Update on ZZ->llnunu Analysis and Sensitivity to Anomalous Couplings

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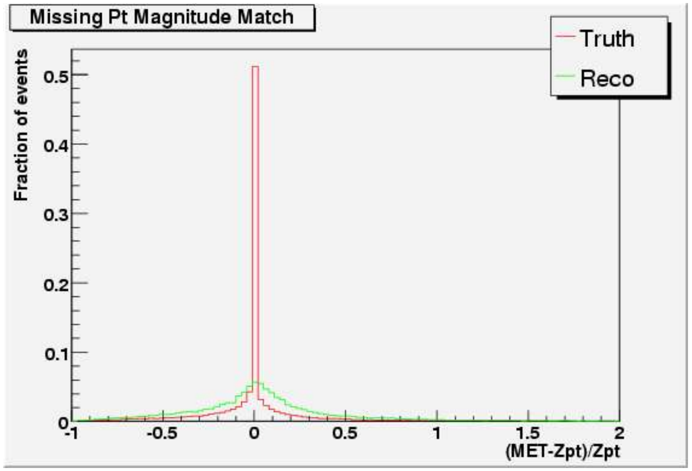
Outline

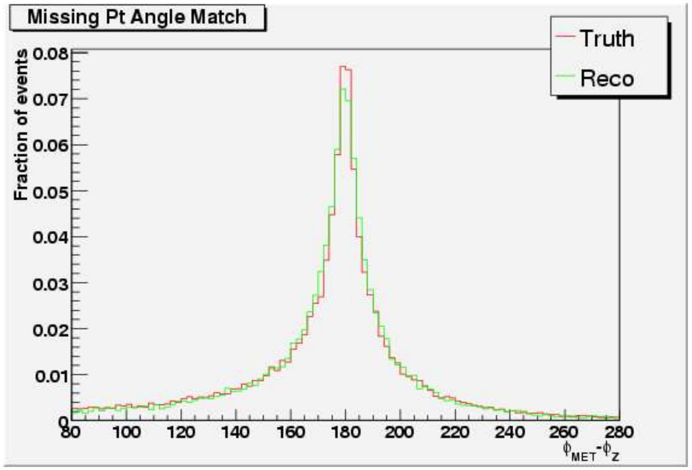
- Update on ZZ->llnunu analysis using CSC11 datasets (Tom Barber)
  - V12 ZZ->llnunu with 1mm bug fixed is not yet available
  - V12 sample with 1mm bug has shifted Z mass peak for electrons
- Very preliminary investigation of limits on anomalous couplings from ZZ->llnunu
  - Very large backgrounds from Z+jets and ttbar
  - Sensitivity of limits to these backgrounds

Update on ZZ->llnunu Event Selection

- Last meeting: cuts used in fast simulation study (S.Hassani ATL-PHYS-2003-022) applied to full simulation (csc11)
  - 2 leptons with pT>20GeV in |eta|<2.5
  - |M(ll) – 91.2 GeV| < 10 GeV (opp charge)
  - MET_final_et > 50 GeV
  - No jet with pT>30 GeV in |eta|<3
  - pT(ll) > 150 GeV
- Expected signal smaller than fast sim study, background very much higher (B/S ~ 15)
- Look for new cuts to remove background

