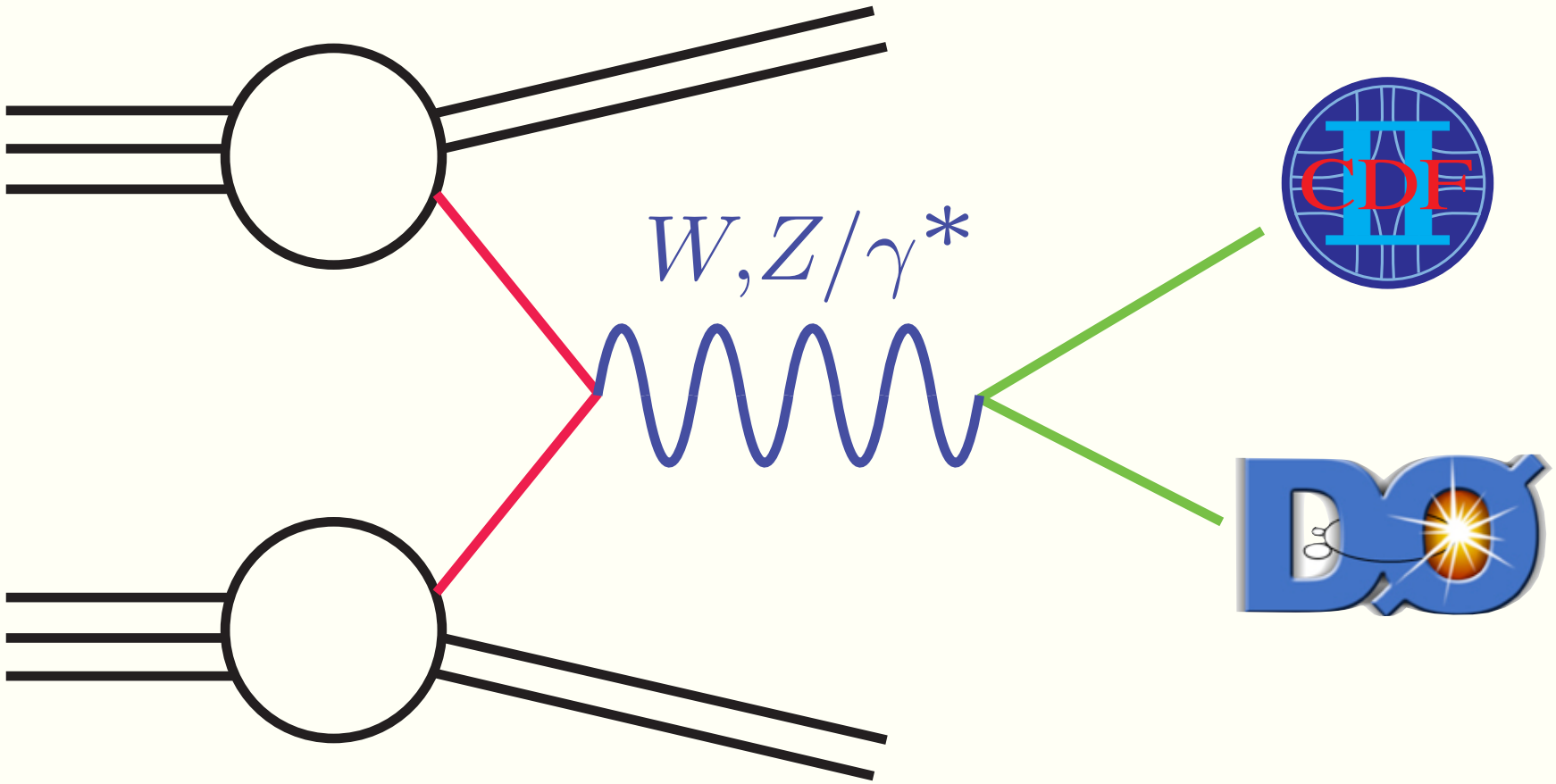
Studies of Single Electroweak Bosons at the Tevatron

Adam Lyon (Fermi National Accelerator Laboratory)
Representing the CDF and DØ Collaborations



DIS 2011, Newport News, April 2011

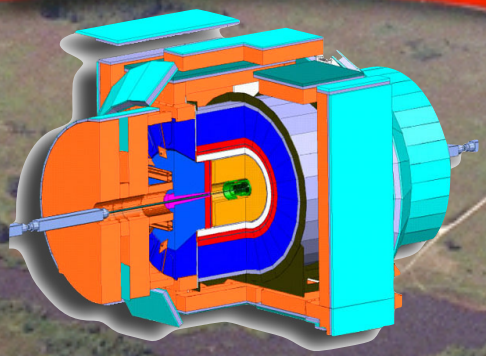
The Standard Model is tested with *precision* Electroweak Measurements

5 Topics

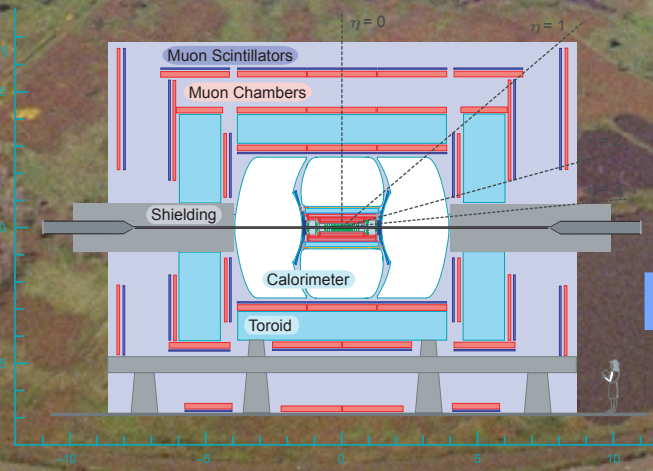
1) ***W*** **Mass and Width**
2) Z/γ^* **Rapidity**
3) Z/γ^* P_T
4) Z/γ^* P_T **via** ϕ^*
5) Z/γ^* **Angular Coefficients**

For other analyses refer to,
Dibosons: Haley, 11:15 today, EW session
W charge & lepton asymmetry: Schellman, Tuesday afternoon
Z/γ^* A_{fb}: Yin, Wednesday morning

