Measurements of the Production and Decay Properties of Gauge Bosons from the Tevatron

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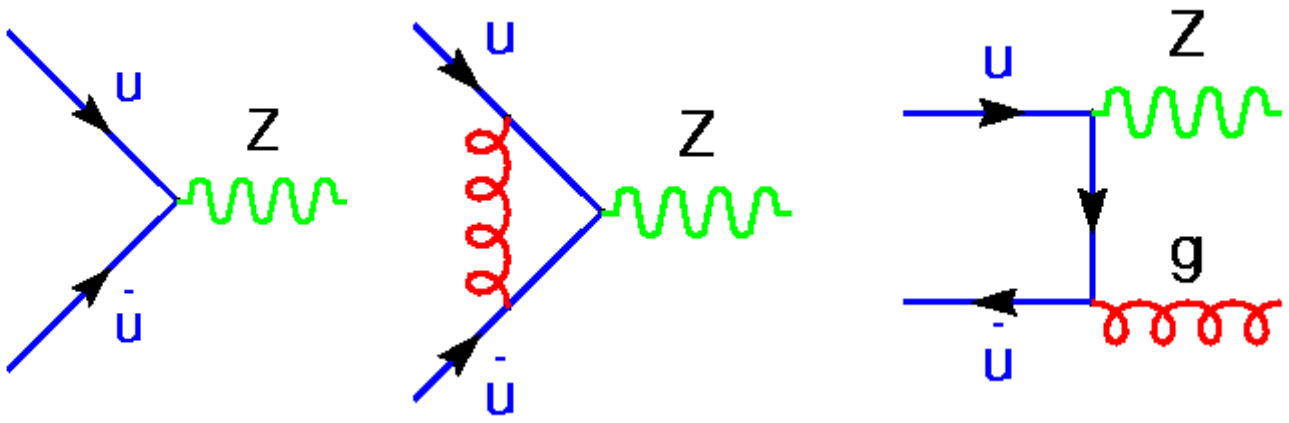
for the DØ and CDF collaborations

1) Data Samples
2) Basics of W and Z's in $p\bar{p}$ collisions
3) W mass from forward-rapidity electrons
4) Cross Section Measurements (Γ_W)
5) $g(\tau)/g(e)$ at $Q^2=M(W)^2$
6) Angular Distributions in W decay
7) Transverse Momentum Measurements

Les Rencontres de Physique de la Vallee d'Aoste
March, 1999

Basics of W's and Z's in $p\bar{p}$ collisions



$$\boldsymbol{Mean\ P_T(W,Z) \approx 10\ GeV}$$

Large cross section:

$$\boldsymbol{p\bar{p}} \qquad \boldsymbol{\sqrt{s} = 1.8\,TeV, \approx 100000\ nb^{-1}}$$

$$\sigma(W) \cong 18 \text{ nb} \quad \sigma(\text{Z}) \cong 5.5 \text{ nb}$$

However, we only use leptonic channels

$\boldsymbol{W \to e\nu}$ $\boldsymbol{W \to \mu\nu}$ $\boldsymbol{W \to \tau\nu}$ **(≅ 11% / mode)**

$\boldsymbol{Z \to ee}$ $\boldsymbol{Z \to \mu\mu}$ **(≅ 3% / mode)**

CDF has also observed Z→bb!

W mass with Forward e's

All measurements so far required e,μ with $|\eta|<1.1$. In theory, contribution of pdf uncertainties to W mass uncertainties vanishes if have full η acceptance.

		cut	
	quantity	ec	cc
Kinematic:	rapidity	1.5-2.5	<1.1
	Pt (e or ν)	30 GeV	25 GeV
	Pt(W)	15	15
	Pt(Z)	-	-
	60<M(ee)<120 GeV		
ID:			
	electromagnetic fraction	0.9	0.9
	H-matrix	200	100
	track match significance	10	5
	isolation	0.15	0.15
	likelihood (matching, em fraction, dEdX, H-matrix)	<4	-
	track	always	always for W

Candidates:

EC W's	11090
CC W's	28420
CC-CC Z's	2091
CC-EC Z's	1265
EC-EC Z's	422

NEW

Forward

Methodology similar to central analyses…

compare data to Monte Carlo templates generated by a fast Monte Carlo whose resolutions are determined by the W,Z samples

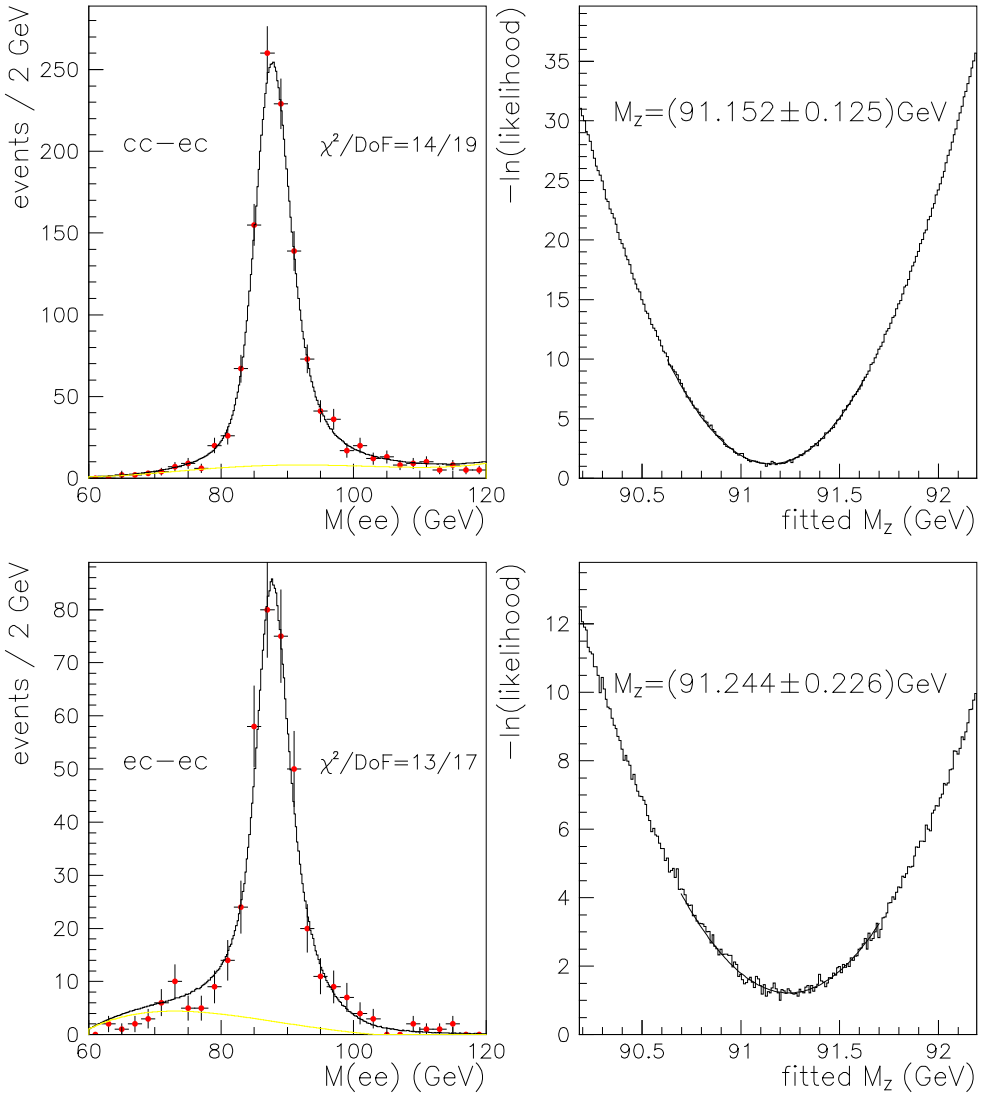
Uncertainties dominated by statistics on Z sample, as it sets the EM energy scale.

		MT fit error (GeV)	
	source	EC	CC+EC
statistical errors:			
	EC-EC Z mass	179	34
	number EC candidates	107	21
	EC-EC Z width	56	4
	CC-EC Z width	47	14
	CC-EC Z mass	37	16
systematic errors:			
	EC EM scale (offset)	50	4
	hadronic resolution	45	21
	pdf's	35	15
	forward tracker-calorimeter alignment	23	6
	PT of W	22	9
	fake EC W's	21	4
	forward tracker radial scale	16	4
	hadronic response	16	10
	W width	10	6
	radiative corrections	4	1
		234	98

PRELIMINARY

Energy Scale

Size of error set by number of CC-EC, EC-EC Z's



CC - EC 91.152 ± 0.125 GeV

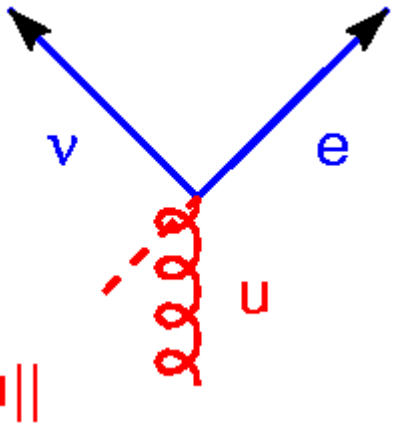
EC - EC 91.244 ± 0.266 GeV

LEP 91.187 GeV PRELIMINARY

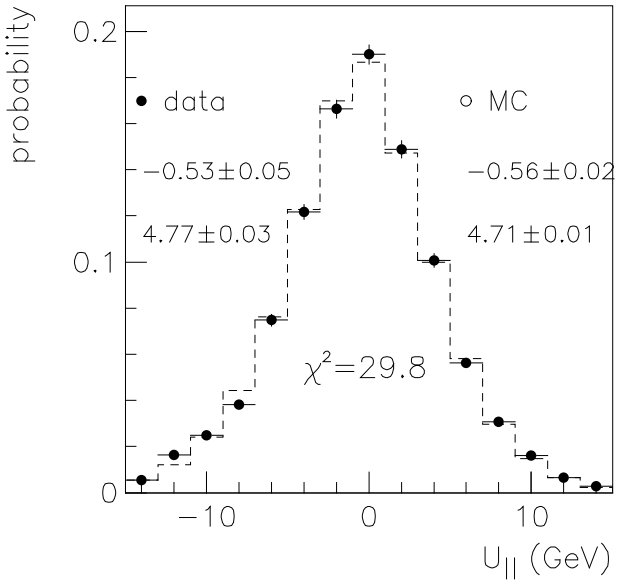
$E_{true} = \alpha E + \delta$ 0.184% uncertainty on α

