Production and Properties of the W Boson at DØ

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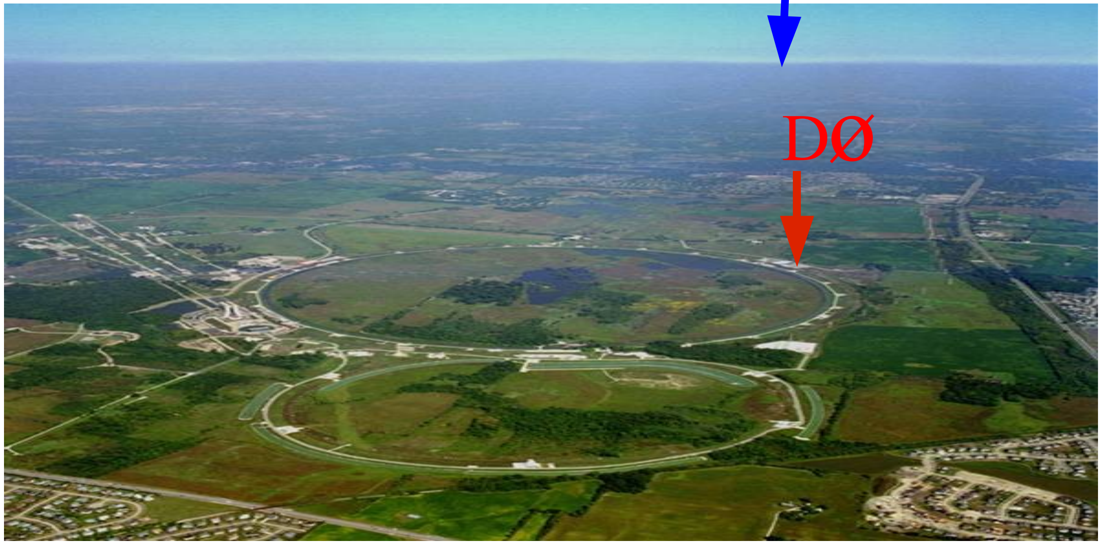
on behalf of the DØ Collaboration

Outline

- The production, decay, and signature of the W boson
- Motivation
- The $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ cross section measurements
- The W charge asymmetry measurement in muon channel
- Measurement Strategies for W Width and Mass
- Preliminary Result for the W Width

I can see my house from here! (Chicago)



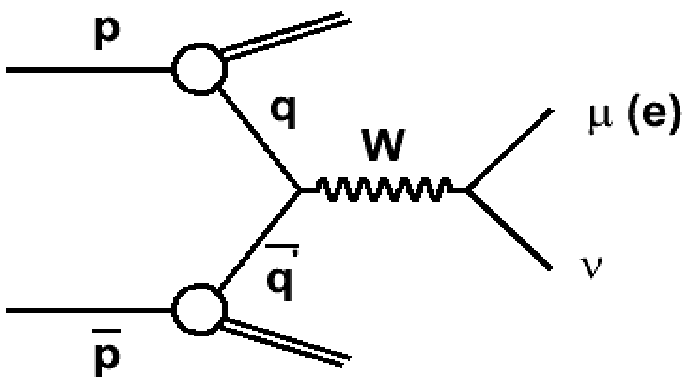
Fermi National Accelerator Lab

W Boson Production and Decay

Dominant Processes for W Production:

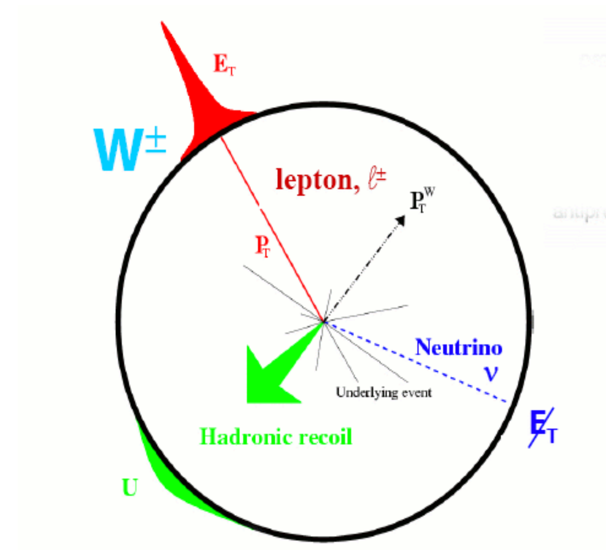
$$u + \bar{d} \rightarrow W^{+} \rightarrow \mu^{+} + \nu_{\mu}$$

$$\bar{u} + d \rightarrow W^{-} \rightarrow \mu^{-} + \bar{\nu}_{\mu}$$



Since the hadronic decay channels are overwhelmed by QCD backgrounds, the decay channel we study is:

$$W \rightarrow \ell\nu$$

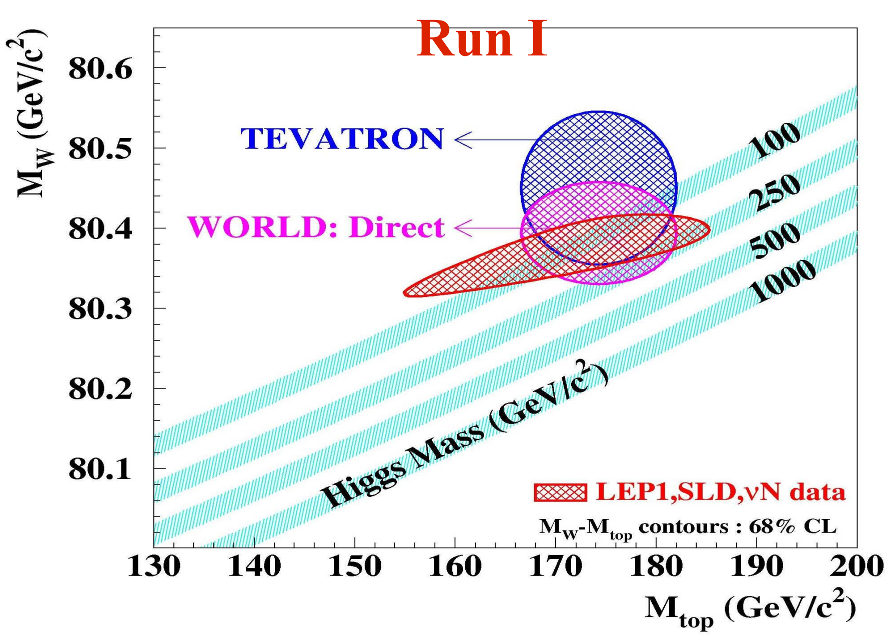


- Isolated, energetic lepton
- Large quantity of missing E_T

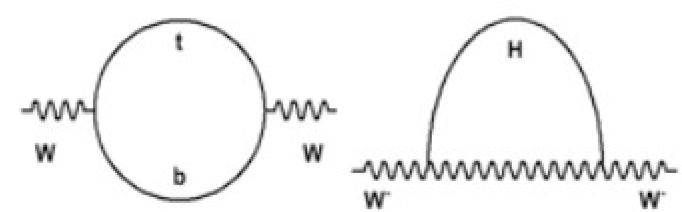
Motivations

Why study the W boson?

- Production mechanisms can help us to probe QCD (PDF's)
- Properties, such as the mass and width help us extrapolate to and constrain physics at higher energies (Higgs, SUSY)



$$m_W{}^2 = \frac{\pi\alpha_{em}}{\sqrt{2}G_F \sin^2\theta_W (1-\Delta r)}$$

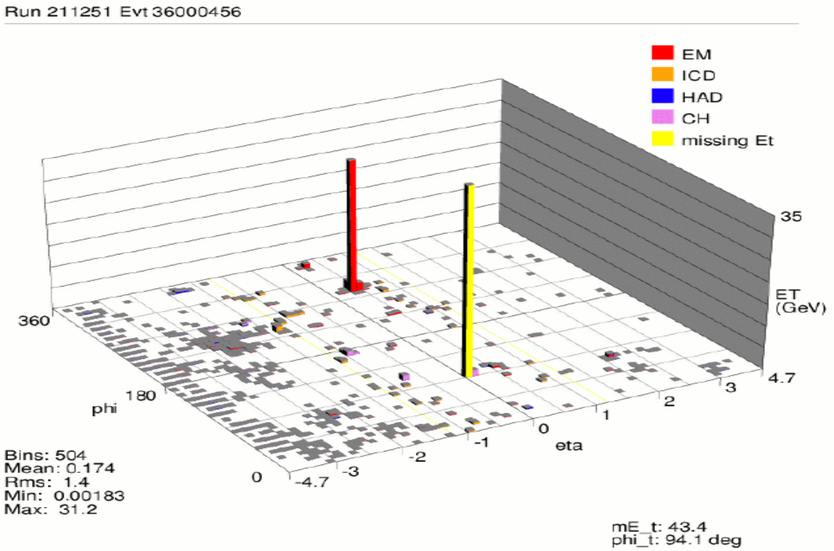


Radiative corrections are sensitive to the Higgs, and other exotic particles

W Cross Section Measurement

We use the formula:

$$\sigma = \frac{N - N_{backg}}{\varepsilon \cdot A \cdot \int L \cdot dt}$$



$W \rightarrow \mu\nu$

- The data sample used is **96pb^{-1}**
- We require: an isolated muon with P_T> 20 GeV, firing single muon trigger, event $\not{E}_T$>20GeV, $\mu\nu$ transverse mass M_T>40GeV
- Main backgrounds: **QCD** ~1%, **$W \rightarrow \tau\nu$** and **$Z \rightarrow \mu\mu$** ~6%
- Main systematic uncertainties: PDF ~1.5%, efficiencies ~1.5%

