BASICS OF FACTORIZATION IN A SCALAR YUKAWA FIELD THEORY

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BASED ON [arXiv:2212.00757 [hep-ph]] by
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GOAL

- ❑ To stress-test the limits of factorization
- ❑ Examine the general properties of pdfs

DIS Factorization

- Parton model .... $F_1(x_B; Q^2) \to \int \frac{d\xi}{\xi} \hat{F}_1(x_B/\xi; Q^2) f(\xi)$

↓

- Renomalizable QFT ... $F_1(x_B; Q^2) \to \int \frac{d\xi}{\xi} \hat{F}_1[x_B/\xi, \mu^2/Q^2; g(\mu)] f[\xi; \mu/\Lambda; g(\mu)] + \mathcal{O}(\frac{m^2}{Q^2})$

- ➢ Do the naïve expectations from a parton model framework hold for the theories that require renormalization?
- ➢ How important are the higher twists?
- ➢ .....

HOW?

❑ Using Yukawa theory

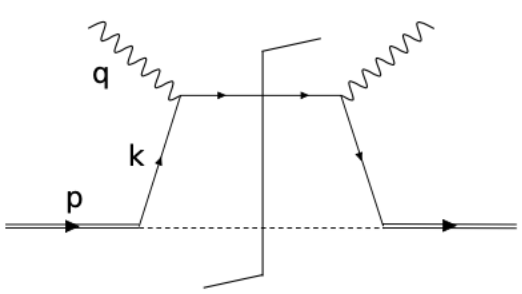
QCD	Yukawa
• Non-perturbative	• Perturbative
• Confinement	• Hadron state is not a bound state
• Asymtotic freedom	• All interactions are pointlike
• Soft gluons	• Renormalizable
• Light-cone divergences	
• Renormalizable	

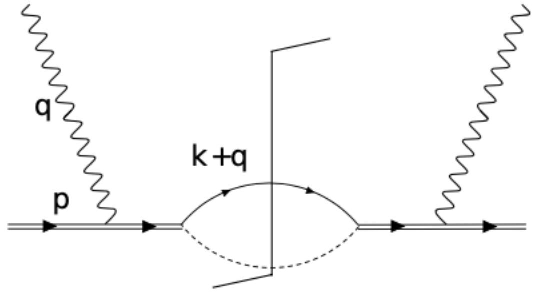
- ➢ Yukawa is simpler than QCD but still useful for highlighting general but subtle properties of parton densities and for examining the limits of factorization while side stepping issues like confinement, large coupling, gauge invariance, and other complicating features of QCD.

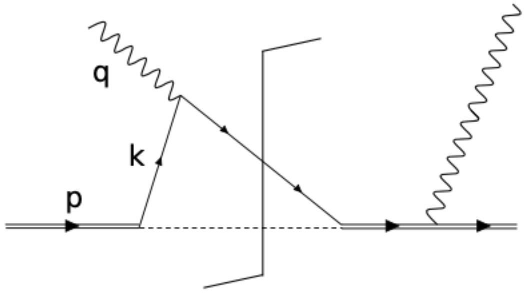
- ➢ It is possible to compare the unfactorized results with standard collinear and TMD factorization treatments.

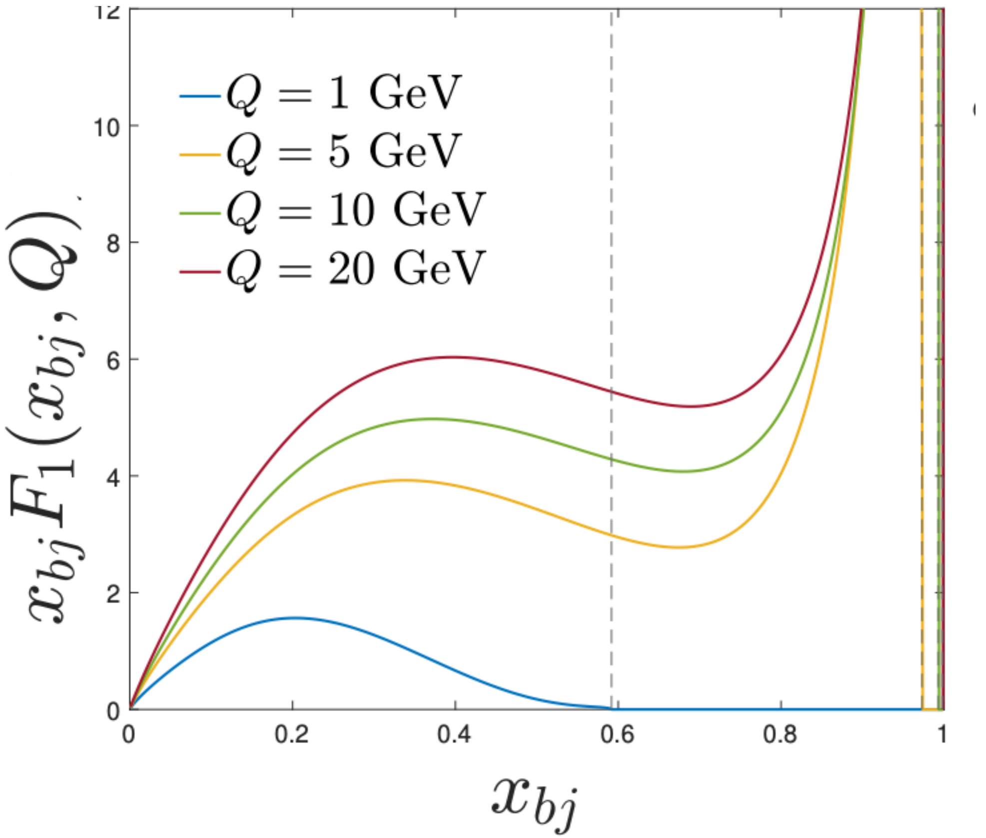
THE EXACT/UNAPPROXIMATED STRUCTURE FUNCTIONS IN YUKAWA MODEL

$$\mathcal{L}_{\text{int}} = -\lambda \overline{\Psi}_N \psi_q \phi \ + \ \text{H.C.}.$$









$$x_{\max} = \frac{Q^2}{[(m_q + m_s)^2 - m_p^2 + Q^2]}.$$

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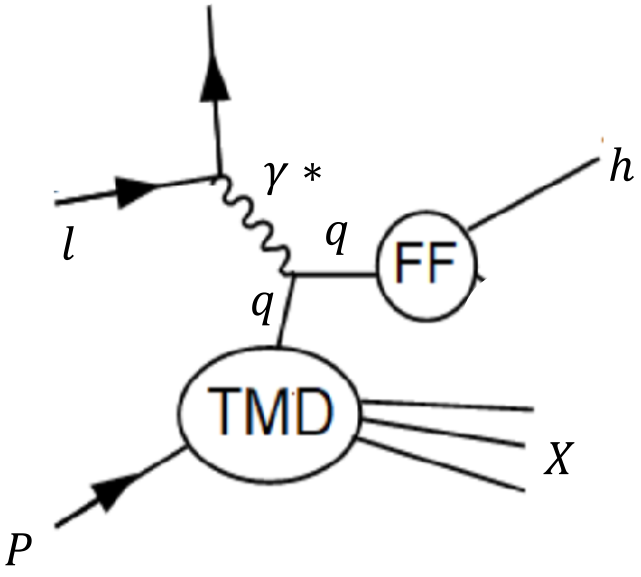
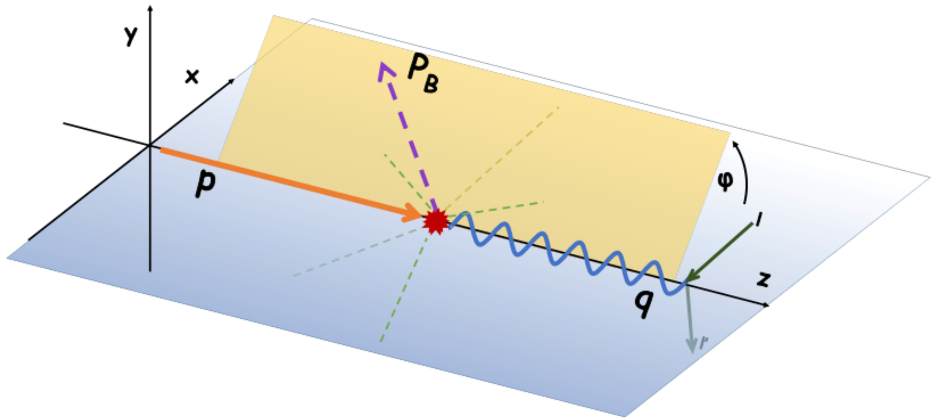
FACTORIZED RESULTS: SIDIS and TMD Factorization