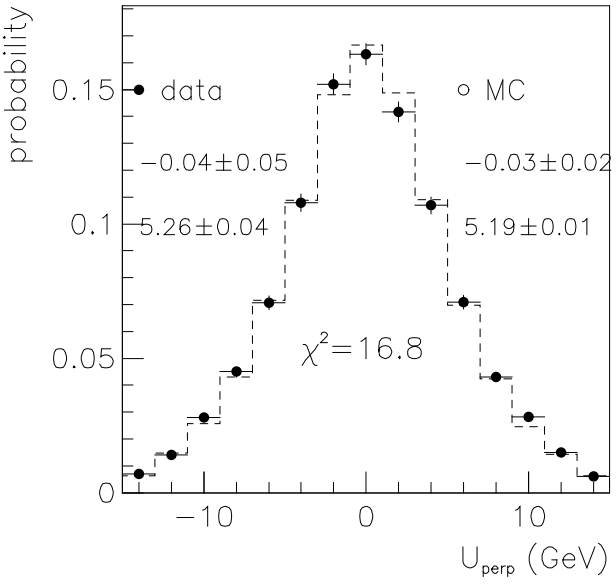
Recoil

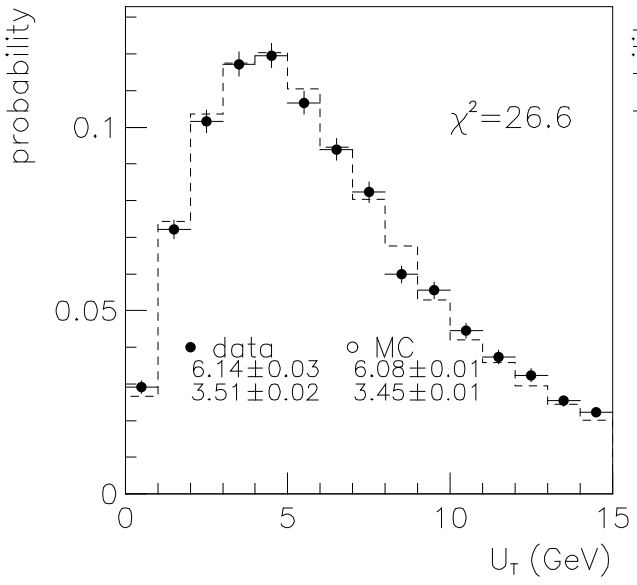
model parameters extracted from Z events and minimum bias events

