Chiral-odd PDFs from dihadron observables and the role of positivity constraints

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Chiral-odd collinear parton distribution functions

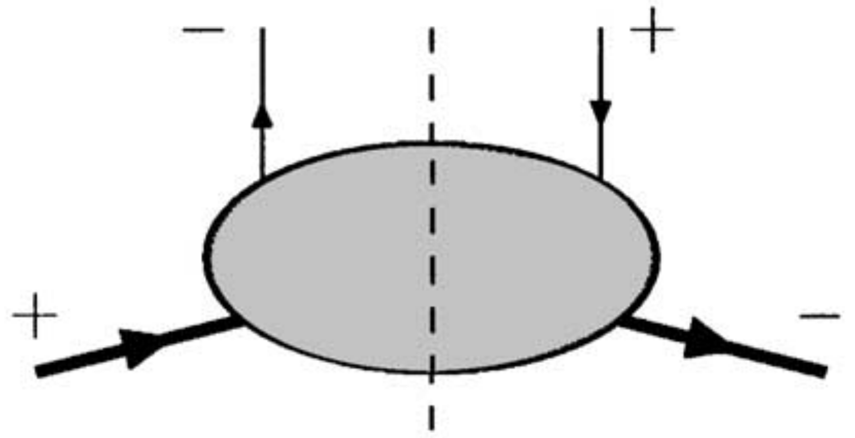
Collinear PDF beyond inclusive DIS — this talk: dihadron observables.
Access to twist-2 and twist-3 distributions.

$$\boxed{\int \frac{d\lambda}{2\pi}\, e^{i\lambda x} \langle PS|\bar{\psi}(0) i\sigma^{\nu\mu}\gamma_5 \psi(\lambda n)|PS\rangle}$$

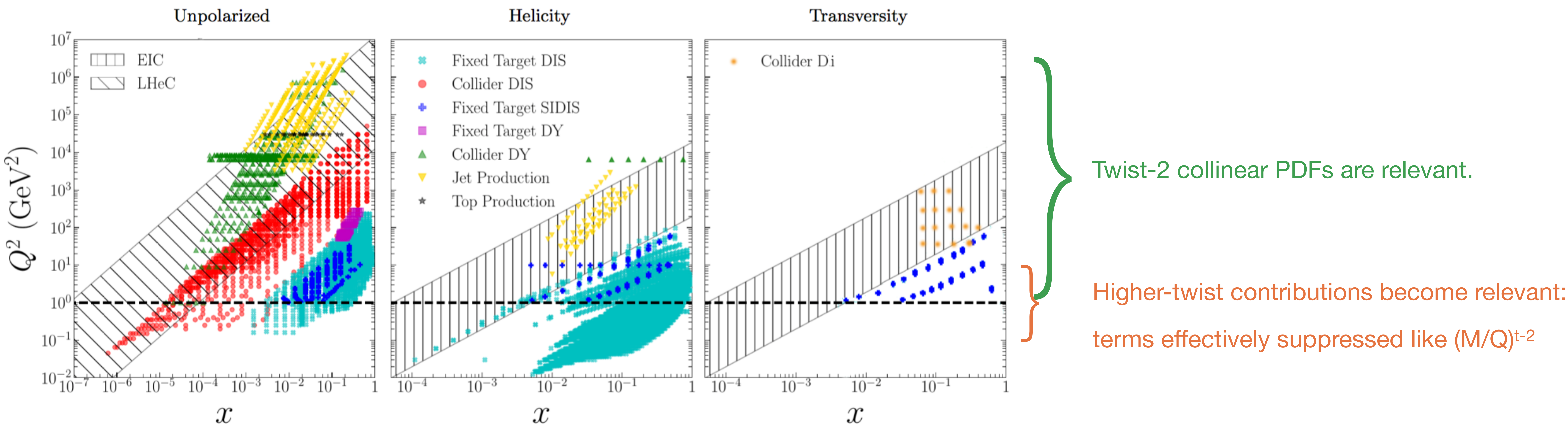
$$\boxed{\frac{1}{2}\int \frac{d\lambda}{2\pi}\, e^{i\lambda x} \langle PS|\bar{\psi}(0)\psi(\lambda n)|PS\rangle = M e(x)}$$

- **Transversity** is the least known twist-2 PDF;
- reduced kinematics coverage *wrt* f_1 and g_1;
- Error treatment must reflect
  - first principle constraints: positivity [large x]
  - integrability [small x]

- **e(x)** is the scalar (twist-3) PDF;
- extremely reduced data sets;
- Point-by-point extraction so far
  - first principle constraints will matter



PDF kinematics coverage: collinear PDFs



[Prog.Part.Nucl.Phys. 121 (2021) 103908]

Fixed Target DIS & SIDIS: M/Q is not so small

- Spurious contaminations
- Spin asymmetries can be defined to get sensitive to twist-3
- Present data: Hermes, COMPASS, JLab.

Ingredients of a fit

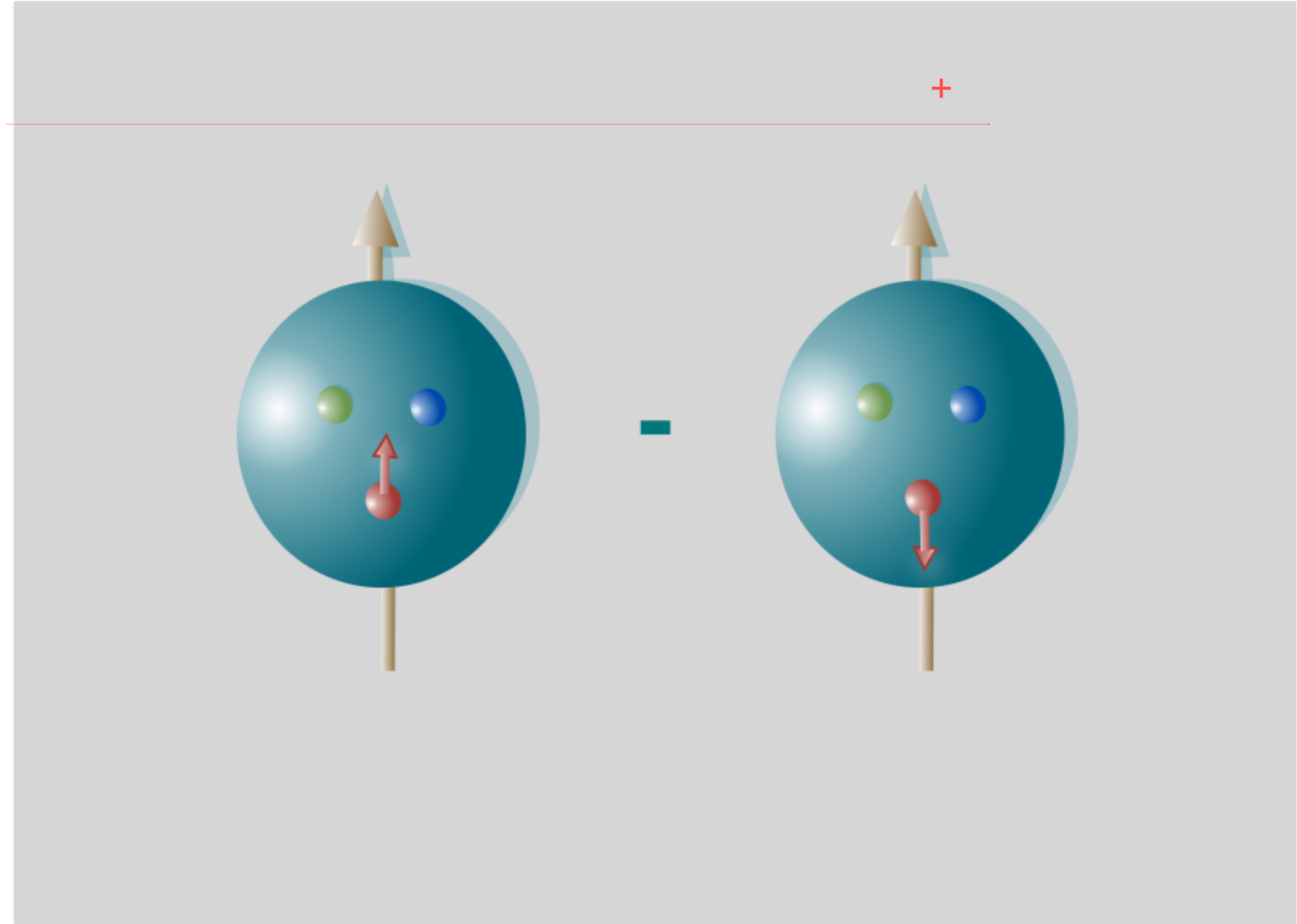
- data;
    - first principles; → untouchable, not assumptions.*
        - theoretical framework;
            - QCD-based assumptions;
                - parametrization
                    - error treatment. → reconciles all previous points in an *elegant* and *physical* way.

* But, the implementation of the first-principle constraints might be data-driven, *e.g.* positivity for g_1 and h_1.

How the uncertainties/tensions between data and first principles are taken care of is a signature of the fit.

→ extensively studied for unpolarized PDFs, especially higher-order corrections and sources of uncertainties.

Statistics: [Kovarik et al, Rev.Mod.Phys. 92 (2020)]
Benchmarking: [PDF4LHC working group, 2203.05506]



Transversity

[Benel et al., EPJC80]

Transversity PDF — constraints

Constraints based on first principles for the Transversity

- Support, e.g. $x \in [0,1]$
- Endpoint behavior, e.g. $h_1(x=1)=0$
- Positivity bounds: Soffer bound

$$\boxed{|h_1^q(x)| \leq \frac{1}{2}\left(f_1^q(x) + g_1^q(x)\right)}$$

Role of first principles on PDF analyses on the spotlight right now [see talk by Nobuo]

Pheno—positivity for polarized PDFs:
[Benel et al., EPJC80]
[d'Alesio et al., PLB803]

Theory—positivity for unpolarized PDFs:
[Candido et al., JHEP11(2020)]
[Collins et al, PRD105]

Sensible flexibility on the constraints might be the key [see, e.g. PDF4LHC working group, 2203.05506]

Transversity PDF — data

Characteristics of the transversity PDF

- Can be assessed in semi-inclusive processes with a chiral-odd partner
- No constraining sum rule
- Its first Mellin moment gives the tensor charge
- Transversity is a non-singlet object

Data → **Dihadron production**

- SIDIS @HERMES, COMPASS
- pp↑ @RHIC
- e^+e^- @Belle

Global analysis: Pavia18 [Radici & Bacchetta, PRL120]

Extended formalism for single hadron production

- SIDIS @HERMES, COMPASS & JLab
- pp↑ @RHIC, more DY and A_N
- e^+e^- @Belle

Global analysis: JAM3D22 [Gamberg et al., 2205.00999]

[see talk by Daniel P.]

Imposing the positivity on the functional form

A crucial step and a physical statement

1. Parametrization that obeys the positivity bounds.

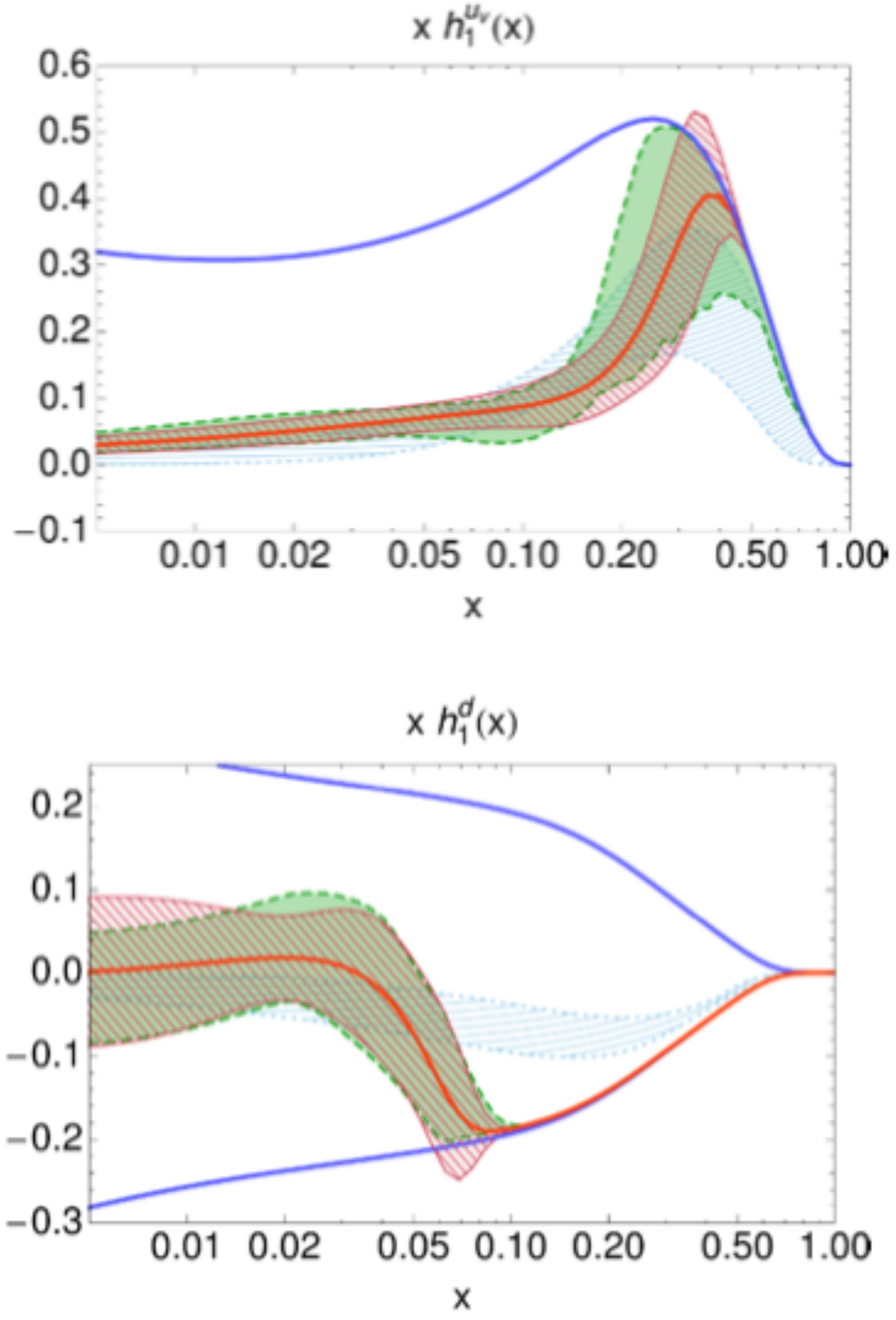
$$\boxed{|h_1^q(x)| \leq \frac{1}{2}\left(f_1^q(x) + g_1^q(x)\right)}$$

Its expression is based on the analyses of the unpolarized f_1 and the helicity g_1 PDFs.

$$x\, h_1(x) \;=\; \frac{F(x)}{|F(x)|} \times x\,\text{Soffer Bound} \qquad \text{with} \qquad F(x) \propto x^{\alpha}(1-x)^{\beta}$$

Good fits are obrained, with a clear **saturation** of the bound.

Recent global fit shows that pp data slightly release that saturation
[Bacchetta & Radici, PRL 120 (2018)], **PAV18**



[Bacchetta, A.C., Radici, JHEP1303]
[Radici, Bacchetta, A.C., Guagnelli, JHEP1505]
PAV15

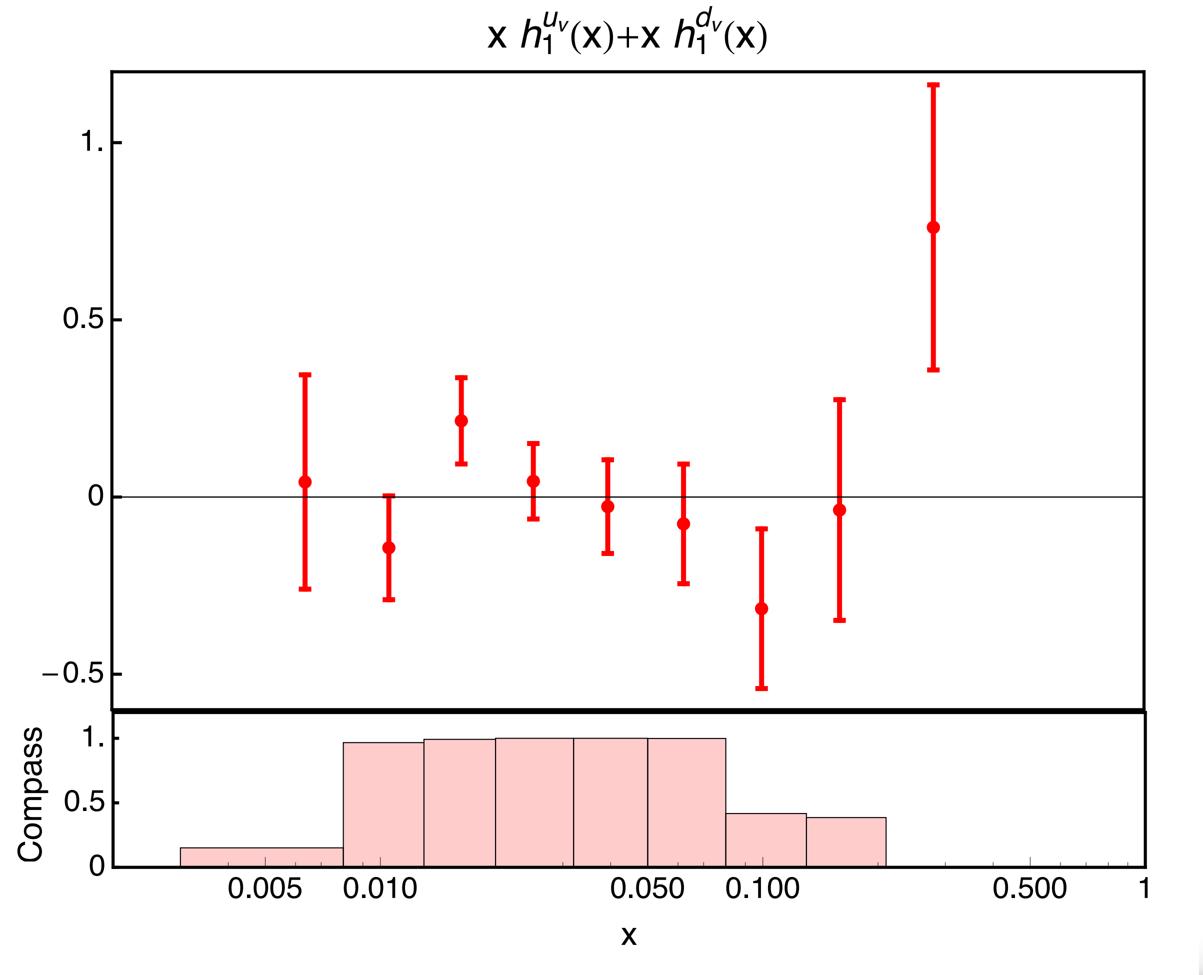
Imposing the positivity by the fitting procedure

[Benel et al., EPJC80]

