Direct Measurement of the W Total Decay Width at DØ

Junjie Zhu

University of Maryland

On behalf of the DØ Collaboration

Outline

- Introduction
- Monte Carlo Simulation
- Event Selection
- Determination of the W Width
- Conclusions

Introduction

- $\Gamma(W)$ is an important parameter in the Standard Model
- The Standard Model Prediction: 2.090 ± 0.008 GeV
- SM Prediction depends on:
  - Number of available decay modes
  - The coupling of W to SU(2) doublets
  - QCD corrections
  - Electroweak radiative corrections
  - W mass
- Measurement of $\Gamma(W)$:
  - A test of SM calculation
  - A probe for possible new physics

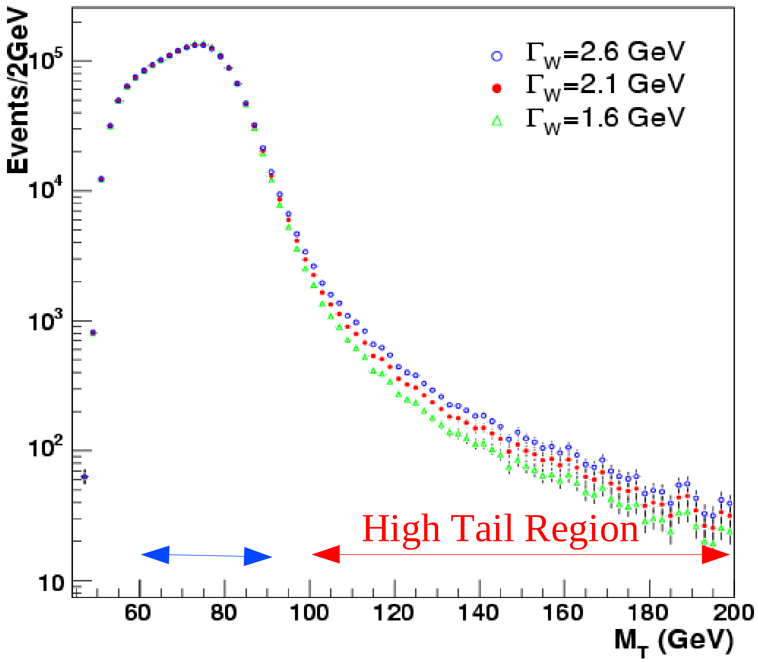
Direct Measurement

- $\Gamma(W)$ can be measured directly from the transverse mass distribution of $W \to e\nu$

$$M_T = \sqrt{2\, p_T(e)\, p_T(\nu)[1-\cos(\phi(e)-\phi(\nu))]}$$

- Away from the Jacobian edge, the Breit-Wigner (width) component falls much more slowly than the Gaussian (detector resolution) component
- The high tail region of M_T spectrum is very sensitive to the W decay width
- Measurement Strategy: Generate MC M_T templates with different W width, compare with data and use a binned maximum likelihood method to extract the W width
- Same method used for W mass measurement

M_T Spectra from MC Simulation

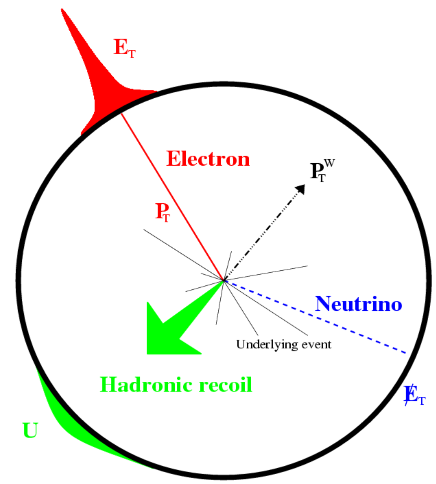


M_W Sensitive Region Γ_W Sensitive Region

Monte Carlo Simulation

- Parameterizations of the detector response of the electron and recoil system
  - Electron simulation: electron energy scale and energy resolution
  - Recoil system simulation:
    - "Hard" component that models the P_T of the W/Z boson
    - "Soft" component that models the underlying events and detector noise
- Detection efficiencies measured from data, applied in Monte Carlo
- Smearing parameters determined mostly from $Z \rightarrow ee$ data
- Main systematic uncertaines dominated by the

