Measurement of W/Z properties at the Tevatron

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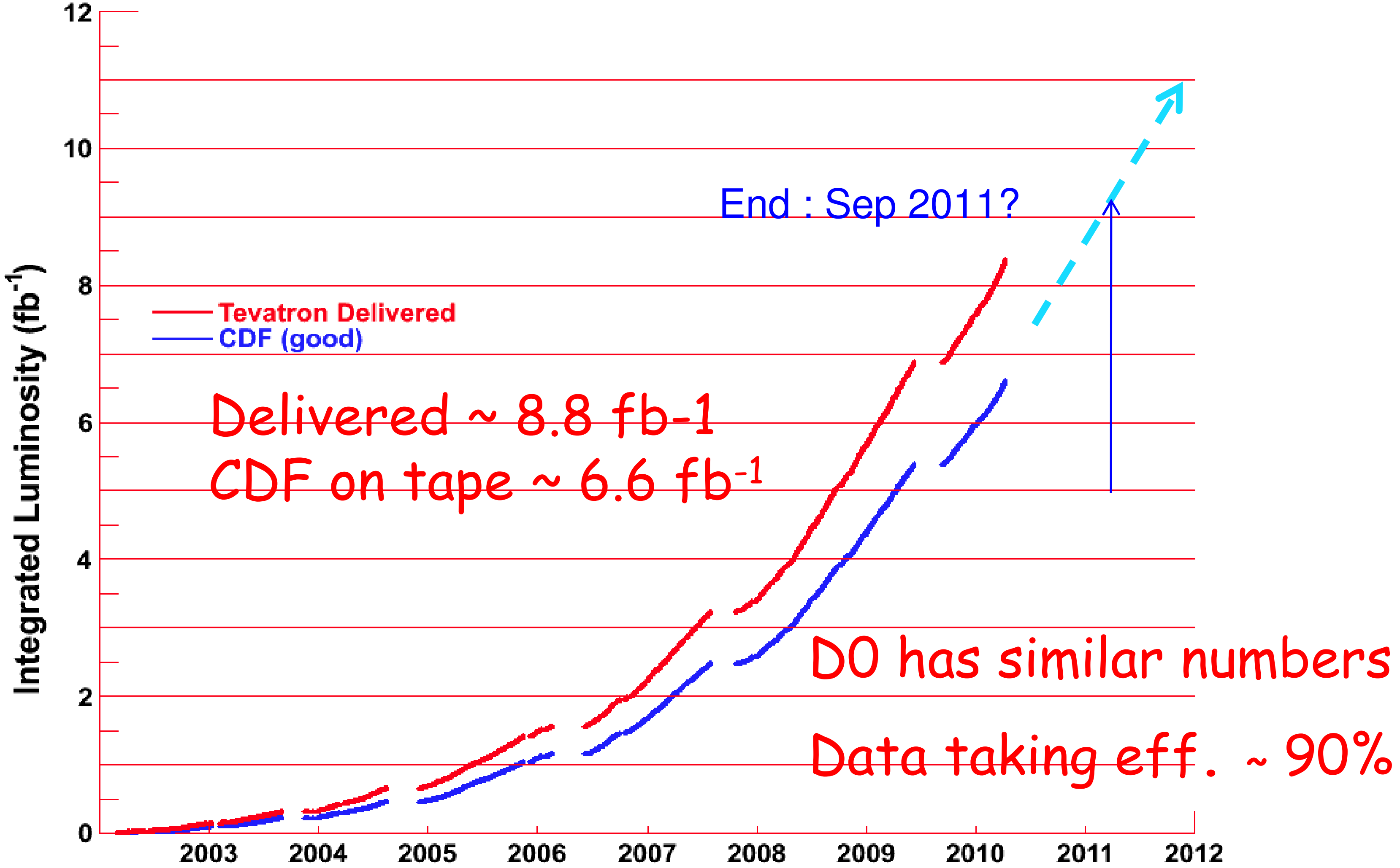
Tevatron Luminosity

Results shown today : 3-5 fb^{-1}

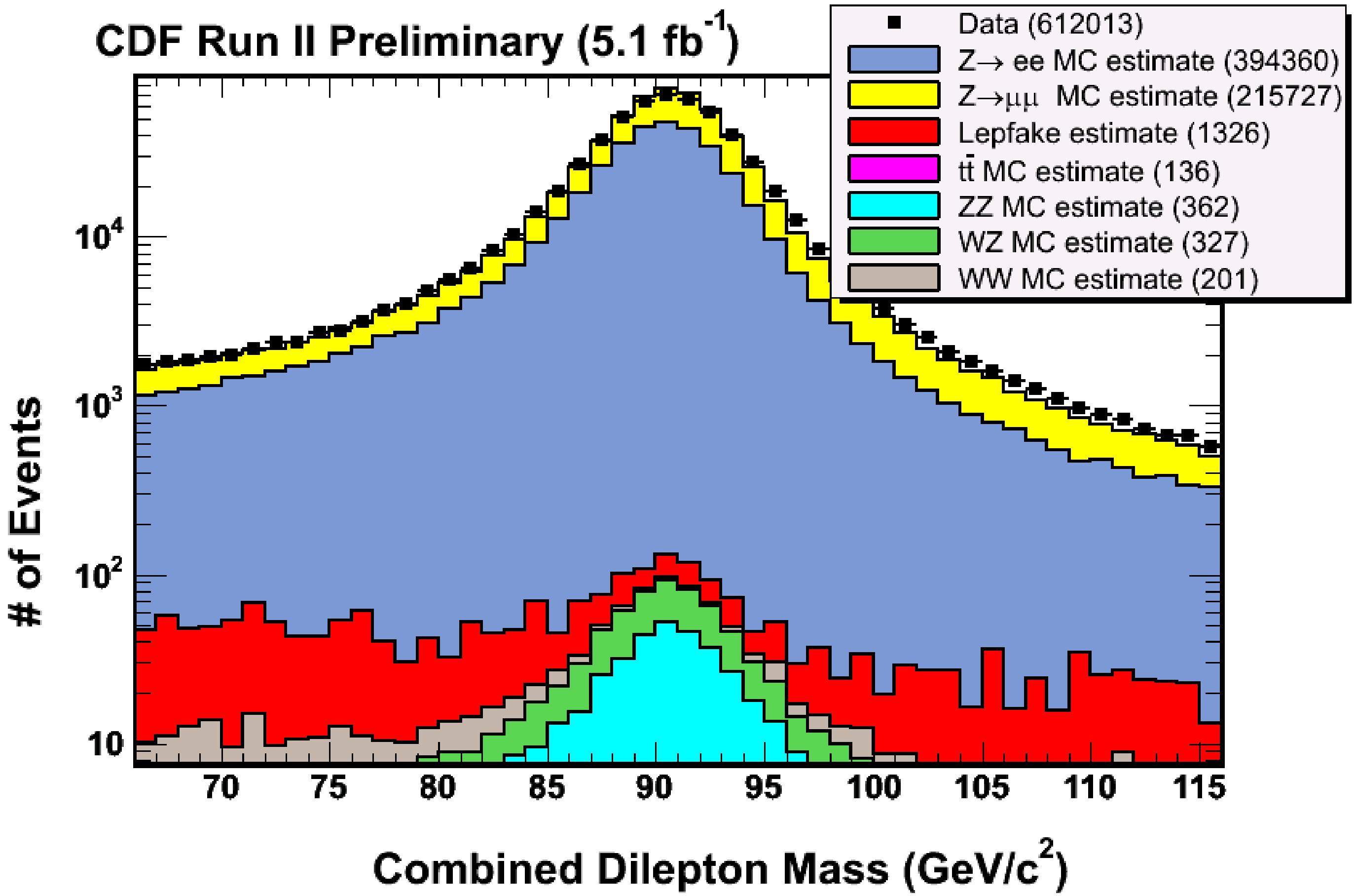


Large dataset

Prolific datasets : 600k Zs, 6M Ws for either e or μ

End of 2011: CDF W & Z samples twice that of LHC (1fb^{-1} @ 7 TeV)

And then there is also the D0 sample which is of similar size (>600K Z→μμ in 6 fb^{-1})

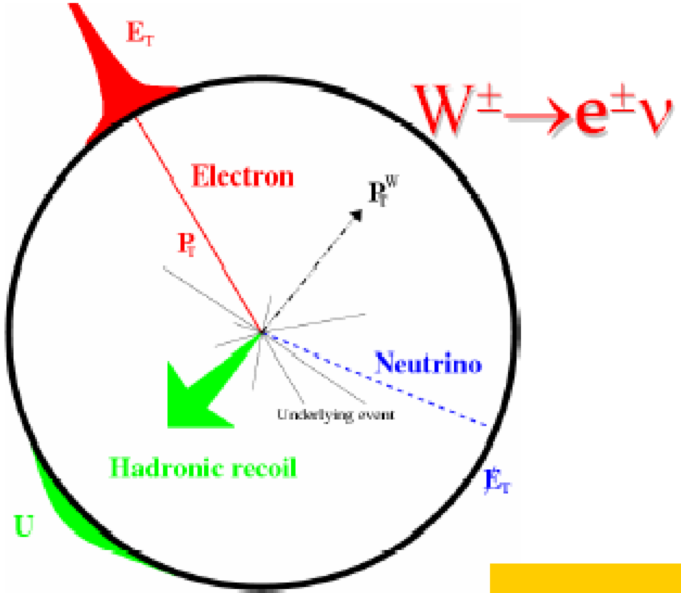


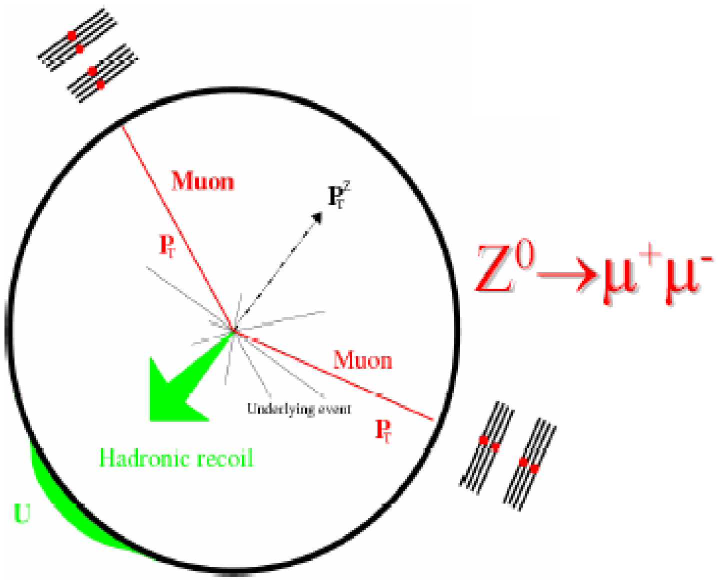
W & Z at the Tevatron

Electron:
EM Calorimeters
High Pt (Track)
Isolated

Muons:
Muon Detectors
High P_T
Isolated

Neutrinos:
Large Missing Energy
Only Transverse ($\not{E}_T$ or Met)





