CT update

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PDF4LHC meeting
CERN Dec13, 2013

Two recent CT papers

Intrinsic Charm Parton Distribution Functions from CTEQ-TEA Global Analysis

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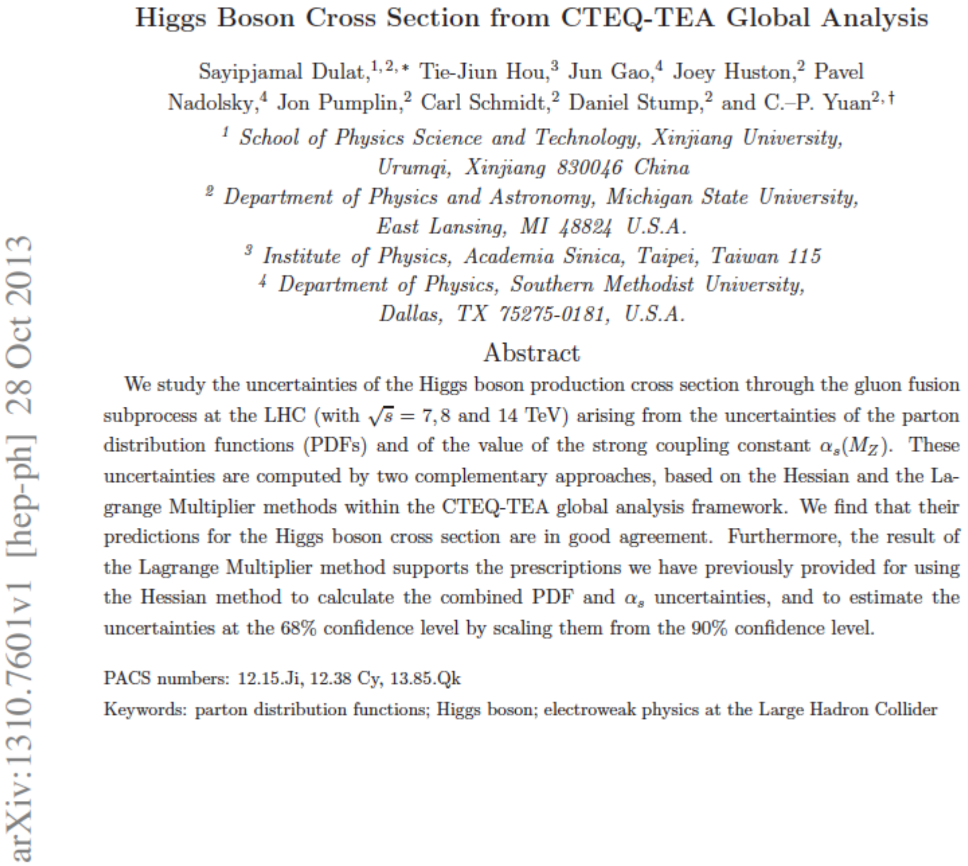
Abstract

We study the possibility of intrinsic (non-perturbative) charm in parton distribution functions (PDF) of the proton, within the context of the CT10 next-to-next-to-leading order (NNLO) global analysis. Three models for the intrinsic charm (IC) quark content are compared: (i) $\hat{c}(x) = 0$ (zero-IC model); (ii) $\hat{c}(x)$ is parametrized by a valence-like parton distribution (BHPS model); (iii) $\hat{c}(x)$ is parametrized by a sea-like parton distribution (SEA model). In these models, the intrinsic charm content, $\hat{c}(x)$, is included in the charm PDF at the matching scale $Q_c = m_c = 1.3$ GeV. The best fits to data are constructed and compared. Correlations between the value of m_c and the amount of IC are also considered.

PACS numbers: 12.15.Ji, 12.38 Cy, 13.85.Qk
Keywords: parton distribution functions; electroweak physics at the Large Hadron Collider



Higgs Boson Cross Section from CTEQ-TEA Global Analysis

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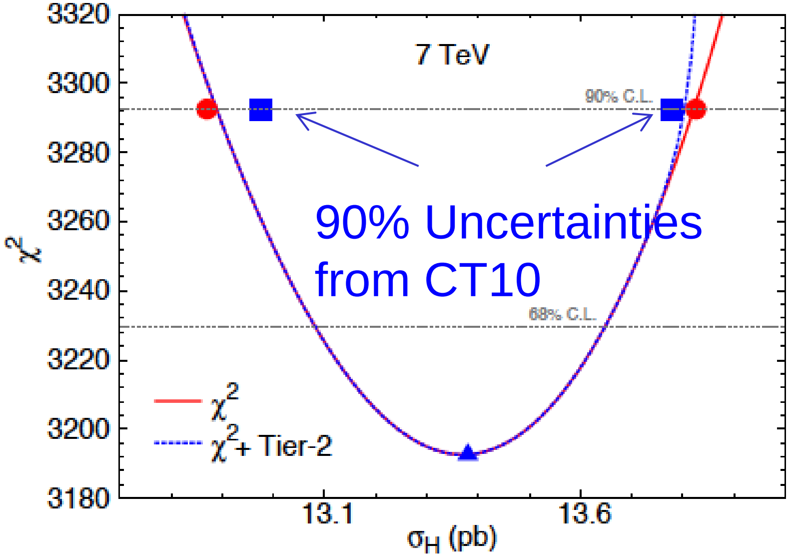
Abstract

