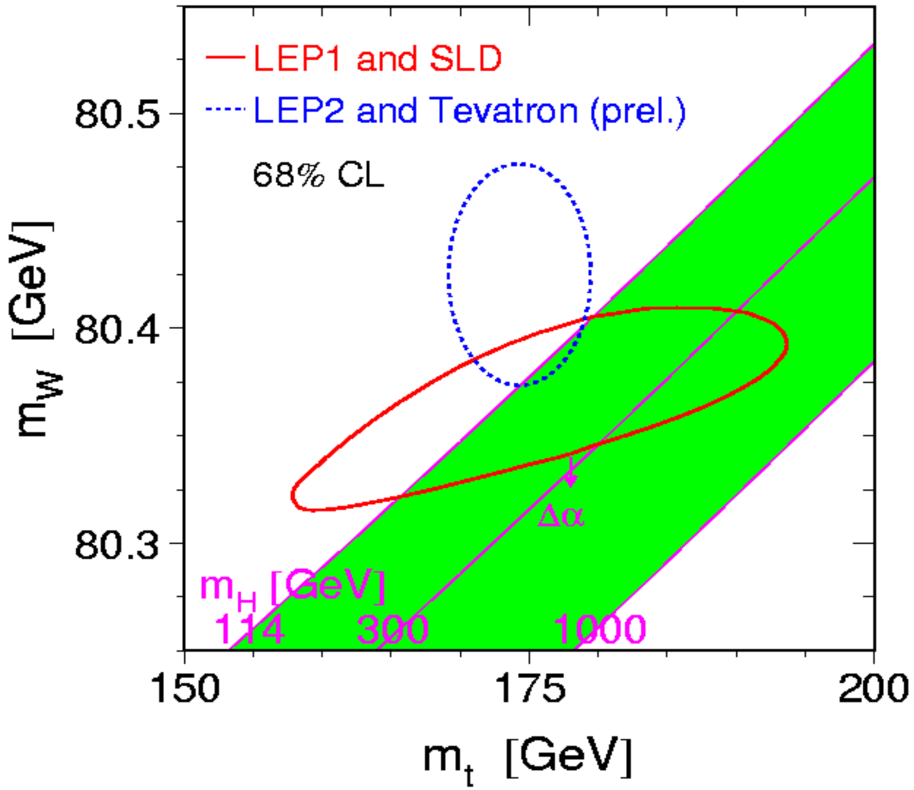
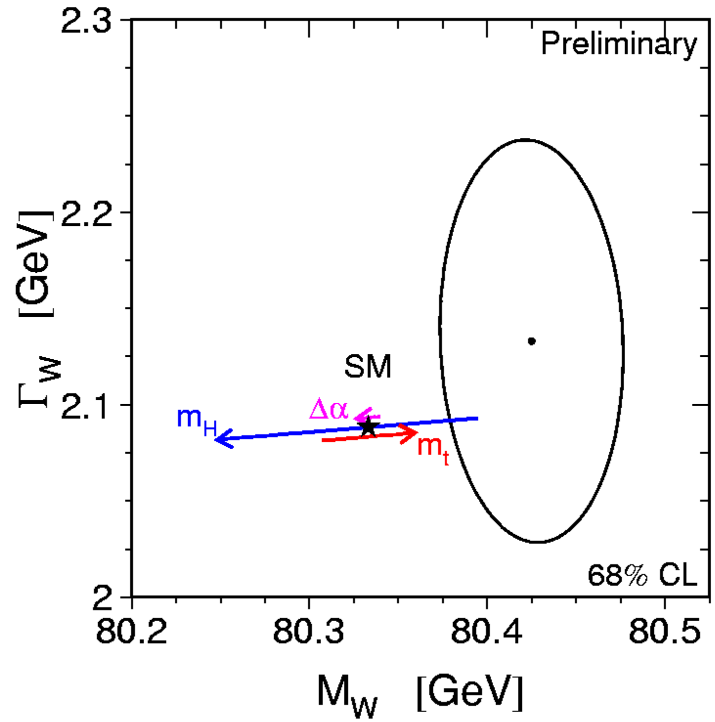
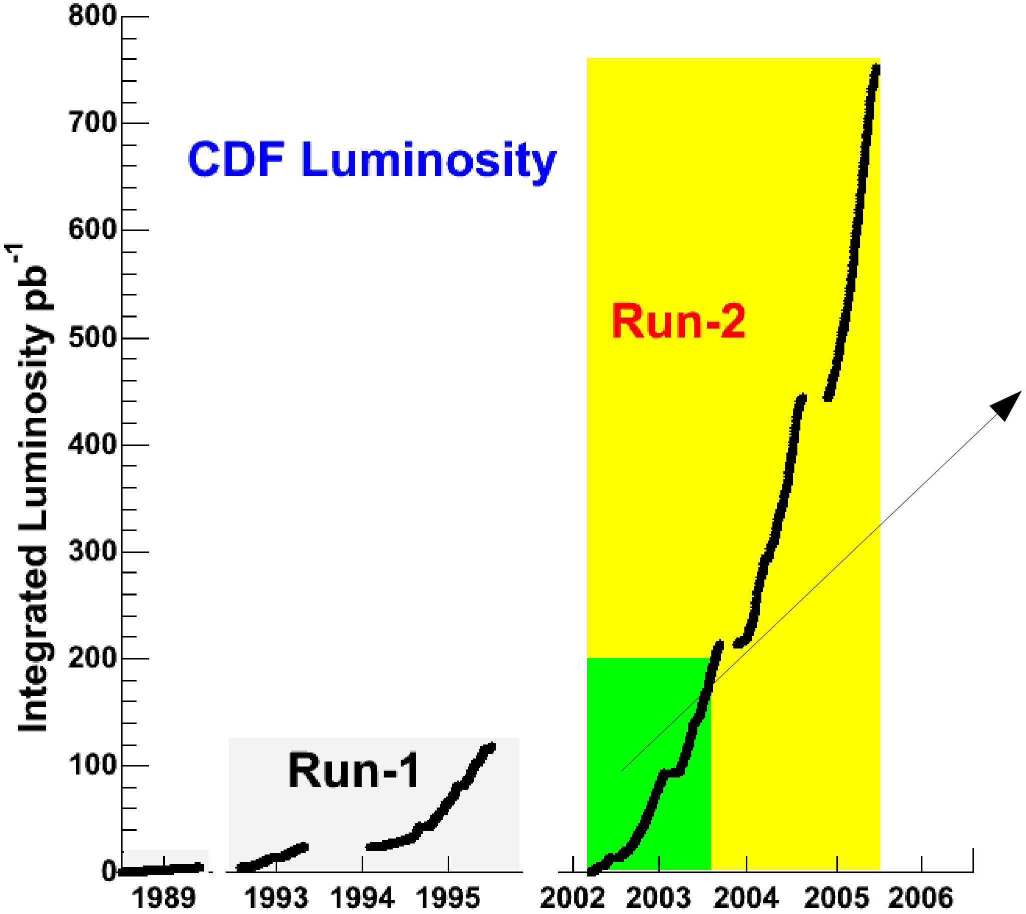
W Mass & Properties

Mark Lancaster on behalf of CDF & DØ
UCL, UK.



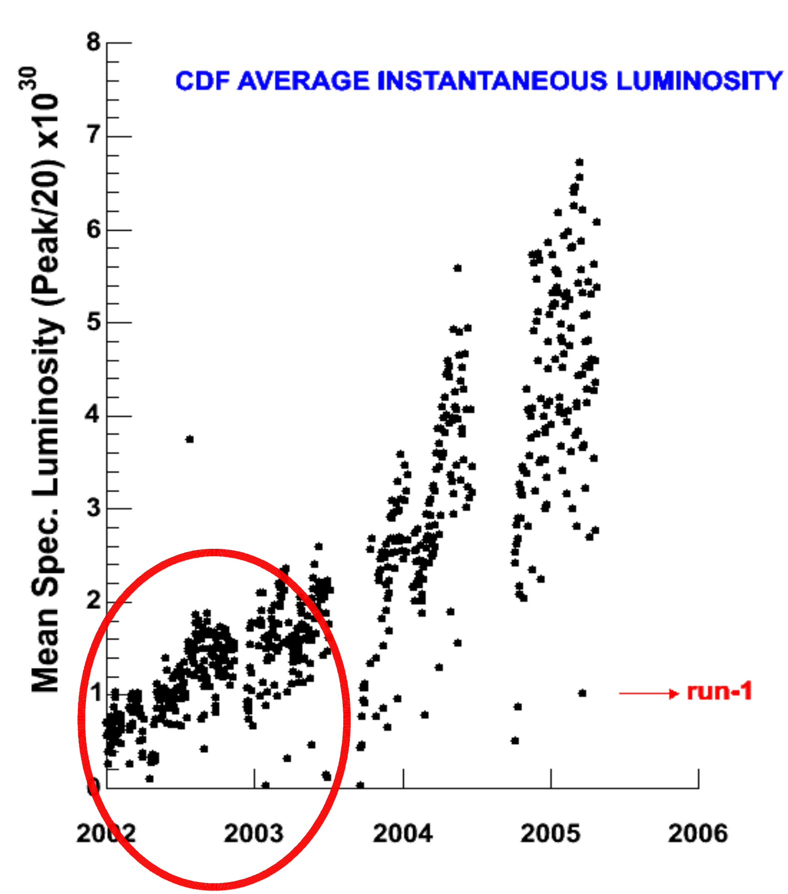
- constrain Higgs mass / new physics
- further vindicate SM





