

Study of the diboson $ZZ \rightarrow 4l$ production with the ATLAS detector

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Protopapadaki Sofia
PhD supervisor : J-F Laporte

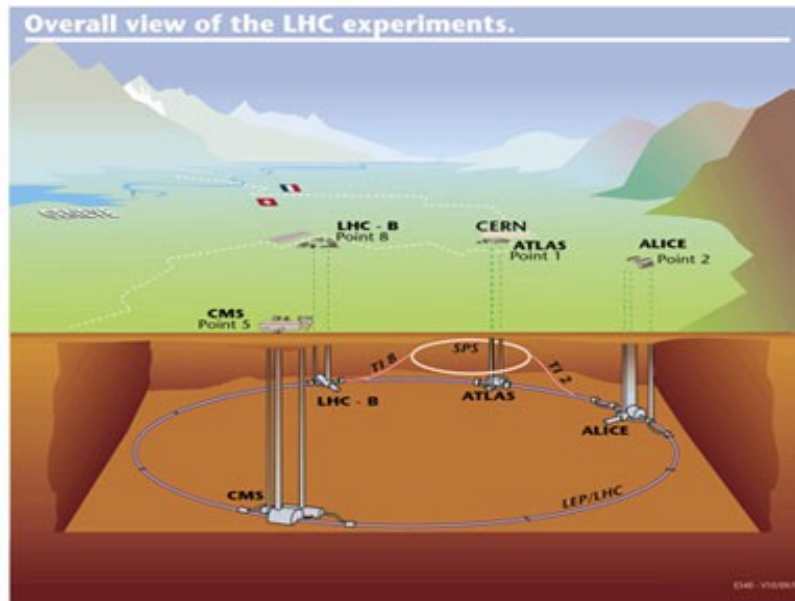


Outline

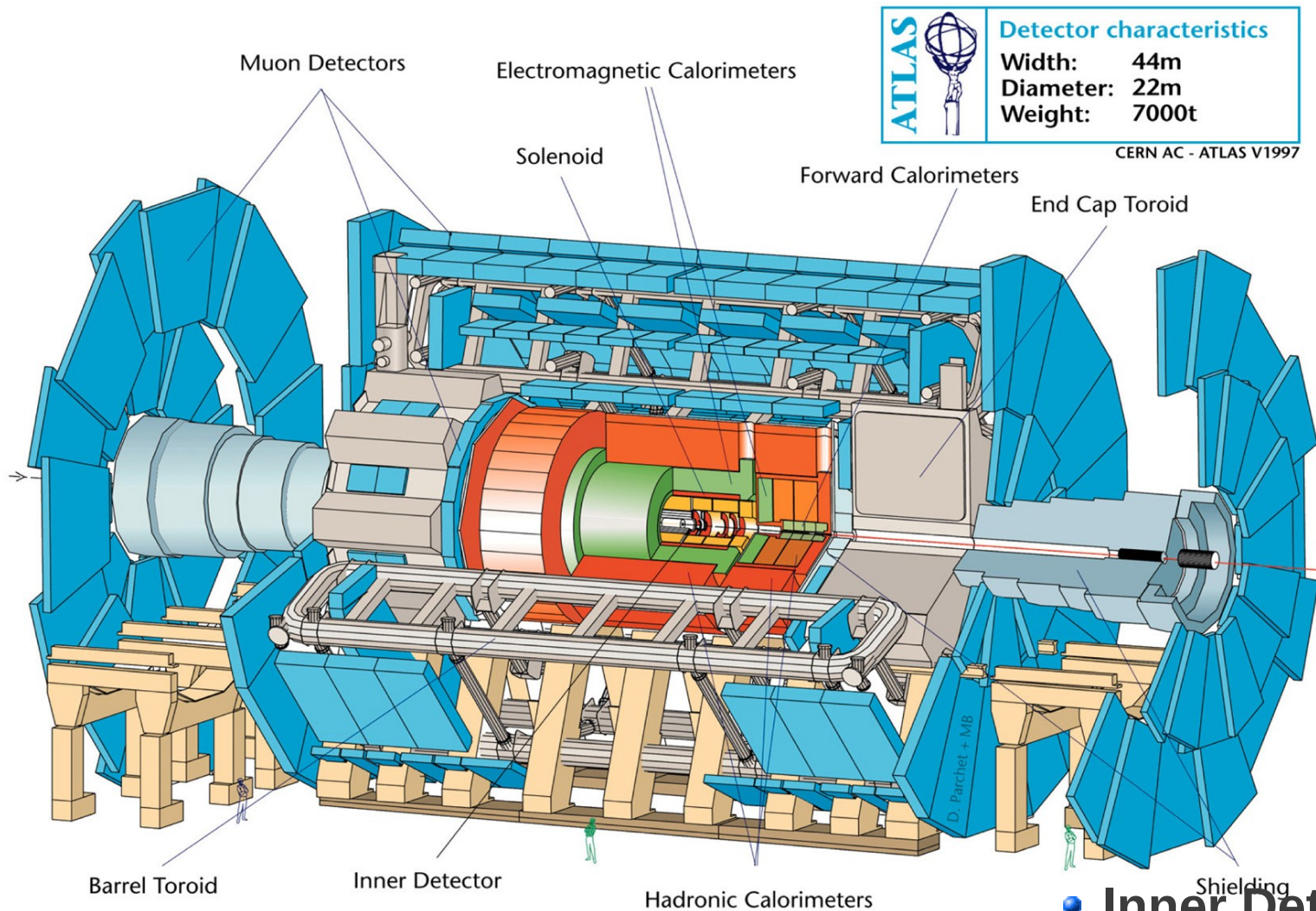
- The LHC and the ATLAS Detector
 - Muon spectrometer and qualification task
- ZZ Analysis :
 - Physics and motivations
 - Selection & Background
 - Cross section extraction
 - Limits on Neutral triple gauge coupling (TGC)

