A Study of Anomalous Triple Gauge Couplings in $Z\gamma \rightarrow ll\gamma$ Decays

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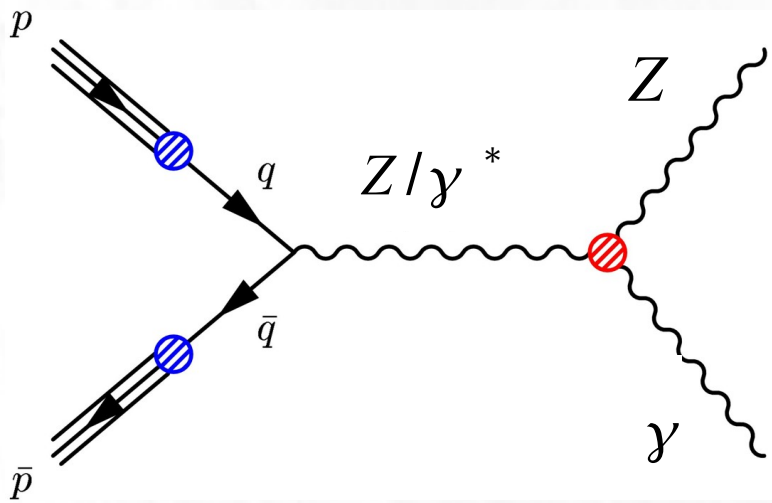
On behalf of the CDF collaboration

What We're Studying



- In the Standard Model, couplings between neutral gauge bosons is nonexistent at tree level

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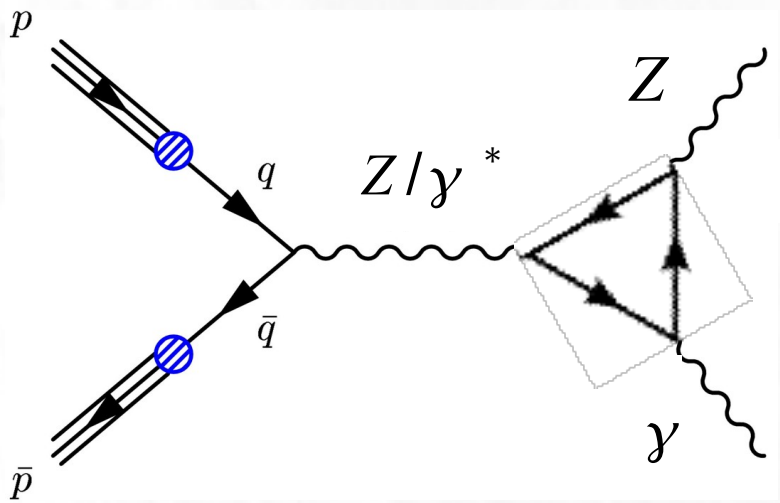
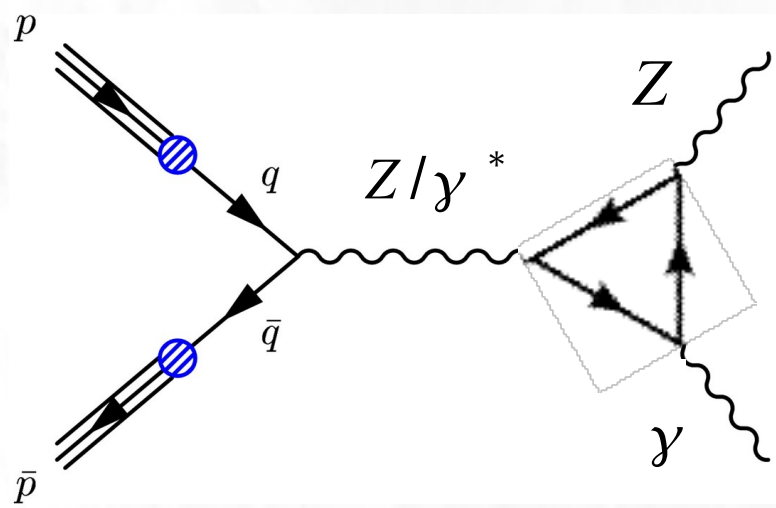


- In the Standard Model, couplings between neutral gauge bosons is nonexistent at tree level
- New physics processes can enhance this coupling at loop level!
  - Especially for high photon E_T

What We're Studying

$$Z\gamma\gamma \rightarrow h_{\gamma}^{3}, h_{\gamma}^{4}$$

$$ZZ\gamma \rightarrow h_{Z}^{3}, h_{Z}^{4}$$



Z Magnetic Quadrupole Moment

$$Q_Z^m = \frac{2\sqrt{10}e}{m_Z^2} h_3^Z$$

Z Electric Dipole Moment

$$d_Z = \frac{-e}{\sqrt{2}m_Z} \frac{E_\gamma^2}{m_Z^2} (h_3^Z - h_4^Z)$$

- In the Standard Model, couplings between neutral gauge bosons is nonexistent at tree level
- New physics processes can enhance this coupling at loop level!
  - Especially for high photon E_T
- CP-conserving processes are parameterized by two values per vertex

Previous ATGC Tevatron Measurements

$$\left.\begin{array}{l} |h_3^{\gamma,Z}| < 0.033 \\ |h_4^{\gamma,Z}| < 0.0017 \end{array}\right\} \quad (D0, \Lambda = 1.5\,TeV)$$

1-3.6 /fb used

ATGC = "Anomalous Triple Gauge Coupling"

Λ → a measure of the energy scale of new physics

$$\left.\begin{array}{l} |h_3^{\gamma}| < 0.051 \\ |h_3^{Z}| < 0.050 \\ |h_4^{\gamma,Z}| < 0.0034 \end{array}\right\} \quad (CDF, \Lambda = 1.2\,TeV)$$

