Report on CMS PDF forum

1) Organization and tools
2) Observables.
3) uPDF

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1.1) Organization and technical work

- **Organization:**
  - Status:
    - Discussion Forum.
  - Meetings :
    - Kick off workshop held in May.
    - Expect future workshops 2/year synchronized with PDF4LHC.
    - 1/month

- **Technique:**
  - **Advise / discuss usage of available PDF sets**
  - **Discuss / learn / standardize how to prepare correlated uncertainties:**
    - **For one observable (including potential statistical correlations)**
    - **For multiple observables within CMS**
    - **For observables at multiple experiments (LHC)**

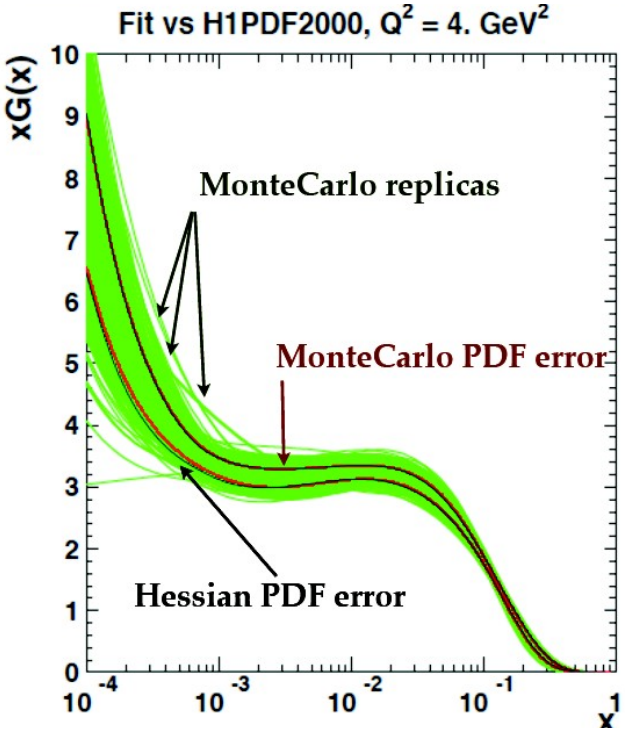
1.2) Goals: Communication

- **Communication:**
  - Educate in:
    - Tool usage, uncertainty derivation, ...
  - Collect requests to global PDF fitting groups and theorists, e.g.:
    - PDFs for: series in α_s, with/without W asymmetry, ...
    - Required theory ingredients (new (N)NLO, electroweak corrections, ...)
  - Address requests to CMS by theorists
  - Prepare for PDF4LHC meetings (Next meeting: 23.05.2012)
  - Discuss in forum pot. exchange with other LHC experiments with respect to:
    - Definition and phase space of observables
    - Comparisons of observables
    - Combinations of observables ?

1.3) Tools

- HERA Fitter :
  - A fitting tool available for fast feedback to analyzers and studies within the experimental working groups.
  - Many new developments in the beta2 version.
- PDF reweighting :
  - Use MC replicas of a given PDF.
  - Weight the replicas according to the preference of a new data sample.
  - See arXiv:1205.4024 for this method applied to MSTW 2008.

- Which tool do we plan to use? :
  - The 2 tools are expected to be equivalent in most of the cases.
  - Both tools are expected to be used: either alone, either comparing them together.

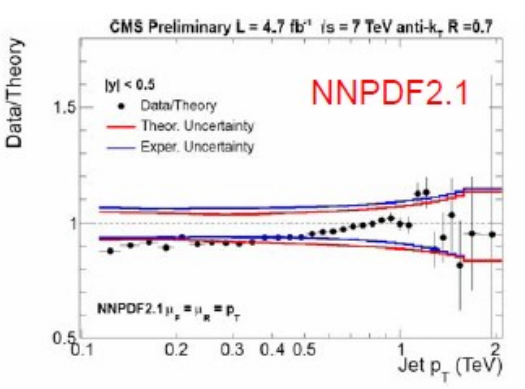


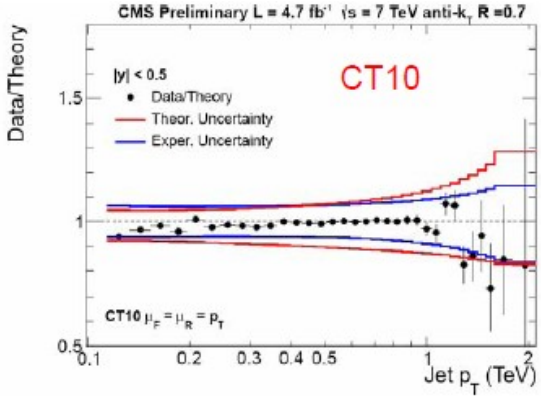
3) Observables

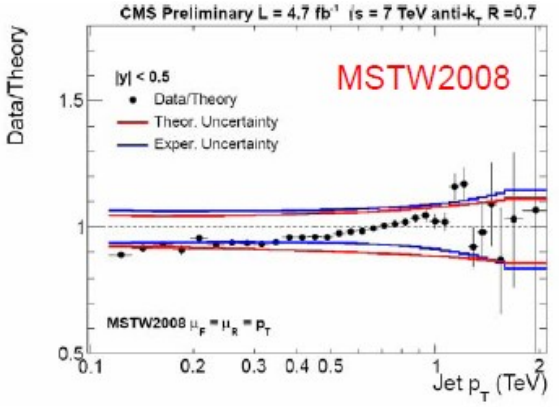
- Jets :
  - Inclusive jets, 2-jets mass, 3-jets
- Photons :
  - Isolated photons
- Weak bosons:
  - Inclusive W/Z production
  - W/Z + jets
  - Off-shell Drell-Yan production
  - W/Z asymmetries
- Top
  - Top pair production
  - Single top production