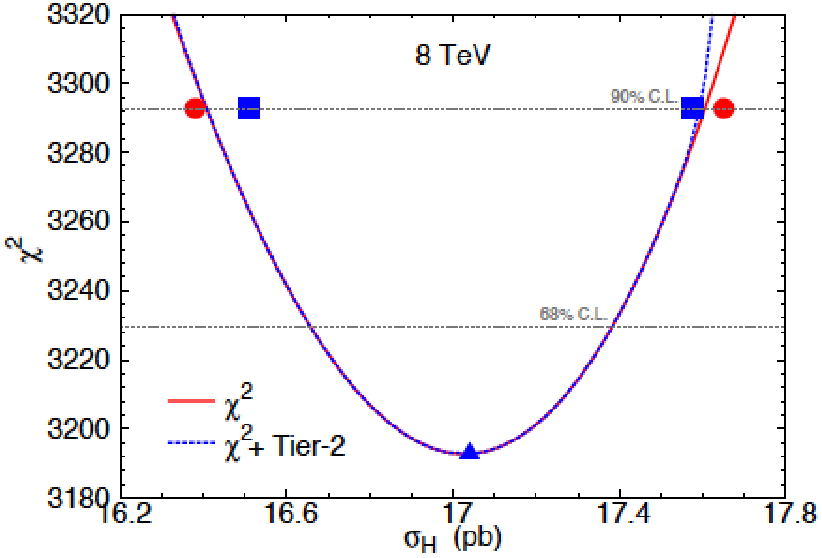
We study the uncertainties of the Higgs boson production cross section through the gluon fusion subprocess at the LHC (with $\sqrt{s} = 7, 8$ and 14 TeV) arising from the uncertainties of the parton distribution functions (PDFs) and of the value of the strong coupling constant $\alpha_s(M_Z)$. These uncertainties are computed by two complementary approaches, based on the Hessian and the Lagrange Multiplier methods within the CTEQ-TEA global analysis framework. We find that their predictions for the Higgs boson cross section are in good agreement. Furthermore, the result of the Lagrange Multiplier method supports the prescriptions we have previously provided for using the Hessian method to calculate the combined PDF and α_s uncertainties, and to estimate the uncertainties at the 68% confidence level by scaling them from the 90% confidence level.

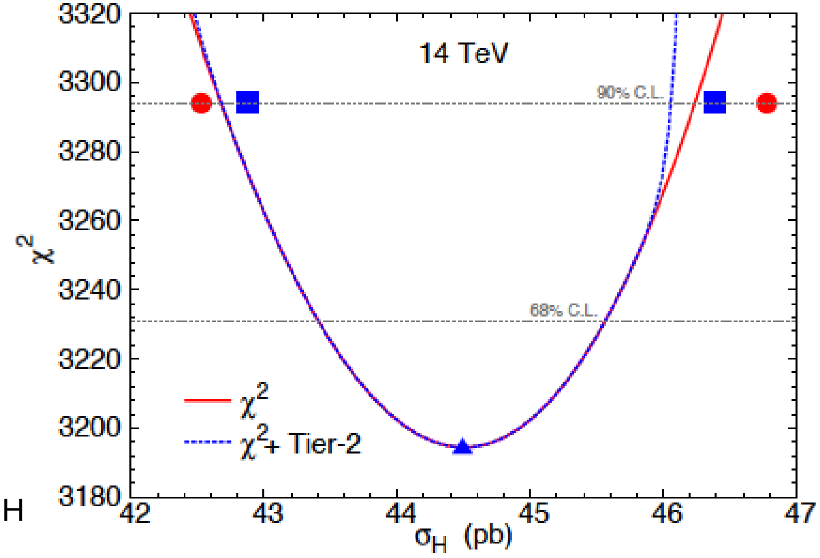
PACS numbers: 12.15.Ji, 12.38 Cy, 13.85.Qk
Keywords: parton distribution functions; Higgs boson; electroweak physics at the Large Hadron Collider

Compare Lagrange Multiplier and Hessian uncertainties for gg->Higgs



90% Uncertainties from CT10





Tier 2 penalty prevents the fit to any one experiment from degrading too Much

all predictions at NNLO using $\mu=m_H$

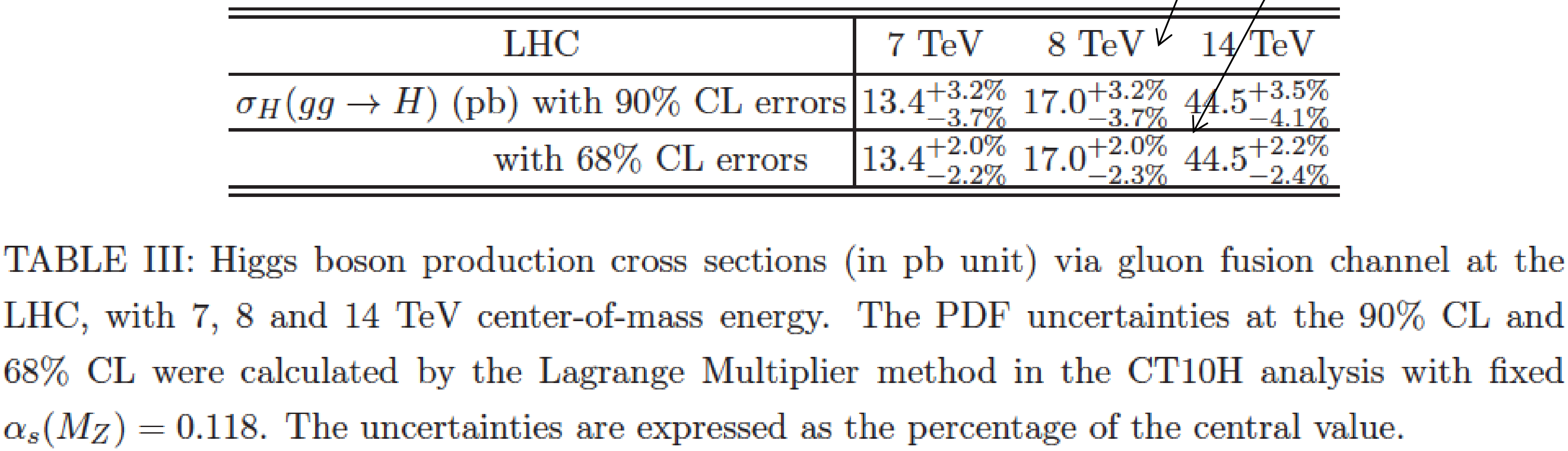
curves are LM calculations of global fit χ^2 vs Higgs σ with (blue) and without (red) ‘Tier 2 penalty’