Fermilab Tevatron Complex $\sqrt{s}$ =1.96 TeV



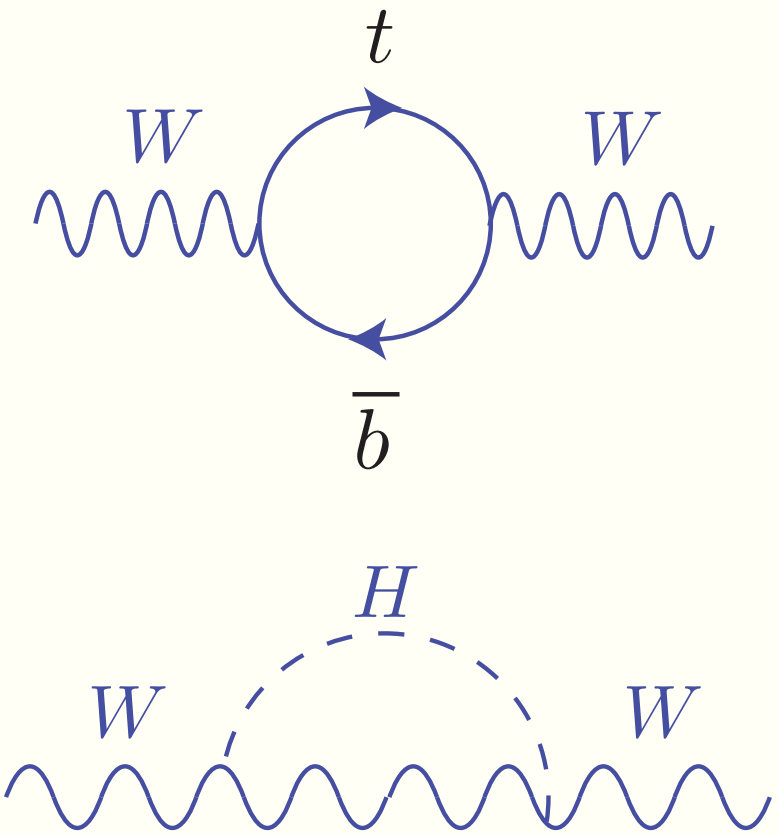
CDF

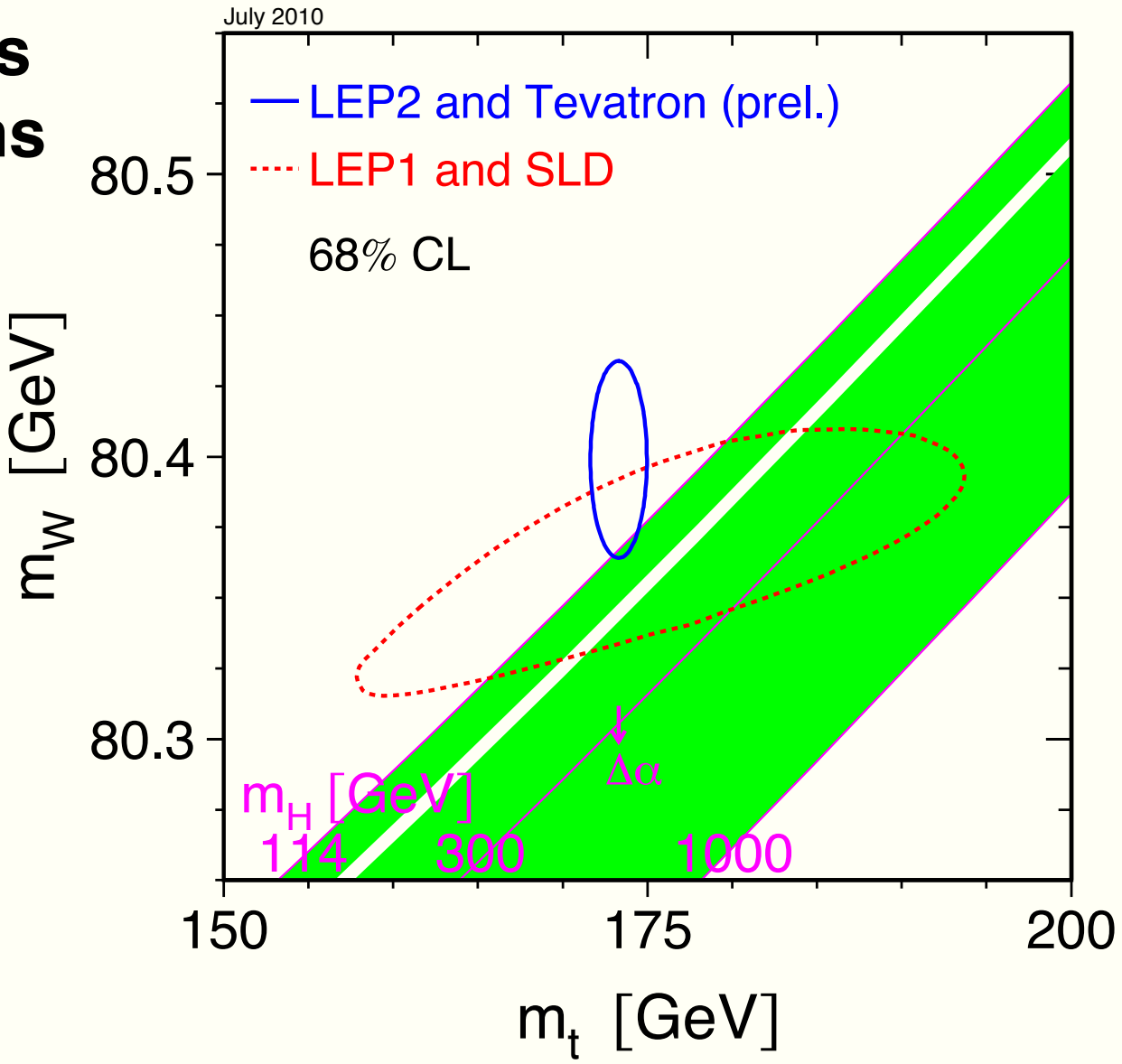


DØ

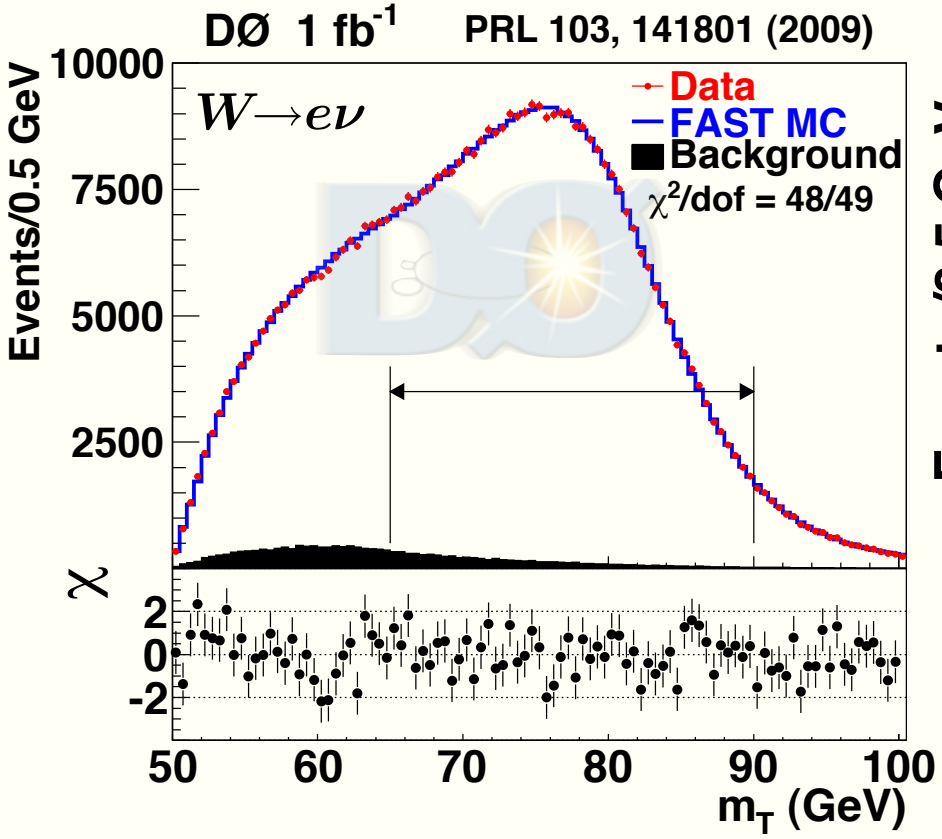
1) Probe the Higgs and New Physics with the *W* mass

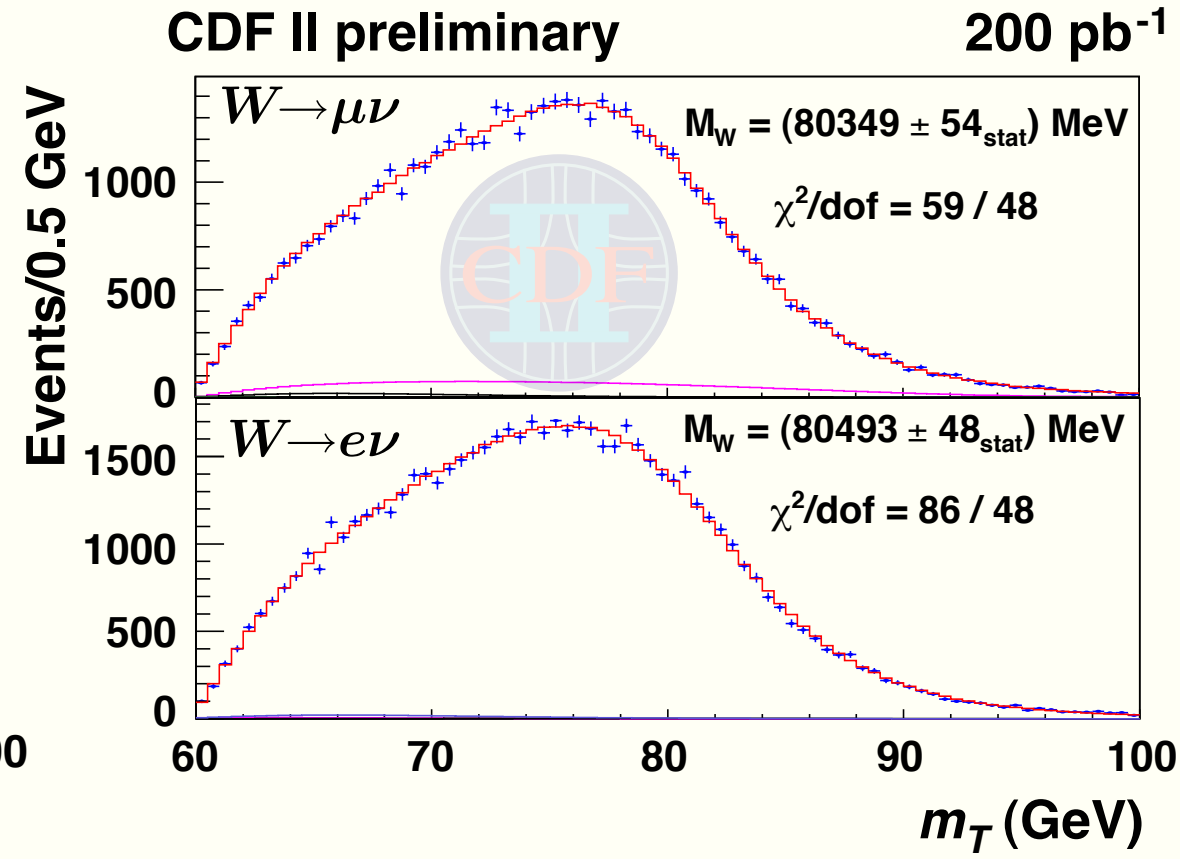
Indirect view of physics via radiative corrections





CDF and DØ measure the *W* mass

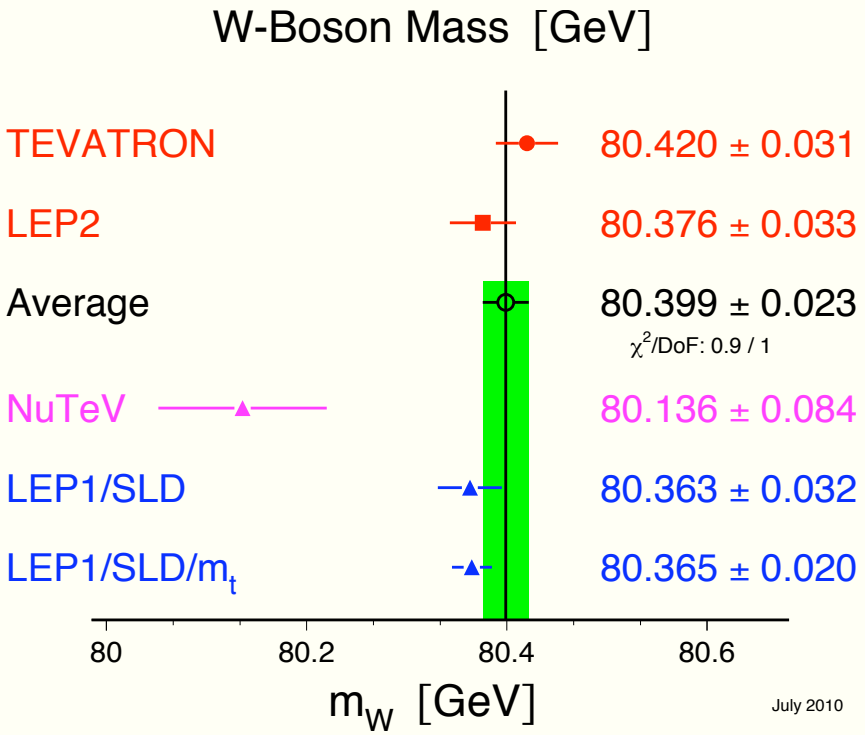


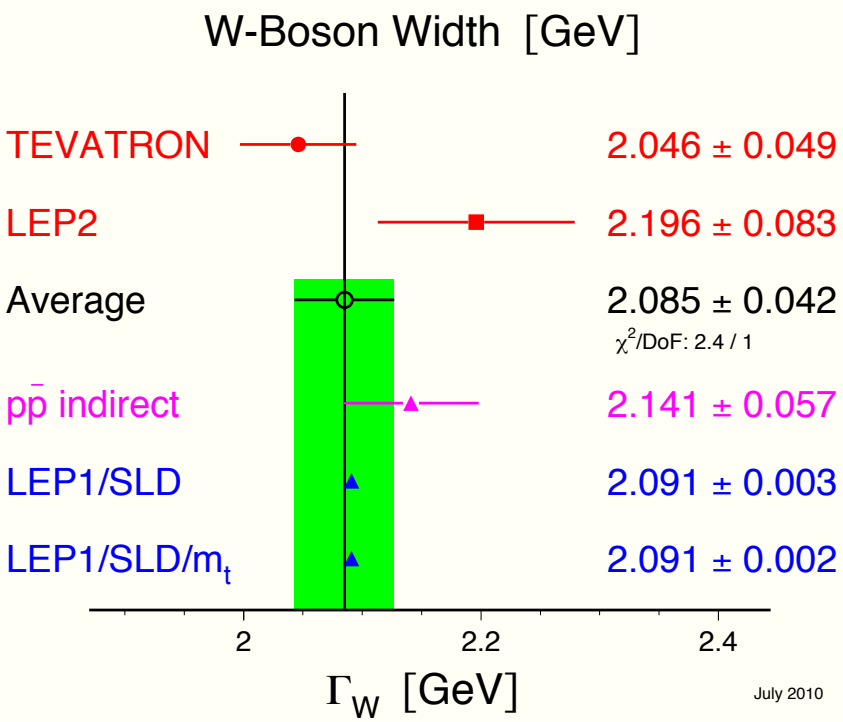


Combine fits to m_T, lepton p_T, MET

	$\mathcal{L}$ [fb^{-1}]	$m_W \pm$ stat $\pm$ sys [GeV/c^2]
CDF $e+\mu$	0.2	$80.413 \pm 0.034 \pm 0.034$
DØ e	1.0	$80.401 \pm 0.021 \pm 0.038$

