Measuring triple-gauge boson anomalous couplings via W+gamma and Z+gamma using CMS

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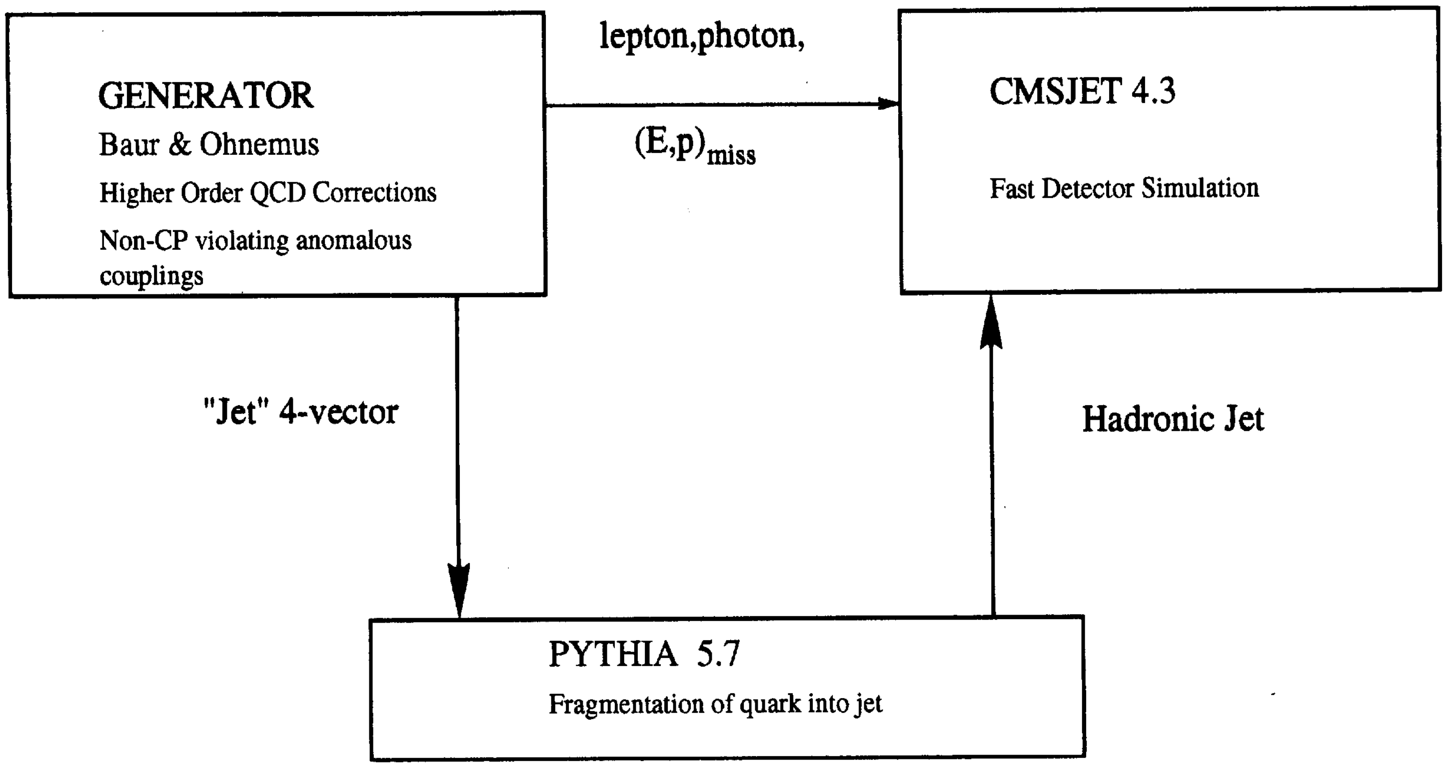
Gauge Boson Anomalous Couplings

The anomalies in the couplings may be exhibited in the $\mathrm{Pt}(\gamma)$, the $\Delta\eta(\gamma,\ell)$, the $\mathrm{M}_T(\gamma,\ell)$ and θ_W distributions.

Here we consider only the $\mathrm{Pt}(\gamma)$ and $\Delta\eta(\gamma,\ell)$.

To effectively simulate the QCD corrections at the LHC the generator of U. Baur (SUNY, Buffalo), Pythia and the fast CMS detector simulation (CMSJET) are used.

Generation and Detector Simulation



CMSJET V4.3

- Fast MC simulation of CMS detector
- UA2 type jet finder used here
- Calorimeter model
  - ECAL $\sigma/E = 5\%/\sqrt{E} \oplus 0.5\%$
  - HCAL $\sigma/E = 82\%/\sqrt{E} \oplus 6.5\%$ with degraded resolution at barrel-endcap crack

CMSJET 4.3 written by Abdullin, Khanov and Stepanov, ITEP Moscow

$pp \to W + \gamma$

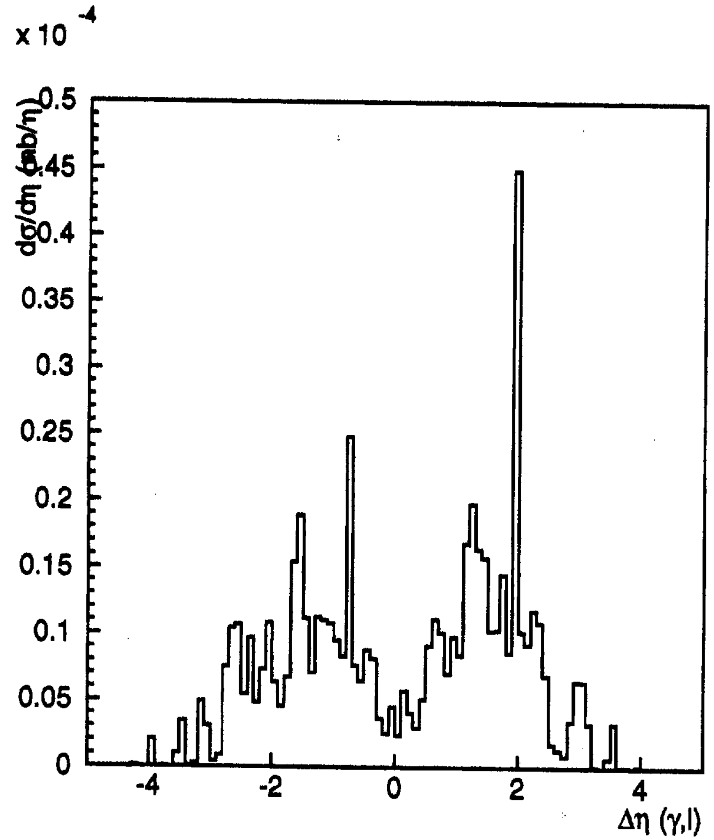
Event Signature

- Isolated high-p_T photon
- Single energetic lepton and missing p_T (W decays)
- Large transverse masses
- Approximately back-to-back topology

