Pion–nucleus Drell–Yan data as a novel constraint for nuclear PDFs

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Introduction

- This work [1] considers the prospects of using the Drell–Yan (DY) dilepton process in pion–nucleus collisions as a novel input in the global analysis of nPDFs.
- It has been suggested [2], that the $\pi^{\pm}+A$ DY process could be used to study the possible differences in valence quark nuclear modifications $R^A_{u_\mathrm{V}}$ and $R^A_{d_\mathrm{V}}$.

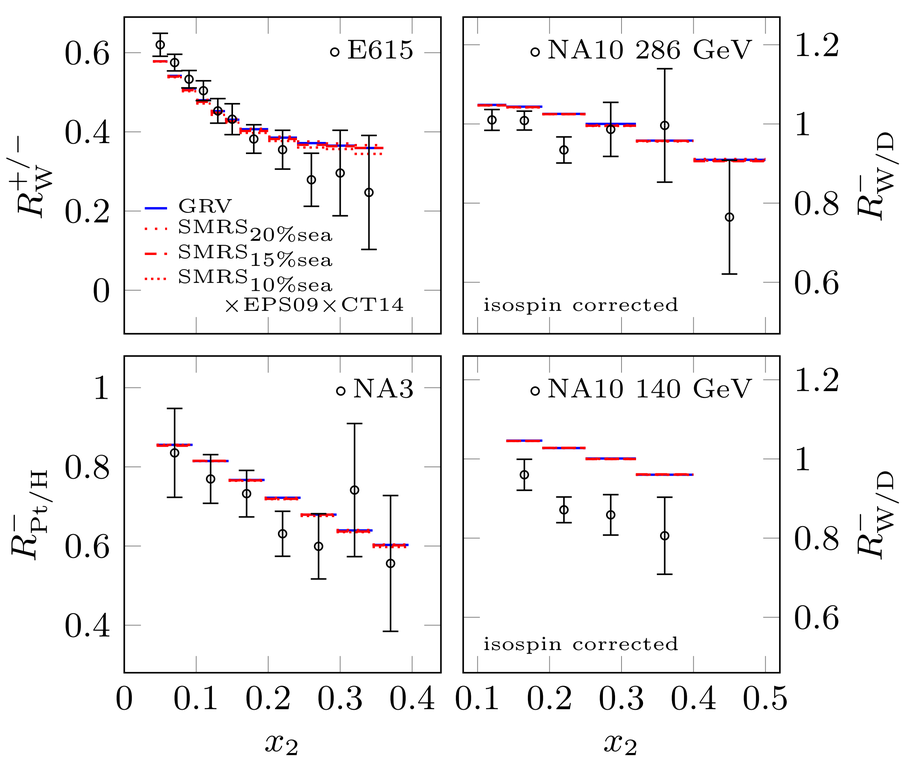
Nuclear ratios and pion PDFs

- In the following cross-section ratios (differential in $x_2 \equiv \frac{M}{\sqrt{s}}\mathrm{e}^{-y}$), when pion sea quarks can be neglected, the dependence on pion PDFs approximately cancels in LO:

$$R_A^{+/-}(x_2) \equiv \frac{\mathrm{d}\sigma_{\mathrm{DY}}^{\pi^+ + A}/\mathrm{d}x_2}{\mathrm{d}\sigma_{\mathrm{DY}}^{\pi^- + A}/\mathrm{d}x_2} \approx \frac{4\bar{u}_A(x_2) + d_A(x_2)}{4u_A(x_2) + \bar{d}_A(x_2)}$$

$$R^-_{A_1/A_2}(x_2) \equiv \frac{\frac{1}{A_1}\mathrm{d}\sigma_{\mathrm{DY}}^{\pi^- + A_1}/\mathrm{d}x_2}{\frac{1}{A_2}\mathrm{d}\sigma_{\mathrm{DY}}^{\pi^- + A_2}/\mathrm{d}x_2} \approx \frac{4u_{A_1}(x_2) + \bar{d}_{A_1}(x_2)}{4u_{A_2}(x_2) + \bar{d}_{A_2}(x_2)}$$

- We have tested that this cancellation works well also in a full NLO calculation:

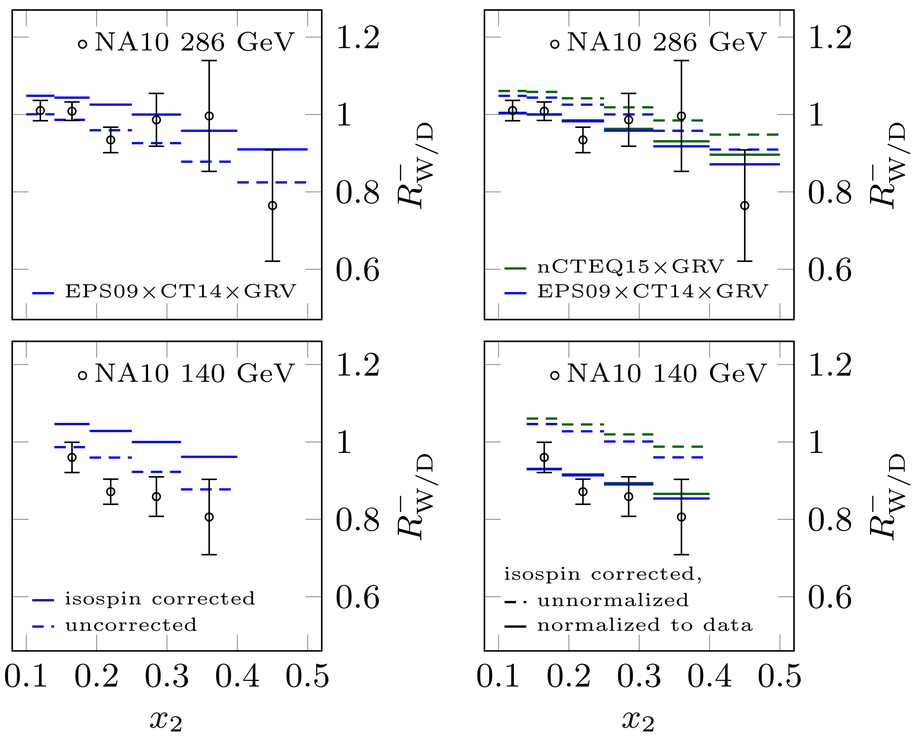


Isospin correction and normalization

- The NA10 collaboration has corrected their data for the isospin effects. We account for this correction by:

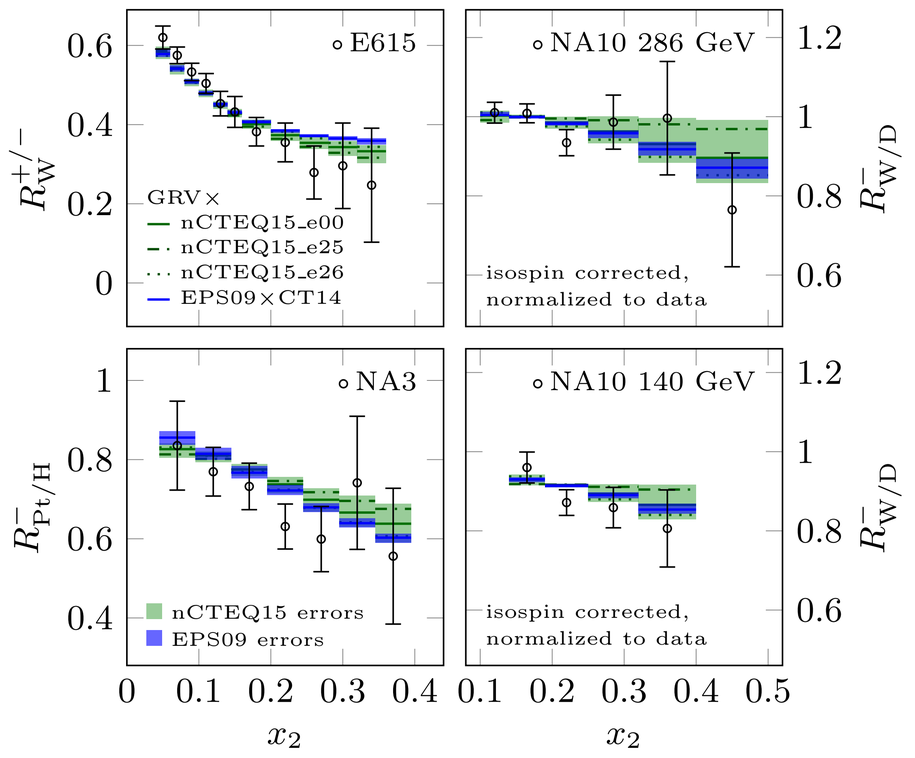
$$(R^-_{\mathrm{W/D}})^{\mathrm{NLO}}_{\text{isospin corrected}} = (R^-_{\text{isocalar-W/W}})^{\mathrm{LO}}_{\text{no nPDFs}} \times (R^-_{\mathrm{W/D}})^{\mathrm{NLO}}$$

- We account for the 6% systematic overall normalization uncertainty in the NA10 data by fixing the normalization with a χ^2 fit. For the higher beam energy the predictions are within the given uncertainty interval, but for the lower energy we need $\sim 12\%$ correction.



Results

- Both the EPS09 [3] and nCTEQ15 [4] nuclear PDFs are in a good agreement with the given data.
- Large differences in the uncertainty estimates from the EPS09 and nCTEQ15.
- A clear mutual separation in the predictions with nCTEQ error sets 25 ($R^A_{u_\mathrm{V}} \ll R^A_{d_\mathrm{V}}$) and 26 ($R^A_{u_\mathrm{V}} \sim R^A_{d_\mathrm{V}}$).
- The studied observables are thus sensitive to mutual differences in valence quark nuclear modifications.