2. Implicitly guide the positivity bounds at large x

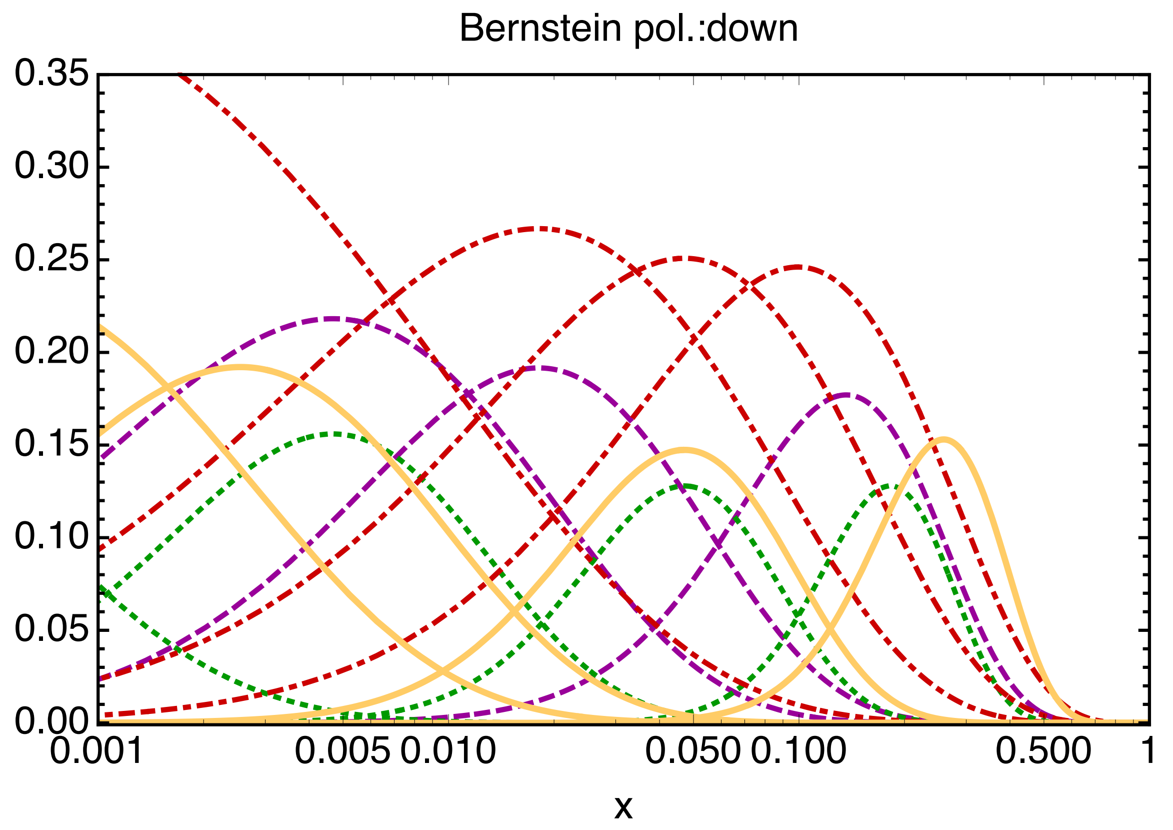
A. Weight by the probability of the positivity bound given the data

$$\chi_r^2\left(\{p^I\}\right) = \sum_j w_j \frac{\left[x_j h_{1\,\mathrm{theo}}^{p/D}\left(x_j;\{p^I\}\right) - \left(x h_1^{p/D}(x)\right)_{j\,,r\,\mathrm{data}}\right]^2}{\sigma_j^2}$$



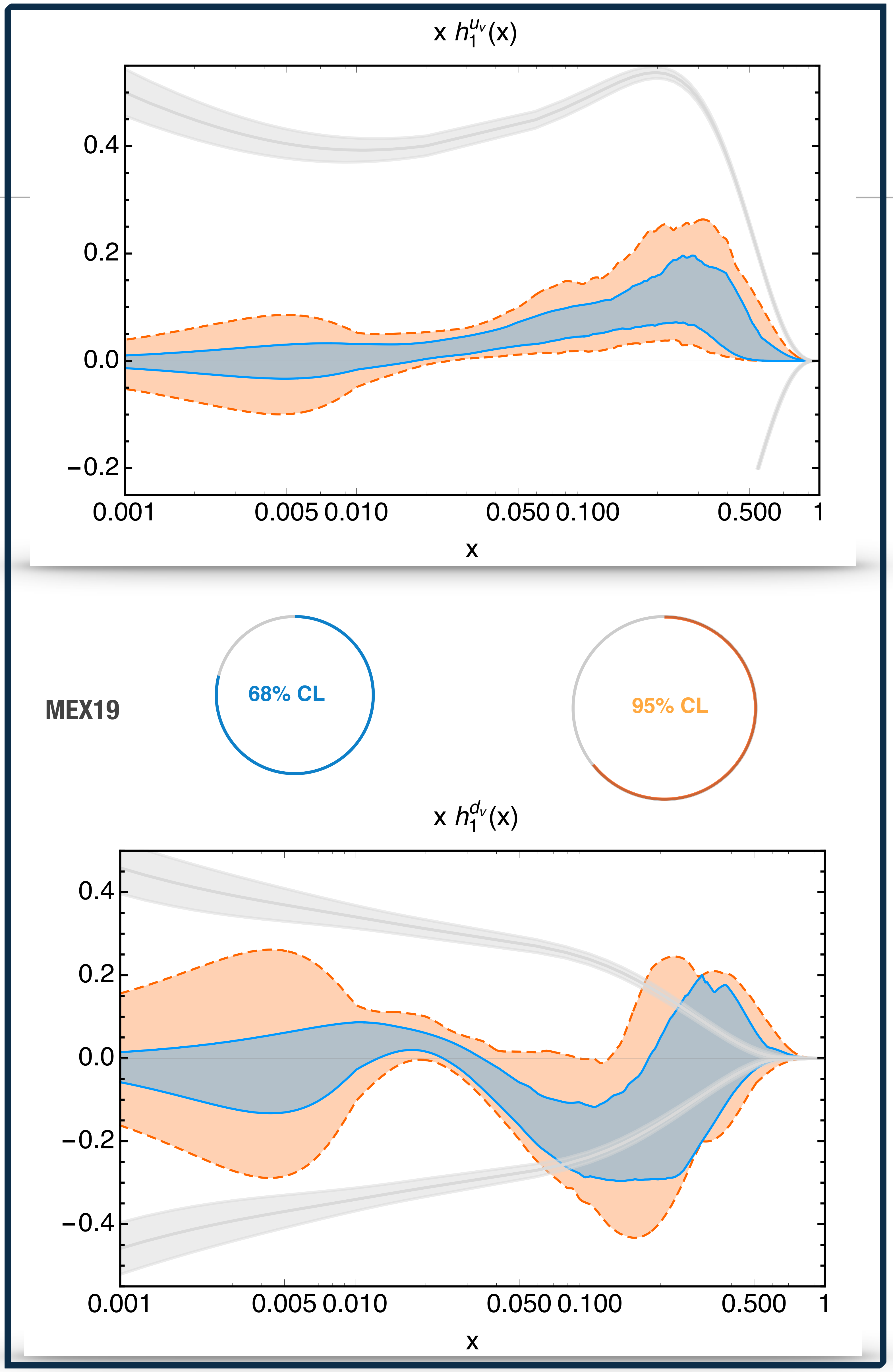
B. Parametrize the x-dependence ; repeat N times (Bootstrap method)

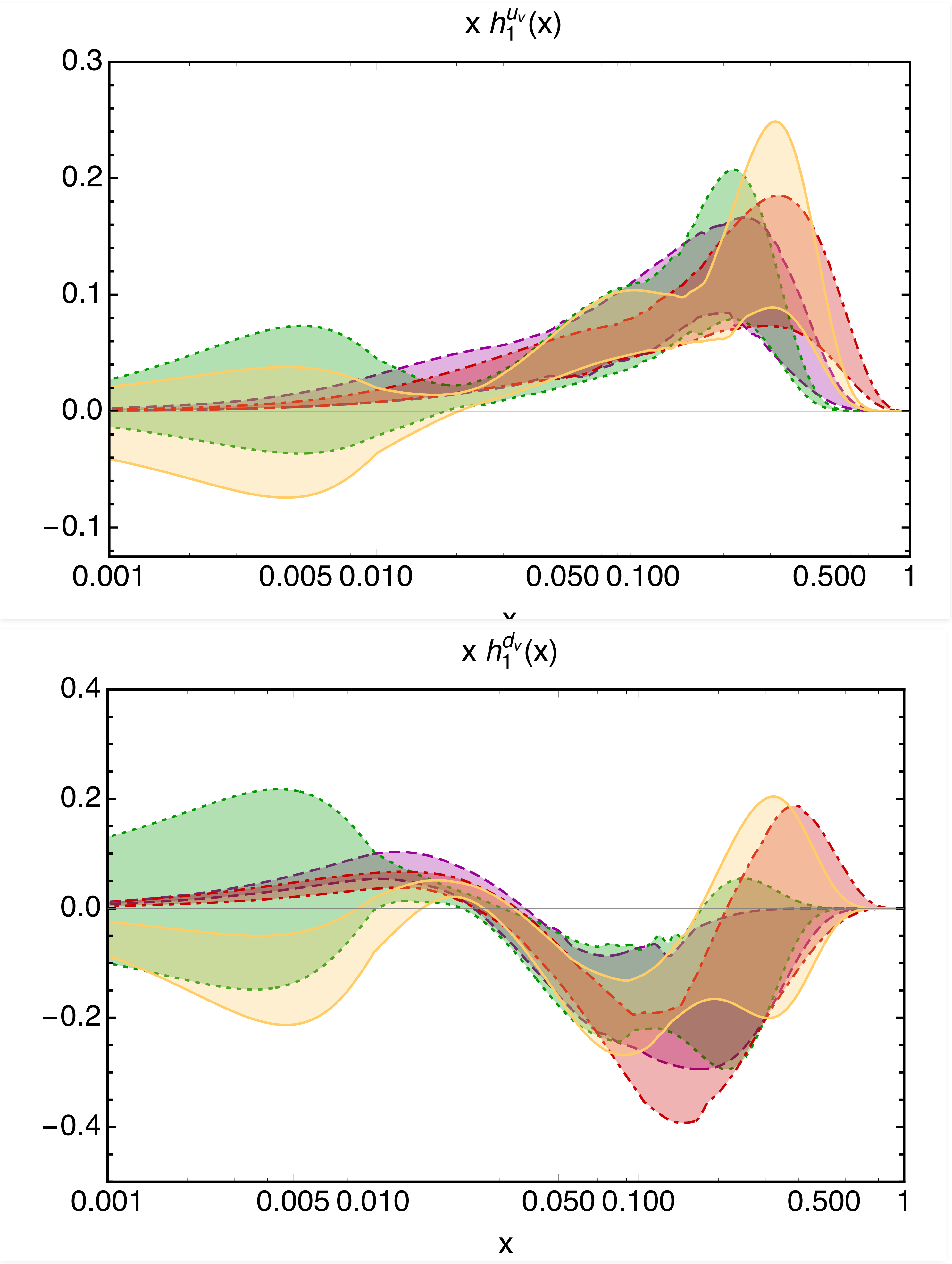
$$x\, h_{1,i}^{q_v}\left(x; p_{i,k}^q\right) = x^{1.25} \sum_{k=\{\kappa_{q,i}\}} p_{i,k}^q\, B_{k,n_i}\left(g(x)\right)$$



C. Constrain the falloff of the PDF at large-x with Lagrange multipliers

$$\begin{aligned} C_{i,j}^{d_V}\left(p_{i,k}^{d\,II}\right) &= h_{1,i}^{q_V}\left(x_j; p_{i,k}^{d\,II}\right) < \epsilon_j \\ C_{i,j}^{d_V}\left(p_{i,k}^{d\,II}\right) &= h_{1,i}^{q_V}\left(x_j; p_{i,k}^{d\,II}\right) > -\epsilon_j \end{aligned}$$





Data-induced relaxation of the bound brings more flexibility at large x.

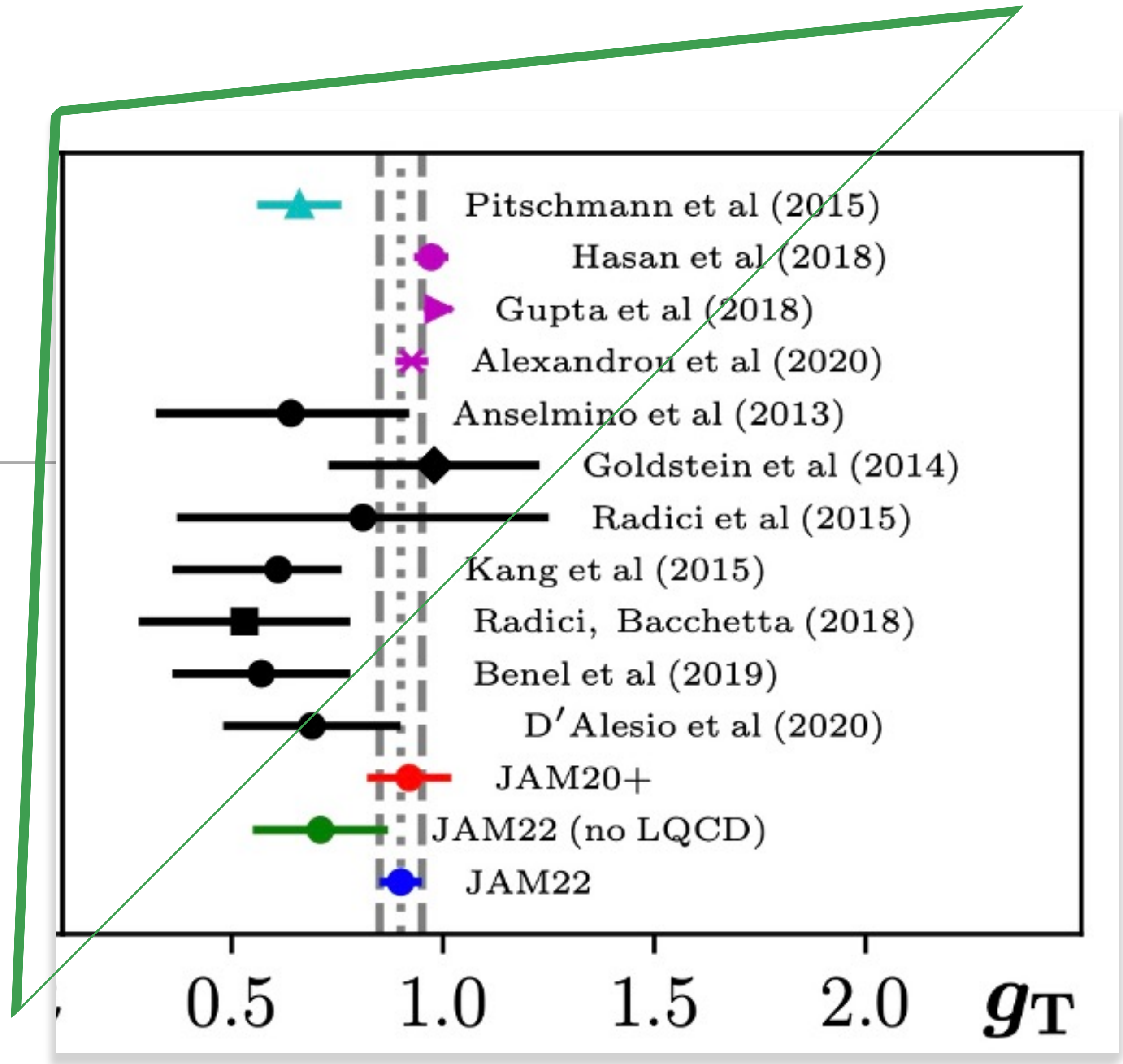
Chosen of functional form allows for a wider uncertainty at both small and large x.

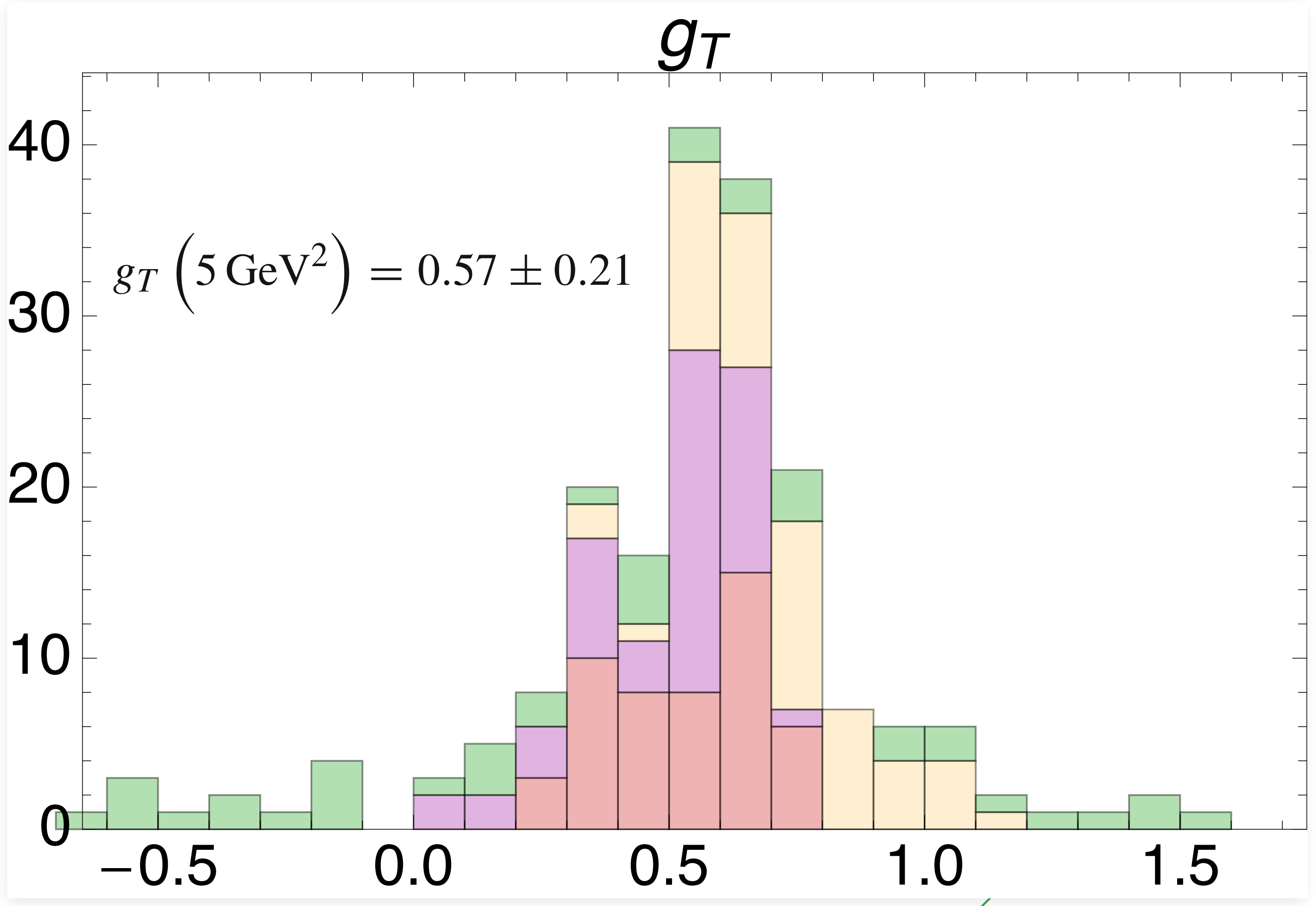
Balanced interplay between constraints and data.

Tensor charge from constrained fit

It is possible to get an **agreement with lattice g_T** with more flexibility in the functional form.

