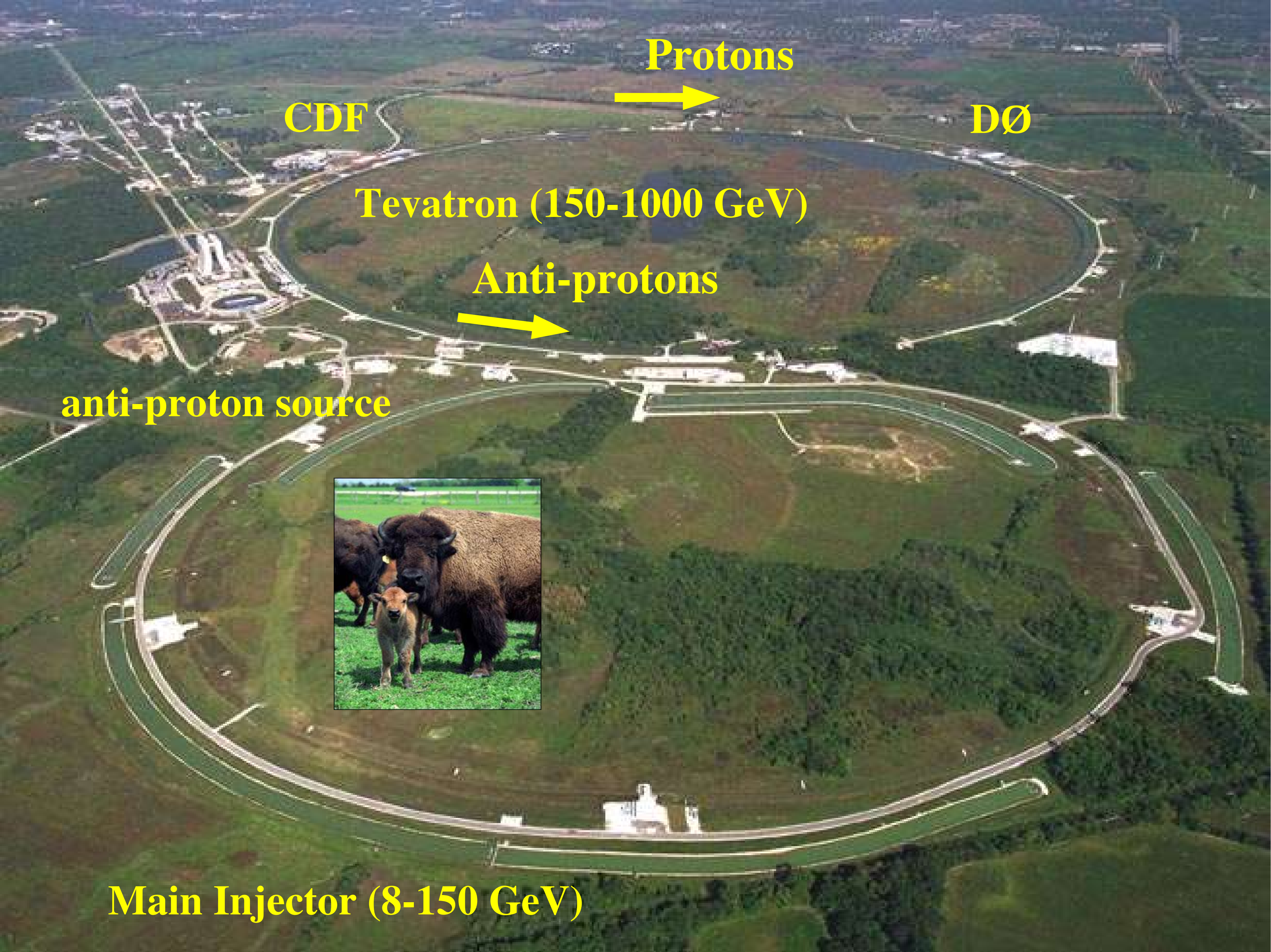
Electroweak Results from DØ

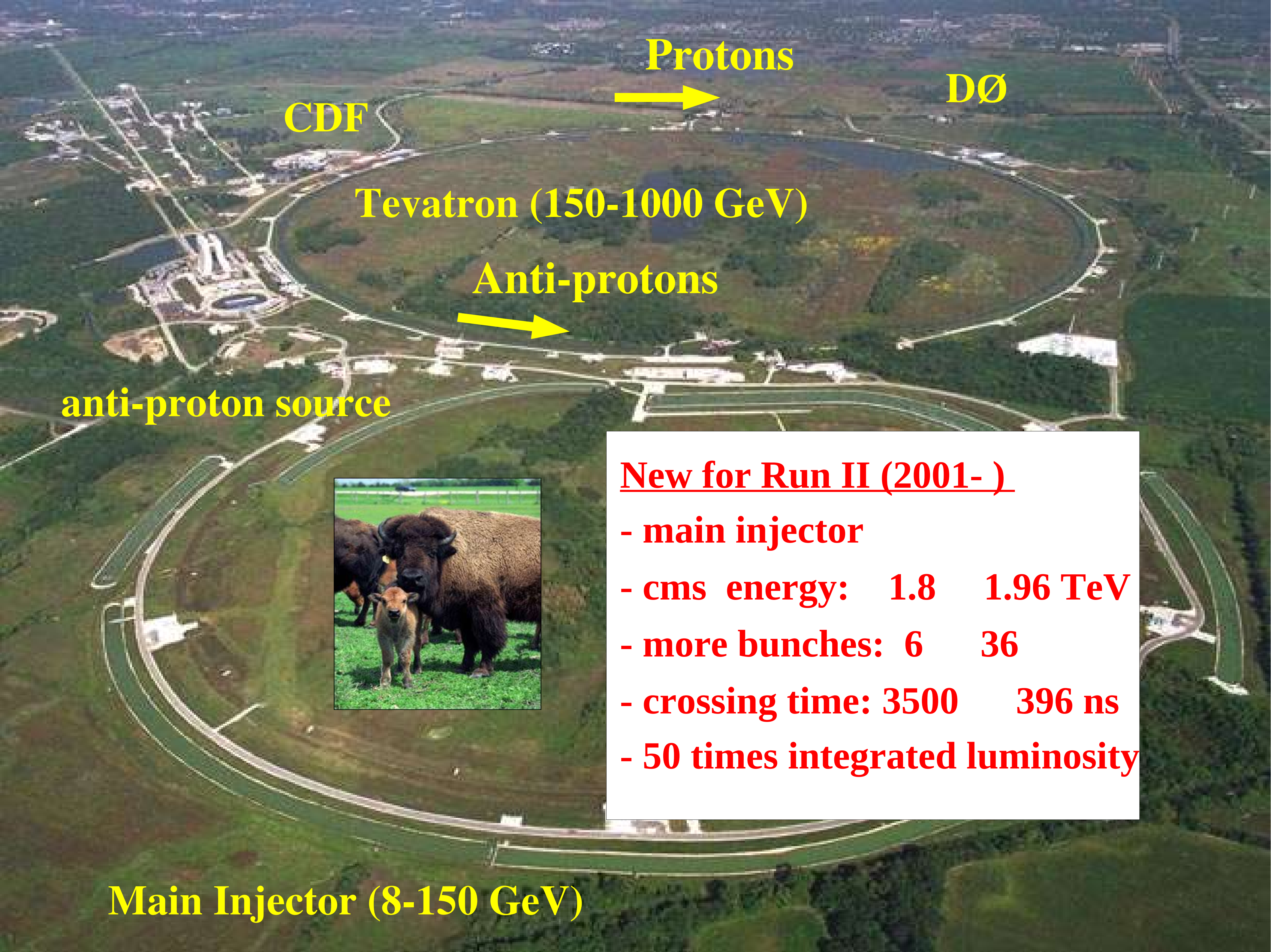
Stefan Söldner-Rembold

MANCHESTER 1824

Les Houches, 19 May 2005

- W and Z cross-sections
- Di-boson cross-sections
- A little bit of top


Protons
CDF
DØ
Tevatron (150-1000 GeV)
Anti-protons
anti-proton source
Main Injector (8-150 GeV)



New for Run II (2001-)

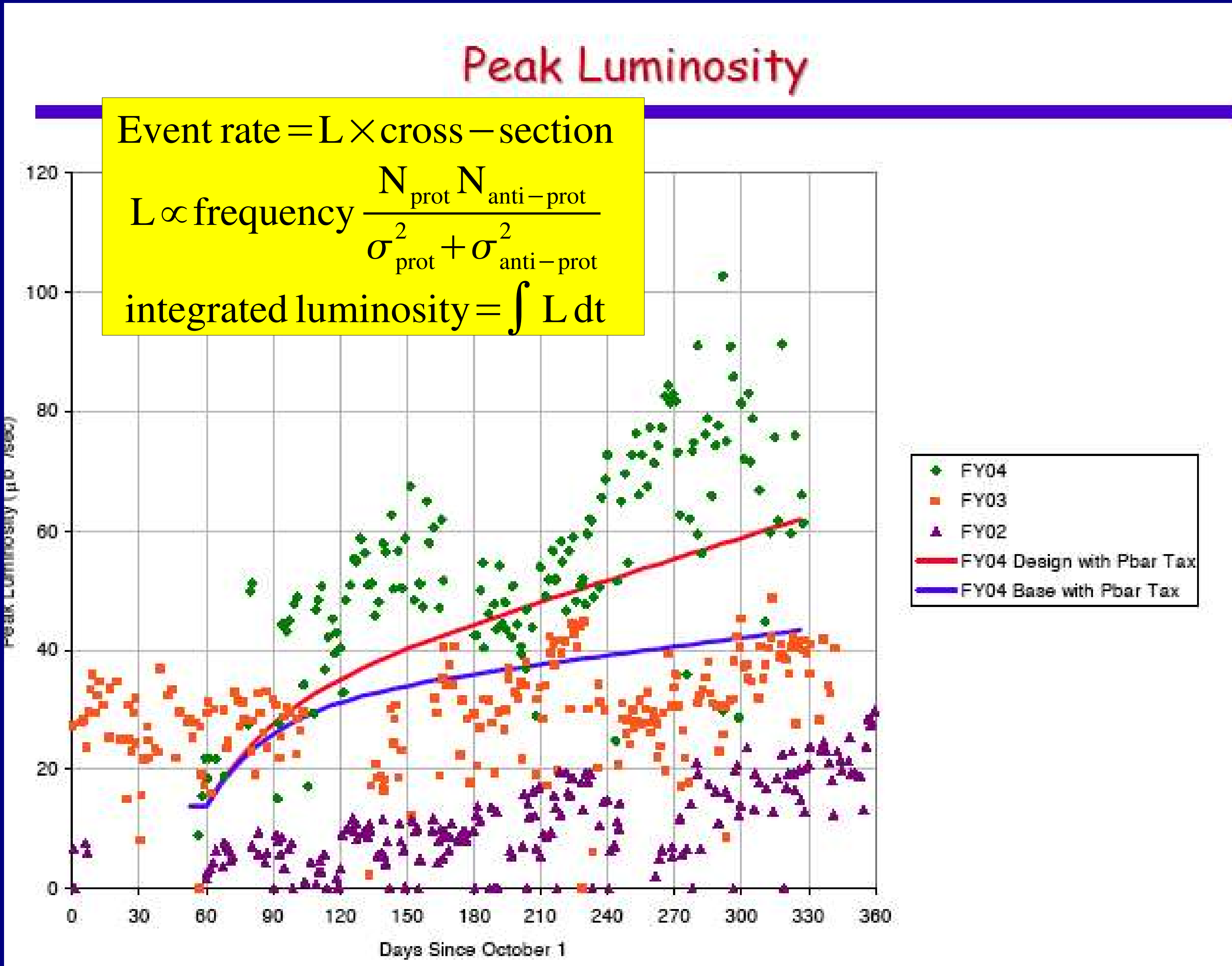
- main injector
- cms energy: 1.8 1.96 TeV
- more bunches: 6 36
- crossing time: 3500 396 ns
- 50 times integrated luminosity

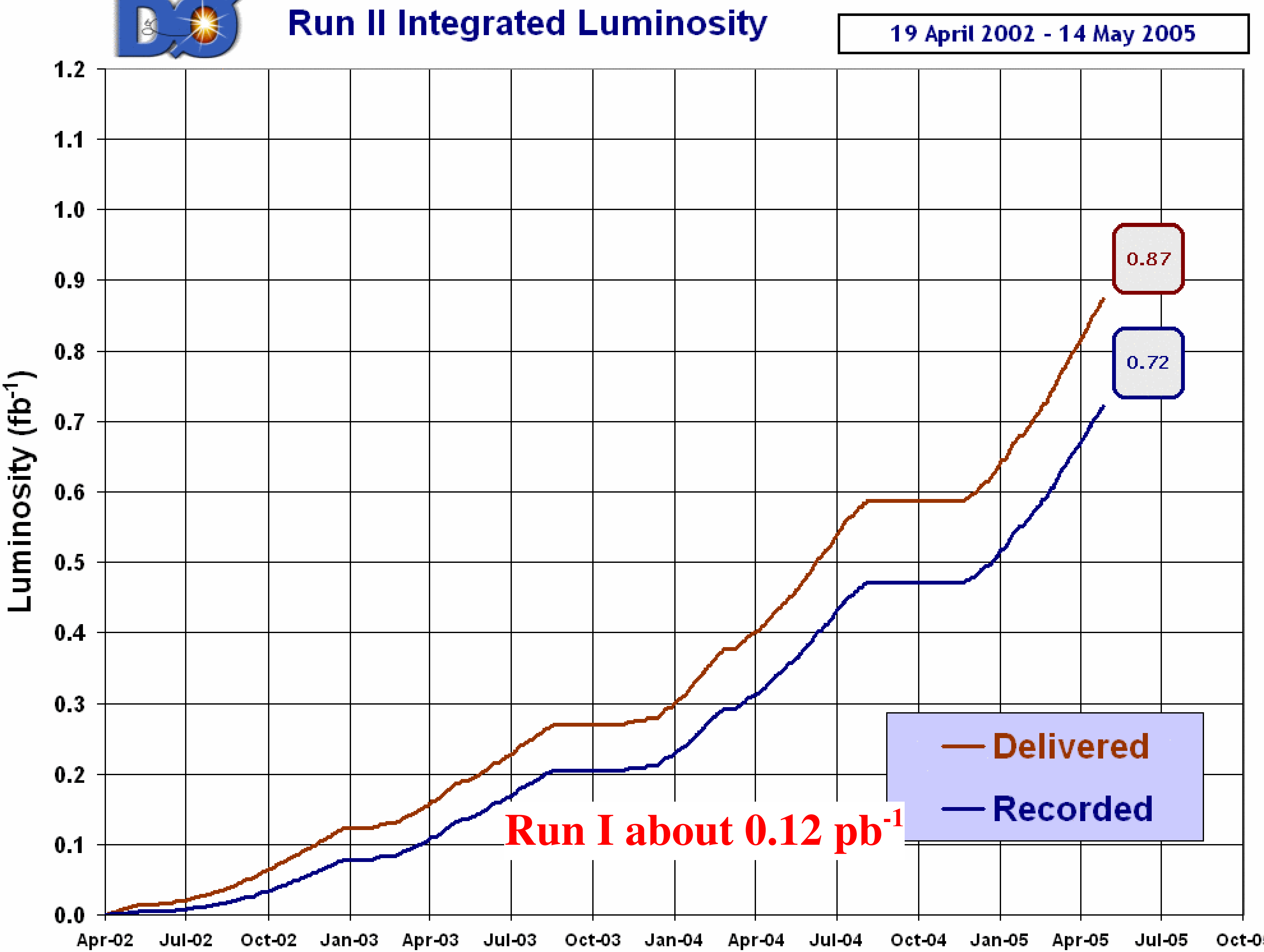
Tevatron Peak Luminosity

$$\text{Event rate} = L \times \text{cross} - \text{section}$$

$$L \propto \text{frequency} \frac{N_{\text{prot}} N_{\text{anti-prot}}}{\sigma^2_{\text{prot}} + \sigma^2_{\text{anti-prot}}}$$