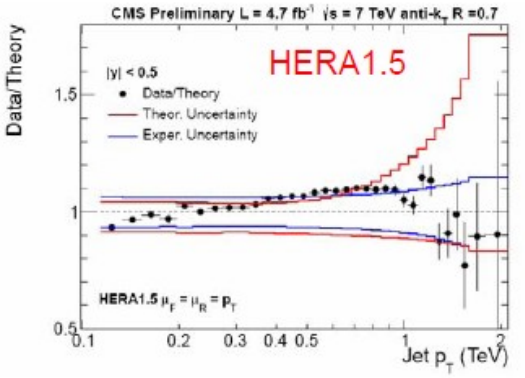
3.1) Observables : jets

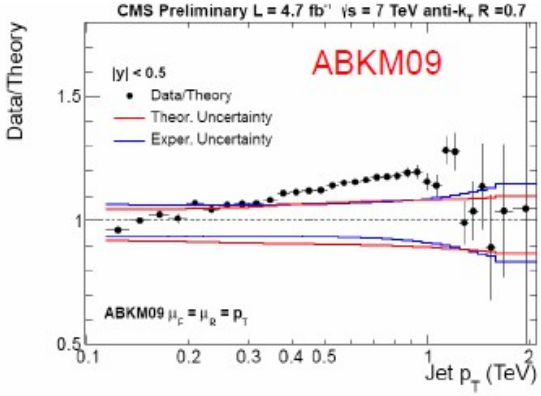
QCD-PAS-11-004











- All PDF sets are compatible with Data within systematic uncertainties
- Differences among the various PDFs are more pronounced at high p_T

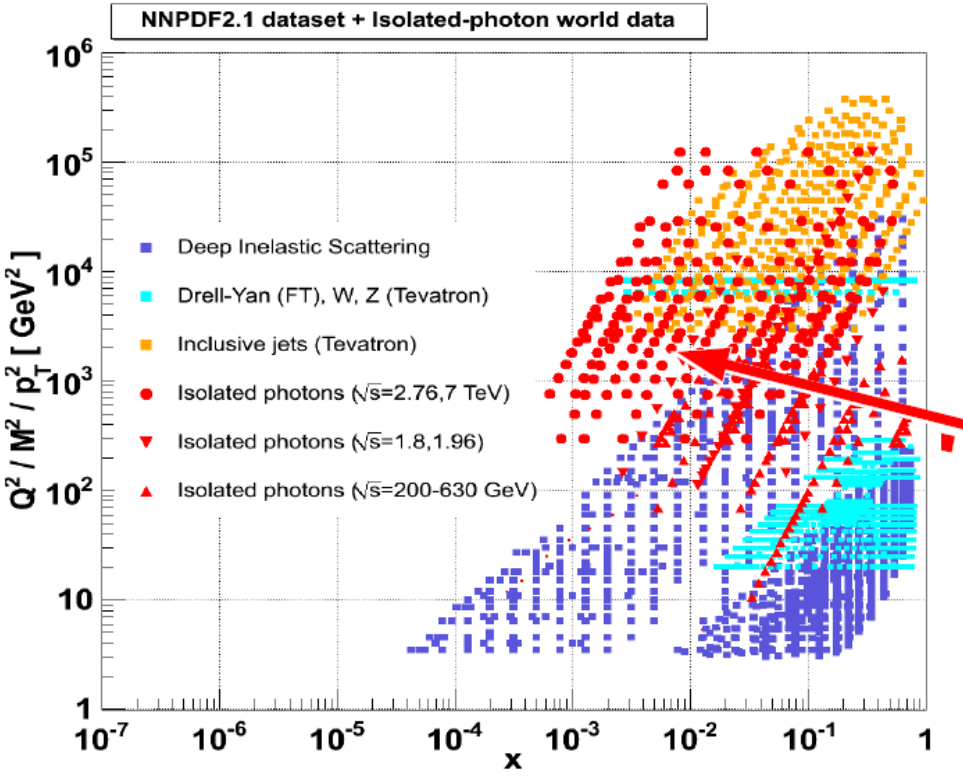
- School case to test the inclusion of systematics into HERA fitter or PDF reweighting.
- Systematic correlations to be included in 2011 data paper.

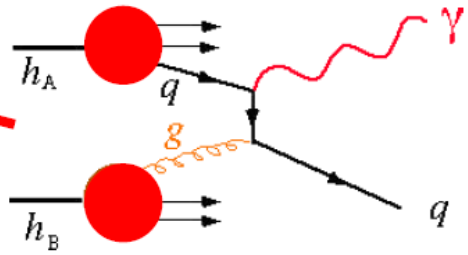
3.2) Observables : prompt photons

(x,Q^2) map of collider isolated-γ datasets

[D.d'E & J.Rojo, NPB 860 (2012) 311]

- Kinematical range of LHC, Tevatron, Sp$\bar{p}$S & RHIC γ_{isol} data:





- Direct sensitivity to gluon PDF over wide (x,Q^2) domain

  [$xG(x,Q^2)$ only constrained indirectly by DIS & directly by p-p jets at high-x]

