The W and Z Cross Sections at DØ in Run 2

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On behalf of the DØ collaboration

DPF 2003, Philadelphia, PA

- **Introduction + Motivation**
- **W/Z→muons**
- **W/Z →electrons**

Why do we care about W/Z Production?

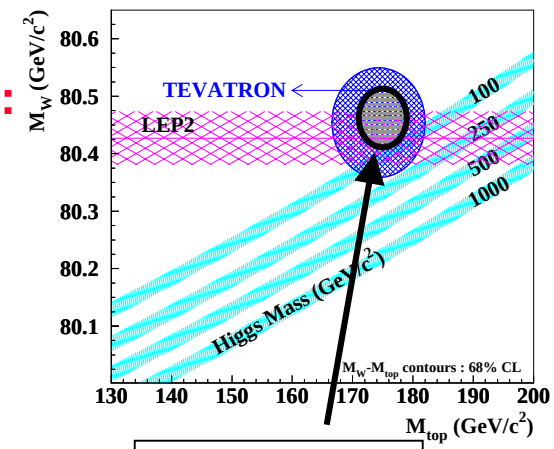
- **Test of SM couplings**
- **Test of higher order QCD corrections**
- **constrain proton PDFs**

New CM energy:

1.8TeV →1.96 TeV

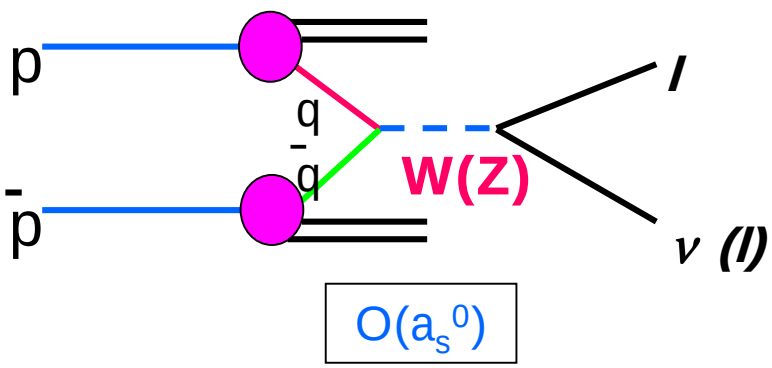
→CS increase by ~9%

- **Gain understanding for Precision EW measurements:**
  - **W mass and width**
- **W can be used to determine luminosity**
- **Tuning of algorithms and Triggers**
- **W+jets Background to top and Higgs signals**



DØ
Run 2a
Prediction

W and Z Production Mechanics



- Production dominated by $q\bar{q}$ annihilation
- Due to very large $p\bar{p} \rightarrow jj$ production, need to use leptonic decays
  - $W \rightarrow l\nu$ (BR ~ 11% per mode)
  - $Z \rightarrow ll$ (BR ~ 3% per mode)
- Distinctive event signatures
  - High p_T isolated leptons (e or μ)
  - One high p_T lepton + Missing E_T (W)
  - Two high p_T leptons (Z)
- Low backgrounds
- Large samples
- Well understood EW vertex

