THE ROYAL SOCIETY
CELEBRATING 350 YEARS

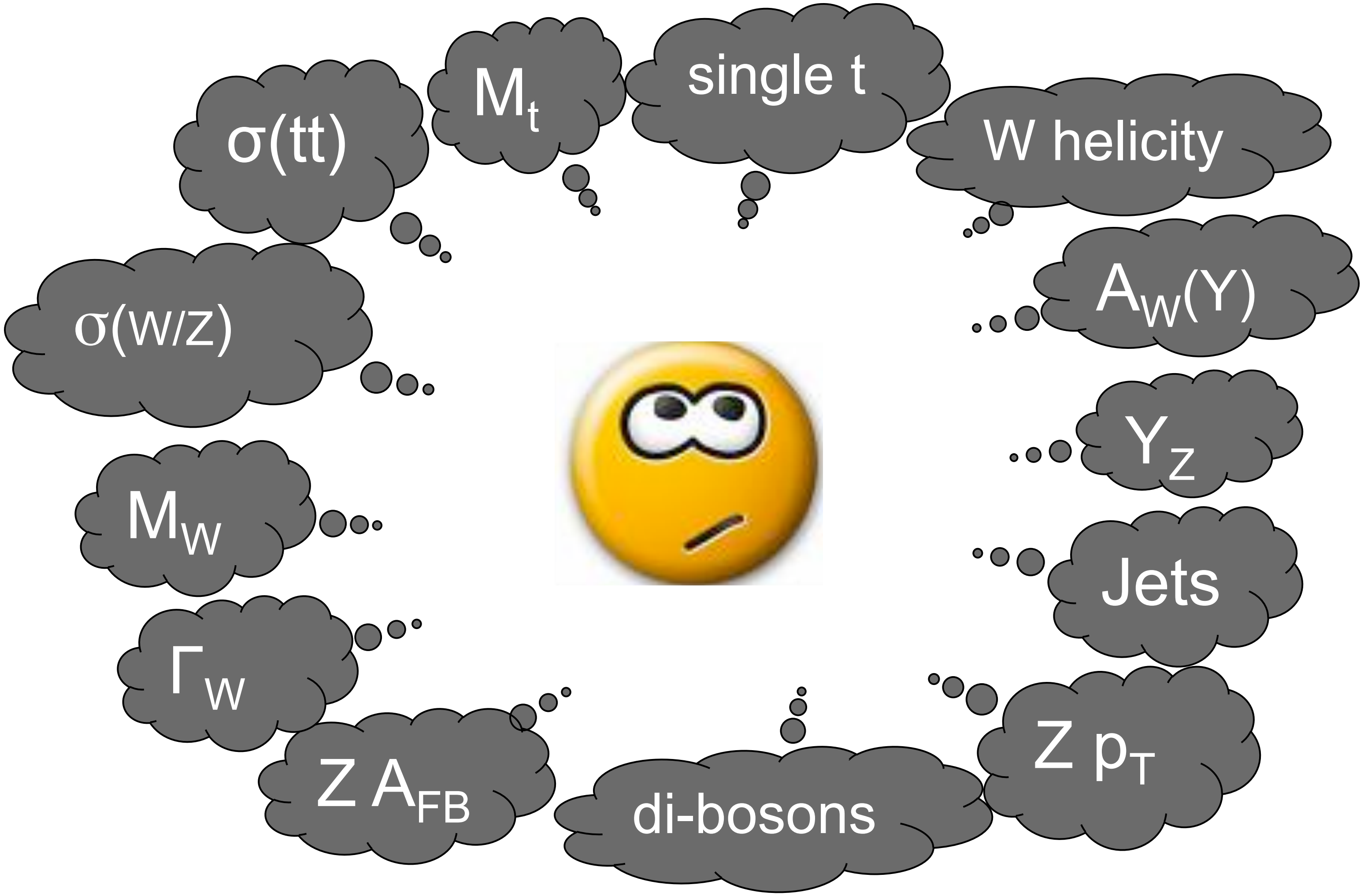
UCL

PDFs, W, top
Talk A

Emily Nurse

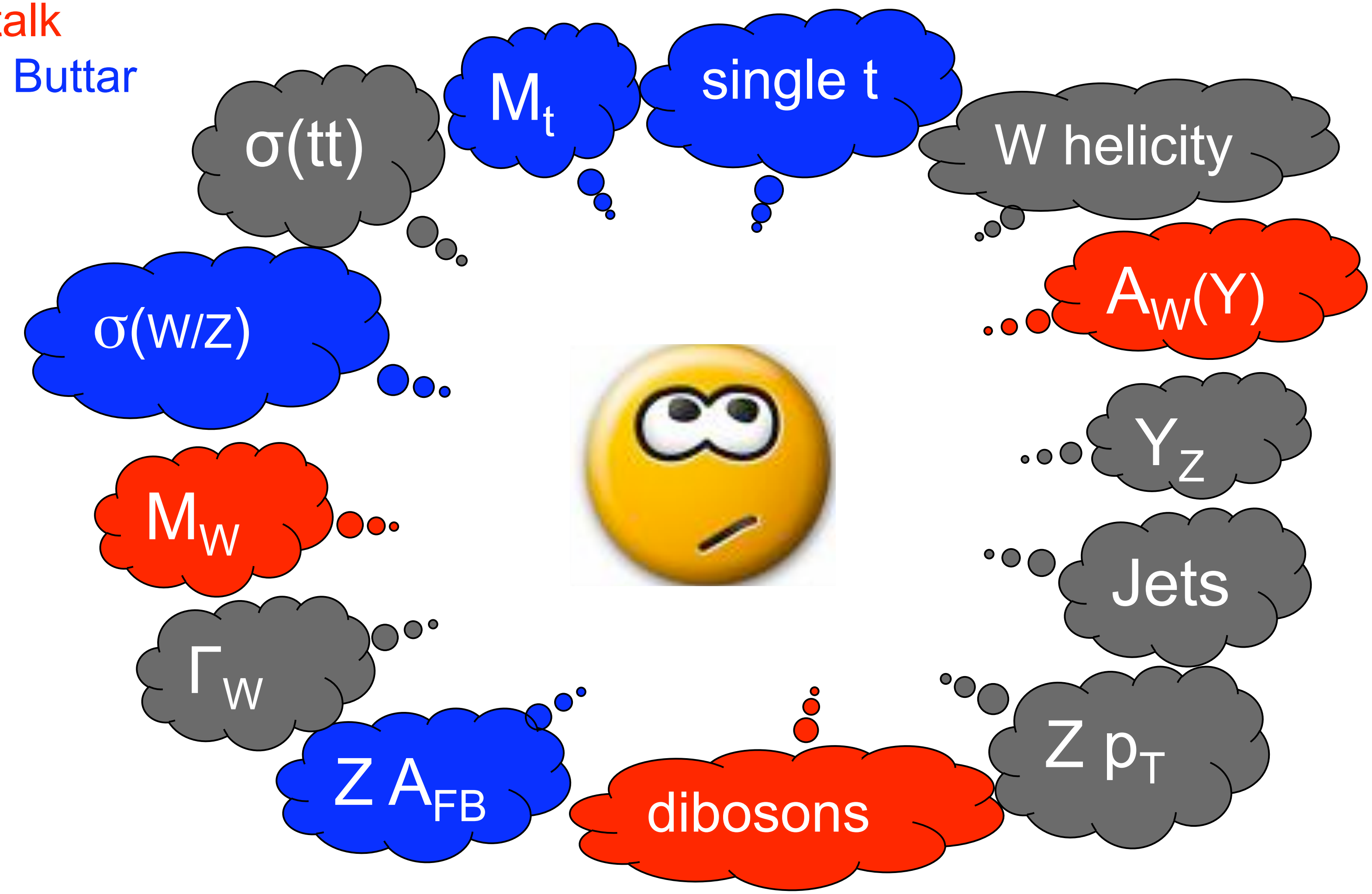
"From the TeVatron to the LHC"
UK HEP Forum, 7-8 May 2009

PDFs, W, top

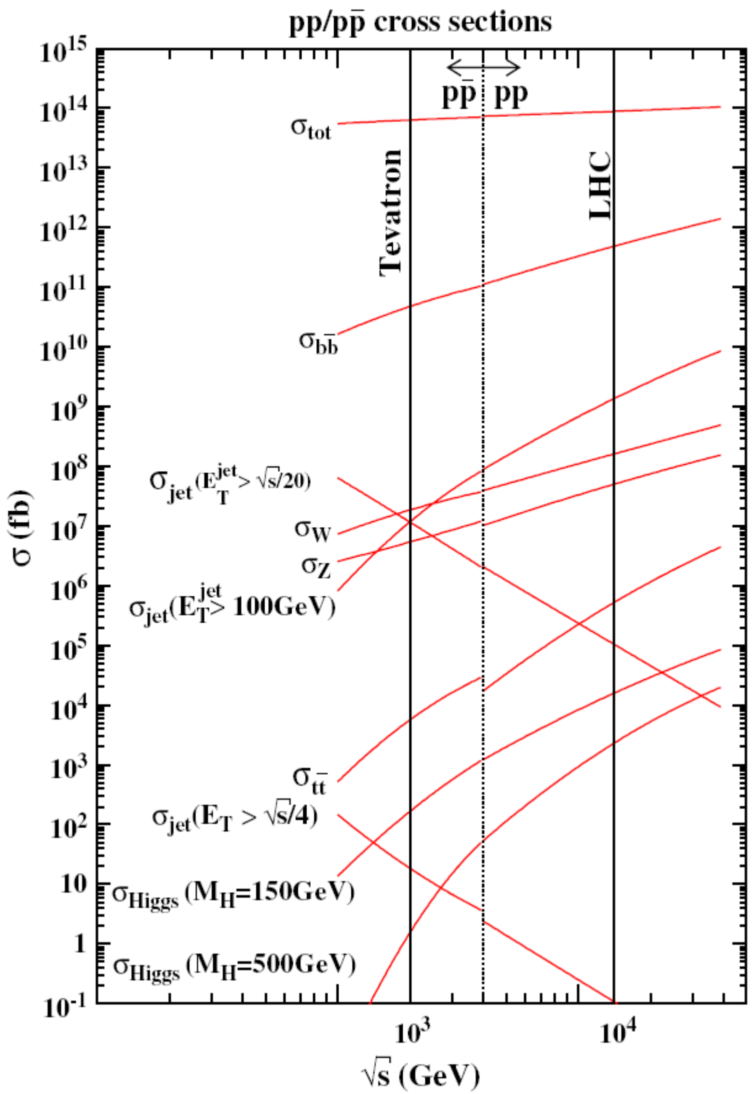

σ(tt)
M_t
single t
W helicity
σ(W/Z)
$A_W(Y)$
Y_Z
M_W
Jets
Γ_W
Z A_{FB}
di-bosons
Z p_T

PDFs, W, top

This talk
Craig Buttar



TeVatron → LHC



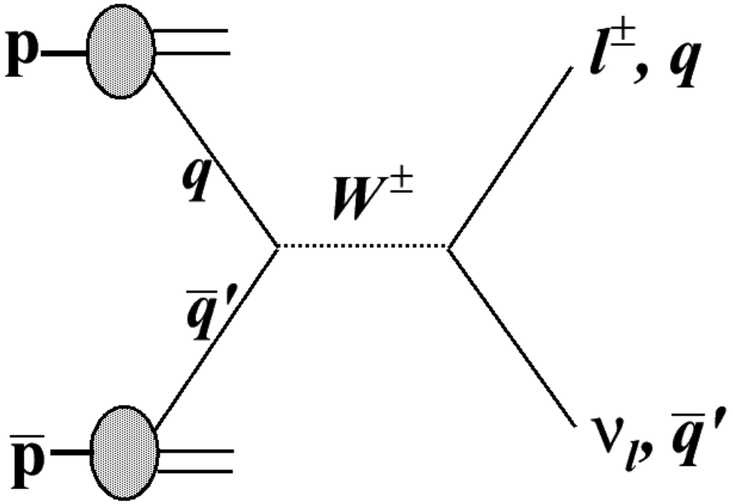
(A) C.O.M. energy : 1.96 → 14 TeV ?

(B) <n> per crossing : 1-10 → 2-25+ ?

(C) Integrated Lumi: 9-12 fb^{-1} → 700 fb^{-1} ?

