South China Normal University

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Probing gluon helicity with heavy flavor at the EIC:

Reweighting Study

Paper in preparation with Xin Dong, Felix Hekhorn, Matthew Kelsey, Sooraj Radhakrishnan, Ernst Sichtermann, Lei Xia, Hongxi Xing, Feng Yuan and Yuxiang Zhao

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Bayesian Reweighting

PDFs are updated with pseudodata information by using Bayes theorem: given a known probability density function $\mathscr{P}(\vec{\alpha})$ (*prior*) of the parameters $\vec{\alpha}$ in a model, one can construct the updated probability density $\mathscr{P}(\vec{\alpha}\,|\,D)$ (*posterior*) given the data set D as

$$\mathscr{P}(\vec{\alpha}\,|\,D) = \frac{\mathscr{P}(D\,|\,\vec{\alpha})}{\mathscr{P}(D)}\mathscr{P}(\vec{\alpha})$$

$\mathscr{P}(D\,|\,\vec{\alpha})$ the conditional probability for a data set D given the parameters $\vec{\alpha}$
$\mathscr{P}(D)$ is the normalization.

New expectation values and variance of observables given the data D are:

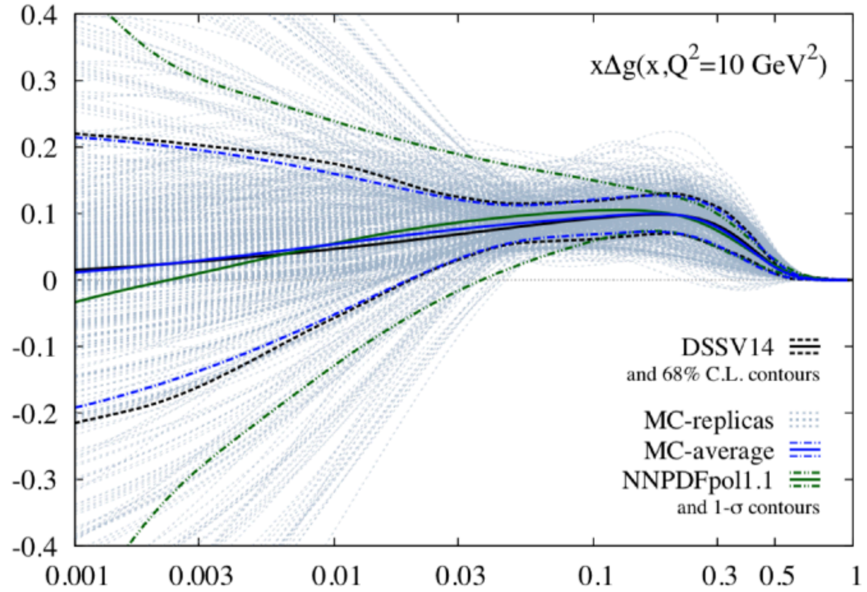
$$\mathrm{E}[\mathscr{O}] = \int d^n\alpha \frac{\mathscr{P}(D\,|\,\vec{\alpha})}{\mathscr{P}(D)}\mathscr{P}(\vec{\alpha})\mathscr{O}(\vec{\alpha}) = \frac{1}{N}\sum_k w_k \mathscr{O}(\vec{\alpha}_k)$$