The LHC

- Ring of 27 Km near Geneva
- p-p collisions at CME 8TeV
- 4 Big experiments



The ATLAS Detector



- Inner Detector
- Electromagnetic calorim.
- Hadronic calorimeter
- Muon spectrometer

Muon Spectrometer & magnetic field

Toroidal magnetic field ~ 0.5 T

Allows to:

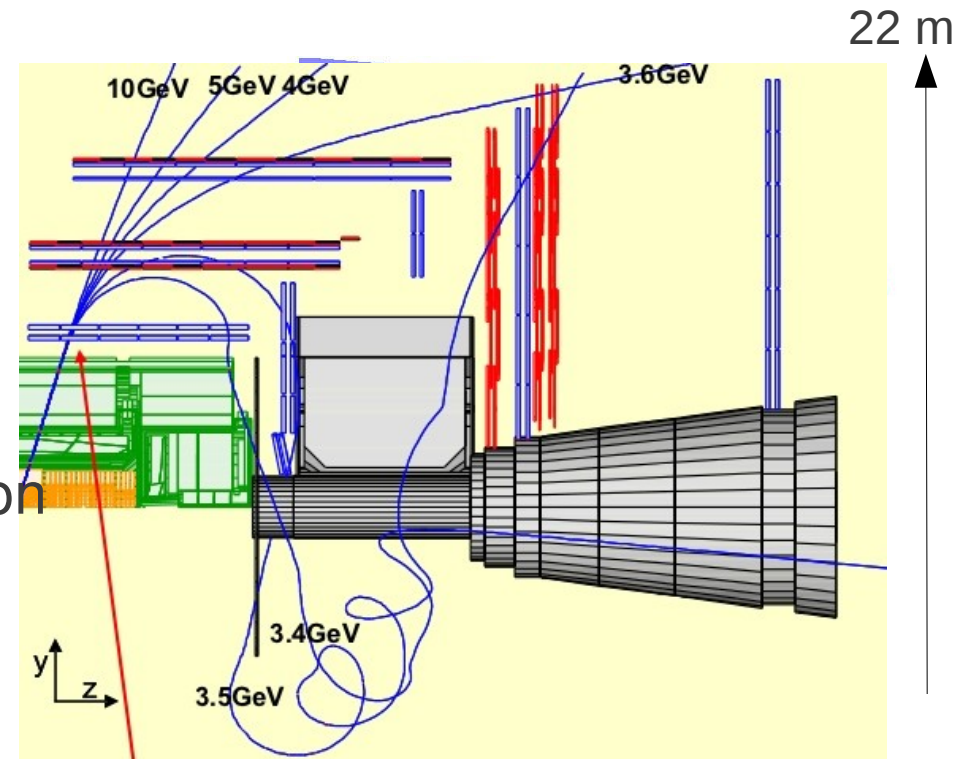
- 1) Identify muons charge
- 2) Determine muon momentum