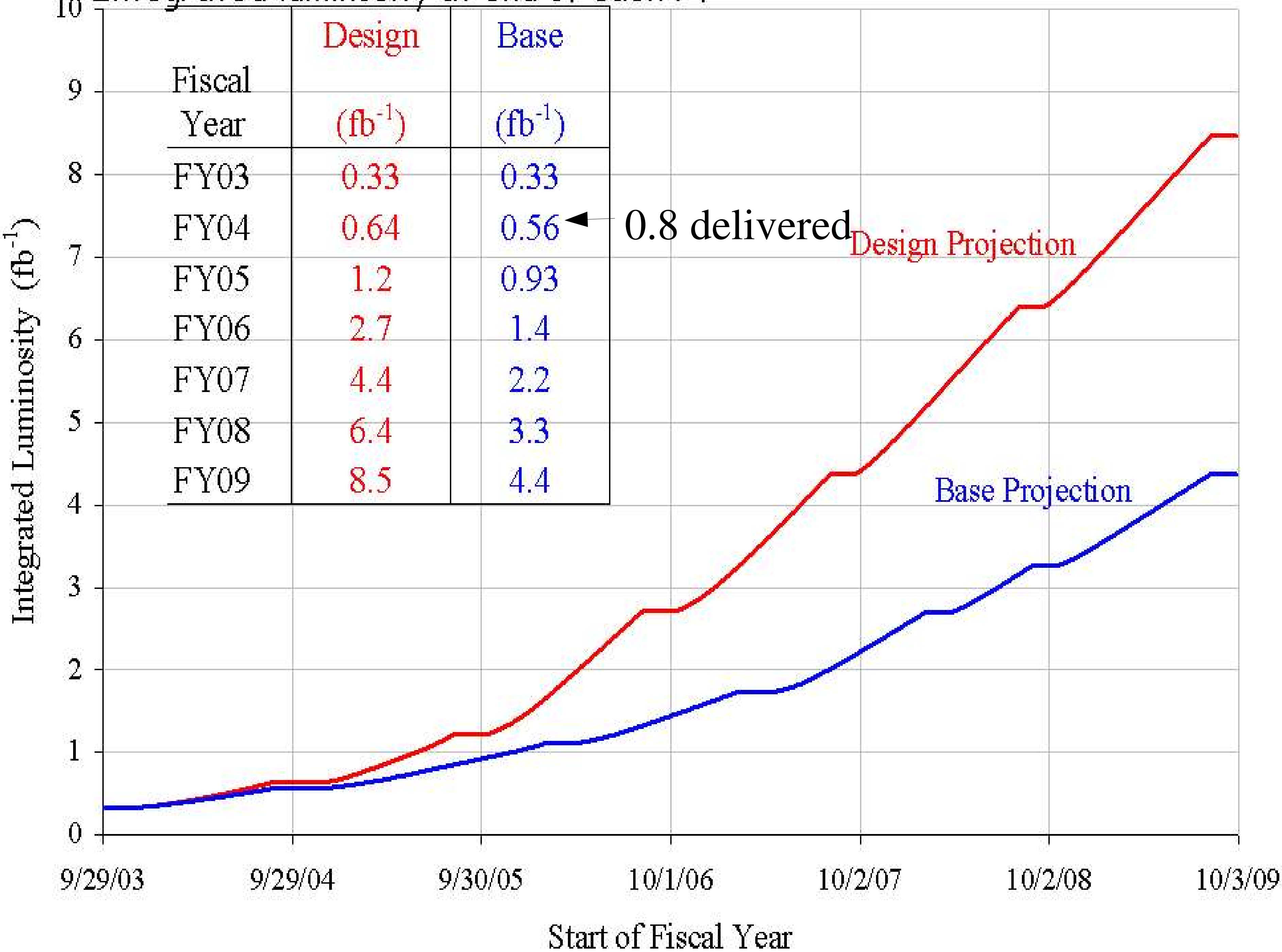
$$\text{integrated luminosity} = \int L \, dt$$

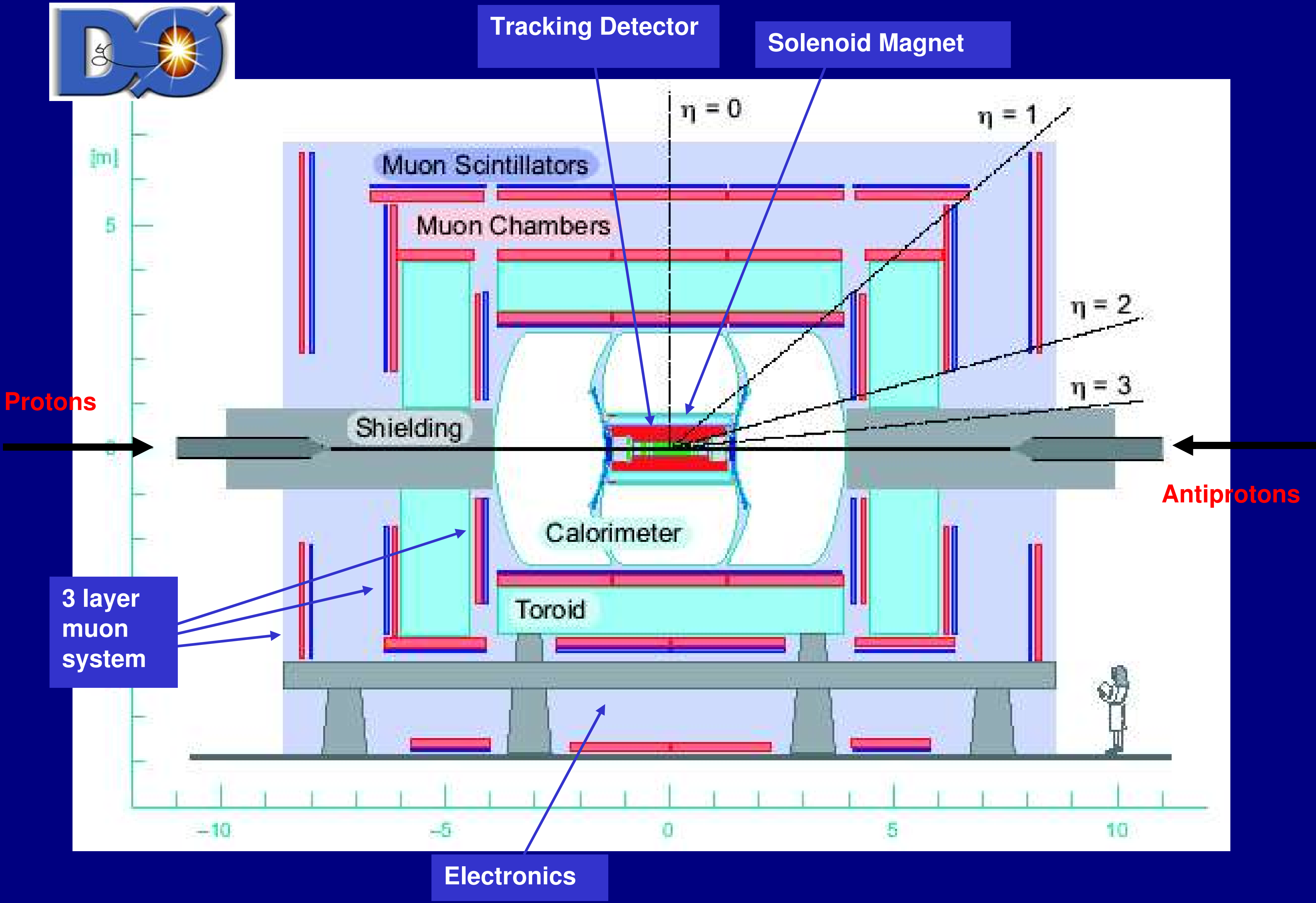


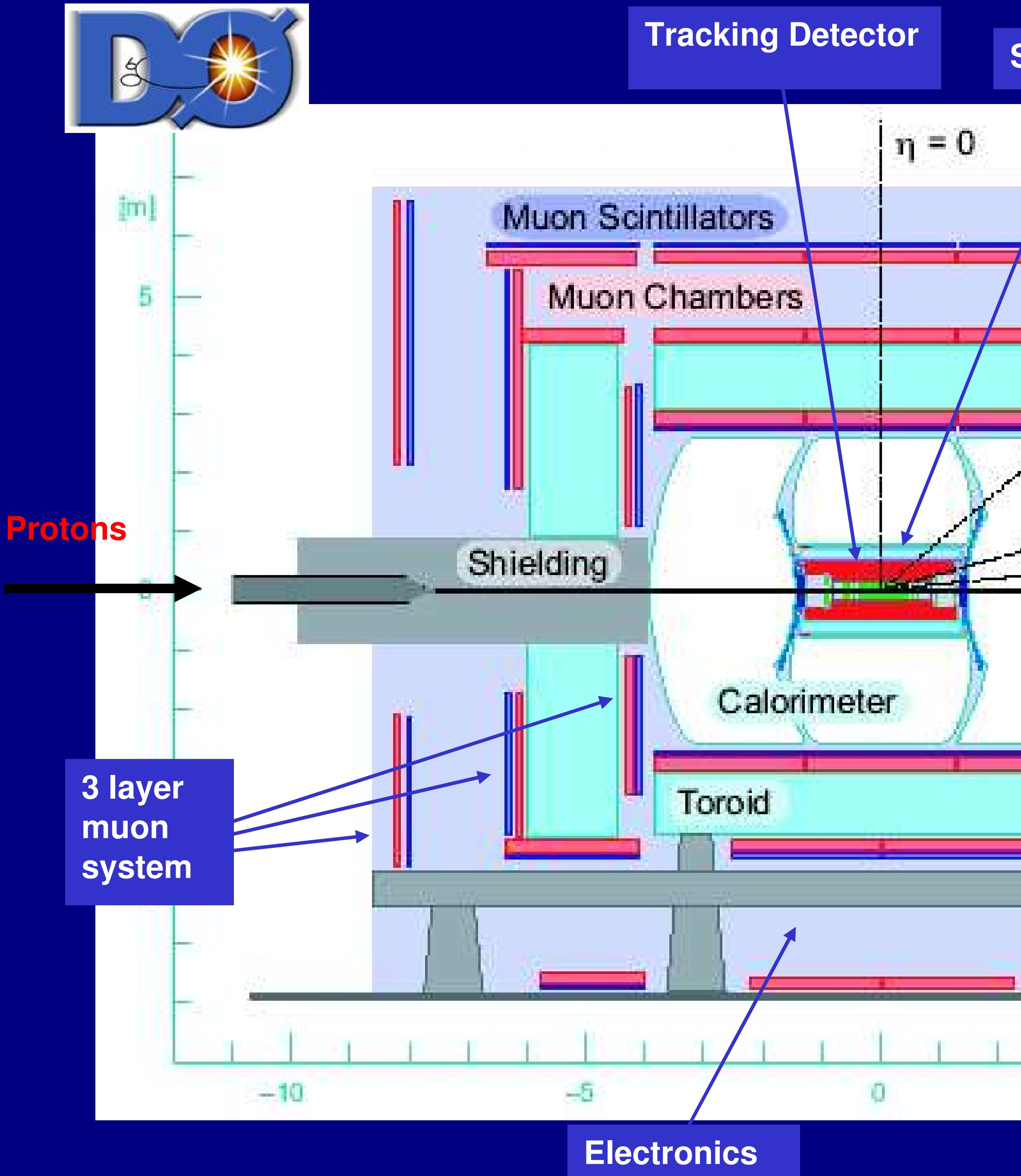

Run II Integrated Luminosity
19 April 2002 - 14 May 2005
Luminosity (fb-1)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
0.87
0.72
Delivered
Recorded
Run I about 0.12 pb-1

Integrated luminosity at end of each FY

Fiscal Year	Design (fb^{-1})	Base (fb^{-1})
FY03	0.33	0.33
FY04	0.64	0.56 ← 0.8 delivered
FY05	1.2	0.93
FY06	2.7	1.4
FY07	4.4	2.2
FY08	6.4	3.3
FY09	8.5	4.4




Tracking Detector
Solenoid Magnet
$\eta = 0$
$\eta = 1$
$\eta = 2$
$\eta = 3$
[m]
5
0
Muon Scintillators
Muon Chambers
Protons
Shielding
Antiprotons
Calorimeter
Toroid
3 layer muon system
−10
−5
0
5
10
Electronics



Retained from Run I:

LAr calorimeter
Central muon detector
Muon Toroid

New for Run II:

Magnetic Tracker
- 2 Tesla Solenoid
- Silicon Microvertex Tracker (SMT)
- Central Fiber Tracker (CFT)

Pre-shower detectors
Forward muon detector
Forward proton detector
FE electronics, Trigger & DAQ

Production of W and Z Bosons

Calibration of detector
with standard process

↓

Measure luminosity with
small experimental and
theoretical uncertainty

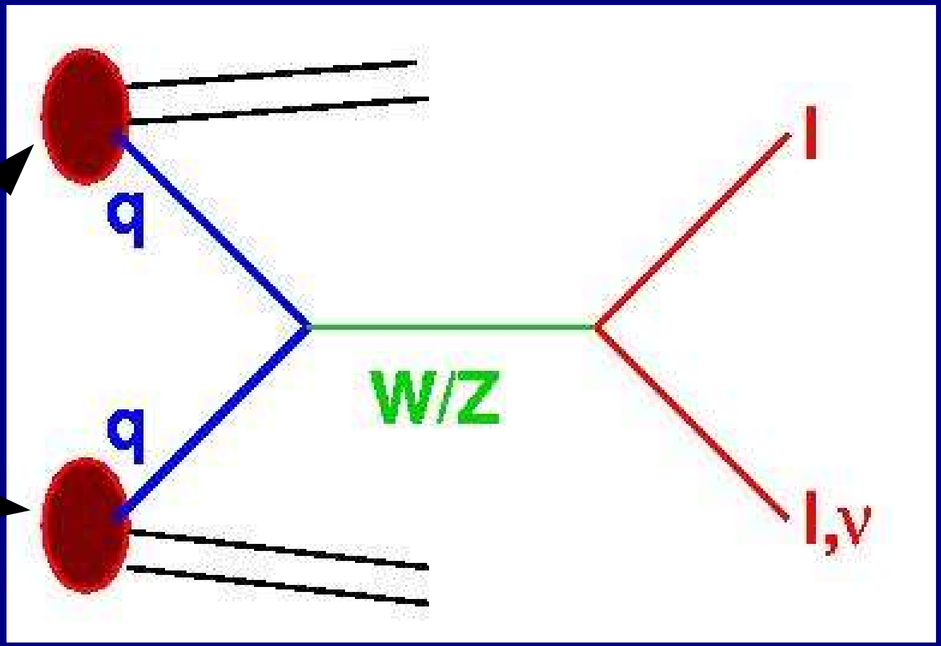
↓

Constrain parton densities

↓

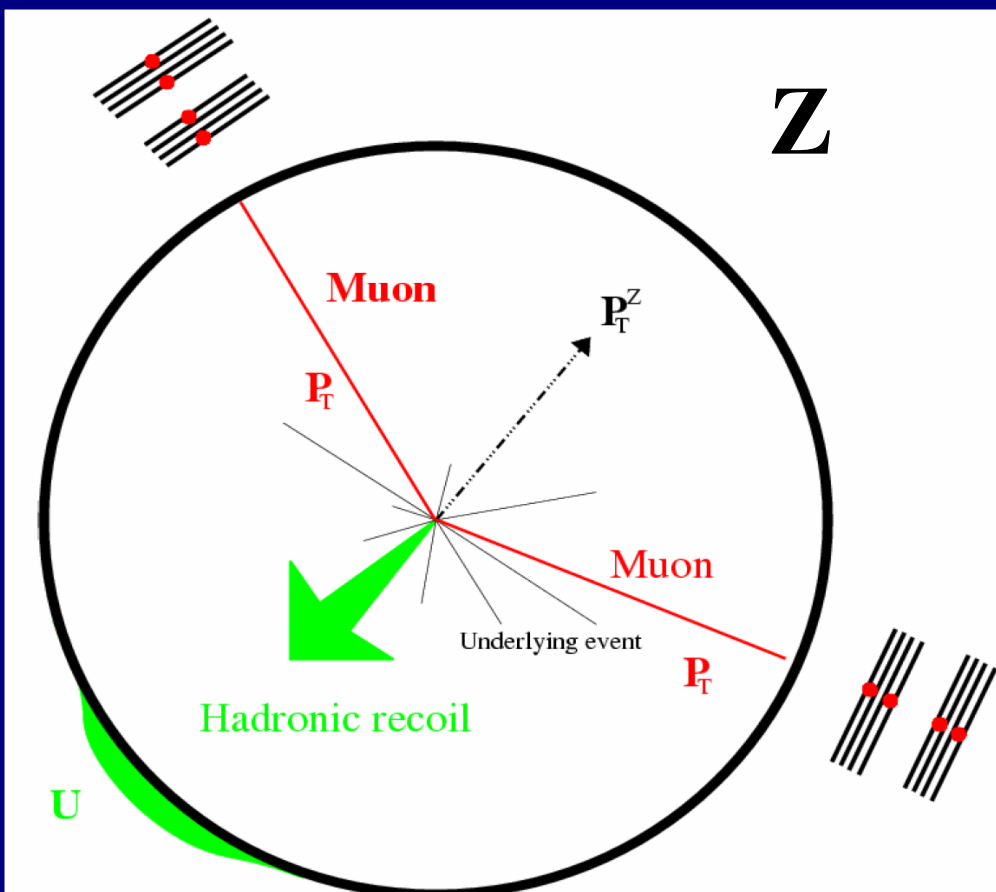
Perform precision measurement
of electroweak parameters
(e.g. W mass and width,
gauge couplings..)

