CTEQ task force on W and Z boson physics

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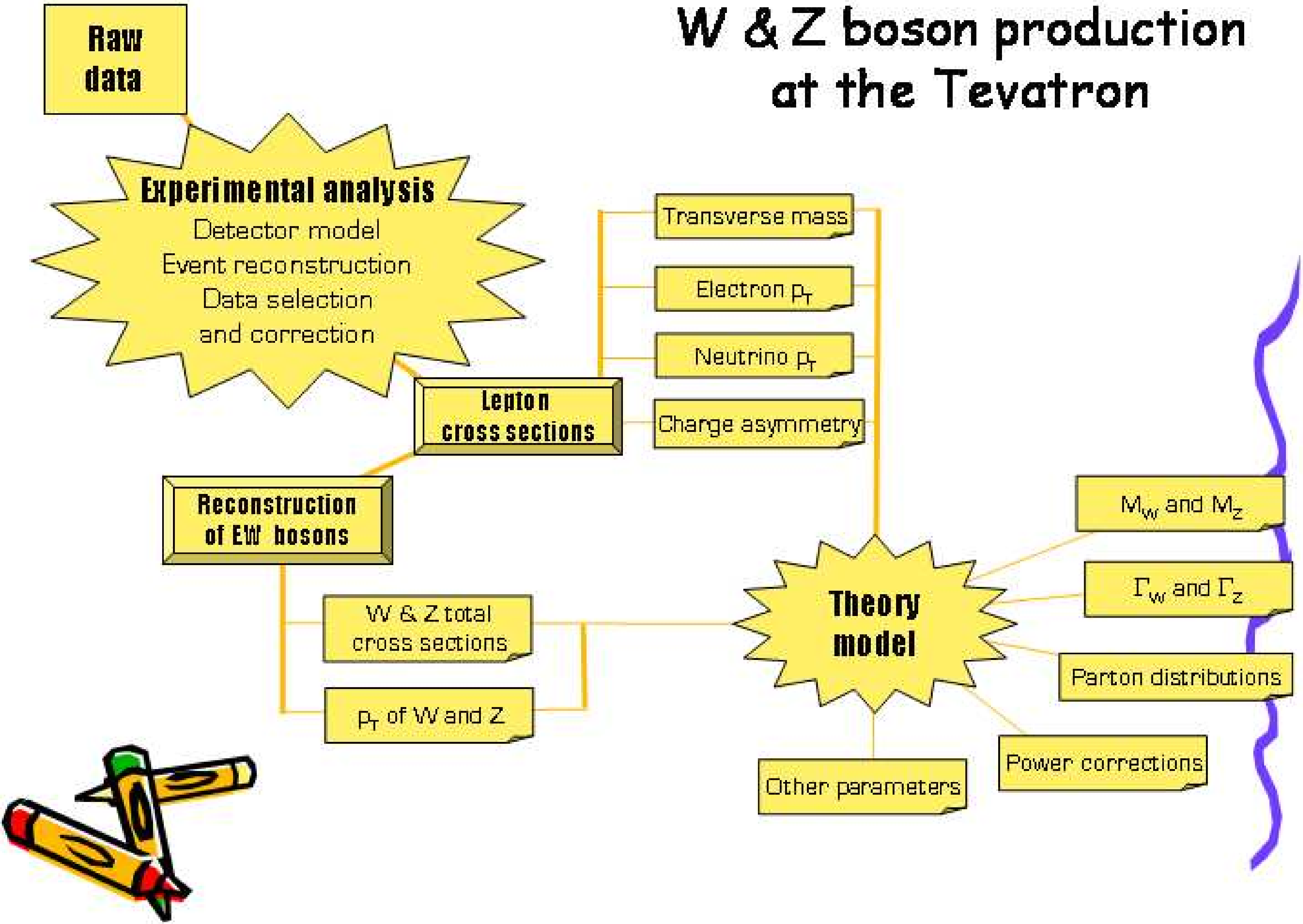
Objective:

- ✓ high-precision model for W and Z boson observables
- ✓ predict uncertainties for the Run-2 measurement of
  - ♦ W and Z total cross sections,
  - ♦ M_W,
  - ♦ p_T distributions,
  - ♦ ...

