UNIVERSITÀ DEGLI STUDI
DI MILANO

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Impact of the LHeC *pdfs* measurements on precision EW physics

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In collaboration with F.Demartin, S.Forte, J.Rojo

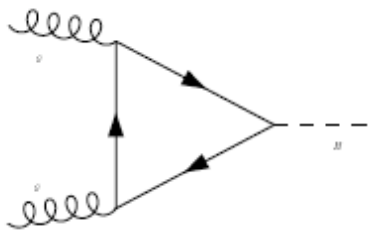
Outline

- The gluon fusion Higgs cross section
- Present experimental uncertainties due to the *pdf*s
- Possible improvement due to small-*x* LHeC data
- Charged current Drell-Yan distributions with LHeC *pdf*s

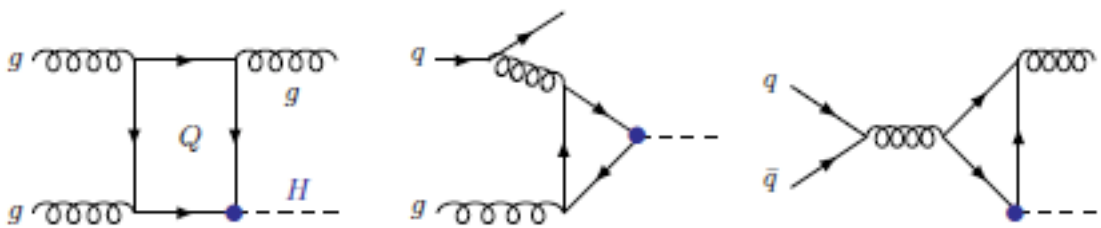
Higgs production at NLO-QCD

$$\sigma(h_1 + h_2 \to H + X) = \sum_{a,b} \int_0^1 dx_1 dx_2 \; f_{a,h_1}(x_1, \mu_F^2)\, f_{b,h_2}(x_2, \mu_F^2) \times$$

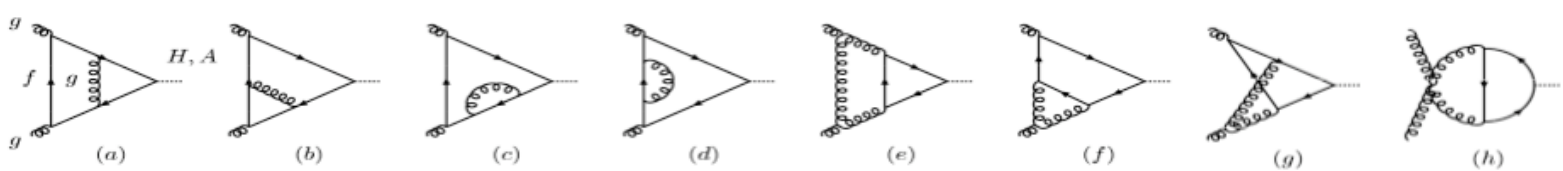
$$\times \int_0^1 dz \; \delta\left(z - \frac{\tau_H}{x_1 x_2}\right) \hat{\sigma}_{ab}(z)\,,$$



LO

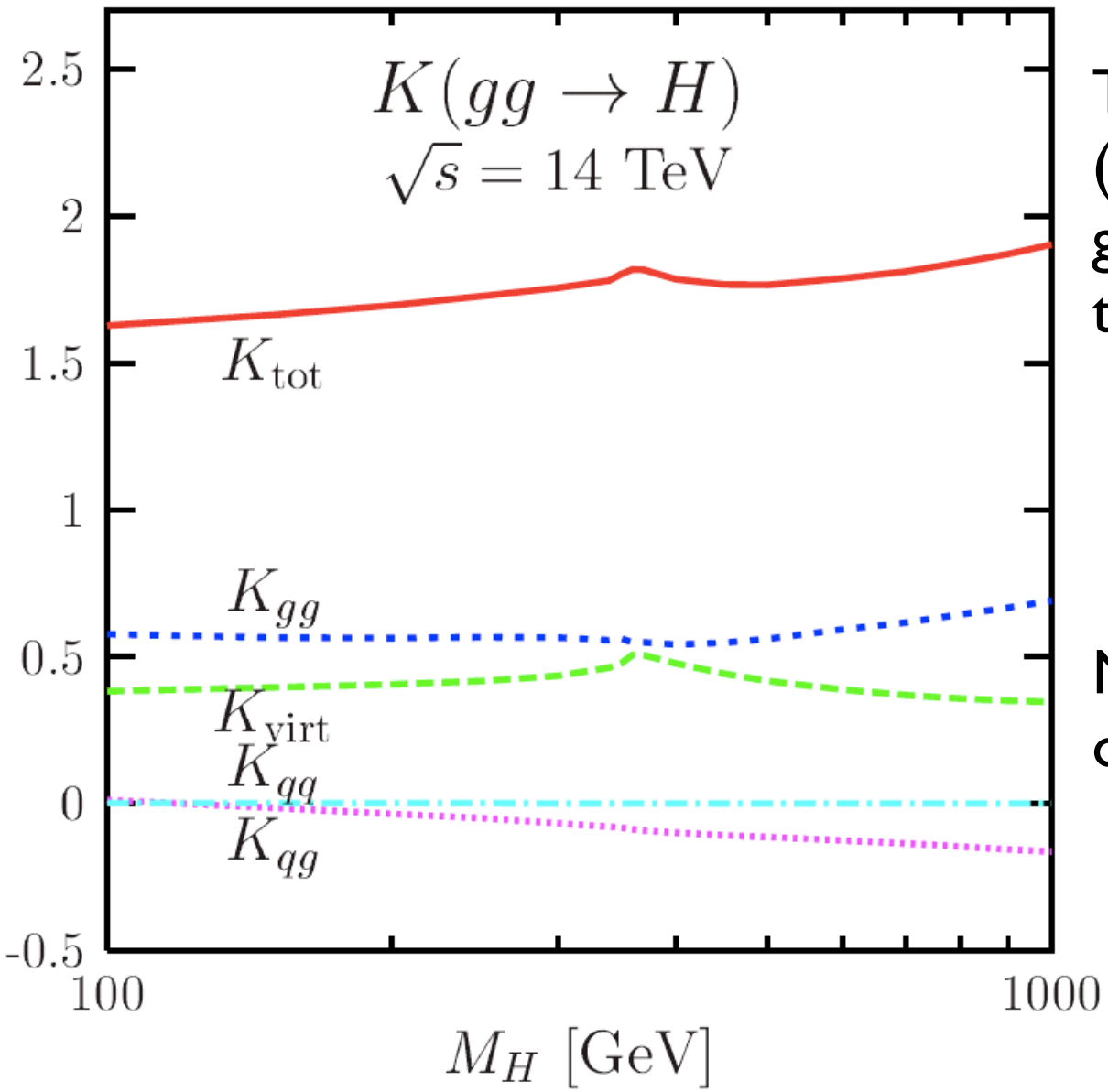


NLO-QCD real



NLO-QCD virtual

Higgs production at NLO-QCD



The gluon subprocesses (both real and virtual) give the largest contribution to the total cross-section

Need to reduce the uncertainty on the gluon pdf

Higgs production beyond NLO-QCD

- NNLO-QCD results in the $m_t \to \infty$ limit (+15%)

  Anastasiou, Melnikov (2002), Harlander,Kilgore (2002)

- finite mt effects at NNLO-QCD (~ 0.5 %)

  Marzani, Ball, Del Duca, Forte,Vicini (2008) Harlander, Ozeren (2009)

- soft-gluon resummation at NNLL-QCD (+ 6%)

  Catani, De Florian, Grazzini, Nason (2003)

- inclusion of leading NNNLO-QCD contributions (+ 5%)

  Moch,Vogt (2005)

- full NLO-EW corrections (+4-7 %)

  Aglietti, Bonciani, Degrassi,Vicini (2004,2005) Actis, Passarino, Sturm, Uccirati (2007,2008), Keung,Petriello (2009)

Further increase of the total cross section: +25-30% of the Born

Stability against renormalization/factorization scale variation

Good accuracy of the partonic cross section

Higgs production at NLO-QCD: *pdfs* uncertainties

The uncertainty due to the experimental errors of the data,
from which the *pdfs* are extracted, is parametrized in different ways:

- Montecarlo replicas
- Hessian method

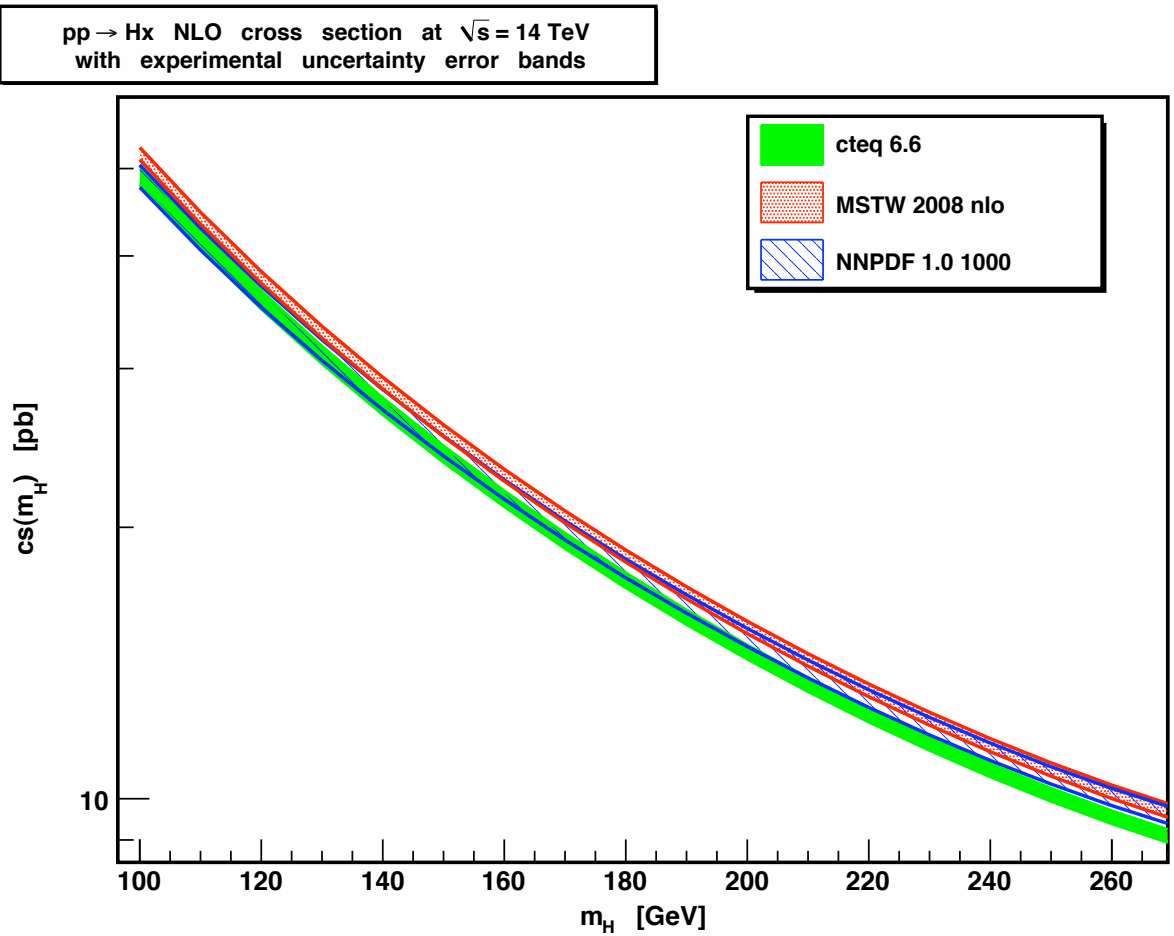
The corresponding definitions to compute the standard deviation
associated to an observable $\mathcal{F}$ is

