Electroweak Physics at CDF

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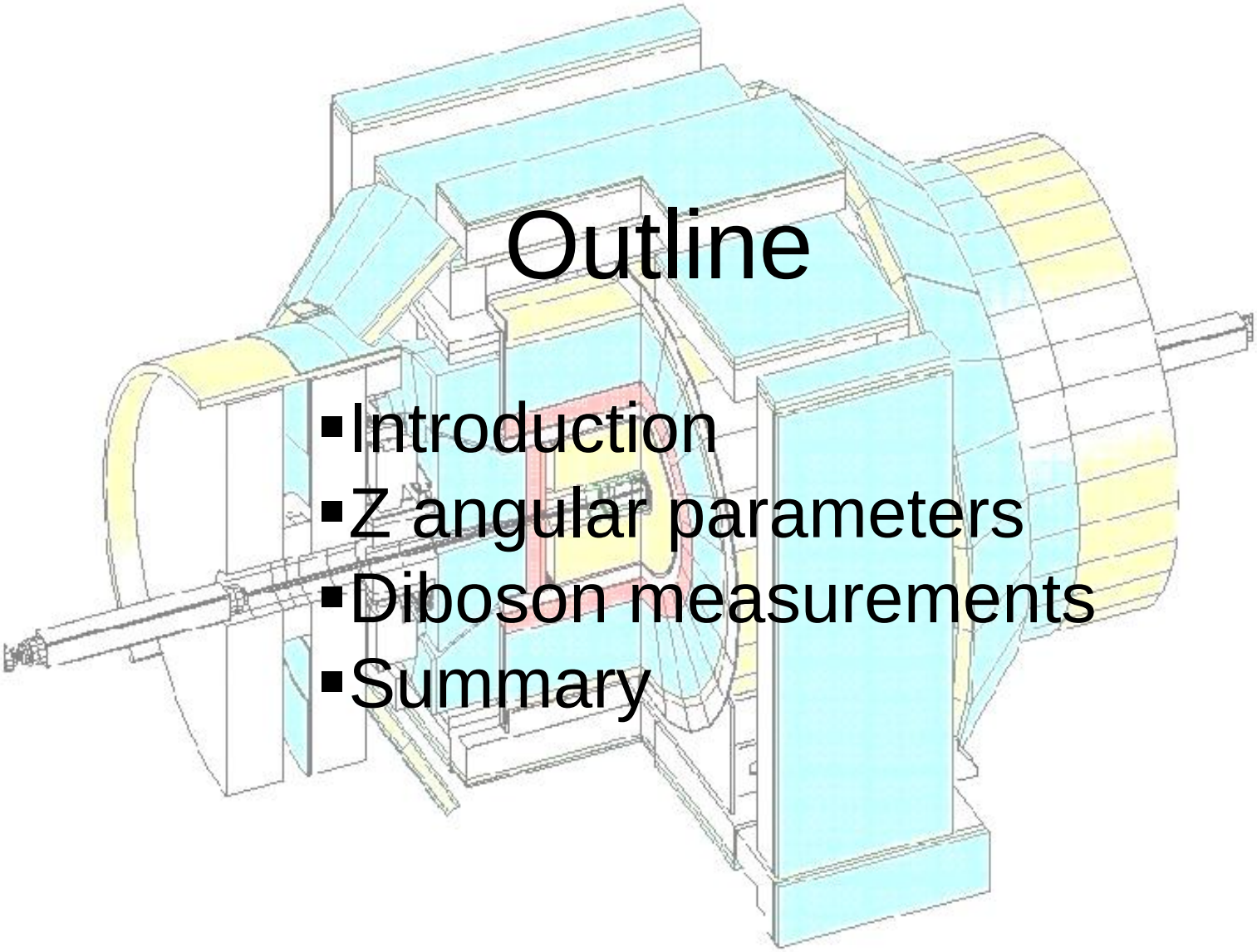
on behalf of the CDF Collaboration

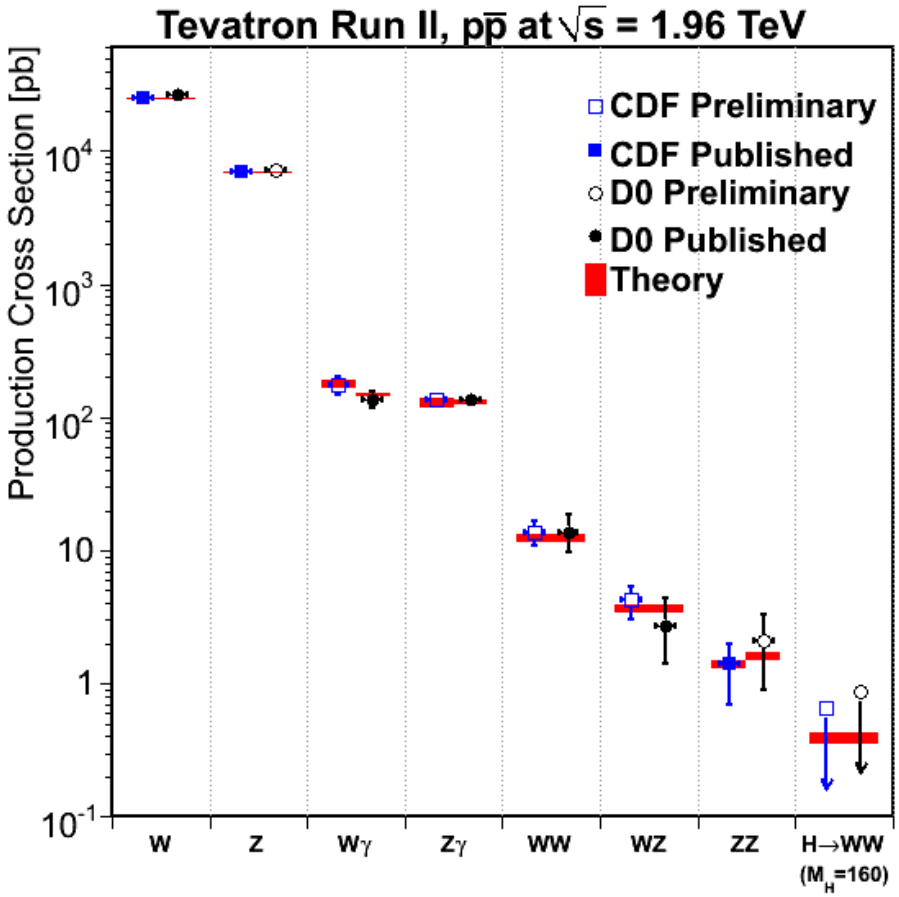
Lake Louise Winter Institute 2011
Alberta, Canada, February 23, 2011



