# Status of high-x section

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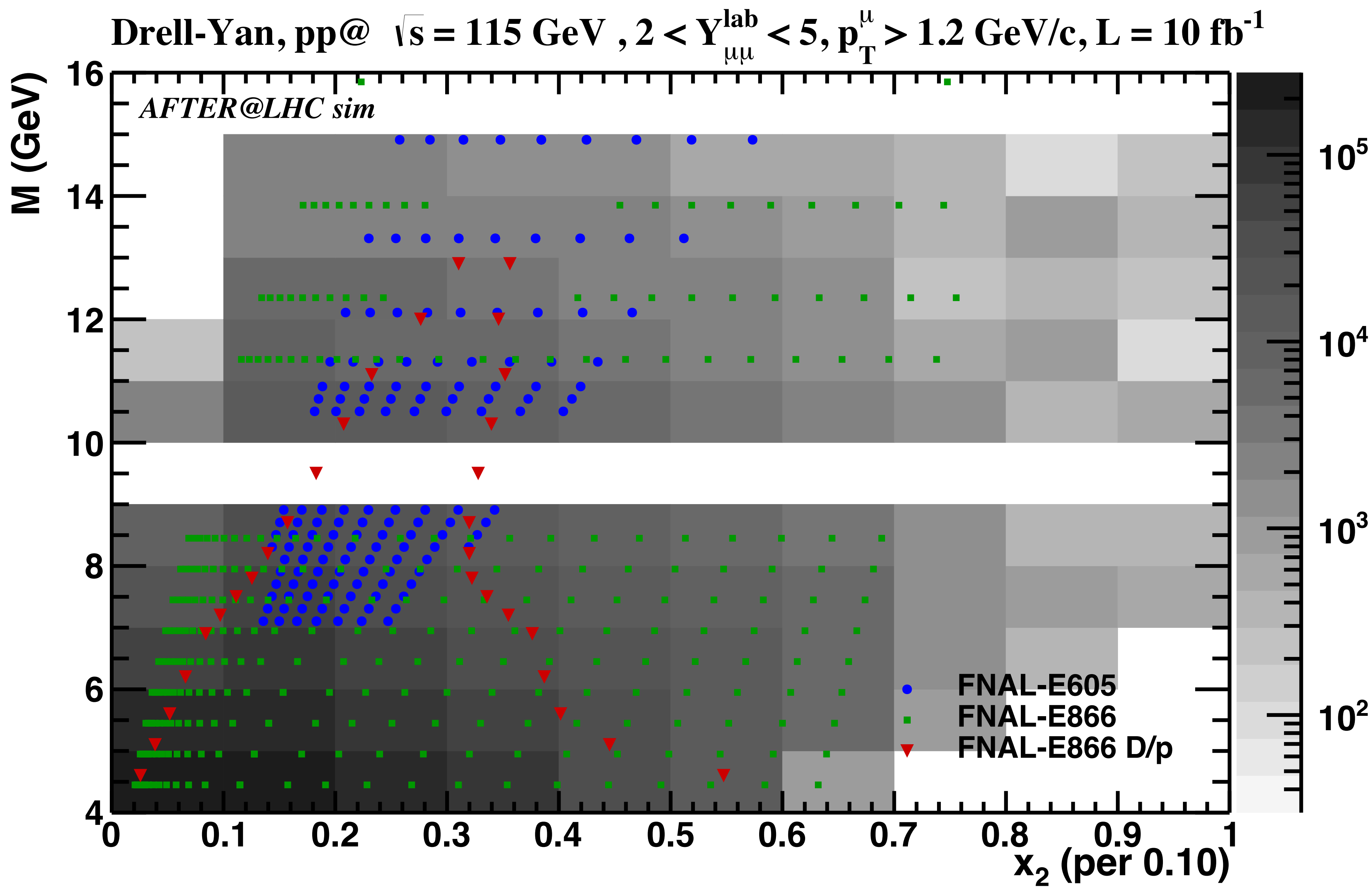
# Outline

- Drell Yan lepton pair production in pp
- W production in pp
- Drell Yan lepton pair production in pA
- The large-x gluon at AFTER in pA
- The large-x gluon at AFTER in pp

# Drell Yan lepton pair production in pp

# Kinematical plan of DY at AFTER




AFTER:

- Extend kinematic plane to very large x (and smaller x, M > 10 GeV)
- Much higher statistics in the region covered by NuSea (E866)

# Hadron structure at large x

- Large-x behaviour: $x\, f_i(x,Q_0) \sim (1-x)^{b_i}$
- Counting rule expectations: $b\_u_v = b\_d_v = 3$
- Currently only $b\_u_v$ relatively well constrained

  $2.6 < b\_u_v < 3.4$ Ball, Nocera, Rojo, arXiv:1604.00024

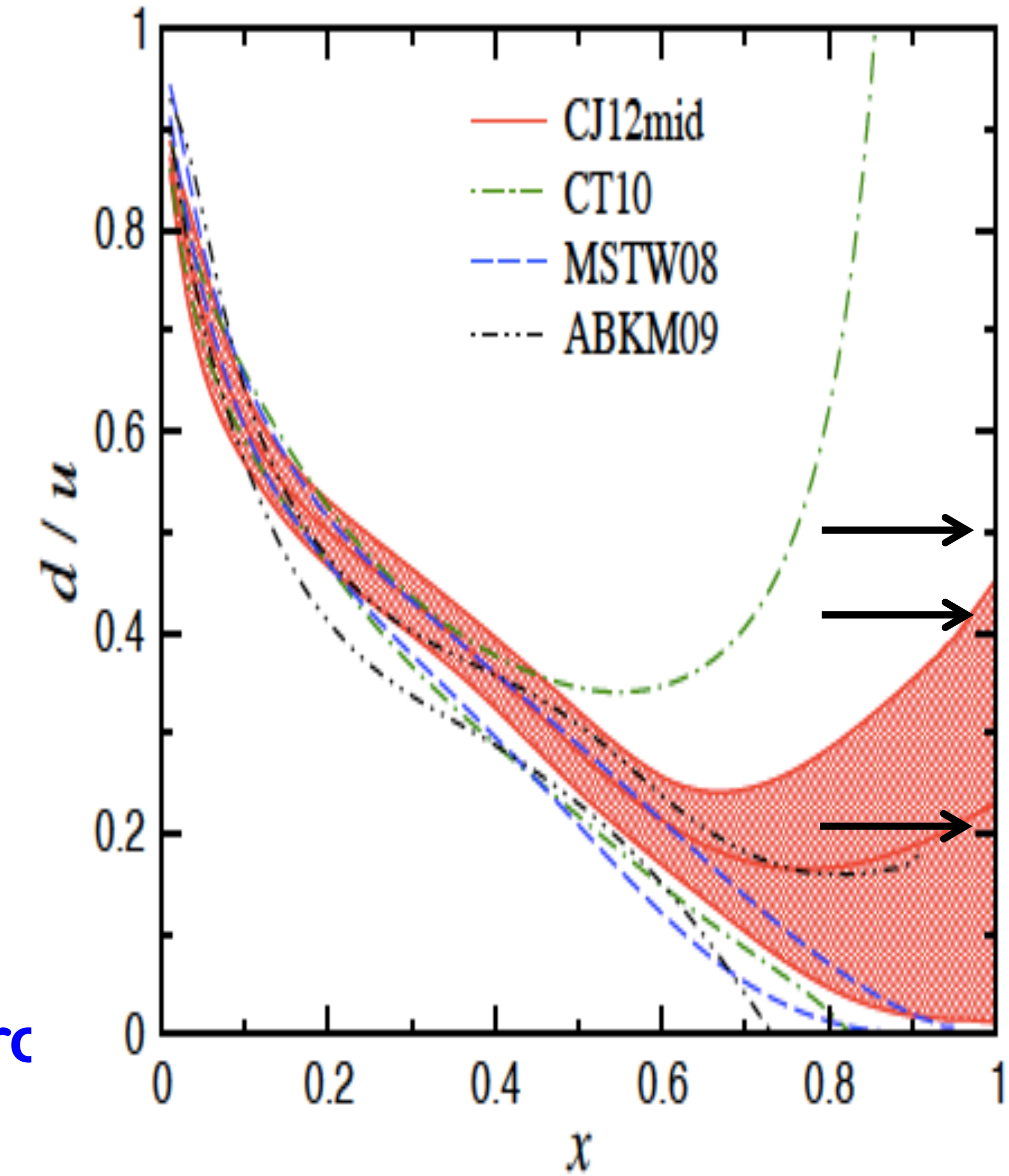
- Down valence quark less well known

  $1.4 < b\_d_v < 4.6$

- Exponents for the sea quarks and the gluon very poorly known

# Hadron structure at large x

- $d/u \to 1/2$ — **SU(6) Spin-flavor symmetry**
- $d/u \to 0$ — **Scalar diquark dominance**
- $d/u \to 1/5$ — **pQCD power counting**
- $d/u \to \dfrac{4\mu_n^2/\mu_p^2 - 1}{4 - \mu_n^2/\mu_p^2} \approx 0.42$ — **Local quark-hadrc duality**




