Di−Boson Physics @ CDF

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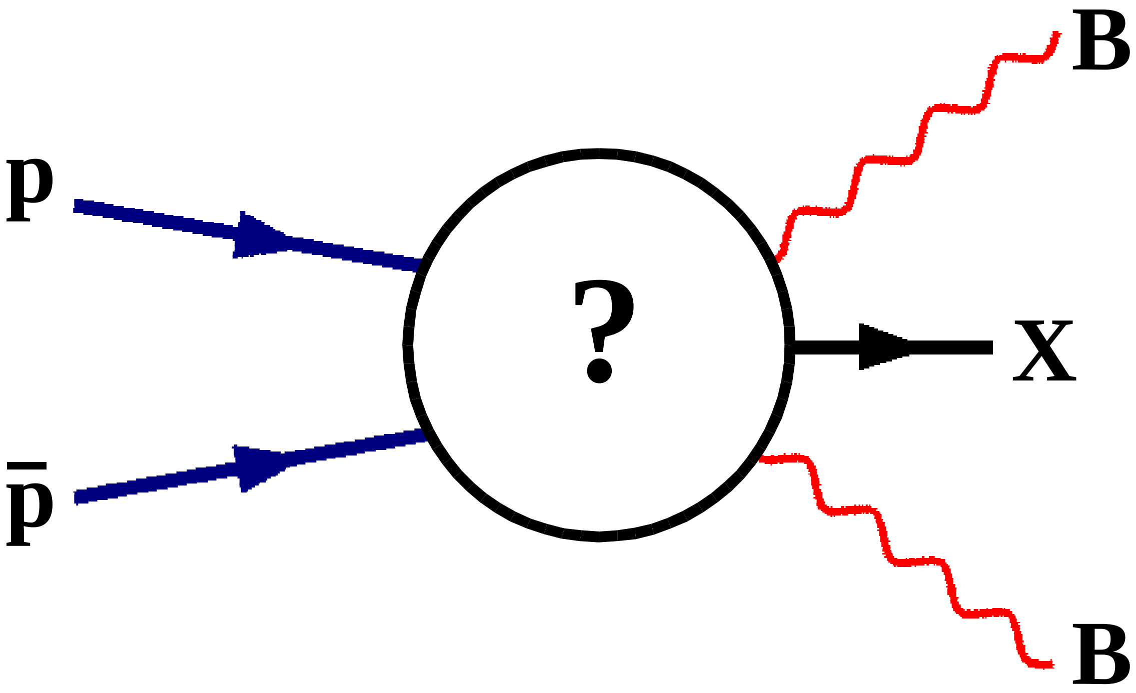
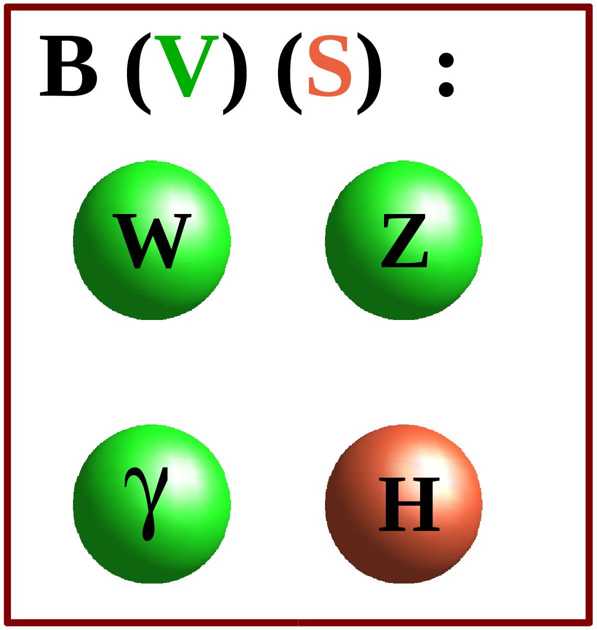
ANL
Duke University
Fermilab
Liverpool University
University College London
UW−Madison
Okayama University
University of Pennsylvania
IPP−Toronto
+
whole of CDF
+
Uli Baur, John Campbell, Keith Ellis

DØ Has Results on All Topics Presented Here

Di−Boson Production at the Tevatron

$$p\bar{p}\rightarrow B\,B+X$$



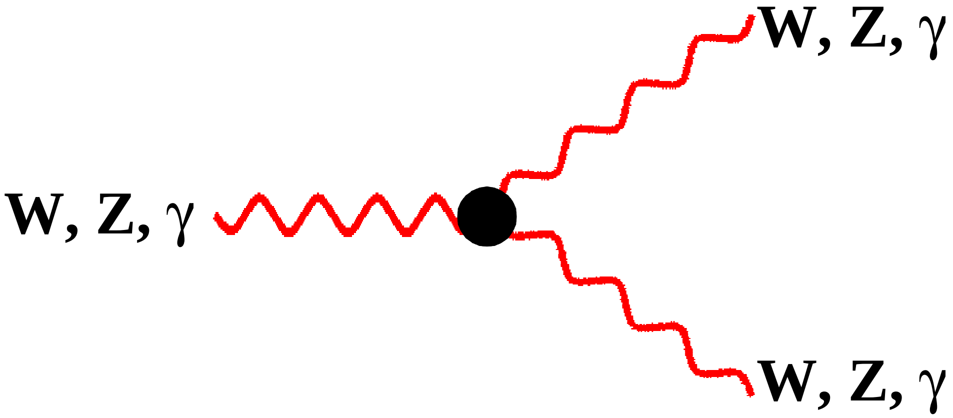


Goals of the Run II program so far :

- Establish di−boson signals.
- Measure cross−sections as inclusively as possible.
- Compare cross−sections & kinematics to theoretical predictions.

Di−Boson Production : New Physics Probe

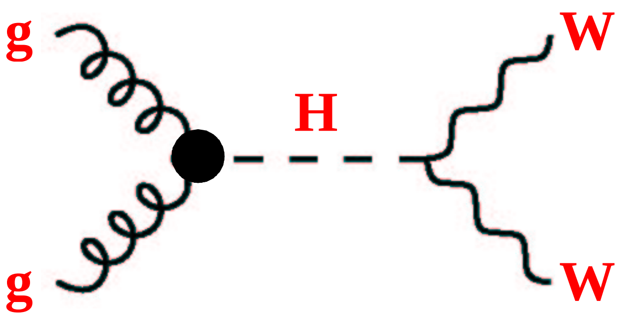
☆ Test Gauge Boson Self Interactions

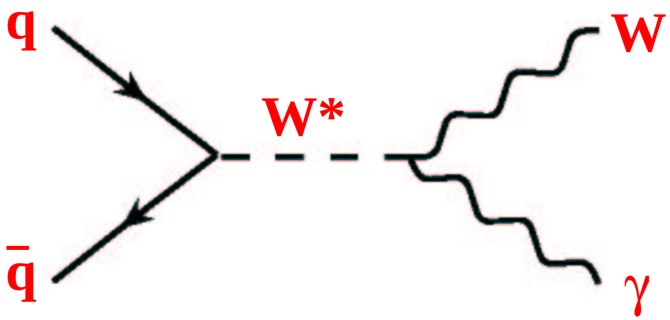


● ~ $SU(2)_L \otimes U(1)_Y$

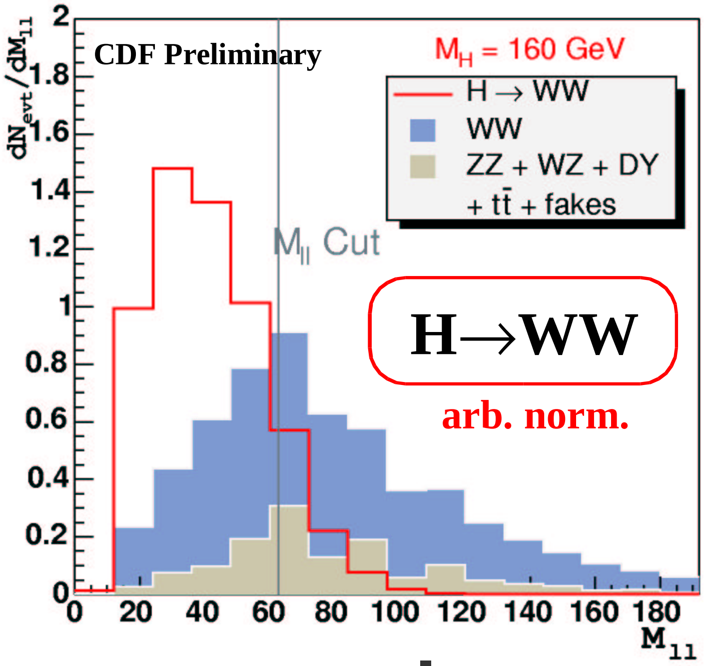
- LEP II results hard to beat, but :
- Complementarity : $W \rightarrow W\gamma$
- Probing couplings at higher $\hat{s}$

☆ Resonance Searches





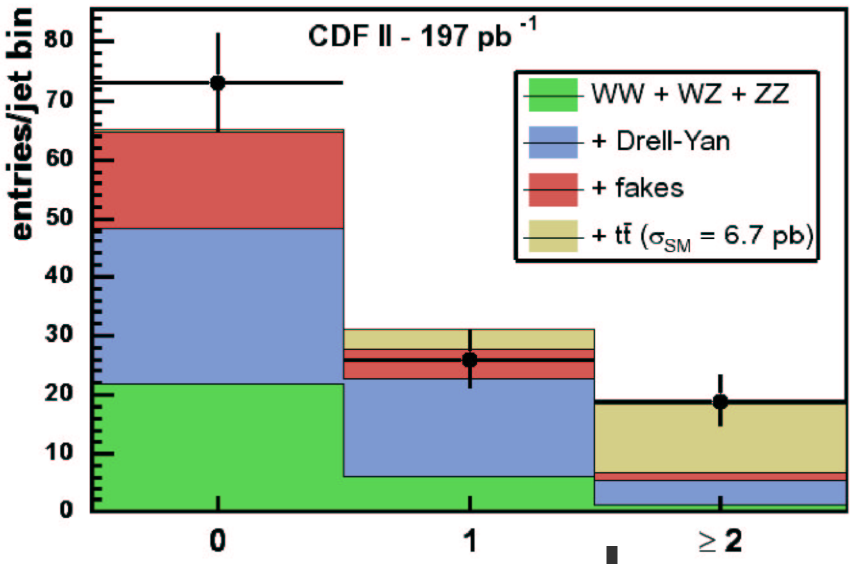
Everyone Else's Background



H→WW

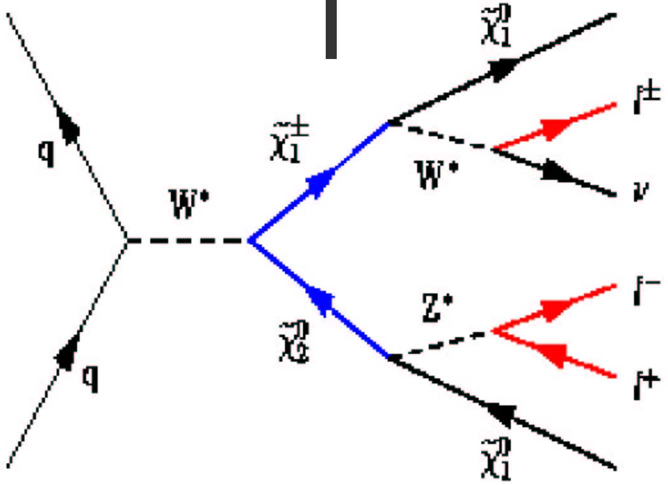
arb. norm.

$t\bar{t} \rightarrow WWb\bar{b}$



irreducible

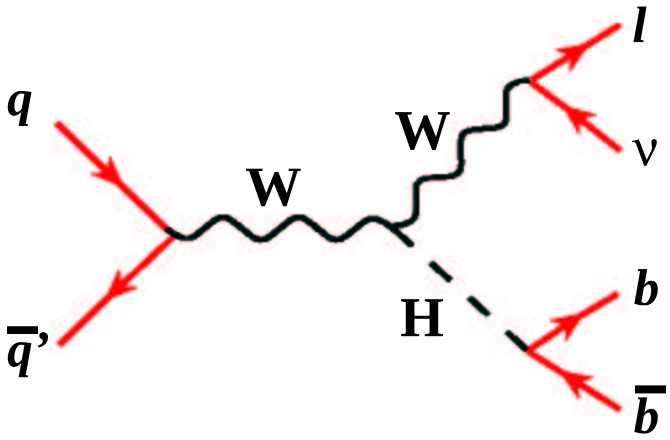
reducible



SUSY/EXOTICA

Relevance to Light Higgs Searches

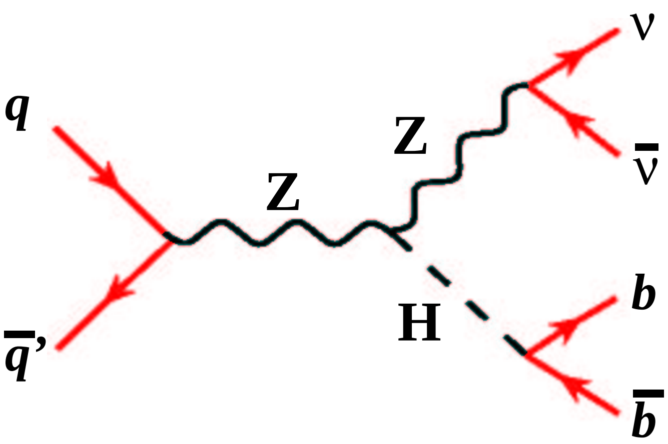
$$p\bar{p} \rightarrow WH \rightarrow l\,\nu\, b\,\bar{b}$$



$\sigma(WH;\, m_H = 115\ \text{GeV}) \approx 0.2$ pb

$\sigma(WZ) \times BR(Z \rightarrow b\bar{b}) \approx 0.6$ pb

$$p\bar{p} \rightarrow ZH \rightarrow \nu\,\bar{\nu}\, b\,\bar{b}$$



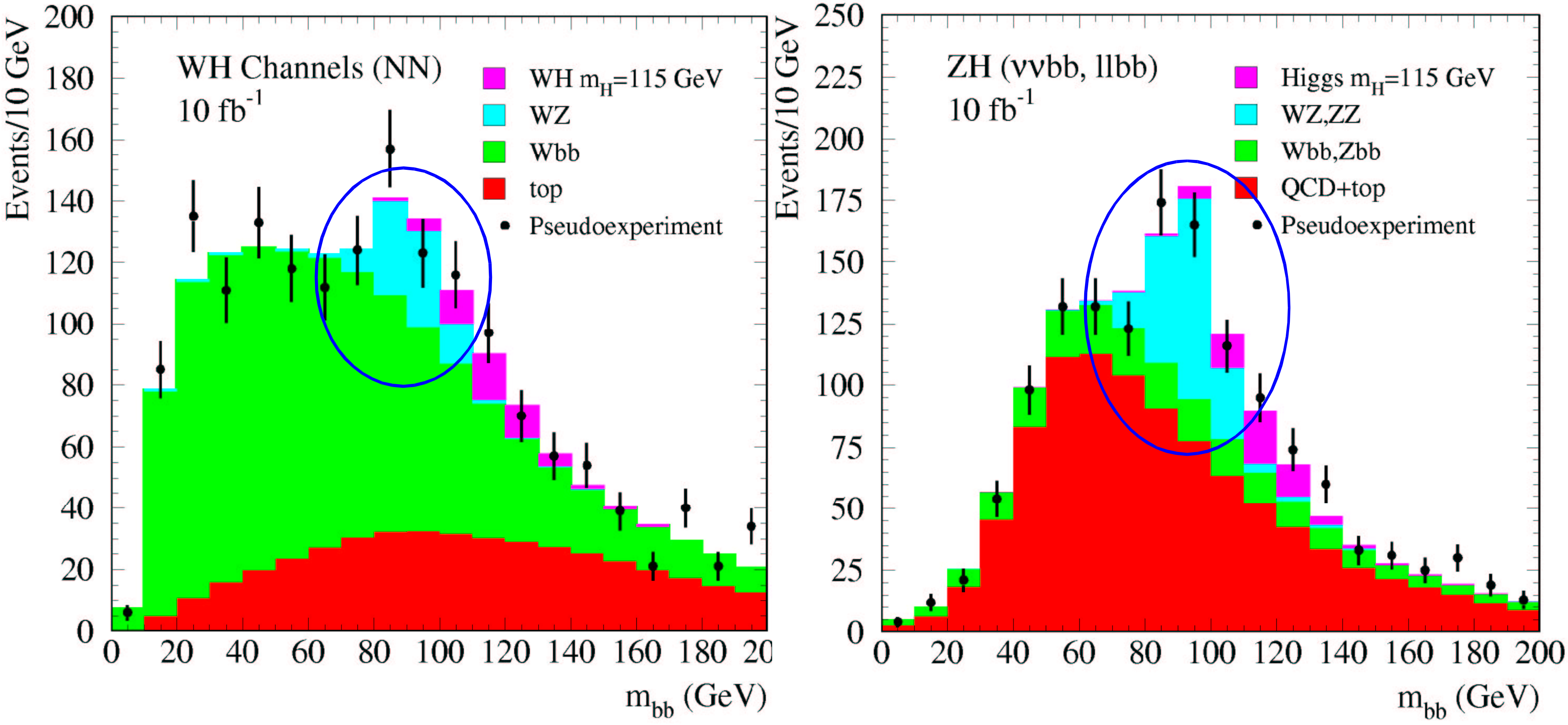
$\sigma(ZH;\, m_H = 115\ \text{GeV}) \approx 0.1$ pb

$\sigma(ZZ) \times BR(Z \rightarrow b\bar{b}) \approx 0.2$ pb

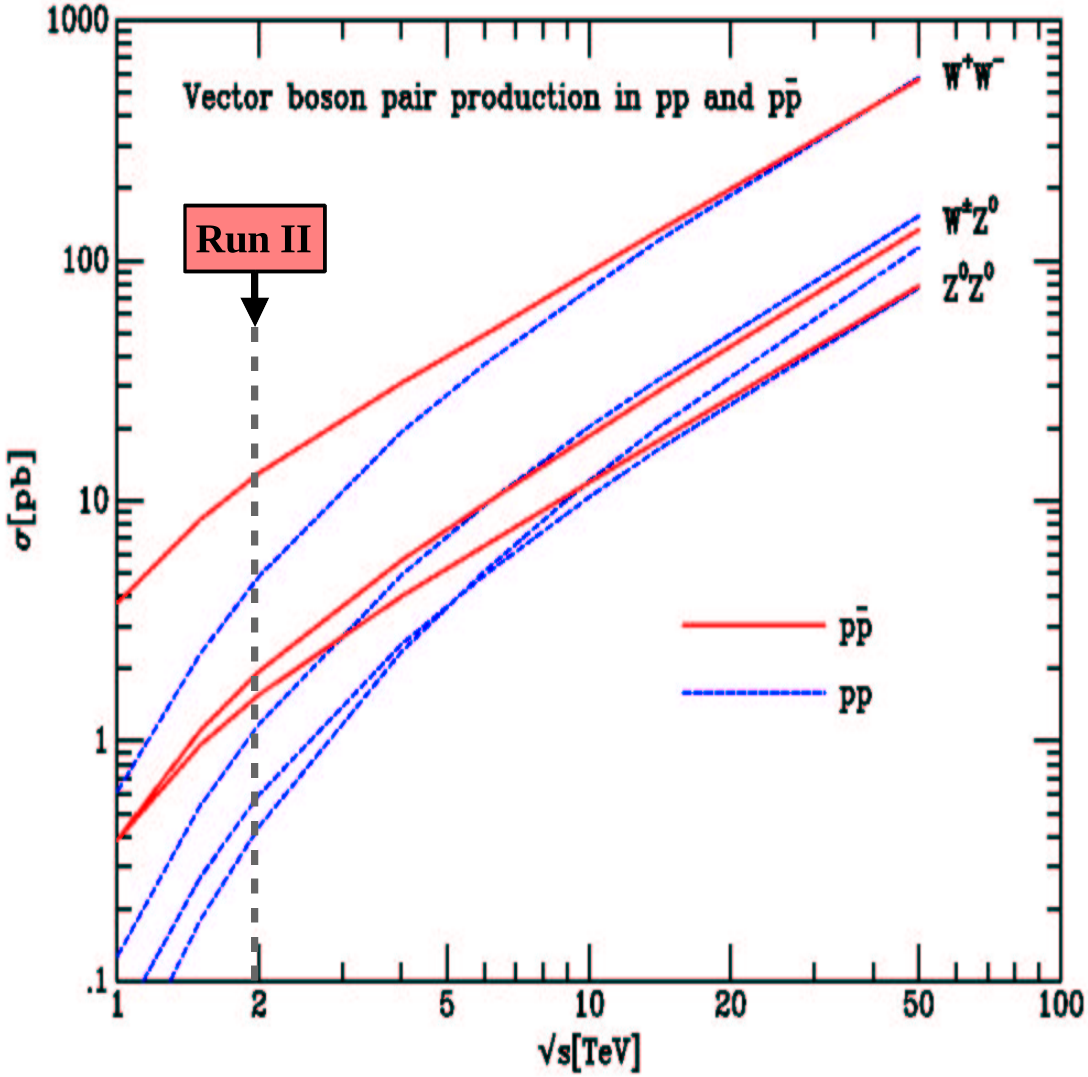
- Major backgrounds
- Calibration signals

Relevance to Light Higgs Searches

"Tevatron Higgs Sensitivity Study", 2003 :



Di−Boson Production : Predictions

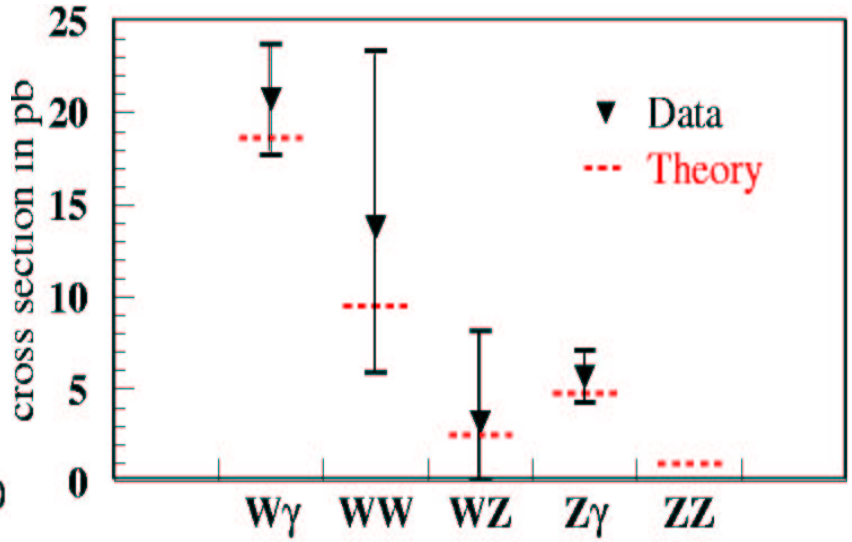


Run II

Heavy BB (NLO) : Campbell & Ellis 99

W/Z+γ (NLO) : Baur, Han, Ohnemus 93/98

CDF Run I results :



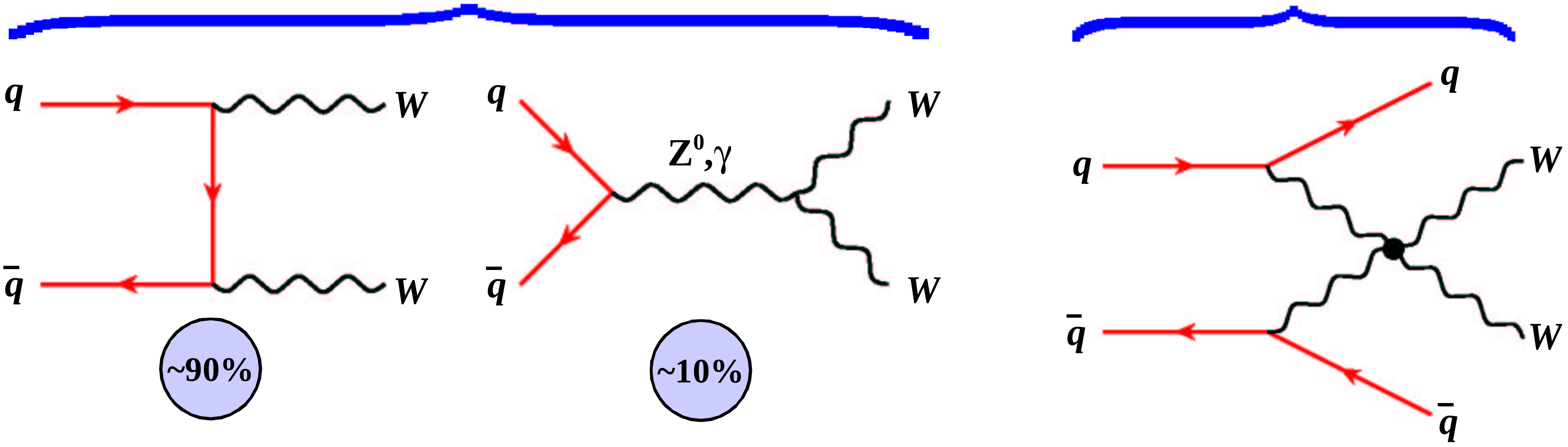
Di−Boson Production : Tevatron to LHC

- Knowledge of di−boson production rates important for many LHC analyses.
- But there are important differences with Tevatron − for example importance of VV scattering.

