Diboson Analysis Summary

UK ATLAS Meeting
IPPP Durham
10/01/08

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Universty of Manchester
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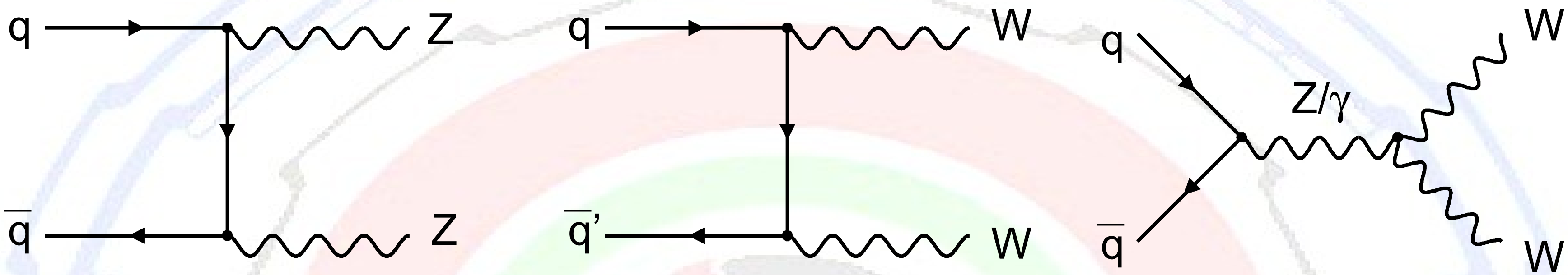
Motivating Diboson Studies



- Diboson studies provide an important test of high energy electroweak interactions.
  - Vector boson self-couplings are a fundamental prediction of SM, fixed by gauge invariance.
  - Search for Anomalous Triple Gauge Couplings is a direct probe for new physics.
  - Useful to understand as a background to Higgs processes.
- UK Diboson work part of overall ATLAS diboson effort.
  - Currently finalising the Diboson CSC Note.
  - UK involved in $ZZ \rightarrow ll\nu\nu$, $ZZ \rightarrow \tau\tau\mu\mu$, WW cross section, $W\gamma\gamma$ Tribosons.
  - $WZ, W\gamma, Z\gamma, ZZ \rightarrow 4l$ channels are not discussed here. (See diboson meeting slides)

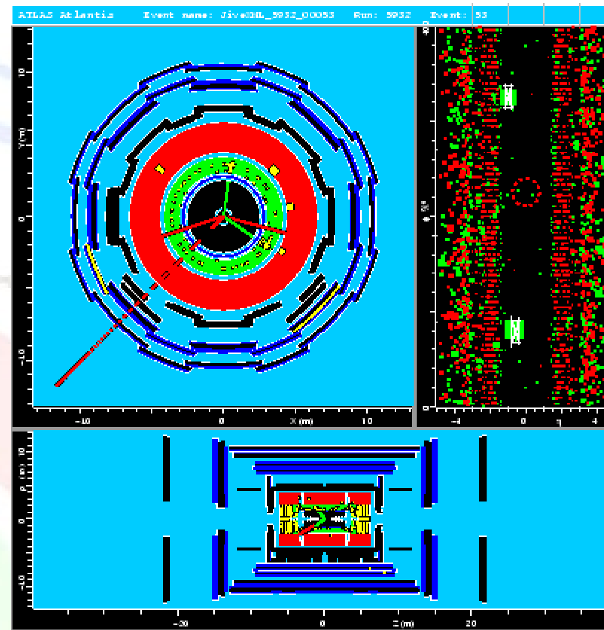
Talk Outline

- Summary of ATLAS Diboson Efforts in the UK.
- $ZZ \rightarrow ll\nu\nu$ Event Selection Study
  - Tom Barber
- $ZZ \rightarrow ll\nu\nu$ Anomalous Coupling Limits
  - Pat Ward
- $ZZ \rightarrow \tau\tau\mu\mu$ Feasibility Study
  - John Chapman
- WW Cross Section Measurement
  - Chris Hays, Gemma Wooden
- $W\gamma\gamma$ *Triboson* Production at the LHC
  - Paul Bell

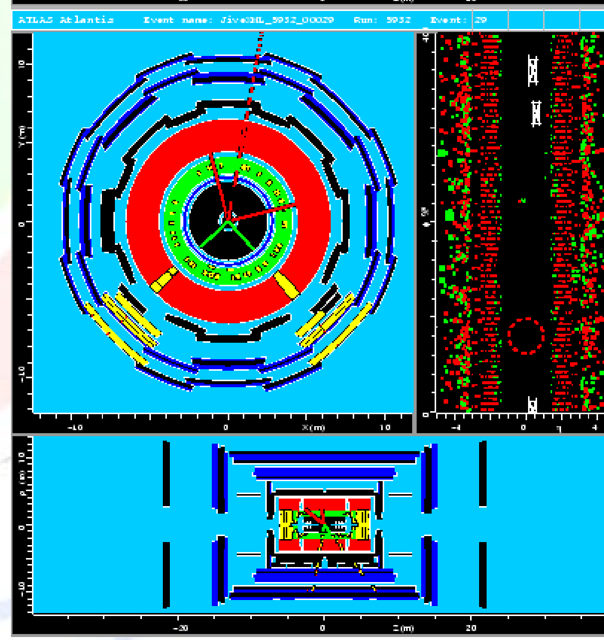
ZZ→llνν Analysis

Thomas Barber, University of Cambridge

- Summary of ZZ→llνν CSC contribution.
- Signal Topology: ZZ→llνν (l=e,μ)
  - Two high p_T leptons
  - Large Missing E_T from neutrinos
  - Cross Section ~6 times higher than ZZ →4l
  - MC@NLO Generator
- Main backgrounds from channels with:
  - Large Cross Section (ttbar and Z→ll)
  - Similar topology (WZ and WW)
  - Variety of generators, MC@NLO, Pythia, Alpgen
- Overlap Removal and NTuple dumping done by Eventview.
- Following plots normalised to unit area with 12.0.6 full simulation.