J. Qiu, NNPSS lecture 2016

# A simple ratio in the limit $x_F \to -1$

- For example:

  $x_F = -0.8$, M = 10 GeV gives $x_2 = 0.8$, $x_1 = 0.01$
  $x_F = -0.8$, M = 15 GeV gives $x_2 = 0.8$, $x_1 = 0.02$

- In this limit with $r_v = d(x_2)/u(x_2)$

$$R = \frac{\sigma^{\mathrm{DY}}(pn)}{\sigma^{\mathrm{DY}}(pp)} \simeq \frac{4\bar{u}(x_1)d(x_2) + \bar{d}(x_1)u(x_2)}{4\bar{u}(x_1)u(x_2) + \bar{d}(x_1)d(x_2)} \simeq \frac{4d(x_2) + u(x_2)}{4u(x_2) + d(x_2)} = \frac{1 + 4r_v}{4 + r_v}$$

- Amusing to note: $1/4 < R < 4$

  similar to the famous Nachtmann ratio for DIS structure functions $1/4 < F_2^n / F_2^p < 4$

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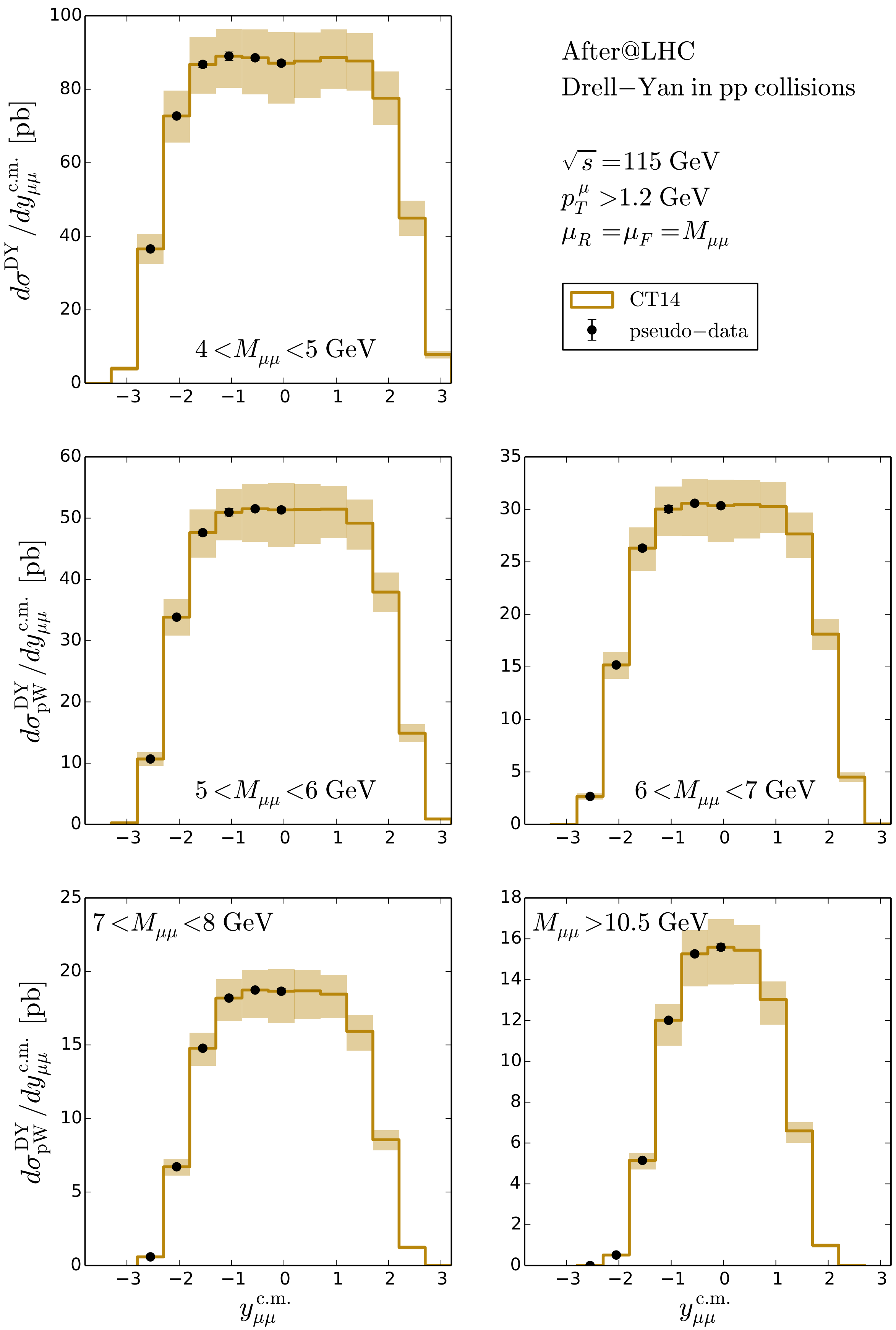
- In this limit with $r_v = d(x_2)/u(x_2)$

$$R_{d/p}(x_2) = \frac{\sigma^{\rm DY}(pd)}{\sigma^{\rm DY}(pp)} = 1 + \frac{\sigma^{\rm DY}(pn)}{\sigma^{\rm DY}(pp)} \simeq 5\, \frac{1 + r_v(x_2)}{4 + r_v(x_2)}\,.$$

$$R_{d/p} \to \begin{cases} 2 & ; \quad r_v = 1 \\ 2.5 & ; \quad r_v = 0 \\ 5 & ; \quad r_v \to \infty \end{cases}$$

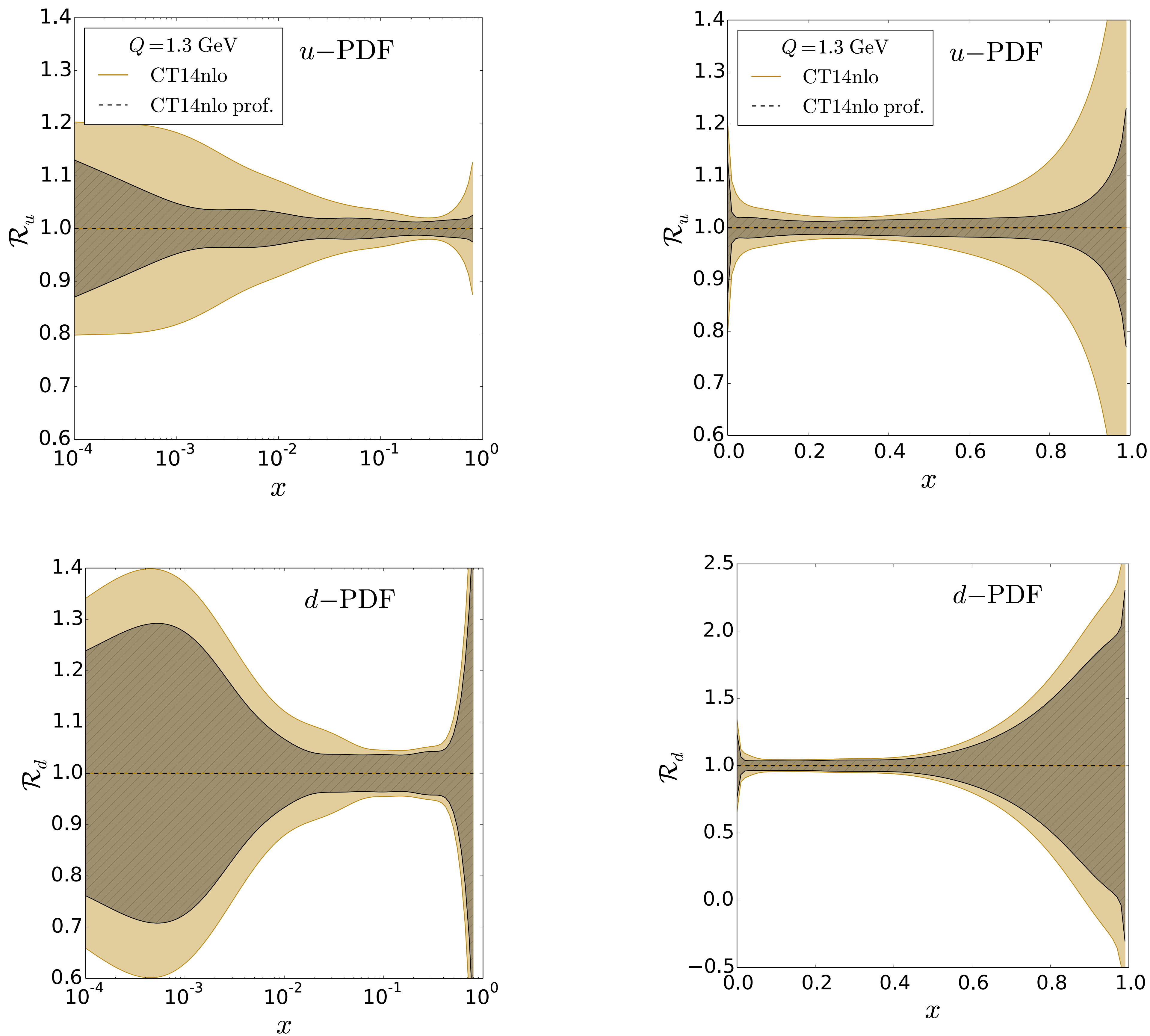
# DY pseudo data compared to NLO theory




- Pseudo-data for the rapidity distributions using MCFM and projected experimental uncertainties (provided by Barbara)
- Need more information how experimental uncertainties have been obtained (stat? sys? bgd?)
- Add description in EoI
- In the figure, the experimental errors are barely visible
- Performed reweighting analysis using the XFitter package

