Electroweak Physics

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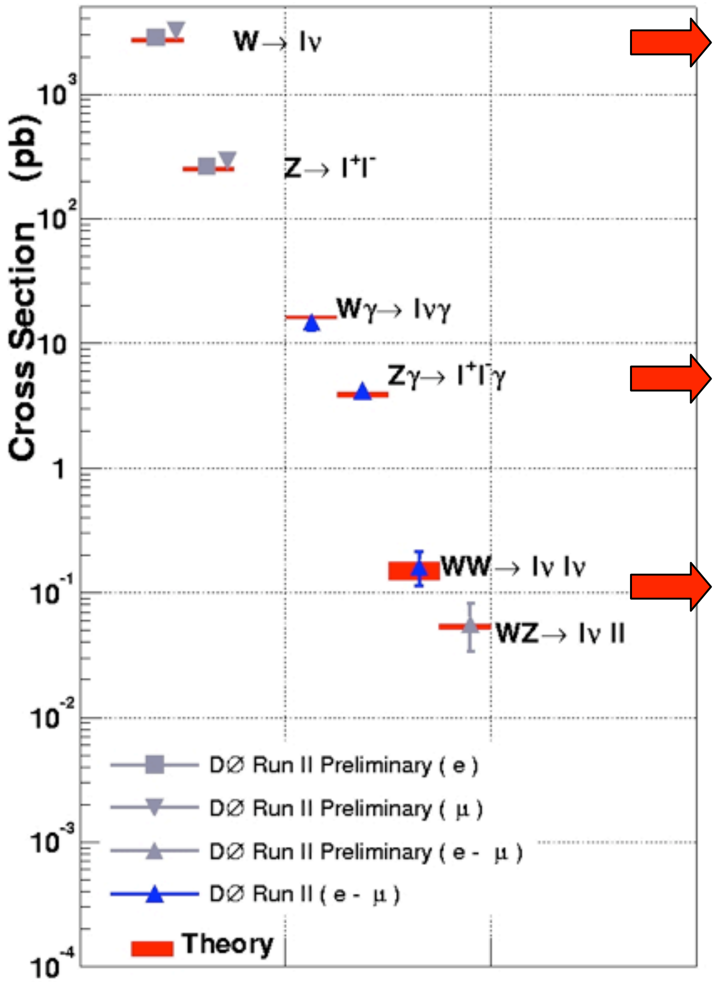
- Recent results (since ICHEP)
- Goals for rest of Tevatron running
- Lessons learnt / issues to be resolved / things I hope the LHC will do better.

Recent Results



Mw Precision (loop) physics (0.2 fb^{-1})

Top SM tests : TGC (1 fb^{-1})

Higgs Discovery / Observation (1-2 fb^{-1})

Latest results

- CDF W mass
- Di-bosons from CDF & DØ

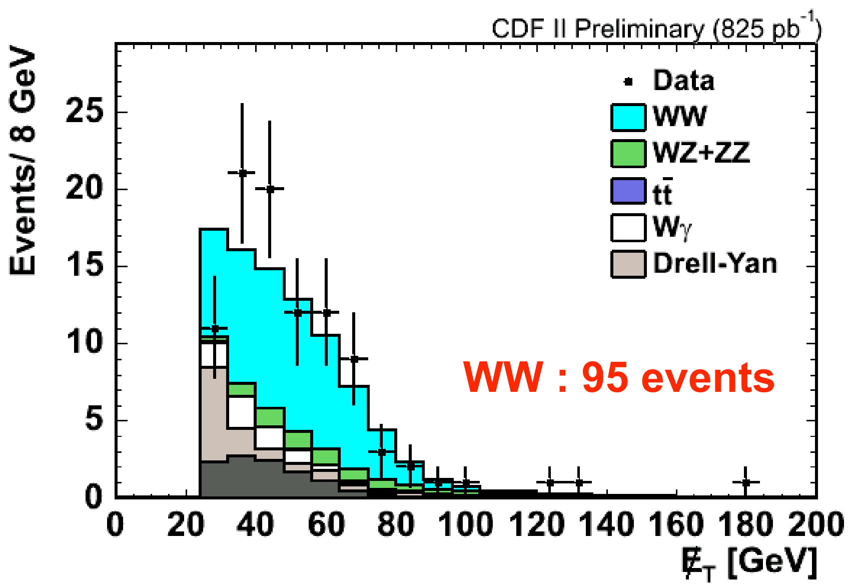
Now have ~ 2fb^{-1} on tape

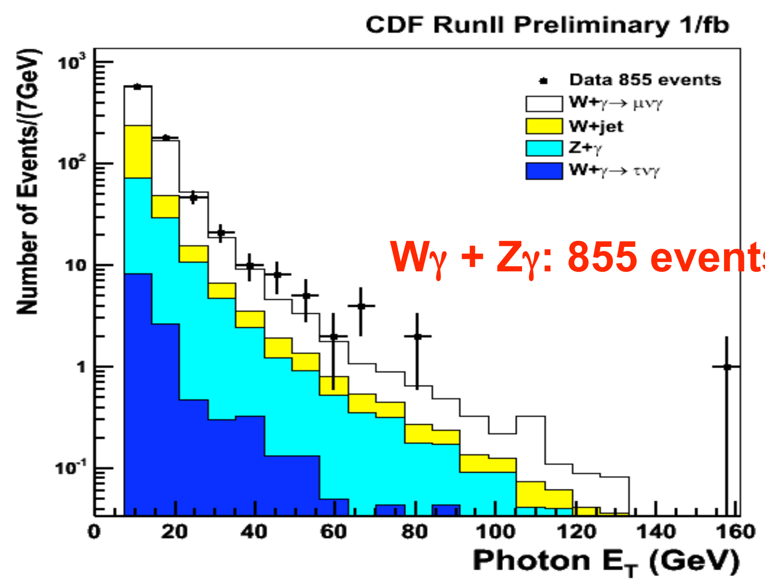
Di-Boson Results

The new SM benchmarks (& backgrounds) for our search programme.

We will need full dataset 4-8 fb^{-1} to be competitive with LEP2.