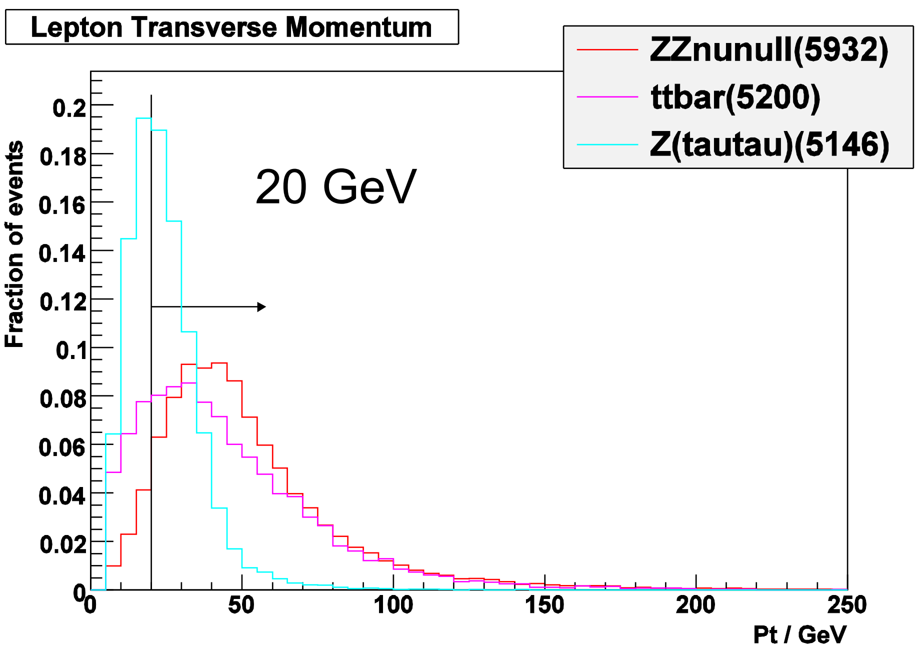
ZZ→eeνν

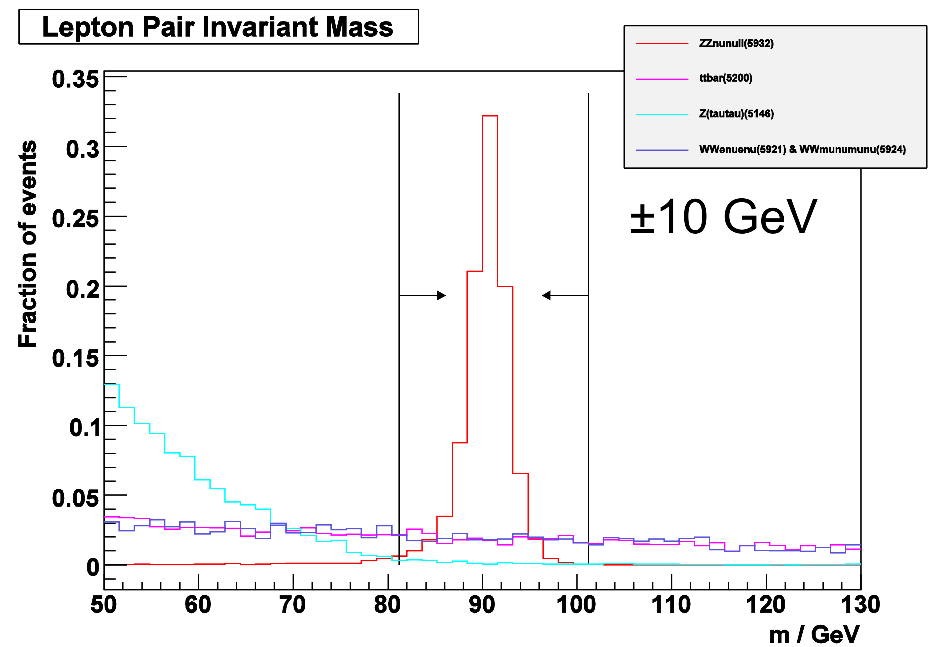


ZZ→μμνν

Lepton Cuts

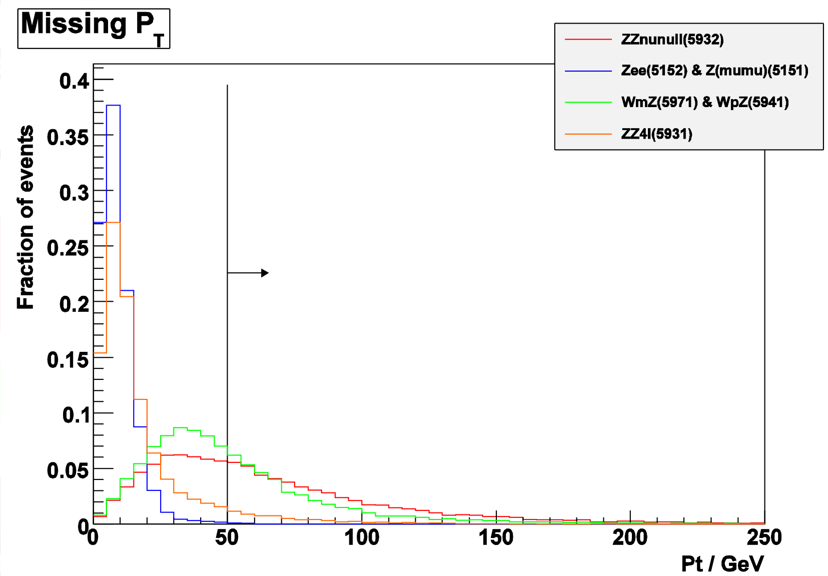
- $ZZ \rightarrow ll\nu\nu$ signal channel shown in red.
- Consider electrons and muons = leptons
- First require *exactly* two leptons in event to reduce WZ background.
- Lepton pT > 20 GeV
  - Reduces soft electron background, eg ttbar (magenta) & $Z \rightarrow \tau\tau$ (turquoise)
- $|m_{ll} - 91.2\ \text{GeV}| < 10$ GeV
  - Reduces non-Z background, ttbar (magneta), $Z \rightarrow \tau\tau$ (turquoise) & $WW \rightarrow l\nu l\nu$ (purple)

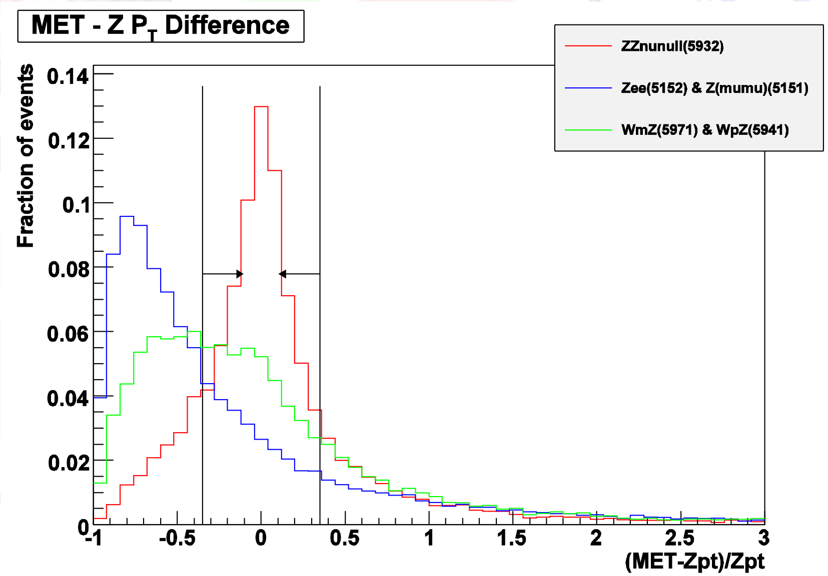




Missing Energy

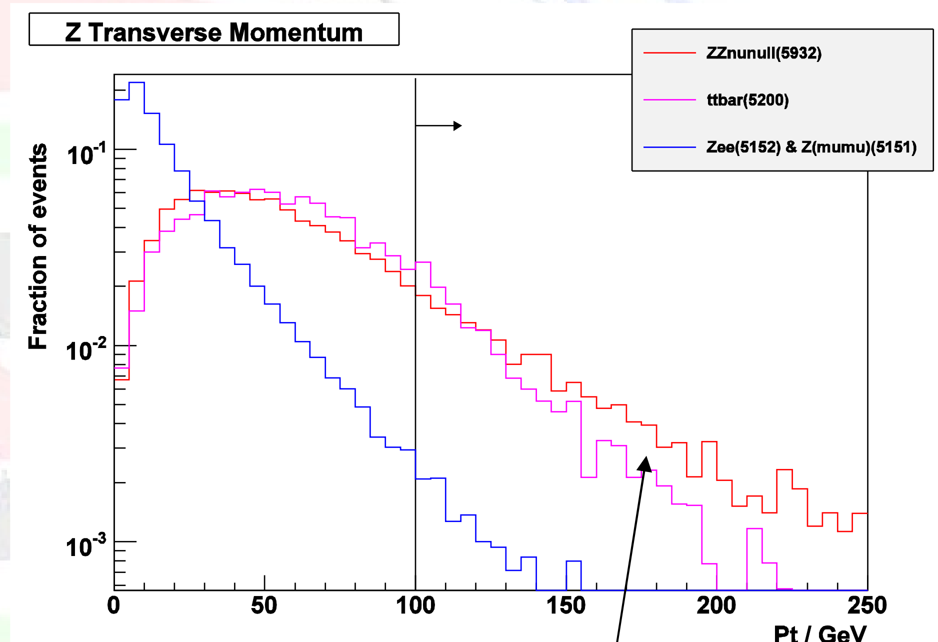
- Absolute MET cut > 50 GeV removes Z→ll (blue), Z→4l (orange).
- Also require MET magnitude and direction to match that of the reconstructed Z.
  - $|MET-Zp_T|/Zp_T < 0.35$
  - $155° < |\phi(z)-\phi(met)| < 215°$
- Both cuts are set at ~2σ from the centre of the signal peak.
- Helps to remove background from the WZ channel.





