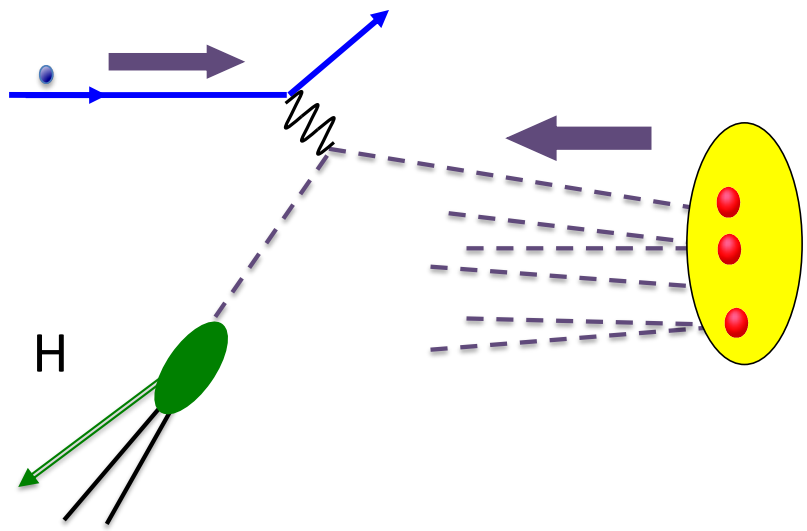
Regions of DIS and Semi-Inclusive DIS

Jefferson Lab/Old Dominion University

SIDIS



Variables and Observables

$$E' \frac{\mathrm{d}\sigma}{\mathrm{d}^3\mathbf{l}'} = \frac{2\,\alpha_{\mathrm{em}}^2}{(s-M^2)\,Q^4}\, L_{\mu\nu} W_{\mathrm{tot}}^{\mu\nu} \qquad \frac{\mathrm{d}\sigma}{\mathrm{d}x_{\mathrm{Bj}}\;\mathrm{d}y\;\mathrm{d}\psi} = \frac{\alpha_{\mathrm{em}}^2 y}{Q^4} L_{\mu\nu} W_{\mathrm{tot}}^{\mu\nu}$$

$$W_{\mathrm{tot}}^{\mu\nu}(P,q) \equiv 4\pi^3 \sum_X \delta^{(4)}(P+q-P_X)\,\langle P,S|j^\mu(0)|X\rangle\langle X|j^\nu(0)|P,S\rangle$$

$$4{P_{\mathrm{B}}}^0 E' \frac{\mathrm{d}\sigma}{\mathrm{d}^3\mathbf{l}'\;\mathrm{d}^3\mathbf{P}_{\mathrm{B}}} = \frac{2\,\alpha_{\mathrm{em}}^2}{(s-M^2)Q^4}\, L_{\mu\nu} W_{\mathrm{SIDIS}}^{\mu\nu} \qquad \frac{\mathrm{d}\sigma}{\mathrm{d}x_{\mathrm{Bj}}\;\mathrm{d}y\;\mathrm{d}\psi\;\mathrm{d}z_{\mathrm{N}}\;\mathrm{d}^2\boldsymbol{P}_{\mathrm{B,T}}} = \frac{\alpha_{\mathrm{em}}^2 y}{4Q^4 z_{\mathrm{N}}}\, L_{\mu\nu} W_{\mathrm{SIDIS}}^{\mu\nu}$$

$$W_{\mathrm{SIDIS}}^{\mu\nu}(P,q,P_{\mathrm{B}}) \equiv \sum_X \delta^{(4)}(P+q-P_{\mathrm{B}}-P_X)\,\langle P,S|j^\mu(0)|P_{\mathrm{B}},X\rangle\langle P_{\mathrm{B}},X|j^\nu(0)|P,S\rangle$$

$$\sum_B \int \frac{\mathrm{d}^2\boldsymbol{P}_{\mathrm{B,T}}\,\mathrm{d}z_{\mathrm{N}}}{4z_{\mathrm{N}}} W_{\mathrm{SIDIS}}^{\mu\nu} = \langle N\rangle W_{\mathrm{tot}}^{\mu\nu}$$

