Sensitivity of ZZ→llνν to Anomalous Couplings

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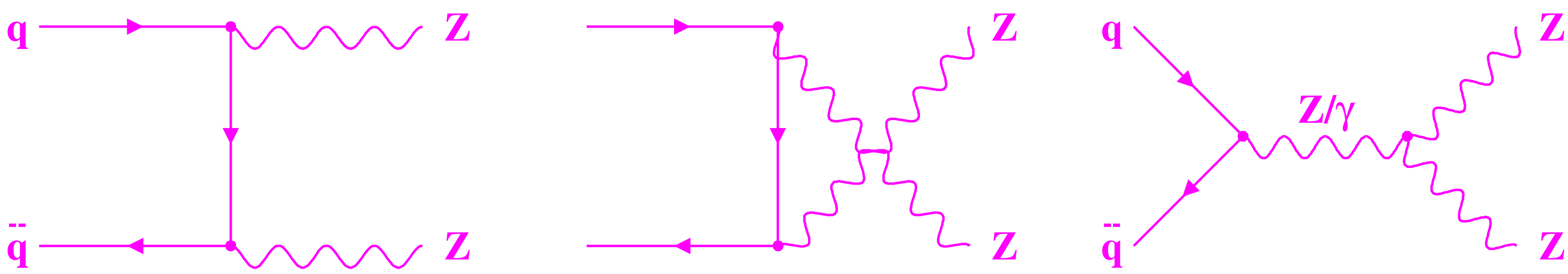
- Neutral Triple Gauge Couplings
- Fit Procedure
- Results
- Outlook

Neutral Triple Gauge Couplings



Forbidden in SM

- ZZZ and ZZγ vertices 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
- All = 0 in SM

Anomalous Couplings

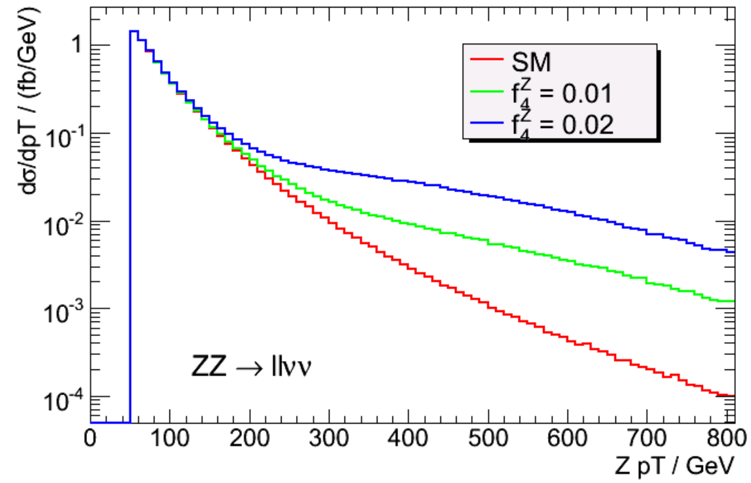
- f_4 violate CP; helicity amplitudes do not interfere with SM; cross-sections depend on f_4^2 and sign cannot be determined
- f_5 violate P; do interfere with SM
- Couplings depend on energy. Usual to introduce a form factor to avoid violation of unitarity:

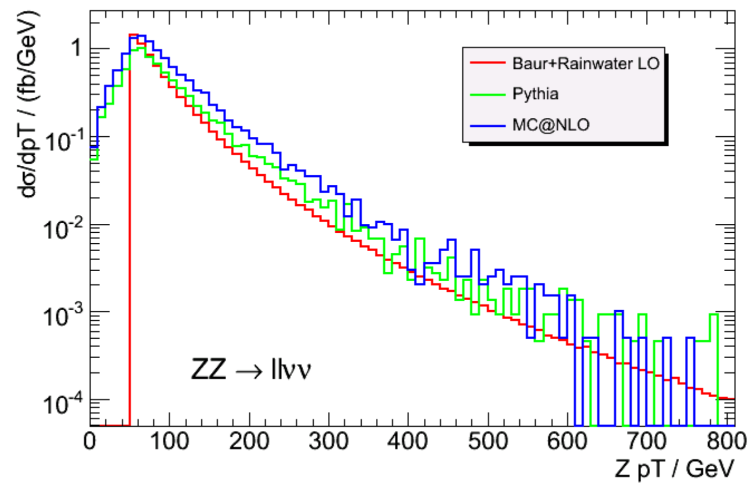
  $$f(s') = f_0 / (1 + s'/\Lambda^2)^n$$

