Leading twist light-cone distribution amplitudes of vector meson from large momentum effective theory

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OUTLINE

- Motivation
- Large momentum effective theory (LaMET)
- One loop results of vector meson distribution amplitudes in UV cut-off scheme
  - Transverse distribution amplitudes
  - Longitudinal distribution amplitudes
- Matching equation
- Matching coefficients with a finite cut-off
- One loop results in dimensional regularization under $\overline{MS}$ scheme
- Summary

Motivation:

- **Light-cone distribution amplitude (LCDA):**
  - Characterize the structure of hadron;
  - Essential for analysis of exclusive processes in factorization theorem;
  - Crucial in perturbative QCD approach (PQCD), light-cone sum rule (LCSR)……
  - **Non-perturbative**, can not be calculated with QCD perturbation theory.

- **Large momentum effective theory (LaMET):**
  - Calculate the **equal-time correlators (quasi quantities)** instead of the light-cone ones;
  - The matrix elements defined by these equal-time correlators can be **simulated on the lattice**.

Large momentum effective theory (LaMET):

- The quasi and light-cone quantities have the **same** infrared (IR) behavior, the ultraviolet (UV) behaviors are **different**, the difference is involved in the matching coefficient.
- Under the large P_z limit, the quasi observables can be **factorized as** the convolution of **perturbatively calculable coefficients** and the **standard light-cone observables**.
- Quasi observables can be extracted from **lattice simulation**. So this work gives the feasibility of evaluating LCDAs from the first principle of QCD.

LCDAs and Quasi DAs

LCDA	Quasi DA
Non-perturbative, LCDAs can not be calculated with QCD perturbation theory.	Time-independent spacelike correlation, can be simulated on a Euclidean lattice.
Light-cone coordinate	Cartesian coordinate
Wilson line is a light-like straight line	Wilson line is along the z-direction
Gauge vector $n^{\mu} = (1,0,\mathbf{0})$ along the n_{+} direction	Gauge vector $n_z^{\mu} = (0,0,0,1)$ along the z-direction

Defined as the ratio of the non-local and local matrix elements:

$$\phi_V^{\Gamma}(x,\mu) = \frac{\langle V, P, \epsilon^* | O_V^{\Gamma}(x) | 0 \rangle}{\langle V, P, \epsilon^* | \mathcal{O}_V^{\Gamma}(0) | 0 \rangle}$$

$$\widetilde{\phi}_V^{\Gamma}(x,\mu) = \frac{\langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle}{\langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle}$$

One loop results in the ultraviolet cut-off scheme:

The distribution amplitude up to one loop level:

$$\widetilde{\phi}_V^{\Gamma}(x, P_z, \Lambda) = \widetilde{\phi}_V^{\Gamma(0)}(x, P_z) + \widetilde{\phi}_V^{\Gamma(1)}(x, P_z, \Lambda) + \mathcal{O}(\alpha_s^2) \qquad \phi_V^{\Gamma(0)}(x) = \widetilde{\phi}_V^{\Gamma(0)} = \delta(x - x_0)$$

The matrix element $\widetilde{O}_V^{\Gamma}(x)$, up to one loop level:

$$\langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle = \langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle^{(0)} (1 + \delta Z_F^{(1)}) + \langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle^{(1)} + \mathcal{O}(\alpha_s^2)$$

Local matrix elements are also corrected at one loop:

$$\langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle = \langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle^{(0)} (1 + \delta Z_F^{(1)} + \delta \widetilde{Z}_V^{\Gamma(1)}) + \mathcal{O}(\alpha_s^2)$$

Quarks' self energy **cancels** between the non-local and local matrix elements, **not contribute** to the DAs.

Then

$$\widetilde{\phi}_V^{\Gamma(0)}(x) = \frac{\langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle^{(0)}}{\langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle^{(0)}},$$

$$\widetilde{\phi}_V^{\Gamma(1)}(x) = \frac{\langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle^{(1)}}{\langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle^{(0)}} - \frac{\langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(x) | 0 \rangle^{(0)}}{\langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle^{(0)}} \int dy \frac{\langle V, P, \epsilon^* | \widetilde{O}_V^{\Gamma}(y) | 0 \rangle^{(1)}}{\langle V, P, \epsilon^* | \widetilde{\mathcal{O}}_V^{\Gamma}(0) | 0 \rangle^{(0)}}.$$