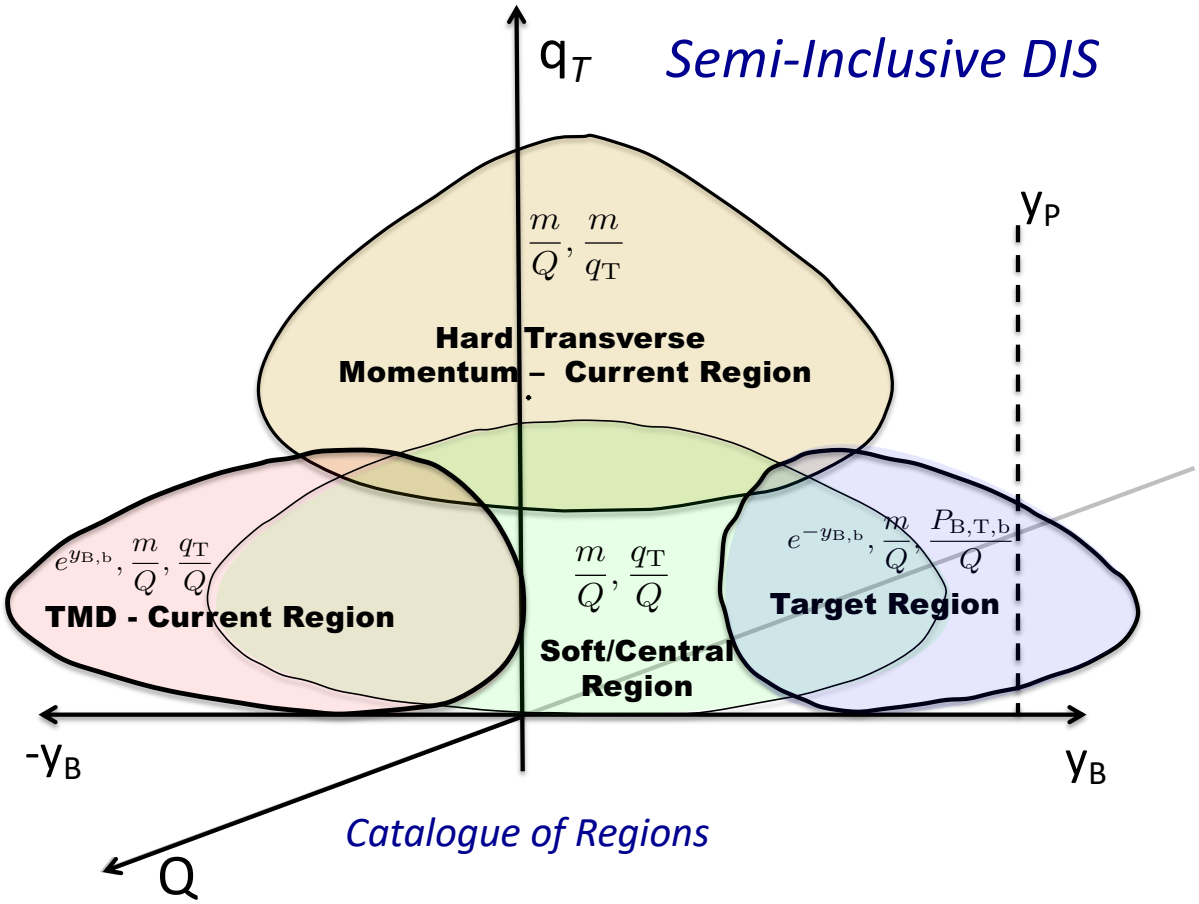
Questions

- Factorization is based on mass/Q expansion.

- Different factorization theorems for different regions of x, z, Q, P_T, etc.

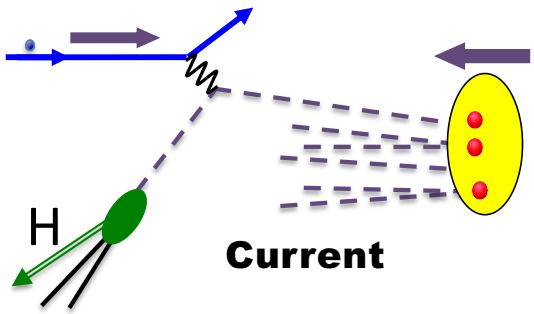
- What are the boundaries to different regions in reality?

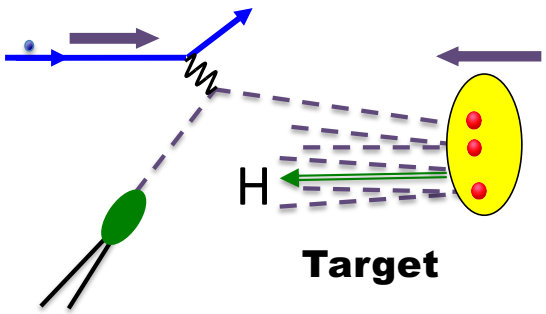
What is the relevant description?