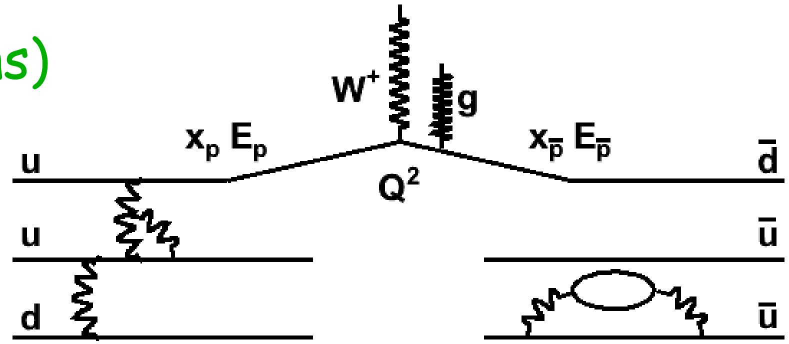
Z Signature: Two Isolated Leptons (diff charge)

W Signature: Isolated Lepton and $\not{E}_T$

QCD W and Z boson production

Test of QCD

- ☞ Can be used to check calculations
  - ⇨ NLO since long time
  - ⇨ NNLO
    - → (recently with full spin correlations)



$$\sigma = \Sigma_{ab} \int dQ\, \delta(Q - 2E_p \sqrt{x_p x_p}) \int dx_p\, f_a(x_p, Q) \int dx_p\, f_b(x_p, Q)\, \sigma(\hat{Q})$$

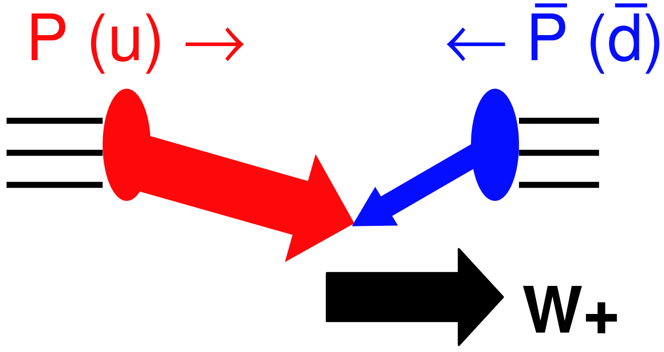
Sum over quarks, gluons

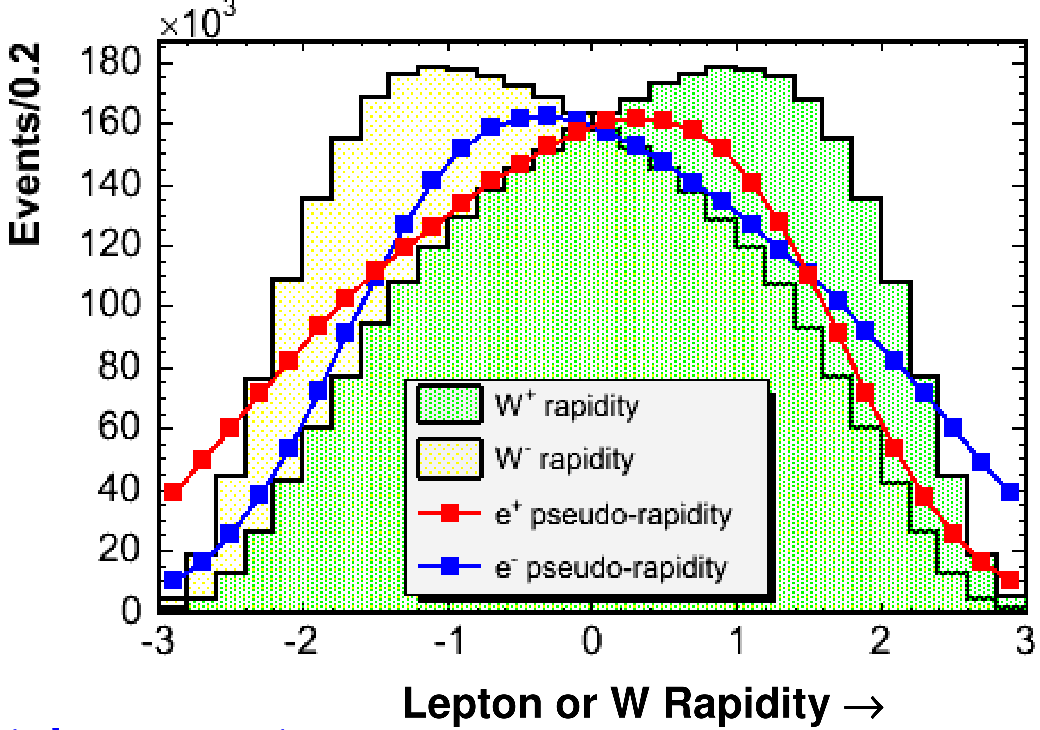
Kinematic constraint

Parton distribution functions

Calculable hard scattering cross section

W Charge Asymmetry





Precision of data now allows to ,measure asymmetries differential in lepton E_T

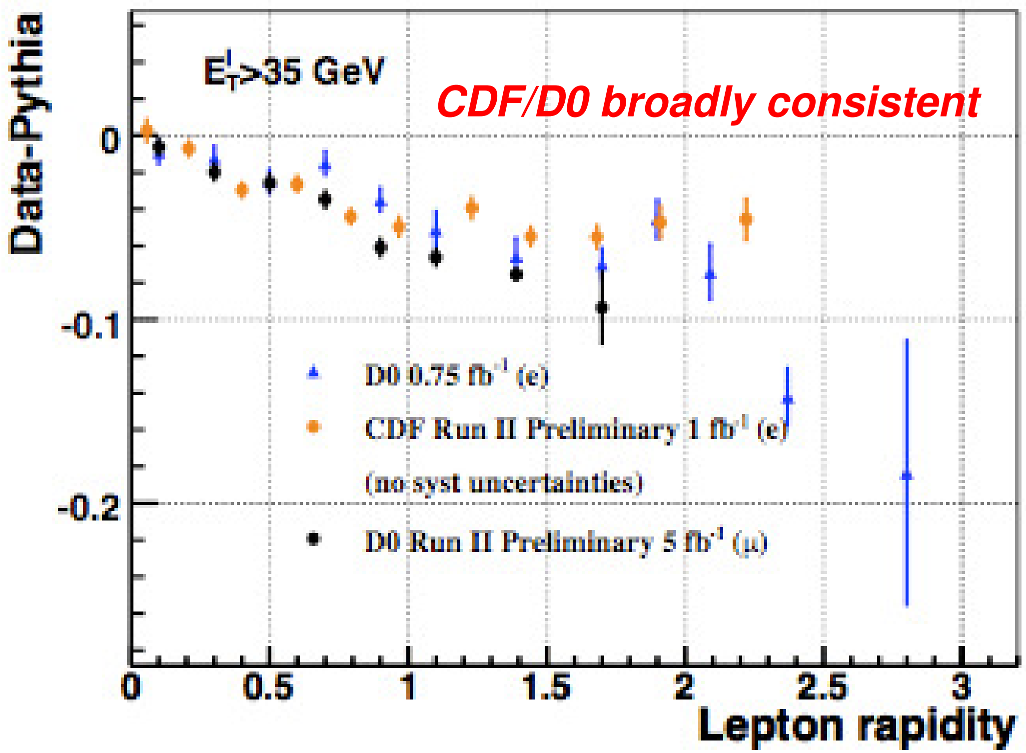
Exposed some inconsistencies with latest PDF fits

Tevatron results also discussed by H.Schellmann this morning in Session 6

W Charge Asymmetry

Number of issues have come to light:

- Compatibility of the CDF and D0 data
- Differences between resummation vs NLO+PS vs NNLO