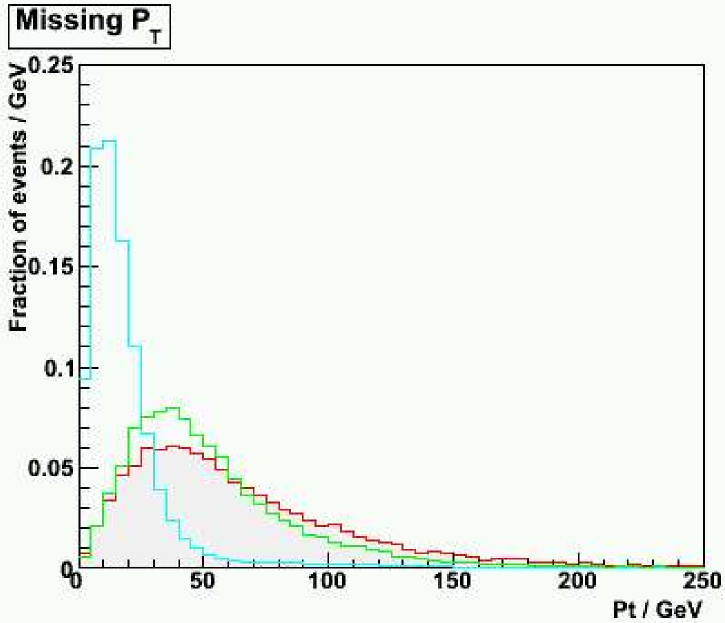
pT Matching

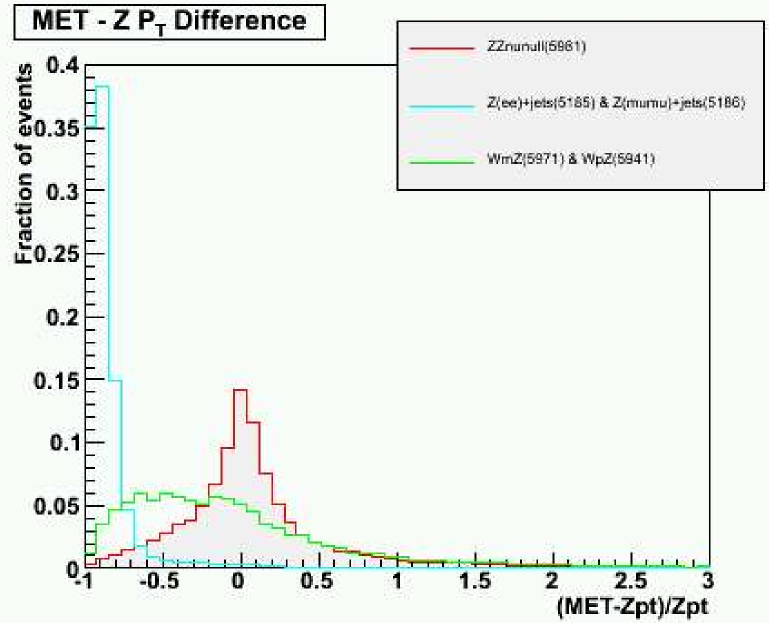


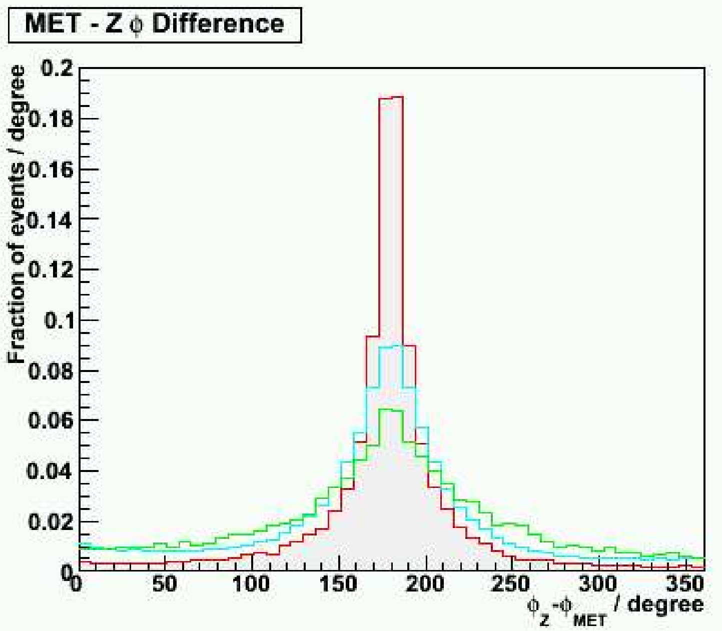


- In signal events missing ET is balanced by pT of observed Z

  Jet veto, necessary to remove Z+jets background, removes signal events with hard gluon
- Require Z(ll) transverse momentum to match the missing ET in magnitude and direction
  - (MET-Zpt)/Zpt
  - phi(MET) – phi(Z)







- Magnitude of MET match discriminates against background
- Angle less powerful

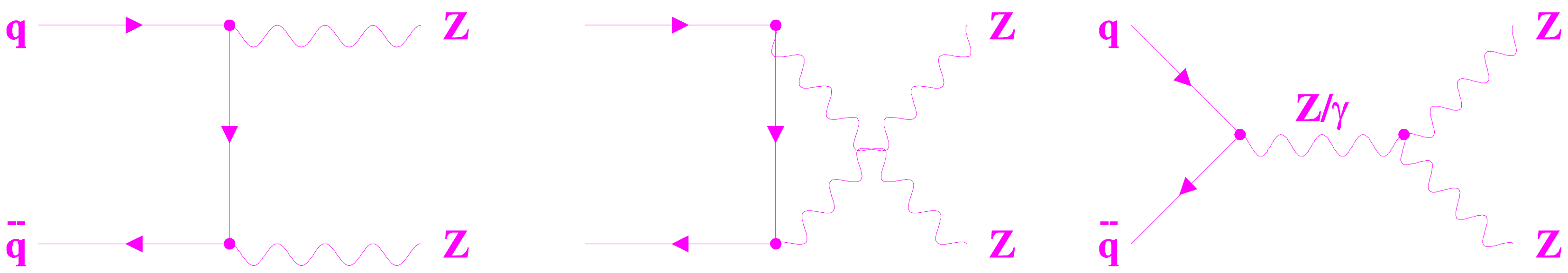
pT Matching

- Apply pT matching cuts:
  |MET-Zpt|/Zpt < 0.1
  170 < phi(MET)–phi(Z) < 190 deg
  (These rather tight – probably need loosening)
- Also veto events with 3rd lepton (reduce WZ)
- Reduce pT(ll) cut from 150 GeV to 100 GeV
- Obtain signal/background ratio of 2.7
- Signal efficiency (for Z(ll) > 100 GeV, 2 leptons in |eta|<2.5 with pT>20 GeV) ~ 23%
- Largest remaining background is WZ

Events Passing New Cuts

Channel	# selected	# for 100 fb-1
$ZZ \to ll\nu\nu$	1192	649
ttbar	0	< 439 (95%CL)
$Z \to ee$, high p_T	0	< 107 (95%CL)
$Z \to \mu\mu$, high p_T	0	< 67 (95%CL)
$W^-Z \to l^-\nu ll$	34	68
$W^+Z \to l^+\nu ll$	97	140

Sensitivity to Anomalous Couplings



Forbidden in SM

- Production of on-shell ZZ probes ZZZ and ZZg anomalous couplings:
  f4Z, f5Z, f4g f5g (all = 0 in SM)
- f4 violate CP; helicity amplitudes do not interfere with SM; cross-sections depend on f4**2 and sign cannot be determined
- f5 violate P; do interfere with SM

