W Mass and Width at the Tevatron

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W Mass Measurement

Precision of direct measurements:

1983:	1989:	1990:	1995:	2000:	2004:
UA1	UA1	UA2	CDF	DØ	LEP
5 GeV	2.9 GeV	900 MeV	180 MeV	91 MeV	42 MeV
					Tevatron
					59 MeV

W mass now known to better than 5 parts in 10,000

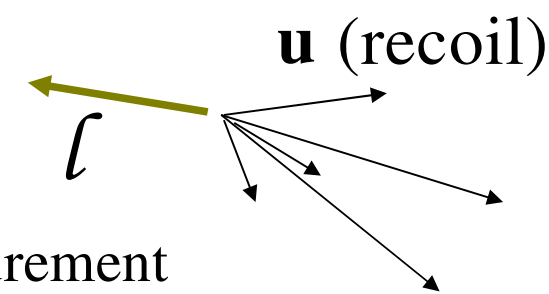
CDF: 79 MeV
DØ: 84 MeV

Looking forward:

* Tevatron Run 2 has quadrupled Run 1 CDF, DØ data sets
* CDF has analyzed first 200 pb^{-1} of data and determined uncertainties

→ Lepton energy scale measured to better than a part per thousand
→ Hadronic recoil understood to better than 50 MeV

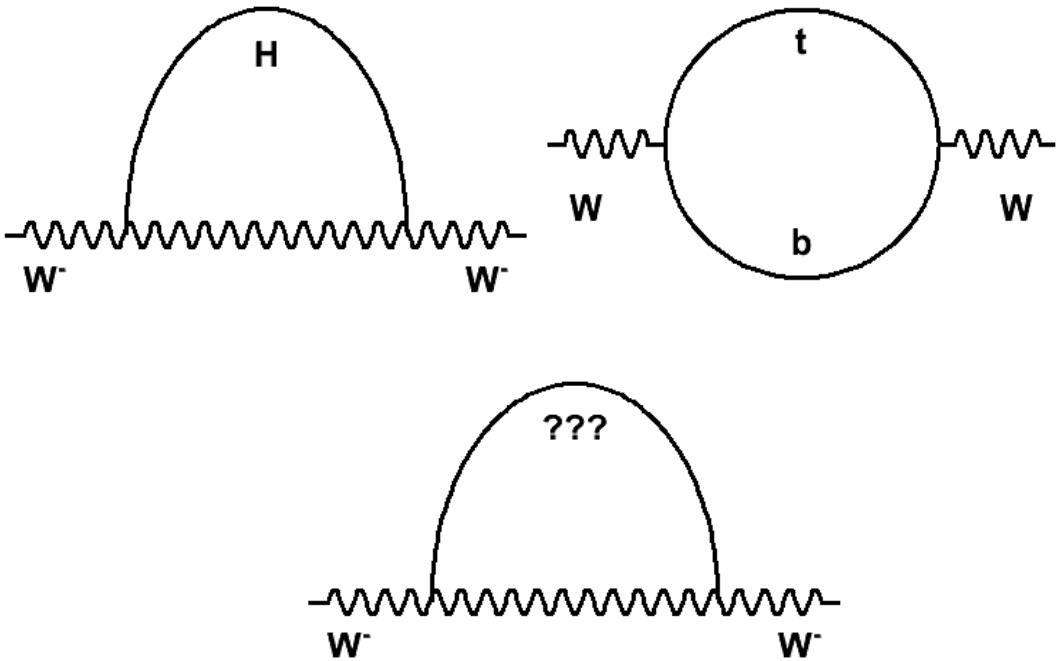
First Run 2 mass measurement coming soon

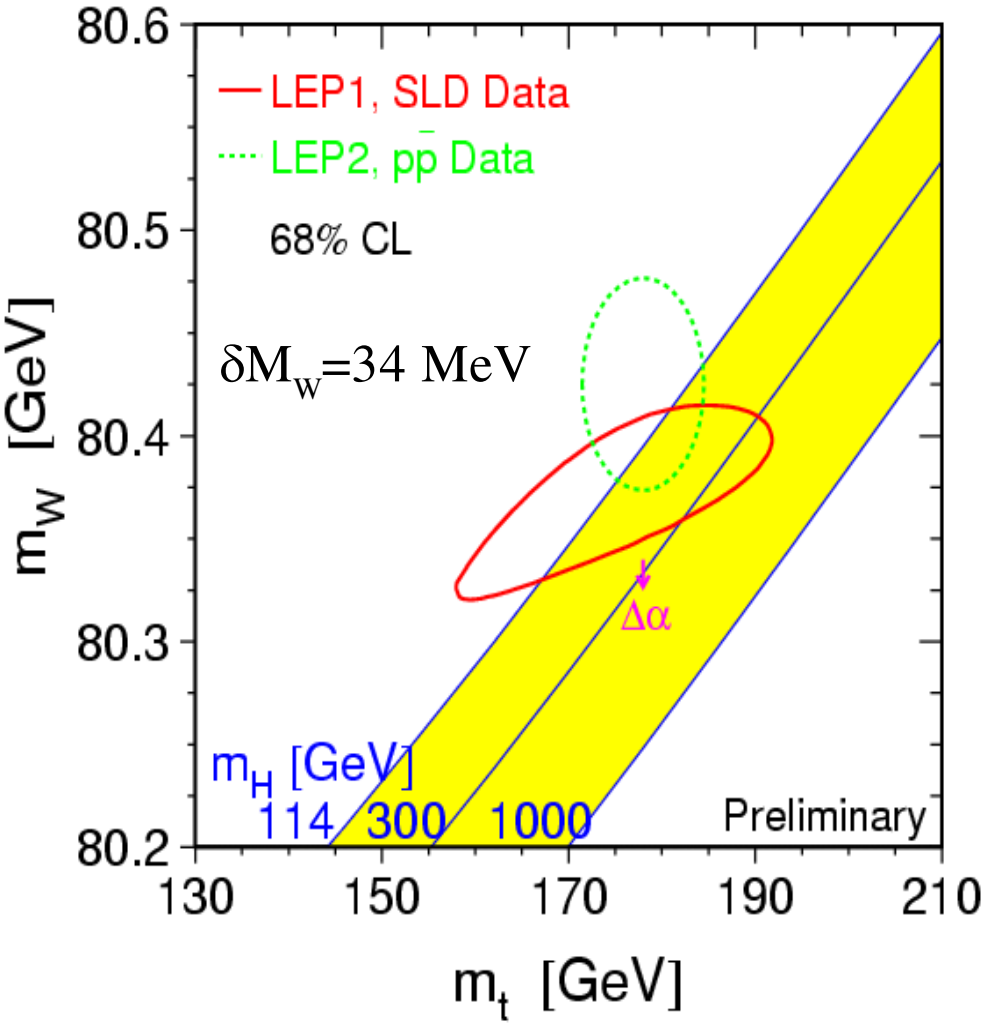


* Current data sets will provide best single-experiment measurement
* Data taken by end of next year will surpass current world precision