The blue (red) points are the Hessian determination of the of the PDF uncertainty with (without) the Tier 2 penalty

Lagrange Multiplier Method

- The Lagrange Multiplier technique is more robust than the Hessian method in that it does not depend on any assumptions about quadratic behavior of χ^2

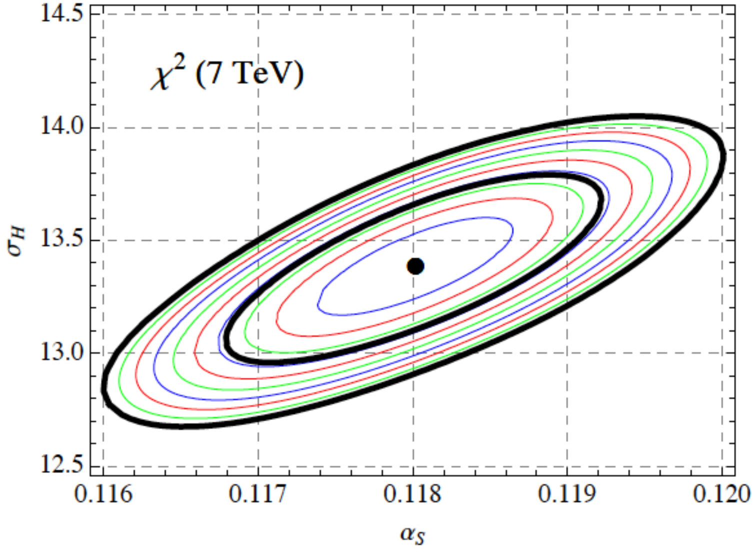
3.45%/2.15%=1.60,
close to
expected
1.645

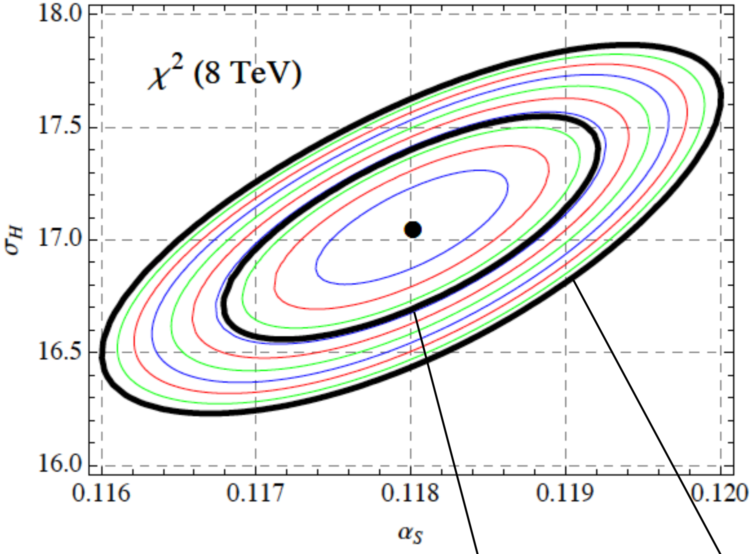


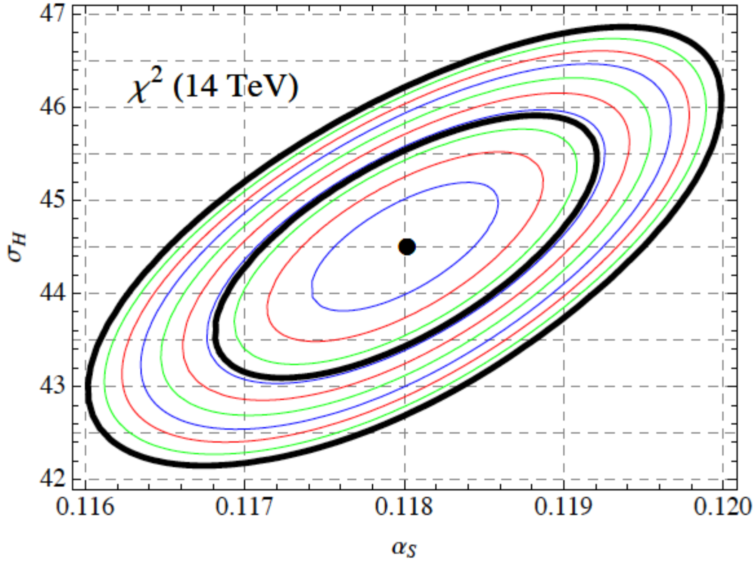
LHC	7 TeV	8 TeV	14 TeV
$\sigma_H(gg \to H)$ (pb) with 90% CL errors	$13.4^{+3.2\%}_{-3.7\%}$	$17.0^{+3.2\%}_{-3.7\%}$	$44.5^{+3.5\%}_{-4.1\%}$
with 68% CL errors	$13.4^{+2.0\%}_{-2.2\%}$	$17.0^{+2.0\%}_{-2.3\%}$	$44.5^{+2.2\%}_{-2.4\%}$

TABLE III: Higgs boson production cross sections (in pb unit) via gluon fusion channel at the LHC, with 7, 8 and 14 TeV center-of-mass energy. The PDF uncertainties at the 90% CL and 68% CL were calculated by the Lagrange Multiplier method in the CT10H analysis with fixed $\alpha_s(M_Z) = 0.118$. The uncertainties are expressed as the percentage of the central value.