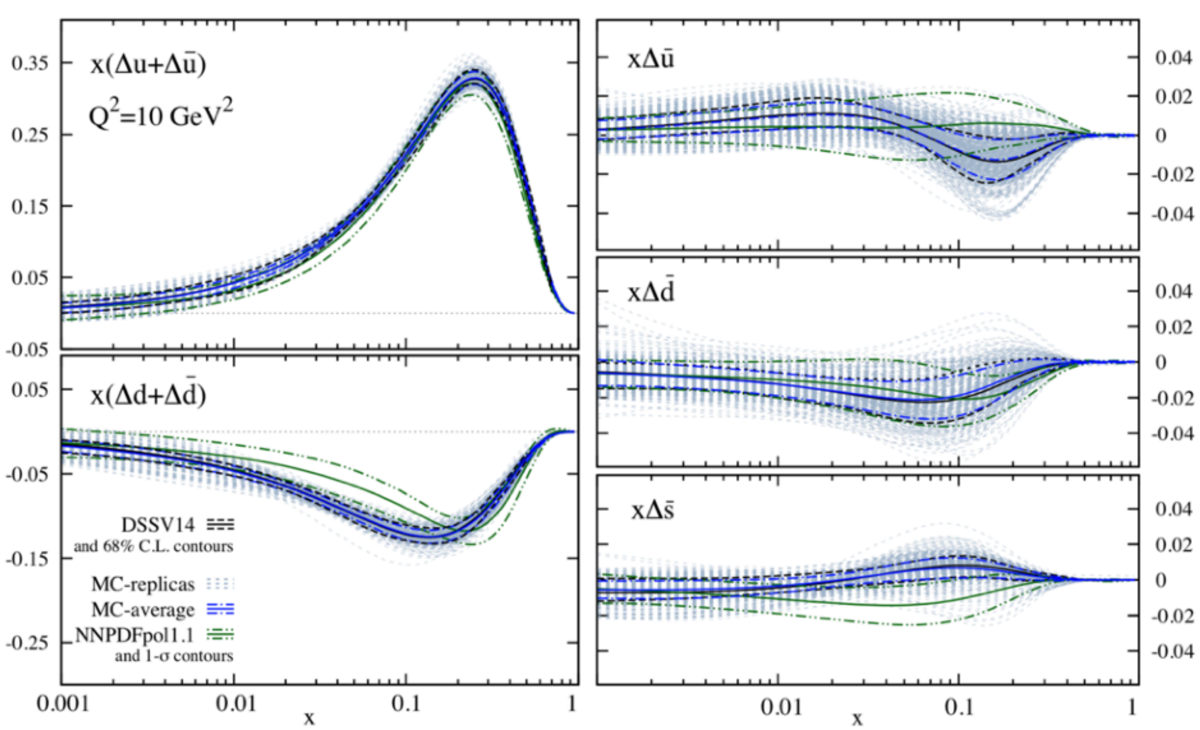
$$\mathrm{Var}[\mathscr{O}] = \frac{1}{N}\sum_k w_k(\mathscr{O}(\vec{\alpha}_k) - E[\mathscr{O}])^2$$

BAYESIAN REWEIGHTING

ArXiv:1902.10548

We consider as a case study DSSV14 polarised PDFs given as a set of 1000 *replicas*





gluon parametrisation ($\mu_0 = 1GeV$)

$$x\Delta g(x,\mu_0) = N_g x^{\alpha_g}(1-x)^{\beta_g} \times (1+\eta_g x^{\kappa_g})\left[1+\delta_g\, x^{\rho_g}(1-x)^{\theta_g}\right]$$

SU(2) and SU(3) flavor constraints

$$\Delta\Sigma_u - \Delta\Sigma_d = (F+D)\left[1+\varepsilon_{\mathrm{SU(2)}}\right],$$

$$\Delta\Sigma_u + \Delta\Sigma_d - 2\Delta\Sigma_s = (3F-D)\left[1+\varepsilon_{\mathrm{SU(3)}}\right],$$

$$\Delta\Sigma_f \equiv \int_0^1 \left[\Delta f_i + \Delta\bar{f}_i\right](x,\mu_0)\,dx$$

quark parametrisation ($\mu_0 = 1GeV$)

$$x\Delta f_i(x,\mu_0) = N_i\, x^{\alpha_i}(1-x)^{\beta_i}(1+\gamma_i\sqrt{x}+\eta_i x^{\kappa_i})$$

Bayesian Reweighting

Weights w_k are calculated according to NNPDF method (*ArXiv:1108.1758, ArXiv:1012.0836*)

$$w_k = \frac{(\chi_k^2)^{(n_{\text{data}}-1)/2} e^{-\frac{1}{2}\chi_k^2}}{\frac{1}{N_{\text{rep}}} \sum_{k=1}^{N_{\text{rep}}} (\chi_k^2)^{(n_{\text{data}}-1)/2} e^{-\frac{1}{2}\chi_k^2}}$$

where $$\chi_k^2 = \chi^2(y, f_k) = \sum_{i,j=1}^{n_{\text{data}}} (y_i - \text{Theory}_i[f_k])\sigma_{ij}^{-1}(y_j - \text{Theory}_j[f_k])$$

Pseudodata point

PDF replica

error matrix
in our case diagonal
as we consider only
uncorrelated errors

THEORY CALCULATION

ArXiv:1805.09026

To calculate D^0 production in DIS ($\overrightarrow{e} + \overrightarrow{p} \to e' + D^0 + X$) we effectively calculate open charm production in DIS @ NLO ignoring:

- ~~hadronization effects of the charm quark into the D meson~~
- ~~electro-weak corrections~~
- ~~target mass corrections or lepton masses~~