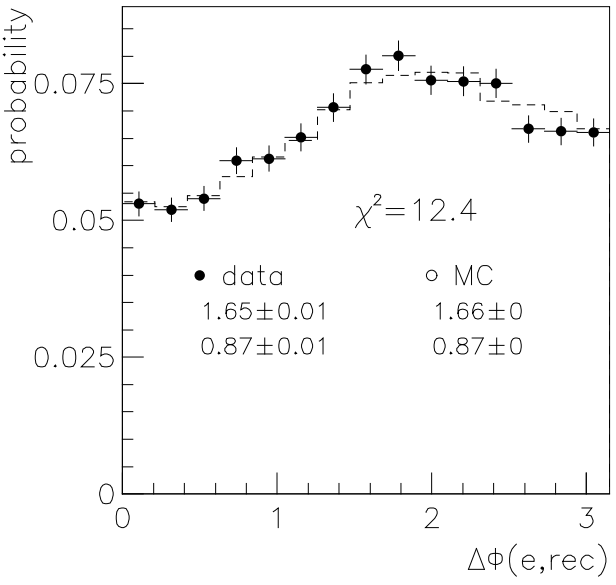


PRELIMINARY



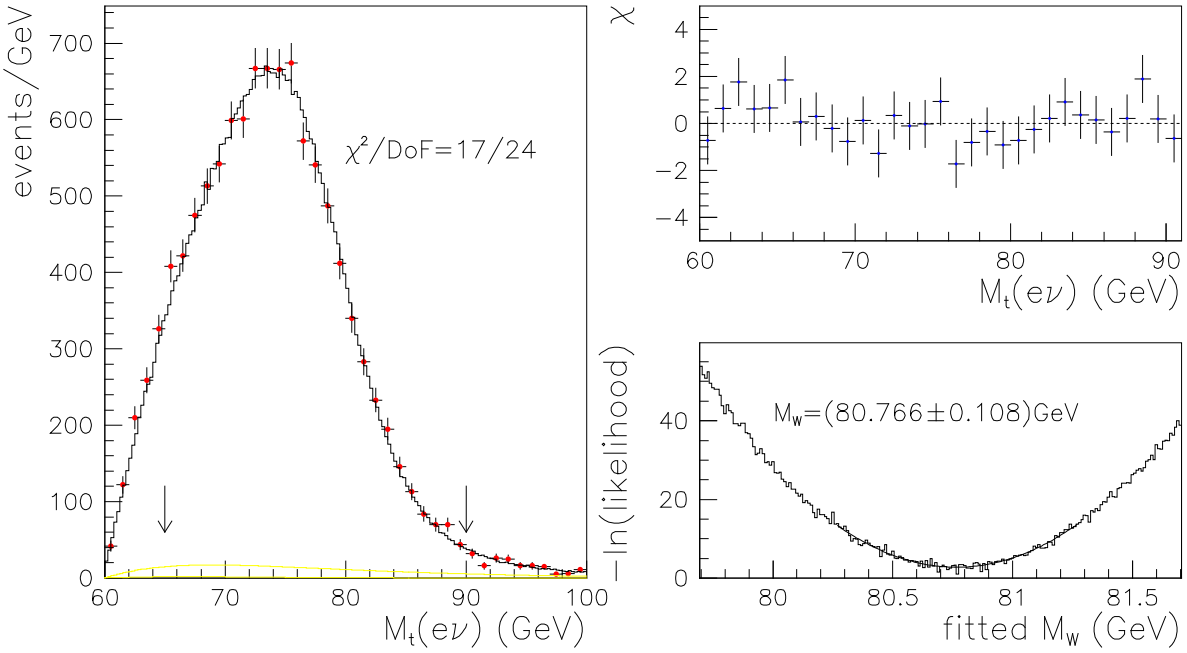






Final Fit

$$M_T = \sqrt{2E_T^e E_T^\nu (1 - \cos(\Delta\phi))}$$

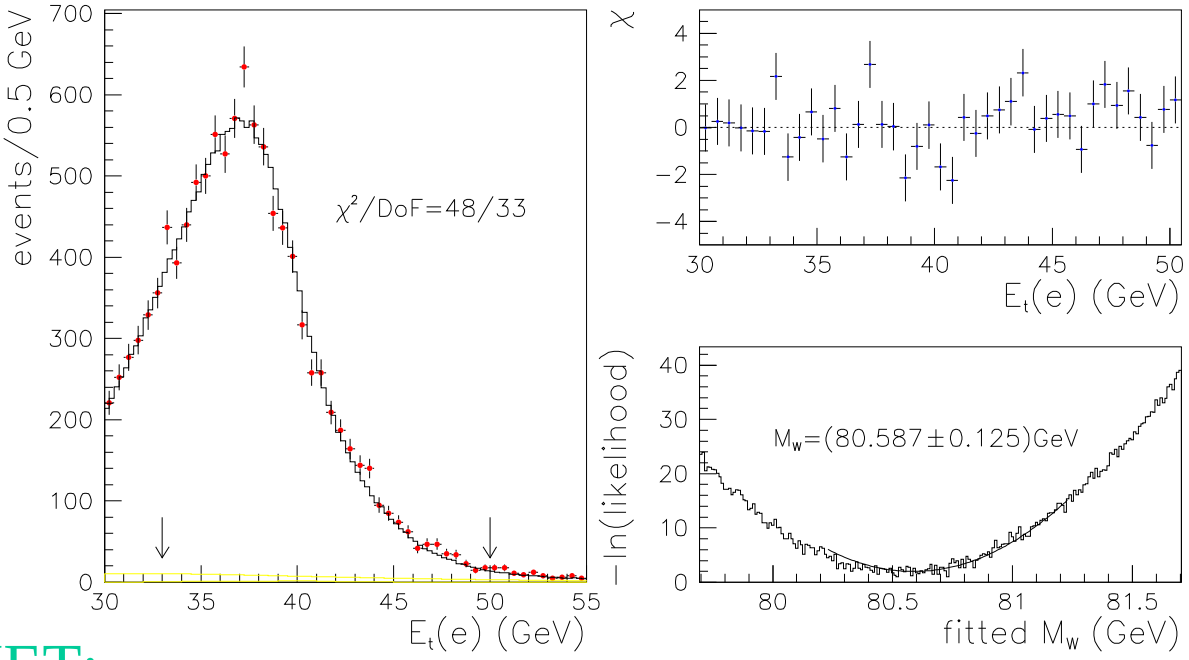


$$1.5 < |\eta| < 2.5$$

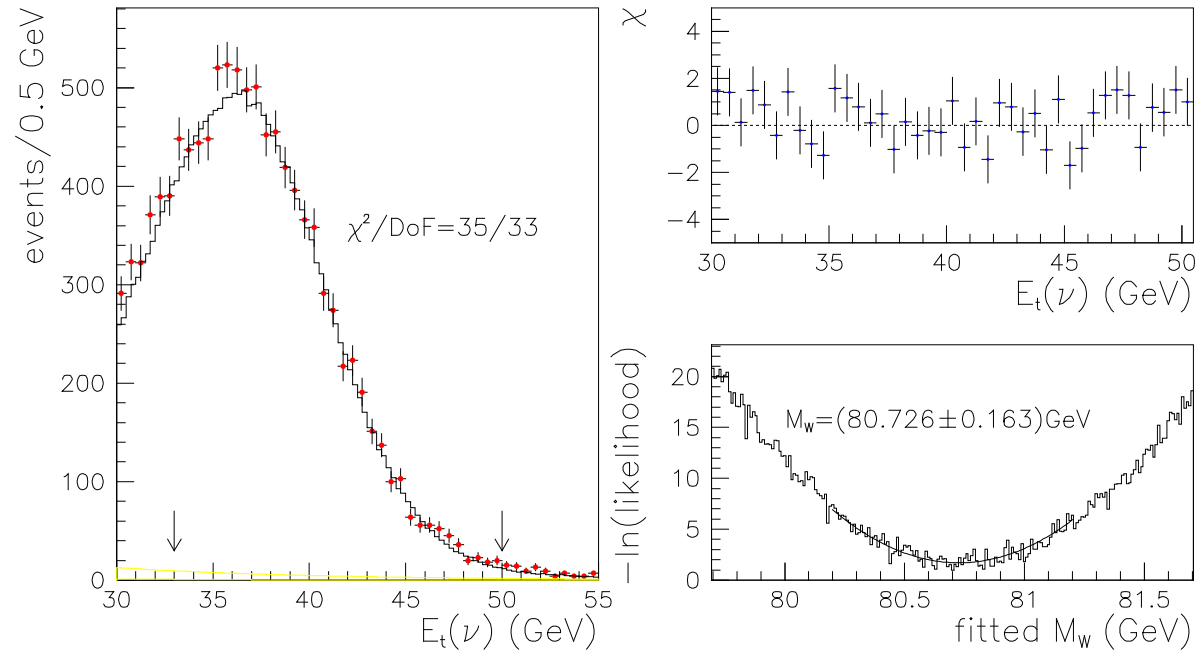
DØ PRELIMINARY

Electron E_T, MET

E_T:



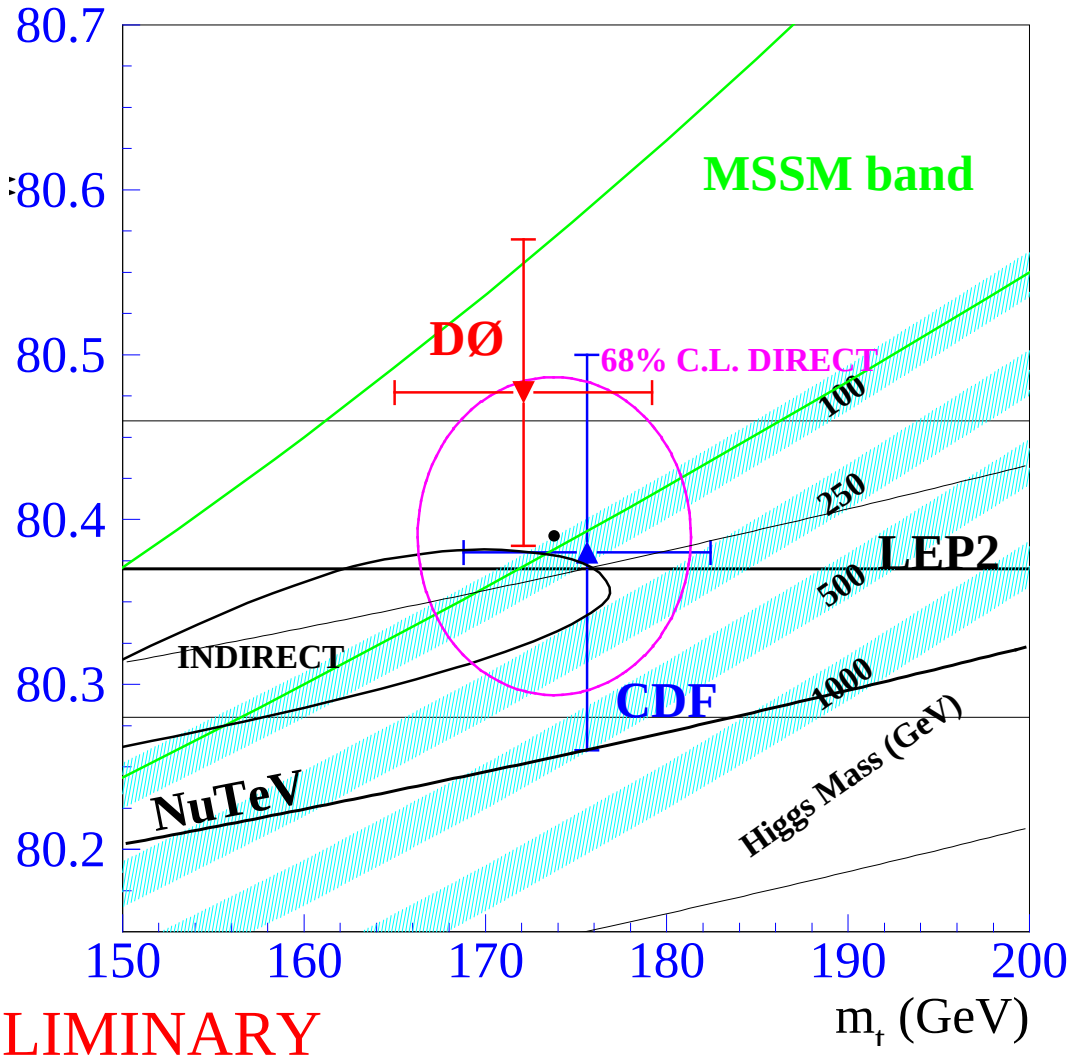
MET:



$1.5 < |\eta| < 2.5$

DØ PRELIMINARY

Summary of W Mass



PRELIMINARY

NEW M(W) EC 1b M_T = 80.766 ± 0.234 GeV

M(W) DØ combined (CC,EC,1a,M_T,e,ν)

= 80.474±0.093 GeV (χ^2=4.3/5)

"Old" Central:

DØ: 80.430 ± 0.110 GeV

CDF: 80.375 ± 0.120 GeV

LEP:

80.380± 0.080 GeV

Cross Sections

$$\sigma(p\bar{p} \to W + X)B(W \to l\nu)$$

$$\sigma(p\bar{p} \to Z + X)B(Z \to ee)$$

1) Test QCD, future source of more precise luminosity measurement

O(α_s^2) prediction (Hamberg, van Neerven, Matsuura)

3% uncertainty (smaller than experimental!)

2) Ratio of cross sections measures the W electronic branching fraction, and indirectly the W width:

measure

$$R \equiv \frac{\sigma(p\bar{p} \to W) \bullet B(W \to e\upsilon)}{\sigma(p\bar{p} \to Z) \bullet B(Z \to ee)}$$

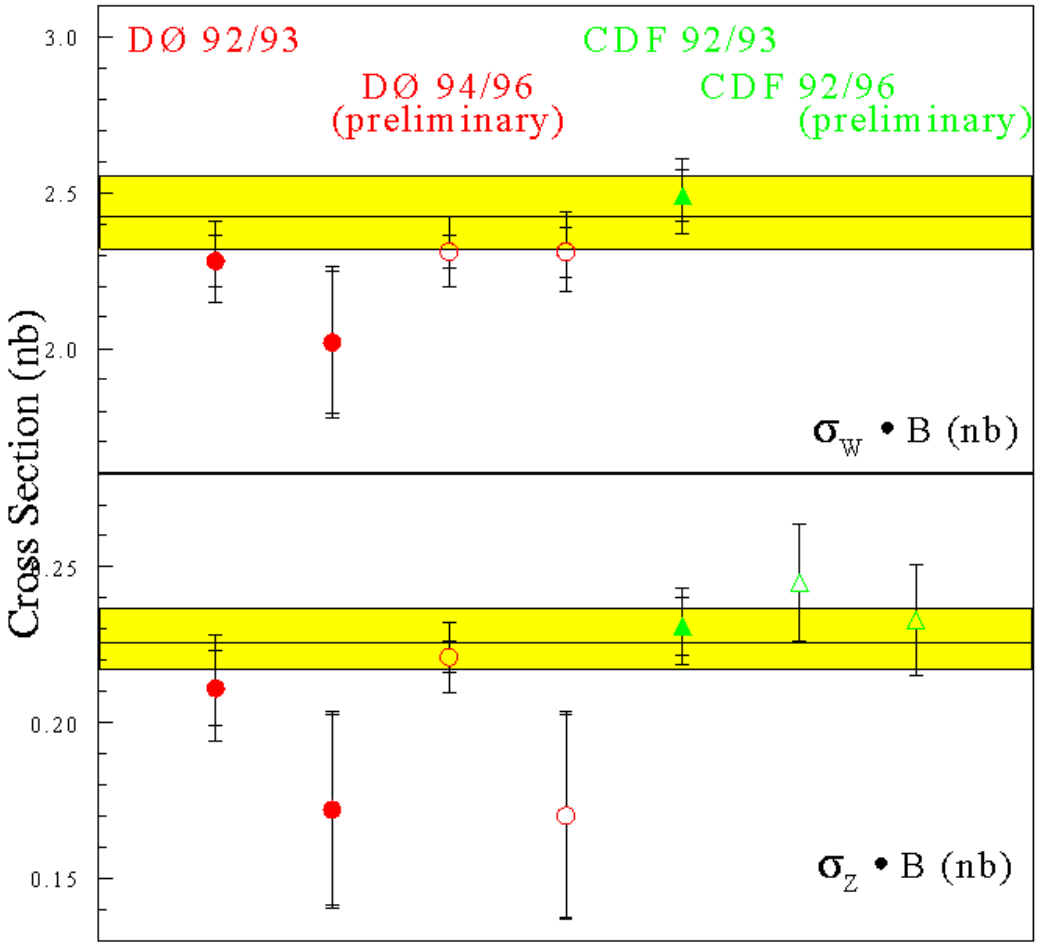
$$= \frac{\sigma(W)}{\sigma(Z)} \bullet \frac{\Gamma(Z)}{\Gamma(Z \to ee)} \bullet \frac{\Gamma(W \to l\nu)}{\Gamma(W)}$$

theory

LEP

extract

Cross Section Results



cross section uncertainty dominated by luminosity uncertainty
4.3% for DØ
7.3% for CDF

