Future of polarized PDFs: JAM perspective

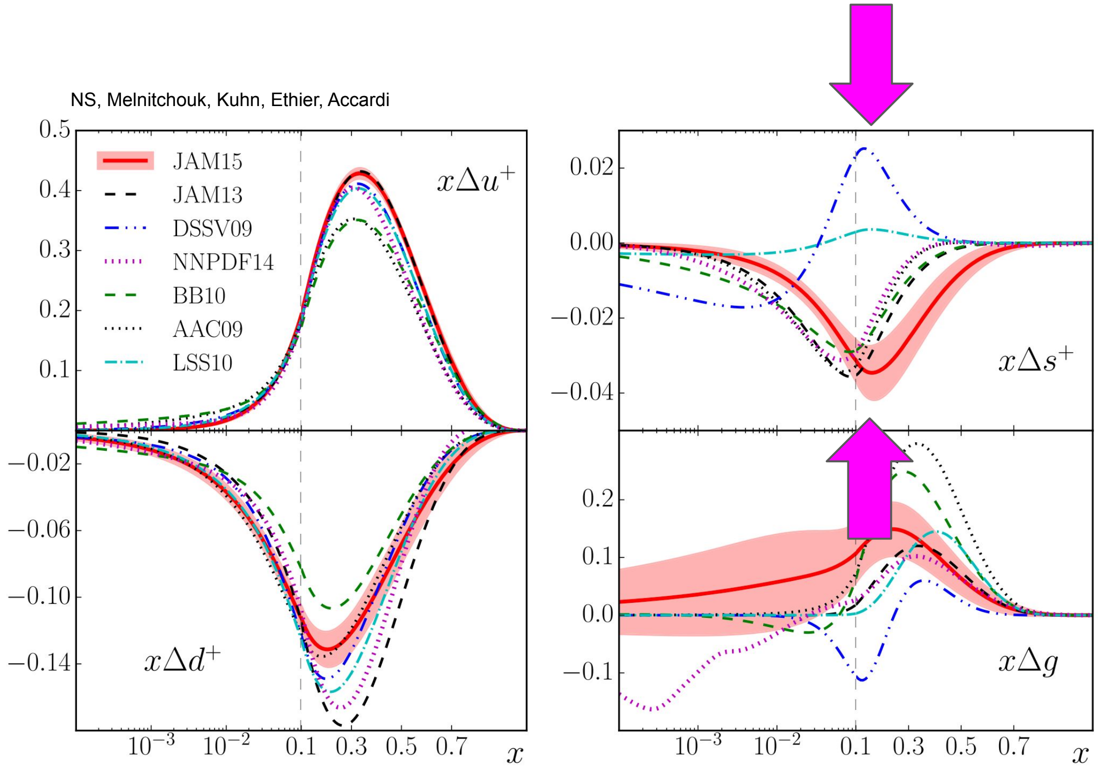
Nobuo Sato

Snowmass 2021 process
Energy Frontier EF6 & EF7

Jefferson Lab

JAM'15 (1D spin-PDFs)

NS, Melnitchouk, Kuhn, Ethier, Accardi



A Possible Resolution of the Strange Quark Polarization Puzzle ?

Elliot Leader, Alexander V. Sidorov, Dimiter B. Stamenov

The strange quark polarization puzzle, i.e. the contradiction between the negative polarized strange quark density obtained from analyses of inclusive DIS data and the positive values obtained from combined analyses of inclusive and semi-inclusive SIDIS data using de Florian et. al. (DSS) fragmentation functions, is discussed. To this end the results of a new combined NLO QCD analysis of the polarized inclusive and semi-inclusive DIS data, using the Hirai et. al. (HKNS) fragmentation functions, are presented. It is demonstrated that the polarized strange quark density is very sensitive to the kaon fragmentation functions, and if the set of HKNS fragmentation functions is used, the polarized strange quark density obtained from the combined analysis turns out to be negative and well consistent with values obtained from the pure DIS analyses.

