Z' search.
-- Z' can explain charge asymmetry observed at the Tevatron.
Basic strategy : di-lepton with the same charge, missing ET, two jet
CMS required two b-tagged jets to reduce $t\bar{t}$ background.
No excess was observed in ATLAS and CMS.

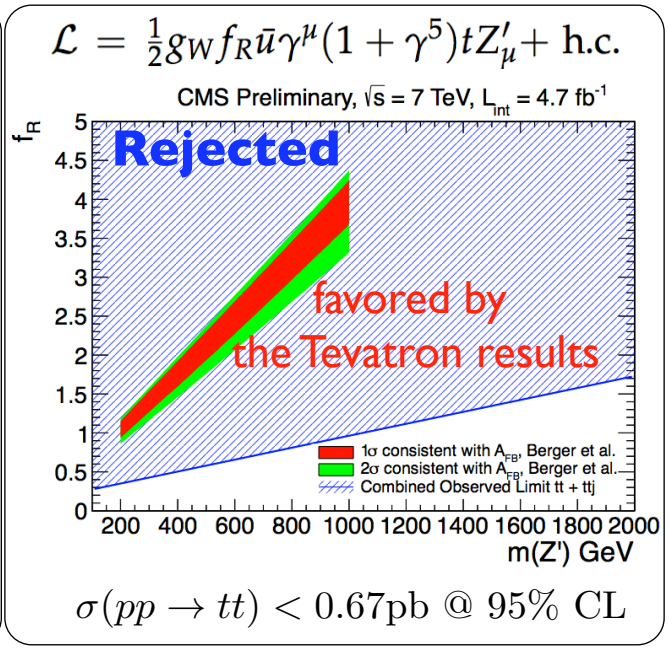








$\sigma(pp \to tt) < 2.0\text{pb}$ @ 95% CL



$\sigma(pp \to tt) < 0.67\text{pb}$ @ 95% CL

Both results excluded Z' parameter region favored by the Tevatron's F/B asymmetry results.

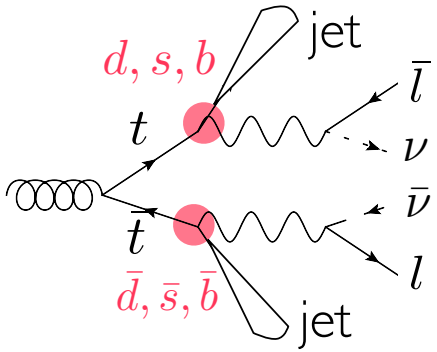
6 R=Br(t->Wb)/Br(t->Wq) measurement

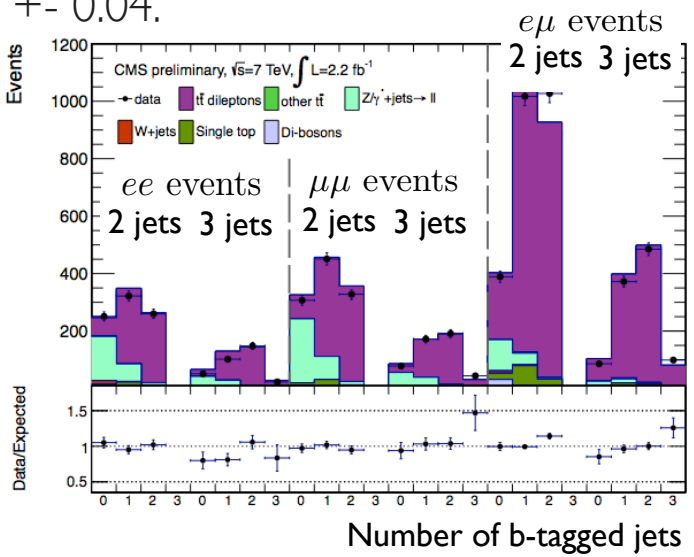
Test of CKM matrix --$|V_{tb}| = 0.999152^{+0.000030}_{-0.000045}$ (PDG2010) and R is expected to be 99.8%

D0 experiment reported some tension : R = 0.90 +- 0.04.

Count the number of b-tagged jets in events with 2 and 3 jets in $t\bar{t}$ di-lepton channel.

$$R = \frac{\mathrm{BR}(t \to Wb)}{\mathrm{BR}(t \to Wq)}$$





Multiplicity(Pk) of b-tagged jets is a function of **R**.

e.g : the simplest case, two jets from the top quarks,

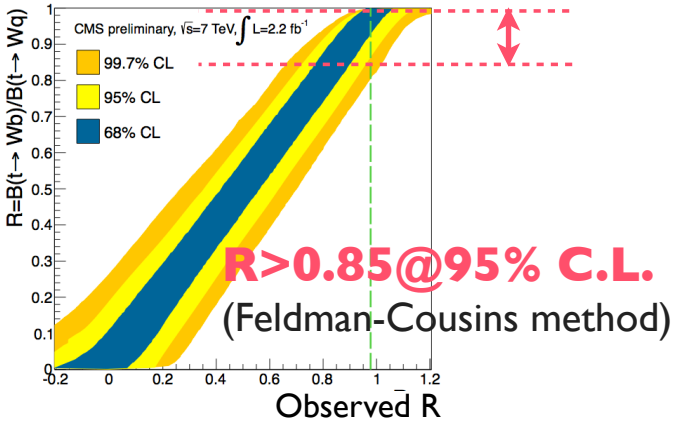
$$P_k = R^2\varepsilon_b^2 + 2R(1-R)\varepsilon_b\varepsilon_q + (1-R)^2\varepsilon_q^2$$

Obtain R from likelihood maximization

observed **expected**

$$\mathcal{L} = \prod_{\ell\ell} \prod_{jets \geq 2} \prod_{k=0}^{jets} \mathcal{P}_{oisson}\left[N_{ev}^{\ell\ell,jets}(k), \hat{N}_{ev}^{\ell\ell,jets}(k)\right] \prod_{x} \mathcal{G}_{aus}(x, \bar{x}, \sigma_x)$$

Nuisance parameters
such as b-tag efficiency



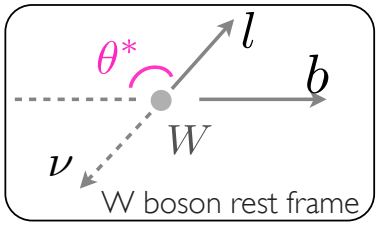
R>0.85@95% C.L.
(Feldman-Cousins method)

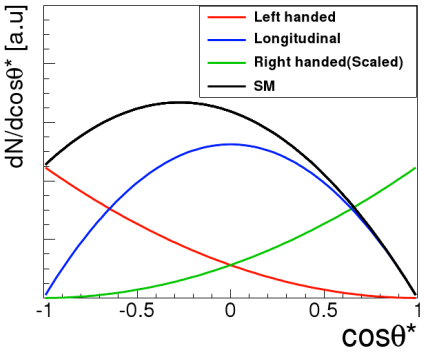
7 W boson polarization measurement

Vertex structure among t-W-b :