3.3) Observables : prompt photons

System	Collab./experiment (collider) [Ref.]	$\sqrt{s}$ (TeV)	$\lvert y_\gamma \rvert$ range	E_T^γ range (GeV)	x range	Data points	Isolation radius, had. energy
$p-p$	ATLAS (LHC) [34]	7.	<0.6	15–100	5×10^{-3}–0.05	8	$R=0.4$, $E_h<5$ GeV
$p-p$	ATLAS (LHC) [34]	7.	0.6–1.37	15–100	3×10^{-3}–0.1	8	$R=0.4$, $E_h<5$ GeV
$p-p$	ATLAS (LHC) [34]	7.	1.52–1.81	15–100	2×10^{-3}–0.1	8	$R=0.4$, $E_h<5$ GeV
$p-p$	ATLAS (LHC) [35]	7.	<0.6	45–400	5×10^{-3}–0.1	8	$R=0.4$, $E_h<4$ GeV
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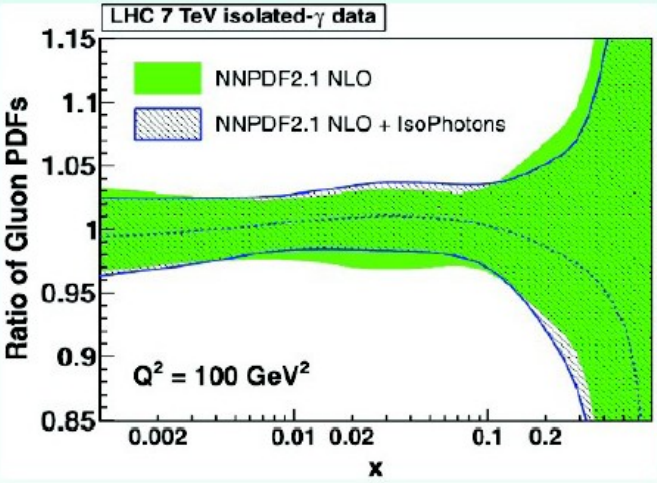
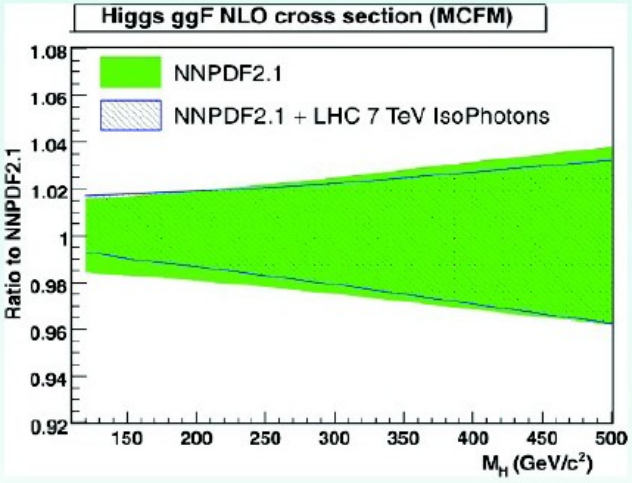
$p-p$	ATLAS (LHC) [35]	7.	1.81–2.37	45–400	2×10^{-3}–0.5	8	$R=0.4$, $E_h<4$ GeV
$p-p$	CMS (LHC) [37]	7.	<1.45	21–300	5×10^{-3}–0.1	11	$R=0.4$, $E_h<5$ GeV
$p-p$	CMS (LHC) [36]	7.	<0.9	25–400	5×10^{-3}–0.2	15	$R=0.4$, $E_h<5$ GeV
$p-p$	CMS (LHC) [36]	7.	0.9–1.44	25–400	2×10^{-3}–0.3	15	$R=0.4$, $E_h<5$ GeV
$p-p$	CMS (LHC) [36]	7.	1.57–2.1	25–400	10^{-3}–0.4	15	$R=0.4$, $E_h<5$ GeV
$p-p$	CMS (LHC) [36]	7.	2.1–2.5	25–400	10^{-3}–0.5	15	$R=0.4$, $E_h<5$ GeV
$p-p$	CMS (LHC) [38]	2.76	<1.45	20–80	10^{-3}–0.05	6	$R=0.4$, $E_h<5$ GeV

- Large list of measurements provided by LHC collaborations.
- Impact of isolated photons on the gluon PDF for x=0.01 – 0.1.

- Isolated γ production directly sensitive to *g(x)*: D. D'Enteria, J. Rojo NPB 860 (2012) 311

NNPDF Reweighing





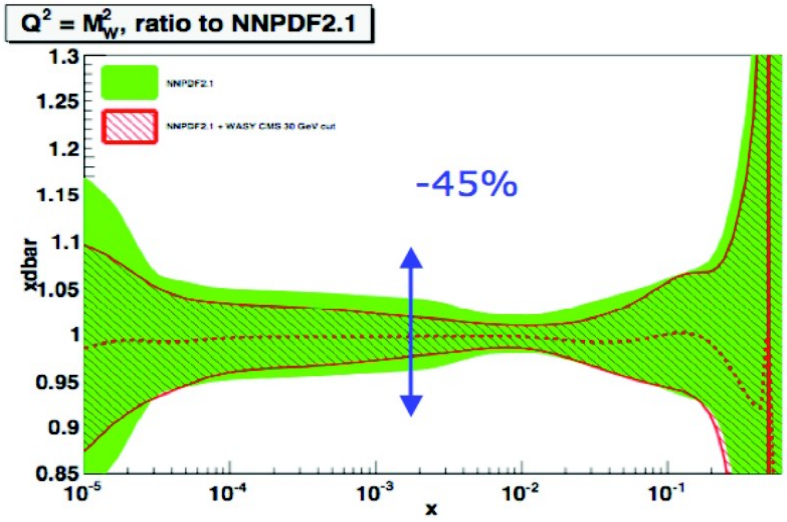
3.4) Observables : EW bosons production

EWK-PAS-11-005

- Inclusive boson production observables:

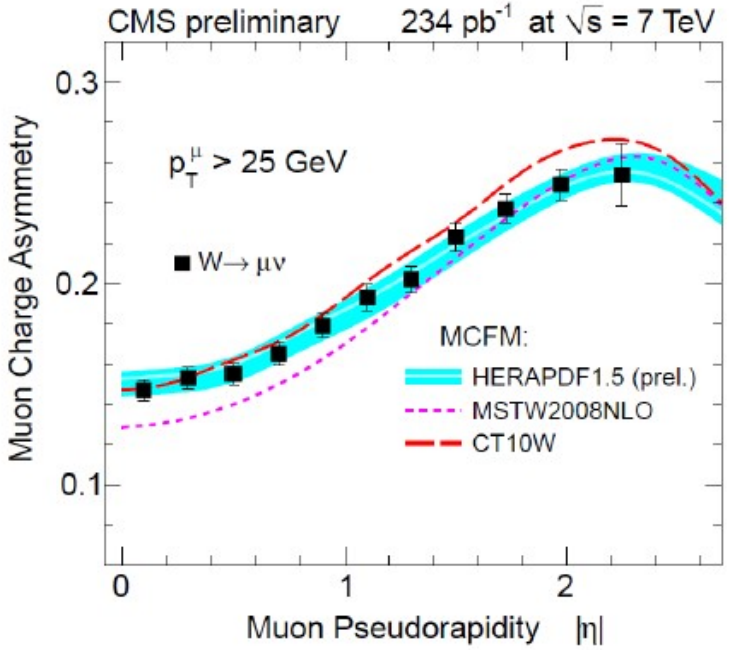
W/Z cross sections,
Inclusive ratios,
Charge asymmetries in inclusive Ws