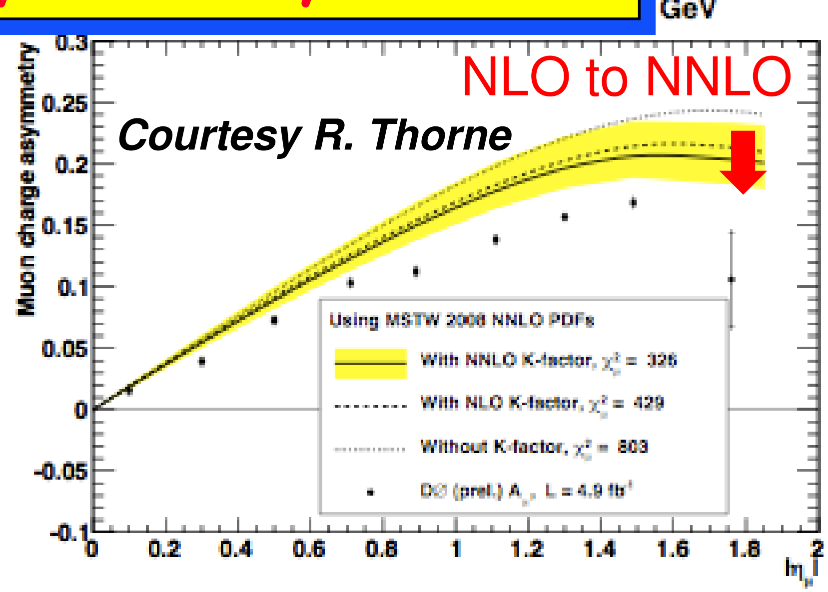


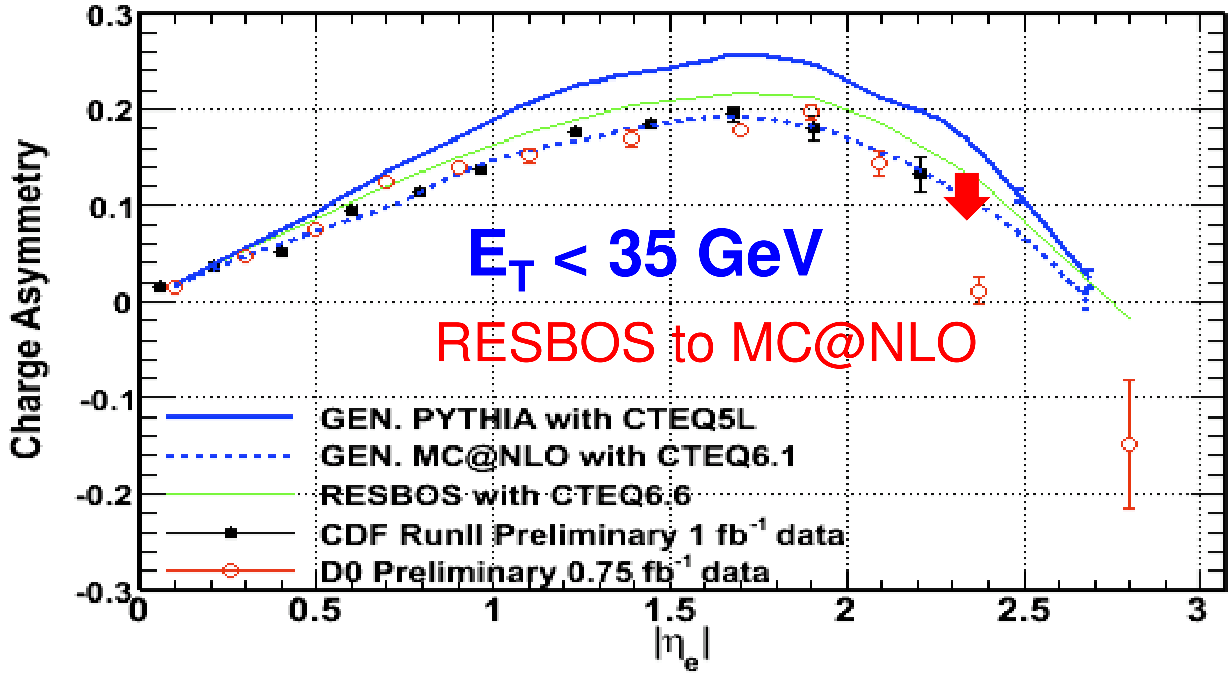
CDF has taken published W asymmetry data & produced lepton asymmetry for the PDF fitters to aid CDF/D0 comparisons

W Charge Asymmetry

- MC@NLO describes data better than RESBOS

- NNLO effects small but not negligible

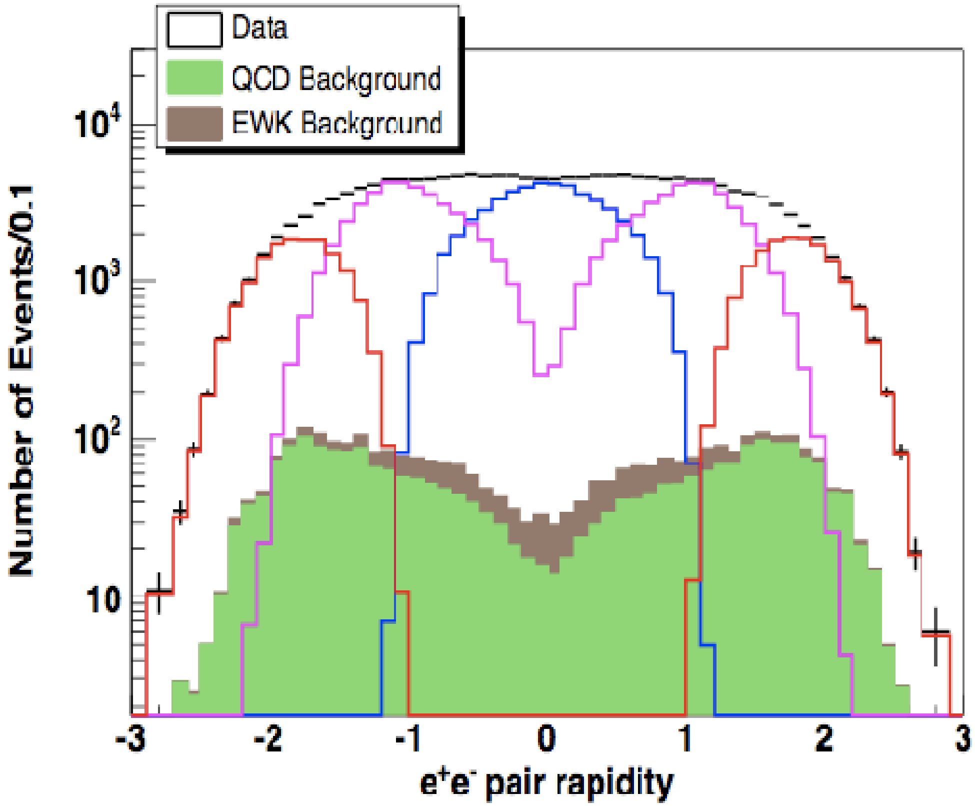




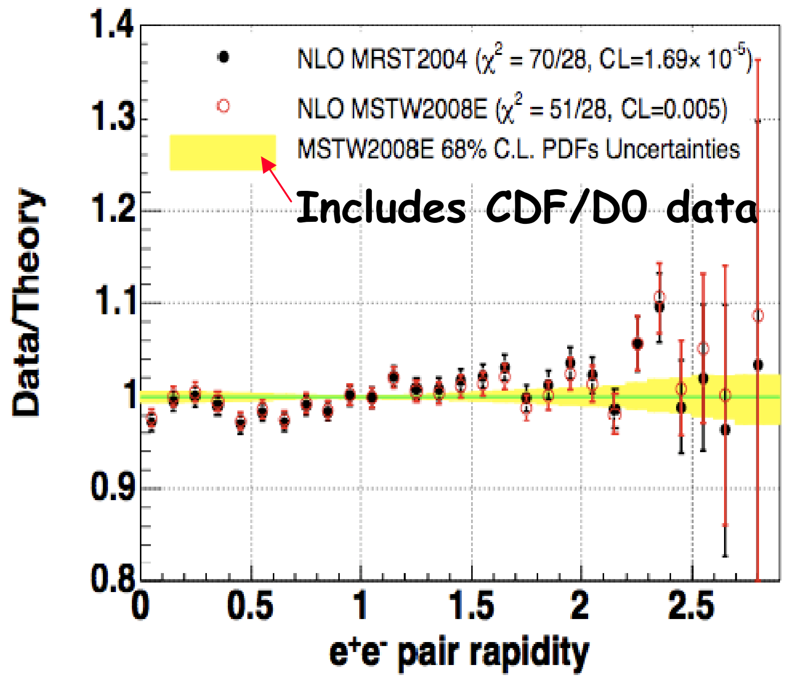
Use Z→ee to constrain PDFs

HERA F_2 / jet & Tevatron jet & W/Z data necessary for accurate PDFs for robust LHC predictions

