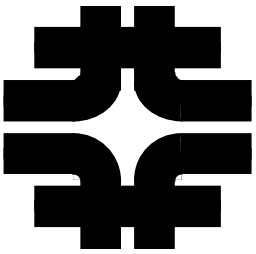


Measurement of the W Mass at the Tevatron

Eric Flattum

Fermilab

for the CDF and DØ Collaborations

XXXIst Rencontres de Moriond: QCD and High Energy Hadronic Interactions

Les Arcs 1800, France

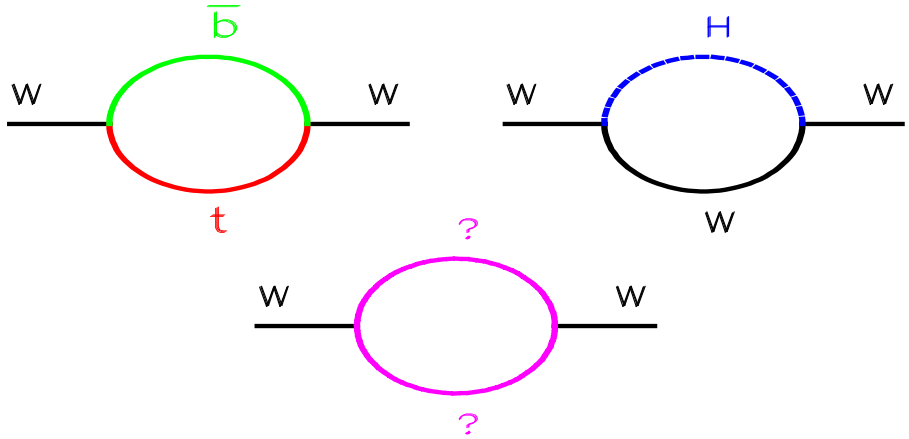
March 25, 1998

Outline

- Motivation
- W/Z Events
- Lepton Energy/Momentum Scale and Resolutions
- Lepton p_T Fits
- Hadronic Energy Scale and Resolutions
- m_T Fits
- Conclusions

Motivation

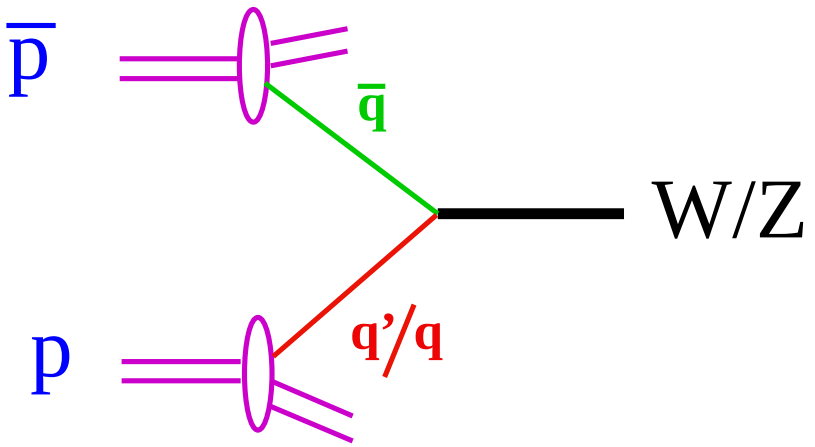
- W mass fixed by α_{em}, G_F, and M_Z at the tree level
  - All precisely measured <25 ppm
  - $\delta M_W/M_W \sim 1000$ ppm
- Measure of EW radiative corrections
  - ~100 MeV on the W mass



- Probe of New physics

Method

- W/Z production similar in $p\bar{p}$
- Z's important calibration tool

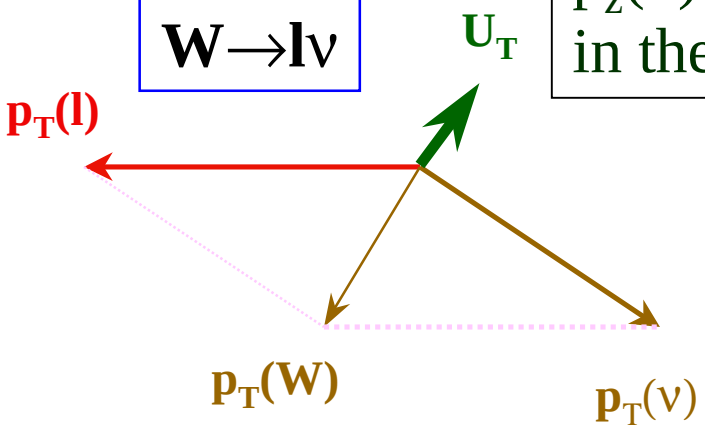


- W/Z produce high p_T isolated leptons
- 1994-95 data set
  - CDF - μν, Preliminary
  - DØ - eν, To be published Physical Review Letters and submitted to Physical Review D
- 1992-93 data set
  - Published

