# Nuclear PDFs from the LHeC perspective

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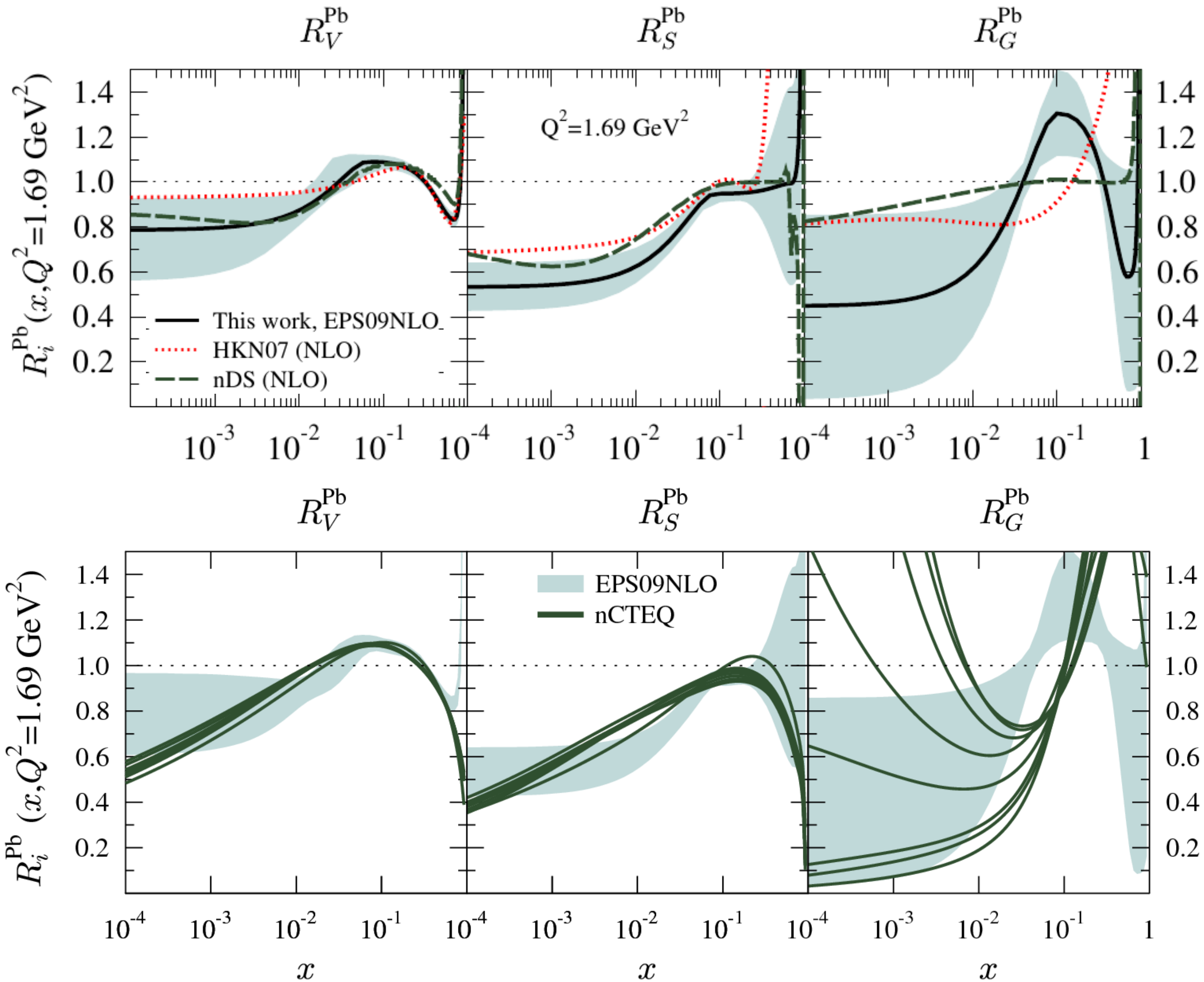
# The nuclear effects in PDFs - far from being "well known"

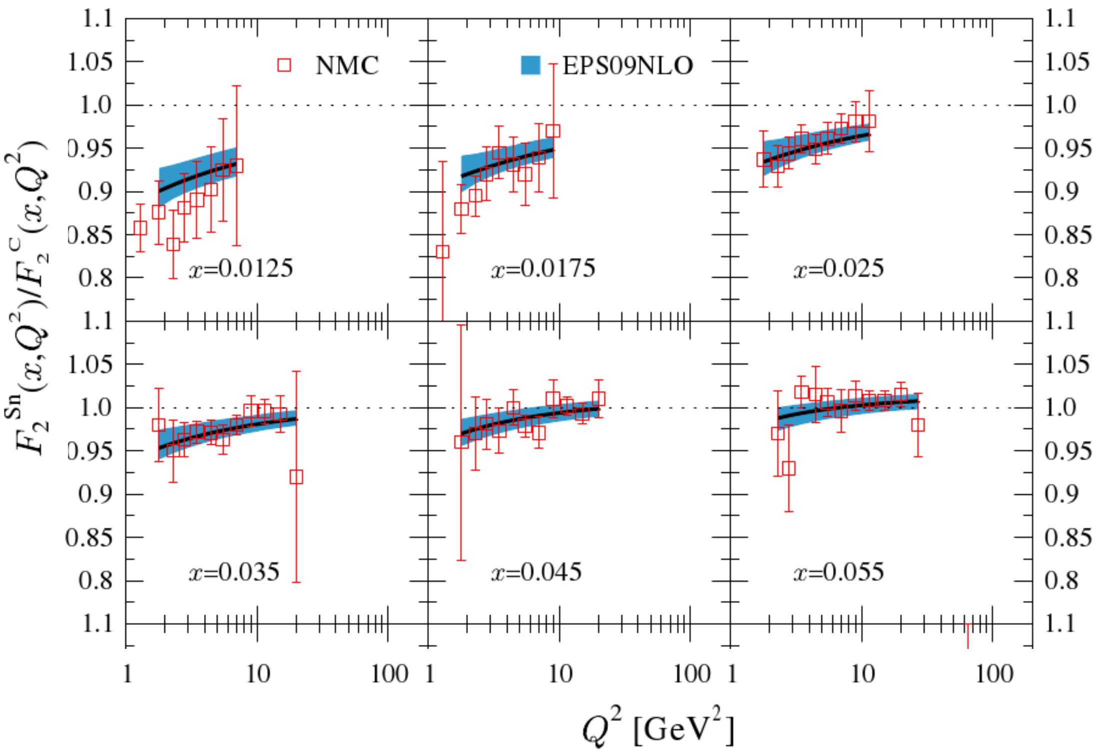
- **Independent nPDF parametrizations contain surprisingly large differences**