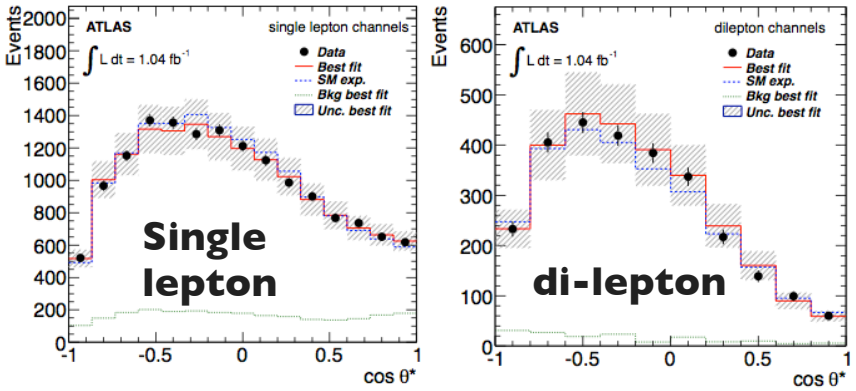
$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}(V_L P_L + V_R P_R)tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{m_W}(g_L P_L + g_R P_R)tW_{\mu}^{-} + \text{h.c.}$$

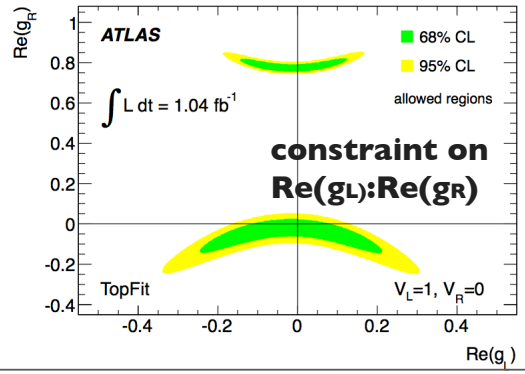
The structure is seen in W boson polarization
-> lepton emission angle distribution.



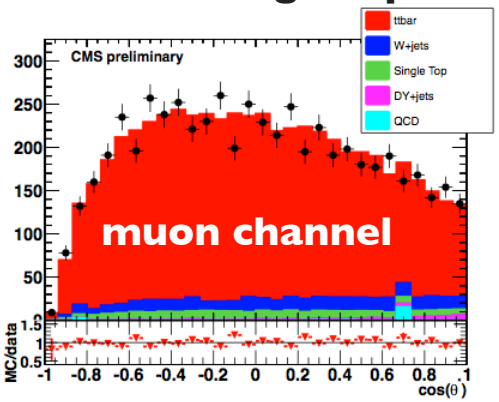


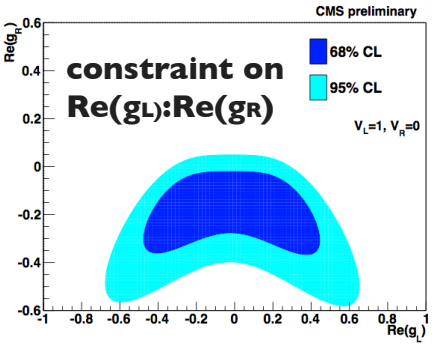
ATLAS : Single lepton +dilepton channel





CMS : Single lepton channel(muon)



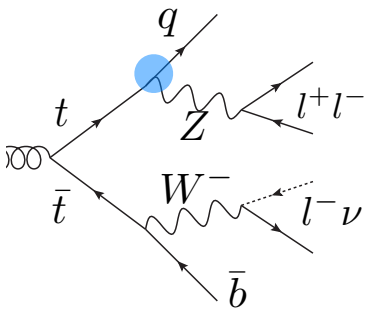


If we look into gR ....($g_R = \sqrt{2}C_{uW}^{33}\frac{v^2}{\Lambda^2}\cdot$)

From **ATLAS** $\mathrm{Re}(C_{uW}^{33})/\Lambda^2 \in [-1.0, 0.5]\mathrm{TeV}^{-2}$
(stat. and syst. included)

From **CMS** $\mathrm{Re}(C_{uW}^{33})/\Lambda^2 =$
$-0.813 \pm 0.615(\mathrm{stat.})^{+0.847}_{-0.951}(\mathrm{syst.})\mathrm{TeV}^{-2}$

8 "tZq" search in top quark pair decay



Basic strategy : $t\bar{t} \to bW + qZ \to bl\nu + qll$ and reconstruction.

ATLAS : reconstruct event based on chi2 minimization.

$$\chi^2 = \frac{\left(m^{\rm reco}_{j_a\ell_a\ell_b} - m_t\right)^2}{\sigma_t^2} + \frac{\left(m^{\rm reco}_{j_b\ell_c\nu} - m_t\right)^2}{\sigma_t^2} + \frac{\left(m^{\rm reco}_{\ell_c\nu} - m_W\right)^2}{\sigma_W^2} + \frac{\left(m^{\rm reco}_{\ell_a\ell_b} - m_Z\right)^2}{\sigma_Z^2},$$

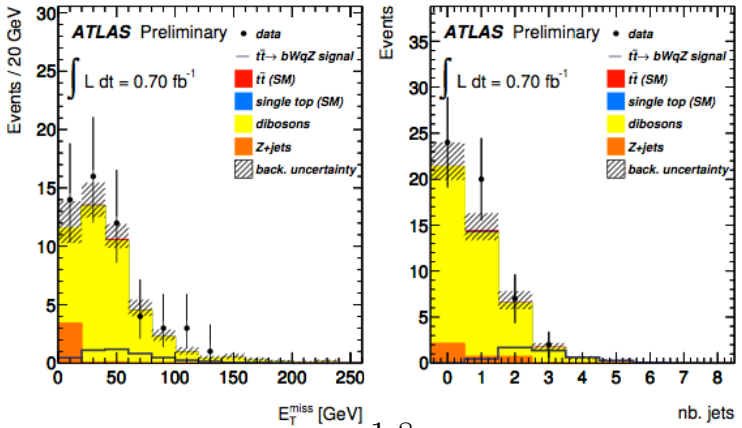
$\sigma_t = 14$ GeV, $\sigma_W = 10$ GeV, $\sigma_Z = 3$ GeV.

Additional cut : $|m^{\rm reco}_{l\nu} - m_W| < 30{\rm GeV}, |M^{\rm reco}_t - M_t| < 40{\rm GeV}$

CMS : reconstruct neutrino momentum from missing ET assuming W boson mass.

