W mass workshop,
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Dzero status

Jan Stark
Laboratoire de Physique Subatomique et de Cosmologie
Grenoble, France

LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

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IN2P3
Institut National de Physique Nucléaire et de Physique des Particules

Introduction

We have made some exciting progress with our measurement recently, and on the next few slides I will give a short glimpse on our results.

I will be extremely brief on most parts, but there are a few differences between the CDF analysis and ours that are important in the context of this workshop. Will try to point them out clearly.

The next few slides are from the Moriond conference last week where this result has been shown for the first time.

First DØ Run II measurement of the W boson mass (preliminary)

1 fb^{-1} of data
using central electrons ($|\eta|<1.05$)

~ 500k W events
~ 19k Z events

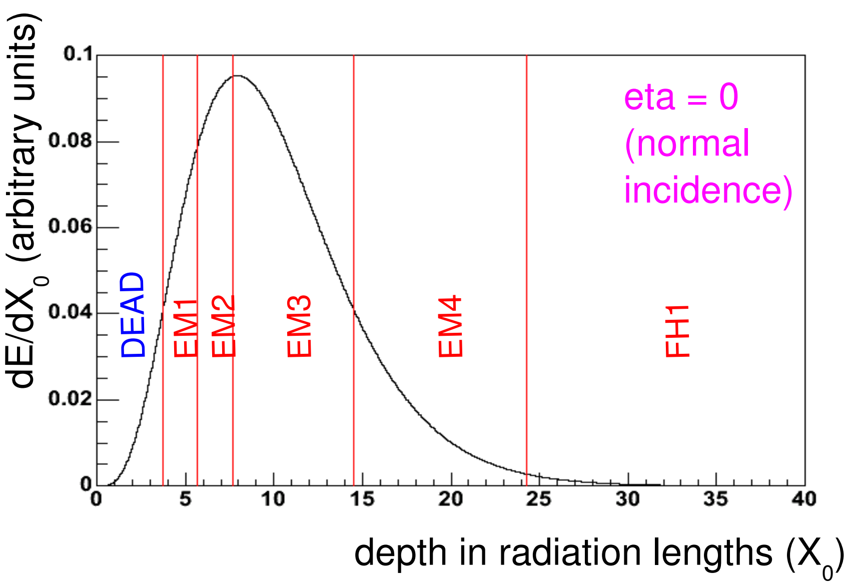
Electrons: energy scale

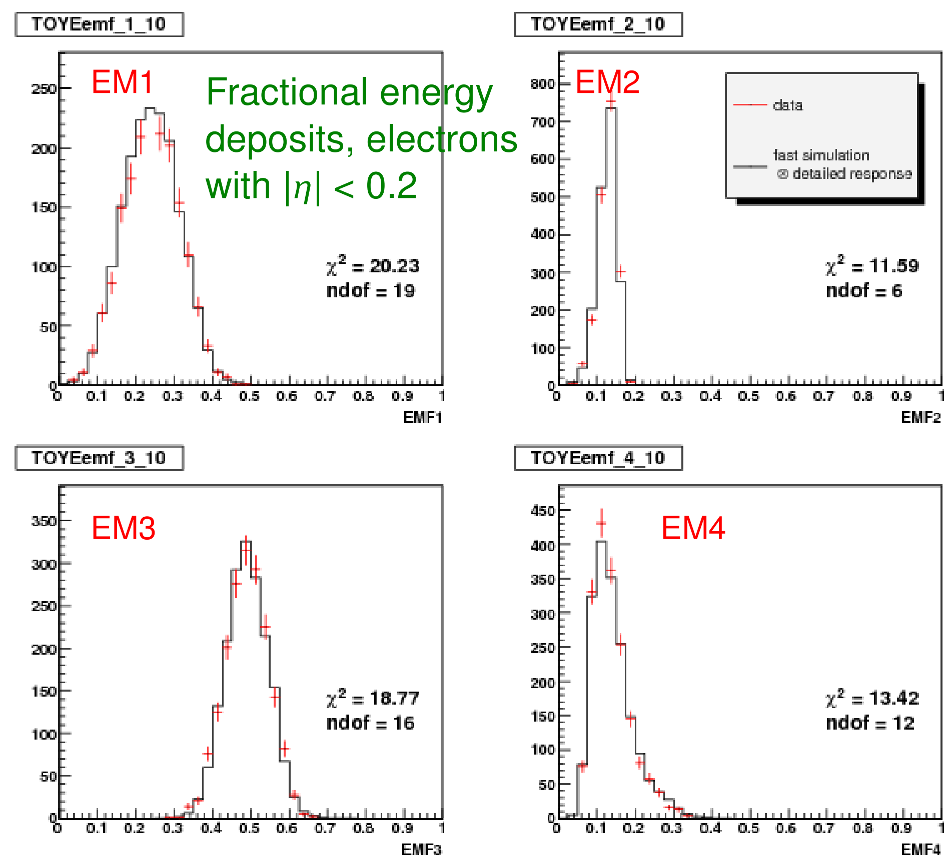
Knowing the amount of dead material is the key to energy response linearity: Measure amount of dead material *in situ* using electrons from $Z \rightarrow e\ e$.

