Top and QCD at the Tevatron

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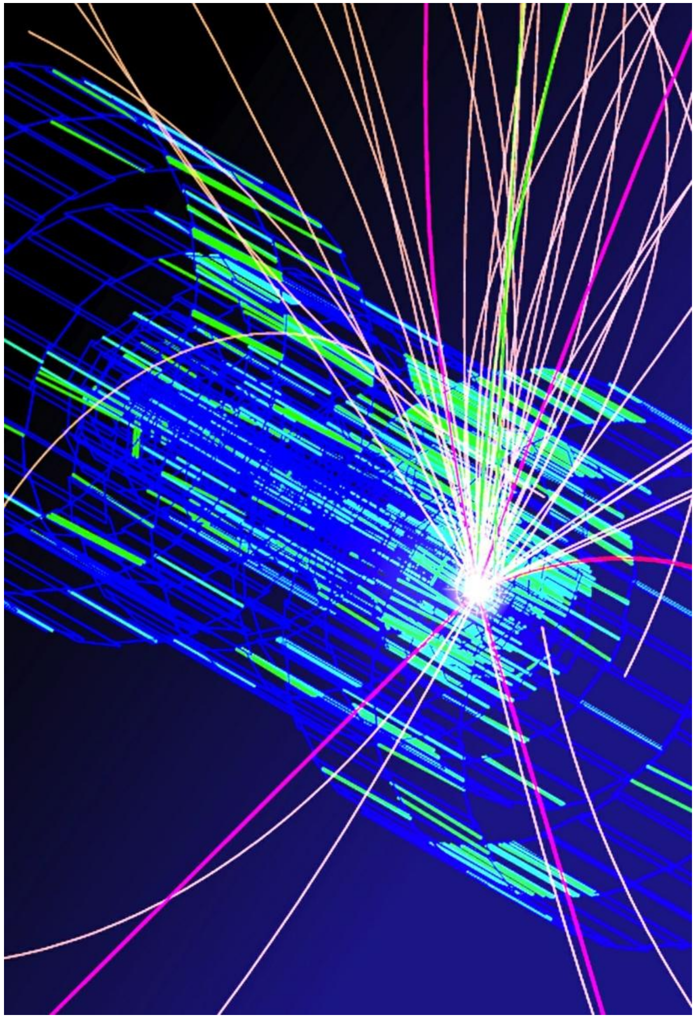
Outline

- Fermilab and Tevatron
- Top Quark Physics
  - Ttbar cross section
  - Top quark mass
  - Forward-backward asymmetry
  - Single top quark production
- QCD Measurements
  - Jet production
  - W+jets/HF production
  - Z+Jets/HF and Photon+HF production
  - Energy scan
- Summary & Remarks

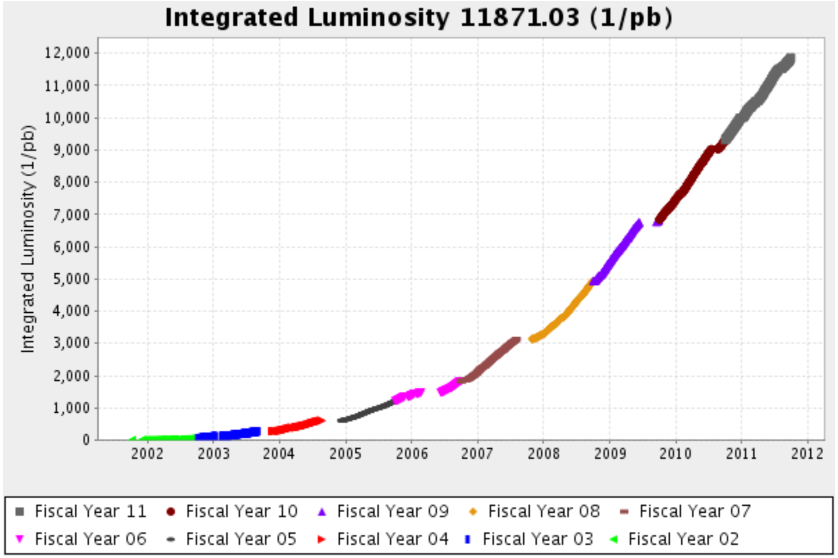


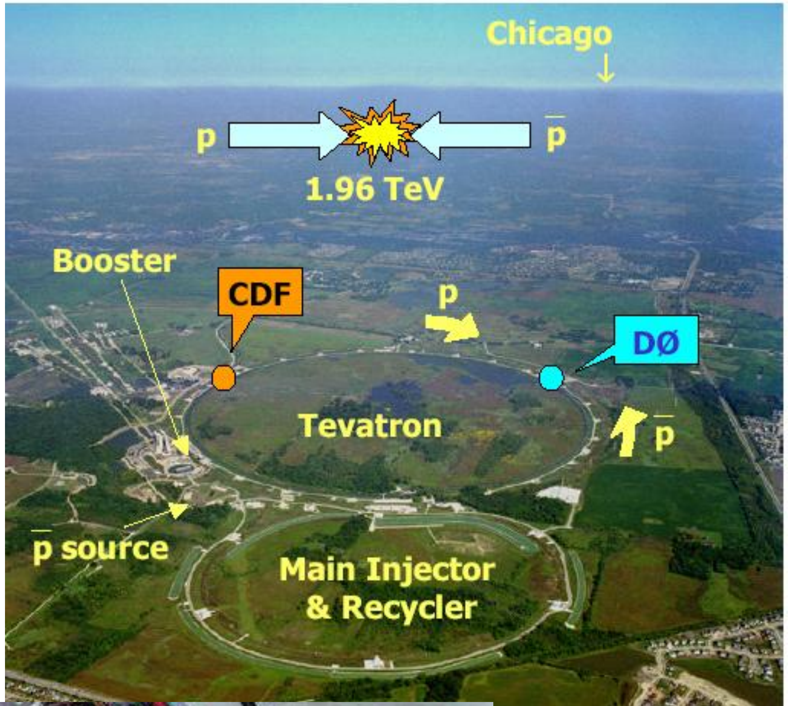
The Fermilab Tevatron

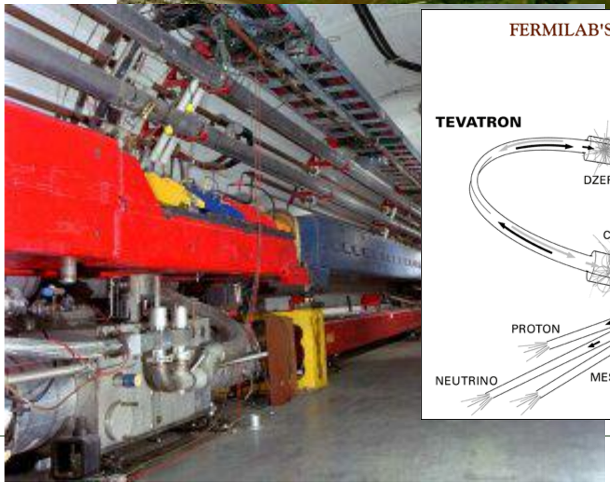
The Fermilab Tevatron

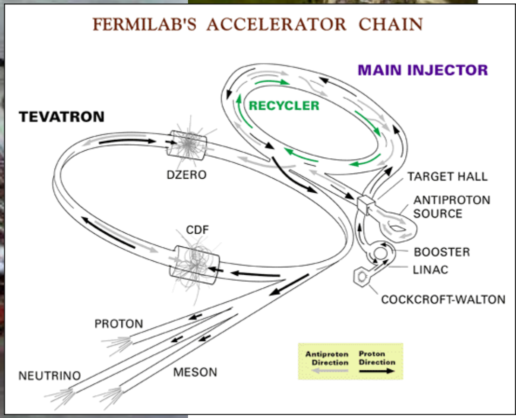
Run II at the Tevatron

- Proton-antiproton collisions at 1.96 TeV
- March 2001 – September 2011
- Peak luminosity 4.3 x 10^{32} $cm^{-2}s^{-1}$
- Delivered integrated luminosity ~12 fb^{-1}





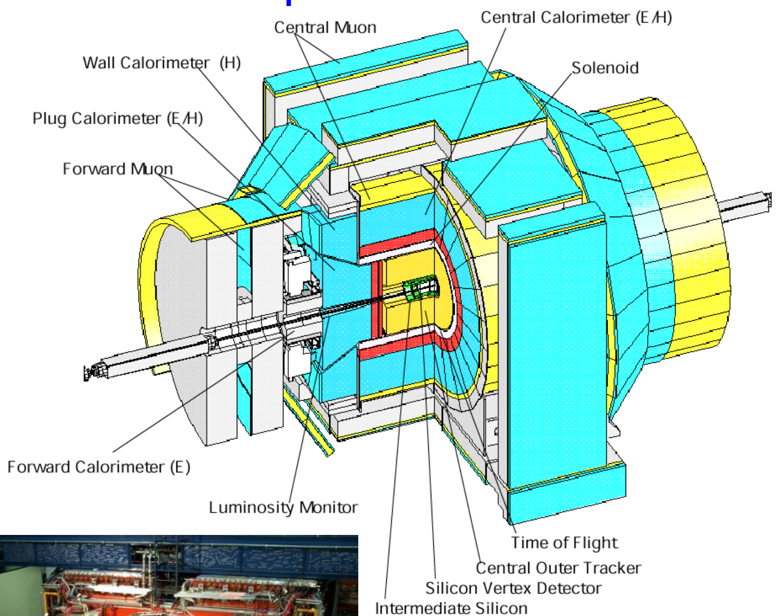


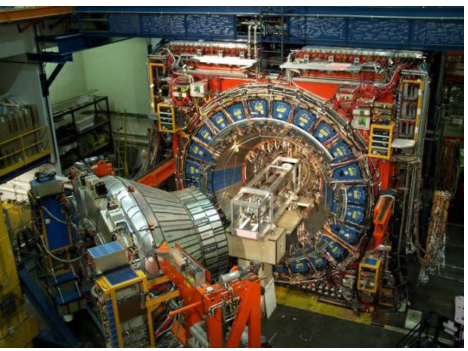


Up to about 10 fb^{-1} of data are available for each experiment

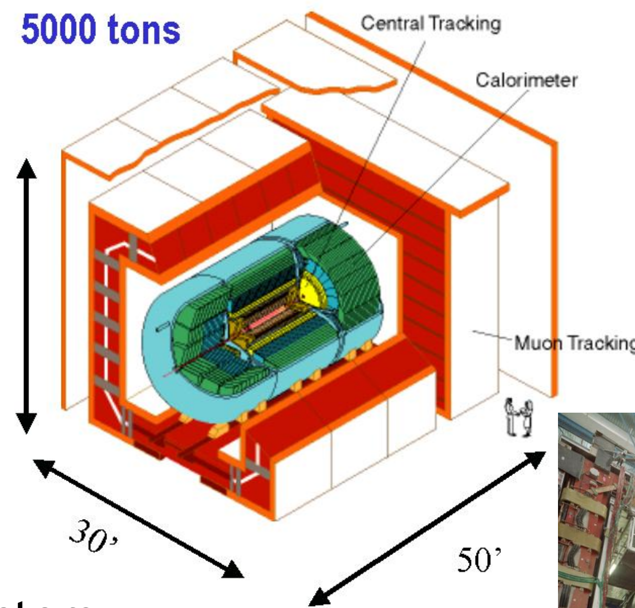
The CDF and D0 Experiments

The CDF Experiment





The DØ Experiment

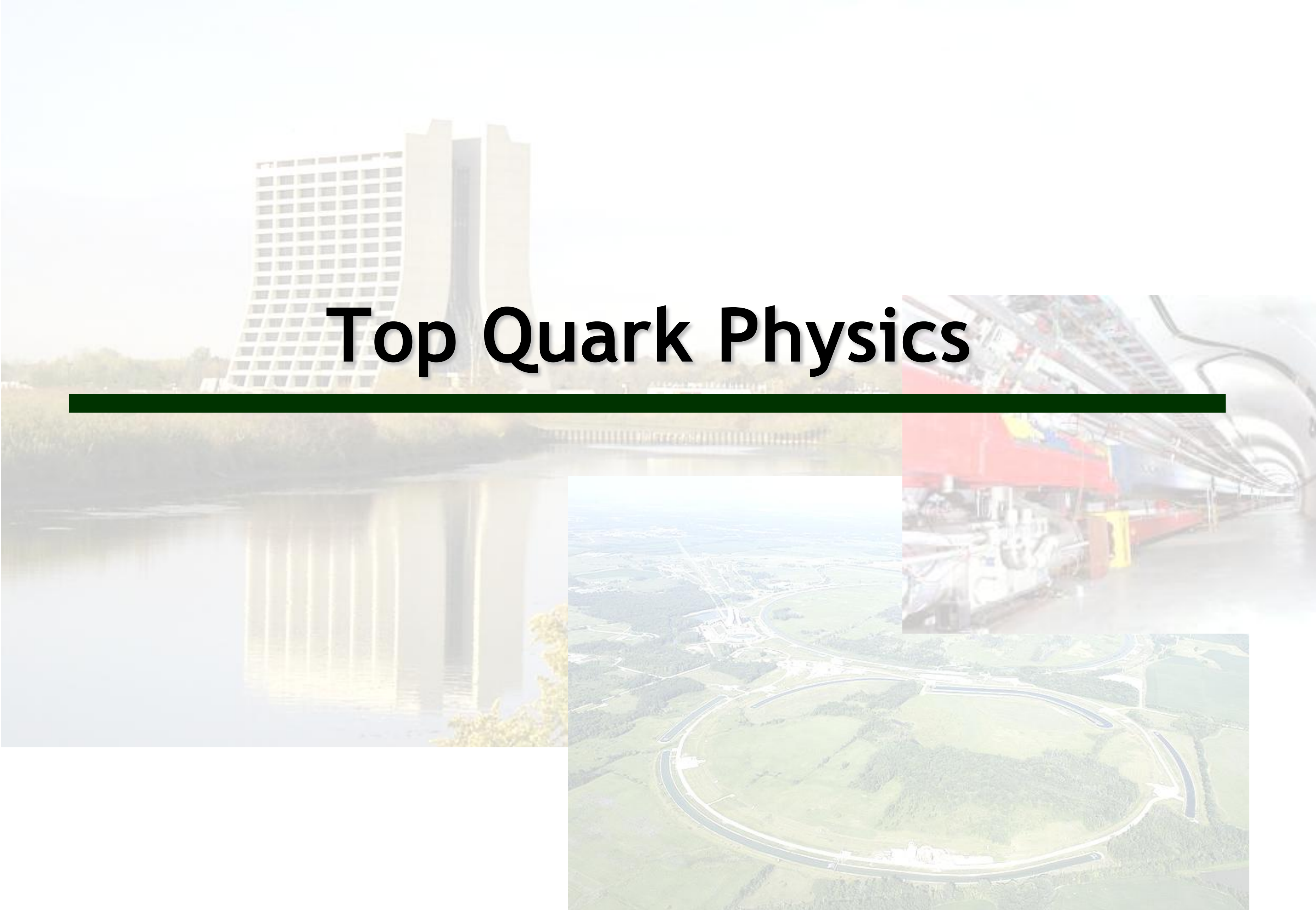


Two multi-purpose detectors

- e, μ, and τ idenficaon
- jet and missing energy measurement
- heavy-flavor tagging through displaced vertices and soft leptons

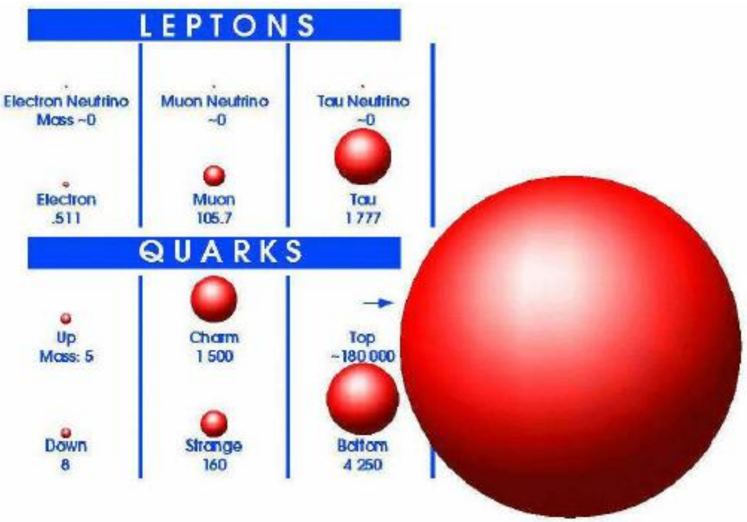
The data-taking efficiency for both experiments was high (> 90%)

Top Quark Physics



Why Study Top at the Tevatron?

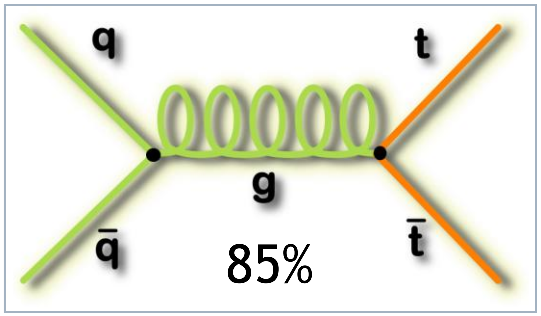
- Predicted by the SM and discovered by CDF&D0 in 1995
- Very unique:
  - m_t ~ 170 GeV vs m_b ~ 5 GeV
  - Top-Higgs Yukawa coupling $\lambda_t \approx 1$
  - may help identify the mechanism of EWSB and mass generation.
  - may serve as a window to new physics that couple preferentially to top.

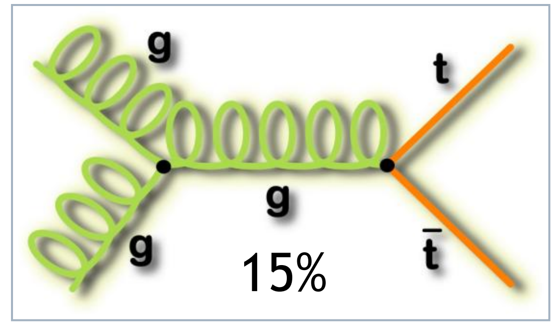


- Successful Tevatron top quark program
  - Only place we could study the top quark until 2010
  - High precision measurements of top quark mass, top pair production cross section, decay properties
  - Basic properties/kinematics still not known precisely: forward-backward asymmetry, spin, width. charge, lifetime, etc

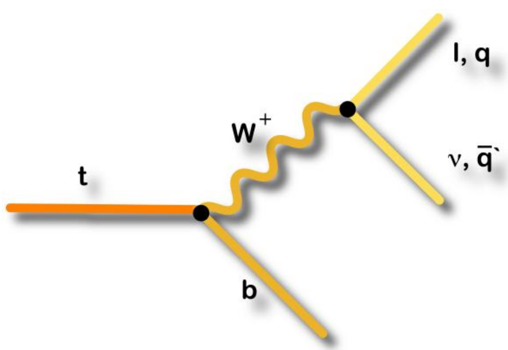
Top Quark Production at the Tevatron

- Top quark is mainly produced in pairs (~7 pb)

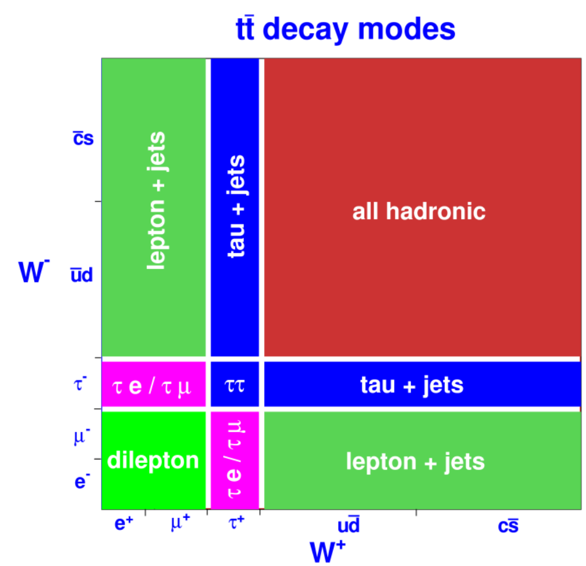




  - Can be also produced singly (~ 3pb). Single top quark production discussed later.
- According to SM: Γ(t →Wb) ~ 100%



Channels:
l+jets: 30%
dileptons: ~5%
(l=e or μ)

