W and Z Cross Section Measurements at CDF

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U.o. Athens and INFN Pisa,
on behalf of CDF collaboration

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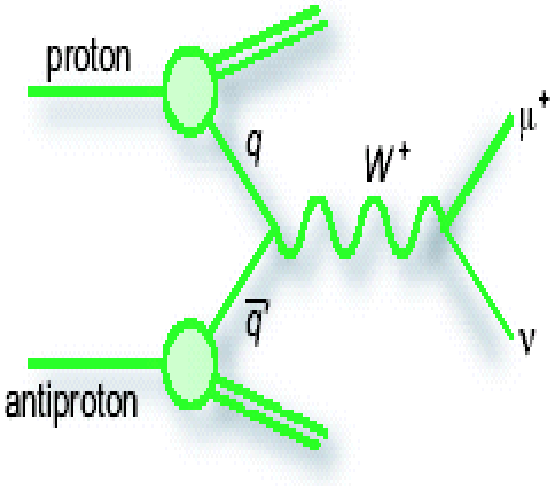
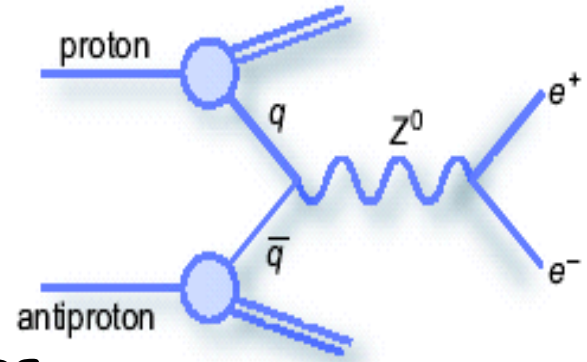
Canada



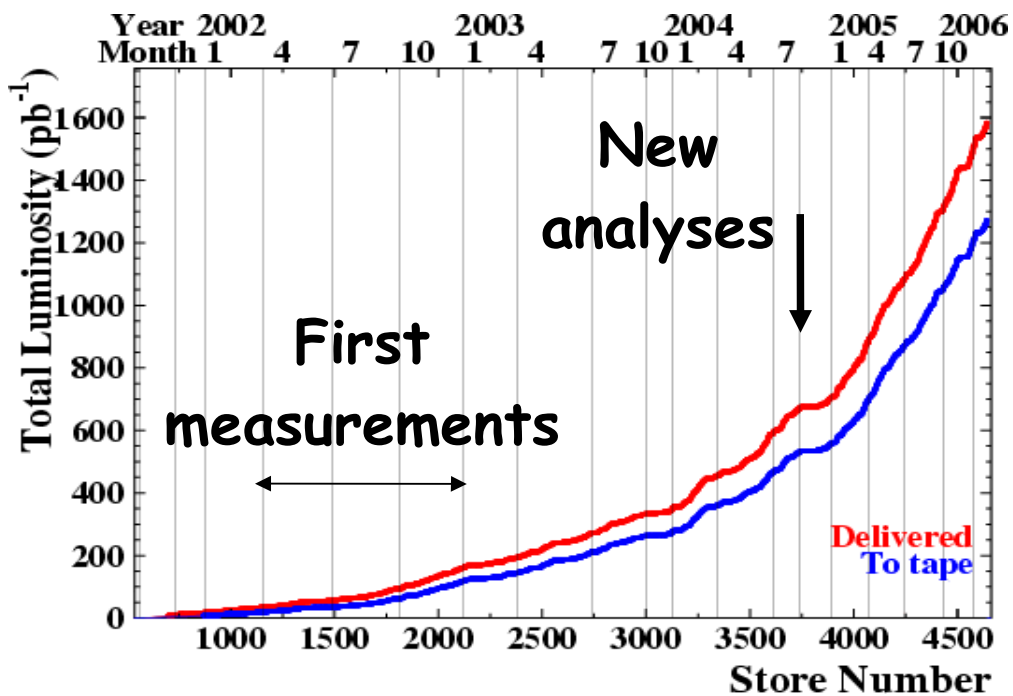
HPRN-CT-2002-00292
Research
Training Networks

Why W&Z cross section?

- Precise Electroweak measurements
  - -> constrain Standard Model (or) suggest Physics beyond SM
- W,Z signal well established
  - -> base of detector performance studies
- Cross section measurements
  - -> ensure good understanding of e,μ,τ identification
  - -> common cross-check for other analyses



- New data available
  - -> first measurements based on 72 pb^{-1} of data collected during 2002-2003
  - -> ~300 pb^{-1} of additional data collected 2003-2004



W and Z cross section at CDF

Tevatron -> W and Z hadronic decay overwhelmed by QCD background

-> bosons identified by leptonic decay

$$\sigma.Br = \frac{N_{EVENTS} - N_{BACKGROUND}}{A \times \varepsilon \times \int Ldt}$$

N_{EVENTS} = # of observed events

$N_{BACKGROUND}$ = # of expected background

ε = efficiency (trigger,reconstruction,ID)

A = geometrical and kinematical efficiency (usually based on Monte Carlo)

$\int Ldt$ = integrated luminosity -> dominant uncertainty of all cross section measurement (6%)

Measurement strategy:

1. identify clean signal and estimate background contamination
2. evaluate efficiencies
3. estimate systematics

Talk Overview:

New results from CDF

⇒$\sigma_W.Br(W\to e\nu)$ $\int Ldt \sim 223pb^{-1}$

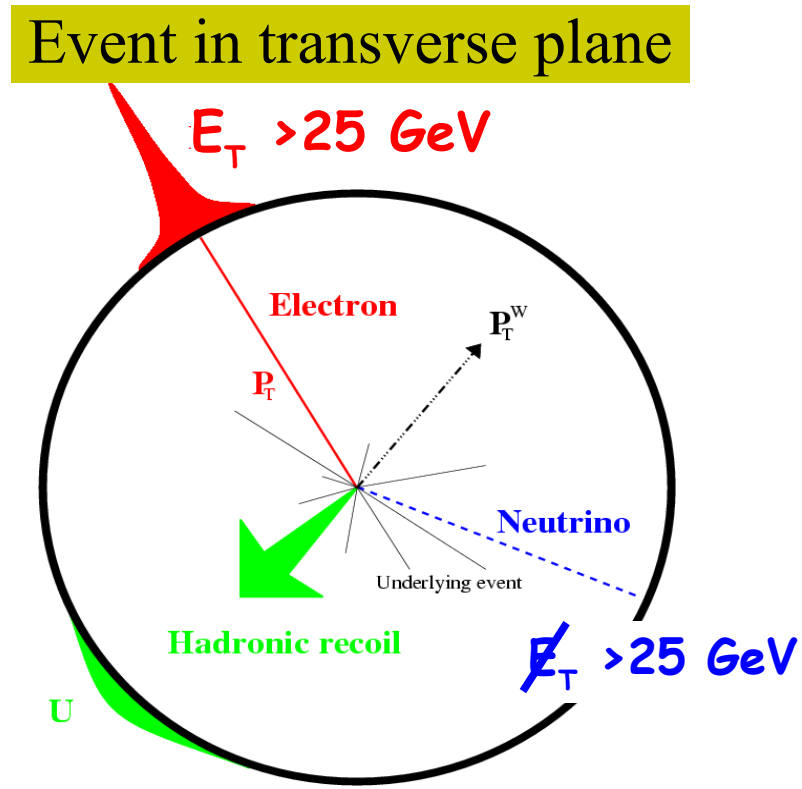
⇒$\sigma_Z.Br(Z\to\mu\mu)$ $\int Ldt \sim 337pb^{-1}$

⇒$\sigma_Z.Br(Z\to\tau\tau)$ $\int Ldt \sim 349pb^{-1}$

W boson signatures at CDF

W->eν signatures

- Large missing energy in transverse plane
- Isolated electron:
  -> combination of calorimeter signal and high p_T track



W analysis for first 72 ± 4.4 pb^{-1} @ CDFII
CDF: PRL 94, 091803 (2005)

- Cross section measurements
- W branching ratio
- W width Γ_W
- V_{cs}
- g_μ/g_e

W measurements based on data collected with central part of detector

$$\sigma.BF(W\to e\nu) = 2.780 \pm 0.014\,(stat) \pm \begin{matrix}0.063(syst)\\0.057(syst)\end{matrix} \pm 0.166(lum)\ nb$$

