PARTON DISTRIBUTIONS AT THE DAWN OF THE LHC

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ICHEP 2010

PARIS, JULY 22, 2010

PDFs: 25 years of progress

PDFs for the SPS (1984)

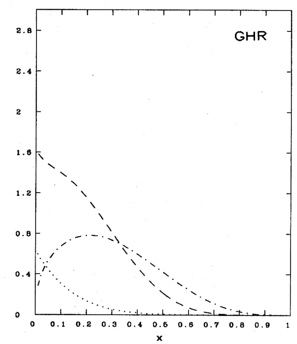


FIG. 25. Parton distributions of Glück, Hoffmann, and Reya (1982), at $Q^2=5$ GeV^2: valence quark distribution $x[u_v(x)+d_v(x)]$ (dotted-dashed line), $xG(x)$ (dashed line), and q_v (dotted line).

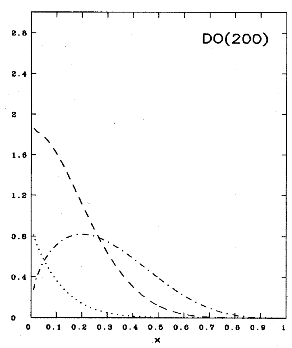


FIG. 27. "Soft-gluon" ($\Lambda=200$ MeV) parton distributions of Duke and Owens (1984) at $Q^2=5$ GeV^2: valence quark distribution $x[u_v(x)+d_v(x)]$ (dotted-dashed line), $xG(x)$ (dashed line), and $q_v(x)$ (dotted line).

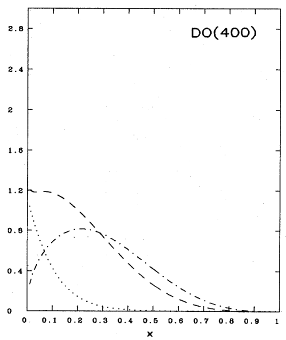
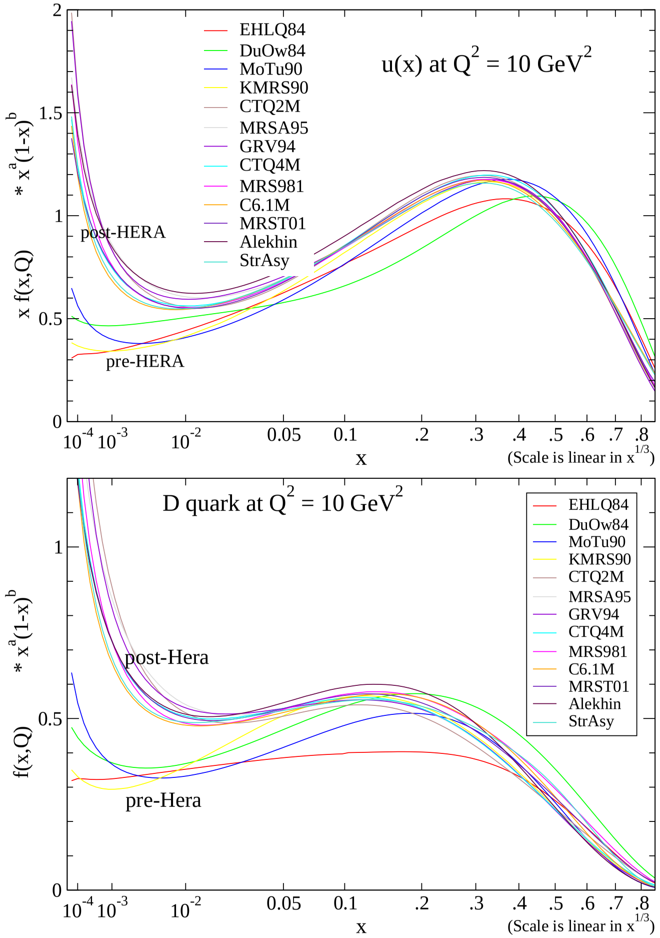


FIG. 26. "Hard-gluon" ($\Lambda=400$ MeV) parton distributions of Duke and Owens (1984) at $Q^2=5$ GeV^2: valence quark distribution $x[u_v(x)+d_v(x)]$ (dotted-dashed line), $xG(x)$ (dashed line), and $q_v(x)$ (dotted line).

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

GHR vs Duke-Owens

20 years of valence PDFs



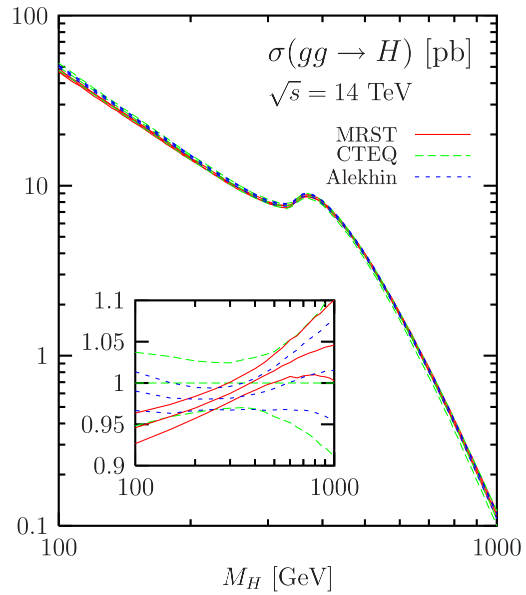
W.-K. Tung, 2004

- hadron colliders circa 1985 ⇒ qualitative QCD: discovery physics
- DIS at NMC and HERA 1995-2005 ⇒ quantitative QCD: precision physics
- hadron colliders circa 2010 ⇒ precision QCD ↔ new physics

PDFS: TOWARDS LHC PHYSICS

THE HIGGS CROSS SECTION

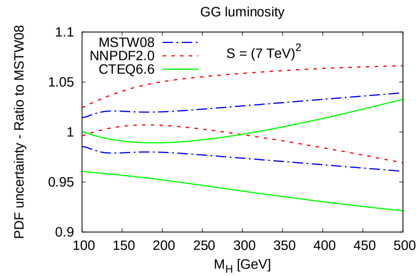
FIRST PDFS WITH UNCERTAINTIES

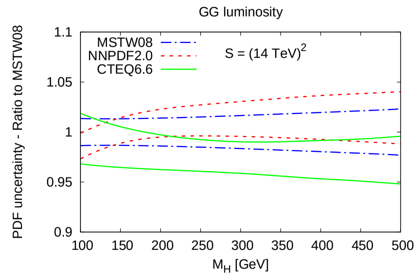


(Djouadi, Ferrag, 2004)

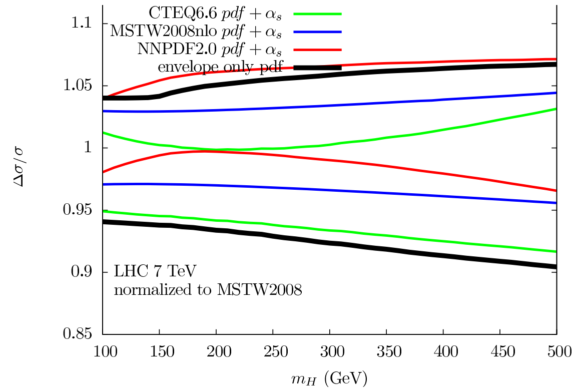
CURRENT GLOBAL PDF SETS

gluon luminosities





gg→H cross section



(Demartin et al., 2010)

PDFS WITH ERROR

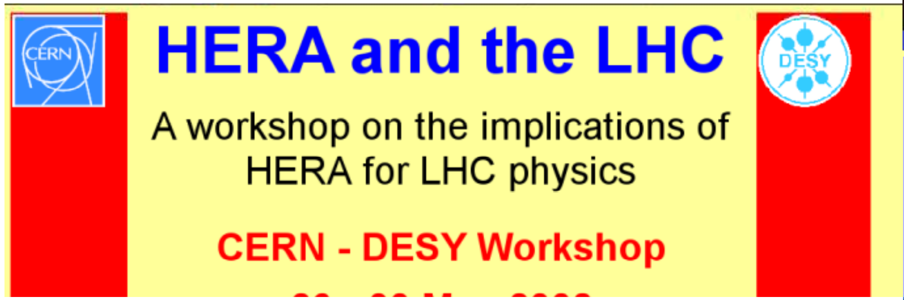
(2002-2003)

CTEQ, MRST (global); Alekhin (DIS)

- WIDELY DIFFERENT UNCERTAINTY ESTIMATES
- UNSATISFACTORY AGREEMENT WITHIN UNCERTAINTIES
- $\Delta\chi^2 = 100$ (CTEQ); 50 (MRST); 1 (ALEKHIN)

- THREE GLOBAL (DIS+HADRONIC) PDF SETS AVAILABLE
- REASONABLE AGREEMENT OF CENTRAL VALUES & UNCERTAINTIES

AN ONGOING EFFORT

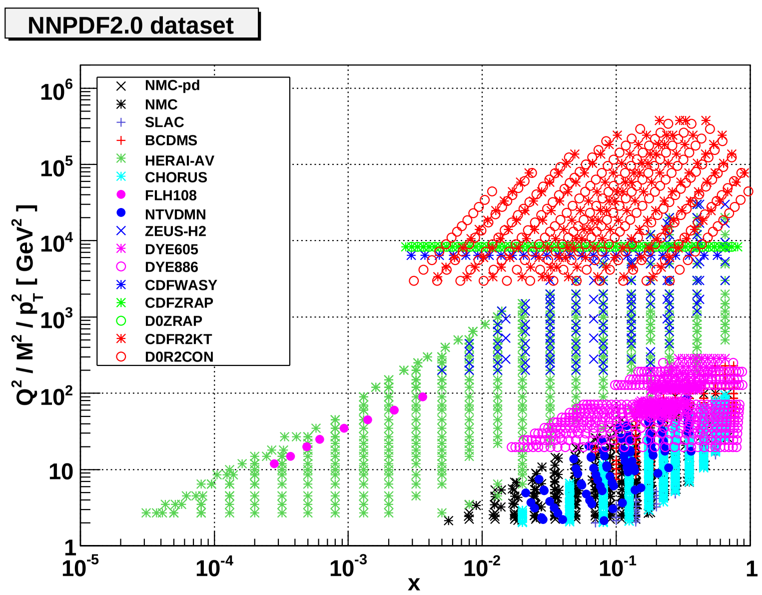


- HERALHC (2004-2008): A WORKSHOP TO TRANSFER KNOWN-HOW FROM HERA TO THE LHC COMMUNITY
  - two sessions (2004-2005; 2006-2007), four plenary meetings, five mid-term and working group meetings
  - two CERN/DESY reports (yellow books): **HEP-PH/0601012-HEP-PH/0601013**; **ARXIV:0903.3861**.
- PDF4LHC (2008 - ONGOING): A PERMANENT WORKING GROUP TO PROVIDE GUIDANCE ON PDF TO LHC EXPERIMENTS AND PHENOMENOLOGY
  - quarterly meetings, 10 since inception in February 2008
  - website `http://www.hep.ucl.ac.uk/pdf4lhc/` and wiki `https://wiki.terascale.de/index.php?title=PDF4LHC_WIKI` resources available
  - fruitful interactions with the LHC Higgs Cross Section WG