Final Cuts

- Jet Veto
  - Reject events containing jets with p_T > 30 GeV and $|\eta| < 3.0$
  - Reduces Z+jets and ttbar backgrounds.
- $Z\rightarrow ll$ p_T Cut
  - Require pT(Z) > 100 GeV
  - Reduces background from ttbar and $Z\rightarrow ll$



Anomalous couplings enhance cross section at high Z pT, so this cut will not harm anomalous coupling studies.

Signal Significance

Dataset	11.0.4	12.0.6
$N_{\text{signal}}(1\ \text{fb}^{-1})$	8.6 ± 0.2	10.2 ± 0.2
$N_{\text{background}}(1\ \text{fb}^{-1})$	3.8 ± 0.9	5.2 ± 2.6
Efficiency	3.2%	2.6%
S/B	2.2 ± 0.2	2.0 ± 0.8
$S/\sqrt{B}(0.1\ \text{fb}^{-1})$	1.4	1.4
$S/\sqrt{B}(1\ \text{fb}^{-1})$	4.4	4.5
$S/\sqrt{B}(10\ \text{fb}^{-1})$	14.0	14.1

ZZ→llnunu

- Number of Events in 1fb^{-1} of data
- $ZZ \rightarrow ll\nu\nu$
  - 10.2 Signal Events
  - 5.2 Background
- Compare with $ZZ \rightarrow 4l$ (Thessaloniki)
  - 11.0 Signal Events
  - 2.2 Background
- $ZZ \rightarrow ll\nu\nu$ has similar number of events, but higher background.

	4μ events	$4e$ events	$2\mu 2e$ events	Total
Signal	3.74 ± 0.06	1.95 ± 0.06	5.34 ± 0.08	11.03 ± 0.12
$Zb\bar{b}$	0.60 ± 0.05	0.009 ± 0.006	0.23 ± 0.03	
$t\bar{t}$	0.69 ± 0.24	0	0.67 ± 0.22	
Total bgr	1.29 ± 0.25	0.009 ± 0.006	0.90 ± 0.22	2.20 ± 0.11

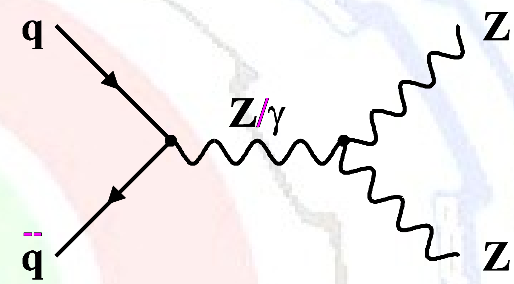
ZZ→4l (From Dinos Bachas, Ilektra Christidi, AUTh)

- How do we use this to put limits on Anomalous Couplings?

Neutral Triple Gauge Couplings

Pat Ward, University of Cambridge

Standard Model Production Diagrams



Forbidden in SM

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

  f_4^Z, f_5^Z, f_4^γ, f_5^γ

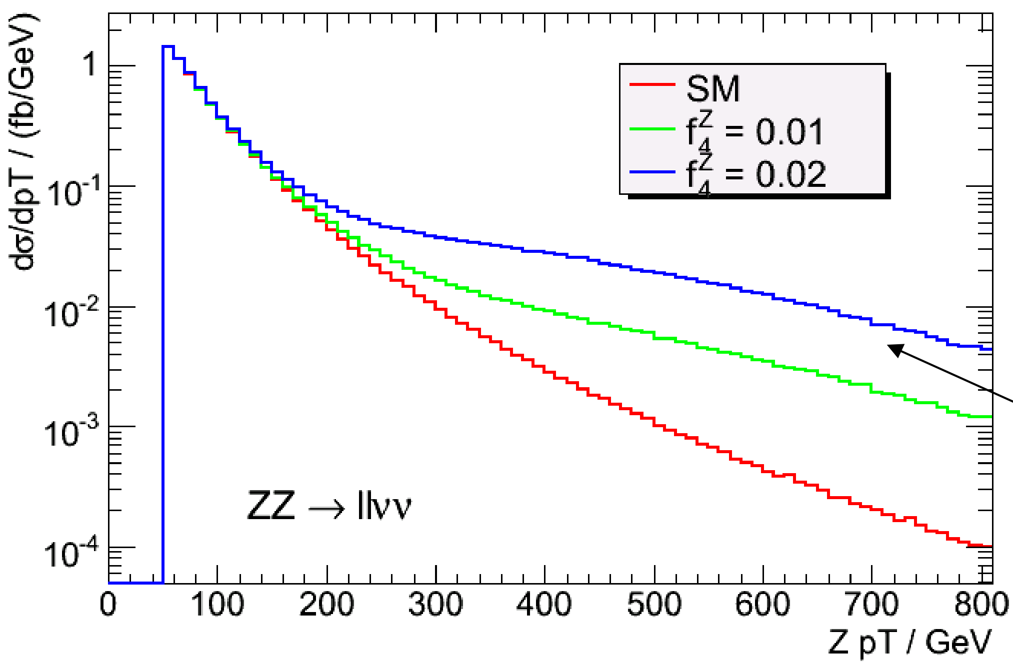
- Usual to introduce a form factor to avoid violation of unitarity:

  $f_i(s') = f_{0i} / (1 + s'/\Lambda^2)^n$

- Studies below use n=3, Λ = 2 TeV
- Also assume couplings are real and only one non-zero: use f_4^Z as example.

Anomalous Coupling MC

- Use Leading Order MC of Baur Rainwater.
- No parton shower, underlying event or detector simulation.
- CTEQ6L PDFs.