  ➔ Test QCD

W's are produced at ~1 Hz @Run 2

Millions of W's

100k Z's

W and Z Cross Sections

A counting experiment…

Backgrounds

$$\sigma \cdot B = \frac{N_{obs} - N_{bkg}}{A\varepsilon \int L dt}$$

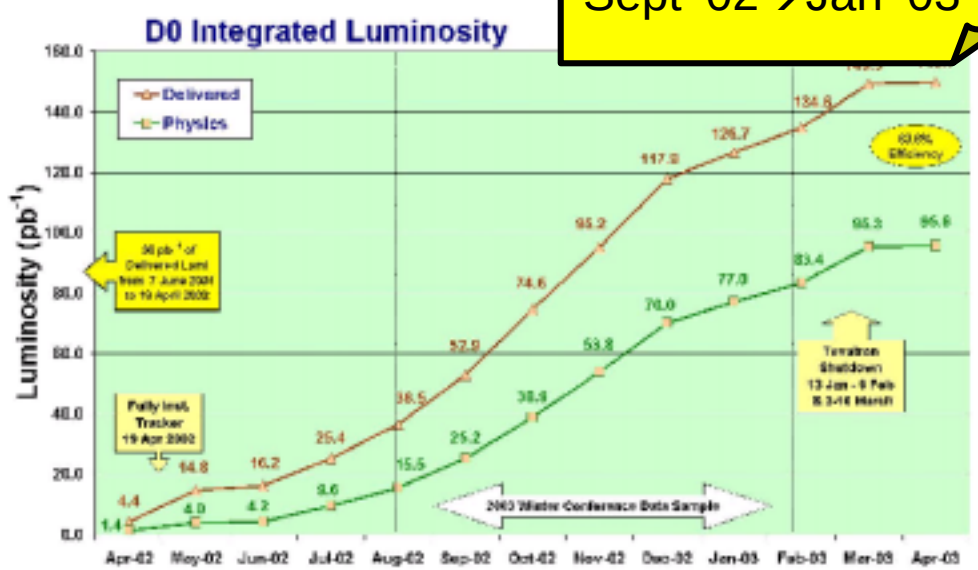
Acceptance from Monte Carlo

Efficiencies from data where possible

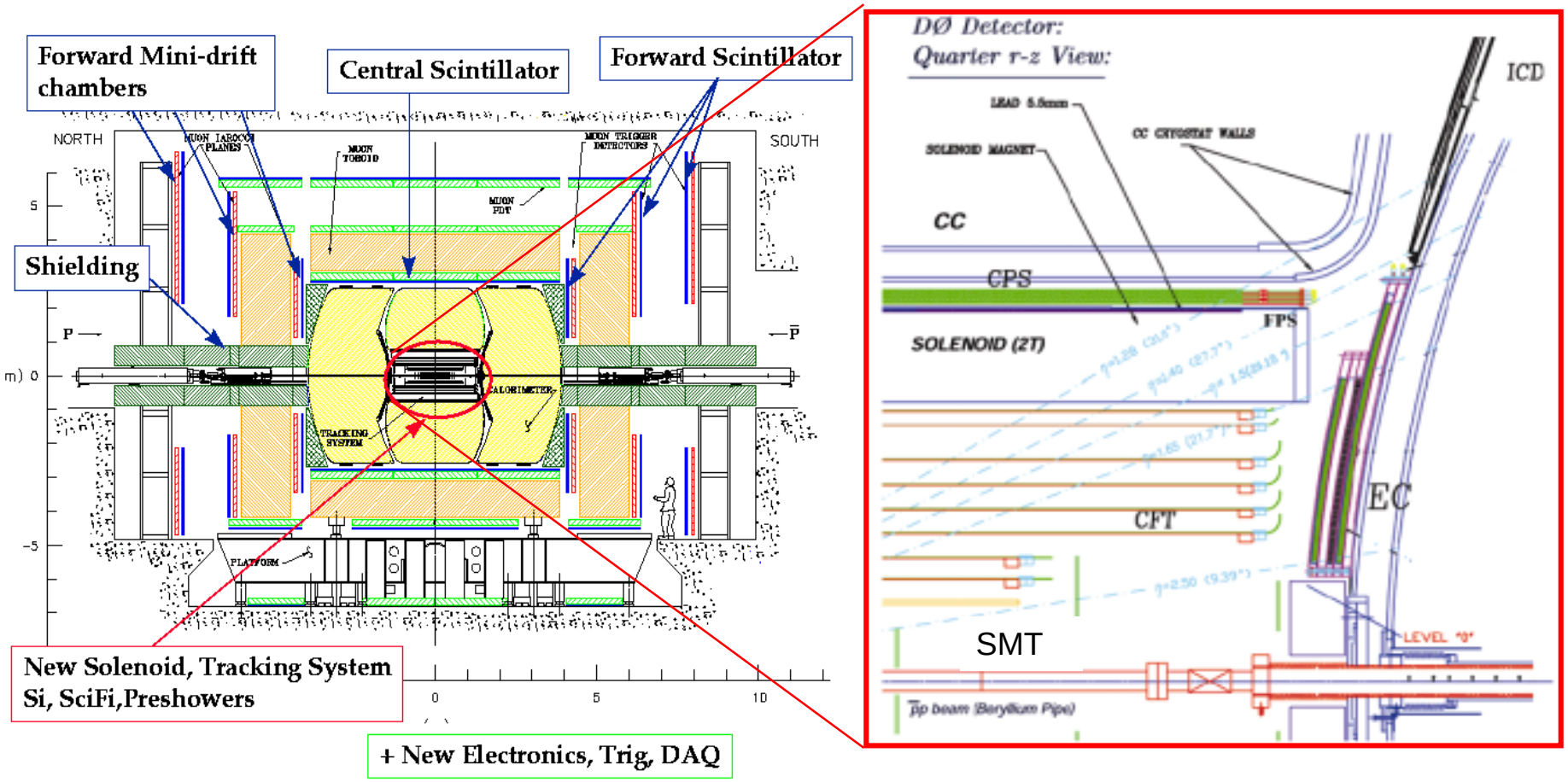
Integrated Luminosity

These measurements use data taken

Sept '02→Jan '03

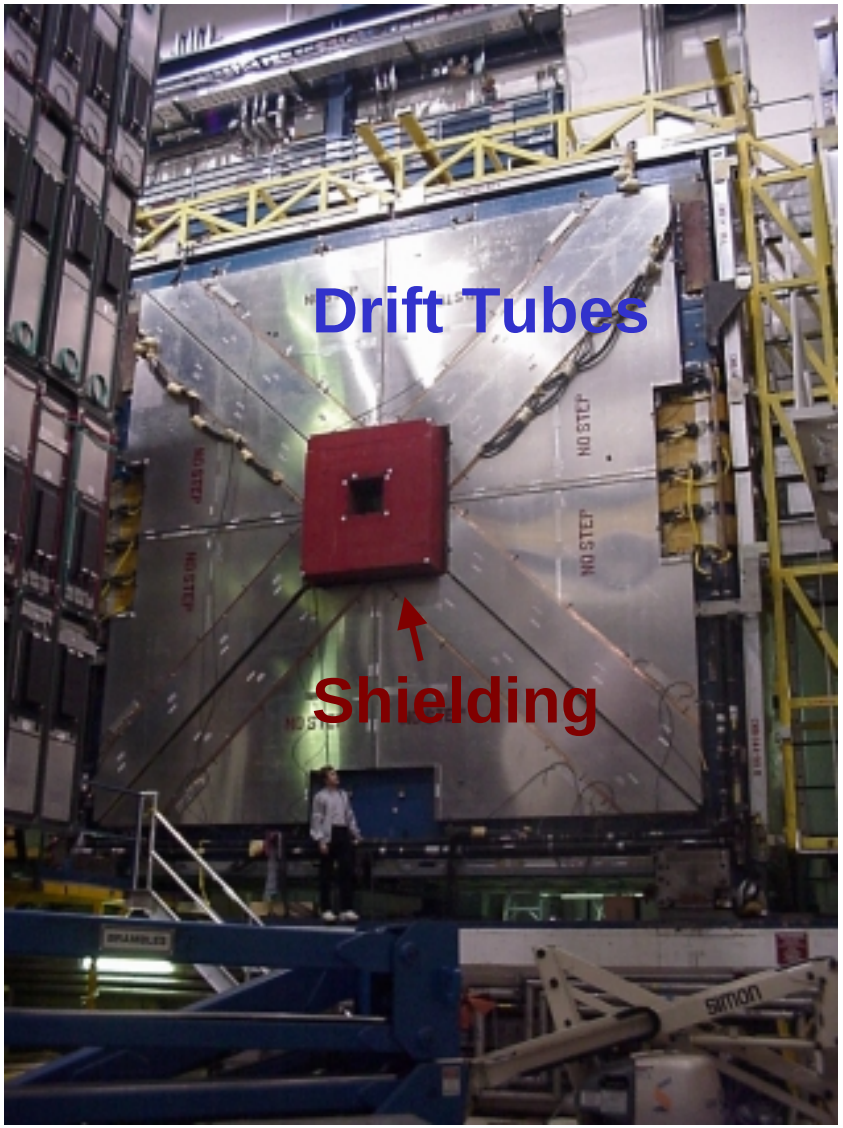


The DØ Run 2 Detector



All parts of the detector used in EW analyses:
Calorimeter/ Muon System and the Tracker

The Muon Detector



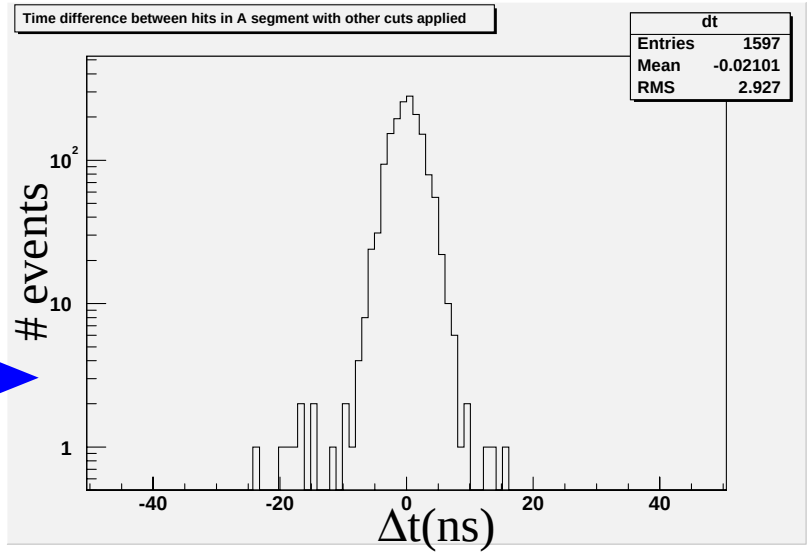
- **Two regions: Central and Forward**
- **Coverage up to $\eta=\pm 2$.**

- **Three layers: one inside (*A*), two outside (*B*, *C*) the toroid magnet**
- **Consists of scintillators and drift tubes**

Z Production (Muon Channel)

sqrt(s) = 1.96 TeV
32 pb^{-1}

- Z selection
  - 2 tracked, oppositely-charged μ's with pT>15 GeV& $|\eta|<1.8$
  - Di-muon trigger
  - At least one muon is isolated
  - $(\Delta R)^2=(\Delta\phi_{\mu\mu})^2+(\Delta\eta_{\mu\mu})^2 >4.0$
  - $|\Delta_t| < 9$ ns in scintillator
  - NO explicit mass requirement



- Background is small
  - b-bbar is 1+–1%
  - Z to $\tau\tau$ is 0.5+–0.1%

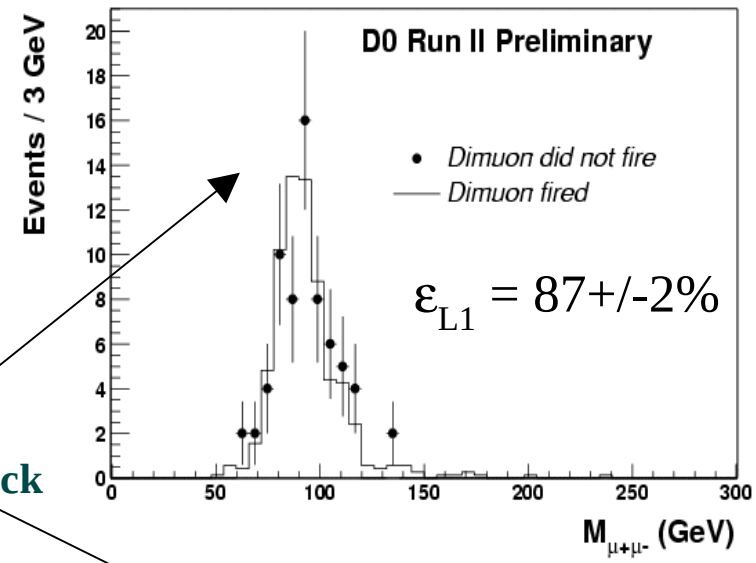
Z→μμ: Efficiencies

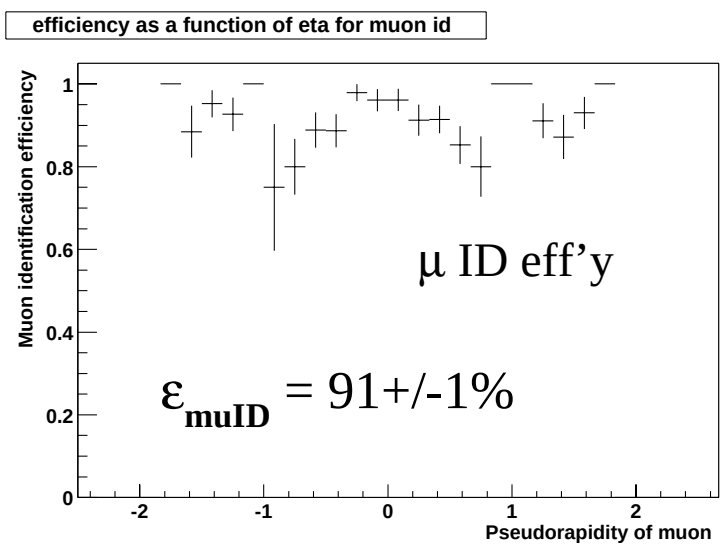
- Acceptance from MC (40+/-1%)
- Efficiencies from data