- Published with 2010 data. Prompt feed back from PDF collaborations.
- Results incoming with 2011 data.



- Lepton charge asymmetry: sensitive to the difference between u and d quarks.

$$A_W = \frac{W^+ - W^-}{W^+ + W^-} \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$$



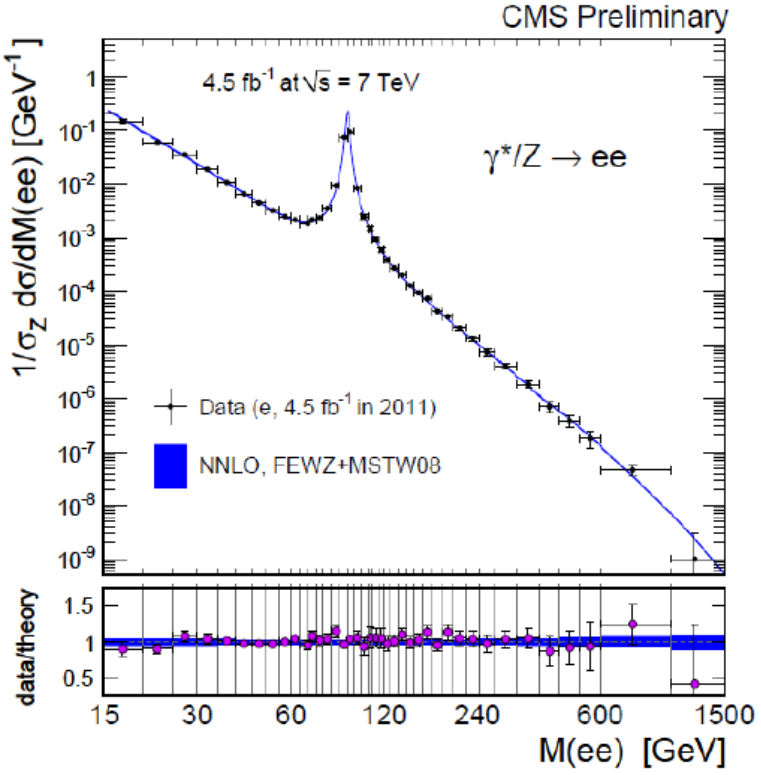
3.5) Observables : EW bosons production

EWK-PAS-11-007

- Based on EWK-11-007 PAS
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEWK11007
  - http://cdsweb.cern.ch/record/1439026/files/EWK-11-007-pas.pdf
- 1D measurement (dsigma/dM)
  - Muon channel
  - Electron channel
- 2D measurement (d2sigma/dM/dY)
  - Muon channel only
  - **First measurement at hadron collider**

The quantification of the impact with NNPDF reweighting technique is under study.

- Cross section normalized to Z peak cross section
  - r-shape

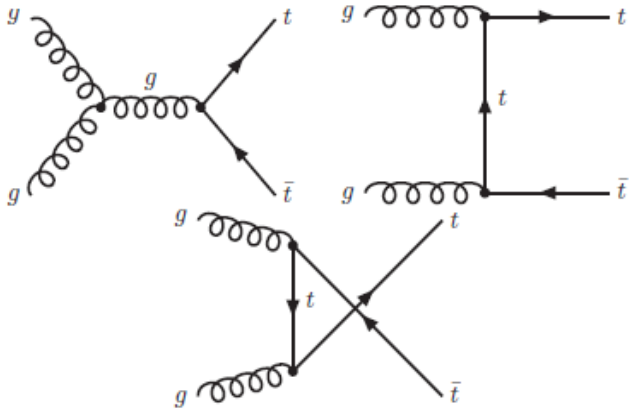


3.6) Observables : ttbar production

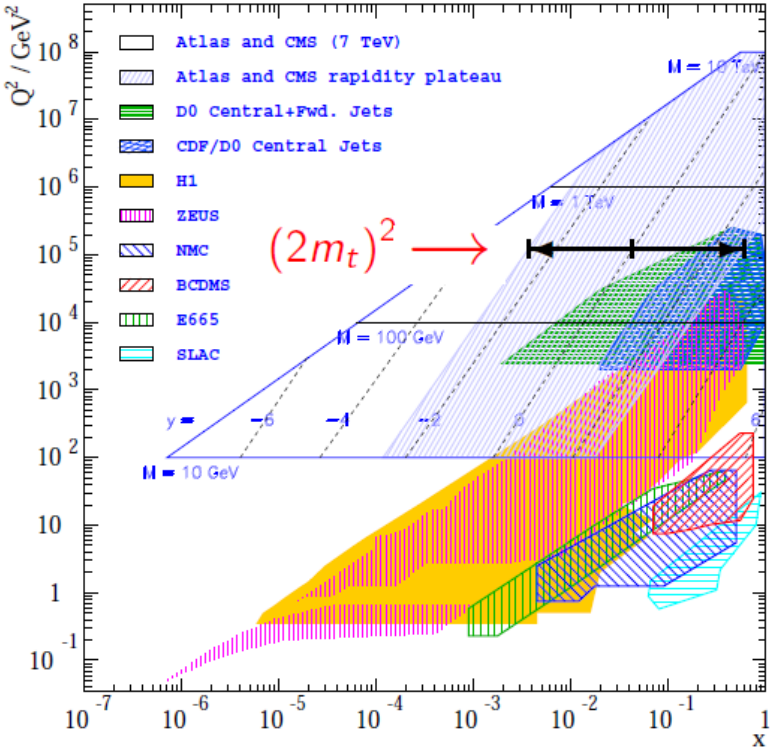
- Pair top production is expected to be sensitive to the gluon PDF.
- Interesting point: we have a well defined hard scale.