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

Signature of Anomalous Couplings

- Anomalous couplings increase cross-section at high p_T
- Use leading order MC of Baur + Rainwater to study anomalous couplings
- Fit p_T distribution to obtain limits on NTGC





Fits to pT Distribution

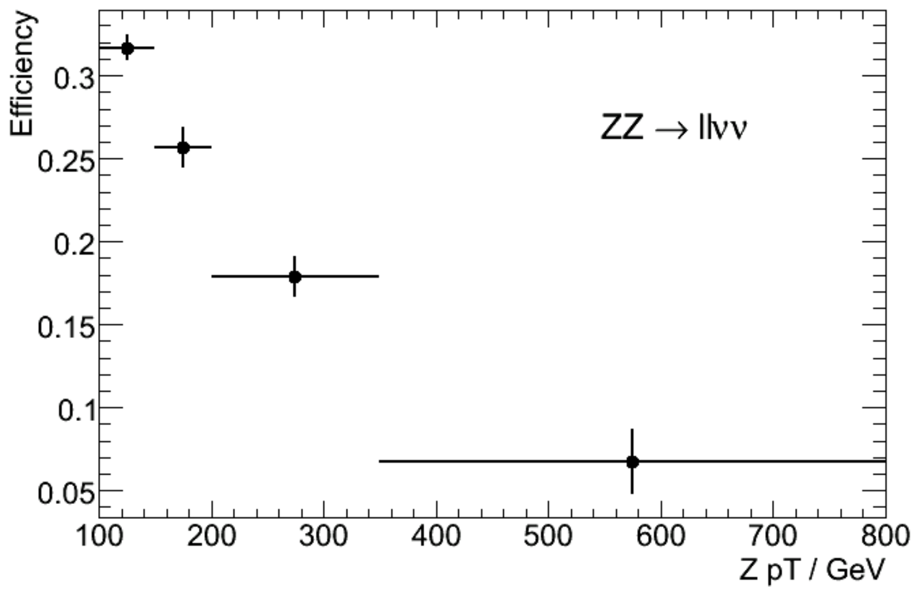
- Estimate limits on anomalous couplings likely to be obtained from early ATLAS data from fit to p_T distribution in $ZZ \rightarrow ll\nu\nu$ channel:
  - Generate `fake data' samples
  - Fit to sum of signal + background
  - Determine mean 95% C.L.
- Use results from Tom's $ZZ \rightarrow ll\nu\nu$ event selection for efficiency and background to obtain realistic limits

Calculation of Signal Distribution

- Use BR MC to calculate LO cross-section at several values of f_4^Z

  $p_T(l) > 20$ GeV, $|\eta(l)| < 2.5$, $p_T(\nu\nu) > 50$ GeV
- Fit to quadratic in f_4^Z to obtain cross-section at arbitrary f_4^Z
- Correct for NLO effects using ratio MC@NLO / BR(SM)
- Expected number of events = cross-section x efficiency x luminosity

Signal Efficiency



Efficiency = events passing selection cuts divided by events generated with $p_T(l) > 20$ GeV, $|\eta(l)| < 2.5$, $p_T(\nu\nu) > 50$ GeV

- Efficiency from full MC using Tom's event selection
- Drops with p_T due to jet veto
- Fit results have some dependence on binning

