PROTON STRUCTURE FOR LHC DISCOVERIES

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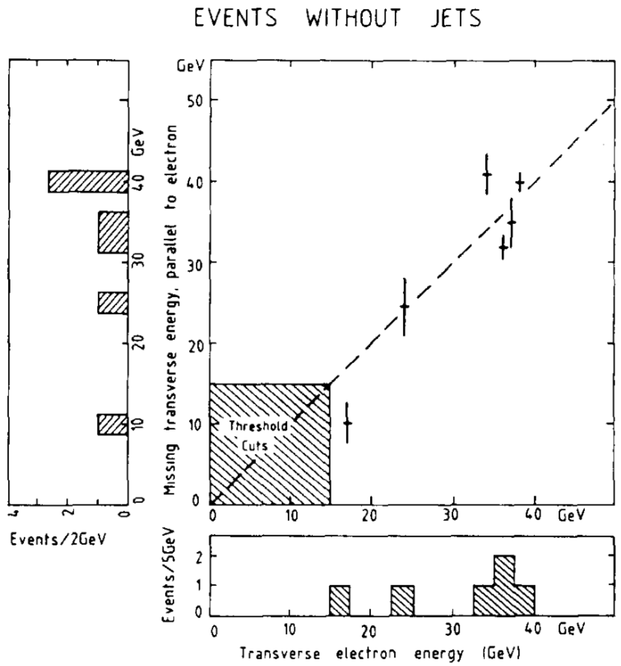
HIGGS-MAXWELL MEETING

EDINBURGH, FEBRUARY 8, 2012

DISCOVERY AT THE S$p\bar{p}$S AND AT THE LHC

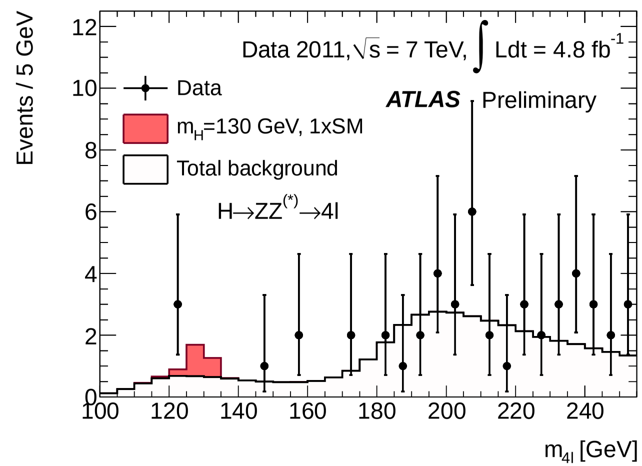
DISCOVERY OF THE W (1984)



p_T distribution of the e and ν

from W decay at UA1 (1984)

DISCOVERY OF THE HIGGS (2011?)



transverse energy distribution

in the four lepton channel at ATLAS (2011)

- HADRON COLLIDER CIRCA 1985 $\Rightarrow$ “CLEAN” DISCOVERY SIGNAL
- HADRON COLLIDER CIRCA 2010 $\Rightarrow$ PRECISION PHYSICS $\leftrightarrow$ NEW PHYSICS

PDFs from the $Sp\bar{p}S$ to the LHC

PDFs in 1984

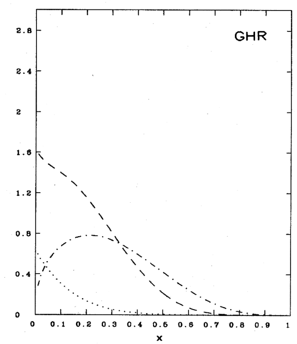


FIG. 25. Parton distributions of Glück, Hoffmann, and Reya (1982), at $Q^2=5$ GeV^2: valence quark distribution $x[u_v(x)+d_v(x)]$ (dotted-dashed line), $xG(x)$ (dashed line), and q_v (dotted line).

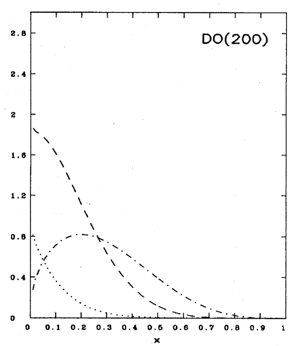


FIG. 27. "Soft-gluon" ($\Lambda=200$ MeV) parton distributions of Duke and Owens (1984) at $Q^2=5$ GeV^2: valence quark distribution $x[u_v(x)+d_v(x)]$ (dotted-dashed line), $xG(x)$ (dashed line), and $q_v(x)$ (dotted line).

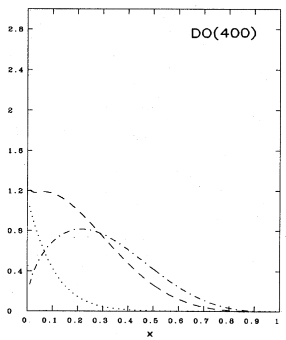


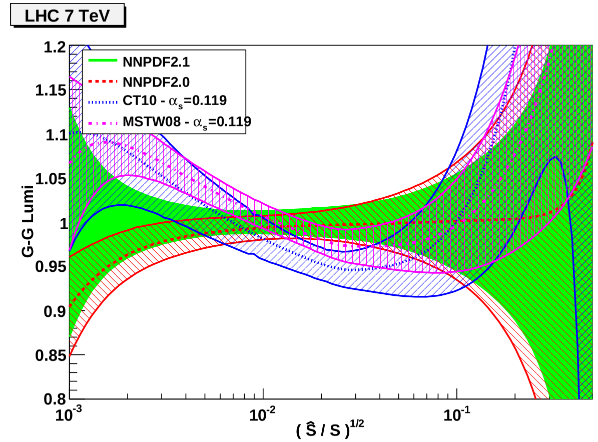
FIG. 26. "Hard-gluon" ($\Lambda=400$ MeV) parton distributions of Duke and Owens (1984) at $Q^2=5$ GeV^2: valence quark distribution $x[u_v(x)+d_v(x)]$ (dotted-dashed line), $xG(x)$ (dashed line), and $q_v(x)$ (dotted line).

Rev. Mod. Phys., Vol. 56, No. 4, October 1984

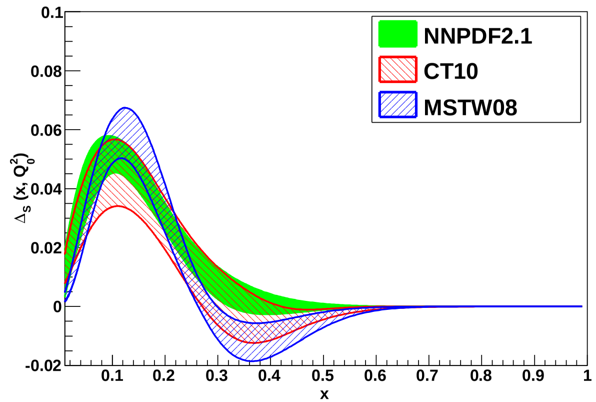
GHR vs Duke-Owens

PDFs in 2011

Gluon-gluon lumi



$\bar{u}-\bar{d}$



NNPDF vs MSTW vs CTEQ, 2011

- hadron colliders circa 1985 $\Rightarrow$ qualitative QCD: discovery physics
- DIS at NMC and HERA 1995-2005 $\Rightarrow$ quantitative QCD: precision physics
- hadron colliders circa 2010 $\Rightarrow$ precision QCD $\leftrightarrow$ new physics

SUMMARY

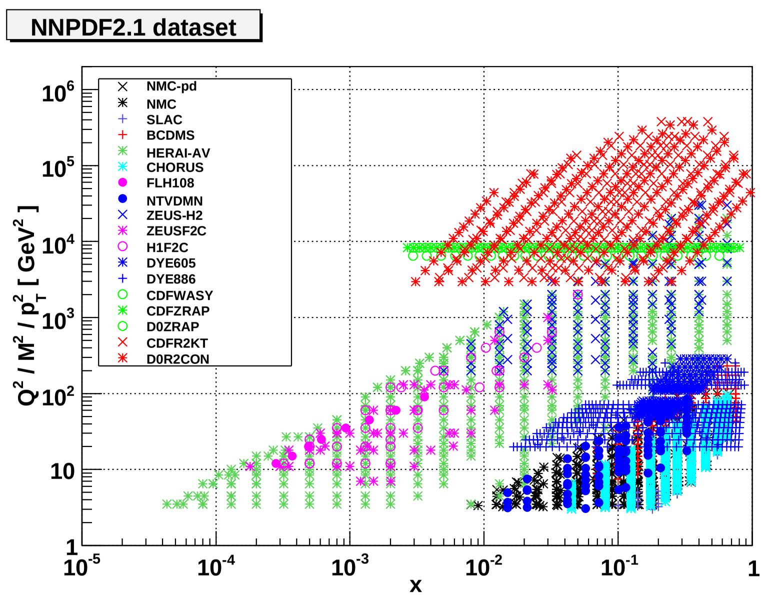
- PROTON STRUCTURE TODAY
  - PDFS, LUMINOSITIES, STANDARD CANDLES
  - RECENT PROGRESS AT NLO AND NNLO
- ISSUES
  - THE MEANING OF PDF UNCERTAINTIES
  - DATA CONSISTENCY
- THE IMPACT OF HADRON COLLIDER DATA
  - JETS AND THE GLUON
  - FLAVOR SEPARATION: DRELL-YAN, W AND Z
- PRECISION PHYSICS AT THE LHC
  - COLLIDER ONLY PDFS
  - THE ROLE OF THE LHC DATA
- A ROAD MAP FOR THE FUTURE

THE STATE OF THE ART

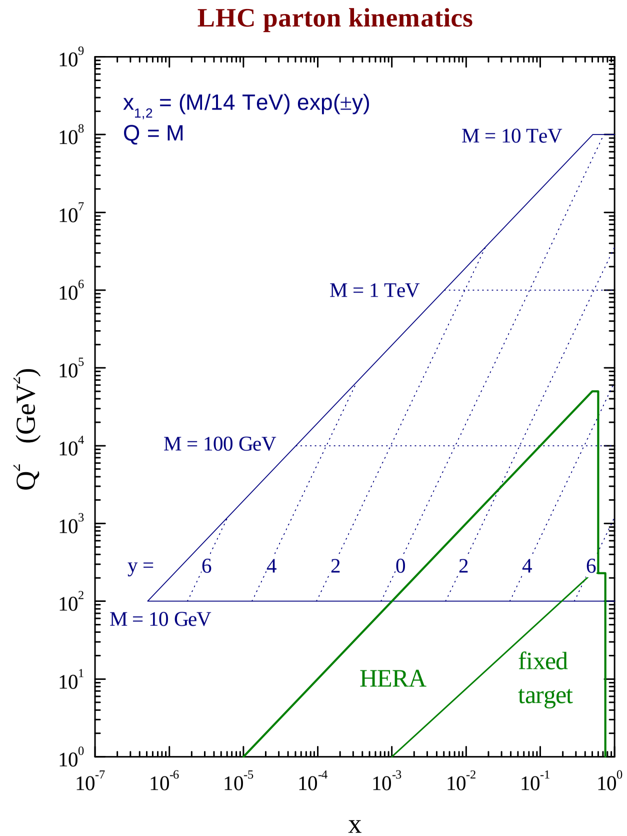
CURRENT PDF SETS

$$\sigma_X(s, M_X^2) = \sum_{a,b} \int_{x_{\min}}^1 dx_1\, dx_2\, f_{a/h_1}(x_1) f_{b/h_2}(x_2) \hat{\sigma}_{q_a q_b \to X}\left(x_1 x_2 s, M_X^2\right)$$

data in global fits



LHC kinematics



- CT10: GLOBAL, LO+NLO, SEVERAL α_s VALUES, VFN
- MSTW08: GLOBAL, LO+NLO+NNLO, SEVERAL α_s VALUES, VFN
- NNPDF2.1-2.2: GLOBAL (INCL. LHC), LO+NLO+NNLO, SEVERAL α_s VALS., VFN
- ALEKHIN ABKM: DIS+SOME DY, NLO+NNLO, SINGLE α_s VALUE, FFN
- HERAPDF1.0 (1.5?): HERA DIS, NLO+NNLO, SEVERAL α_s VALS, VFN
- SETS BASED ON MODEL ASSUMPTIONS (GRV/GJR, STATISTICAL PDFS,...)

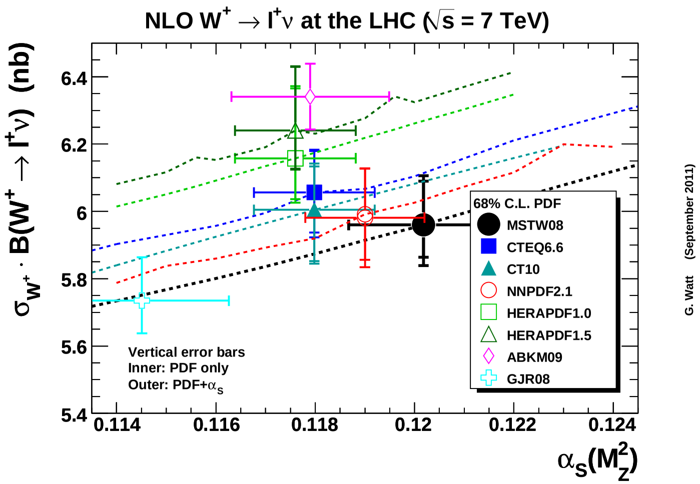
FEATURES, TRADEOFFS AND CHOICES

- DATASET: CTEQ, MSTW, NNPDF FIXED TARGET + COLLIDER, eP AND $\bar{P}P$ DATA (NNPDF: LHC); ABKM, GJR GLOBAL DIS+ FIXET-TARGET DY; HERAPDF: HERA DIS ONLY
- STATISTICAL TREATMENT: CTEQ, MSTW HESSIAN WITH DYNAMICAL TOLERANCE; HERAPDF, STANDARD HESSIAN+PARM. ERROR ANALYSIS; GJR, HESSIAN WITH FIXED TOLERANCE; ABKM STANDARD HESSIAN; NNPDF MONTE CARLO (ALSO STUDIED BY HERAPDF, MSTW)
- PARTON PARAMETRIZATION: CTEQ, MSTW, HERAPDF $x^\alpha(1-x)^\beta\times$ POLYNOMIALS; GJR: DITTO + VALENCELIKE ASSUMPTION; NNPDF NEURAL NETS; CHEBYSHEV POLYNOMIALS STUDIED BY HERAPDF;
- α_s VALUE: CTEQ, NNPDF: EXTERNAL PARAMETER, SEVERAL VALUES AVAILABLE; MSTW: FITTED, BUT ALSO VARIABLE AS EXT.PARAMETER; ABKM, GJR: FITTED, NOT VARIABLE AS EXT. PARAMETER
- PERTURBATIVE ORDER: CTEQ: LO+NLO; MSTW: LO+NLO+NNLO; NNPDF LO+NLO+NNLO; ABKM, HERAPDF, GJR: NLO+NNLO
- HEAVY QUARKS: CTEQ: GM-VFN (SACOT-χ SCHEME); MSTW: GM-VFN (ACOT+TR' SCHEME); NNPDF: GM-VFN (FONLL SCHEME); ABKM: FFN ($N_f = 3, 4$ MATCHED WITH BMSN SCHEME); GJR: FFN ($N_f = 3$)

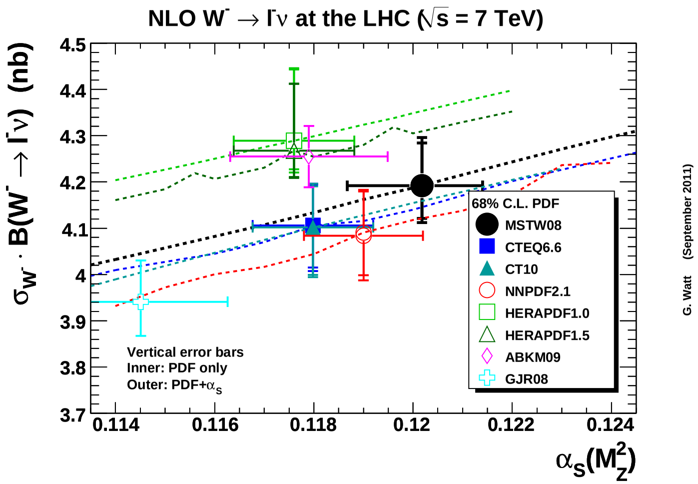
LISTED IN DECREASING ORDER OF IMPORTANCE!