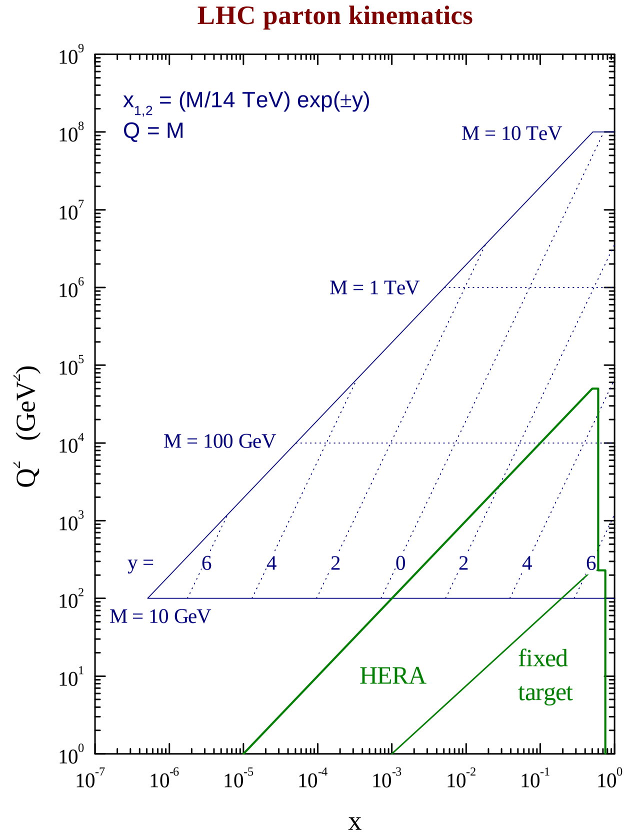
CURRENT PDF SETS

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

data for a global fit (NNPDF2.0)



LHC kinematics



- CTEQ6.6: GLOBAL, NLO, VFN WITH HQ MASS, SEVERAL α_s VALUES
- MSTW08: GLOBAL, NLO & NNLO, VFN WITH HQ MASS, SEVERAL α_s VALUES
- NNPDF2.0: GLOBAL, NLO, VFN WITHOUT HQ MASS, SEVERAL α_s VALUES
- ALEKHIN ABKM: DIS+SOME DY, NLO & NNLO, BMSN (FFN), SINGLE α_s VALUE
- HERAPDF1.0: ONLY HERA DATA, NLO, VFN WITH HQ MASS, SEVERAL α_s VALS.
- SETS BASED ON MODEL ASSUMPTIONS (GRV/GJR, STATISTICAL PDFs,...)

FEATURES, TRADEOFFS AND CHOICES

- DATASET:CTEQ, MSTW, NNPDF FIXED TARGET AND COLLIDER, eP AND $\bar{P}P$ DATA; ABKM, GJR GLOBAL DIS+ FIXET-TARGET DY; HERAPDF: HERA ONLY
- STATISTICAL TREATMENT: CTEQ HESSIAN WITH TOLERANCE; MSTW HESSIAN WITH DYNAMICAL TOLERANCE; HERAPDF, ABKM, GJR, STANDARD HESSIAN; NNPDF MONTE CARLO (ALSO STUDIED BY HERAPDF)
- PARTON PARAMETRIZATION:CTEQ, MSTW, HERAPDF $x^{\alpha}(1-x)^{\beta}\times$ POLYNOMIALS; GJR: DITTO + VALENCELIKE ASSUMPTION; NNPDF NEURAL NETS; CHEBYSHEV POLYNOMIALS STUDIED BY HERAPDF;
- HEAVY QUARKS:CTEQ: GM-VFN (SACOT-χ SCHEME); MSTW: GM-VFN (ACOT+TR' SCHEME); NNPDF: ZM-VFN, PRELIM: GM-VFN (FONLL-A SCHEME); ABKM: FFN ($N_f = 3, 4$ MATCHED WITH BMSN SCHEME); GJR: FFN ($N_f = 3$)
- PERTURBATIVE ORDER:CTEQ: NLO, BUT DY LO WITH K-FACTORS; MSTW: NNLO, BUT DY LO WITH K-FACTORS; NNPDF FULL NLO; ABKM, GJR: FULL NNLO
- 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

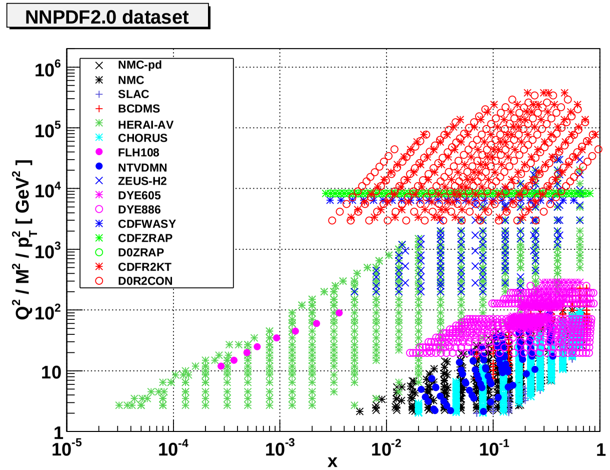
THE PDF4LHC RECOMMENDATION

- AT NLO, ENVELOPE OF CTEQ, MSTW, NNPDF
- AT NNLO, MSTW WITH UNCERTAINTY RESCALED MY MSTWNLO/NLOENVELOPE

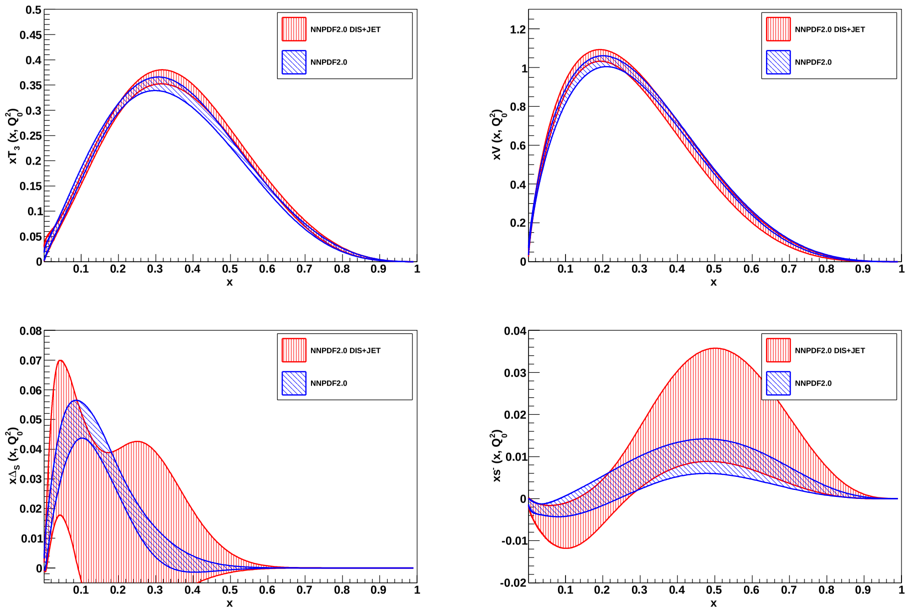
DATASET: WHY GLOBAL FITS?

IMPACT OF DRELL-YAN DATA ON THE NNPDF2.0 FIT

	DIS	DIS+JET	NNPDF2.0
$\chi^2_{\rm tot}$	1.20	1.18	1.21
NMC-pd	0.85	0.86	0.99
NMC	1.69	1.66	1.69
SLAC	1.37	1.31	1.34
BCDMS	1.26	1.27	1.27
HERAI	1.13	1.13	1.14
CHORUS	1.13	1.11	1.18
FLH108	1.51	1.49	1.49
NTVDMN	0.71	0.75	0.67
ZEUS-H2	1.50	1.49	1.51
CDFR2KT	0.91	0.79	0.80
D0R2CON	1.00	0.93	0.93
DYE605	7.32	**10.35**	**0.88**
DYE866	2.24	**2.59**	**1.28**
CDFWASY	13.06	**14.13**	**1.85**
CDFZRAP	3.12	**3.31**	**2.02**
D0ZRAP	0.65	**0.68**	**0.47**



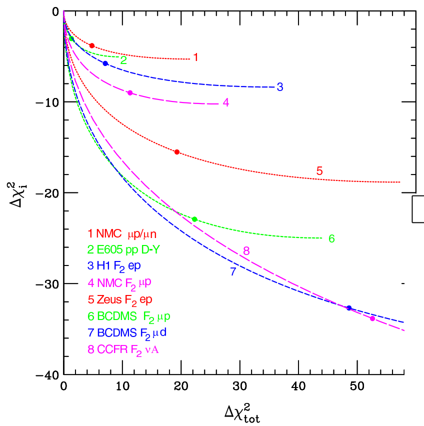
- VERY SUBSTANTIAL IMPROVEMENT IN FIT QUALITY WHEN DATA INCLUDED ⇒ SOME PDF COMBINATIONS POORLY DETERMINED WITHOUT THESE DATA
- HUGE IMPROVEMENT IN SEA ASYM $\bar{u} - \bar{d}$ & STRANGENESS $s - \bar{s}$
- SIGNIFICANT IMPROVEMENT IN TOTAL VALENCE $(\sum_i (q_i - \bar{q}_i))$ & ISOTRIPLET $(u + \bar{u}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



STATISTICAL TREATMENT: HESSIAN APPROACH
CTEQ TOLERANCE CRITERION & MSTW DYNAMICAL TOLERANCE

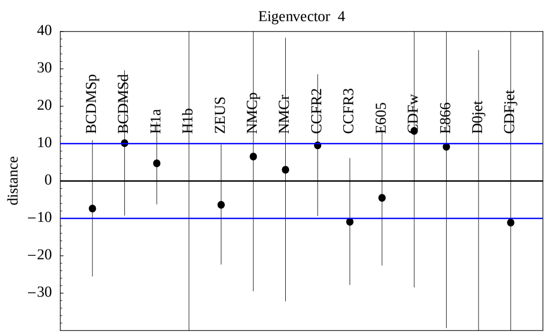
- STANDARD $\Delta\chi^2 = 1$ BANDS TOO NARROW $\Rightarrow$ LARGE DISCREPANCIES FOR INDIVIDUAL EXPERIMENTS
- TOLERANCE $\Rightarrow$ ENVELOPE OF UNCERTAINTIES OF EXPERIMENTS
- DYNAMICAL $\Rightarrow$ SEPARATELY DETERMINED FOR EACH HESSIAN EIGENVECTOR

MINIMUM χ_i^2 VS GLOBAL χ^2

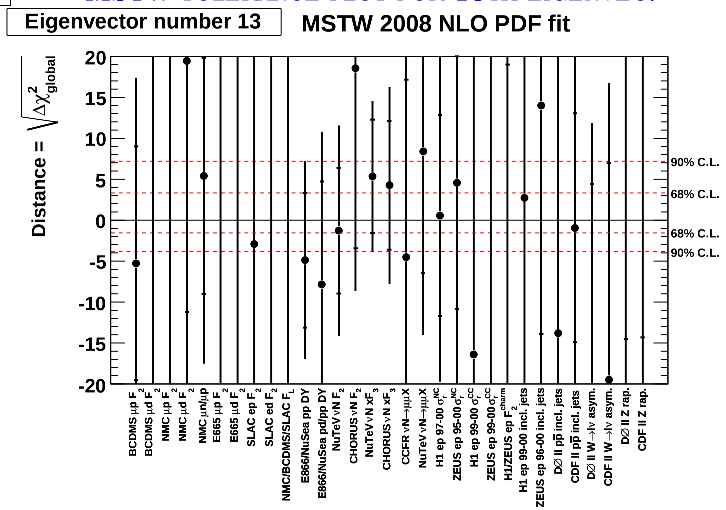


Collins, Pumplin 2001

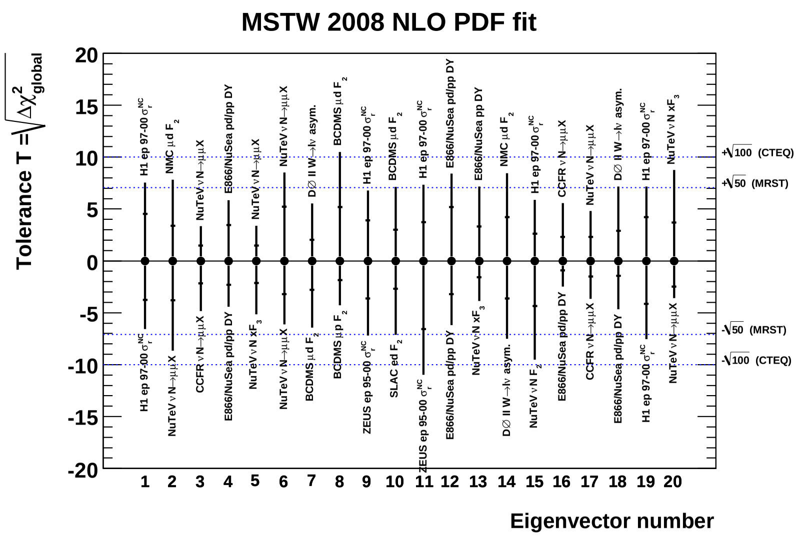
CTEQ TOLERANCE PLOT FOR 4TH EIGENVEC.



