Proton Structure in the Higgs Era

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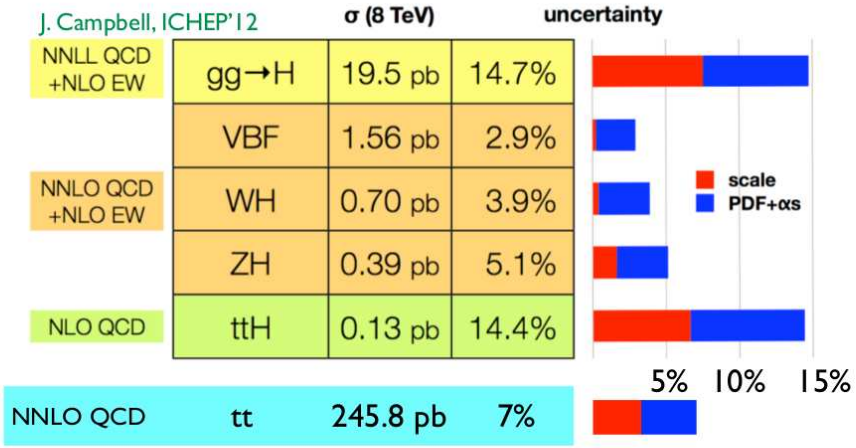
ISMD 2013

IIT, Chicago, IL, Sept. 17, 2013

PROTON STRUCTURE: WHY DO WE CARE?

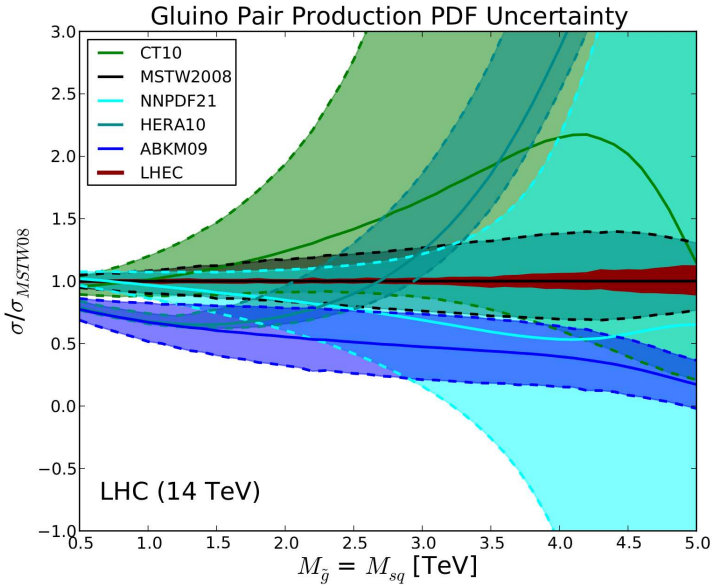
PRECISION: HIGGS

Impact of PDFs uncertainties



- PDF uncertainties at least comparable to missing higher orders ones
- Note that a non-negligible fraction of the PDF+α_S uncertainty comes from α_S

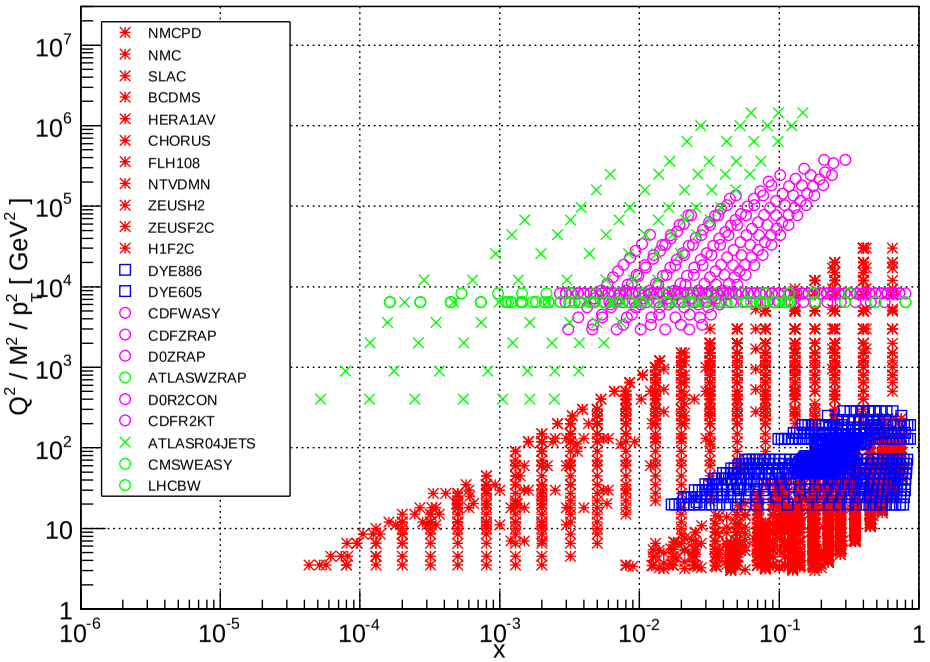
DISCOVERY: NEW PHYSICS



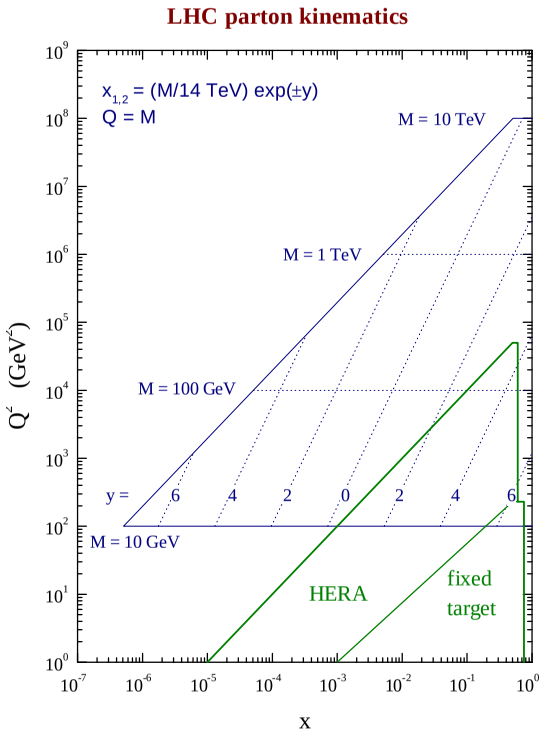
CURRENT PDF SETS: THE DATA

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

NNPDF2.3 Dataset



LHC KINEMATICS



	MSTW08	CT10	NNPDF2.3	HERAPDF1.5	ABM11	JR09
HERA DIS	✔	✔	✔	✔	✔	✔
FIXED-TARGET DIS	✔	✔	✔	✗	✔	✔
FIXED-TARGET DY	✔	✔	✔	✗	✔	✔
TEVATRON $W+Z$+JETS	✔	✔	✔	✗	✗	✗
LHC $W+Z$+JETS	✗	✗	✔	✗	✗	✗

CURRENT PDF SETS: THE APPROACH

METHODOLOGY

- 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, MSTW;
- COVARIANCE MATRIX, NORMALIZATION UNCERTAINTIES, OUTLIERS, THEORETICAL UNCERTAINTIES . . .

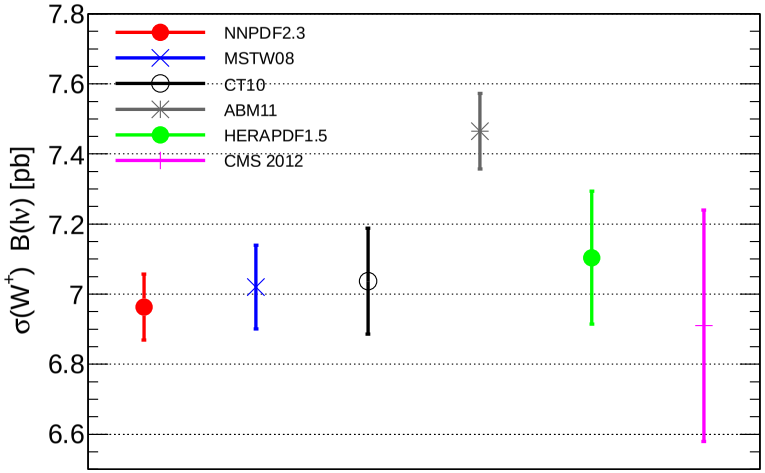
THEORY

- α_s VALUE: CTEQ: EXTERNAL PARAMETER, SEVERAL VALUES AVAILABLE; NNPDF: EXTERNAL PARAMETER, SEVERAL VALUES AVAILABLE, BEST-FIT DETERMINED; MSTW: FITTED, BUT ALSO VARIABLE AS EXT.PARAMETER; ABKM: FITTED, VARIABLE AS EXT.PARAMETER (ONLY CENTRAL VALUE); GJR: FITTED, NOT VARIABLE AS EXT. PARAMETER;
- 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 ($N_f = 3$)
- NUCLEAR CORRECTIONS, HIGHER TWISTS, KINEMATIC CUTS, "INITIAL SCALE", . . .

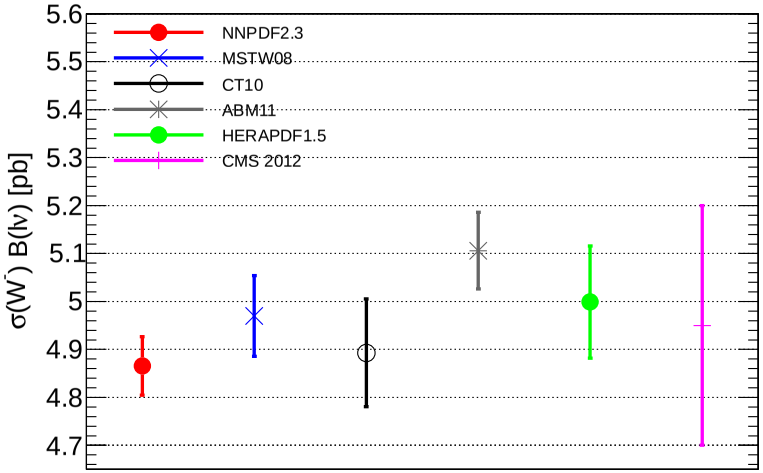
	MSTW08	CT10	NNPDF2.3	HERAPDF1.5	ABM11	JR09
NO. OF PDFS	7	6	7	5	6	5
STATISTICS	HESS.+DT	HESS.+DT	MC	HESS.+MODEL+PARM.	HESS.	HESS.+T
PDF PARMS.	20+8	25	259	14	24	12
HEAVY QUARKS	VFN TR	VFN ACOT	VFN FONLL	VFN TR	FFN	FFN

LHC EW STANDARD CANDLES

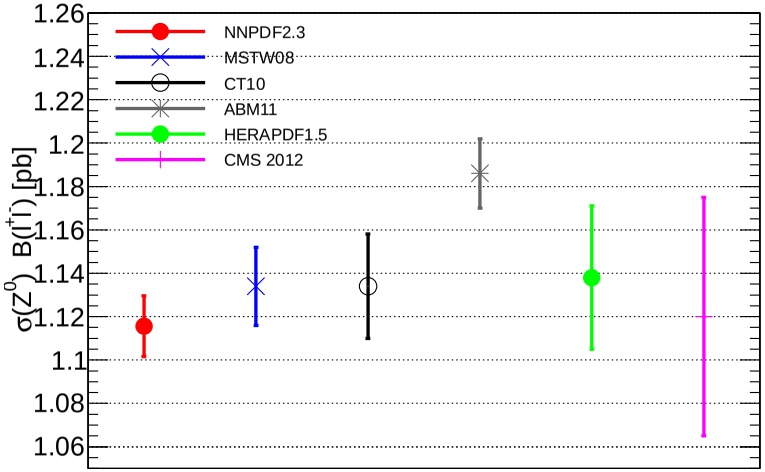
W^+



W^-



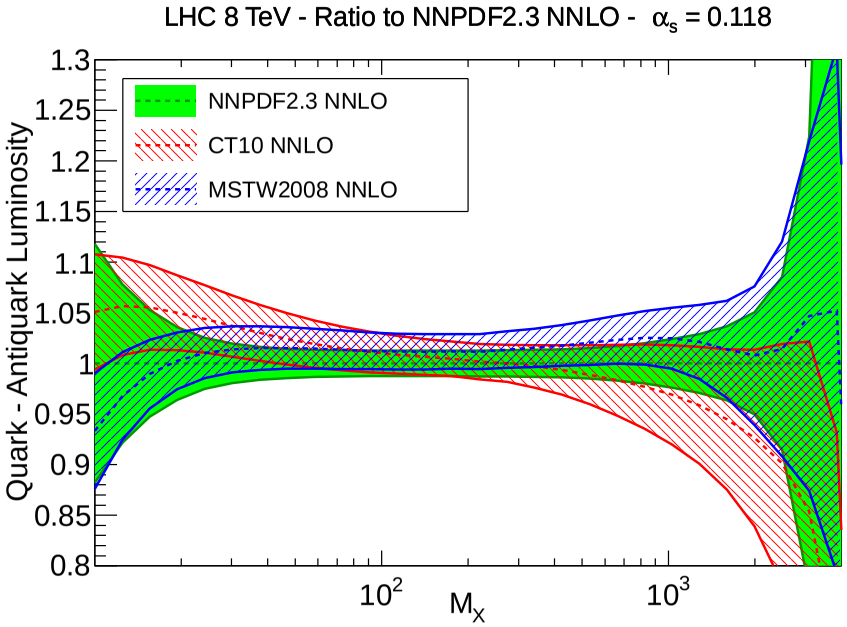
Z



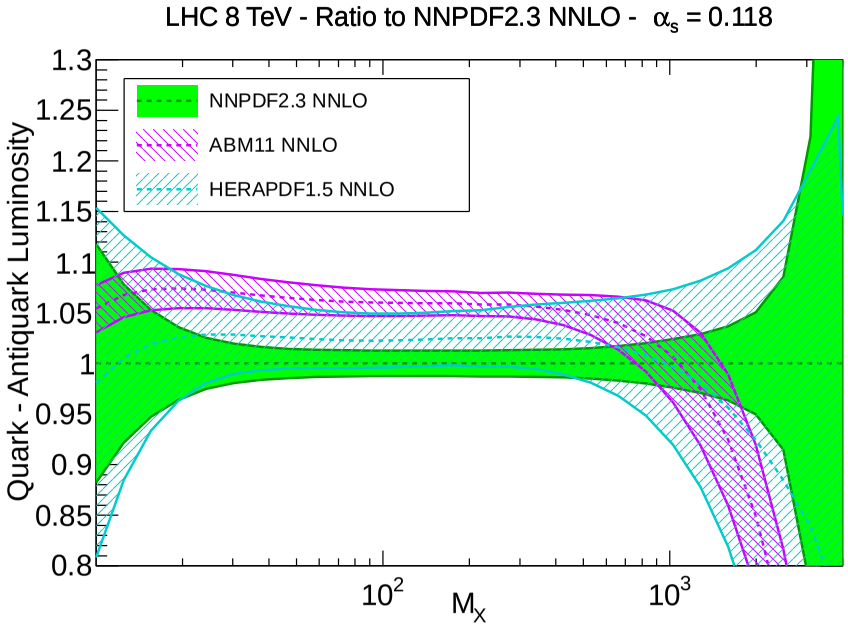
- GLOBAL FITS IN GOOD MUTUAL AGREEMENT
- DIS-ONLY FIT SAFE (HERAPDF) SAFE, BUT LARGE UNCERTAINTY
- WEAK DEPENDENCE ON α_s
- LHC DATA SOON TO PROVIDE COMPETITIVE CONSTRAINTS

PARTON LUMINOSITIES: QUARK SECTOR ($q\bar{q}$)

GLOBAL PDF SETS
(ratio to NNPDF2.3)



OTHER PDF SETS
(ratio to NNPDF2.3)

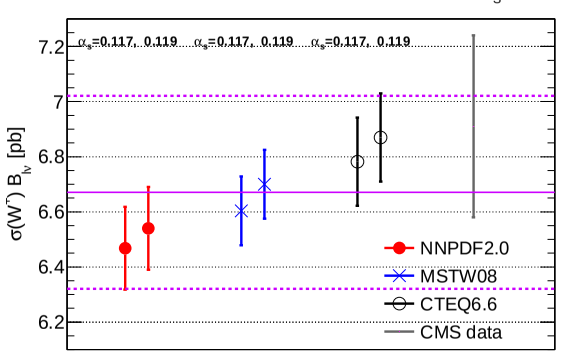


- CROSS-SECTIONS REFLECT UNDERLYING LUMINOSITIES
  FEWER DATA $\rightarrow$ LARGER UNCERTAINTIES (OR SYSTEMATIC BIAS)
- GLOBAL SETS: GOOD AGREEMENT IN THE REGION OF THE EW SCALE
- UNCERTAINTIES BLOW UP FOR LARGE-MASS FINAL STATES

