Lightcone and quasi distribution amplitudes for light octet and decuplet baryons

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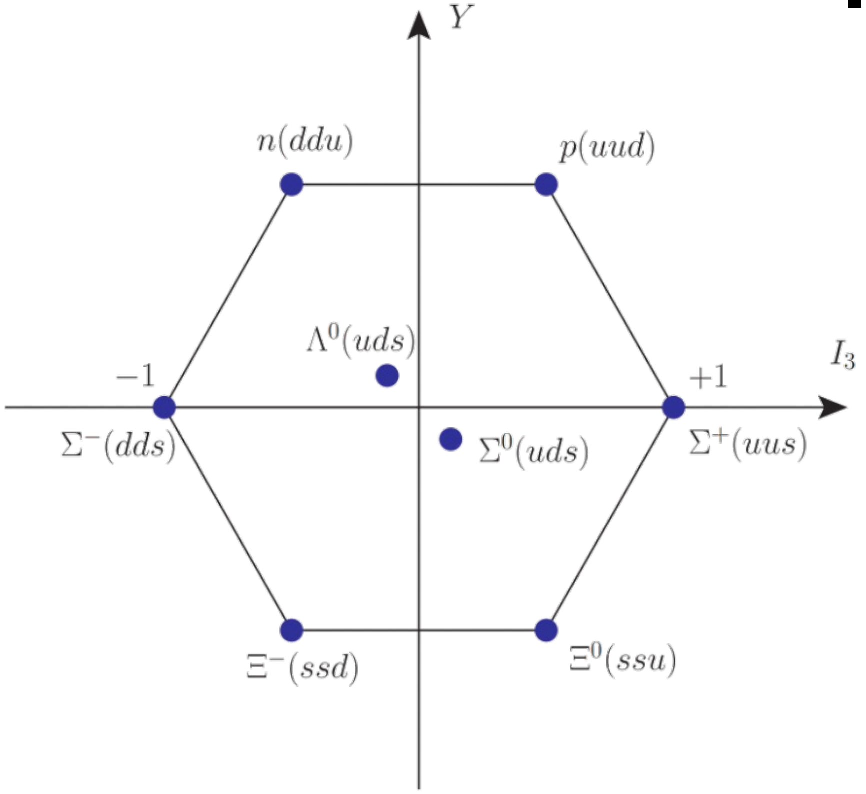
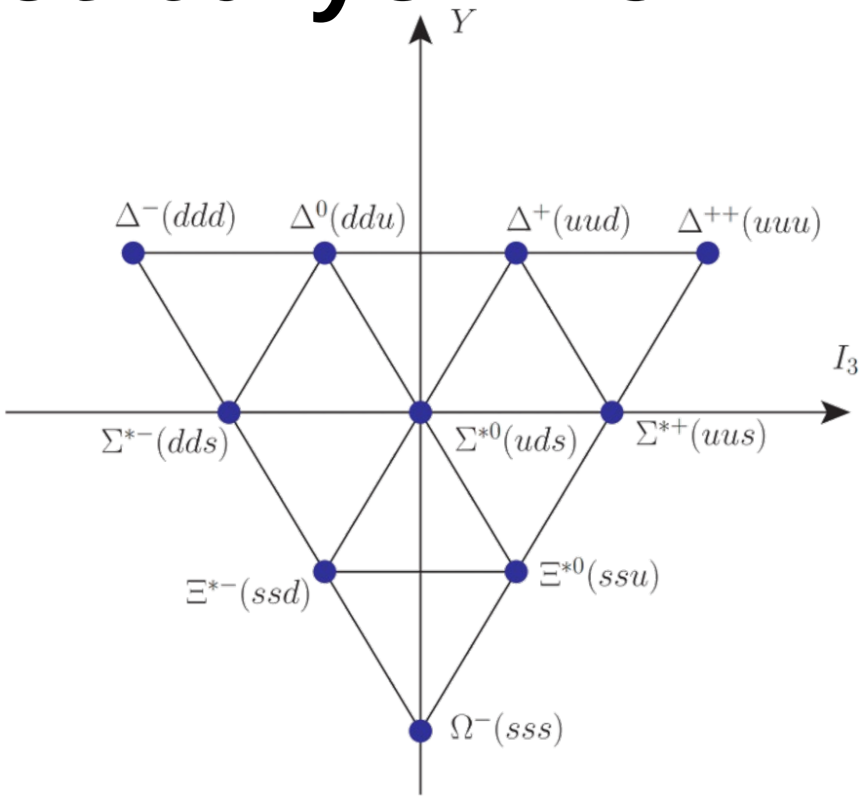
Outline