  size of $Z \rightarrow ee$ events

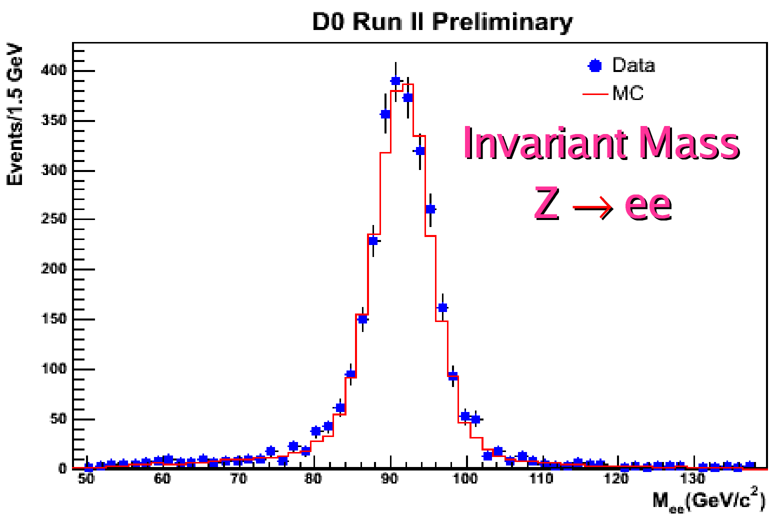


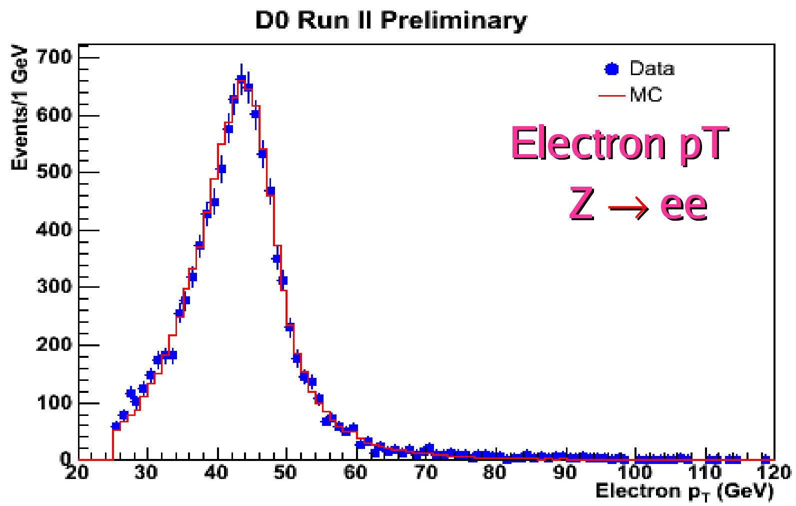
Event Selection

- Integrated Luminosity: 177 pb^{-1}
- **$Z \to ee$ Selection**
  - At least two isolated EM clusters in the calorimeter fiducial region with $|\eta| < 1.05$ and $p_T(e) > 25$ GeV;
  - Each EM cluster has a matched track;
  - $70 < M(ee) < 110$ GeV;
  - 3,169 $Z \to ee$ candidates.
- **$W \to e\nu$ Selection**
  - At least one isolated EM cluster in the calorimeter fiducial region with $|\eta| < 1.05$ and $p_T(e) > 25$ GeV;
  - EM cluster has a matched track;
  - Missing Transverse Momentum > 25 GeV;
  - $p_T(W) < 20$ GeV;
  - 75,910 $W \to e\nu$ candidates;
  - 625 candidates with M_T between [100, 200] GeV (~ 0.8%).