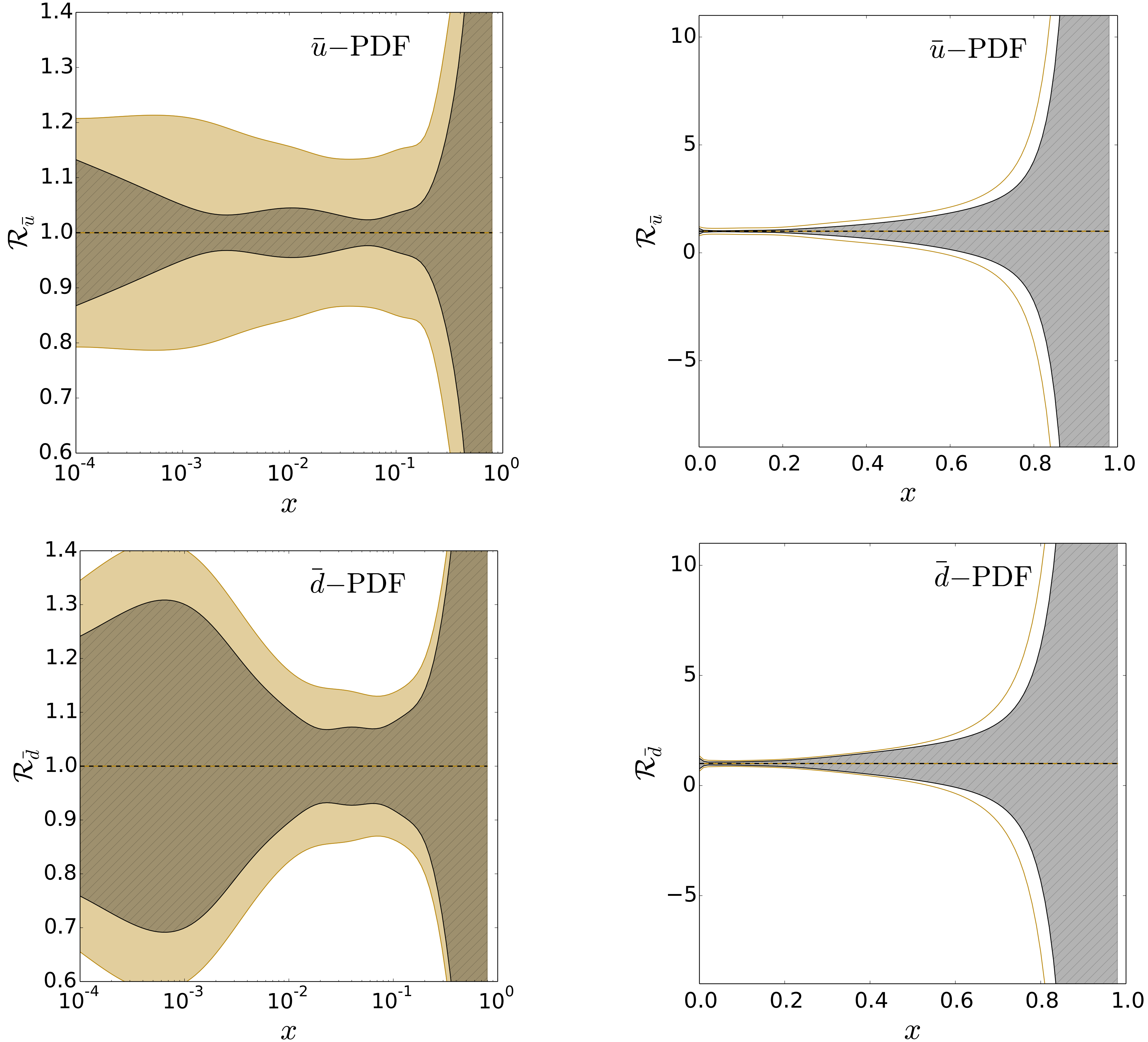
# Impact of DY pp data on proton PDFs

FOM



# Impact of DY on proton PDFs

FOM



# Questions/Outlook/ToDo

- Results of the reweighting analysis in pp look very promising
- Potential to reduce PDF uncertainty of light quarks at small/medium x and high x
- ToDo:
  - Refining discussion of large-x hadron structure models; add references
  - Discussion of projected experimental uncertainties
  - Include nuclear corrections for deuteron?

# W production

# Motivation

- W production close to threshold never been measured

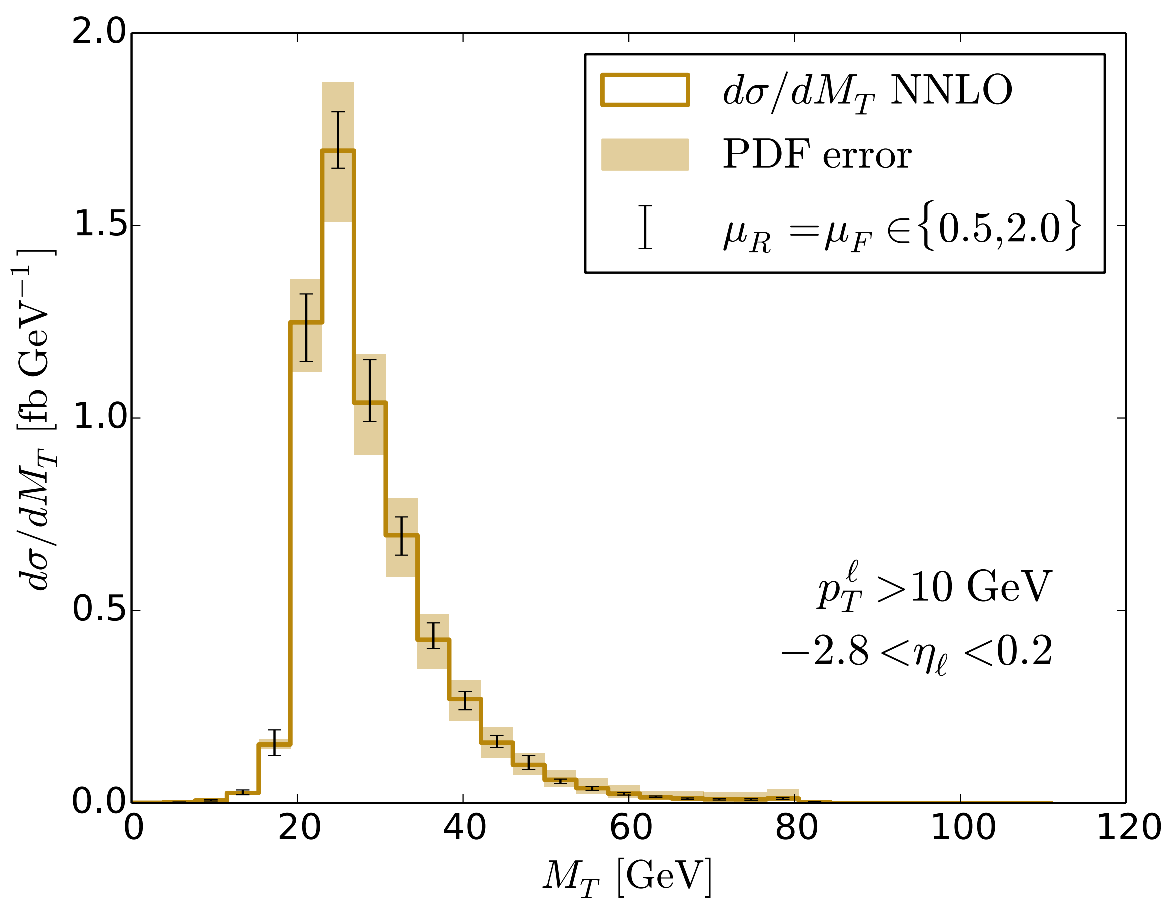
  Proxy for heavy resonance searches at the LHC

- Potential to provides constraints on light quark sea and the valence quarks (flavor separation)

# Predictions for W-boson production at AFTER

| $pp$ | $W^+$ NLO | $W^+$ NNLO | $W^+$ Counts/year | $W^-$ NLO | $W^-$ NNLO | $W^-$ Counts/year |
|---|---|---|---|---|---|---|
| $p_T^l > 10$ GeV | $22.5^{+4.8}_{-4.3}$ | $25.9^{+4.8}_{-5.0}$ | $259 \pm 49$ | $5.5^{+1.3}_{-1.3}$ | $6.2^{+1.1}_{-1.4}$ | $62 \pm 13$ |
| $p_T^l > 20$ GeV | $1.9^{+1.2}_{-0.7}$ | $2.3^{+1.3}_{-1.1}$ | $23 \pm 12$ | $0.38^{+0.29}_{-0.20}$ | $0.50^{+0.25}_{-0.25}$ | $5 \pm 2.5$ |
| $p_T^l > 30$ GeV | $0.28^{+0.91}_{-0.27}$ | $0.27^{+0.72}_{-0.24}$ | $2.7 \pm 4.8$ | $0.035^{+0.091}_{-0.039}$ | $0.04^{+0.09}_{-0.04}$ | $0.4 \pm 0.7$ |

TABLE I Cross section at NLO and NNLO integrated over the rapidity range $2 < \eta_\mu < 5$ and imposing a cut $p_T^\mu > 10$ GeV in [fb]. The results have been obtained for $pp$ collisions at $\sqrt{s} = 115$ GeV with FEWZ [98] using the CT14 PDFs [99]. The asymmetric uncertainties have been calculated using the error PDFs. The expected number of events has been obtained with a yearly luminosity of 10 fb$^{-1}$.