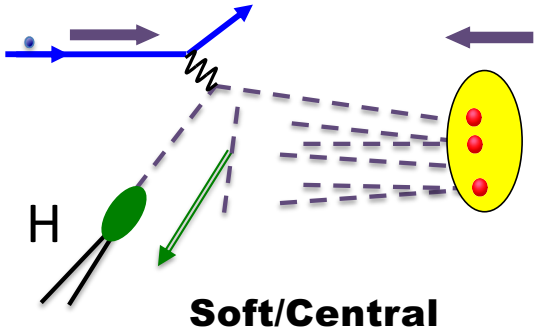


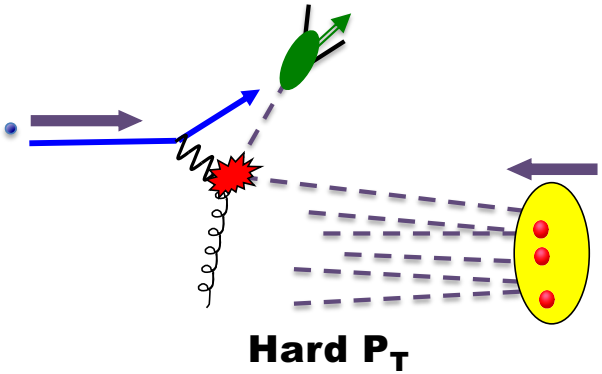
Catalogue of Regions

Subregions



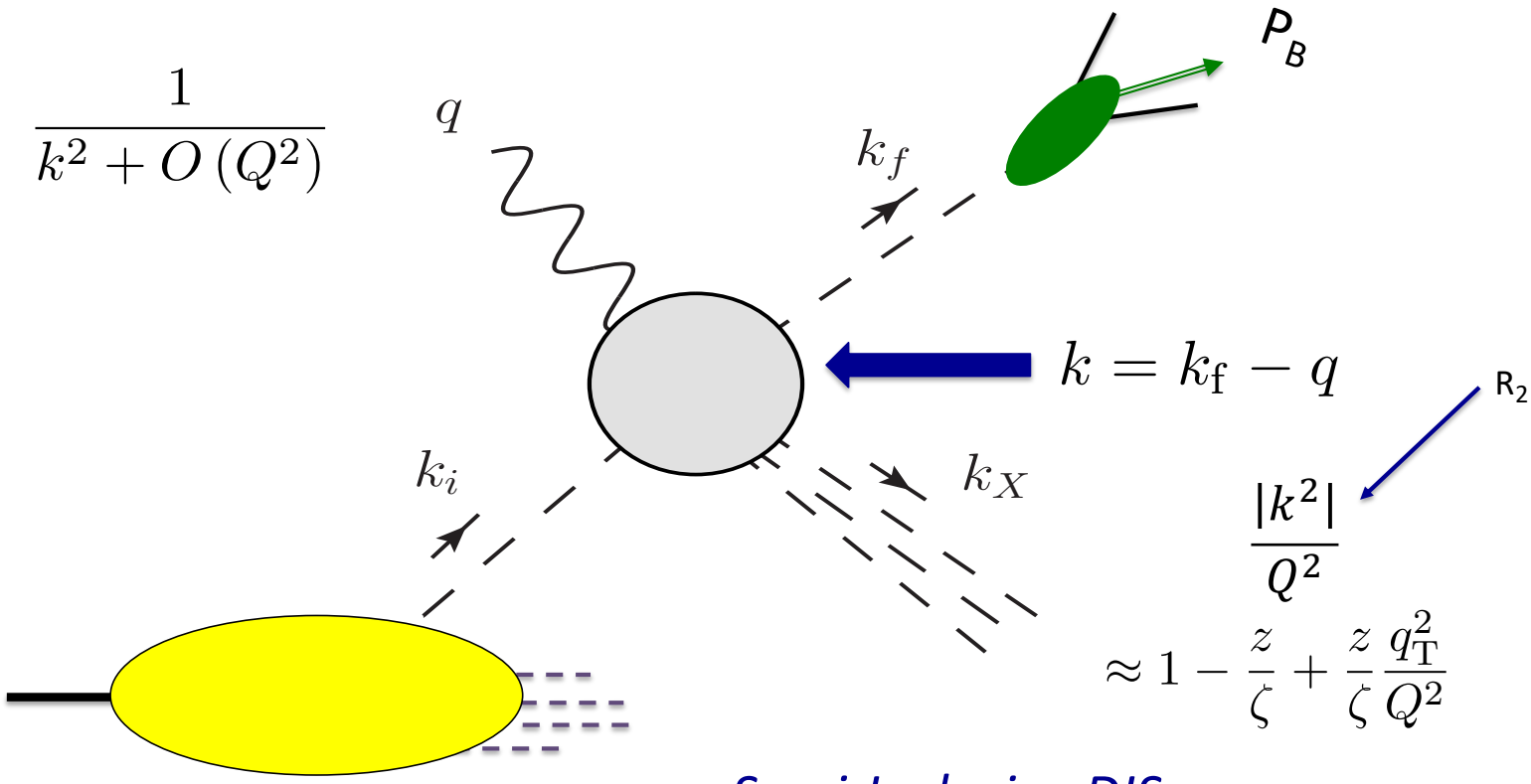






Large and Small Transverse Momentum

