Recent Electroweak Results from DØ

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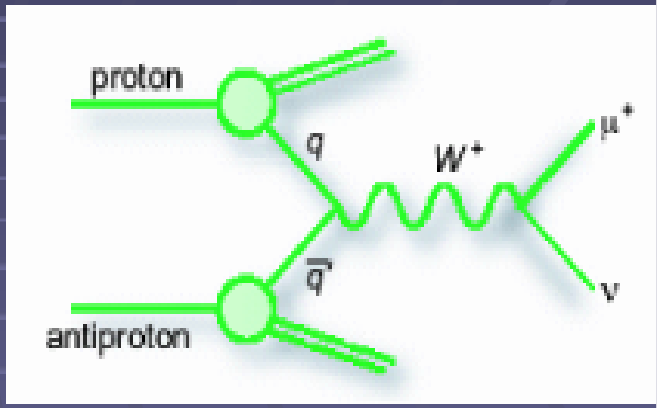
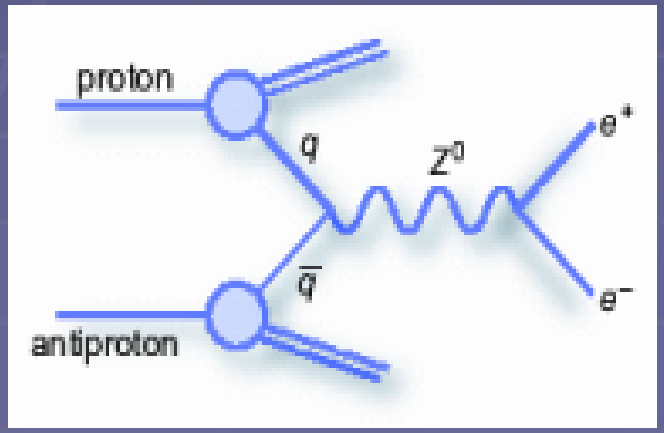
On Behalf of the DØ Collaboration

Outline

- Introduction
  - The DØ Detector
  - Motivation for W and Z analysis
  - W and Z selection and backgrounds



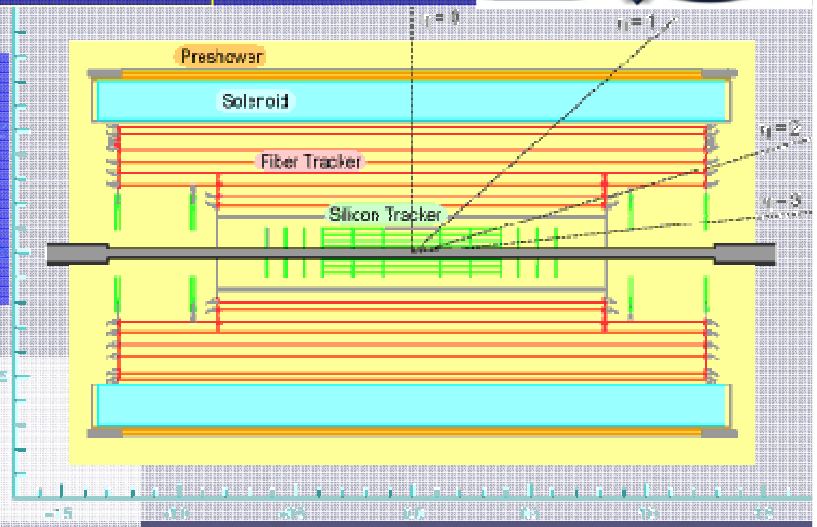


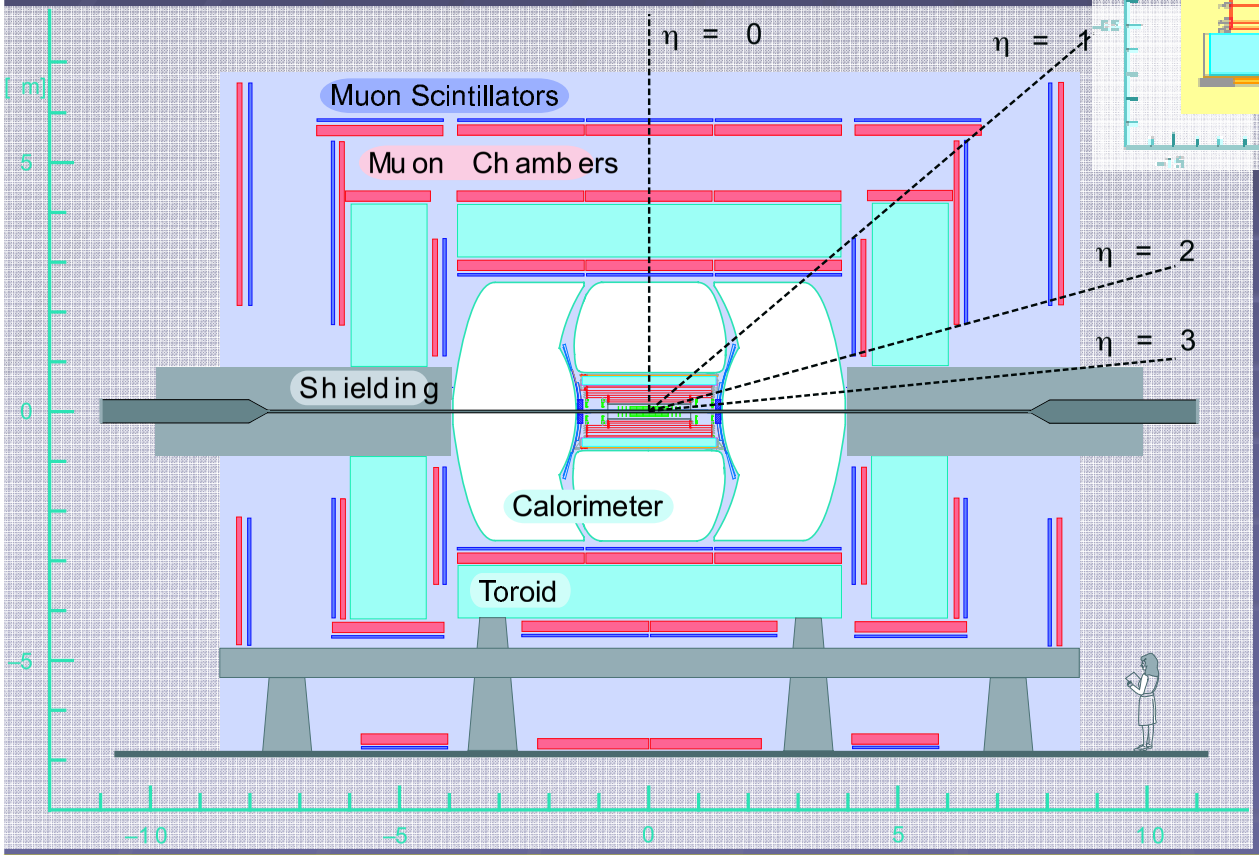
- Results
  - W and Z production cross-sections
  - W and Z properties
  - Di-Boson cross-sections
- Summary

The RunIIA DØ Detector

The DØ detector is a general purpose detector

- **Silicon micro-strip vertex tracker**
- **Scintillating fiber central tracker**
- **2 T superconducting solenoid magnet**





- **Liquid Argon U calorimeter**
- **Wire tracking and scintillation counters muon system with 1.8 T iron core toroid**
- **Three Trigger Levels**

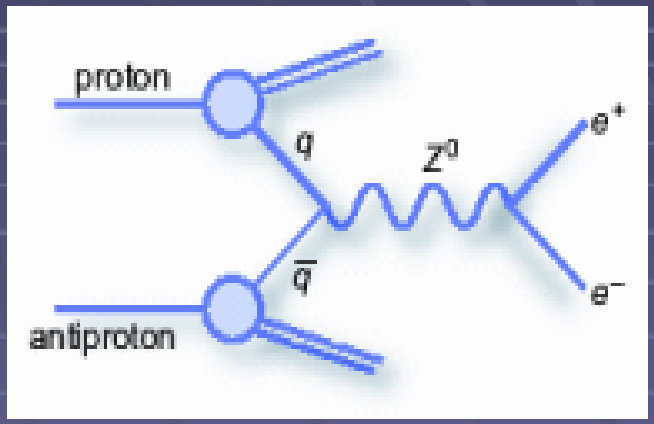
Motivation

- Measuring W & Z Boson properties are Precision Tests of the SM
  - Cross-section of W & Z
  - Tests of QCD predictions from PDFs
  - Indirect/Direct measure of W boson width
- Probes for new physics
  - W mass constrains the Higgs mass window
  - Di-Boson physics provides probes for new physics

W and Z Boson Production

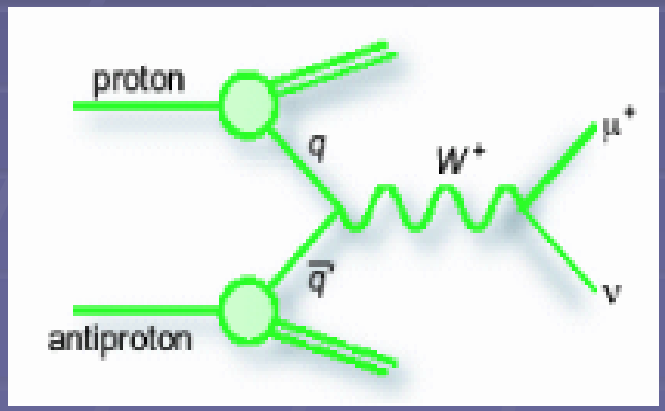
Look at the leptonic decays of W and Z

Hadronic decays difficult to extract from QCD.