Electron Simulation

- Electron Energy Scale: determined by varying energy scale in MC until it reproduces the peak position of Z $\rightarrow$ ee data
- Electron Energy Resolution: Determined by varying electron energy resolution in MC until it reproduces the width of Z $\rightarrow$ ee data

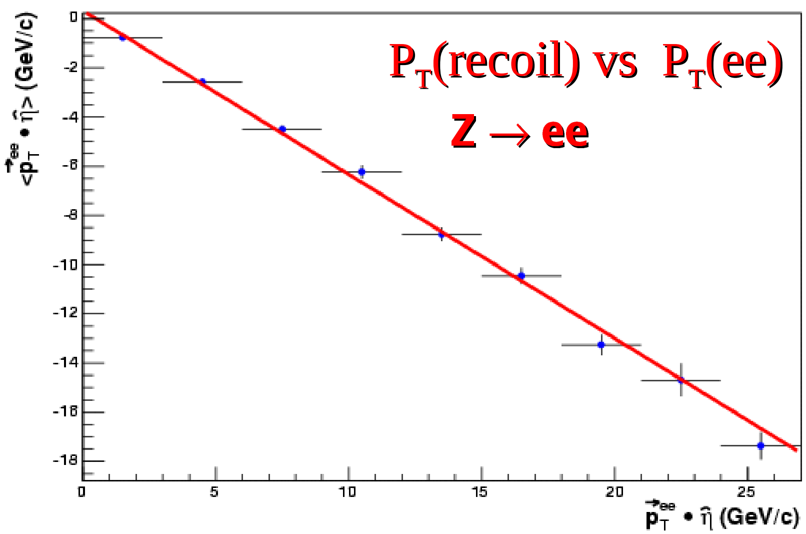




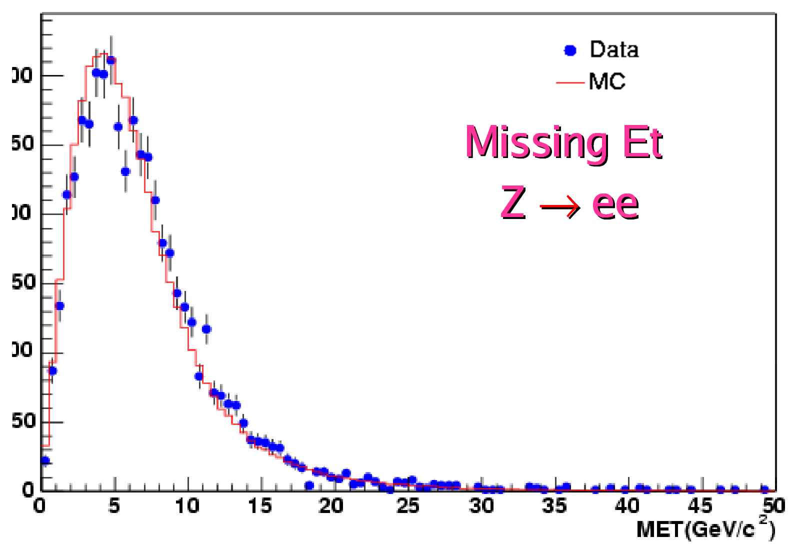
Recoil System Simulation ("Hard" component)

- $\vec{P}_T$(recoil) = $\vec{P}_T$ of everything in the event except electron(s)
- Recoil response: comparing P_T(ee) with P_T(recoil) for $Z \to ee$ events
- Recoil resolution: determined from di-jet events and photon+jet events