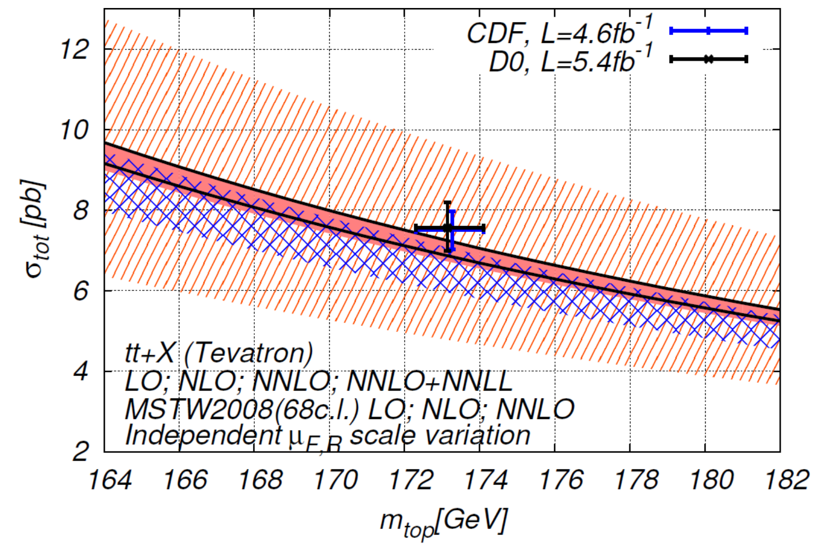


Ttbar Cross Section Measurements

- Ttbar cross section prediction computed at NNLO+NNLL accuracy

$$\sigma_{t\bar{t}} = 7.24^{+0.15}_{-0.24}(\text{scale})^{+0.18}_{-0.12}(\text{PDF})[\text{pb}]$$

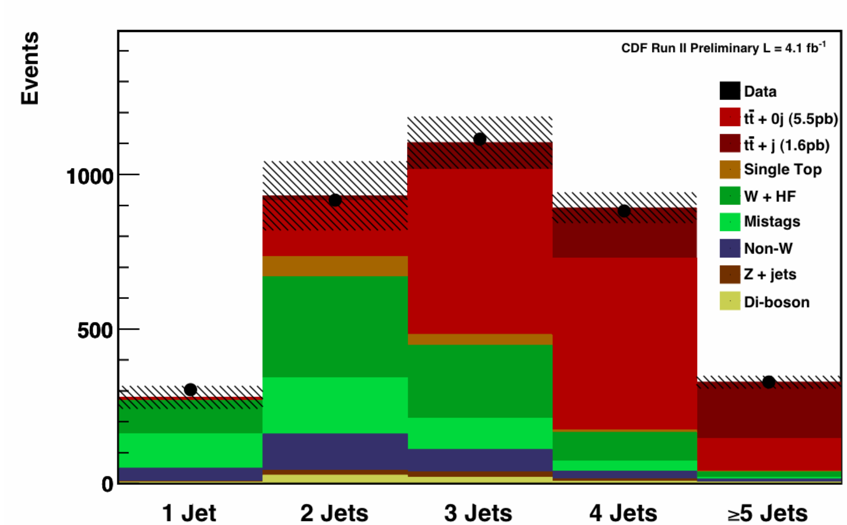
  depends on its mass (~3%/GeV)



- Measurement basics:

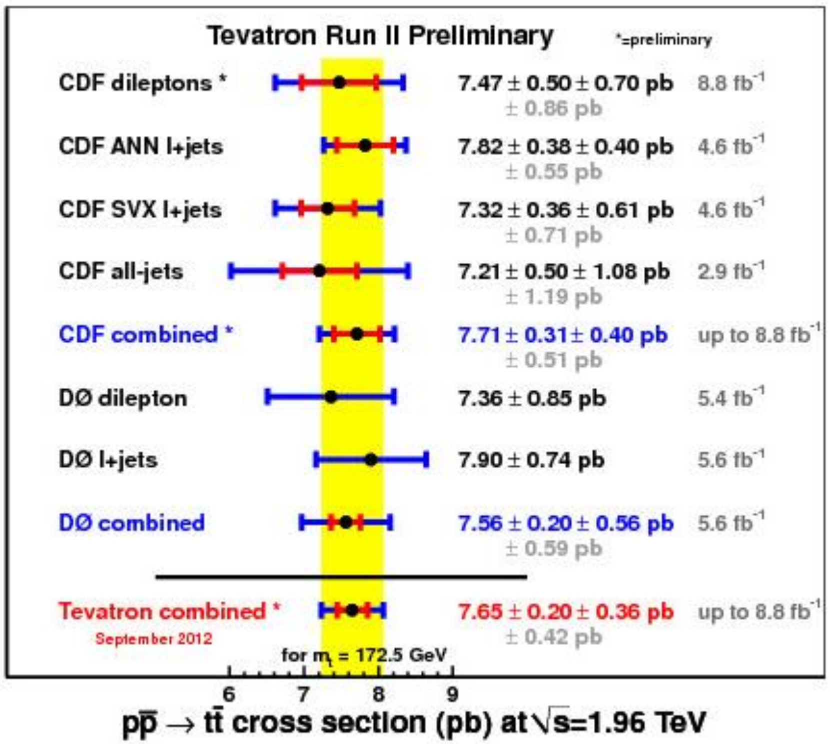
$$\sigma = \frac{N_{\text{data}} - N_{\text{BG}}}{\mathcal{BR} \cdot \mathcal{A} \cdot \mathcal{L}}$$

  - $L(\sigma) = P(N_{data}, N_{pred})$ maximized w.r.t. σ where P(x,μ) is the Poission probability dist.
  - Fit a predicted binned distribution to data
  - Actual likelihood is more complicated due to systematics



Ttbar Cross Section Measurements

- The first measurements with the complete Tevatron dataset have started coming
- Measurements consistent amongst various channels
- Limitation from systematic uncertainties (JES, b-tag, W+jets)



- Combination:

$$\sigma(p\bar{p} \to t\bar{t} \text{ @ } 1.96\text{TeV}) = 7.65 \pm 0.20(\text{stat}) \pm 0.29(\text{syst}) \pm 0.22(\text{lumi})\text{pb}$$

reaching to the NNLO prediction accurancy

$$\text{NNLO+NNLL: } \sigma(p\bar{p} \to t\bar{t}) = 7.24^{+0.15}_{-0.24}(\text{scale})^{+0.18}_{-0.12}(\text{PDF})[\text{pb}]$$

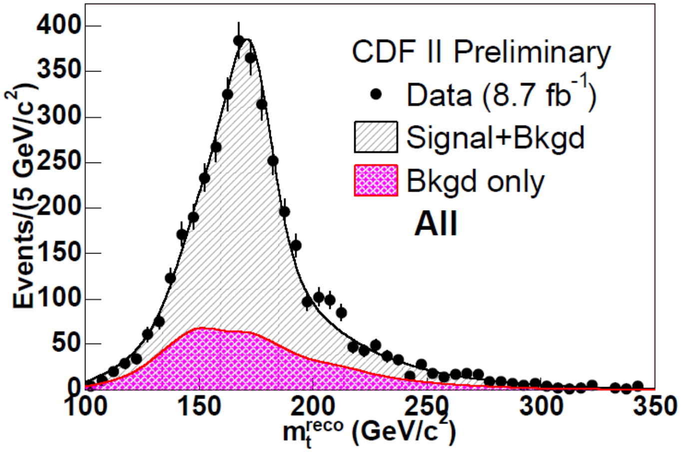
(Barneruther, Czakon, Mitov)

Top Quark Mass in the l+jets Channel

CDF Conf. Note 10761

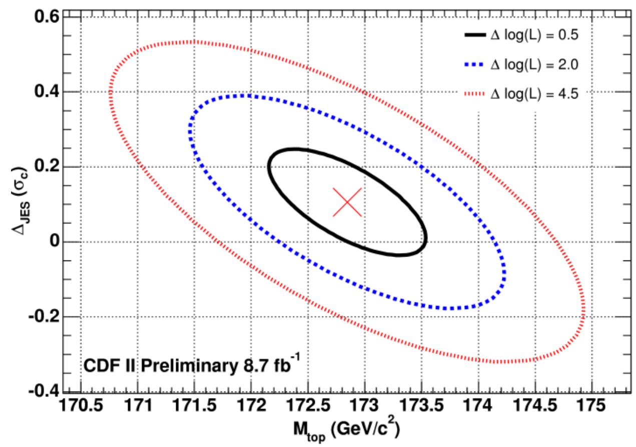
- Top mass close to the scale of EWSB
  - Special role in EWSB?
- Huge mass gives importance to QCD corrections for top quark

… M_{top} with M_{higgs} & M_W provides a fundamental tests of SM



- Measurement uses a “template” method:
  - m_t^{reco} from a kinematic fitter:

$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i^2}+\Sigma_{j=x,y}\frac{(U_j^{fit}-U_j^{meas})^2}{\sigma_j^2}$$
$$+\frac{(M_{jj}-M_W)^2}{\Gamma_W^2}+\frac{(M_{\ell\nu}-M_W)^2}{\Gamma_W^2}+\frac{(M_{bjj}-m_t^{reco})^2}{\Gamma_t^2}+\frac{(M_{b\ell\nu}-m_t^{reco})^2}{\Gamma_t^2}$$



- Three M_{top} sensitive variables: m_t^{reco}, $m_t^{reco(2)}$, m_{jj}
  Mapped to M_{top} and ΔJES by a likelihood fit & signal (bkg) probability density function

$m_t = 172.85 \pm 0.71$ (stat) ± 0.84 (syst) GeV/c^2
$= 172.85 \pm 1.10$ GeV/c^2

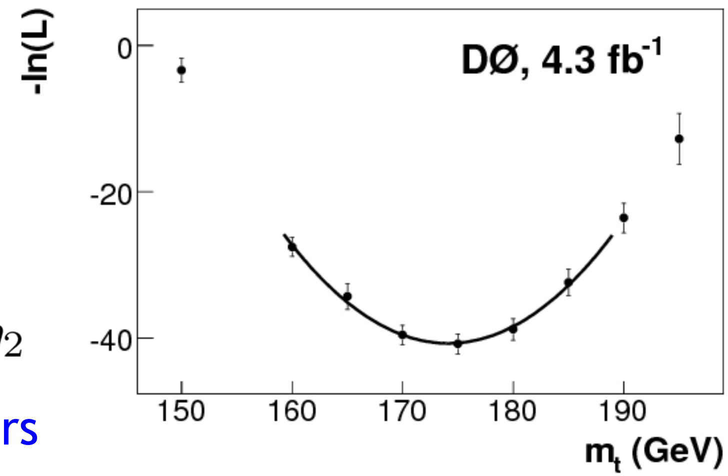
arXiv:1201.5172, accepted by Phys. Rev. D

Top Quark Mass in Dilepton Channel

- Based on neutrino weighting technique (matrix element method)
- Jet calibration (& JES systematic reduction) is achieved by using the energy scale derived from in lepton+jets measurements: k_{JES} = 1.013 ± 0.008 (stat)
- Neutrino weighting technique
  - The kinematics underconstrained due to two neutrinos
  - Probability density function depends on η of neutrinos

$$\mathcal{W} \propto \int \mathcal{P}(\eta_1|m_t)\mathcal{P}(\eta_2|m_t)\rho_{\eta 1}\rho_{\eta 2} d\eta_1 d\eta_2$$

from MC ttbar events resolution factors



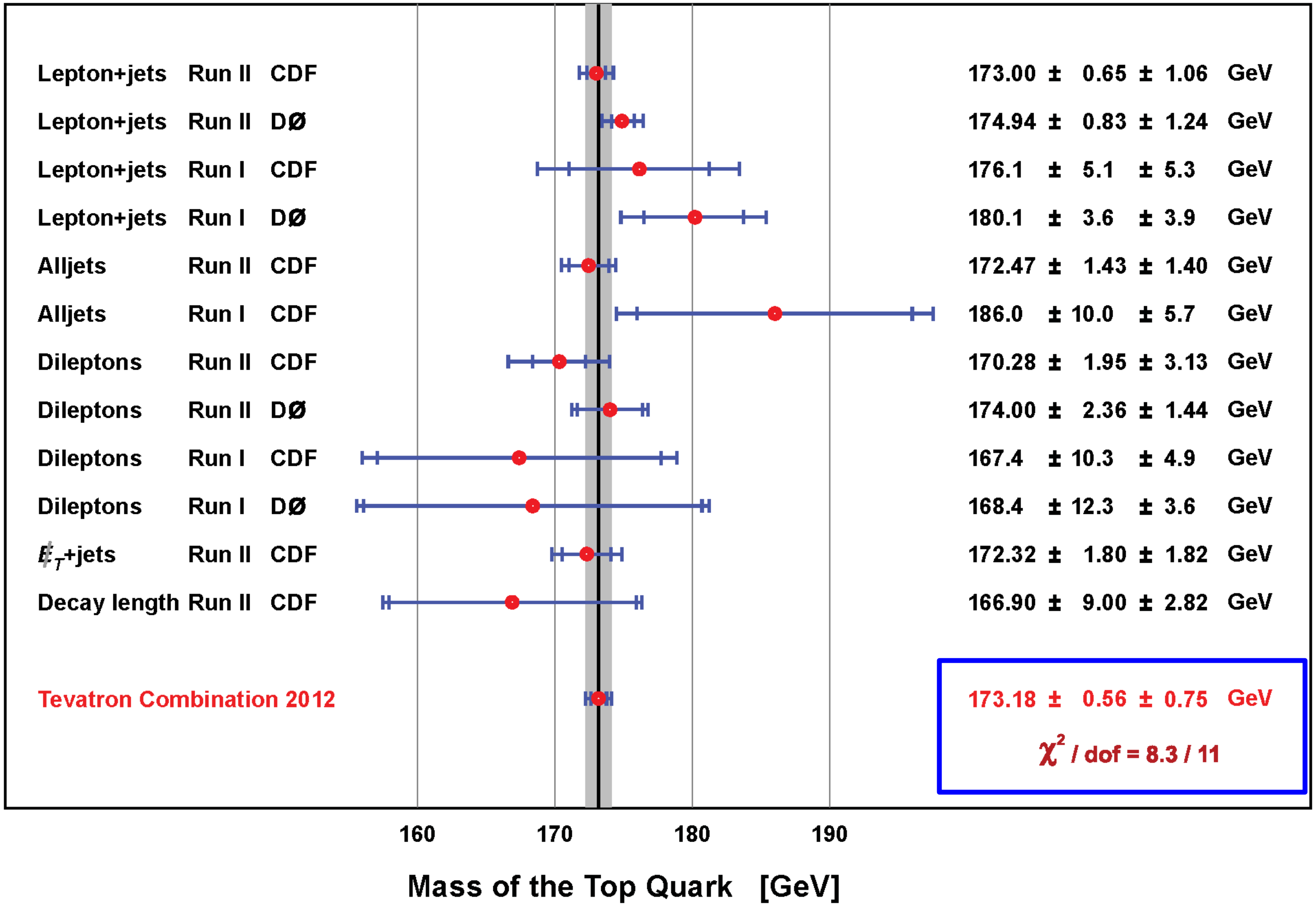
  - Binned likelihood fit is used for final mass determination

Combined with other 1fb^{-1} dataset (total 5.3 fb^{-1})

m_t = 174.0 ± 2.4 (stat) ± 1.4 (syst) GeV/c^2
= 174.0 ± 2.8 GeV/c^2

arXiv:1207.1069, accepted by Phys. Rev. D

Top Quark Mass Combination



Uncertainty below 1%!

Forward-Backward Asymmetry (A_{FB})

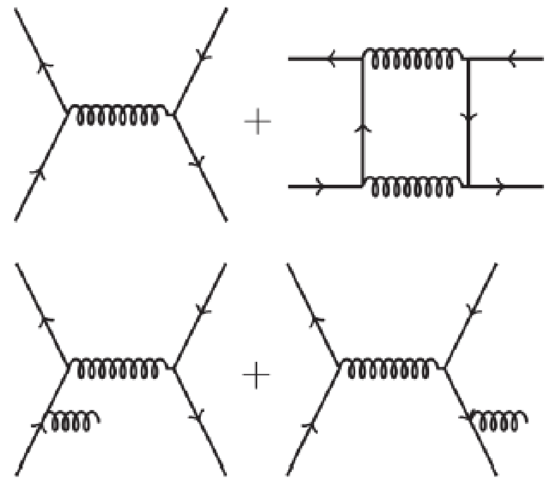
- Do tops have a preference to travel along the proton or antiproton direction?
- Measure "asymmetry" in Δy

$$A_{\rm FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

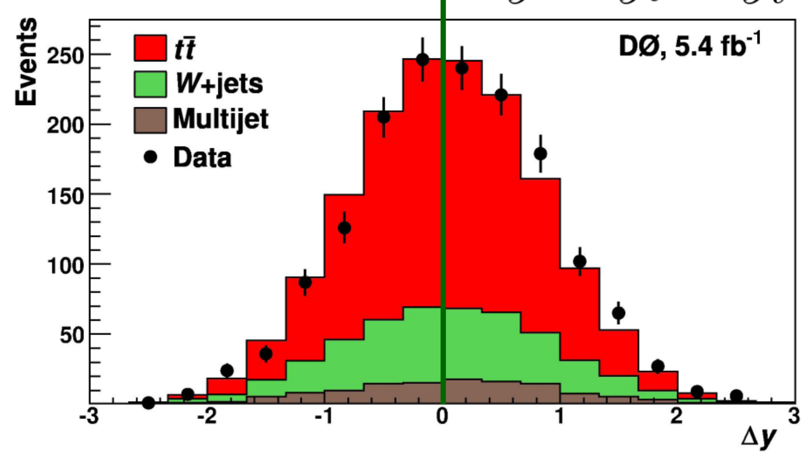
- Leading-order:
  SM predicts no asymmetry
- Next-to-leading-order: small positive asymmetry $A_{\rm FB} = 6.6\%$

POWHEG: JHEP 0709, 126 (2007)
EW Corrections: Phys. Rev. D 84, 093003 (2011)
JHEP 1201, 063 (2012); arXiv:1201.3926 [hep-ph]

- BSM ideas:
  - Massive chiral color octets, RS gluon, W', Z', etc

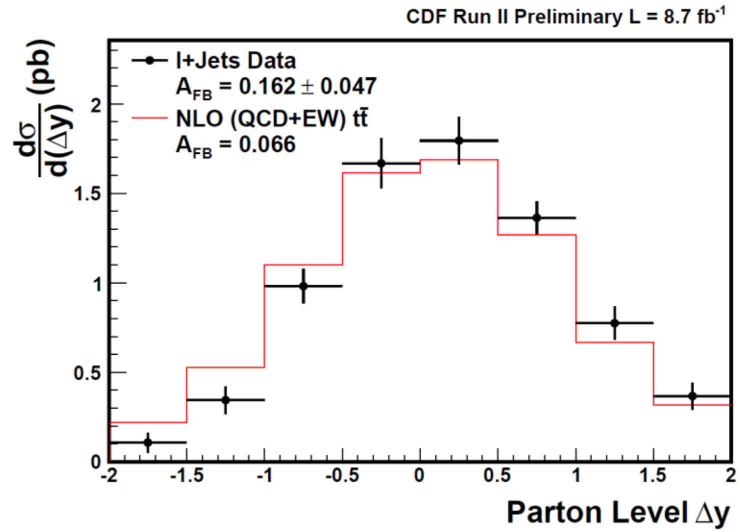


$$\Delta y = y_t - y_{\bar{t}}$$



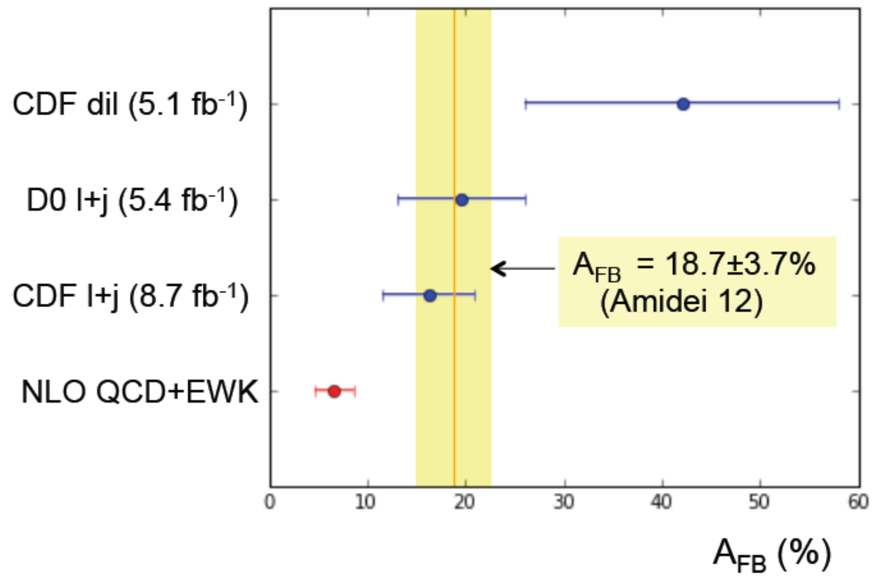
A_{FB} in l+jets Channel

- Measurement based on 8.7 fb^{-1} of l + MET + >=4jets + btag events
  - 2498 events, bkg = 505 ± 123
- Full ttbar reconstruction
  - M_W, M_{top} constraints, best χ^2