WW + Wγ now measured with ~ $1fb^{-1}$

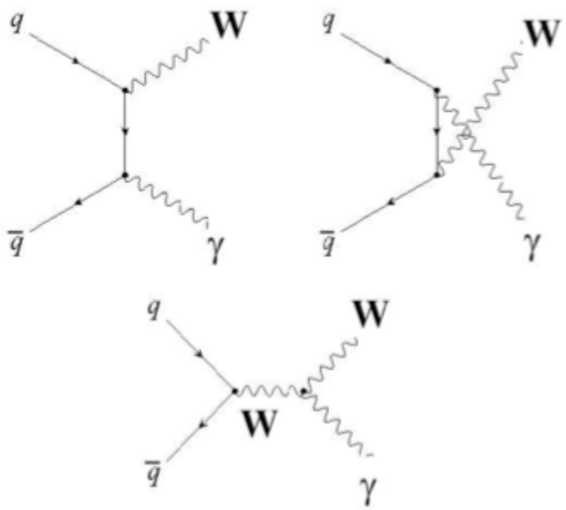


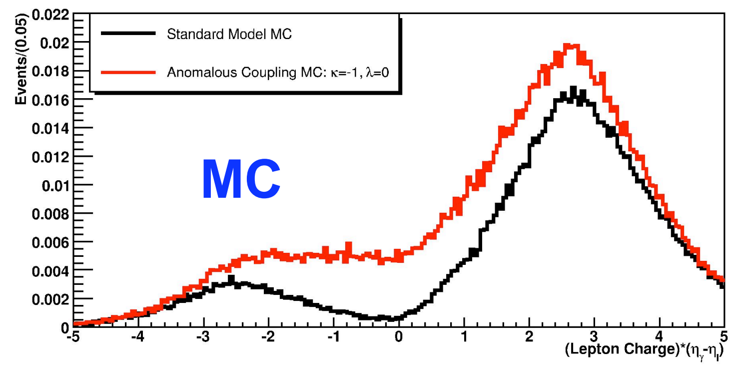


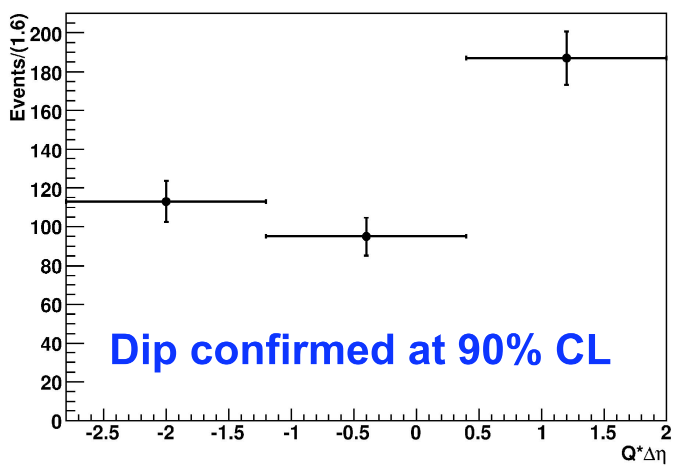
σ : now measured at 15% level (lumi ~ 6%); theory uncertainties ~ 7%

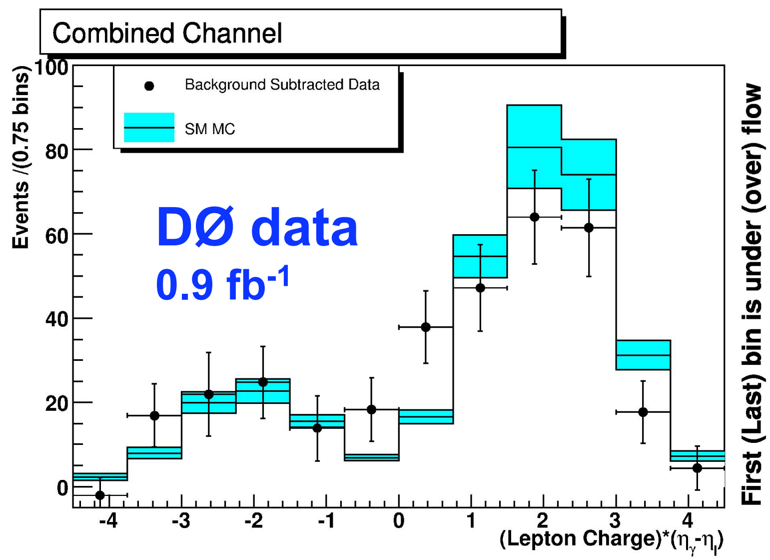
Wγ : Radiation Zero

Amplitude is zero for $\cos(\theta_{CM}) = -(1 + 2Q_d)$ but use $\eta_\gamma - \eta_{lepton}$ not θ_{CM}