MSTW TOLERANCE PLOT FOR 13TH EIGENVEC.



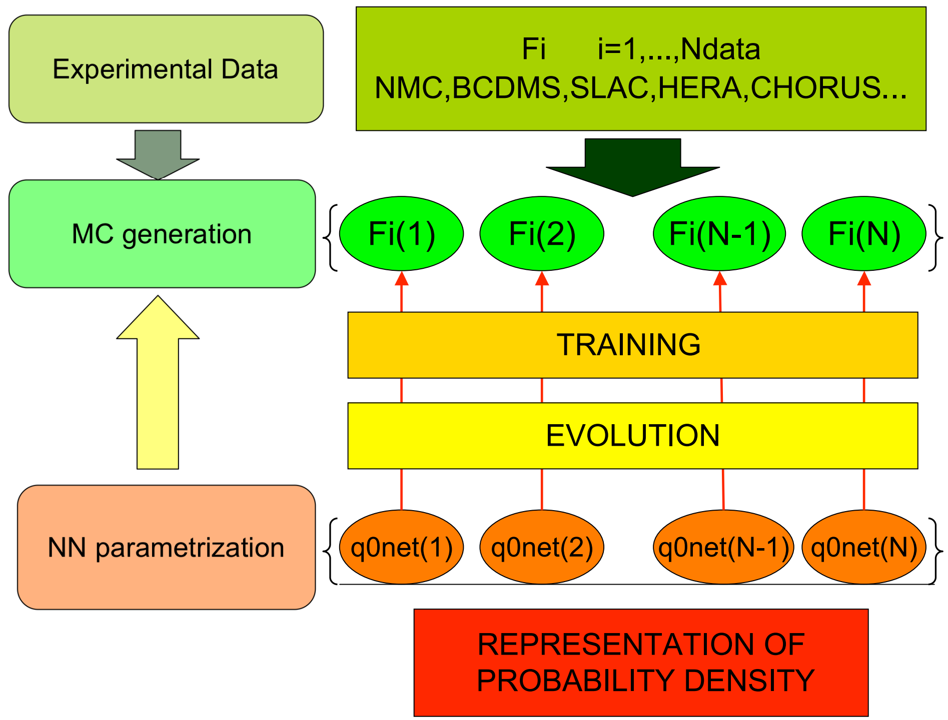
GLOBAL MSTW TOLERANCE



STATISTICAL TREATMENT: MONTE CARLO 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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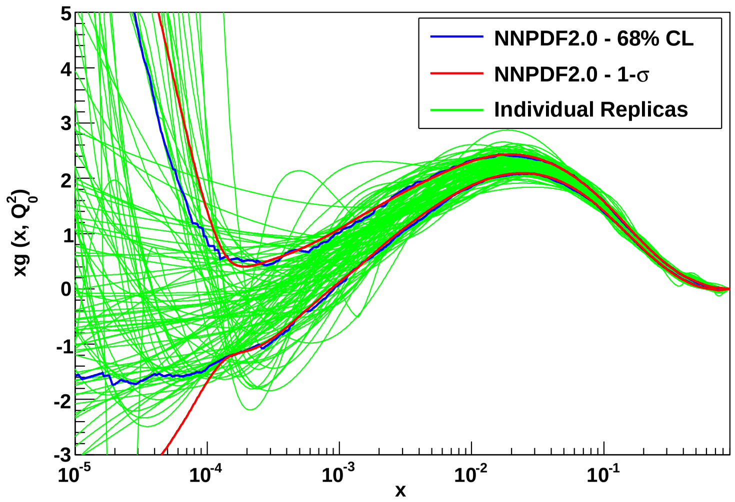
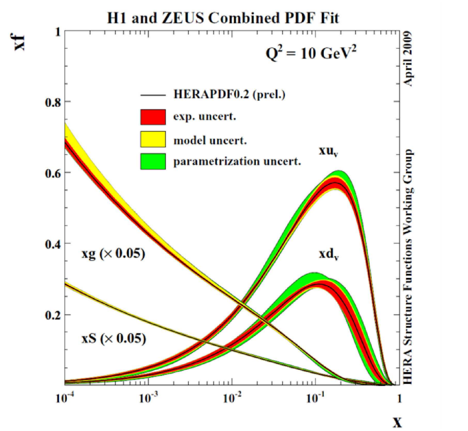
CAN DETERMINE BOTH 68C.L.& 1-σ



PARTON PARAMETRIZATION: HESSIAN UNCERTAINTIES

EXPLORING THE SPACE OF PARAMETERS

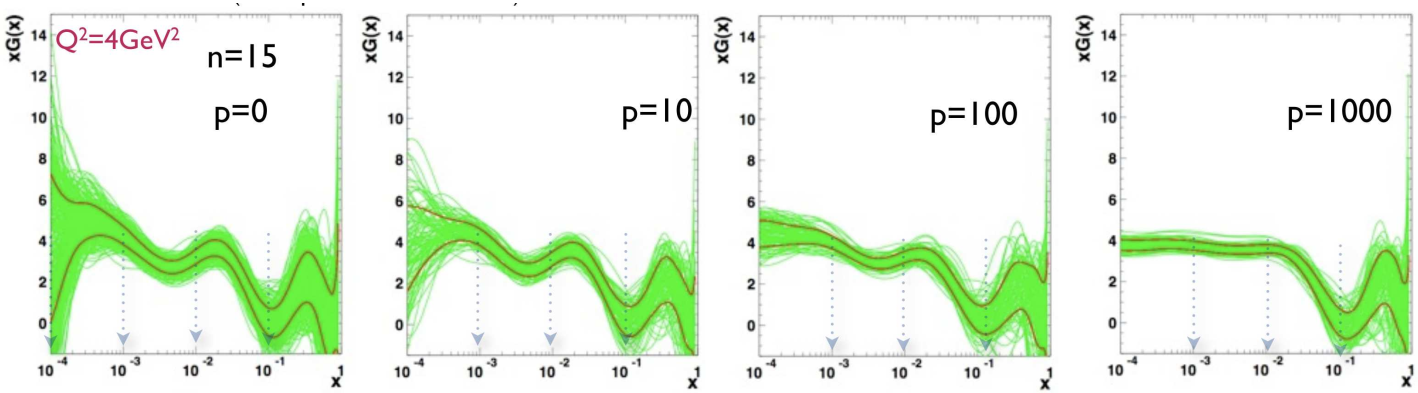
- IN HESSIAN APPROACH CAN VARY THE FUNCTIONAL FORM, ASSUMPTIONS, STARTING SCALE
- DONE IN THE HERAPDF1.0 FIT: VARIATION OF STRANGENESS FRACTION, LARGE x BEHAVIOUR, HIGHER ORDER POLYNOMIAL TERMS
- NO TOLERANCE ($\Delta\chi^2 = 1$), UNCERTAINTY DOUBLED



- Red: experimental uncertainties
- Yellow: model uncertainties
- Green: pdf parametrization uncertainties

ORTHOGONAL POLYNOMIALS

- OLD IDEA (PARISI, SOURLAS, 1978; ZOMER 1996): EXPAND PDFS OVER BASIS OF ORTHOGONAL POLYNOMIALS
- GLAZOV, RADESCU, 2009: COUPLED TO MONTE CARLO METHOD
- LENGTH PENALTY TO STABILIZE THE FIT



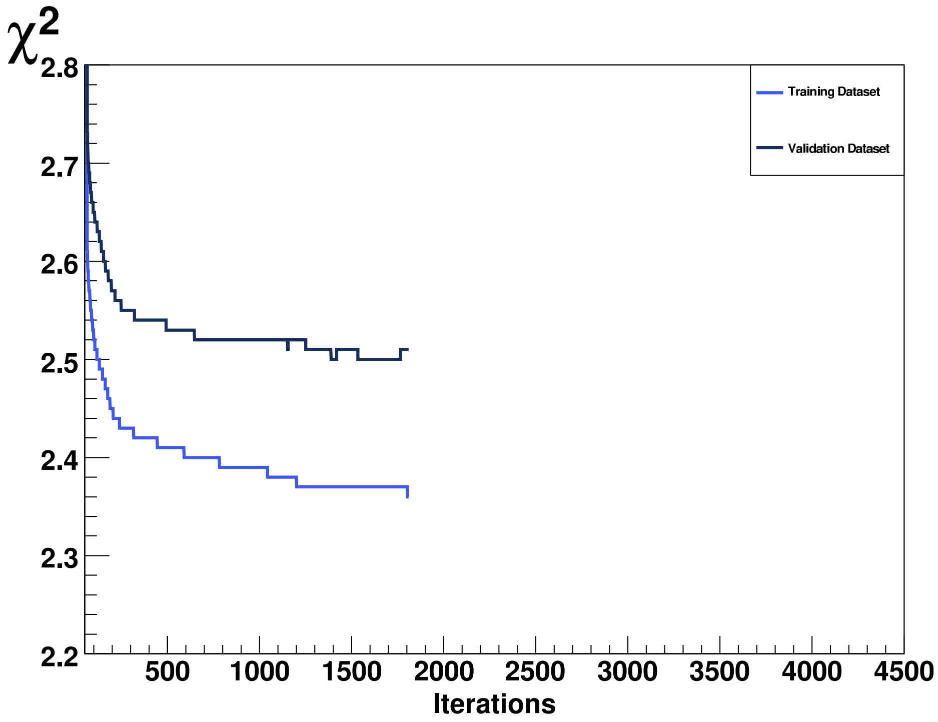
(Glazov, Radescu, 2009)