Method

$p_z(\nu)$ not known $\Rightarrow$ work in the transverse plane

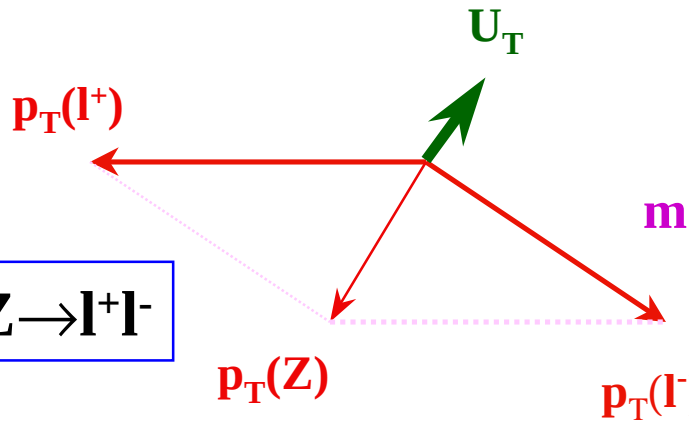
$W \rightarrow l\nu$



$$\not{p}_T = -(\vec{U}_T + \vec{p}_T(l))$$

$$m_T = \sqrt{2 p_T(l) \not{p}_T (1 - \cos\phi)}$$

$Z \rightarrow l^+ l^-$

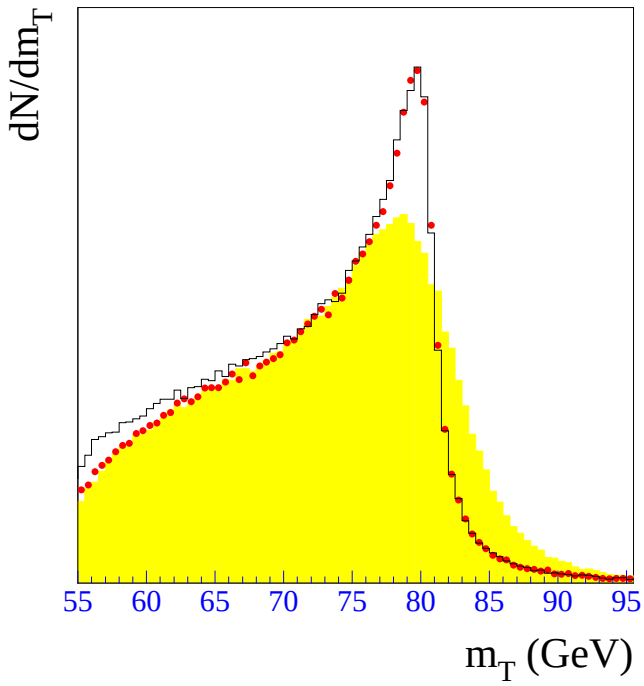


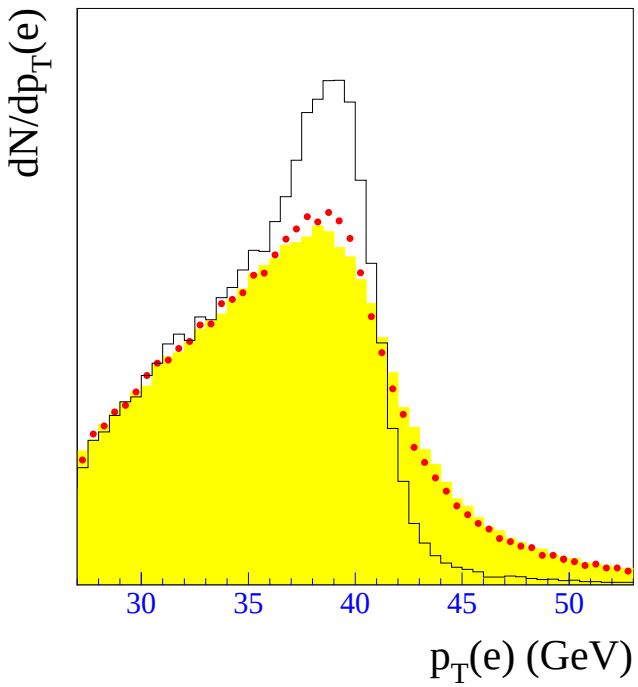
$$m = \sqrt{2 p(l^+) p(l^-) (1 - \cos\gamma)}$$

- m_T and p_T used to measure M_W
  - No simple analytical form
    - $\Rightarrow$ Monte Carlo

Extracting the W Mass

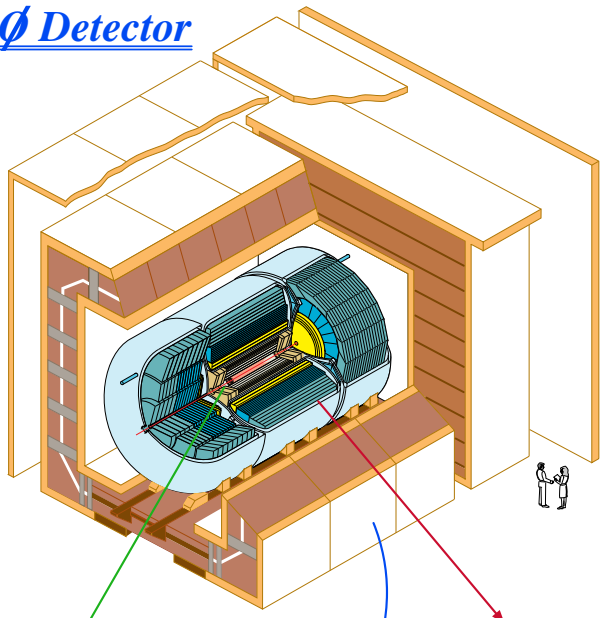
- Monte Carlo
  - $p\bar{p} \rightarrow W/Z$ production
  - Detector effects
    - Need to understand the leptonic and hadronic energy scale and resolutions
  - Selection cuts, efficiencies, and acceptances





The Detectors

DØ Detector



Emphasize Calorimetry:
Compact U-LAr

TRACKING

σ(z vertex)=6 mm
σ(rφ) = 60 μm (VTX)
= 180 μm (CDC)
= 200 μm (FDC)

MUON

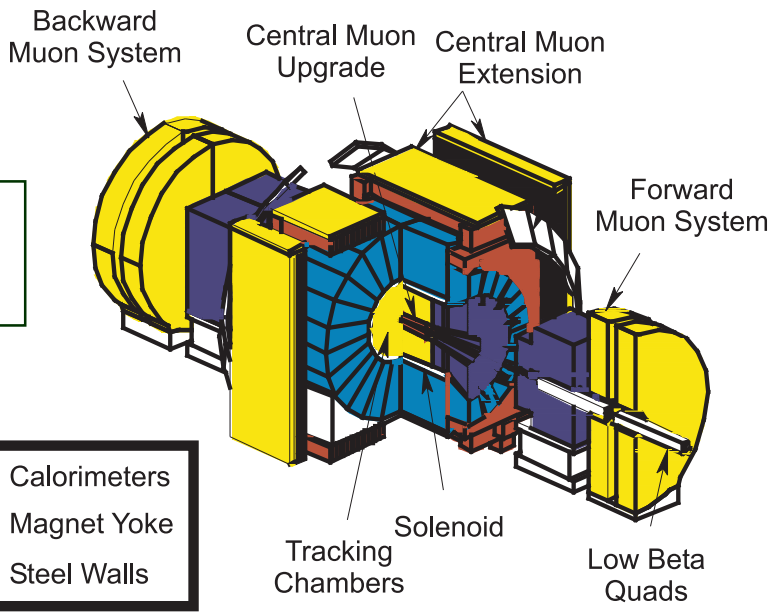
$|\eta| < 3.3$

$\frac{\delta p}{p} = 0.2 \oplus 0.01p$

CALORIMETRY

$|\eta| < 4$
$\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
$\sigma(EM) = 15\%/\sqrt{E}$
$\sigma(HAD) = 50\%/\sqrt{E}$

CDF Detector



Emphasize Tracking:
1.4T Magnet

Event Selection

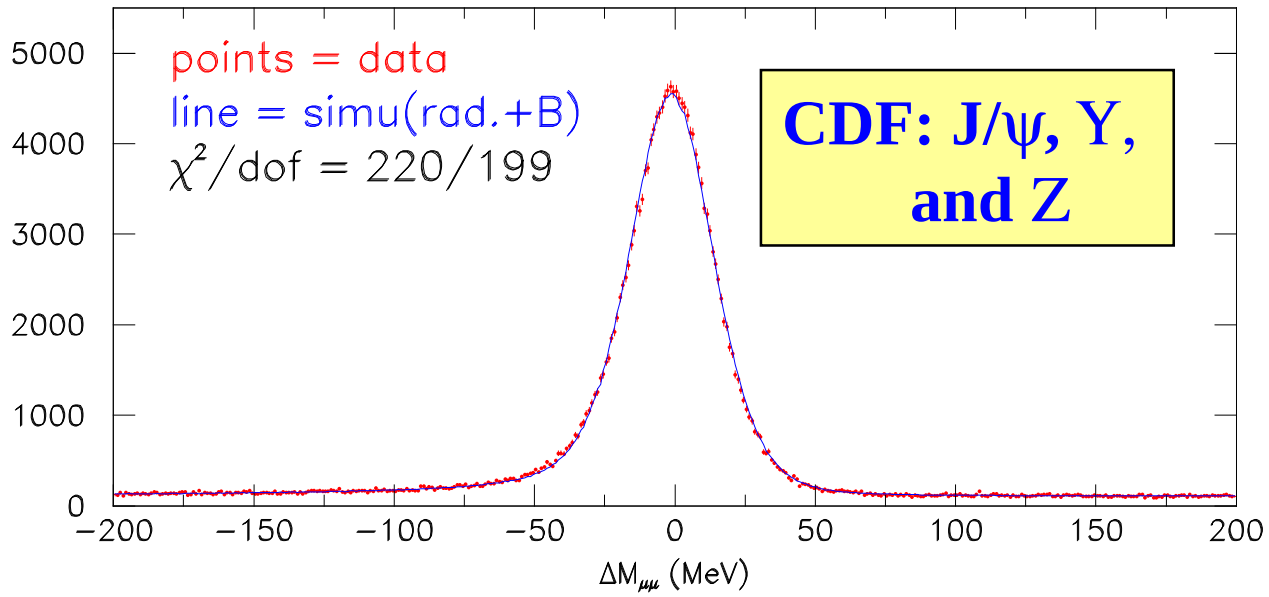
- CDF - 90 pb^{-1}
  - $25 < p_T(\mu) < 60$ GeV
  - $25 < \not{p}_T < 60$ GeV
  - $|U_T| < 20$ GeV
  - $|\eta| \lesssim 1$
  - μ Quality
    - MIP in Calorimeter
    - Cosmic Removal
    - Track Match
  - $50 < m_T < 110$ GeV