Main production mechanisms:

gg fusion (dominant at LHC)

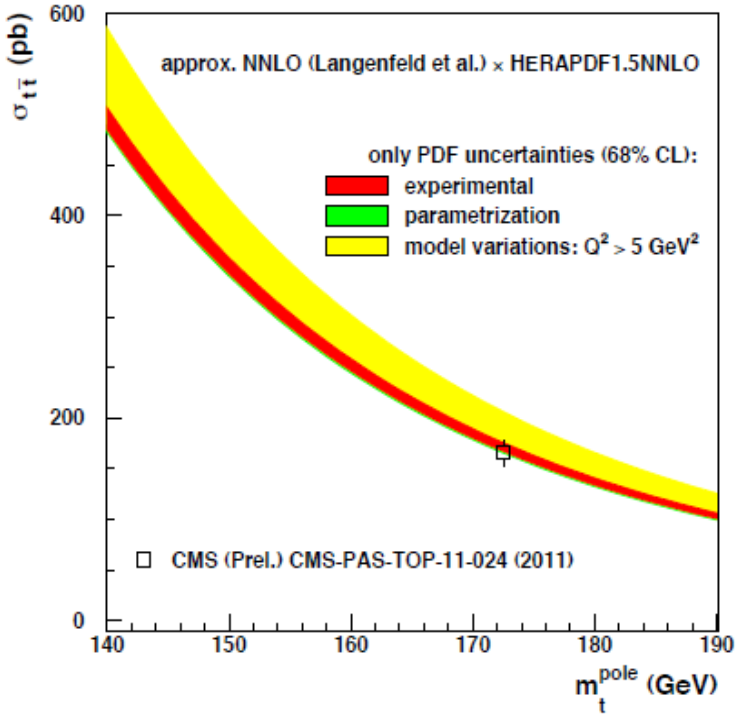


Kinematic regime:



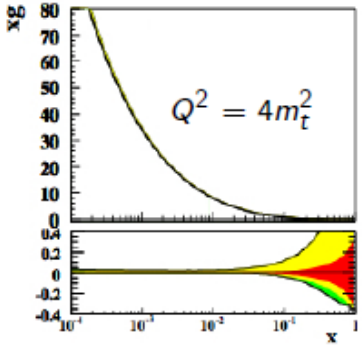
3.7) Observables : ttbar production

Huge impact of Q^2_{cut} variation (5.0 instead of 3.5 GeV^2) in HERAPDF15NNLO on the predicted $\sigma_{t\bar{t}}$



That variation excludes data in a kinematic regime more sensitive to non-DGLAP effects

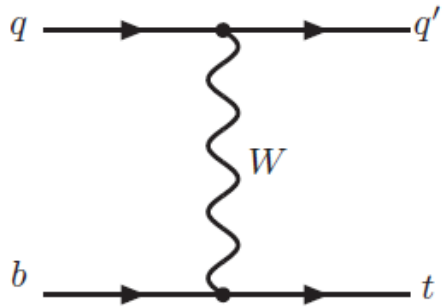
The gluon PDF at high x is very sensitive to this:



The measured $\sigma_{t\bar{t}}$ should help to constrain those uncertainties (without giving up flexibility in the parametrization of the gluon PDF)

3.8) Observables : single top production

Uncertainty due to b-PDF



Studies with POWHEG (NLO, 5-flavor scheme) for t-channel production:

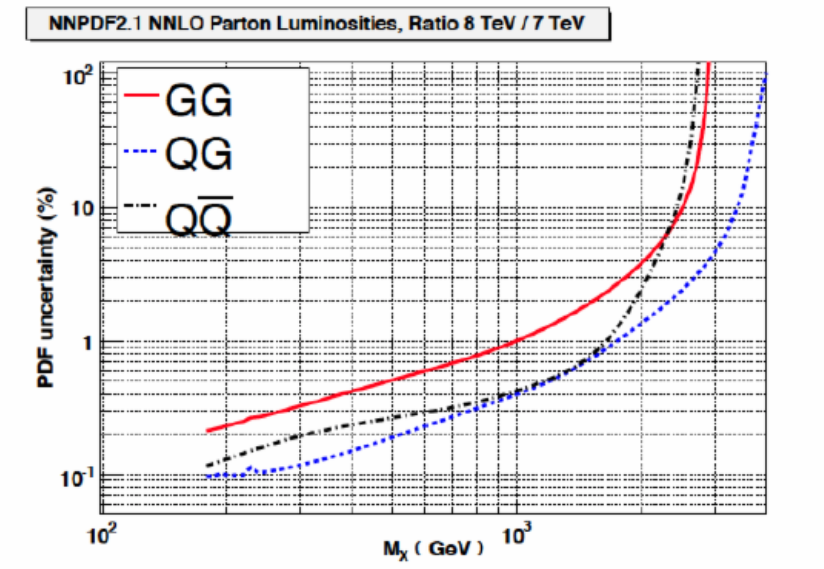
Variation	$\Delta\sigma/\sigma$
CTEQ6M $\rightarrow$ MSTW2008NLO	+0.8%
CTEQ6M $\rightarrow$ HERAPDF15NLO	−1.7%
HERAPDF15NLO: $m_b = 4.75 \rightarrow 4.3$ GeV	+4.0%
HERAPDF15NLO: $m_b = 4.75 \rightarrow 5.0$ GeV	−2.0%