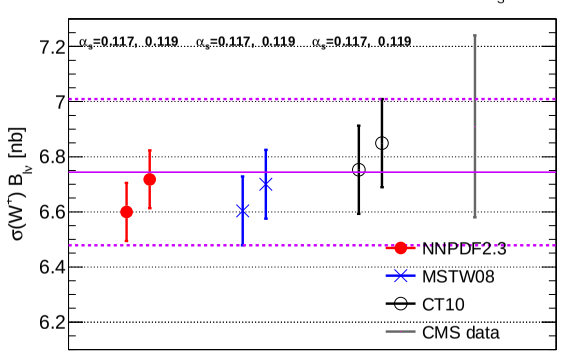
CONTINUOUS PROGRESS

GLOBAL PDF SETS: THE W^+ CROSS-SECTION

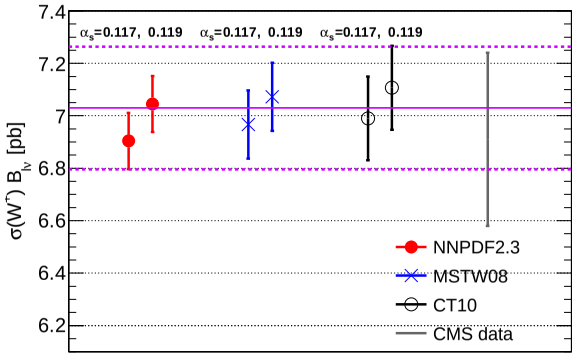
2010 NLO PDFs



2012 NLO PDFs



2012 NNLO PDFs



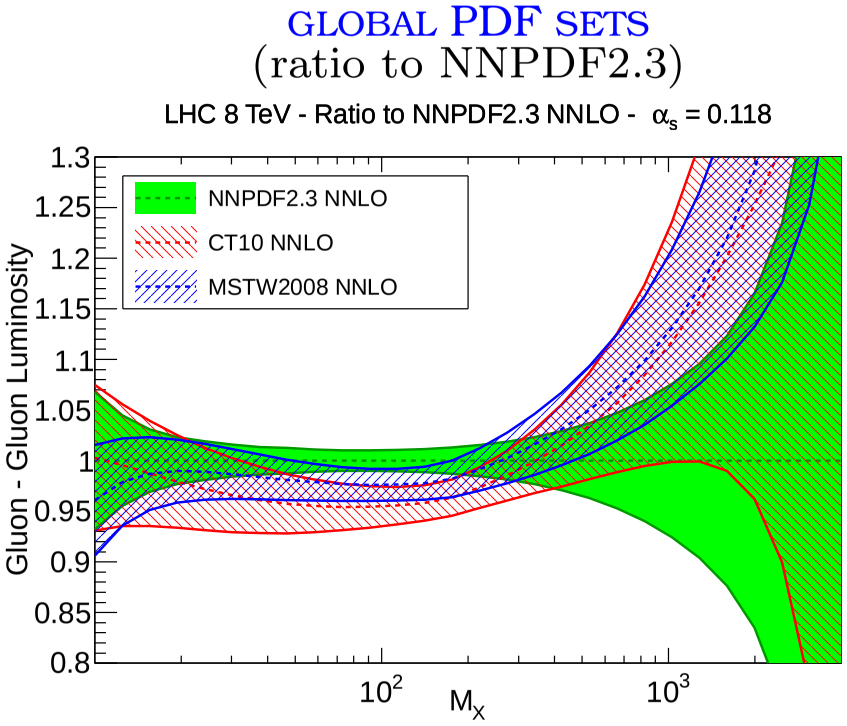
- Each datapoint includes PDF+α_s uncertainty; $\Delta\alpha_s = 0.001$
- $\alpha_s = 0.117$ and $\alpha_s = 0.119$ predictions given for each set (note all PDFs depend on α_s)
- horizontal (purple) line show envelope of predictions

IMPROVEMENTS

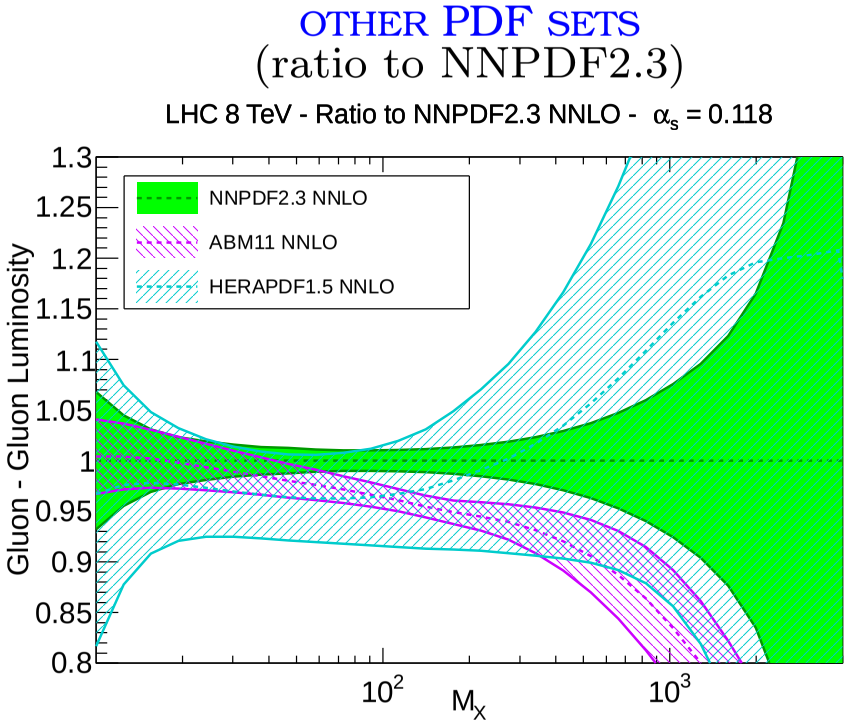
- MORE GENERAL PARAMETRIZATION (CTEQ, MSTW)
- NNLO FITS AVAILABLE (NNPDF, CTEQ)
- FULL TREATMENT OF CHARM MASS (NNPDF)
- CONTINUOUS BENCHMARKING

PARTON LUMINOSITIES: GLUON SECTOR

GLOBAL PDF SETS
(ratio to NNPDF2.3)

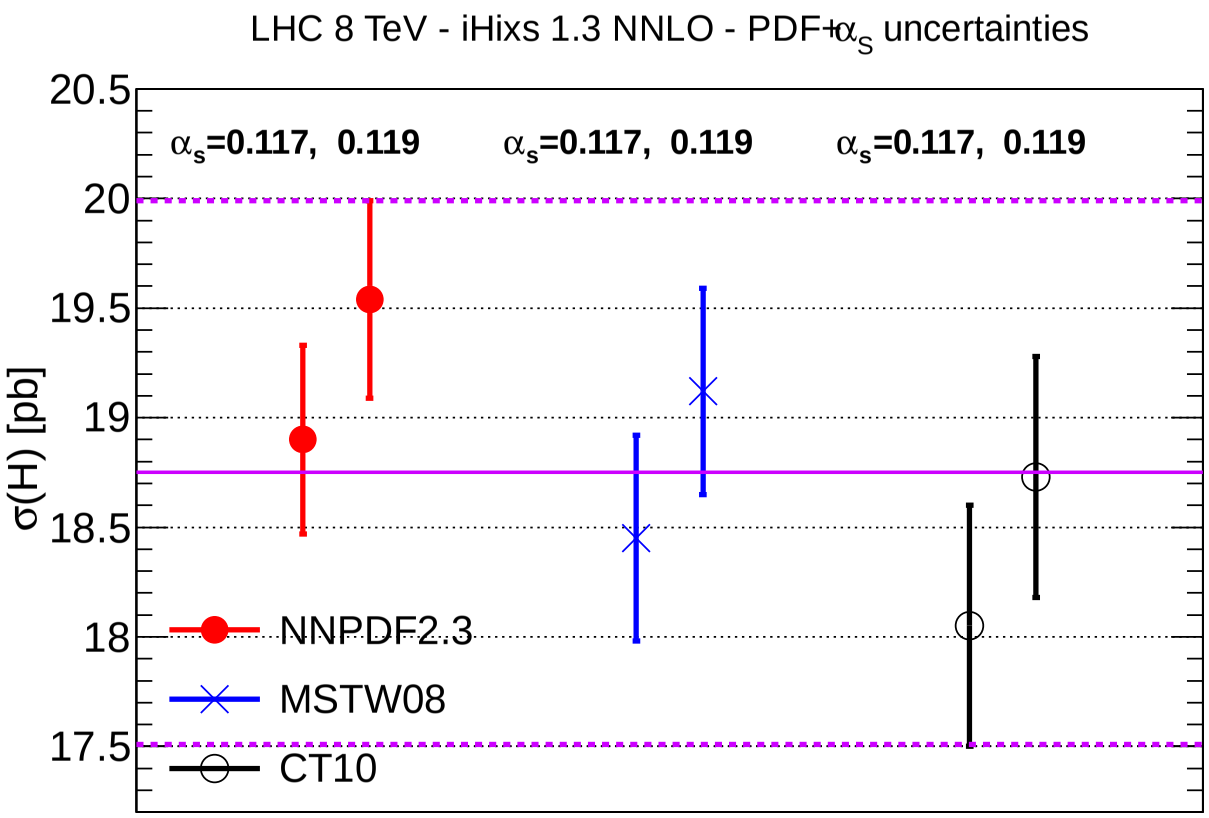


OTHER PDF SETS
(ratio to NNPDF2.3)



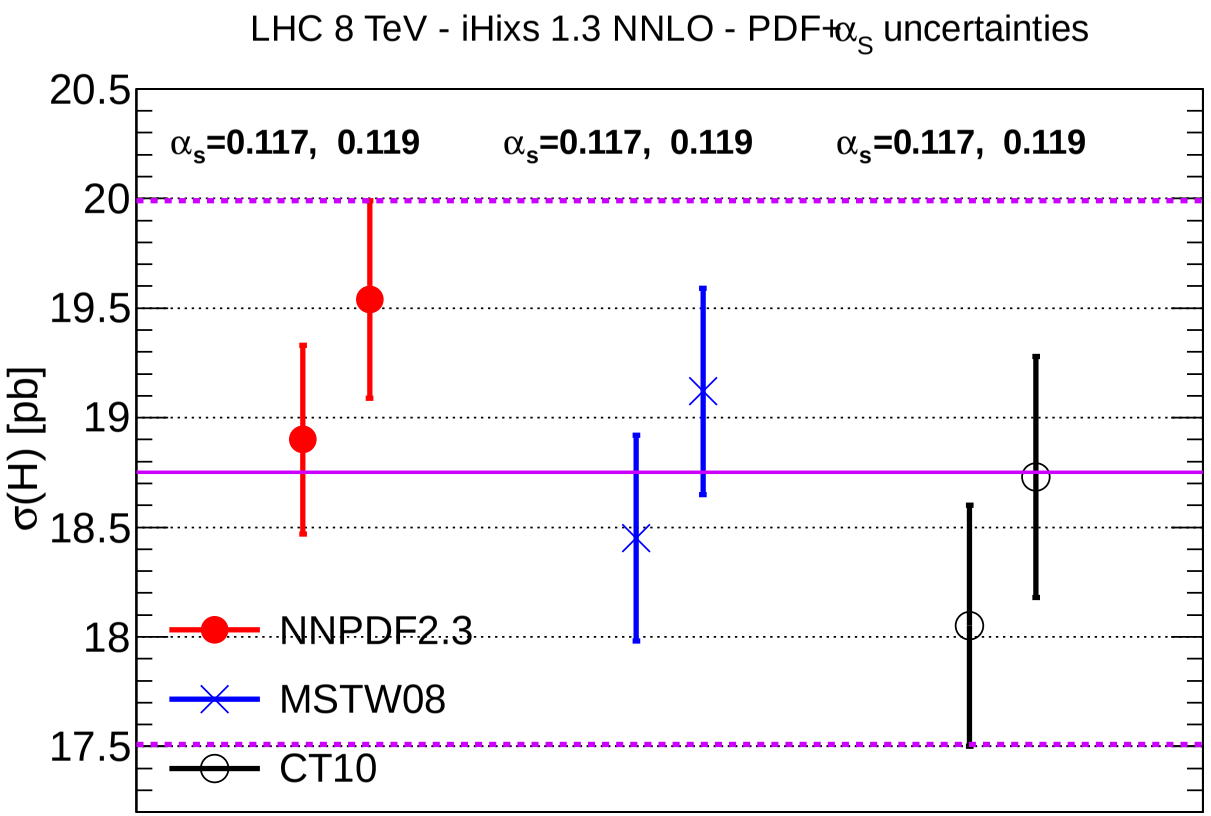
- FEWER DATA $\rightarrow$ LARGER UNCERTAINTIES (OR SYSTEMATIC BIAS)
- GLOBAL SETS: NOT SO GOOD AGREEMENT IN THE REGION OF THE EW SCALE
- UNCERTAINTIES BLOW UP FOR LARGE-MASS FINAL STATES

THE PDF4LHC PRESCRIPTION
HIGGS IN GLUON FUSION



- HOW CAN ONE HANDLE DISCREPANCIES WHICH ARE NOT UNDERSTOOD?
- CONSERVATIVE ANSWER: TAKE THE ENVELOPE OF RESULTS

THE PDF4LHC PRESCRIPTION
HIGGS IN GLUON FUSION

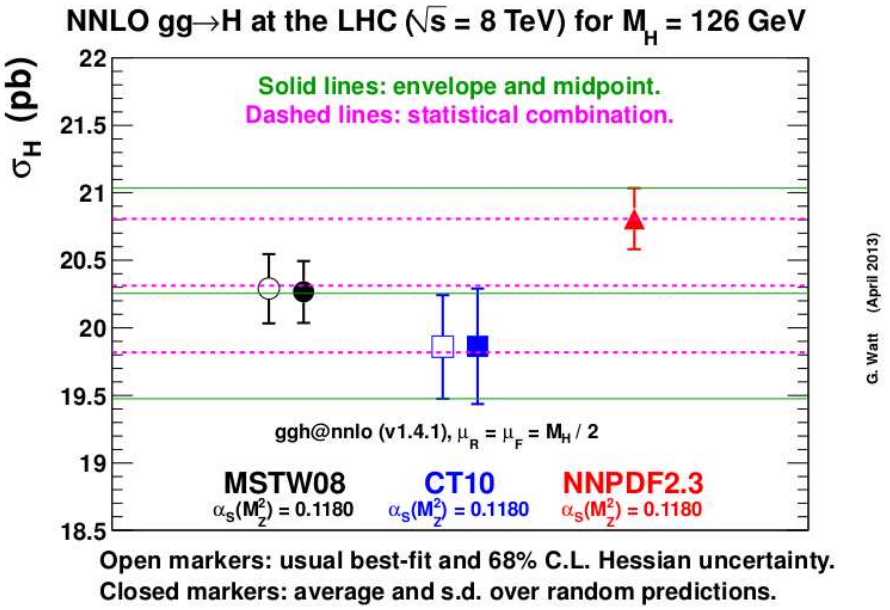


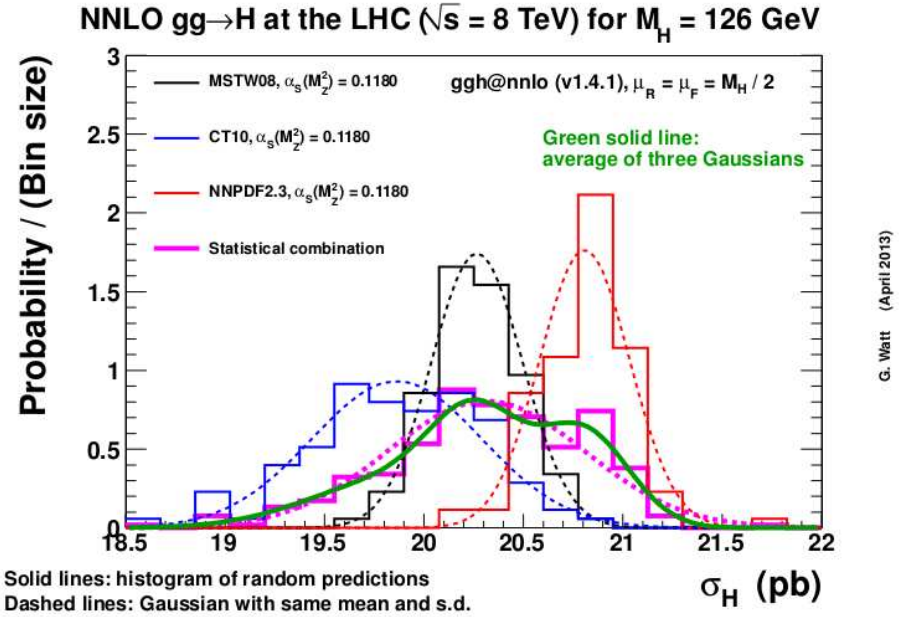
- HOW CAN ONE HANDLE DISCREPANCIES WHICH ARE NOT UNDERSTOOD?
- CONSERVATIVE ANSWER: TAKE THE ENVELOPE OF RESULTS