Tevatron :

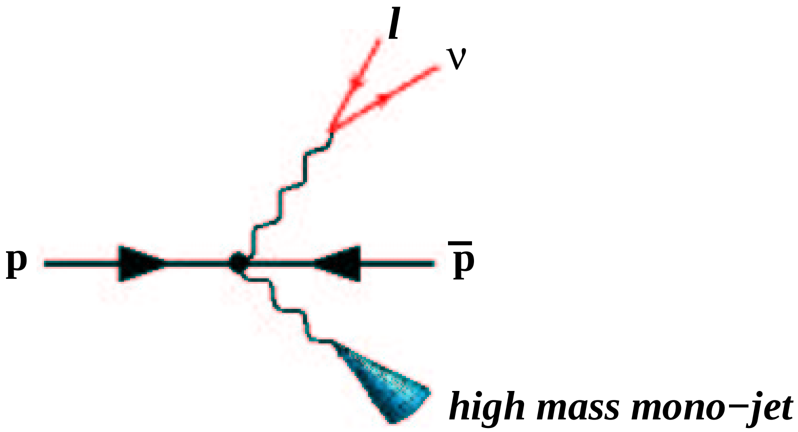
O(10) pb

O(0.1) pb

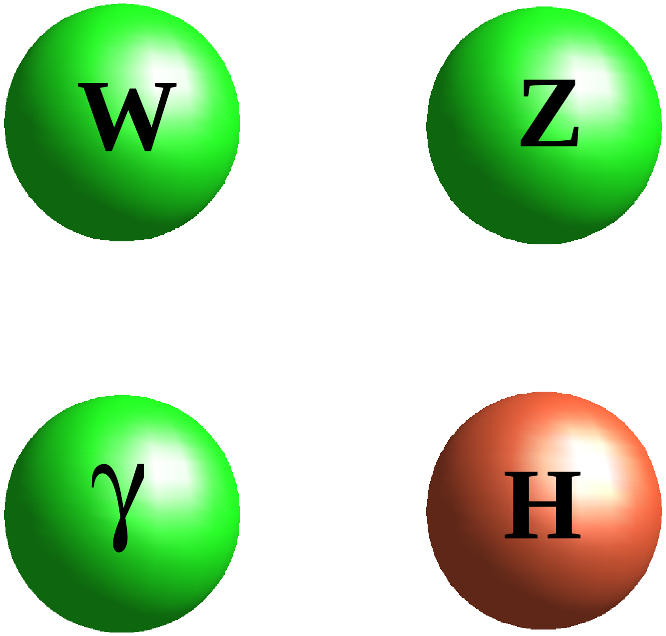


- In addition, LHC is so far above threshold that novel detection methods also available :

Butterwoth, Cox, Forshaw 02

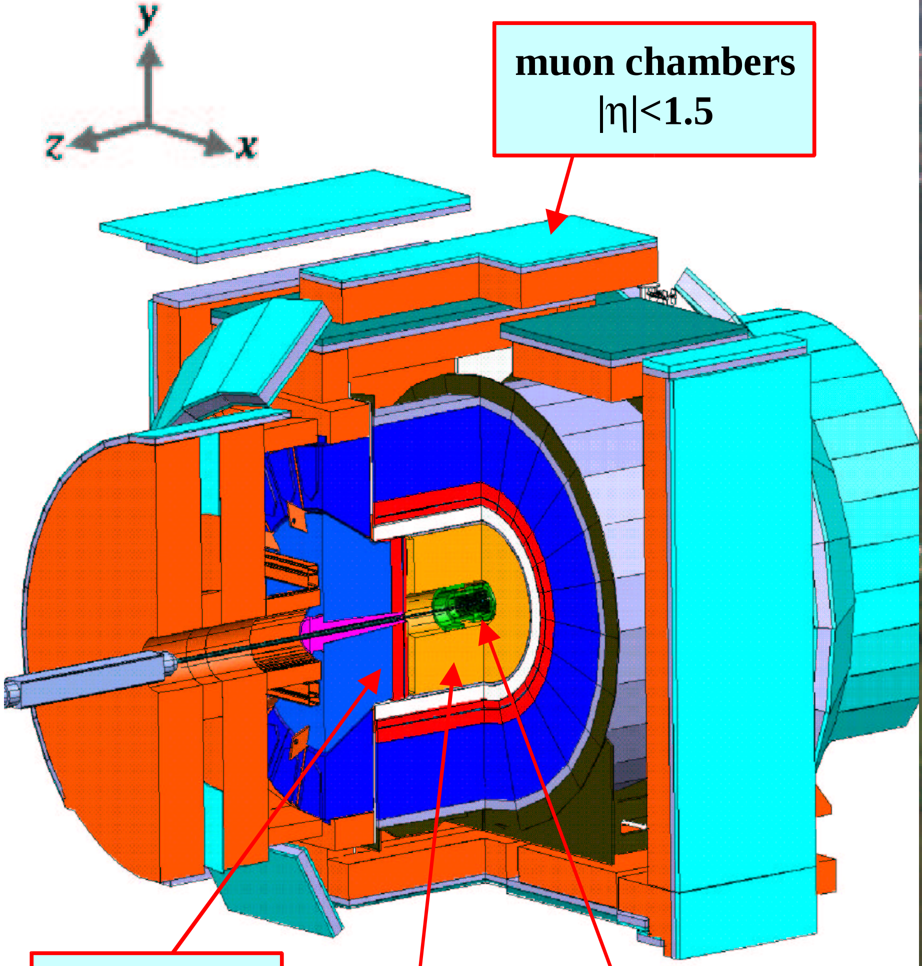


- **Tevatron & CDF**
- $\gamma\gamma$
- W/Z + γ
- WW
- WZ/ZZ
- H→WW



CDF

$$\eta = -\ln[\tan(\vartheta/2)]$$

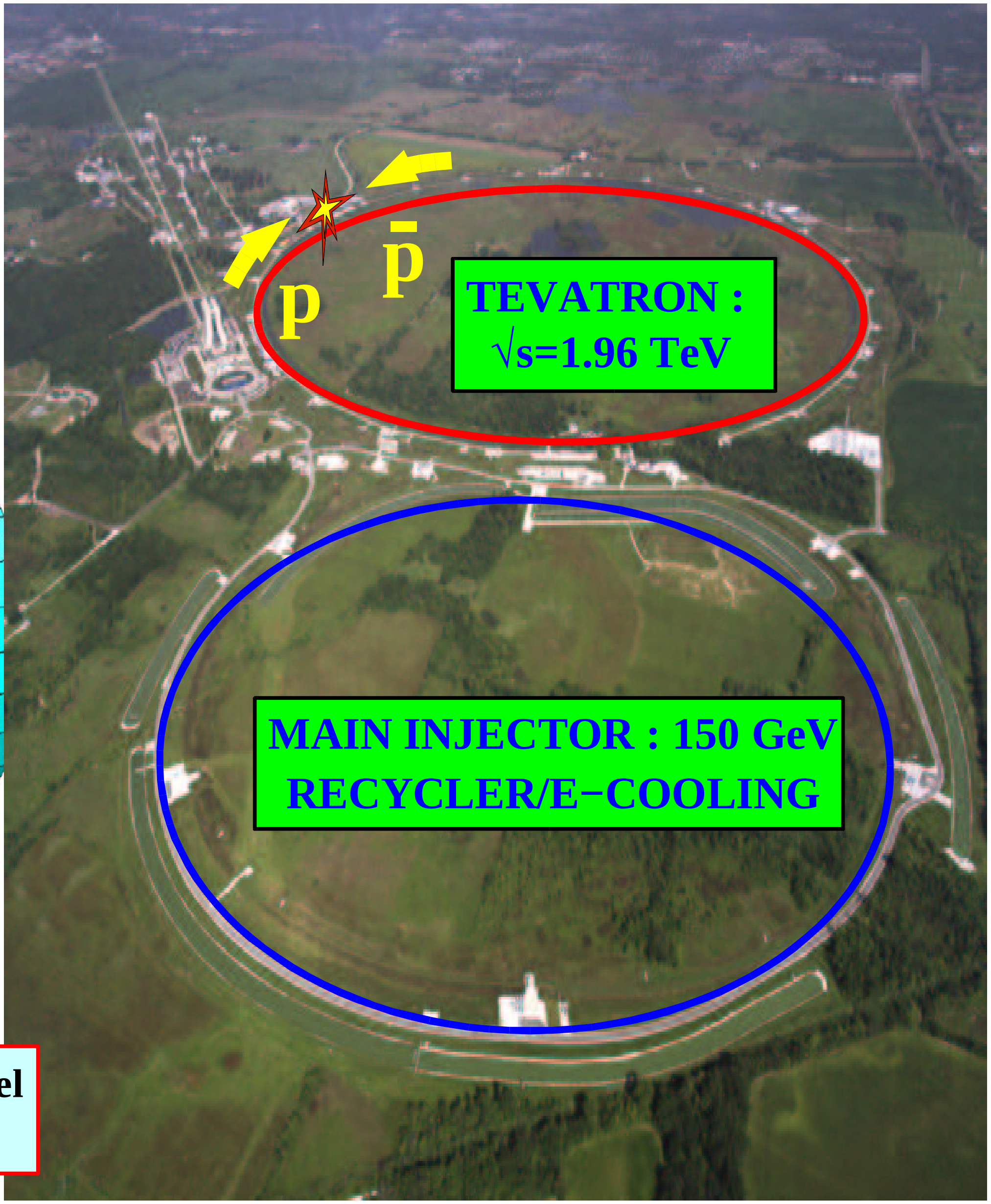


muon chambers
$|\eta|<1.5$

plug calorimeters
$|\eta|<3.6$

central tracker (COT)

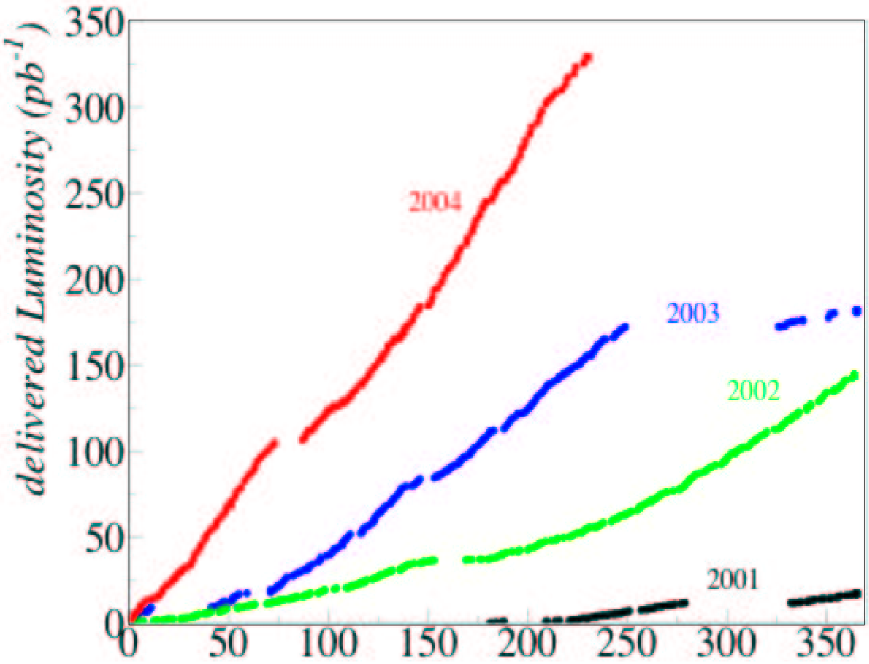
8−layer, 750k channel Si Vertex Detector



TEVATRON : $\sqrt{s}$=1.96 TeV

MAIN INJECTOR : 150 GeV
RECYCLER/E−COOLING

Luminosities & Event Rates

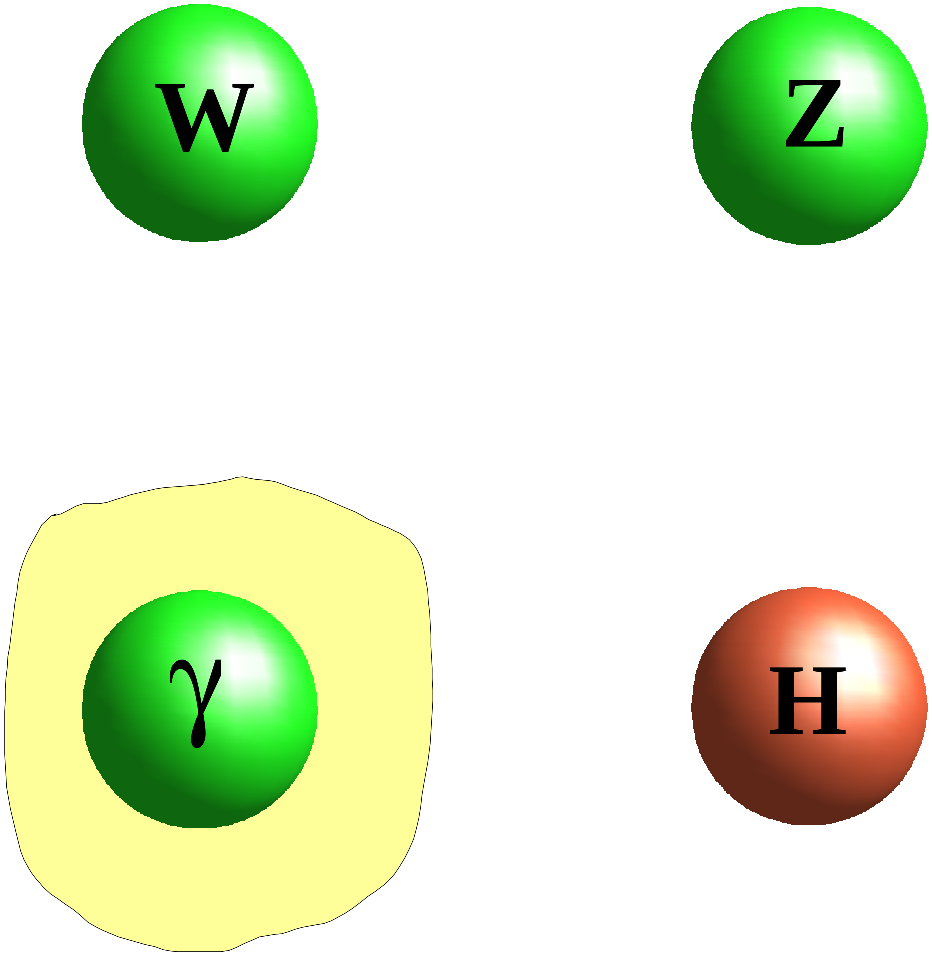


- ~ 680 pb^{-1} delivered so far in Run II.
- ~ 350 pb^{-1} being analysed now.
- Results here based on 200 pb^{-1} collected up until September 2003.

- At high luminosities, Tevatron is a factory for many massive states including boson pairs.

Process	Events/Week
$t\bar{t}$	50
$W \to e \nu_e$	18,000
$Z \to e^+ e^-$	1700
WW	90
$W\gamma \to e\nu\gamma$ (high–$p_T\gamma$)	130
$gg \to H$ (M_H=115 GeV)	6

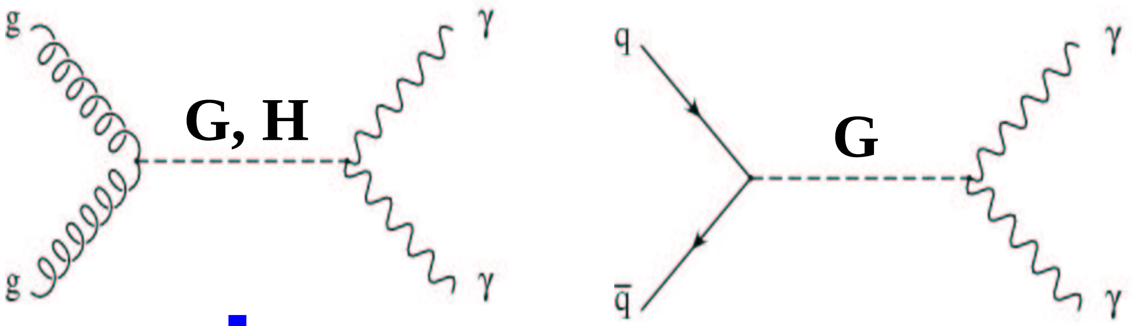
- $\gamma\gamma$
- W/Z + γ
- WW
- WZ/ZZ
- H→WW



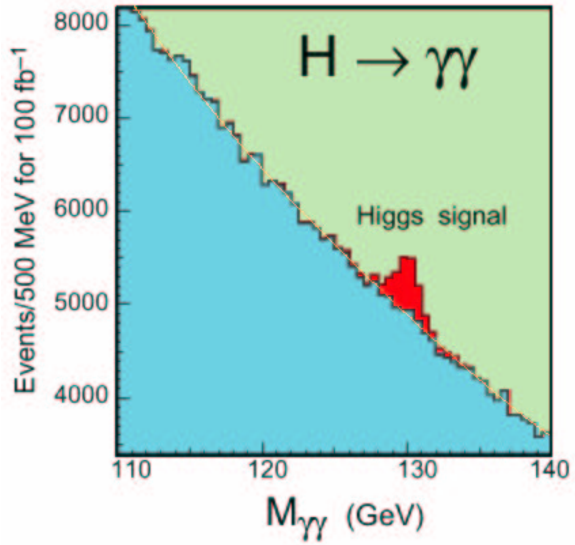
Di−Photon Production

Standard Model :

New Physics :

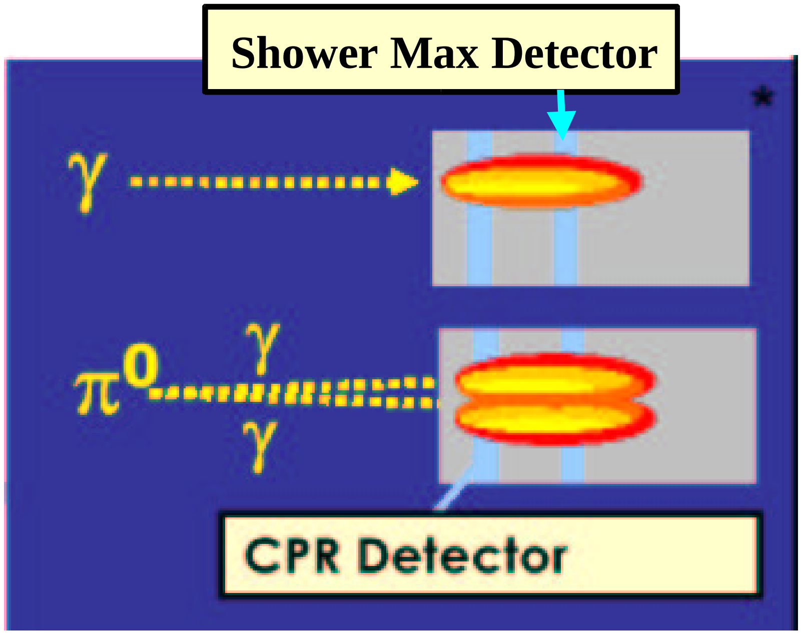


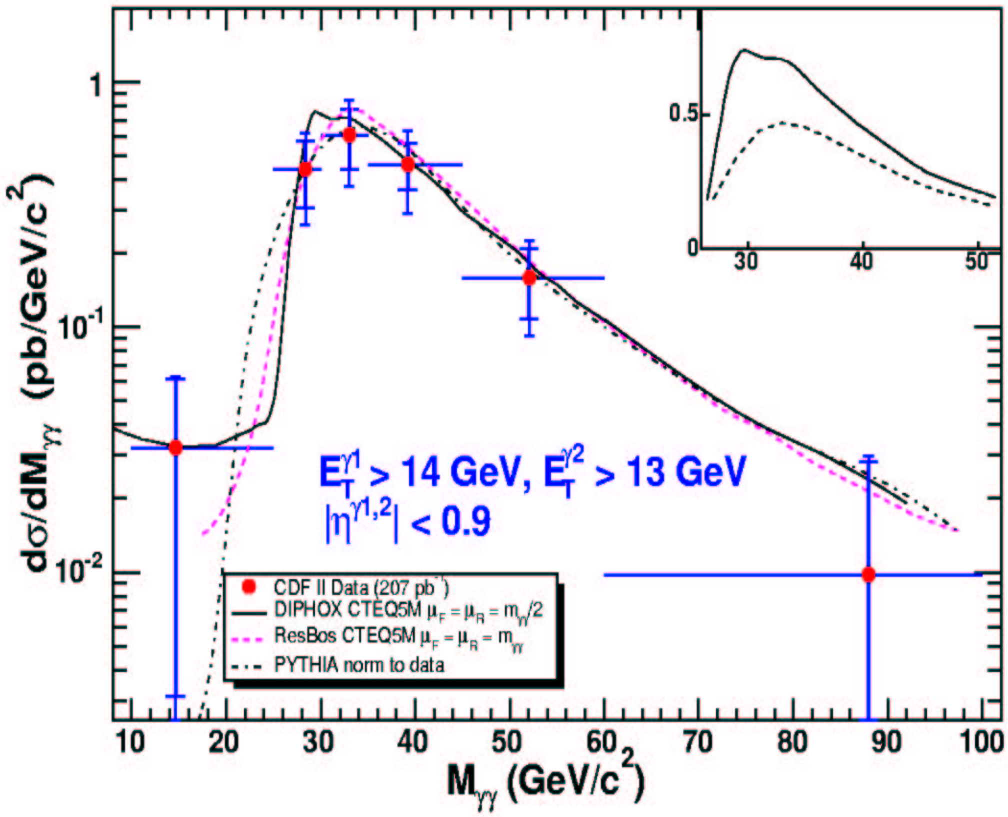
- CMS : 3 years
- Critical to know backgrounds well



Di−Photon Production

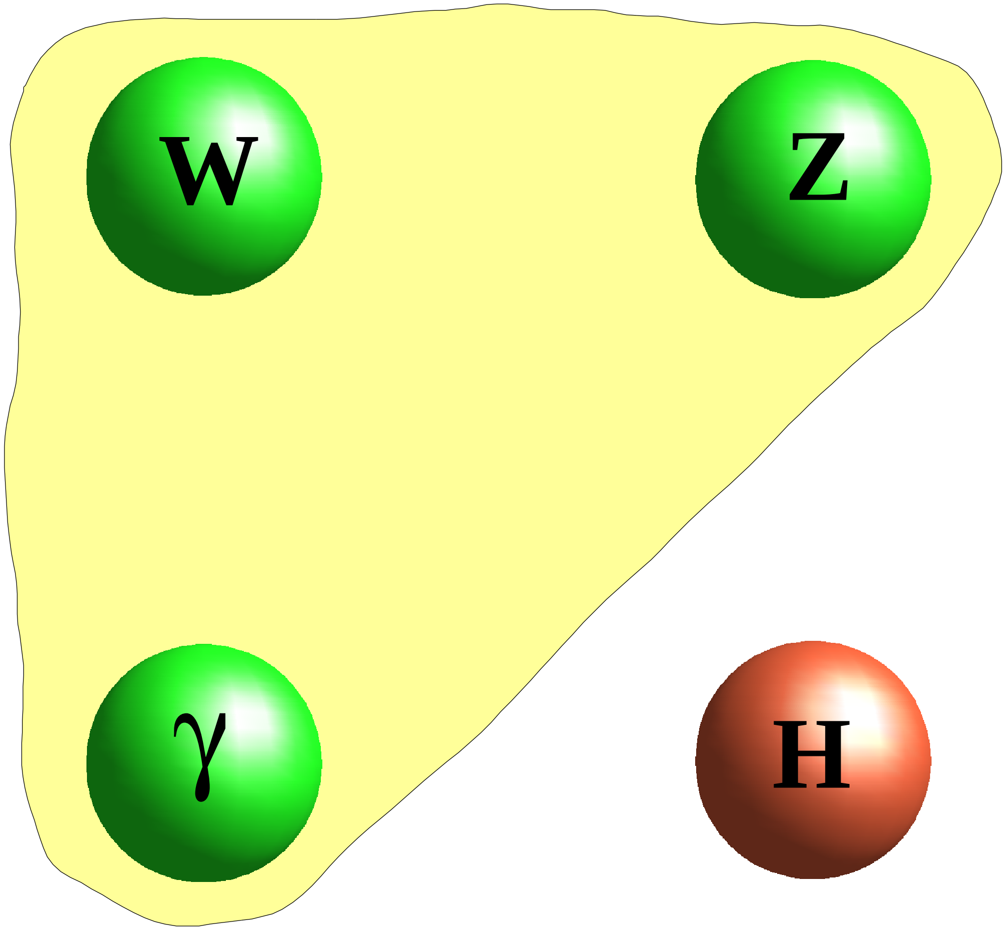
- Select two photons with $E_T > 13$ (14) GeV
- Subtract background (mainly $\pi^0 \to \gamma\gamma$) statistically :





- Data in good agreement with NLO prediction.
- PYTHIA describes shapes well; normalisation off by factor of ~ 2.

