# Structure Functions and Parton Densities: Theory

- Global Fits
  - data
  - theory
  - methodology
- Miscellany
- Future perspectives

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Warsaw Apr 2014

# Global PDFs: updates

Current Public sets: http://projects.hepforge.org/lhapdf

At DIS14 all the main groups presented work in progress, mainly to include LHC data.

- MSTW08 (2008): becomes HMMT14? Thorne
- CT10 (2010-12): becomes CT1X Schmidt
- NNPDF2.3 (2012): becomes NNPDF3.0 Ubiali
- HERAPDF1.5 (2010): becomes HERAPDF2.0 Radescu
- ABM11/12 (2011-13): becomes ABM14? Alekhin
- CJ12 (2012): becomes CJ14 Accardi

PDF4LHC prescription (2010): combine MSTW,CT10,NNPDF

Stated at NLO: but now also works at NNLO

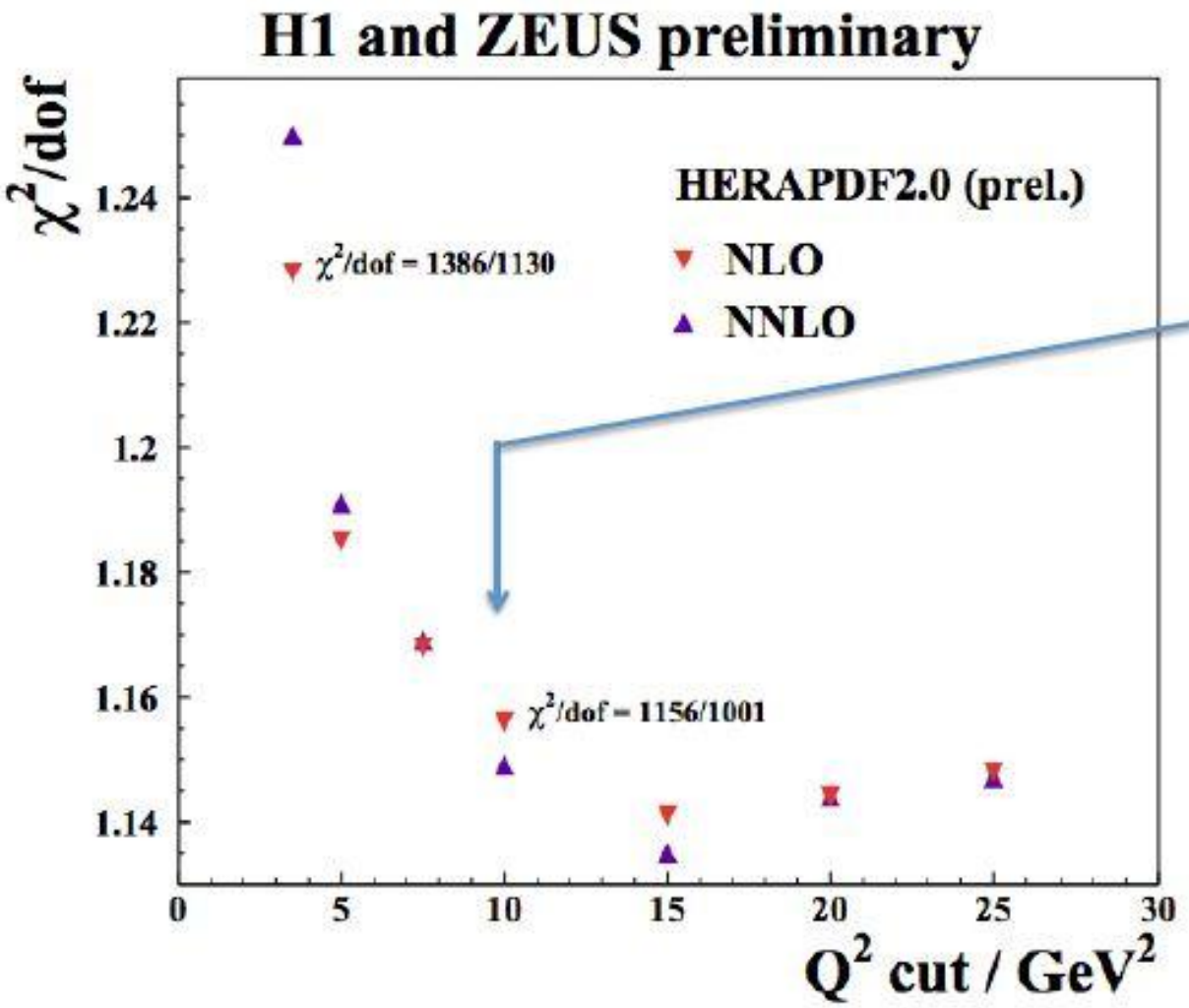
# Data

| | MSTW08 | CT10 | NNPDF2.3 | HERAPDF1.5 | ABM11 | CJ12 |
|---|---|---|---|---|---|---|
| HERA DIS | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Fixed-target DIS | ✔ | ✔ | ✔ | ✗ | ✔ | ✔ |
| Fixed-target DY | ✔ | ✔ | ✔ | ✗ | ✔ | ✔ |
| Tevatron $W+Z$+jets | ✔ | ✔ | ✔ | ✗ | ✗ | ✔ |
| LHC $W+Z$+jets | ✗ | ✗ | ✔ | ✗ | ✗/✔ | ✗ |

- HERA2 data: wait for combination — Turkot
- LHC W/Z data: impact on u/d — Newman
- LHC incl jet data: mild impact on g — Sieber
- LHC W+c data: mild impact on strangeness — Aad, Placakyte

PDF fitters need data with fully correlated systematics
and need to know if systematics additive or multiplicative

(to avoid d'Agostini bias)




At $Q^2_{min}$ = 10 is when the fit stabilises with respect of chi2/dof vs $Q^2$cut