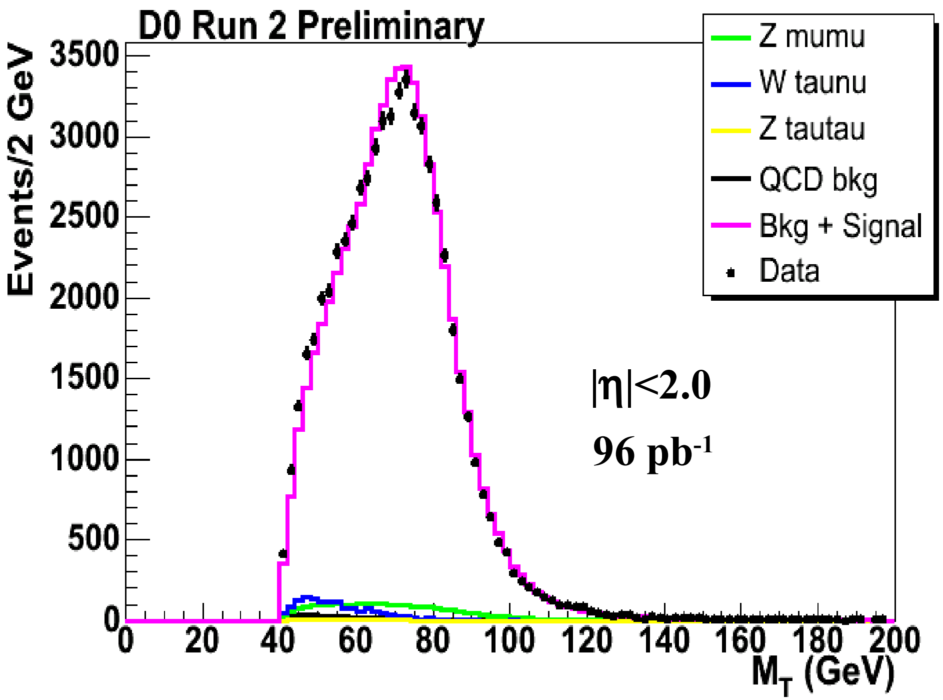
$W \rightarrow e\nu$

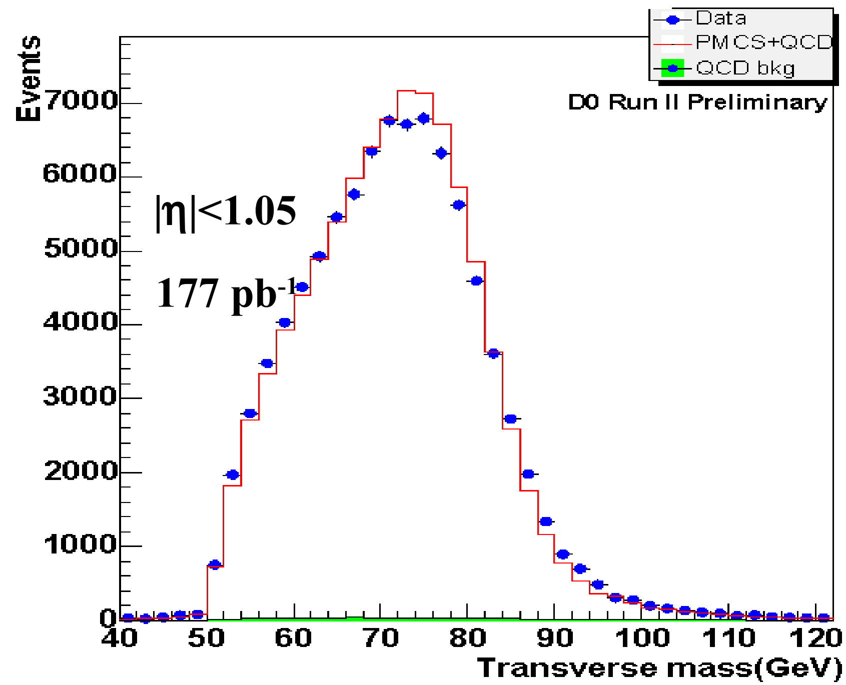
- The data sample used is **177pb^{-1}**
- We require: an electron with E_T> 25GeV, $|\eta|$<1.05(central) , $\not{E}_T$> 25GeV,
- Main background: **QCD** ~2%, **$W \rightarrow \tau\nu$** and **$Z \rightarrow ee$** ~2%
- Main systematic uncertainties: PDF ~1.0%,electron identification ~1.5%

