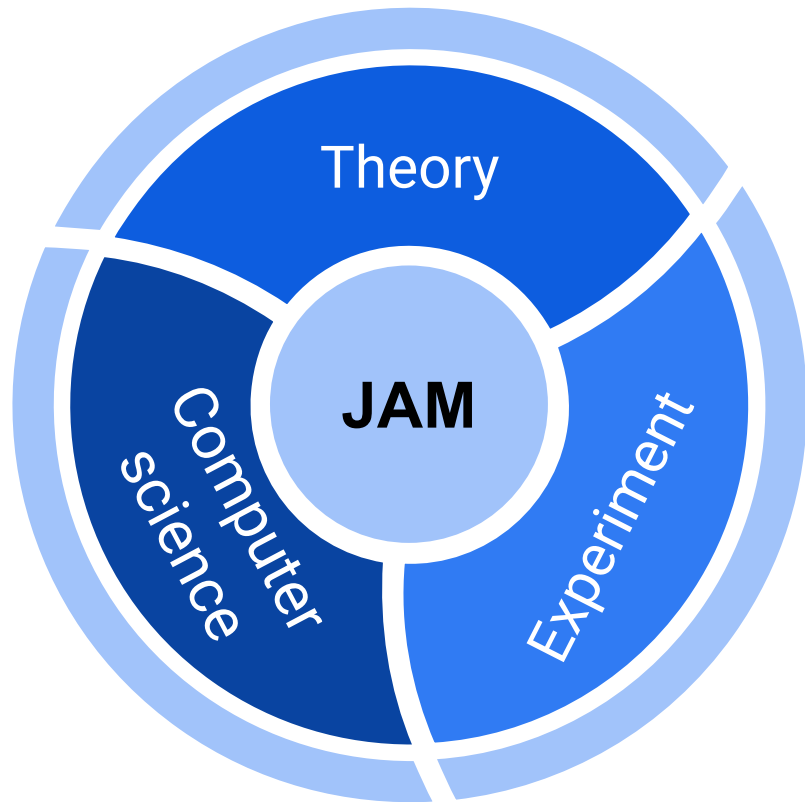


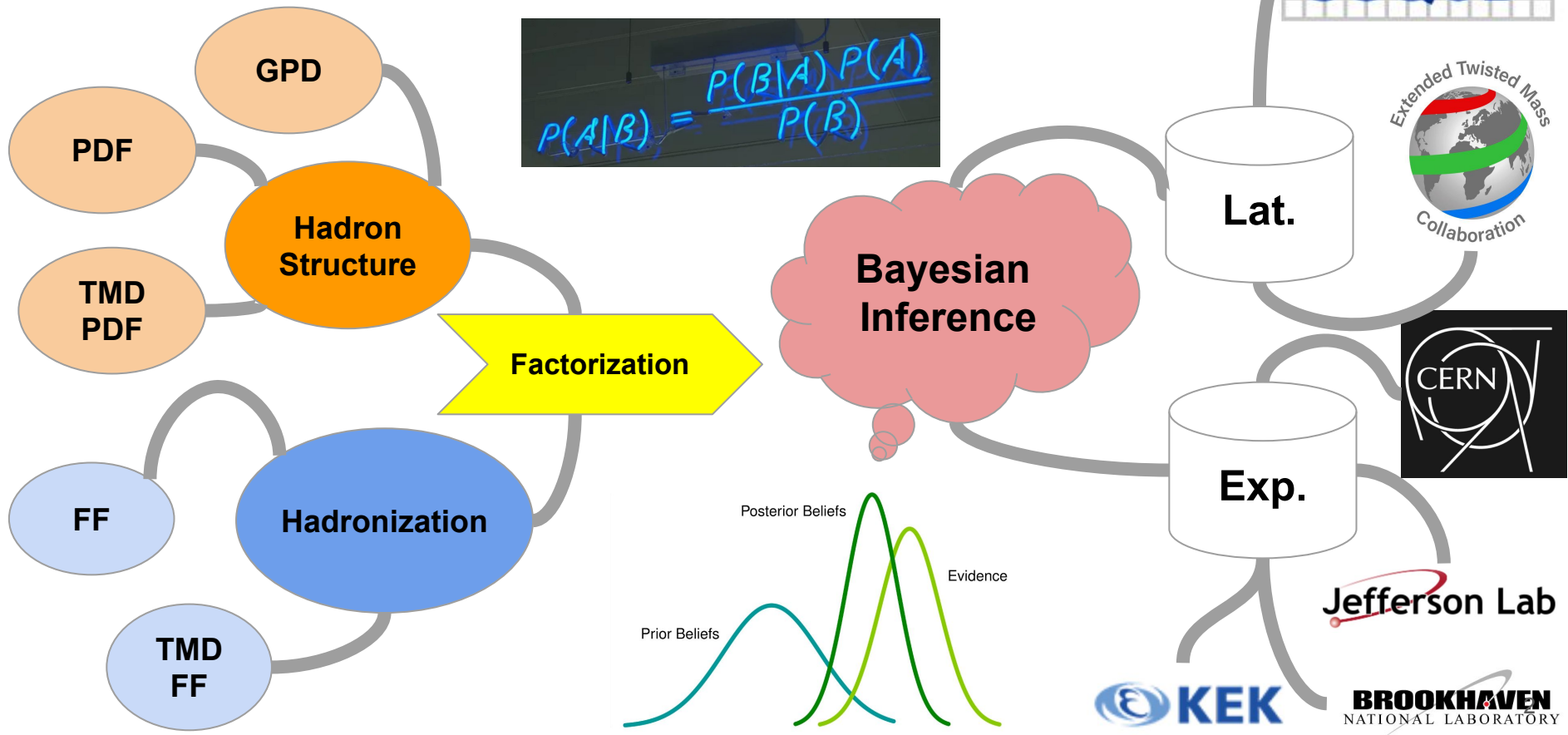
Recent updates from **JAM** collaboration