Contributions to W Mass

W propagator includes H, tb, new particle(?) loops





Precise knowledge of m_W constrains SM m_H, as well as hypothetical new particles

Tevatron Run 1 W Mass and Width

Combined results incorporate correlated & uncorrelated uncertainties (hep-ex/0311039)

Correlated uncertainties due to the production and decay model:

Mass

Source	CDF	DØ
Parton Dist. Functions	15	8
Radiative Corrections	11	12
Γ_W	10	10

Correlated uncertainty: 19 MeV

$M_W = 80.454 \pm 0.059$ GeV

Width

Source	CDF	DØ
Parton Dist. Functions	15	27
Radiative Corrections	10	10
M_W	10	15

Correlated uncertainty: 26 MeV

$\Gamma_W = 2.115 \pm 0.105$ GeV

Uncorrelated uncertainties:

* Lepton energy scale and resolution
* $p_T(W)$, recoil model
* Selection bias and backgrounds

CDF Run 2 W Mass Status

~200 pb^{-1} of e,μ data analyzed

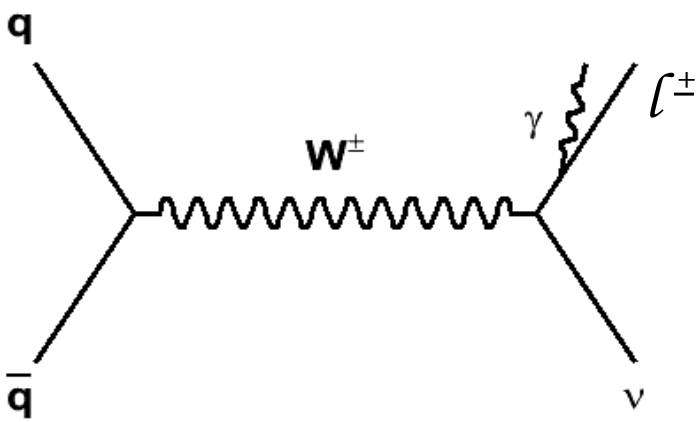
* First-pass of analysis complete, uncertainties determined
* Cross-checks underway
* *W* mass fit results blinded with hidden offset

Production and Decay Model Uncertainties

Source	μ	e
Parton Distribution Functions	15	15
QED Radiative Corrections	20	15
W p_T model	13	13
Γ_W	12	12