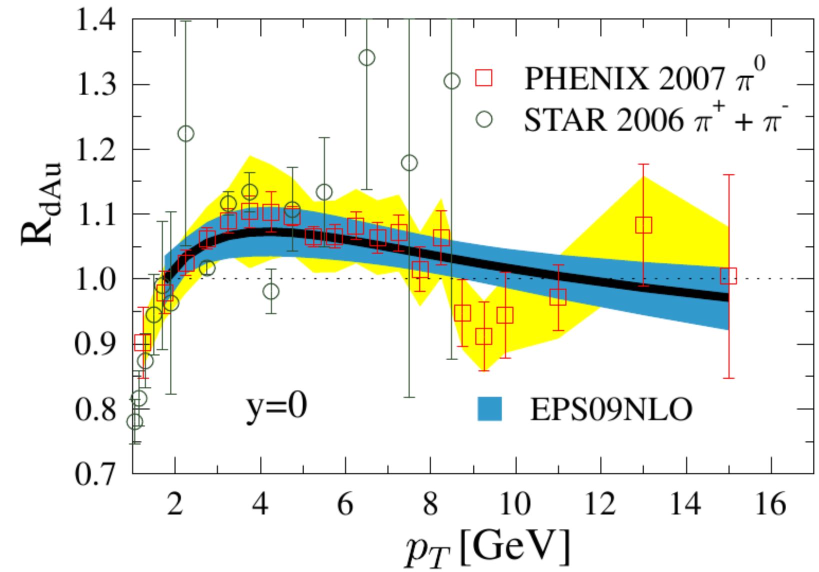
$$R_i^{\mathrm{Pb}}(x,Q^2) \equiv \frac{f_i^{\mathrm{Pb}}(x,Q^2)}{f_i^{\text{free proton}}(x,Q^2)}$$



# The nuclear effects in PDFs - far from being "well known"

- Especially the gluon modification is highly controversial
- At the moment, the only constraints are the $F_2$-slopes & inclusive pion production