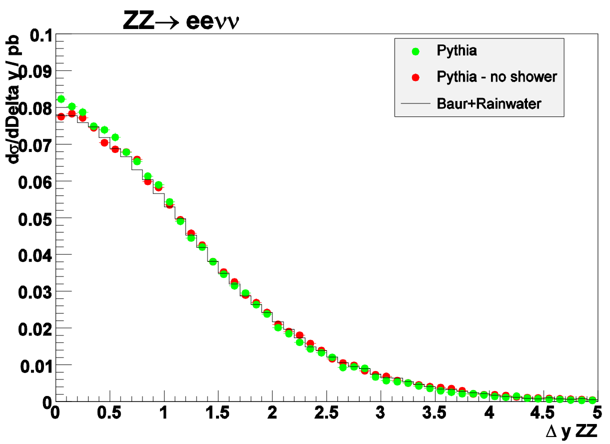
Sensitivity to Anomalous Couplings

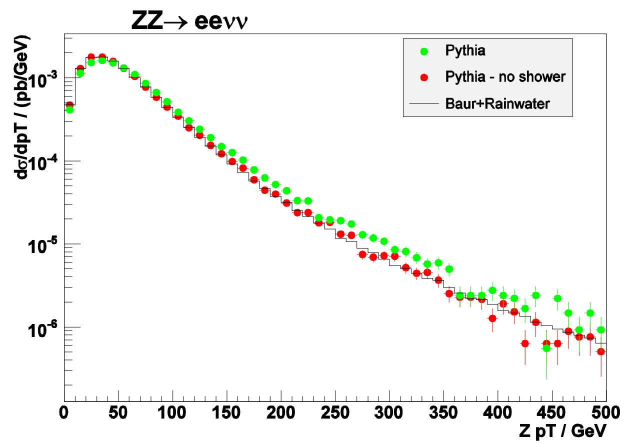
- Couplings depend on energy. Usual to introduce a form factor to avoid violation of unitarity:

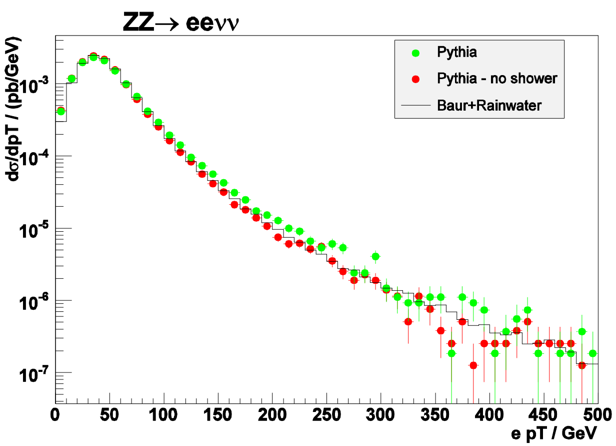
  f(s') = f0 / (1 + s'/Lambda**2)**n
- Studies below use n=3, Lambda = 2 TeV
- Also assume couplings are real and only one non-zero
- Study AC using LO Monte Carlo of Baur and Rainwater
- N.B. jet veto removes hard gluons, so LO not so bad