Additional cut : at least one b-tagged jet, $|M_{Zj} - M_t| < 25{\rm GeV}, |M_{Wb} - M_t| < 35{\rm GeV}$

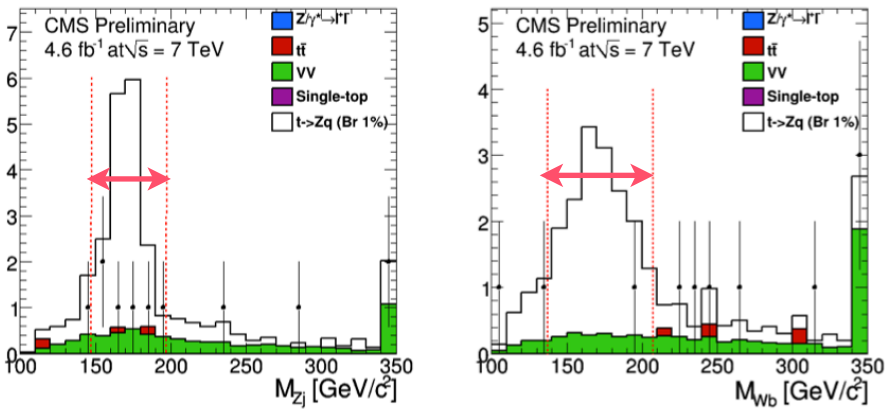
Distributions after the basic selection.



Expected BG $= 2.4^{+1.8}_{-0.3}$ events, 2 observed

Br(t->Zq)<1.13% 95%C.L.

Distributions after reconstruction.

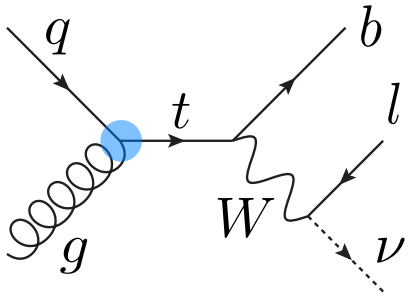


Expected BG $= 0.6^{+0.1}_{-0.1}$ events, 0 observed

Br(t->Zq)<0.34% 95%C.L.

9 "tqg" in single top production

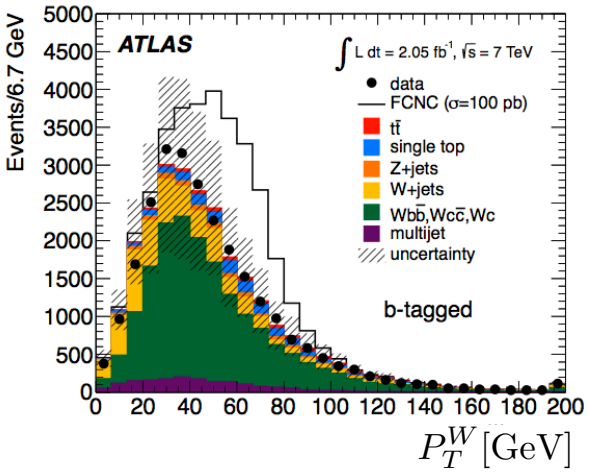
Target : Single top production via the FCNC + leptonic decay
Basic selection : exact one lepton and b-tagged jet, large missing ET.

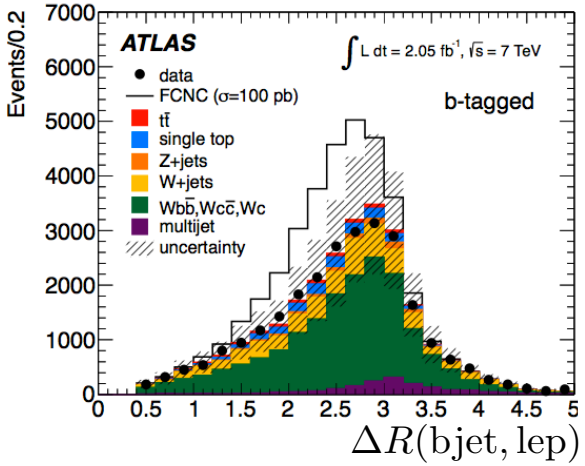


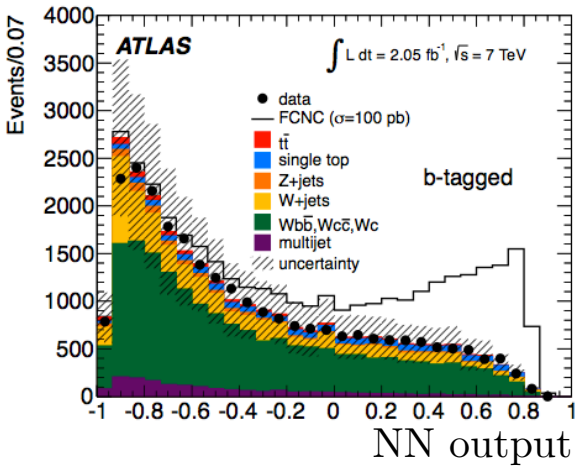
Neural Network to separate from SM background : 11 inputs

P_T^W : is large since W boson emitted from a top quark.

$\Delta R(\mathrm{bjet}, \mathrm{lep})$: is large since top quark is produced almost without transverse momentum.







Upper limit is set

$$\sigma(qg \to t) < 3.9\mathrm{pb}\ (95\%\ \mathrm{CL.})$$

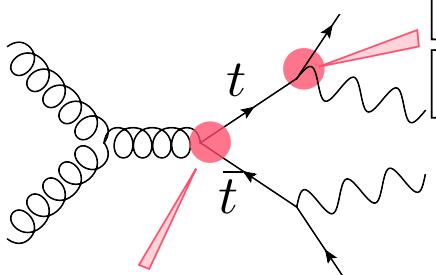
and it corresponds to

$$\mathrm{Br}(t \to ug) < 5.7 \cdot 10^{-5}$$
$$\mathrm{Br}(t \to cg) < 2.7 \cdot 10^{-4}$$

10 Summary and prospect

Top quark physics is in the precision measurement phase.

from **ATLAS** and **CMS**



t->Wb decay $R > 0.85@95\%\mathrm{CL}$

W boson helicity

$\mathrm{Re}(C_{uW}^{33})/\Lambda^2 \in [-1.0, 0.5]\mathrm{TeV}^{-2}$

$\mathrm{Re}(C_{uW}^{33})/\Lambda^2 =$

$-0.813 \pm 0.615(\mathrm{stat.})^{+0.847}_{-0.951}(\mathrm{syst.})\mathrm{TeV}^{-2}$

Charge asymmetry

$A_C = -0.018 \pm 0.028(\mathrm{stat.}) \pm 0.023(\mathrm{syst.})$

$A_C = 0.004 \pm 0.010(\mathrm{stat.}) \pm 0.012(\mathrm{syst.})$

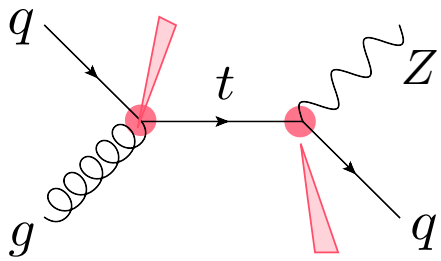
Same-sign top quark pairs

$\sigma(pp \to tt) < 2.0\mathrm{pb}$ @ 95% CL $\sigma(pp \to tt) < 0.67\mathrm{pb}$ @ 95% CL

FCNC tqg

$\mathrm{Br}(t \to ug) < 5.7 \cdot 10^{-5}$

$\mathrm{Br}(t \to cg) < 2.7 \cdot 10^{-4}$



FCNC tZq

$\mathrm{BR}(t \to Zq) < 1.13\mathrm{pb}(95\%\ \mathrm{CL})$

$\mathrm{Br}(t \to Zq) < 0.34\%(95\%\ \mathrm{C.L.})$

ATLAS top quark physics public results : https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults
CMS top quark physics public results : https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP

Full data analyses are coming.

