Inclusive W/Z Production at DØ

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for the DØ collaboration

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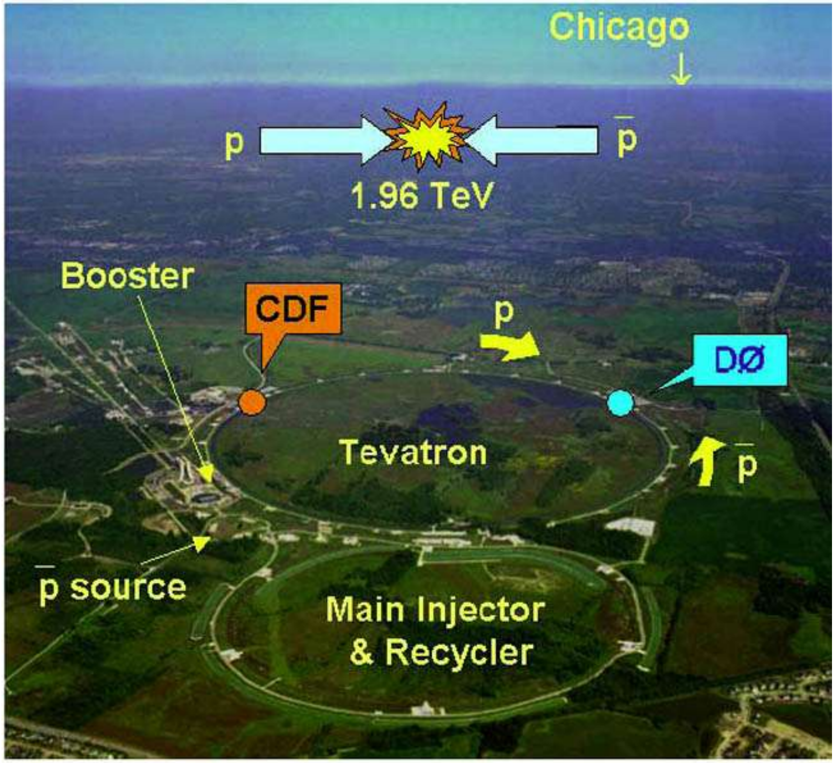
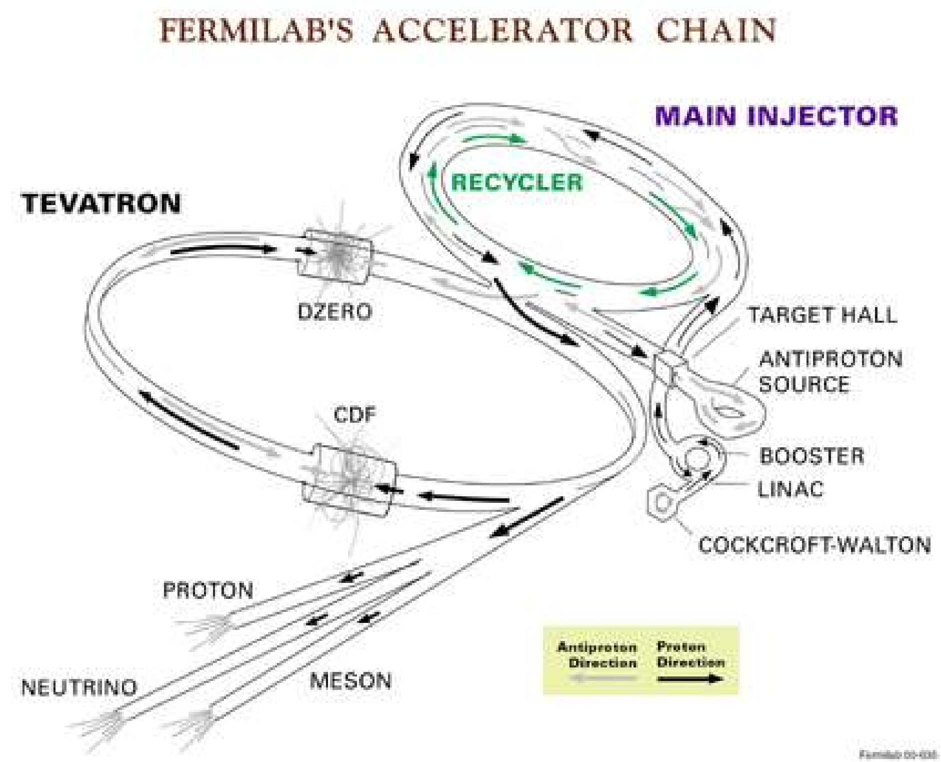
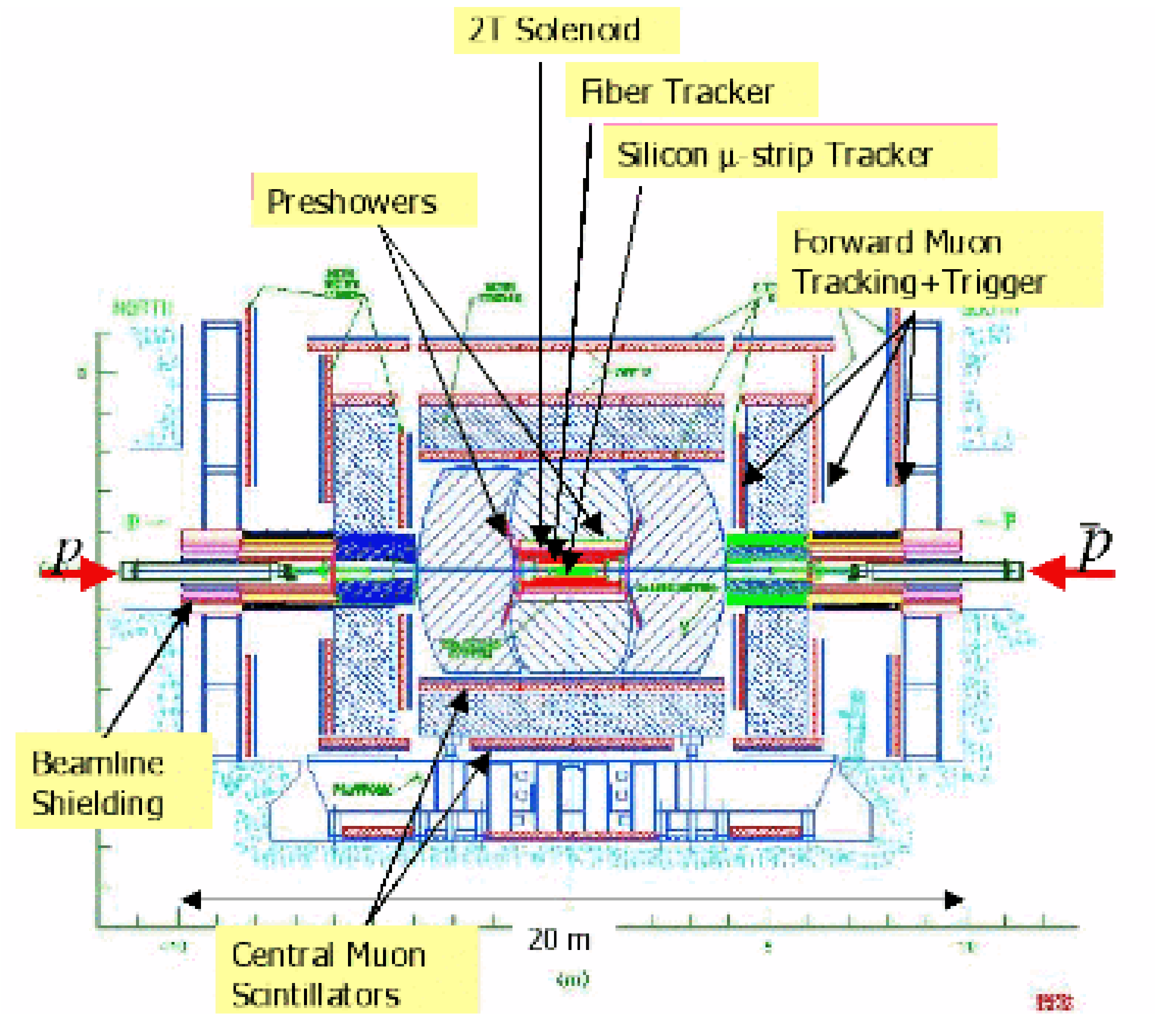
Tevatron Collider