CRITICISM

- IT IS VERY CONSERVATIVE: α_s UNCERTAINTY COUNTED TWICE
- TAKING AN ENVELOPE HAS NO CLEAR STATISTICAL MEANING

THE PDF4LHC PRESCRIPTION
IMPROVEMENT





A LESS CONSERVATIVE PRESCRIPTION:

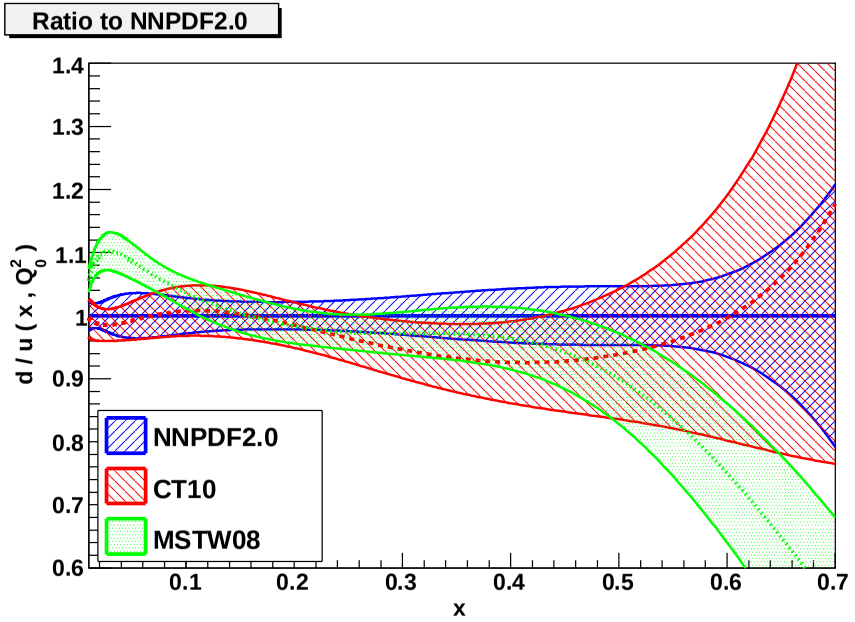
- COMBINE PDF UNCERTAINTIES WITH SINGLE CENTRAL α_s VALUE
- PERFORM STATISTICAL COMBINATION OF THREE SETS (COMBINE HISTOGRAMS)
- ADD α_s UNCERTAINTY IN THE END

(G.Watt, Higgs WG Theoretical Uncertainty Task Force, in progress)

DISCREPANCIES vs. DATA

AN EXAMPLE: THE d/u RATIO

THE d/u RATIO



- LONG-STANDING DISCREPANCY IN THE d/u RATIO BETWEEN MSTW AND OTHER GLOBAL FITS

DISCREPANCIES vs. DATA

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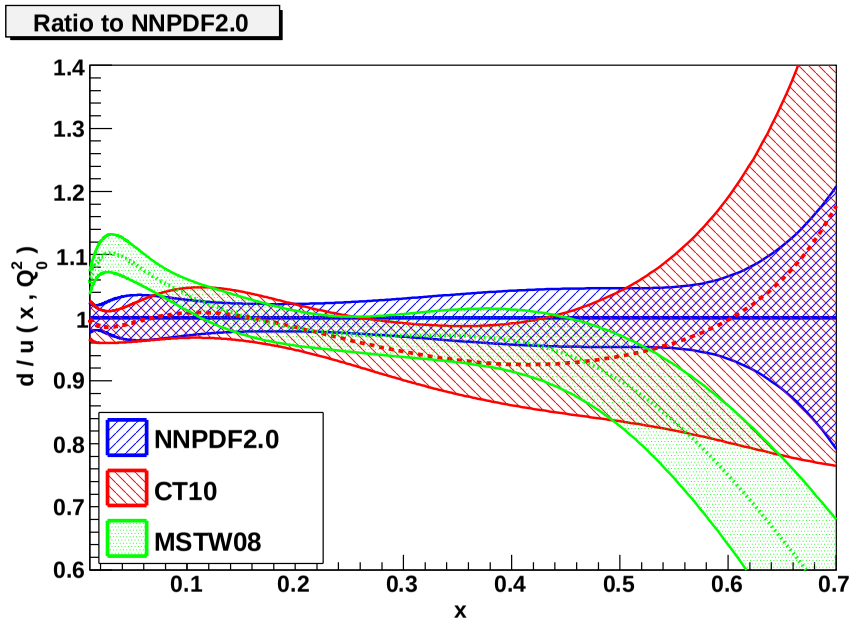
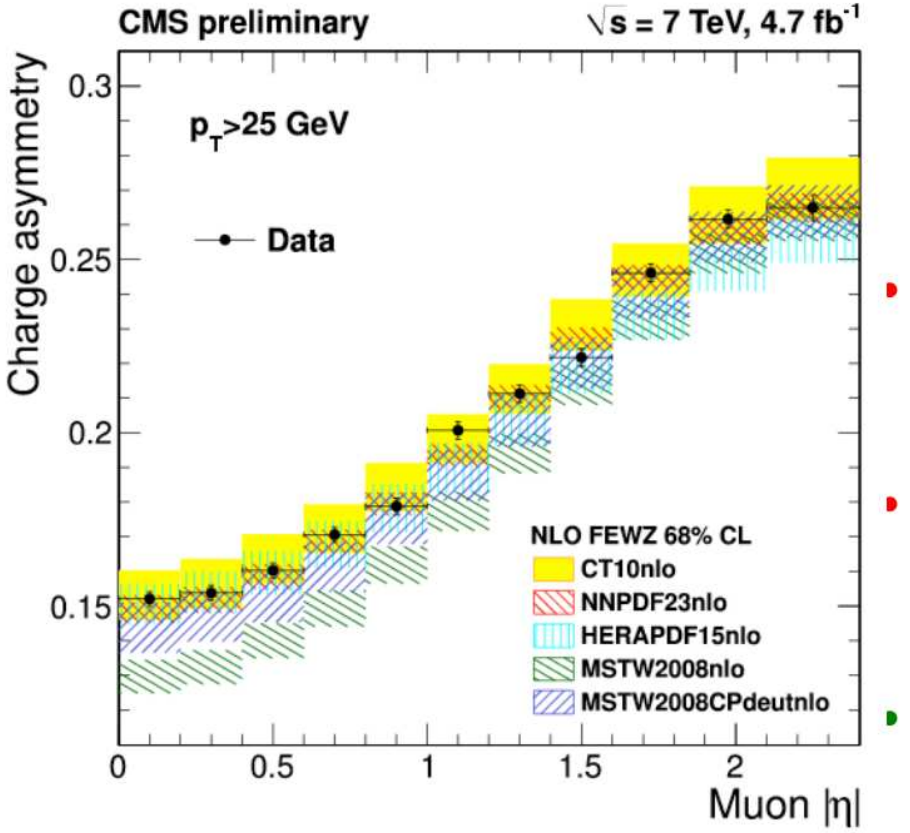


THE CMS W ASYMMETRY

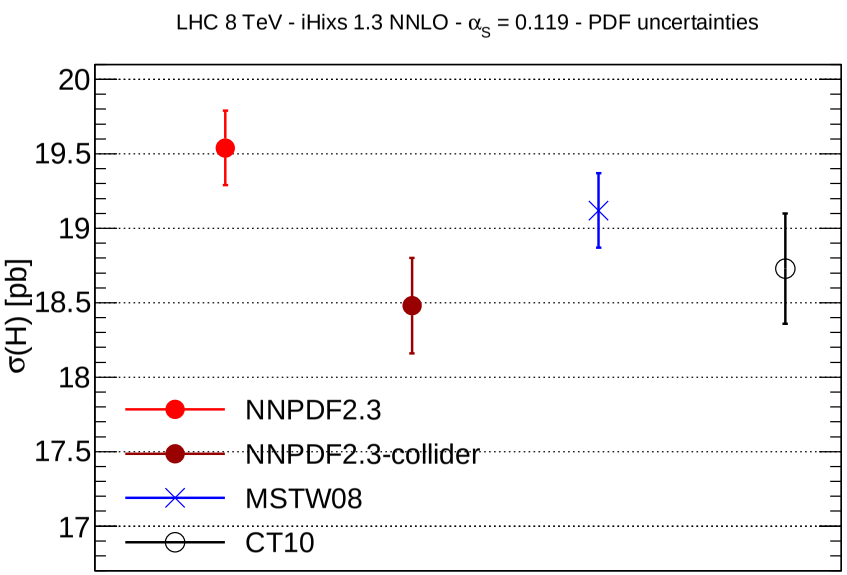


- LONG-STANDING DISCREPANCY IN THE d/u RATIO BETWEEN MSTW AND OTHER GLOBAL FITS
- RESLOVED BY CMS W ASYMMETRY DATA
- EXPLAINED BY INSUFFICIENTLY FLEXIBLE PDF PARAMETRIZATION $\rightarrow$ NEW MSTW08DEUT SET

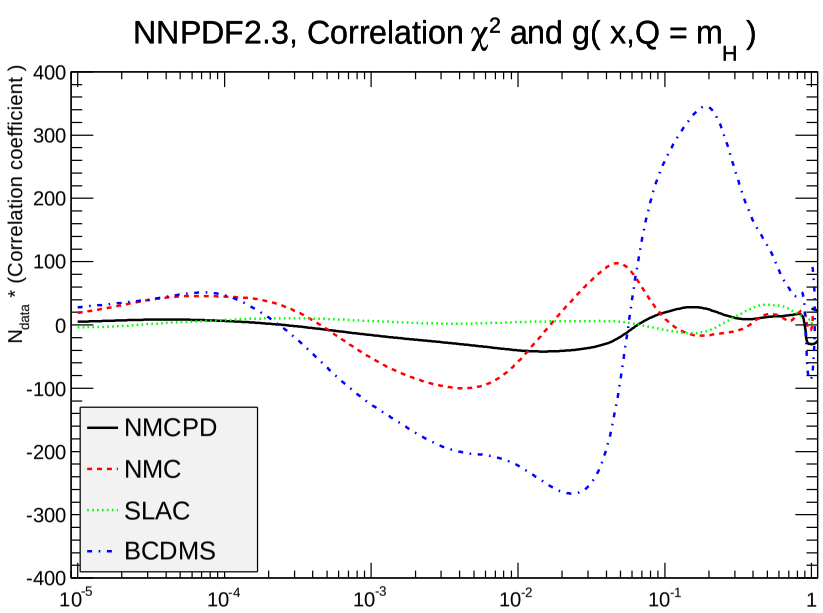
DISCREPANCIES vs. DATA

WHAT'S HE PROBLEM WITH THE GLUON?

HIGGS IN GLUON FUSION



CORRELATION BETWEEN GLUON AND EXPT χ^2



- REMOVE FIXED-TARGET DATA FROM GLOBAL FIT ⇒ NNPDF-COLLIDER AGREES WITH CTEQ
- VARIOUS FIXED-TARGET DATA MIGHT BE AFFECTED BY ISSUES (NEUTRINO DATA, NMC KNOWN TO HAVE INTERNAL INCONSISTENCIES...)
- CORRELATION BETWEEN THESE DATASETS & GLUON OBSERVED
- ONGOING BENCHMARKING WITHIN THE LES HOUCHES WORKSHOP & PDF4LHC

THE SOLUTION!

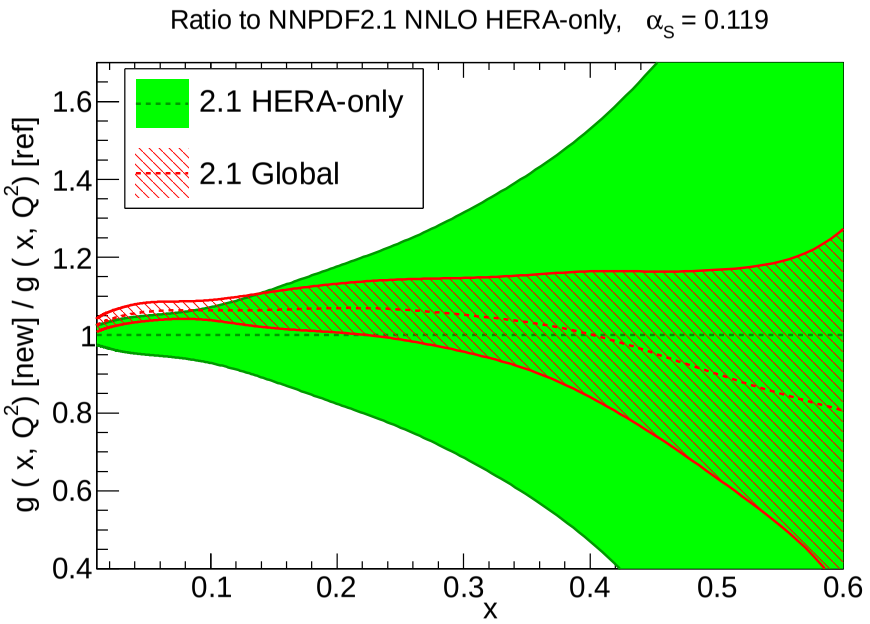
NEW DATA FROM LHC

EXAMPLE: TOP PRODUCTION & THE GLUON

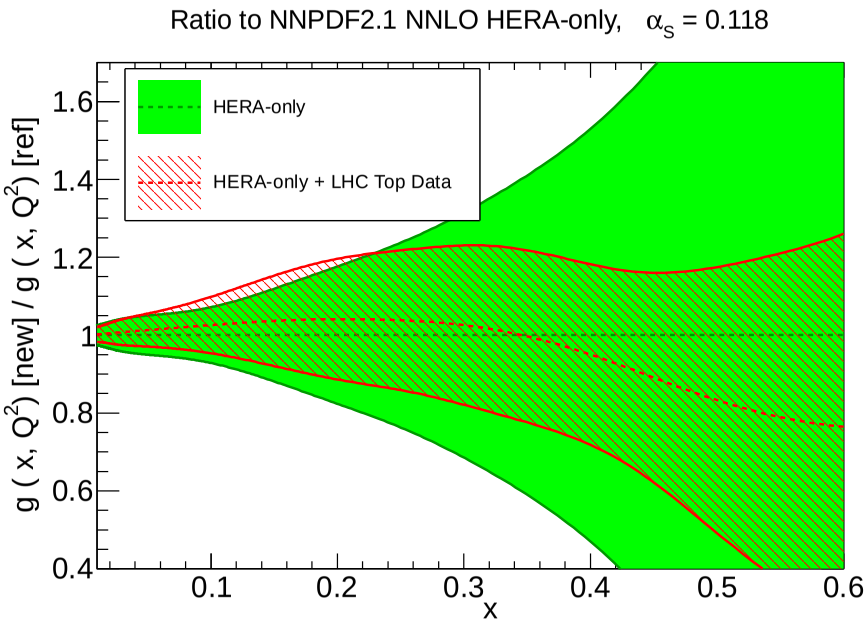
- GLUON IN GLOBAL FIT DETERMINED MOSTLY FROM SCALING VIOLATIONS (DIS) & JET DATA
- REMOVING ALL DATA BUT HERA $\Rightarrow$ CLEAN DETERMINATION, BUT LARGE UNCERTAINTIES
- TOP PRODUCTION ALONE CAN PROVIDE SAME INFORMATION AS ALL DATA BESIDES HERA IN GLOBAL FITS $\Rightarrow$ POTENTIALLY VERY CLEAN DETERMINATION

DETERMINATION OF THE GLUON DISTRIBUTION

HERA ONLY VS GLOBAL FIT



HERA ONLY VS HERA+TOP



(Czakon, Mangoano, Mitov, Rojo, 2013)

LHC DATA

A SHOPPING LIST

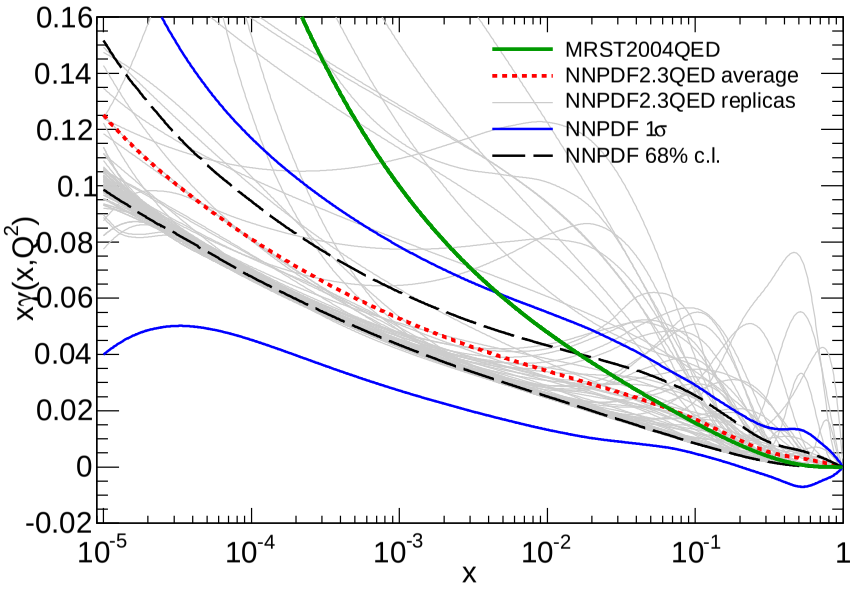
THE GOAL: A "COLLIDER ONLY" PDF DETERMINATION

- MEDIUM & LARGE x GLUON
  - TOP RAPIDITY DISTRIBUTIONS (NNLO SOON)
  - INCLUSIVE W, Z p_T DISTRIBUTIONS (NNLO SOON)
  - JETS (PARTIAL NNLO)
  - DIJETS
  - PROMPT PHOTONS (NLO)
  - W POLARIZATION (NLO)
- LIGHT FLAVOR SEPARATION
  - LOW–MASS & HIGH–MASS DRELL-YAN (NNLO)
  - DOUBLE-DIFFERENTIAL DY RAPIDITY DISTRIBUTIONS (NNLO)
  - Z RAPIDITY DISTRIBUTIONS (NNLO)
  - W ASYMMETRIES (NNLO)
- STRANGENES & HEAVY FLAVORS
  - STRANGENESS $\Rightarrow$ $W + c$ (NLO)
  - CHARM $\Rightarrow$ $Z + c$, $\gamma + c$ (NLO)
  - BOTTOM $Z + b$ (NLO)
- DATA FOR MOST OF THESE ALREADY AVAILABLE (AT LEAST IN PRELIM. FORM)
- NNLO THEORY AVAILABLE OR SOON AVAILABLE FOR MANY
- RATIOS AND DOUBLE RATIOS (8TEV/7TEV) IMPORTANT IN REDUCING UNCERTAINTIES
- COMPLETE INFORMATION ON CORRELATED SYSTEMNATICS CRUCIAL!