Outline

- Introduction
- Z angular parameters
- Diboson measurements
- Summary

CDF Electroweak Program



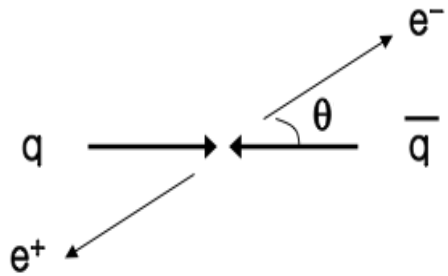
Precision measurements of

- W mass
- W width
- W & Z Cross section
- Z decay property
  - Angular Coefficient
- Diboson Process
  - WW
  - WZ
  - Zγ
  - ZZ

Differential cross section of $Z/\gamma^* \rightarrow l^+l^-$

- Collins-Soper frame : the center of mass frame of dilepton

$q\bar{q} \rightarrow Z/\gamma* \rightarrow \ell^+\ell^-$



in lepton plane

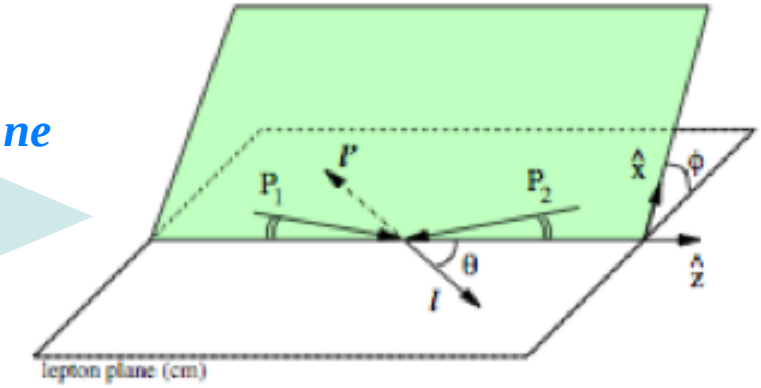


FIG. 1: The Collins-Soper frame.

$$\frac{d\sigma}{dP_T^2 dy d\cos\theta d\phi} \propto (1+\cos^2\theta)$$ → ***LO term***

$$+ \frac{1}{2}A_0(1-3\cos^2\theta)$$ → ***$\cos^2\theta$: higher order term***

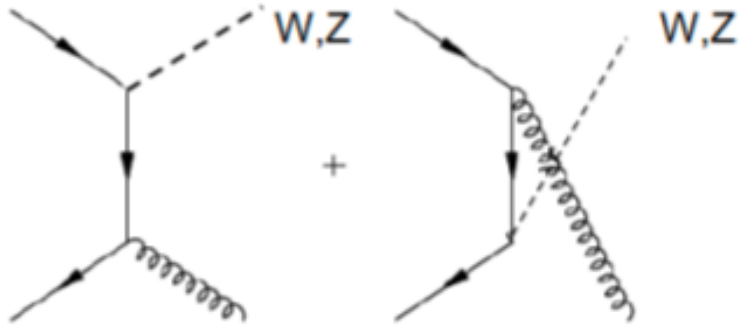
$$+ A_1 \sin 2\theta \cos\phi + \frac{1}{2}A_2 \sin^2\theta \cos 2\phi + A_3 \sin\theta \cos\phi$$ → ***(θ, φ) terms***

$$+ A_4 \cos\theta$$ → ***LO term : determine A_{fb}***

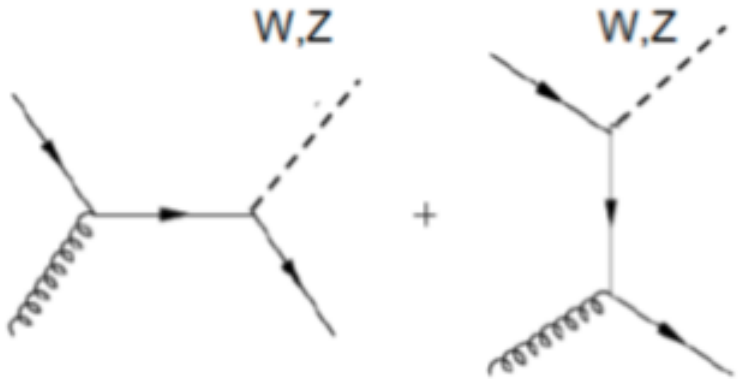
$$+ A_5 \sin^2\theta \sin 2\phi + A_6 \sin 2\theta \sin\phi + A_7 \sin\theta \sin\phi$$ → ***very small terms***