Exploit longitudinal segmentation of our EM calorimeter:
fractional electron energy deposits in each of the four readout sections of our EM calorimeter (EM1, ..., EM4) are very sensitive to amount of dead material.

=> compare fractional deposits in data and detailed simulation

adjust material in simulation (5% correction to nominal material model) to match data





Amount of uninstrumented material determined to within less than $0.01X_0$!

Electrons: energy scale

After having corrected for the effects of the uninstrumented material:
final energy response calibration, using $Z \rightarrow e\,e$, the known Z mass value from LEP, and the standard "f_z method":

$$E_{measured} = \alpha \times E_{true} + \beta$$

Use energy spread of electrons in Z decay to constrain α and β .

In a nutshell: the f_Z observable allows you to split your sample of electrons from $Z \rightarrow e\,e$ into subsamples of different true energy; this way you can *"scan" the electron energy response as a function of energy*.

$$f_Z = (E(e1)+E(e2))(1-\cos(\gamma_{ee}))/m_Z$$

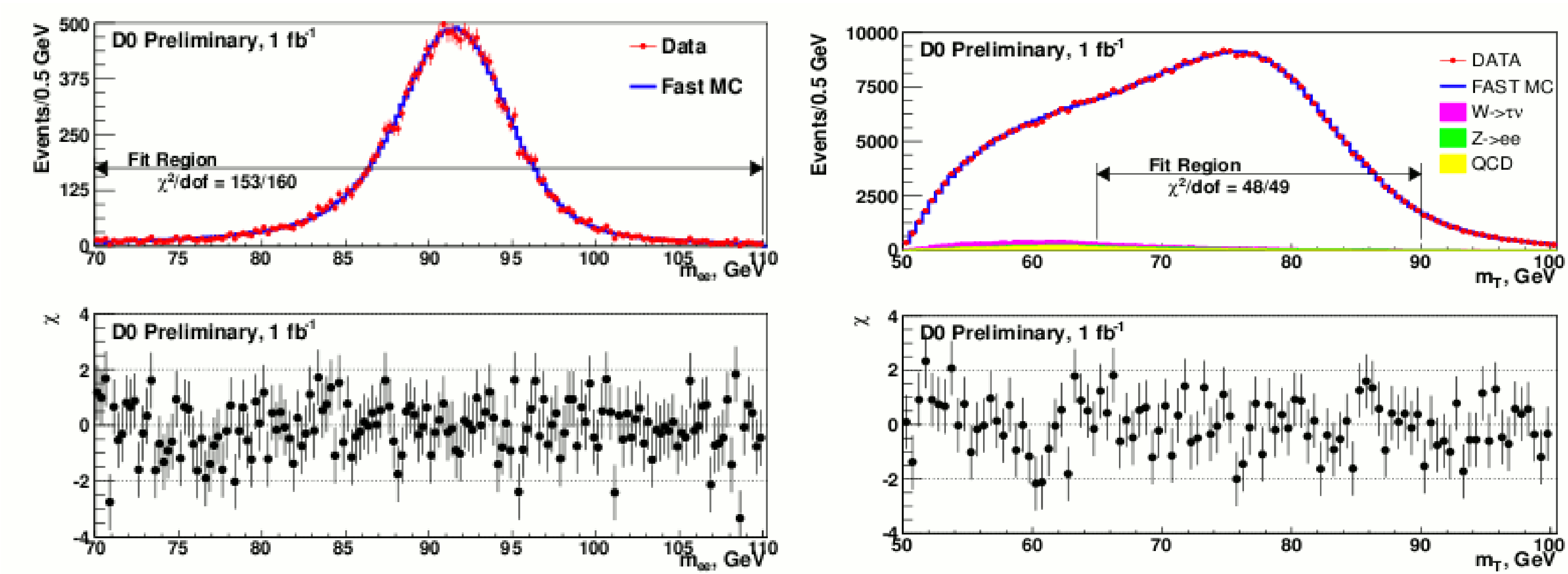
γ_{ee} is the opening angle between the two electrons

Result: $\alpha = 1.0111 \pm 0.0043$
$\beta = -0.404 \pm 0.209$ GeV
correlation: -0.997

This corresponds to the dominant systematic uncertainty (by far) in the W mass measurement (but this is really just Z statistics ... more data will reduce it) :