D0 Run II Preliminary

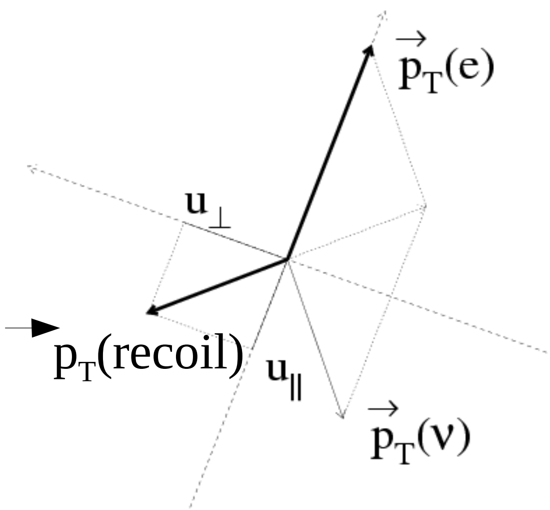


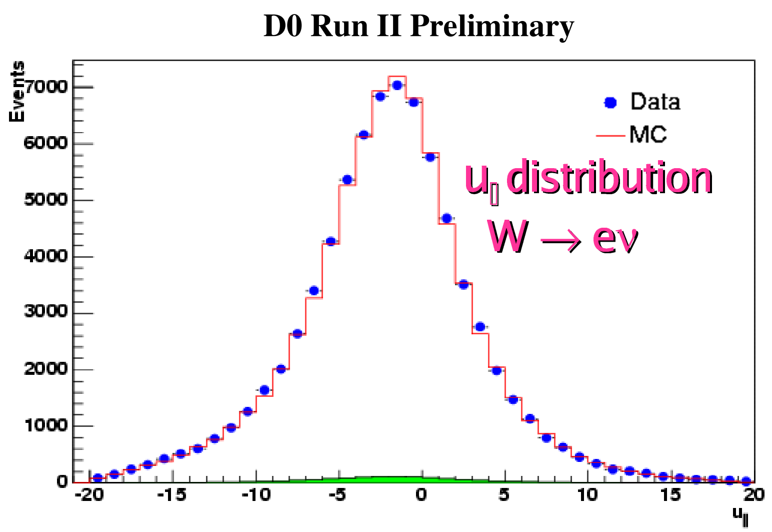
D0 Run II Preliminary



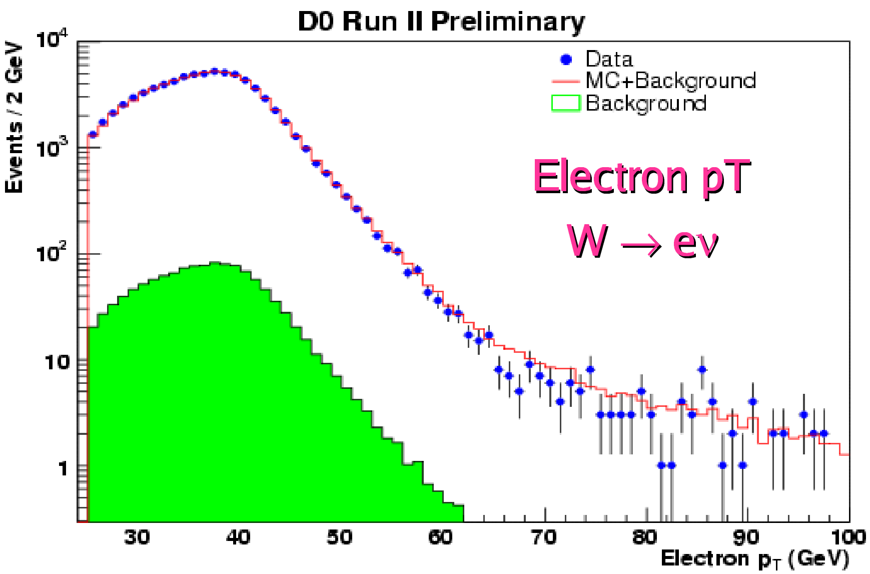
Recoil System Simulation ("Soft" component)

- "Soft" component: use the transverse momentum balance measured from a minimum bias event recorded in the detector, then scale it to reflect the difference between the W underlying event with a real minimum bias event
- Scale factor adjusted until $u_{\parallel}$ distribution from MC simulation agrees with data
- $U_{\parallel}$ = the projection of the momentum of the recoil system along the electron