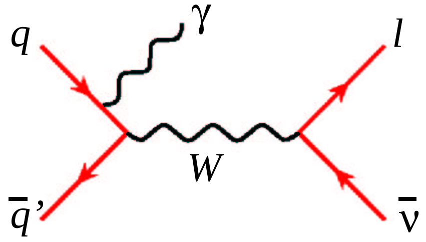
- $\gamma\gamma$
- **W/Z + γ**
- **WW**
- **WZ/ZZ**
- **H→WW**



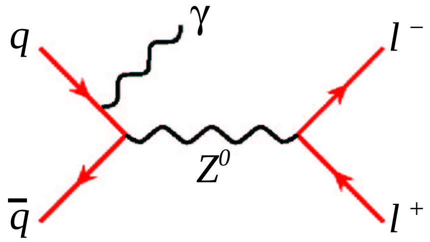
W/Z+γ

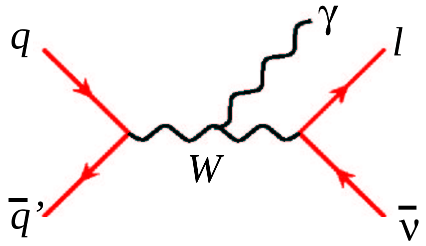
$p\bar{p}\rightarrow W(\gamma)+X\rightarrow l\,\nu\,\gamma+X \quad (l=e,\mu)$

$p\bar{p}\rightarrow Z(\gamma)+X\rightarrow l^{+}l^{-}\gamma+X \quad (l=e,\mu)$

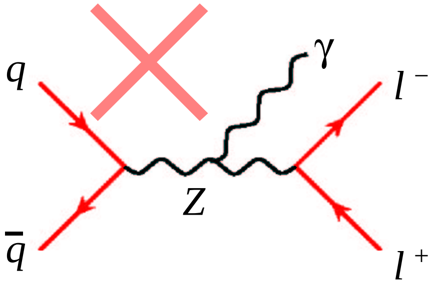


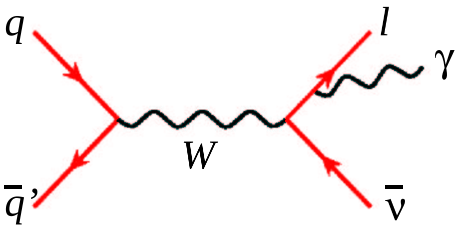
ISR



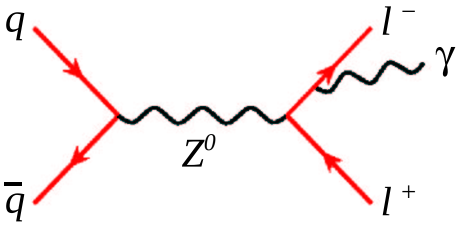


VVγ

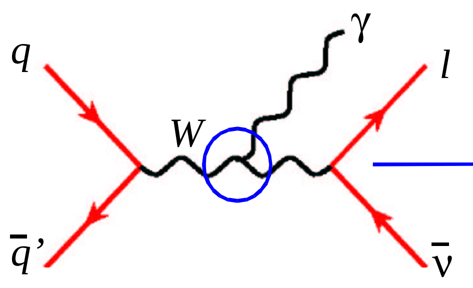




FSR



W/Z+γ : How Might New Physics Manifest Itself ?

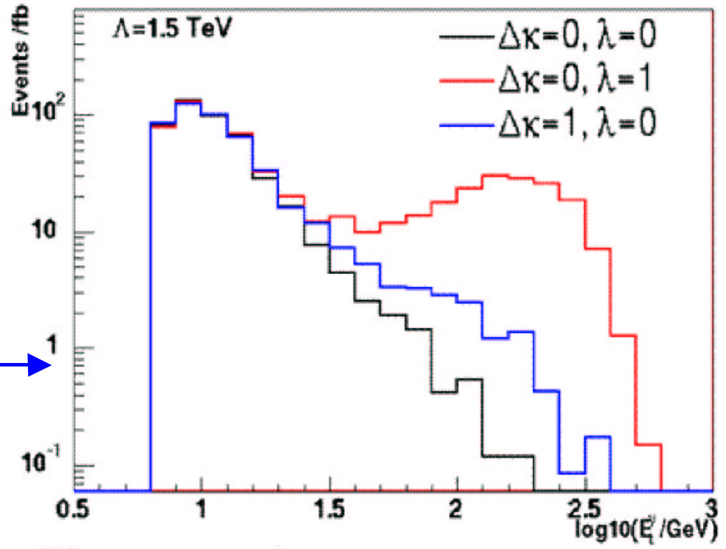


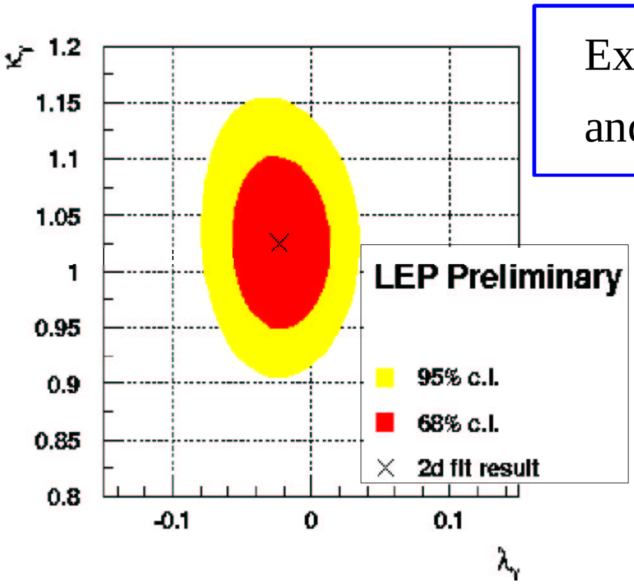
Anomalous couplings : Δκ, λ

$$\mu_W = e(1+\kappa_\gamma+\lambda_\gamma)/2m_W$$

$$q_W = -e(\kappa_\gamma-\lambda_\gamma)/m_W^2$$

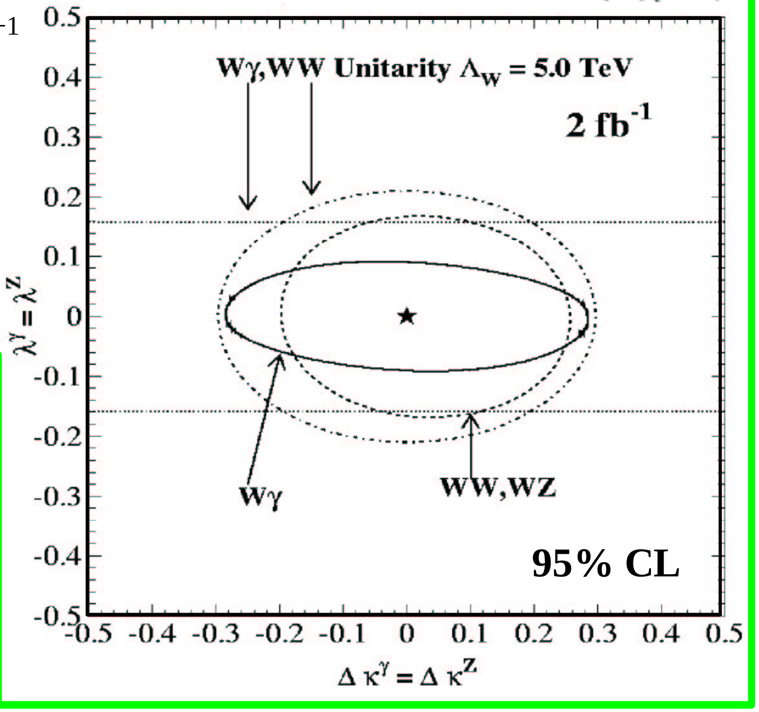
Excess at large photon E_T and ΔR(*l*γ).

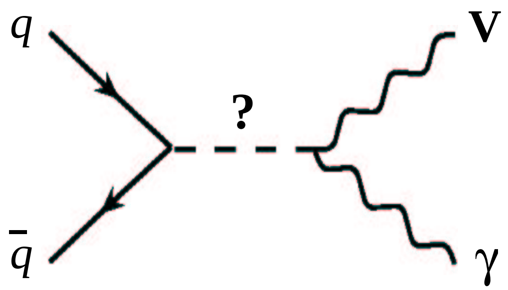




- Tevatron competitive @ high luminosity −few fb^{-1}
- Complementarity :

  $$W \to W\gamma \quad (\text{no } Z)$$
- Probing couplings at higher $\hat{s}$

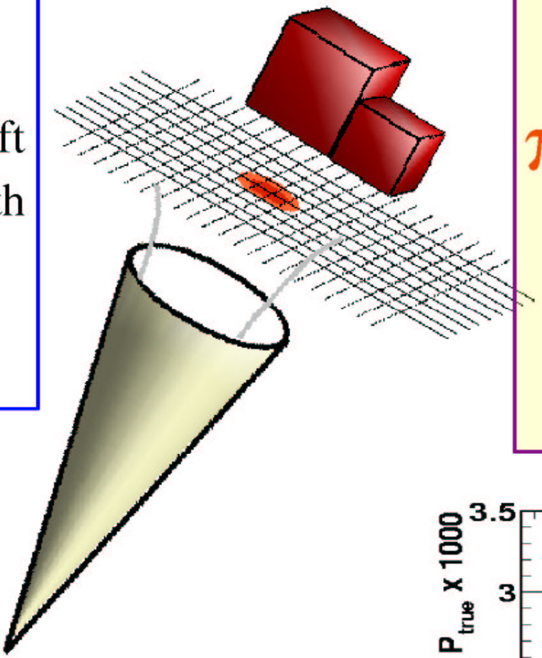


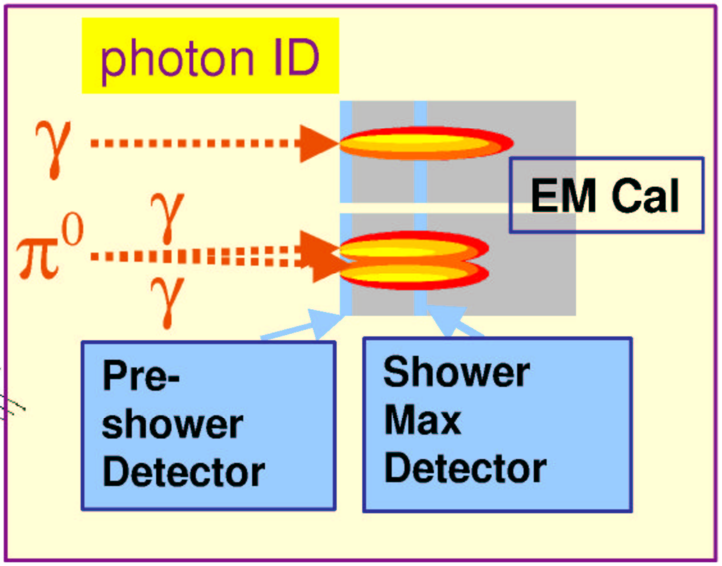


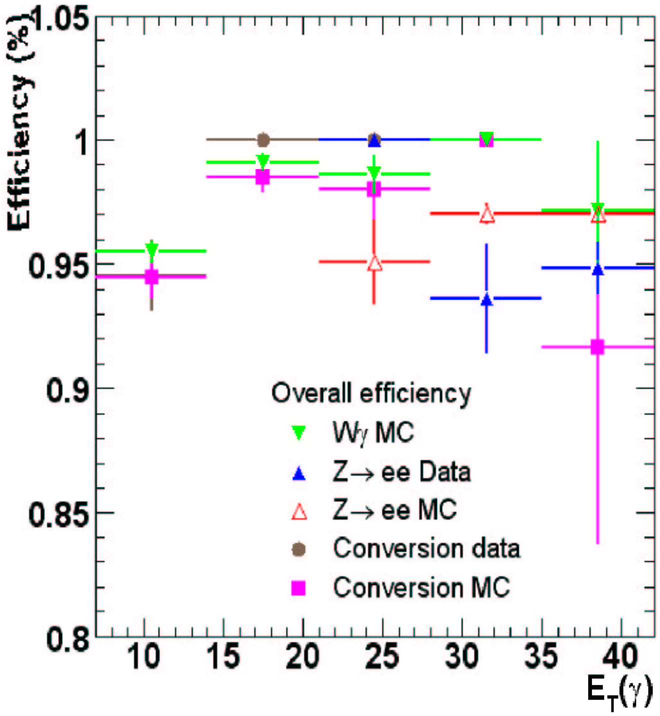
- W*, Z*, *l**, …
- Resonance or high mass excess

W/Z+γ : Photon Identification

- EM cluster with $E_T > 7$ GeV
- $|\eta^{\gamma}| < 1.1$ and $\Delta R(l,\gamma) > 0.7$
- EM fraction consistent with γ
- If ∃ matching track→must be soft
- Well reconstructed cluster in both views of shower- max detector.
- Calorimeter isolation.
- Tracking isolation.

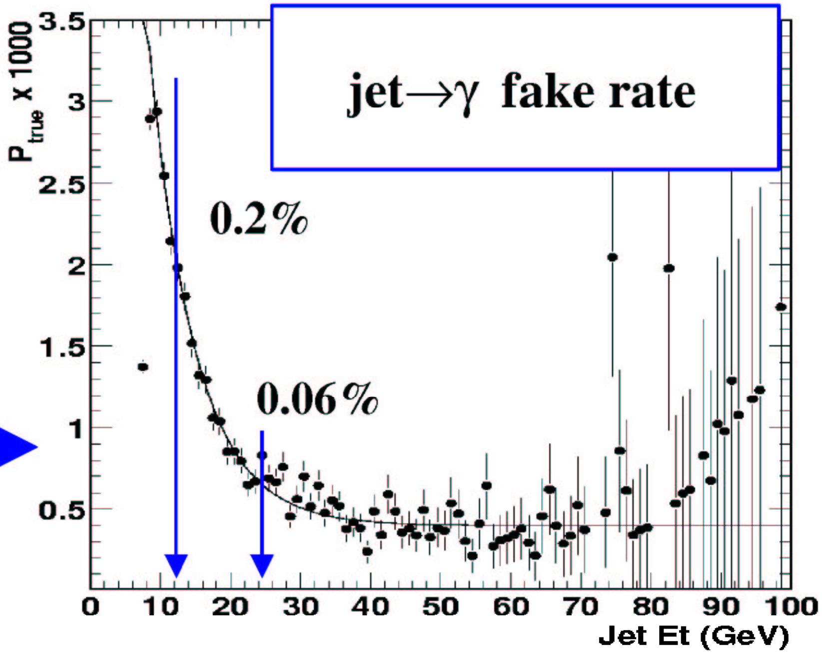






Efficiency
(before iso)

Purity



jet→γ fake rate

W+γ

(1) Select W→lν events :

- Electrons : E_T>25 GeV; $\not{E}_T$>25 GeV
- Muons : E_T>20 GeV; $\not{E}_T$>20 GeV
- 30 < $M_T(l\nu)$ < 120 GeV

(2) Search for additional photons

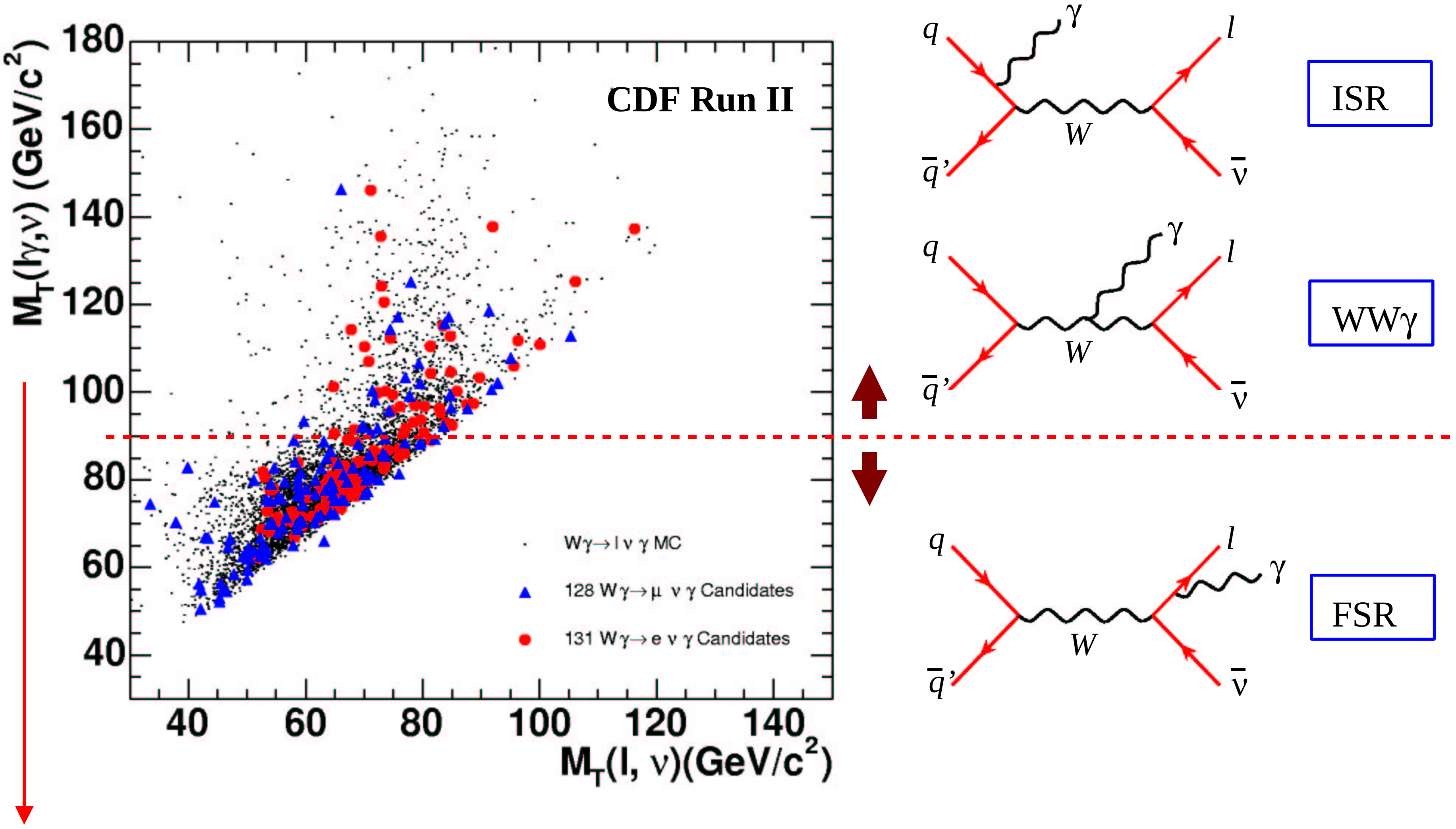
- Use previously described cuts.