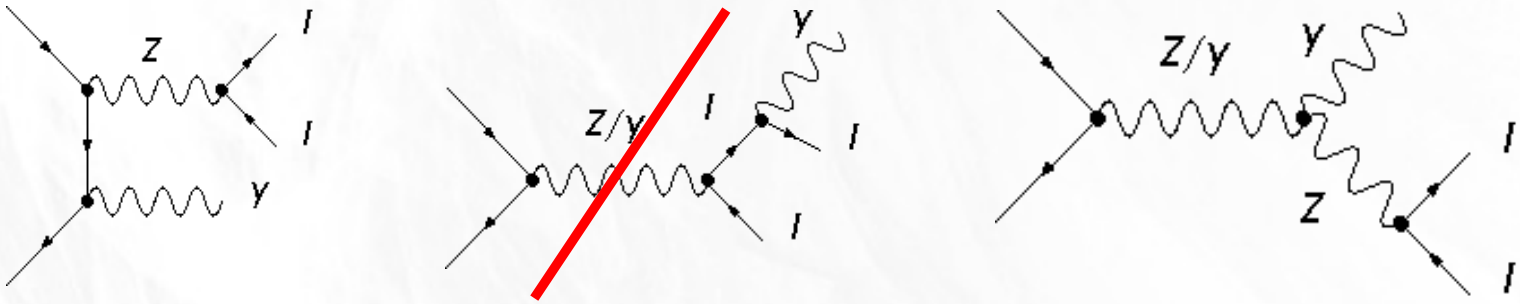
1-2 /fb used

ATGC measurements are statistically limited → good to update!

The Events

- We have 5.1 /fb of data available from the CDF experiment
- Want to select $Z\gamma$ candidate events:
  - $E_{T\gamma} > 50\,GeV$
  - Two lepton candidates with well-understood fake rates
    - $E_{T,l1} > 20\,GeV$, $E_{T,l2} > 10\,GeV$
    - $dR(l,\gamma) > 0.7$

The Events



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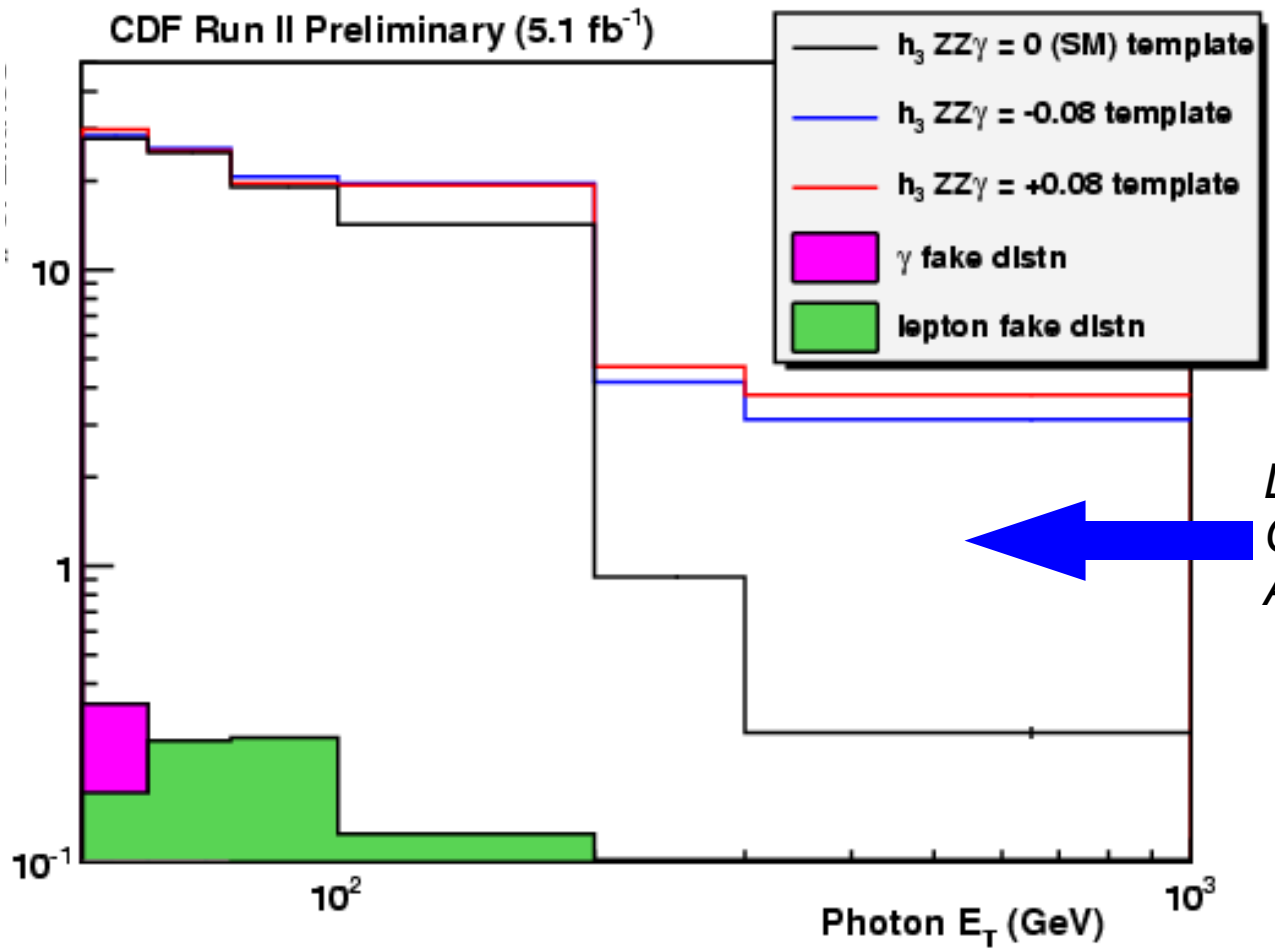
    - $dR(l,\gamma) > 0.7$
  - $M_{ll\gamma} > 100\,GeV/c^2$

Using these basic selection cuts, we have 92 candidate events to work with

The Method

EXPECT:

89 Z+photon
<<1 photon fakes
<<1 lepton fakes

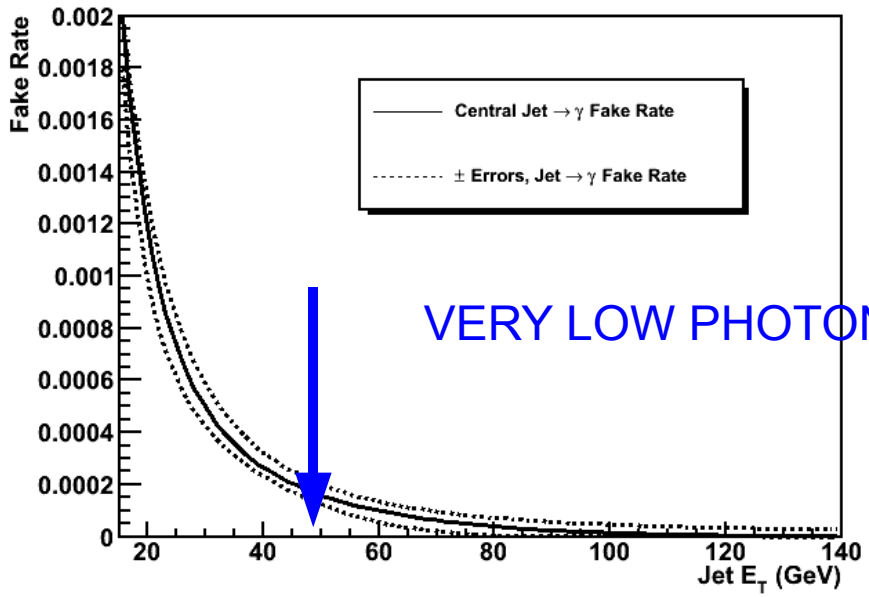


DIFFERENCE GREATEST AT HIGH ET!

- To measure the TGC parameters, will perform a binned likelihood fit to the photon Et distribution using templates which are functions of $h_3^\gamma, h_3^Z, h_4^\gamma, h_4^Z$

Three Types of Event

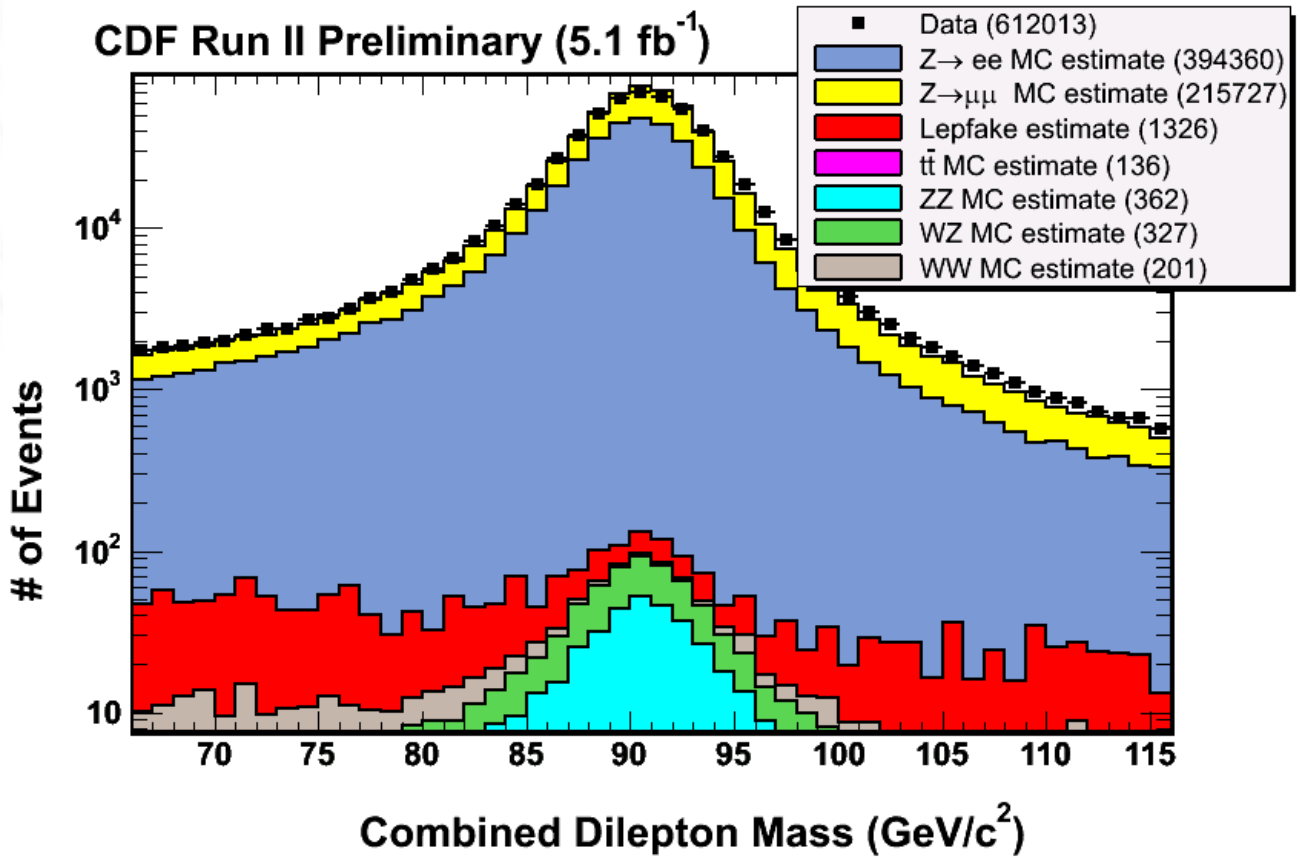
- True Z+photon
  - Model with MC, using theory cross section
- True Z, jet “fakes” a photon
  - Negligible background (<< 1) given our photon Et cut
  - Apply a parameterized fake rate to jets in Z candidate events
- True photon, jet “fakes” a lepton
  - Also negligible; similar technique to jet faking a gamma



VERY LOW PHOTON FAKE RATE GIVEN OUR CUT

Calculating the Scale Factors

- In general, can't expect the selection cut efficiency in data to be the same as in MC → adjust by a scale factor, “SF”
- For the dilepton candidate pairs, take advantage of
  - Well known Z cross section
  - Very low background