	$\sigma_W B(W \to l\nu)$ (nb)	$\sigma_Z B(Z \to ll)$ (nb)
DØ, e, 1b NEW	$2.31 \pm 0.01 \pm 0.05 \pm 0.10$	$0.221 \pm 0.003 \pm 0.004 \pm 0.010$
DØ, μ, 1b UPDATE	$2.31 \pm 0.08 \pm 0.10$	$0.170 \pm 0.023 \pm 0.023 \pm 0.007$
DØ, e, 1a UPDATE	$2.28 \pm 0.02 \pm 0.08 \pm 0.10$	$0.211 \pm 0.008 \pm 0.008 \pm 0.009$
DØ, μ, 1a UPDATE	$2.02 \pm 0.06 \pm 0.22 \pm 0.09$	$0.172 \pm 0.022 \pm 0.021 \pm 0.008$
CDF, e, 1b		$0.245 \pm 0.005 \pm 0.018$
CDF, μ, 1b		$0.233 \pm 0.005 \pm 0.017$
CDF, e, 1a	$2.49 \pm 0.02 \pm 0.08 \pm 0.09$	$0.231 \pm 0.006 \pm 0.007 \pm 0.008$

D Ø Ratio Results

luminosity uncertainty cancels in the ratio

Source of uncertainty	Size
backgrounds to the W sample from di-jets	0.158
statistics of the Z sample	0.149
ratio of W and Z acceptance	0.095
ratio of the lepton identification efficiencies for W's and Z's	0.063
backgrounds to the Z sample from di-jets	0.054
backgrounds to the W sample from Z's	0.029
background to W->eν from W->τν	0.022
NLO corrections to Z->eeγ	0.104
sum of systematic uncertainties	0.205
sum	0.274

$$R = 10.43 \pm 0.15(stat) \pm 0.20(syst) \pm 0.10(NLO)$$

$$\Rightarrow B(W \to e\upsilon) = 0.1066 \pm 0.0015 \pm 0.0021 \pm 0.0016(theory)$$

and assuming standard model $\Gamma(W \to e\nu)$

$$\Rightarrow \Gamma(w) = 2.130 \pm 0.030 \pm 0.042 \pm 0.031(\text{theory}) \text{ GeV}$$

$$= 2.130 \pm 0.060 \text{ GeV}$$

PRELIMINARY

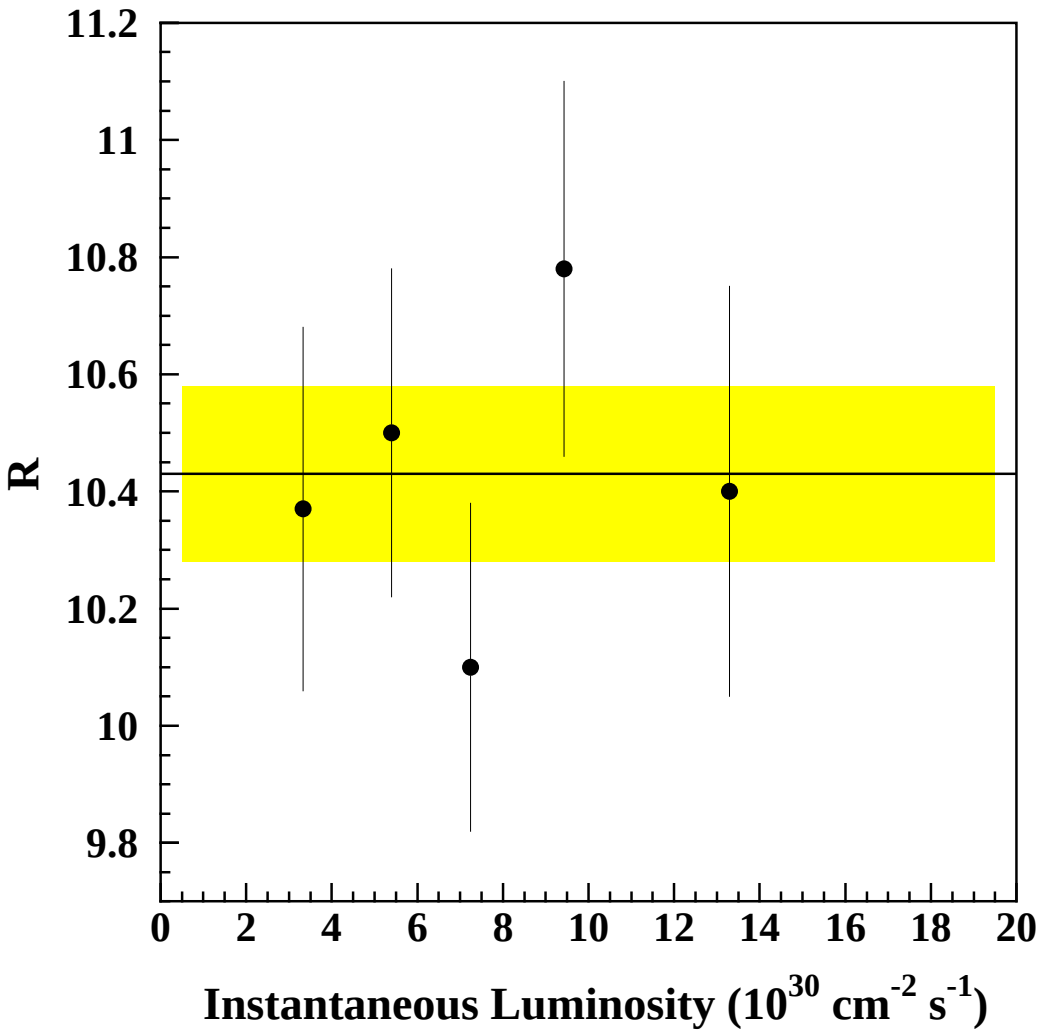
PDG value: 2.06 ± 0.06 GeV

Standard Model: 2.094±0.006 GeV

NEW

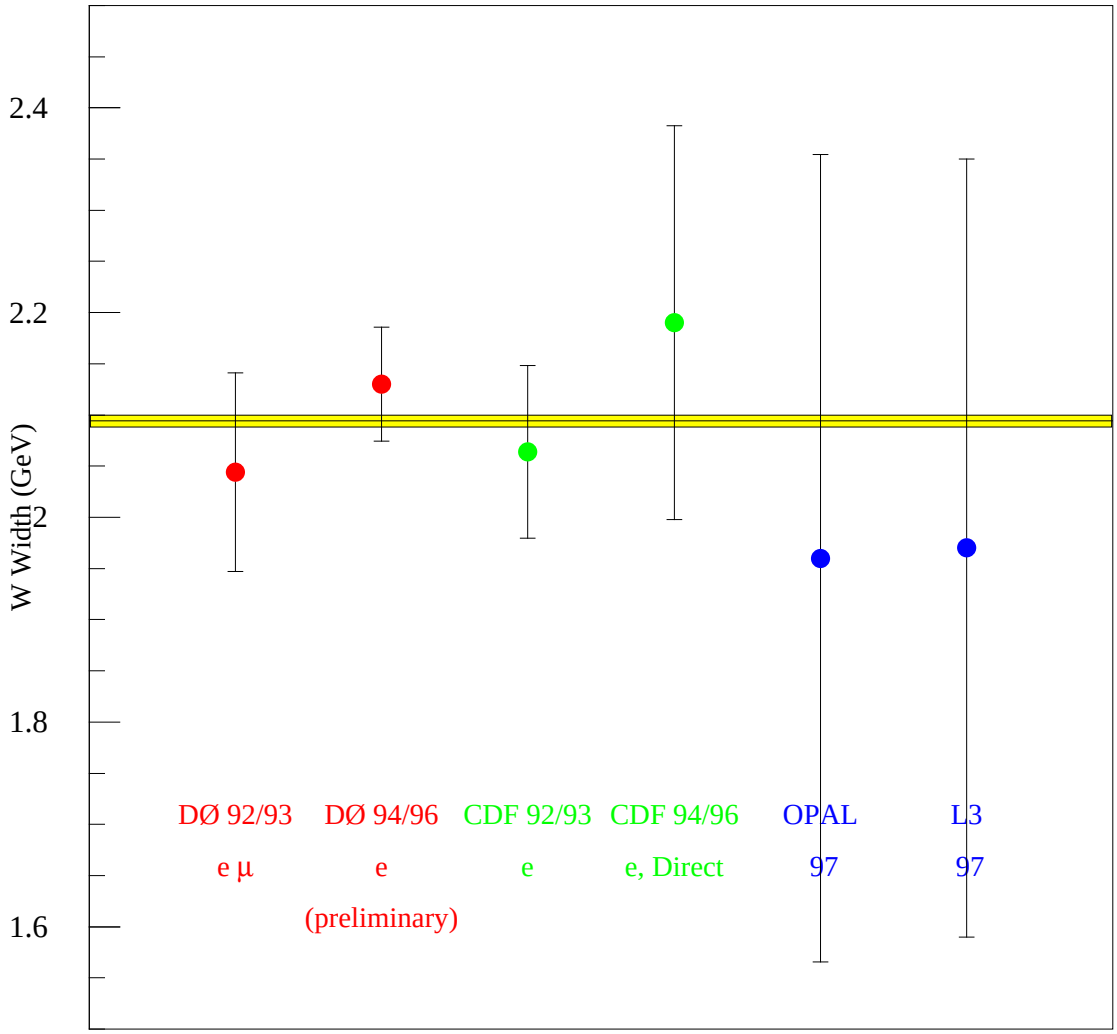
our width > standard model, so no interesting limits...

