A Decade of QCD and EW Physics at DØ

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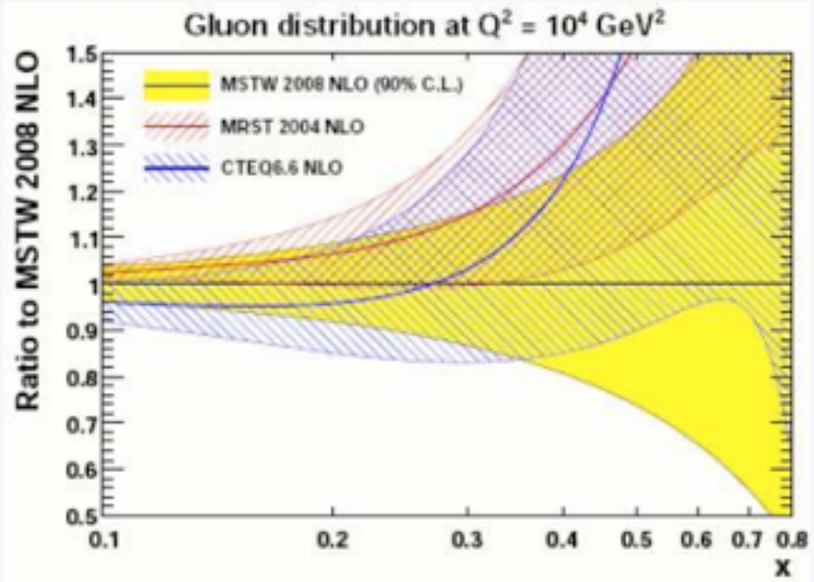
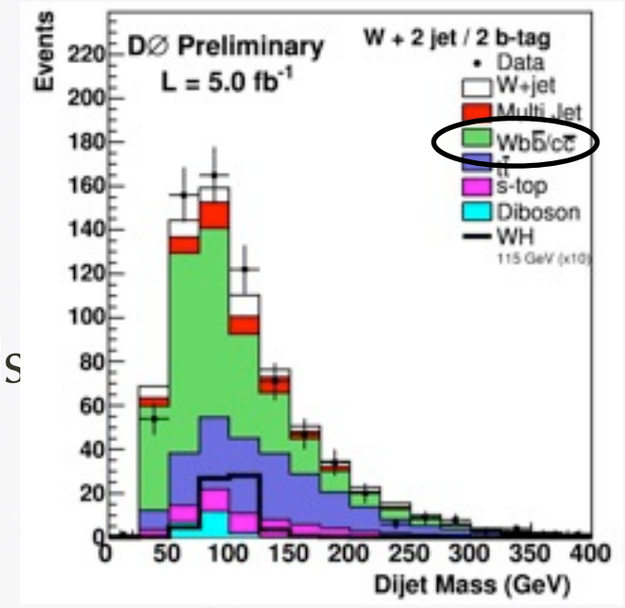
September 30, 2011
DØ Collaboration Meeting

Three Main Motivations

- Test best available theory predictions
  - Explore new kinematic regimes
  - provide important inputs to PDFs
- Search for New Physics
  - anomalous cross sections
  - resonances in diboson or jet final states
  - use SM as a guide
- Measure important backgrounds to New Physics
  - N(N)LO predictions not available for many processes of interest, particularly those with large jet multiplicities and heavy flavor components => data measurements crucial
  - New Physics share signatures with irreducible backgrounds that are currently being pinned down.
  - Interplay between fragmentation models, tunes, PDFs and scale choices needs to be understood to model SM backgrounds





RunII Publications

Electroweak Physics

2011

- Wγ Production and Limits on Anomalous WWγ Couplings in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Submitted 9/20/11: Phys. Rev. Lett., arXiv:1109.4432 plots 4.2 fb^{-1}
- 32. Measurement of the $\sin^2\theta^l_{eff}$ and Z-Light Quark Couplings Using the Forward-Backward Charge Asymmetry in $p\bar{p} \to Z/\gamma^* \to e^+e^-$ Events with L = 5.0 fb^{-1} at $\sqrt{s}$ = 1.96 TeV
  Published 7/26/11: Phys. Rev.D **84**, 012007 (2011), arXiv:1104.4590 plots 5.0 fb^{-1}
- 31. Measurement of the ZZ Production Cross Section in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 7/6/11: Phys. Rev. D **84**, 011103 (2011), arXiv:1104.3078 plots 6.4 fb^{-1}

2010

- 30. Precise Study of the Z/γ^* Boson Transverse Momentum Distribution in $p\bar{p}$ Collisions Using a Novel Technique
  Published 3/21/11: Phys. Rev. Lett. **106**, 122001 (2011), arXiv:1010.0262 plots 7.3 fb^{-1}
- 29. Measurement of the WZ → lνll Cross Section and Limits on Anomalous Triple Gauge Couplings in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 10/23/10: Phys. Lett. B **695**, 67 (2011), arXiv:1006.0761 plots 4.1 fb^{-1}
- 28. Measurement of the Normalized $Z/\gamma^* \to \mu^+\mu^-$ Transverse Momentum Distribution in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 9/16/10: Phys. Lett. B **693**, 522 (2010), arXiv:1006.0618 plots 1.0 fb^{-1}

2009

- 27. Direct Measurement of the W Boson Width
  Published 12/4/09: Phys. Rev. Lett. **103**, 231802 (2009), arXiv:0909.4814 plots 1.0 fb^{-1}
- 26. Measurement of the WW Production Cross Section with Dilepton Final States in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV and Limits on Anomalous Trilinear Gauge Couplings
  Published 11/2/09: Phys. Rev. Lett. **103**, 191801 (2009), arXiv:0904.0673 plots 1.1 fb^{-1}
- 25. Measurement of the W Boson Mass
  Published 10/1/09: Phys. Rev. Lett. **103**, 141801 (2009), arXiv:0908.0766 plots 1.0 fb^{-1}
- 24. Measurement of Trilinear Gauge Boson Couplings from WW + WZ → lνjj Events in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 9/23/09: Phys. Rev. D **80**, 053012 (2009), arXiv:0907.4398 plots 1.1 fb^{-1}
- 23. A Novel Method for Modeling the Recoil in W Boson Events at Hadron Colliders
  Published 8/27/09: Nucl. Instrum. Methods in Phys. Res. Sect. A **609**, 250 (2009), arXiv:0907.3713 plots
- 22. Measurement of the Zγ → ννγ Production Cross Section and Limits on Anomalous ZZγ and Zγγ Couplings in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 5/22/09: Phys. Rev. Lett. **102**, 201802 (2009), arXiv:0902.2157 plots 2.6 fb^{-1}
- 21. Evidence of WW+WZ Production with Lepton+Jets Final States in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 4/21/09: Phys. Rev. Lett. **102**, 161801 (2009), arXiv:0810.3873 plots 1.1 fb^{-1}

2008

- 20. Search for a Scalar or Vector Particle Decaying into Zγ in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 12/10/08: Phys. Lett. B **671**, 349 (2009), arXiv:0806.0611 plots 1.0 fb^{-1}
- 19. Measurement of the Electron Charge Asymmetry in $p\bar{p} \to W + X \to e\nu + X$ Events at $\sqrt{s}$ = 1.96 TeV
  Published 11/19/08: Phys. Rev. Lett. **101**, 211801 (2008), arXiv:0807.3367 plots 0.70 fb^{-1}
- 18. Measurement of $\sigma(p\bar{p} \to Z + X)Br(Z \to \tau^+\tau^-)$ at $\sqrt{s}$ = 1.96 TeV
  Published 11/8/08: Phys. Lett. B **670**, 292 (2009), arXiv:0808.1306 plots 1.0 fb^{-1}
- 17. Measurement of the Forward-Backward Charge Asymmetry and Extraction of $\sin^2\theta_W^{eff}$ in $p\bar{p} \to Z/\gamma^* + X \to e^+e^- + X$ Events Produced at $\sqrt{s}$ = 1.96 TeV
  Published 11/6/08: Phys. Rev. Lett. **101**, 191801 (2008), arXiv:0804.3220 plots 1.1 fb^{-1}
- 16. Observation of ZZ Production in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 10/23/08: Phys. Rev. Lett. **101**, 171803 (2008), arXiv:0808.0703 plots 2.7 fb^{-1}
- 15. $ZZ \to l^+l^-\nu\bar{\nu}$ Production in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 10/6/08: Phys. Rev. D **78**, 072002 (2008), arXiv:0808.0269 plots 2.7 fb^{-1}
- 14. First Study of the Radiation-Amplitude Zero in Wγ Production and Limits on Anomalous WWγ Couplings at $\sqrt{s}$ = 1.96 TeV
  Published 6/20/08: Phys. Rev. Lett. **100**, 241805 (2008), arXiv:0803.0030 plots 0.70 fb^{-1}
- 13. Search for ZZ and $Z\gamma^*$ Production in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV and Limits on Anomalous ZZZ and $ZZ\gamma^*$ Couplings
  Published 4/2/08: Phys. Rev. Lett. **100**, 131801 (2008), arXiv:0712.0599 plots 1.0 fb^{-1}
- 12. Measurement of the Shape of the Boson-Transverse Momentum Distribution in $p\bar{p} \to Z/\gamma^* \to e^+e^- + X$ Events Produced at $\sqrt{s}$ = 1.96 TeV
  Published 3/11/08: Phys. Rev. Lett. **100**, 102002 (2008), arXiv:0712.0803 plots 1.0 fb^{-1}
- 11. Measurement of the Muon Charge Asymmetry from W Boson Decays
  Published 1/23/08: Phys. Rev. D **77**, 011106 (2008), arXiv:0709.4254 plots 0.30 fb^{-1}

Quantum Chromodynamics

2011

- Measurements of Inclusive W+Jets Production Rates as a Function of Jet Transverse Momentum in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Submitted 6/9/11: Phys. Lett. B, arXiv:1106.1457 plots 4.2 fb^{-1}
- High Mass Exclusive Diffractive Dijet Production in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Submitted 9/13/10: Phys. Lett. B, arXiv:1009.2444 plots 30 pb^{-1}
- Measurement of Three-Jet Differential Cross Sections $d\sigma_{3jet}/dM_{3jet}$ in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Accepted 9/13/11: Phys. Lett. B, arXiv:1104.1986 plots 0.7 fb^{-1}
- 16. Azimuthal Decorrelations and Multiple Parton Interactions in γ + 2 Jet and γ + 3 Jet Events in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 3/23/11: Phys. Rev. D **83**, 052008 (2011), arXiv:1101.1509 plots 1.0 fb^{-1}
- 15. Measurement of the Ratio of Inclusive Cross Sections $\sigma(p\bar{p} \to Z + b\text{-Quark Jet}) / \sigma(p\bar{p} \to Z + \text{Jet})$ at $\sqrt{s}$ = 1.96 TeV
  Published 2/28/11: Phys. Rev. D **83**, 031105 (2011), arXiv:1010.6203 plots 4.2 fb^{-1}

2010

- 14. Measurement of the Dijet Invariant Mass Cross Section in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 9/17/10: Phys. Lett. B **693**, 531 (2010), arXiv:1002.4594 plots 0.7 fb^{-1}
- 13. Measurement of Direct Photon Pair Production Cross Sections in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 5/12/10: Phys. Lett. B **690**, 108 (2010), arXiv:1002.4917 plots 4.2 fb^{-1}
- 12. Double Parton Interactions in γ+3 Jet Events in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 3/31/10: Phys. Rev. D **81**, 052012 (2010), arXiv:0912.5104 plots 1.0 fb^{-1}

2009

- 11. Determination of the Strong Coupling Constant from the Inclusive Jet Cross Section in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 12/29/09: Phys. Rev. D **80**, 111107 (2009), arXiv:0911.2710 plots 0.7 fb^{-1}
- 10. Measurement of Z/γ^*+jet+X Angular Distributions in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 11/13/09: Phys. Lett. B **682**, 370 (2010), arXiv:0907.4286 plots 1.0 fb^{-1}
- 9. Measurement of Dijet Angular Distributions at $\sqrt{s}$ = 1.96 TeV and Searches for Quark Compositeness and Extra Spatial Dimensions
  Published 11/5/09: Phys. Rev. Lett. **103**, 191803 (2009), arXiv:0906.4819 plots 0.70 fb^{-1}
- 8. Measurements of Differential Cross Sections of Z/γ^*+jets+X Events in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 5/29/09: Phys. Lett. B **678**, 45 (2009), arXiv:0903.1748 plots 1.0 fb^{-1}
- 7. Measurement of γ + b + X and γ + c + X Production Cross Sections in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 5/12/09: Phys. Rev. Lett. **102**, 192002 (2009), arXiv:0901.0739 plots 1.0 fb^{-1}

2008

- 6. Measurement of Differential Z/γ^* + jet + X Cross Sections in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 10/8/08: Phys. Lett. B **669**, 278 (2008), arXiv:0808.1296 plots 1.0 fb^{-1}
- 5. Measurement of the Inclusive Jet Cross Section in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV **TOPCITE = 50+**
  Published 8/6/08: Phys. Rev. Lett. **101**, 062001 (2008), arXiv:0802.2400 plots 0.70 fb^{-1}
- 4. Measurement of the Differential Cross Section for the Production of an Isolated Photon with Associated Jet in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV
  Published 8/3/08: Phys. Lett. B **666**, 435 (2008), arXiv:0804.1107 plots 1.0 fb^{-1}
- 3. Measurement of the Ratio of the $p\bar{p} \to W$ + c-jet Cross Section to the Inclusive $p\bar{p} \to W$ + jets Cross Section
  Published 7/4/08: Phys. Lett. B **666**, 23 (2008), arXiv:0803.2259 plots 1.0 fb^{-1}

2007

2006

- 2. Measurement of the Isolated Photon Cross Section in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV **TOPCITE = 50+**
  Published 5/5/06: Phys. Lett. B **639**, 151 (2006), hep-ex/0511054 plots 326 pb^{-1}
  Erratum published 6/27/07: Phys. Lett. B **658**, 285 (2008)

2005

- 1. Measurement of Dijet Azimuthal Decorrelations at Central Rapidities in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV **TOPCITE = 50+**
  Published 6/7/05: Phys. Rev. Lett. **94**, 221801 (2005), hep-ex/0409040 plots 150 pb^{-1}

clearly cannot cover all recent results

My sincere apologies for not covering all interesting physics results

Analysis Subjects

Jets and W/Z+jets

- jet cross sections and extractions of α_s
- jet shapes
- W/Z + light, heavy jet rates and kinematics

Inclusive W/Z

- W and Z mass, cross sections
- Z p_T studies
- forward/backward asymmetries

Diboson

- WW, WZ, ZZ, Wγ, Zγ
- diphotons
- limits on anomalous couplings

Diffraction & Elastic Scattering

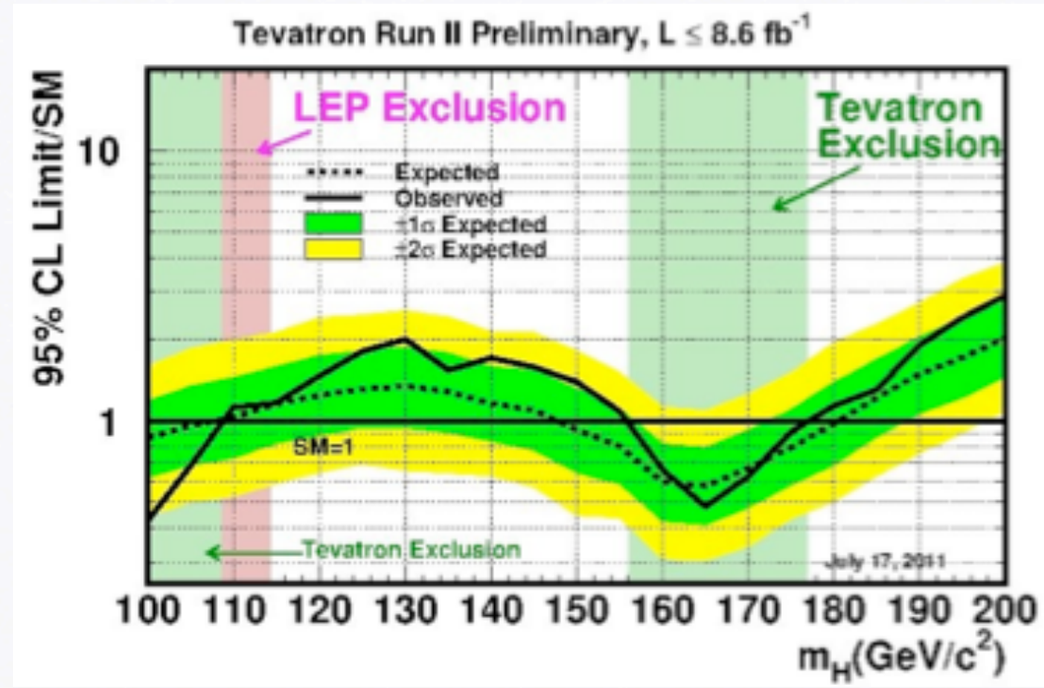
- total elastic scattering cross section
- diffractive jet, W, Z production
- forward physics

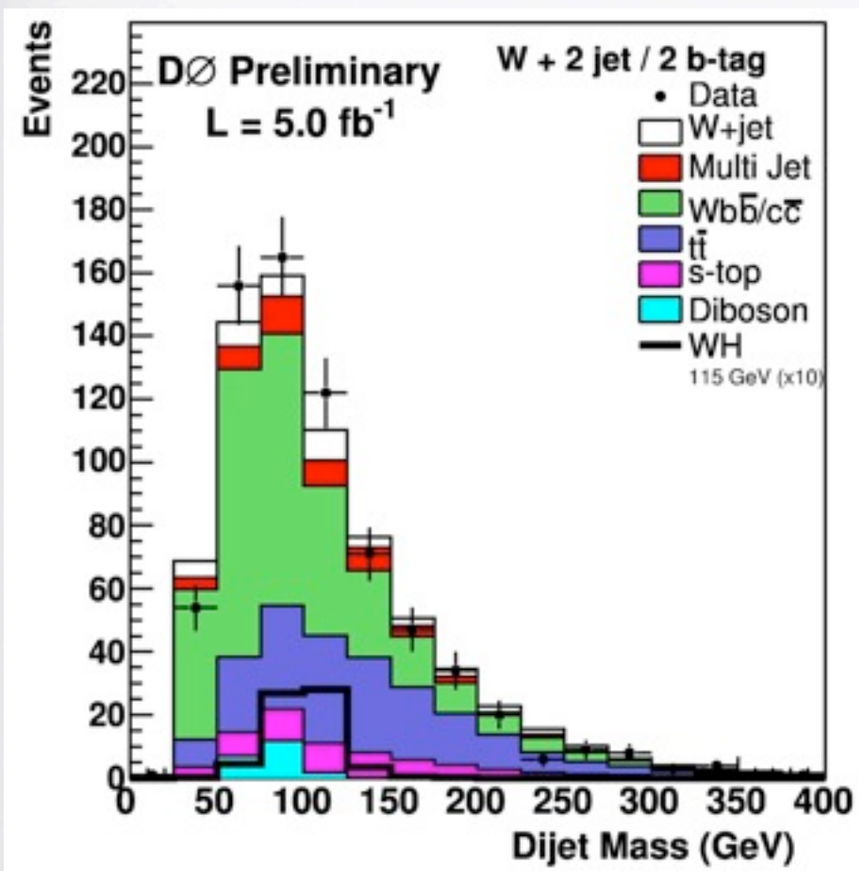
Soft, MinBias, MPI Physics

- universal backgrounds many analyses don't think much about
- soft and hard scales
- double parton scattering