- Differential xsec in Δy
  - Unfolded to the parton level
  - Integrated AFB:

$$A_{\rm FB}(\text{measured}) \ = \ (16.2 \pm 4.7)\%$$



CDF Conf. Note 10807

A_{FB}: Δy & Pt (ttbar) Dependence

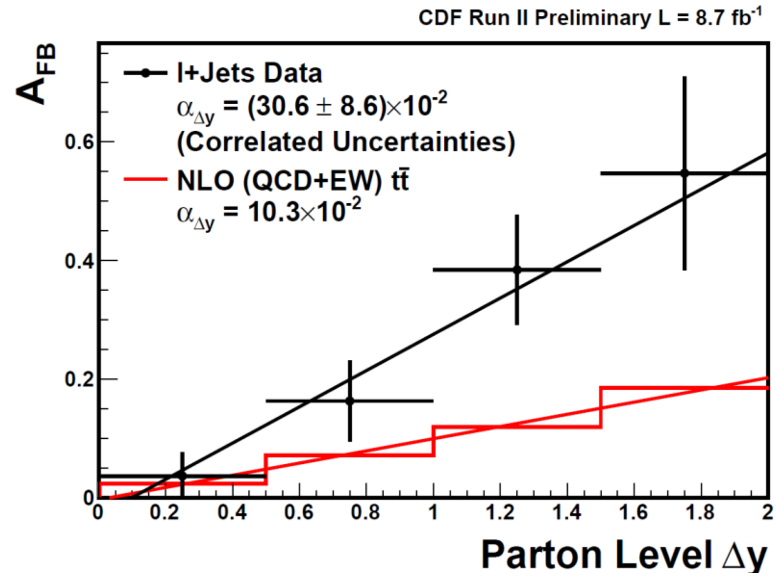
- Rapidity dependence

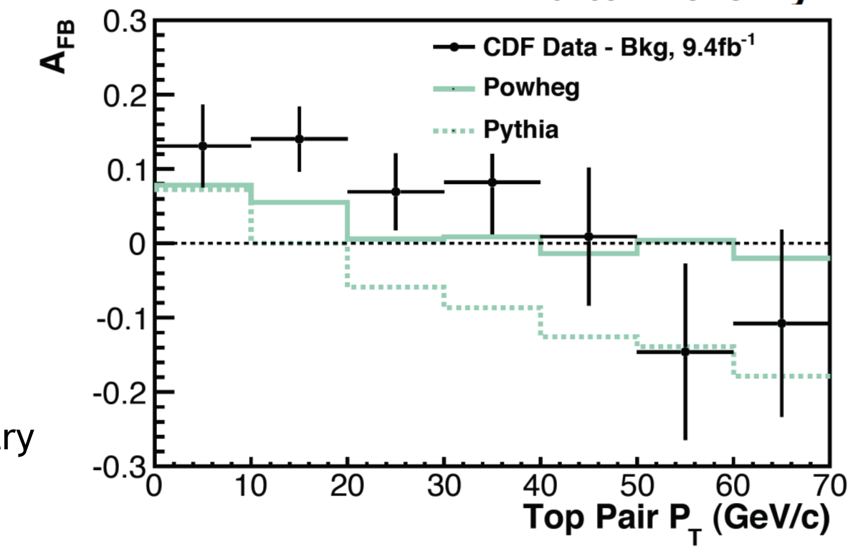
$$A_{FB}(|\Delta y|) = \frac{N(|\Delta y|) - N(-|\Delta y|)}{N(|\Delta y|) + N(-|\Delta y|)}$$

  - Line fit measures correlated significance:
    slope > 3σ from 0 (2.4 σ from SM)

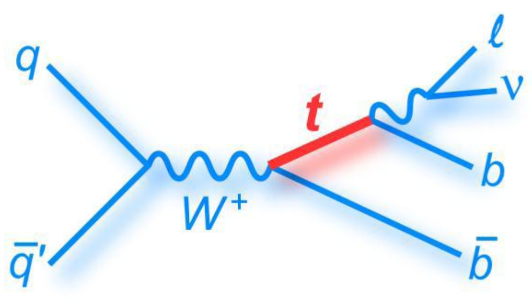
- Pt(ttbar) dependence
  - Due to color coherence
  - Noted first by a D0 study [PRD 84, 112005 (2011)]
  - The "trend" is as expected
  - Data above predictions

- Other studies:
  - Lepton asymmetries, lepton-top asymmetry ratio, etc
  - A_C measurement at the LHC

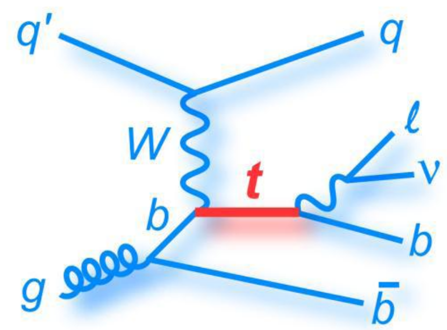




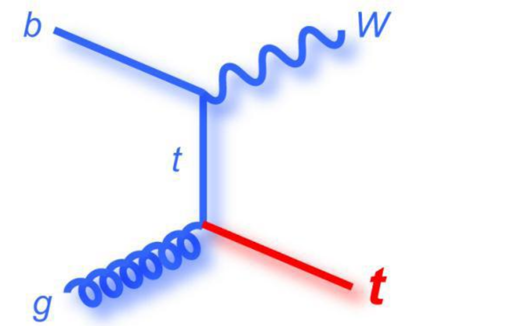
Single Top Quark Production



s-channel production



t-channel production



Associated Wt production

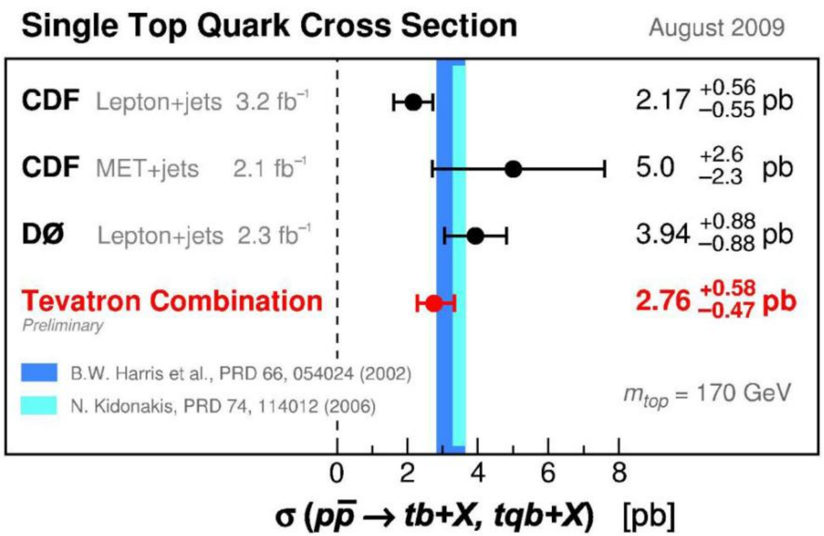
	tb [pb]	tqb [pb]	tW [pb]
Tevatron (1.96 TeV)	1.04 ↓x4.4	2.26 ↓x28	0.3 ↓x26
LHC (7 TeV)	4.59	64.2	7.8

PRD 74, 114012 (2006)
PRD 81, 054028 (2010)
PRD 83, 091503 (2011)

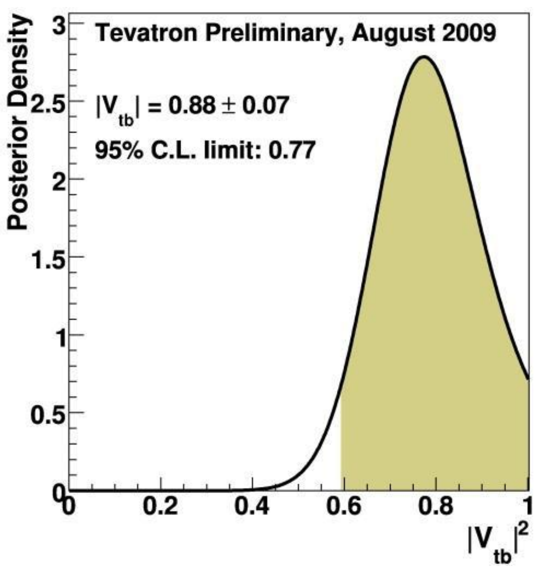
- Motivation:
  - Direct measurement of CKM matrix element $|V_{tb}|$ ($\sigma_{s+t} \sim |V_{tb}|^2$)
  - Sensitive to New Physics (FCNC, W'…) and CP violation
  - Additional channel for top quark properties study
- Experimental challenge:
  - Extract small signal out of a large background with large uncertainty

Observation by D0 & CDF

- Observed by CDF and D0 in 2009
  CDF: PRL 101, 252001
  D0: PRL103, 092001

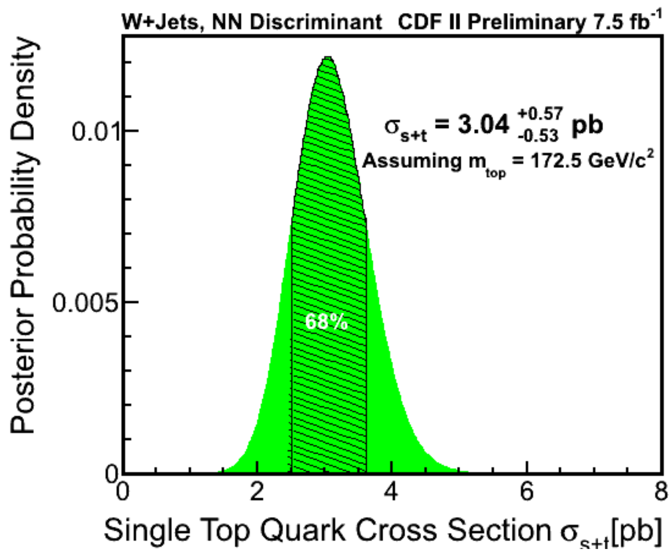


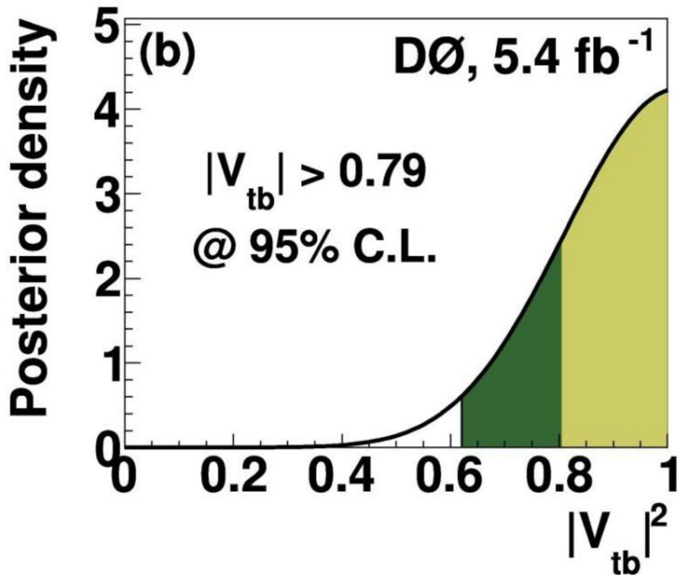
- Combination (arXiv:0908.2171)
  - CDF: Four multivariate analyses in lepton+jets with 3.2fb^{-1} data.
  - CDF: MET+Jets with 2.1fb^{-1} data
  - D0: Three multivariate analysis in lepton+jets with 2.3fb^{-1} data.



Recent Analyses in Lepton+Jets

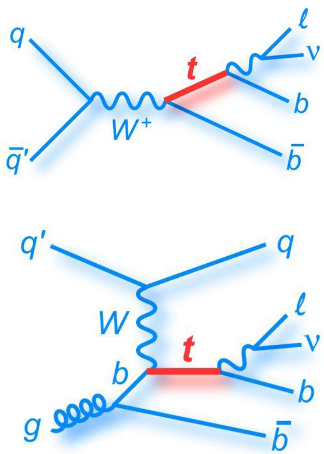
- D0 with 5.4 fb^{-1}:
  - three multivariate (MVA) methods to extract signal: Boosted decision tree, neural network, neuro-evolution of augmented topologies
- CDF with 7.5 fb^{-1}:
  - neural network discriminant
  - High quality, high P_T isolated track: ~15% gain in single top acceptance
- Measured cross section:
  - σ_{s+t} = 3.43 +0.73-0.74 pb (D0)
  - σ_{s+t} = 3.04 +0.57-0.53 pb (CDF)
- Limits on $|V_{tb}|$
  - $|V_{tb}|$ > 0.79 at 95% CL (D0)
  - $|V_{tb}|$ > 0.79 at 95% CL (CDF)

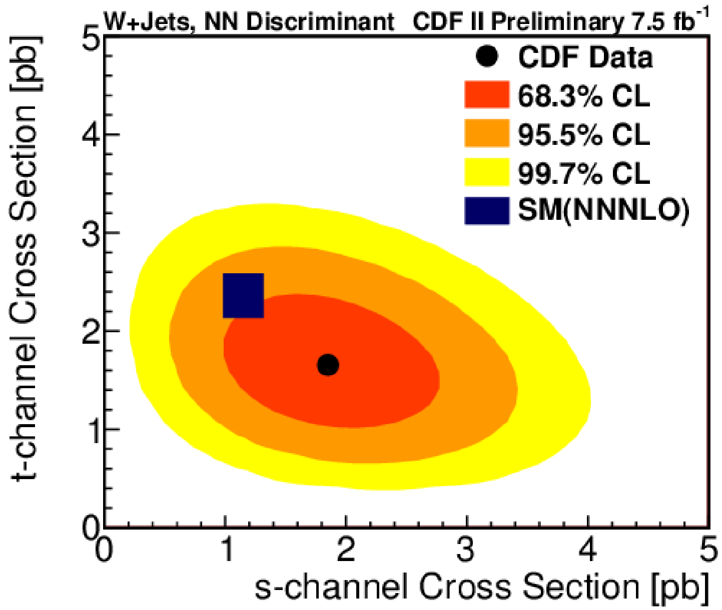


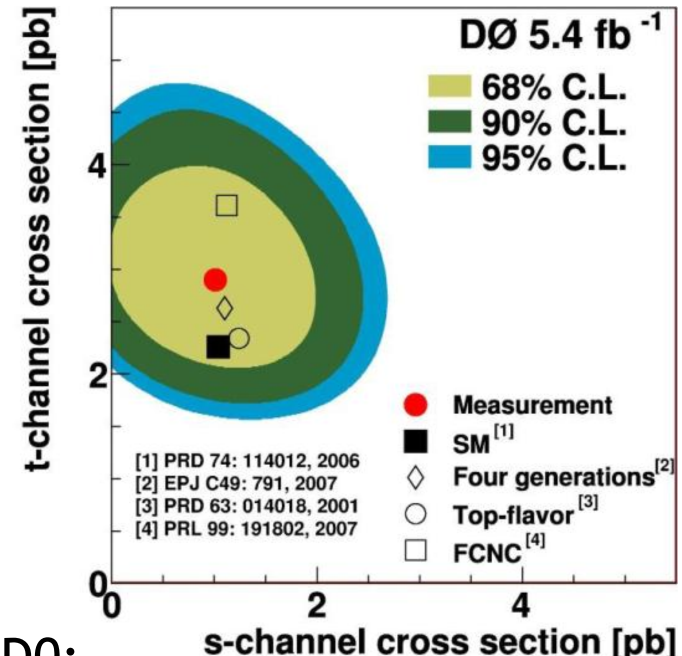


Simultaneous σ_s-σ_t Measurements

New physics may affect s- and t-channels differently
Remove the s/t channel constraint





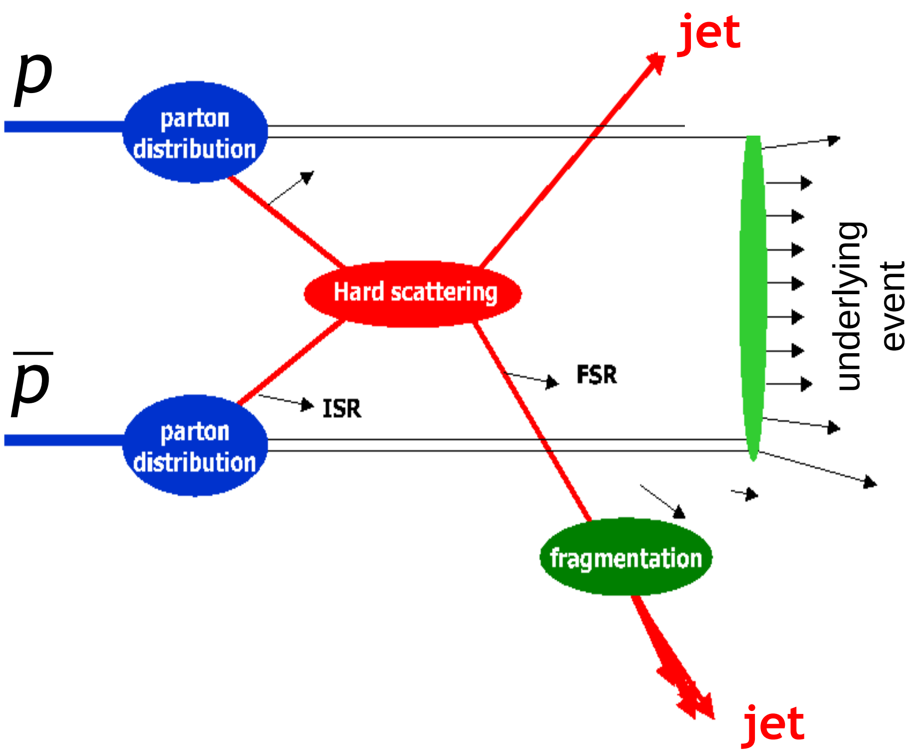


- CDF:
  - σ_s = 1.81+0.63-0.58 pb (±~33%)
  - σ_t = 1.49+0.47-0.42 pb
- D0:
  - σ_s = 0.98 ± 0.63 pb
  - σ_t = 2.90 ± 0.59 pb (±~20%)
- SM prediction:
  - σ_s = 1.04 ± 0.04 pb
  - σ_t = 2.26 ± 0.12 pb

QCD Physcis

Jet Production at the Tevatron

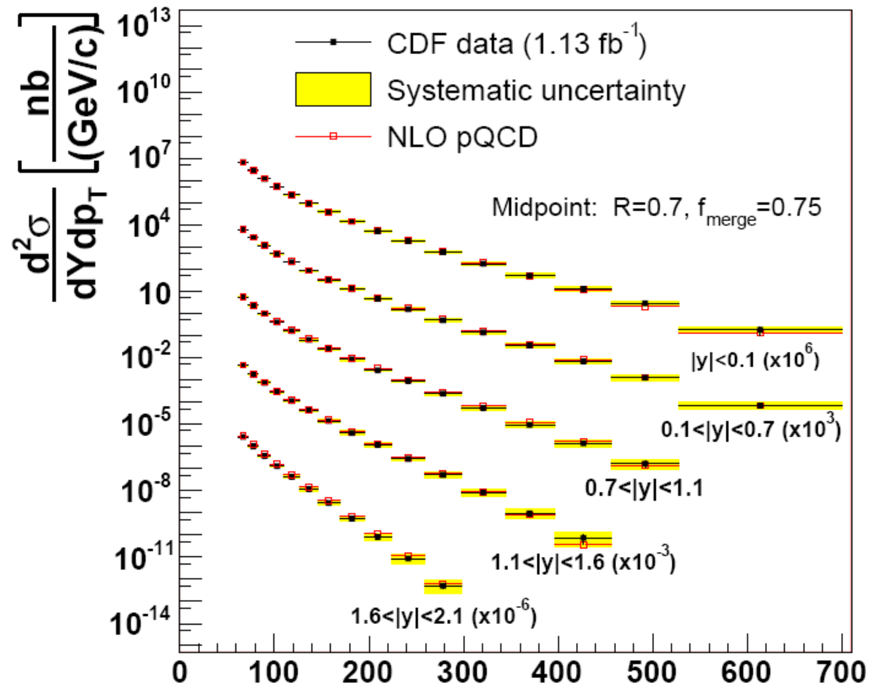
$$d\sigma_{jet} = \sum_a \sum_b \overbrace{f_{a/p}(x_p, \mu_F^2)\, f_{b/\bar{p}}(x_{\bar{p}}, \mu_F^2)}^{\text{PDFs}} \otimes \underbrace{\hat{\sigma}_{a,b}(x_p, x_{\bar{p}}, \alpha_s, \mu_R^2)}_{\text{Hard Scatter}}$$

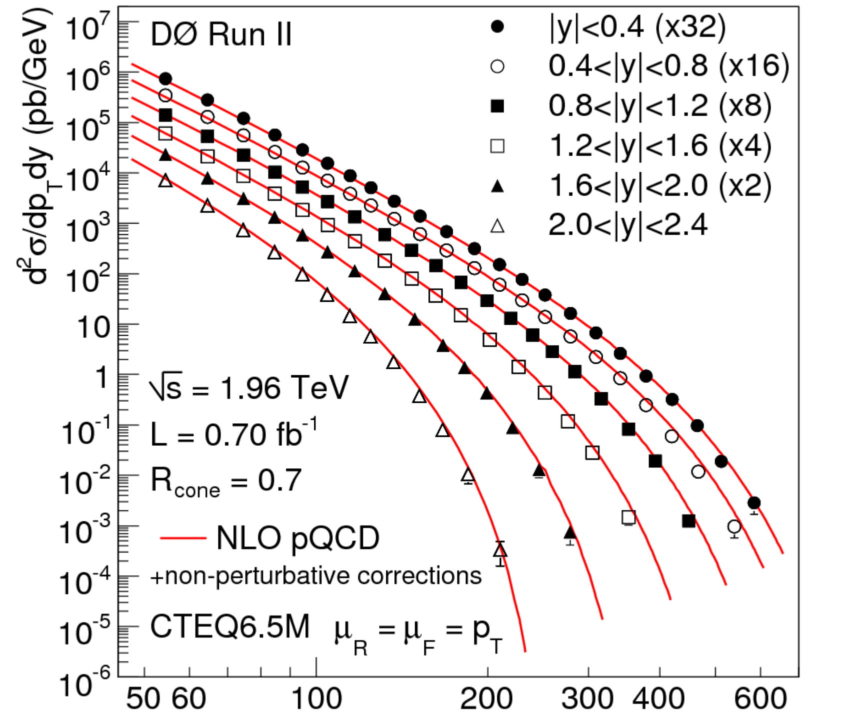


- Test pQCD
- Based on pQCD: extract PDFs and α_s. Study/test matrix element calculations.