Cross Checks



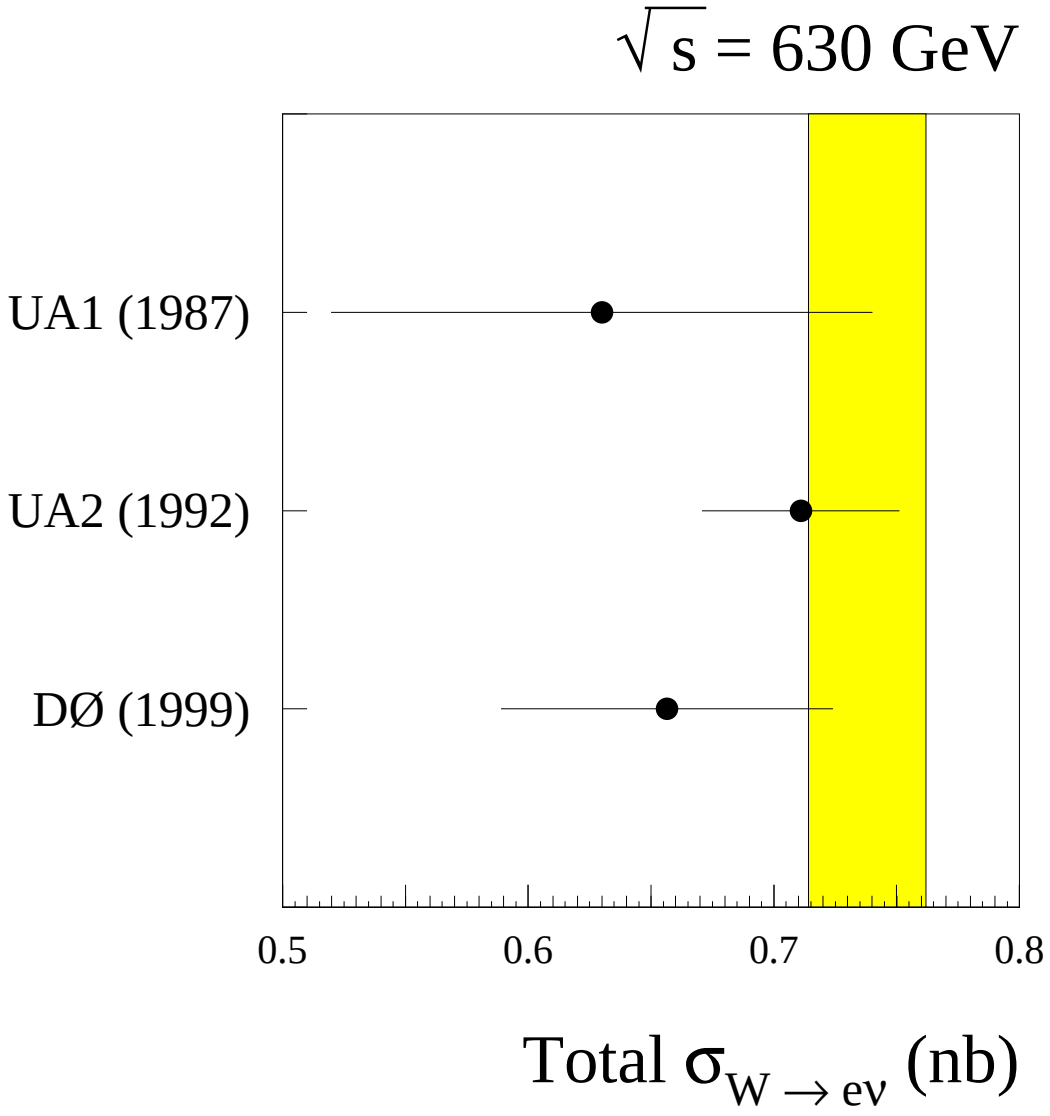
PRELIMINARY

Tevatron W width Results



DØ **(e + μ) 1a**		**2.044 ± 0.097 GeV**
DØ (e) 1b	PRELIMINARY	**$2.130 \pm 0.030 \pm 0.052$ GeV** NEW
CDF (e) 1a		**$2.064 \pm 0.060 \pm 0.059$ GeV**
CDF (e, direct) 1b		**$2.19 \pm 0.170 \pm 0.090$ GeV**
OPAL ('97)		**$1.96 \pm 0.34 \pm 0.20$ GeV**
L3 ('97)		**1.97 ± 0.38 GeV**

W Cross Section at 630 GeV



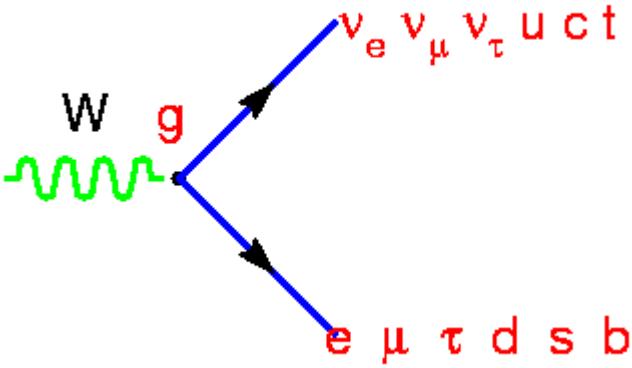
DØ

$$\sigma(p\bar{p} \to W) = 658 \pm 67 \text{ pb @ } \sqrt{s} = 630 \text{ GeV}$$

PRELIMINARY

NEW

$g(\tau)/g(e)$ $(Q^2=M_W^2)$



$$\left(\frac{g_\tau^W}{g_e^W}\right) = \frac{\sigma_W \bullet B(W \to \tau\nu)}{\sigma_W \bullet B(W \to e\nu)}$$

check of tau identification for large tan(β) susy searches

New method from CDF. promising for future high statistics running.

- select W sample with low threshold on electron E_T (>12 GeV)
- fit electron impact parameter distribution to sum of W->eν, W->τν, background

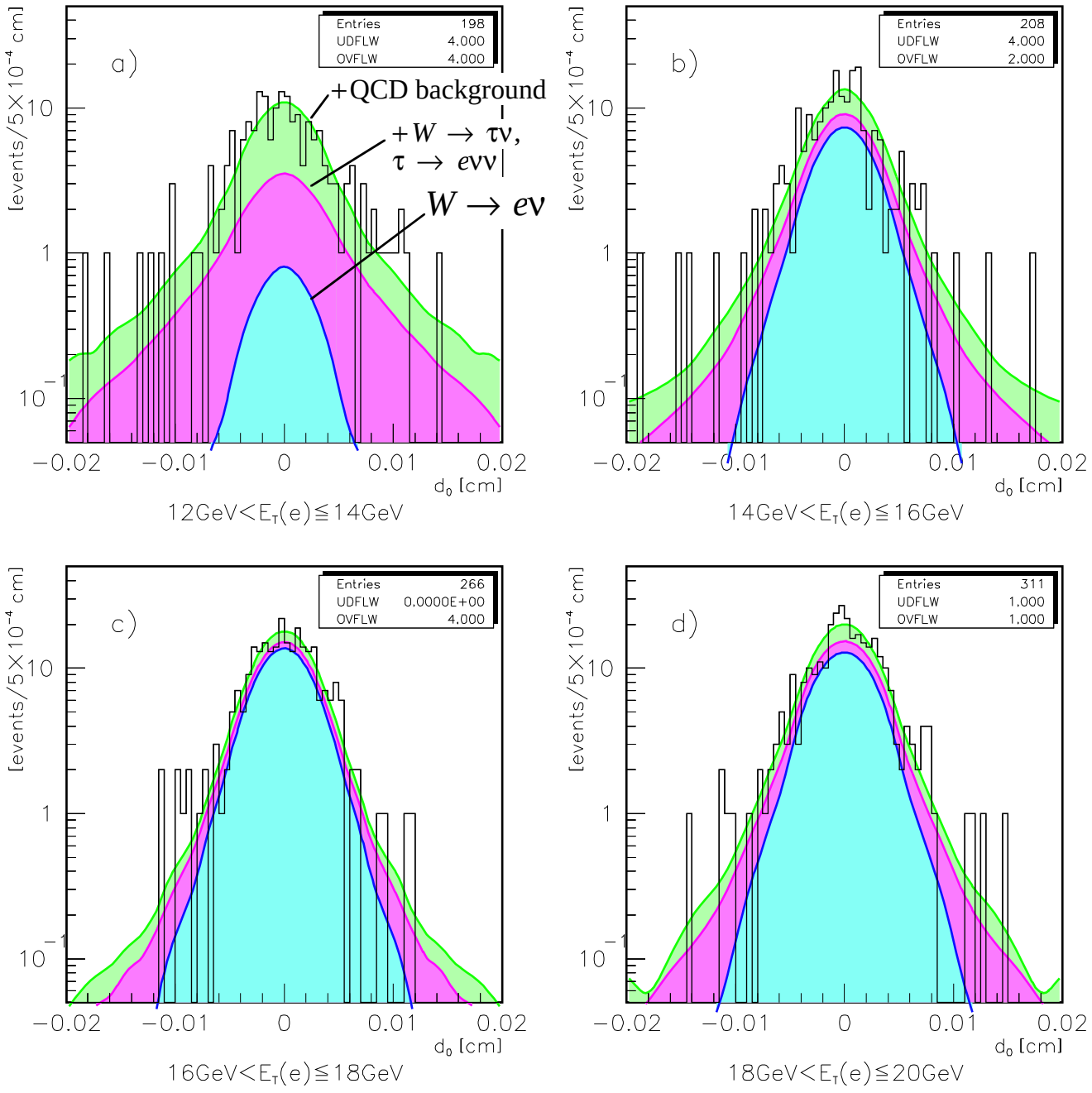
$g(\tau)/g(e)$ ($Q^2=M(W)^2$)