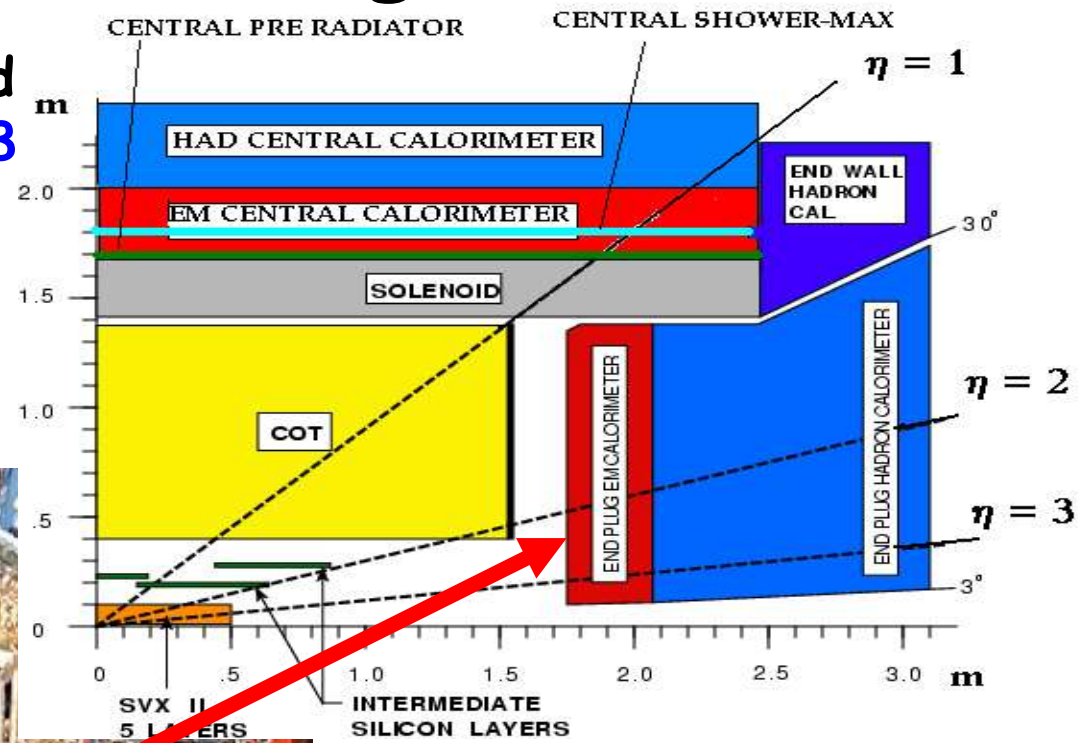
combined results for e and μ

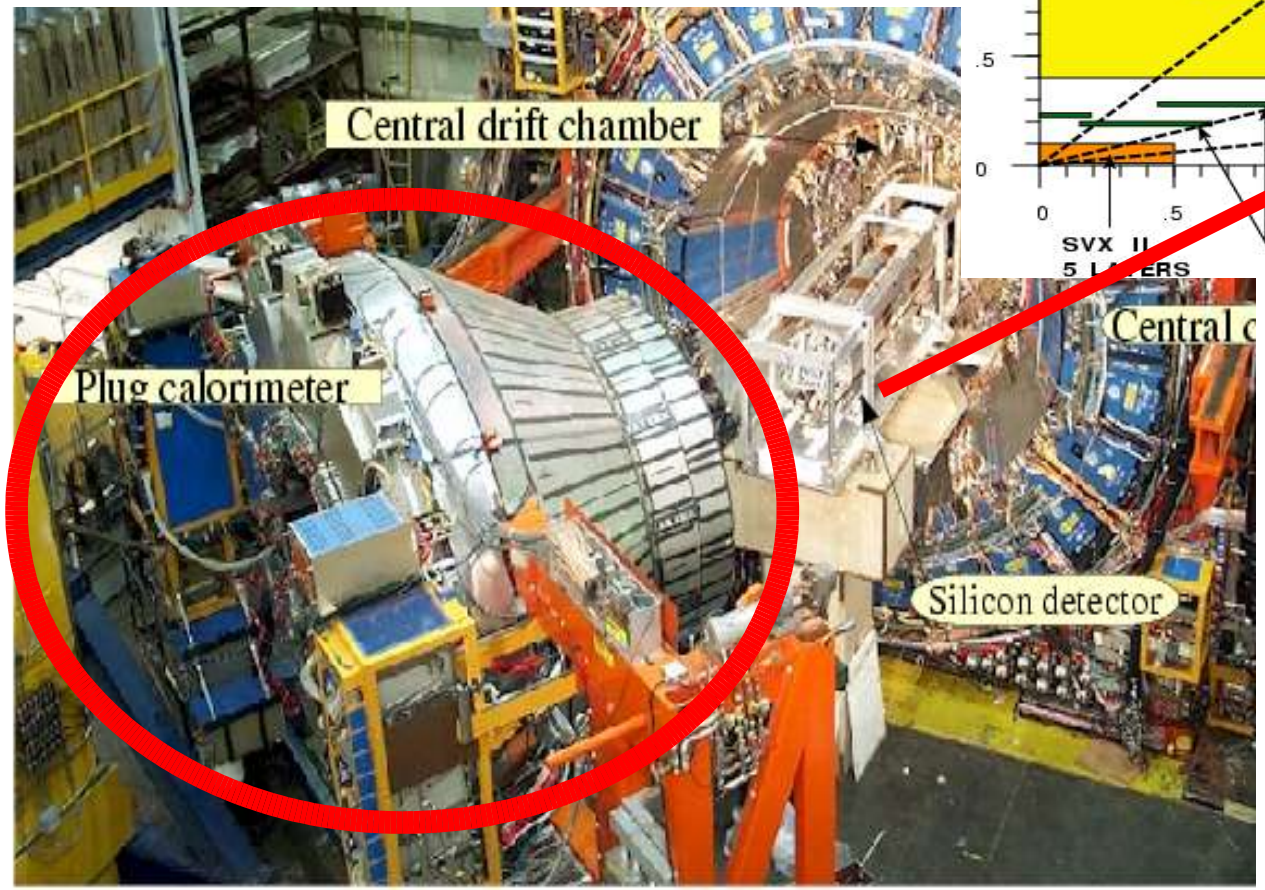
$$\sigma.BF(W\to l\nu) = 2.775 \pm 0.010\,(stat) \pm 0.053(syst) \pm 0.166(lum)\ nb$$

W boson in forward region of CDF

Extension of electron ID to forward region of detector -> 1.2 <|η|< 2.8

Used combined information from forward EM calorimeters and extended tracking system (ISL)





$$\eta = -\ln\left(\tan\frac{\Theta}{2}\right)$$

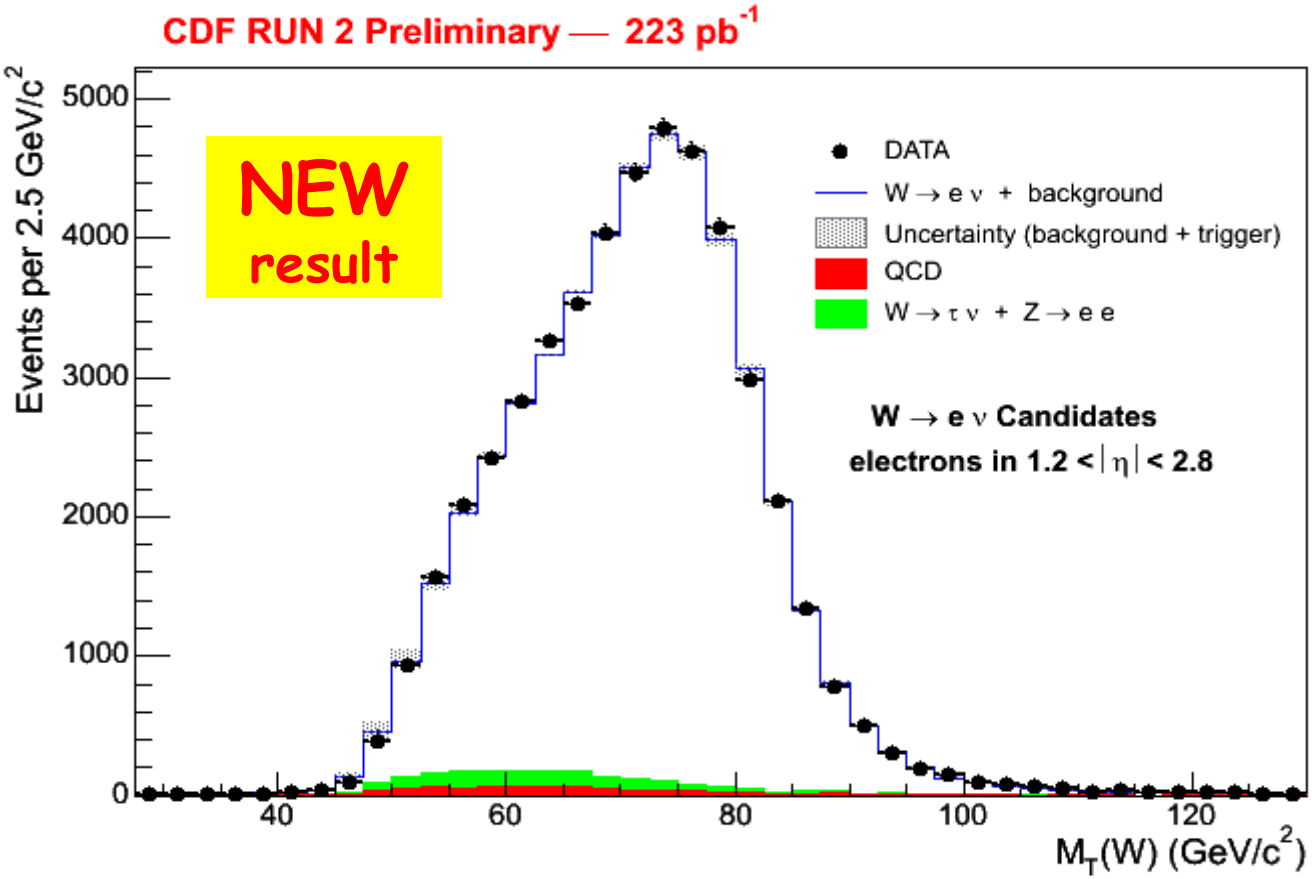
Increases sample size at given luminosity for many analyses:
ttbar sample increase by ~ 15% with forward region included

W boson in forward region of CDF

1.2 <|η|< 2.8

W->eν in numbers:

- 48144 W candidates with ~4.5% background contaminations
- acceptance x efficiency of signal selection ~7%
- largest source of systematics coming from acceptance ~2% (PDF)



Forward CDF W cross section measurement with 223 pb^{-1}

$\sigma.BF(W\text{->}e\nu) = 2.815 \pm 0.013\,(stat) + 0.094(syst) - 0.089(syst) \pm 0.169(lum)$ nb

$\sigma(pp\text{->}W)_{Th}@\sqrt{1.96}$ TeV = $2.687 \pm 0.054_{(Th)}$ nb(NNLO), (Stirling, van Neerven)