$$\frac{1}{k^2 + O\left(Q^2\right)}$$



$$\frac{|k^2|}{Q^2} \approx 1 - \frac{z}{\zeta} + \frac{z}{\zeta}\frac{q_{\mathrm{T}}^2}{Q^2}$$

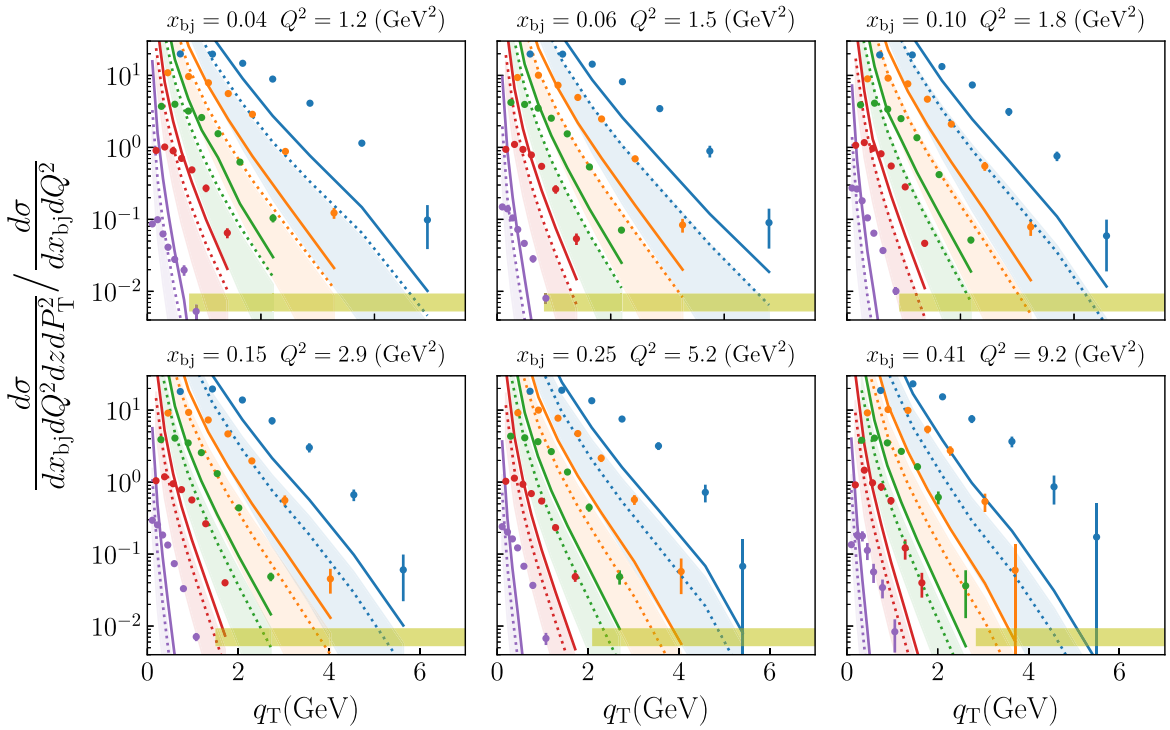
Semi-Inclusive DIS

SIDIS

- NLO study near the valence region.