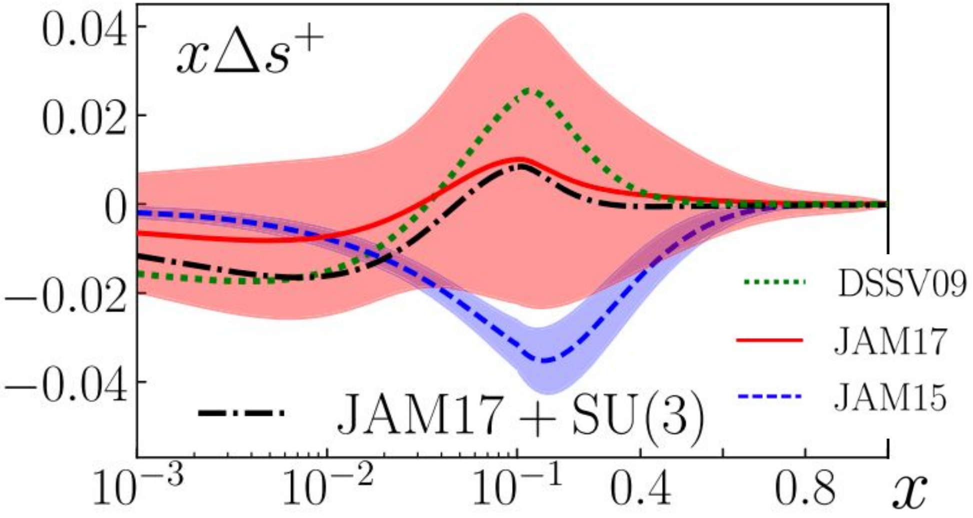
"...It is demonstrated that the polarized strange quark density is very sensitive to Kaon FF."

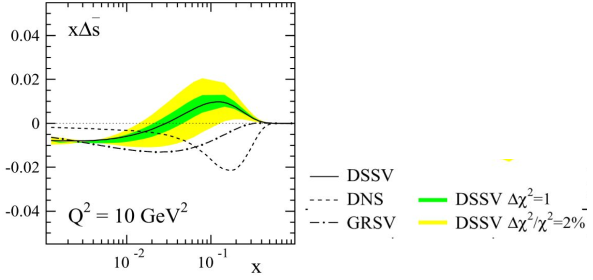
SU(3) constraints:

$$\Delta u^+(1,Q^2) + \Delta d^+(1,Q^2) - 2\Delta s^+(1,Q^2) = a_8,$$

Role of SIDIS and SIA ?

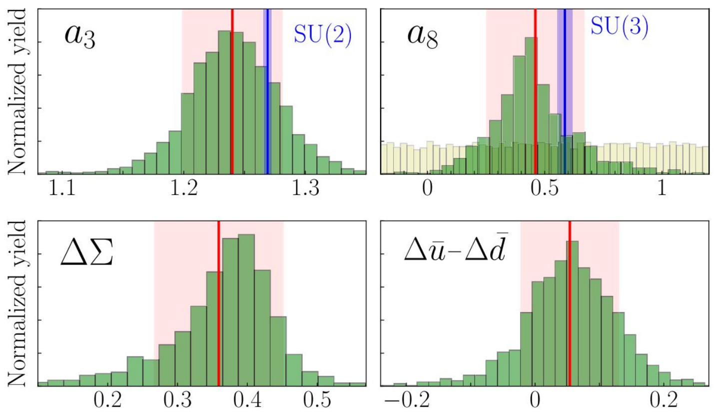
JAM’17 (1D simultaneous extraction of spin PDFs and FFs)