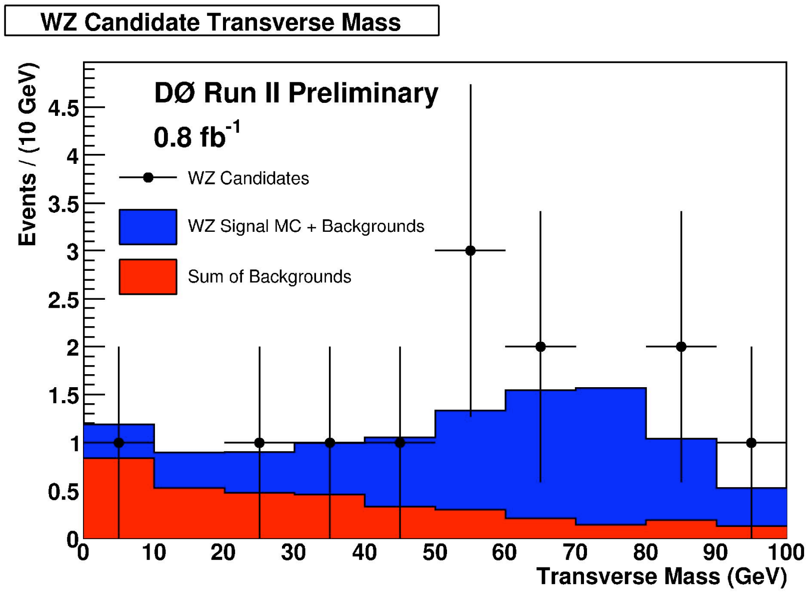




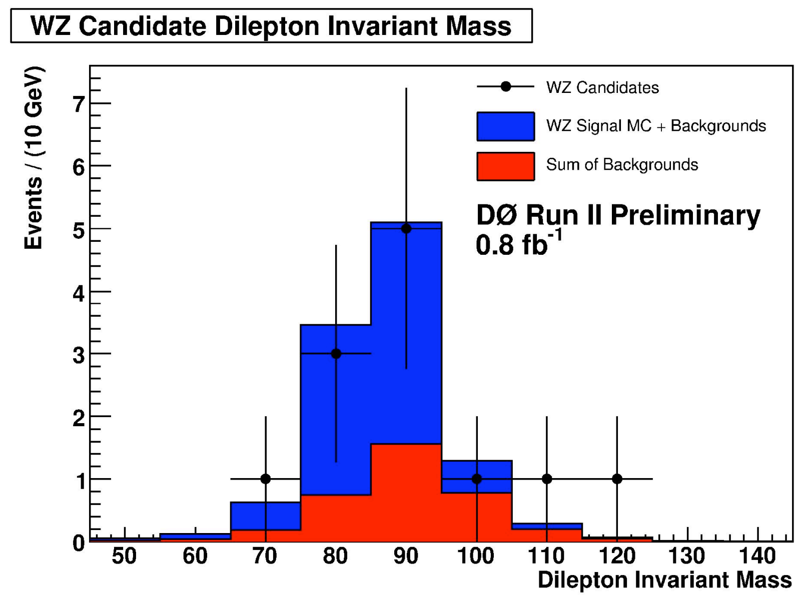




First Observation of WZ

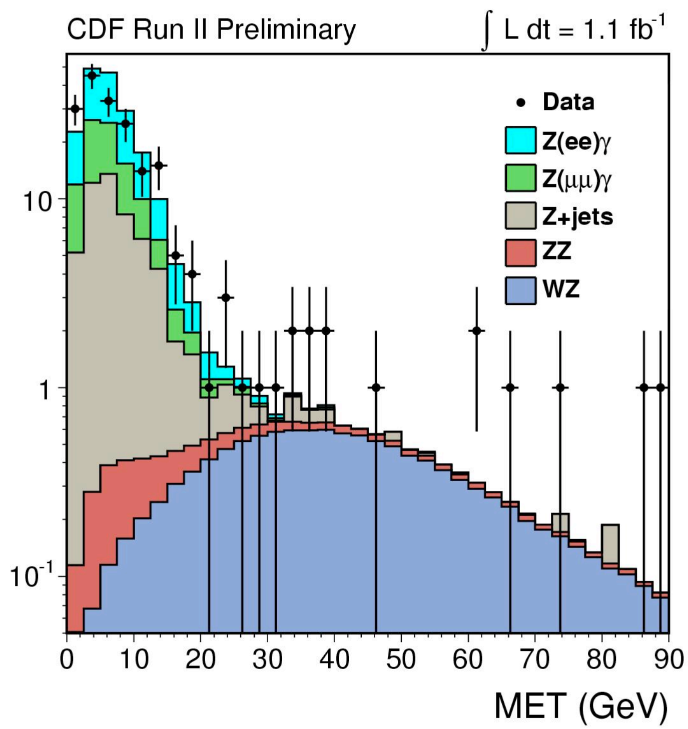


12 events (BG ~ 3.6)



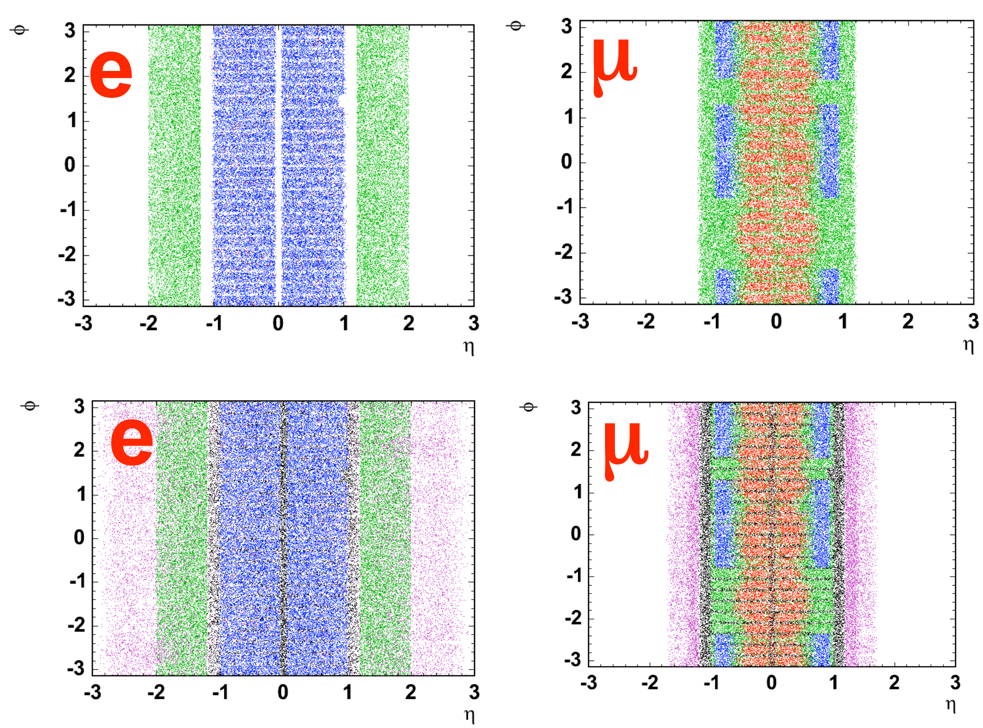
Significance : 3.3 σ

WZ Cross Section Measurement



Significance ~ 6σ

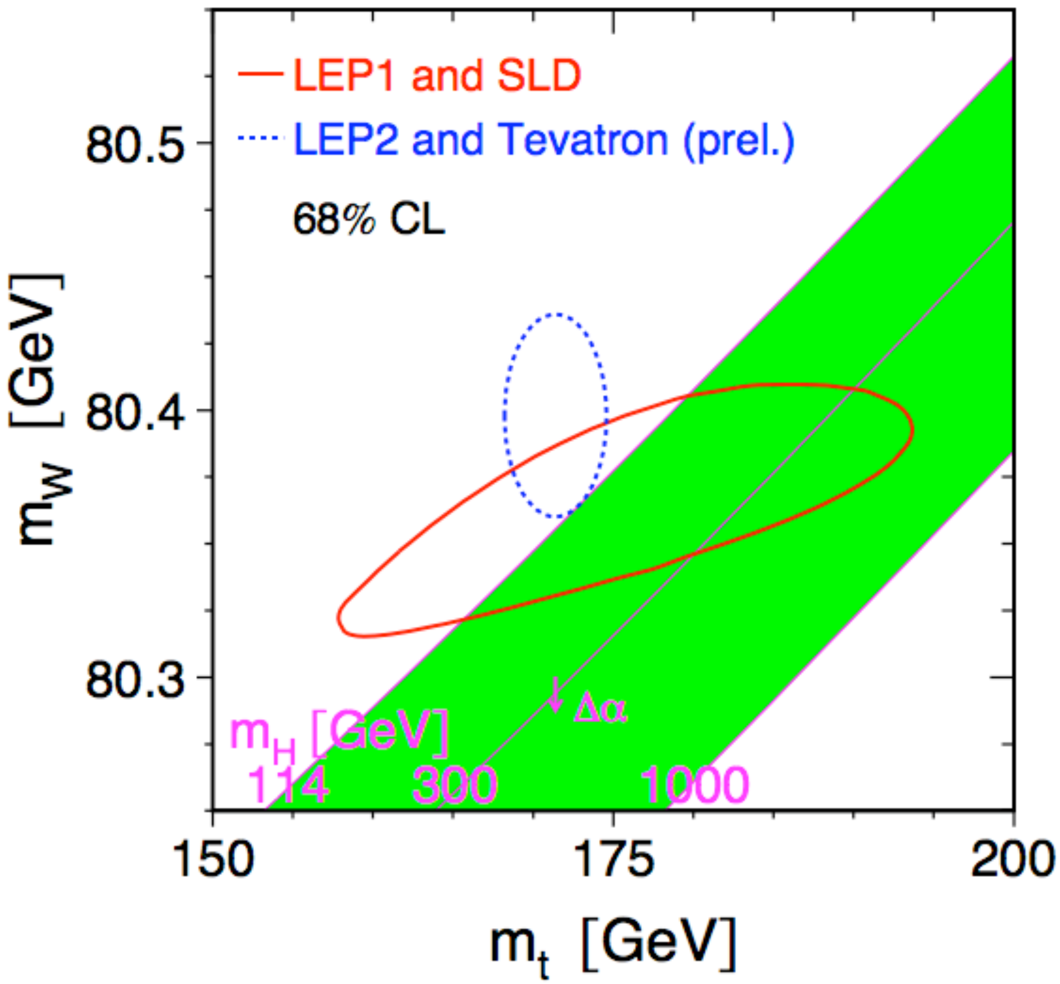
Made possible due to significant improvements in lepton acceptance



$$\sigma(p\bar{p} \rightarrow WZ) = 5.0^{+1.8}_{-1.6}\,\text{pb (Theory} = 3.7 \pm 0.3\ \text{pb)}$$