Some analysis van be updated with full statistics of 5/fb data in 2011

8 TeV collision data!

Cross section of top quark pairs is increased by +40%.

It increases the potential of new physics appearance in top quark creation such as FCNC.

This year also will be an exciting year for top quark physics!

Backup slides

12 Links to the documents

Charge asymmetry

1/fb : http://arxiv.org/abs/1203.4211

4.7/fb : http://cdsweb.cern.ch/record/1428152?ln=en

Same-sign top-quark production

1/fb : http://www.springerlink.com/content/p572k4h1h328m353/?MUD=MP

4.7/fb : https://cdsweb.cern.ch/record/1434376/files/SUS-11-020-pas.pdf

Top quark decay branching ratio(Vtb)

2.2/fb : http://cdsweb.cern.ch/record/1429972?ln=en

W boson polarization

1/fb : http://arxiv.org/abs/1205.2484

2.2/fb : http://cdsweb.cern.ch/record/1423370?ln=en

FCNC production and decay

2/fb(tqg) : http://arxiv.org/abs/1203.0529

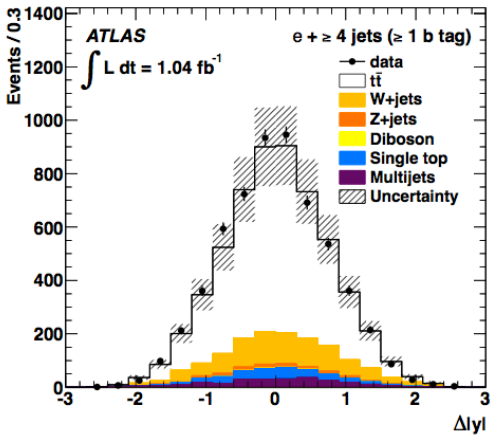
0.7/fb(tZq) : https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-154/

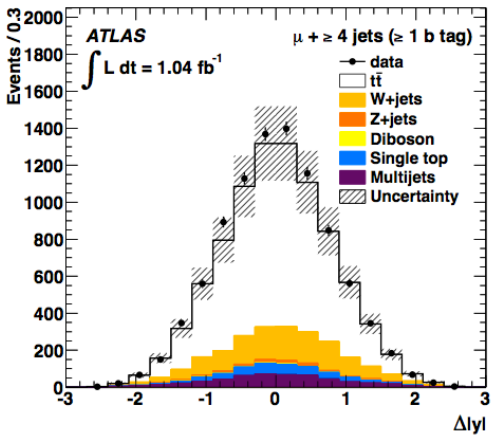
4.6/fb (tZq) : http://cdsweb.cern.ch/record/1429971?ln=en

13 Charge asymmetry

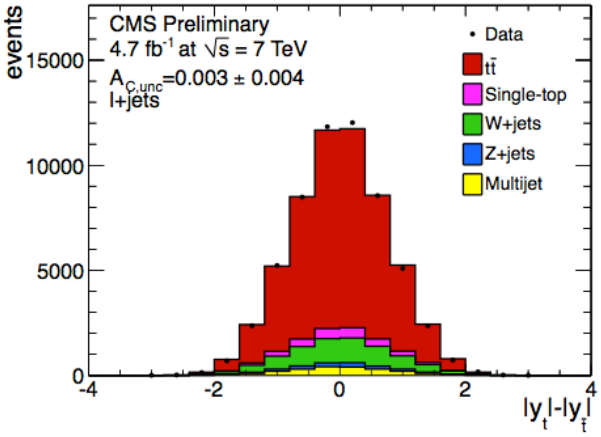
Measured delta eta distribution

ATLAS



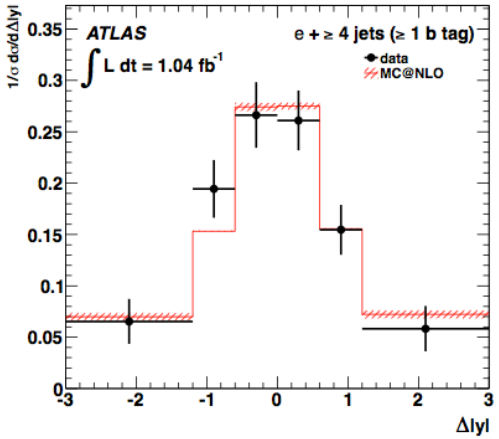


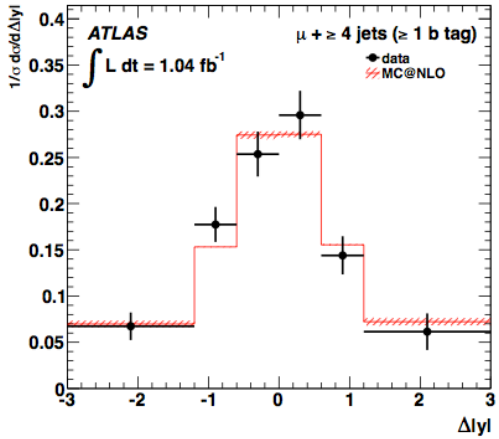
CMS



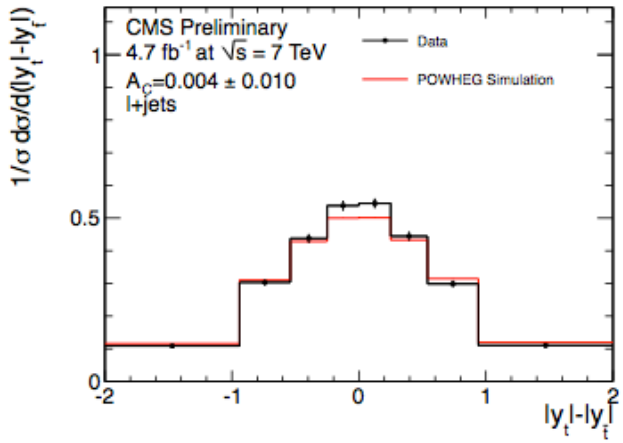
Unfolded delta eta distribution

ATLAS





CMS



14 Charge asymmetry

ATLAS Systematic uncertainties

Source of systematic uncertainty on A_C	Electron channel	Muon channel
Detector modelling		
Jet energy scale	0.012	0.006
Jet efficiency and resolution	0.001	0.007
Muon efficiency and resolution	<0.001	0.001
Electron efficiency and resolution	0.003	0.001
b-tag scale factors	0.004	0.002
Calorimeter readout	0.001	0.004
Charge mis-ID	<0.001	<0.001
b-tag charge	0.001	0.001
Signal and background modelling		
Parton shower/fragmentation	0.010	0.010
Top mass	0.007	0.007
$t\bar{t}$ modelling	0.011	0.011
ISR and FSR	0.010	0.010
PDF	<0.001	<0.001
W+jets normalization and shape	0.008	0.005
Z+jets normalization and shape	0.005	0.001
Multijet background	0.011	0.001
Single top	<0.001	<0.001
Diboson	<0.001	<0.001
MC Statistics	0.006	0.005
Unfolding convergence	0.001	0.001
Unfolding bias	0.004	<0.001
Luminosity	0.001	0.001
Total systematic uncertainty	0.028	0.023