$$Y_Z = 0.5 \ln\left(\frac{x_p}{x_{\bar{p}}}\right)$$



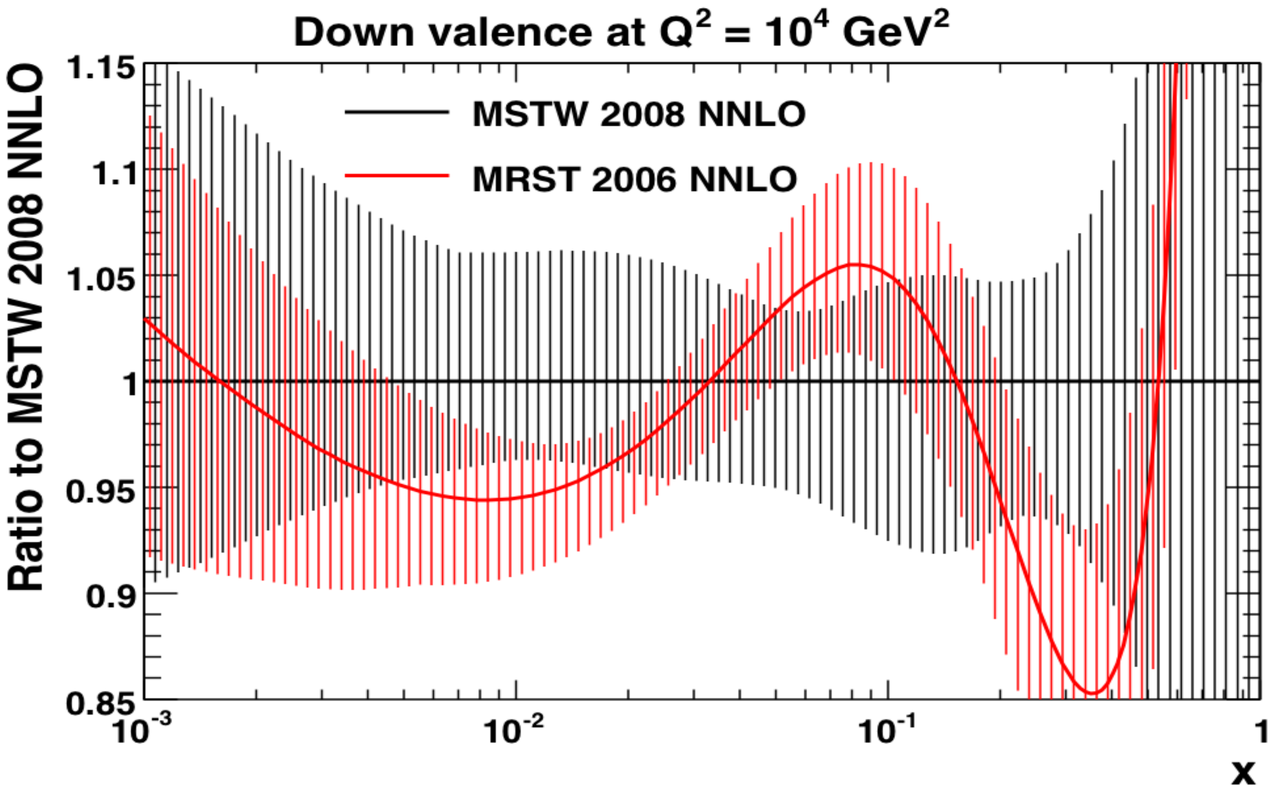
OLD PDF NLO χ^2/df = 70/28
NEW PDF NLO χ^2/df = 51/28



Constraining PDFs

u-valence already well constrained from F_2 data (e_Q^2)

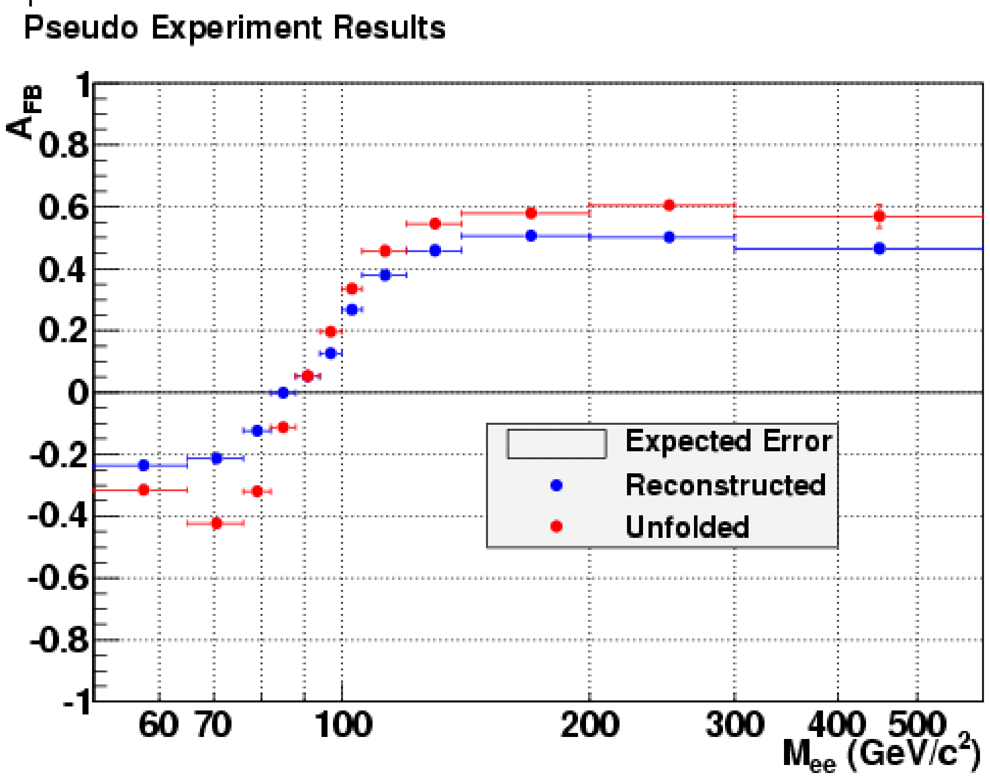
CDF Z rapidity allows more robust determination of d-valence at high-x albeit with a larger error than before !

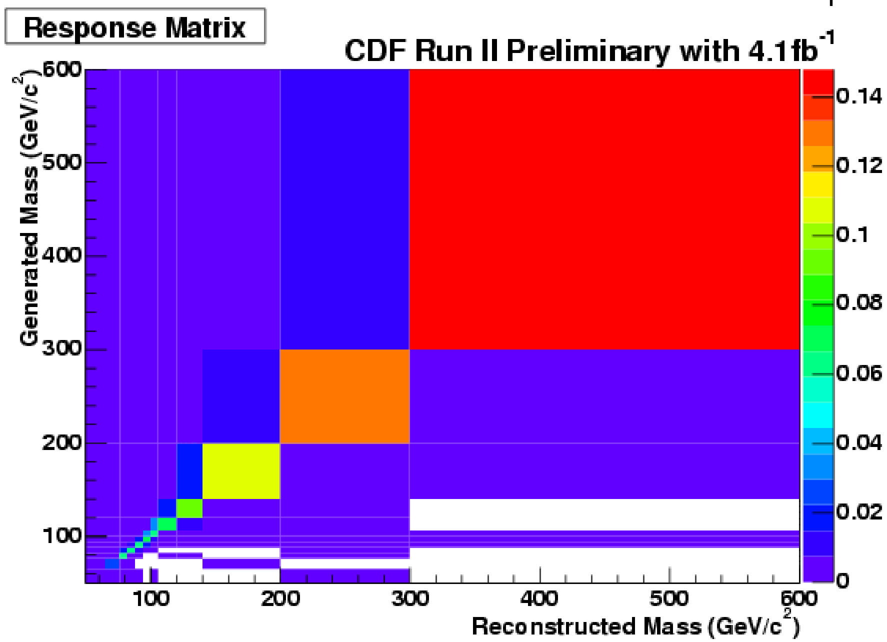


Z Forward Backward Asymmetry

Sensitive to:

- Quark and lepton Z couplings ($\sin^2\theta_W$)
- Possible new Z'

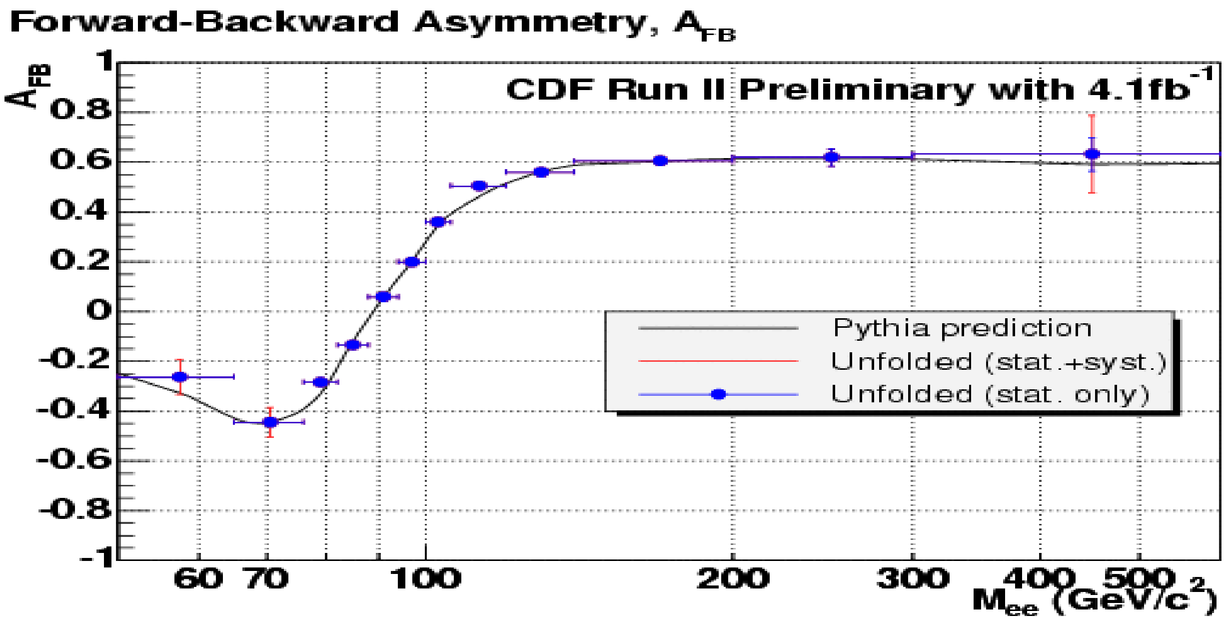




$$\frac{d\sigma}{d\cos\theta} = A(1+\cos^2\theta) + B\cos\theta$$

A_{fb} for Z→ee

Expect to extract $\sin^2\theta_W$ with precision of 0.0007.