$$\sigma_{\mathcal{F}} = \left(\frac{1}{N_{\rm set}-1} \sum_{k=1}^{N_{\rm set}} \left(\mathcal{F}[\{q^{(k)}\}] - \langle \mathcal{F}[\{q\}] \rangle \right)^2 \right)^{1/2}$$

$$\sigma_{\mathcal{F}}^{\rm hepdata} = \frac{1}{2C_{90}} \left(\sum_{k=1}^{N_{\rm set}/2} \left(\mathcal{F}[\{q^{(2k-1)}\}] - \mathcal{F}[\{q^{(2k)}\}] \right)^2 \right)^{1/2}$$

In our exercise $\mathcal{F}$ is the inclusive Higgs production cross section at NLO-QCD

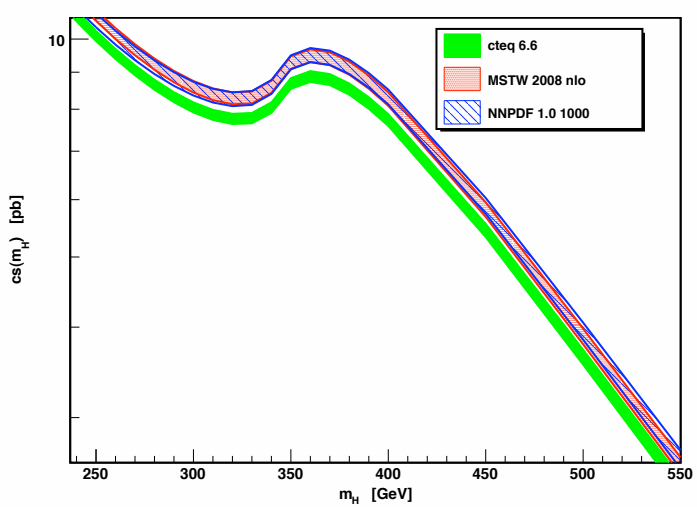
Higgs total cross section at NLO-QCD: actual *pdfs* uncertainties

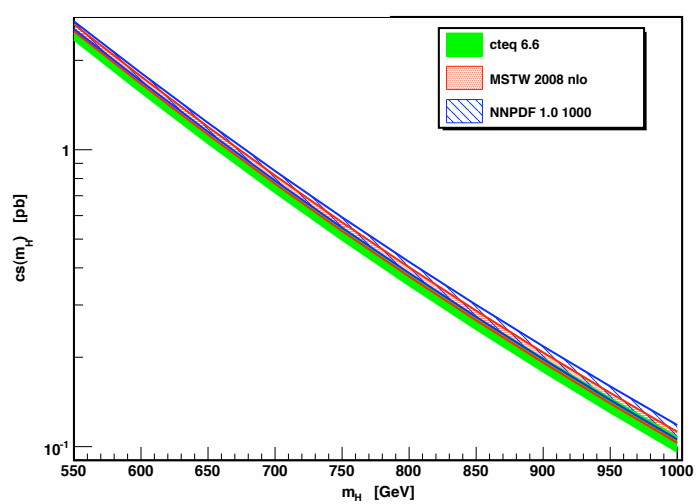


MSTW2008 and CTEQ6.6
do not overlap for MH<500 GeV

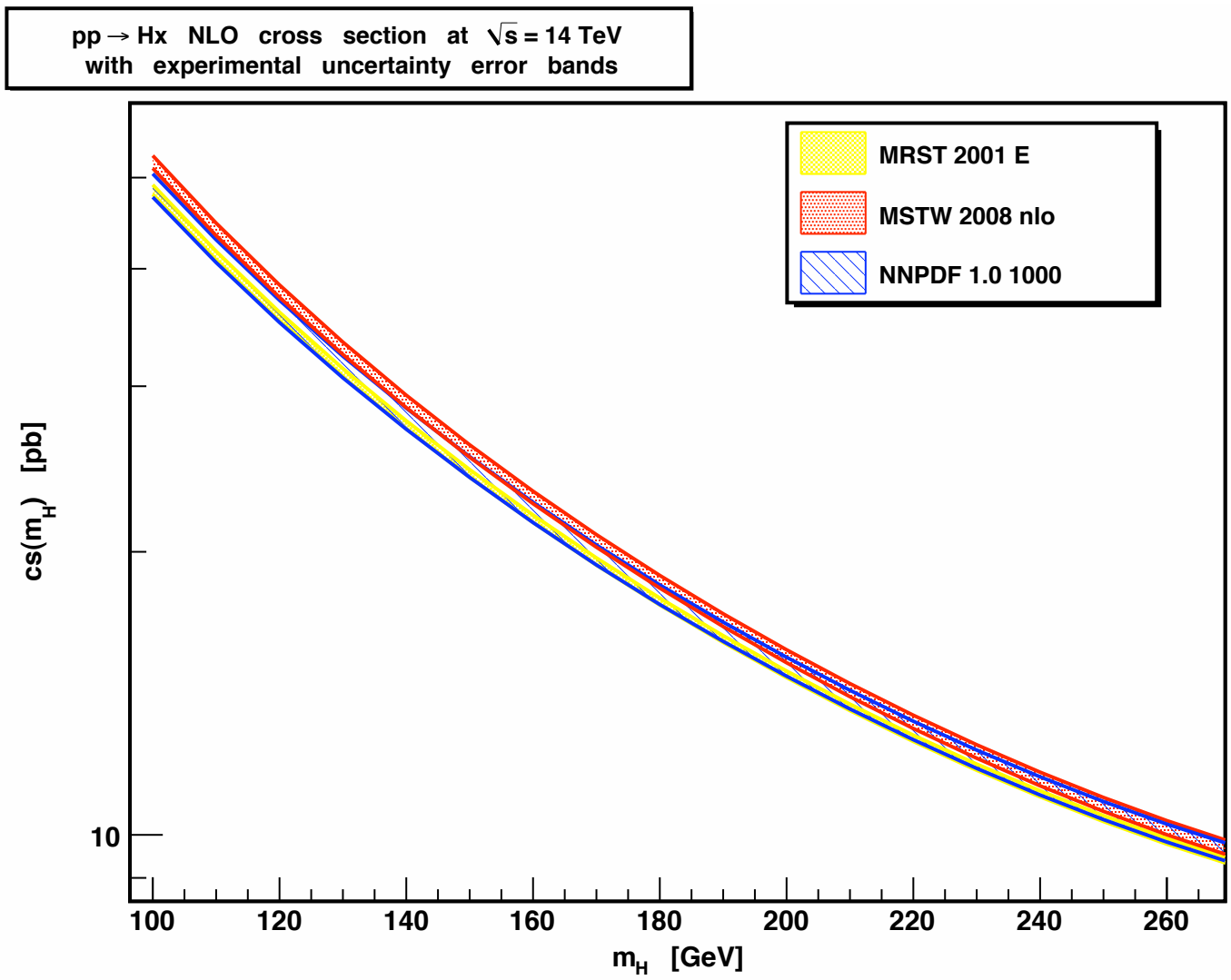
NNPDF1.0 agrees
with CTEQ6.6 for MH<200 GeV
with MSTW for MH>200 GeV

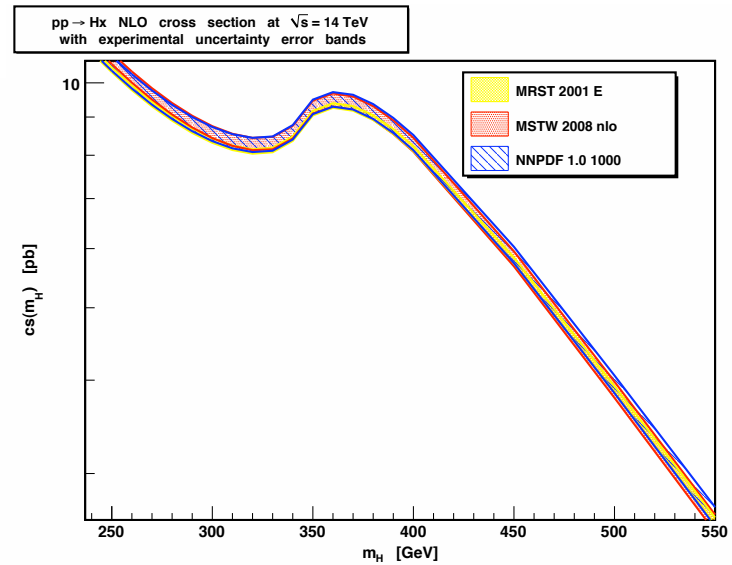
$$\alpha_s(m_Z) = \begin{array}{ll} \text{CTEQ6.6} & 0.118 \\ \text{NNPDF1.0} & 0.119 \\ \text{MSTW2008} & 0.120 \end{array}$$

