Report from PDF4LHC Workshop

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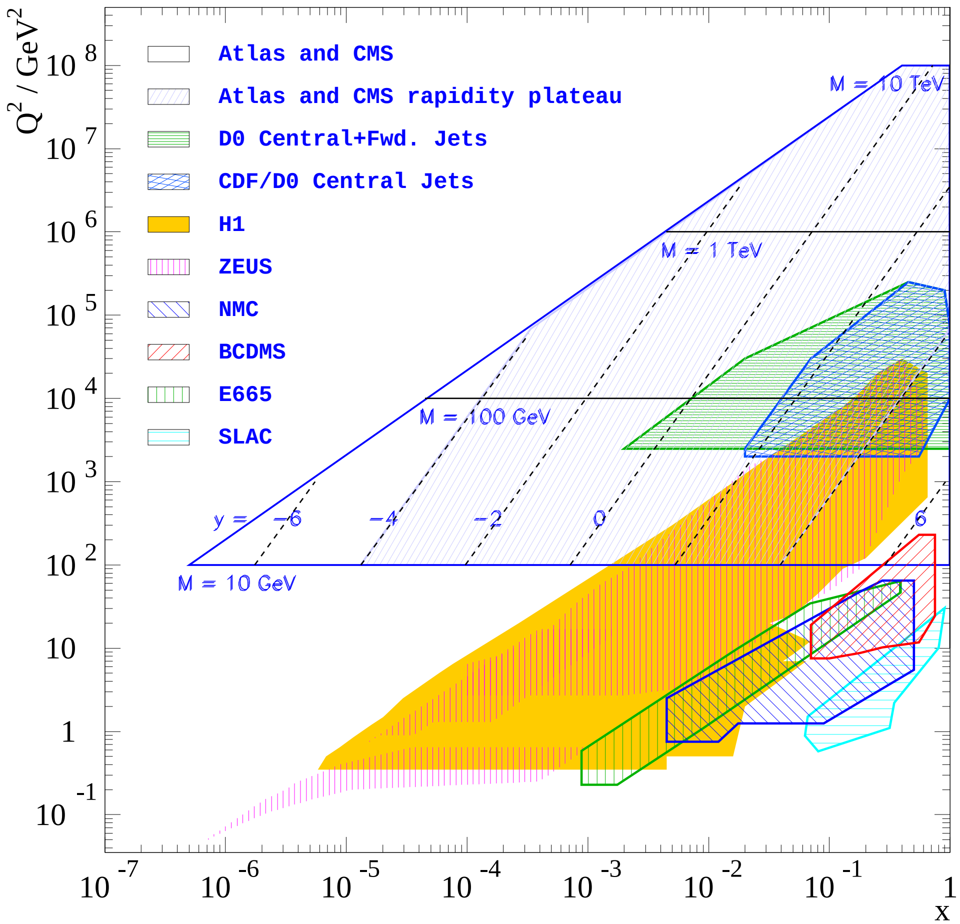
DESY

MC4LHC Readiness Workshop, CERN, 31 March 2010

PDF & LHC



- Input from HERA, Tevatron, fixed target experiments.
- PDF fits / evolution to bring to LHC energy
- Input for/from LHC.

PDF4LHC Workshop Series - the mission

PDF4LHC initiative started as a continuation of HERALHC workshop with the main goals

- Getting the best PDFs, including the PDF uncertainties, based on the present data.
- Devise strategies to use future LHC data to improve the PDFs.

The main PDF groups.

Recent fits from the main active PDF groups:

- **CTEQ6.6** [arXiv:0802.0007] General-Mass Variable-Flavor-Number Scheme (GM-VFNS, ACOT) fit to DIS, DY and jet data, available in 2008.
- **MSTW08** [arXiv:0901.0002] GM-VFNS (TR) fit to DIS, DY and jet data, available in 2008. Also NNLO.
- **NNPDF2.0** [arXiv:1002.4407] Zero-Mass VFNS fit to DIS, DY and jet data, updated to modern data.
- **HERAPDF1.0** [arXiv:0911.0884] GM-VFNS (TR) fit to HERA only data
- **ABKM09** [arXiv:0908.2766] Fixed-Flavor-Number Scheme (FFNS) fit DIS and DY data. Also NNLO.
- **GJR08** [arXiv:0708.0614] FFNS fit to DIS, DY and jet data, with extra assumptions on PDFs at the starting scale ("dynamical pdfs"). Alos NNLO.

Different assumptions for PDF uncertainties: large tolerance criteria (CTEQ,MSTW), flexible parameterization (NNPDF), separation of experimental, model and parameterization errors (HERAPDF).

Input data

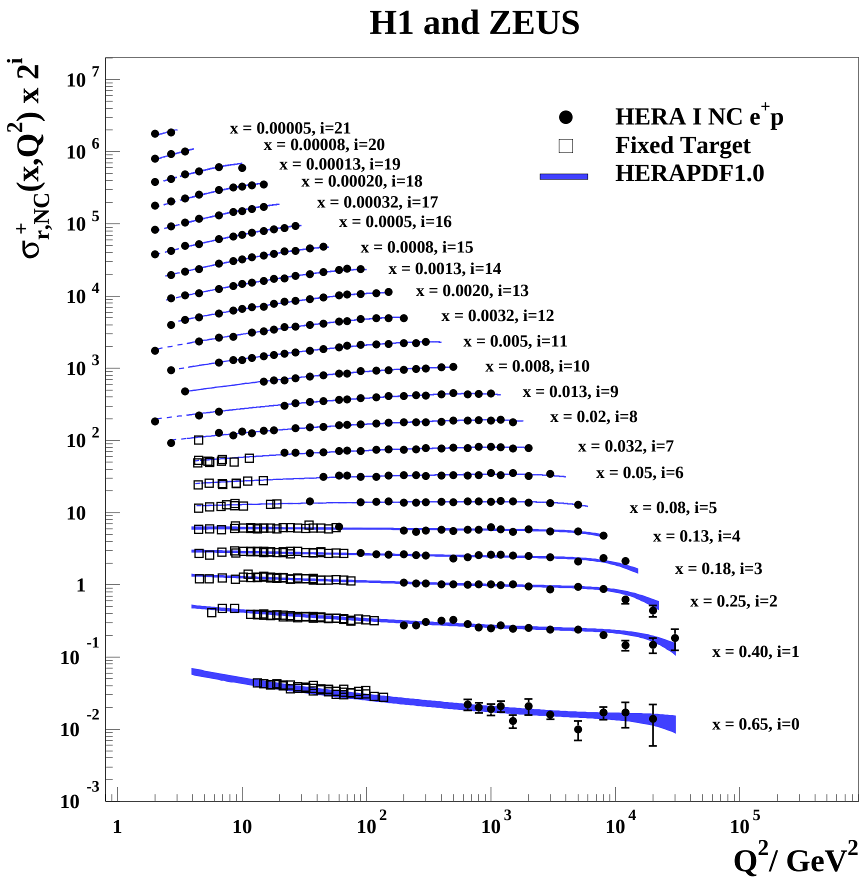
PDF4LHC workshop helps to propagate knowledge about new input data sets to PDF fit groups. Feedback on consistency of the data with QCD expectations. Recent data sets include:

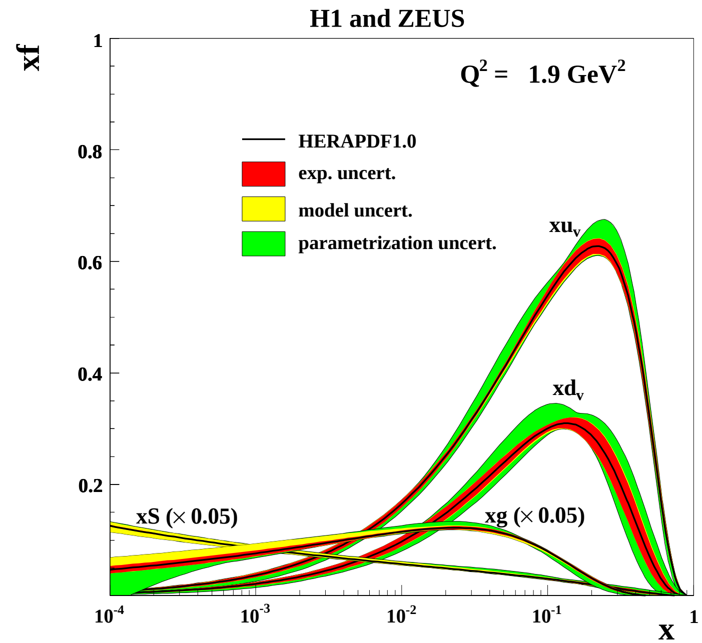
- Combined H1 and ZEUS inclusive DIS cross section measurement
- Tevatron Run-II measurements of jet production, $W^{\pm}$ asymmetry, Z rapidity distribution.

More data are expected to come. In particular, from HERA:

- Inclusive data from HERA-II period ($\times 3.5$ luminosity vs HERA-I)
- Combined H1 and ZEUS $c-$ and $b-$ quark data.

HERA input: Combined inclusive measurement





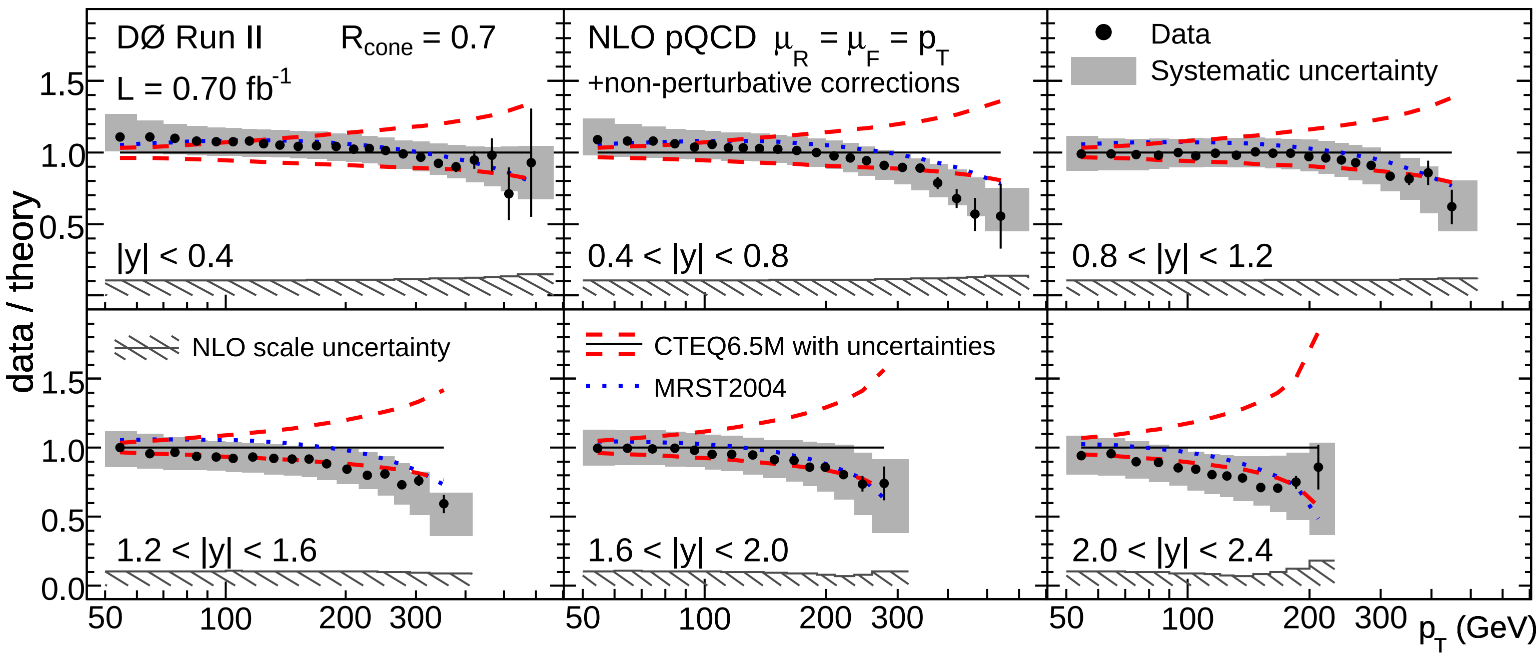
HERAPDF1.0 Set.

Data consistency: $\chi^2/dof = 637/656$ (for the data combination)

Theory check: $\chi^2/dof = 574/582$.