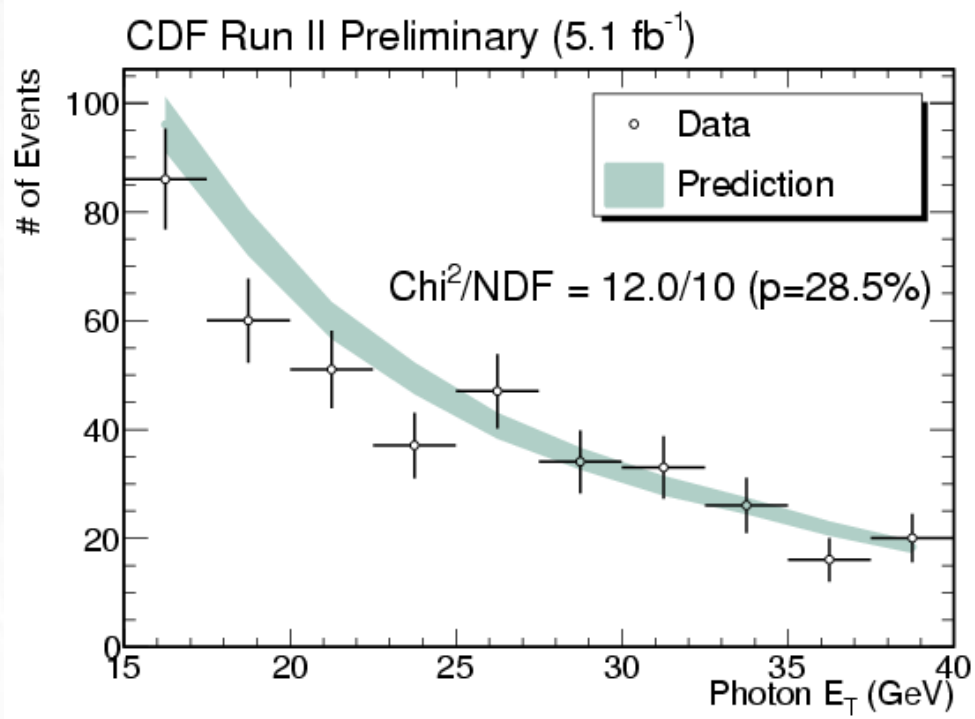


Verification

GOOD AGREEMENT SEEN

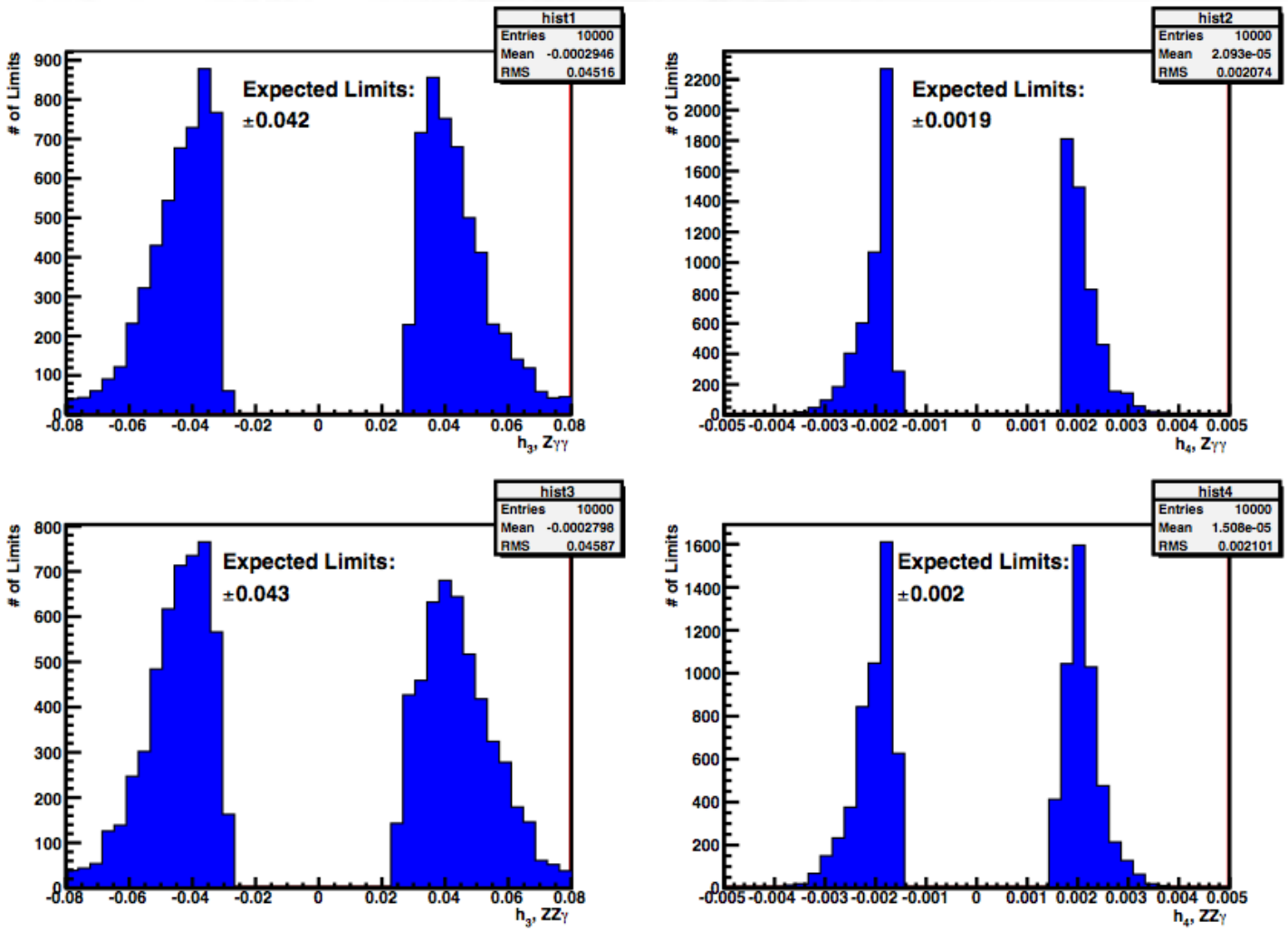
↓

CONFIDENT IN OUR TEMPLATES AND OUR PSEUDOEXPERIMENTS



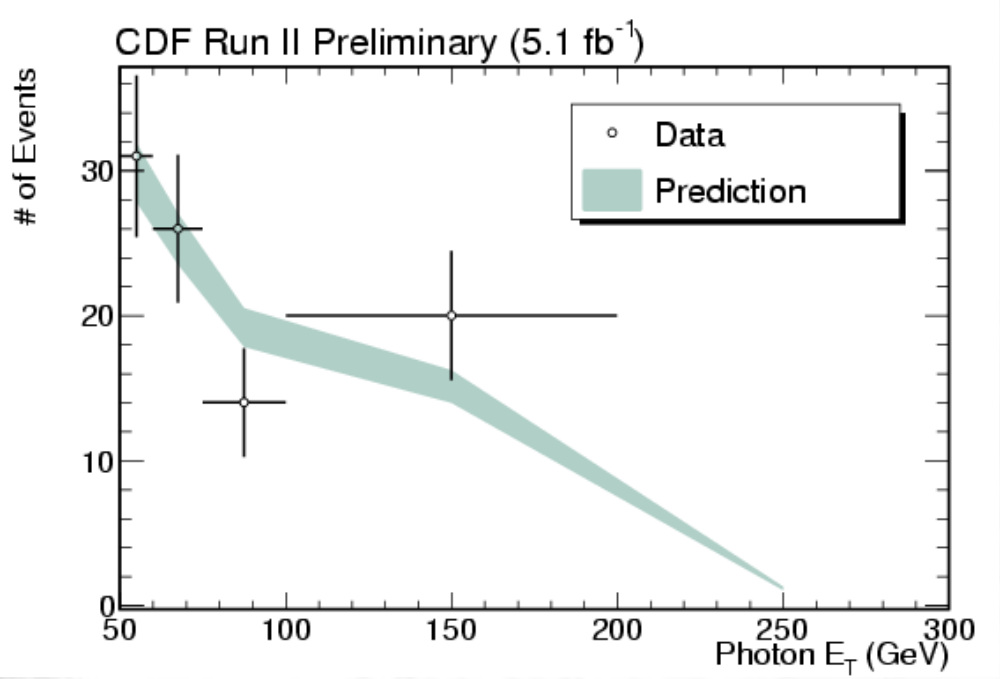
- Prediction band
  - Built in the same manner as our templates
    - Z+photon MC, lepton fake estimate, photon fake estimate