Nobuo Sato

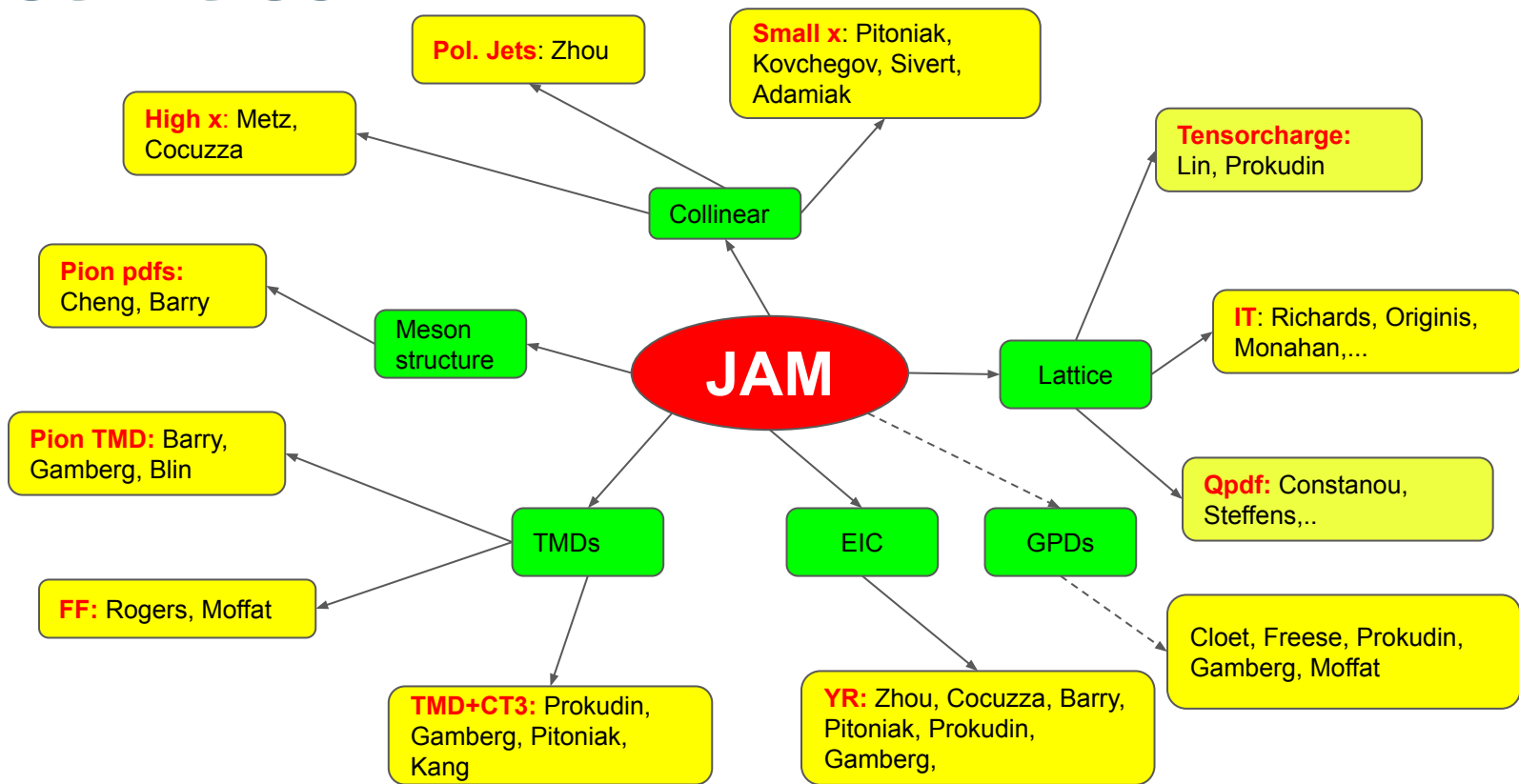


QCD Evolution 10-14 May 2021

Simultaneous paradigm



Activities



Newsstand 20-21

Revisiting quark and gluon polarization in the proton at the EIC

Y. Zhou (William-Mary Coll.), C. Cocuzza (Temple U.), F. Delcarro (Jefferson Lab), W. Melnitchouk (Jefferson Lab), A. Metz (Temple U.) et al. (May 10, 2021)

e-Print: [2105.04434](#) [hep-ph]

Isvector EMC effect from global QCD analysis with MARATHON data

C. Cocuzza (Temple U.), C.E. Keppel (Jefferson Lab), H. Liu (Massachusetts U., Amherst), W. Melnitchouk (Jefferson Lab), A. Metz (Temple U.) et al. (Apr 14, 2021)

e-Print: [2104.06946](#) [hep-ph]

Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report

R. Abdul Khalek (Vrije U., Amsterdam and Nikhef, Amsterdam), A. Accardi (Hampton U. and Jefferson Lab), J. Adam (Brookhaven), D. Adamiak (Ohio State U.), W. Akers (Jefferson Lab) et al. (Mar 8, 2021)

e-Print: [2103.05419](#) [physics.ins-det]