	Electron	**Muon**
W+ γ MC	126.8 ± 5.8	95.2 ± 4.9
W+jet BG	59.5 ± 18.1	27.6 ± 7.5
W+ γ (tau)	1.5 ± 0.2	2.3 ± 0.2
Z+ γ	6.3 ± 0.3	17.4 ± 1.0
Total SM	194.1 ± 19.1	142.4 ± 9.5
data	195	128
σ*BR	19.4 ± 2.1 ± 2.9	16.3 ± 2.3 ± 1.8

$$\sigma(\mathbf{W}\gamma) \times \mathbf{BR(W\rightarrow l\nu) = 18.1 \pm 1.6_{STAT} \pm 2.4_{SYST} \pm 1.2_{LUM}\ pb}$$

$$\sigma(W\gamma) \times BR(W\rightarrow l\nu)\ (\mathbf{SM}) = \mathbf{19.3 \pm 1.4}\ pb$$

W+γ



cluster transverse mass : $M_T^2(l\gamma,\not{E}_T) = [(M_{l\gamma}^2 + |\vec{p_T}(l) + \vec{p_T}(\gamma)|^2)^{1/2} + \not{E}_T]^2 - |\vec{p_T}(l) + \vec{p_T}(\gamma) + \vec{\not{E}}_T|^2$

$Z+\gamma$

(1) Select $Z \rightarrow l^+l^-$ events :

- Electrons : $E_T > 25$ GeV, $|\eta^e| < 2.6$
- Muons : $E_T > 20$ GeV, $|\eta^\mu| < 1.0$
- $40 < M(l^+l^-) < 130$ GeV

→

(2) Search for additional photons

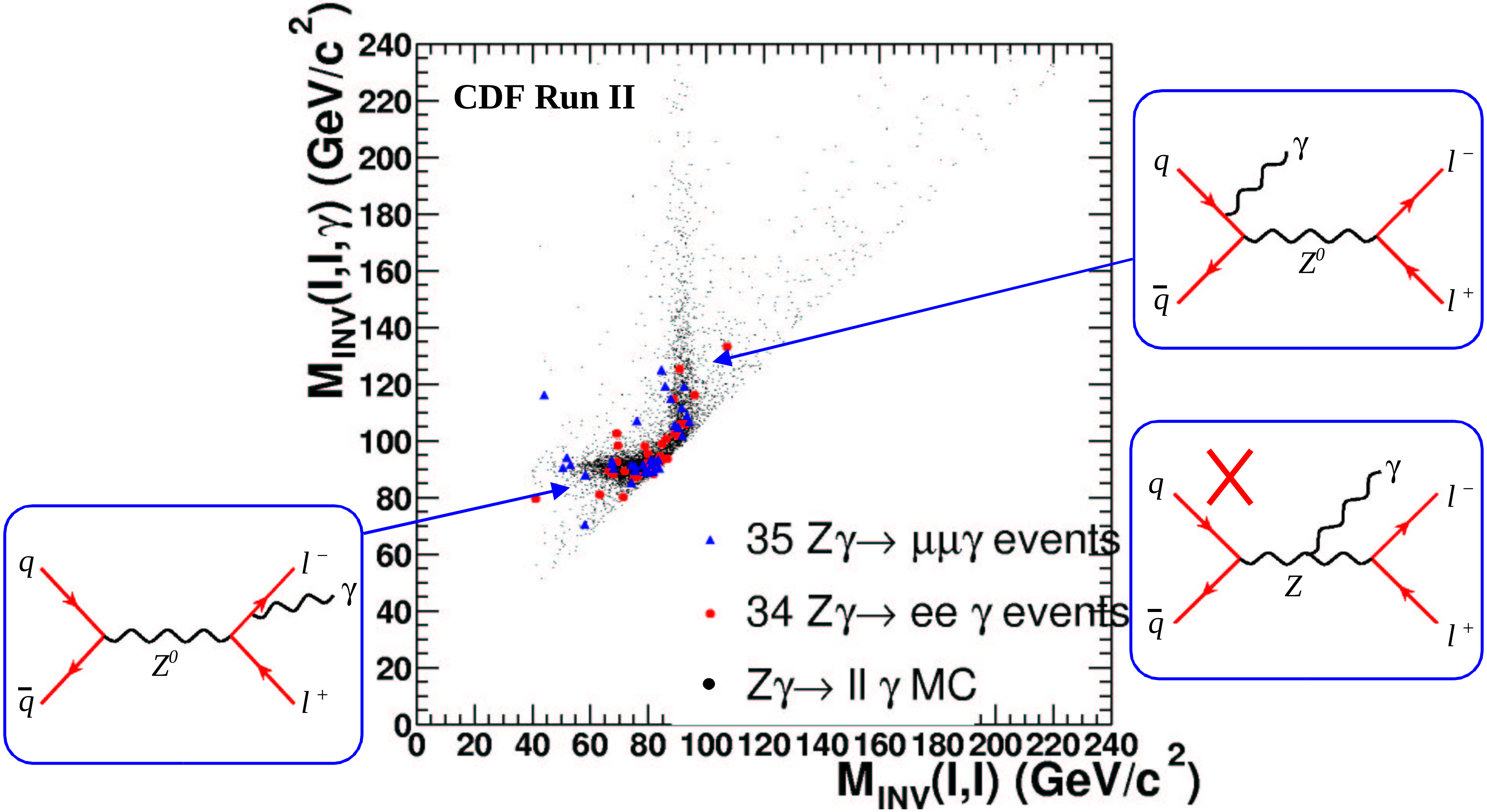
- Use previously described cuts.

	Electron (±sys)	Muon (± sys)
$Z+\gamma$ MC	30.9 ± 1.6	33.2 ± 1.5
Z+jet BG	2.8 ± 0.9	2.1 ± 0.7
Total SM	33.7 ± 1.8	35.3 ± 1.6
data	35	35
σ*BR	4.7 ± 0.8 ± 0.3	4.5 ± 0.8 ± 0.2

$$\sigma(Z\gamma) \times \mathrm{BR}(Z \rightarrow l^+l^-) = 4.6 \pm 0.5_{\mathrm{STAT}} \pm 0.2_{\mathrm{SYST}} \pm 0.3_{\mathrm{LUM}}\ \mathrm{pb}$$

$$\sigma(Z\gamma) \times \mathrm{BR}(Z \rightarrow l^+l^-)\ (\mathbf{SM}) = \mathbf{4.5} \pm \mathbf{0.3}\ \mathrm{pb}$$

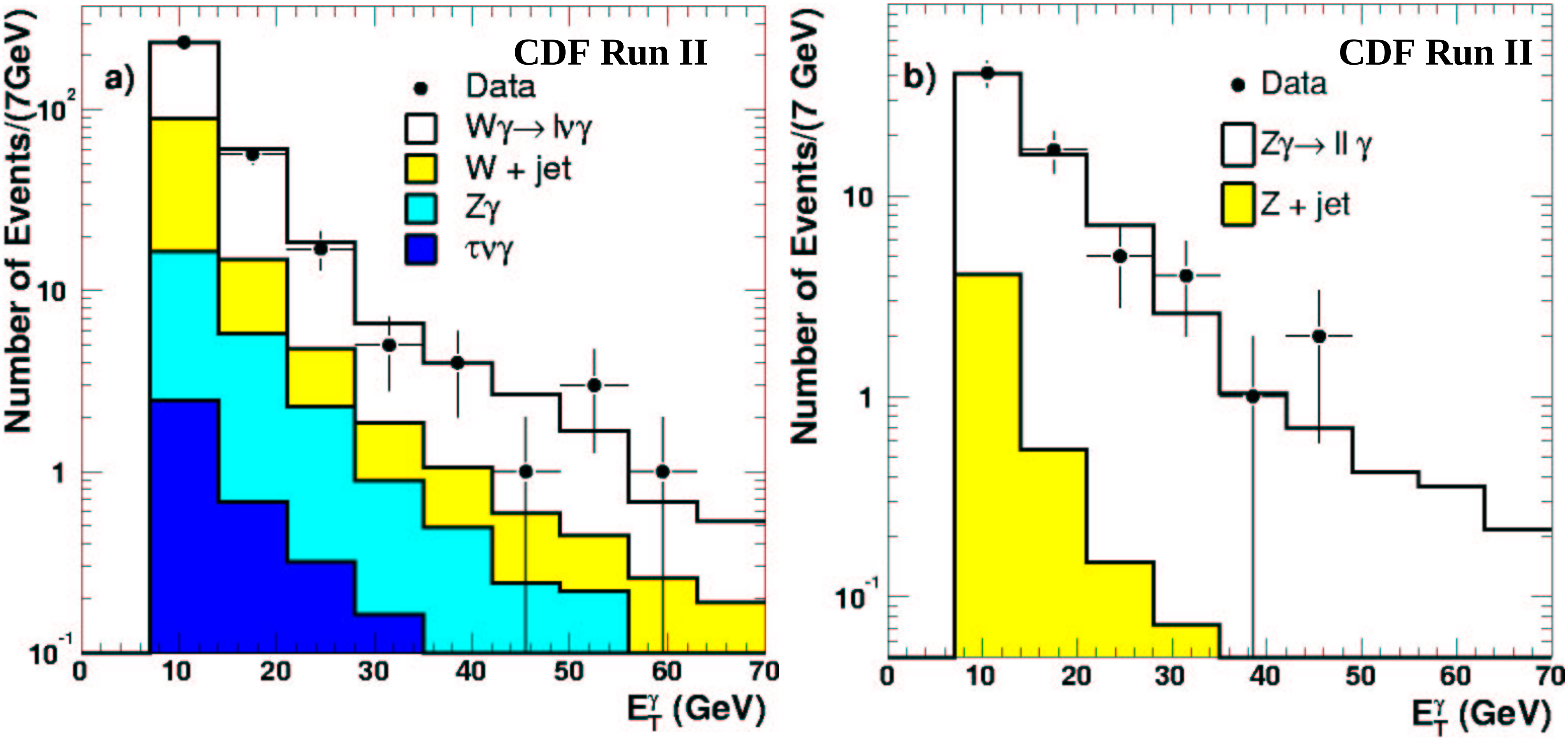
Z+γ


CDF Run II
$M_{INV}(l,l,\gamma)$ (GeV/c^2)
$M_{INV}(l,l)$ (GeV/c^2)
0
20
40
60
80
100
120
140
160
180
200
220
240
35 Zγ→ μμγ events
34 Zγ→ ee γ events
Zγ→ ll γ MC
q
$\bar{q}$
l^-
l^+
γ
Z^0
q
$\bar{q}$
l^-
l^+
γ
Z^0
q
$\bar{q}$
l^-
l^+
γ
Z

W/Z+γ : Kinematic Distributions

W(γ)→lνγ

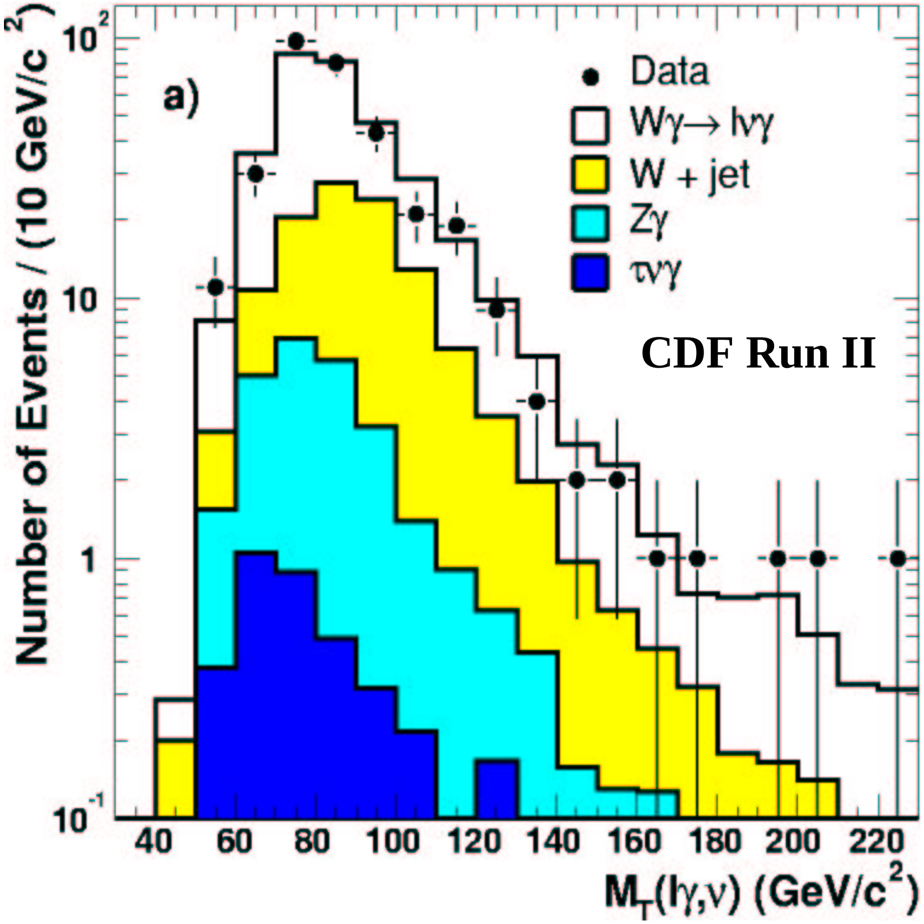
Z(γ)→l⁺l⁻γ



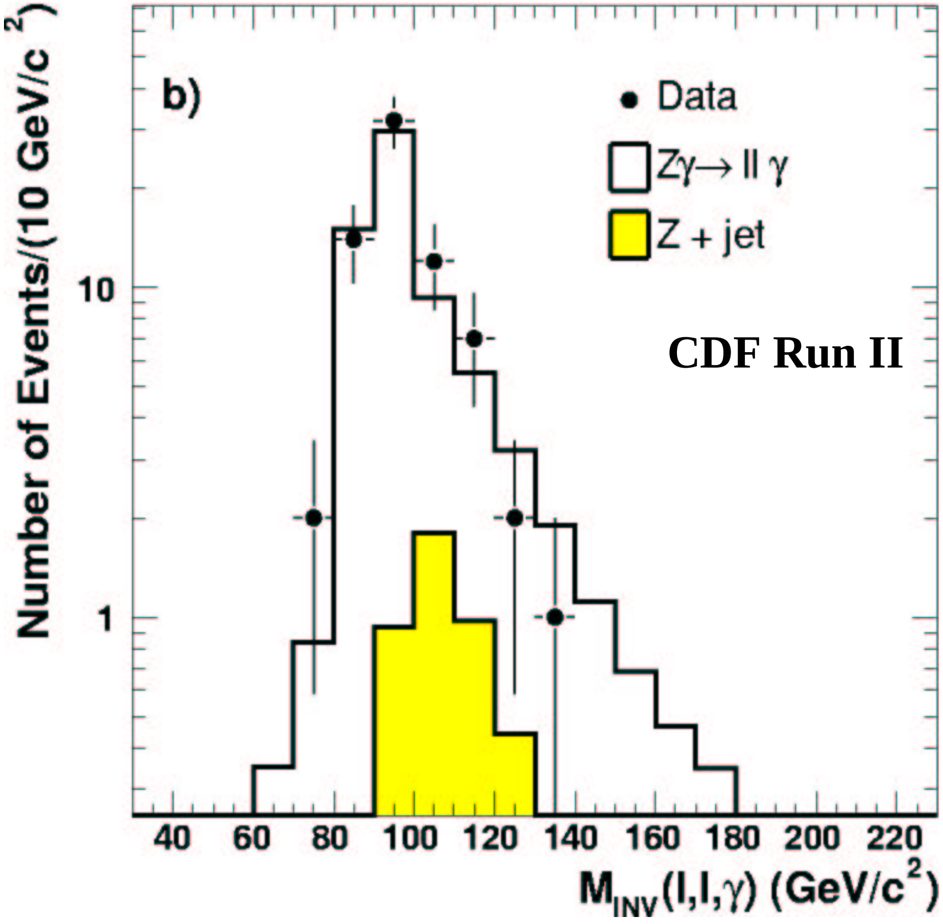
- Data agree well with SM prediction.
- These distributions sensitive to anomalous WWγ and ZZγ couplings.

W/Z+γ : Kinematic Distributions

$W(\gamma)\rightarrow l\nu\gamma$



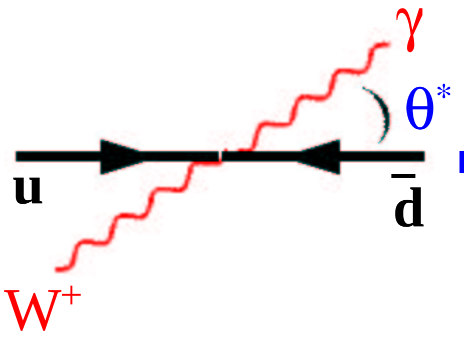
$Z(\gamma)\rightarrow l^+l^-\gamma$



- Data agree well with SM prediction.
- No hint of new physics/resonances at high mass.

W/Z+γ : Testing EWK SM

Radiation Amplitude Zero :

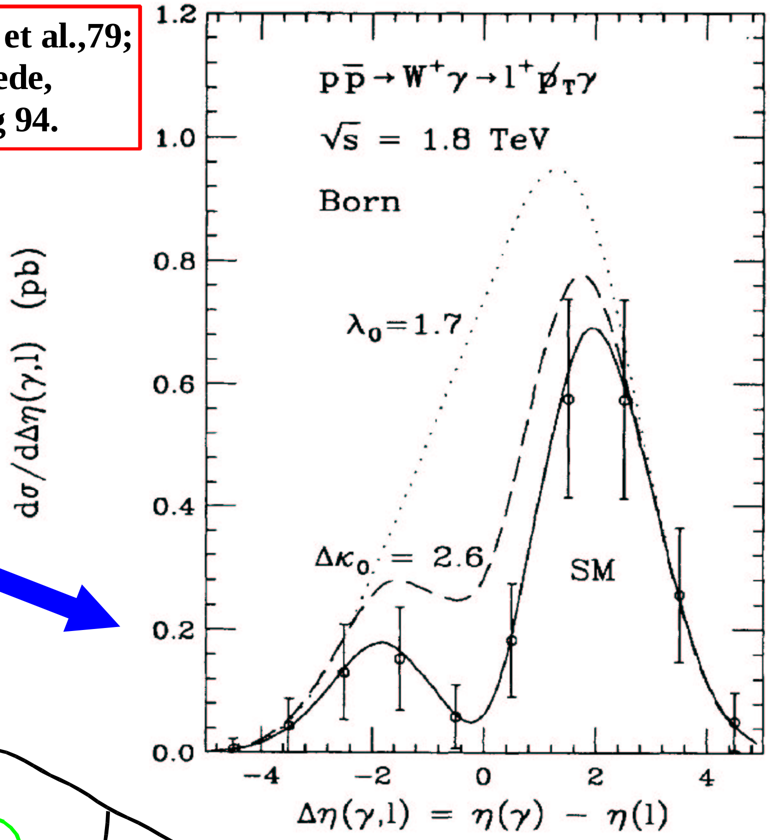


Mikaelain et al.,79; Baur, Errede, Landsberg 94.

$$\left| A^{t(ISR)}+A^{WW\gamma} \right| = 0$$

@ cosθ* = –1/3

observable as γ–lepton rapidity correlation

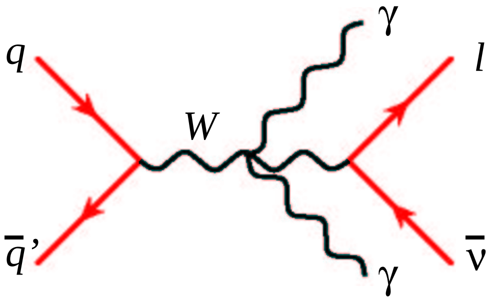


Cross−Section Ratios :

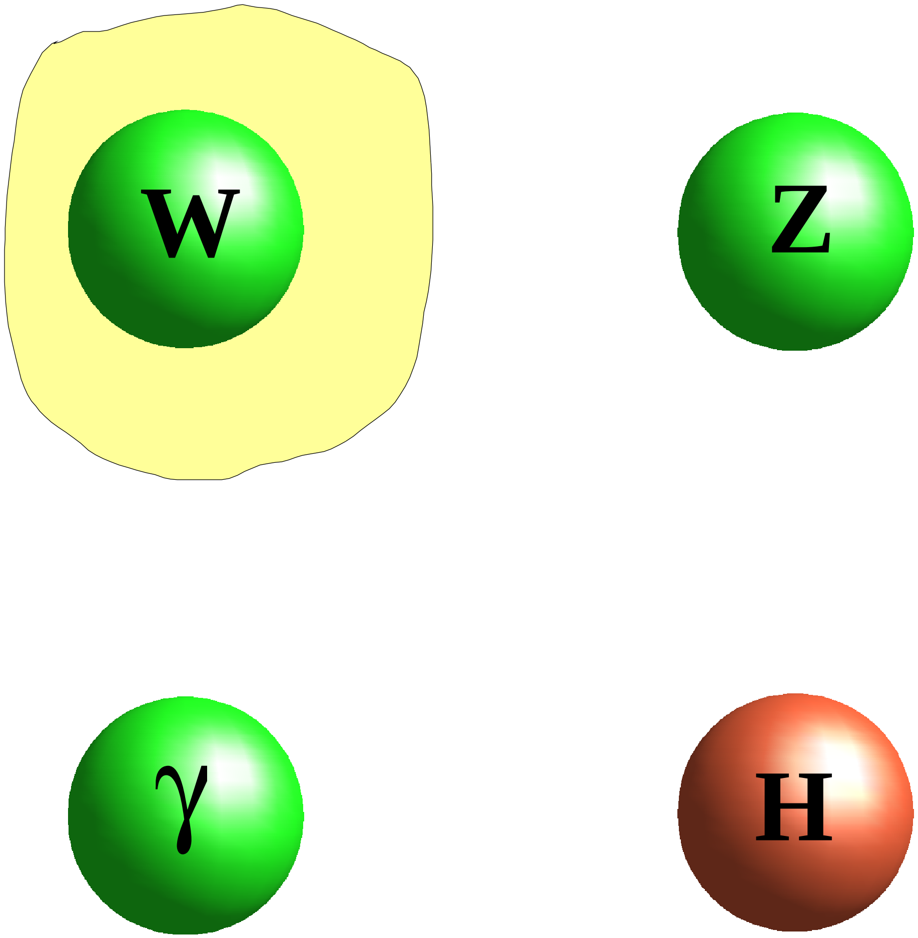
inclusive : $$1/R = \frac{\sigma(Z)\times BR(Z\rightarrow l^+l^-)}{\sigma(W)\times BR(W\rightarrow l\nu)} = 9.16 \pm 0.18\ \%$$

radiative : $$1/R = \frac{\sigma(Z\gamma)\times BR(Z\rightarrow l^+l^-)}{\sigma(W\gamma)\times BR(W\rightarrow l\nu)} = 25 \pm 5\ \%$$

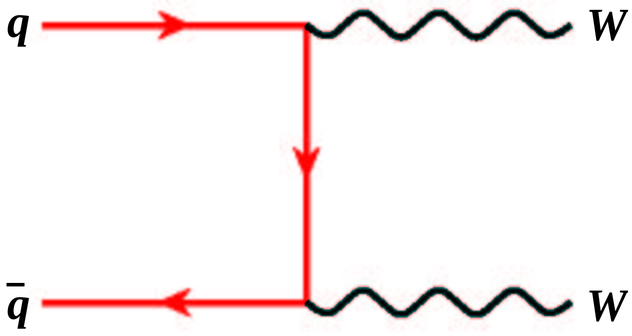
Quartic Couplings :

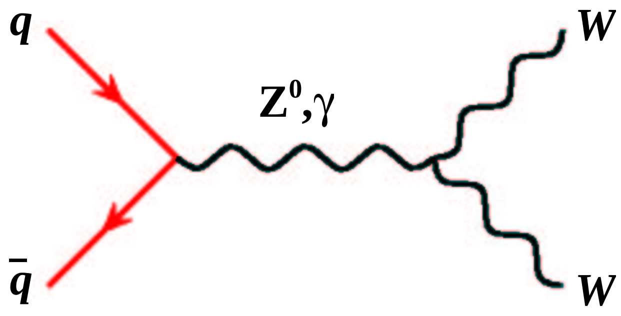


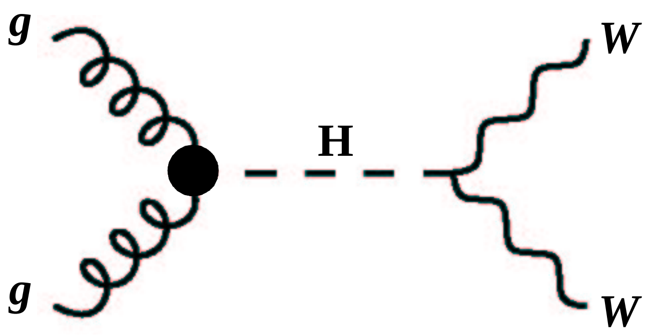
- $\gamma\gamma$
- W/Z + γ
- **WW**
- WZ/ZZ
- H→WW

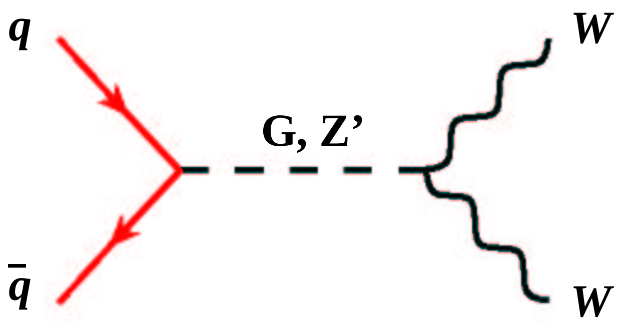


WW : Why ?