  - Incorporates all systematic uncertainties on the distribution: on scale factors, Z+photon theory cross section, and fake rates

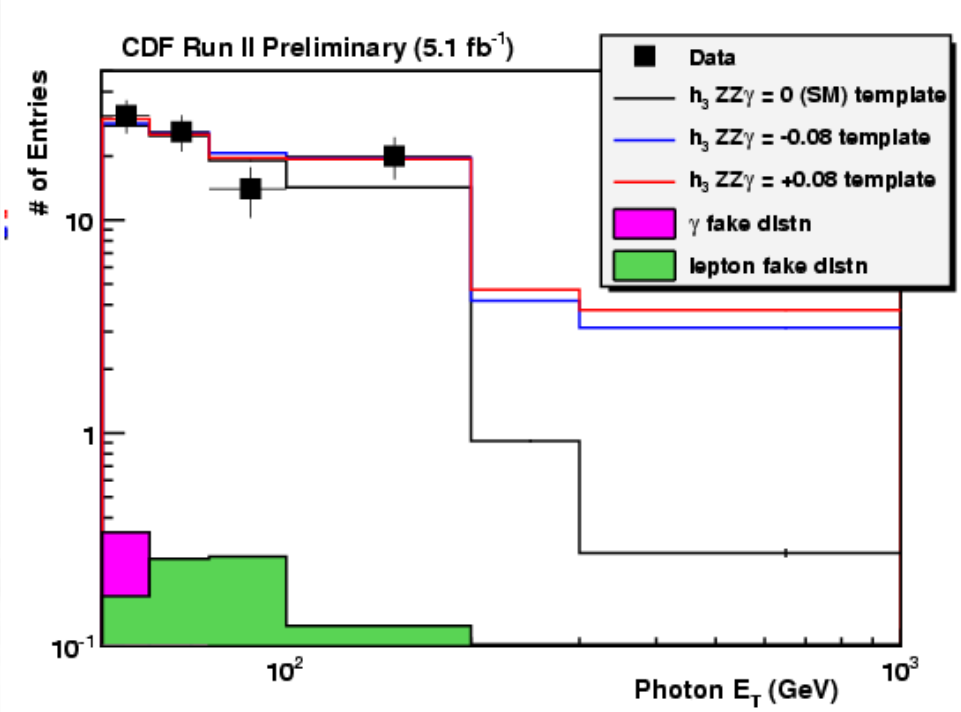
Expected Limits



- Given a likelihood as a function of one ATGC parameter, take the central 95% coverage about the peak to establish +/- limits

The Measurement (I)