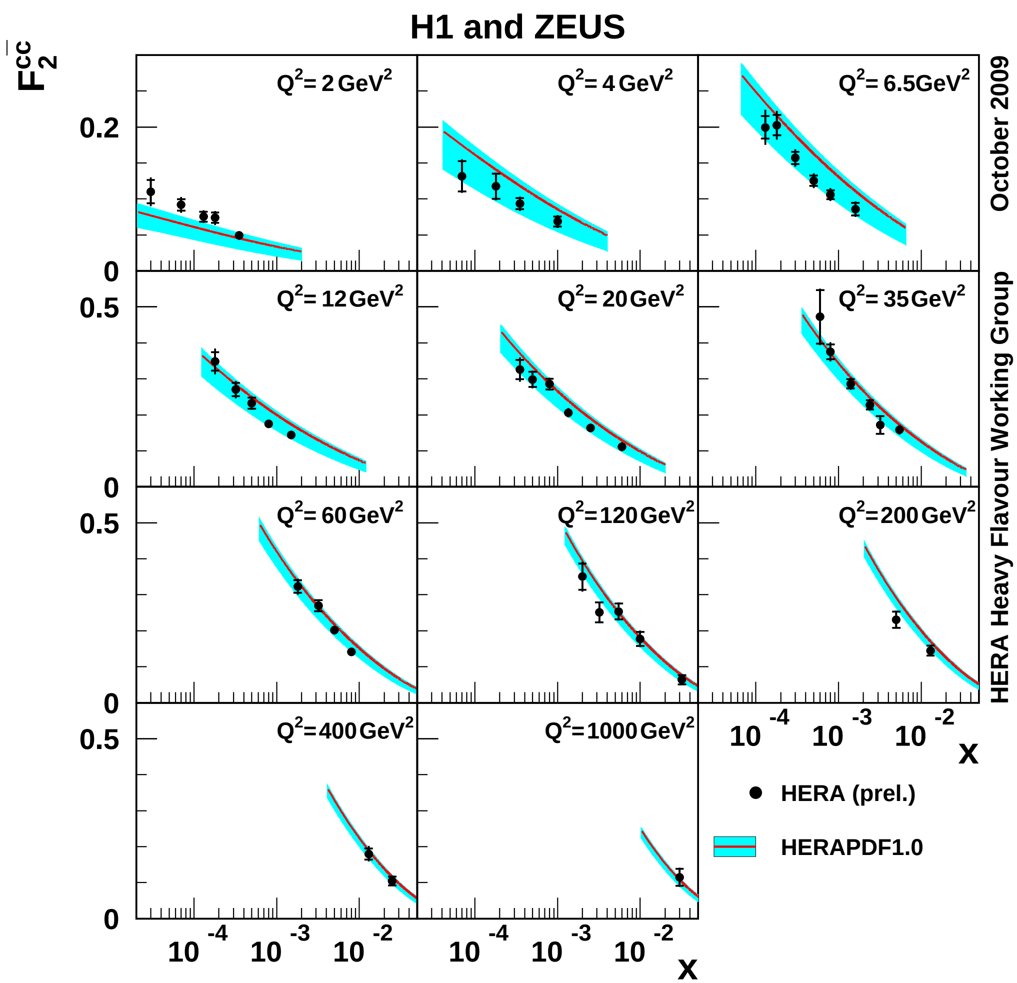
Precision reaches 1%.

Tevatron Jets



- Inclusive Jet cross section data from Tevatron provides information on gluon density at high *x*.
- Recent run-II data from CDF and D0, D0 data reaches impressive 1.2% precision for the jet energy scale.
- Softens gluon density distribution compared to Run-I results.

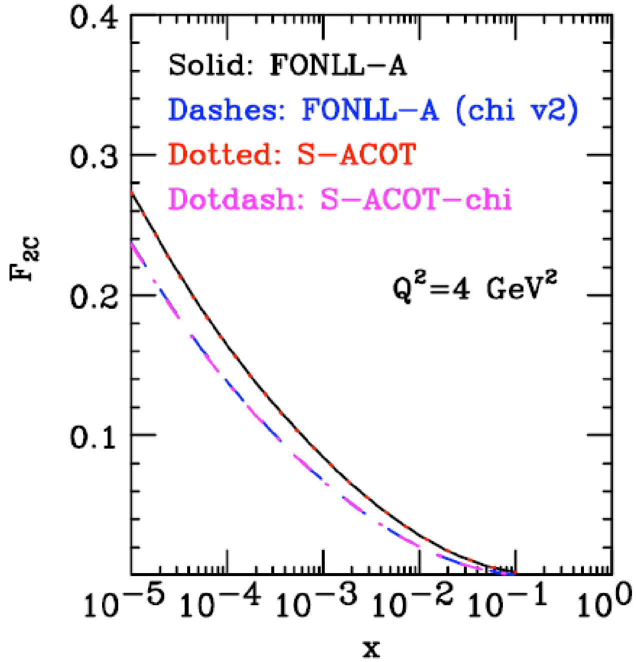
Importance of Heavy flavors



- Inclusive HERA data at low x have significant contribution from c-quark.
- Change from massless to massive c-quark treatment changes predictions for W, Z production at the LHC by $\sim 8\%$.
- HERA charm data allows to study threshold description.

Massive quark treatment for all but NNPDF2.0 sets. Difference btw different treatments is under investigation.