Δ m(W) = 34 MeV, 100 % correlated between all three observables

Mass fits

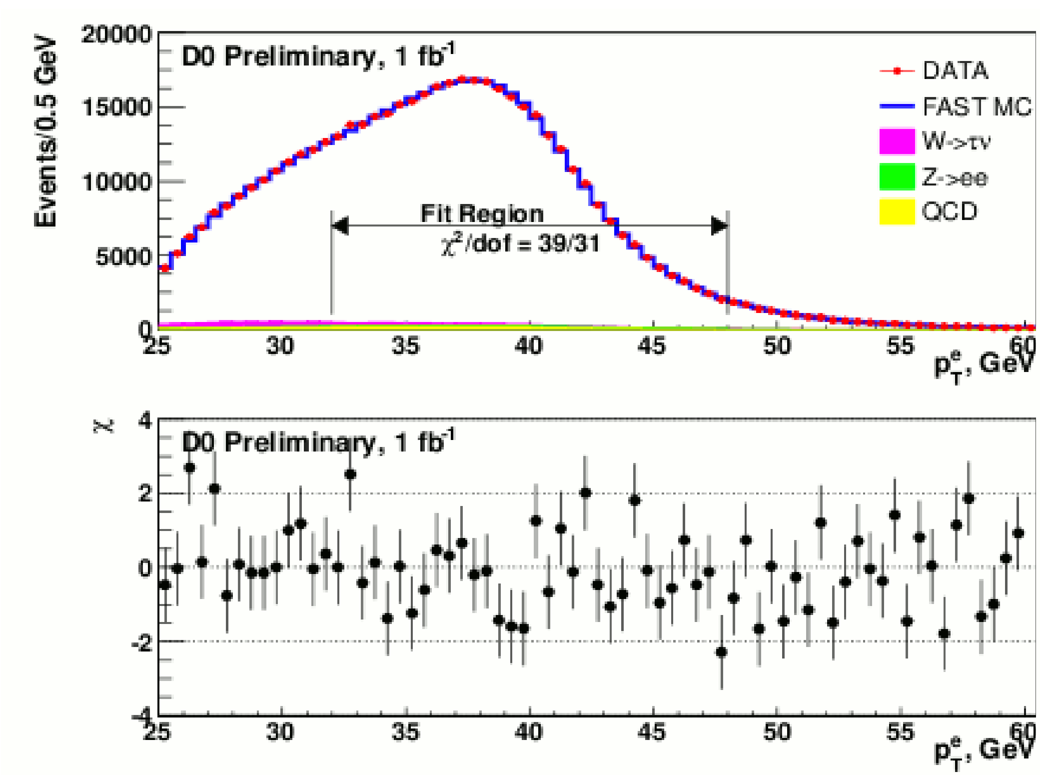


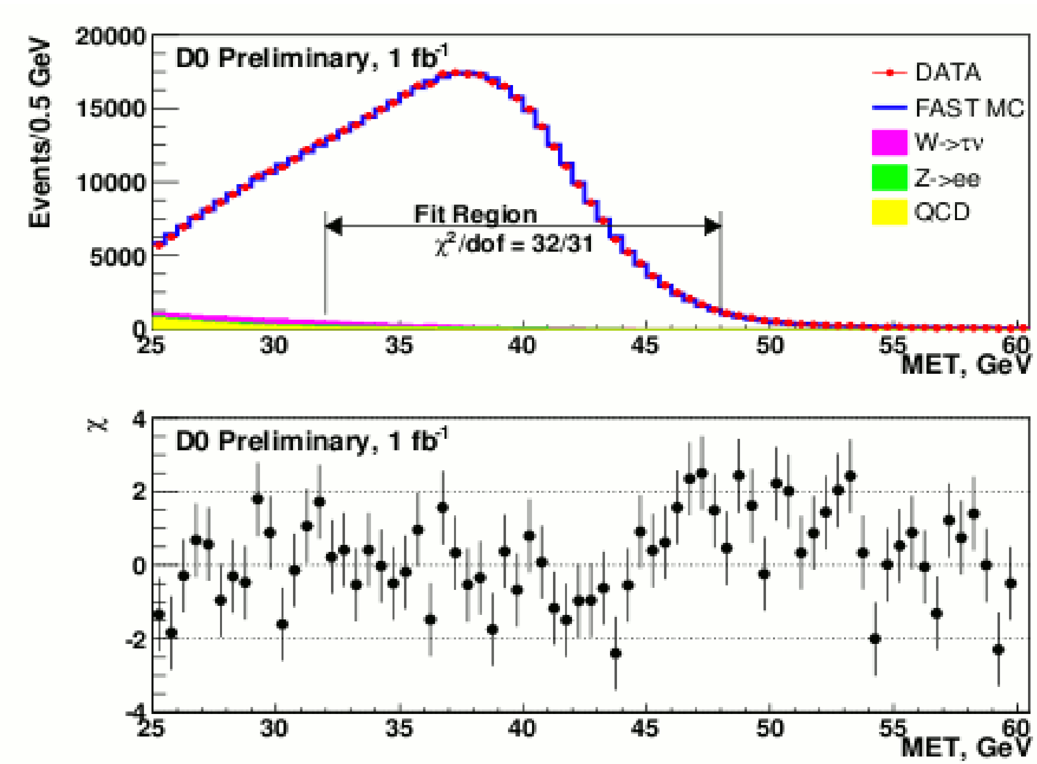
m(Z) = 91.185 ± 0.033 GeV (stat)

(remember that Z mass value from LEP was an input to electron energy scale calibration, PDG: m(Z) = 91.1876 ± 0.0021 GeV)

m(W) = 80.401 ± 0.023 GeV (stat)

Mass fits





m(W) = 80.400 ± 0.027 GeV (stat)