PARTON PARAMETRIZATION: NNPDF UNCERTAINTIES
CROSS-VALIDATION

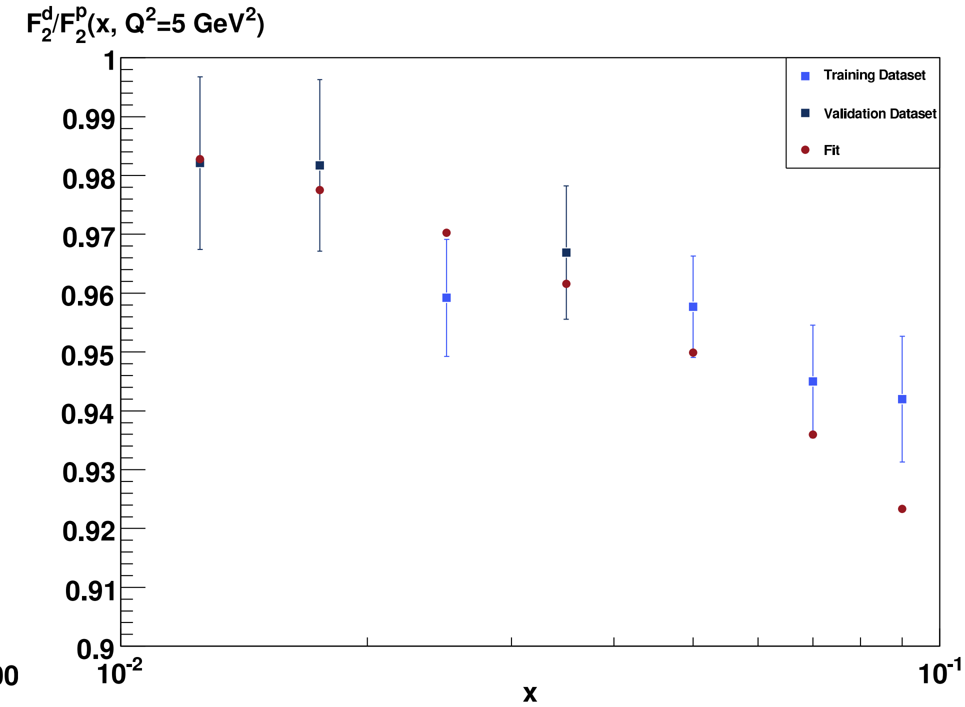
- REPLICAS ARE FITTED TO A DATA SUBSET
- A DIFFERENT SUBSET OF DATA USE FOR EACH REPLICA
- OPTIMAL FIT WHEN FIT TO VALIDATION (CONTROL) DATA STOPS IMPROVING
-

OPTIMAL FITTING

χ^2



FIT TO DATA

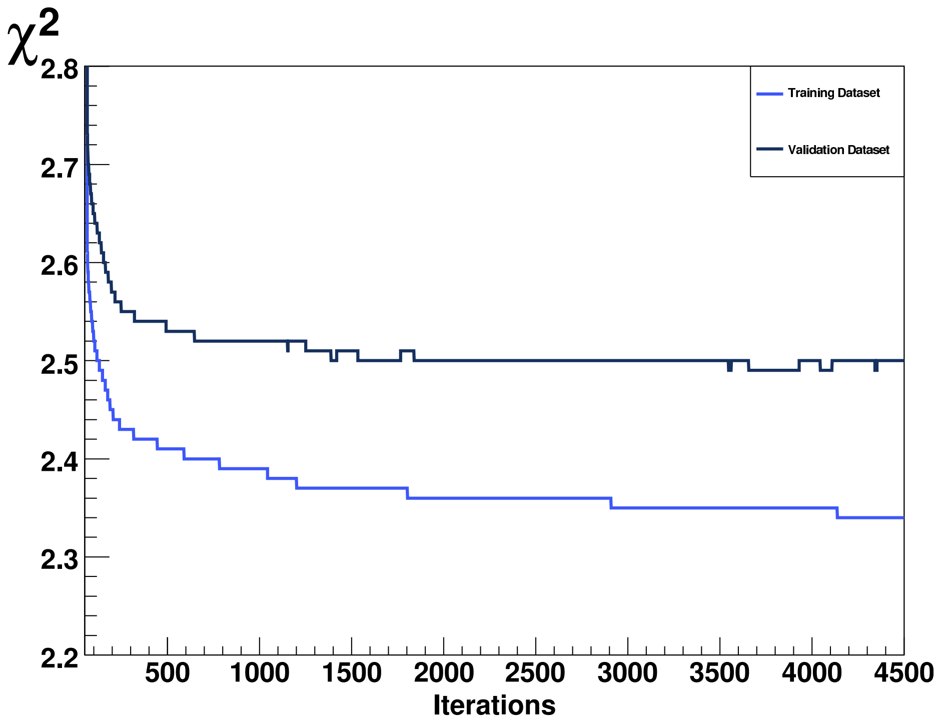


PARTON PARAMETRIZATION: NNPDF UNCERTAINTIES
CROSS-VALIDATION

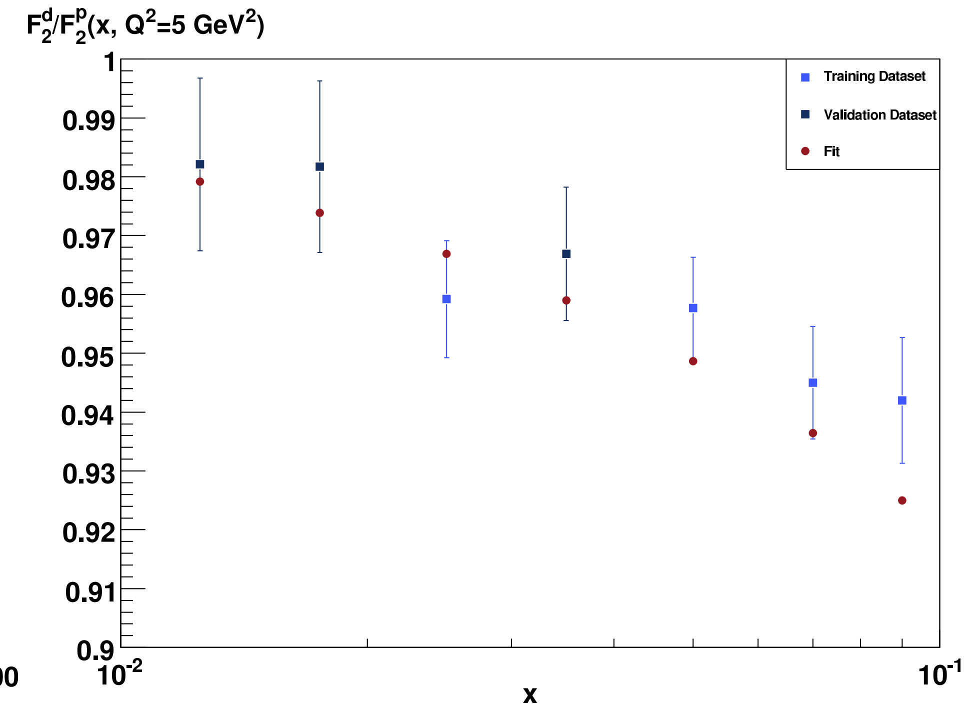
- REPLICAS ARE FITTED TO A DATA SUBSET
- A DIFFERENT SUBSET OF DATA USE FOR EACH REPLICA
- OPTIMAL FIT WHEN FIT TO VALIDATION (CONTROL) DATA STOPS IMPROVING
- THE BEST FIT IS NOT AT THE MINIMUM OF THE χ^2

OVERFITTING

χ^2

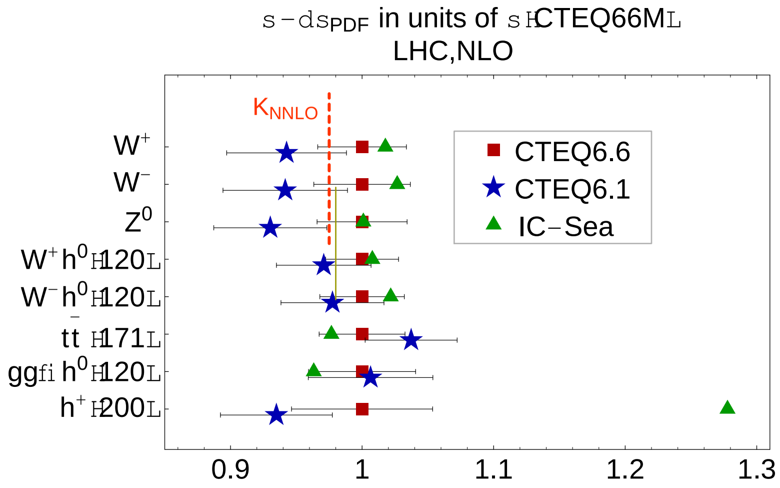


FIT TO DATA



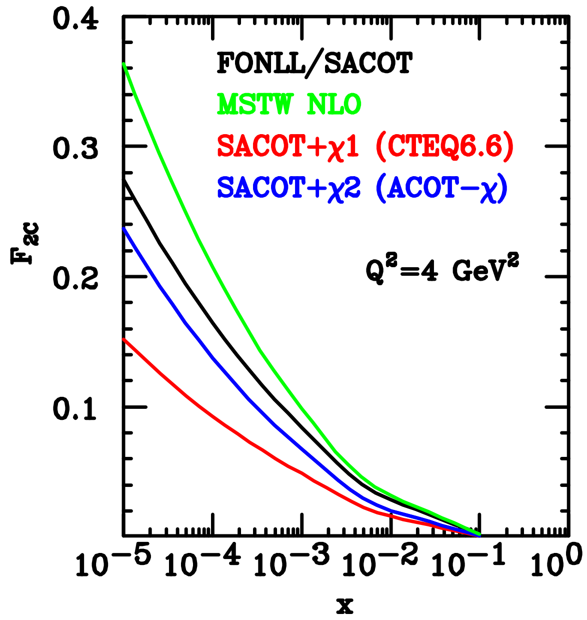
HEAVY QUARKS:
AN OLD PROBLEM

- MANY FITS (CTEQ<6, NNPDF, ALEKHIN<09) TREAT CHARM AS MASSLESS ABOVE THRESHOLD ⇒ "ZMVFN" SCHEME
- COMBINED MATCHED SCHEMES AVAILABLE SINCE LONG (ACOT94, FONLL98) INCLUDING CHARM MASS ALONG WITH LL RESUMMATION; ALTERNATIVE TR/TR' PROCEDURE IMPLEMENTED SINCE '98 IN MRST
- WHEN CTEQ IMPLEMENTED ACOT IN 2008, SURPRISING CHANGE CTEQ61→CTEQ6.5 IN σ_W, & AGREEMENT WITH MRST SPOILED (LATER RESTORED)



(Nadolsky et al., 2008)

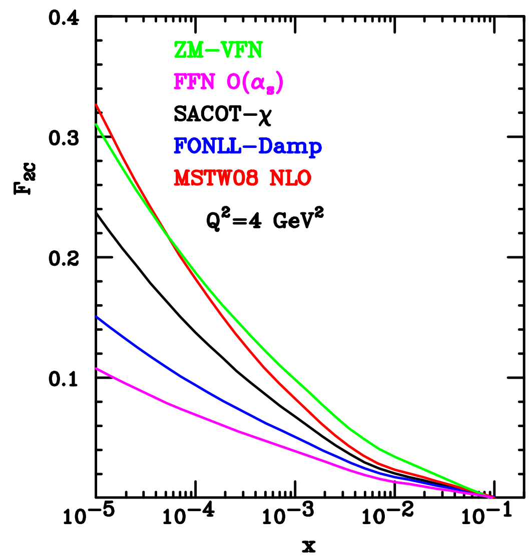
RECENT PROGRESS:
THE LES HOUCHES 2009 BENCHMARKS



(Rojo et al., 2010)

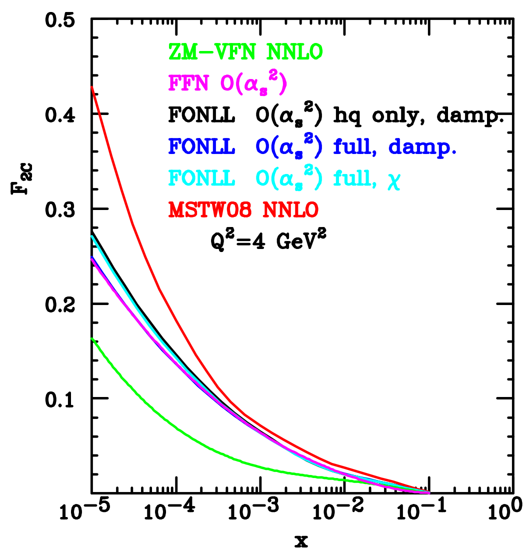
- FONLL PRESCRIPTION RECENTLY ALSO IMPLEMENTED FOR DIS, AVAILABLE TO $O(\alpha_s^2)$ (LIKE TR/TR', ACOT ONLY TO $O(\alpha_s)$)
- $O(\alpha_s)$ FONLL, ACOT COINCIDE EXACTLY, TR' DIFFERS BY SUBLEADING $O(\alpha_s^2(m_c))$ Q^2–INDEP. TERM
- VARIOUS PRESCRIPTIONS FOR HANDLING SUBLEADING TERMS ("χ–SCALING"): DIFFERENCES SIZABLE