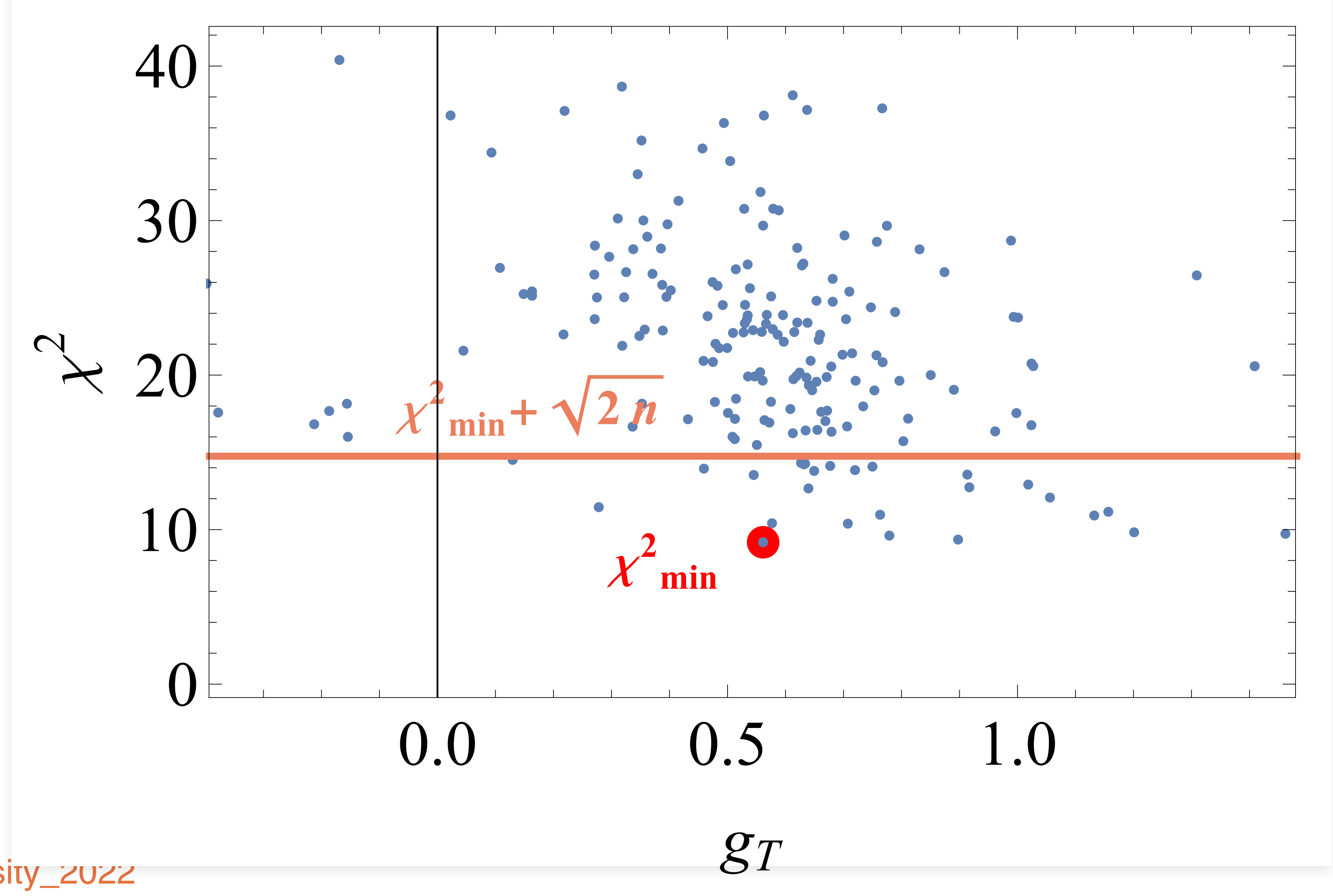
Stacked histogram of contribution from the four functional forms

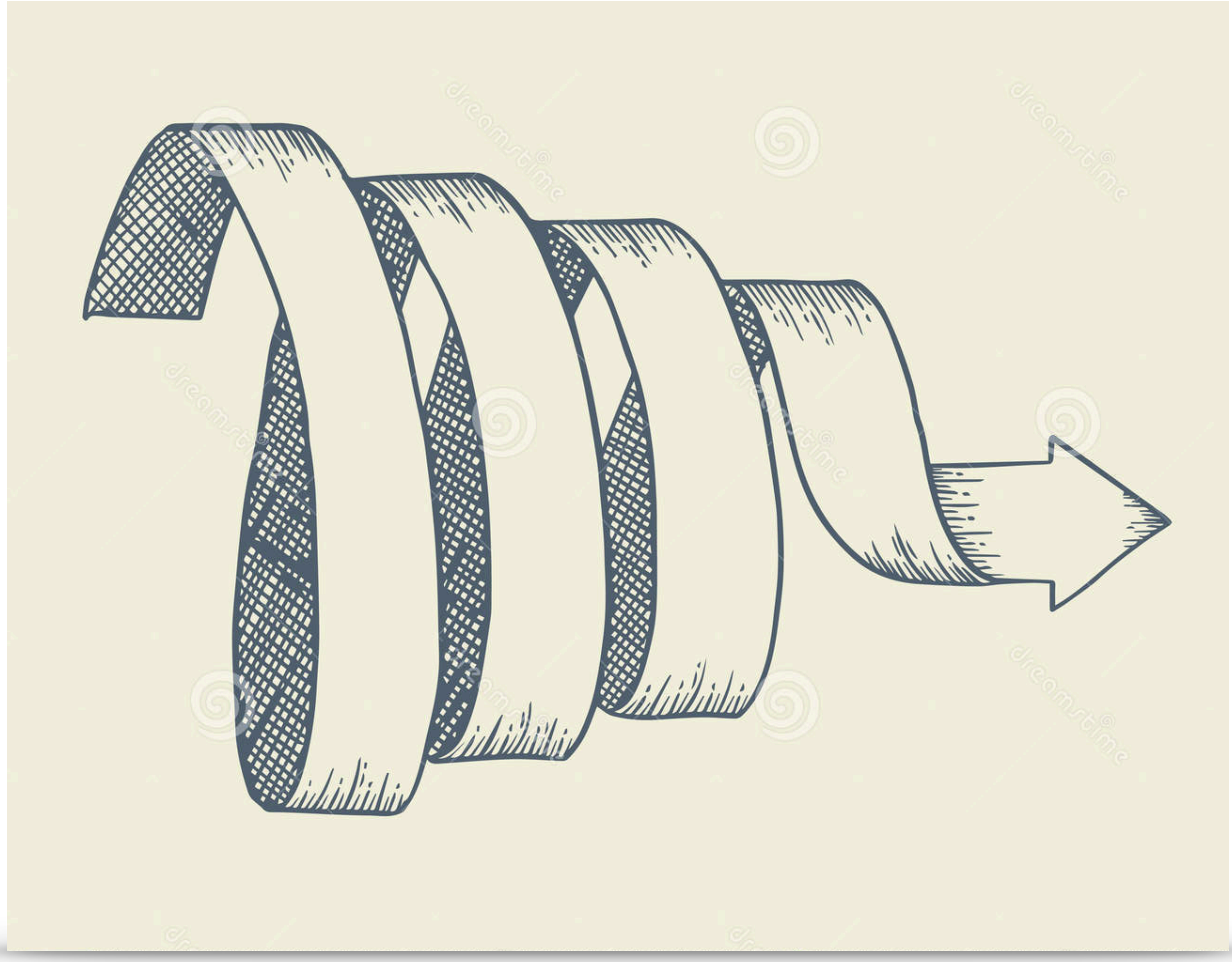




Can we learn from the distribution of the chi square and g_T?

[A.C., 2108.01741]





$e(x)$ | [Courtoy et al., 2203.14975]

Beam spin asymmetry at CLAS and CLAS12

see talk by Christopher Dilks

- dihadron SIDIS on proton target — sensitive to $e^P \equiv \frac{1}{9}(4\, e^{u_V} - e^{d_V})$;

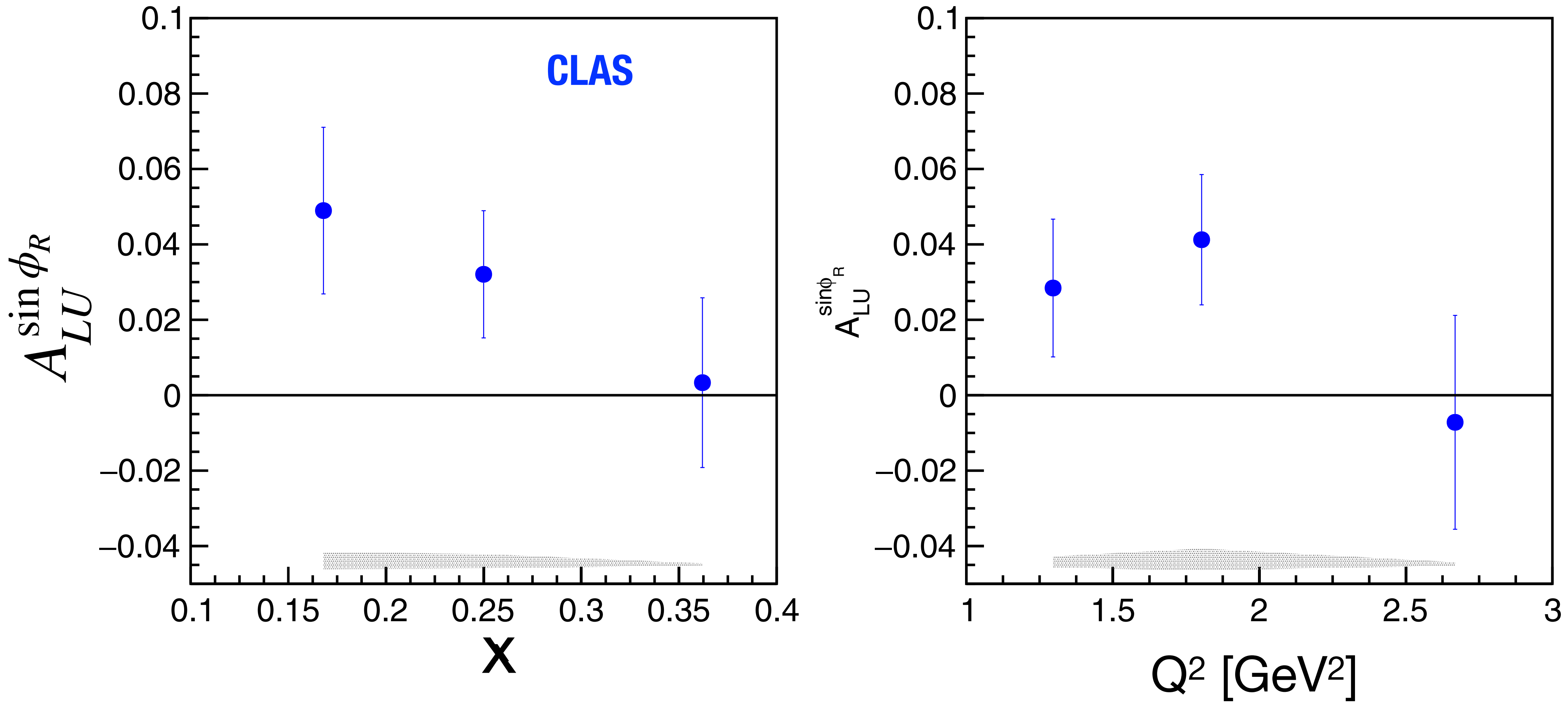
[Bacchetta & Radici, *PRD*69 (2004)]
[Courtoy, 1405.7659]

- non-vanishing twist-3 effects at CLAS12;

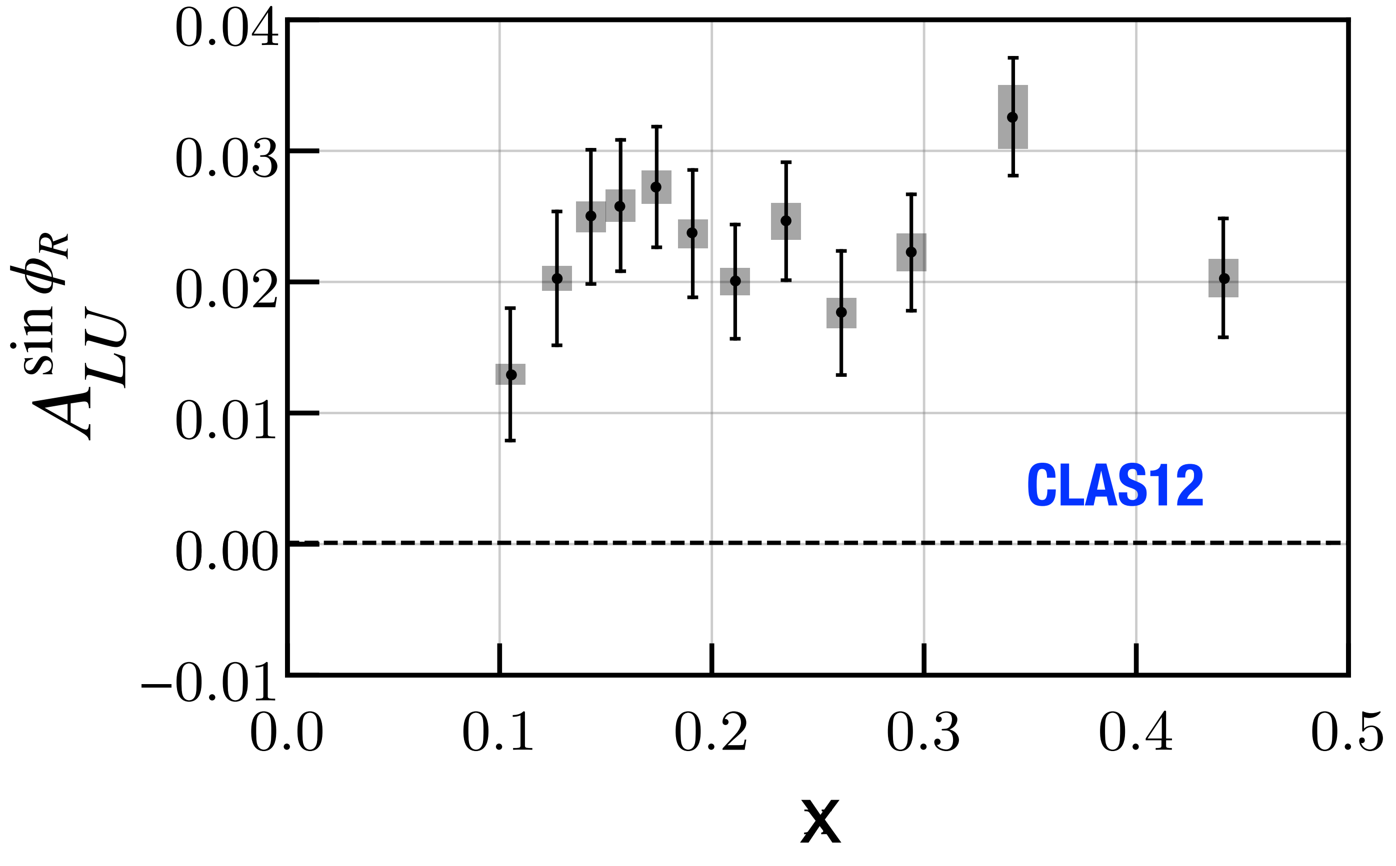
- projections of beam spin asymmetries on $(x, z, M_h; Q^2, y)$

➡ (x, z, M_h) triptych from the parton distribution and fragmentation function.

Road map for e(x) extraction and (global) analysis.



[CLAS Collaboration, PRL126 (2021) 6, 062002]



[CLAS Collaboration, PRL126 (2021) 152501]

Extraction of $e(x)$ from CLAS data

$$A_{LU}^{\sin\phi_R}(x,z,m_{\pi\pi}) \propto \frac{M}{Q}\frac{\sum_q e_q^2\left[xe^q(x)\,H_{1,sp}^{\sphericalangle,q}(z,m_{\pi\pi}) + \frac{m_{\pi\pi}}{zM}\,f_1^q(x)\,\tilde{G}_{sp}^{\sphericalangle,q}(z,m_{\pi\pi})\right]}{\sum_q e_q^2\,f_1^q(x)\,D_{1,ss+pp}^q(z,m_{\pi\pi})}$$

leading-twist DiFFs

$\tilde{G}^{\sphericalangle} = \text{genuine twist-3}$

Twist-2 Dihadron Fragmentation Functions

- Phenomenologically tested for the twist-2 <u>transversity PDF</u> —see above
- we get the ratio R that is believed to be universal (<u>portable</u>) *up to evolution effects*

$$\boxed{R(z,M_h) = \frac{|\boldsymbol{R}|}{M_h}\,\frac{H_1^{\sphericalangle\,u}(z,M_h;Q_0^2)}{D_1^u(z,M_h;Q_0^2)}}$$

How to treat twist-3 Dihadron Fragmentation Functions?

Extraction of e(x) from CLAS data

$$A_{LU}^{\sin\phi_R}(x,z,m_{\pi\pi}) \propto \frac{M}{Q}\frac{\sum_q e_q^2\left[xe^q(x)\, H_{1,sp}^{\sphericalangle,q}(z,m_{\pi\pi}) + \frac{m_{\pi\pi}}{zM} f_1^q(x)\, \tilde{G}_{sp}^{\sphericalangle,q}(z,m_{\pi\pi})\right]}{\sum_q e_q^2\, f_1^q(x)\, D_{1,ss+pp}^q(z,m_{\pi\pi})}$$

$\tilde{G}^{\sphericalangle}$ = genuine twist-3

Twist-3 Dihadron Fragmentation Functions

- Unknown phenomenologically;
- Model evaluations for genuine twist-3 DiFF: $\tilde{D}^{\sphericalangle}$ [Luo et al.,PRD100], $\tilde{G}^{\sphericalangle}$ [Yang et al., PRD99]
- Estimate of Interference FF through the asymmetries on longitudinally-polarized target at COMPASS [Sirtl, PhD thesis, 2017]

$$A_{UL}^{\sin(\phi_R)} = -\frac{M}{Q}\frac{|\boldsymbol{R}|}{M_h}\frac{\sum_q e_q^2\left[xh_L^q(x)H_1^{\angle q,sp}(z,M_h^2) + \frac{M_h}{Mz}g_1^q(x)\tilde{G}^{\angle q,sp}(z,M_h^2)\right]}{\sum_q e_q^2 f_1^q(x) D_1^{q,ss+pp}(z,M_h^2)}$$

$$A_{LL}^{\cos(\phi_R)} = \frac{M}{Q}\frac{|\boldsymbol{R}|}{M_h}\frac{\sum_q e_q^2\left[xe_L^q(x)H_1^{\angle q,sp}(z,M_h^2) - \frac{M_h}{Mz}g_1^q(x)\tilde{D}^{\angle q,sp}(z,M_h^2)\right]}{\sum_q e_q^2 f_1^q(x) D_1^{q,ss+pp}(z,M_h^2)}.$$

$$A_{UL}^{\sin(\phi_R)} = 0.0050 \pm 0.0010(\text{stat}) \pm 0.0007(\text{sys}).$$

$$A_{LL}^{\cos(\phi_R)} = -0.0135 \pm 0.0064(\text{stat}) \pm 0.0046(\text{sys}).$$

$$\Rightarrow |A_{LL}^{\cos\phi_R}| >> A_{UL}^{\sin\phi_R}$$

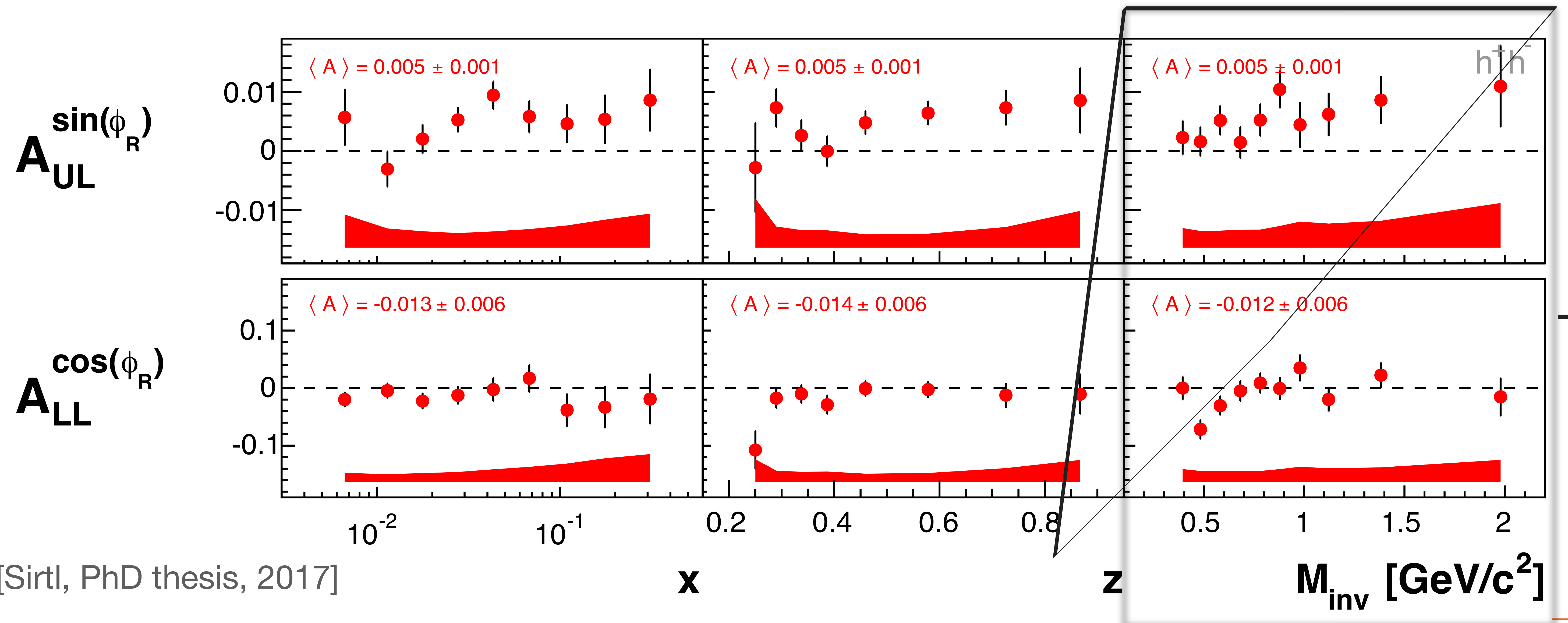
Twist-3 dihadron fragmentation functions: COMPASS

Can we understand $|A_{LL}^{\cos\phi_R}| >> A_{UL}^{\sin\phi_R}$ in the usual approximations?