→ Has to be **modeled** for the reconstruction procedure: Magnetic field map (B-map)

Service task (~ 6 months work):

- For the magnetic field reconstruction: ~ 1700 magnetic field sensors
→ Sensor stability → classification
- Study of agreement between B-map prediction and sensors measurement
- Investigation of observed fluctuations in the measured magnetic field

CDS address : <https://cds.cern.ch/record/1495223?>



Physics Analysis

Analysis Introduction

- The Standard Model :

- ★ Electroweak sector:

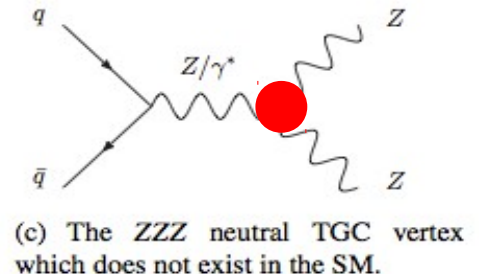
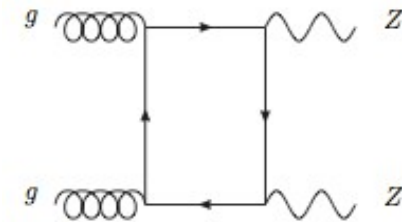
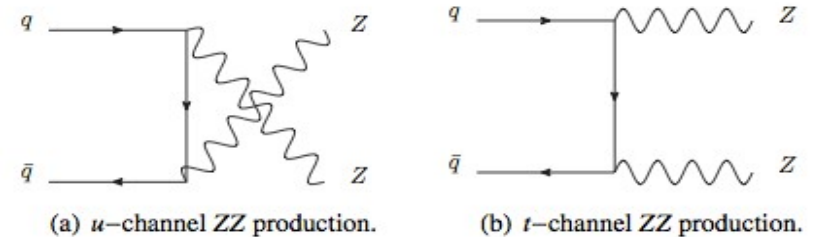
$SU(2)_L \times U(1)_Y$ non-abelian gauge group

- ★ Neutral Triple Gauge Couplings predicted to be 0 (c) but can be introduced using an effective Lagrangian

$$\mathcal{L}_{VZZ} = -\frac{e}{M_Z^2} \left[f_4^V (\partial_\mu V^{\mu\beta}) Z_\alpha (\partial^\alpha Z_\beta) + f_5^V (\partial^\sigma V_{\sigma\mu}) \tilde{Z}^{\mu\beta} Z_\beta \right]$$

- Motivation

- Now enough CME and luminosity for precise ZZZ measurement
- Probe standard model (TGC: new physics)
- Main irreducible background to Higgs



Event selection

Muon and electron selection:

- High Transverse Momentum
- Isolated

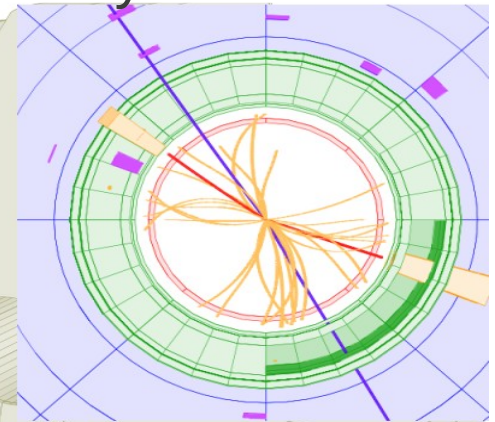
$ZZ \rightarrow 4l$ final state

- Very clear signature
- Still dominated by the low statistics

ZZ selection:

- Z Invariant Mass 90 GeV

$ZZ \rightarrow 2e2\mu$ event



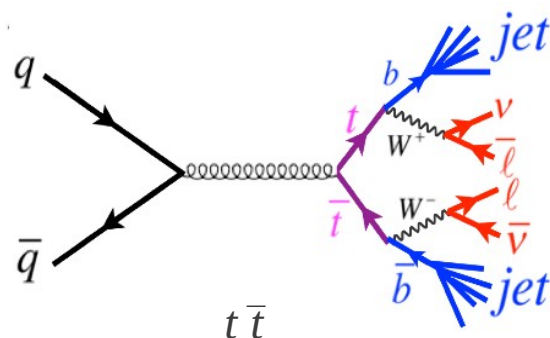
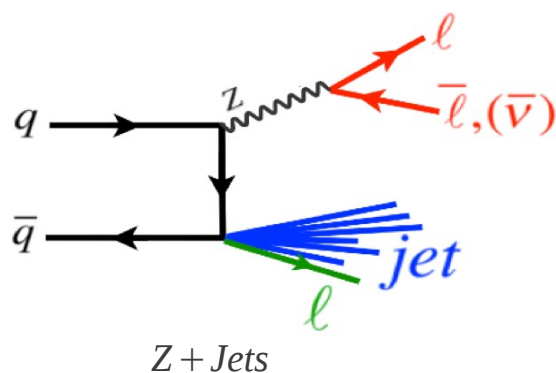
Background estimation

1) Reducible background (fake leptons) :

- $Z+X$ (jet or γ)
- Top (single top or $t\bar{t}$)
- WZ/WW + jets

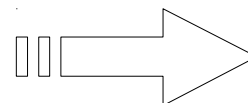
Fully Data Driven estimation :

⇒ ★ Use data to estimate the number of Background contamination in our selection



2) Irreducible background (all 4 true leptons):

- $t \bar{t} + Z$
- ZVV



Estimated from Monte Carlo

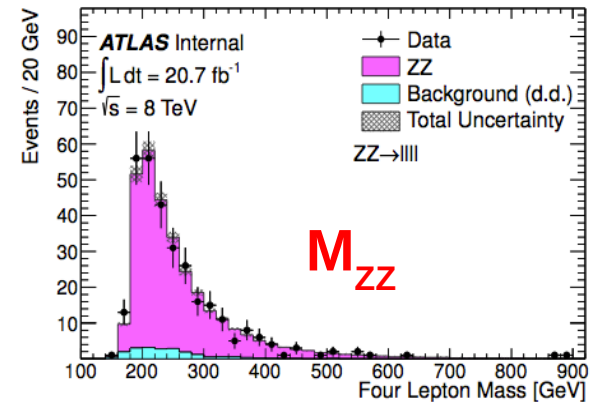
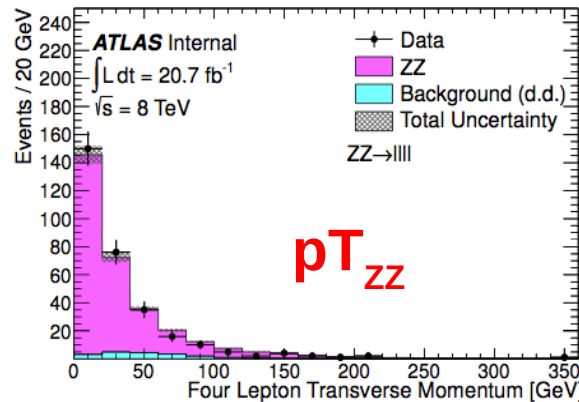
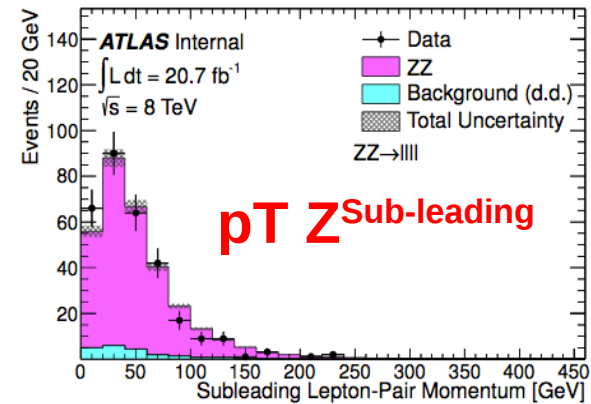
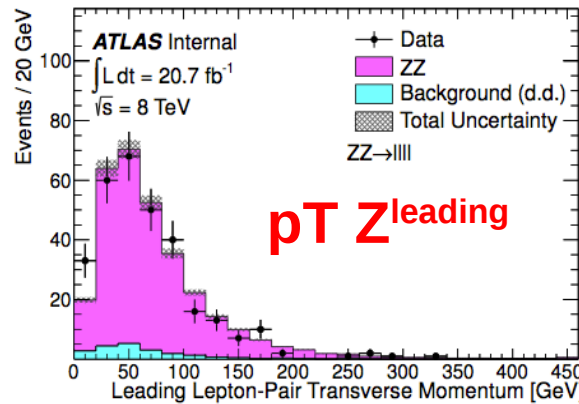
Observed events and kinematic distributions