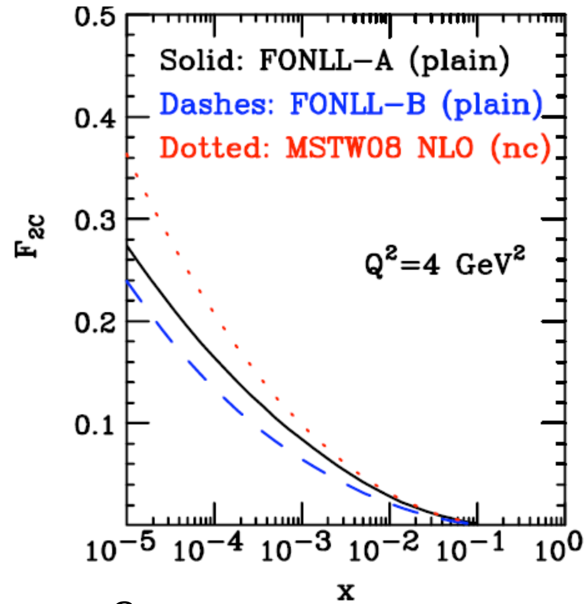
Understanding of Heavy Flavors



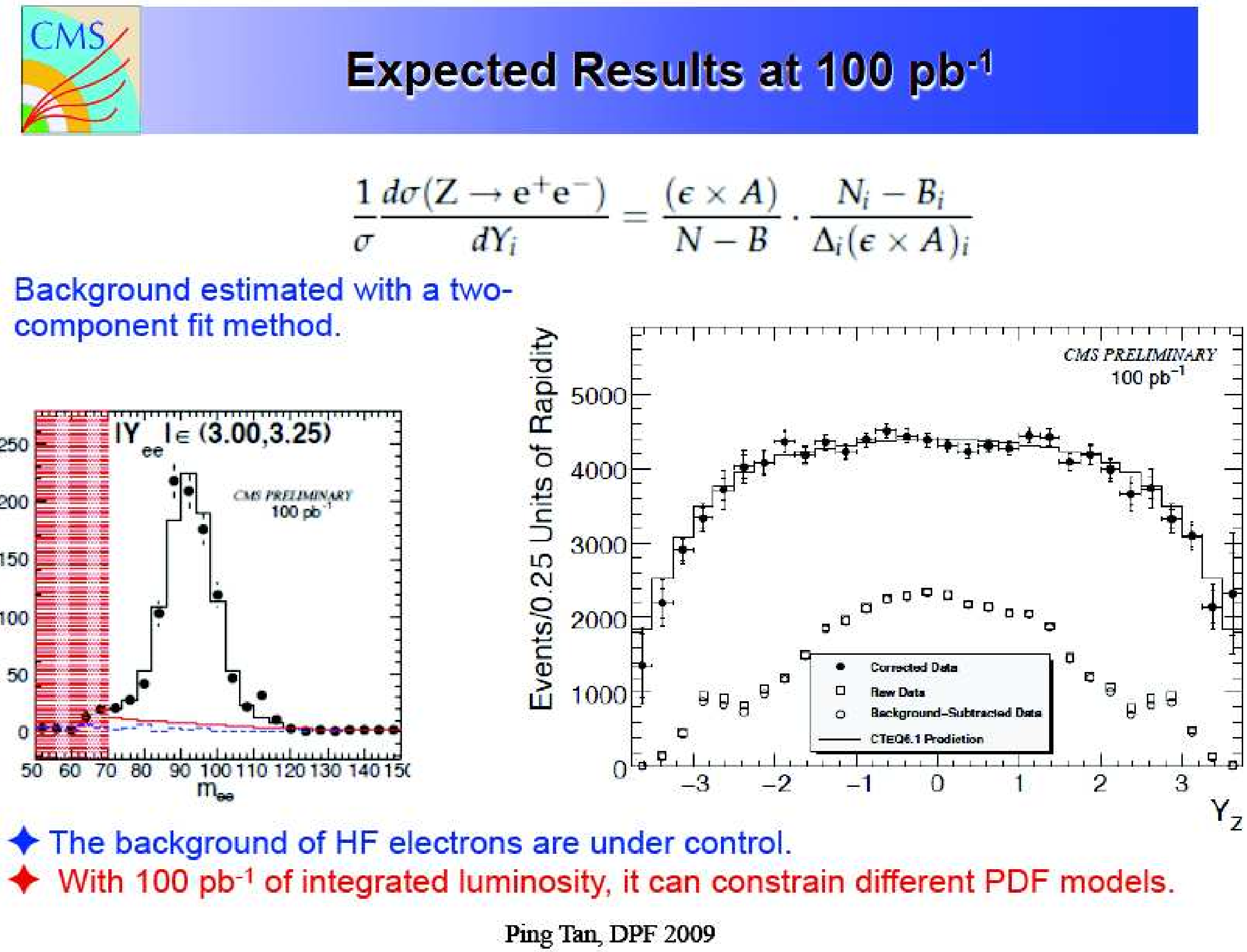
New heavy flavor scheme:
FONLL [arXiv:1001.2312]
FONLL scheme A: $O(\alpha_S)$ massless and masive, similar to ACOT.
Indeed, essentially identical schemes.

FNOLL scheme B: $O(\alpha_S)$ massless and $O(\alpha_S^2)$ massive. (like TR sheme) However, FNOLL scheme B is different prescription vs TR.

Juan Roho, PDF4LHC, 29 Jan 2010

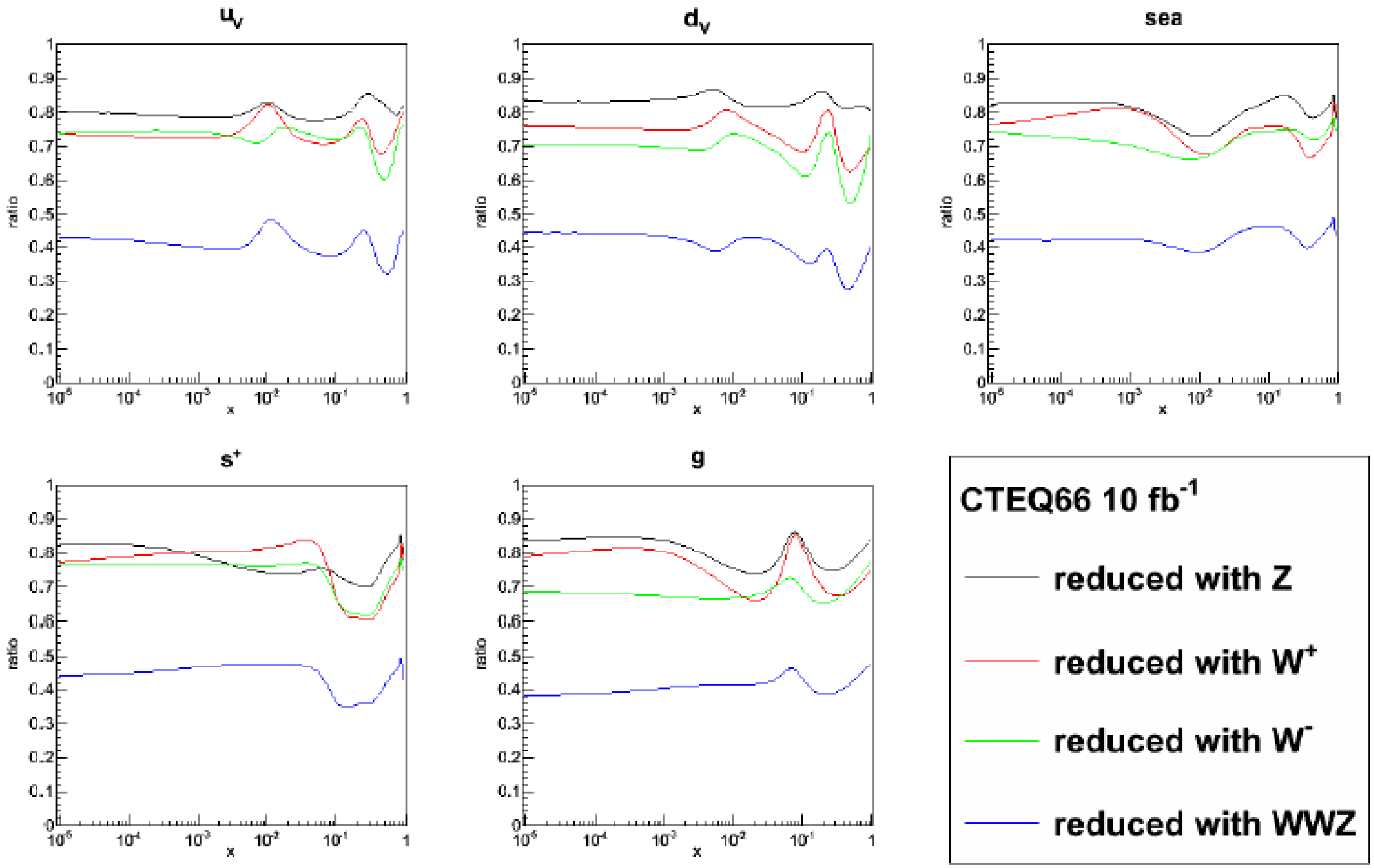


CMS: Z rapidity in extended y range



Dedicated fwd electron reconstruction allows to extend measurement y range.