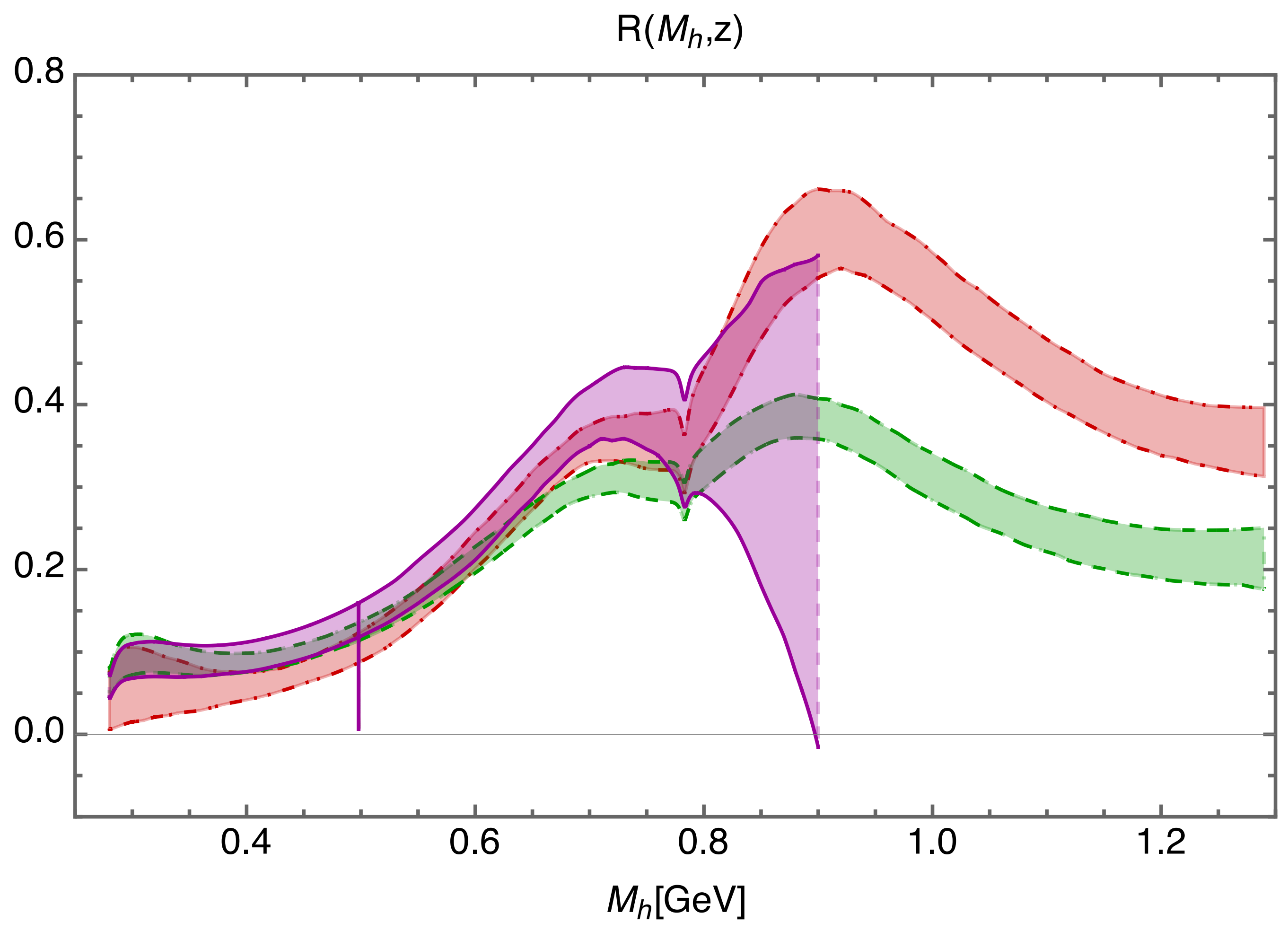
Can we single out twist-3 DiFFs through this approximation?

$$A_{LL}^{\cos\phi_R} \stackrel{?}{=} -\frac{M}{Q}\frac{|\mathbf{R}|}{M}\frac{\sum_q e_q^2 g_1(x)/z\,\tilde{D}^{\sphericalangle}}{\sum_q e_q^2 f_1(x) D_1}$$

Our goal here is to find a proportionality factor κ such that $\max\left\{\int \tilde{G}^{\sphericalangle}\right\} \equiv \int \tilde{D}^{\sphericalangle} = \kappa \int \tilde{H}_1^{\sphericalangle}$



[Sirtl, PhD thesis, 2017]



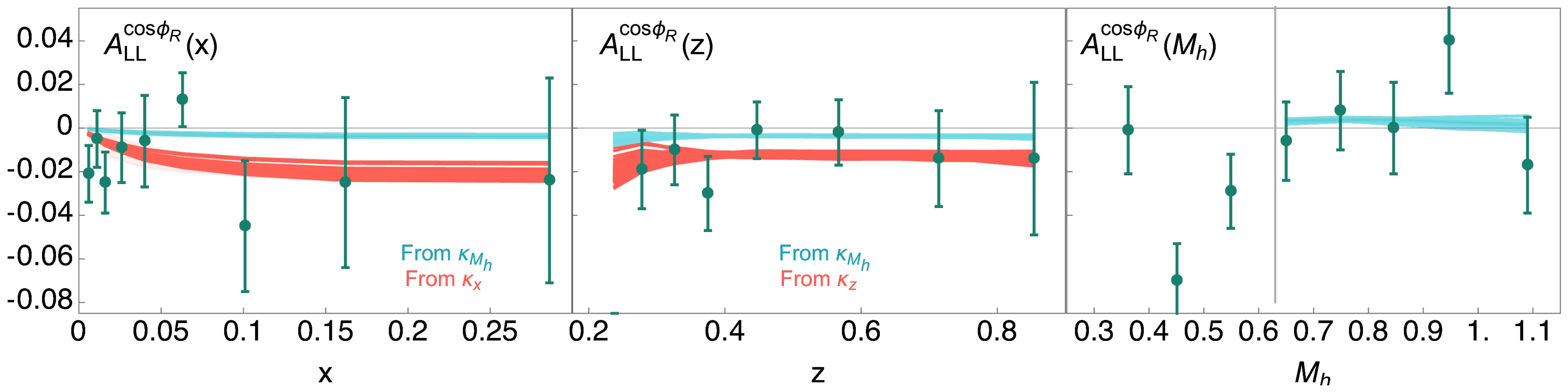
[Radici, AC, Bacchetta, *JHEP* 05 (2015)]

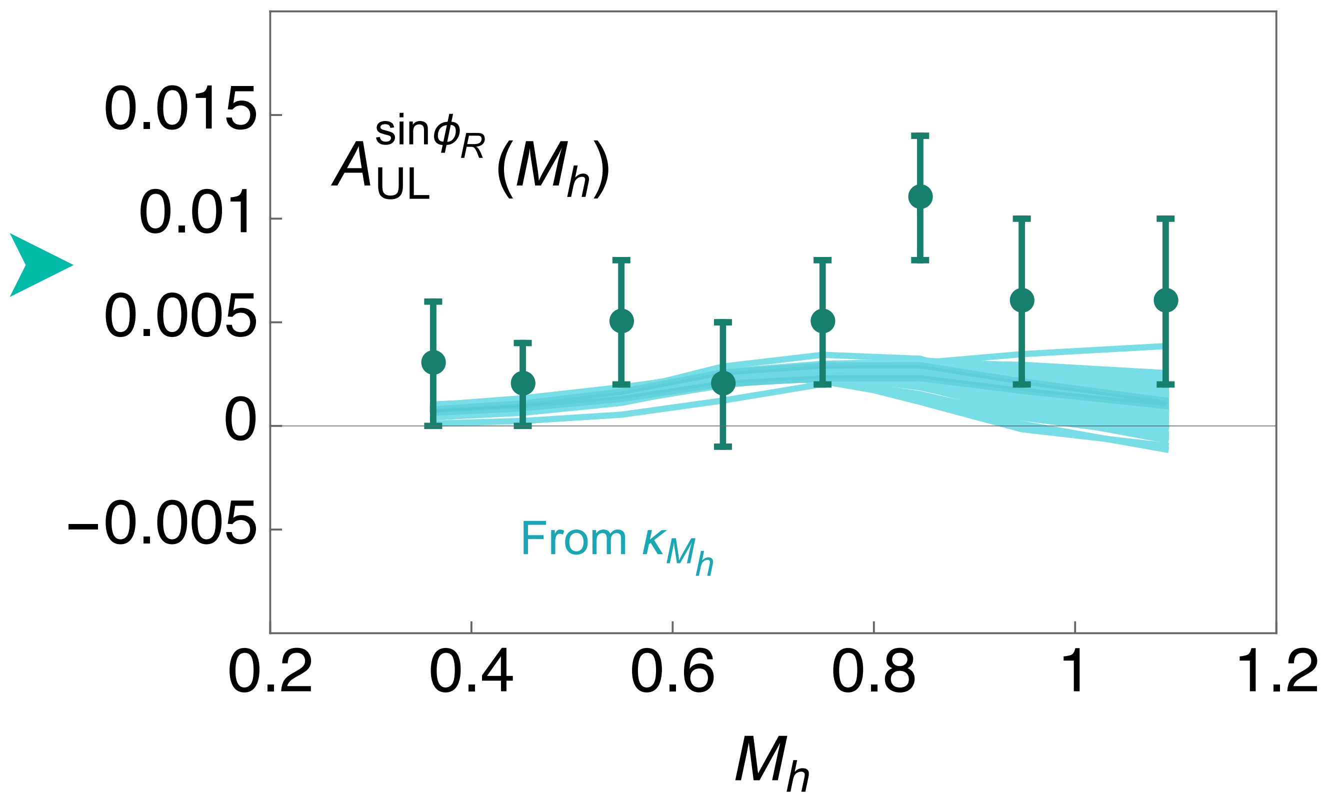
Our ansatz for the twist-3 DiFF contribution

- CLAS12: split invariant-mass regions $M_h >$ or < 0.63 GeV to pinpoint vector meson contributions
- We assume the trend of all interference DiFFs in the invariant mass is similar for $M_h > 0.63$ GeV (up to overall sign)

  $\Rightarrow$ supported by model evaluation of $\tilde{D}^{\sphericalangle}$ and $\tilde{G}^{\sphericalangle}$

- Reproducing $A_{LL}^{\cos\phi_R}$ in that range sets our upper bound to $\kappa \Rightarrow \kappa_{M_h}$
- κ_{M_h} reproduces the order of magnitude for $A_{UL}^{\sin\phi_R}$ adequately





$\Rightarrow$ invariant-mass behavior is key, twist-2 DiFF alone not enough to interpret all M_h -projected twist-3 asymmetries.

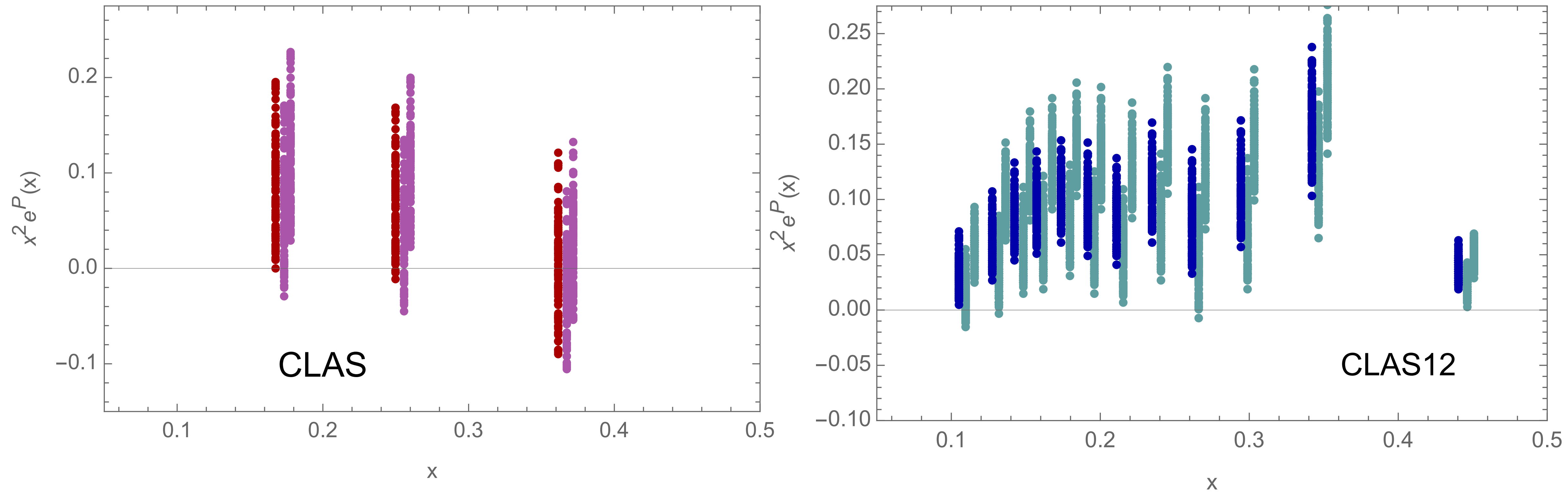
Point-by-point e(x) from CLAS data

- Scenario I: Wandzura-Wilczek approximation

$$\frac{e^V(x)}{f_1^\Sigma(x)}\frac{\tilde{H}_1^\sphericalangle}{D_1} \propto \frac{Q}{M} A_{LU}^{\sin\phi_R}$$

- Scenario II: beyond WW approximation

$$\frac{e^V(x)}{f_1^\Sigma(x)}\frac{\tilde{H}_1^\sphericalangle}{D_1} \propto \frac{Q}{M} A_{LU}^{\sin\phi_R} \pm \kappa \frac{f_1^V(x)}{f_1^\Sigma(x)}\frac{\tilde{H}_1^\sphericalangle}{D_1}$$

