Summary of the SIDIS/Jets parallel session

2nd IP workshop
March 18, 2020

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General purpose

- Try to find which SIDIS and Jet related measurements would benefit from higher luminosity at lower cms energies
- What can be gained from complementarity?

Sato

Helicity (but also more general statement)

Low Q vs high Q

$$\gamma^2 = 4M^2x^2/Q^2,$$

$$A_{\|} = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\downarrow\Uparrow} + \sigma^{\uparrow\Uparrow}} = D(A_1 + \eta A_2)$$

$$A_{\perp} = \frac{\sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}}{\sigma^{\downarrow\Rightarrow} + \sigma^{\uparrow\Rightarrow}} = d(A_2 - \zeta A_1)$$

$$\Rightarrow$$

$$A_1 = \frac{(g_1 - \gamma^2 g_2)}{F_1}$$

$$A_2 = \gamma\frac{(g_1 + g_2)}{F_1}$$

$$\Rightarrow$$

$$g_1 = g_1^{(\tau 2)} + g_1^{(\tau 3)} + g_1^{(\tau 4)}$$

$$g_2 \stackrel{???}{=} g_2^{(\tau 2)} + g_2^{(\tau 3)}$$

High-Q physics is much simpler

Low-Q physics is more interesting (TMCs, HTs,...)

$$A_1 = \frac{(g_1 - \cancel{\gamma^2} g_2)}{F_1}$$

$$A_2 = \gamma\cancel{\frac{(g_1 + g_2)}{F_1}}$$

$$g_1 = g_1^{(\tau 2)} + \cancel{g_1^{(\tau 3)}} + \cancel{g_1^{(\tau 4)}}$$

$$\cancel{g_2} = \cancel{g_2^{(\tau 2)}} + \cancel{g_2^{(\tau 3)}}$$

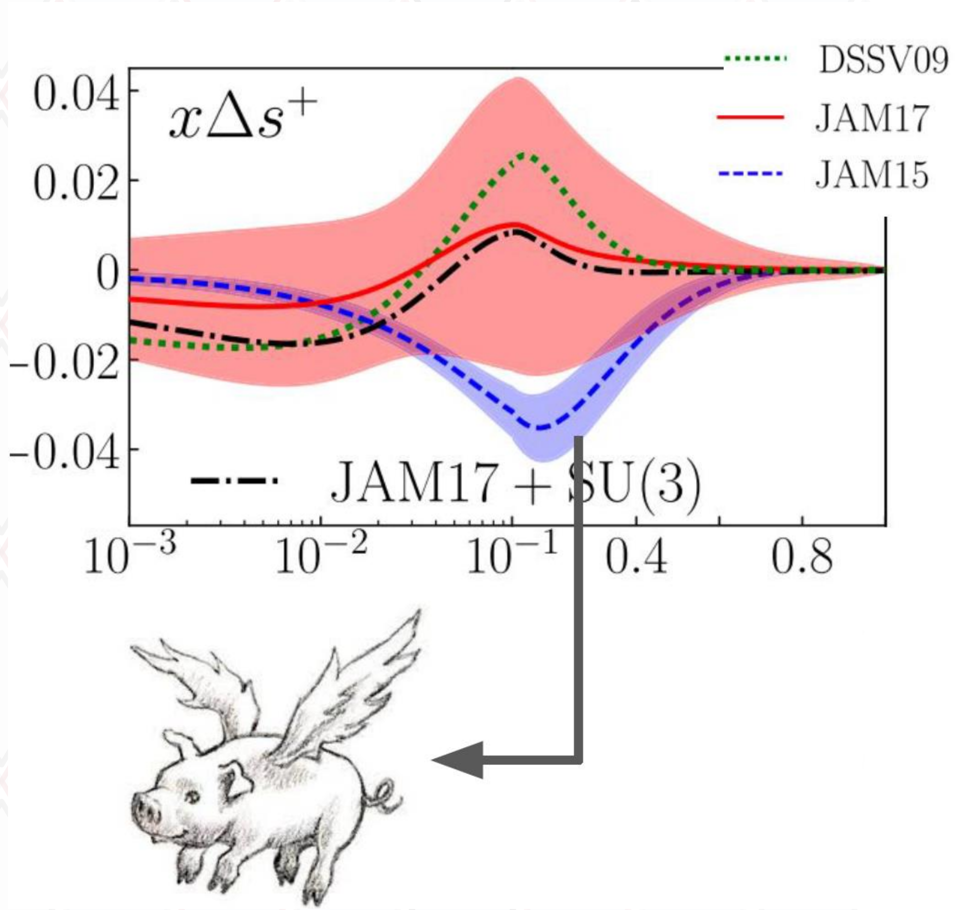
4

But QED radiative effects important at high x/Q^2 at EIC, also important for SIDIS measurements