W measurements are combined

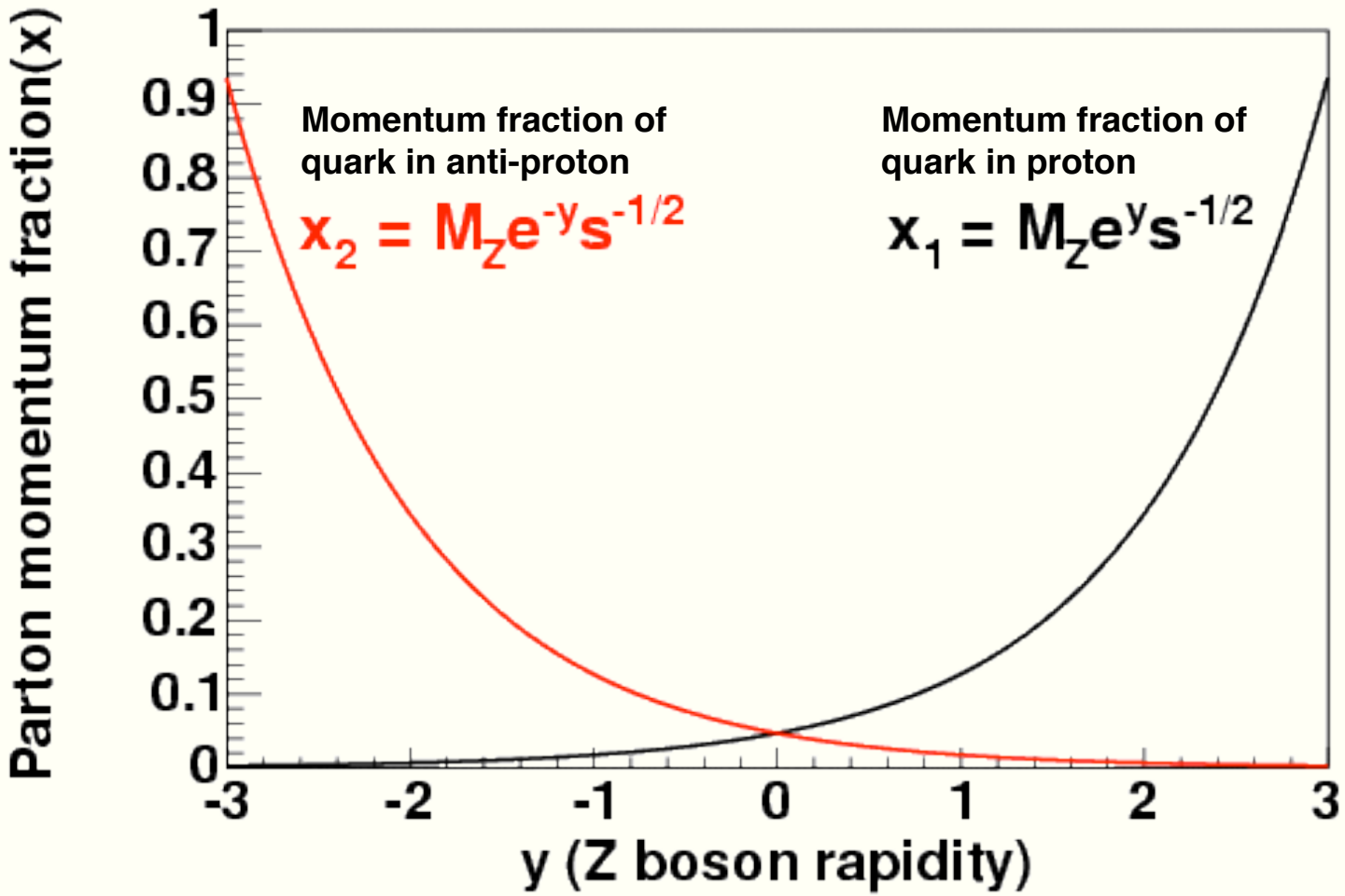




LEP and Tevatron EW Working Groups
[Tevatron arXiv:0908.1374 (2009), arXiv:1003.282 (2010)]

Both experiments are aiming for ~ 25 MeV/c^2 precision in future results.

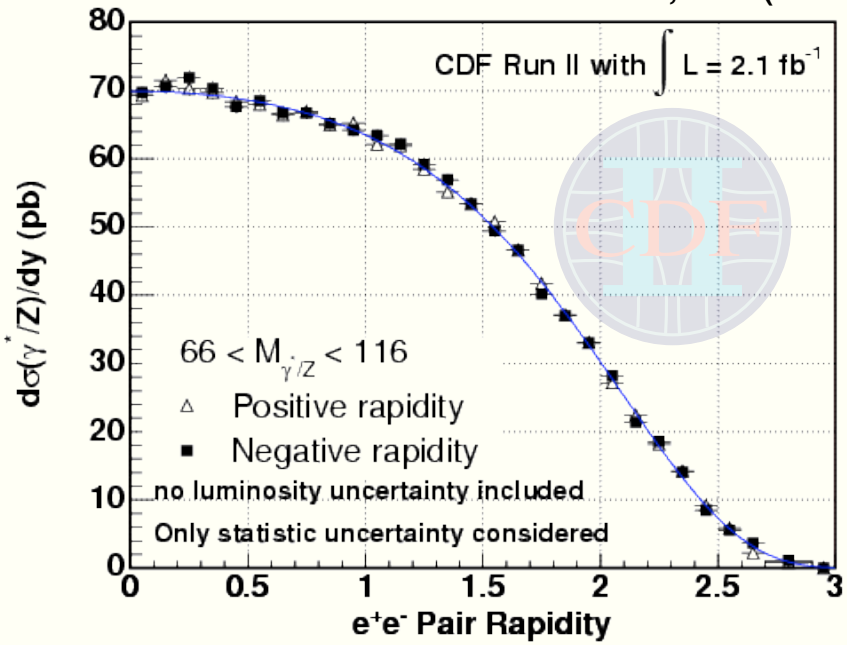
2) CDF tests pQCD with $d\sigma/dy$ of Drell-Yan ee pairs

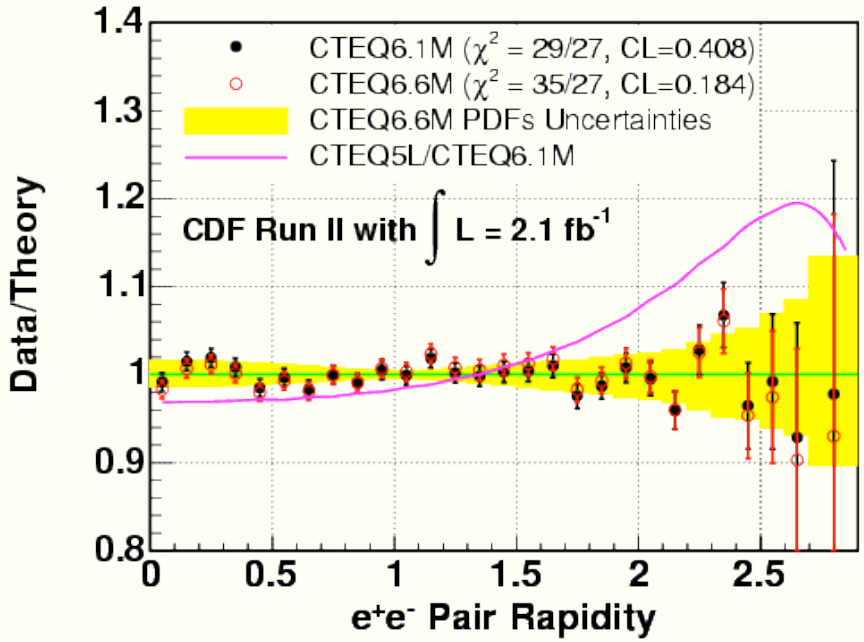


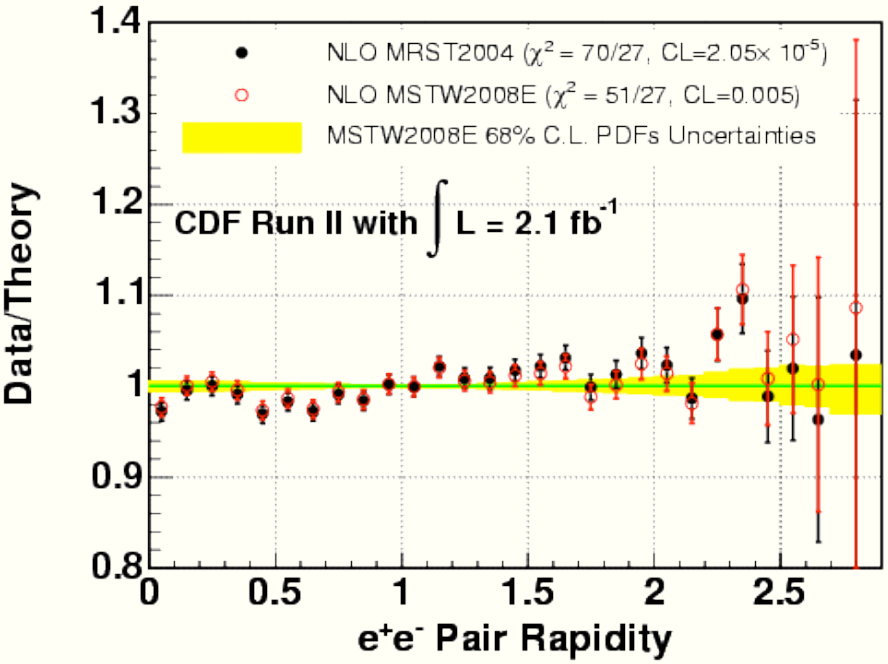
High rapidity tests PDFs at high *x*

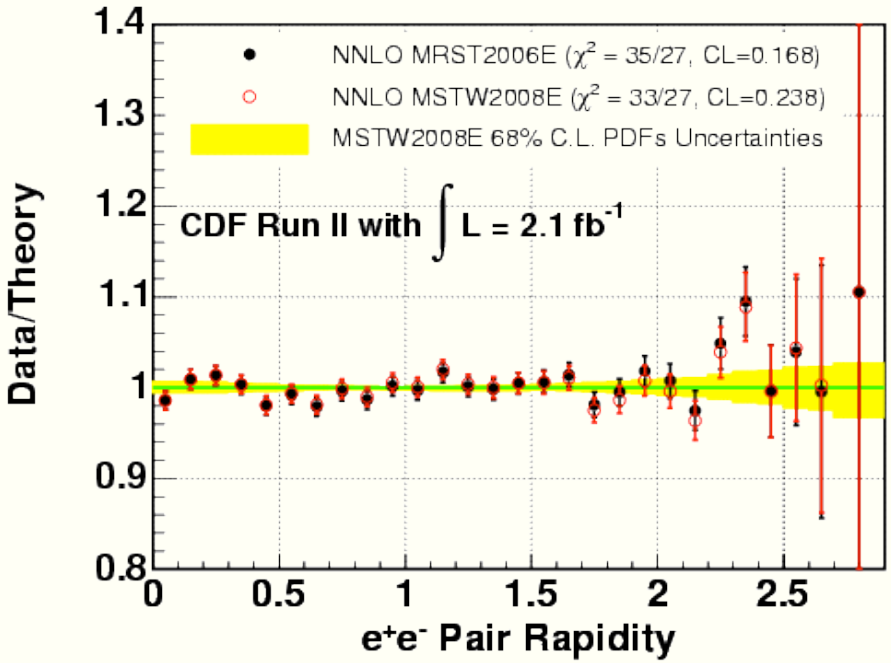
CDF compares $d\sigma/dy$ to predictions from PDFs

Unfolded distribution PLB 692, 232 (2010)