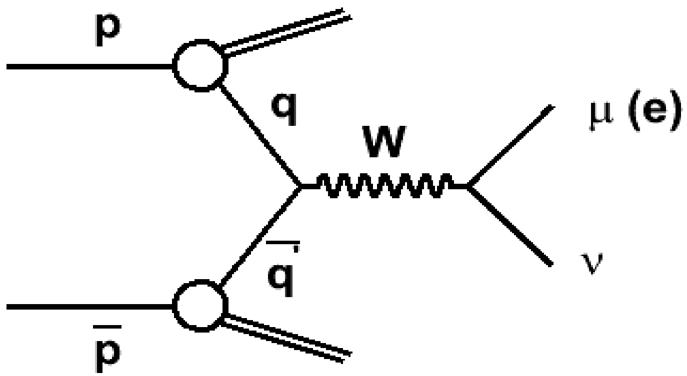
- Located at Fermilab, Batavia, Illinois
- Proton – antiproton interactions
- World's highest center of mass energy $\sqrt{s} = 1.96\,\text{TeV}$

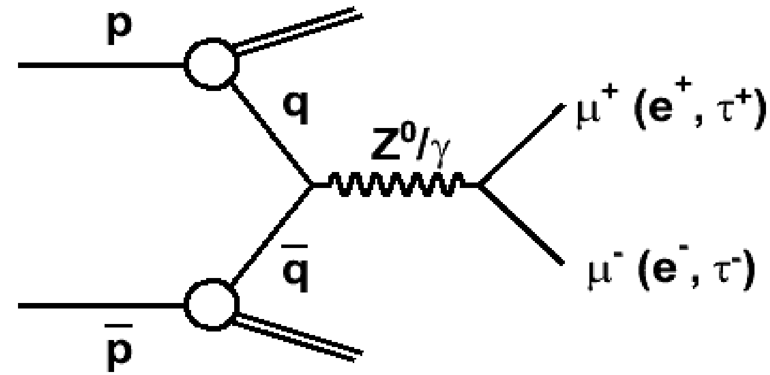
DØ Run II Detector Overview



- Tracking system:
  - Silicon microstrip tracker
  - Central fiber tracker
- Superconducting 2T solenoid
- EM and hadron calorimeter
  - Central calorimeter
  - 2 end calorimeters
- Muon system:
  - Central muon system: scintillation counters and proportional drift tubes
  - Forward muon system: scintillation counters and mini drift tubes
  - 1.8T toroids

- Excellent angular coverage
  - Muon system: $|\eta| < 2$
  - Tracking system: $|\eta| < 3$
  - Calorimeter: $|\eta| < 4$





- Cross section:

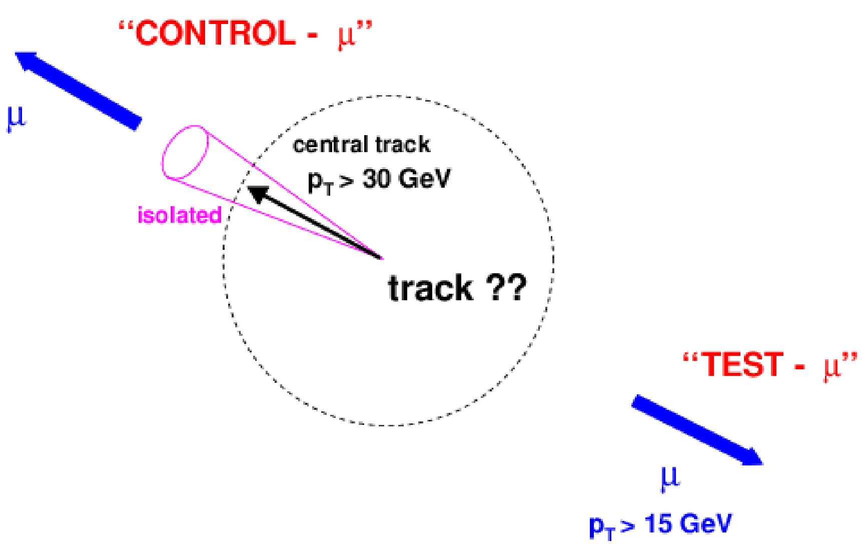
$$\sigma = \frac{N - N_{backg}}{\varepsilon \cdot A \cdot \int L \cdot dt}$$