Sato

Strange sea quark helicity

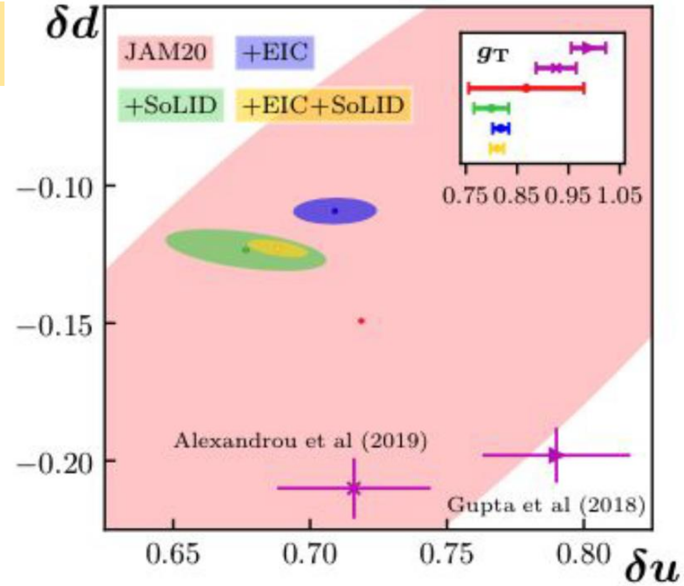
- Need precise data to understand strange contribution as currently dominated by $SU(3)_F$ and Fragmentation assumptions
- Measurements over large range in x/Q^2 will reduce dependence on assumptions