LHCb: PDF uncertainty reduction



$$ratio = \frac{\delta_{after}}{\delta_{before}}$$

F. De Lorenzi PDF4LHC 15

Forward coverage of LHCb allows to probe x as low as 10^{-5}.

PDFs and MC Generators

- “PDF critical” processes should use NLO MC generators whenever available (i.e. ATLAS uses MC&NLO for W, Z inclusive production measurements).
- The main workhorse are however LO MC generators (PYTHIA6).
- LO PDFs do not contain all dynamics
  - LO theory often requires large K factors
  - x shapes of LO pdfs is usually not correct.
- Solutions, discussed at PDF4LHC workshops:
  - NLO PDFs for LO MC (better x shape at least)
  - Dedicated LO PDF sets for MC generators – preferred option.

Modified PDF sets

- MSTW and CTEQ have produced "modified" LO PDF sets:
  - MSTW:
    - Release momentum sum rule and use NLO α_S
  - CTEQ:
    - Fit existing data AND LHC benchmark processes to LO evolution.
    - Systematic study of effects of momentum sum rule, α_S, scale choices, selection of data points.
- The sets are available at LHAPDF.

Status of LO* implementation

Tunes for Modified LO PDFs

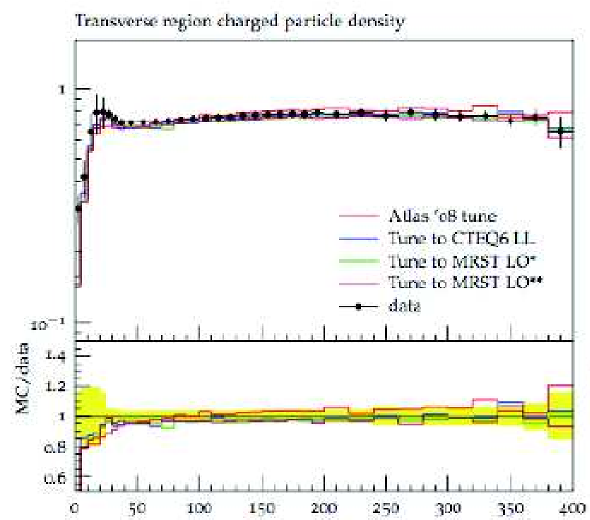
Tune to CDF/D0 data using RIVET/PROFESSOR

A. Buckley
PDF4LHC meeting
29th May 09

Tune parameters compared

Absolute values

Param		Atlas tune	Professor tunes CTEQLL	LO*	LO**
PARP(64)	ISR α_s scale	1.0	0.89	0.92	0.97
PARP(71)	FSR max virt.	4.0	1.72	1.29	1.20*
PARP(78)	FS colour reconn.	0.3	0.17	0.14	0.13
PARP(79)	Remnant x enh.	2.0	1.10	1.11	3.69
PARP(80)	Remnant cnctn.	0.1		0.01	
PARP(82)	MPI $p_{\perp 0}$	2.1	1.83	2.10	2.28
PARP(83)	Matter overlap 1	0.8	1.72	1.68	1.67
PARP(84)	Matter overlap 2	0.7		N/A	
PARP(89)	MPI reg ref scale	1800		1800	
PARP(90)	MPI reg power	0.16	0.20	0.20	0.21
PARP(91)	$k_\perp$ width	2.0	1.85	2.15	2.11
PARP(93)	$k_\perp$ cutoff	5.0	6.86	6.79	5.08



- ATLAS uses modified LO PDFs for MC production.

Understanding of PDF uncertainties

Main topic of the PDF4LHC workshops is understanding of PDF uncertainties.

- Global **CTEQ** and **MSTW** fits use large tolerances of $\Delta\chi^2 = 100$ and 50 to determine PDF uncertainties, while other groups use $\Delta\chi^2 = 1$.
- **NNPDF** uses flexible PDF parameterization, most of the uncertainty comes from the parameterization error.
- **HERAPDF** separates experimental, model and parameterization errors. Largest contribution typically arises from parameterization variation.
- **GJR** uses extra assumptions on PDF shapes at the starting scale to reduces the errors.