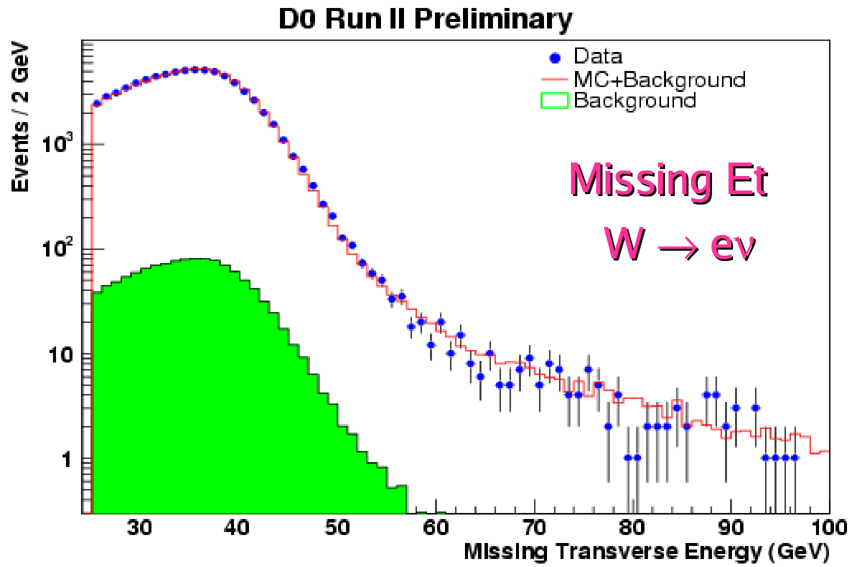




Data MC Comparison for $W \rightarrow e\nu$ Events



χ^2/ d.o.f = 83.1 / 75

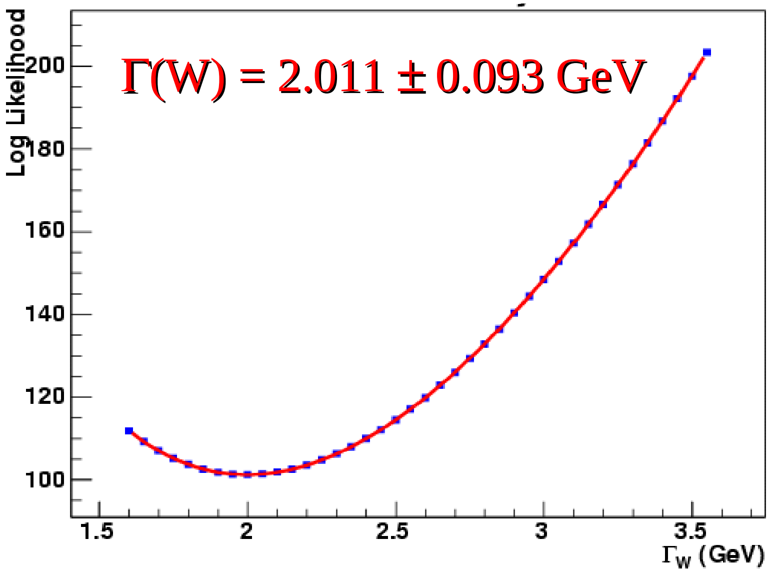


χ^2/ d.o.f = 82.5 / 75

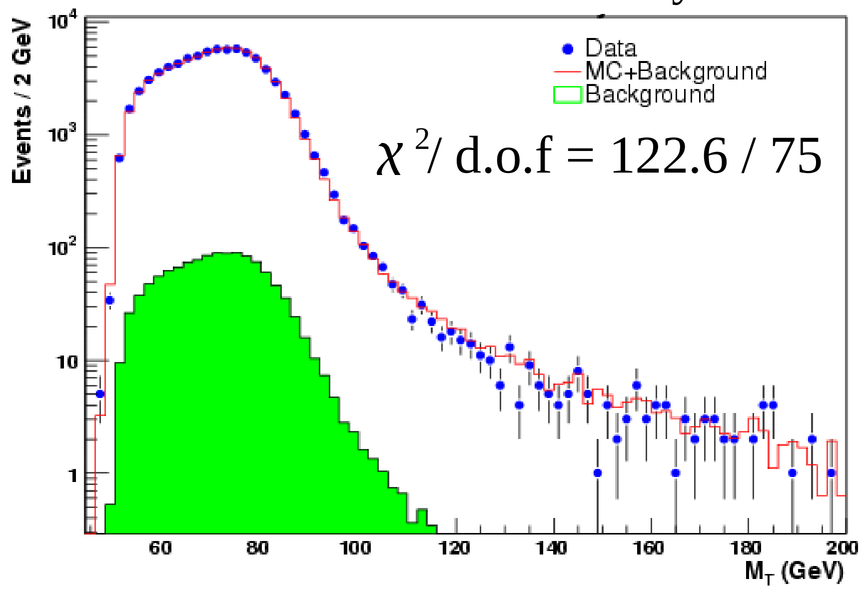
Determination of the W Width

- MC Templates are prepared for the W transverse mass using the detector simulation described above: W width from 1.6 to 3.6 GeV in step of 50 MeV
- Normalize data and MC+Background M_T spectra in [50, 100] GeV region
- Calculate a binned log-likelihood for [100, 200] GeV region