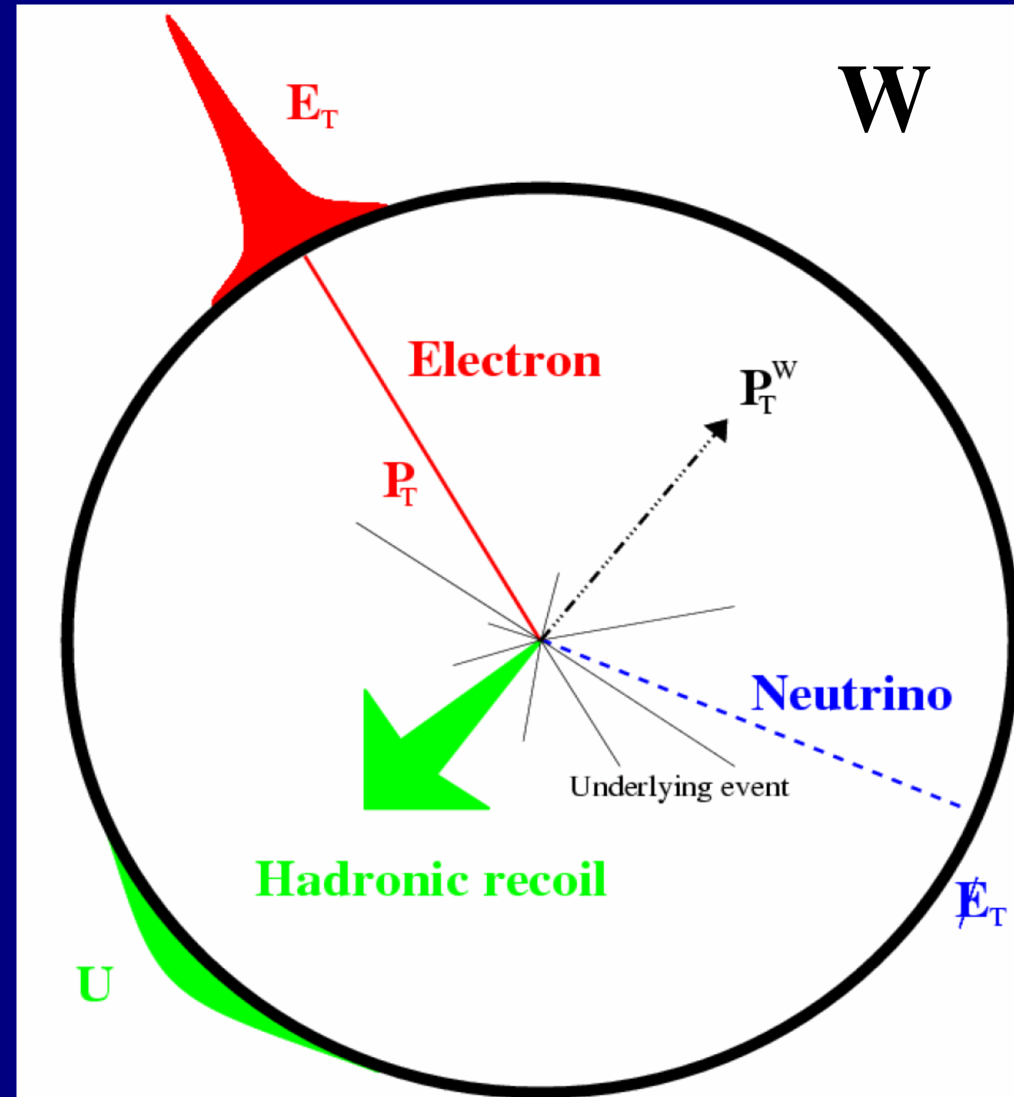
dominant W/Z production process



Run II: expect $>10^5$ Z decays
and $>10^6$ W decays
into e,

Event Topologies

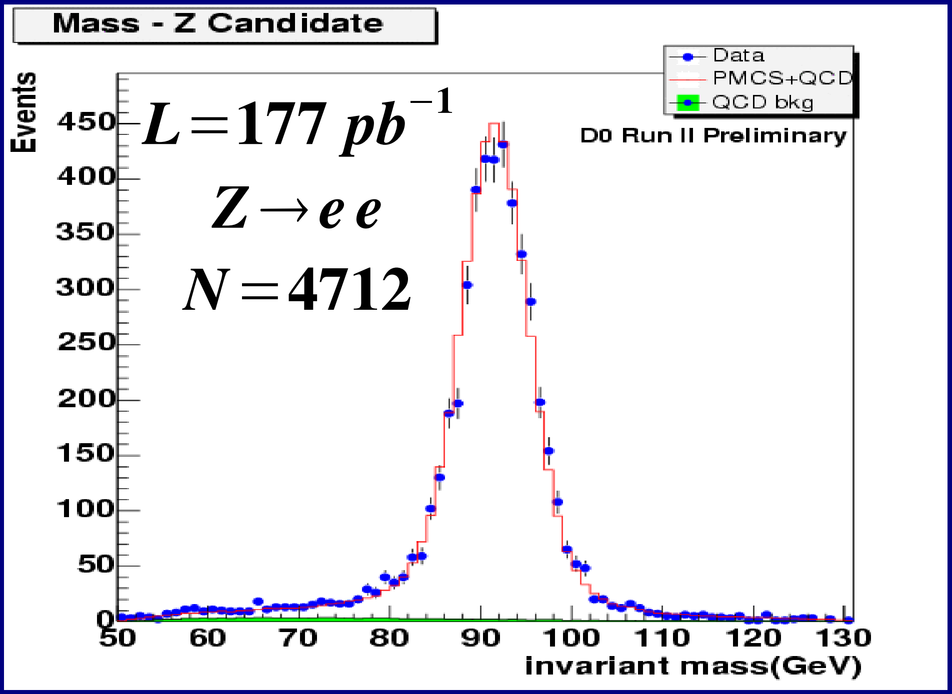




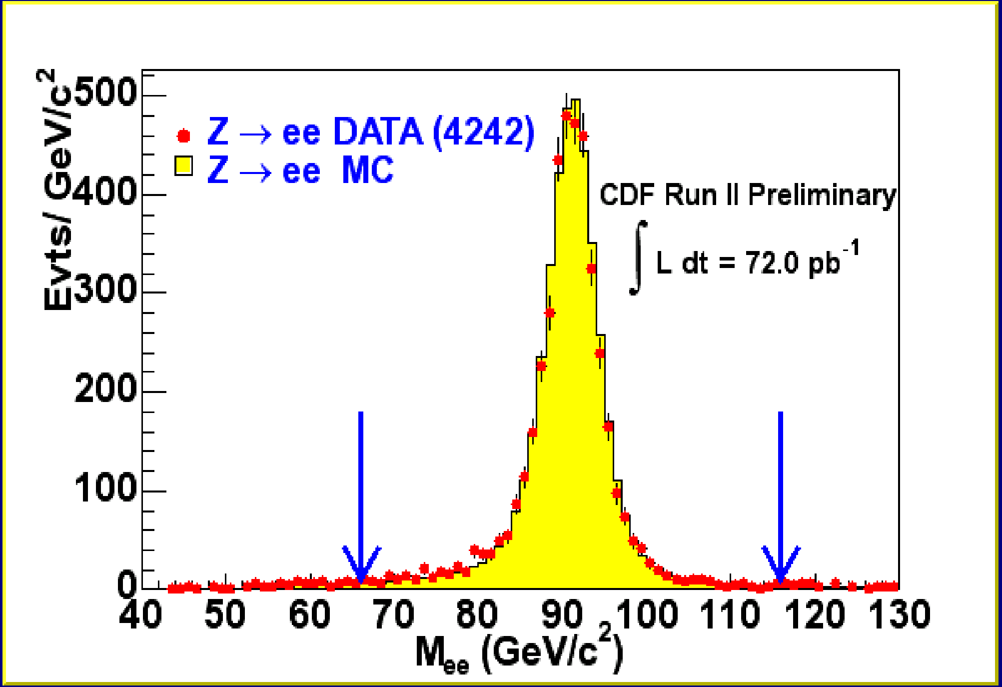
$$M_T = \sqrt{(\not{E}_T + p_T)^2 - (\not{E}_x + p_x)^2 - (\not{E}_y + p_y)^2}$$

DØ

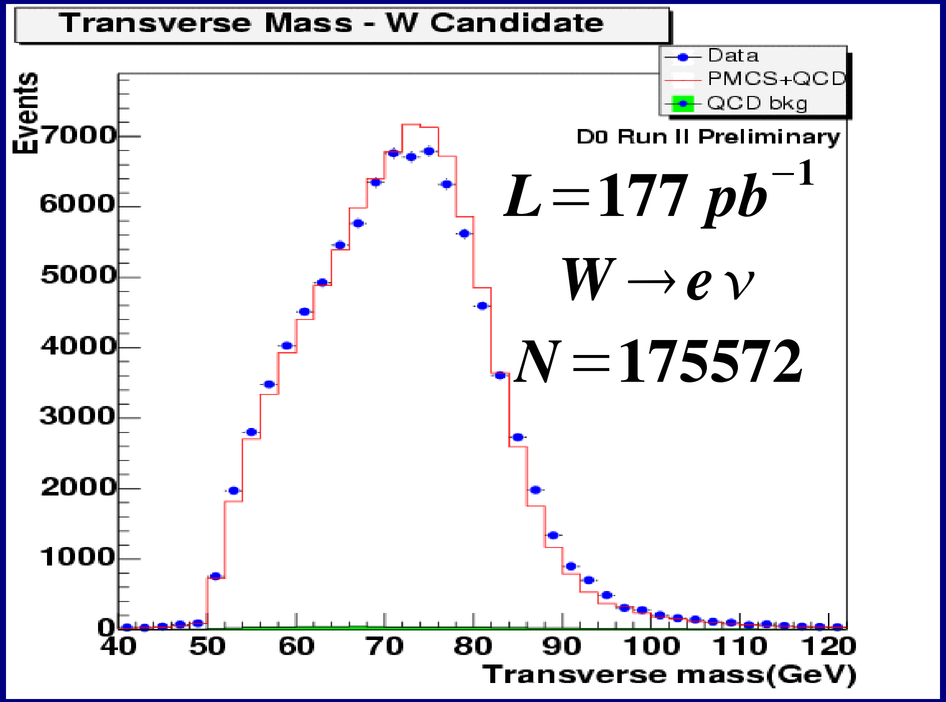
CDF



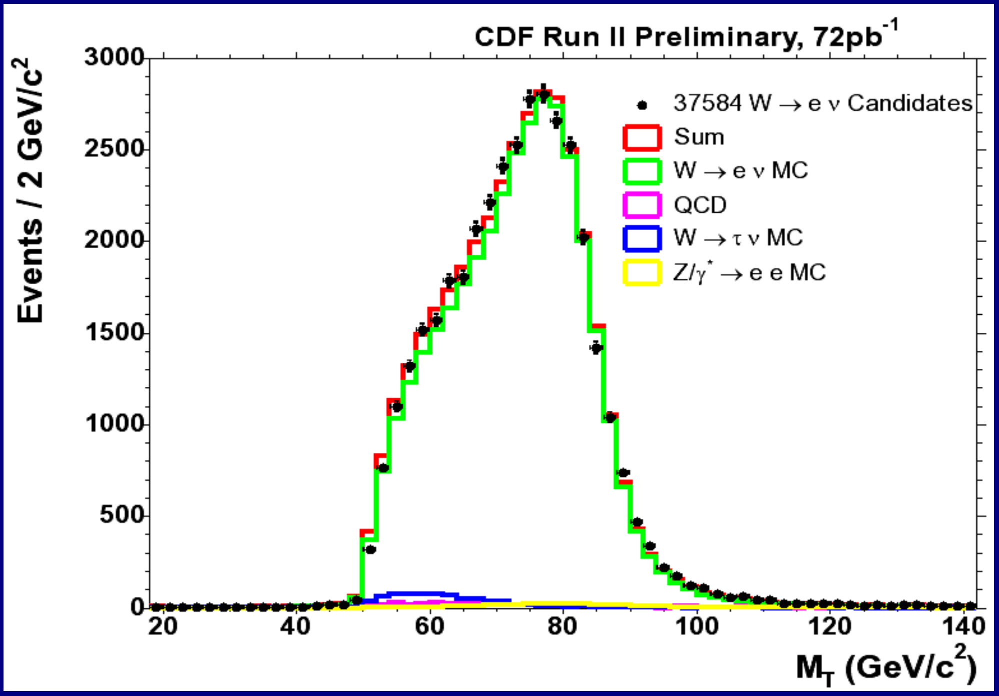
Mass - Z Candidate
Data
PMCS+QCD
QCD bkg
D0 Run II Preliminary
$L = 177\ pb^{-1}$
$Z \to e\,e$
$N = 4712$
Events
invariant mass(GeV)



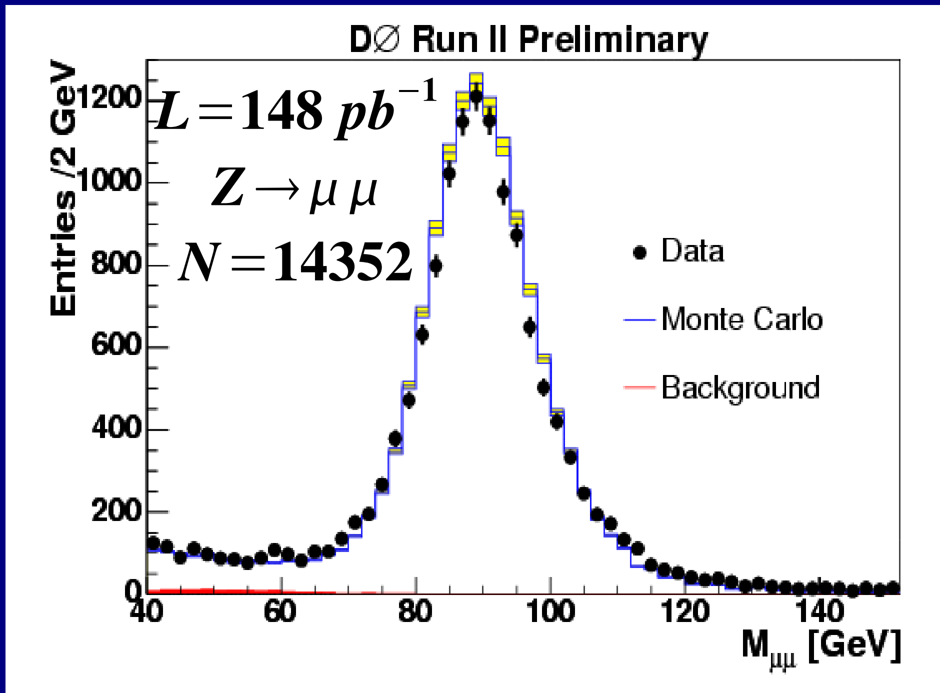
$Z \to ee$ DATA (4242)
$Z \to ee$ MC
CDF Run II Preliminary
$\int L\ dt = 72.0\ pb^{-1}$
Evts/ GeV/c^2
M_{ee} (GeV/c^2)

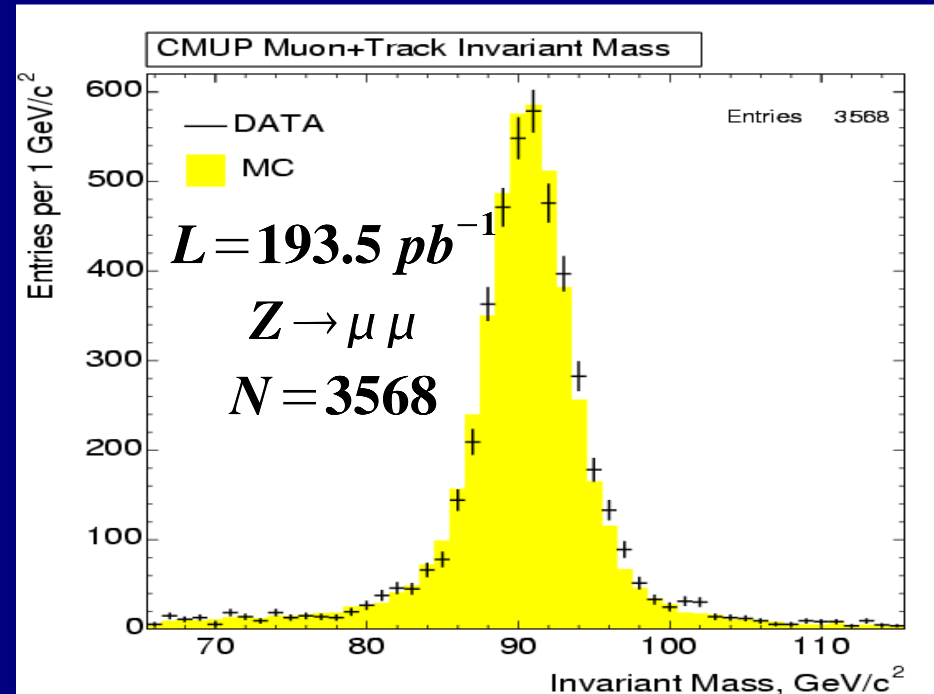


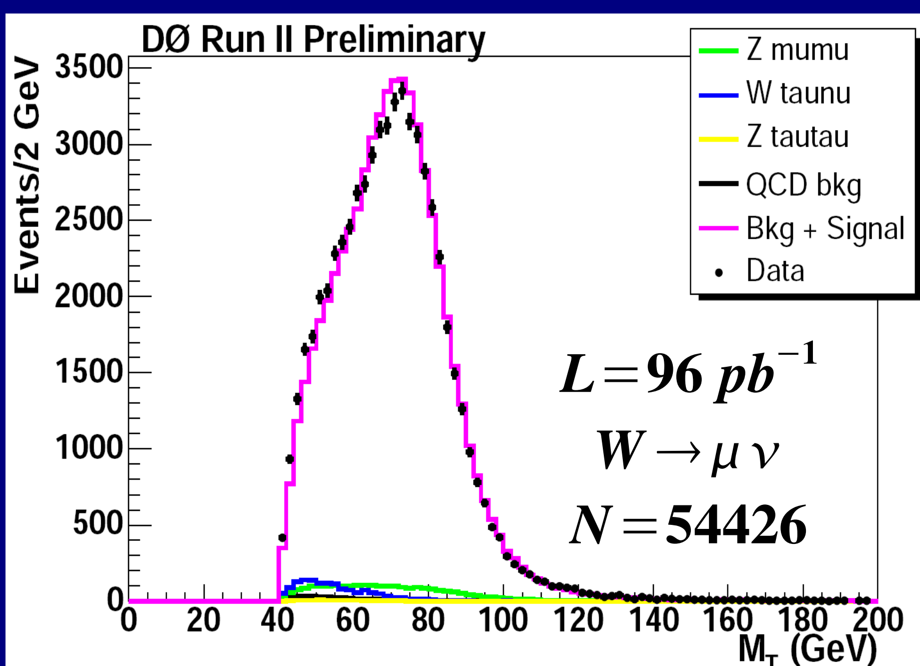
Transverse Mass - W Candidate
Data
PMCS+QCD
QCD bkg
D0 Run II Preliminary
$L = 177\ pb^{-1}$
$W \to e\,\nu$
$N = 175572$
Events
Transverse mass(GeV)

