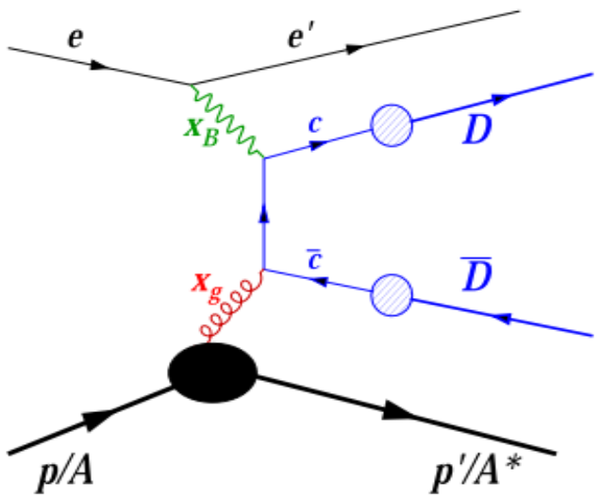
Charm Structure Functions and Gluon nPDFs

Xin Dong / LBNL

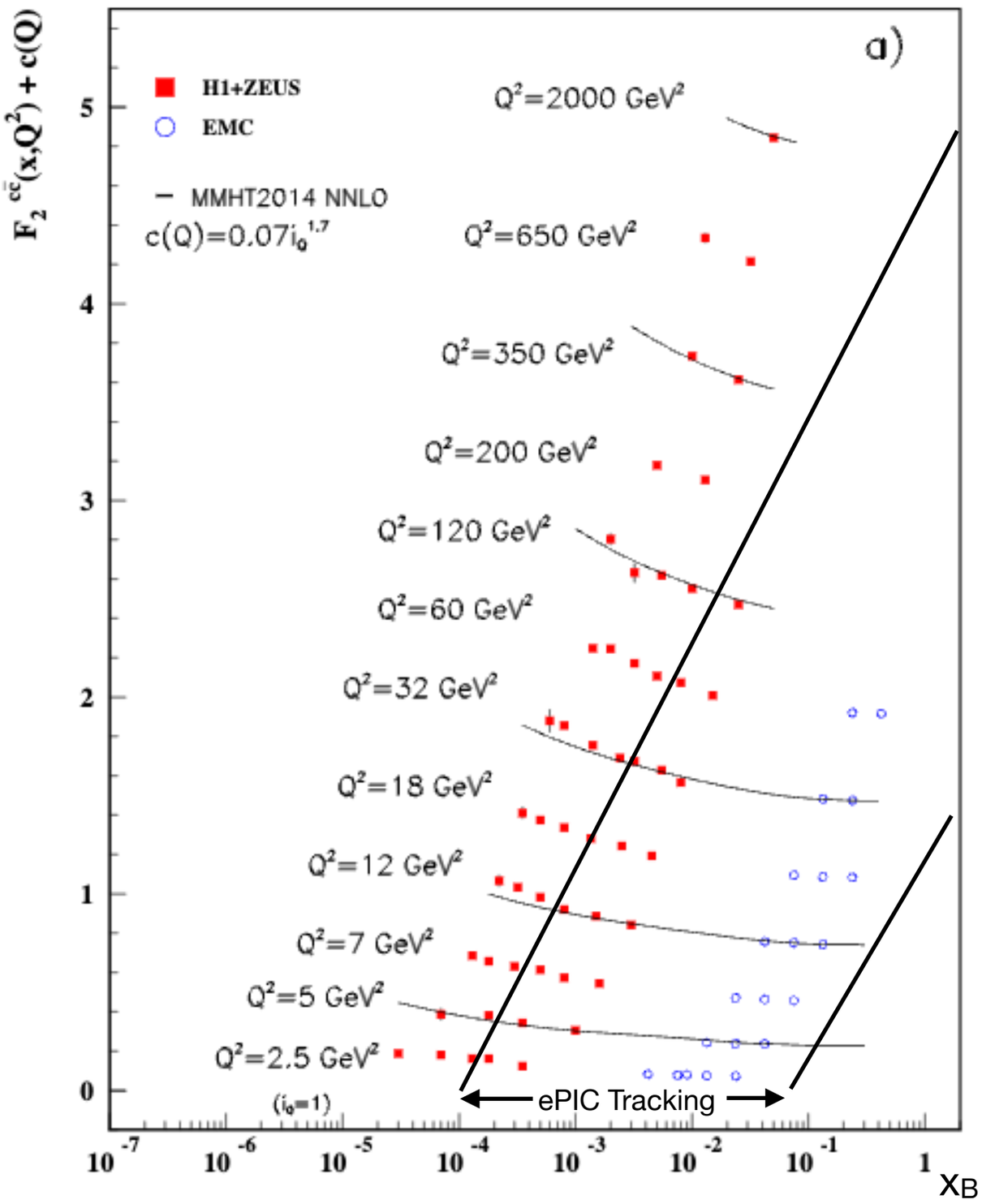


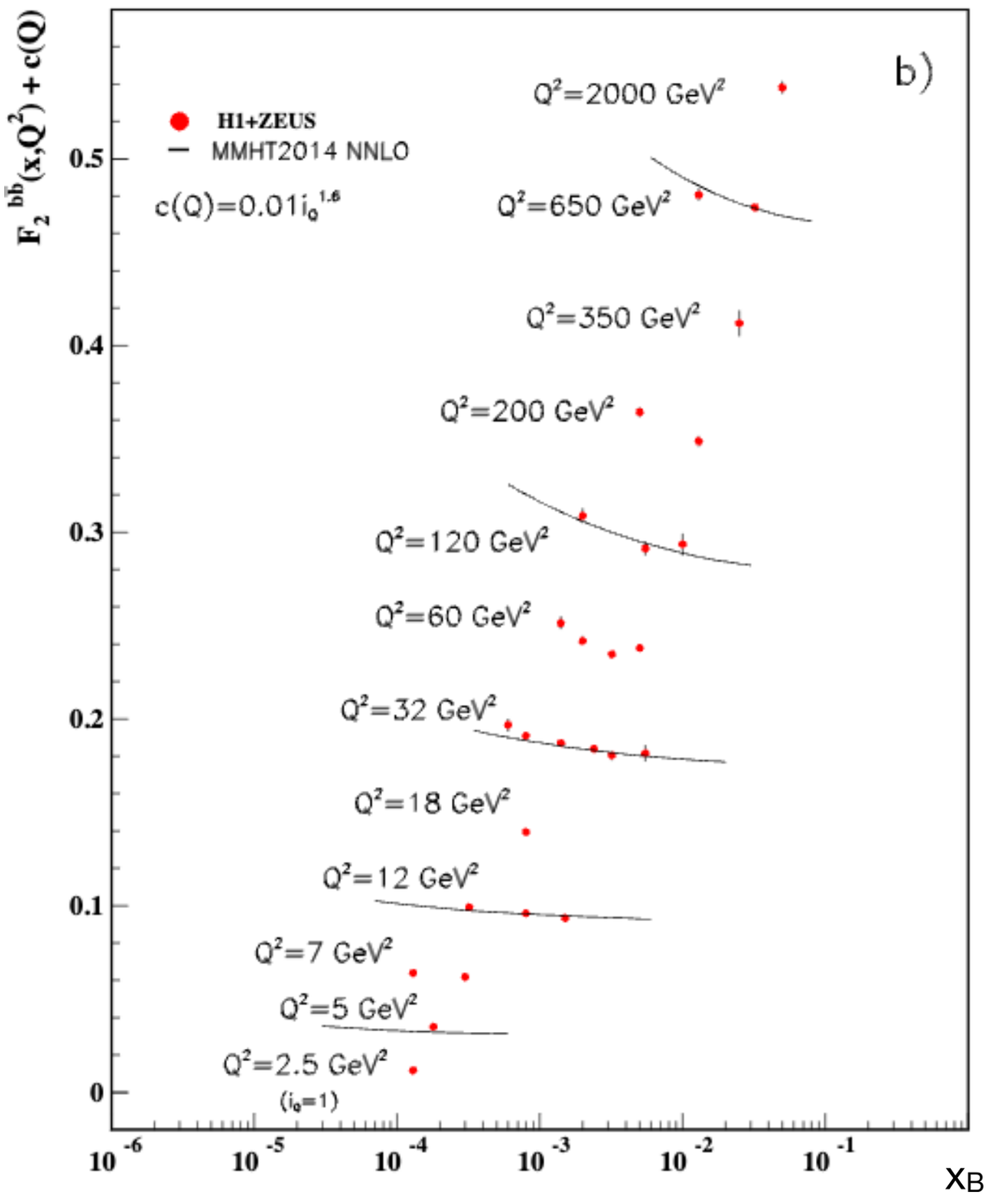
Heavy Flavors:

direct and clean access to gluon (spin-dependent) distributions in nucleon/nucleus at LO

- charm structure functions: $F_2^{c\bar{c}}$, $F_L^{c\bar{c}}$ etc.
- intrinsic charm distribution
- gluon nPDF in nuclei
- gluon spin-dependent PDFs, TMDs etc.