W Cross Section Measurement

62285 candidates are observed after selection

$\sigma(W \rightarrow \mu\nu) = 2989 \pm 15(stat) \pm 81(sys) \pm 194$ (lumi) pb





$\sigma(W \rightarrow e\nu) = 2865 \pm 8.3(stat) \pm 63(sys) \pm 186$ (lumi) pb

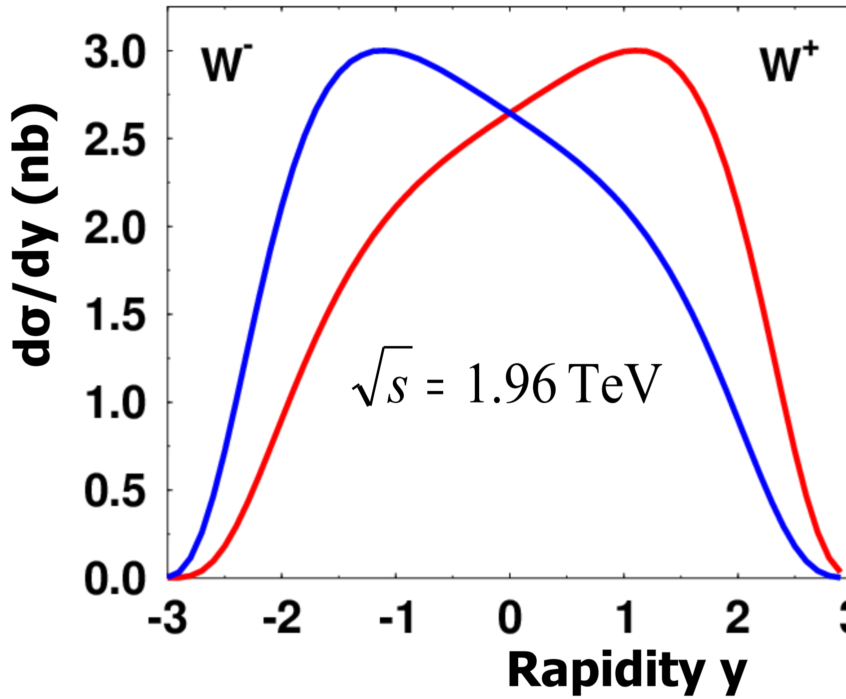
116569 candidates are observed after selection cuts

W Charge Asymmetry in μ Channel

$$u + \bar{d} \rightarrow W^+ \rightarrow \mu^+ + \nu_\mu$$

$$\bar{u} + d \rightarrow W^- \rightarrow \mu^- + \bar{\nu}_\mu$$

- On average, the up quark carries more of the momentum.
- The W+ is boosted along the direction of the proton beam, and the W- along the anti-proton.
- This asymmetry can tell us about the parton distribution function (PDF).



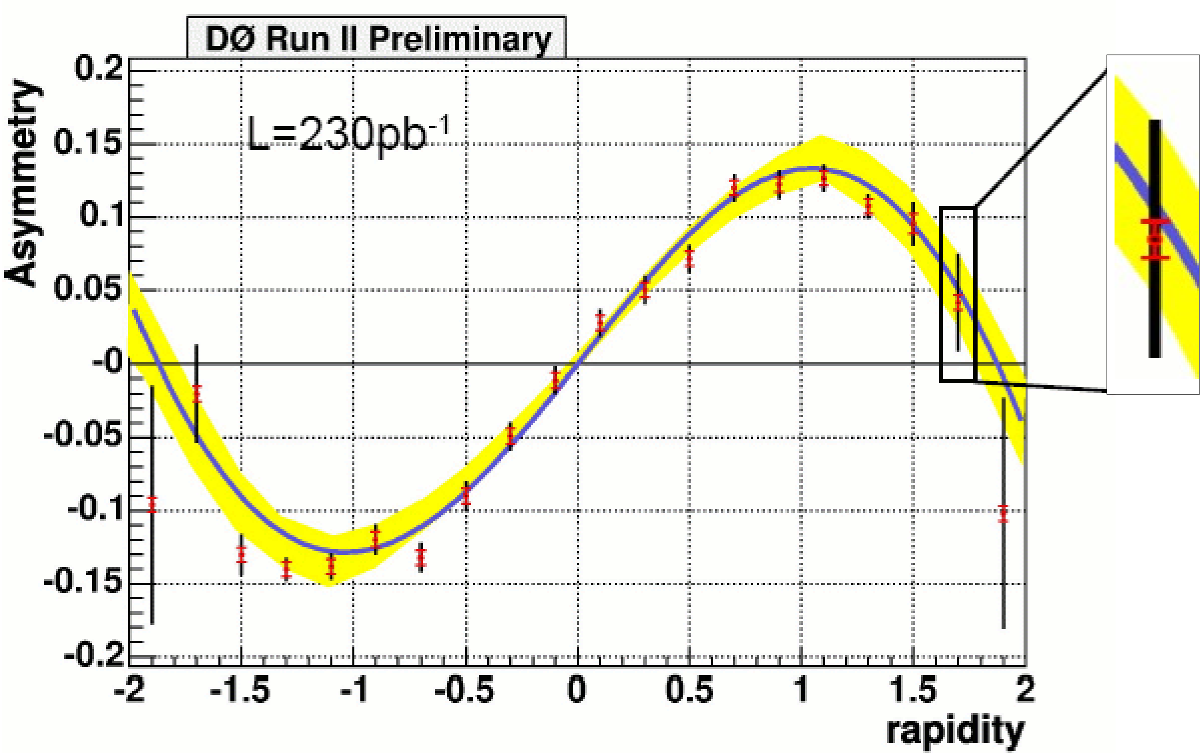
$$A(y_w) = \frac{\frac{d\sigma(W^+)}{dy} - \frac{d\sigma(W^-)}{dy}}{\frac{d\sigma(W^+)}{dy} + \frac{d\sigma(W^-)}{dy}} = \frac{\frac{d\sigma(l^+)}{dy} - \frac{d\sigma(l^-)}{dy}}{\frac{d\sigma(l^+)}{dy} + \frac{d\sigma(l^-)}{dy}}$$