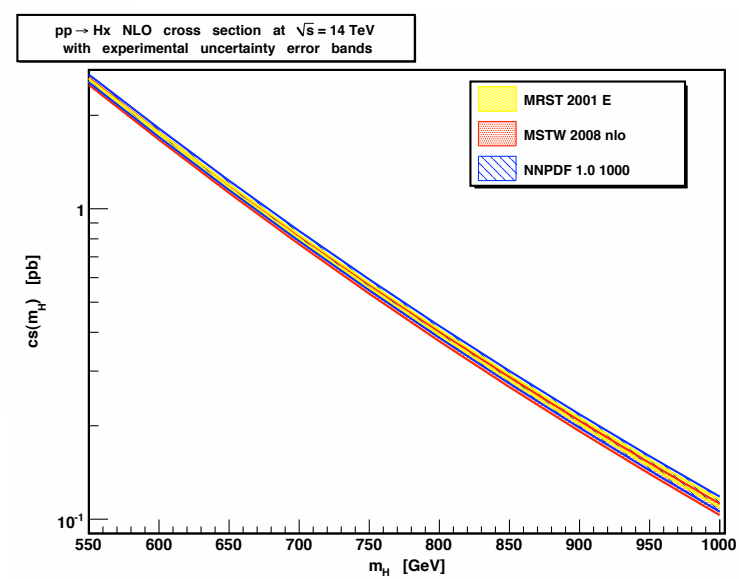




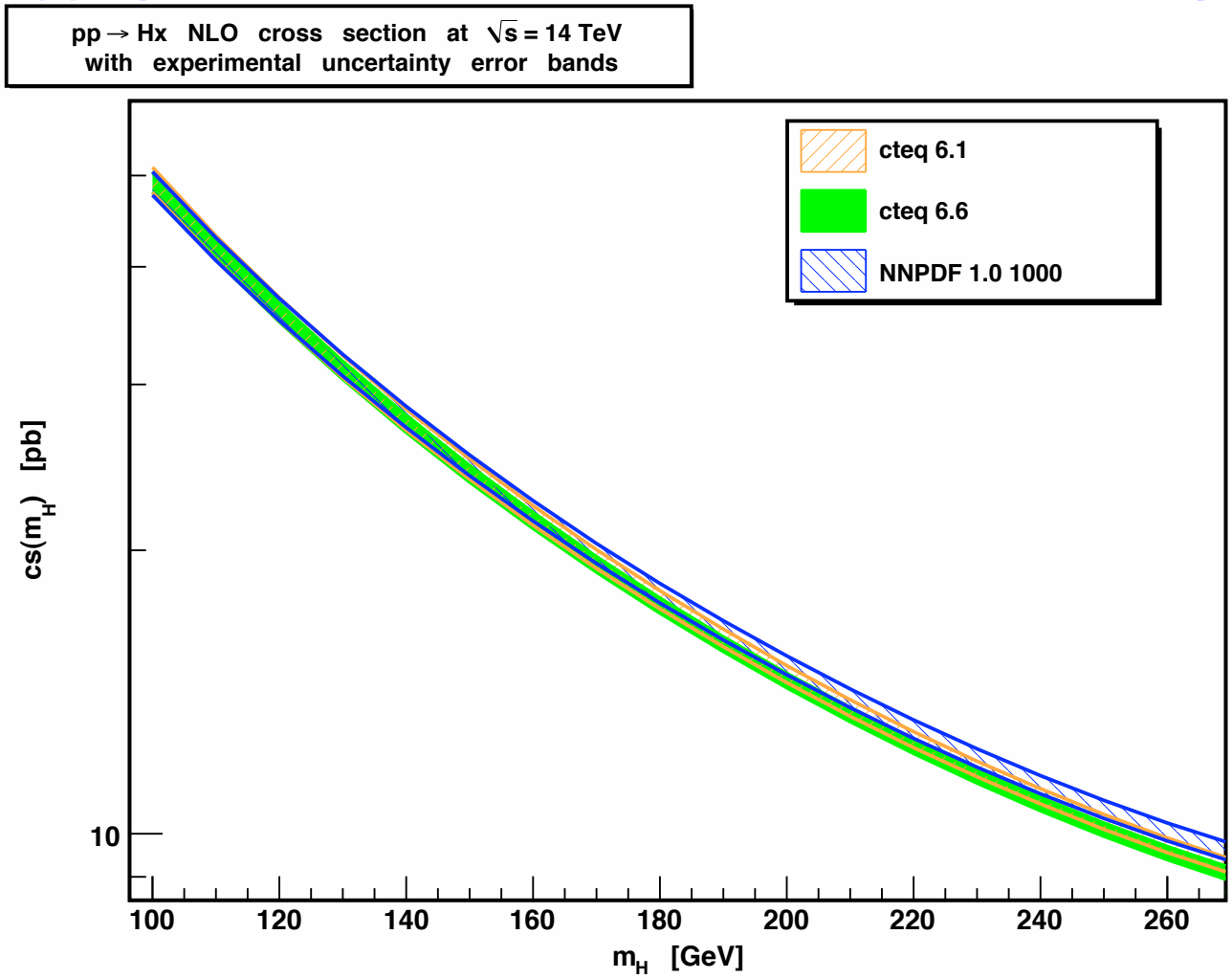
Higgs production at NLO-QCD: historical *pdfs* uncertainties evolution

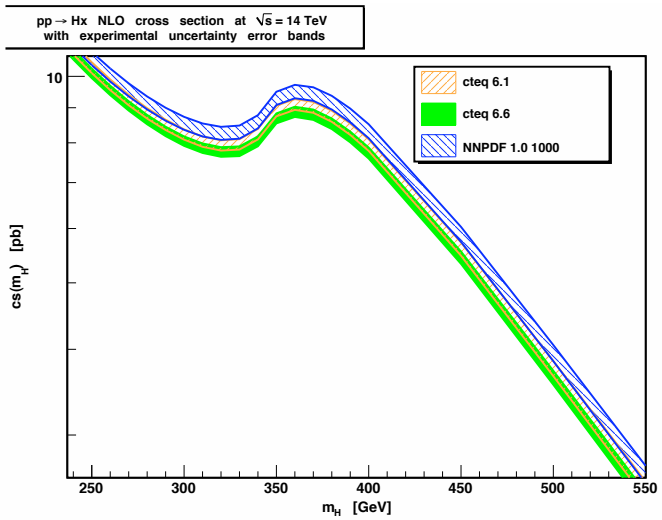


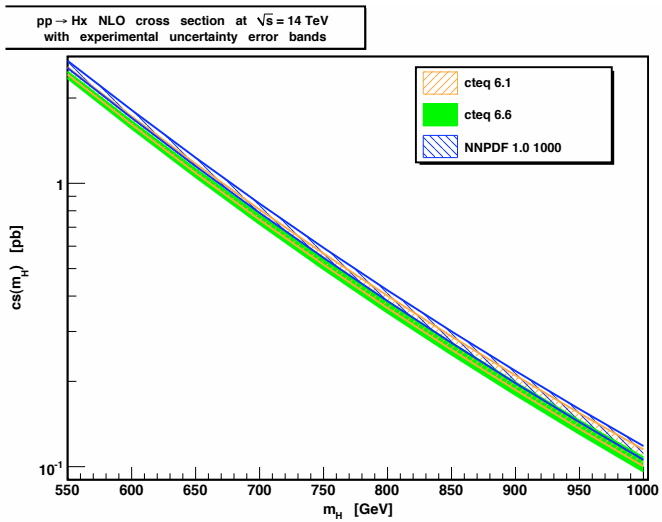




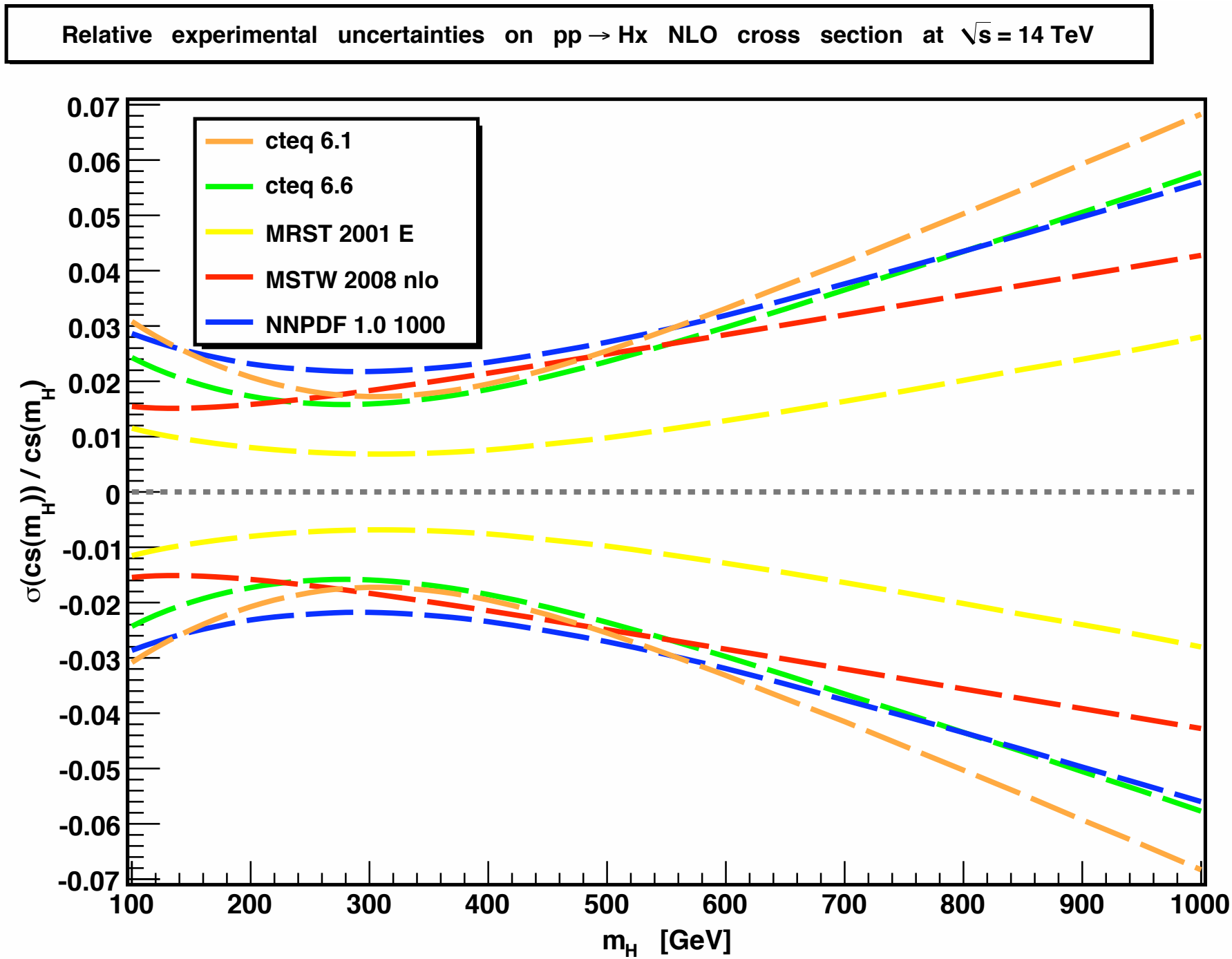
Higgs production at NLO-QCD: historical *pdfs* uncertainties evolution