TGCs though not yet competitive with LEP2

W Mass Motivation



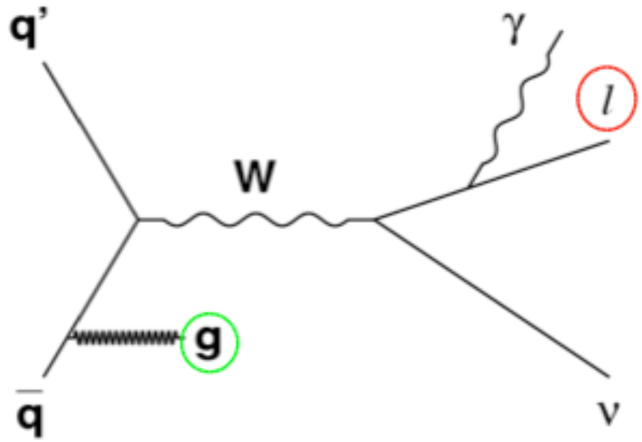
$\Delta m_T \sim$ 2.1 GeV (1.2%)

$\Delta m_w \sim$ 25 MeV (0.03%)

But we need improvements in Δm_w to leverage a better Higgs constraint

$\Delta m_W \rightarrow$ 15 MeV

W Mass Strategy



Lepton Momentum
- calibrate from J/ψ and upsilons
- cross check with $Z \rightarrow \mu\mu$

Lepton Energy
- calibrate using E/p
- cross check with $Z \rightarrow ee$

Backgrounds
- reduce below 1% by cuts

Lepton Rapidity / QCD
- PDFs
- cross check with W charge asymmetry

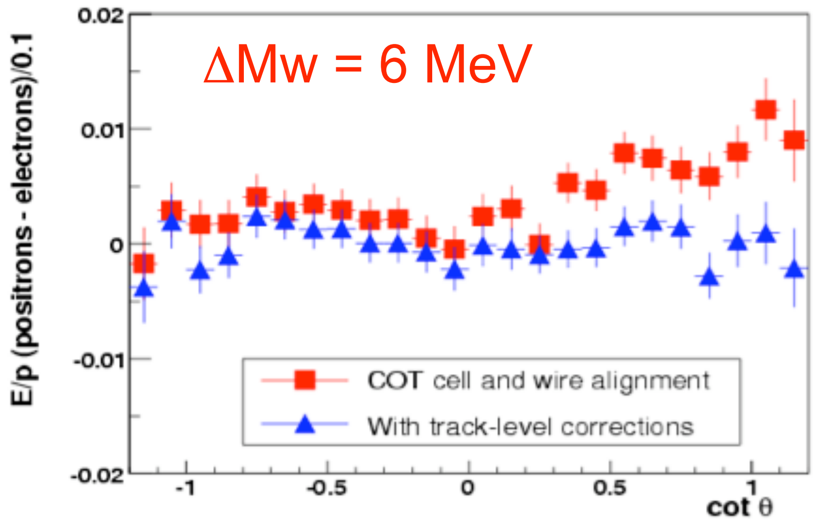
Neutrino / QCD
- P_T of W and Z from “theory” & fits to Z data
- ad-hoc “recoil” model for underlying event, QCD ISR, minbias tuned to Z

Photons / QED
- rely on available codes (WGRAD, PHOTOS, Berends-Kleiss)

Mw : Momentum Calibration

Key ingredients

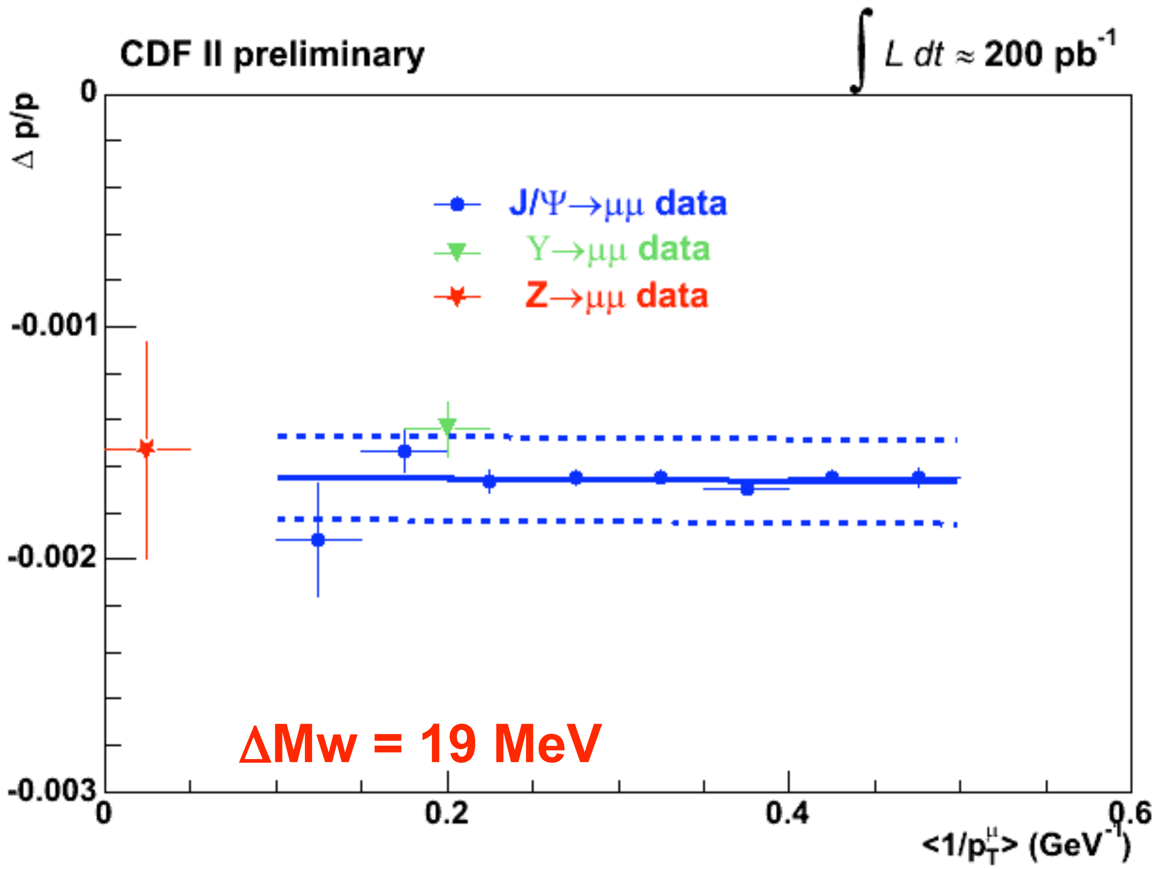
- material map : amount and type (CDF has ~ 0.2% X_0)
- tracker alignment
  - use cosmics & W events
  - use E/p from low energy inclusive lepton events
  - there are always residual alignment "features"