W boson in forward region of CDF

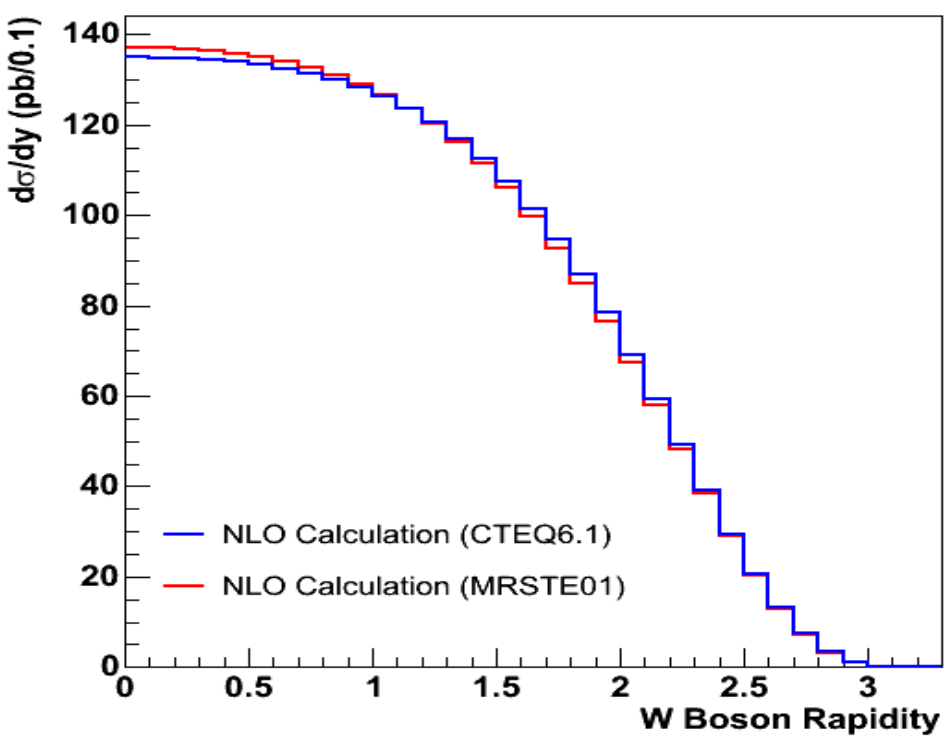
$1.2 < |\eta| < 2.8$

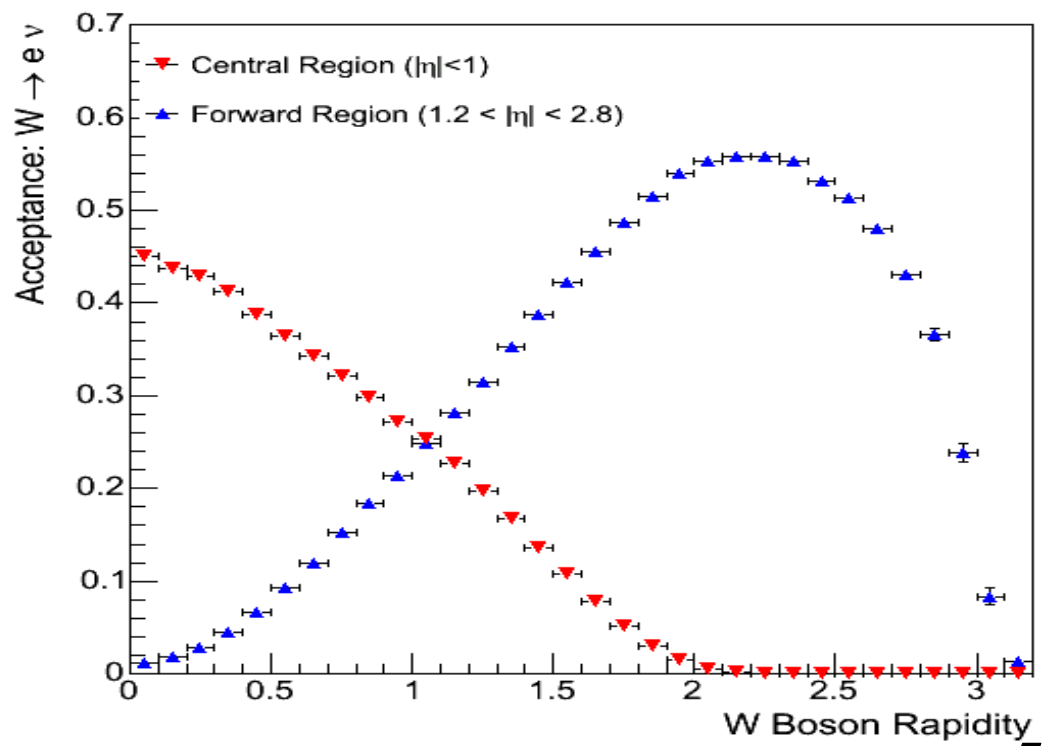
Next steps:

- Comparison of experimental measurements of central and forward W production (ratio of cross sections)
- Test of theoretical predictions in different lepton pseudorapidity range -> different sensitivity to PDF source of uncertainty (hep-ph/0405130)

Looking at the future -> luminosity measurement at LHC collider based on process with high production cross section, clean signature and well known theoretical uncertainties

$$\sigma(W)_{th} = \frac{1}{\int L dt} \frac{N^{obs}}{A_W}$$

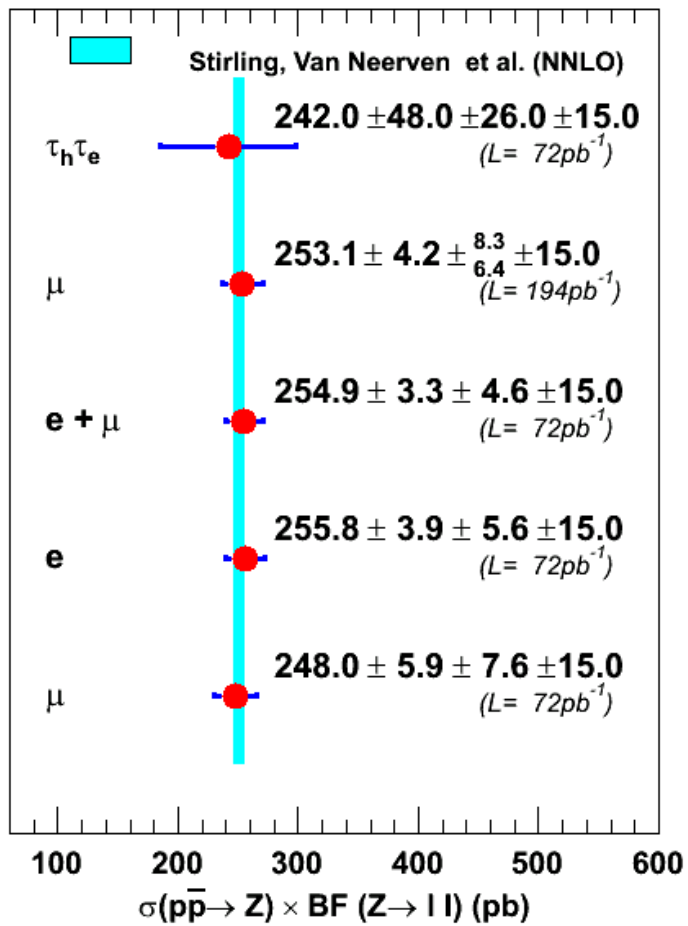


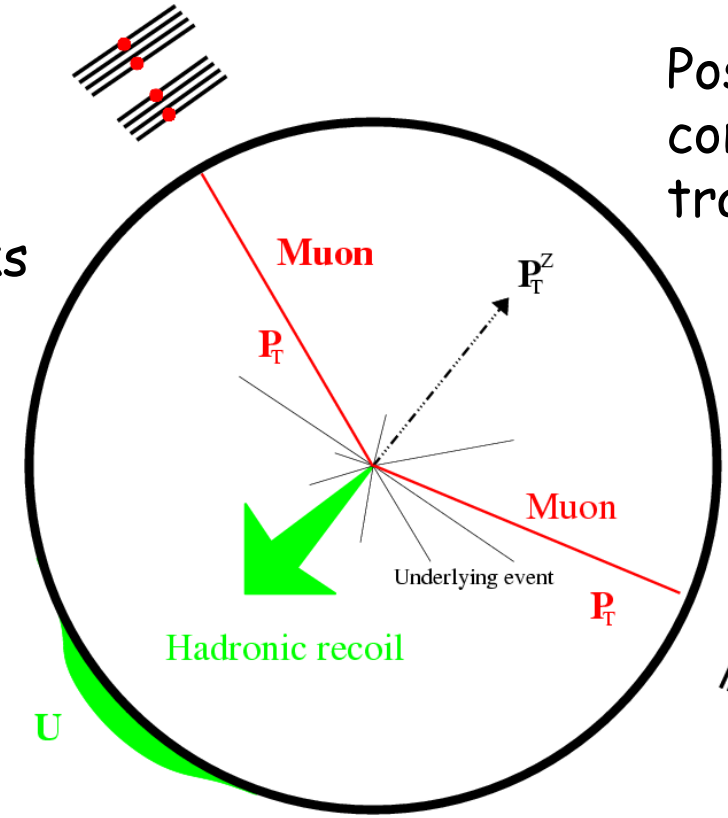


Z->μμ signatures at CDF

Muon signatures:

- Signal in muon detectors (|η|<1)
- Isolated high p_T tracks





Position of detected μ consistent with extrapolated track

Z signature:

Two isolated μ (leptons) with opposite charge

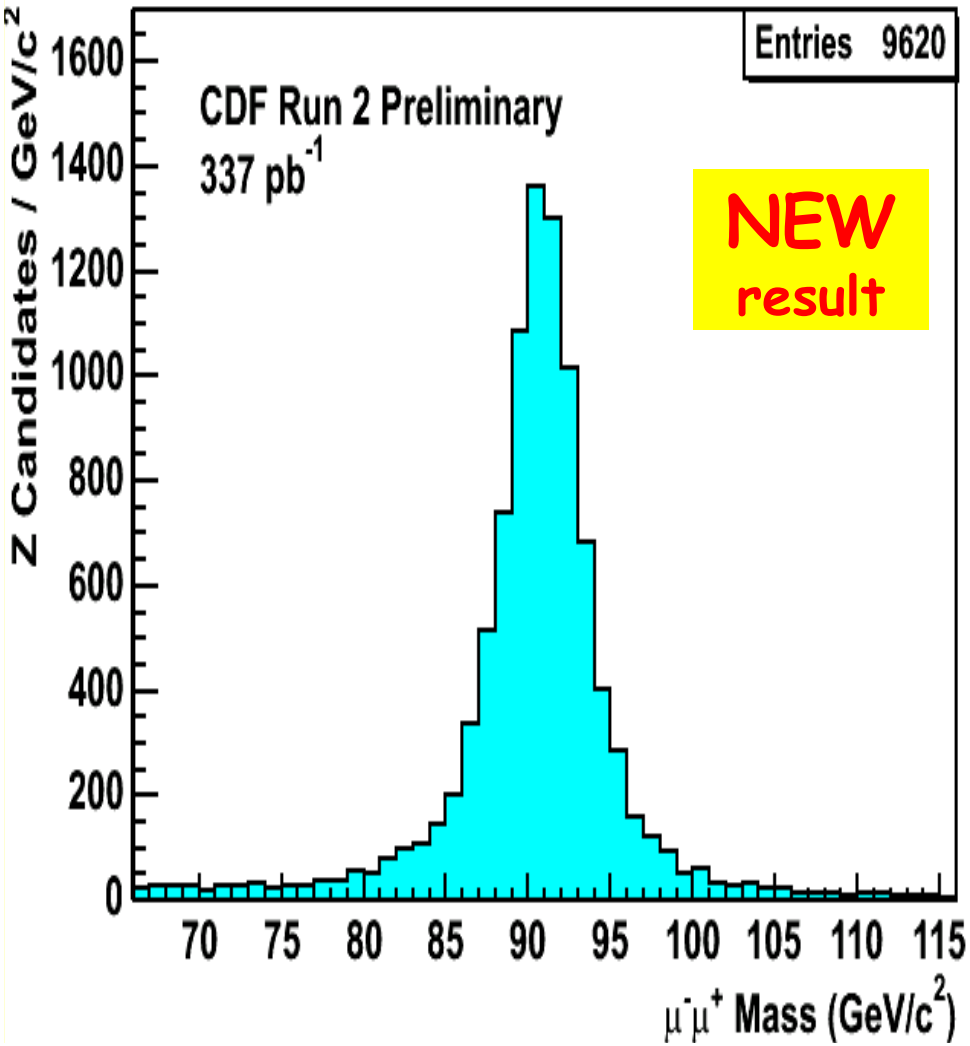
- Measurement using first 72 pb^{-1} showed good agreement with NNLO
- Results combined with W cross section measurement to extract Γ_W

$\sigma_Z.B(Z/\gamma^* \to \mu\mu) = 248.0 \pm 5.9_{stat} +8.0_{syst} -7.2_{syst} \pm 15.1_{lum}$ pb

combined $\sigma_Z.B(Z/\gamma^* \to ll) = 254.9 \pm 3.3_{stat} \pm 4.6_{syst} \pm 15.2_{lum}$ pb

Z->μμ cross section using 337 pb^{-1}

The new result -> first step towards Z boson $d\sigma/dp_T$ measurement



Changes:

- new generation of reconstruction software and Monte Carlo samples
- Modified selection criteria
  -> optimized for Z boson p_T distribution measurement

Z->μμ in number:

- 9620 Z candidates with 8 background events
- Overall efficiency ~ 10%
- Luminosity is dominant uncertainty

NNLO @ √1.96 TeV (Stirling,van Neerven)

$\sigma(pp\to Z)_{Th}=251.3 \pm 5.0_{(Th)}$ pb

$\sigma(pp\to Z/\gamma^*).B(Z/\gamma^*\to\mu\mu) = 261.2 \pm 2.7_{stat} +5.8_{syst} -6.9_{syst} \pm 15.1_{lum}$ pb

τ identification and Z->ττ cross section

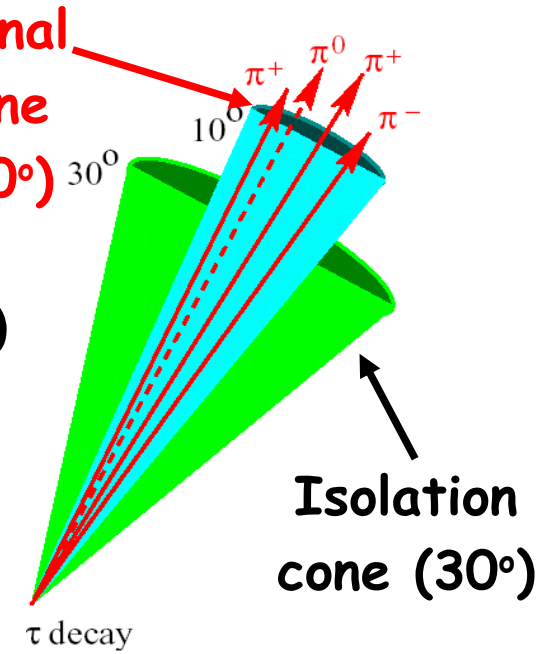
Taus -> difficult to reconstruct at hadron colliders

Z->ττ -> exploit event topology to suppress backgrounds (QCD & W+jet)

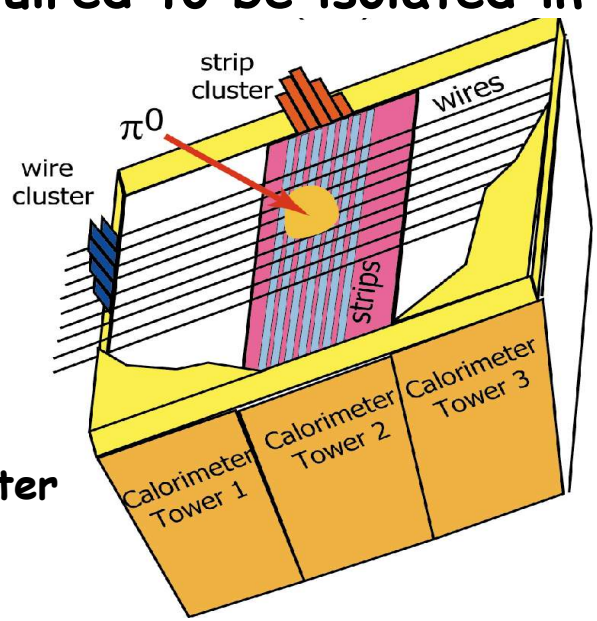
-> measurement of cross section important for Higgs and SUSY analyses

CDF strategy of hadronic τ reconstruction:

1. Charged tracks -> define signal and isolation cone
   isolation: require no tracks in isolation cone
2. Hadronic calorimeter clusters (to suppress e background)
3. π^0 identified by shower maximum detector (CES)
   -> π^0 required to be isolated in signal cone



CES
-> resolution 2-3mm
-> proportional strip/wire drift chamber at $6X_0$ of EM calorimeter



Channel for Z->ττ: e +isolated track

τ->e (E_T>10GeV)

τ->h (p_T>15GeV/c)

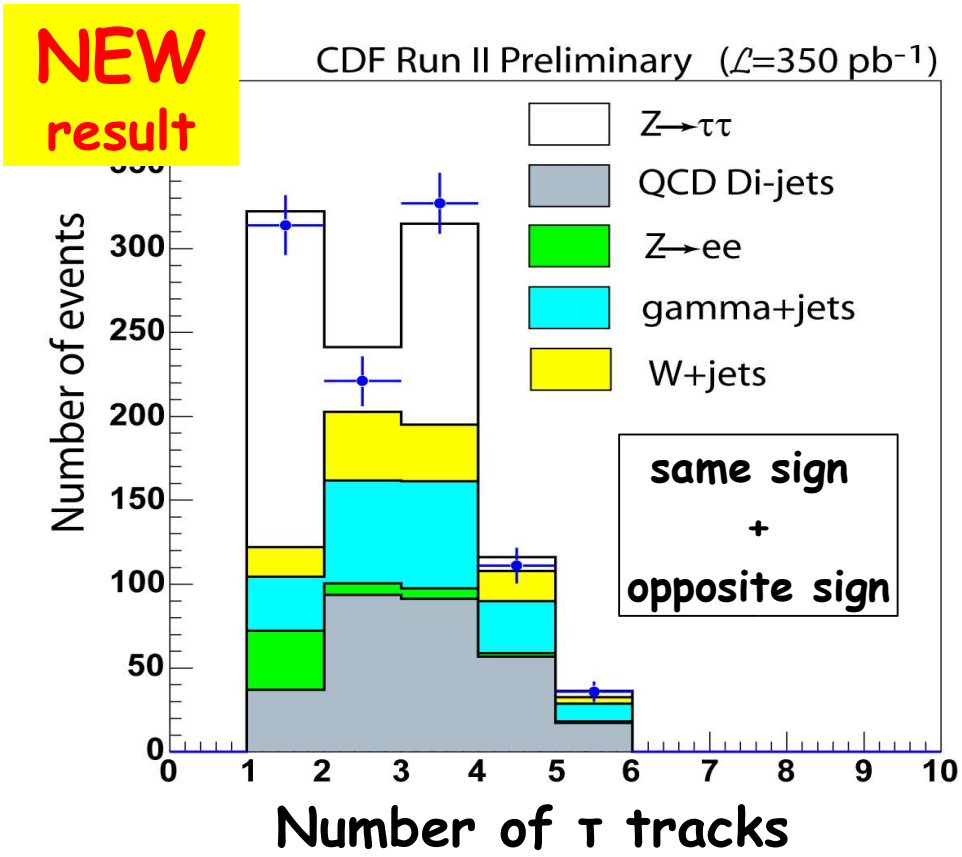
+ remove DY(ee) and apply event topology cuts for non-Z background