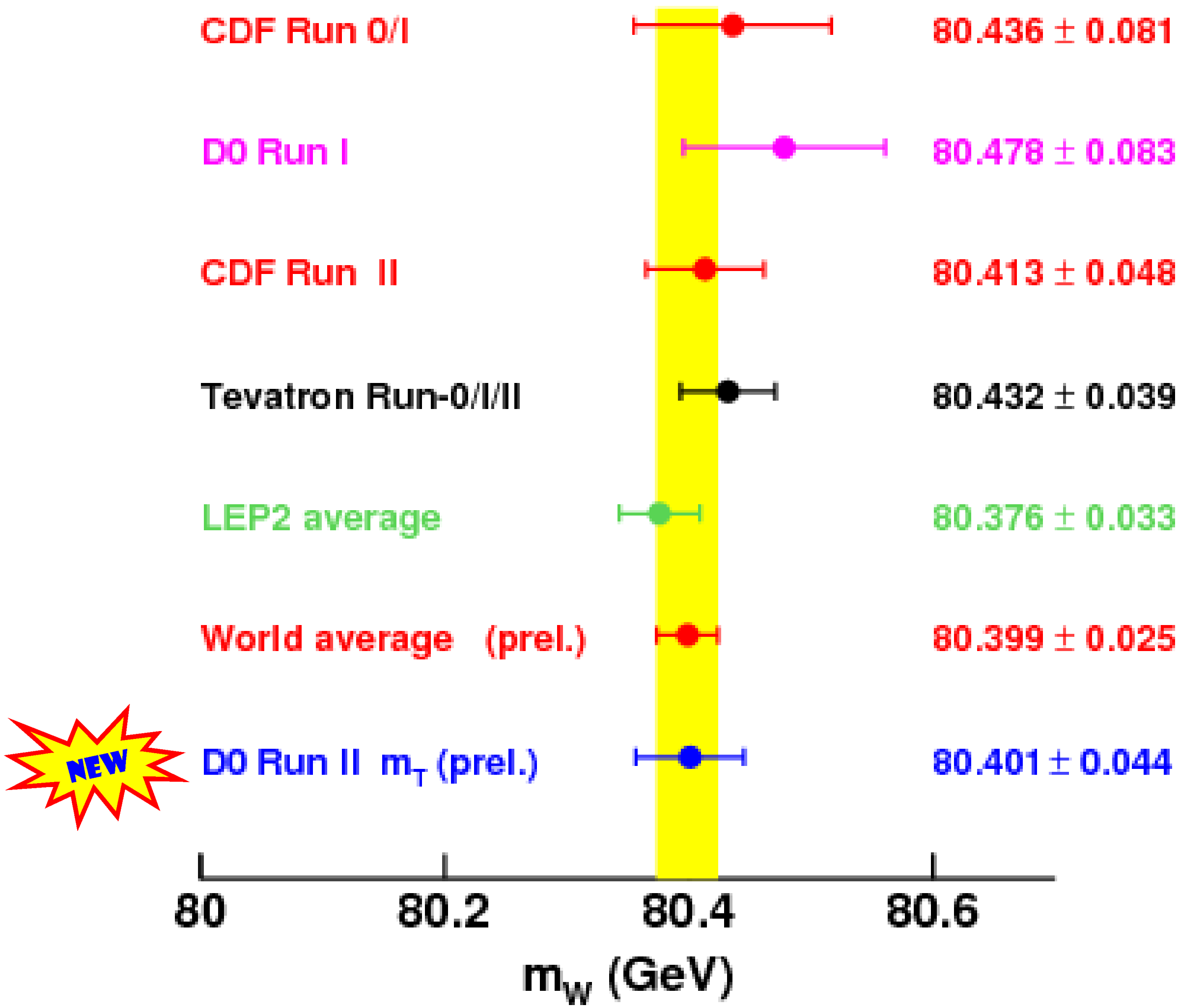
m(W) = 80.402 ± 0.023 GeV (stat)

Summary of uncertainties

systematic uncertainties

Source	$\sigma(m_W)$ MeV m_T	$\sigma(m_W)$ MeV p_T^e	$\sigma(m_W)$ MeV $\not{E}_T$
Experimental			
Electron Energy Scale	34	34	34
Electron Energy Resolution Model	2	2	3
Electron Energy Nonlinearity	4	6	7
W and Z Electron energy loss differences (material)	4	4	4
Recoil Model	6	12	20
Electron Efficiencies	5	6	5
Backgrounds	2	5	4
Experimental Total	35	37	41
W production and decay model			
PDF	9	11	14
QED	7	7	9
Boson p_T	2	5	2
W model Total	12	14	17
Total	37	40	44
statistical	23	27	23
total	44	48	50

W mass: summary of results



The new result from DØ is the single most precise measurement of the W boson mass to date.

So far, we quote our m_T result as the main result. Will combine results from the three observables; expect ~ 10 % improvement in total error over m_T alone.

The new result is in good agreement with previous measurements.

Model of W production and decay

Tool	Process	QCD	EW
RESBOS	W,Z	NLO	-
WGRAD	W	LO	complete $\mathcal{O}(\alpha)$, Matrix Element, ≤ 1 photon
ZGRAD	Z	LO	complete $\mathcal{O}(\alpha)$, Matrix Element, ≤ 1 photon
PHOTOS			QED FSR, ≤ 2 photons

Our main generator is “ResBos+Photos”. The NLO QCD in ResBos allows us to get a reasonable description of the p_T of the vector bosons. The two leading EWK effects are the first FSR photon and the second FSR photon. Photos gives us a reasonable model for both.
We use W/ZGRAD to get a feeling for the effect of the full EWK corrections.