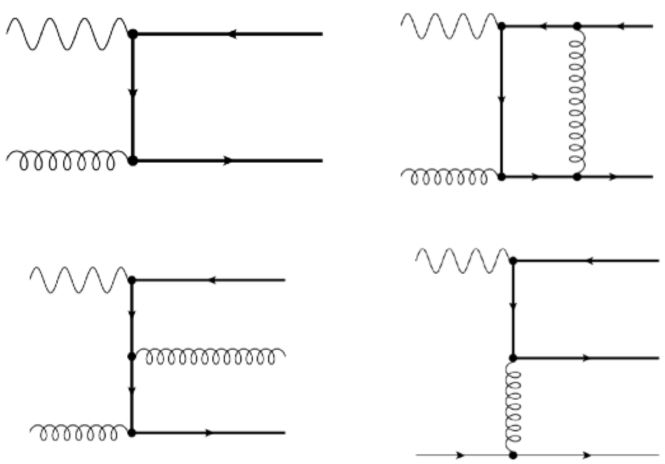
$$A_{LL}^{c}(x,Q^2) = \frac{g_1^c(x,Q^2)}{F_1^c(x,Q^2)}$$

$$g_1^c(x,Q^2) = \sum_{j=g,q,\bar{q}} \int_x^{z_{max}} \frac{dz}{z} \Delta f_j\left(\frac{x}{z},\mu_F^2\right) \Delta c_{1,j}(z,Q^2)$$

$$z_{max} = Q^2/(4m^2+Q^2)$$

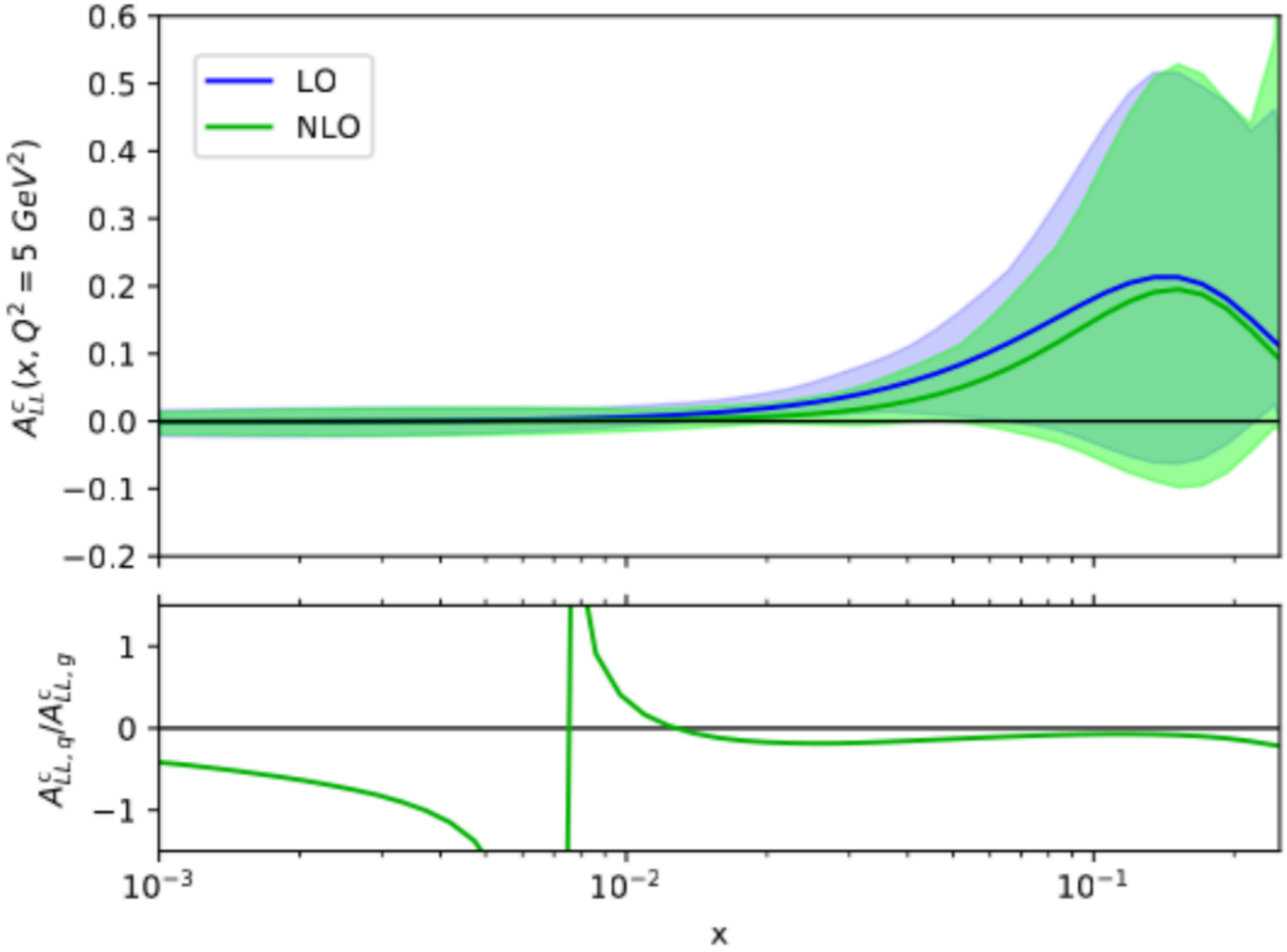
$$F_{1/2}^c(x,Q^2) = \sum_{j=g,q,\bar{q}} \int_x^{z_{max}} \frac{dz}{z} f_j\left(\frac{x}{z},\mu_F^2\right) c_{1/2,j}(z,Q^2)$$