Select Z bosons with:

- single and two (di) electron/muon triggers
- require two reconstructed leptons
- cut on lepton transverse momentum ~ 20 GeV



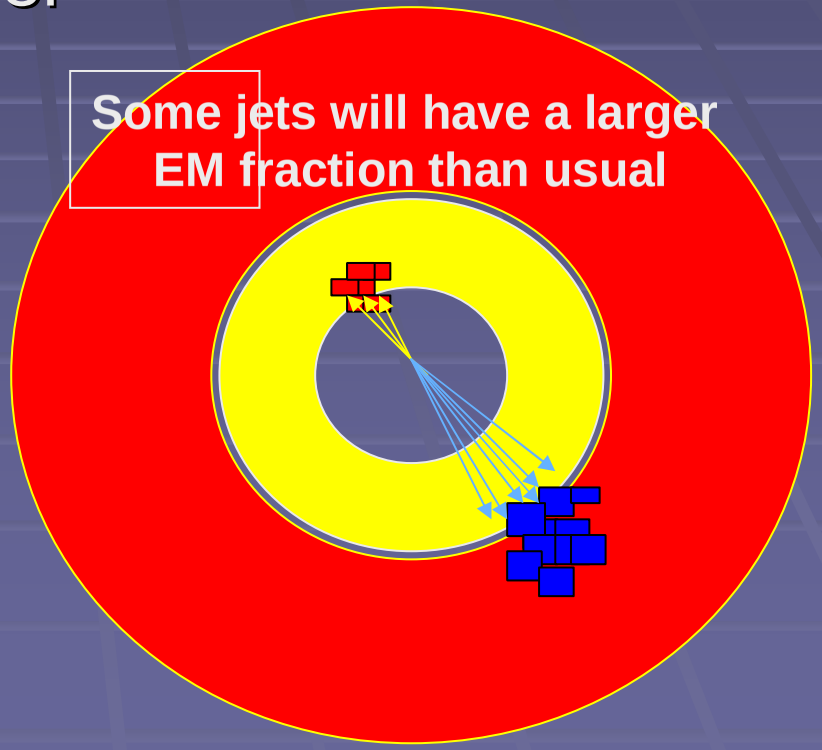
Select W bosons with:

- single electron/muon triggers
- lepton identification cuts
- cut on lepton transverse momentum ~20 GeV
- cut on missing transverse momentum ~20 GeV

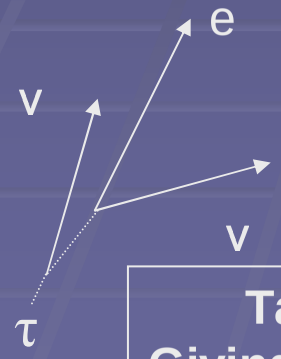
Common Backgrounds

- Biggest Contributing Background is from QCD
  - Heavy Flavor decays
  - electron like jets
- Next largest are usually Other Boson Decays
  - W or Z to taus
  - Z to electrons or muons
- Cosmic Ray muons

Heavy Flavor decays give real leptons

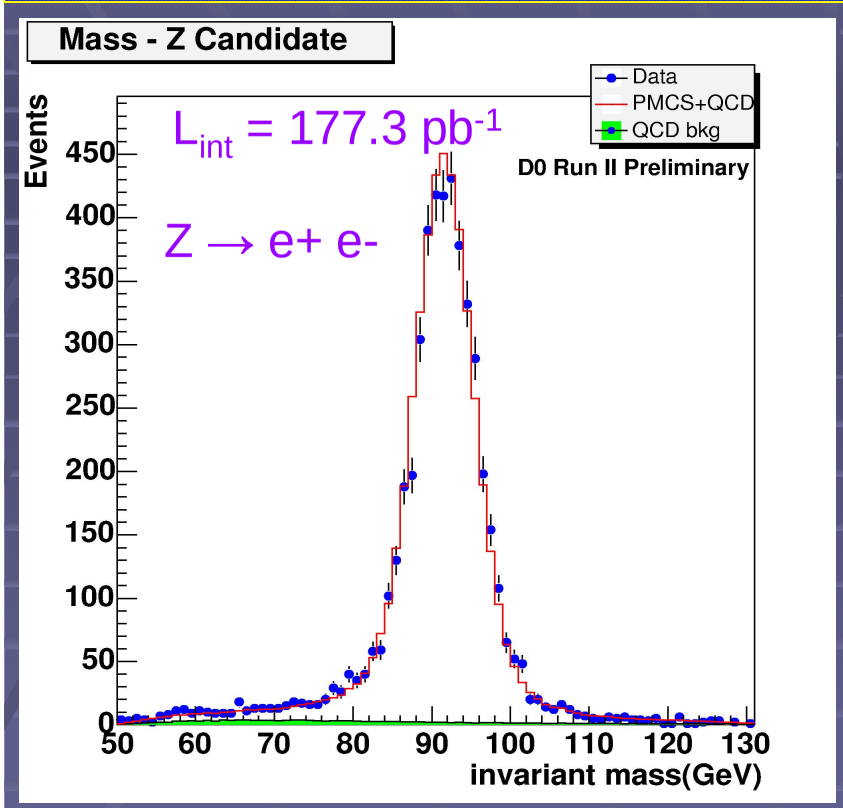


Some jets will have a larger EM fraction than usual



Taus will decay in flight Giving a lepton plus missing E_T

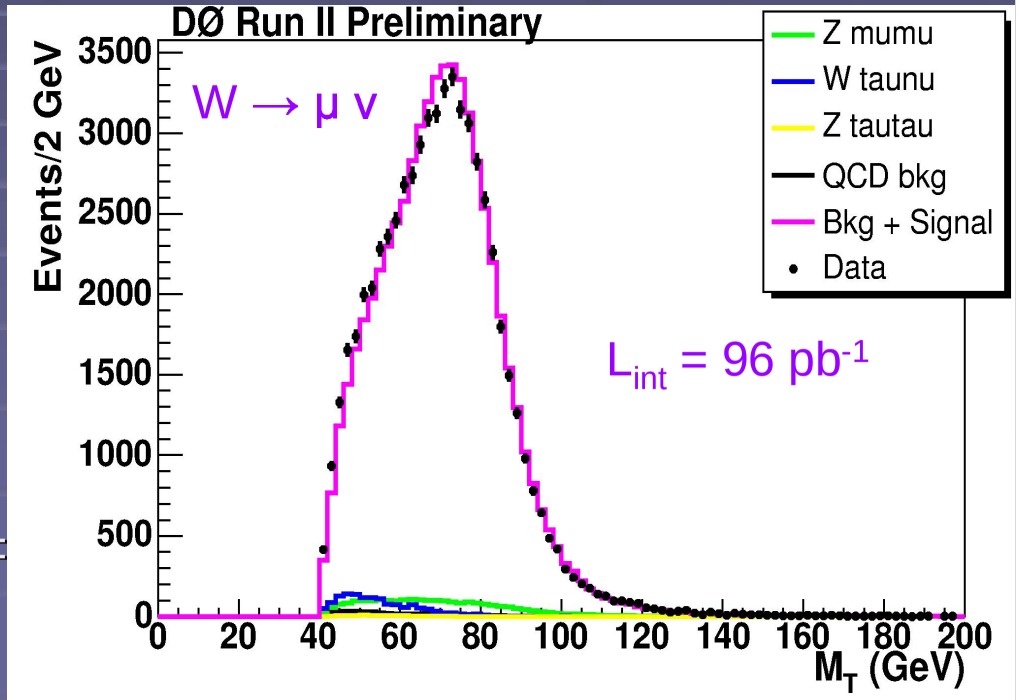
W & Z Cross-sections



σ_W x Br (W → e υ) = 2865.2 ± 8.3 (stat) ± 62.8 (sys) ± 40.4 (pdf) ± 186.2 (lumi) pb

σ_Z x Br (Z → e$^+$ e$^-$) = 264.9 ± 3.9 (stat) ± 8.5 (sys) ± 5.1 (pdf) ± 17.2 (lumi) pb

R (e channel) = 10.82 ± 0.16 (stat) ± 0.25 (sys) ± 0.13 (pdf)