CMS Systematic uncertainties

Systematic uncertainty	inclusive A_C
JES	0.002
JER	0.002
Pileup	0.001
Generator	0.001
Migration matrix	0.002
Unfolding	0.008
W+jets	0.004
Multijet	0.001
Lepton ID/sel. efficiency	0.006
Q^2 scale	0.002
Hadronization	0.001
PDF	0.002
Total	0.012

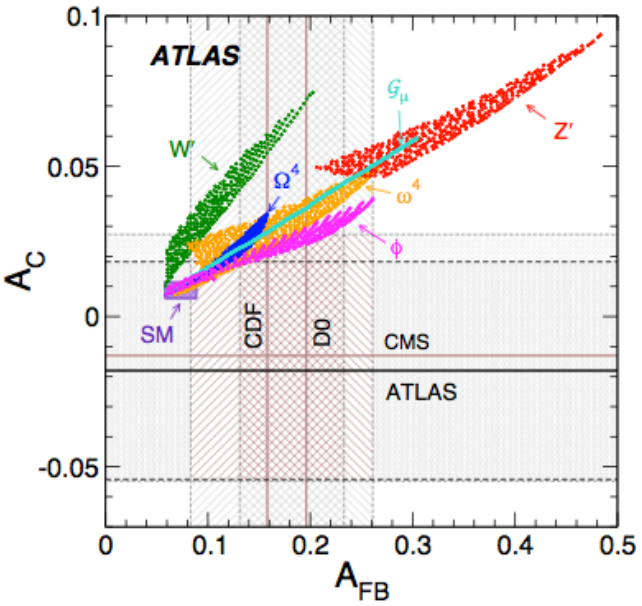
Unfolding : extra jets of I/FSR and PT of ttbar system due to it.

15 Charge asymmetry

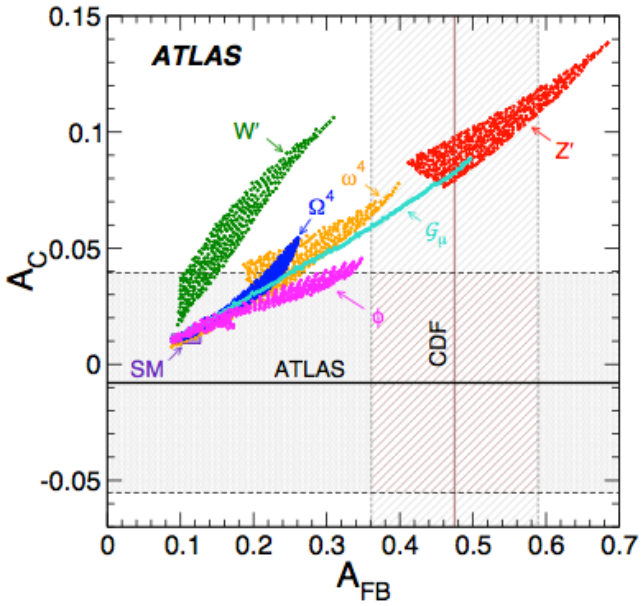
ATLAS

Correlation between the result and new physics candidates

Inclusive



$m_{t\bar{t}} > 450\mathrm{GeV}$



A_C : from ATLAS
A_{FR} : from the tevatron

16 Same sign top-quark production

ATLAS Systematic uncertainties

Source	Uncertainty on tt acceptance (%)	Uncertainty on b' acceptance (%)	Uncertainty on background acceptance (%)
Jet energy scale	$+1.7, -2.3$	$+0.5, -0.5$	$+7.1, -5.5$
Jet energy resolution	$+0.7, -0.8$	$+0.7, -0.8$	$+4.1, -4.2$
Jet reconstruction efficiency	$+0.1, -0.1$	$+0.1, -0.1$	$+0.1, -0.1$
Electron energy scale	$+0.5, -0.7$	$+0.2, -0.3$	$+1.1, -1.2$
Electron energy resolution	$+0.1, -0.3$	$+0.1, -0.1$	$+0.8, -0.8$
Electron efficiency	$+3.5, -4.2$	$+3.3, -4.9$	$+1.8, -2.0$
Muon energy scale	$+0.1, -0.1$	$+0.1, -0.1$	$+0.1, -0.1$
Muon energy resolution	$+0.2, -0.3$	$+0.1, -0.2$	$+0.6, -0.7$
Muon efficiency	$+4.7, -5.8$	$+4.3, -5.2$	$+2.3, -3.0$
Missing transverse momentum	$+0.8, -0.8$	$+0.8, -0.8$	$+0.9, -0.9$
LAr calorimeter readout	$+2.0, -3.0$	$+2.0, -3.0$	$+1.0, -2.0$

CMS Main systematic uncertainties

Lepton	5%
b-tagging	4%(Pt<240GeV)
	15%(Pt>240GeV)
Jet energy scale	8%
Luminosity	4.5%

These depends on the kinematics of new physics.

lepton : mainly uncertainty of isolation requirement. THe difference of hadron activity between Z boson and hadron ic cascade decay of SUSY.

17 Same sign top-quark production

ATLAS

SM background events and observed data.