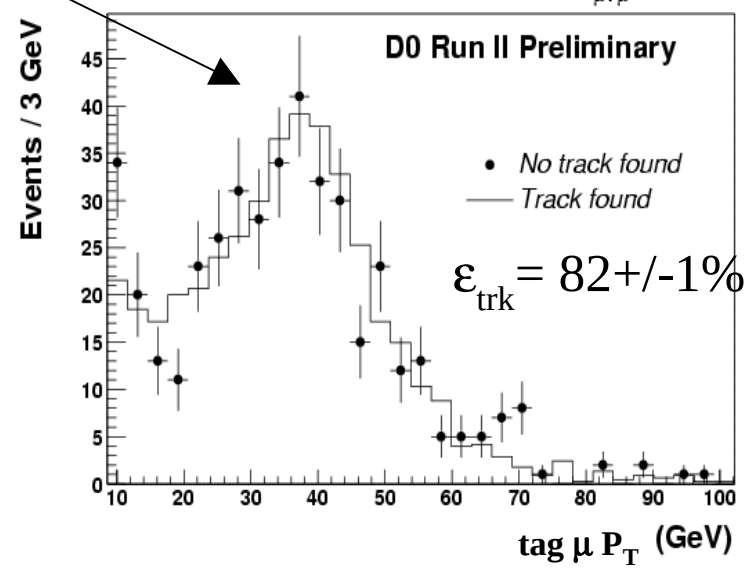
Z

μ_{tag} L1+L2, central track

μ_{probe} L1 OR no L1, track OR no track

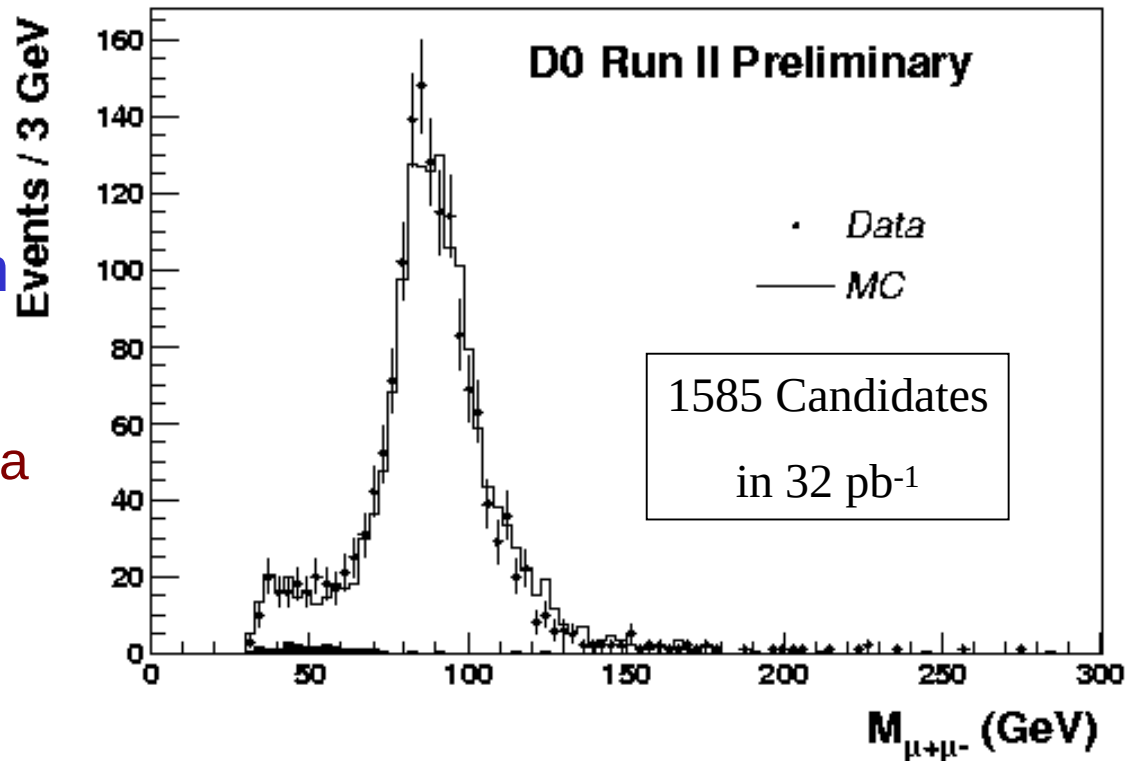






Z Production (Muon Channel)

- Drell-Yan contribution
  - Correct for 12+–1% DY+interference, determined from Pythia (4%, if restricted to 75<M(μμ)<105 GeV)



$$\sigma(Z)\text{x B}(Z \rightarrow \mu\mu) = 264 \pm 7_{Nz} \pm 17_{sys} \pm 26_{lum'y}\ pb$$

D0's first Z→μμ cross section in Run 2!

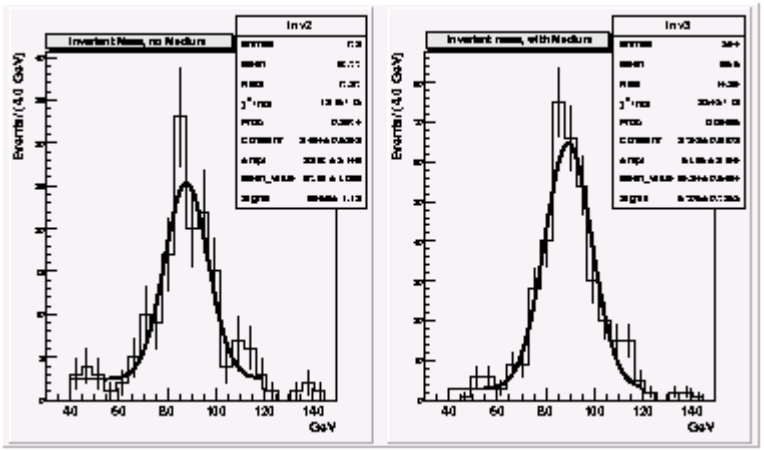
$W \rightarrow \mu\nu$: Data Selection

- Trigger:
  - L1: Scintillator based single muon trigger (no p_T cut)
  - L2: At least one muon with p_T>5 GeV
  - L3: At least one track with p_T>10 GeV

$L=17\ pb^{-1}$

- Offline
  - One isolated muon matched with central track, p_T>20 GeV
  - In fiducial region of the trigger: $|\eta|<1.6$
  - Muon corrected Missing transverse energy > 20 GeV
  - no second muon in event ($Z \rightarrow \mu\mu$ veto)

W→μν: Efficiencies



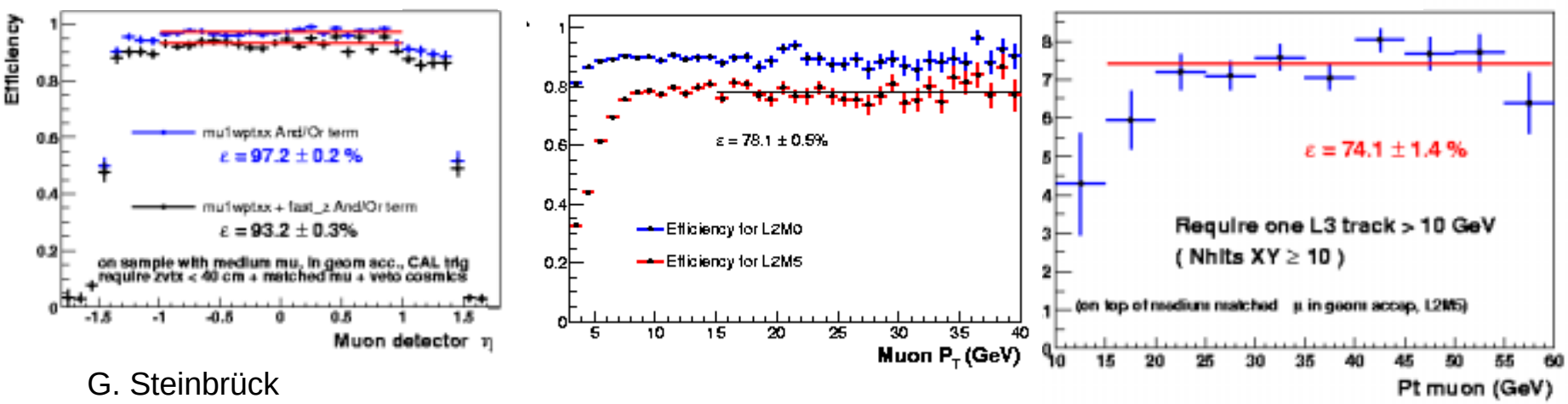
1μ+1 calor only 2μ's

Muon reconstruction efficiency:

From calorimeter Muons (Track + Calor deposit)

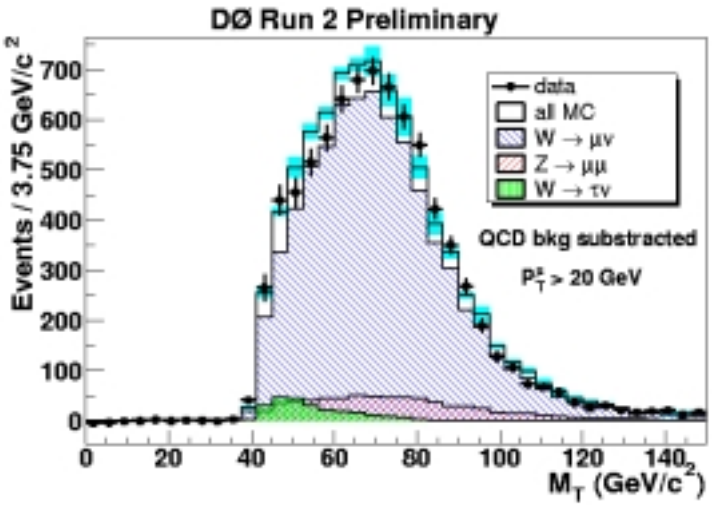
Trigger efficiencies (wrt offline)

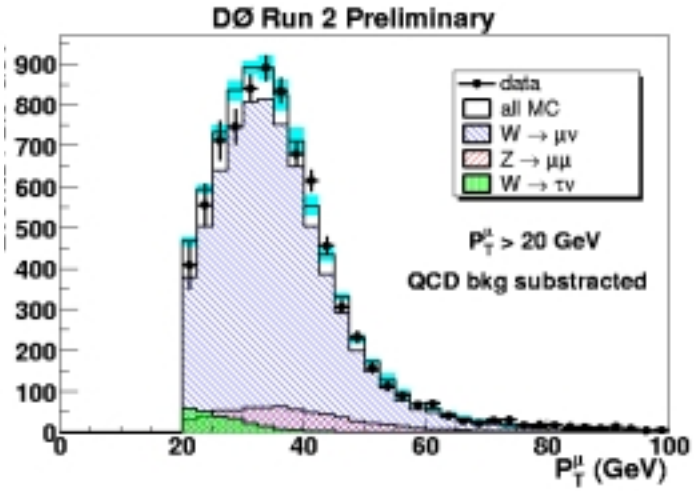
L1 L2 L3



G. Steinbrück

W→μν

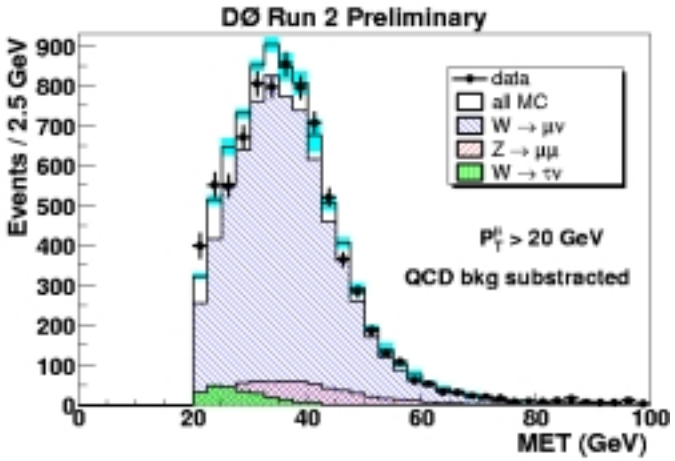




7352 Candidates

in 17 pb^{-1}

QCD background estimated from data.

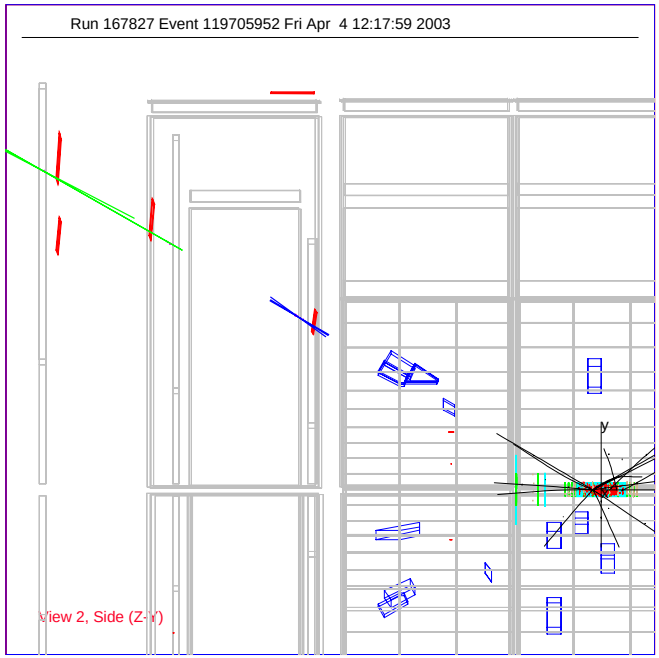


Backgrounds:

- bb, b→μν where μ passes isolation cut
  - 5.8%, subtracted from above distributions
- Other:
  - Z→μμ: ~9%
  - W→τν→μνν: 3.6%