WHERE DO WE STAND?
LHC STANDARD CANDLES (NLO)

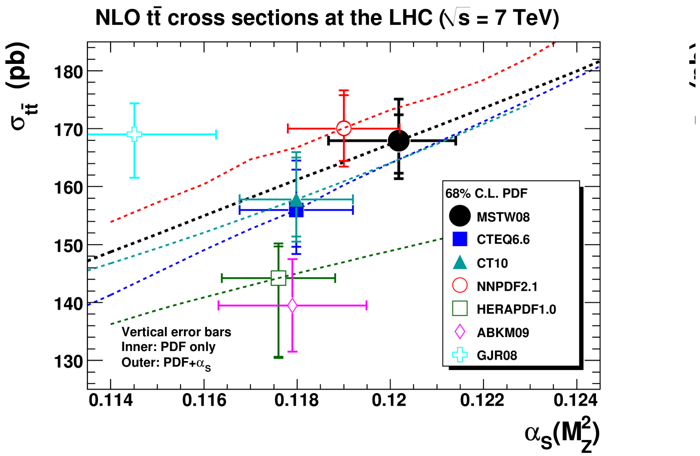
W^+



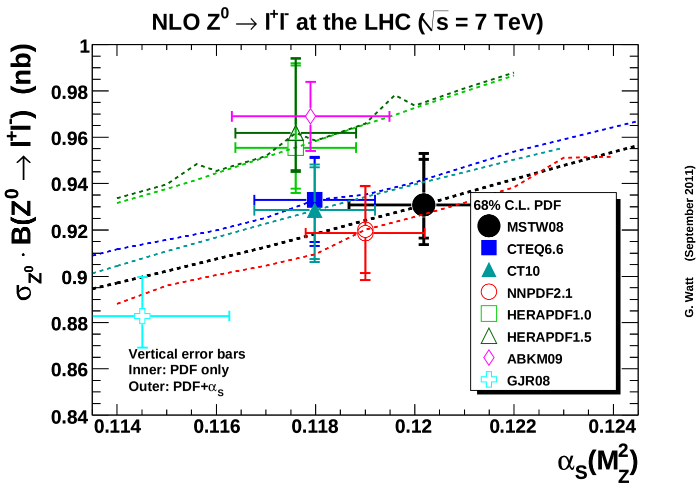
W^-



TOP



Z

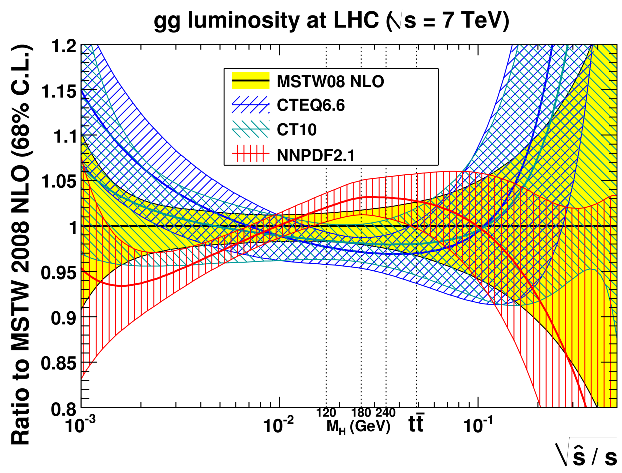


(G. Watt, 2011)

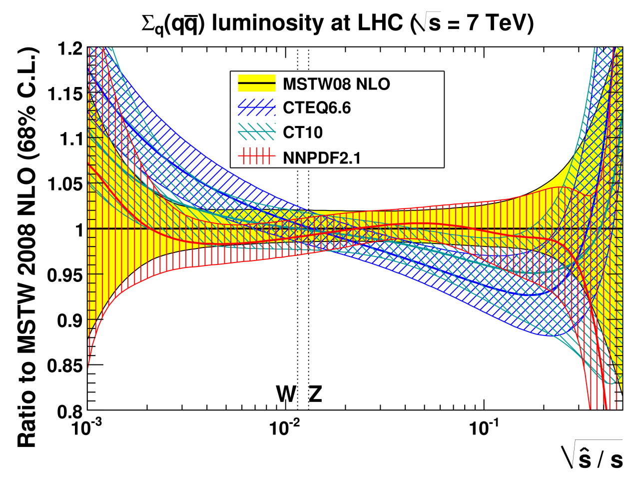
- GLOBAL FITS IN GOOD MUTUAL AGREEMENT
- CHOICE OF α_s VALUE IMPORTANT
- PDF4LHC RECOMMENDATION: ENVELOPE OF CTEQ, MSTW, NNPDF

WHERE DO WE STAND?
PARTON LUMINOSITIES (NLO)

GLUON-GLUON

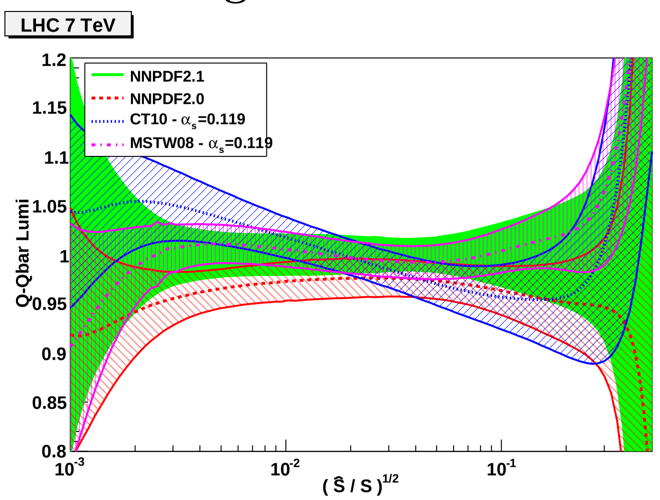


QUARK-QUARK

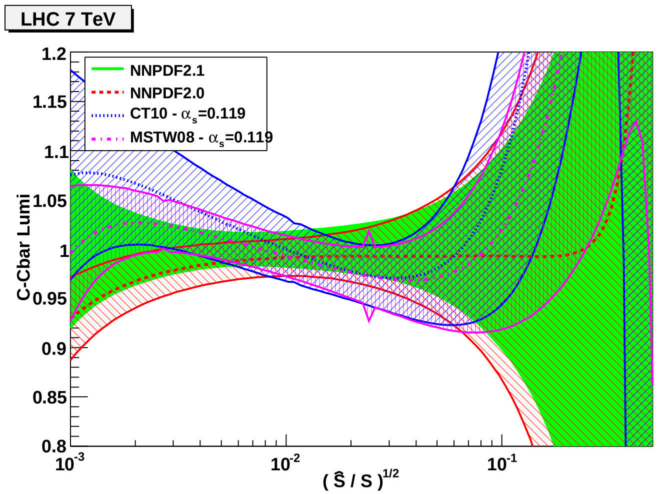


(G. Watt, 2011)

QUARK-GLUON



CHARM-CHARM



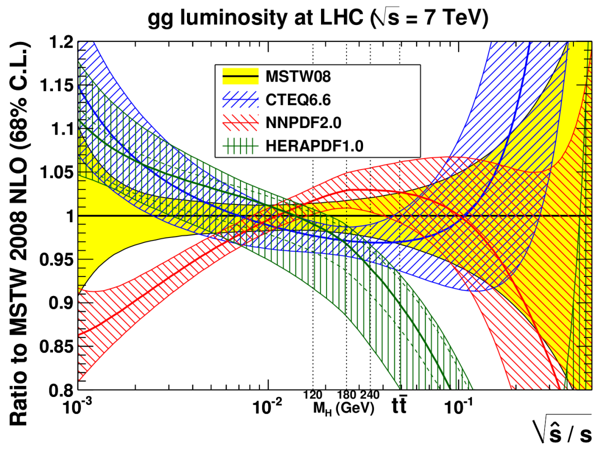
(NNPDF, 2011)

CONTINUOUS PROGRESS

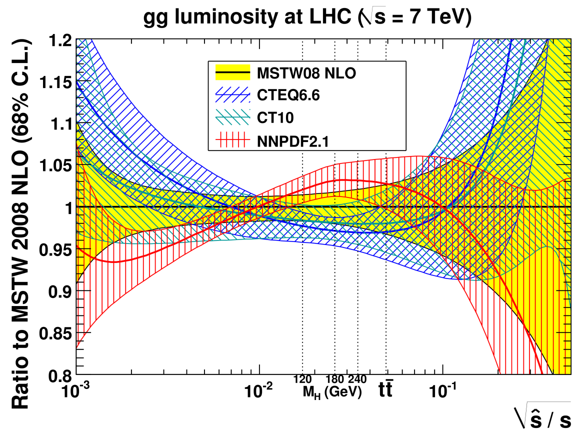
PARTON LUMINOSITIES (NLO)

GLUON-GLUON

2010

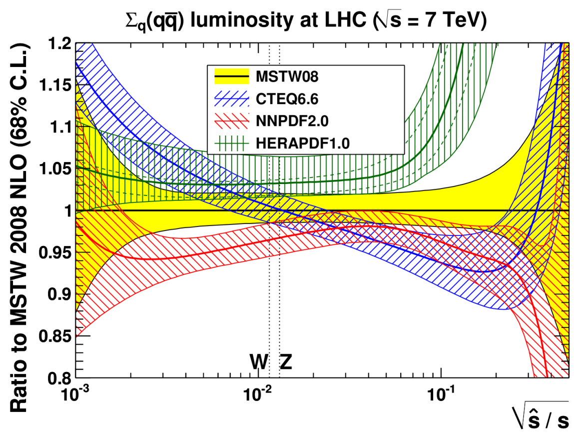


2011

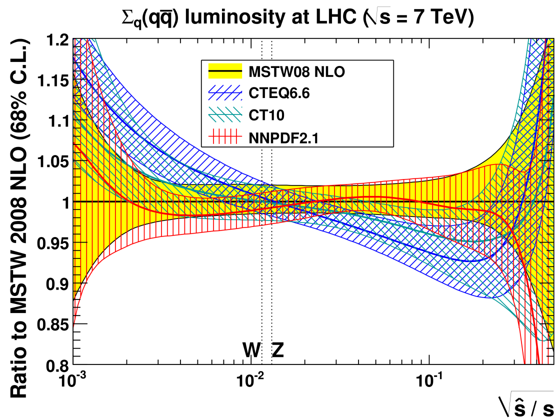


QUARK-QUARK

2010



2011



(G. Watt, 2011)

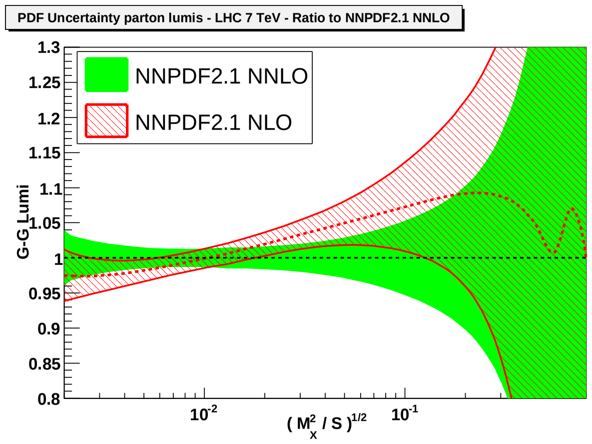
- NNPDF2.0 $\rightarrow$ NNPDF2.1: INCLUSION OF HW MASSES
- CTEQ6.6 $\rightarrow$ CT10: IMPROVED STATISTICS, PARAMETRIZATION, DATA
- CONSIDERABLY IMPROVED AGREEMENT!

CONTINUOUS PROGRESS

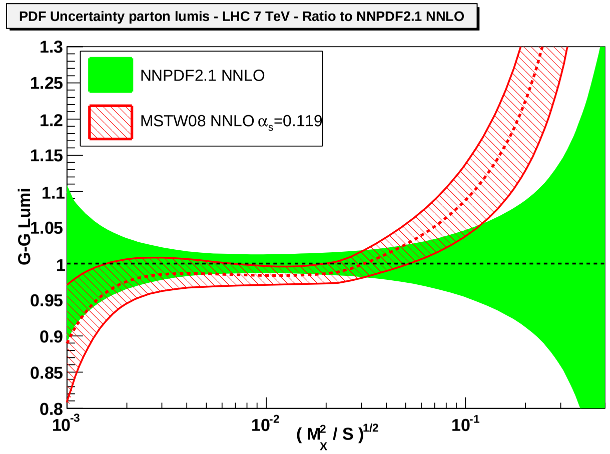
PARTON LUMINOSITIES (NNLO)