- Underlying event makes the measurement complicated
  - Good place to study nature of underlying event

Inclusive Jet Cross Section





PRD 78, 052006 (2008)

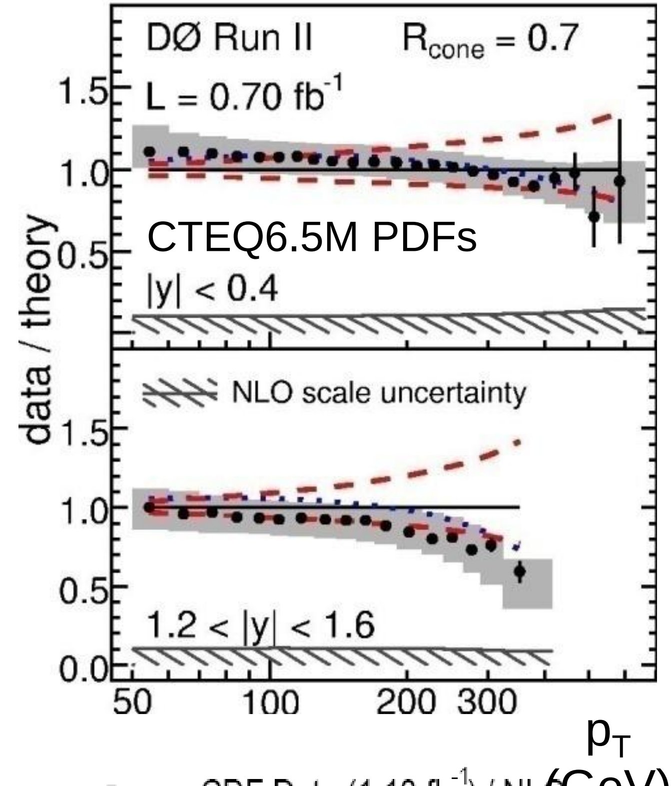
PRL 101, 062001 (2008)

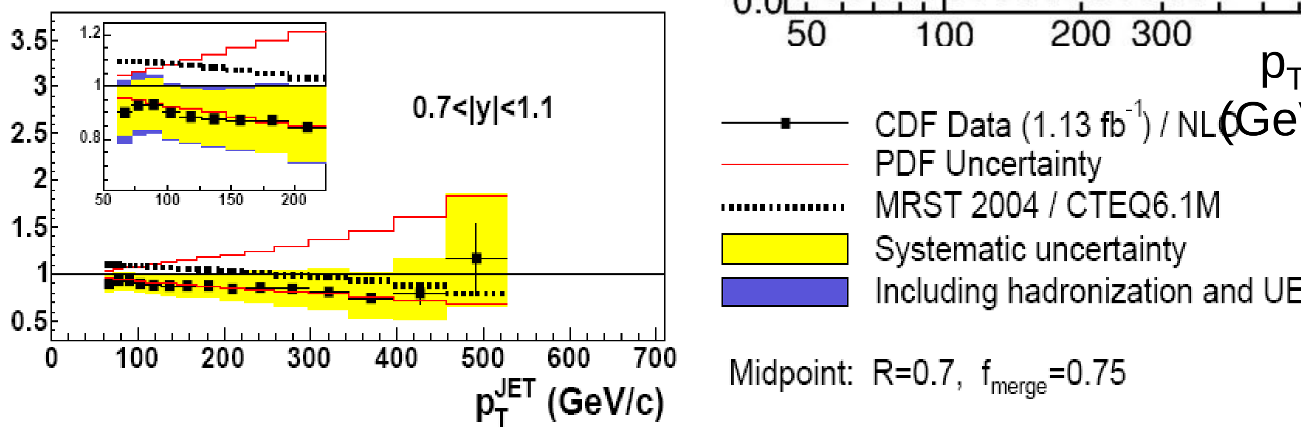
PRD 85, 052006 (2012)

- Test pQCD over 8 order of magnitude in $d\sigma^2/dp_Tdy$
- Highest p_T^{jet} > 600 GeV/c

Inclusive Jet Cross Section

- Both CDF and D0 measurements are in agreement with NLO predictions
  - Both in favor of somewhat softer gluons at high-x
- Experimental uncertainties: smaller than PDF uncertainties

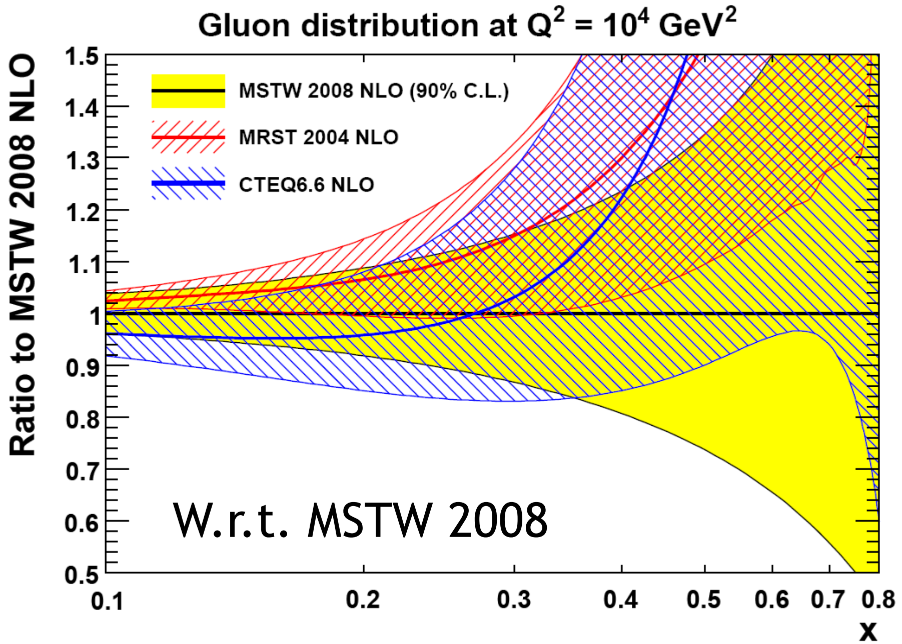


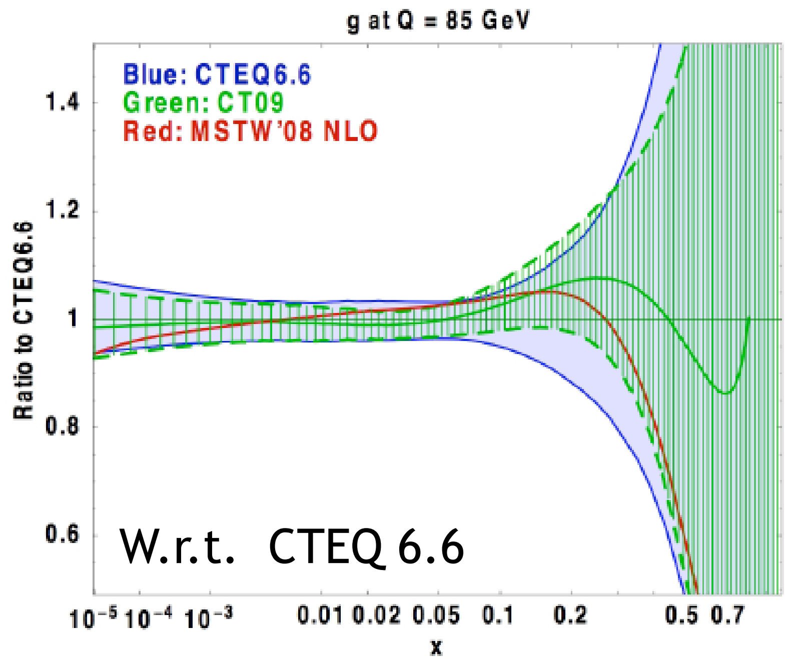


PDF with Tevatron Run II Jet Data

MSTW08: arXiv:0901.0002, Euro. Phys. J. C

CT09: Phys.Rev.D80:014019,2009.

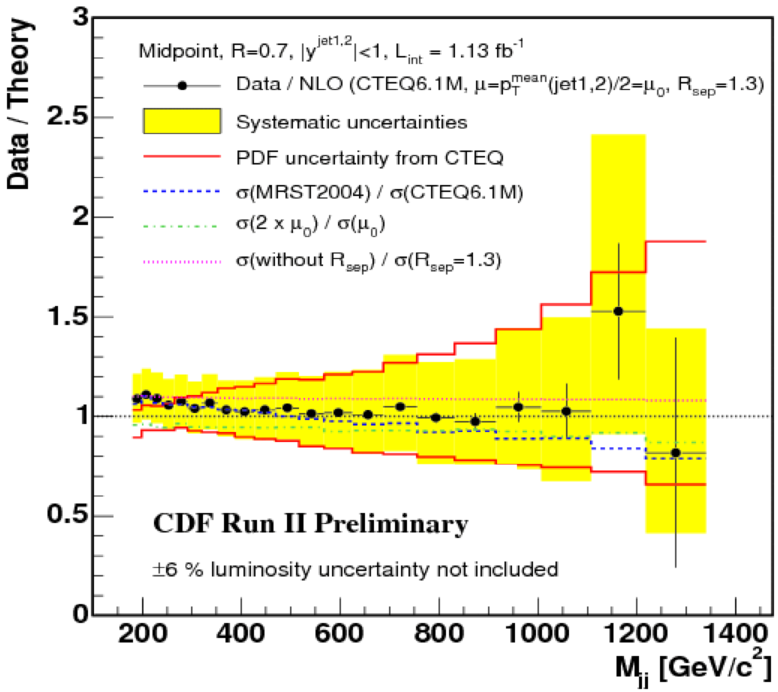


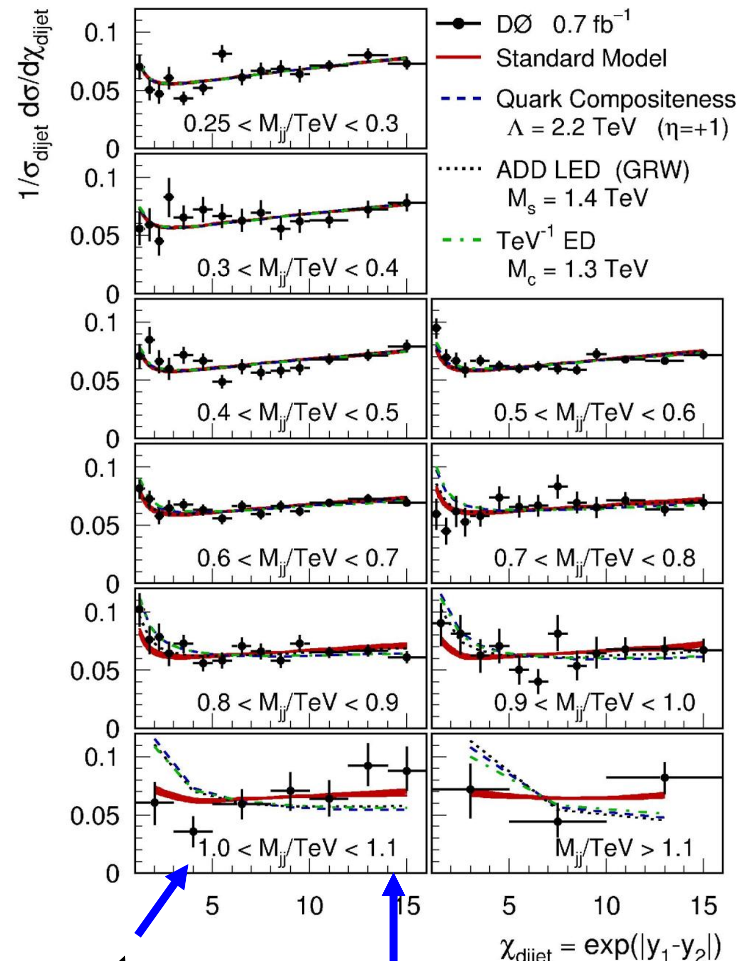


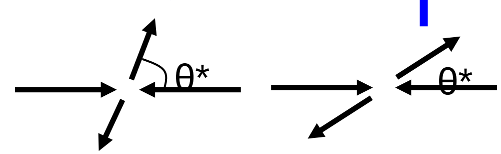
- Tevatron Run II data lead to softer high-x gluons (more consistent with DIS data than Run I) and help reducing uncertainties

PRD 79, 112002 (CDF), PRL 103, 191803 (D0)

Dijet Mass & Angular Distributions





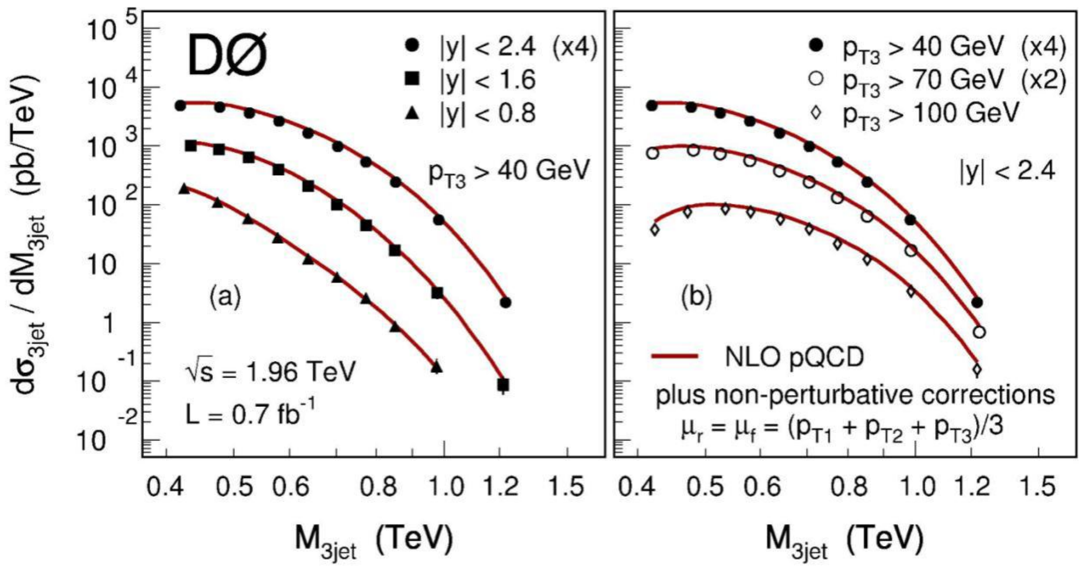


Data well described by pQCD
No significant indication of new physics

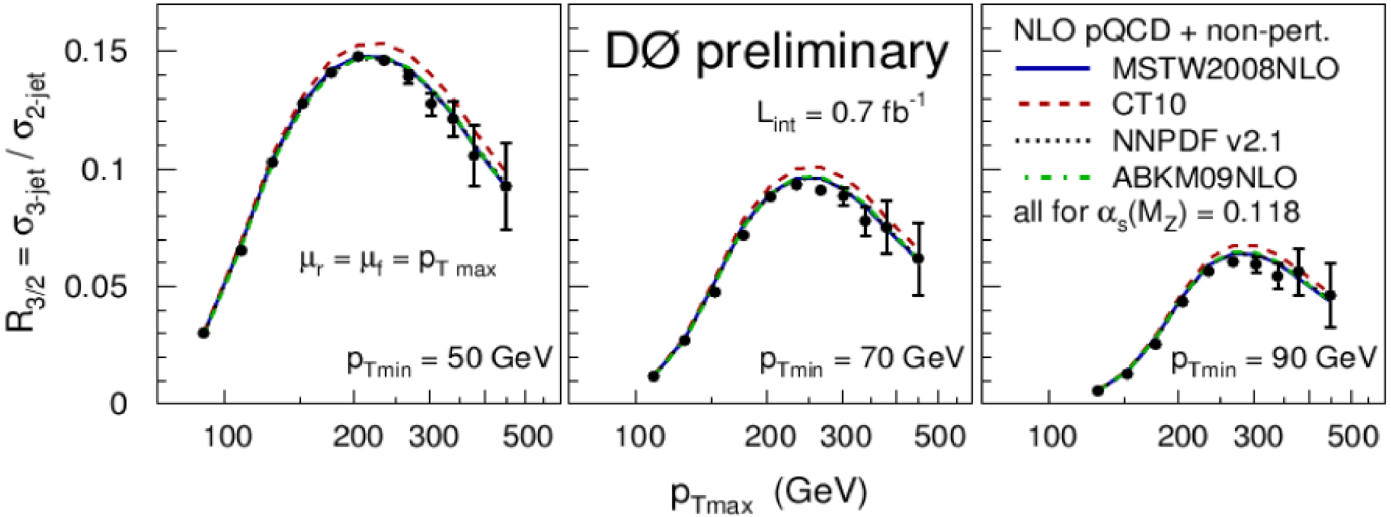
$$\chi_{dijet} = \frac{1+\cos\theta^*}{1-\cos\theta^*} \text{ @ LO}$$

Three Jet Cross Section (Ratio)

- Test QCD at $O(\alpha_s^3)$
- Decorrelate α_s and PDFs in $\sigma_{3\text{-jet}}/\ \sigma_{2\text{-jet}}$ ratio



- Data well described by pQCD

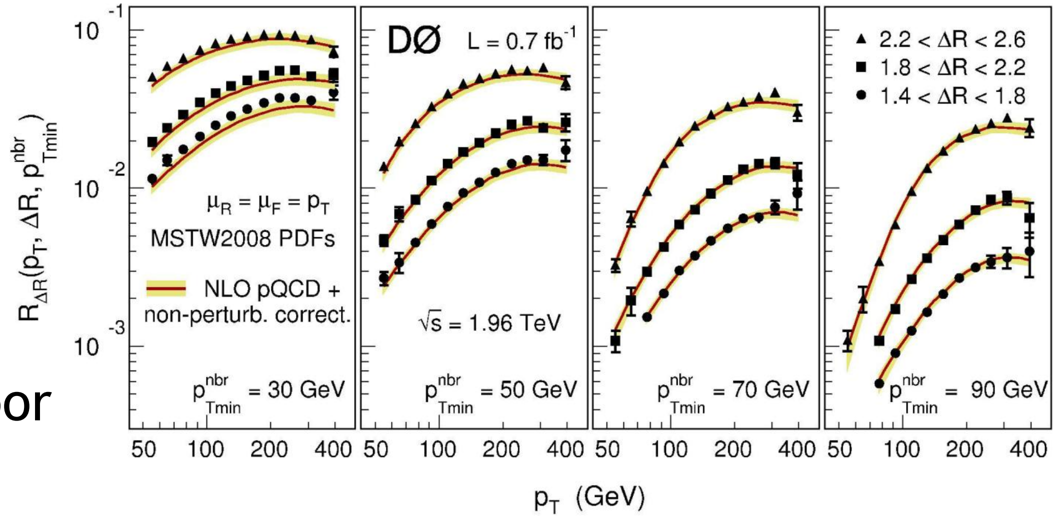


arXiv:1207.4957, Accepted by PLB

Angular Correlations of Jets

- Observable: $R_{\Delta R}$ average number of neighboring jets for jets from an inclusive jets sample
- It depends on three variables
  - inclusive jet p_T
  - distance ΔR to neighbor jet in $(\Delta\varphi, \Delta y)$
  - neighbor jet $p_T^{nbr}{}_{min}$ requirement
- Sensitive to strong coupling constant