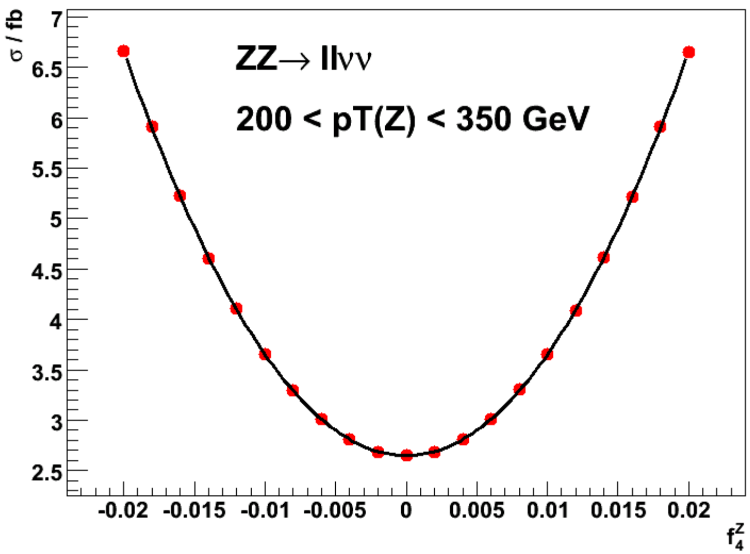


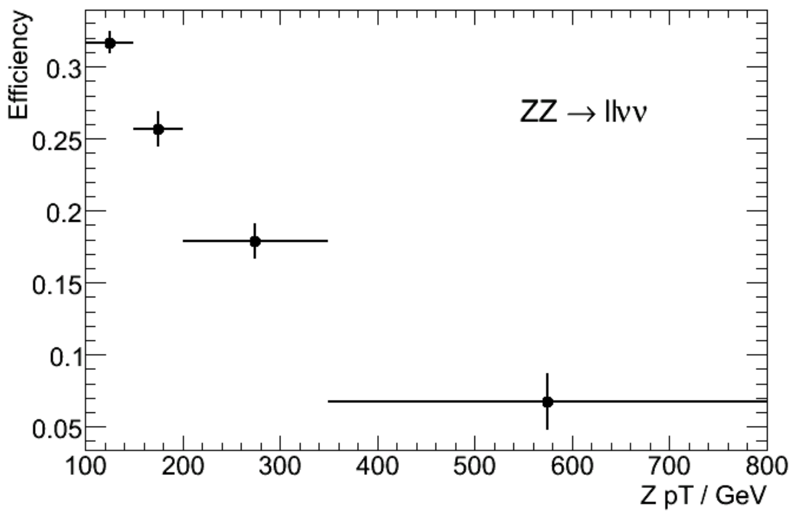
$p_T(l) > 20$ GeV
$|\eta(l)| < 2.5$
$p_T(\nu\nu) > 50$ GeV

Anomalous couplings increase cross section at high pT
Fit pT distribution to obtain NTGC limits.

Signal Distribution

- Use BR MC to fit to quadratic in f_4^Z to obtain cross-section at arbitrary f_4^Z in bins of Z p_T
  - $p_T(l) > 20$ GeV, $|\eta(l)| < 2.5$, $p_T(\nu\nu) > 50$ GeV
- Expected number of events = cross-section x efficiency x luminosity
- Efficiency vs. Z p_T from SM analysis.
- Drops with p_T due to jet veto.
  - Modify jet veto in future to improve efficiency at high p_T

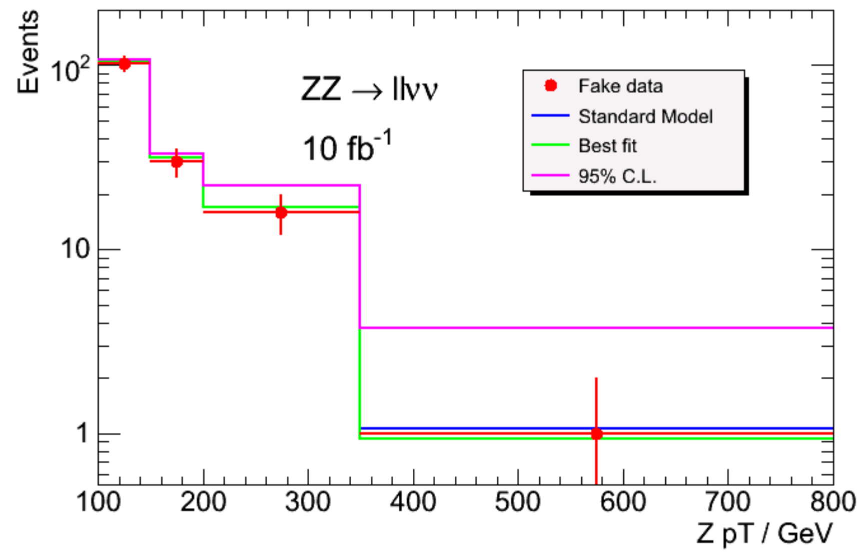




Fits to p_T Distribution

- Construct fake data samples from expected numbers of signal and background.
- Assume background / SM signal flat:

  0.51 ± 0.21
- Add Gaussian and Poisson fluctuations.
- Fit p_T distribution using a one-parameter binned maximum likelihood fit to f_4^Z
- Minimize $L = -\,ln(\Pi_i\, L_i)$
- 95% C.L. from $L - L_{min} = 1.92$



- Mean fitted parameter in excellent agreement with input parameter

Results from Likelihood Fit

Lumi / fb^{-1}	95% C.L.
1	0.024
10	0.012
30	0.009

- Mean 95% C.L. on $|f_4^Z|$ from 1000 fits
- Other Results:
  - f_5^Z gives similar limits
  - f^γ limits ~20% higher
- $ZZ \rightarrow 4l$ Limits
  - Same sensitivity at ~ $1 fb^{-1}$
  - More sensitive at high luminosity (lower background)
- Future work
  - Unbinned fits from early data.

With as little as 1 fb^{-1} can improve LEP limits by order of magnitude

LEP: $|f_4^Z| < 0.3$
no form factor

Feasibility study for the selection of ZZ→ττμμ events (1)

John Chapman, University of Cambridge

- Aims:
  - look into selecting a sample of ZZ→ττμμ events
  - use to increase ZZ event statistics → better probe anomalous NTGC's?
  - Atlas Note: ATL-COM-PHYS-2007-105
- No standard production ZZ→ττμμ sample exists, so a 10000 event sample was privately generated using MC@NLO + 12.0.6.5 job transforms.
- Consider 6 possible final states of ττ decay:

ττ →Hadrons + missing E_T

ττ →Hadrons + μ + missing E_T

ττ →μμ + missing E_T

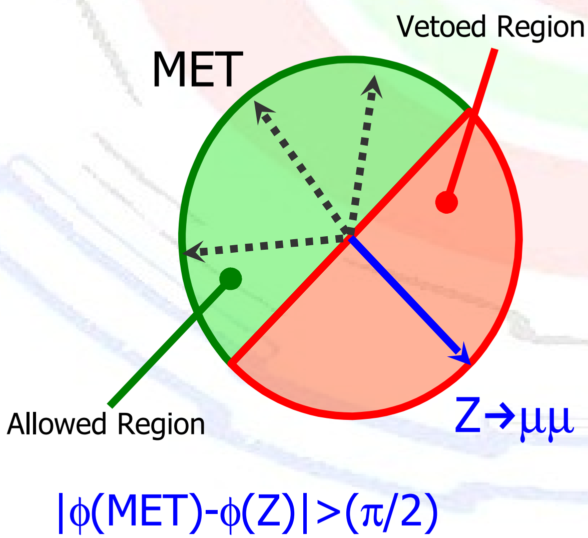
ττ →Hadrons + e + missing E_T

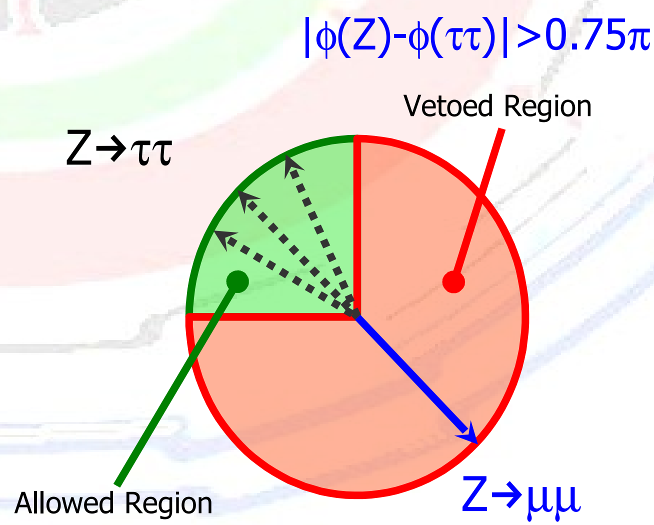
ττ →ee + missing E_T

ττ →eμ + missing E_T

Feasibility study for the selection of $ZZ \rightarrow \tau\tau\mu\mu$ events (2)

