

Search for FCNC in top-quark events

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on behalf of the ATLAS Collaboration

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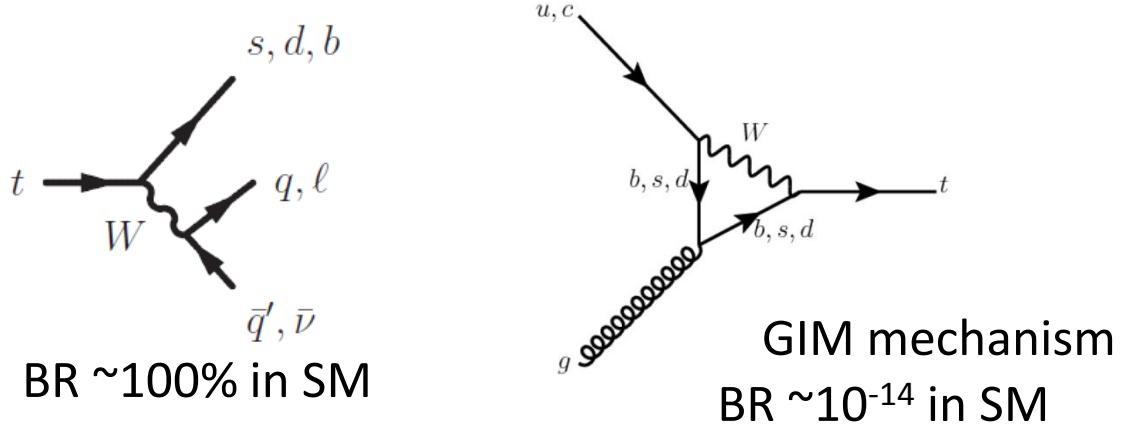


06 July 2012

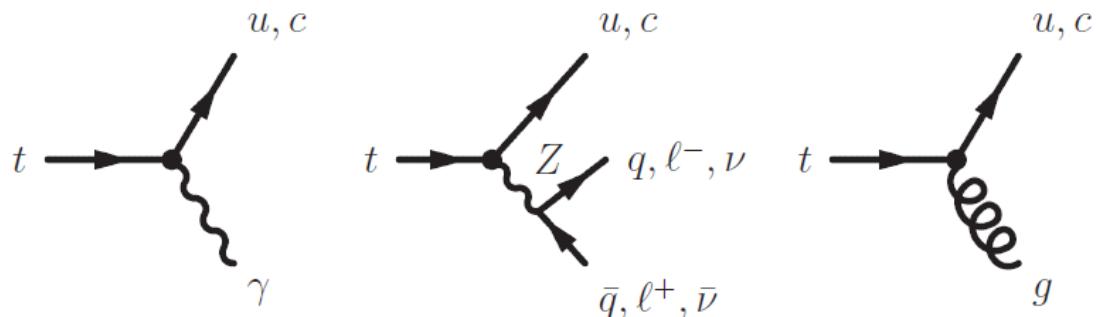
Flavour-changing neutral currents



Top quark decays
in Standard Model

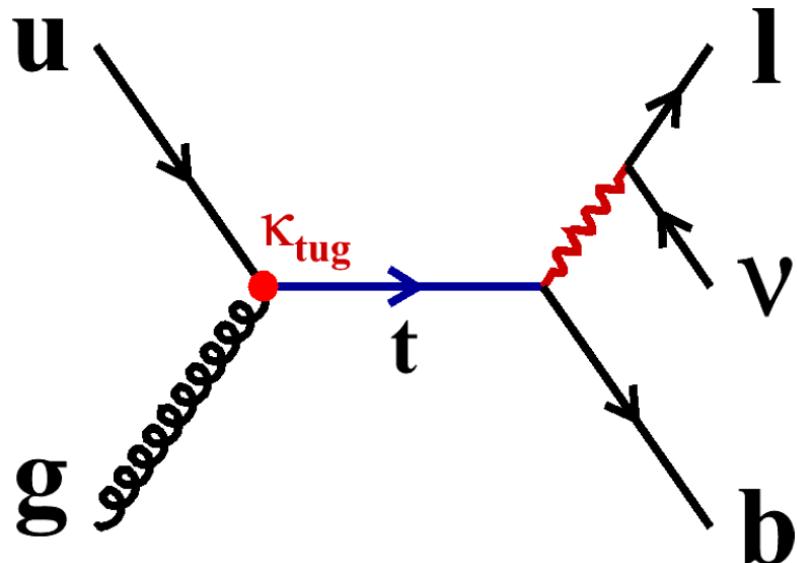


FCNC can be enhanced
in models beyond SM



	SM	QS	2HDM	FC 2HDM	MSSM	R	SUSY	TC2	RS	Observed limits
$t \rightarrow q\gamma$	$\sim 10^{-14}$	$\sim 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-9}$	0.59% (ZEUS)
$t \rightarrow qZ$	$\sim 10^{-14}$	$\sim 10^{-4}$	$\sim 10^{-7}$	$\sim 10^{-10}$	$\sim 10^{-6}$	$\sim 10^{-5}$	$\sim 10^{-4}$	$\sim 10^{-4}$	$\sim 10^{-5}$	3.2% (D0)
$t \rightarrow qg$	$\sim 10^{-12}$	$\sim 10^{-7}$	$\sim 10^{-4}$	$\sim 10^{-8}$	$\sim 10^{-5}$	$\sim 10^{-4}$	$\sim 10^{-4}$	$\sim 10^{-4}$	$\sim 10^{-9}$	0.02-0.39% (D0)