Towards the 3-dimensional parton structure of the pion: integrating transverse momentum data into global QCD analysis

N.Y. Cao (Harvard U.), P.C. Barry (North Carolina State U. and Jefferson Lab), N. Sato (Jefferson Lab), W. Melnitchouk (Jefferson Lab) (Mar 2, 2021)

e-Print: [2103.02159](#) [hep-ph]

Electron-Ion Collider impact study on the tensor charge of the nucleon

#7

Leonard Gamberg (Penn State U., Berks-Lehigh Valley), Zhong-Bo Kang (UCLA), Daniel Pitonyak (Lebanon Valley Coll.), Alexei Prokudin (Jefferson Lab), Nobuo Sato (Jefferson Lab) et al. (Jan 15, 2021)

Published in: *Phys.Lett.B* 816 (2021) 136255 • e-Print: [2101.06200](#) [hep-ph]

First analysis of world polarized DIS data with small- x helicity evolution

#6

Daniel Adamiak (Ohio State U., Columbus (main)), Yuri V. Kovchegov (Ohio State U., Columbus (main)), W. Melnitchouk (Jefferson Lab), Daniel Pitonyak (Lebanon Valley Coll.), Nobuo Sato (Jefferson Lab) et al. (Feb 11, 2021)

e-Print: [2102.06159](#) [hep-ph]

Simultaneous Monte Carlo analysis of parton densities and fragmentation functions

#8

Eric Moffat (Old Dominion U.), Wally Melnitchouk (Jefferson Lab), Ted Rogers (Jefferson Lab and Old Dominion U.), Nobuo Sato (Jefferson Lab) (Jan 12, 2021)

e-Print: [2101.04664](#) [hep-ph]

Confronting lattice parton distributions with global QCD analysis

#10

J. Bringewatt (Maryland U., College Park), N. Sato (Jefferson Lab), W. Melnitchouk (Jefferson Lab), Jian-Wei Qiu (Jefferson Lab), F. Steffens (Bonn U.) et al. (Oct 1, 2020)

Published in: *Phys.Rev.D* 103 (2021) 1, 016003 • e-Print: [2010.00548](#) [hep-ph]

Origin of single transverse-spin asymmetries in high-energy collisions

Jefferson Lab Angular Momentum Collaboration • Justin Cammarota (Coll. William and Mary and Lebanon Valley Coll.) et al. (Feb 19, 2020)

Published in: *Phys.Rev.D* 102 (2020) 5, 054002 • e-Print: [2002.08384](#) [hep-ph]

Simultaneous Monte Carlo analysis of parton densities and fragmentation functions

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[Eric Moffat](#) (Old Dominion U.), [Wally Melnitchouk](#) (Jefferson Lab), [Ted Rogers](#) (Jefferson Lab and Old Dominion U.), [Nobuo Sato](#) (Jefferson Lab) (Jan 12, 2021)

e-Print: [2101.04664](#) [hep-ph]

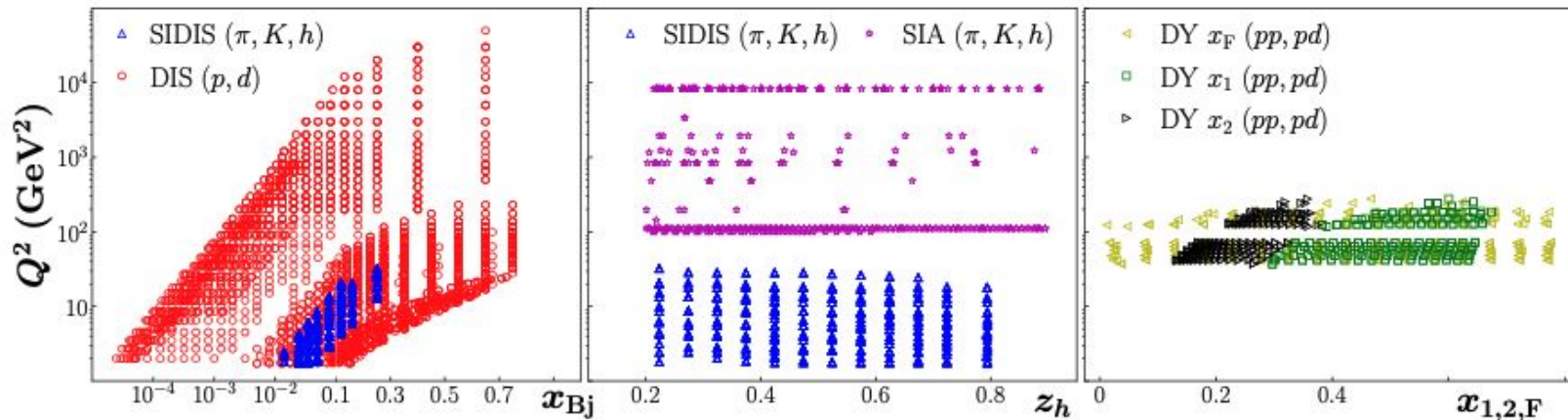
$$\frac{d\sigma_{\text{DIS}}}{dQ^2 dx_{\text{Bj}}} = \sum_{i \in \text{flavors}} \mathcal{H}_i^{\text{DIS}} \otimes f_i,$$