CDF

Impact parameter (d_0) distributions

Histograms: Data

CDF Preliminary



$g(\tau)/g(e)=1.004\pm0.17$
±0.09

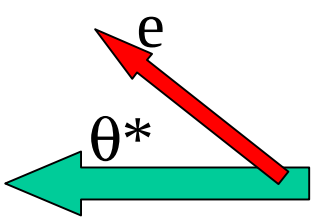
hadronic values:

CDF '89: 0.970± 0.070

DØ 1b: 1.004± 0.032

Angular Distributions

NEW



z direction

Collins-Soper
W rest frame

Born: $\propto (1 + P(W)\cos\theta^*)^2$

$O(\alpha_s^2)$: $\propto 1 + P(W)\alpha_1 \cos\theta^* + \alpha_2 \cos^2\theta^*$

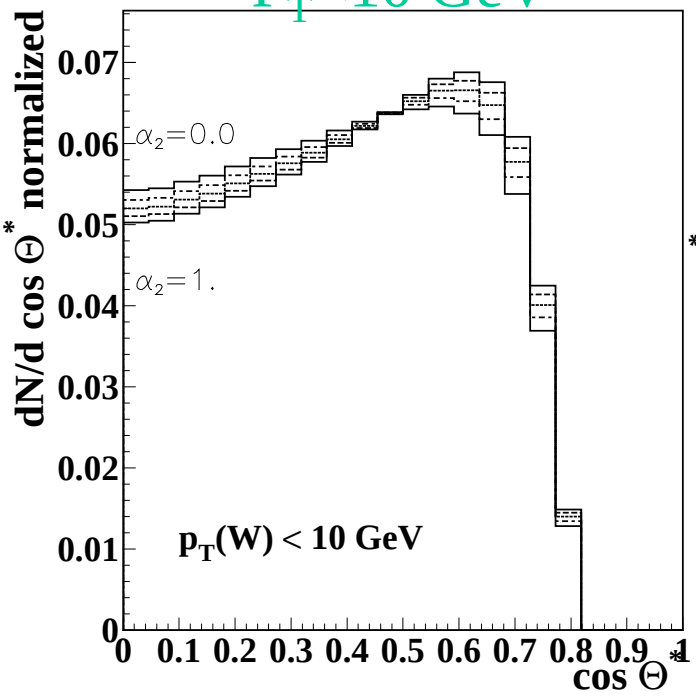
Mirkes, Nucl. Phys. B387, 3

α's are predicted, and depend on the boson P_T

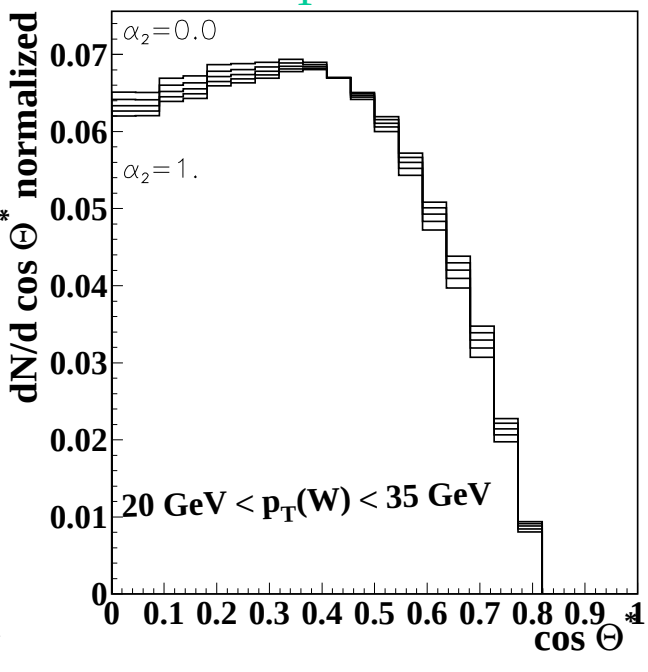
independent test of QCD

since DØ doesn't measure charge, only sensitive to α_2

P_T<10 GeV

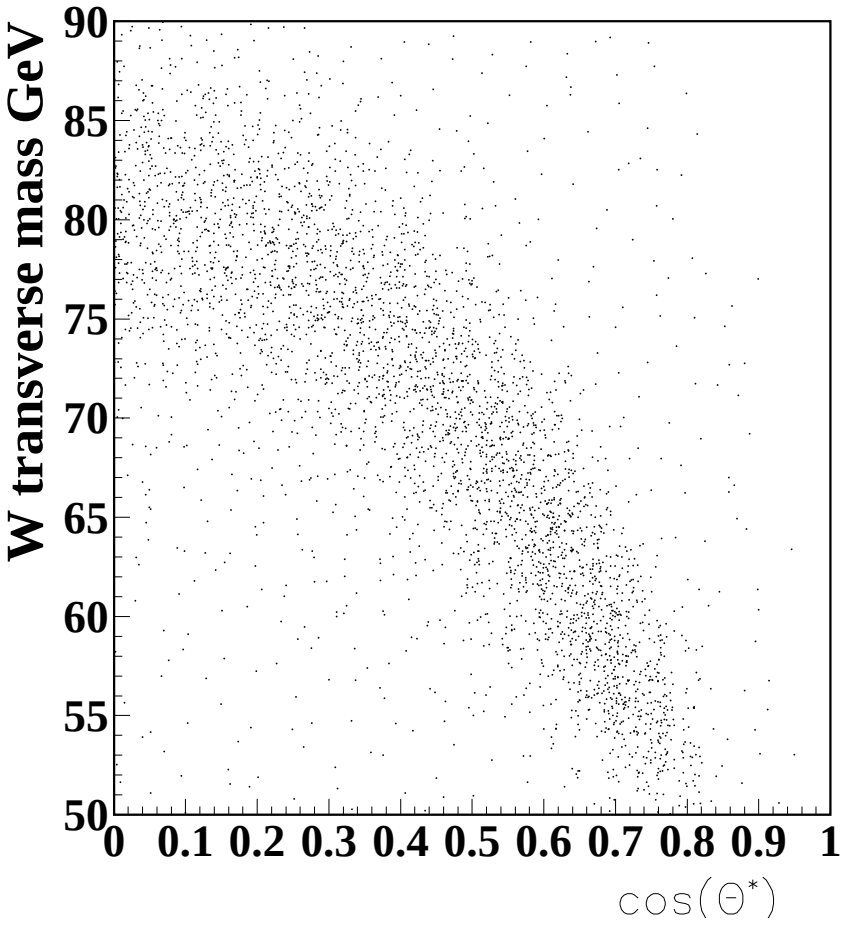


20<P_T<35 GeV



Angular Distributions

We can not reconstruct $P_Z(W)$, because we can not measure $P_Z(\nu)$. However, in the Collins-Soper frame, there is a strong correlation between M_T and $\cos(\theta^*)$.



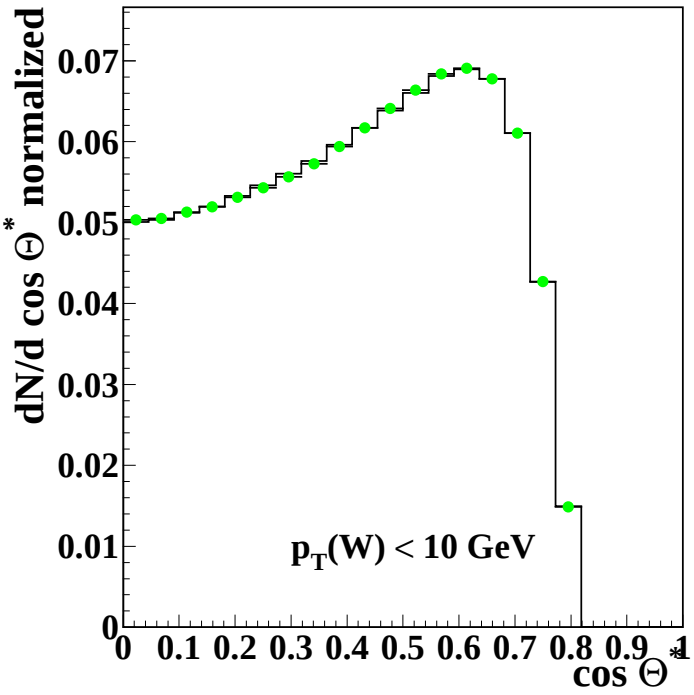
From the M_T spectrum, we reconstruct, for different $P_T(W)$ ranges, the cos(θ*) distribution using a Bayesian weighting technique.