Transverse distribution amplitudes

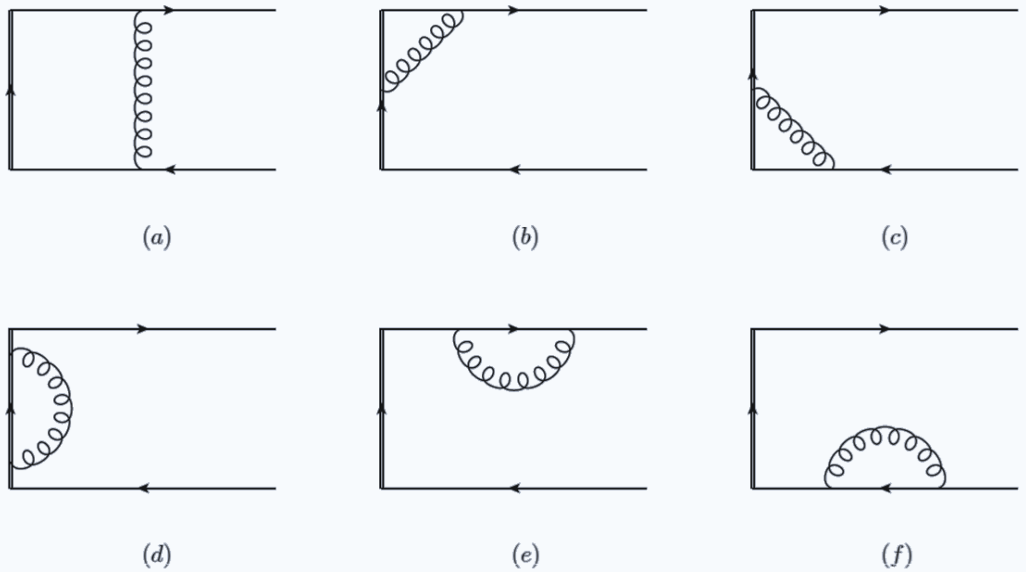
$$\phi_V^{\perp(1)}(x,\Lambda)\Big|_{\text{Fig. }1(a)} = \tilde{\phi}_V^{\perp(1)}(x,P_z,\Lambda)\Big|_{\text{Fig. }1(a)} = 0$$

$$\phi_V^{\perp(1)}(x,\Lambda)\Big|_{\text{Fig. }1(b)} = \frac{\alpha_s C_F}{2\pi}\begin{cases}\left[\frac{x}{x_0(x-x_0)}\ln\frac{m_g^2 x}{\Lambda^2 x_0}\right]_+, & 0<x<x_0,\\ 0, & \text{others}\end{cases}$$

$$\tilde{\phi}_V^{\perp(1)}(x,P_z,\Lambda)\Big|_{\text{Fig. }1(b)} = \frac{\alpha_s C_F}{2\pi}\begin{cases}\left[\frac{x}{x_0(x-x_0)}\ln\frac{x}{x-x_0}-\frac{1}{2(x-x_0)}\right]_+, & x<0\\ \left[\frac{x}{x_0(x-x_0)}\ln\frac{m_g^2}{4P_z^2 x_0(x_0-x)}+\frac{2x-x_0}{2x_0(x-x_0)}\right]_+, & 0<x<x_0\\ \left[\frac{x}{x_0(x-x_0)}\ln\frac{x-x_0}{x}+\frac{1}{2(x-x_0)}\right]_+, & x>x_0\end{cases}$$

$$\phi_V^{\perp(1)}(x,\Lambda)\Big|_{\text{Fig.1(c)}} = \phi_V^{\perp(1)}(x,\Lambda)\Big|_{\text{Fig.1(b)}}(x_0\to 1-x_0, x\to 1-x)$$

$$\tilde{\phi}_V^{\perp(1)}(x,P_z,\Lambda)\Big|_{\text{Fig.1(c)}} = \tilde{\phi}_V^{\perp(1)}(x,P_z,\Lambda)\Big|_{\text{Fig.1(b)}}(x_0\to 1-x_0, x\to 1-x)$$



In Fig. 1(b, c), one end of the internal gluon is attached to the Wilson line, thus there is an eikonal propagator, which is proportional to $1/(x - x_0)$

X. ~Ji, J. ~H. ~Zhang and Y. ~Zhao,

Transverse distribution amplitudes

Wilson line's self energy corrections, which is proportional to n^2, n is the gauge vector in Wilson line.