HEAVY QUARKS:
NEW PROBLEMS



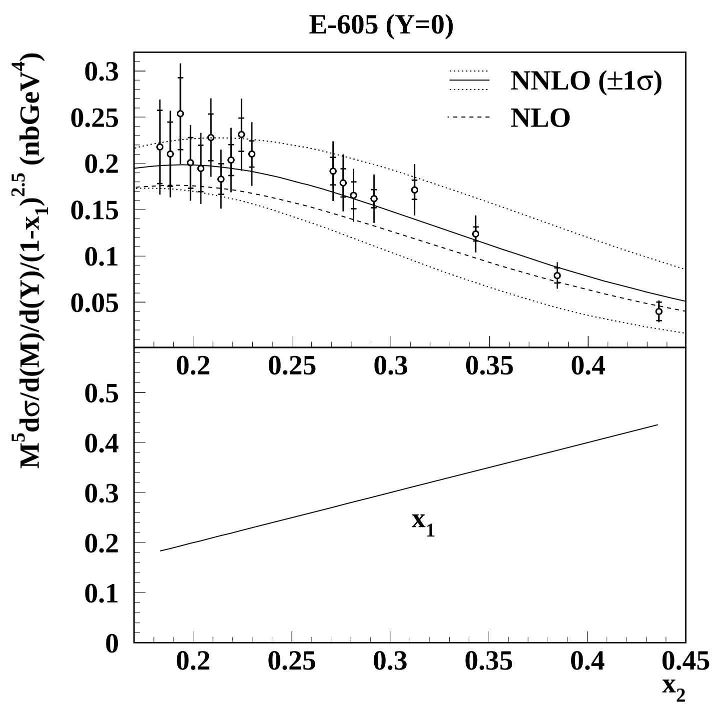
- IMPACT OF SUBLEADING TERMS SIZABLE CLOSE TO THRESHOLD
- DIFFERENCE BETWEEN DIFFERENT PRESCRIPTIONS (ACOT-χ–SCALING, FONLL-DAMPING, MSTW-MATCHING) AS LARGE AS DIFFERENCE BETWEEN FFN (NO DGLAP RESUMMATION FOR CHARM) AND ZMVFN (NO CHARM MASS)

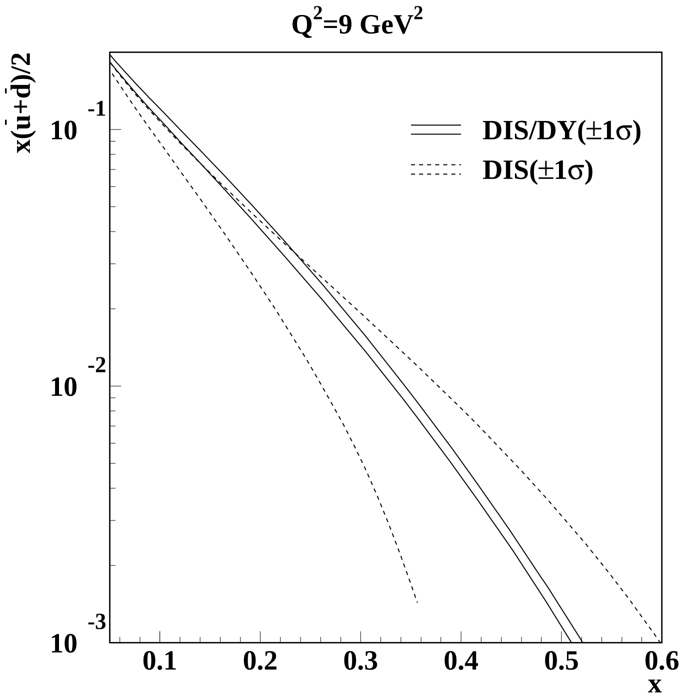
THE SOLUTION:
GO UP ONE ORDER



- IF EVERYTHING AT ONE EXTRA ORDER IN α_s, DIFFERENCES MINOR
- IN FONLL, CAN COMBINE $O(\alpha_s^2)$ TREATMENT OF HQ WITH STANDARD NLO $O(\alpha_s)$ TREATMENT OF LIGHT QUARKS $\Rightarrow$ EXCELLENT APPROX TO FULL RESULT (s.f., Laenen, Nason, Rojo 2010)
- RECENT PROGRESS: $O(\alpha^3)$ MASSLESS LIMIT OF HQ PRODUCTION COEFF. FCTNS. COMPUTED (Bierenbaum, Blümlein, Klein, 2009)

NNLO CORRECTIONS





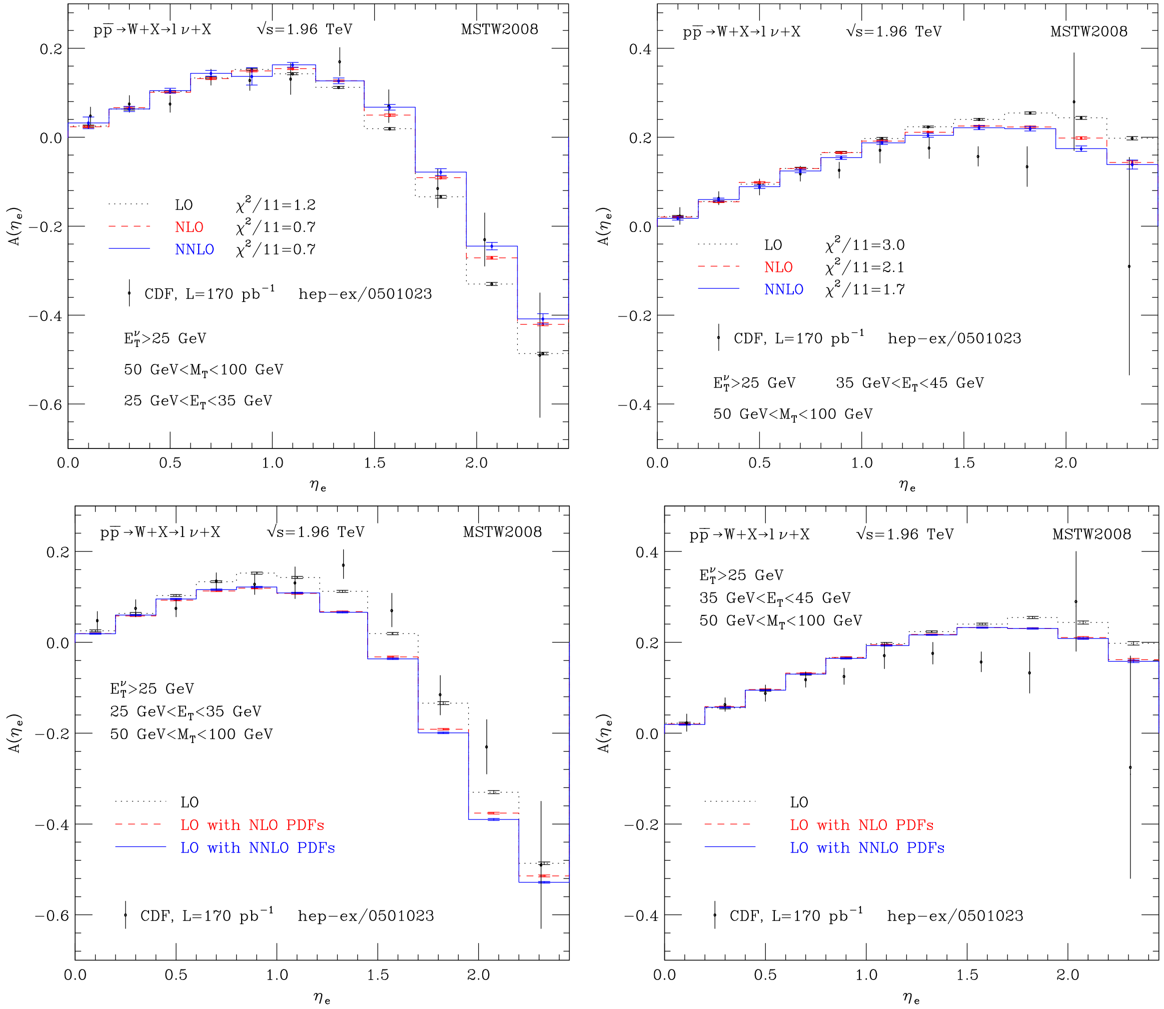
Alekhin, Melnikov, Petriello, 2006

- NNPDF IS AT NLO
- MSTW NNLO TREATS DIS AT NNLO, JETS AT NLO, DRELL-YAN AT LO+K–FACTORS
- ALEKHIN-SERIES FITS GENUINELY NNLO, BUT ONLY DIS+ TWO FIXED–TARGET DY EXPERIMENTS INCLUDED
- BUT IMPACT NOT NEGLIGIBLE...

WHY NOT INCLUDED? CONVOLUTIONS ARE HARD!

PROBLEM: NNLO NEEDED FOR STANDARD CANDLES

EXAMPLE: THE W CHARGE ASYMMETRY



Catani, Ferrera, Grazzini, 2010

- NNLO CORRECTIONS VISIBLY IMPROVE AGREEMENT WITH DATA
- EFFECT ON MATRIX ELEMENT COMPARABLE TO EFFECT ON PDFs, BUT IN DIFFERENT REGIONS

TOWARDS NNLO TOOLS:

GRID–BASED METHODS AT NLO

ORIGINAL IDEA

EXPANSION OF PDFS ON BASES OF POLYNOMIALS (PASCAUD, ZOMER, 2001

- PRECOMPUTE CONVOLUTION WITH BASIS FUNCTIONS
- EXPAND PDF OVER BASIS
- CONVOLUTIONS REDUCED TO LINEAR COMBINATIONS → MATRIX MULTIPLICATION

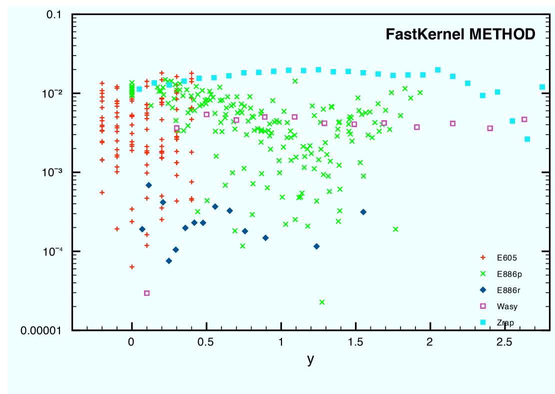
THE GRID IDEA

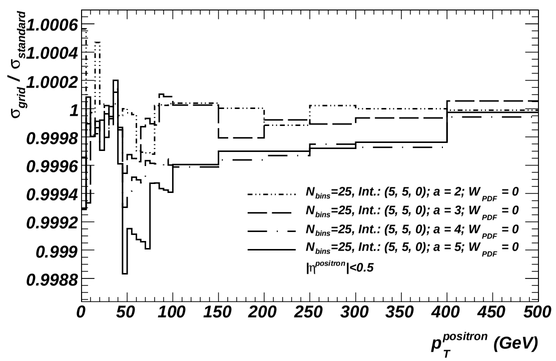
(CARLI, SALAM, SIEGERT 2005)

- REPRESENT PDFS ON INTERPOLATED GRID
- BASIS FCTNS ↔ INTERPOLATING FCTNS
- DO CONVOLUTIONS OVER BASIS FUNCTIONS (IF MONTE CARLO USED, BASIS FCTNS → WEIGHTS FOR MC INTEGRAL)
- GRID CAN BE OPTIMIZED