→ Results using all 2012 data at a CME = 8TeV

$ZZ \rightarrow \ell\ell\ell'\ell'$	$e^+e^-e^+e^-$	$\mu^+\mu^-\mu^+\mu^-$	$e^+e^-\mu^+\mu^-$	$\ell^+\ell^-\ell'^+\ell'^-$
Observed ZZ	62	85	158	305
Expected ZZ	$59.53 \pm 0.46 \pm 3.95$	$90.23 \pm 0.59 \pm 2.68$	$142.71 \pm 1.04 \pm 5.54$	$292.47 \pm 1.28 \pm 10.53$
Expected Bkg ZZ	$10.04 \pm 1.75 \pm 1.41$	$1.06 \pm 1.42 \pm 0.45$	$9.25 \pm 2.08 \pm 3.11$	$20.35 \pm 2.91 \pm 4.96$

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Good Data – MC Agreement!



Cross-section extraction

Total cross section :

$$\sigma_{ZZ}^{tot} = \frac{N_{llll}^{obs} - N_{llll}^{bkg}}{L \times BR(ZZ \rightarrow llll) \times A_{ZZ \rightarrow llll} \times C_{ZZ \rightarrow llll}}$$

L : Luminosity

BR : Branching ratio $ZZ \rightarrow 4l$

$A_{ZZ \rightarrow llll}$: Corrects for detector acceptance

$C_{ZZ \rightarrow llll}$: Corrects for detector efficiency

$$\sigma_{ZZ}^{tot} = 7.1_{-0.4}^{+0.5} (stat) \pm 0.3 (syst) \pm 0.2 (lumi) pb$$

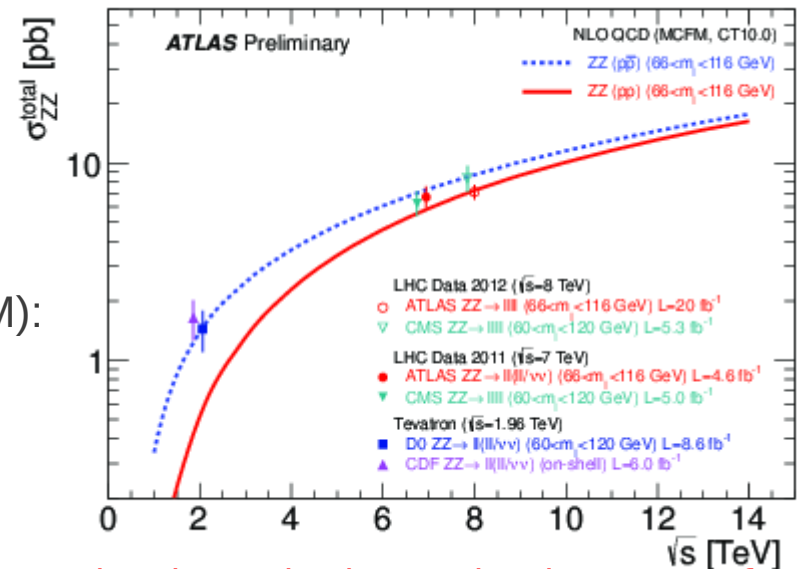
To be compared with the theoretical NLO prediction (MCFM):

$$\sigma_{ZZ}^{tot} = 7.2_{-0.2}^{+0.3} pb$$

→ Statistics still low

Systematic uncertainties :

- Object uncertainties $\sim 3.3\%$:
→ Lepton energy calibration
→ Reconstruction & identification
- Theoretical uncertainties $\sim 1\%$
- Luminosity 2.8%