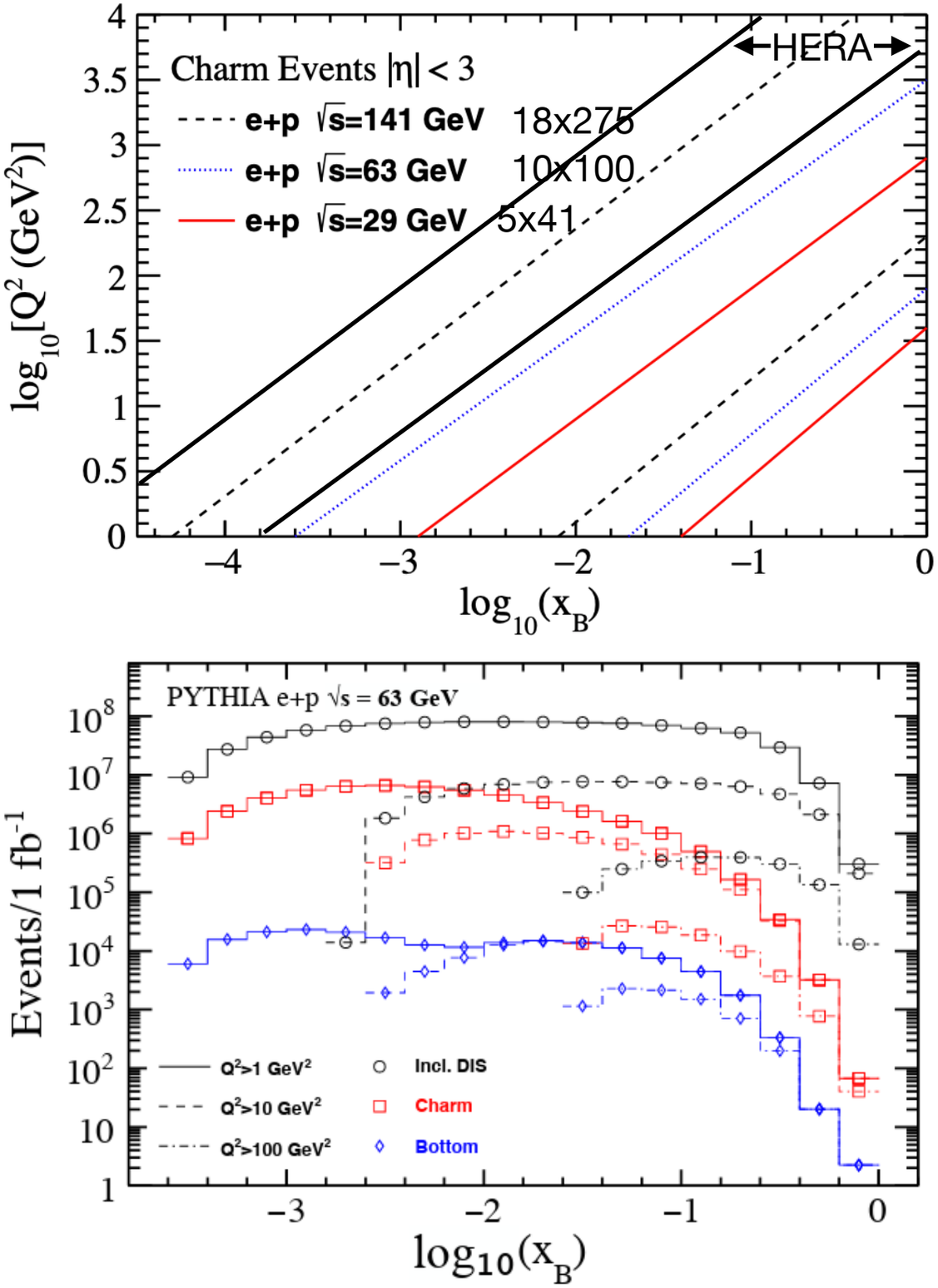
Charm- and Bottom Structure Functions



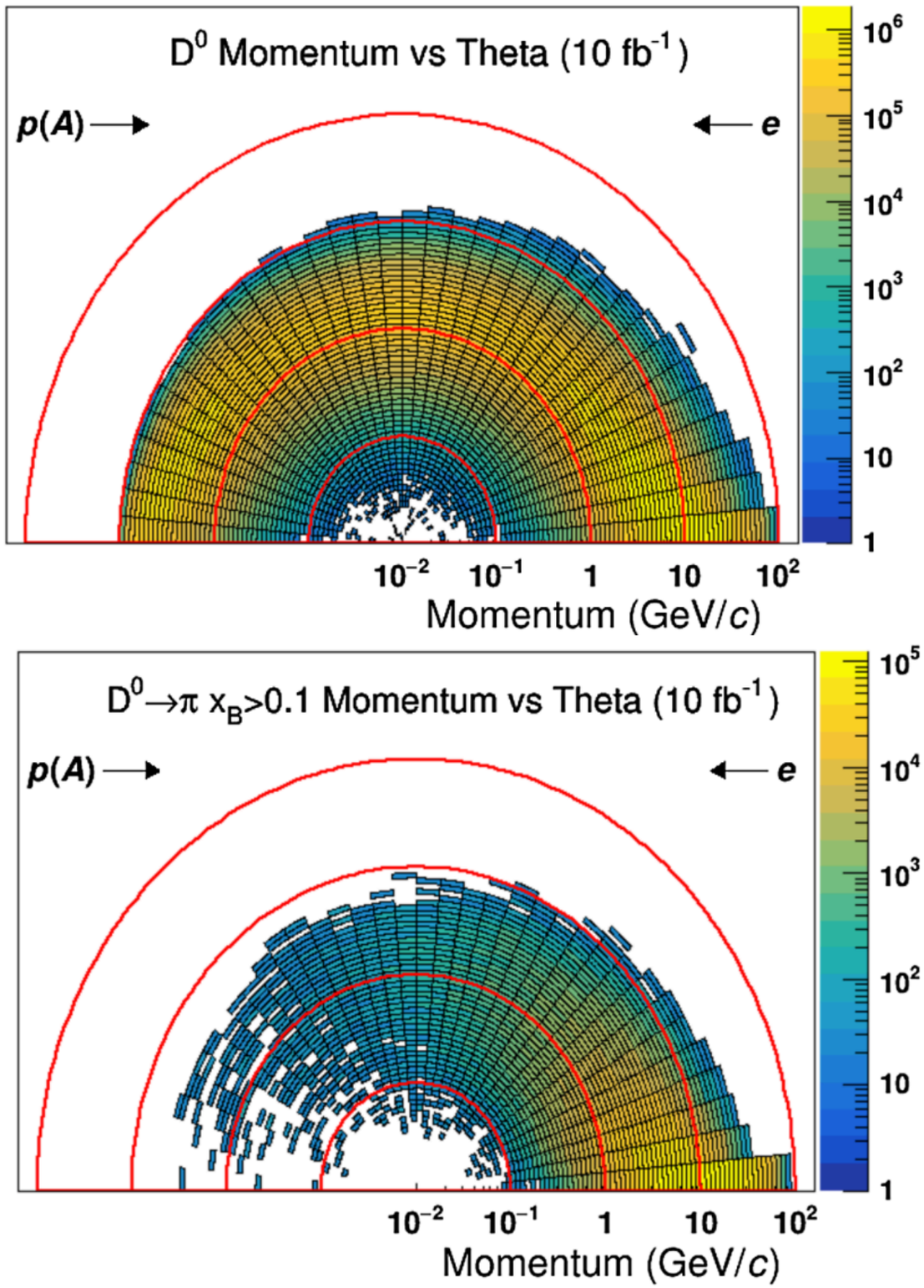


https://pdg.lbl.gov

Kinematics



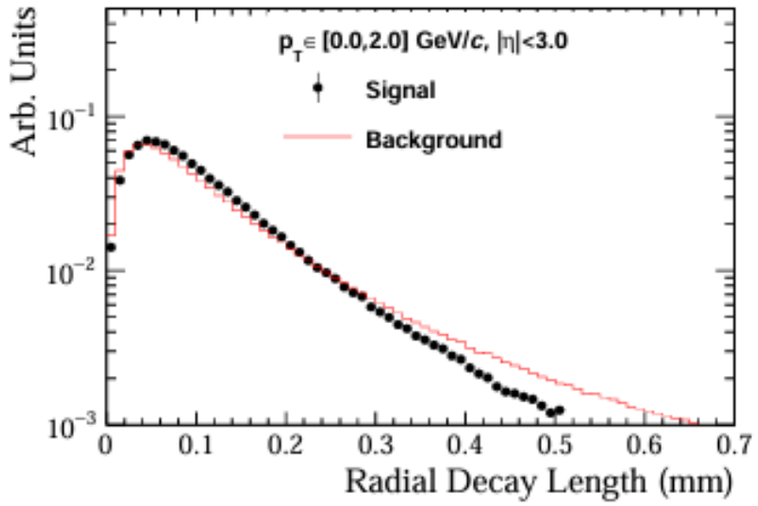
10 (e) x 100 (p)

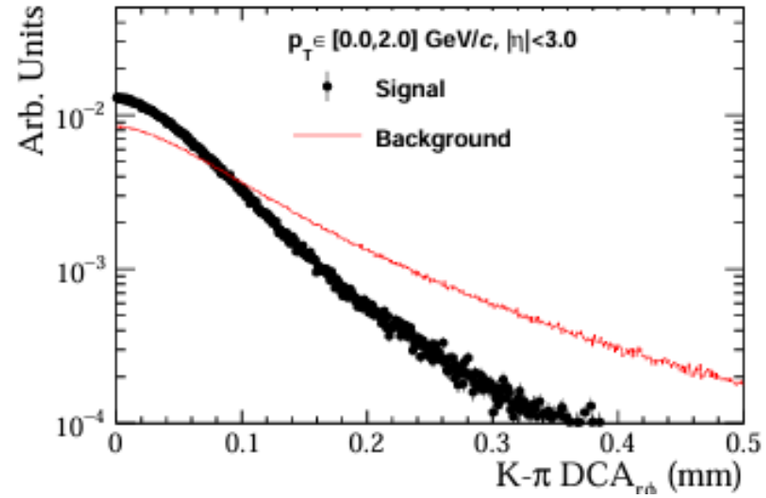


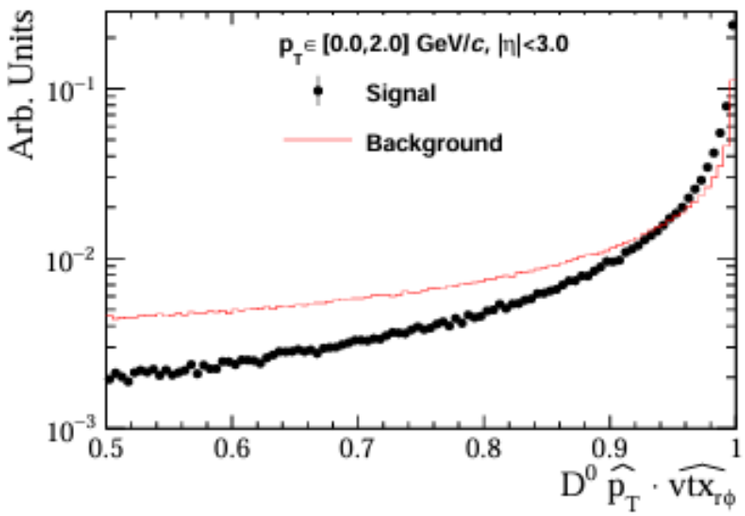
M. Kelsey et. al., PRD 104 (2021) 054002