For $Q^2_{min}$ = 3.5 GeV$^2$

Chi2/dof (NLO) = 1386/1130

Chi2/dof(NNLO)= 1414/1130

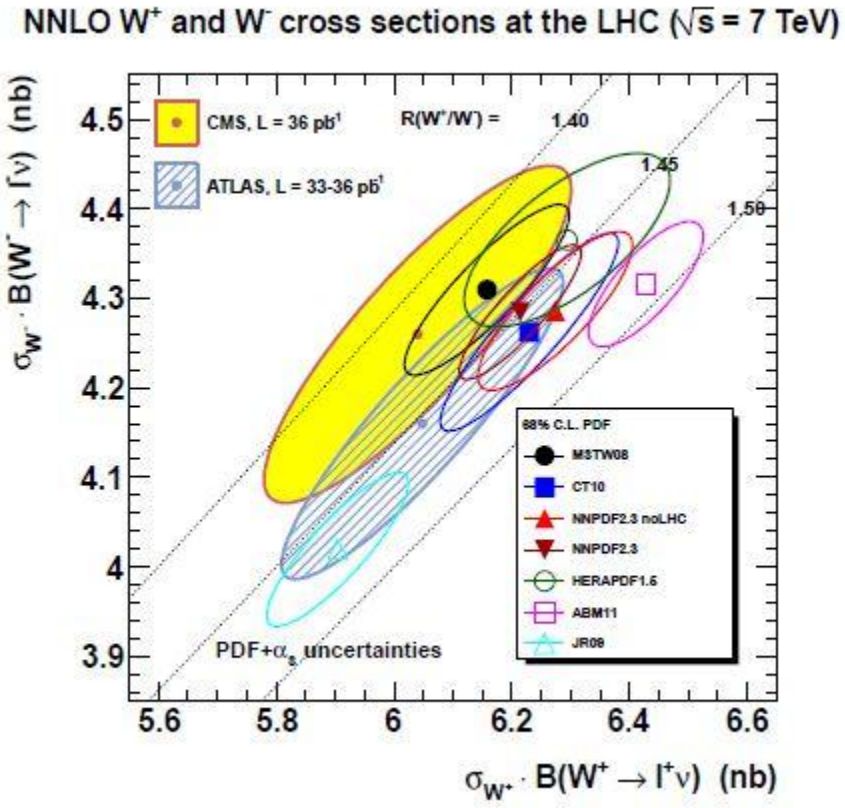
For $Q^2_{min}$ = 10 GeV$^2$

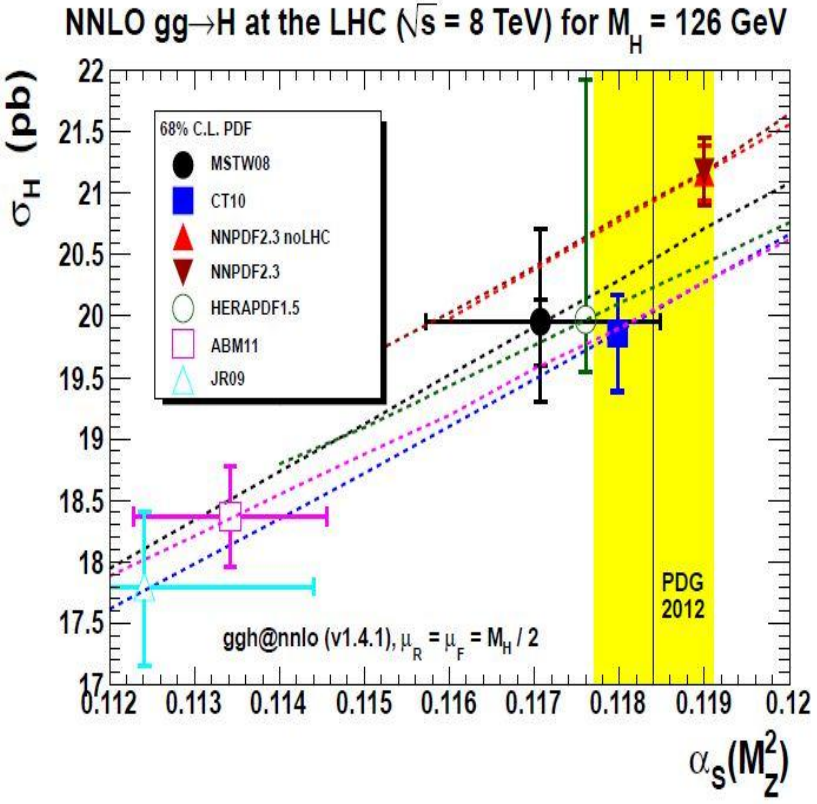
Chi2/dof (NLO) = 1156/1001

Chi2/dof(NNLO)= 1150/1001

Limitations of NNLO pt at small x?