GLUON-GLUON

NNPDF NLO vs. NNLO

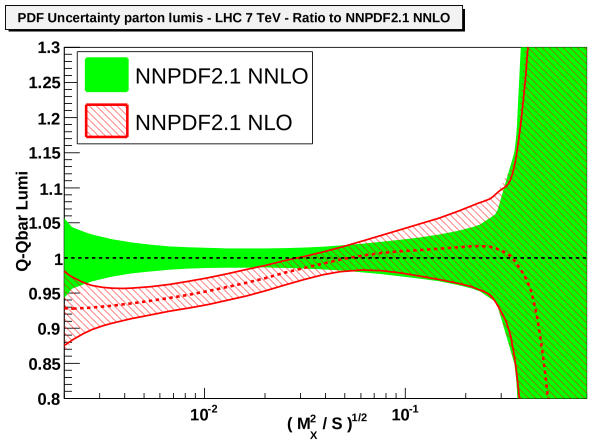


NNLO NNPDF2.1 vs. MSTW08

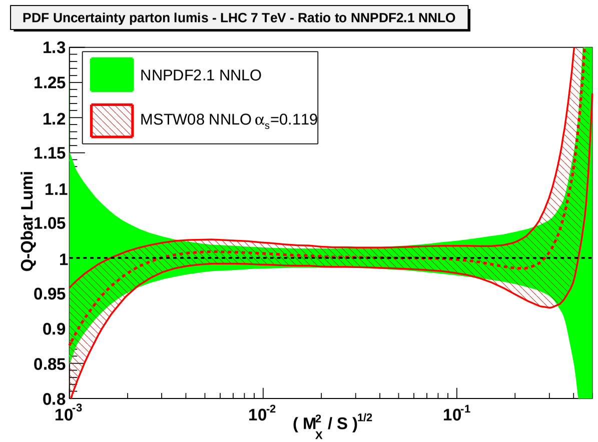


QUARK-QUARK

NNPDF NLO vs. NNLO



NNLO NNPDF2.1 vs. MSTW08



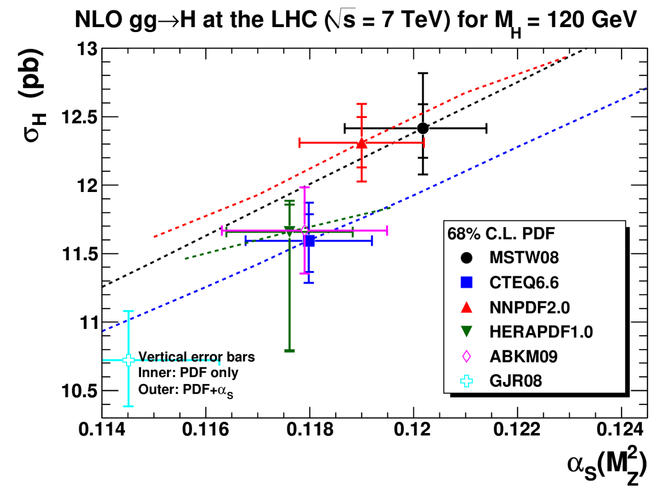
(NNPDF, 2011)

- NNPDF2.1 NLO vs NNLO $\rightarrow$ stability
- NNPDF2.1 vs MSTW08 $\rightarrow$ good agreement in EW $M_x \sim 100$ GeV region, but MSTW gluon unstable at small x

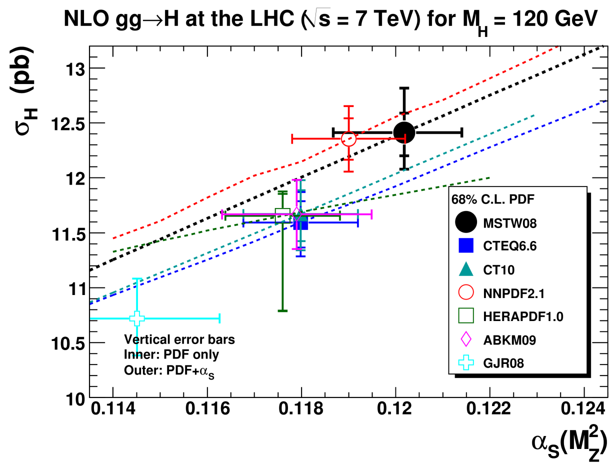
CONTINUOUS PROGRESS

THE HIGGS CROSS SECTION

$m_H = 120$ GeV: 2010

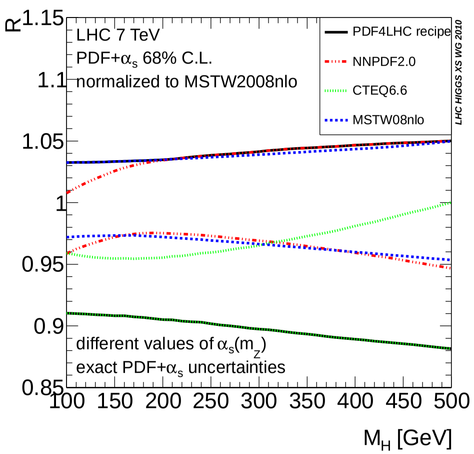


$m_H = 120$ GeV: 2011

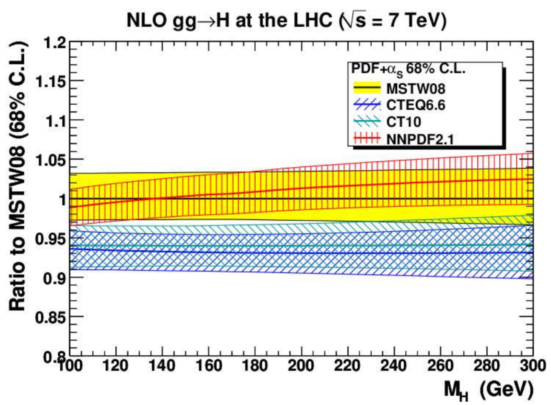


(G. Watt)

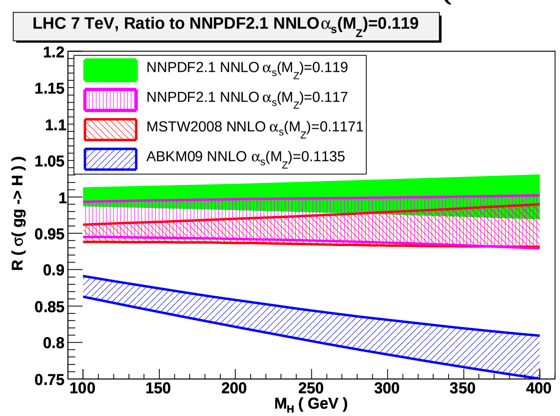
HIGGS WG NLO 2010



NLO 2011 ENVELOPE (WATT)



NNLO 2011 ENVELOPE (NNPDF)



- NLO: 2010 → 2011 IMPROVED AGREEMENT OF GLOBAL FITS
- NNLO: MSTW-NNPDF AGREEMENT ALMOST PERFECT

ISSUES

PDF UNCERTAINTIES:
DO THEY HAVE A STATISTICAL MEANING?

SOMETIMES STATED THAT "PDF UNCERTAINTIES ARE THEORETICAL UNCERTAINTIES" (THUS DEVOID OF STATISTICAL MEANING) IS IT TRUE?

PDF UNCERTAINTIES: DO THEY HAVE A STATISTICAL MEANING?

SOMETIMES STATED THAT "PDF UNCERTAINTIES ARE THEORETICAL UNCERTAINTIES" (THUS DEVOID OF STATISTICAL MEANING) IS IT TRUE?

A WAY OF TESTING:
NEW DATA ⇒ BAYES' THEOREM

$$\langle \mathcal{O} \rangle_{\rm new} = \int \mathcal{O}[f]\, \mathcal{P}_{\rm new}(f)\, Df, = \mathcal{N}_\chi \int \mathcal{O}[f]\, \mathcal{P}(\chi^2|f) \mathcal{P}_{\rm old}(f)\, Df,$$

IN A MONTE CARLO APPROACH...

$$\langle \mathcal{O} \rangle_{\rm new} = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} \mathcal{N}_\chi \mathcal{P}(\chi^2|f_k) \mathcal{O}[f_k] = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k\, \mathcal{O}[f_k], \quad w_k = \mathcal{N}(\chi^2_k)^{n/2-1} e^{-\frac{1}{2}\chi^2_k}$$

⇒ EFFECT OF NEW DATA IS ACCOUNTED FOR BY
REWEIGHTING MONTE CARLO AVERAGES

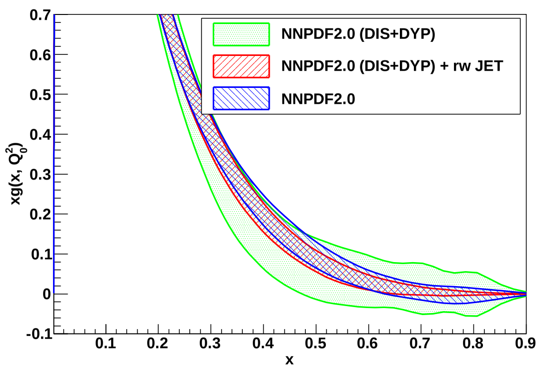
(CAN ALSO BE IMPLEMENTED IN HESSIAN FRAMEWORK (de Lorenzi, McNulty, 2010-2011))

- DETERMINE PDFS INCLUDING SOME DATA BY BAYES' THEOREM (REWEIGHTING)
- DETERMINE PDFS BY ENLARGING THE DATASET TO THE NEW DATA (REFITTING)
- COMPARE RESULTS ⇒ IF THEY AGREE, PDFS DO HAVE A STATISTICAL INTERPRETATIONS ALRIGHT!

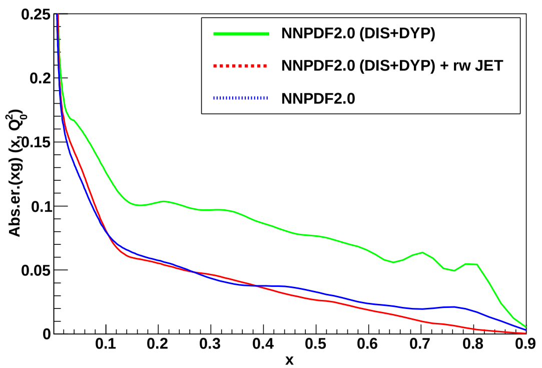
RUNNING THE TEST

INCLUSION OF JET DATA: REWEIGHTING VS. REFITTING
NNPDF2.0DIS+DY VS. NNPDF2.0FULL

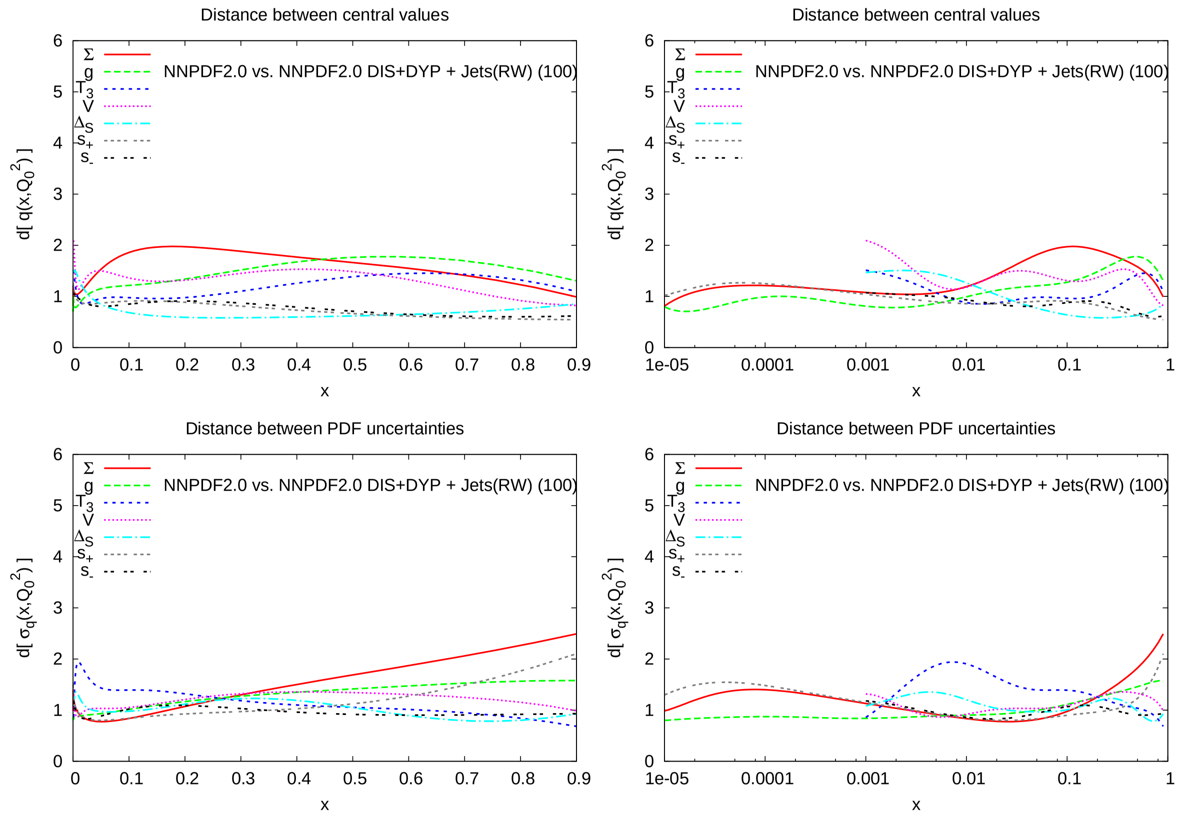
GLUON



GLUON UNCERTAINTY



DISTANCES



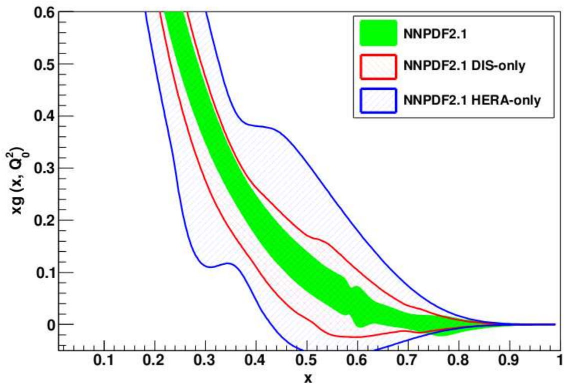
$d \sim 1 \Rightarrow$ STATISTICAL EQUIVALENCE
($d = n \Leftrightarrow n\ \sigma$ DISCREPANCY)

STATISTICAL INTERPRETATION VALIDATED

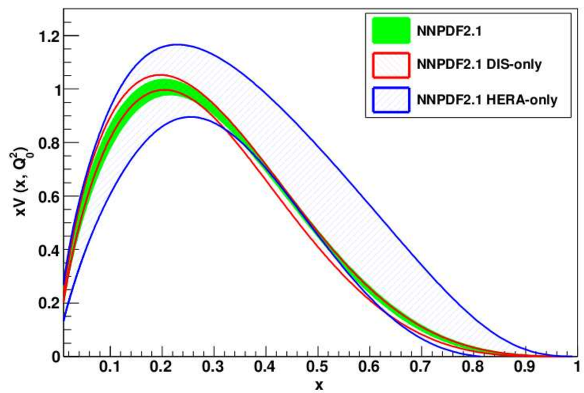
DATA CONSISTENCY: WHY WE NEED IT

- DIS ONLY FIT $\Rightarrow$ SIGNIFICANT LOSS IN ACCURACY
- LARGE x GLUON: NEED JETS!
- LIGHT AND STRANGE FLAVOUR SEPARATION: NEED DRELL-YAN AND W PRODUCTION

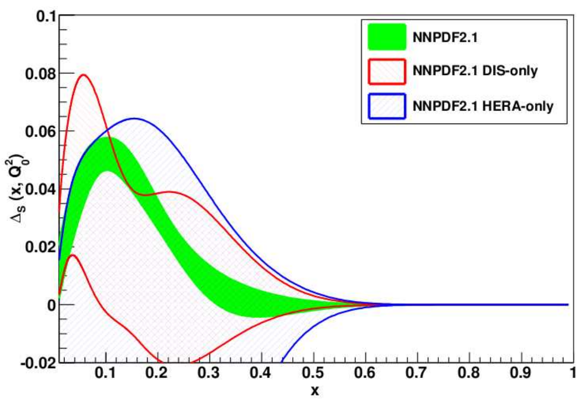
GLUON



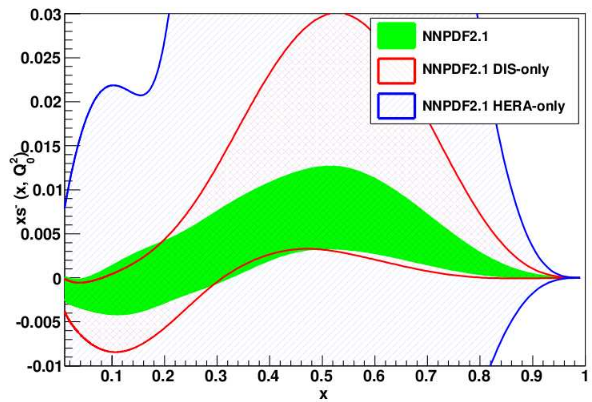
VALENCE



SEA ASYM: $\bar{u} - \bar{d}$



STRANGE: $s - \bar{s}$

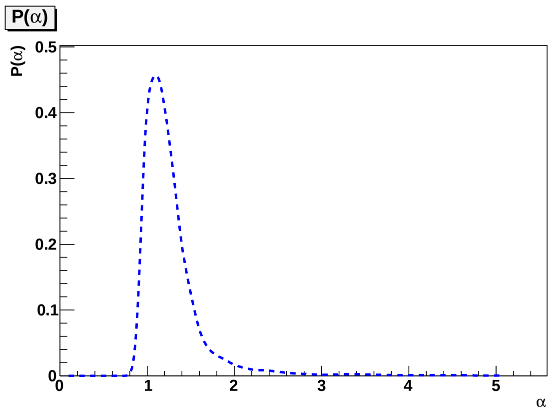


A HERA ONLY FIT IS A TERRIBLE IDEA!