$$\phi_V^{\perp(1)}(x,\Lambda)\Big|_{\mathrm{Fig.~1}(d)} = 0$$

$$\boldsymbol{n_\perp^2 = 0 \qquad n_z^2 = -1}$$

$$\tilde{\phi}_V^{\perp(1)}(x,P_z,\Lambda)\Big|_{\mathrm{Fig.~1}(d)} = \frac{\alpha_s C_F}{2\pi}\begin{cases}\left[\frac{1}{x-x_0}+\frac{\Lambda}{(x-x_0)^2 P_z}\right]_+, & x<x_0\\ \left[-\frac{1}{x-x_0}+\frac{\Lambda}{(x-x_0)^2 P_z}\right]_+, & x>x_0\end{cases}$$

Linear divergence!

Power divergence in Wilson line's self energy can be canceled by introducing a "**mass counter term**" of the Wilson line. To do this, we replace the operator in this figure by the "improved" operator:

$$\tilde{O}_V^{\Gamma\ \mathrm{imp.}}(x) = \int \frac{dz}{2\pi} e^{-ixzP_z - \delta m|z|}\tilde{O}^\Gamma(z)$$

Phys.Rev.Lett.120,112001(2018), X. Ji, J.H. Zhang and Y. Zhao,

the mass counter term δ_m of the Wilson line can be extracted by using the static quark potential.

Perturbative calculation shows that the contribution from δ_m cancels the linearly divergent term in $\tilde{\phi}_V^{\perp(1)}$.

Longitudinal distribution amplitudes

$$\phi_V^{\|(1)}(x,\Lambda)\Big|_{\text{Fig. 1}(a)} = \frac{\alpha_s C_F}{2\pi}\begin{cases} \left[-\dfrac{x}{x_0}\ln\dfrac{m_g^2 x}{\Lambda^2 x_0}\right]_+, & 0<x<x_0 \\ \left[-\dfrac{x-1}{x_0-1}\ln\dfrac{m^2(x-1)}{\Lambda^2(x_0-1)}\right]_+, & x_0<x<1 \\ 0, & \text{others} \end{cases}$$

$$\tilde{\phi}_V^{\|(1)}(x,P_z,\Lambda)\Big|_{\text{Fig. 1}(a)} = \frac{\alpha_s C_F}{2\pi}\begin{cases} \left[\dfrac{x-1}{x_0-1}\ln\dfrac{x-1}{x-x_0}-\dfrac{x}{x_0}\ln\dfrac{x}{x-x_0}\right]_+, & x<0 \\ \left[-\dfrac{x}{x_0}\ln\dfrac{m_g^2}{4P_z^2 x_0(x_0-x)}-\dfrac{x-1}{x_0-1}\ln\dfrac{x-x_0}{x-1}\right]_+, & 0<x<x_0 \\ \left[-\dfrac{x-1}{x_0-1}\ln\dfrac{m_g^2}{4P_z^2(x_0-1)(x_0-x)}-\dfrac{x}{x_0}\ln\dfrac{x-x_0}{x}\right]_+, & x_0<x<1 \\ \left[\dfrac{x}{x_0}\ln\dfrac{x}{x-x_0}-\dfrac{x-1}{x_0-1}\ln\dfrac{x-1}{x-x_0}\right]_+, & x>1 \end{cases}$$

$$\phi_V^{\|(1)}(x,\Lambda)\Big|_{\text{Fig. 1}(b)} = \frac{\alpha_s C_F}{2\pi}\begin{cases} \left[\dfrac{x}{x_0(x-x_0)}\ln\dfrac{m_g^2 x}{\Lambda^2 x_0}\right]_+, & x_0<x<1 \\ 0, & \text{others} \end{cases}$$