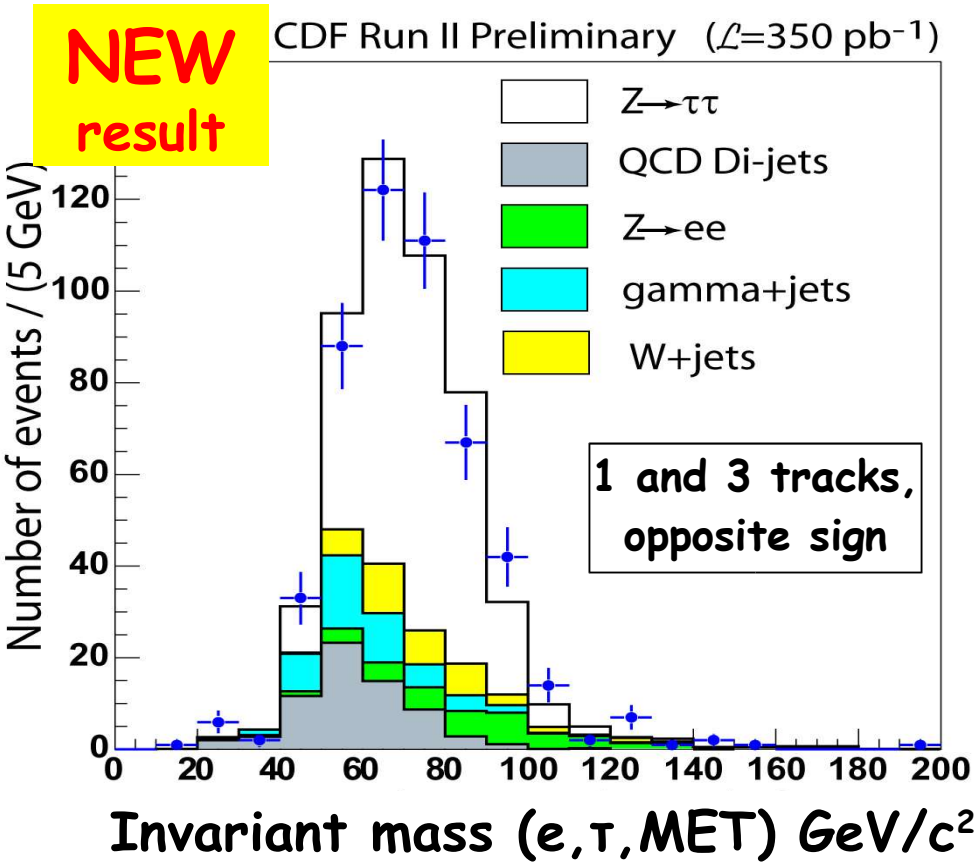
Z->ττ cross section using 349pb^{-1}

Z->ττ in numbers:

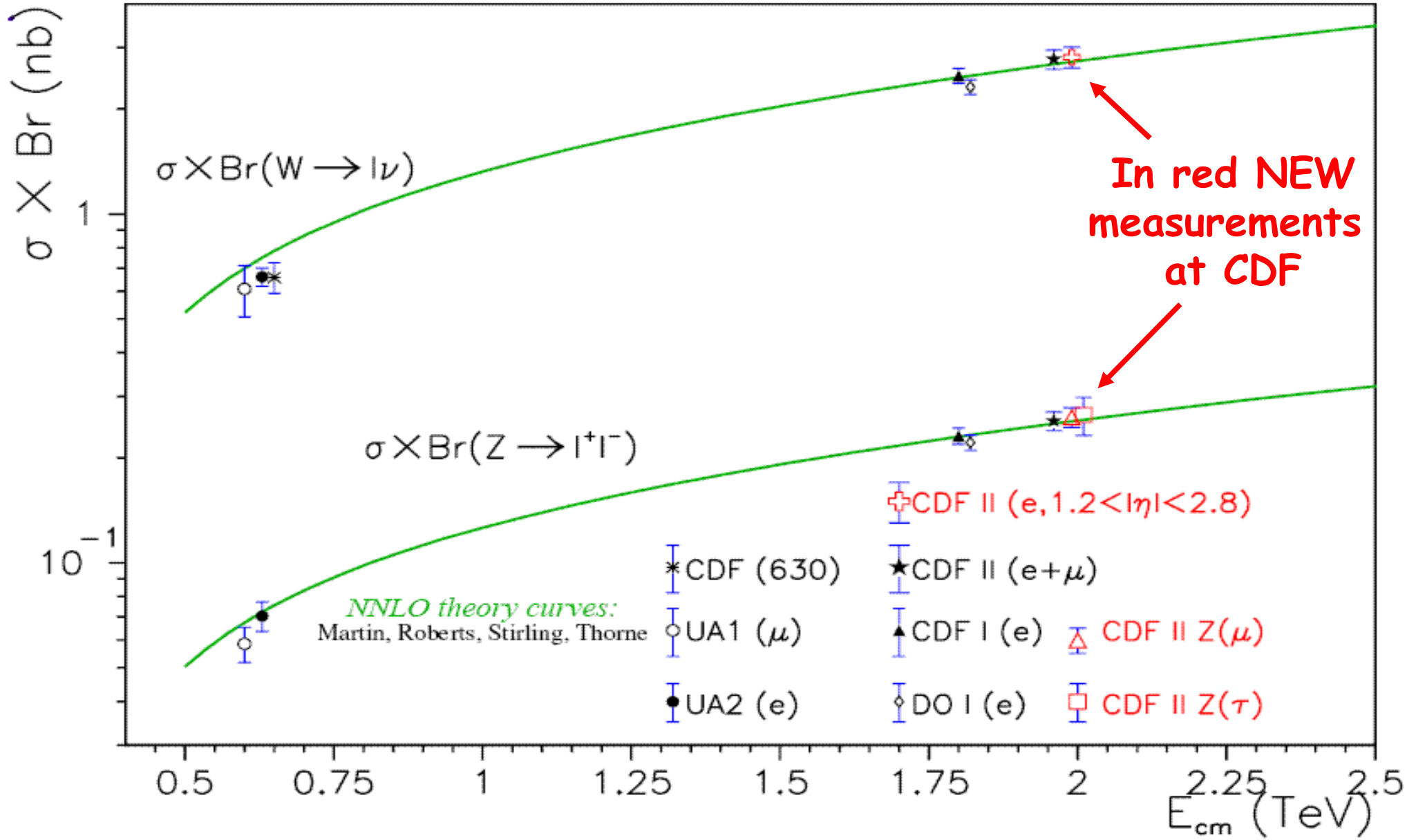
- 316 Z boson candidates
- Most systematic uncertainties data-driven
  - -> will be reduced with more luminosity
- τ identification eff ~60% with uncertainty about 3%

$\sigma_Z.B(Z\to\tau_e\tau_h) = 265 \pm 20\ (stat) \pm 21(syst) \pm 15(lum)$ pb





20 years of W & Z cross section measurements at hadron colliders



Summary

New cross section measurements from CDF

- W->ev in forward region (1.2 <|η|< 2.8) using 223 pb^{-1}
- Z->μμ using 337 pb^{-1}
- Z->$\tau_e\tau_h$ using 349 pb^{-1}

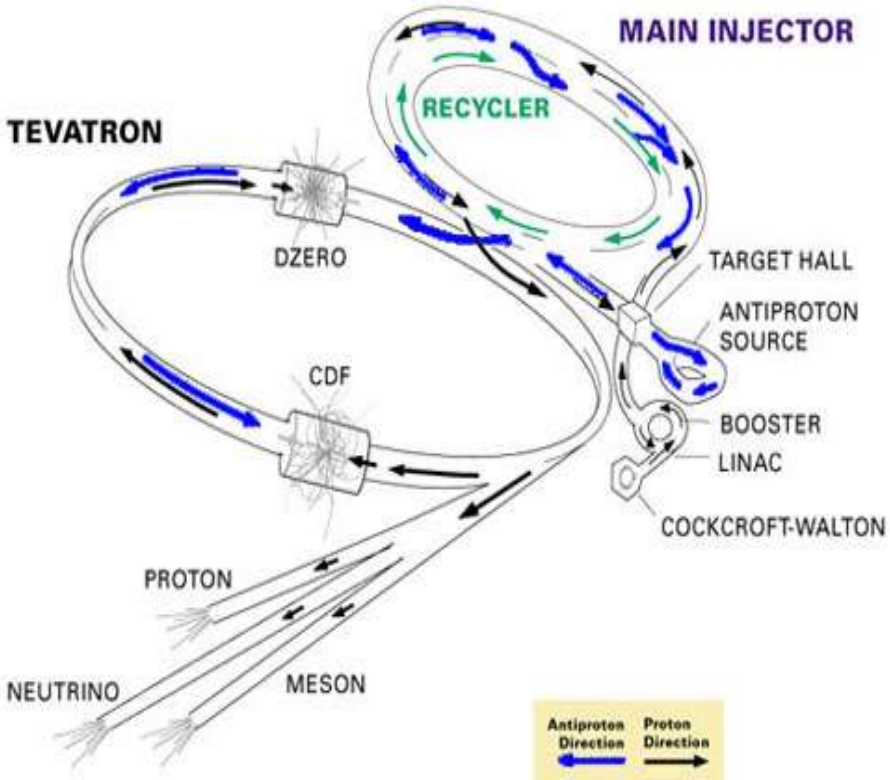
Excellent base for next set of analyses

- $d\sigma/dy_e$ for W->ev
- $d\sigma/dp_T$ for Z->μμ
- Tau widely used in SM measurements and SUSY, H boson searches

New generation of W&Z measurements
(R,WW,WZ,W charge asymmetry...)
on the way -> stay tuned!