σ_H vs χ^2





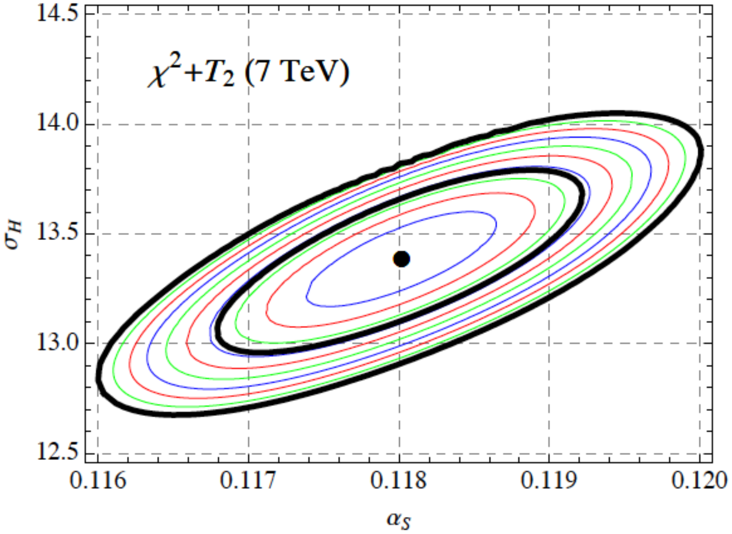


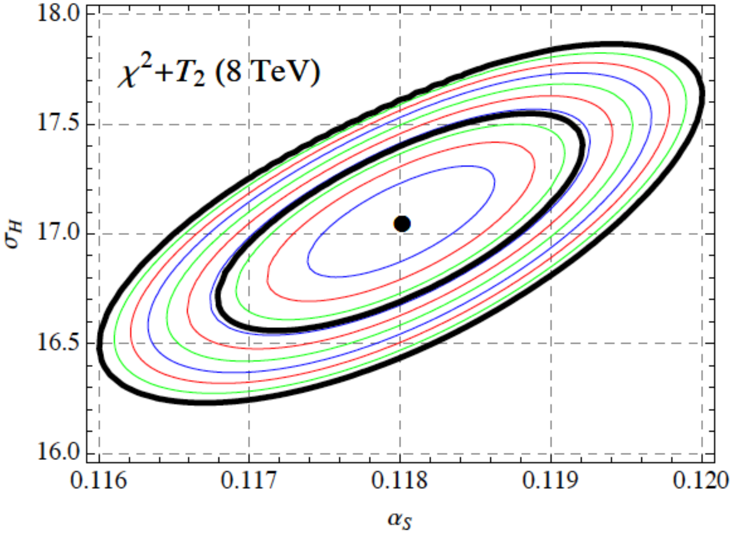
no Tier 2
penalties

contour for
PDF+α_s errors
at 90%CL
(0.118+/-0.002)

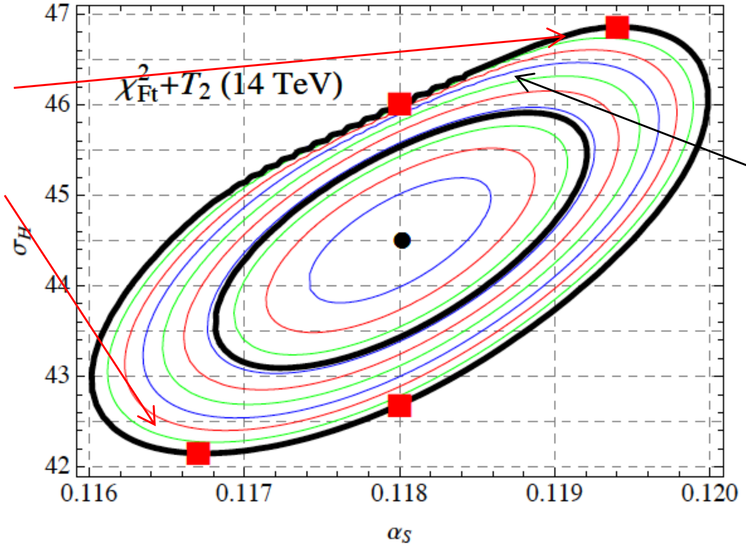
contour for
PDF+α_s errors
at 68%CL

σ_H vs χ^2





memorize these two extreme points for later

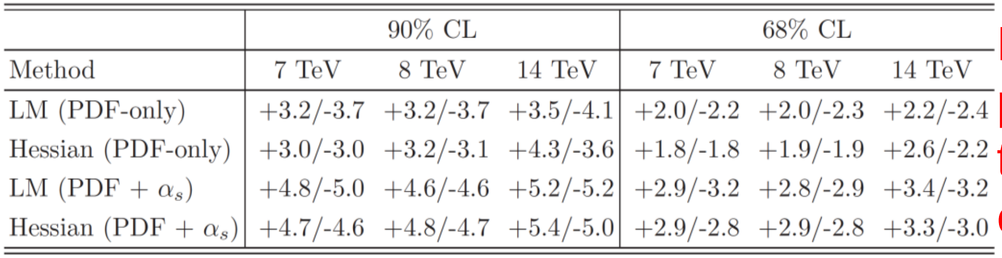


now with Tier 2 penalties

major effect is at 14 TeV

PDF+α_s uncertainties

- LM estimates of PDF(+α_s) uncertainties slightly larger than Hessian determinations, but close, especially for the combined PDF+α_s errors

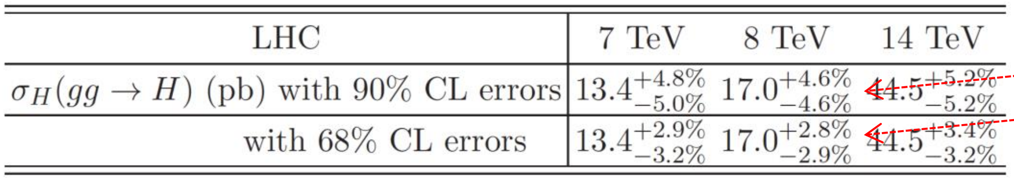


	90% CL			68% CL		
Method	7 TeV	8 TeV	14 TeV	7 TeV	8 TeV	14 TeV
LM (PDF-only)	+3.2/-3.7	+3.2/-3.7	+3.5/-4.1	+2.0/-2.2	+2.0/-2.3	+2.2/-2.4
Hessian (PDF-only)	+3.0/-3.0	+3.2/-3.1	+4.3/-3.6	+1.8/-1.8	+1.9/-1.9	+2.6/-2.2
LM (PDF + α_s)	+4.8/-5.0	+4.6/-4.6	+5.2/-5.2	+2.9/-3.2	+2.8/-2.9	+3.4/-3.2
Hessian (PDF + α_s)	+4.7/-4.6	+4.8/-4.7	+5.4/-5.0	+2.9/-2.8	+2.9/-2.8	+3.3/-3.0

Note that validates the prescription of adding the PDF and α_s errors in quadrature

TABLE V: Uncertainties of $\sigma_H(gg \to H)$ computed by the LM method and by the Hessian method with Tier-2 penalty included. The 90% and 68% CL errors are given as percentage of the centra value, and the PDF-only uncertainties are for $\alpha_s = 0.118$.