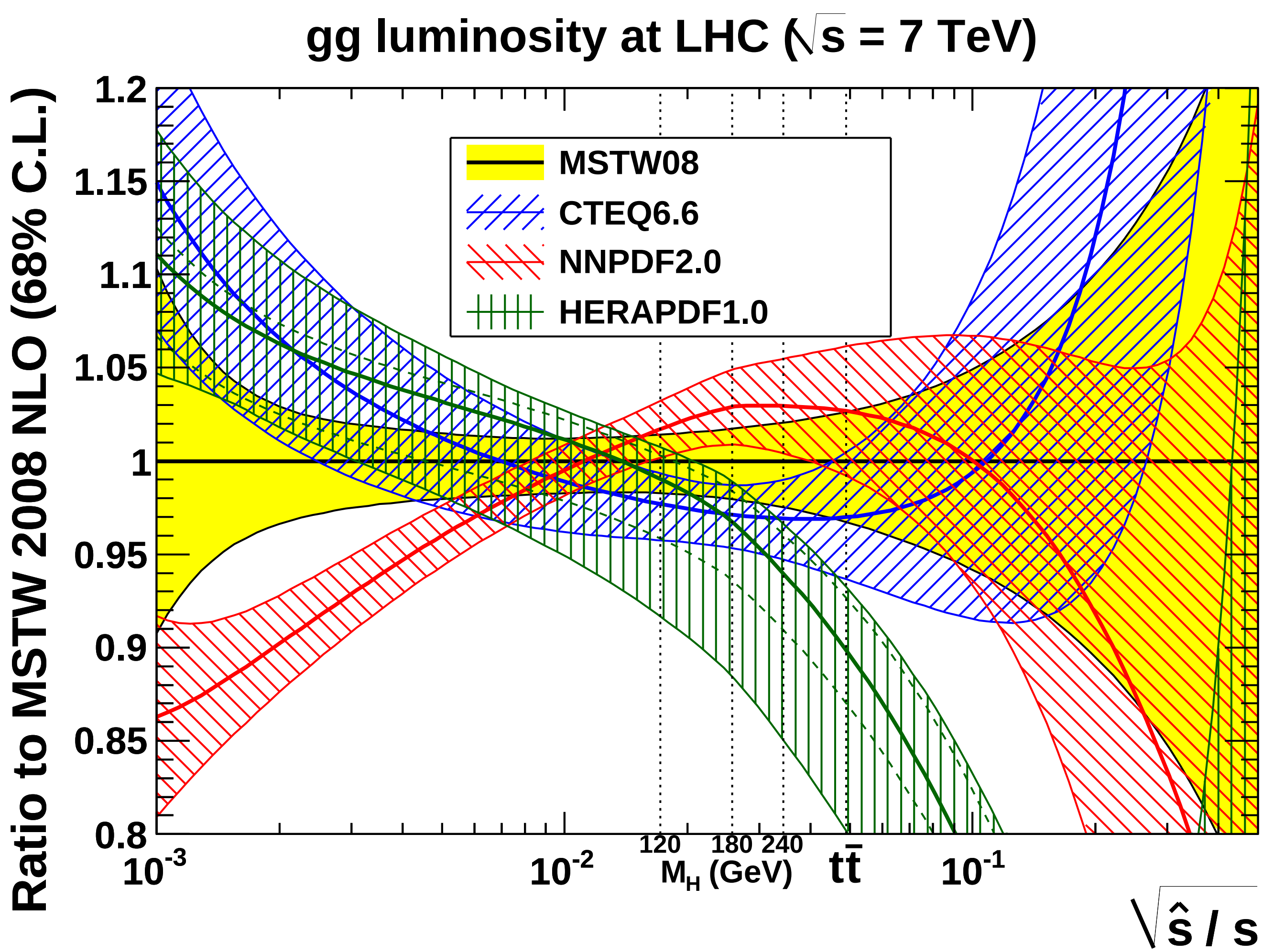
Remarkably, different groups arrive to comparable PDF uncertainties for the LHC observables (see next slides). The main reason why large tolerance criteria for **CTEQ** and **MSTW** are required are parameterization uncertainty and to lesser extend data incompatibility.

Benchmarking of PDF sets

Compare predictions from different PDF sets:

- W^+,W^-,Z $t\bar{t}$ and H production (at $m_H = 120, 160$ and 240 GeV).
- LHC CME of 7 TeV and 14 TeV.
- NLO calculations using MCFM5.7 with agreed set of parameters. Input files by J. Campbell and J. Huston.
- First results are available from the last PDF4LHC workshop, on 26 March 2010 [http://indico.cern.ch/conferenceDisplay.py?confId=87871].
- Finalized results will be given on a wiki [https://wiki.terascale.de/index.php?title=PDF4LHC_WIKI].

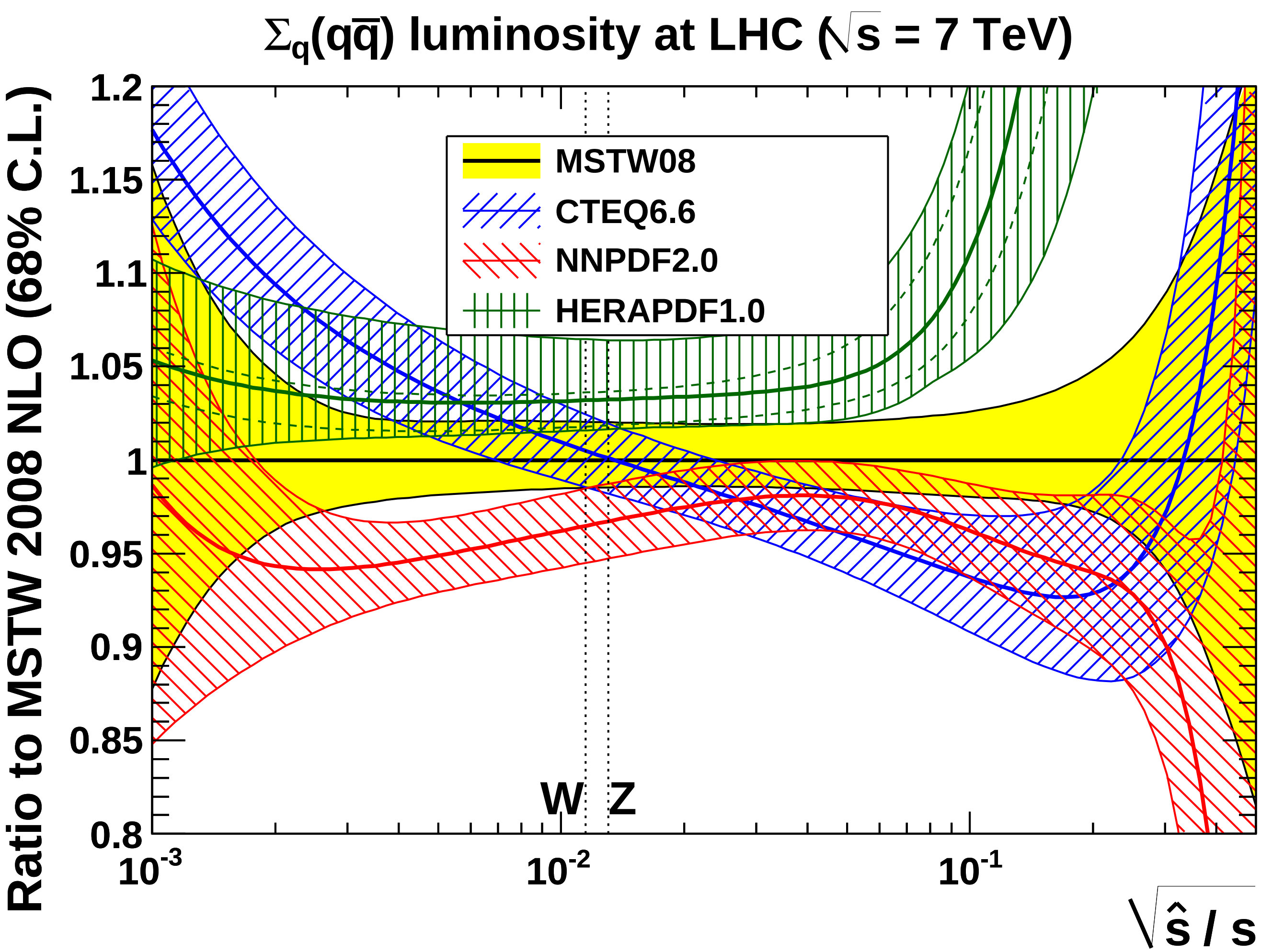
Gluon-Gluon luminosity



G. Watt, PDF4LHC, 26 March 2010

HERAPDF1.0: no jet input; NNPDF2.0: ZM-VFS.

