MEASUREMENT OF TOTAL ZZ-->4l PRODUCTION CROSS SECTION AND LIMITS ON ANOMALOUS TRIPLE GAUGE COUPLINGS WITH THE ATLAS DETECTOR

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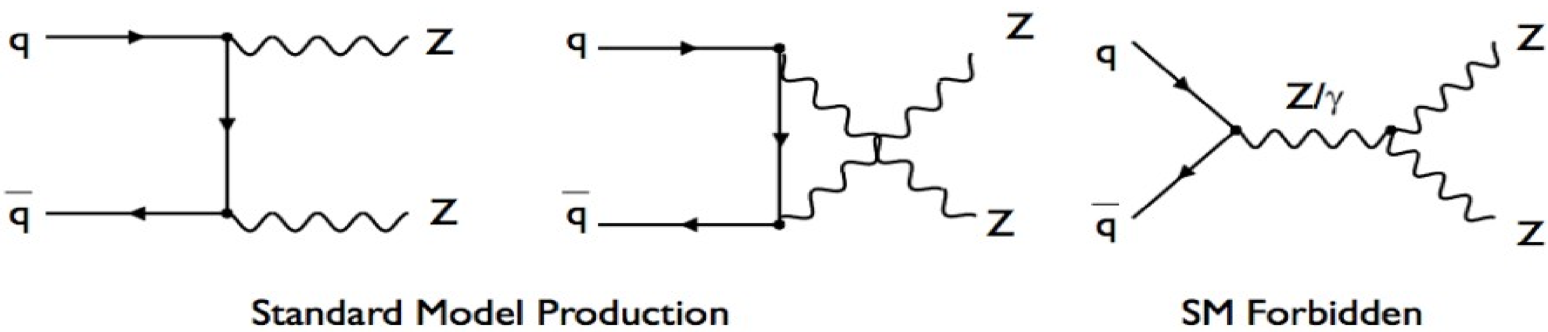
Outline:

- Introduction to the measurement
- Analysis overview (Event selection, Background estimate, ZZ candidate distributions)
- ZZ Cross section result with 4.7 fb^{-1}
- Limits on aTGC with 1 fb^{-1}
- Conclusions and future perspectives

INTRODUCTION

- ZZ production is a rare process but with clear signature and very low background
- Irriducibile background to the H->ZZ->4l channel
- Stringent SM test of the structure of the electroweak sector
- Gluon-gluon fusion contributions is **6.3%** of the cross section



Public results on the topic:

1 fb^{-1} measurement: Phys. Rev. Lett. 108, 041804 (2012) http://arxiv.org/abs/1110.5016

4.7 fb^{-1} measurement: ATLAS-CONF-2012-026 https://cdsweb.cern.ch/record/1430735

ATLAS DETECTOR & OBJECT SELECTION

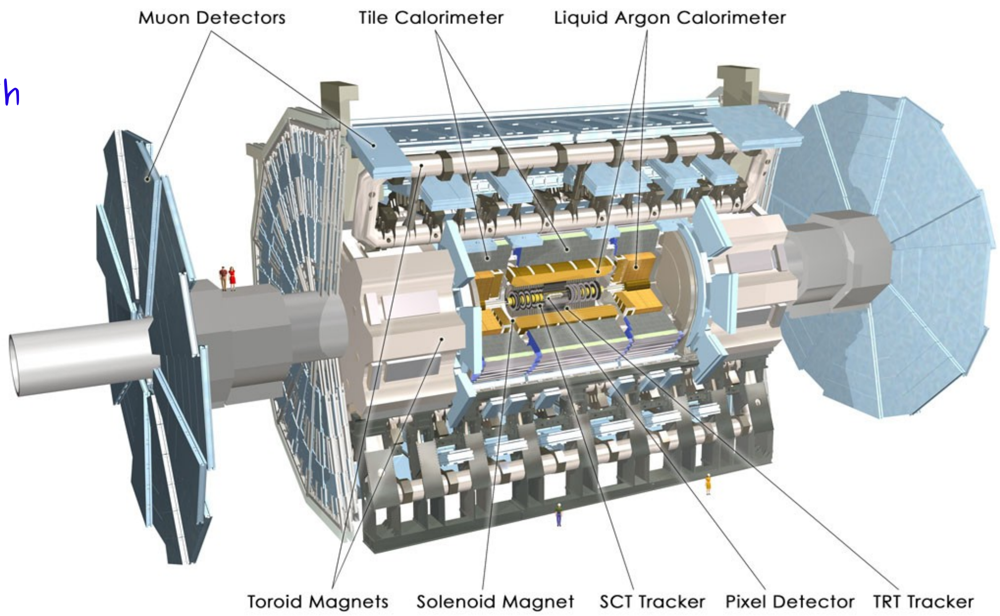
- All main ATLAS subsystems are used to perform the measurement