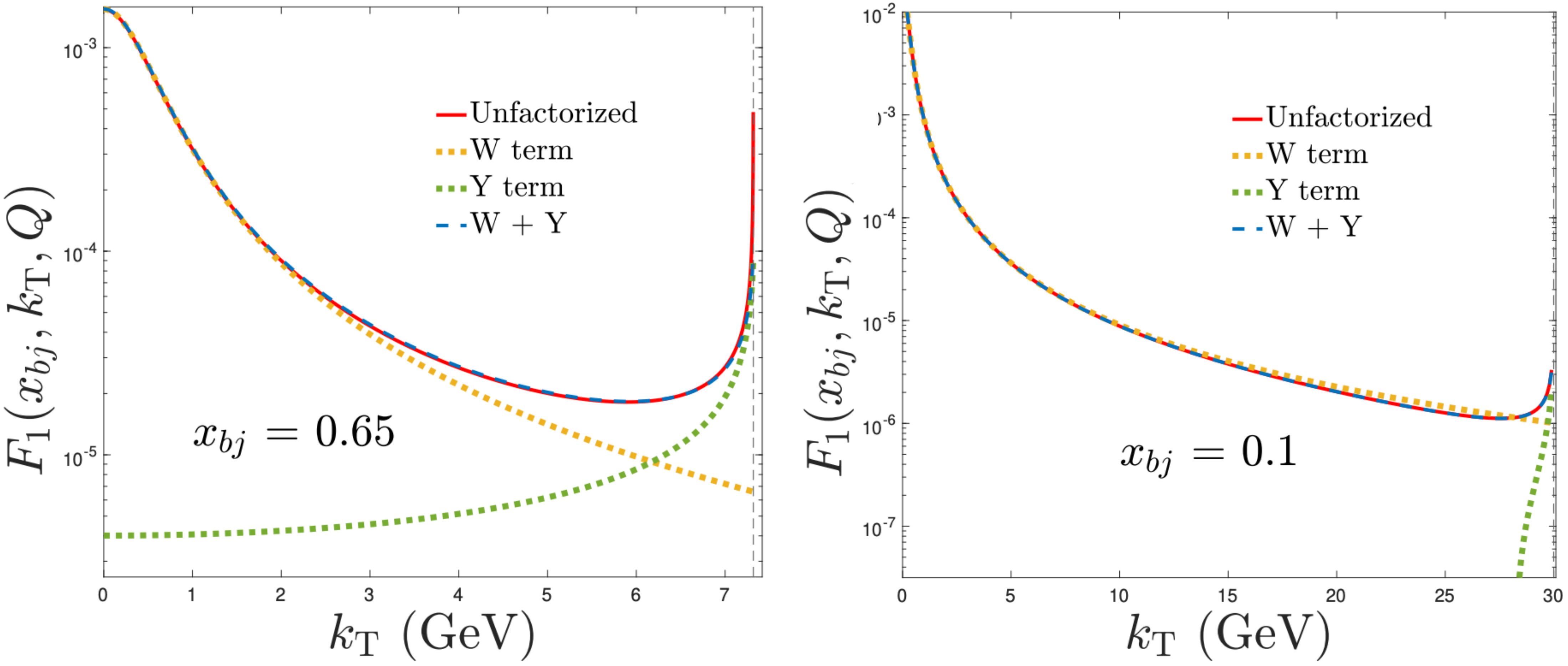


Two types of factorization schemes!

$$F_1(x_{\rm bj}, Q, \boldsymbol{k}_{\rm T}) = {\rm T}_{\rm small} F_1(x_{\rm bj}, Q, \boldsymbol{k}_{\rm T}) + {\rm T}_{\rm large}\left[F_1(x_{\rm bj}, Q, \boldsymbol{k}_{\rm T}) - {\rm T}_{\rm small} F_1(x_{\rm bj}, Q, \boldsymbol{k}_{\rm T})\right] + \mathcal{O}\left(\frac{k_{\rm T}^2}{Q^2} \times \frac{m^2}{k_{\rm T}^2}\right).$$

$$= \text{W-term} + \text{Y-term} + \mathcal{O}\left(\frac{m^2}{Q^2}\right).$$

EXACT VS FACTORIZED RESULTS



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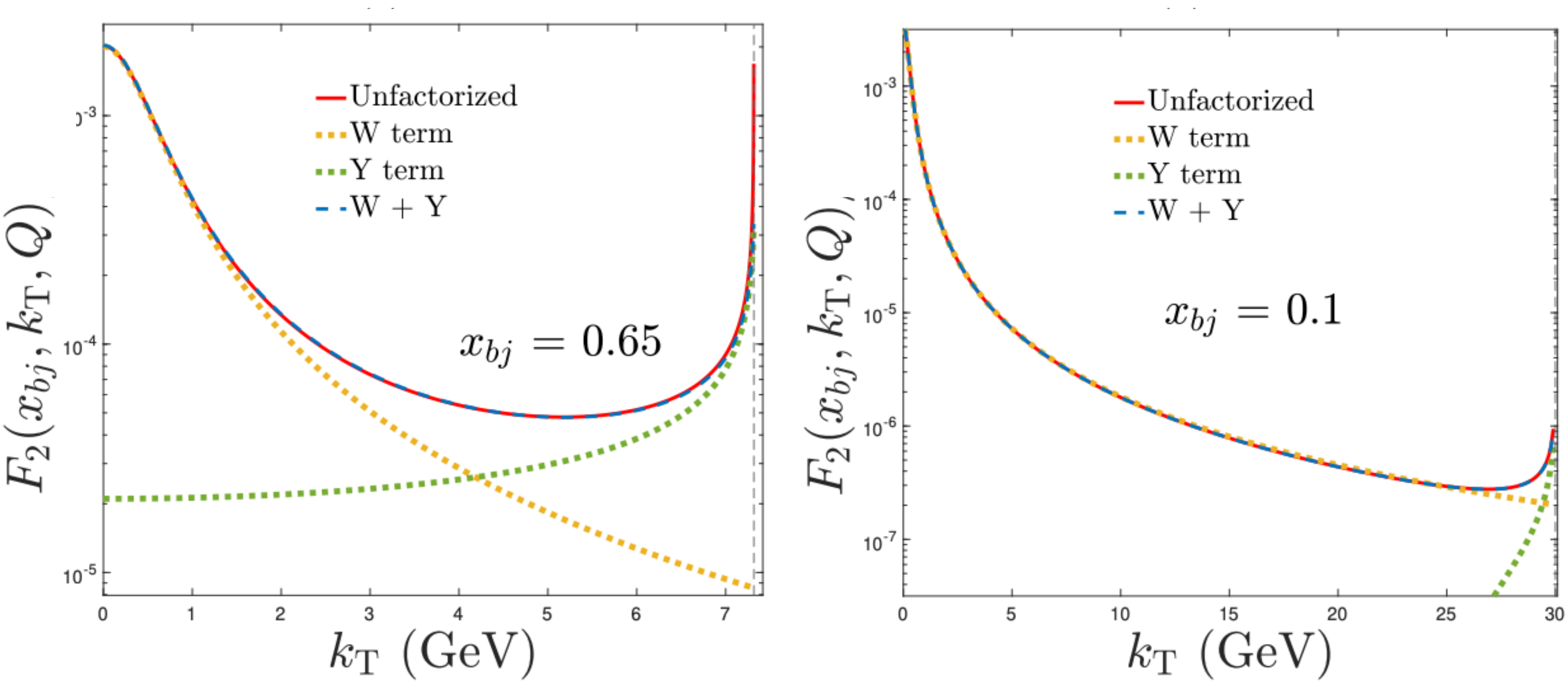