Longitudinal distribution amplitudes

$$\tilde{\phi}_V^{\parallel(1)}(x,P_z,\Lambda)\Big|_{\text{Fig. 1}(b)} = \frac{\alpha_s C_F}{2\pi}\begin{cases} \left[\frac{x}{x_0(x-x_0)}\ln\frac{x}{x-x_0} - \frac{1}{2(x-x_0)}\right]_+, & x<0 \\ \left[\frac{x}{x_0(x-x_0)}\ln\frac{m_g^2}{4P_z^2 x_0(x_0-x)} + \frac{2x-x_0}{2x_0(x-x_0)}\right]_+, & 0<x<x_0 \\ \left[\frac{x}{x_0(x-x_0)}\ln\frac{x-x_0}{x} + \frac{1}{2(x-x_0)}\right]_+, & x>x_0 \end{cases}$$

$$\phi_V^{\parallel(1)}(x,\Lambda)\Big|_{\text{Fig.1(c)}} = \phi_V^{\parallel(1)}(x,\Lambda)\Big|_{\text{Fig.1(b)}}(x_0 \to 1-x_0, x \to 1-x)$$

$$\tilde{\phi}_V^{\parallel(1)}(x,P_z,\Lambda)\Big|_{\text{Fig.1(c)}} = \tilde{\phi}_V^{\parallel(1)}(x,P_z,\Lambda)\Big|_{\text{Fig.1(b)}}(x_0 \to 1-x_0, x \to 1-x)$$

$$\phi_V^{\parallel(1)}(x,\Lambda)\Big|_{\text{Fig. 1}(d)} = 0$$

$$\tilde{\phi}_V^{\parallel(1)}(x,P_z,\Lambda)\Big|_{\text{Fig. 1}(d)} = \frac{\alpha_s C_F}{2\pi}\begin{cases} \left[\frac{1}{x-x_0} + \frac{\Lambda}{(x-x_0)^2 P_z}\right]_+, & x<x_0 \\ \left[-\frac{1}{x-x_0} + \frac{\Lambda}{(x-x_0)^2 P_z}\right]_+, & x>x_0 \end{cases}$$

THE MATCHING EQUATION

In LaMET, the quasi-DAs can be factorized as

$$\widetilde{\phi}^{\Gamma}(x, P_z, \Lambda) = \int_0^1 dy Z_{\Gamma}(x, y, P_z, \Lambda)\phi^{\Gamma}(y, \Lambda)$$

The matching coefficient Z_{Γ} is the perturbatively calculable function, can be expanded into the series of α_s as

$$\begin{aligned} Z_{\Gamma}(x, y, P_z, \Lambda) &= \sum_{n=0}^{\infty} \left(\frac{\alpha_s}{2\pi}\right)^n Z_{\Gamma}^{(n)}(x, y, P_z, \Lambda) \\ &= \delta(x-y) + \frac{\alpha_s}{2\pi} Z_{\Gamma}^{(1)}(x, y, P_z, \Lambda) + \mathcal{O}(\alpha_s^2) \end{aligned}$$

one loop correction to the matching coefficient can be related to the difference between LCDA and quasi-DAs at one loop level:

$$\frac{\alpha_s}{2\pi} Z_{\Gamma}^{(1)}(x, x_0, P_z, \Lambda) = \widetilde{\phi}^{\Gamma(1)}(x, P_z, \Lambda) - \phi^{\Gamma(1)}(x, \Lambda)$$

Then the one loop corrections to the matching coefficients $Z_{\perp}^{(1)}$:

Plus distribution is to subtract the singularities located at $x = y$

$$
Z_{\perp}^{(1)}(x,y,P_z,\Lambda) = C_F \begin{cases}
\left[\frac{x}{y(x-y)}\ln\frac{x}{x-y} - \frac{x-1}{(y-1)(x-y)}\ln\frac{x-1}{x-y} + \frac{1}{x-y} + \frac{\Lambda}{(x-y)^2 P_z}\right]_+, & x<0<y \\
\left[\frac{x}{y(x-y)}\ln\frac{\Lambda^2}{4P_z^2 x(y-x)} - \frac{x-1}{(y-1)(x-y)}\ln\frac{x-1}{x-y} + \frac{x+y}{y(x-y)} + \frac{\Lambda}{(x-y)^2 P_z}\right]_+, & 0<x<y \\
\left[\frac{x-1}{(y-1)(x-y)}\ln\frac{\Lambda^2}{4P_z^2(1-x)(x-y)} + \frac{x}{y(x-y)}\ln\frac{x-y}{x} + \frac{1}{y-1} + \frac{\Lambda}{(x-y)^2 P_z}\right]_+, & y<x<1 \\
\left[\frac{x}{y(x-y)}\ln\frac{x-y}{x} - \frac{x-1}{(y-1)(x-y)}\ln\frac{x-y}{x-1} - \frac{1}{x-y} + \frac{\Lambda}{(x-y)^2 P_z}\right]_+, & y<1<x
\end{cases}
$$