σW x Br (W → μ υ) = 2989 ± 15 (stat) ± 81 (sys) ± 194 (lumi) pb

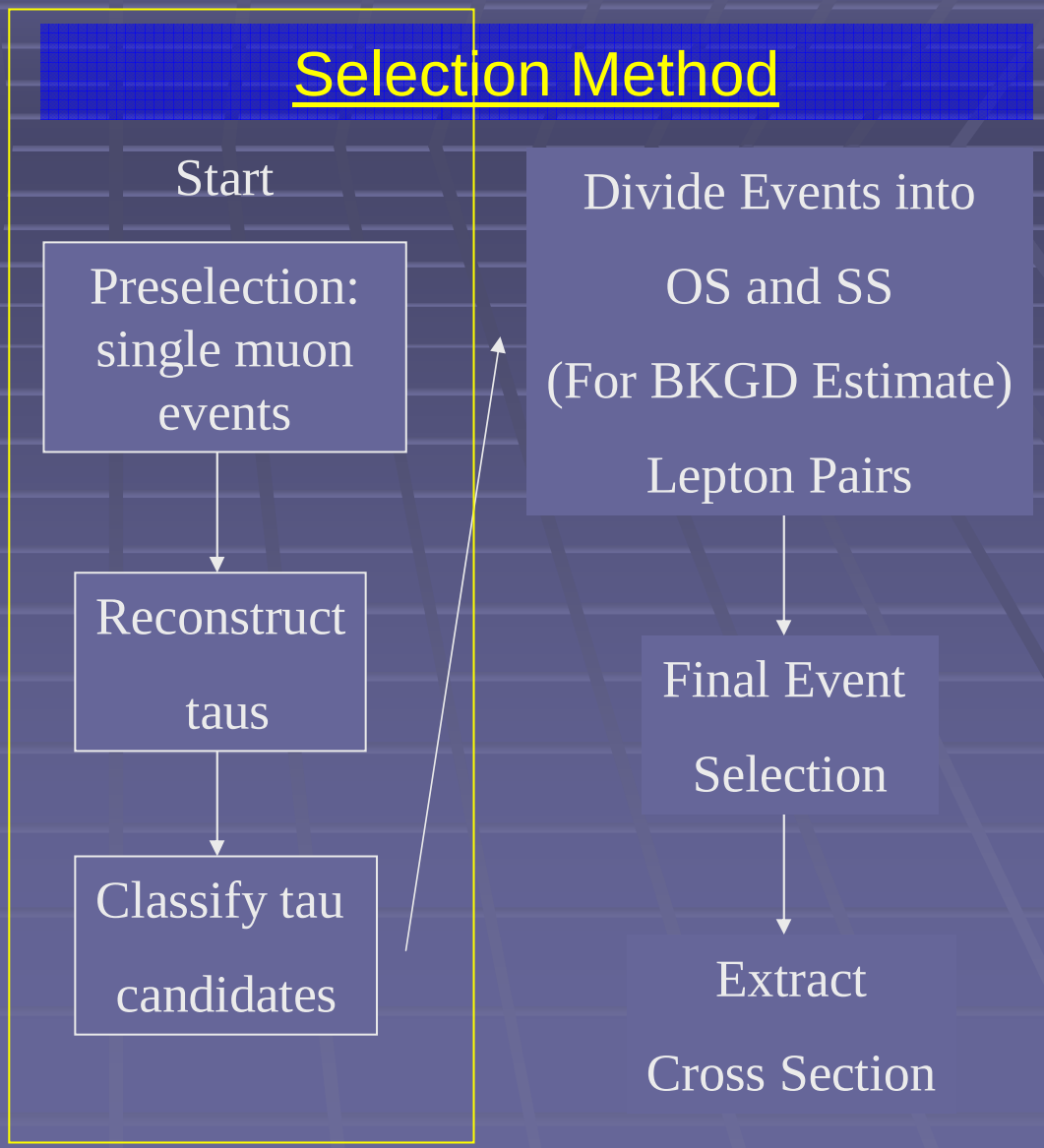
σZ x Br (Z → μ$^+$ μ$^-$) = 291.3 ± 3.0 (stat) ± 6.9 (sys) ± 18.9 (lumi) pb

Z → tau tau Cross-section

Physics Motivation

- § Test consistency of SM couplings to all leptons
  - § Consistency check to LEP studies.
- § Benchmark our level of understanding of the experiment.
  - § Tau is most difficult lepton to ID
  - § Develop Tau ID, Efficiencies, backgrounds

Selection Method



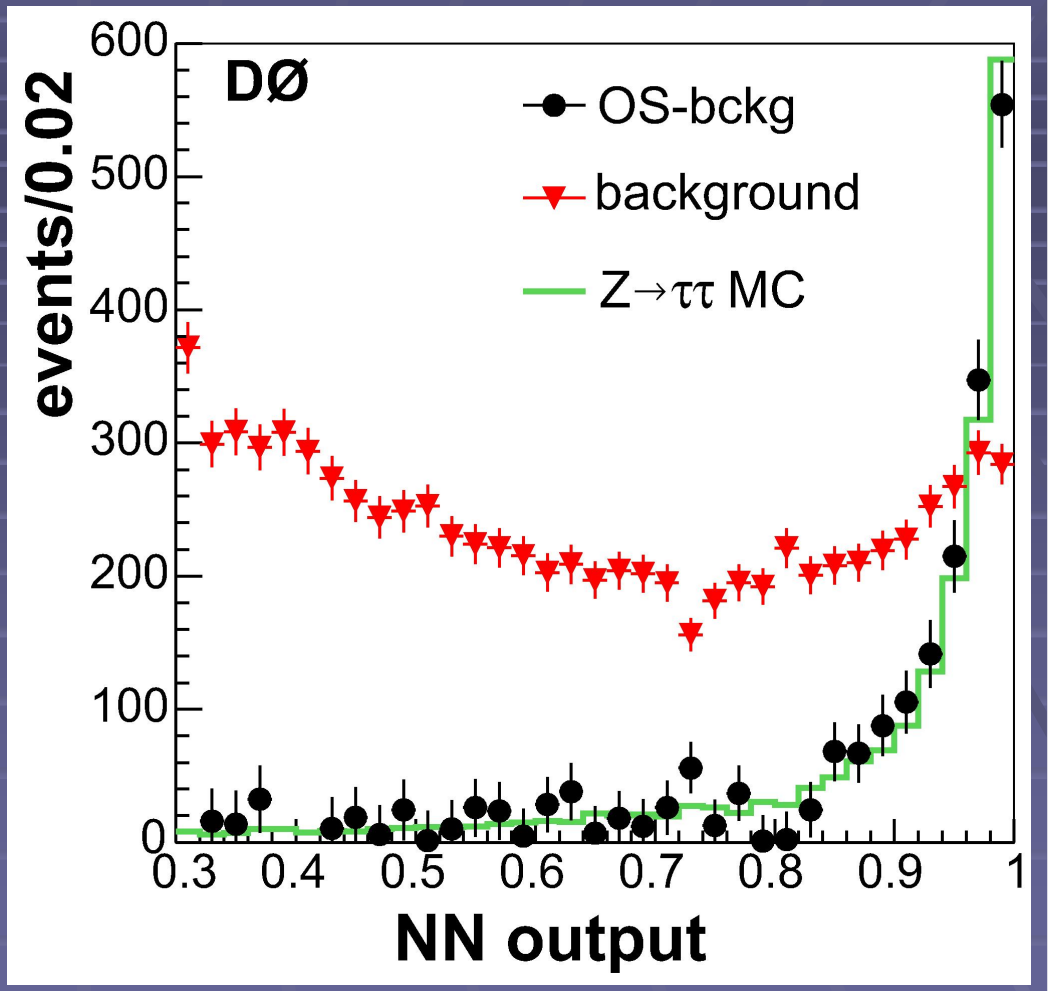
$Z \rightarrow \tau\tau$ Cross-section

$\sigma Z \times Br(Z \rightarrow \tau\tau) = 237 \pm 15\ (stat) \pm 18\ (sys) \pm 15\ (lumi)$ pb

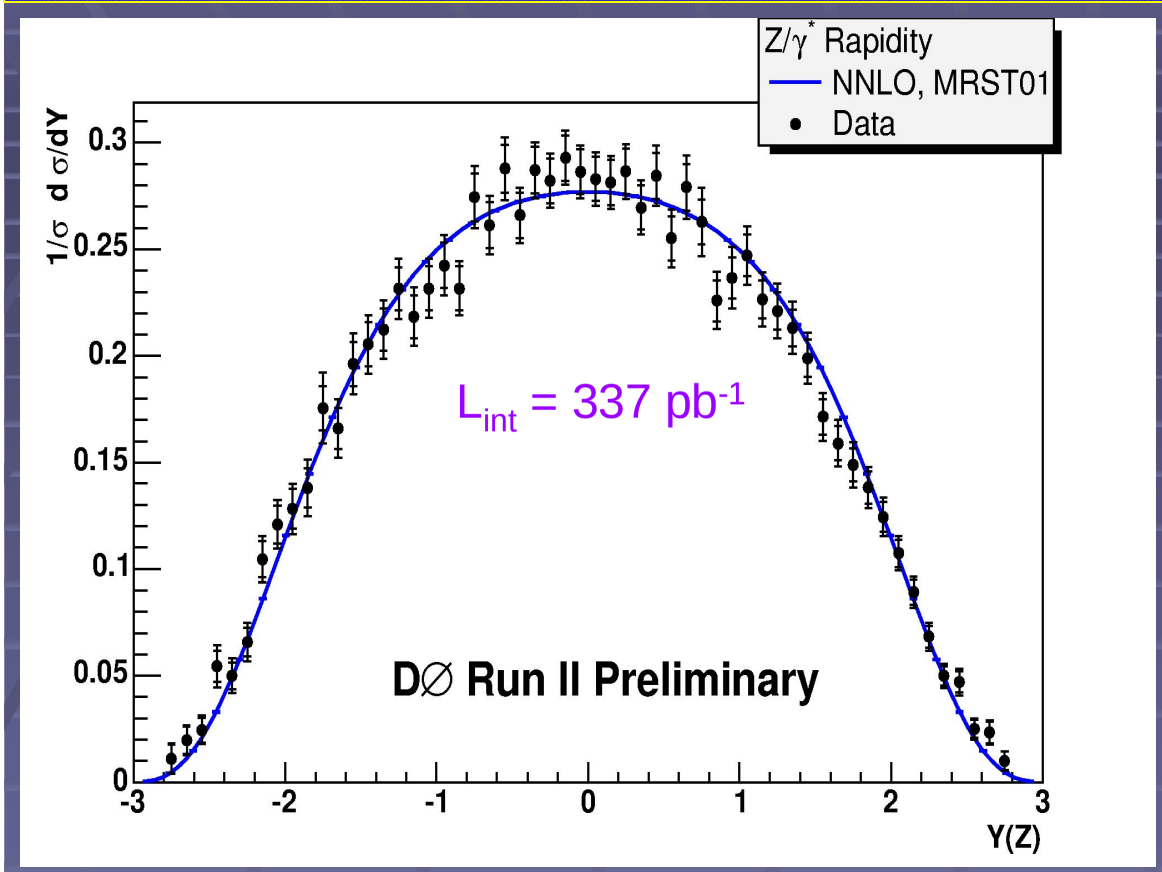
$\sigma Z = 242^{+}_{-}9$ pb (SM)

PRD vol. 71, 2005

$\sigma Z \times Br(Z \rightarrow \tau\tau)$ has never been measured before in pp collisions