******All higher order terms are zero at Pt=0***

Dilepton angular distribution with p_T



Annihilation diagram



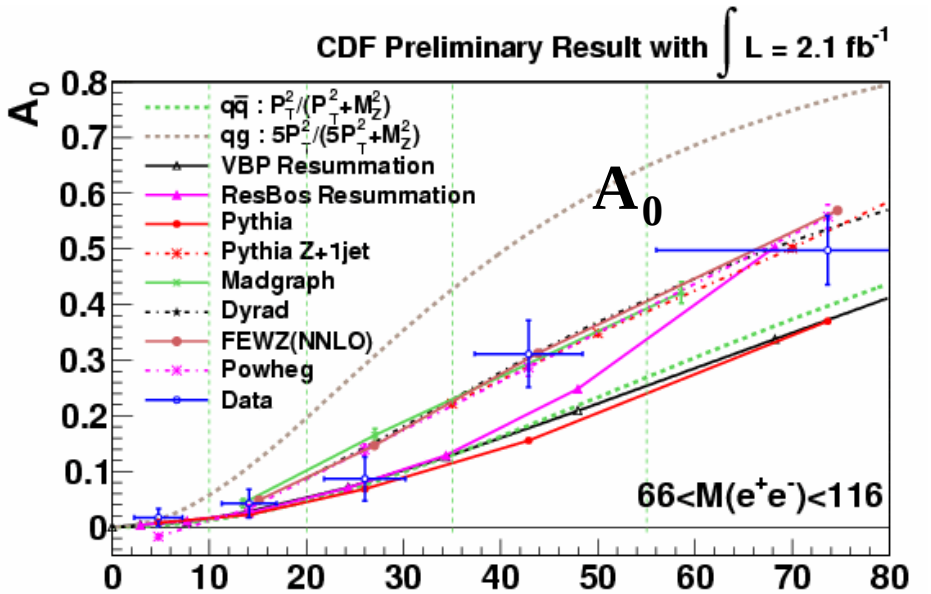
Compton diagram

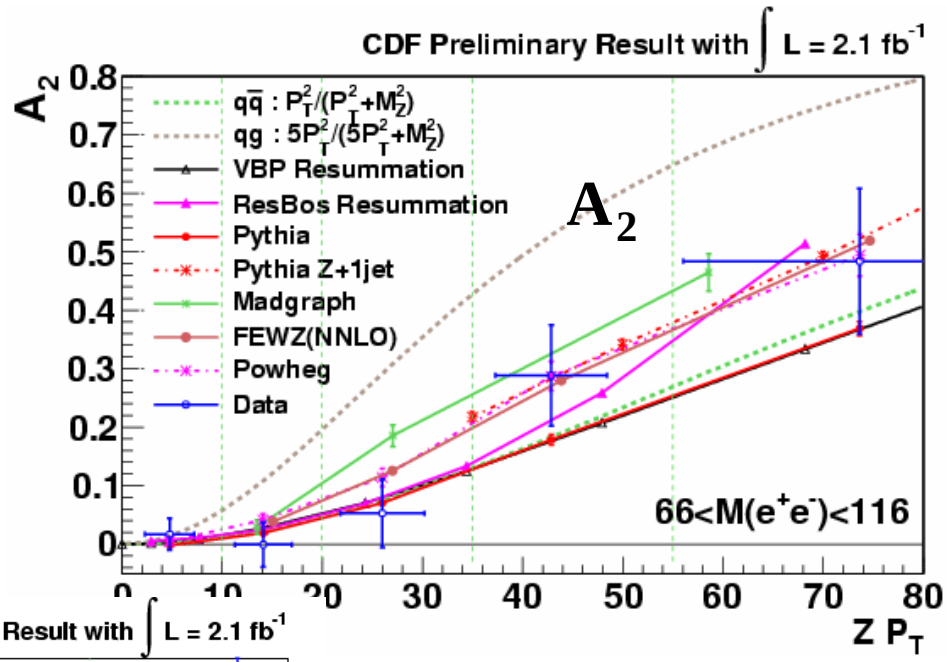
$$A_0^{q\bar{q}} = A_2^{q\bar{q}} = \frac{P_T^2}{M_{\ell\ell}^2 + P_T^2}$$

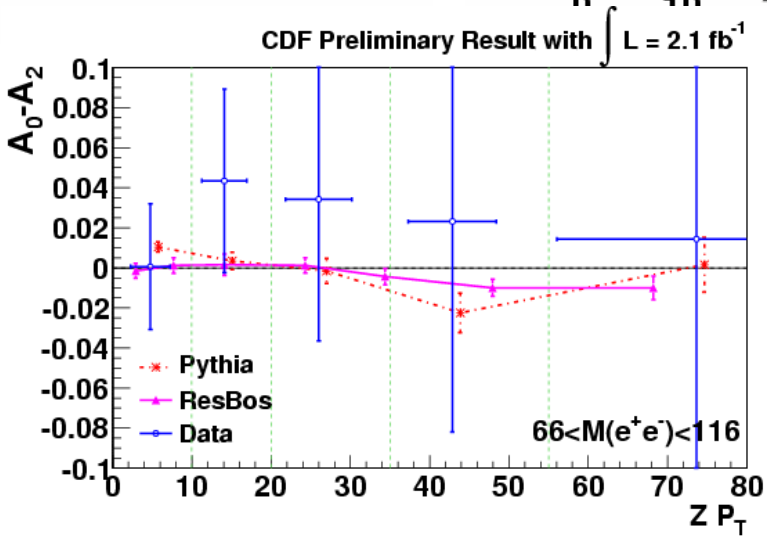
$$A_0^{q\bar{q}} = A_2^{q\bar{q}} = \frac{5P_T^2}{M_{\ell\ell}^2 + 5P_T^2}$$

- A_0 and A_2 predictions in p_T is different in each process
  - A_0=A_2 (spin 1 gluon); Lam-Tung Relation
- A measurement of the angular distribution in p_T provides a detailed test of the production mechanism of gauge boson with finite p_T

$A_{0,2}$ in Z boson p_T







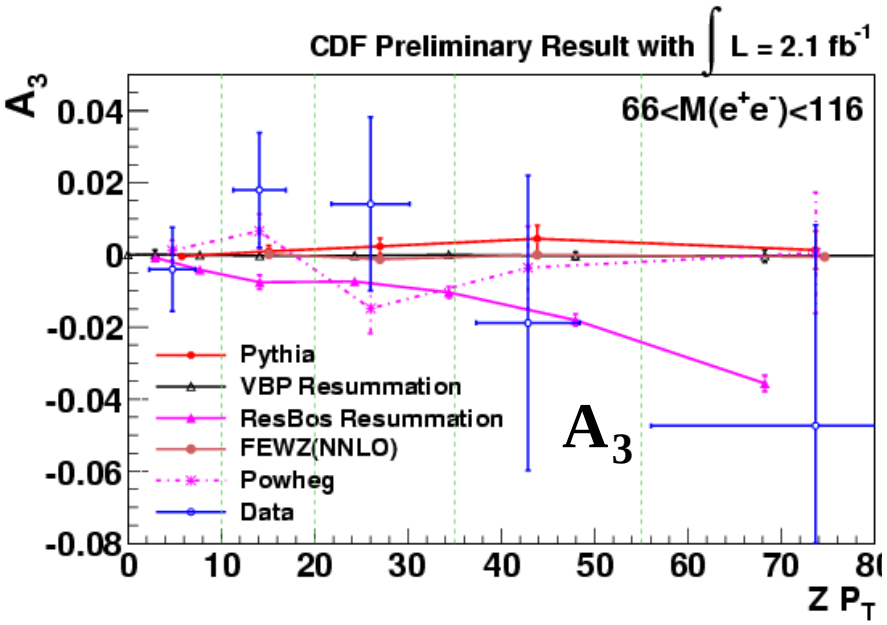
$Z/\gamma^* \rightarrow ee$ channel
$66<M<116$ GeV/c^2

