Top FCNC studies @ LHC

— status report —

Nuno Castro

nfcastro@lipc.fis.uc.pt

Flavour in the era of the LHC

Working Group 1

CERN, 15th May 2006

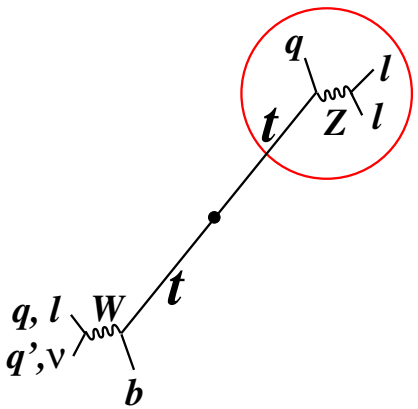
Top quark FCNC decays

- GIM suppressed in the SM
- higher BR in some SM extensions
  (2-Higgs doublet, SUSY, exotic fermions, . . .)

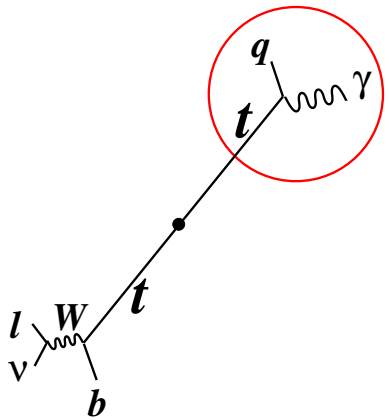
	BR in SM	2HDM	MSSM	$\not{R}$ SUSY	QS
$t \to qZ$	$\sim 10^{-14}$	$\sim 10^{-7}$	$\sim 10^{-6}$	$\sim 10^{-5}$	$\sim 10^{-4}$
$t \to q\gamma$	$\sim 10^{-14}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-9}$
$t \to qg$	$\sim 10^{-12}$	$\sim 10^{-4}$	$\sim 10^{-5}$	$\sim 10^{-4}$	$\sim 10^{-7}$

- 3 top decay channels studied:

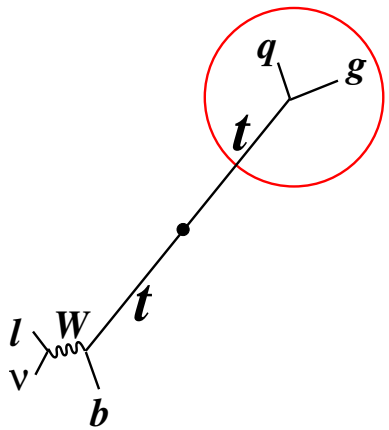
$t \to qZ$ (2jets+1l+1γ+missing)



$t \to q\gamma$ (3jets+1l+missing)