Higgs

- SM Higgs Search arguably the most important work in hadronic collider physics today
- Background modeling very challenging
- Many dominant systematics are from poorly constrained background cross sections





D0: Single Tag (ST) $ZH \to \ell\ell b\bar{b}$ analysis relative uncertainties (%)

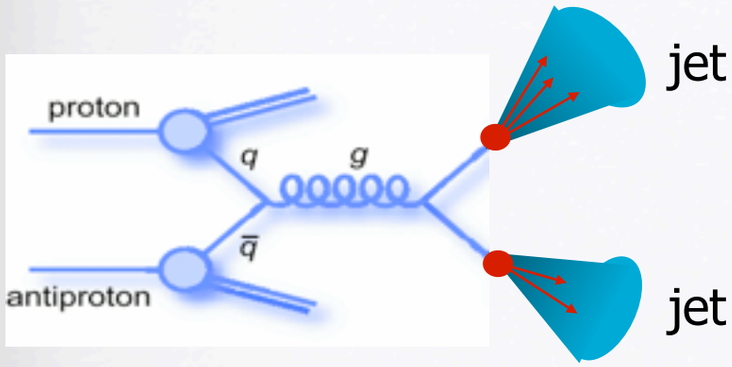
Contribution	WZ/ZZ	Zbb/Zcc	Zjj	$t\bar{t}$	Multijet	ZH
Luminosity	6	6	6	6	0	6
EM ID/Reco eff.	2	2	2	2	0	2
Muon ID/Reco eff.	2	2	2	2	0	2
Jet ID/Reco eff.	2	2	2	2	0	2
Jet Energy Scale (shape dep.)	5	5	5	5	0	5
b-tagging/taggability	5	5	5	5	0	5
Cross Section	6	30	6	10	0	6
MC modeling	0	4	4	0	0	0
Instrumental-ZH	0	0	0	0	50	0

D0: Double Tag (DT) $WH \to \ell\nu b\bar{b}$ analysis relative uncertainties (%)

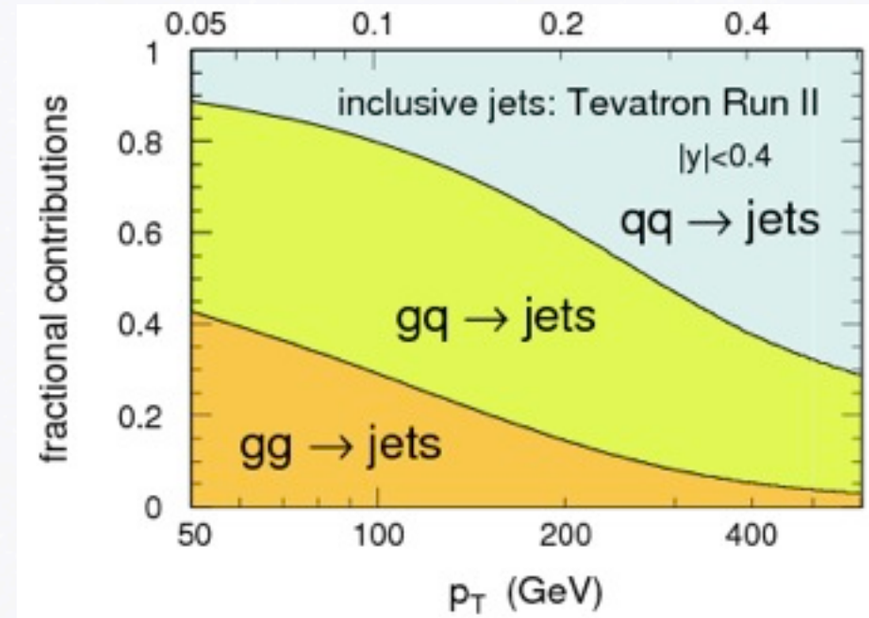
Contribution	WZ/WW	Wbb/Wcc	Wjj/Wcj	$t\bar{t}$	single top	Multijet	WH
Luminosity	6	6	6	6	6	0	6
Trigger eff.	2–5	2–5	2–5	2–5	2–5	0	2–5
EM ID/Reco eff./resol.	3	3	3	3	3	0	3
Muon ID/Reco eff./resol.	4.1	4.1	4.1	4.1	4.1	0	4.1
Jet ID/Reco eff.	2	2	2	2	2	0	2
Jet Energy Scale	3	3	3	3	3	0	3
Jet mult./frag./modeling	3.5	3.5	3.5	3.5	3.5	0	3.5
b-tagging/taggability	6	6	20	6	6	0	6
Cross Section	6	9	9	10	10	0	6
Heavy-Flavor K-factor	0	20	0	0	0	0	0
Instrumental-WH	0	0	0	0	0	26	0

Jets and W/Z+Jets

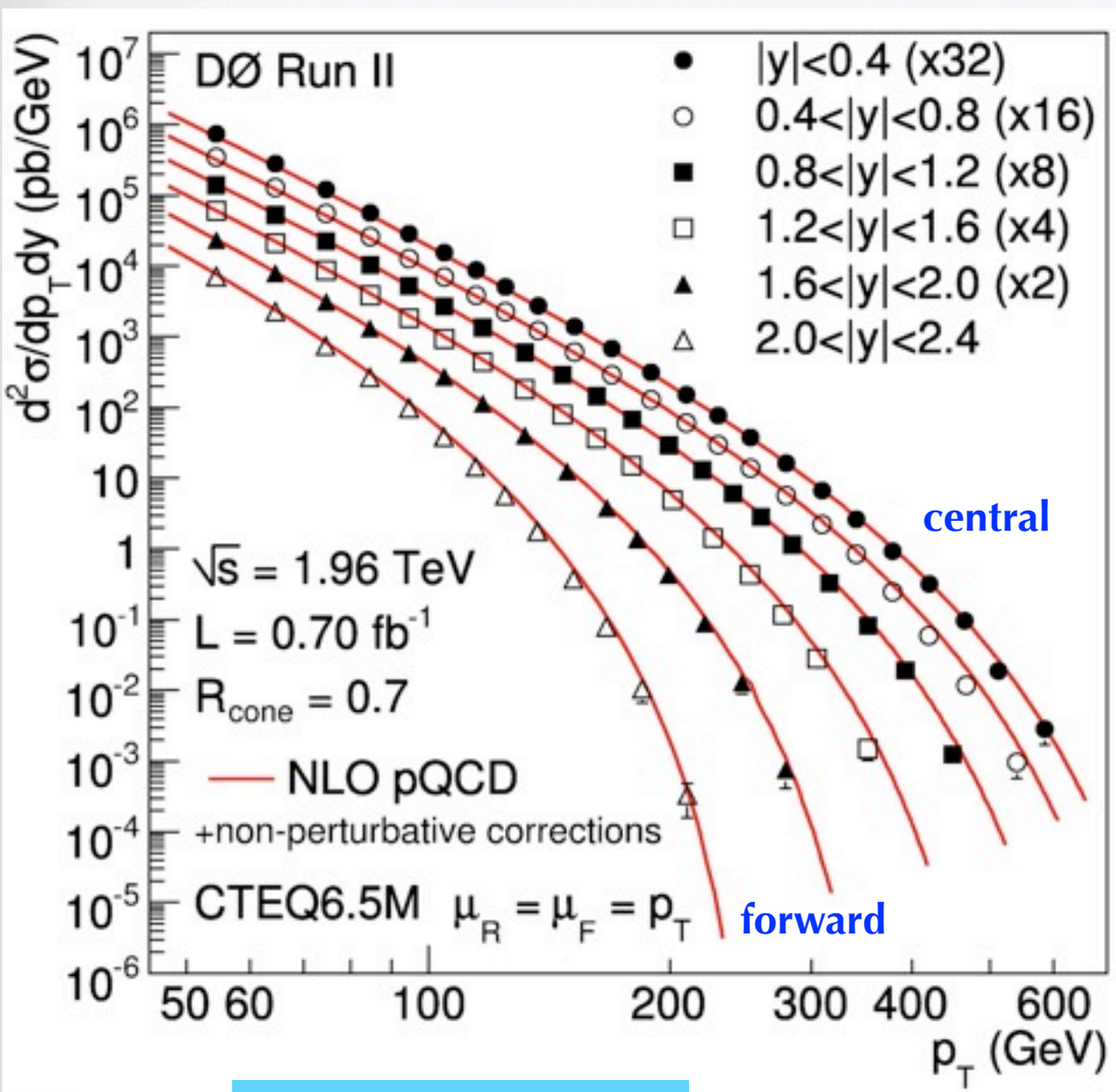
Inclusive Jets



Sensitive to gluon content of the proton



NLO theory is accurate to ~10% (in the absence of new physics)



PRL 101, 062001 (2008)

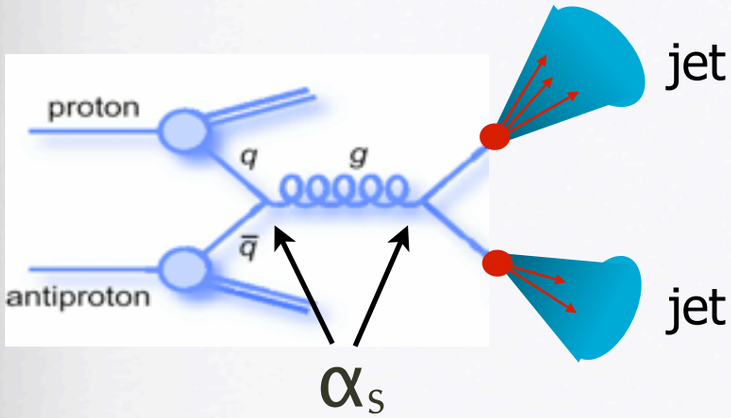
steeply falling p_T spectrum:

- 1% error in jet energy calibration
- 5-10% (10-25%) error in central (forward) x-section

benefit from:

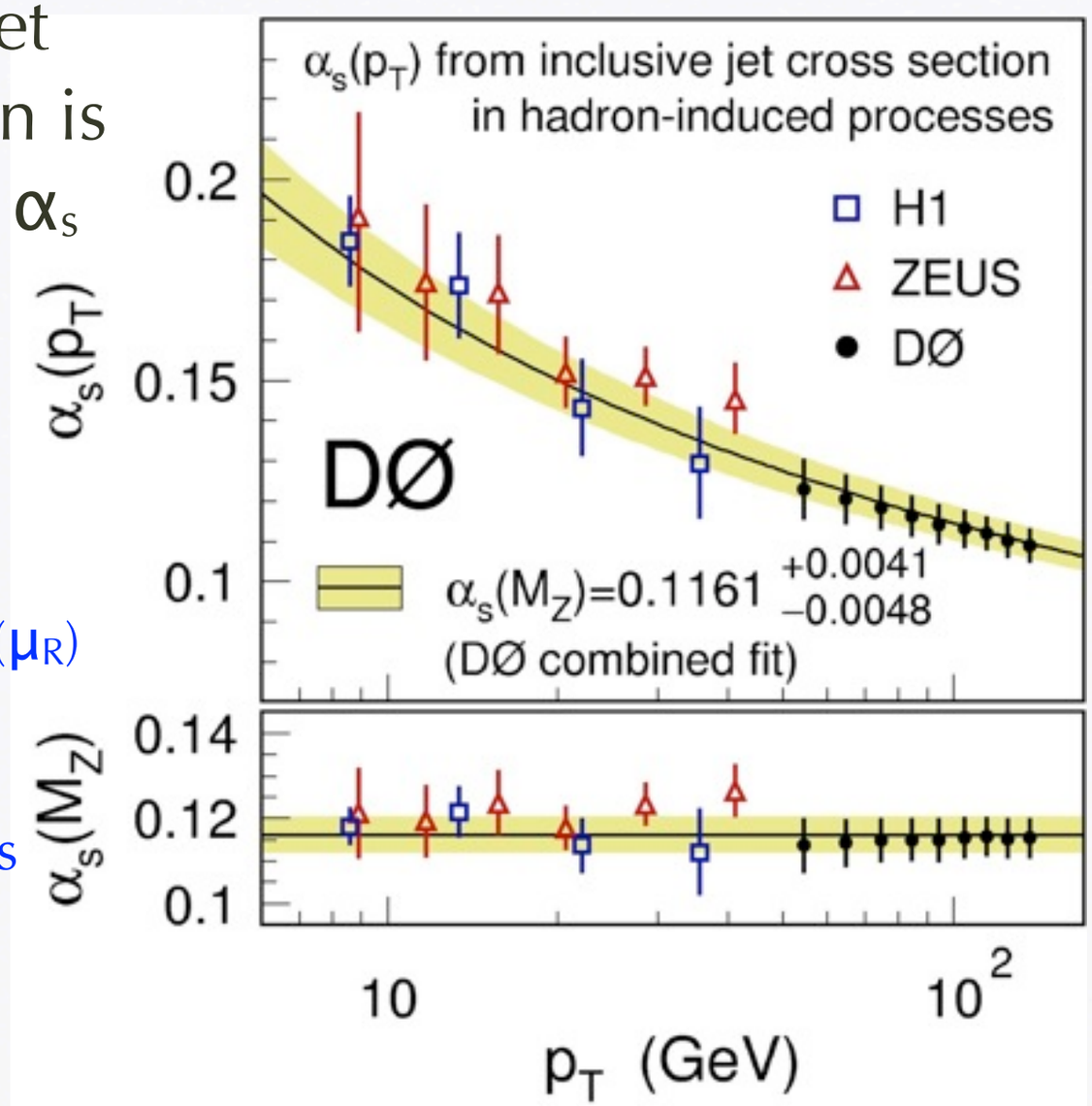
- high luminosity in Run II
- increased Run II cm energy → high p_T
- hard work on jet energy calibration

α_s extraction



Inclusive Jet Cross Section is sensitive to α_s

$$\sigma_{\text{pert}}(\alpha_s) = \left(\sum_n \alpha_s^n c_n\right) \otimes f_1(\alpha_s) \otimes f_2(\alpha_s)$$



The coupling strength, α_s, is scale dependent: $\alpha_s(\mu_R)$
Renormalization Group Equation predicts μ_R-dependence
Extract α_s from 22 (out of 110) inclusive jet cross section data points at $50<p_T<145$ GeV
→ Exclude data points with large influence on PDF set

- NLO + 2-loop threshold corrections
- MSTW2008NNLO PDFs
- Extends results from HERA to high p_T

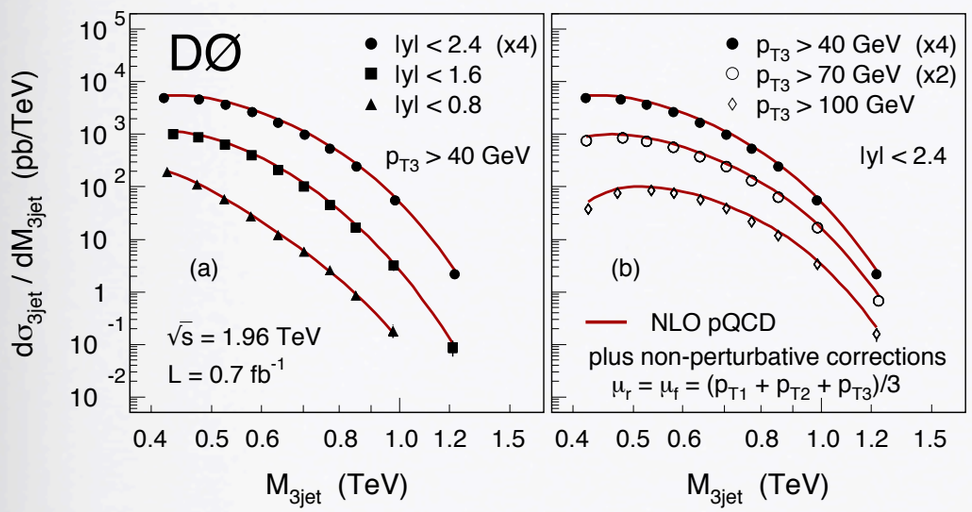
Very precise α_s measurement:

$$\alpha_s(M_Z) = 0.1161^{+0.0041}_{-0.0048}$$

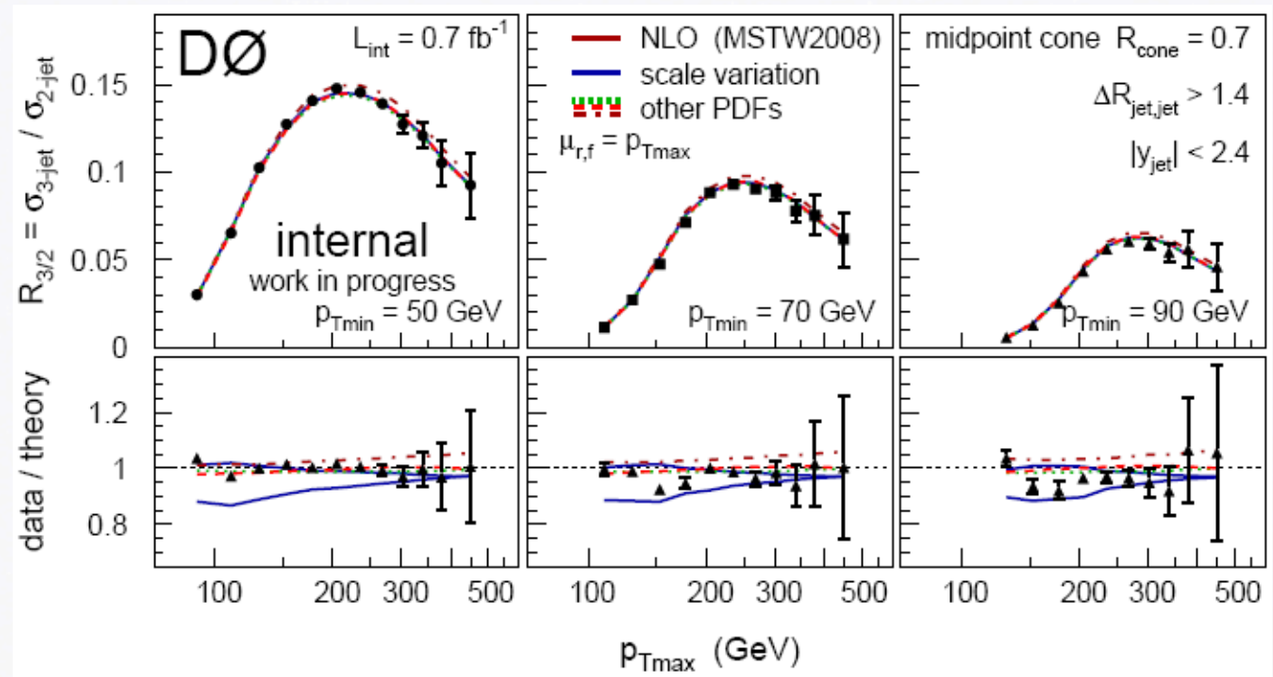
Trijets and R3/2

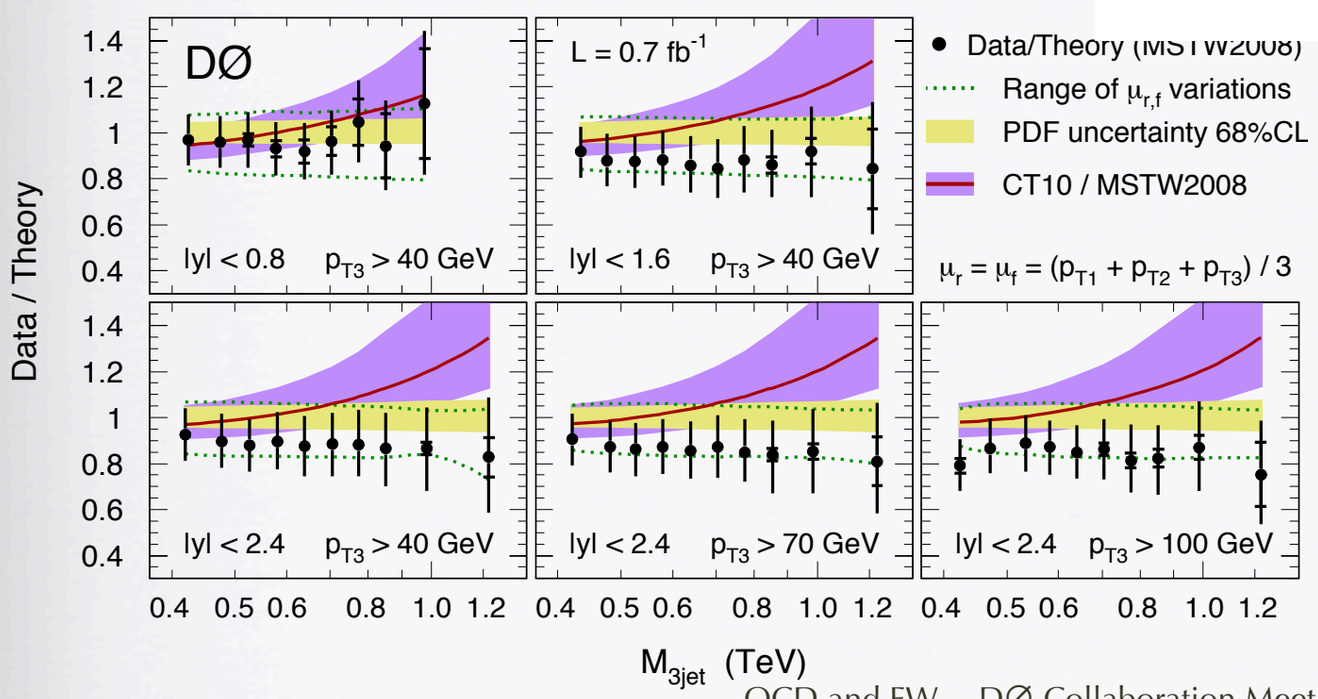
- Tests of pQCD at high jet multiplicity
- Additional opportunities to extract α_s at larger scales

3-jet mass



σ(3jet)/σ(2jet)



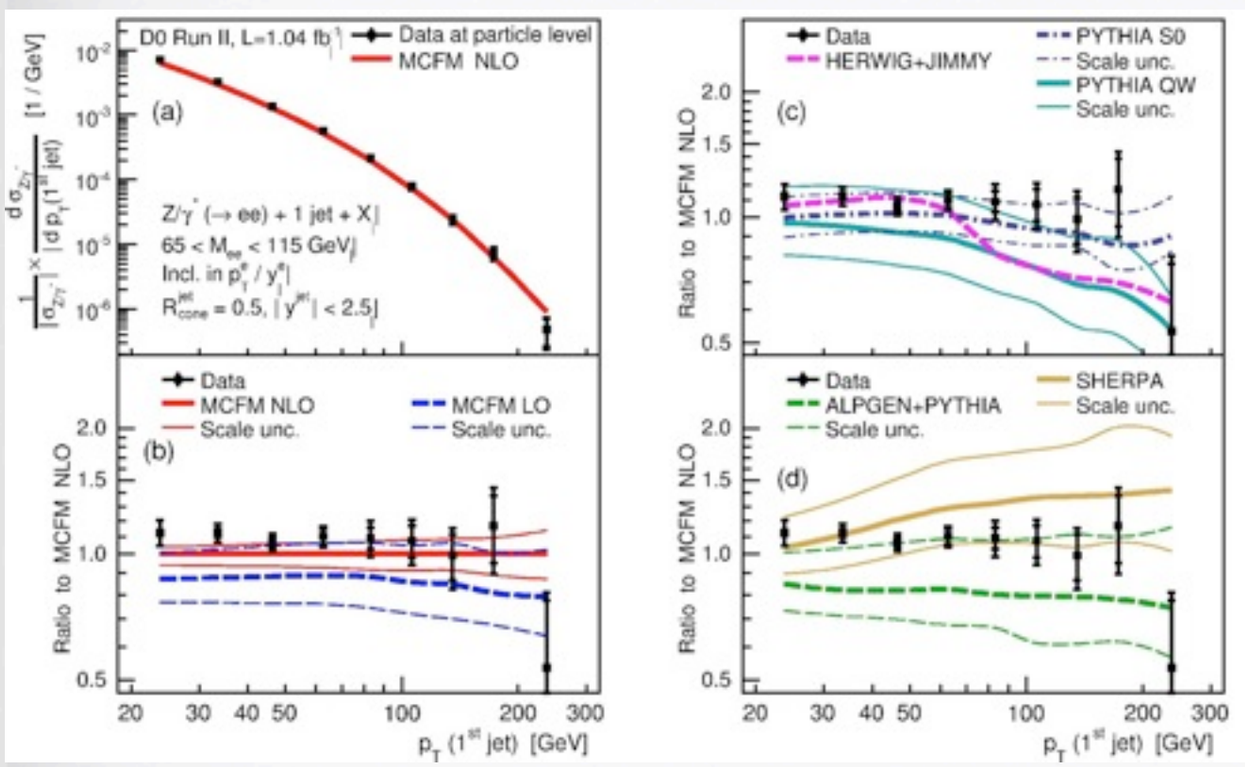


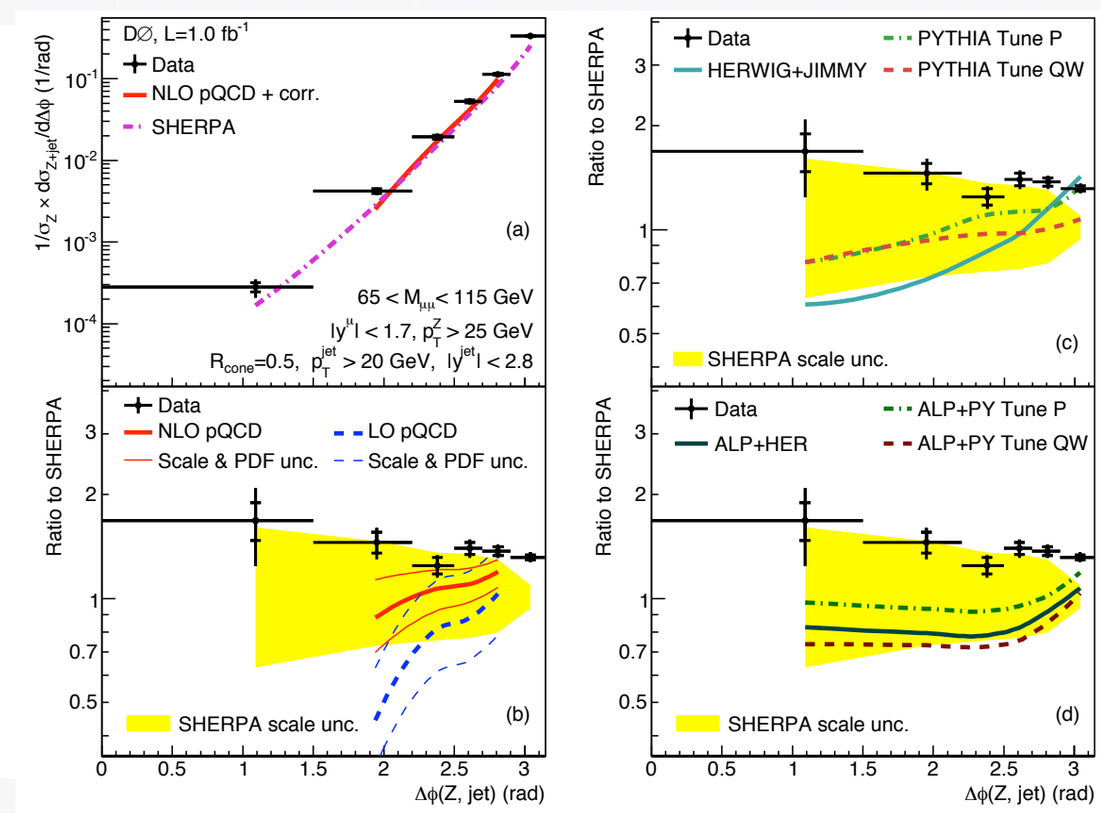
Differential cross sections measurements:

- data are corrected to particle level
- particle level measurements are compared to NLO theory
- NLO theory is corrected to particle level using parton shower MC

$Z/\gamma^* \rightarrow ll$ + jets

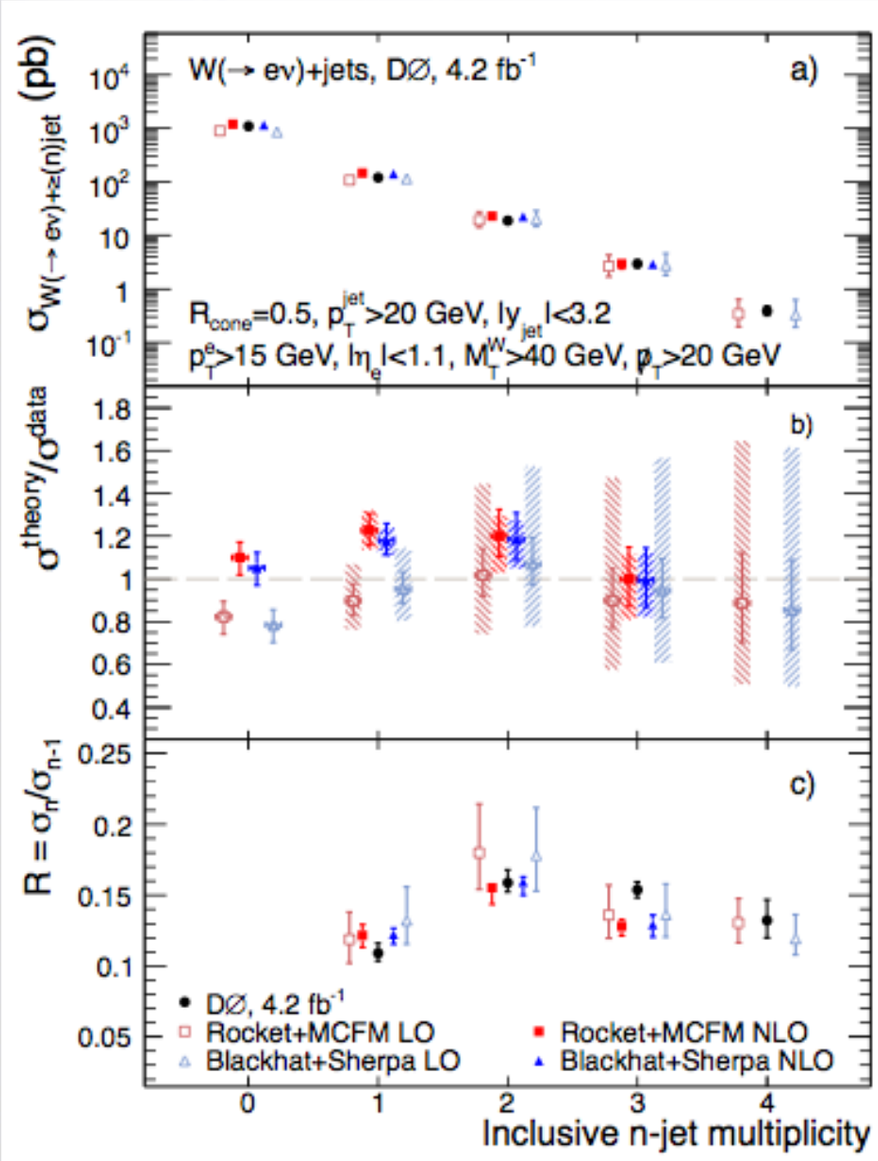
- Z provides colorless probe of collision and hard scale → study kinematics of hadronic recoil
- Extensive set of measurements carried out in electron and muon decay channels which examined jet p_T (1,2,3 jets), Z p_T, angular correlations
- Novel techniques employed for unfolding, thorough study of systematics
- Careful studies of different theoretical effects: NLO corrections, PDFs, MC tunes
- Techniques have been carried forward to other V+jets measurements





W→ eν+jets

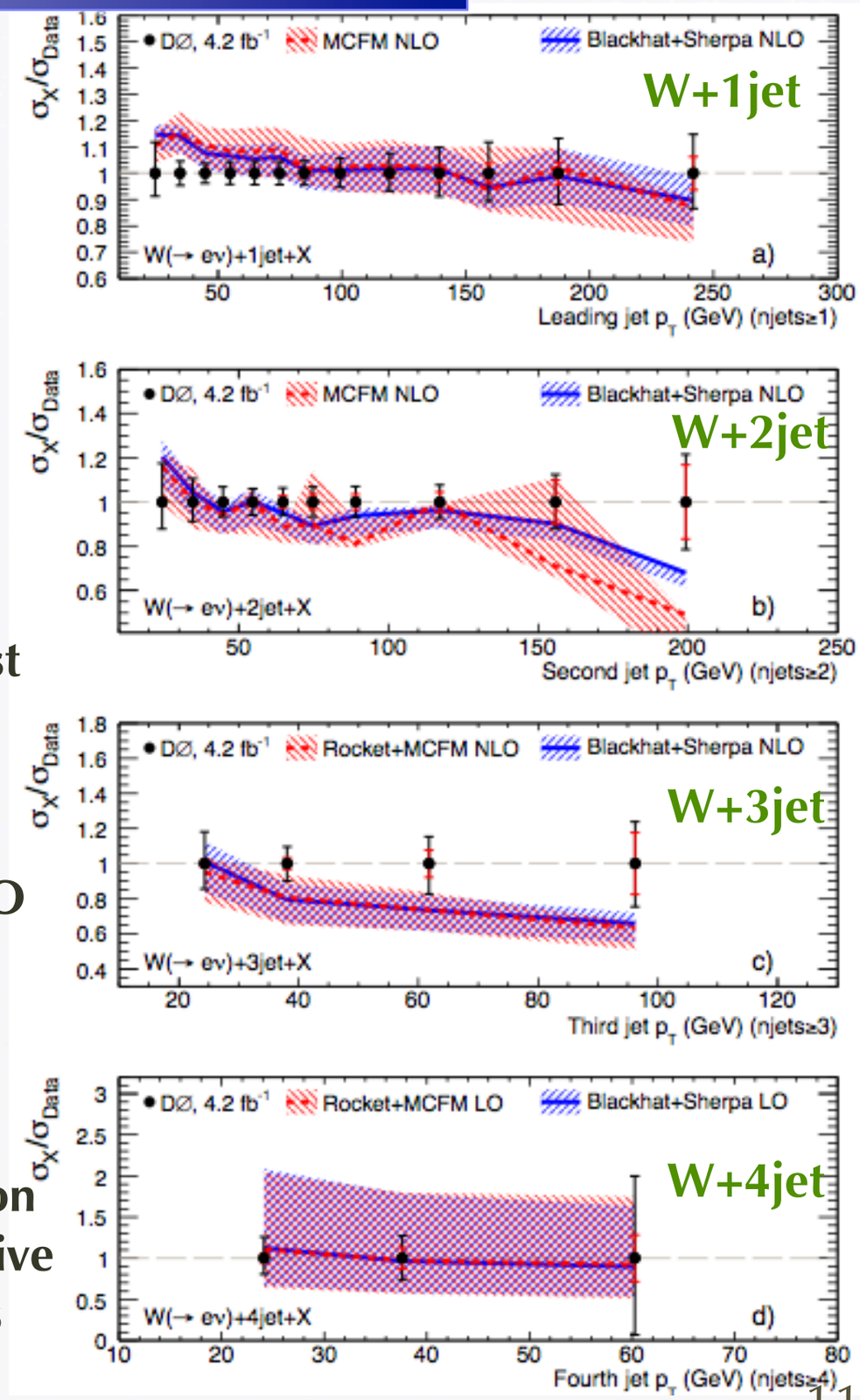
- Precise measurements of W+(n)jet (n=1,2,3,4) inclusive cross sections and differentially as function of nth jet p_T
- Small data uncertainties allow detailed study of NLO theory



Large theoretical strides in V+jets calculations in last year or so.