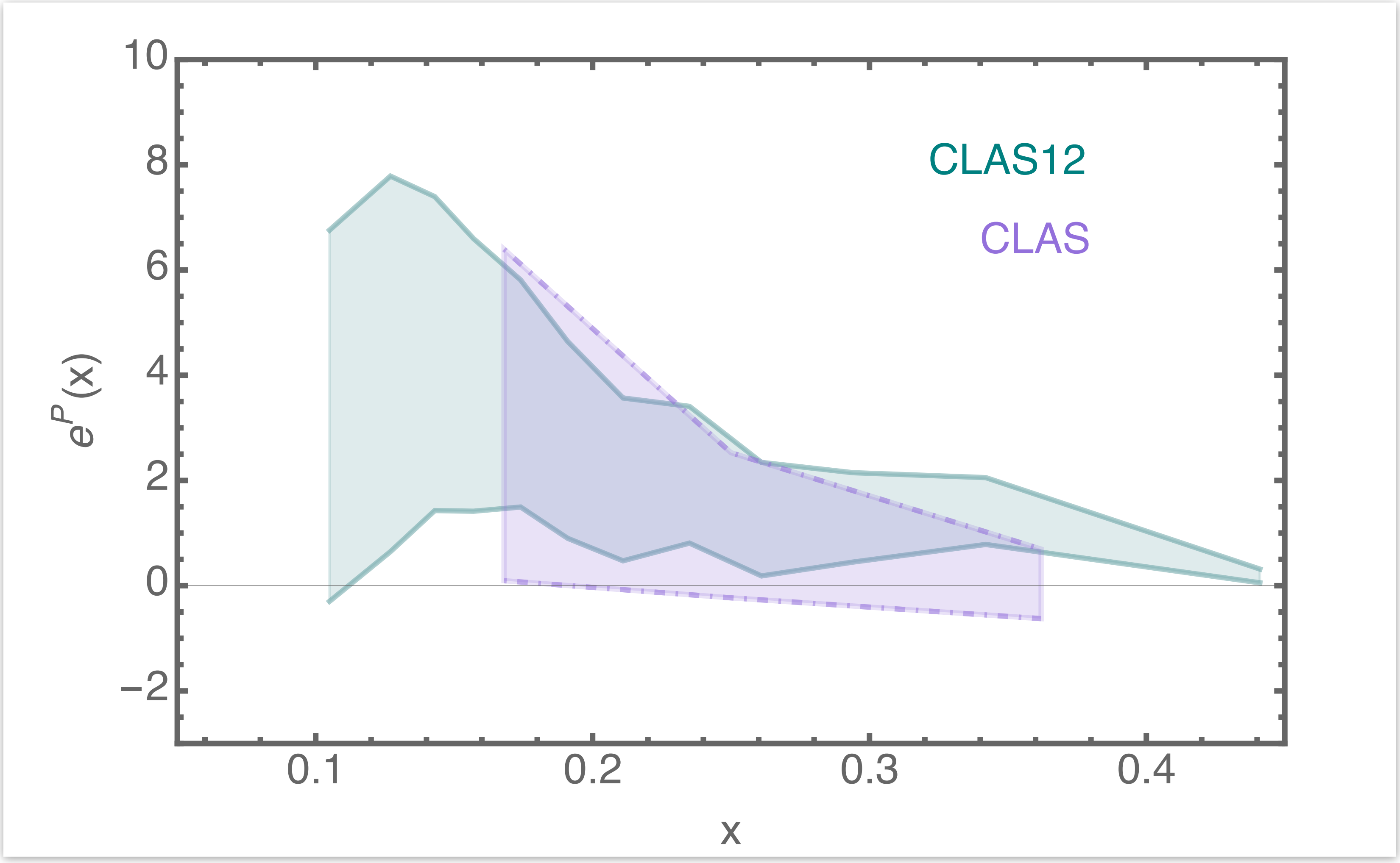


Evolution omitted thanks to low-Q² values —Q=1GeV

Uncertainty on unpolarized PDF taken into account

Sign of twist-3 DiFFs undetermined

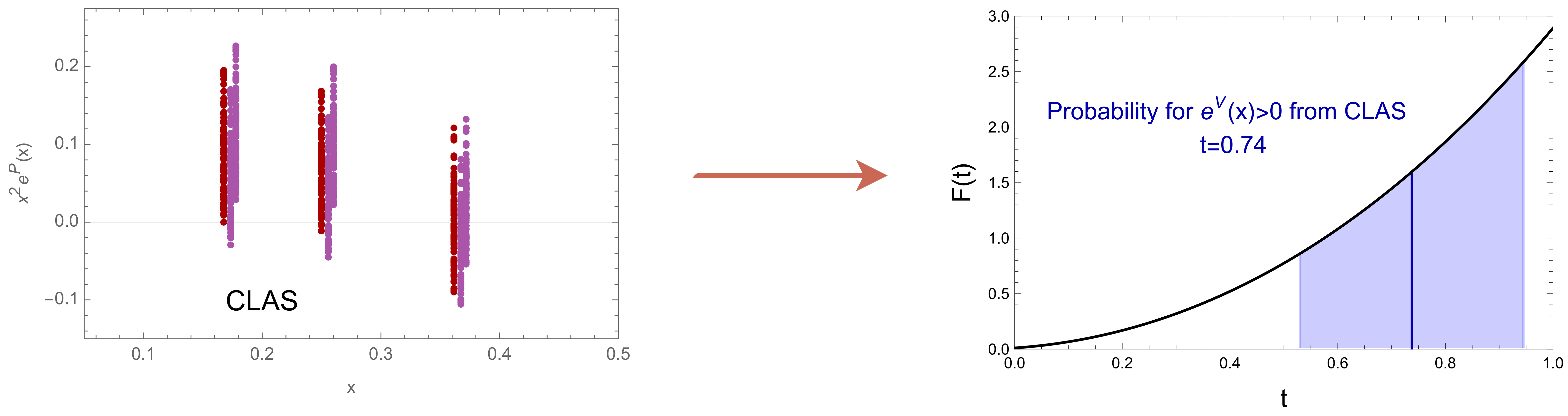
Combining the uncertainty at 90% CL⇒



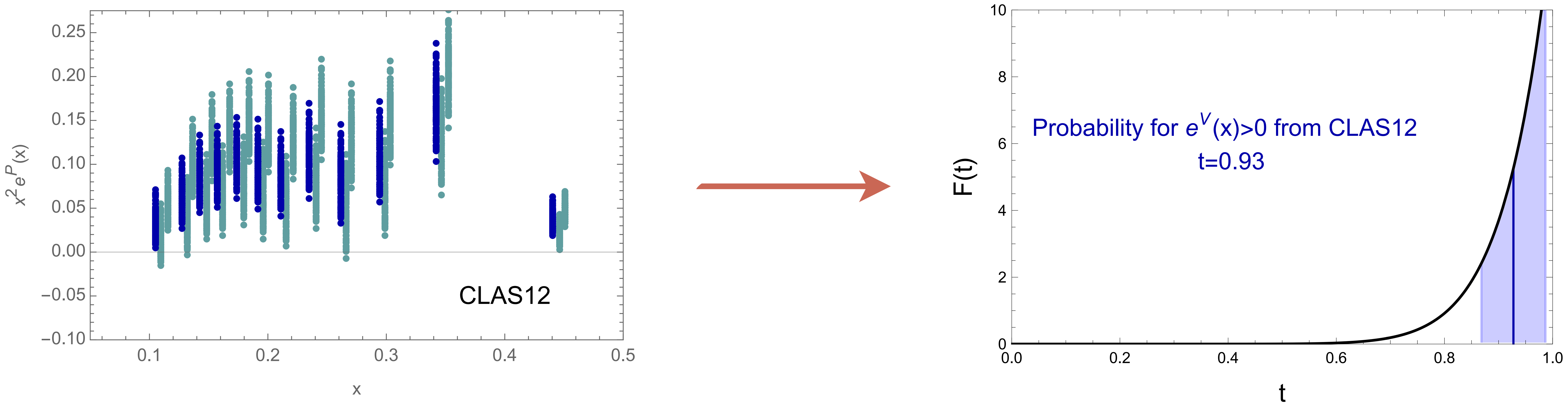
[Courtoy, 1405.7659]
[Courtoy et al., 2203.14975]

What is the probability for $e^P(x)$ to be non-zero?

Probability that the proton combination is <u>greater</u> than zero —not exactly "how incompatible with zero is it?"— is a useful information from the point-by-point extraction of a collinear twist-3 PDF with a minimum set of approximations.



Mostly far from zero!



Conclusions

We have discussed the extraction of chiral-odd collinear PDF through the dihadron framework.

We have discussed an alternative way to account for **relaxed positivity constraints** on the transversity fit.
We have presented a **truly updated extraction of the scalar PDF, e(x)**. It is non-zero to more than 75% probability.

Studies of chiral-odd PDFs are important:

- *Precision imaging of nucleons.*
- *Emergence of hadronic mass —from the scalar PDF.*
- *Possible tensor and scalar interactions beyond the standard model.*

- *Collinear-to-PDF interpretations.*
- *Understanding of the mid-to-high energy transitions.*

- *Could benefit from the experience gained from the unpolarized PDFs — statistical analyses-wise.*

Backup

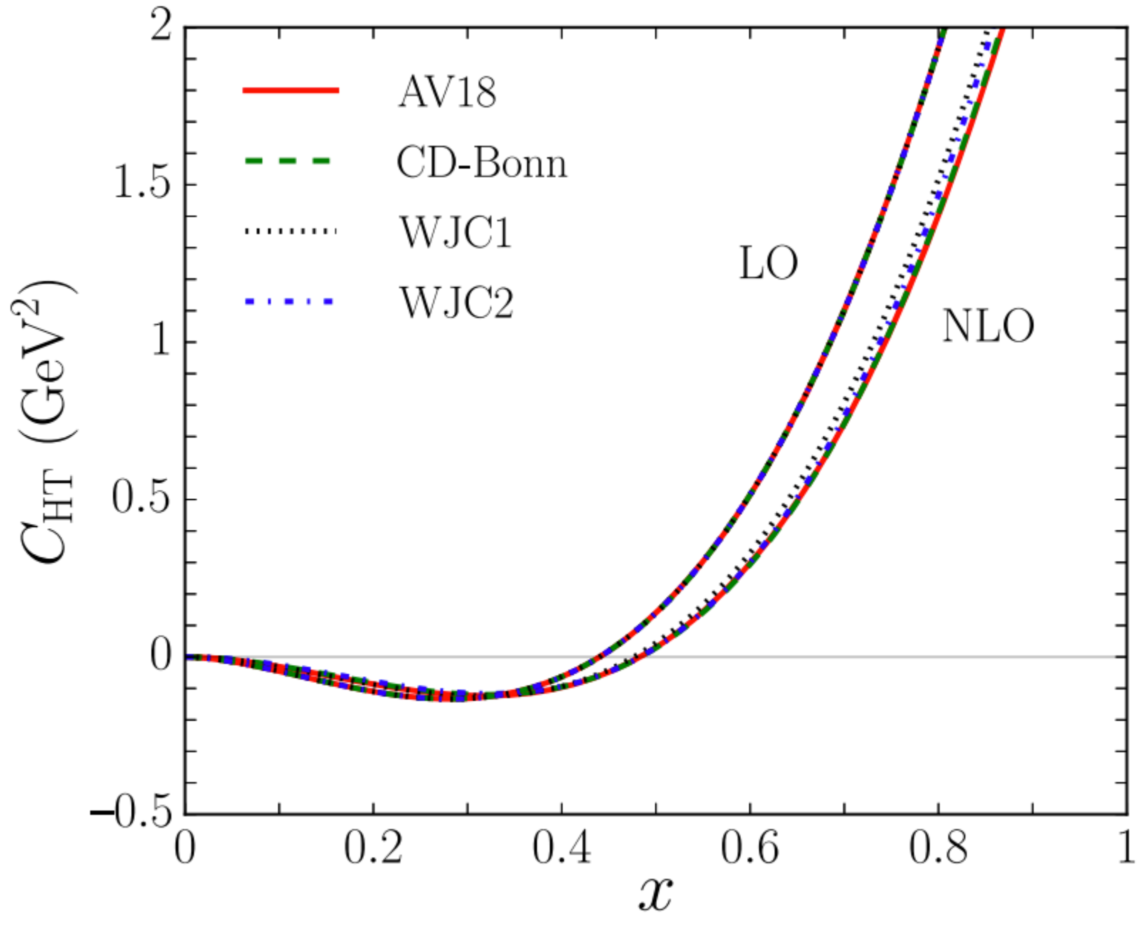
Higher-twist corrections

- **From spurious contaminations…**

CJ15 global analysis includes lower cuts on W^2. [Accardi et al., PRD93]

$$F_2(x,Q^2) = F_2^{\rm LT}(x,Q^2)\left(1+\frac{C_{\rm HT}(x)}{Q^2}\right)$$

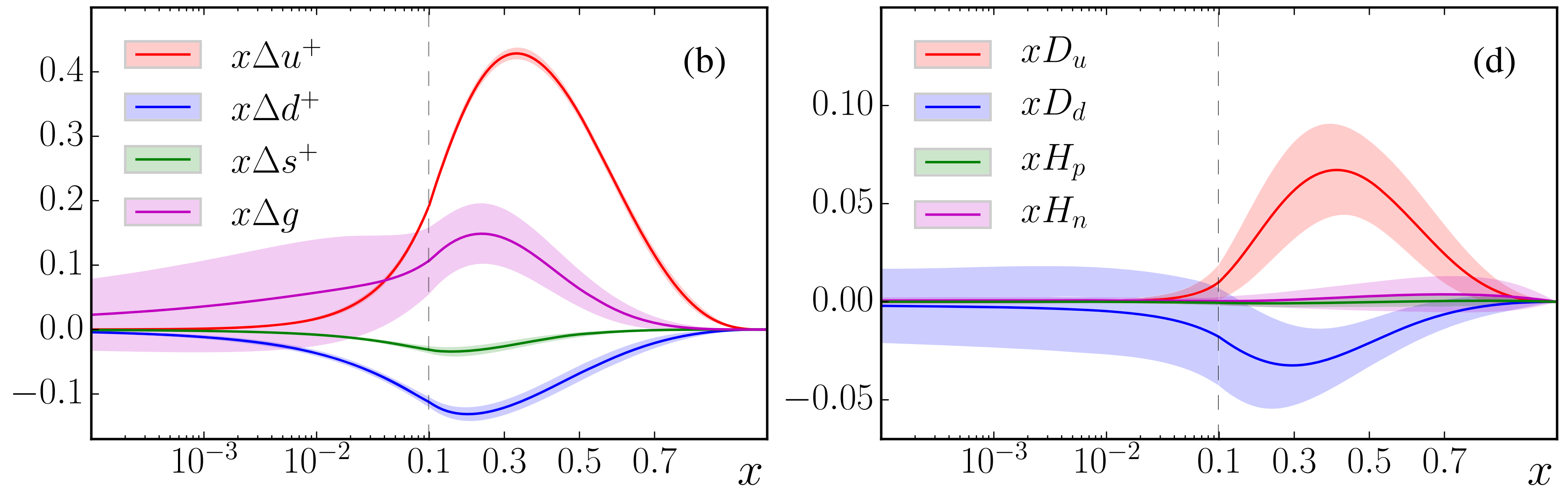
HT's role in fulfilling duality [e.g. Melnitchouk et al., Phys.Rept.406]



- **…to genuine effects**

JAM analysis of the helicity PDF g_1 extends to g_T, with $g_T=g_1+g_2$. [Sato et al., PRD93]

$$g_2^{(\tau 3)}(x,Q^2) = D(x,Q^2) - \int_x^1 \frac{dz}{z} D(z,Q^2)$$



Twist-3 PDF in observables

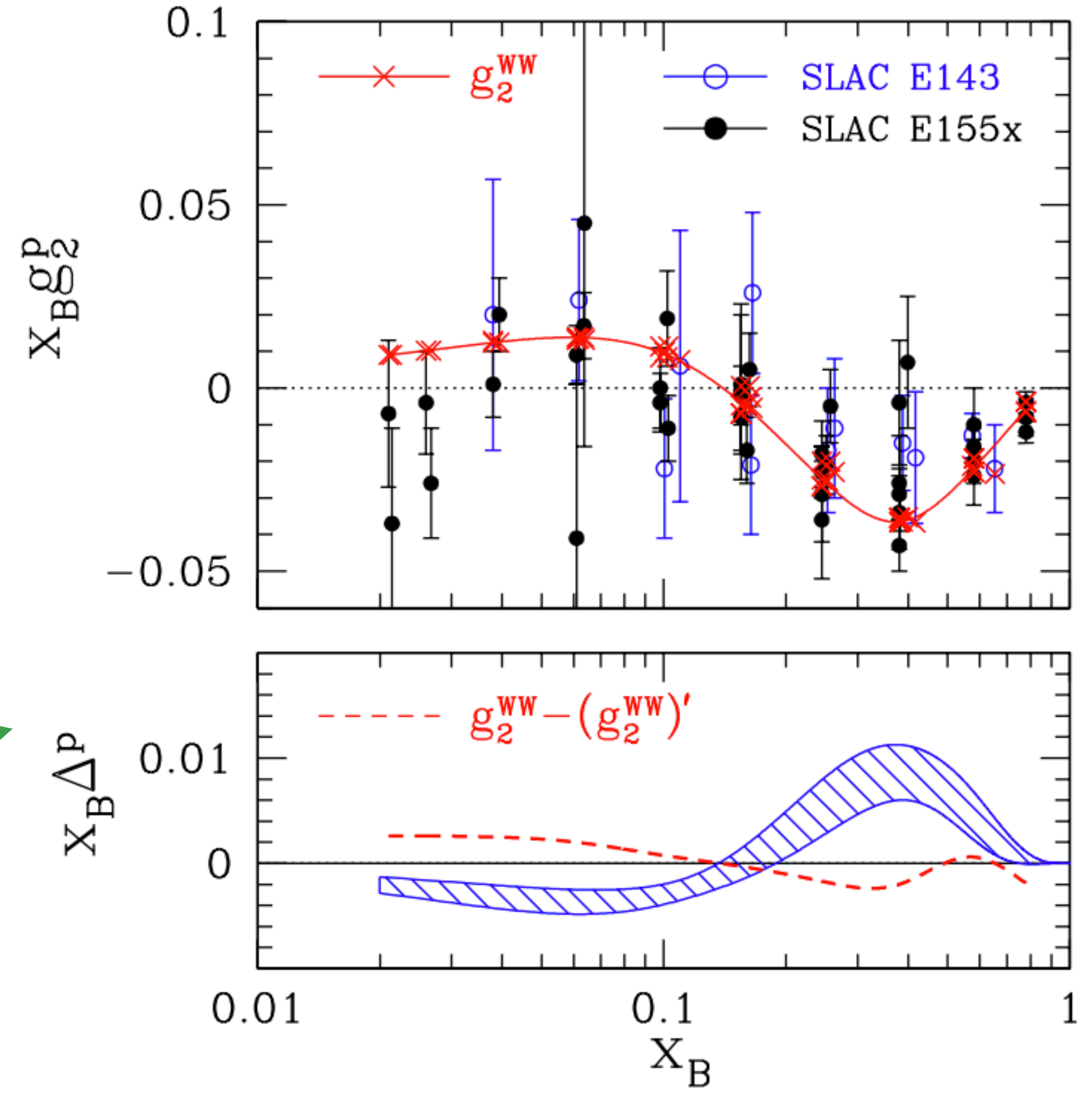
- Only twist-3 PDF accessible through inclusive DIS: g_T

[e.g.,Tangerman & Mulders, eprint/9408305]

- Experimentally accessed at SLAC E142 & E155x and JLab-Hall A E99-117 & E01-012.

- Exploratory studies suggest that quark-gluon-quark correlations are non-zero.

$$\boxed{\Delta_{\rm ex}(x_B, Q^2) = g_2^{\rm ex}(x_B, Q^2) - g_2^{\rm WW}(x_B, Q^2)}$$

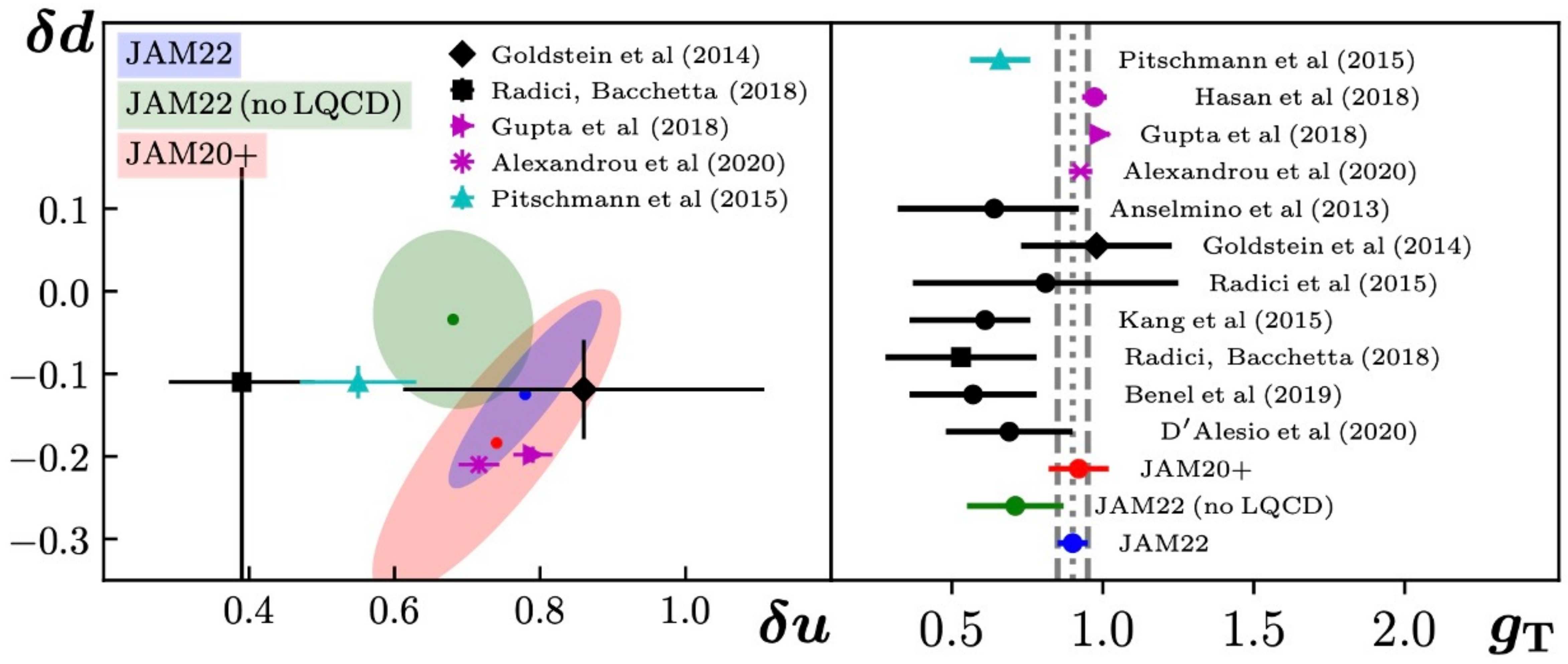


[Accardi et al, JHEP11 (2009)]

