ZZ Diboson Event Selection in ATLAS

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Overview

- Introduction
  - Motivation
  - Channels of interest:
    - ZZ→4l
    - ZZ→2l2ν
- Lepton Pre-selection
  - Electron Preselection
  - Muon Preselection
- Analysis Cut Selection and Yields at 10 TeV
  - ZZ → 4l
  - ZZ → llνν
  - Overall selection efficiency
- Reweighting to 7 TeV
- Anomalous Coupling Outlook

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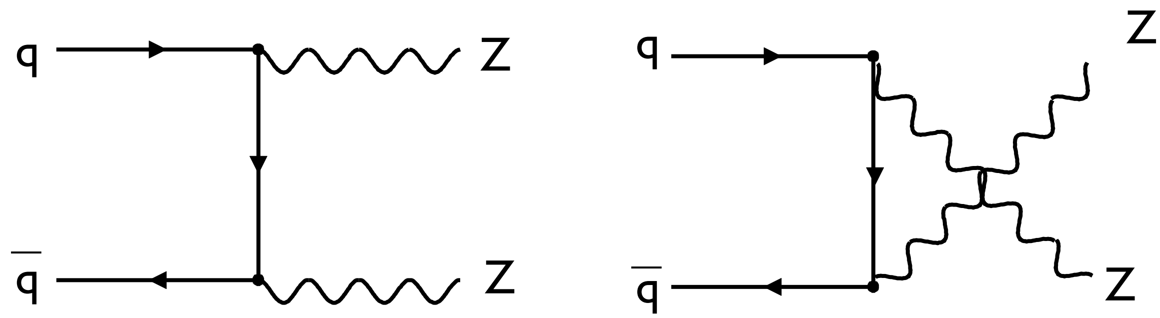
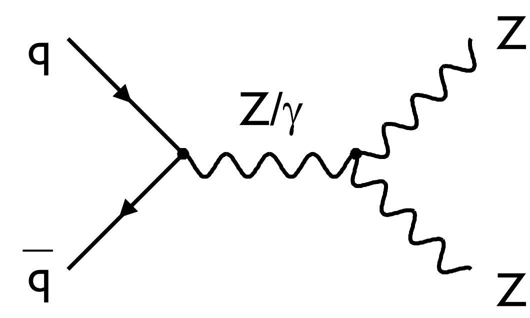
ZZ Diboson Production