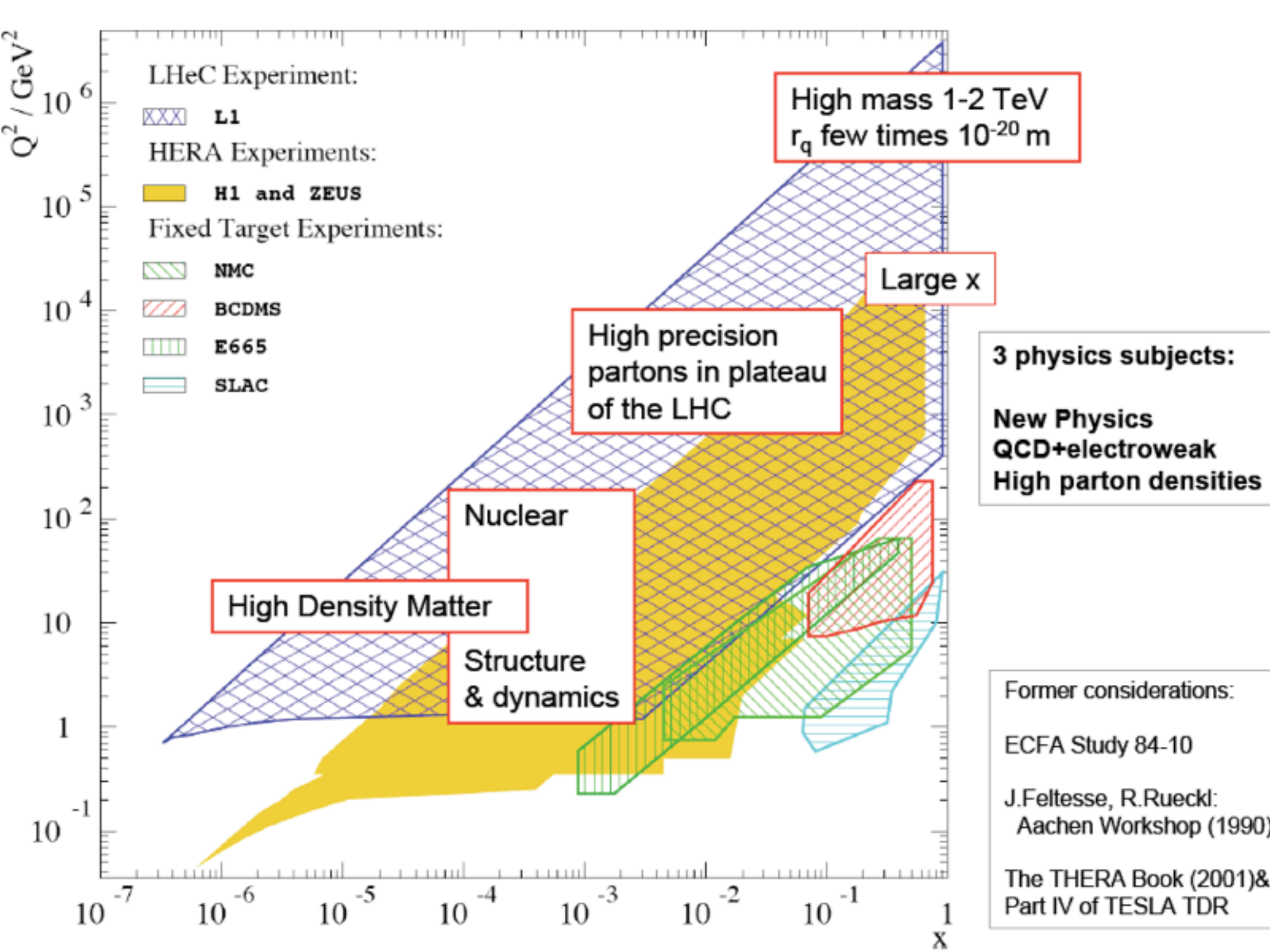


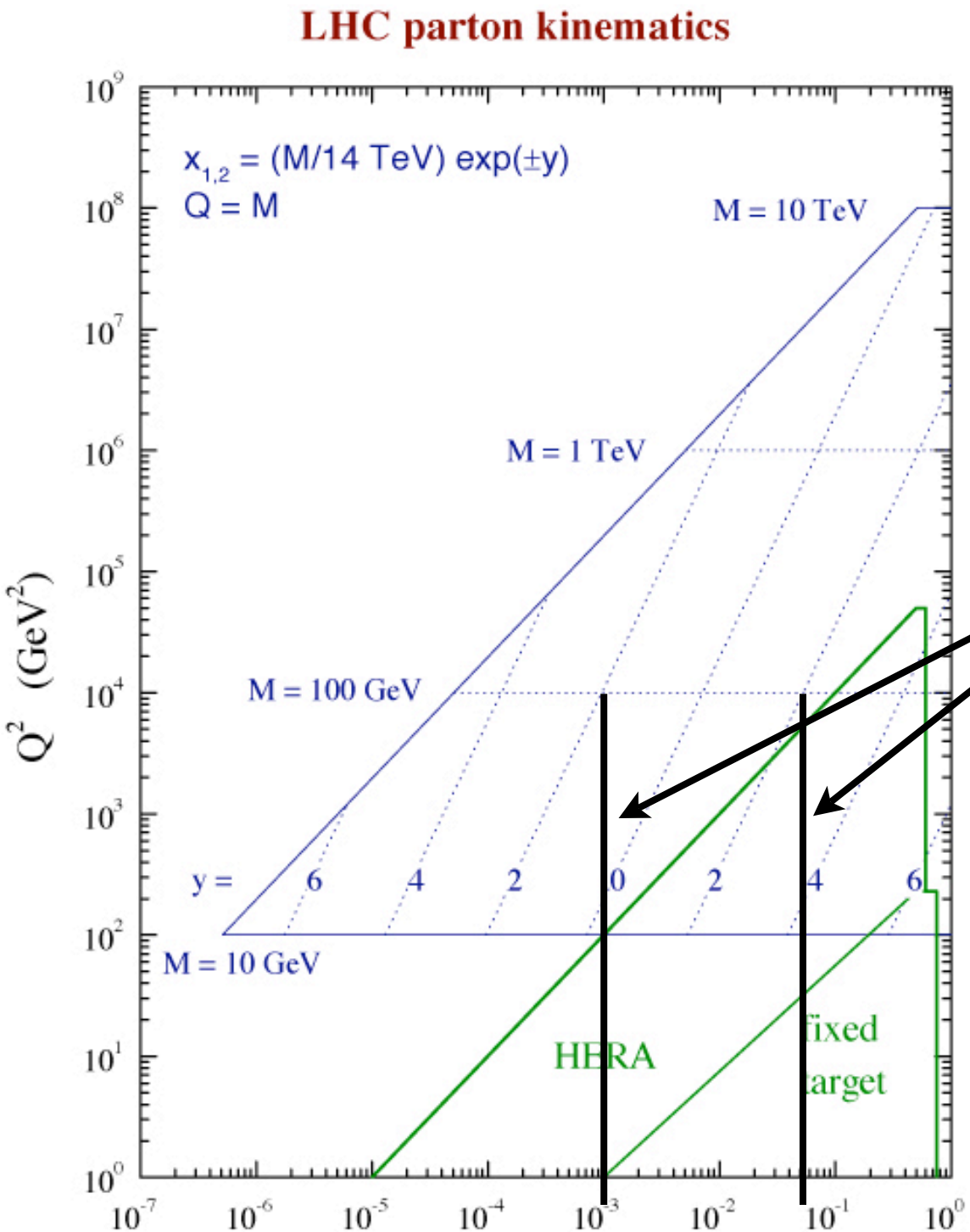
Higgs production at NLO-QCD: summary of the *pdf*s uncertainties



How much could the LHeC *pdfs* measurement improve the determination of some relevant SM cross-sections?

- Generation of LHeC pseudo-data
- Inclusion of the pseudo-data in the NNPDF fit
- Determination of improved parton densities
- Evaluation of relevant cross-sections (Higgs, DY,...) with improved partons


LHeC Experiment:
L1
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
NMC
BCDMS
E665
SLAC
Q^2 / GeV^2
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
High mass 1-2 TeV
r_q few times 10^{-20} m
Large x
High precision
partons in plateau
of the LHC
Nuclear
High Density Matter
Structure
& dynamics
3 physics subjects:
New Physics
QCD+electroweak
High parton densities
Former considerations:
ECFA Study 84-10
J.Feltesse, R.Rueckl:
Aachen Workshop (1990)
The THERA Book (2001)&
Part IV of TESLA TDR

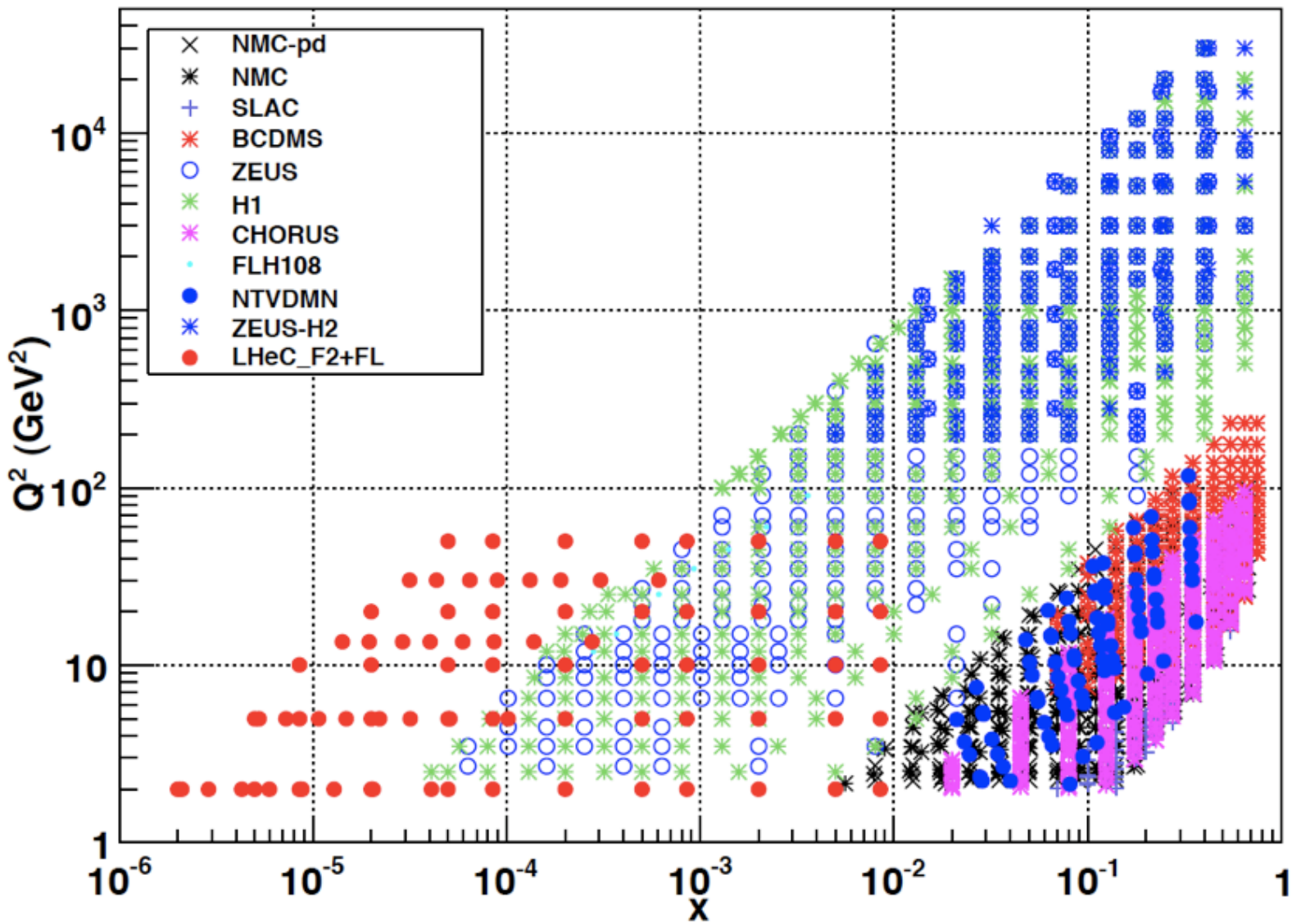


values of *x* relevant
to produce a final state with
invariant mass of 100 GeV
in the central rapidity interval