Collaboration with experimental groups

☞ decide on contact persons from CDF and DØ

W & Z boson production at the Tevatron



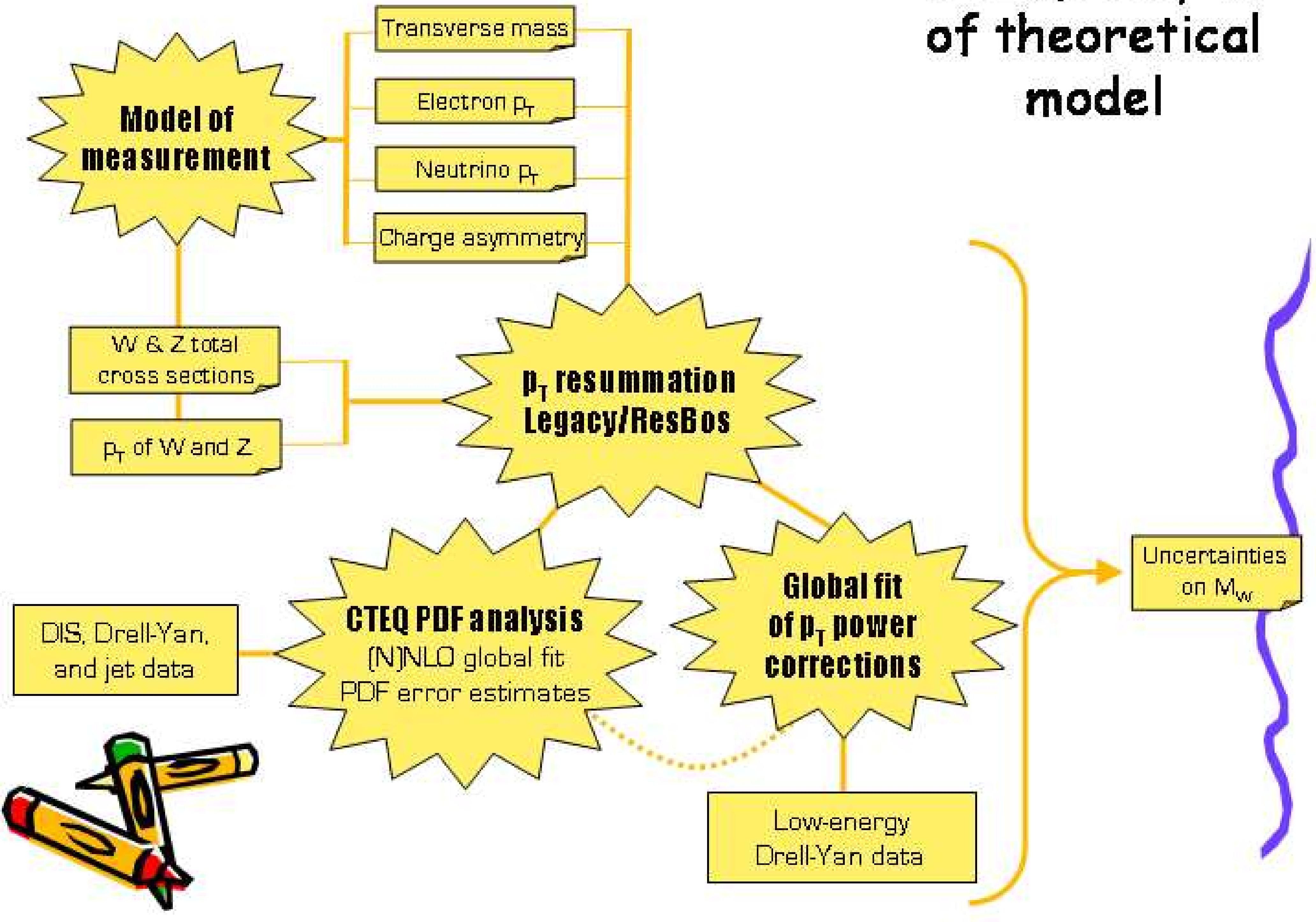
Variations in the fitted M_W in Run-1 (in MeV)

Source	Central electrons ($\|y_\ell\| \leq 1$)				Forward electrons ($1 \leq \|y_\ell\| \leq 2.5$)		
	δM_W (m_T)	δM_W (p_T^e)	δM_W (p_T^ν)		δM_W (m_T)	δM_W (p_T^e)	δM_W (p_T^ν)
statistics	70	85	105		107	128	159
$p_T(W)$ spectrum	10	50	25		22	37	44
MRSR2	5	26	3		−11	−21	−43
MRS(A′)	−5	16	−31		−7	−43	−19
CTEQ5M	−8	6	−22		14	9	−17
CTEQ4M	10	11	−18		1	−21	22
CTEQ3M	0	64	−9		13	30	28
(Many) other	...	...	...		...	...	...

DØ Collaboration, Phys. Rev. D62, 092006 (2000)