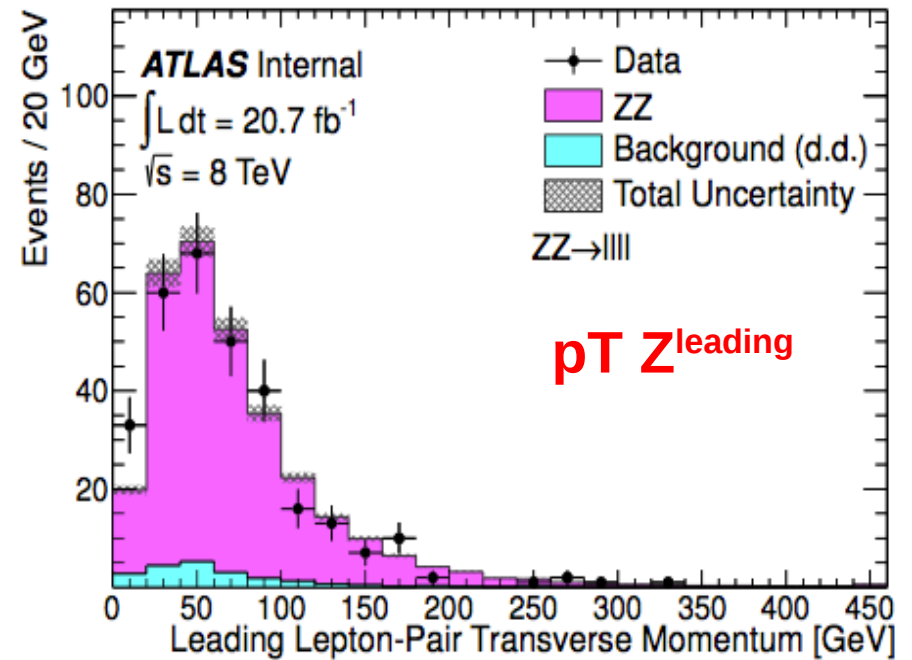
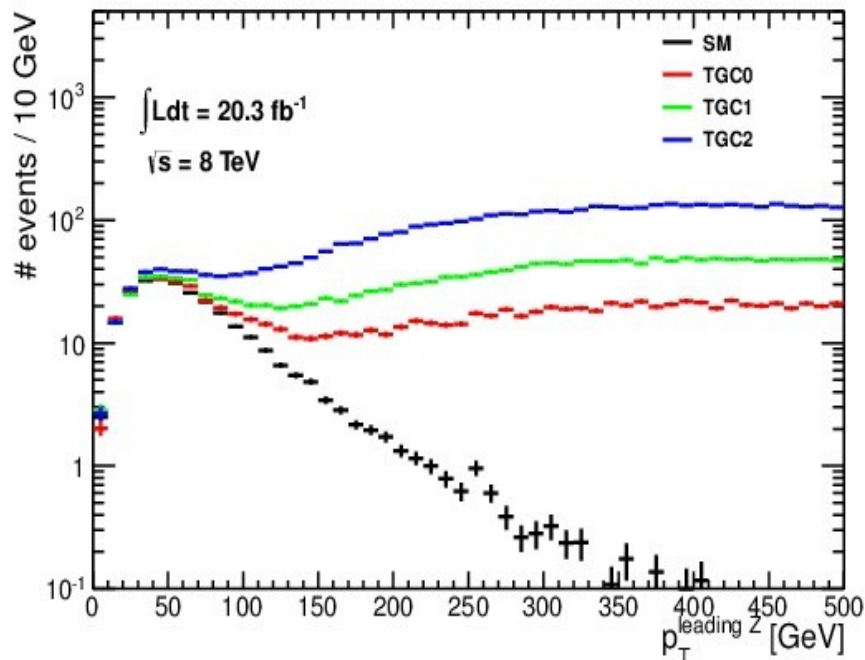
Results shown in the Moriond 2013 conference
Conference Note : ATLAS-COM-CONF-2013-020
<https://cds.cern.ch/record/1517443>

aTGC limits

- Parametrize signal as a function of the 4 couplings:

$$N_{expected}(f_4^\gamma, f_4^Z, f_5^\gamma, f_5^Z)$$

- aTGC sensitivity in high Z^{leading} P_t bins



Limits fitting each coupling separately

7TeV results :