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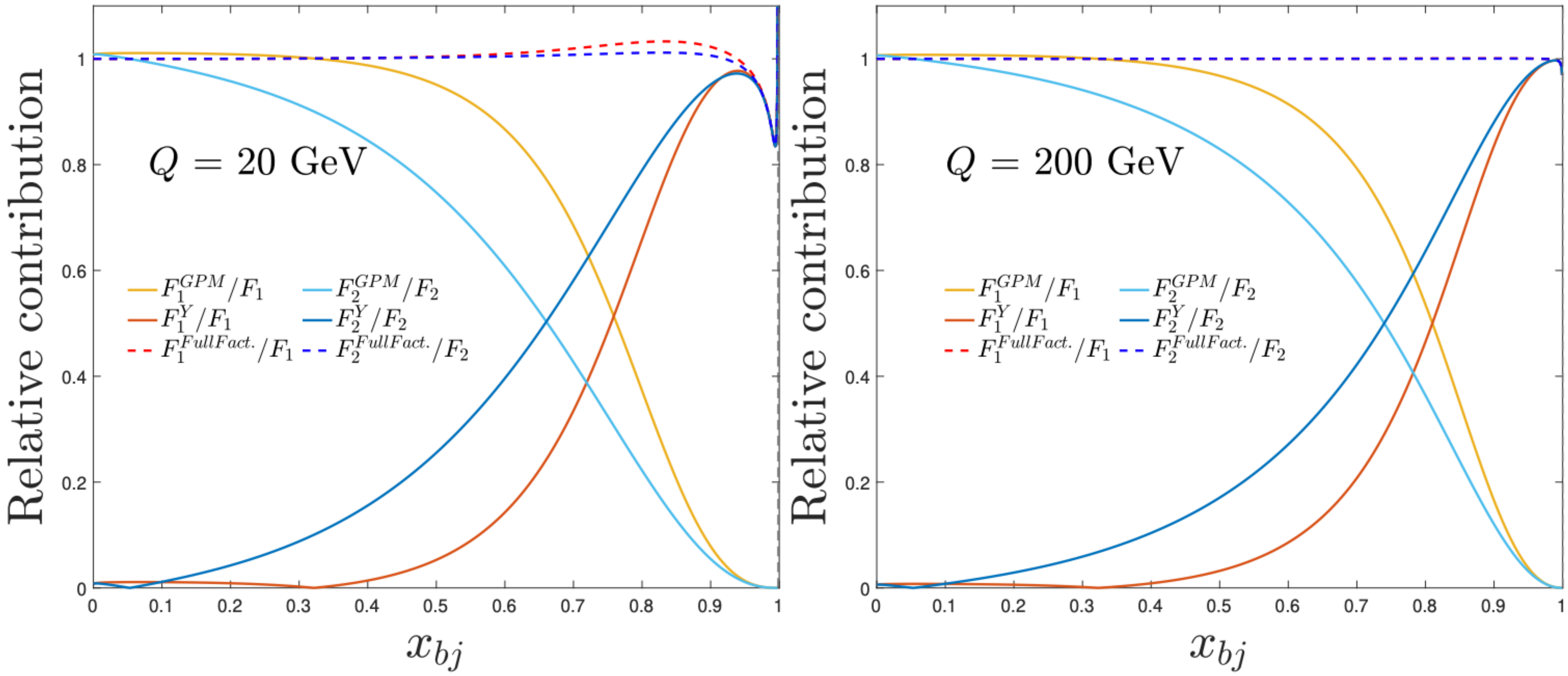