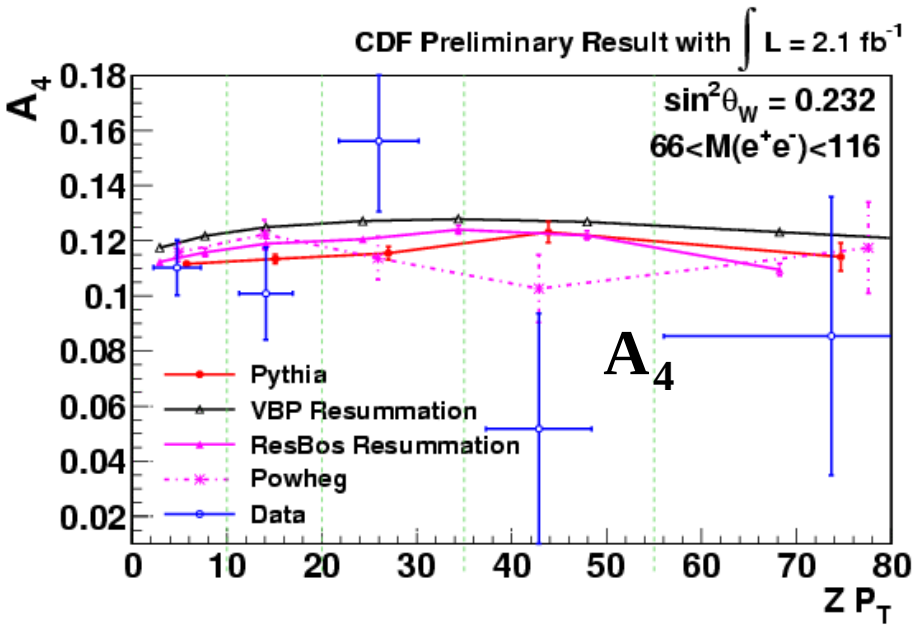
Confirms $A_0 \simeq A_2$

✓ *spin 1 gluon*

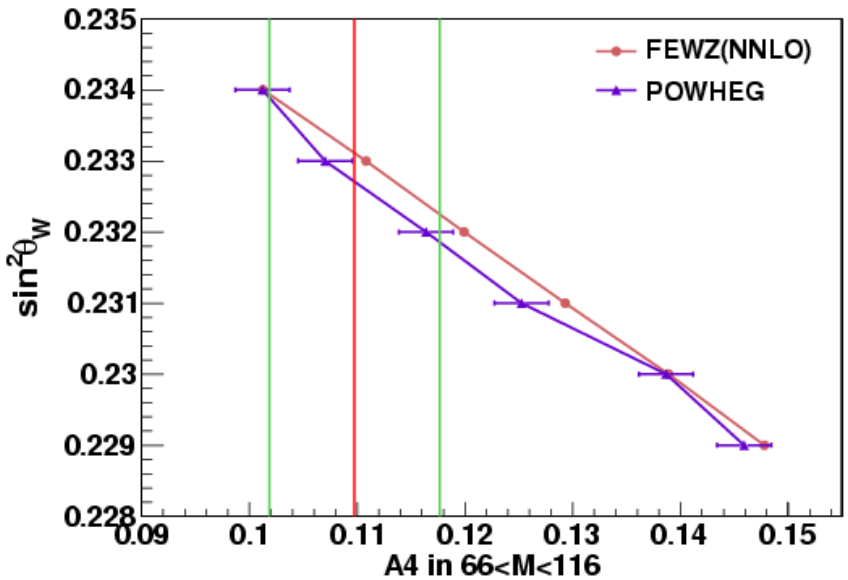
✓ *Lam-Tung Relation*

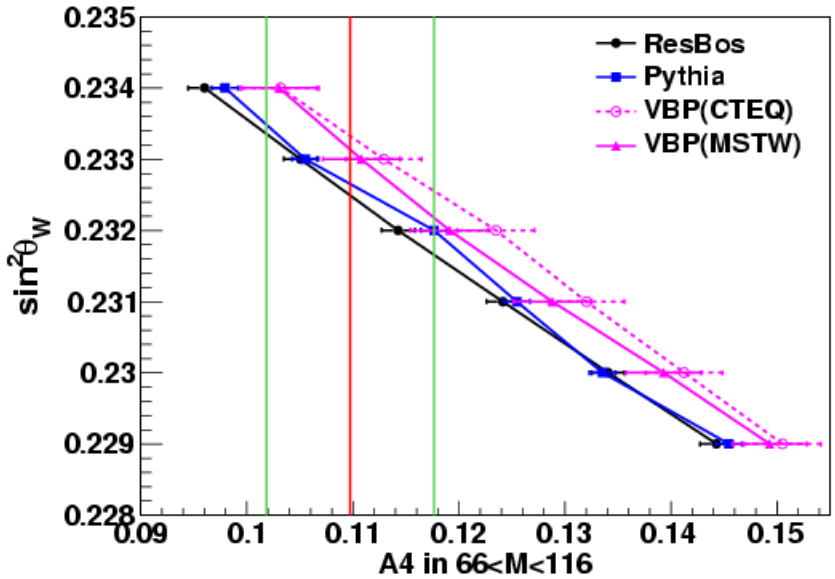
$A_{3,4}$ in Z boson p_T

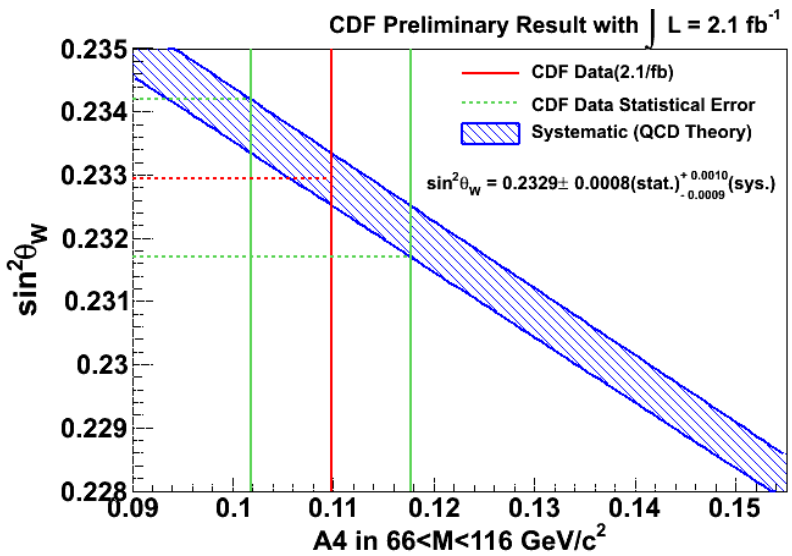




A_4 and $\sin^2\theta_W$





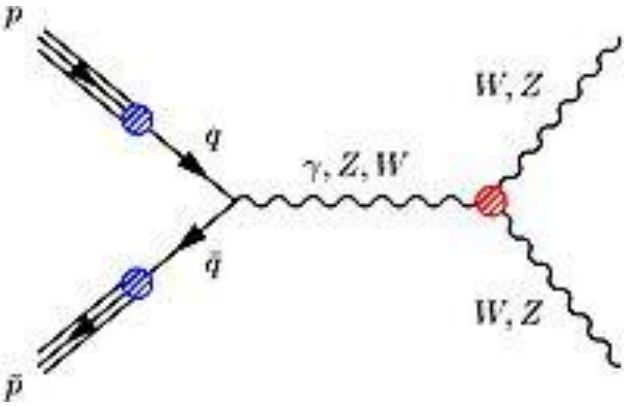


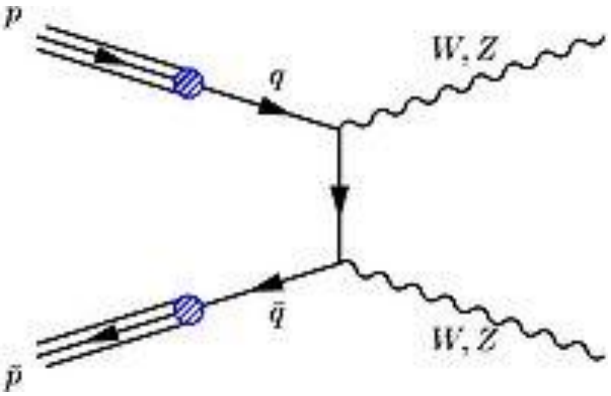
- A_4 using 2.1 fb^{-1} data = 0.1098 ± 0.0079
- The translated $\sin^2\theta_W$ in FEWZ :

  $\sin^2\theta_W = 0.2331 \pm 0.0008$
- The translated $\sin^2\theta_W$ in POWHEG :

  $\sin^2\theta_W = 0.2328 \pm 0.0008$

Diboson

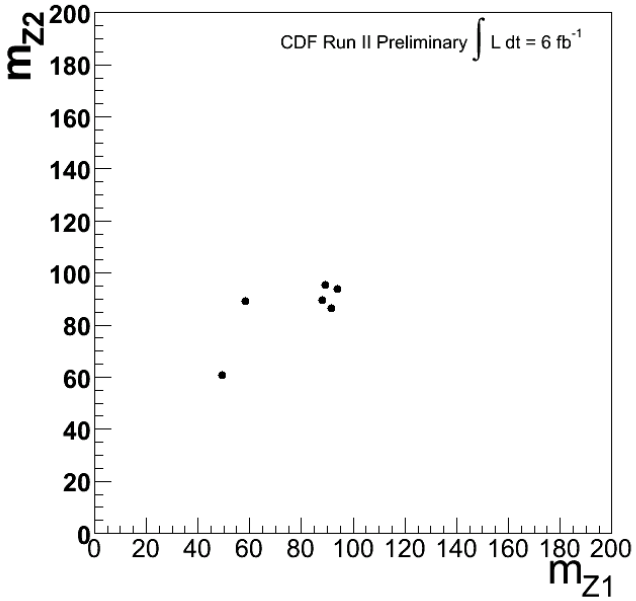


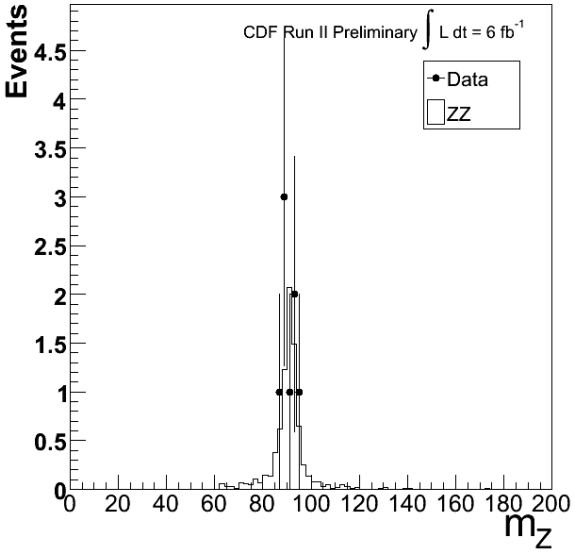