Coefficient functions Δc_1 , c_1 are calculated using this type of diagrams



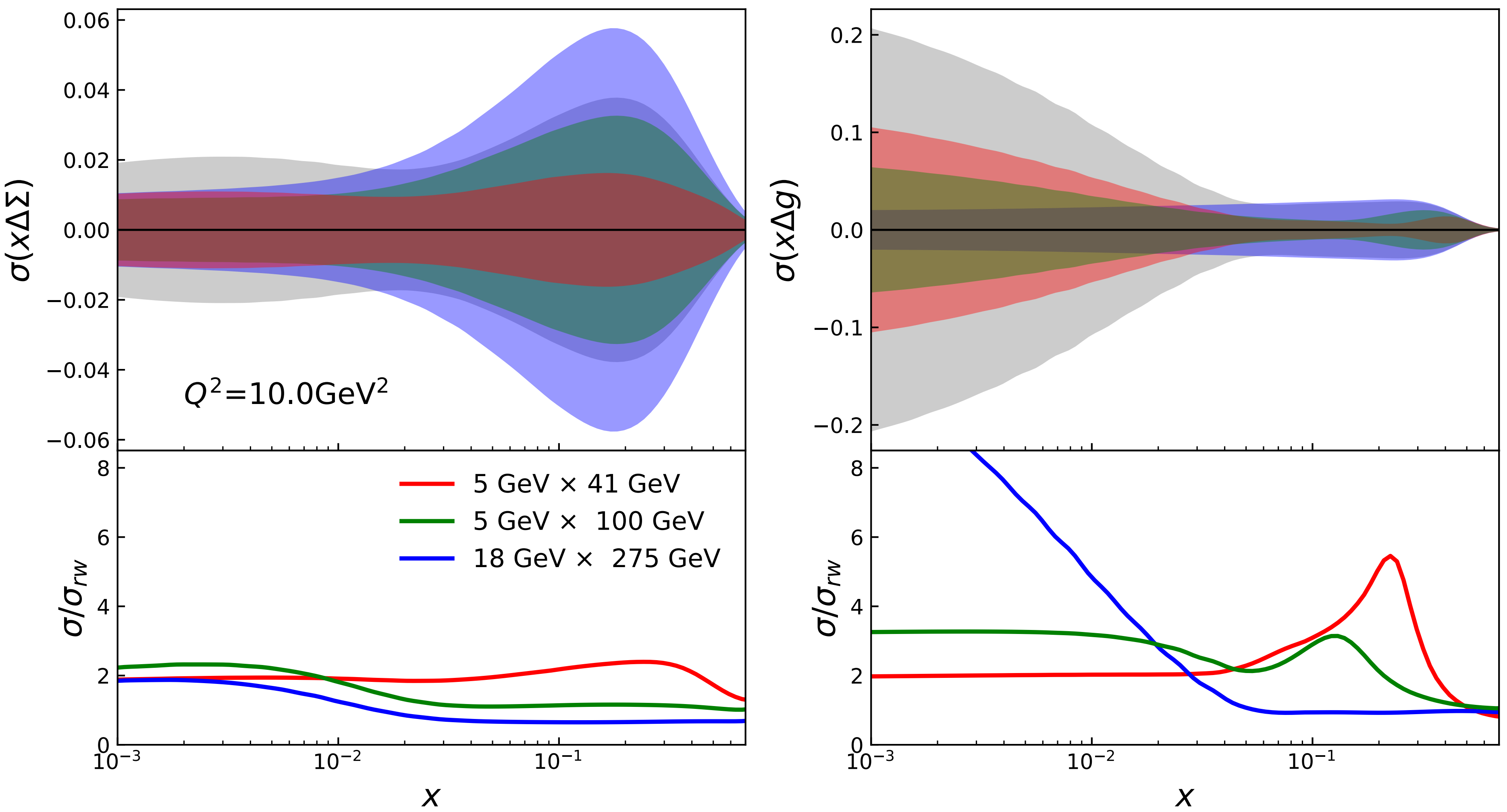
Theory Calculation

The theory calculation is dominated by gluon contribution in the high x-region



Results

Uncertainty bands before and after reweighting with 50 fb^{-1} of integrated luminosity