If $\varepsilon^+ = \varepsilon^-$ →

$$A(y_\mu) = \frac{N_{\mu^+}(y_\mu) - N_{\mu^-}(y_\mu)}{N_{\mu^+}(y_\mu) + N_{\mu^-}(y_\mu)}$$

W Charge Asymmetry in μ Channel

- The asymmetry plot is formed after background subtraction
- Systematic uncertainties are due to charge misidentification, uncertainties in ε·A, and uncertainties in background
- Note that this result is statistics limited.
- More data is on hand!



The yellow band is the CTEQ6 uncertainty

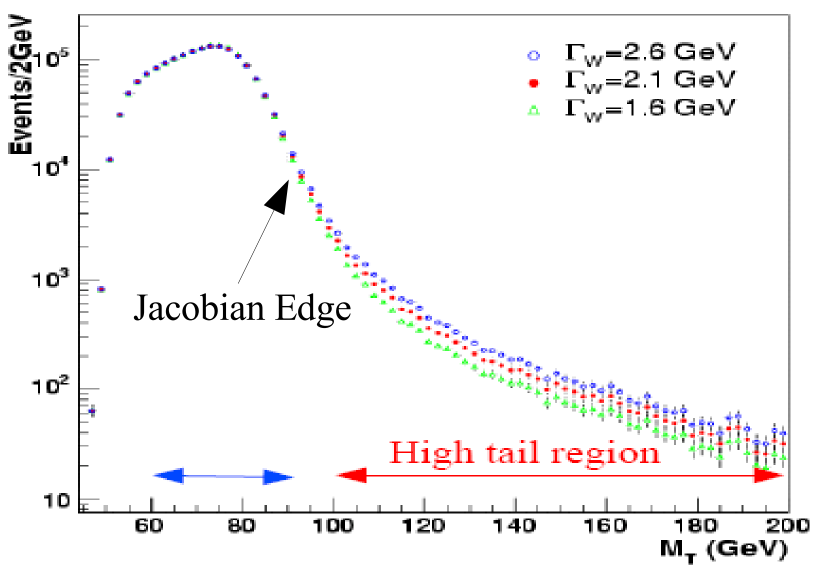
The blue line is the MRST central value

The red bars are our systematic uncertainty

W Mass and Decay Width: Measurement Strategy

Fit an observable (M_T, electron p_T, $\not{E}_T$) with simulated distributions generated at various values for the Mass/Width.

M_T spectra from MC simulation



M_W sensitive region Γ_W sensitive region

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

- We cannot measure neutrinos - we infer their energy from conservation of momentum (missing energy)
- In hadron colliders we cannot know p_z
- Must use transverse momenta, and define a transverse mass

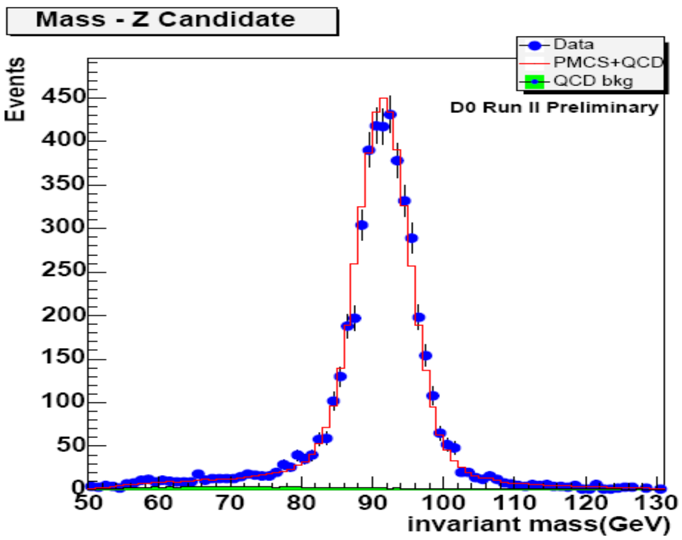
W Mass and Decay Width: Measurement Strategy

We need a fast, parameterized Monte Carlo model to generate high statistics templates for fine steps in M_W and Γ_W.