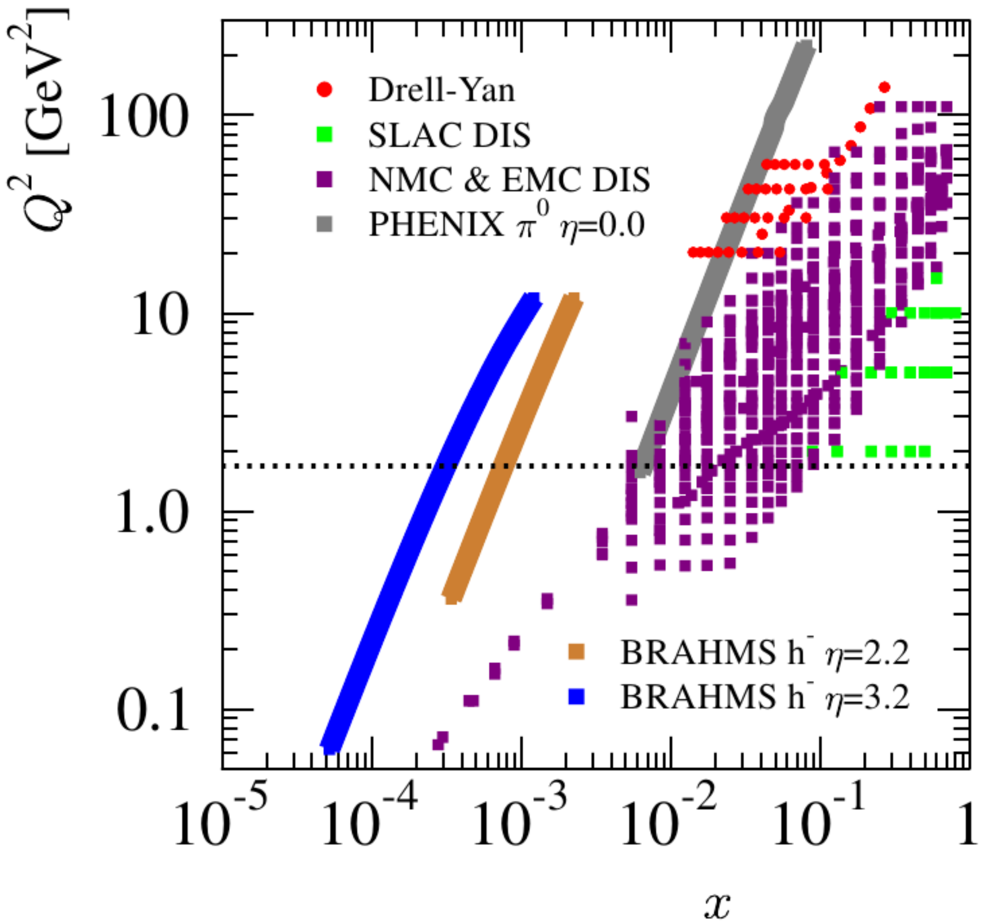


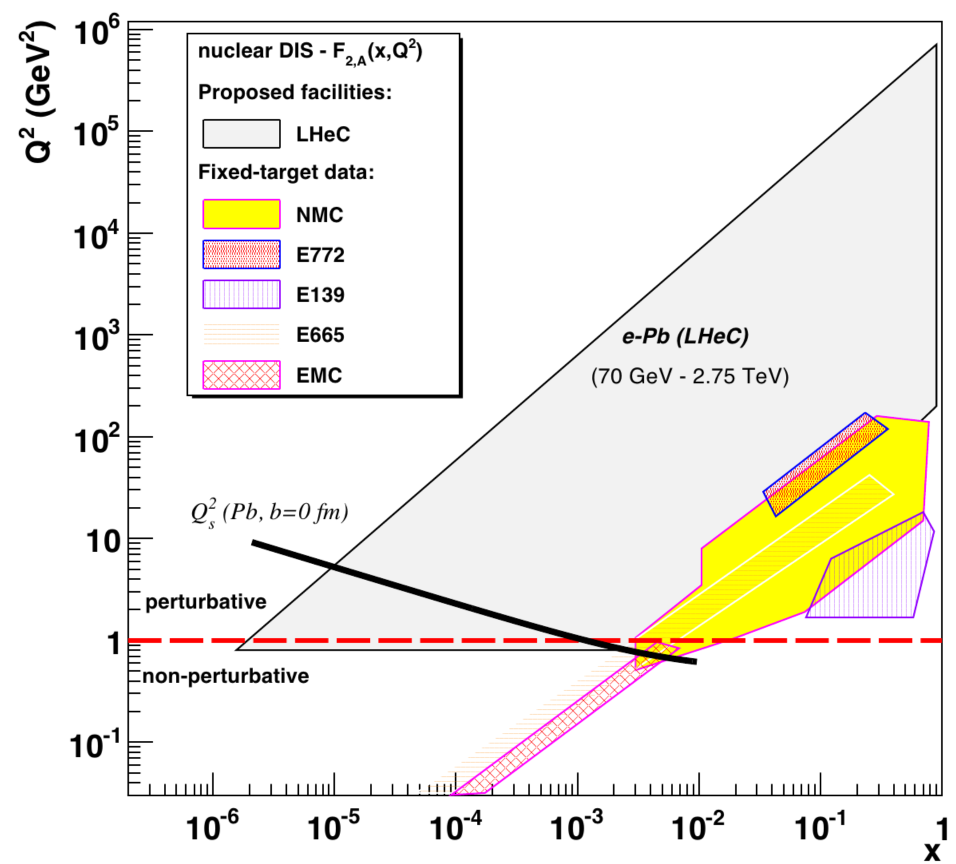




- Too large $Q^2$-cut and leaving out the pion data will leave the gluons unconstrained
- The p+Pb data from the LHC should improve the situation, but for the ultimate precision, lepton-ion collider like LHeC would be needed.

# LHeC kinematics

- The proposed LHeC collider would hugely enlarge the kinematic coverage in nuclear DIS.




- We estimate the impact of the LHeC data on the nPDFs by a fit to a sample of pseudodata

# The LHeC pseudodata

- A sample of pseudodata (by N. Armesto) for reduced cross-sections

$$\sigma_r^{NC} = \frac{Q^4 x}{2\pi\alpha^2 Y_+} \frac{d^2\sigma^{NC}}{dx dQ^2} = F_2 \left[1 - \frac{y^2}{Y_+} \frac{F_L}{F_2}\right] \qquad Y_+ = 1 + (1-y)^2$$

was generated from using assuming:

$E_{lepton}$ = 50 GeV, $E_p$ = 7000 GeV, $E_{Pb}$ = 2750 GeV , $E_{Ca}$ = 3500 GeV

in the kinematical window: $x < 0.01$ & $Q^2 < 1000$ GeV$^2$

- The e+p cross-sections from a pQCD based simulation, nuclear effects according to a dipole model (Eur. Phys. J. C26 (2002) 35-43)

- The inclusive cross-sections were combined to ratios

$$\frac{\sigma^{\rm Ca}_{\rm reduced}(x,Q^2)}{\sigma^{\rm p}_{\rm reduced}(x,Q^2)}, \quad \text{and} \quad \frac{\sigma^{\rm Pb}_{\rm reduced}(x,Q^2)}{\sigma^{\rm p}_{\rm reduced}(x,Q^2)}$$

- Flavor-decomposed quantities were also considered

$$\frac{\sigma^{\rm Ca,\,Pb}_{\rm reduced,\,charm}(x,Q^2)}{\sigma^{\rm p}_{\rm reduced,\,charm}(x,Q^2)} \quad \text{and} \quad \frac{\sigma^{\rm Ca,\,Pb}_{\rm reduced,\,bottom}(x,Q^2)}{\sigma^{\rm p}_{\rm reduced,\,bottom}(x,Q^2)}$$

# The framework of the pQCD analysis

- **We define the bound proton PDFs by** $f_k^{\text{proton},A}(x,Q^2) = R_k^A(x,Q^2)\, f_k^{\text{proton}}(x,Q^2)$

- **The cross-sections are computed at NLO with the SACOT prescription for the heavy quark treatment**

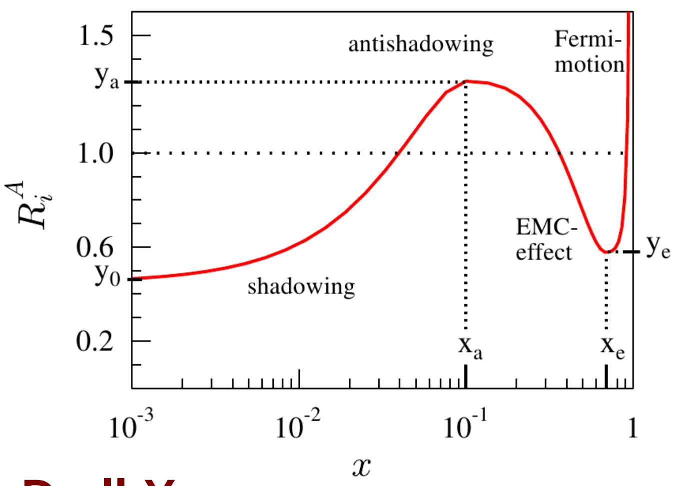
$$\sigma_{\text{DIS}}^{\ell+A\to\ell+X} = \sum_{i=q,\overline{q},g} \underbrace{f_i^A(\mu^2)}_{\text{Nuclear PDFs, obeying the standard DGLAP}} \otimes \underbrace{\hat{\sigma}_{\text{DIS}}^{\ell+i\to\ell+X}(\mu^2)}_{\text{Usual pQCD partonic cross-sections}}$$