Two searches for FCNC

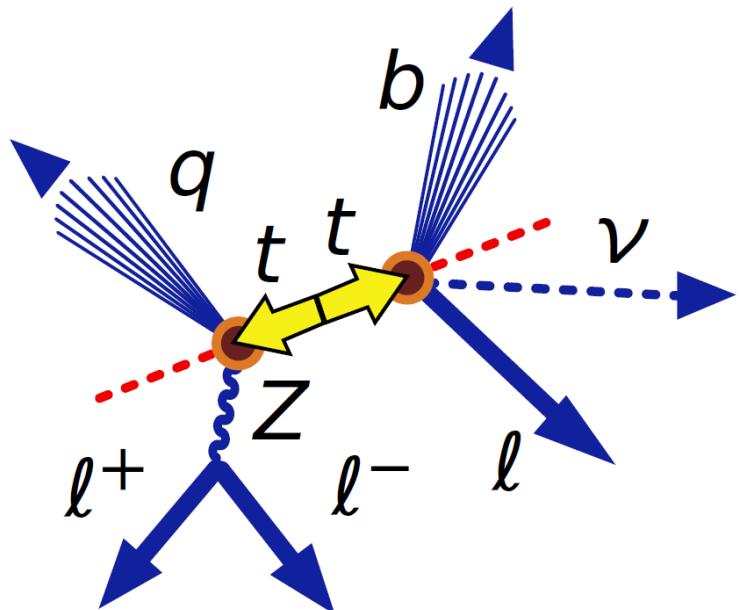


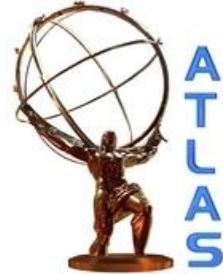
$t \rightarrow qZ$

- Search in $t\bar{t} \rightarrow qZ bW \rightarrow qll blv$
- Final state with three leptons

$t \rightarrow qg$

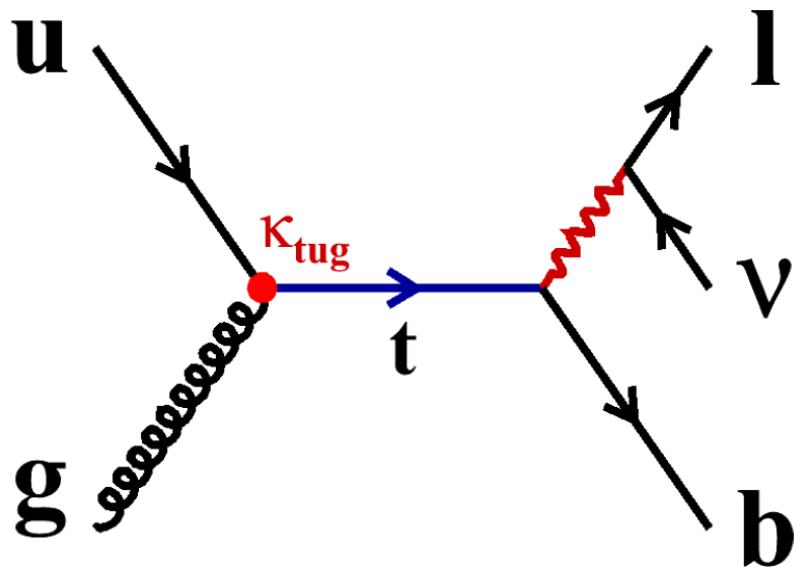
- Search in $qg \rightarrow t \rightarrow blv$
- Single top production





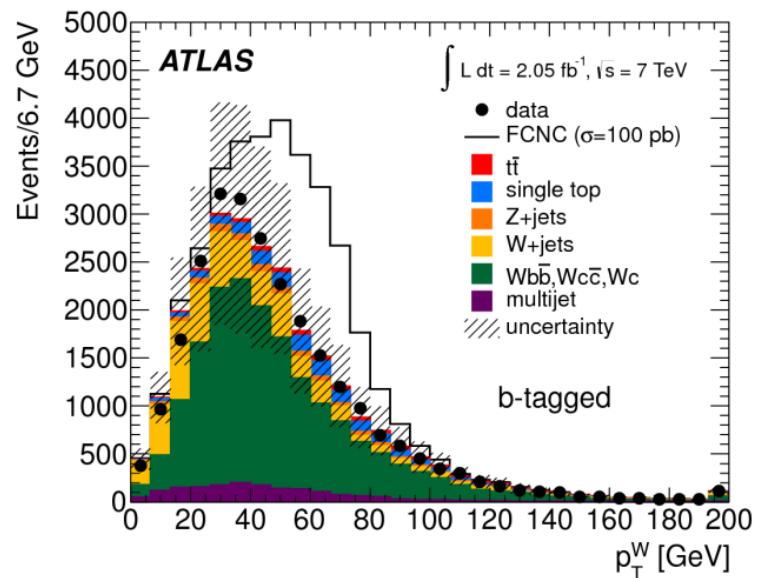
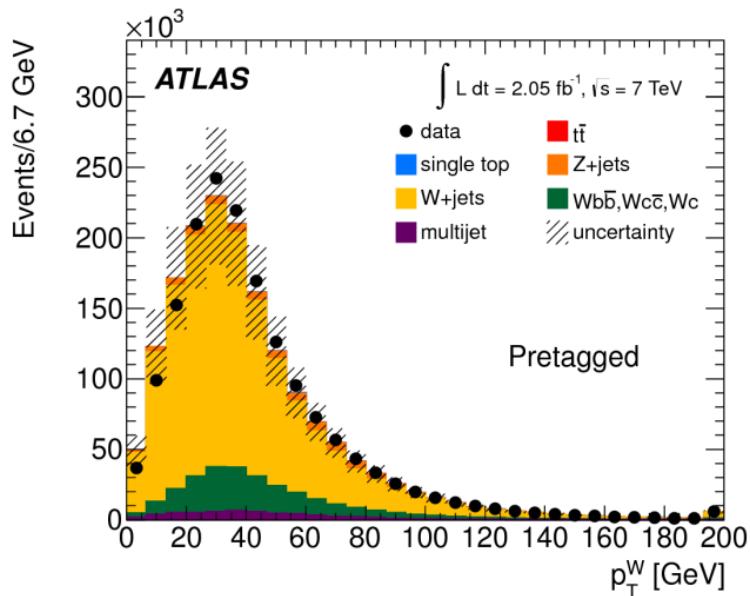
Search for FCNC in single top-quark production (2.05/fb)

Phys. Lett. B 712(2012) 351, published 12-Jun-2012



- One lepton ($p_T > 25$ GeV)
- One jet ($p_T > 25$ GeV), b-tagged
- $E_T^{\text{miss}} > 25$ GeV
- $m_T^W + E_T^{\text{miss}} > 60$ GeV

Control sample and background estimate



Background estimation

- Strategy as for single top t-channel measurement
- $W + \text{jets}$
 - simulation and control region
- QCD multijets
 - templates with jet-electrons