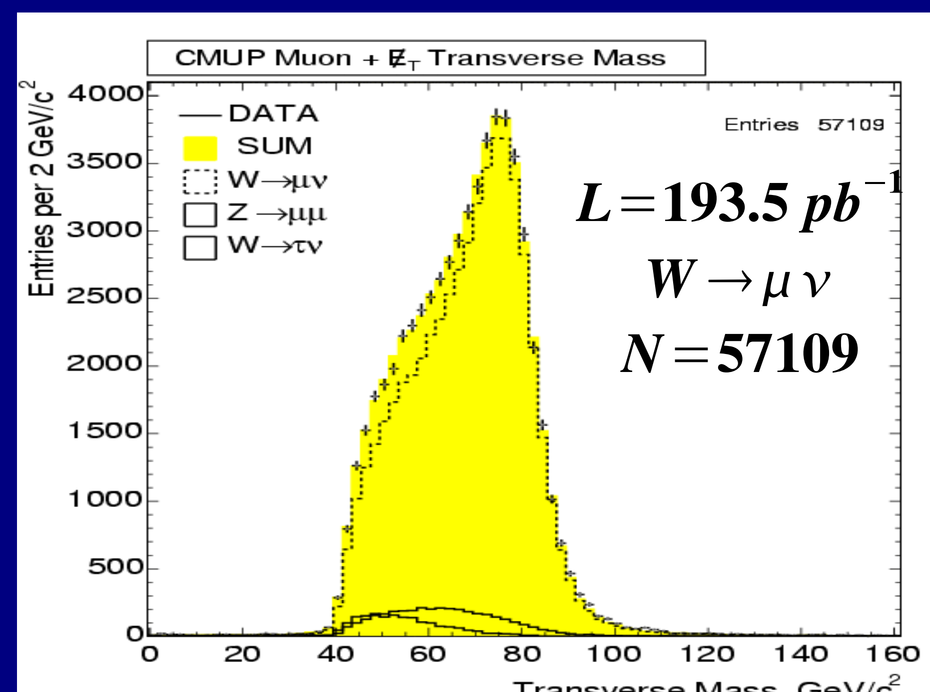


CDF Run II Preliminary, 72pb^{-1}
37584 $W \to e\,\nu$ Candidates
Sum
$W \to e\,\nu$ MC
QCD
$W \to \tau\,\nu$ MC
$Z/\gamma^* \to e\,e$ MC
Events / 2 GeV/c^2
M_T (GeV/c^2)


DØ Run II Preliminary
Entries /2 GeV
L = 148 pb^-1
Z → μ μ
N = 14352
Data
Monte Carlo
Background
M_μμ [GeV]


CMUP Muon+Track Invariant Mass
Entries per 1 GeV/c^2
DATA
MC
Entries 3568
L = 193.5 pb^-1
Z → μ μ
N = 3568
Invariant Mass, GeV/c^2


DØ Run II Preliminary
Events/2 GeV
Z mumu
W taunu
Z tautau
QCD bkg
Bkg + Signal
Data
L = 96 pb^-1
W → μ ν
N = 54426
M_T (GeV)

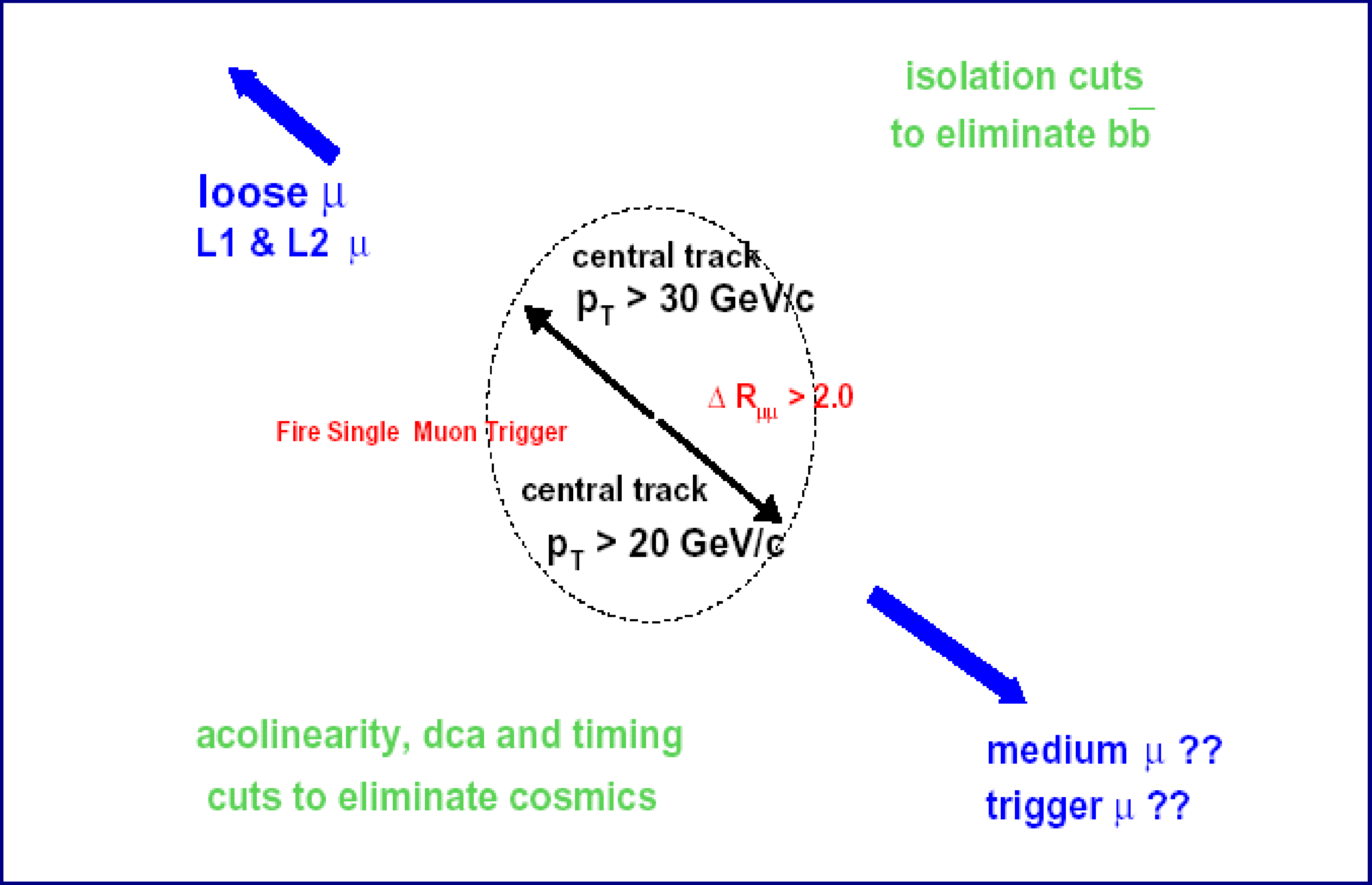

CMUP Muon + E̸_T Transverse Mass
Entries per 2 GeV/c^2
DATA
SUM
W→μν
Z→μμ
W→τν
Entries 57109
L = 193.5 pb^-1
W → μ ν
N = 57109
Transverse Mass, GeV/c^2

Analysis Method

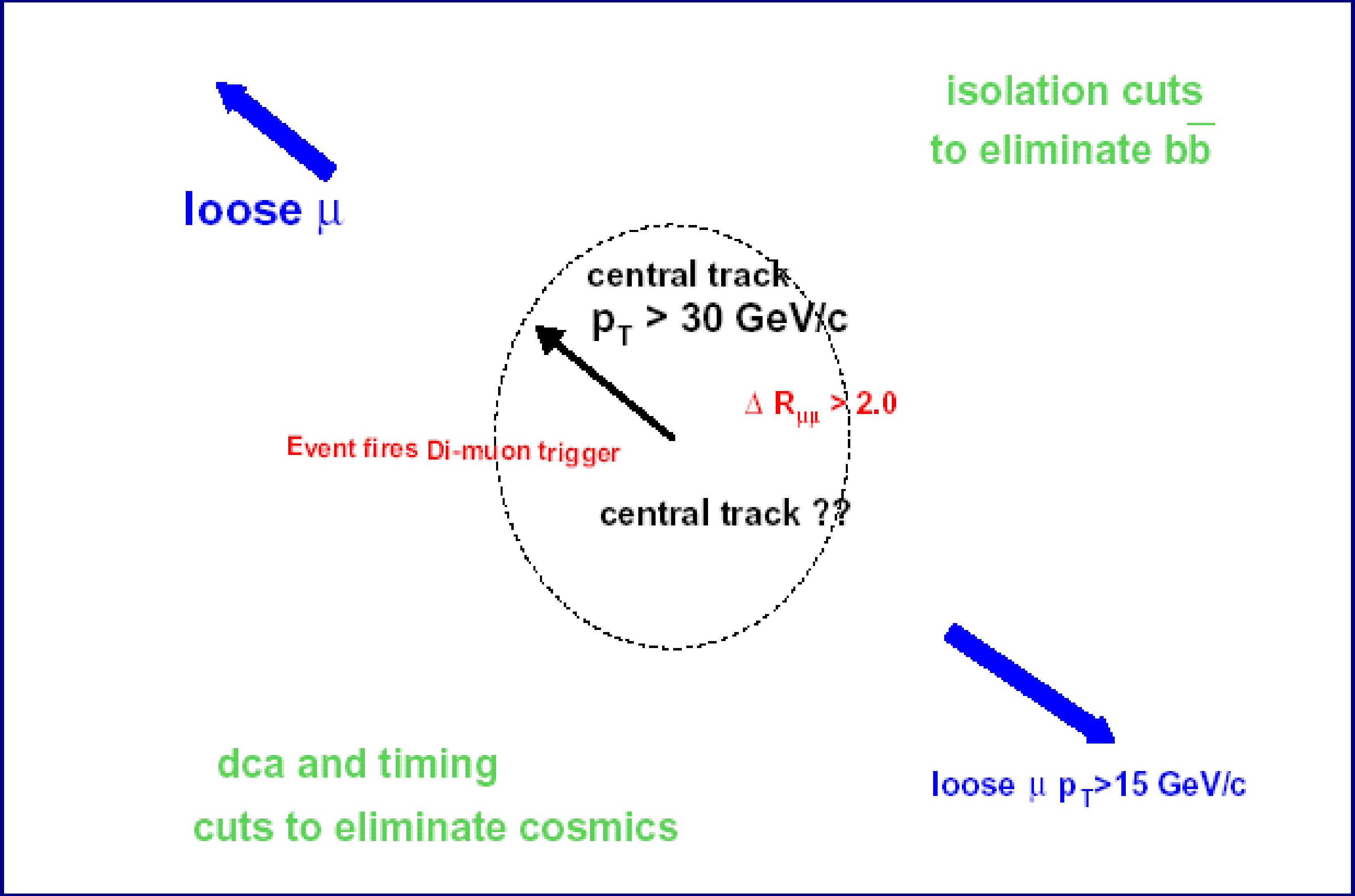
$$\sigma \times \mathbf{Br} = \frac{\mathbf{N}^{\text{candidates}} - \mathbf{N}^{\text{background}}}{\varepsilon \times \mathbf{Acc} \times \int \mathcal{L}}$$

- Look for high p_T e or μ, often with a track match
- Backgrounds:
  - Larger and/or QCD background, such as multijet or W+jet, estimated from data using 'Matrix Methods'
  - Smaller and/or EW background, such as $t\bar{t}$ or diboson, estimated from MC
- Measure efficiencies from data
- Determine acceptance from PYTHIA MC and (parametrized) detector simulation

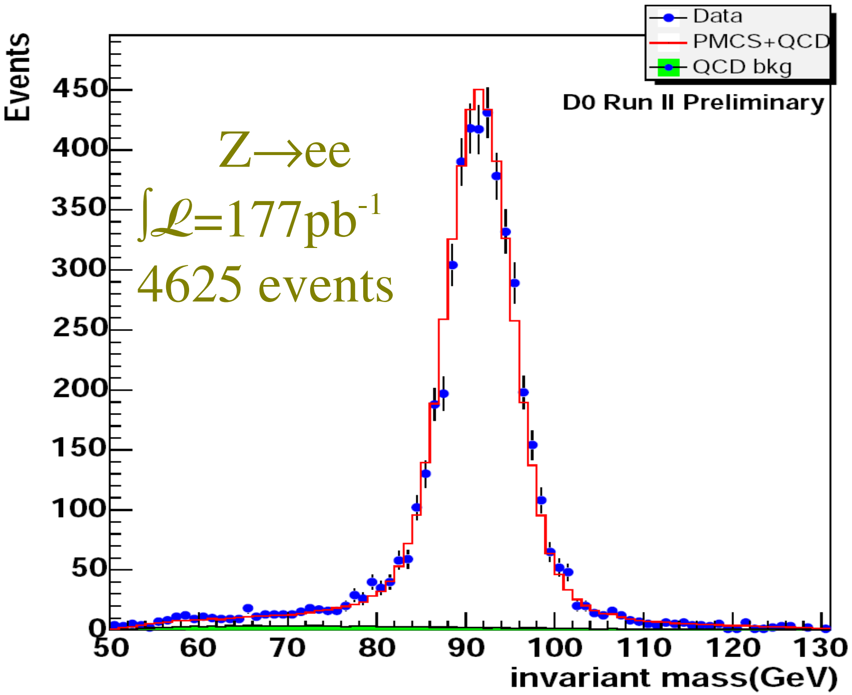
Trigger, Muon Identification, Isolation, Tracking - all these efficiencies are determiend from data using tag and probe method:



Tracking efficiency:



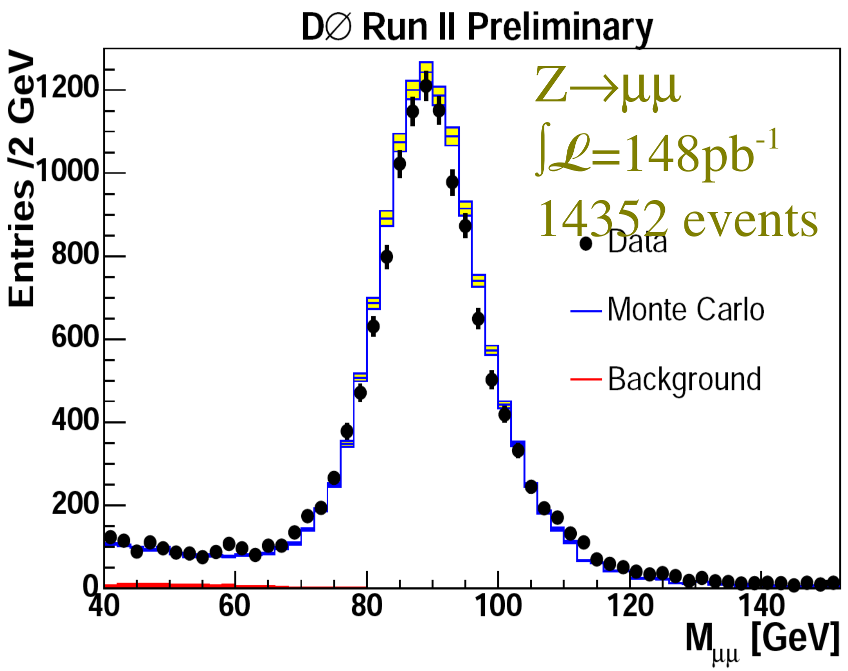
- or $\mu^+\mu^-$



Main backgrounds:

–

Z→μμ)



Main Syst. Uncertainties:

EM ID ~2.9%

PDFs ~1.8%

→μμ)

Detector modelling ~1% (Z→μμ)

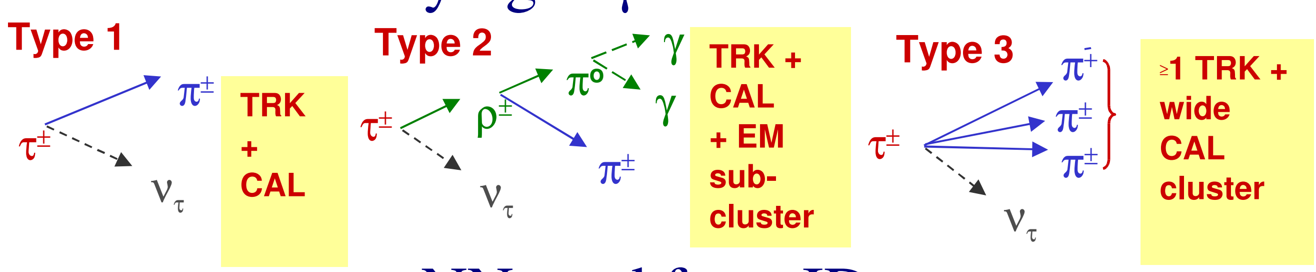
DØ Prelim: $\sigma \times Br(Z\to ee) = 264.9 \pm 3.9_{stat} \pm 9.9_{syst} \pm 17.2_{lumi}$ pb