Many sources of sizeable correlated errors

CTEQ analysis of theoretical model

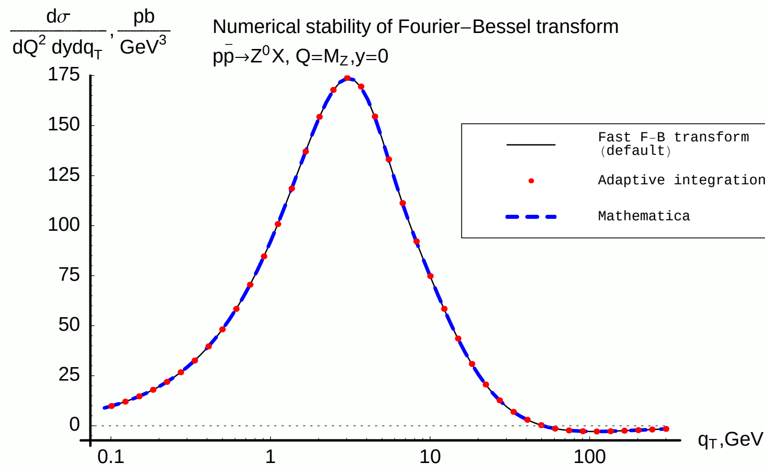


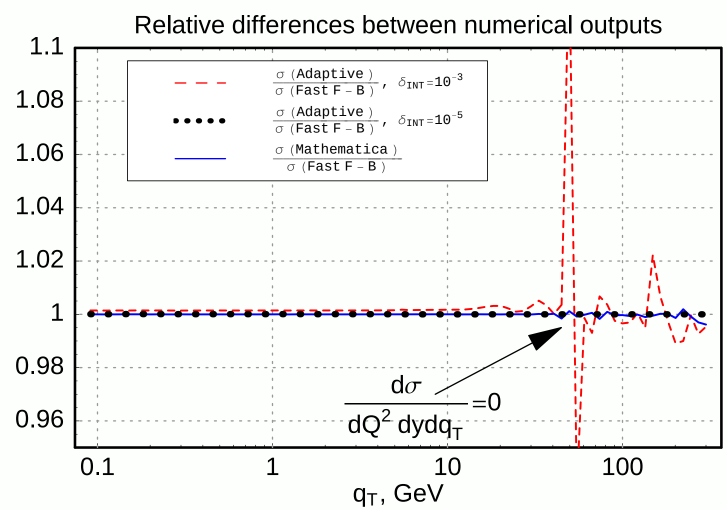
Simplified model of experimental measurements

- ✓ Central ($-1 \leq y_e \leq 1$) and forward ($|y_e| > 1$) regions
- ✓ $p_{Te} > 25$ GeV
- ✓ Missing p_T >25 GeV
- ✓ Electron energy smearing
- ✓ ...?

Fast and accurate resummation program

- ✓ Resummation part re-written in C++
- ✓ Adaptive integration and fast Fourier-Bessel transform routines
- ✓ Improvement up to a factor 800 (80000%) in speed
- ✓ Accuracy of F-B transform better than 0.1% at $q_T^2 \ll M_W^2$





Suitable for intensive CPU calculations within the CTEQ fitting analysis

Universality of resummed q_T distributions in $h_1 h_2 \to VX$

(Landry, Brock, P.N., Yuan, Phys.Rev. D67, 073016 (2003))

As PDF's include the universal nonperturbative part,resummed q_T distributions are expected to include a universal nonperturbative function

$$\left.\frac{d\sigma}{dx_1 dx_2 dq_T^2}\right|_{q_T\to 0} \propto \int \frac{d^2b}{(2\pi)^2} e^{i\vec{q}_T\cdot\vec{b}} W^{pert}(b, x_1, x_2) e^{-S^{NP}(b,Q,x_1,x_2)},$$

where

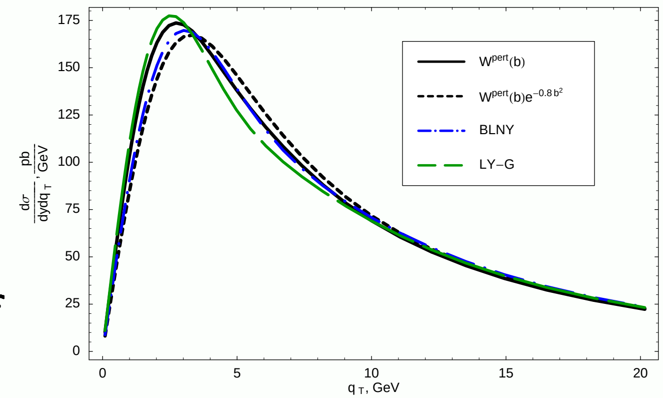
$$S^{NP}(b) = b^2 (g_1 + g_2 \ln Q) \quad \text{(Davies,Webber,Stirling, 1985)}$$
$$S^{NP}(b) = b^2 (g_1 + g_2 \ln Q) + b g_1 g_3 \ln(100 x_1 x_2) \quad \text{(Ladinsky,Yuan, 1993)}$$
$$S^{NP}(b) = b^2 (g_1 + g_2 \ln Q + g_1 g_3 \ln(100 x_1 x_2)) \quad \text{(BLNY, 2002)}$$

The last form more preferable theoretically *(CSS; Korchemsky, Sterman)*

Are nonperturbative contributions important for Tevatron?

We find strong sensitivity of the Run 1 Z data to $S^{NP}(b)$ at $q_T \lesssim 10$ GeV

Recently, Qiu and Zhang suggested that such dependence may be an artifact of "b_* prescription" for $S^{NP}(b)$ They suggest that Z data is described well just by the perturbative part of the resummed cross section



While W and Z boson cross sections are dominated by perturbative terms, neglecting (or changing) $S^{NP}(b)$ may shift the peak of $d\sigma/dq_T$ by 200-500 MeV (large effect given a targeted $\delta M_W \sim 50$ MeV)

- The global analysis of $S^{NP}(b, Q)$ and its Q dependence remains very necessary