$ZZ \rightarrow 4l$

$p_{T1} > 20$ GeV/c
$p_{T2,3,4} > 15$ GeV/c
$M(4l) < 300$ GeV/c^2
$76 < M(ee, \text{or } \mu\mu) < 106$ GeV/c^2
4 final events

- Deviations from the SM prediction
  - Anomalous trilinear gauge coupling
  - Large Extra Dimensions
- Important background to $H \rightarrow ZZ$





Total backgrounds <0.01

$\sigma(p\bar{p} \rightarrow ZZ) / \sigma(p\bar{p} \rightarrow Z) = (2.3^{+1.5}_{-0.9}(\text{stat.}) \pm 0.3(\text{syst.})) \times 10^{-4}$
$\sigma(p\bar{p} \rightarrow ZZ) = 1.7^{+1.2}_{-0.7}(\text{stat.}) \pm 0.2(\text{syst.})$ pb

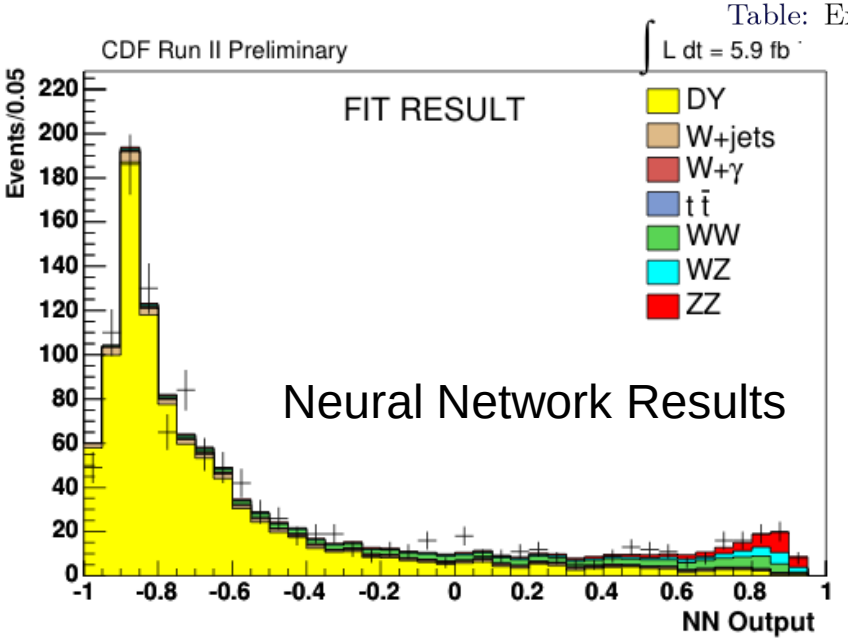
SM prediction is $1.21^{+0.06}_{-0.05}$ pb at NLO