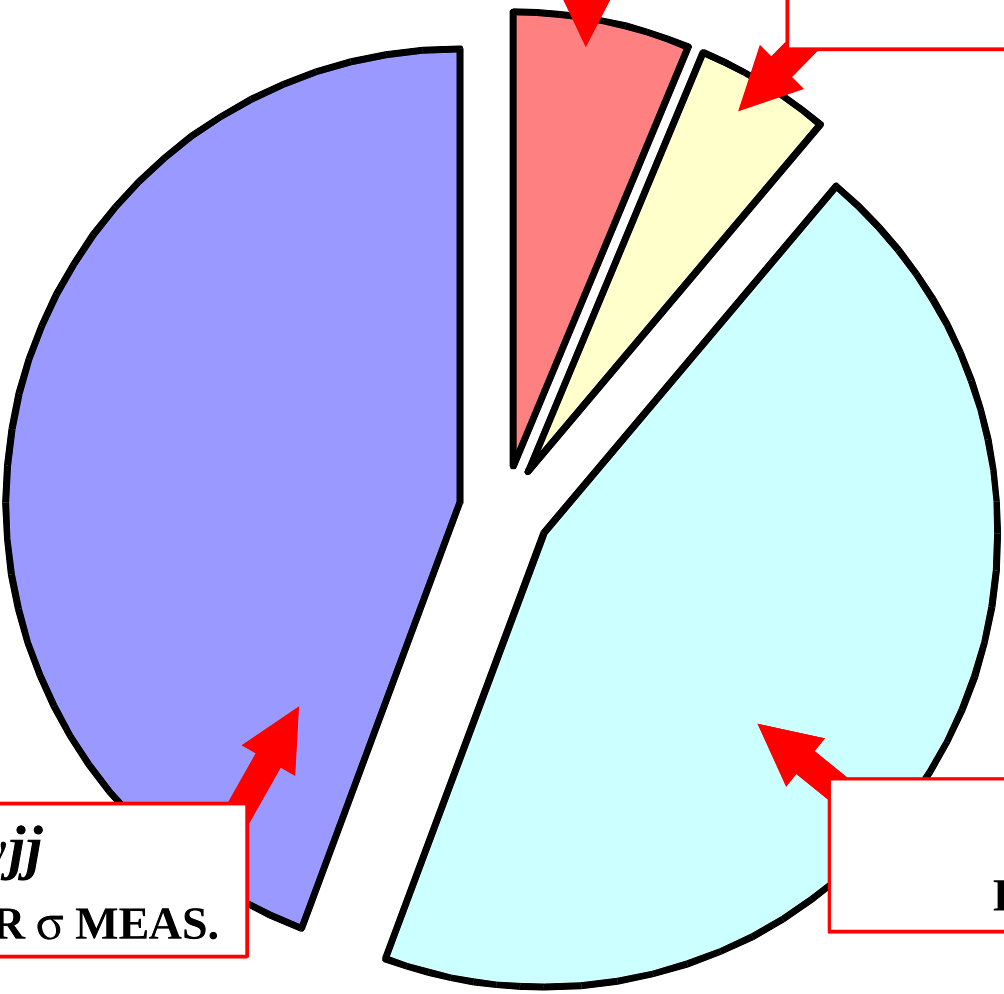


- Detected with very limited significance in Run I @ CDF : 5 events observed with 1.2 ± 0.3 background :

$$\sigma\left(WW\right) = 10.2^{+6.3}_{-5.1} \pm 1.6 \text{ pb}$$

- Many interesting tests of the Standard Model are possible.
- Critical channel @ LHC (background & signal).

WW : Decay Channels



$WW\rightarrow\tau\nu l\nu$ ($l=e,\mu$)

LOW BR × EFFICIENCY

$WW\rightarrow l\nu l\nu$ ($l=e,\mu$)

BR ≈ 5%

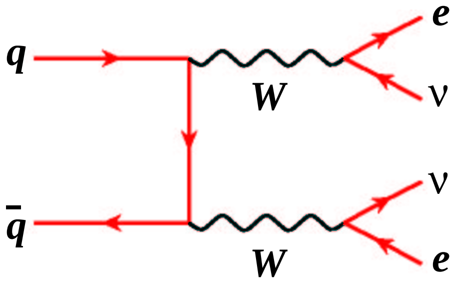
$WW\rightarrow l\nu jj$

DIFFICULT FOR σ MEAS.

$WW\rightarrow jjjj$

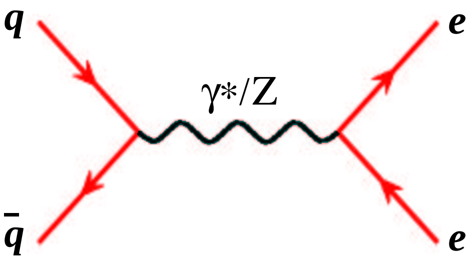
IMPOSSIBLE

WW : Backgrounds



<u>Signal:</u>

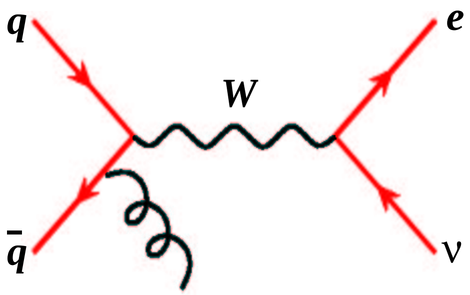
$\sigma(p\bar{p}\rightarrow WW\rightarrow e\nu e\nu) \sim 0.15$ pb



<u>Drell−Yan :</u>

$\sigma(p\bar{p}\rightarrow\gamma^{*}/Z\rightarrow ee) \sim 250$ pb

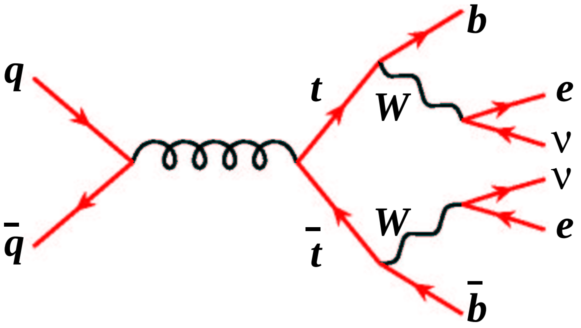
Must have "fake" missing−E_T.



<u>W+jets :</u>

$\sigma(p\bar{p}\rightarrow W(\rightarrow e\nu)+\geq 1\text{−jet}) \sim 500$ pb

Jet must fake a lepton.



<u>$t\bar{t}$:</u>

$\sigma(p\bar{p}\rightarrow t\bar{t}\rightarrow e\nu e\nu b\bar{b}) \sim 0.1$ pb

Contains additional jets.

WW : Analysis Strategies

- Central electron/muon & plug electron triggers.
- An isolated E_T>20 GeV lepton(e or μ) with full identification criteria applied :
  - central : $|\eta^{e,\mu}| < 1.0$; plug :$1.1 < |\eta^{e}| < 2.5$
- $\not{E}_T > 25$ GeV.

- Second isolated E_T>20 GeV lepton (e or μ) with full identification criteria applied.
- Topological cuts (mainly MET−significance) to remove Drell−Yan events; applied only to like−flavour leptons with $76 < M(l^+l^-) < 106$ GeV.
- Remove top background by requiring no additional jets.

"**DILEPTON**"

- **high purity**

- Second isolated track with P_T>20 GeV/c.
- Topological cuts (mainly MET−significance) to remove Drell−Yan events.
- Allow 0−jet and 1−jet events.

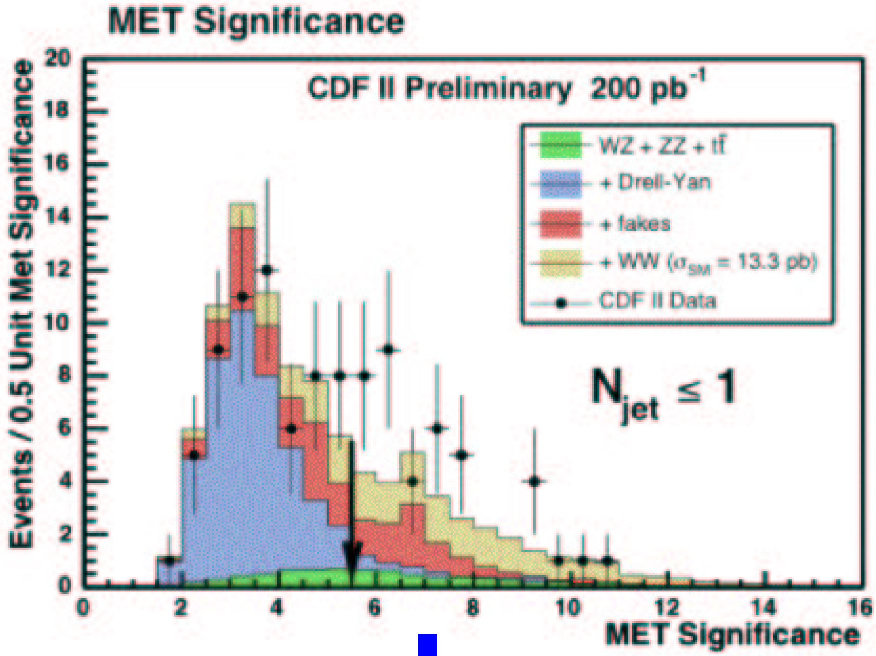
"**LEPTON + TRACK**"

- **lower purity**
- **additional acceptance (1−jet bin; 1−prong tau decays)**

WW : Drell−Yan Background

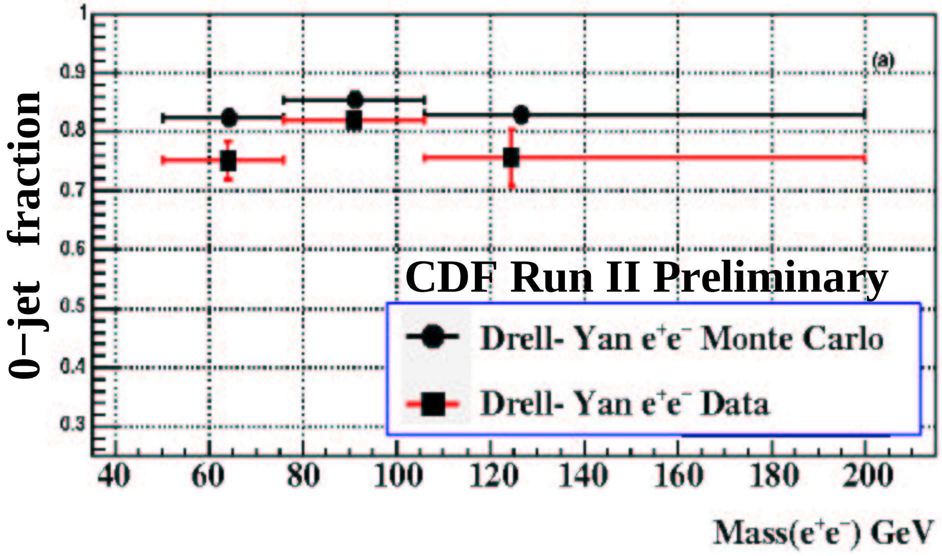
- Background due to large / mis−measured $\not{E}_T$.
- Reject events consistent with $\not{E}_T$ being a fluctuation of the total transverse energy flow :

$$\not{E}_T - \text{significance} = \frac{\not{E}_T}{\Sigma E_T}$$

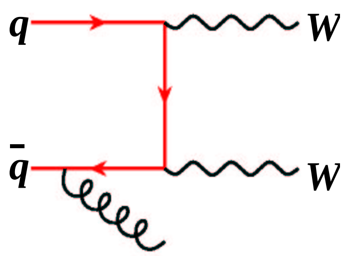


- May not be well described by Monte Carlo − estimate DY background using data−based methods.

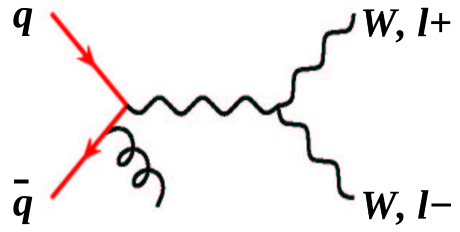
- Drell−Yan is also the most important control sample in this analysis.
- For example, measuring the rate of production of additional jets :



WW

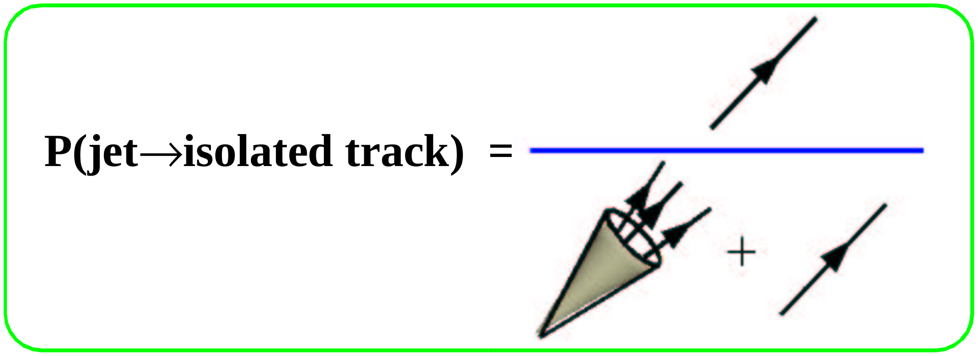


WW & Drell−Yan

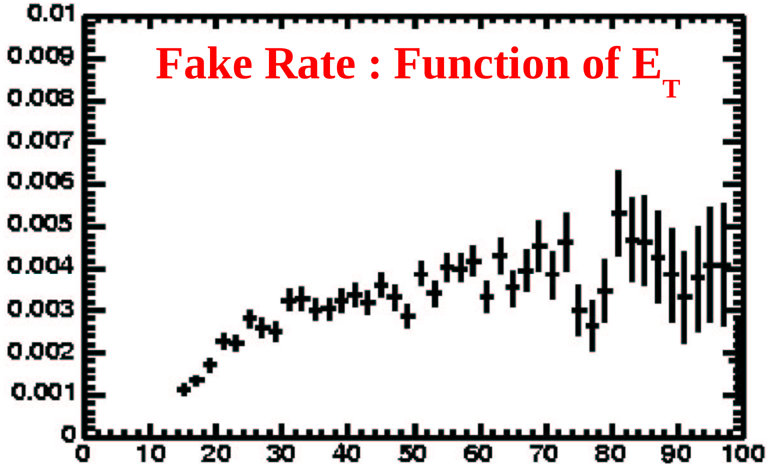


WW : Fake Background

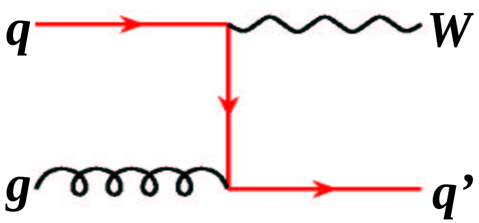
- Mainly from W+jet(s) events.
- Additional fake lepton due to jet fragmentation fluctuations, punch−through, heavy quark decays, photon conversions etc.
- Measure "fake rates" in jet samples :



P(jet→isolated track) =



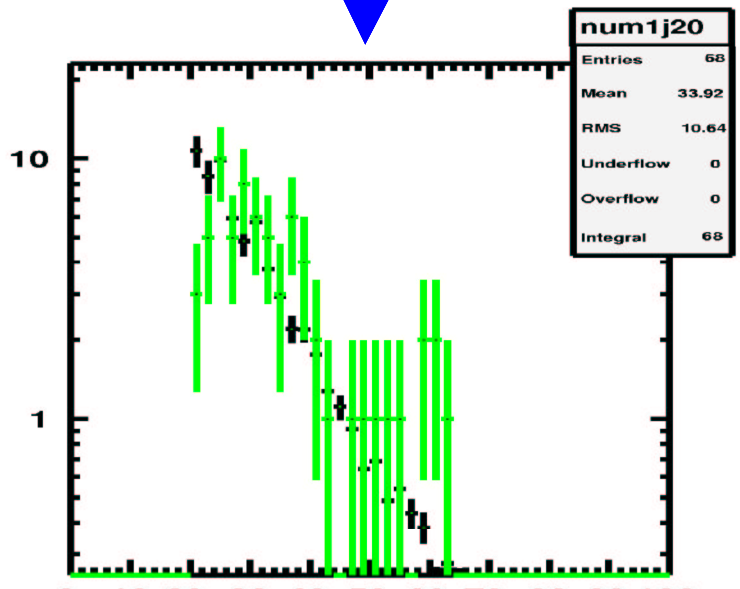
- Apply fake rates to events that contain 1 lepton and 1 jet but which are identical in all other respects to WW events.
- Correct for some subtle effects such as charge correlations :



Check : apply Jet50 rates to Jet20 sample

● = predicted

🟢 = measured



WW : Results

	DILEPTON	LEPTON+TRACK (STAT ERR.)
WW Signal	11.3 ± 1.3	16.3 ± 0.4
Drell–Yan Background	1.8 ± 0.4	1.8 ± 0.3
Fake Background	1.1 ± 0.5	9.1 ± 0.8
Other Background	1.9 ± 0.2	4.2 ± 0.1
Total Background	4.8 ± 0.7	15.1 ± 0.9
Total Expected	16.1 ± 1.6	31.5 ± 1.0
Data Observed	17	39
σ(WW) [pb]	$14.3^{+5.6}_{-4.9}\,(\mathrm{stat})\pm1.6\,(\mathrm{syst})\pm0.9\,(\mathrm{lum})$	$19.4\pm5.1\,(\mathrm{stat})\pm3.5\,(\mathrm{syst})\pm1.2\,(\mathrm{lum})$

- Two measurements statistically consistent given estimated acceptance overlap.
- ~ 3σ significance.

$$\boxed{\sigma(WW)^{\mathrm{THEORY}}_{\mathrm{NLO}} = 12.4 \pm 0.8 \;\; \mathrm{pb}}$$

WW : Systematics

Backgrounds

Uncertainties large for instrumental and fake backgrounds :

- Drell−Yan (fake $\not{E}_T$) : ~ 40 %
- W+jets (fake lepton) : ~ 40 – 50%

$$\sigma(WW) = \frac{N_{\mathrm{DATA}} - N_{\mathrm{BKG}}}{\epsilon \times L \times BR(WW \rightarrow l\nu l\nu)}$$