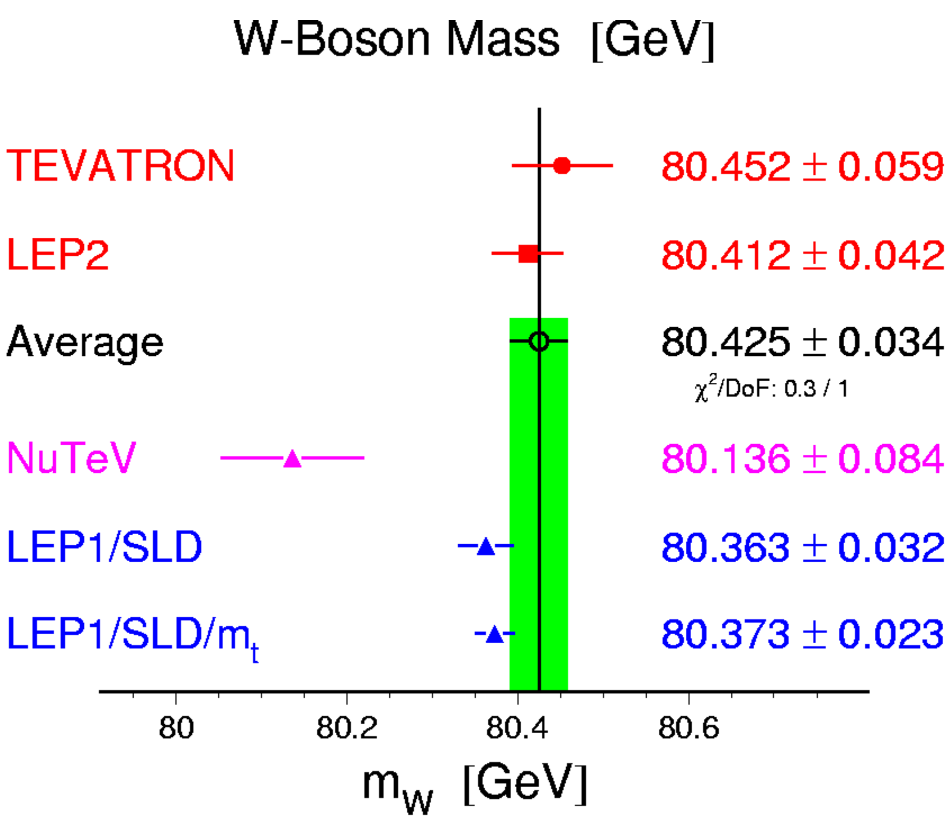
Tevatron has now delivered in excess of $1 fb^{-1}$

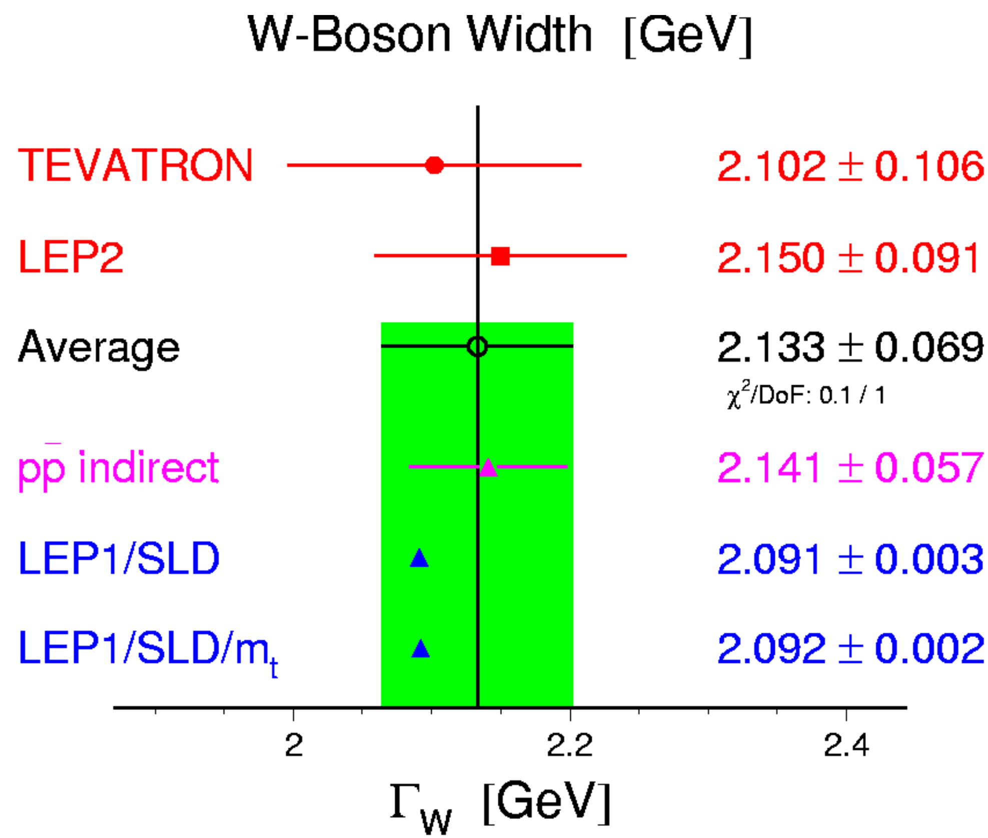
Analyses presented here are based on ~ twice the run-1 data i.e ~ $200 pb^{-1}$



Current Results

- aim with current datasets under analysis is to better the LEP2 uncertainties



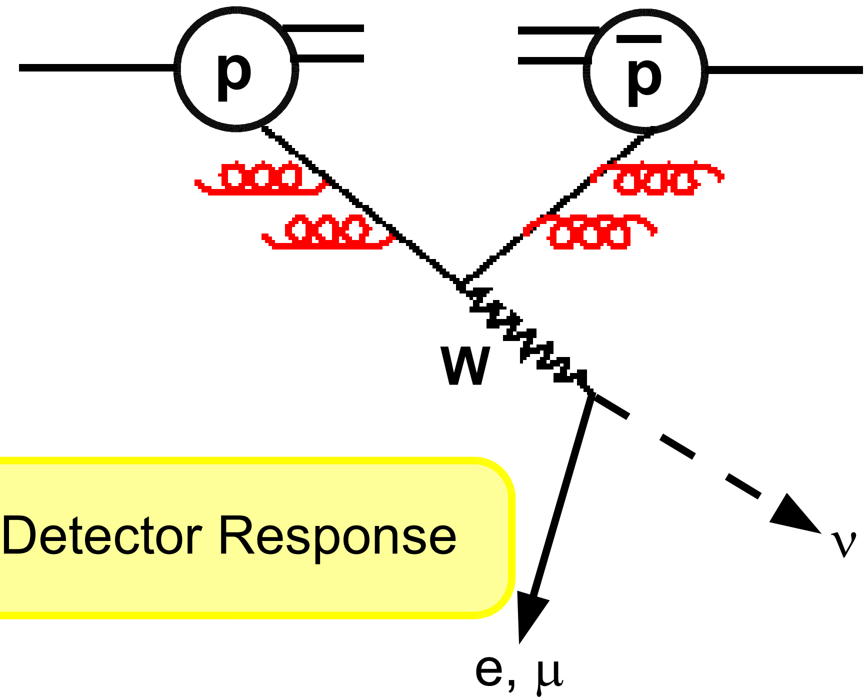


- ultimately with 2 fb^{-1} datasets, expect:

ΔMw ~ 30 MeV (CDF + DØ)
$\Delta\Gamma$w ~ 40 MeV (CDF + DØ)

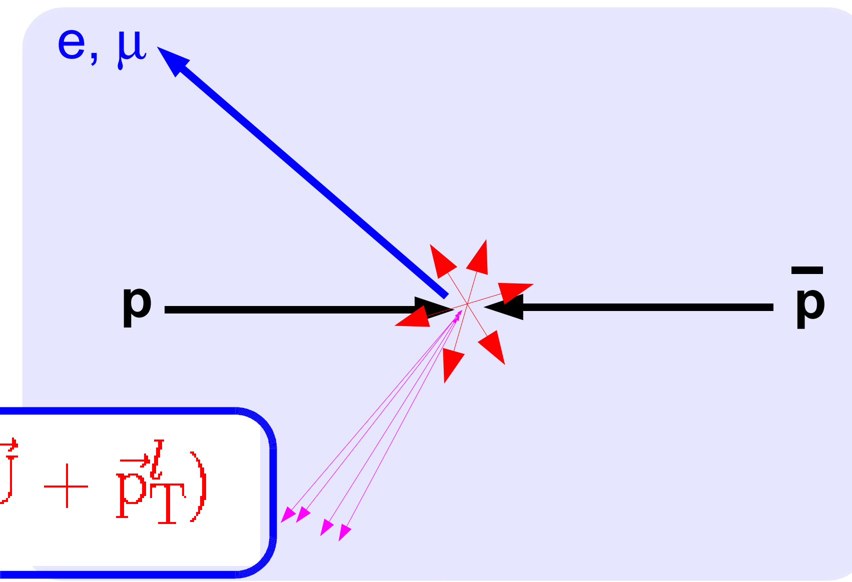
Transverse Mass

- measurement of W mass and width are principally done from transverse mass with cross checks made using the charged lepton or neutrino transverse momenta



W production model: rapidity (PDFs)
pT (QCD radiation)

Detector Response



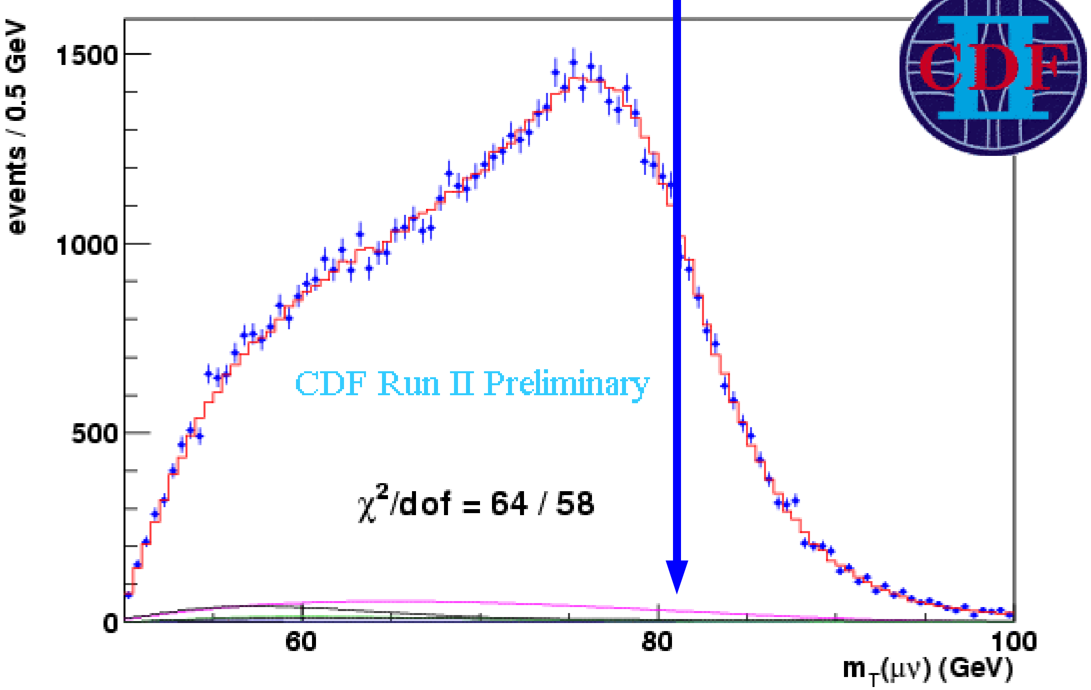
Energy (excluding charged lepton) in transverse plane is called **U**