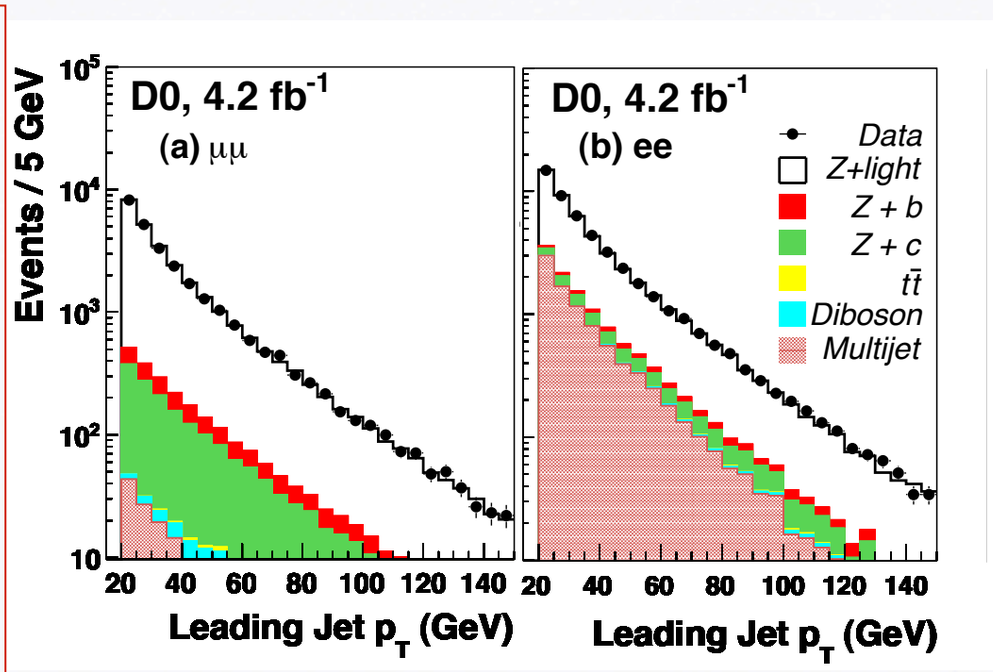
Data compared to two indep. NLO implementations - led to bug fixes in MCFM

PRD in preparation with comprehensive set of observables



Z+b jets

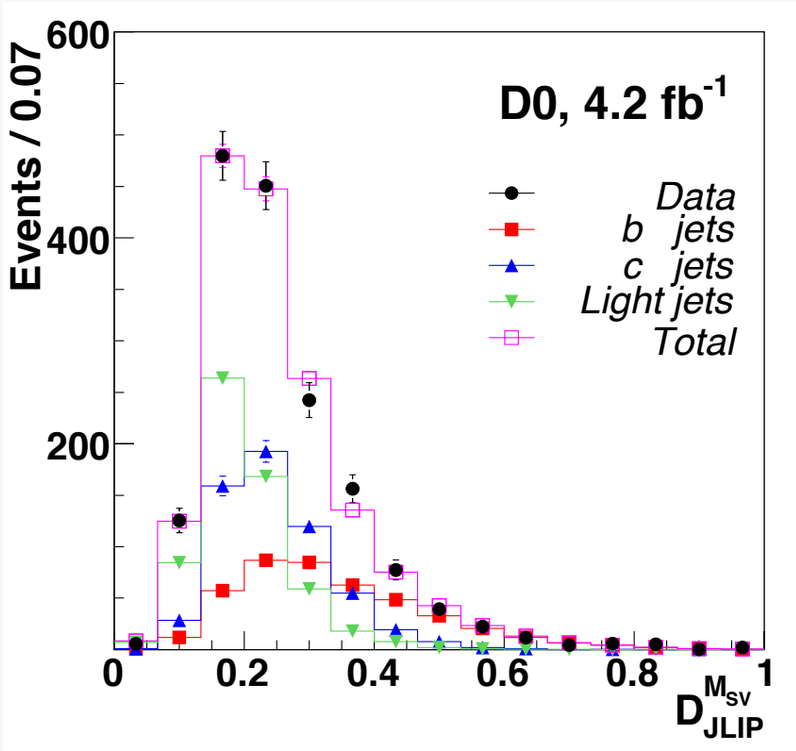
- ❖ Interesting test of pQCD predictions and b-quark fragmentation.
- ❖ Important background to the SM Higgs search in the ZH(→bb) channel.
- ❖ Probe of b-quark parton distribution function
- ❖ σ(Z+b) / σ(Z+j) benefits from cancellations of many systematic uncertainties
  ⇒ precise comparison with theory



Z+b/Z+jet = .0193 ± .0022(stat) ± .0015 (syst)
-- in agreement with NLO pQCD
(which has 20-25% scale uncertainty)

γ+b differential cross section vs p_T also in agreement with NLO

new W+b and updated W+c, Z+b, γ+b, γ+c measurements in preparation



Inclusive W and Z

Z/γ* transverse momentum

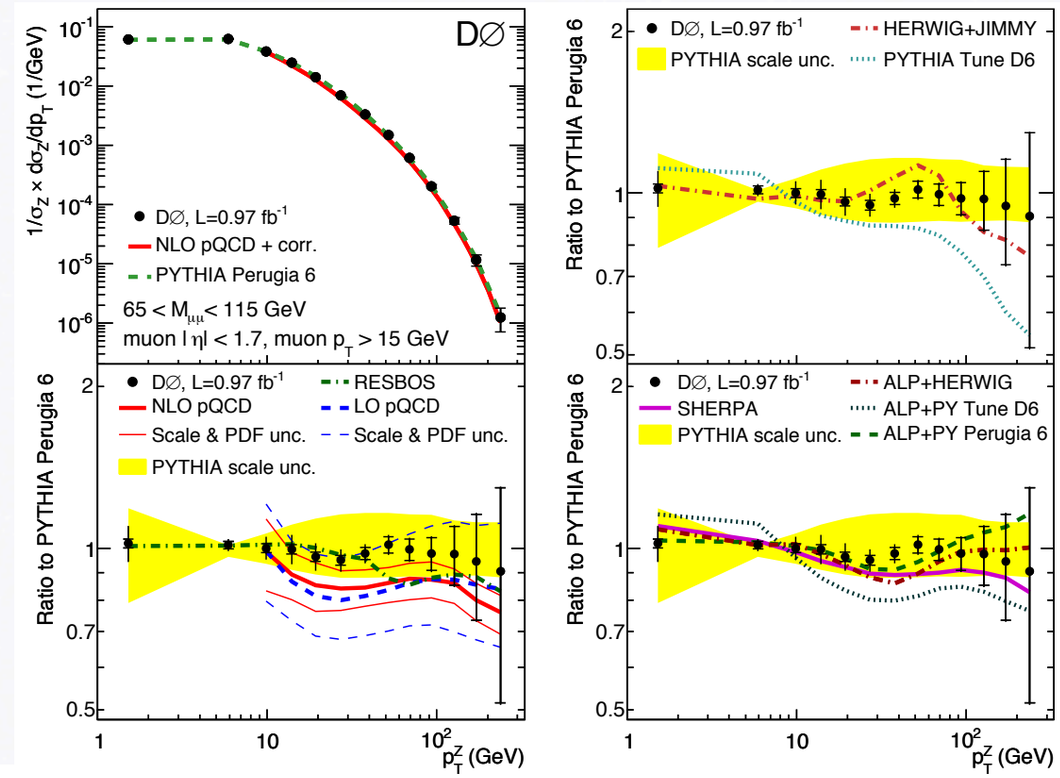
- Z/γ* kinematics provides colorless probe of underlying collision process
- Z /γ* p_T is excellent probe of ISR
- results are presented at particle level
- Pythia Perugia6 gives best description of data over entire kinematic range
- p_T distribution uncertainty dominated by detector resolution and efficiencies
- alternate approach:

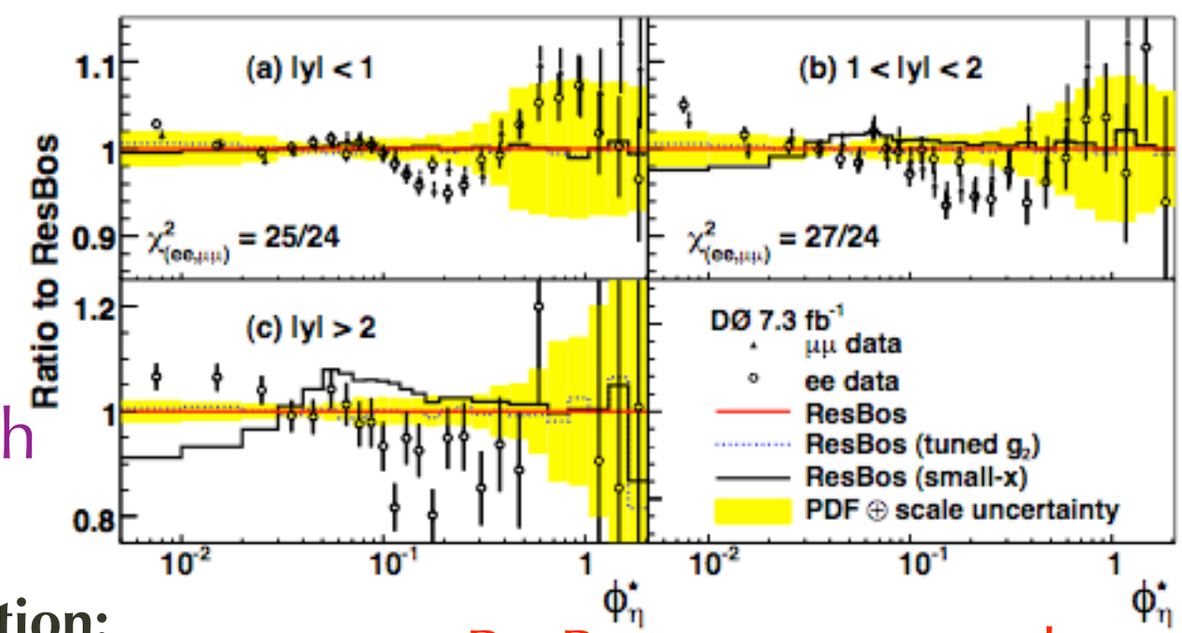
$$\phi^*_\eta = \tan([(\pi - \Delta\phi)/2]\sin\theta^*$$

where

$$\cos\theta^* = \tanh[(\eta^{(-)} - \eta^{(+)})/2]$$

- sensitive to same physics, but much reduced detector uncertainties





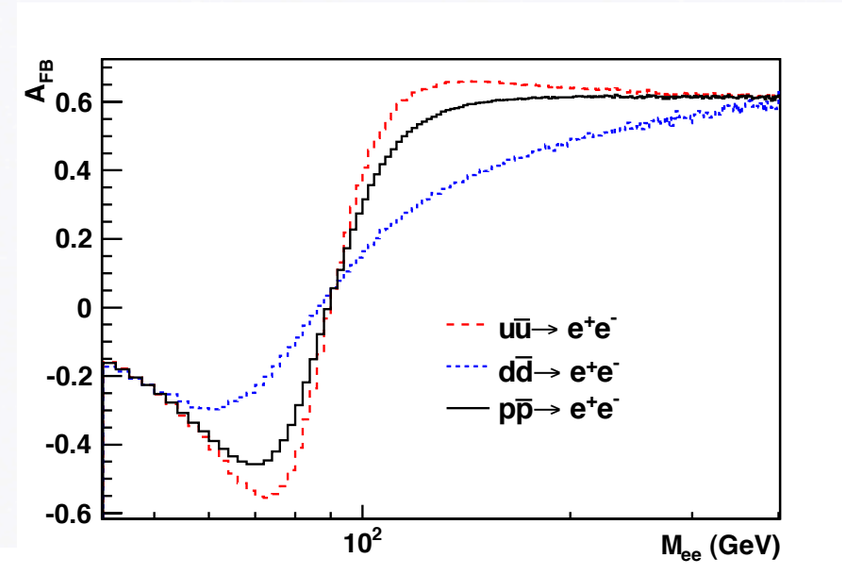
Data are compared with resummed calculation: small uncertainties allow for detailed comparison

ResBos cannot reproduce data everywhere

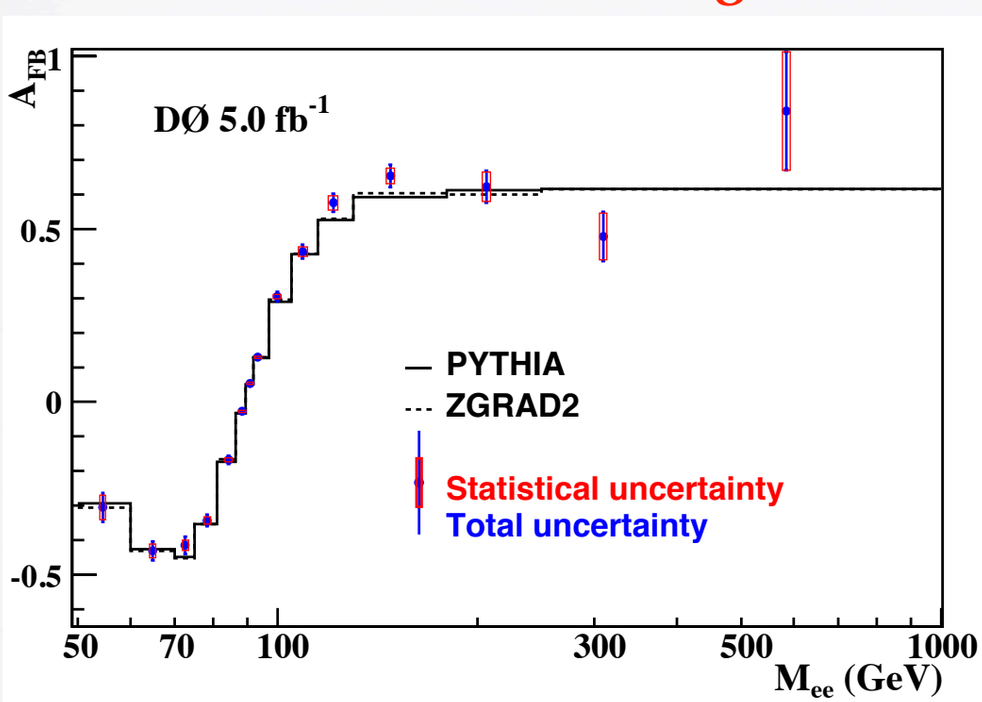
Z/γ* Forward-Backward Asymmetry

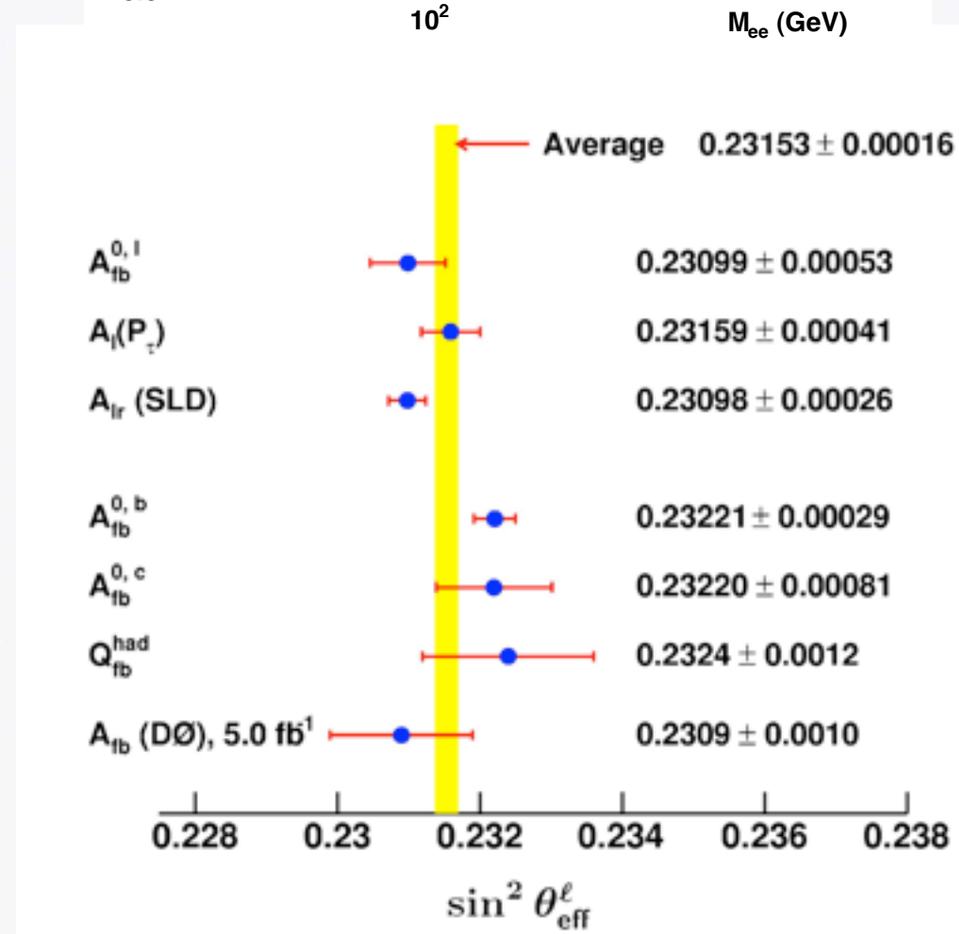
$A_{FB} = (\sigma_F - \sigma_B)/(\sigma_F + \sigma_B)$ where σ_F (σ_B) is $\theta>0$ ($\theta<0$)

Interference between Z and γ* diagrams leads to an enhanced symmetry away from Z pole
- -- high mass dominated by Z - γ* interference
- -- near the Z pole, sensitive to **$\sin^2\theta_{eff}$**



Extraction of effective weak mixing angle:
$\sin^2\theta_{eff}$ = .2309 ± .0008 (stat) + .0006 (syst)
- agrees well with world average