- It must accurately reproduce all relevant detector effects (on both signal and background)
- This model must be tunable to an independent data sample ($Z \rightarrow ee$ events)

The Recipe:

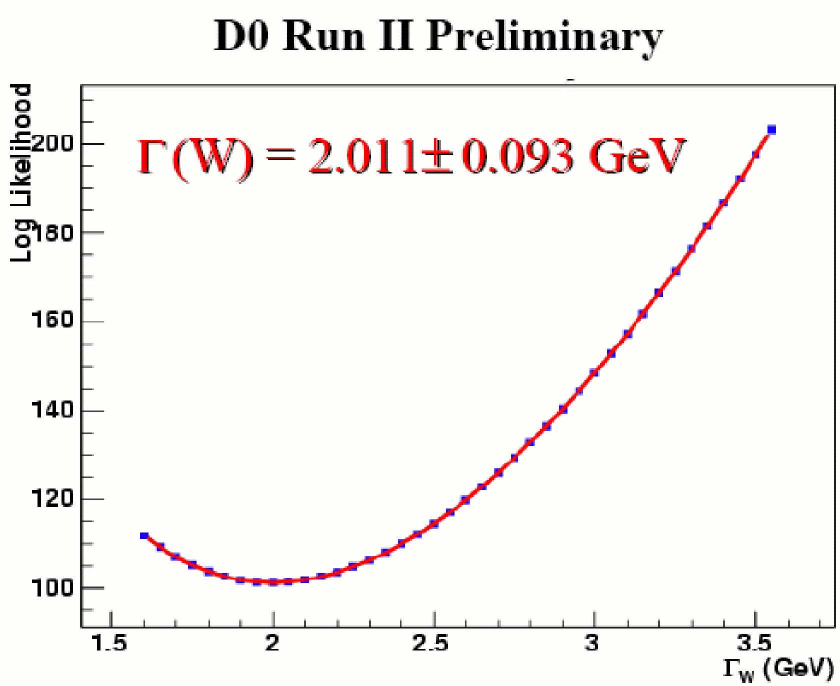
- Resbos + Photos output to generate $W \rightarrow e\nu$ events
- Simulate efficiencies, acceptance, underlying energy, zero-suppression, etc.
- Parametrically smear electron energies to reflect EM calorimeter
- Parametrically smear the recoil