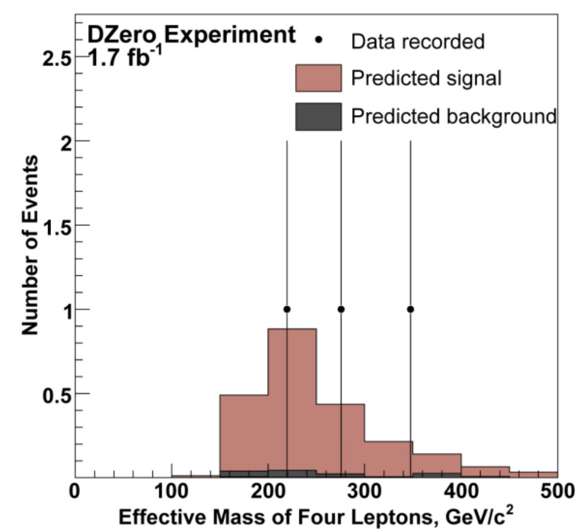


Standard Model Production



SM Forbidden

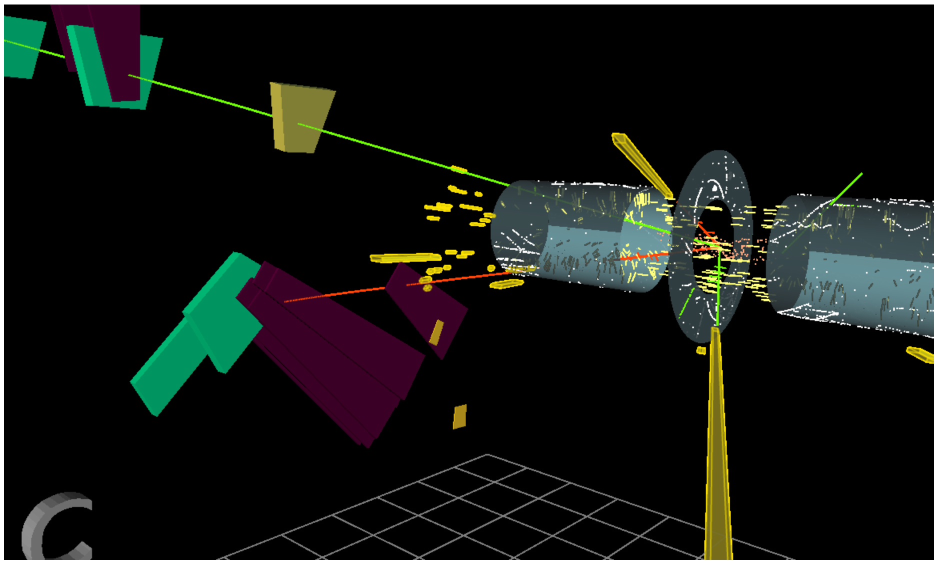
- ZZ Diboson tests high energy electroweak theory
  - Vector boson self-couplings are a fundamental prediction of Standard Model
    - fixed by gauge invariance
  - Search for Anomalous Triple Gauge Couplings
    - direct probe for new physics.
- Current ZZ diboson measurements
  - Observed at LEP2, just above threshold
    - hep-ex/0511027v2
  - Handful of events from the Tevatron
    - ZZ→4l Events: 3 + 3 (D0 + CDF)
    - arXiv:0810.3443v1 [hep-ex]



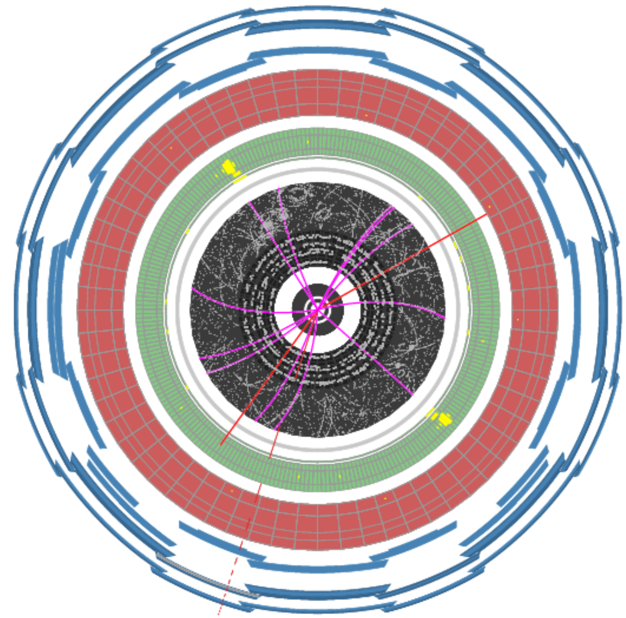
http://www.fnal.gov/pub/presspass/press_releases/Dzero_zzdiboson.html