Charm Hadron Reduced Cross Section

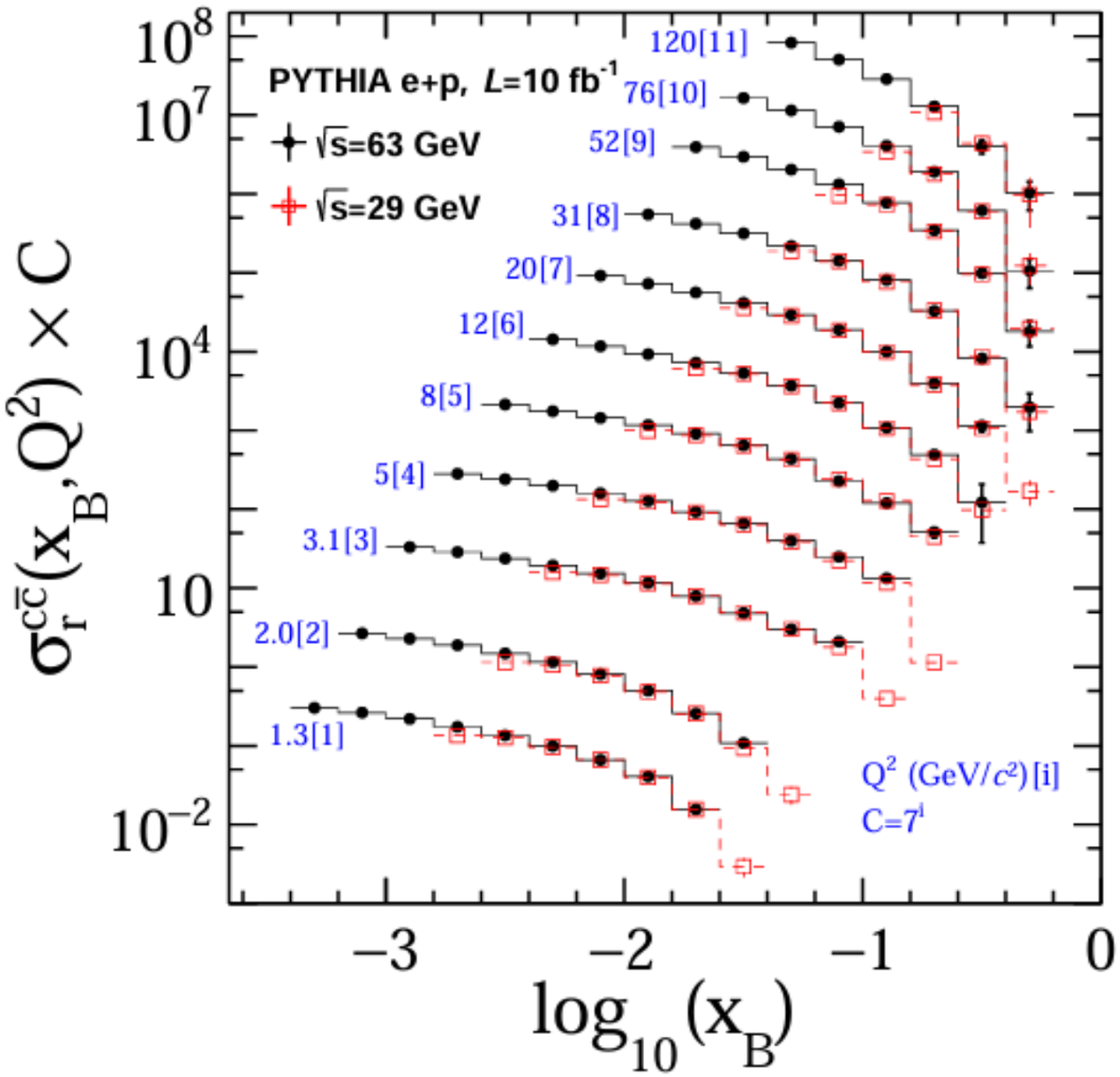
YR performance parameters







$$\sigma_r^{c\bar{c}}(x_B, Q^2) = \frac{dN(D^0 + \overline{D}^0)/2}{\mathcal{L} \cdot \varepsilon \cdot \mathcal{B}(D^0 \to K\pi) \cdot f(c \to D^0) \cdot \mathrm{d}x_B \mathrm{d}Q^2} \times \frac{x_B Q^4}{2\pi\alpha^2[1 + (1-y)^2]},$$