Dominated by 2-photon FSR

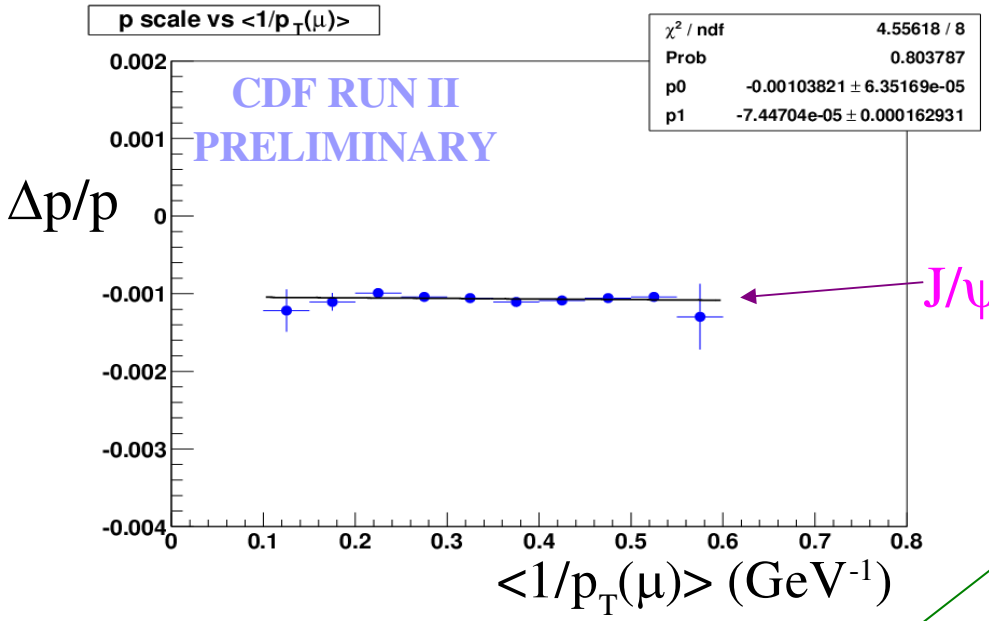
CDF RUN II PRELIMINARY



Constrained by Run 1 $p_T(Z)$ measurement

CDF Run 2 Muon Momentum Calibration

Set momentum scale using J/ψ and upsilon decays to muons

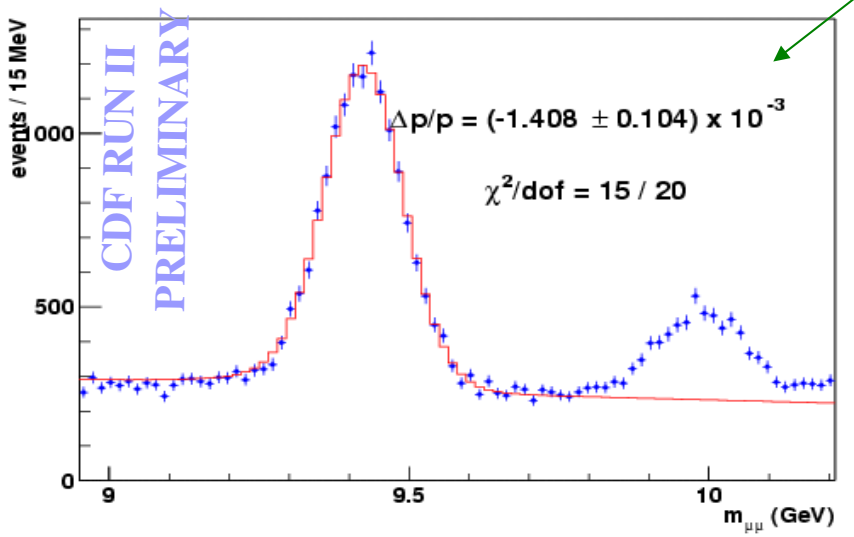


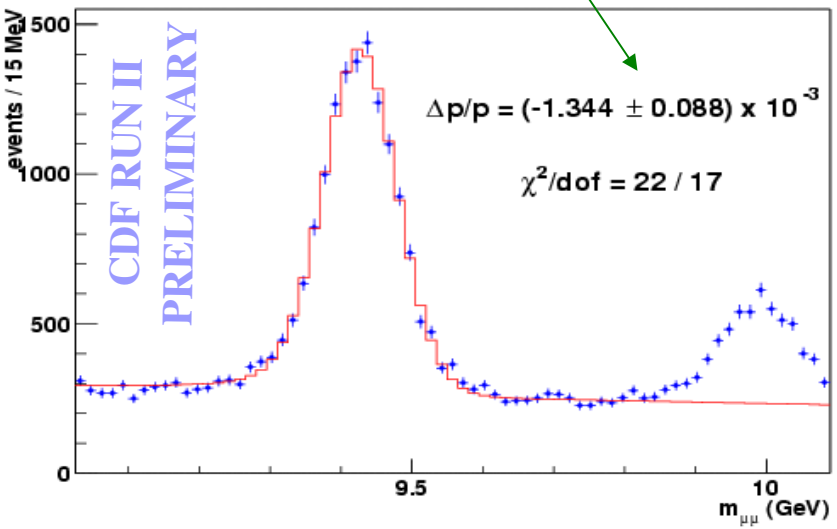
momentum determined to 3 parts in 10000:

$\delta M_W = \pm 25$ MeV

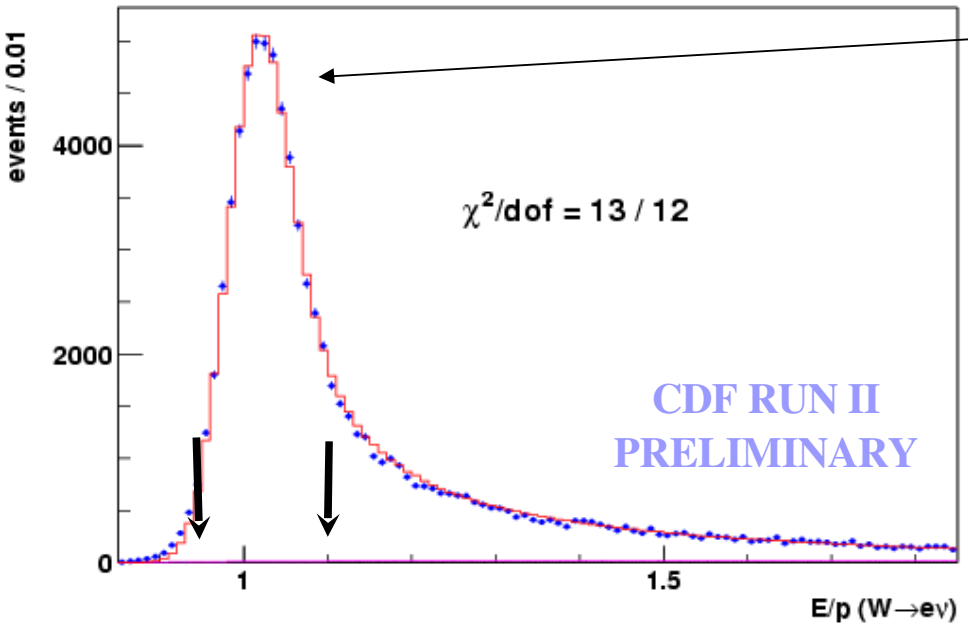
J/ψ mass independent of muon momentum

Upsilon mass consistent using beam-constrained or non-beam-constrained tracks





CDF Run 2 Electron Calibration



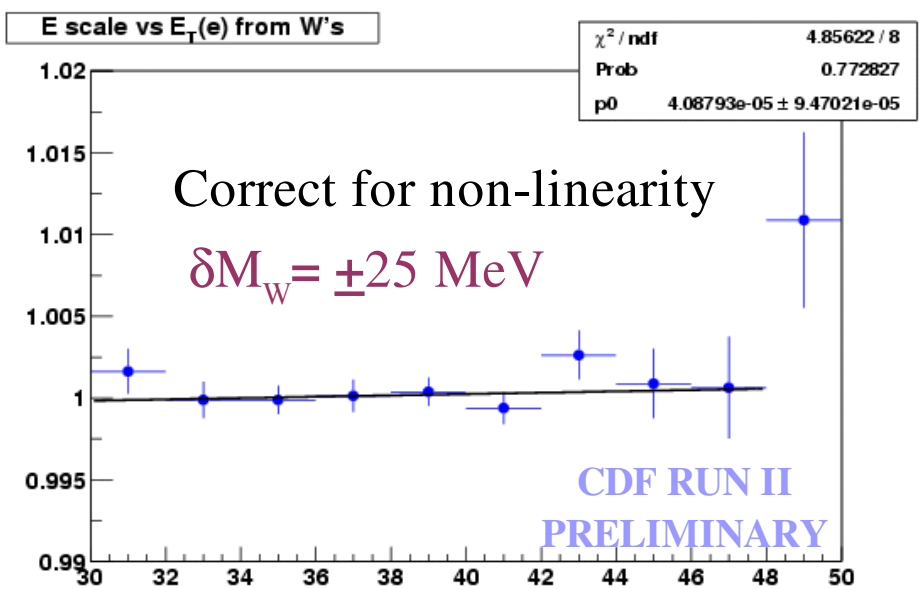
Set energy scale using *E/p* peak

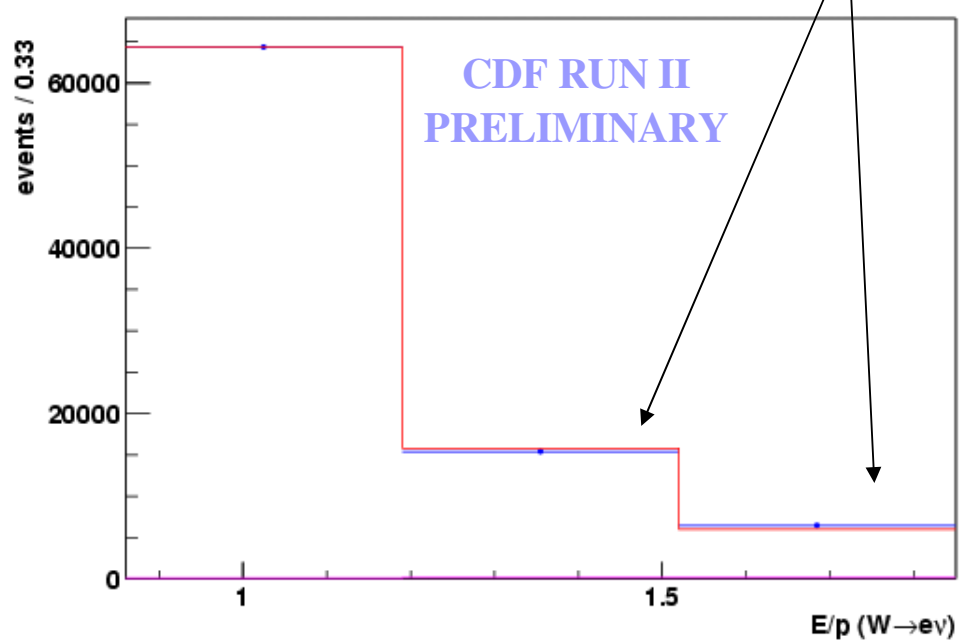
$\delta M_W = \pm 35$ MeV

Tune upstream passive material using tail of *E/p* distribution

Crucial to modelling external bremsstrahlung

$\delta M_W = \pm 55$ MeV





CDF Run 2 Z Mass Cross-Check

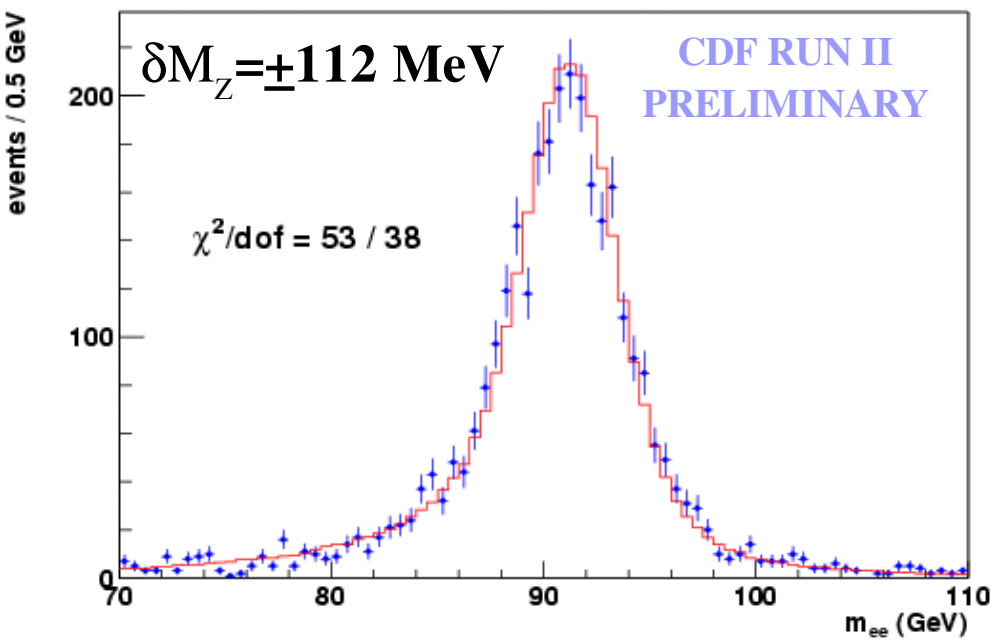
Use Z mass fits for tuning and cross-checks