Background Distribution

- Too few full MC events pass cuts to determine background shape
- Before cuts, background / signal fairly flat for p_T > 100 GeV
- Assume background / SM signal flat:

  background / SM signal = 0.51 +- 0.21

  (error from MC stats)
- Background level has only small effect on limits

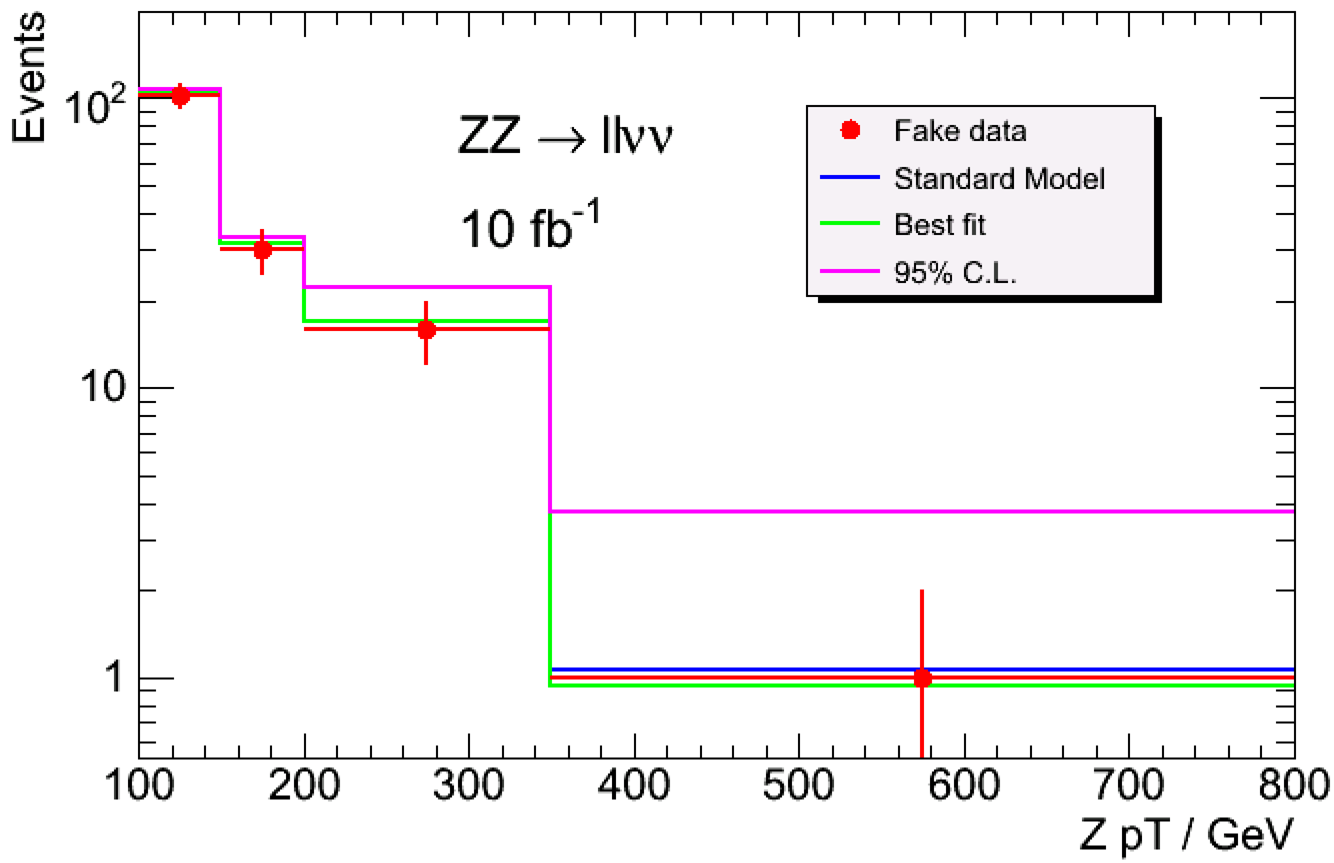
`Fake Data' Samples

- Construct from expected numbers of SM signal and background events
- Add Gaussian fluctuations for systematic errors:
  - Signal: 7.2% correlated (6.5% lumi, 3% lepton ID) plus MC stat error on efficiency in each bin
  - Background: 41% correlated (MC stats)
- Add Poisson fluctuation to total number of events