And for $Z_{\parallel}^{(1)}$:

$$Z_{\parallel}^{(1)}(x,y,P_z,\Lambda)=C_F\begin{cases}\left[\frac{x-1}{y-1}\left(1-\frac{1}{x-y}\right)\ln\frac{x-1}{x-y}-\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{x}{x-y}\right.\\ \left.+\frac{1}{x-y}+\frac{\Lambda}{(x-y)^2P_z}\right]_+, & x<0<y\\ \left[\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{4P_z^2(y-x)x}{\Lambda^2}-\frac{x-1}{y-1}\left(1-\frac{1}{x-y}\right)\ln\frac{x-y}{x-1}\right.\\ \left.-\frac{x+y}{y(x-y)}+\frac{\Lambda}{(x-y)^2P_z}\right]_+, & 0<x<y\\ \left[\frac{x-1}{y-1}\left(1-\frac{1}{x-y}\right)\ln\frac{4P_z^2(1-x)(x-y)}{\Lambda^2}-\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{x-y}{x}\right.\\ \left.+\frac{1}{y-1}+\frac{\Lambda}{(x-y)^2P_z}\right]_+, & y<x<1\\ \left[\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{x}{x-y}-\frac{x-1}{y-1}\left(1-\frac{1}{x-y}\right)\ln\frac{x-1}{x-y}\right.\\ \left.-\frac{1}{x-y}+\frac{\Lambda}{(x-y)^2P_z}\right]_+. & y<1<x\end{cases}$$

Thus we have **proved the LaMET factorization** for vector meson DAs at one loop level.

As we have discussed before, the **linear divergence** can be subtracted by introducing the mass counter term of Wilson line. Therefore, the improved matching coefficients **only contains the logarithm UV divergence**. The relation between improved matching coefficients and the matching coefficients $Z_{\perp}^{(1)}$ and $Z_{\parallel}^{(1)}$ is given by

$$Z_{\Gamma}^{(1),\text{imp.}}(x,y,P_z,\Lambda) = Z_{\Gamma}^{(1)}(x,y,P_z,\Lambda) - C_F\left[\frac{\Lambda}{(x-y)^2 P_z}\right]_+$$

Since LCDAs do not depend on P_z, we can take derivative with ln P_z on both sides of the factorization formula, and get an **evolution equation** of quasi-DAs with P_z:

$$\frac{d\tilde{\phi}_V^{\Gamma,\text{imp.}}(x,P_z)}{d\ln P_z} = \frac{\alpha_s}{\pi}\int dy V_\Gamma(x,y)\ \tilde{\phi}^{\Gamma,\text{imp.}}(y,P_z)$$

With the evolution kernels

These evolution of quasi-DAs with P_z shares the same behavior with the scale evolution of LCDAs.

$$V_\perp(x,y) = \left[\frac{x}{y(x-y)}\theta(y-x)\theta(x)\right]_+ + \left[\frac{x-1}{(y-1)(x-y)}\theta(x-y)\theta(1-x)\right]_+,$$

$$V_\parallel(x,y) = \left[\frac{x}{y}\left(1-\frac{1}{x-y}\right)\theta(y-x)\theta(x)\right]_+ + \left[\frac{x-1}{y-1}\left(1-\frac{1}{x-y}\right)\theta(x-y)\theta(1-x)\right]_+$$

Matching Coefficients with a Finite Cut-off

- In the $\Lambda \to \infty$ limit, the $\mathcal{O}(P_z/\Lambda)$ contributions can be **neglected**.
- However, it is **difficult** to take too large value of P_z in lattice simulations, in fact, Λ and xP_z are **of the same order** in a practical calculation on the lattice.
- It is valuable to consider the finite Λ corrections to the matching coefficients.

$$Z_\perp^{(1)}(x,y,P_z,\Lambda) = Z_\perp^{(1)}(x,y,P_z,\Lambda) + \delta Z_\perp^{(1)}(x,y,P_z,\Lambda)$$

$$Z_\parallel^{(1)}(x,y,P_z,\Lambda) = Z_\parallel^{(1)}(x,y,P_z,\Lambda) + \delta Z_\parallel^{(1)}(x,y,P_z,\Lambda)$$