NEW

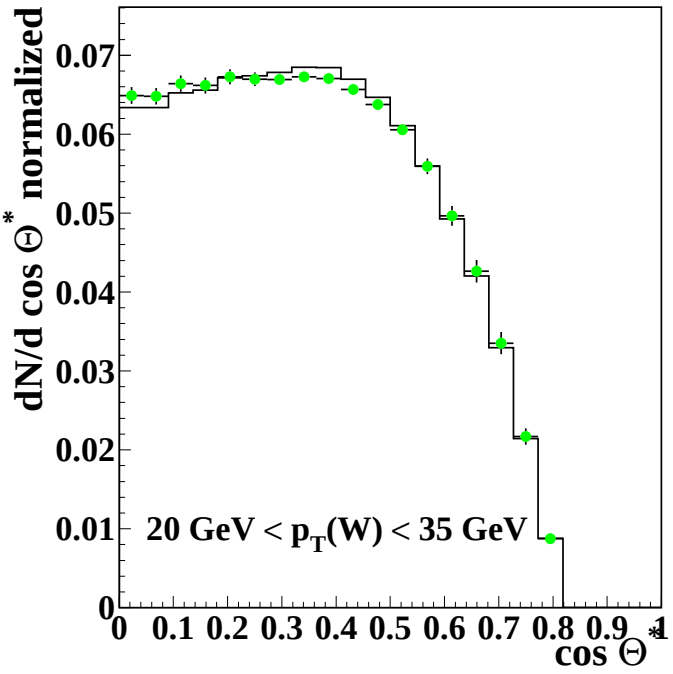
Reconstructed cos(θ*) Distributions

and distribution from best fit for α_2

DØ



P_T<10 GeV



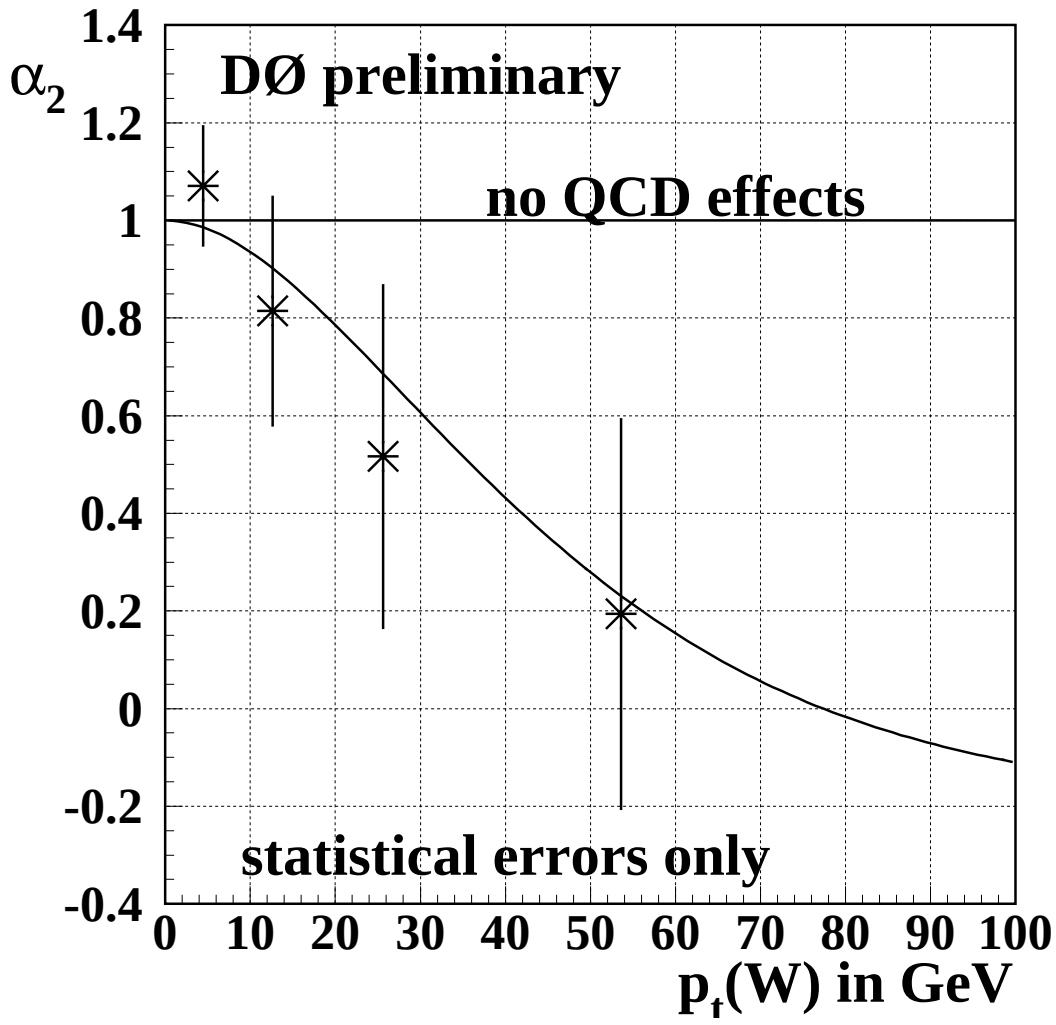
20 <P_T< 35 GeV

PRELIMINARY

NEW

α_2 versus P_T

DØ



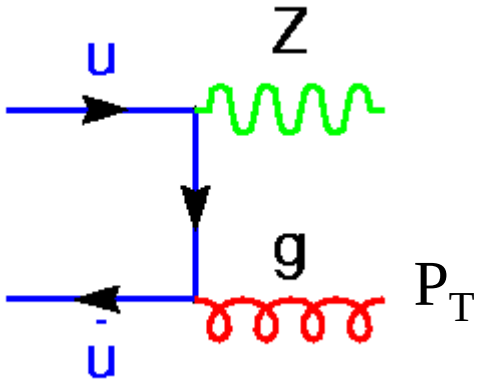
QCD prefered over V-A by $\approx 2\sigma$

First Measurement of α_2

PRELIMINARY

NEW

Boson P_T Distributions



Theory:

P_T>20 GeV => Perturbative QCD

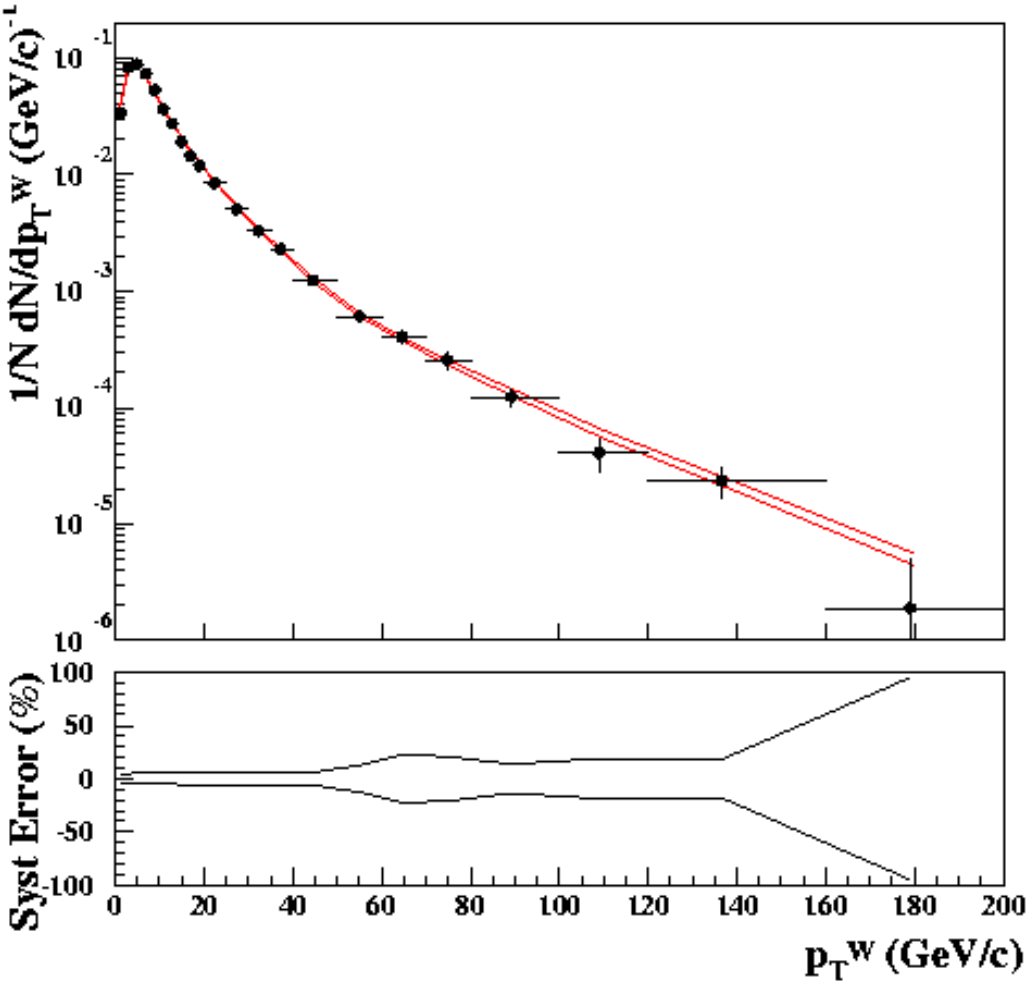
Λ_{QCD}<P_T<10 GeV => resummation techniques

PT<Λ_{QCD} => parameterization of non-perturbative effects

Data:

W P_T	DØ e 1b	(preliminary)	NEW
	DØ e 1a		
	CDF e 1a+1b	(preliminary)	
Z P_T	DØ e 1a+1b	(preliminary)	
	CDF e 1a+1b	(preliminary)	

DØ 1b W P_T spectrum



For W P_T, resolution effects dominate at low P_T (<5 GeV)