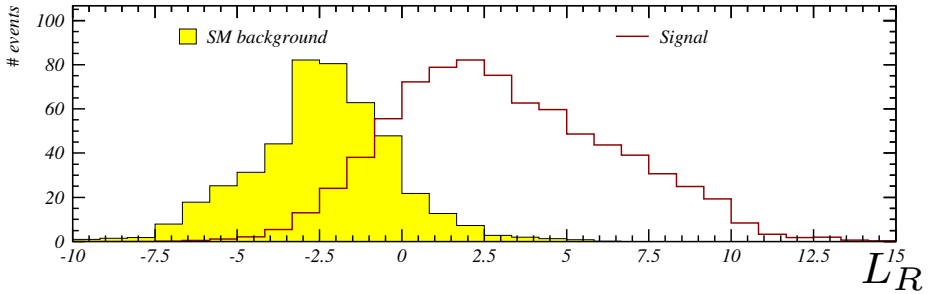
$t \to qg$



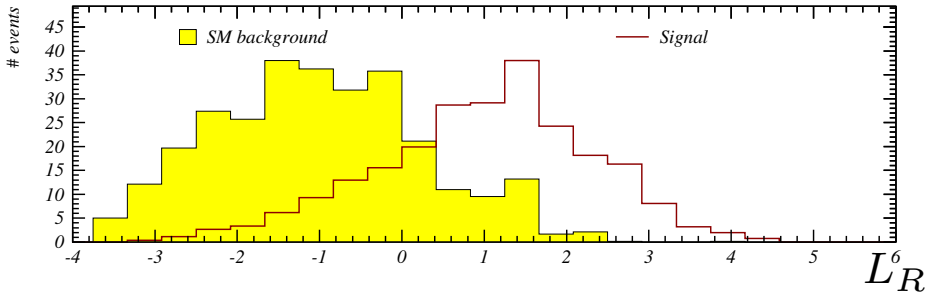
Top FCNC studies @ LHC — Status Report

- ATLAS (ATL-PHYS-PUB-2005-009 and ATL-PHYS-2001-007)
  - Sequential analysis
  - Probabilistic analysis $\longrightarrow$ discriminant variable: $L_R = \ln(L_S/L_B)$

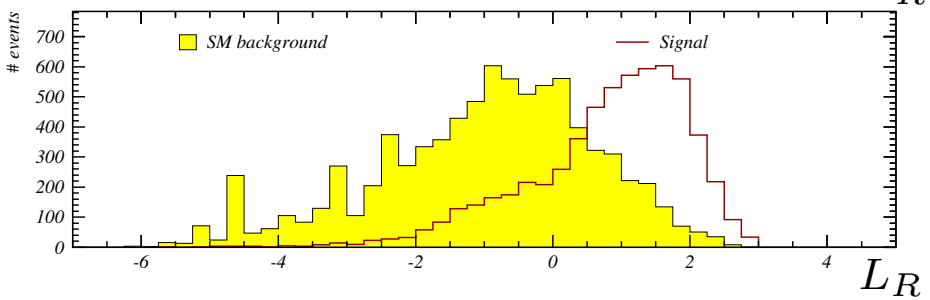
qZ **channel** $\longrightarrow$



$q\gamma$ **channel** $\longrightarrow$



qg **channel** $\longrightarrow$



Top FCNC studies @ LHC — Status Report

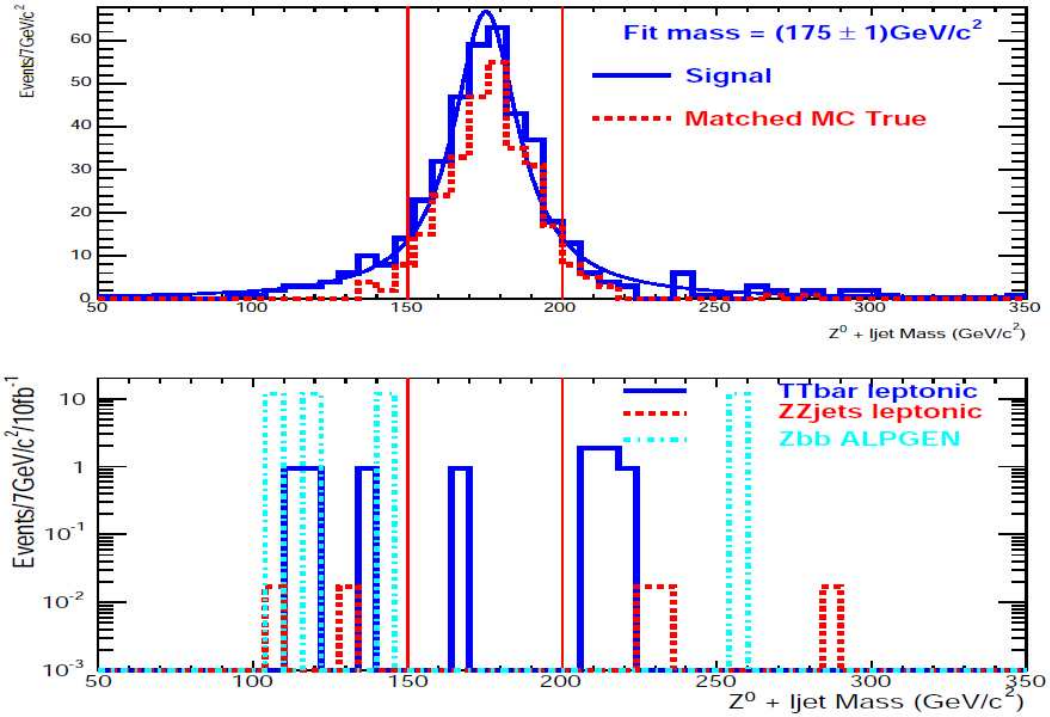
- ATLAS (ATL-PHYS-PUB-2005-009 and ATL-PHYS-2001-007)
  - 95% CL level expected upper limits (evaluated with MFLM):