Simulation of LHeC data and determination of "LHeC *pdfs*"

Consider LHeC F_2 and F_L pseudo-data at small-x (P.Newmann)

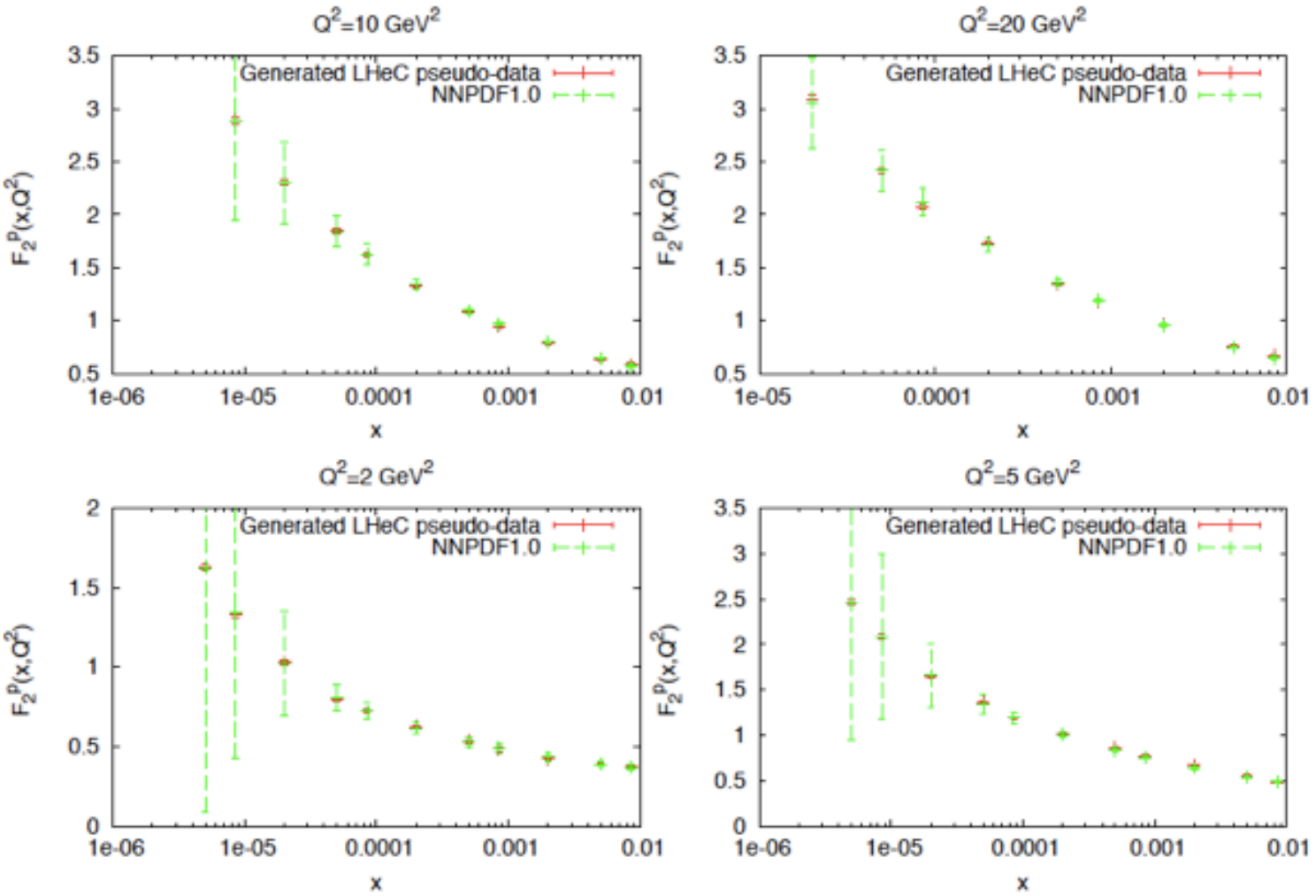
$E_e = 70$ GeV $\quad \int \mathcal{L} = 1\text{fb}^{-1} \quad \theta_e \leq 179^o \quad x \leq 0.01, Q^2 \leq 50\text{GeV}$



Constraining PDFs at the LHeC - Results

F_2^p and F_2^L NLO DGLAP in NNPDF analysis:

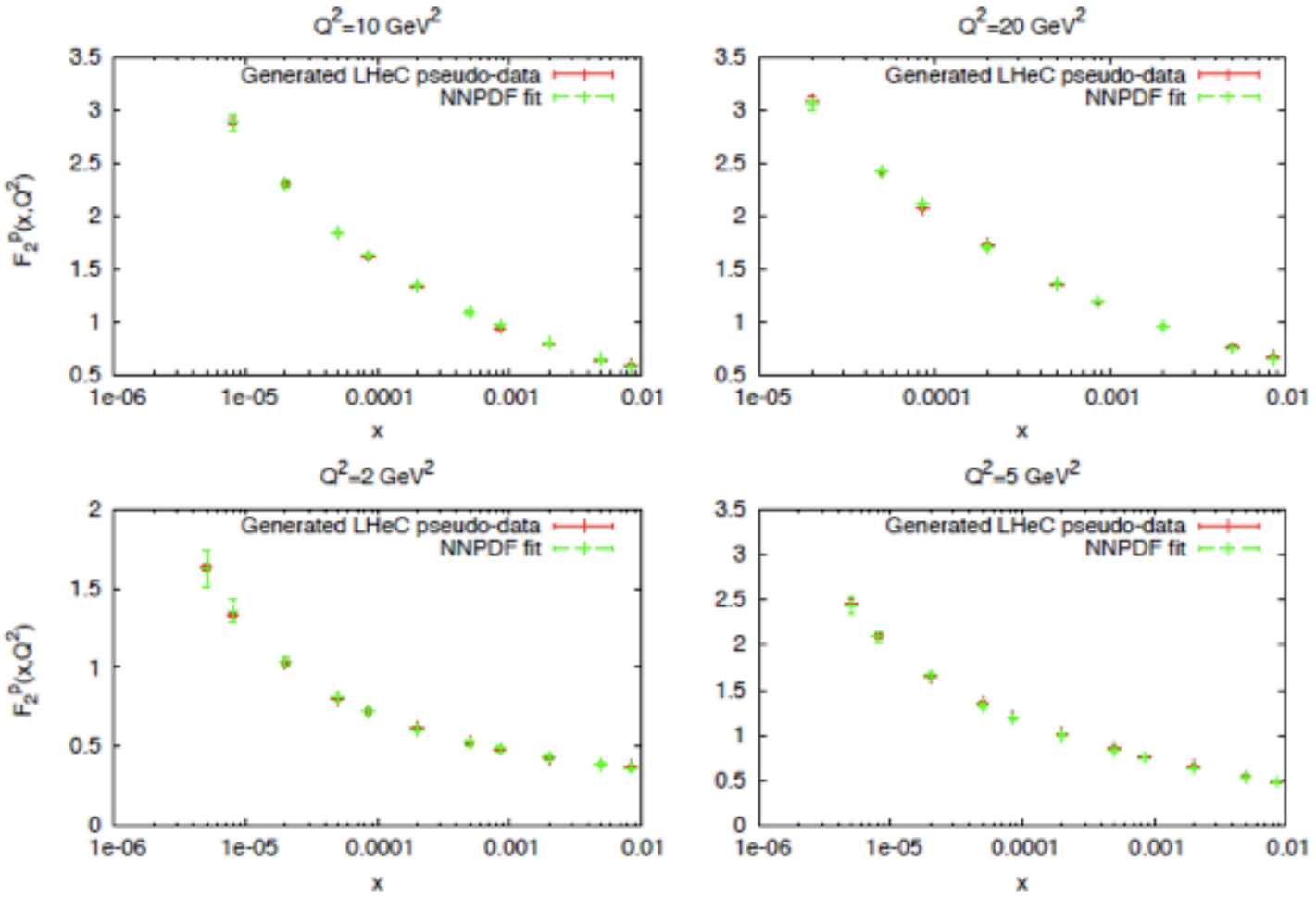
Before the fit ... (Notice small statistical errors at low$-x$)



Constraining PDFs at the LHeC - Results

F_2^p and F_2^L NLO DGLAP in NNPDF analysis:

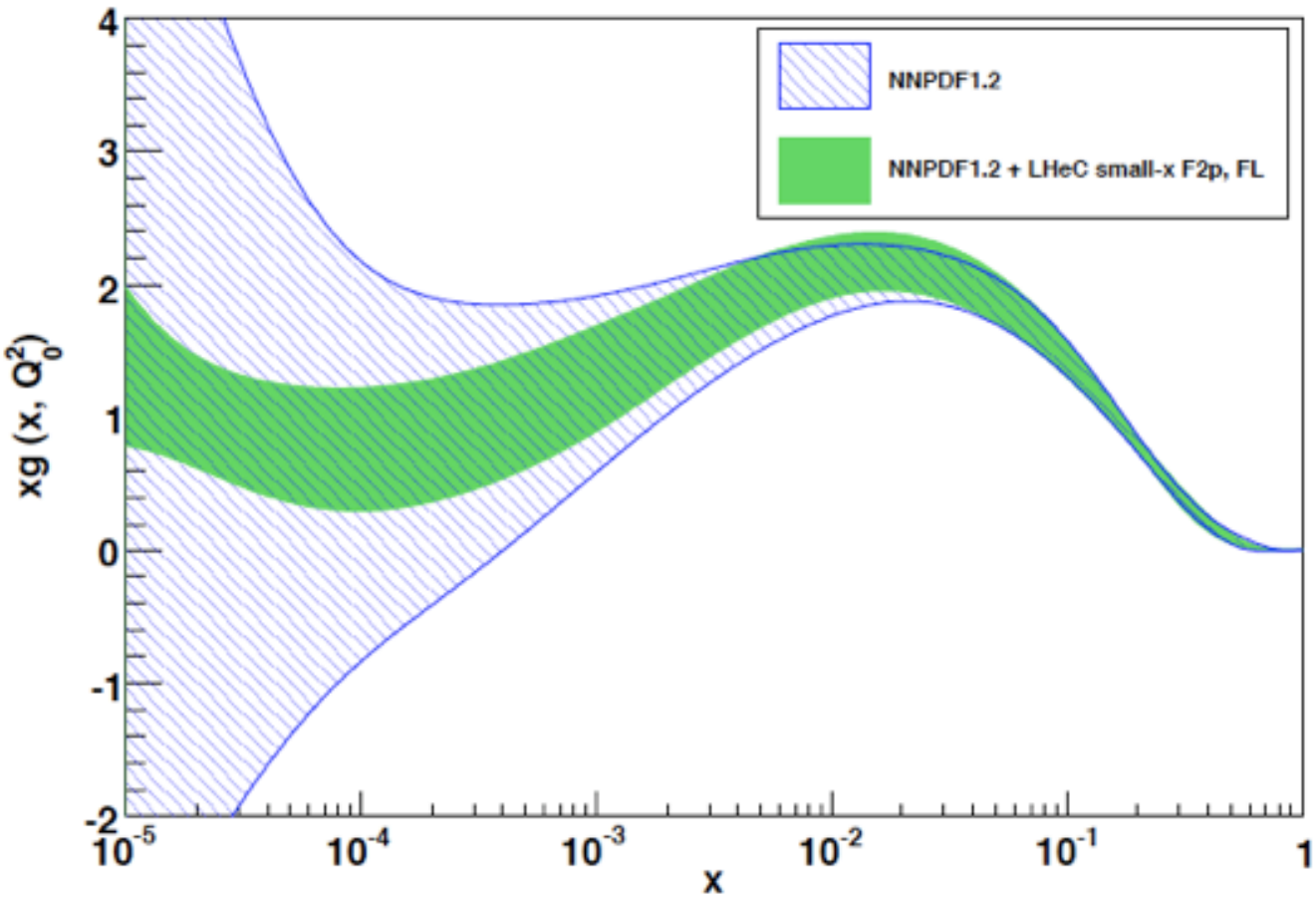
... and after the fit → Huge error reduction in F_2^p predictions



Comparison of LHeC vs current *pdfs*

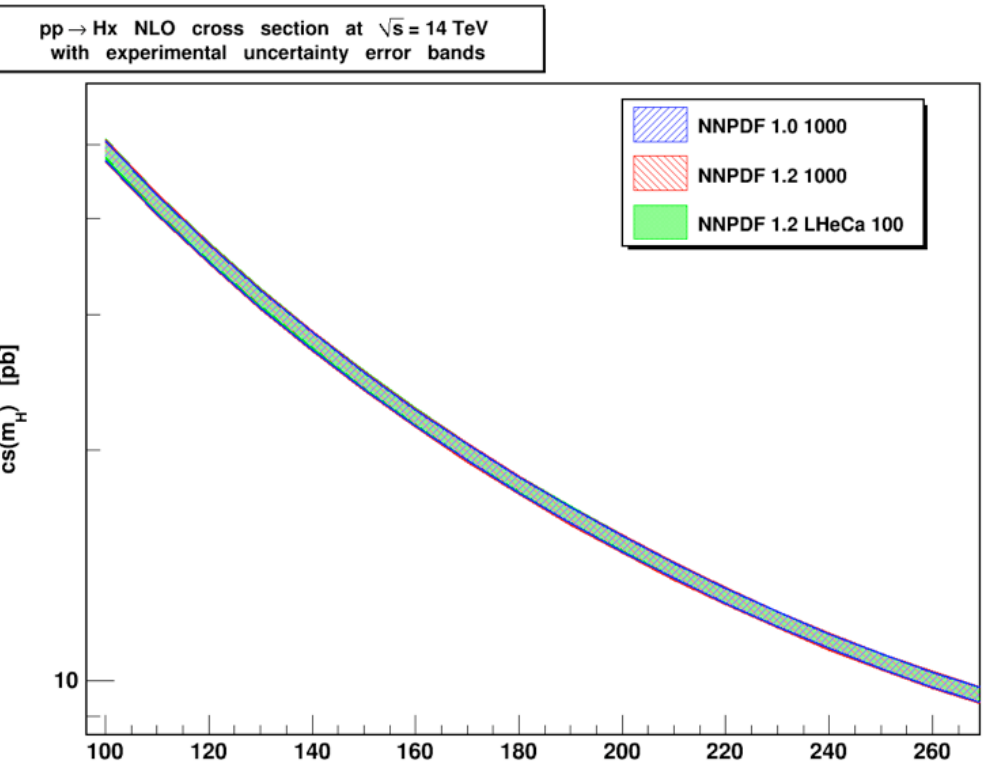
F_2^P and F_2^L NLO DGLAP in NNPDF analysis:

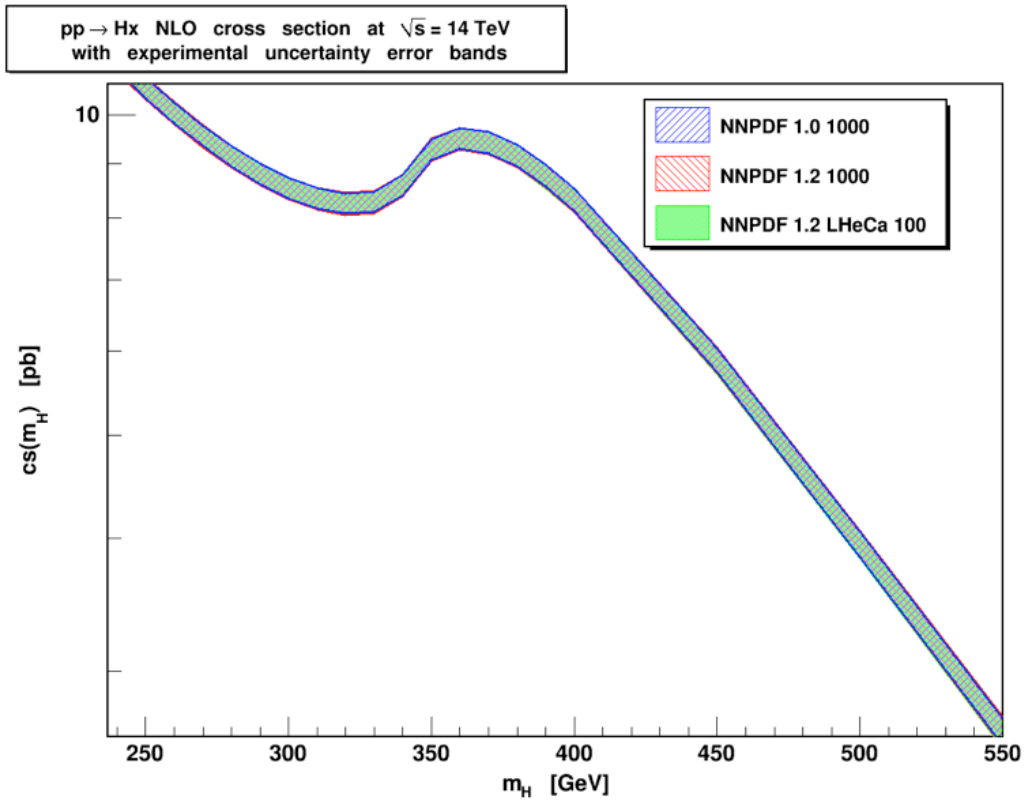
Gluon uncertainties with F_2^P and F_L^P LHeC data