W+γ Signal

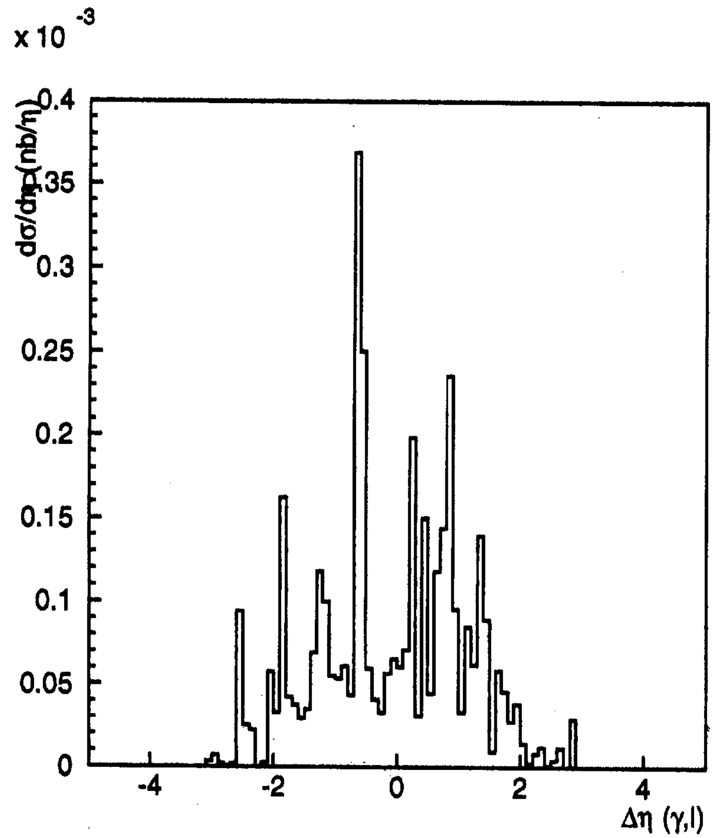
2$\rightarrow$ 3 Process

PARTON LEVEL



W+γ Signal

2$\to$ 4 Process with jet veto

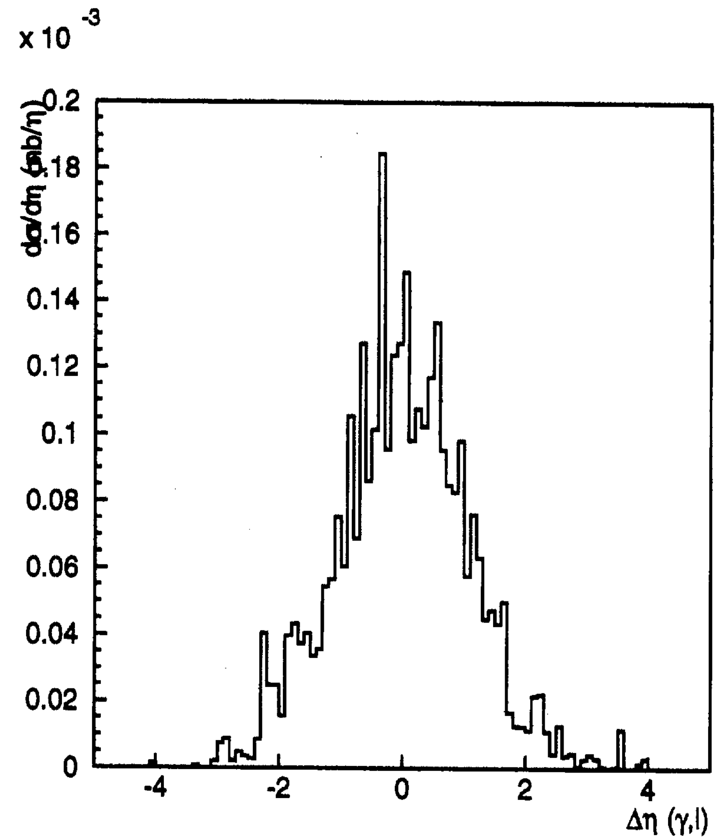


PARTON LEVEL

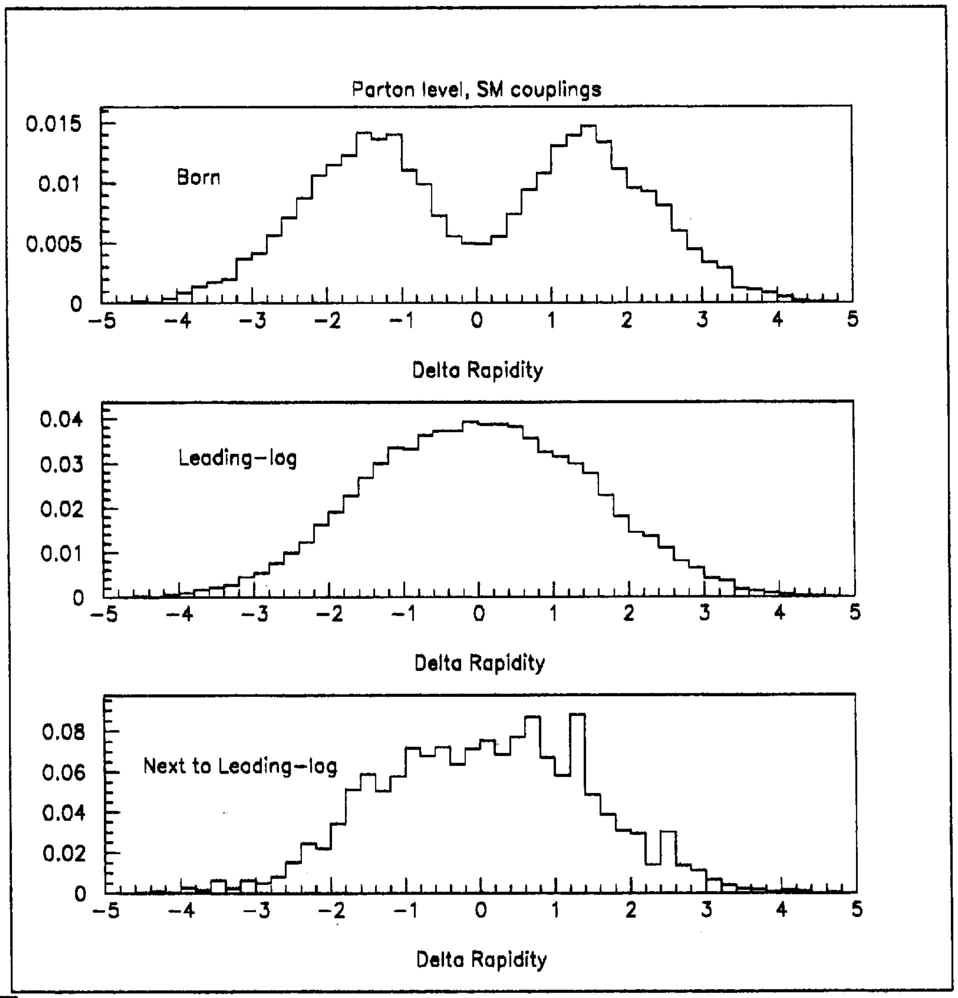
W+γ Signal

PARTON LEVEL

Bremsstrahlung



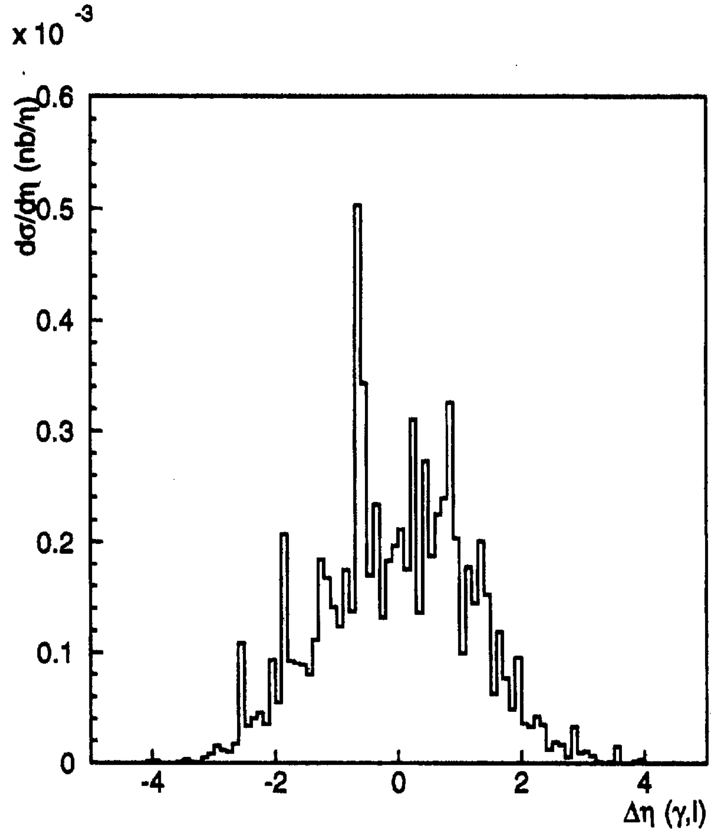
Radiation Zero Higher Order Corrections



W+γ Signal

$\Delta\eta(\gamma, l)$ with jet isolation

PARTON LEVEL



$\mathbf{pp} \to \mathbf{W}\gamma$

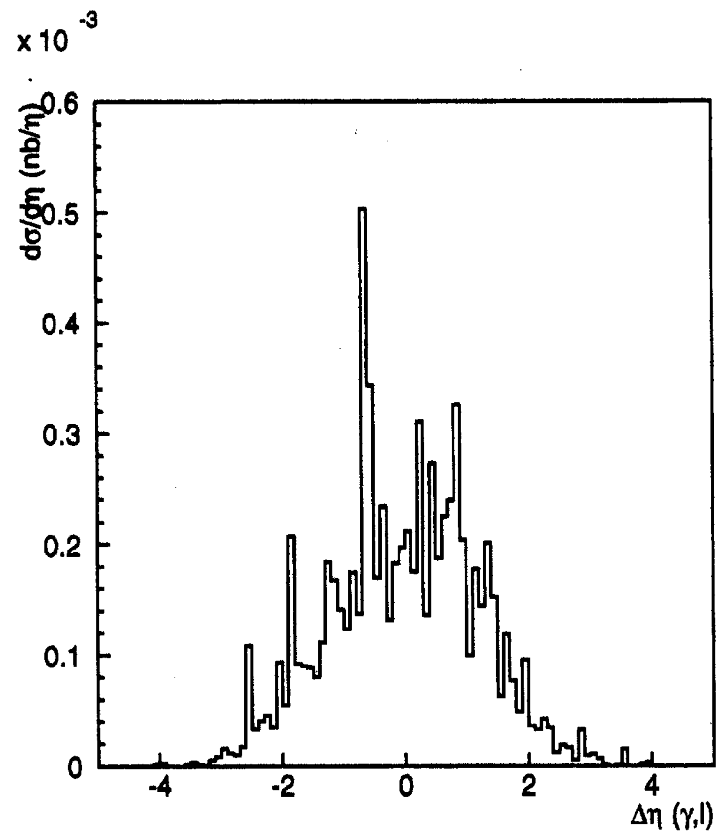
Event Selection

- $p_T(\gamma) > 100 GeV$
- $\eta_{(\gamma)} < 2.5$
- $p_T(l) > 25 GeV$
- $\eta_{(l)} < 2.5$
- Jet Veto
- $\eta_{(jets)} < 2.6$
- $p_{T missing} > 50 GeV$
- $\Delta R(\gamma, l) > 0.7$
- $M_T(l\gamma, p_{T missing}) > 90 GeV$

W+γ Signal

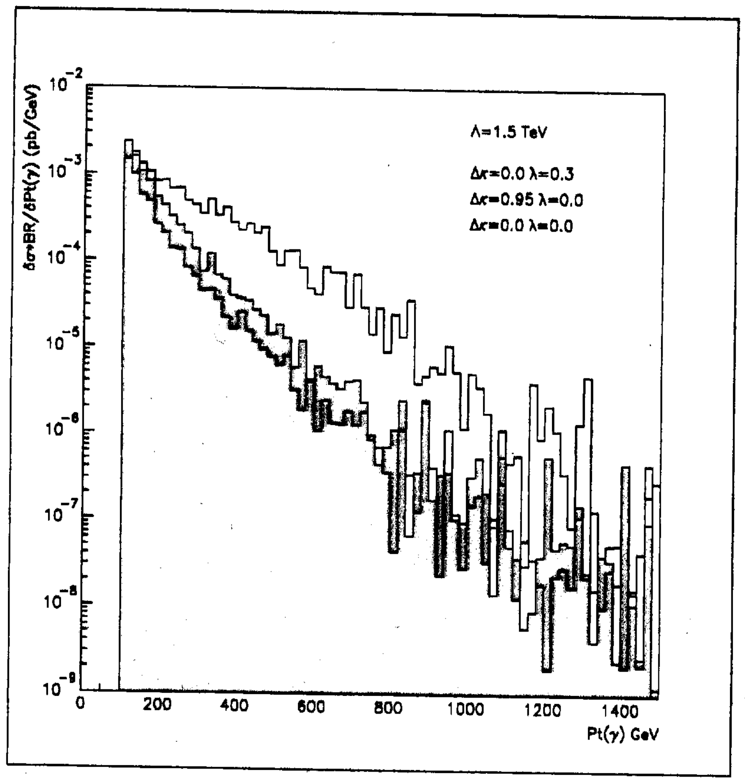
$\Delta\eta(\gamma, l)$ with jet isolation