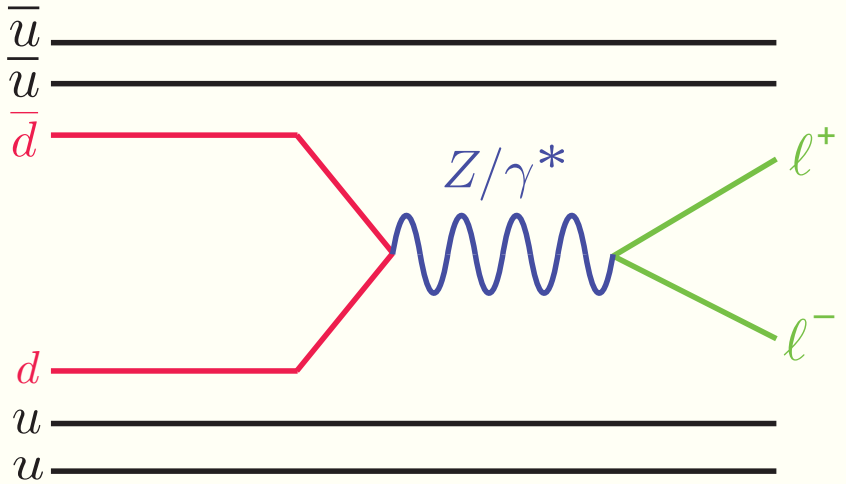


CDF compares the total cross section

Model (PDF)	Order	Total σ [pb]
CTEQ5L	LO	183.3
MRST2001E	NLO	$241.0^{+2.8}_{-3.4}$
MRST2004	NLO	241.2
MSTW2008E	NLO	$242.6^{+4.6}_{-5.5}$
CTEQ6.1M	NLO	$236.1^{+9.3}_{-9.2}$
CTEQ6.6M	NLO	$238.7^{+7.1}_{-7.0}$
MRST2006E	NNLO	$251.6^{+2.8}_{-3.1}$
MSTW2008E	NNLO	$248.7^{+5.1}_{-4.0}$
CDF Data 2.1 fb^{-1}	$256.6 \pm 0.7_{\text{stat}} \pm 2.0_{\text{sys}} \pm 15.4_{\text{lum}}$	

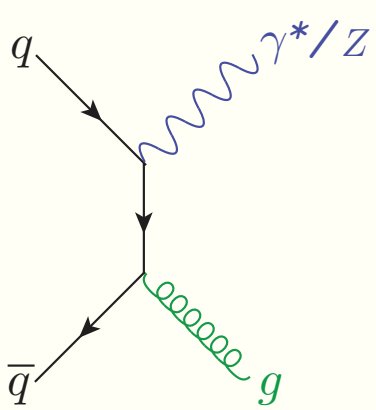
3-5) Study Z/γ^* P_T

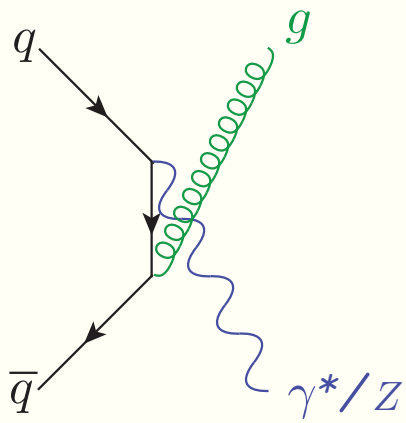
LO Annihilation



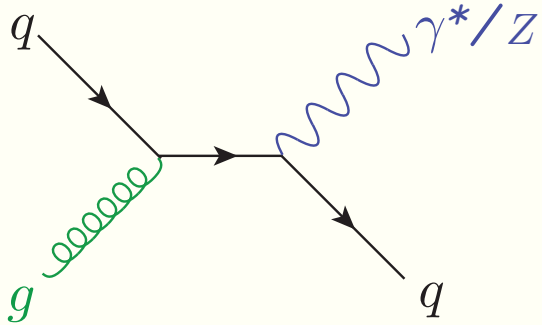
LO QCD Corrections:

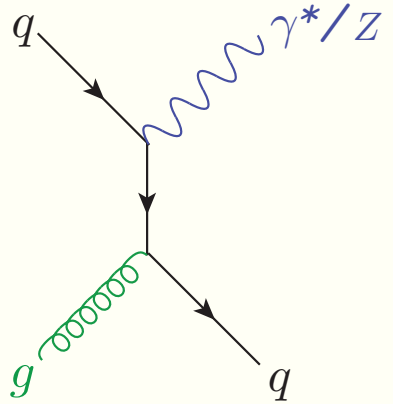
Annihilation



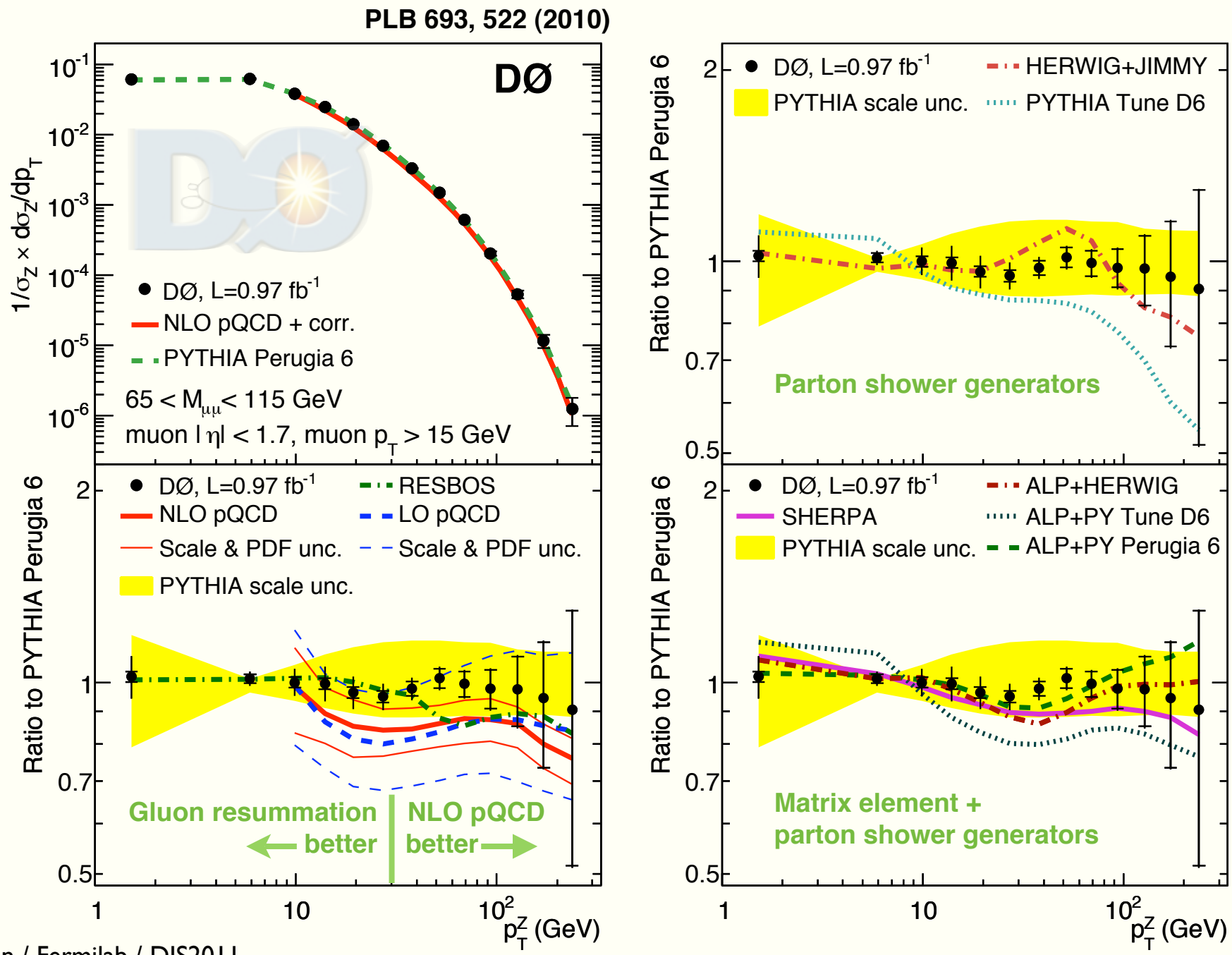


Compton



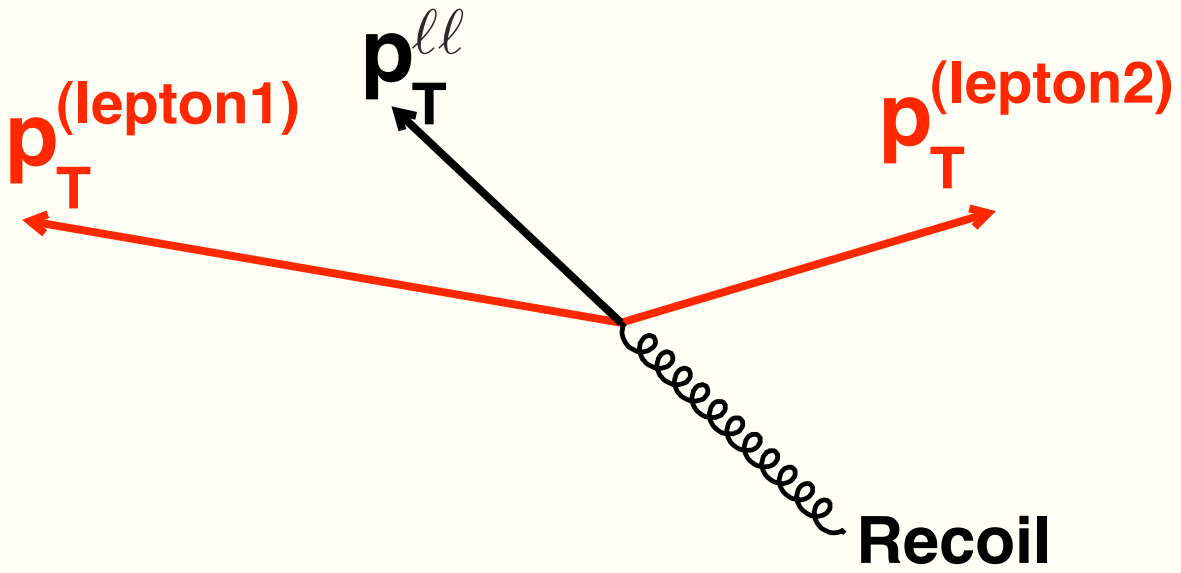


3) DØ Tests resummation and pQCD with Drell-Yan $p_T^{\mu\mu}$



4) DØ improves precision of Z/γ^* P_T by using angles

In the transverse plane...