(D) p$\bar{p}$ → pp

W production

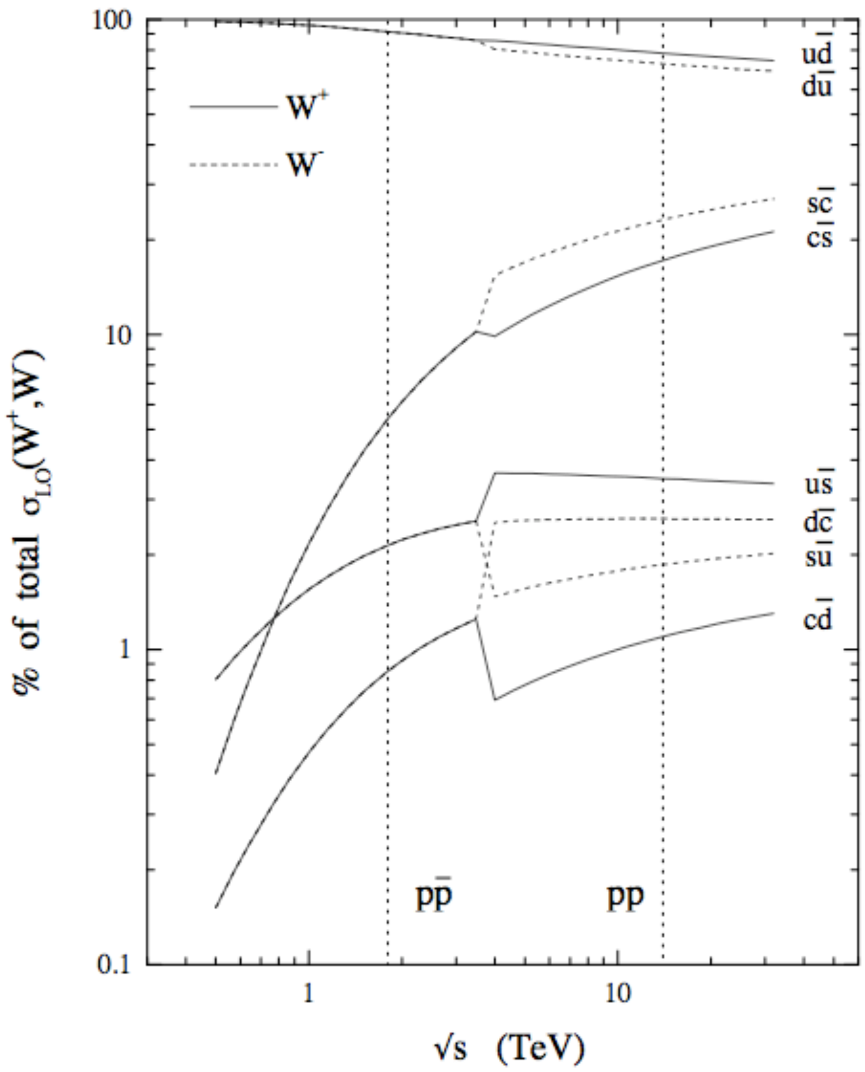


TeV $\sigma(p\bar{p} \to W^{\pm} \to l\nu) \sim 2.8$ nb

$\mathcal{L} \sim 3\times10^{32} \to 0.8\ s^{-1}$

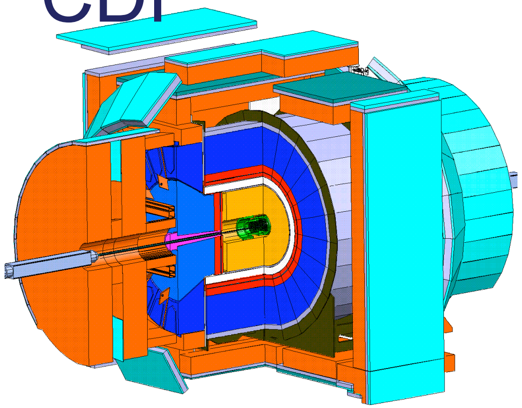
LHC $\sigma(pp \to W^{\pm} \to l\nu) \sim 20$ nb

$\mathcal{L} \sim 1\times10^{34} \to 200\ s^{-1}$



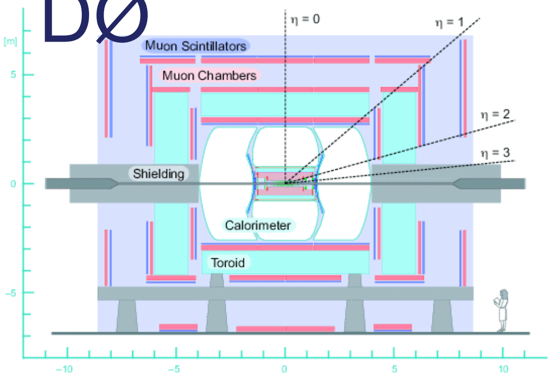
W/Z detection

CDF



$|\eta_{e(trk)}|<2.8$, $|\eta_{\mu}|<1$

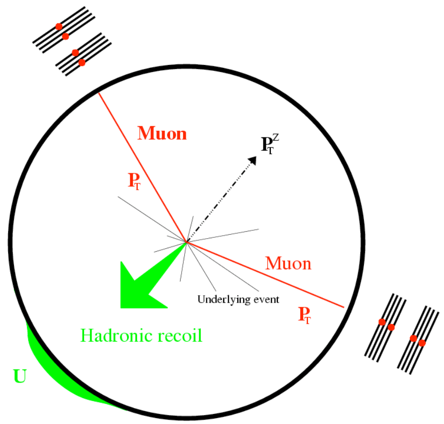
DØ



$|\eta_{e(trk)}|<3.2$, $|\eta_{\mu}|<2$

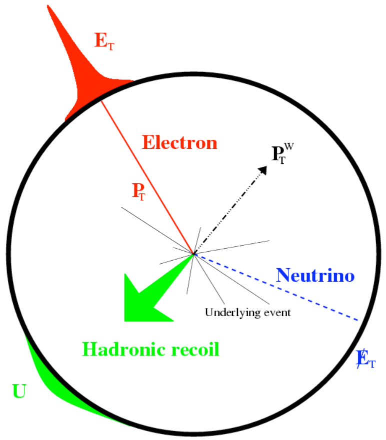
Z events:

- 2 high p_T charged leptons ($\mu^+\mu^-$ or e^+e^-).
- Both charged leptons are detected and their momenta measured.
- Muons: central tracker, muon detectors
- Electrons: central tracker, calorimeter



W events:

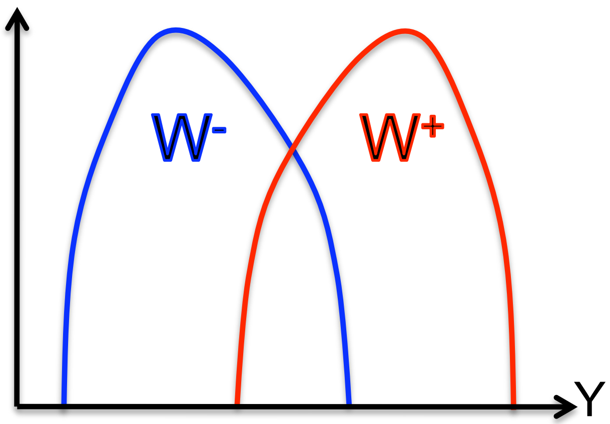
- 1 high p_T charged lepton, 1 high p_T neutrino ($\mu\nu$ or $e\nu$).
- Charged lepton is detected and momentum measured.
- Neutrino cannot be detected! p_T^{ν} is inferred by the "missing E_T (E_T^{miss})" in the detector.

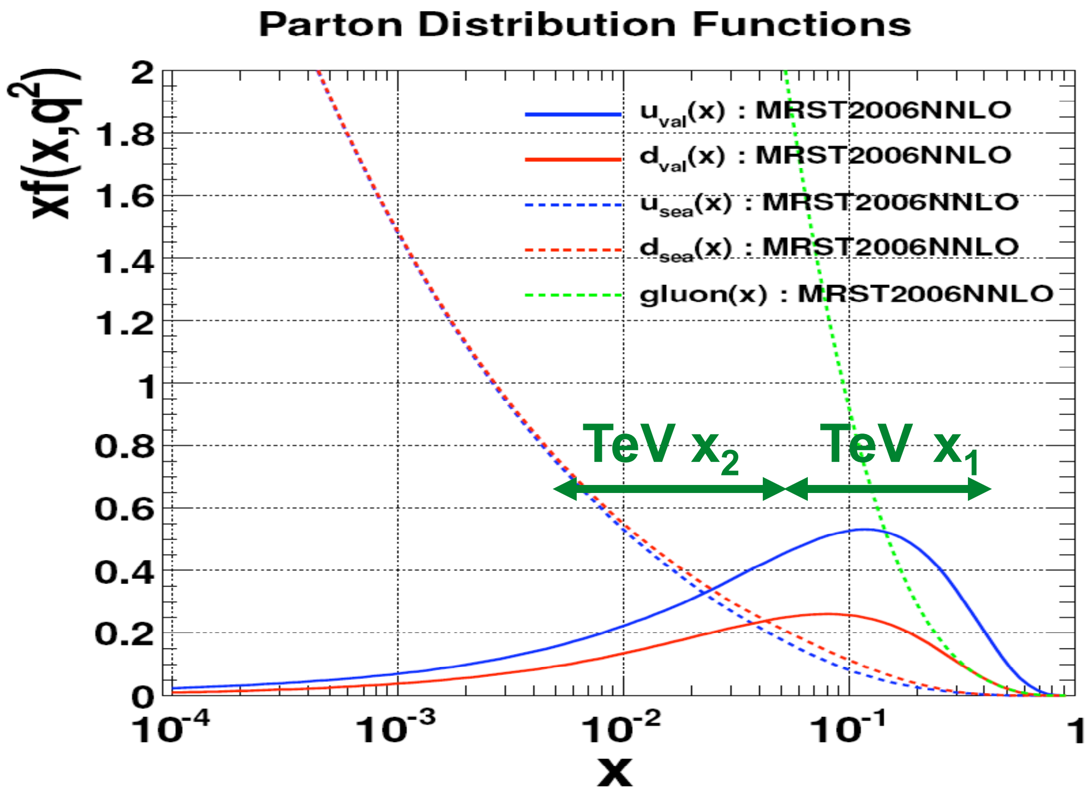


$A_W(Y)$ W charge asymmetry (TeV)

$u \longrightarrow W^+ \longleftarrow \bar{d}$

$d \longrightarrow W^- \longleftarrow \bar{u}$

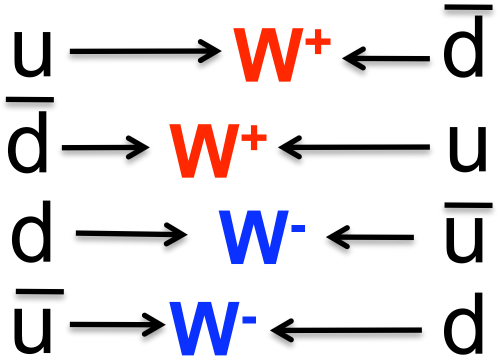


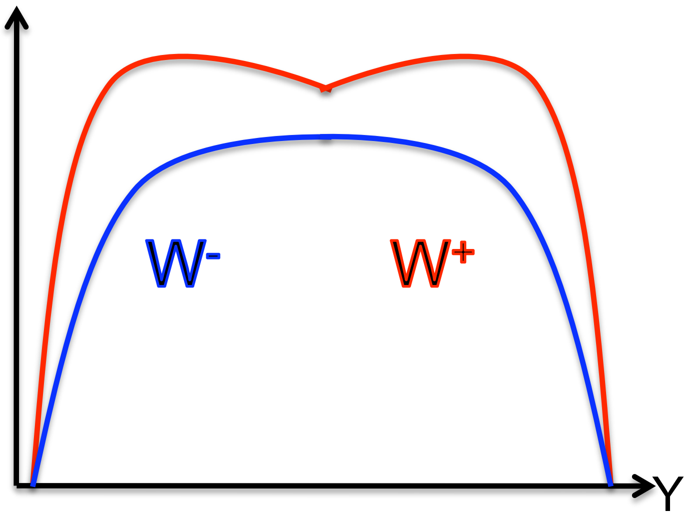


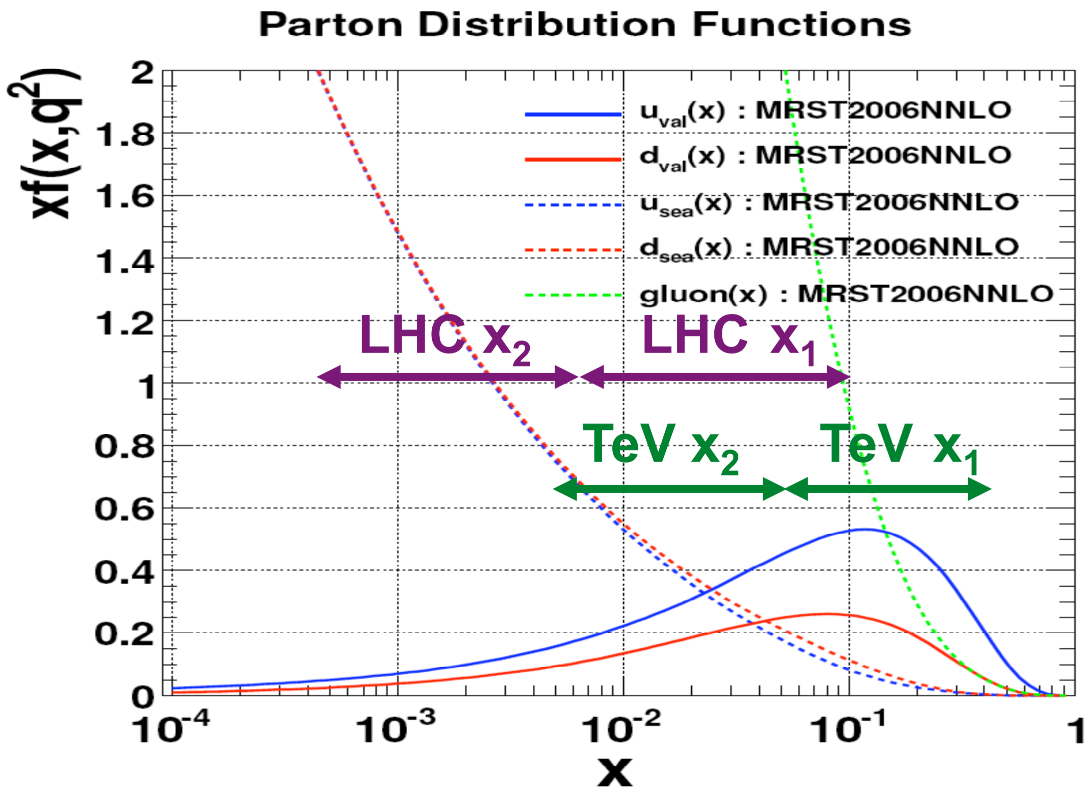
$$A(y_W) = \frac{d\sigma_+/dy_W - d\sigma_-/dy_W}{d\sigma_+/dy_W + d\sigma_-/dy_W}$$

$$\frac{d\sigma_-/dy_W}{d\sigma_+/dy_W} \approx \frac{d(x_1)u(x_2)}{d(x_2)u(x_1)} = \frac{d(x_1)/u(x_1)}{d(x_2)/u(x_2)}$$