B. Wang, J. O. Gonzalez-Hernandez, TR, N. Sato
Phys. Rev. D 99, 094029

https://jeffersonlab.github.io/BigTMD/_build/html/index.html



Solid = NLO
Dotted = LO

$q_T > \grave{Q}$

Bands = variation of RG scale

Kinematics And Masses

- Final state momentum fraction

$$x_{\mathrm{N}} = -\frac{q^+}{P^+} = \frac{2x_{\mathrm{Bj}}}{1+\sqrt{1+\frac{4x_{\mathrm{Bj}}^2 M^2}{Q^2}}}$$

$$z_{\mathrm{N}} = \frac{P_{\mathrm{B}}^-}{q^-}$$

$$z_{\mathrm{N}} = \frac{x_{\mathrm{N}} z_{\mathrm{h}}}{2x_{\mathrm{Bj}}}\left(1+\sqrt{1-\frac{4M^2 M_{\mathrm{B,T}}^2 x_{\mathrm{Bj}}^2}{Q^4 z_{\mathrm{h}}^2}}\right)$$

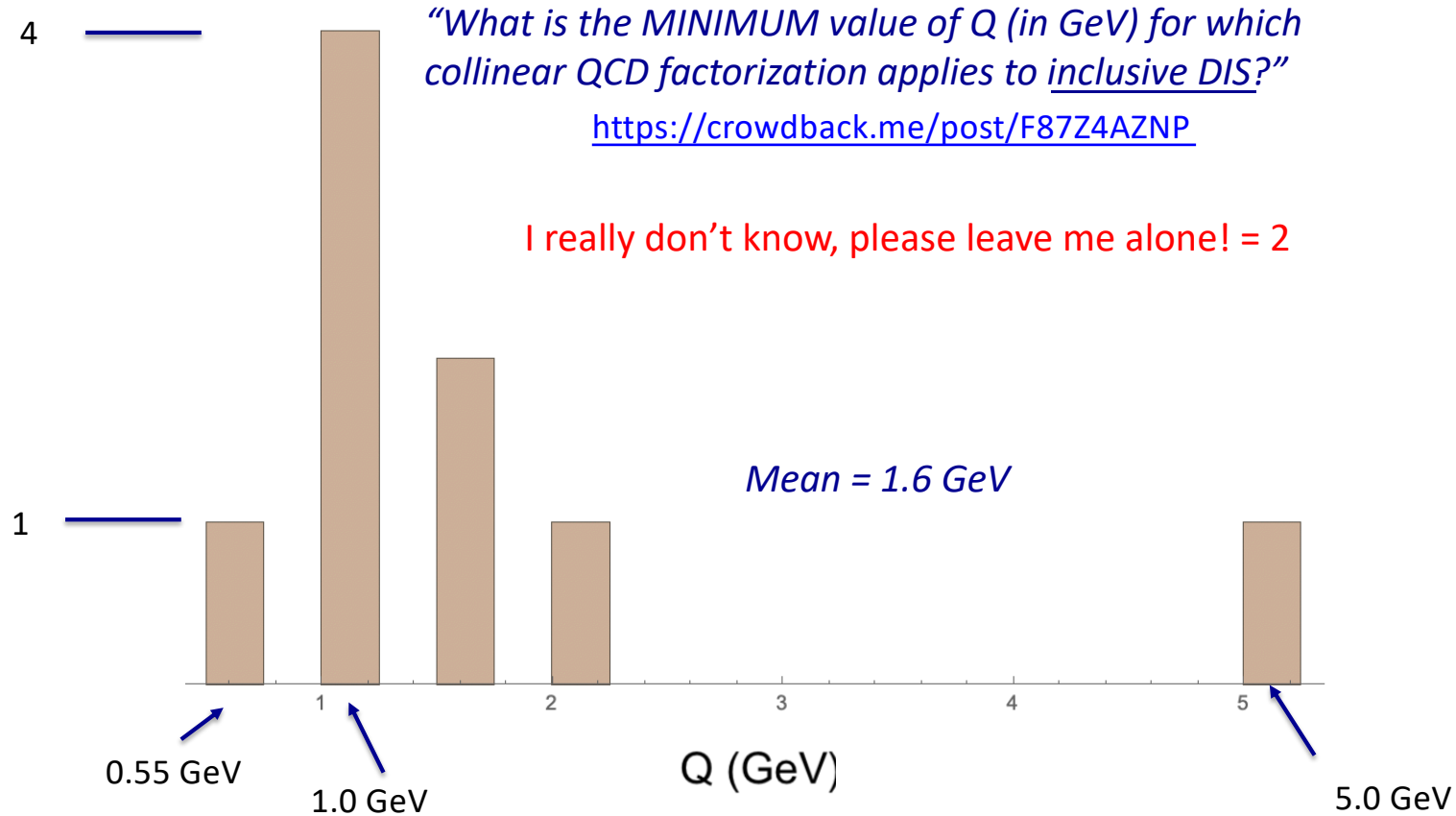
$$= z_{\mathrm{h}}\left(1-\frac{x_{\mathrm{Bj}}^2 M^2}{Q^2}\left(1+\frac{P_{\mathrm{B,T}}^2}{z_{\mathrm{h}}^2 Q^2}\right)+\left(\frac{x_{\mathrm{Bj}}^2 M^2}{Q^2}\right)^2\left(\frac{P_{\mathrm{B,T}}^2}{z_{\mathrm{h}}^2 Q^2}-\frac{P_{\mathrm{B,T}}^4}{z_{\mathrm{h}}^4 Q^4}+2-\frac{M_{\mathrm{B}}^2}{z_{\mathrm{h}}^2 M^2 x_{\mathrm{Bj}}^2}\right)+O\left(\left(\frac{x_{\mathrm{Bj}}^2 M^2}{Q^2}\right)^3\right)\right)$$