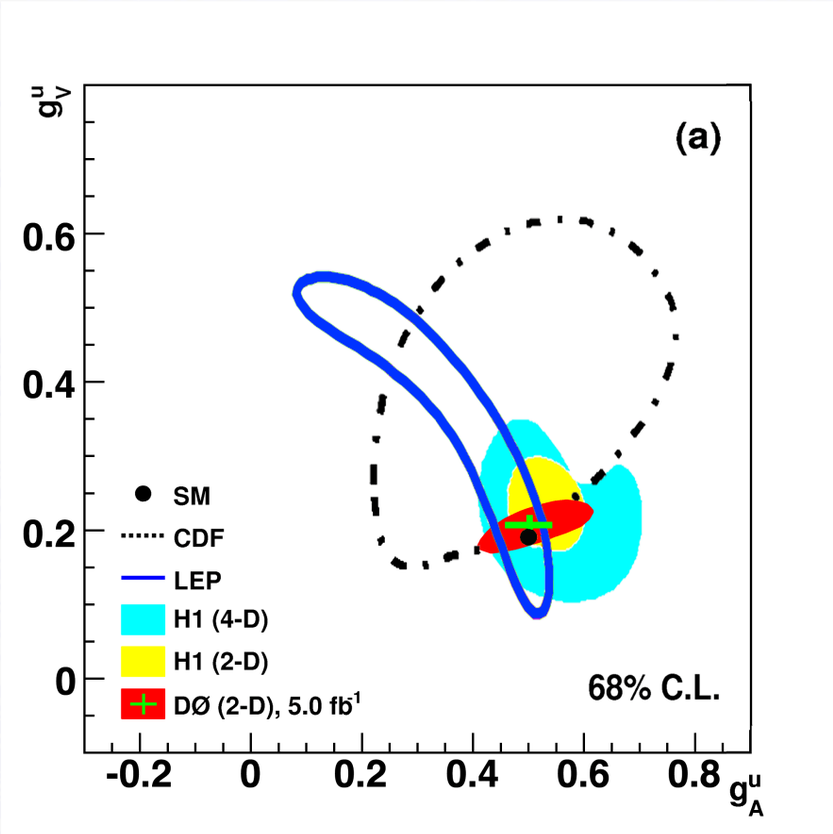
Z/γ* Forward-Backward Asymmetry

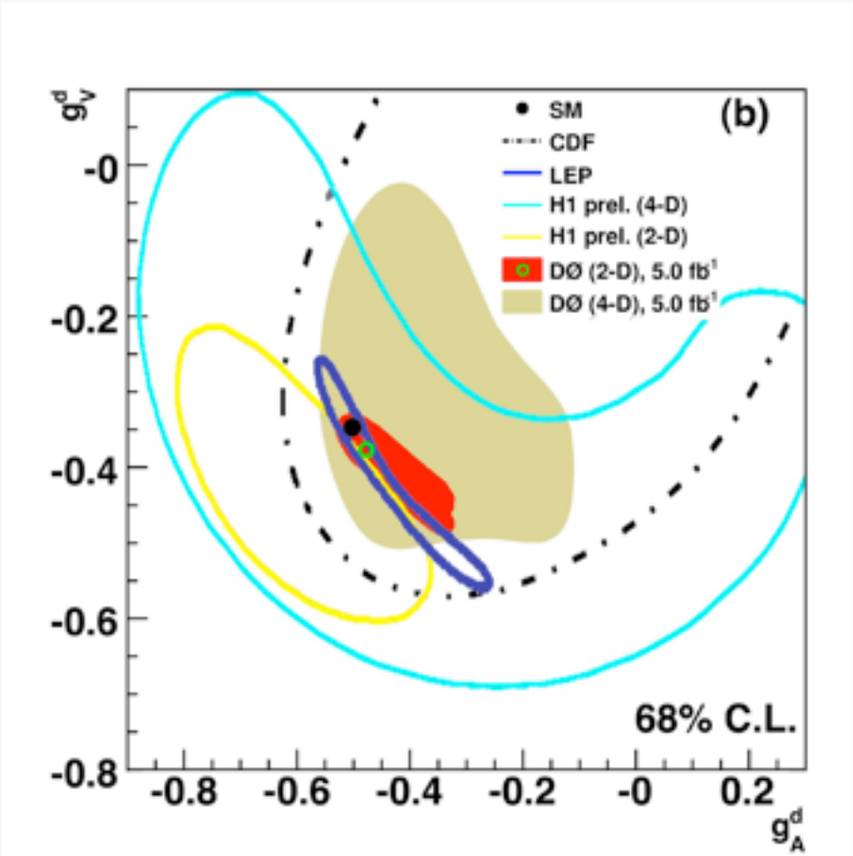
$A_{FB} = (\sigma_F - \sigma_B)/(\sigma_F + \sigma_B)$ where σ_F (σ_B) is $\theta>0$ ($\theta<0$)

A_{FB} sensitive to couplings of the light quarks to the Z

most precise measurements of these light quark couplings to the Z to date!

2-D and 4-D fits are made to u, d vector and axial vector couplings to Z
68% confidence level contours of g_V^u , g_A^u and g_V^d , g_A^d
compared to other experiments



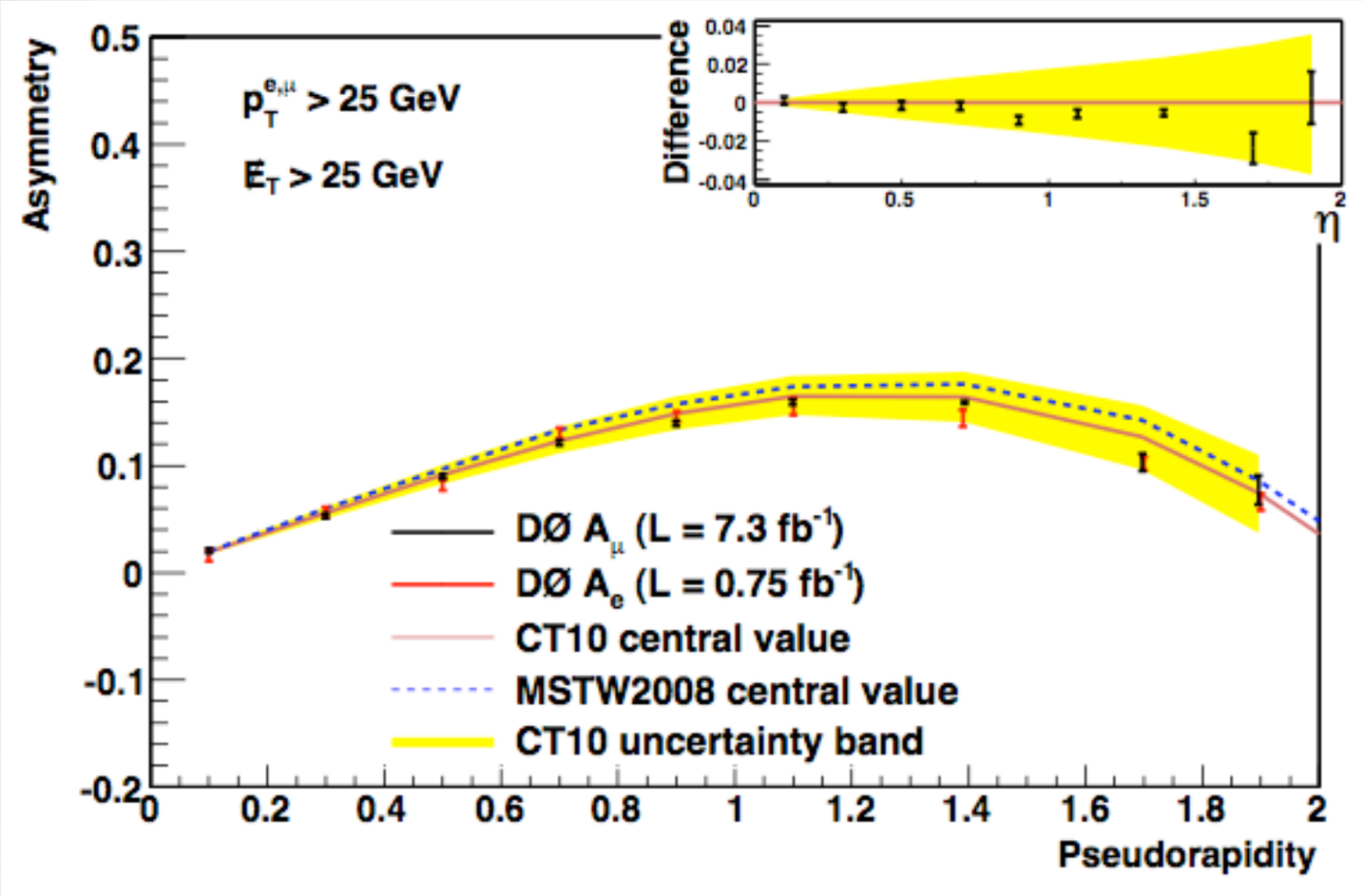


Lepton Charge Asymmetry in W→lν

$$A(\eta) = \frac{d\sigma(\mu^+)/d\eta - d\sigma(\mu^-)/d\eta}{d\sigma(\mu^+)/d\eta + d\sigma(\mu^-)/d\eta}$$

Lepton asymmetry is convolution of W boson asymmetry and asymmetry from (V-A) nature of W boson decay

Precise measurement provides important PDF inputs



Data precision better than PDFs

Excellent agreement between electron and muon channels

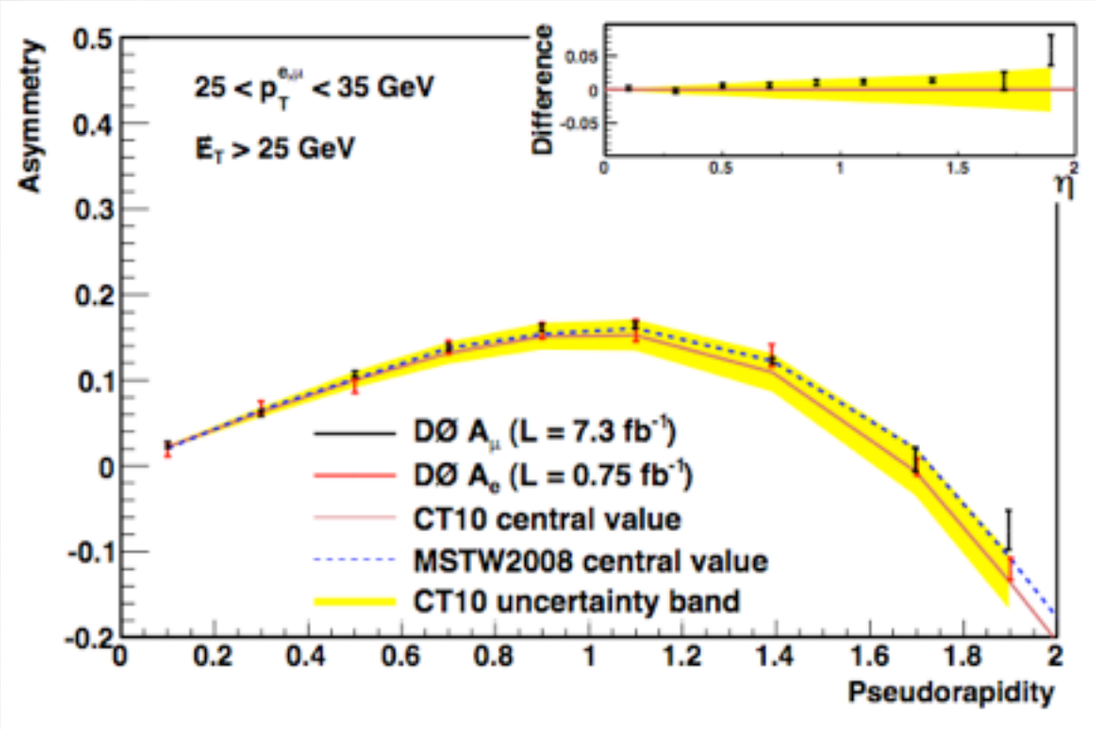
Lepton Charge Asymmetry in W→lν

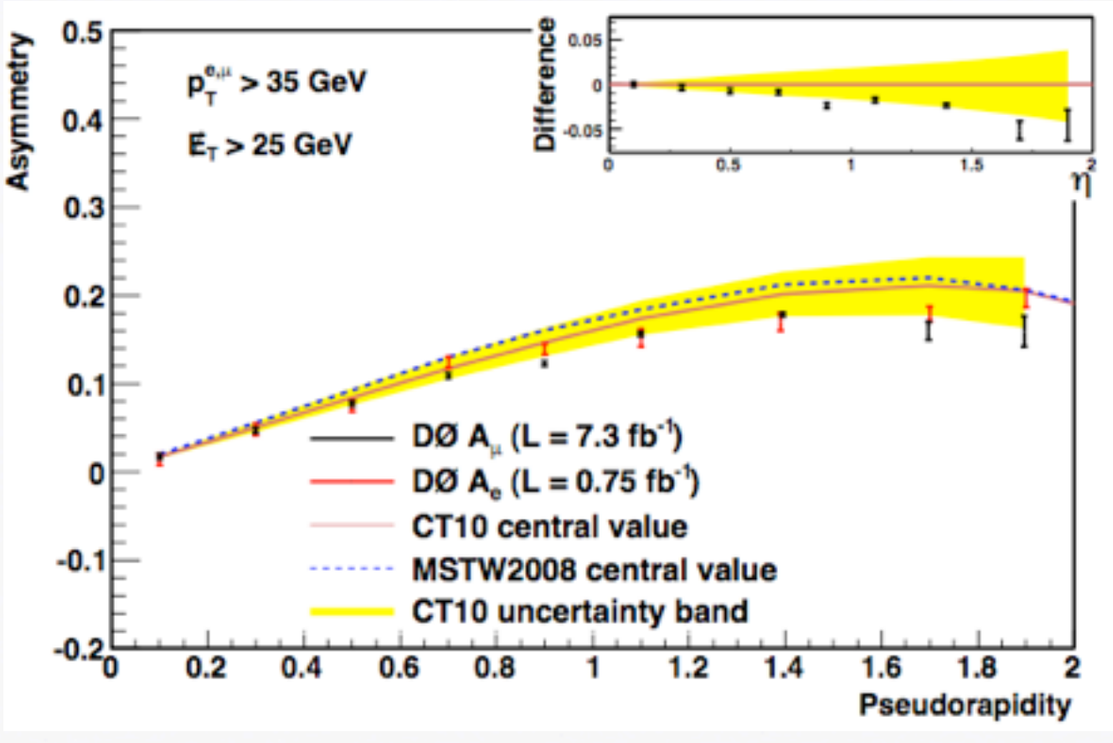
$$A(\eta) = \frac{d\sigma(\mu^+)/d\eta - d\sigma(\mu^-)/d\eta}{d\sigma(\mu^+)/d\eta + d\sigma(\mu^-)/d\eta}$$

Lepton asymmetry is convolution of W boson asymmetry and asymmetry from (V-A) nature of W boson decay

Precise measurement provides important PDF inputs

Two bins of lepton E_T probe different regions of W rapidity → finer probe of x-dependence

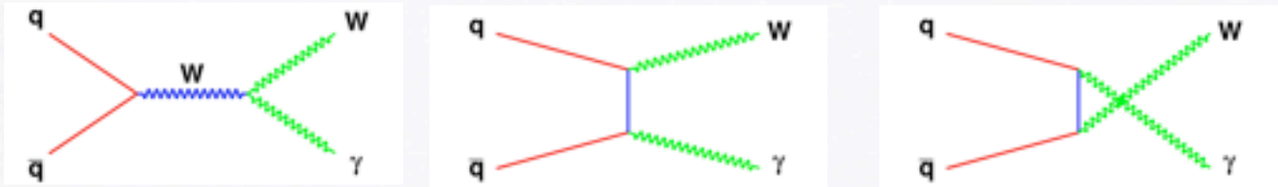




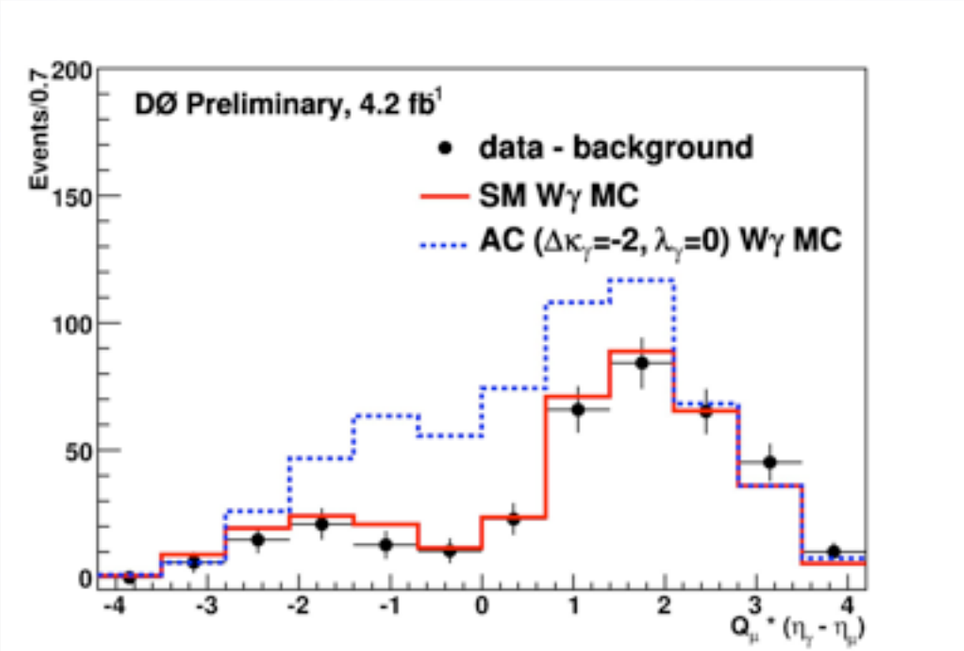
Dibosons

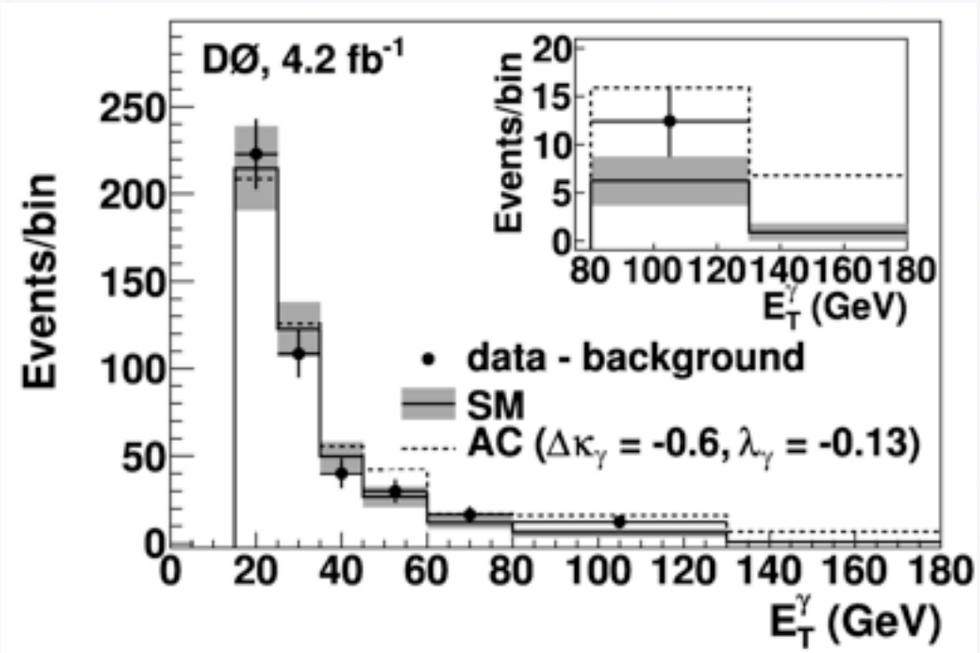
Dibosons - Wγ

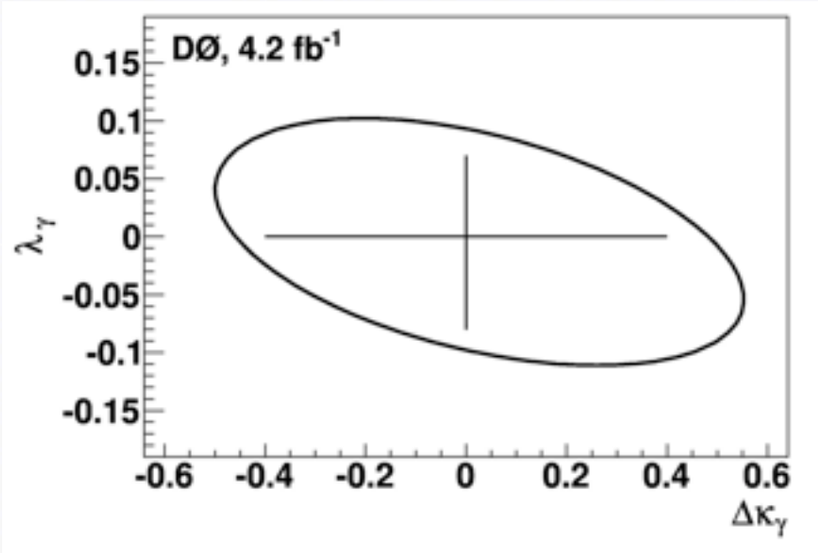
Wγ



- search for radiation amplitude zero (RAZ)
- seen as a dip in signed γ-l rapidity difference
- look for anomalous couplings