# A simple ratio in the limit of large $x_1$, $x_2$

- W-production at AFTER is close to the threshold
(In fact, it's dominated by off-shell W bosons)

- Both, $x_1$ and $x_2$ are large. In this limit:

$$R^W = \frac{\frac{d\sigma}{dy}(pn \to W^+ + W^-) - \frac{d\sigma}{dy}(pp \to W^+ + W^-)}{\frac{d\sigma}{dy}(pn \to W^+ + W^-) + \frac{d\sigma}{dy}(pp \to W^+ + W^-)} = 1 - 2\frac{\frac{d\sigma}{dy}(pp \to W^+ + W^-)}{\frac{d\sigma}{dy}(pd \to W^+ + W^-)}$$

$$= \frac{[u(x_1) - d(x_1)][\bar{u}(x_2) - \bar{d}(x_2)] + [\bar{u}(x_1) - \bar{d}(x_1)][u(x_2) - d(x_2)]}{[u(x_1) + d(x_1)][\bar{u}(x_2) + \bar{d}(x_2)] + [\bar{u}(x_1) + \bar{d}(x_1)][u(x_2) + d(x_2)]}.$$

- At $y^*=0$, $x_1=x_2$ on has access to $r_s$= dbar(x)/ubar(x)

$$R^W(y=0) = \frac{(1-r_v)(1-r_s)}{(1+r_v)(1+r_s)}$$

# Questions/Outlook/ToDo

- Would be good to add up the event numbers for the electron and the muon channel weighted by the detection efficiencies!

- Do estimate the uncertainty on $R^W$

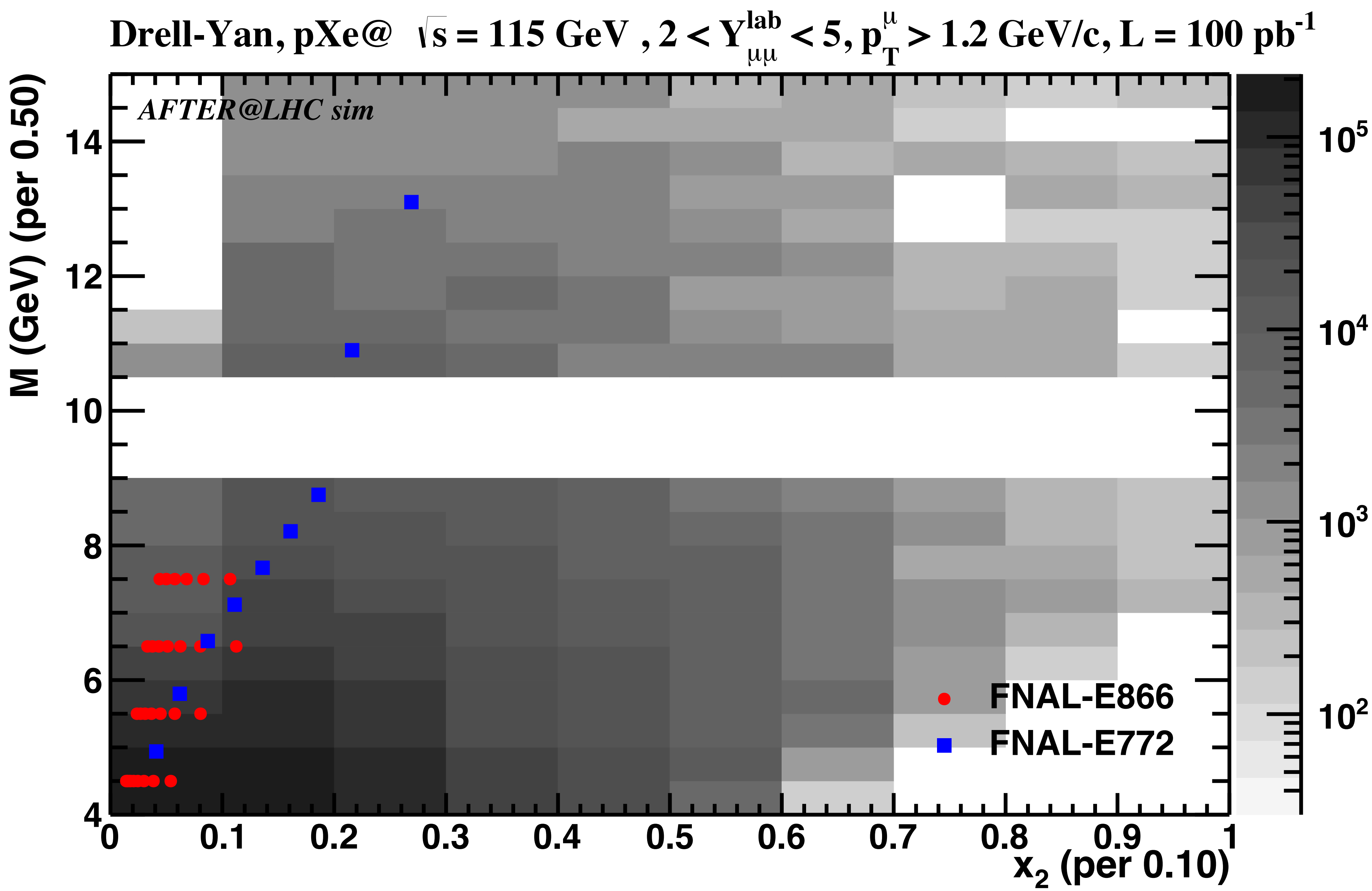
  (a quick estimate gave a 30% relative uncertainty for R which would constrain the large-x sea)

- A reweighting analysis would be interesting

- Consider the effect of Fermi motion?