Issues

- non-linearity (extrapolating the calibration to W)
- muons aren't the same as electrons (brems)
- complications of beam-constraining tracks (brems, decays)

Mw : Momentum Calibration



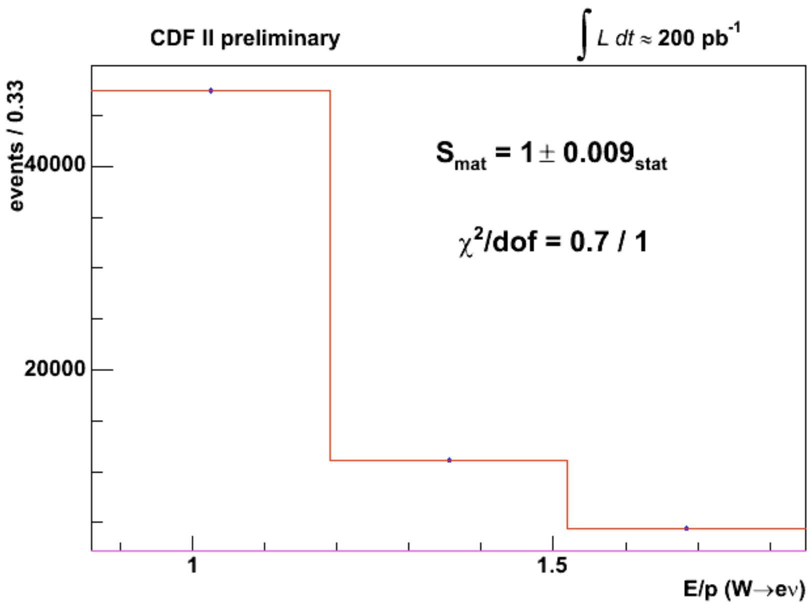
Lever arm in Zs at LHC probably enough to constrain non-linearities

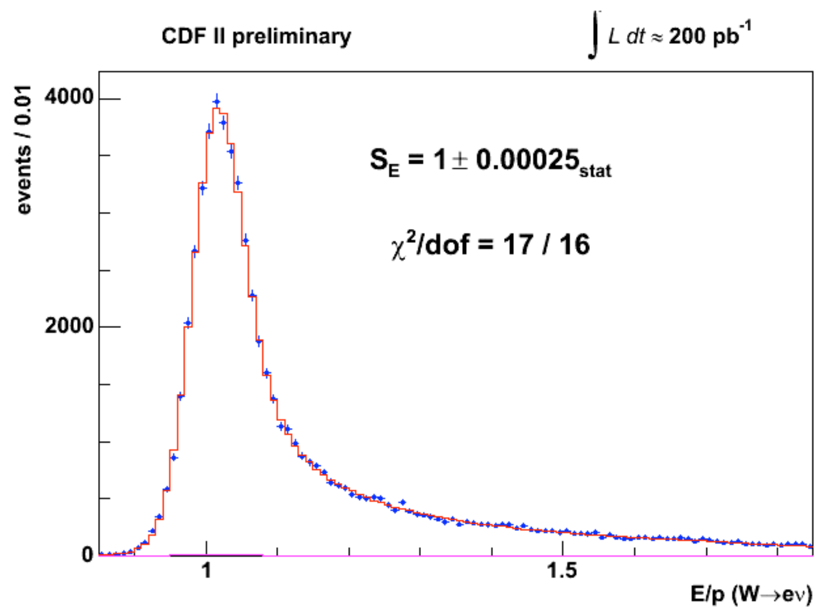
But Upsilons (prompt) may be useful cross-check.

Mw : Energy Calibration

Key Ingredients / Issues

- material map - needs to be easily tunable (scale factors)
- simulation of brem physics down to KeV (not all in GEANT…)
- modeling scale and resolution changes as function of E, # clusters
- modeling / determining calorimeter non-linearity