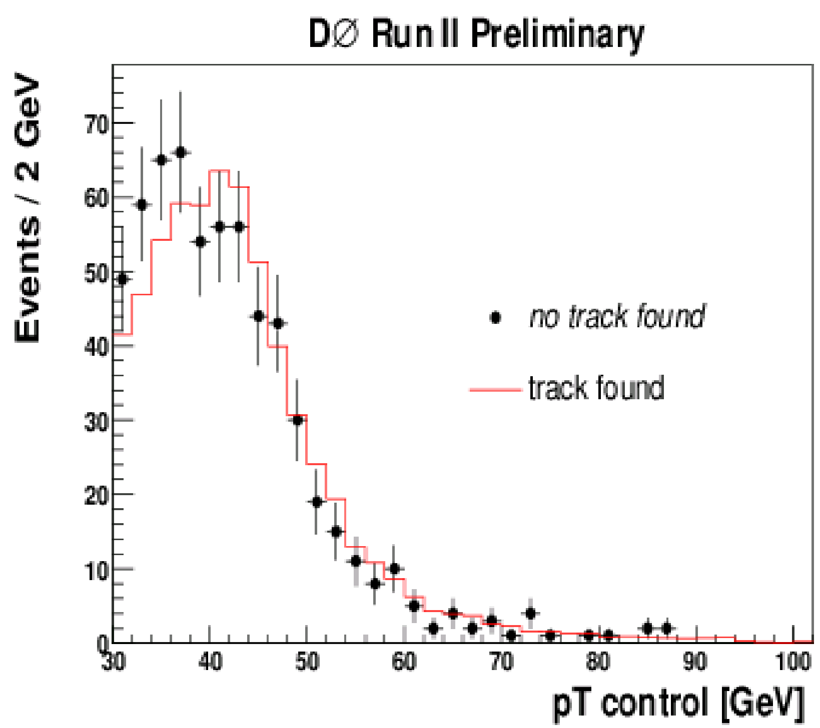
- N - number of selected events, that passed all cuts
- N_{backg} - number of background events
- $\varepsilon \cdot A$ – efficiencies × acceptance for the specific process
- $\int Ldt$ - data sample integrated luminosity

- Reasons for choosing lepton final states:
  - Clean and well known signals
  - Comparison of the experiment with the Standard Model predictions
  - Can be used to cross check the luminosity measurements
- Experimental uncertainties:
  - Luminosity ~ 6 %
  - Parton distribution functions (PDF) ~1.5 %
  - Others (lepton identification, Z statistics, …) ~1%

Central Tracker Efficiency

- Use $Z \rightarrow \mu^+\mu^-$ events to study muon detection efficiencies
- Select di-muon events with only one of the muons required to have central tracker track match:
  - "Control muon": isolated high P_T(>30GeV) muon with central track match
  - "Test muon": reconstructed in muon detectors high P_T^{local}(>15GeV) muon with ("efficient") or w/o ("inefficient") central track match

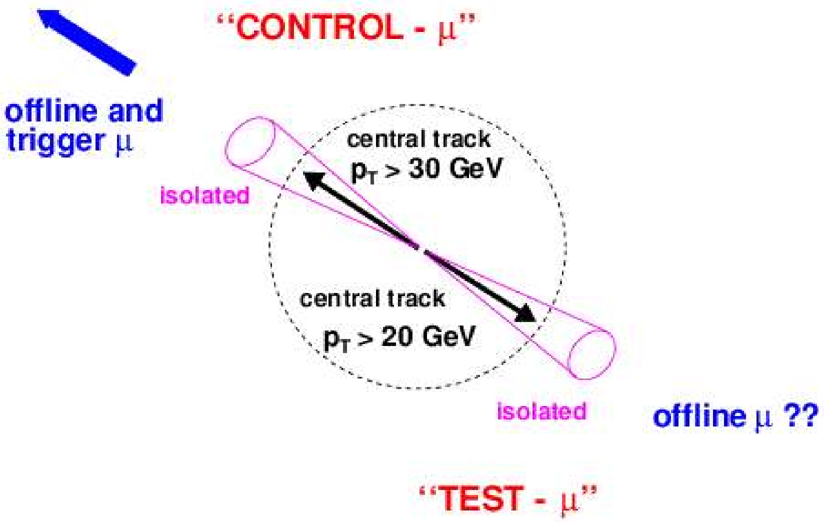


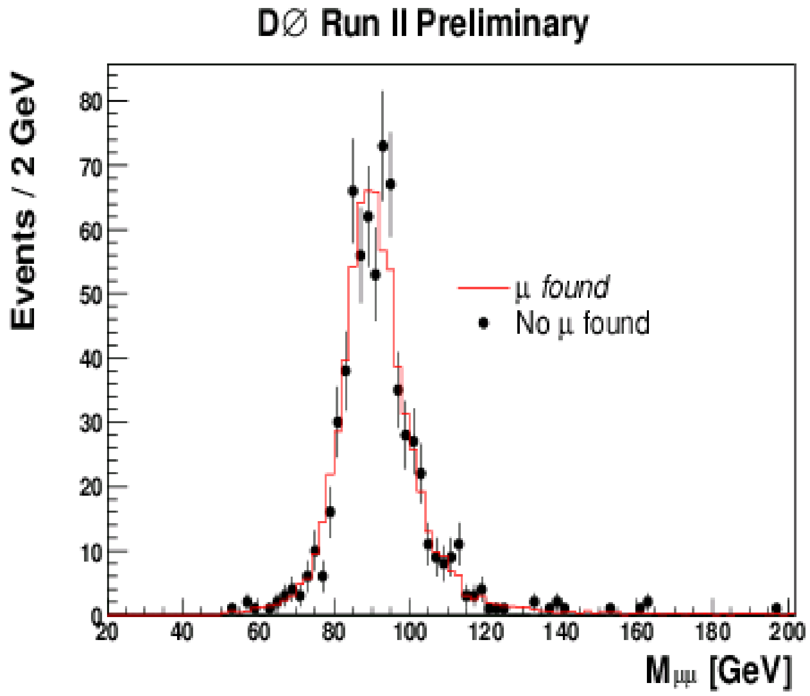


- Central tracker efficiency:

$$\epsilon_{track} = N_{efficient} / N_{total} = 0.950 \pm 0.002$$

- Trigger on and select di-muon events requiring one of the muons to fire the trigger and to be reconstructed in the muon detectors:
  - "Control muon": isolated high P_T(>30GeV) muon that fired single muon trigger and has central tracker and muon detectors track match
  - "Test muon": high P_T(>20GeV) isolated central tracker track. If it has matching muon track and satisfies muon identification requirements it is called "efficient"