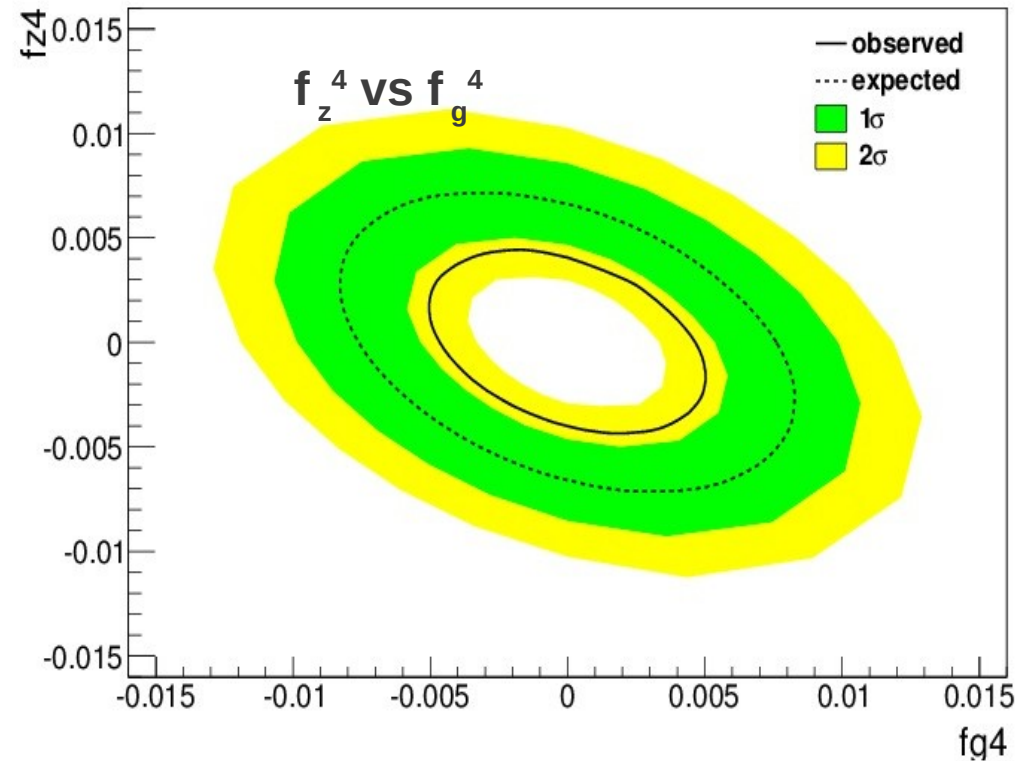
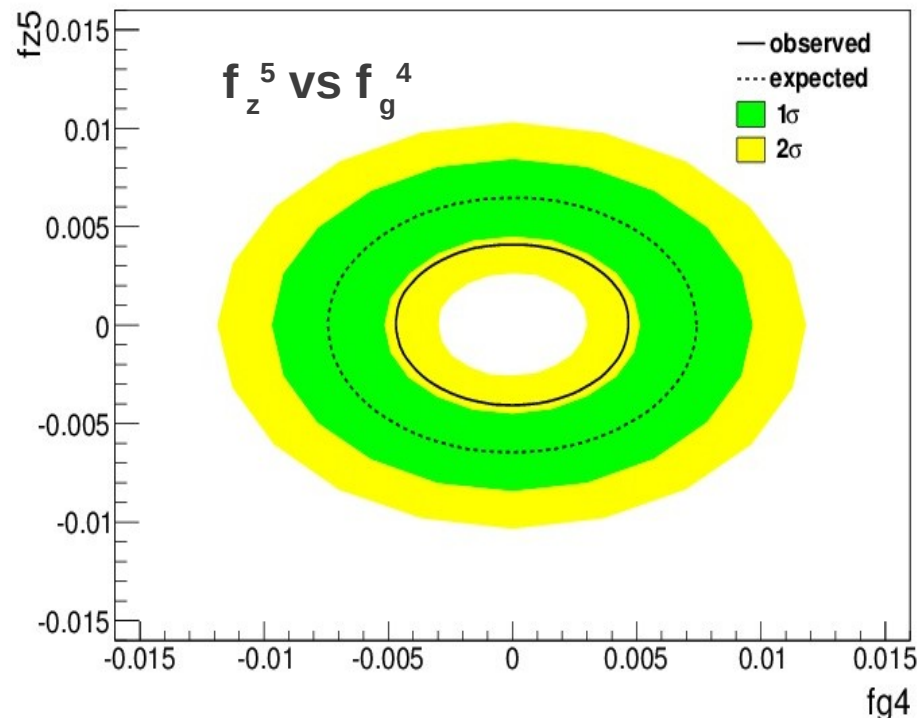
4 Z p_T bins	expected	$[-0.017, 0.017] \pm 0.005$	$[-0.015, 0.015] \pm 0.004$	$[-0.017, 0.017] \pm 0.005$	$[-0.015, 0.015] \pm 0.004$
	observed	$[-0.020, 0.020]$	$[-0.017, 0.017]$	$[-0.020, 0.020]$	$[-0.017, 0.017]$