- Select $Z \rightarrow \mu\mu$ candidates with $|m_Z - m_{\mu\mu}| < 10$ GeV
- Find at least two oppositely charged, good quality τ lepton decay candidates (e, μ, τ-jet) within $|\eta|<2.5$.
- Select the best pairing by minimising $|p_T(Z)-p_T(\tau\tau)|$
  - ($p_T(Z)$ refers to the transverse momentum of the first muon pair and $p_T(\tau\tau)$ refers to the combined transverse momentum of the τ lepton decay candidates and any missing energy contributions.)
- Cut on maximum value of the invariant mass of the two τ lepton decay candidates.
- Angular cuts $|\phi(MET)-\phi(Z)|>(\pi/2)$ and $|\phi(Z)-\phi(\tau\tau)|>0.75\pi$ (see below).
- Missing energy cuts (if necessary).





Feasibility study for the selection of $ZZ \rightarrow \tau\tau\mu\mu$ events (3)

$Z \rightarrow \mu\mu + Z \rightarrow \tau\tau \rightarrow$ …	Signal	Background
$h\nu h\nu$	0.9±0.2	--
$h\nu\mu\nu\nu$	1.6±0.3	0.2±0.2
$\mu\nu\nu\mu\nu\nu$	0.9±0.2	--
$h\nu e\nu\nu$	3.2±0.4	280.4±242.3
$e\nu\nu e\nu\nu$	0.7±0.2	11.5±5.0
$\mu\nu\nu e\nu\nu$	2.6±0.4	0.2±0.2
Total	9.9±0.7	292.3±242.4

(Event numbers normalised to 10 fb^{-1})

- Background in channels with final state electrons is much higher than in other channels. (NB These numbers are based on a handful of remaining events.)
- Monte Carlo predicts 9.9 events out of a possible 162 in truth would be selected for 10fb^{-1} of ATLAS data.
- Conclusions
  - More statistics needed, particularly at higher Z p_T values.
  - Other backgrounds, such as Zbb, should be considered in any future study.
  - $ZZ \rightarrow \tau\tau\mu\mu$ channel would be worth returning to look at in more detail for 100fb^{-1} of ATLAS data.

WW Cross Section Measurement

Chris Hays
Gemma Wooden

Basic selection:

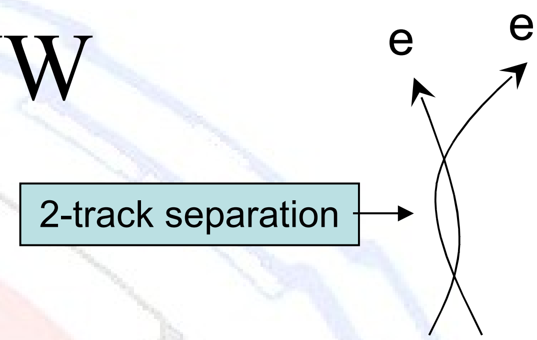
- Two opposite-sign leptons with p_T > 20 GeV
- No jet with E_T > 20 GeV
- $\not{E}_T$ > 50 GeV
- $|m_{ll} - m_Z|$ > 15 GeV

Expected events in 1 fb^{-1}:

Channel	Signal	Background
ee	26	6 + <199 $Z \rightarrow ee$
μμ	55	217 (198 $Z \rightarrow \mu\mu$)
eμ	74	20

- $Z \rightarrow ll$ a dominant residual background in *ee* and μμ channels
- Not yet included in background: W + jets and W + γ
- Oxford investigations suggest *W* + γ could be significant
- Work in progress to obtain reliable W + γ and W + jets background estimate

Wγ Background to WW



- Background comes from $W\gamma \rightarrow e\nu\gamma$
  - 2^{nd} electron from photon conversion to e^+e^-
  - If one electron has high p_T, could fake signal
- Search for tracks forming a conversion with electron track.
  - Tracks nearly form a common vertex.
- O(100 events) with basic selection and standard ATLAS conversion finder (v.11)
  - Cut in half with custom conversion removal
- Reduced to < 20 events with B-layer hit requirement (n > 0)
  - B-layer requirement now also incorporated into other analyses

- Need to investigate with v.12 and improved conversion removal
- Existing MC insufficient for background studies
  - No FSR, minimum photon E_T = 25 GeV
- Collaborating with Duke and Taiwan to implement Baur and Sherpa $W+\gamma$ generators
- Plan to validate background prediction with *W*+conversion control region

Wγγ Production at the LHC

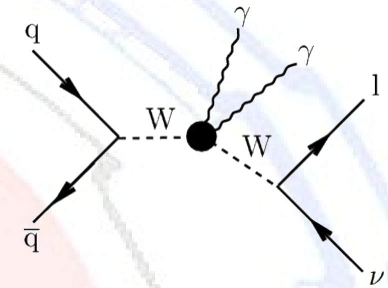
Paul Bell

Introduction

Wγγ tri-vector boson production can be studied through the pp → lνγγ process

- Probes the *quartic gauge coupling* **WWγγ**
- Contains a SM "radiation amplitude zero" (as in Wγ prodn.)

(-Useful in other studies, e.g. H → γγ, W mass measurement)



Existing MC generator contains all LO diagrams for the $l^{\pm}\nu\gamma\gamma$ ($l=e,\mu$) final state and includes effective Lagrangian terms for anomalous WWγγ couplings:

$$\mathcal{L}_6^0 = -\frac{\pi\alpha\beta_0^W}{2} F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha$$

$$\mathcal{L}_6^c = -\frac{\pi\alpha\beta_c^W}{4} F_{\mu\nu}F^{\mu\nu}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta + W^{-\alpha}W^+_\beta)$$

Seek to constrain the β_0^W and β_c^W parameters
(= 0 in the Standard Model)

Basic selection for generator level studies:

Two photons:	$P_{T\gamma}$ > 15 GeV, $\lvert\eta_\gamma\rvert$<2.5
Charged lepton:	P_{Tl} > 25 GeV, $\lvert\eta_l\rvert$<2.5
Missing pT:	$P_{T\nu}$ > 25 GeV
Separations:	ΔR > 0.4

σ(SM) = 9.8 fb

Expect ~300 events in 30fb^{-1}

$W\gamma\gamma$ Production at the LHC

Paul Bell

Generator-Level Likelihood Analysis

The effects of any anomalous couplings at the $WW\gamma\gamma$ vertex are seen in the tails of various distributions.