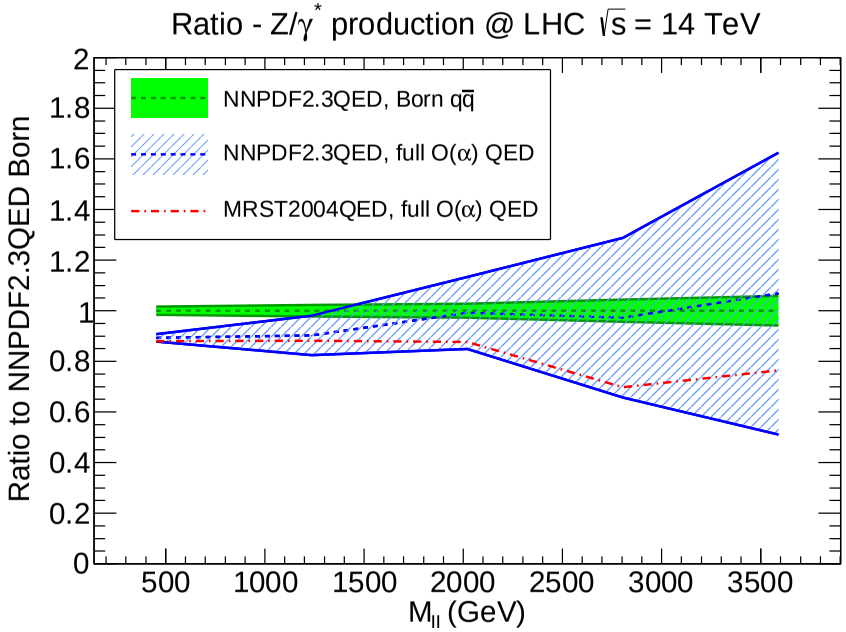
THEORETICAL UNCERTAINTIES
QED/EW CORRECTIONS

- ACCURACY AT THE PRECENT LEVEL $\Rightarrow$ QED & ELECTROWEAK CORRECTIONS TO EW STANDARD CANDLES IMPORTANT
- MUST DETERMINE A PHOTON PDF, INCLUDE QED EVOLUTION
- ONLY ONE SET (MRST2004) AVAILABLE PREVIOUSLY, PHOTON PDF DETERMINED FROM MODEL
- RECENT DETERMINATION OF A PDF SET WITH PHOTON FROM LHC DRELL-YAN DATA (NNPDF2.3QED)

THE PHOTON PDF



NC DRELL-YAN: $O(\alpha)$ VS. BORN

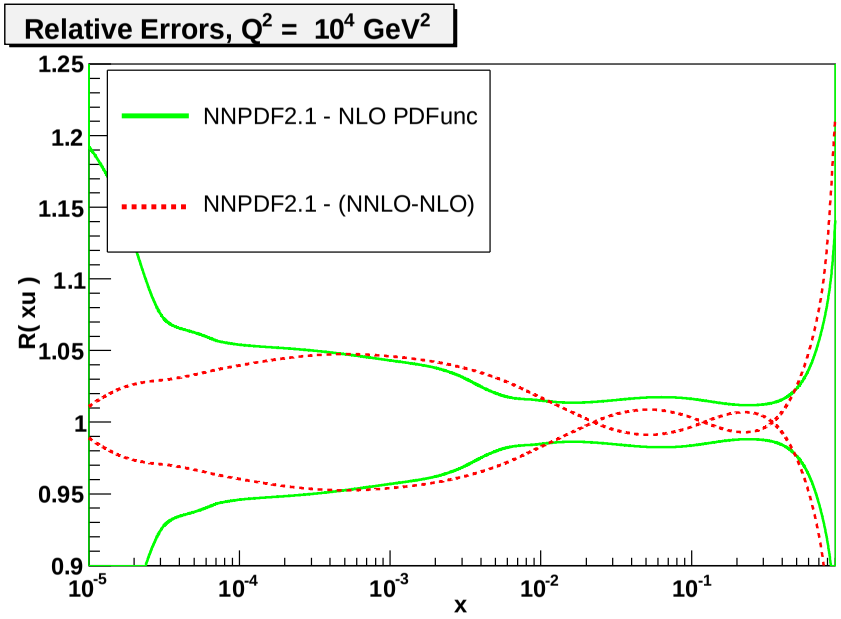


THEORETICAL UNCERTAINTIES ON PDFS

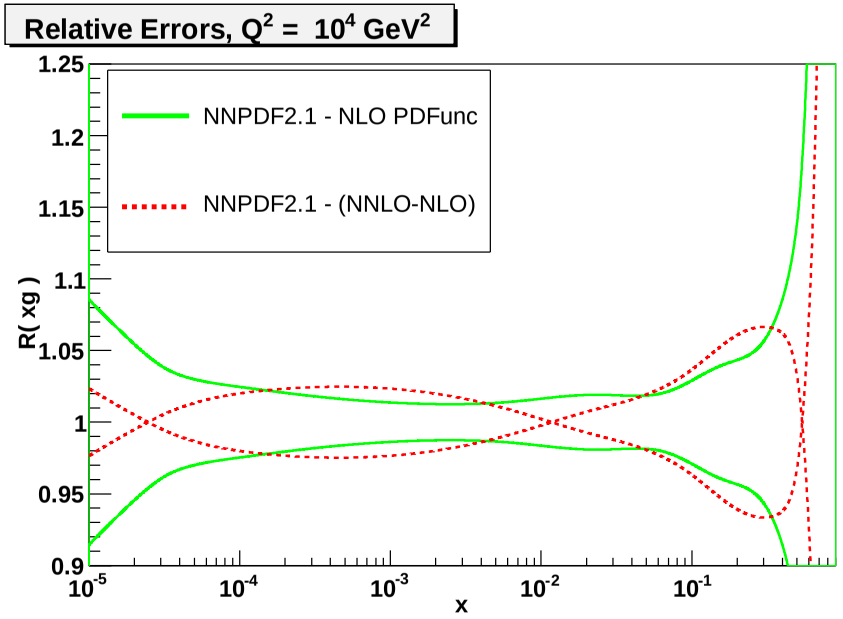
- PDFS CHANGE WITH PERTURBATIVE ORDER → HOW DO WE ESTIMATE UNCERTAINTY AT ANY GIVEN ORDER?
- AT NLO, WE KNOW: NLO-NNLO SHIFT ∼ TH. UNCERTAINTY ON THE NLO
- TURNS OUT TO BE COMPARABLE TO THE (STANDARD, STAT) PDF UNCERTAINTY
- .
- .
- .

NNLO-NLO SHIFT & (STAT) PDF UNCERTAINTY

UP



GLUON



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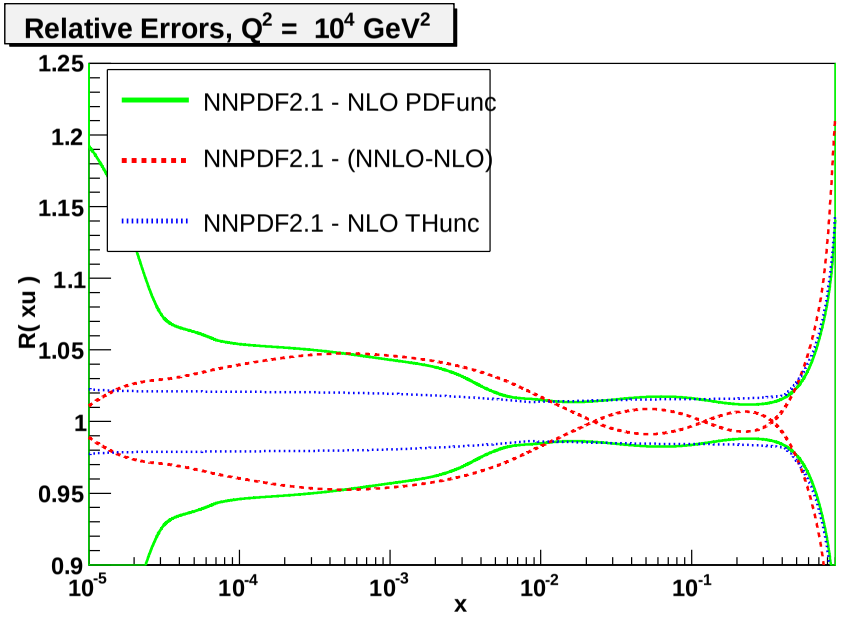
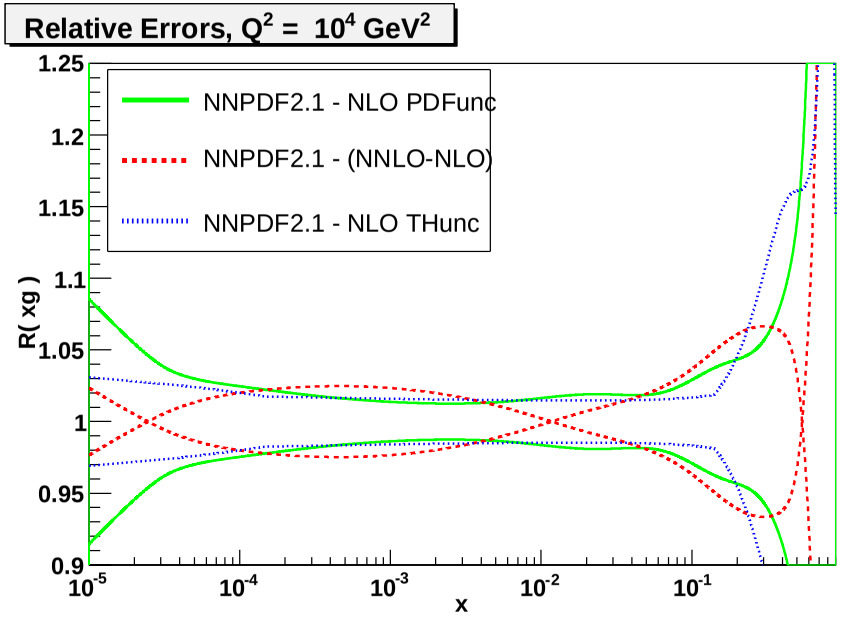
- CACCIARI-HOUDEAU (2011) METHOD ⇒ ESTIMATE NEXT ORDER BASED ON PREVIOUS KNOWN ORDERS
- DOES PRETTY WELL AT NLO WHERE ANSWER KNOWN
- .

NNLO-NLO SHIFT & (STAT) PDF UNCERTAINTY

UP



GLUON



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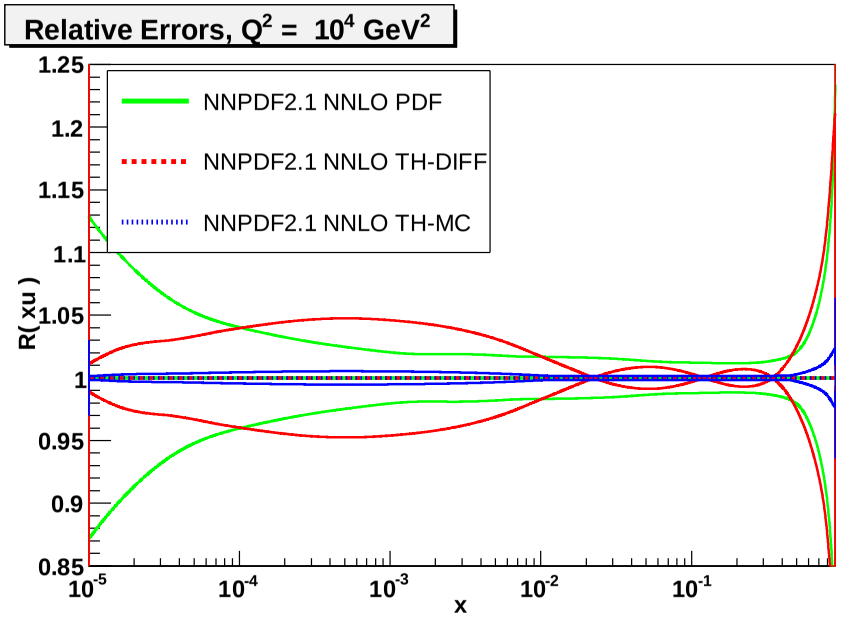
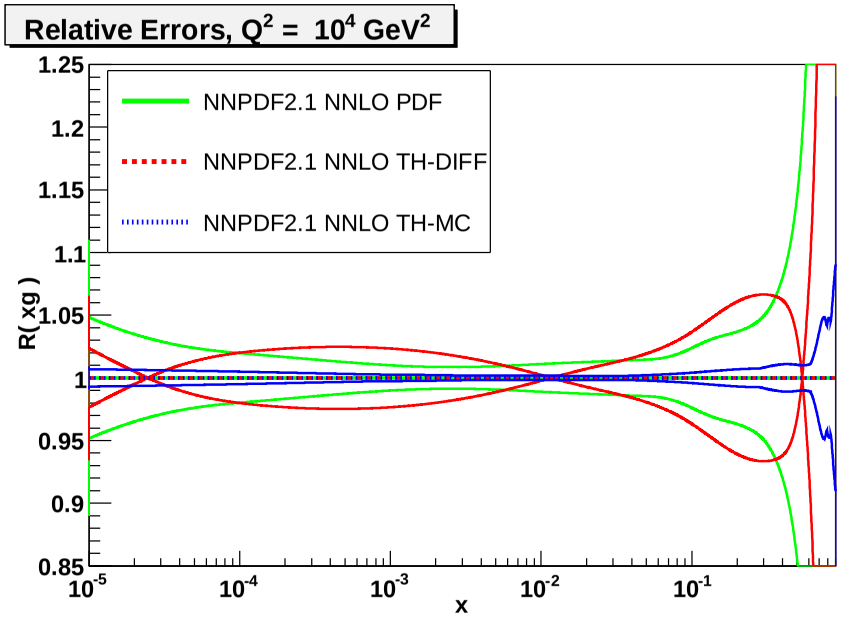
NNLO-NLO SHIFT & (STAT) PDF UNCERTAINTY

UP



GLUON



N^3LO PDFs
AND HIGGS PRODUCTION

- N^3LO QCD RESULTS: HIGGS IN GLUON FUSION (Anastasiou et al, in progress)
- DO WE NEED N^3LO PDFs?