# Drell Yan lepton pair production in pA

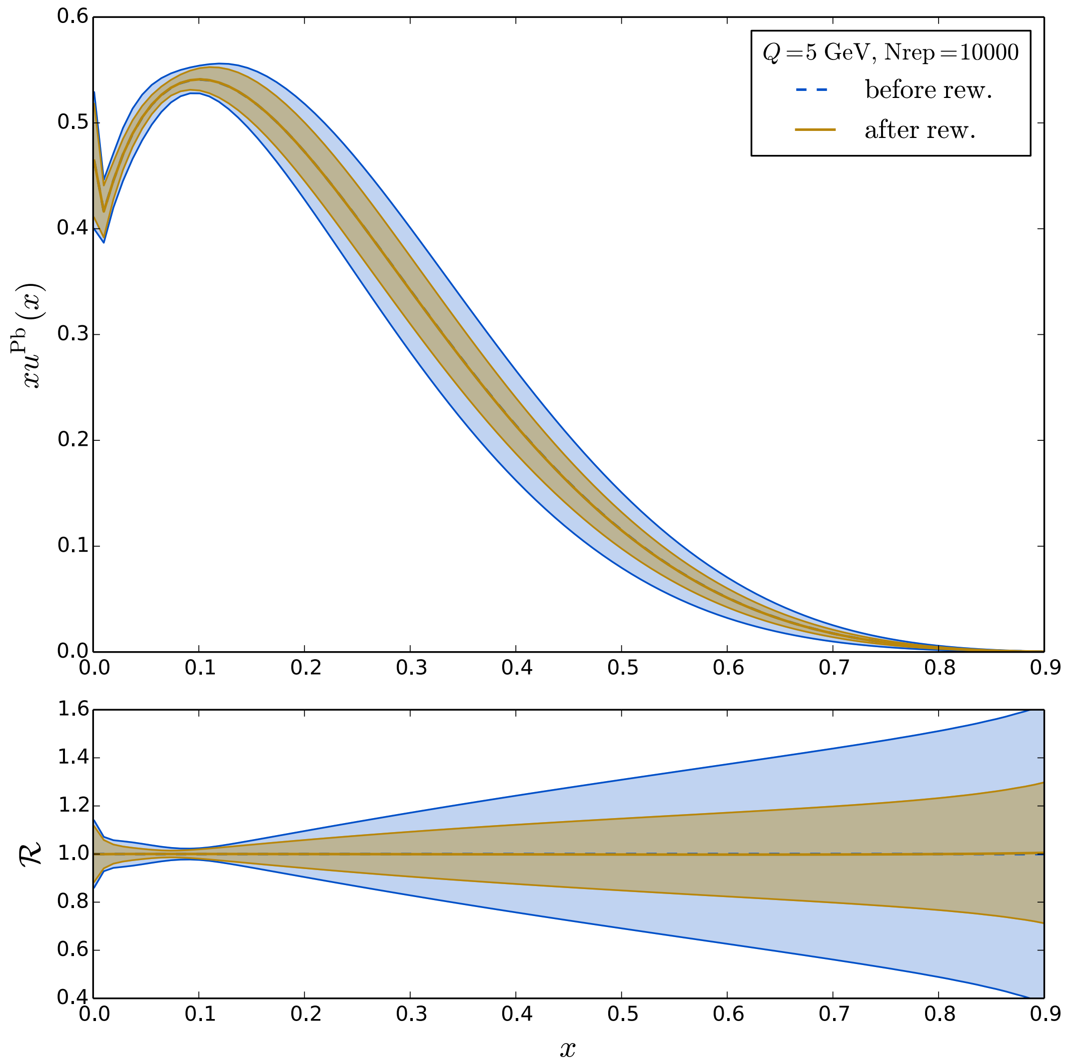
# Kinematical plan of DY in p-Xe

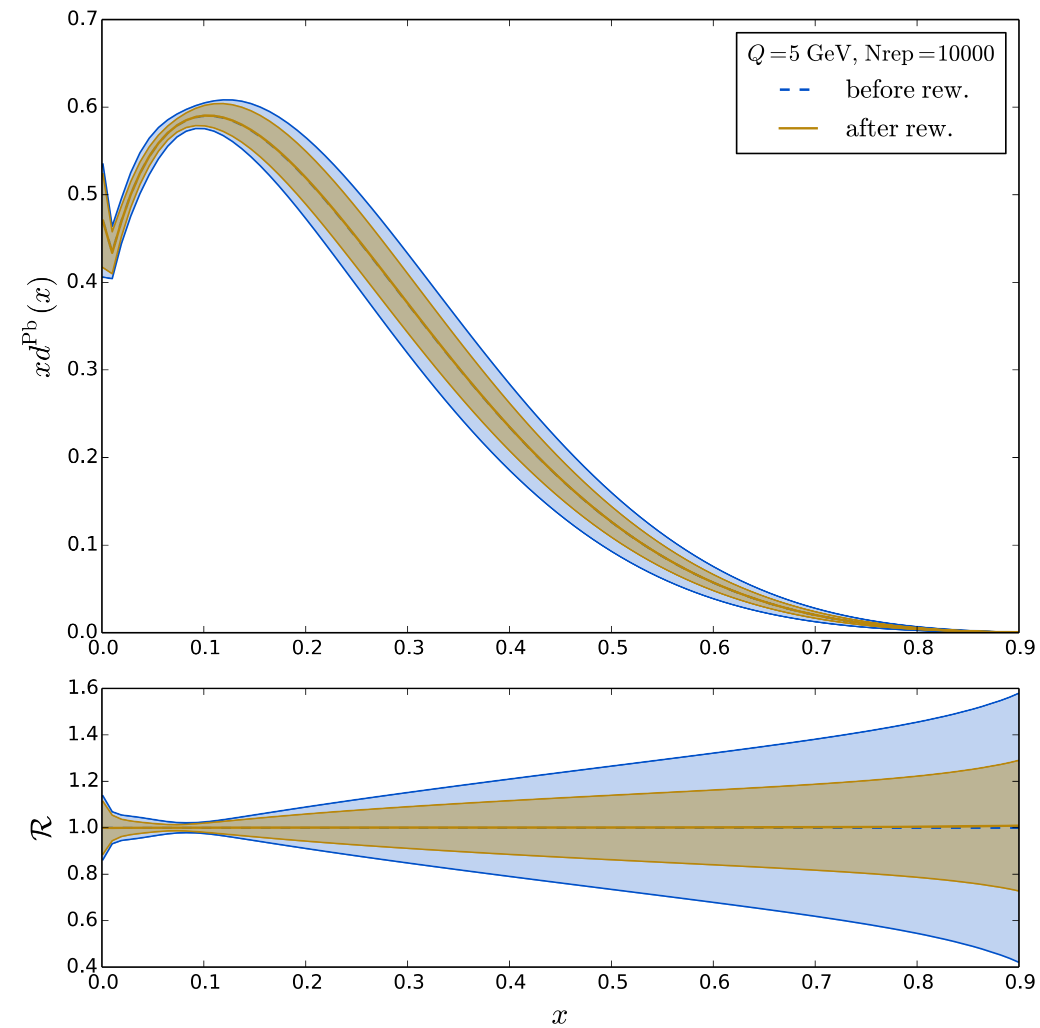



AFTER:

- Spectacular potential to improve the current state-of-the-art
- Different targets can be used (here Xe)

# Impact of DY pA data on nCTEQ15 NPDFs



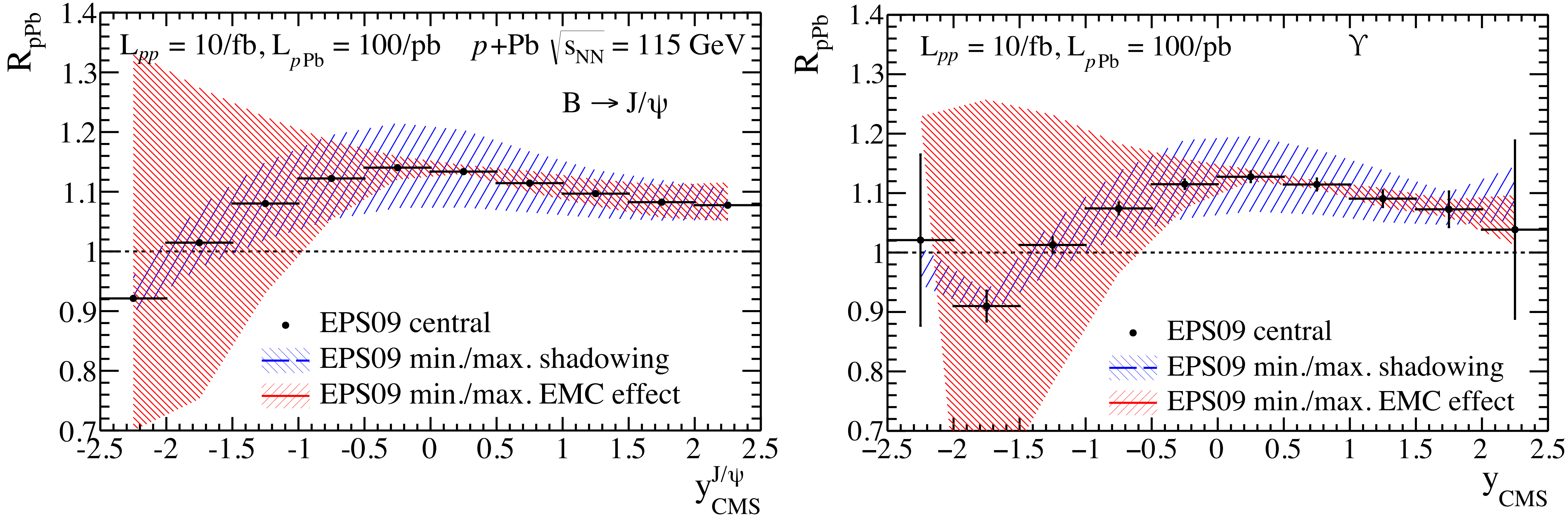

FOM: Figures to be polished

# Questions/Outlook/ToDo

- FOM to be polished
- Repeat reweighting analysis with EPPS'16 would be interesting