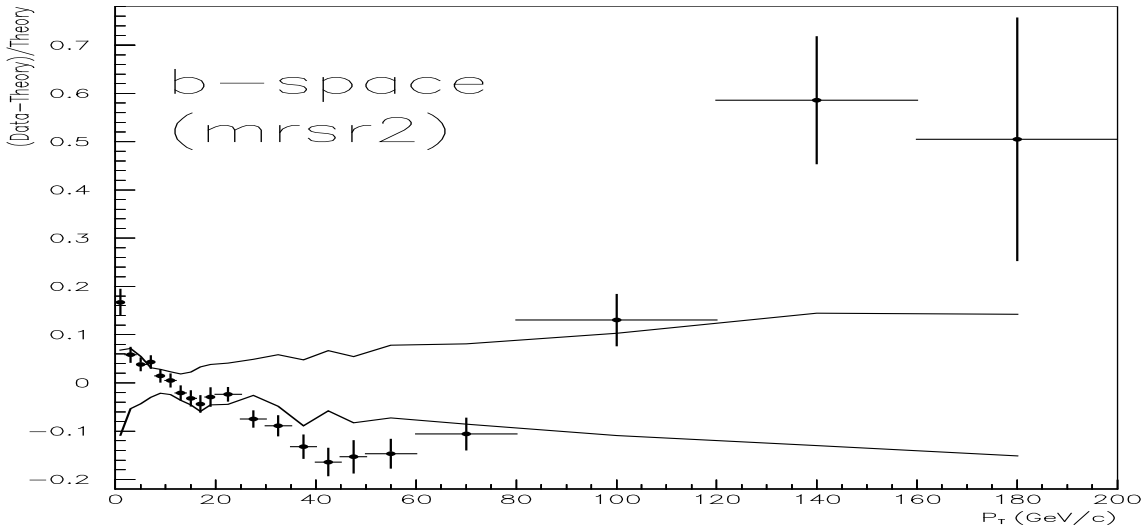
high P_T -> statistics (backgrounds)

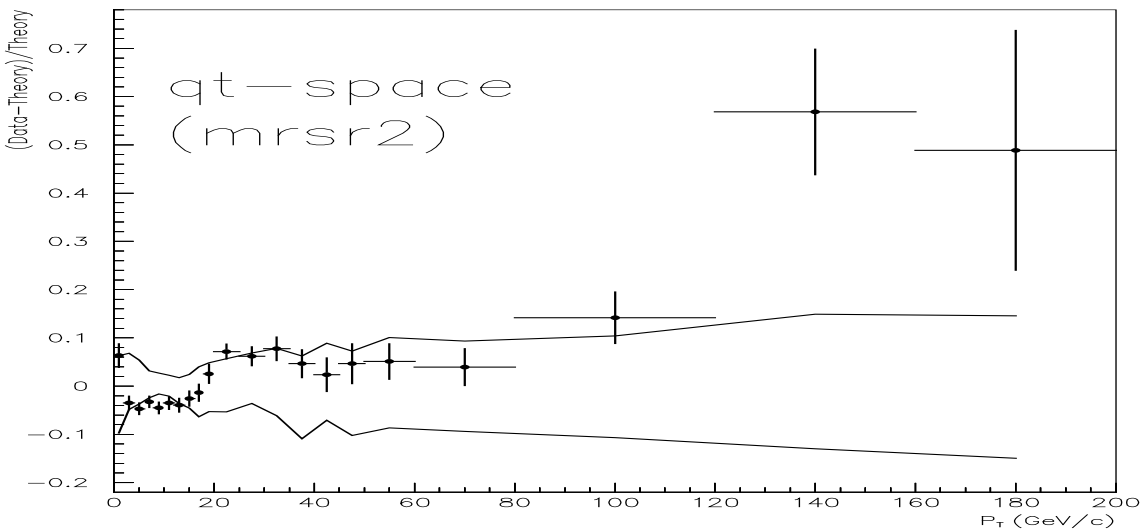
DØ W P_T PRELIMINARY

NEW

W P_T

CDF

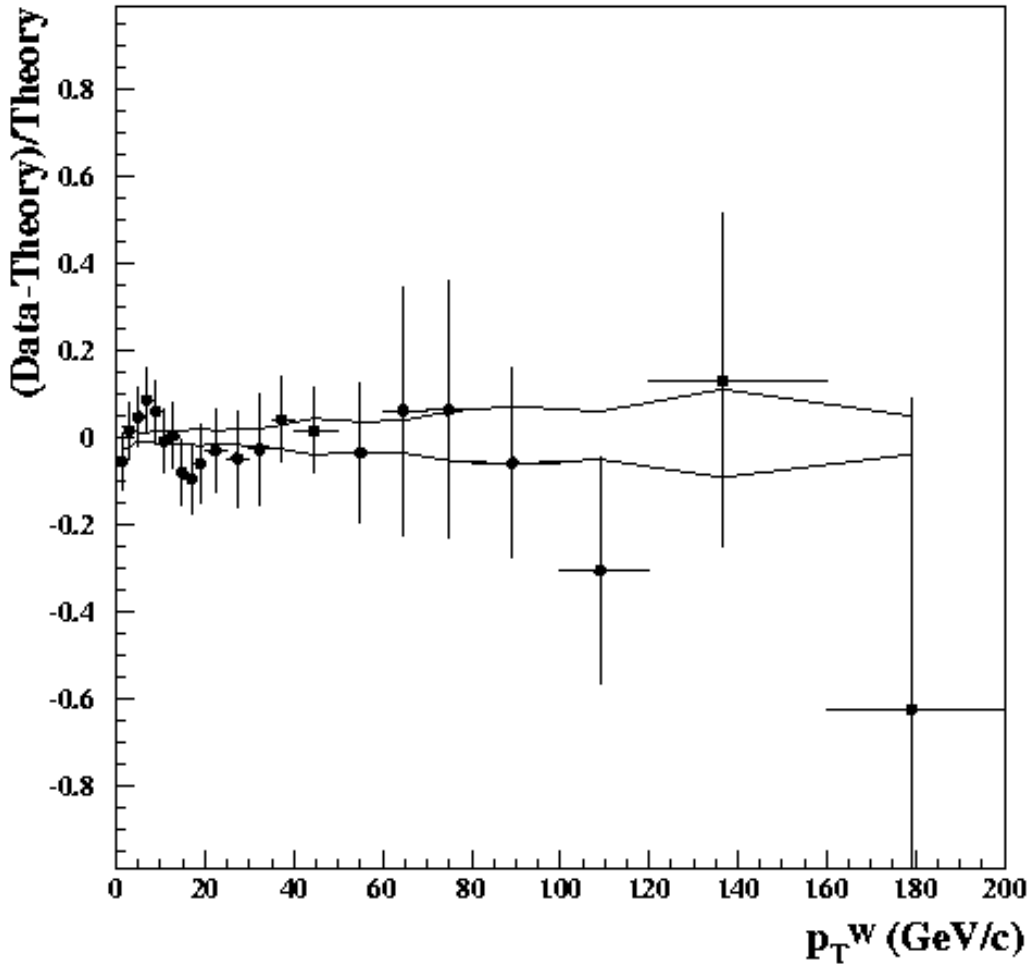




compared to theory through detector simulation

W P_T

DØ



χ^2 / *dof* = **9.5 / 21** $P_T < 200$ **GeV**

= **8.6 / 19** $P_T < 120$ **GeV**

= **6.8 / 11** $P_T <$ **50 GeV**

= **7.0 / 14** $P_T <$ **30 GeV**

Arnold-Kauffman O(α^2) resummation after detector simulation (b -space) MRSA'

PRELIMINARY

NEW

Conclusions

W mass including forward electrons:

80.474±0.093 GeV (DØ) PRELIMINARY

W width:

PRELIMINARY

2.130±0.030±0.052 GeV (DØ)

W cross section at 630 GeV in agreement with UA1/UA2 measurements (DØ) PRELIMINARY

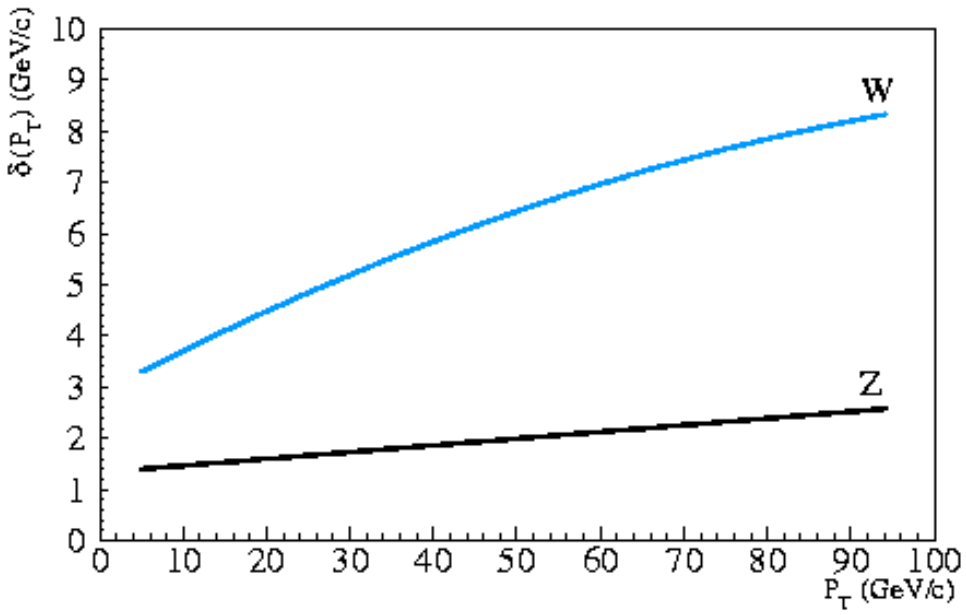
g(t)/g(e):

1.004±0.19 (CDF)

effects of QCD on angular distributions in W decay seen (DØ) PRELIMINARY

P_T(W) spectra in agreement with perturbative QCD (CDF, DØ) PRELIMINARY

Boson P_T Distributions



DØ

For Z P_T: statistics main source of uncertainty