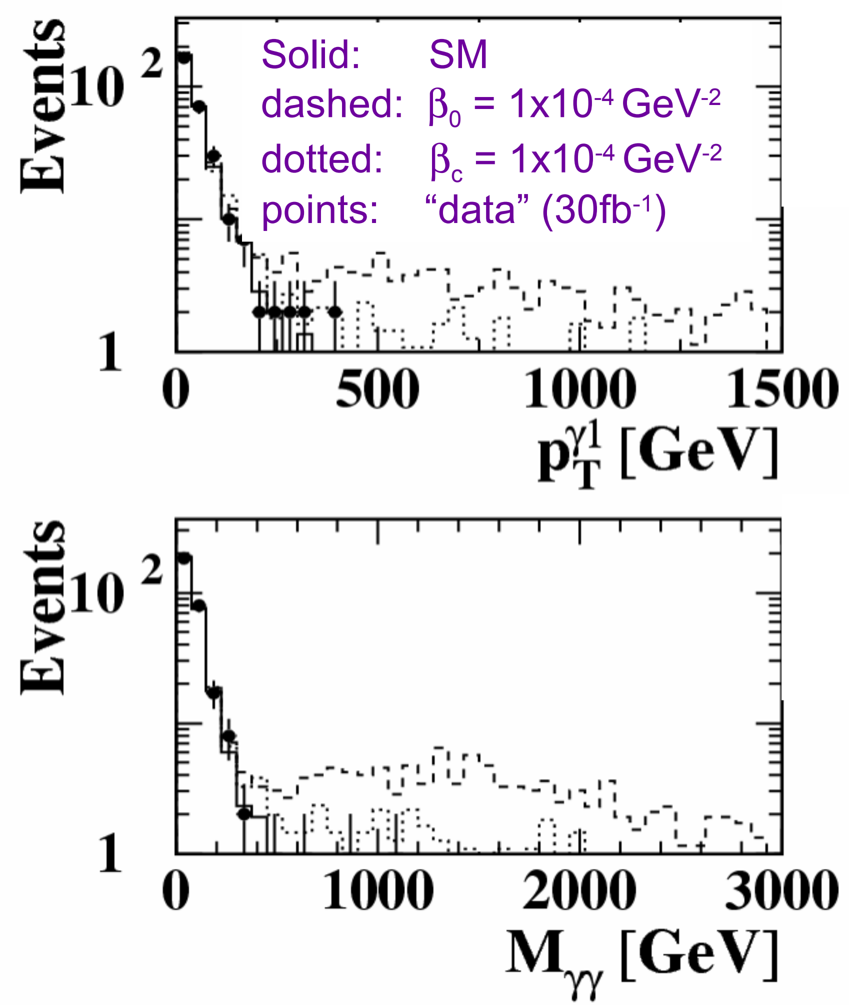
The distribution of the invariant mass of the two photons, $M_{\gamma\gamma}$, is found to be the most sensitive

Assuming 30fb^{-1} of data, the expected 95% CL limits obtained by fitting to the shape of the $M_{\gamma\gamma}$ distribution are:

$$-2.0 < \beta_0 < 1.7 \quad \times 10^{-5}\ \mathrm{GeV}^{-2}$$

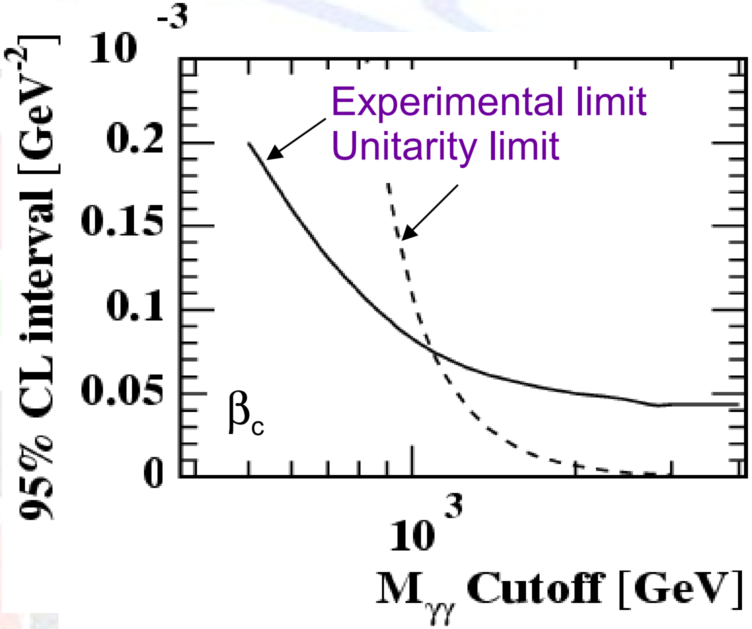
$$-3.2 < \beta_c < 3.5 \quad \times 10^{-5}\ \mathrm{GeV}^{-2}$$

These limits are about 200 times tighter than those available from LEP
(in the plots, the anomalous β values are about 0.02 x the LEP limits)



Wγγ Production at the LHC

Paul Bell



Unitarity Considerations

Limits refer to the *bare couplings.*

It can be shown that to preserve unitarity, a "cutoff" must be applied on the *M*γγ scale at around 1TeV: *Events above this cannot be used to extract limit on the couplings*

=> weakens the limits by factor ~2

ATLAS Simulation:

- Working to have the MC approved as part of the ATLAS software
- Interface to Pythia available for showering and hadronisation
- First SM samples have been made with full and fast detector simulation
- Currently understanding the correct Pythia settings (ISR, FSR, etc)
- Principle backgrounds expected to arise from jets misidentified as photons: e.g. W+jets, Wγ+jets, Z+jets, Zγ+jets

Summary

- Wide variety of Diboson activities underway in the UK.
- $ZZ \rightarrow ll\nu\nu$ channel
  - In 10fb^{-1} of data, expect 102 signal events, 52 background.
  - With 1fb^{-1} of data can obtain limits of $|f_4^Z| < 0.023$, ~10 times better than LEP.
- $ZZ \rightarrow \tau\tau\mu\mu$ channel
  - Expect 9.9 signal events in 10fb^{-1} of data.
  - Possible large backgrounds, statistics limited
  - Return to this channel after 100fb^{-1}?
- WW Cross Section Measurement
  - Large background from Z, studies suggest $W\gamma$ also significant
  - Future plans to investigate with v12 and implement new Monte Carlo
- $W\gamma\gamma$ Production at the LHC
  - Obtain limits on $WW\gamma\gamma$ couplings from fits to $M_{\gamma\gamma}$ distribution
  - Improve LEP limits by 200 with 30fb^{-1} of data.