Muons

- Combine Muon Spectrometer tracks with Inner Detector tracks
- Kinematic acceptance: $|\eta| < 2.7$, $p_T > 7$ GeV

Electrons

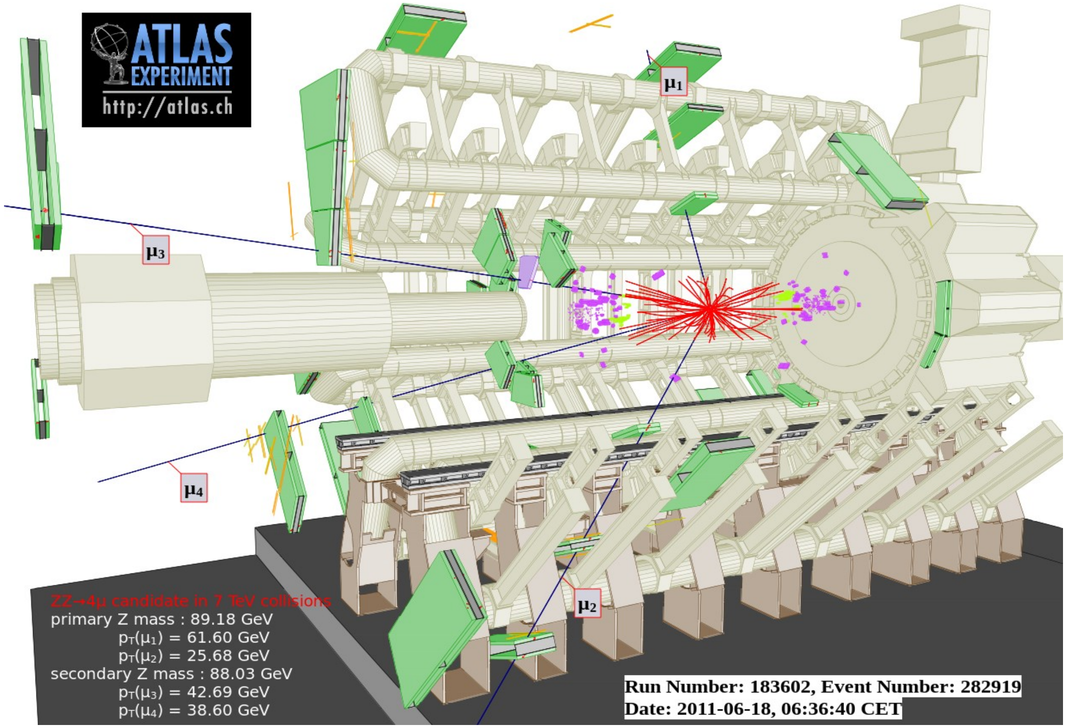
- Combine electromagnetic clusters with Inner Detector tracks
- Kinematic acceptance: $|\eta| < 2.47$, $p_T > 7$ GeV



- Apply requirements to leptons on ID track isolation, calorimeter isolation and longitudinal and transverse impact parameters to reject fake leptons

- Leading lepton must have $p_T > 25$ (20) GeV for electrons (muons)

EVENT SELECTION



Display of a selected ZZ->$\mu^+\mu^-\mu^+\mu^-$ event with $m^{4\mu}$ = 239.7 GeV and $Pt^{4\mu}$ = 22.0 GeV

Trigger using single electron and muon triggers, with pT thresholds 18-22 GeV

Select events with exactly four leptons passing the object selection described previously