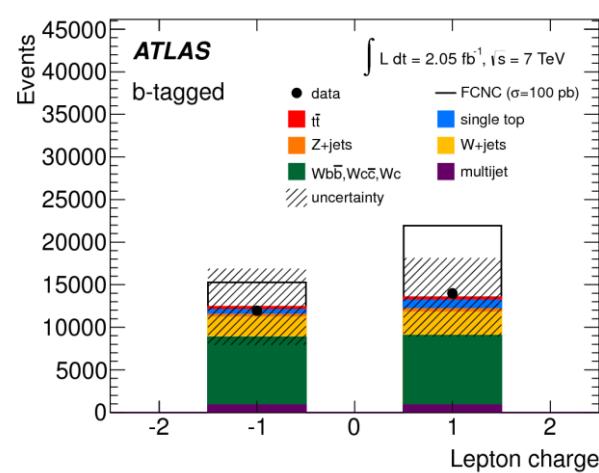
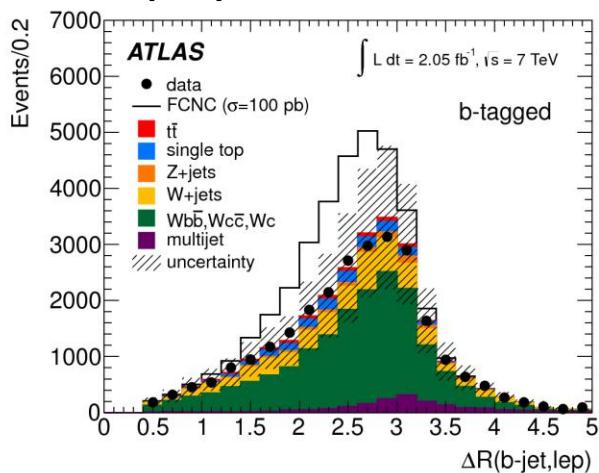
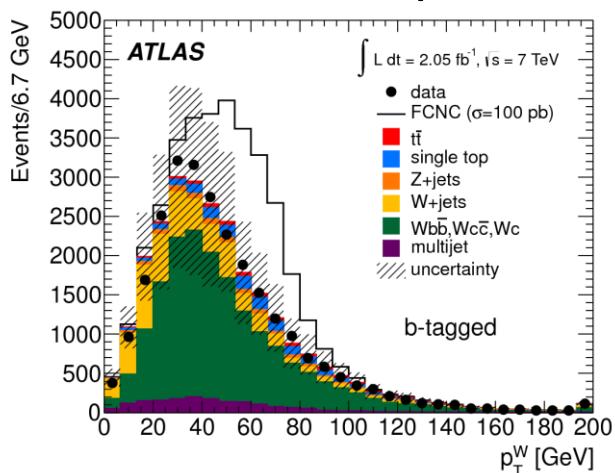
Process	Expected events
SM single top	1460 ± 150
$t\bar{t}$	660 ± 70
$W + \text{light jets}$	4700 ± 1100
$Wb\bar{b}/Wc\bar{c} + \text{jets}$	2700 ± 1500
$Wc + \text{jets}$	12100 ± 6700
$Z + \text{jets/diboson}$	700 ± 170
Multijet	1600 ± 800
Total background	$24\,000 \pm 7000$
Observed	26 223
Signal efficiency	5.5%

Analysis strategy



Signal characteristics

- $p_T(\text{top}) \sim 0 \rightarrow W \text{ and } b \text{ are back-to-back}$
- $p(W)$ large
- 4x more top than anti-top quarks

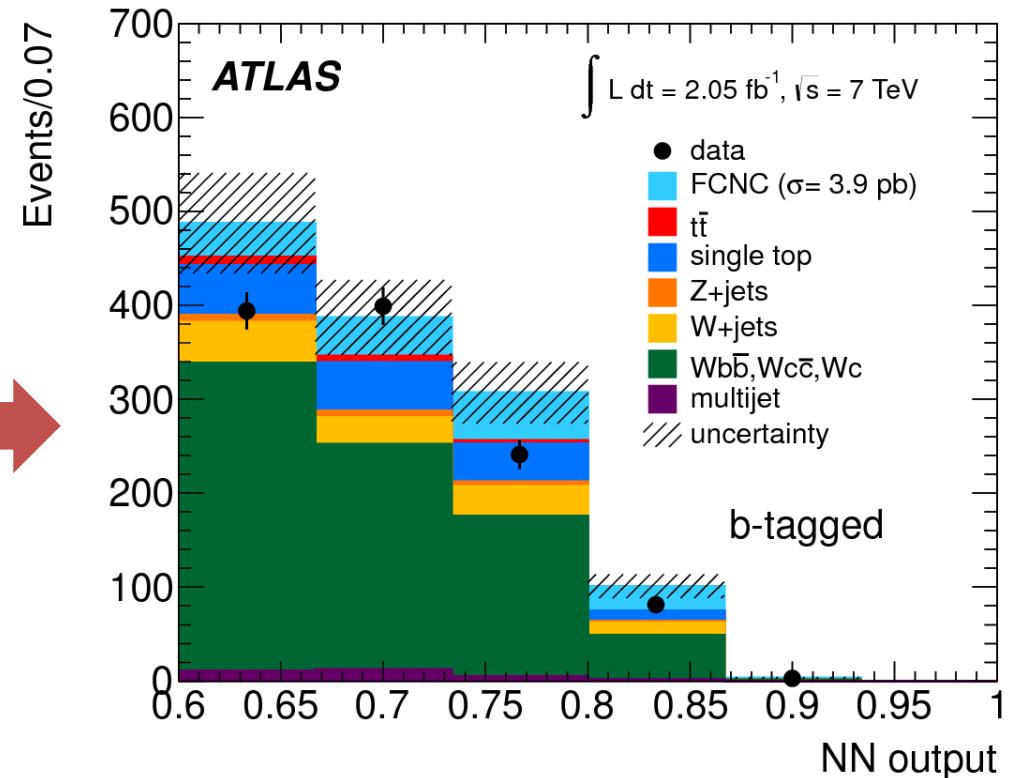
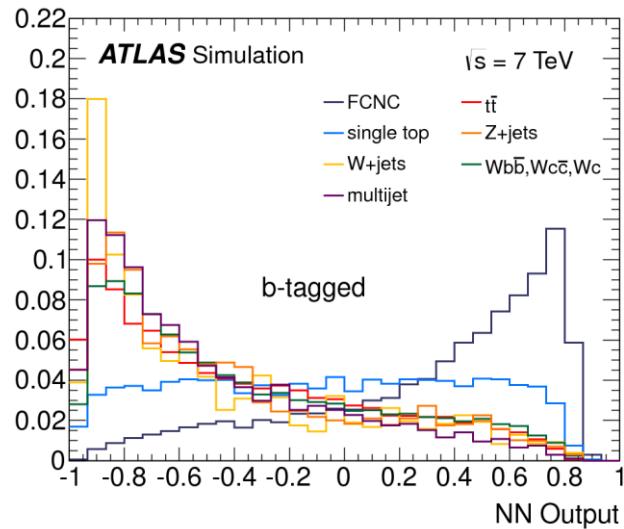