N^3LO PDFs
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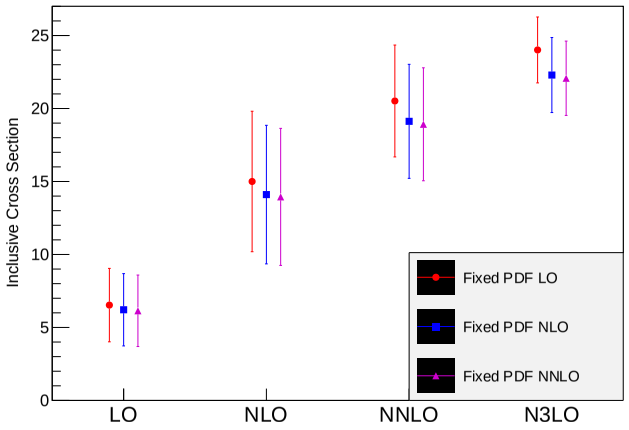
N^{3}LO PDFs
AND HIGGS PRODUCTION

- N^{3}LO QCD RESULTS: HIGGS IN GLUON FUSION (Anastasiou et al, in progress)
- DO WE NEED N^{3}LO PDFs? IN PRINCIPLE, YES
- STUDY THE HIGGS CROSS SECTION AS A FUNCTION OF THE PERTURBATIVE ORDER OF THE PDF AND THE CROSS SECTION

HIGGS IN GLUON FUSION, LHC8 (in pb)

SCALE UNCERTAINTY:

DEP. ON PERTURBATIVE ORDER



(s.f., Isgrò, Vita, prelim.)

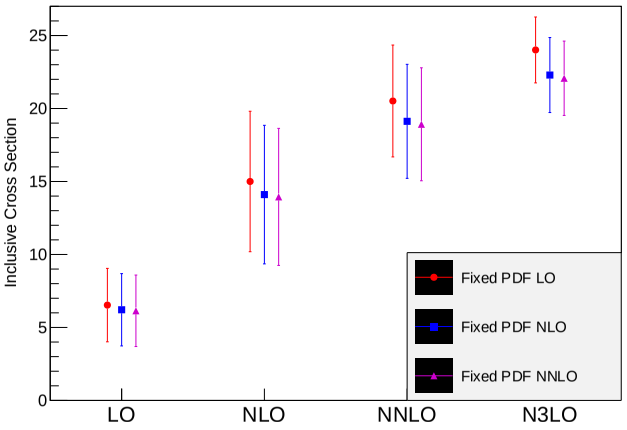
N^{3}LO PDFs
AND HIGGS PRODUCTION

- N^{3}LO QCD RESULTS: HIGGS IN GLUON FUSION (Anastasiou et al, in progress)
- DO WE NEED N^{3}LO PDFS? IN PRINCIPLE, YES
- STUDY THE HIGGS CROSS SECTION AS A FUNCTION OF THE PERTURBATIVE ORDER OF THE PDF AND THE CROSS SECTION
- PERTURBATIVE DEP. OF PDF NEGLIGIBLE IN COMPARISON TO MATRIX ELEMENT $\Rightarrow$ TH. UNCERTAINTY ALMOST ENTIREY DUE TO MATRIX ELEMENT
- IN PRACTICE, CAN USE NNLO PDFS WITH N^{3}LO MATRIX ELEMENT (AT LEAST FOR HIGGS)

HIGGS IN GLUON FUSION, LHC8 (in pb)

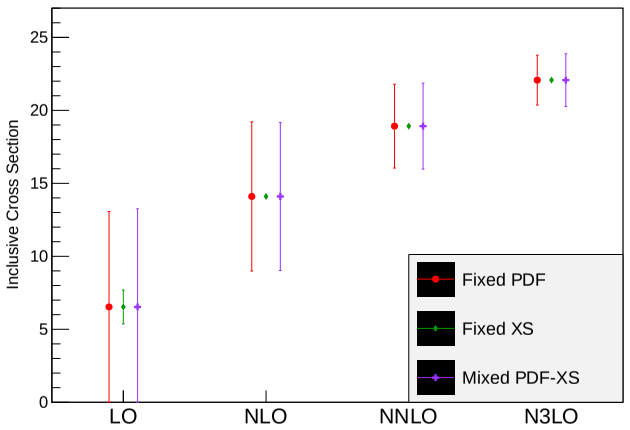
SCALE UNCERTAINTY:

DEP. ON PERTURBATIVE ORDER



TH UNCERTAINTY:

PDF; MATRIX ELEMENT; TOTAL



(s.f., Isgrò, Vita, prelim.)

THEORETICAL ISSUES

ANOTHER SHOPPING LIST

METHODOLOGY

- THEORETICAL UNCERTAINTIES ON PDFS
- CLOSURE TEST: FULL CONTROL OF PDF UNCERTAINTIES (NNPDF, prelim.)

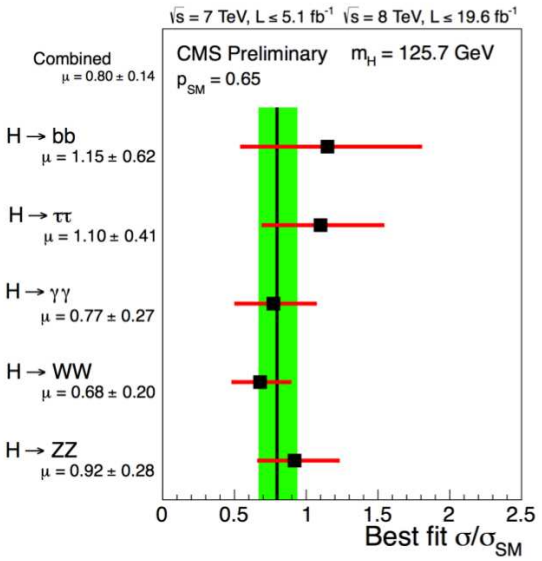
THEORY

- INTRINSIC CHARM (CTEQ, prelim.); $\overline{\rm MS}$ MASSES (ABM)
- QED EVOLUTION AND PHOTON PDFS (NNPDF: LO);
  INCLUSION OF EW EFFECTS
- RESUMMED PDFS
- MC PDFS

OUTLOOK

THE HIGGS COUPLINGS

STATUS OF HIGGS COUPLINGS



- UNDERSTANDING THE HIGGS SECTOR WILL NEED HIGGS COUPLINGS AT THE PERCENT LEVEL
- THE DATA ARE GETTING THERE QUICKLY
- WHAT ABOUT THE THEORY?

EXTRAS

FFN PDFs

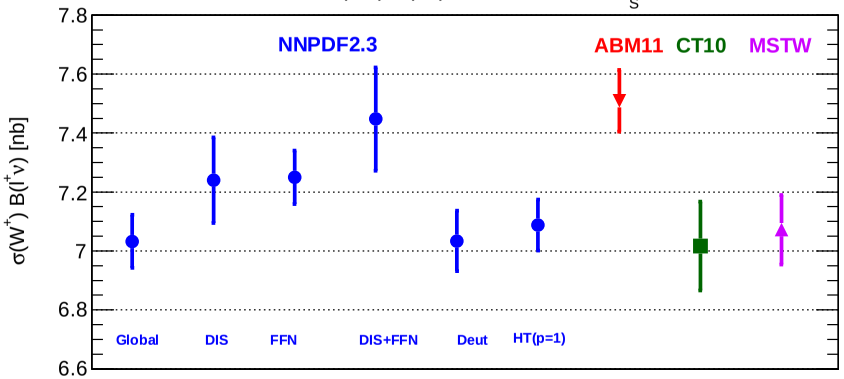
- SOME PDF SETS ADOPT A FFN SCHEME (ABM, JR)
- ABM ALSO INCLUDES HIGHER TWIST & NUCLEAR CORRECTIONS
- ALSO, ABM MOSTLY BASED ON DIS DATA

  (ONLY HADRONIC DATA IS FIXED-TARGET DY)
- WHAT IS THE RELATIVE SIZE OF ALL THESE EFFECTS?
- NNPDF WITH FFN &DIS DATA SET AGREES WITH ABM;

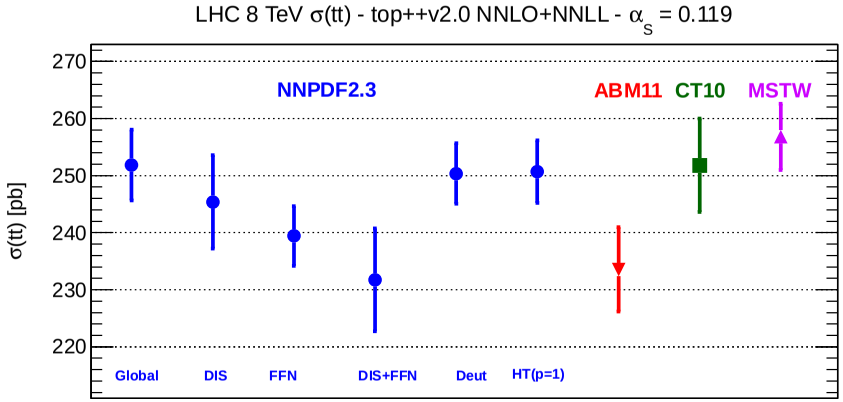
  HIGHER TWIST & NUCLEAR CORRRECTIONS HAVE SMALL & LOCALIZED EFFECT;

  SIMILAR RESULTS FOUND BY MSTW AND CTEQ

W^+



TOP



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 $\Rightarrow$ 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...

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

$\Rightarrow$ EFFECT OF NEW DATA IS ACCOUNTED FOR BY REWEIGHTING MONTE CARLO AVERAGES

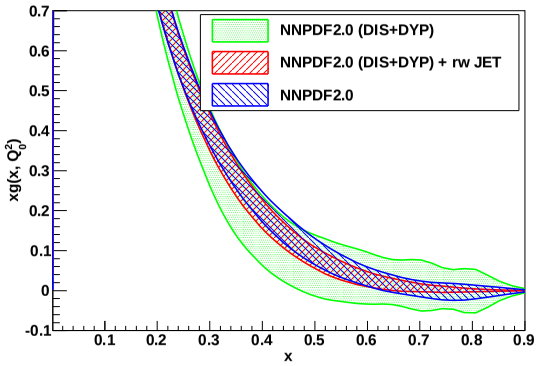
- DETERMINE PDFS INCLUDING SOME DATA BY BAYES' THEOREM (REWEIGHTING)
- DETERMINE PDFS BY ENLARGING THE DATASET TO THE NEW DATA (REFITTING)
- COMPARE RESULTS $\Rightarrow$ IF THEY AGREE, PDFS DO HAVE A STATISTICAL INTERPRETATIONS ALRIGHT!
- ALSO DONE BY MSTW IN A HESSIAN-MC FRAMEWORK footnotesize (Thorne, Watt, 2012)

RUNNING THE TEST

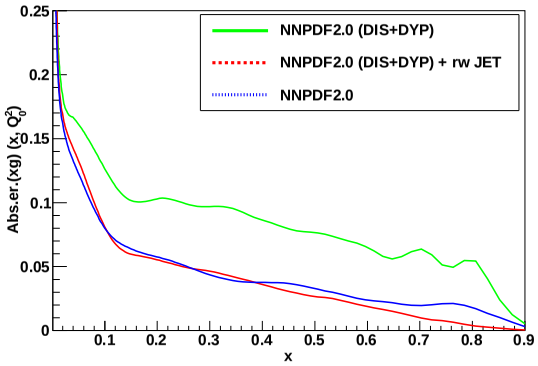
INCLUSION OF JET DATA: REWEIGHTING VS. REFITTING

NNPDF2.0DIS+DY VS. NNPDF2.0FULL

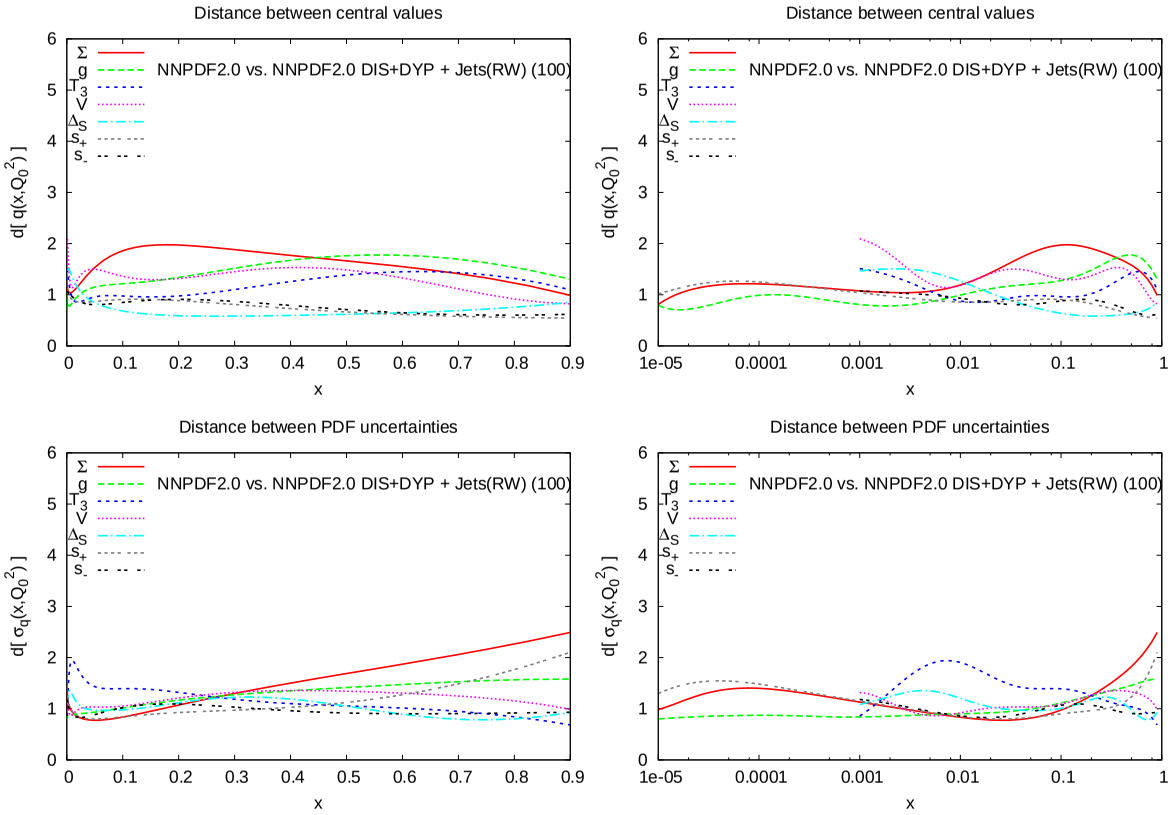
GLUON



GLUON UNCERTAINTY



DISTANCES



$d \sim 1 \Rightarrow$ STATISTICAL EQUIVALENCE

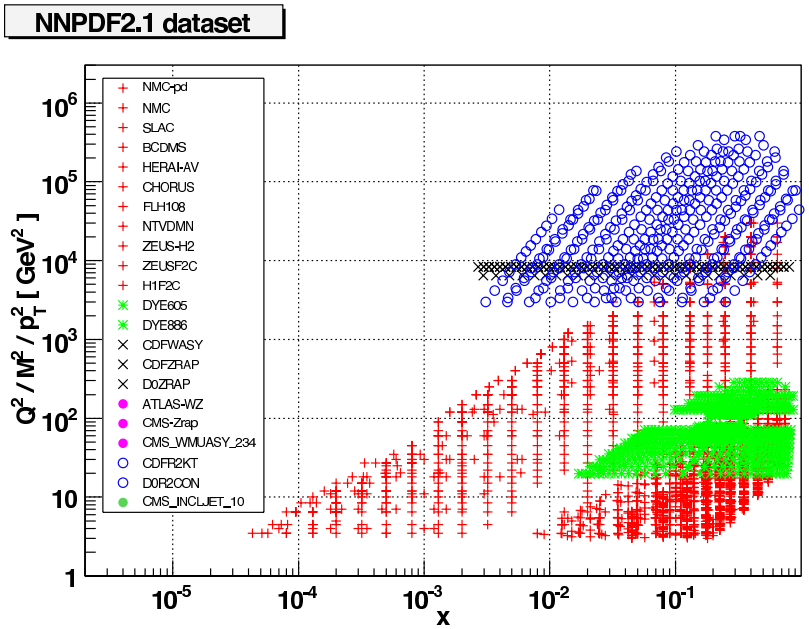
$(d = n \Leftrightarrow n\ \sigma$ DISCREPANCY$)$

STATISTICAL INTERPRETATION VALIDATED

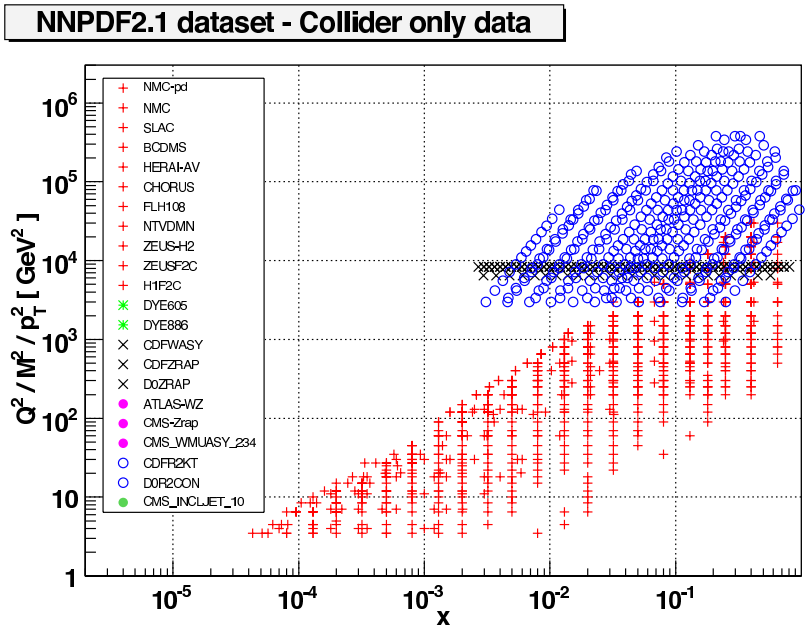
COLLIDER ONLY FITS?