Z Boson Rapidity

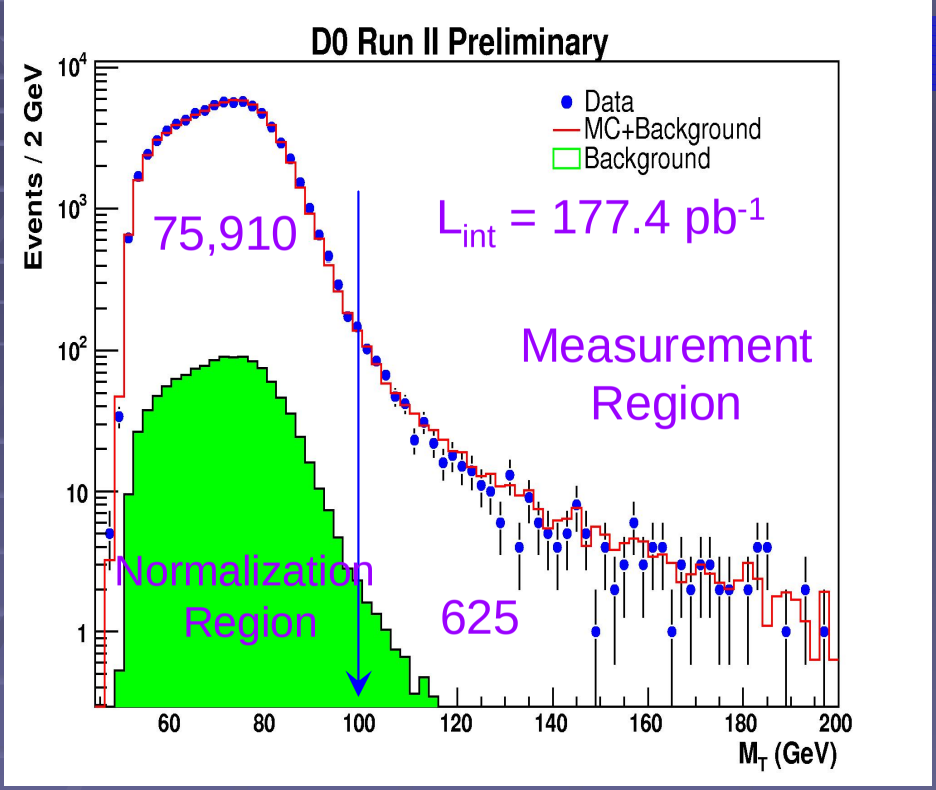


- Precision measurement of Z boson rapidity
  - Gives sensitivity to PDFs at NNLO
  - Depends Bjorken x of initial quarks
- Uncertainties are carefully accounted for
- Careful tuning of detector in MC is required

$$\frac{1}{\sigma}\frac{d\sigma(p\bar{p} \rightarrow Z/\gamma^* \rightarrow e^+ e^-)}{dY} = \frac{1}{\sigma}\frac{N_i - B_i}{(\varepsilon \times A)_i \Delta_i L}$$

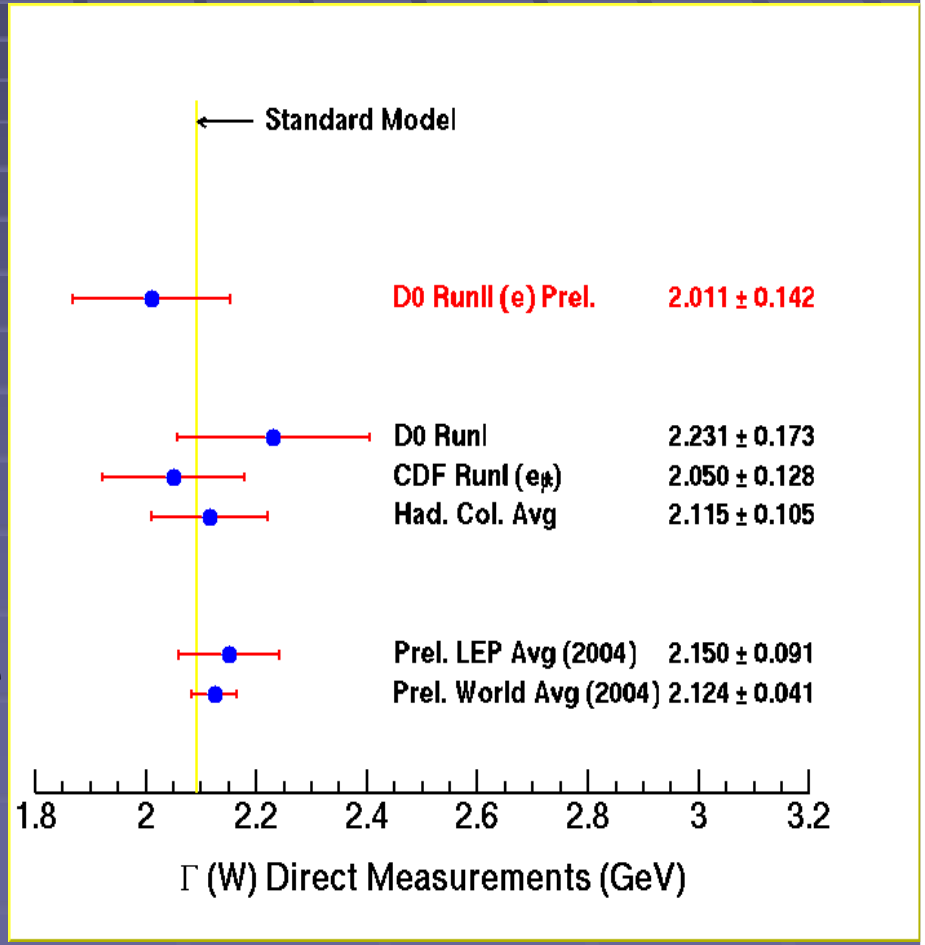
$$Y = \tfrac{1}{2} \ln \frac{E^Z + p^Z{}_z}{E^Z - p^Z{}_z}$$

W Boson Width



Γ_W = 2.011 ± 0.093 (stat) ± 0.107 (sys) GeV

2.090 ± 0.008 GeV (SM)

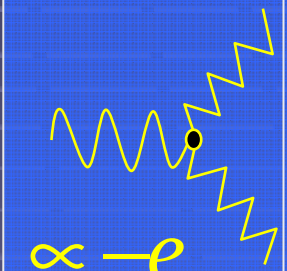


- Large M_T is sensitive to W width
- Z boson is extensively used to calibrate the simulation process
- Binned Likelihood fit is used to determine the W width

Di-Boson Physics

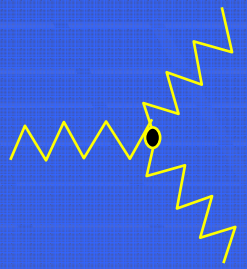
- Multiple vector bosons provide
  - high-pT Standard Model process with cross section predictable with high precision
  - interesting physics
- Cross sections are useful for New Phenomena search analyses.
- A SM parameter to measure: the gauge boson "self-couplings"