Selection Efficiency

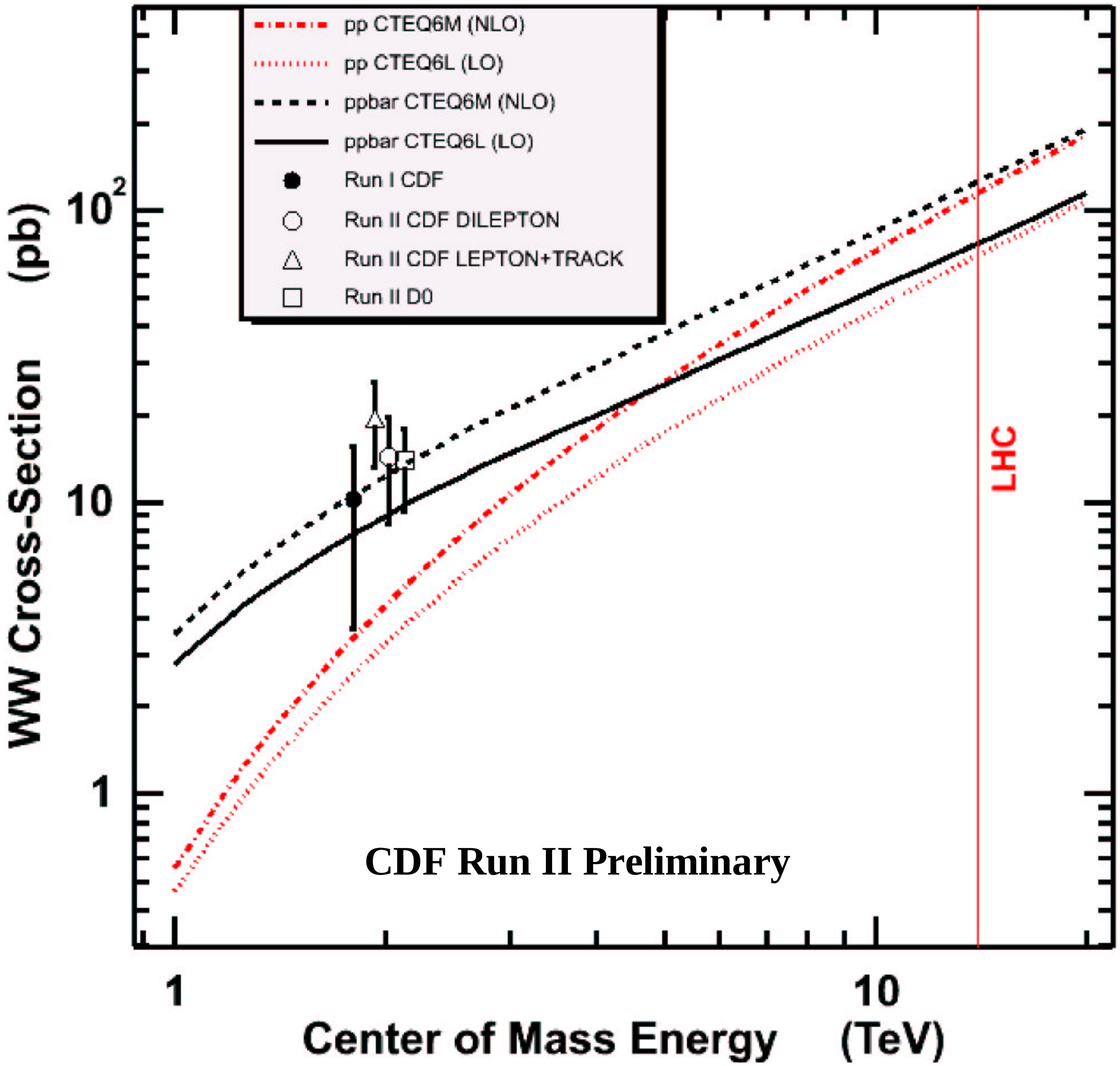
~10%

- signal modelling
- acceptance & identification uncertainties

Luminosity

6%

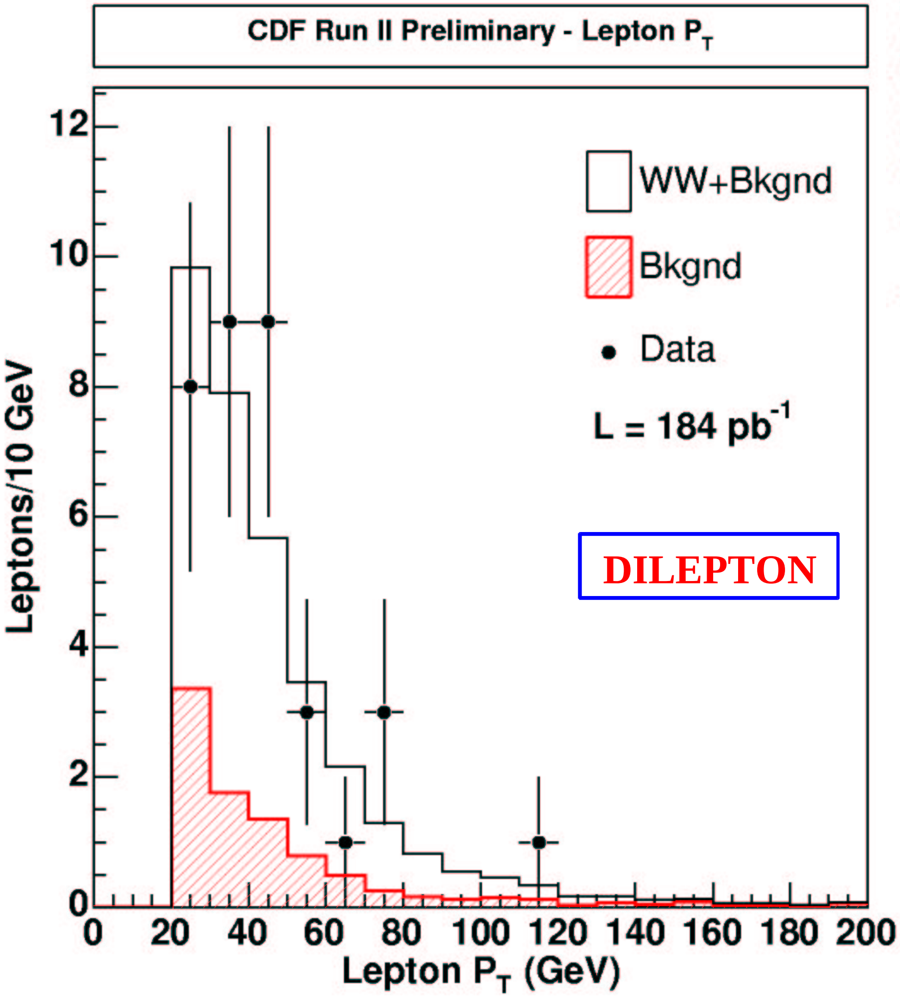
WW : Results

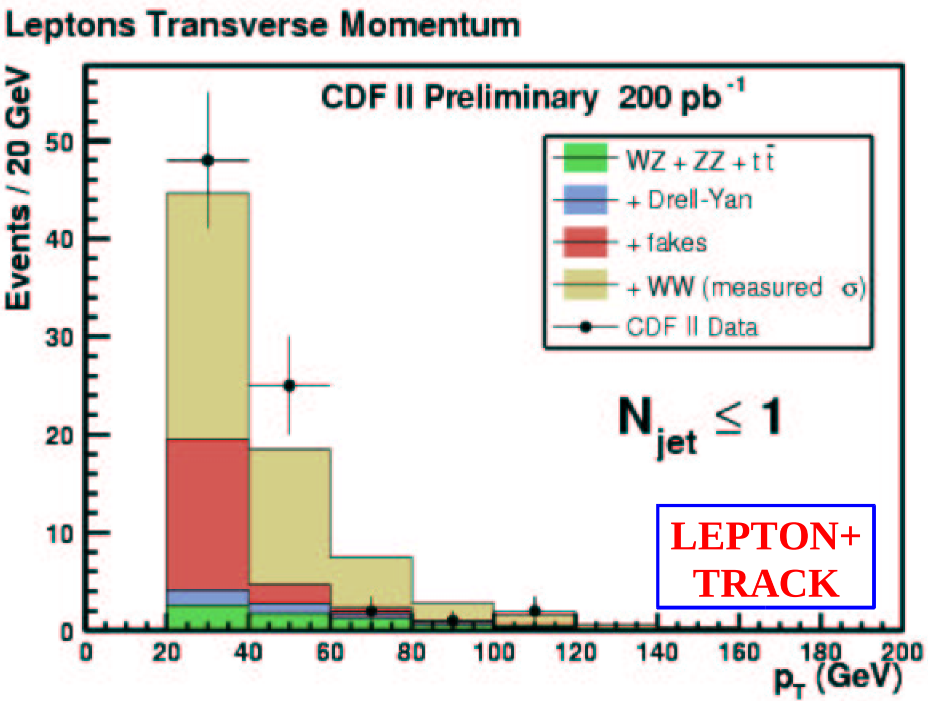


CDF Run II Preliminary

NLO Prediction @ 1.96 TeV : 12.4 ± 0.8 pb

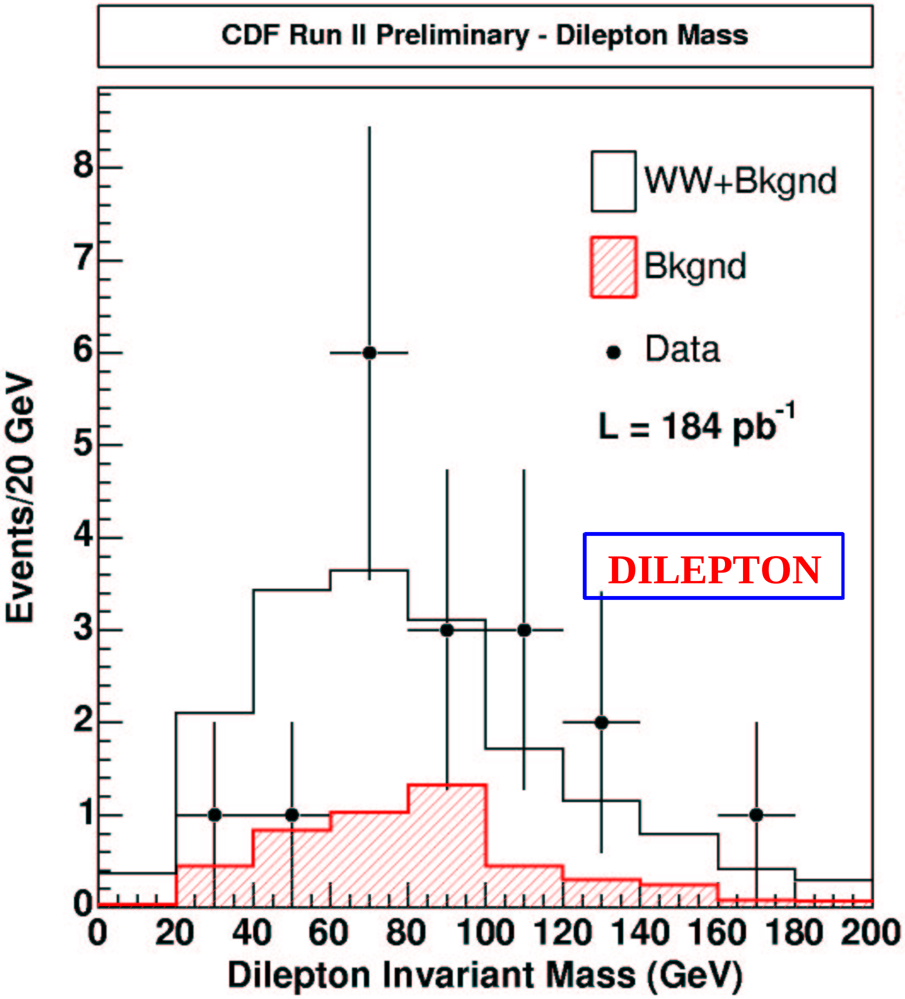
WW : Kinematic Distributions

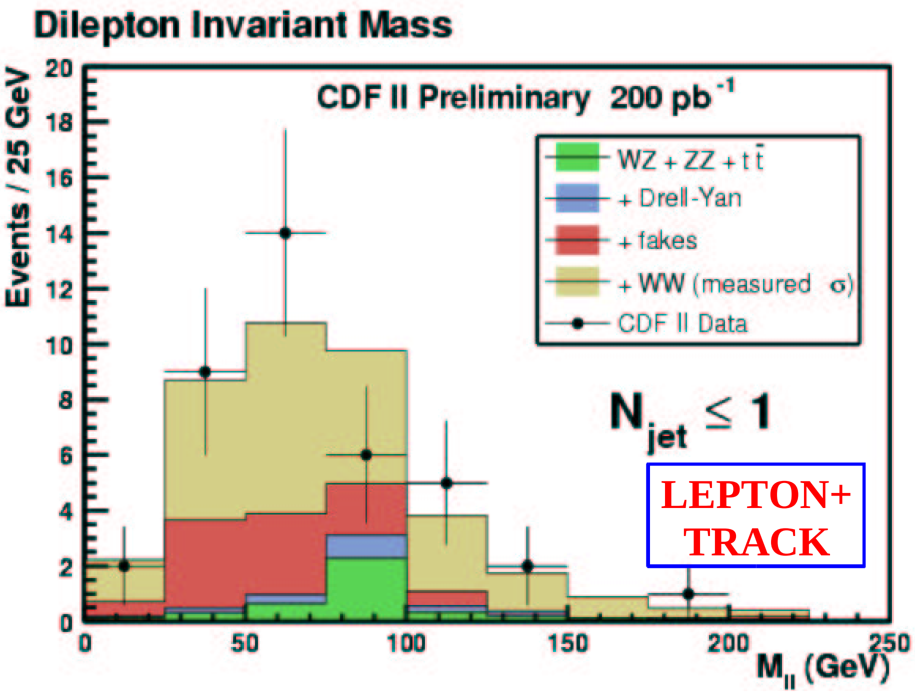




- Good agreement with signal plus background expectation.
- These distributions are being fitted to extract anomalous coupling limits.

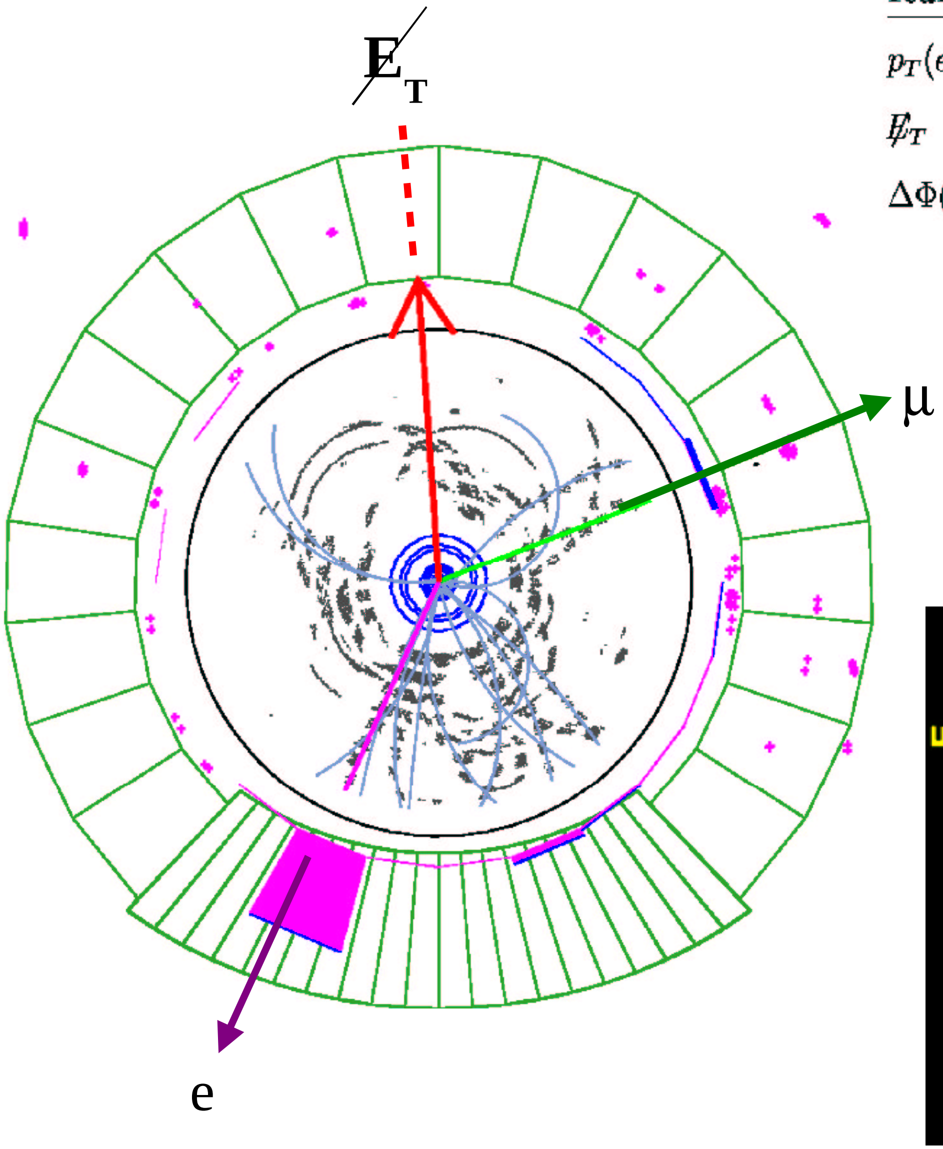
WW : Kinematic Distributions





- No sign of unexpected structure in dilepton mass distributions.

WW : Events



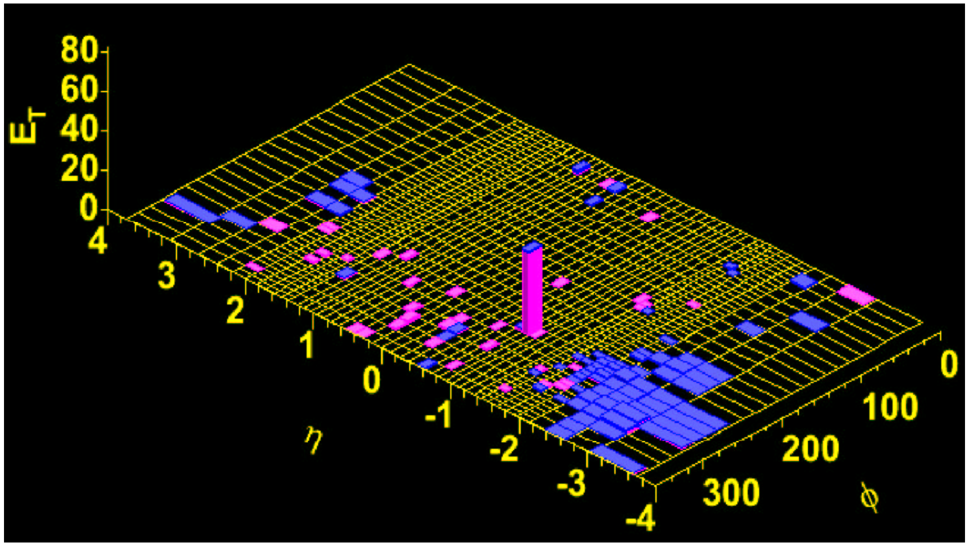
Run 155364 Event 3494901 : $WW \to e^+\nu_e\mu^-\bar{\nu}_\mu$ Candidate

$p_T(e) = 42.0$ GeV/c; $p_T(\mu) = 20.0$ GeV/c; $M_{e\mu} = 81.5$ GeV

$\not\!E_T = 64.8$ GeV; $\Phi(\not\!E_T) = 1.6$

$\Delta\Phi(\not\!E_T$, lepton$) = 1.3$; $\Delta\Phi(e,\mu) = 2.4$; Opening-Angle(e,μ)=2.6

- eμ channel has little Standard Model background
- Signal/Background ≈ 4

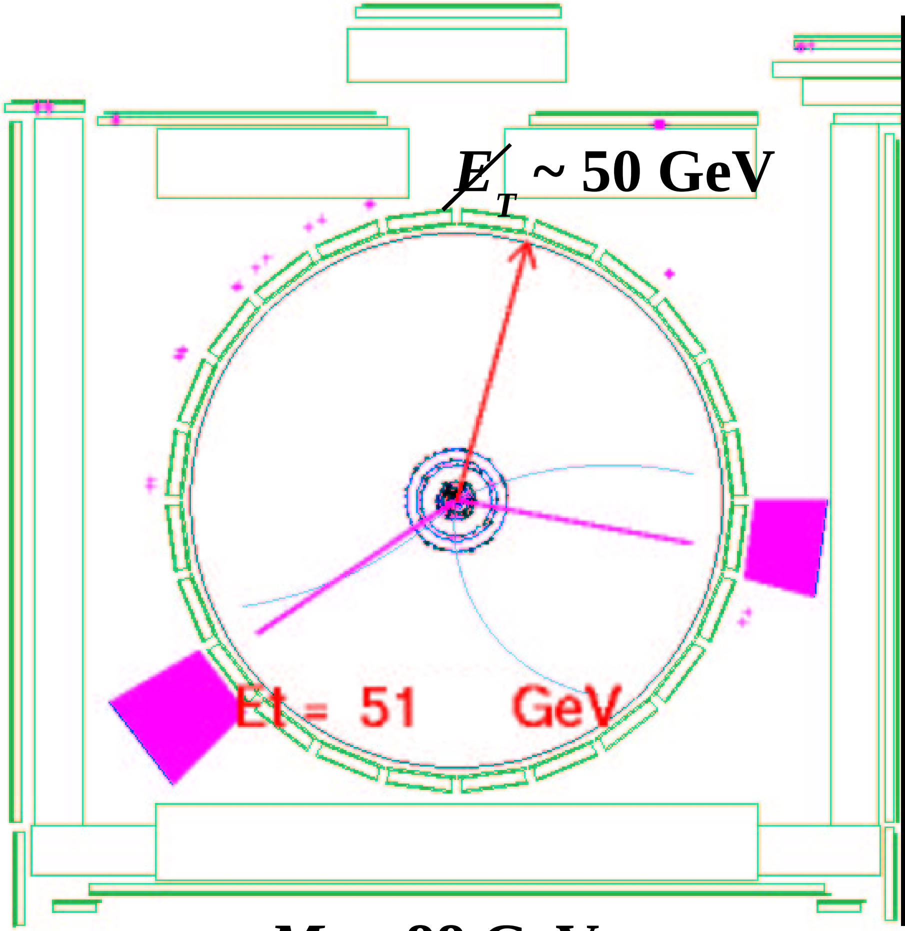


WW : Events

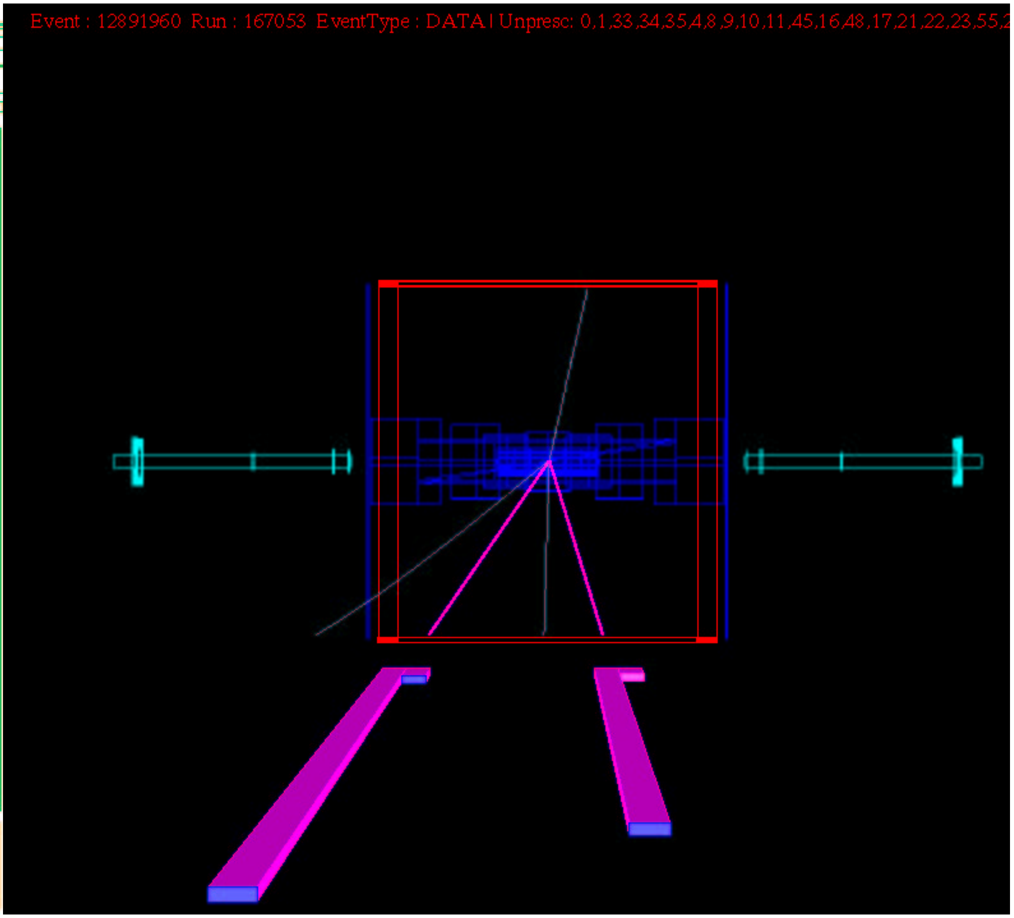
$W^+W^- \to e^+e^-\nu\bar{\nu}$?

... or ...

$Z^0Z^0 \to e^+e^-\nu\bar{\nu}$?

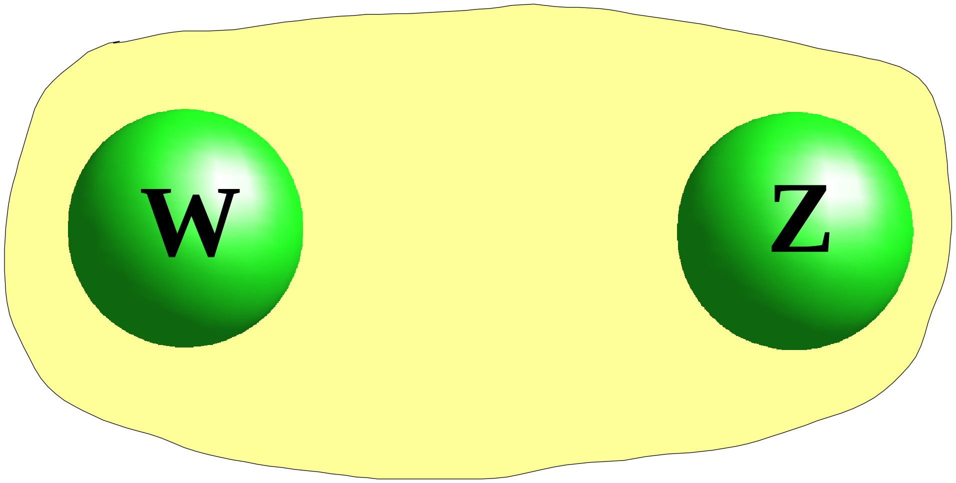


$\not{E}_T$ ~ 50 GeV

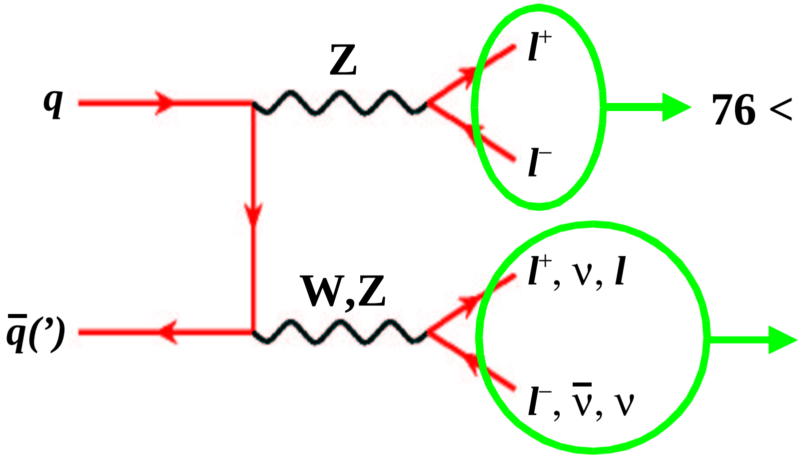


M_{ee} = 88 GeV

- $\gamma\gamma$
- W/Z + γ
- WW
- **WZ/ZZ**
- H→WW



ZZ+ZW



76 < M(l^+l^-) < 106 GeV

l^+l^- : 76 < M(l^+l^-) < 106 GeV

$l\,\nu$: lepton + $\not{E}_T$ > 20 GeV

$\nu\bar{\nu}$: large $\not{E}_T$−significance

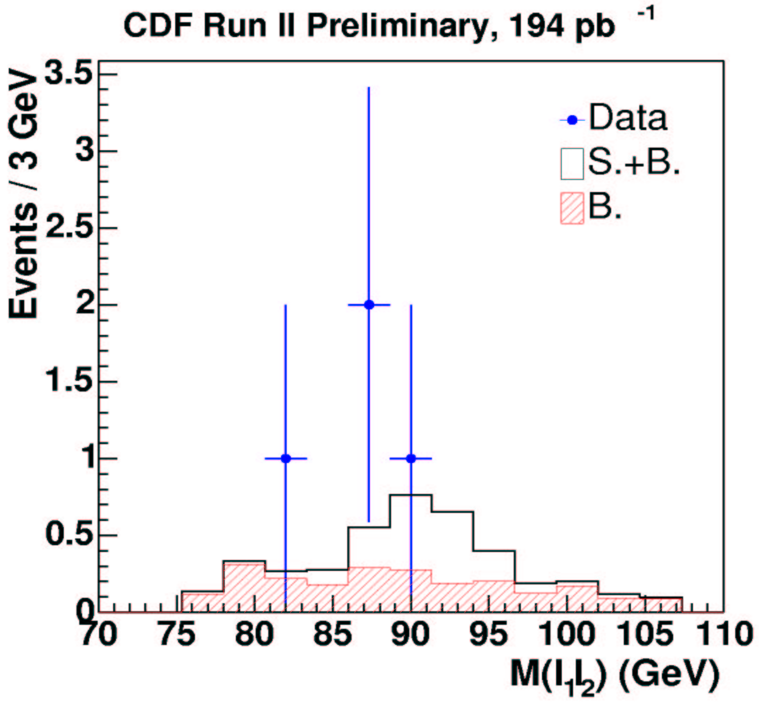
CDF Run II Winter 2004 Preliminary, $\mathcal{L}$=194 pb^{-1}