Nonperturbative function in the resummation formalism

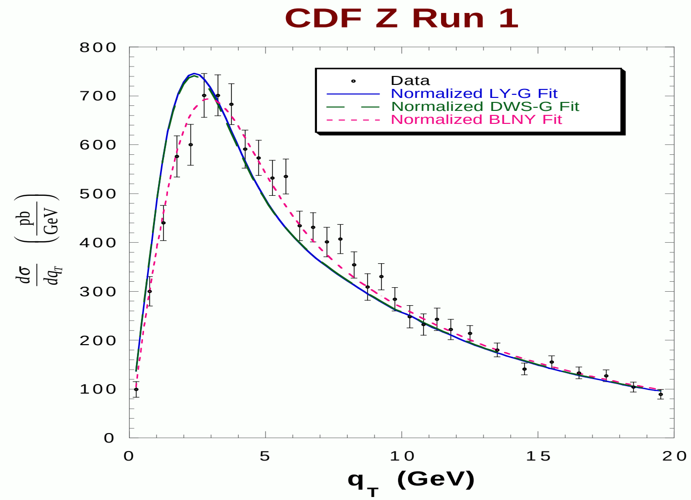
BLNY study:

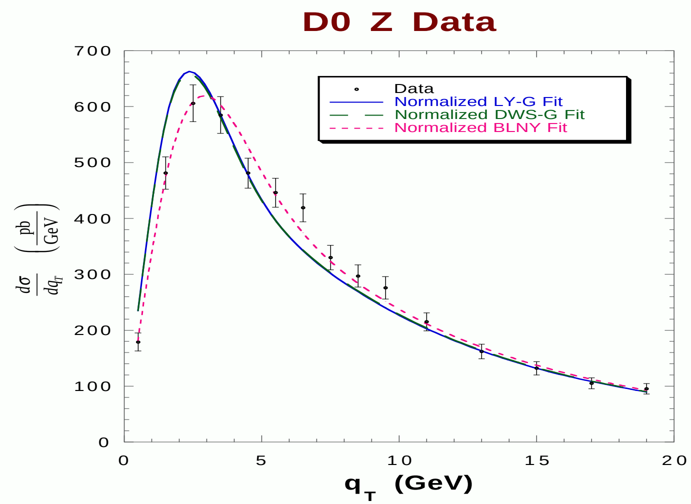
✓ first global fit of the Drell-Yan and Tevatron Run 1 Z data

✓ extended set of data ($\sim$ 100 data points vs. 31 point in earlier studies)

✓ All 3 forms of $S^{NP}(b)$ updated

✓ Gaussian form (BLNY) strongly preferred by the data; $\chi^2/d.o.f. = 176/119 \sim 1.48$ vs. 3.42 and 3.47 for other forms

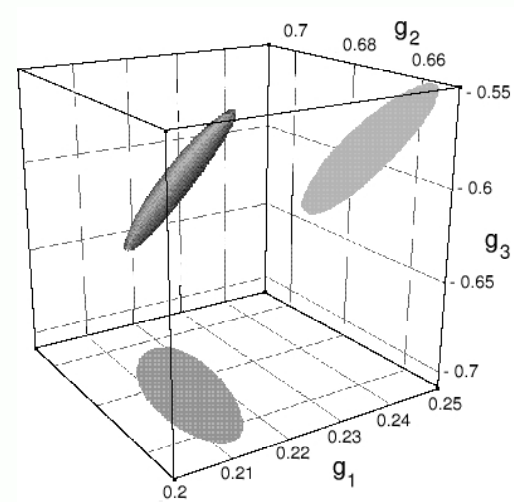




❀ Strong evidence for universality of $S^{NP}(b, Q)$

Nonperturbative contributions: further studies

- ✓ Explore new proposals for the model of nonperturbative terms
- ✓ Examine an updated b_* prescription with $b_{max} \sim 1$ GeV^{-1}
- ✓ Obtain true confidence intervals for $S^{NP}(b,Q)$ in presence of systematical errors
- ✓ Study correlation between nonperturbative Sudakov factor $S^{NP}(b,Q)$ and parton distributions
  - ♦ Refit $S^{NP}(b,Q)$ for 41 eigenvector PDF sets
  - ♦ Merge global fits of the PDFs and p_T distributions



Global analysis (CTEQ)

✓ Analysis of a large data set (~ 2000 data points) from deep inelastic scattering, lepton pair and jet production