Data analysis

- 11 discriminating variables
- Combine in a NN with 6 background templates

p_T^W
 $\Delta\phi(W, b\text{-jet})$
 p_T^{lep}
 $\Delta R(b\text{-jet, lep})$
 $p_T^{b\text{-jet}}$
 m_{top}
 $m_{b\text{-jet}}$
 $\cos\theta^*$
 $\Delta R(W, b\text{-jet})$

Result



Dominant systematics

- jet energy scale
- initial/final state radiation
- b-tag efficiency and mistag rate

No excess found

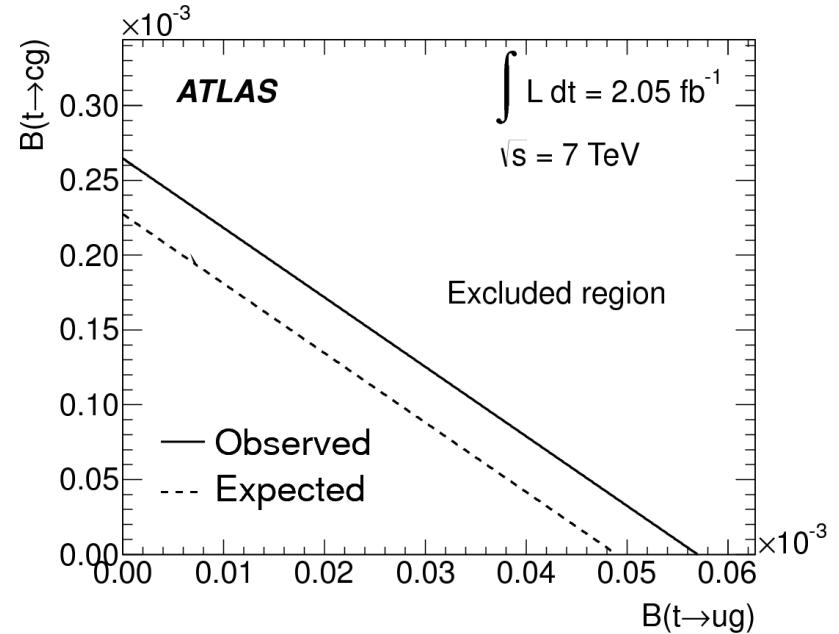
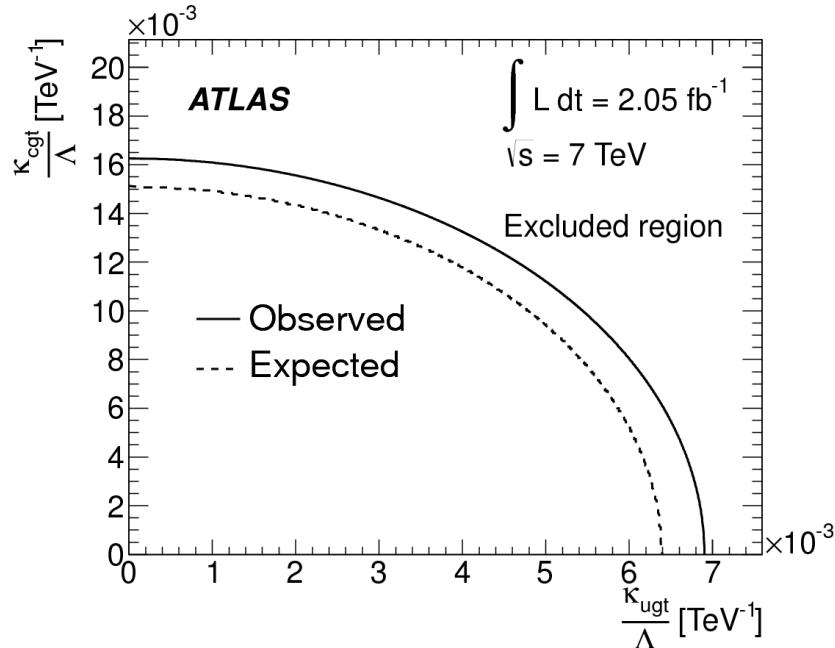
- Binned likelihood fit
- Extract upper limit

Observed limit @ 95% C.L.

- $\sigma < 3.9 \text{ pb}$ (2.4 pb expected)

Interpretation

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



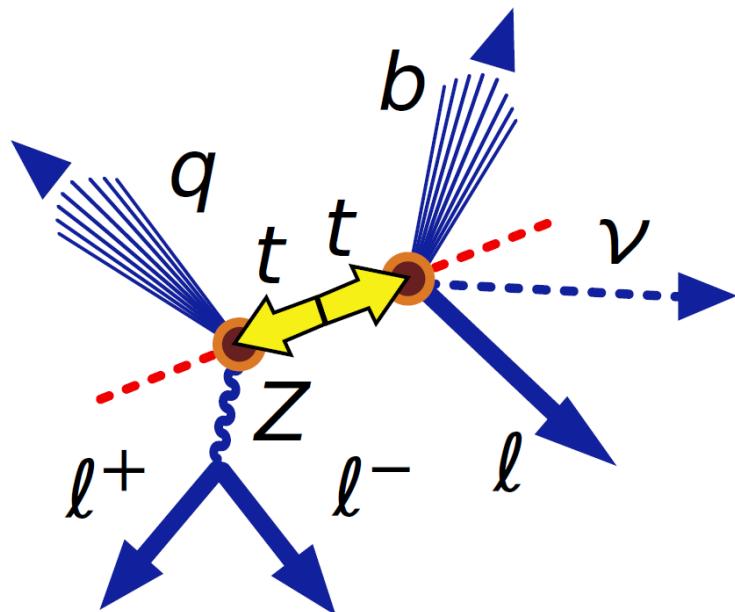
$$\frac{\kappa_{ug}}{\Lambda} < \frac{6.9 \cdot 10^{-3}}{\text{TeV}}$$

$$\frac{\kappa_{cg}}{\Lambda} < \frac{1.6 \cdot 10^{-2}}{\text{TeV}}$$

$BF(t \rightarrow ug) < 5.7 \cdot 10^{-5}$
 $BF(t \rightarrow cg) < 2.7 \cdot 10^{-4}$