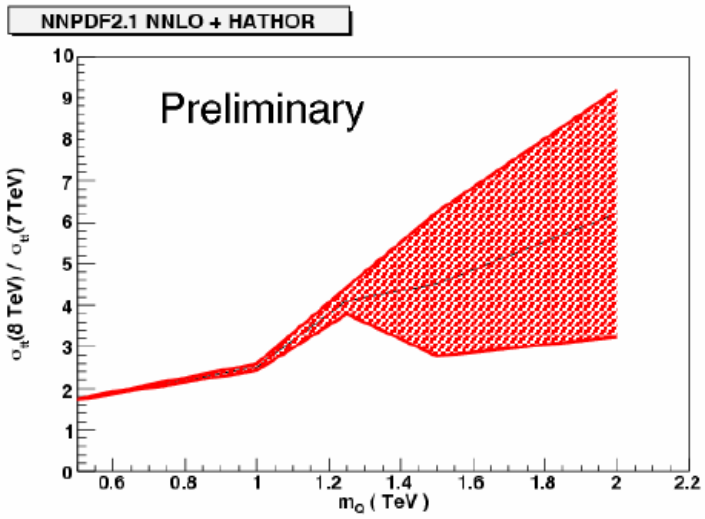
Steffen Röcker (Karlsruhe)

$\rightarrow$ Variation of *b*-quark mass has a sizeable effect on the t-channel cross section (not considered in current measurements)

Likely that this variation has a similar effect in tW production

3.9) Observables : 8 TeV / 7 TeV ratio





- Percentage PDF uncertainty in the ratio of parton luminosities between 8 TeV and 7 TeV, for the *gg*, *gq* and *qq* partonic subchannels, computed with the NNPDF2.1 NNLO set.

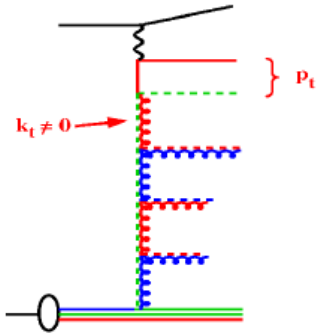
- The ratio of production cross sections between 8 and 7 TeV of a new heavy quark boson with mass m_Q at the TeV scale. The band represents the PDF uncertainties only.

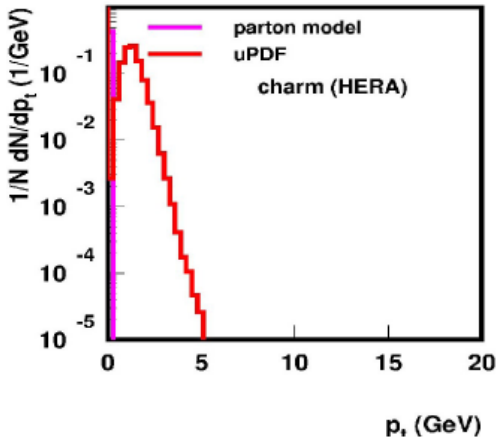
(Experimental systematic uncertainties are expected to cancel in the ratio)