Comparison with lattice

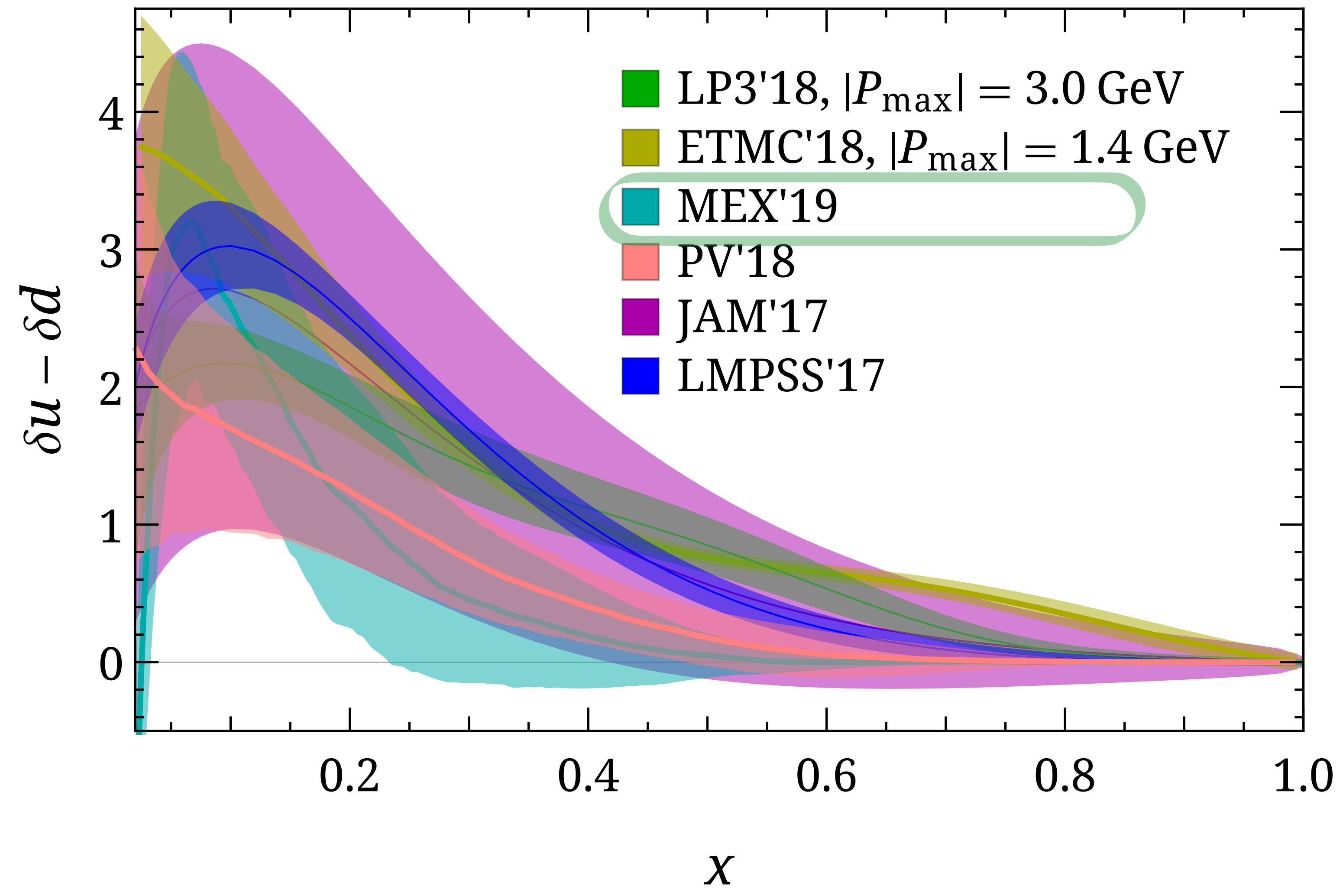
1. Tensor charge

JAM3D22



2. Quasi/Pseudo PDFs

PDFLattice [2006.08636]



It is possible to get an **agreement with lattice g_T** with more flexibility in the functional form.

δu is the most problematic and yet most determined.

Scalar PDF

Lots of interests for that function in the past years

[Schweitzer and Efremov, JHEP08006]
[Burkardt & Koike, NPB632]
[Ji, NPB960]
[Lorcé, Pasquini, Schweitzer, JHEP01 (2015)]
[Pasquini & Rodini, PLB788]
[Hatta & Zhao, PRD102]
[Bhattacharya et al., PRD102]

The composition of the scalar PDF is worked out through the EoM of QCD:

$$e^q(x) = e^q_{\mathrm{loc}}(x) + e^q_{\mathrm{gen}}(x) + e^q_{\mathrm{mass}}(x)$$

"local" term

originates from singularity

genuine qgq correlation

originates from covariant derivative

quark mass term

originates from kinetic+mass

$$\boxed{e^q_{\mathrm{loc}}(x) = \frac{1}{2M}\int \frac{d\lambda}{2\pi}\, e^{i\lambda x}\langle P|\bar{\psi}_q(0)\psi_q(0)|P\rangle = \frac{\delta(x)}{2M}\langle P|\bar{\psi}_q(0)\psi_q(0)|P\rangle}$$

<u>Only observable-related contribution to the proton mass:</u>

the singularity of e(x) is proportional to the pion-nucleon sigma term through sum rules [e.g. Kodaira & Tanaka, PTP, Vol. 101]

Proton mass decomposition

QCD mass decomposition

$$\boxed{M_P = M_m + M_a + M_q + M_g}$$

quark mass $M_m = \sum_q \sigma_q$

trace anomaly

quark and gluon energy $\propto < x >_{q,g}$

[Ji, PRL 74; Ji, PRD 52]
[Lorcé, EPJC78; Lorcé et al, 2109.11785]

Sigma terms

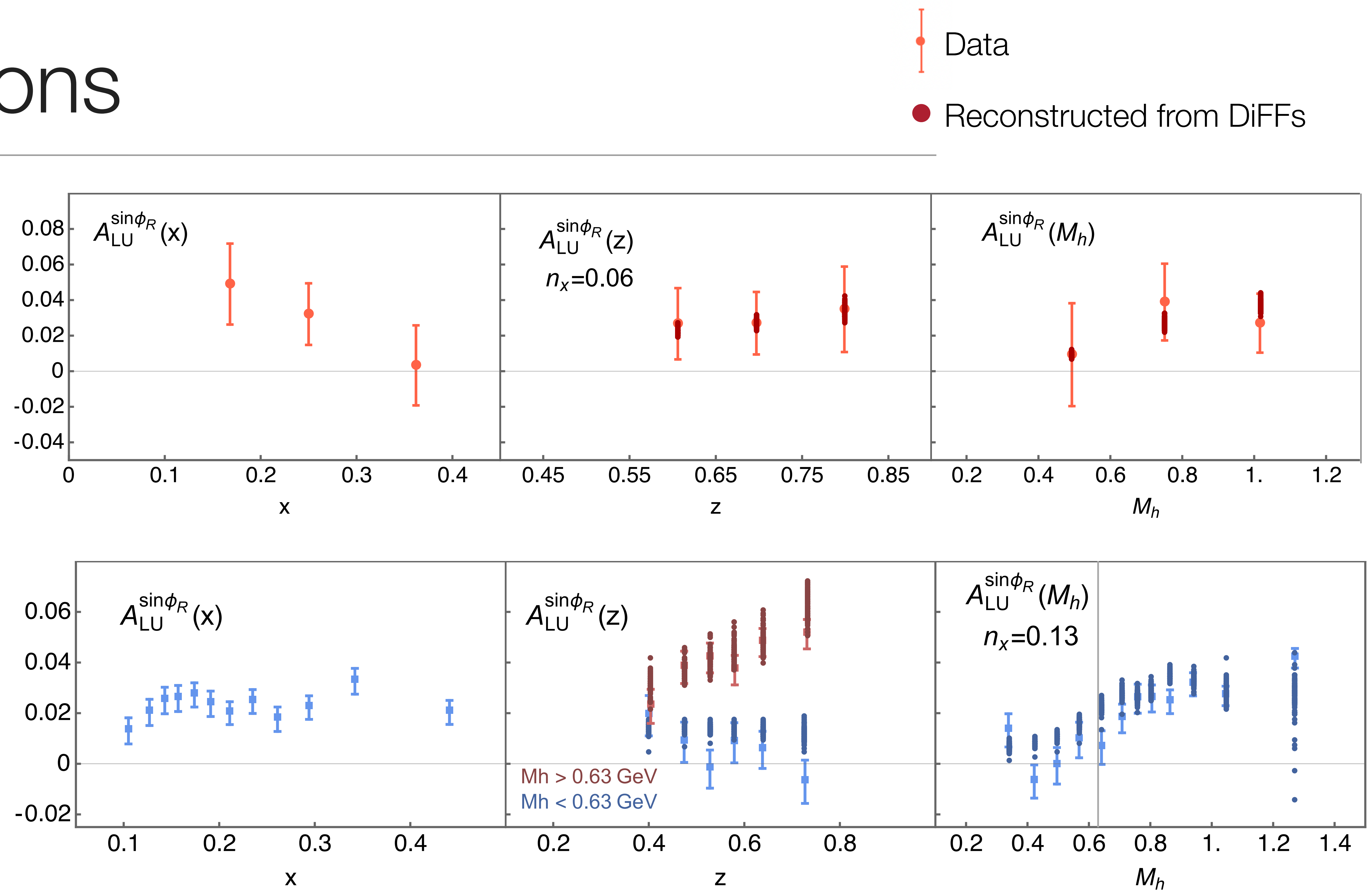
$$\langle P | m_u \bar{u}u + m_d \bar{d}d | P \rangle = \sigma_{\pi N} \quad \& \quad \langle P | m_s \bar{s}s | P \rangle = \sigma_s$$

- have been determined from theoretical analysis of πN data [Meissner et al.]
- have been evaluated on the lattice [Constantinou et al.]
- are related to the twist-3 PDF $e(x)$ via sum rules [e.g. Kodaira & Tanaka, PTP, Vol. 101]

$$\frac{\langle P | \bar{q}q | P \rangle}{2M} = \int dx e_q(x)$$

Universality of non-perturbative functions

- Dihadron fragmentation functions
  - ➡ DiFF extracted in e+e-, to be tested against SIDIS multiplicities
  - ➡ Consistency check on SIDIS (z, M_h) dependence at CLAS & CLAS12
  - ➡ Determination of the integral of $e^P(x)$ from reconstruction: n_x



- Twist-2 and -3 PDFs
  - ➡ Universality of transversity in pp and SIDIS [Radici et al, PRD94]
  - ➡ Global analysis of the transversity possible [Radici & Bacchetta, PRL120; JAM Coll., PRD102]
  - ➡ Are twist-3 PDFs universal?

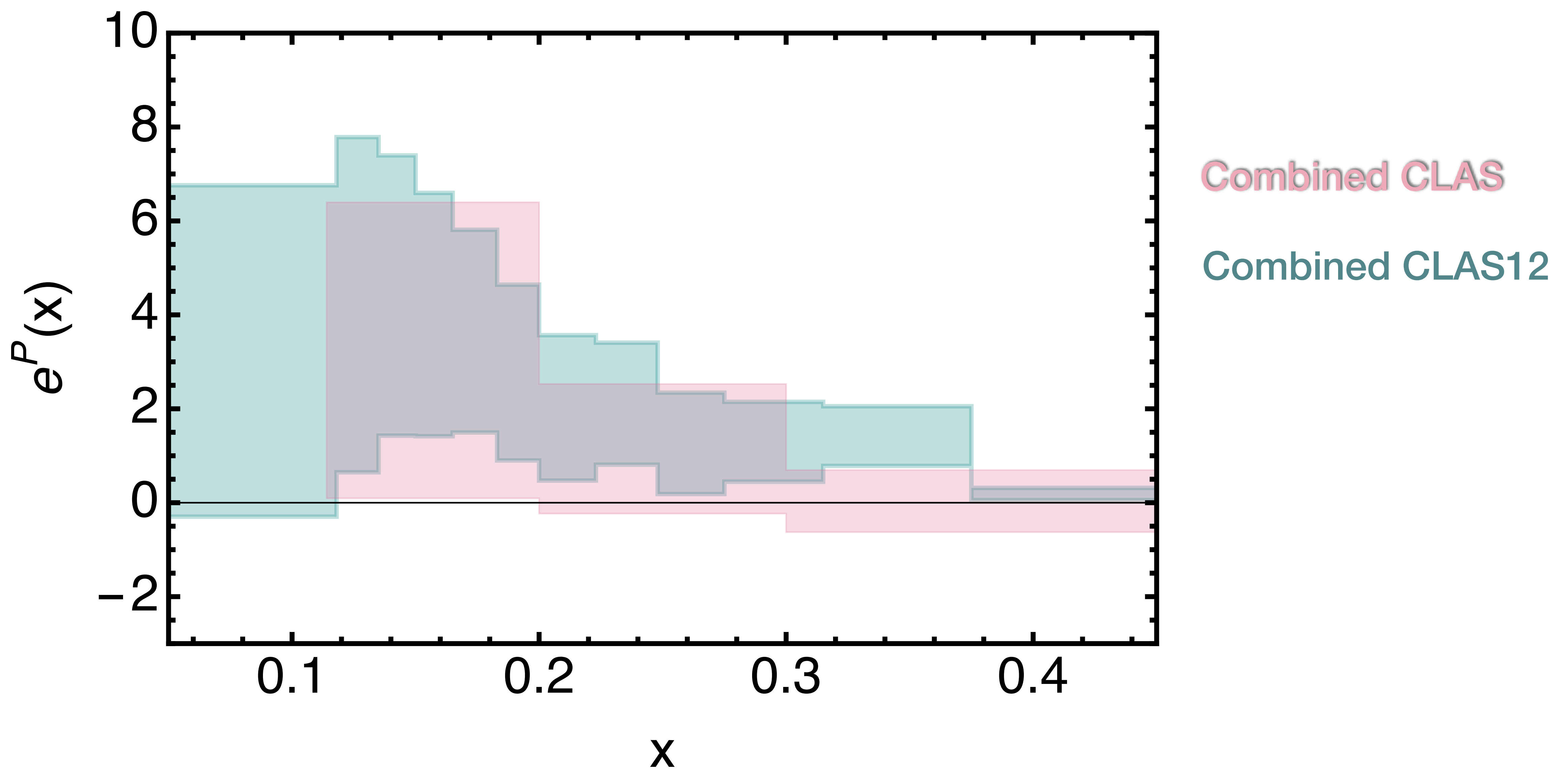
    Yet to be answered.

    Examples through TMD and dynamical twist-3 relations (e.g. Sivers and Qiu-Sterman)

Consequences of the extraction

1. Are twist-3 PDFs non-zero? Yes, to a certain CL.

2. Can we access qgq correlations and more non-perturbative information? Let's take the example of e(x).



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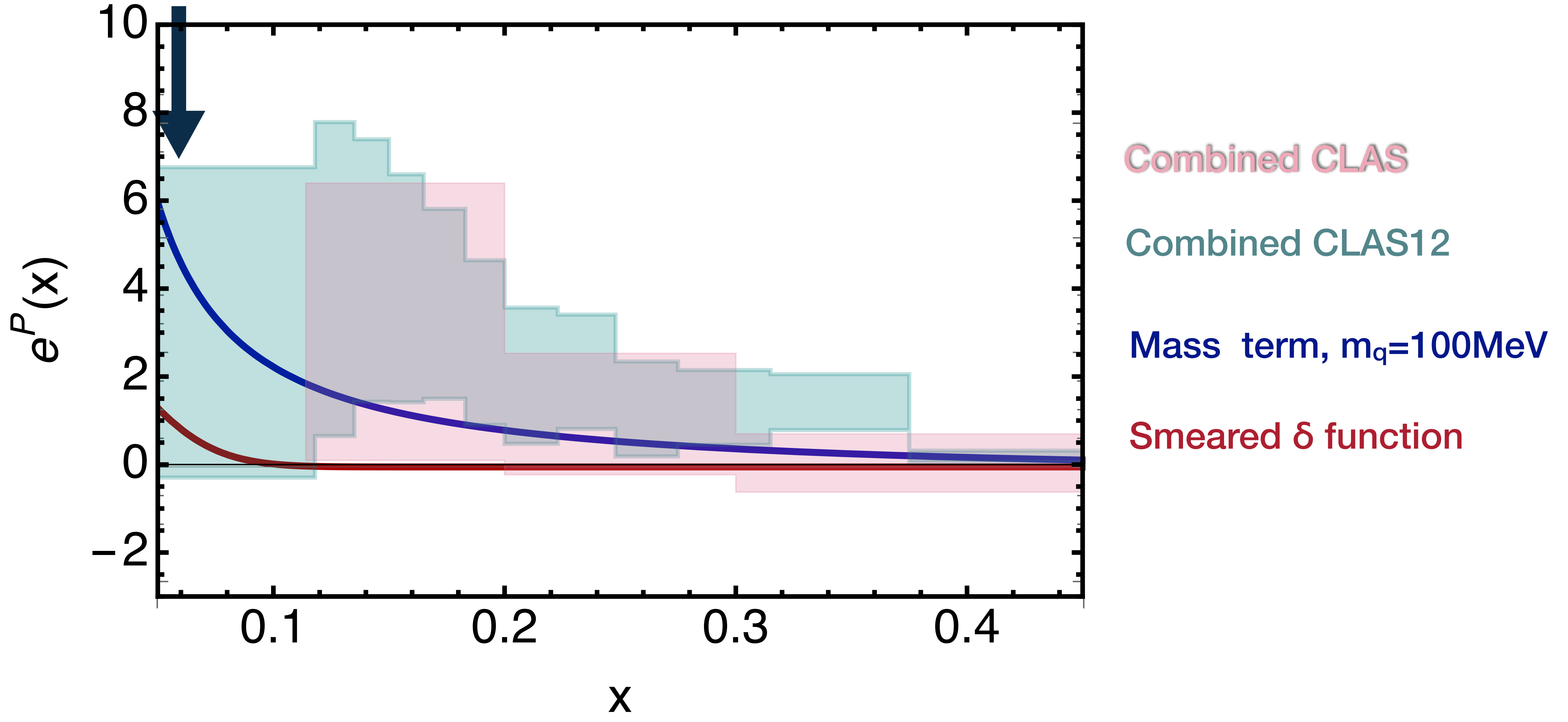
Some nonperturbative effects expected in the small(ish)-x region