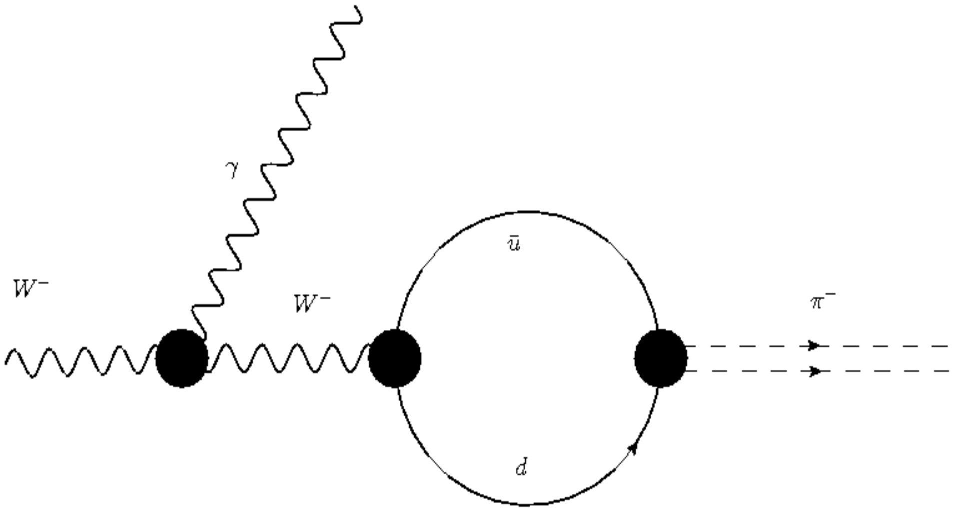


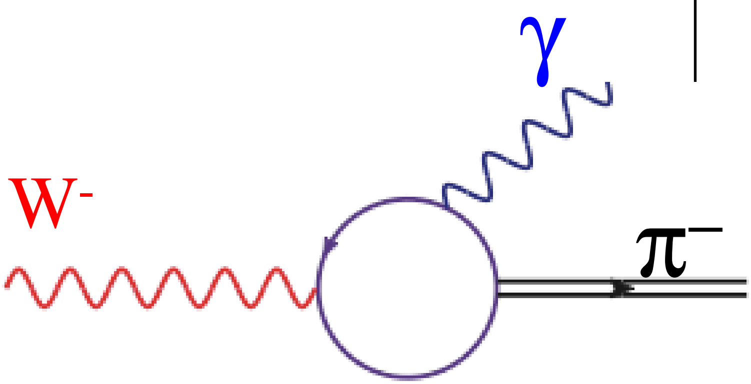
D0 results with 1 fb^{-1} in PRL 101, 191801

$\sin^2\theta_W = 0.2326 \pm 0.0018(stat) \pm 0.0006(syst)$

With about 8 fb^{-1} per experiment to be collected in Run II we expect to reach (Tevatron only) the WA accuracy

W rare decays



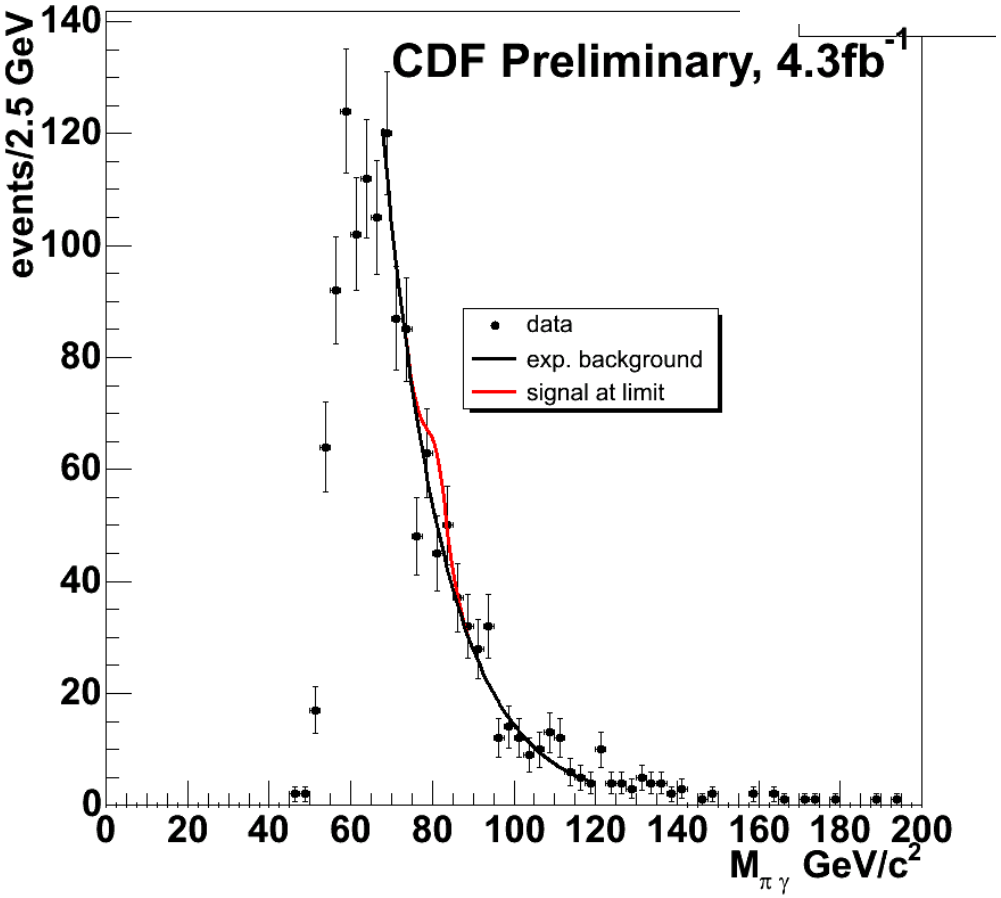


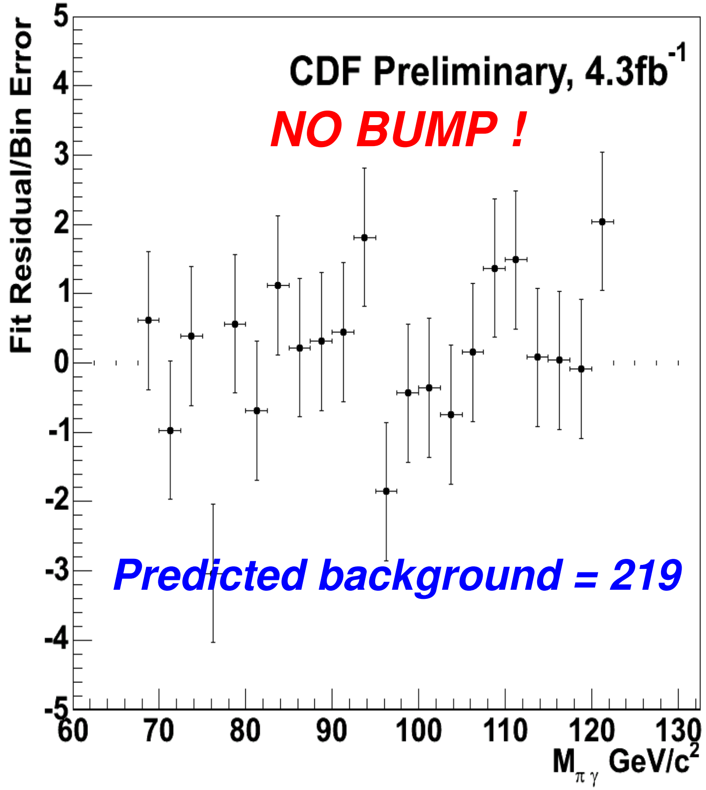
Clean final state : enhanced by BSM physics.
SM branching fraction : 10^{-6} - 10^{-8}

Will become very interesting at the LHC…

W rare decays..

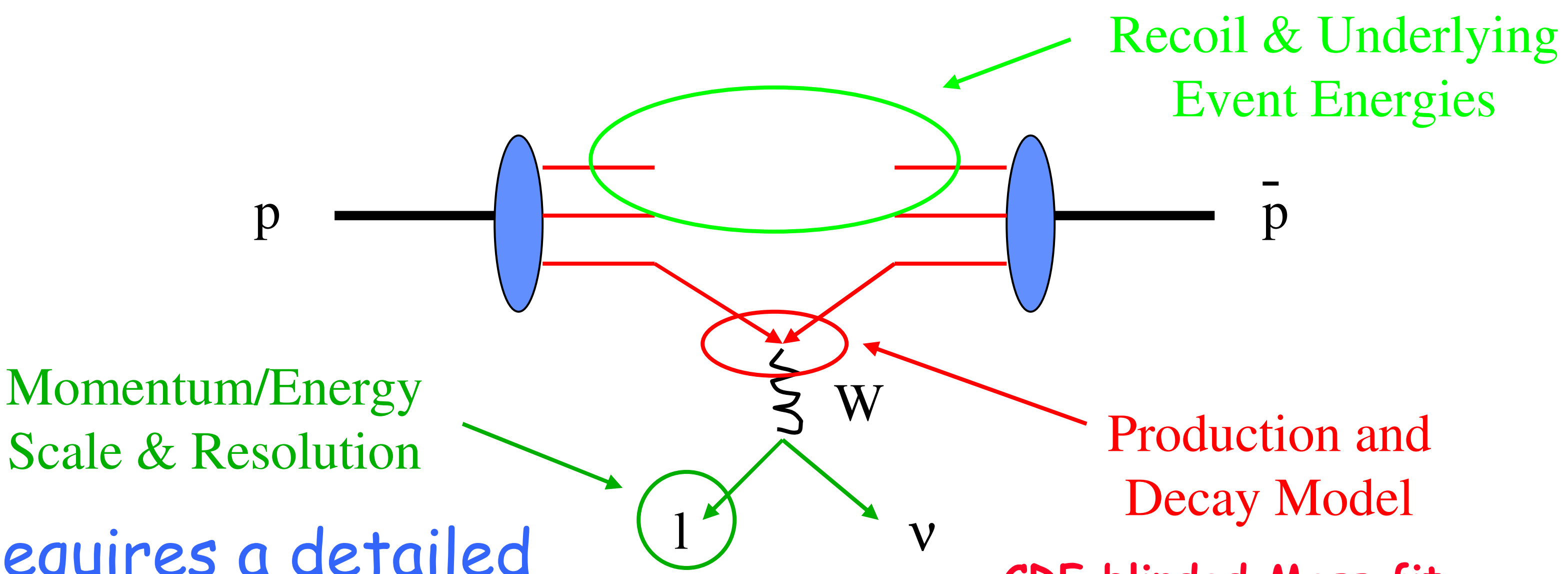
206 candidate events in signal ($75 < M_{\pi\gamma} < 85$ GeV) region