Form two same-flavour opposite-sign pairs, choosing the pairing which minimises sum of distances from Z mass: $|m_{12}-m_Z|+|m_{34}-m_Z|$

Both pairs required to be on-shell: $66 < m_Z < 116$ GeV

BACKGROUND ESTIMATE

•Main backgrounds are $Z \to l^+l^-$ with additional jets or photons, t- tbar, single-top and other diboson processes (WW, WZ). All involve one or more fake leptons

There are True Leptons (T) and objects that can Fake Leptons (F), with a probability f for the fake object to be identified as a lepton

The background is:

$$N_{4\ell}^{\rm fake} = N_{TTFF} \times f \times f + N_{TTTF} \times f$$

We can measure the number of selected leptons (L) and number of lepton-like jets that fail one or two of the lepton ID cuts (J)

The estimated background is:

$$N_{4\ell}^{\rm fake} = (N_{LLLJ} - N_{LLLJ}^{ZZ}) \times FF - N_{LLJJ} \times FF^2$$

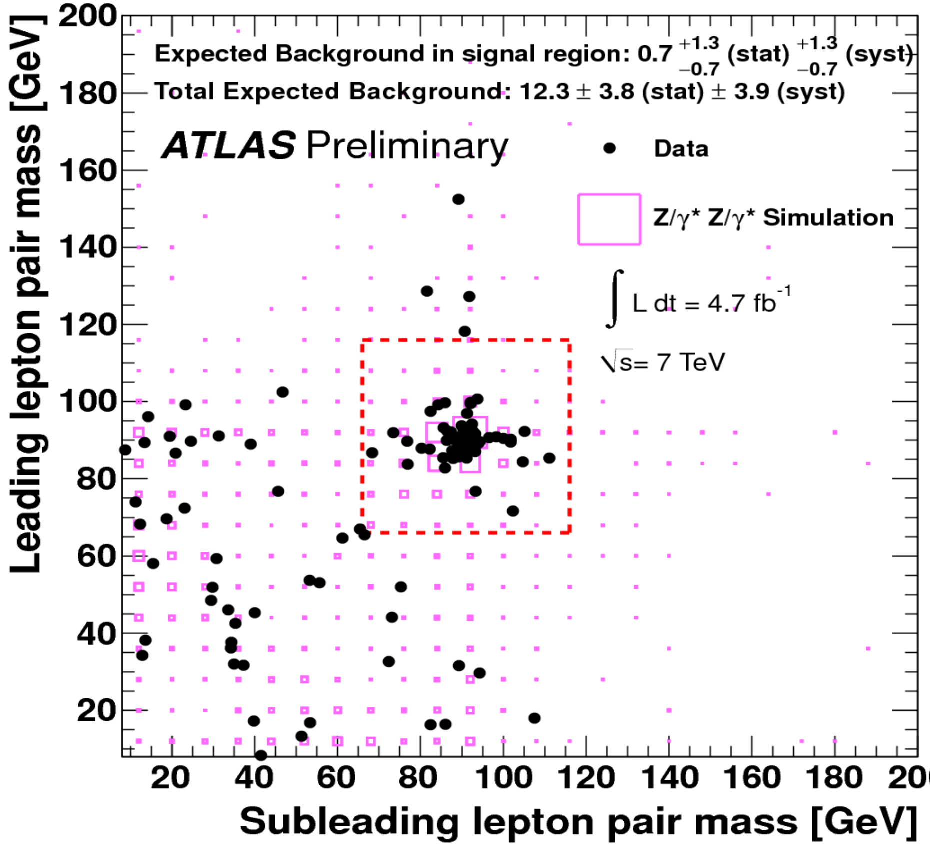
Fake Factors FF, the ratio of "selected" leptons to "lepton-like" jets in data, are mesured using Z tag method

Final state	$eeee$	$\mu\mu\mu\mu$	$ee\mu\mu$	combined ($\ell\ell\ell\ell$)
Bkg(d.d.)	$0.6^{+0.7+0.8}_{-0.6-0.6}$	$< 0.3^{+0.5}_{-0.2}$	$0.3^{+0.9+0.8}_{-0.3-0.3}$	$0.7^{+1.3+1.3}_{-0.7-0.7}$
Bkg(MC)	0.3 ± 0.3	< 0.8	0.6 ± 0.6	1.0 ± 0.6