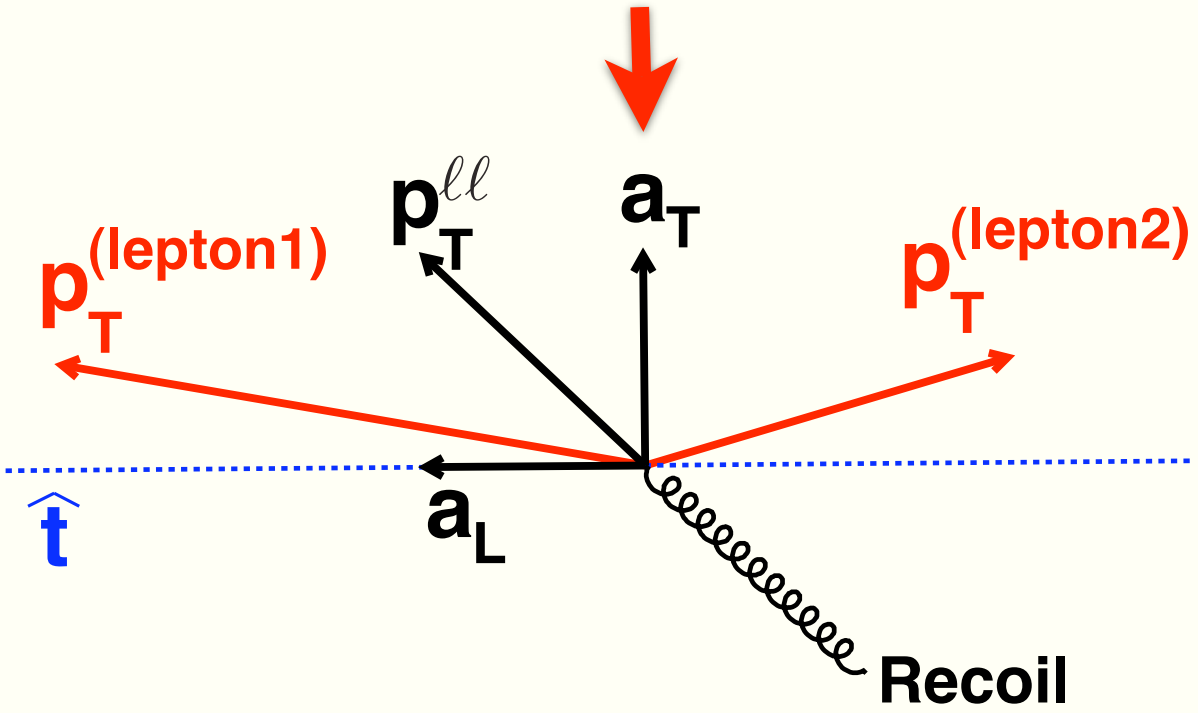


For low P_T, correction of resolutions and efficiencies dominates uncertainty

Bin widths governed by resolution and not statistics

A new variable is introduced to improve precision

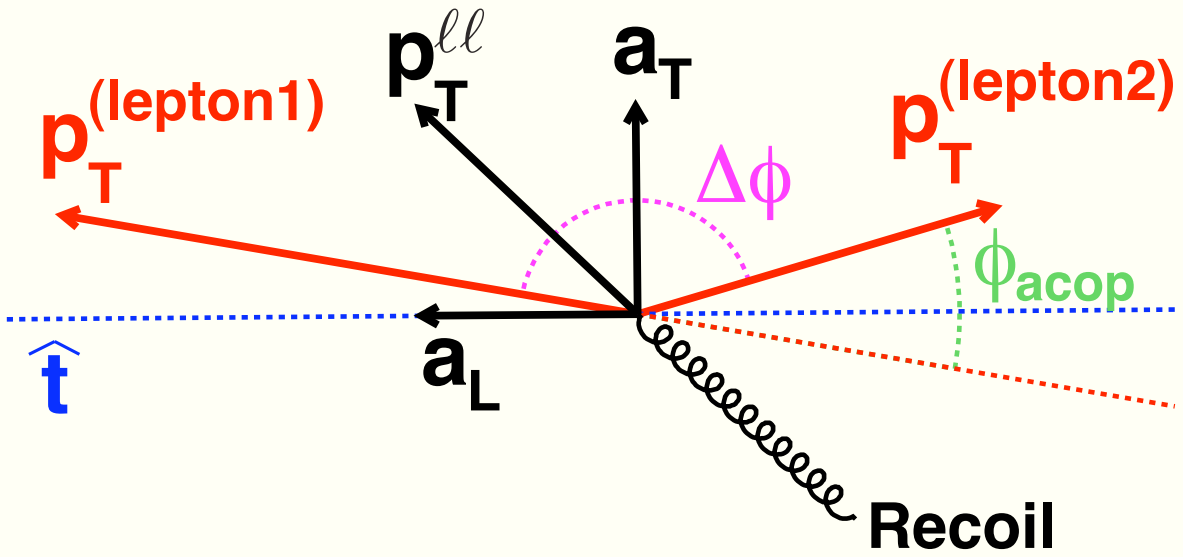
Better...



a_T is less susceptible to resolution and efficiencies
Vesterinen & Wyatt, NIM A602, 432 (2009)

Using angles may give further improvement

Best… use angles



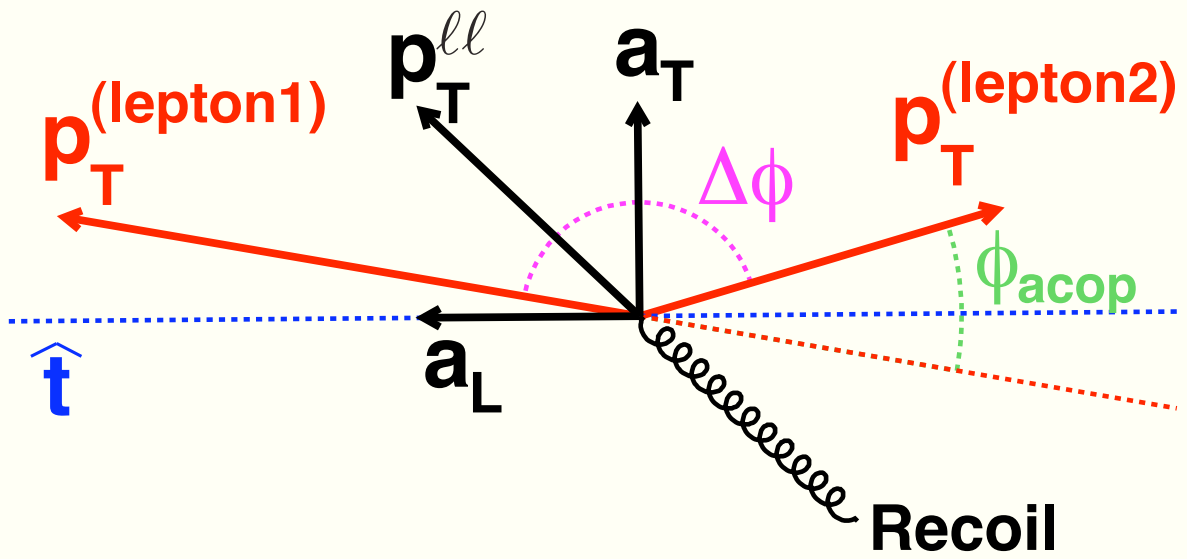
Could use $\Delta\phi$ but to construct need θ^*; less sensitive to physics than a_T

[θ^* is the scattering angle of the leptons relative to beam direction in dilepton rest frame]

Instead, correct event by event for scattering angle θ^*

DØ introduces a new angle to measure for best precision

Banfi et. al., Eur. Phys. J. C 71, 1600 (2011)

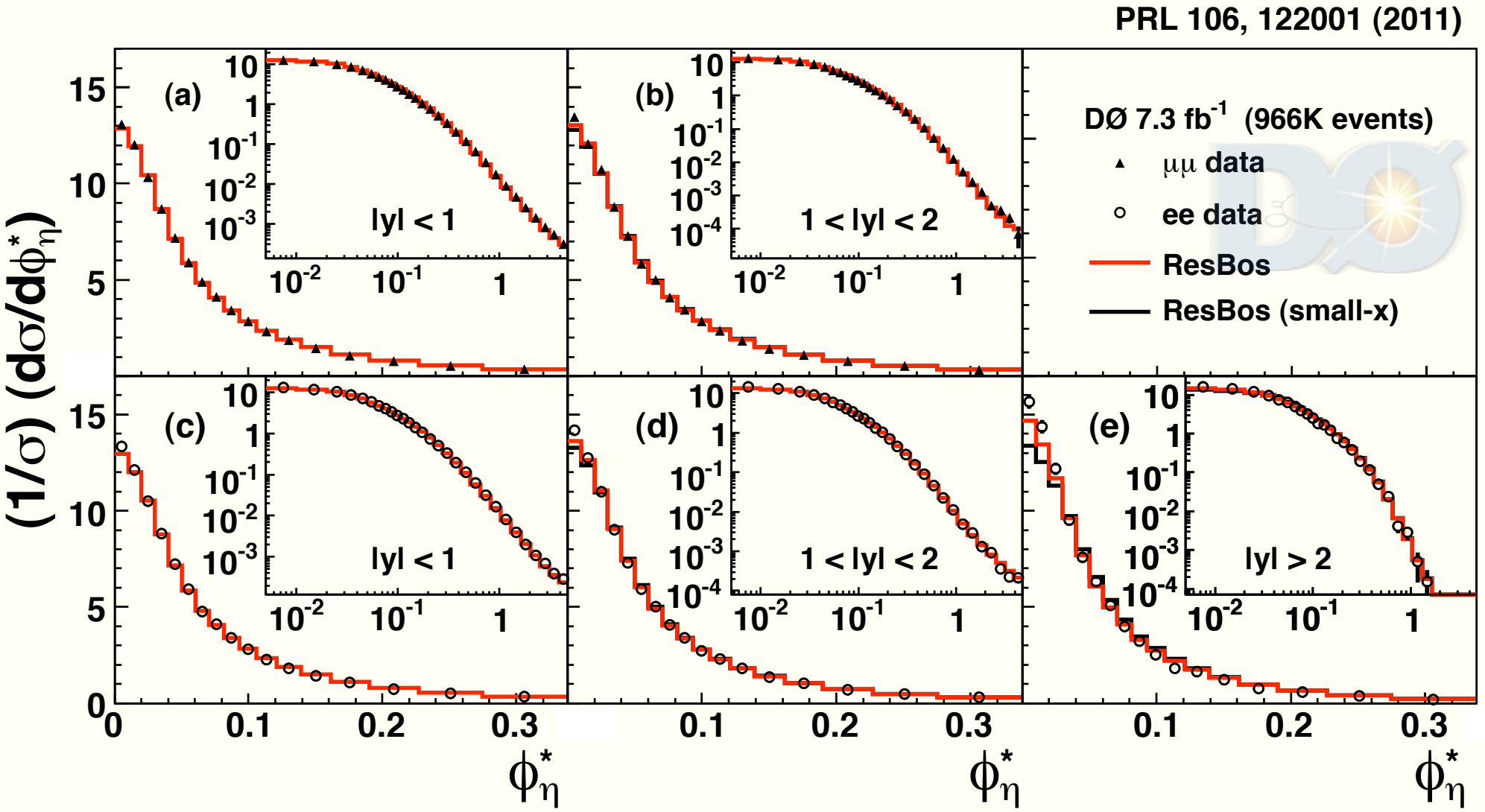


$$\phi_\eta^* = \tan(\phi_{\rm acop}/2)\sin(\theta_\eta^*) \qquad \cos(\theta_\eta^*) = \tanh\left(\frac{\eta^- - \eta^+}{2}\right)$$

Boost applied along beam direction so leptons are back-to-back in *r*-θ plane

Based entirely on measured track directions
Highly correlated with $a_T/m_{\ell\ell}$
Resolution on directions at DØ is a milliradian or better