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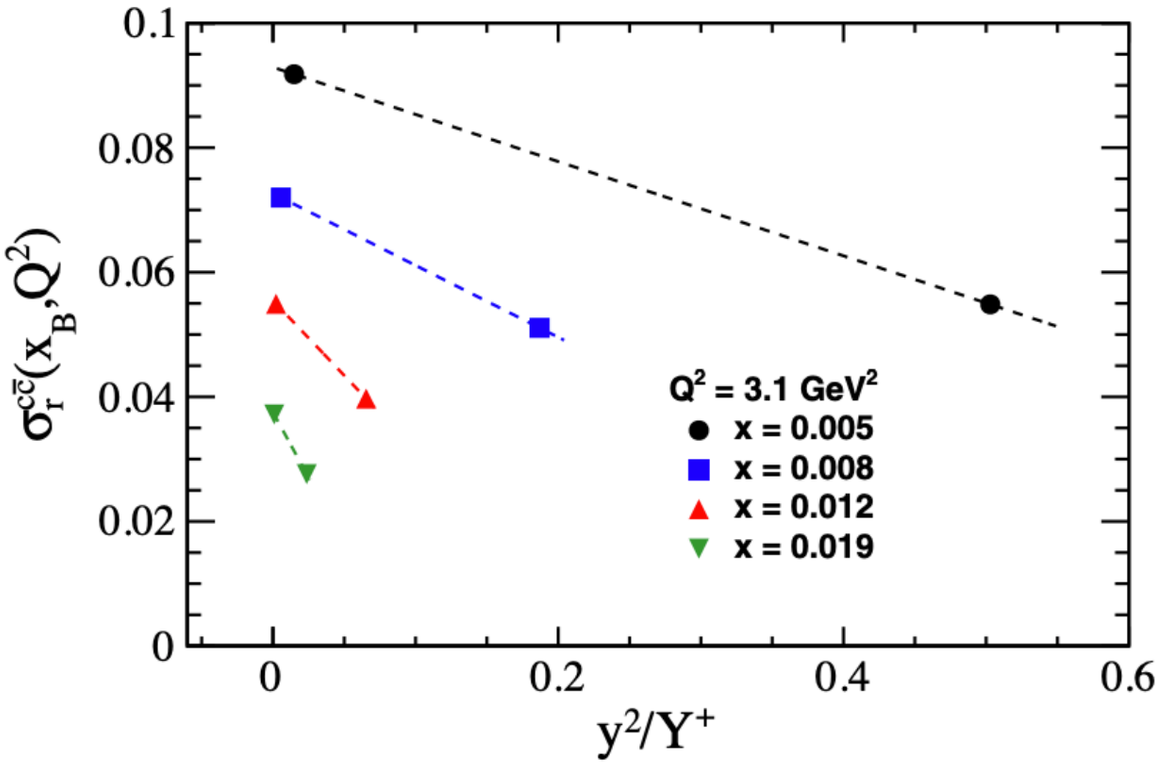
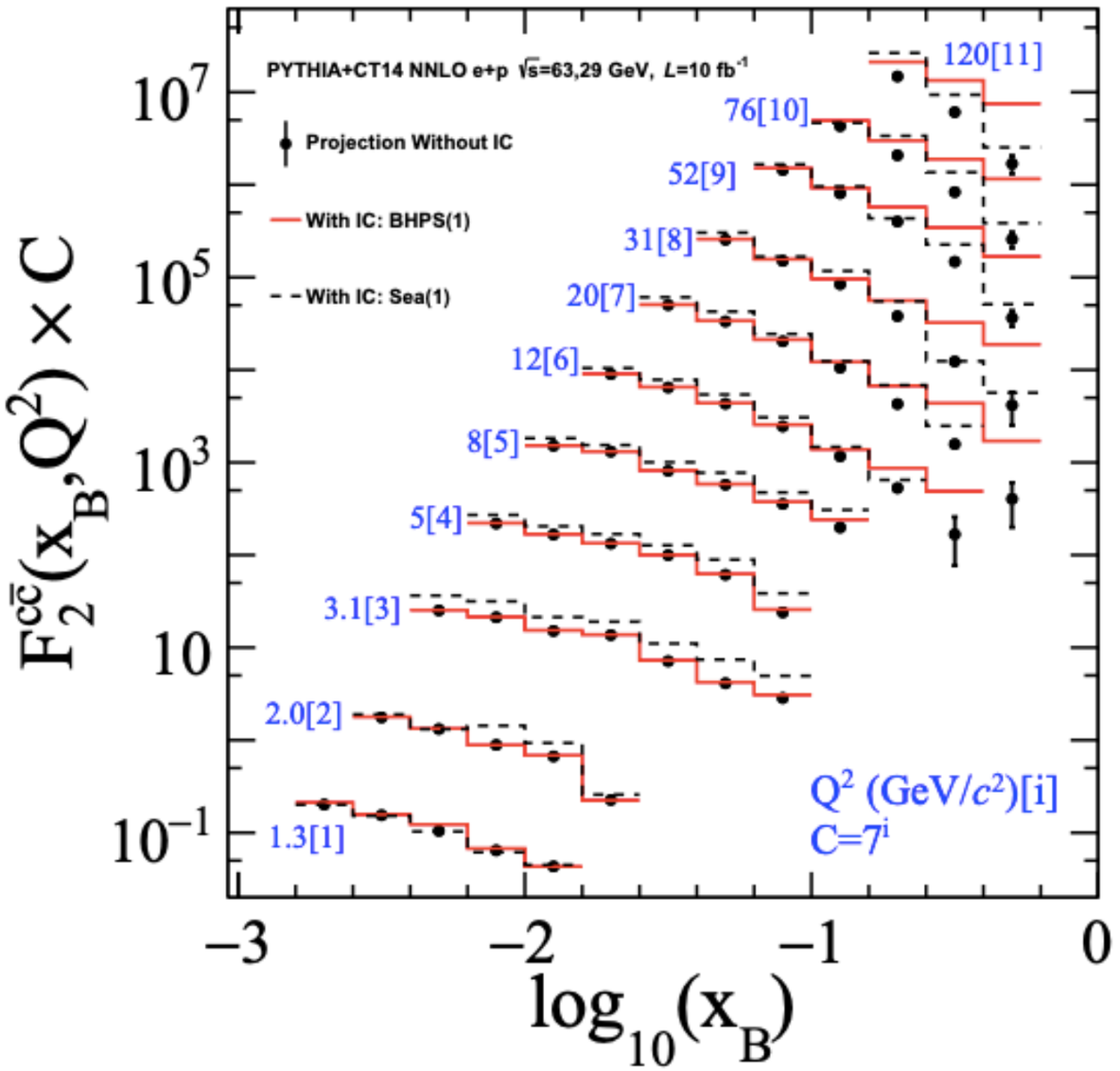
Charm Structure Function $F_2^{c\bar{c}}$

$$\sigma_r^{c\bar{c}}(x_B, Q^2) = F_2^{c\bar{c}}(x_B, Q^2) - \frac{y^2}{Y^+} F_L^{c\bar{c}}(x_B, Q^2),$$