Florian, Sassot, Stratmann, Vogelsang

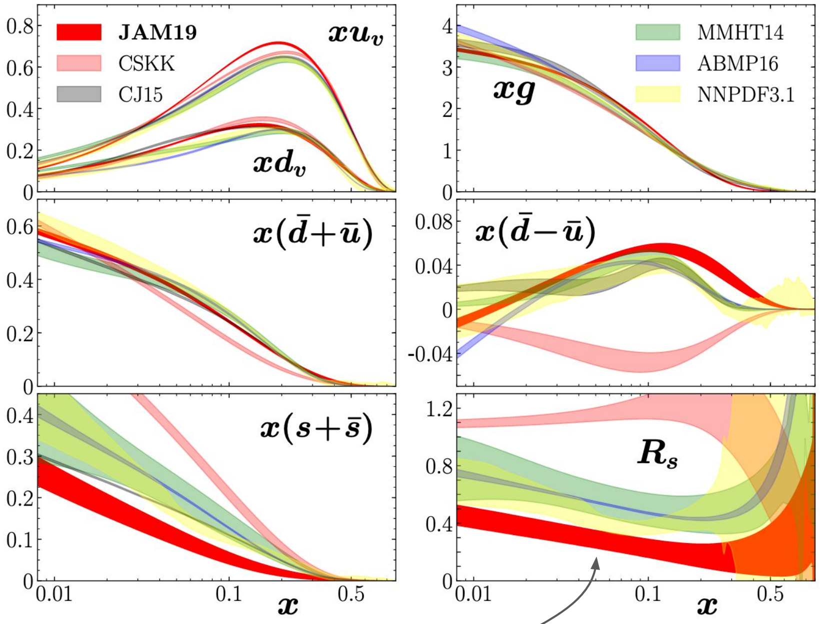
Ethier, NS, Melnitchouk

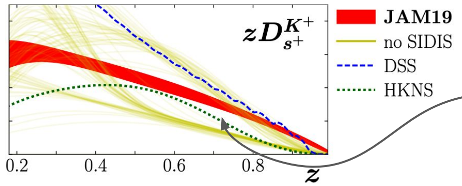


- Use of pol. DIS, SIDIS and SIA
- No SU(2) no SU(3) constraints
- Empirical evidence of g_3 ~ g_A 2%
- No strange puzzle - need more data

JAM'19 (1D simul. extraction of spin-averaged PDFs and FFs)

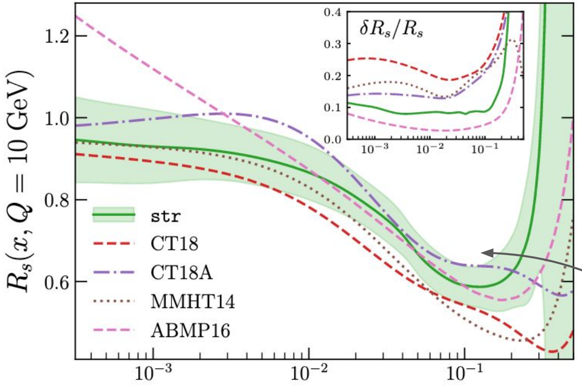
NS, Andres, Melnitchouk





SIA (kaon) prefers large strange -> Kaon FF

Faura, Iranipour, Nocera, Rojo, Ubiali



SIDIS (kaon) suppresses strange PDF

Strange suppression disfavored by collider W+c data

Parity violating DIS at the EIC (Yellow Report)

Coccuza *et al.* (2020)