From now
on backup

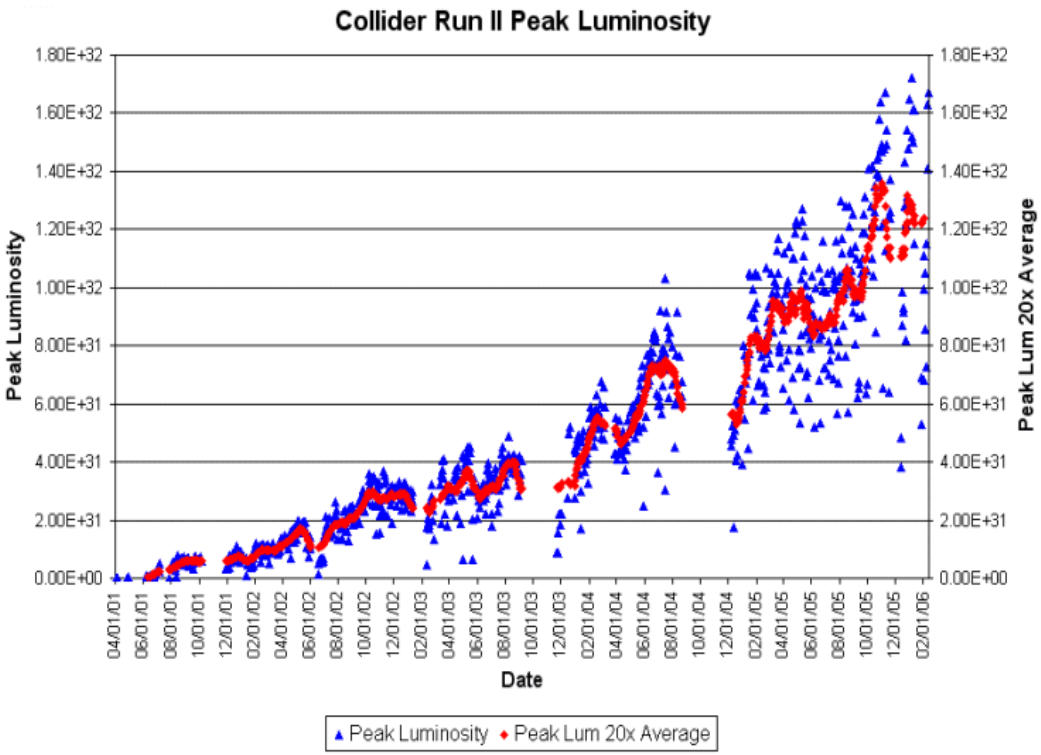
Tevatron

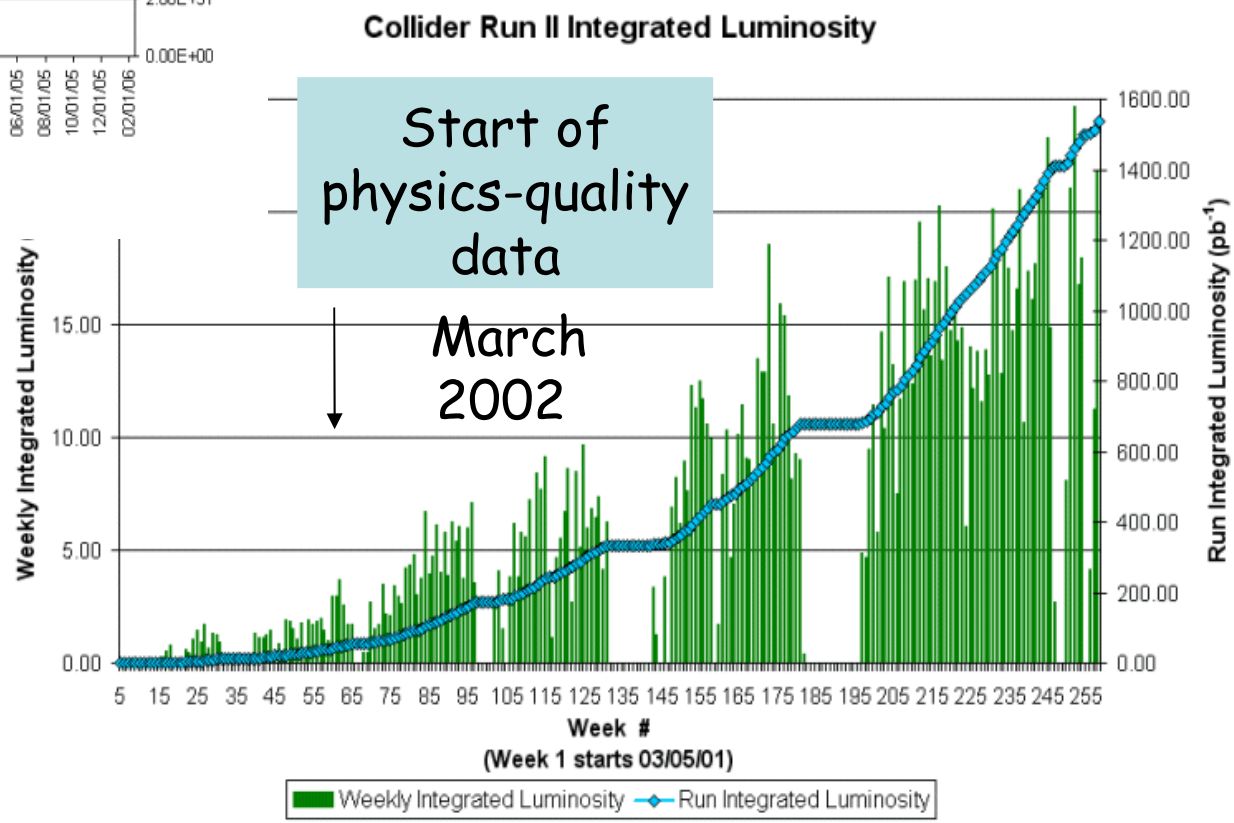


$s_{RunI} = 1.8$ TeV

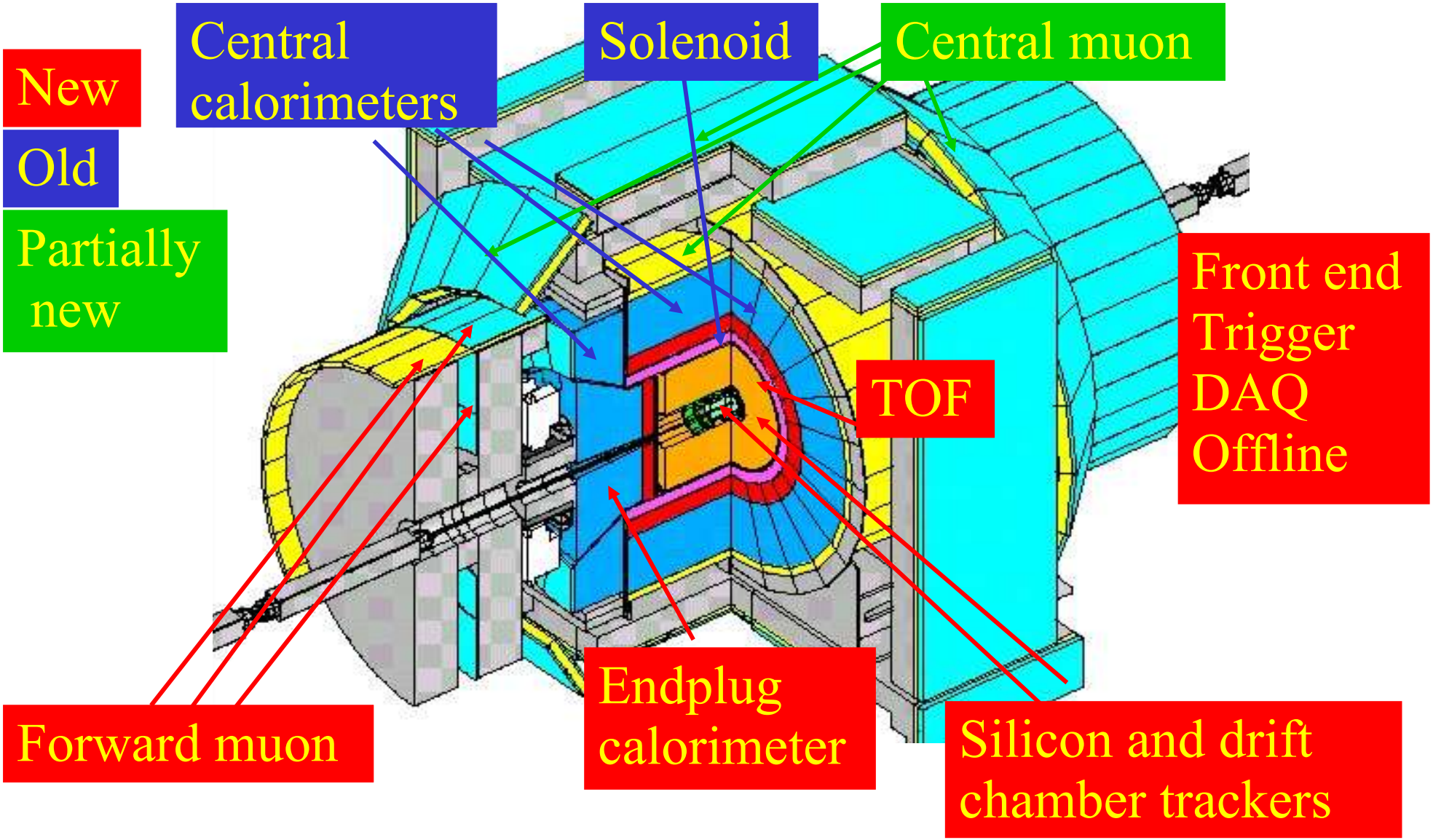
Now $s_{RunII} = 1.96$ TeV

Tevatron


Collider Run II Peak Luminosity
Peak Luminosity
Peak Lum 20x Average
Date
Peak Luminosity
Peak Lum 20x Average