D0 Run II Preliminary



D0 Run II Preliminary



Systematic Uncertainties

- The systematic uncertainties are due to effects that could alter the transverse mass spectrum
- Vary each input parameter in the MC Simulation by one standard deviation

Source	$\Delta\Gamma(W)$ (MeV)
EM Energy Resolution	51
HAD Energy Resolution	50
W Underlying Event vs MB events	47
HAD Momentum Response	40
EM Energy Scale	23
pT(W)	29
PDF	27
W Boson Mass	15
Primary Vertex	10
Selection Bias	10
Position Resolution	7
Underlying Event Correction	4
Backgrounds	3
Radiactive Decays	3
Total Systematic Uncertainty	107
Total Statistical Uncertainty	93
Total Uncertainty	142

Conclusions

- First Direct Measurement of the W Width from DØ Run II

  $\Gamma(W) = 2.011 \pm 0.093\ (\text{stat.}) \pm 0.107\ (\text{syst.})$

  $= 2.011 \pm 0.142\ (\text{GeV})$

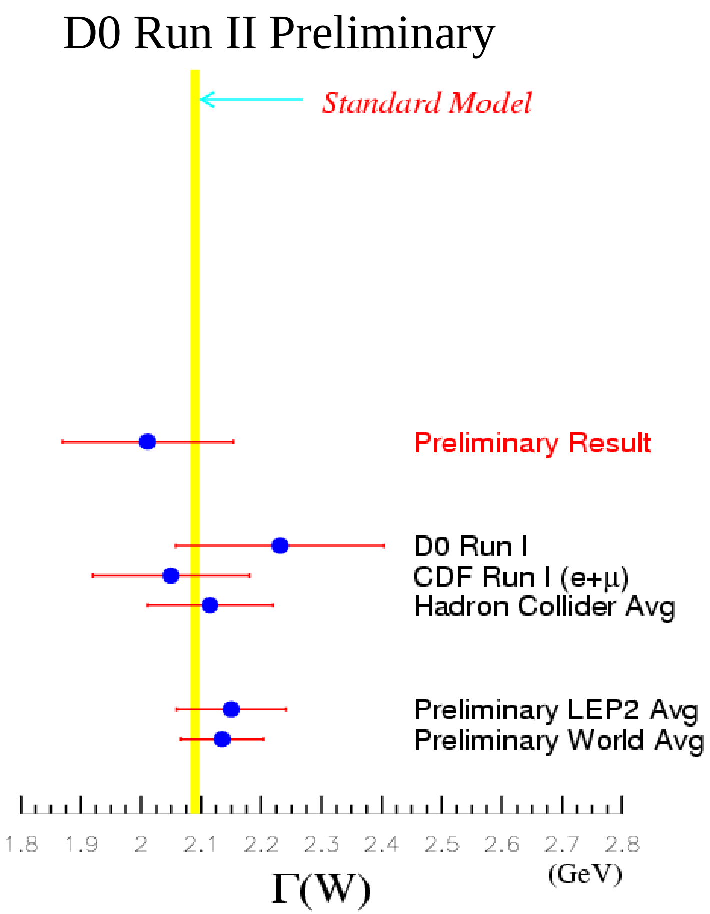
- Consistent with SM prediction

  $\Gamma(W) = 2.090 \pm 0.008\ (\text{GeV})$

- Consistent with the result from indirect measurement (W width extracted from the ratio of $W \to l\nu$ and $Z \to ll$ cross sections)