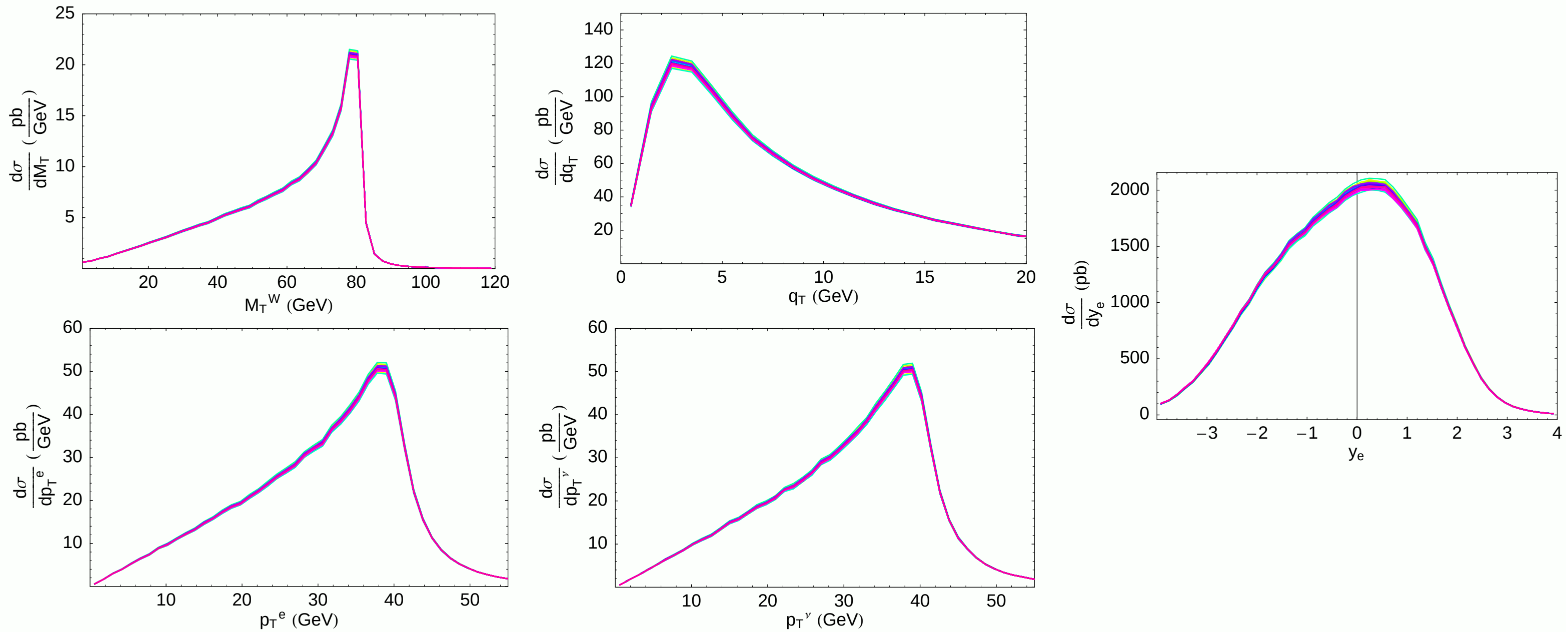
✓ Methods for handling many (~ 200) sources of systematic errors

✓ Complete analysis of the PDF parameter space in the vicinity of $\min \chi^2$ with inclusion of all published correlated systematic errors

✓ Quantitative estimates of uncertainties in the PDFs and physical observables

- ♦ Lagrange mutliplier method
- ♦ 1 central PDF set $+ 20 \times 2$ extreme PDF sets ☜
  - ∗ Calculate the observable 41 times
  - ∗ Calculate PDF uncertainty using a master formula

W^+ production at $\sqrt{s} = 1.96$ TeV; $M_W = 80.423$ GeV; no lepton cuts



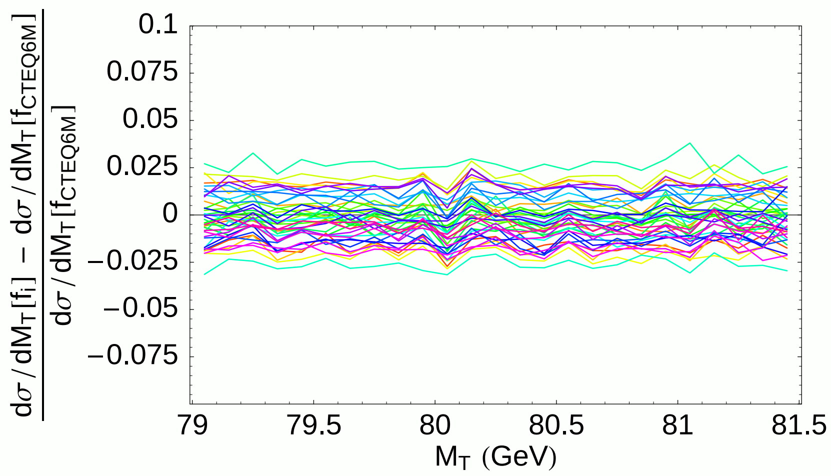
Color legend for PDF sets

Concentrate on the ratios to the distribution for CTEQ6M PDF set instead

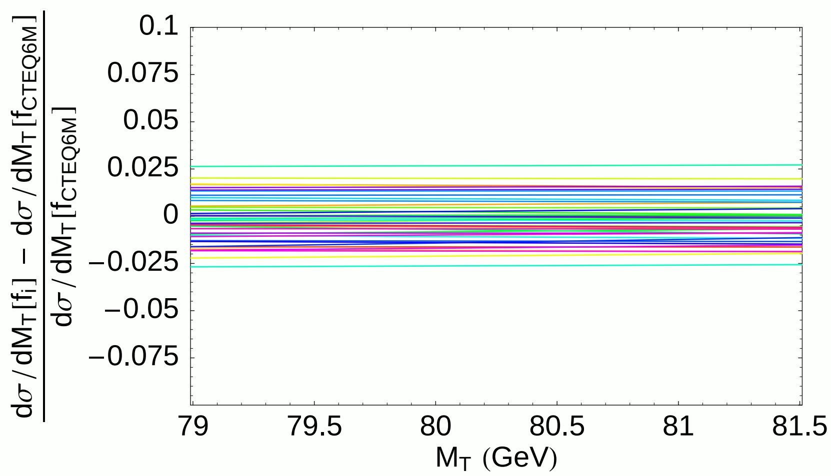
PDF dependence of the ratio for M_T distribution (VERY PRELIMINARY)