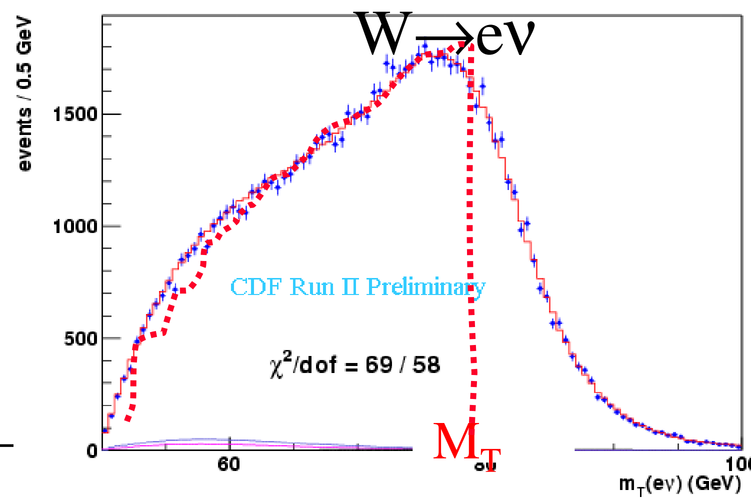
BR(W->$\pi\gamma$)/BR(W->eν) < 6.4 x 10^{-5} at 95% confidence

W Mass Measurement



Requires a detailed understanding (~10 MeV) of all aspects of W boson production and detection

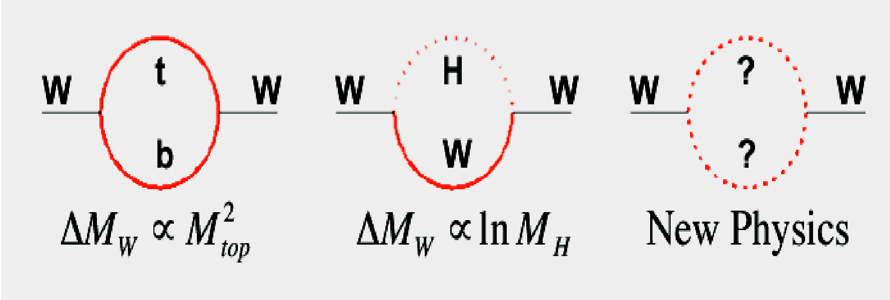
CDF blinded Mass fit



Fit a bidimensional distribution in M_T, Γ_W

What is at stake...

Together with M_{top} constrains the EWSB sector



- ☞Logarithmic corrections
- ☞For equal contribution $\Delta M_W \approx 0.006 \Delta M_{top}$
- ☞Current ΔM_{top} =1.3 GeV/c²
- ☞Imply ΔM_W =8 MeV (current: 23)

Experimental Challenge

That's what we like!

How to deal with..

M_W cannot be directly reconstructed due to missing neutrino P_z

- ☞ Use estimators
  - ⇨ $M_T=\sqrt{2P_{Tl}*P_{T\nu}(1-\cos(l,\nu))}$
  - ⇨ $P_T(l, \nu)$ where l is a charged lepton (e or mu)

- ☞ CDF: uses both leptons
- ☞ D0: only electrons

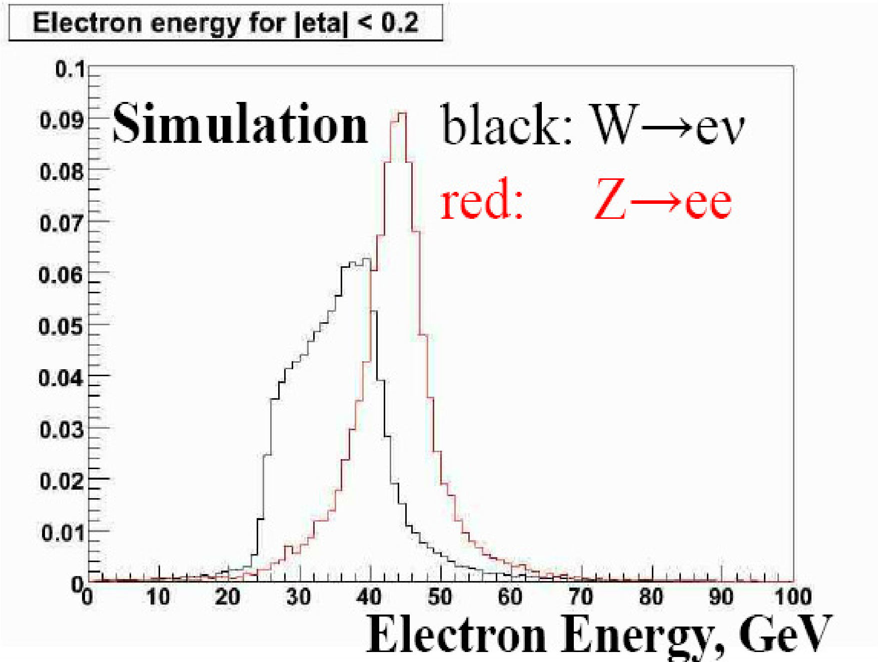
- ☞ Underlying event enters through subtle effects

- ☞ For the electron channel, understanding the energy scale is the key

Example: D0

Z→ee provides calibration to tune effects in MC

- With increased Z statistics better understanding of energy scale
- Material
  - Longitudinal shower development
  - dE/dx, etc
  - MC material model tuning



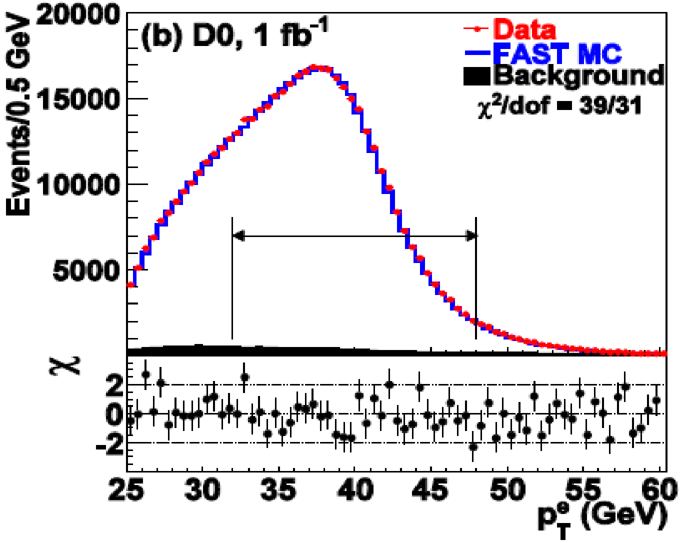
Linear response model:

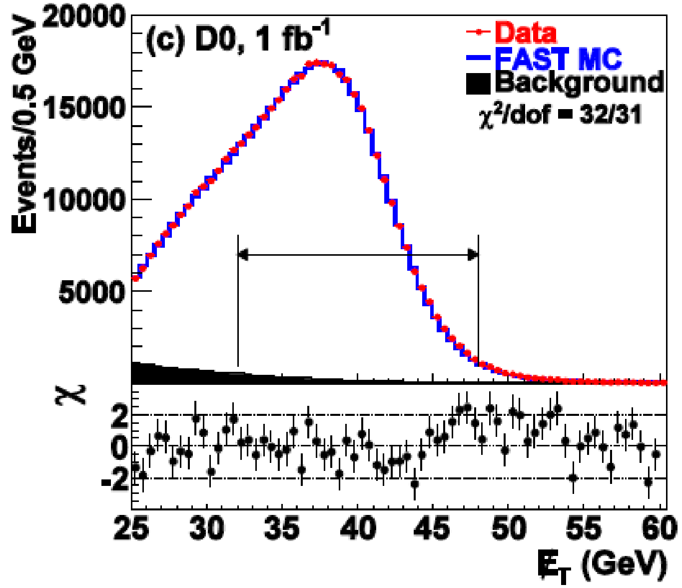
$E_{True}=E_{meas}*\alpha+\beta$

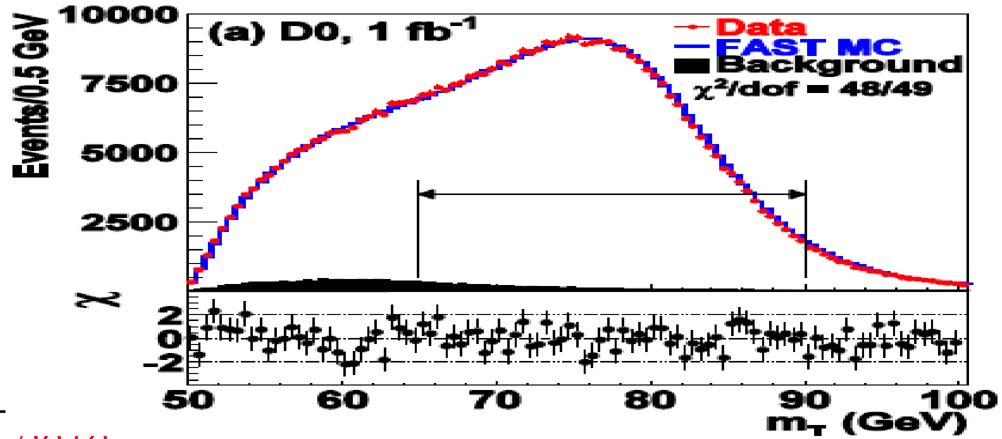
Estimators

Three different estimators (100% correlated):

☞ M_T, P_Te, $P_T\nu$







M_W results

CDF and D0 had several measurements in Run Ia, b. In Run II

- CDF (200 pb^{-1})
  - 80.413±0.034(stat)±0.034(syst)
- D0 (1 fb^{-1})
  - 80.401±0.021(stat)±0.038(syst)

- Can we beat LEP?