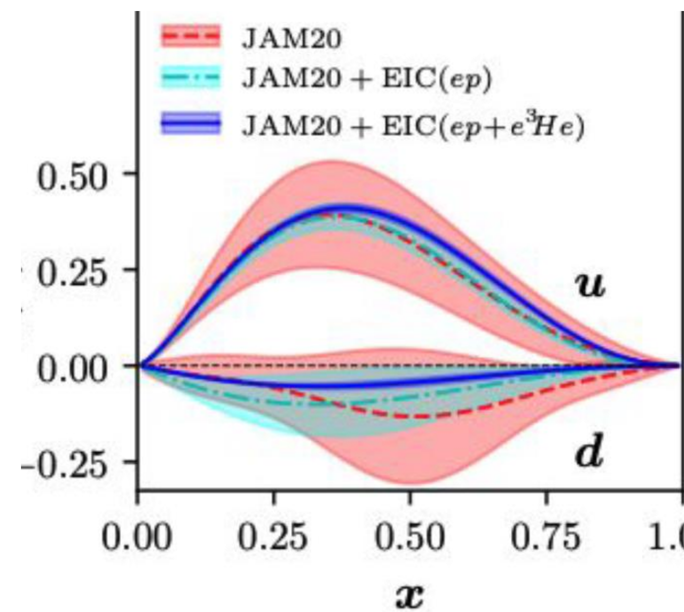
Sato

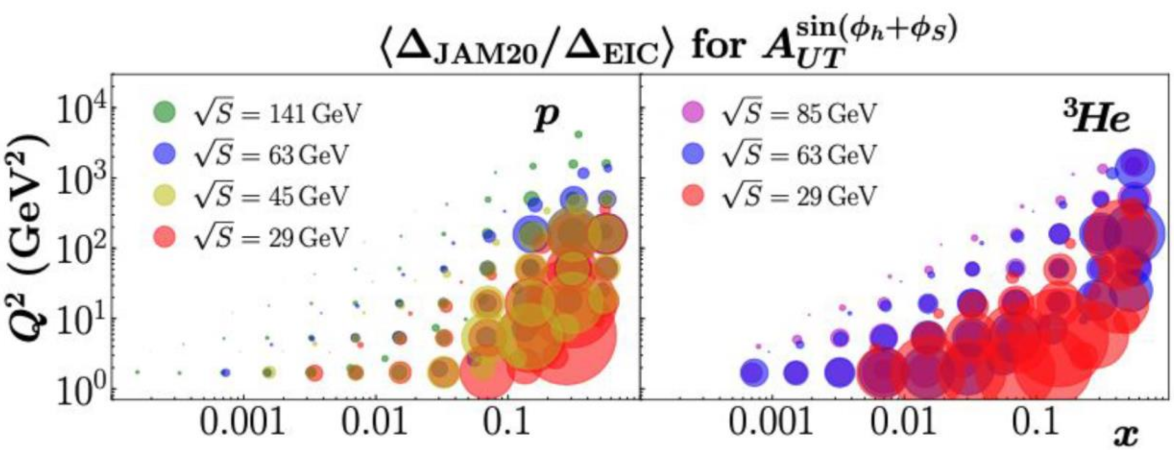
Transversity

- Interplay between fixed target and EIC data
- Overlap at higher x important
- High enough precision to compare to Lattice



Accuracy vs. Precision

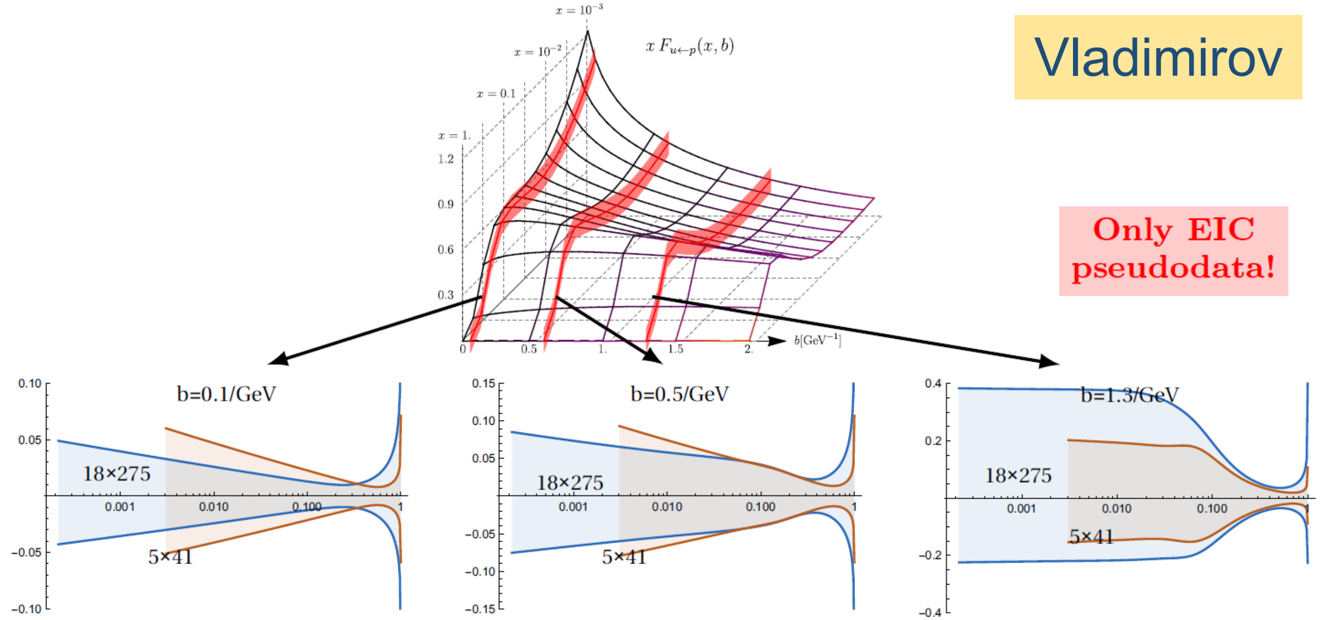




High-x region provides significant constraints

TMDs

Vladimirov



Only EIC pseudodata!

- Different collision energies provide complementary information for low/high b/k_T regions of TMDs
- Also complementary x coverage

IR1 (18 x 275)

- Smaller x
- Smaller b/larger k_T
- Gluons
- More collinear physics!