# The large-x gluon at AFTER in pA

# RpA for non-prompt J/Psi and Υ

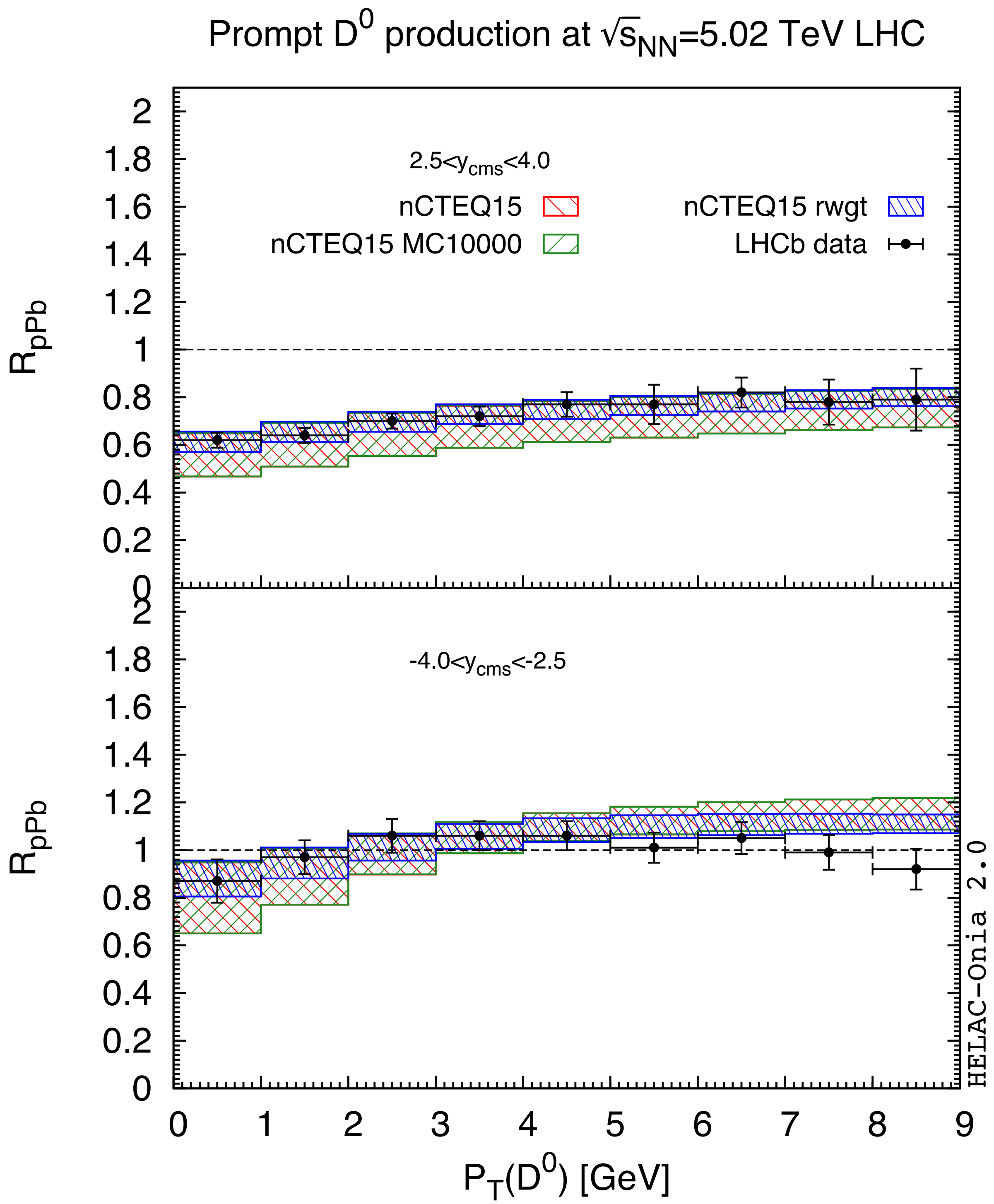


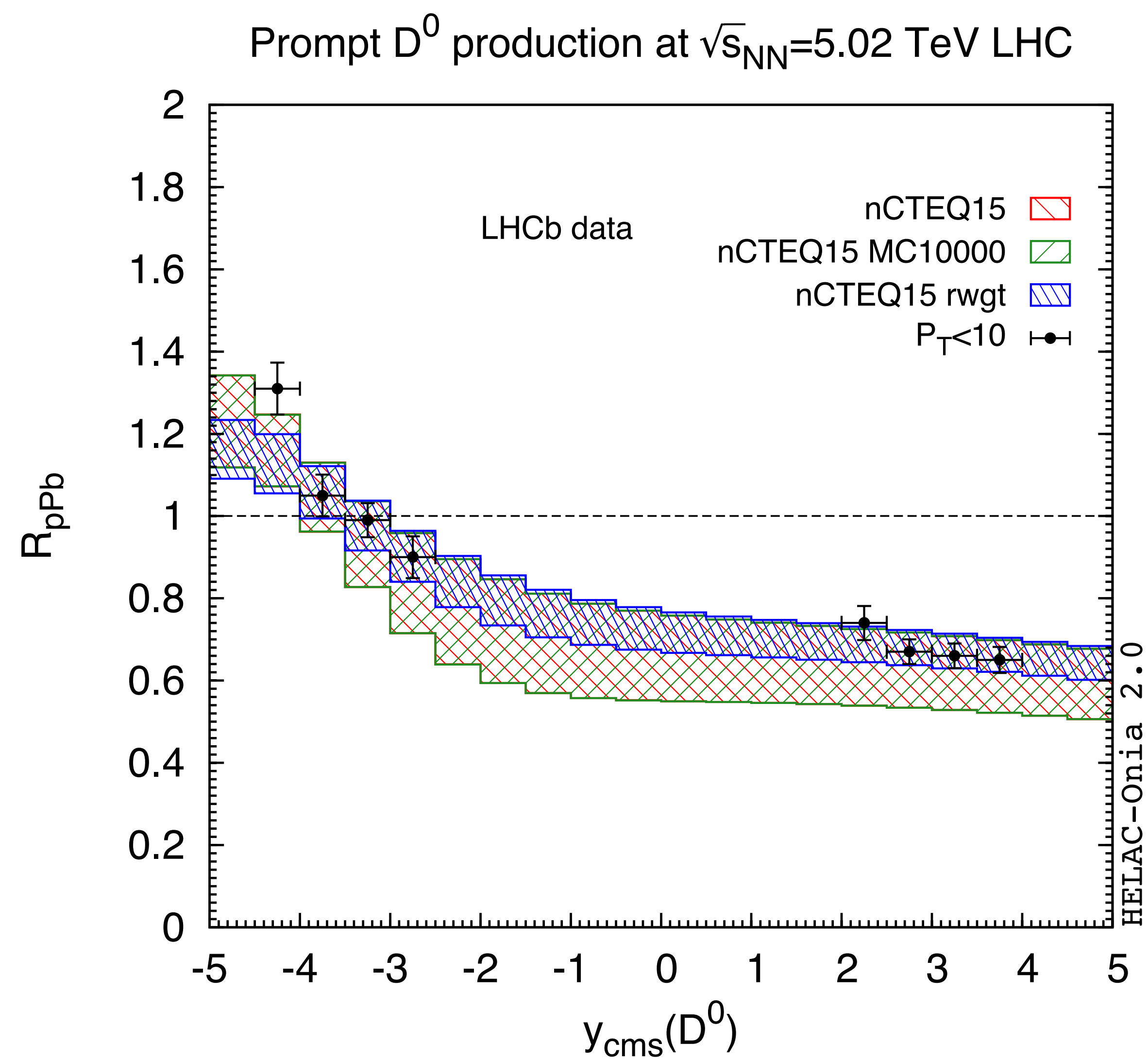

Massacrier, Trecziak et al

- Projected statistical uncertainties after subtracting the bgd compared to typical nPDF uncertainties

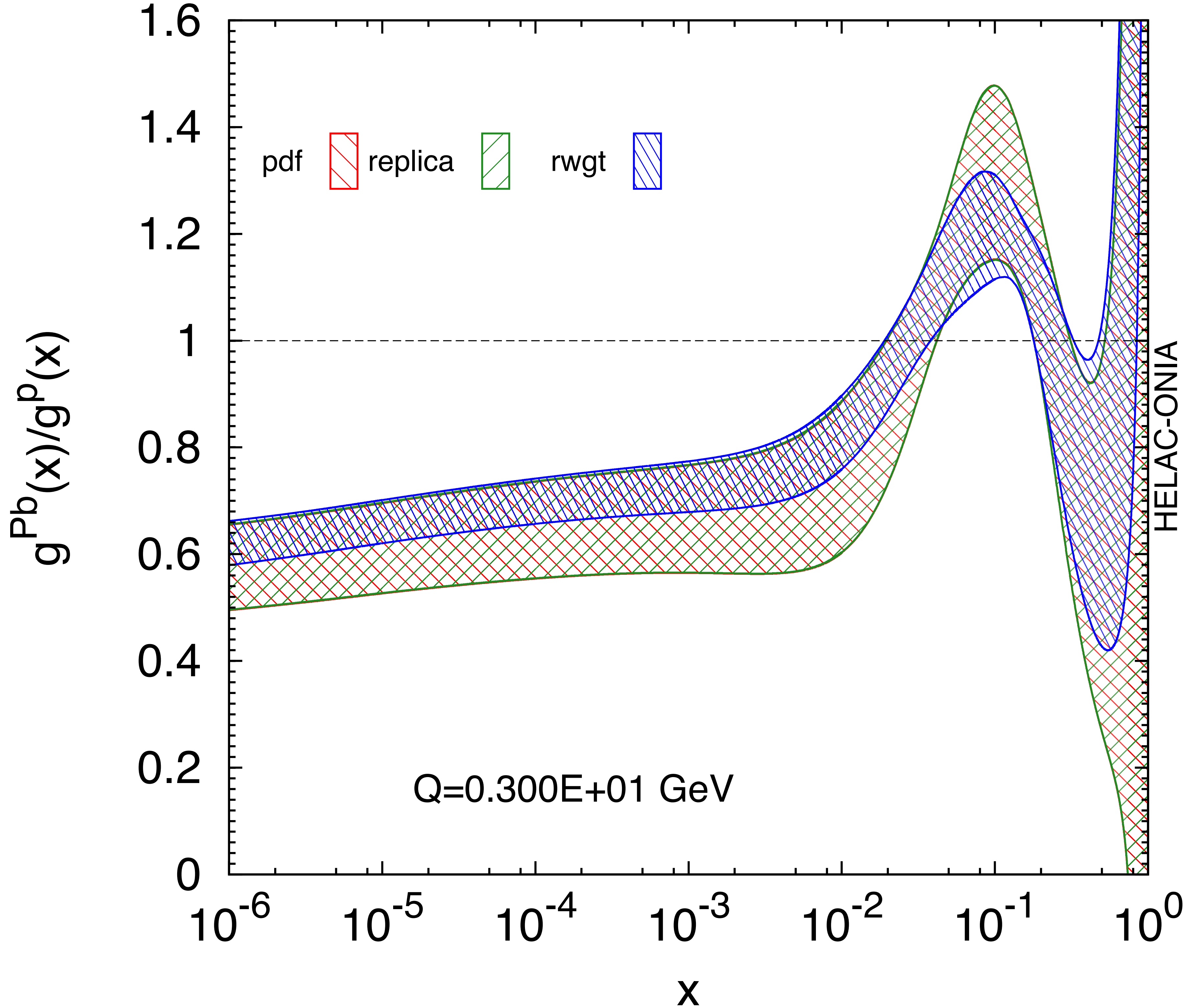
- Next step: reweighting analysis on pseudo data