Search for FCNC in top-quark decay (2.05/fb)

submitted to JHEP 01-Jun-2012, arXiv:1206.0257



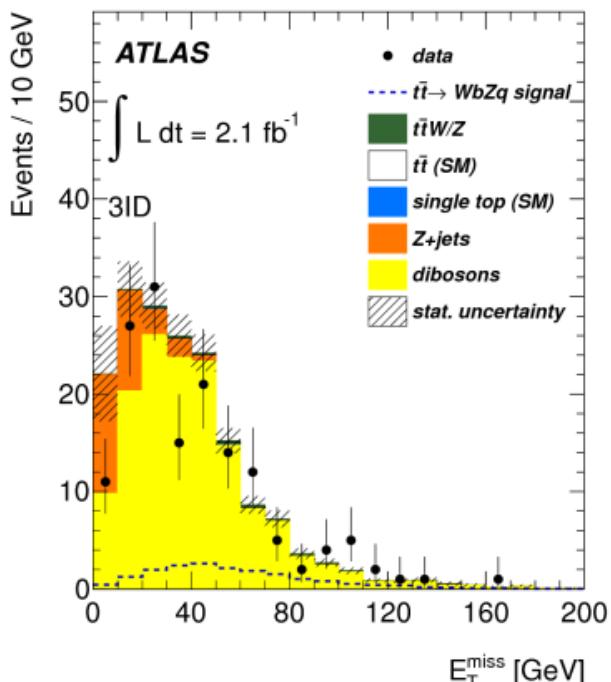
Event selection strategy

$t\bar{t} \rightarrow qZ bW \rightarrow qll blv$

- 3 leptons ($p_T > 20$ GeV)
- 2 same flavour $|m(l^+l^-) - m(Z)| < 15$ GeV
- $E_T^{\text{miss}} > 20$ GeV, ≥ 2 jets ($p_T > 25$ GeV)

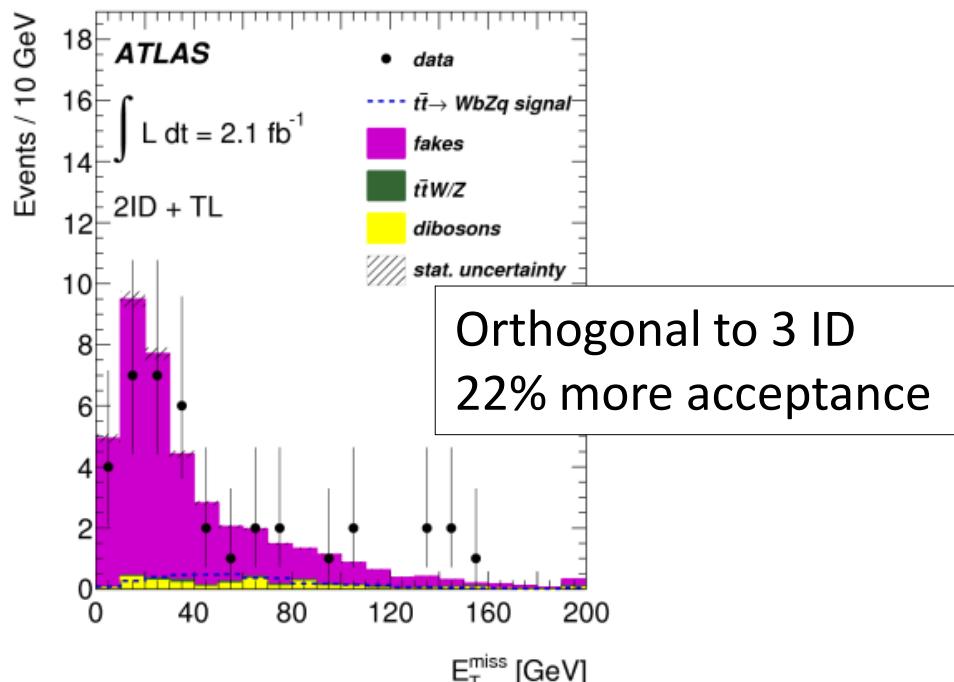
3 ID selection

- p_T (1st) > 25 GeV



2ID+TL selection

- 2ID + ‘track lepton’, p_T (TL) > 25 GeV



Event reconstruction and yield

Minimisation of

$$\chi^2 = \frac{(m_{j_a \ell_a \ell_b}^{\text{reco}} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_b \ell_c \nu}^{\text{reco}} - m_t)^2}{\sigma_t^2} + \frac{(m_{\ell_c \nu}^{\text{reco}} - m_W)^2}{\sigma_W^2} + \frac{(m_{\ell_a \ell_b}^{\text{reco}} - m_Z)^2}{\sigma_Z^2}$$