channel	type		$BR\ (L = 10\ \text{fb}^{-1})$	$BR\ (L = 100\ \text{fb}^{-1})$
$t \to Zu(c)$	sequential	hadronic	–	2.8×10^{-4}
		leptonic	–	6.3×10^{-5}
		combined	–	6.3×10^{-5}
	probabilistic		3.5×10^{-4}	6.5×10^{-5}
$t \to \gamma u(c)$	probabilistic		6.6×10^{-5}	1.8×10^{-5}
$t \to gu(c)$	probabilistic		1.4×10^{-3}	4.3×10^{-4}

Top FCNC studies @ LHC — Status Report

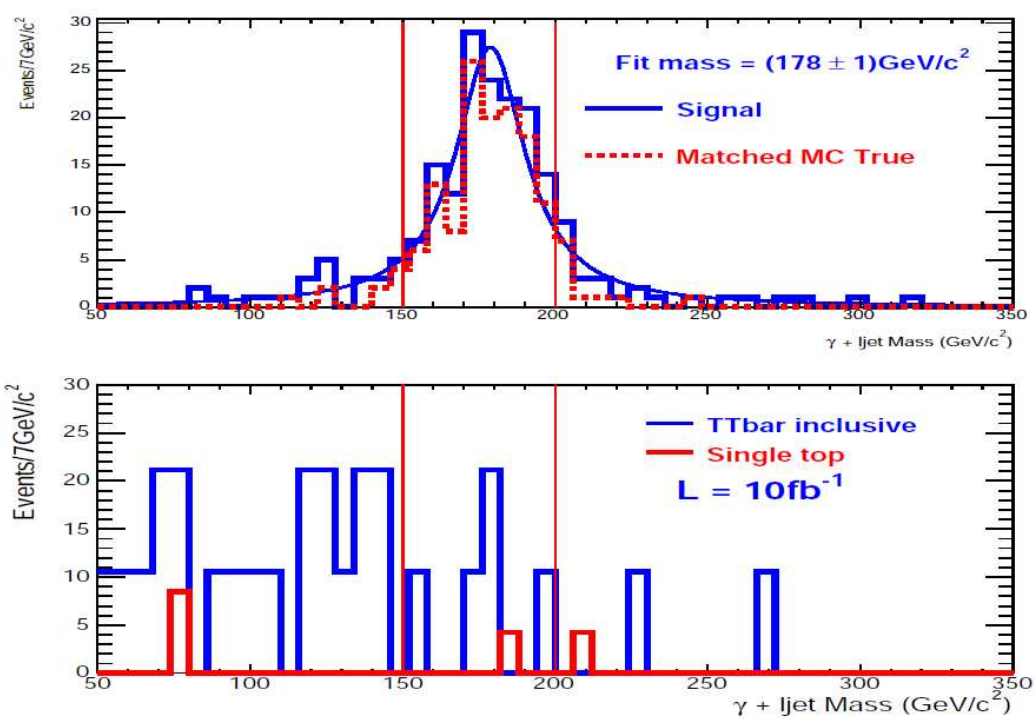
- CMS (new analysis described in CMS Analysis Note 2006/74)