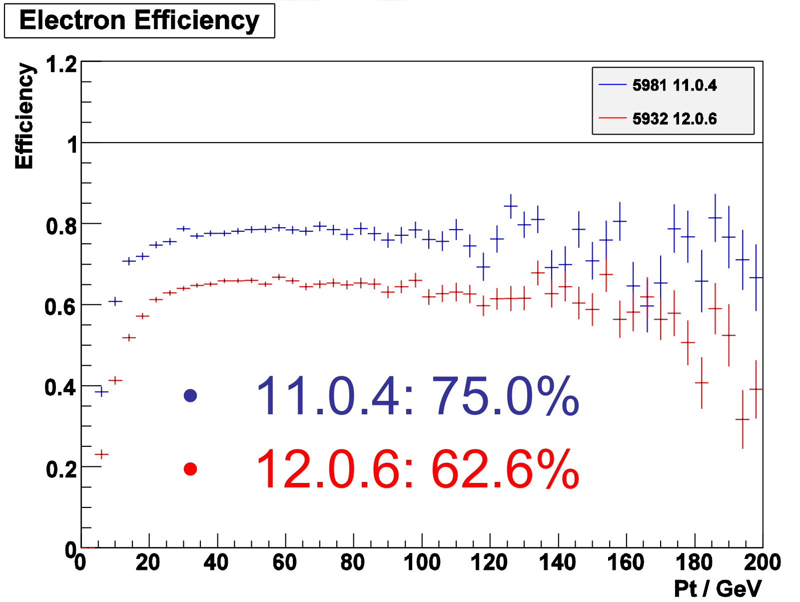
Backup Slides

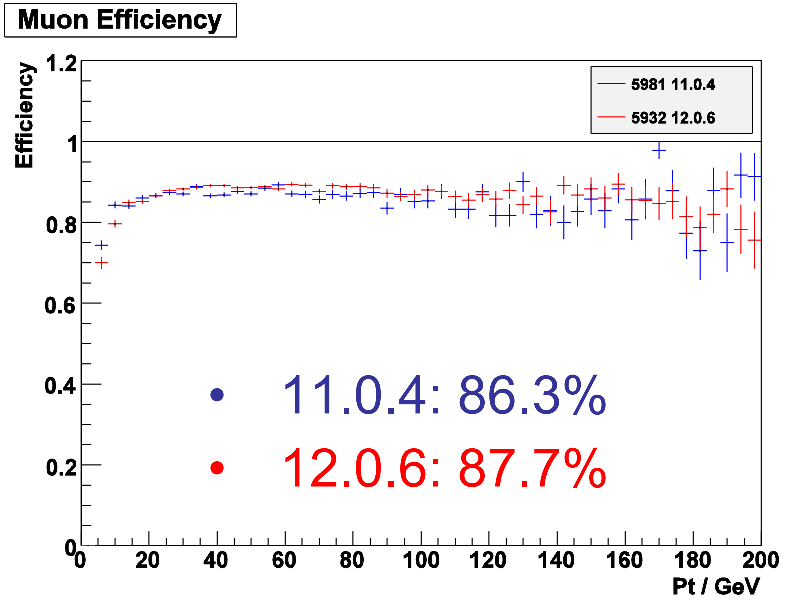
ZZ→llnunu Lepton Efficiency

- **Electrons from *egamma***
  - (isEM & 0x7FF) == 0 no TRT
  - Isolation: Et(ΔR=0.45) < 8 GeV
  - $p_T > 5$ GeV, $|\eta| < 2.5$
  - Efficiency lower in 12.0.6
- **Muon from *MuID***
  - Require a *best* match, with

  $\chi2$(match)/ndof < 10

  $\chi2$(fit)/ndof < 5
  - Isolation: Et(ΔR=0.45) < 5 GeV
  - pT > 5 GeV, $|\eta| < 2.5$
- **Both have similar kinematics**
  - Consider them together for rest of analysis.





ZZ→llnunu Version 11.0.4 Datasets

Run	Channel	Events	Generator	Generator Cuts	σ/pb
5981	$ZZ \rightarrow ll\nu\nu$	48700	PYTHIA	2l $p_T > 4.5$ GeV, $\|\eta\| < 2.7$	0.265
5931	$ZZ \rightarrow llll$	20952	MC@NLO		0.0668
5921	$W^+W^- \rightarrow e\nu e\nu$	43100	MC@NLO		1.30
5924	$W^+W^- \rightarrow \mu\nu\mu\nu$	10950	MC@NLO		1.25
5927	$W^+W^- \rightarrow \tau\nu\tau\nu$	45850	MC@NLO		1.41
5941	$W^+Z \rightarrow l\nu ll$	40900	MC@NLO		0.427
5971	$W^-Z \rightarrow l\nu ll$	18700	MC@NLO		0.267
5152	$Z \rightarrow ee$	69550	MC@NLO	$M_{ee} > 60$ GeV, $1l p_T > 10$ GeV, $\|\eta\| < 2.7$	1608.
5151	$Z \rightarrow \mu\mu$	82600	MC@NLO	$M_{\mu\mu} > 60$ GeV, $1l p_T > 5$ GeV, $\|\eta\| < 2.8$	1662.
5146	$Z \rightarrow \tau\tau$	12118	PYTHIA	$M_{\tau\tau} > 60$ GeV, $2l p_T > 5$ GeV, $\|\eta\| < 2.8$	74.5
5185	$Z \rightarrow ee$	58700	PYTHIA	$p_T(Z) > 100$ GeV, $2l p_T > 10$ GeV, $\|\eta\| < 2.7$	21.
5186	$Z \rightarrow \mu\mu$	95500	PYTHIA	$p_T(Z) > 100$ GeV, $2l p_T > 10$ GeV, $\|\eta\| < 2.8$	21.34
5187	$Z \rightarrow \tau\tau$	28000	PYTHIA	$p_T(Z) > 100$ GeV, $2l p_T > 5$ GeV, $\|\eta\| < 2.8$	22.15
5183	$Z \rightarrow \nu\nu$	47300	PYTHIA	$p_T(Z) > 50$ GeV	715.
5500	Wt	71250	AcerMC	No tau decays and no FSR	26.7
5200	$t\bar{t}$	428747	MC@NLO	No all hadronic channels.	461.

ZZ→ llnunu Version 12.0.6 Datasets

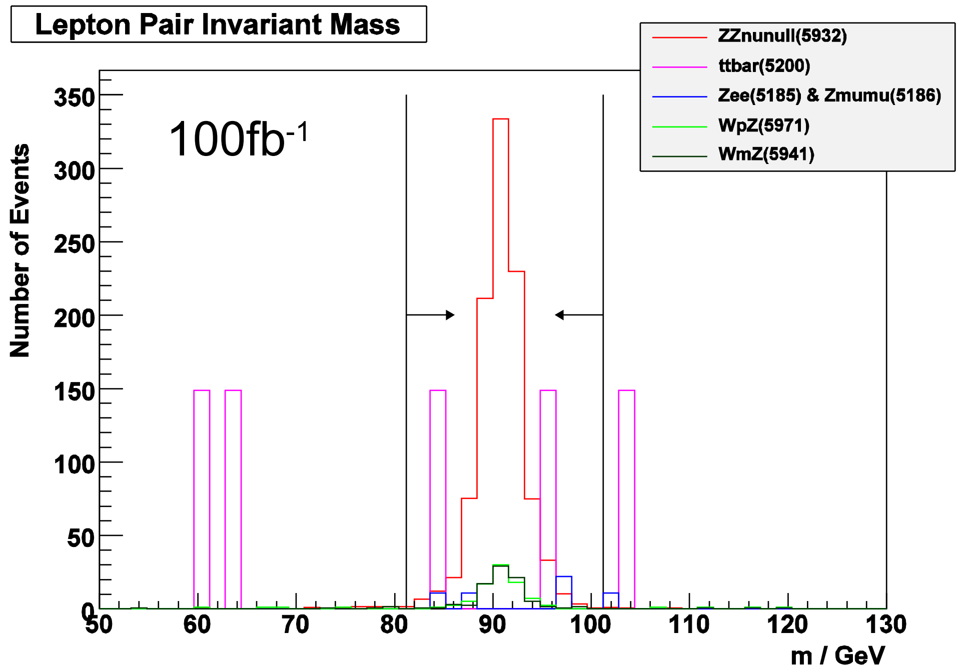
Run	Channel	Events	Generator	Generator Cuts	σ/pb
5981	$ZZ \rightarrow ll\nu\nu$	118000	MC@NLO		0.397
5931	$ZZ \rightarrow llll$	49250	MC@NLO		0.0668
5921	$W^+W^- \rightarrow e\nu e\nu$	19900	MC@NLO		1.30
5922	$W^+W^- \rightarrow e\nu\mu\nu$	19850	MC@NLO		1.27
5923	$W^+W^- \rightarrow e\nu\tau\nu$	19750	MC@NLO		1.35
5924	$W^+W^- \rightarrow \mu\nu\mu\nu$	10000	MC@NLO		1.25
5925	$W^+W^- \rightarrow \mu\nu e\nu$	20000	MC@NLO		1.27
5926	$W^+W^- \rightarrow \mu\nu\tau\nu$	20000	MC@NLO		1.33
5927	$W^+W^- \rightarrow \tau\nu\tau\nu$	19950	MC@NLO		1.41
5928	$W^+W^- \rightarrow \tau\nu e\nu$	13749	MC@NLO		1.35
5929	$W^+W^- \rightarrow \tau\nu\mu\nu$	20000	MC@NLO		1.33
5941	$W^+Z \rightarrow l\nu ll$	52078	MC@NLO		0.427
5971	$W^-Z \rightarrow l\nu ll$	52619	MC@NLO		0.267
5152	$Z \rightarrow ee$	99950	MC@NLO	$M_{ee} > 60$ GeV, $1lp_T > 10$ GeV, $\|\eta\| < 2.7$	1608.
5151	$Z \rightarrow \mu\mu$	99150	MC@NLO	$M_{\mu\mu} > 60$ GeV, $1lp_T > 5$ GeV, $\|\eta\| < 2.8$	1662.
5146	$Z \rightarrow \tau\tau$	98950	PYTHIA	$M_{\tau\tau} > 60$ GeV, $2lp_T > 5$ GeV, $\|\eta\| < 2.8$	74.5
5185	$Z \rightarrow ee$	171150	PYTHIA	$p_T(Z) > 100$ GeV, $2lp_T > 10$ GeV, $\|\eta\| < 2.7$	21.
5186	$Z \rightarrow \mu\mu$	198400	PYTHIA	$p_T(Z) > 100$ GeV, $2lp_T > 10$ GeV, $\|\eta\| < 2.8$	21.34
5200	$t\bar{t}$	422450	MC@NLO	No all hadronic channels.	461.