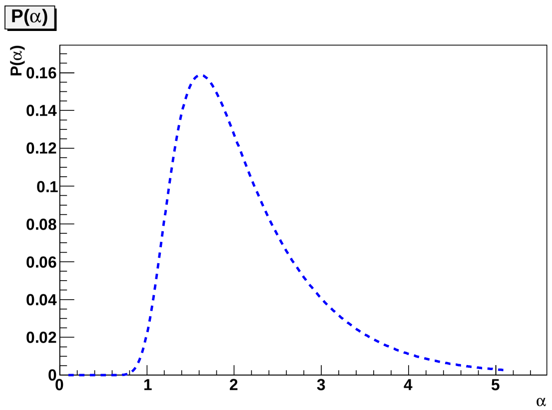
DATA CONSISTENCY: HOW TO TEST FOR IT

- INCONSISTENT DATA $\Leftrightarrow$ UNDERESTIMATED UNCERTAINTIES
- RESCALE ALL UNCERTAINTIES IN A GIVEN EXPERIMENT BY SOME FACTOR α: $\chi^2_\alpha = \chi^2/\alpha^2$ (TOLERANCE)
- DETERMINE PROBABILITY DISTRIBUTION OF α VALUES BY BAYES' THEOREM $\Rightarrow$ REWEIGHTING: $\mathcal{P}(\alpha) = \frac{\mathcal{N}}{\alpha}\sum_{k=1}^{N} w_k(\alpha)$.

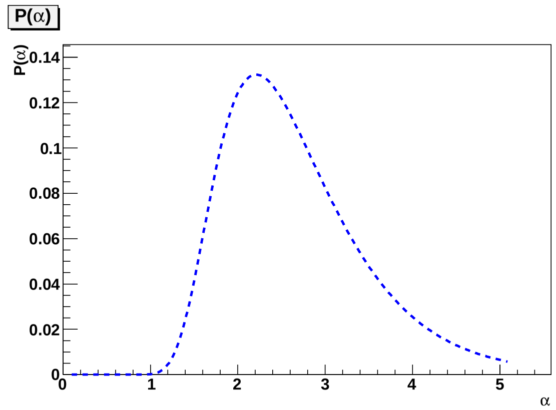
JETS



D0 e INCLUSIVE



D0 e HIGH E_T

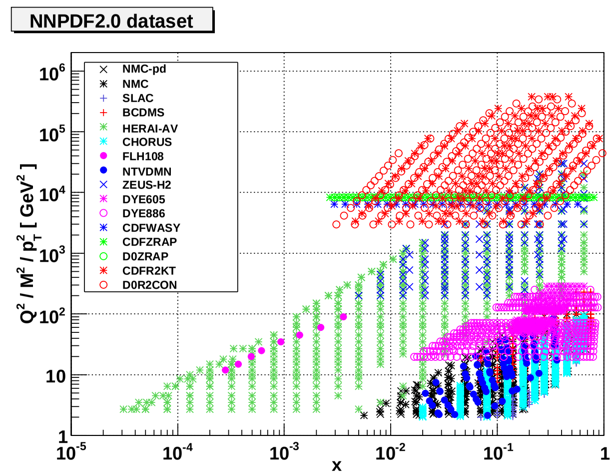


- JETS: $\Rightarrow$ CONSISTENT DATA
- $W^\pm$ CHARGE ASYMMETRIES, D0 INCLUSIVE e DATA $\Rightarrow$ UNCERTAINTIES UNDERESTIMATED BY $\sim 70\%$ (PROB. PEAKS AT $\alpha \sim 1.7$)
- $W^\pm$ CHARGE ASYMMETRIES, D0 e DATA WITH $E_T > 35$ GEV $\Rightarrow$ INCONSISTENT DATA

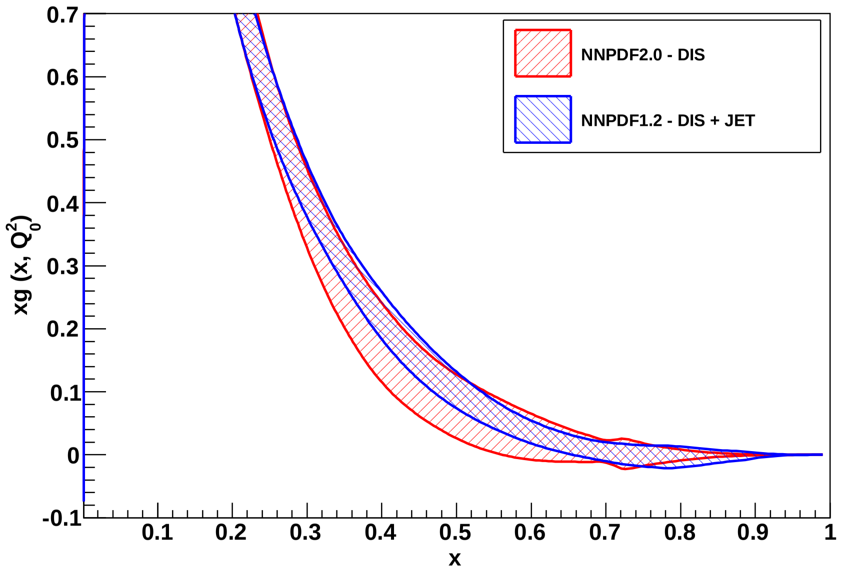
THE IMPACT OF HADRON COLLIDER DATA

JETS AT THE TEVATRON

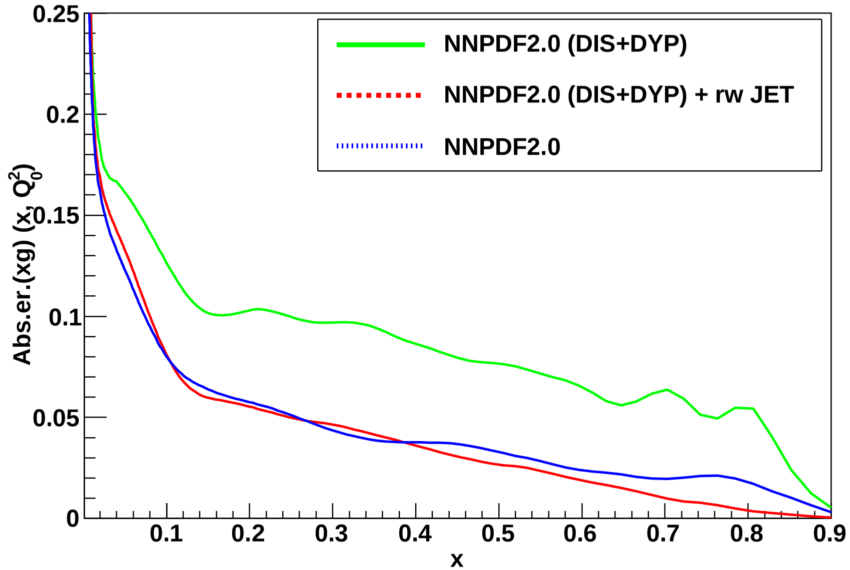
- GOOD CONSISTENCY $\Rightarrow$ ONE-JET INCLUSIVE RUN II DATA WELL REPRODUCED EVEN WHEN NOT FITTED (LARGE x GLUON WELL DETERMINED BY SCALING VIOLATIONS)
- IMPACT ON LARGE x GLUON
- SIGNIFICANT IMPROVEMENT IN GLUON ACCURACY FOR $0.1 \lesssim x \lesssim 0.7$



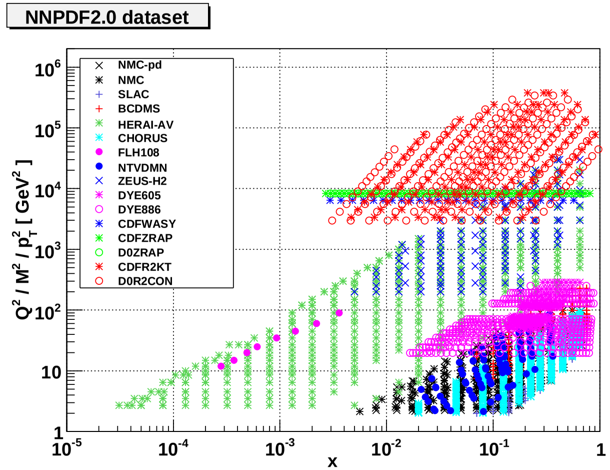
GLUON



GLUON UNCERTAINTY

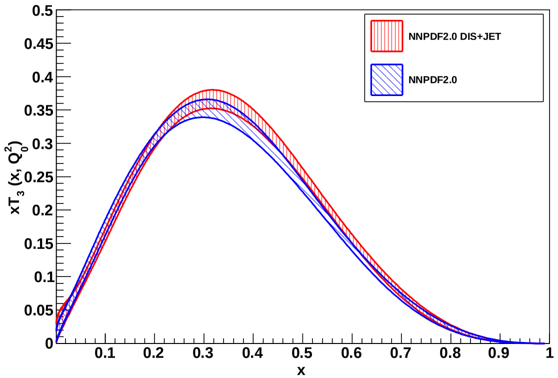


Tevatron Drell-Yan+W, Z-production

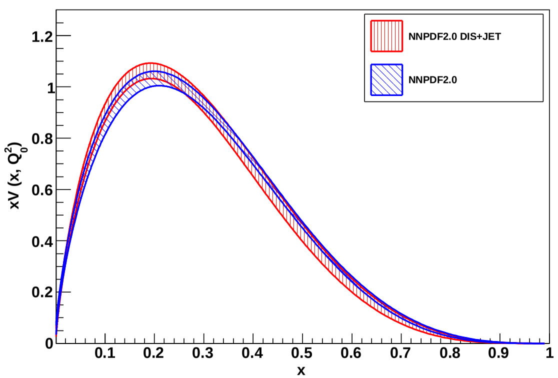


- VERY SUBSTANTIAL IMPROVEMENT IN FIT QUALITY WHEN DATA INCLUDED $\Rightarrow$ SOME PDF COMBINATIONS POORLY DETERMINED WITHOUT THESE DATA
- HUGE IMPROVEMENT IN SEA ASYM $\bar{u}-\bar{d}$ & STRANGENESS $s-\bar{s}$
- SIGNIFICANT IMPROVEMENT IN TOTAL VALENCE $(\sum_i (q_i-\bar{q}_i))$ & ISOTRIPLET $(u+\bar{u}-(d+\bar{d}))$

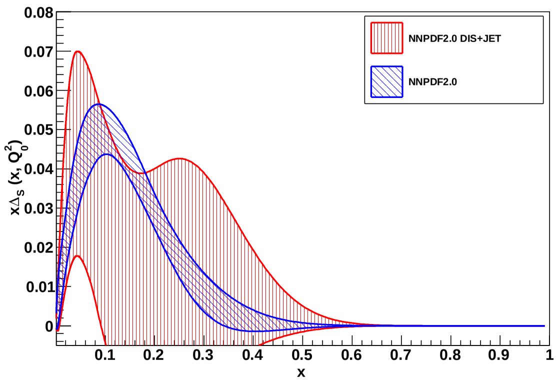
ISOTRIPLET



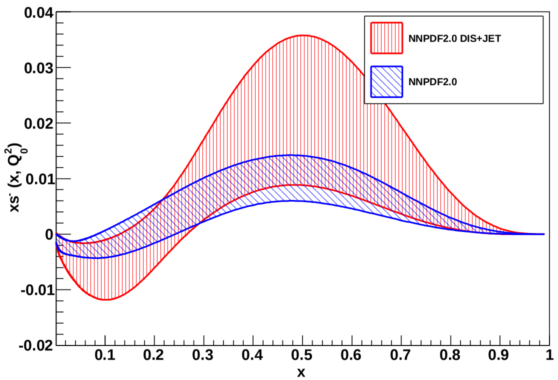
VALENCE



$\bar{d}-\bar{u}$



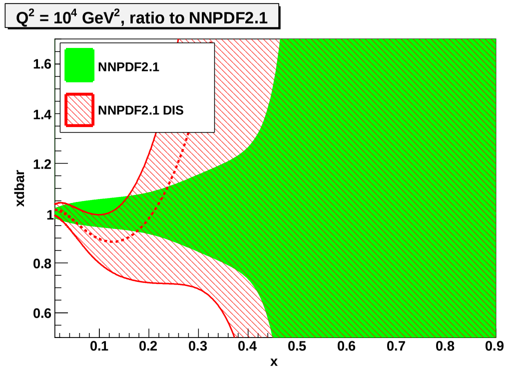
$s-\bar{s}$



Tevatron vs DIS: consistency issues?