Channels and Datasets

ZZ→2e2μ



ZZ→2e2ν

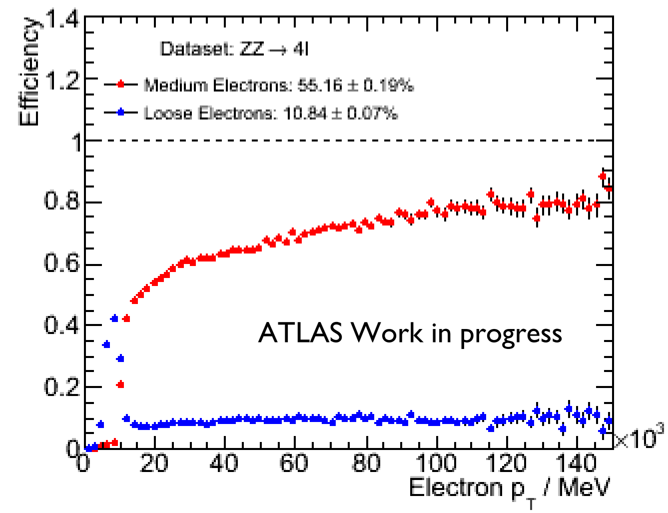


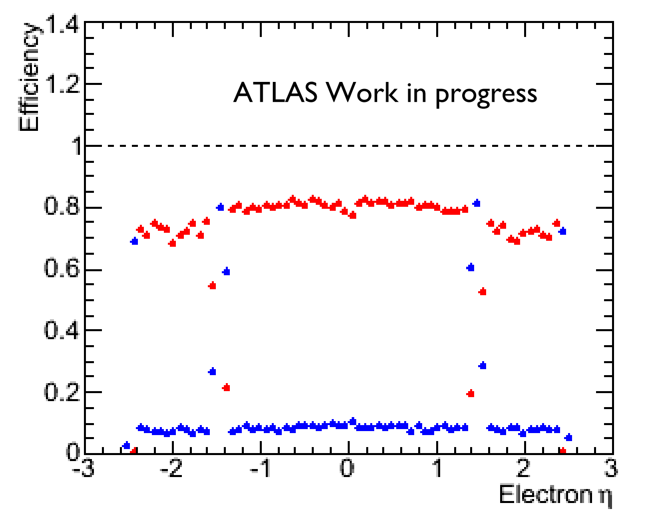
- Investigating selection efficiency of
  - ZZ→4l Channel:
    - very clean signal, background free
  - ZZ→2l2ν Channel:
    - higher background, but ~6 times higher cross section

- Using 10 TeV simulated data samples
  - No longer a likely scenario…
  - Reweighting to estimate 7 TeV yields
  - Official 7 TeV currently in production

Electron Preselection

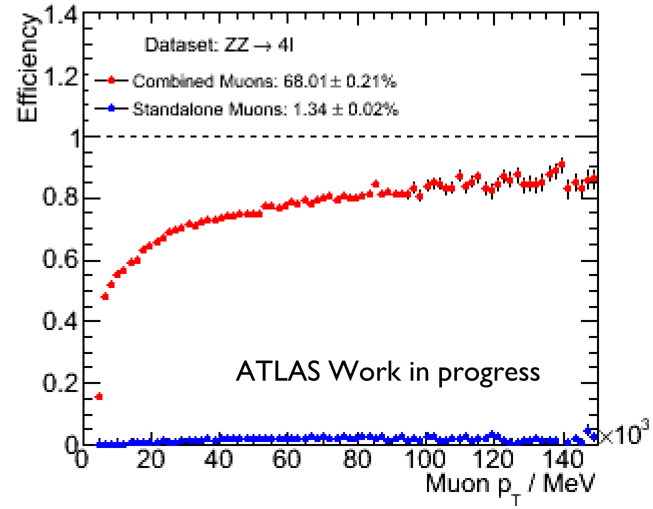
- Two types of electrons defined here
  - Physics Electrons
    - Used for Z formation
      - pT > 5 GeV, | η | < 2.5
      - Exclude region 1.37 < | η | < 1.52
      - Pass "Medium" criteria on track matches and calorimeter shower shapes
  - Veto Electrons
    - Used to reject background, so looser cuts
      - pT > 5 GeV, |eta| < 3.0
      - Crack region included
      - "Loose" electron criteria
  - Overlap removed between the two types
- Efficiency definition:
  - Only consider truth electrons coming from a Z boson in the ZZ sample
  - Efficiency = Number of true electrons matching a reconstructed electron / total number of true electrons