Average number of neighboring jets within ΔR to an inclusive jet

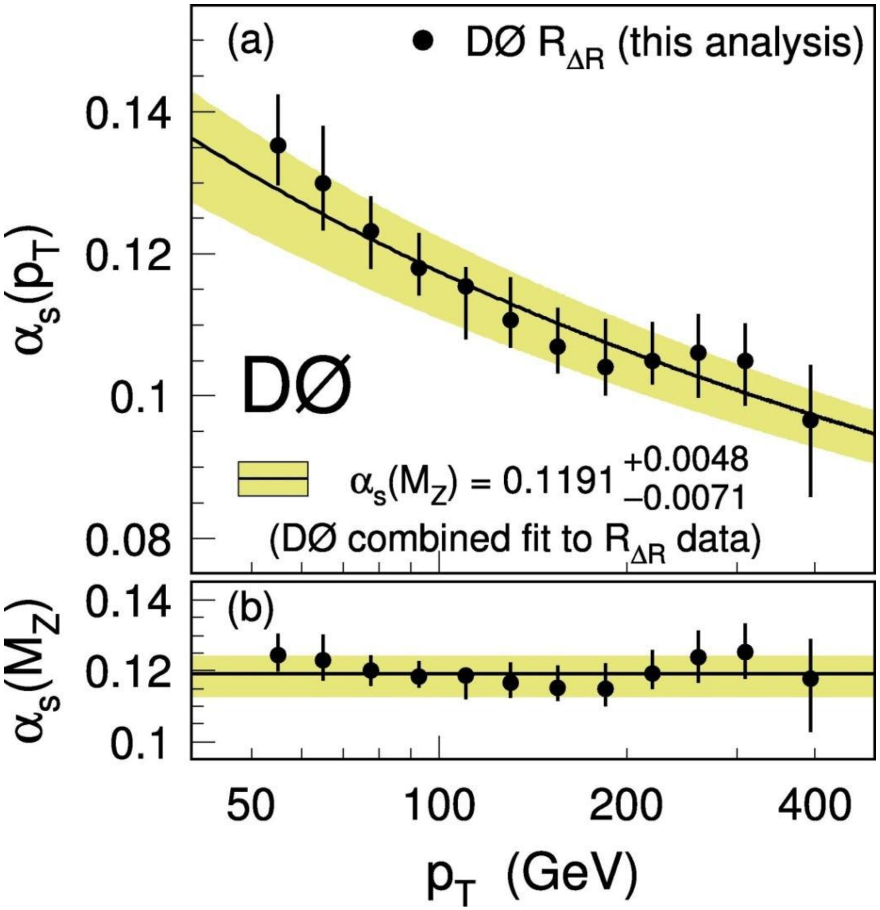


- Uncertainties 2-5%!
- Dependence of $R_{\Delta R}$ on (p_T , ΔR, $p_T^{nbr}{}_{min}$) described by pQCD

arXiv:1207.4957, Accepted by PLB

Running of Strong Coupling Constant

- Extract α_s from $R_{\Delta R}$ measurement
  - $p_T^{nbr}{}_{min}$ >= 50, 70, 90 GeV
  - At each p_T, combine all data points with different $p_T^{nbr}{}_{min}$ and ΔR requirements
- $\alpha_s(p_T)$ measurement up to 400 GeV!
- $\alpha_s(p_T)$ decreases with p_T as predicted by the RGE



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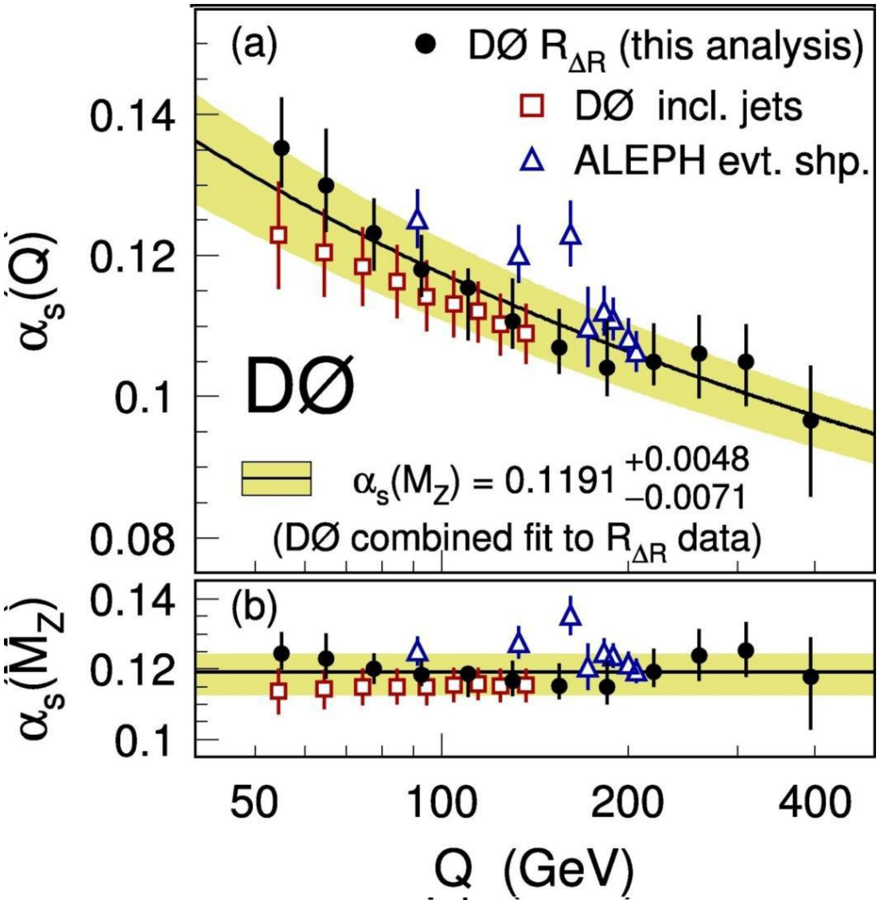

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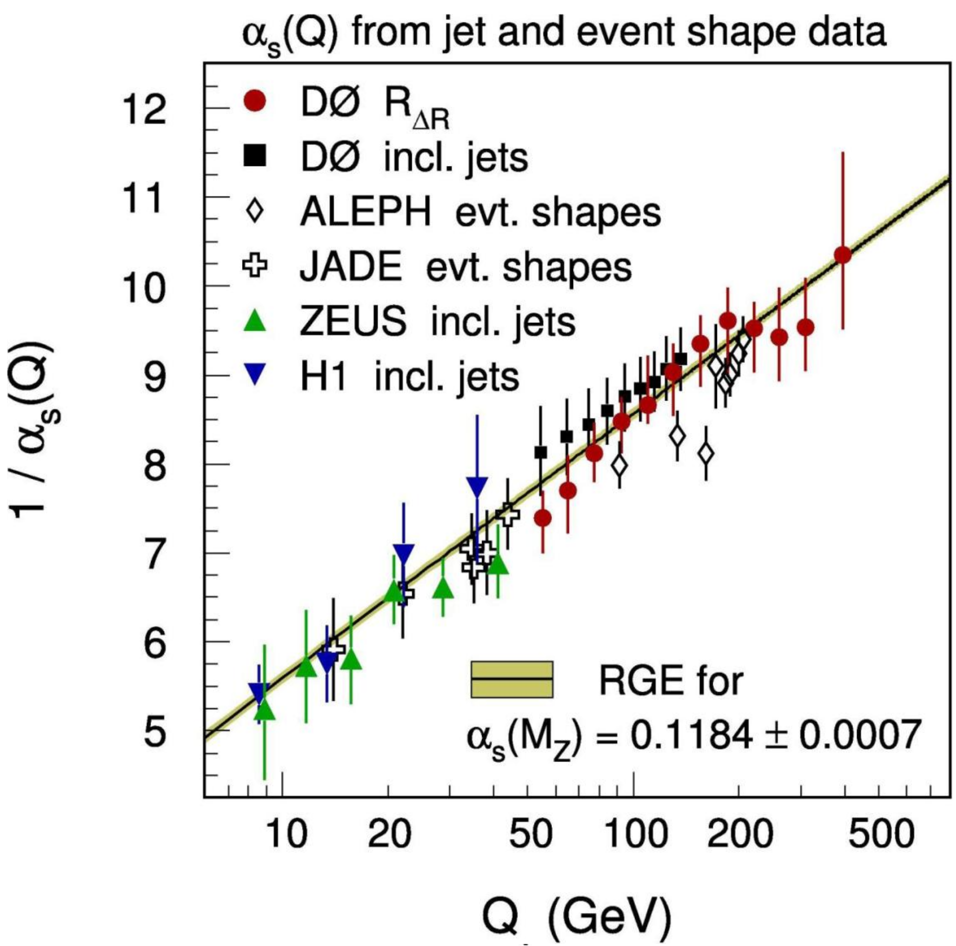
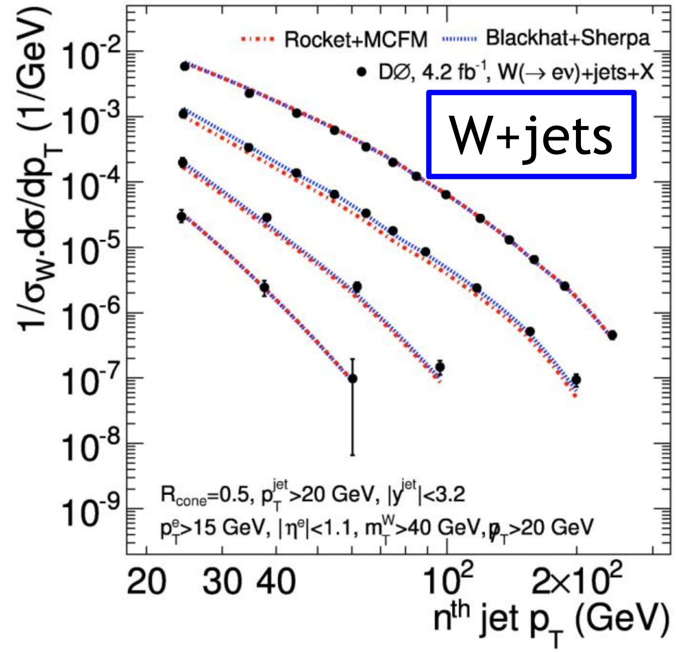


Consistent with other results from jet and event shape data

PLB 705, 200 (2011), arXiv:1207.4957, Accepted by PLB

W+Jets/HF Production

- Fundamental test of pQCD, at high momentum scales.
- W+jets are critical for physics at the Tevatron and LHC: top, Higgs, SUSY, and other BSM
  - Large theory uncertainties (30%-40%) on W+HF production limits our physics potentials



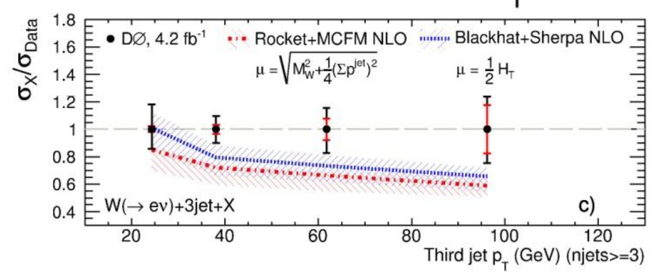
W+b+X

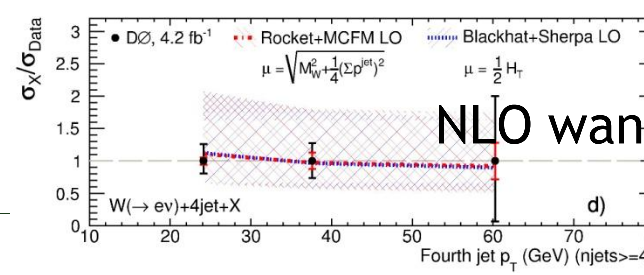
$$\sigma(W+b)\cdot\mathcal{B}(W\to\mu\nu) =$$
$$1.04 \pm 0.05\,(\text{stat.}) \pm 0.12\,(\text{syst.})\ \text{pb.}$$

Theory (MCFM):

$$1.34^{+0.40}_{-0.33}(\text{scale}) \pm 0.06(\text{PDF})^{+0.09}_{-0.05}(m_b)\text{pb}$$

Sharpa: 1.21, Madgraph5: 1.52 (pb)





NLO wanted!

Z+Jets

Motivation:

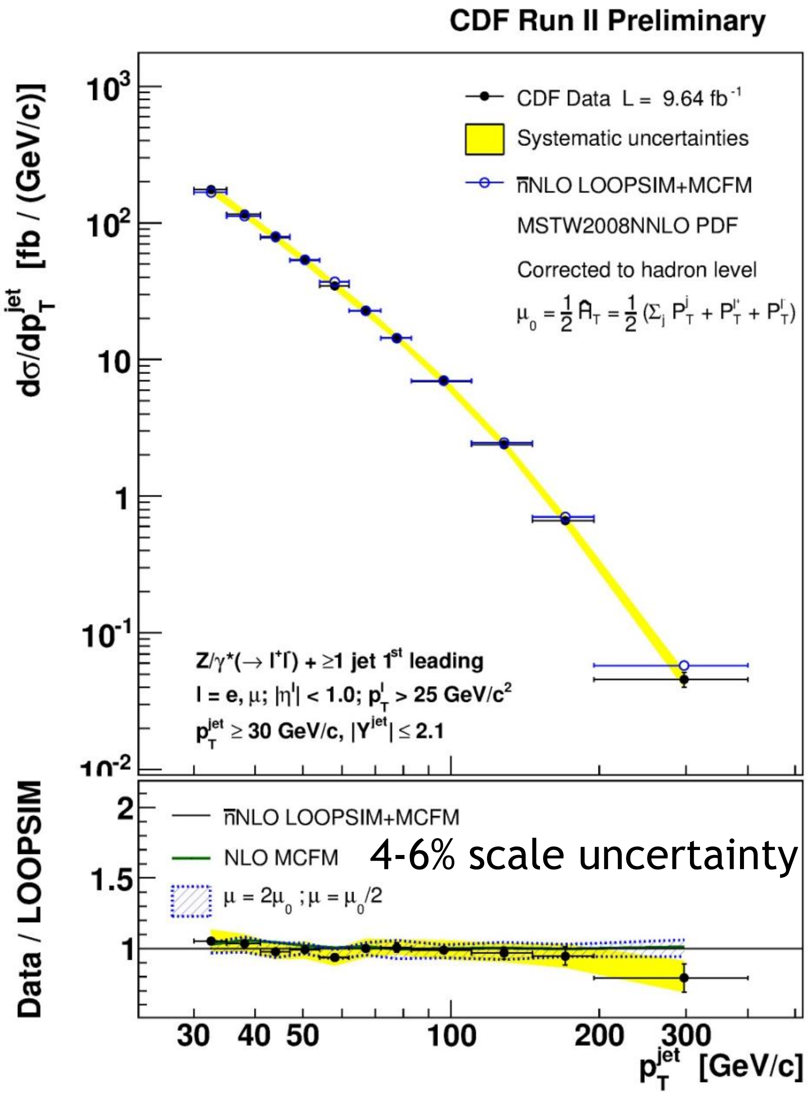
- Fundamental test of pQCD, at high momentum scales.
- Background for rare SM processes (top, diboson) and BSM searches

Measurement:

- Full dataset 9.6 fb^{-1}. $Z \rightarrow ll$, l=e, μ.

Theory for comparisons:

- MCFM&BLACKHAT+SHERPA: NLO pQCD
- ALPGEN+PYTHIA: Matched LO-ME+PS
- POWHEP+PYTHIA: Merged NLO+PS
- LOOPSIM+MCFM: Approximate nNLO
- arXiv:1103.0914: NLO QCD+NLO EW (EW corr. important at high p_T)



Overall good agreement between data and predictions

Z+Jets

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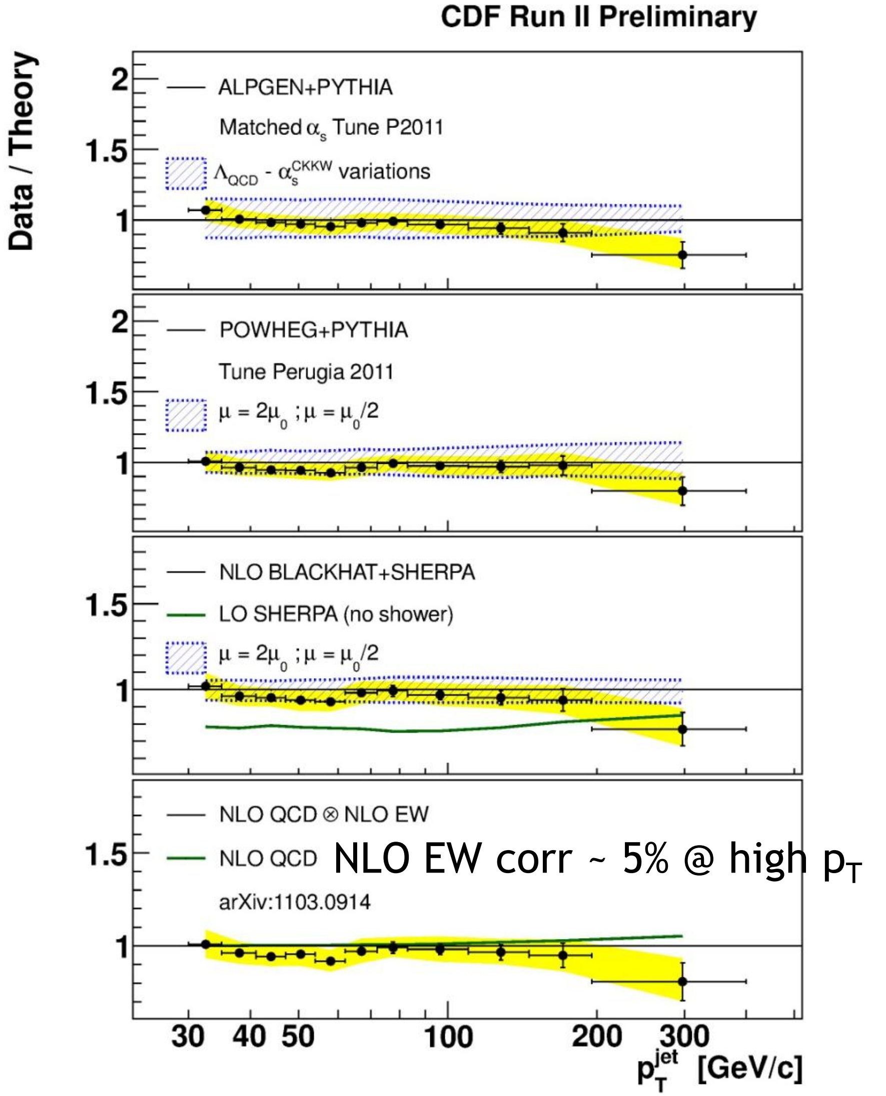