**Nuclear PDFs, obeying the standard DGLAP**

**Usual pQCD partonic cross-sections**

- **Parametrize the nuclear modifications at Q=1.3 GeV**

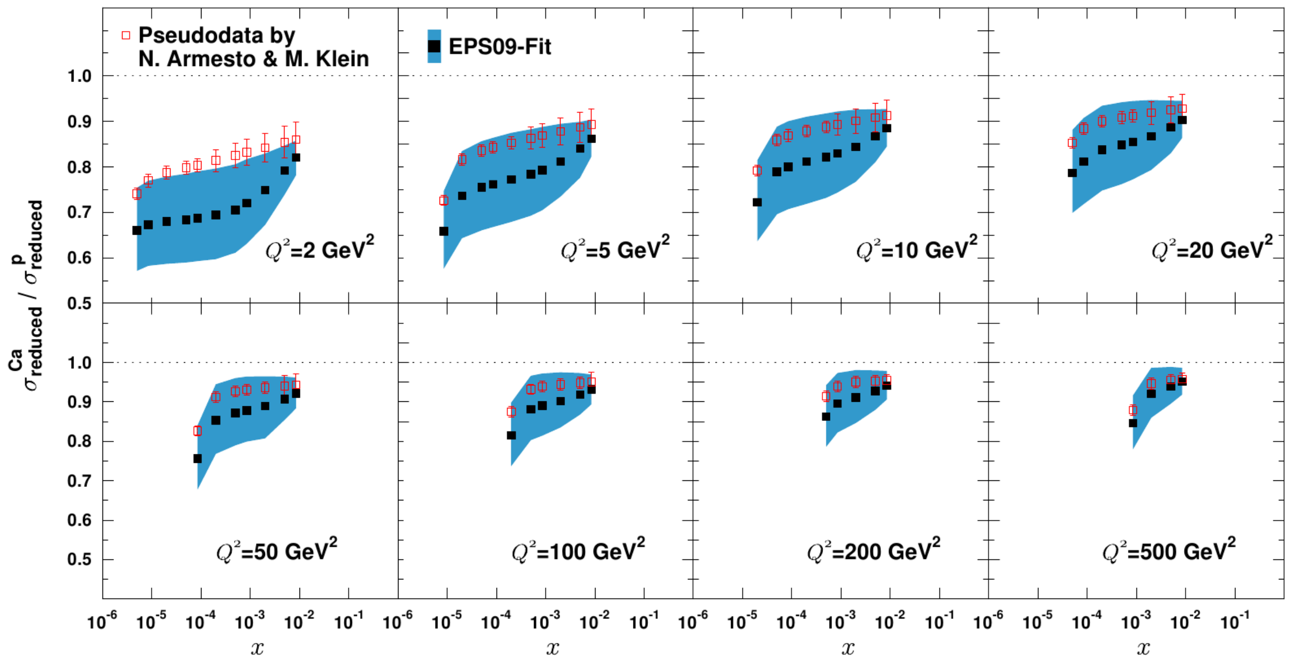
| | |
|---|---|
| $R_V^A(x,Q_0^2)$ | for all valence quarks |
| $R_S^A(x,Q_0^2)$ | for all sea quarks |
| $R_G^A(x,Q_0^2)$ | for gluons |

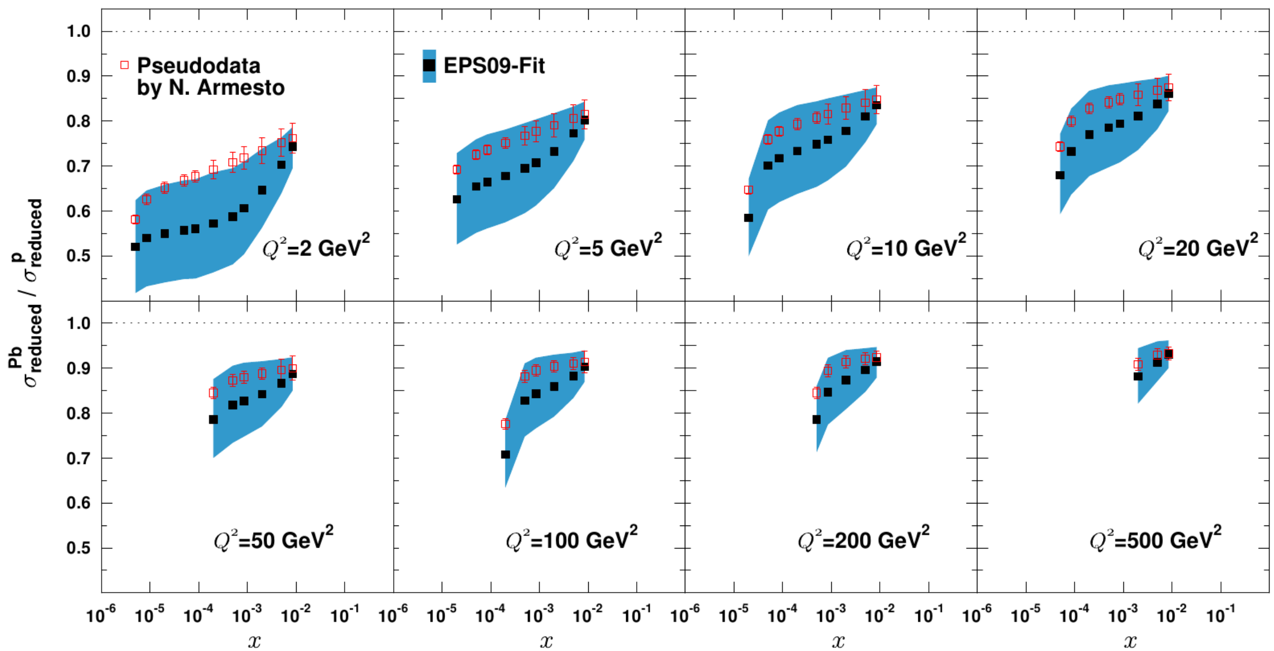



- **The LHeC pseudodata is added on top of all other DIS, Drell-Yan, and inclusive pion data, that were included in EPS09.**

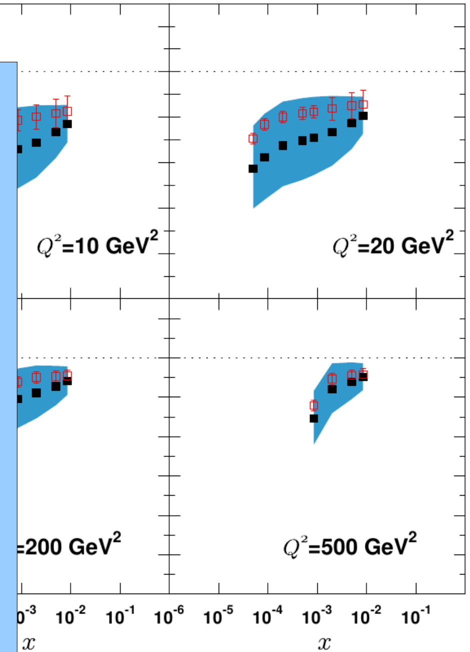
- **Standard $\chi^2$-fit with Hessian error analysis with $\Delta\chi^2 = 50$**