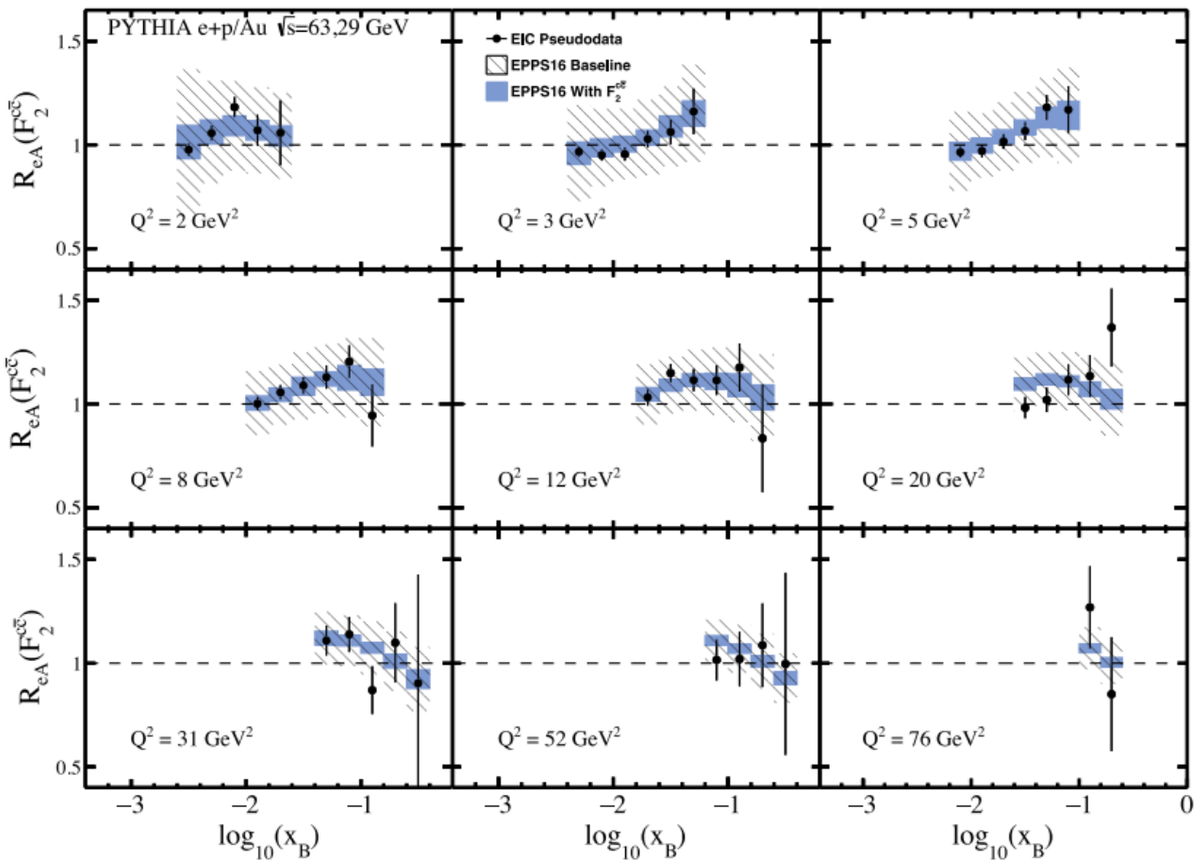
Projections with D-meson + DMT requirement



unpolarized e+p collisions:
5x41 GeV, 10 fb^{-1}
10x100 GeV, 10 fb^{-1}

- Extend charm structure function measurements at HERA to high x region.
- Unique opportunity to access intrinsic charm.

Gluon nPDF using Bayesian Reweighting



PDF replicas with weighting factors

$$f_{new} = f_0 + \sum_i \left(\frac{f_{i,+} + f_{i,-}}{2}\right)\left[\frac{1}{N_{rep}}\sum_k w_k r_{k,i}\right]$$

$$w_k = \frac{exp[-\chi_k^2/2]}{\frac{1}{N_{rep}}\sum_k exp[-\chi_k^2/2]}$$

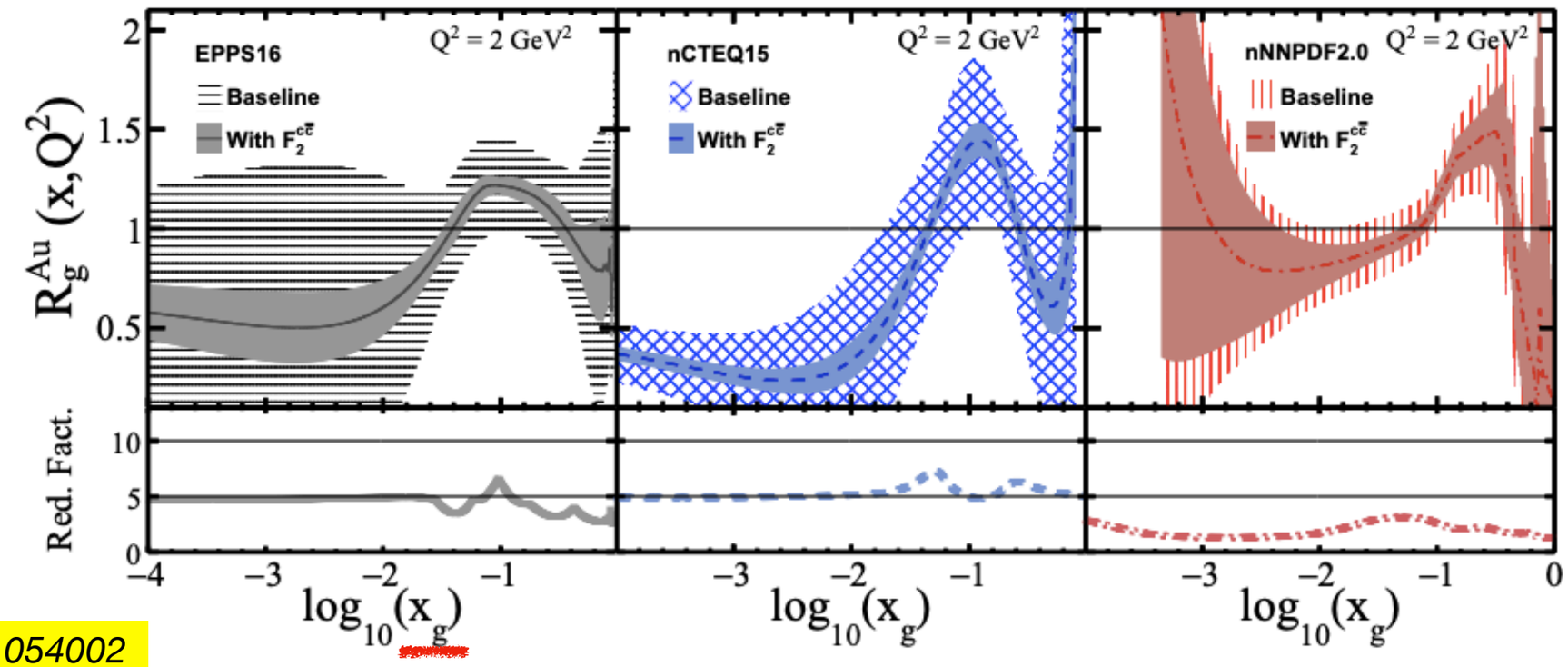
map x_B to x: LO - $x = x_{\mathrm{Bj}} \cdot \left(1 + \frac{\hat{s}}{Q^2}\right)$

- Constrain gluon nPDF with ep/eA collision, especially at high x region

Projections with D-meson + DMT requirement

At each collision energy
5x41 GeV
10x100 GeV
1 fb^{-1} ep + **1 fb^{-1}/A eA**

Au beam is preferred!