  $\Gamma(W) = 2.079 \pm 0.041\ (\text{GeV})\ (\text{CDF})$

  $\Gamma(W) = 2.101 \pm 0.064\ (\text{GeV})\ (\text{DØ})$



Backup Slides

Monte Carlo Simulation

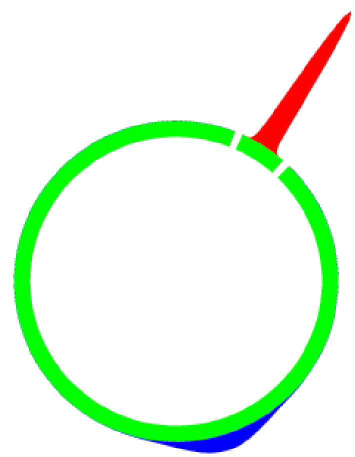
- Parameterizations of the detector response of the electron and recoil system
- Energy of the electron

$$E(e) = R_{EM}(E_0) \otimes \sigma_{EM}(E_0)$$

- Recoil System (all particles recoiling against the W and Z bosons):
  'Hard Component' (models the pT of W and Z bosons) and
  'Soft Component' (models detector noise and underlying events)

$$\vec{u}_T = -[R_{rec}(q_T) \otimes \sigma_{rec}(q_T)]\hat{q}_T - \Delta u_{\parallel} \hat{p}_T(e) + \alpha_{mb} \vec{E}_T^{mb}$$

- Smearing parameters determined mostly from Z $\rightarrow$ ee data
- Apply detection efficiencies measured from Data