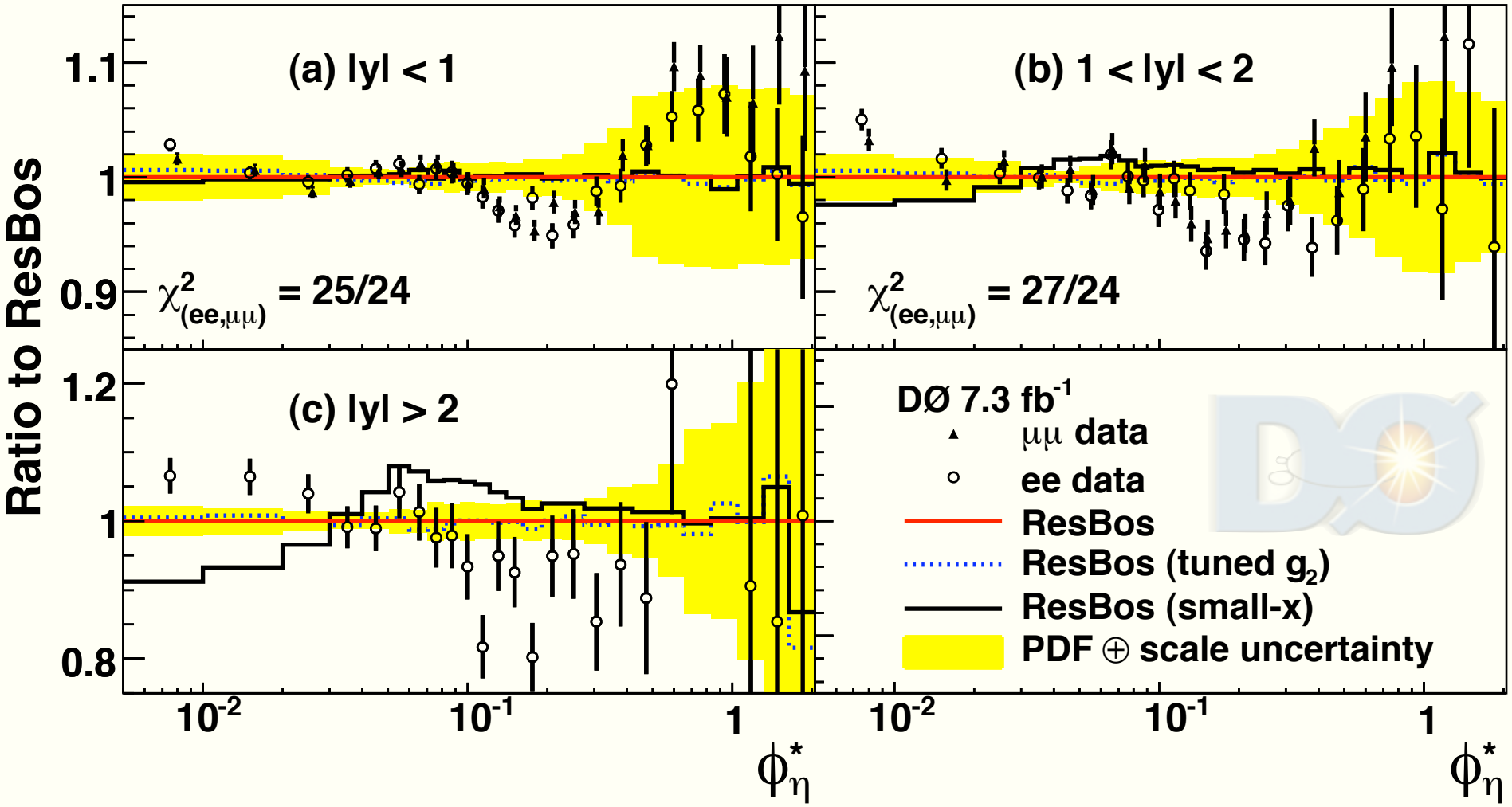
DØ measures the angle in bins of dilepton rapidity



In nearly all bins of angle, the total systematic uncertainty is substantially smaller than statistical uncertainty

DØ compares angle distributions to RESBOS with unprecedented precision

PRL 106, 122001 (2011)



10% deficit at large angle is evident; and disfavors small-x broadening

For phenomenological aspects, see Marzani talk today 11:15 in QCD session and arXiv:1102.3594 [hep-ph]

5) CDF Tests pQCD with Angular Coefficients of Drell-Yan ee pairs and $\mathrm{p_T^{ee}}$

From pQCD in Collins-Soper CM Frame:

$$\frac{d\sigma}{d\cos\theta d\phi} \propto (1+\cos^2\theta) + \frac{1}{2}\mathbf{A_0}(1-3\cos^2\theta) + \mathbf{A_1}\sin 2\theta cos\phi + \frac{1}{2}\mathbf{A_2}\sin^2\theta\cos 2\phi + \mathbf{A_3}\sin\theta\cos\phi + \mathbf{A_4}\cos\theta + \mathbf{A_5}\sin^2\theta\sin 2\phi + A_6\sin 2\theta\sin\phi + A_7\sin\theta\sin\phi$$

Determine these coefficients vs. Drell-Yan ee pair P_T

For <u>lots</u> more detail, see Bodek talk in last QCD session today

$$\mathbf{A_i} = \mathbf{f}(\mathbf{M_{\ell\ell}}, \mathbf{y}, \mathbf{p_T^{\ell\ell\ lab}})$$

$$\mathbf{A_5} = \mathbf{A_6} = \mathbf{A_7} \sim \mathbf{0}$$

$$\mathbf{A_0^{q\bar{q}}} = \mathbf{A_2^{q\bar{q}}} = \frac{\mathbf{P_T^2}}{\mathbf{M_{\ell\ell}^2}+\mathbf{P_T^2}}$$

not dependent on PDF, *y*

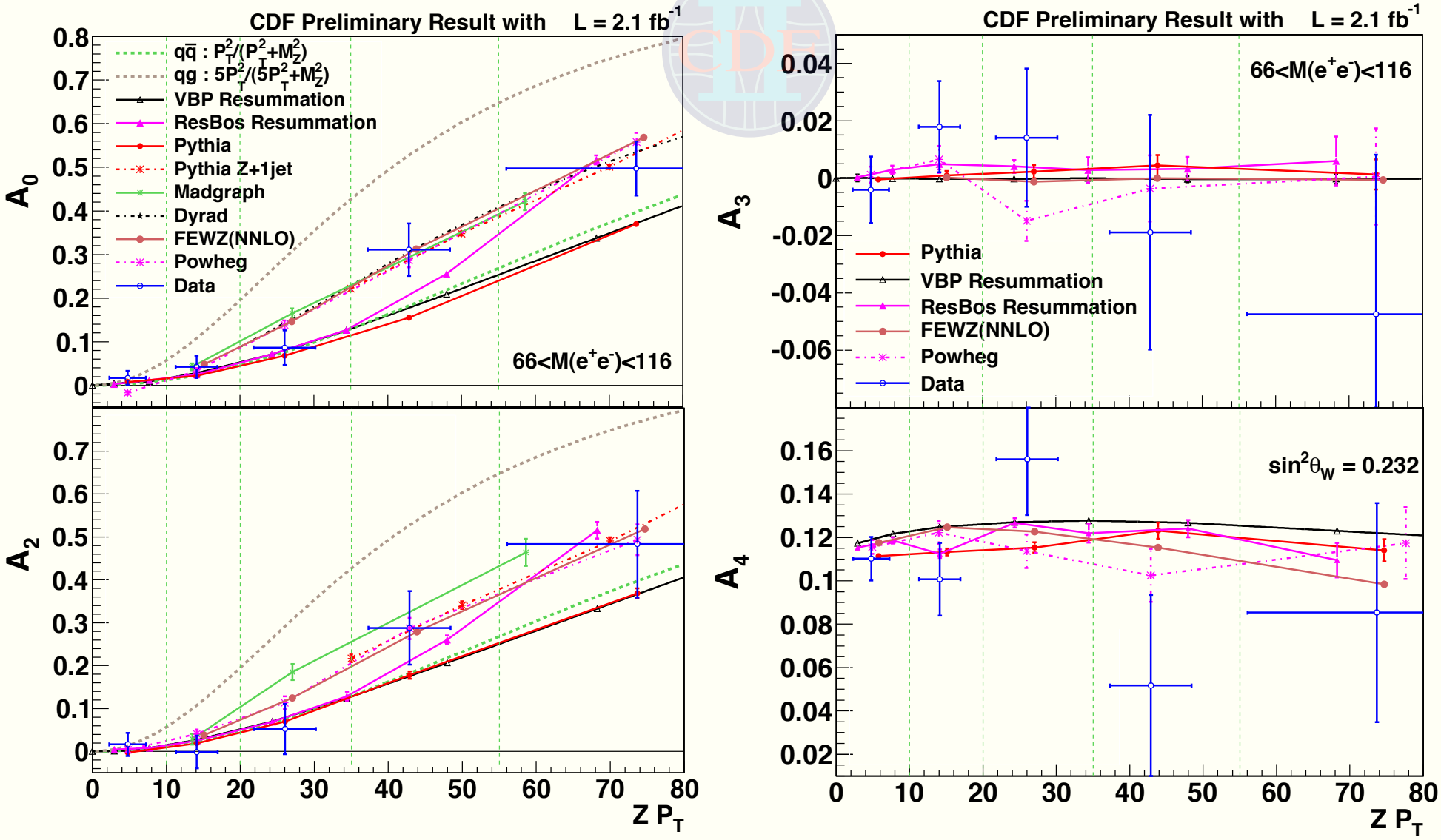
$$\mathbf{A_0^{qg}} = \mathbf{A_2^{qg}} \approx \frac{\mathbf{5P_T^2}}{\mathbf{M_{\ell\ell}^2}+\mathbf{5P_T^2}}$$

with some PDF & rapidity dependence

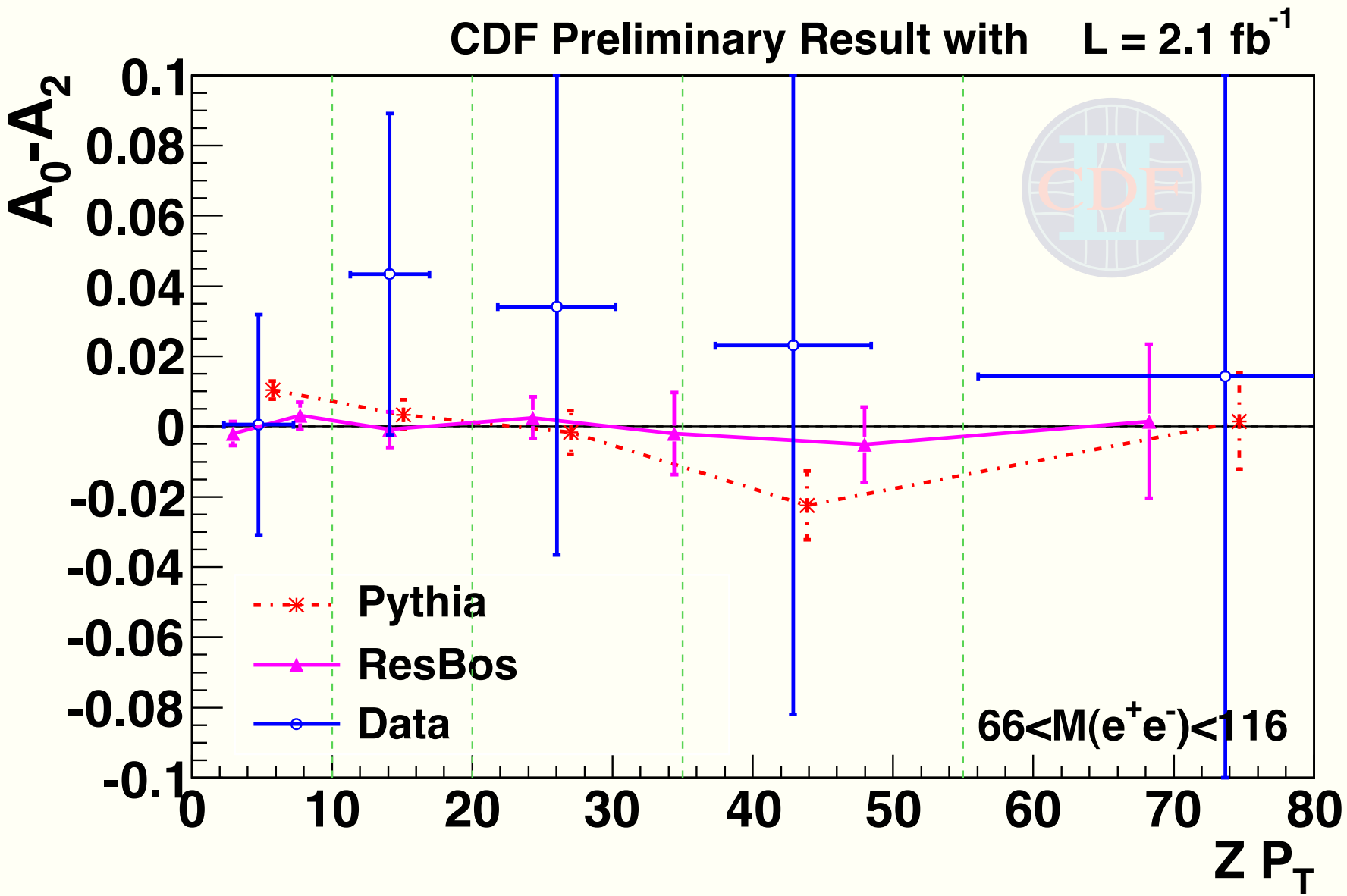
$\mathbf{A_0} = \mathbf{A_2}$ **is Lam-Tung relation; only valid if gluon has spin 1**