YES, WE CAN

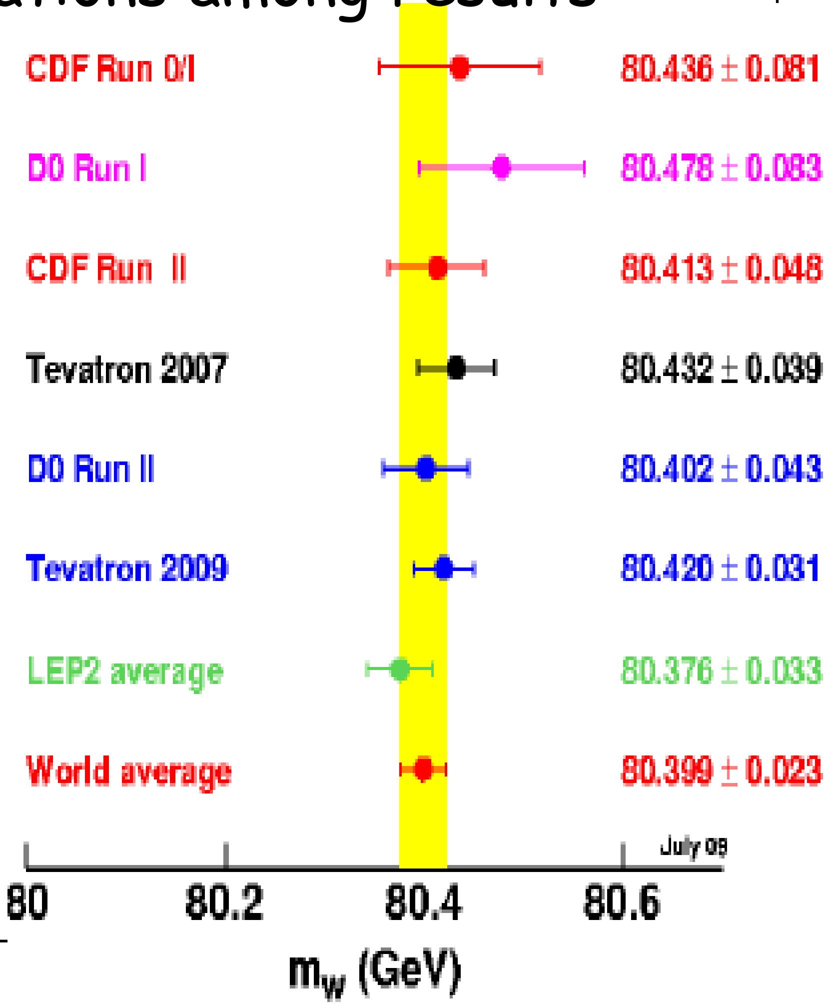
M_W combination

Combine all Tevatron results using the B.L.U.E. method

- ☞Take into account all correlations among results
- ☞Rescale RunI results to take into account
  - ⇨New pdfs
  - ⇨New Γ_W

Tevatron Avg:80.420±0.031

WA: 80.399±0.023



Mw Perspectives

We can do better:

- Statistics:
  - More than 6 fb^{-1} to tape per experiment
- Systematics

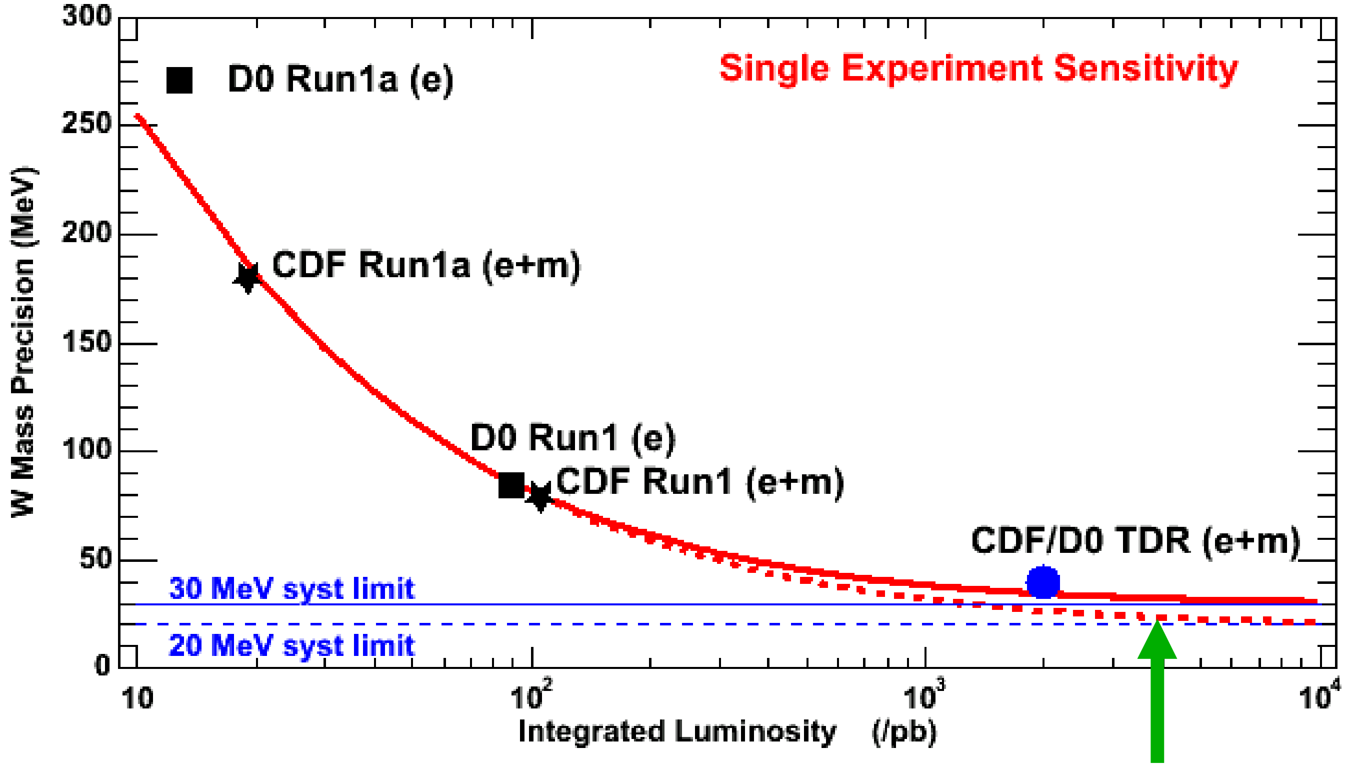
	L = 200 pb^{-1}			L = 200 pb^{-1}			L = 200 pb^{-1}		
m_T Uncertainty [MeV]	Electrons	Muons	Common	Electrons	Muons	Common	Electrons	Muons	Common
Lepton Scale	30	17	17	30	17	17	30	17	17
Lepton Resolution	9	3	0	9	3	0	9	5	0
Recoil Scale	9	9	9	17	17	17	15	15	15
Recoil Resolution	7	7	7	3	3	3	30	30	30
$u_{\parallel}$ Efficiency	3	1	0	5	6	0	16	13	0
Lepton Removal	8	5	5	0	0	0	16	10	10
Backgrounds	8	9	0	9	19	0	7	11	0
$p_T(W)$	3	3	3	9	9	9	5	5	5
PDF	11	11	11	20	20	20	13	13	13
QED	11	12	11	13	13	13	9	10	9
Total Systematic	39	27	26	45	40	35	54	46	42
Statistical	48	54	0	58	66	0	57	66	0
Total	62	60	26	73	77	35	79	80	42

M_T $P_T(l,\nu)$ MET

Largest experimental: lepton scale

Largest theoretical: pdfs

More fb^{-1}...