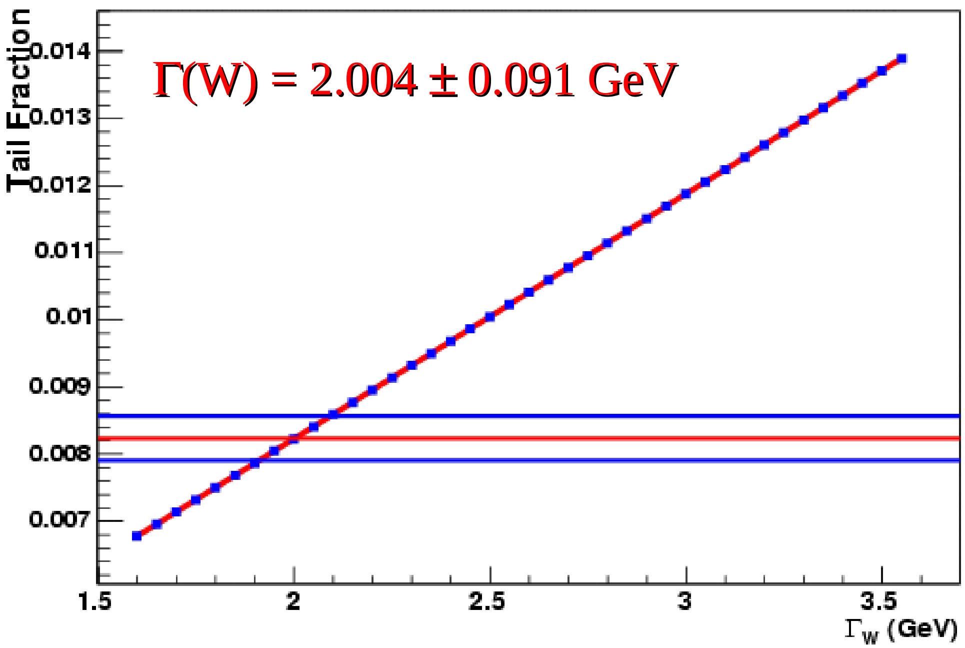


Ratio Fit

- Ratio Fit

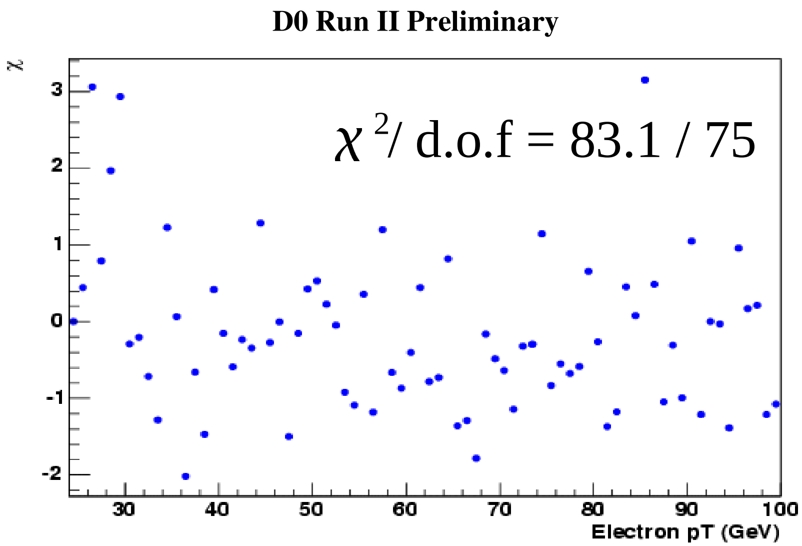
$$R = \frac{\text{Num of events with between [100, 200] GeV}}{\text{Num of events with between [50, 200] GeV}}$$

D0 Run II Preliminary

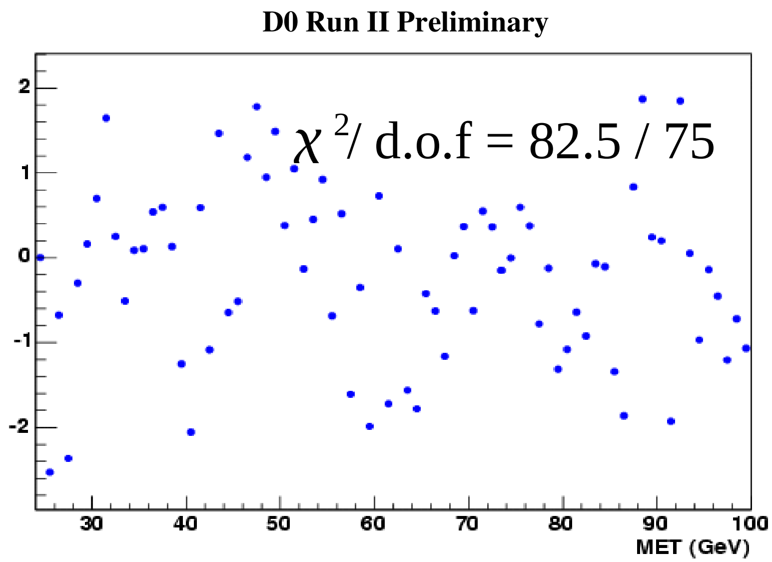


Residual Plots for Electron pT and MET Spectra

Electron pT Spectrum



MET Spectrum



Transverse Mass

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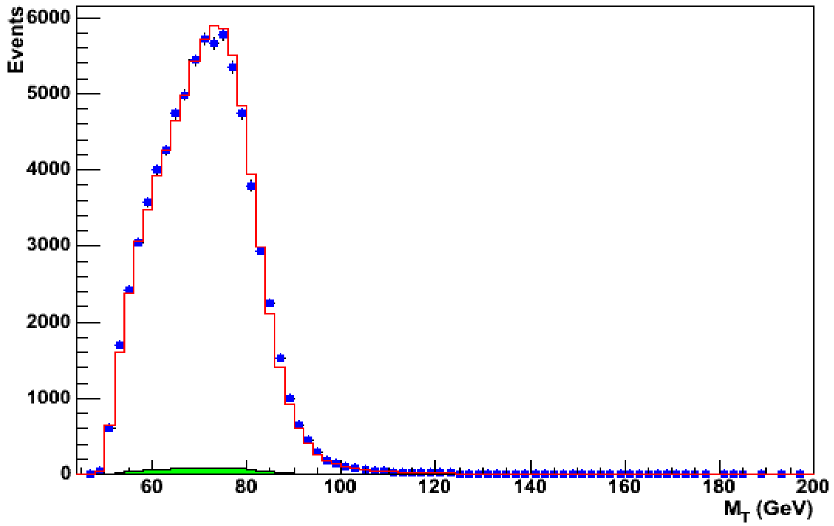

D0 Run II Preliminary