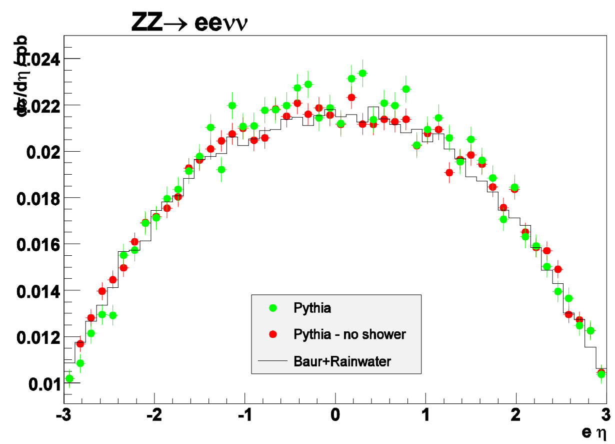
Comparison with Pythia

- Check BR MC: compare with Pythia for SM

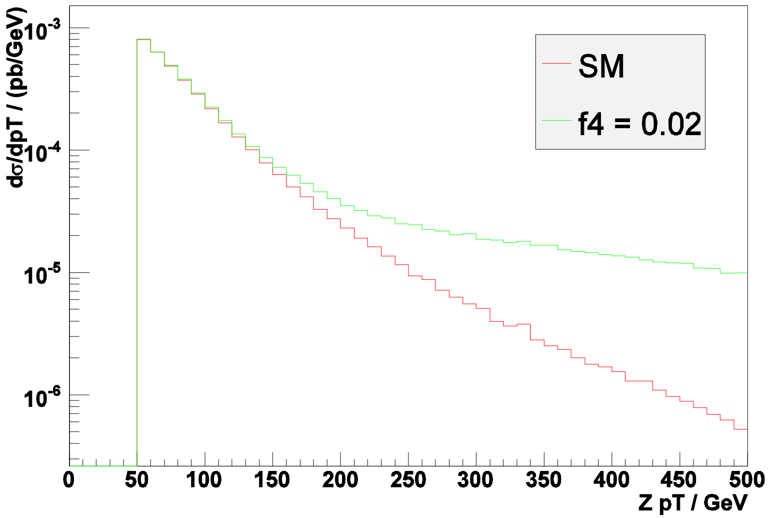








Signature of Anomalous Couplings



e.g above for ZZ->eenunu

with pT(e) > 15 GeV,

|eta(e)| < 2.5

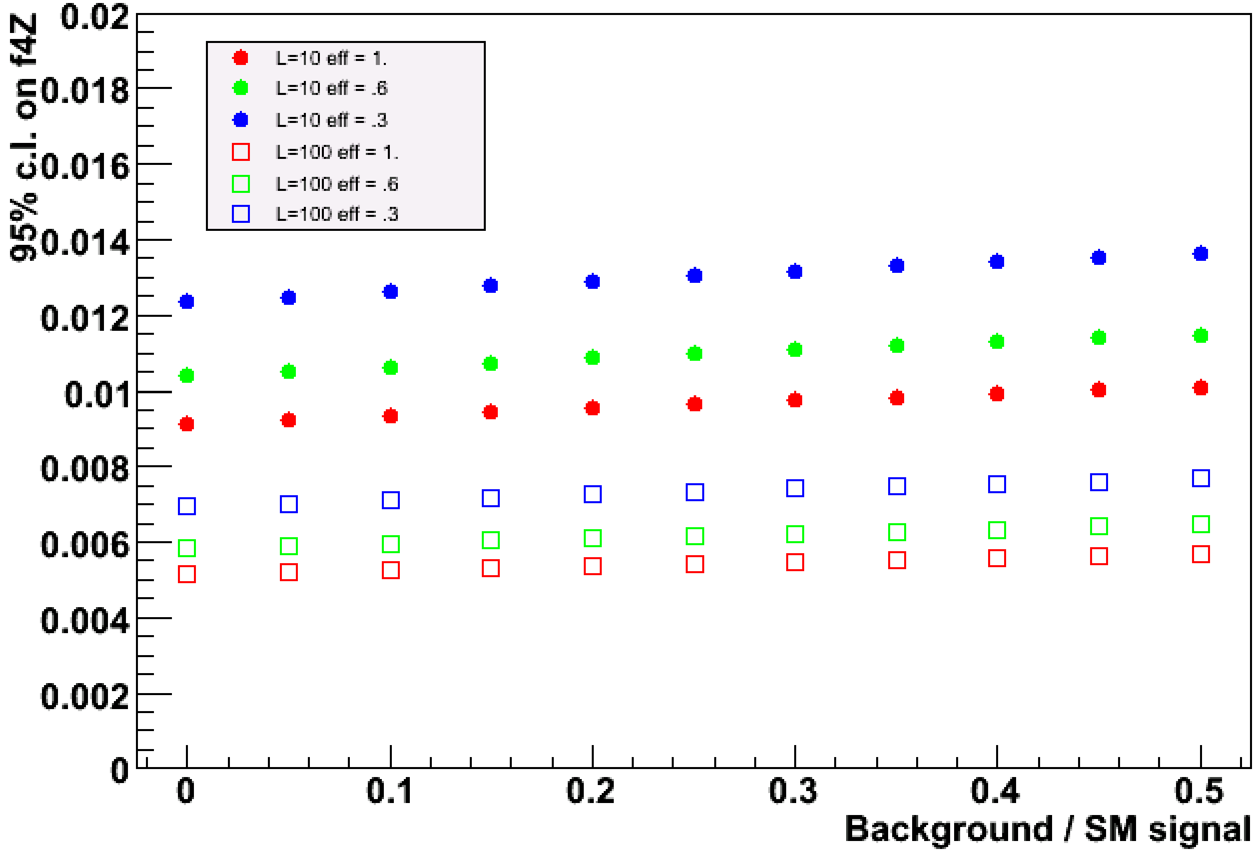
- Anomalous couplings produce increase in ZZ invariant mass, Z pT and lepton pT distributions
- For ZZ->llnunu can use high pT(Z) cross-section to obtain limit, or fit Z pT distribution

Limits from Cross-section Measurement

- First consider measurement of ZZ->llnunu cross-section for pT(l) > 20 GeV, |eta(l)| < 2.5, Z(pT) > 100 GeV
- Calculate cross-section, hence expected events as function of f4Z
- Use chi-squared comparison between expected and ‘observed’ (=SM) numbers of events to determine 95% c.l. on coupling
- Calculate limit as function of ratio of background to SM signal
- First assume statistical errors only, then consider effect of a systematic error on the background