A_4 is sensitive to weak mixing angle

CDF compares measured coefficients vs *ee* P_T to models

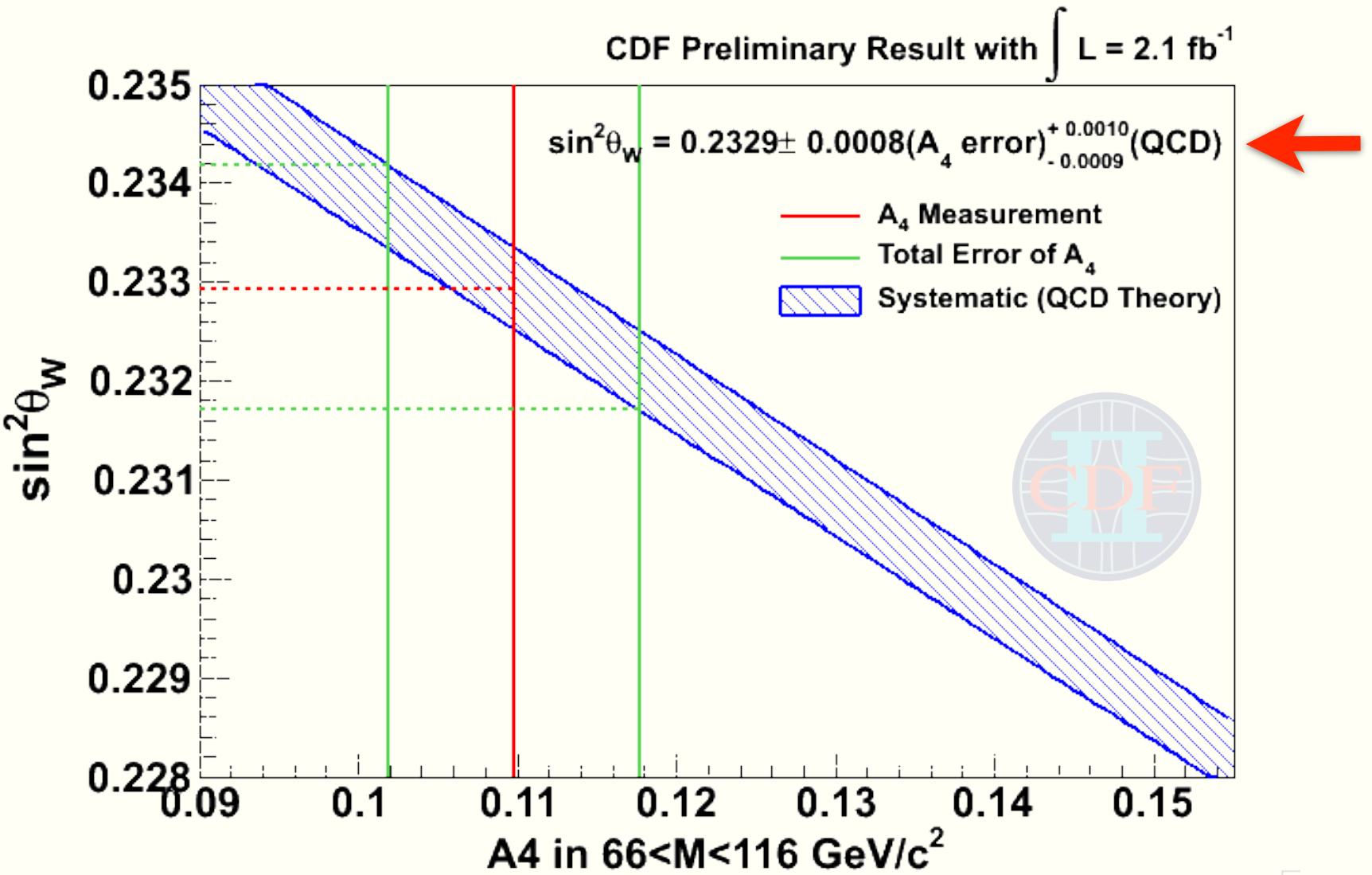


CDF tests the Lam-Tung relation (gluon has spin 1)



Average $\mathbf{A_0 - A_2} = 0.017 \pm 0.023$

CDF extracts the weak mixing angle from A_4



Many recent precision results were presented here

A rich program of precision measurements with single bosons continues at the Tevatron

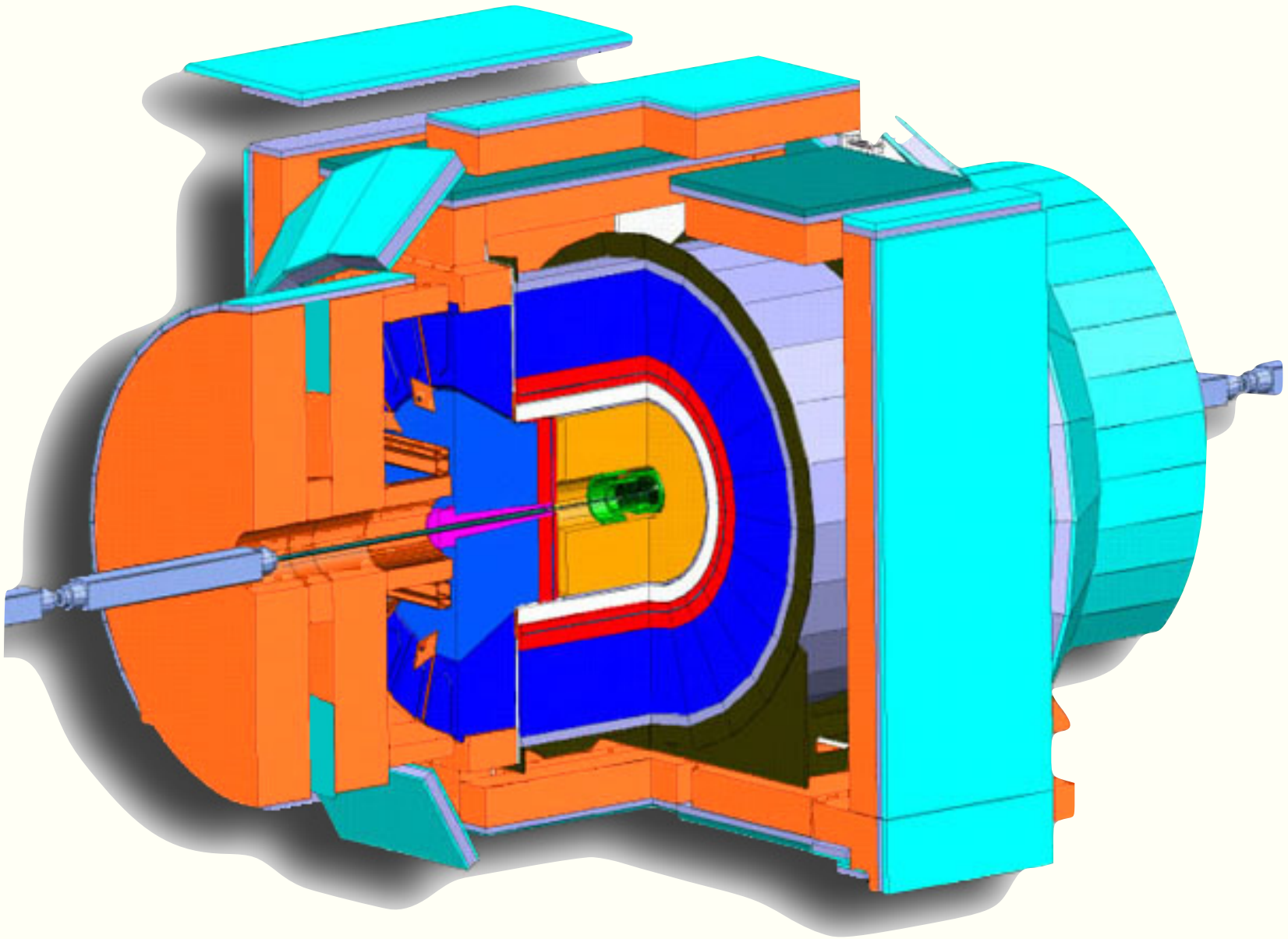
CDF and DØ test the Standard Model, PDFs, and generators with unprecedented precision

Results are important for Higgs searches and LHC results; complementary to LHC

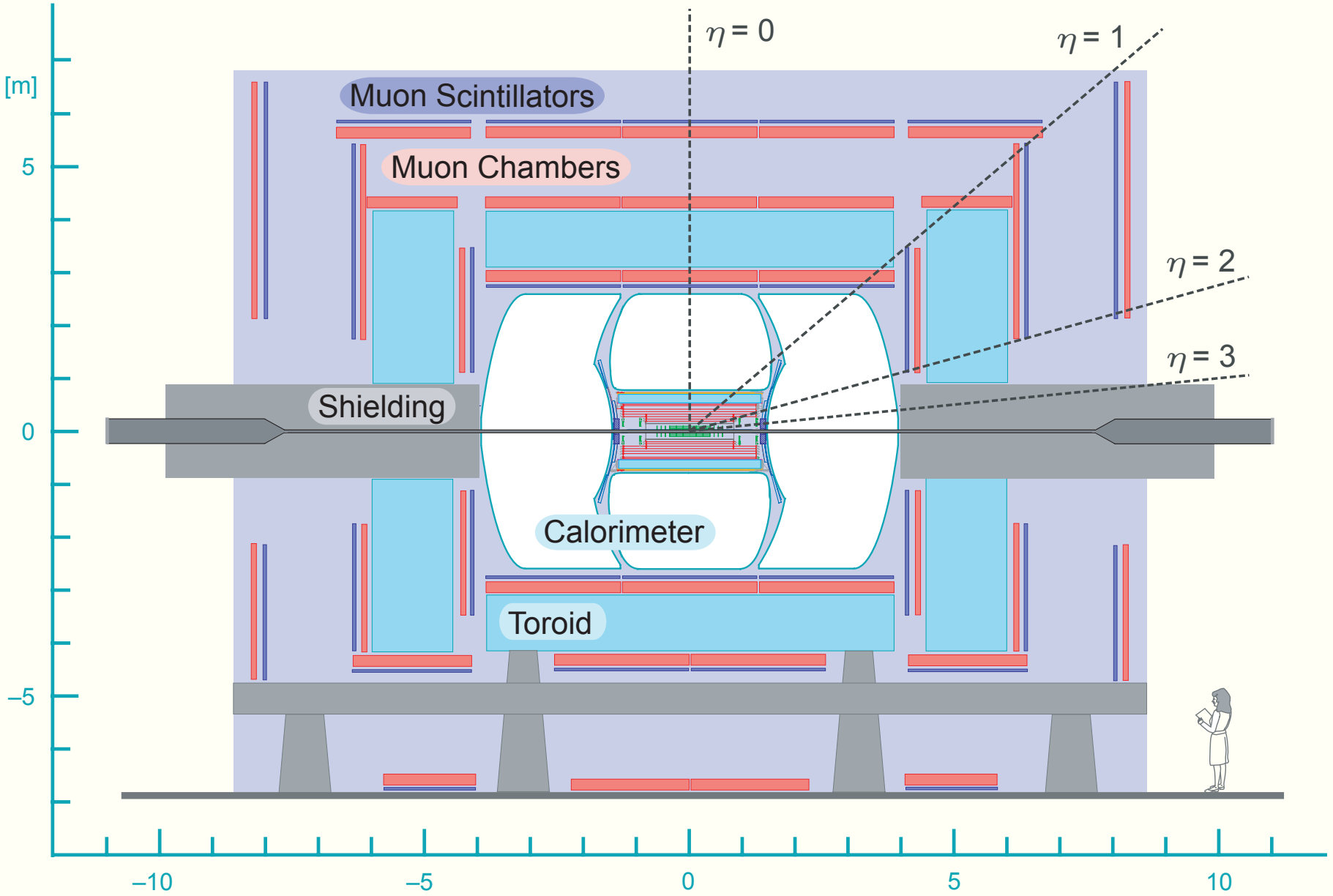
Updates with final Tevatron dataset are forthcoming