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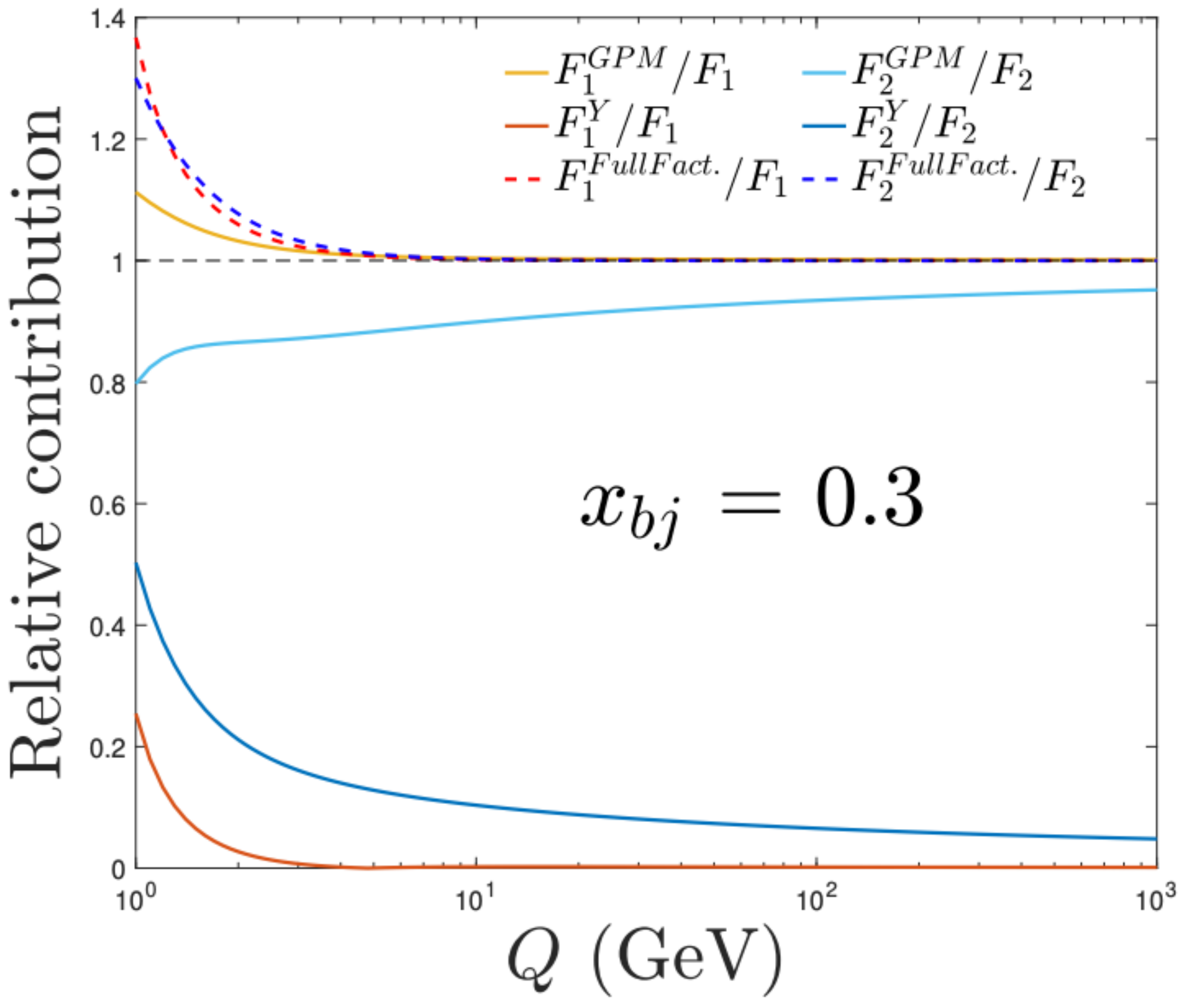
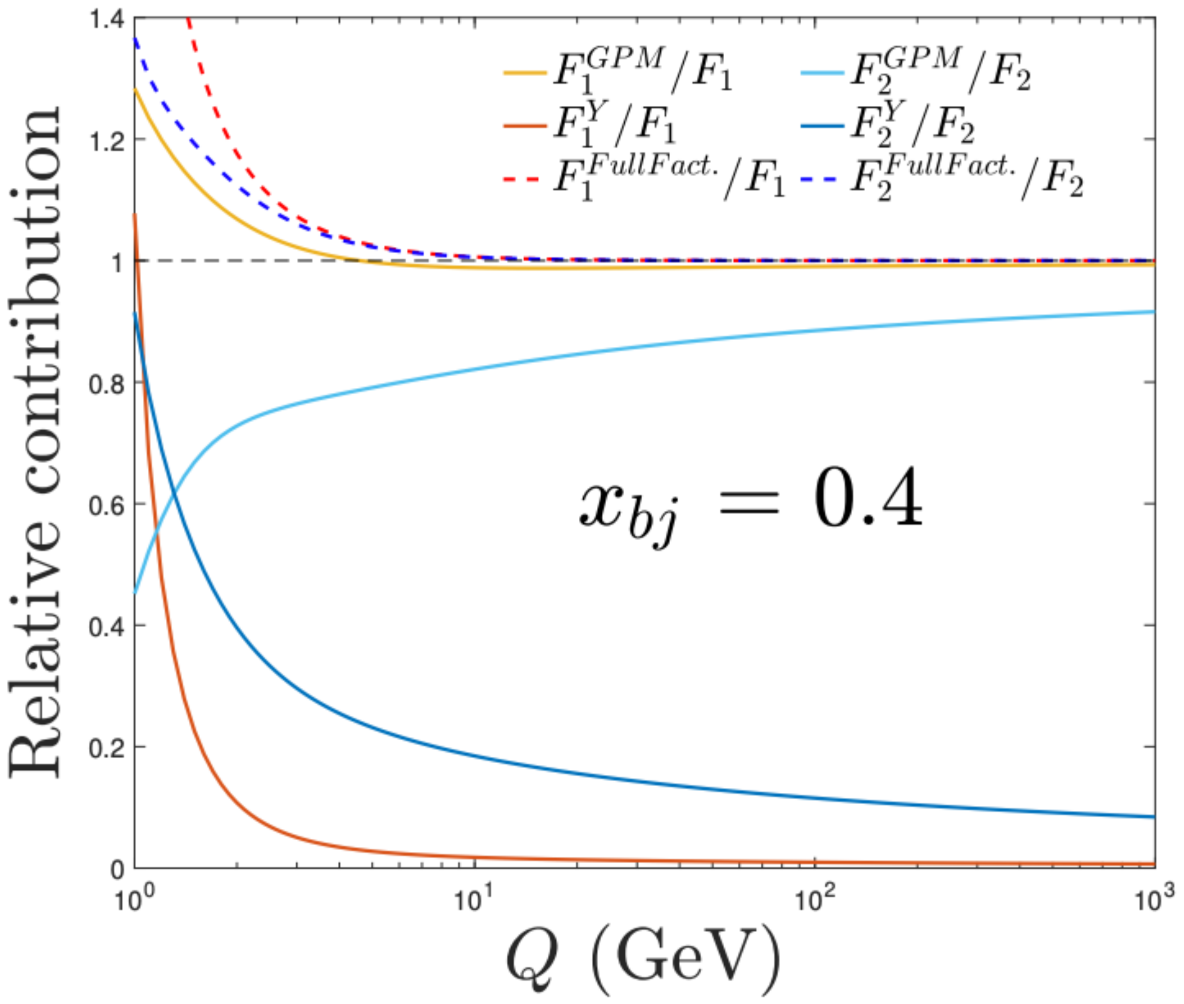
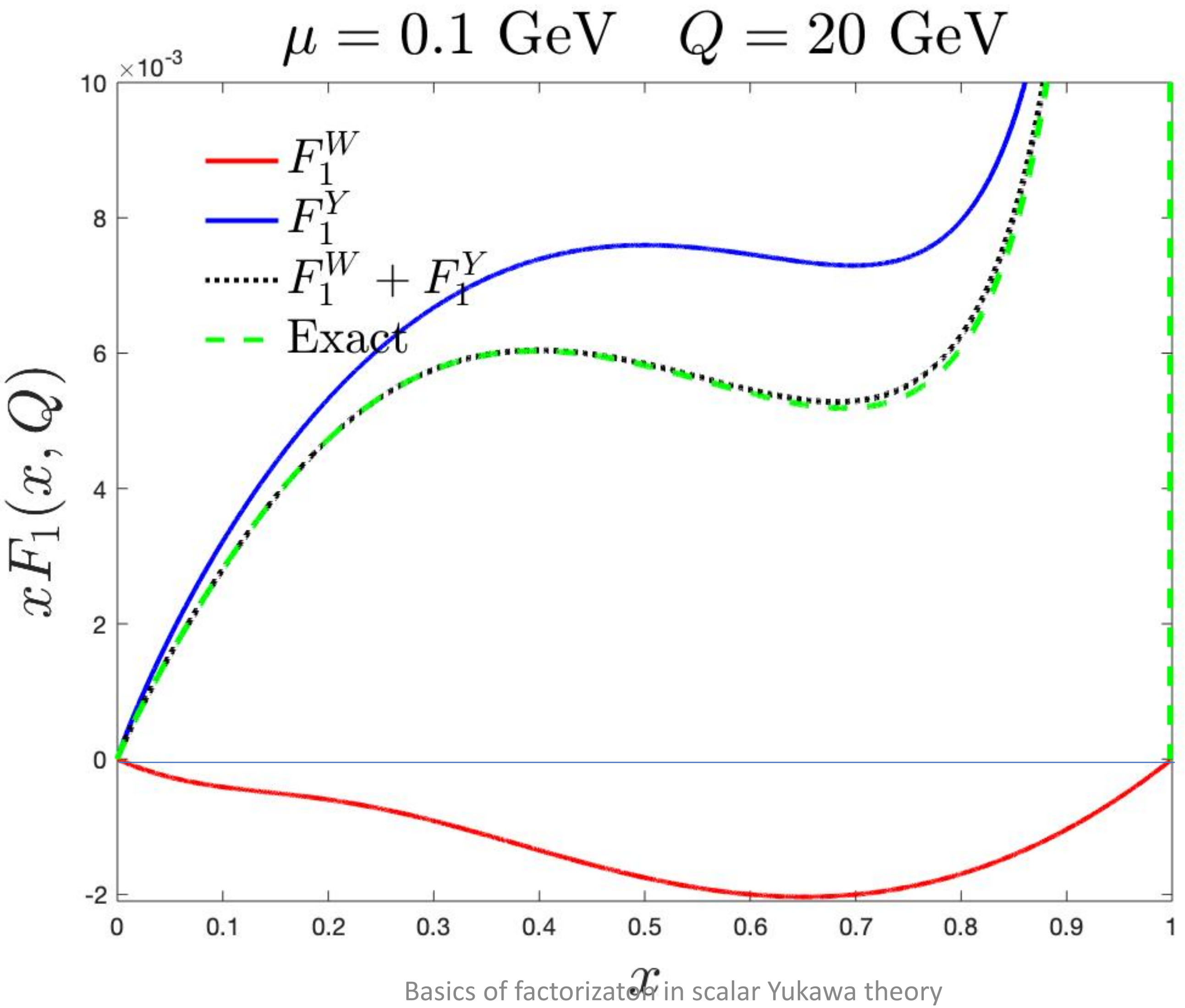




EXACT VS FACTORIZED RESULTS

$$F_{1,2}(x_{\rm bj}, Q; \mu) = F^{W}_{1,2}(x_{\rm bj}, Q; \mu) + F^{Y}_{1,2}(x_{\rm bj}, Q; \mu) + \mathcal{O}\left(\frac{m^2}{Q^2}\right).$$