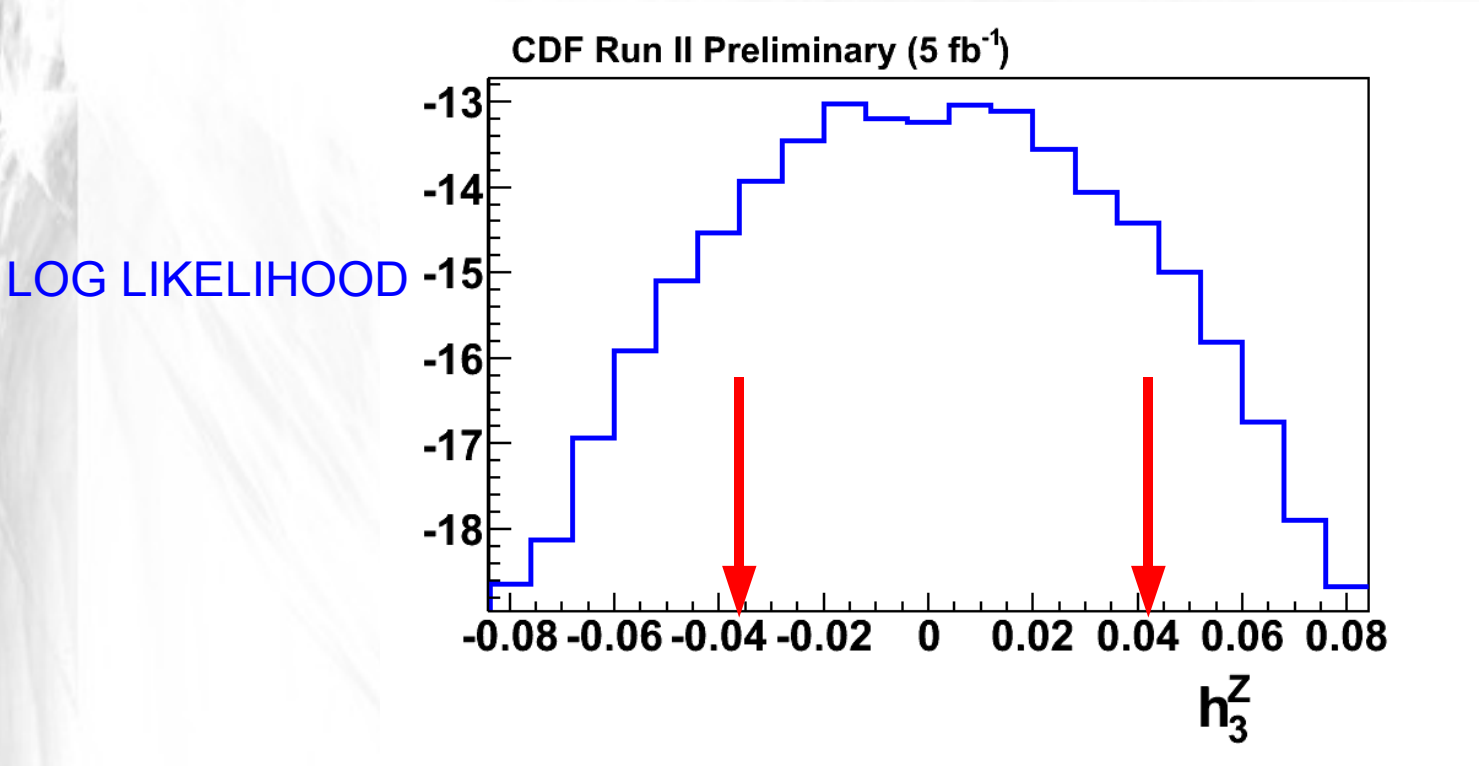




- The photon Et distribution in data...

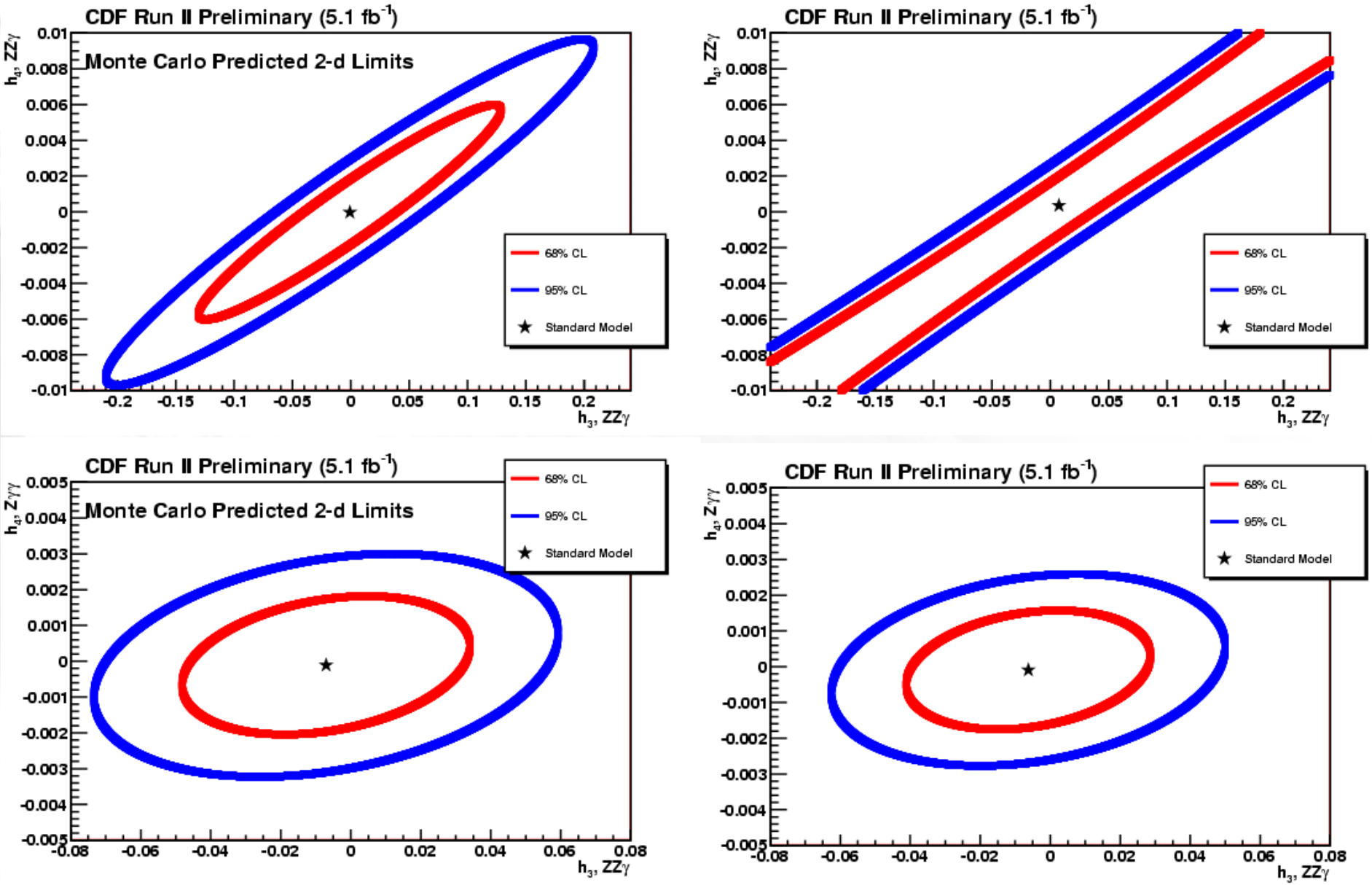
The Measurement (II)