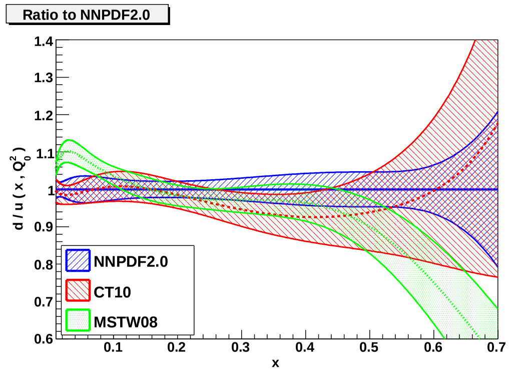
DIS vs DIS+DY:

antidown



comparison between sets:

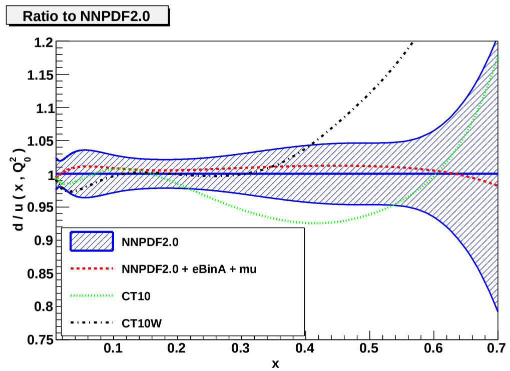
u/d at $Q^2 = 2$ GeV^2



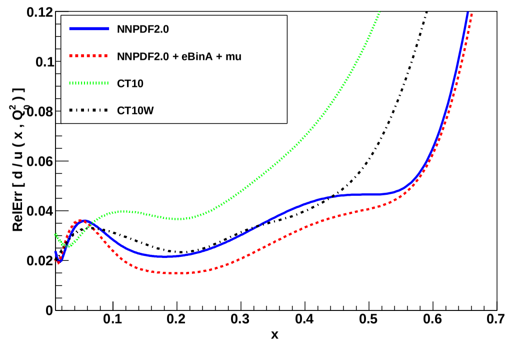
- down and up/down: tension between DIS and DY data
- perhaps nuclear corrections & higher twists play a role in NMC, BCDMS DIS
- different PDF sets in partial disagreement

Tevatron run II W asymmetry data

u/d at $Q^2 = 2$ GeV^2



relative uncertainty



- CTEQ: no globally consistent fit found: CT10W with W data, CT10 without
- NNPDF: sizable reduction in uncertainty

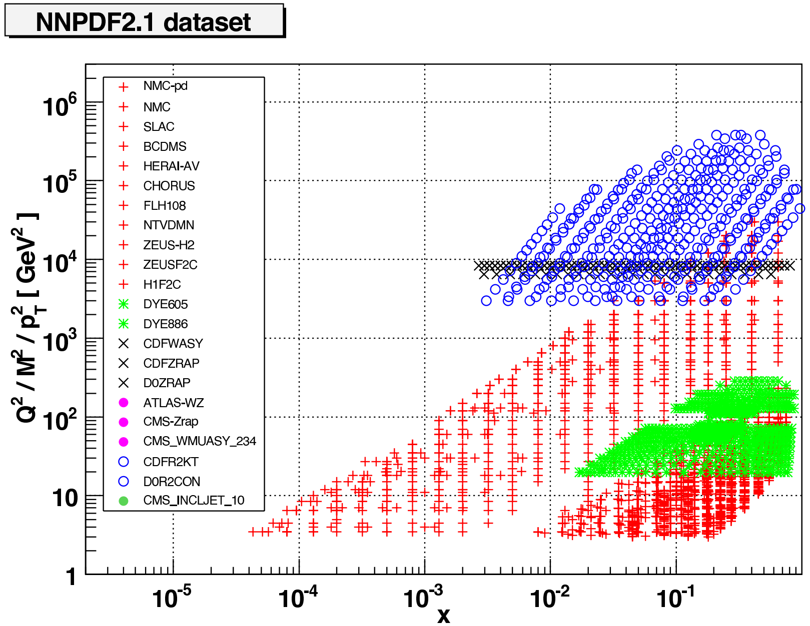
- W asymmetry data determine the u/d ratio accurately, tension with DIS data
- better to do without NMC/BCDMS data (no low Q^2 data, no nuclear targets)

PRECISION PHYSICS AT THE LHC

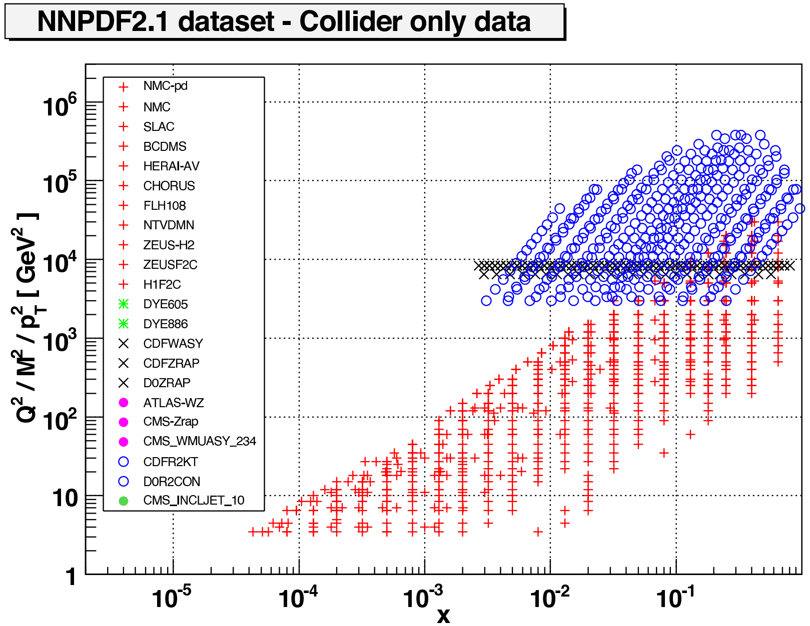
COLLIDER ONLY FITS?

NO FIXED TARGET DATA $\Leftrightarrow$ NO LOW-ENERGY TROUBLE

THE NNPDF2.1 DATASET



NNPDF2.1 - COLLIDER ONLY

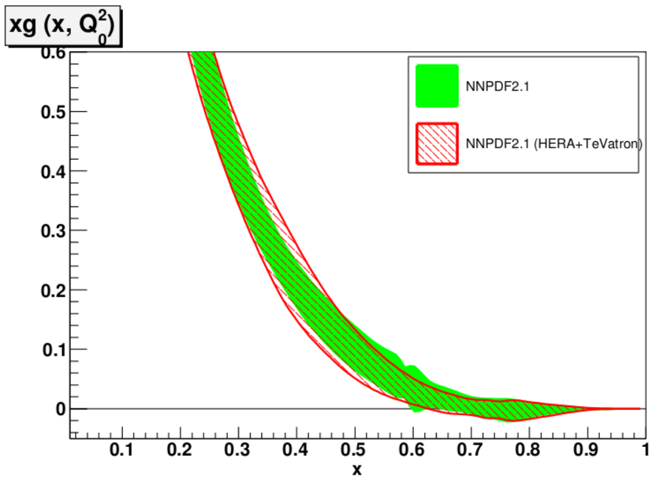


PDFs FROM HERA+TEVATRON DATA?

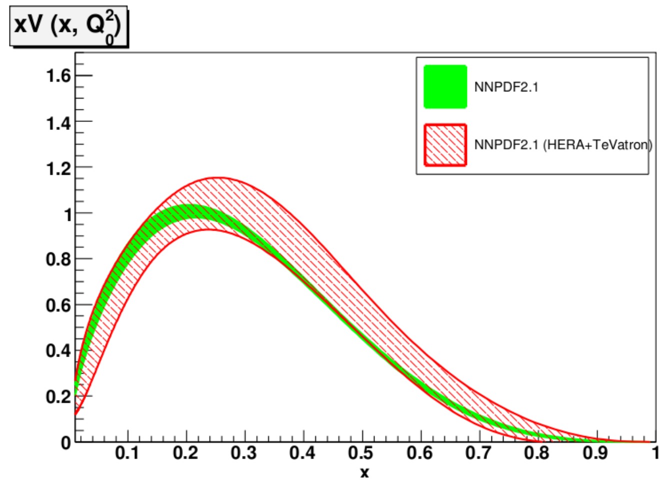
COLLIDER ONLY FITS?

THE PDFs

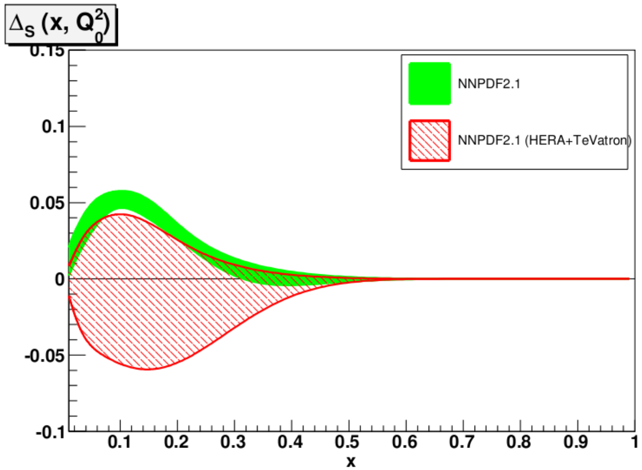
GLUON



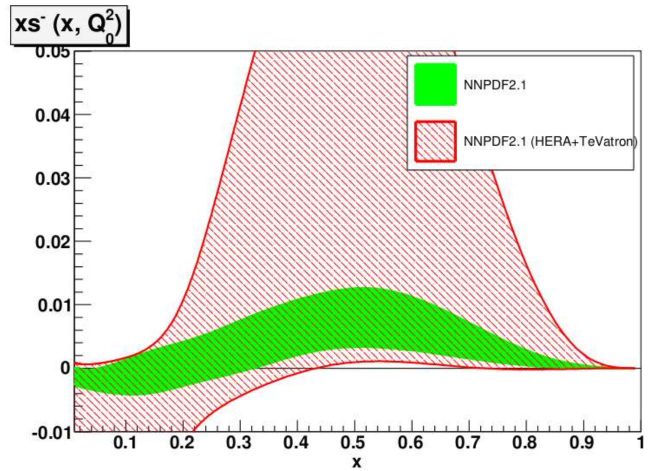
VALENCE



SEA ASYM: $\bar{u} - \bar{d}$



STRANGE: $s - \bar{s}$

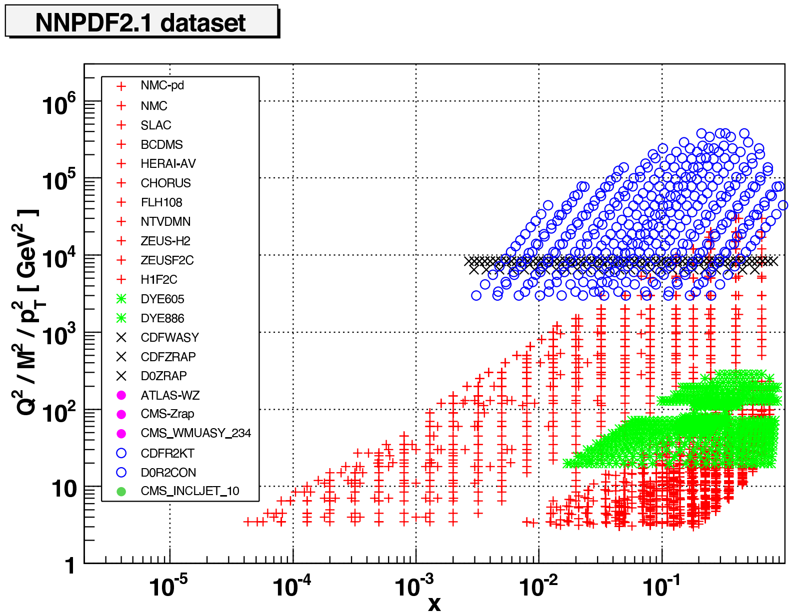


- GOOD ACCURACY FOR GLUON
- GREAT LOSS OF ACCURACY FOR FLAVOR SEPARATION

COLLIDER ONLY FITS?

NO FIXED TARGET DATA $\Leftrightarrow$ NO LOW-ENERGY TROUBLE

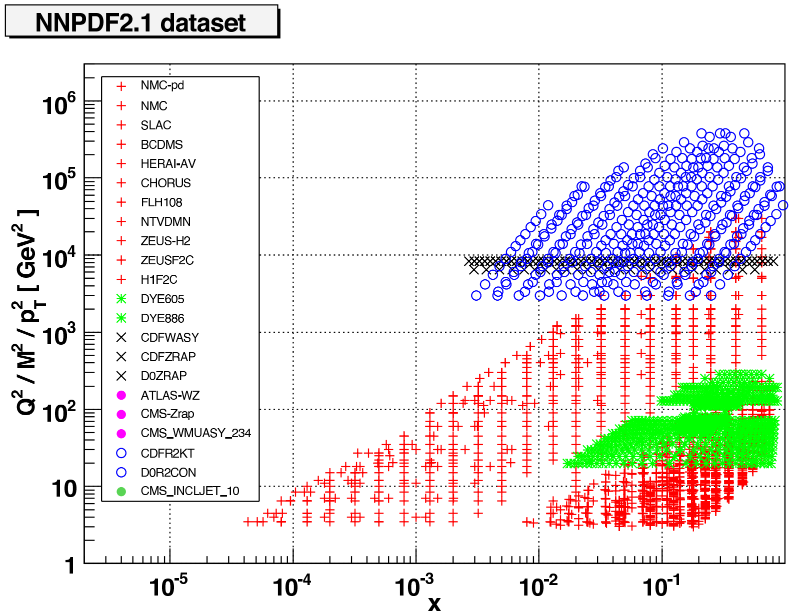
THE NNPDF2.1 DATASET



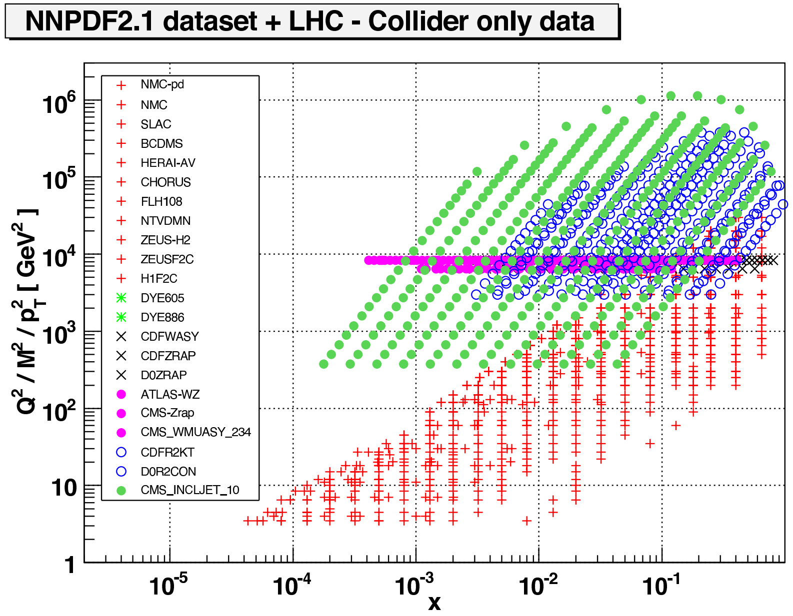
COLLIDER ONLY FITS?

NO FIXED TARGET DATA $\Leftrightarrow$ NO LOW-ENERGY TROUBLE

THE NNPDF2.1 DATASET



NNPDF2.1 COLL. ONLY+LHC



LHC DATA CAN PROVIDE THE MISSING INFORMATION!