Good agreement between Data Driven and MC background estimation

OBSERVED EVENTS

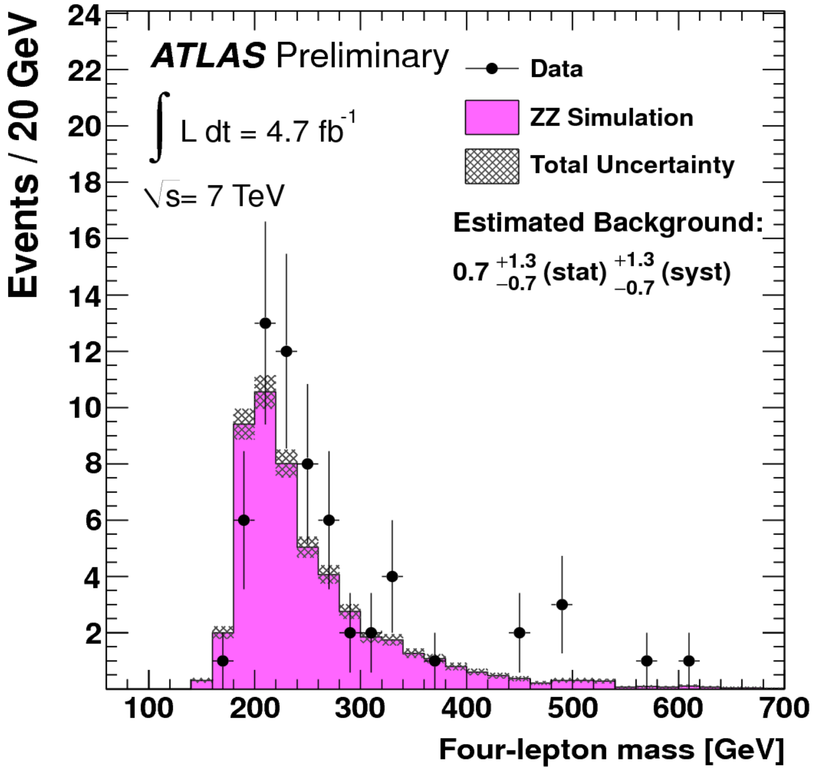
- Observed candidate events in 4.7 fb^{-1} of data:
  - **62 candidates:**
    15 eeee 21 μμμμ 26 eeμμ
  - Predicted background:
    $0.7^{+1.3}_{-0.7}$ (stat) $^{+1.3}_{-0.7}$ (syst)
  - Predicted signal (MC):
    53.2 ±1.1 (stat) ± 1.9 (syst)
- Sherpa (LO) used for signal predictions, scaled to predicted cross section of MCFM (NLO)
  - Cross checked with Pythia and gg2ZZ and found to be consistent
- Dominant systematics arise from uncertainty on lepton identification efficiencies
  - Evaluate using Tag and Probe measurements on large samples of Z->ll events