PARTON LEVEL



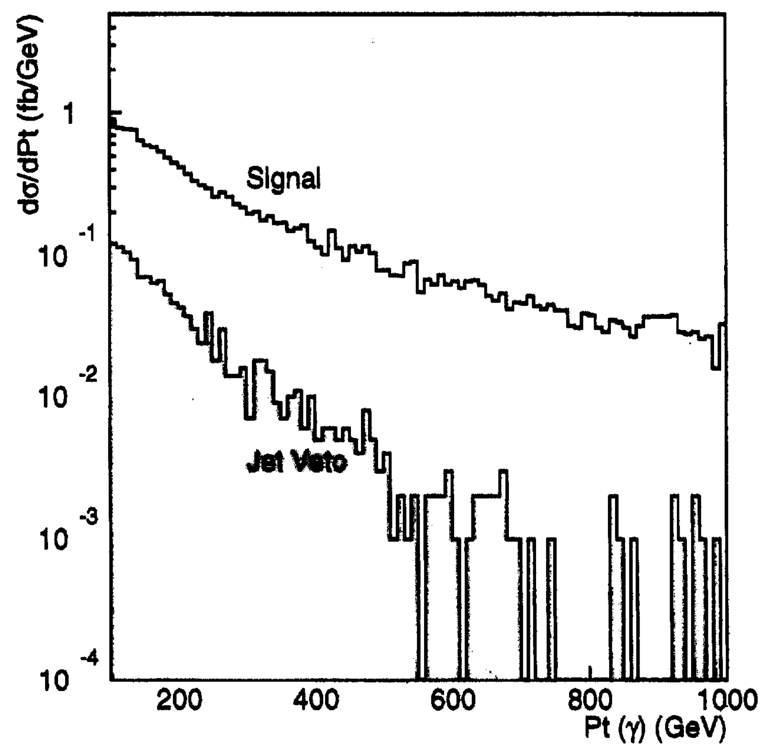
W+γ Signal

Pt(γ) Distribution
$\mathcal{L}$=50pb^{-1}



$pp \to W+\gamma$

$Pt(\gamma)$ Distribution with and without a jet veto



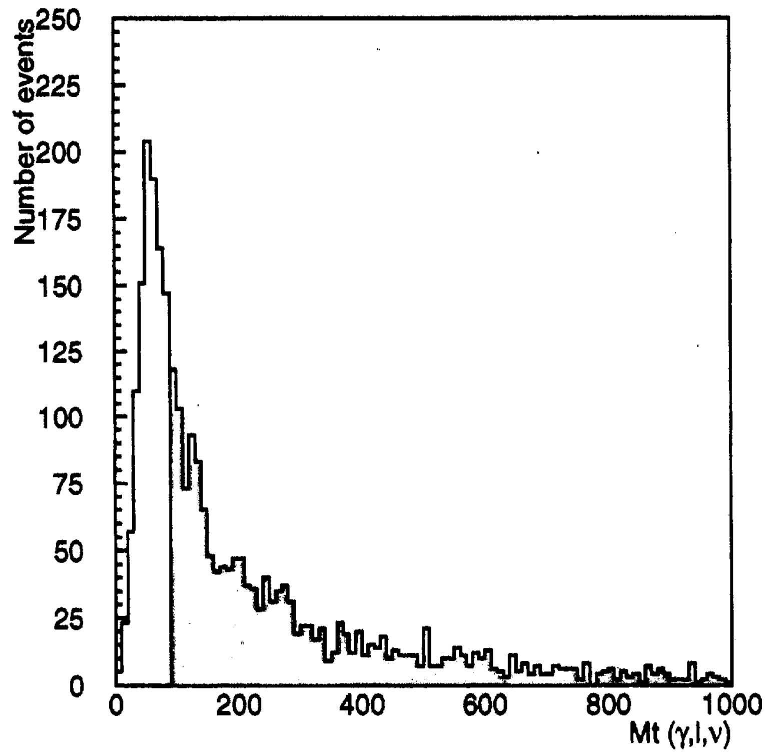
Backgrounds

Main Sources of Background

- Radiative W decays
- W+jet - with jet misidentified as an isolated photon
- Quark-gluon fusion
- Large top quark production cross-section
- $b\bar{b}$ semi-leptonic decay misidentification
- $Z\gamma$ (for muon decay)