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

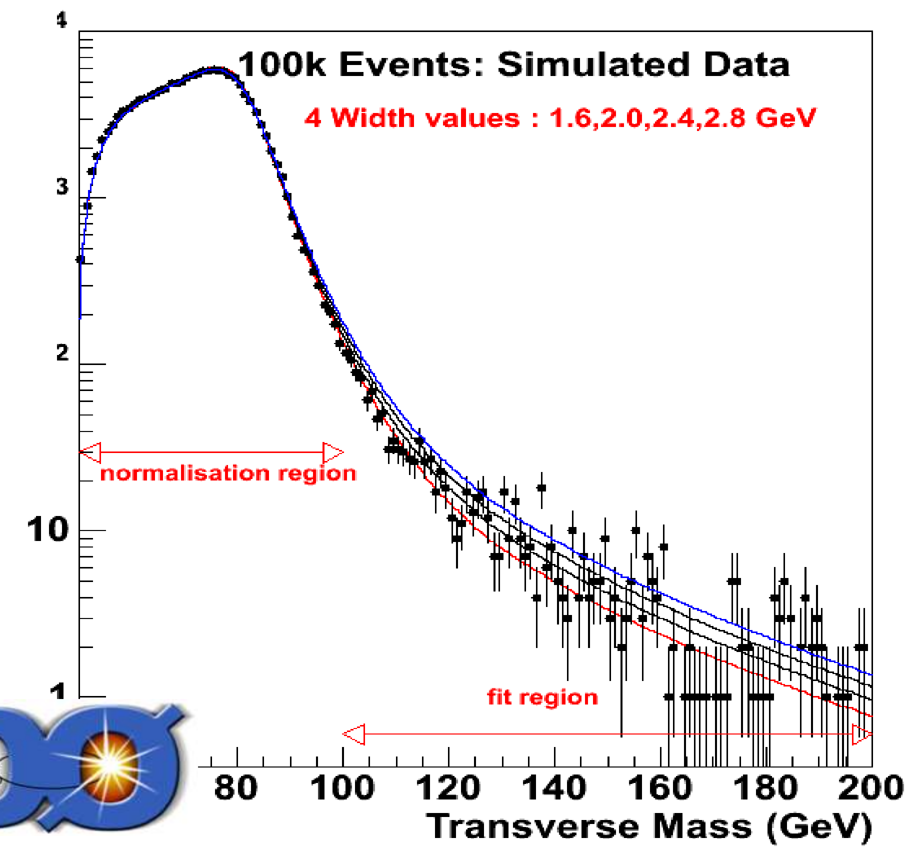
From this transverse neutrino momenta is inferred and transverse mass is defined as :

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

Mw determined from "edge" in m_T



CDF uncertainty analysis for electron and muon channels



Γ_W determined from # of events in high m_T region (mT > 100 GeV)

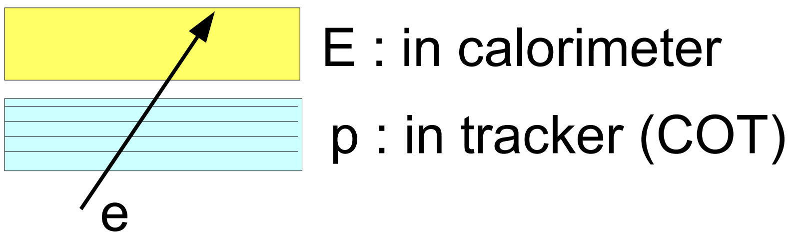
DØ results from electron channel

CDF W Mass Strategy

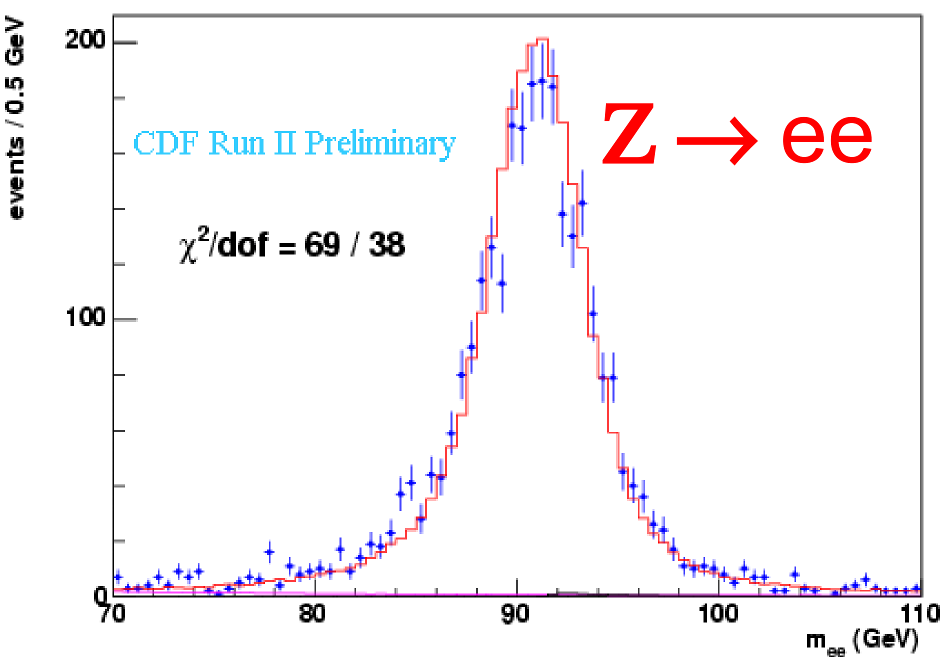
- use Z events to calibrate the recoil and charged lepton resolution

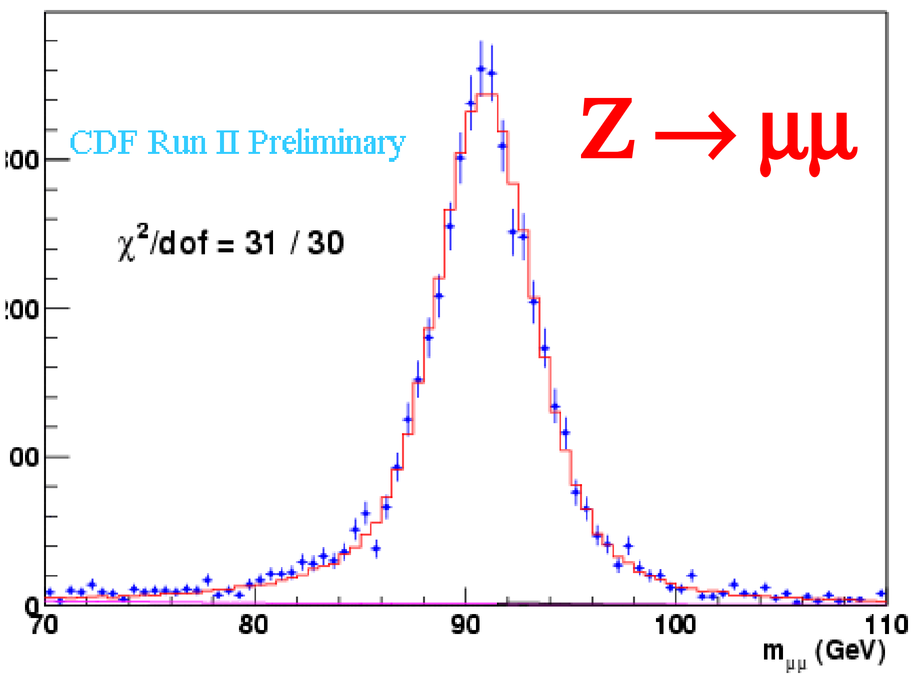
- use Z events to cross check the charged lepton scale but obtain scale using

  - J/Ψ + Upsilon mass for momentum scale
  - E/p in W events for energy scale



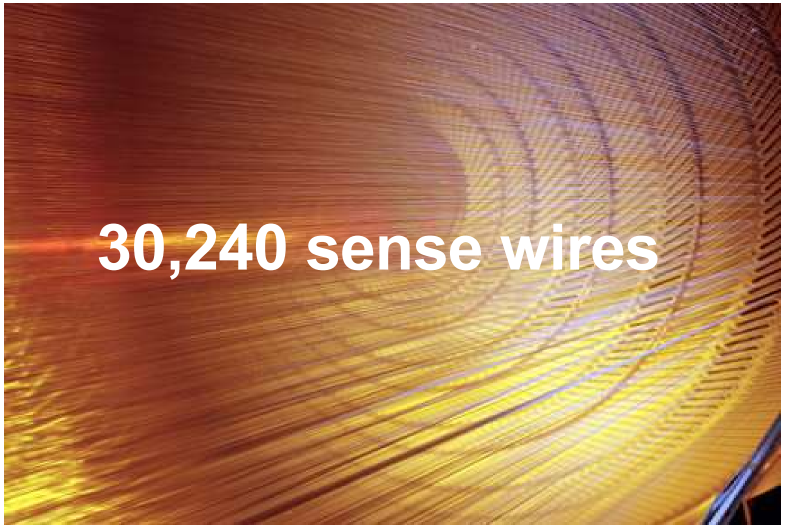
- these afford greater statistical precision than Z samples for scale.