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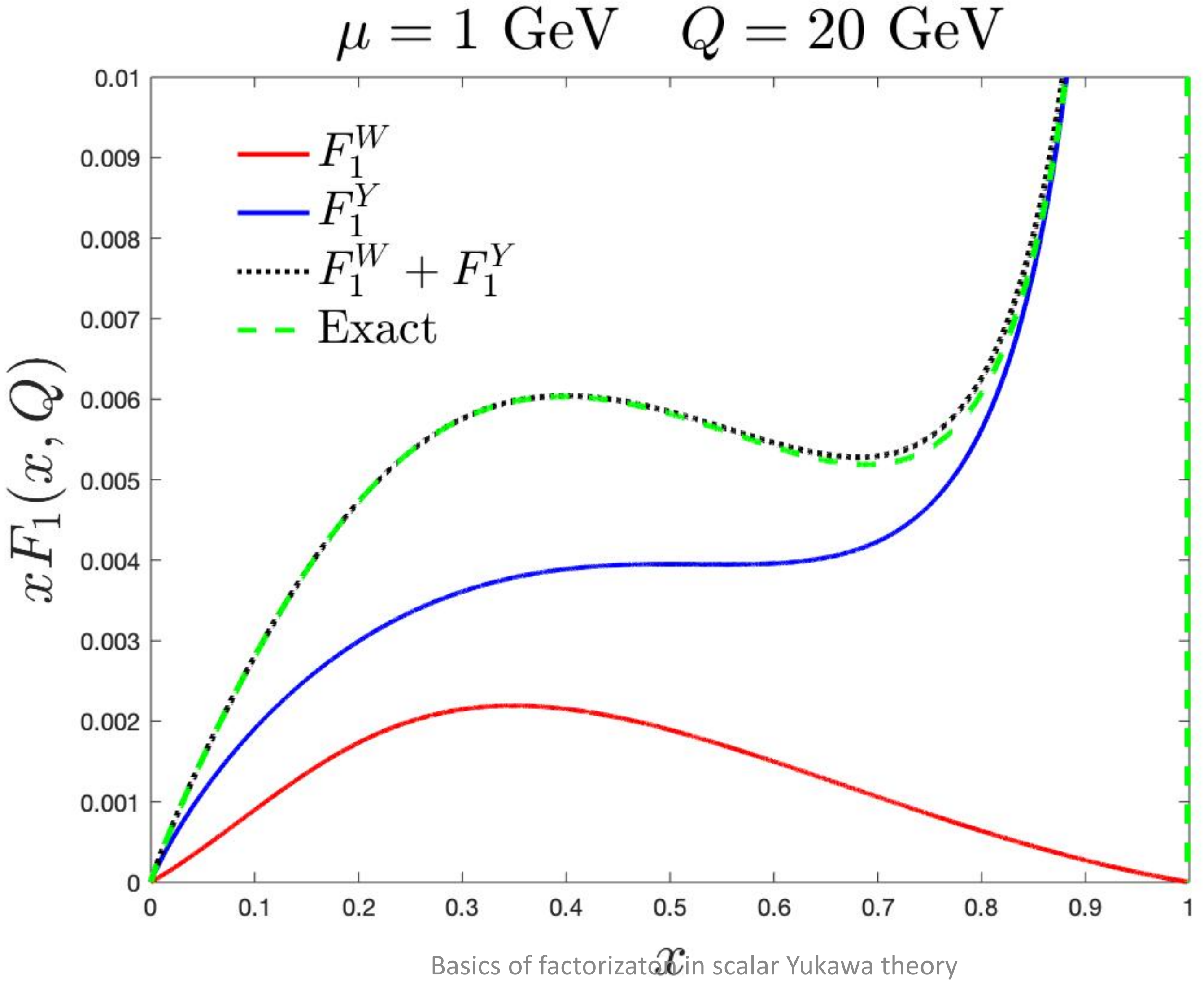

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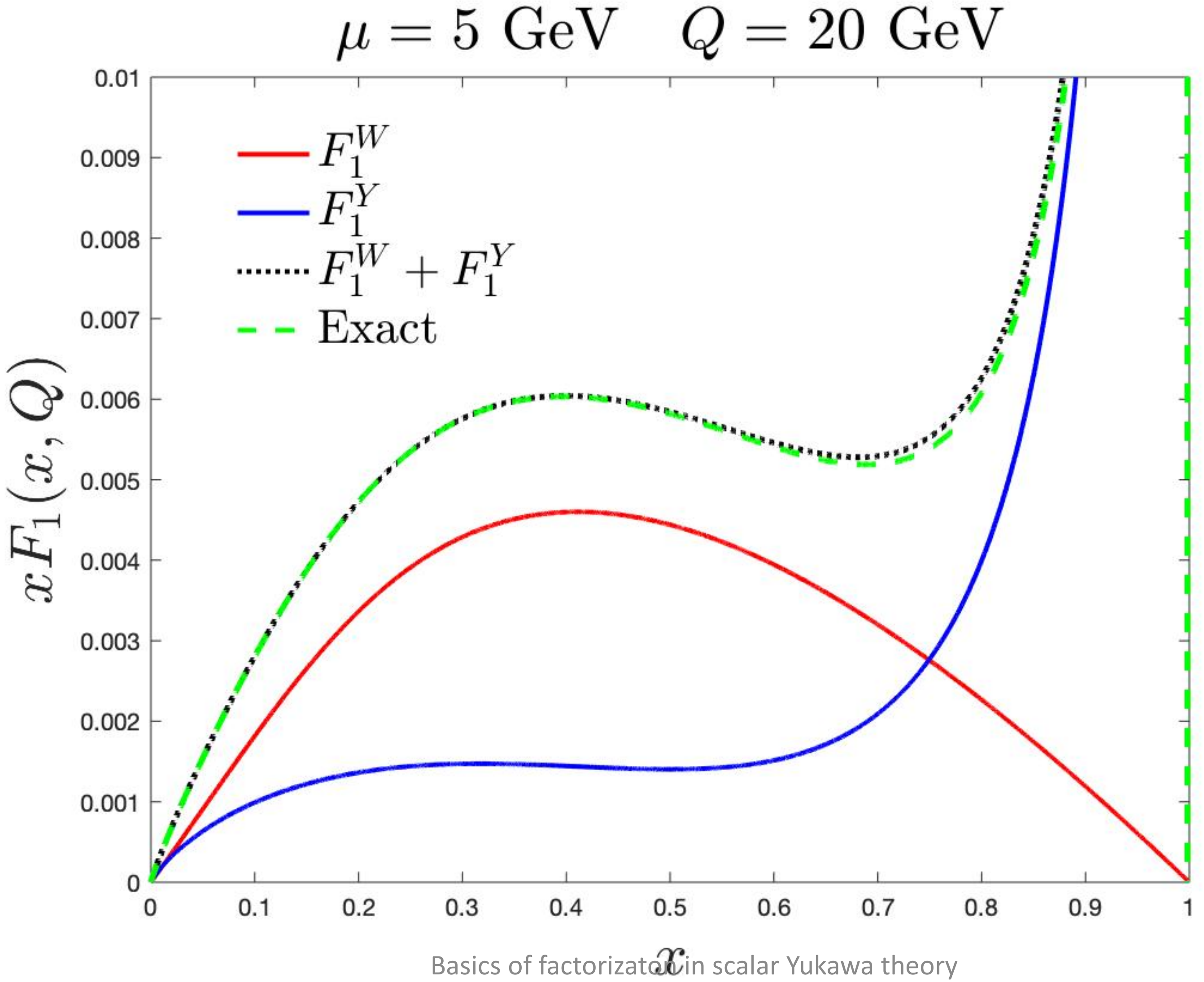