Combined W^+ and W^- sample, $-1 \leq y_e \leq 1$, $p_{Te} > 25$ GeV

Raw ResBos output

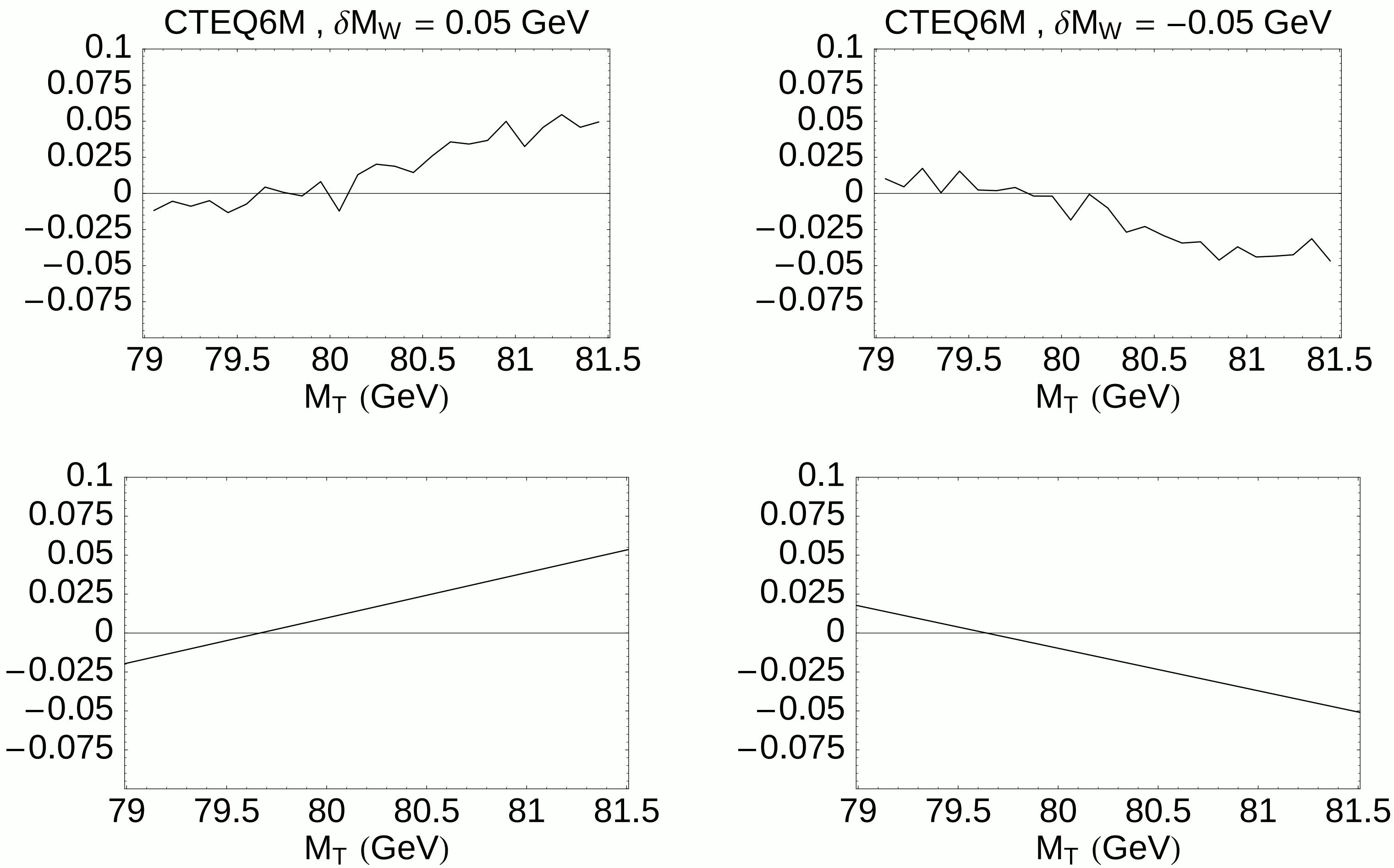


Linear fit



PDF variation changes normalization and not the slope

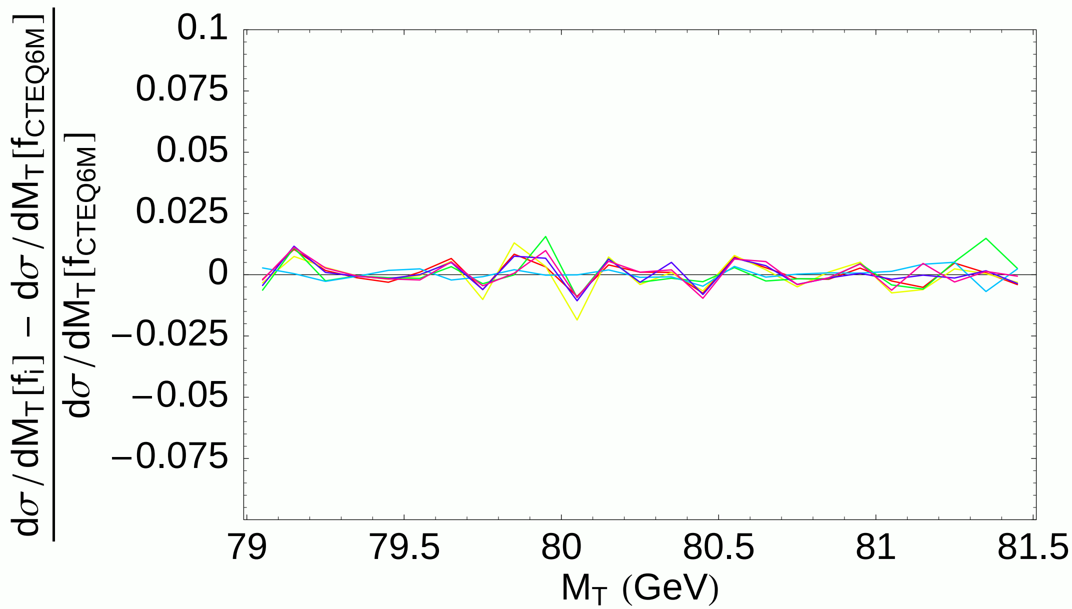
Variation of M_W by $\delta M_W = \pm 50$ MeV (VERY PRELIMINARY)



Visible variation in the slope (corresponding to the shift of the Jacobian peak)

$\therefore$ PDF error on M_W from M_T distribution is much smaller than 50 MeV

Variation of $S^{NP}(b,Q)$ within the 1σ ellipse from the BLNY paper (VERY PRELIMINARY)