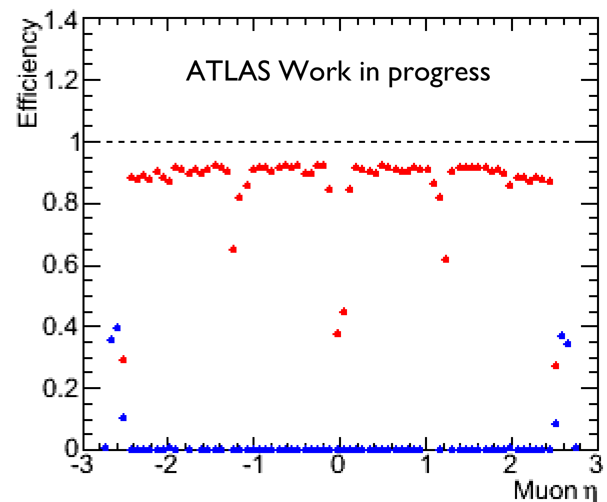




Muon Preselection

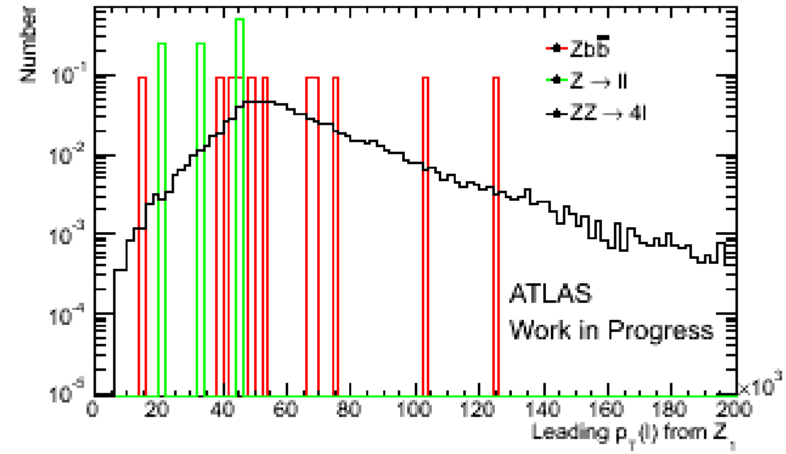
- Also define two types of muons:
- Combined Muons
  - Tracks in both Inner Detector and Muon systems
    - pT > 5 GeV, |η| < 2.5
    - Isolation: Et in ΔR < 0.4 / Et < 0.2
    - Muon-ID track match χ^2/ndof < 15
    - Global Fit (Muon+ID) χ^2/ndof < 15
- Standalone Muons
  - Only require hits in muon chambers
    - pT > 5 GeV, | η | < 2.7
    - Isolation: Et in ΔR < 0.4 / Et < 0.2
    - Track Fit (Muon) χ^2/ndof < 15
- Both types are used for Z formation

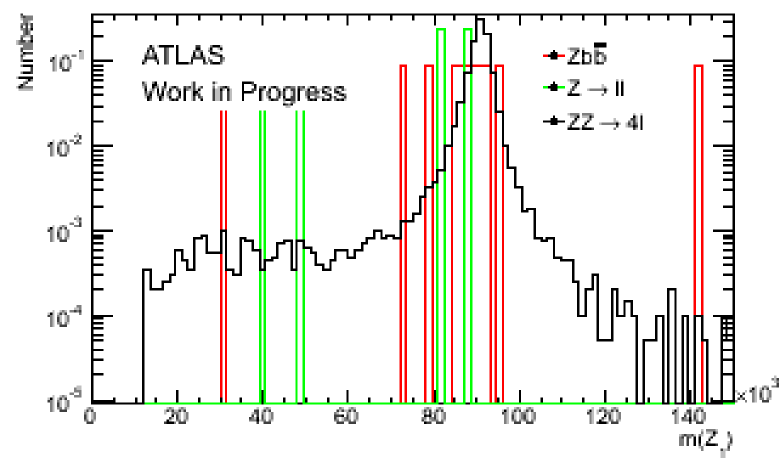




ZZ→4l Selection

- Main Backgrounds
  - Zbb and Z→ll with fake leptons
- Lepton Cuts
  - Require 2 pairs of leptons to make Zs
  - pT > 6 GeV
- Z Invariant mass
  - Order Zs by distance from the true Z mass
  - For closest Z:
    - | m(Z) – 91.2GeV | < 20 GeV
  - For second Z (to keep Z*):
    - m(Z) > 20 GeV





ZZ → 4l Yields @ 10 TeV

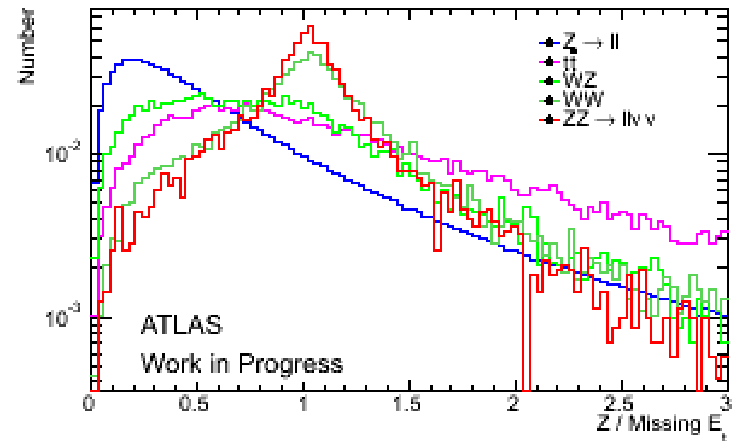
Cut	ZZ→4e	ZZ→4m	ZZ→2e2m	Z(ee)bb	Z(mm)Bb	ZZ→llbb	WZ
n(Z) = 2	1.99	4.00	5.37	0.44	0.45	0.007	0.08
Lepton pT	1.99	3.87	5.28	0.34	0.20	0.006	0.08
Z1 mass	1.96	3.76	5.14	0.25	0.18	0.004	0.07
Z2 mass	1.90	3.51	4.87	0.07	0.05	0.003	0.07
Trigger	1.90	3.51	4.69	0.07	0.05	0.003	0.07