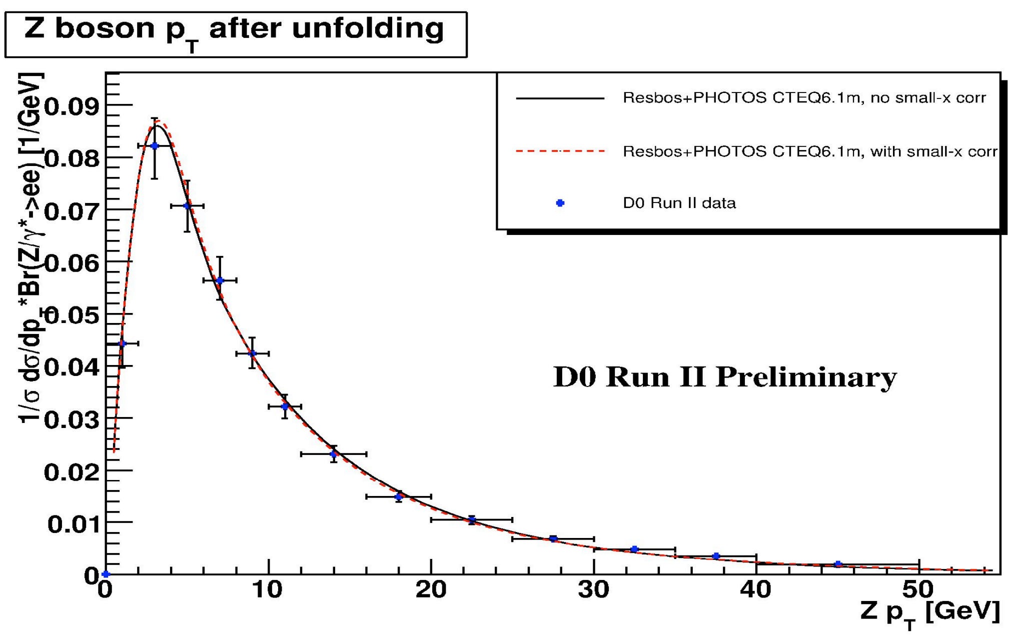




Mw : Vector Boson P_T

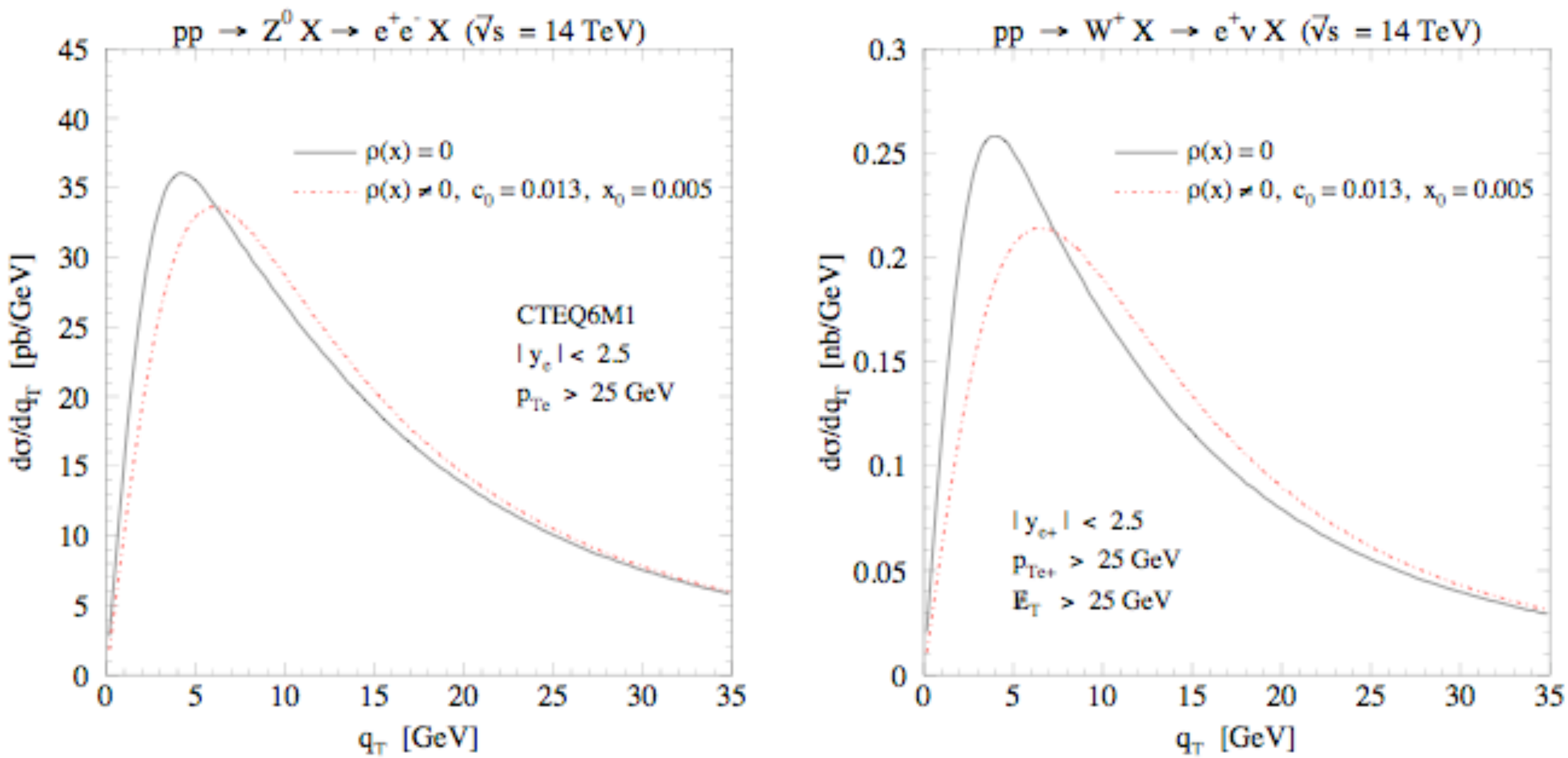
Issues

- a MC which contains all the physics (some of which is uncertain e.g. BFKL effects) of boson p_T (non ptb, resummation, (N)NLO ME) with dependence on s-hat, rapidity etc which is quick & easily tunable to data.
- and which contains all the other physics : QED etc



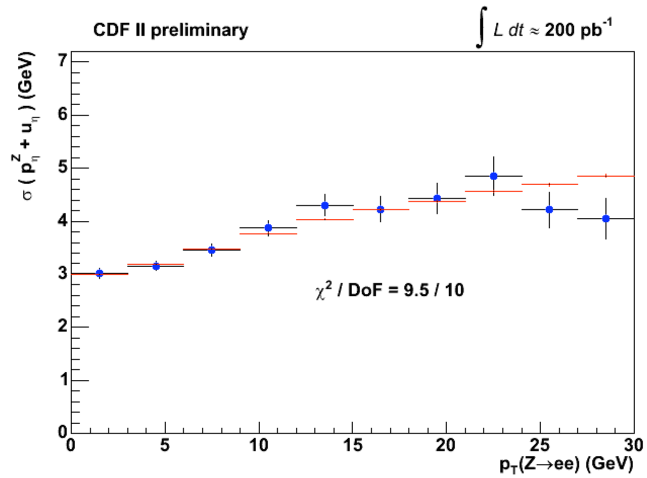
Mw : Vector Boson Uncertainty

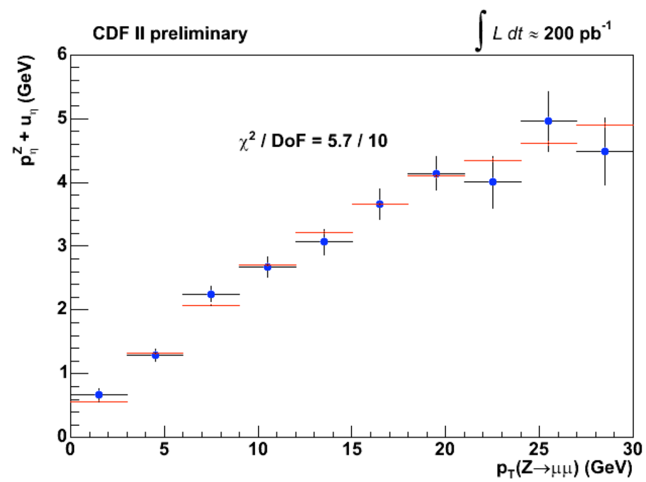
- LHC data on this will be very interesting



Mw : Recoil Model

- Arguably the least well founded part of the analysis
- Ad-Hoc models guided by Z and minbias data
- Not a particle level model but an aggregated model : PYTHIA & HERWIG not precise enough for 10 MeV systematic





Issues

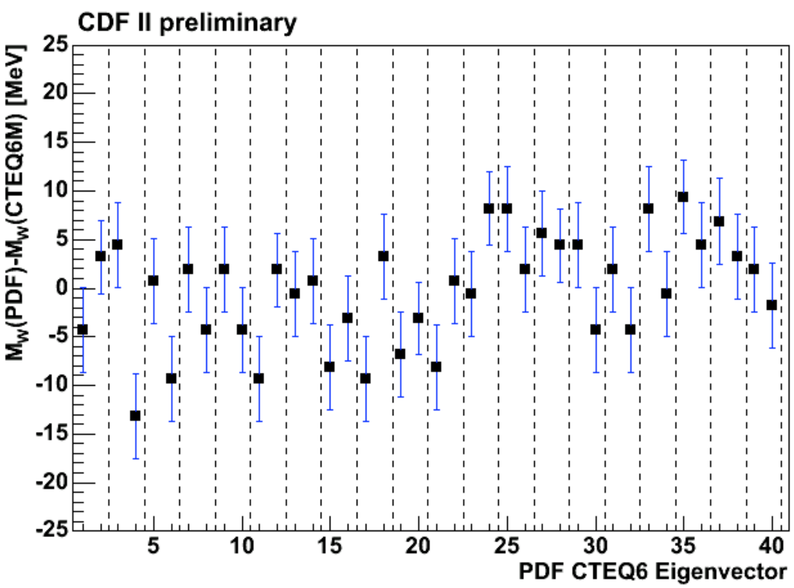
- strong correlation between response and resolution parameters that define detector's response to UE, QCD, minbias, QED and boson p_T
- backgrounds in Z and W are different
- selection biases in Z and W are different
- kinematic region of Z and W are potentially different (Y_W unknown)
- to get required precision requires large number (10+) of tunable parameters