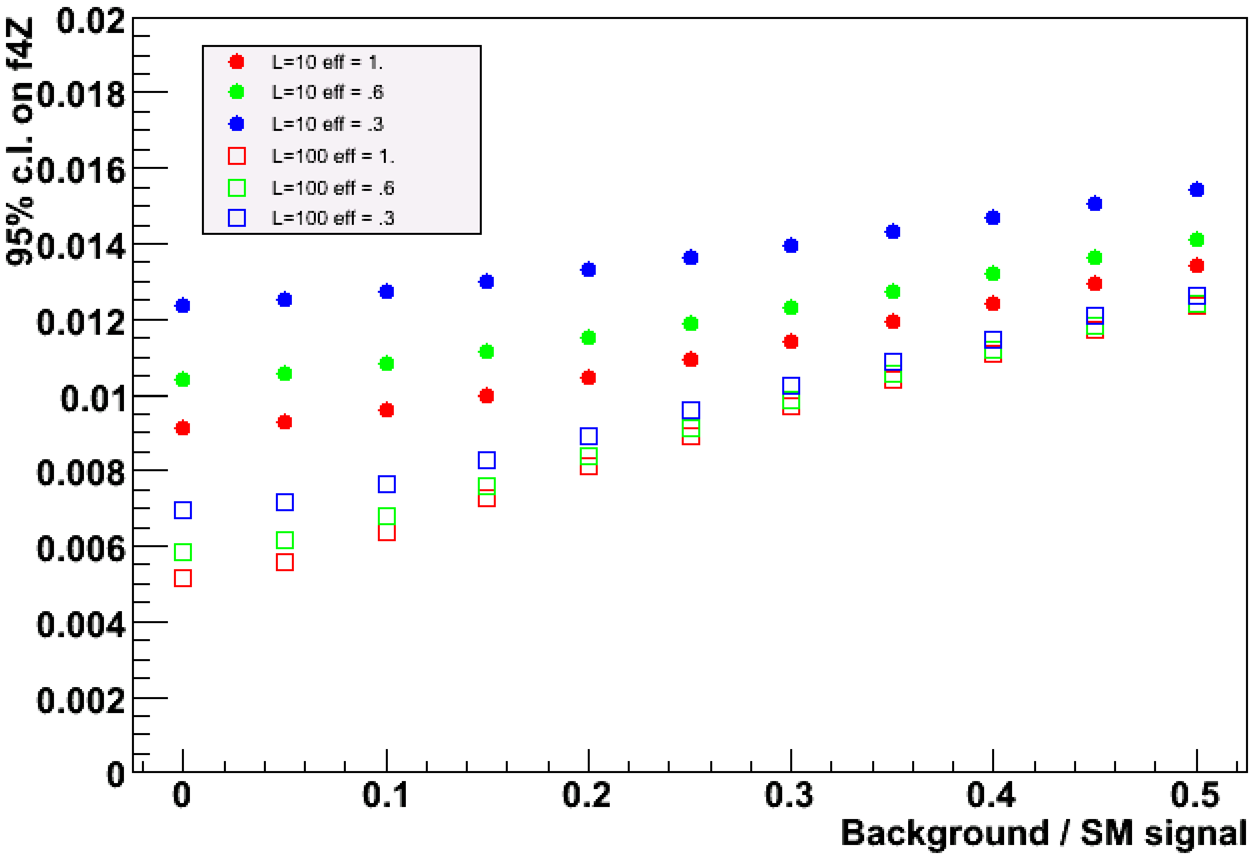
Statistical errors only

Little dependence on background fraction



20% systematic error on background

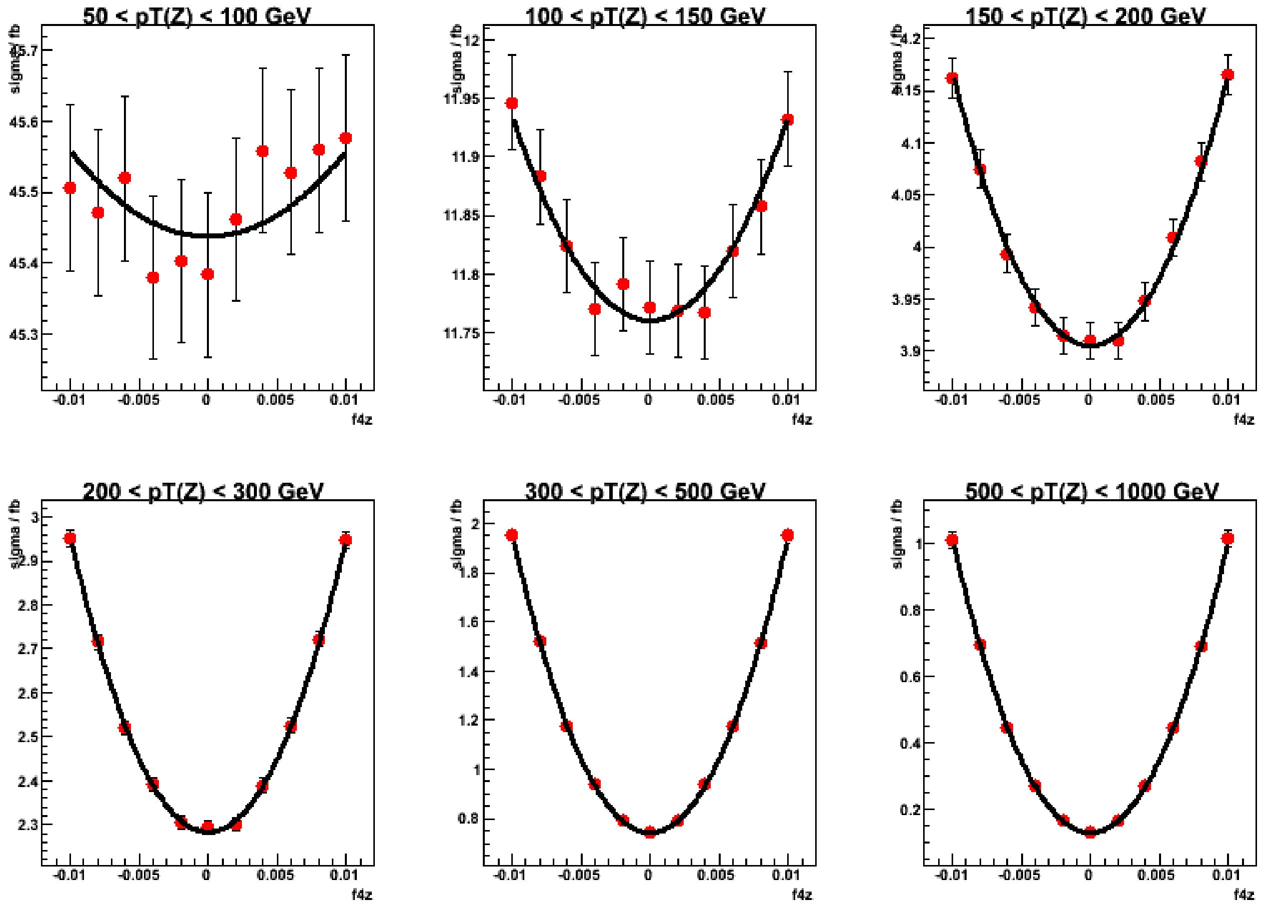
Strong dependence on background: limits independent of luminosity for high background



Limits from Fits to pT Distribution

- Limits from a simple cross-section measurement depend on pT cut – harder pT cut can give better limit despite much lower statistics
- Therefore better to fit pT distribution
- Results below are for ZZ->llnunu with pT(l)>20 GeV, |eta(l)| <2.5
- Use BR program to generate pT distributions for several values of couplings (only one non-zero at a time)
- In each pT bin fit cross-section to quadratic in coupling to obtain distribution at arbitrary value