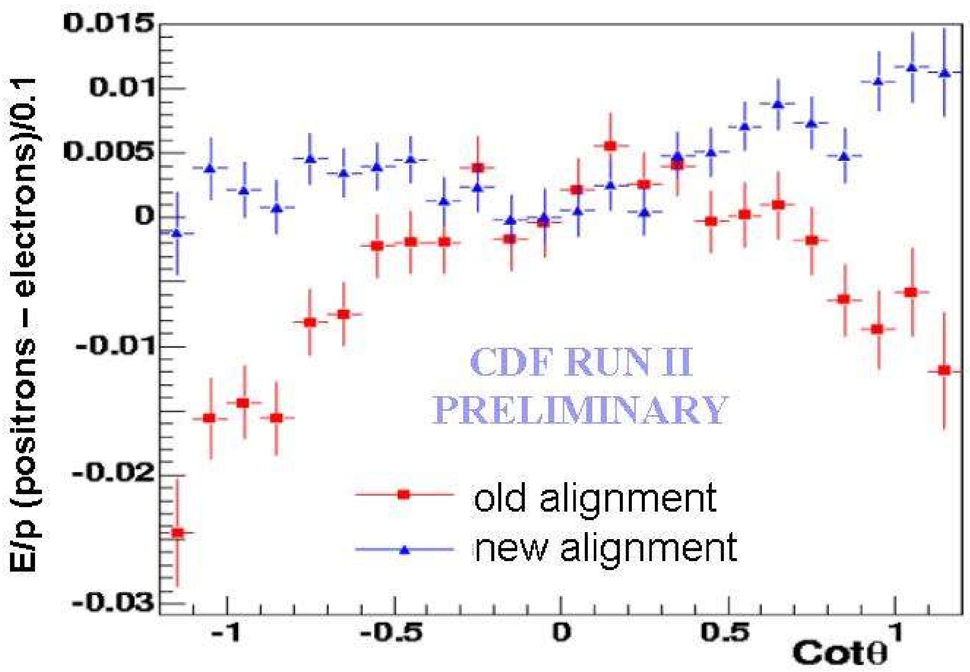


CDF W Mass : Momentum Scale Determination

- CDF tracker (COT) : has 96 planes in 8 superlayers



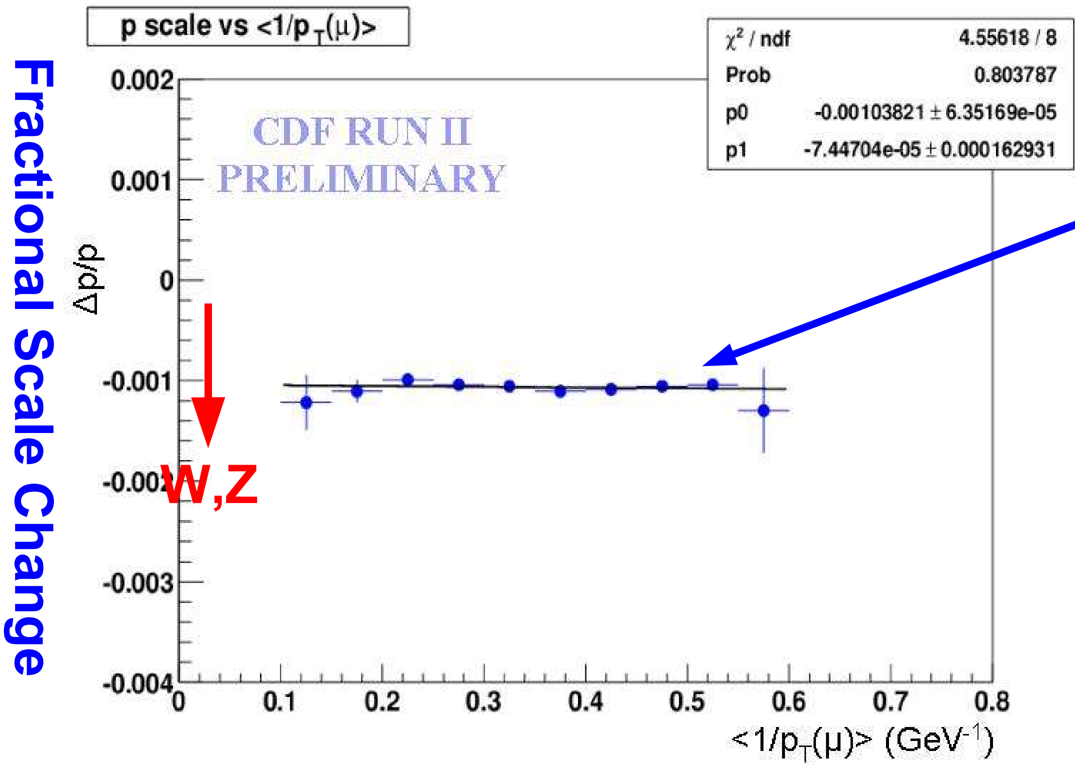
Cosmic ray data are used to fit for cell position at end-plates and wire displacements due to gravity/electrostatics.



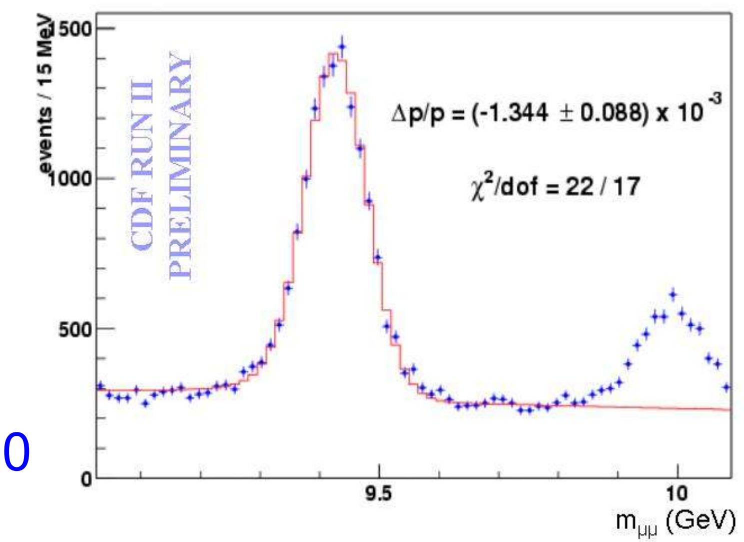
After alignment : charge dependence in E/p vs cot(θ) is almost flattened.

CDF W Mass : Momentum Scale Determination

- momentum scale set using J/Ψ + upsilon → μμ & cross-checked with Z → μμ



Significance of scale dependence (after corrections for energy loss in material) on p is small - allows a reliable extrapolation to W,Z scale.



Momentum scale determined to 3 parts per 10,000

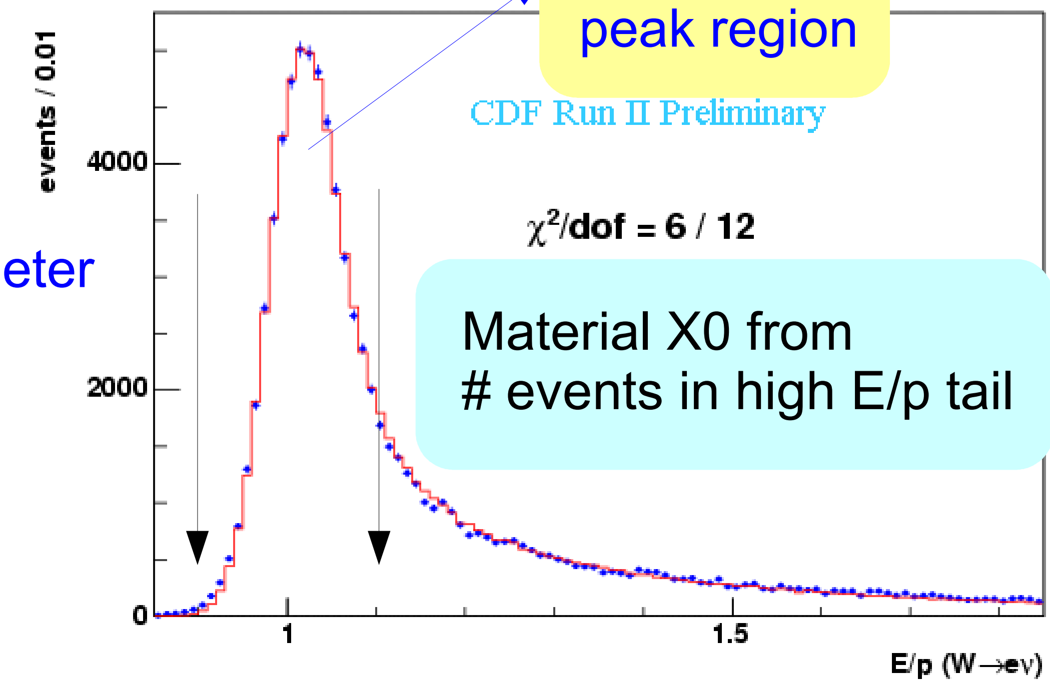
ΔMw ~ 25 MeV

CDF W Mass : Energy Scale Determination

Energy scale set using E/p with additional checks using Z data

Three error sources:

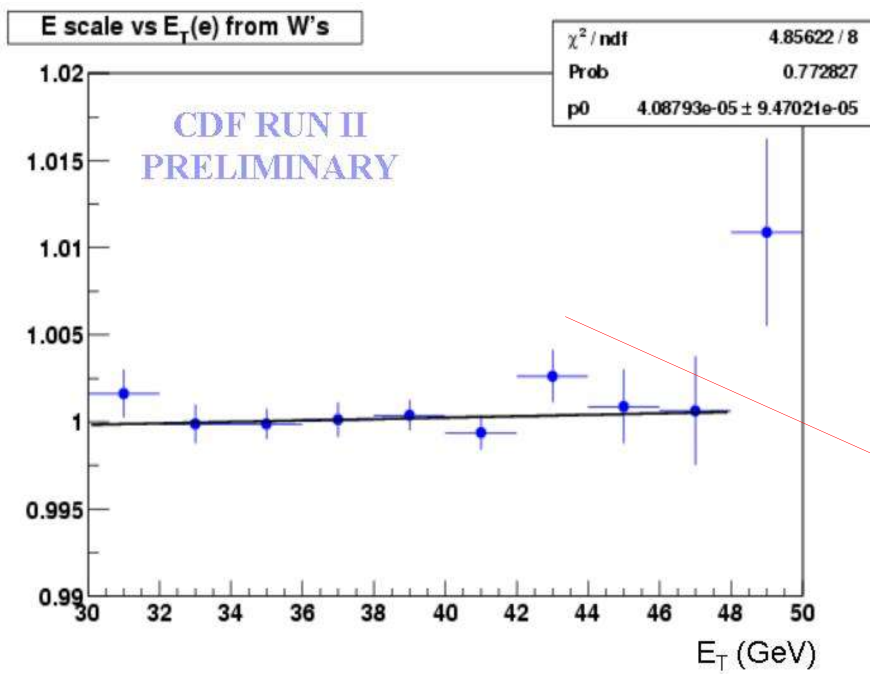
- statistical : 35 MeV
- two systematic :