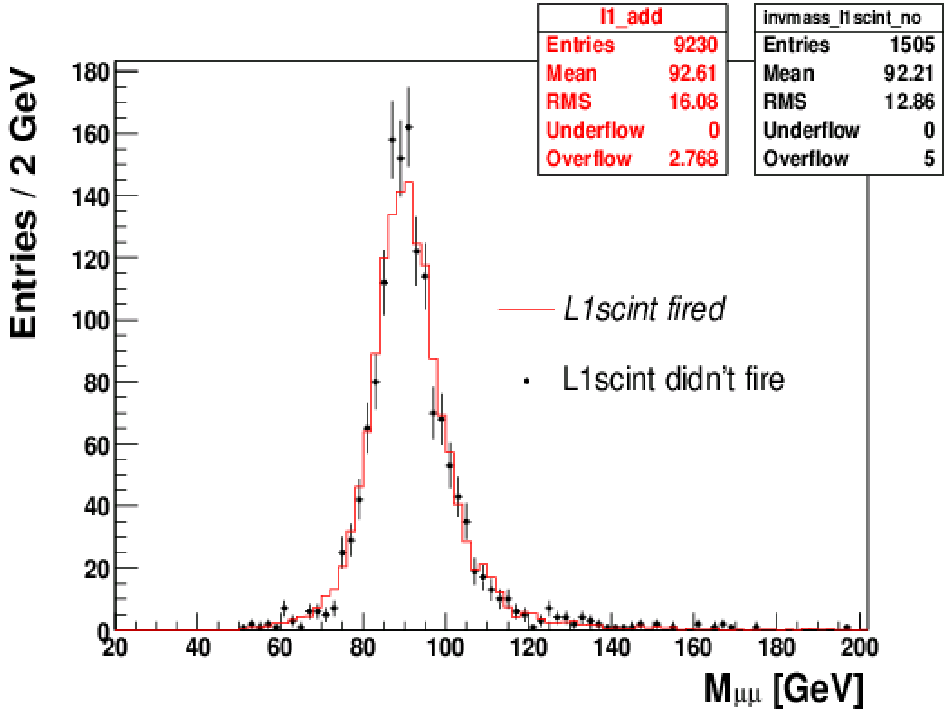


- Muon identification efficiency:

$$\epsilon_{ID} = N_{efficient} / N_{total} = 0.939 \pm 0.002$$

Muon Trigger Efficiency

- For the trigger efficiency measurements events passing all selection criteria except different trigger requirements are used
- "Control muon" isolated high P_T(>30GeV) muon that fired single muon trigger and has central tracker and muon detectors track match
- "Test muon" must pass identification and trigger requirements
- 3 trigger levels at DØ:
  - Level 1 trigger – requires hits in muon detectors
  - Level 2 trigger – preliminary track fit using muon detectors
  - Level 3 trigger – final track fit matching muon detectors track and central tracker track

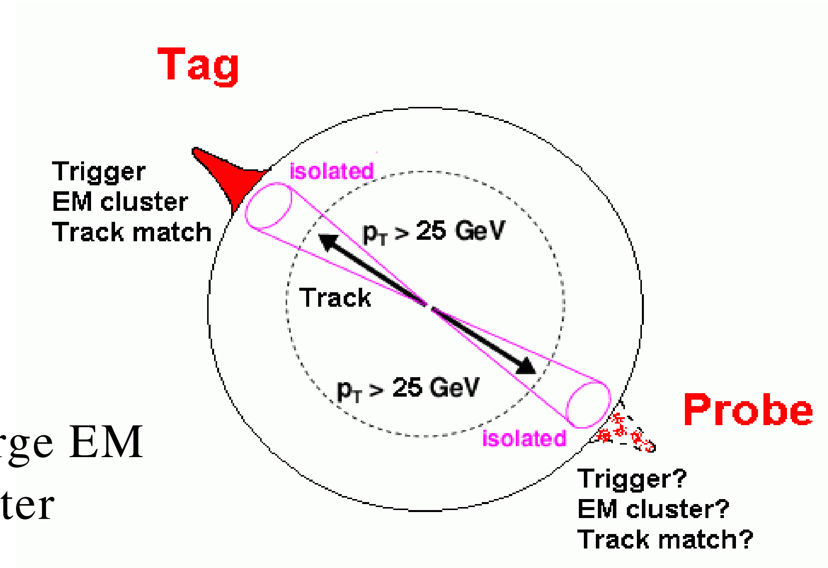


- Muon detection efficiencies summary table

Efficiency of	ε
Muon Tracking	0.950±0.002
Muon ID	0.939±0.002
Trigger	0.458±0.003

Electron Detection Efficiencies

- Use $Z \to e^+e^-$ events to measure electron detection efficiencies
- Efficiencies:
  - Trigger
  - EM cluster identification
  - Track matching