# Reweighting analysis using LHC5 data



# Reweighting analysis using LHC5 data



# Questions/Outlook/ToDo

- This is work in progress but looks promising

- Currently doing a reweighting analysis with D-meson and J/Psi data in pPb collisions at LHC5 (LHCb, ALICE, ...)

  This constrains the gluon at small-x!

- Will use the same procedure with AFTER pseudo data for pA.

  Need to validate this method for the AFTER kinematics (large-x! how important is the gg-channel?)

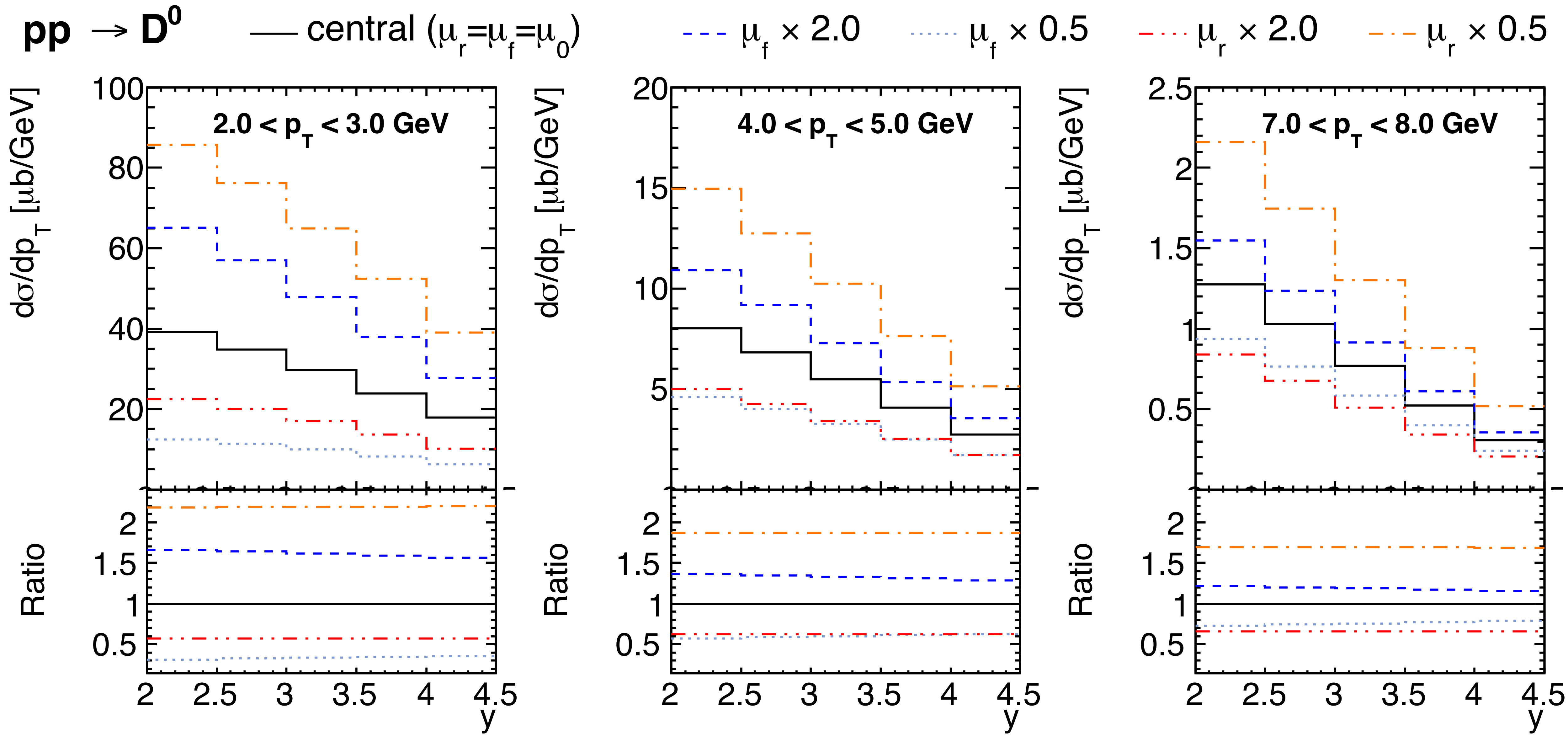
# The large-x gluon at AFTER in pp

# PROSA study

O. Zenaiev et al, EPJC75(2015)396

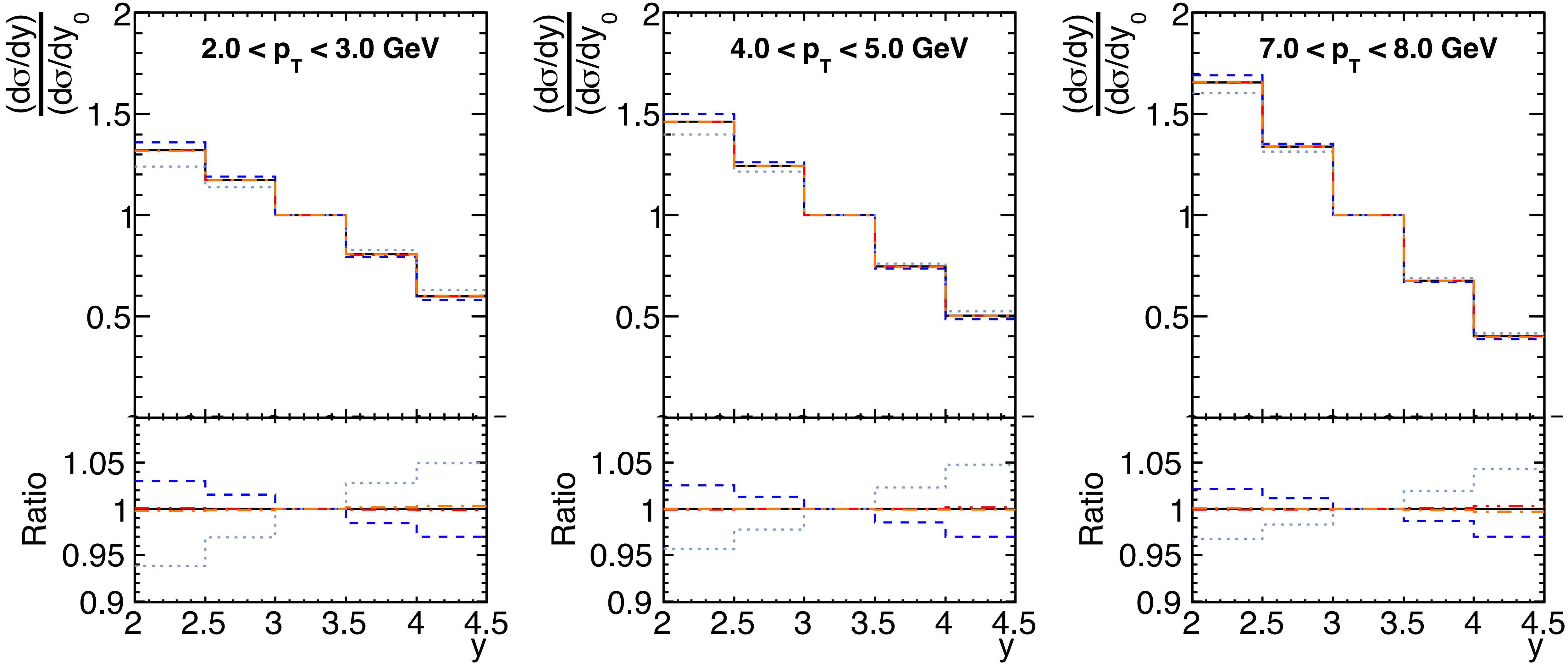
- NLO QCD analysis of impact of data for heavy quark production in ep and pp collisions on PDFs
- Theory for heavy quark production in ep, pp: FFNS at NLO
- Data:
  - HERA: Inclusive DIS cross sections in ep
  - HERA: Heavy flavour production cross sections in ep
  - LHCb: Differential cross sections for c ($D^0$, $D^+$, $D^{*+}$, $D_s^+$, $\Lambda_c$) and b ($B^+$, $B^0$, $B_s^0$) production in pp at LHC7
- Result:
  LHCb data impose constraints on low-x gluon and quark sea