- wrt jet-lepton combinations
- $p_\nu(z)$ solution from E_T^{miss}

Additional requirements

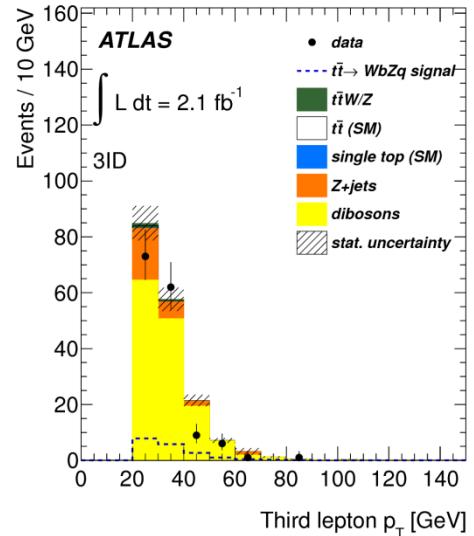
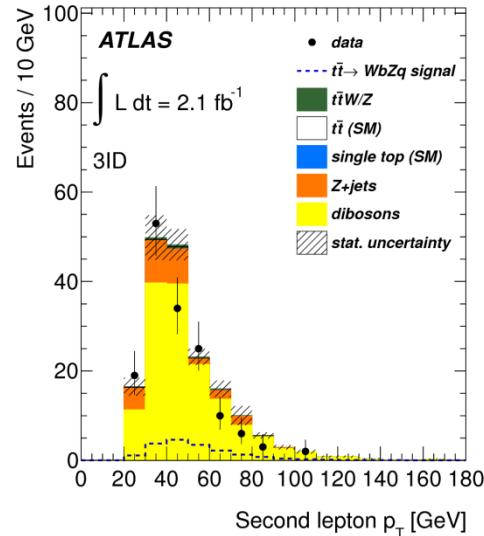
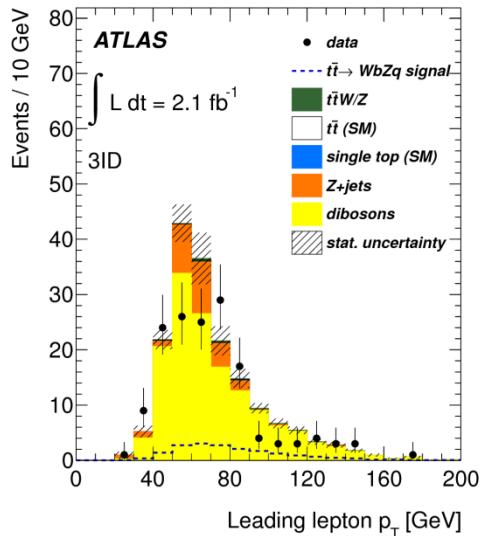
- $|m_t - 172.5 \text{ GeV}| < 40 \text{ GeV}$
- $|m_W - 80.4 \text{ GeV}| < 30 \text{ GeV}$
- 1 b-tag for 2ID+TL

Background determination



3 real leptons: ZZ, WZ, $t\bar{t}W$, $t\bar{t}Z$

- at least three real leptons → MC simulation



	3ID	2ID+TL
ZZ and WZ	9.5 ± 4.4	1.0 ± 0.5
$t\bar{t}W$ and $t\bar{t}Z$	0.51 ± 0.14	0.25 ± 0.05

Background determination



3 real leptons: ZZ, WZ, t̄W, t̄Z

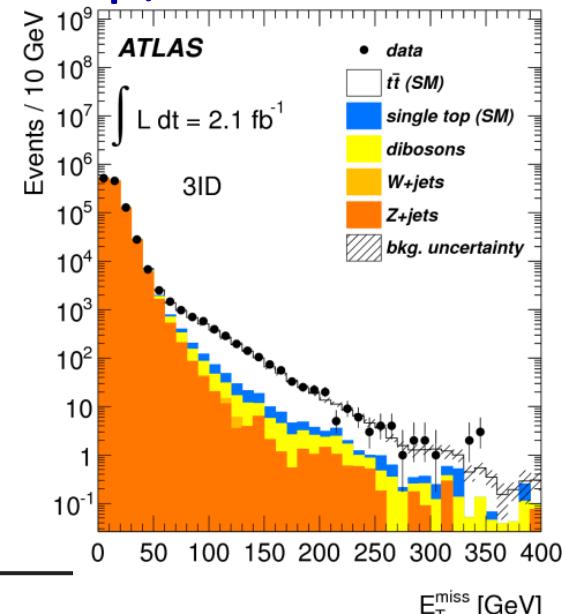
- at least three real leptons → MC simulation

2 real leptons: Z+jets, t̄t dilepton, Wt single top, WW

- loose lepton selection
- Z+jets dominant: data driven method
 - control regions in E_T^{miss} vs $m(l\bar{l})$ in bins of E_T^{miss}

$$[N_{Z+\text{jets}}^{\text{Data}}]_{\text{SR}} = \left[\frac{N^{\text{Data}} - N^{\text{MC}}_{\text{Other backgrounds}}}{N^{\text{MC}}_{Z+\text{jets}}} \right]_{\text{CR}} \cdot [N_{Z+\text{jets}}^{\text{MC}}]_{\text{SR}}$$

	3ID			2ID+TL		
ZZ and WZ	9.5	±	4.4	1.0	±	0.5
t̄W and t̄Z	0.51	±	0.14	0.25	±	0.05
t̄t, WW	0.07	±	0.02			
Z+jets	1.7	±	0.7			
Single top	0.01	±	0.01			
2+3 f						



Background determination

3 real leptons: ZZ, WZ, t̄W, t̄Z

- at least three real leptons → MC simulation

2 real leptons: Z+jets, t̄t dilepton, Wt single top, WW

- loose lepton selection
- Z+jets dominant: data driven method (others: MC simulation)
 - control regions in E_T^{miss} vs $m(l\bar{l})$ in bins of E_T^{miss}