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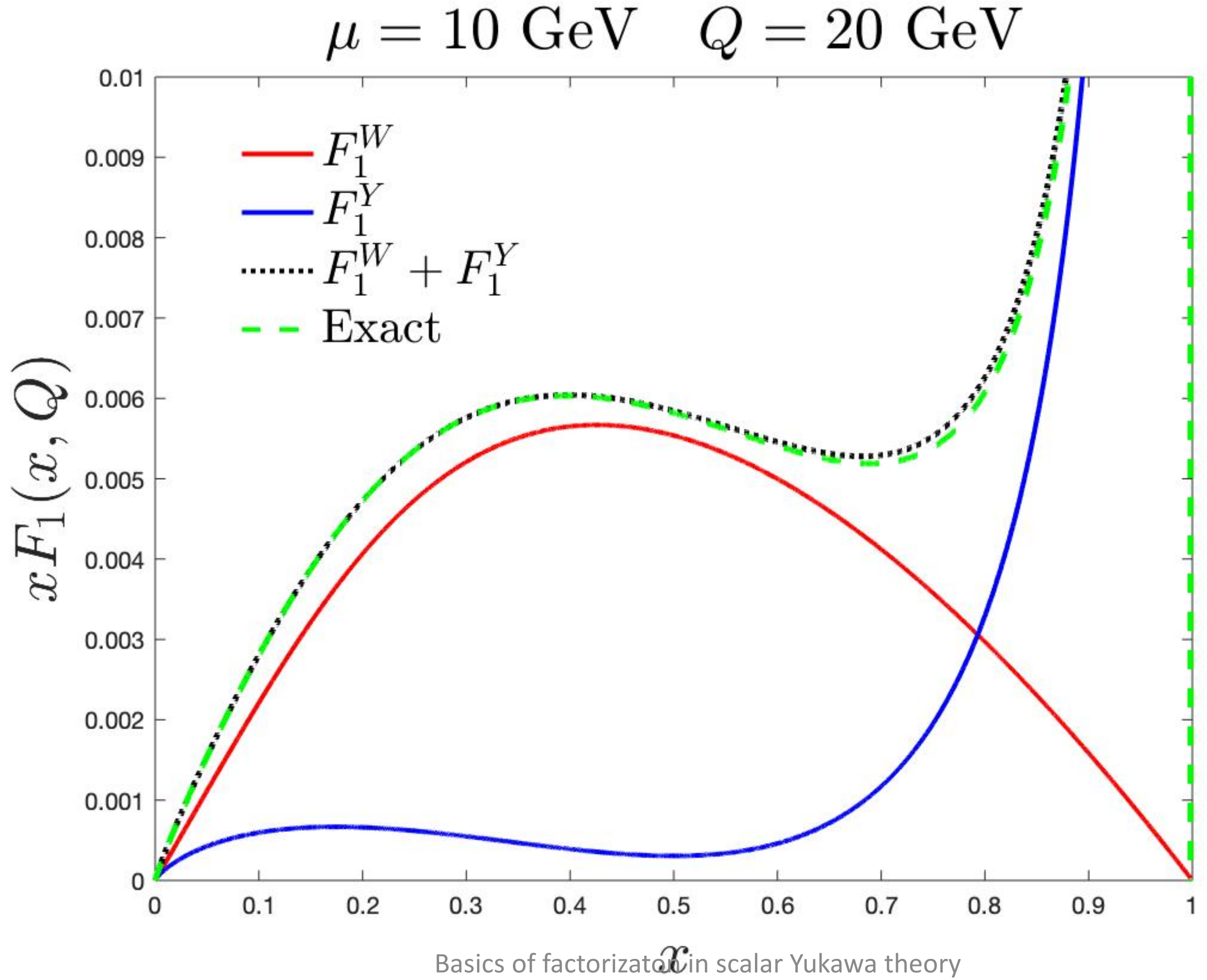

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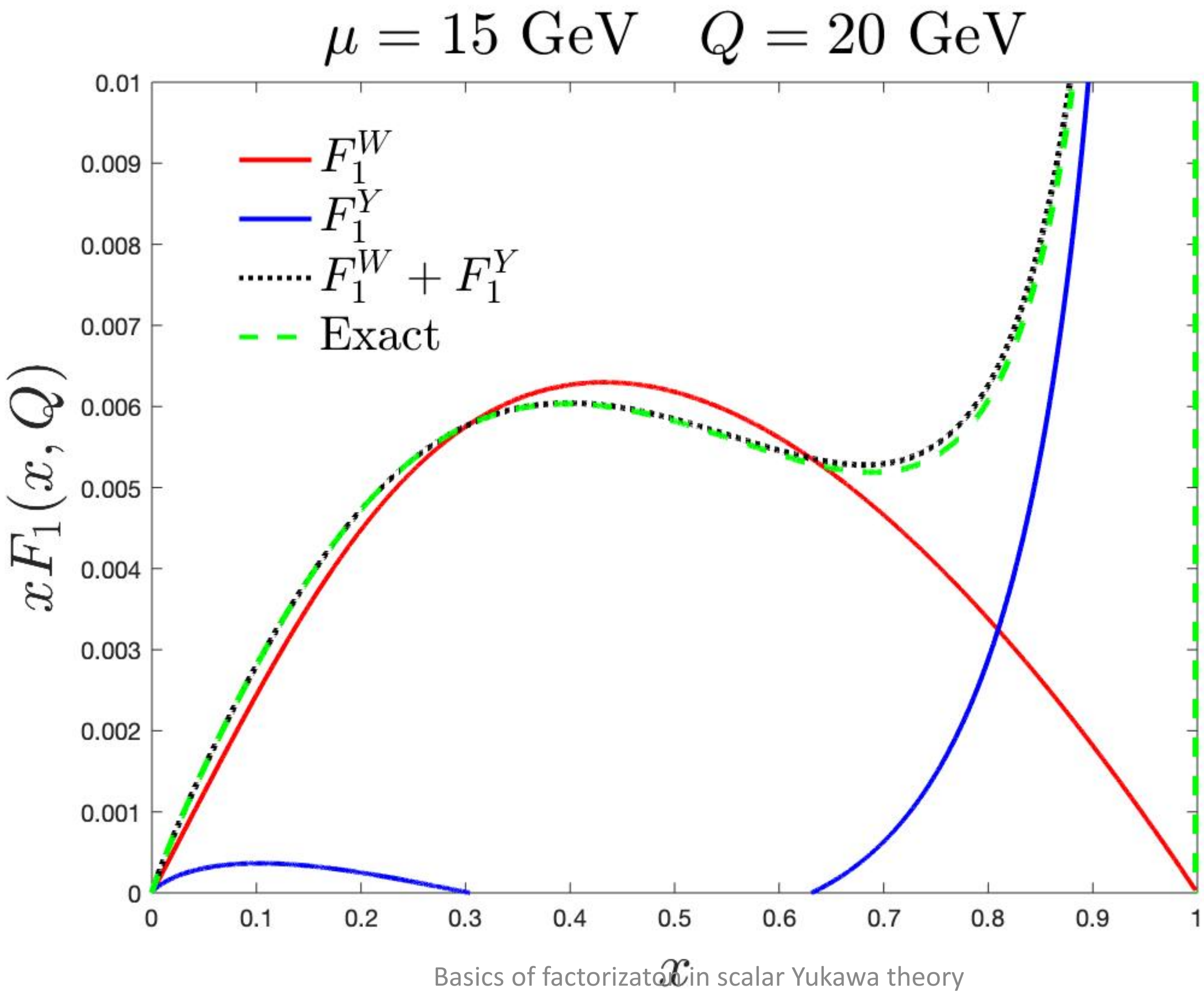