$t \to qZ$ sequential analysis



m_{qZ}

$t \to q\gamma$ sequential analysis

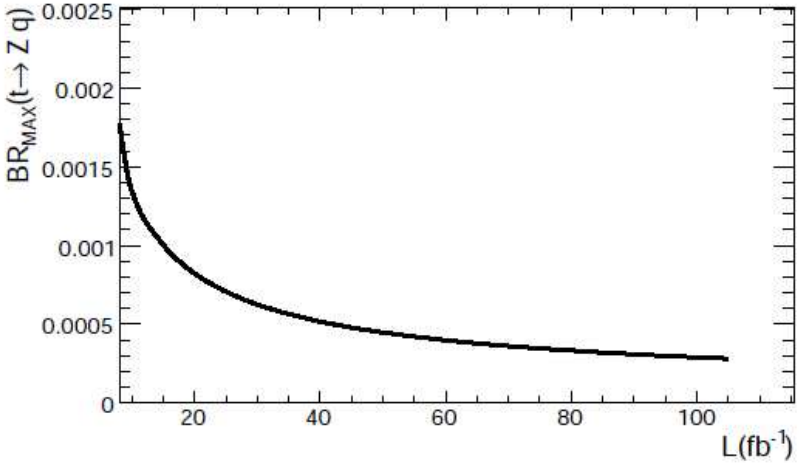


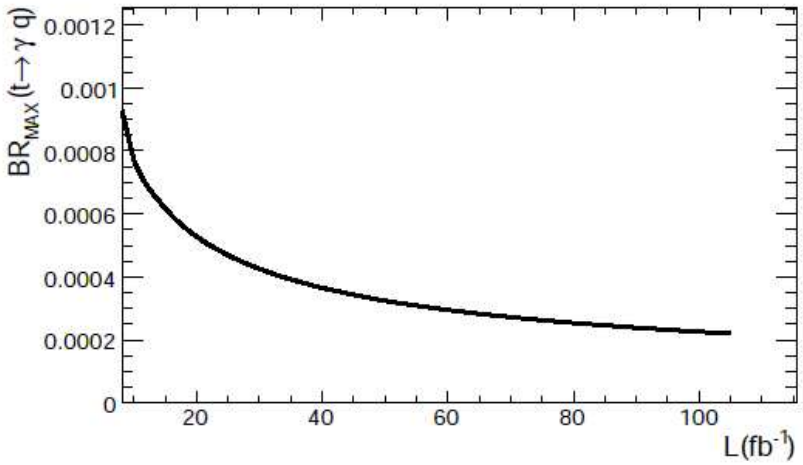
$m_{q\gamma}$

Top FCNC studies @ LHC — Status Report

- CMS (new analysis described in CMS Analysis Note 2006/74)
  - Sensitivity estimation (5σ):
    $S_{c12} = 5 = 2(\sqrt{B+S} - \sqrt{B})$

$(L = 10\ \text{fb}^{-1})$	S	$(\Delta S/S)_{STAT}$	$(\Delta\epsilon/\epsilon)_{STAT}$	BR_{MAX}	ΔBR_{MAX}
$t \to qZ$	11.2	0.223	0.053	11.4×10^{-4}	2.6×10^{-4}
$t \to q\gamma$	43.0	0.058	0.076	5.7×10^{-4}	0.5×10^{-4}