1. Baryon LCDA
2. LaMET
3. Quasi-DA, perturbative calculation
4. Hybrid Renormalization
5. Matching kernel
6. Conclusion

1-Octet and decuplet baryon LCDA





- Octet and decuplet--spatial, spin, color, and flavor
- Light-cone Distribution Amplitude (LCDA)
    - Non-perturbative
    - Longitudinal momentum fraction
    - Application--weak decay

1.1-Baryon LCDA definition

$$\varepsilon^{ijk} \times \langle 0| f_{\alpha}^{i'}(z_1)\, U_{i'i}(z_1, z_0)\, g_{\beta}^{j'}(z_2)\, U_{j'j}(z_2, z_0)\, h_{\gamma}^{k'}(z_3)\, U_{k'k}(z_3, z_0)\, |B(P_B, \lambda)\rangle$$

$$U(x, y) = \mathcal{P} \exp\left[ig \int_0^1 \mathrm{d}t (x-y)_{\mu} A^{\mu}(tx + (1-t)y)\right].$$

Octet	n	p	Σ^-	Σ^0	Σ^+	Ξ^-	Ξ^0				Λ
Decuplet	Δ^0	Δ^+	Σ^{*-}	Σ^{*0}	Σ^{*+}	Ξ^{*-}	Ξ^{*0}	Δ^{++}	Δ^-	Ω^-	
fgh	ddu	uud	dds	$\frac{1}{\sqrt{2}}(uds + dus)$	uus	ssd	ssu	uuu	ddd	sss	uds

1.2-baryon LCDAs decomposition

- Parity, spin and Lorentz invariance；leading twist Braun, Fries, Mahnke, Stein '2001
- For octet Chernyak, Zhitnitsky '1984)

$$\langle 0 | f_\alpha(z_1 n) g_\beta(z_2 n) h_\gamma(z_3 n) | B(P_B,\lambda)\rangle$$
$$= \frac{1}{4} f_V \left[(\not P_B C)_{\alpha\beta} (\gamma_5 u_B)_\gamma V^B(z_i n\cdot P_B) + (\not P_B \gamma_5 C)_{\alpha\beta} (u_B)_\gamma A^B(z_i n\cdot P_B)\right]$$
$$+ \frac{1}{4} f_T (i\sigma_{\mu\nu} P_B^\nu C)_{\alpha\beta} (\gamma^\mu \gamma_5 u_B)_\gamma T^B(z_i n\cdot P_B)$$

- For decuplet Farrar, Zhang, Ogloblin, Zhitnitsky '1989

$$\langle 0 | f_\alpha(z_1 n) g_\beta(z_2 n) h_\gamma(z_3 n) | B(P_B,\lambda)\rangle$$
$$= \frac{1}{4}\lambda_V \left[(\gamma_\mu C)_{\alpha\beta} \Delta^\mu_\gamma V^B(z_i n\cdot P_B) + (\gamma_\mu\gamma_5 C)_{\alpha\beta} (\gamma_5 \Delta^\mu)_\gamma A^B(z_i n\cdot P_B)\right]$$
$$- \frac{1}{8}\lambda_T (i\sigma_{\mu\nu} C)_{\alpha\beta} (\gamma^\mu \Delta^\nu)_\gamma T^B(z_i n\cdot P_B) - \frac{1}{4}\lambda_\varphi \left[(i\sigma_{\mu\nu} C)_{\alpha\beta} \left(P_B^\mu \Delta^\nu - \frac{1}{2} M_B \gamma^\mu \Delta^\nu\right)_\gamma \varphi^B(z_i n\cdot P_B)\right]$$