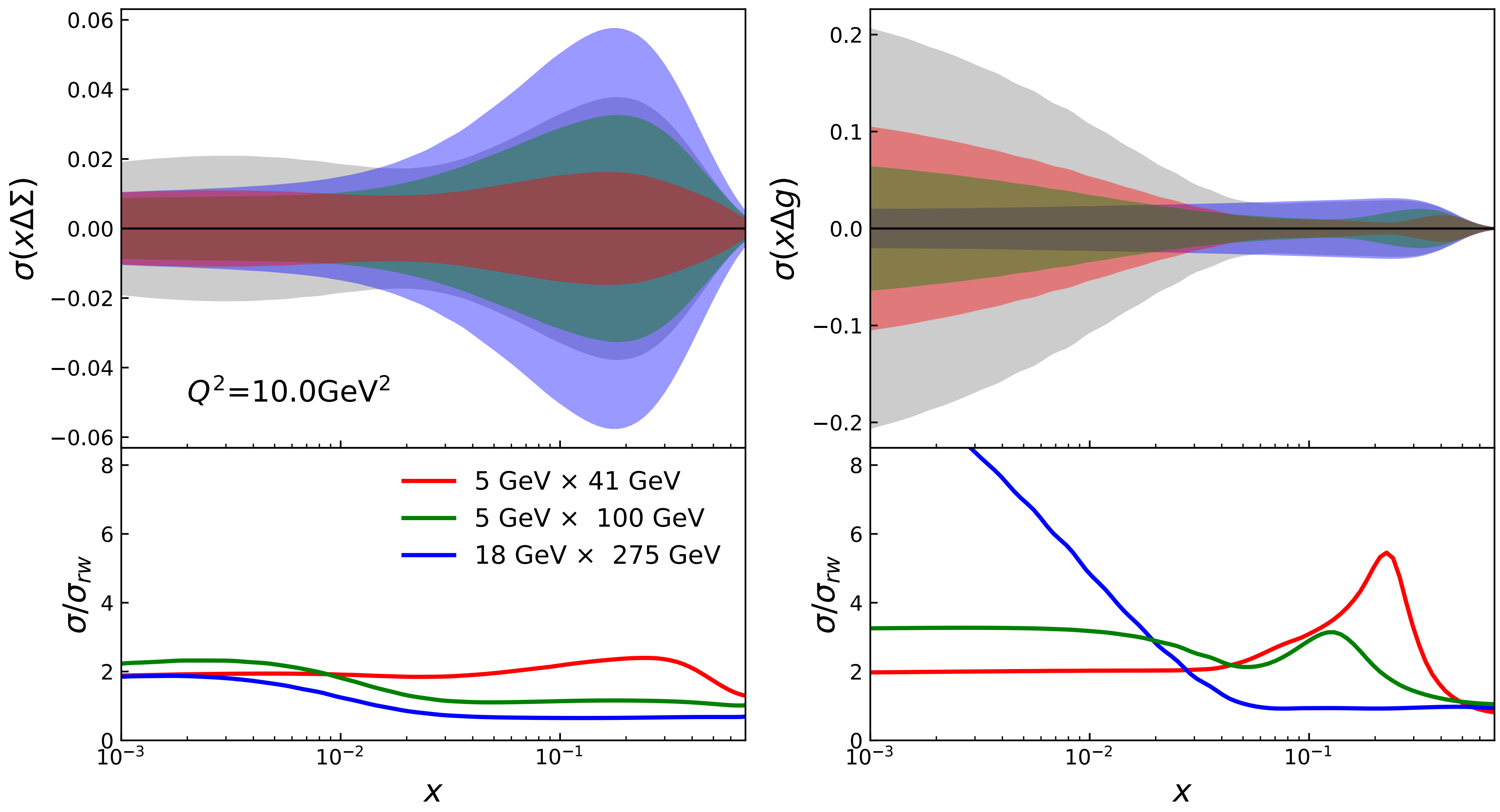


Effective # of replicas

Collision energy -> Luminosity(1/fb) I V	5 GeV X 41 GeV	5 GeV X 100 GeV	18 GeV X 275 GeV
10	661.76	881.34	792.59
50	382.67	347.26	292.86