As you have seen, the final “QED” uncertainty we quote is 7/7/9 MeV (m_T,p_T,MET).
This is the sum of different effects; the two main ones are:

- Effect of full EWK corrections, from comparison of W/ZGRAD in “FSR only” and in “full EWK” modes (5/5/5 MeV).
- Very simple estimate of “quality of FSR model”, from comparison of W/ZGRAD in FSR-only mode vs Photos (5/5/5 MeV).

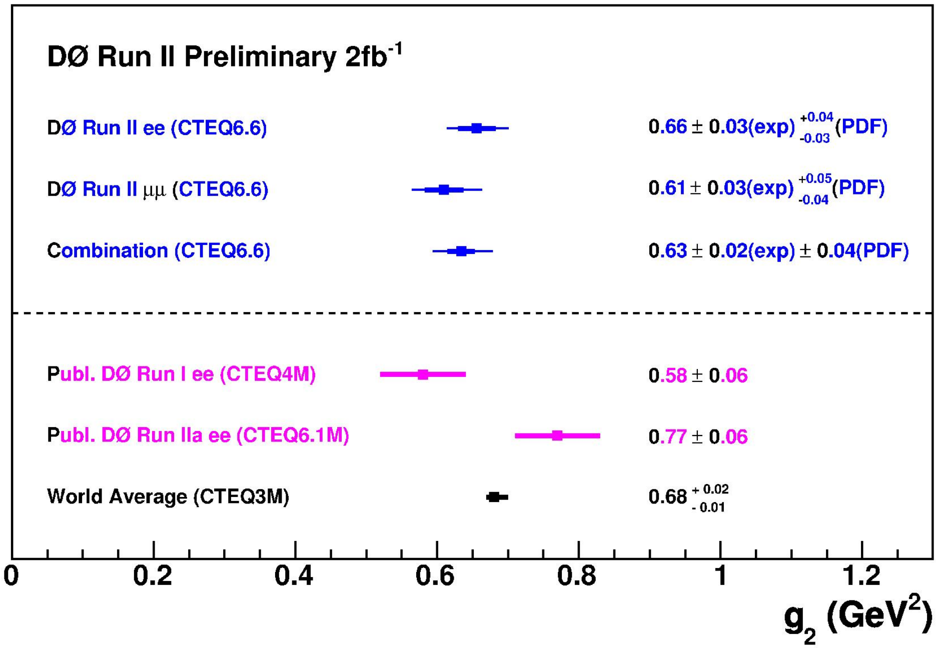
Model of W production and decay

As we have seen, at Dzero we really measure the ratio of the masses of the W and the Z.
So our comparisons of two generators (or two setups of one generator) typically look like the one below.
Here we study the effect of a variation of the δs cut in W/ZGRAD. The cut is shown in the first two columns of the table. The fitted m_W moves around (columns 3-5), but so does the fitted Z mass (column 6), and the mass ratios (columns 7-9) turn out to be stable within toy MC statistics in this case.

δs	$E_\gamma cut$ (MeV)	ΔM_W (M_T) (MeV)	ΔM_W (P_T) (MeV)	ΔM_W (MET) (MeV)	ΔM_Z (Z Mass) (MeV)	$\Delta(\frac{M_W}{M_Z})$ (M_T) ($\times 10^{-5}$)	$\Delta(\frac{M_W}{M_Z})$ ($p_T(e)$) ($\times 10^{-5}$)	$\Delta(\frac{M_W}{M_Z})$ (MET) ($\times 10^{-5}$)
0.00025	10	-25 ± 3	-23 ± 4	-22 ± 4	-34 ± 2	5.5	7.7	8.8
0.0005	20	-29	-29	-27	-30	-2.8	-2.8	-0.6
0.0006	24	-24	-27	-24	-32	4.6	1.3	4.6
0.0007	28	-24	-29	-19	-32	4.6	-0.85	10.0
0.0008	32	-21	-23	-20	-33	8.9	6.7	10.0
0.001	40	-20	-20	-20	-27	4.2	4.2	4.2
0.003	120	-17	-22	-14	-21	1.7	-3.8	5.0
0.005	200	-10	-13	-12	-15	3.5	0.25	1.3
0.01	400	0	0	0	0	0	0	0
0.015	600	5	8	6	11	-5.2	-1.9	-4.1
0.02	800	18	20	15	26	-5.4	-3.2	-8.7

Table 4: Mass shift of W and Z due to δs variation.

On the non-perturbative form factor in ResBos



Had a very useful discussion with Pavel on this topic yesterday, including different parameterisations etc.

Anyway, for the time being Dzero discuss the form factor in terms of "g_2".

The present public results of our measurements of g2 are shown on the left.

The one thing that I would like to point out is the (not unexpected) interplay between PDFs and g_2.

It would be good to have simultaneous parameterisations of the PDFs and the form factor.
Will try to present Dzero data in a way that is most useful for such combined fits.