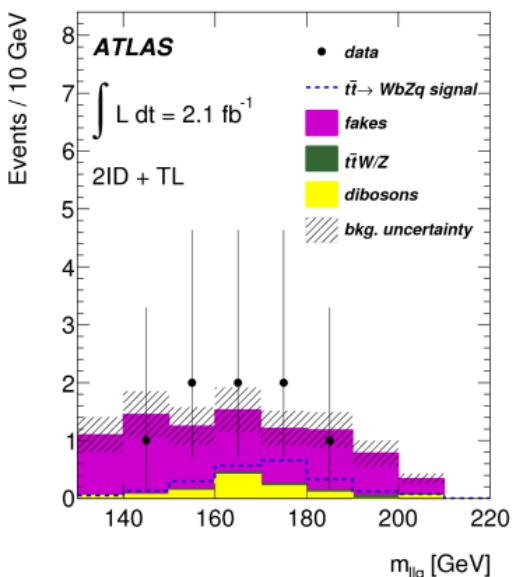
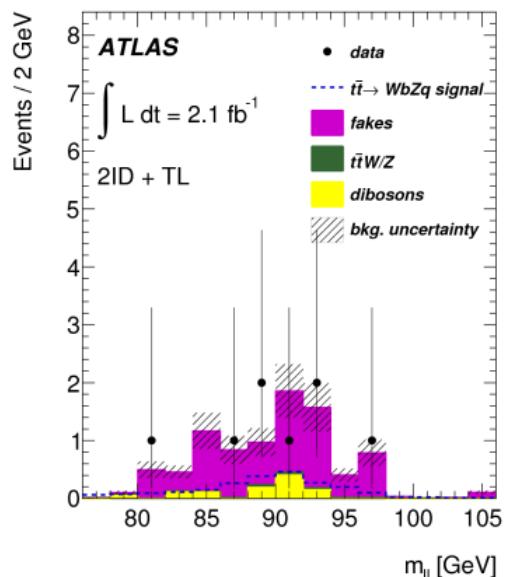
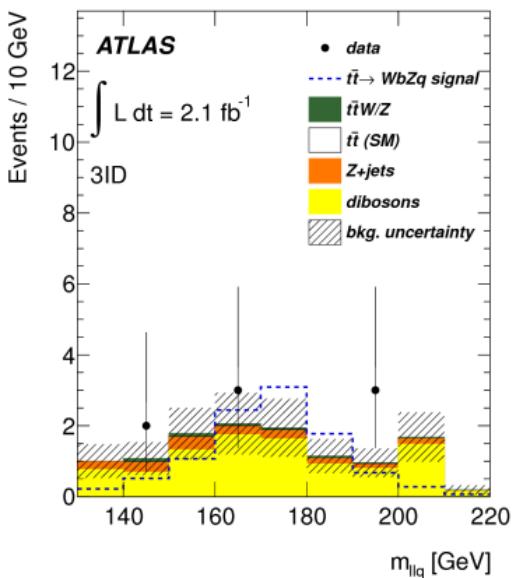
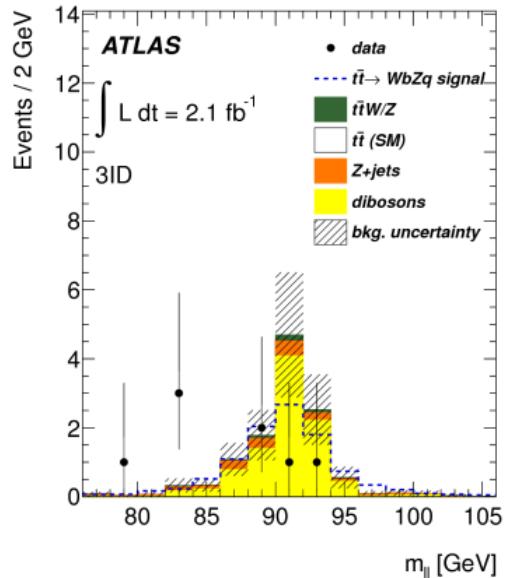
≤ 1 real leptons: t̄t lepton+jets, W+jets, single top, multijet

- data control region: three same-sign leptons
- no events observed with looser selection

	3ID			2ID+TL		
ZZ and WZ	9.5	\pm	4.4	1.0	\pm	0.5 0.6
t̄W and t̄Z	0.51	\pm	0.14	0.25	\pm	0.05
t̄t, WW	0.07	\pm	0.02			
Z+jets	1.7	\pm	0.7			
Single top	0.01	\pm	0.01			
2+3 fake leptons	0.0	\pm	0.2			

} TL fake probability
determined in bins of
 p_T and N_{vtx}

Result



Main syst. uncertainties

- Diboson modeling (3ID)
- Fake-TL (2ID+TL)

Final event selection

- 16 events observed
- 20 ± 7 expected

Limit extraction

- Using CLs
- Expected limit: $9.3 \cdot 10^{-3}$

BF($t \rightarrow qZ$) < $7.3 \cdot 10^{-3}$

Summary



Two searches for FCNC at ATLAS with 2.05 fb^{-1}

$t \rightarrow qg$

- Search in single top production $qg \rightarrow t \rightarrow b\bar{l}\nu$
- Background determination as in single-top
- Neural-network trained
- $\text{BF}(t \rightarrow ug) < 5.7 \cdot 10^{-5}$ and $\text{BF}(t \rightarrow cg) < 2.7 \cdot 10^{-4}$

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$t \rightarrow qZ$

- Search in $t\bar{t} \rightarrow qZ b\bar{W} \rightarrow q\bar{q} l\bar{l} b\bar{l}\nu$
- Two channels used: 3ID and 2ID+TL
- Background determination according to number of fake leptons
- $\text{BF}(t \rightarrow qZ) < 7.3 \cdot 10^{-3}$

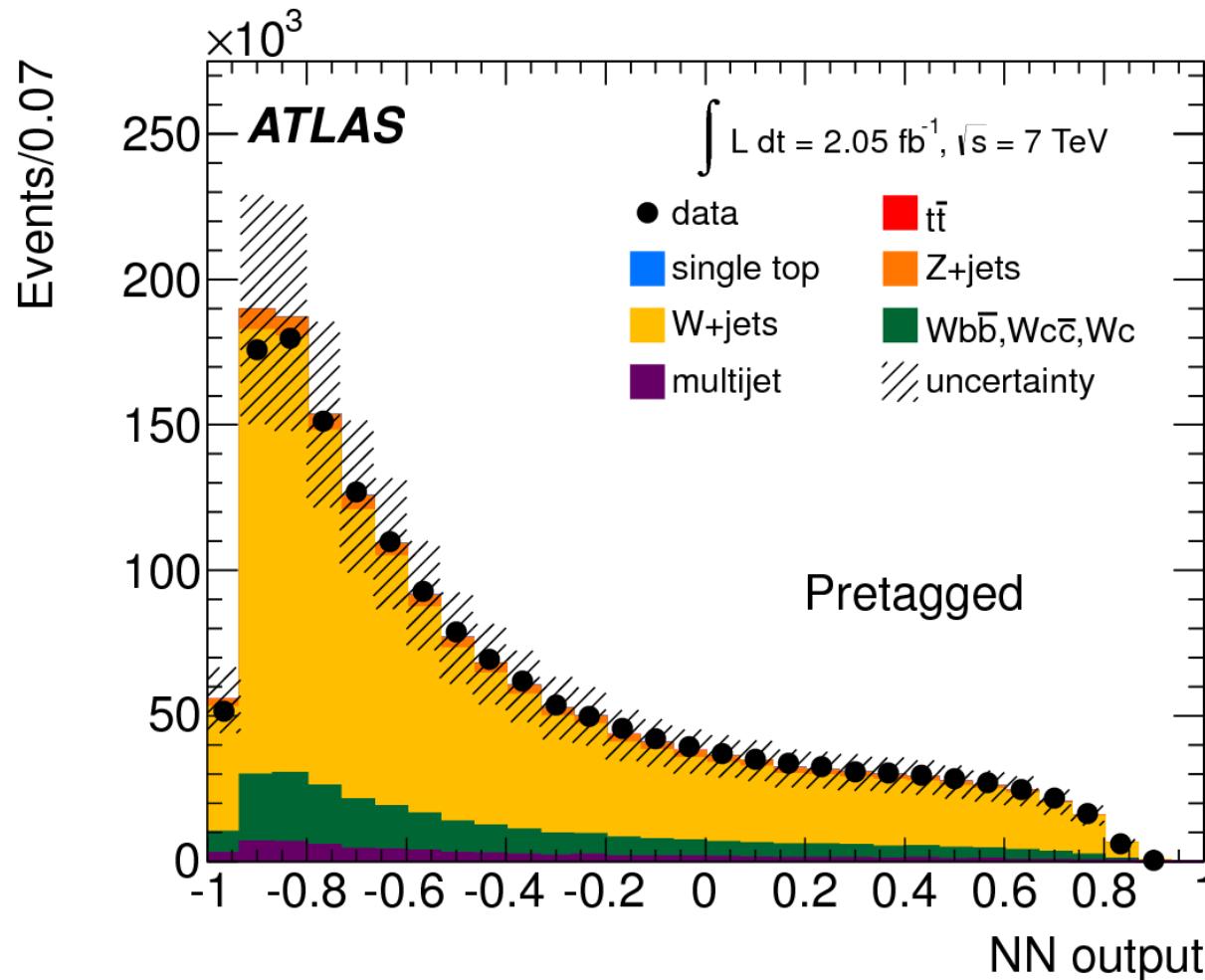
submitted to JHEP 01-Jun-2012, arXiv:1206.0257