RESULTS

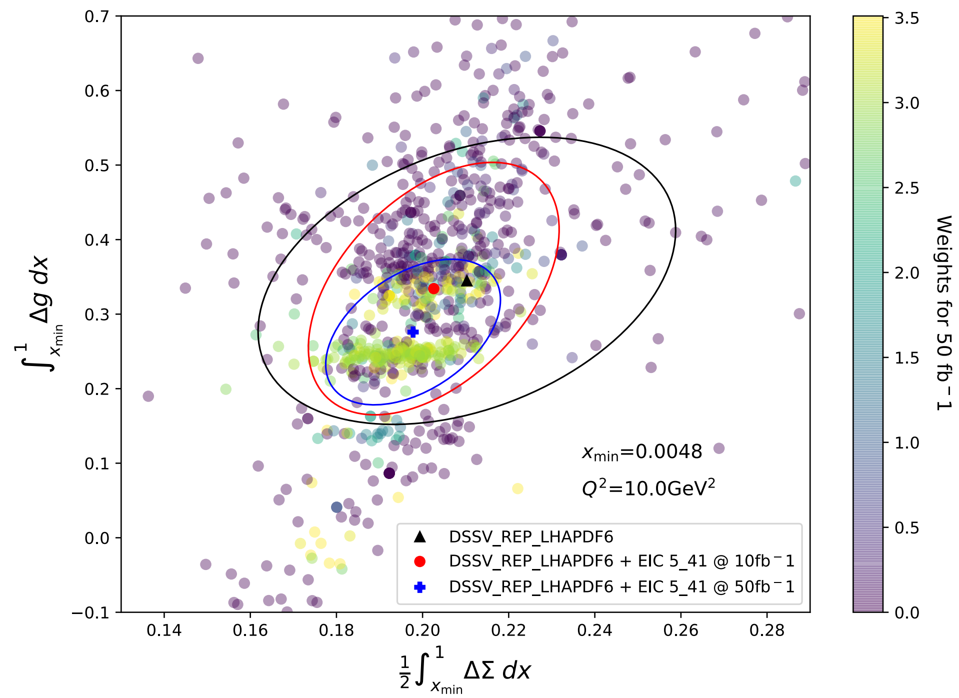
Uncertainty bands before and after reweighting with 50 fb^{-1} of integrated luminosity



- *Measurement sensitive to gluon*
- *Lower energy = greater sensitivity to higher x (and viceversa)*
- *At higher energy quark sector unconstrained for high x: gluon dominates reweighting in the low x region and replicas surviving are driven by fixed parametrisation in the high x region of the quark sector*