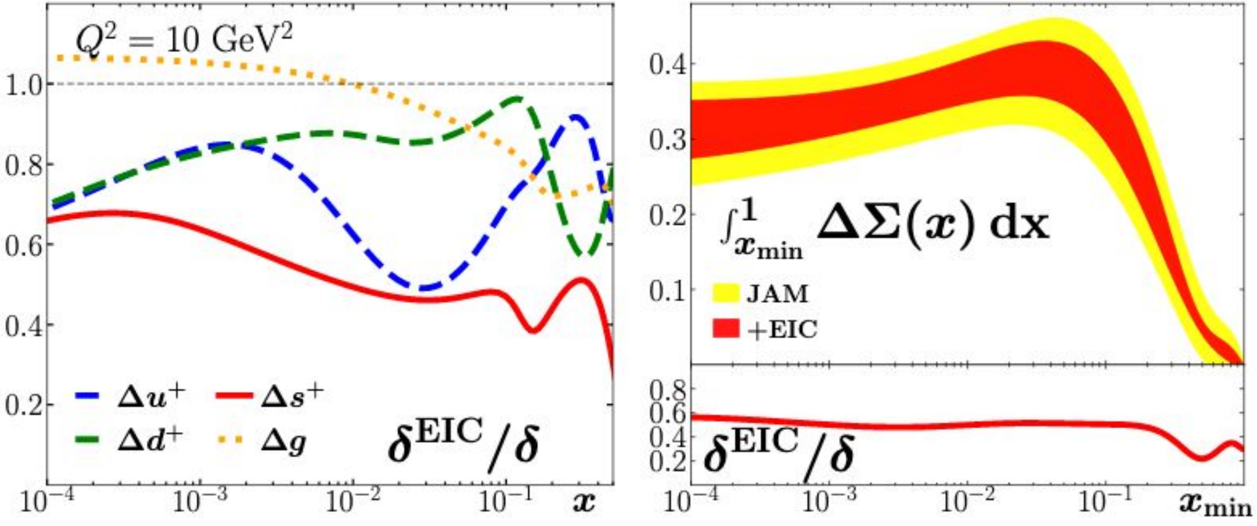
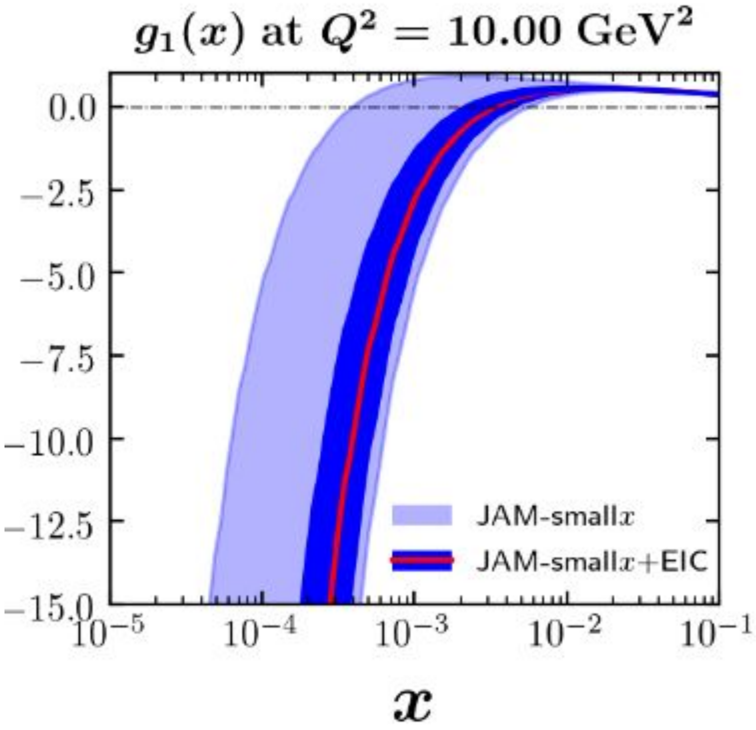


Figure 7.18: (Left panel) Ratio of uncertainties on the helicity PDFs including EIC data on the parity-violating DIS asymmetry A_{PV}^{had} to those without EIC data, at $Q^2 = 10\,\text{GeV}^2$. (Right panel) Impact of EIC A_{PV}^{had} data on the truncated moment of the quark singlet distribution, $\int_{x_{min}}^{1} \Delta\Sigma(x)dx$, as a function of x_{min}.