DØ Prelim: $\sigma \times Br(Z\to \mu\mu) = 291.3 \pm 3.0_{stat} \pm 6.9_{syst} \pm 18.9_{lumi}$ pb

Important for other analyses

Selection:

Isolated τ decaying to μ back to back with:



NN used for τ ID

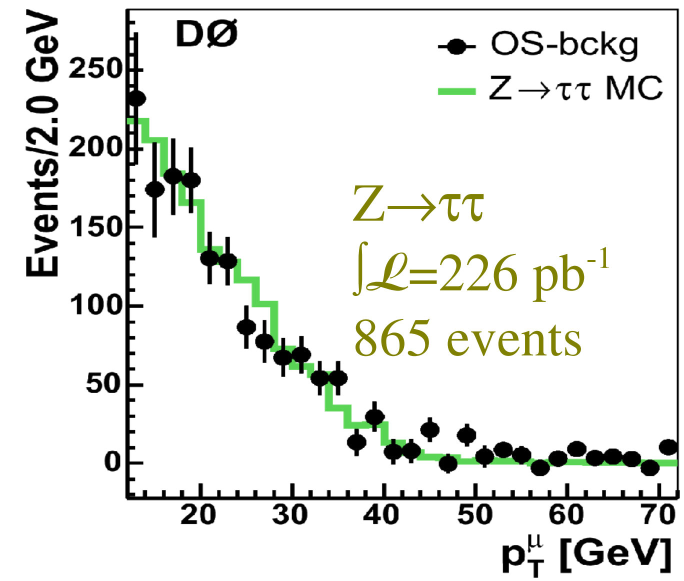
Main backgrounds:

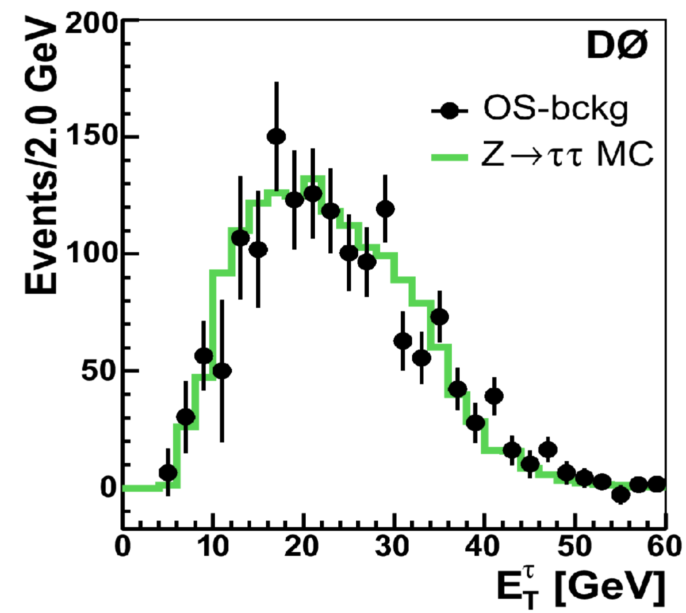
QCD ~49%, W/Z→μ+jet ~6%

Main Systematic Uncertainties:

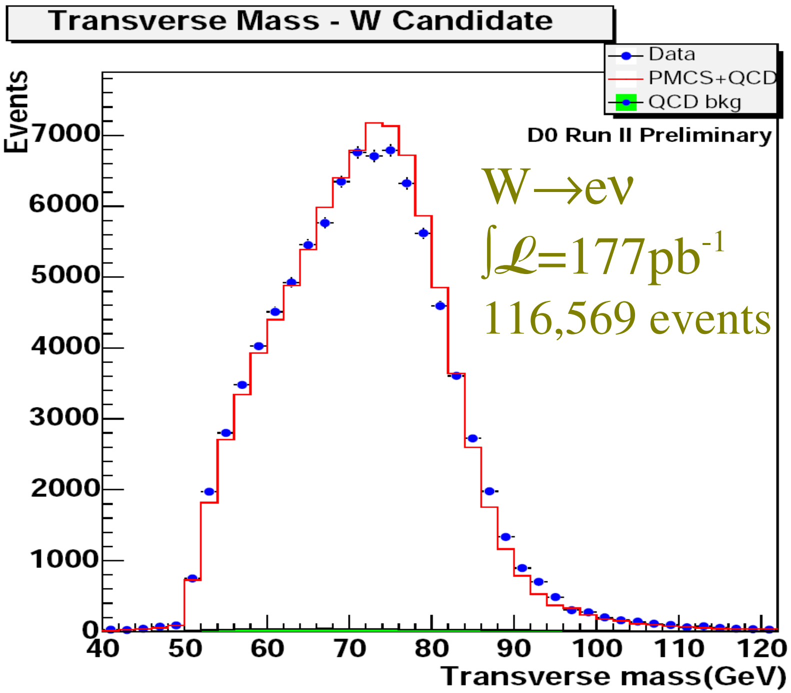
Trigger 3.5%, QCD BG 3.5%

$\sigma \times Br(Z\to\tau\tau)$: $237 \pm 15_{stat} \pm 18_{sys} \pm 15_{lumi}$ pb





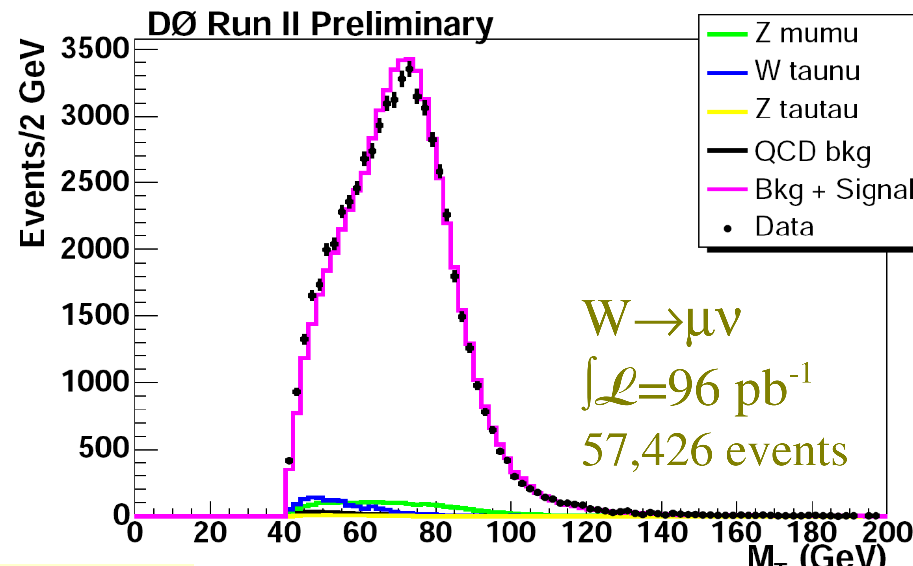
Accepted by PRD
hep-ex/0412020



Main backgrounds:

Multijet events ~30%

$b\bar{b}$, $Z\rightarrow\tau\tau$ ~3-4%



Main Syst. Uncertainties:

PDFs ~1.4%

$\varepsilon \times$ Acceptance (excl. pdf) ~1.5% -2%

$\sigma \times Br(W\rightarrow e\nu)$: $2865 \pm 8.3_{stat} \pm 76_{syst} \pm 186_{lumi}$ pb

$\sigma \times Br(W\rightarrow \mu\nu)$: $2989 \pm 15_{stat} \pm 81_{syst} \pm 194_{lumi}$ pb

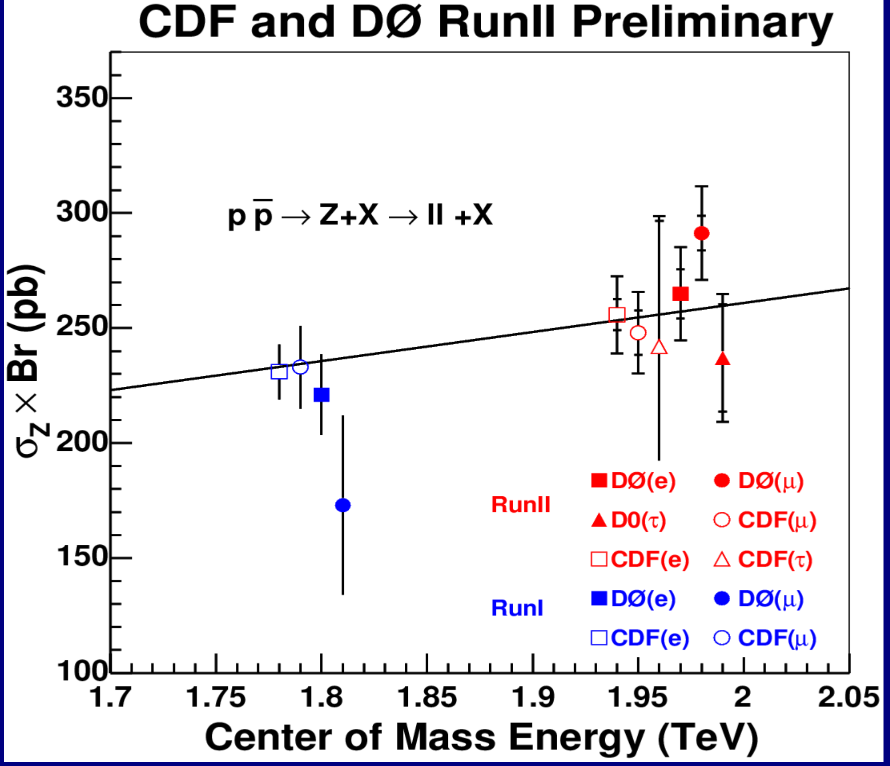
Luminosity uncertainty (about 6-7%) is dominant

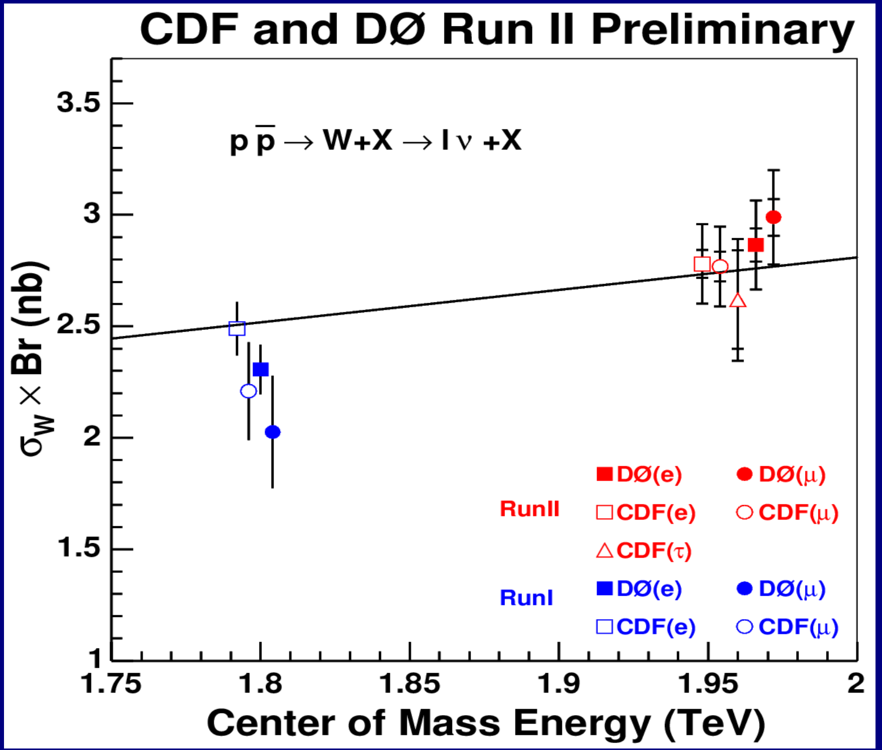
For comparison: luminosity uncertainty at LEP is less than 1%

The integrated luminosity is determined using total inelastic p-pbar cross-section

Ratios of cross-sections are not affected (-> partial widths)

NNLO:
C. R. Hamberg, W.L. van Neerven and T. Matsuura, Nucl. Phys. B359 (1991) using CTEQ4M PDF

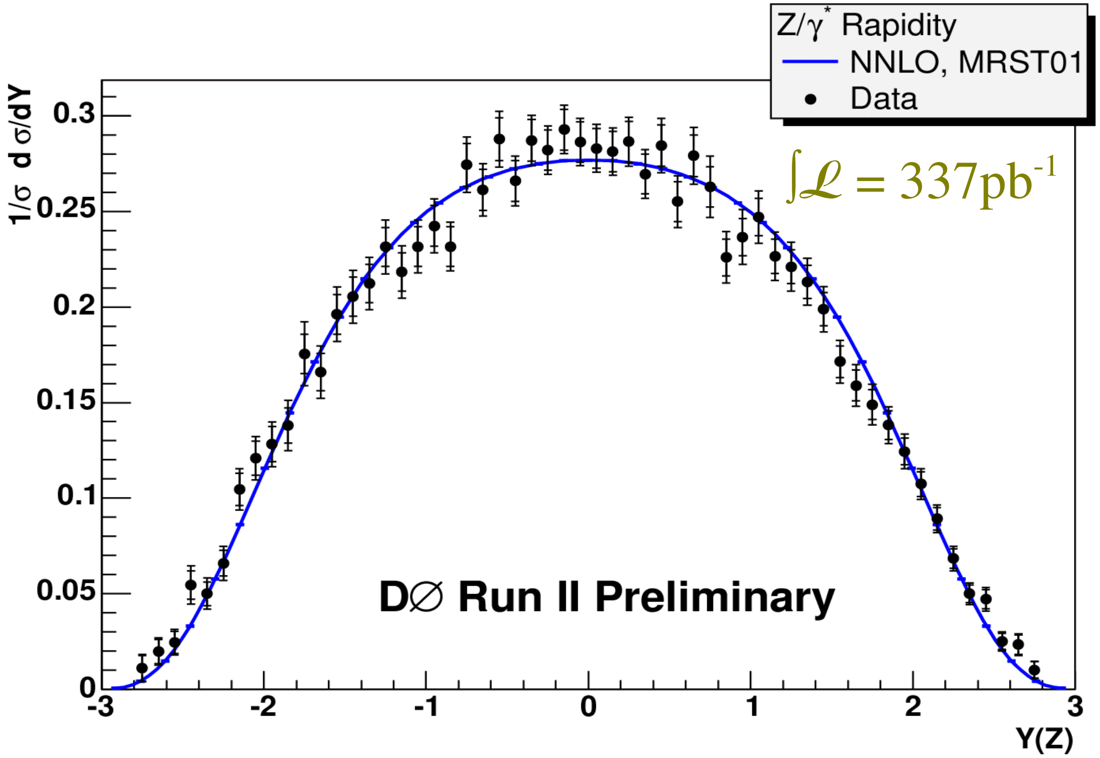




$$\frac{d\sigma}{dY}$$

–

$$x_{1,2} = \frac{M_Z}{\sqrt{s}} e^{\pm Y}$$



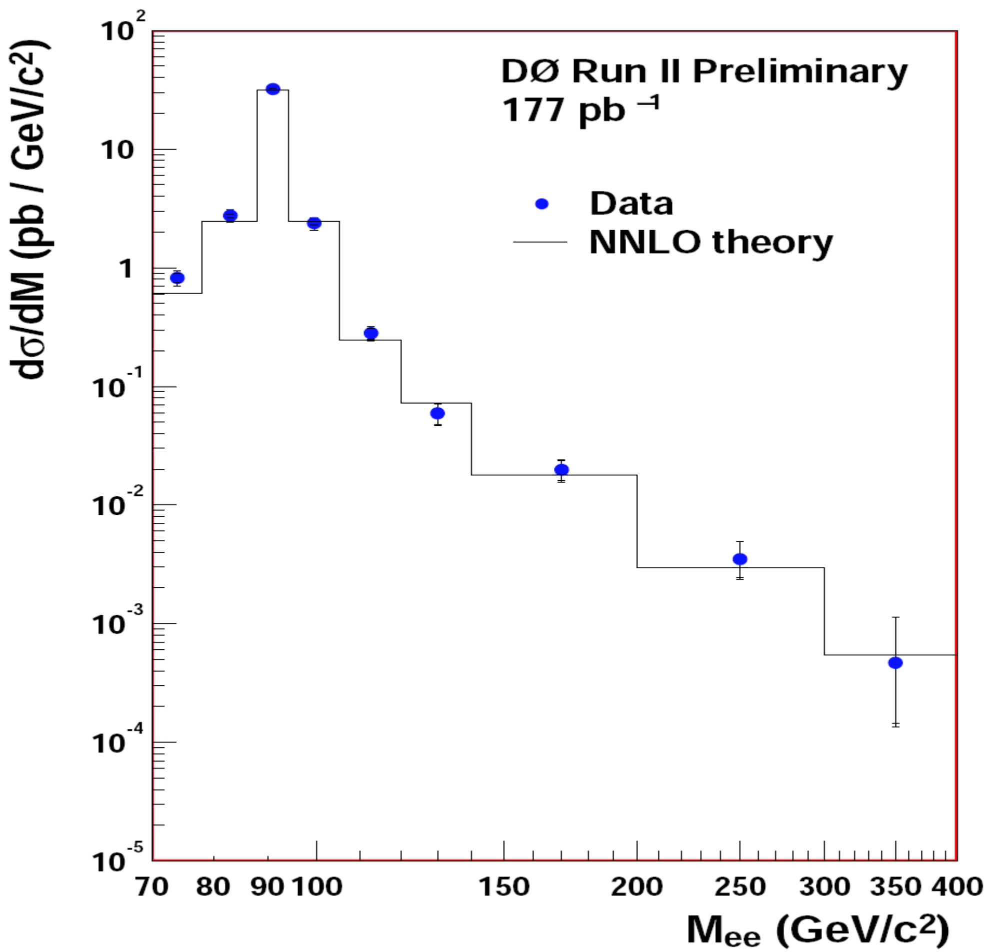
*NNLO Curve from Anastasiou, et. al., 2004