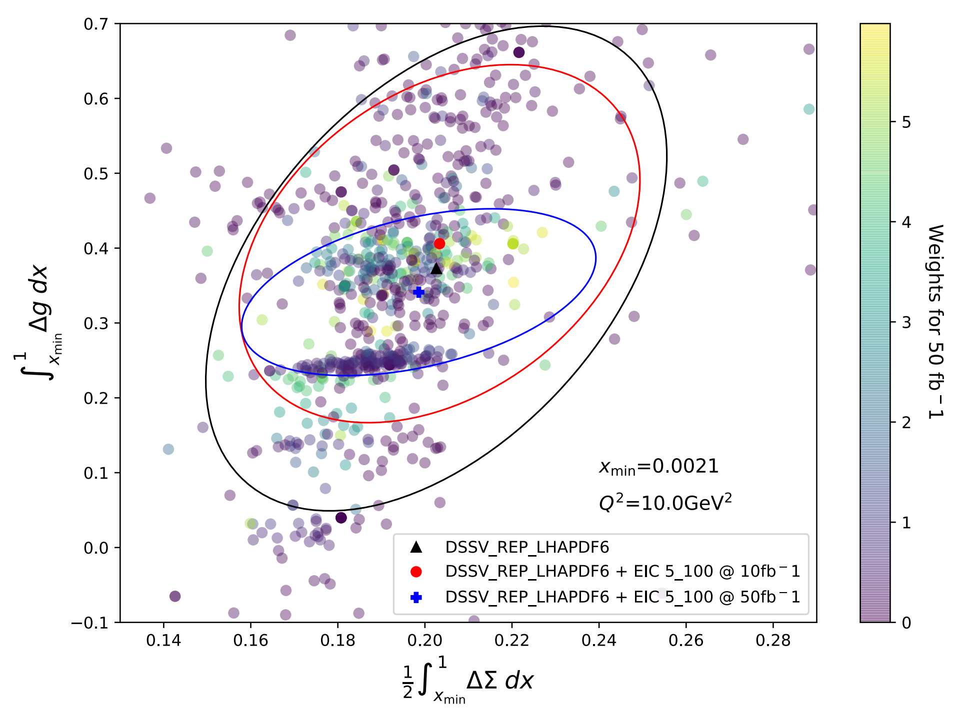
RESULTS

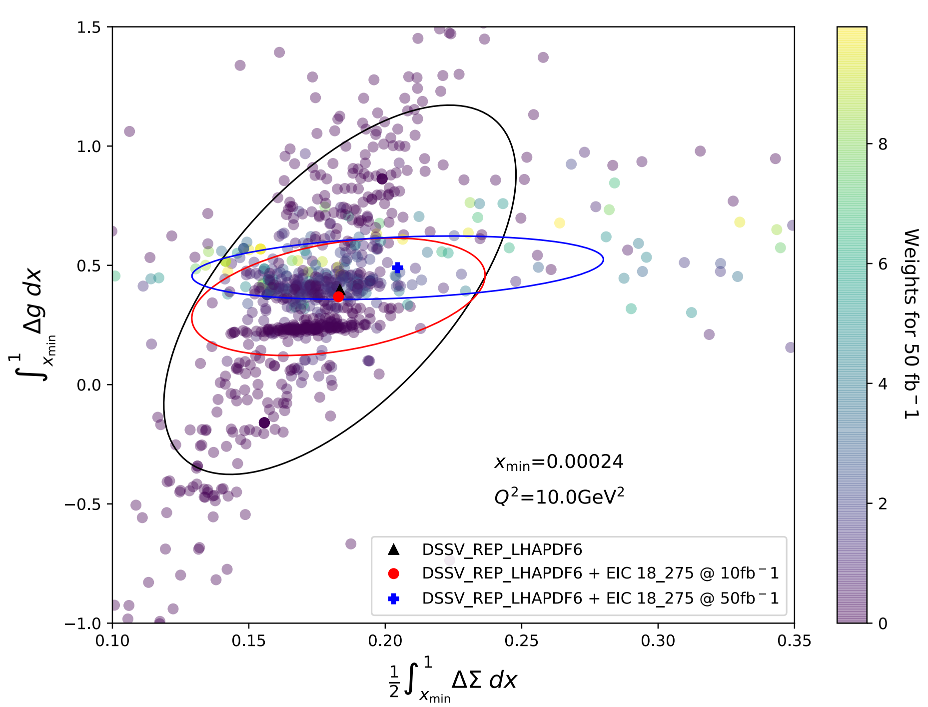
Correlation plots of truncated first moments



Jaffe-Manohar-decomposition

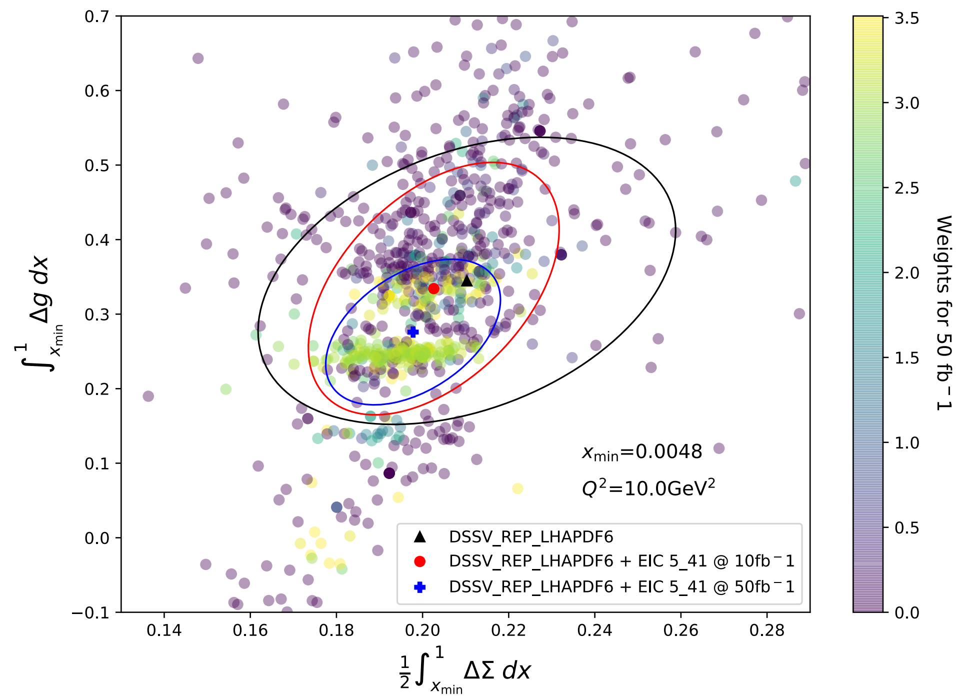
$$\text{Proton Spin} \rightarrow \frac{1}{2} = \frac{1}{2}\int_0^1 \Delta\Sigma(x)\, dx + \int_0^1 \Delta g(x)\, dx + L_q + L_g$$