Cross-section v f4Z in pT bins



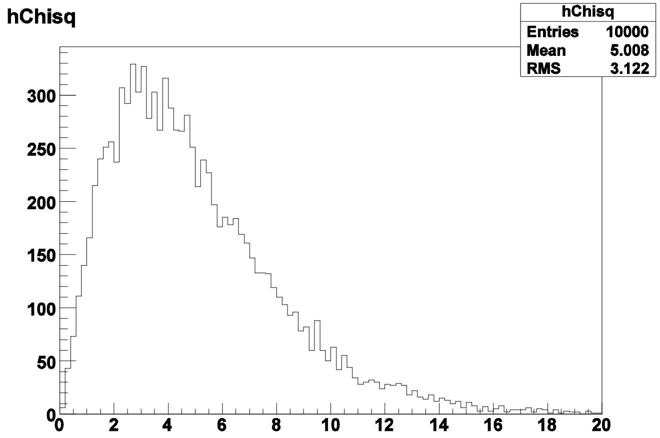
Limits from Fits to pT Distribution

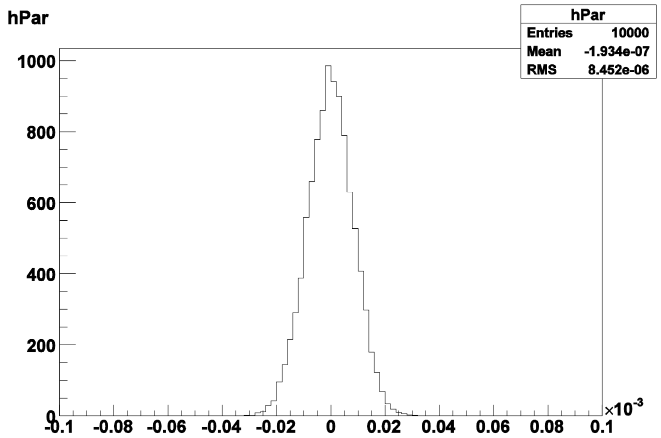
- Create ‘fake data’ sample:
  - Calculate expected SM events in each pT bin
  - Add background – constant fraction of SM
  - Apply Gaussian smearing
- Construct error matrix
  - Statistical errors plus systematic error on background assumed fully correlated
- Fit fake data sample
  - One parameter fit to f4Z**2 or f5Z
  - 95 % c.l. from X**2 – X**2min = 3.84

Limits from Fits to pT Distribution

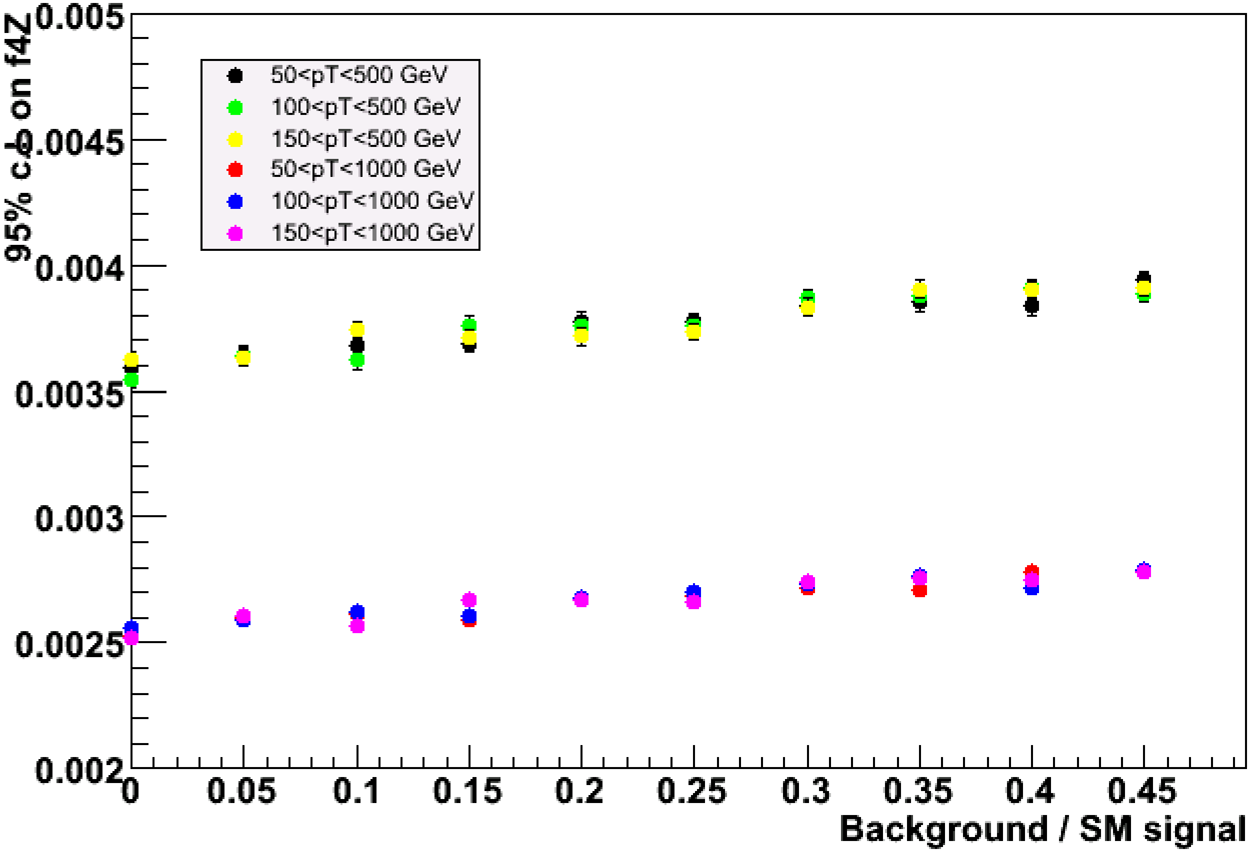
- Generate 1000 fake data samples for each value of background fraction and each value of background systematic
- Mean X**2/dof = 1
- Mean f4**2 = 0