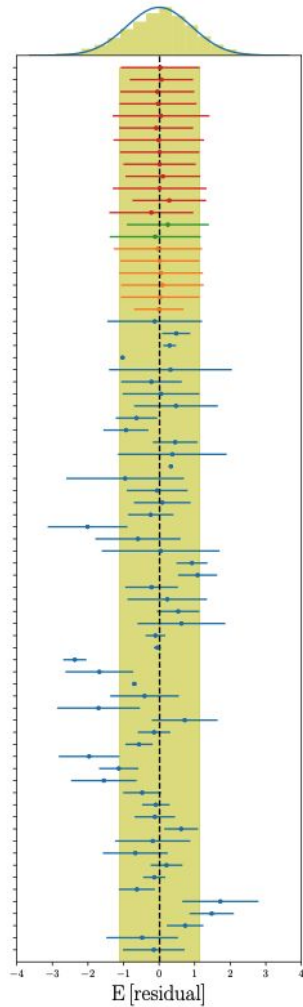
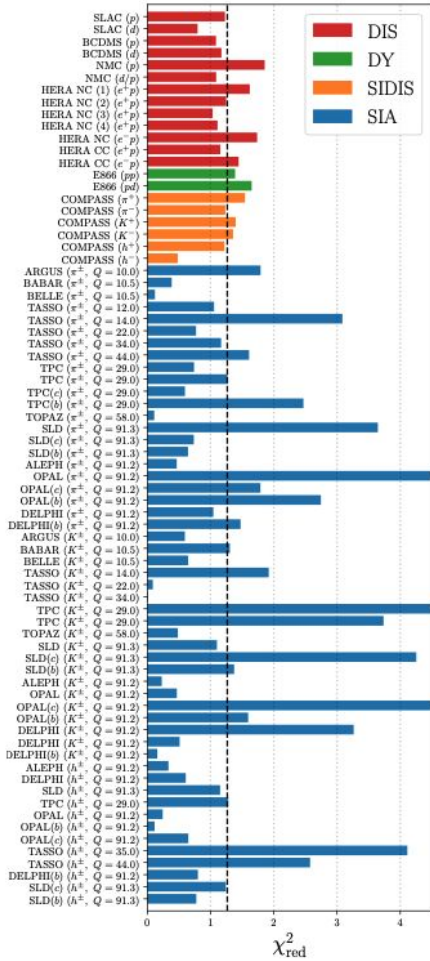
$$\frac{d\sigma_{\text{SIDIS}}}{dQ^2 dx_{\text{Bj}} dz_h} = \sum_{ij \in \text{flavors}} \mathcal{H}_{ij}^{\text{SIDIS}} \otimes f_i \otimes D_j^h,$$

$$\frac{d\sigma_{\text{DY}}}{dQ^2 dx_{\text{F}}} = \sum_{ij \in \text{flavors}} \mathcal{H}_{ij}^{\text{DY}} \otimes f_i \otimes f_j,$$

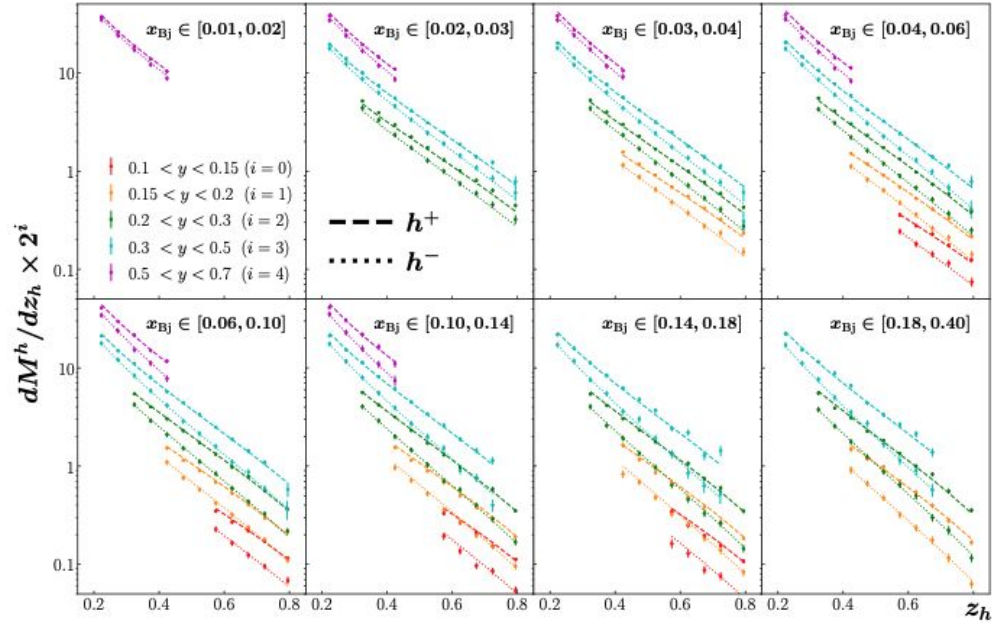
$$\frac{d\sigma_{\text{SIA}}}{dQ^2 dz_h} = \sum_{j \in \text{flavors}} \mathcal{H}_j^{\text{SIA}} \otimes D_j^h,$$

- Inclusion of unidentified charge hadron COMPASS data (pT integrate)
- Important for upol TMD analysis
- More flexible parametrization relative to previous analysis