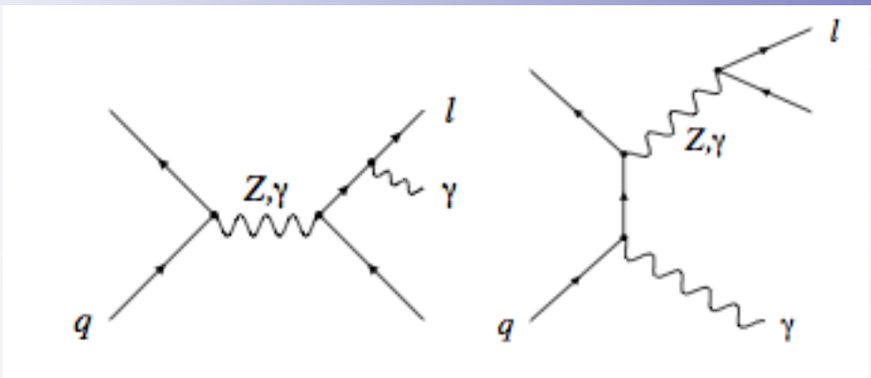


Results are in agreement with SM prediction, and we produce some of the best AC limits at hadron collider to date!

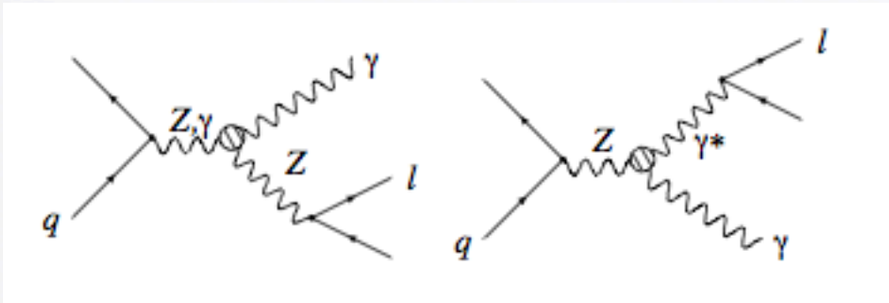
Submitted to PRL arXiv:1109.4432

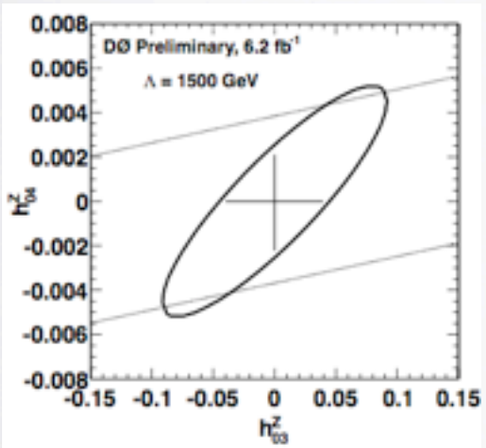
Dibosons - Zγ

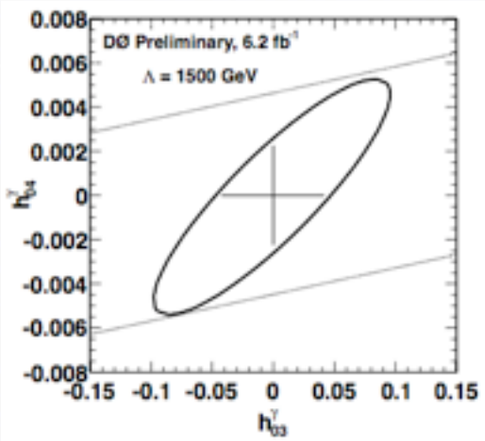
Zγ

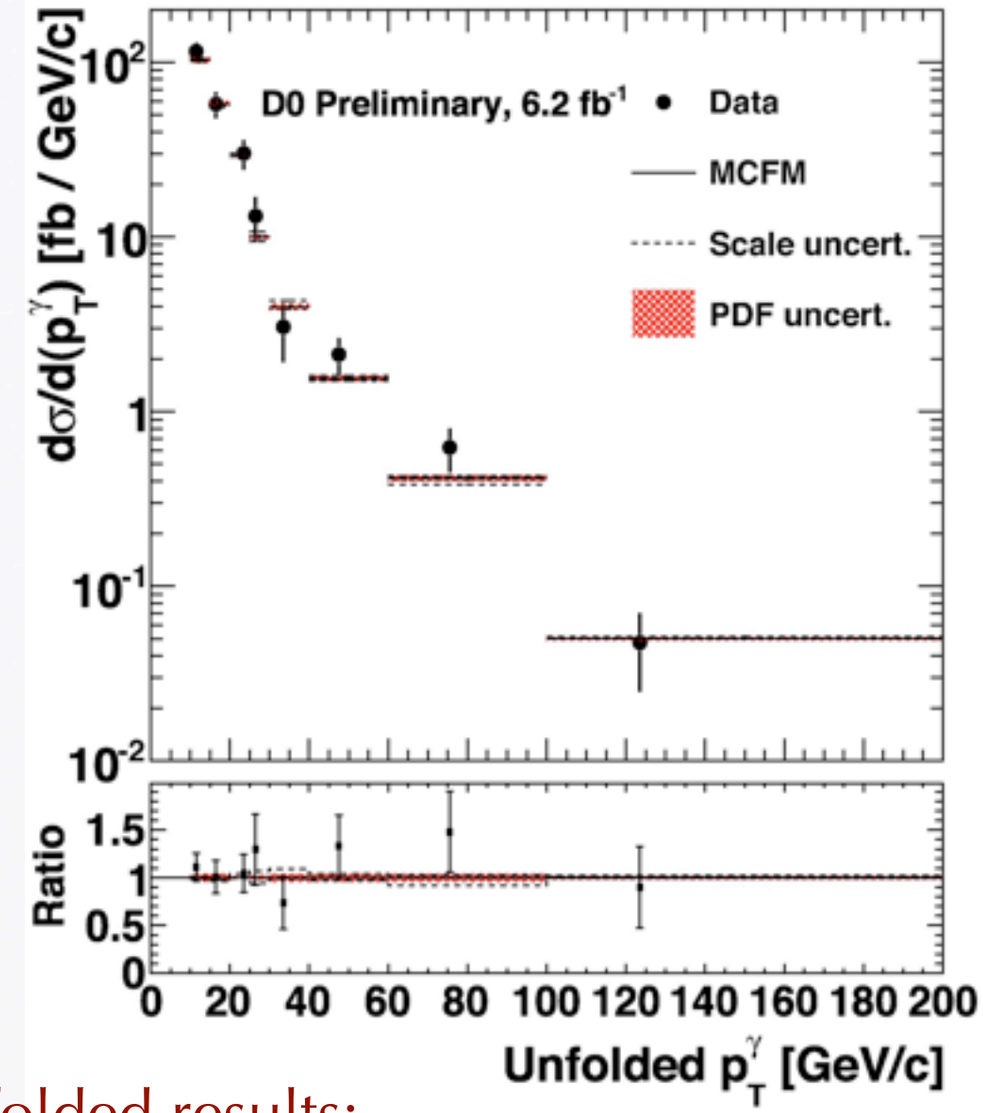


- Zγ couplings not allowed in SM
- search for anomalous ZZγ couplings :









Fully unfolded results:

	$\sigma \times \mathcal{B}$ [pb]
$ee\gamma$ Data	1.03 ± 0.06 (stat.) ± 0.06 (syst.)
$\mu\mu\gamma$ Data	1.16 ± 0.06 (stat.) ± 0.07 (syst.)
$ll\gamma$ Combined Data	1.09 ± 0.04 (stat.) ± 0.07 (syst.)
NLO MCFM	1.10 ± 0.03

Dibosons - WW, WZ, ZZ

Large dataset allows us to measure processes with σ as low as~ 1pb

- 100 leptonic WW events in 1.1 fb-1

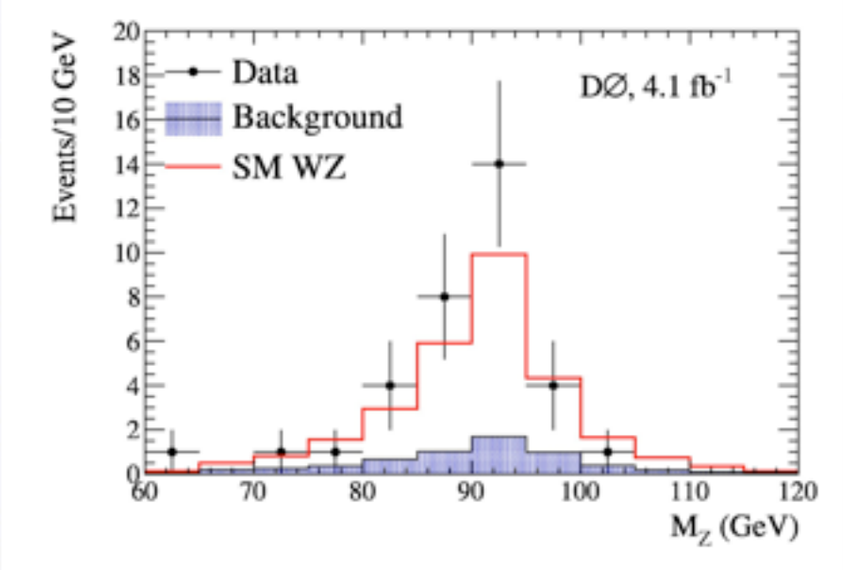
  $\sigma(p\bar{p} \to WW) = 11.5 \pm 2.1(syst + stat) \pm 0.7(lumi)$

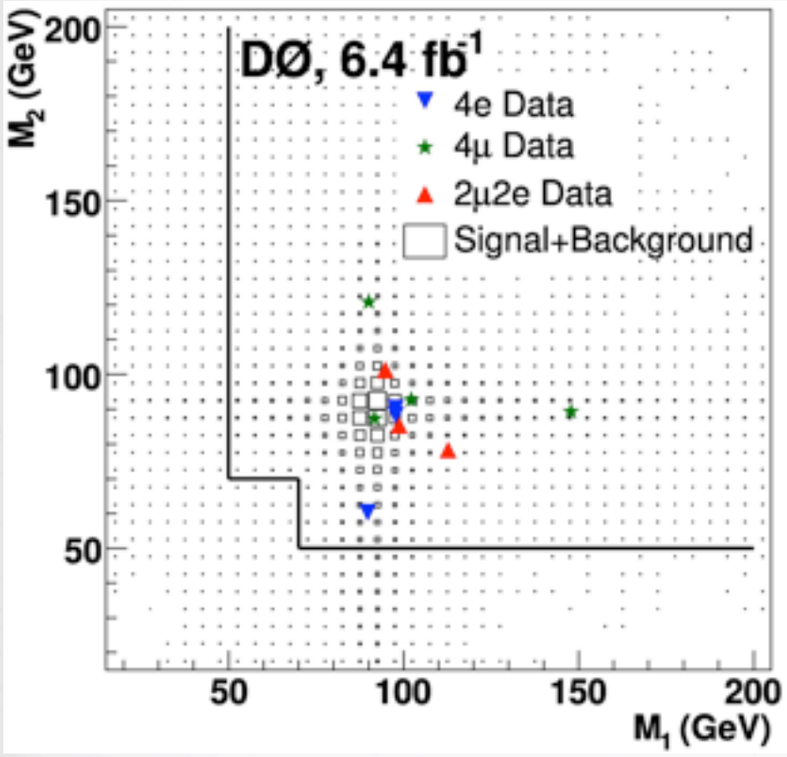
- 34 leptonic WZ events in 4.1 fb-1

  $\sigma(p\bar{p} \to WZ) = 3.9^{+1.06}_{-0.9}\ pb$

- 10 leptonic ZZ events in 6.4 fb-1

  $\sigma(p\bar{p} \to ZZ) = 1.45^{+0.53}_{-0.43}\ pb$



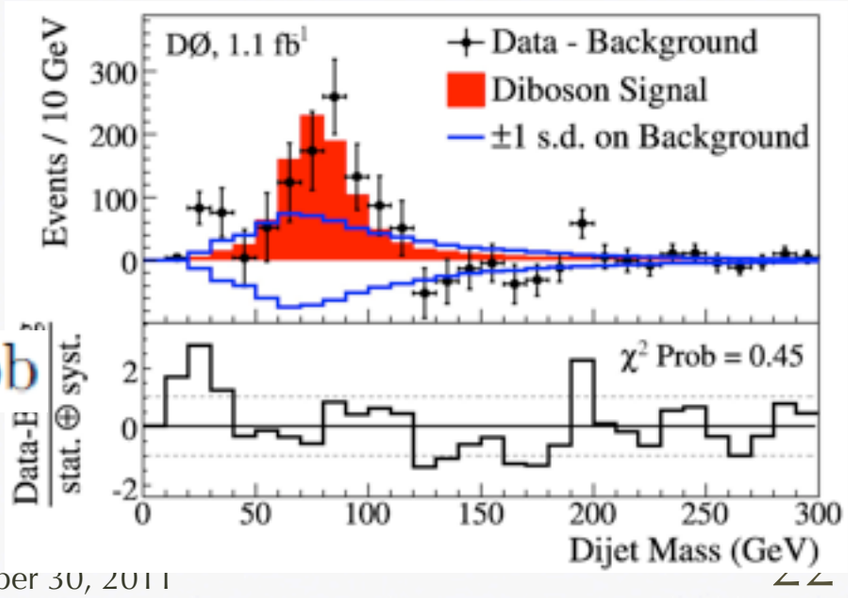


All in agreement with SM, stringent AC limits set

Coupling relation	95% C.L. Limit
$\Delta g_1^Z = \Delta\kappa_Z = 0$	$-0.075 < \lambda_Z < 0.093$
$\lambda_Z = \Delta\kappa_Z = 0$	$-0.053 < \Delta g_1^Z < 0.156$
$\lambda_Z = \Delta g_1^Z = 0$	$-0.376 < \Delta\kappa_Z < 0.686$
$\Delta\kappa_Z = 0$ (HISZ)	$-0.075 < \lambda_Z < 0.093$
$\lambda_Z = 0$ (HISZ)	$-0.027 < \Delta\kappa_Z < 0.080$

First evidence (4.2σ) for WV→lνjj at the Tevatron

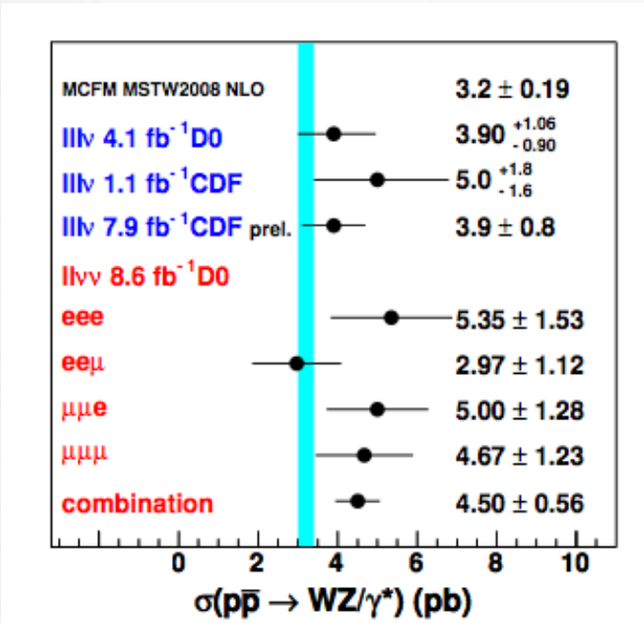
$\sigma(WV) = 20.2 \pm 4.5$ pb

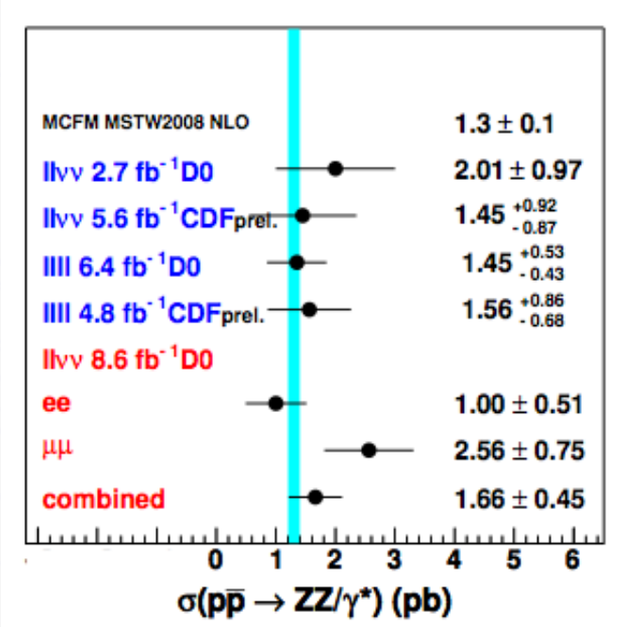


Dibosons - WZ, ZZ

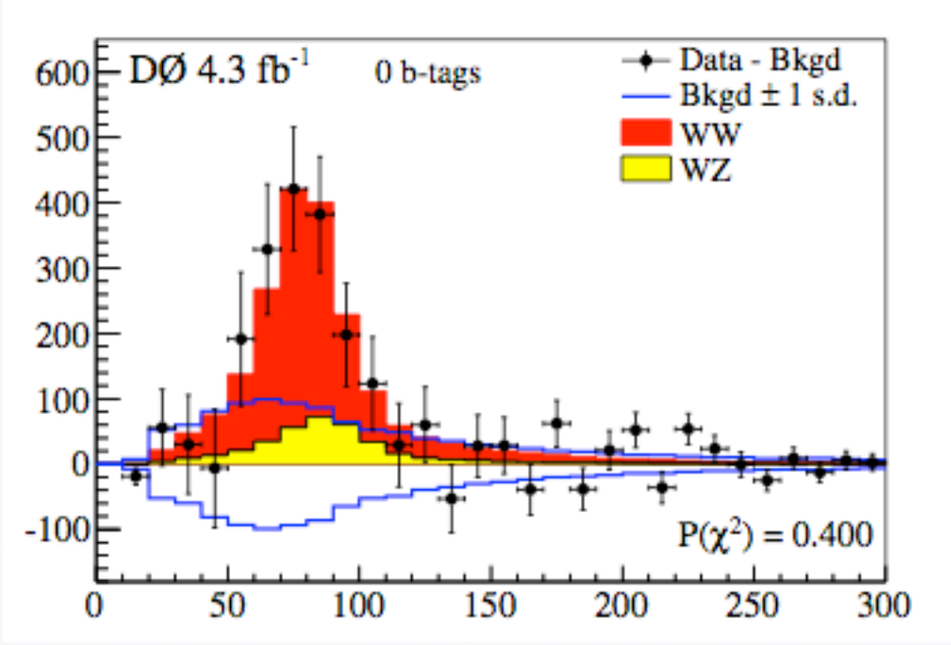
work in progress!