# NLO QCD predictions for charm LHCb data



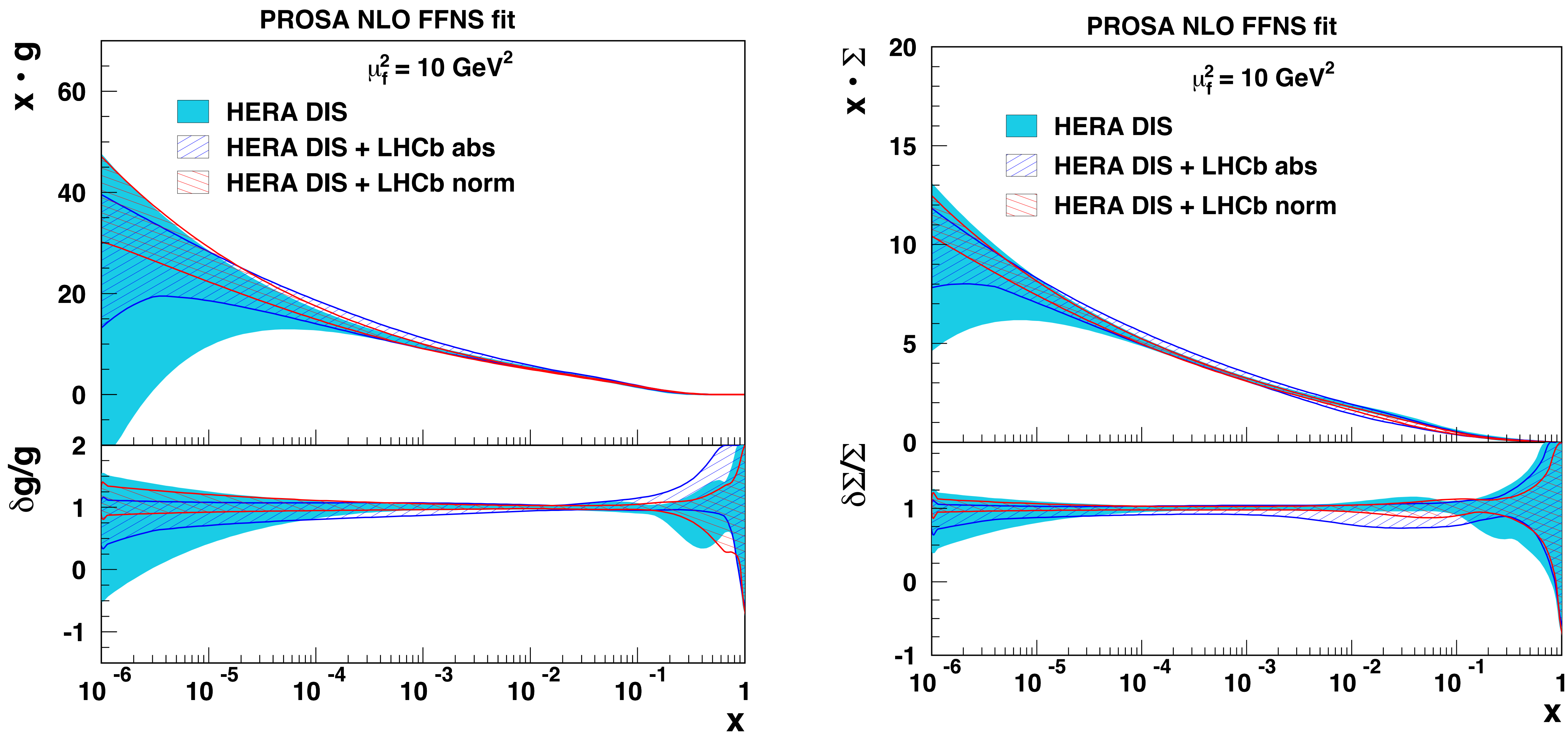

- Central scale $\mu_0 = m_T$
- Large scale uncertainties!
- Mostly change the normalization, shape less affected

# NLO QCD predictions for charm LHCb data




- Normalized cross sections w.r.t. dσ/dy in the bin 3<y<3.5
- Very small scale uncertainties now!
- Shape remains sensitive to gluon

# Results for the gluon and the sea




- The uncertainties on the gluon and the sea are significantly reduced using LHCb data
- In the normalised case by a factor 3 at $x \sim 5 \times 10^{-6}$

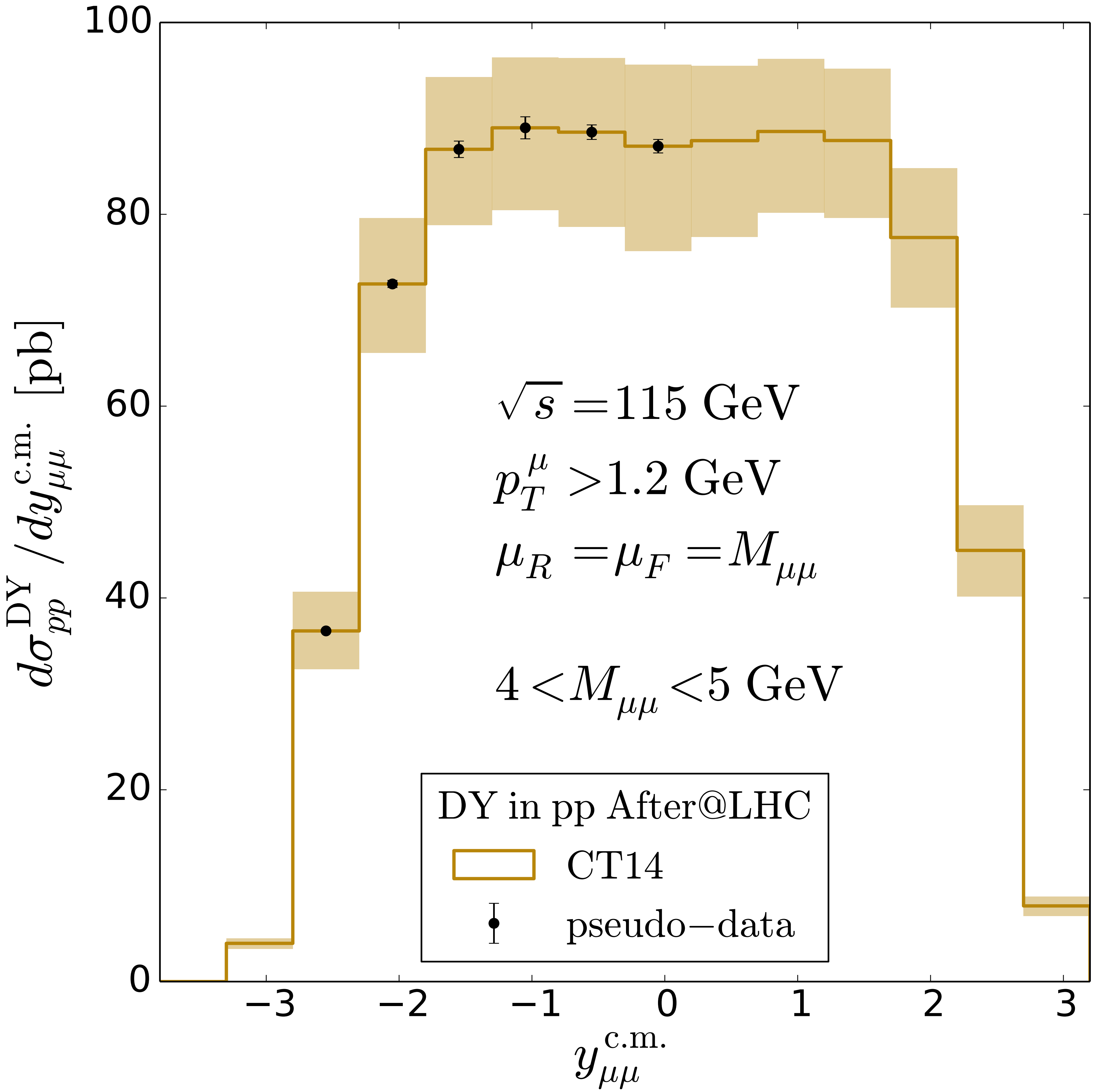
# Questions/Outlook/ToDo

- Work to be done!
- The differential cross sections have very large scale uncertainties
- Use normalized cross sections (as in PROSA) $R_y = (d\sigma^{pPb}/dy)/(d\sigma^{pPb}/dy(y_0))$
- Directly sensitive to nuclear gluon and sea PDF
- Advantage: a lot of experimental systematics cancel

# Questions/Outlook/ToDo

- Need careful comparison with state-of-the-art extractions of the large-x gluon using t-tbar data to see whether AFTER can have an impact!

# Thank you




Wednesday 21 June 17