W AND Z PRODUCTION AT THE LHC

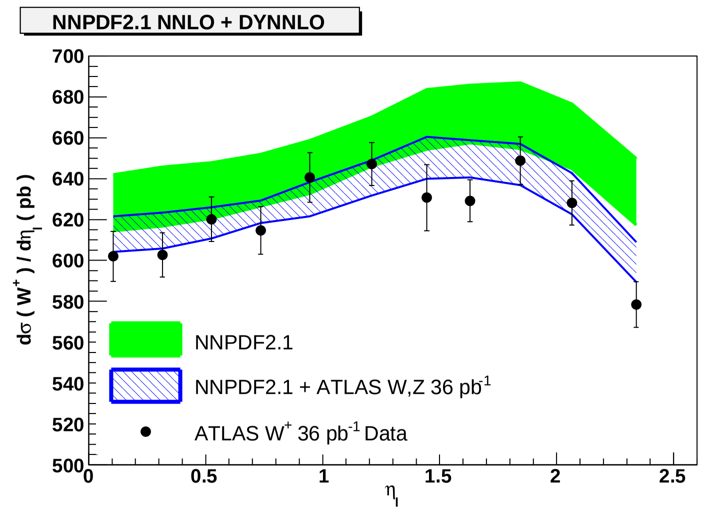
- $W^{\pm}$, Z RAPIDITY DISTRIBUTIONS MEASURED BY ATLAS WITH $|\eta| < 2.4,\ 3.2$, 36 pb^{-1}, FULLY CORRELATED SYSTEMATICS
- CMS, SAME KIN., SYST. YET UNAVAILABLE, MUON ASYMMETRIES W. 234 pb^{-1}
- LHCB, $2 < \eta| < 4.5$, 36 pb^{-1}, SYST. YET UNAVAILABLE

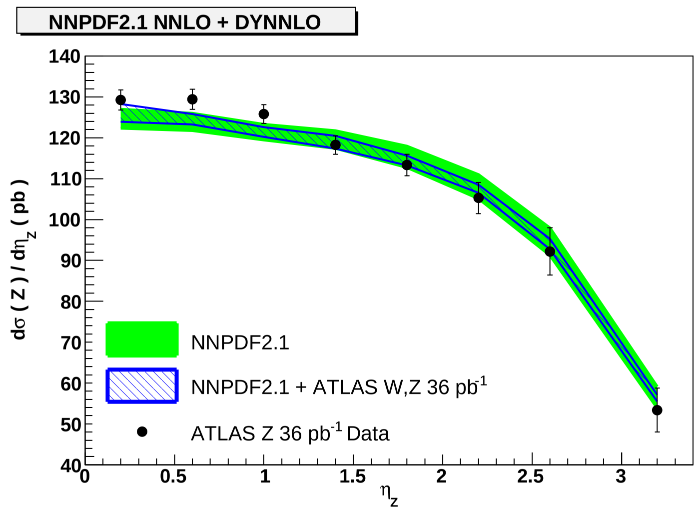
FIT QUALITY: PDF SETS

DATASET	χ^2 NNPDF2.1	χ^2 MSTW08	χ^2 HERAPDF1.5
ATLAS W^+ 36 PB^{-1}	5.7	6.5	5.3
ATLAS W^- 36 PB^{-1}	2.5	4.1	6.4
ATLAS Z 36 PB^{-1}	1.8	3.7	2.9
CMS Z RAPIDITY 36 PB^{-1}	1.9	2.9	3.0
CMS MUON ASYMMETRY 234 PB^{-1}	2.0	3.4	2.1
LHCB Z RAPIDITY 36 PB^{-1}	1.1	0.7	0.8
LHCB W LEPTON ASYMMETRY 36 PB^{-1}	0.5	0.6	0.5

- CONSIDERABLE DISCRIMINATING POWER (BIG DIFFERENCES BETWEEN SETS)
- CORRELATED SYSTEMATICS CRUCIAL (OTHERWISE WASHES OUT DIFFERENCES)

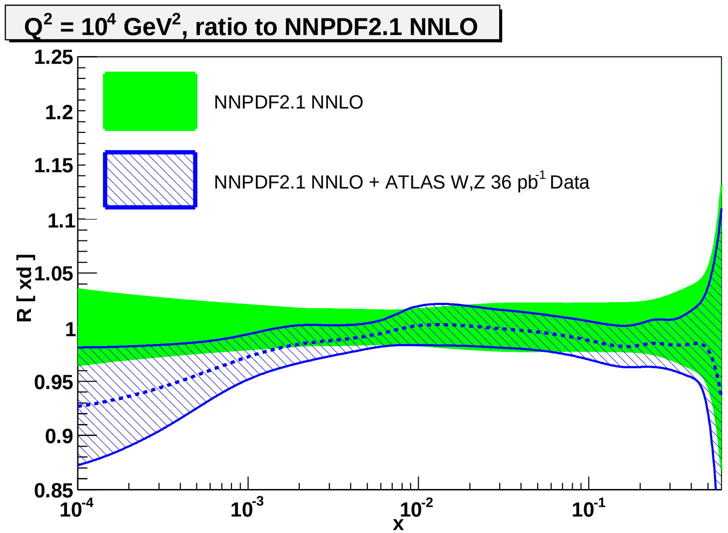
W AND Z PRODUCTION AT THE LHC
FITTING THE ATLAS DATA



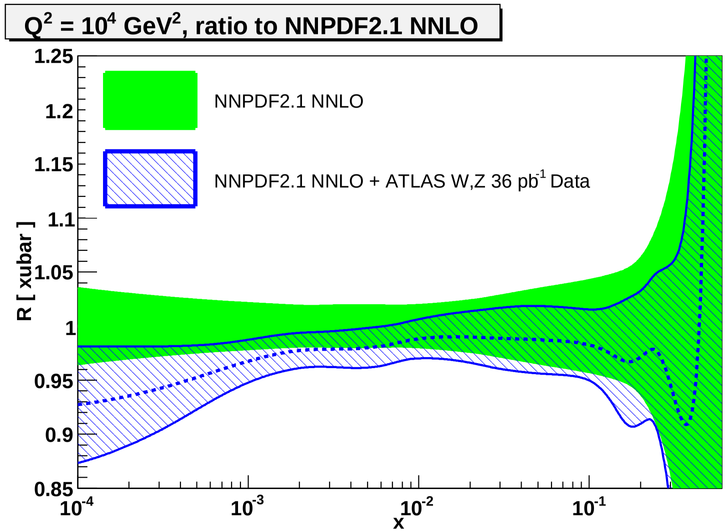


IMPACT ON LIGHT QUARK PDFs

DOWN



ANTIUP

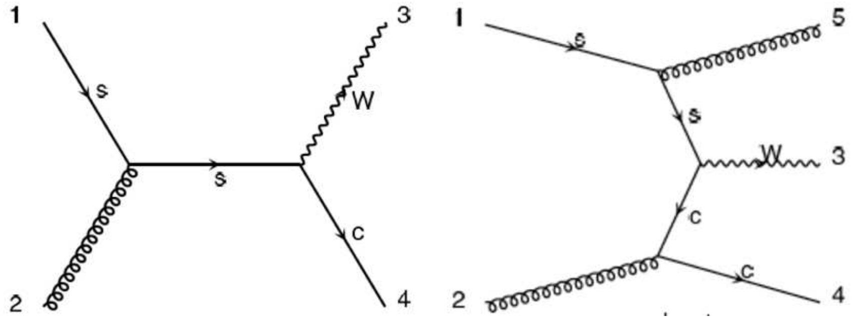


(NNPDF, 2012 prelim.)

- SIGNIFICANT IMPACT ON THE SHAPE
- SIZABLE REDUCTION OF THE UNCERTAINTY

$W + c$ PRODUCTION AT THE LHC

- STRANGENESS PROBED DIRECTLY
- MIGHT REPLACE NEUTRINO DATA



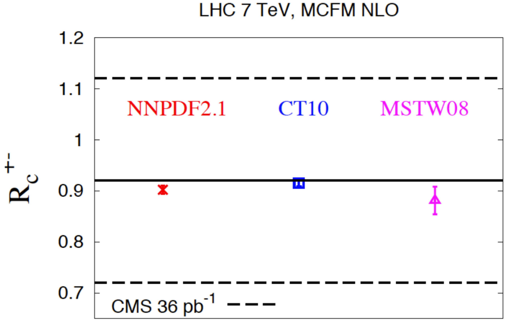
THE CMS MEASUREMENT

$$R_c^{\pm} \equiv \frac{\sigma(W^+ + \bar{c})}{\sigma(W^- + c)}; \quad R_c \equiv \frac{\sigma(W+c)}{\sigma(W+\text{jets})}$$

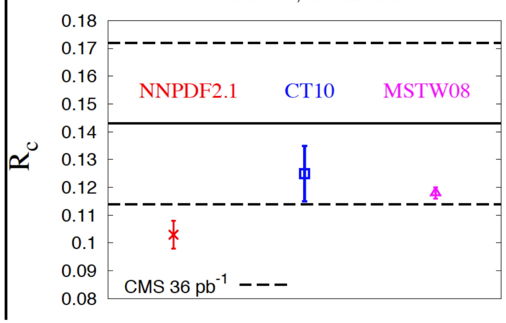
$$R_c^{\pm} = 0.92 \pm 0.19\text{stat.} \pm 0.04\text{syst.}$$
$$R_c = 0.143 \pm 0.015\text{stat.} \pm 0.024\text{syst.}$$

Ratio	MCFM (CT10)	MCFM (MSTW08)	MCFM (NNPDF21)
$R_c^{\pm}$	$0.915^{+0.006}_{-0.006}$	$0.881^{+0.022}_{-0.032}$	0.902 ± 0.008
R_c	$0.125^{+0.013}_{-0.007}$	$0.118^{+0.002}_{-0.002}$	0.103 ± 0.005

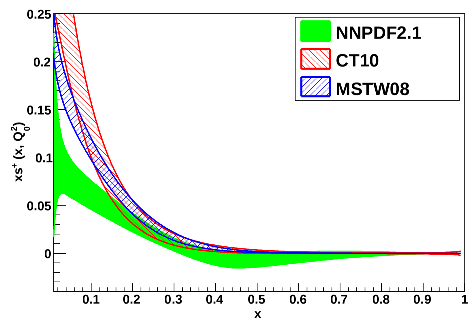
$R_c^{\pm}$ DATA VS TH.



R_c DATA VS TH.



TOTAL STRANGENESS



- DIFFERENCES BETWEEN AVAILABLE SETS SIZABLE
- DATA STILL TOO IMPRECISE, BUT...

$W + c$ PRODUCTION AT THE LHC

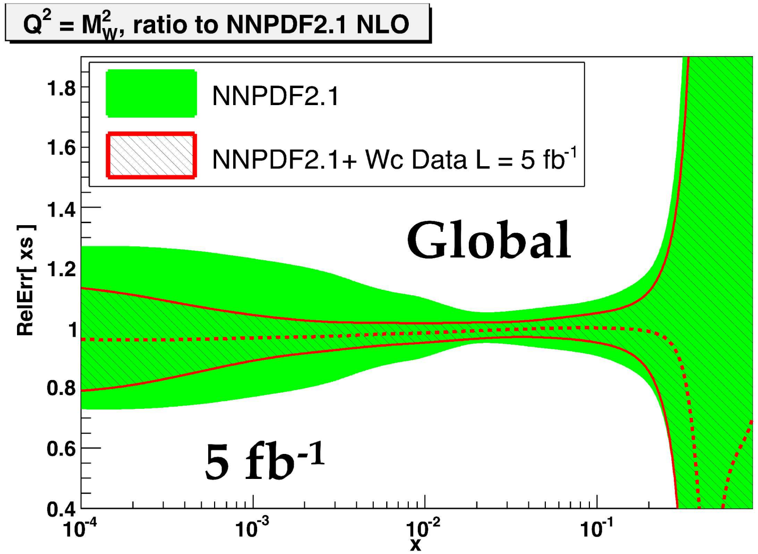
- SIMULATED MEASUREMENT OF c RAPIDITY DISTRIBUTION WITH AMC@NLO

  (J. Rojo, S. Frixione, M. Mangano, 2012, prelim.)

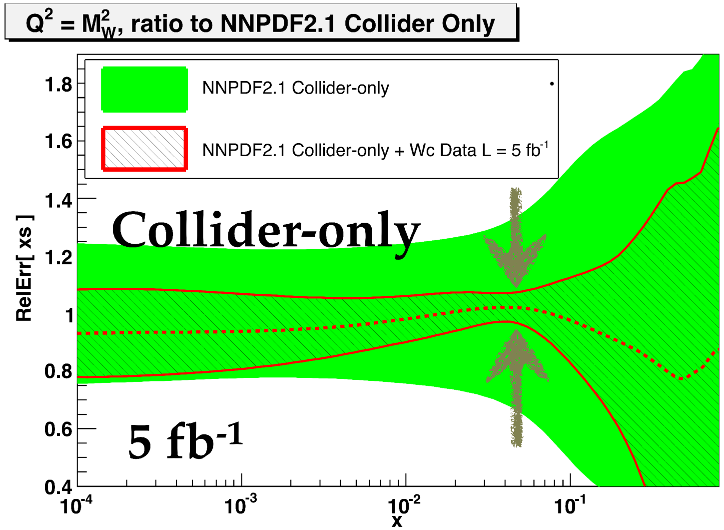
- CMS KINEMATICS $p_T^{\rm jet} > 20$ GeV, $p_T^{\mu} > 25$ GeV $\eta^{\rm jet}$, $\eta^{\mu} < 2.1$
- 15% CHARM TAGGING EFFICIENCY (CMS)
- CURRENTLY 36 PB^{-1}, BUT 5 FB^{-1} SUFFICIENT

THE IMPACT ON STRANGENESS

IN THE NNPDF2.1 FIT



IN THE COLLIDER-ONLY FIT

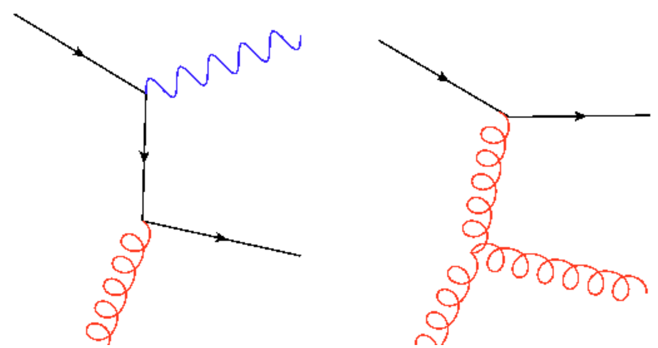


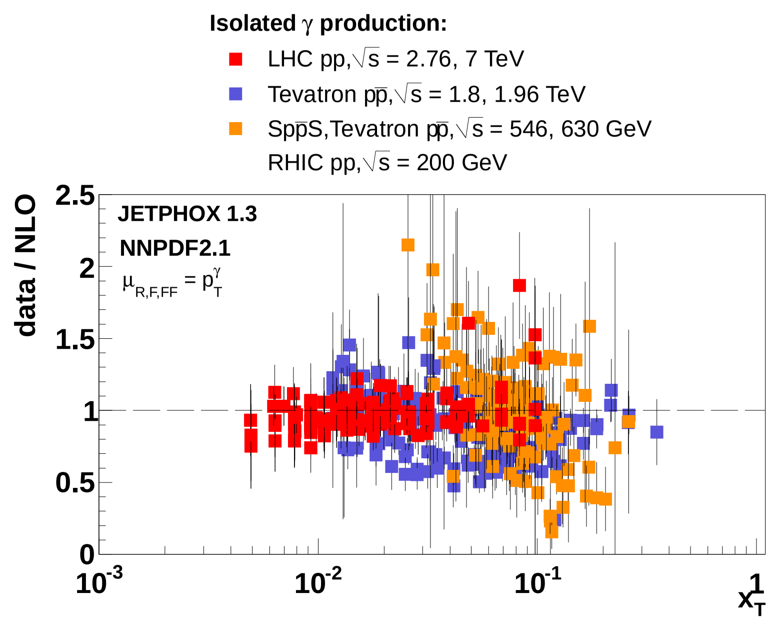
- IMPACT SIGNIFICANT EVEN ON CURRENT GLOBAL FIT
- COULD DO WITHOUT NEUTRINO DATA

PROMPT PHOTON PRODUCTION

(D. d'Enterria, J. Rojo, 2012, prelim.)