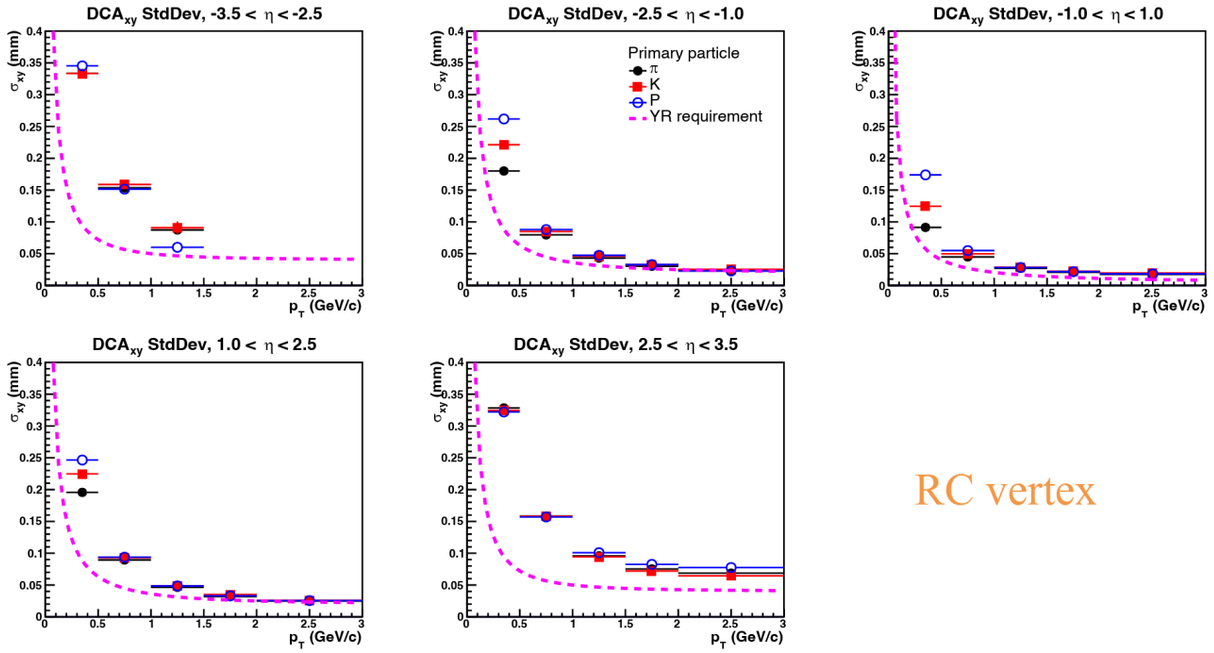


M. Kelsey et. al., PRD 104 (2021) 054002

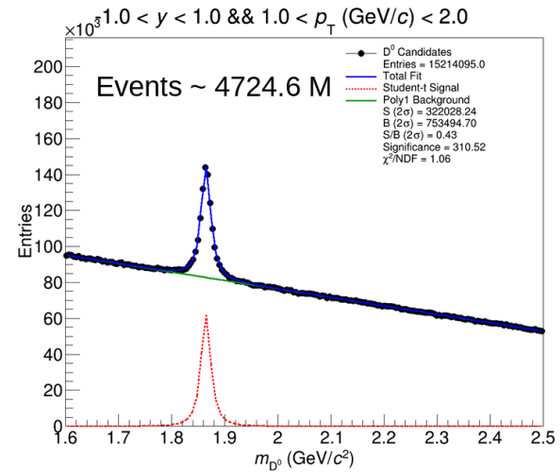
To-do Items

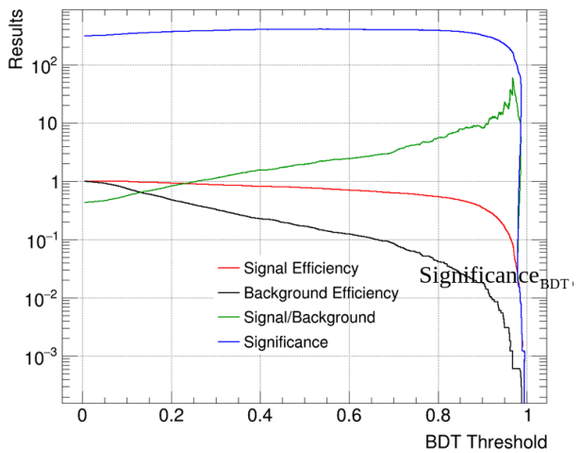
Realistic ePIC simulation + EICrecon + secondary vertexing

1) D^0 reconstruction in each (x_B, Q^2) bin
2) Statistical projections on $\sigma_r^{c\bar{c}}(x_B, Q^2)$, $F_2^{c\bar{c}}(x_B, Q^2)$.
3) Estimate on statistical error projections on $R_{eA}(F_2^{c\bar{c}})$.
4) Impact estimate on gluon nPDFs using Bayesian reweighting.



RC vertex





Connie, Shyam, Rongrong

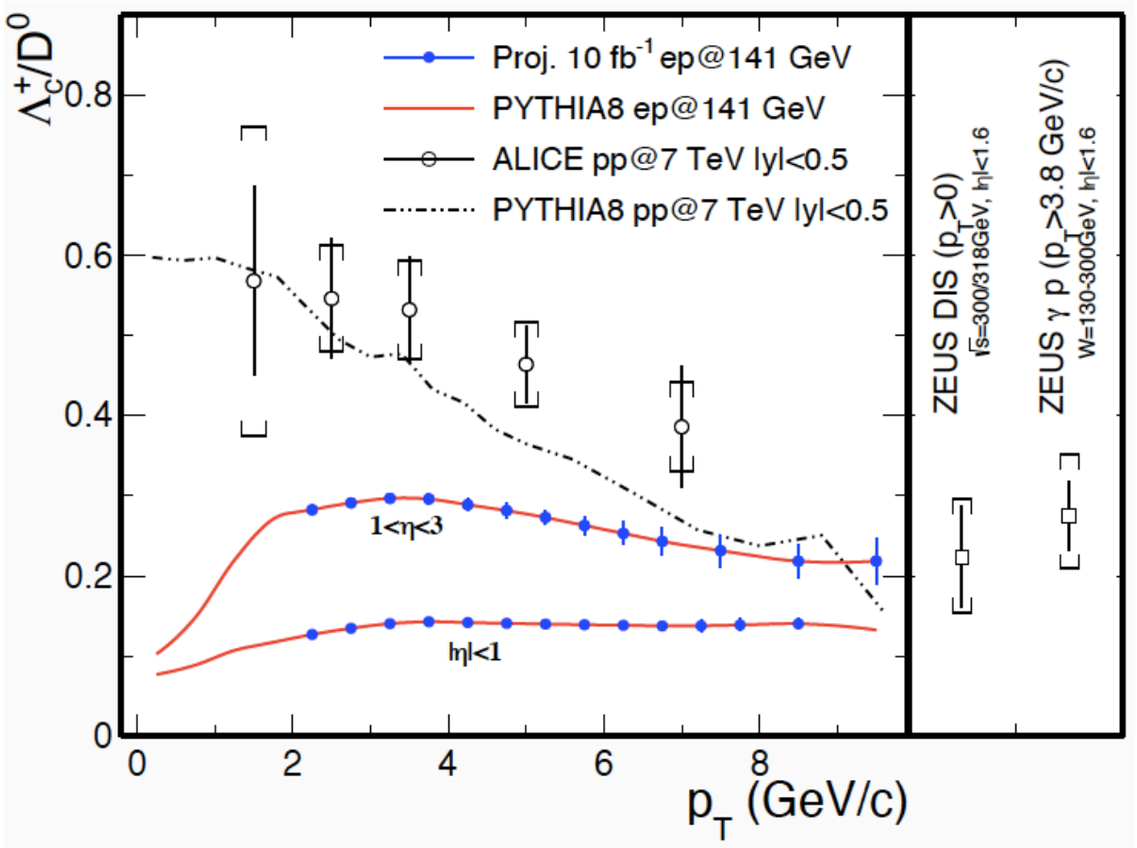
Current status

Currently available
✓: small statistics
✓✓: good statistics

Need for preTDR
Need for ES

		5x41	10x100	10x130	10x250	18x275
ep	D0	Submitted (900k)	✓✓		Need	✓
	Lc		Submitted (750k)			✓
	DIS	✓✓	✓✓	Need (Q^2>10)	Need	✓✓
		5x41	10x100			
eAu	D0	Submitted (650k)	Submitted (700k)			
	Lc		Submitted (640k)			
	DIS	Submitted (10M)	Submitted (10M)			
			10x115			
eRu/Cu	D0					
	DIS		✓✓			

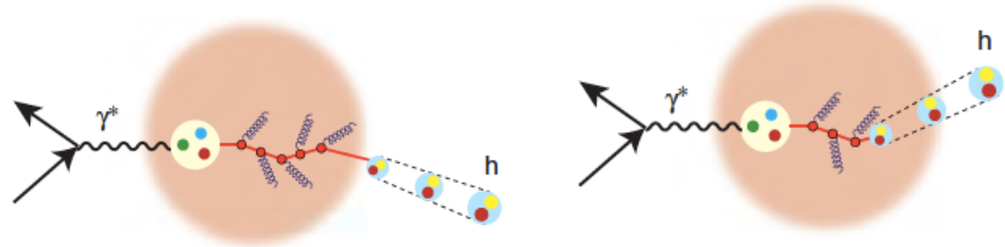
Fragmentation/Hadronization/Cold Nuclear Matter Effect