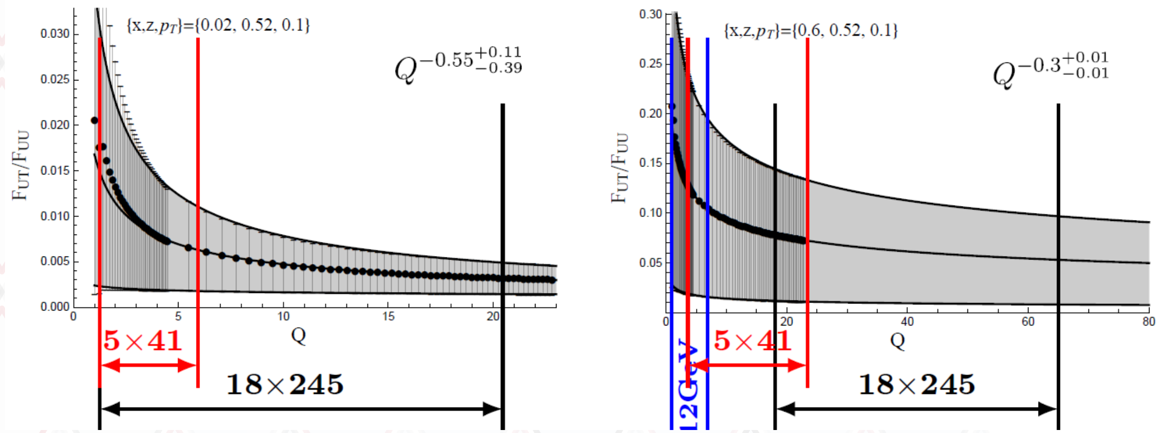
IR2 (5 x 41)

- Larger x
- Larger b/smaller k_T
- Higher twists(?)
- More TMD physics!

TMD evolution of asymmetries / Sivers

Vladimirov

- TMD evolution reduces size of asymmetries
- However within EIC Q^2 range only slow decline
- Again complementarity of energies for x ranges + sea quark access

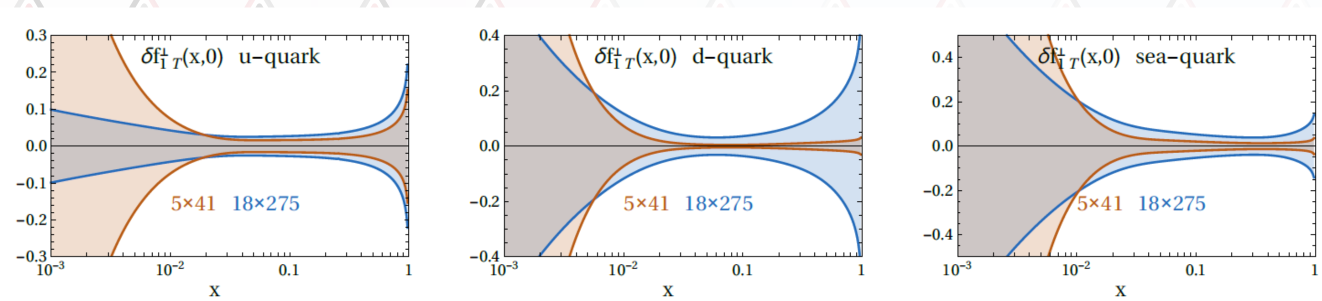


Complementarity in integrals:

$$A = \int_0^1 dx\, f_{1T;u}^{\perp}(x,0)$$

$$\delta A_{\mathrm{IR1}} \sim 6\%, \qquad \delta A_{\mathrm{IR2}} \sim 12\%$$

$$\delta A_{\mathrm{IR1}\cup\mathrm{IR2}} \sim 3\%$$



Courtoy

Higher Twist observables: g_T

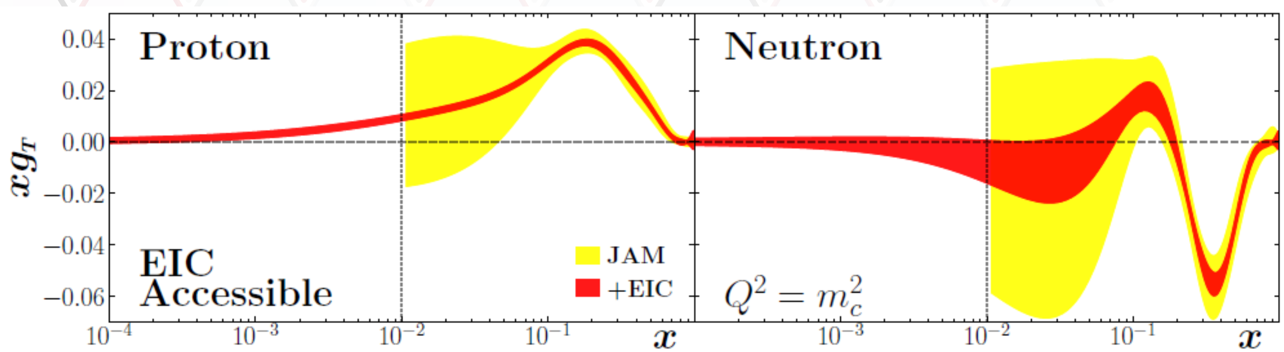
$$
\begin{aligned}
\int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle PS|\bar\psi(0)\gamma_\mu\psi(\lambda n)|PS\rangle &= 2\left\{\boxed{f_1(x)}\, p_\mu + M^2 f_4(x) n_\mu\right\},\\
\int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle PS|\bar\psi(0)\gamma_\mu\gamma_5\psi(\lambda n)|PS\rangle &= 2\left\{\boxed{g_1(x)}\, p_\mu S\cdot n + g_T(x) S_{\perp\mu} + M^2 g_3(x) n_\mu S\cdot n\right\},\\
\int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle PS|\bar\psi(0)\psi(\lambda n)|PS\rangle &= 2e(x),\\
\int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle PS|\bar\psi(0)i\sigma_{\mu\nu}\gamma_5\psi(\lambda n)|PS\rangle &= 2\{\boxed{h_1(x)}\,(S_{\perp\mu}p_\nu - S_{\perp\nu}p_\mu)/M\\
&\quad + h_L(x) M(p_\mu n_\nu - p_\nu n_\mu) S\cdot n\\
&\quad + h_3(x) M(S_{\perp\mu}n_\nu - S_{\perp\nu}n_\mu)\},
\end{aligned}
$$

twist-2 PDFs

twist-3 PDFs

- Complementarity to fixed target data

- $g_T = g_1 + g_2$
- JAM+EIC: $g_T = g_T^{WW} + \tilde g_T$
- hints of non-vanishing twist-3 effect in DIS
  - extend to genuine twist-3 with EIC
  - study the scale dependence/factorization
  - complementarity of x range



Golden channel

- fully inclusive DIS: $A_{LT} \Rightarrow g_T$

HT function e(x)