WWγ Coupling



$$\propto -e$$

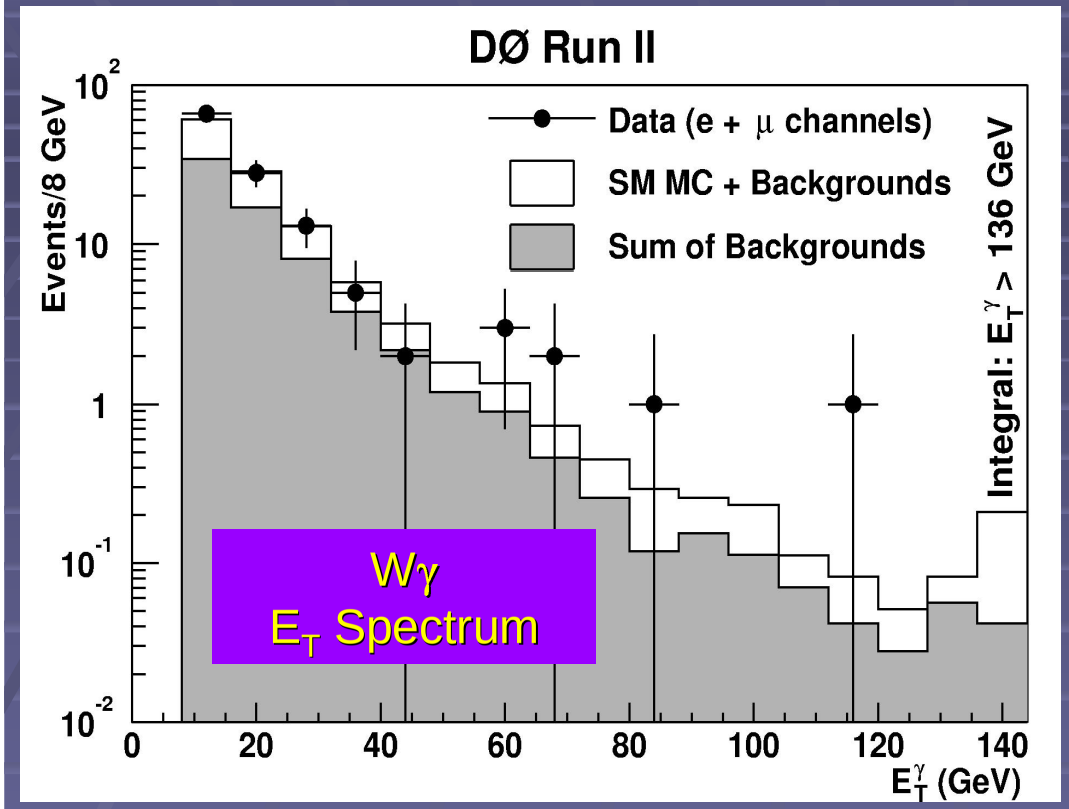
WWZ Coupling



$$\propto -e\cot(\theta_w)$$

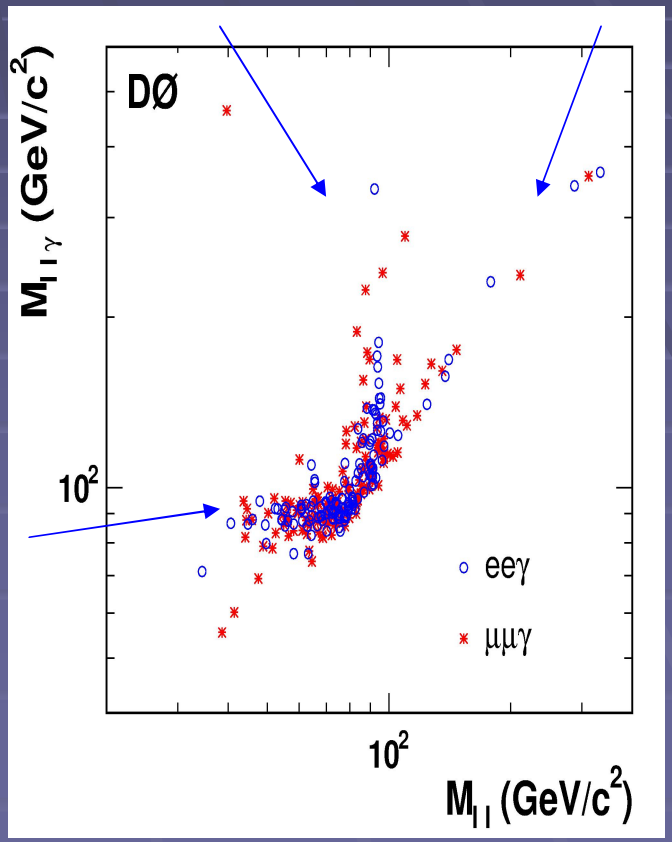
Also are major backgrounds and decay channels for scalar bosons, such as the Higgs

Zγ and W γ Physics



σ(Zγ) = 4.2 ± 0.4 (stat + sys) ± 0.3 (lumi) pb
PRL vol. 95, 2005

ISR DY



FSR

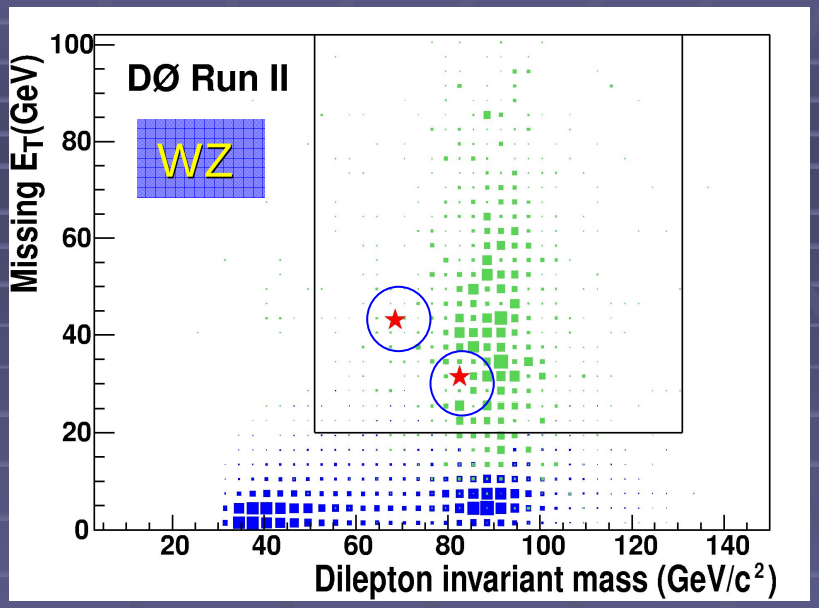
σ(Wγ) = 14.8 ± 1.6 (stat) ± 1.0 (sys) ± 1.0 (lumi) pb
PRD RC vol. 71, 2005

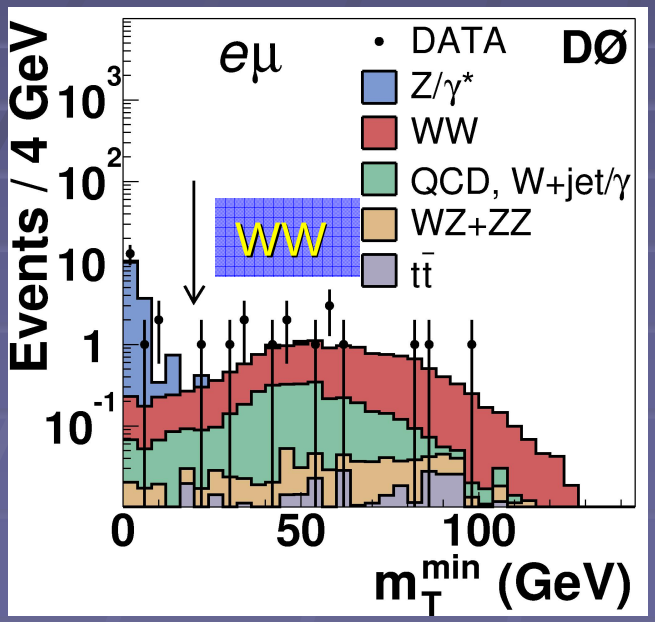
WZ and WW Physics

- Found 3 Candidates in ~0.3 fb^{-1}
- Expected 0.71 background events
- P(0.71 bkgd) -> 3 Candidates is 3.5%
- PRL vol. 95, 2005

$\sigma(WZ) < 13.3$ pb @ 95%CL

$\sigma(WZ) = 4.5\ ^{+3.5}_{-2.6}$ pb

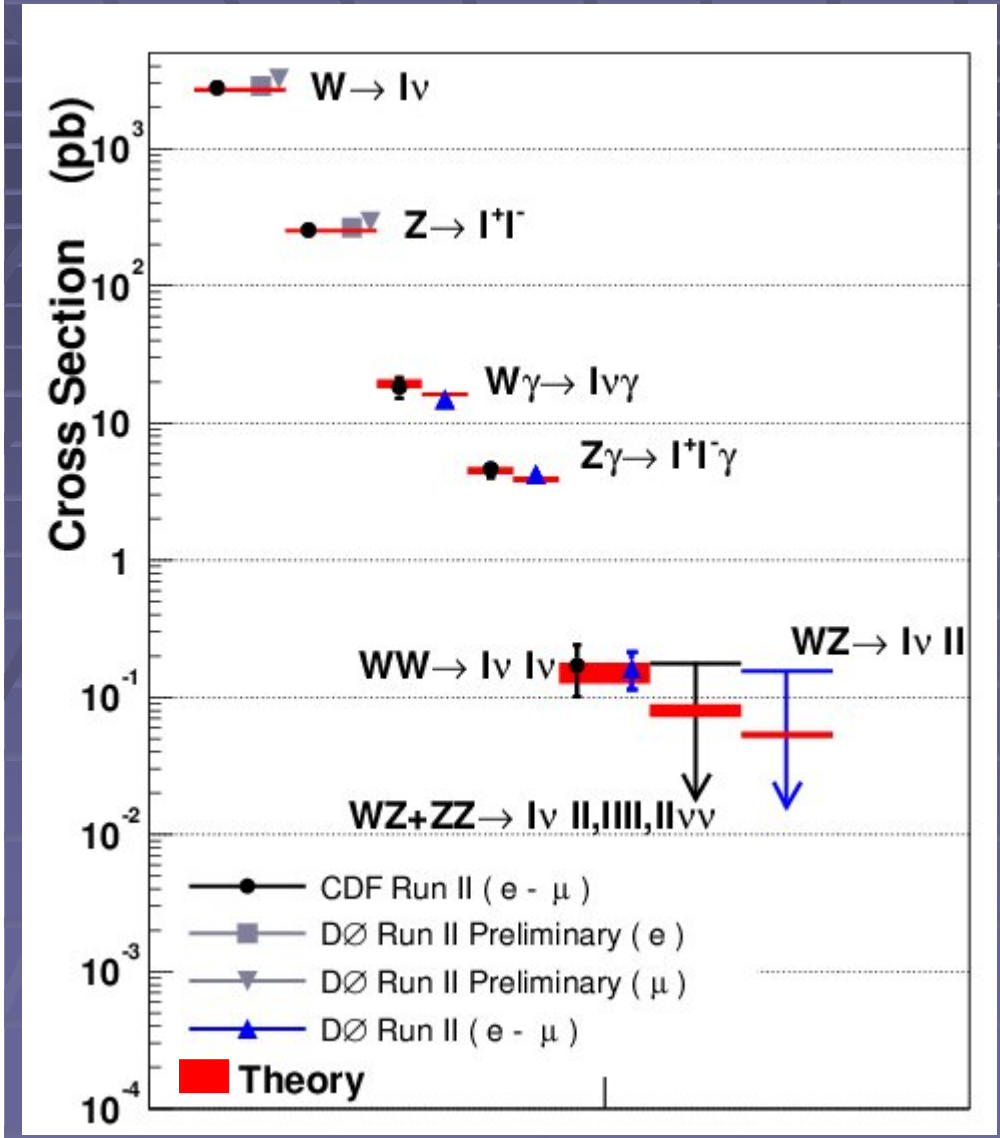




- look for two leptons plus missing E_T
- Found 25 Candidates in ~237pb^{-1}
- Expected background
  - 8.1 ± 0.6 (stat) ± 0.6 (sys) ± 0.5 (lumi)
- This is a 5.2 sigma measurement
- PRL vol. 94, 2005

$\sigma(WW) = 13.8\ ^{+4.3}_{-3.8}(stat)\ ^{+1.2}_{-0.9}$ (sys) ± 0.9 (lumi) pb

Summary



- DØ Has a rich electroweak program
- Presented was just a hint at what is to come
- With more data and improved techniques we are on the verge measuring new cross sections setting better limits
- Look forward to hearing from us soon.