8TeV results :

	Expected limits	Observed limits
f_4^γ	$[-0.008 ; 0.007] \pm 0.002$	$[-0.005; 0.005]$
f_4^Z	$[-0.006 ; 0.006] \pm 0.002$	$[-0.004; 0.004]$
f_5^γ	$[-0.007 ; 0.007] \pm 0.002$	$[-0.005; 0.005]$
f_5^Z	$[-0.006 ; 0.006] \pm 0.002$	$[-0.004; 0.004]$

- 8TeV limits, as expected, tighter than 7TeV
- Analysis optimization ongoing!

Limits fitting simultaneously two couplings



- Observed limits in 2 sigma band
- Same image for all 6 pairs of couplings

Conclusion

- During the first year worked on service task
→ An internal note was written
- Cross section measurement with 2012 data : 7.1 ± 0.6 bp
→ In agreement with theory: 7.2 ± 0.4 pb
→ Results presented at the moriond conference
- First look at aTGC limits
→ Limits using 2012 data significantly tighter
→ A paper should be published by the beginning of Autumn

Back up

→ Determine cross-sections with a log-likelihood fit with Gaussian nuisance parameters:

$$-\ln L = \sum_{i=0}^{n_{bins}} -\ln \frac{N_{\text{exp}}^i N_{\text{obs}}^i e^{-N_{\text{exp}}^i}}{N_{\text{obs}}^i !} + \sum \frac{x_k^2}{2}$$

→ Next aTGC parametrisation

$$\begin{aligned} N_{\text{expected}} = & Y_{00} + f_4^Y Y_{01} + f_4^Z Y_{02} + f_5^Y Y_{03} + f_5^Z Y_{04} \\ & + (f_4^Y)^2 Y_{11} + f_4^Y f_4^Z Y_{12} + f_4^Y f_5^Y Y_{13} + f_4^Y f_5^Z Y_{14} \\ & + (f_4^Z)^2 Y_{22} + f_4^Z f_5^Y Y_{23} + f_4^Z f_5^Z Y_{24} \\ & + (f_5^Y)^2 Y_{33} + f_5^Y f_5^Z Y_{34} \\ & + (f_5^Z)^2 Y_{44} \end{aligned}$$

Systematics

Source %	$eeee$	$\mu\mu\mu\mu$	$ee\mu\mu$	$llll$
Reconstruction Uncertainties				
e momentum smearing	0.00	0.00	0.04	0.02
e energy scale	0.42	0.02	0.12	0.12
e identification efficiency	5.30	0.00	2.60	2.37
e isolation/ $z0/d0$ Sig	1.75	-	0.81	0.76
e reconstruction	3.13	0.00	1.53	1.39
μ energy smearing	0.00	0.03	0.01	0.02
μ energy scale	0.00	0.05	0.03	0.02
μ reconstruction	0.00	1.16	0.58	0.64
μ isolation/ $z0/d0$ Sig	0.00	2.62	1.31	1.45
Trigger	0.03	0.20	0.09	0.11
Total Reconstruction Uncertainty (C_{ZZ})	6.41	2.83	3.44	3.27
Theoretical Uncertainties				
	ZZ			
MC Generator Difference (C_{ZZ})	1.7	0.9	1.8	1.5
Scale (C_{ZZ})	0.1	0.1	0.01	0.03
PDF (C_{ZZ})	0.02	0.02	0.002	0.002
PDF & Scale (A_{ZZ})	0.95			
MC Generator Difference (A_{ZZ})	0.78			
Total (A_{ZZ})	1.3			
Total (C_{ZZ})	6.63	2.97	3.88	3.60
Luminosity	2.8			

Service task