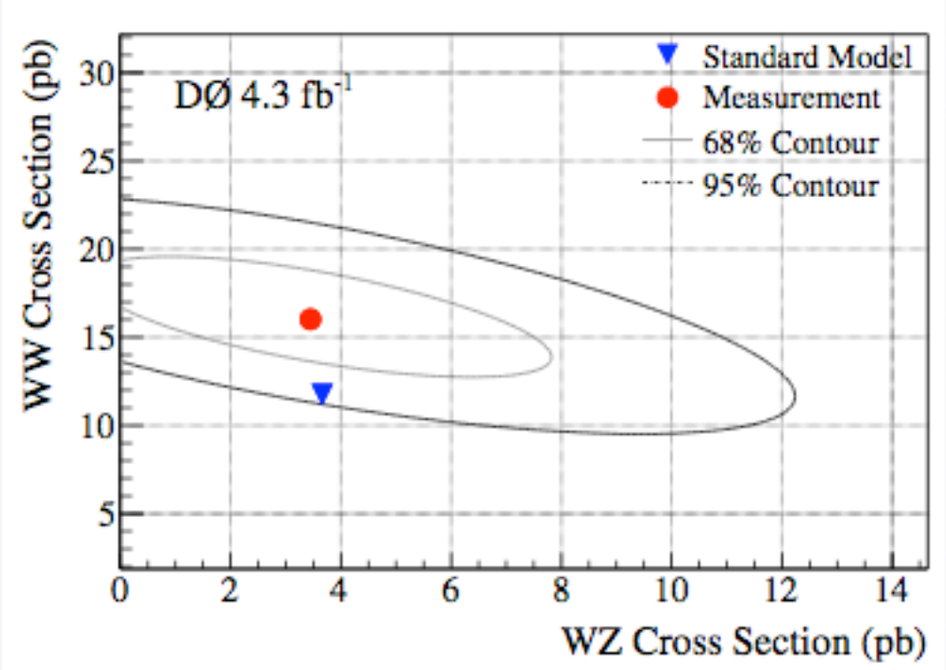
Fully leptonic final state





Lepton + jets final state

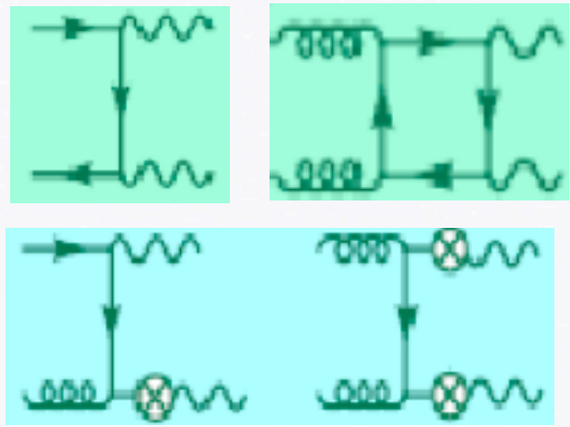




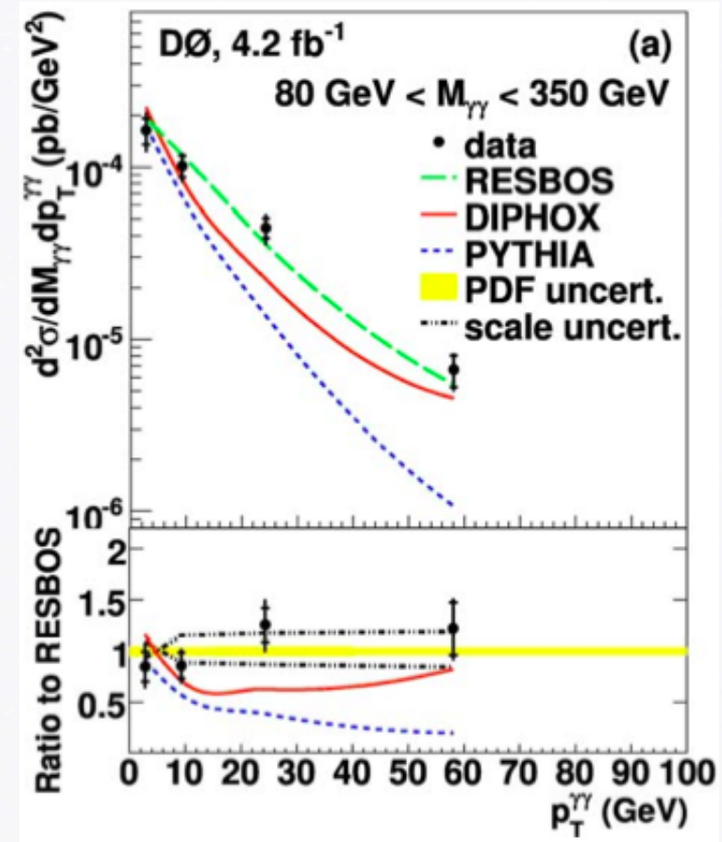
Updated measurement uses 8.6 fb^{-1}

Prompt Diphoton Production

- Prompt diphotons are produced directly in hard scattering or through quark fragmentation
- sensitive to energy scale, ISR, fragmentation, PDFs



H->γγ currently main channel for SM Higgs discovery at low mass at LHC



Theory predictions:

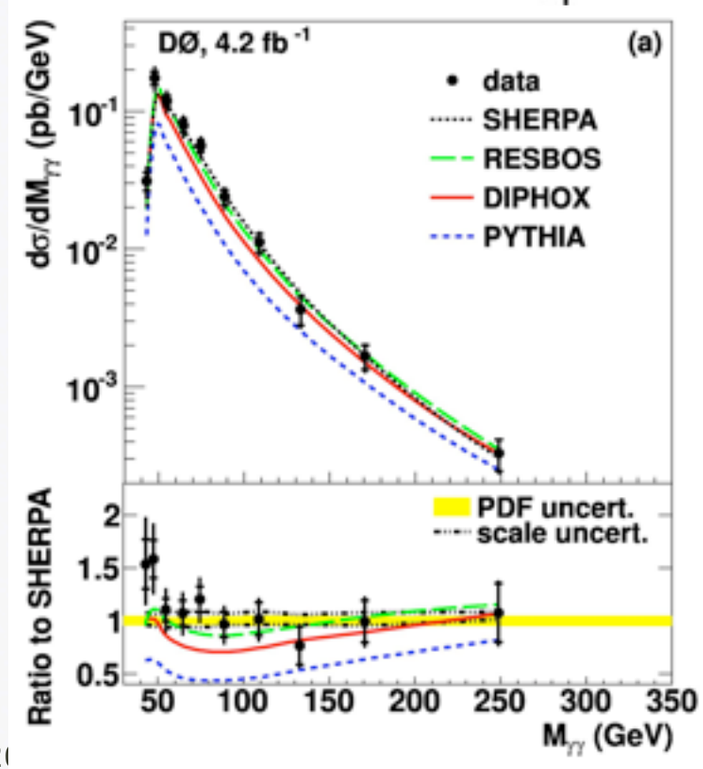
PYTHIA: Parton Shower

DIPHOX: fixed order NLO calculation

RESBOS: Resummed calculation (to NNLL)

In region where SM Higgs and New Physics is of most interest, RESBOS gives excellent data description

Data is not described by any theory at lowest diphoton masses

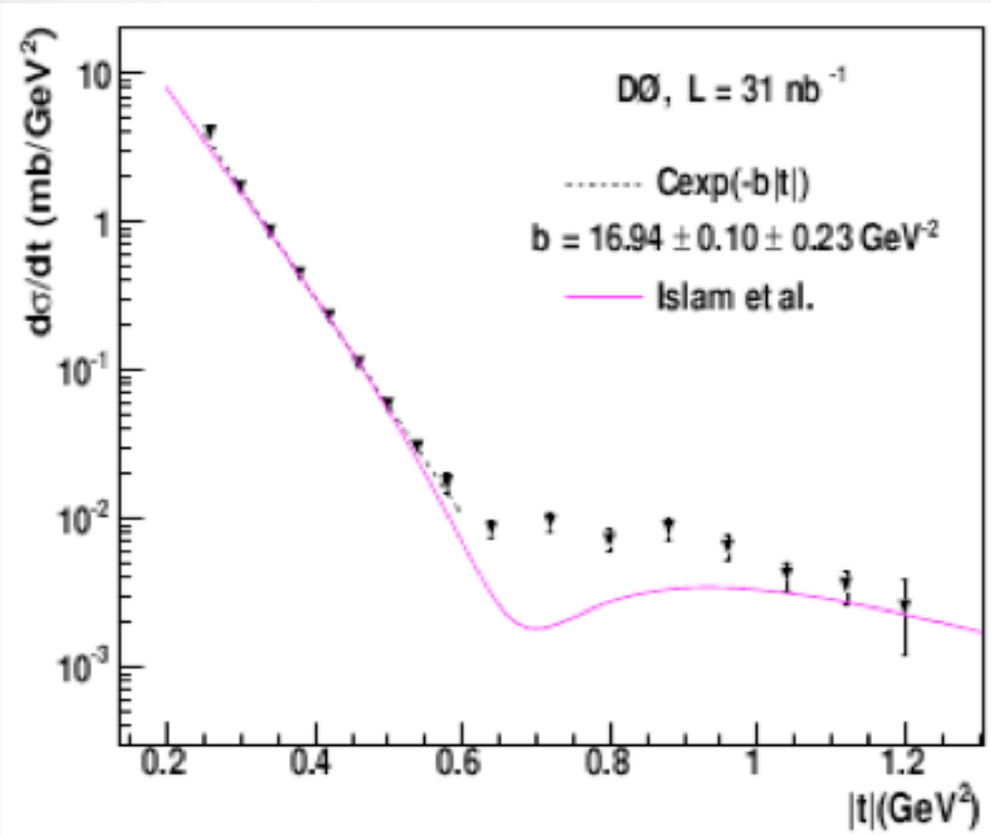


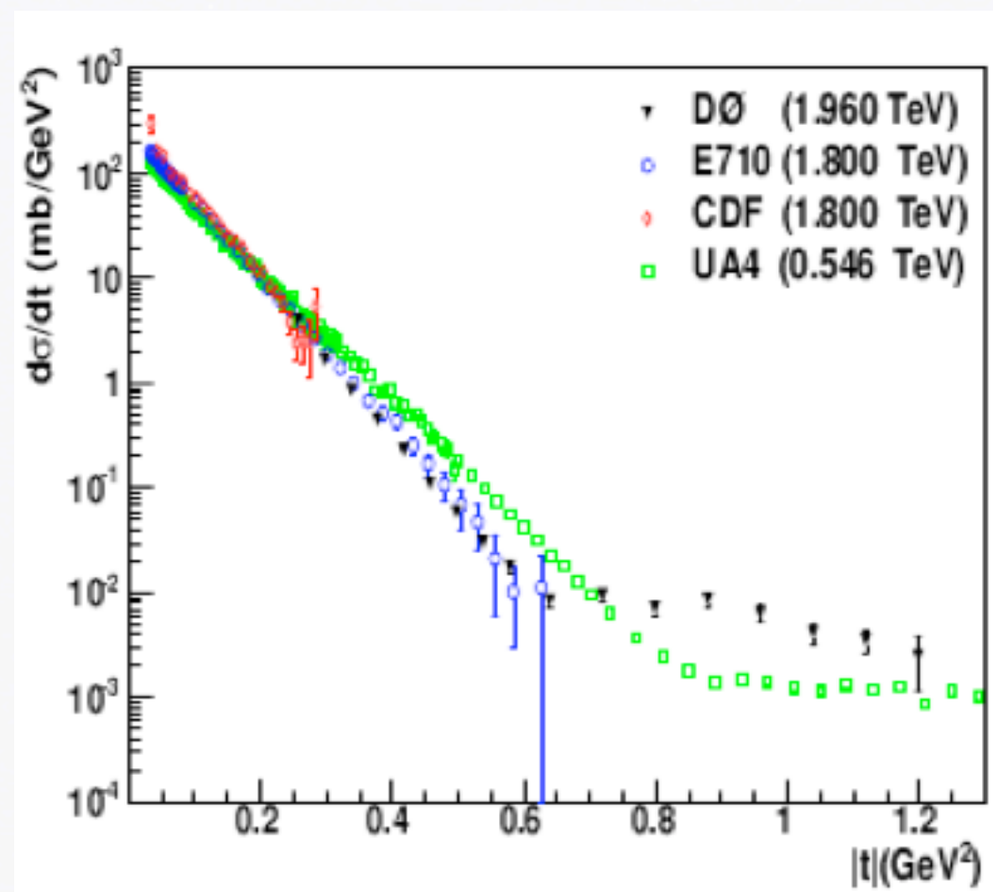
Phys. Lett. B **690**, 108 (2010), arXiv.org:1002.4917

Diffraction and Elastic Scattering

Total Elastic Cross Section

- Fundamental measurement of $d\sigma/dt$ t = 4-momentum transfer
- Gives information on nucleon structure, non-perturbative effects
- First measurement using FPD, data taken in special runs
- Compare to phenomenological models, other experiments





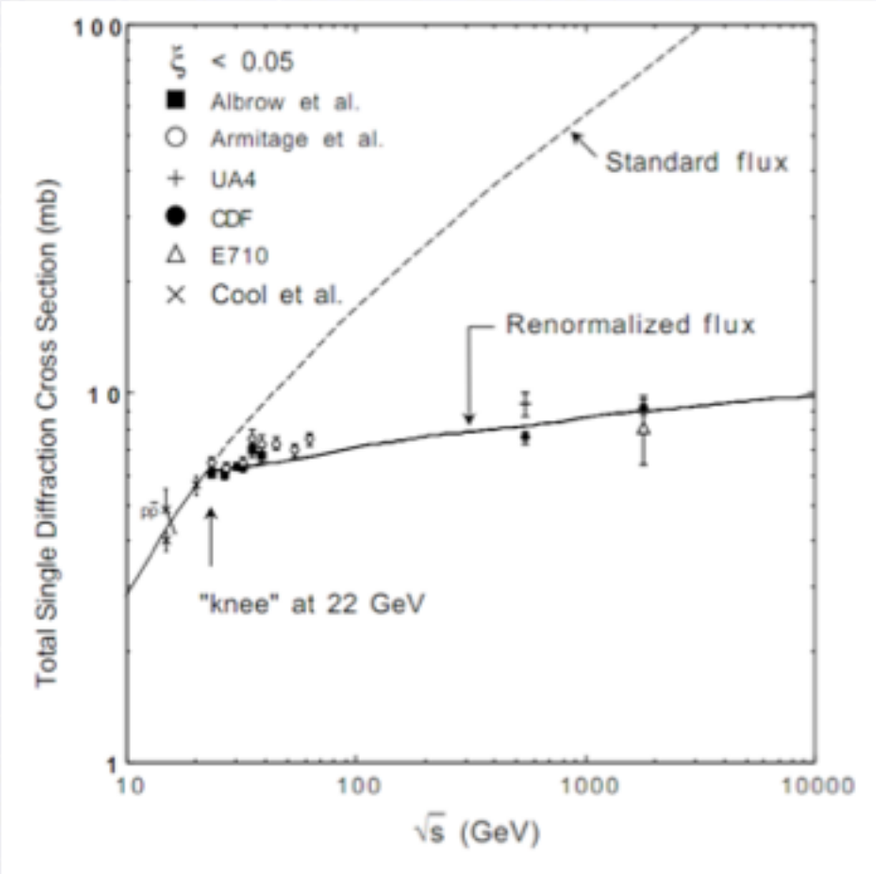
Single Diffractive Xsec

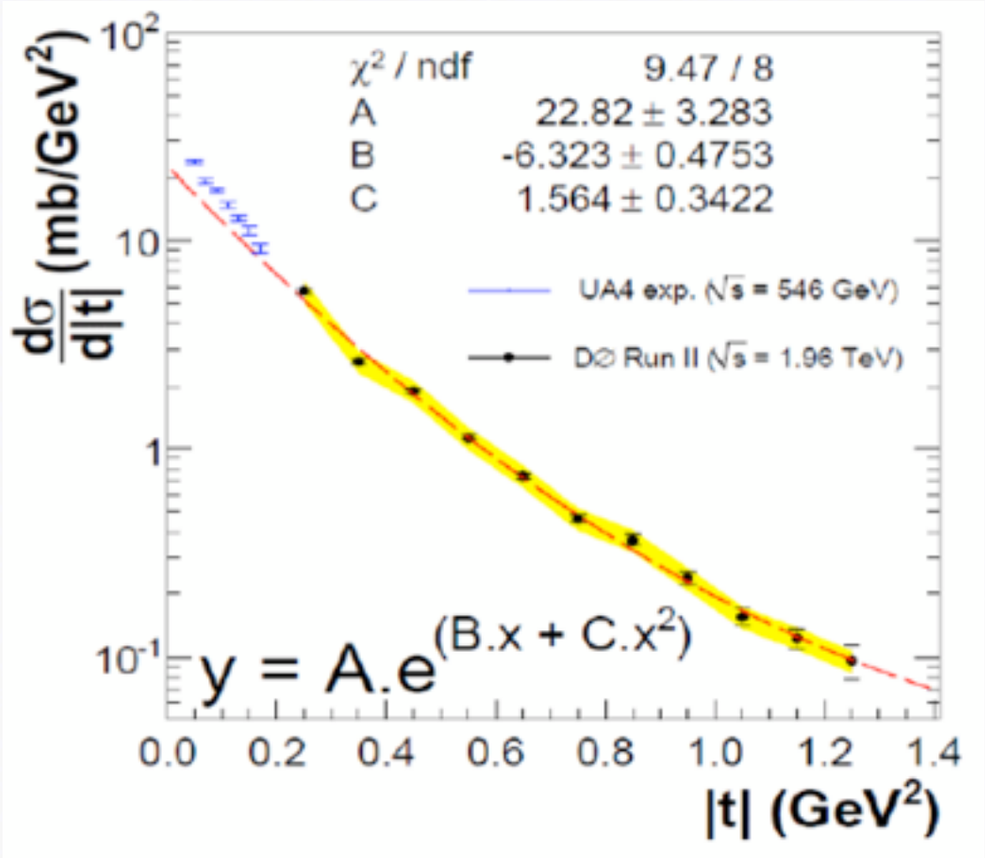
Test of Regge approach with renormalized pomeron flux