Fits to p_T Distribution

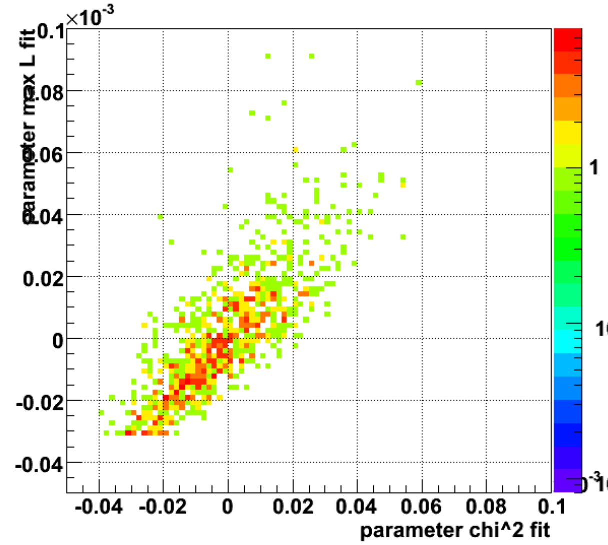
- One-parameter fit to $(f_4^Z)^2$
  - Negative $(f_4^Z)^2$ allows for downward fluctuations
  - Lower limit to prevent negative predictions
- X^ fit using full correlation matrix
  - 95 % c.l. from $X^2 – X^2min = 3.84$
  - Only suitable for high statistics
- Binned maximum likelihood fit including systematic errors by convolution with predictions
  - 95% c.l. from -ln(L) - -ln(L)min = 1.92

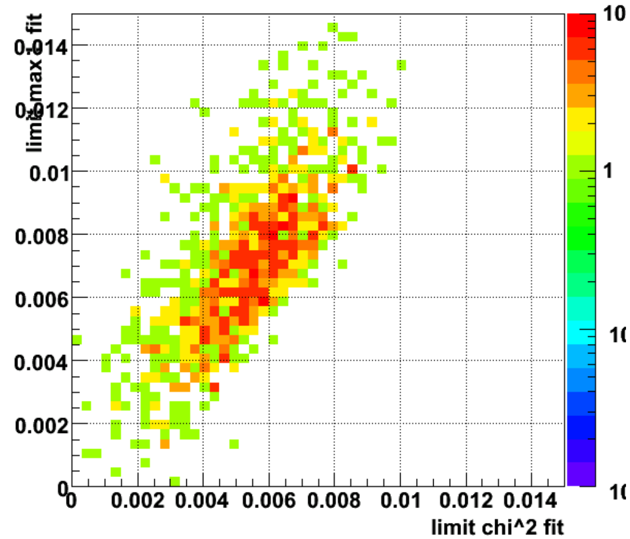
Example Fit


Events
10^2
10
1
$ZZ \rightarrow ll\nu\nu$
10 fb^{-1}
Fake data
Standard Model
Best fit
95% C.L.
100
200
300
400
500
600
700
800
Z pT / GeV

Test fits on 100 fb^{-1}

- Generate 1000 fake data samples for high lumi and fit with both fits
- Good correlation between parameter values at minimum
- 95% C.L. limits tend to be higher for max likelihood fit – seems to result from treatment of systematic errors, but not understood





Results from Max L Fit

Lumi / fb^{-1}	95% C.L.
1	0.023
10	0.011
30	0.0088

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

- Mean 95% C.L. on f_4^Z from 1000 fits
- Background level and systematic errors not important for early data
- No background: limits improve by 10%
- No sys errors: limits improve by 7%

Summary and Outlook

- Expect to achieve worthwhile limits with as little as 1 fb^{-1} of data
- Much still to do for a `real' analysis:
  - Understand why max L fit gives higher limits
  - How to determine background distribution from data?
  - Include 4-lepton channel
  - Set up framework for 2-D couplings