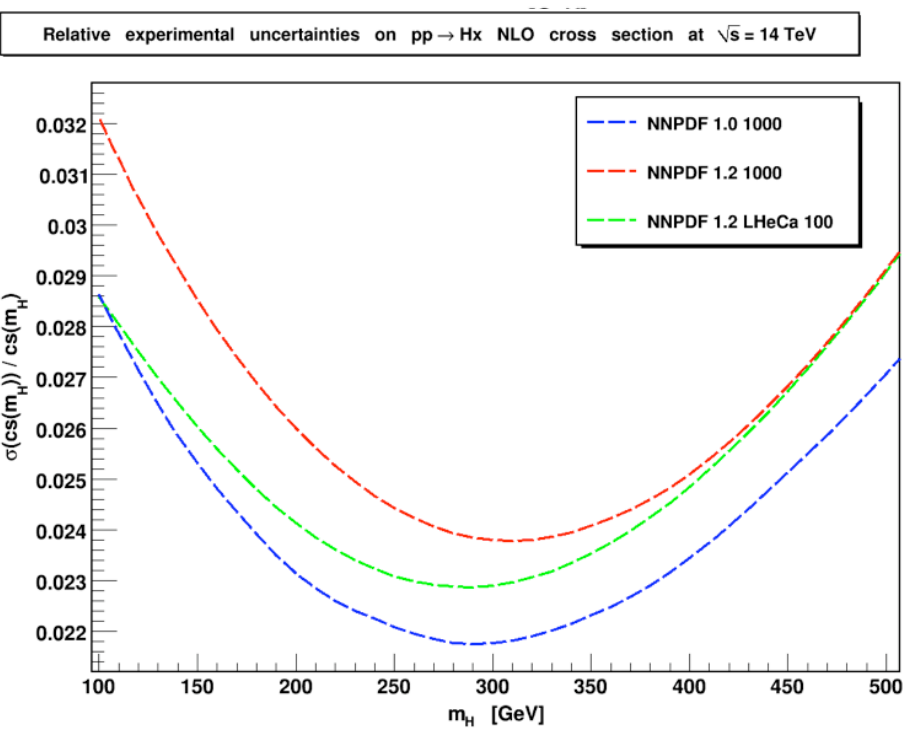


→ Sizable error reduction of gluon at small-x requires LHeC F_L data

Higgs production and improvement due to LHeC *pdfs*







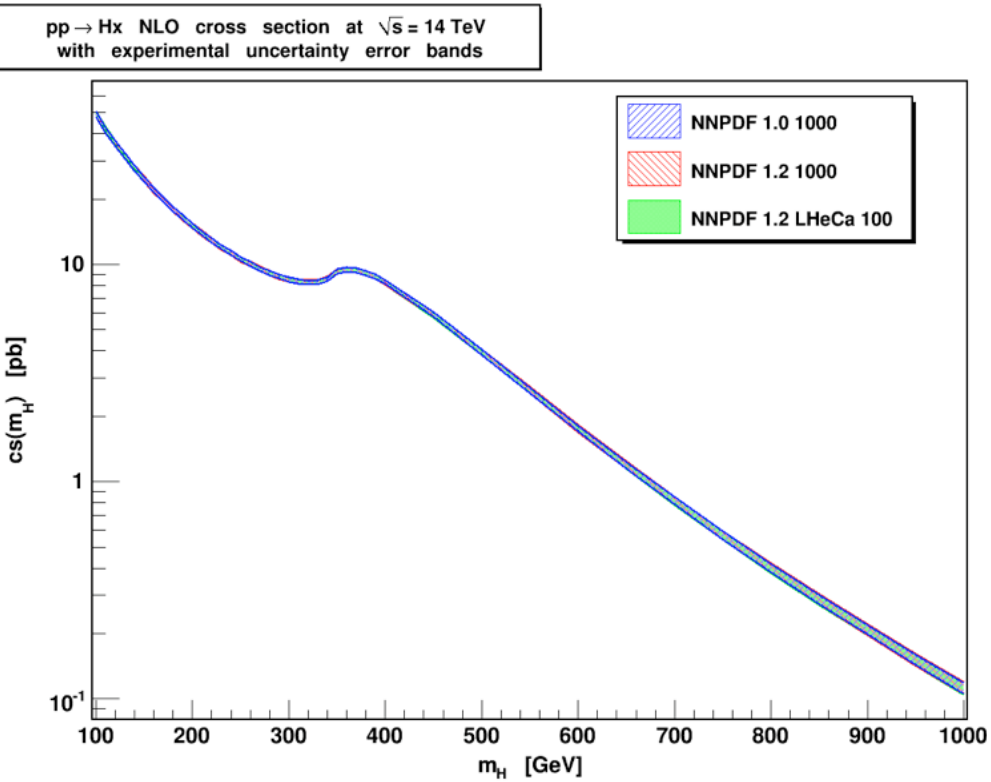
Comparison of

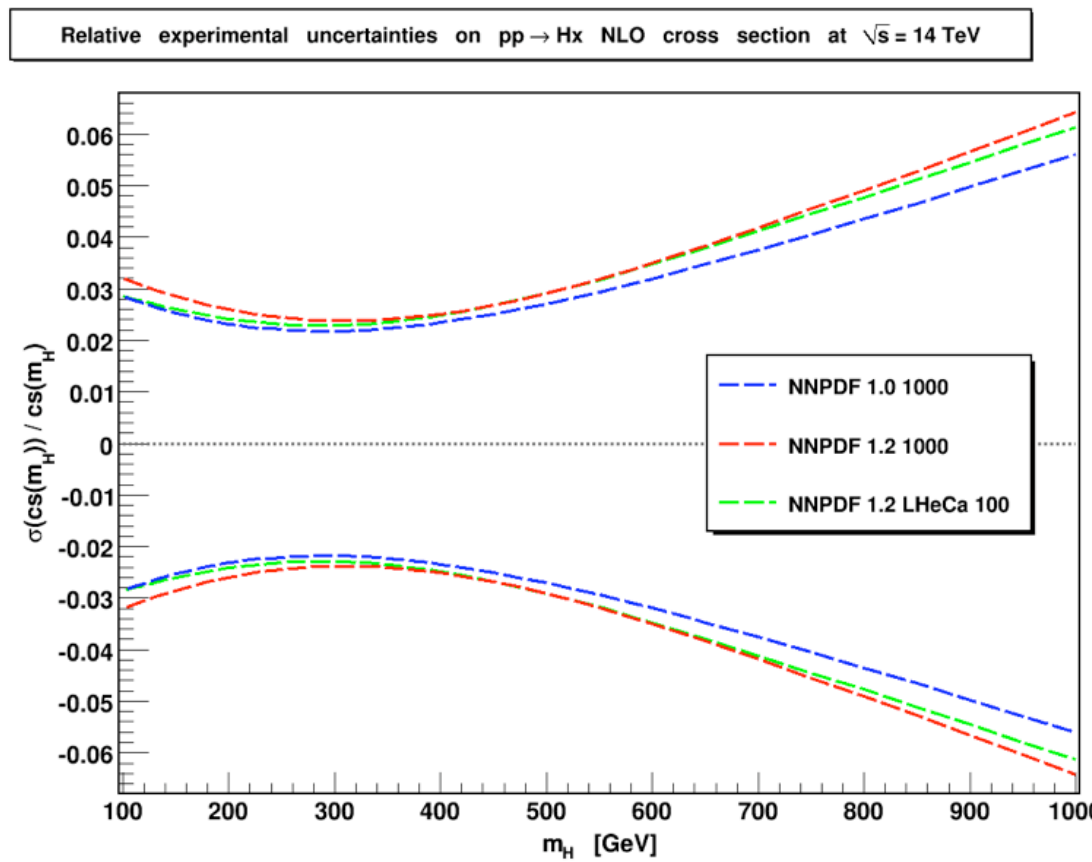
NNPDF1.2 vs NNPDF1.2LHeC

Tiny improvement (0.3 %)

for small values of mH

Higgs production and improvement due to LHeC *pdfs*





Higgs production and improvement due to LHeC *pdf*s

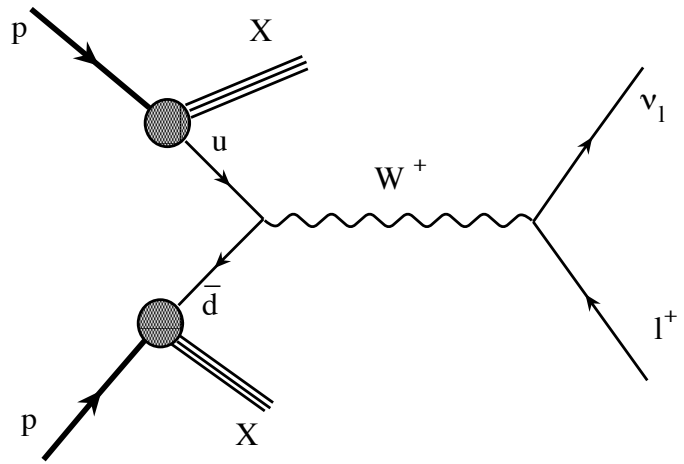
The small-*x* region plays a minor role in the evaluation of the inclusive cross section (dominated by lowest-order threshold kinematics)

Cross section dominated by the lowest order threshold kinematics
Large contribution due to soft gluon emission at the threshold
One small-*x* value in one pdf requires a large-*x* value in the other, but the steep fall of the gluon density suppresses these contributions

The full LHeC (pseudo-)dataset including DIS-jets, CC will constrain the large-*x* gluon density and lead to a more significant reduction of the *pdf*s uncertainty

➔ need to repeat the analysis
after the inclusion of all the LHeC pseudo-data (DIS-jets, CC)

Charged current Drell-Yan and improvement due to LHeC



LHC central detector region $p_\perp^l, p_\perp^{miss} > 25\mathrm{GeV}$

$$\eta_l < 2.5$$

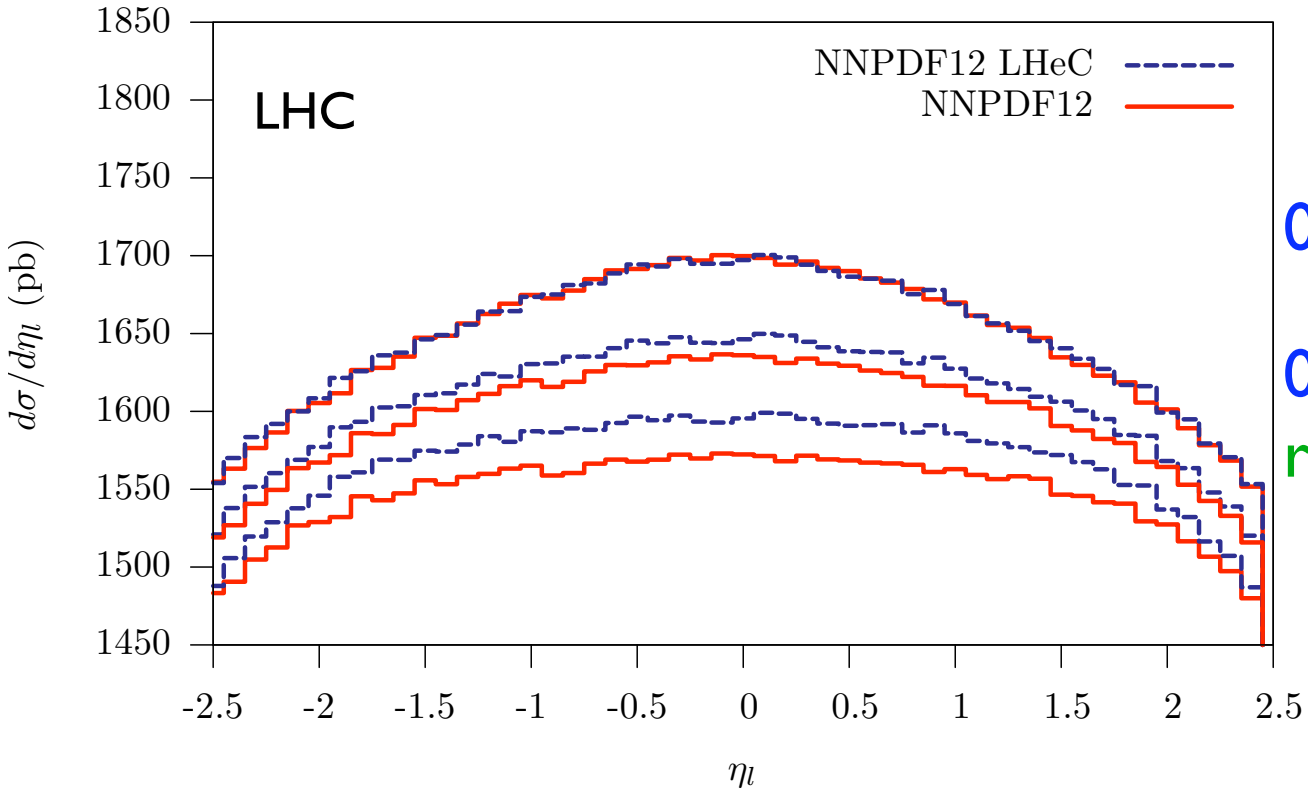
At the LHC large contribution to Drell-Yan due to sea quarks

HORACE: fully exclusive Montecarlo event generator

Study of lepton pseudorapidity and transverse momentum

for fixed $p_\perp^l \ (\eta_l)$ all the others d.o.f. are integrated, spanning the available interval for $x_{1,2}$