Also uses FPD, measures in same kinematic region as elastic measurement

Nice agreement between result and theoretical model being tested, as well as other experiments

Calc. method	$\|t\|$ range	Total σ_{sd}
DØ Data fit	0.2 - 1.3	2.694 ± 0.044 (stat.) ± 0.338 (syst.) mb
DØ Data fit + extrapolation	0.0 - 1.3	7.950 ± 0.324 (stat.) ± 1.007 (syst.) mb
DØ Data + UA4 Data fit	0.0 - 1.3	9.681 ± 0.048 (stat.) ± 1.219 (syst.) mb

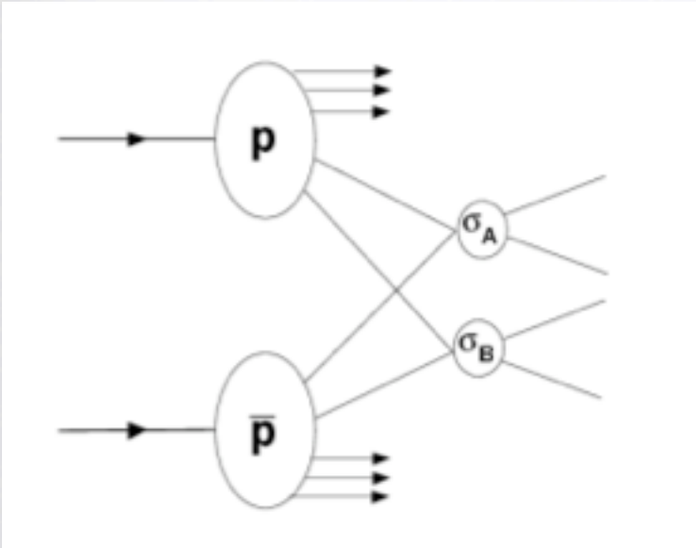




MPI, soft physics, underlying event

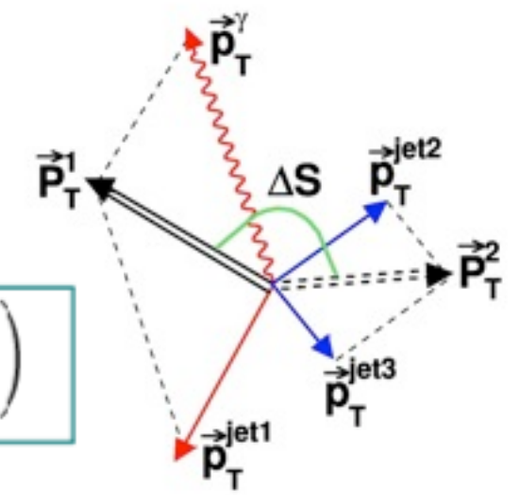
Double Parton Interactions

Look for two hard scatters in same p-pbar interaction



✦ **Provides complementary information on proton structure**
✦ **May be important background for high-p_T searches**

Uses γ + 3 jet topology



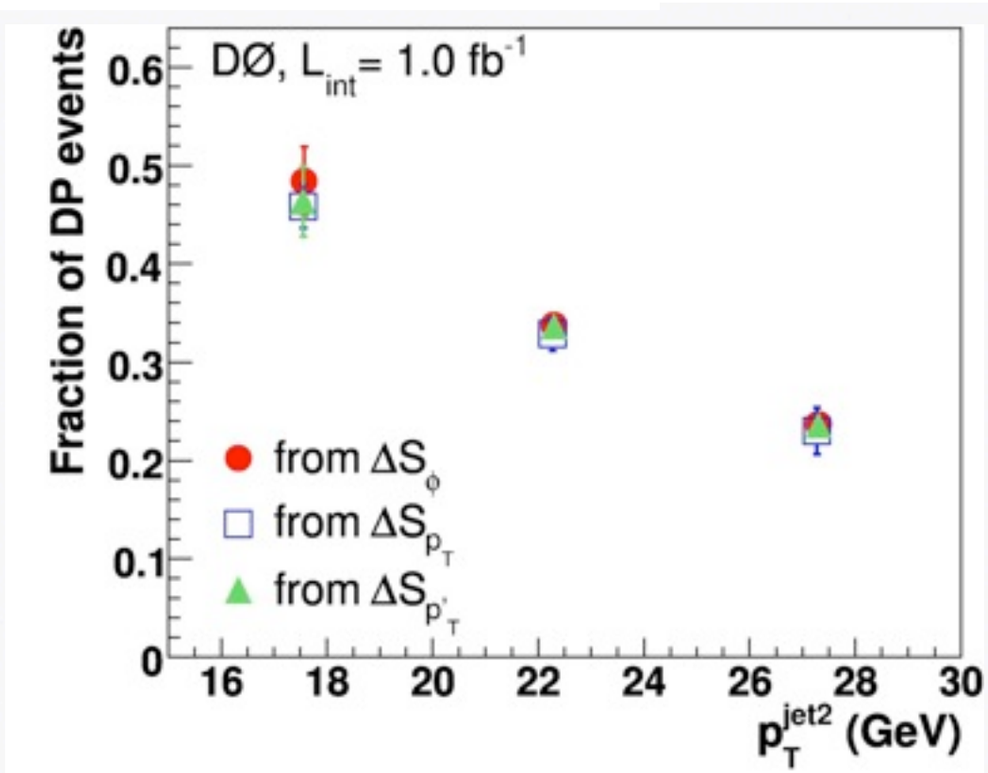
Discriminant:

$$\Delta S = \Delta\phi\left(\mathbf{p}_T^{\gamma,jet_i},\ \mathbf{p}_T^{jet_j,jet_k}\right)$$

Δϕ - an azimuthal angle between two best pT-balanced pairs.

DP Updates in the works:

- unfolding distributions
- triple parton interactions
- γ + b + 2 jets topology
- parton x correlations
  ➡ provides information for building optimal MPI model



Summary and Conclusion

- QCD and EW legacy measurements
  - unprecedented precision
  - extract fundamental constants like α_s and $\sin^2\theta_W$ from measurements
  - we will learn much more by looking at the full dataset
- Precision physics => this has taken us years to achieve, techniques have been ported to the LHC experiments
- Our inputs to PDF fits have large impact
- W/Z/γ + jets, diboson measurements crucial for understanding backgrounds to New Physics and SM Higgs searches
- Anomalous coupling limits are some of the world's best
- Dedicated, small group of physicists working extremely diligently to make the most of the terrific performance of the Tevatron
- Expect to see several new results using the full 10 fb-1 in 2012

Additional Slides

Outlook

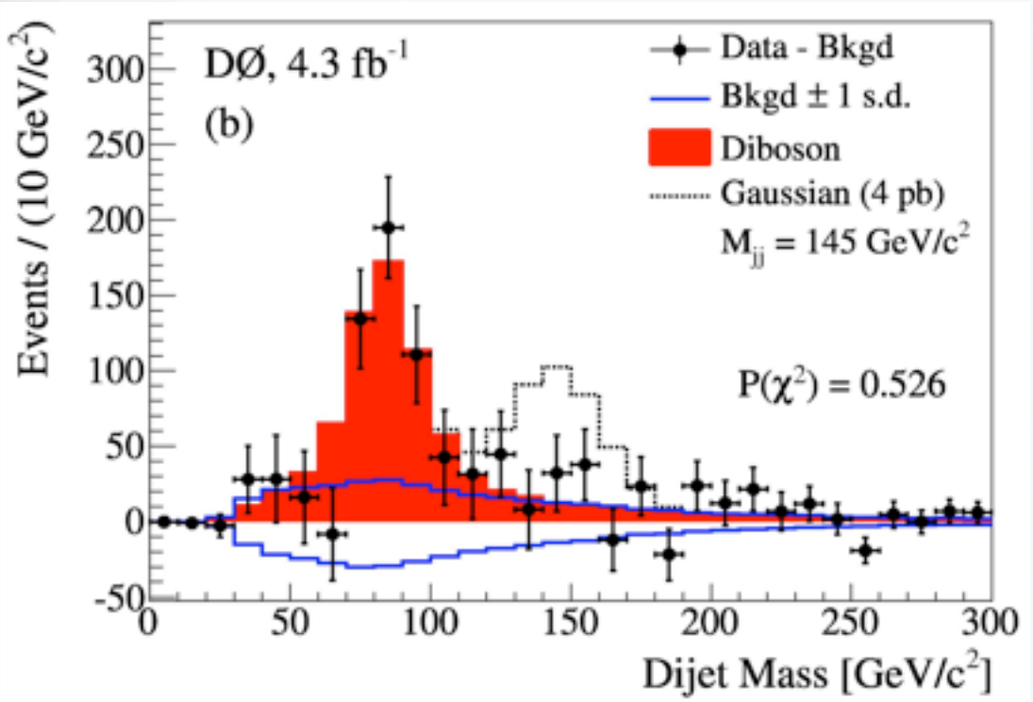
★ QCD and EW Physics with the full dataset

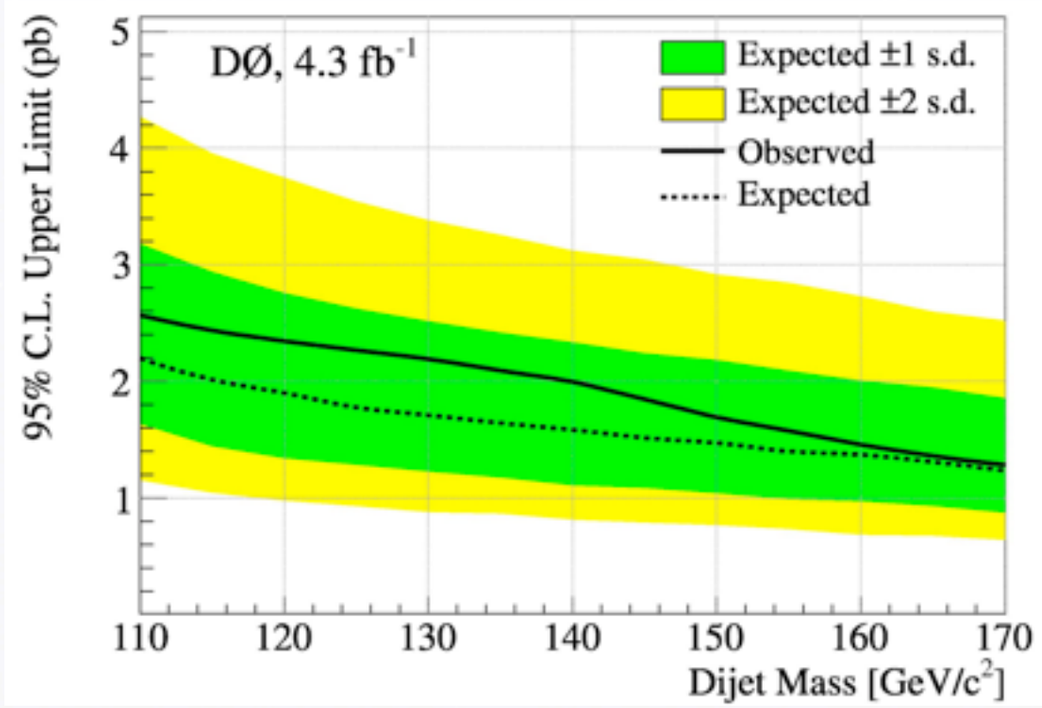
- Inclusive Jets at high pT
- Determinations of α_s from multijet production
- Dijets: triple differential cross sections are ultimate source of PDF information
- W/Z/γ + b(b) and c(c) cross sections
- b-jet energy scale from Z->bb
- Diphoton cross sections in central, forward region
- Double parton scattering in other final states
- Combined D0/CDF A_{FB} results
- increased precision of diboson cross sections and better limits on anomalous gauge couplings
- W mass with full dataset
- WZ with Z->bbar

Measurements covered in dedicated plenary talks

- W Mass - see Thursday's talk by Jan Stark
- Diboson with heavy flavor tagging - see Wednesday's talk by Gabe Facini

Anamolous W+2jet production (aka CDF bump)

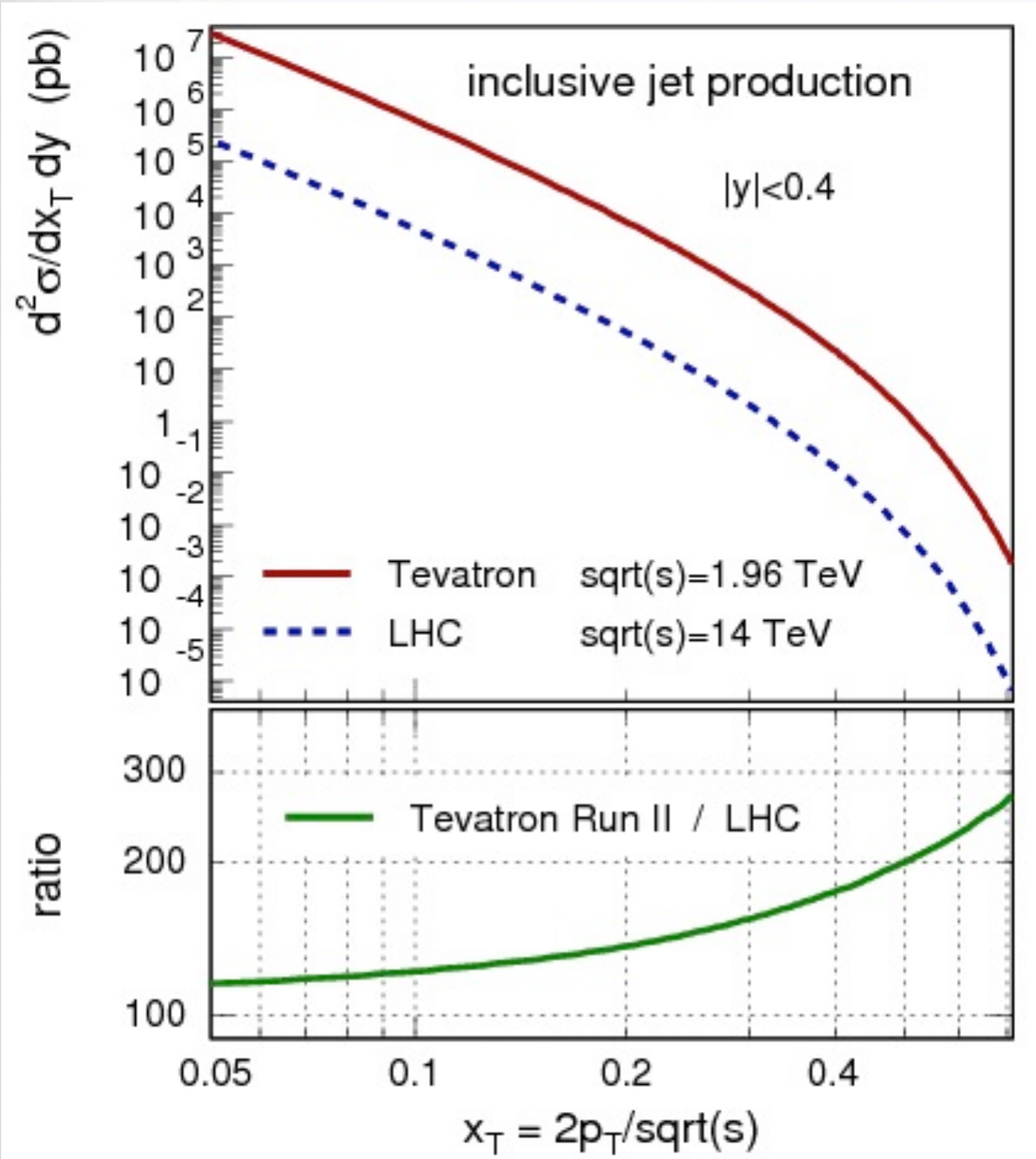




- Significance of the CDF bump is 4.1σ (with systematics), 4.8σ without systematics
- D0 does not see evidence for a signal
- Serious issue for CDF to understand this

For more info: http://www-cdf.fnal.gov/physics/ewk/2011/wjj/7_3.html

Inclusive Jets: Tevatron vs LHC



PDF sensitivity:

→ compare jet cross section at fixed $x_T = 2\ p_T$ / sqrt(s)

Tevatron (ppbar)

>100x higher cross section @ all x_T

>200x higher cross section @ x_T >0.5

LHC (pp)

- need more than 2400 fb^{-1} luminosity to improve Tevatron@12 fb^{-1}
- more high-x gluon contributions
- but more steeply falling cross sect. at highest p_T (=larger uncertainties)

Tevatron Results will dominate high-x gluon for several years