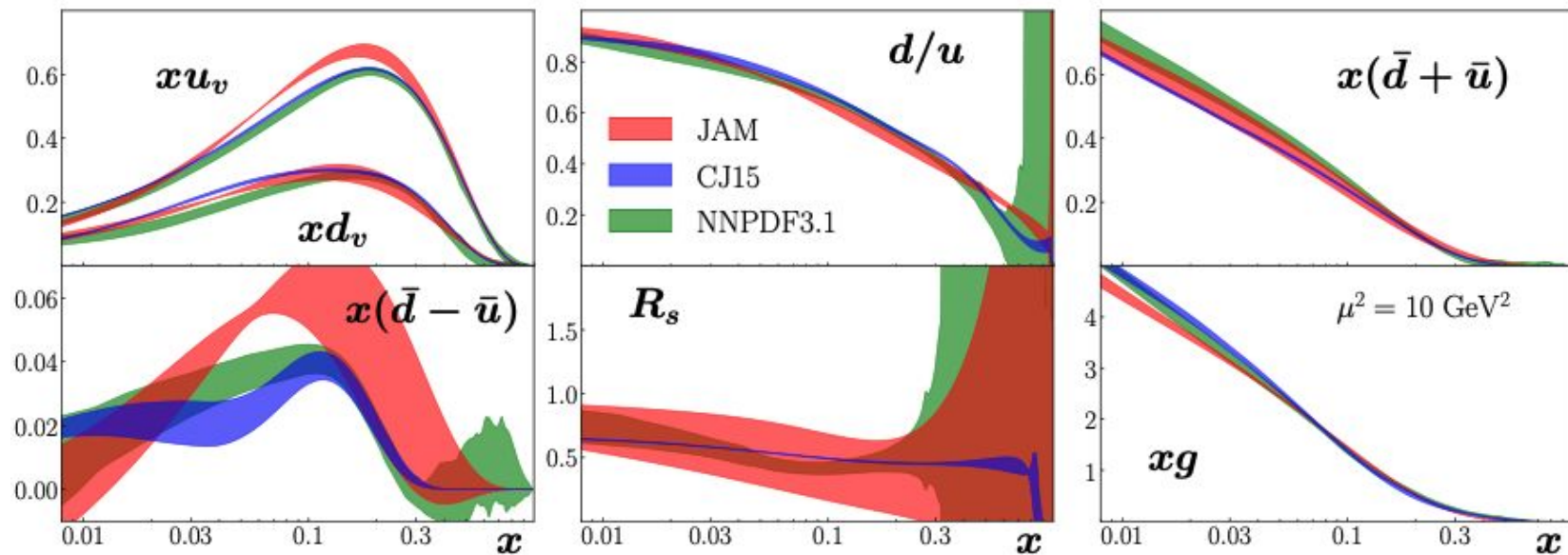
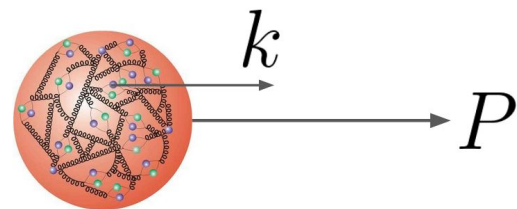




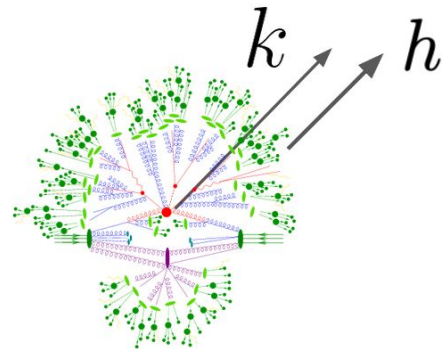
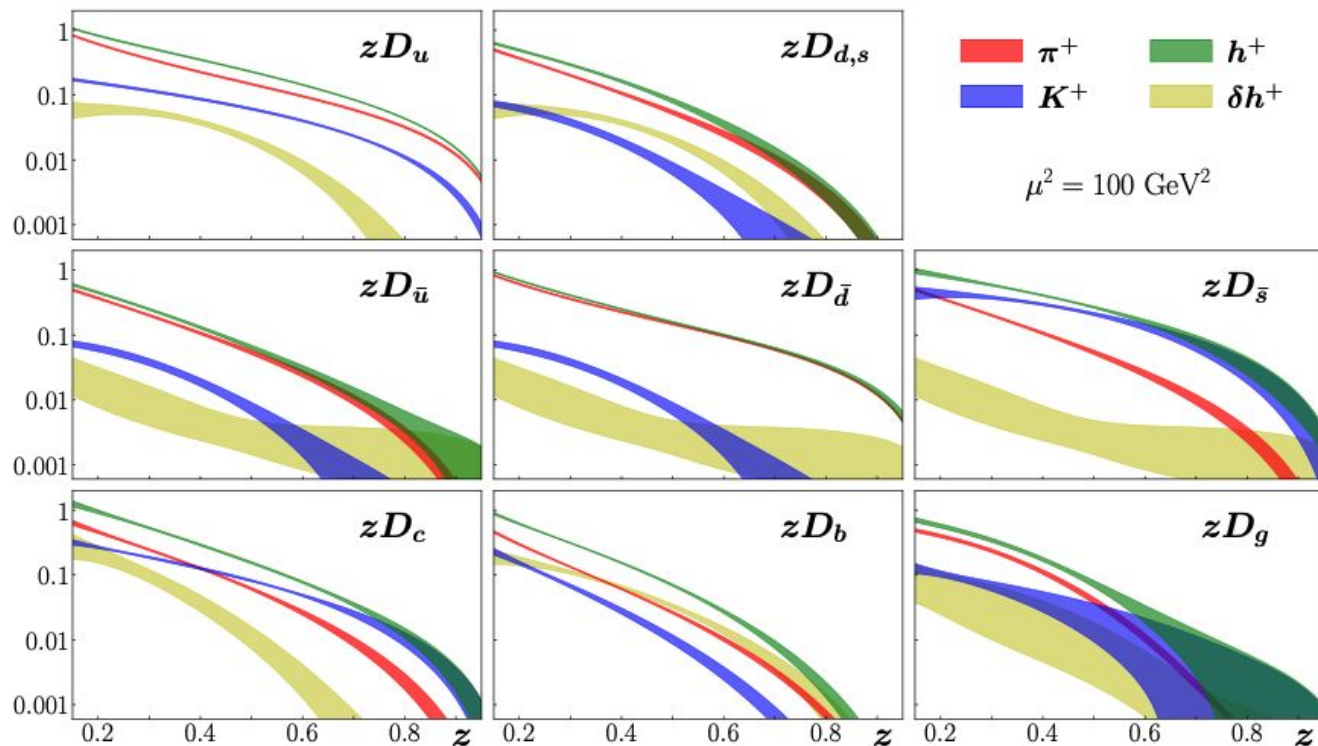
SIDIS multiplicities