Comparison of nPDFs

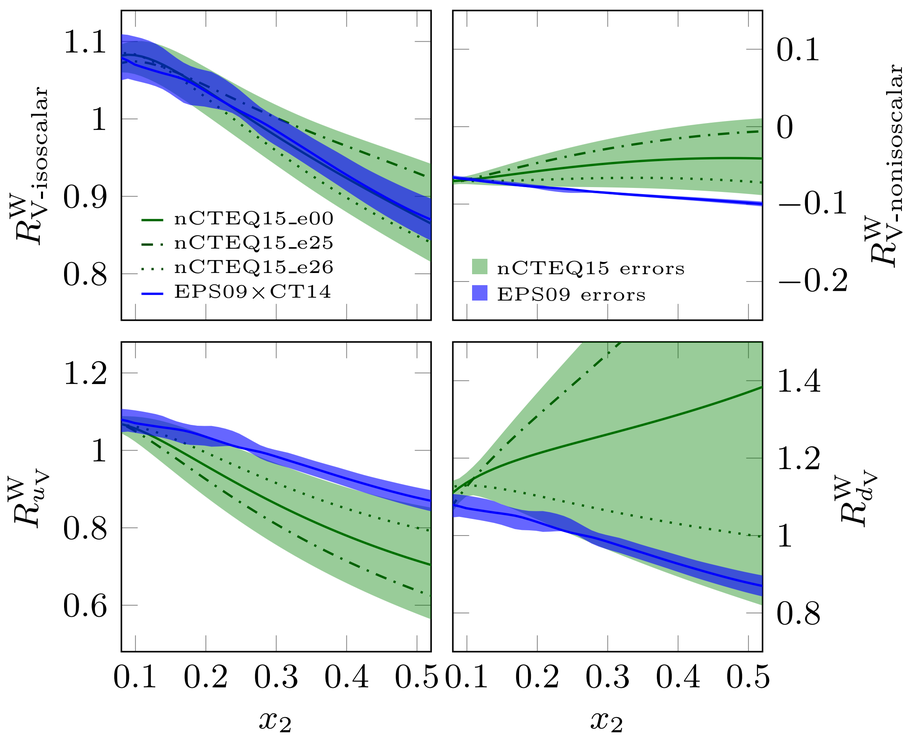
- Study the $R^-_{\mathrm{W/D}}$ ratio measured by NA10 at large x_2, where only the valence quarks in nuclei contribute. In LO we have:

$$R^-_{\mathrm{W/D}} \overset{x_2\to 1}{\approx} R^{\mathrm{W}}_{\text{V-isoscalar}} + R^{\mathrm{W}}_{\text{V-nonisoscalar}},$$

where

$$R^A_{\text{V-isoscalar}} \equiv \frac{u^{\mathrm{V}}_{p/A} + d^{\mathrm{V}}_{p/A}}{u^{\mathrm{V}}_p + d^{\mathrm{V}}_p}, \quad R^A_{\text{V-nonisoscalar}} \equiv \left(\frac{2Z}{A} - 1\right)\frac{u^{\mathrm{V}}_{p/A} - d^{\mathrm{V}}_{p/A}}{u^{\mathrm{V}}_p + d^{\mathrm{V}}_p}$$

- The nCTEQ15 error bands are large due to a significant uncertainty in $R^A_{u_\mathrm{V}}$ and $R^A_{d_\mathrm{V}}$. In their analysis the flavor dependence of valence modifications was allowed, but not well constrained.
- On the other hand, the EPS09 error sets underestimate the true uncertainty because flavor dependence of valence quark nuclear modifications was not allowed.



Conclusions and outlook

- The considered data are compatible with modern nPDFs and can thus be used in a global analysis without causing significant tension.
- The measured cross-section ratios are insensitive to pion PDFs and hence the inclusion of these data will not impose significant new theoretical uncertainties to the analysis.
- These cross-section ratios are sensitive to the possible u/d -asymmetry of nuclear modification factors but the data are not precise enough to pin down this difference completely.
- The given data are in agreement with u/d -symmetric (EPS09) nuclear modifications.
- The most extreme differences in u and d quark nuclear modifications as given by particular nCTEQ15 error sets are disfavored by the NA3 and NA10 data.
- These data sets have now been included in the EPPS16 global nPDF analysis [5].

References

[1] P. Paakkinen, K. J. Eskola, H. Paukkunen, arXiv:1609.07262 [nucl-th]
[2] D. Dutta, J. C. Peng, I. C. Cloet, D. Gaskell, Phys. Rev. C **83** (2011) 042201
[3] K. J. Eskola, H. Paukkunen and C. A. Salgado, JHEP **0904** (2009) 065
[4] K. Kovarik *et al.*, Phys. Rev. D **93** (2016) no.8, 085037
[5] K. J. Eskola, P. Paakkinen, H. Paukkunen, C. A. Salgado, arXiv:1612.05741 [hep-ph]