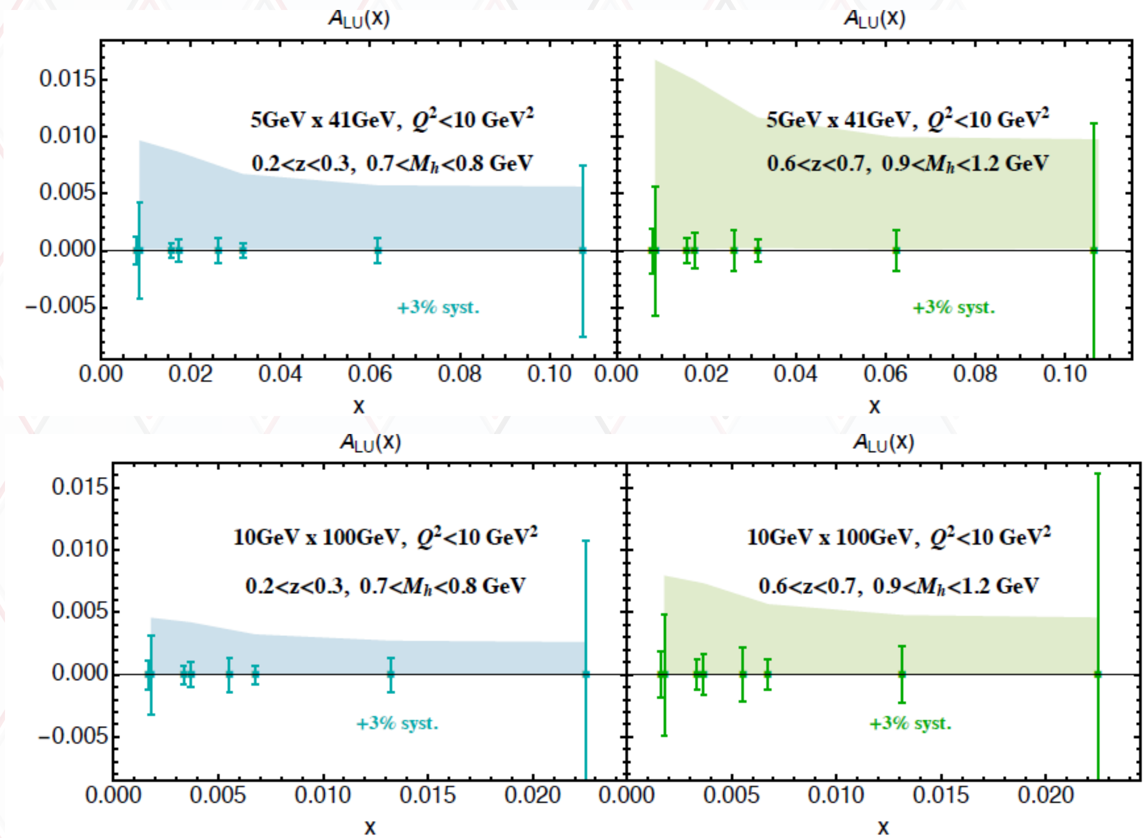
Courtoy

$$A_{LU} \propto \text{twist-3 PDF} \times \underbrace{\boxed{\frac{\text{twist-2 FF} + \text{twist-2 PDF}}{\text{unpolarized}}}}_{\textit{known} \text{ twist-2 quantities}} \times \text{twist-3 FF}$$

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

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

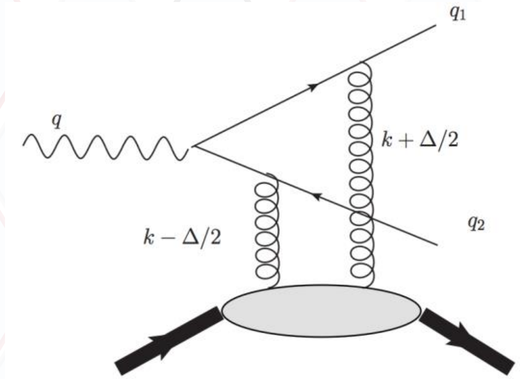
- Large interest in this function
- Accessible via single and di-hadron A_{LU} measurements

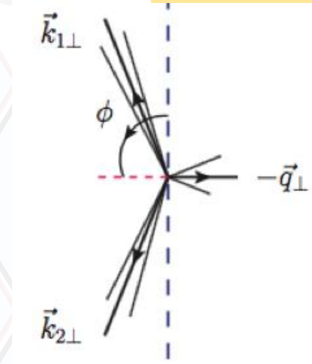


Yuan

Jet observables

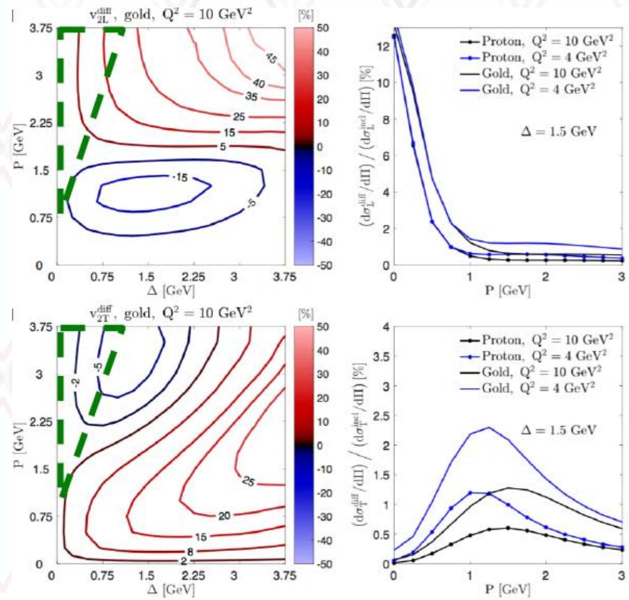
- Exclusive di-jets as access to gluon OAM and Wigner functions
- Requires detection of recoil proton
- Currently low-x theoretical framework, but measurements not limited to low-x