$x_t = x_1 x_2$ RANGE

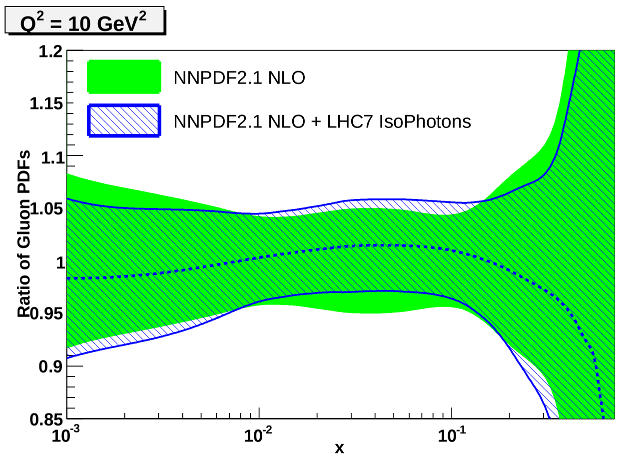




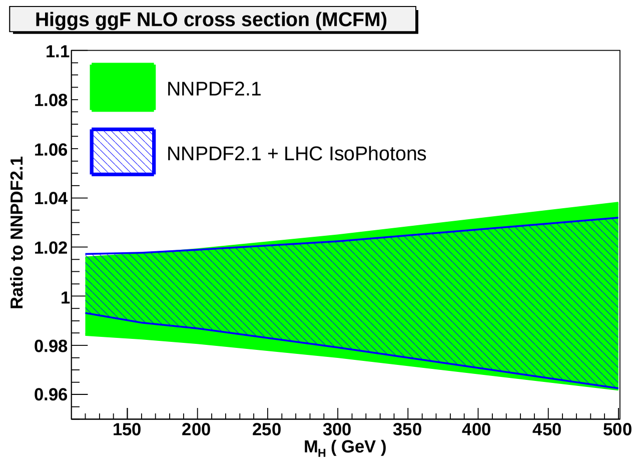
- DIRECT PROBE OF THE qg LUMINOSITY
- MEASURED BY CMS+ATLAS

THE IMPACT OF LHC PROMPT PHOTON DATA

GLUON



HIGGS FROM GLUON FUSION



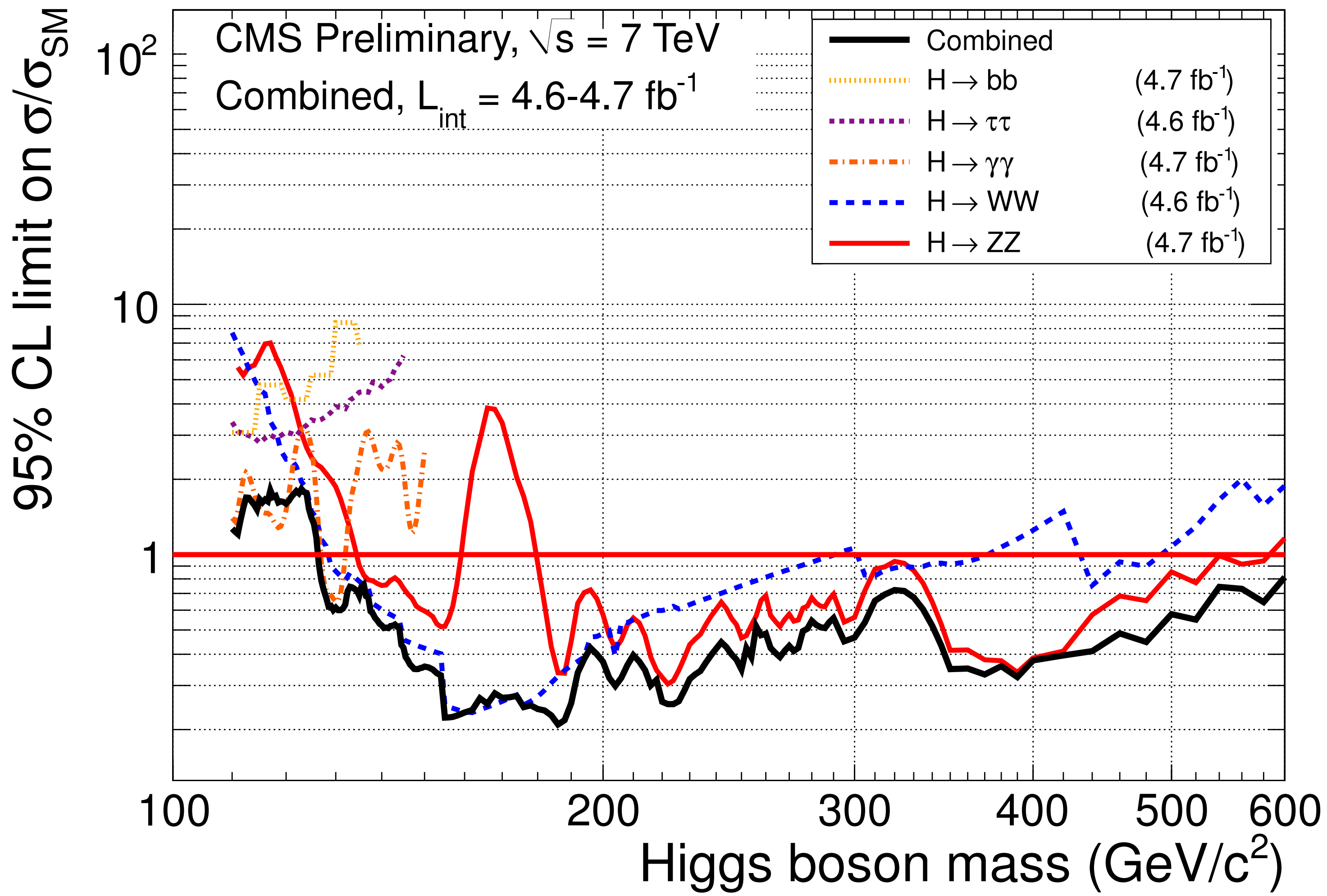
- MODERATE IMPACT ON GLOBAL FIT (BUT COULD RESOLVE DISCREPANCIES)
- SUFFICIENT TO AFFECT HIGGS CROSS SECTION

OUTLOOK

WISHLIST ⇔ ROADMAP

- PRECISION LHC PHYSICS MUST USE PRECISE LHC DATA
- A "COLLIDER ONLY" HERA+LHC PDF FIT
  (TEVATRON DATA MIGHT BE SUPERFLUOUS)
  - MEDIUM & LARGE x GLUON
    * PROMPT PHOTONS
    * (PRECISION) JETS
    * INCLUSIVE W p_T DISTRIBUTIONS
  - LIGHT FLAVOR SEPARATION
    * LOW–MASS DRELL-YAN
    * HIGH–MASS DRELL-YAN
    * Z RAPIDITY DISTRIBUTIONS
    * W ASYMMETRIES
  - STRANGENES & HEAVY FLAVORS
    * STRANGENESS $\Rightarrow W + c$
    * CHARM $\Rightarrow Z + c$, $\gamma + c$
    * BOTTOM $Z + b$
- MOST OF THESE ALREADY AVAILABLE (AT LEAST IN PRELIM. FORM)
- ATLAS JETS AND W, Z RAP. DISTNS. FULLY AVAILABLE (36 PB^{-1})

FOR DISCOVERY, WE NEED TO TRUST OUR SIGNAL!



EXTRAS

NMC DATA: A PROBLEM?

- NMC PROTON AND DEUTERON DATA FOR DIS F_2 STRUCTURE FUNCTION
- F_2STRUCTURE FUNCTION DATA USED IN MSTW, CTEQ, NNPDF FITS,
  WOULD THE USE OF CROSS SECTION DATA MAKE A DIFFERENCE?
  (Alekhin, Blümlein, Moch, 2011)
  $\widetilde{\sigma}(x, y, Q^2) = F_2(x, Q^2)\left(2 - 2y + y^2/[1 + R(x, Q^2)]\right)$

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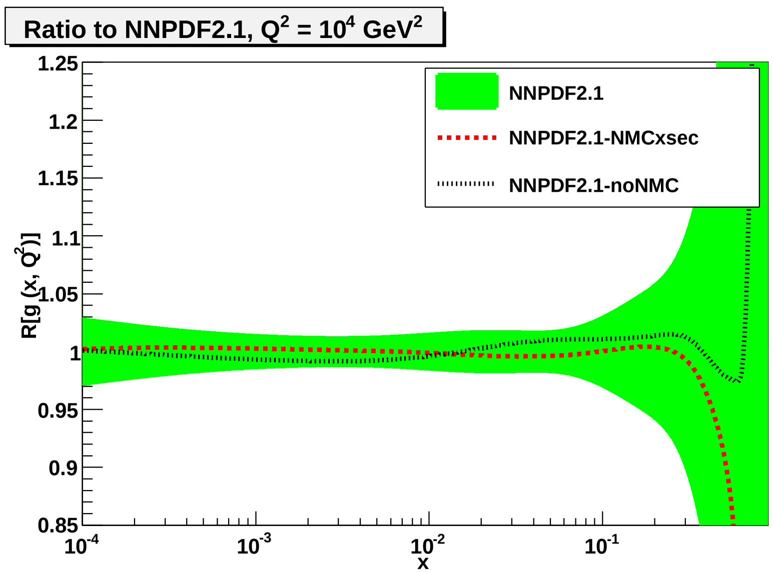
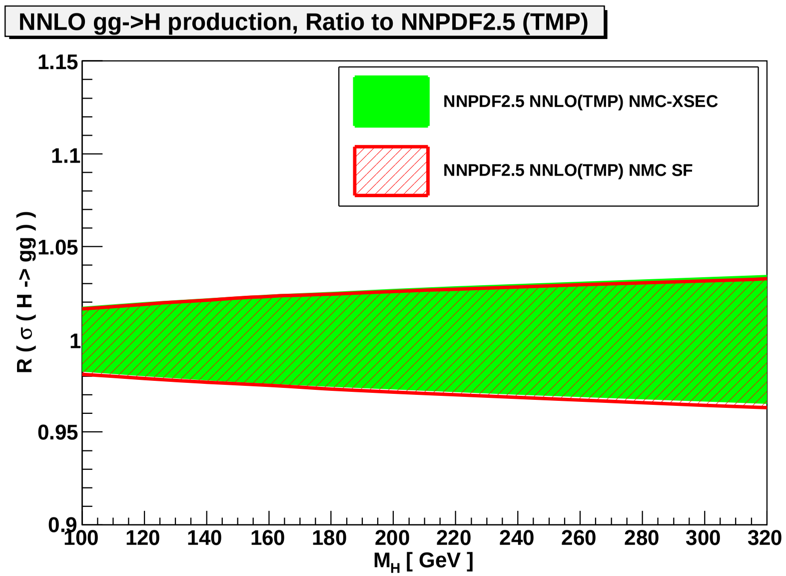
NNPDF FIT REPEATED WITH NMC XSECT OR NO NMC

(NLO: arXiv:1102.3182; NNLO: preliminary)

EFFECT ON GLUON



EFFECT ON HIGGS XSECT



NO SIGNIFICANT CHANGE OBSERVED

NMC DATA: A PROBLEM?

A CLOSER LOOK

- ALEKHIN ET AL. SEE LARGE SHIFT IN BEST-FIT α_s: FROM 0.1170 (NMC F_2) TO 0.1135 (NMC α_s)
- HOW MUCH OF THEIR CHANGE IN HIGGS XSECT ($\sim 8\%$) DUE TO CHANGE IN α_s?
- BASED ON POWER COUNTING, EXPECT $2.8\Delta\alpha_s = 8\%$ (!)
- EITHER REMOVE NMC DATA, OR CHANGE VALUE OF α_s IN MSTW FIT (Thorne, presented by Watt at PDF4LHC 2011):

NMC DATA: A PROBLEM?

A CLOSER LOOK

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- BASED ON POWER COUNTING, EXPECT $2.8\Delta\alpha_s = 8\%$ (!)
- EITHER REMOVE NMC DATA, OR CHANGE VALUE OF α_s IN MSTW FIT (Thorne, presented by Watt at PDF4LHC 2011):
  - IMPACT OF NMC DATA NEGLIGIBLE
  - IMPACT OF α_s VALUE COMPARABLE (SOMEWHAT SMALLER) TO WHOLE ABKM EFFECT
  - MSTW AND ABKM RESULTS STILL QUITE DIFFERENT EVEN FOR SAME $\alpha_s = 0.113$

NNLO PDF	$\alpha_S(M_Z^2)$	σ_H at Tevatron	σ_H at 7 TeV LHC
MSTW08	**0.1171**	**0.342 pb**	**7.91 pb**
Use R_{1990} for NMC	0.1167	−0.7%	−0.9%
Cut NMC ($x < 0.1$)	0.1162	−1.2%	−2.1%
Cut all NMC data	0.1158	−0.7%	−2.1%
Fix $\alpha_S(M_Z^2)$	0.1130	−11%	−7.6%
ABKM09	0.1135	−26%	−11%

THE VALUE OF α_s

- DEDICATED MUNICH MEETING (FEB 2011):
  S. BETHKE PROPOSES TWO UPDATED VALUES:
  - (1) $\alpha_s = 0.1174 \pm 0.0011$
  - (2) $\alpha_s = 0.1187 \pm 0.0006$
  - BOTH INCLUDE NEW VALUE FROM τ DECAYS $\alpha_s = 0.1213 \pm 0.0014$ (WAS $\alpha_s = 0.1197 \pm 0.0016$)
  - VALUE (1) ALSO INCLUDES NEW SCET VALUE FROM e^+e^- THRUST (Abbate et al., 2010) $\alpha_s = 0.1135 \pm 0.0010$, BUT ALL UNCERTAINTIES RESCALED BY FACTOR 2
  - VALUE (2) EXCLUDES IT
- AVERAGING THE TWO MOST RELIABLE VALUES (GLOBAL EW FIT & τ, BOTH N^3LO, NO DEP. ON HADRON STRUCTURE) GIVES $\alpha_s = 0.1209 \pm 0.0013$

THE VALUE OF α_s

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  $\alpha_s = 0.1209 \pm 0.0013$