Fit scale in peak region

Material X0 from # events in high E/p tail

1) Uncertainty on amount/distribution of passive material before calorimeter



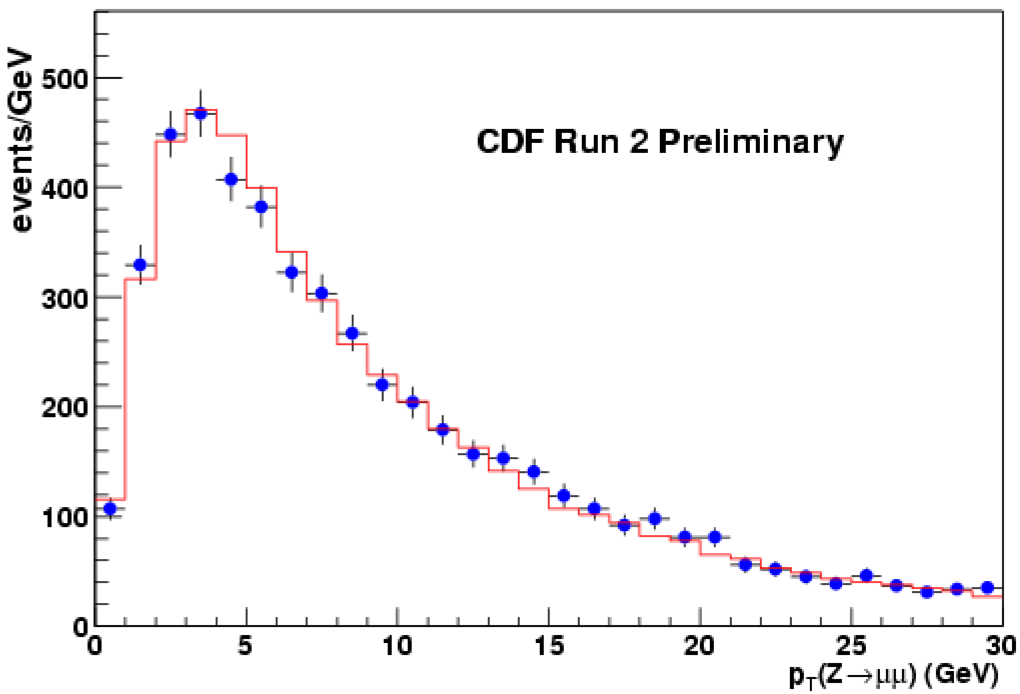
2) Non-linearity of calorimeter response

ΔMw ~ 35 (stat) + 55 (material) + 25 (non-lin) MeV

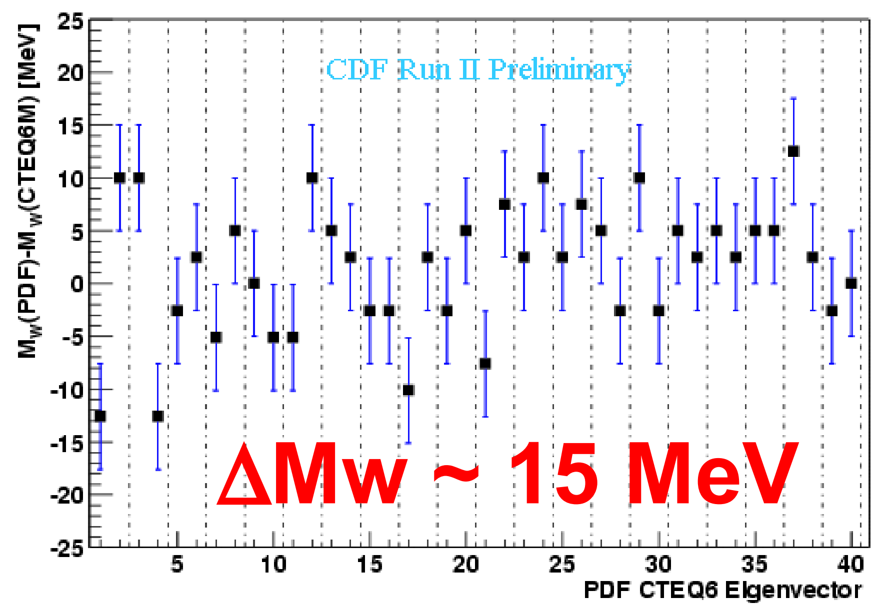
CDF W Mass : W production model

- **QED** : uncertainties from 1vs 2 photon simulations and bias from sampling NLO WGRAD from RESBOS. **ΔMw ~ 15 MeV**

- **QCD** : W pT : using RESBOS/LY parameterisation with "g" parameters taken from run-1 fits. **ΔMw ~ 15 MeV**



PDFs : uncertainty based on the CTEQ6 sets & checked with MRST



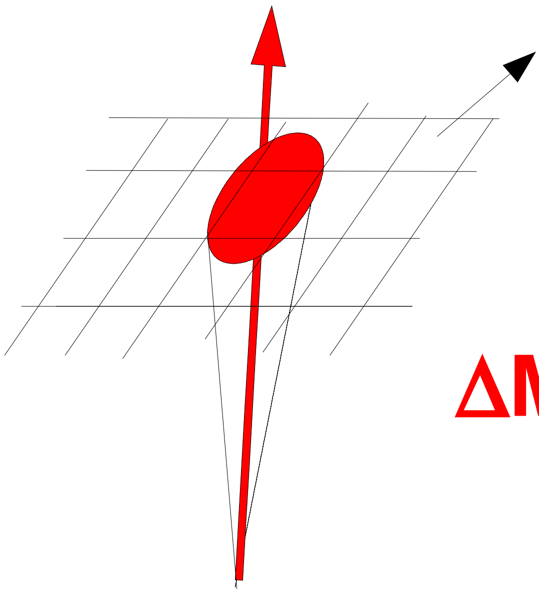
ΔMw ~ 15 MeV

Total ΔMw ~ 25 MeV (production model)

CDF W Mass : Hadronic Recoil

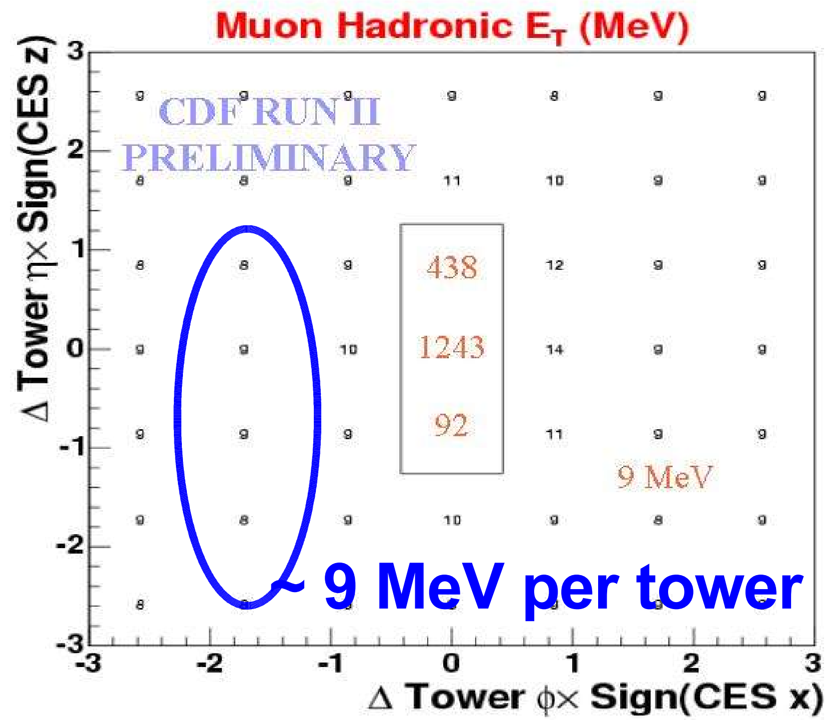
1) Take care of energy in lepton calorimeter towers from underlying event(s)/recoil

- look at towers adjacent (in ϕ) to e/mu



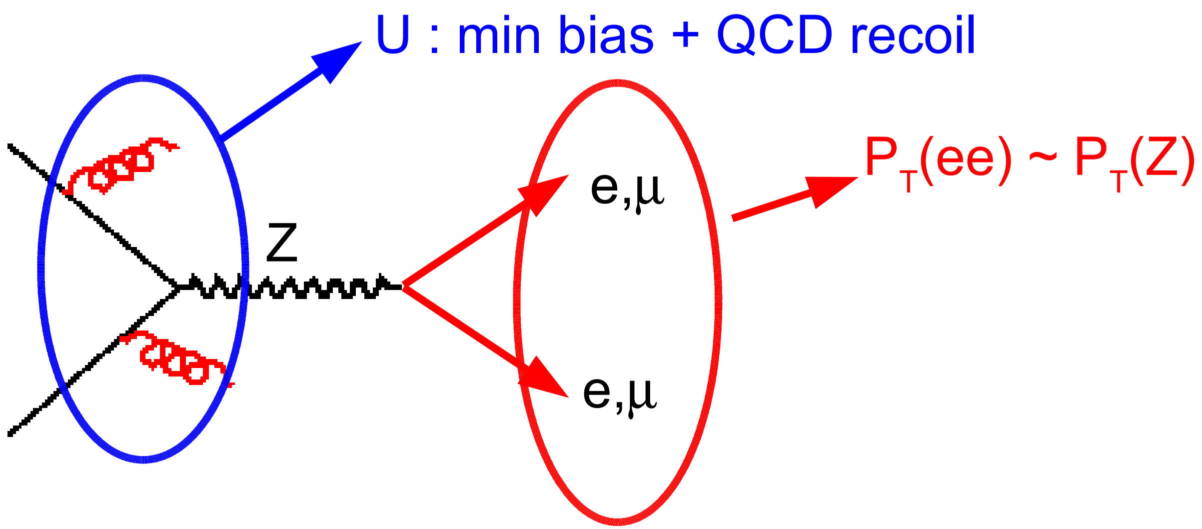
0.1 (η) x 15^0 (ϕ)

ΔMw ~ 10 MeV



2) Exploit similar production model of Z events to create ad-hoc model for recoil in W events that depends on luminosity

CDF W Mass : Hadronic Recoil



Hadronic Recoil has two components:

1) Min Bias : luminosity dependent but no $P_T(Z)$ or direction dependence
2) QCD : has $P_T(Z)$ dependence and is largest along the $P_T(Z)$ direction

Measure detector ***"response"*** to "U" by comparing measured U against $P_T(Z)$
- find that only measure ~ 0.5 of QCD recoil.