$A_W(Y)$ W charge asymmetry (LHC)







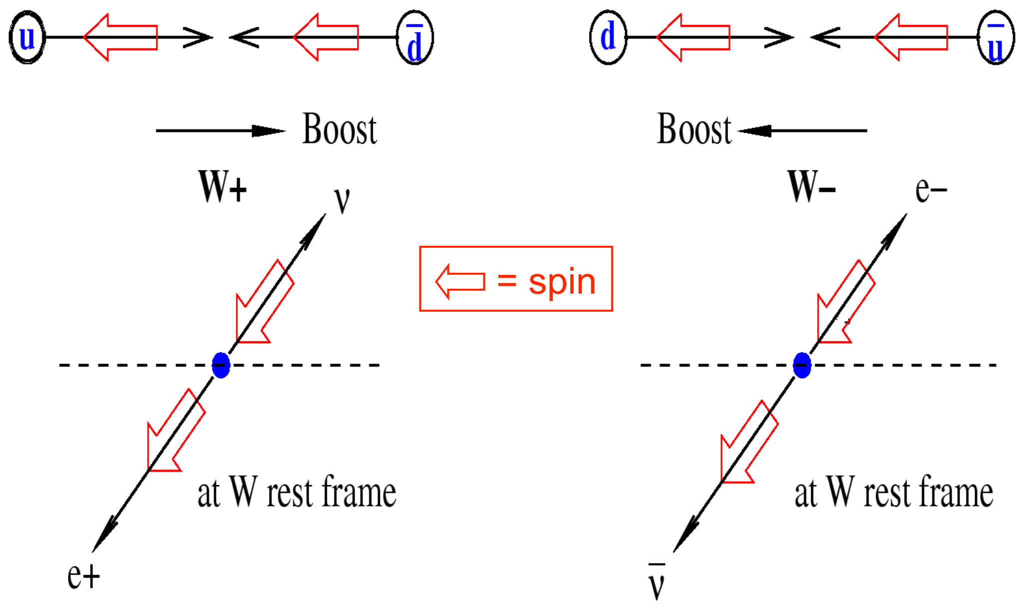
$$A(y_W) = \frac{d\sigma_+/dy_W - d\sigma_-/dy_W}{d\sigma_+/dy_W + d\sigma_-/dy_W}$$

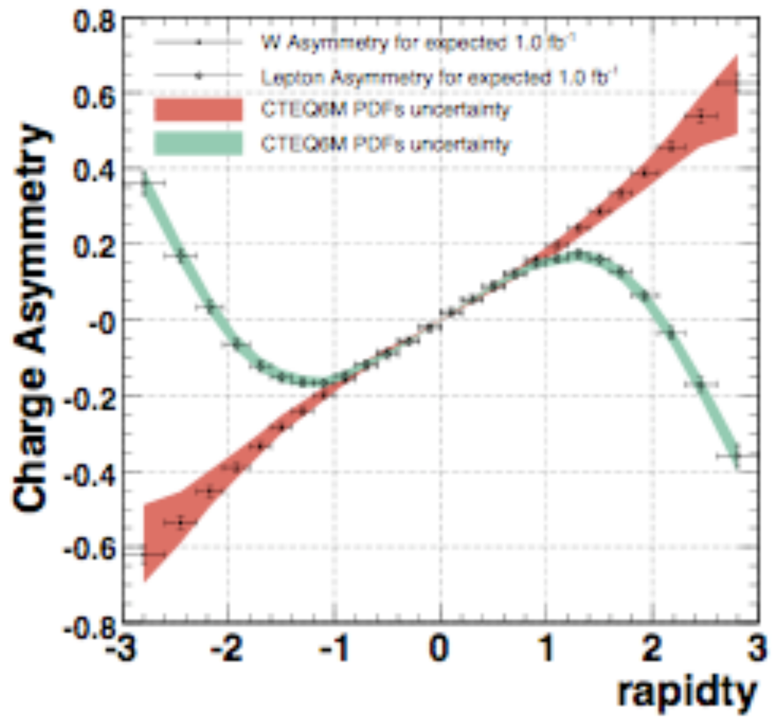
$$\frac{d\sigma_-/dy_W}{d\sigma_+/dy_W} \approx \frac{d(x_1)\bar{u}(x_2)}{\bar{d}(x_2)u(x_1)} = \frac{d(x_1)/u(x_1)}{\bar{d}(x_2)/\bar{u}(x_2)}$$

$A_W(Y)$ Or lepton charge asymmetry?

- Traditionally measure *lepton charge asymmetry* :
- Also depends on V-A decay :

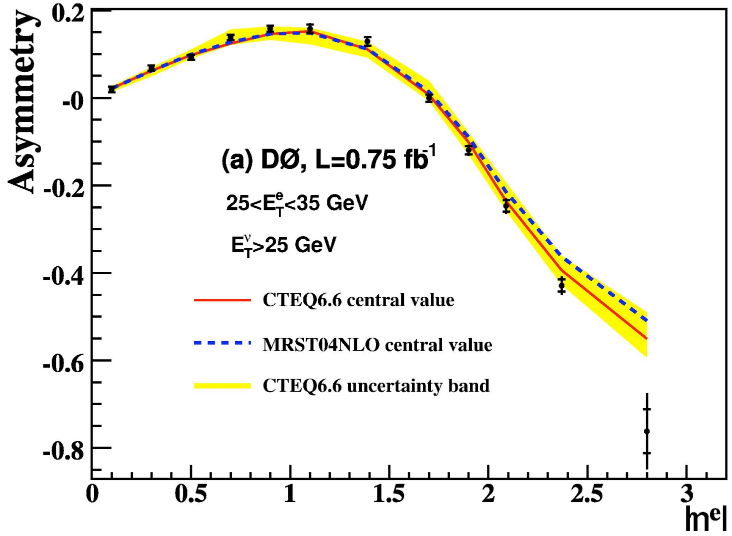
$$A(\eta_l) = \frac{d\sigma_+/d\eta_l - d\sigma_-/d\eta_l}{d\sigma_+/d\eta_l + d\sigma_-/d\eta_l}$$

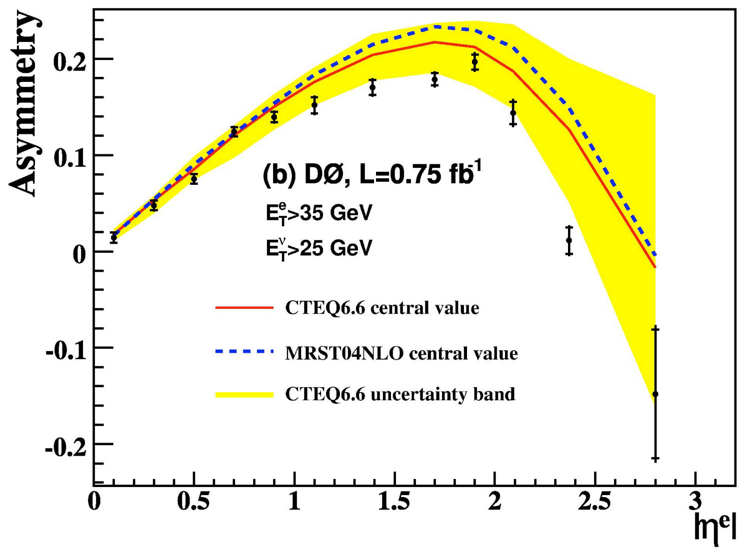




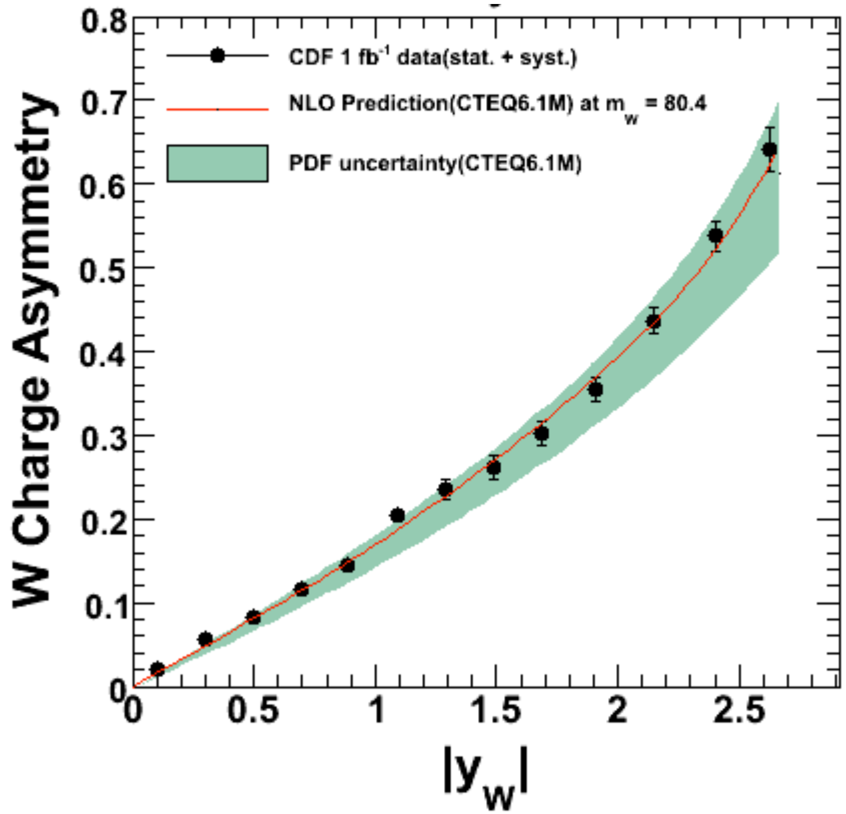
- Can also extract $A(y_W)$ directly:
  - p_L^{ν} determined by constraining M_W = 80.4 GeV→ two possible y_W solutions.
  - Each solution receives a weight probability according to V-A decay and $\sigma(y_W)$

Results





~490,000 $W \rightarrow e\nu$ events with $|\eta_e|<2.8$



~715,000 $W \rightarrow e\nu$ events with $|\eta_e|<2.8$

$A_W(Y)$ What should we measure?

$A(Y_W)$	$A(\eta_l)$
Most sensitive to valence d/u ratio	Also some sensitivity to sea quarks

"There was a joke at the DIS meeting that CDF can work back to W-asymmetry and D0 stick with lepton asymmetry. In fact that doesn't seem like a bad idea from our point of view."

- Robert Thorne

Best solution : publish everything!

	A_W	$A_l\,(p_T^1)$	$A_l\,(p_T^2)$
Y_1			
Y_2			
....			

Less of an issue at the LHC

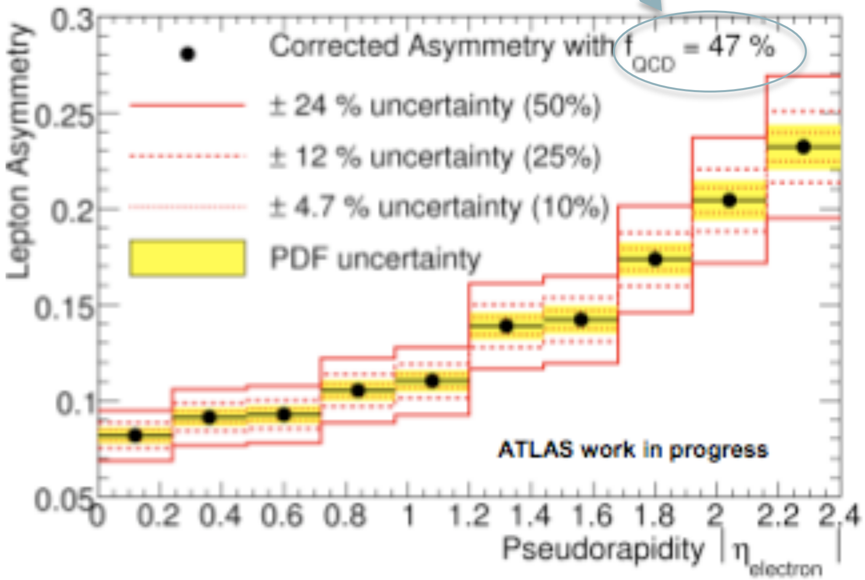
Systematic issues

- Lepton ID efficiency vs η
- Recoil (p_L^{ν})
- Charge mis-ID
- Multijet background