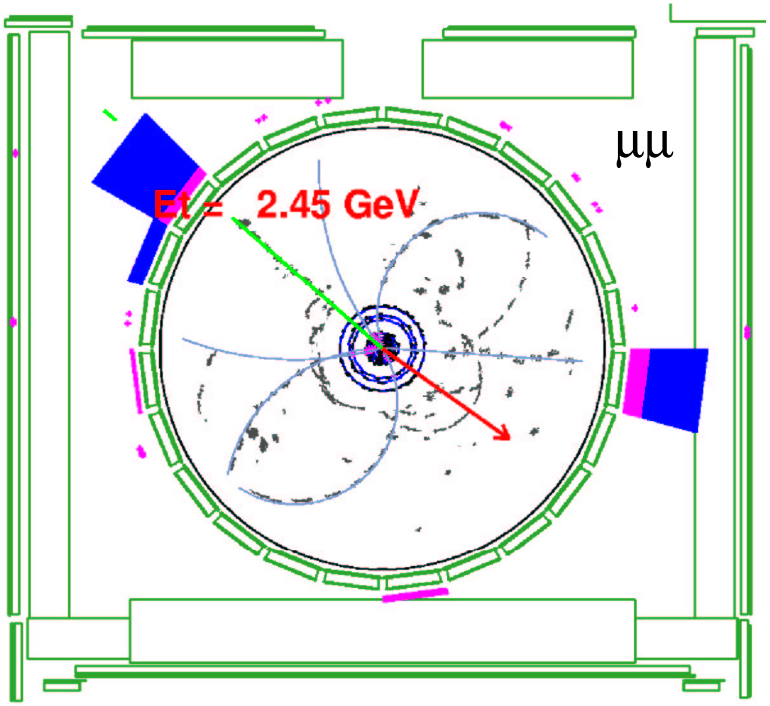
Process	$l_1 l_2 l_3 l_4$	$l_1 l_2 l_3 \not{E}_T$	$l_1 l_2 \not{E}_T$	Combined
ZZ	0.07 ± 0.01	0.13 ± 0.01	0.87 ± 0.14	1.07 ± 0.15
ZW	-	0.81 ± 0.07	0.86 ± 0.14	1.67 ± 0.19
ZZ+ZW	0.07 ± 0.01	0.94 ± 0.08	1.73 ± 0.27	2.72 ± 0.33
WW	-	-	1.26 ± 0.20	1.26 ± 0.20
Fake	0.01 ± 0.02	0.07 ± 0.06	0.56 ± 0.30	0.64 ± 0.34
Drell-Yan	-	-	0.31 ± 0.13	0.31 ± 0.13
$t\bar{t}$	-	-	0.08 ± 0.02	0.08 ± 0.02
Total Background	0.01 ± 0.02	0.07 ± 0.06	2.21 ± 0.38	2.29 ± 0.42
Expected S. + B.	0.08 ± 0.02	1.01 ± 0.10	3.94 ± 0.57	5.01 ± 0.64
Data	0	0	4	4

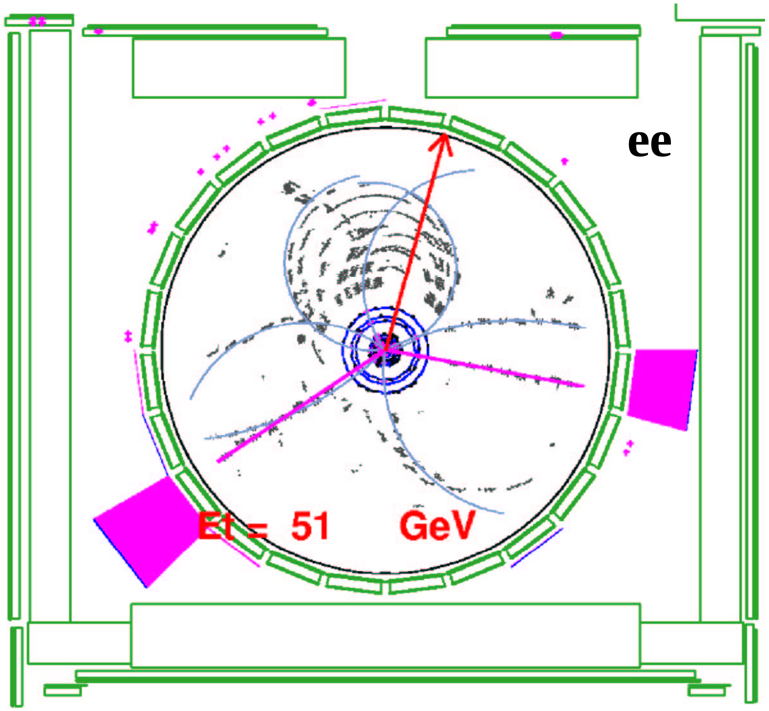
ZZ+ZW

$$\sigma\left(p\bar{p}\rightarrow ZZ/ZW+X\right) \ < \ 13.9 \quad \mathrm{pb}$$

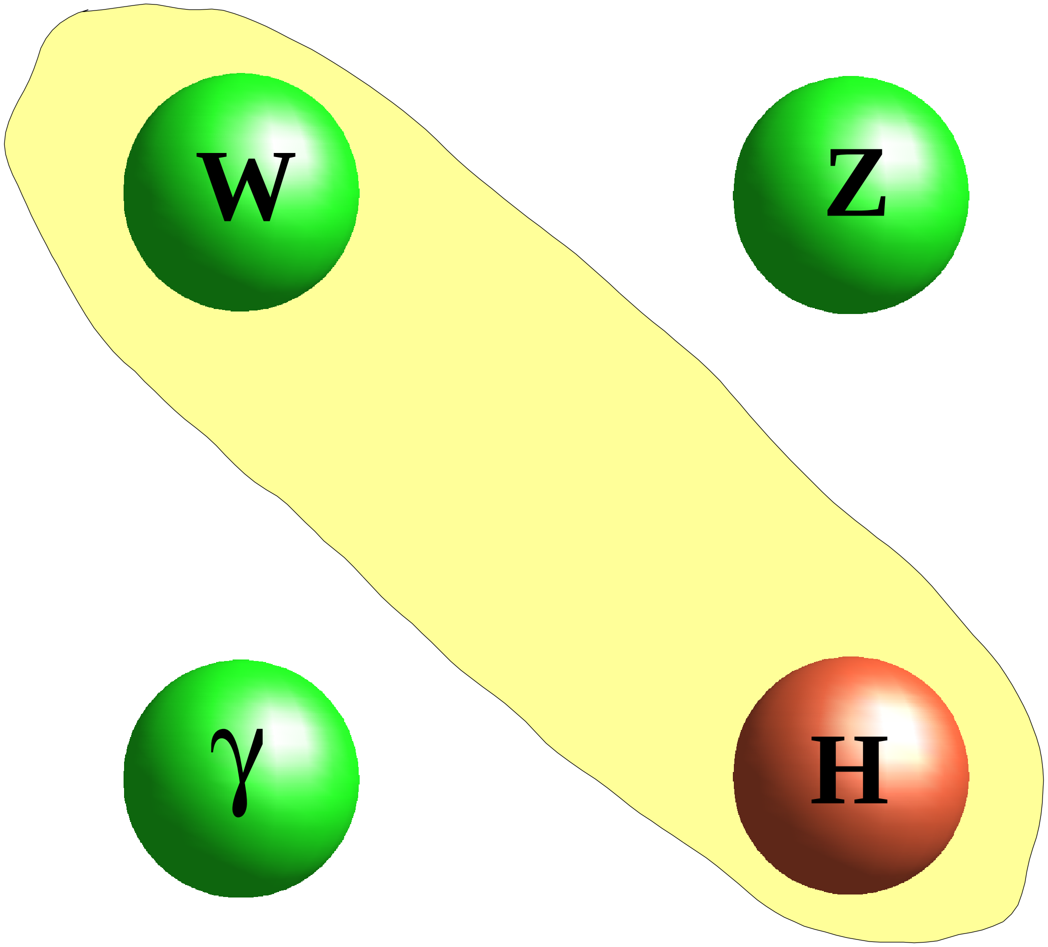
$$\sigma\left(p\bar{p}\rightarrow ZZ/ZW+X\right)_{\mathrm{NLO}} \ = \ 5.0\pm0.4 \quad \mathrm{pb}$$





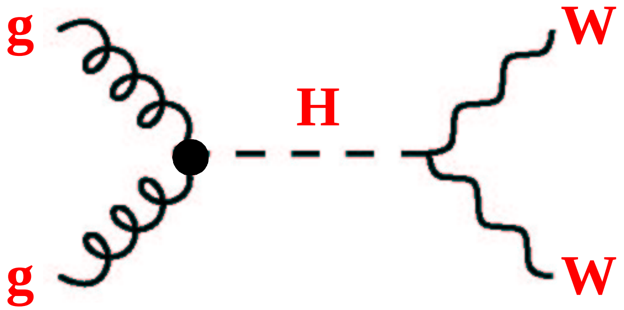


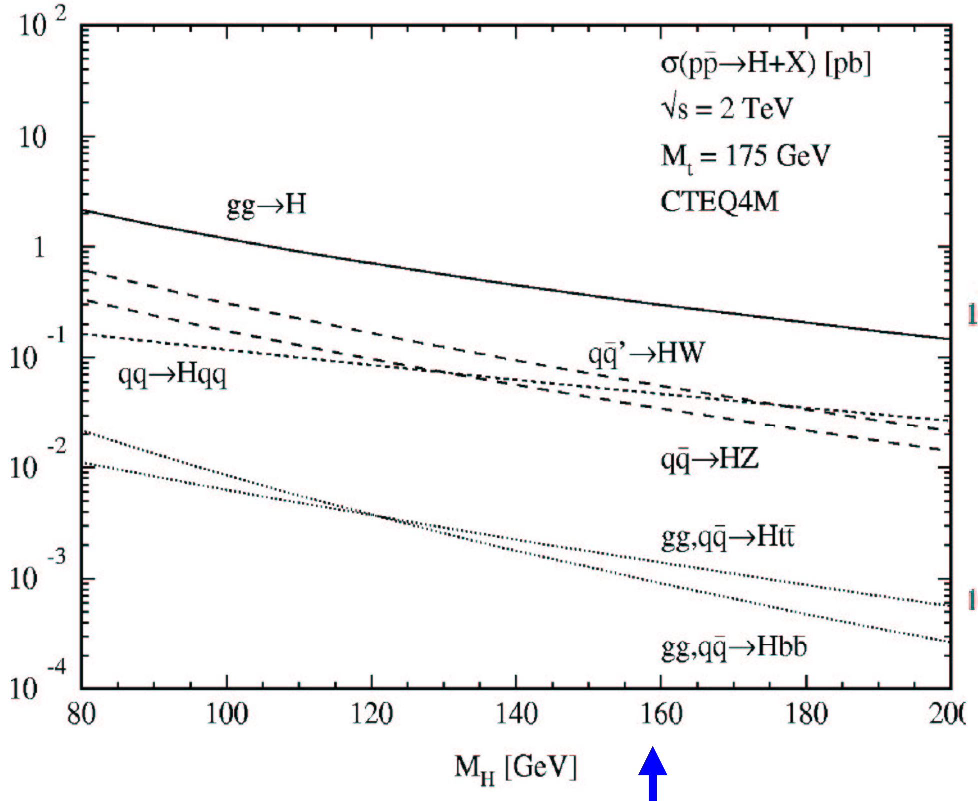
- $\gamma\gamma$
- W/Z + γ
- WW
- WZ/ZZ
- **H→WW**

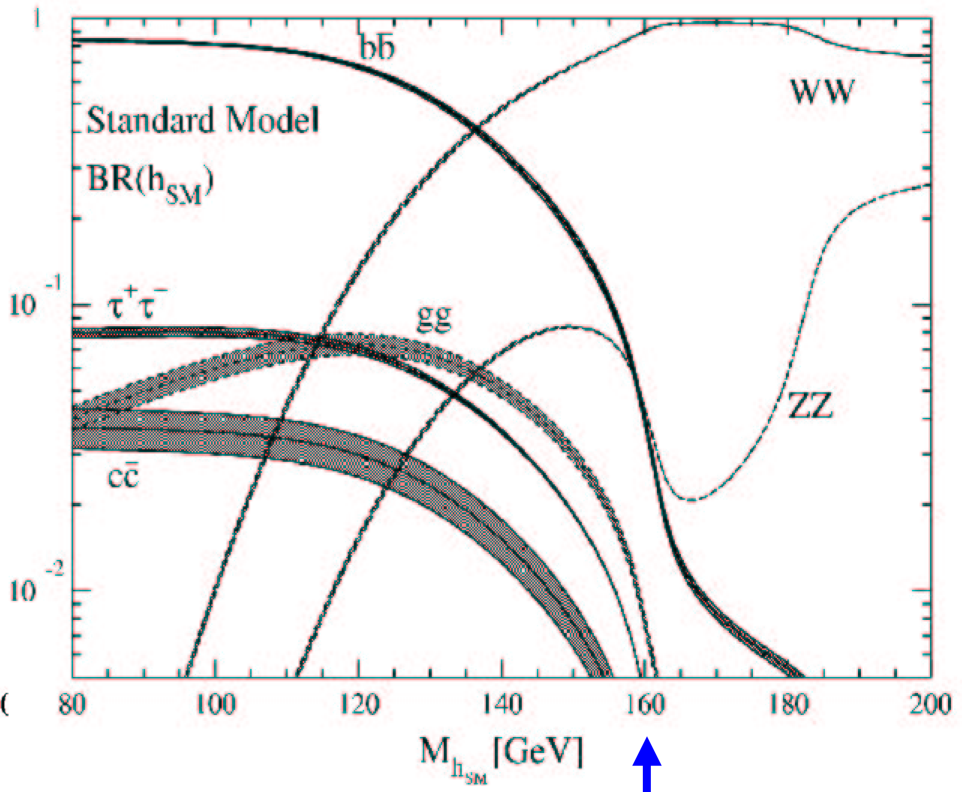


$H \rightarrow WW^{(*)}$

- Take advantage of largest (gluon−gluon) production cross−section.
- Large branching ratio to $WW^{(*)}$ above 140 GeV.
- Relatively low backgrounds.

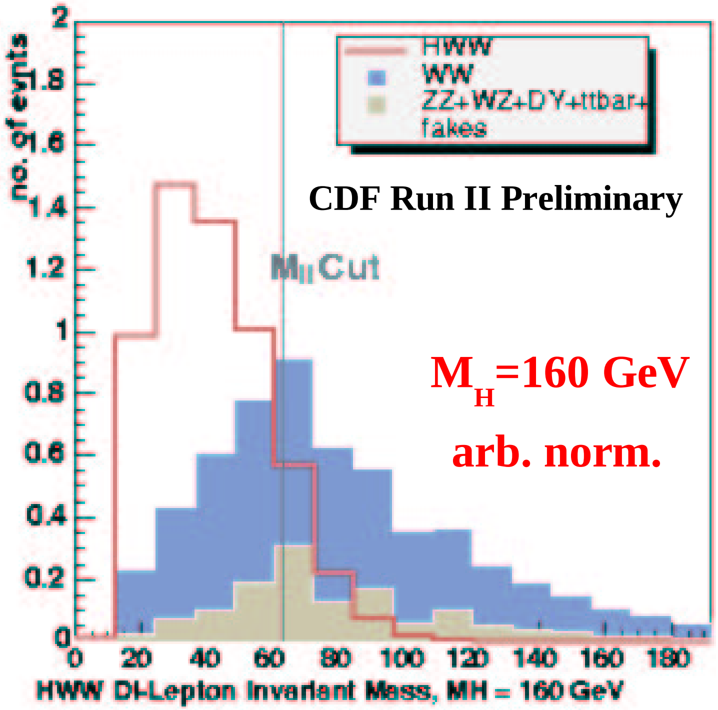






$\sigma(gg \rightarrow H)$ ~ 0.3 pb @ 160 GeV

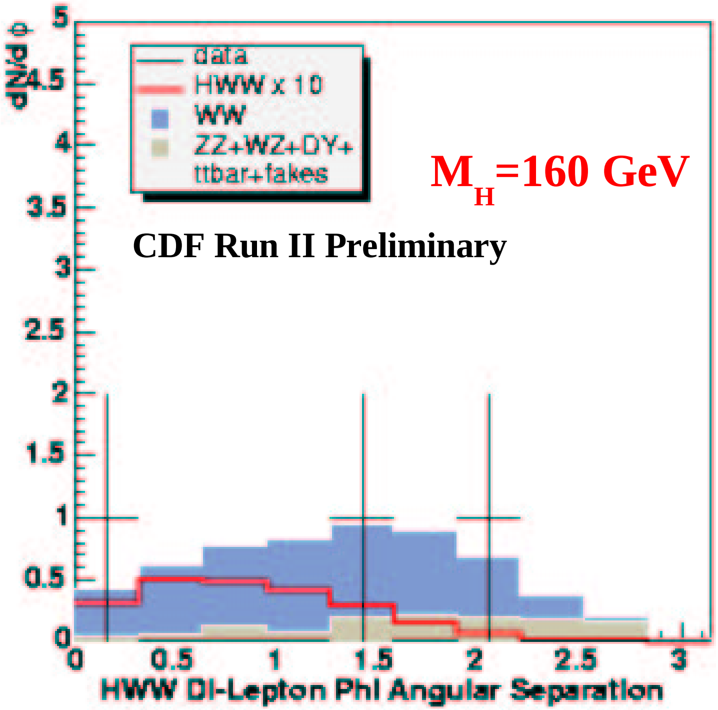
BR(H→WW) ~ 90%@ 160 GeV



CDF Run II Preliminary

M_H=160 GeV

arb. norm.



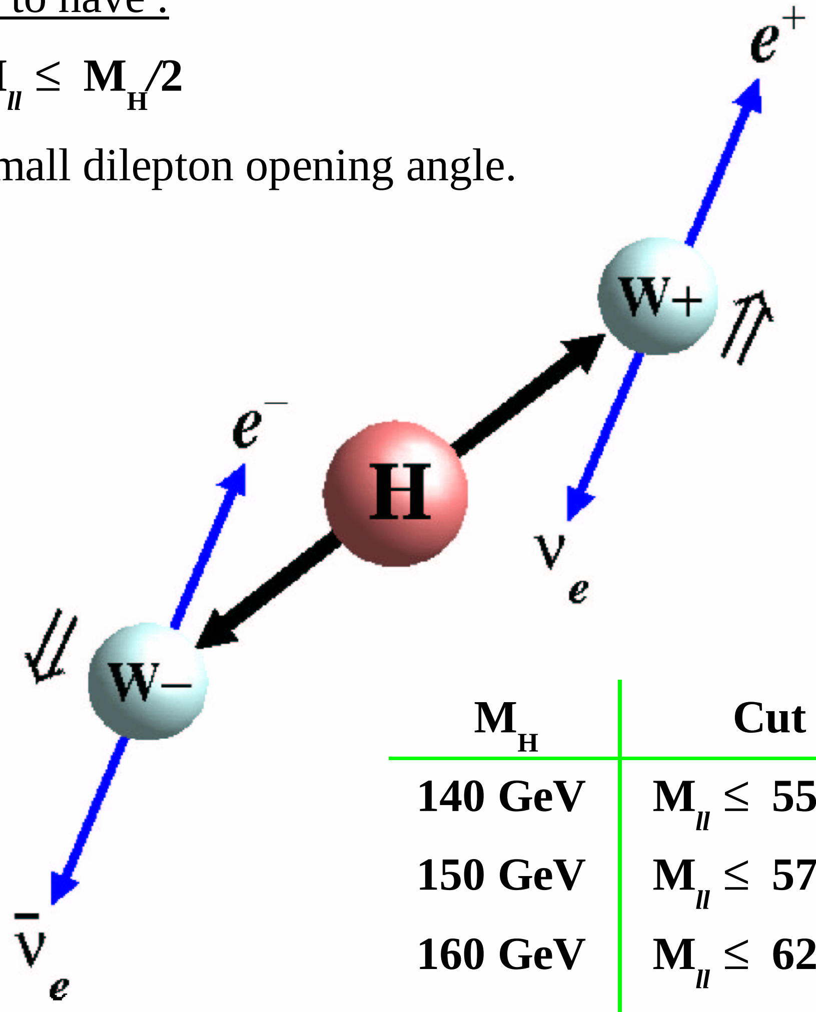
M_H=160 GeV

CDF Run II Preliminary

H→WW$^{(*)}$ Kinematics

<u>Tend to have :</u>

- **$M_{ll} \le M_H/2$**
- Small dilepton opening angle.



M_H	Cut
140 GeV	$M_{ll} \le$ 55.0 GeV
150 GeV	$M_{ll} \le$ 57.5 GeV
160 GeV	$M_{ll} \le$ 62.5 GeV
170 GeV	$M_{ll} \le$ 70.0 GeV
180 GeV	$M_{ll} \le$ 80.0 GeV

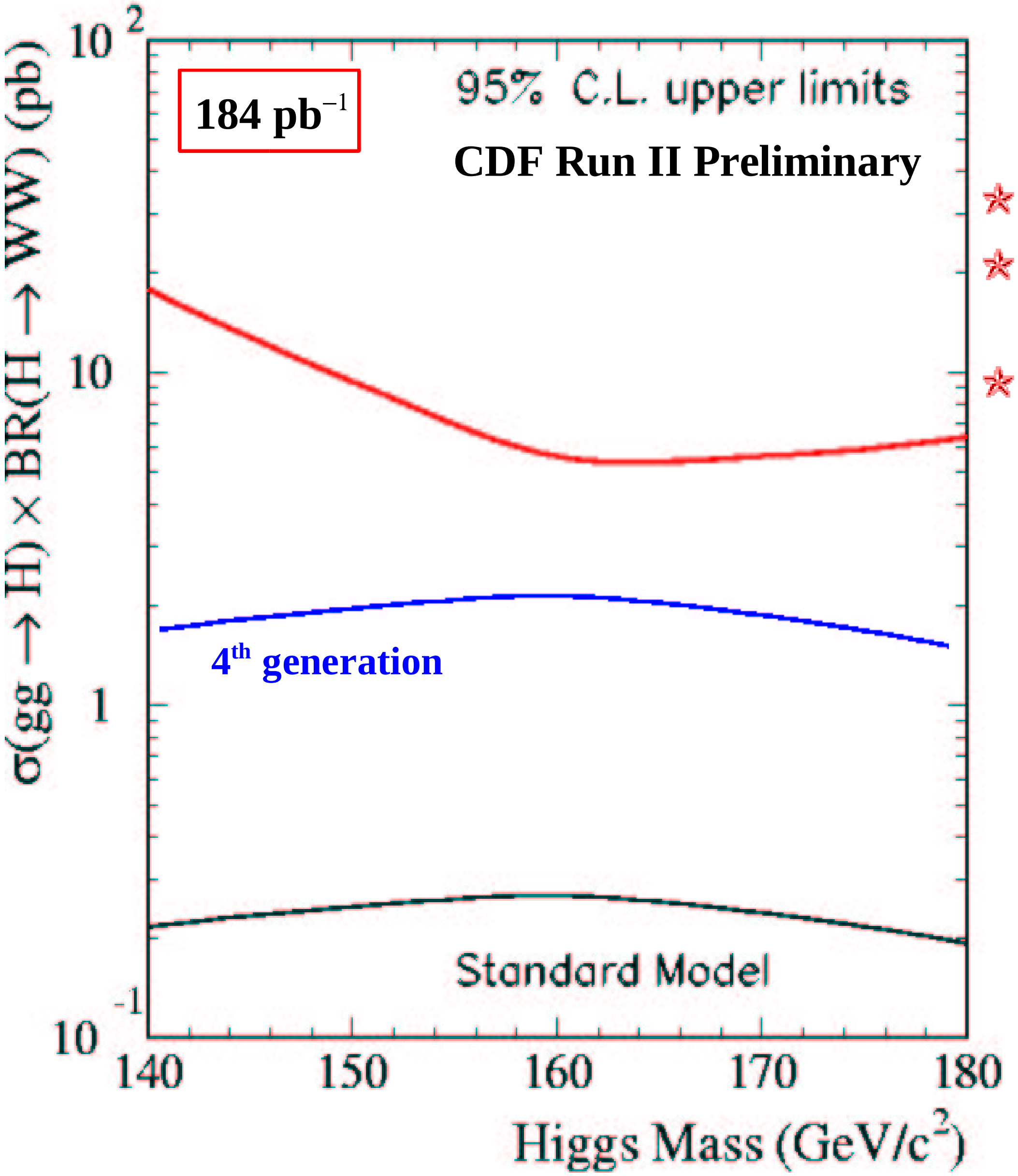
$H \to WW^{(*)}$

(1) Start with WW analysis.
(2) Apply dilepton mass cut.
(3) Fit dilepton ΔΦ distribution. Find maximum allowed Higgs contribution.