	e^-e^-	$\mu^-\mu^-$	$e^-\mu^-$	e^+e^+	$\mu^+\mu^+$	$e^+\mu^+$
Fake	$0.2 \pm 0.3 \pm 0.1$	$0.7 \pm 0.3^{+0.6}_{-0.3}$	$0.5 \pm 0.2^{+0.7}_{-0.3}$	$0.8 \pm 0.6^{+0.2}_{-0.4}$	$1.0 \pm 0.3^{+0.6}_{-0.4}$	$3.3 \pm 1.1^{+1.6}_{-1.4}$
Charge flip	$0.3 \pm 0.1^{+0.3}_{-0.1}$	$0 \pm 0^{+0.1}_{-0.0}$	$0.3 \pm 0.1^{+0.2}_{-0.1}$	$0.3 \pm 0.1^{+0.3}_{-0.1}$	$0 \pm 0^{+0.1}_{-0.0}$	$0.4 \pm 0.1^{+0.3}_{-0.1}$
Real	$0.8 \pm 0^{+0.3}_{-0.6}$	$1.0 \pm 0^{+0.4}_{-0.6}$	$2.3 \pm 0^{+0.8}_{-1.9}$	$1.9 \pm 0^{+0.7}_{-1.5}$	$1.6 \pm 0^{+0.7}_{-0.9}$	$4.4 \pm 0^{+1.3}_{-3.1}$
Total	$1.4 \pm 0.3^{+0.4}_{-0.6}$	$1.7 \pm 0.3 \pm 0.7$	$3.1 \pm 0.2^{+1.1}_{-1.9}$	$3.0 \pm 0.6^{+0.8}_{-1.5}$	$2.6 \pm 0.3^{+0.9}_{-1.1}$	$8.1 \pm 1.1^{+2.2}_{-3.4}$
Data	1	2	2	2	1	10
tt_{LL}	$0.2 \pm 0 \pm 0.1$	$0.2 \pm 0 \pm 0.1$	$0.5 \pm 0 \pm 0.3$	$30.1 \pm 0 \pm 5.0$	$30.4 \pm 0 \pm 4.8$	$64.2 \pm 0 \pm 10.3$
tt_{LR}	$0.02 \pm 0 \pm 0.01$	$0.001 \pm 0^{+0.01}_{-0.001}$	$0.02 \pm 0 \pm 0.02$	$3.8 \pm 0 \pm 0.6$	$4.2 \pm 0 \pm 0.7$	$8.3 \pm 0 \pm 1.3$
tt_{RR}	$0.5 \pm 0 \pm 0.3$	$0.1 \pm 0 \pm 0.2$	$0.8 \pm 0 \pm 0.3$	$35.5 \pm 0 \pm 6.0$	$29.5 \pm 0 \pm 4.6$	$65.7 \pm 0 \pm 10.4$
b' 450 GeV	$1.8 \pm 0 \pm 0.3$	$2.1 \pm 0 \pm 0.3$	$4.3 \pm 0 \pm 0.5$	$1.8 \pm 0 \pm 0.3$	$2.7 \pm 0 \pm 0.4$	$5.0 \pm 0 \pm 0.7$

CMS

Distribution of the events after selections. (SR1 : basic cut)

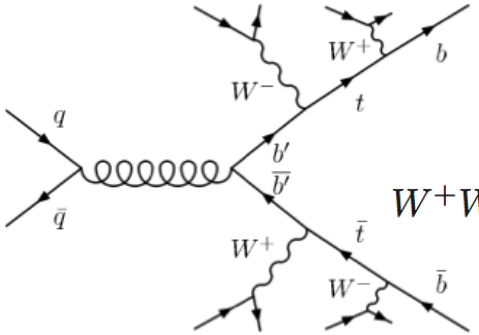
	SR1	SR2	SR3	SR4	SR5	SR6	SR7
No. of jets	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 3
No. of btags	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 3
Lepton charges	$++/--$	$++$	$++/--$	$++/--$	$++/--$	$++/--$	$++/--$
$\not{E}_T$	≥ 30 GeV	≥ 30 GeV	≥ 120 GeV	≥ 50 GeV	≥ 50 GeV	≥ 120 GeV	≥ 50 GeV
H_T	≥ 80 GeV	≥ 80 GeV	≥ 200 GeV	≥ 200 GeV	≥ 320 GeV	≥ 320 GeV	≥ 200 GeV
q-flip BG	1.1 ± 0.2	0.5 ± 0.1	0.05 ± 0.01	0.3 ± 0.1	0.12 ± 0.03	0.026 ± 0.009	0.008 ± 0.004
Fake BG	3.4 ± 2.0	1.8 ± 1.2	0.32 ± 0.50	1.5 ± 1.1	0.81 ± 0.78	0.15 ± 0.45	0.15 ± 0.45
Rare SM BG	3.2 ± 1.6	2.1 ± 1.1	0.56 ± 0.28	2.0 ± 1.0	1.04 ± 0.52	0.39 ± 0.20	0.11 ± 0.06
Total BG	7.7 ± 2.6	4.4 ± 1.6	0.9 ± 0.6	3.7 ± 1.5	2.0 ± 0.9	0.6 ± 0.5	0.3 ± 0.5
Event yield	7	5	2	5	2	0	0
N_{UL} (12% unc.)	7.4	6.9	5.2	7.3	4.7	2.8	2.8
N_{UL} (20% unc.)	7.7	7.2	5.4	7.6	4.8	2.8	2.8
N_{UL} (30% unc.)	8.1	7.6	5.8	8.2	5.1	2.8	2.8

18 Same sign top-quark production

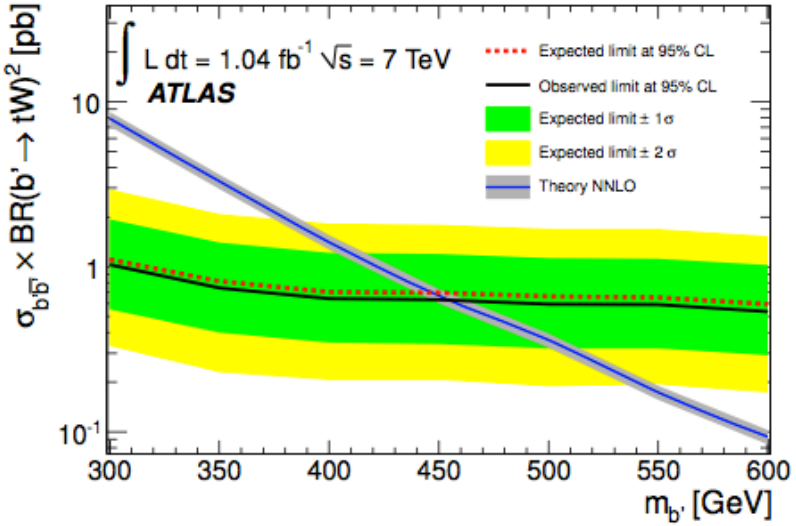
Another interpretation of the results

ATLAS

as a forth generation chiral quark search.

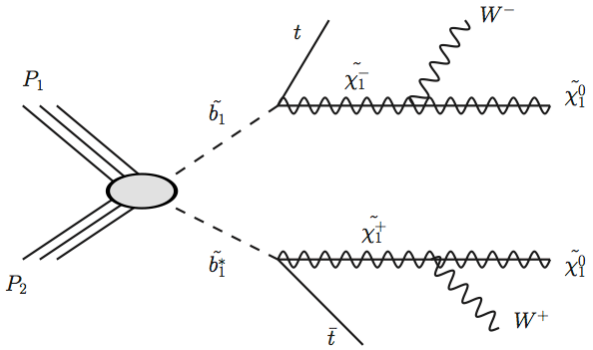


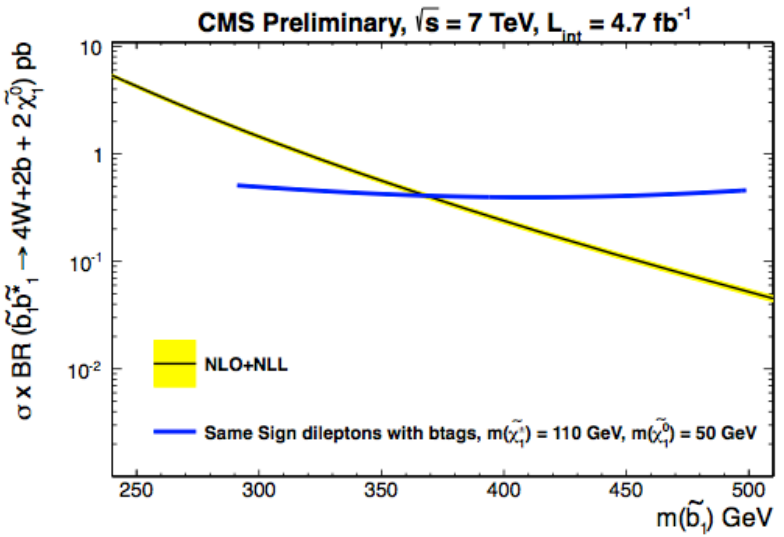
$W^+W^-\bar{b}W^-W^+b.$



CMS

as a sbottom search.