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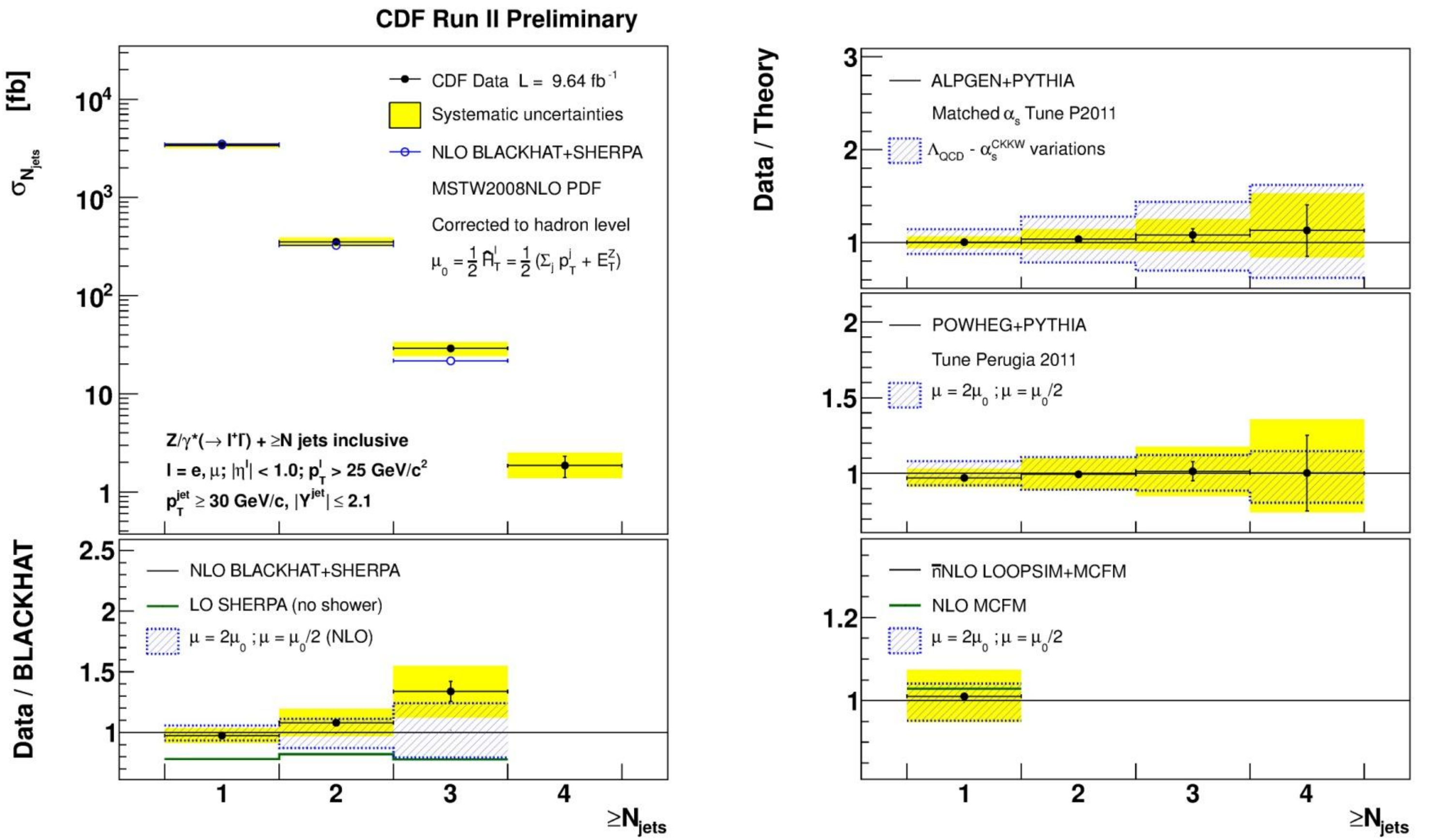
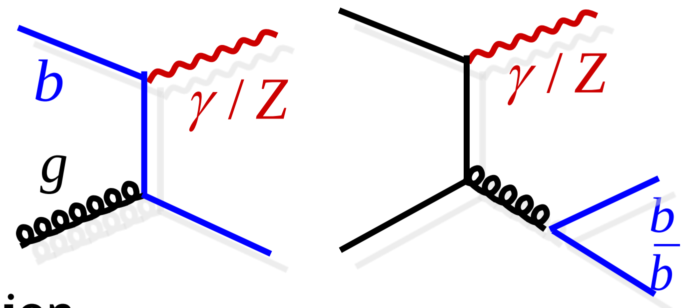
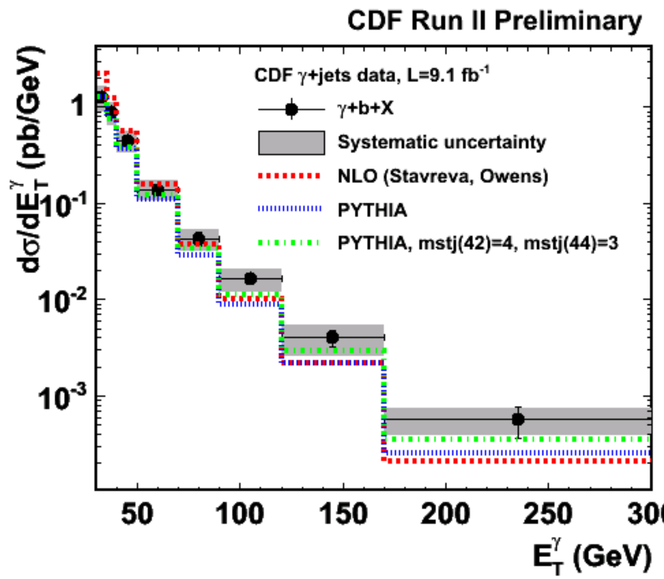
Z+Jets



- Blackhat+Sherpa NLO for Z+3jets!
- LOOPSIM+MCFM scale variation lower than experimental uncertainty

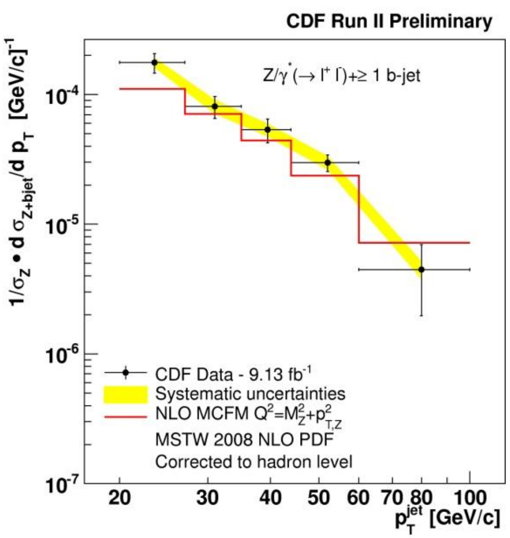
Z/γ+HF Production

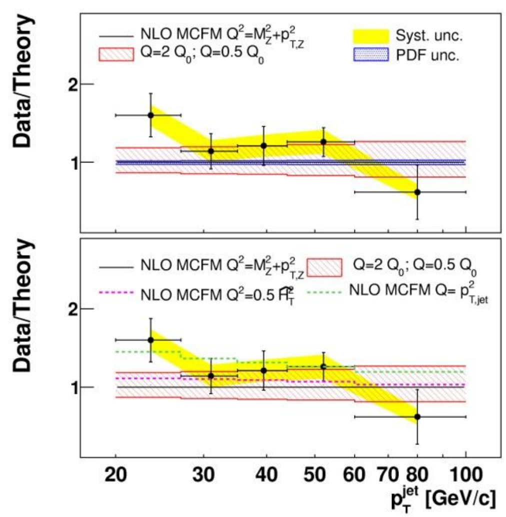


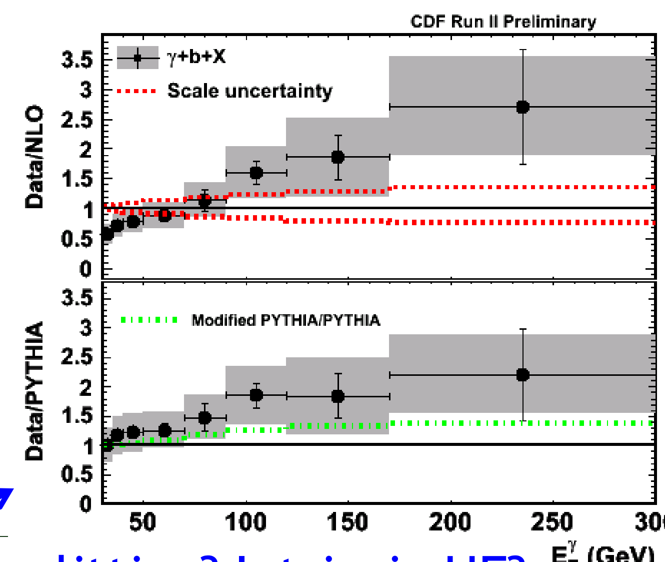


Motivation

- Sensitive to HF-content of proton
- Bkgd for many BSMs





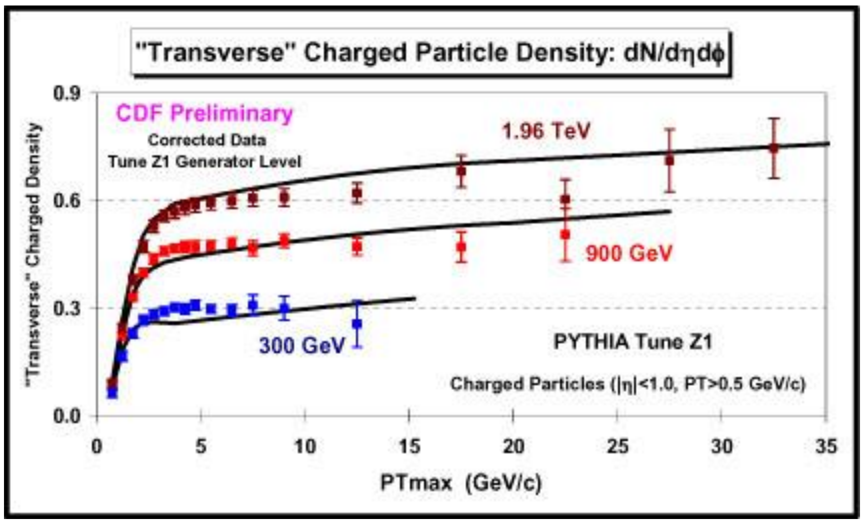


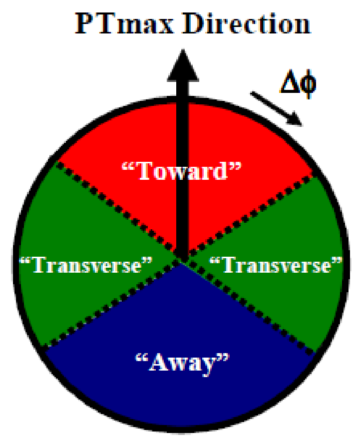
Higher order effects? Gluon splitting? Intrinsic HF?

http://www-cdf.fnal.gov/physics/new/qcd/ue_escan/escan/index.html

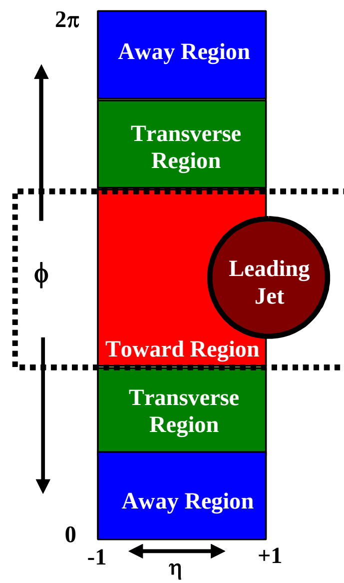
Energy Scan and Underlying Event (UE)

- Just before the shutdown, Tevatron delivered small amount (a few 10 M of events) of data at 300 & 900 GeV
- Transverse region sensitive to UE





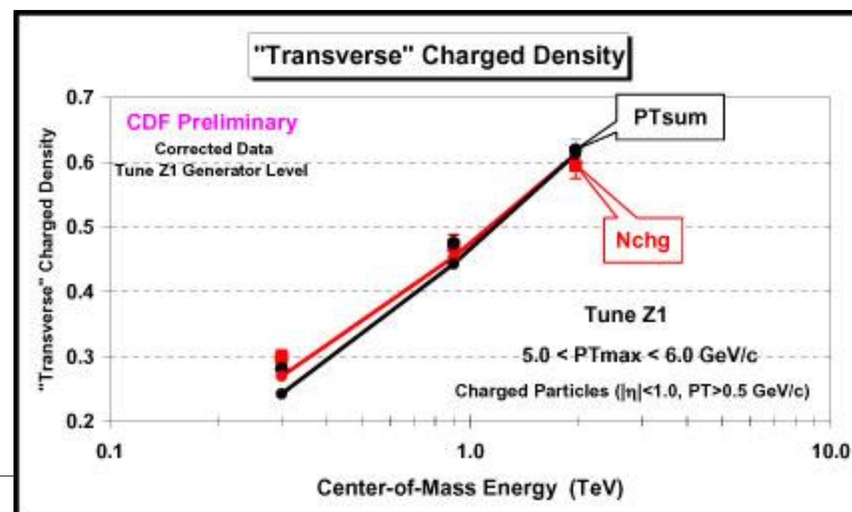
Transverse plane



η-φ Plane

Measurements will allow for

- Deeper understanding of MPI
- More precise prediction to projections to next LHC energies



Summary

Tremendous effort has been made to advance understanding of top quark and QCD at the Tevatron

- Data taking ended last fall, but still analyses with full dataset are on-going
- Many areas of studies are competitive and complimentary to results from the LHC
- Ttbar x-section, top quark mass are measured to 5%, 1% accuracy. AFB is rather unique at the Tevatron.
- Tevatron QCD measurements provide important inputs/feedback for PDF determination, QCD modeling, and MC tuning

More results on top and QCD physics from Tevatron can be found on:

- http://www-cdf.fnal.gov/physics/new/top/top.html
- http://www-d0.fnal.gov/Run2Physics/top/
- http://www-cdf.fnal.gov/physics/new/qcd/QCD.html
- http://www-d0.fnal.gov/Run2Physics/qcd/

Acknowledgement

- Many thanks to:

  Dmitry Bandurin, Andreas Jung, Christina Mesropian, Larry Nodulman, David Toback, Homer Wolfe, Jay Dittmann, Jon Wilson

  who gave me inputs for the talk.

  Some of the information in this talk was collected from contributions to the TOP2012 workshop (September 16-21, 2012), QCD@LHC2012 workshop (Aug 20-24, 2012), and ICHEP 2012 (July 4-11, 2012), especially the talks by Gianluca Petrillo, Pavol Bartos, Dan Amidei, Jyoti Joshi, Markus Wobisch, Rick Field, and Costas Vellidis.

Backup

Spin Correlation

- Top pairs are produced with a definite spin state depending on production mechanism:
  - Quark-Antiquark Annihilation (~85%): Spin 1
  - Gluon Fusion (~15%): Spin 0
- Top decays before hadronization (only known quark to do so!)
  - Spin information passed to decay products – the correlated spins can be measured from decay product angular distributions
- Correlation strength (frame dependent!) is defined as:

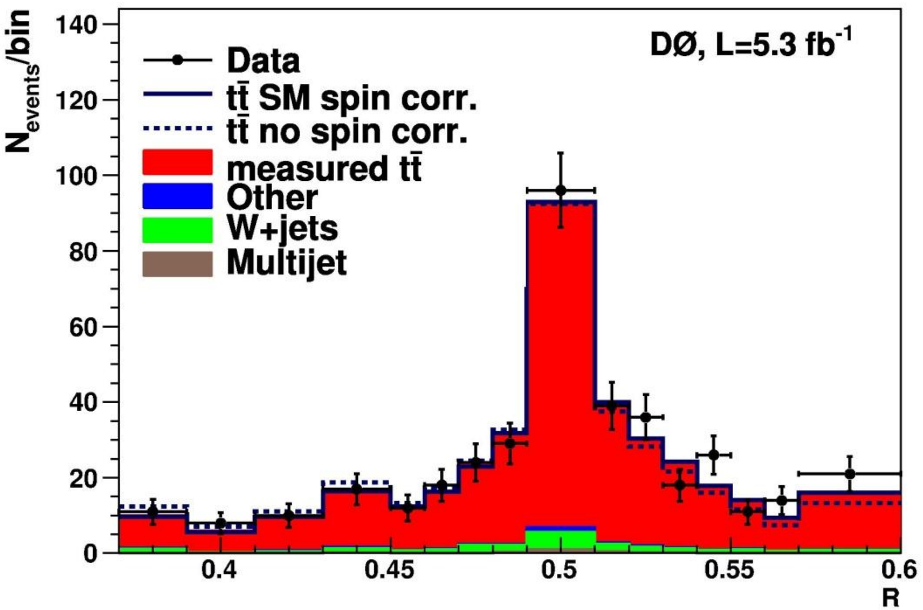
$$A = \frac{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} - N_{\uparrow\downarrow} - N_{\downarrow\uparrow}}{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} + N_{\uparrow\downarrow} + N_{\downarrow\uparrow}}$$

- Theory prediction: $A_{beam}^{SM} = 0.78^{+0.03}_{-0.04}$ (Nucl. Phys. B 690, 81(2004))

PRL 108, 032004 (2012)

Spin Correlation

- New matrix element approach
  - Significantly increased sensitivity
  - Likelihood fit based on probabilities that events are signal events and do (or do not) contain SM spin correlation

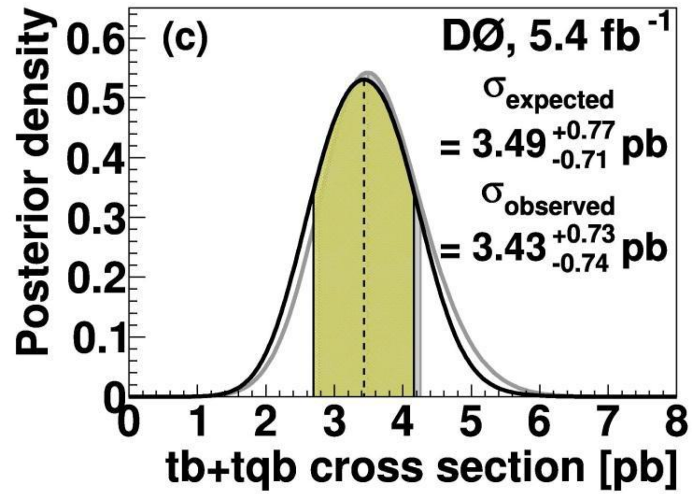


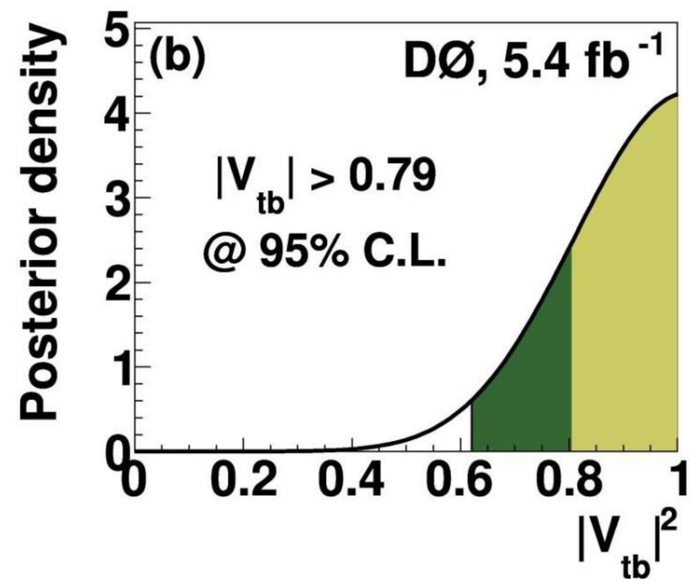
- 3 sigma evidence for spin correlations!

$$A = 0.66 \pm 0.23(\text{stat.}\oplus\text{syst.})$$

Lepton+Jets from 5.4 fb^{-1}: D0

- Use three multivariate (MVA) methods to extract signal:
  - Boosted decision tree, neural network, neuro-evolution of augmented topologies
- Six analysis channels:
  2, 3 or 4 jets with 1 or 2 b-tags
- Cross section measured using Bayesian approach
  - Posterior density peak for x-section, with 68% interval as uncertainty.
- Since $\sigma_{s+t} \propto |V_{tb}|^2$, directly measure $|V_{tb}|$ from σ_{s+t} posterior
  - Assuming $|V_{td}|^2 + |V_{ts}|^2 \ll |V_{tb}|^2$
  - Pure V-A and CP conserving W_{tb} vertex