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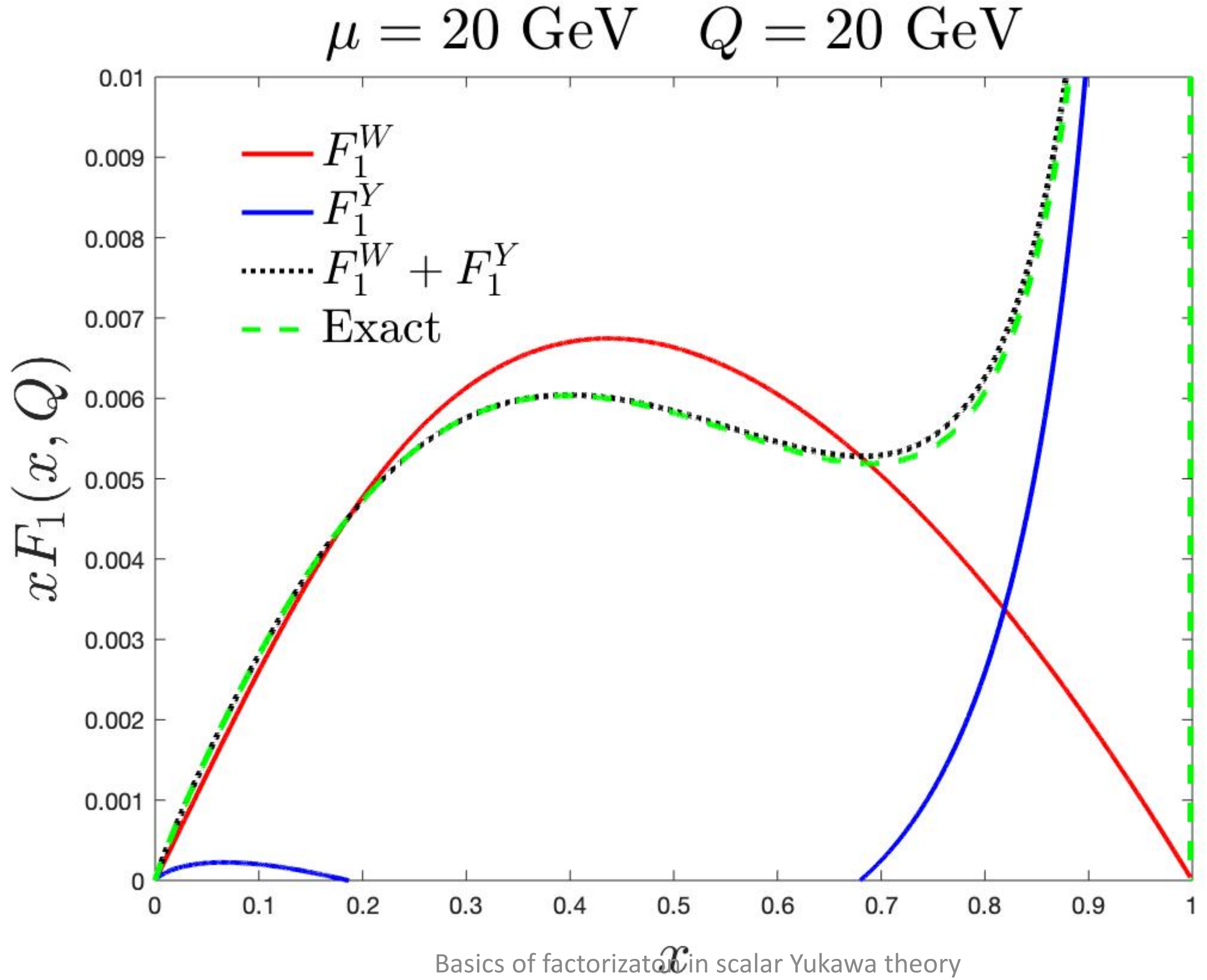
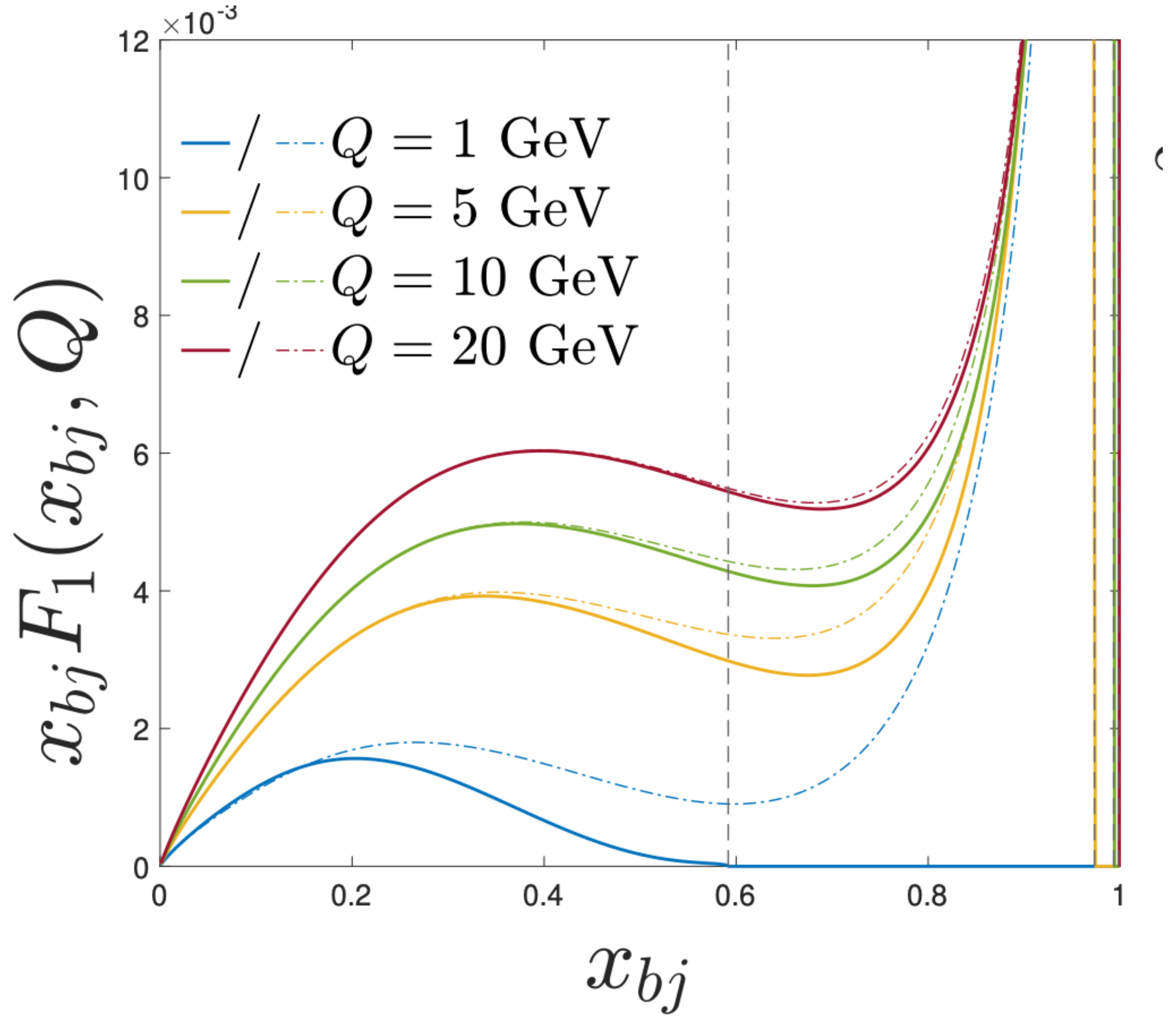