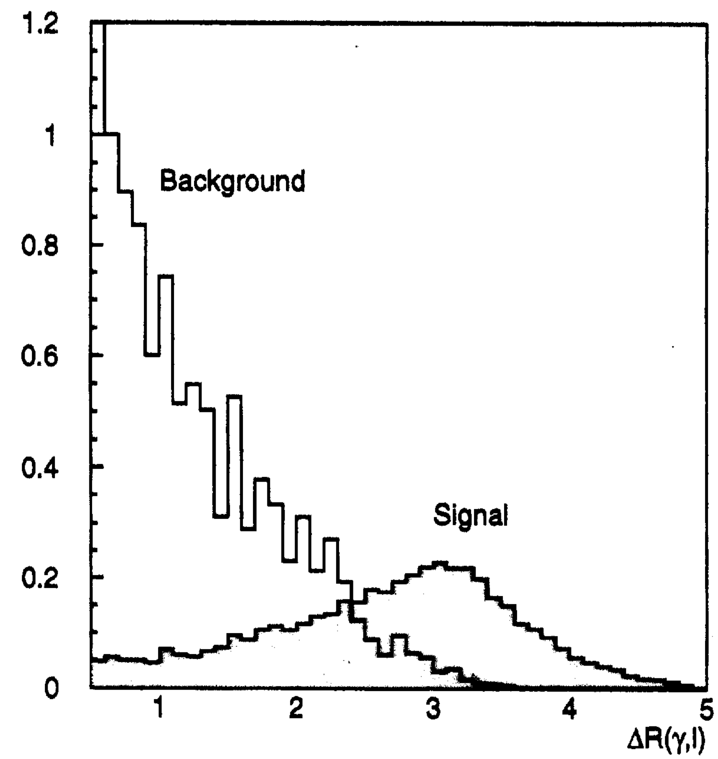
Radiative W Decays

$M_T(\gamma, \ell, \nu)$ Distribution



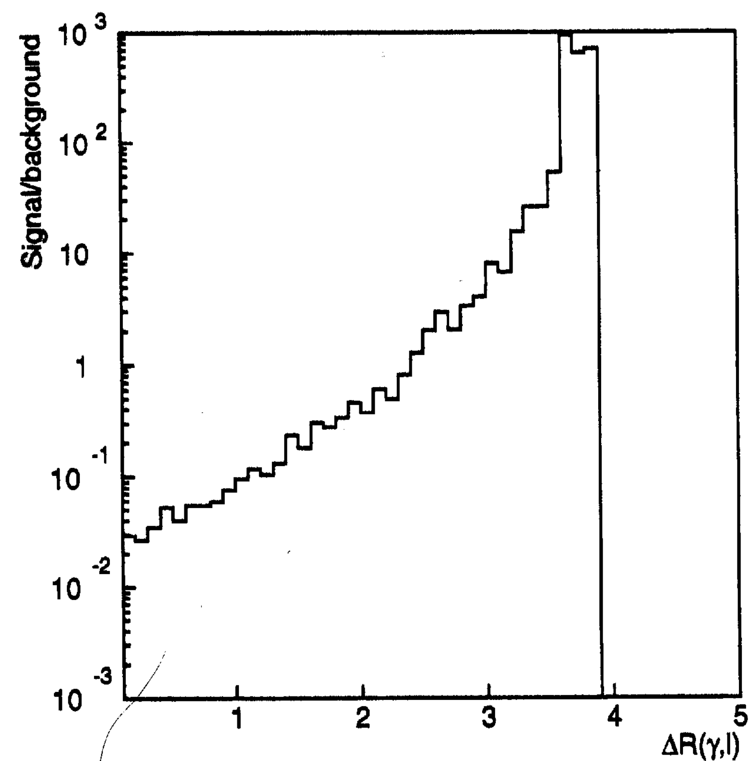
Radiative W Decays

$\Delta R(\gamma, \ell)$ Distribution

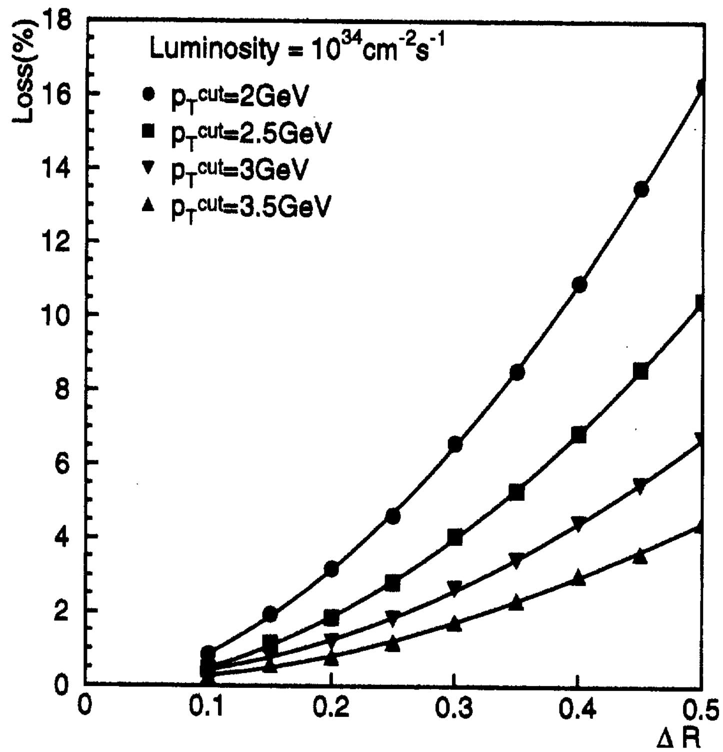


Radiative W Decays

$\Delta R(\gamma, \ell)$ Distribution

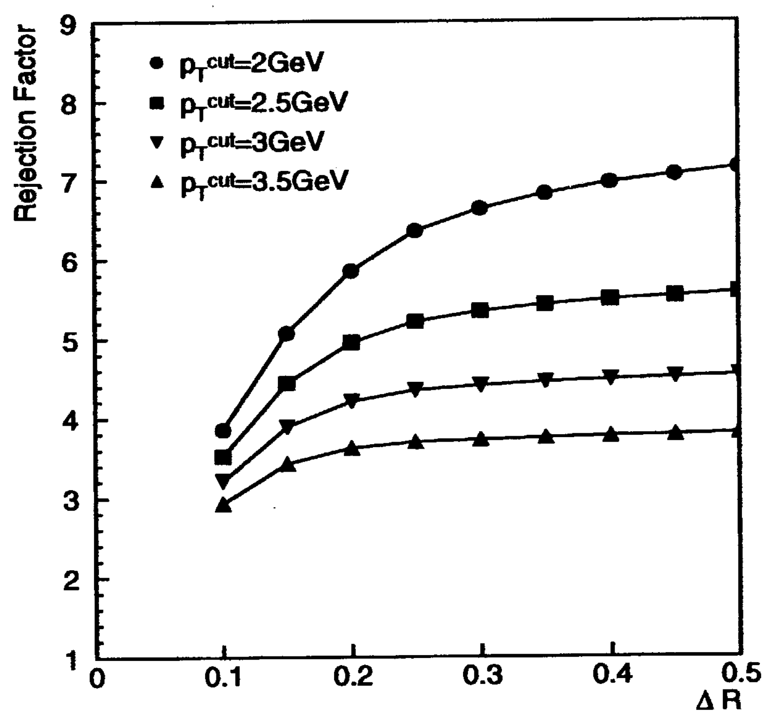


Loss Due To Pile-up



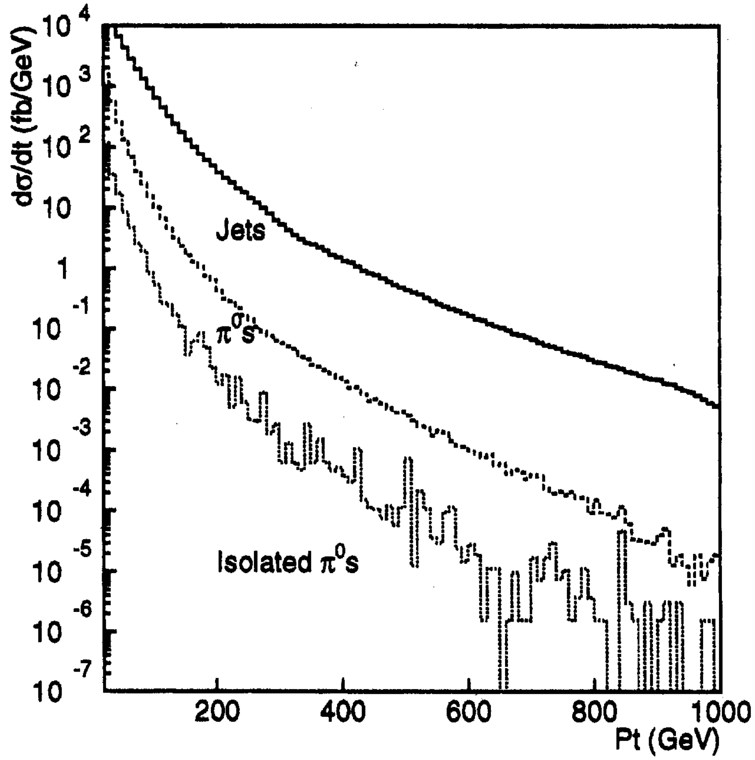
Photon Isolation

$$\Delta R = (\Delta\eta^2 + \Delta\phi^2)^{(1/2)} \qquad (8)$$



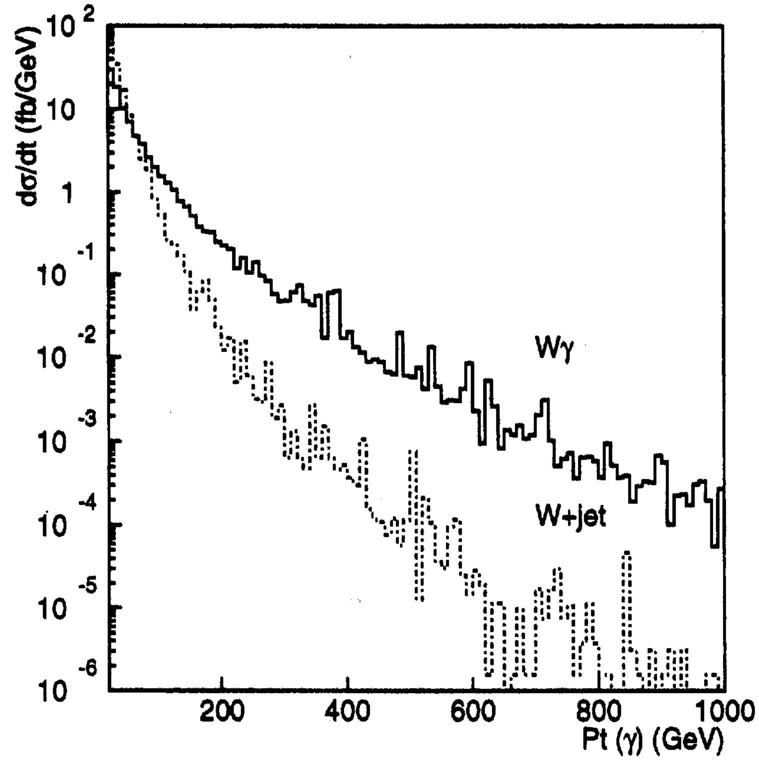
$pp \rightarrow W + Jet$

Pt Distribution



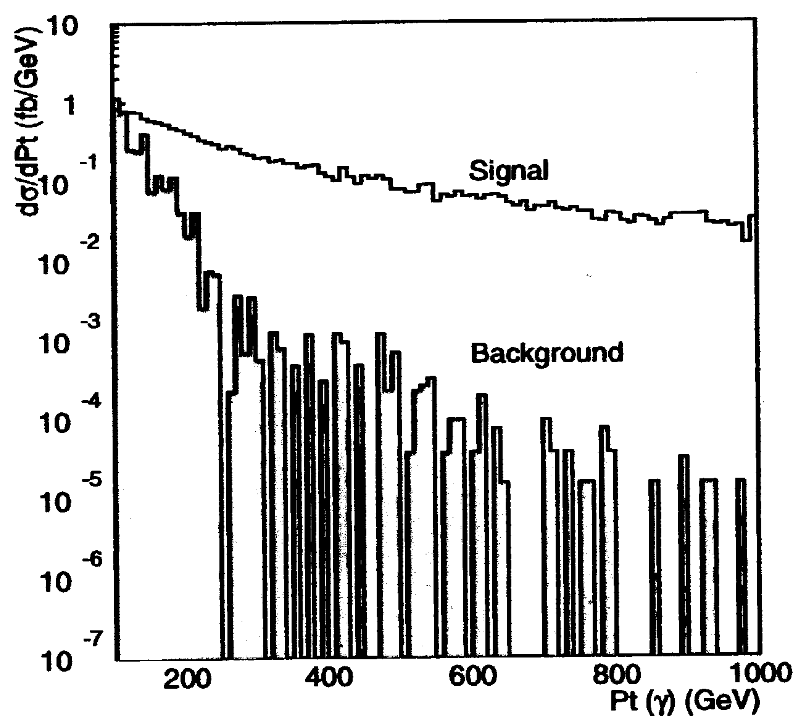
$pp \to W + Jet$

$Pt(\gamma)$ Distribution



pp → W+γ

Pt(γ) Distribution
Background = W+jet and Radiative W



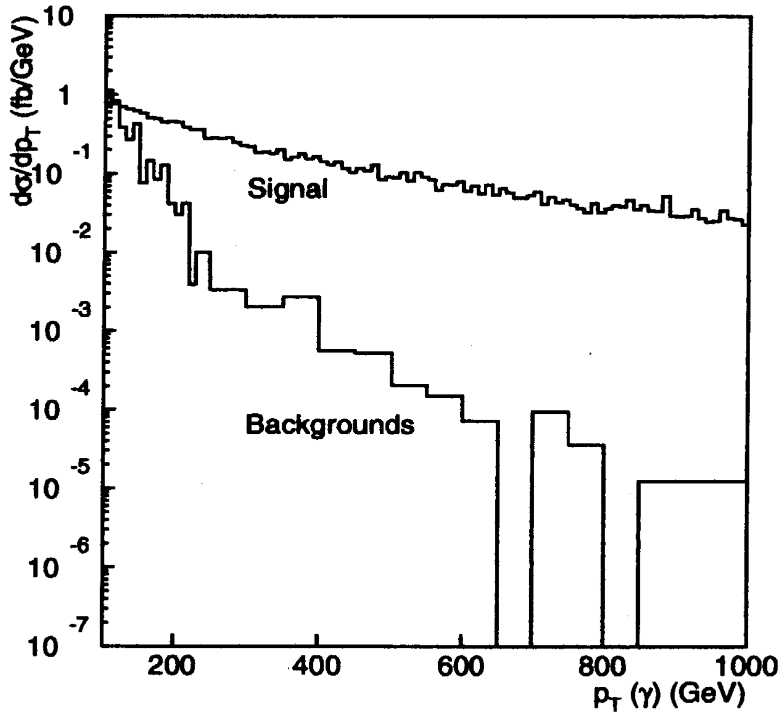
Efficiency Of Cuts

% of events remaining after each cut individually