ZZ→llνν

ee and μμ
p_{T1}>20 GeV/c
p_{T2}>10 GeV/c
76<M(ll)<106 GeV/c^2
MET_ax > 25 GeV

CDF Run II Preliminary	$\int \mathcal{L} = 5.9$ fb^{-1}		
$t\bar{t}$	5.8	±	1.1
DY	881	±	158
WW	85	±	8
WZ	35.4	±	5.0
W+jets	42	±	11
$W\gamma$	13.9	±	4.2
Total Background	1113	±	158
ZZ	49.8	±	6.3
Data	1162		

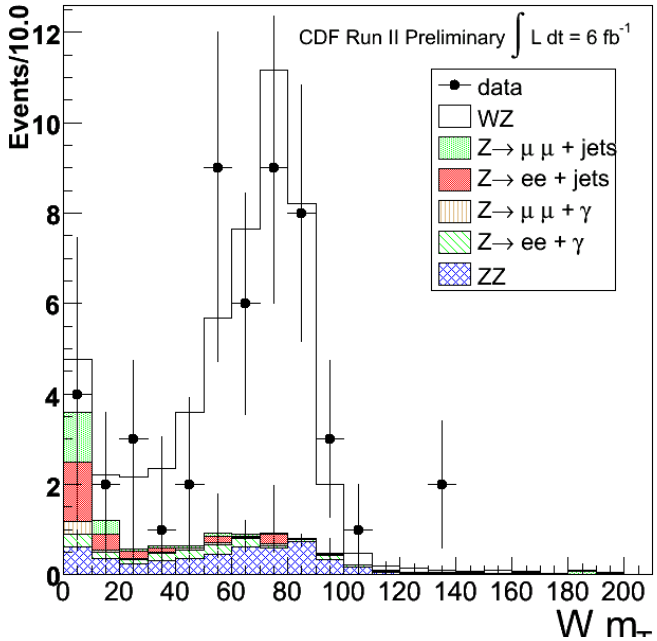
Table: Expected and Observed number of events.



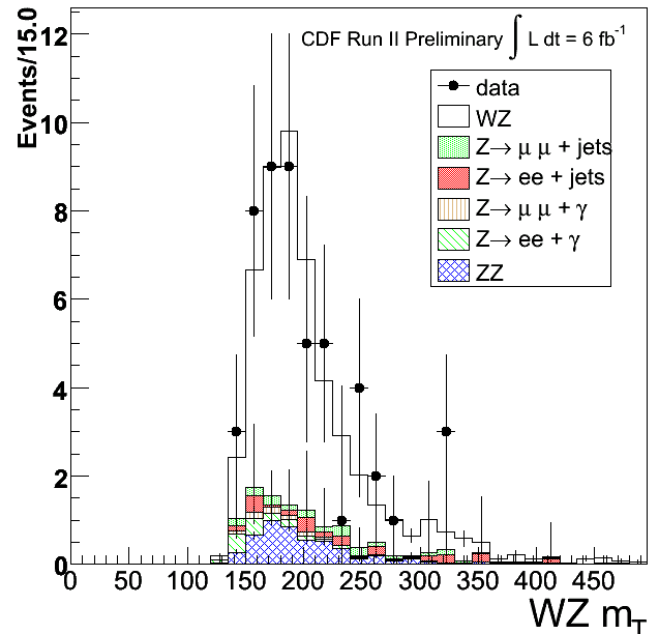
$$\sigma(p\bar{p} \to ZZ) = 1.45^{+0.45}_{-0.42}(stat.)^{+0.41}_{-0.30}(syst.)\ \text{pb}$$

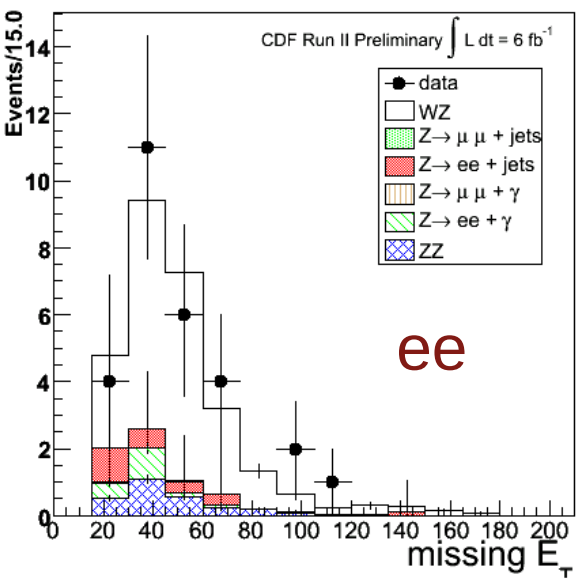
in agreement with the Standard Model prediction of $1.21^{+0.06}_{-0.05}$ pb at NLO

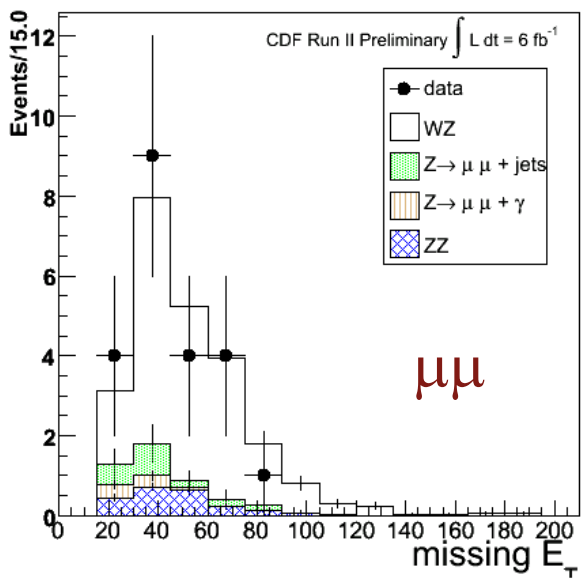
WZ→3l+ν



p_T>15 GeV/c
76<M(ll)<106 GeV/c^2
MET > 25 GeV
50 candidate events
28 (ee), 22(μμ)