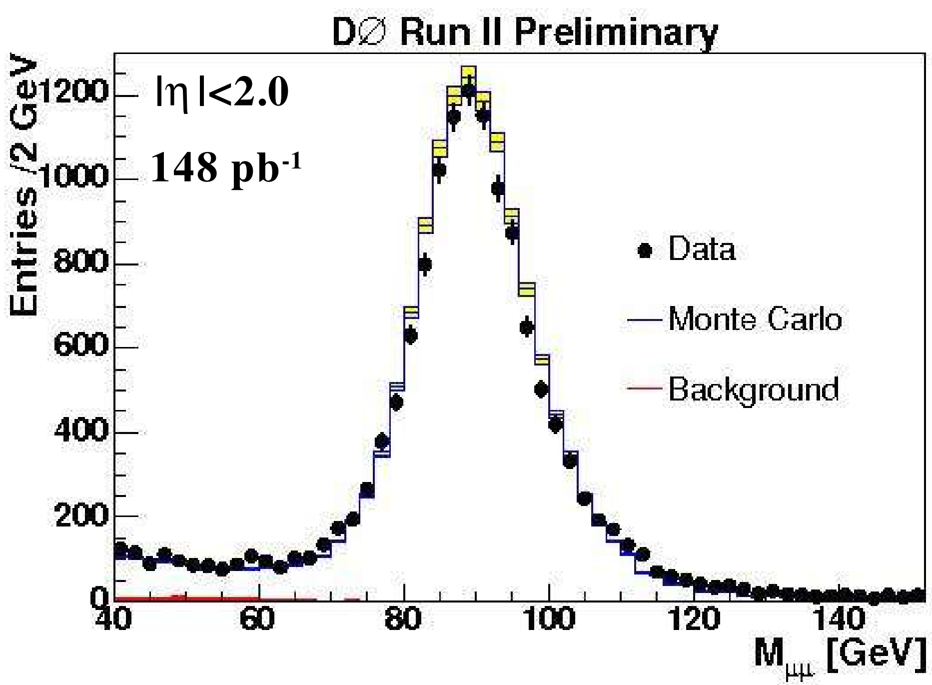


- Efficiencies are measured using a "tag-probe" method:
  - The tag-"tight electron"-**(a)** high P_T(>25GeV) isolated electron that passes shower shape requirements, has large EM Fraction(>0.9) and **(b)** a track matched to the calorimeter cluster, fires single EM triggers
  - The probe-"loose electron" (Tag **(a)** properties)

- Apply cut related to the efficiency under study to the probe electron; the event is "efficient" if the probe passes cuts
- Electron detection efficiencies summary table:

Efficiency of	ε, central calorimeter	ε, end calorimeters
Trigger	0.980±0.004	0.939±0.010
EM cluster ID	0.907±0.003	0.870±0.006
Track Matching	0.774±0.004	0.721±0.008

$Z \to \mu^+\mu^-$: Events Selection and Cross Section



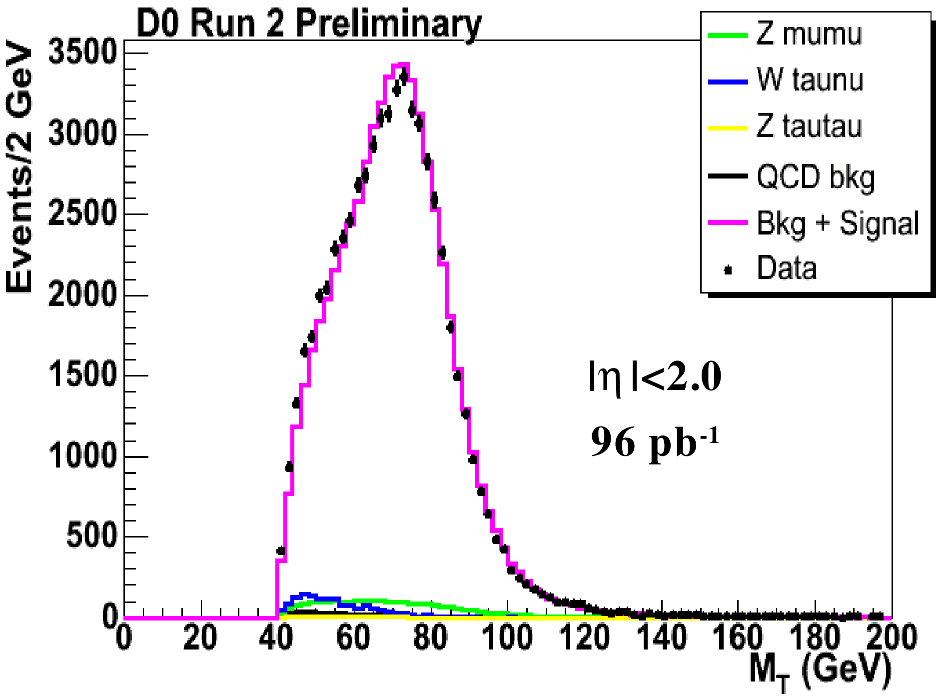
- Data sample: 148pb^{-1}
- Requirements: 2 isolated opposite charged muons with P_T>15 GeV, firing single or di-muon trigger, $M_{\mu\mu}$>40GeV
- $\varepsilon \cdot A$ ~23%
- Backgrounds ~1 % (QCD, $Z \to \tau\tau$...)
- Main systematic uncertainties: efficiencies ~1%,Drell Yan correction ~1.5%, PDF ~1.5 %

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

After all selection cuts 14352 candidates are observed

$\sigma(Z \to \mu^+\mu^-) = 291.3 \pm 3.0(stat) \pm 6.9(sys) \pm 18.9\ (lumi)\ pb$