# Before the fit: the pseudodata vs. EPS09



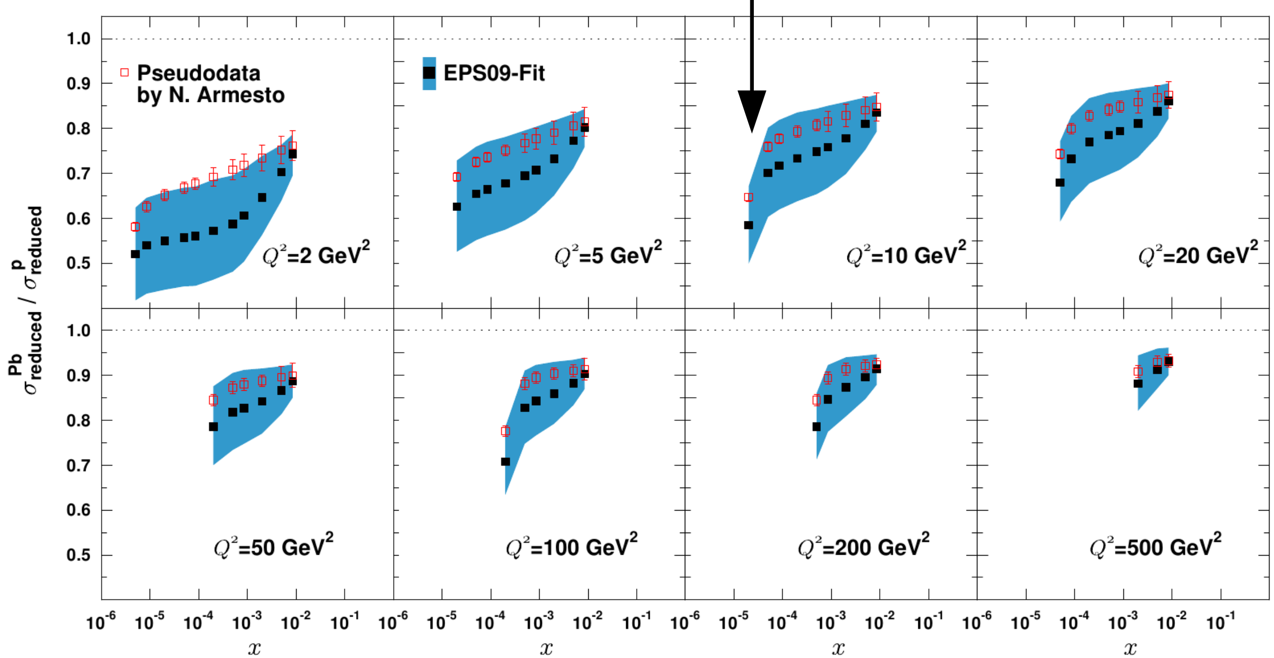
# Before the fit: the pseudodata vs. EPS09



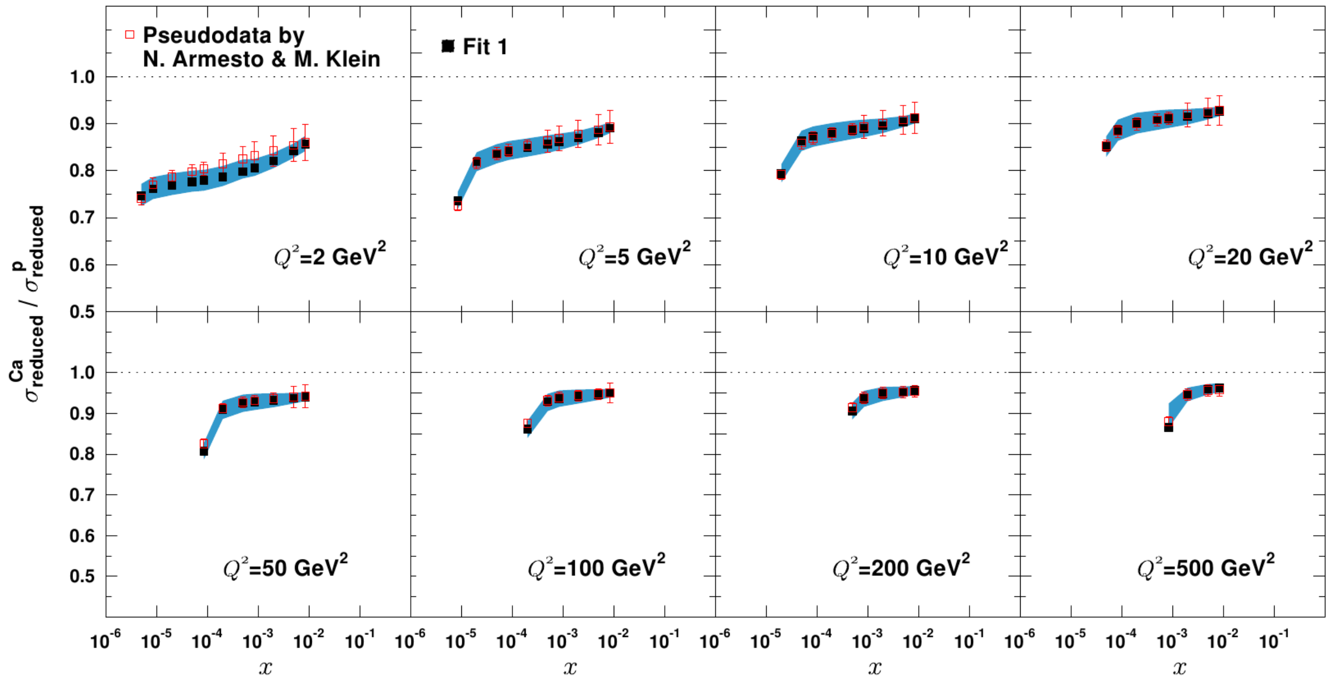

The $F_L$ kicks in here!