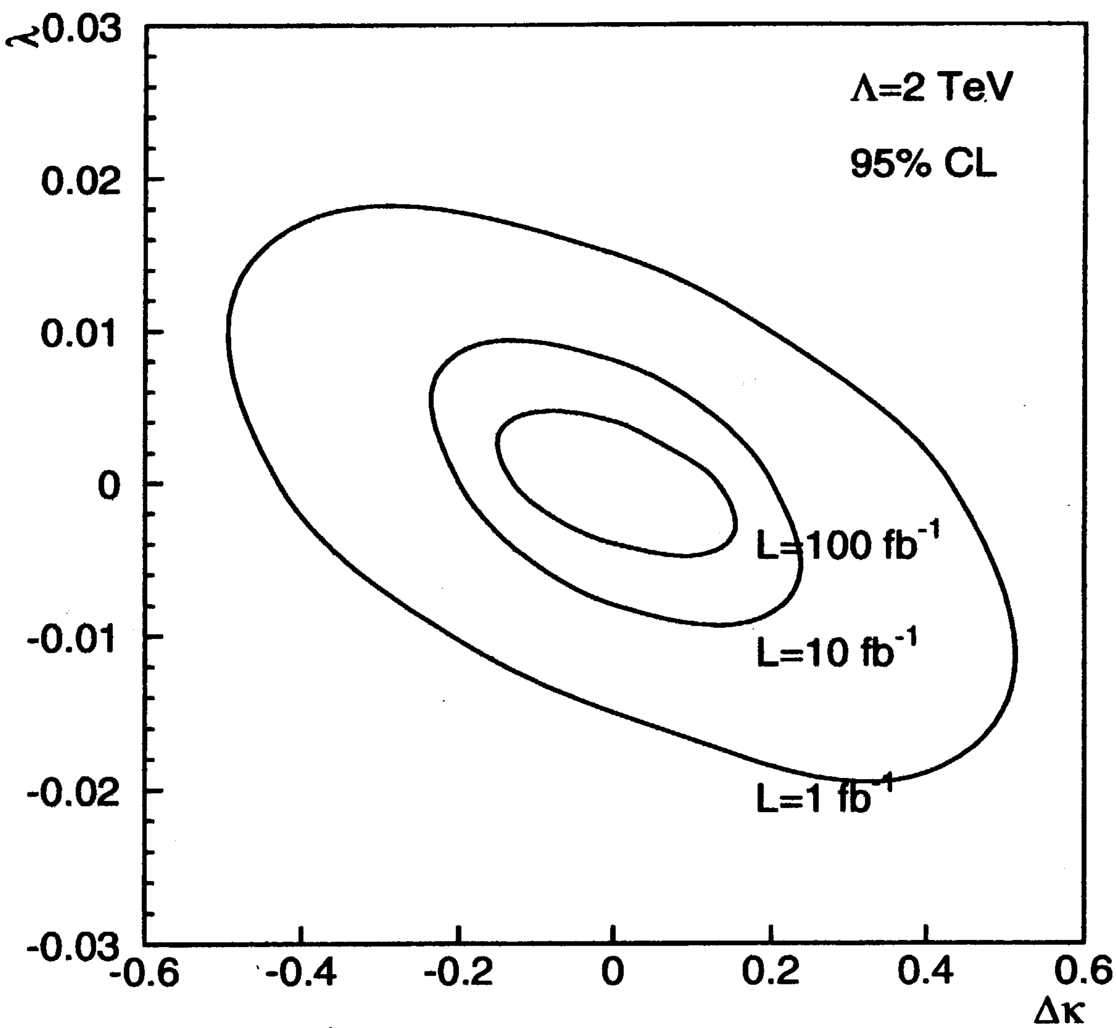
Cut	Signal %	Background %		
		W+jet	$t\bar{t}\gamma$	$b\bar{b}\gamma$
$P_t(\gamma)$	67±0.49	0.06±0.008	72±5.33	84±0.22
$P_t(\ell)$	84±0.52	62±0.25	5±1.02	0.2±0.001
$M_T(\gamma,\ell,\nu)$	85±0.52	19±0.14	87±4.2	0.3±0.0115
$\Delta R(\gamma,\ell)$	95±0.55	94±0.3	95±4.4	94±0.23
$P_t(\nu)$	86±0.53	60±0.25	43±2.9	28±0.124
2nd jet	89±0.54	42±0.2	0+0.2	34±0.14
All Cuts	55±0.42	0.33±0.018	0+0.2	0.006±0.0019

$pp \rightarrow W+\gamma$

$p_T(\gamma)$ Distribution



Sensitivity To $\Delta\kappa$ and λ



Using the DØ binned $p_T(\delta)$ fit
(G. Landsberg, ANL-HEP-CP-93-92 (1992) p303)

Axis and Unitarity Limits

Luminosity (fb^{-1})	95% C.L.		68% C.L.	
	$\Delta\kappa$	λ	$\Delta\kappa$	λ
1	$\pm$ .43	$\pm$ 0.015	$\pm$ 0.15	$\pm$ 0.0045
10	$\pm$ 0.22	$\pm$ 0.008	$\pm$ 0.06	$\pm$ 0.002
100	$\pm$ 0.13	$\pm$ 0.004	$\pm$ 0.03	$\pm$ 0.001

Unitarity	$\mid \Delta\kappa \mid$	1.85	$\mid \lambda \mid$	1.0

Conclusion

At CMS the anomalous couplings of the $W\gamma$ channel can be effectively measured using the $Pt(\gamma)$ distribution. The $\Delta\eta$ distribution is not so effective at the LHC because of the large QCD corrections.

Using a variety of cuts on the photon, lepton and missing energy the backgrounds can be effectively reduced so as to enable the couplings to be measured.

Studies are presently being made on the limits of the anomalous couplings at CMS.

- Better detector simulation
- Look for optimal combination of observables
- Check assumptions
- $t\bar{t}\gamma$ generator!
- Understand fitting systematic error

JUST A START – LOTS TO DO!

CMS Detector

We used the DØ binned p_T (6) fit
(G. Landsberg ANL-HEP-CP-93-92 (1992) p 303)
Different grid from previous plot!