$W \to \mu\nu$: Events Selection and Cross Section

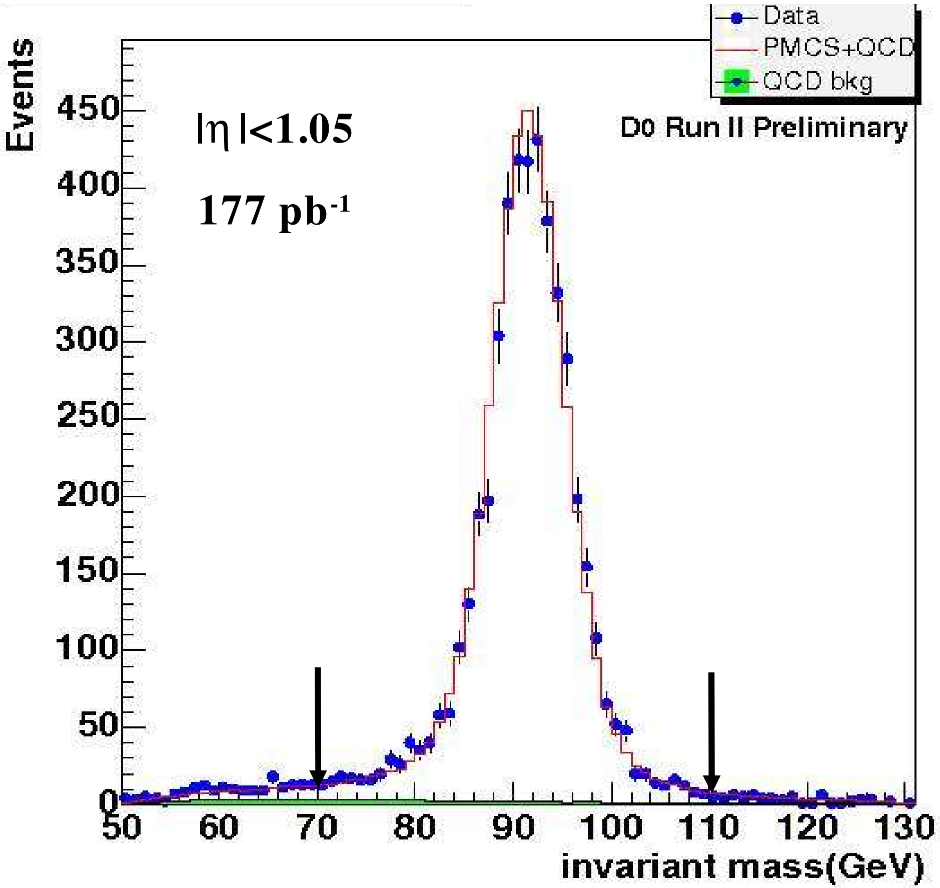


- Data sample: $96 pb^{-1}$
- Requirements: isolated muon with $P_T > 20$ GeV, firing single muon trigger, event $\not{E}_T > 20$GeV, $\mu\nu$ transverse mass $M_T > 40$GeV
- $\varepsilon \cdot A \sim 20\%$
- Main backgrounds: QCD ~1%, $W \to \tau\nu$ and $Z \to \mu\mu$ ~6%
- Main systematic uncertainties: PDF ~1.5%, efficiencies ~1.5%

After all selection cuts 62285 candidates are observed

$$\sigma(W \to \mu\nu) = \mathbf{2989 \pm 15(stat) \pm 81(sys) \pm 194\ (lumi)\ pb}$$

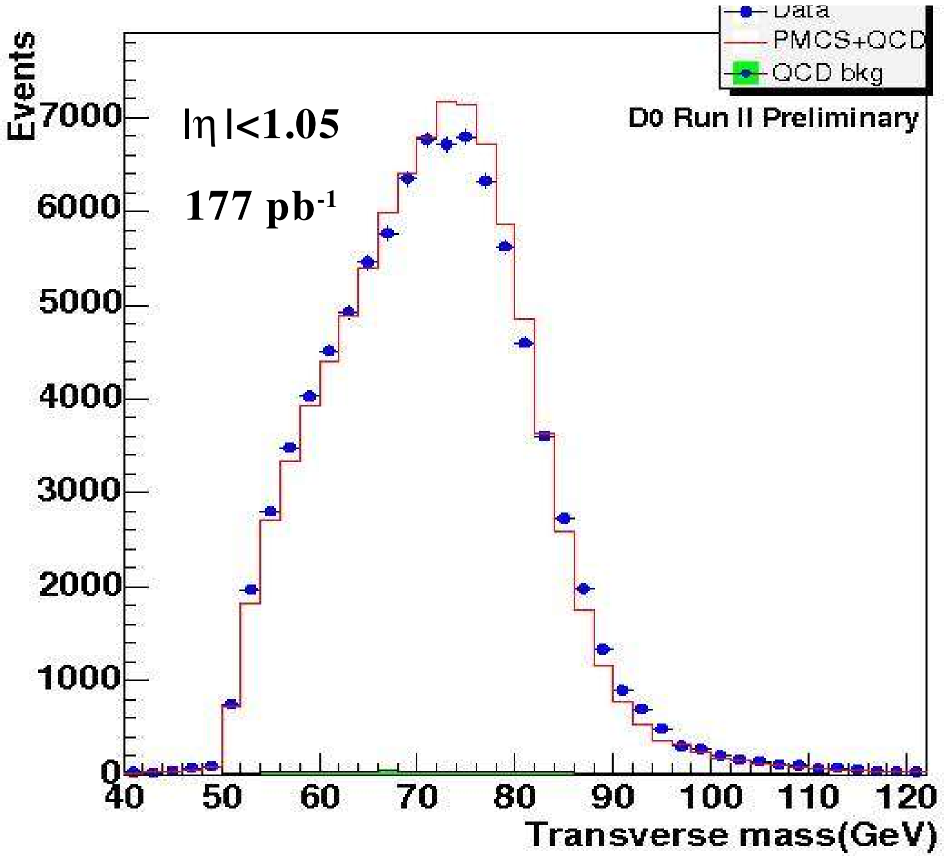
$Z \rightarrow e^+e^-$: Events Selection and Cross Section



- Data sample: 177pb^{-1}
- Requirements: 2 electrons with E_T > 25 GeV, one of electron candidates must fire single EM trigger
- 70GeV<M_{ee}<110GeV
- $\varepsilon \cdot A$ ~19%
- Main background: QCD ~2%, $W \rightarrow \tau\nu$ ~1%
- Main systematic uncertainties: PDF ~1.5%, electron identification ~2%

After all selection cuts 4712 candidates are observed

$$\sigma(Z \rightarrow e^+e^-) = \mathbf{264.9 \pm 3.9(stat) \pm 9.9(sys) \pm 17.2\ (lumi)\ pb}$$



- Data sample: $177 pb^{-1}$
- Requirements: electron with $E_T > 25$GeV (central) or $E_T > 20$GeV(forward) firing trigger with calorimeter EM objects requirement; event $\not{E}_T > 25$GeV
- $\varepsilon \cdot A \sim 22\%$
- Main background: QCD ~2%, $W \rightarrow \tau\nu$ and $Z \rightarrow ee$ ~2%
- Main systematic uncertainties: PDF ~1.0%, electron identification ~1.5%

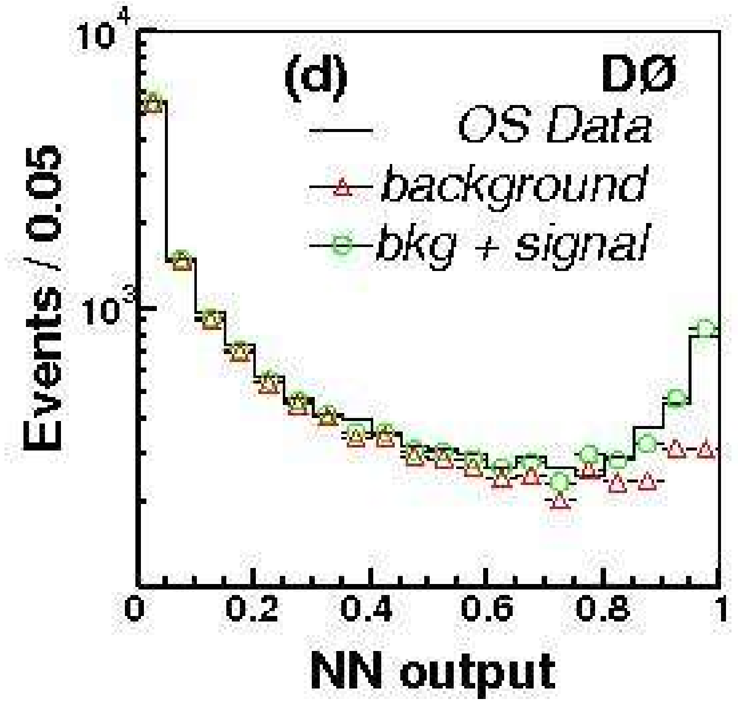
After all selection cuts 116569 candidates are observed