Main Syst. uncertainties:

PDFs ~1.5% - 10%

Efficiencies: ~1.2% - 20%

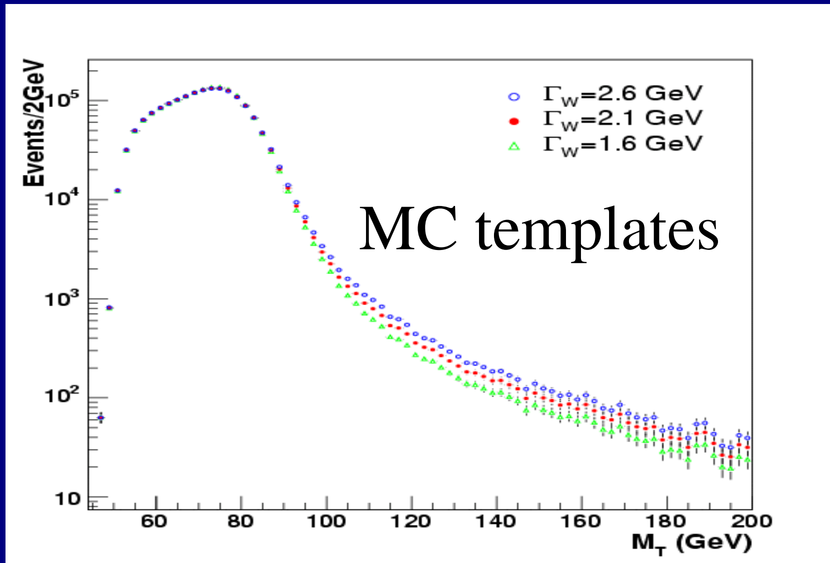
$$\frac{d\sigma}{dM}$$

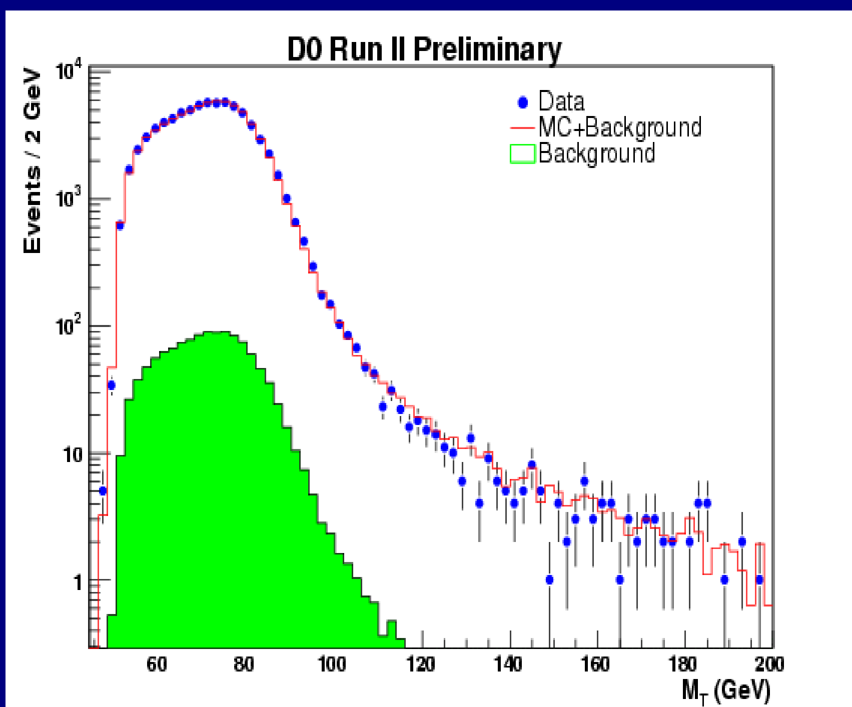


Main systematic uncertainties:

*NNLO curve from
Hamberg, van Neerven, and Matsuura 1991.

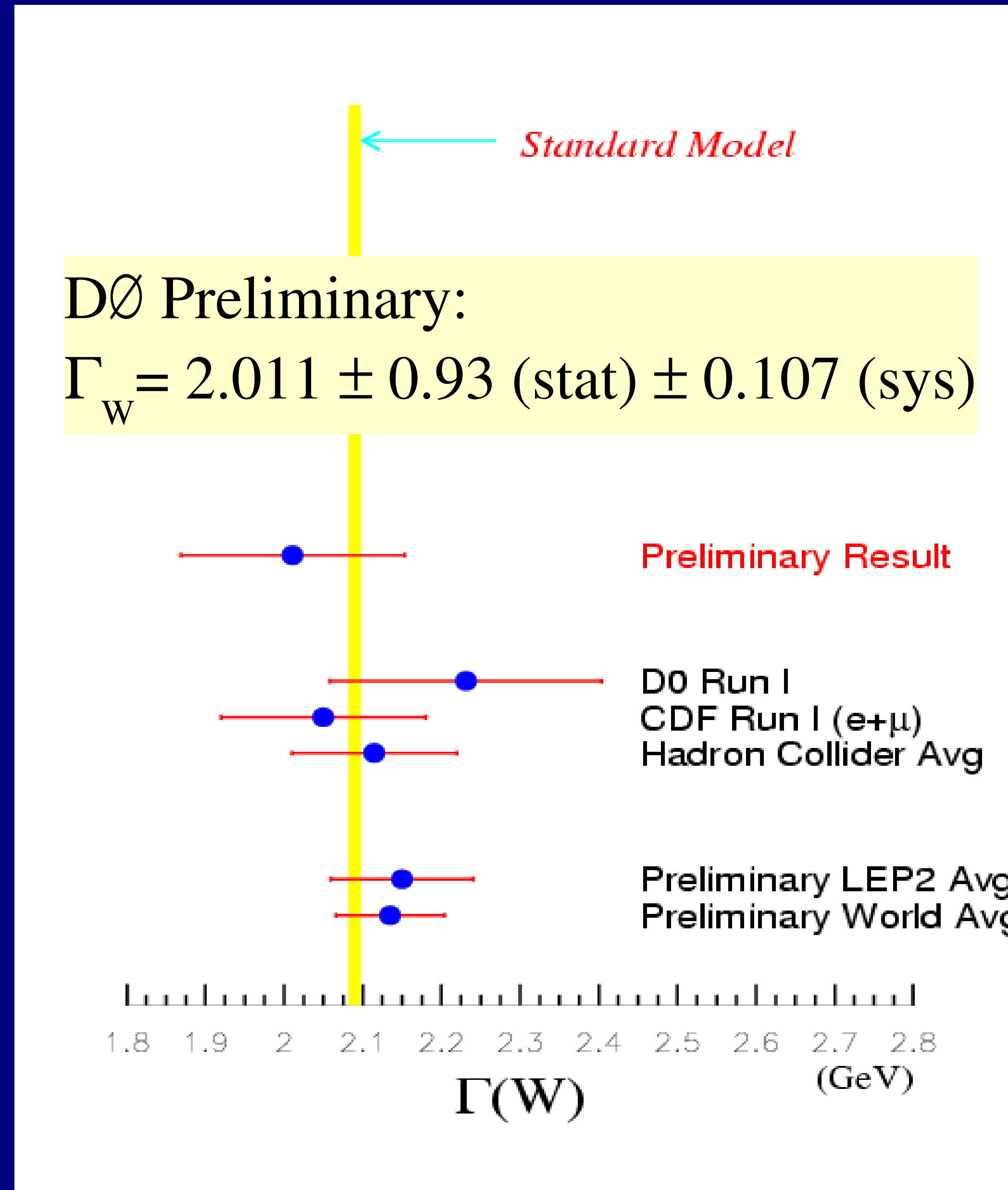
Direct Measurement of the Total W Width





Main Systematic Uncertainties:

- Hadronic response & resolution ~64 MeV
- Underlying event ~47 MeV
- EM resolution ~30 MeV



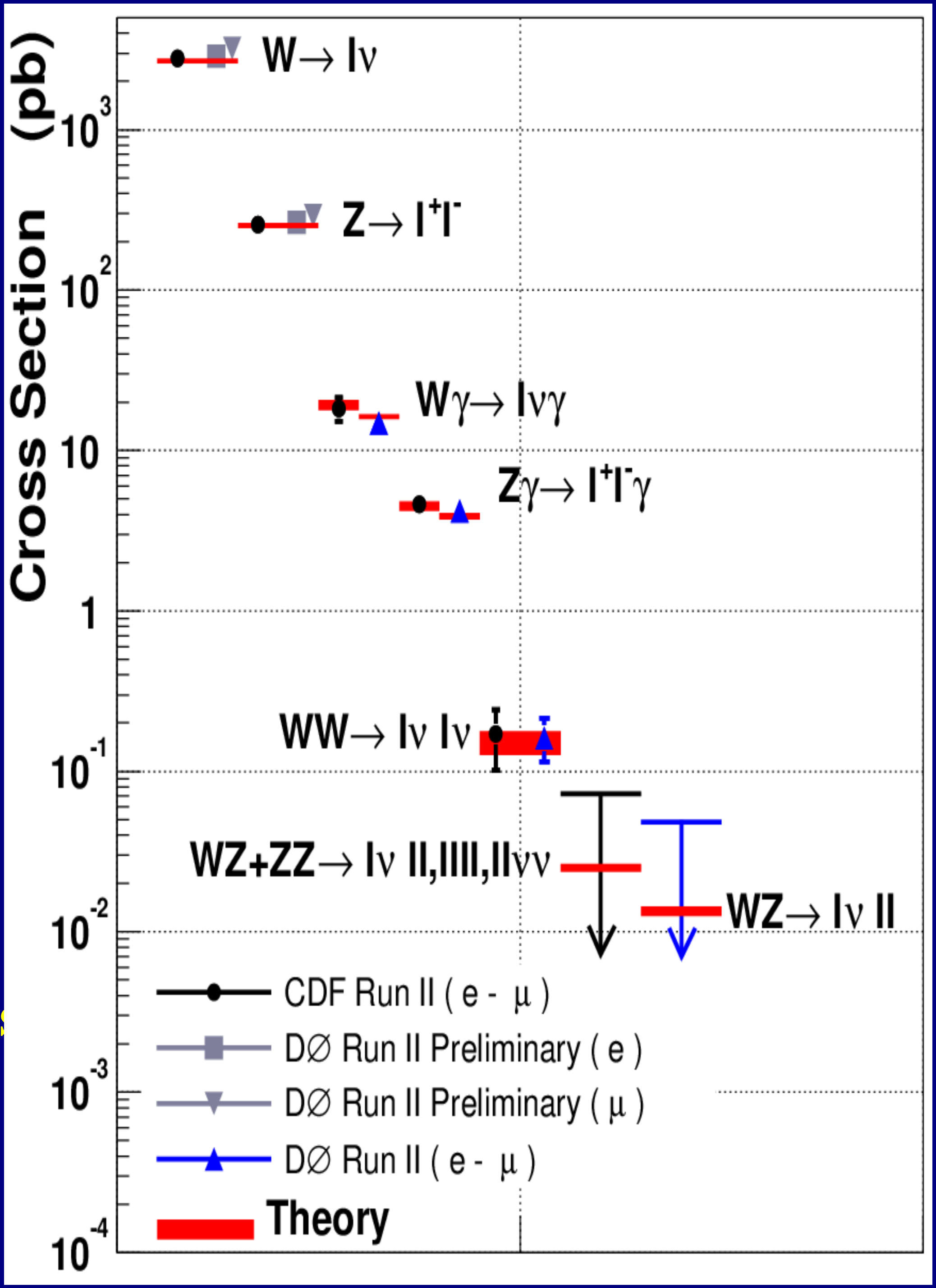
DØ Preliminary:

$$\Gamma_W = 2.011 \pm 0.93 \text{ (stat)} \pm 0.107 \text{ (sys)}$$

Other cross-sections:

- W+photon
- Z+photon
- WW
- WZ+ZZ (limit)

These measurements are also used to set limits on anomalous couplings



Events in $L=100\ pb^{-1}$

100,000

10,000

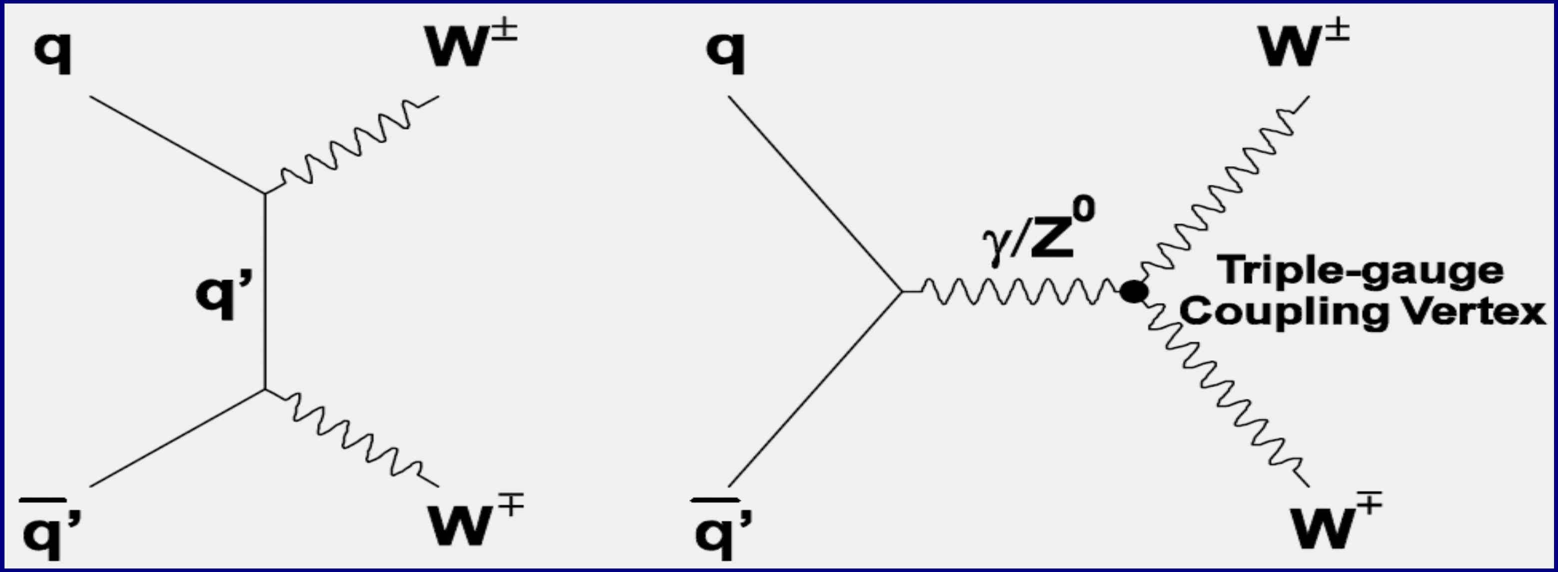
1,000

100

10

1

WW Production



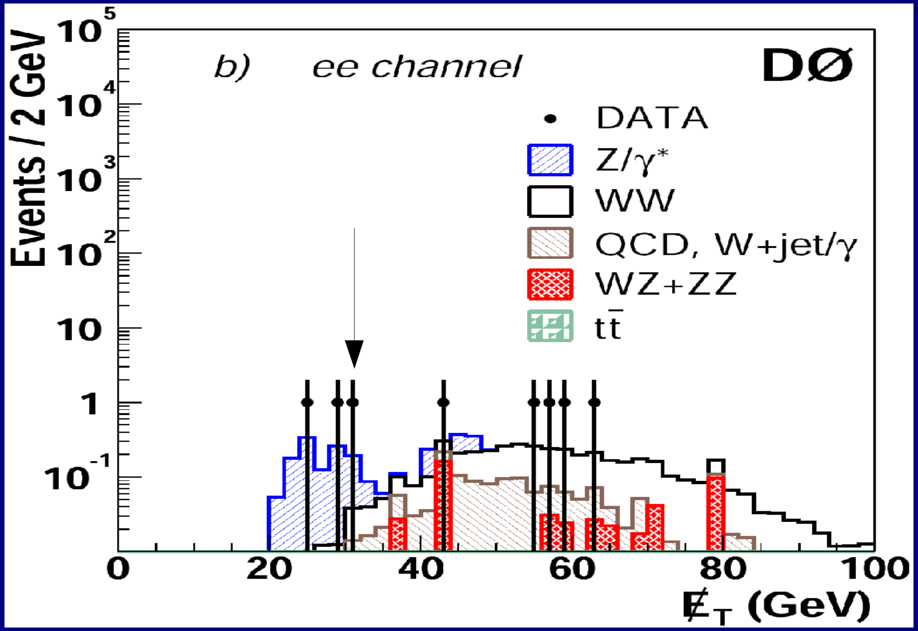
- Background for Higgs and NP searches
- Di-lepton analysis in the channels ee, μμ, eμ
- Sensitive to WWZ /WWγ