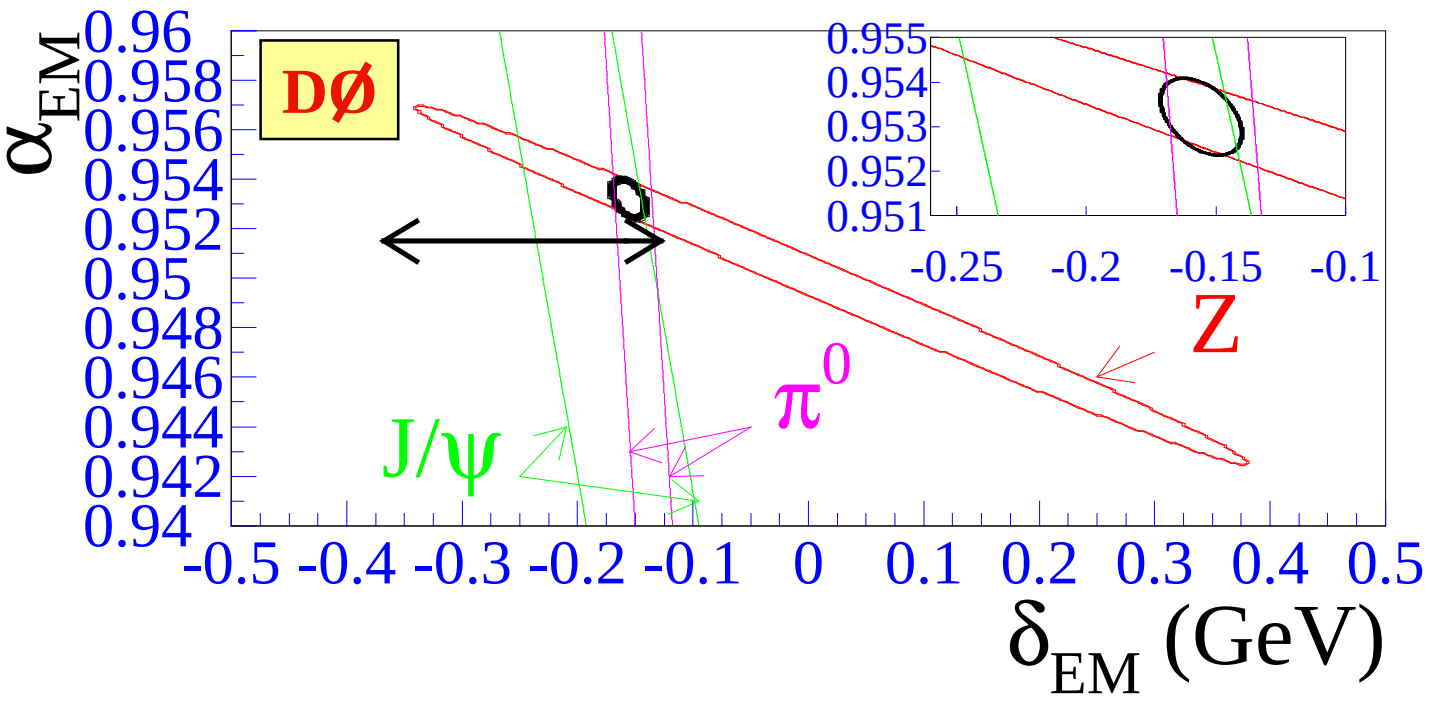
- DØ - 82 pb^{-1}
  - $p_T(e) > 25$ GeV
  - $\not{p}_T > 25$ GeV
  - $|U_T| < 15$ GeV
  - $|\eta| \lesssim 1$
  - e Quality
    - Isolation
    - Shower Shape
    - Track Match