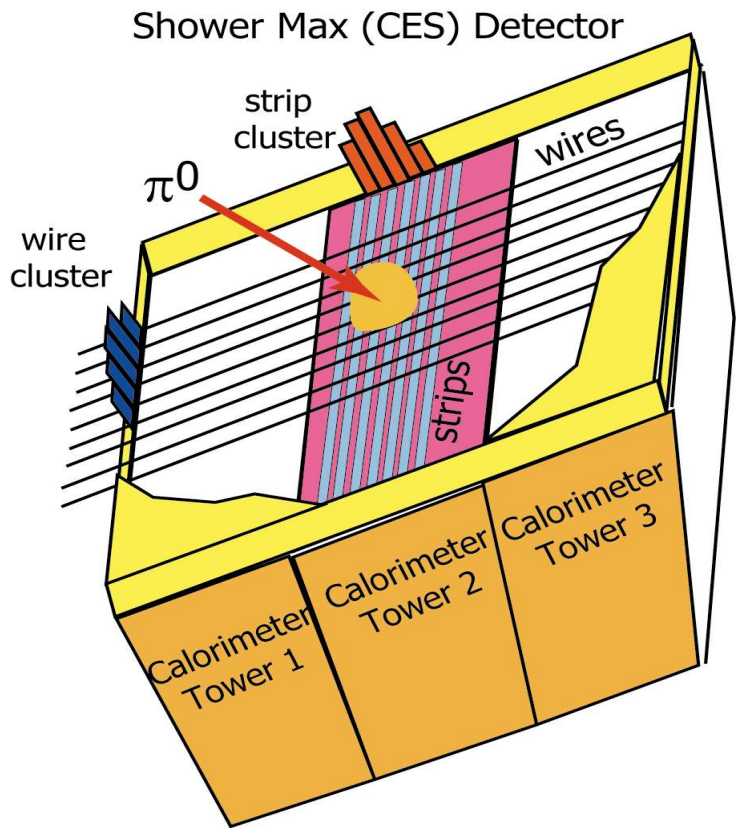

Collider Run II Integrated Luminosity
Start of physics-quality data
March 2002
Weekly Integrated Luminosity
Run Integrated Luminosity (pb^{-1})
Week #
(Week 1 starts 03/05/01)
Weekly Integrated Luminosity
Run Integrated Luminosity

CDF Run II


New
Old
Partially new
Central calorimeters
Solenoid
Central muon
Front end
Trigger
DAQ
Offline
TOF
Endplug calorimeter
Silicon and drift chamber trackers
Forward muon

CES detector

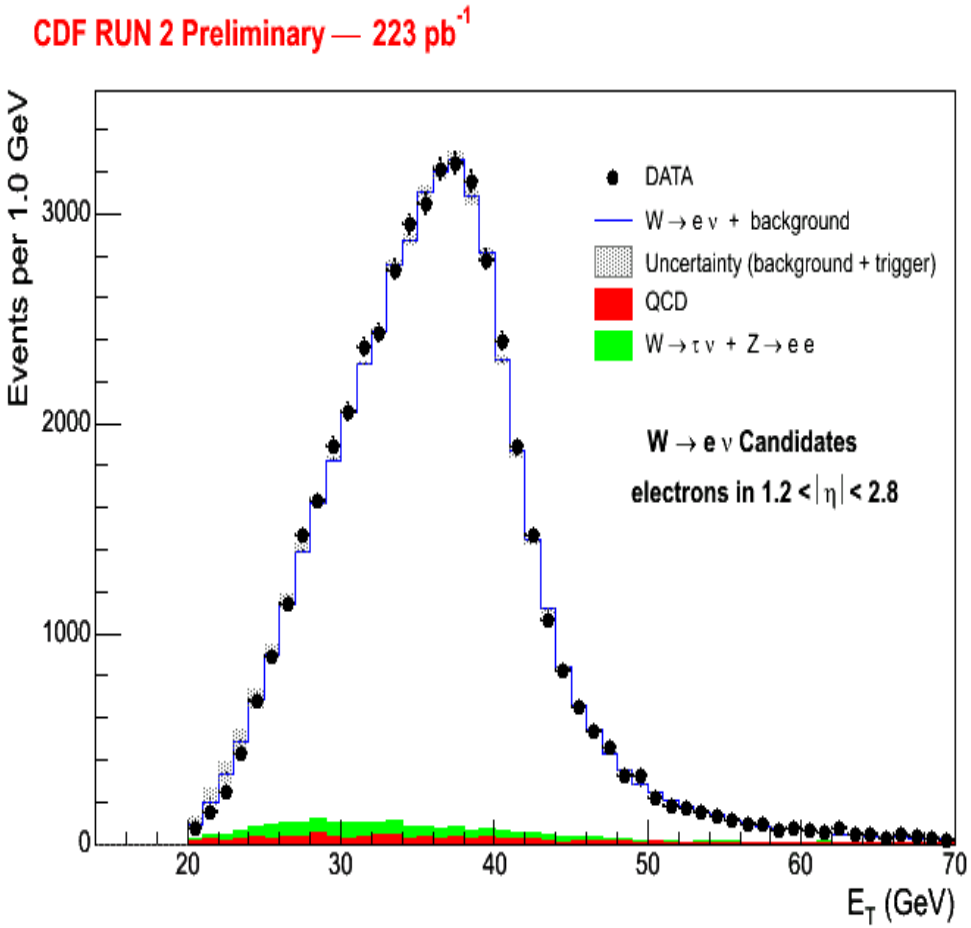
CES
-> resolution
2-3mm
-> proportional
strip/wire
drift chamber
at $6X_0$
of EM calorimeter

