Search for FCNC in t decays

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Bundesministerium
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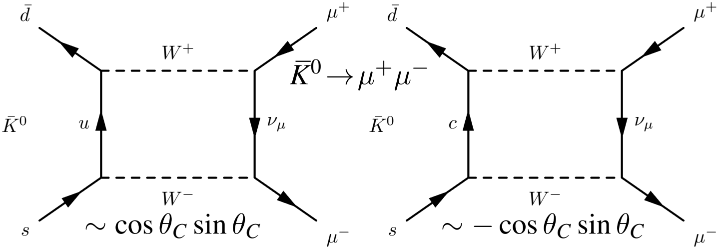
LHCb

BABAR

FCNC in the Standard Model

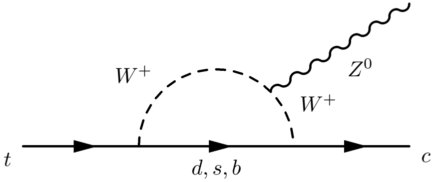
- FCNC transition are not allowed at tree-level within the Standard Model
- Loop contributions usually suppressed by the GIM mechanism



- In case of exact Flavour-SU$(4) \to$ Decay not allowed
- $m_c \neq m_u$ breaks Flavour-SU$(4) \to$ Decay suppressed
- $\mathcal{B}(\overline{K}^0 \to \mu^+\mu^-) \sim 10^{-9}$

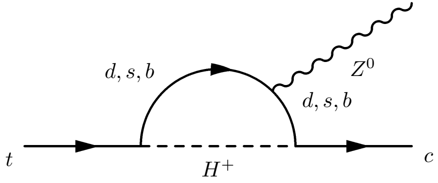
FCNC t decays

- Study FCNC decay $\mathcal{B}(t \to Z^0 q)$ - GIM suppressed decay



$\sim 10^{-14}$

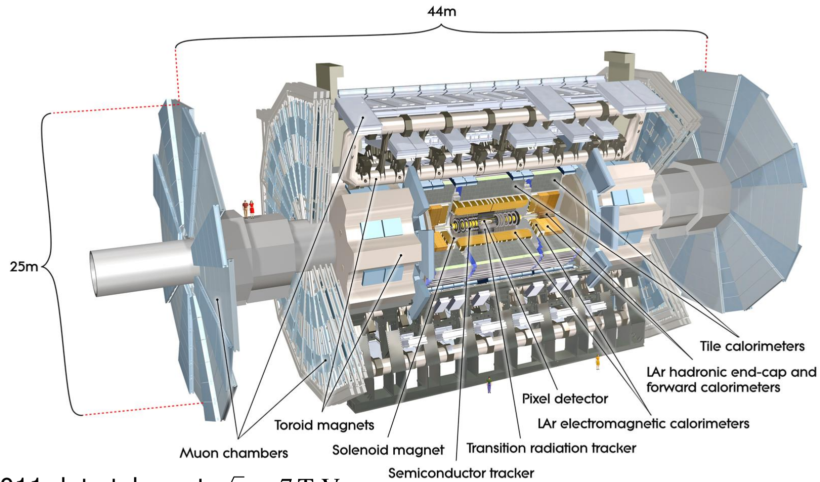
- $\mathcal{B}(t \to Z^0 q)$ enhanced through 2HDM contributions



$\sim 10^{-4}$

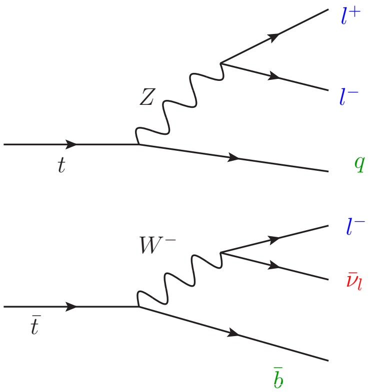
- Current Limit $\mathcal{B}(t \to Z^0 q) < 3.2\%$ @95 C.L. (D0 Collaboration)

ATLAS experiment



- 2011 data taken at $\sqrt{s} = 7\,\mathrm{TeV}$
- $L = 2.1\,\mathrm{fb}^{-1}$

Event selection



- Single-lepton trigger (μ or e)
- Exactly 3 isolated quality leptons
  - one lepton spatially matched to trigger with p_T >25 GeV
  - leading lepton p_T >25 GeV
  - subleading leptons p_T >20 GeV
- $N_{\text{jets}} \geq 2$
  - Anti-Kt with $\Delta R = 0.4$
  - $p_T > 25$ GeV
- $E^T_{miss} > 20$ GeV