21,000 W's	28,000 W's
1,400 Z's	2,200 Z's

Lepton Momentum and Energy Scale

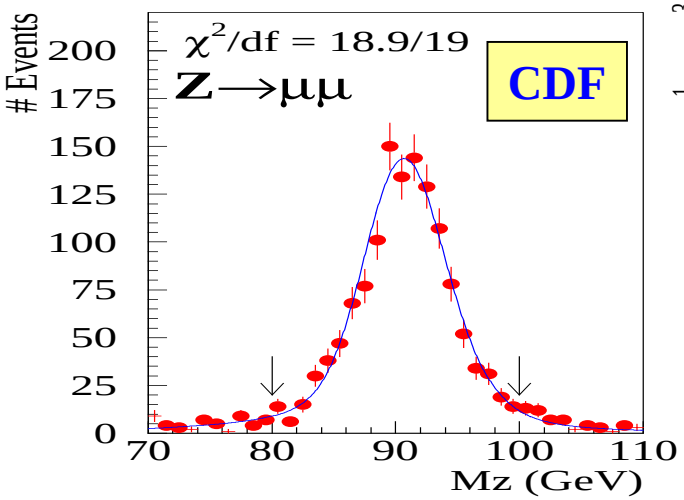
- Calibrate to known resonances

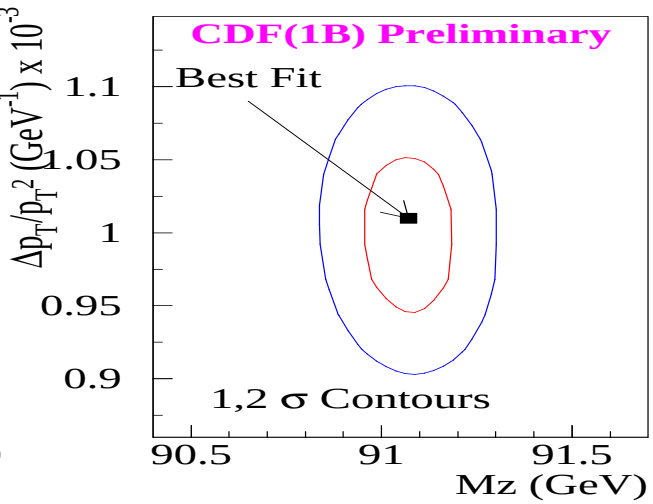




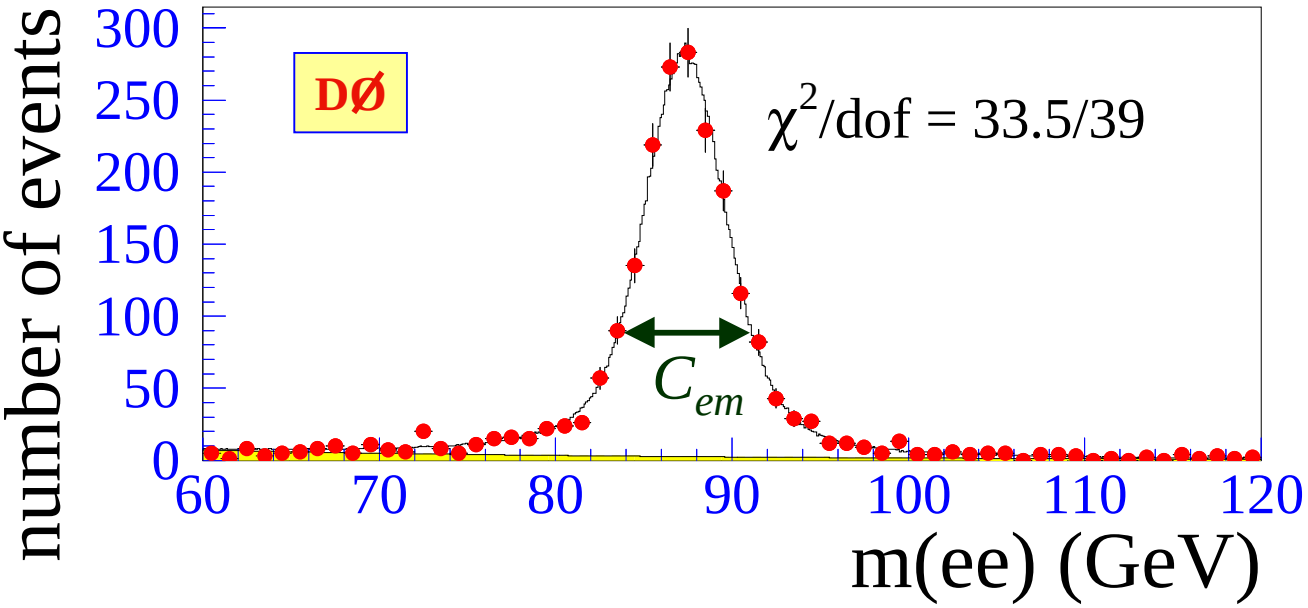
Lepton Momentum and Energy Resolution

- 2D fit for M_Z and $\sigma(1/p_T)$

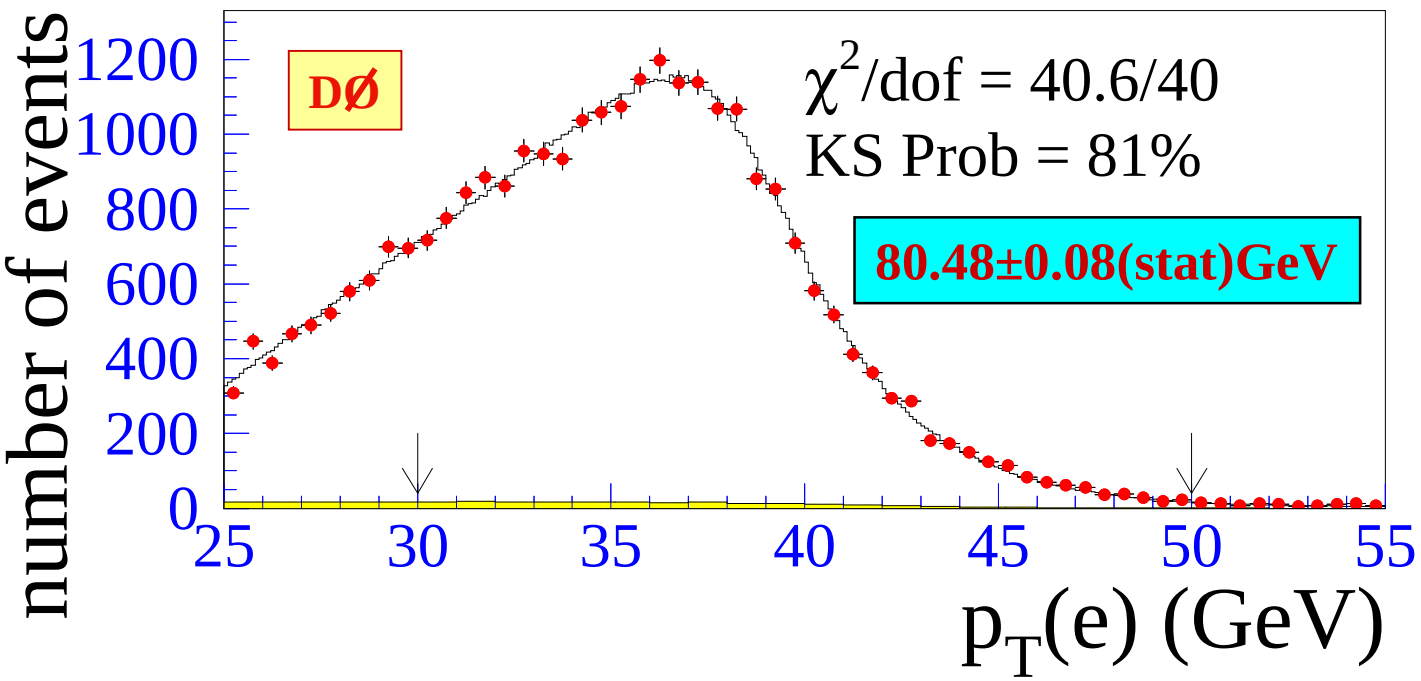


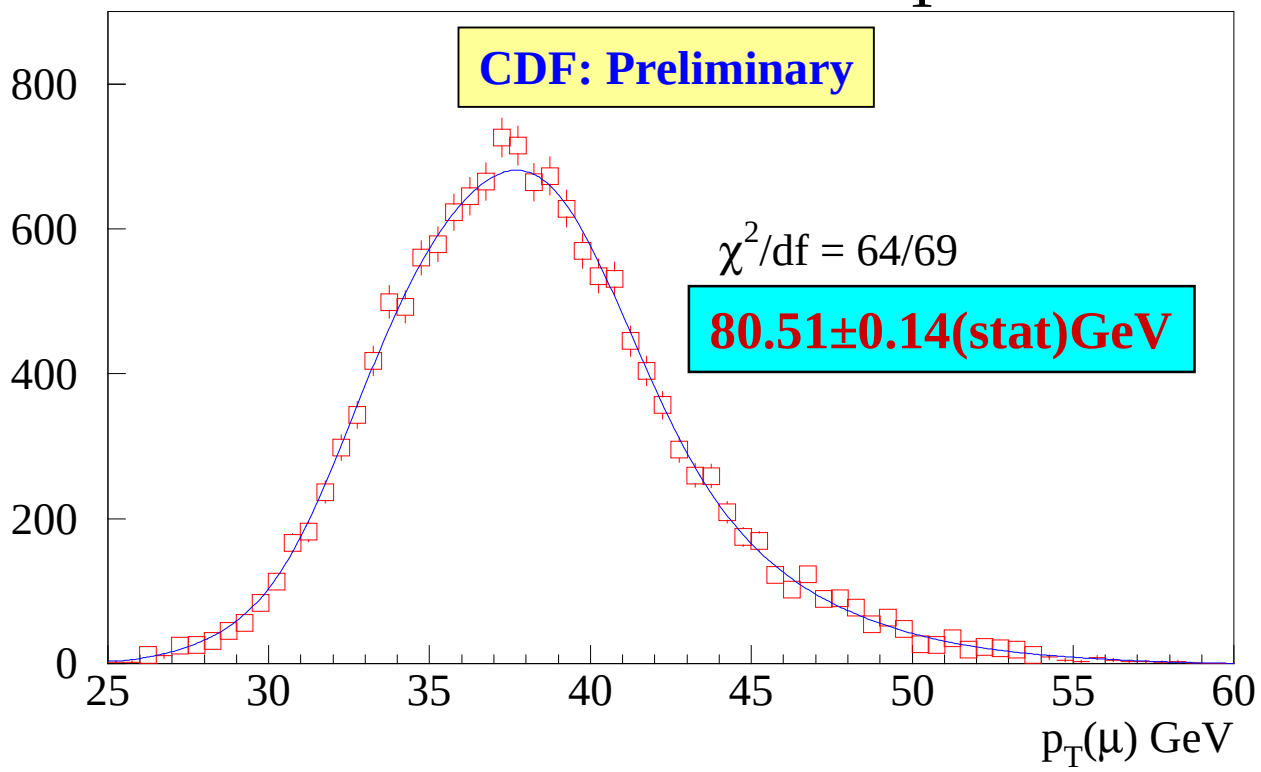


- $\Delta E = C_{em} E \oplus S_{em}\sqrt{E} \oplus N_{em}$



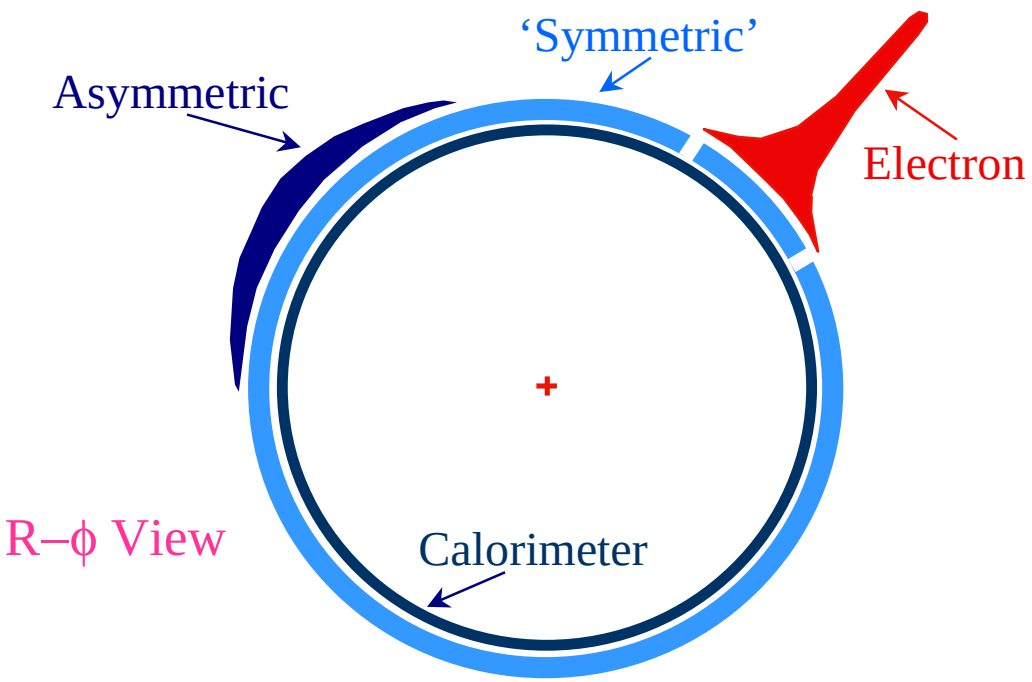
Lepton Fits


DØ
χ^2/dof = 40.6/40
KS Prob = 81%