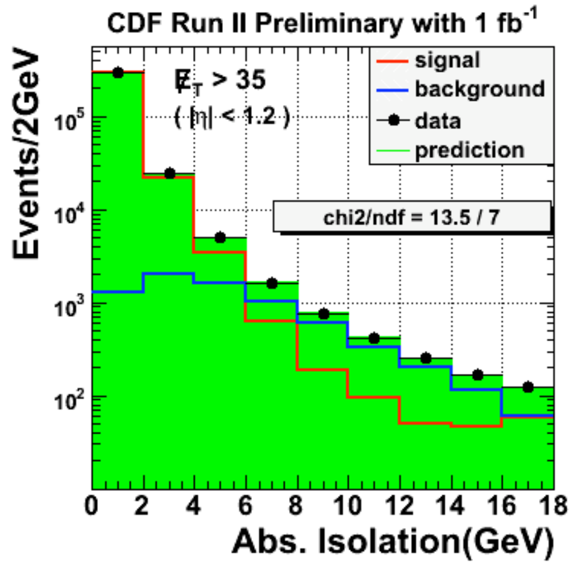
~ scale with statistics

D0 : 0.8%
CDF : 0.7 – 1.2 %

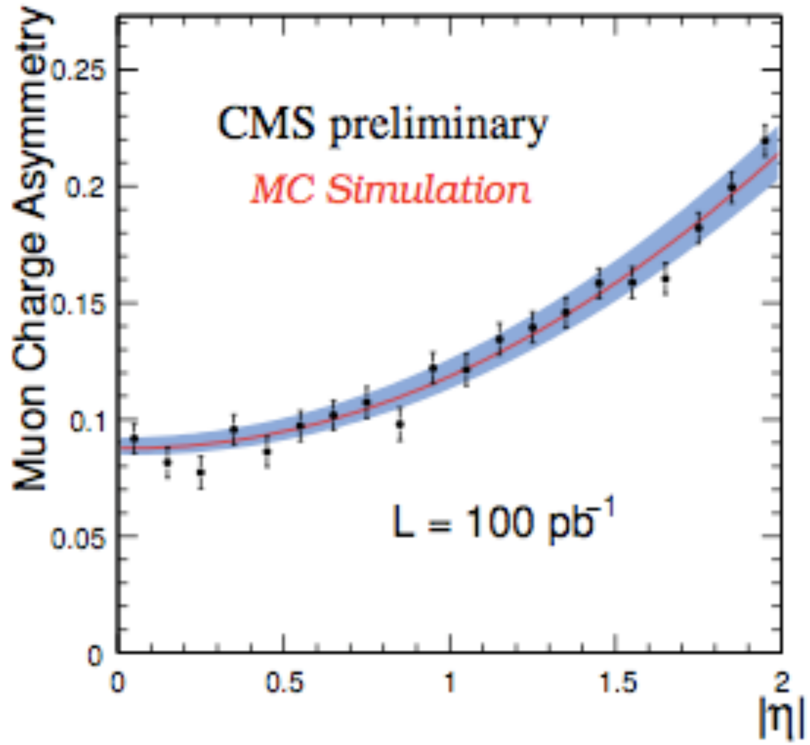
Note : "official" ATLAS σ(W->eν) analysis quotes a 7% multijet background



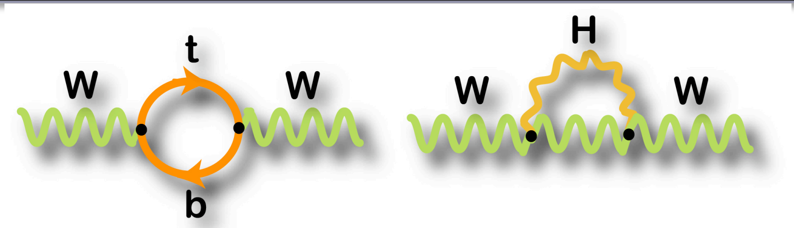
K. Lohwasser, IOP talk

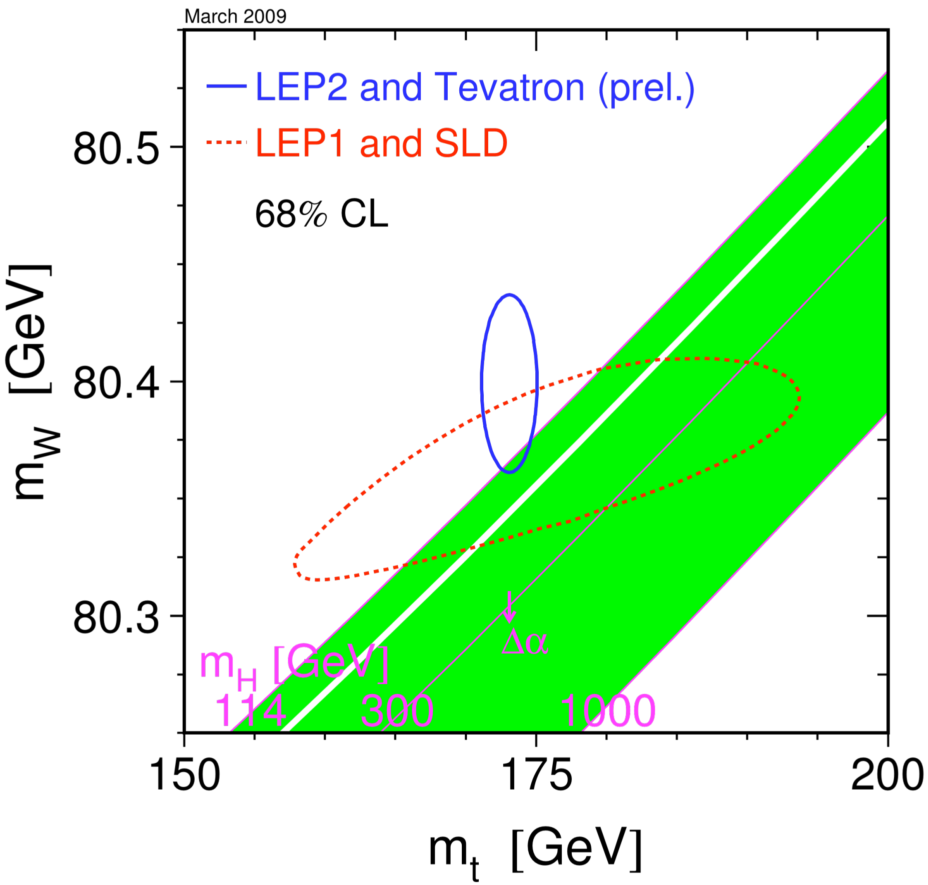


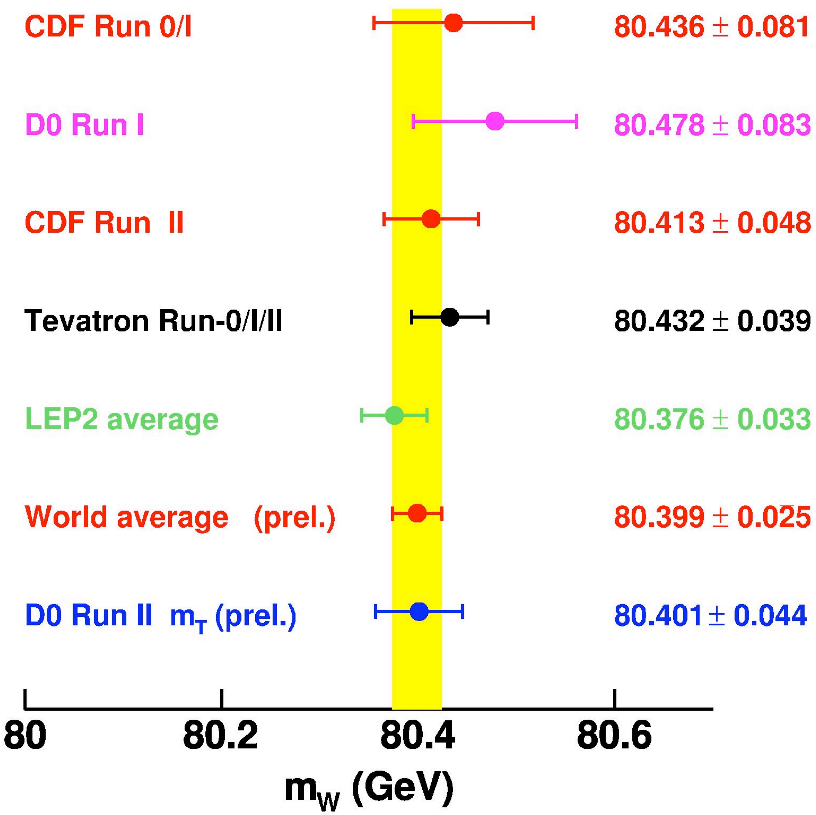
Early PDF constraints?



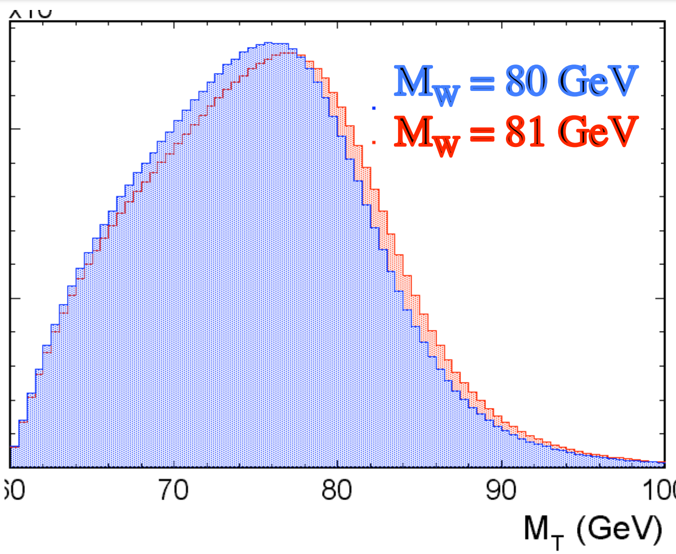
W and top mass





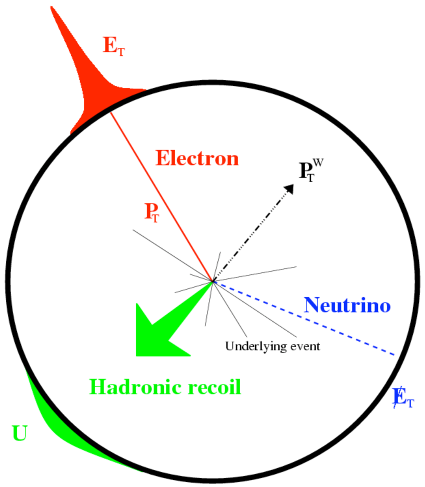


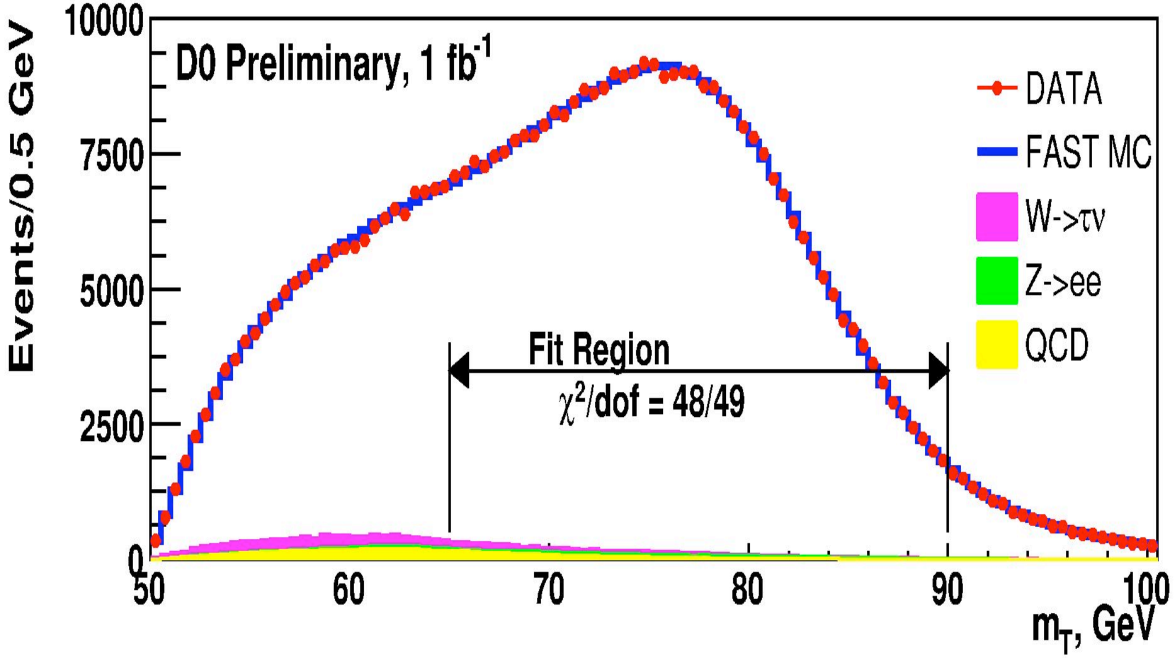
Technique



$$m_T = \sqrt{2 p_T^{\,l} p_T^{\,\nu} (1 - \cos\phi_{l\nu})}$$

$$\vec{p}_T^{\,\nu} = -(\vec{U}_T + \vec{p}_T^{\,l})$$





Systematics

CDF II : 200 pb^{-1}

m_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	9	9	9
Recoil Resolution	7	7	7
$u_{\|\|}$ Efficiency	3	1	0
Lepton Removal	8	5	5
Backgrounds	8	9	0
$p_T(W)$	3	3	3
PDF	11	11	11
QED	11	12	11
Total Systematic	39	27	26
Statistical	48	54	0
Total	62	60	26