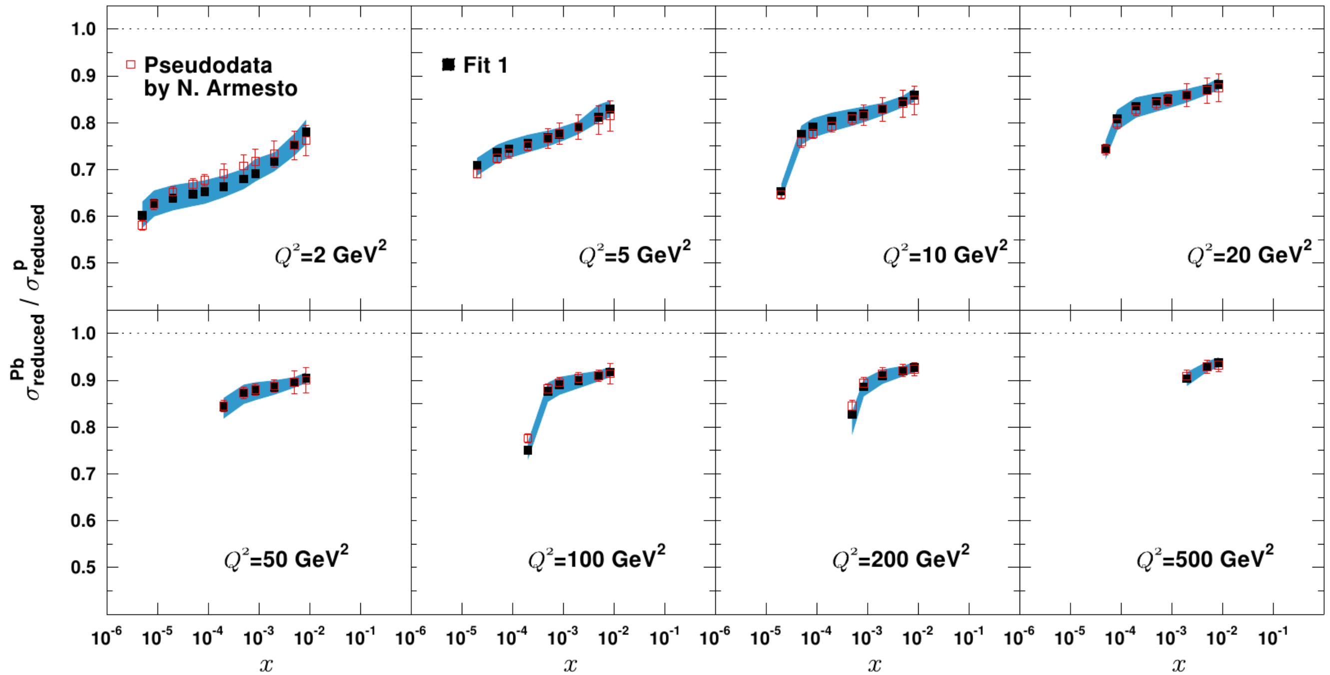
$$\sigma_r^{NC} = \frac{Q^4 x}{2\pi\alpha^2 Y_+} \frac{d^2\sigma^{NC}}{dx dQ^2} = F_2 \left[1 - \frac{y^2}{Y_+} \frac{F_L}{F_2}\right]$$

The leading order analyses would no longer do...