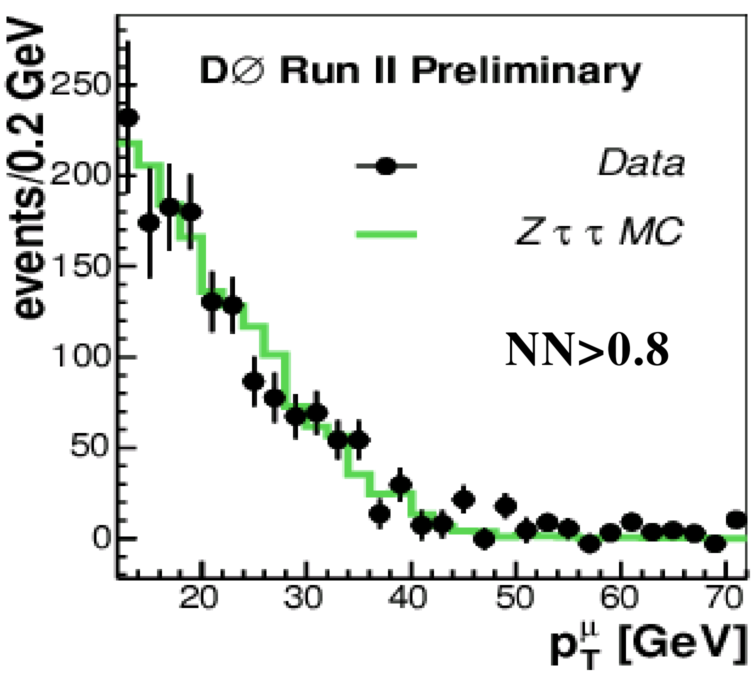
$$\sigma(W \rightarrow e\nu) = 2865 \pm 8.3(stat) \pm 63(sys) \pm 186\ (lumi)\ pb$$

$Z \rightarrow \tau^+\tau^-$: Events Selection and Cross Section

• $Z \rightarrow \tau\tau$ events selection: one τ decays into isolated muon with P_T>12GeV back to back with:

1. τ "π like": one track + calorimeter cluster (no EM subclusters)
2. τ "ρ like": one track + calorimeter cluster + EM subclusters
3. 2 or 3 tracks consistent with tau mass and a calorimeter cluster

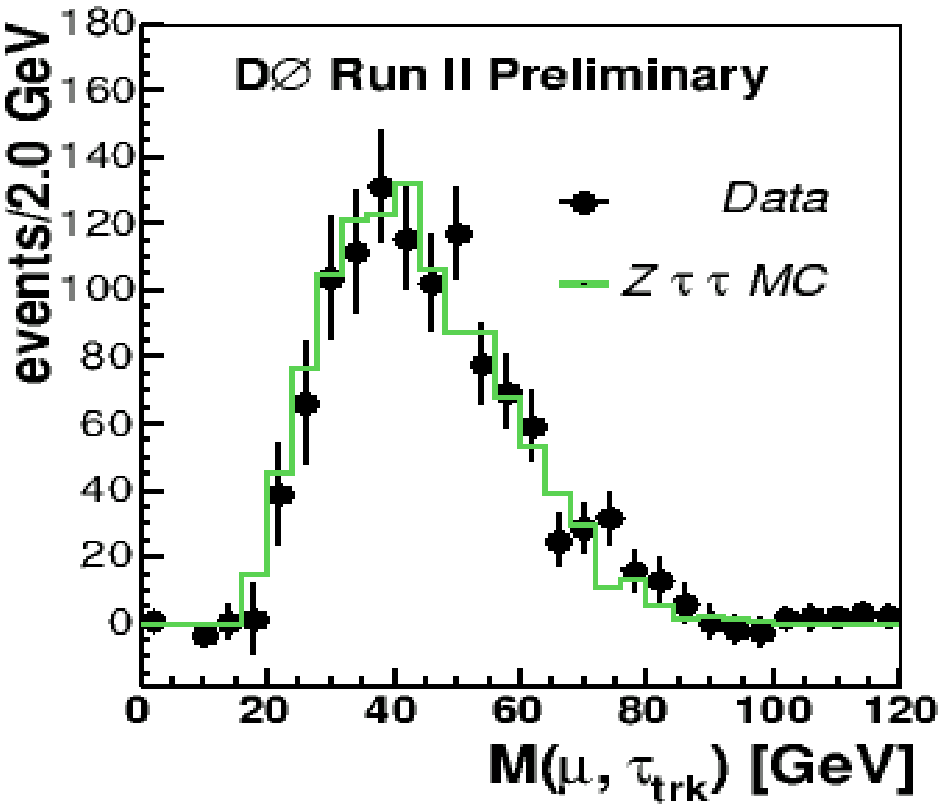




• τ types are identified using Neural Networks

- Single input layer with 8 variables, single hidden layer and single output
- Use 8 various calorimeter and tracking parameters to identify τ decay
- Train NN on $Z \rightarrow \tau\tau$ MC (signal) and **jet+μ** (background)