The End

The Tevatron

Proton anti-proton collider

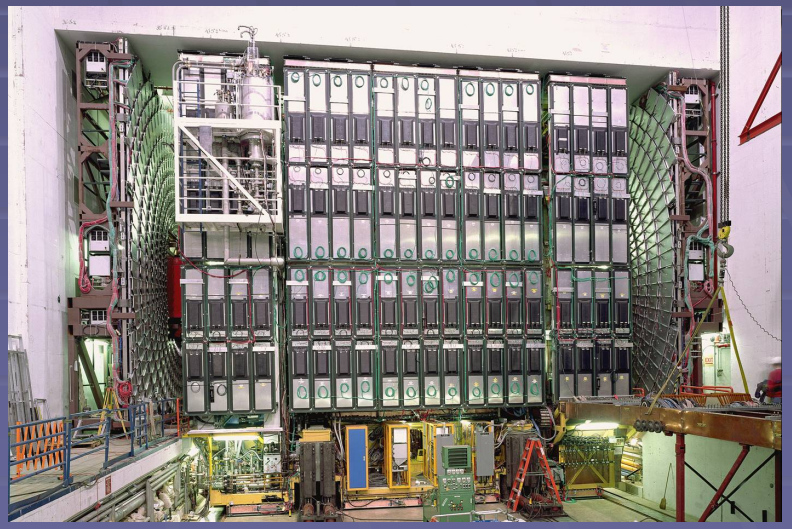
1.96 TeV with 396ns bunch spacing

Delivered Luminosity ~1.4 fb^{-1}

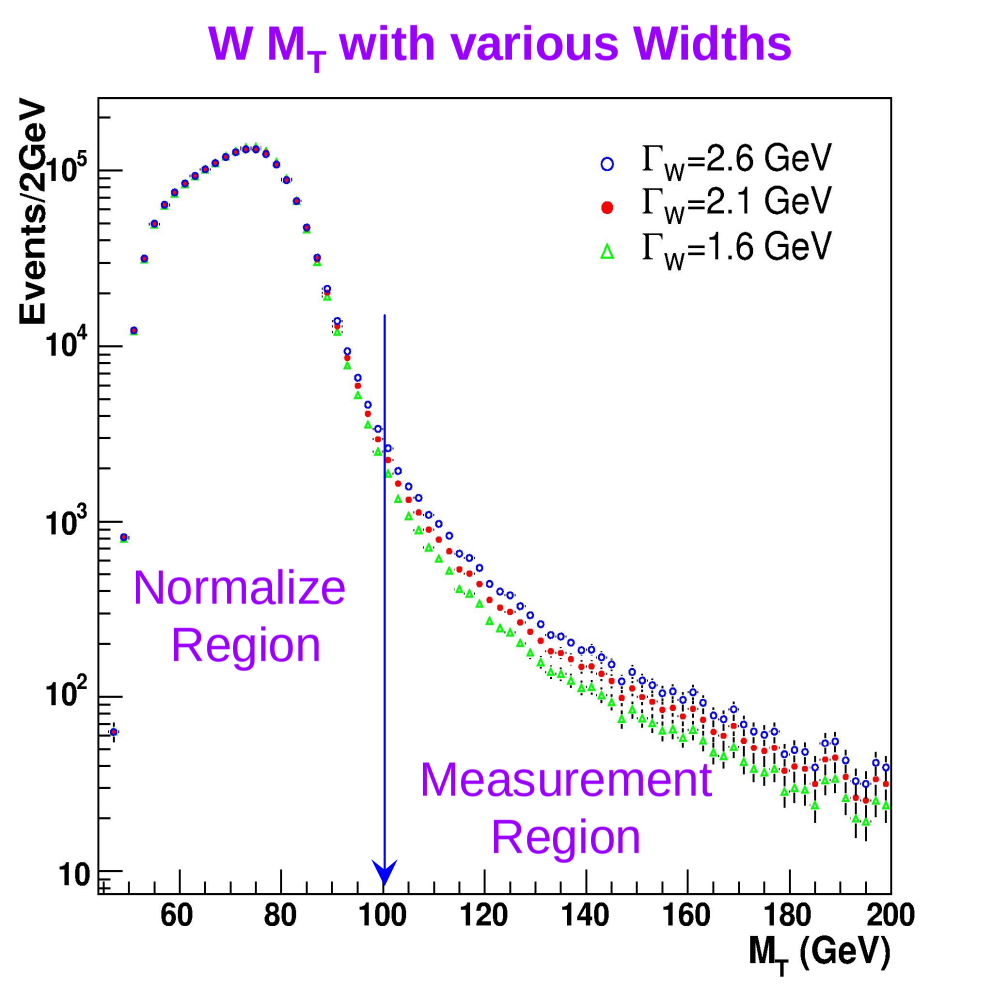
To the DØ Detector

with ~1.2 fb^{-1} recorded

Most analysis presented here contain < 0.3 fb^{-1}

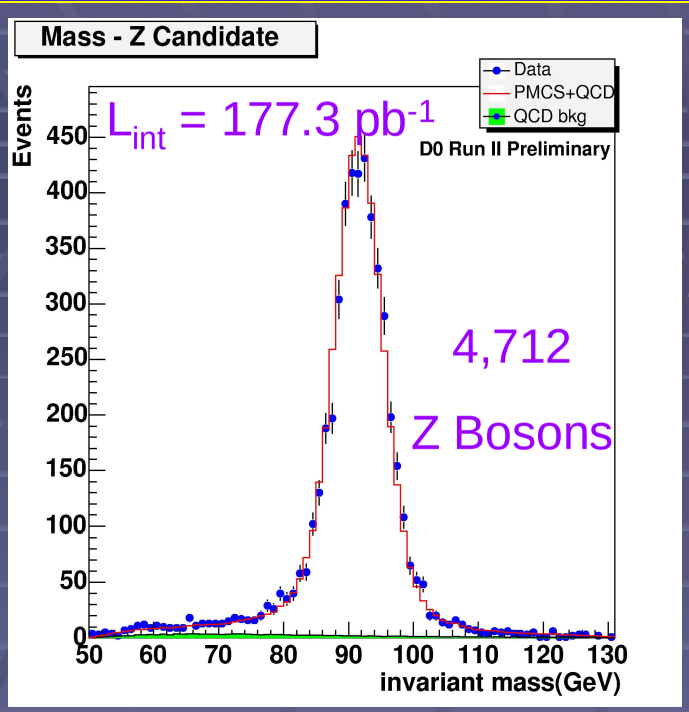


W Boson Width

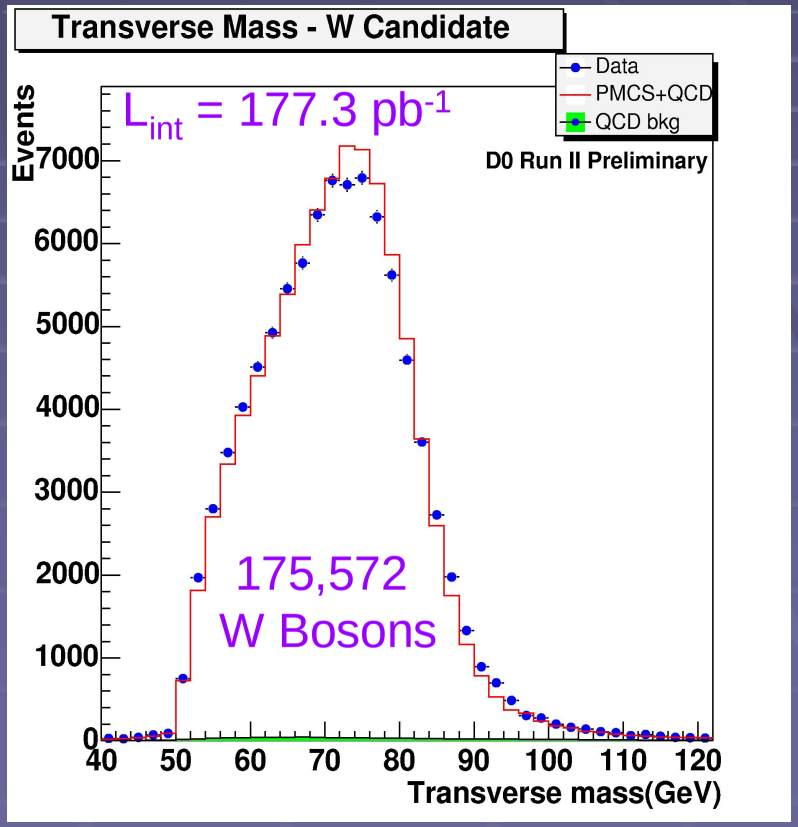


- Test of the Standard Model
  - 2.090 ± 0.008 GeV (SM)
- Measured directly using the transverse mass distribution.
- Tail in M_T is mostly caused by the natural width of the W boson.
- Precision measurement
  - Error dominated by detector response uncertainty

W & Z Cross-sections



- W backgrounds
  - 59003 ± 341 events from QCD
  - 1.25 ± 0.3 % W → tau + ν (from MC)
  - 0.26 ± 0.05 % Z → e^+e^- (from MC)
- Z QCD background estimate
  - 87.1 ± 68.0 events