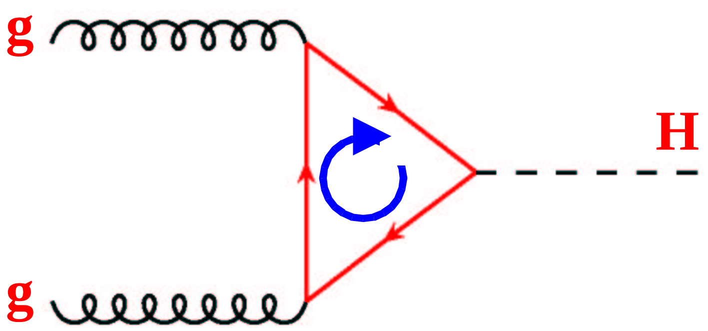
CDF Run II Preliminary : 200/pb

Higgs Mass	140 GeV	160 GeV	180 GeV
$\sigma_{SM}(gg \to H)$	0.45 pb	0.30 pb	0.21 pb
$BR_{SM}(H \to WW)$	0.48	0.90	0.94
Expected Signal	0.10±0.01	0.22±0.03	0.17±0.02
WW Background	3.51±0.41	4.45±0.52	6.49±0.76
Other Backgrounds	0.68±0.16	1.34±0.35	2.40±0.55
DATA	2	3	8
Counting Limit (95% CL)	18.4 pb	6.2 pb	8.8 pb
ΔΦ– Fitting Limit – Obtained (95% CL)	17.8 pb	5.6 pb	6.4 pb

$H\to WW^{(*)}$

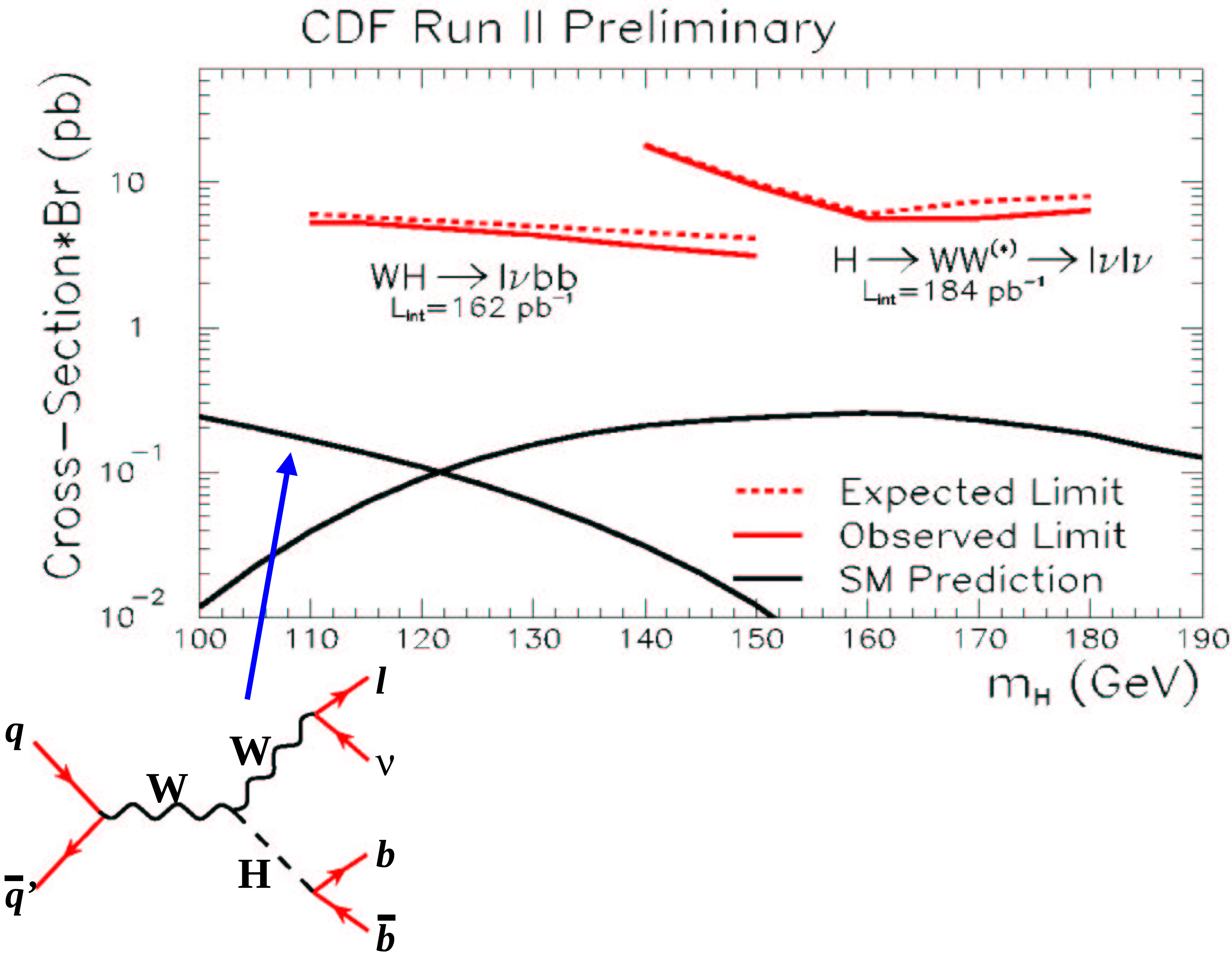


- Cuts will be optimised for Higgs search.
- Maximal use of kinematic information to separate Higgs from SM WW.
- Will soon set model limits − for example on 4th quark generation :



$$\sigma(gg\to H;\ 4G) \sim 9 \times \sigma(gg\to H;\ 3G)$$

CDF Run II Higgs : Summary



The Future ...

Future : Global Analyses

- Many of the signals we are trying to isolate are not cleanly separable from each other :

$$p\bar{p}\rightarrow WW$$

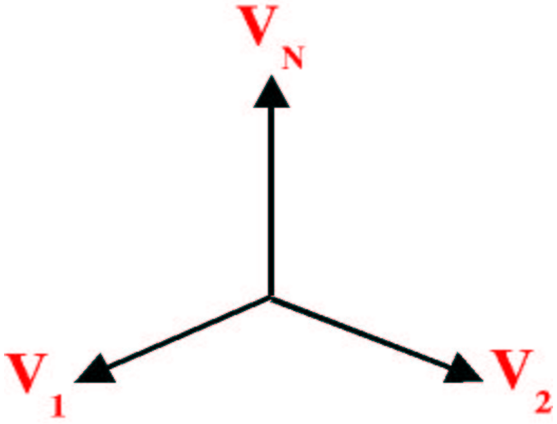
$$p\bar{p}\rightarrow t\bar{t}\rightarrow WWb\bar{b}$$

$$p\bar{p}\rightarrow Z\rightarrow l^{+}l^{-}$$

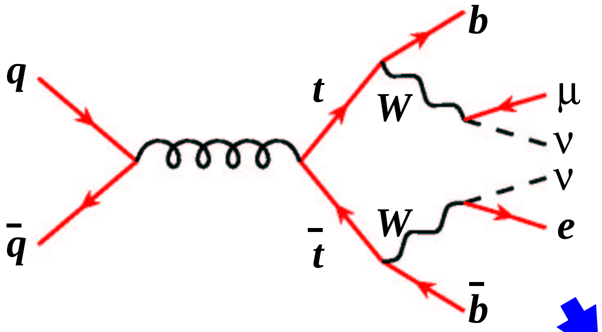
$$p\bar{p}\rightarrow H\rightarrow WW$$

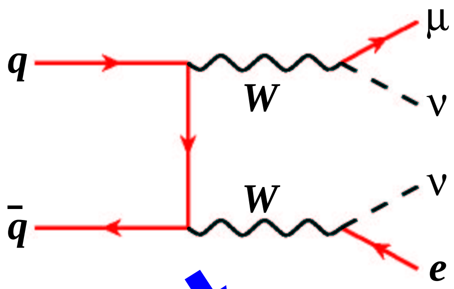
...

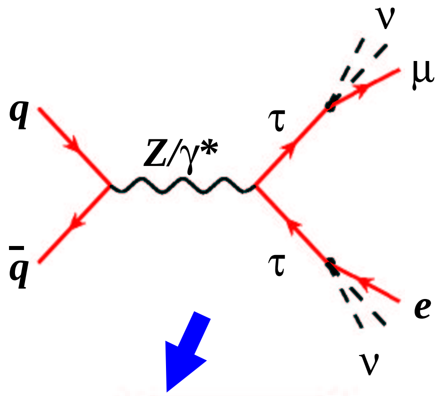
- "Cut & Count" experiments may not be making best use of the available data.
- Another approach is to fit the data in a space of N variables to shapes corresponding to each contribution :



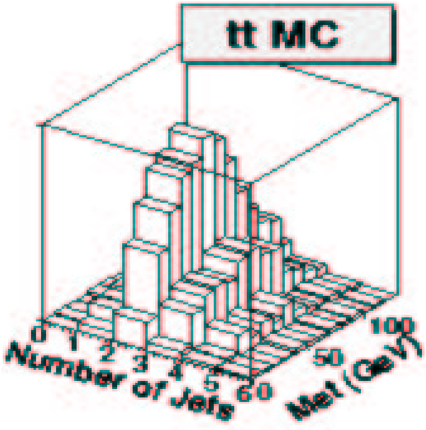
Future : Global Analyses

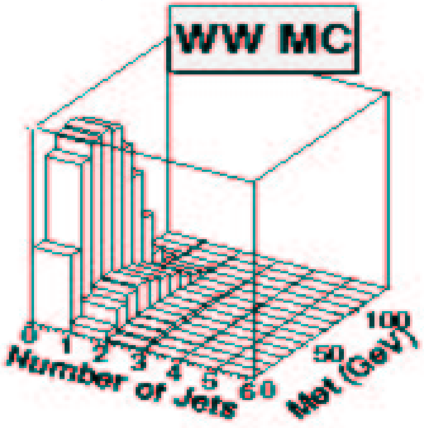


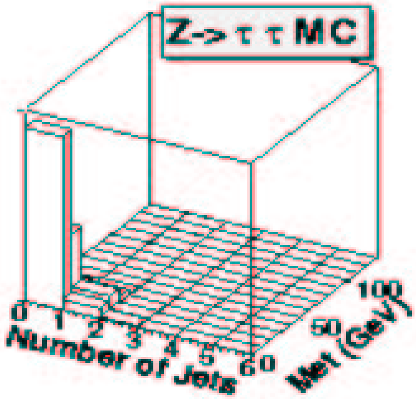


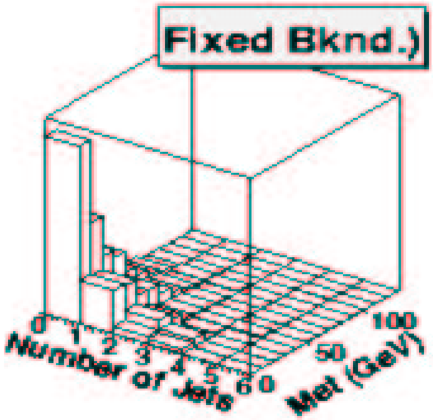


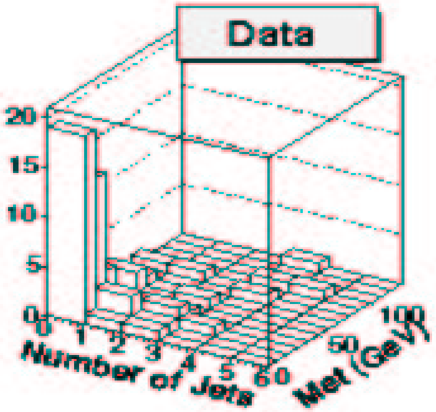
- 2 isolated leptons.
- No other cuts.











CDF II Preliminary

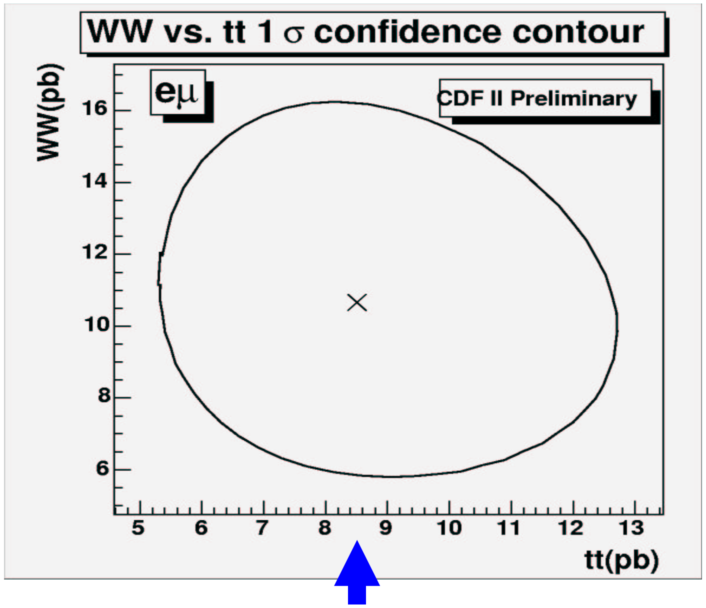
eμ space

low background

Future : Global Analyses

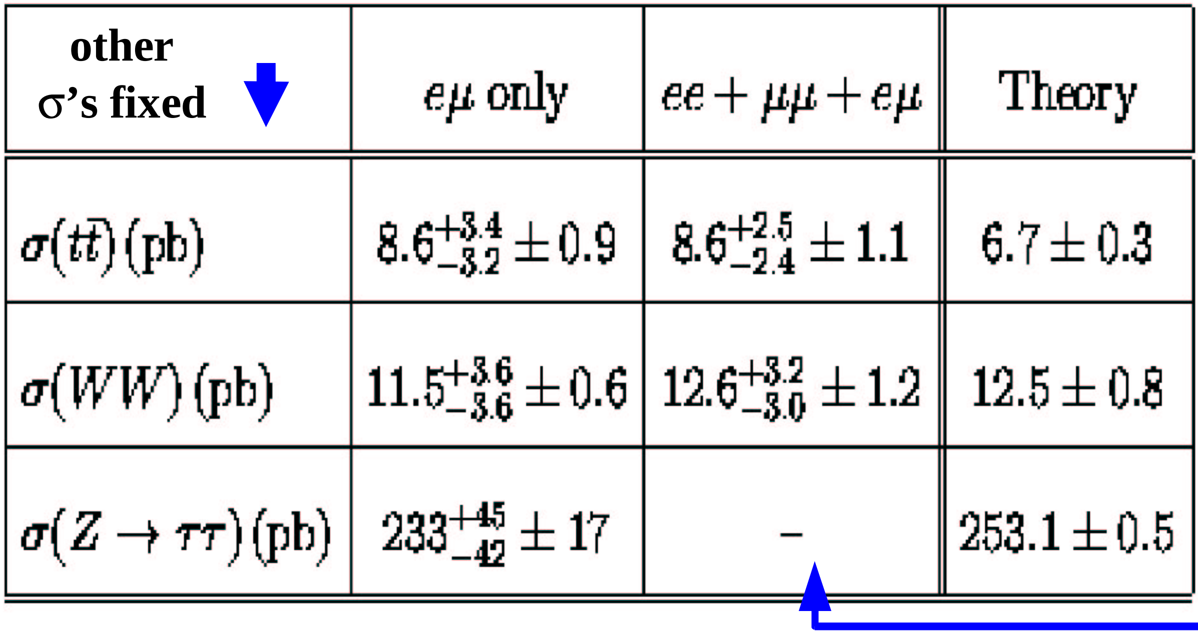
- Fit the data to 2D shapes corresponding to different physics processes :

$$\frac{d^2 N_{\mathrm{EVT}}}{d\not{E}_T \, dN_{\mathrm{jets}}} = \alpha N_{t\bar{t}} + \beta N_{WW} + \gamma N_{Z\to\tau\tau} + n_{\mathrm{other}}$$



example likelihood contour

CDF Run II Preliminary $\quad$ 200pb^{-1}



other σ's fixed	$e\mu$ only	$ee+\mu\mu+e\mu$	Theory
$\sigma(t\bar{t})$ (pb)	$8.6^{+3.4}_{-3.2} \pm 0.9$	$8.6^{+2.5}_{-2.4} \pm 1.1$	6.7 ± 0.3
$\sigma(WW)$ (pb)	$11.5^{+3.6}_{-3.6} \pm 0.6$	$12.6^{+3.2}_{-3.0} \pm 1.2$	12.5 ± 0.8
$\sigma(Z\to\tau\tau)$ (pb)	$233^{+45}_{-42} \pm 17$	–	253.1 ± 0.5

- Statistical precision compares favourably with individual cut based analyses − full power of data being used.
- Method may be particularly useful for searches.

extra $\not{E}_T^{\mathrm{SIG}}$ cut in ee & μμ channels

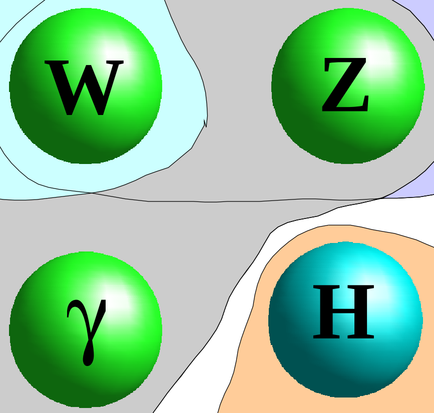
Future

WW

- ✯ measure WWγ/WWZ couplings
- ✯ examine kinematics & event properties in more detail with larger samples
- ✯ use jets channels WW→lνjj
- ✯ WW+γ ; quartic couplings
- ✯ optimise & utilise global analysis techniques

WZ/ZZ

- ✯ measure WZ cross−section with ~ 1 fb^{-1}



W/Z+γ

- ✯ measure WWγ couplings
- ✯ radiation amplitude zero
- ✯ ratio measurements
- ✯ W/Z+2γ ; quartic couplings

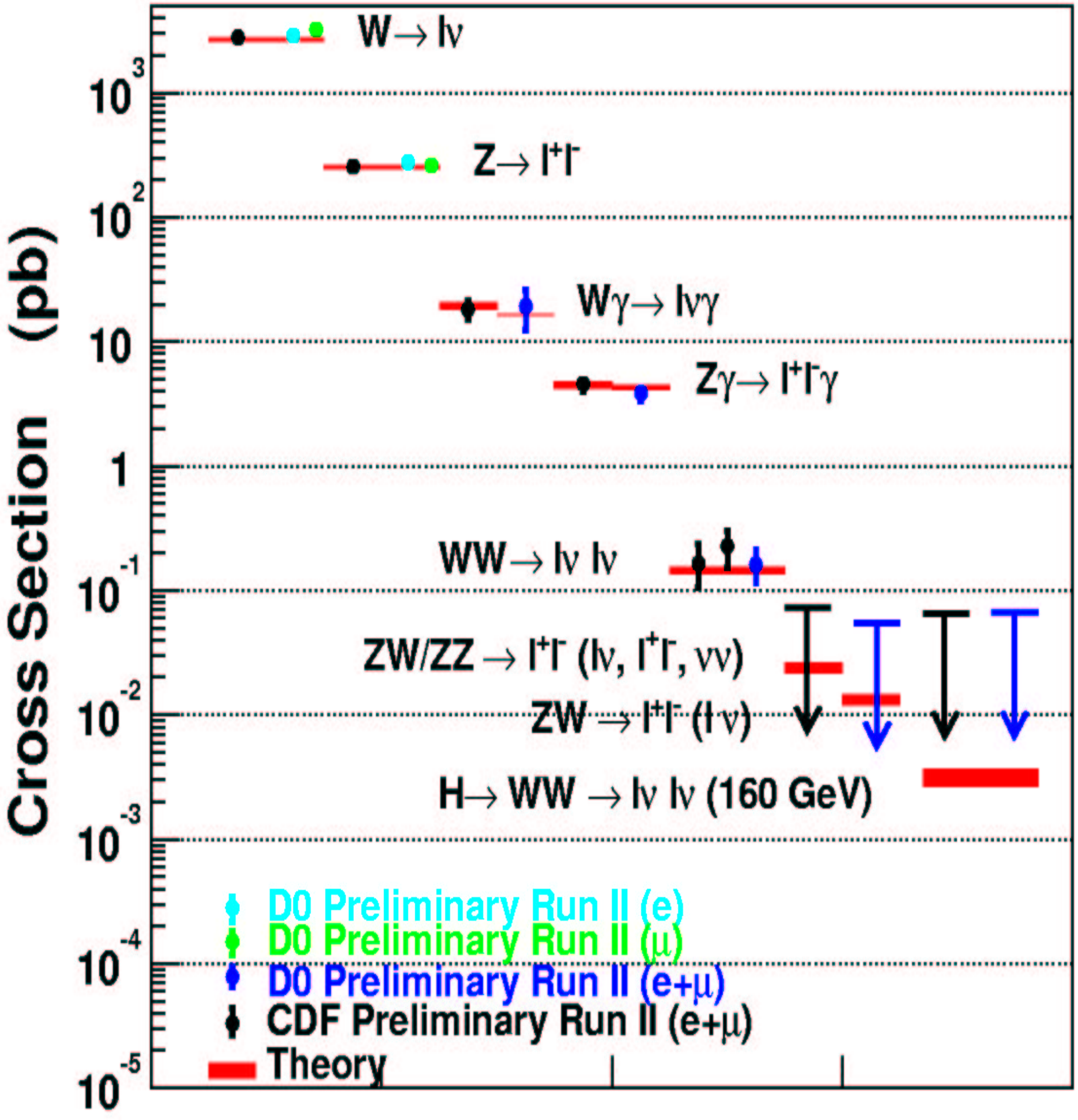
H→WW

- ✯ optimise selection for scalar production

All Analyses :

- ✯ extend acceptance
- ✯ deal with effects of higher instantaneous luminosity

Summary



- Di−boson signals established in Run II :
  - W/Z+γ with substantially improved significance over Run I.
  - WW for the first time at the Tevatron.
- Looking forward to analyses made possible with more data :
  - precision di−boson measurements.
  - discovery of ZW/ZZ production
  - discovery of, or stringent limits on, new physics.