Cut Flow Table

- Plot shows events after cuts, normalised to $100fb^{-1}$

11.0.4	12.0.6
ε = 3.2%	**ε = 2.6%**
S/B =2.25	**S/B =1.96**

- Errors on ttbar & Z→ll large due to low statistics.

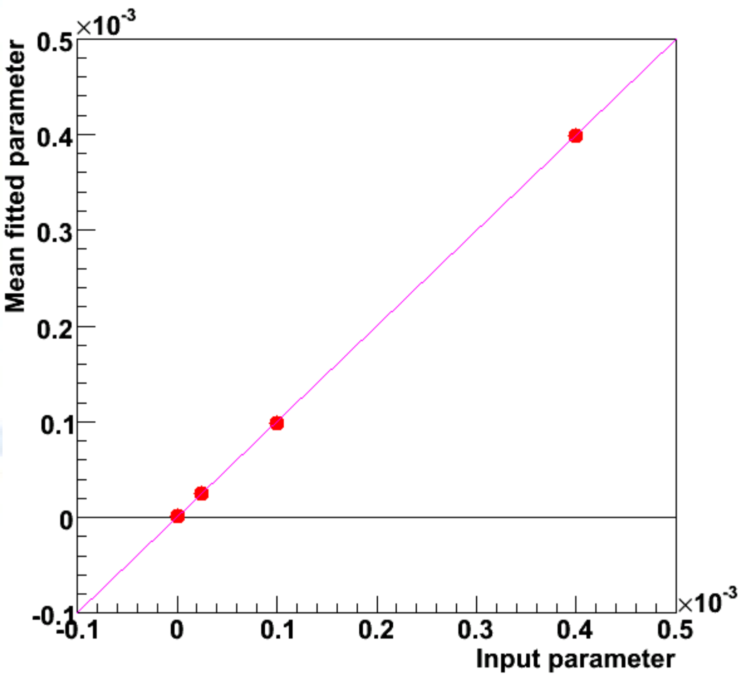


Process	$ZZ \rightarrow ll\nu\bar{\nu}$	$ZZ \rightarrow 4l$	$Z + jets$	$t\bar{t}$	WZ	Wt	WW	$Z \rightarrow \tau\tau$
$p_T^l > 20$ GeV, $\lvert\eta_l\rvert < 2.5$	13006	5430	1.31 10^6	4.53 10^5	27122	225	49110	2.17 10^5
Third lepton veto	10187	311	1.90 10^5	42887	5287	75	37556	1.69 10^5
$\lvert m_{ll} - 91.2$ GeV$\rvert < 10$ GeV	10016	265	1.74 10^5	11020	4530	38	8377	4014
$p_T^{miss} > 50$ GeV $\lvert p_T^{miss} - p_T^Z\rvert / p_T^Z < 0.35$ $\phi_{miss} - \phi_Z < 35°$	3795	34	378	1787	942	0	1826	0
Jet Veto ($p_t^{jet} > 30$ GeV and $\lvert\eta_{jet}\rvert < 3$)	3443	30	44	596	763	0	1668	0
$p_T(l^+l^-) > 100$ GeV	**1016**	**8**	**44**	**298**	**167**	**0**	**2**	**0**
Statistical Error:	23	1	22	211	13	0	23	0

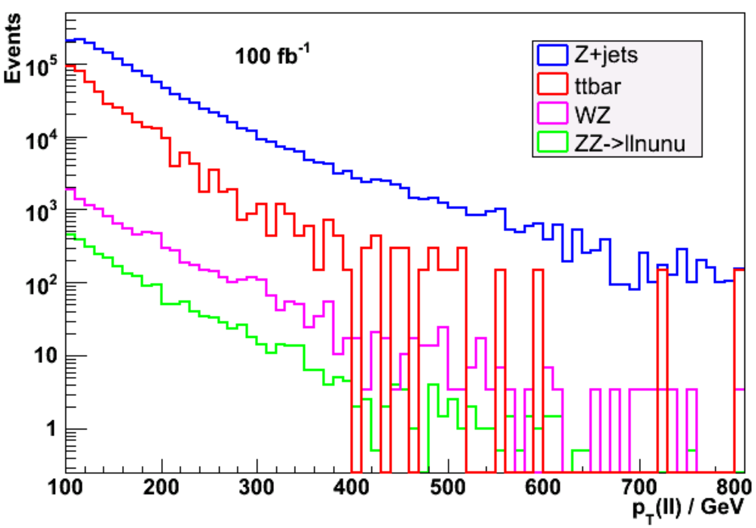
Events expected in $100fb^{-1}$ of data

Anomalous Coupling Fitting Plots

- Fit comparison



- Background Distribution



ZZ→mumutautau Samples Used

Run	Channel	No.Events	Release	Generator	Generator Cuts
Private Sample	**ZZ→ $\mu\mu\tau\tau$**	10000	12.0.6.5	MC@NLO	-
R5146	**Z→ $\tau\tau$**	80900	11.0.4.2	PYTHIA	$m_{\tau\tau}$>60GeV, 2 leptons with p_T>5GeV and |η|<2.8
R5151	**Z→ $\mu\mu$**	2600	11.0.4.2	MC@NLO	$m_{\mu\mu}$>60GeV, 1 lepton with p_T>5GeV and |η|<2.8
R5152	**Z→ ee**	69550	11.0.4.2	MC@NLO	m_{ee}>60GeV, 1 lepton with p_T>10GeV and |η|<2.7
R5185	**Z→ ee**	58700	11.0.4.2	PYTHIA	Z p_T>100GeV, 2 leptons with p_T>10GeV and |η|<2.7
R5186	**Z→ $\mu\mu$**	95500	11.0.4.2	PYTHIA	Z p_T>100GeV, 2 leptons with p_T>5GeV and |η|<2.8
R5200	**t t-bar**	10000	11.0.4.2	MC@NLO	No all hadronic events
R5924	**WW→ lνlν**	10950	11.0.4.2	MC@NLO	-
R5931	**ZZ→ llll**	9000	11.0.4.2	MC@NLO	-
R5981	**ZZ→ ll$\nu\nu$**	10000	11.0.4.2	PYTHIA	2 leptons with p_T>4.5GeV and |η|<2.7