Unpol. PDFs

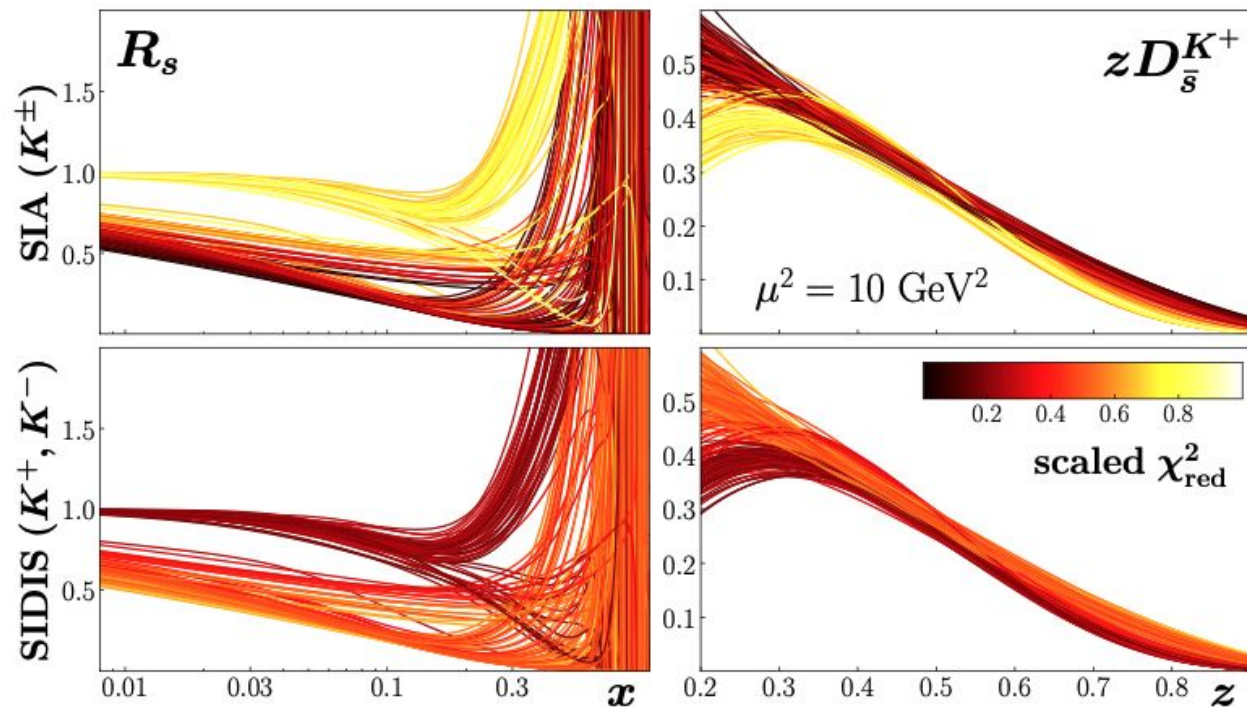


Fragmentation Functions



All hadron flavors of FFs fitted simultaneously

A less strange nucleon



$$R_s = \frac{s + \bar{s}}{\bar{u} + \bar{d}}$$

The simultaneous fit of PDFs and FFs provides new insights on nucleon strangeness