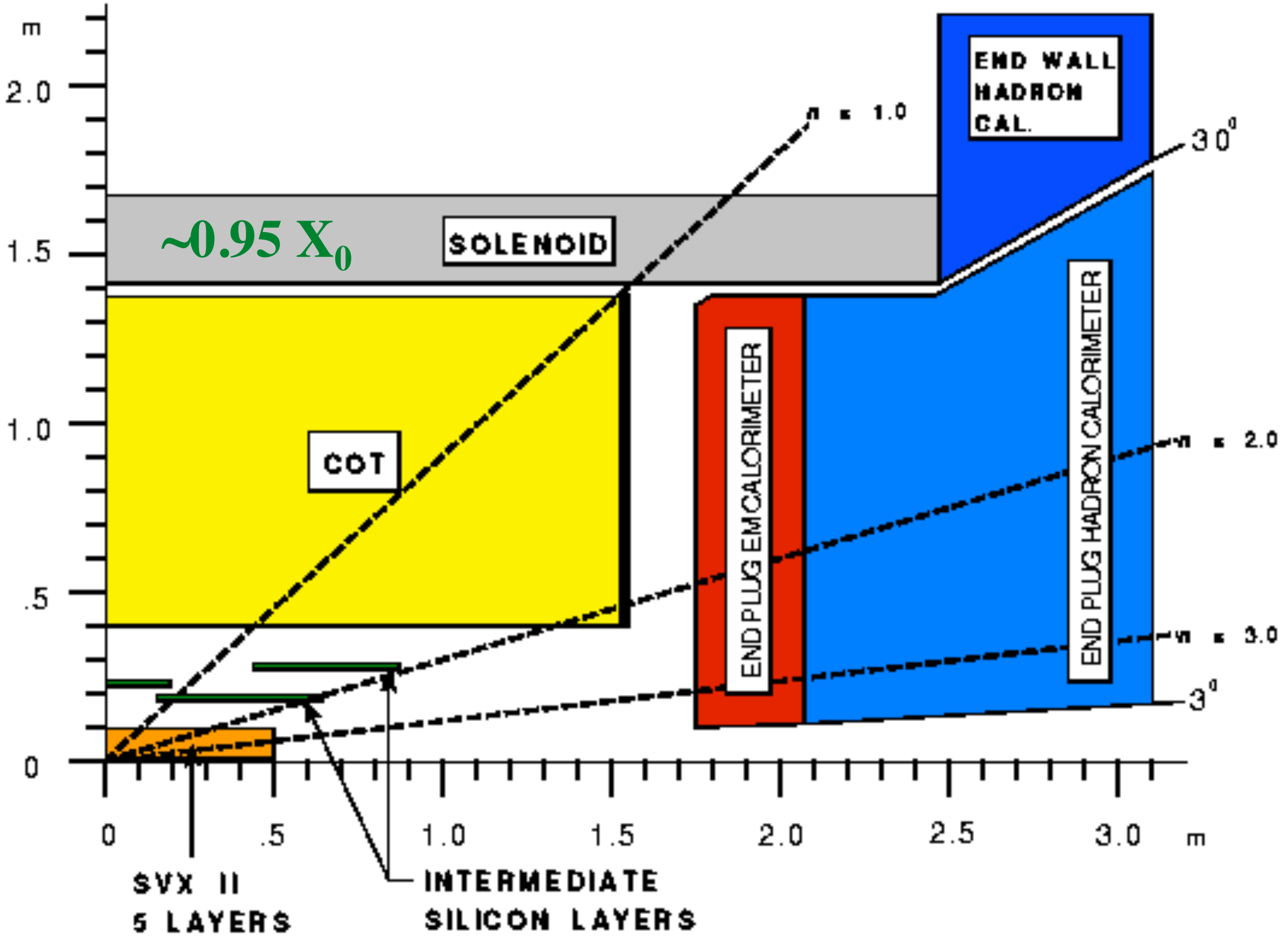
Total	**48**

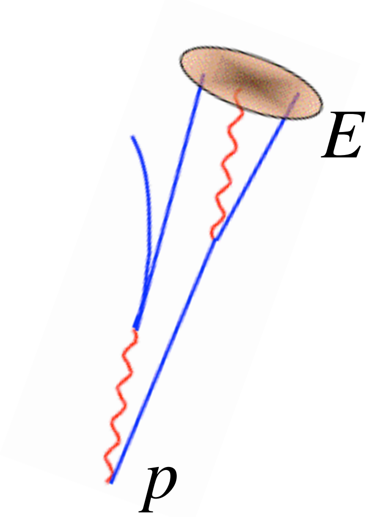
D0 Preliminary : 1 fb^{-1}

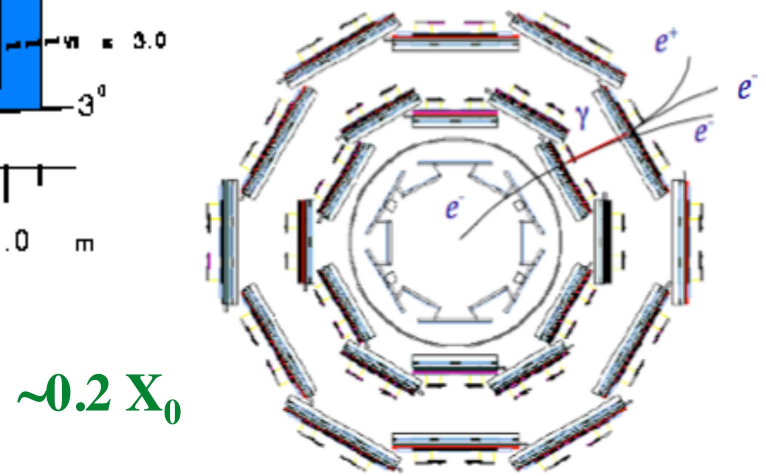
Source	$\sigma(m_W)$ MeV m_T
Experimental	
Electron Energy Scale	34
Electron Energy Resolution Model	2
Electron Energy Nonlinearity	4
W and Z Electron energy loss differences	4
Recoil Model	6
Electron Efficiencies	5
Backgrounds	2
Experimental Total	35
W production and decay model	
PDF	9
QED	7
Boson p_T	2
W model Total	12
Total	37

Statistical	23
Total	**44**

Radiation


m
2.0
1.5
1.0
.5
0
~0.95 X_0
SOLENOID
COT
END WALL
HADRON
CAL.
END PLUG EM CALORIMETER
END PLUG HADRON CALORIMETER
η = 1.0
η = 2.0
η = 3.0
30°
3°
.5
1.0
1.5
2.0
2.5
3.0
SVX II
5 LAYERS
INTERMEDIATE
SILICON LAYERS


E
p


~0.2 X_0
e+
e-
e-
γ
e-

Calibration

CDF : 200 pb^{-1}

Track calibration (0.021%)

$J/\Psi \to \mu\mu$; $\Upsilon(1S) \to \mu\mu$; $Z \to \mu\mu$

EM CAL calibration (0.037%)

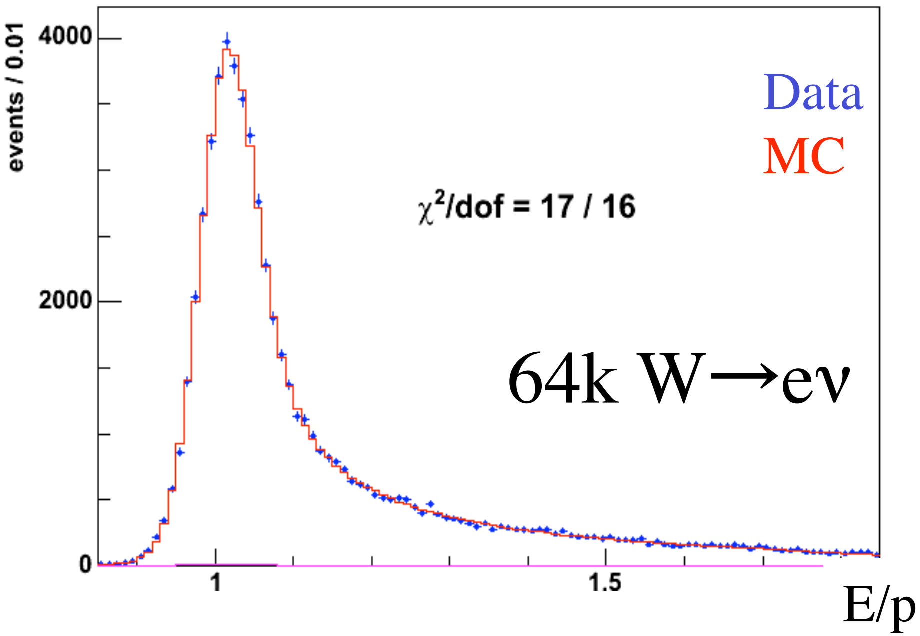
E/p ($W \to e\nu$) ; $Z \to ee$

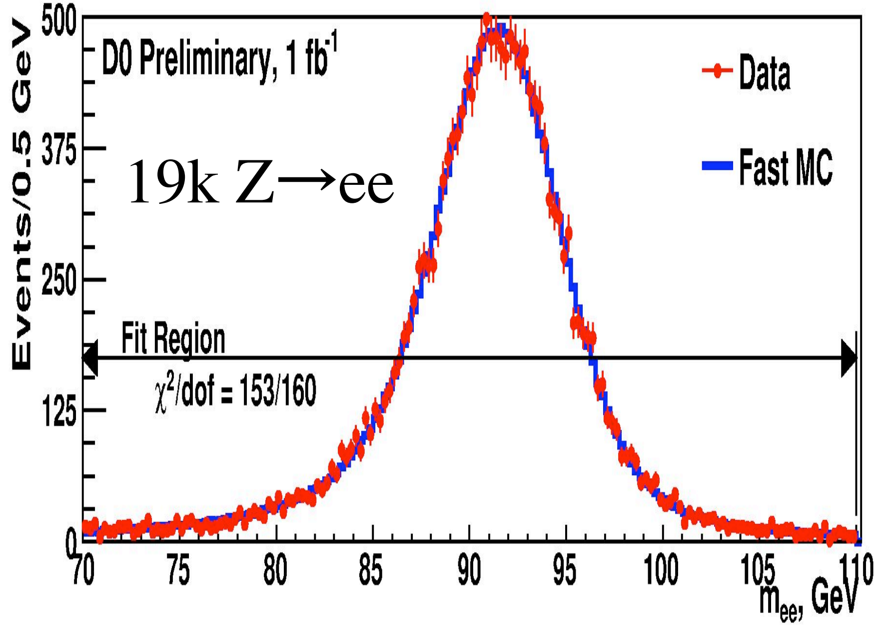
D0 Preliminary : 1 fb^{-1}

EM CAL calibration (0.042%)

$Z \to ee$

~4 X_0 before CAL determined using EM longitudinal granularity with sub-samples in η





Other systematics

M_T fits

$\Delta(M_W)$ MeV	CDF e (μ) (200 pb^{-1})	D0 e (1 fb^{-1})	ATLAS[1] e(μ) (10 fb^{-1})
scale	30 (17)	34	4 (4)
Lepton ID	3 (1)	6	5 (<1)
recoil	11 (11)	6	5 (5)
bckgd	8 (9)	2	2 (2)
PDFs	11 (11)	9	1 (1)
Total syst.	39 (27)	37	8 (7)
Stat.	48 (54)	23	2 (2)
Total	62 (60)	44	8 (7)

← Choose ID cuts carefully

← "Best guess" from CDF result

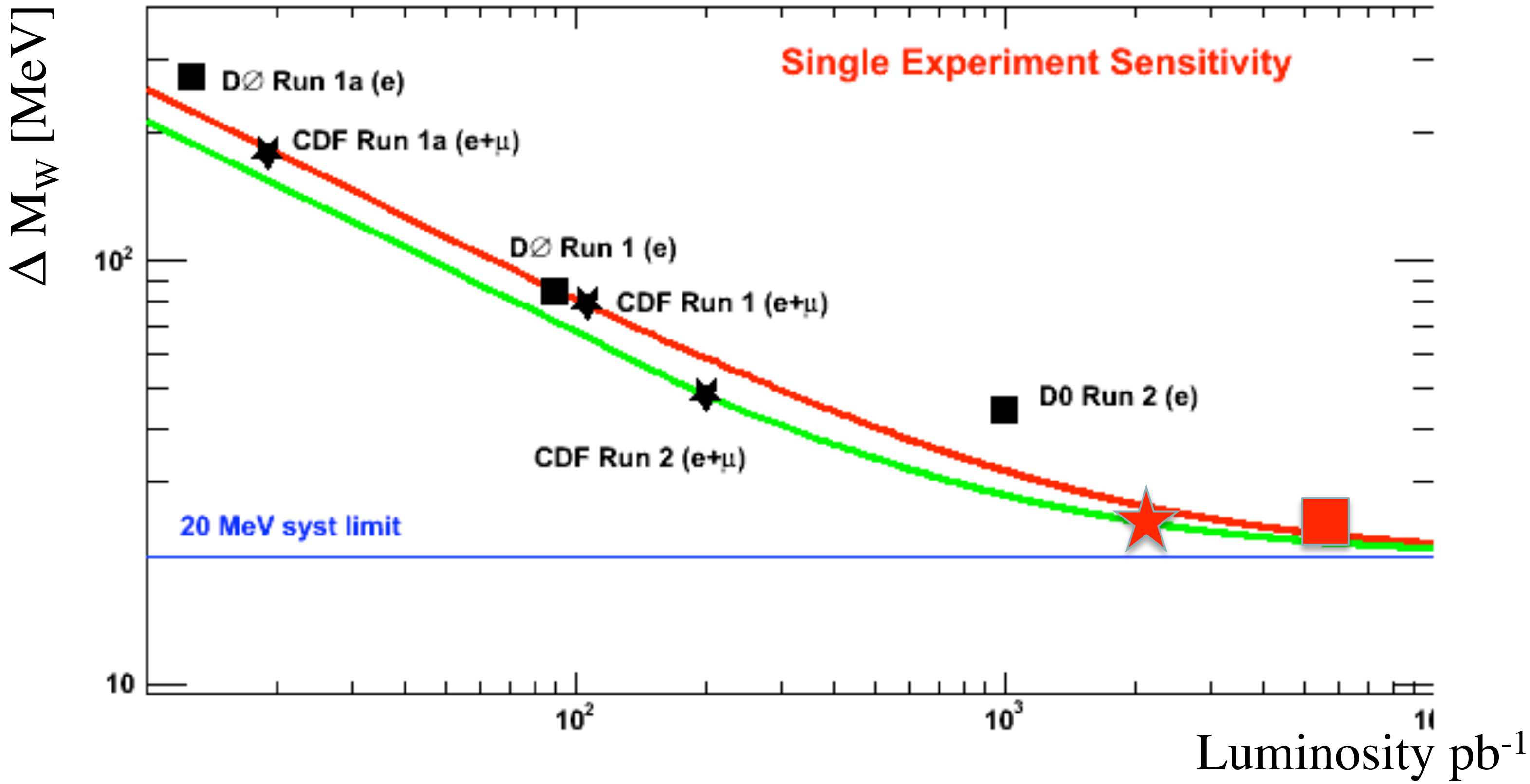
← Multijet : 0.2 ± 0.1 % assumed

← Assuming constraint from Y_Z

Systematics at this level are hard !! Internal cross checks are vital.