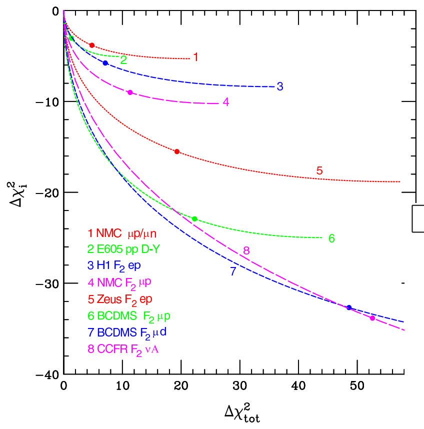
- UNCERTAINTY LARGER THAN 0.002 QUITE UNLIKELY

METHODOLOGY: "STANDARD" (HESSIAN) APPROACH

THE TOLERANCE PROBLEM

- CHOOSE A FIXED FUNCTIONAL FORM ($\sim 25 \div 30$ PARMS. GLOBALLY) AND FIT PARMS TO DATA
- UNCERTAINTIES DETERMINED FROM HESSIAN MATRIX AT MINIMUM
- STANDARD $\Delta\chi^2 = 1$ BANDS TOO NARROW $\Rightarrow$ LARGE DISCREPANCIES FOR INDIVIDUAL EXPERIMENTS
- TOLERANCE $\Rightarrow$ ENVELOPE OF UNCERTAINTIES OF EXPERIMENTS
- DYNAMICAL $\Rightarrow$ SEPARATELY DETERMINED FOR EACH HESSIAN EIGENVECTOR

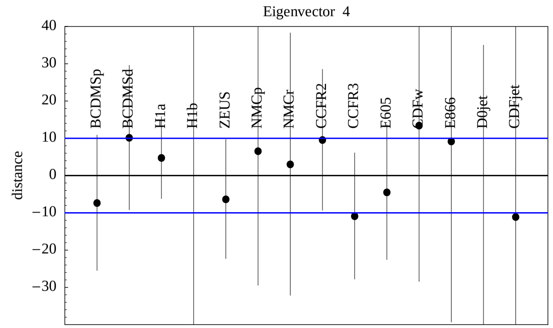
MINIMUM χ_i^2 VS GLOBAL χ^2



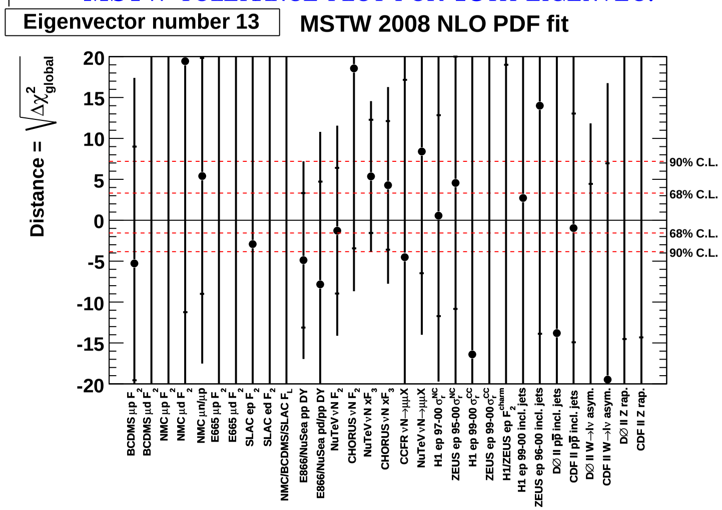
Collins, Pumplin

2001

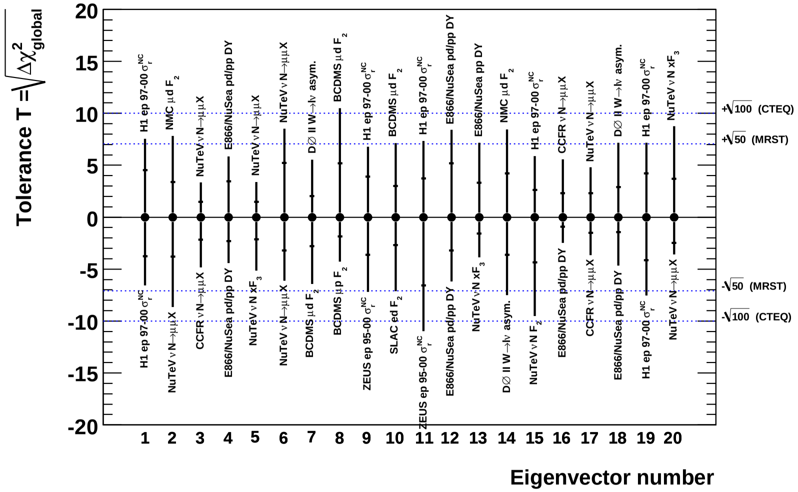
CTEQ TOLERANCE PLOT FOR 4TH EIGENVEC.



MSTW TOLERANCE PLOT FOR 13TH EIGENVEC.



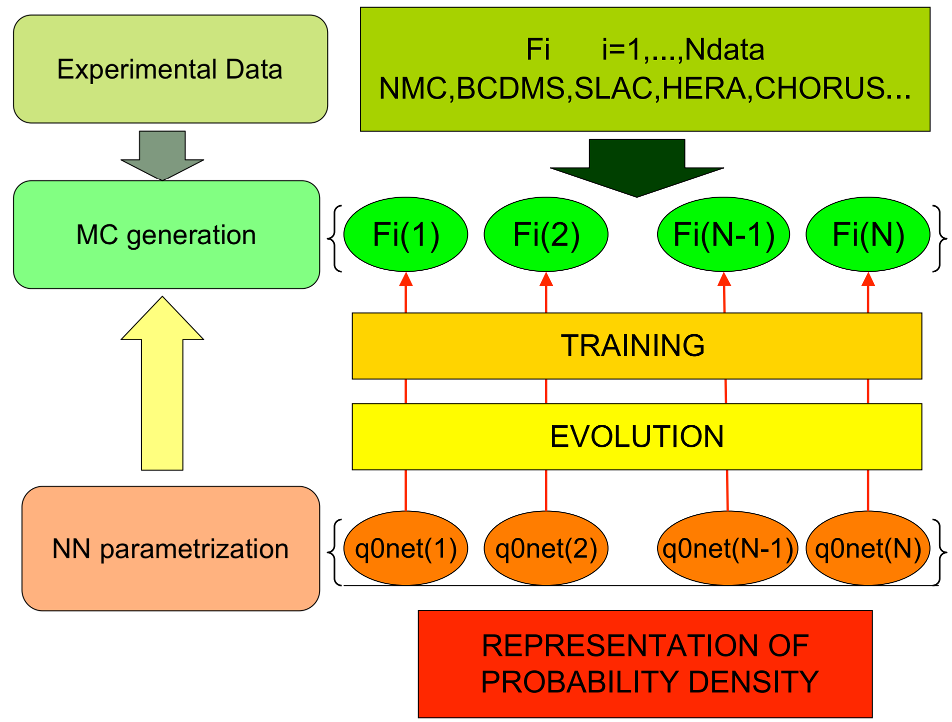
GLOBAL MSTW TOLERANCE



METHODOLOGY: NNPDF APPROACH

BASIC IDEA: MONTE CARLO SAMPLING
OF THE PROBABILITY MEASURE IN THE (FUNCTION) SPACE OF PDFs

- START FROM MONTE CARLO SAMPLING OF DATA SPACE
- EACH PDF$\leftrightarrow$ NEURAL NETWORK PARAMETRIZED BY 37 PARAMETERS (NNPDF2.0: $37 \otimes 7 = 259$ PARMS)
  "INFINITE" NUMBER OF PARAMETERS$\Rightarrow$ CAN REPRESENT ANY FUNCTION
- FIT STOPS WHEN QUALITY OF FIT TO RANDOMLY SELECTED "VALIDATION" DATA (NOT FITTED) STOPS IMPROVING



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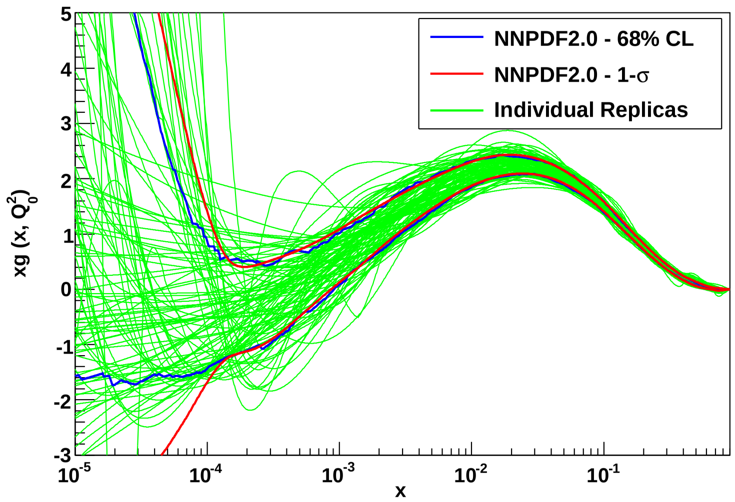
OF THE PROBABILITY MEASURE IN THE (FUNCTION) SPACE OF PDFs

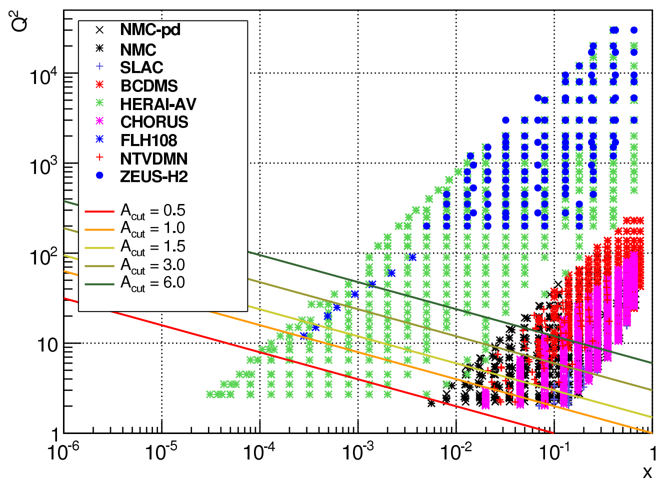
- START FROM MONTE CARLO SAMPLING OF DATA SPACE
- EACH PDF$\leftrightarrow$ NEURAL NETWORK PARAMETRIZED BY 37 PARAMETERS (NNPDF2.0: $37 \otimes 7 = 259$ PARMS)
  "INFINITE" NUMBER OF PARAMETERS$\Rightarrow$ CAN REPRESENT ANY FUNCTION
- FIT STOPS WHEN QUALITY OF FIT TO RANDOMLY SELECTED "VALIDATION" DATA (NOT FITTED) STOPS IMPROVING

CAN DETERMINE BOTH 68C.L.& 1-σ



BEYOND DGLAP?

DISCOVERING A NEW QCD EFFECT IN HERA DATA

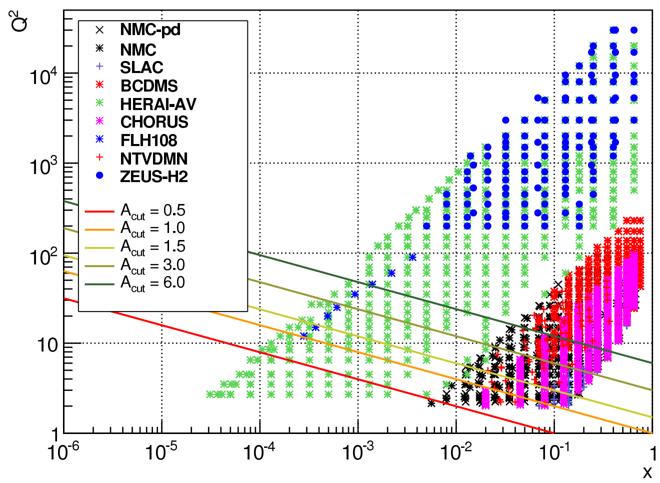


IDEA: (Gélis, 2008, $\Rightarrow$ Caola, s.f. ,Rojo 2010)

- CUT OUT DATA IN THE "DANGEROUS" (SMALL x) REGION
- DETERMINE PDFs IN THE "SAFE" (LARGE x AND Q^2) REGION
- EVOLVE BACKWARDS AND COMPARE TO DATA

BEYOND DGLAP?

DISCOVERING A NEW QCD EFFECT IN HERA DATA



IDEA: (Gélis, 2008, ⇒ Caola, s.f. ,Rojo 2010)

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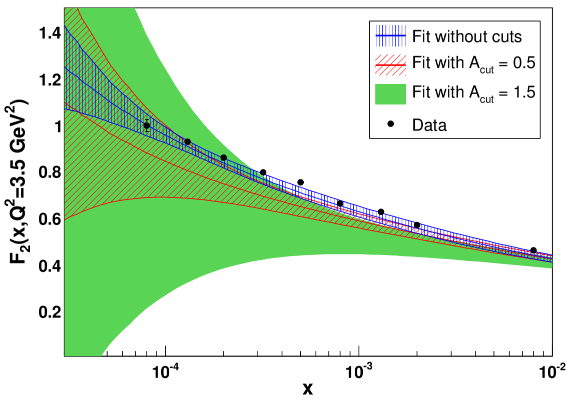
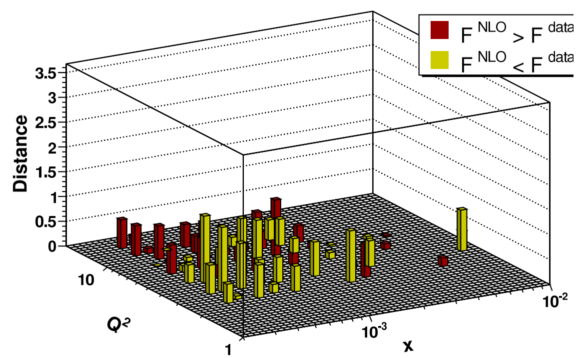
OLD HERA DATA

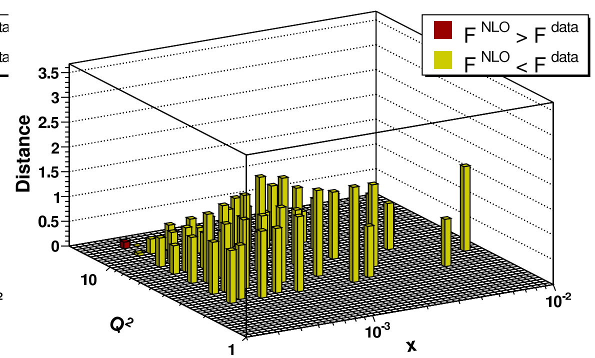
BACKWARD EV. VS DATA



DAT/TH DIST: NO CUT



DAT/TH DIST: CUT



- BACKWARD EVOLVED FIT LIES SYSTEMATICALLY BELOW DATA
- DATA AT LOW x AND Q^2 SHOW LESS EVOLUTION THAN PREDICTED BY NLO DGLAP
- IF LOW x AND Q^2 DATA INCLUDED, THE FIT COMPENSATES READJUSTING PDFs