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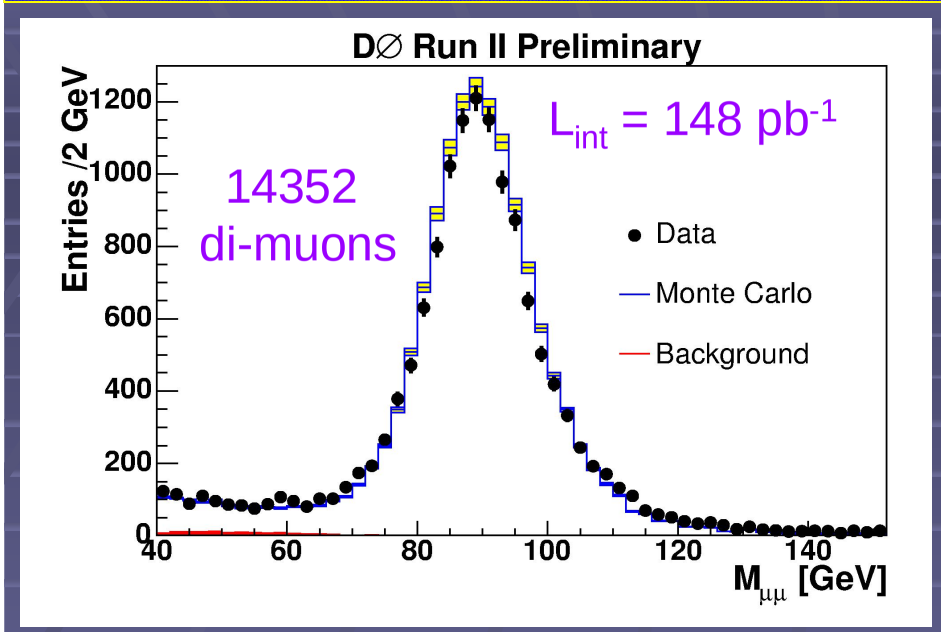
σ_Z x Br (Z → e^+ e^-) = 264.9 ± 3.9 (stat) ± 8.5 (sys) ± 5.1 (pdf) ± 17.2 (lumi) pb

R = 10.82 ± 0.16 (stat) ± 0.25 (sys) ± 0.13 (pdf)

Z and W Cross-Sections



Z→μ μ

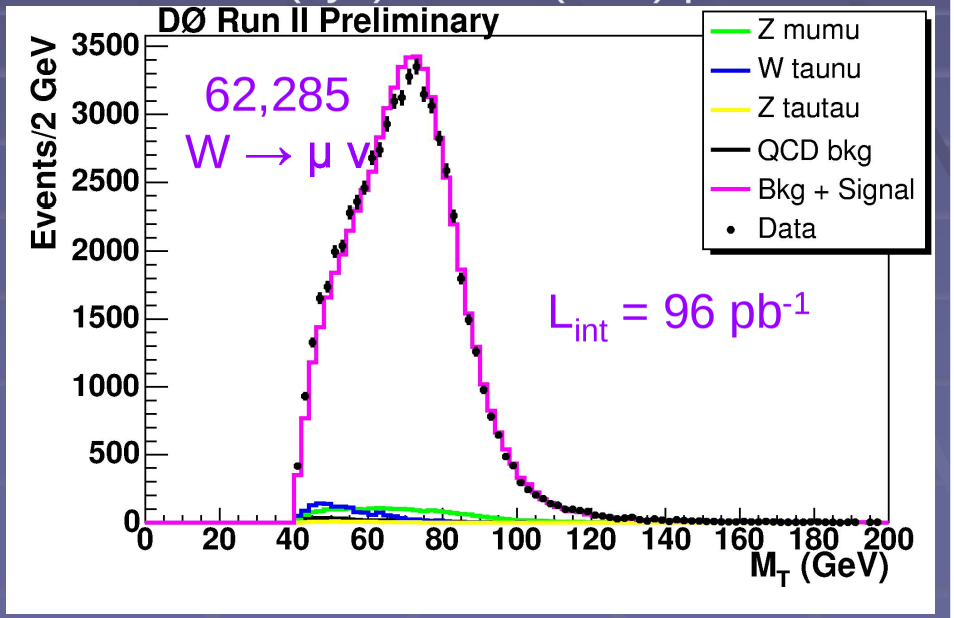
0.5 ± 0.3% bb

0.1 ± 0.1% cosmics

0.5 ± 0.1% Z → tau tau

0.2 ± 0.1% W → μ ν & dibosons

σ_Z x Br (Z → $\mu^+ \mu^-$) = 291.3 ± 3.0 (stat) ± 6.9 (sys) ± 18.9 (lumi) pb

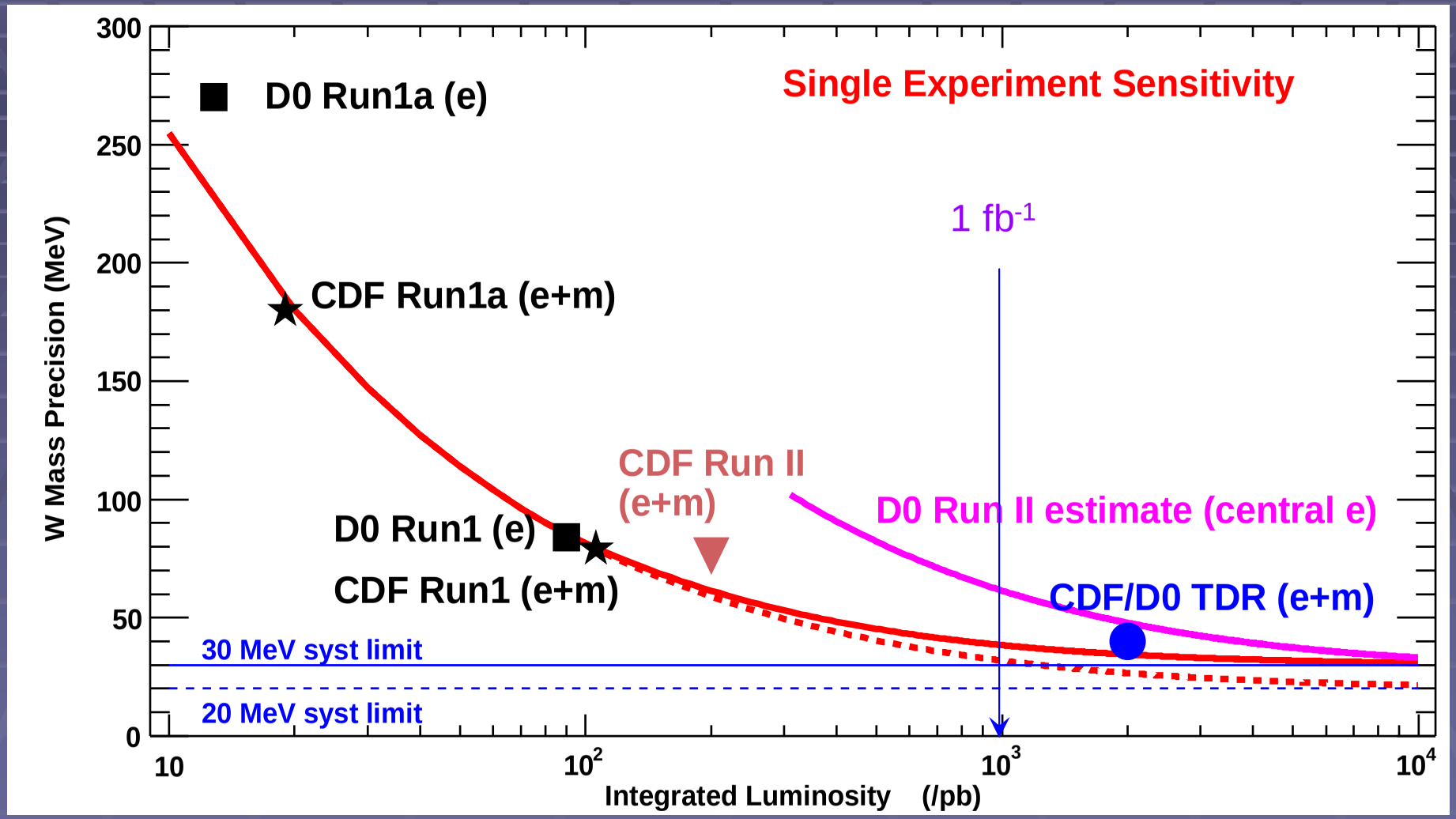


W →μ ν

- 0.025 ± 0.001 W → tau ν events
- 0.043 ± 0.002 Z → μ μ
- 0.0018 ± 0.0001 Z → tau tau

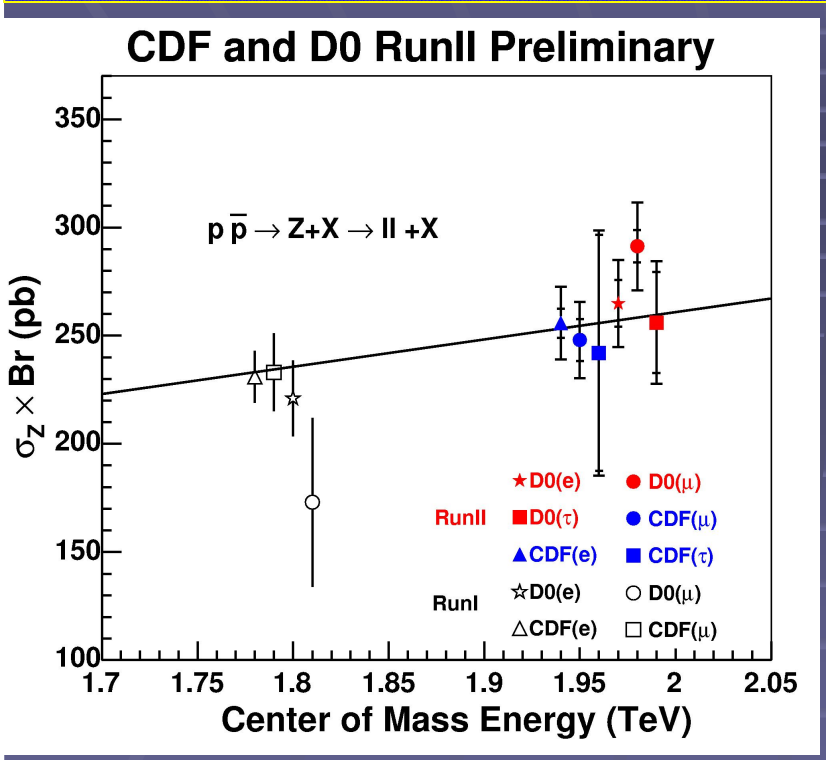
σW x Br (W → μ ν) = 2989 ± 15 (stat) ± 81 (sys) ± 194 (lumi) pb