No visible change in slope

Note: The above error on $S^{NP}(b,Q)$ (for $\delta\chi^2 = 1$) underestimates the true error (dominated by systematic uncertainties)

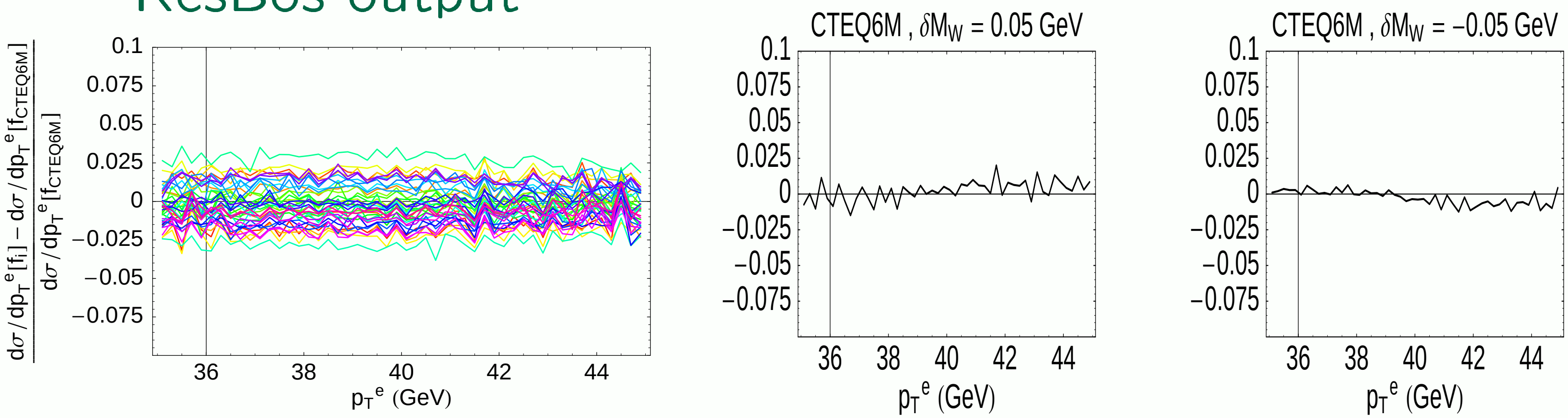
Variations in the slopes of $d\sigma/dM_T$ ratios (VERY PRELIMINARY)			
Source	δ(Slope) (pb/GeV^2)	Comparable δM_W (MeV)	Comments
$\delta M_W = 50$ MeV	0.003	50	
PDF error	0.002	5	$\delta\chi^2$(PDF) = 100
$\delta S^{NP}(b, Q)$	0.0008	3	$\delta\chi^2$(BLNY) = 4

Monte-Carlo error is ~ 0.001 (2 MeV)