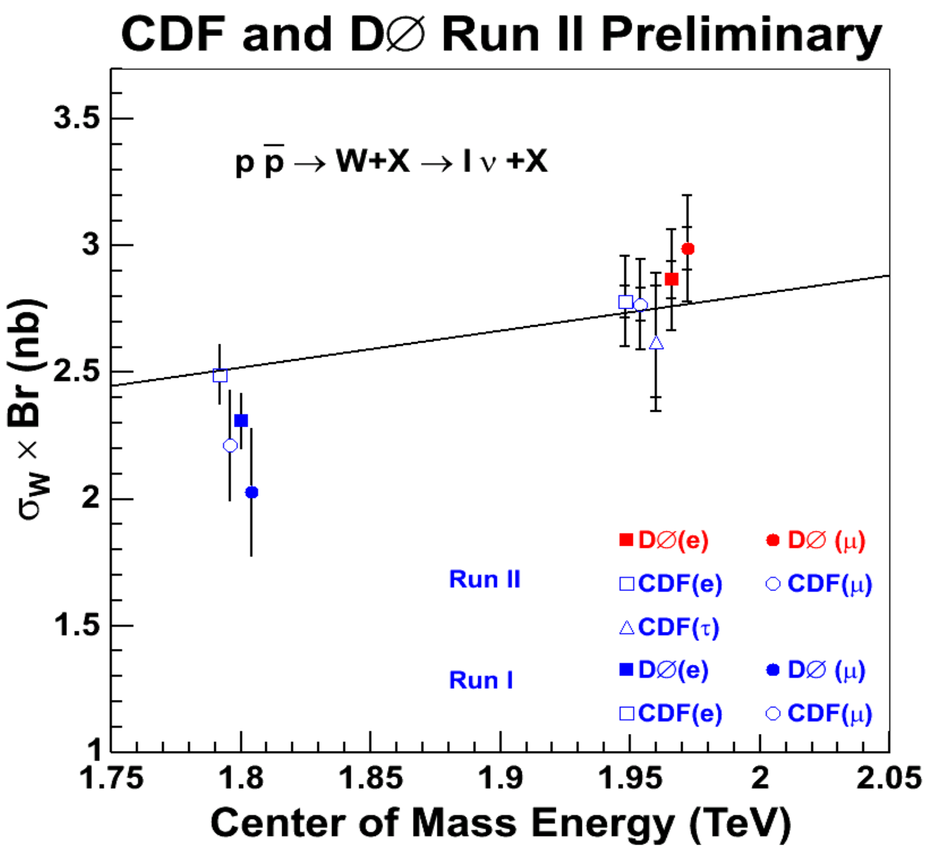
$Z \rightarrow \tau^+\tau^-$: Events Selection and Cross Section

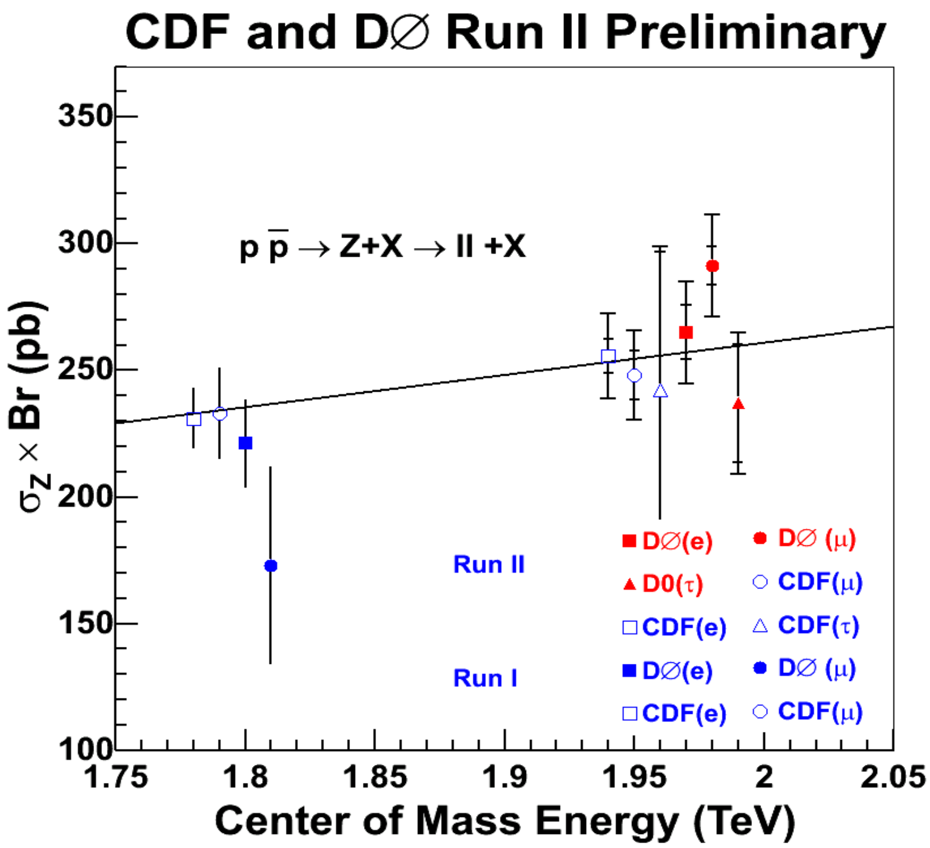


- Data sample: $226 pb^{-1}$
- Requirements: isolated muon with P_T>12GeV and tau candidate
- $\varepsilon \cdot A$~1.5%
- Main background: QCD ~ 49%, $W \rightarrow \mu\nu$ and $Z \rightarrow \mu\mu$ ~6 %
- Main systematic uncertainties: trigger ~3.5 %, QCD background ~3.5%

After all selection cuts 2008 candidates are observed

$$\sigma(Z \rightarrow \tau^+\tau^-) = \mathbf{237 \pm 15(stat) \pm 18(sys) \pm 15\ (lumi)\ pb}$$





- Within errors both W and Z cross sections are in agreement with Standard Model predictions: C.R. Hamberg, W.L van Neerven and T. Matsuura, Nucl. Phys. B359, 343 (1991)

Conclusions

- DØ Run II W/Z cross sections summary table:

Decay mode	Integrated luminosity, pb^{-1}	Cross section, pb
$Z \to \mu^+\mu^-$	148	$291.3 \pm 3.0(stat) \pm 6.9(sys) \pm 18.9$ (lumi)
$W \to \mu\nu$	96	$2989 \pm 15(stat) \pm 81(sys) \pm 194$ (lumi)
$Z \to e^+e^-$	177	$264.9 \pm 3.9(stat) \pm 9.9(sys) \pm 17.2$ (lumi)
$W \to e\nu$	177	$2865 \pm 8.3(stat) \pm 76(sys) \pm 186$ (lumi)
$Z \to \tau^+\tau^-$	226	$237 \pm 15(stat) \pm 18(sys) \pm 15$ (lumi)

- W/Z to electrons, muons and tau cross sections obtained are in agreement with Standard Model predictions
- Data currently used in analysis: till April 2004
- Expecting from $4fb^{-1}$ to $8fb^{-1}$ integrated luminosity by 2009