EIC can constrain polarized strange PDF

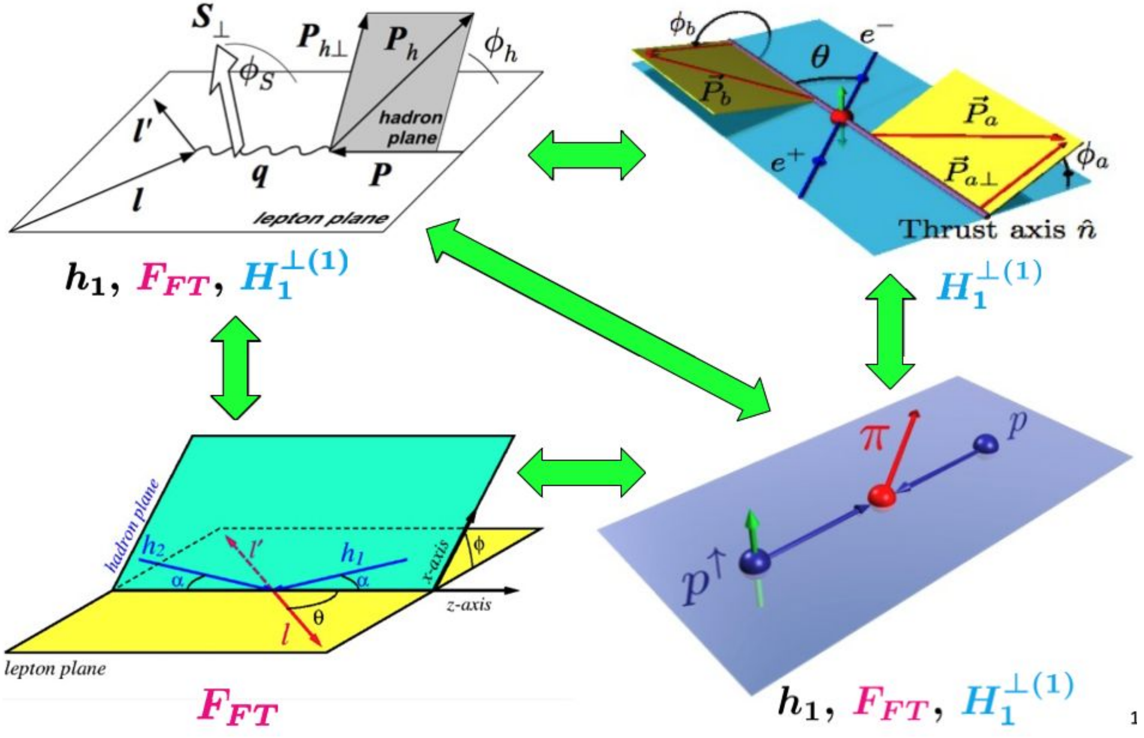
Small-x evolution at the EIC (Yellow Report)

Pitonyak *et al.* (2020)



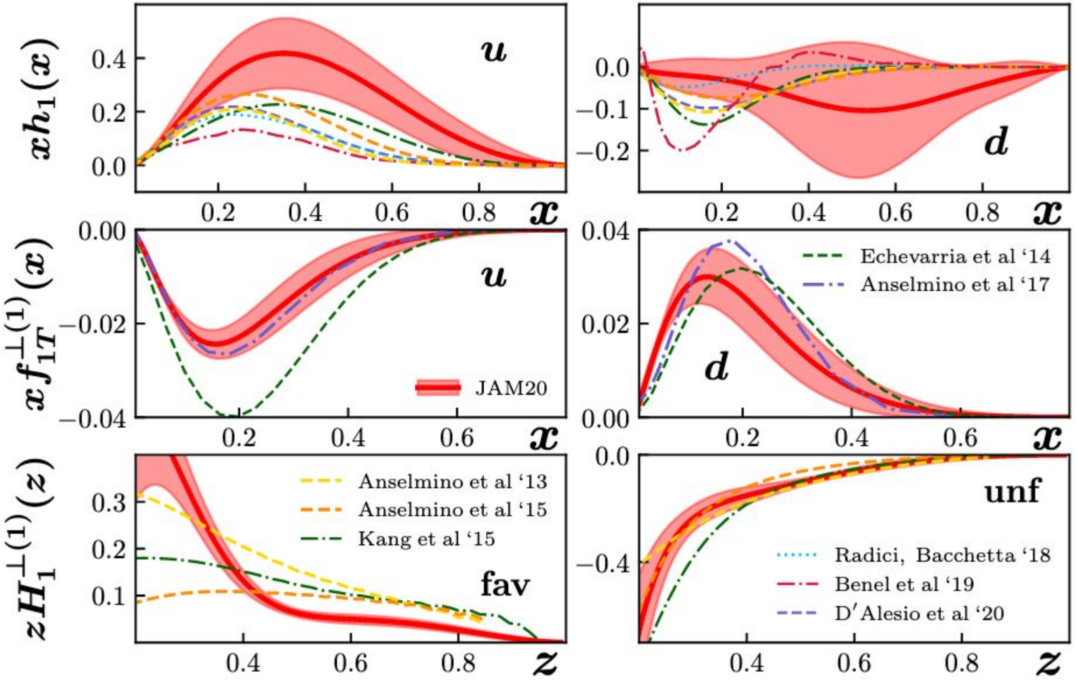
- First ever MC global analysis of A_{LL} (DIS) using KPS equations
- Color dipole amplitudes tuned to DIS data 0.01<x<0.1
- Small x evolution can predict the small x behavior of g_1
- EIC is needed to test and validate small x physics in spin PDFs