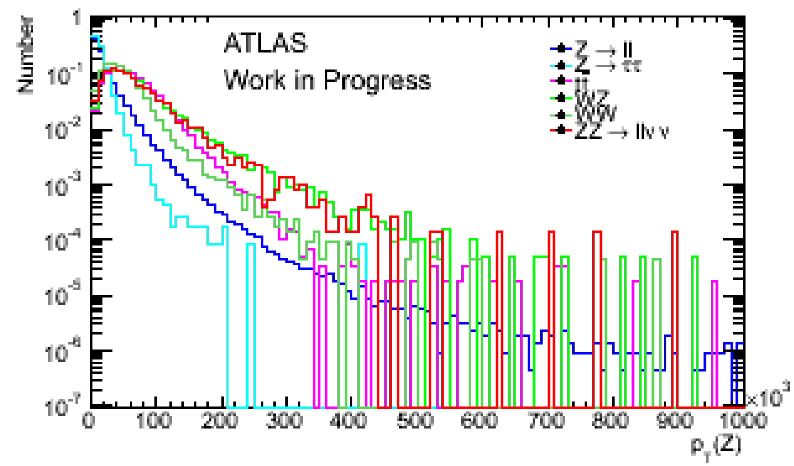
- Expected number of events in 1 fb^{-1}
  - Backgrounds are sum from all 3 sub-channels
  - High pT single lepton trigger applied
    - Typically ~99.9% efficient after all other cuts

Signal 10.1 / Background 0.14 ~74

ZZ → llνν Event Selection

- Lepton Kinematics
  - Lepton pT > 20 GeV (Reduces Z→ll)
  - | m(ll) – 91.2GeV | < 20 GeV
  - Reduces non-resonant background
  - ttbar, WW
- Missing Transverse Energy
  - Require Missing Et > 50 GeV
  - Also 0.65 < pT(Z) / MET < 1.35
  - Reduces ttbar and WZ
- Lepton Veto
  - Require n(Muons + Electrons) = 2
  - Reduces WZ background
- Jet Veto
  - Using Anti-Kt jet finding algorithm
  - Veto events with jets with Pt > 30 Gev, |eta| < 3.0
  - Reduces ttbar background
- Require a high pT Z
  - pT(Z) > 100 GeV
  - Reduces most backgrounds!





