



Quarkonia As Tools 2020

12-18 January, 2020
Centre Paul Langevin
Aussois, France

Opportunities for Measuring TMDs at EIC

(Discussion session on TMDs)

Jianwei Qiu

Theory Center, Jefferson Lab

January 15, 2020

TMDs at EIC

EIC White Paper

□ Semi-Inclusive production of **single hadron** (π , K , ρ , J/ψ , ...):

- ✧ Two-scale: p_T of observed hadron $\ll Q$ in virtual photon – hadron frame
- ✧ Theory: Factorization is solid

- **Low P_{hT} ($P_{hT} \ll Q$) – TMD factorization:**

$$\sigma_{\text{SIDIS}}(Q, P_{h\perp}, x_B, z_h) = \hat{H}(Q) \otimes \Phi_f(x, k_\perp) \otimes \mathcal{D}_{f \rightarrow h}(z, p_\perp) \otimes \mathcal{S}(k_{s\perp}) + \mathcal{O}\left[\frac{P_{h\perp}}{Q}\right]$$

- **High P_{hT} ($P_{hT} \sim Q$) – Collinear factorization:**

$$\sigma_{\text{SIDIS}}(Q, P_{h\perp}, x_B, z_h) = \hat{H}(Q, P_{h\perp}, \alpha_s) \otimes \phi_f \otimes D_{f \rightarrow h} + \mathcal{O}\left(\frac{1}{P_{h\perp}}, \frac{1}{Q}\right)$$

- **P_{hT} Integrated - Collinear factorization:**

$$\sigma_{\text{SIDIS}}(Q, x_B, z_h) = \tilde{H}(Q, \alpha_s) \otimes \phi_f \otimes D_{f \rightarrow h} + \mathcal{O}\left(\frac{1}{Q}\right)$$

- **Very high $P_{hT} \gg Q$ – Collinear factorization:**

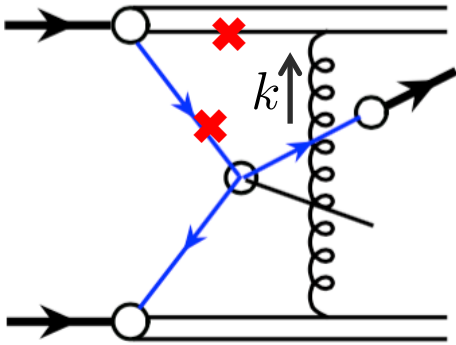
$$\sigma_{\text{SIDIS}}(Q, P_{h\perp}, x_B, z_h) = \sum_{abc} \hat{H}_{ab \rightarrow c} \otimes \phi_{\gamma \rightarrow a} \otimes \phi_b \otimes D_{c \rightarrow h} + \mathcal{O}\left(\frac{1}{Q}, \frac{Q}{P_{h\perp}}\right)$$

□ Lepton/photo production of **two high p_T jets, particles, or combination**:

- ✧ Two-scale: Total and relative momentum of two-jets/particles
- ✧ Theory: Factorization breaking in hadron-hadron does not apply here

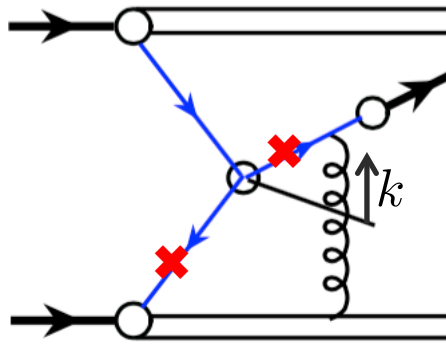
In general, theory is simpler than hadron-hadron case

Pinch, color flow and TMD factorization



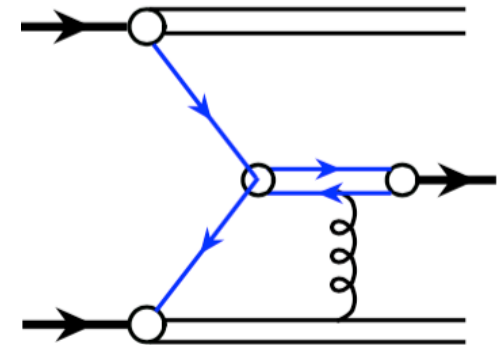
Pinch – Glauber region:

$$k^- = \mathcal{O}(k_{\perp}^2/p^+) \pm i\epsilon$$



No Pinch:

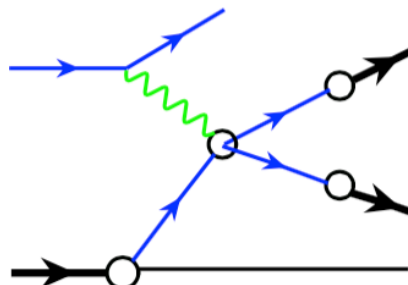
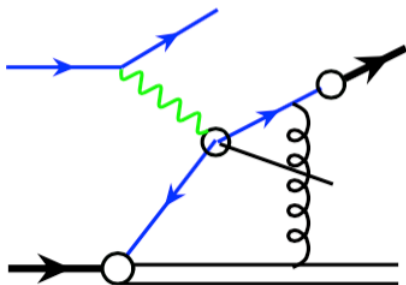
Need p_{\perp} for factorization



Co-mover:

Break the universality of hadronization

□ **SIDIS has no pinch to force into Glauber region, no co-mover problem:**



Jet, D^0 , ...

Same color as initial-state active parton's color

Collins, Qiu, 2007

- ✧ **Factorization breaking in hadron-hadron to 2 jets does not apply here!**
- ✧ **Angular modulation helps to separate various TMDs – Advantage of SIDIS!**
- ✧ **Need other process to help test the universality – TMD FFs**