- Scaling the 90%CL error from the CT10 eigenvector set by a factor of 1.645 agrees well with the LM more exact determination



LHC	7 TeV	8 TeV	14 TeV
$\sigma_H(gg \to H)$ (pb) with 90% CL errors	$13.4^{+4.8\%}_{-5.0\%}$	$17.0^{+4.6\%}_{-4.6\%}$	$44.5^{+5.2\%}_{-5.2\%}$
with 68% CL errors	$13.4^{+2.9\%}_{-3.2\%}$	$17.0^{+2.8\%}_{-2.9\%}$	$44.5^{+3.4\%}_{-3.2\%}$

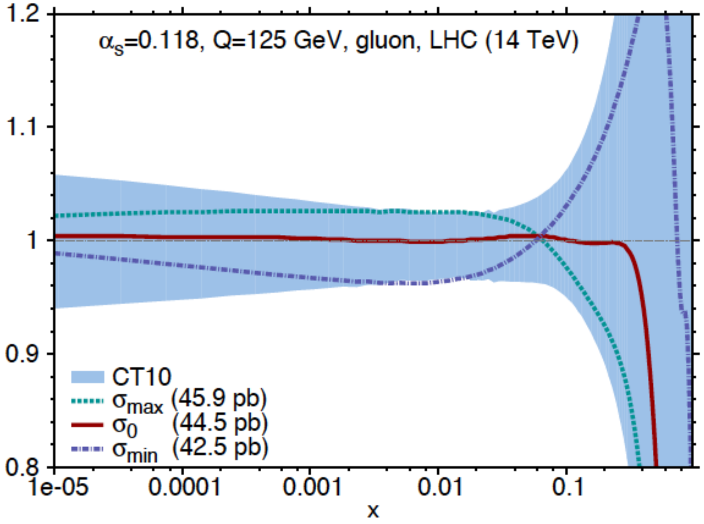
e.g. 4.7%/1.645 =2.85%

TABLE IV: Higgs boson production cross sections via gluon fusion channel at the LHC, with 7, 8 and 14 TeV. The combined PDF and α_s uncertainties at the 90% CL have been calculated by the Lagrange Multiplier method in the CT10H analysis. The errors are expressed as the percentage of the central value.

CT10H (extreme sets)

- Choose extreme PDF sets in slide 6 (red squares)
  - upper uncertainty corresponds to α_s=0.1194 while lower uncertainty to 0.1167
  - other two red squares give PDF uncertainty at α_s=0.118

Note that the two extreme PDF sets saturate the gluon distribution in the x-range relevant for gg->Higgs



sets are available at CTEQ-TEA website

see also Jun's talk on META-PDFs

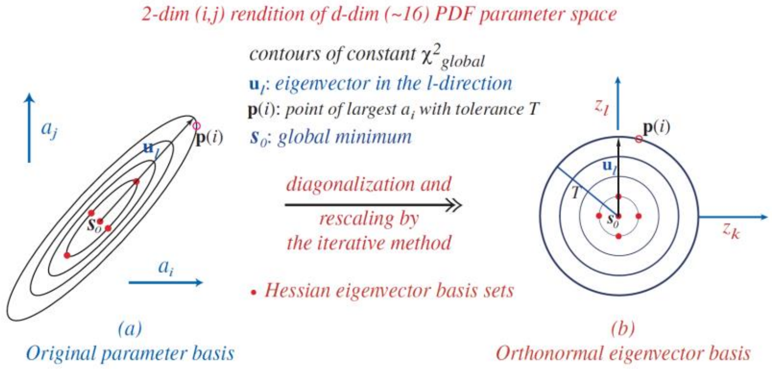
FIG. 9: CT10H gluon PDFs at the momentum scale 125 GeV, compared to the CT10 error band, at the 90% CL. These CT10H fits give the central prediction (σ_0), and the minimum (σ_{min}) and maximum (σ_{max}) predictions obtained using the Lagrange Multiplier method, for σ_H at the LHC with 14 TeV, as listed in Table III. Also, $\alpha_s(M_Z) = 0.118$.

CT10 eigenvectors: brief review

- Each eigenvector has components along the directions of all of the free parameters in the global fit (26 for CT10NLO)
- Sometimes (as in CTEQ6.1) an eigenvector will lie mostly along one particular direction; for CTEQ6.1 and eigenvector 15, that direction saturates the uncertainty for the high x gluon distribution
- But not reproduced for example in CT10

(b)

. **5.8** Distribution of systematic parameters λ_α of the combined HERA-1 data set [?]
CT10 best fit (CT10.00).