ZZ → llνν Yields @ 10 TeV

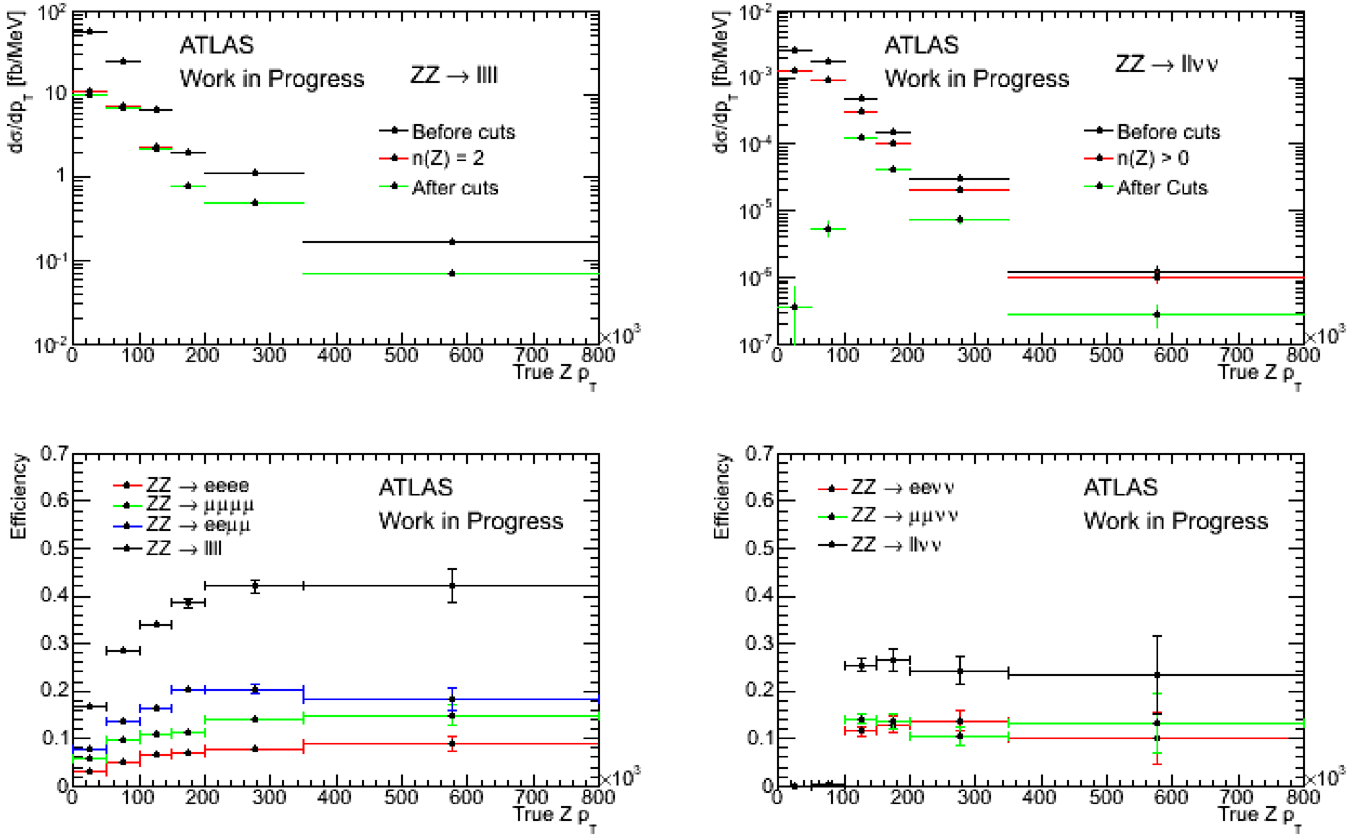
Cut Name	ZZ→eenn	ZZ→mmnn	Z→ll	ttbar	WZ	WW
n(Z) = 1	58.17	76.08	9.15E+05	7.00E+03	249.45	1060.60
Lepton pT	49.54	63.63	8.10E+05	4.72E+03	211.14	731.26
n(Lepton) = 2	47.46	59.82	7.79E+05	3.95E+03	60.38	693.13
Z mass	47.17	59.31	7.45E+05	1.15E+03	49.95	202.26
MET	18.10	22.39	156.24	261.97	11.50	44.40
n(Jets) = 0	14.69	18.95	31.78	8.25	7.32	35.01
pT(Z)	4.66	5.15	1.62	0.73	1.28	0.57
Trigger	**4.66**	**5.06**	**1.62**	**0.73**	**1.23**	**0.57**