ΔMw ~ 20 MeV - from uncertainty in response (driven by Z statistics)

CDF W Mass : Hadronic Recoil

Recoil **Resolution** has two components:

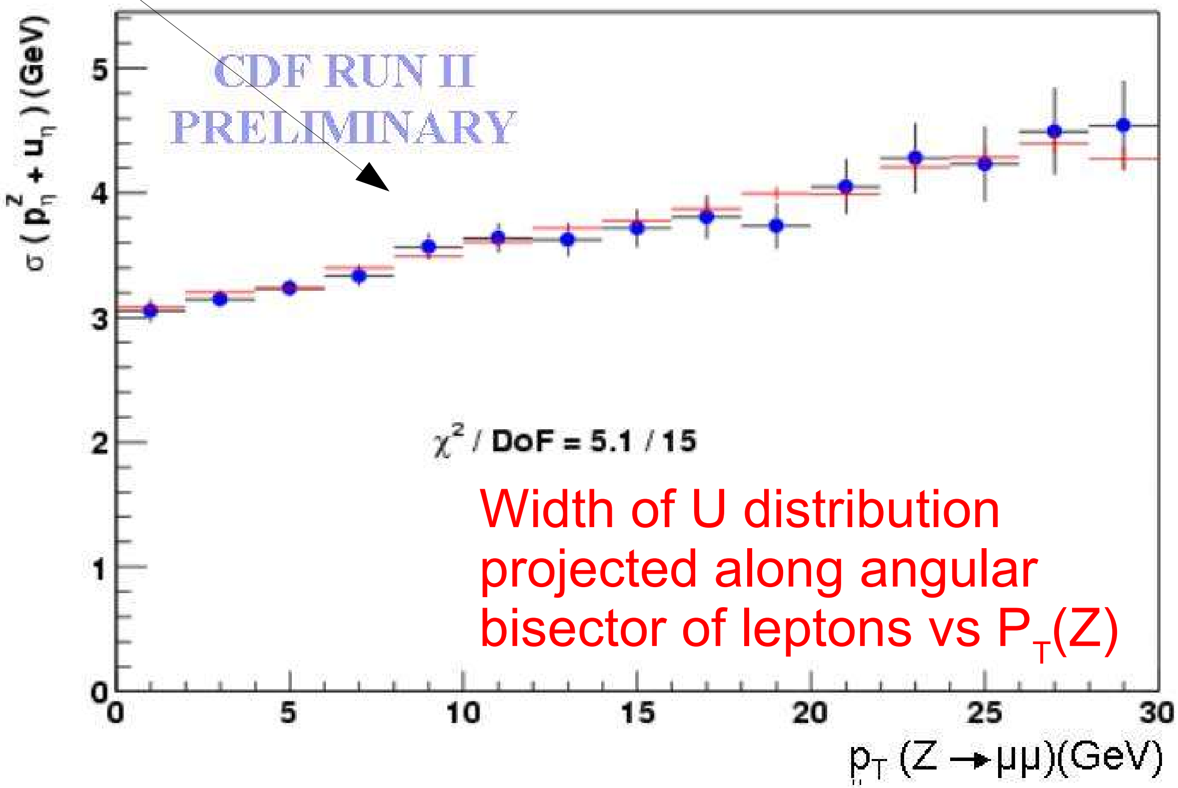
1) Min Bias : luminosity dependent but no $P_T(Z)$ dependence

- fit from minimum bias events

2) QCD : has $\sqrt{P_T(Z)}$ dependence

- fit from Z events

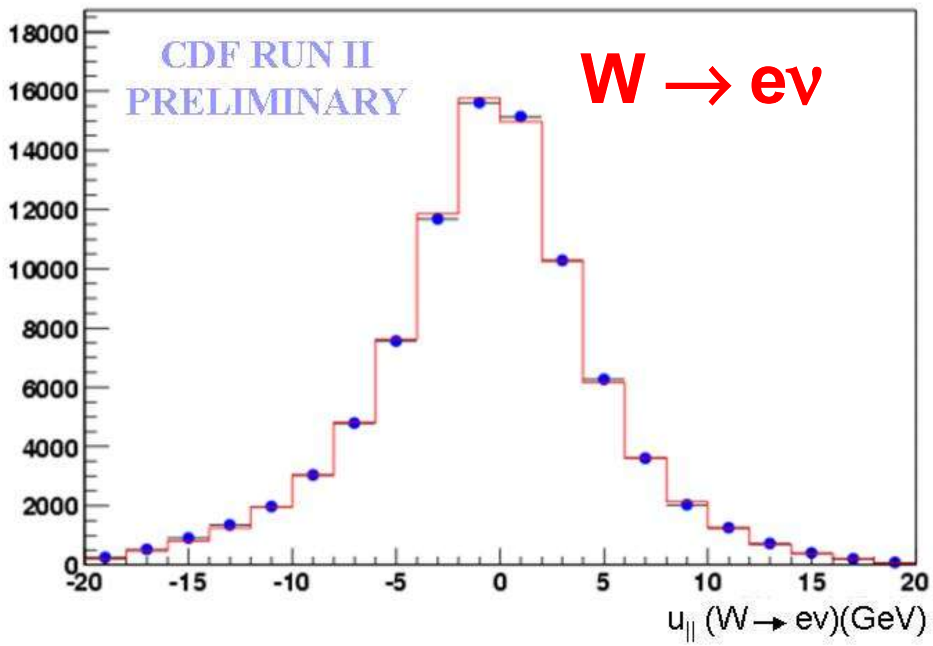
ΔMw ~ 40 MeV

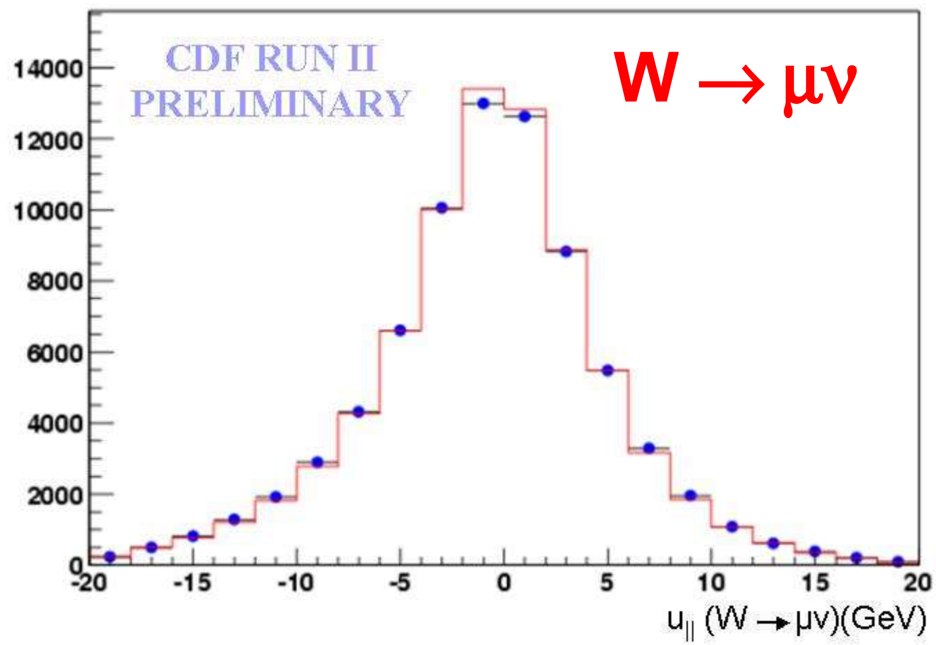


CDF W Mass : Recoil Model

- take model from fits to Z & min bias data and compare to W events

    - look at component of U along electron or muon direction : $U_{||}$





CDF W Mass : Backgrounds

- Z events where one lepton is not detected are estimated from MC
- $W \rightarrow \tau\nu$ & $\tau \rightarrow e,\mu\nu\nu$ are also estimated from MC

Other backgrounds are estimated from data by loosening cuts and extrapolation

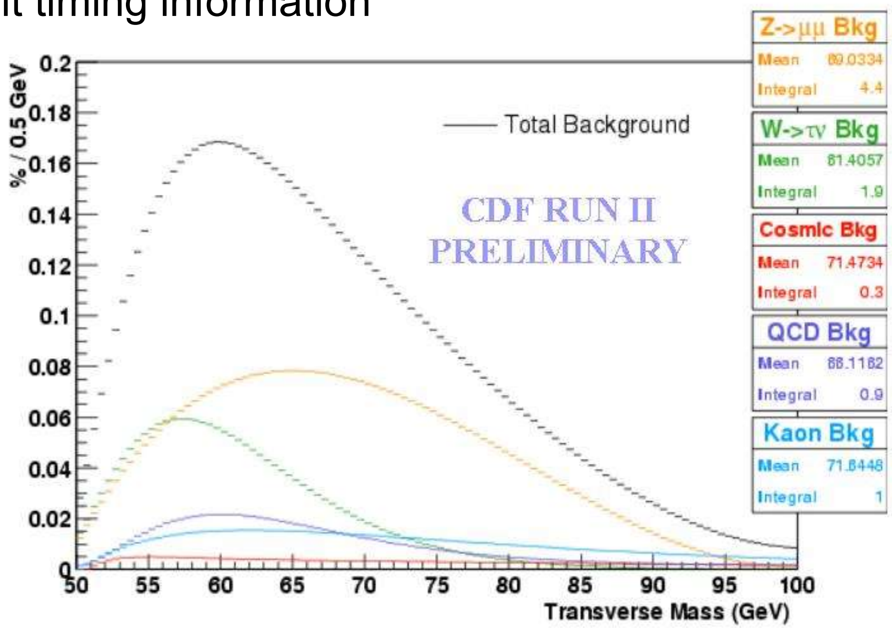
Background	%
QCD jets	0.9 ± 0.5
Kaons	1.0 ± 1.0
Cosmic Rays	0.3 ± 0.1
Z	4.4 ± 0.2
$W \rightarrow \tau\nu$	1.9 ± 0.1

QCD jets: look at MET distribution in events where lepton is not isolated.