Understanding the origin of single spin asymmetries (SSA)

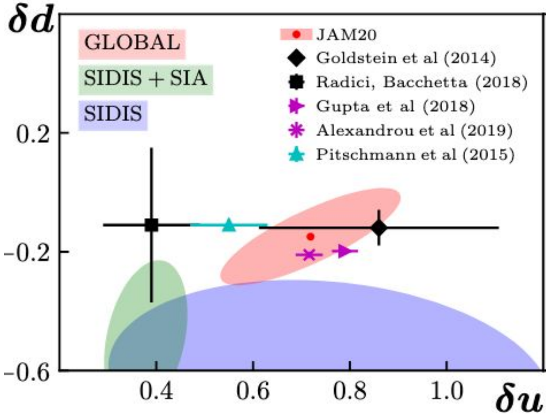


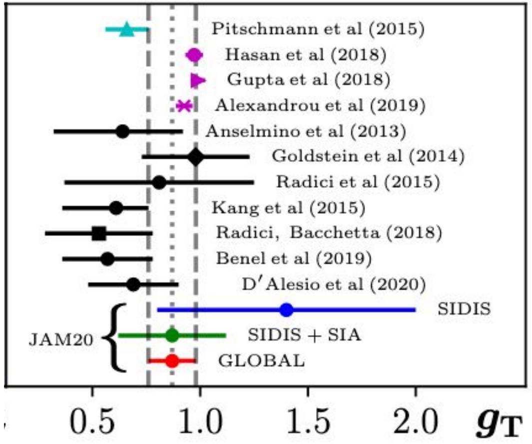
JAM'20 first ever demonstration of TMD + collinear twist 3 framework

JAM'20 (global analysis of all SSA)

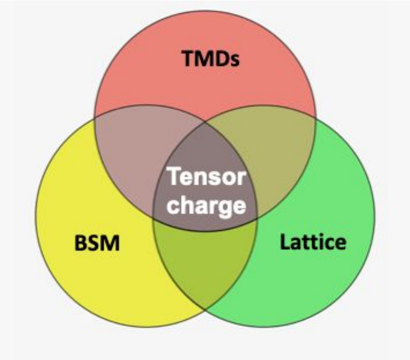


Cammarota, Gamberg, Kang, Miller, Pitonyak, Prokudin, Rogers, NS





Tensor charge at the EIC (Yellow Report)