Tune:
* COT hit resolution
* EM calorimeter resolution

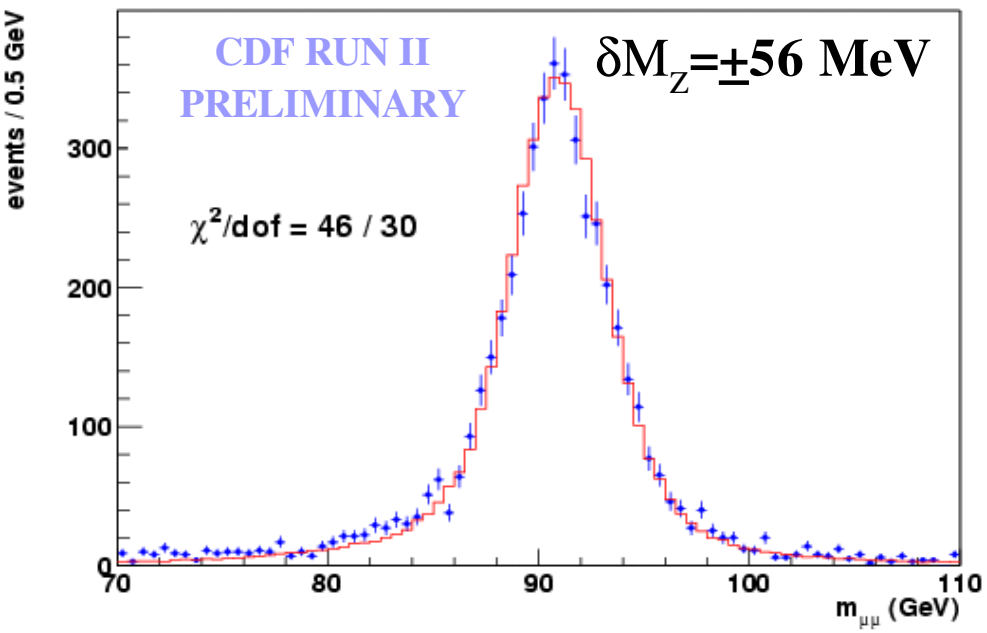
Cross-check:
* Energy scales
* QED FSR

Measured masses agree to within 1.5σ of PDG

Electrons



Muons

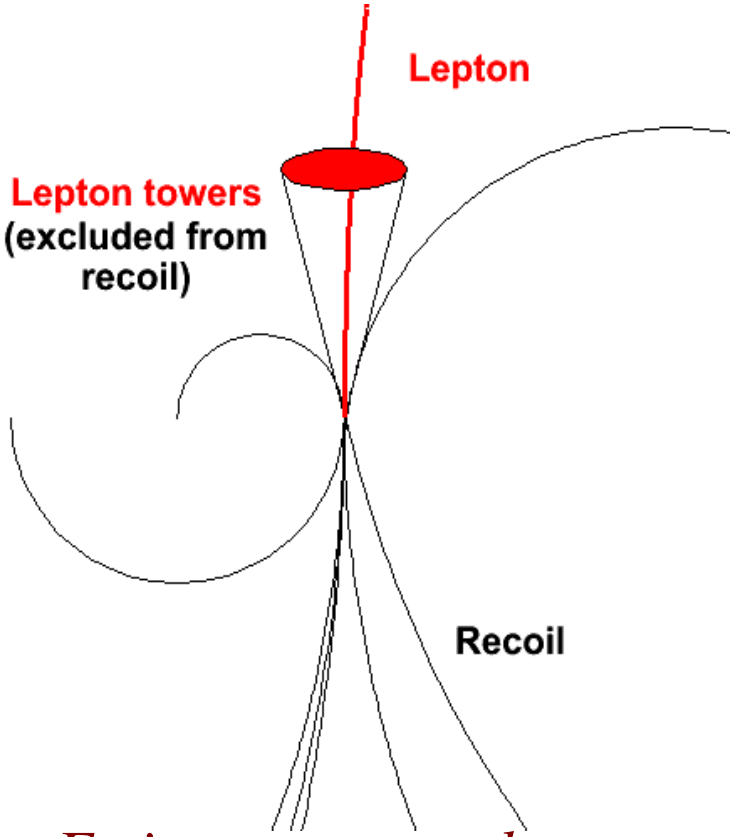


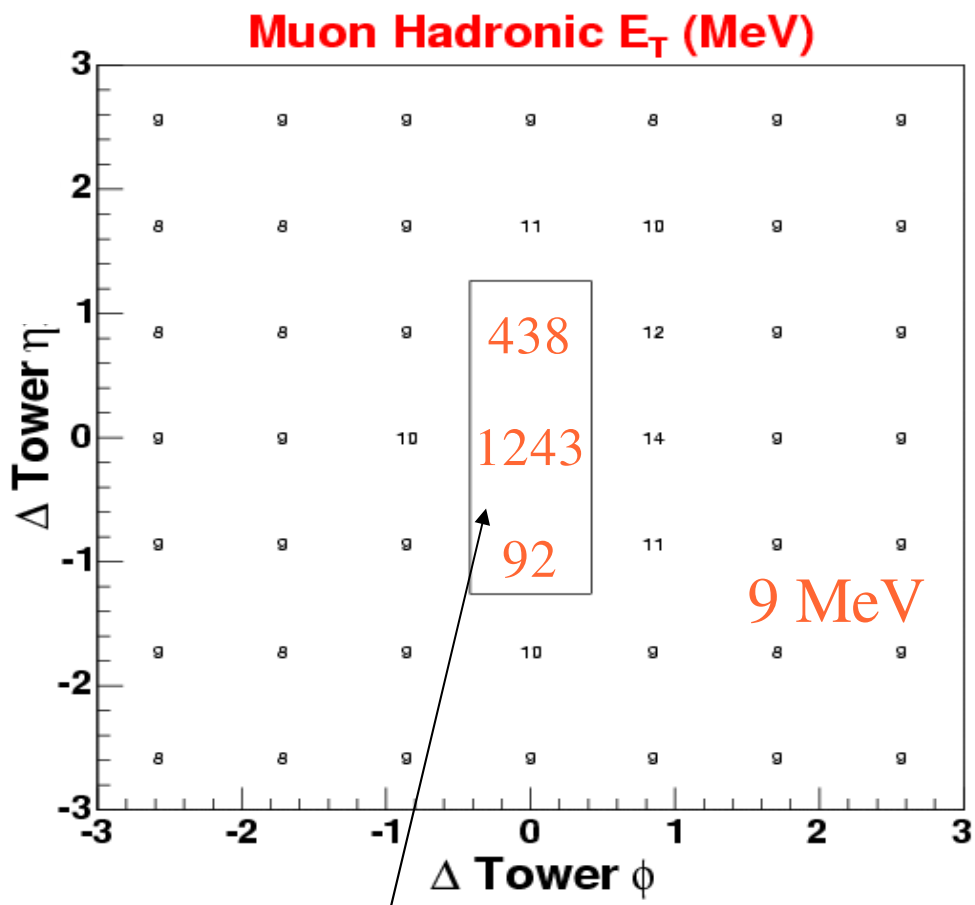
CDF Run 2 Recoil Measurement

Measure hadronic recoil by summing over all calorimeter towers

* Remove towers with energy deposited by lepton

0.1 x 0.25 η–φ





Estimate removed recoil energy using towers separated in φ

Removed muon towers

$\delta M_W = \pm 10$ MeV

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CDF Run 2 Recoil Model

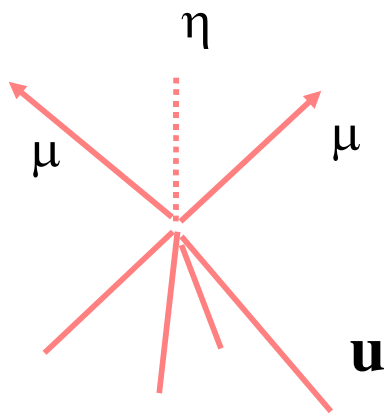
* Parametrize hadronic response: $R = \mathbf{u}_{meas}/\mathbf{u}_{true}$