Kaons: decay in COT leads to track mismeasurement & MET opposite track; use $\Delta\phi$ (l,MET) to estimate background

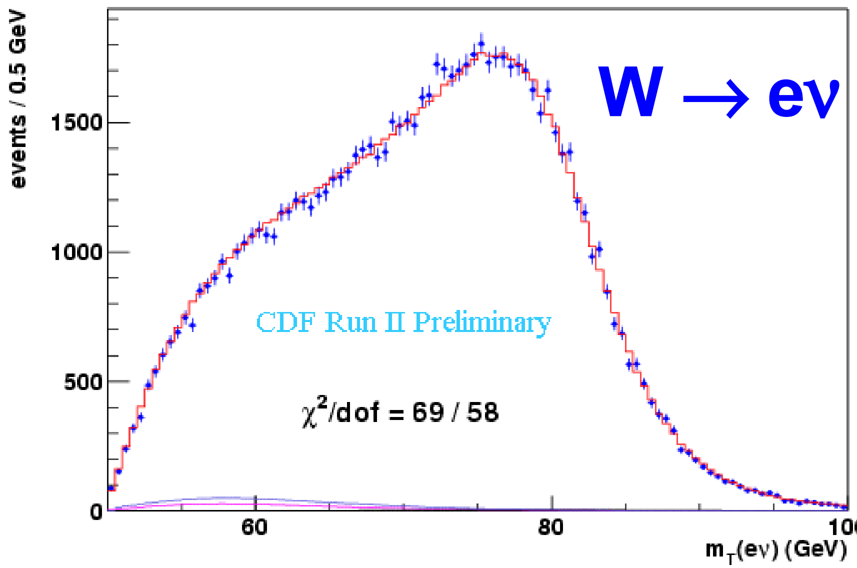
Cosmic Rays: from track hit timing information

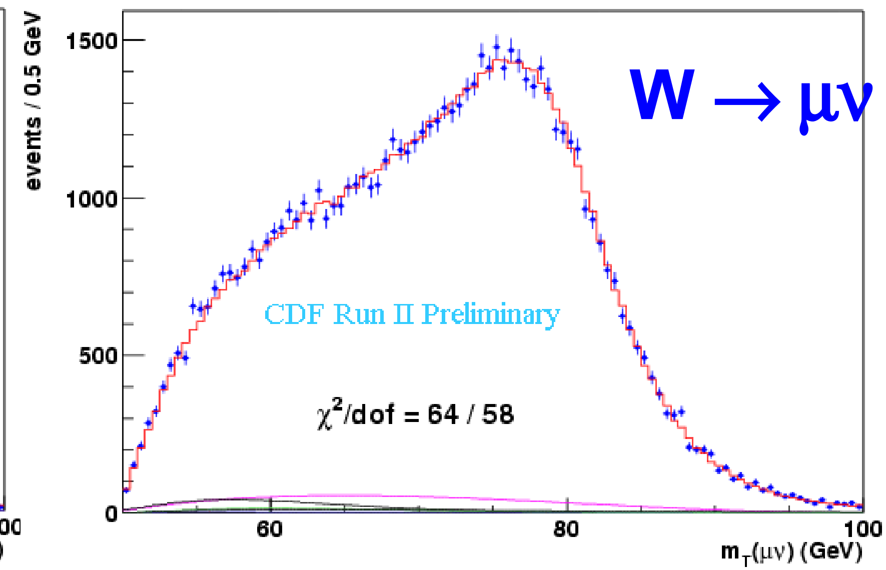
$\Delta Mw \sim 20$ MeV



CDF W Mass : Mass Fits

- fits blinded with offset !



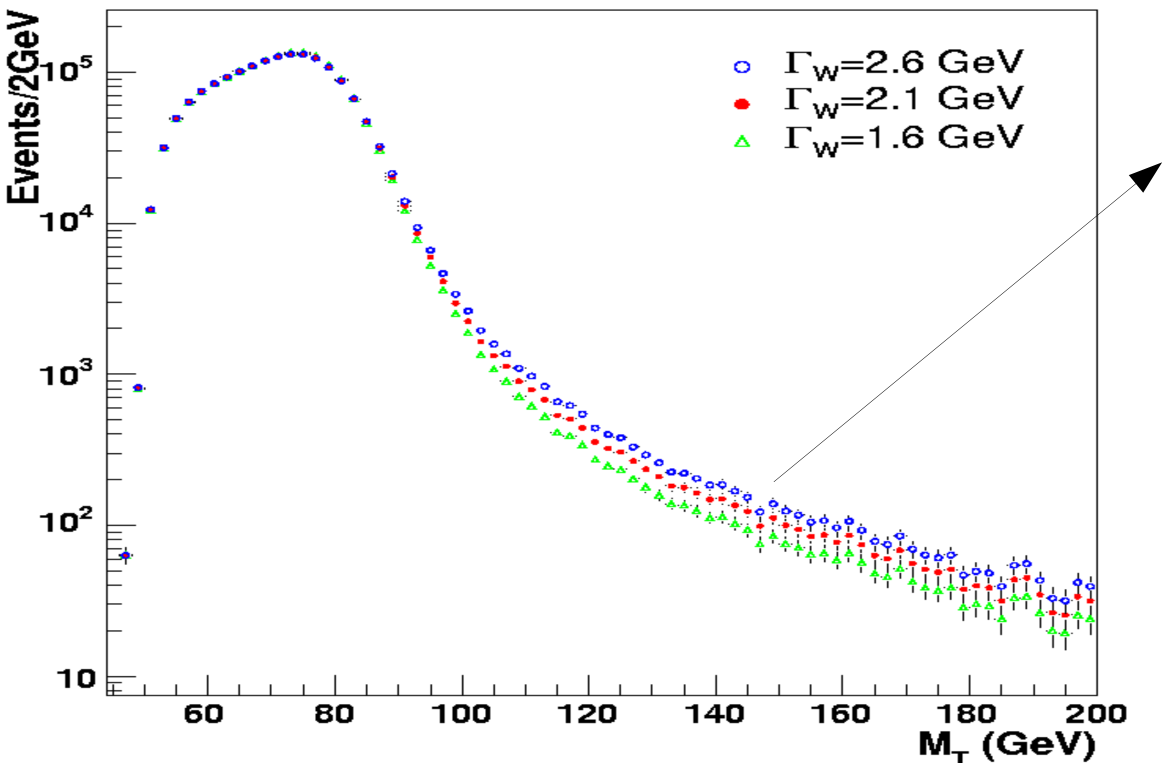


Systematic Source	Electrons (run 1b)	Muons (run 1b)	Common (run 1b)
Production & Decay Model	30 (30)	30 (30)	25 (15)
Lepton E or p Scale & Resolution	70 (80)	30 (90)	25 (0)
Recoil Scale & Resolution	50 (35)	50 (35)	50 (0)
Backgrounds	20 (5)	20 (25)	
Statistics	45 (65)	50 (100)	
Total	105 (110)	95 (140)	60 (15)

ΔMw (run-2) = 76 MeV *c.f.* 79 MeV (run 1)

DØ W Width

- indirect measurements from W/Z σ ratio (see talk by S. Protopopescu) rely on NNLO W,Z σ calculation and LEP BRs : **$\Delta\Gamma_W$ ~ 40 MeV**
- a model independent determination is possible from measurements of high transverse mass tail.

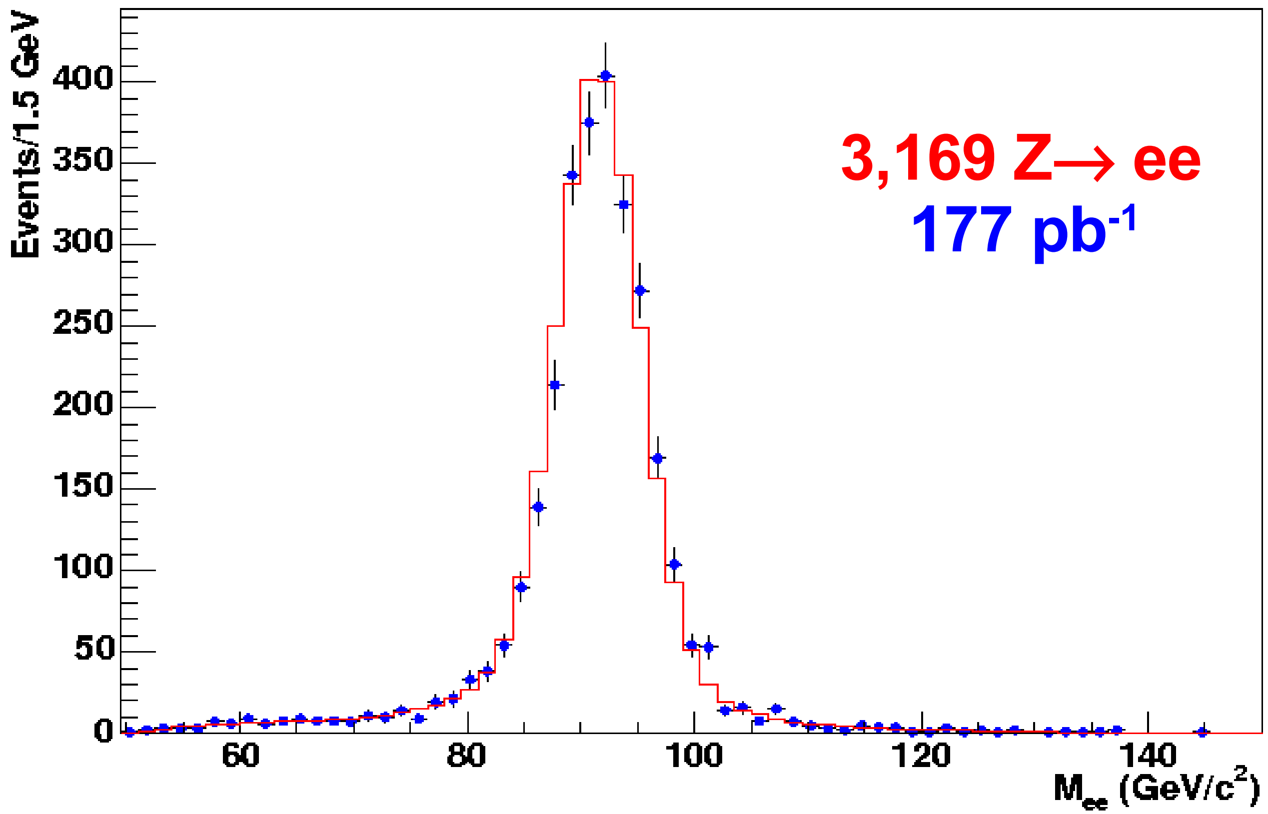


Events beyond "Jacobian" edge caused by finite W width, detector resolution effects and backgrounds.

Understanding of lepton, recoil scale, resolution and any scale non-linearities are key to measurement.