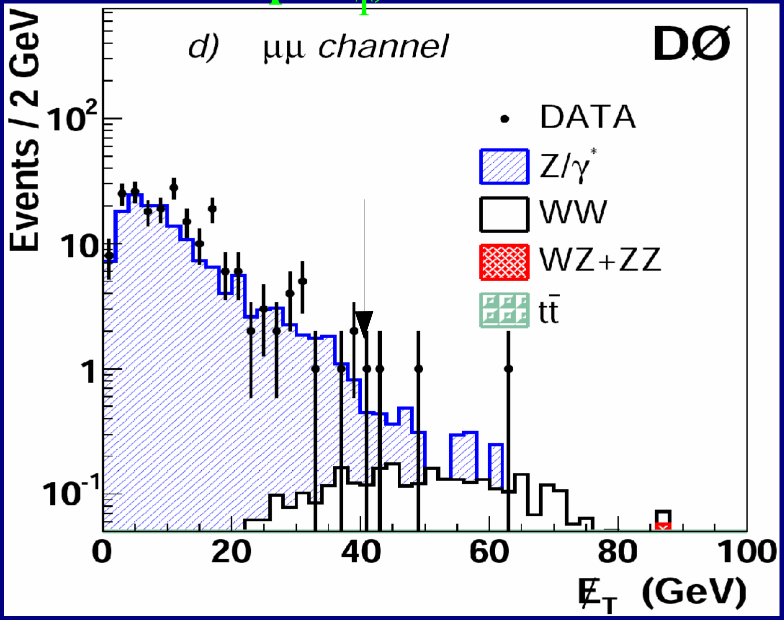
- Main Backgrounds:
  - W+j/γ, dijet
  - Drell-Yan
  - top pairs
  - WZ, ZZ

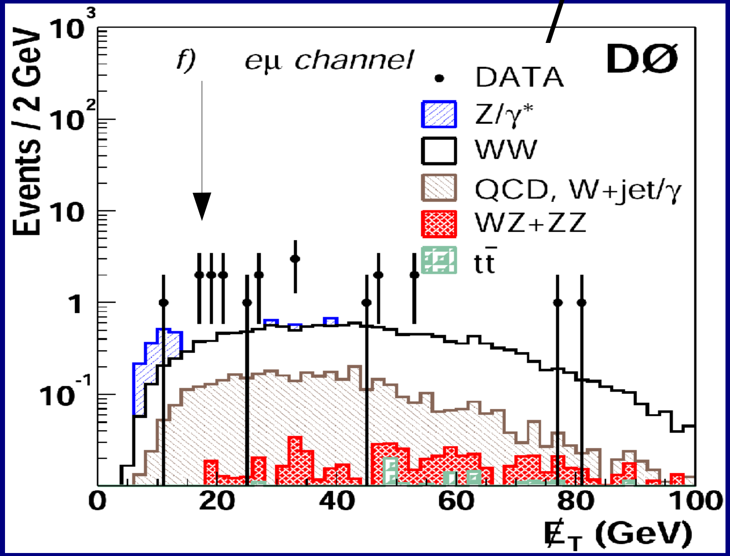
WW Event Selection

Good Agreement between data and signal+background MC

(Plots show data, MC after all cuts except E_T)







	ee	μμ	eμ
$\int\mathcal{L}$ (pb^{-1})	252	224	235
Efficiency(%)	8.71± 0.13	6.22± 0.15	15.4 ± 0.2
Expected Background	2.30± 0.21	1.95± 0.41	3.81± 0.17
Expected WW	3.42± 0.05	2.10± 0.05	11.1 ± 0.1
# Candidates	6	4	15

$$\sigma(pp\rightarrow W^+W^-) = 13.8^{+4.3}_{-3.8}(\text{stat})^{+1.2}_{-0.9}(\text{sys})\pm 0.9(\text{lum})\ \text{pb}$$

SM* 12.0-13.5 pb

Diboson Analyses: Wγ WW WZ Zγ

Test for AC via L_{eff}:

$$L_{WWV} / g_{WWV} = \boxed{g_V^1}(W^\dagger_{\mu\nu} W^\mu V^\nu - W^\dagger_\mu V_\nu W^{\mu\nu}) + \boxed{\kappa_V} W^\dagger_\mu W_\nu V^{\mu\nu} + \frac{\boxed{\lambda_V}}{M_W^2} W^\dagger_{\lambda\mu} W^\mu_\nu V^{\nu\lambda}$$

Where V = Z, γ

In SM: $g^1_V = \kappa_V = 1$

$\lambda_V = 0$

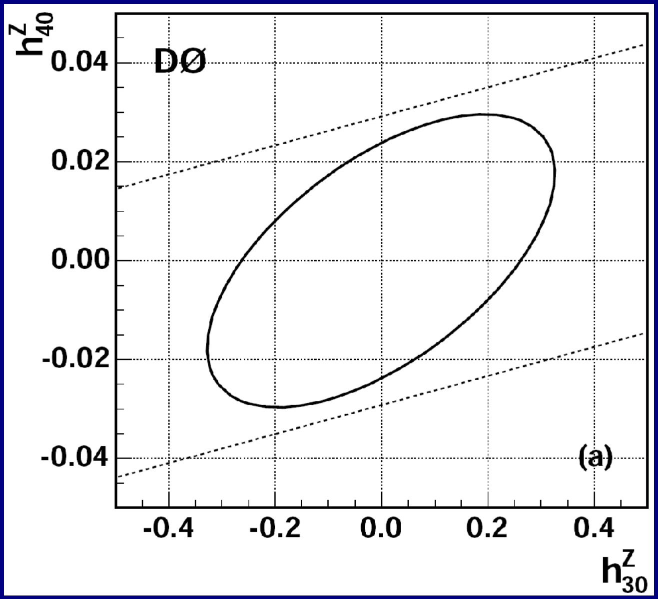
Determine from data:

$\Delta g^1_V = g^1_V - 1$; λ_V; $\Delta\kappa_V = \kappa_V - 1$

Coupling Limits

Zγ Production

channel	Observed	Expected (SM)	BG	$\int \mathcal{L}$ (pb^{-1})
eeγ	138	95.3 ± 4.9	23.6 ± 2.3	320
μμγ	152	126.0 ± 7.8	22.4 ± 3.0	290

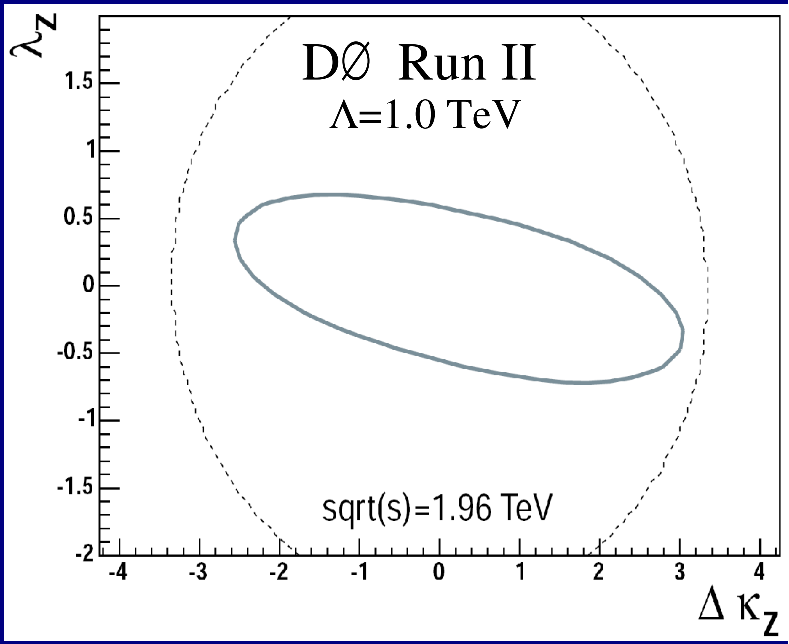


ZZγ Coupling Limits

WZ Production:

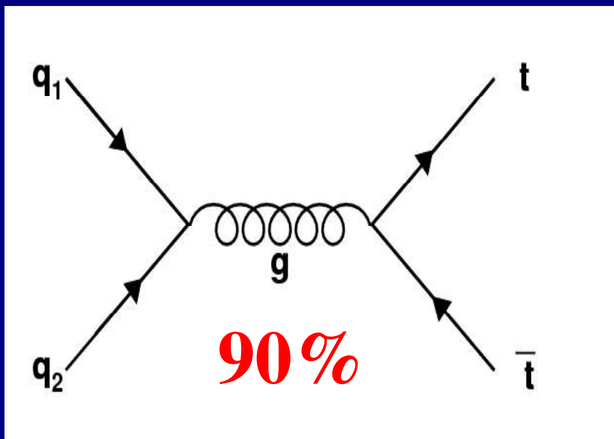
3 events observed

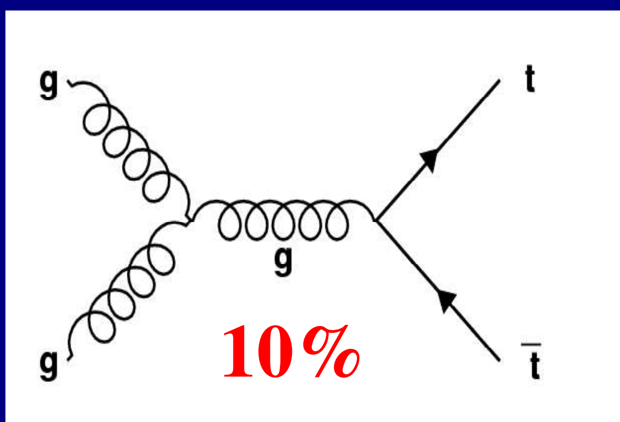
0.71 BG events expected

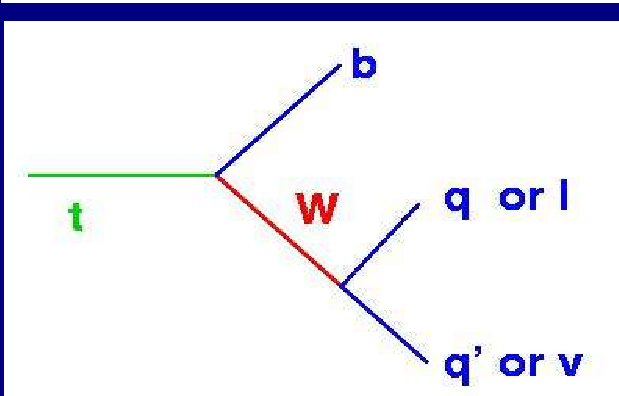


WWZ Anomalous Coupling Limits

Top Quark Production and Decay

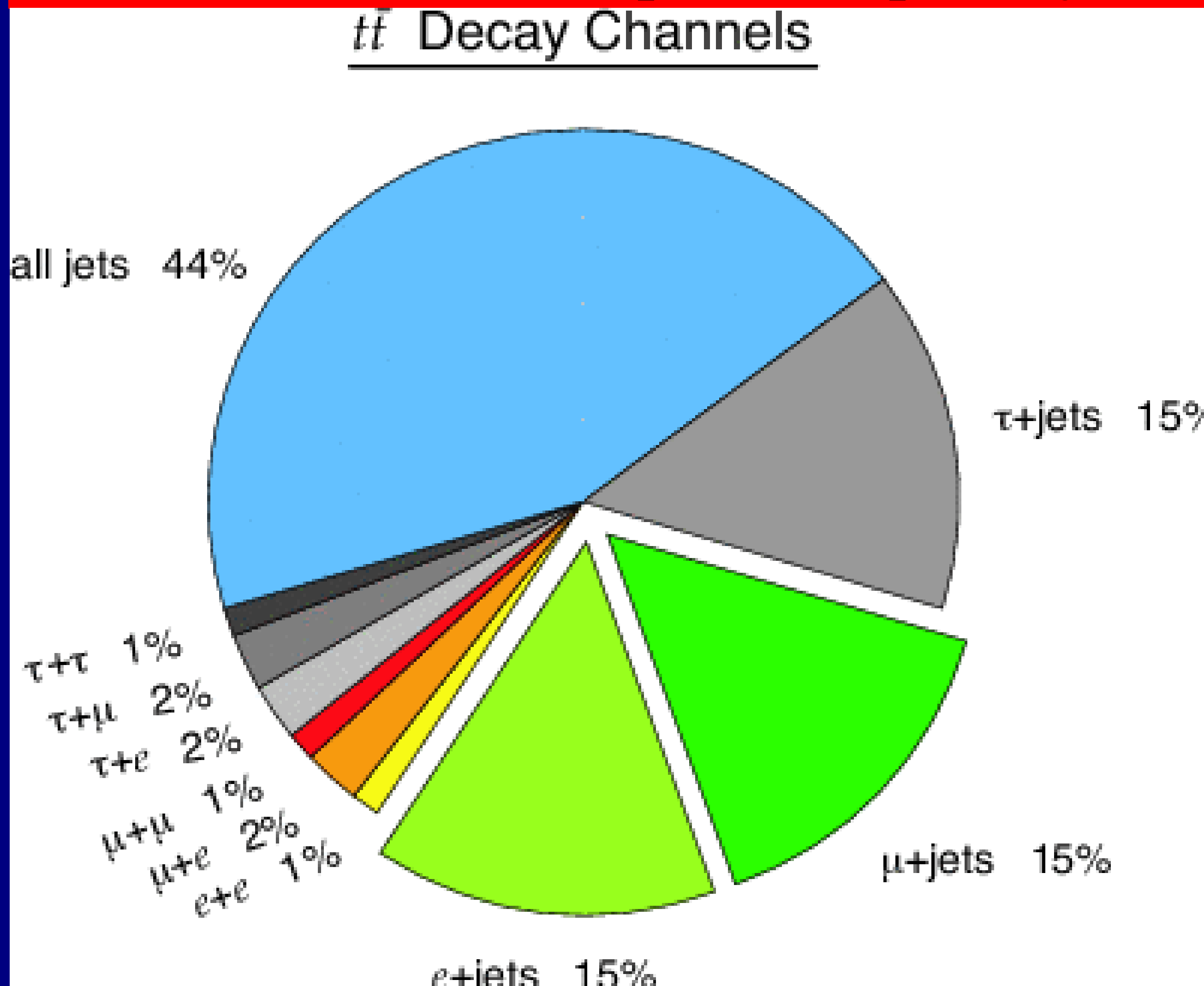




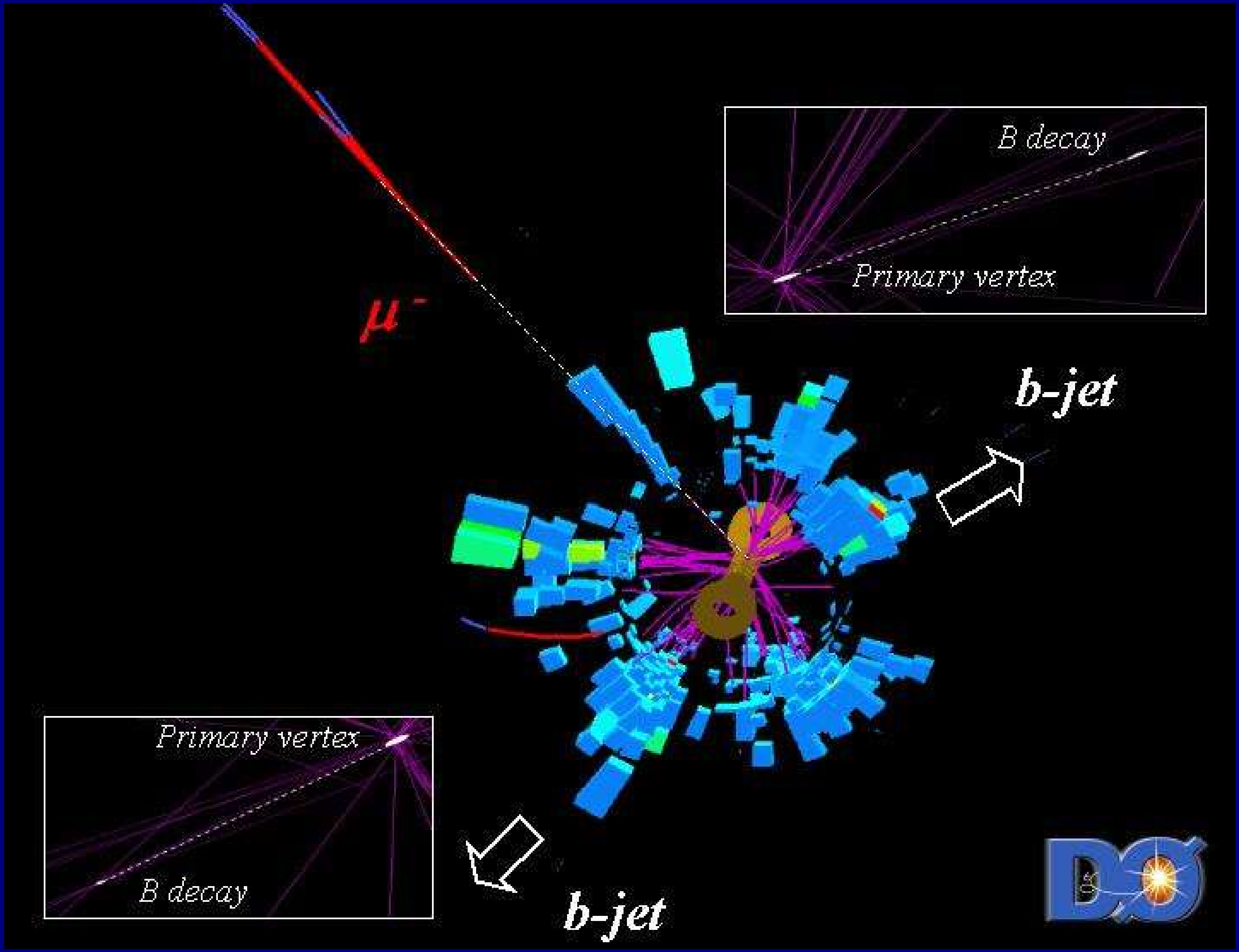


Br($t \rightarrow Wb$) ≅100% (SM)