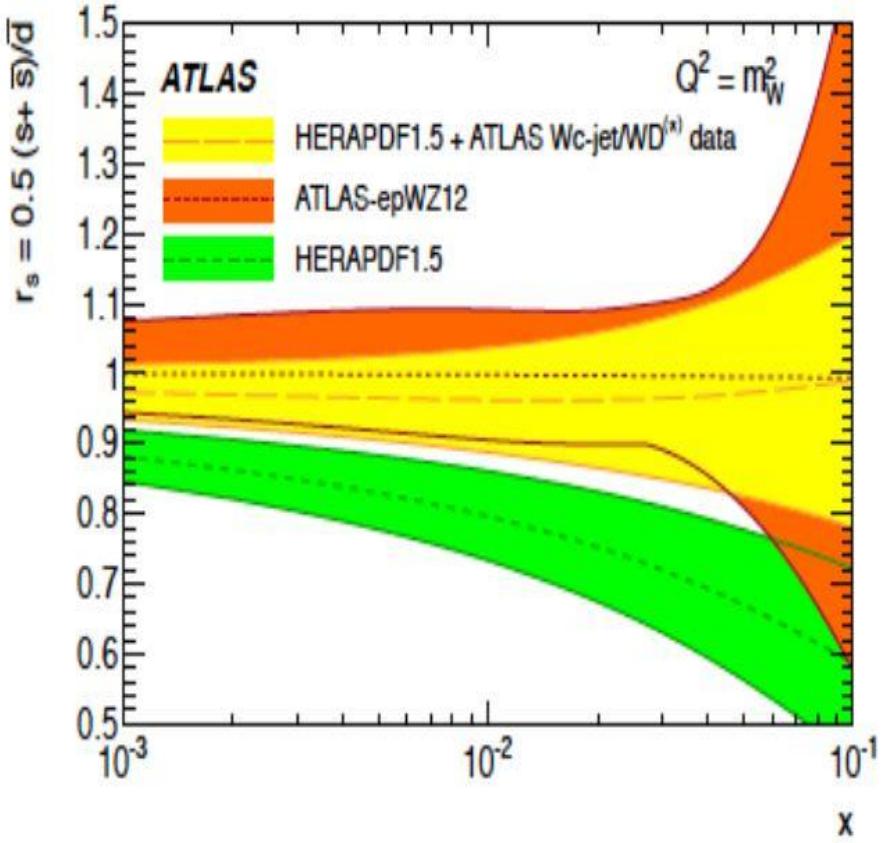
Radescu



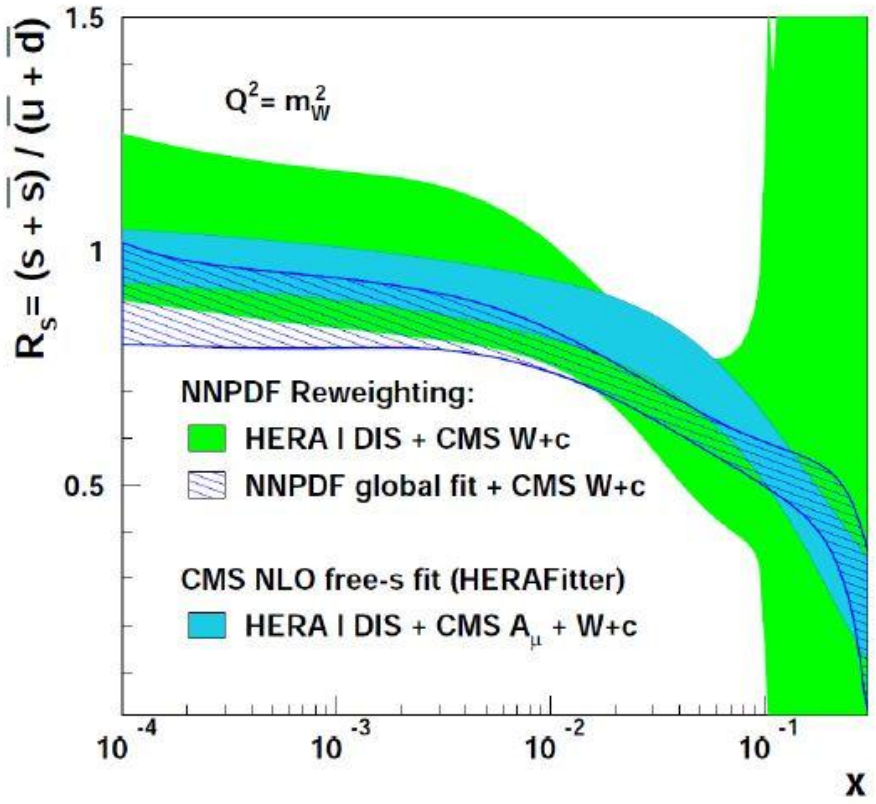




Forte and Watt arXiv: 1301.6754

# Strangeness




Aad




Placakyte

More compatible with usual expectations, eg dimuon data, NOMAD Alekhin

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| LHC $W+Z$+jets | ✗ | ✗ | ✔ | ✗ | ✗/✔ | ✗ |