$\boldsymbol{\delta Z_\Gamma^{(1)} \to 0}$ **when** $\boldsymbol{\Lambda \to \infty}$

$$\delta Z_\perp^{(1)}(x,y,P_z,\Lambda) = C_F\left[\frac{x}{y(x-y)}\left(\ln\frac{\Lambda(x)+P_z x}{\Lambda(x-y)+P_z(x-y)} + \frac{\Lambda(x-y)-\Lambda(x)}{2P_z}\right) + \frac{\Lambda(x-y)-\Lambda(0)}{2(x-y)^2 P_z}\right]_+ + (x\to 1-x,\ y\to 1-y),$$

$$\delta Z_\parallel^{(1)}(x,y,P_z,\Lambda) = C_F\left[\frac{x}{y}\ln\frac{\Lambda(x)-P_z x}{\Lambda(x-y)-P_z(x-y)} + \frac{x}{y(x-y)}\left(\ln\frac{\Lambda(x)+P_z x}{\Lambda(x-y)+P_z(x-y)} + \frac{\Lambda(x-y)-\Lambda(x)}{2P_z}\right) + \frac{\Lambda(x-y)-\Lambda(0)}{2(x-y)^2 P_z}\right]_+ + (x\to 1-x,\ y\to 1-y),$$

One loop results in dimensional regularization under $\overline{MS}$ scheme

$$
Z_\perp^{(1)}(x,y,P_z,\mu) = C_F \begin{cases}
\left[\frac{x}{y(x-y)}\ln\frac{x}{x-y} - \frac{x-1}{(y-1)(x-y)}\ln\frac{x-1}{x-y} + \frac{1}{x-y}\right], & x<0<y \\
\left[\frac{x}{y(x-y)}\ln\frac{\mu^2}{4P_z^2 x(y-x)} - \frac{x-1}{(y-1)(x-y)}\ln\frac{x-1}{x-y} + \frac{x+y}{y(x-y)}\right], & 0<x<y \\
\left[\frac{x-1}{(y-1)(x-y)}\ln\frac{\mu^2}{4P_z^2(1-x)(x-y)} + \frac{x}{y(x-y)}\ln\frac{x-y}{x} + \frac{1}{y-1}\right]_+, & y<x<1 \\
\left[\frac{x}{y(x-y)}\ln\frac{x-y}{x} - \frac{x-1}{(y-1)(x-y)}\ln\frac{x-y}{x-1} - \frac{1}{x-y}\right]_+, & y<1<x
\end{cases}
$$

The P_z dependence in cut-off and DR schemes are all the same, so the evolution equations and kernels are not changed.

and for $Z_{\parallel}^{(1)}$, the result reads

$$Z_{\parallel}^{(1)}(x,y,P_z,\mu)=C_F\begin{cases}\left[\frac{x-1}{y-1}\left(1+\frac{1}{x-y}\right)\ln\frac{x-1}{x-y}-\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{x}{x-y}\right]_+, & x<0<y\\ \left[\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{4P_z^2(y-x)x}{\mu^2}-\frac{x-1}{y-1}\left(1+\frac{1}{x-y}\right)\ln\frac{x-y}{x-1}\right. & \\ \left.+\frac{x}{y(x-y)}+\frac{x}{y}\right]_+, & 0<x<y\\ \left[\frac{x-1}{y-1}\left(1-\frac{1}{x-y}\right)\ln\frac{4P_z^2(1-x)(x-y)}{\mu^2}-\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{x-y}{x}\right. & \\ \left.+\frac{1-x}{(y-1)(x-y)}+\frac{1-x}{1-y}\right]_+, & y<x<1\\ \left[\frac{x}{y}\left(1-\frac{1}{x-y}\right)\ln\frac{x}{x-y}-\frac{x-1}{y-1}\left(1+\frac{1}{x-y}\right)\ln\frac{x-1}{x-y}\right]_+. & y<1<x\end{cases}$$

Summary

- One loop calculation on the leading twist LCDAs and quasi DAs of the vector meson in the framework of large momentum effective theory.
- Based on the perturbative calculation under UV cut-off and DR schemes, we have examined the LaMET factorization and determined the matching coefficients at one loop accuracy.
- The **collinear divergence** cancels out between LCDAs and quasi-DAs, thus the matching coefficients are **free** of IR divergence. The **linear divergence** is subtracted by the **mass counter term** δ_m of Wilson line.
- The results of this work will be useful to extract the vector mesons' LCDAs from the future lattice simulations.

Thank you!