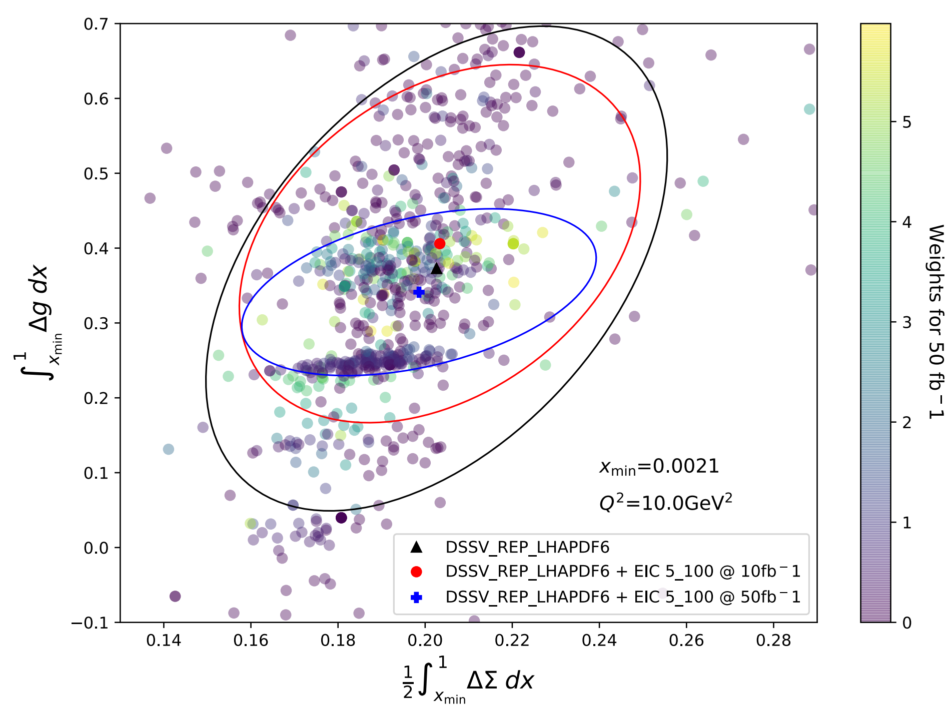


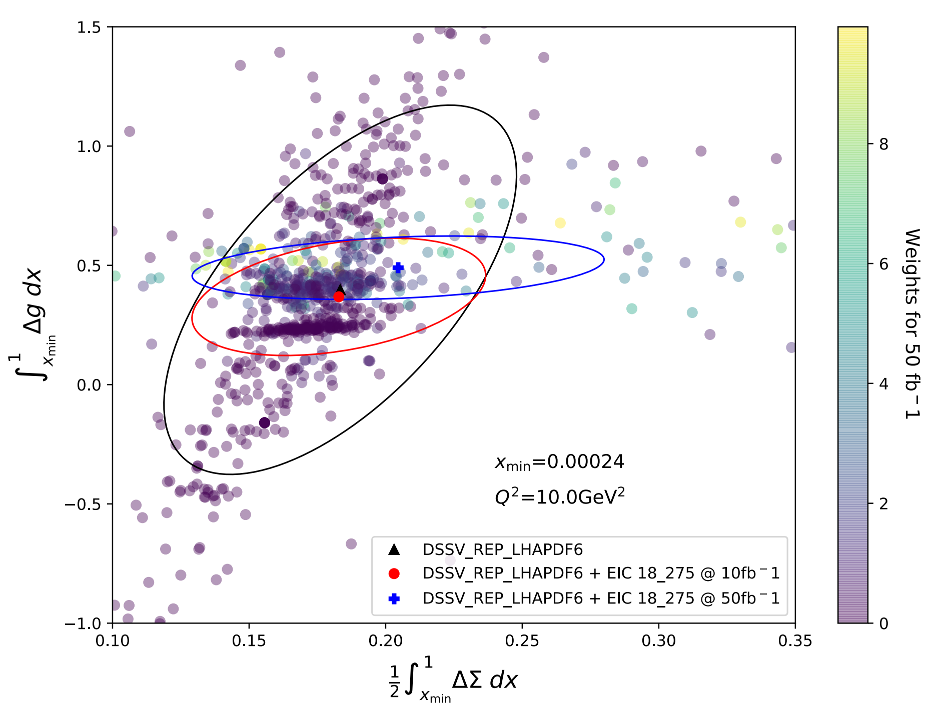
RESULTS

Correlation plots of truncated first moments



- *sensitivness to gluon increases with higher energy*
- *ellipses have different angles → independent ingredients (gluon-sensitive inputs) into the world data*





Conclusions

- The measurement has direct sensitivity to the polarised gluon distribution due to the dominating gluon channel
- Heavy flavour production offers a unique opportunity to constrain the gluon distribution in the moderate and high x region
- The measurement offers independent input to the proton spin gluon contribution

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Thanks for Your Attention