Pitonyak , et al

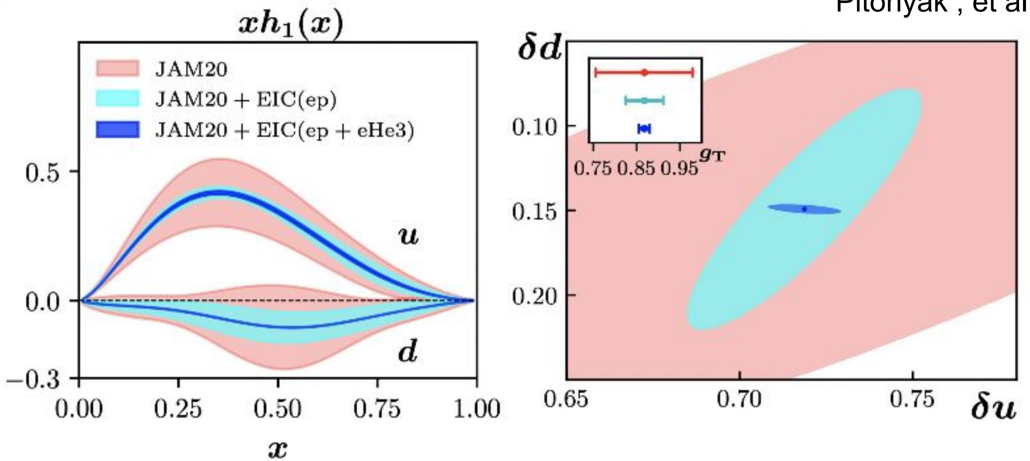
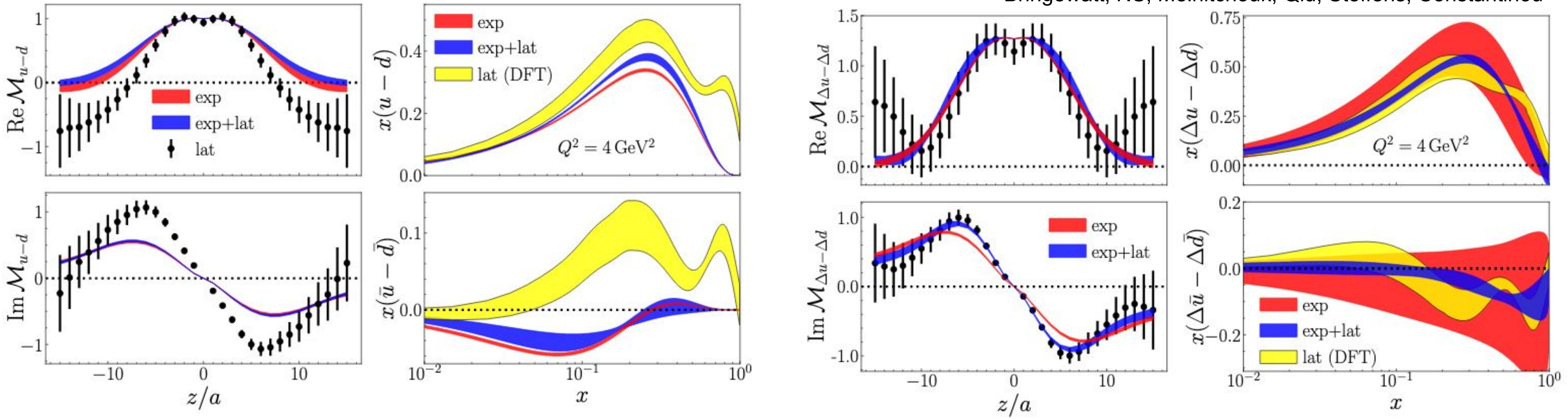


Figure 7.47: Left: Expected impact on the up and down quark transversity distributions as a function of x when including EIC Collins effect SIDIS pseudo-data from e+p and e+He collisions. Right: The impact on the up quark (δu), down quark (δd), and isovector (g_T) tensor charges using those transversity functions.

- The tensor charge of the nucleon is one of its fundamental charges and is important for BSM studies (beta decay, EDM).
- Processes sensitive to TMDs can play an important role in these efforts (Courtoy, et al. (2015); Liu, et al. (2018),…).
- Lattice QCD has also calculated the tensor charges with great precision (Gupta, et al. (2018); Hasan, et al. (2019), Alexandrou, et. (2019),…).

JAM'20 (1D experiment + lattice QCD: quasi-PDFs)