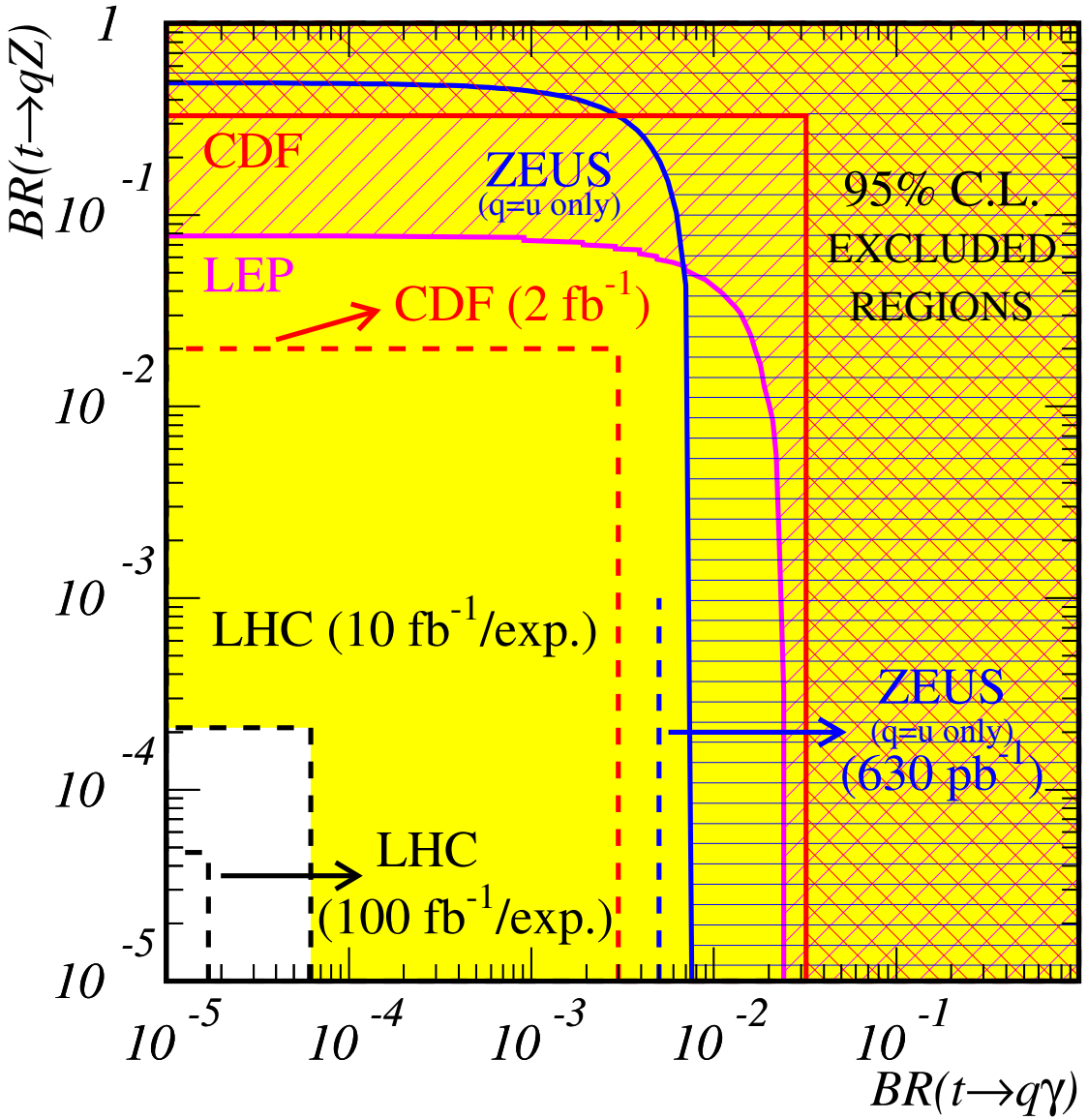
Top FCNC studies @ LHC — Status Report

- Preliminary ATLAS/CMS results combination:
  - 95% CL level expected upper limits (evaluated with MFLM):

channel	L=10 fb^{-1}/exp.	L=100 fb^{-1}/exp.
$t \to qZ$	2.1×10^{-4}	4.7×10^{-5}
$t \to q\gamma$	6.2×10^{-5}	1.7×10^{-5}