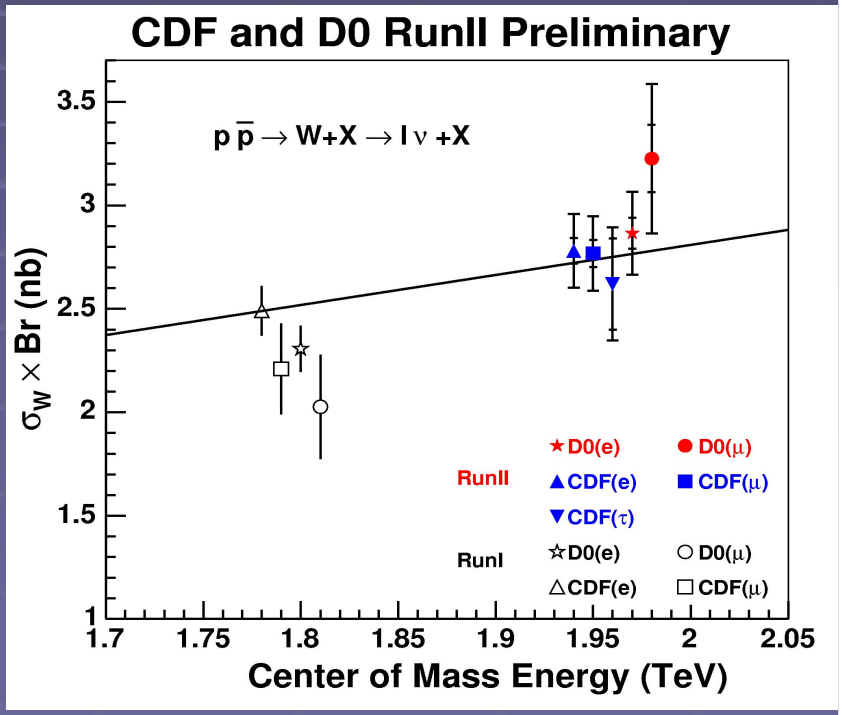
Future W Mass Precision



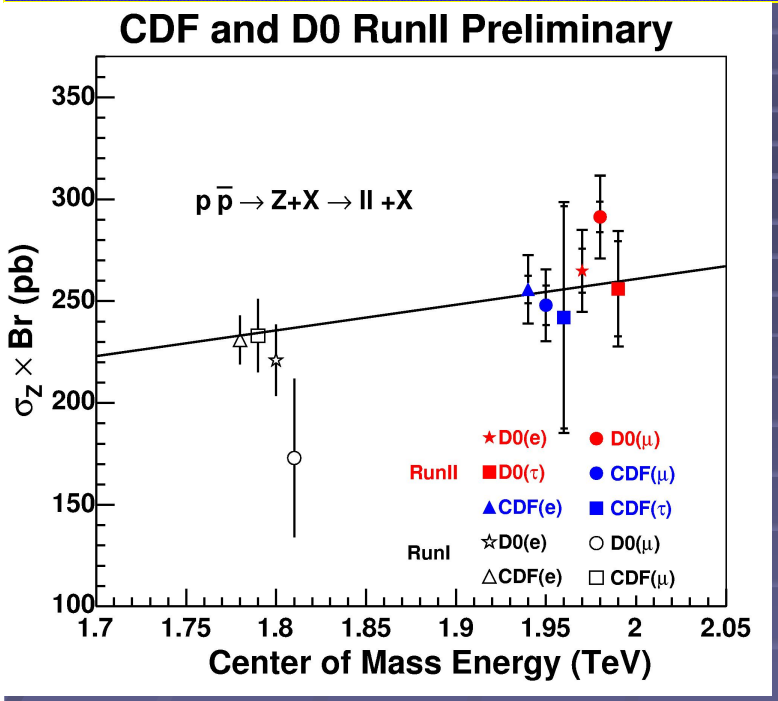
Sensitivity to W Mass as a function of Integrated Luminosity

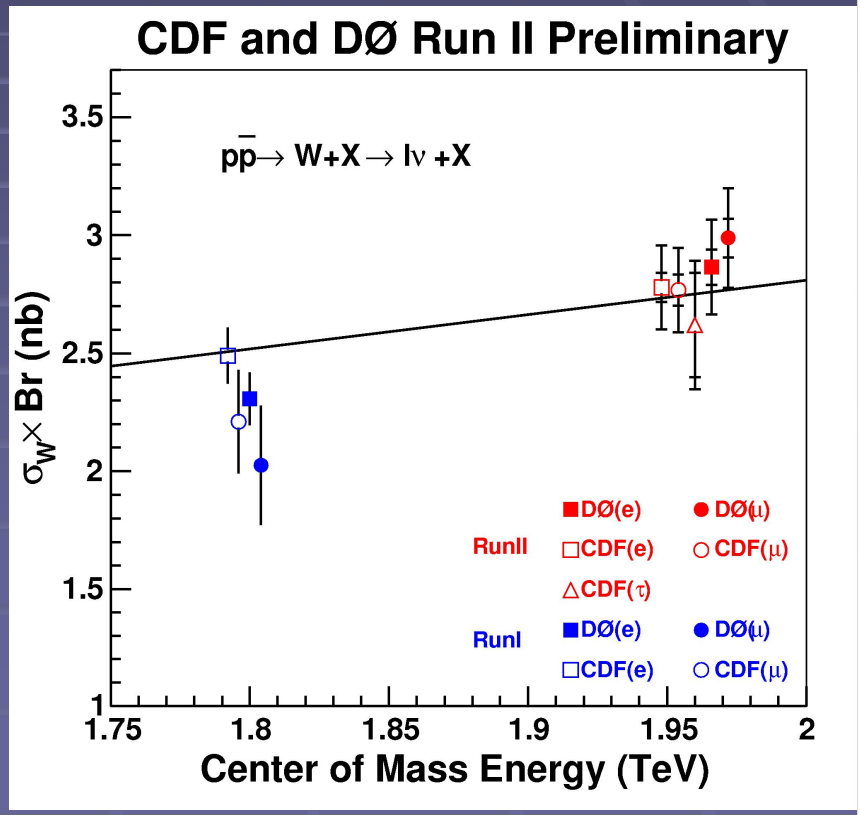
Z and W Cross-Sections



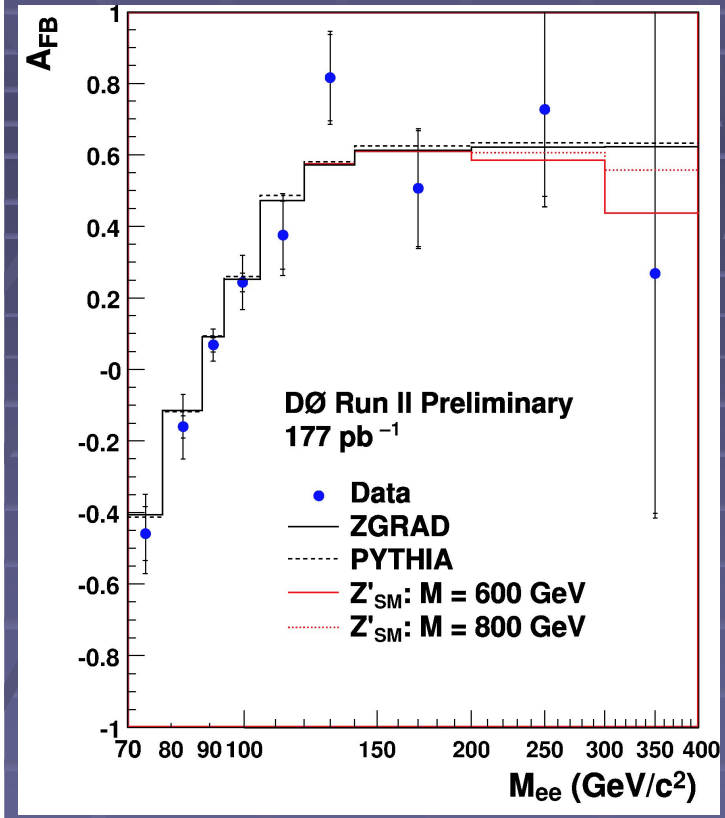


Z and W Cross-Sections





Z Boson Asymmetry



Measurement of

- inclusive Drell-Yan to e^+e^- differential cross-section
- forward backward asymmetry is function of dielectron invariant mass from 70 GeV/c^2 to 400 GeV/c^2
- Extends reach of LEP
- Probe for new Physics

Presence of both vector and axial coupling of quarks and leptons to Z creates an asymmetry in the polar emission angle, θ, of the electron in the rest frame of the dielectron pair.

$$\frac{d\sigma}{d(\cos\theta)} = A(1+\cos^2\theta) + B\cos\theta$$

- A & B: functions of isospin, charge of quarks, di-electric invariant mass
- Use Collins-Soper reference frame. Minimizes dependence on quark P_T

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

$$\sigma_F = \int_0^1 \frac{d\sigma}{d(\cos\theta^*)}\, d(\cos\theta^*) \qquad \sigma_B = \int_{-1}^0 \frac{d\sigma}{d(\cos\theta^*)}\, d(\cos\theta^*)$$