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# Theory

| | MSTW08 | CT10 | NNPDF2.3 | HERAPDF1.5 | ABM11/12 | CJ12 |
|---|---|---|---|---|---|---|
| NNLO | ✔ | ✔ | ✔ | ✔ | ✔ | ✗ |
| varying $\alpha_s$ | ✔ | ✔ | ✔ | ✔/✗ | ✔ | ✗ |
| PDF + $\alpha_s$ unc? | ✔ | ✔ | ✔ | ✔ | ✗ | ✗ |
| Heavy quarks | VFN TR | VFN ACOT | VFN FONLL | VFN TR | FFN | VFN ZM |
| $s + \bar{s}$ fitted | ✔ | ✔ | ✔ | ✗ | ✔ | ✗ |
| $s - \bar{s}$ fitted | ✔ | ✗ | ✔ | ✗ | ✗ | ✗ |
| $c \pm \bar{c}$ fitted | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |

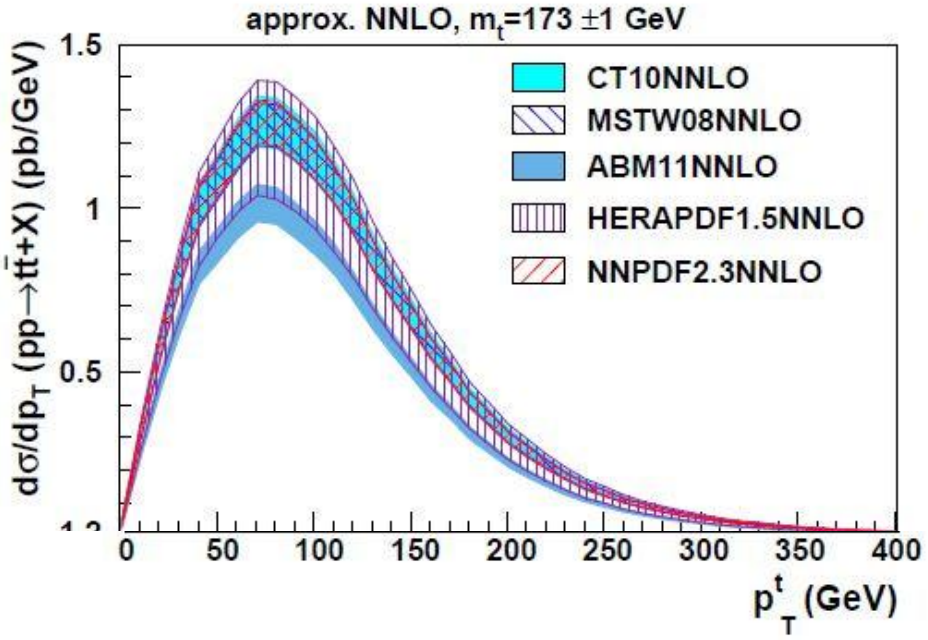
- c,b,t: VFN vs FFN: fragmentation fns

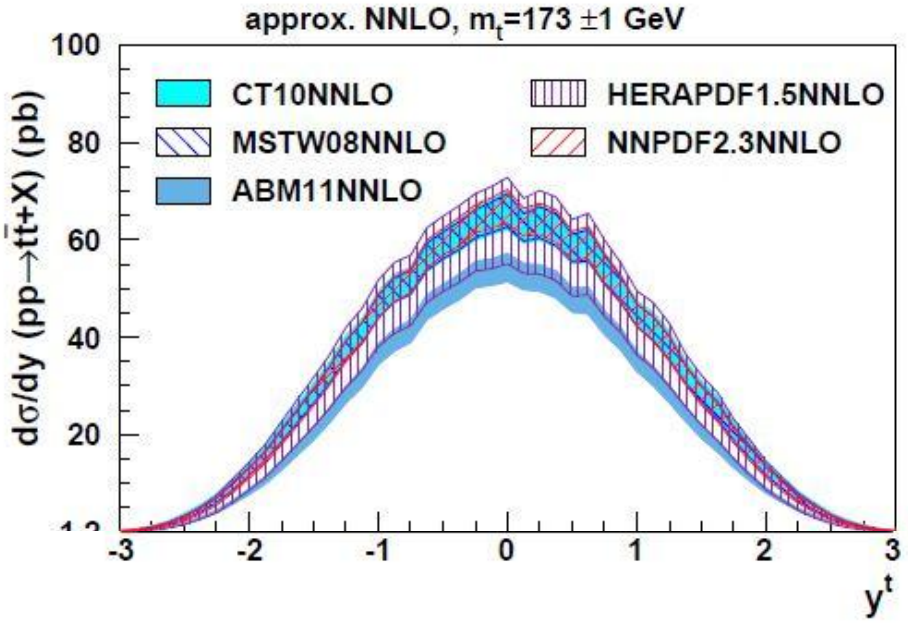
  Libov, Ubiali, Pietrulewicz
- NNLO ttbar (Top++, HATHOR, Difftop) Guzzi
- NNLO inclusive jets (gg channel only, rest soon) Thorne