<u>Schematic models for illustration purpose only!</u>

<u>Moments will matter.</u>

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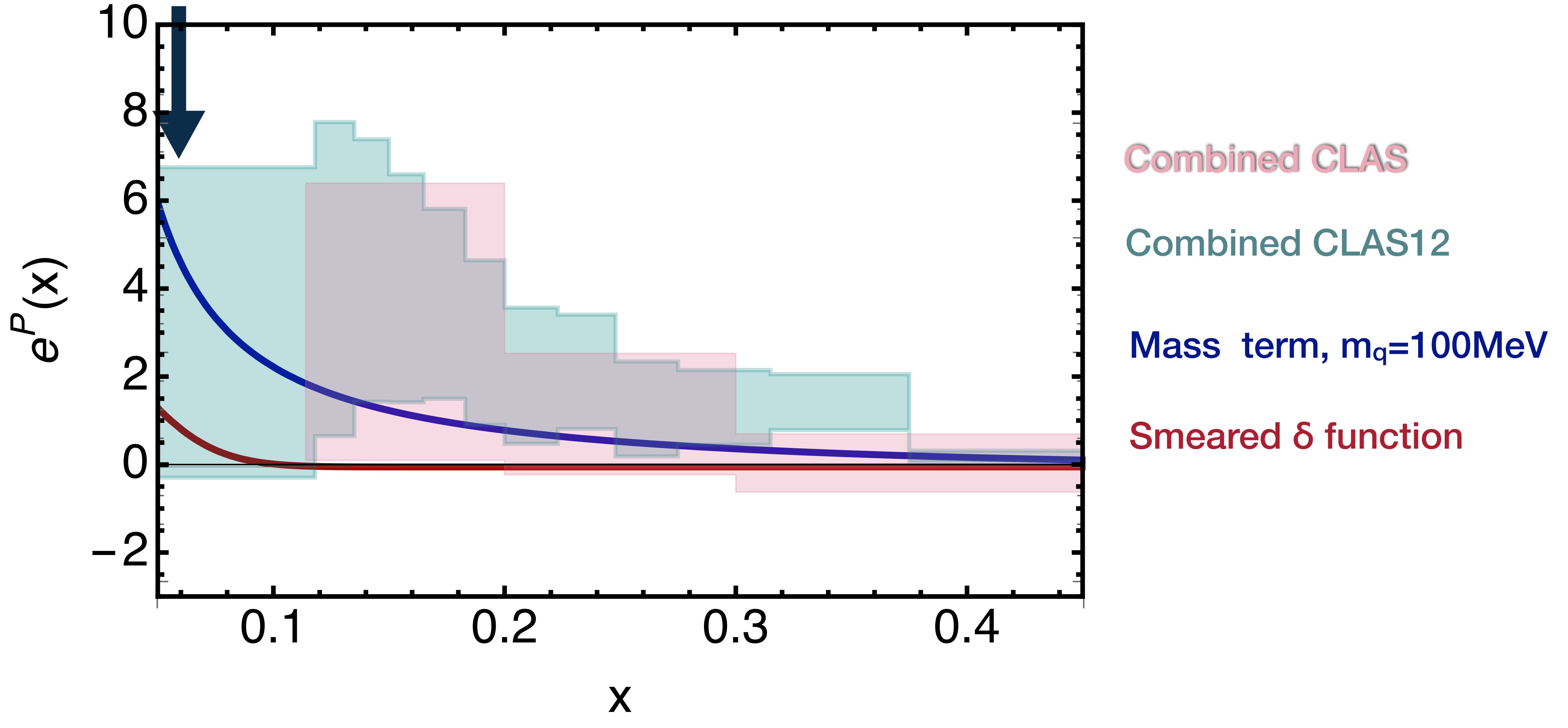
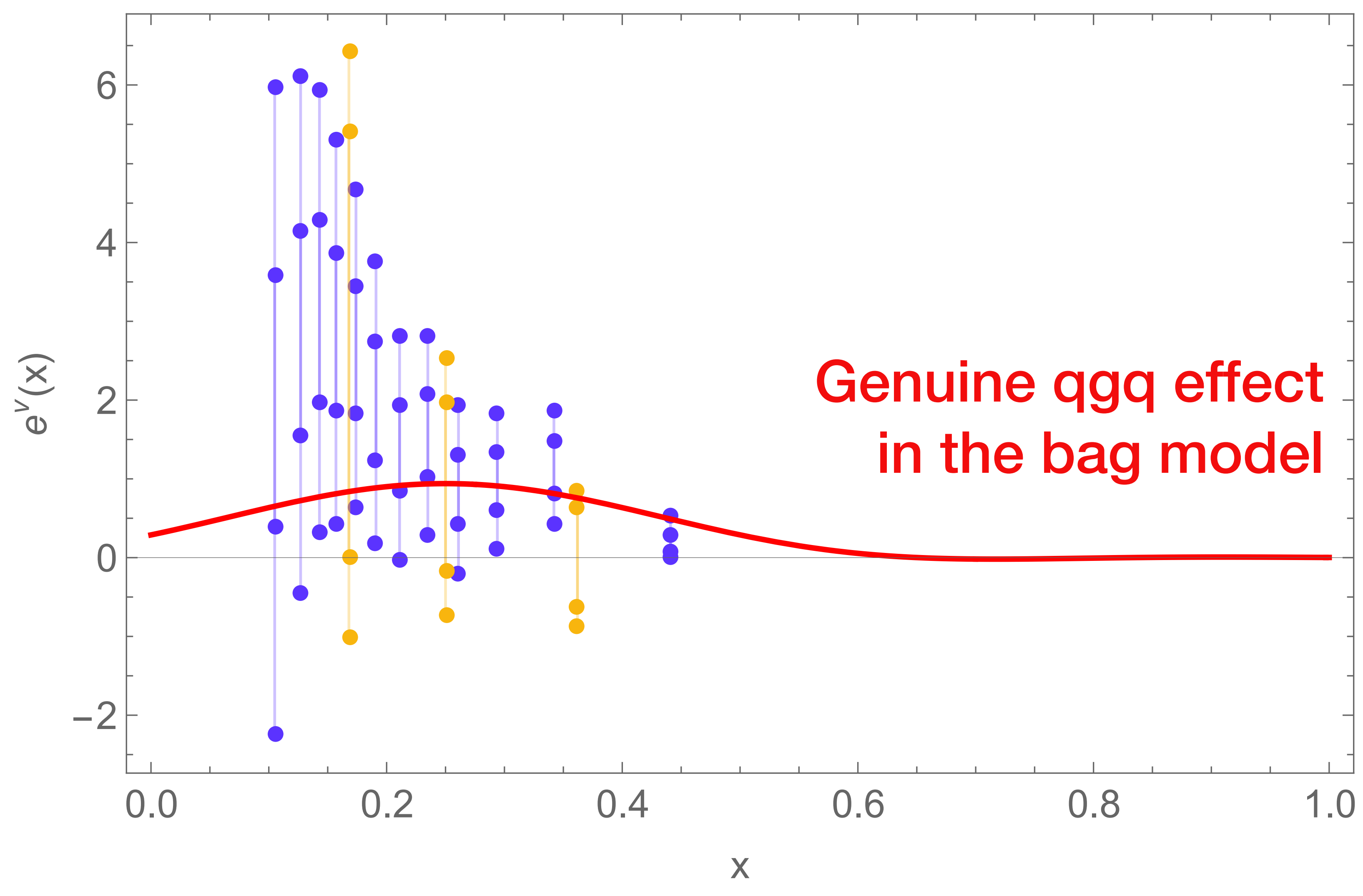


Other nonperturbative effects at not so small x



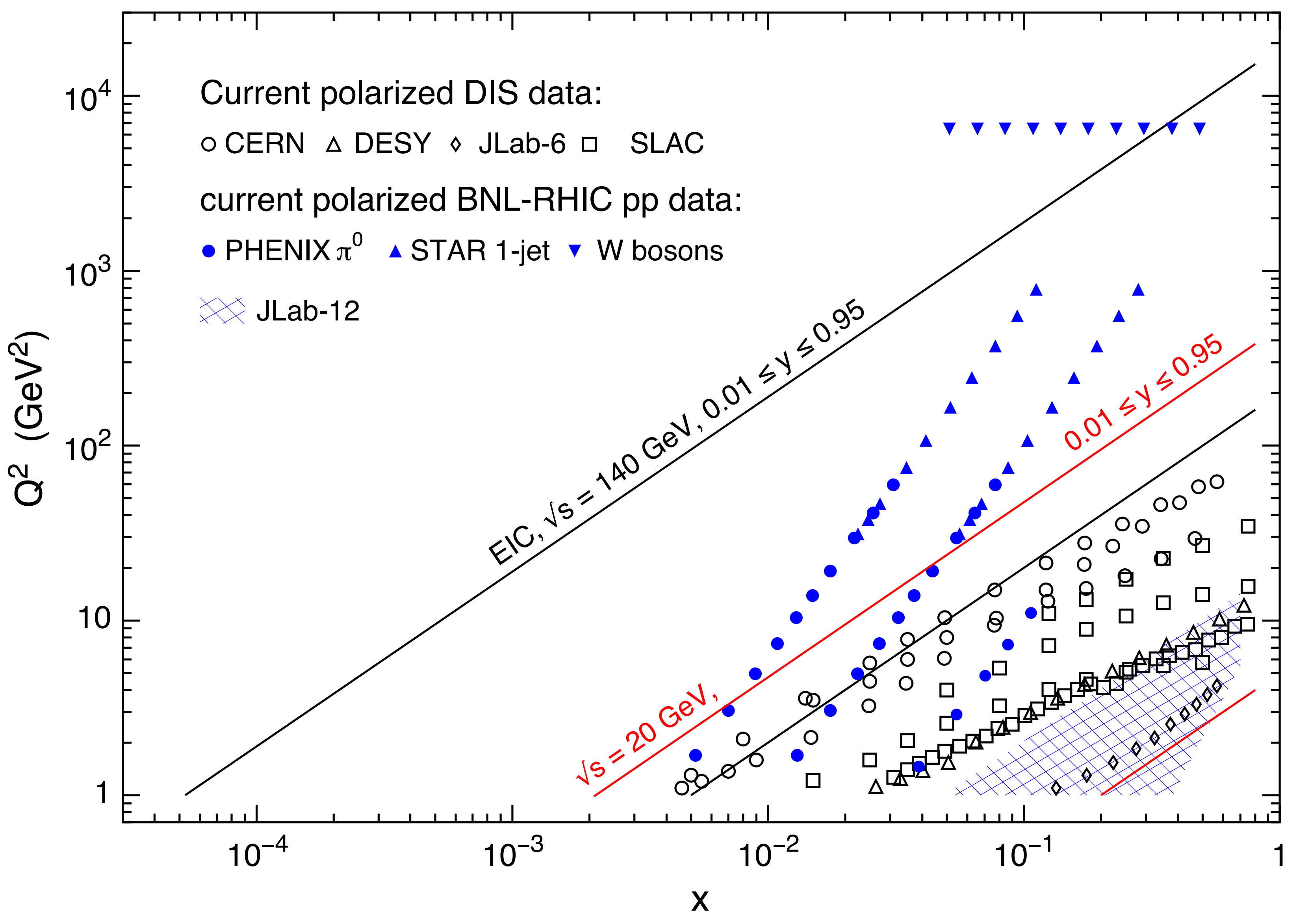
Courtesy of S. Calderón-Acosta
to be updated…

Schematic models for illustration purpose only!

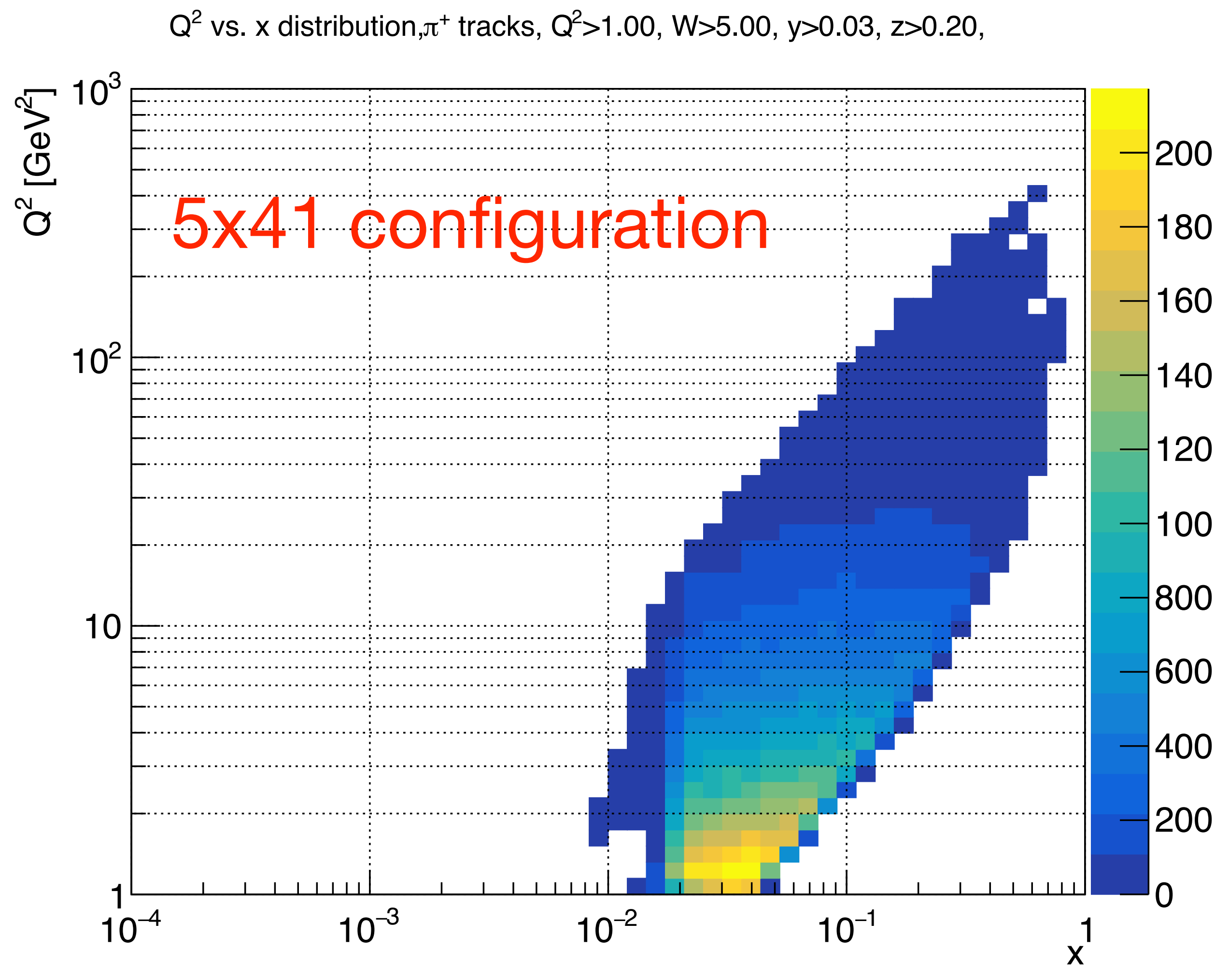
Moments will matter.

Can we study qgq correlation at the EIC?

EIC Yellow Report [2103.05419]



Projections for IR2@EIC White Paper
by A. Vossen



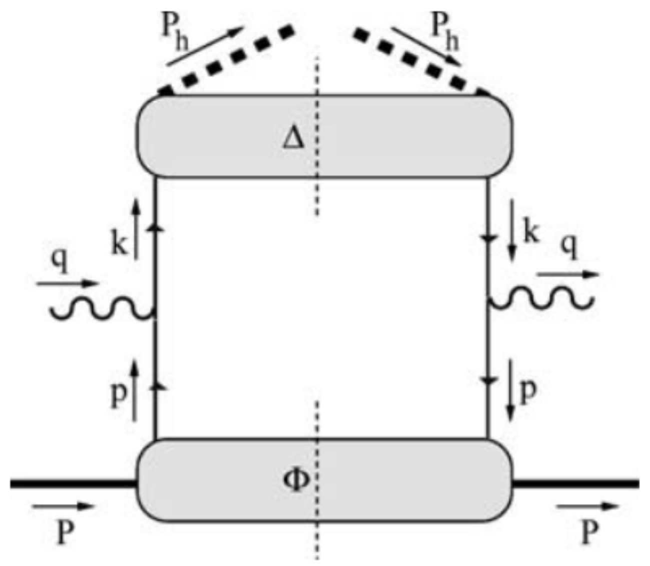
EIC will cover low- to mid-Q^2 and smallish x values

➡ Proposal for a 2nd interaction region — IR2@EIC

➡ Discuss the complementarity with present data.

Twist-3 in semi-inclusive DIS

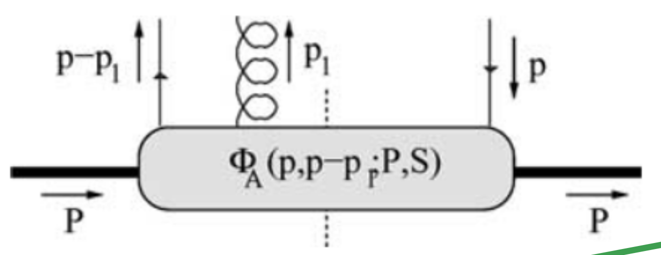
By detecting a hadronization product, more Lorentz structures become available: semi-inclusive DIS

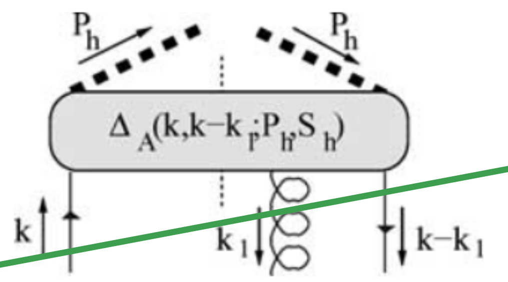


$$\Phi \propto [\text{twist-2 PDFs}] + \frac{M}{P^+}[\text{twist-3 PDFs}]$$

$$\Delta \equiv \text{fragmentation functions}$$

[Boer, Mulders & Pijlman, NPB 667]
[Bacchetta et al, JHEP02 (2007)]





$$\Phi_A \Rightarrow \int \frac{d\xi^-}{2\pi} \left[\langle PS|\bar{\psi}(0) i A(\xi)\psi(\xi)|PS\rangle\right]$$

$$\propto \text{qgq correlations}$$

- HERMES and CLAS collaborations have measured various twist-3 TMD distributions through asymmetries.
- Not all small.
- However, the distributions are very intertwined and render extraction very hypothesis-dependent.