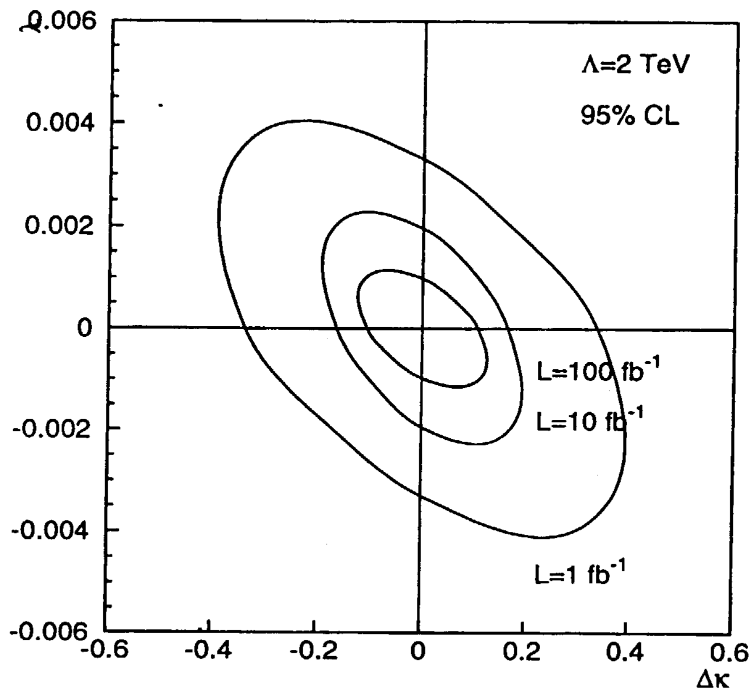


Figure 33: The 95% confidence level limits on the anomalous couplings $\Delta\kappa$ and λ for integrated luminosities of 1, 10 and 100 fb^{-1}

AXIS LIMITS (95% CL)

$\mathcal{L}$ = 10 fb^{-1} $\quad -0.34 < \Delta\kappa < 0.34$
$\quad -0.034 < \lambda < 0.034$

= 100 fb^{-1} $\quad -0.10 < \Delta\kappa < 0.10$
$\quad -0.0009 < \lambda < 0.0009$

MUST IMPROVE/UNDERSTAND THE INTERPOLATION SYSTEMATICS.

$Z\gamma$

$\frac{d\sigma}{dp_T(\gamma)}$ (Current L3 & DØ limits shown)

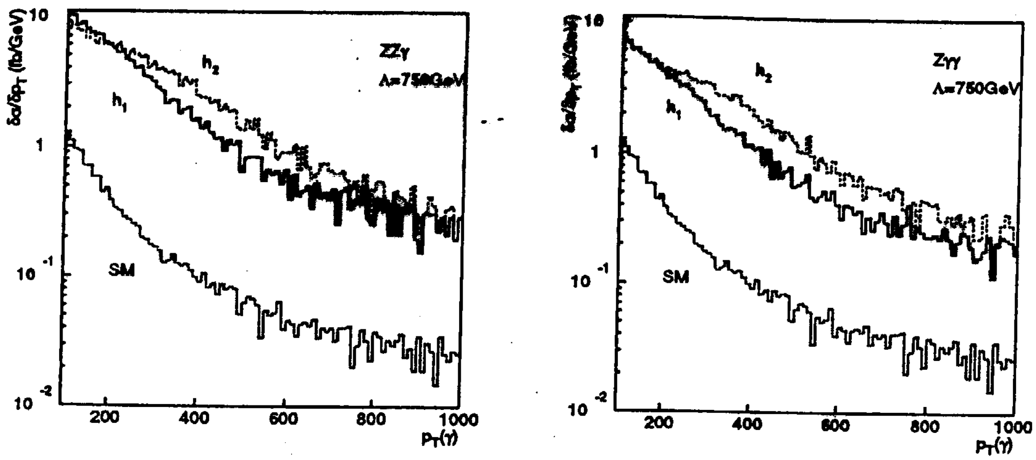


Figure 7: $d\sigma/dp_T(\gamma)$ spectrum for the SM and anomalous CP-violating coupling limits at $\Lambda = 750$ GeV for (left) the $ZZ\gamma$ vertex and (right) the $Z\gamma\gamma$ vertex

$p_T(\gamma) > 100$ GeV, $p_T(\ell) > 15$ GeV, $p_T(j) > 10$ GeV

$\Delta R_{\ell\gamma} > 0.7$, $M_{\ell\ell} > 10$ GeV

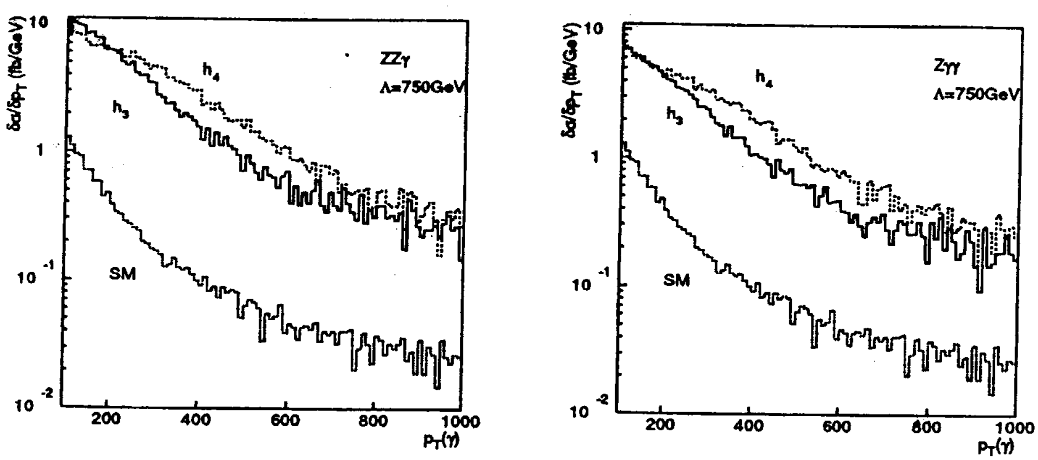


Figure 8: $d\sigma/dp_T(\gamma)$ spectrum for the SM and anomalous CP-conserving coupling limits at $\Lambda = 750$ GeV for (left) the $ZZ\gamma$ vertex and (right) the $Z\gamma\gamma$ vertex

Uses BAUR* generator + CMSJET + PYTHIA for jet

* Baur, Han, Ohnemus, PRD 57 (1998) 2823

Zγ

$\frac{d\sigma}{dM(\ell,\ell\gamma)}$

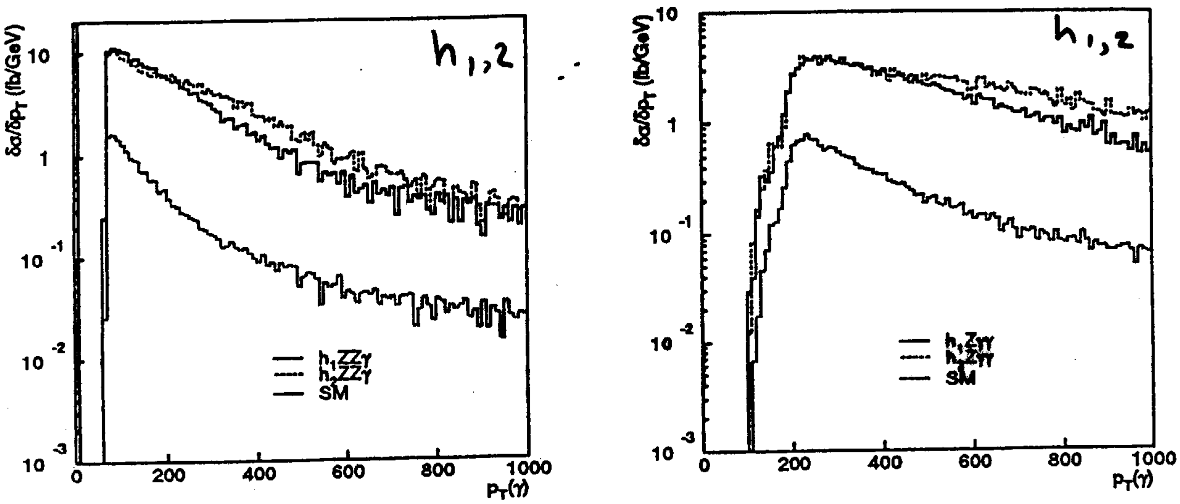


Figure 9: $d\sigma/dM(\ell\ell\gamma)$ spectrum for the SM and anomalous CP-violating coupling limits at $\Lambda = 750$ GeV for (left) the $ZZ\gamma$ vertex and (right) the $Z\gamma\gamma$ vertex