19 "tqg" in single top production

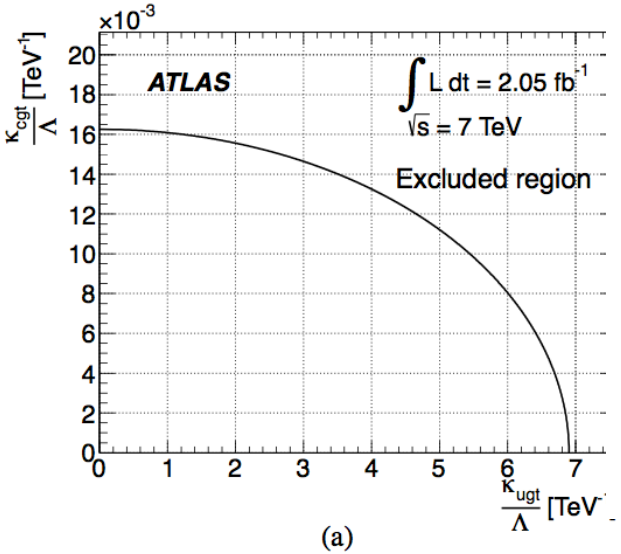
ATLAS

11 parameters put into a neural network

Variable	Significance (σ)
p_T^W	57
ΔR(b-jet,lep)	28
Lepton charge	22
m_{top}	20
$m_{\text{b-jet}}$	15
$\eta_{\text{b-jet}}$	12
$\Delta\phi$(W,b-jet)	11
p_T^{lep}	12
$p_T^{\text{b-jet}}$	6.5
$\cos\theta^*$	5.7
ΔR(W,b-jet)	5.0

Interpretation to the limit on effective Lagrangian

$$\mathcal{L}_{\text{eff}} = g_s \sum_{q=u,c} \frac{\kappa_{qgt}}{\Lambda} t\sigma^{\mu\nu} T^a (f_q^L P_L + f_q^R P_R) q G^a_{\mu\nu} + h.c.,$$

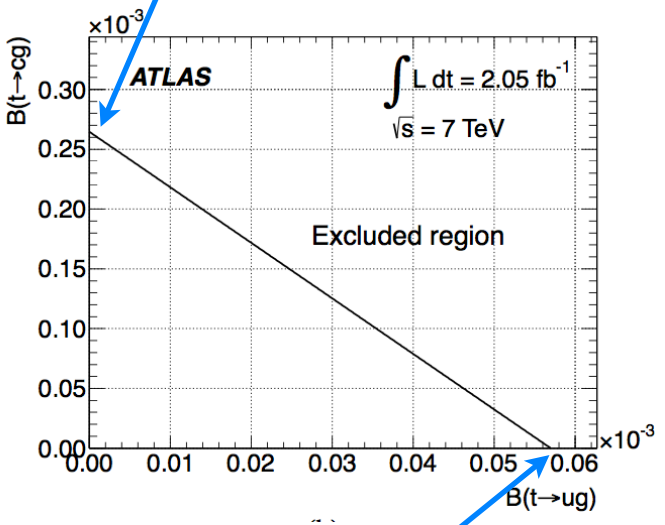


(a)

Interpretation to the BR

$$\text{Br}(t \to cg) < 2.7 \cdot 10^{-4}$$

D0 experiment : B(t→gc) < 3.9 × 10^{-3}

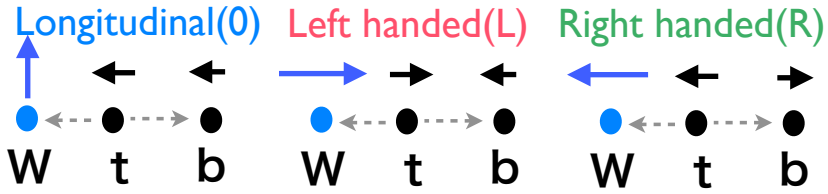


$$\text{Br}(t \to ug) < 5.7 \cdot 10^{-5}$$

D0 experiment : B(t→gu) < 2.0 × 10^{-4}

(D0 paper : PLB **693**, 81 (2010))

20 W boson polarization measurement



$$F_i = \frac{\Gamma_i}{\Gamma_{all}} \quad (i = L, R, 0)$$

Theoretical expectation.

$$F_0 = 0.687$$
$$F_L = 0.311$$
$$F_R = 0.0017$$

Naming convention

	LHC experiments	Tevatron experiments
Left handed	FL	f-
Longitudinal	F0	f0
Right	FR	f+

ATLAS

$$F_0 = 0.67 \pm 0.03\ (\text{stat.}) \pm 0.06\ (\text{syst.}),$$
$$F_{\rm L} = 0.32 \pm 0.02\ (\text{stat.}) \pm 0.03\ (\text{syst.}),$$
$$F_{\rm R} = 0.01 \pm 0.01\ (\text{stat.}) \pm 0.04\ (\text{syst.}).$$

A_+

A_-

CMS

$$F_0 = 0.567 \pm 0.074(\text{stat.}) \pm 0.047(\text{syst.})$$
$$F_L = 0.393 \pm 0.045(\text{stat.}) \pm 0.029(\text{syst.}),$$

D0 + CDF

F0= $f_0 = 0.722 \pm 0.081$
$[\pm\ 0.062\ (\text{stat.}) \pm 0.052\ (\text{syst.})]$,

FR= $f_+ = -0.033 \pm 0.046$
$[\pm\ 0.034\ (\text{stat.}) \pm 0.031\ (\text{syst.})]$