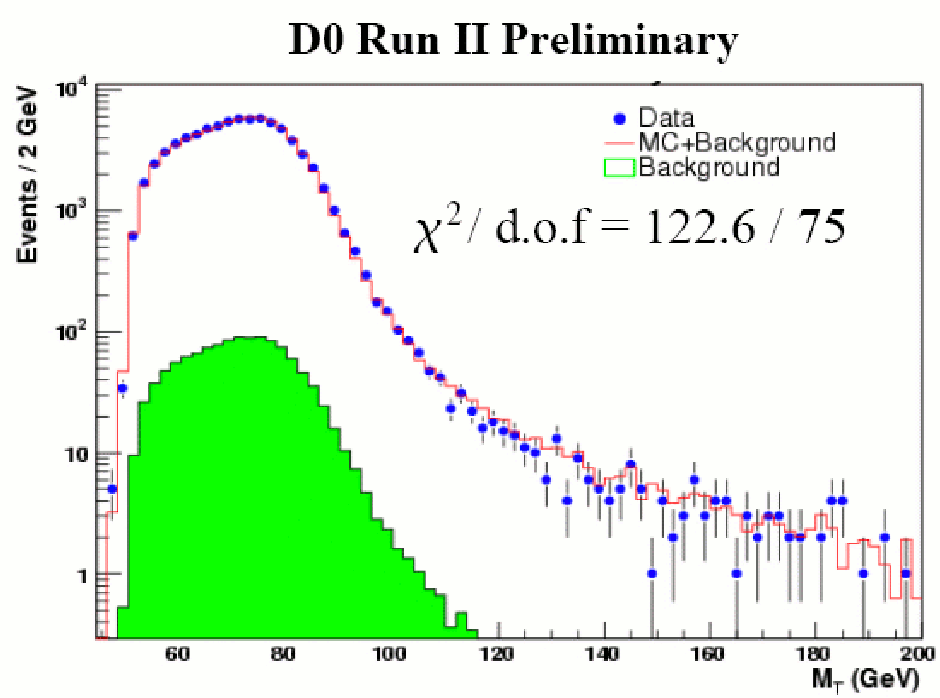


$Z \rightarrow ee$, 177 pb^{-1}

W Width Preliminary Results

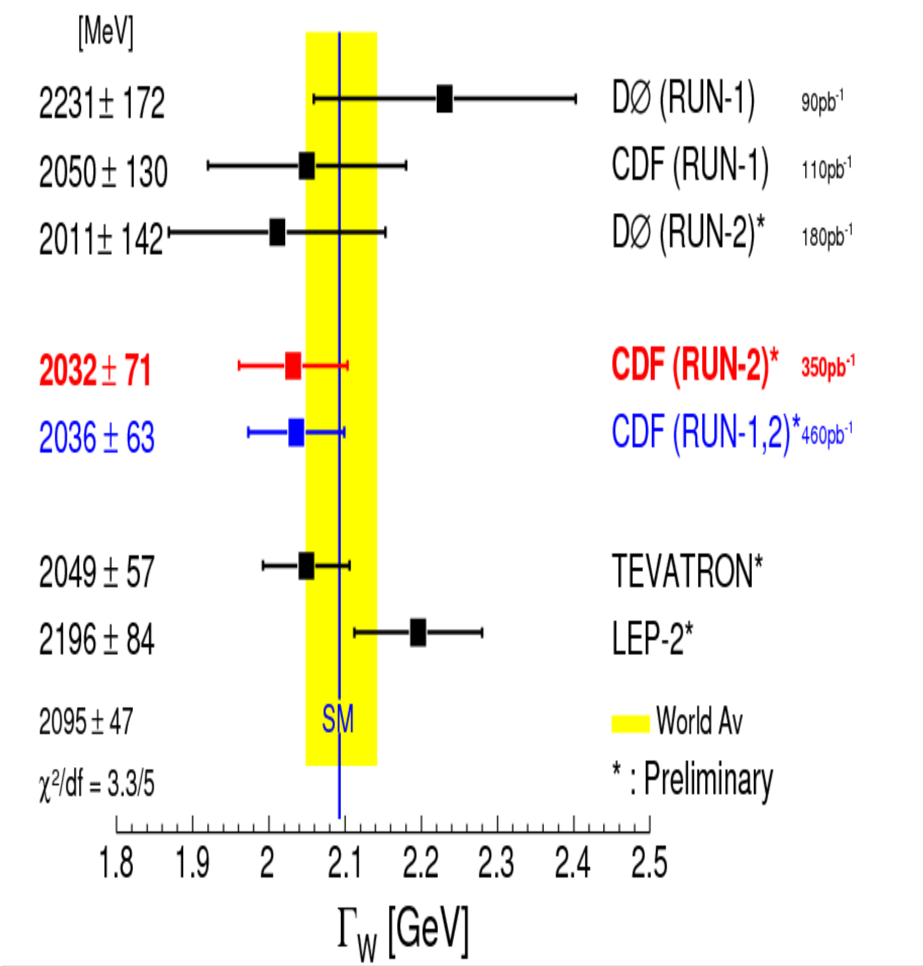
Integrated Luminosity: **177 pb^{-1}**





- Fit done to fast Monte Carlo templates generated at width values varying from 1.6 to 3.6 GeV in increments of 50 MeV
- These templates were normalized over the region excluded by the fit, [50,100] GeV
- Binned log-likelihood with data is calculated in the tail region, [100,200] GeV

W Width Preliminary Results



Our preliminary result is:

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

$= 2.011 \pm 0.142$ (GeV)

Which is in good agreement with both the Standard Model:

$\Gamma(W) = 2.090 \pm .008$ (GeV)

And other Tevatron results:

$\Gamma(W) = 2.032 \pm .071$ (GeV) (CDF RunII prelim.)

$\Gamma(W) = 2.231 \pm .172$ (GeV) (D0 RunI)

Integrated Luminosity: **177 pb^{-1}**

Prospects For the W Width

Source	$\Delta\Gamma_W$ (MeV)
EM Energy Resolution	51
HAD Energy Resolution	50
Underlying Event	47
HAD Momentum Response	40
EM Energy Scale	23
p_T^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

With only **177 pb^{-1}**

We are now using ~1 fb^{-1} of data (and there's more waiting)!

Not just more data, a better model...

The Run II Mass and Width measurements are not merely a repeat of the Run I measurement with more data. Conditions of the measurement are different.