- ...and the corresponding measurements



Parameter	Expected Limit (Symm.)	Measured Limits
h_3^Z	0.043 +0.013 -0.009	[-0.038 , 0.040]
h_3^γ	0.042 +0.012 -0.008	[-0.037 , 0.038]
h_4^Z	0.0020 +0.0005 -0.0003	[-0.0017, 0.0017]
h_4^γ	0.0019 +0.0005 -0.0002	[-0.0017 , 0.0017]

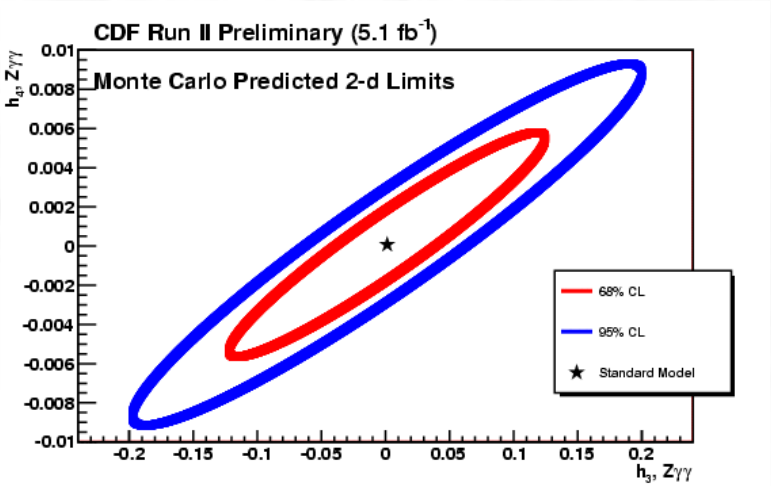
Predicted vs. Data

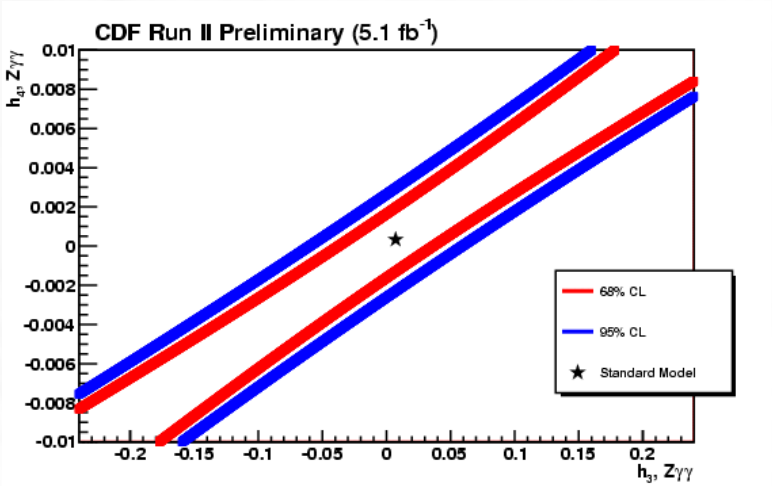


Conclusions

- With 5.1 /fb, CDF has seen significant improvement on its neutral ATGC limits
  - No sign of ATGC's, however!
- Plan is to add in information from the $Z\gamma \rightarrow \nu\nu\gamma$ channel
  - Statistically limited: “The more data, the merrier”