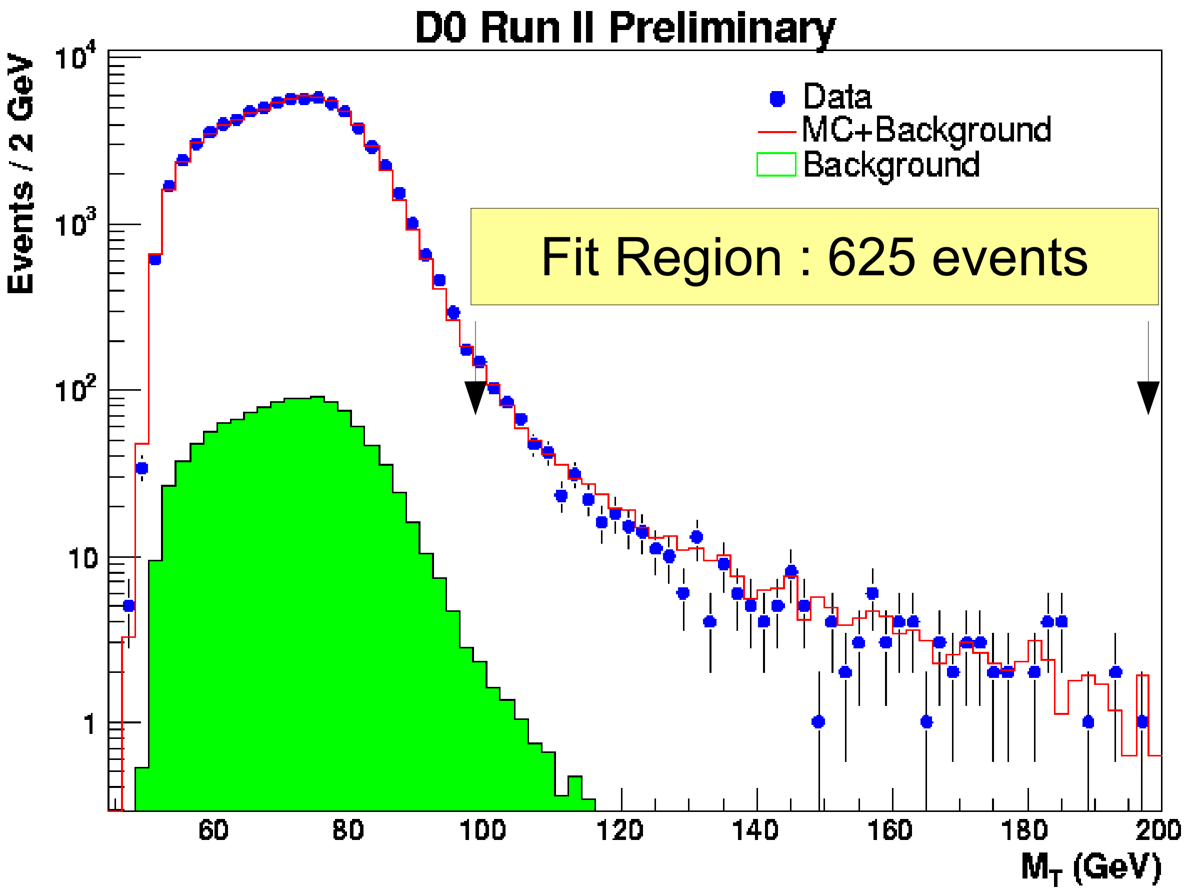
DØ W Width

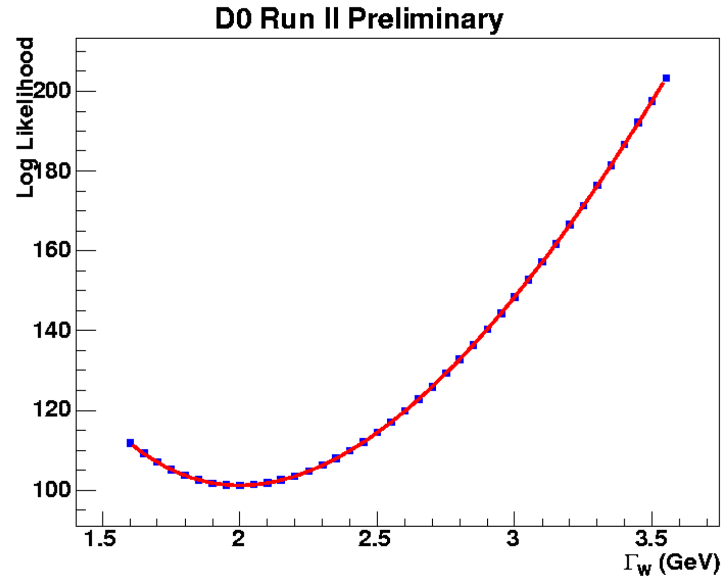
- analysis uses only electron sample in central ($|\eta| < 1$) region.
- electron scale / resolution set by $Z \to ee$ sample



- analysis very similar to CDF W mass except no use made of E/p

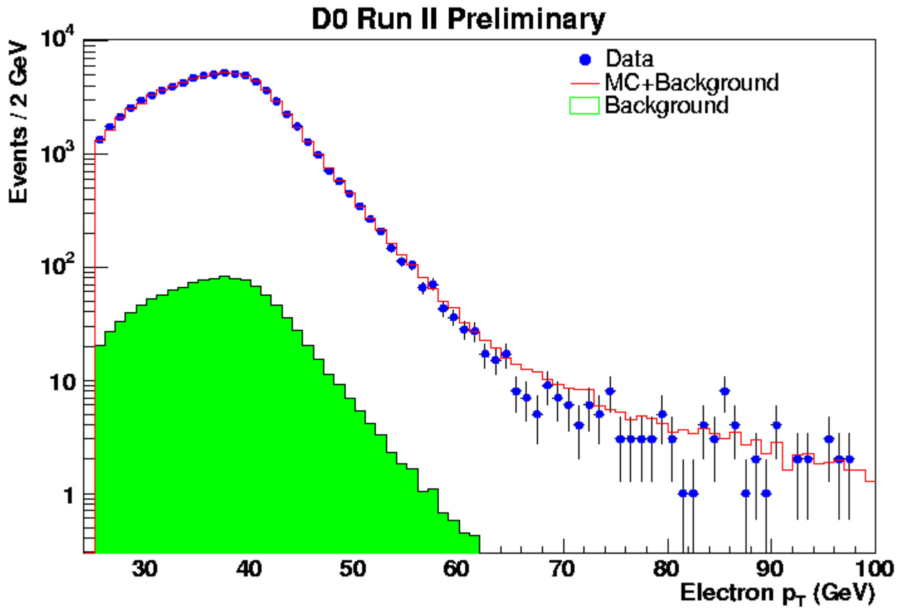
DØ W Width





$$\Gamma_W = 2011 \pm 93 \text{ (stat) MeV}$$

DØ W Width



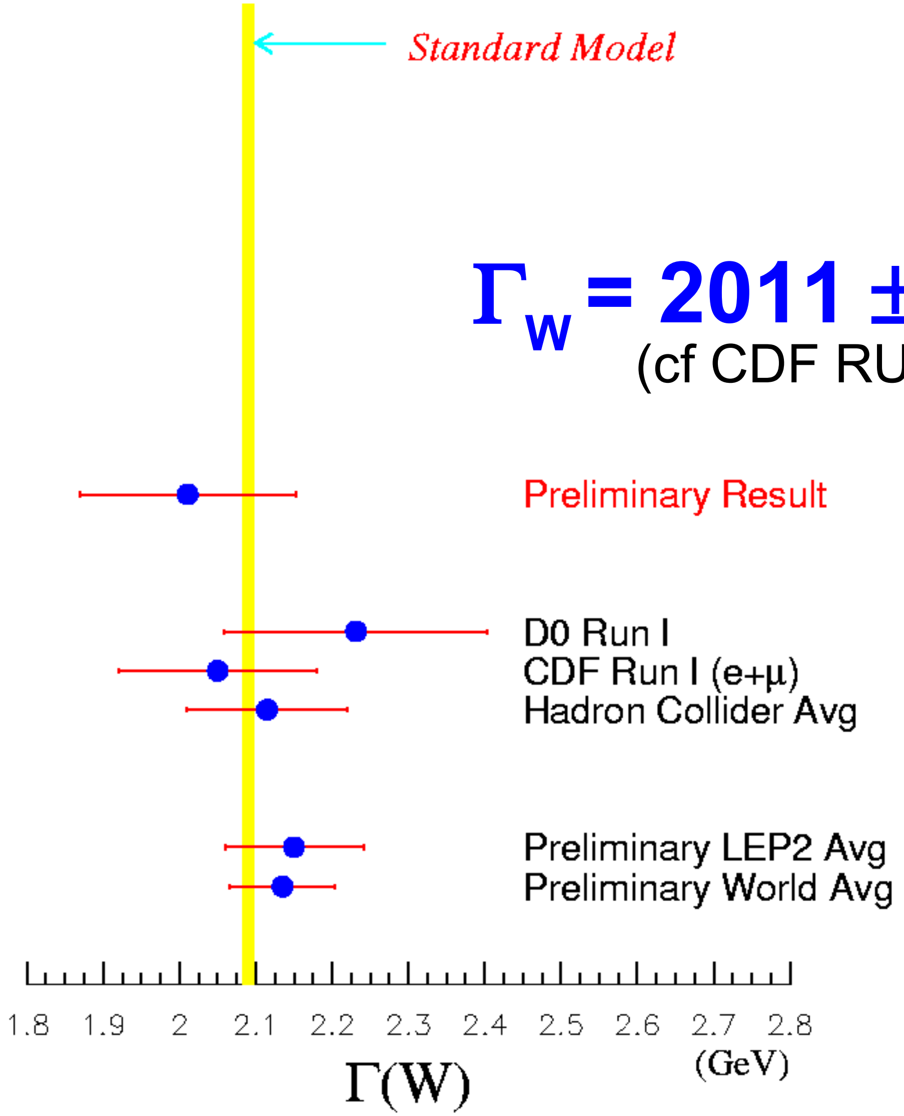
- cross check with $p_T(e)$ fit

Systematic Source	Error (MeV)
Electron scale & resolution	55
Recoil scale & resolution	80
Angular resolution	10
Backgrounds & Selection Bias	10
PDFs	25
$P_T(W)$	30
M_W	15
Total	**107**

DØ W Width

$$\Gamma_W = 2011 \pm 93 \pm 107 \ \text{MeV}$$

(cf CDF RUN1 : $\Gamma_W = 2050 \pm 130$ MeV)



Tevatron Outlook

Tevatron W mass and width measurements have and continue to provide important SM contraints

Near Future:

- 200 pb^{-1} CDF W mass (e & μ) imminent with error better than run-1 : 75 MeV
- 200-400 pb^{-1} width measurements when combined will be better than LEP2.

Now:

Experiments already have in hand 750 pb^{-1} of good W data and next W analyses will use > 1fb^{-1} of data.

Next 2 years:

2 fb^{-1} analyses will produce W masses and width uncertainties below LEP2 :

ΔMw ~ 40 MeV per experiment (cf OPAL : ~ 53 MeV)

$\Delta\Gamma$w ~ 50 MeV per experiment (cf DELPHI : ~ 120 MeV)