Other comments

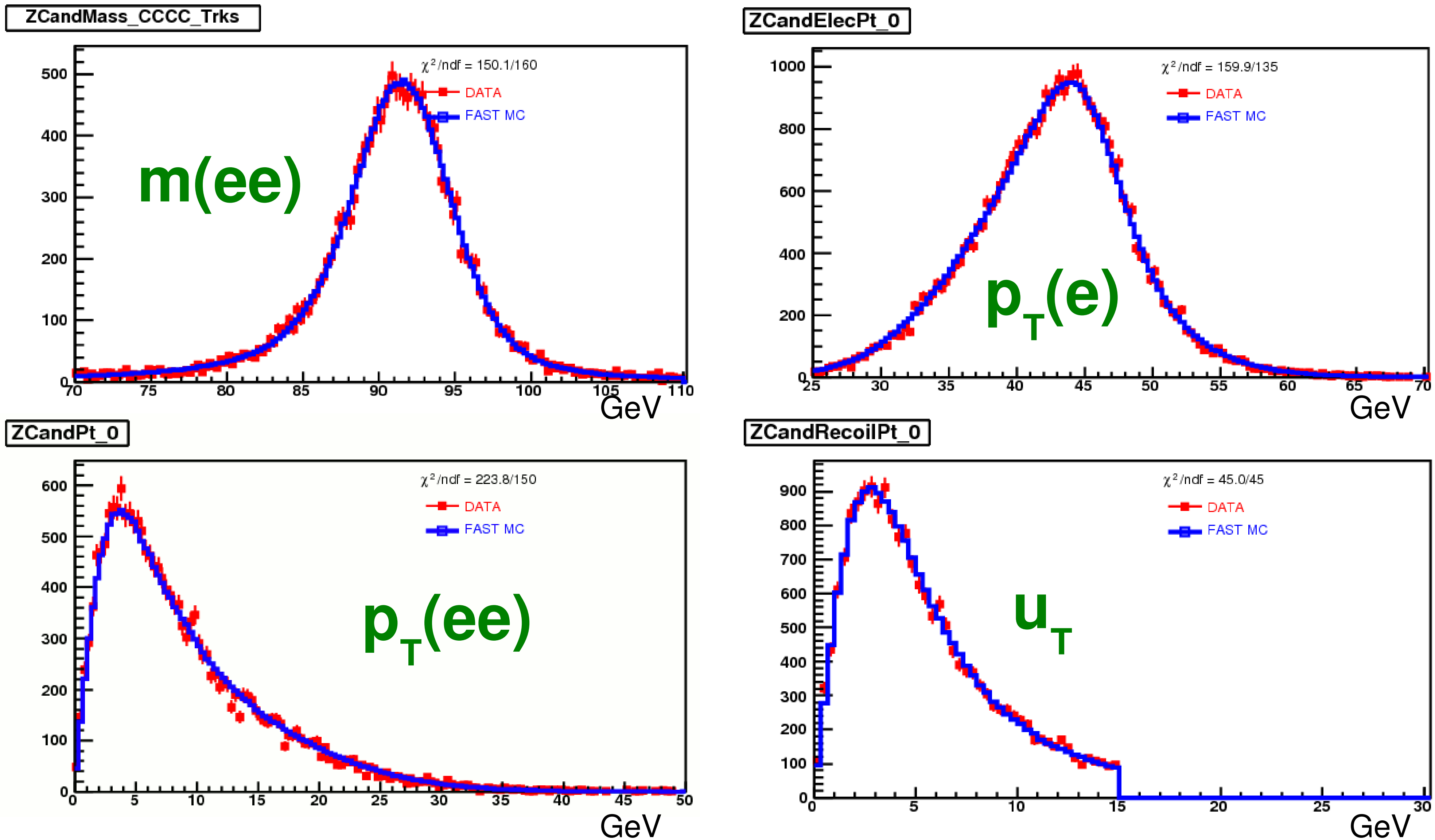
Some other comments, without any specific order, that have crossed my mind, either during the work on the Dzero analysis or during the discussions at the workshop:

- We strongly prefer public codes. Even if they contain bells, whistles and switches that we do not have to / want to play with, being able to run ourselves at least allows us to check a few obvious things like numerical stability. Also, you may or may not fully appreciate the enormous size of the samples that we need to generate.

- The last thing we would use is a "library" of four-vectors produced centrally by theorists. Such libraries may be useful for theory discussions and comparisons of different calculations, but they are inappropriate for data analysis.