- New fitting tool, HERAfitter Pirumov, Lisovyi
- to include hadronic data in fits, need tools like

  fastNLO (+toolkit), FastKernel, Applgrid,… Britzger

# DiffTop




Guzzi

# Theory

| | MSTW08 | CT10 | NNPDF2.3 | HERAPDF1.5 | ABM11/12 | CJ12 |
|---|---|---|---|---|---|---|
| NNLO | ✔ | ✔ | ✔ | ✔ | ✔ | ✗ |
| varying $\alpha_s$ | ✔ | ✔ | ✔ | ✔/✗ | ✔ | ✗ |
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| Heavy quarks | VFN TR | VFN ACOT | VFN FONLL | VFN TR | FFN | VFN ZM |
| $s + \bar{s}$ fitted | ✔ | ✔ | ✔ | ✗ | ✔ | ✗ |
| $s - \bar{s}$ fitted | ✔ | ✗ | ✔ | ✗ | ✗ | ✗ |
| $c \pm \bar{c}$ fitted | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |

- c,b,t: VFN vs FFN: fragmentation fns

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- New fitting tool, HERAfitter Pirumov, Lisovyi
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# Methodology

| | MSTW08 | CT10 | NNPDF2.3 | HERAPDF1.5 | ABM11/12 | CJ12 |
|---|---|---|---|---|---|---|
| No. of PDFs | 7 | 6 | 7 | 5 | 6 | 5 |
| Statistics | Hess.+DT | Hess.+DT | MC | Hess.+Par. | Hess. | Hess.+T |
| NLO par. | 20+8 | 26 | 259 | 10 | 24 | 25 |
| NNLO par. | 20+8 | 25 | 259 | 14 | 24 | no fit |
| Closure test | (✔) | (✔) | ✔ | ✗ | ✗ | ✗ |
| Reweighting | (✔) | (✗) | ✔ | (✔) | ✗ | ✗ |

- Tolerance, and Dynamical Tolerance
- Closure tests: if statistical methodology perfect