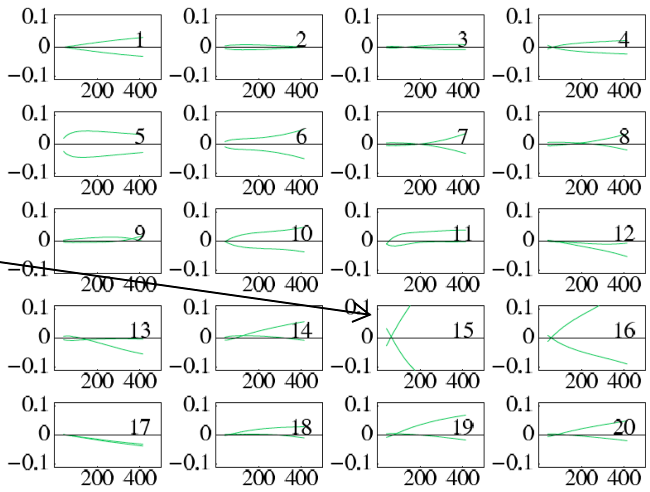
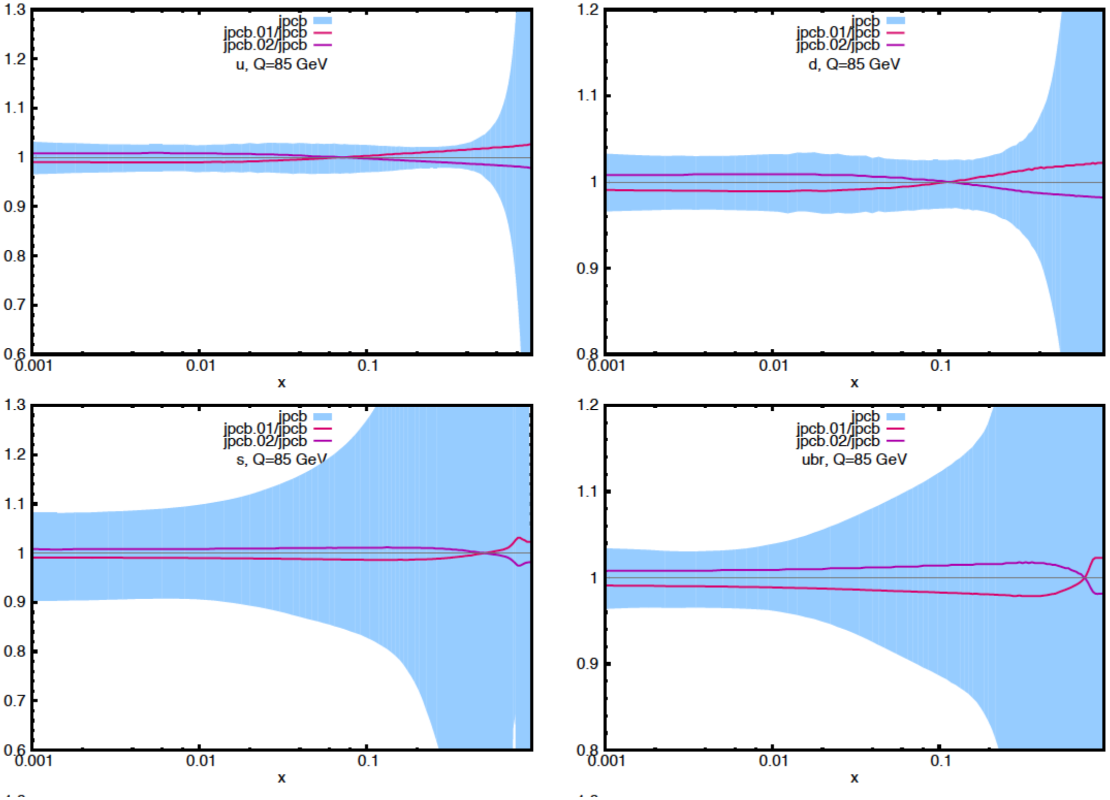


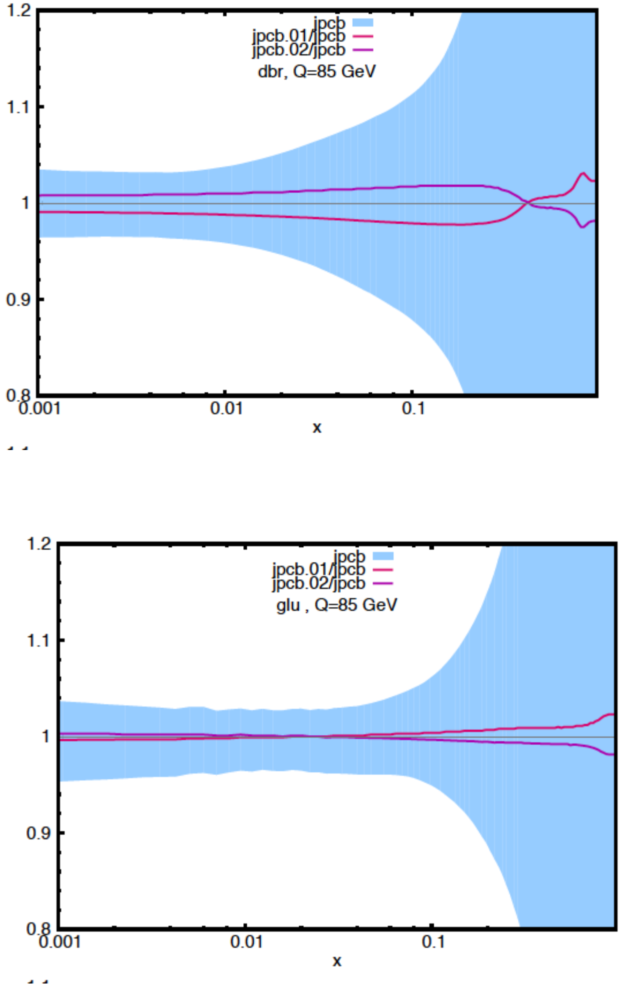
Fig. 5.10 The PDF errors for the CDF inclusive jet cross section in Run 1 for the 20 different eigenvector directions contained in the CTEQ6.1 pdf error set. The vertical axes show the fractional deviation from the central prediction and the horizontal axes the jet transverse momentum in GeV.