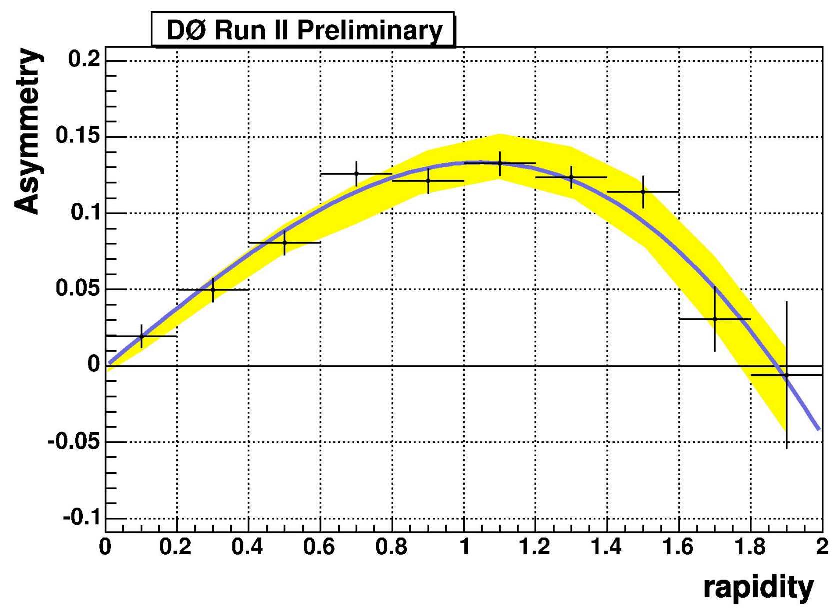
Mw : PDFs

Issues

- differences between error estimates of CTEQ and MRST

- while some Tevatron data is in fit, we don't yet have the machinery to optimise PDFs (consistent with other data in the global fits) on our own data and do the error analysis.





Mw : QED

Issues

- there are no complete $0(\alpha)^2$ QED generators that have N(NLO) QCD

- arguably the most sophisticated generator (WGRAD) is only $0(\alpha)$ and it is very slow and has zero QCD

- estimates of systematic due to a second photon rely on incomplete models

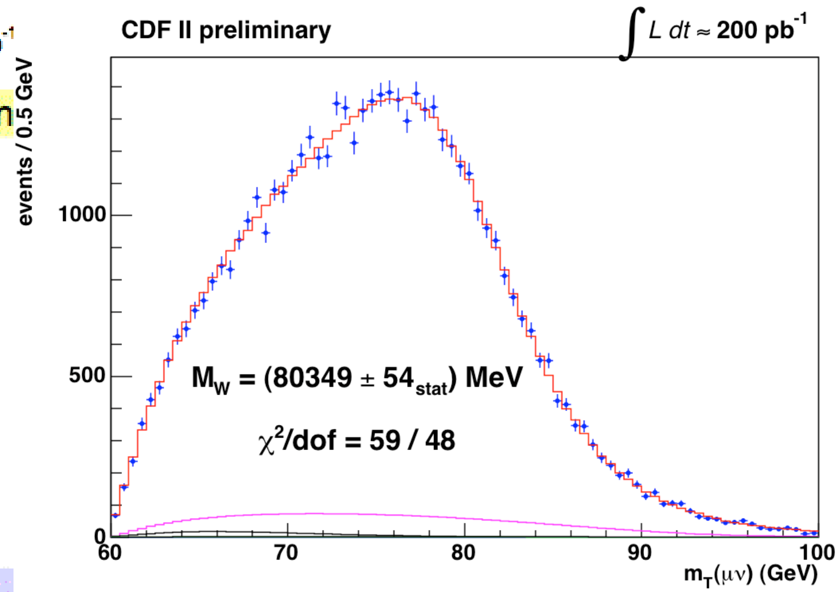
- initial (quark) QED and the interplay with QED-enhanced PDFs

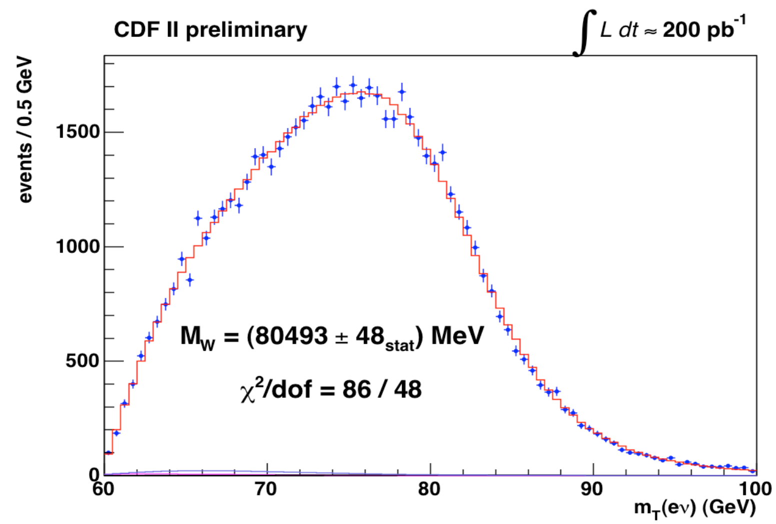
- this has been a 10-15 MeV systematic since 1995.