W→μν: Result

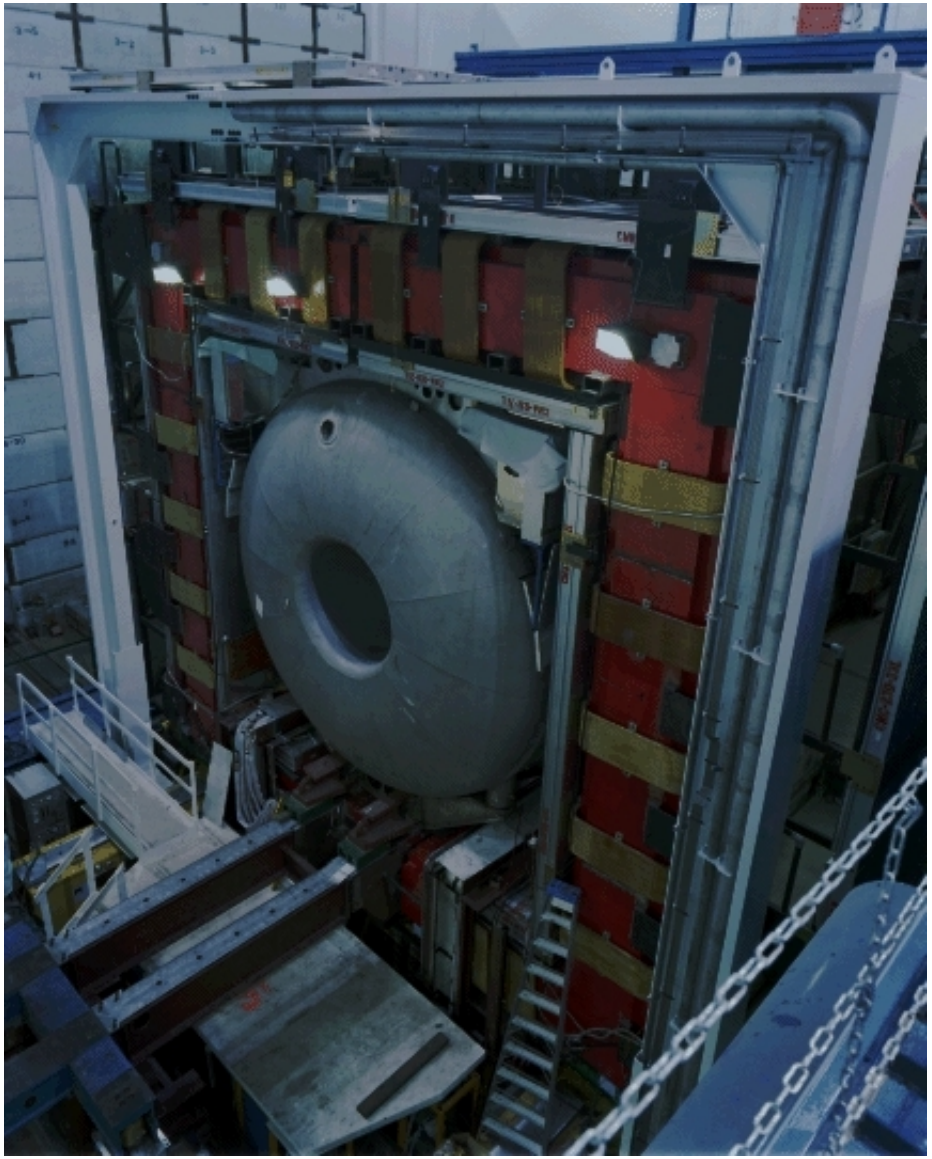
Luminosity for MU_W_L2M5_TRK10	$17.3 \pm 1.7\ pb^{-1}$
Efficiencies ±(stat) ±(sys) (in %)	
Timing cut	99 ± 0.5(stat)
Geometrical acceptance	63.1 ± 0.85(sys)
Pt cut	84 ± 0.2(sys)
medium ID	$74 \pm 2 \pm 1$
L1 trigger	84.7 ± 0.8(stat)
L2 trigger	78.1 ± 0.5(stat)
Tracking/Matching	81.5 ± 0.6(stat)
L3 trigger	74 ± 1(stat)
MET cut	95 ± 1.5(sys)
Veto cut	98.8 ± 0.3(stat)
Total without isolation cut	$14.5 \pm 0.5 \pm 0.4$
isolation cut efficiency	$90.6 \pm 1.4 \pm 0.5$
total efficiency	$13.2 \pm 0.5 \pm 0.3$



$$\sigma(W) \times B(W \to \mu\nu) = 3226 \pm 128_{Nw} \pm 100_{sys} \pm 323_{lum'y}\ pb$$

D0's First W→μν Cross section in Run2!

W/Z→ e: The Calorimeter



- Using Run 1 calorimeter
- Uranium-Liquid Argon
  - stable, uniform response, rad. hard, fine segmentation
- Uniform, hermetic coverage $|\eta| < 4.2$
- Good energy resolution
- New readout electronics to operate in Run 2 environment

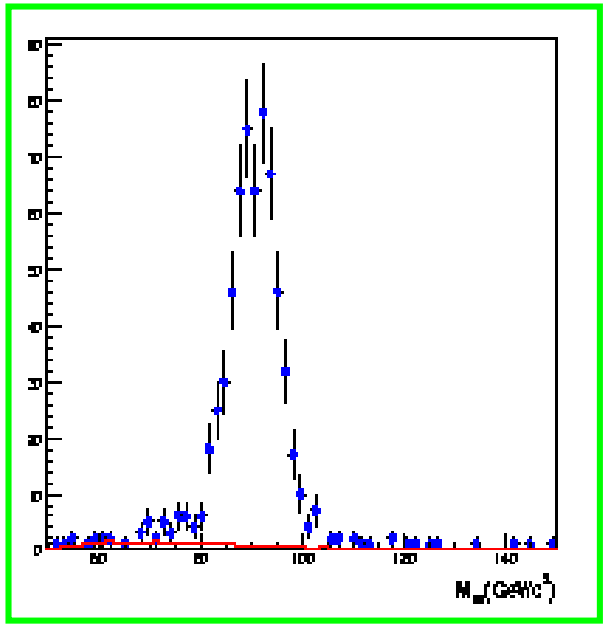
W/Z→e: Event Selection

$L=42\ pb^{-1}$

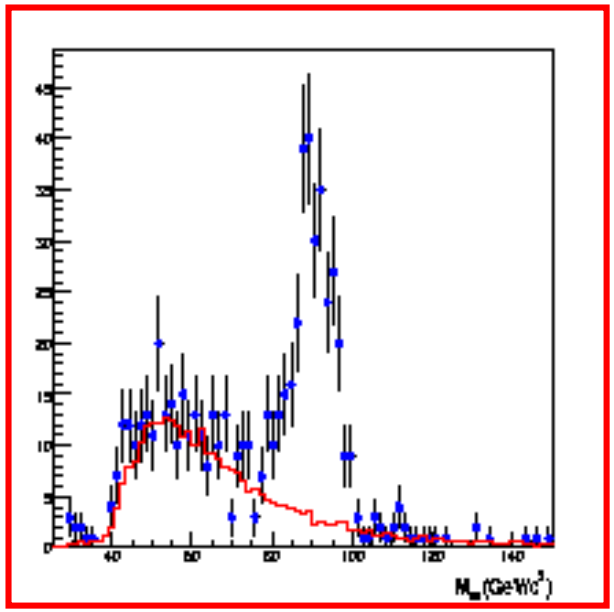
- Trigger:
  - L1: 1 calorimeter tower > 10 GeV (or 2 > 5 GeV)
  - L3: Electron candidate > 20 GeV, shower shape cut
- Electrons:
  - Isolated EM Cluster in the Calorimeter, E_T> 25 GeV with large EM fraction, Shower shape consistent with MC expectation
- W→eν
  - Missing transverse energy > 25 GeV
  - Electron candidates matched with central tracks
- Z→ee
  - 70 GeV < m_{ee} < 110 GeV

Efficiencies

- Estimated from Z→ee events
- Require one tight electron. The second electron can be used as an unbiased probe

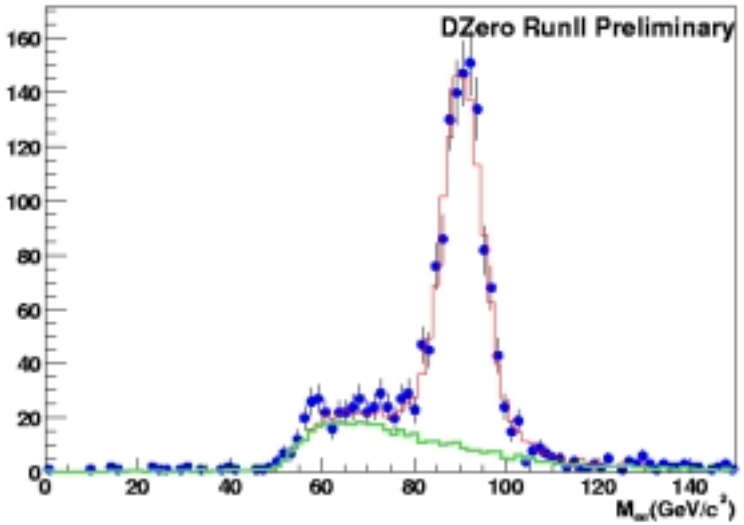


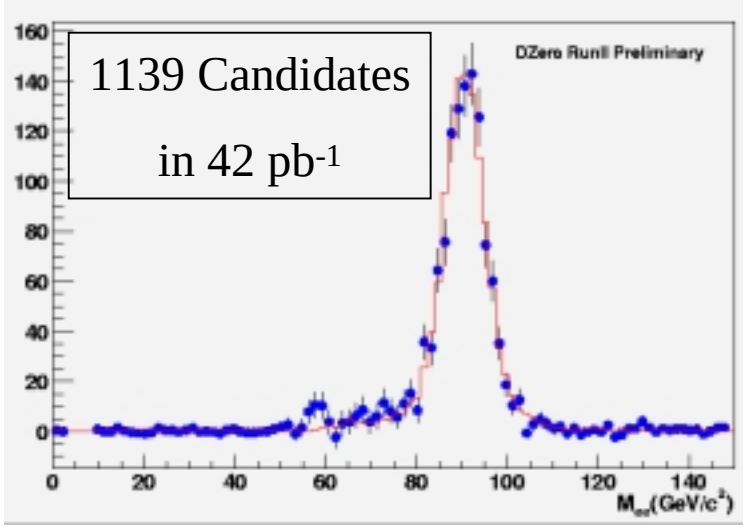
- Efficiencies per electron:
  - Trigger 98+/- 2%
  - EMF, isolation ~100%
  - Shower shape 86+/-1%
  - Tracking + Matching 73+/-2 %