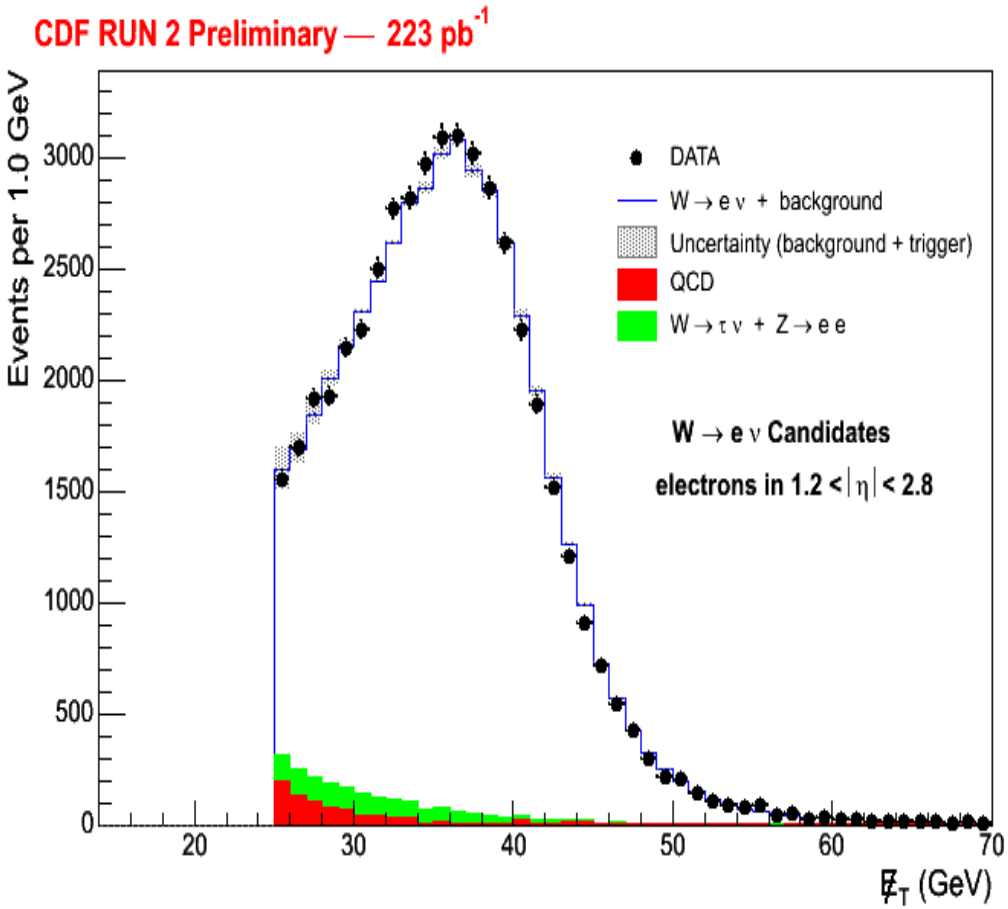


W boson in forward region of CDF

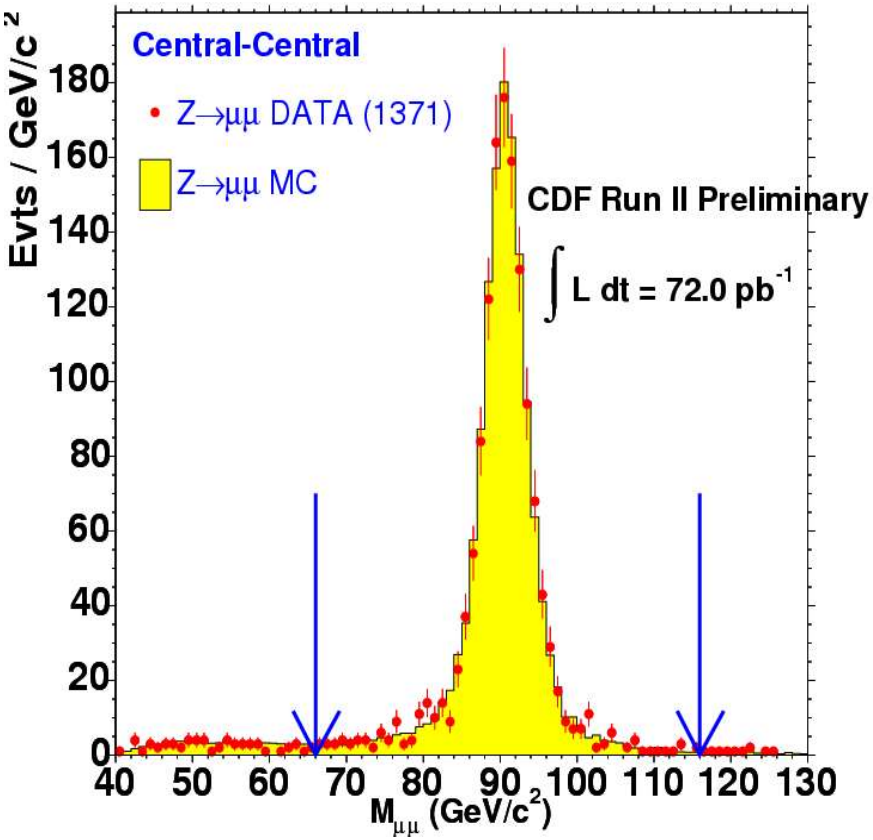
N. candidate events	48144	
N. background QCD events	87759 (stat)	438 (sys)
N. background Z events	2333 (stat)	
N. background $W \rightarrow \tau\nu$ events	107312 (stat)	
Lumin (pb^{-1})	223	13 (sys)
ε	0.07320.0011(s tat)	$^{+0.0021}_{-0.0019}$(sys)

W boson in forward region of CDF





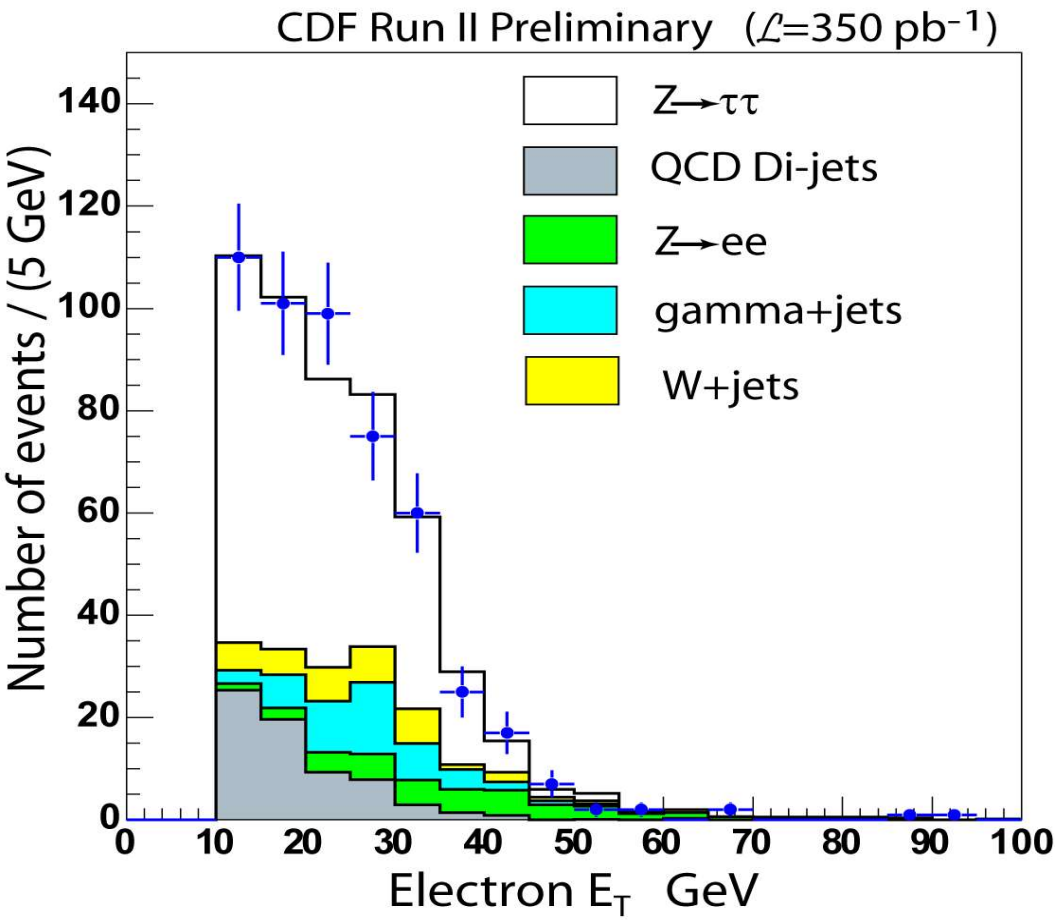
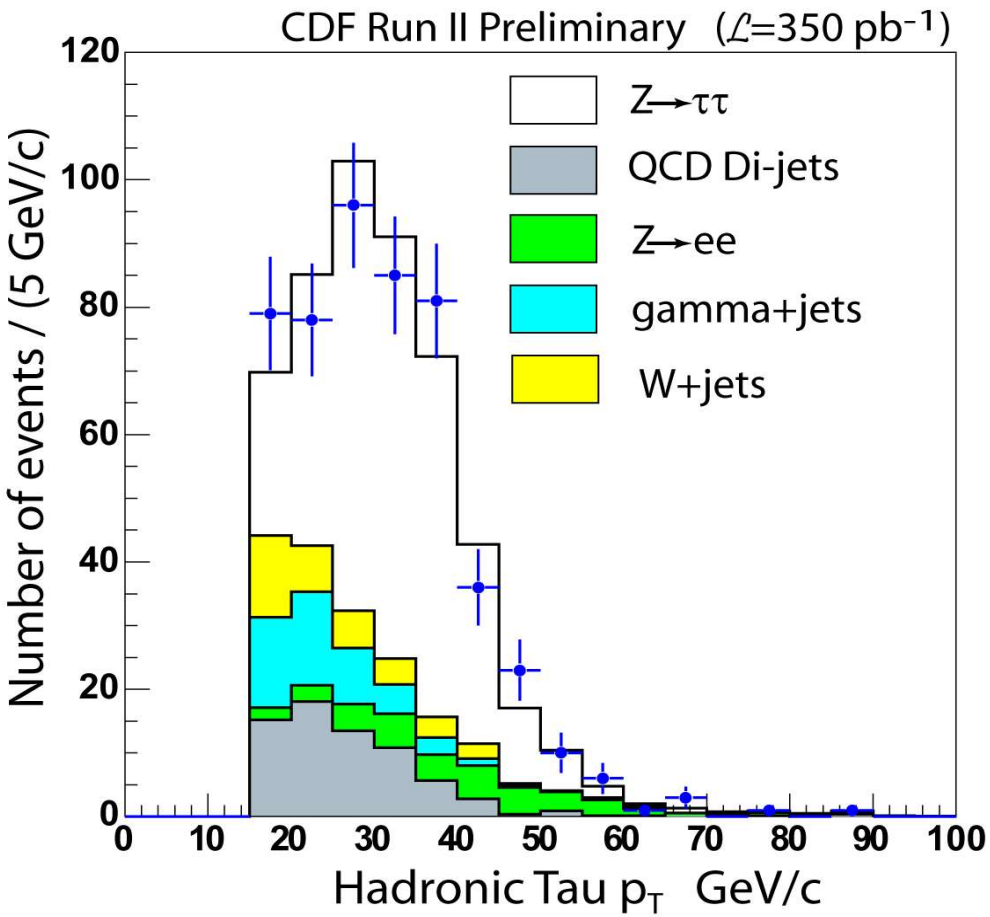
Z->μμ cross section



$Z/\gamma^* \rightarrow \mu\mu$ with mass between 66 and 116 GeV/c^2 CDF Run 2 Preliminary	
Number of Z/γ^* Candidates	9620
Background $Z \rightarrow \tau\tau$ WW, Cosmic, Top, QCD	 8 ± 2 Smaller and neglected
Acceptance (Including Efficiencies)	$0.1091 + 0.0024 - 0.0029$
Luminosity	337 ± 20 pb^{-1}
Cross Section × Branching Ratio	261.2 ± 2.7 (stat) $+ 5.8 - 6.9$ (syst) ± 15.1 (lum) pb

Z->ττ cross section

Process	Yield (in number of events)
$Z \to ee$	$34.8 \pm 1.4 \pm 7.0$
W+jets	$36.6 \pm 3.5 \pm 4.9$
γ+jets	$47.8 \pm 2.2 \pm 12.0$
QCD di-jets	68.6 ± 3.6
Total:	$187.7 \pm 5.7 \pm 15.0^*$
Data	504
$Z \to \tau\tau$	$316 \pm 23 \pm 15$

	Systematic Uncertainty [%]
Signal events yield $N_{Z\to\tau\tau} = 316 \pm 23 \pm 15$	
Geometrical and kinematical acceptance (incl. PDFs)	3.0
Electron ID	1.9
Tau ID	3.0
Electron Trigger Efficiency	2.0
Tau Trigger Efficiency	2.0
Topology cuts	2.8
Background estimation	4.7
Total:	7.7
Cross-Section $\sigma(p\bar{p} \to Z)Br(Z \to \tau\tau) = 265 \pm 20(stat) \pm 21(syst) \pm 15(lumi)$ pb	

Z->ττ cross section