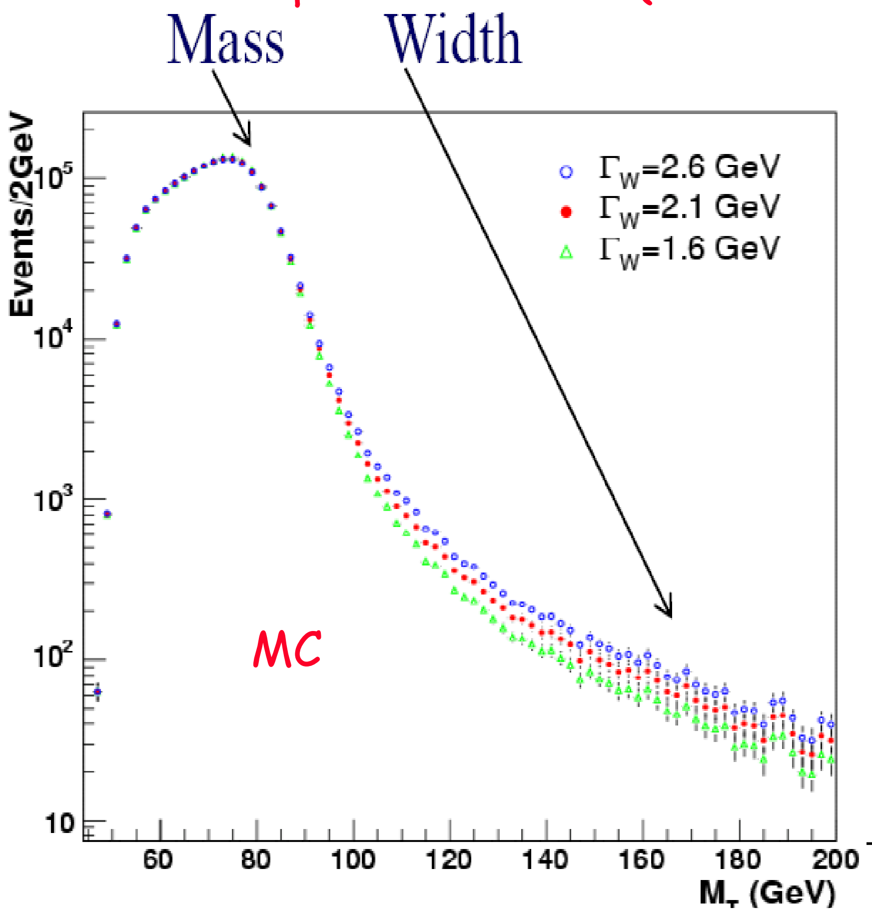
Beyond a few fb^{-1} overall uncertainty does not improve significantly without better understanding of systematics, but energy scale systematics is statistically limited

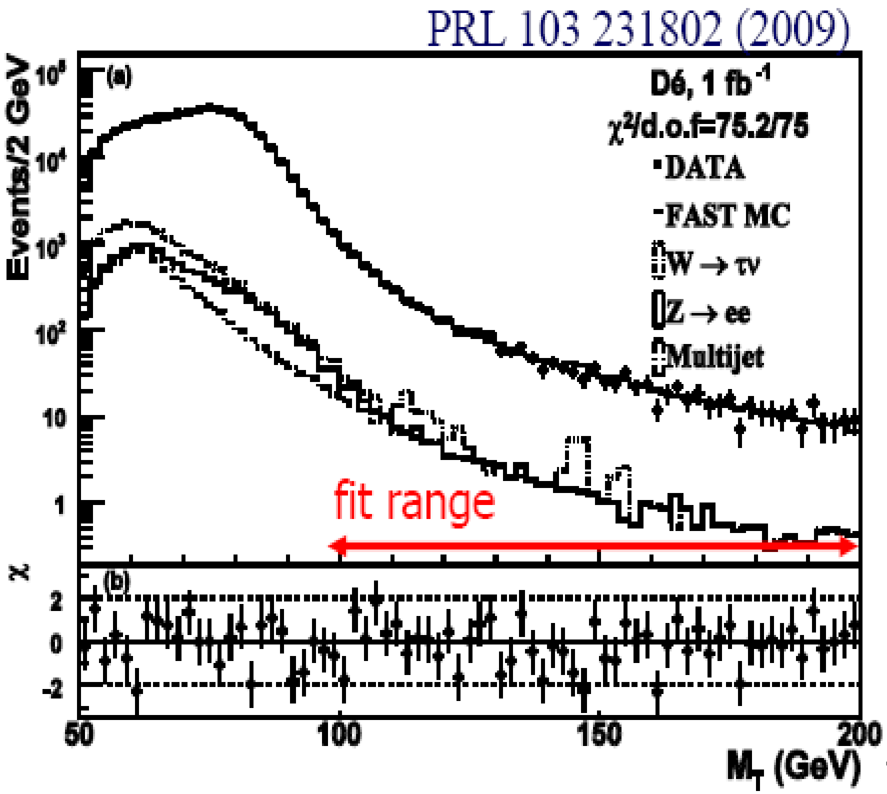
W width

Expected to agree with SM

☞Deviations could be very interesting..

Measurement exploits
tail of M_T distribution (Lorentz shape)

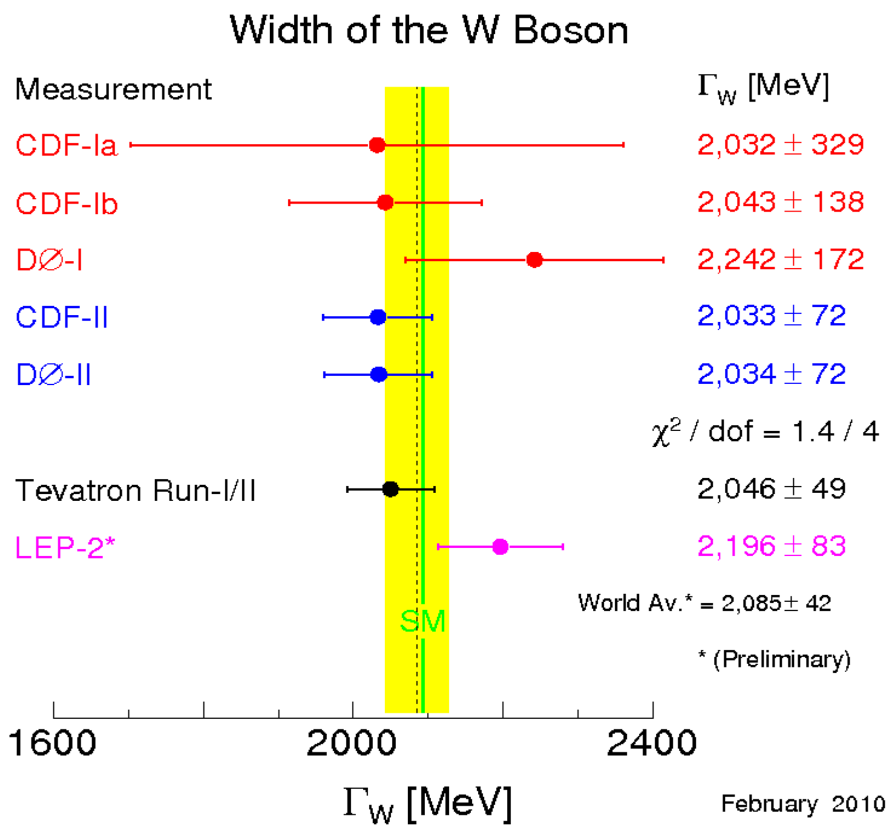




Combined result

Tevatron has (Feb. 2010) a new combination:

D0=2.028±0.038(stat)±0.061(syst.) (1 fb^{-1})
CDF=2.032±0.045(stat)±0.053(syst) (350pb^{-1})



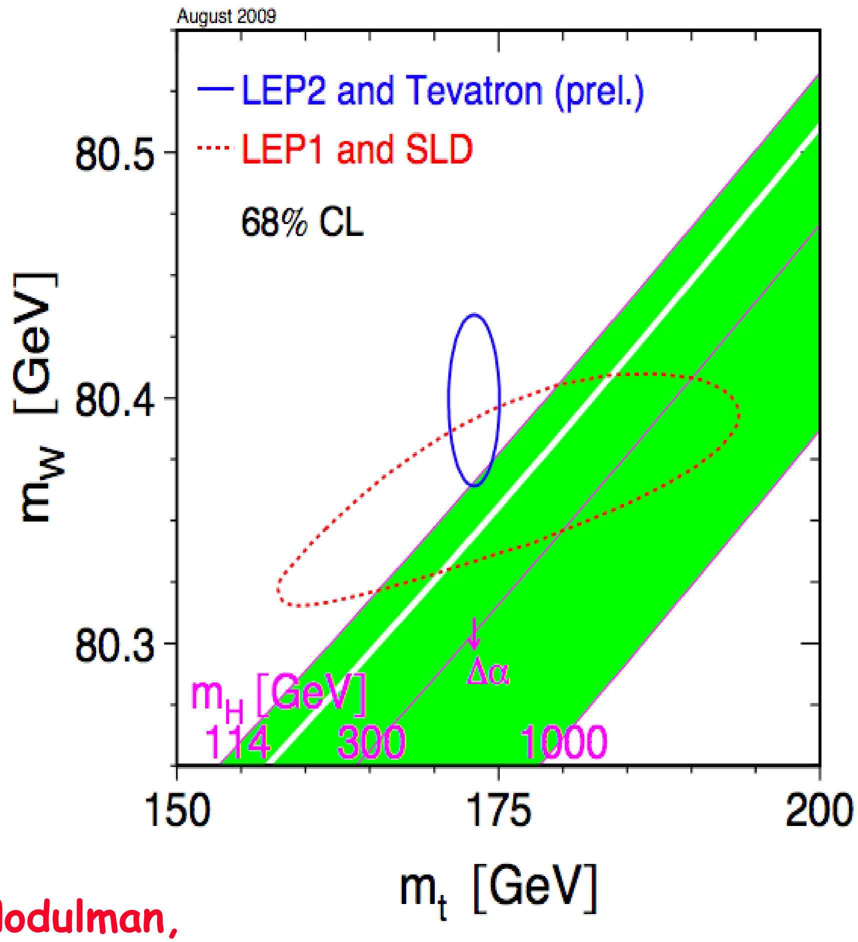
Tevatron:2.046±0.049 GeV/c^2

WA: 2.085±0.042 GeV/c^2

CONCLUSION

CDF and D0 have a very large sample of Ws, Zs

- ☞ Detectors well understood
- ☞ Backgrounds under control
  - ⇨ EWK precision tests ($sin_2\theta_W$)are possible
- ☞ Constraining PDFs is one of the (many) things that TeV can do for LHC
- ☞ M_W will be one of the lasting heritages
  - ⇨ It will also constrain the Higgs sector before actual Higgs obseravation



Many thanks to: Mark Lancaster, Larry Nodulman, Junjie Zhu, Jan Stark + many others from CDF and D0!