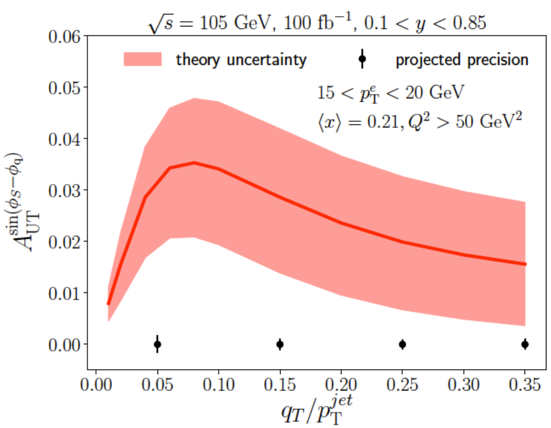
$$A_{\sin(\phi_q-\phi_\Delta)} \propto \frac{(\bar{z}-z)|\vec{q}_\perp||\vec{\Delta}_\perp|}{\vec{q}_\perp^{\,2}+\mu^2}\mathcal{L}_g(\xi,t)$$

$$x\mathcal{W}_g^T(x,|\vec{q}_\perp|,|\vec{b}_\perp|)+2\cos(2\phi)x\mathcal{W}_g^\epsilon(x,|\vec{q}_\perp|,|\vec{b}_\perp|)$$

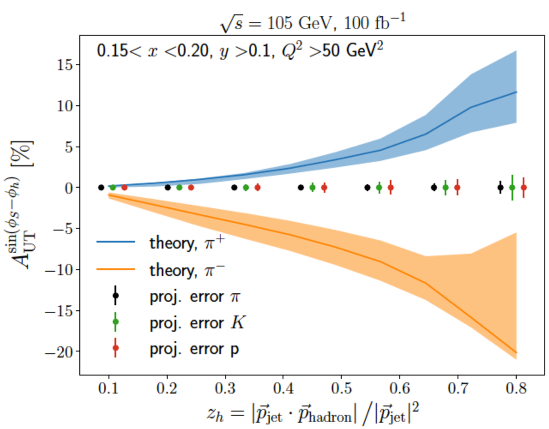


TMD additions from Jets

- Additional input to TMDs from jets
  - Allows to remove part of the convolutions for Sivers: (almost TMD PDF only)
  - Allows to decouple transversity from Collins FF (almost TMD FF only)
- More Jet-substructure measurements also possible
- Generally multidim. measurements → potentially luminosity hungry



Sivers asymmetry



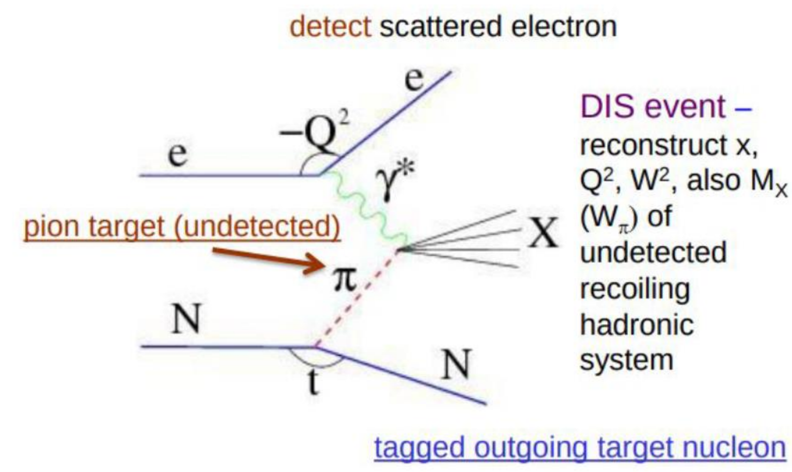
Collins asymmetry

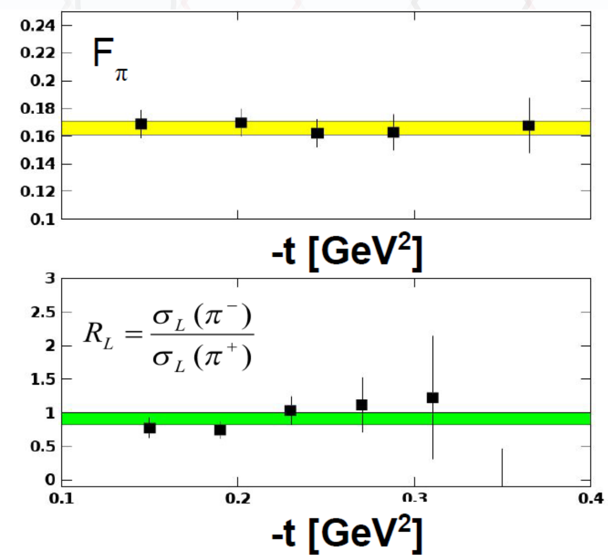
Phys.Rev.D 102 (2020) 7, 074015

Trotta

Meson structure

- Exciting possibilities to study meson structure via Sullivan Process: virtual emission of pion, kaon and scattering on that meson
- Requires detection of forward-going nucleon or Λ to control t
- Interpretation valid for
  - π: -t< 0.6 GeV^2
  - K: -t< 0.9 GeV^2