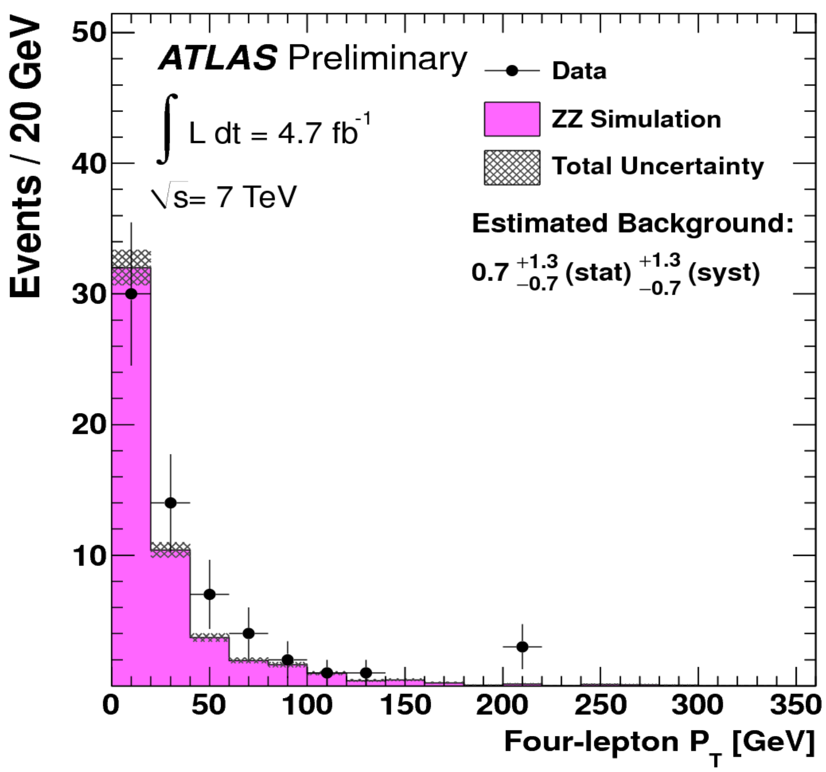


Leading Z candidate: highest pT Z candidate

CANDIDATE DISTRIBUTIONS

- Invariant mass (left) and transverse momentum (right) of the four lepton system
- Good agreement between data and Monte-Carlo





ZZ->4l CROSS SECTION MEASUREMENT/1

- First we measure cross section in a fiducial phase space close to experimental selection

Fiducial region:
- $ZZ \to l^+l^-l^+l^-$ ($l = e,\mu$)
- lepton Pt > 7 GeV
- lepton $|\eta| < 2.7$
- Both Z: $66 < M_Z < 116$ GeV

$$\sigma^{fid}_{ZZ \to 4l} = \frac{N_{obs} - N_{bkg}}{L \cdot C_{ZZ}}$$

$$C_{ZZ} = \frac{N^{\text{MC Pass All Cuts}}_{\text{Reconstructed } ZZ \to \ell\ell\ell'\ell'} \times \text{SF}}{N^{\text{MC Fiducial Volume}}_{\text{Generated } ZZ \to \ell\ell\ell'\ell'}}$$

Channel	C_{ZZ}
$eeee$	$0.4661 \pm 0.0163 \pm 0.0361$
$\mu\mu\mu\mu$	$0.8097 \pm 0.0135 \pm 0.0158$
$ee\mu\mu$	$0.6036 \pm 0.0112 \pm 0.0232$
$llll$	$0.6190 \pm 0.0160 \pm 0.0215$

- First uncertainty is statistical, the second is systematics
- Systematics uncertainty is mostly due to e and mu recostruction ID and isolation efficiencies **(~3.5 %)**

ZZ->4l CROSS SECTION MEASUREMENT/2

- Then we extrapolate to the total cross-section, correcting for the acceptance (A_{ZZ}) of the fiducial cuts estimated using the MCFM NLO generator and the Z->ll branching ratios

$$\sigma^{fid}_{ZZ\to 4l} = \frac{N_{obs} - N_{bkg}}{L \cdot C_{ZZ}}$$

↓

$$\sigma^{tot}_{ZZ} = \frac{N_{obs} - N_{bkg}}{L \cdot BR(ZZ \to 4l) \cdot A_{ZZ} \cdot C_{ZZ}}$$

$$A_{ZZ} = \frac{N^{\text{MC Fiducial Volume}}_{\text{Generated } ZZ\to\ell\ell\ell'\ell'}}{N^{\text{MC All}}_{\text{Generated } ZZ\to\ell\ell\ell'\ell'}}$$

Fiducial Volume is the same for each channel so A_{zz} is the same:

A_{ZZ} = 0.6484 ± 0.0117

(systematic uncertainty 1.8%)

$$\sigma^{\text{fid}}_{ZZ\to\ell^+\ell^-\ell^+\ell^-} = 21.2^{+3.2}_{-2.7}\,(\text{stat})\ ^{+1.0}_{-0.9}\,(\text{syst})\ \pm 0.8\,(\text{lumi})\ \text{fb}$$

$$\sigma^{\text{tot}}_{ZZ} = 7.2^{+1.1}_{-0.9}\,(\text{stat})\ ^{+0.4}_{-0.3}\,(\text{syst})\ \pm 0.3\,(\text{lumi})\ \text{pb}$$