[1][Eur. Phys. J. C (2008) 57]

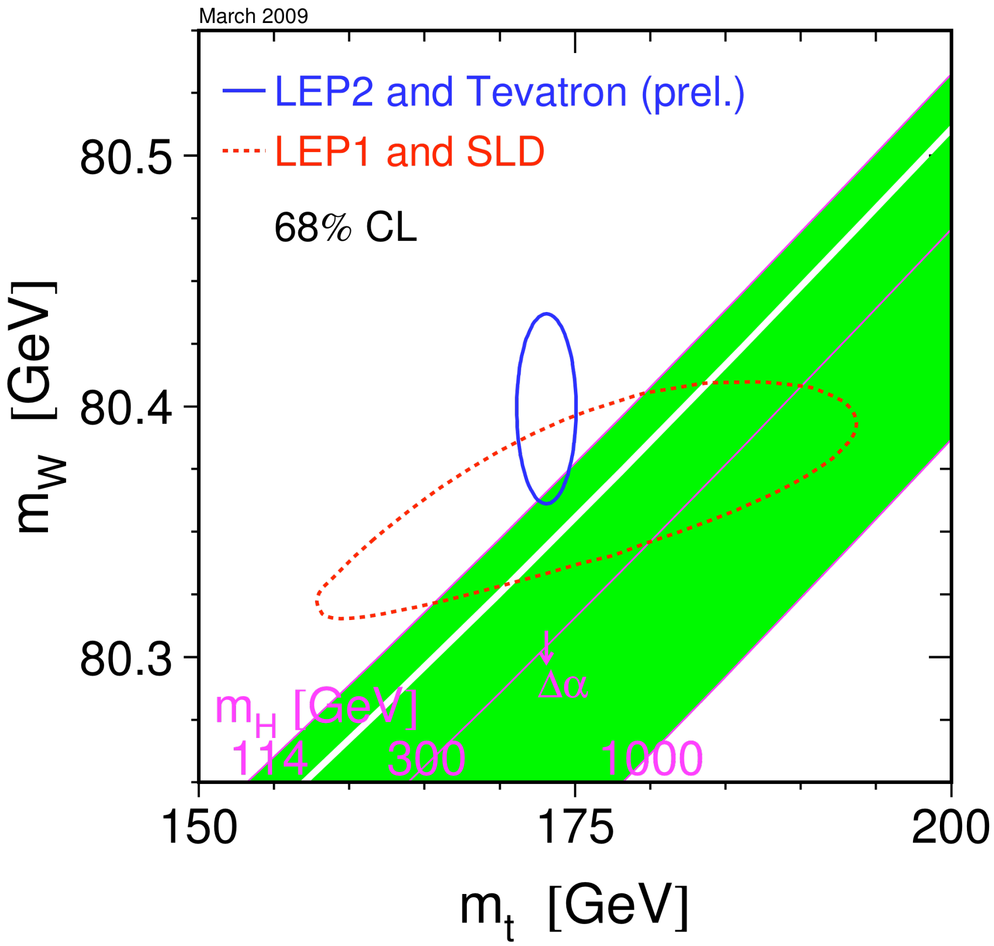
TeVatron projections



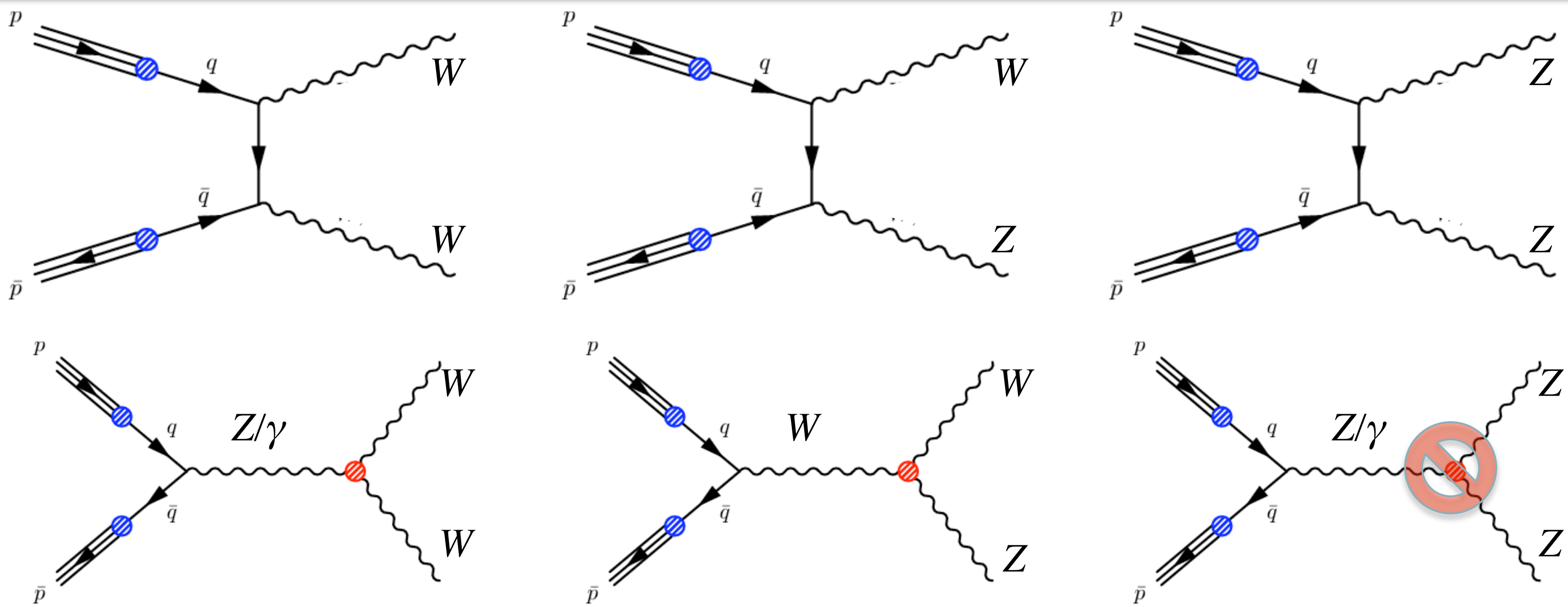
CDF [2.3 fb^{-1}]/D0 [5 fb^{-1}] : <~ 25 MeV ??

ATLAS/CMS[10 fb^{-1}] : ~ 7-8 MeV per channel in 10 fb^{-1} ????

W mass


March 2009
LEP2 and Tevatron (prel.)
LEP1 and SLD
68% CL
80.5
80.4
80.3
m_W [GeV]
m_H [GeV]
114
300
1000
Δα
150
175
200
m_t [GeV]

Heavy dibosons

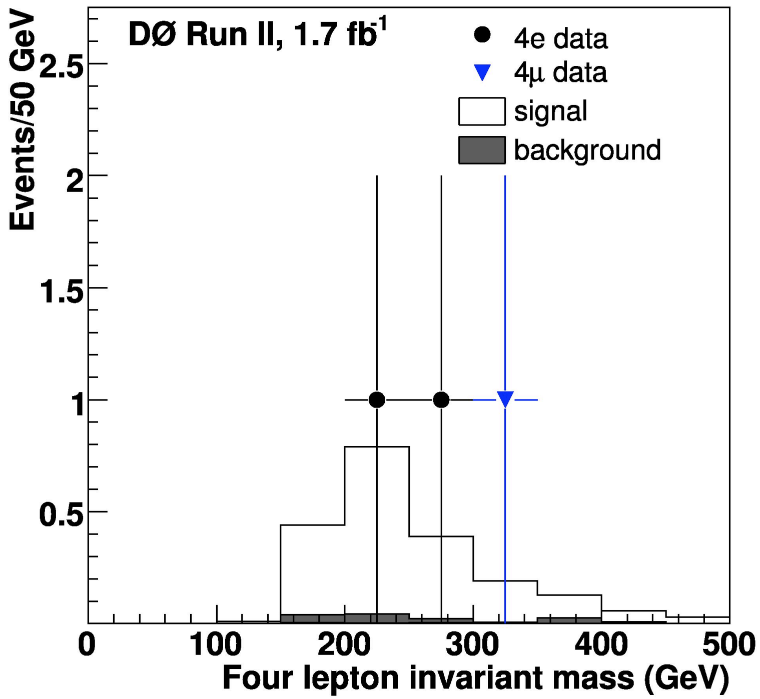


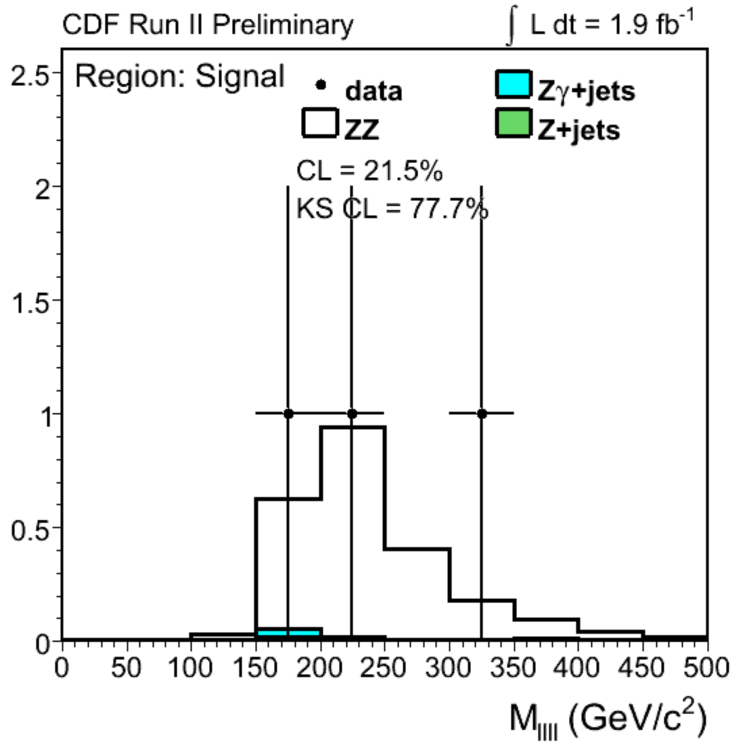
	WW	WZ	ZZ
CDF:	12.1 ± 2.3 pb	4.3 ± 1.8 pb	1.4 ± 0.7 pb
D0:	11.5 ± 2.2 pb	2.7 ± 2.1 pb	1.6 ± 0.7 pb
LHC (SM):	112 pb	48 pb	15 pb

Observations of all expected early (100 pb^{-1} for WW, WZ, 1fb^{-1} for ZZ)

V V

ZZ observation

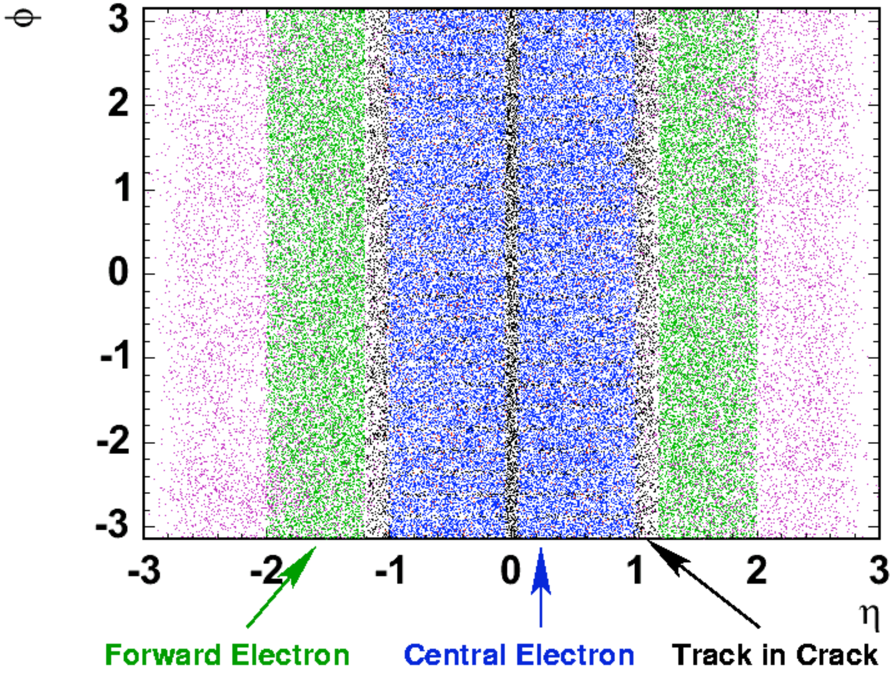


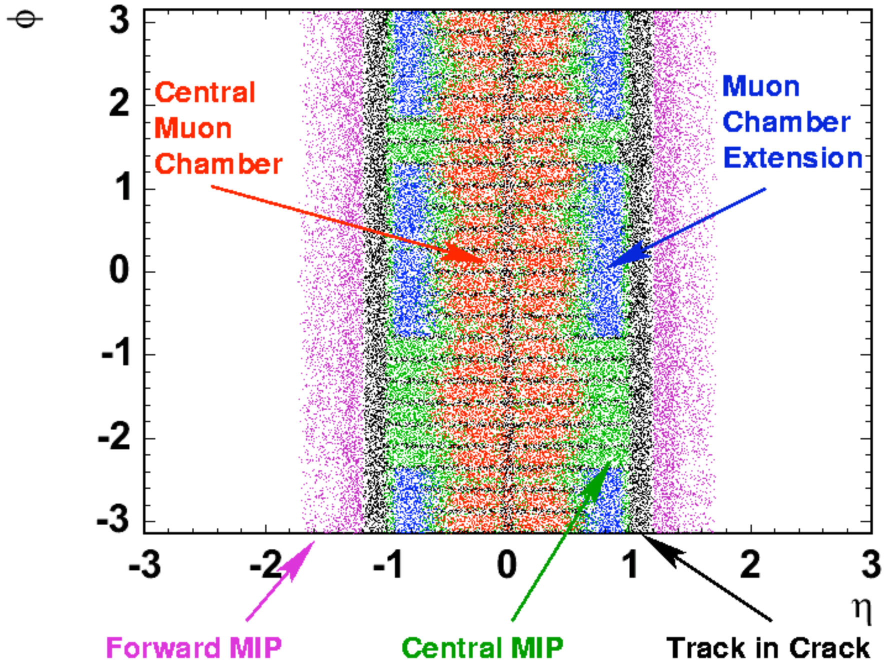


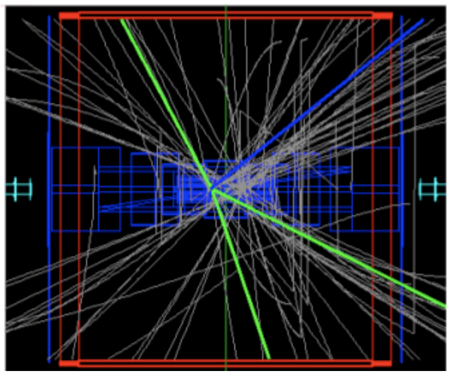
5.3 σ significance
(5.7 σ including Z→ll, Z→νν)