Yuanjing Ji

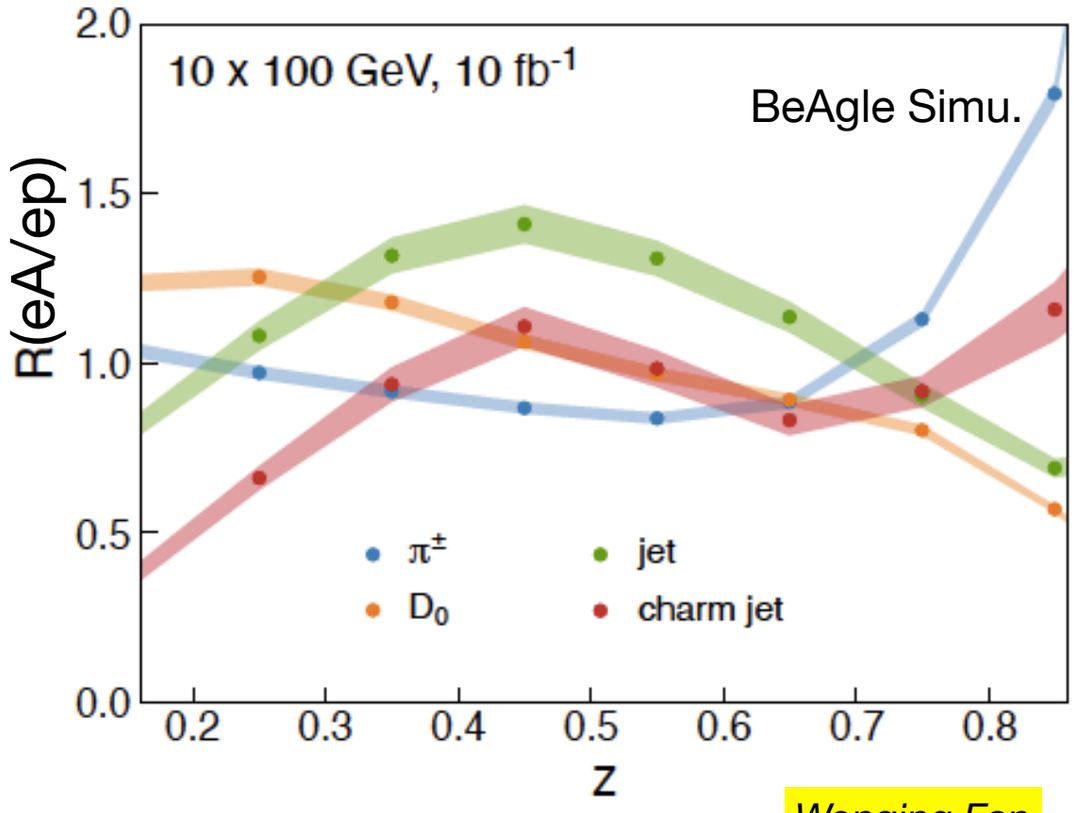
arXiv: 2102.08337

- Systematic measurement of charm baryons
  - multi-differential (p_T, multiplicity etc)
- Charm/light fragmentation measurement in ep/eA
  - fragmentation/cold nuclear matter effect



10 fb^{-1} ep + **10 fb^{-1}/A eA**

10x100 GeV



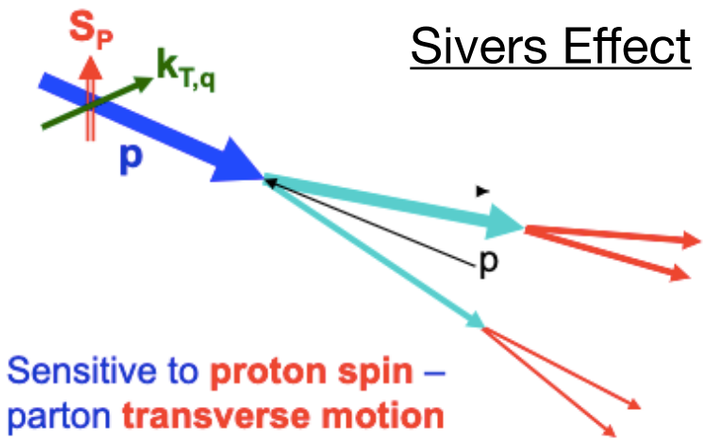
Wenqing Fan

Heavy Flavor Pair - Probe Gluon TMDs

Charm/anti-charm pair in transverse polarized exp.
- gluon Sivers functions

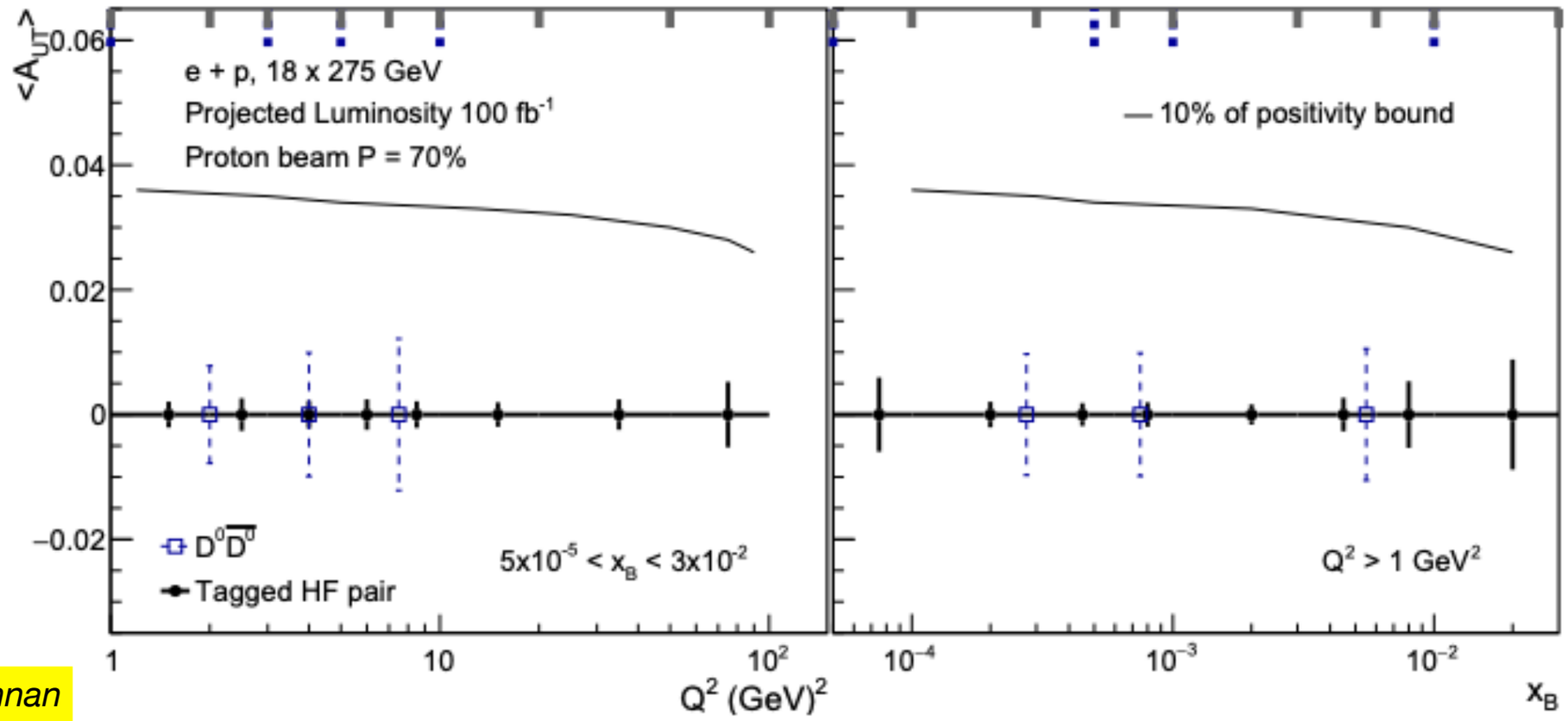
L. Zheng et. al., PRD 98 (2018) 034011

$$A_{UT}(\phi_{kS}, k_T) = \frac{d\sigma^{\uparrow}(\phi_{kS}, k_T) - d\sigma^{\downarrow}(\phi_{kS}, k_T)}{d\sigma^{\uparrow}(\phi_{kS}, k_T) + d\sigma^{\downarrow}(\phi_{kS}, k_T)} \propto \frac{\Delta^N f_{g/p^{\uparrow}}(x, k_{\perp})}{2 f_{g/p}(x, k_{\perp})},$$