SOME IMPLEMENTATIONS:

- FASTNLO: FAST INTERFACE FOR JET CROSS SECTIONS (Kluge, Rabbertz, Wobisch 2006)
- FASTKERNEL: GRID METHOD INTERFACED TO N-SPACE COMPUTATION OF GLAP GREEN FUNCTIONS, INTERFACED TO FASTNLO FOR JETS AND TO SUITABLE FAST-DY (NNPDF, 2010)
- APPLGRID: OPTIMIZED GRID, POTENTIALLY UNIVERSAL INTERFACE, IMPLEMENTED FOR JETS, W AND Z PRODUCTION (Carli et al., 2010)





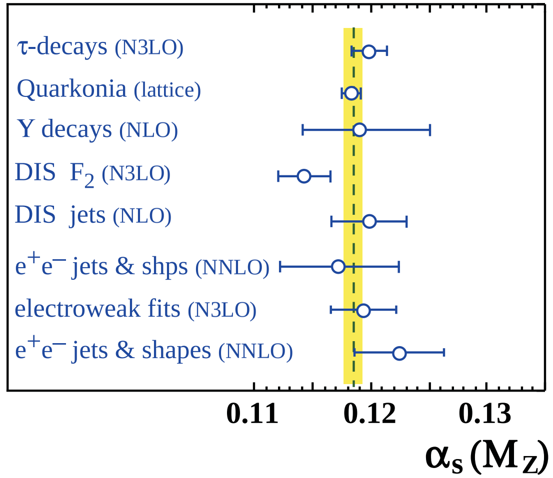
α_s: AN OUTSTANDING PROBLEM

NEW GLOBAL α_s DETERMINATION BY BETHKE (2009):

$$\alpha_s = 0.1184 \pm 0.0007$$

ADOPTED BY PDG WEB UPDATE (2009)

"older measurements not included because [of]...their large ... uncertainties"



WHAT'S THE PROBLEM?

- N^3LO DETERMINATION (Blümlein, Böttcher, Guffanti, 2006) FROM NONSINGLET SCALING VIOLATIONS: $\alpha_s = 0.114 \pm 0.002$ (NLO: $\alpha_s = 0.115 \pm 0.002$) AT THREE σ FROM AVERAGE

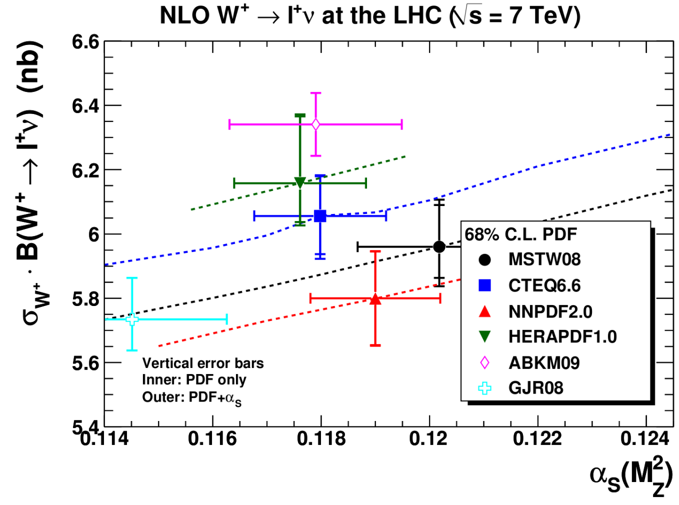
- DO WE UNDERSTAND HIGHER ORDERS?
  MSTW (2010) SEE A CHANGE OF 2 SIGMA FROM NLO TO NNLO
  $\alpha_s = 0.1202^{+0.0012}_{-0.0015}$ TO $\alpha_s = 0.1171 \pm 0.0014$

- DO WE UNDERSTAND EXTRAPOLATION? IF TRUNCATED MOMENTS ARE USED (NO ASSUMPTIONS) NLO RESULT FROM NONSINGLET SCALING VIOLATIONS IS (s.f. et al., 2002) $\alpha_s = 0.124^{+0.005}_{-0.008}$

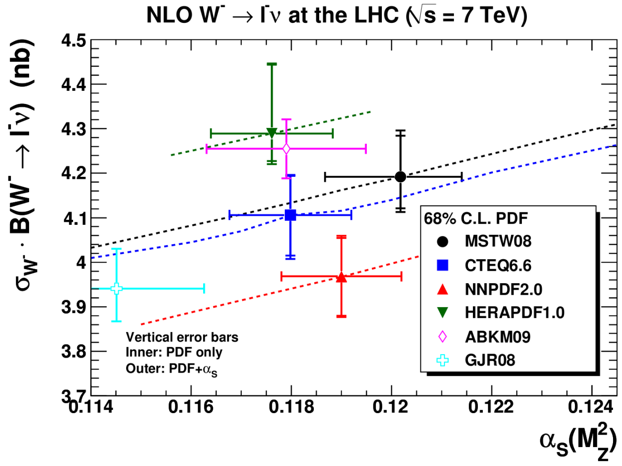
WE NEED A BELIEVABLE CONSERVATIVE α_s AVERAGE FOR PHENOMENOLOGY

WHERE DO WE STAND?
LHC STANDARD CANDLES

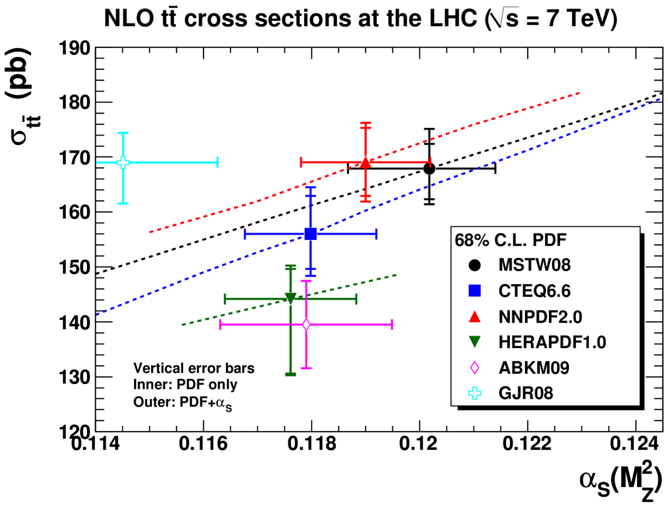
W^+



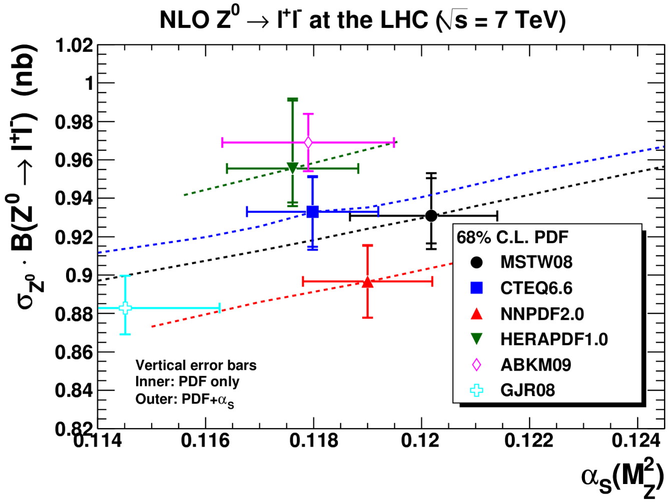
W^-



TOP



Z



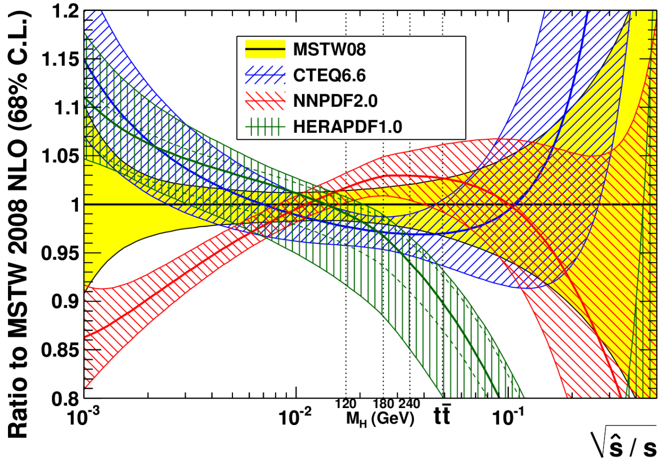
(G. Watt, 2010)

- GLOBAL FITS IN GOOD MUTUAL AGREEMENT
- CHOICE OF α_s VALUE IMPORTANT

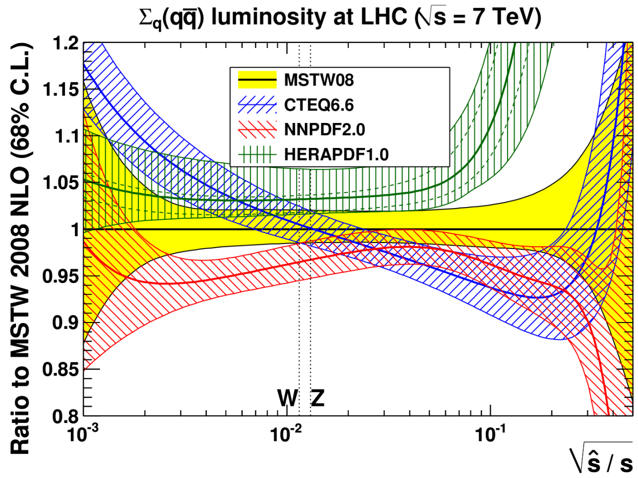
WHERE DO WE STAND?

PARTON LUMINOSITIES

GLUON-GLUON



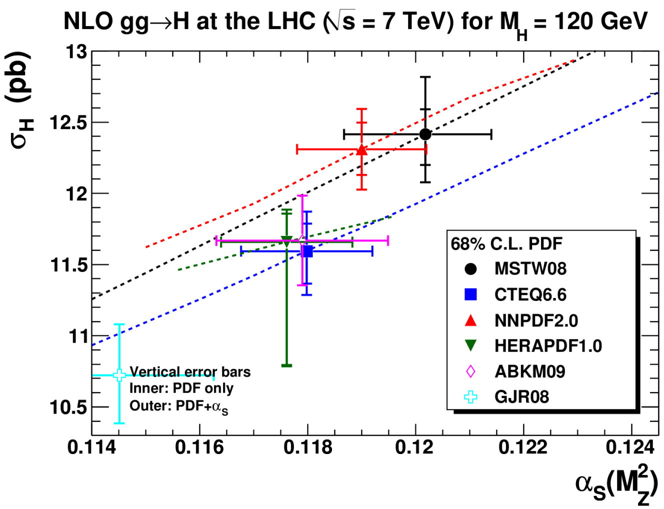
QUARK-QUARK



(G. Watt, 2010)

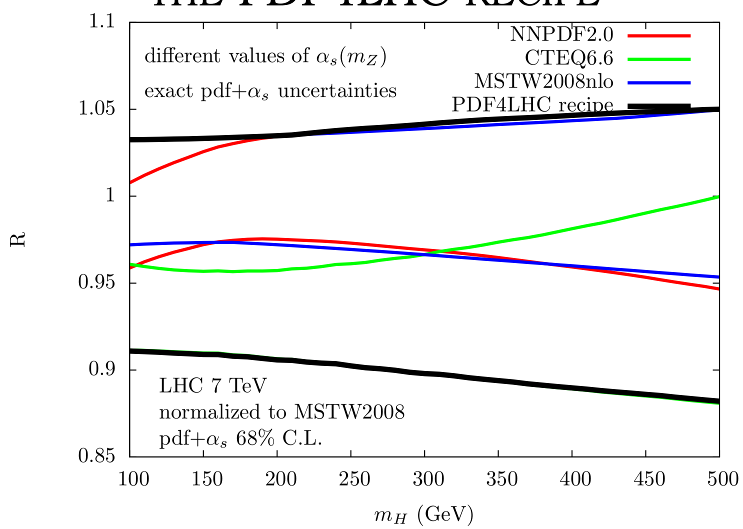
THE HIGGS CROSS SECTION

$m_H = 120$ GeV: DIFFERENT GROUPS



(G. Watt, 2010)