As expected



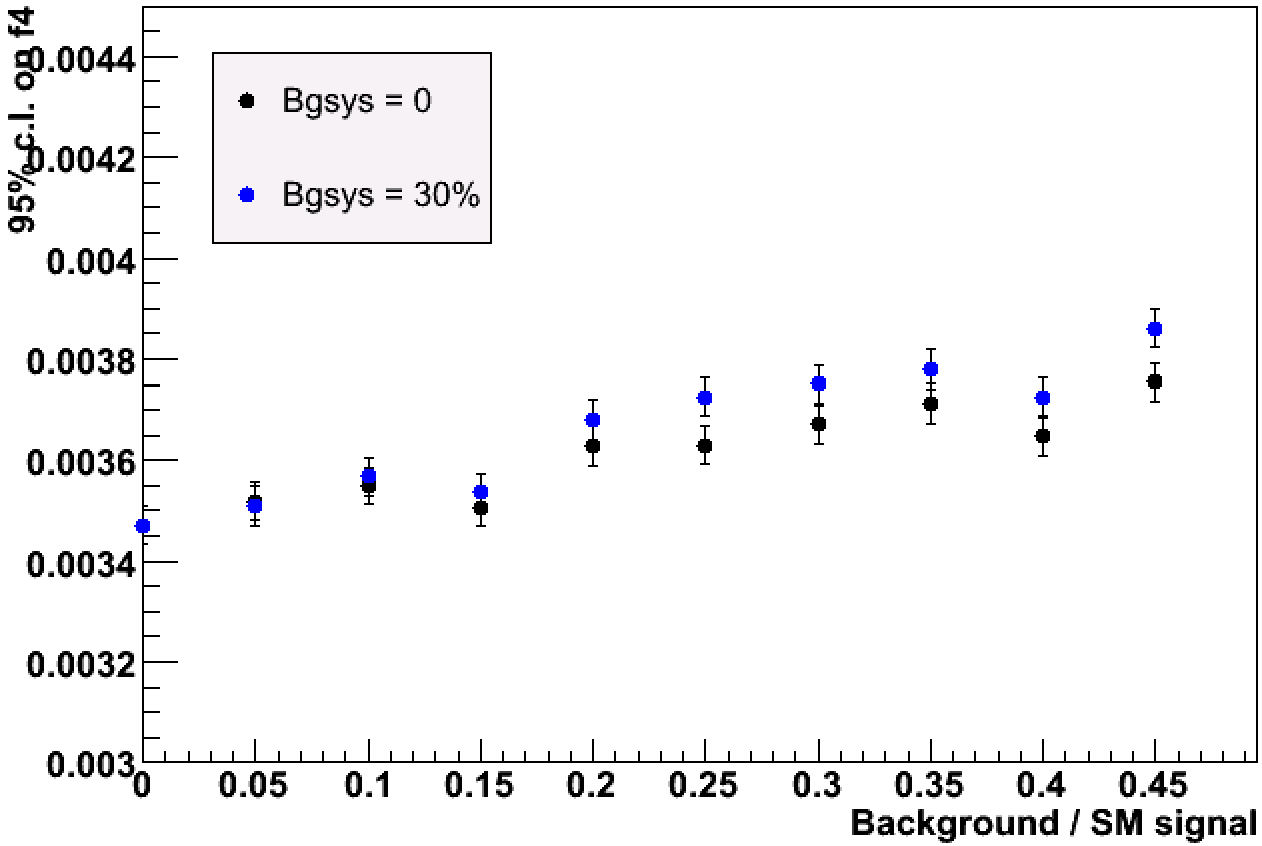


Results for 100 fb-1, eff = 1.0 from Different Fit Ranges (statistical errors only)



- Lower pT cut has ~no effect on limits
- Important to go to as high pT as possible

Results for 100 fb-1, eff = 0.3 from Fit in Range 100 GeV < pT < 1000 GeV



- With uniform background, systematic error has little effect

Effect of Different Background Assumptions

- Assuming 100 fb-1, eff = 30%

  (systematic error 0 – 30%)

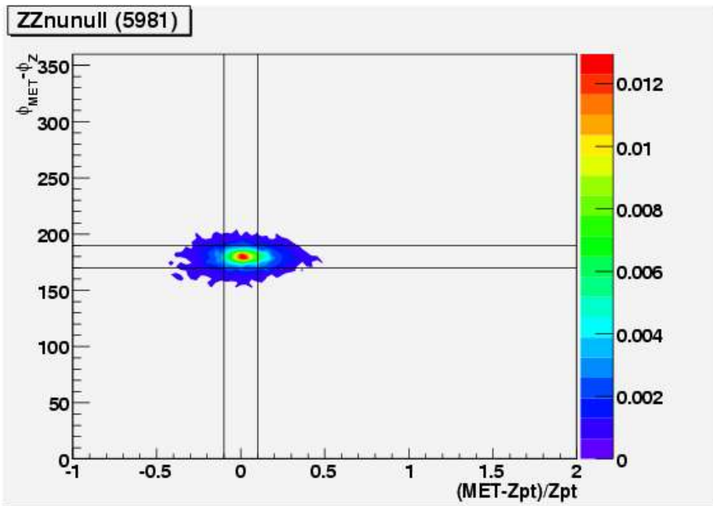
Background Form	95% c.l. on f4Z
No background	0.0035
Uniform 30%	0.0037 – 0.0038
Rising from 30% to 80%	0.0040 – 0.0041
25% + 0.1 event/GeV	0.0052 – 0.0059