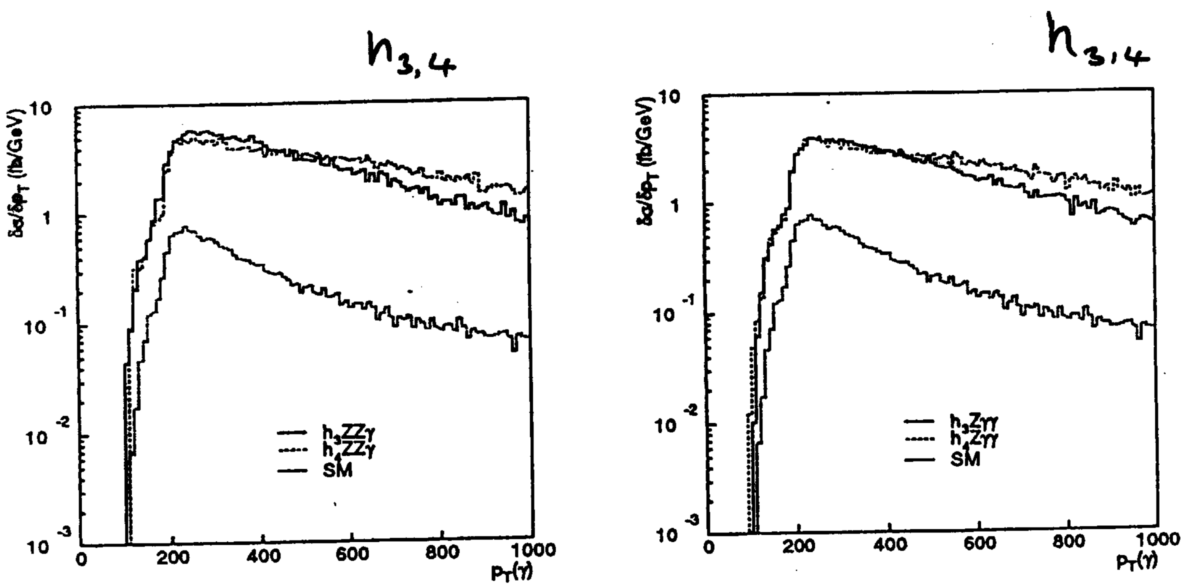


Figure 10: $d\sigma/dpM(\ell\ell\gamma)$ spectrum for the SM and anomalous CP-conserving coupling limits at $\Lambda = 750$ GeV for (left) the $ZZ\gamma$ vertex and (right) the $Z\gamma\gamma$ vertex

Zγ

Δη(γ, ℓ) distributions

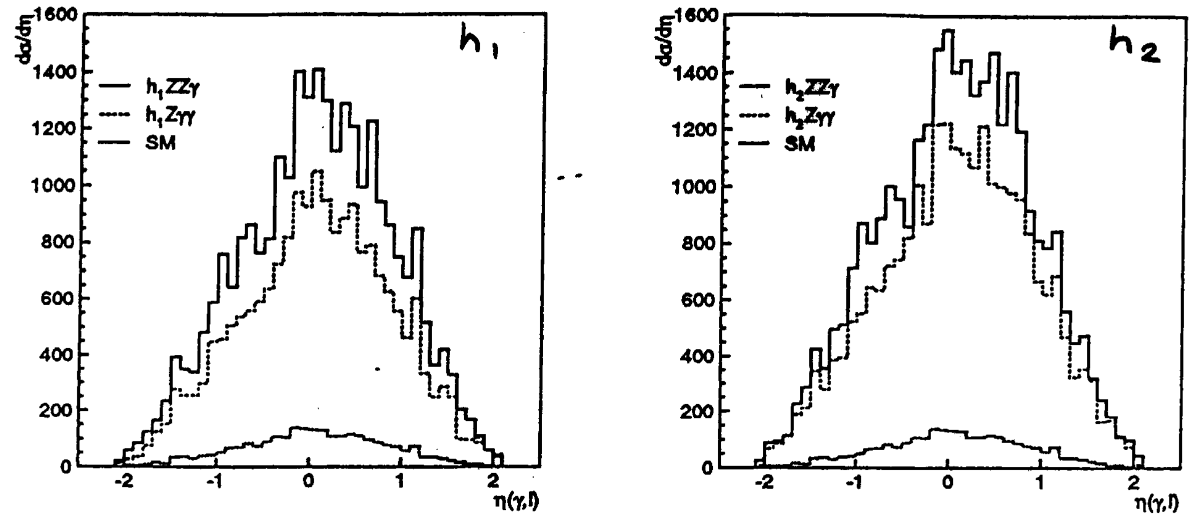


Figure 18: $\Delta\eta(\gamma,\ell)$ distributions for SM and anomalous h_1^V couplings (left) and h_2^V couplings (right)

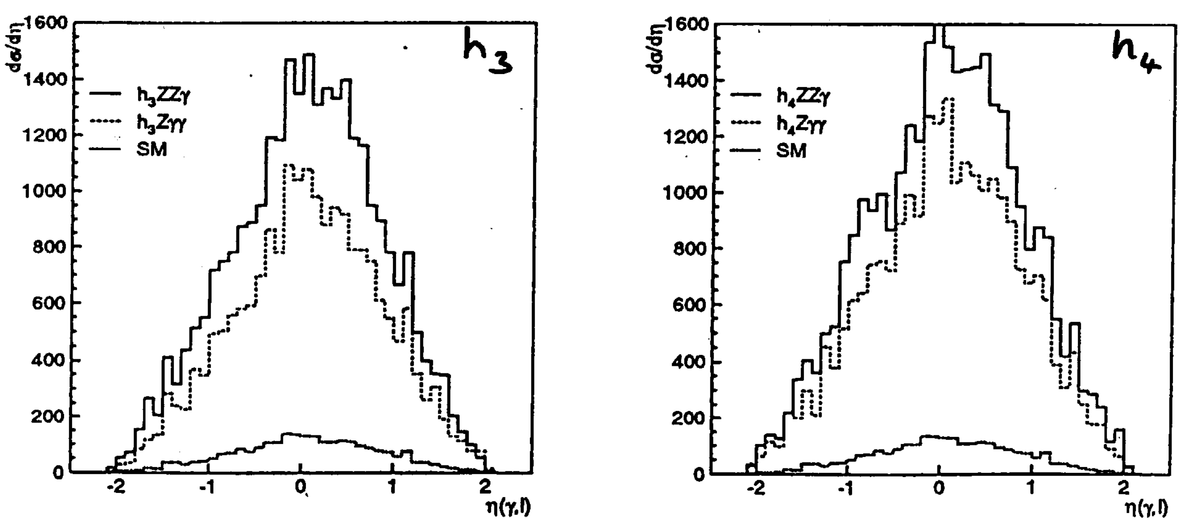


Figure 19: $\Delta\eta(\gamma,\ell)$ distributions for SM and anomalous h_1^V couplings (left) and h_2^V couplings (right)