THE PDF4LHC RECIPE



(A. Vicini, 2010)

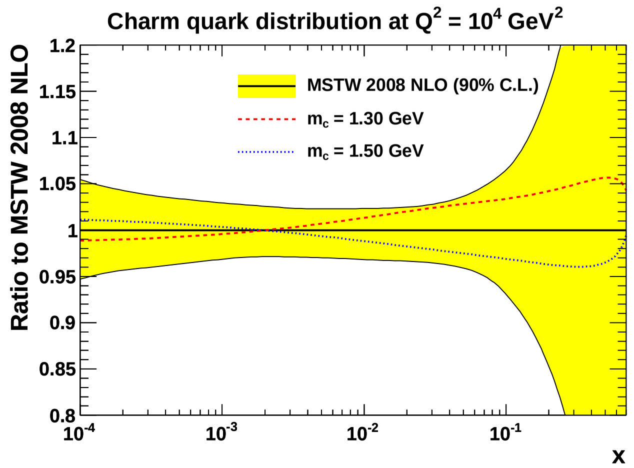
ENVELOPE TAKES CARE OF POORLY UNDERSTOOD DISAGREEMENTS

WHERE ARE WE GOING?
THEORETICAL UNCERTAINTIES

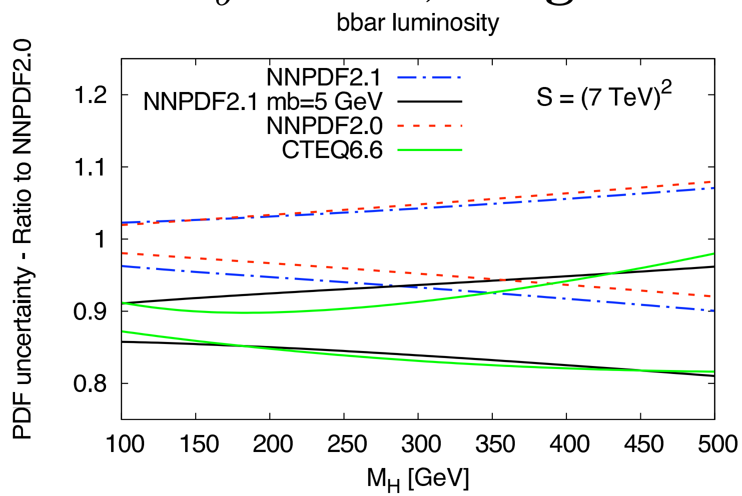
α_s UNCERTAINTIES: CAN BE COMBINED IN QUADRATURE WITH PDF UNCERTAINTIES (Lai et al, CTEQ, 2010); AVAILABLE FOR CTEQ, HERAPDF, MSTW, NNPDF

IN PROGRESS:
DEPENDENCE ON c & b MASS

m_c: MSTW08



m_b: NNPDF, CTEQ

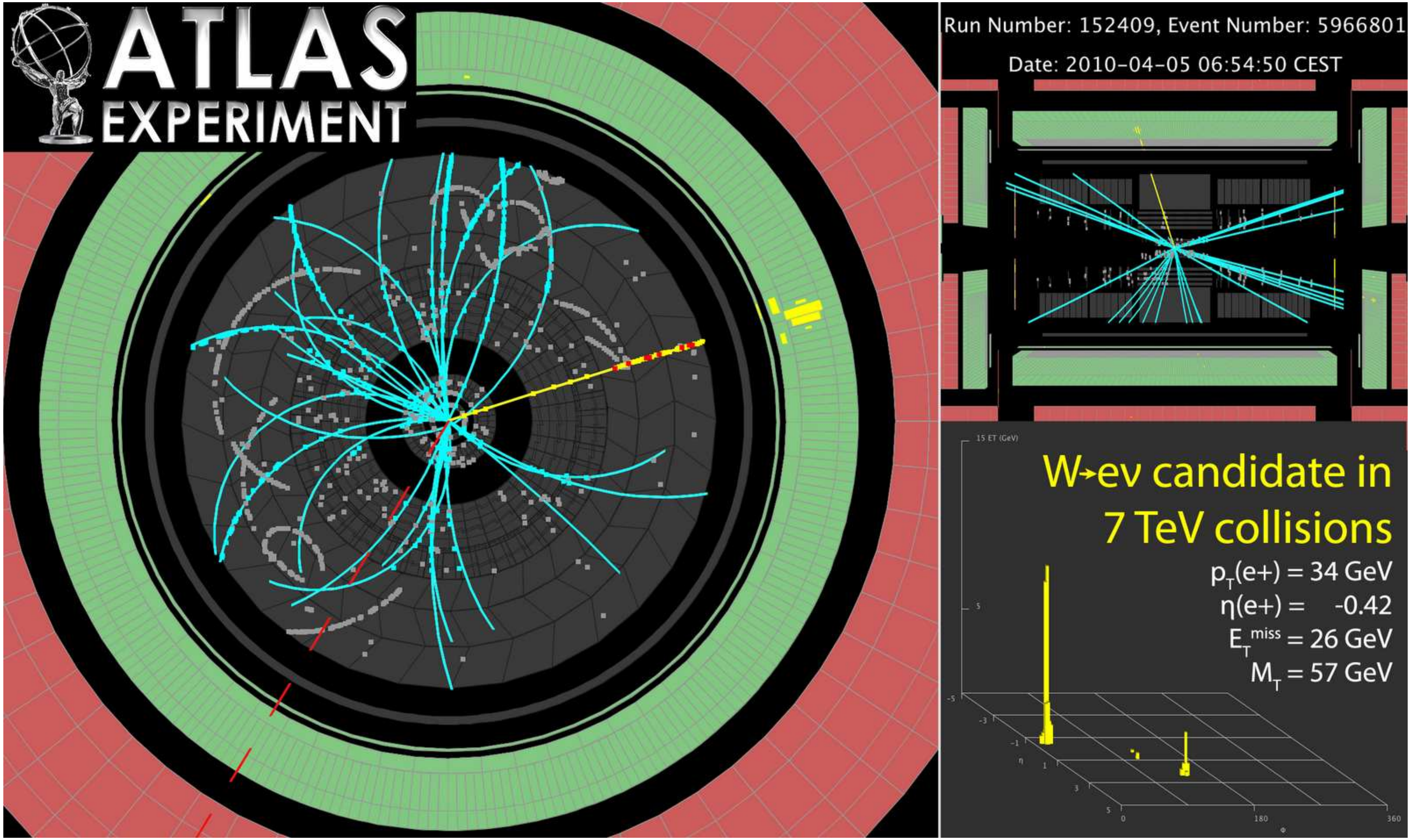


NEEDED:

- ORDERS: RENORMALIZATION AND FACTORIZATION SCALE VARIATION
- HEAVY QUARKS: MATCHING SCHEME VARIATION
- RESUMMATION: SMALL x REGION AT HERA, LARGE τ REGION FOR FIXED-TARGET DY

CONCLUSION

THIS IS JUST THE BEGINNING!



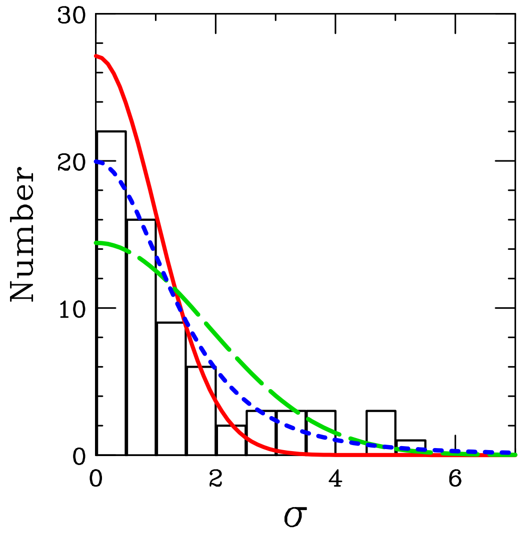
EXTRAS

WHERE IS THE HESSIAN UNCERTAINTY COMING FROM?

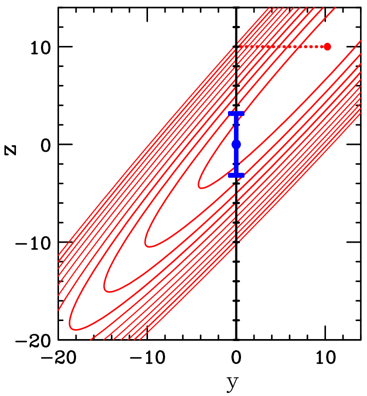
WHY DOES ONE NEED LARGE TOLERANCES?

DATA INCOMPATIBILITY (Pumplin, 2009)

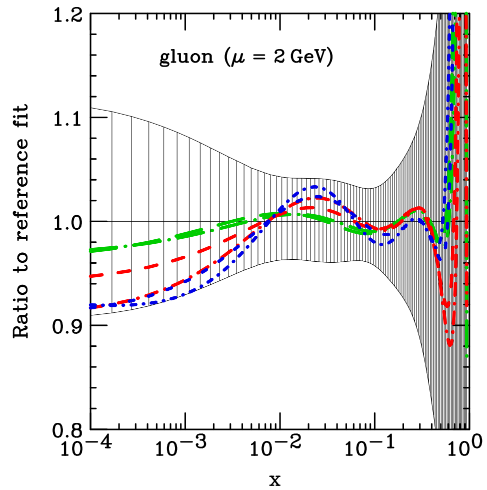
- CAN "REDIAGONALIZE": DIAGONALIZE SIMULTANEOUSLY χ^2 FOR TOTAL AND i–TH EXPT $\Rightarrow$ COMPATIBILITY OF EACH EXPT WITH GLOBAL FIT
- STUDY DISTRIBUTION OF DISCREPANCIES
- APPROX. GAUSSIAN WITH UNCERTAINTIES RESCALED BY 2 $\Rightarrow$ $\Delta\chi^2 \sim 10$ FOR 90%C.L.



FUNCTIONAL BIAS (Pumplin, 2009)



- IF PARM. NOT GENERAL ENOUGH, GLOBAL MIN. IS NOT TRUE MIN.
- ONE-σ VARIATION ABOUT FAKE MIN CORRESP. TO LARGE χ^2 VARIATION
- USE OF CHEBYSHEV POLYNOMIALS SUGGESTS "MOST GENERAL" PARM. WITHIN $\Delta\chi^2 = 10$ OF CTEQ6.6 PARM.



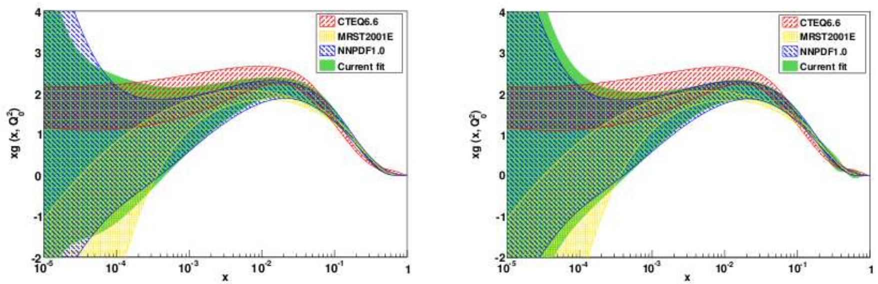
WHERE IS THE MONTE CARLO UNCERTAINTY COMING FROM?