- Expected number of events in 1 fb-1
- More challenging channel than ZZ→4l

  Main backgrounds from Z→ll and WZ

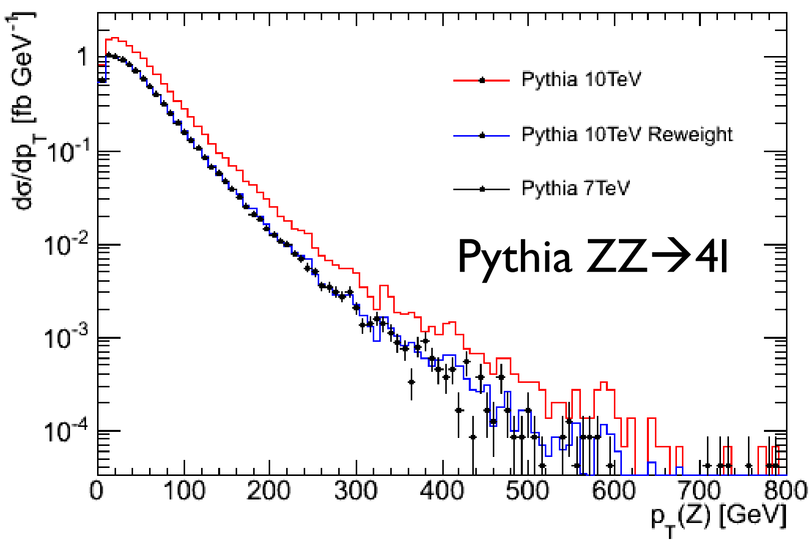
Signal 9.7 / Background 3.9 = 2.5

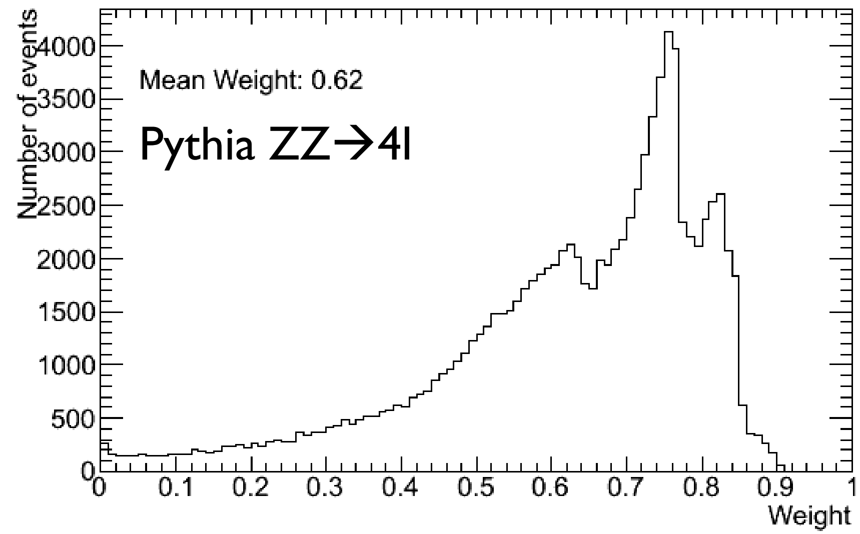
Z Selection Efficiency



- True Z pT spectrum for both channels, before & after cuts
- Selection efficiency = true Z(pT) of events passing all cuts / true Z(pT) vs pT
  - Use this to produce toy MC for Anomalous coupling studies

Reweighting To 7 TeV





- ATLAS has potential collect 1fb^{-1} at 7 TeV in next 2 years
- As a first estimate, can reweight 10 TeV events
  - Take generator level-PDF information to reweight to 7 TeV
- Good agreement between 7 TeV and Reweighted 10 TeV
  - Reweighted 10 TeV→7 TeV **= 33.24 fb** (cf 53.37 fb before reweight)
  - Cross Section @ 7 TeV **= 33.23 fb**

Comparison of Energies

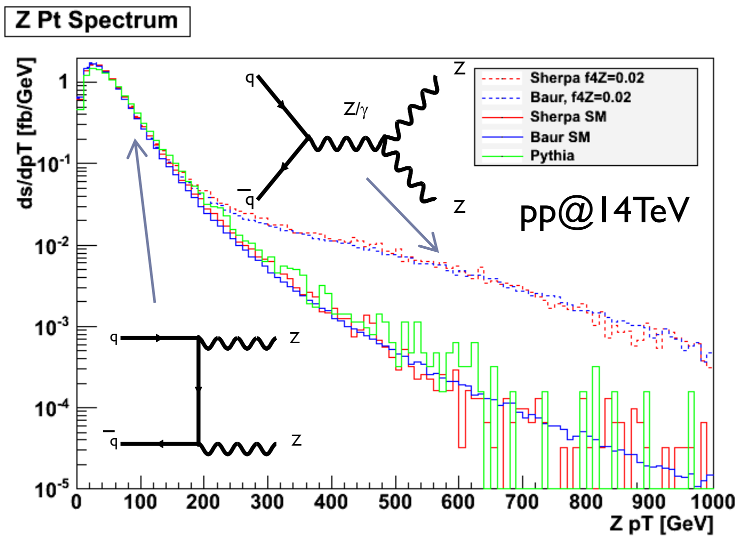
Energy / TeV	7	10	14
ZZ-> 4e	1.29	1.90	3.17
ZZ -> 4mu	2.36	3.51	7.56
ZZ -> 2e2mu	3.16	4.69	5.72
Total	**6.80**	**10.10**	**16.45**
Background	**0.08**	**0.14**	**2.00**
S / B	**84.7**	**73.9**	**8.3**
S / √B	**24.0**	**27.0**	**5.7**