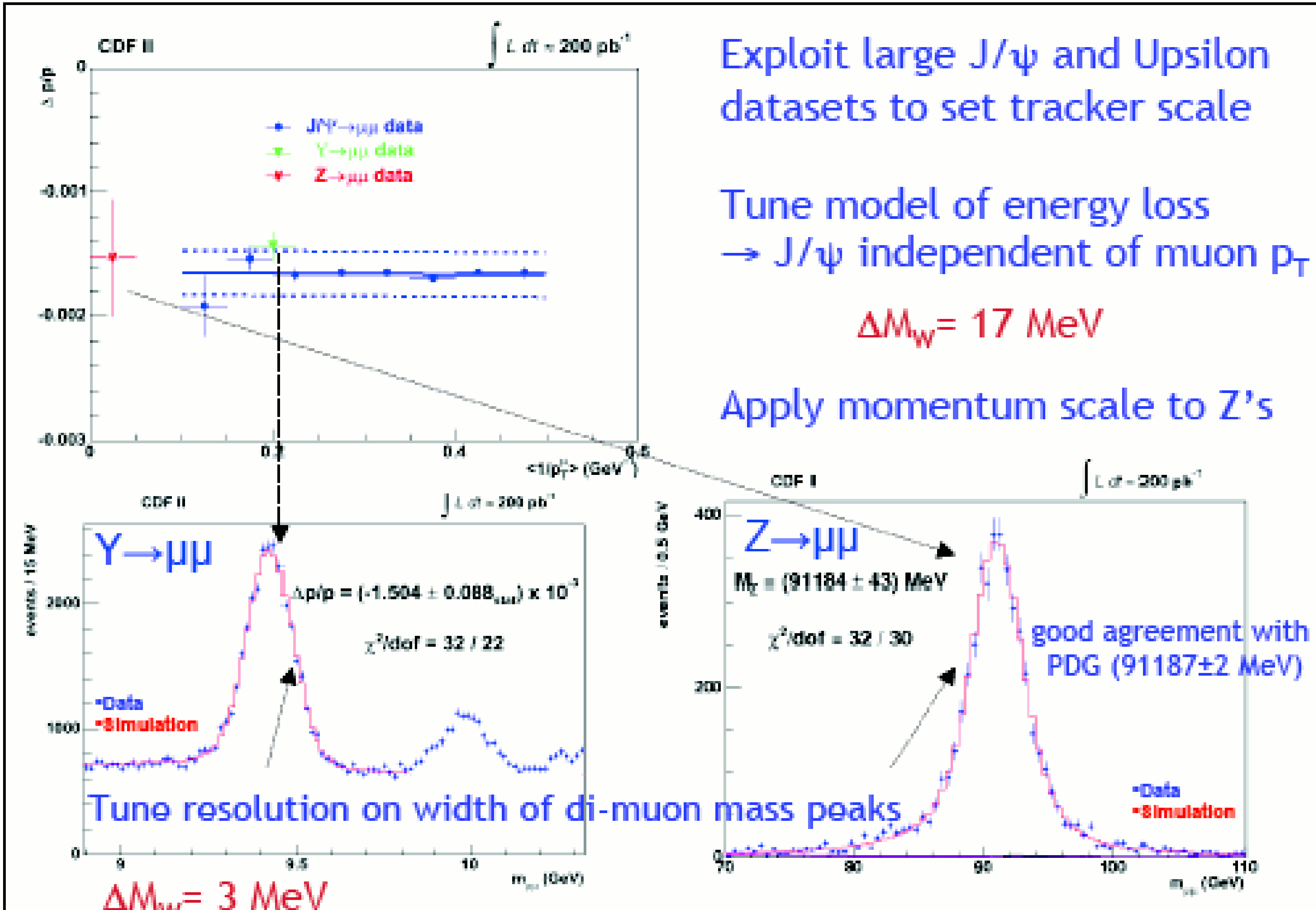
Backup slides

Results: $Z \rightarrow e\,e$ data



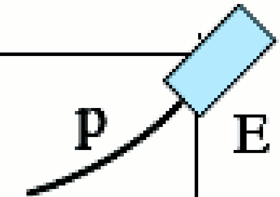
✓ **Good agreement between parameterised MC and collider data.**