  Perfect data + Perfect theory = Perfect fit  Ubiali

  1) Take a set of data, an assumed theory (eg NLO QCD), and some prior pdf, $f_0$

  2) Generate a set of perfect pseudodata from $f_0$ , by MC, using data errors

  3) Fit the pseudodata using you statistical methodology, giving fitted pdf, f

  4) If the methodology is perfect, should find chisq=1, $f = f_0$

- Reweighting and Monte Carlo  Lisovyi, Paukkunen

# Miscellany

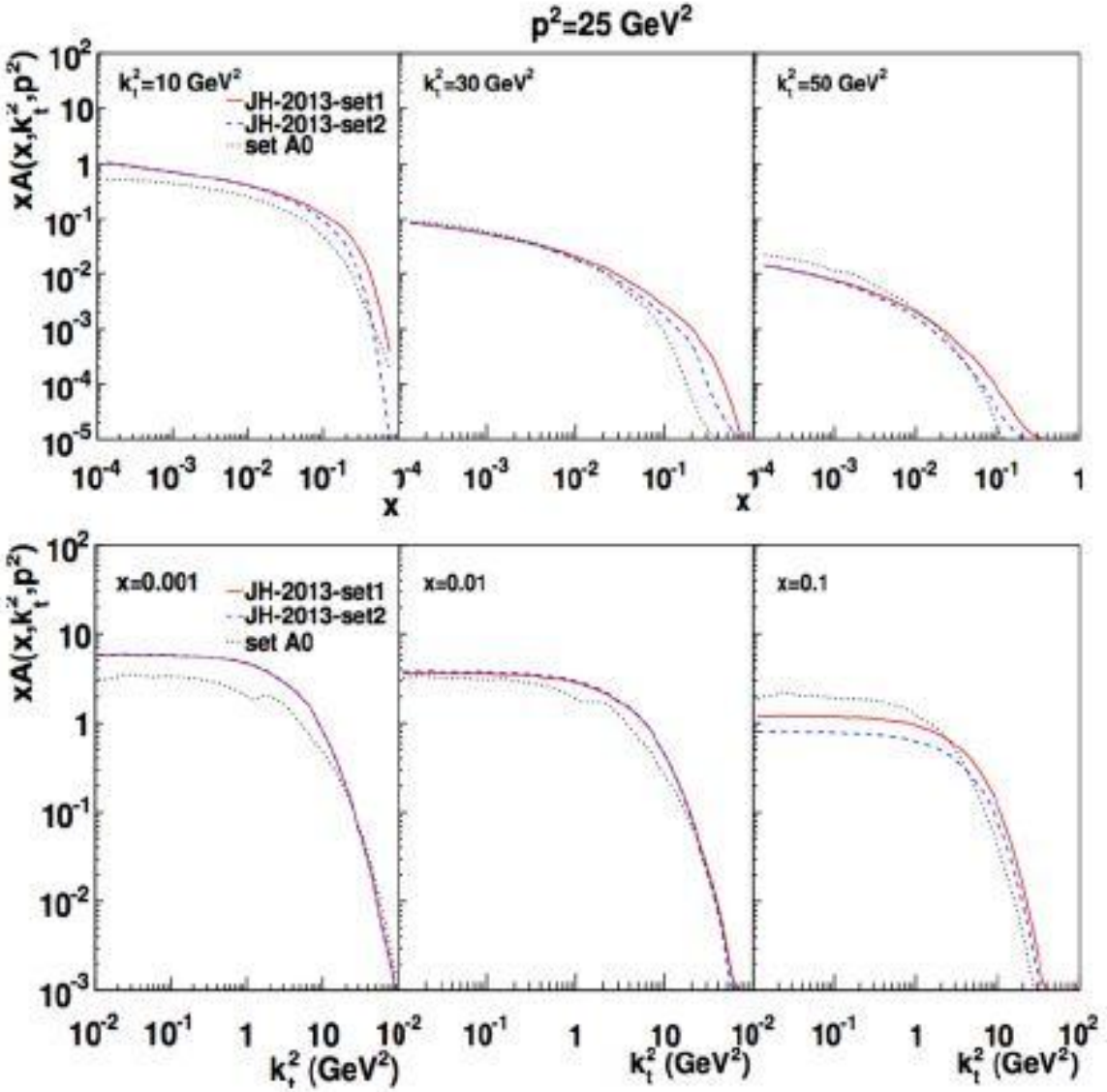
- Collider only fits (eg HERAPDF) – need better data
- LO fits: MSTW, CTEQ, NNPDF, HERAPDF, for MC

  Sarkar
- PDFs with QED corrections: new set from NNPDF

  Schmidt
- Polarized PDFs (see WG6) Accardi, Nocera
- Nuclear PDFs (nCTEQ soon) Paukkunen, Kusina
- Unintegrated (TMD) PDFs (getting there…)

  Jung, Vladimirov

# CCFM gluon




Jung

# Summary & Outlook

Better data:

Now: FT + HERA + Tev + LHC

Future: HERA + Tev + LHC

Far future: LHeC + LHC

Theorists need to keep up:

Better theory: NNLO, tools, resummation

Better methodology: closure tests

Thanks to all the speakers!