BACKUPS


CDF Run II Preliminary (5.1 fb^{-1})
Monte Carlo Predicted 2-d Limits
h_4, $Z\gamma\gamma$
h_3, $Z\gamma\gamma$
68% CL
95% CL
Standard Model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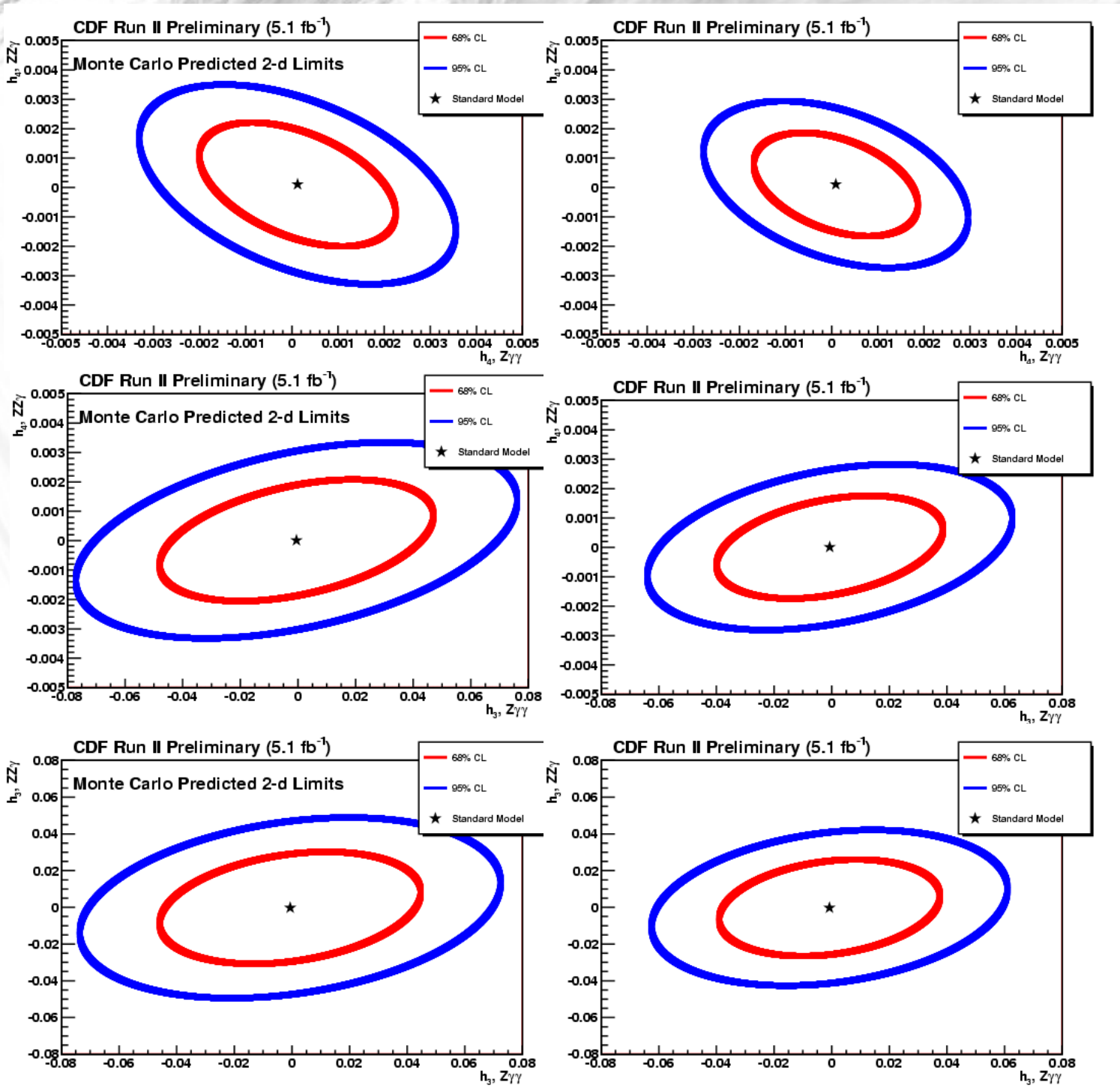
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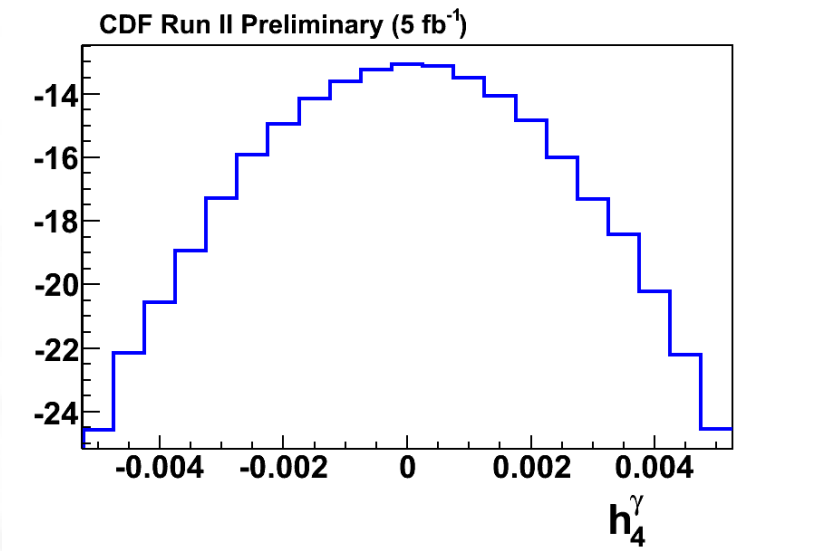
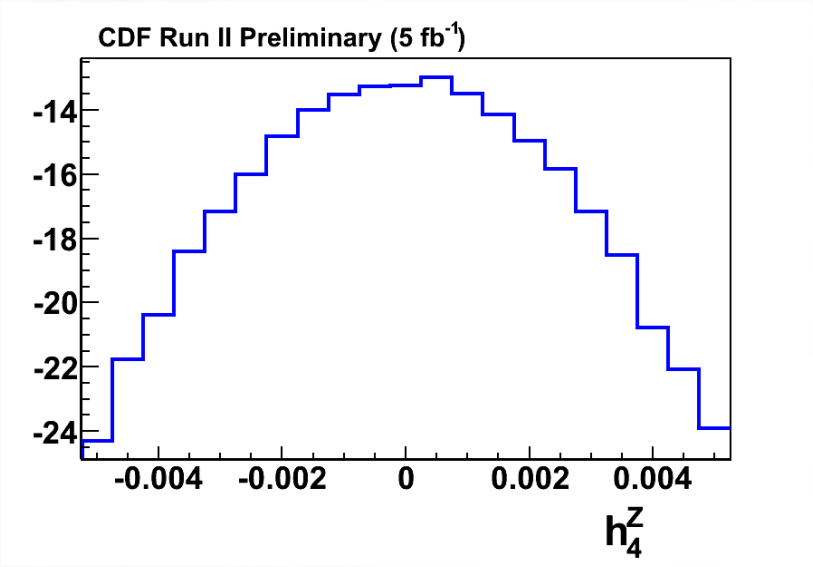

CDF Run II Preliminary (5 fb^{-1})
-14
-16
-18
-20
-22
-24
-0.004
-0.002
0
0.002
0.004
h_4^γ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-16
-18
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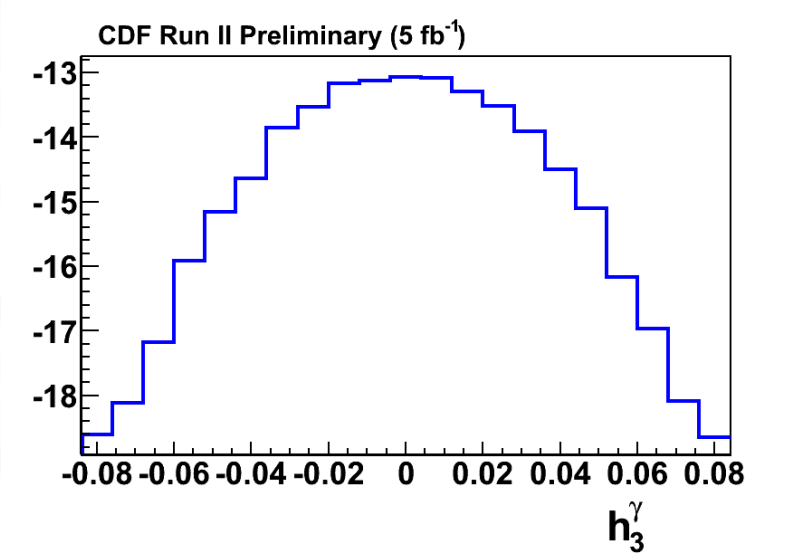
-24
-0.004
-0.002
0
0.002
0.004
h_4^Z


CDF Run II Preliminary (5 fb^{-1})
-13
-14
-15
-16
-17
-18
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
h_3^γ