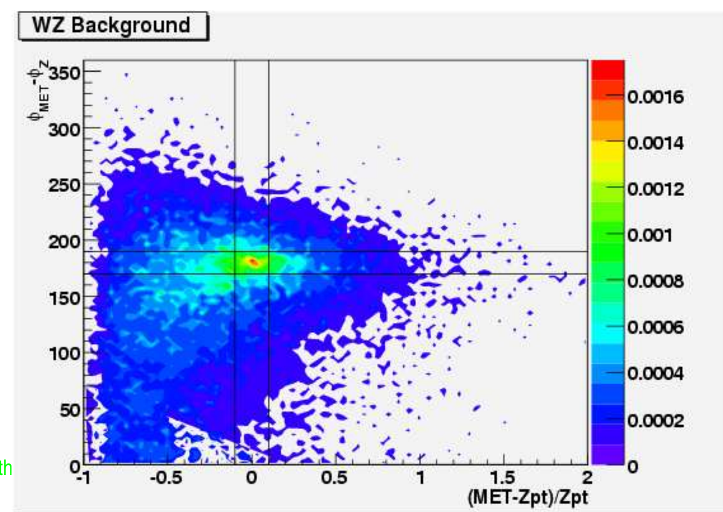
Summary and Plans

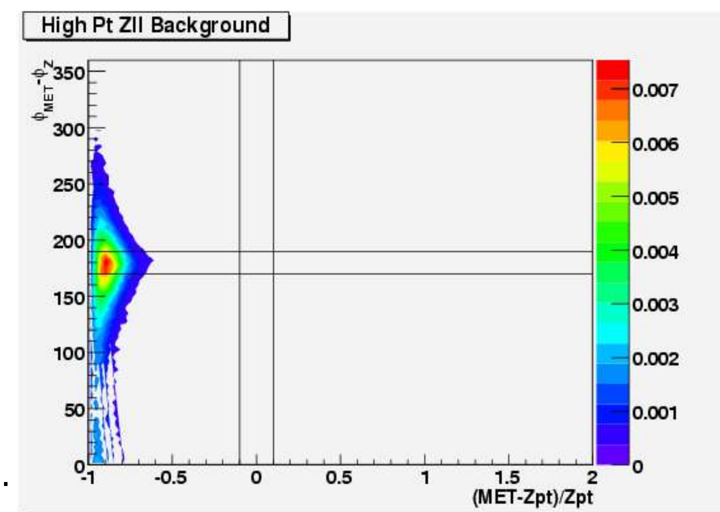
- Cut on pT match gives good background rejection
  - Need to optimise cuts
  - Investigate remaining background – e.g. missing lepton in WZ?
  - Investigate estimation of background from data / Atlfast
  - Redo study with 12.0.6 when signal sample available
- First look at sensitivity to anomalous couplings:
  - Uniform background not a problem if it is well-known
  - More realistic background will give some degradation in limits
  - Optimal binning of pT distribution will depend on luminosity
  - Need to think how to predict expected pT distribution for serious analysis (reweighting, fast MC etc.)
- Finally: John Chapman has started feasibility study of ZZ->lltautau channel

Missing Pt Background

- Check correlations by making 2D histograms of angle and magnitude match for signal and background.
- Lines at:
- |MET-Zpt|/Zpt < 0.1
- 170 < phi(MET)-phi(Z) < 190
- Very effective at Z+jets removal.
- WZ has peak in same region, but wider distribution.







Full Simulation Yields:

Channel	Run	Nevents	Neffective	sigma/fb	Nelectrons	100fb-1	Nmuons	100fb-1	Total	**100f-1**	**(90% cl)**
ZZnunull	5981	48700	48700	265	599	325.95	593	322.68	1192	**648.62**	**648.6**
ZZnunull	5932	118018	79238	265	306	102.34	619	207.02	925	**309.35**	**309.4**
ZZllll	5931	25367	15221	66.8	13	5.71	10	4.39	23	**10.09**	**10.1**
Z(tautau)+jets	5187	28000	28000	22150	0	0	0	0	0	**0**	**181.9**
Z(tautau)	5146	12114	12114	74500	0	0	0	0	0	**0**	**1414.5**
Z(nunu)+jets	5183	47300	47300	715000	0	0	0	0	0	**0**	**3476.7**
Z(mumu)+jets	5186	95500	95500	21340	0	0	0	0	0	**0**	**51.4**
Z(mumu)	5151	83557	69451	1.66E+006	0	0	0	0	0	**0**	**4574.8**
Z(ee)+jets	5185	58700	58700	21000	0	0	0	0	0	**0**	**82.3**
Z(ee)	5152	69558	58290	1.61E+006	0	0	0	0	0	**0**	**5317.0**
WWv12	5921	58006	39512	1300	0	0	0	0	0	**0**	**5.2**
WWtaunutaunu	5927	45850	31138	1300	0	0	0	0	0	**0**	**6.5**
WWmunumunu	5924	10950	7454	1300	0	0	1	17.44	1	**17.44**	**17.4**
WWenuenu	5921	43102	29360	1300	1	4.43	0	0	1	**4.43**	**4.4**
Wtop	5500	71250	71250	26700	0	0	0	0	0	**0**	**86.2**
WpZ	5941	41770	29550	427	55	79.48	42	60.69	97	**140.17**	**140.2**
WmZ	5971	19154	13400	267	17	33.87	17	33.87	34	**67.75**	**67.7**
ttbar	5200	428879	313435	461000	0	0	0	0	0	**0**	**247.2**
								Total:	156	**239.87**	**15683.7**

S/B = 2.7, signal efficiency 2.45%