4.1) uPDFs

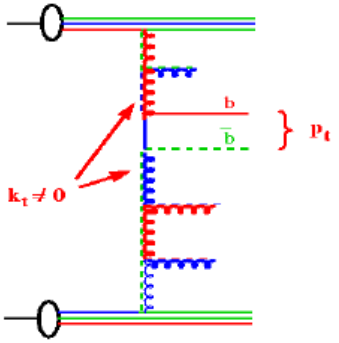
J. Collins, H. Jung hep-ph/0508280

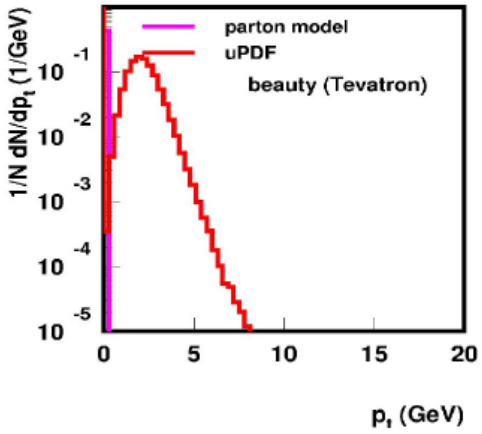
heavy quarks at HERA



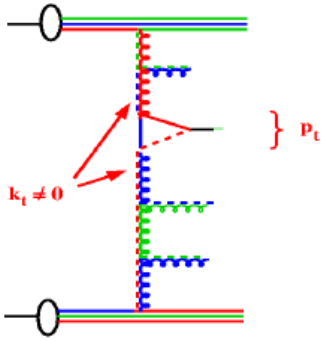


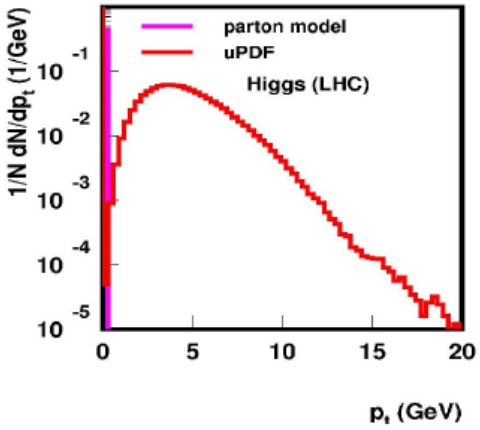
heavy quarks in pp





Z/W/Higgs in pp





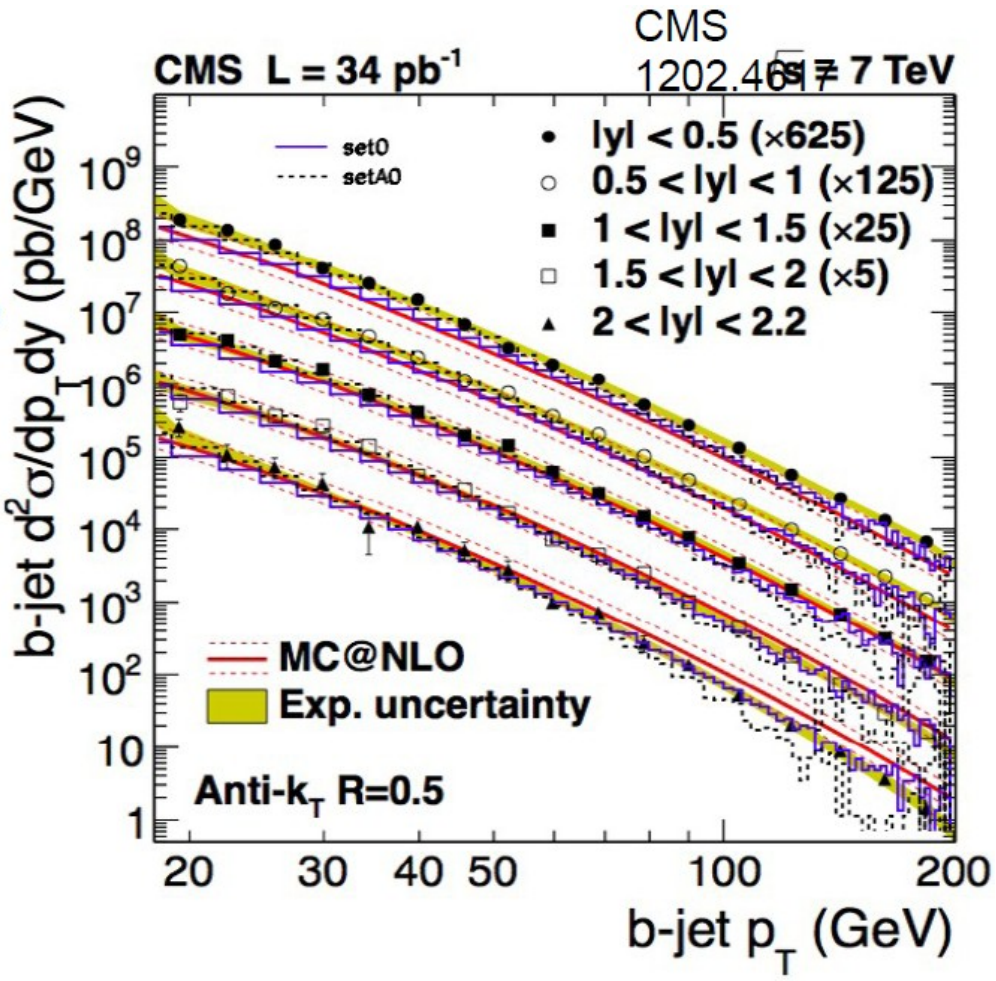
➔ doing kinematics correctly already at LO reduces NLO corrections …

➔ finite transverse momenta are important for x-section calculations

H. Jung, Determination of uPDFs, CMS-PDF workshop, 7. May 2012

4.2) uPDFs

- $pp \to b\bar{b} + X$ is a prefect probe for gluon initiated processes
- b-jet production over wide range in p_t and $|y|$
- new uPDF (set 0) preform better, especially at high p_t
- prediction close to MC@NLO at small p_t, at large p_t even better



SUMMARY

1) The activities around PDF analysis of CMS SM data are about to be organized around a Discussion forum which aims to:

- Organize the communication inside CMS.
- Help analyzers to perform the QCD analysis of their observables.
- Agree on a common format of data/correlations production optimal for the PDF extraction tools.
- The results would go in standard CMS publications.

1) CMS plans to test the PDF impact by the new data using the available tools like HERAFitter or NNPDF reweighting.

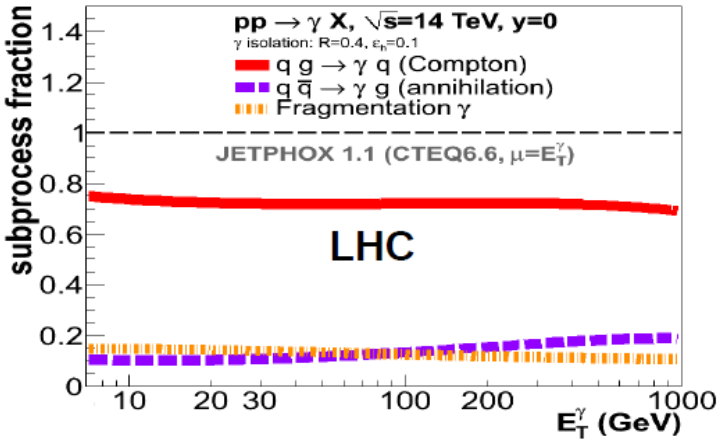
2) A large spectrum of observables is foreseen: fully hadronic observables, EW bosons production, EW bosons + jets, top quark.

3) For many of them the PDF analysis already started.