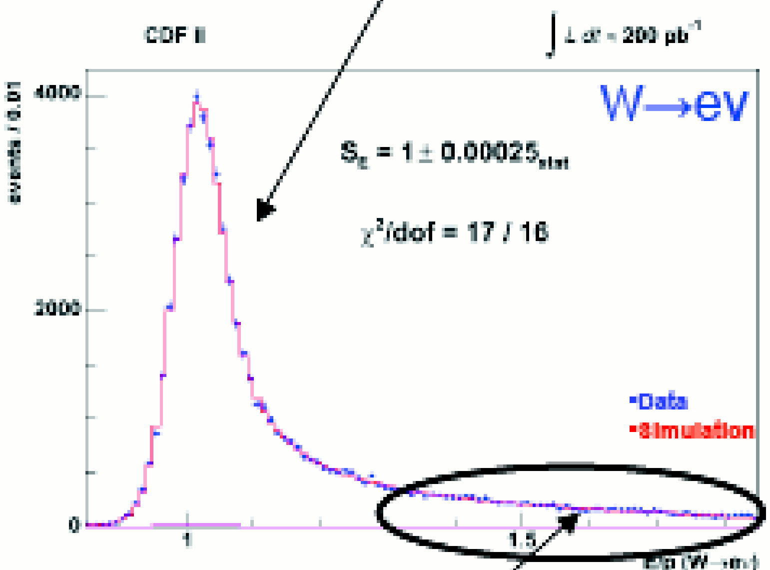
Comparison to CDF: Lepton scale



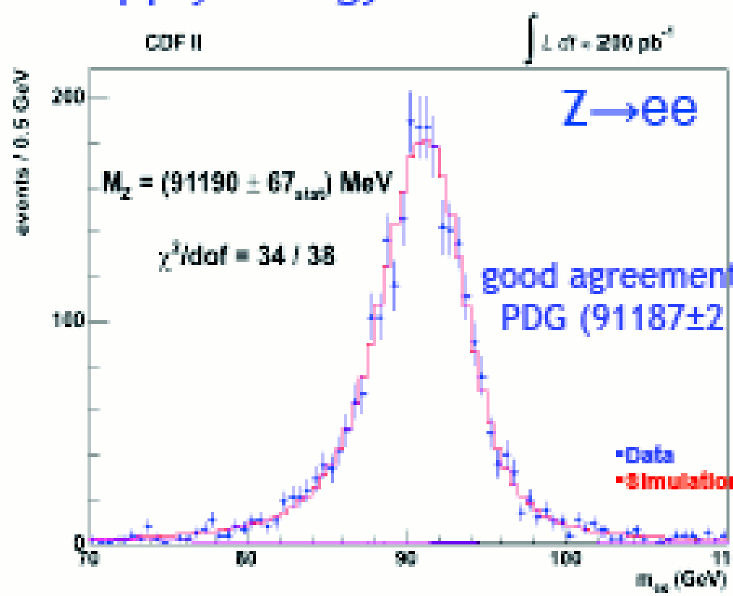
CDF: Lepton energy scale

Transfer momentum calibration to calorimeter using E/p distribution of electrons from W decay by fitting peak of E/p





Apply energy scale to Z's



good agreement with PDG (91187±2 MeV)

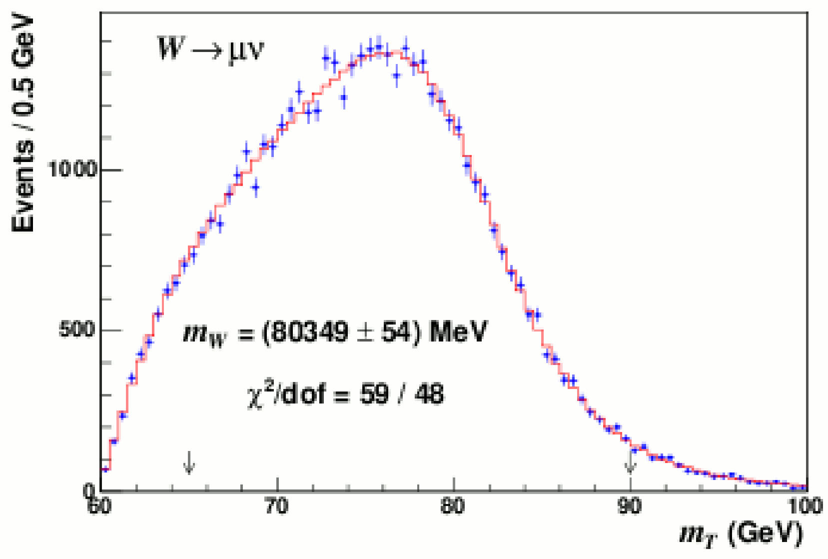
Tune number of radiation lengths with E/p radiative tail

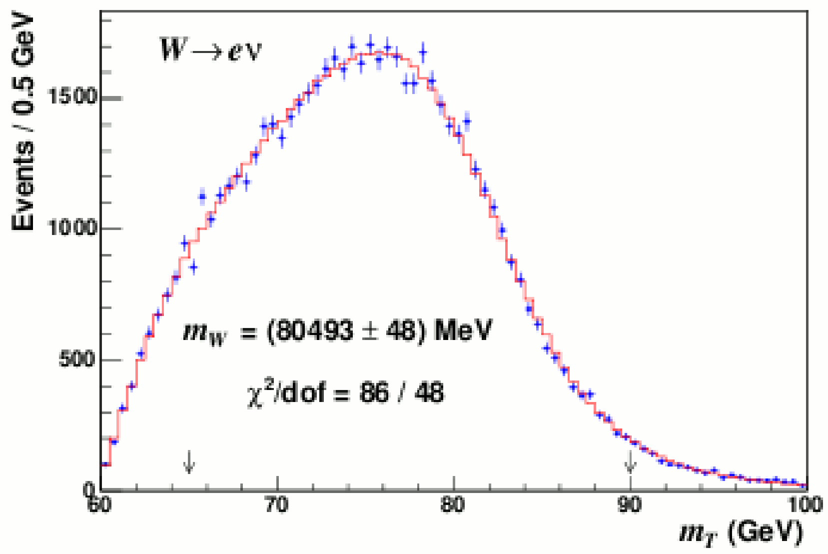
Add Z Mass fit to calibration (30% weight) $\Delta M_W = 30$ MeV

Correct for calibration E_T dependence

Tune resolution on E/p and Z mass peak $\Delta M_W = 9$ MeV

CDF: Result and uncertainties





m_T Fit Uncertainties			
Source	$W \to \mu\nu$	$W \to e\nu$	Correlation
Tracker Momentum Scale	17	17	100%
Calorimeter Energy Scale	0	25	0%
Lepton Resolution	3	9	0%
Lepton Efficiency	1	3	0%
Lepton Tower Removal	5	8	100%
Recoil Scale	9	9	100%
Recoil Resolution	7	7	100%
Backgrounds	9	8	0%
PDFs	11	11	100%
W Boson p_T	3	3	100%
Photon Radiation	12	11	100%
Statistical	54	48	0%
Total	60	62	-

Combined result (electrons, muons; three observables):

m(W) = 80.413 ± 0.048 GeV

Phys.Rev.Lett.99:151801 (2007)
Phys.Rev.D77:112001 (2008)