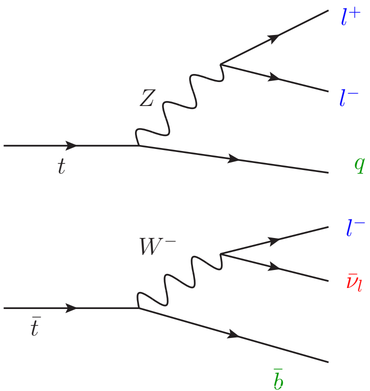
- Lots of objects in the final state
  $\rightarrow$ Use decay topology for further discrimination

Reconstruction of the $t\bar{t}$ pair

$$\chi^2 = \frac{(m^{reco}_{j_a l_a l_b} - m_t)^2}{\sigma_t^2} + \frac{(m^{reco}_{j_b l_c \nu} - m_t)^2}{\sigma_t^2} + \frac{(m^{reco}_{l_c \nu} - m_W)^2}{\sigma_W^2} + \frac{(m^{reco}_{l_a l_b} - m_Z)^2}{\sigma_Z^2}$$

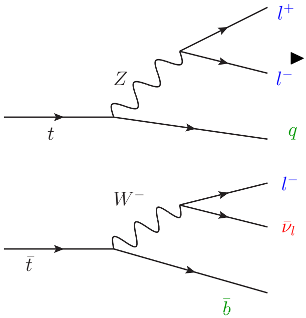
$$m_t = 172.5\,\mathrm{GeV}/c^2 \quad m_{W^\pm} = 80.4\,\mathrm{GeV}/c^2 \quad m_{Z^0} = 91.2\,\mathrm{GeV}/c^2$$

$$\sigma_t = 14\,\mathrm{GeV}/c^2 \quad \sigma_{W^\pm} = 10\,\mathrm{GeV}/c^2 \quad \sigma_{Z^0} = 3\,\mathrm{GeV}/c^2$$



- Require $Z^0 \to \mu^+\mu^-$ or $Z^0 \to e^+e^-$
- Choose the combination with the smallest χ^2
- Keep events with
  - $|m_t^{\mathrm{Reco}} - m_t| < 40\,\mathrm{GeV}/c^2$
  - $|m_W^{\mathrm{Reco}} - m_W| < 30\,\mathrm{GeV}/c^2$
  - $|m_{Z^0}^{\mathrm{Reco}} - m_{Z^0}| < 15\,\mathrm{GeV}/c^2$
- $\varepsilon_{\mathrm{Signal}} = (79 \pm 2)\%$
- $\varepsilon_{\mathrm{Background}} = (47 \pm 7)\%$

Main background



- Signal final state:
  - 3 leptons 2 jets (light flavour and b), 1 neutrino
- Main background:
  - 3 real leptons case
    - WZ+jets $\rightarrow \nu, \ell, \ell, \ell$, jet(s)
    - ZZ+jets
      - ℓ, ℓ, ℓ, ℓ (not reconstructed $\rightarrow E_T^{miss}$), jet(s)
      - $\ell, \ell, \tau_{had}, \tau \rightarrow (\nu$, W, $\rightarrow (\nu, \ell))$
    - Estimated by MC simulation
    - Normalised by cross section
  - 2 real + 1 fake
    - Z + jets $\rightarrow \ell, \ell$, jets (fake)

Background: Z^0 +jets

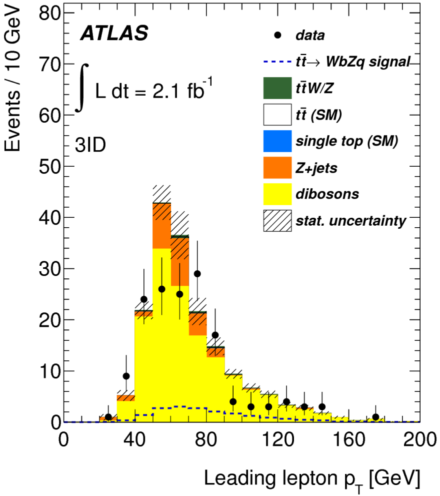
- $\sigma(Z^0 + \text{jets})$ is not well known $\rightarrow$ Data driven estimation
- Control region definition
  - Select Z^0 candidates $|91.2GeV - m_{\ell\ell}^{reco}|$ <15GeV
  - Relaxed Lepton ID in order increase statistics in control region $\rightarrow$ Correct to signal region with MC ($c_{relaxed} = 0.063 \pm 0.013$)
- Extraction of a scale factor using the control region
- Estimation of Z^0 +jets yield expected number of events in the signal region

$$\left[N_{Z^0+\text{Jets}}^{\text{Data}}\right]_{\text{SR}} = \left[\frac{N^{\text{Data}} - N_{\text{other backgrounds}}^{\text{MC}}}{N^{\text{MC}_{Z^0+\text{jets}}}}\right]_{\text{CR}} \times \left[N_{Z^0+\text{jets}}^{\text{MC}}\right]_{\text{SR}}$$