80.48±0.08(stat)GeV
number of events
1200
1000
800
600
400
200
0
25
30
35
40
45
50
55
p_T(e) (GeV)


CDF: Preliminary
χ^2/df = 64/69
80.51±0.14(stat)GeV
800
600
400
200
0
25
30
35
40
45
50
55
60
$p_T(\mu)$ GeV

Hadronic Recoil Model

- Symmetric Component
  - Energy flow from spectator partons, multiple interactions, calorimeter noise
- Asymmetric Component
  - Recoil from the $p_T(W)$

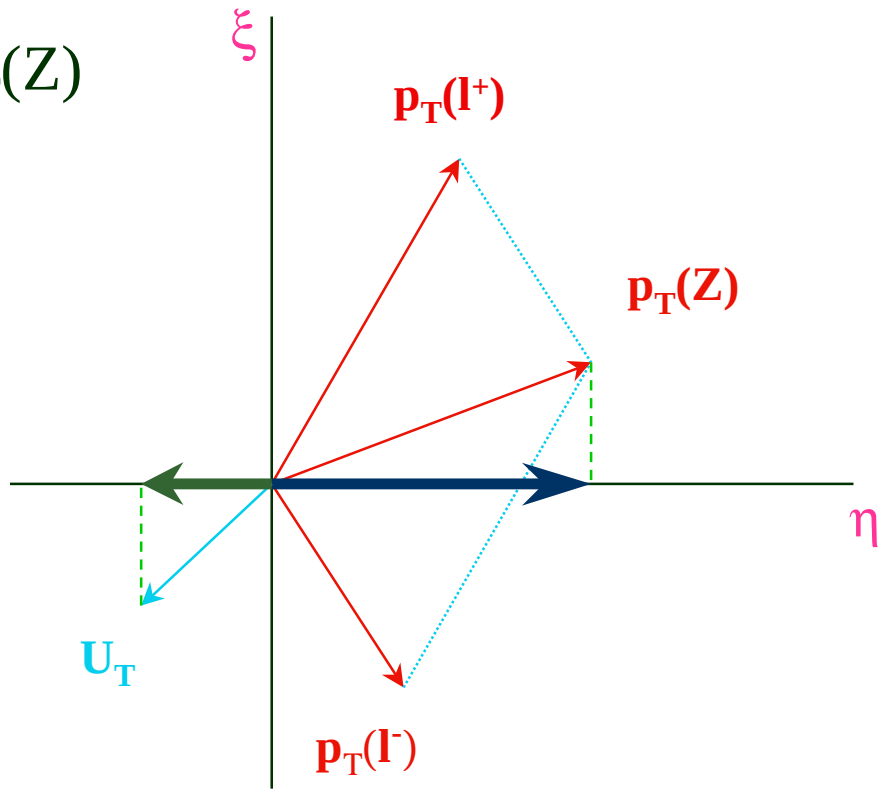


Hadronic Recoil Model

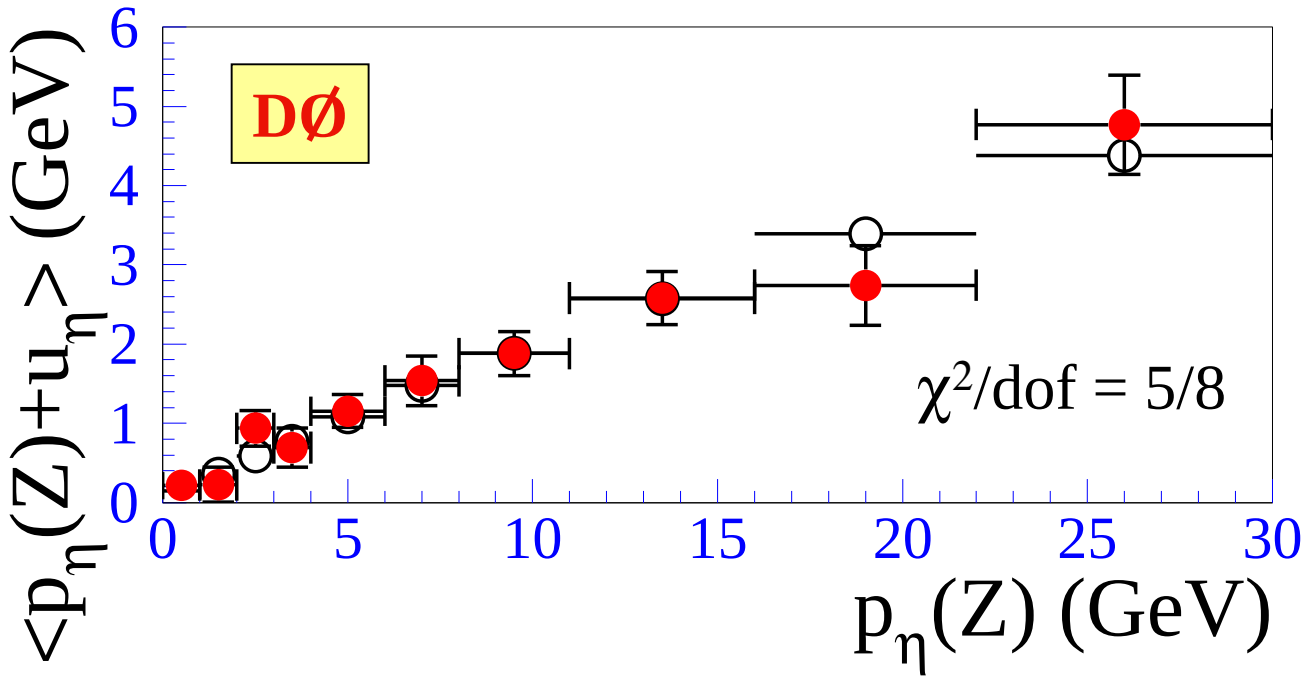
- Response measured relative to the lepton energy scale