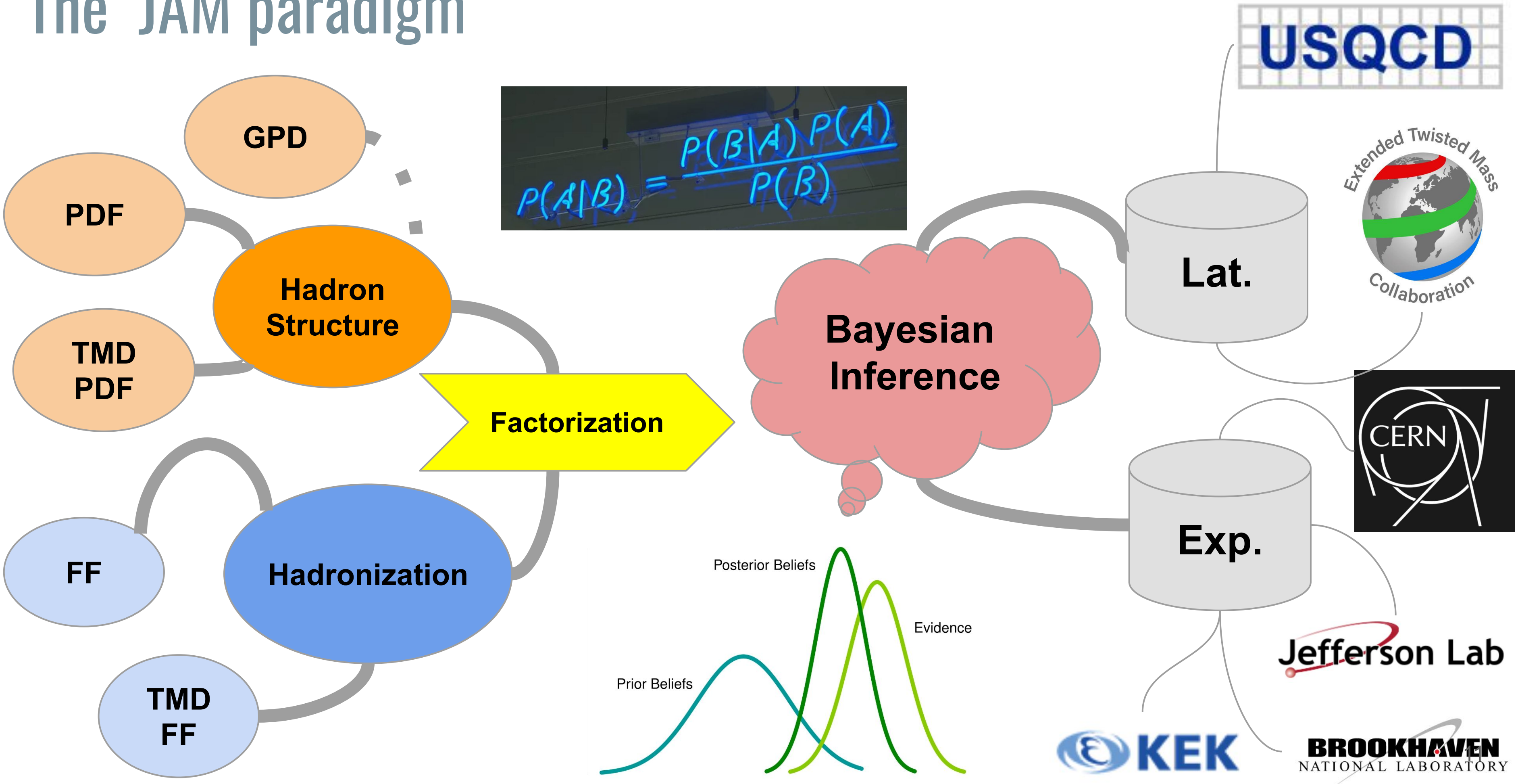
Bringewatt, NS, Melnitchouk, Qiu, Steffens, Constantinou



$$\mathcal{M}_q(z,\mu) = \int_{-\infty}^{\infty} dx\, e^{-ixP_3 z} \int_{-1}^{1} \frac{d\xi}{|\xi|} C_q\left(\frac{x}{\xi}, \frac{\mu}{\xi P_3}\right) f_q(\xi,\mu)$$

$$\mathcal{M}_{\Delta q}(z,\mu) = \int_{-\infty}^{\infty} dx\, e^{-ixP_3 z} \int_{-1}^{1} \frac{d\xi}{|\xi|} C_{\Delta q}\left(\frac{x}{\xi}, \frac{\mu}{\xi P_3}\right) \Delta f_q(\xi,\mu)$$

The JAM paradigm



Summary and Outlook

A new paradigm

- Simultaneous extraction of all hadronic structures
- MC methods for reliable uncertainty quantification
- Inclusion of lattice data as Bayesian priors

The future

- Spin physics **is not just** collinear PDFs
- Spin physics needs to involved 3D structures
- Hadronization dependent observables **needs to be included** in QCD global analysis

JAM Collaboration

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