Mw : CDF Result

CDF II preliminary L = 200 pb^{-1}

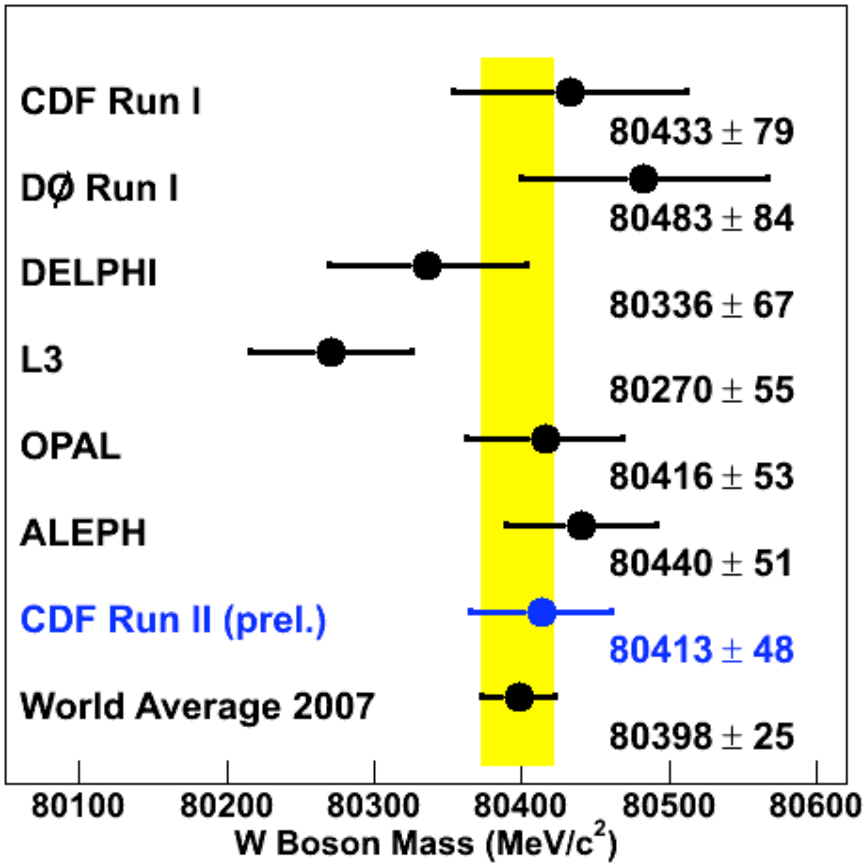
m_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	9	9	9
Recoil Resolution	7	7	7
$u_{\|\|}$ Efficiency	3	1	0
Lepton Removal	8	5	5
Backgrounds	8	9	0
$p_T(W)$	3	3	3
PDF	11	11	11
QED	11	12	11
Total Systematic	39	27	26
Statistical	48	54	0
Total	62	60	26





$M_W = 80413 \pm 48$ MeV

Mw : Comparisons



M_H < 153 GeV at 95% CL

Electroweak : The Future

- Measurements with high precision and to highest energy of :
    - $Z\ A_{FB}$, $W\gamma$, $Z\gamma$, WW, WZ, ZZ cross sections : TGCs

- Reduction in PDF uncertainties
    - Zs at large rapidity
    - W charge asymmetry
    - Forward/Central W cross section

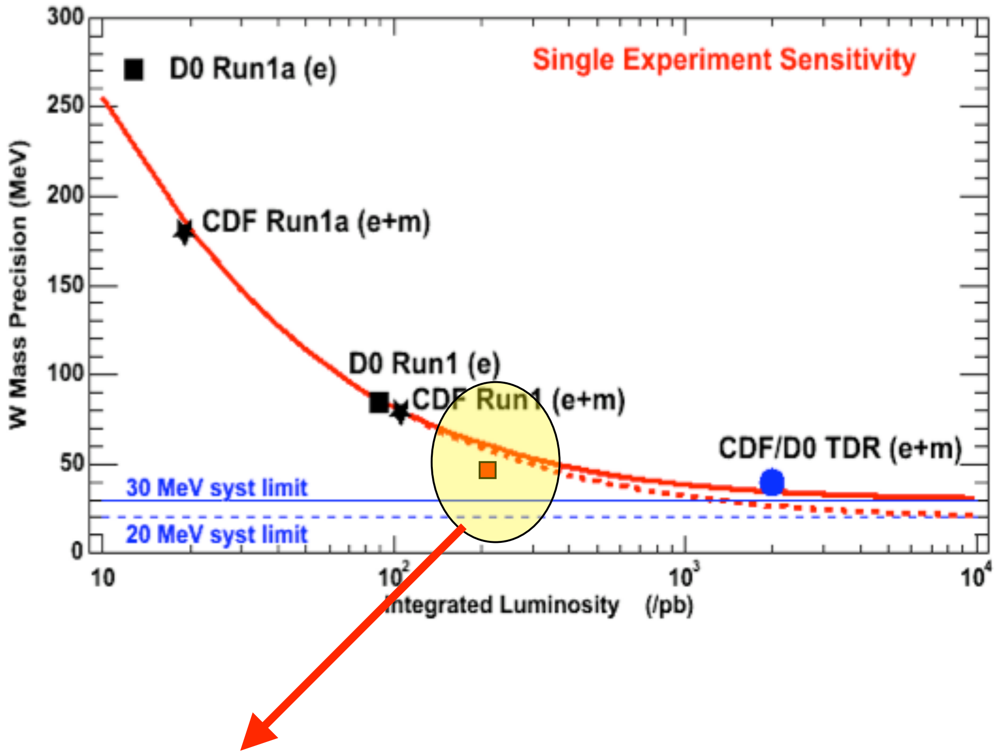
- Better measurement of Z p_T over wider rapidity range

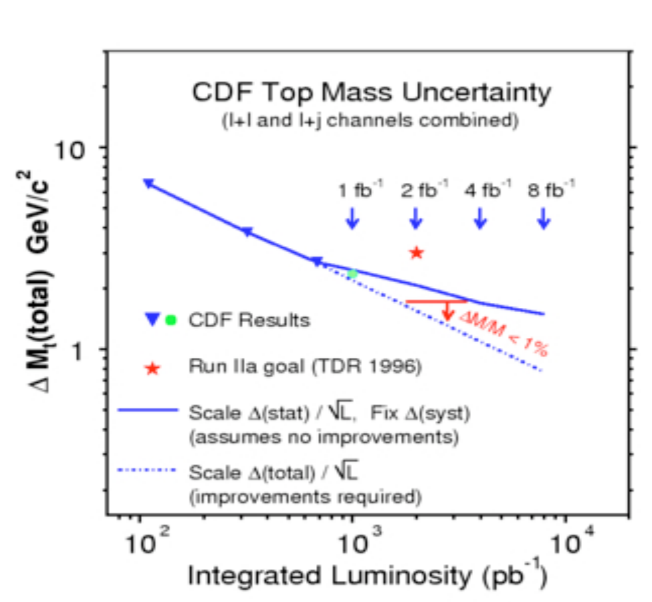
- Direct W width measurement (better than LEP2 combined)

- Definitive W mass with $4fb^{-1}$

Mw : The Future

- from a year ago





Beware extrapolations - for Mw & Mt we have done better than expected.

Statistically : ΔMw ~ 10 MeV but key will be progress on : PDFs, QED, p_T(Z) {mostly from theorists} and recoil, calorimeter non linearity {expt}

Mw : Wish List

Items needed for 15 MeV at LHC or Tevatron

- a degree of insanity (CDF measurements have taken 3 yrs each with handful of people)
- a simulation that is :
  - very, very fast : millions of events per hour - Grid ?
  - tunable for material (scalable look-up table)
    - even though you measure everything going in
    - adding a known radiator at a known place
- progress on boson pT
  - is non perturbative element universal
  - reliability of the Z/W pT ratio in NP region and dependence on s-hat
- progress on PDF errors and ability to utilise own data in global fits
- understanding differences between W & Zs in context of recoil model
- understanding calorimeter response and resolution vs number, energy of clusters
- precise 2 photon QED treatment

Conclusion

We need one single fast, bug-free, tunable MC that has NNLO QCD (to pT = 0) + NLO QED and PDFs with reduced uncertainties

Why are experimenters still hacking MCs !!