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

THE NNPDF2.1 DATASET



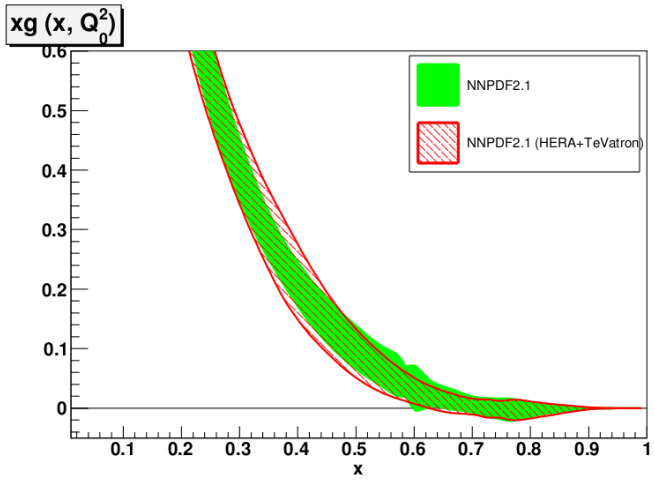
NNPDF2.1 - COLLIDER ONLY



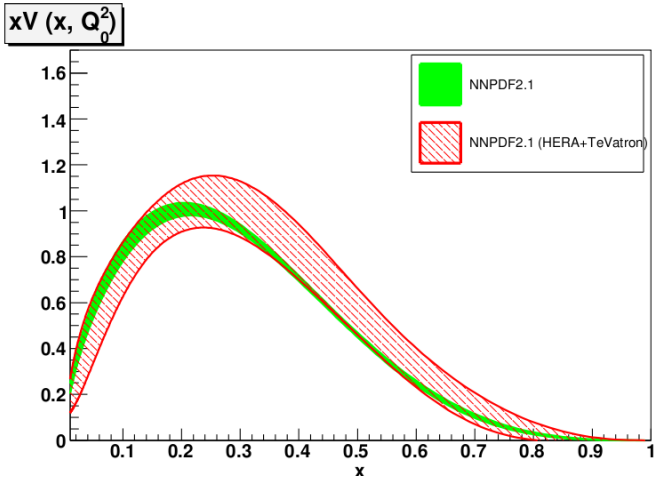
PDFS FROM HERA+TEVATRON DATA?

COLLIDER ONLY PDFs?

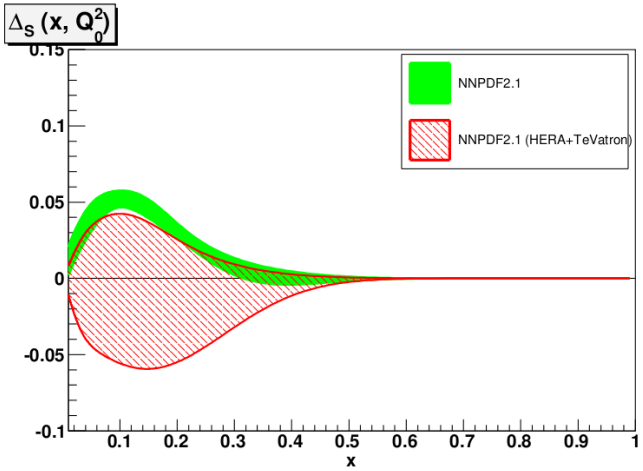
GLUON



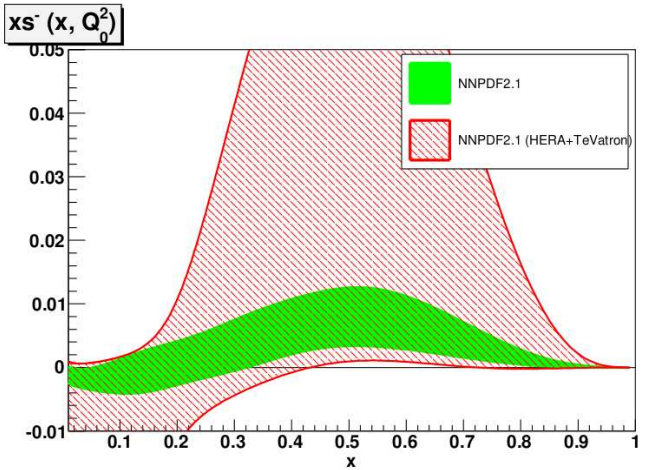
VALENCE



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



STRANGE: $s - \bar{s}$

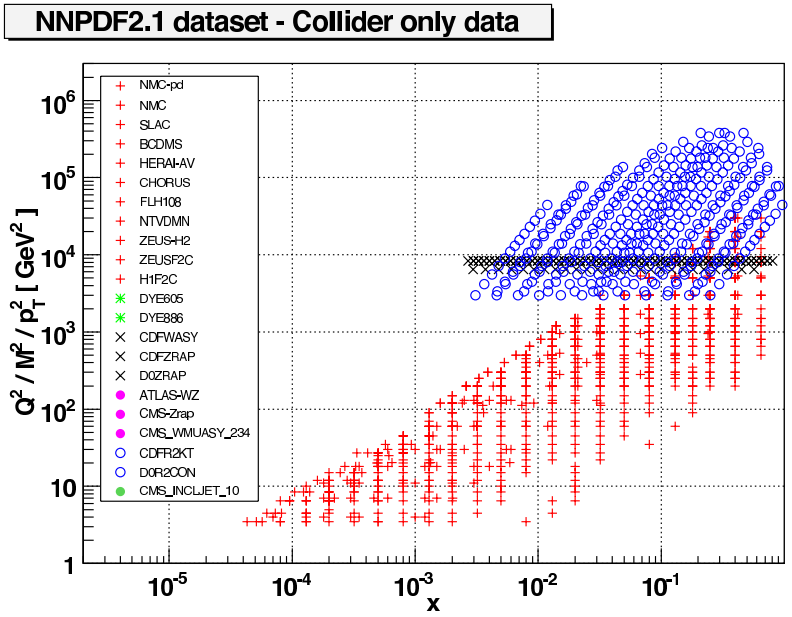


- GOOD ACCURACY FOR GLUON
- GREAT LOSS OF ACCURACY FOR FLAVOR SEPARATION

COLLIDER ONLY FITS?

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

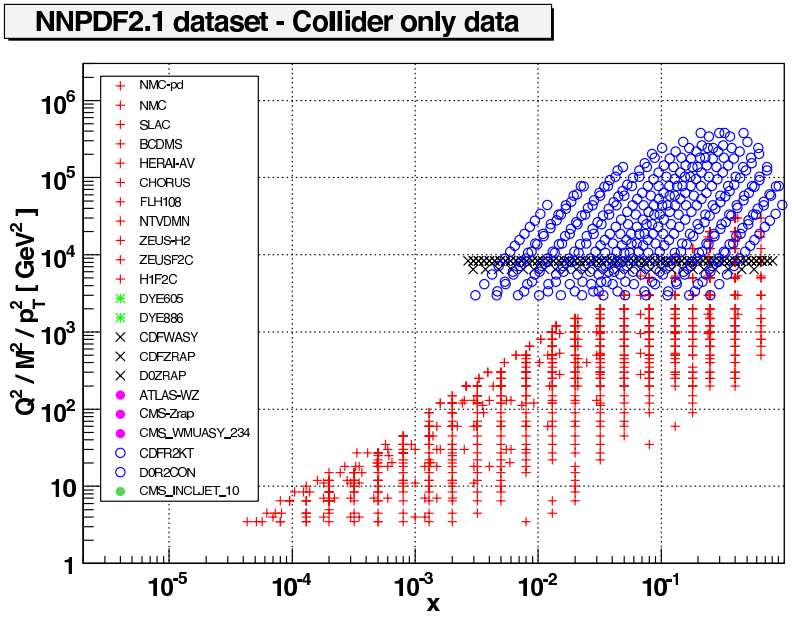
NNPDF2.1 - COLLIDER ONLY



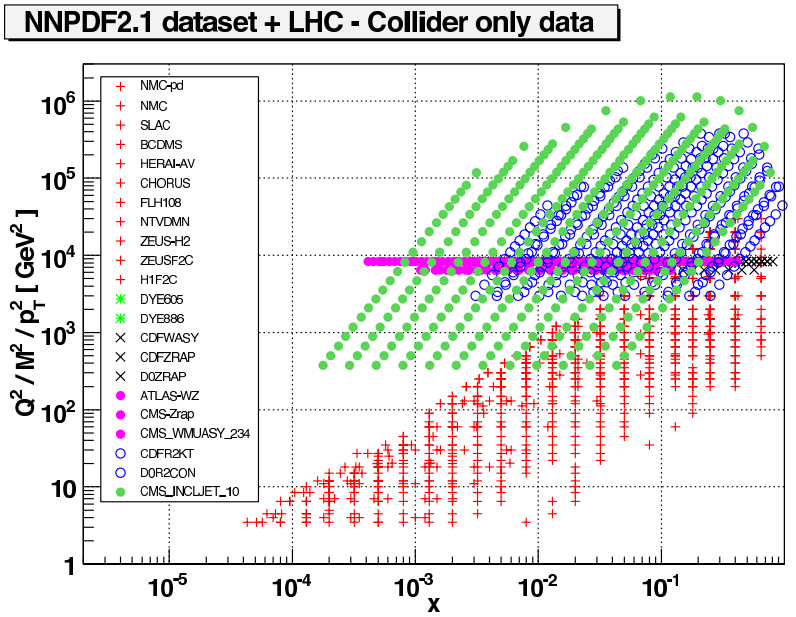
COLLIDER ONLY FITS?

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

NNPDF2.1 - COLLIDER ONLY



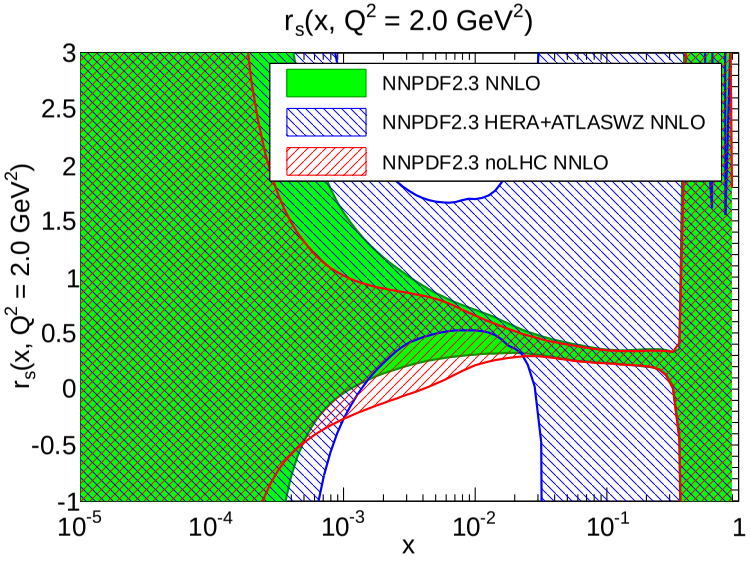
NNPDF2.3 - COLLIDER ONLY

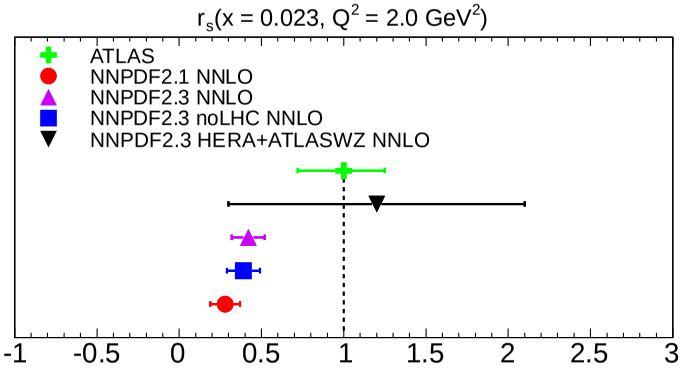


LHC DATA CAN PROVIDE THE MISSING INFORMATION!

COLLIDER ONLY PDFs TODAY

A CASE STUDY: THE NUCLEON STRANGE FRACTION





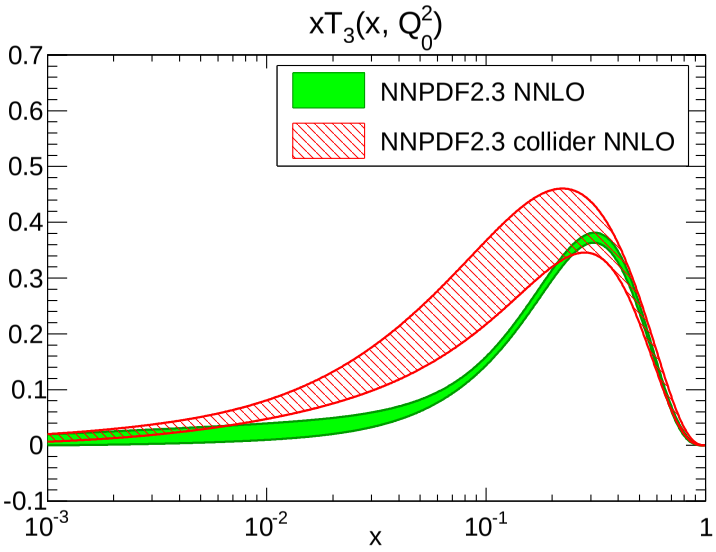
- ATLAS (2012) CLAIMS LARGE (≈ 1) VALUE OF $r_s(x,Q^2) = \frac{s(x,Q^2)+\bar{s}(x,Q^2)}{2\bar{d}(x,Q^2)}$
- RESULT BASED ON THE HERAPDF+HERAFITTER APPROACH APPLIED TO HERA+ATLAS DATA
- NNPDF2.3 FINDS HERA+ATLAS DATA CANNOT DETERMINE STRANGENESS WITH SUFFICIENT ACCURACY
- STRANGENESS IN GLOBAL NNPDF2.3 FIT ACCURATELY DETERMINED, BUT LHC DATA HAVE MINOR IMPACT

COLLIDER ONLY PDFs TODAY

NNPDF2.3 COLLIDER PDFs

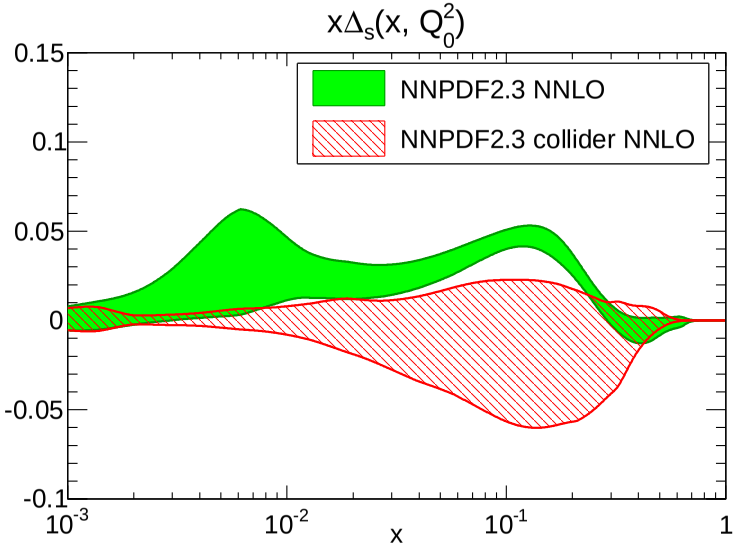
ISOTRIPLET:

$(u + \bar{u}) - (d + \bar{d})$



SEA ASYMMETRY:

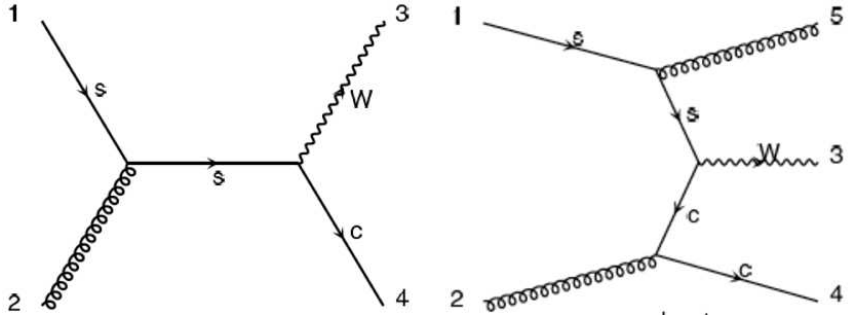
$\bar{d} - \bar{u}$



- NNPDF2.3COLLIDER PDFs AFFECTED BY LARGE UNCERTAINTIES
- CRUCIAL MISSING INFORMATION FROM NEUTRINO AND DIS+DY WITH DEUTERON TARGETS
- POOR DETERMINATION OF LIGHT FLAVOR DECOMPOSITION

$W + c$ PRODUCTION AT THE LHC

- STRANGENESS PROBED DIRECTLY
- MIGHT REPLACE NEUTRINO DATA



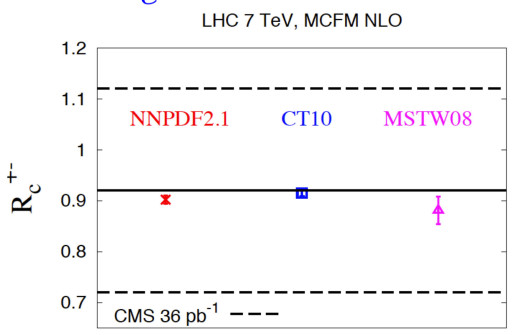
THE CMS MEASUREMENT

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

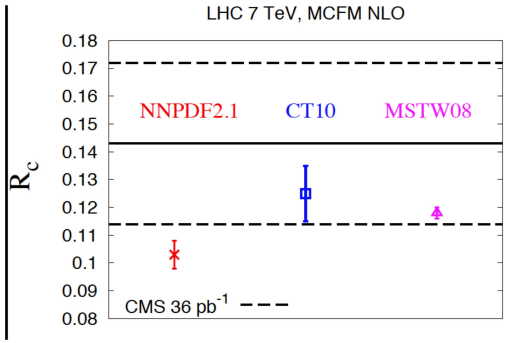
$$R_c^{\pm} = 0.92 \pm 0.19\text{stat.} \pm 0.04\text{syst.}$$
$$R_c = 0.143 \pm 0.015\text{stat.} \pm 0.024\text{syst.}$$

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

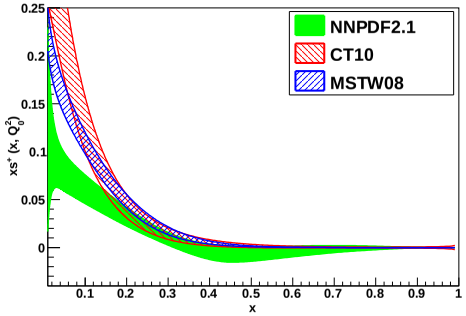
$R_c^{\pm}$ DATA VS TH.



R_c DATA VS TH.



TOTAL STRANGENESS



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

$W + c$ PRODUCTION AT THE LHC

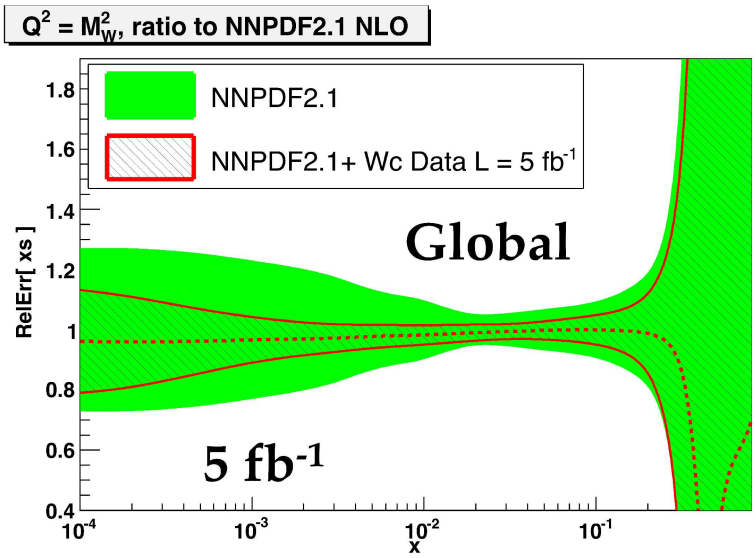
- SIMULATED MEASUREMENT OF c RAPIDITY DISTRIBUTION WITH aMC@NLO

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

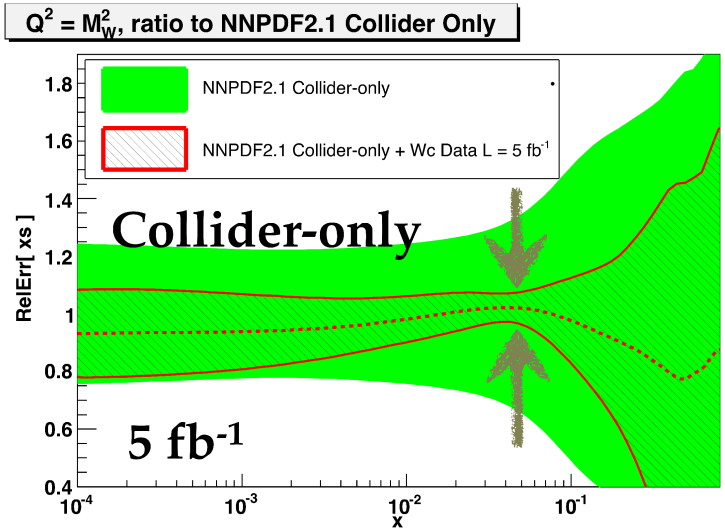
- CMS KINEMATICS $p_T^{\rm jet} > 20$ GeV, $p_T^{\mu} > 25$ GeV $\eta^{\rm jet}$, $\eta^{\mu} < 2.1$
- 15% CHARM TAGGING EFFICIENCY (CMS)
- CURRENTLY 36 PB^{-1}, BUT 5 FB^{-1} SUFFICIENT

THE IMPACT ON STRANGENESS

IN THE NNPDF2.1 FIT



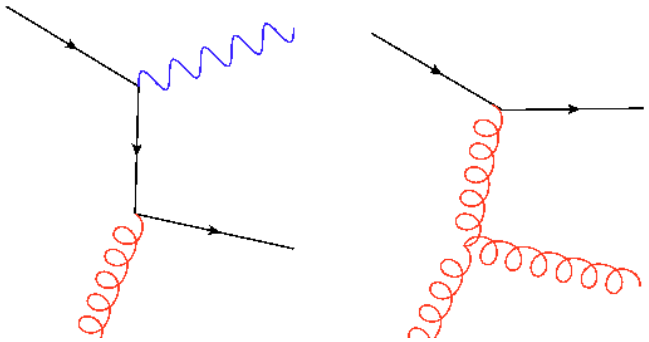
IN THE COLLIDER-ONLY FIT



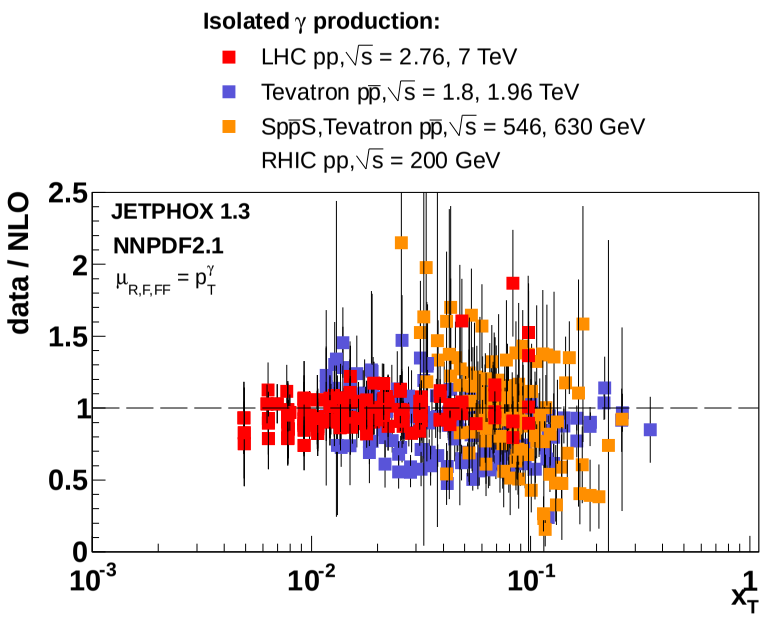
- IMPACT SIGNIFICANT EVEN ON CURRENT GLOBAL FIT
- COULD DO WITHOUT NEUTRINO DATA

PROMPT PHOTON PRODUCTION

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



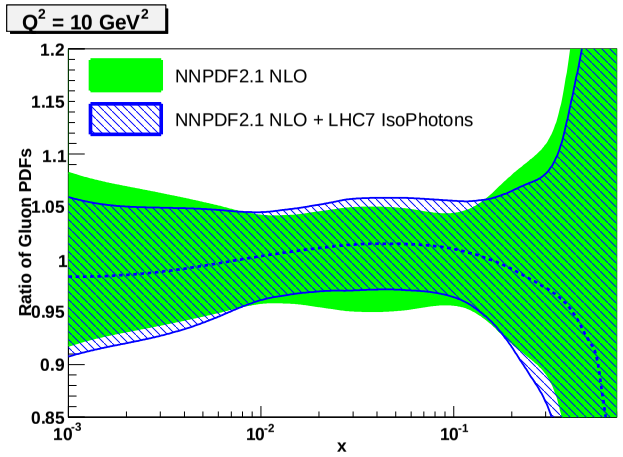
$x_t = x_1 x_2$ RANGE



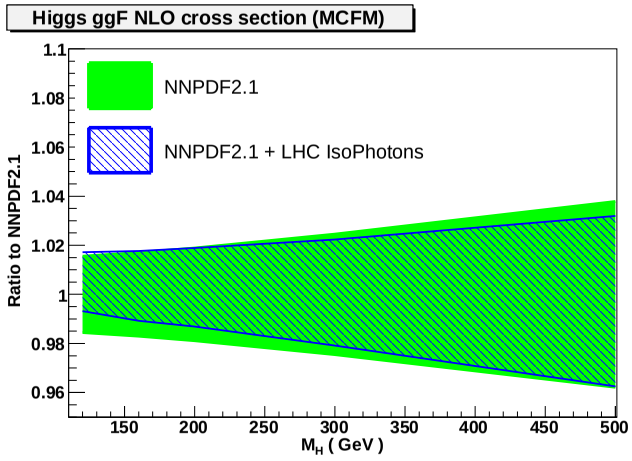
- DIRECT PROBE OF THE qg LUMINOSITY
- MEASURED BY CMS+ATLAS

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

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^{3}LO, NO DEP. ON HADRON STRUCTURE) GIVES
  $\alpha_s = 0.1209 \pm 0.0013$

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 $\alpha_s = 0.1197 \pm 0.0016$)
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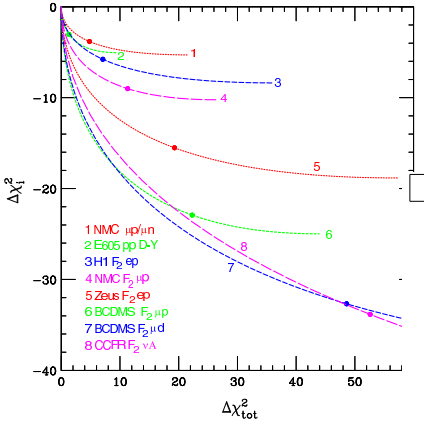
  $\alpha_s = 0.1209 \pm 0.0013$
- UNCERTAINTY LARGER THAN 0.002 QUITE UNLIKELY

METHODOLOGY: "STANDARD" (HESSIAN) APPROACH

THE TOLERANCE PROBLEM

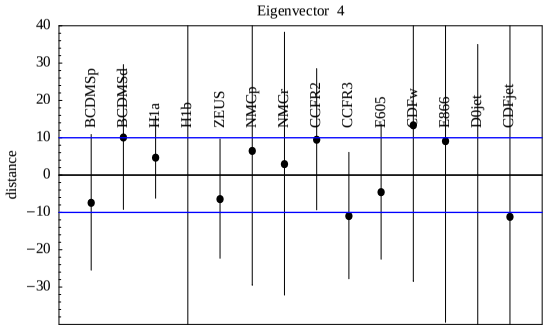
- CHOOSE A FIXED FUNCTIONAL FORM ($\sim 25 \div 30$ PARMS. GLOBALLY) AND FIT PARMS TO DATA
- UNCERTAINTIES DETERMINED FROM HESSIAN MATRIX AT MINIMUM
- STANDARD $\Delta\chi^2 = 1$ BANDS TOO NARROW $\Rightarrow$ LARGE DISCREPANCIES FOR INDIVIDUAL EXPERIMENTS
- TOLERANCE $\Rightarrow$ ENVELOPE OF UNCERTAINTIES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

MINIMUM χ^2_i VS GLOBAL χ^2

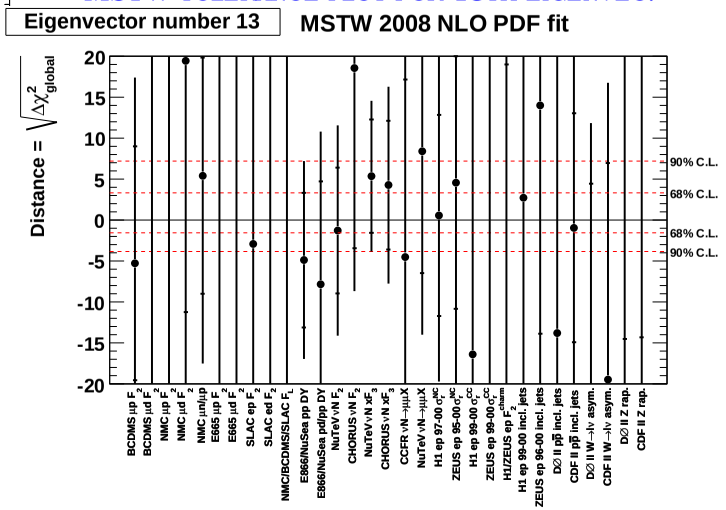


Collins, Pumplin 2001

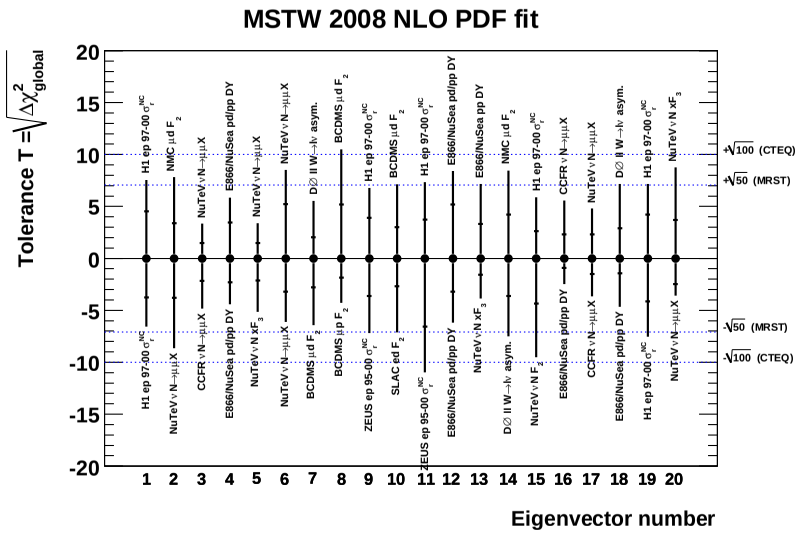
CTEQ TOLERANCE PLOT FOR 4TH EIGENVEC.



MSTW TOLERANCE PLOT FOR 13TH EIGENVEC.