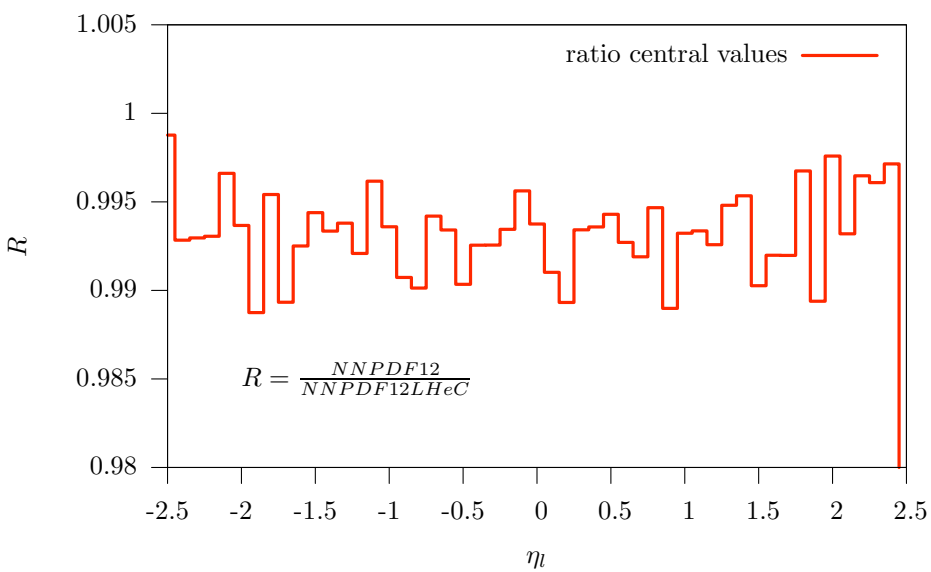
Charged-current Drell-Yan: lepton pseudo-rapidity

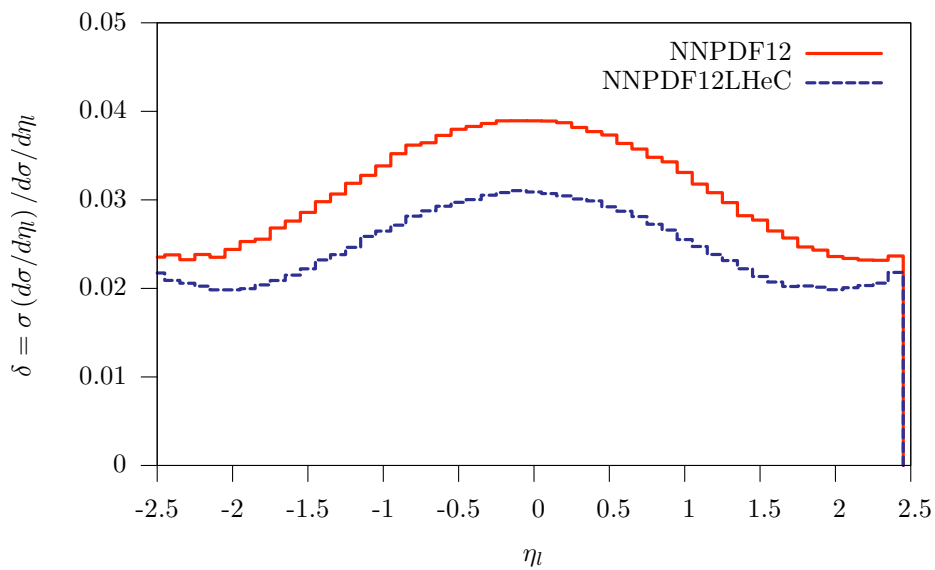


$p_\perp^l, p_\perp^{miss} > 25\text{GeV} \quad \eta_l < 2.5$

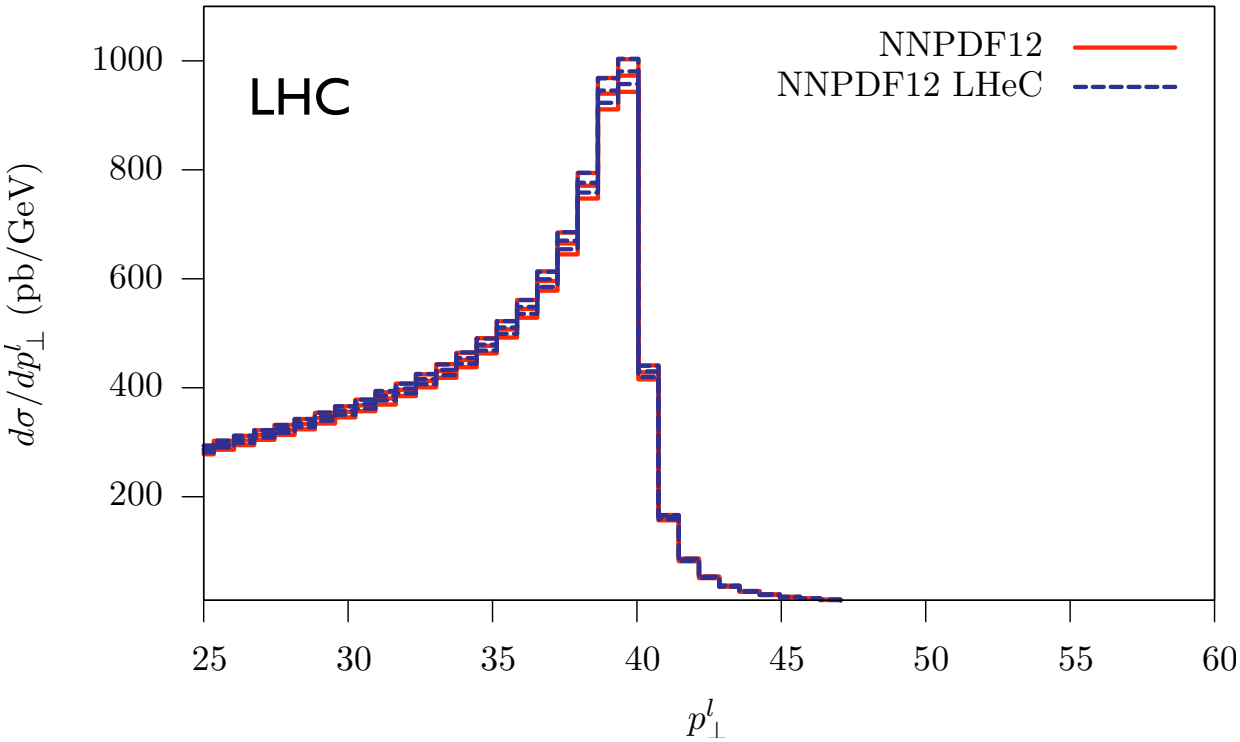
0.5% increase of central value

0.2-1.0 % non constant reduction of uncertainty band





Charged-current Drell-Yan: lepton transverse momentum

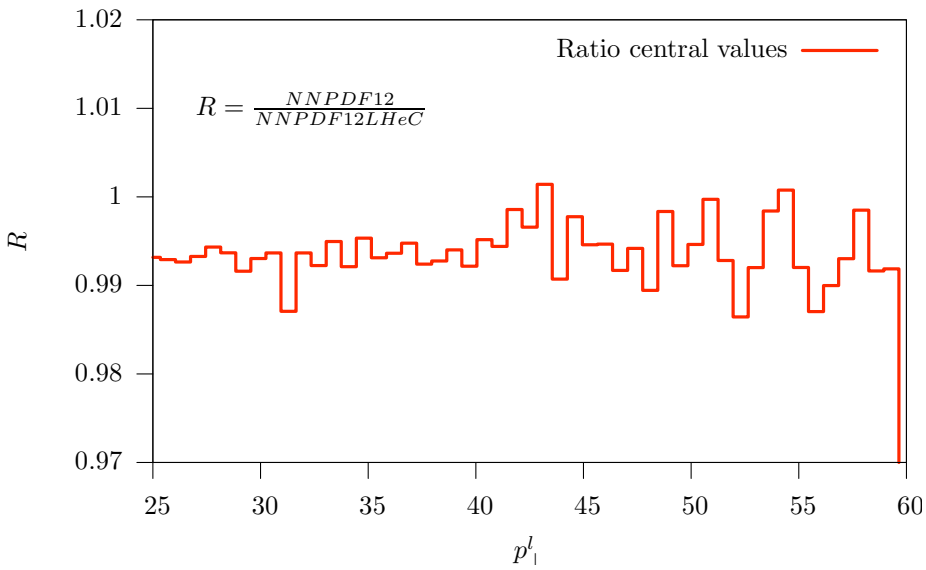


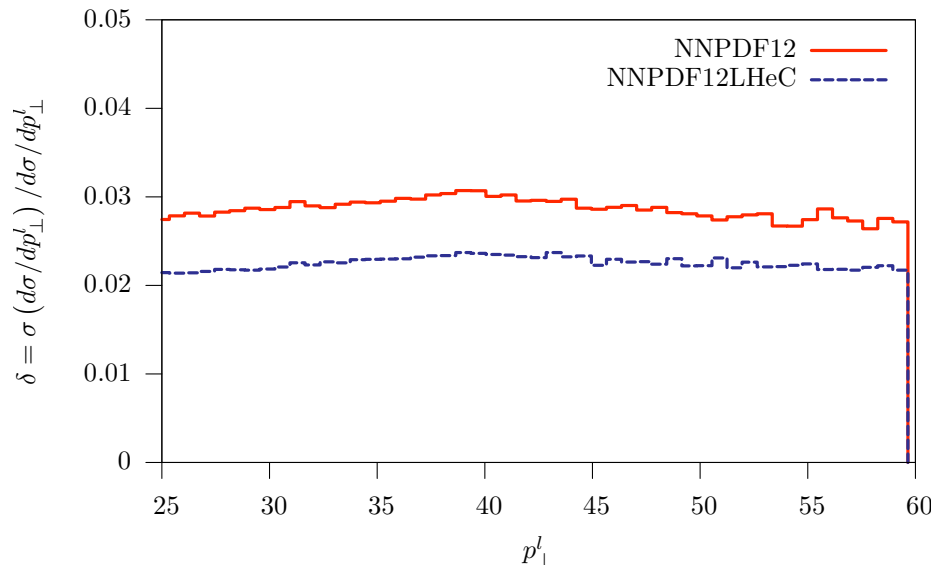
$$p_\perp^l, p_\perp^{miss} > 25\text{GeV} \qquad \eta_l < 2.5$$

0.5% increase of central value

0.7 % flat reduction of the uncertainty band

it will help to improve the W mass determination





Conclusions

- Tiny sensitivity of the inclusive gluon-fusion Higgs cross-section to the LHeC *pdf*s improvement in the small-*x* region

➔ the inclusion of all the LHeC pseudo-data (DIS-jets, F2c) reducing the uncertainty of the gluon density for medium-large *x* might lead to a more significant reduction of the cross-section uncertainty

- Lepton distributions in the charged-current Drell-Yan are sensitive to a larger range of *x* values

➔ they might benefit of the small-*x* LHeC improvement because of the important role of the sea quarks

To do:

- Include all the available LHeC pseudodata to repeat in a more complete form this exercise
- Study more exclusive Higgs distributions and/or include Higgs decay products
- Repeat the Drell-Yan analyses including QCD corrections consider e.g. the impact on the W mass measurement
- Repeat the analyses when NNPDF2.0 will become available