4.4 σ significance

Lepton acceptance







Anomalous TGC limits

Signature: enhanced cross section at high M_T^W / p_T^Z

TeV ➔LHC :

- Factor 10 in σ
- > 10 in $\mathcal{L}$
- Increase in C.O.M. also improves sensitivity to anomalous TGC

Diboson, (fit spectra)	λ_Z	$\Delta\kappa_Z$	Δg_1^Z	$\Delta\kappa_\gamma$	λ_γ
* WZ, (M_T)	[-0.015, 0.013]	[-0.095, 0.222]	[-0.011, 0.034]		
* WW, (M_T)	[-0.040, 0.038]	[-0.035, 0.073]	[-0.149, 0.309]	[-0.088, 0.089]	[-0.074, 0.165]
WZ (CDF) (1.9 fb^{-1})	[-0.13, 0.14]	[-0.76, 1.18]	[-0.13, 0.23]		
WW (D0) (1 fb^{-1})			[-0.14, 0.30]	[-0.54, 0.83]	[-0.14, 0.18]
WW, (LEP) ($\lambda_\gamma = \lambda_Z, \Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \tan^2\theta_W$)			[-0.051,0.034]	[-0.105,0.069]	[-0.059,0.026]

* ATLAS, 10 fb^{-1}

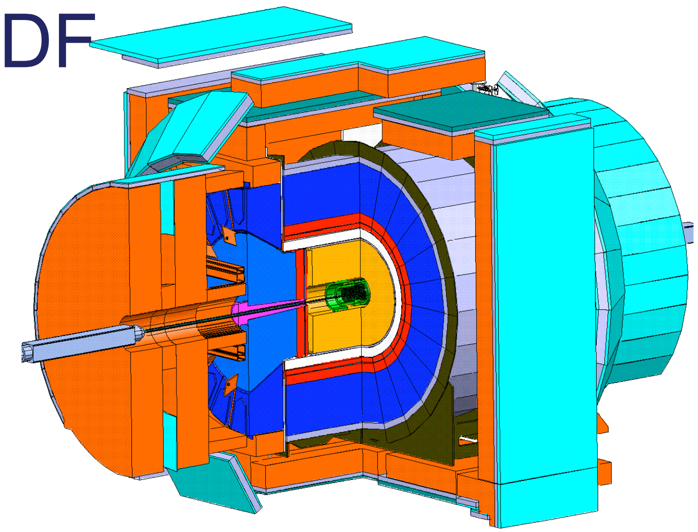
Summary

- W charge asymmetry
  - LHC complimentary to TeVatron
  - Should get constraints on PDFs early.
  - Watch out for multijet background!
  - Best to give as much information as possible in paper.
- W mass
  - CDF and D0 expect updates (<~ 25 MeV each?)
  - Significant improvement possible at the LHC, but it will not happen fast.
  - Watch out for radiation, recoil, multijet, lepton ID, PDFs…
  - Use internal cross checks as much as possible.
- Dibosons
  - Observations likely early
  - Sensitivity will quickly surpass the TeVatron
  - Acceptance, acceptance, acceptance

BACK UP

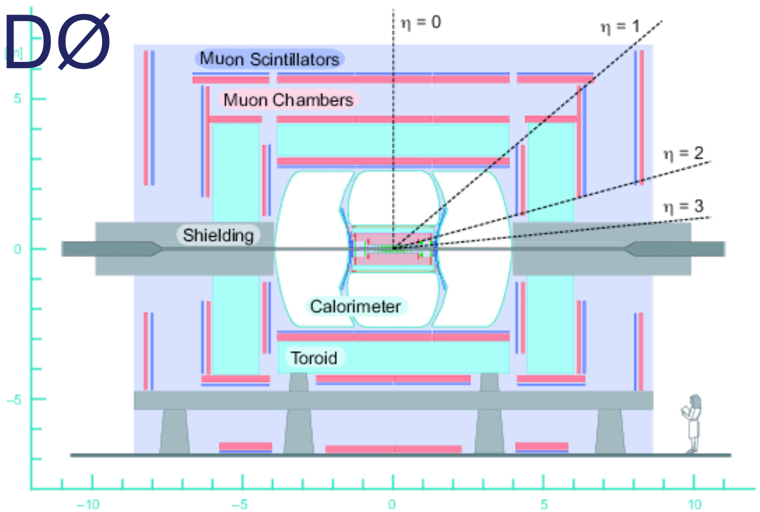
W/Z detection at DØ/CDF

CDF



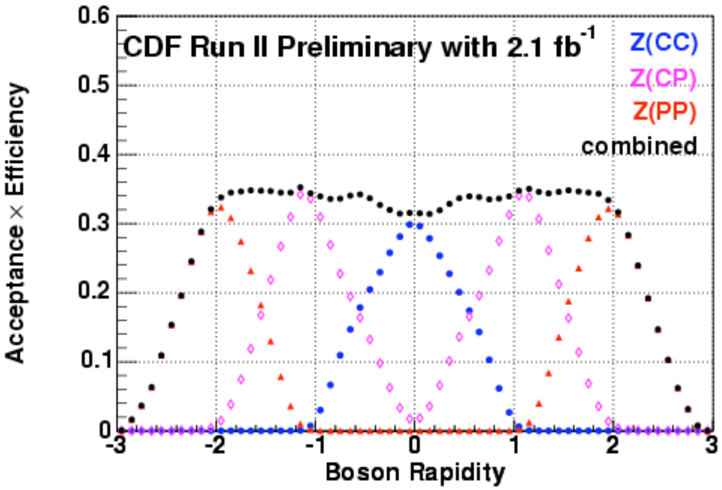
- Silicon detectors ($|\eta|<\sim 2.8$)
- Central drift chambers ($|\eta|<\sim 1.5$)
- Tracking resolution : $\sigma(p_T)/p_T \sim 0.05\% \times p_T$
- Segmented sampling calorimeters ($|\eta|<\sim 3.6$)
  EM: $\sigma(E)/E \sim 13.5\% / \sqrt{E_T} \oplus 1.5\%$
- Muon detectors ($|\eta|<\sim 1.0$)

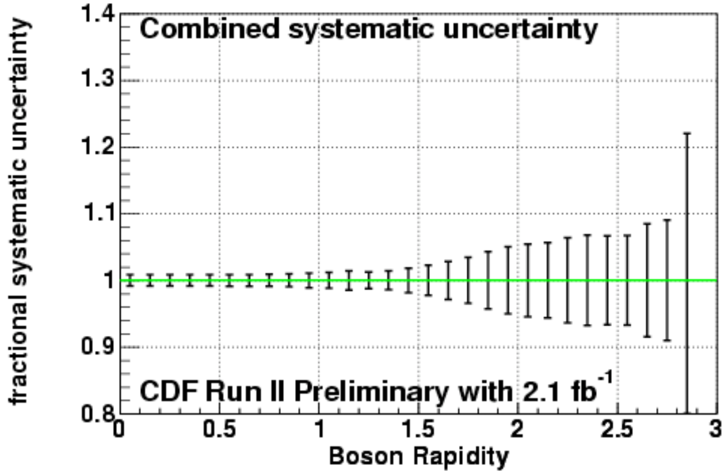
DØ

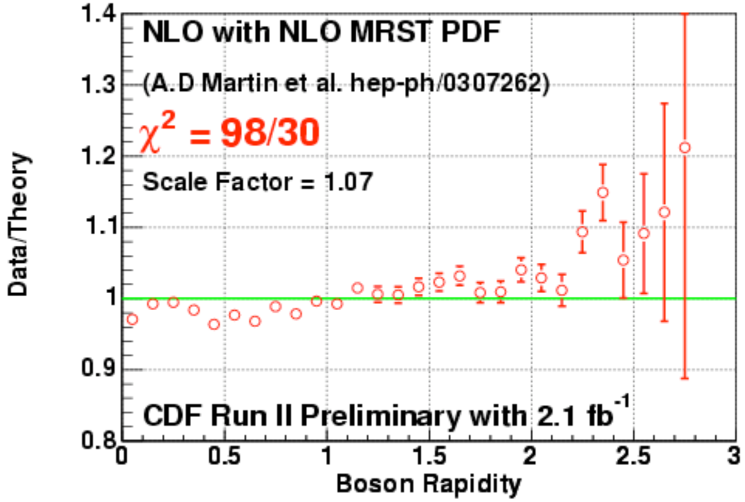


- Silicon detectors ($|\eta|<\sim 3.2$)
- Central fiber tracker ($|\eta|<\sim 2$)
- Tracking resolution : $\sigma(p_T)/p_T \sim 0.2\% \times p_T$
- Segmented sampling calorimeters ($|\eta|<\sim 4.2$)
  EM: $\sigma(E)/E \sim 15\% / \sqrt{E} \oplus 4\%$
- Muon detectors ($|\eta|<\sim 2.0$)