1.3-leading twist baryon LCDAs

- **Octet**

$$\left\langle 0\left| f^T(z_1 n)(C\not{n})g(z_2 n)h(z_3 n)\right| B\right\rangle = -f_V V^B(z_i n\cdot P_B)P_B^+\gamma_5 u_B$$
$$\left\langle 0\left| f^T(z_1 n)(C\gamma_5\not{n})g(z_2 n)h(z_3 n)\right| B\right\rangle = f_V A^B(z_i n\cdot P_B)P_B^+ u_B$$
$$\left\langle 0\left| f^T(z_1 n)(iC\sigma_{\mu\nu}n^\nu)g(z_2 n)\gamma^\mu h(z_3 n)\right| B\right\rangle = 2f_T T^B(z_i n\cdot P_B)P_B^+\gamma_5 u_B$$

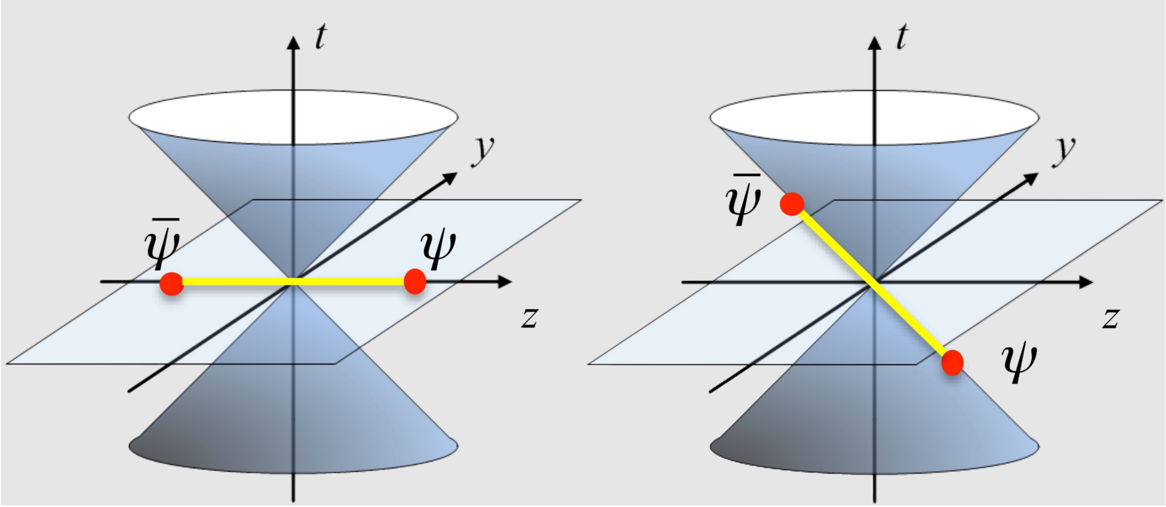
- **Decuplet**

$$\left\langle 0\left| f^T(z_1 n)(C\not{n})g(z_2 n)h(z_3 n)\right| B\left(P_B,\frac{1}{2}\right)\right\rangle = -\lambda_V V^B(z_i n\cdot P_B)\gamma_5(n\cdot\Delta)$$
$$\left\langle 0\left| f^T(z_1 n)(C\gamma_5\not{n})g(z_2 n)h(z_3 n)\right| B\left(P_B,\frac{1}{2}\right)\right\rangle = \lambda_V A^B(z_i n\cdot P_B)(n\cdot\Delta)$$
$$\left\langle 0\left| f^T(z_1 n)(iC\sigma_{\mu\nu}n^\nu)g(z_2 n)\gamma^\mu h(z_3 n)\right| B\left(P_B,\frac{1}{2}\right)\right\rangle = -\lambda_T T^B(z_i n\cdot P_B)(n\cdot\Delta)$$
$$\left\langle 0\left| f^T(z_1 n)(iC\sigma^{\mu\nu}n_\mu)g(z_2 n)h(z_3 n)\right| B\left(P_B,\frac{3}{2}\right)\right\rangle = -\lambda_\varphi \varphi^B(z_i n\cdot P_B)P_B^+\Delta^\nu$$