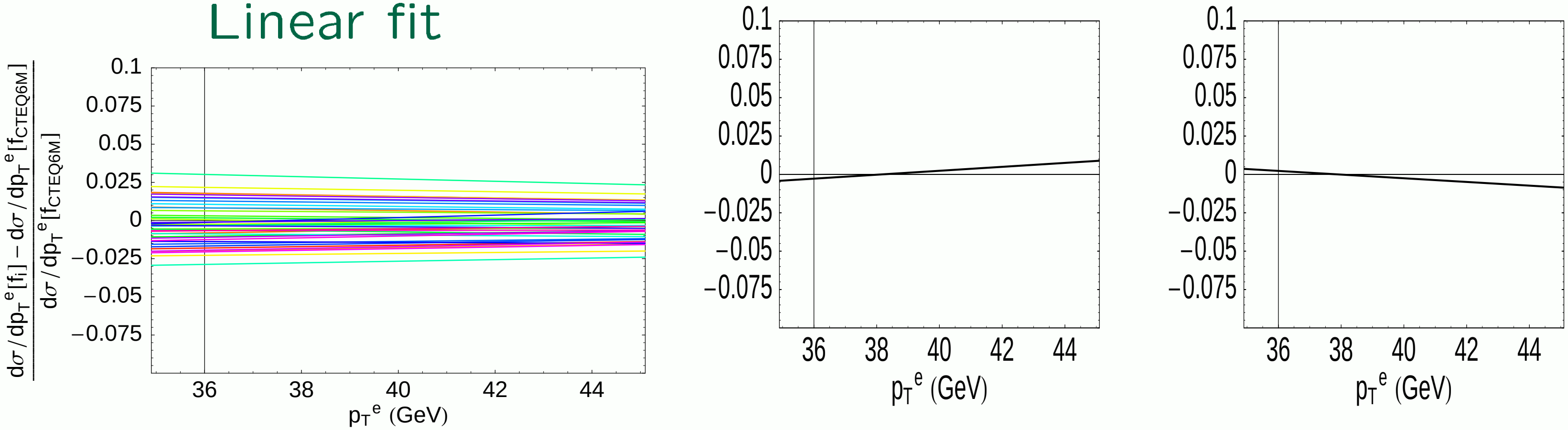
PDF dependence of the ratio for the electron p_T distribution (VERY PRELIMINARY)

Combined W^+ and W^- sample, $-1 \leq y_e \leq 1$, $p_{Te} > 25$ GeV

ResBos output



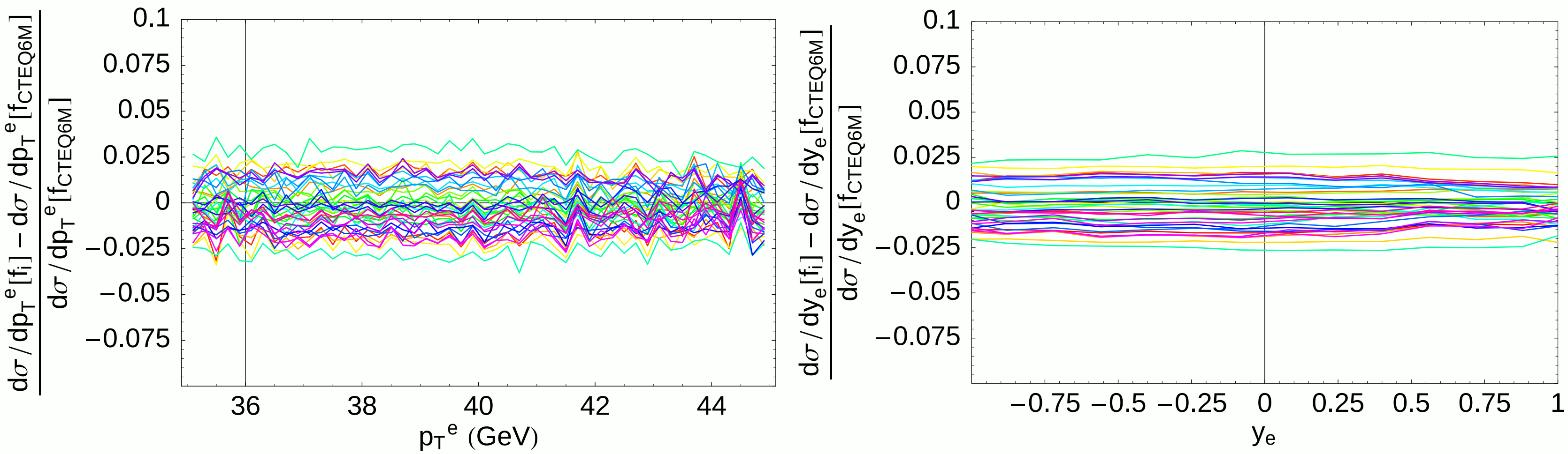
Linear fit



Variations in the slopes of $d\sigma/dM_T$ ratios (VERY PRELIMINARY)			
Source	δ(Slope) (pb/GeV^2)	Comparable δM_W (MeV)	Comments
$\delta M_W = 50$ MeV	0.0012	50	
PDF error	0.0014	60	$\delta\chi^2$(PDF) $= 100$
$\delta S^{NP}(b,Q)$	0.0008	30	$\delta\chi^2$(BLNY) $= 4$

Monte-Carlo error is ~ 0.00016 (7 MeV)

Correlation between p_T^e and y_e (VERY PRELIMINARY)



Better measurement of charge asymmetry will reduce the PDF error?