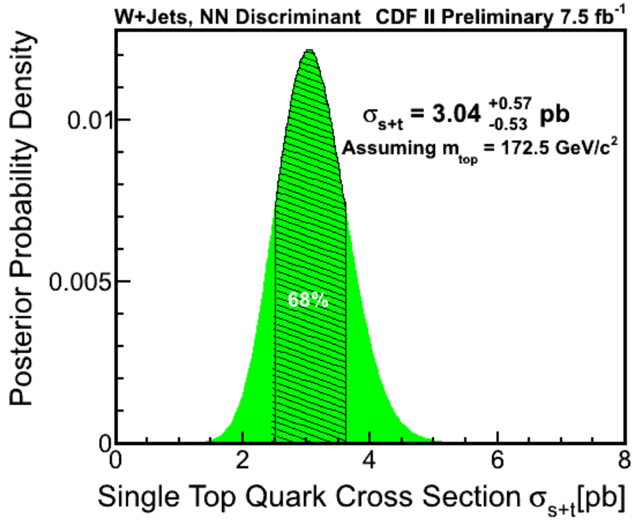




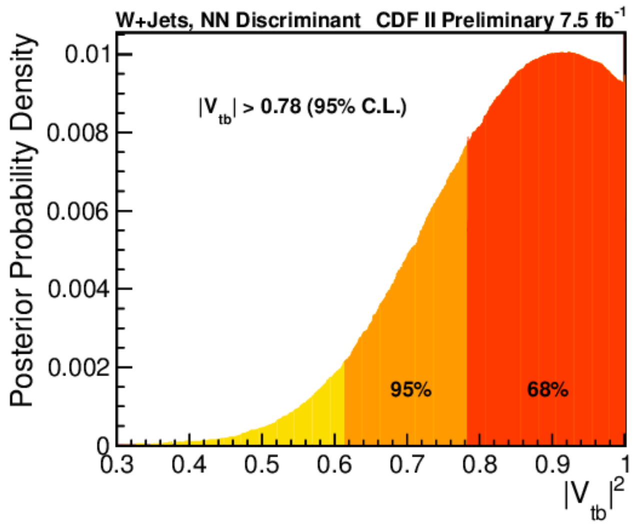
CDF Conf. Note 10793

Lepton+Jets from 7.5 fb^{-1}: CDF

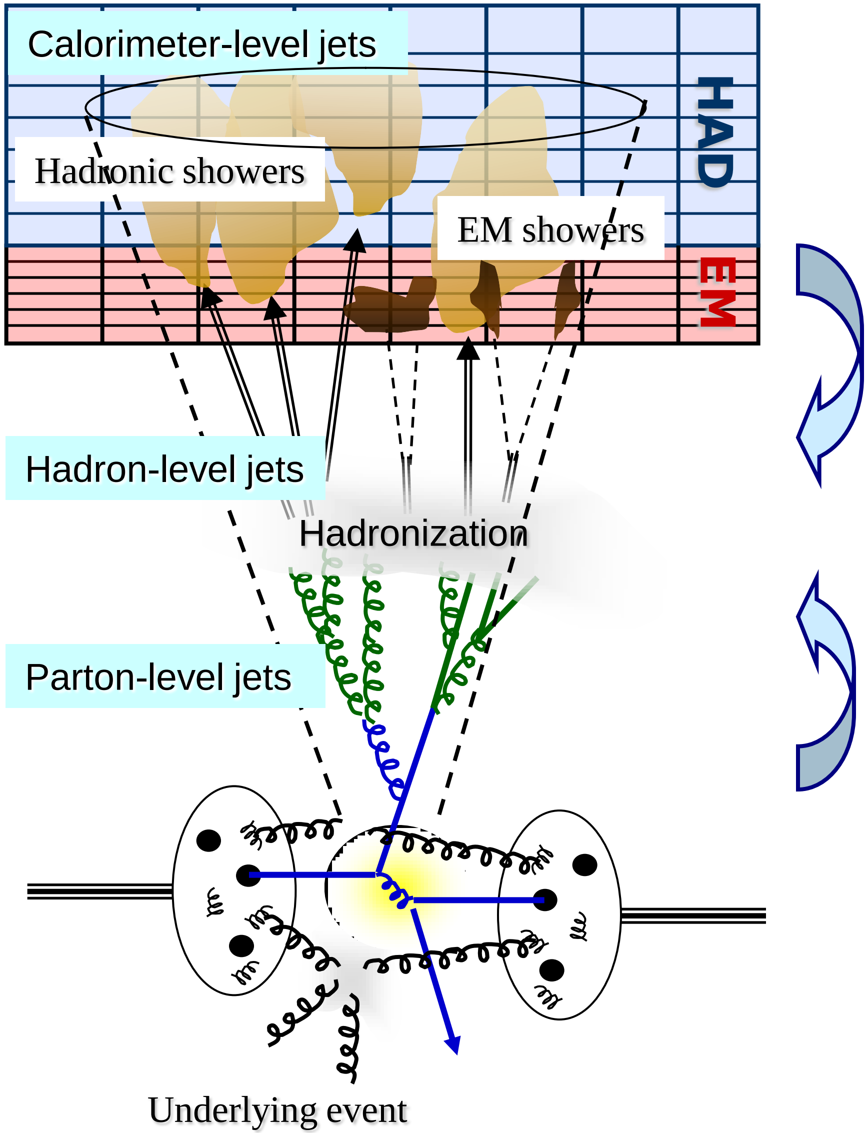
- Use a neural network discriminant
- Add new lepton category: ISOTRK
  - High quality, high PT isolated track: ~15% gain in single top acceptance
- POWHEP for signal modeling



- Assuming mtop = 172.5 Gev/c^2,
  - Measured cross section: σ_{s+t} = 3.04 +0.57-0.53 pb
  - From the cross section posterior set limit: $|V_{tb}|$ > 0.78 at 95% CL
  - Extracted $|V_{tb}|$ = 0.92 +0.10-0.08 (stat.+sys.) ± 0.05(theory)



Jet Production and Measuremnt

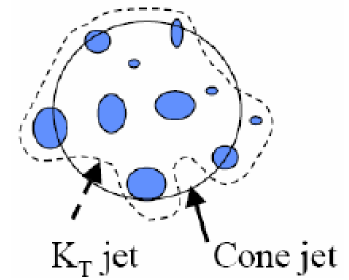


Unfold measurements to the hadron (particle) level

Correct parton-level theory for non-perturbative effects (hadronization & underlying event)

Jet Algorithms

Two main categories of jet algorithms



- Cone Algorithms
  - E.g. Midpoint Algo.: Extensive use at Tevatron in Run II (as suggested in Run II workshop in 1999, **hep-ex/0005012**)
  - Cluster objects based on their proximity in $y(\eta)$-ϕ space
  - Identify "stable" cones (kinematic direction = geometric center)
  - Pros: simpler for underlying-event and pileup corrections
    Cons: infrared-unsafe in high order pQCD & overlapping stable cones.
- Successive Combination Algorithms
  - E.g. Kt Algorithm: Extensive use at HERA. A few Tevatron analyses.
  - Cluster objects based on a certain metric. Relative Kt for Kt algorithm.
  - Pros: Infrared-safe in all order of perturbative QCD calculations.
    Cons: Jet geometry can be complicated. Complex corrections.

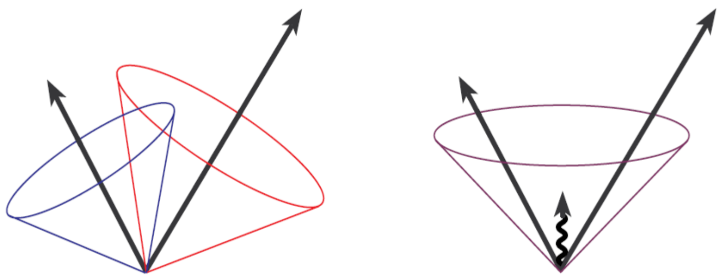
A lot of developments in recent years.

- SISCone, Cambridge-Aachen, Anti-Kt, etc.
- Extensively studied in LHC experiments. Will benefit future studies.

Jet "Definitions" - Jet Algorithms

Midpoint cone-based algorithm

Infrared unsafety:
soft parton emission changes jet clustering



- Cluster objects based on their proximity in y-ϕ space
- Starting from seeds (calorimeter towers/particles above threshold), find stable cones
  (kinematic centroid = geometric center).
- Seeds necessary for speed, however source of infrared unsafety.
- In recent QCD studies, we use "Midpoint" algorithm, i.e. look for stable cones from middle points between two adjacent cones
- Stable cones sometime overlap
  → merge cones when p_T overlap > 75%

Jet "Definitions" - Jet Algorithms

Midpoint cone-based algorithm

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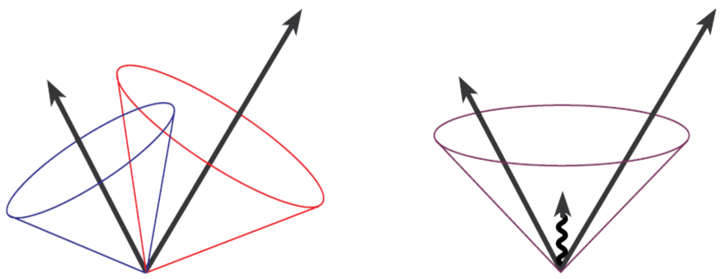


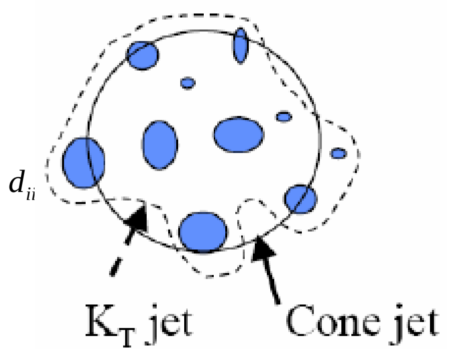
More advanced algorithm(s) available now, but negligible effects on this measurement.

Jet "Definitions" - Jet Algorithms

k_T algorithm

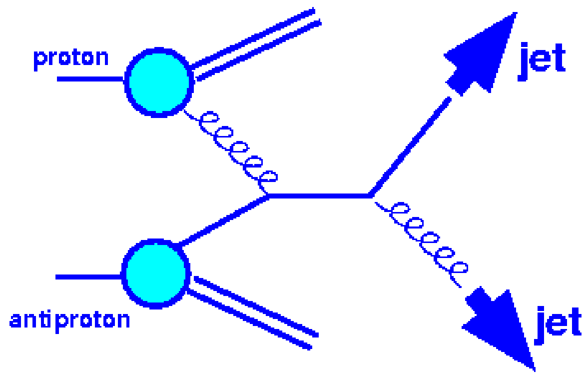
- Cluster objects in order of increasing their relative transverse momentum (k_T)
  - $d_{ii} = p_{T,i}^2, \quad d_{ij} = \min(p_{T,i}^2, p_{T,j}^2)\dfrac{\Delta R^2}{D^2}$

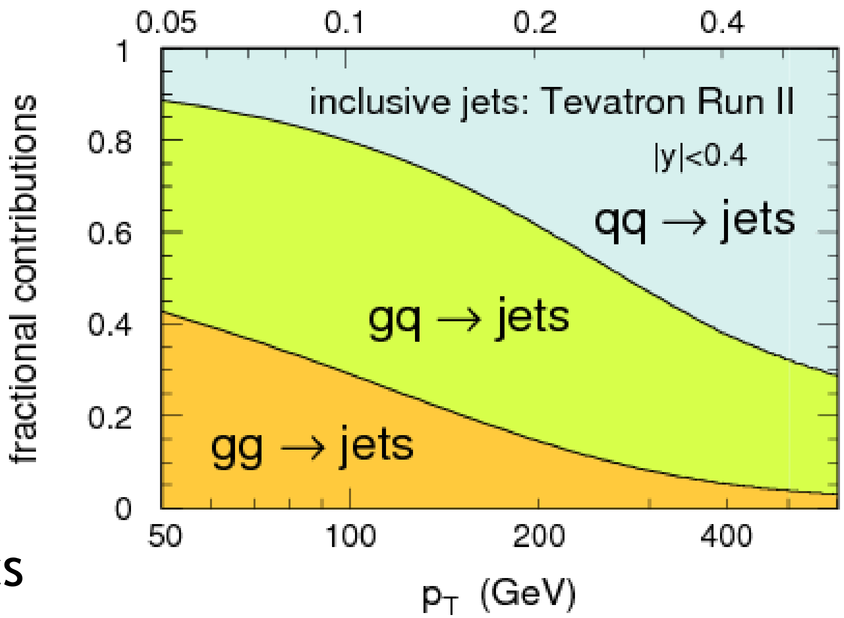
  until all objects become part of jets



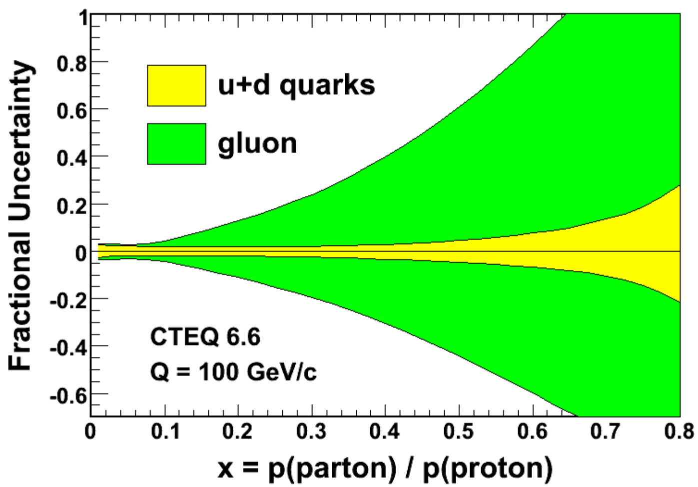
- D parameter controls merging termination and characterizes size of resulting jets
- No issue of splitting/merging. Infrared and collinear safe to all orders of QCD.
- Every object assigned to a jet: concerns about vacuuming up too many particles.
- Successful at LEP & HERA, but relatively new at the hadron colliders
  - More difficult environment (underlying event, multiple *pp* interactions…)

Jet Production at the Tevatron

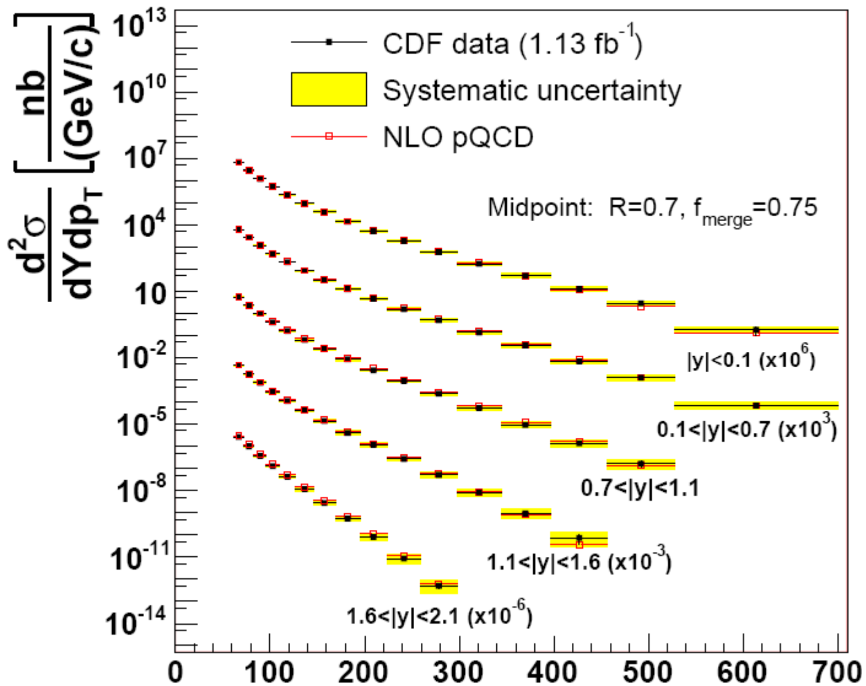




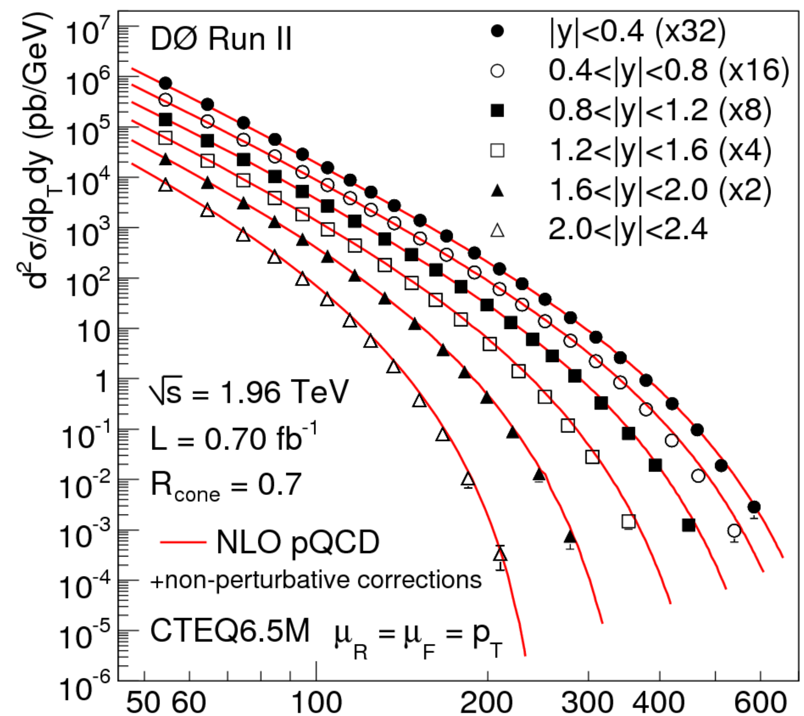
- Test pQCD at highest Q^2.
- Unique sensitivity to new physics
  - Compositeness, new massive particles, extra dimensions, …
- Constrain PDFs (especially gluons at high-x)
- Measure α_s



Inclusive Jet Cross Section



Phys. Rev. D 78, 052006 (2008) p_T (GeV/c)



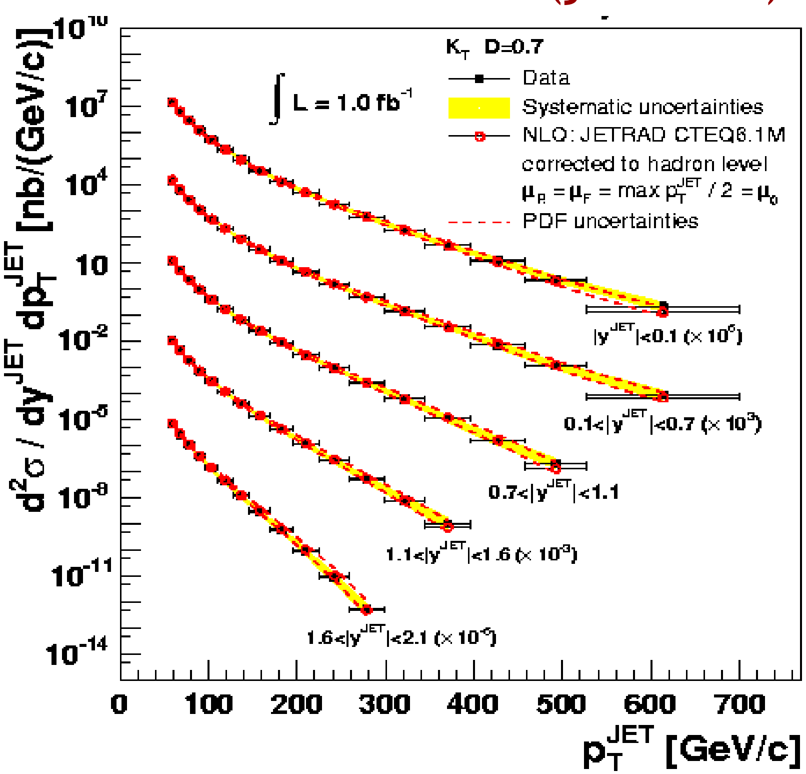
Phys. Rev. Lett. 101, 062001 (2008) p_T (GeV/c)

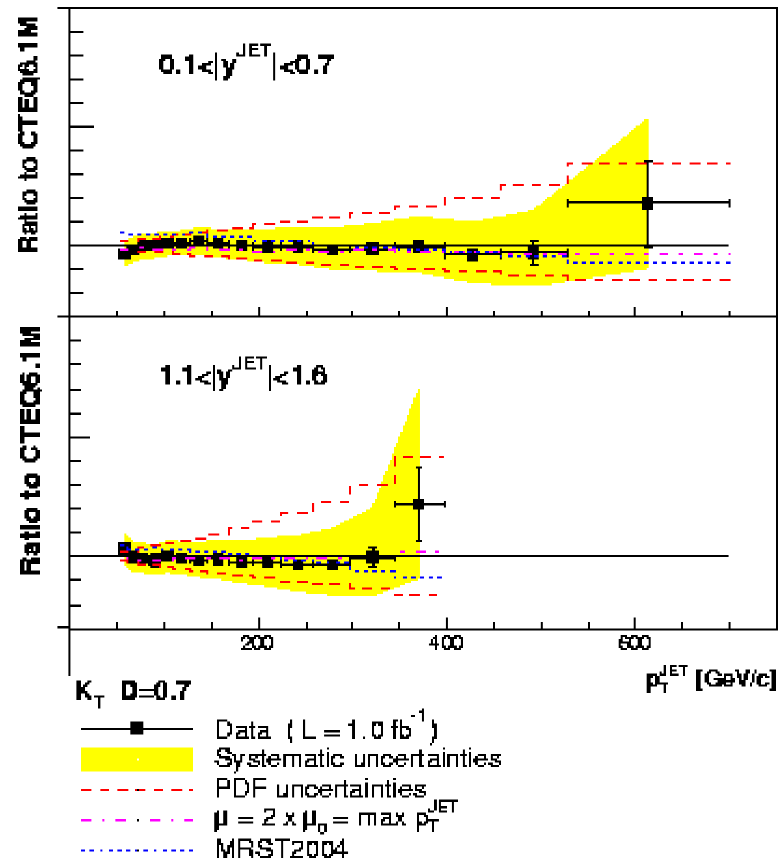
- Test pQCD over 8 order of magnitude in $d\sigma^2/dp_Tdy$
- Highest p_T^{jet} > 600 GeV/c
- Jet energy scale (JES) is dominant uncertainty: CDF (2-3%), D0 (1-2%)
- Spectrum steeply falling: 1% JES error → 5—10% (10—25%) central (forward) x-section