2nd electron passes/fails Shower shape cut

Z→ee





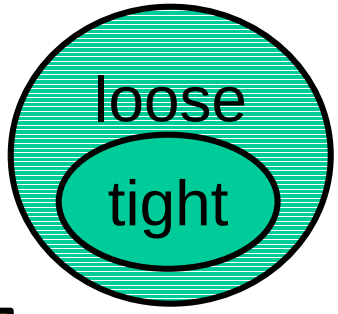
QCD background removed by fitting to signal and background

DY contribution small (1.7%) due to 70 GeV < m_{ee} < 110 GeV

W→eν: Backgrounds

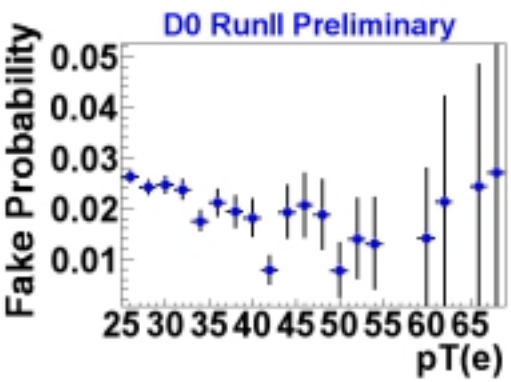
- Dominant background from QCD multijet events
- Estimated from data
- $N_{loose} = N_W + N_b$
- $N_{tight} = N_W \varepsilon_{trk} + N_b \varepsilon_f$

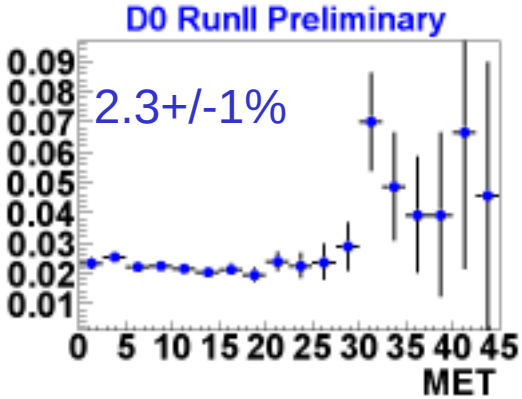
Solve for N_W



tight = loose +track match

From QCD dijet sample

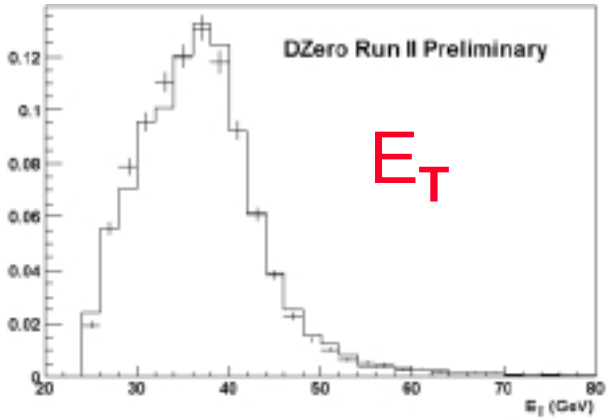


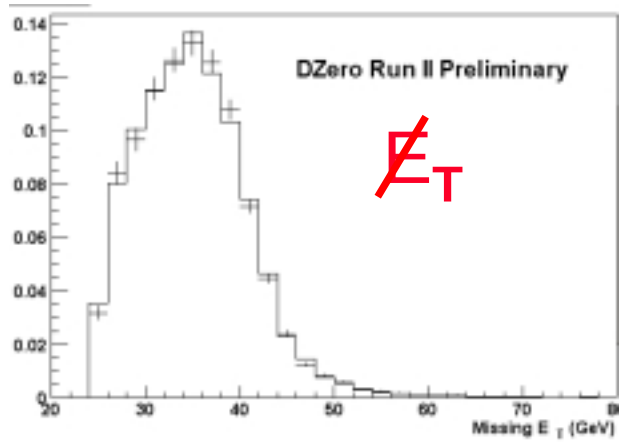


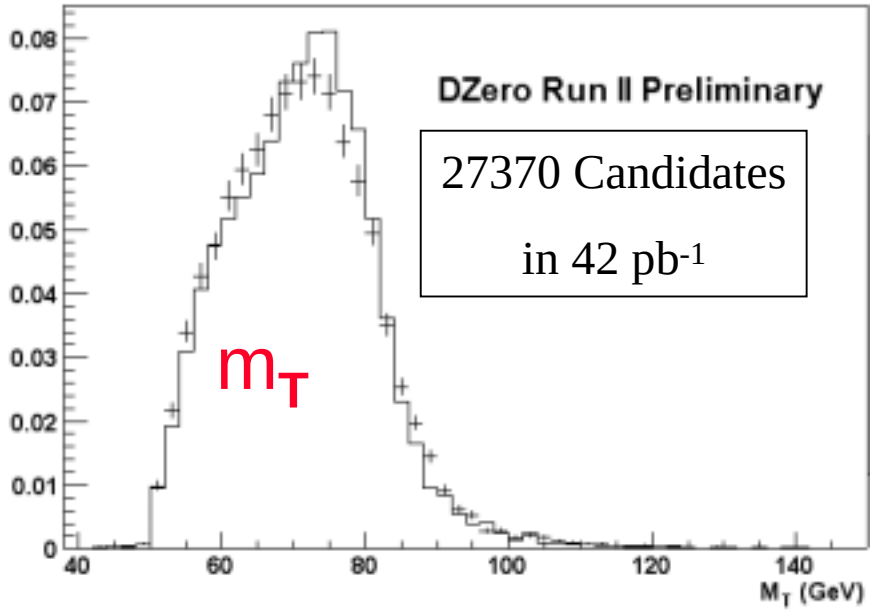
Other backgrounds:

- W→τν→eνν (1.5 %, MC)
- Z→ee (very small)