- More material in front of calorimeter
  - Solenoid
  - Pre-shower detector + lead
  - Silicon tracking

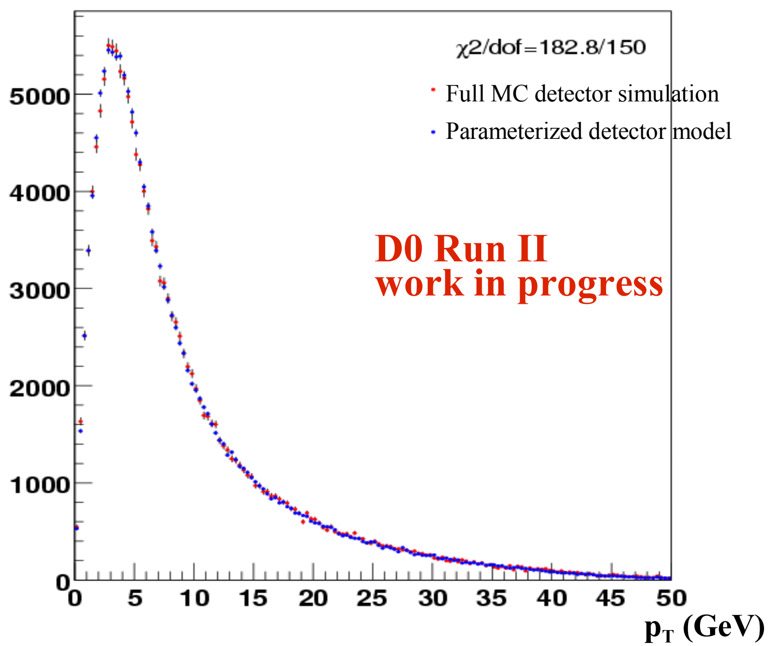
- Shorter Integration Time
- Tighter zero-suppression thresholds

We have undertaken an extensive study of our calorimeter, and developed a new and more accurate model, since the preliminary Γ measurement. **This better understanding means significantly lower systematics!**

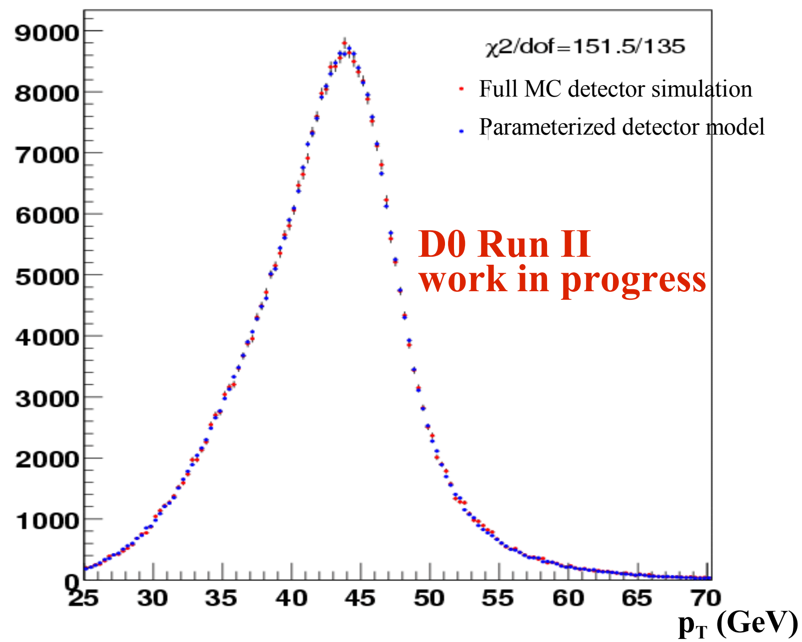
Prospects For the W Mass

- We tune our fast Monte Carlo using our independent Z→ee sample.
- We can test the accuracy of our model by comparing various observables in our parameterized model with data-like full Geant Monte Carlo (the equivilent of 6 fb^{-1}).
- These promising plots below show good agreement between our fast Monte Carlo model and full Monte Carlo Z→ee events, using the same methods we will use on data.
- They demonstrate that we have a tunable fast Monte Carlo model that can reproduce detector effects for different observables in a data-like environment.

Z Candidate - Boson pT



Z Candidate - Electron pT



Conclusions

- Preliminary Electroweak results for D0 are promising in Run II.
- Cross section, asymmetry measurement, and W width are consistent with our expectations.
- We are now using 1 fb^{-1} of data, with even more in hand.
- Not only has our statistical power improved, but also, in the case of the mass and width measurement, we have a far better understanding of the calorimeter.
- The comparisons with Z boson full Monte Carlo demonstrate that we have a bias-free measurement technique using methods that can be applied to real Z and W data.
- You'll be hearing from us soon!

Backup Slides...

W Width Data Used

Integrated Luminosity:
177 pb^{-1}

Z→ee Sample: **3169 Candidates**

- At least 2 isolated EM clusters in the fiducial region of the Central Calorimeter with pT>25.
- Each EM cluster has a matching track
- 70<M(ee)<110 GeV

W→eν Sample: **75910 Candidates, 625 w/ M_T between [100,200] GeV**

- At least 1 isolated EM clusters in the fiducial region of the Central Calorimeter with pT>25.
- The EM cluster has a matching track
- ET>25 GeV
- 70<M(eν)<110 GeV

Upgraded RunII Detector

- •New Silicon and Fiber Tracker
- •Sonlenoid (2 Tesla)
- •Upgraded Muon System
- •Upgraded DAQ/Trigger System

Upgraded DØ Detector