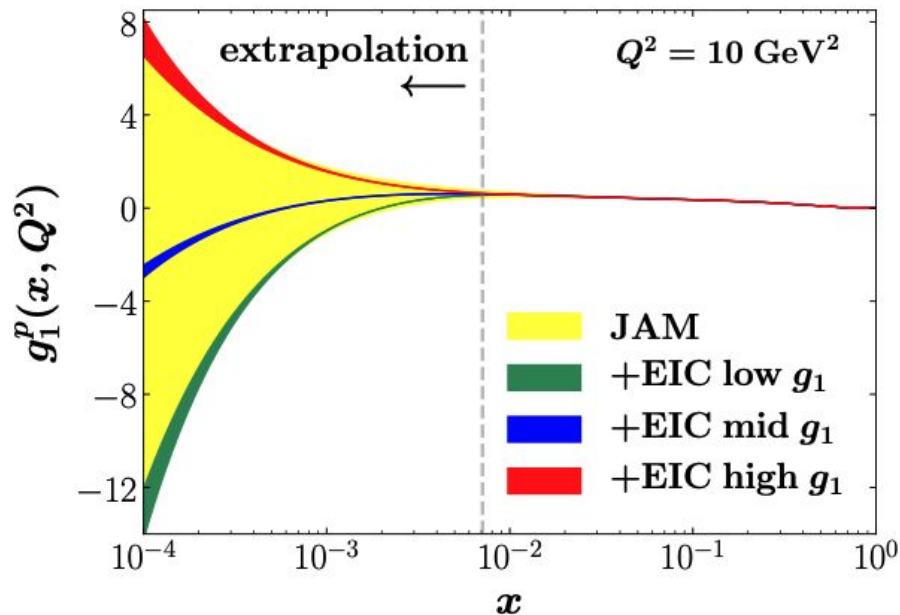
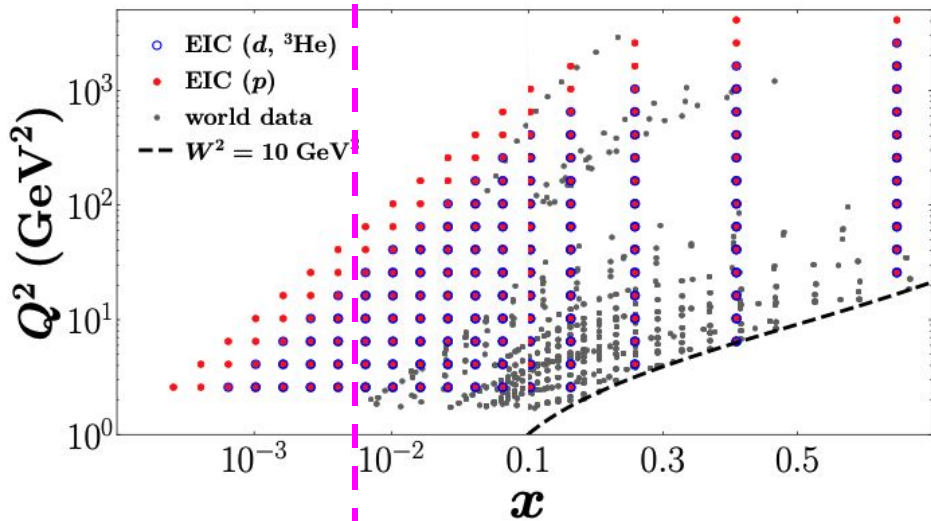
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e-Print: [2105.04434](#) [hep-ph]

Q1: role of small x extrapolation

No data



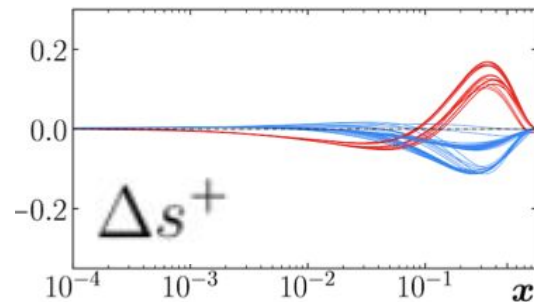
Q2: role of theory assumptions

$$\int_0^1 dx [\Delta u^+(x, Q^2) - \Delta d^+(x, Q^2)] = g_A,$$
$$\int_0^1 dx [\Delta u^+(x, Q^2) + \Delta d^+(x, Q^2) - 2\Delta s^+(x, Q^2)] = a_8,$$

$$g_A = 1.269(3), \quad [\text{SU}(2)]$$

$$a_8 = 0.586(31), \quad [\text{SU}(3)]$$

The strange PDF is largely unconstrained. SU(3) favors negative strange



Inclusive observables

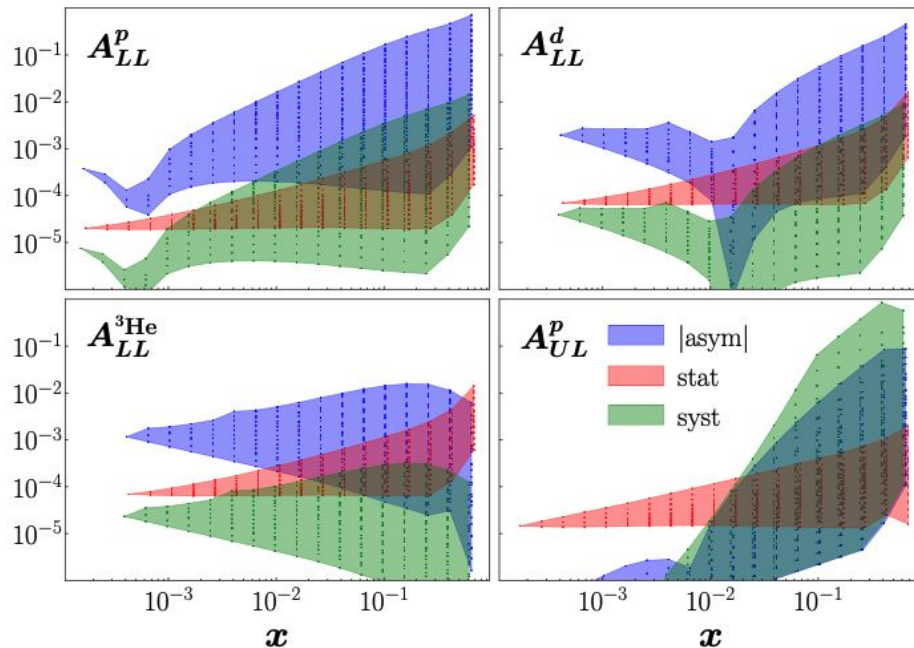
$$A_{LL} = \frac{y(2-y)}{y^2 + 2(1-y)(1+R)} \frac{g_1}{F_1}.$$

$$A_{UL} = \frac{G_F x Q^2}{2\sqrt{2}\pi\alpha} \left(\frac{g_A^e Y^- g_1^{\gamma Z} + g_V^e Y^+ g_5^{\gamma Z}}{x y^2 F_1 + (1-y) F_2} \right)$$