A new study (useful to experimentalists)

Largest eigenvalue: nothing much happening

Eigenvector 1:



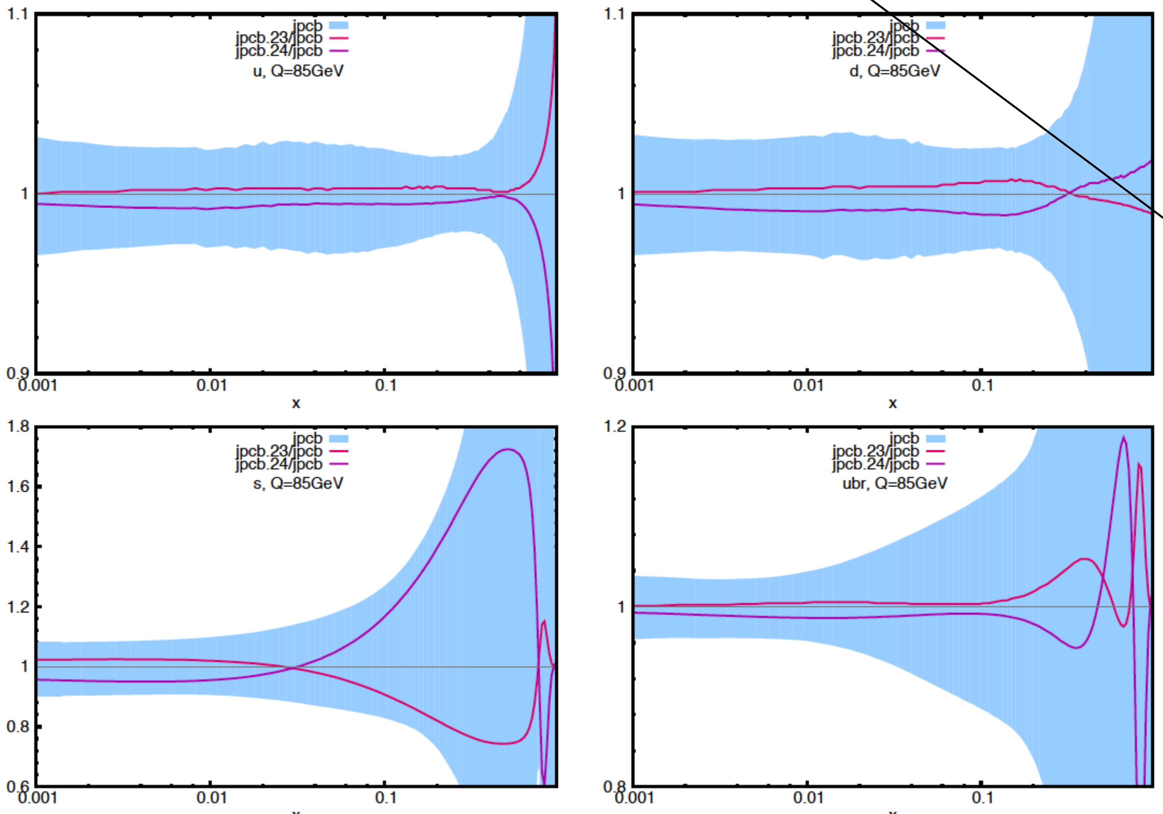


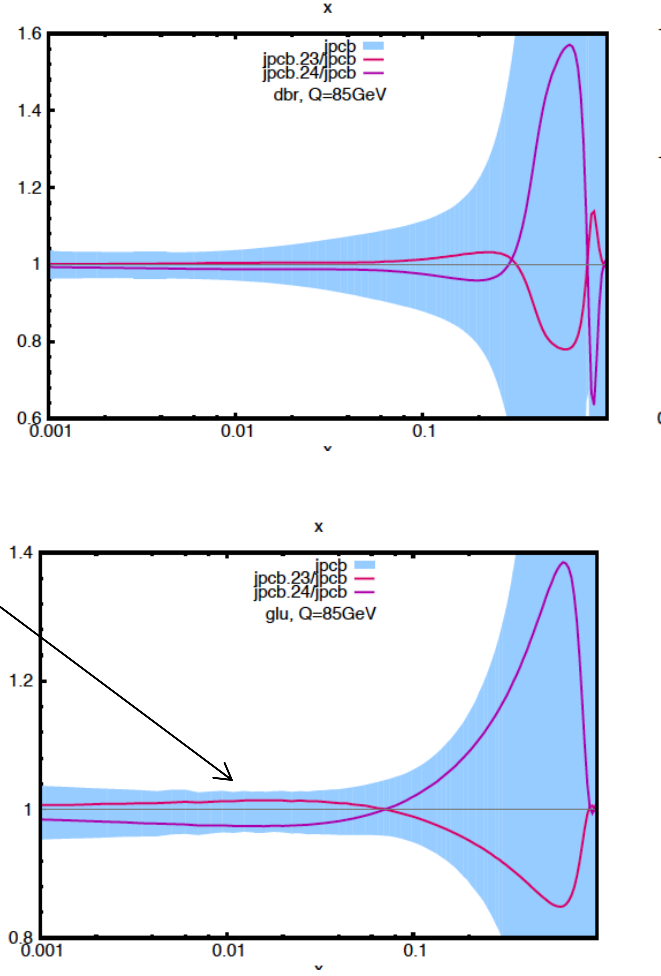
blue band is total PDF uncertainty; curves are contribution from eigenvector

Eigenvector 12

has a fair amount of the gluon uncertainty in the x range for gg->Higgs (as well as at higher x)