$\mathbf{u}_{true}$ given by $p_T(Z)$

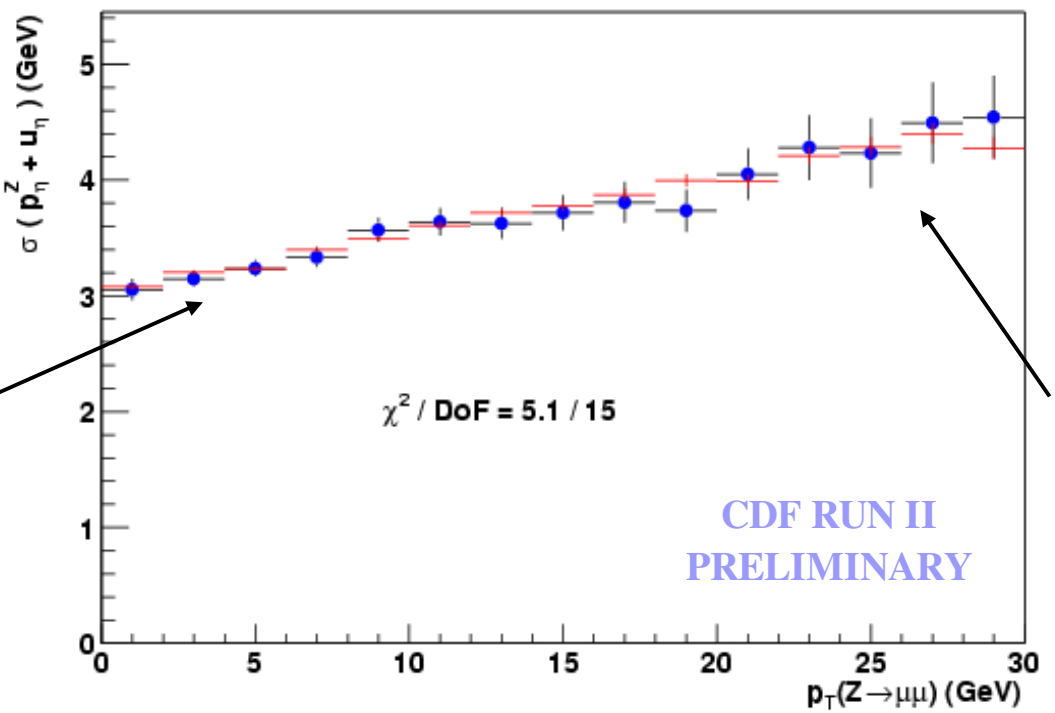
$\delta M_W = \pm 20$ MeV

* Resolution model incorporates terms from underlying event and jet resolution

Tune parameters using Z → μμ events



Resolution at low $p_T(Z)$ dominated by underlying event



Resolution at high $p_T(Z)$ dominated by jet resolution

$\delta M_W = \pm 42$ MeV

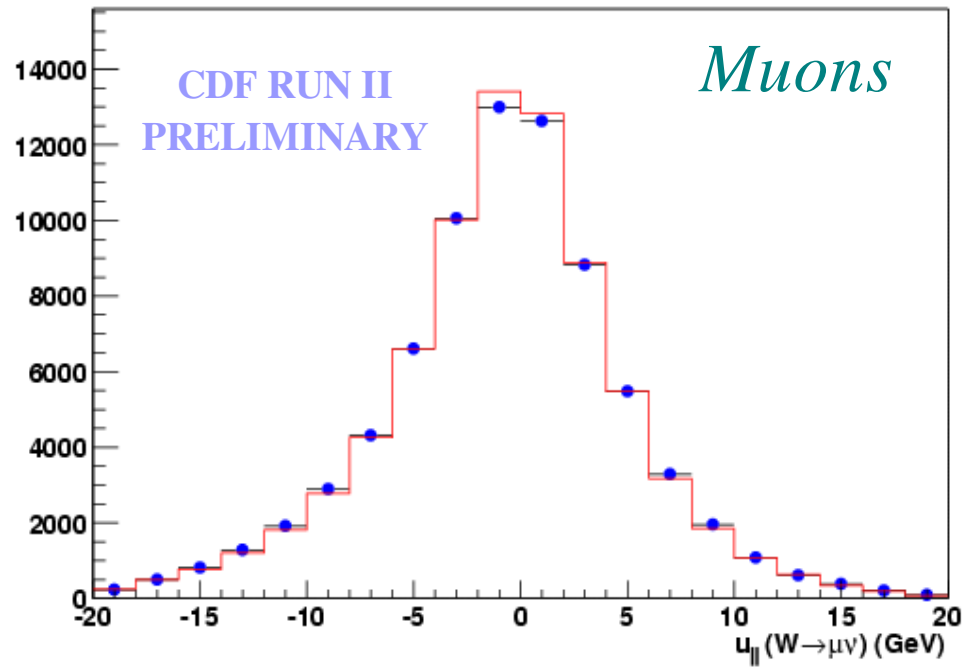
Model underlying event with minimum-bias data (inelastic collisions)

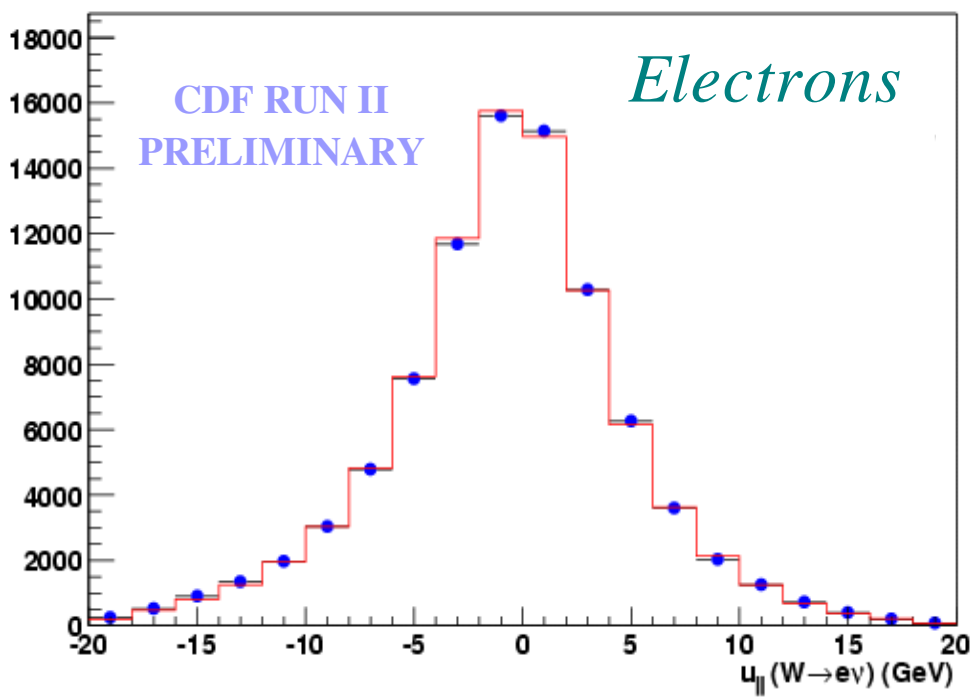
CDF Run 2 Recoil Cross-Check

Any bias in recoil along lepton direction ($u_{||}$) translates into bias in W mass