Sivers Effect

Sensitive to **proton spin** – parton **transverse motion** correlations



Sooraj Radhakrishnan

PRD 107 (2023) 074022

e + p(T), 18x275 GeV, 100 fb^{-1}

Gluon Helicity $\Delta g/g$

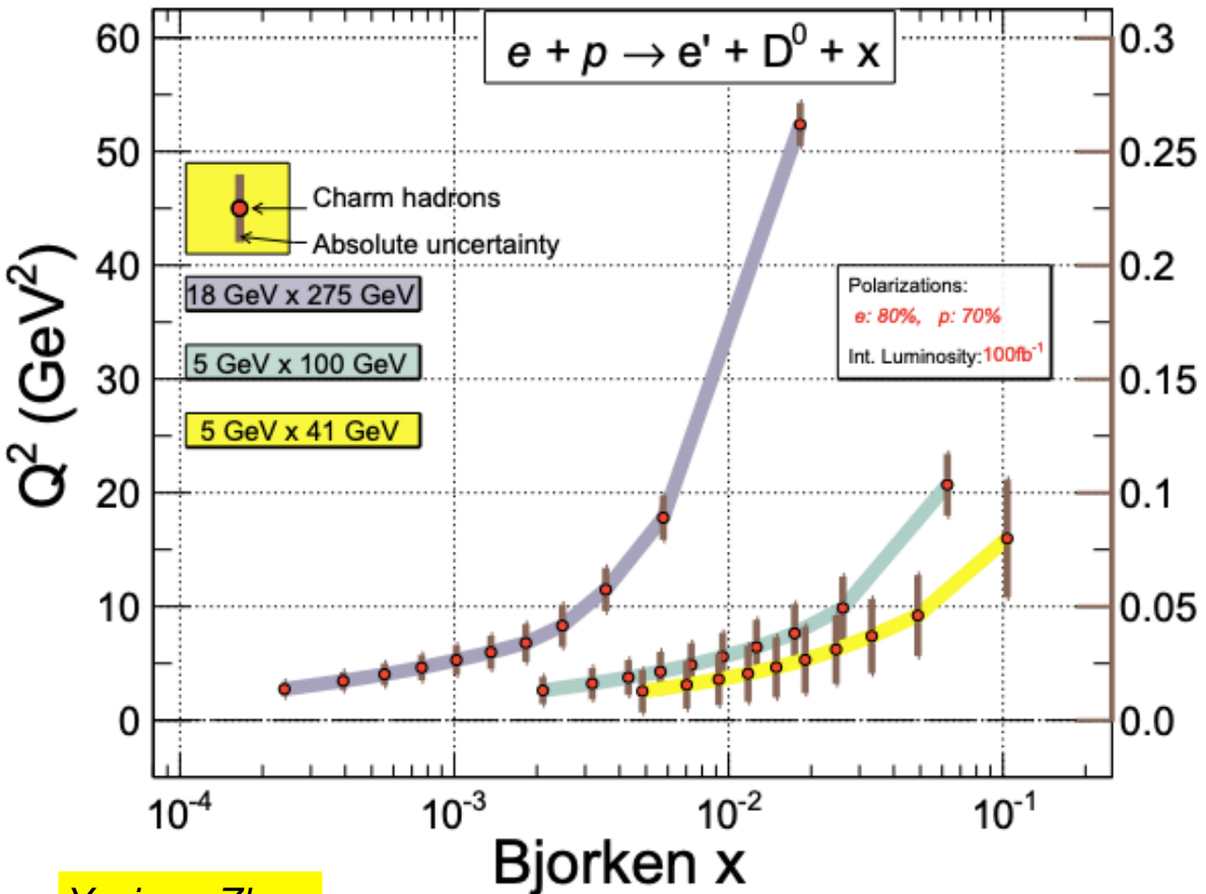
Understanding proton spin is one of the EIC science goals

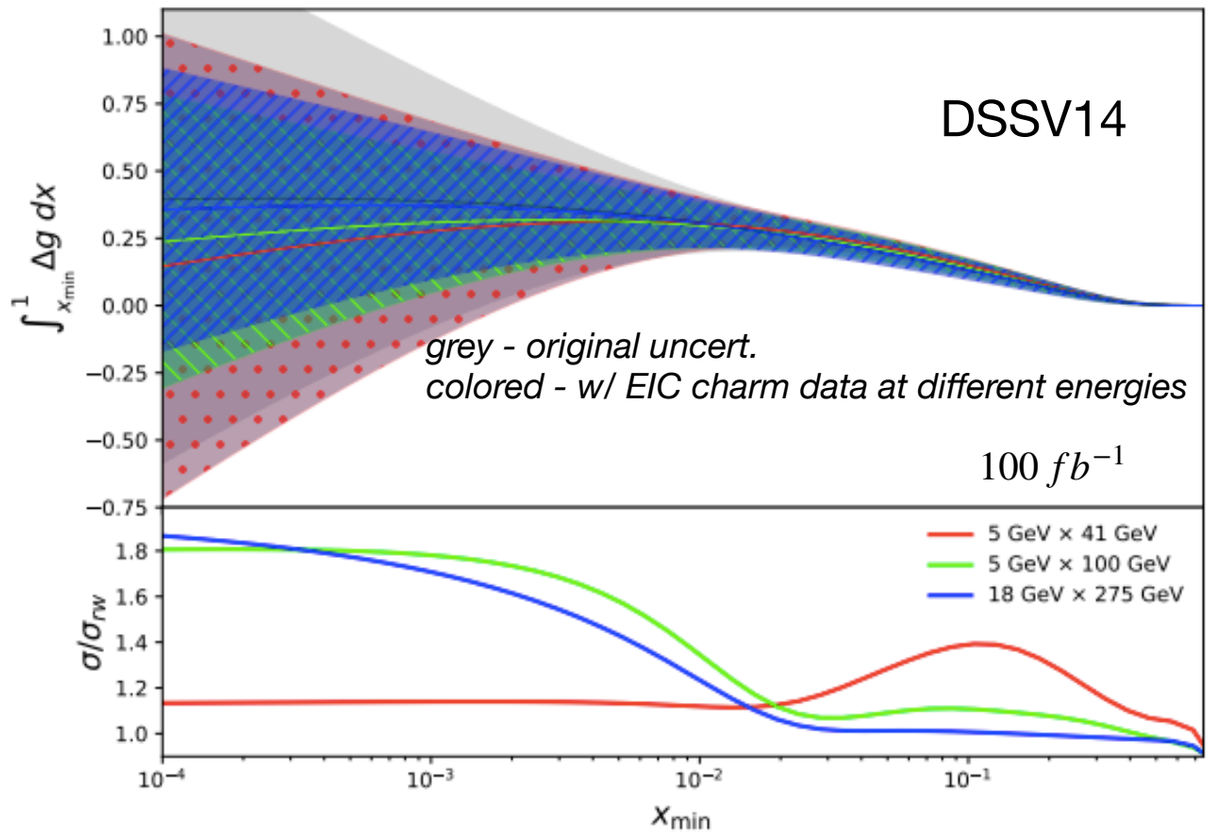
HF - better sensitivity to the gluon dynamics
- complementary to the inclusive measurement
- direct access to $\Delta g/g$ LO $A_{LL} \propto \hat{a}_{LL} \times \Delta g/g$

data placed at each measured (x_B, Q^2) position

error bars - uncertainty of A_1^c

$$A_1^c \equiv \frac{g_1^c(x,Q^2)}{F_1^c(x,Q^2)} = \frac{1}{D(y)} \frac{1}{P_e P_p} \frac{N^{++} - N^{+-}}{N^{++} + N^{+-}}$$





Yuxiang Zhao

PRD 104 (2021) 114039

e(L) + p(L), 5x41 and 18x275 GeV, 100 fb^{-1} each

Guidance

- Beam: e+A, e+p
- Energy: electron 5-10 GeV
- Polarization
  - Year 1-2: no polarization
  - Year 3: transversely polarized protons
  - Year 4: longitudinally polarized protons
  - Year 5: polarized He-3 (L/T)
  - Year 6: electron polarization
- Luminosity: waiting for guidance from machine