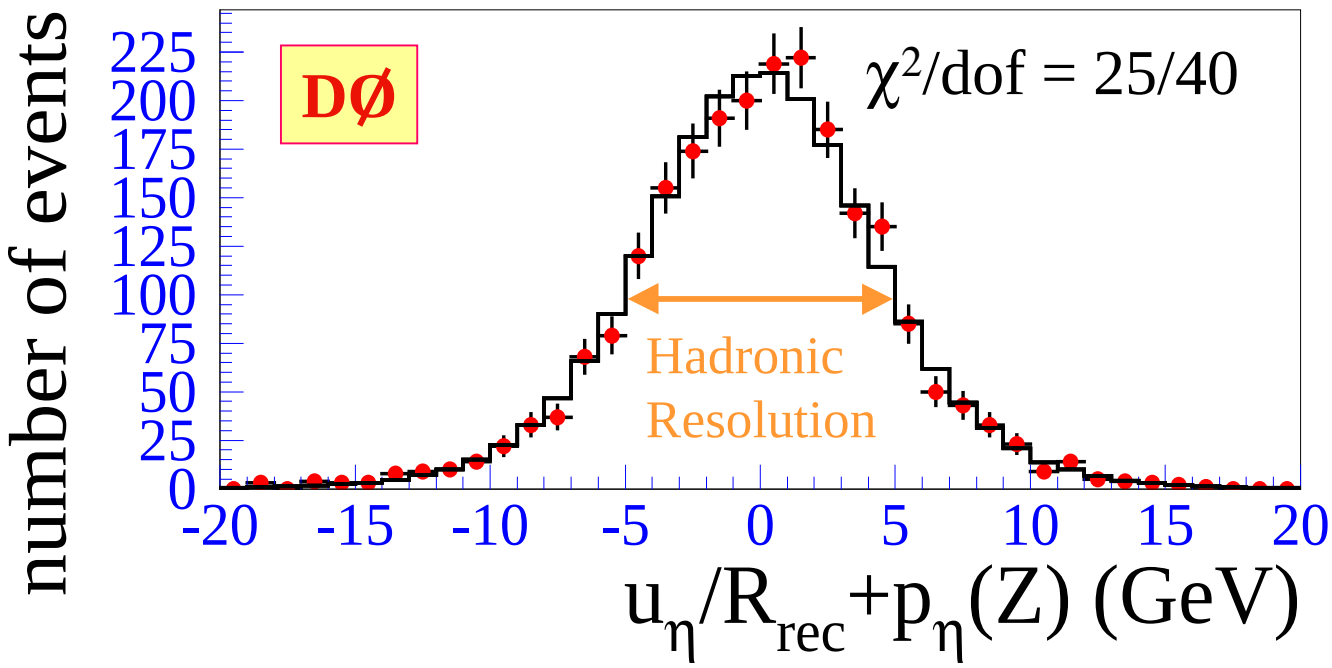
$$U_T = R_{res} \cdot p_T(Z)$$

$(\vec{p}_T(Z)+\vec{U}_T) \cdot \hat{\eta}$
Eta Balance

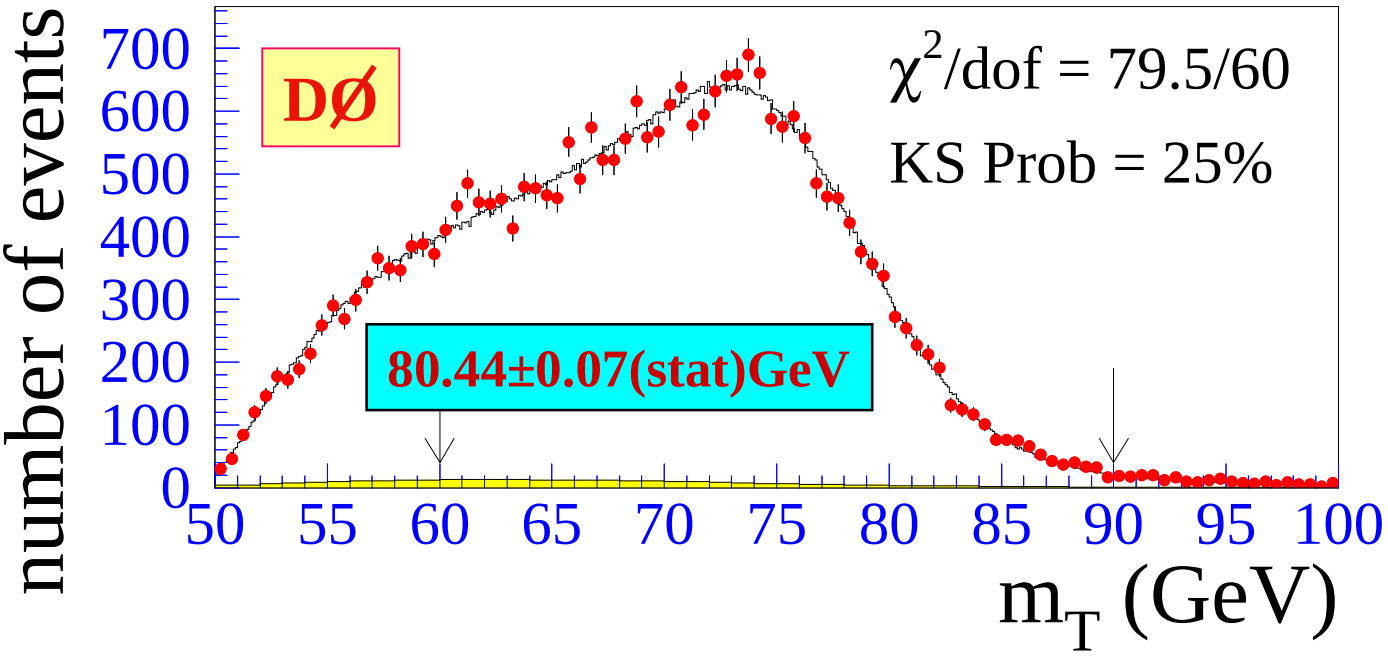


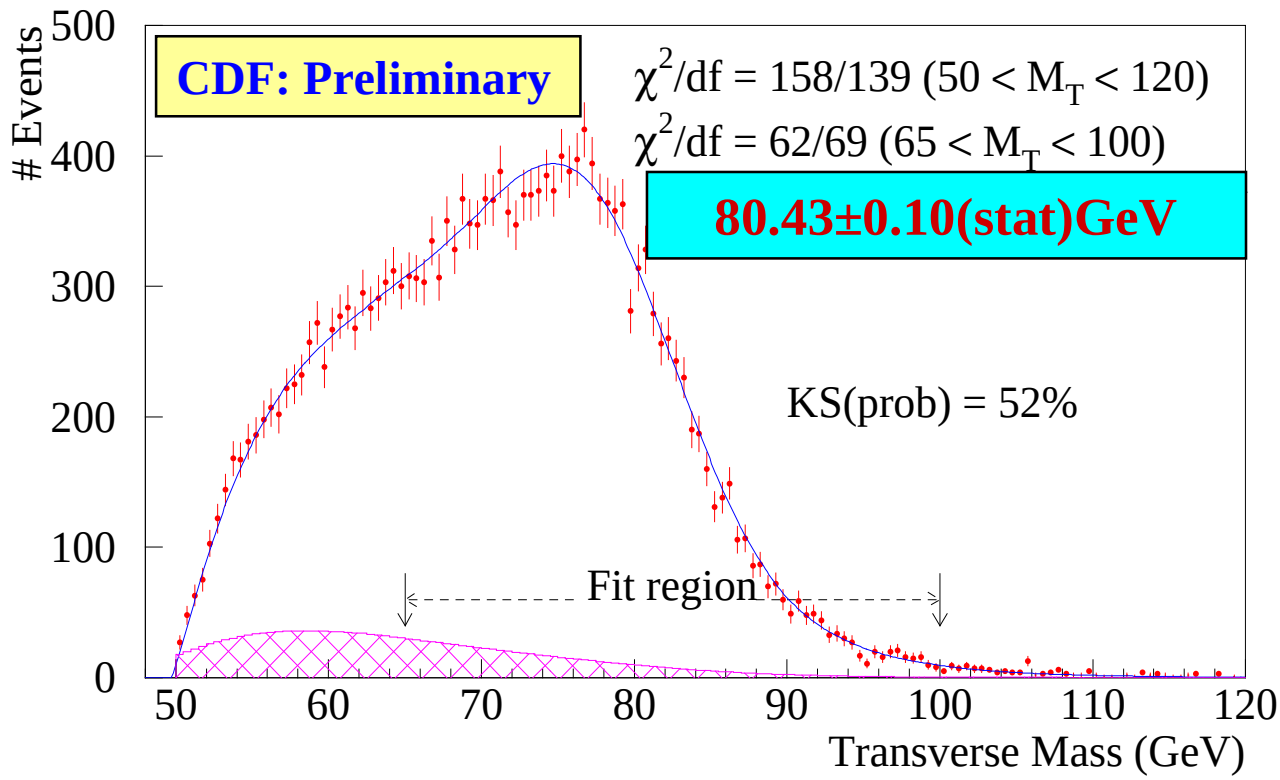
Hadronic Recoil Model





Transverse Mass Fits





Summary of the Errors

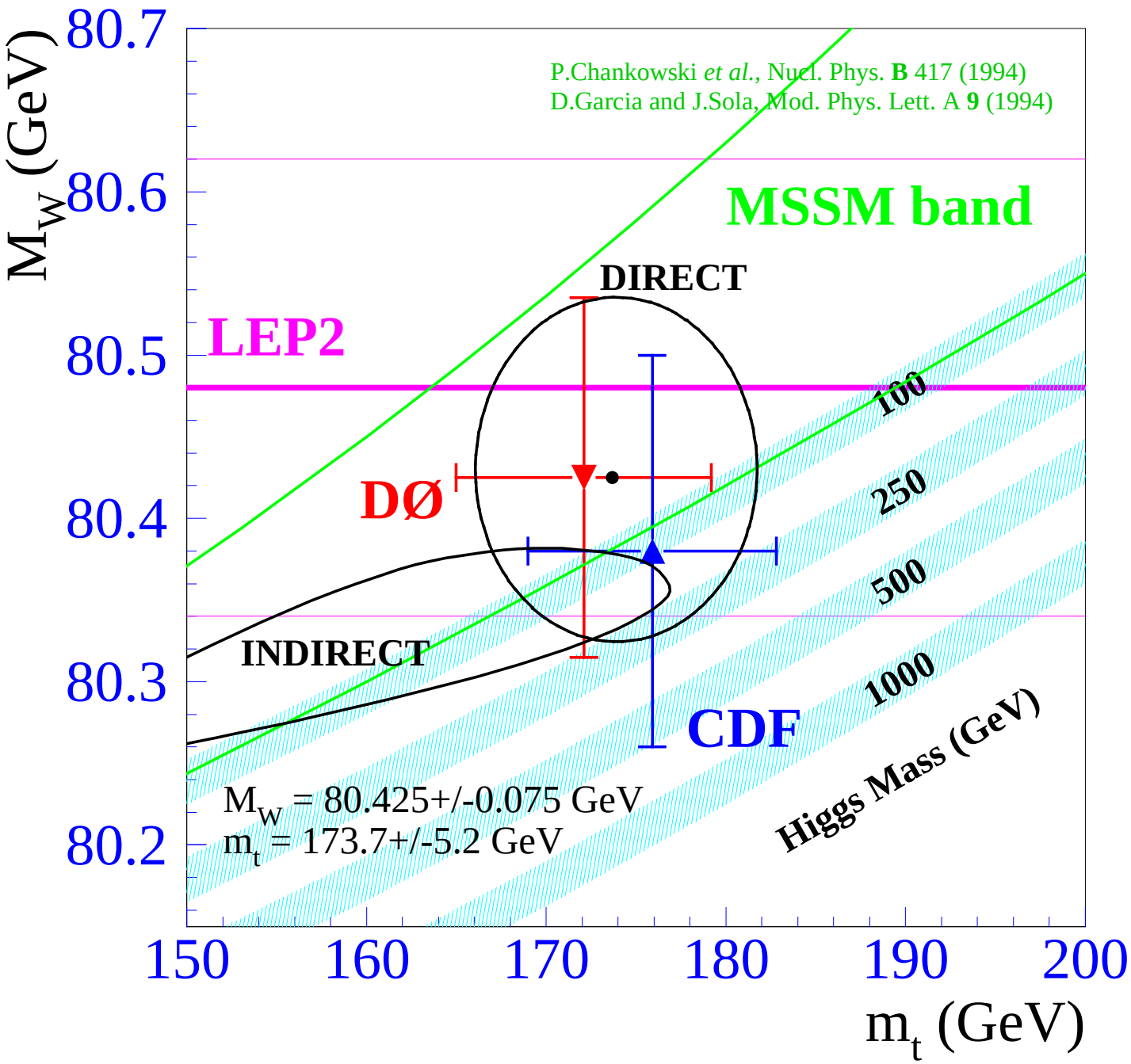
	CDF	DØ	
Statistical	100	70	} 95 (stat)
Momentum/Energy Scale	40	65	
Calorimeter Linearity	—	20	
Lepton Resolution	25	20	
Recoil Modeling	90*	40	
Input p_T(W) and PDF's	50	25	
Radiative Decays	20	15	
Higher Order Corrections	20	—	
Backgrounds	25	10	
Lepton Angle Calibration	—	30	
Fitting	10	—	
Miscellaneous	20	15	
Systematics	115	70	
Total (MeV)	**155**	**120**	