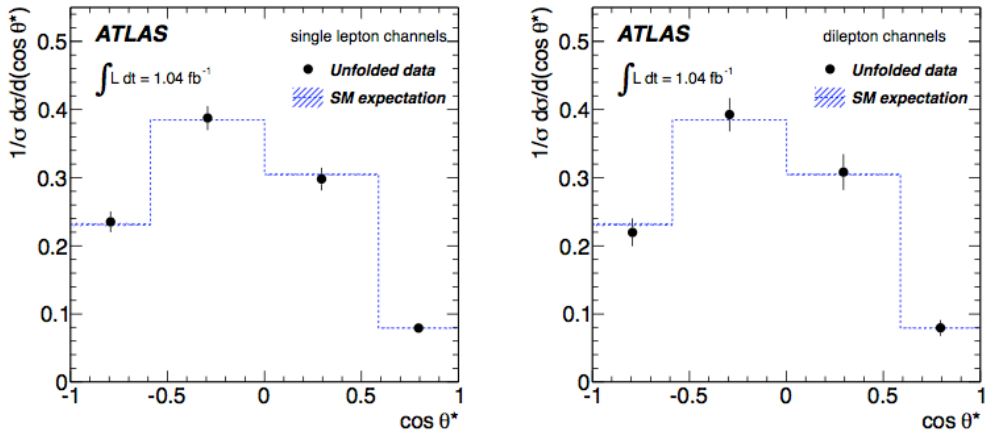
PRD **85**, 091104

21 W boson polarization measurement

Asymmetry parameter in cos theta distribution.

$$A_{\pm} = \frac{N(\cos\theta^* > z) - N(\cos\theta^* < z)}{N(\cos\theta^* > z) + N(\cos\theta^* < z)} \qquad z = \pm(1 - 2^{2/3}) \text{ for } A_{\pm}$$

ATLAS



Theoretical expectation.

$$A_+ = 0.537 \pm 0.004$$

$$A_- = -0.841 \pm 0.006$$

Result

$$A_+ = 0.53 \pm 0.02$$

$$A_- = -0.84 \pm 0.02.$$

22 W boson polarization measurement

ATLAS

Systematic uncertainties

Source	Uncertainties		
	F_0	F_L	F_R
Signal and background modelling			
Generator choice	0.012	0.009	0.004
ISR/FSR	0.015	0.008	0.007
PDF	0.011	0.006	0.006
Top quark mass	0.016	0.009	0.008
Misidentified leptons	0.020	0.013	0.007
W+jets	0.016	0.008	0.008
Other backgrounds	0.006	0.003	0.003
Method-specific uncertainties	0.031	0.016	0.035
Detector modelling			
Lepton reconstruction	0.013	0.006	0.007
Jet energy scale	0.026	0.014	0.012
Jet reconstruction	0.012	0.005	0.007
b-tagging	0.007	0.003	0.004
Calorimeter readout	0.009	0.005	0.004
Luminosity and pileup	0.009	0.004	0.005
Total systematic uncertainty	0.06	0.03	0.04

Systematic uncertainties

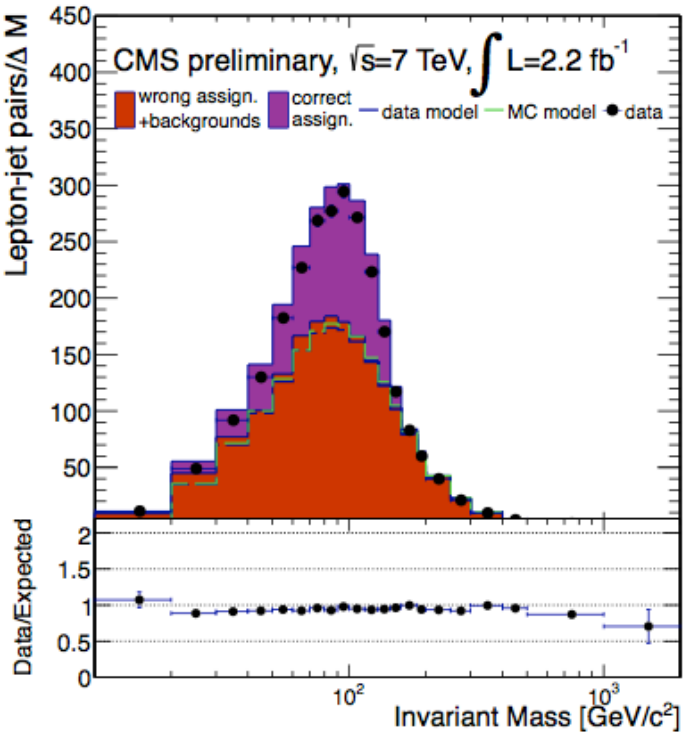
CMS

Systematic check	Fitting F_0, F_L and $\mathcal{F}_{t\bar{t}}$ **3D fit**		Fitting F_0 and $\mathcal{F}_{t\bar{t}}$ **2D fit**
	$\pm$ Uncertainty F_0	$\pm$ Uncertainty F_L	$\pm$ Uncertainty F_0
b-Tag ($\frac{\epsilon^{DATA}_{b-tag}}{\epsilon^{MC}_{b-tag}}$)	0.007	0.009	0.010
QCD Norm	0.007	0.002	0.003
Single-t Norm	0.003	0.007	0.010
DY Norm	0.018	0.003	0.010
W+jet Norm	0.020	0.006	0.029
muon (no $\frac{\epsilon^{DATA}_{\mu}}{\epsilon^{MC}_{\mu}}$)	0.002	0.003	0.003
PDF	0.001	0.001	0.002
JES scale	0.018	0.011	0.005
top Q^2 scale	0.014	0.007	0.021
DY,W Q^2 scale	0.022	0.003	0.014
top mass (± 3 GeV/c^2)	0.019	0.021	0.025

23 R=Br(t->Wb)/Br(t->Wq) measurement

CMS

Invariant Mass distribution
before subtracting "wrong assignment"



CMS Systematic uncertainties

Source	Uncertainty
ε_b	0.031
ε_q	0.011
Jet energy scale	0.002
Jet energy resolution	0.004
Pile-up	0.006
Q^2	0.023
Jet-parton matching scale	0.011
DY contamination	0.012
$t\bar{t}$ contribution	0.002
Total	0.044

24 "tZq" search in top quark pair decay

ATLAS

Systematic uncertainties

Source	Background	Signal
Luminosity	4%	4%
Electron trigger	<1%	<1%
Electron reco. efficiency	<1%	<1%
Electron identification	9%	6%
Electron energy scale	1%	<1%
Electron energy resolution	1%	<1%
Muon trigger	9%	5%
Muon reconstruction	1%	<1%
Muon identification	<1%	<1%
Muon momentum scale	3%	<1%
Muon momentum resolution	2%	<1%
Jet energy scale	13%	1%
Jet reco. efficiency	3%	2%
Jet energy resolution	7%	<1%
CellOut and Soft Jet	1%	<1%
LAr readout problem	<1%	<1%
Pile-up	1%	<1%
Top quark mass	<1%	4%
ISR/FSR	<1%	4%
ZZ and WZ generator	36%	—
Total	42%	11%

CMS

Systematic uncertainties

Source	Percent
Trigger Efficiency	4
Luminosity	5
Parton Distribution Functions	6
Lepton selection	7
Pile-up events	7
Missing energy resolution	8
b tagging*	0 (9)
Jet energy scale	10
Cross sections	11
Total	21 (23) for HT_S-tag (b-cut) based selection