- Method applied in (E_T^{miss}, $m_{\ell\ell}$)-plane
  $\rightarrow$ scale factor provided per 2D-bin
- Finally: $N_{Z+jets}^{data} = (\sum_{i,j} N_{i,j}) \times c_{\text{relaxed}}$

Summary table background

Source	Contribution
$Z^0 Z^0$ and WZ^0	9.5 ± 4.4
$t\bar{t}W$ and $t\bar{t}Z^0$	0.51 ± 0.14
$t\bar{t}$ and WW	0.07 ± 0.02
$Z^0 +$ jets	1.7 ± 0.7
Single top	0.01 ± 0.01
$2+3$ fake leptons	$0.0^{+0.2}_{-0.0}$
Expectation	11.8 ±4.4
Data	8



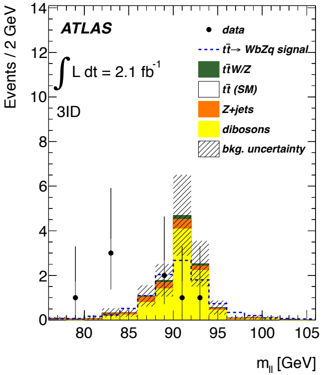
Systematic uncertainties

	Signal	Background
$\sigma_{t\bar{t}}$	8%	$< 1\%$
Z^0Z^0 and WZ^0 shape	-	33%

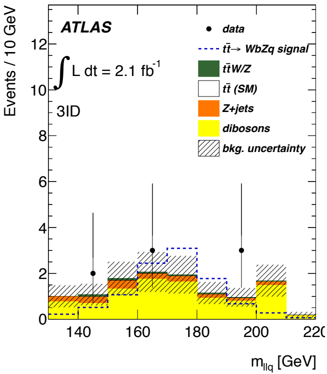
- $\sigma_{t\bar{t}}$ is taken from NNLO calculations due to modelling of hard scattering
- Uncertainty on the Boson shape due to MC models

Data results

Z^0 Mass



Top quark mass



Result

Determination of the limit

No Evidence for the decay $\mathcal{B}(t \to Z^0 q)$

- Assume $\mathcal{B}(t \to Z^0 q) + \mathcal{B}(t \to W^+ b) = 1$
- C.L. is determined using CL_s method
- Calculate $\mathcal{B}(t \to Z^0 q) < 0.82\%$ with $q = c, u$ @ 95% C.L.

Interpretation

- In agreement with the Standard Model
- No exclusion of mentioned BSM models
- Related CMS analysis yields
  $\mathcal{B}(t \to Z^0 q) < 0.21\%$ @ 95% C.L. ($L = 5\,\mathrm{fb}^{-1}$@$\sqrt{s} = 7\,\mathrm{TeV}$)

Backup

Jet reconstruction in ATLAS

Jet reconstruction is performed by the anti-kt algorithm:

1. Compute $d = \text{mean}(d_{ij}, d_{iBeam})$ i, j = particles, protojets
2. If $d = d_{ij}$ then merge protojets i and j, goto 1
3. If $d = d_{iBeam}$ then define i as a jet, remove it from list

   where

   - $d_{ij} = \text{min}(p_{Ti}^{-2}, p_{Tj}^{-2}) \frac{\Delta R_{ij}^2}{R^2}$
   - $d_{iBeam} = p_{Ti}^{-2}$
   - $\Delta R_{ij}^2 = \sqrt{\Delta\phi_{ij}^2 + \Delta\eta_{ij}^2}$

   In the analysis R=0.4.

Anti-kt tend to separate better high pT component.
The algorithm is collinear and infrared safe.

Main systematic uncertainties

	Source	Background	Signal
a.	Luminosity	4%	4%
b.	Electron reconstruction modelling	10%	3%
c.	Muon reconstruction modelling	7%	1%
d.	Jet energy scale	11%	1%
e.	$\sigma_{t\bar{t}}$	$< 1\%$	8%
f.	ZZ and WZ shape	33%	–
	Total	38%	12%

- a. Van Der Meer Scan
- b. - c. Mainly due to electromagnetic calorimeter for electrons and MS-ID matching for muons
- d. Many effects due to algorithm definition (out of cone, pile-up, underlying events, etc..)
- e. Theoretical uncertainty on $t\bar{t}$ cross section
- f. Data-driven estimation.