Parity violating DIS



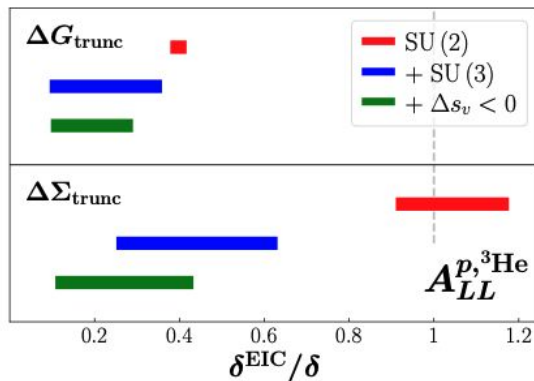
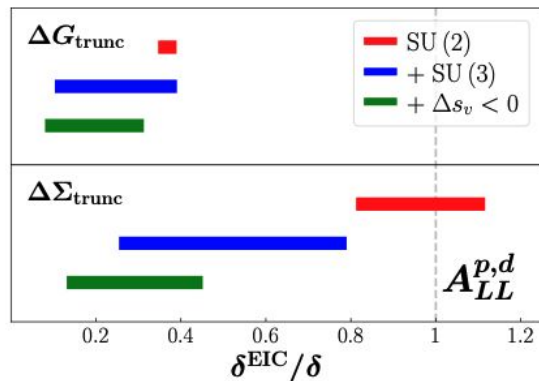
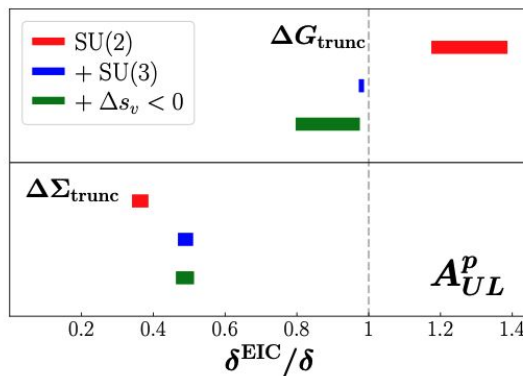
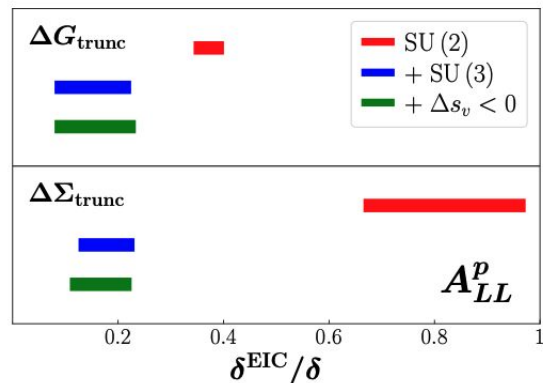
$$g_1^{\gamma Z,p}(x, Q^2) \approx \frac{1}{9} \Delta \Sigma(x, Q^2),$$



EIC impact

$$\Delta G_{\text{trunc}}(Q^2) \equiv \int_{x_{\min}}^1 dx \Delta g(x, Q^2),$$

$$\Delta \Sigma_{\text{trunc}}(Q^2) \equiv \int_{x_{\min}}^1 dx \sum_q \Delta q^+(x, Q^2), \quad x_{\min} = 10^{-4}.$$



- Impact of ALL on delta G is stable against extrapolation and assumptions
- PVDIS is needed in order to constraint further delta sigma at small x

Summary & outlook

Staff / Faculty

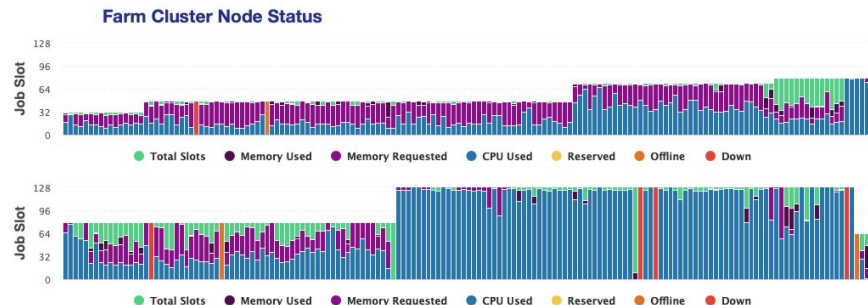
W. Melnitchouk (JLab), T. Rogers (ODU/JLab),
A. Prokudin (PSU), D. Pitonyak (LVC), L. Gamberg
(PSU), Z. Kang (UCLA) J. Qiu (JLab), A. Accardi
(Hampton/JLab), A. Metz (Temple), C.-R. Ji (NCSU),
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Y. Kovchegov (OSU), M. Sievert (NMSU), I. Cloet
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Students / Postdocs

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J. Ethier (Nikhef), C. Andres (JLab), F. Delcarro
(JLab), A. Hiller-Blin (JLab), D. Adamiak (OSU), A.
Freese (WU)...



FY 2020 JAM used 22 Million job
hours (10% of the farm)



Backup

Multi-step strategy