Backup



NN distribution pre-tagged

- good background modeling

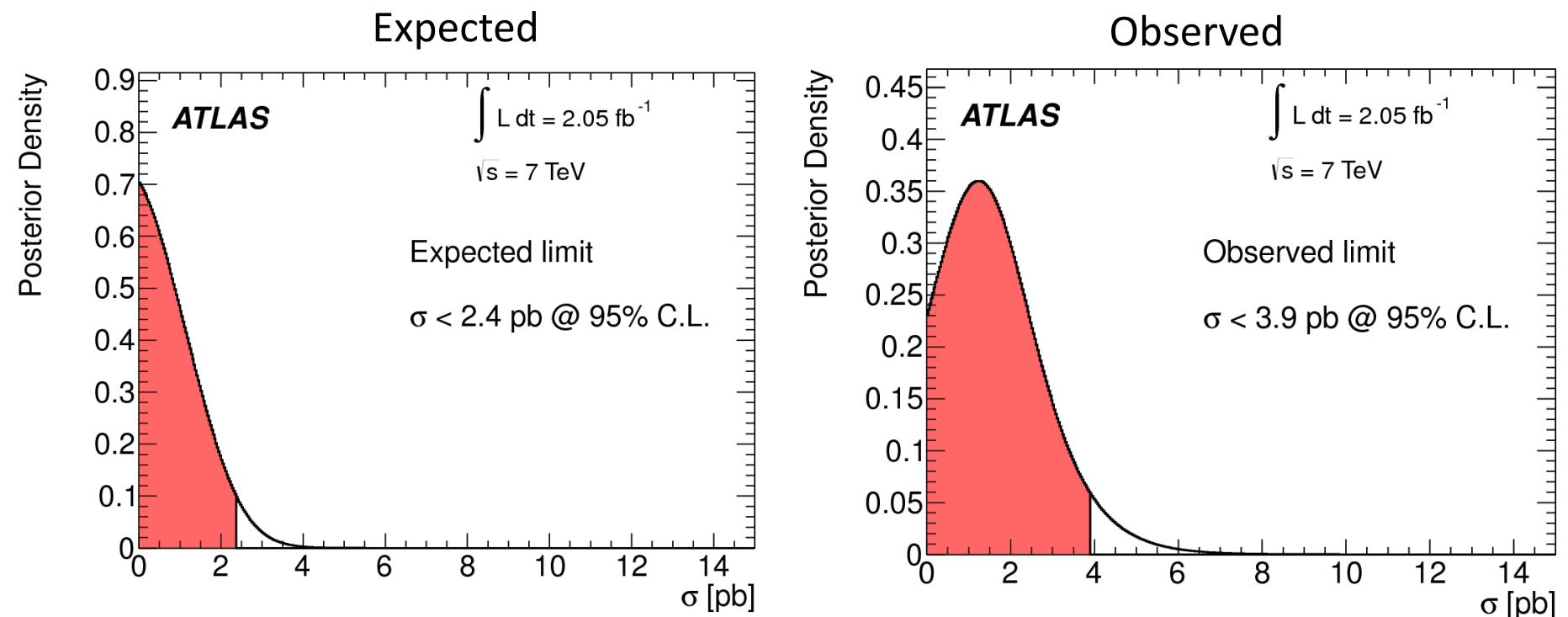


Backup



Posterior probability function

- direct sampling approach with same Gaussian shifts applied to each source, process and bin for each uncertainty
- large number of samples of syst. shifts created



Systematic uncertainties for FCNC in decay

Source	3ID		2ID+TL	
	Background	Signal	Background	Signal
Luminosity	4%	4%	<1%	4%
Electron trigger	4%	1%	<1%	<1%
Electron reconstruction modelling	10%	3%	<1%	2%
Muon trigger	3%	1%	<1%	<1%
Muon reconstruction modelling	7%	1%	<1%	1%
TL reconstruction modelling	—	—	2%	1%
Jet energy scale	11%	1%	1%	1%
Jet reconstruction efficiency	5%	2%	<1%	<1%
Jet energy resolution	1%	3%	1%	4%
E_T^{miss} modelling	4%	1%	<1%	<1%
LAr readout problem	3%	1%	<1%	1%
Pile-up	4%	<1%	<1%	<1%
b -tagging	—	—	1%	6%
Top quark mass	<1%	2%	—	3%
$\sigma_{t\bar{t}}$	<1%	8%	—	8%
ISR/FSR	<1%	3%	—	6%
PDFs	—	3%	—	3%
ZZ and WZ shape	33%	—	5%	—
ZZ and WZ cross section	4%	—	<1%	—
ZZ and WZ heavy-flavour content	—	—	<1%	—
Fake leptons	1%	—	17%	—
Total	38%	12%	18%	15%

3ID and 2ID+TL contributions

channel	observed	(-1σ)	expected	($+1\sigma$)
3ID	0.81%	0.63%	0.95%	1.4%
2ID+TL	3.2%	2.15%	3.31%	4.9%
Combination	0.73%	0.61%	0.93%	1.4%