How low in Q?

"What is the MINIMUM value of Q (in GeV) for which collinear QCD factorization applies to inclusive DIS?"

https://crowdback.me/post/F87Z4AZNP

I really don't know, please leave me alone! = 2



Mean = 1.6 GeV

How low in Q?

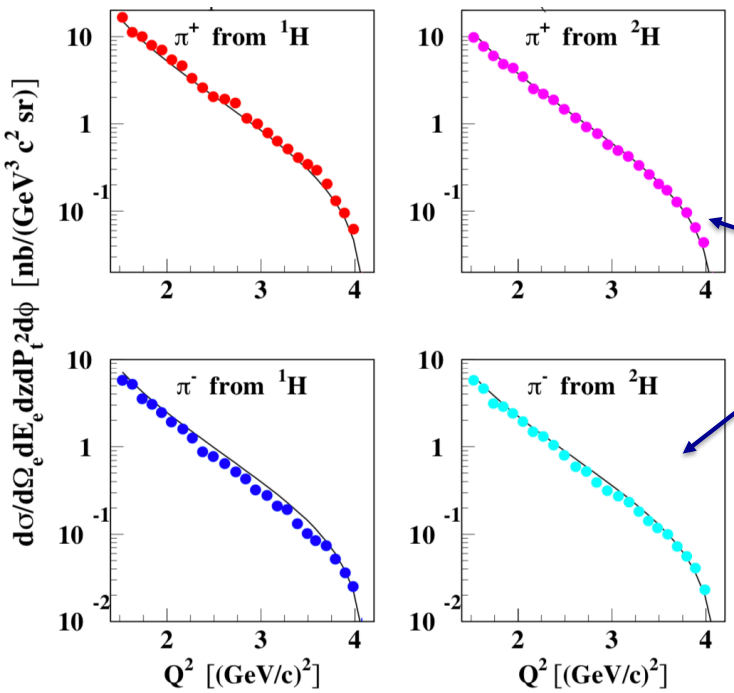


FIG. 10: (Color online) The ^{1,2}H(e,e′$\pi^{\pm}$)X cross sections at fixed values of $x = 0.40$ and $z = 0.55$, as a function of Q^2. The solid curves are the simple quark-parton model calculations following a high-energy factorized description. Solid symbols are data after events from diffractive ρ production are subtracted (see text).

$$P_t^2 < 0.2\ (\mathrm{GeV}/c)^2$$

Semi-Inclusive Charged-Pion Electroproduction off Protons and Deuterons: Cross Sections, Ratios and Access to the Quark-Parton Model at Low Energies

$$F(Q^2) = 1 + C_1 \cdot \ln(Q^2) + \frac{C_2}{Q^2} + \frac{C_3}{Q^4}. \qquad (14)$$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}x_{\mathrm{Bj}}\ \mathrm{d}y\ \mathrm{d}\psi\ \mathrm{d}z_{\mathrm{N}}\ \mathrm{d}^2\boldsymbol{P}_{\mathrm{B,T}}} = \frac{\alpha_{\mathrm{em}}^2 y}{4Q^4 z_{\mathrm{N}}}\ L_{\mu\nu} W^{\mu\nu}_{\mathrm{SIDIS}}$$

Conclusion

- The question of the where the between different factorization-based and partonic pictures apply is an open (empirical) question.

- The question can nevertheless be systematized…