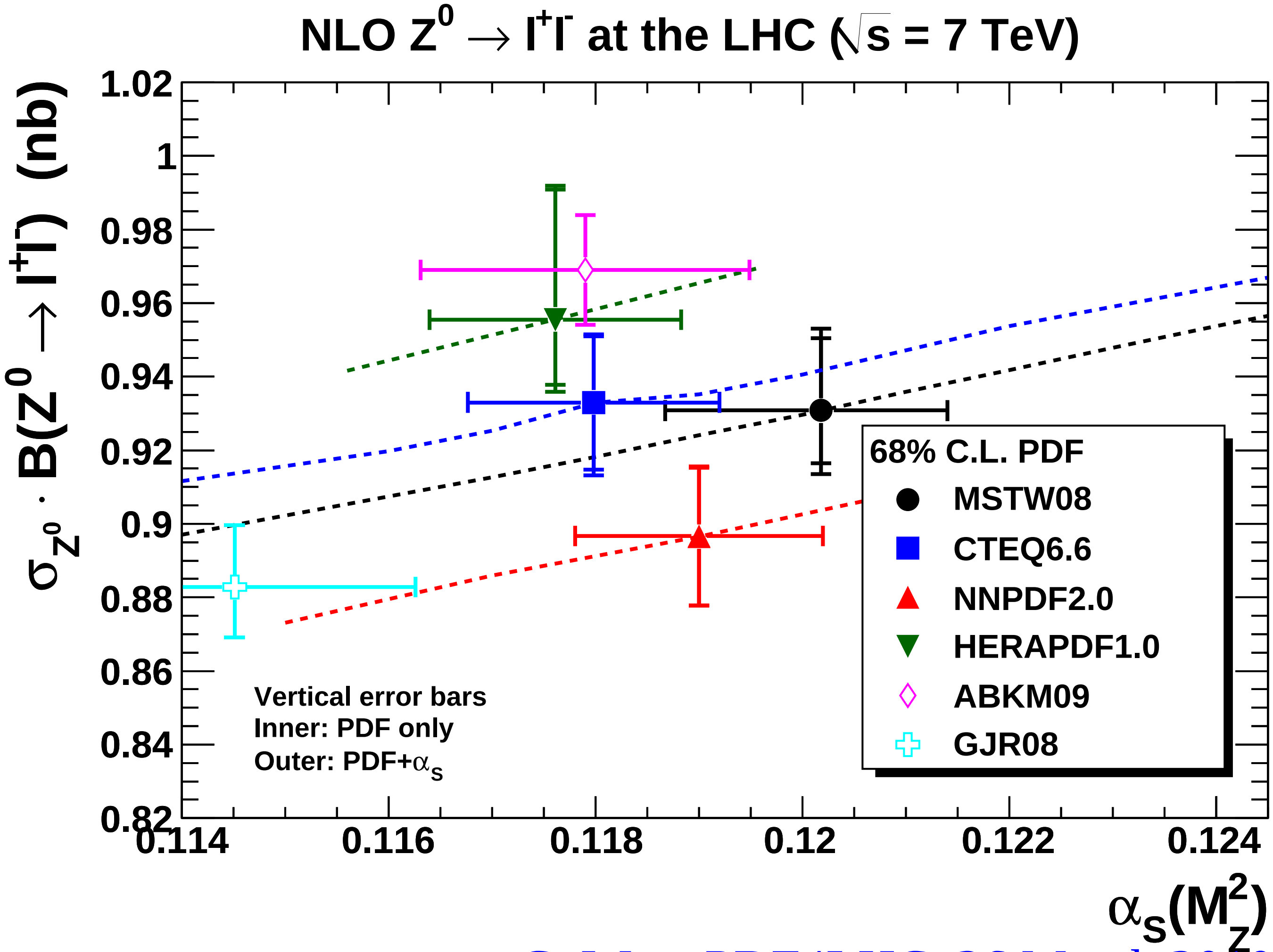
Quark-quark luminosity



G. Watt, PDF4LHC, 26 March 2010

NNPDF2.0: ZM-VFS; CTEQ6.6, MSTW08: no resent HERA data; HERAPDF1.0 at high *x*: no jet data.