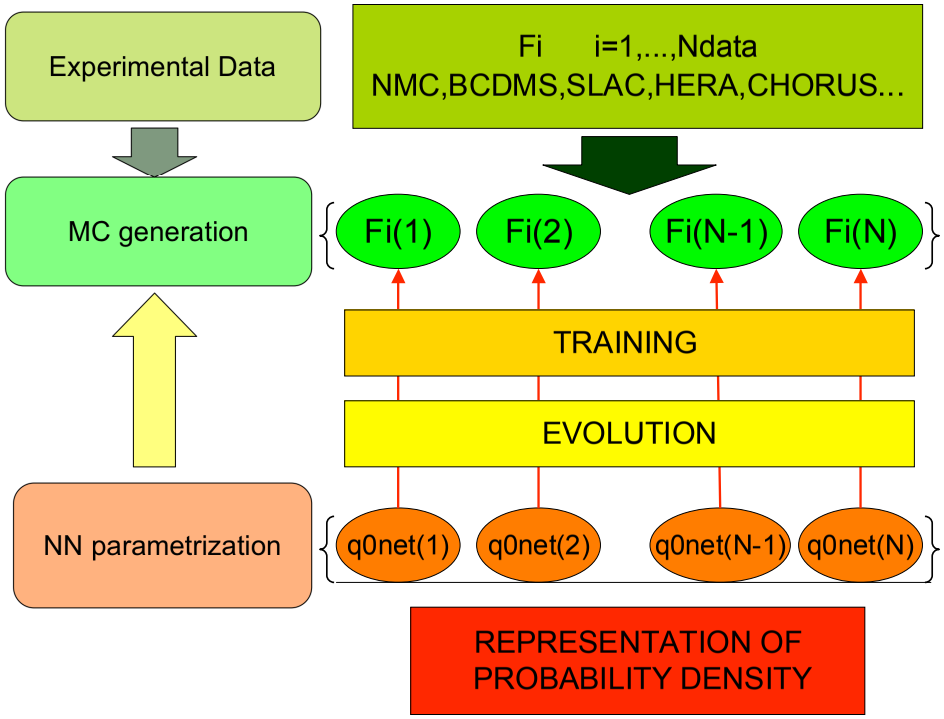
GLOBAL MSTW TOLERANCE



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



METHODOLOGY: NNPDF APPROACH

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

CAN DETERMINE BOTH 68C.L.& $1\text{-}\sigma$

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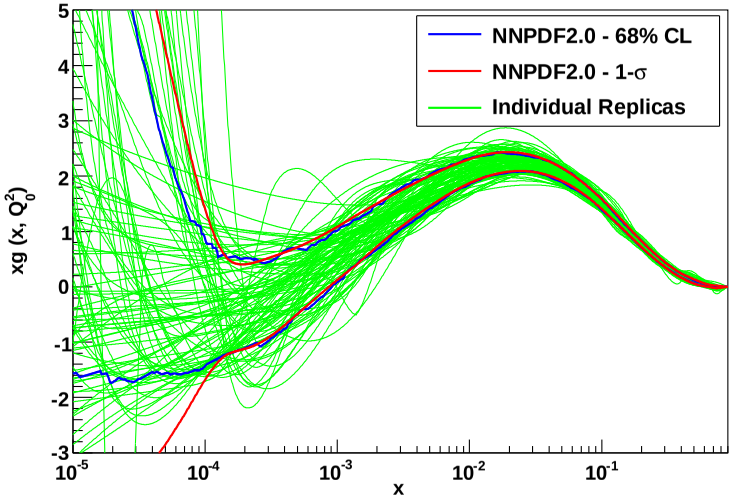
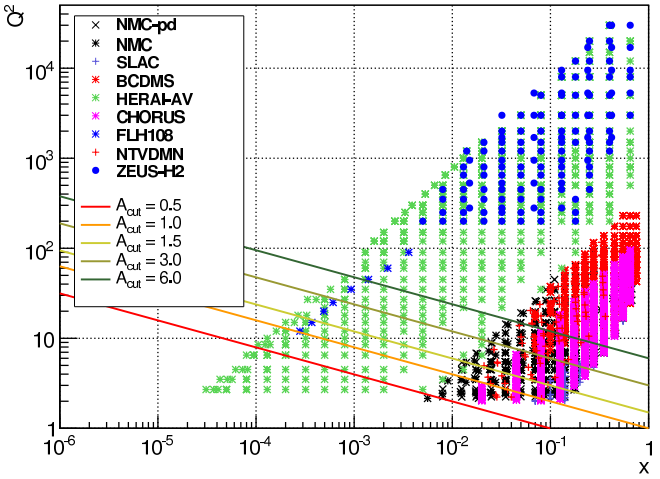


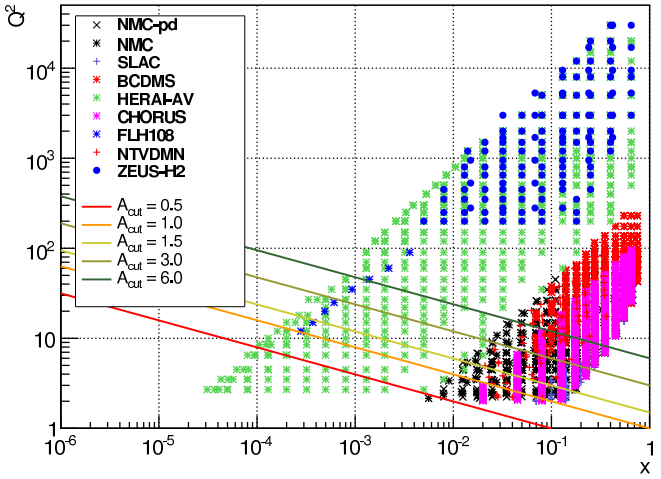
BEYOND DGLAP?
DISCOVERING A NEW QCD EFFECT IN HERA DATA



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



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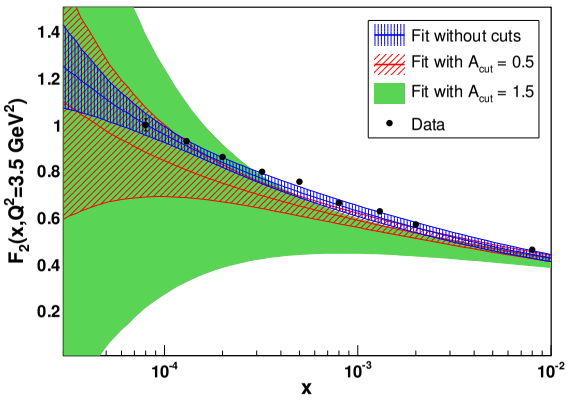
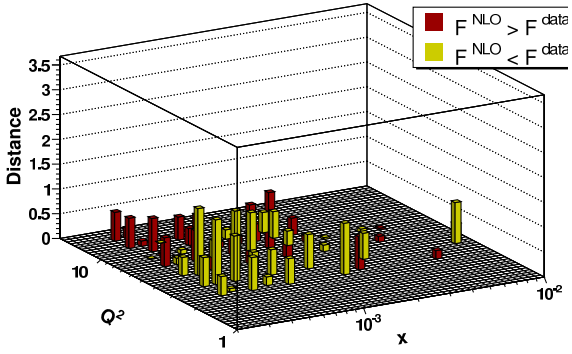
OLD HERA DATA

BACKWARD EV. VS DATA



DAT/TH DIST: NO CUT



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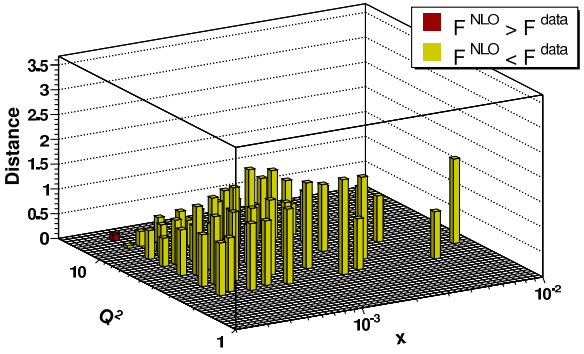
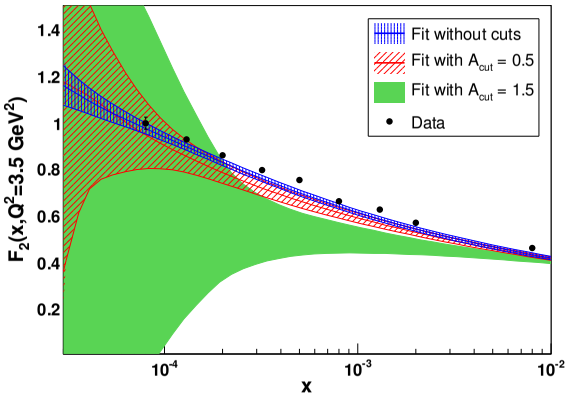


- BACKWARD EVOLVED FIT LIES SYSTEMATICALLY BELOW DATA
- DATA AT LOW x AND Q^2 SHOW LESS EVOLUTION THAN PREDICTED BY NLO DGLAP
- IF LOW x AND Q^2 DATA INCLUDED, THE FIT COMPENSATES READJUSTING PDFs

NEW COMBINED HERA DATA

BACKWARD EV. VS DATA



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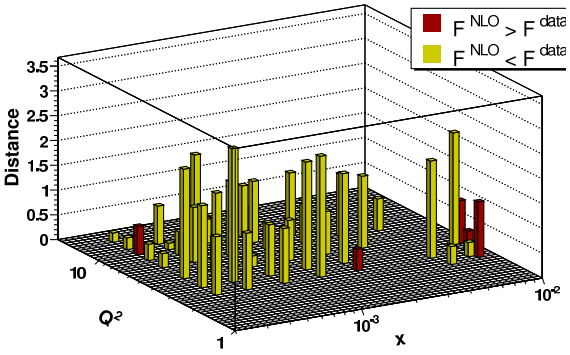

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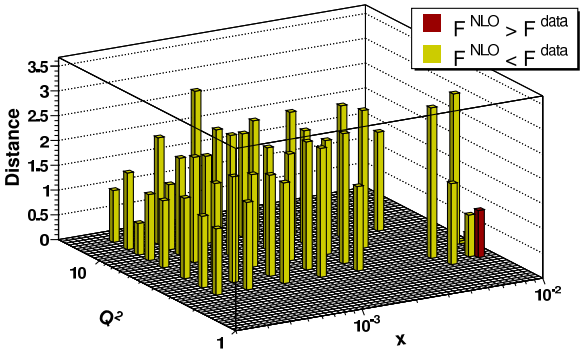
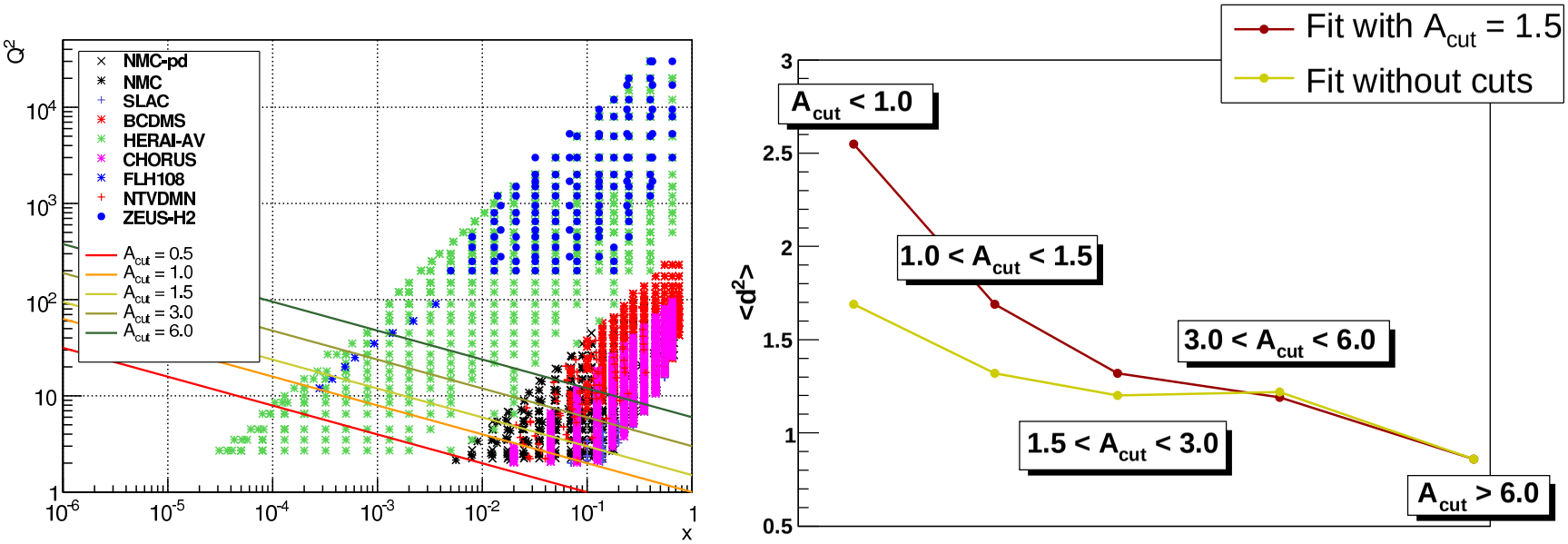


- DATA AT LOW x AND Q^2 SHOW LESS EVOLUTION THAN PREDICTED BY NLO DGLAP
- BACKWARD EVOLVED FIT LIES SYSTEMATICALLY BELOW DATA
- WITH MORE PRECISE DATA, THE FIT NO LONGER MANAGES TO COMPENSATE BY READJUSTING THE PDFS: EVEN FULL FIT LIES BELOW DATA

DETERIORATION IN FIT QUALITY:

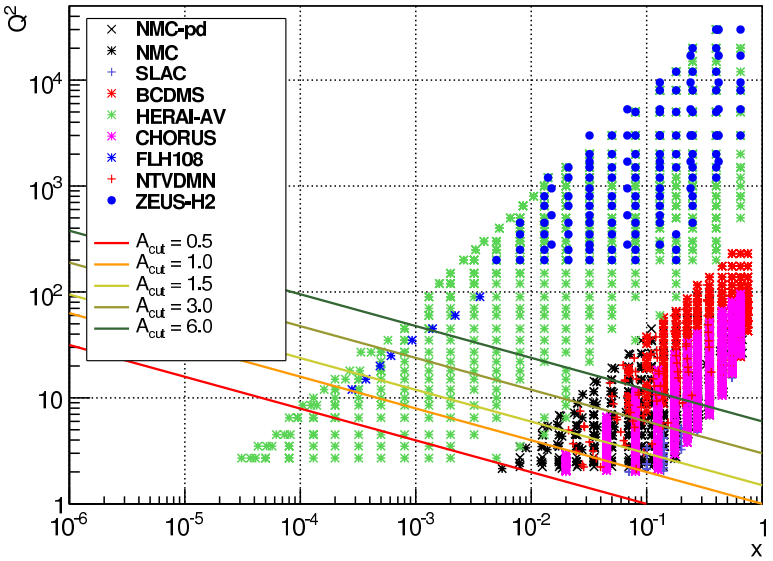
$\langle d^2 \rangle$ VS x SLICES

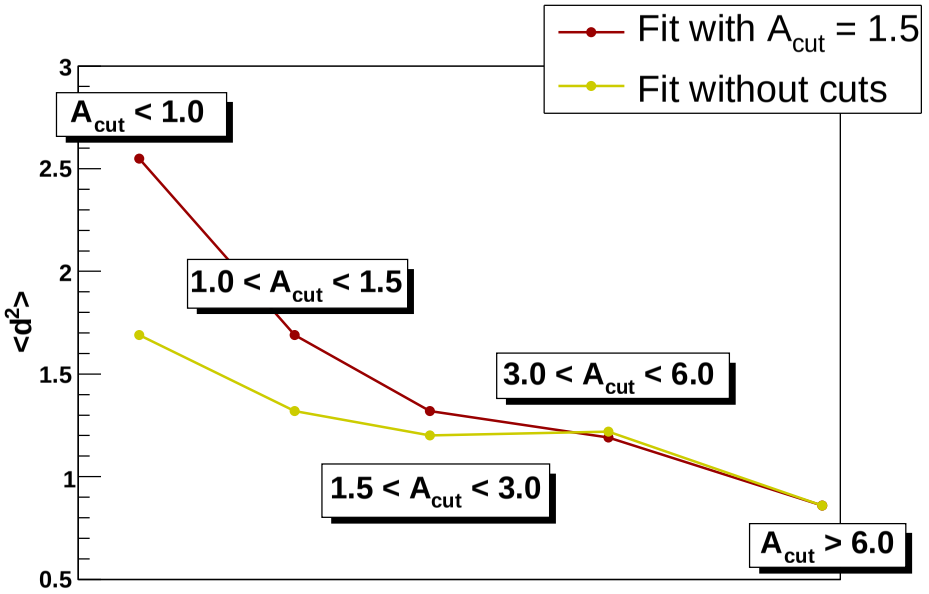


- QUALITY OF UNCUT FIT DETERIORATES IN LOW x REGIONS
- QUALITY OF CUT FIT INCREASINGLY POOR AS x DECREASES
- DISTANCE RISES DESPITE HUGE INCREASE IN UNCERTAINTY

DETERIORATION IN FIT QUALITY:

$\langle d^2 \rangle$ VS x SLICES





- QUALITY OF UNCUT FIT DETERIORATES IN LOW x REGIONS
- QUALITY OF CUT FIT INCREASINGLY POOR AS x DECREASES
- DISTANCE RISES DESPITE HUGE INCREASE IN UNCERTAINTY
- IN HESSIAN FIT (CTEQ) RESULTS DEPEND ON PARAMETRIZATION $\Rightarrow$ EVIDENCE INCONCLUSIVE

χ^2 VS x SLICES FOR CT10