BACKUP

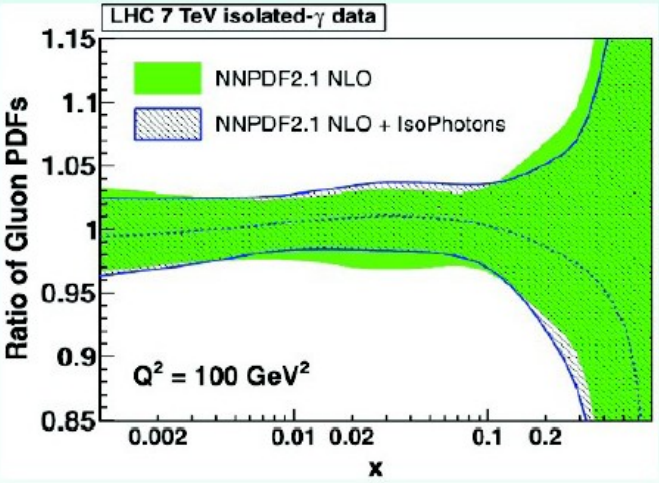
3.3) Observables : prompt photons

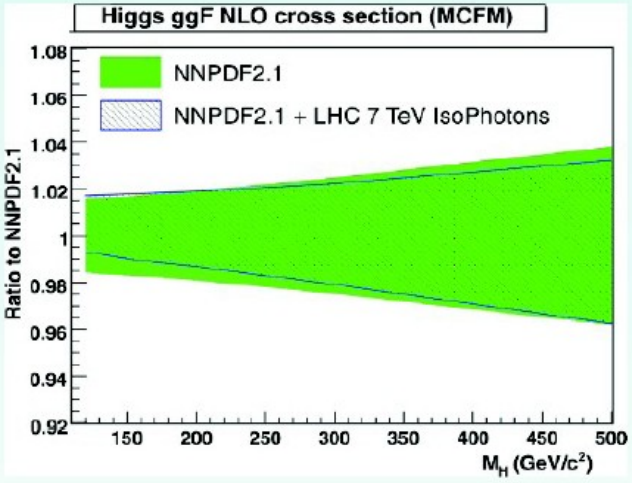
- Isolated photons weakly contaminated by photons from the fragmentation.



- Isolated γ production directly sensitive to *g(x)*: D. D'Enteria, J. Rojo NPB 860 (2012) 311

NNPDF Reweighing





2.1) Tools: HERA Fitter

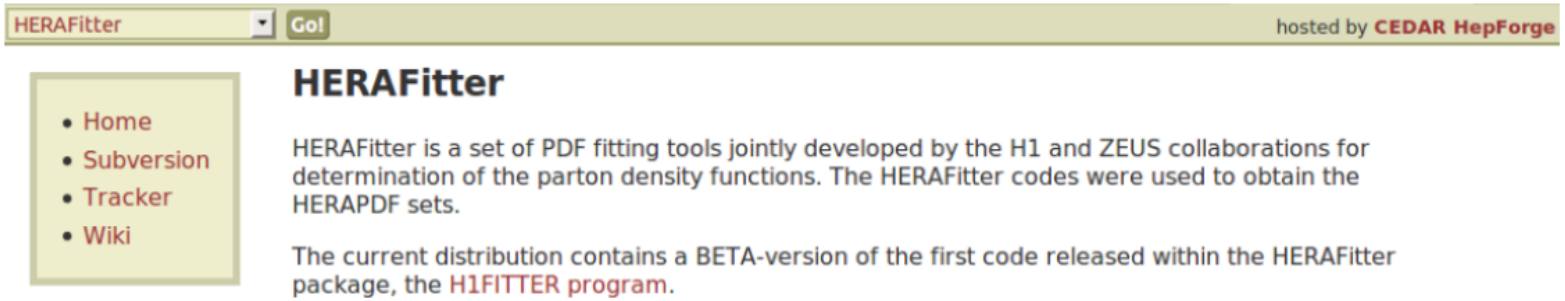
PDF Tools

All PDF sets are encouraged to be used for cross section predictions at LHC

- PDF groups also provide PDF tools for cross checks and specific studies

PDF tools:

A fitting tool available for fast feedback to analysers and studies within the experimental working groups: **HERAFitter**



NNPDF group: reweighting tool
using NNPDF mechanism to assess the impact of new data on NNPDF set
now also in HERAfitter!

AB(K)M group: open source code
now also in HERAfitter!

2.2) Tools: HERA Fitter

HERAFitter: New Developments

- Data file storage (published Tevatron, LHC data)
  https://znwiki3.ifh.de/HERAFitter/HERAFitter/downloads/datatables
- New interfaces to DIS, DY, Applgrids and FASTNLO modules
- Developments in the top area: ttbar cross section using HATHOR
- Possibility to link to LHAPDF
- Addition of the NNPDF reweighting tool
- Diffractive fits (ZEUS)
- Additions to HERAFitter package: HERAaverager

  → used for combining the measurements

- Heavy flavour schemes:
  - ZM-VFNS (QCDNUM)
  - GM-VFNS RT from R. Thorne
  - ACOT VFNS (F.Olness)
  - FFNS (QCDNUM)
  - FFNS (ABM, running mass)
- Others developments for cross model benchmarking:
- DIPOLE Models
- Kt-evolution for unintegrated PDFs

CMS Experiment at the LHC, CERN

2.3) PDF reweighting

PDF Reweighting: Theoretical Formalism

- When **new experimental data** becomes available, within a Monte Carlo approach two ways to include the **new information on PDF constraints**
  - Generate a new PDF probability distribution by **refitting** old and new data together
  - Update the existing PDF probability distribution accounting the constrains from new data: PDF **reweighting**

$$\langle \mathcal{O} \rangle = \int \mathcal{O}[f]\, \mathcal{P}(f)\, Df = \frac{1}{N} \sum_{k=1}^{N} \mathcal{O}[f_k]$$

$$\langle \mathcal{O} \rangle_{\text{new}} = \int \mathcal{O}[f]\, \mathcal{P}_{\text{new}}(f)\, Df = \frac{1}{N} \sum_{k=1}^{N} w_k \mathcal{O}[f^{(k)}]$$

- Reweighting is **statistically identical** to refitting, but much simpler: it only requires
  - The **theory predictions** for a given observable computed **for all MC replicas**
  - The corresponding χ^2 **of each MC replica** compared to experimental data data

2.4) PDF reweighting

PDF Uncertainties: Hessian vs Monte Carlo

- Hessian and Monte Carlo methods **statistically equivalent** if gaussian quadratic approximation is realistic and no tolerances are introduced
- HERA-LHC workshop proceedings: with the **HERAPDF** framework, Hessian and Monte Carlo methods shown to be **numerically equivalent** in a QCD analysis of H1 data
- **Monte Carlo method more flexible** with deviations from the quadratic approximation and combinations of many experiments
- MC method used by the **NNPDF** analisys, but also studies by **MSTW** and **HERAPDF**