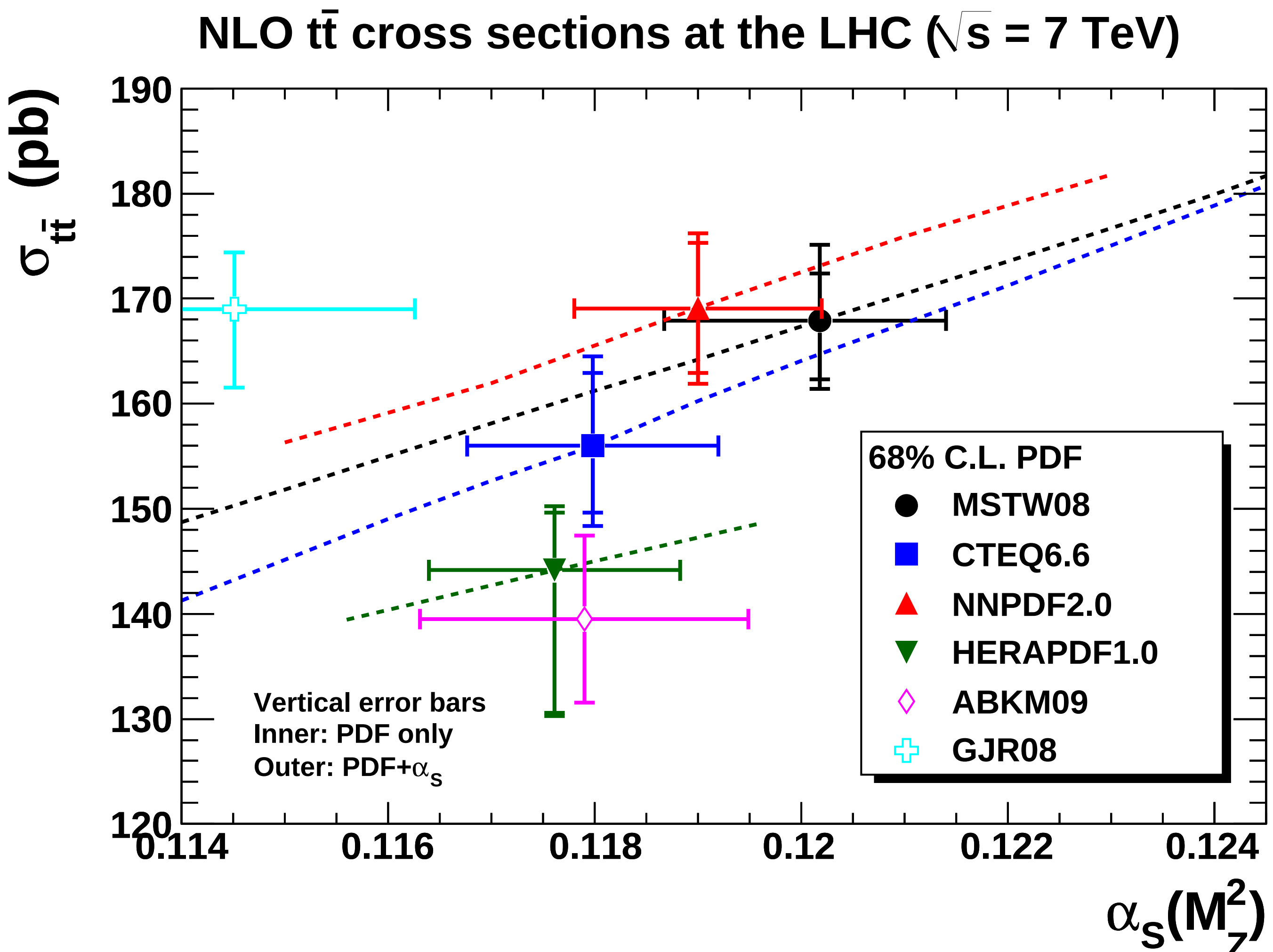
Predictions for Z



G. Watt, PDF4LHC, 26 March 2010

Relatively week α_S dependence for $\bar{q}q$ dominated channels.

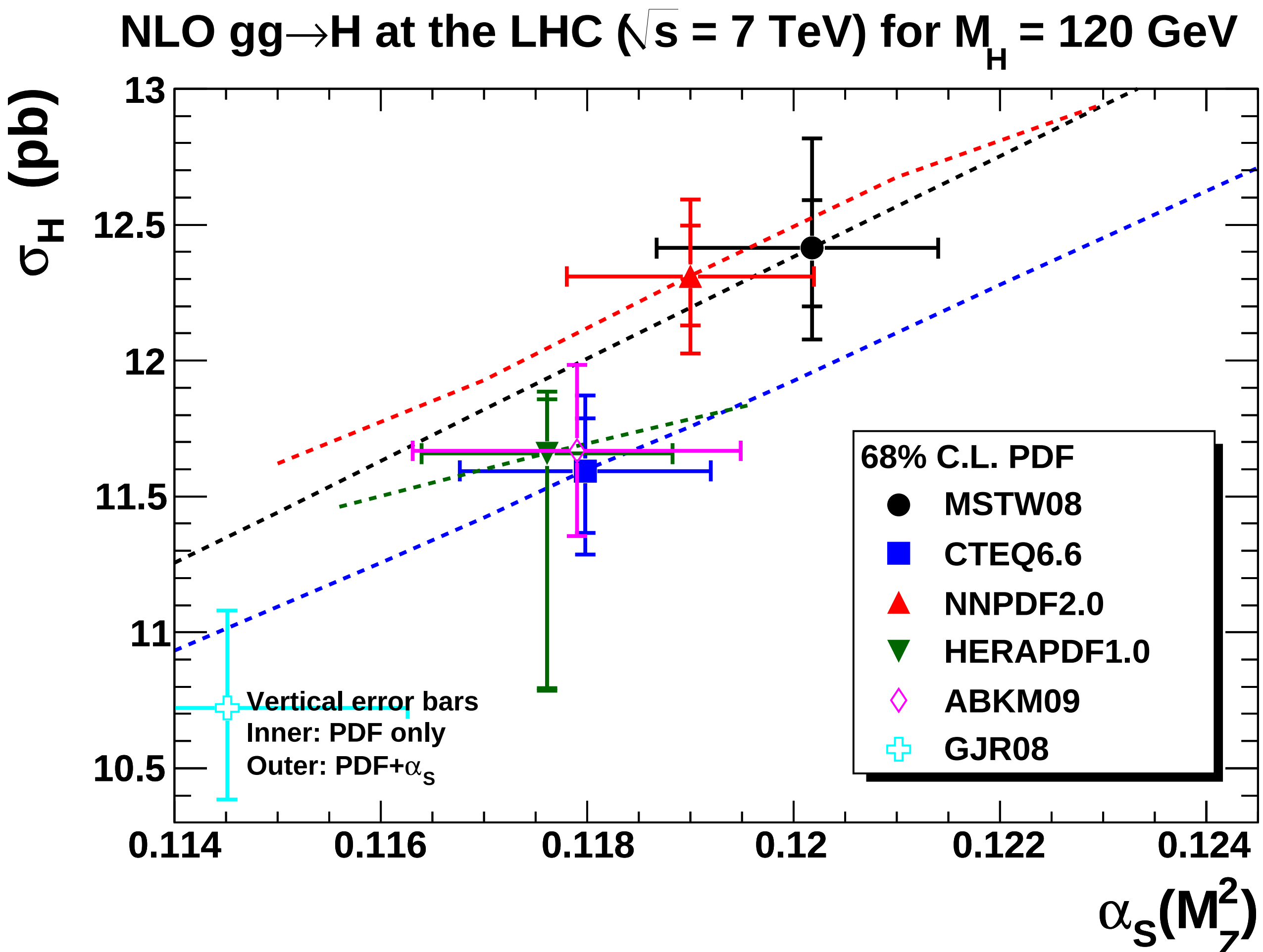
Predictions for $t\bar{t}$



G. Watt, PDF4LHC, 26 March 2010

Strong α_S dependence for gg dominated channels.

Predictions for Higgs



G. Watt, PDF4LHC, 26 March 2010

Same strong dependence on α_S for H production. More comparisons at [http://indico.cern.ch/materialDisplay.py?contribId=0&materialId=slides&confId=87871]

Summary

- PDF4LHC workshop series are very successful in bringing experimentalists, providing input of PDF fits, theorists, performing PDF fits and experimentalists using PDFs for their LHC analyses together.
- This communication triggered rapid development in
  - Understanding of data internal consistency (combined HERA set)
  - Development of LO MC-tuned PDF sets (from MSTW and CTEQ)
  - Understanding of sources of PDF uncertainties, in particular parameterization uncertainty (due to rapid development of NNPDF sets).
- Further steps are detailed understanding of the differences among PDFs for the LHC observables and development of recommendations for the LHC experiments how to evaluate PDF related errors.