W→eν: Data versus MC







Agreement between data and MC

We understand the detector and backgrounds

Putting it all together

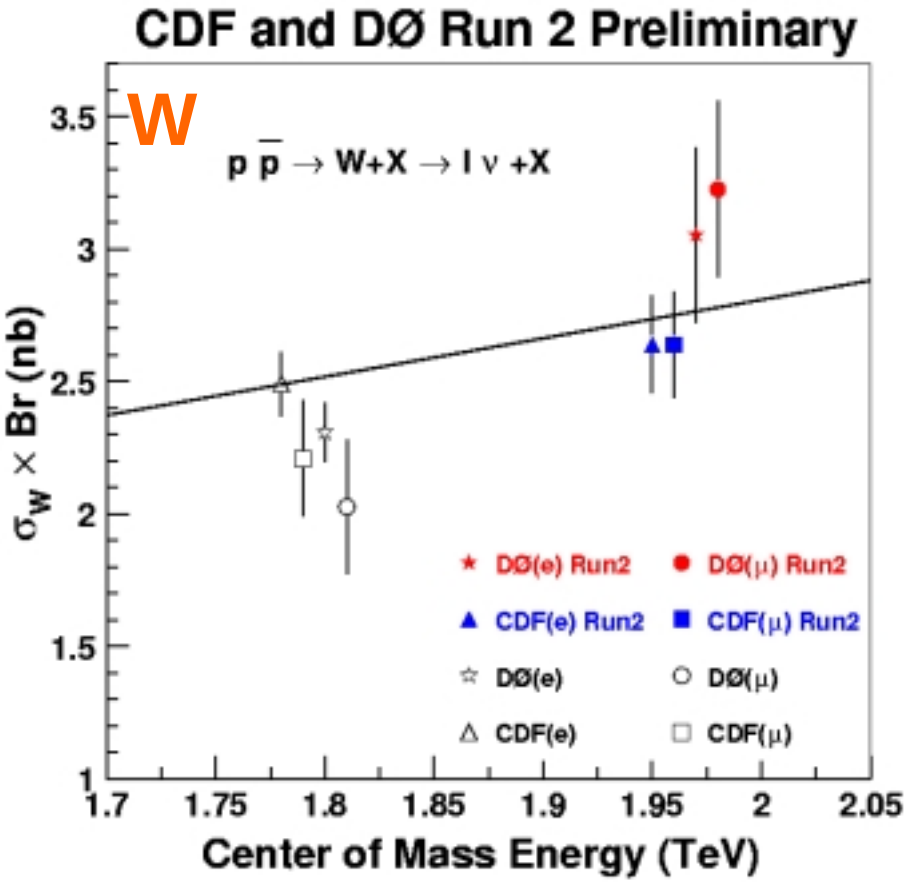
Table of Uncertainties

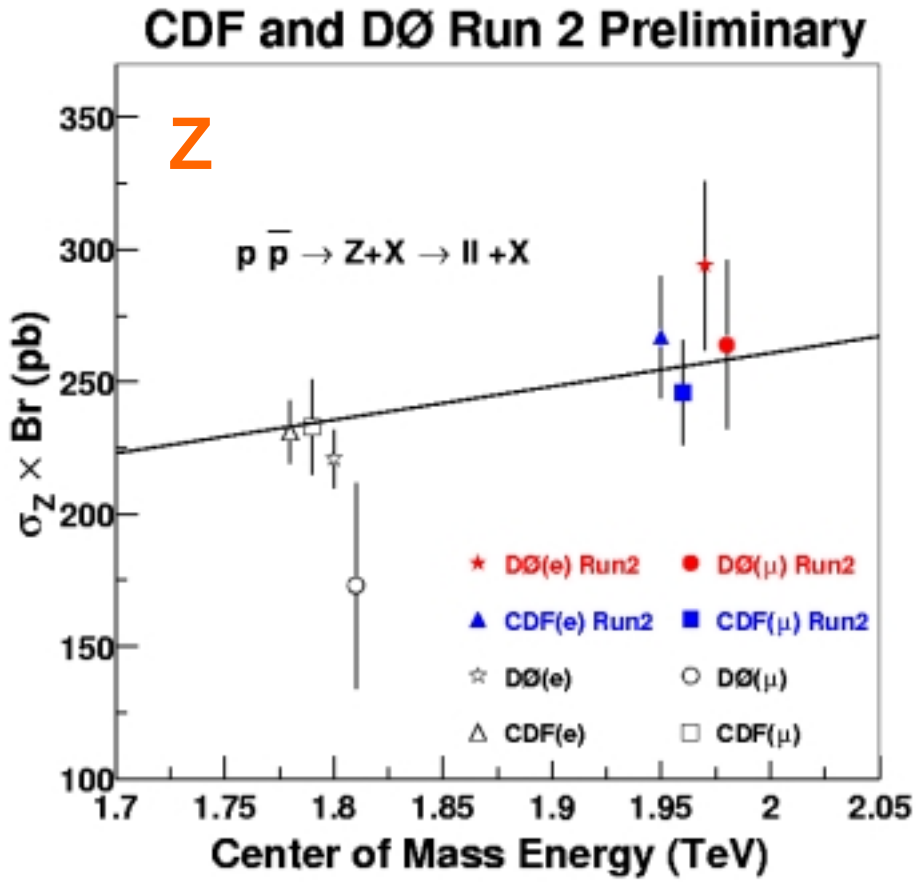
	Value	Uncertainty
Trigger Efficiency	98%	2%
EMID Efficiency	85.6%	1%
Tracking Efficiency	73%	2%
Track Match Fake Probability	2.3%	1%
MC Acceptance: Ws	25.7%	0.4%
MC Acceptance: Zs	12.7%	0.2%
Number of Ws	27370	898
Number of Zs	1139	42
Luminosity	41.6 pb^{-1}	4.16 pb^{-1}

$$\sigma(W)\text{x B}(W \rightarrow e\nu) = 3054 \pm 100_{Nw} \pm 86_{sys} \pm 305_{lum'y}\ pb$$

$$\sigma(Z)\text{x B}(Z \rightarrow ee) = 294 \pm 11_{Nw} \pm 8_{sys} \pm 29_{lum'y}\ pb$$

Results





C. R. Hamberg, W.L. van Neerven and T. Matsuura, Nucl. Phys. B359 (1991) 343

CTEQ4M PDF

Conclusions

- **W and Z cross sections:**
  - Test consistency with SM
  - QCD corrections
  - Sensitive to PDFs
  - W's can and will be used for luminosity determination
  - Benchmark measurements for understanding our detector

- **Four new W and Z cross section measurements**

$$\sigma(\mathrm{Z})\mathrm{x}\ \mathrm{B}(\mathrm{Z} \rightarrow \mu\mu) = 264 \pm 7_{Nz} \pm 17_{sys} \pm 26_{lum'y}\ pb$$

$$\sigma(W)\mathrm{x}\ \mathrm{B}(W \rightarrow \mu\nu) = 3226 \pm 128_{Nw} \pm 100_{sys} \pm 323_{lum'y}\ pb$$

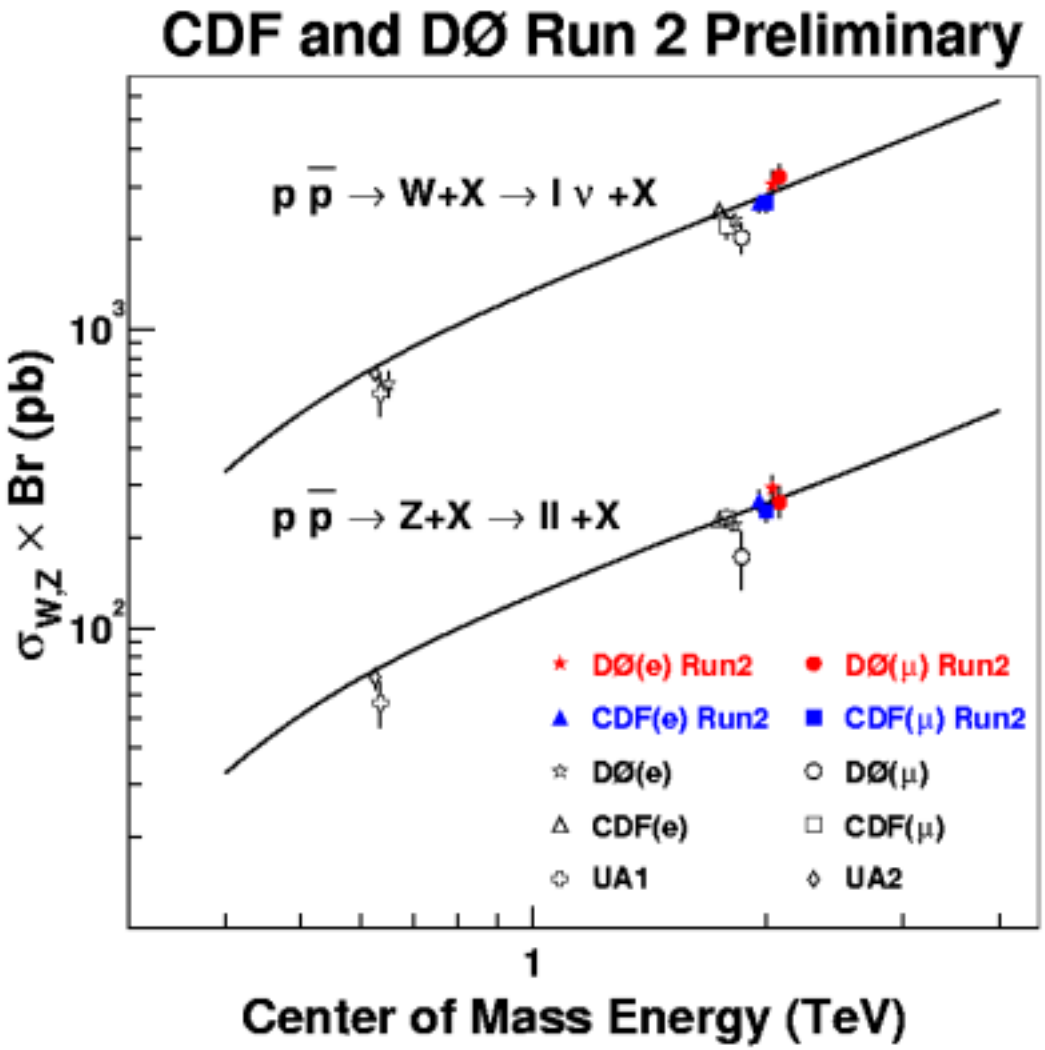
$$\sigma(\mathrm{Z})\mathrm{x}\ \mathrm{B}(\mathrm{Z} \rightarrow ee) = 294 \pm 11_{Nz} \pm 8_{sys} \pm 29_{lum'y}\ pb$$

$$\sigma(W)\mathrm{x}\ \mathrm{B}(W \rightarrow e\nu) = 3054 \pm 100_{NW} \pm 86_{sys} \pm 305_{lum'y}\ pb$$