$\sigma(p\bar{p}\rightarrow WZ)/\ \sigma(p\bar{p}\rightarrow Z)$
$= (5.5\pm0.9)\times10^{-4}$

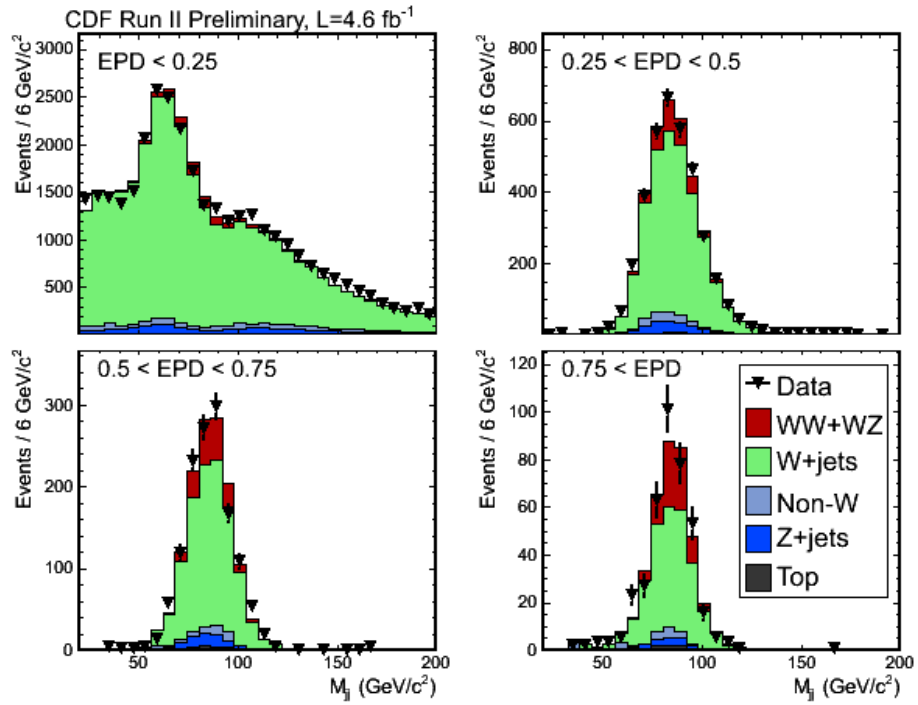
$\sigma(p\bar{p}\rightarrow WZ) = 4.1\pm0.7$ pb

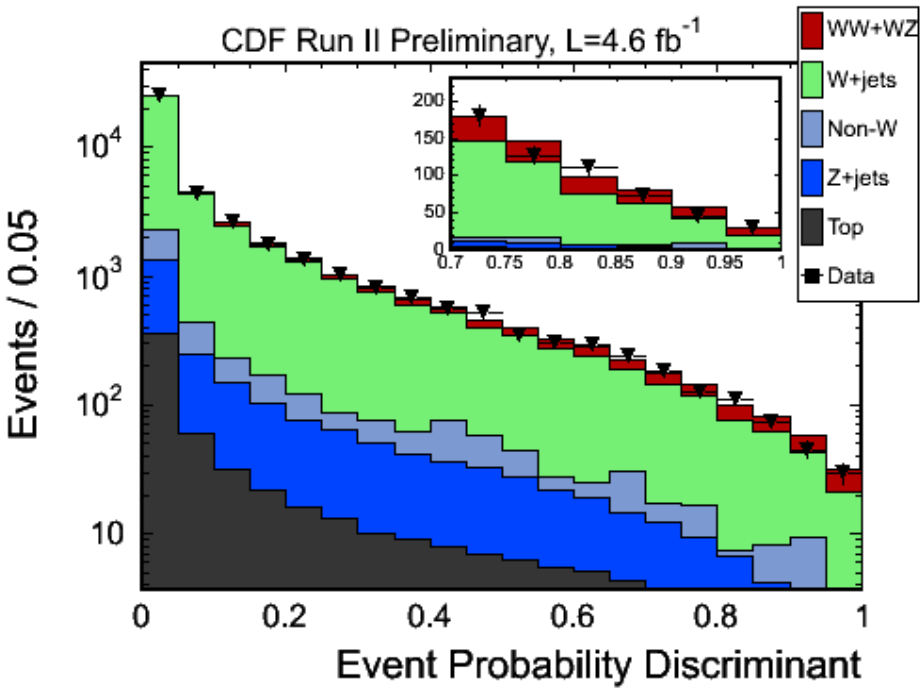
SM : 3.46±0.21 pb

WW/WZ→lνjj

l(e or μ)ν(MET)jj channels
Matrix Element Method

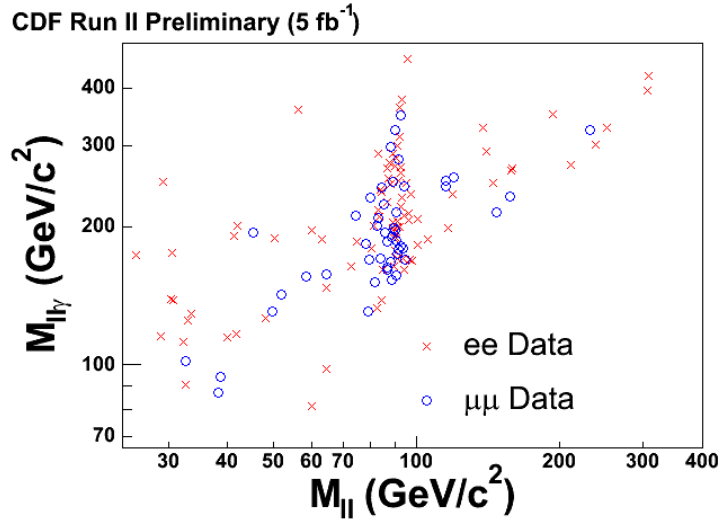
Event Probability Discriminant





Likelihood fit of the sum of signal and background EPD to data returns,
$\sigma(WW+WZ) = 16.5^{+3.3}_{-3.0}$ pb
5.4σ significance