Backup Slides Beyond this Point

CDF



DØ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η = 1
η = 2
η = 3
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
[m]
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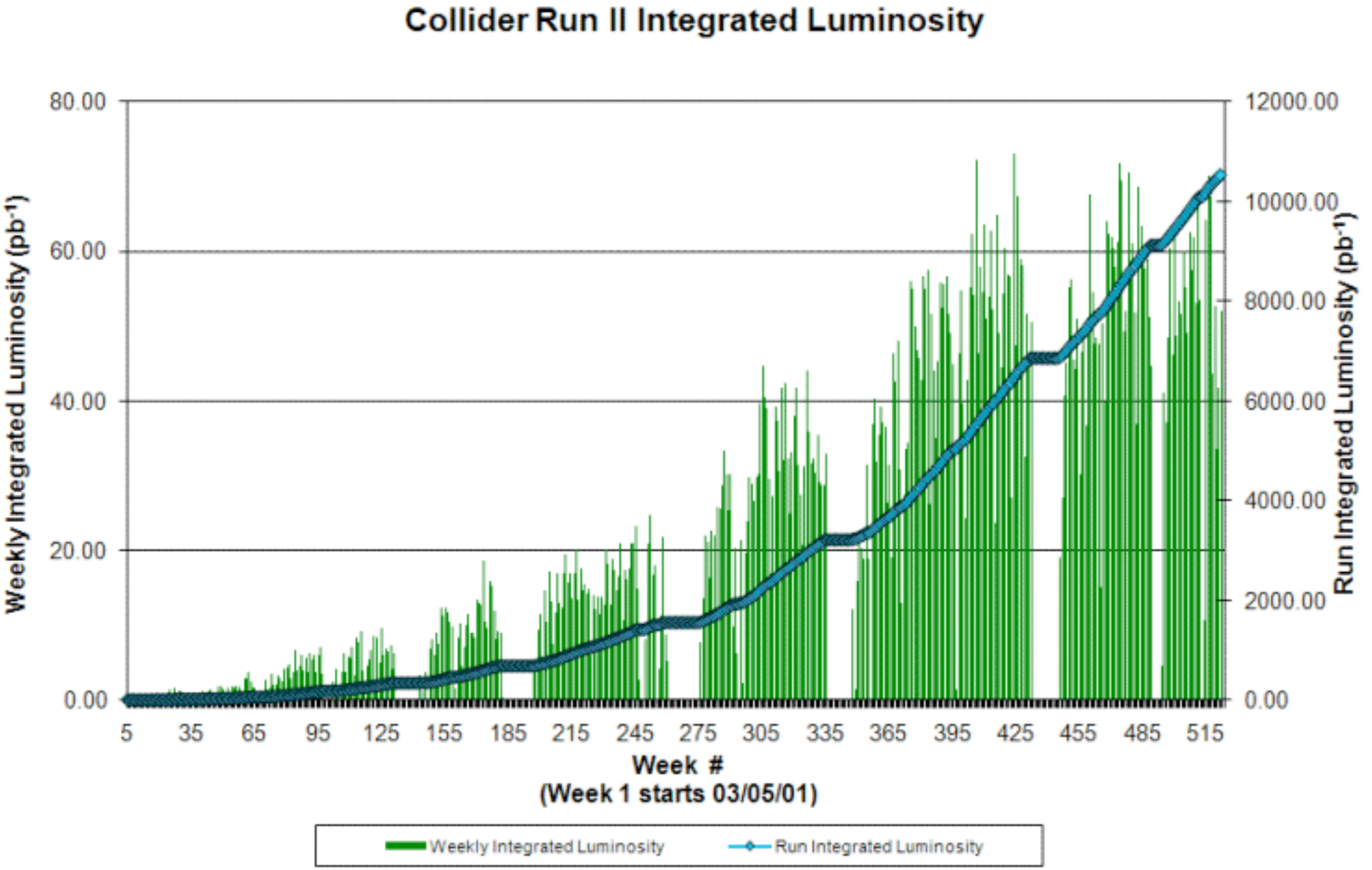
Collider Run II Integrated Luminosity
Weekly Integrated Luminosity (pb-1)
Run Integrated Luminosity (pb-1)
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245
275
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365
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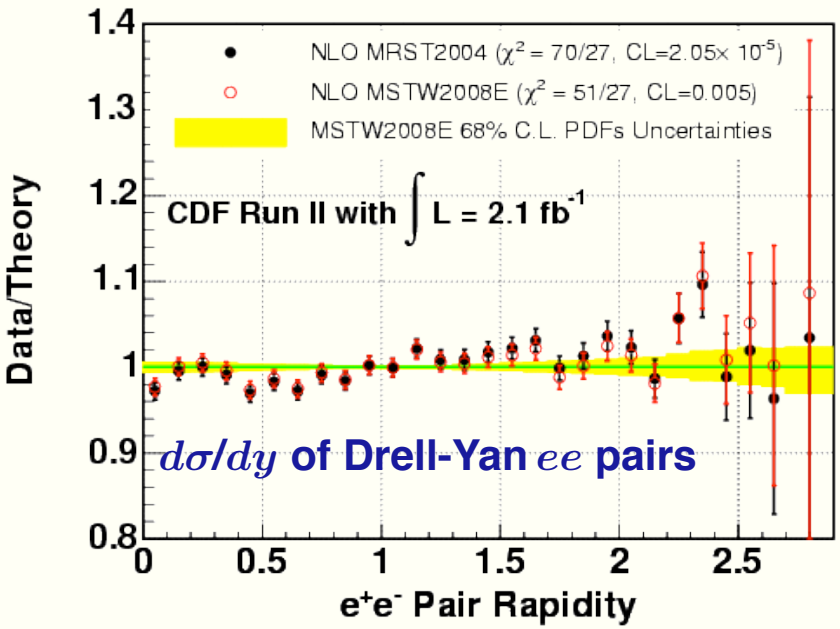
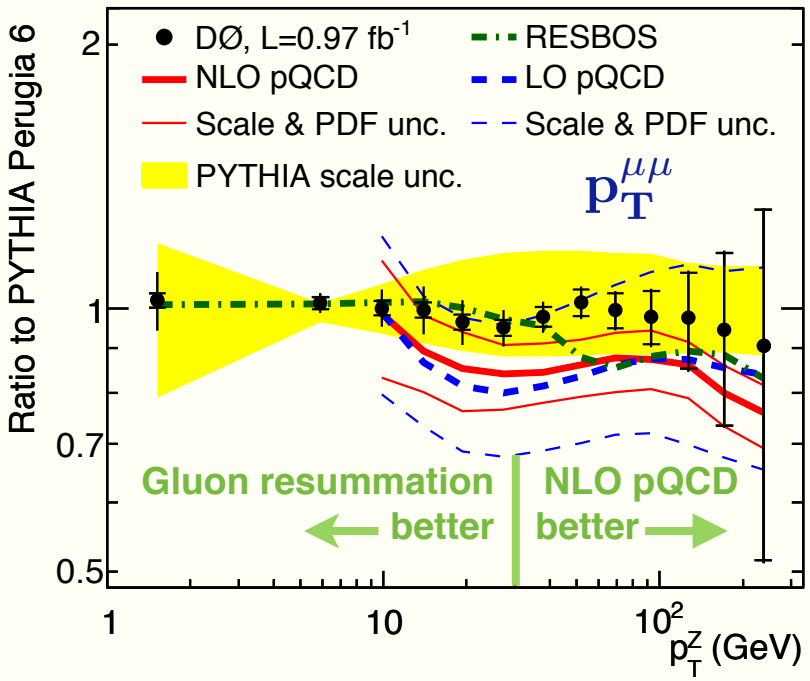
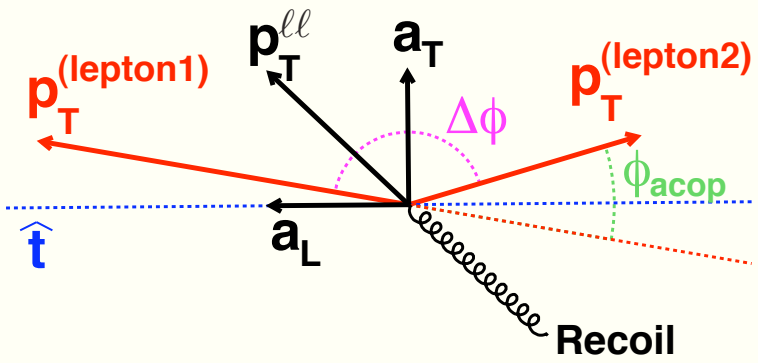
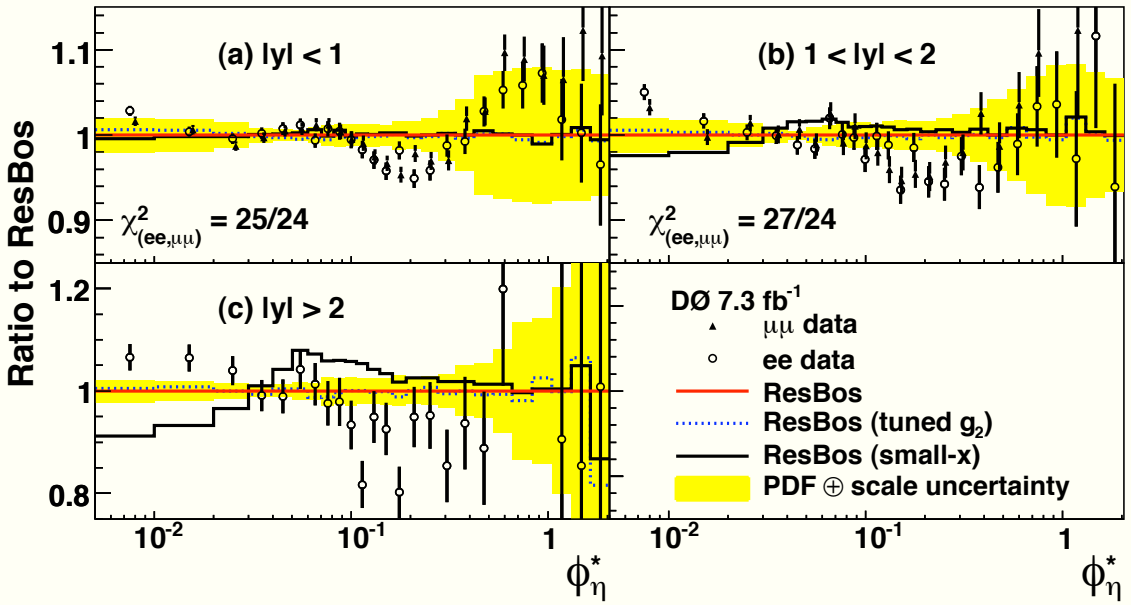
Week #
(Week 1 starts 03/05/01)
Weekly Integrated Luminosity
Run Integrated Luminosity

Studies of Single Electroweak Bosons at the Tevatron

A Story of Precision Measurements