Inclusive Jets with Kt Algorithm

- Data/theory comparison consistent between measurements with cone and Kt algorithms and with different D values (jet sizes)

Phys. Rev. D 75, 092006 (2007)



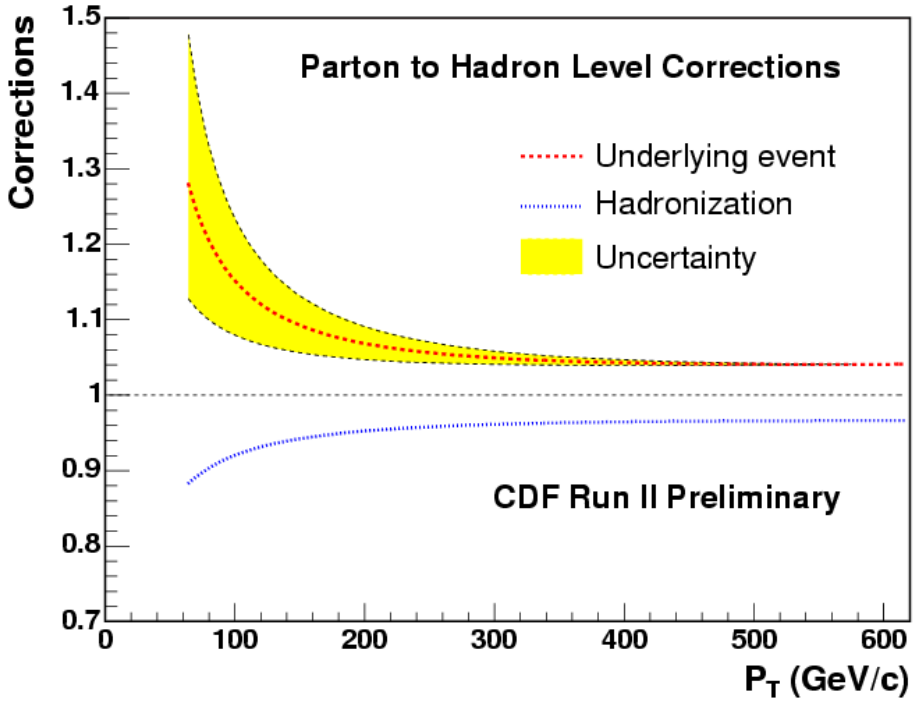


From Particle to Parton Level

use models to study effects
of non-perturbative processes
(PYTHIA, HERWIG)

- hadronization correction
- underlying event correction

CDF study for cone R=0.7
for central jet cross section

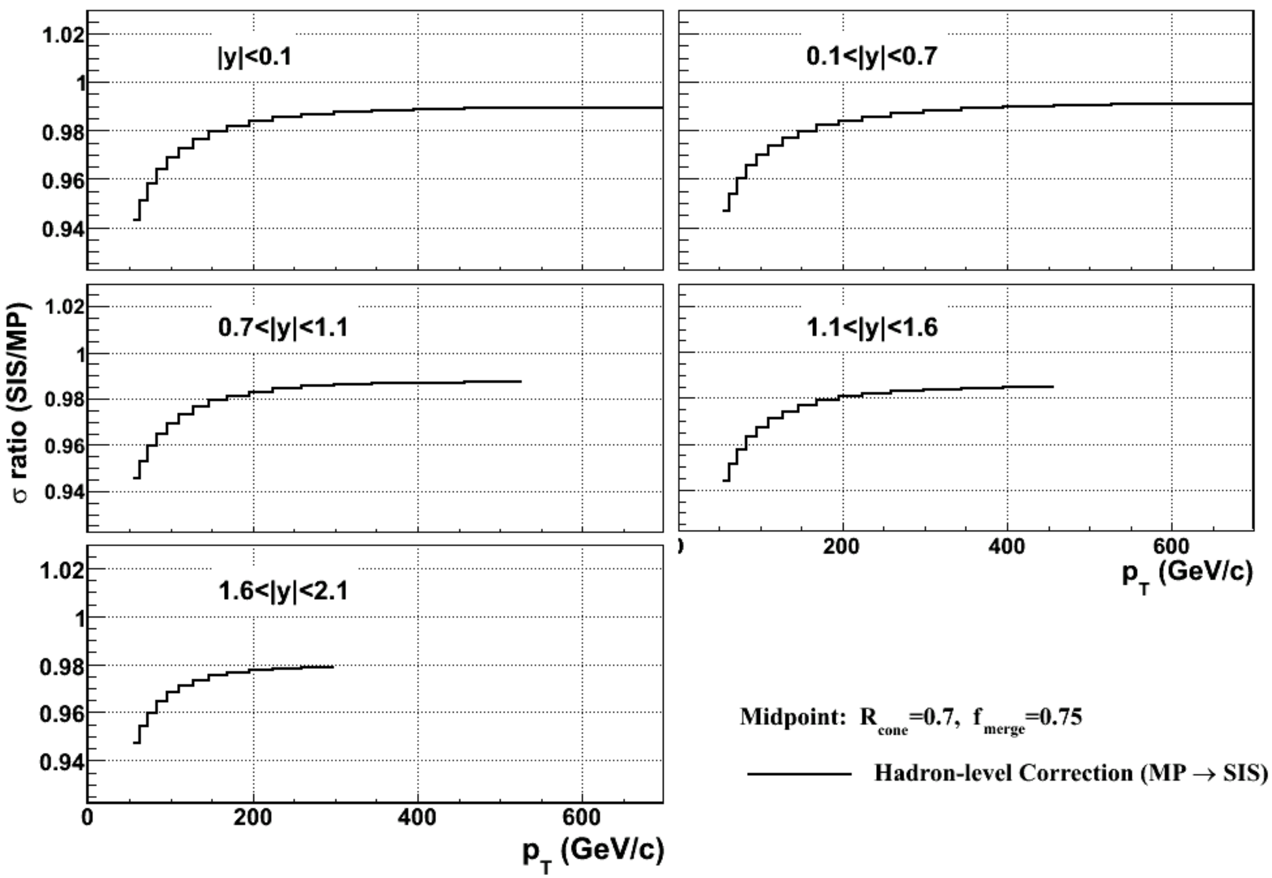


→ apply this correction to the pQCD calculation
→ to be used for future MSTW/CTEQ PDF results
→ first time consistent theoretical treatment of jet data in PDF fits

new in Run II !!!

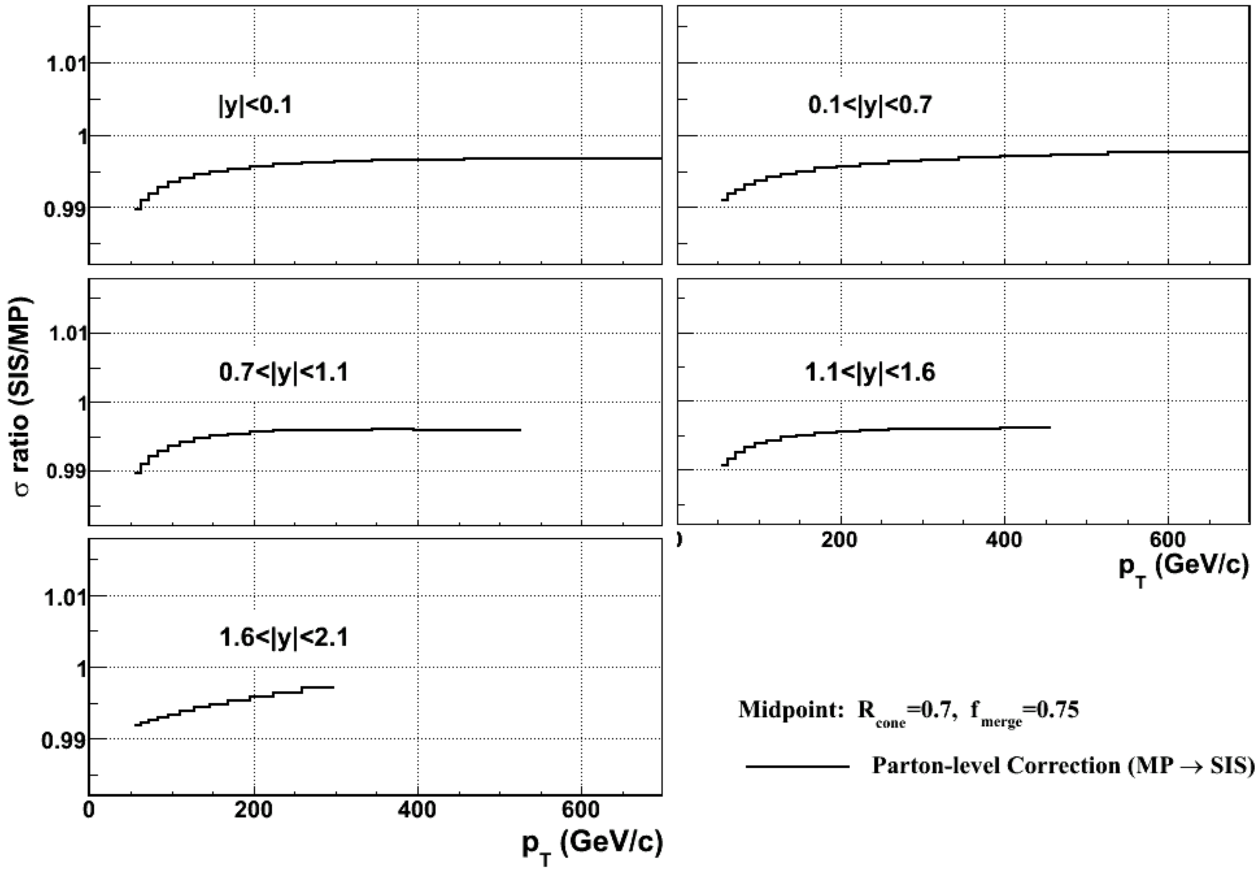
Midpoint vs SIScone: hadron level

- Differences between the currently-used Midpoint algorithm and the newly developed SIScone algorithm in MC at the hadron-level.



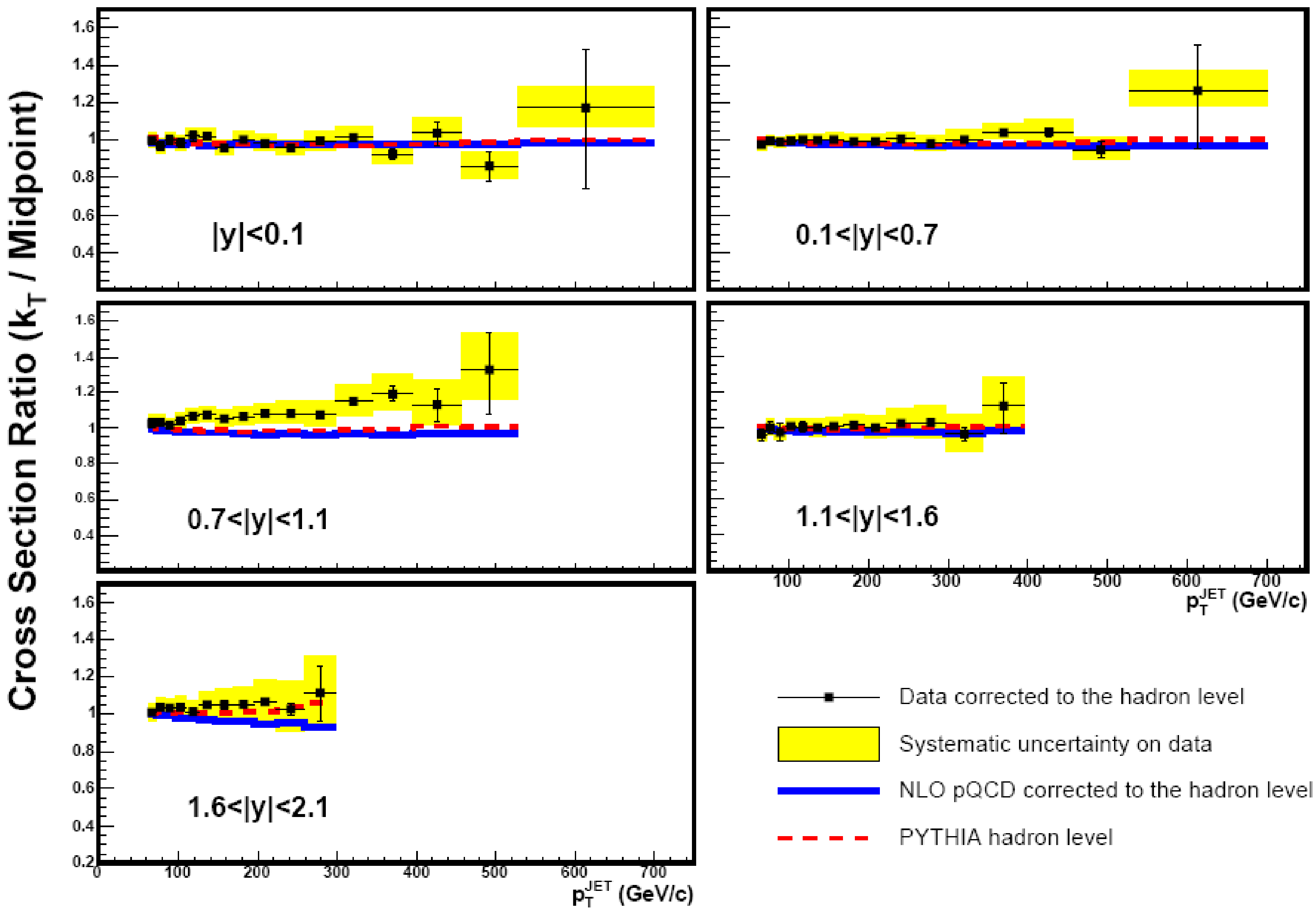
Midpoint vs SIScone: parton level

- Differences between the currently-used Midpoint algorithm and the newly developed SIScone algorithm at the parton-level.



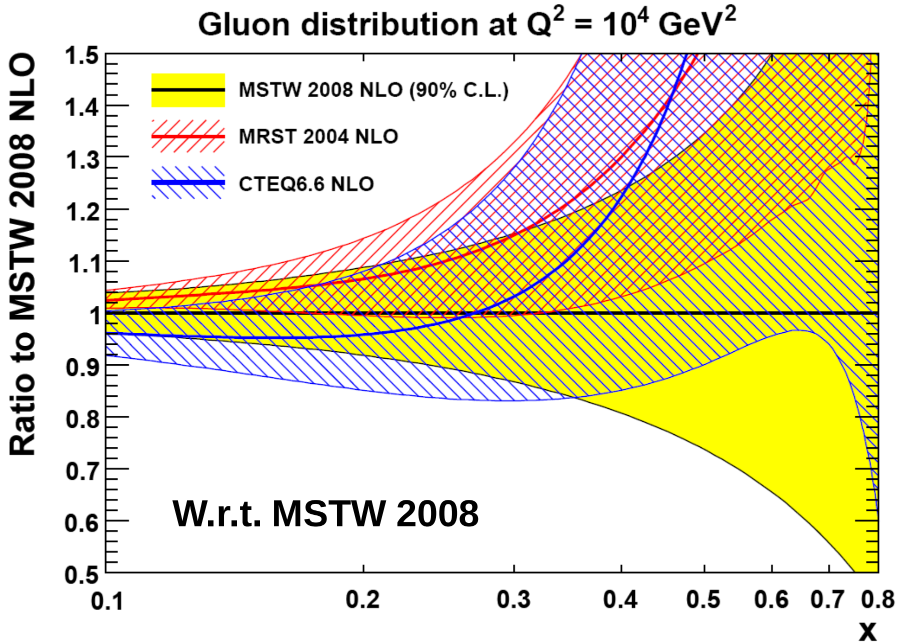
Differences < 1% → negligible effects on data-NLO comparisons

Inclusive Jets: Cone vs Kt Algorithms

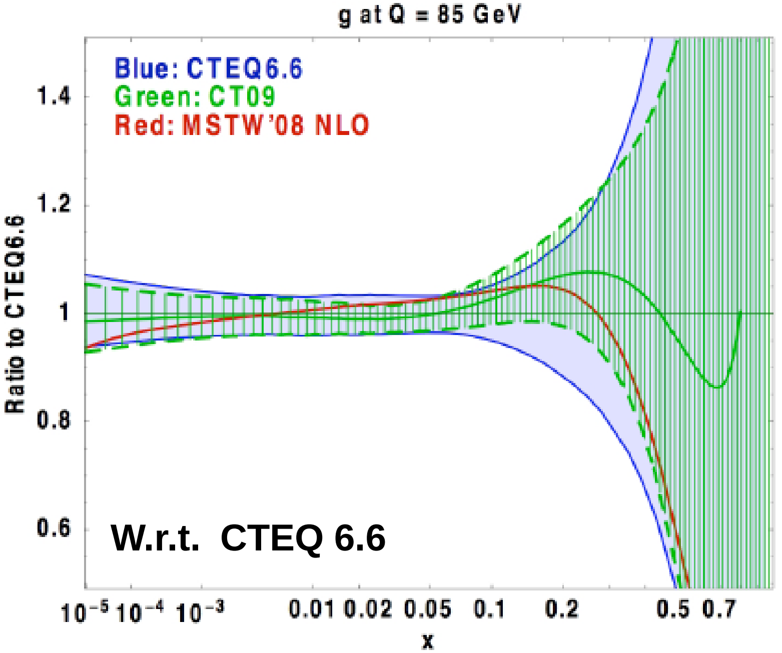


PDF with Tevatron Run II Jet Data

MSTW08: arXiv:0901.0002, Euro. Phys. J. C



CT09: Phys.Rev.D80:014019,2009.



- Tevatron Run II data lead to softer high-x gluons (more consistent with DIS data) and help reducing uncertainties
- MSTW08 does not include Tevatron Run 1 data any longer while CT09 (CTEQ TEA group) still does, which makes MSTW08 high-x even softer (consistent within uncertainty)

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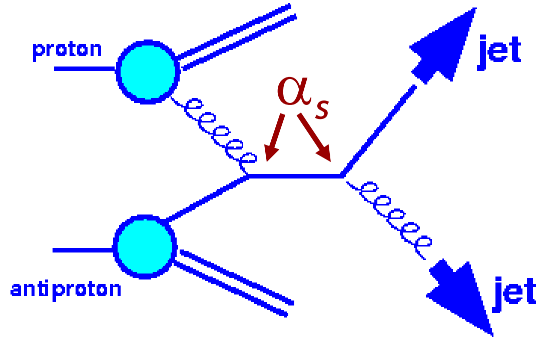
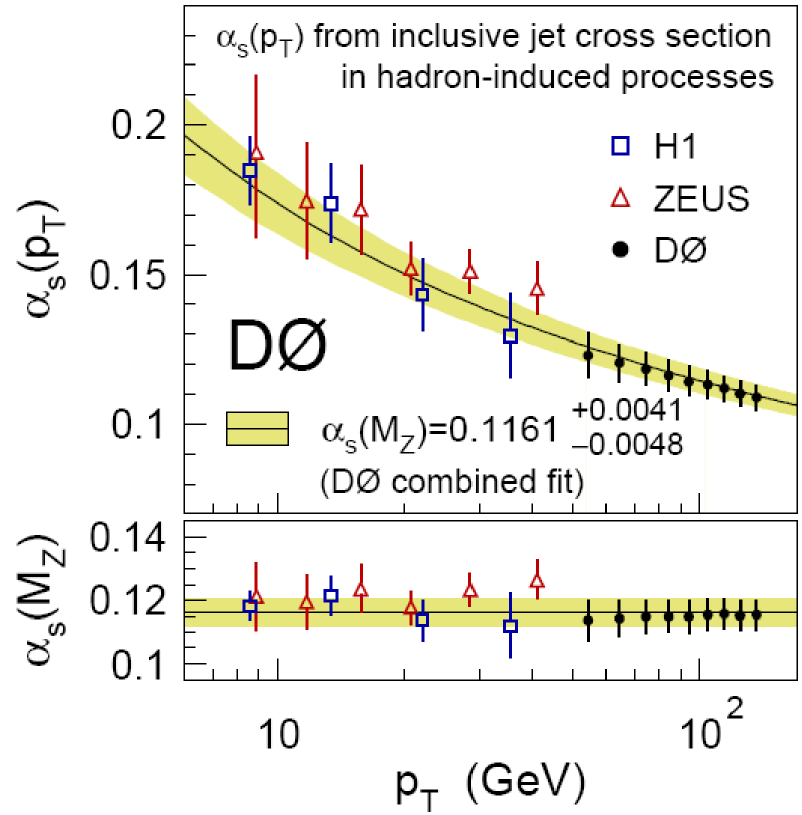
Strong Coupling Constant



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

From 22 (out of 110) inclusive jet cross section data points at 50 < p_T < 145 GeV/c



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

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

3.5-4.1% precision