Study $u_{||}$ model in W events

Simulation includes:
* Tower-removal correction
* Backgrounds
* Inefficiencies as function of $u_{||}$





Means of simulation and data match to 30 MeV
Resolutions match to ~1%

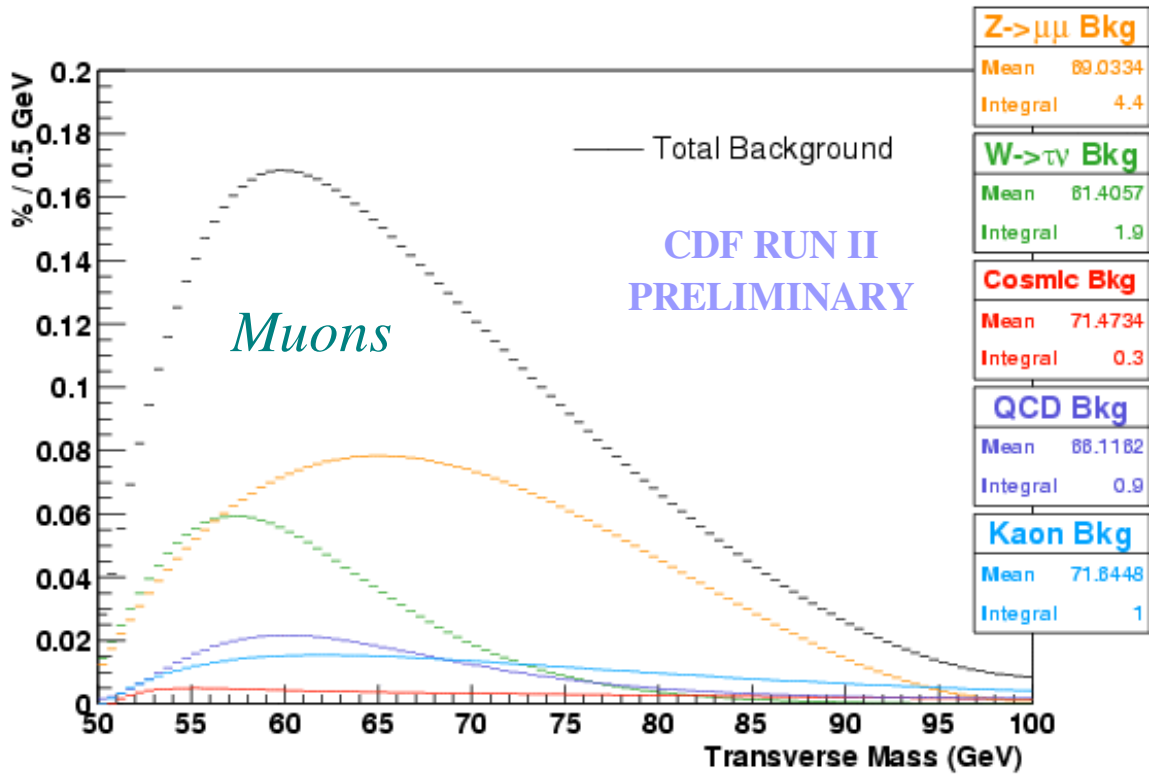
CDF Run 2 Backgrounds

Muons

Background	%
Hadronic Jets	0.9 ± 0.5
Kaons	1.0 ± 1.0
Cosmic Rays	0.3 ± 0.1
$Z \longrightarrow \mu\mu$	4.4 ± 0.2
$W \longrightarrow \tau\nu$	1.9 ± 0.1

Electrons

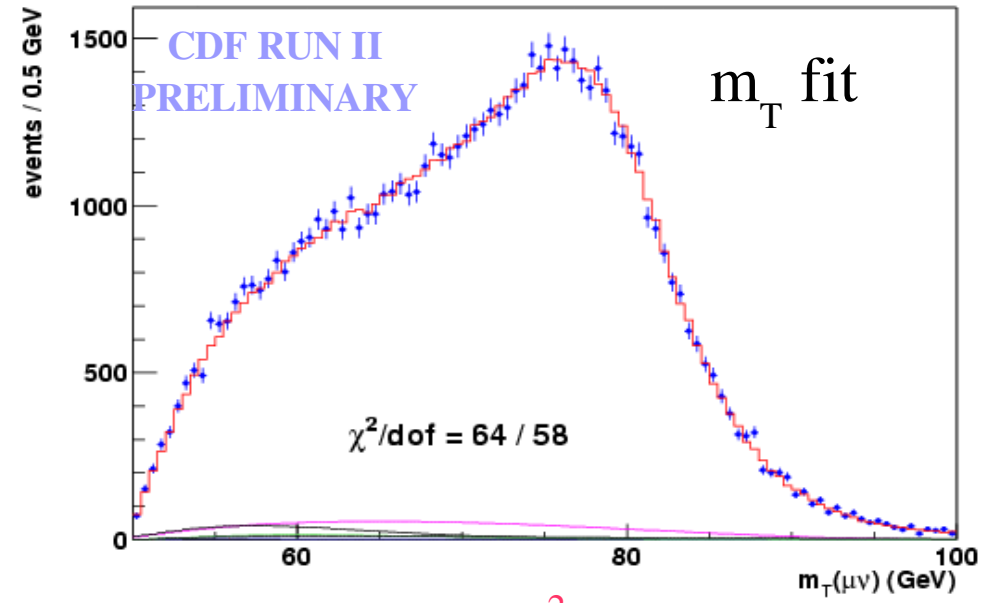
Background	%
Hadronic Jets	1.1 ± 0.4
$Z \longrightarrow ee$	0.27 ± 0.03
$W \longrightarrow \tau\nu$	1.9 ± 0.1