Backup: Z rapidity

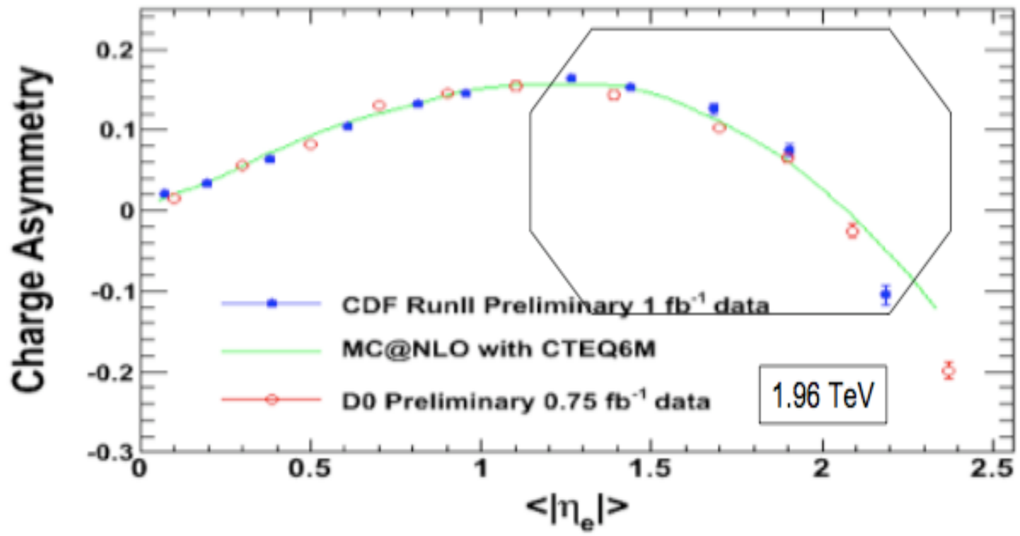


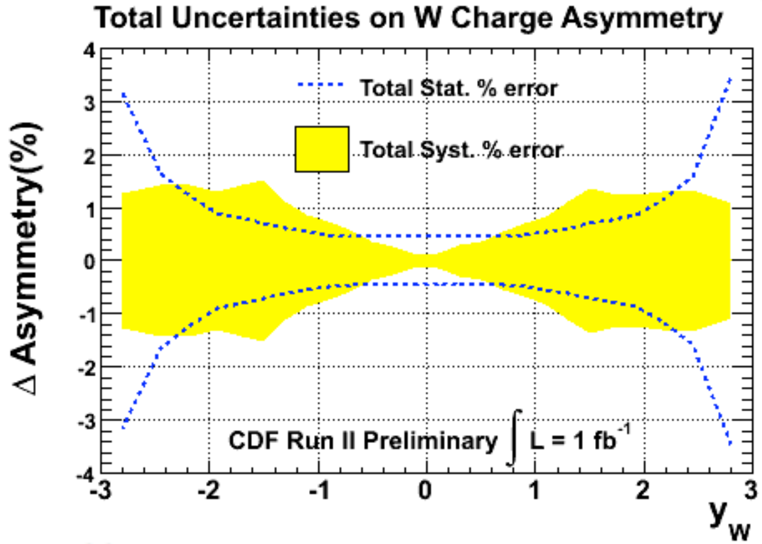




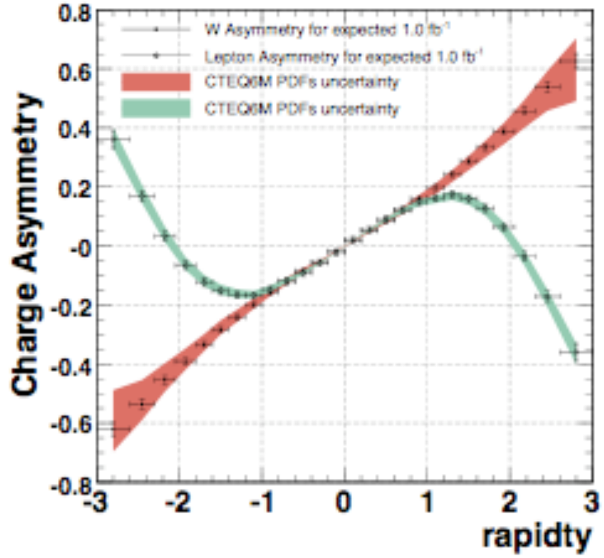
PDF constraint: ~0.75 < y < ~2

Backup: W charge asymmetry

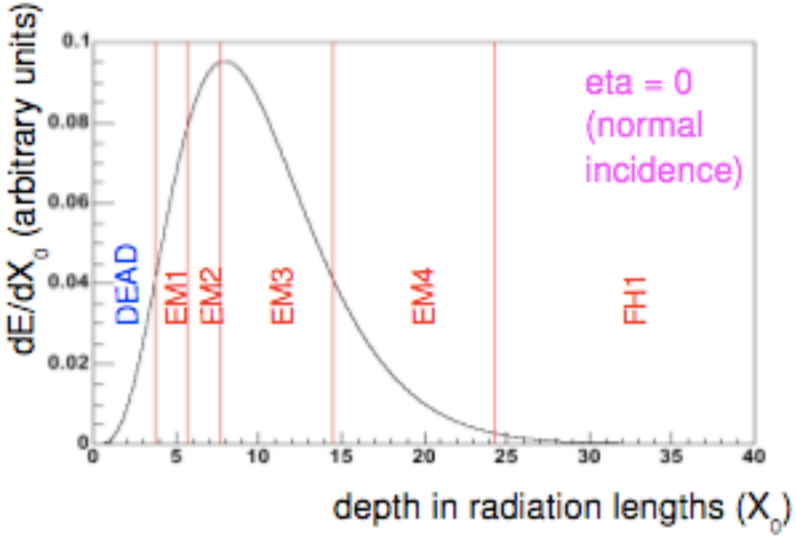


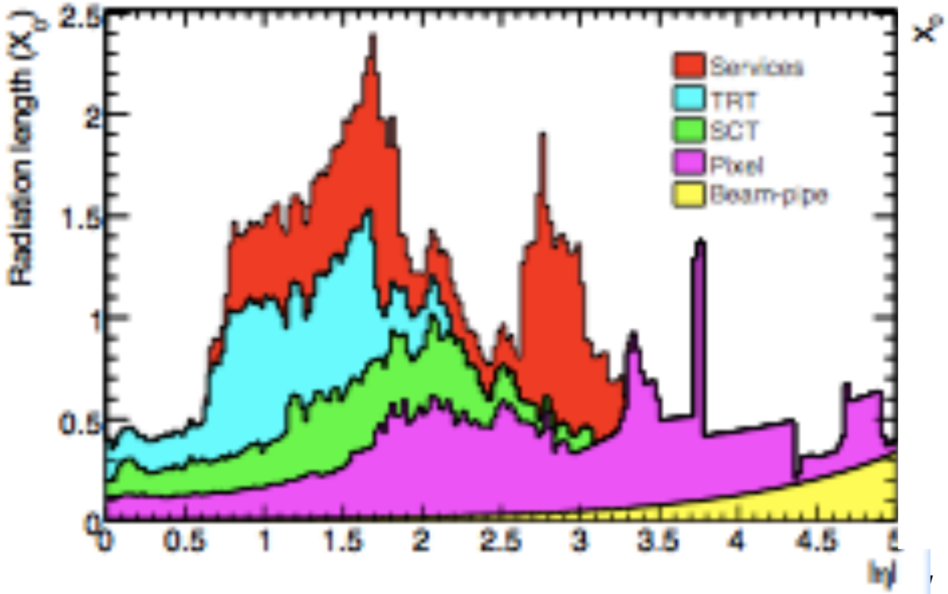


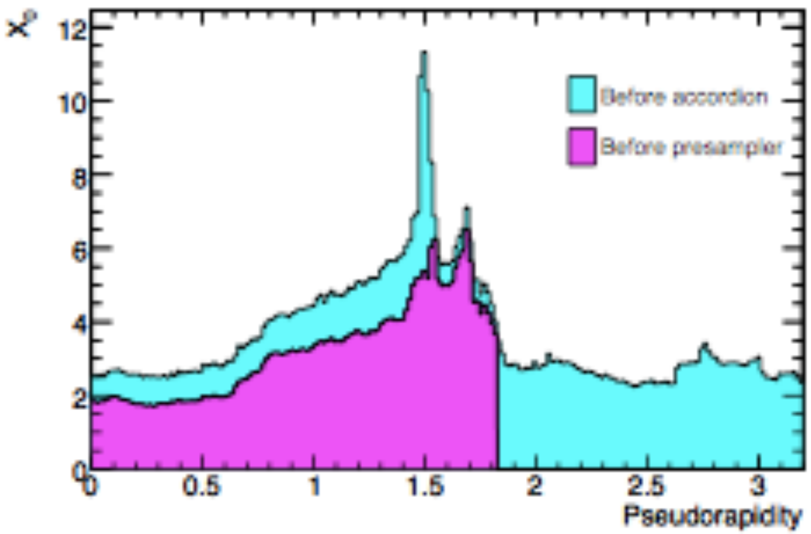
$\|y_W\|$	CFR	BKG	EM	Recoil	Trig	ID	PDF	Stat. (1fb^{-1})
	$\Delta A(\|y_W\|)\ (\times 10^{-2})$							
0.0 - 0.2	0.02	0.04	0.01	0.11	0.03	0.02	0.03	0.31
0.2 - 0.4	0.01	0.09	0.04	0.22	0.08	0.07	0.08	0.32
0.4 - 0.6	0.02	0.11	0.06	0.22	0.13	0.17	0.15	0.33
0.6 - 0.8	0.03	0.15	0.07	0.34	0.14	0.30	0.22	0.32
0.8 - 1.0	0.03	0.20	0.07	0.42	0.11	0.47	0.24	0.34
1.0 - 1.2	0.04	0.18	0.08	0.33	0.09	0.69	0.27	0.38
1.2 - 1.4	0.05	0.18	0.15	0.67	0.06	0.78	0.28	0.43
1.4 - 1.6	0.04	0.14	0.14	1.10	0.04	0.85	0.28	0.50
1.6 - 1.8	0.08	0.12	0.26	0.92	0.03	0.89	0.29	0.55
1.8 - 2.05	0.22	0.13	0.31	0.82	0.06	0.80	0.34	0.62
2.05 - 2.3	0.44	0.21	0.53	0.59	0.17	0.85	0.42	0.83
2.3 - 2.6	0.45	0.19	0.62	0.40	0.27	0.86	0.50	1.10
2.6 - 3.0	0.14	0.10	0.60	0.43	0.28	0.65	0.53	2.30



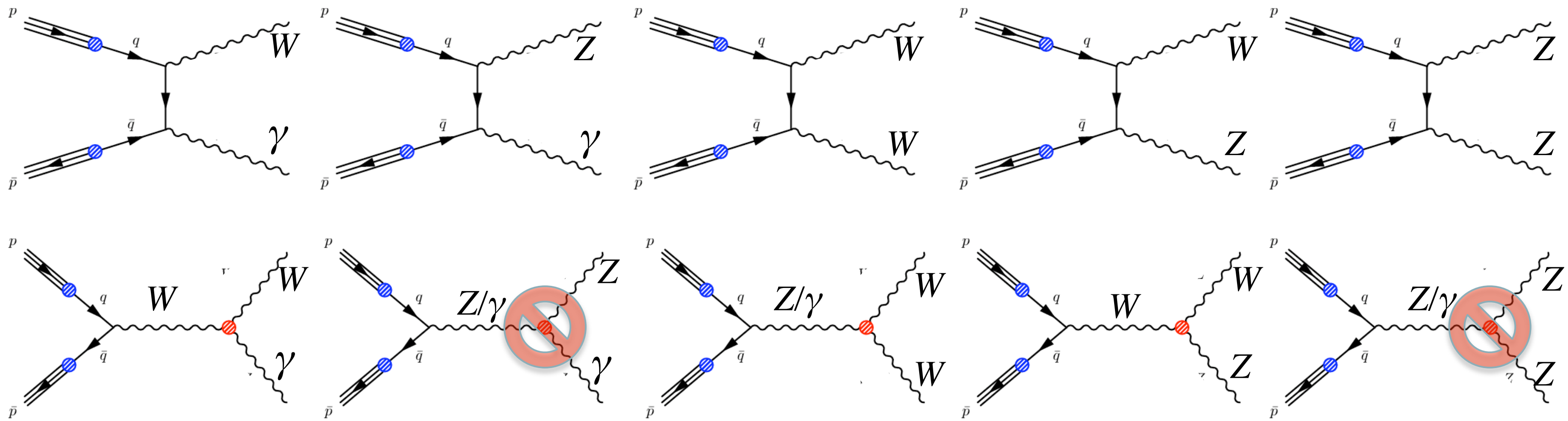
Backup : W mass







Di bosons



	Wγ	Zγ	WW	WZ	ZZ
CDF:	18.0 ± 2.8 pb	4.6 ± 0.5 pb	12.1 ± 2.3 pb	4.3 ± 1.8 pb	1.4 ± 0.7 pb
	($E_T^\gamma > 7$ GeV)				
D0:	14.8 ± 2.1 pb	5.0 ± 0.4 pb	11.5 ± 2.2 pb	2.7 ± 2.1 pb	1.6 ± 0.7 pb
	($E_T^\gamma > 8$ GeV)				
LHC (SM):	451 pb	219 pb	112 pb	48 pb	15 pb

TGC limits

Diboson, (fit spectra)	λ_Z	$\Delta\kappa_Z$	Δg_1^Z	$\Delta\kappa_\gamma$	λ_γ
WZ, (M_T)	[-0.015, 0.013]	[-0.095, 0.222]	[-0.011, 0.034]		
$W\gamma$, (p_T^γ)				[-0.26, 0.07]	[-0.05, 0.02]
WW, (M_T)	[-0.040, 0.038]	[-0.035, 0.073]	[-0.149, 0.309]	[-0.088, 0.089]	[-0.074, 0.165]
WZ (CDF) (1.9 fb^{-1})	[-0.13, 0.14]	[-0.76, 1.18]	[-0.13, 0.23]		
Wγ (D0) (0.7 fb^{-1})				[-0.51, 0.51]	[-0.12, 0.13]
WW, (LEP) ($\lambda_\gamma = \lambda_Z, \Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \tan^2\theta_W$)			[-0.051,0.034]	[-0.105,0.069]	[-0.059,0.026]
WW (D0) (1 fb^{-1})			[-0.14, 0.30]	[-0.54, 0.83]	[-0.14, 0.18]

	f_4^Z	f_5^Z	f_4^γ	f_5^γ
$ZZ \to \ell\ell\ell\ell$	[–0.010, 0.010]	[–0.010, 0.010]	[–0.012, 0.012]	[–0.013, 0.012]
$ZZ \to \ell\ell\nu\nu$	[–0.012, 0.012]	[–0.012, 0.012]	[–0.014, 0.014]	[–0.015, 0.014]
Combined	[–0.009, 0.009]	[–0.009, 0.009]	[–0.010, 0.010]	[–0.011, 0.010]
LEP Limit	[–0.30, 0.30]	[–0.34, 0.38]	[–0.17, 0.19]	[–0.32, 0.36]

TGC limits

Effective Lagrangian for charged (trilinear) couplings (WWγ/WWZ):

$$\frac{L_{WWV}}{g_{WWV}} = ig_1^V(W_{\mu\nu}^* W^\mu V^\nu - W_\mu^* V_\nu W^{\mu\nu}) + i\kappa_V W_\mu^* W_\nu V^{\mu\nu} + i\frac{\lambda_V}{M_W^2} W_{\lambda\mu}^* W_\nu^\mu V^{\nu\lambda}$$

$$- g_4^V W_\mu^* W_\nu (\partial^\mu V^\nu + \partial^\nu V^\mu) + g_5^V \varepsilon^{\mu\nu\lambda\rho}(W_\mu^* \partial_\lambda W_\nu - \partial_\lambda W_\mu^* W_\nu) V_\rho + i\tilde{k}_V W_\mu^* W_\nu \tilde{V}^{\mu\nu} + i\frac{\tilde{\lambda}_V}{M_W^2} W_{\lambda\mu}^* W_\nu^\mu \tilde{V}^{\nu\lambda}$$

$g_1^V, \kappa_V, \lambda_V \rightarrow$ C and P conserving

$g_4^V, \tilde{\kappa}_V, \tilde{\lambda}_V \rightarrow$ CP violating

$g_5^V \rightarrow$ CP conserving (but C, P violating)

$q\bar{q}' \rightarrow WZ$: WWZ ⇐ g_1^Z, κ_Z, λ_Z couplings

$q\bar{q}' \rightarrow WW$: WWZ, WWγ ⇐ κ_γ, λ_γ and κ_Z, λ_Z interference

SM: $g_1^Z = \kappa_V = 1,\ \lambda_V = 0 \quad (V = Z, \gamma)$