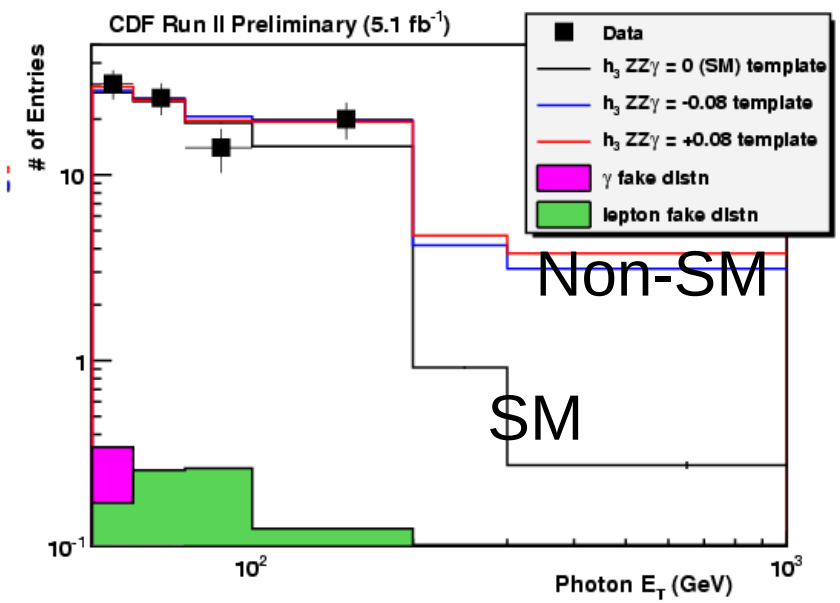
$Z\gamma \rightarrow l^+l^-(\text{or } \nu\nu)+\gamma$

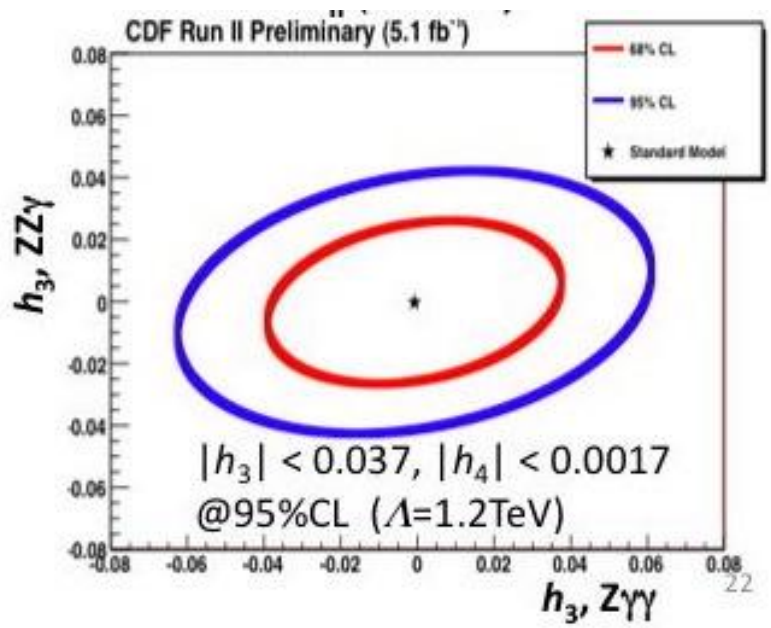


Potential anomalous couplings between Z's and photons

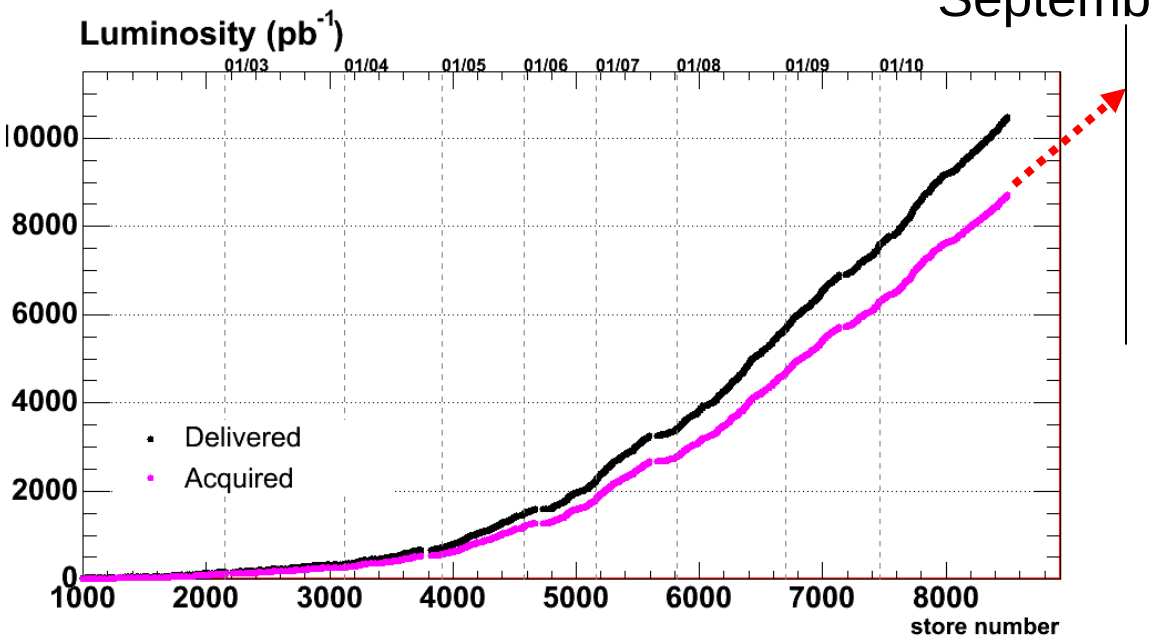
Central photons
$Z \rightarrow ee(\text{or } \mu\mu) + \text{photon}$
$Z \rightarrow \nu\nu+\gamma$

Assume CP conserving couplings.
Anomalies parameterized in terms of h_3&h_4 (0 in SM)





Summary

- CDF provides imporstant results on electroweak physics up to 6 fb^{-1}
  - Precision measurement of W and Z production
  - Z angular parameters (2.1 fb^{-1})
  - Strong diboson programs
- Continues to produce results up to ~10 fb^{-1}

September (?), 2011