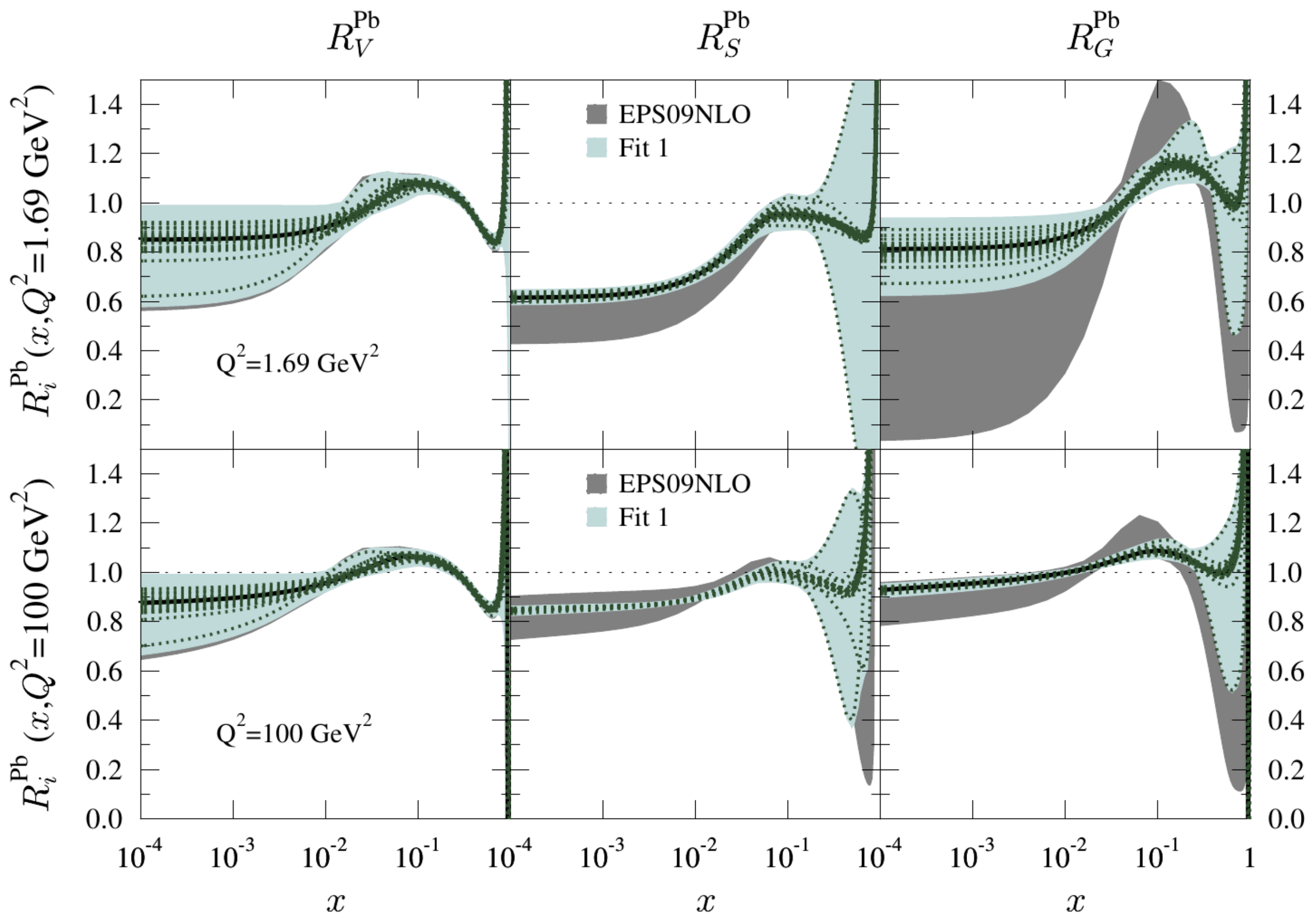


# After the fit



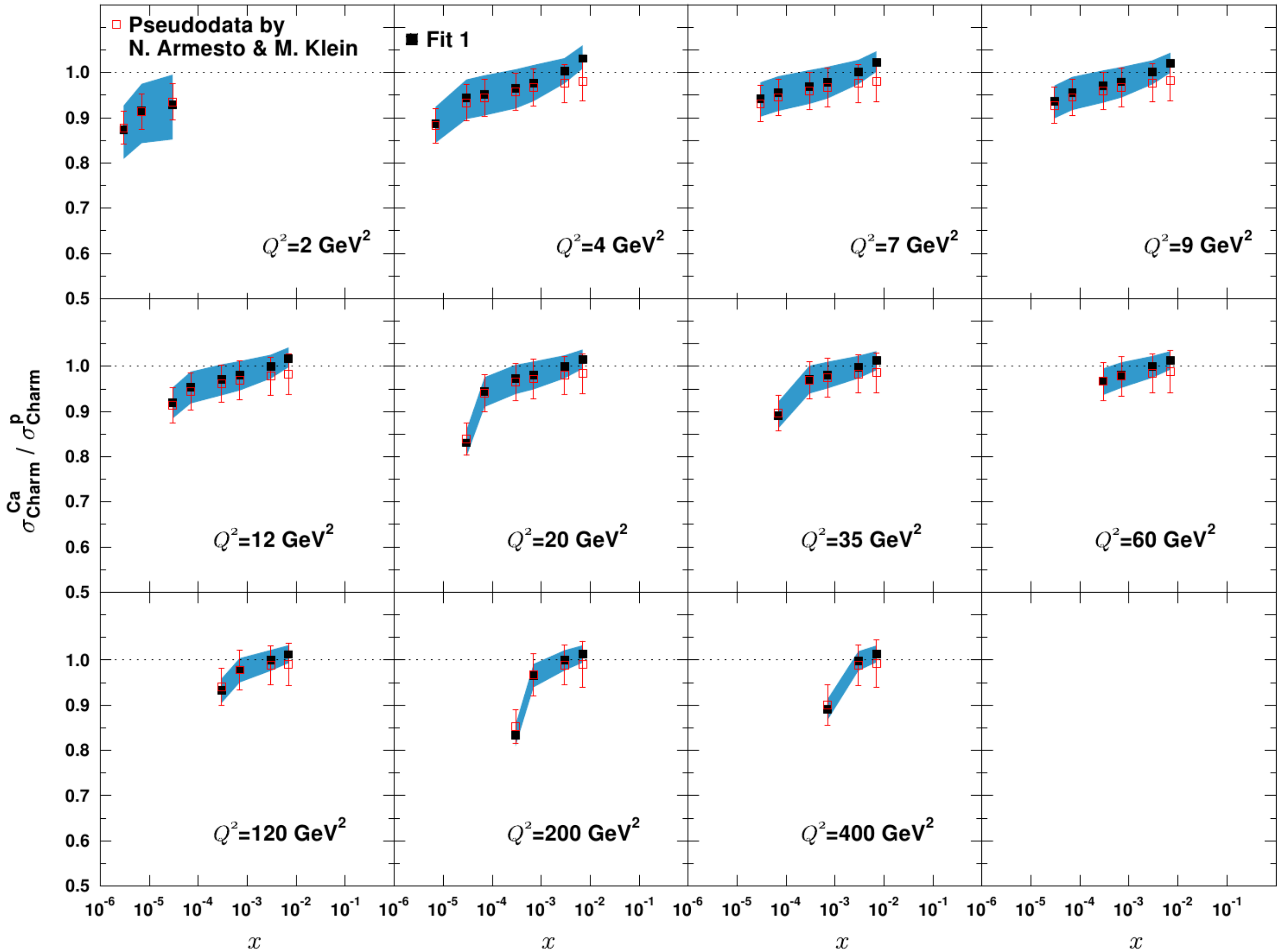



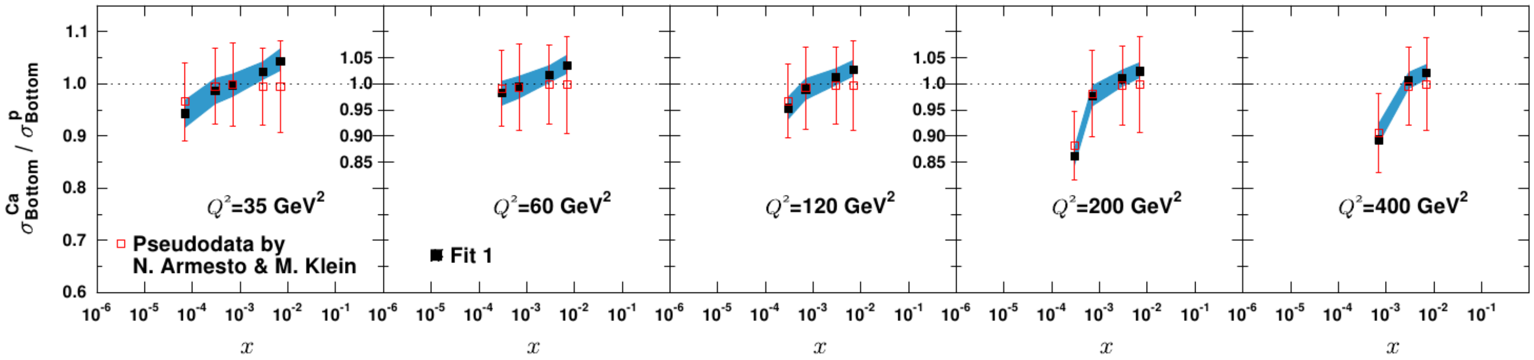
# Effect in the nuclear modificaton factors