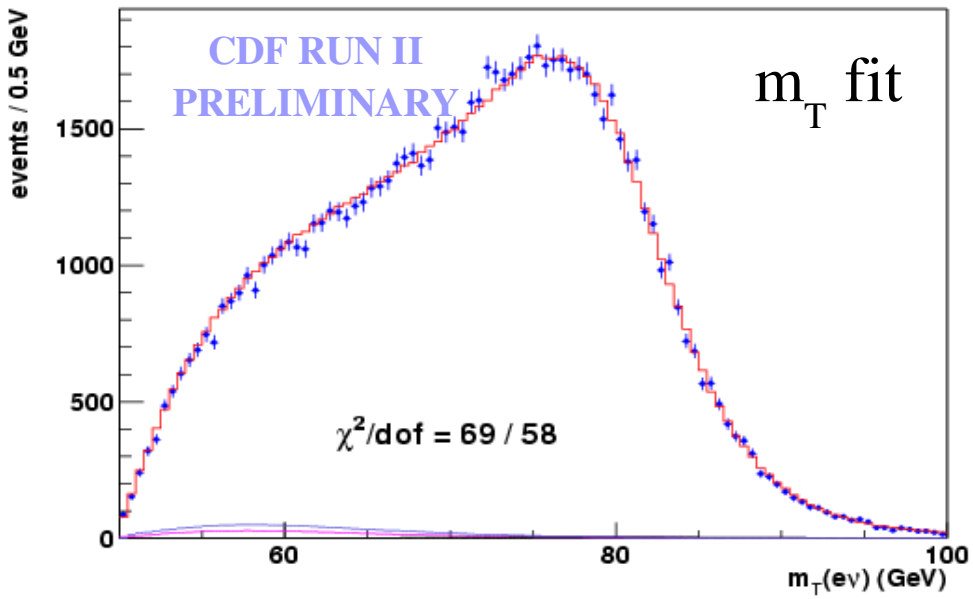
$\delta M_W = \pm 20$ MeV

CDF Run 2 W Mass Fits

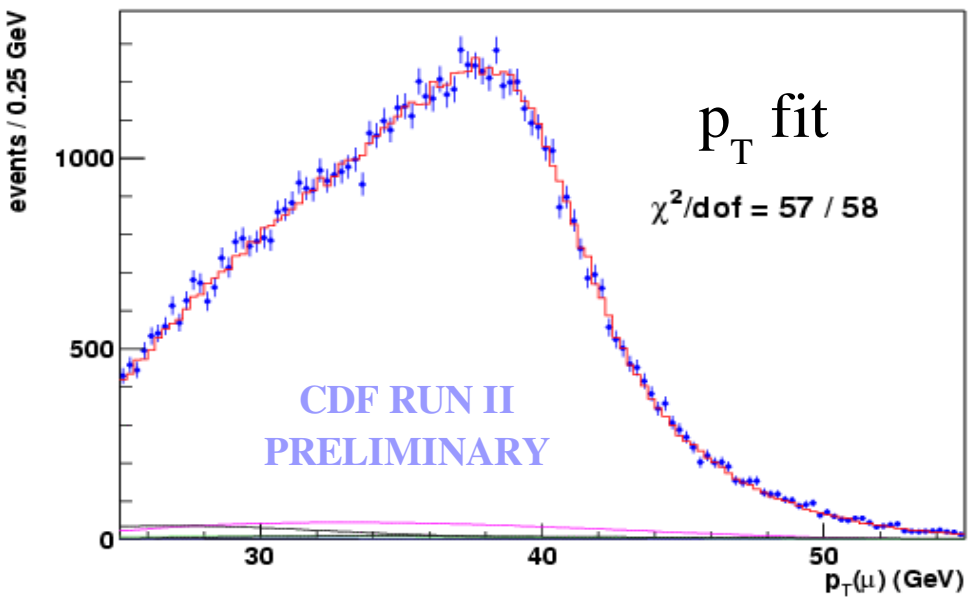
Muons



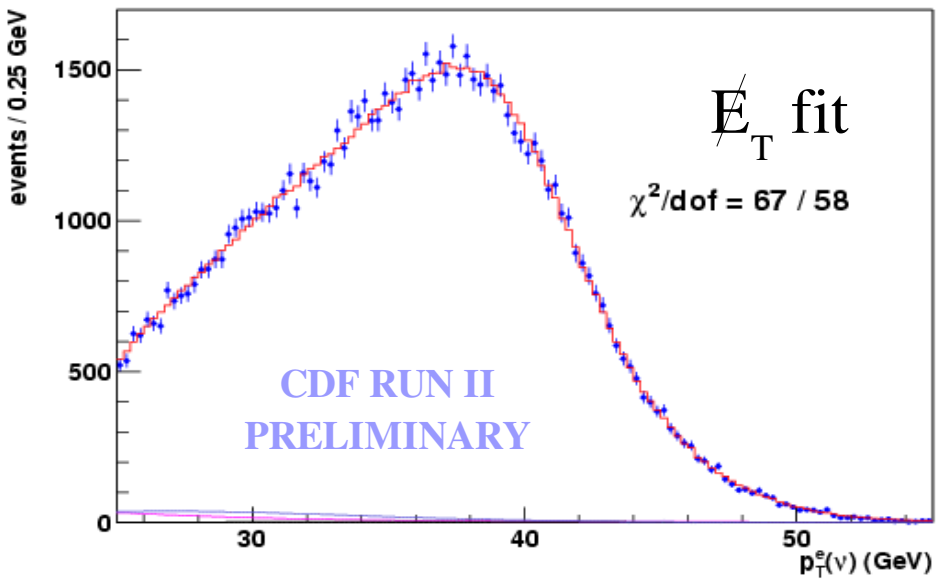
Electrons



Good χ^2 for fits



Fits blinded with [-100,100] MeV offset



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CDF W Mass Systematic Uncertainties

Systematic	Electrons (Run 1b)	Muons (Run 1b)
Lepton Energy Scale and Resolution	70 (80)	30 (87)
Recoil Scale and Resolution	50 (37)	50 (35)
Backgrounds	20 (5)	20 (25)
Statistics	45 (65)	50 (100)
Production and Decay Model	30 (30)	30 (30)
Total	105 (110)	85 (140)

CDF RUN II PRELIMINARY

Total uncertainty (76 MeV) already lower than Run 1 (79 MeV)

Some uncertainties scaled better than statistics:

* Muon energy scale → now using J/ψ's, upsilons to set scale

Work in progress on other sources of uncertainty:

* Recoil resolution → to understand hard interaction better

* Electron energy scale → to understand passive material better

Have twice the data on tape

Could approach 50 MeV combined uncertainty by next year

Conclusions

Extremely successful W measurement program at the Tevatron

Mass

Run 1 combined mass uncertainty 59 MeV (cf LEP 42 MeV)

Run 2 CDF W mass analysis in advanced stage – uncertainty lower than Run 1

Expect DØ and CDF to provide highest-precision single-experiment measurements in next ~year

Run 2 (~1 fb^{-1} by end of 2005) promises lower uncertainty than current world average

Direct Width

Run 1 combined width uncertainty 105 MeV (cf LEP 91 MeV)

Run 2 DØ and CDF W width analyses in progress