Observed total cross section is consistent with the Standard Model cross section, calculated with MCFM and PDF set MSTW2008, of **$6.5^{+0.3}_{-0.2}$** pb

Anomalous Triple Gauge Coupling (aTGC)

Search for general ZZV couplings where V = (Z,γ), introduced using an effective Lagrangian

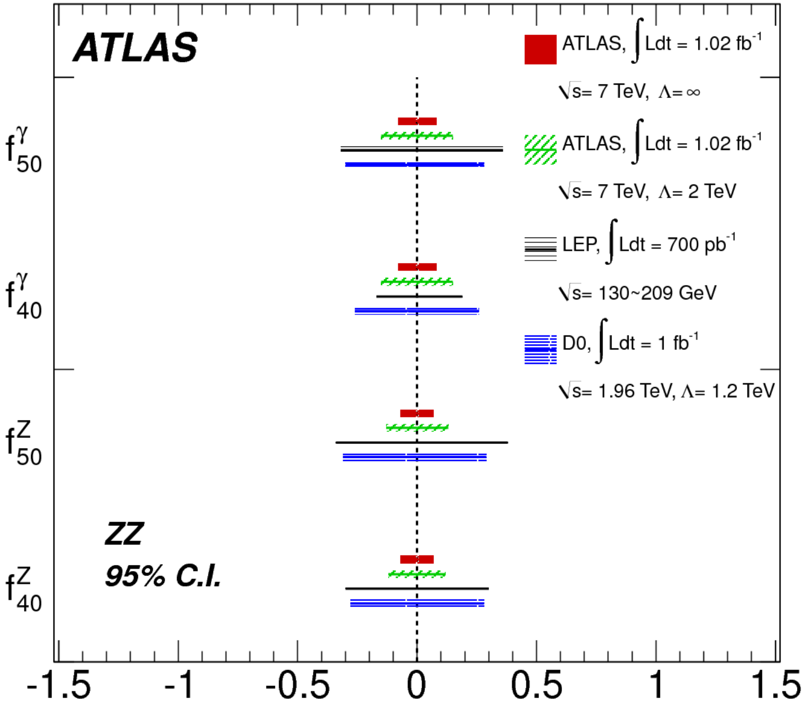
$$L = -\frac{e}{M_Z^2}[f_4^V(\partial_\mu V^{\mu\beta})Z_\alpha(\partial^\alpha Z_\beta) + f_5^V(\partial^\sigma V_{\sigma\mu})\tilde{Z}^{\mu\beta}Z_\beta]$$

- Couplings paramaterised by two CP-violating ($f^V{}_4$) nd two CP-conserving ($f^V{}_5$) complex parameters. All are zero in the SM
- Signature for aTGCs is enhanced cross section at high energies and large scattering angles => observables proportional to M^{ZZ}, P_T^{ZZ} sensitive to aTGCs

LIMITS ON aTGC (1 fb^{-1})

- Limits on aTGCs set using ZZ->4l cross section measured with the first 1 fb^{-1} of the 2011 dataset using the observed number of events only

- Limits are comparable with, or tighter than, those derived with measurements from LEP and the Tevatron



Coupling 95% CI	f_4^{γ}	f_4^{Z}	f_5^{γ}	f_5^{Z}
Λ = 2 TeV	$[-0.15, 0.15]$	$[-0.12, 0.12]$	$[-0.15, 0.15]$	$[-0.13, 0.13]$
$\Lambda = \infty$	$[-0.08, 0.08]$	$[-0.07, 0.07]$	$[-0.08, 0.08]$	$[-0.07, 0.07]$

Conclusions and Future Perspectives

- ZZ cross section measurement provides a stringent SM test in the electroweak sector

- ZZ->4l cross section measurement with 4.7 fb^{-1} of data using the ATLAS detector has been presented. Value obtained is consistent with SM prediction

- Limits on aTGC set using cross-section measured with 1 fb^{-1} statistics show no deviation from SM prediction

- Differential cross-section measurements

- Update aTGC using full 2011 dataset and differential distributions

- Push detector acceptance even further including forward electrons and calorimeter tagged muons