Top FCNC studies @ LHC — Status Report

- $BR(t \to qZ)$ vs. $BR(t \to q\gamma)$



Top FCNC studies @ LHC — Status Report

- Ongoing work:
  - Common framework for ATLAS/CMS limits evaluation
  - ATLAS/CMS results combination
  - Draft of the top FCNC studies section for the yellow report

Study of the LHC sensitivity to FCNC top quark decays

— *Flavour in the era of the LHC* Workshop —
Working Group 1

Top Physics Subgroup

Send comments to: nuno.castro@cern.ch and leonardo.benucci@pi.infn.it

May 9, 2006

Flavour Changing Neutral Currents are strongly suppressed in the SM due to the Glashow-Iliopoulos-Maiani (GIM) mechanism. Although absent at tree level, small FCNC contributions are expected at one loop level, according to the CKM mixing matrix [1]. In the top quark sector of the SM, these contributions limit the FCNC decay branching ratios to the gauge bosons, $BR_{t\to qX}$ $(X = Z, \gamma, g)$, to below 10^{-10}. There are however extensions of the SM, like supersymmetry (SUSY) [2], multi-Higgs doublet models [3] and SM extensions with exotic (vector-like) quarks [4], which predict the presence of FCNC contributions already at tree level and significantly enhance the FCNC decay branching ratios compared to the SM predictions (up to $BR(t \to qg) \sim 10^{-4}$ for some SUSY models [5]).

Due to its large mass, much higher than any other known fermion, the top quark is a very good laboratory to look for physics beyond the SM. If the top quark has FCNC anomalous couplings to the gauge bosons, its decay properties would be affected, and possibly measured at colliders, in addition to the dominant decay mode $t \to bW$. Indeed one of the most prominent signatures of FCNC processes at the Large Hadron Collider (LHC), would be the direct observation of a top quark decaying into a charm or an up quark together with a γ, g or Z boson. In the effective Lagrangian approach [6] the new top quark decay rates to the gauge bosons,

$$\Gamma(t \to qg) = \left(\frac{\kappa_{tq}^g}{\Lambda}\right)^2 \frac{8}{3}\alpha_s m_t^3 \quad , \quad \Gamma(t \to q\gamma) = \left(\frac{\kappa_{tq}^\gamma}{\Lambda}\right)^2 2\alpha m_t^3, \tag{1}$$

$$\Gamma(t \to qZ)_\gamma = \left(|v_{tq}^Z|^2 + |a_{tq}^Z|^2\right) \alpha m_t^3 \frac{1}{4M_Z^2 \sin^2 2\theta_W} \left(1 - \frac{m_Z^2}{m_t^2}\right)^2 \left(1 + 2\frac{m_Z^2}{m_t^2}\right), \tag{2}$$

$$\Gamma(t \to qZ)_\sigma = \left(\frac{\kappa_{tq}^Z}{\Lambda}\right)^2 \alpha\, m_t^3 \frac{1}{\sin^2 2\theta_W} \left(1 - \frac{m_Z^2}{m_t^2}\right)^2 \left(2 + \frac{m_Z^2}{m_t^2}\right), \tag{3}$$

can be expressed in terms of the κ_{tq}^g, κ_{tq}^γ, $(|v_{tq}^Z|^2 + |a_{tq}^Z|^2)$ and κ_{tq}^Z anomalous couplings to the g, γ and Z bosons respectively. The energy scale associated with this new physics is represented by Λ, while α_s and α are, respectively, the strong and electromagnetic coupling constants. The electroweak mixing angle is represented by θ_W and the top and Z masses are represented, respectively, by m_t and m_Z.

Although FCNC processes associated with the production [7, 8] and decay [9] of top quarks have been studied at colliders ($BR_{t\to Zu(c)} < 7.8\%$ [7], $BR_{t\to\gamma u(c)} < 2.4\%$ [7] and $BR_{t\to gu(c)} < 13\%$ [8]), the amount of data collected up to now is not comparable with the statistics expected at the LHC. In the LHC low luminosity phase, several millions of top quarks per year and experiment will be produced,

1