FIT TO REPLICAS VS RANDOM SUBSET OF CENTRAL VAL.S

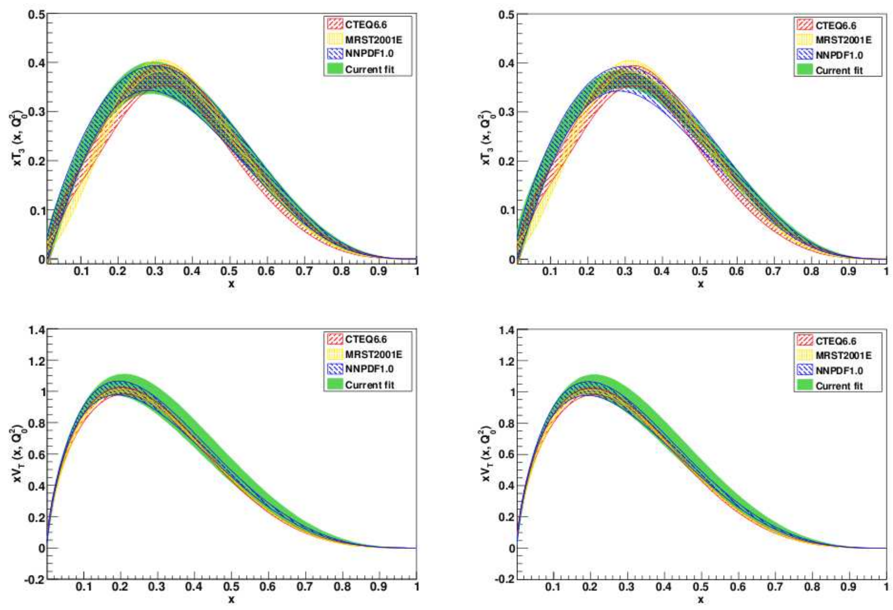
	REPLICAS	CENTRAL V.
χ^2	1.32	1.32
$\langle\chi^2\rangle_{\rm rep}$	2.79 ± 0.24	1.65 ± 0.20
$\langle\sigma^{\rm dat}\rangle$	0.039	0.035

GLUE

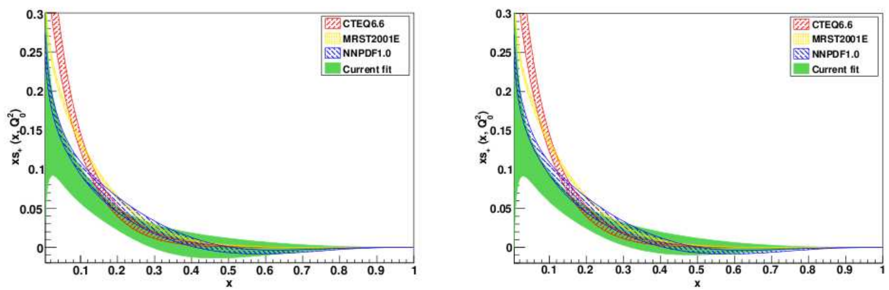
replicas c. vals.



LIGHT QUARKS



STRANGE



- QUALITY OF FIT &PDFs UNCHANGED
- REDUCTION OF $\langle\chi^2\rangle_{\rm rep}$ BY FACTOR $\sim 2 \Rightarrow$ FLUCTUATIONS ABOUT TRUE VALUE HALVED
- UNCERTAINTY ON DATA ONLY REDUCED BY $1.1 \Rightarrow$ EXPT. UNCERTAINTIES UNDERESTIMATED OR UNDERLYING INCOMPRESSIBLE UNCERTAINTY

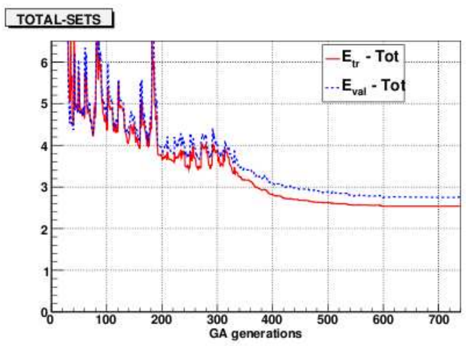
WHERE IS THE MONTE CARLO UNCERTAINTY COMING FROM?

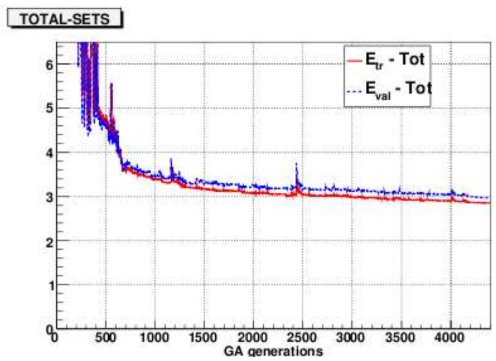
CENTRAL VALUES: VARYING PARTITION VS FIXED PARTITION

	REPLICAS	CENTRAL VALUE	FIXED PARTITION
χ^2	1.32	1.32	$\sim$1.3
$\langle\chi^2\rangle_{\rm rep}$	2.79 ± 0.24	1.65 ± 0.20	$\sim 1.6 \pm 0.2$
$\langle\sigma^{\rm dat}\rangle$	0.039	0.035	$\sim$0.03

fixed partition results obtained averaging over 5 different choices of partition (100 replicas each); more partitions needed for accurate results

- QUALITY OF FIT UNCHANGED
- $\langle\chi^2\rangle_{\rm rep}$ UNCHANGED $\Rightarrow$ CENTRAL FIT UNCHANGED
- UNCERTAINTY ON PREDICTION (I.E. ON PDFS) REDUCED

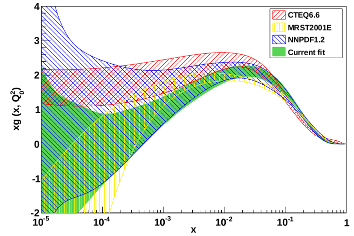




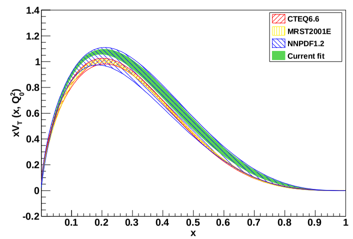
FUNCTIONAL UNCERTAINTY

- MORE THAN HALF OF UNCERTAINTY DUE TO "FUNCTIONAL FORM": $\langle\sigma^{\rm dat}\rangle =\sim 0.03$ SMALLER FOR HERA DATA
- REMAINING UNCERTAINTY ROUGHLY SCALES WITH DATA UNCERTAINTY: $\langle\sigma^{\rm dat}\rangle =\sim 0.005$ CENT.; $\langle\sigma^{\rm dat}\rangle =\sim 0.009$ REP.

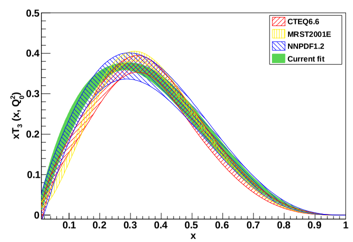
GLUE



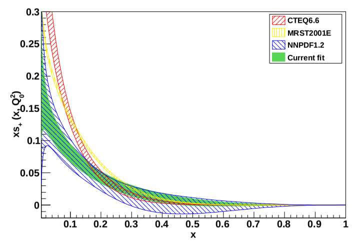
VALENCE



TRIPLET



STRANGE



WHY UNCERTAINTIES ARE IMPORTANT: THE NUTEV ANOMALY...

$$R_{\rm PW} \equiv \frac{\sigma(\nu\mathcal{N}\to\nu X)-\sigma(\bar\nu\mathcal{N}\to\bar\nu X)}{\sigma(\nu\mathcal{N}\to\ell X)-\sigma(\bar\nu\mathcal{N}\to\bar\ell X)} = \frac{1}{2}-\sin^2\theta_{\rm W}+\left(\frac{(U^- - D^-)+(C^- - S^-)}{\mathcal{Q}^-}\frac{1}{6}\left(3-7\sin^2\theta_{\rm W}\right)\right),$$

- PASCHOS-WOLFENSTEIN RATIO CAN BE MEASURED IN NEUTRINO DIS
- RESULT DEPENDS ON EW MIXING ANGLE, VALENCE ISOSPIN BREAKING (WITH ISOSINGLET TARGET), STRANGENESS VALENCE MOMENTUM ASYMMETRY
- STRANGENESS VALENCE MOMENTUM
  ASSUMED BY NUTEV TO VANISH $\Rightarrow$ THREE σ DISCREPANCY WITH GLOBAL FIT

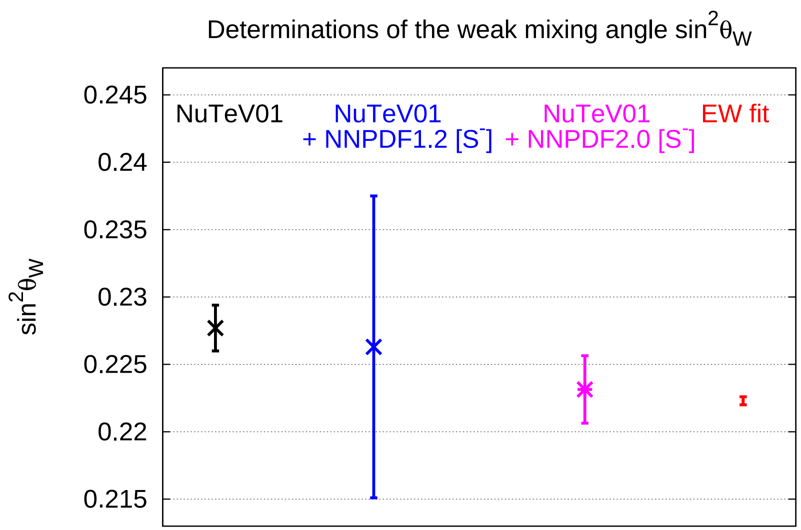
WHY UNCERTAINTIES ARE IMPORTANT: THE NUTEV ANOMALY...

$$R_{\rm PW} \equiv \frac{\sigma(\nu\mathcal{N}\to\nu X)-\sigma(\bar\nu\mathcal{N}\to\bar\nu X)}{\sigma(\nu\mathcal{N}\to\ell X)-\sigma(\bar\nu\mathcal{N}\to\bar\ell X)} = \frac{1}{2}-\sin^2\theta_{\rm W}+\left(\frac{(U^- - D^-)+(C^- - S^-)}{\mathcal{Q}^-}\frac{1}{6}\left(3-7\sin^2\theta_{\rm W}\right)\right),$$

- PASCHOS-WOLFENSTEIN RATIO CAN BE MEASURED IN NEUTRINO DIS
- RESULT DEPENDS ON EW MIXING ANGLE, VALENCE ISOSPIN BREAKING (WITH ISOSINGLET TARGET), STRANGENESS VALENCE MOMENTUM ASYMMETRY
- STRANGENESS VALENCE MOMENTUM ASSUMED BY NUTEV TO VANISH ⇒ THREE σ DISCREPANCY WITH GLOBAL FIT

...IS GONE

- ONCE UNCERTAINTY ON STRANGENESS ASYMMETRY KEPT INTO ACCOUNT (DIS ONLY FIT: NNPDF1.2) THE EFFECT LOSES STATISTICAL SIGNIFICANCE
- IF HADRONIC DATA INCLUDED (NNPDF2.0 GLOBAL FIT), STRANGENESS ASYMMETRY DETERMINED QUITE ACCURATELY → CORRECTED RESULT IN IMPRESSIVE AGREEMENT WITH SM GLOBAL FIT



(NNPDF2.0, 2010)