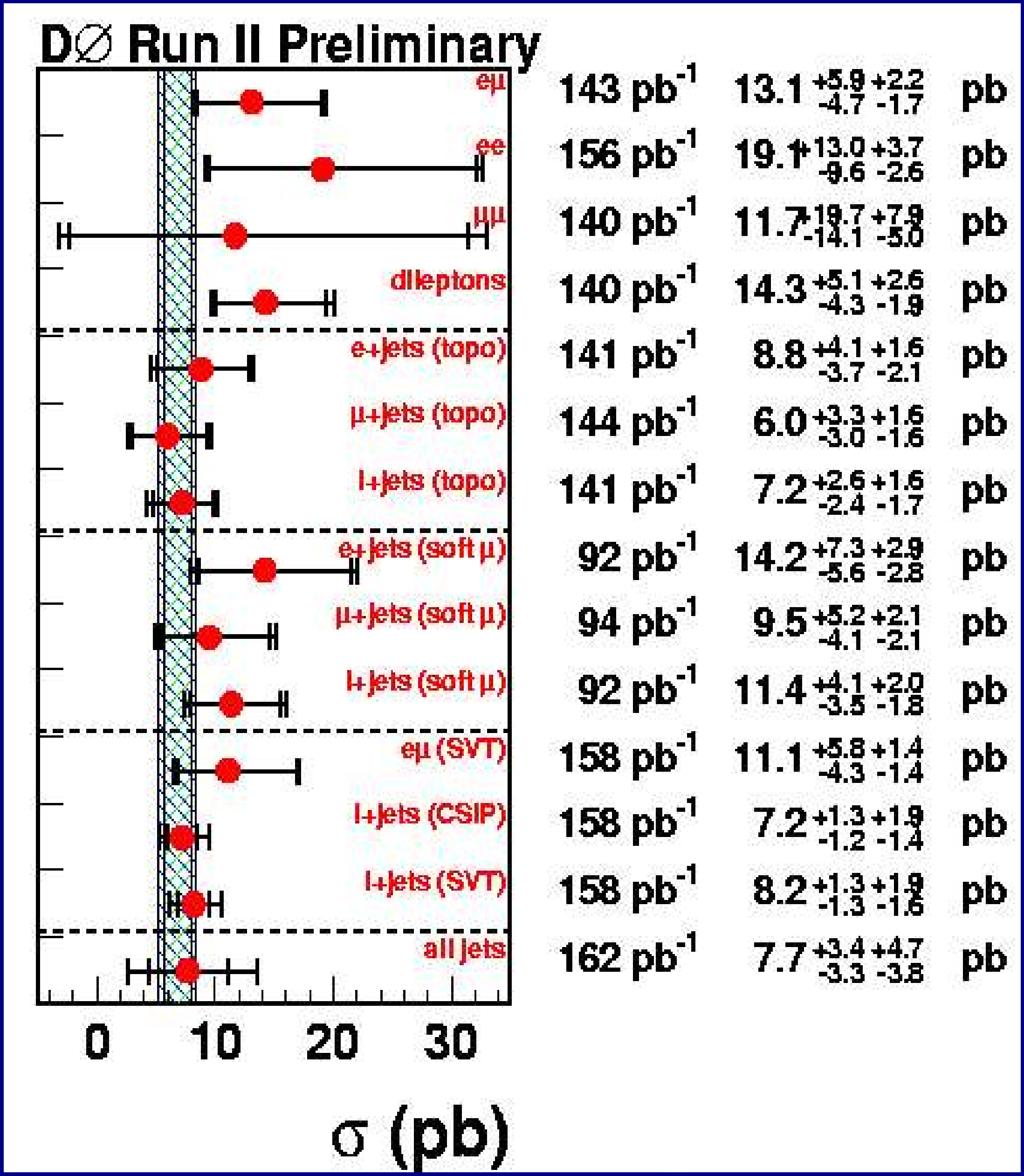
both W bosons decay in jets: 'fully hadronic'
both W bosons decay in e, : 'di-leptons'
one W hadronic & one leptonic: 'leptons+jet'



Top candidate: muon + jets with two b tags



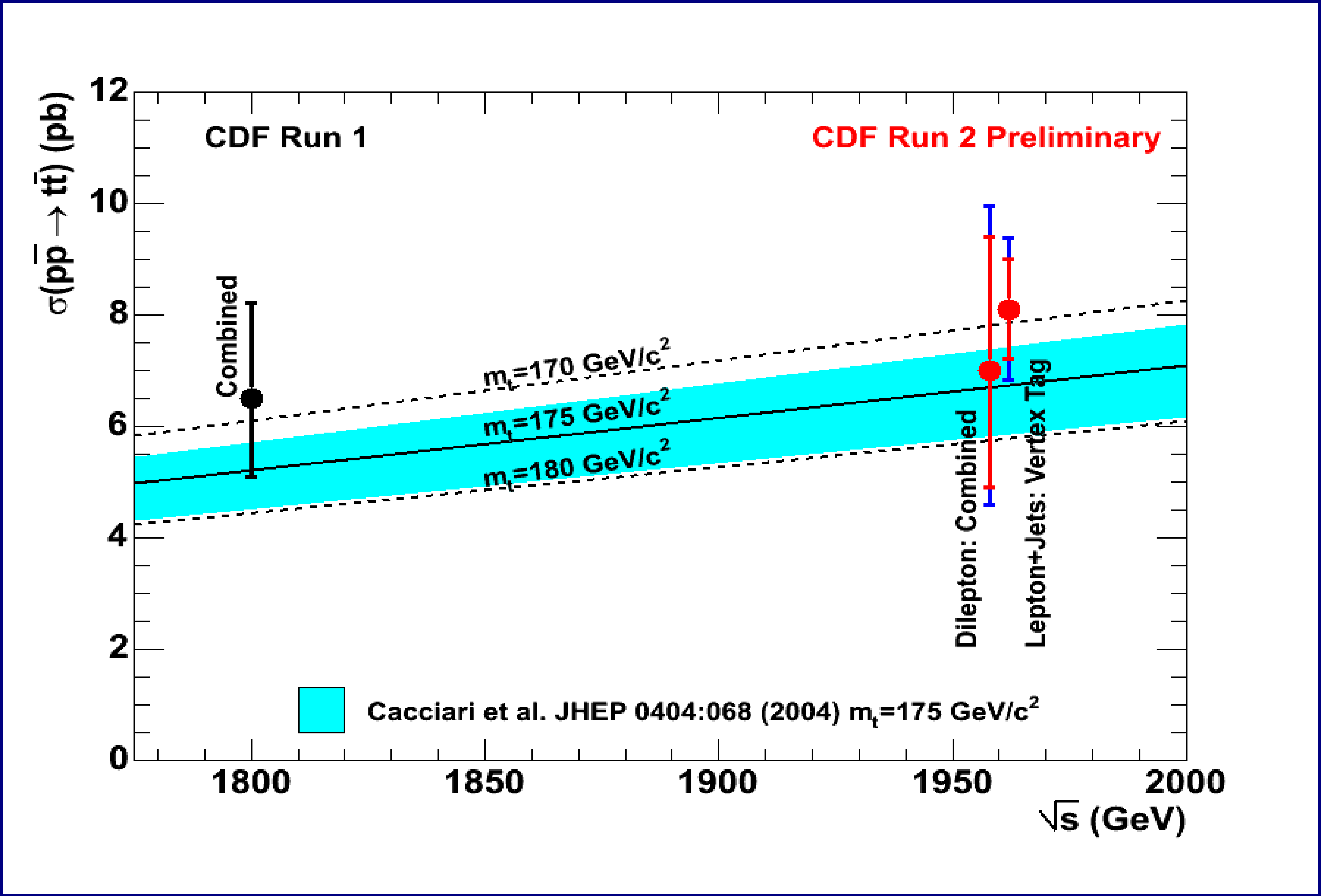
Preliminary Run II Top Pair Cross-sections:



Correlated uncertainties !

Cross-section about 30% larger than at Run I

Preliminary Run II Top Pair Cross-sections:



Cross-section about 30% larger than at Run I

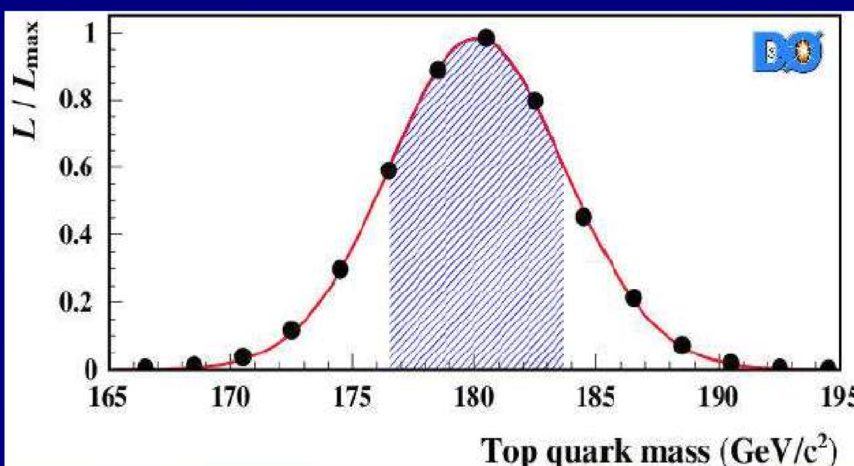
Top Mass (DØ Run I)

'Matrix Element Method: Event by event likelihood as function of top mass

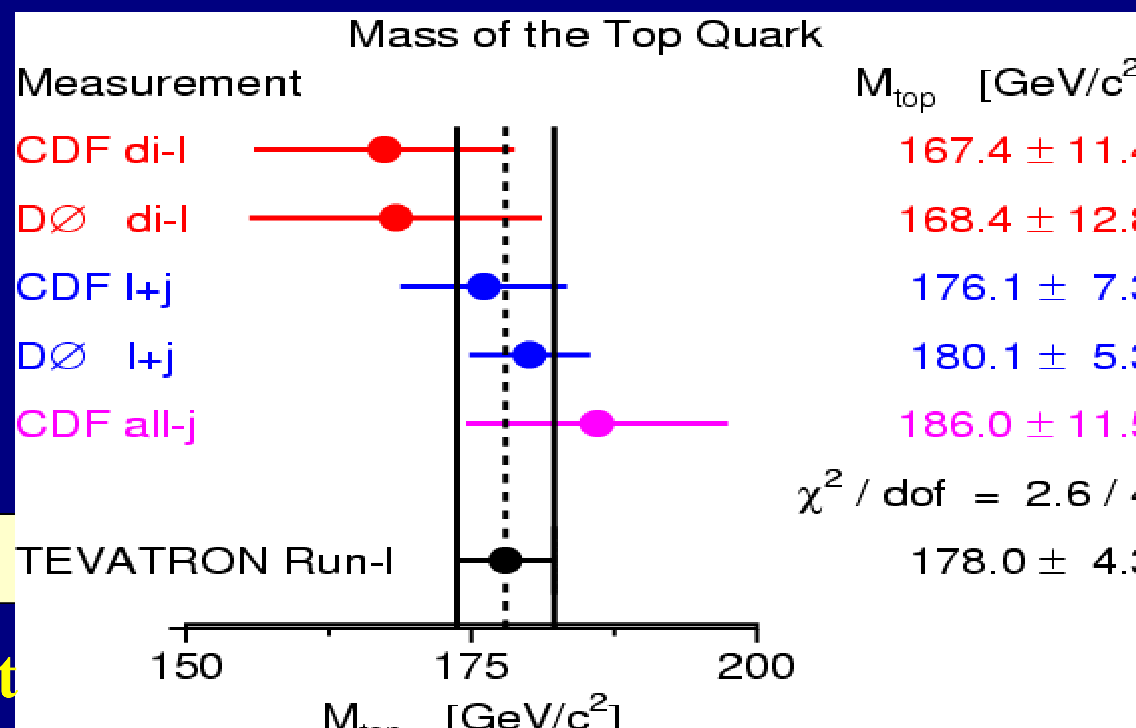
Probability density using LO matrix element and detector response:

$$P(x, m_T) = \frac{1}{\sigma(m_T)} \int \underbrace{d\sigma(y, m_T)}_{\text{Phase space x LO ME}} dq_1 dq_2 \underbrace{f(q_1) f(q_2)}_{\text{PDFs}} W(x, y)$$

Transfer function (resolution)



m_t = 180.1±3.6(stat)±3.9(syst) GeV

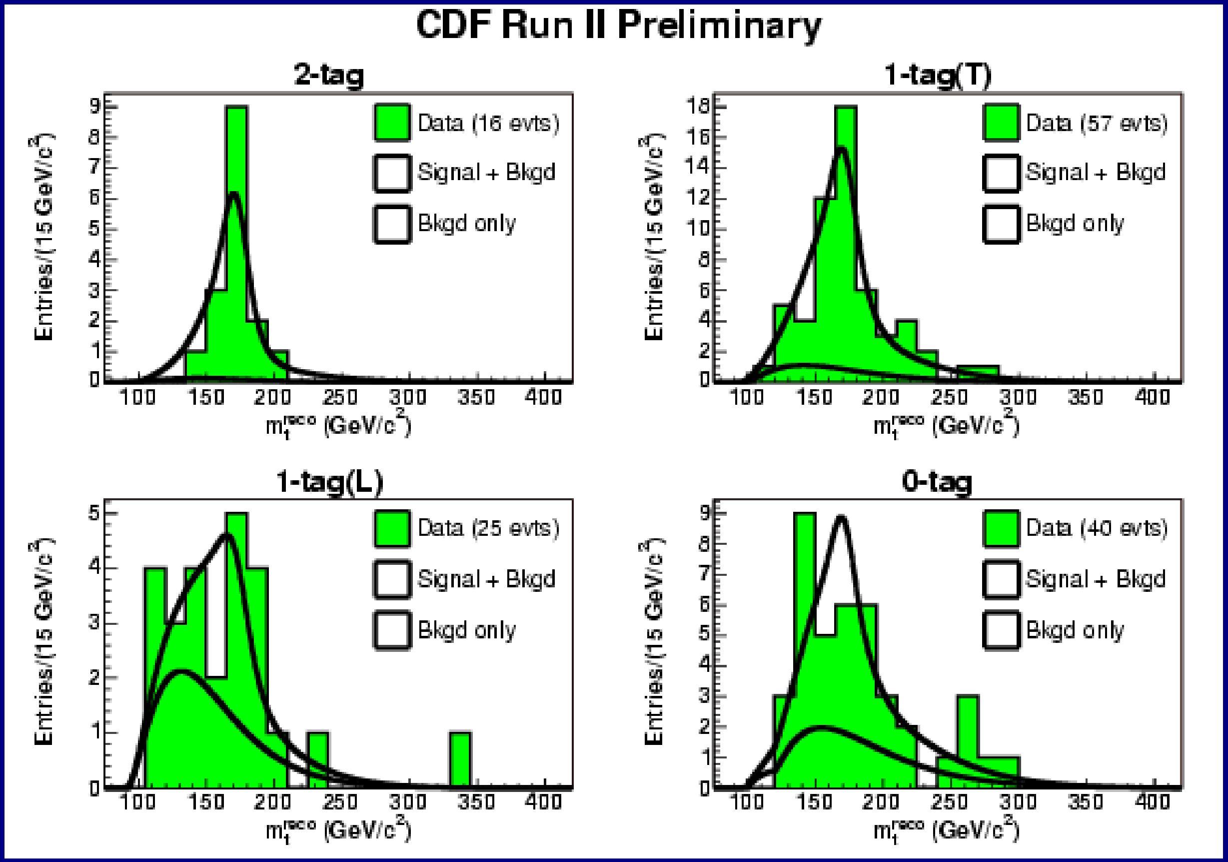


single most precise measurement

increases m_H by 21 GeV

Top Mass (CDF Run II)

Lepton + Jets with b tags



m_t = 173.5±3.7(stat+JES)±1.7(syst) GeV

single most precise Run II measurement

Summary

- Many Run II results with $L=150\text{-}250\ pb^{-1}$ (about twice Run I luminosity)
- High statistics & high precision measurements of W and Z cross-sections
- Other results: Di-bosons, top cross-section & mass

Thanks to Terrence Tool for some of the transparencies

Workshop Tasks ?

- Better understanding of modelling uncertainties & prescriptions for their determination (pdf, MC based acceptance..)
- Systematic comparison of Tevatron results with state of the art generators and calculations