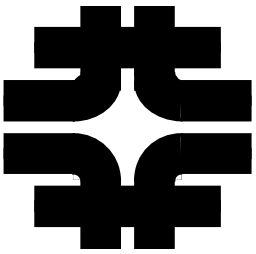
* reduced error anticipated

Combined Results

- Tevatron
  - DØ 1992-93(e) and 94-95(e)
    - M_W = 80.43±0.11 GeV
  - CDF 1989(e/μ), 92-93(e/μ), and 94-95(μ)
    - M_W = 80.38±0.12 GeV
- DØ, CDF, and UA2
  - **M_W = 80.405±0.090 GeV**
    - 50 MeV common error
- LEP2: CERN-PPE/97-154
  - M_W = 80.48±0.14 GeV
- World Average
  - **M_W = 80.425±0.075 GeV**

Higgs


P.Chankowski et al., Nucl. Phys. B 417 (1994)
D.Garcia and J.Sola, Mod. Phys. Lett. A 9 (1994)
MSSM band
DIRECT
LEP2
DØ
INDIRECT
CDF
100
250
500
1000
Higgs Mass (GeV)
M_W = 80.425+/-0.075 GeV
m_t = 173.7+/-5.2 GeV
M_W (GeV)
m_t (GeV)
80.7
80.6
80.5
80.4
80.3
80.2
150
160
170
180
190
200



Prospects from the Tevatron Collider

- Data continues to be analyzed from Run 1: ~100 pb^{-1}
  - CDF
    - electron/muon channel
      - ΔM_W ~90 MeV
  - DØ
    - electron channel in the forward calorimeters
      - ΔM_W ~100 MeV
  - Tevatron
    - ΔM_W ~ 70 to 80 MeV
- Run 2: ~2 fb^{-1}
  - ΔM_W ~ 40 MeV
- TeV33: ~30 fb^{-1}
  - ΔM_W ~ 20 MeV

Theory Uncertainties

- $p_T(W)$ distribution
  - Input $d\sigma/dydp_T$
    - Ladinksy and Yuan, Phys. Rev. D **50** (1994)
- Parton distribution functions
  - CTEQ/MRS
- Radiative decays
  - Theory
    - Berends and Kleiss, Z.Phys C **27** (1985)
    - Baur *et al.*, Phys. Rev. D **56** (1997)…
  - Implementation
- Γ_W
    - S.Abachi *et al.*, Phys. Rev. Lett. **75** (1995)

$p_T(W)$ Distribution

- Non-perturbative physics parameterized by
  - g_1, g_2, and g_3
  - Λ_{QCD}
- Constrain parameters with $p_T(Z)$
  - fit simultaneously g_2 and Λ_{QCD}
    - where Λ_{QCD} allowed to vary only from 150-250 MeV
  - variation from g_1 and g_3 is small compared to g_2 and Λ_{QCD}

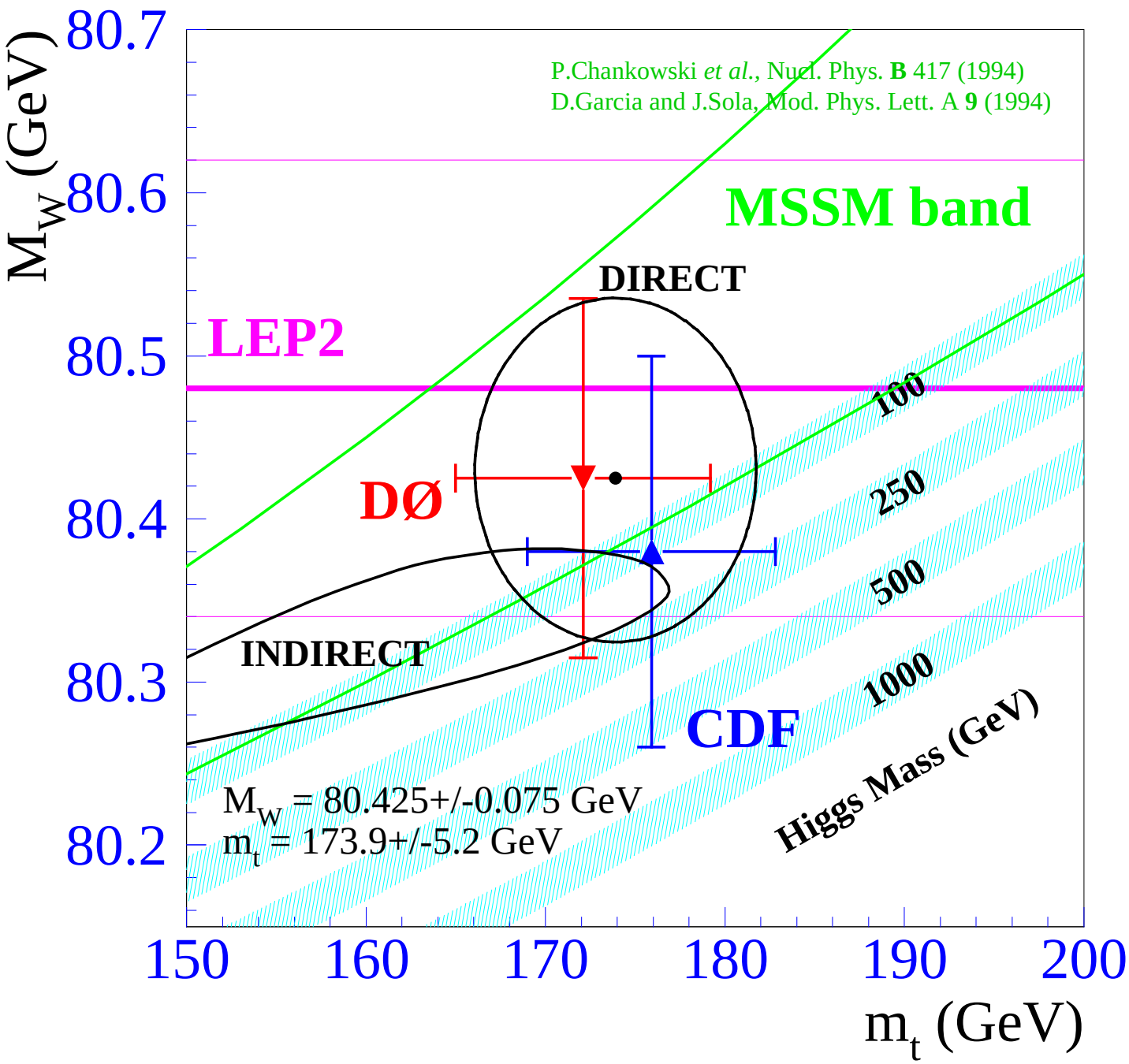
$p_T(W)$ spectrum:	10 MeV

Parton Distribution Functions

- Mass variation due to
  - Parton luminosity
  - rapidity
    - lepton asymmetry data
  - $p_T(W)$
    - $p_T(Z)$
- g_2 measured for each pdf
  - CTEQ2M, CTEQ3M, MRSA-', and MRSA'

Parton Luminosity:	10 MeV
Parton Distribution Functions:	20 MeV

Higgs


80.7
80.6
80.5
80.4
80.3
80.2
M_W (GeV)
P.Chankowski *et al.*, Nucl. Phys. **B** 417 (1994)
D.Garcia and J.Sola, Mod. Phys. Lett. A **9** (1994)
MSSM band
DIRECT
LEP2
DØ
INDIRECT
CDF
100
250
500
1000
Higgs Mass (GeV)
M_W = 80.425+/-0.075 GeV
m_t = 173.9+/-5.2 GeV
150
160
170
180
190
200
m_t (GeV)