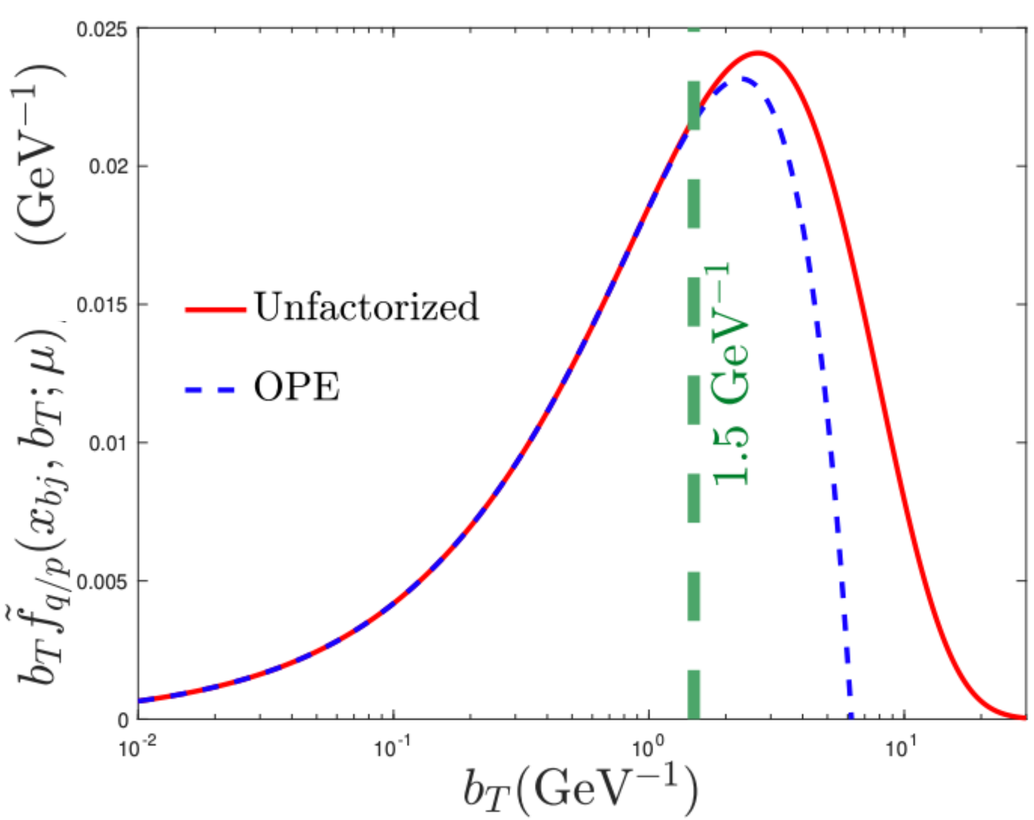
THE INPUT SCALE (Q_0)

$$F_1(x_B;Q^2) \to \int \frac{d\xi}{\xi}\hat{F}_1[x_B/\xi, \mu^2/Q^2; g(\mu)] f[\xi;\mu/\Lambda; g(\mu)] + \mathcal{O}(\frac{m^2}{Q^2})$$

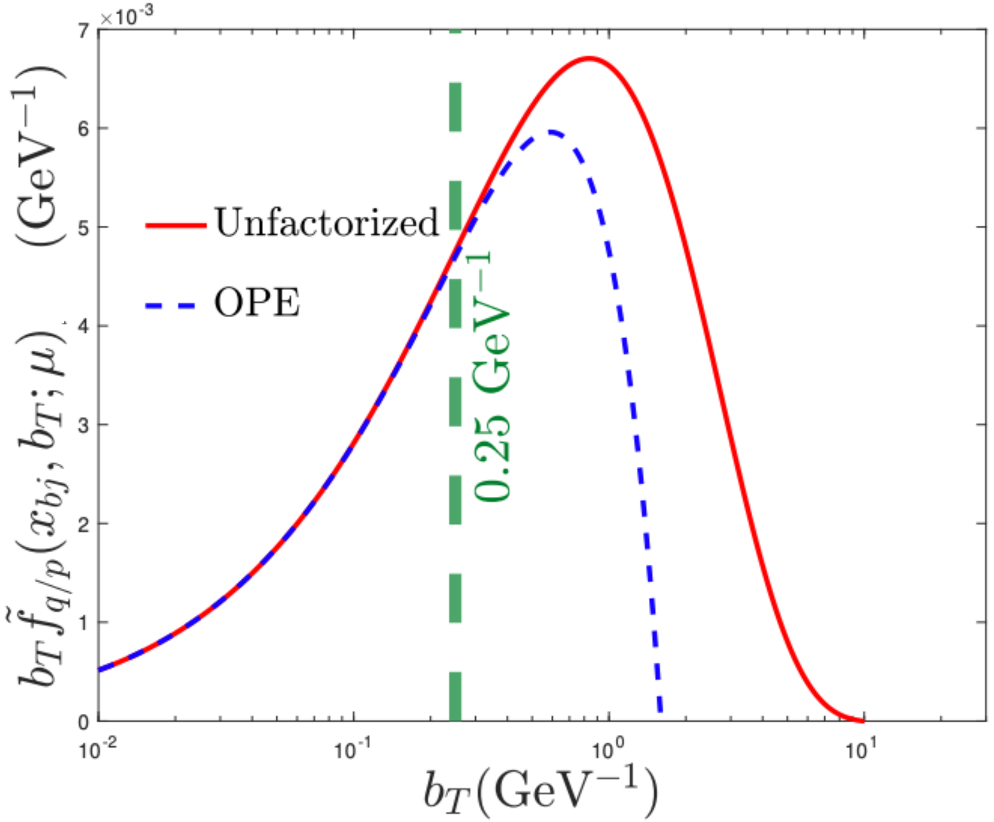


TRANSVERSE COORDINATE (b_T) SPACE

$$f(x_{bj}, \mathrm{b_T}) = \begin{cases} f^{\mathrm{OPE}}(x_{bj}, b_*) & b_T \ll b_{max} \\ f^{\mathrm{OPE}}(x_{bj}, b_*) e^{-g(x_{bj}, b_T)} & b_T > b_{max} \end{cases}$$



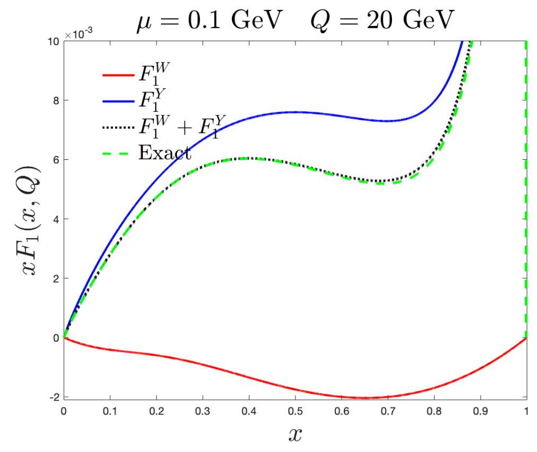
$m_q = 0.3$ GeV, $m_p = 1.0$ GeV, $m_s = 1.0$ GeV

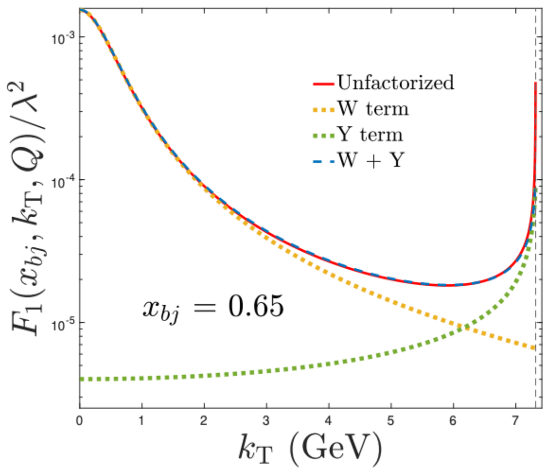


$m_q = 0.3$ GeV, $m_p = 1.0$ GeV $m_s = 1.5$ GeV

CONCLUSIONS

- The naïve expectations from a parton model framework may not hold for the theories that require renormalization
- The Y-term contribution is necessary to maintain a good agreement with the exact results





OUTLOOK

- Repeating the calculation for the polarized case

THANK YOU FOR YOUR ATTENTION