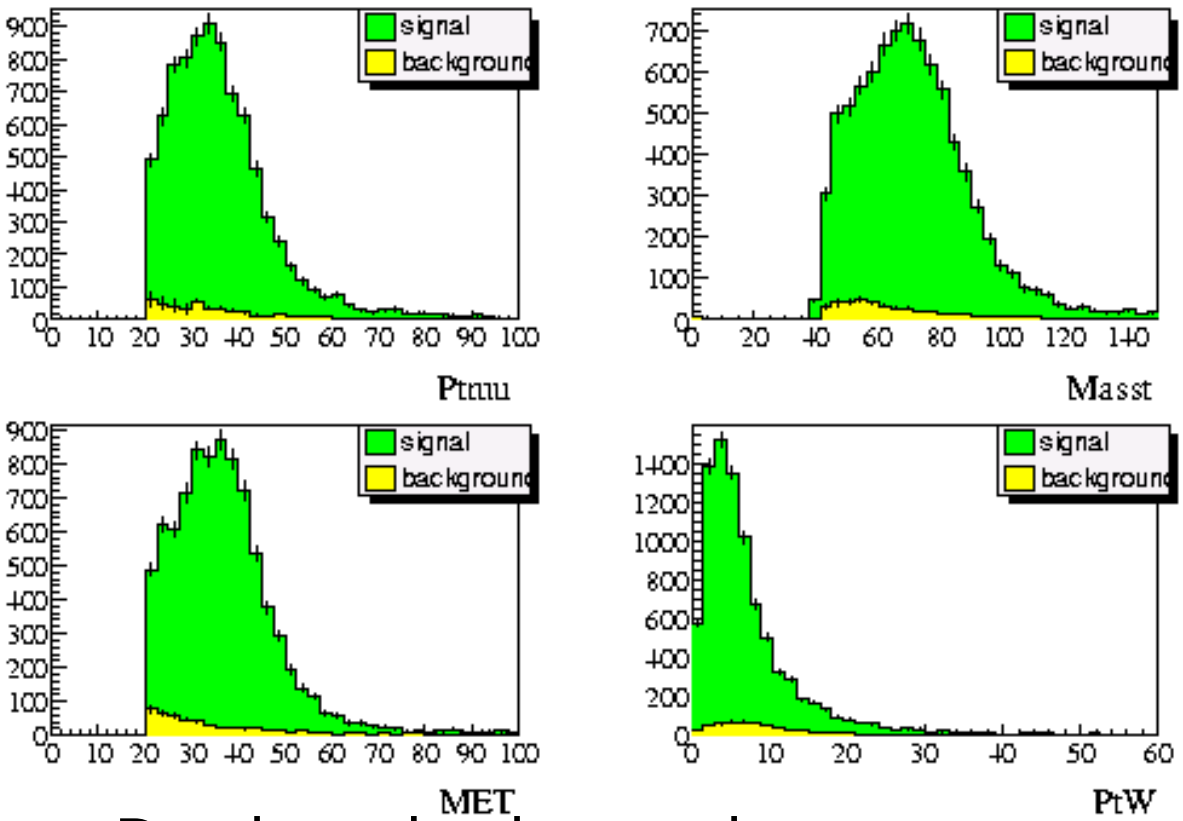
- **D0's first Run2 W/Z CS measurement in the Muon channel!**

Spares

Results


CDF and DØ Run 2 Preliminary
p p̄ → W+X → l ν +X
p p̄ → Z+X → ll +X
σW,Z × Br (pb)
10^3
10^2
1
Center of Mass Energy (TeV)
DØ(e) Run2
DØ(μ) Run2
CDF(e) Run2
CDF(μ) Run2
DØ(e)
DØ(μ)
CDF(e)
CDF(μ)
UA1
UA2

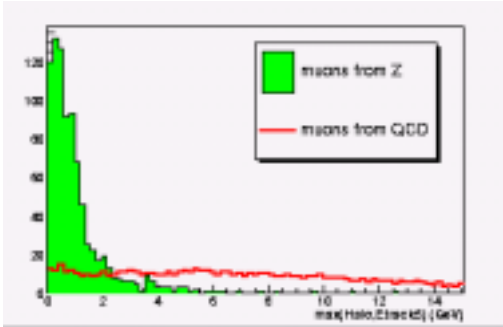
W→μν



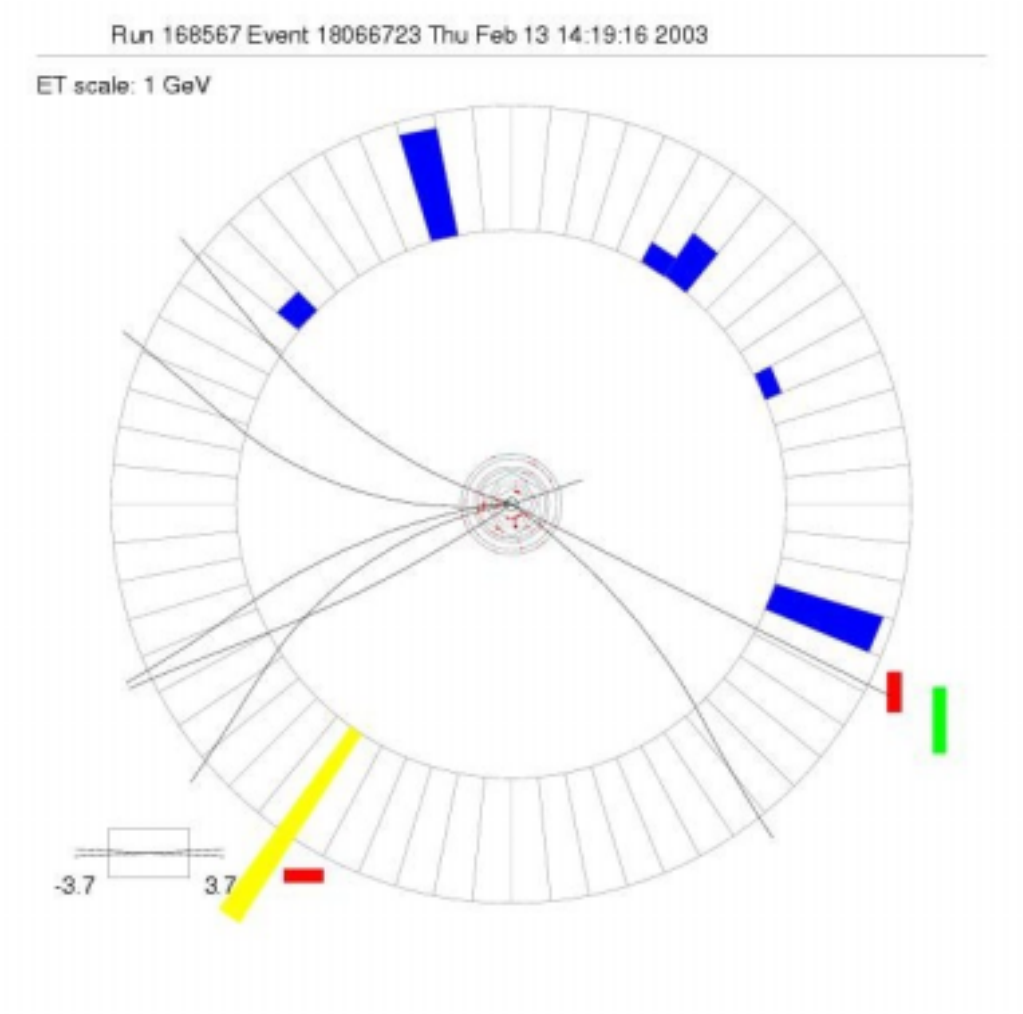
Background estimated from data.

Dominant background:

- bbar, b→μν events where the muon passes isolation cuts



W→μν


Run 168567 Event 18066723 Thu Feb 13 14:19:16 2003
ET scale: 1 GeV
-3.7
3.7