Extraction of e(x) from CLAS data

$$A_{LU}^{\sin\phi_R}(x, z, m_{\pi\pi}) \propto \frac{M}{Q} \frac{\sum_q e_q^2 \left[x e^q(x)\, H_{1,sp}^{\sphericalangle,q}(z, m_{\pi\pi}) + \frac{m_{\pi\pi}}{zM}\, f_1^q(x)\, \tilde{G}_{sp}^{\sphericalangle,q}(z, m_{\pi\pi}) \right]}{\sum_q e_q^2\, f_1^q(x)\, D_{1,ss+pp}^q(z, m_{\pi\pi})}$$

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leading-twist DiFFs

Twist-2 Dihadron Fragmentation Functions

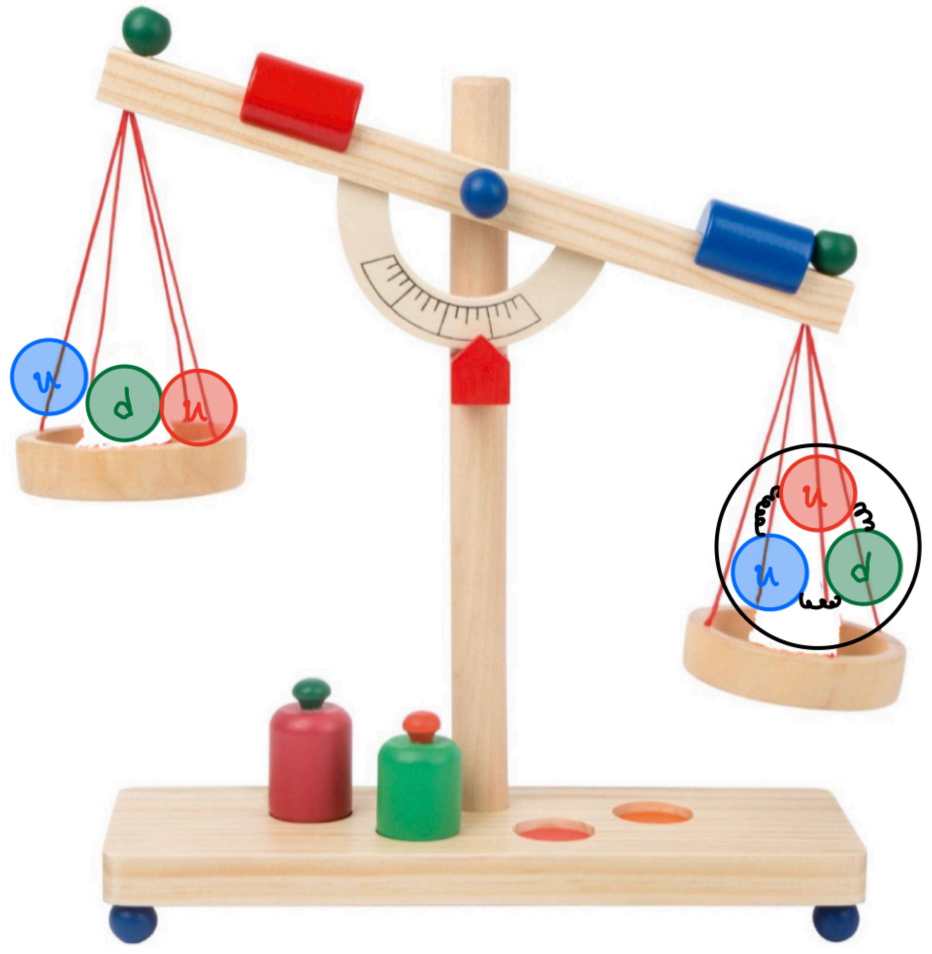
- Phenomenologically tested for the twist-2 transversity PDF [Bacchetta, AC & Radici, PRL107 and follow-ups]
- extracted in e^+e^- at Belle [A.C., Bacchetta, Radici & Bianconi, PRD85]
- we get the ratio R that is believed to be universal (portable) *up to evolution effects*

$$\boxed{R(z,M_h) = \frac{|\boldsymbol{R}|}{M_h}\,\frac{H_1^{\sphericalangle\,u}(z,M_h;Q_0^2)}{D_1^u(z,M_h;Q_0^2)}}$$

chiral-odd DiFF

unpolarized DiFF

Scalar PDF and the proton mass



QCD mass decomposition

$$\boxed{M_P = M_m + M_a + M_q + M_g}$$

quark mass $M_m = \sum_q \sigma_q$

trace anomaly

quark and gluon energy $\propto < x >_{q,g}$

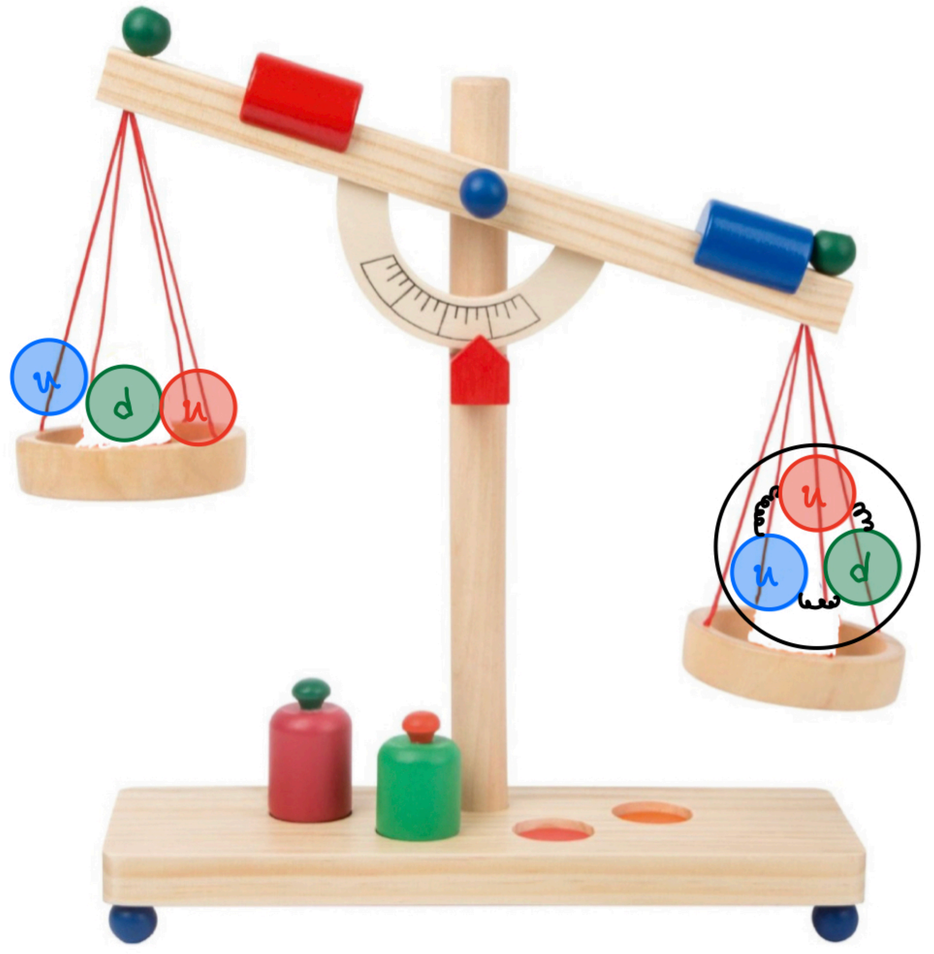
[Ji, PRL 74; Ji, PRD 52]
[Lorcé, EPJC78; Lorcé et al, 2109.11785]

Sigma terms

$$\langle P | m_u \bar{u} u + m_d \bar{d} d | P \rangle = \sigma_{\pi N}$$

- have been determined from theoretical analysis of πN data [Meissner et al.]
- have been evaluated on the lattice [Constantinou et al.]
- pheno analysis of $e(x)$ could pave the way towards another possible determination

Scalar PDF and the proton mass



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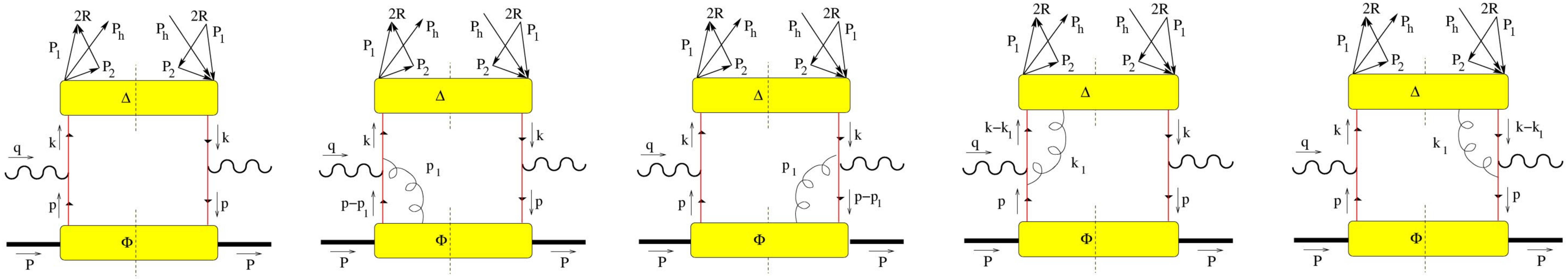
- can be accessed through single-hadron SIDIS
  —see talk by Timothy Hayward
  & [Efremov et al, PRD67]
- can be accessed through dihadron SIDIS
  this talk

Twist-3 in SIDIS dihadron production

[Bacchetta & Radici, PRD69]



- modulations of spin asymmetries single out:

$$\frac{\left[\text{twist-3 PDF} \times \text{twist-2 FF}\right] + \left[\text{twist-2 PDF} \times \text{twist-3 FF}\right]}{\text{unpolarized}}$$

- Scalar PDF from the beam spin asymmetry

$$A_{LU}^{\sin\phi_R}(x, z, m_{\pi\pi}) \propto \frac{M}{Q} \frac{\sum_q e_q^2 \left[x e^q(x)\, H_{1,sp}^{\sphericalangle,q}(z, m_{\pi\pi}) + \frac{m_{\pi\pi}}{zM}\, f_1^q(x)\, \tilde{G}_{sp}^{\sphericalangle,q}(z, m_{\pi\pi}) \right]}{\sum_q e_q^2\, f_1^q(x)\, D_{1,ss+pp}^q(z, m_{\pi\pi})}$$

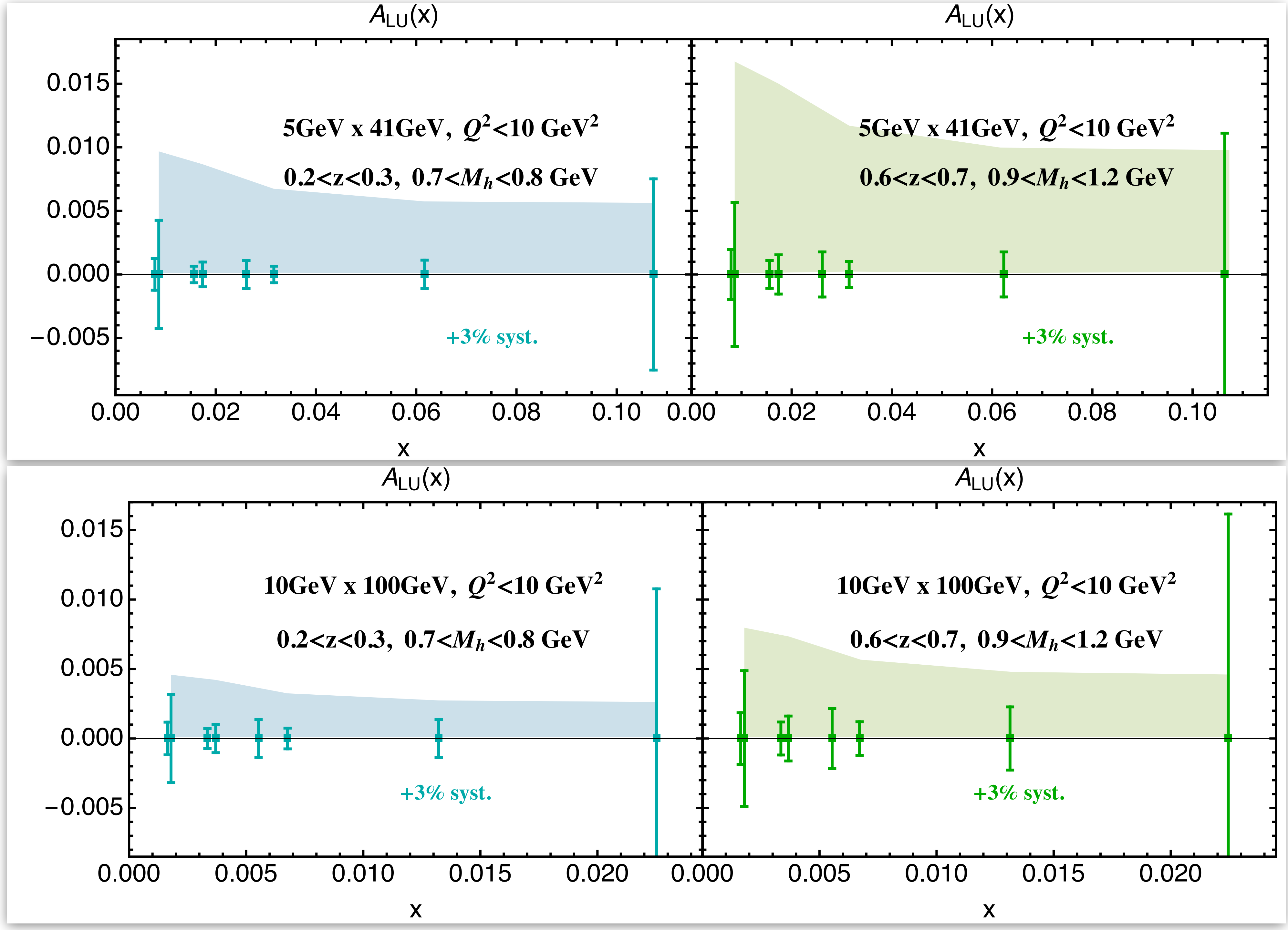
EIC coverage

EIC Yellow Report [2103.05419]

- EIC error projections (from transversity studies)
- Proton target shown, but need for neutron
- Models × DiFFs predictions
  - LC model [Pasquini & Rodini, PLB 788]
  - made-up mass-term contribution with m_q=300MeV
- Non-negligible for lowest beam configurations

↓

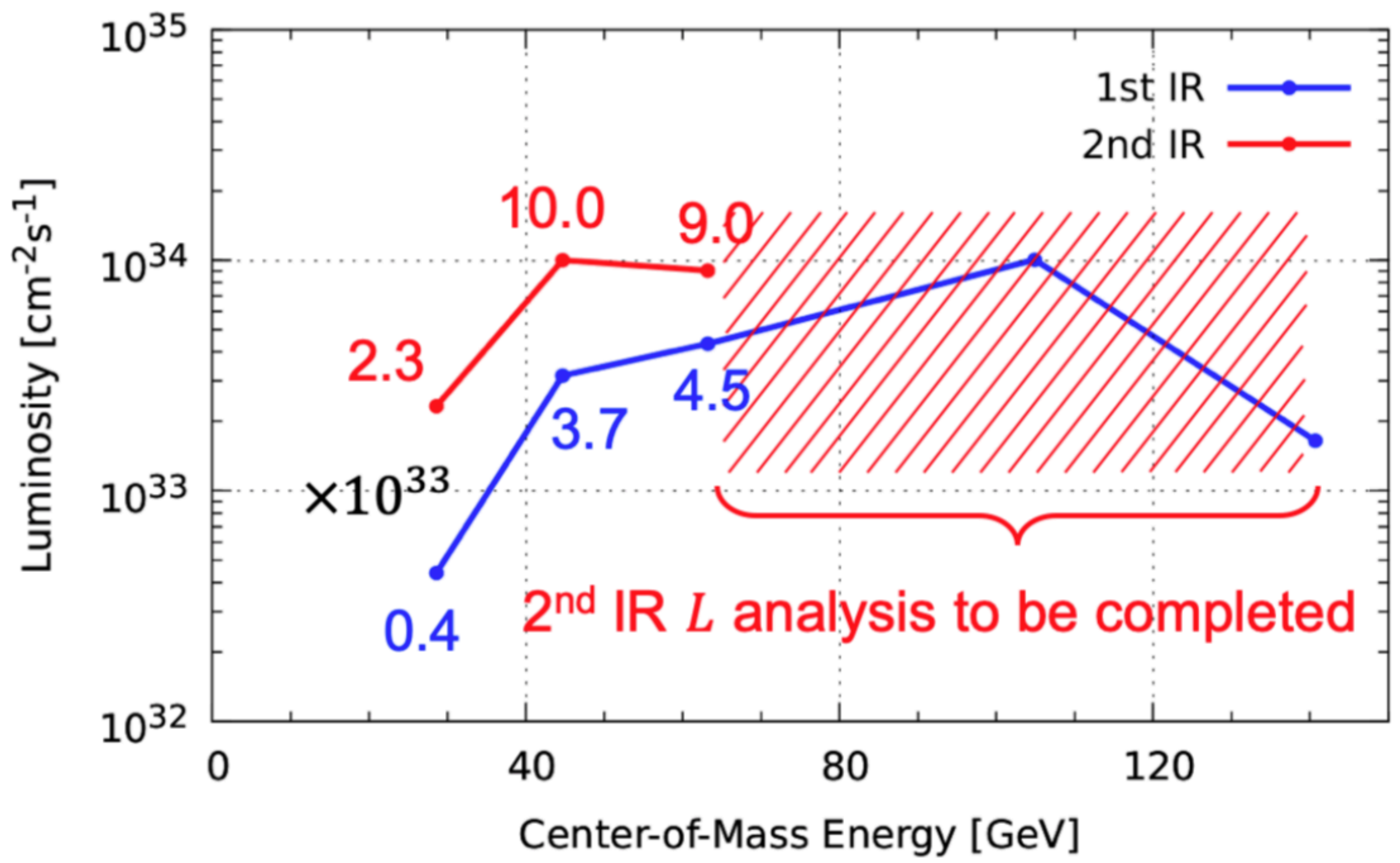
Archetype of observables for IR2@EIC

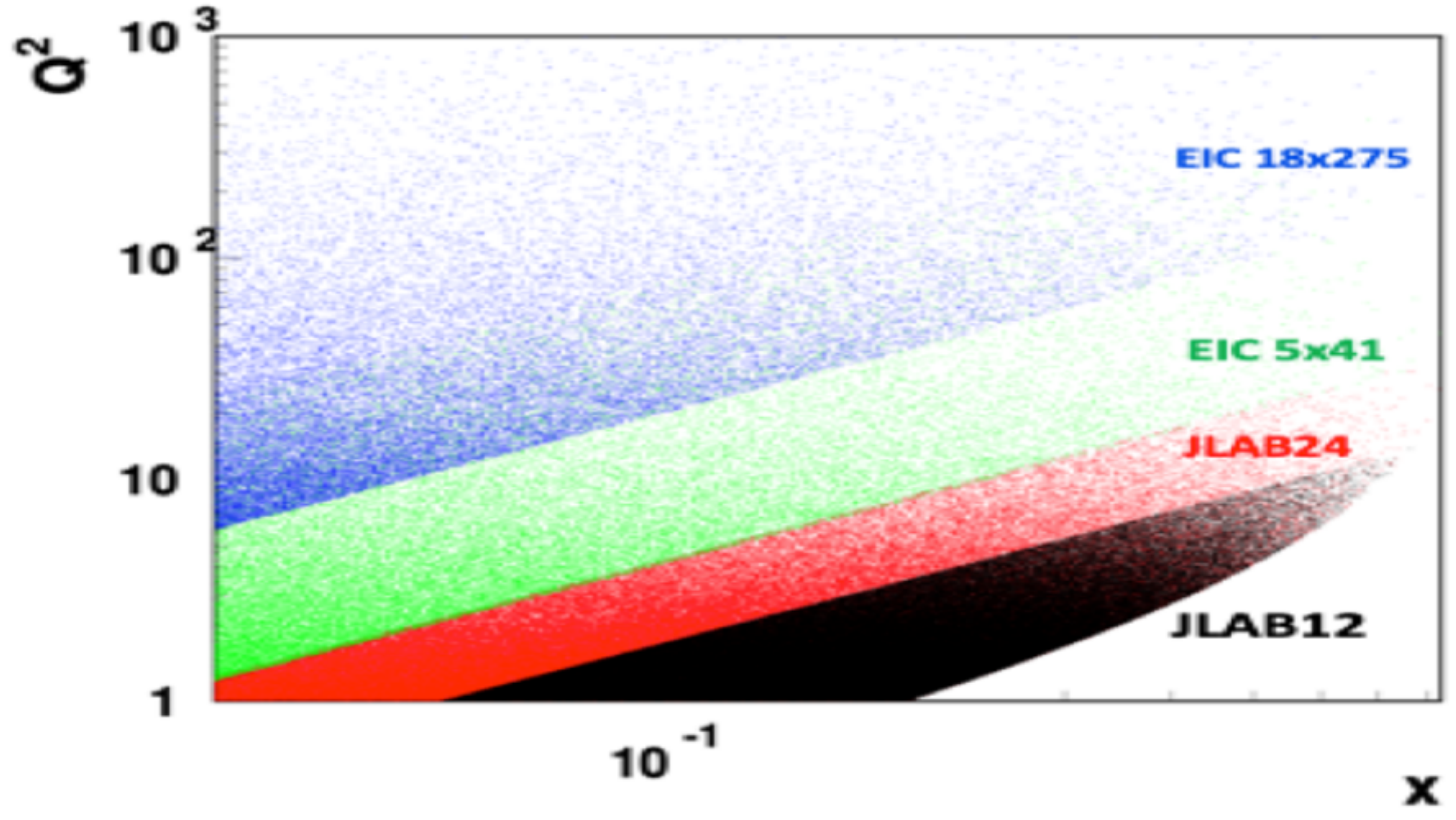


QCD and twist-3 PDFs

Underlying and omitted in all this presentation: Q^2-evolution!

from H. Avakian
& White Paper for IR2@EIC.





- Evolution equations for genuine qgq twist-3 known in most cases;
- Understanding of the various contributions to twist-3 PDFs;
- Especially “hot” for TMD studies.
- Require a second interaction region @EIC.