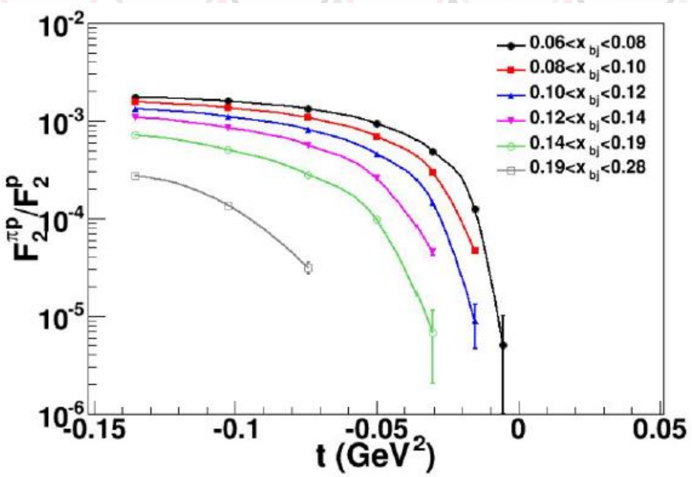


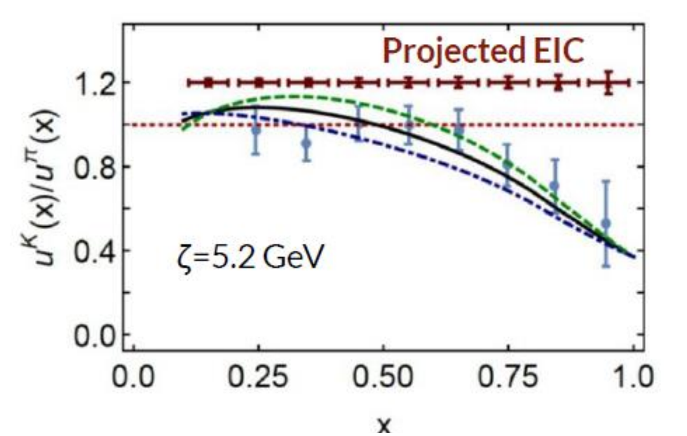


T. Horn, C.D. Roberts, J. Phys. G43 (2016) no.7, 073001
G. Huber et al, PRL112 (2014)182501
R. J. Perry et al., arXiV:1811.09356 (2019)

Trotta

Meson structure sensitivity + requirements





- Large improvement over existing HERA + Meson DY data
- Complementary with AMBER
- Stringent detection requirements in very forward region

For π^+/n...

- For all energies, the neutron detection efficiency is ~100% with planned ZDC
- Lower energies [5 on 41, 5 on 100], **require at least 60cmx60cm size** to access wider range of energies

For π^+/n and K^+/Λ...

- All energies need good ZDC angular resolution for the required t resolution
- High energies [10 on 100, 10 on 135, 18 on 275] **require resolution of 1 cm or less**

K^+/Λ benefits from low energies [5 on 41, 5 on 100] and also need...

- $\Lambda \rightarrow n+\pi^0$: additional high-res/granularity
  - **EMCal+tracking before ZDC** (seems doable)
- $\Lambda \rightarrow p+\pi^-$: additional trackers/veto in opposite charge direction on path to ZDC (more challenging)

Summary

See also A. Vossen / Z. Kang talk from Wednesday

- Drivers for higher lumi at lower cms energy:
  - Higher twist effects (e(x), g_T ; at least 1/Q suppressed)
  - Meson structure DIS (rare process, very FW Λ decay acceptance for Kaon structure favors lower energies)
  - Exclusive di-jet measurements (exclusive, currently low-x framework description)
  - Some TMD measurements (Tensor charge, Sivers function, but sea contributions also very important)
  - Jet TMD/substructure measurements similar to SIDIS requirements
  - TMD evolution (effects only slowly decrease with Q^2, large lever arm in both x and Q^2 to disentangle structure and evolution effects)
- Complementarity and independent measurements with 2 IRs key for EIC success (both at low and high cms energies)