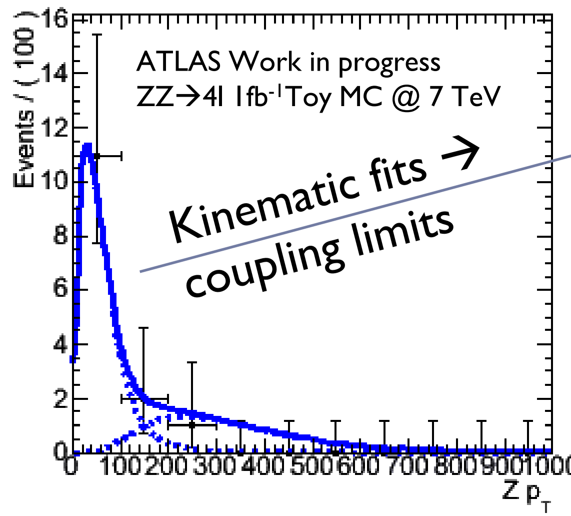
Energy / TeV	7	10	14
ZZ->2e2nu	2.76	4.66	3.51
ZZ->2mu2nu	2.87	5.06	6.66
Total	**5.62**	**9.72**	**10.17**
Background	**2.34**	**4.23**	**5.00**
S / B	**2.4**	**2.3**	**2.0**
S / √B	**3.7**	**4.7**	**4.5**

- Numbers are predicted yields with 1fb^{-1} at 7,10,14 TeV
  - 14 TeV numbers are from CERN-OPEN-2008-020
    - Some differences in cuts applied
  - 7 and 10 TeV are using exactly the same cuts
- By the end of my PhD (October)
  - Optimistically 100 pb^{-1} of 7 TeV
  - Perhaps a single real diboson event!

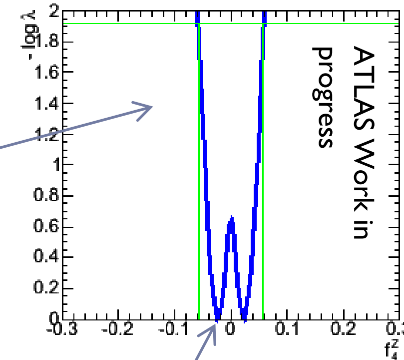
12 Events in 1 fb^{-1} @ 7 TeV

Anomalous Couplings Limits





Kinematic fits → coupling limits



Input coupling

$f_4^Z = 0.05$

- Production of on-shell ZZ probes ZZZ and ZZγ anomalous couplings:

  f_4^Z, f_5^Z, f_4^γ, f_5^γ

  - Cross section is quadratic in the couplings
- Aim to place limits on the coupling strength in ATLAS
  - Specialist Generators (Baur/Rainwater, Sherpa)
  - Re-shape spectrum with ATLAS detector response
  - Fit shape of Z transverse momentum spectrum
  - Obtain 95% confidence limits using log likelihood ratio
- Work ongoing to estimate sensitivity after $1\,fb^{-1}$ at 7 TeV

Current Limits

$|f_{4,5}^{Z,g}| \lesssim 0.1$

(LEP, D0, CDF)

Conclusions and Next steps

- ZZ selection at 10 TeV with 7 TeV Reweighting
  - $ZZ \rightarrow 4l$ channel
    - 4 high pT leptons
  - $ZZ \rightarrow 2l2l\nu$
    - 2 high pT leptons with missing transverse energy
  - Good prospects for measuring ZZ with 1 fb^{-1}
    - ~7 $ZZ \rightarrow$ 4l events
    - ~6 $ZZ \rightarrow 2l2\nu$, with ~2 background
- Anomalous Coupling Limits
  - Obtained by fitting Z kinematic spectrum
  - Watch this space!

Backup Slides

Basic Trigger Analysis

	Electrons	Muons
L1	EM18	MU10
L2	em20	mu10
EF	em20	mu10

Simple single lepton triggers

- Trigger applied after all other offline cuts
  - Trigger type is matched to leptons in channel
  - In the case of ZZ→2e2mu, require both electron and muon triggers
- Require all three levels to pass
- Efficiency after offline selection is very high:
  - Typically ~ 99.9%