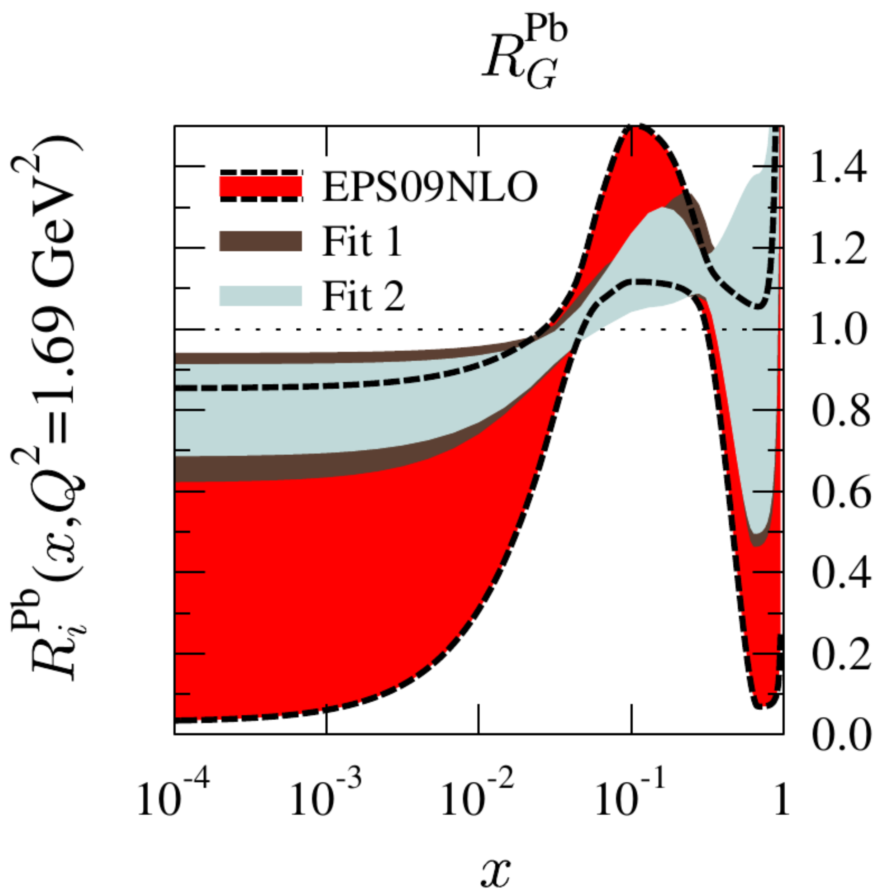

- **A drastic reduction in the small-x gluon and sea quark uncertainties**

# The heavy flavor cross-sections



# The effect of heavy flavor cross-sections



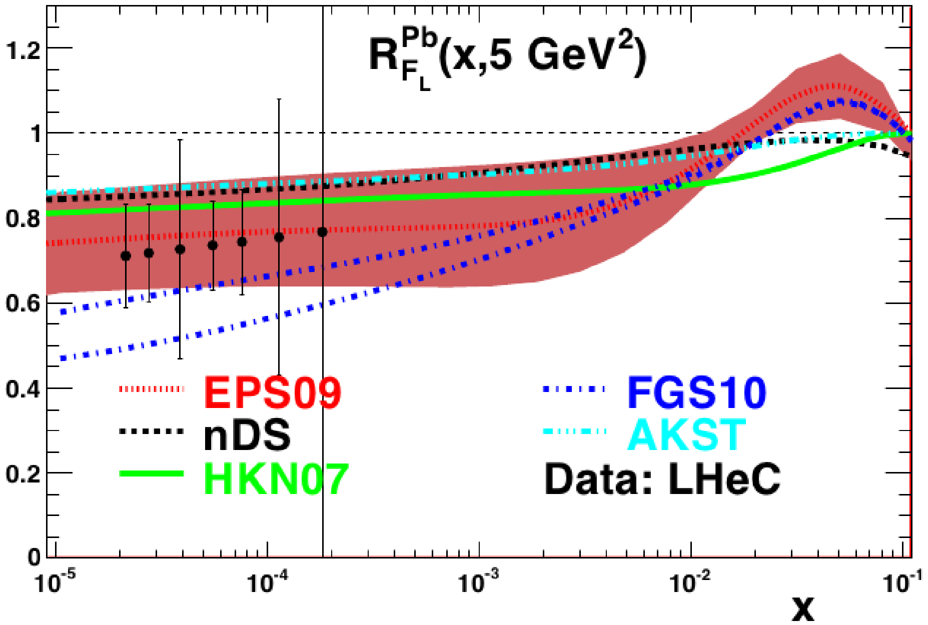

- The heavy flavor production is of gluonic origin $g + \gamma^* \longrightarrow g + h + \overline{h}$

→ Some extra constraints for gluons

# The longitudinal structure function

- **The longitudinal structure function could be experimentally determined at the LHeC by varying the $E_{lepton}$**

$$\sigma_r^{NC} = \frac{Q^4 x}{2\pi\alpha^2 Y_+} \frac{d^2\sigma^{NC}}{dx dQ^2} = F_2 \left[ 1 - \frac{y^2}{Y_+} \frac{F_L}{F_2} \right]$$



# Summary

- The inclusive DIS measurements at the LHeC would give an enormous impovement in the nPDF determination.

- Here, we considered only the small-x region in neutral-current reactions, but LHeC could also do e.g.

  **Large-x measurements:** few-percent accuracy up to x=0.6 at very large scale, $Q^2 > 1000$ GeV

  **Charged-current cross-sections:** flavor dependence of the nuclear effects, cross-check for the neutrino DIS

  **High-pT jets in eA:** even more information on gluons

  **Electron-deuteron scattering:** nuclear effects in deuteron neutron structure functions

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