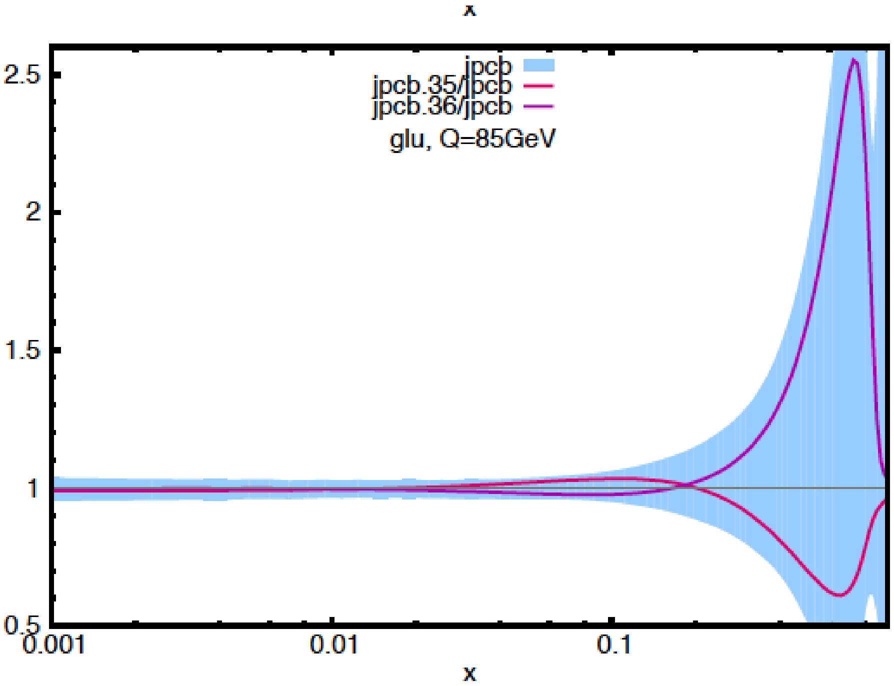
Eigenvector 12:





Eigenvector 18

- Has much of the high x gluon uncertainty



In general…

Eigenvectors 6, 12, and 13 at $x = 0.1$, eigenvectors 15 and 20 at $x = 0.2$, and eigenvectors 18 and 23 $x = 0.4$ contribute the most to the gluon PDF uncertainty, while the others contribute very little.

Eigenvector 10 at $x = 0.1$, eigenvectors 15 and 19 at $x = 0.2$, and eigenvectors 18 and 23 $x = 0.4$ give the dominant contribution to the $\bar{u}$ PDF uncertainty, while the others contribute very little.

Eigenvector 10 at $x = 0.1$, eigenvectors 15 and 19 at $x = 0.2$, and eigenvectors 18 and 23 $x = 0.4$ give the dominant contribution to the $\bar{u}$ PDF uncertainty, while the others contribute very little.

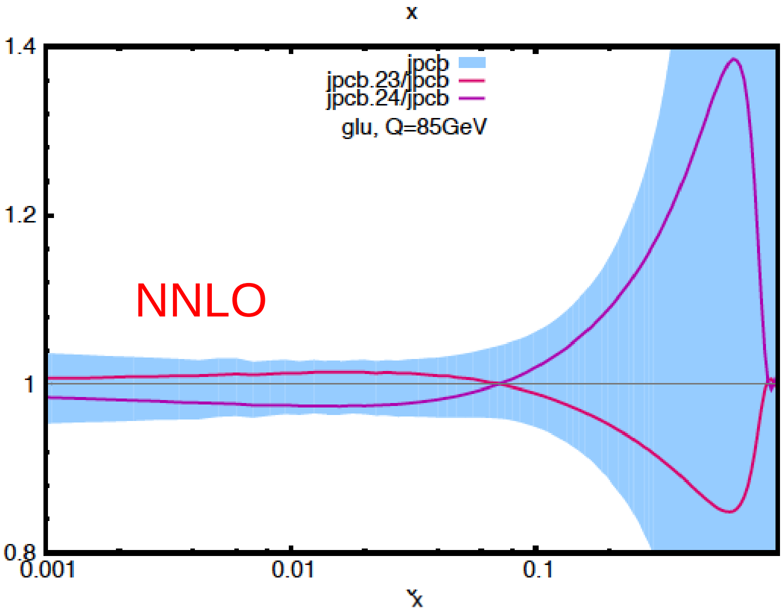
Eigenvectors 10 and 11 at $x = 0.1$, eigenvectors 15 and 20 at $x = 0.2$, and eigenvectors 18 and 23 $x = 0.4$ give the dominant contribution to the $\bar{d}$ PDF uncertainty, while the others contribute very little.

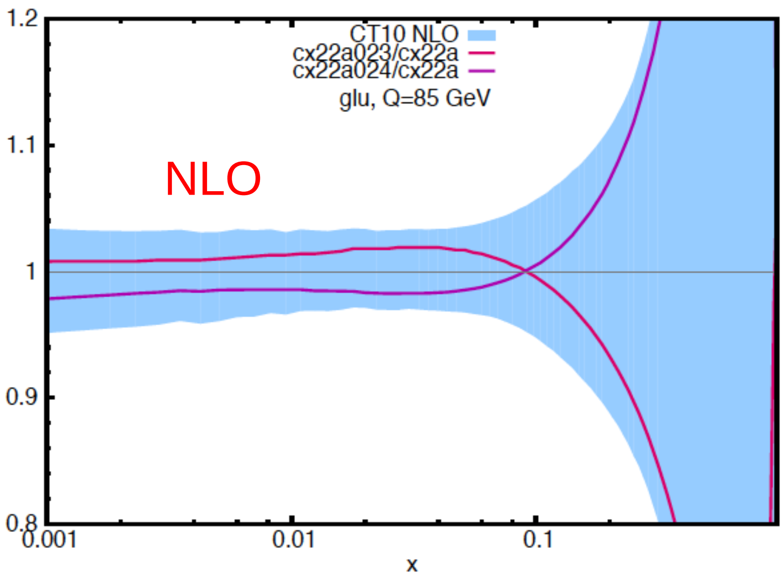
Eigenvectors 9, 12, and 13 at $x = 0.1$, eigenvectors 15,18, 19, 20 and 23 $x = 0.4$ give the dominant contribution to the $s - quark$ PDF uncertainty, while the others contribute very little.

NLO and NNLO

- Eigenvectors have similar behavior at NLO and NNLO

Eigenvector 12





Summary

- Lagrange multiplier study indicates that
  - Hessian errors scale from 90%CL to 68%CL for gg->Higgs (not necessarily for other processes)
  - addition of PDF and α_s errors in quadrature borne out
- LHC data for jets, photons, DY, tT being incorporated into new CT global fits at NLO and NNLO
  - looking forward to full NNLO calculations for inclusive jet and tT differential cross sections

CMS: 8 TeV jet results

SMP-12-012-pas