- **momentum**

$$\Phi^B(x_1,x_2,x_3,\mu) = \int_{-\infty}^{+\infty}\frac{n\cdot P d z_1}{2\pi}\frac{n\cdot P d z_2}{2\pi}\times e^{ix_1 n\cdot P z_1 + ix_2 n\cdot P z_2}\times\Phi_R^B(z_1 n\cdot P, z_2 n\cdot P, 0,\mu),$$

2-LaMET



- LCDA:
  light-cone, non-perturbative
  Lattice QCD, moment

- Large momentum effective theory (LaMET) *Ji 2013*
  - Basic spirit
  - Quasi-distribution amplitude: $\tilde{M}(z_1, z_2, z_3, P^z, \mu) = \langle 0 | u^T(z_1) \tilde{\Gamma} d(z_2) s(z_3) | P(P, \lambda) \rangle$
  - Partonic state perturbative calculation
  - Renormalization
  - Matching

$$\tilde{\Phi}(x_1, x_2, P^z, \mu) = \int dy_1 dy_2 \mathcal{C}(x_1, x_2, y_1, y_2, P^z, \mu) \Phi(y_1, y_2, \mu) + \mathcal{O}\left(\frac{\Lambda_{\rm QCD}}{x_1 P^z}, \frac{\Lambda_{\rm QCD}}{x_2 P^z}, \frac{\Lambda_{\rm QCD}}{(1 - x_1 - x_2) P^z}\right)$$

- Lattice QCD to Light-cone quantities

3 Quasi-DA

- 3.1 spatial correlators

- 3.2 Perturbative calculations

3.1 Quasi-DA definition

- **Octet**

$$\widetilde{M}_V^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|f^T\left(z_1n_z\right)\left(C\gamma^z\right)g\left(z_2n_z\right)h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{1}{2})\right\rangle=-f_V\tilde{V}^B(z_1,z_2,z_3,P_B^z)P_B^z\gamma_5u_B$$

$$\widetilde{M}_A^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|f^T\left(z_1n_z\right)\left(C\gamma_5\gamma^z\right)g\left(z_2n_z\right)h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{1}{2})\right\rangle=f_A\tilde{A}^B(z_1,z_2,z_3,P_B^z)P_B^zu_B$$

$$\widetilde{M}_T^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|f^T\left(z_1n_z\right)\left(\frac{1}{2}C[\gamma^z,\gamma^\mu]\right)g\left(z_2n_z\right)\gamma_\mu h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{1}{2})\right\rangle=2f_T\tilde{T}^B(z_1,z_2,z_3,P_B^z)P_B^z\gamma_5u_B$$

- **Decuplet helicity 1/2**

$$\widetilde{M}_V^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|\left(f\left(z_1n_z\right)\right)^T\left(C\gamma^z\right)g\left(z_2n_z\right)h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{1}{2})\right\rangle=-\lambda_V\tilde{V}^B\left(z_1,z_2,z_3,P_B^z\right)\gamma_5(n_z\cdot\Delta)$$

$$\widetilde{M}_A^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|\left(f\left(z_1n_z\right)\right)^T\left(C\gamma_5\gamma^z\right)g\left(z_2n_z\right)h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{1}{2})\right\rangle=\lambda_A\tilde{A}^B\left(z_1,z_2,z_3,P_B^z\right)(n_z\cdot\Delta)$$

$$\widetilde{M}_T^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|\left(f\left(z_1n_z\right)\right)^T\left(\frac{1}{2}C[\gamma^z,\gamma^\mu]\right)g\left(z_2n_z\right)\gamma_\mu h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{1}{2})\right\rangle=-\lambda_T\tilde{T}^B\left(z_1,z_2,z_3,P_B^z\right)(n_z\cdot\Delta)$$

- **Decuplet helicity 3/2**

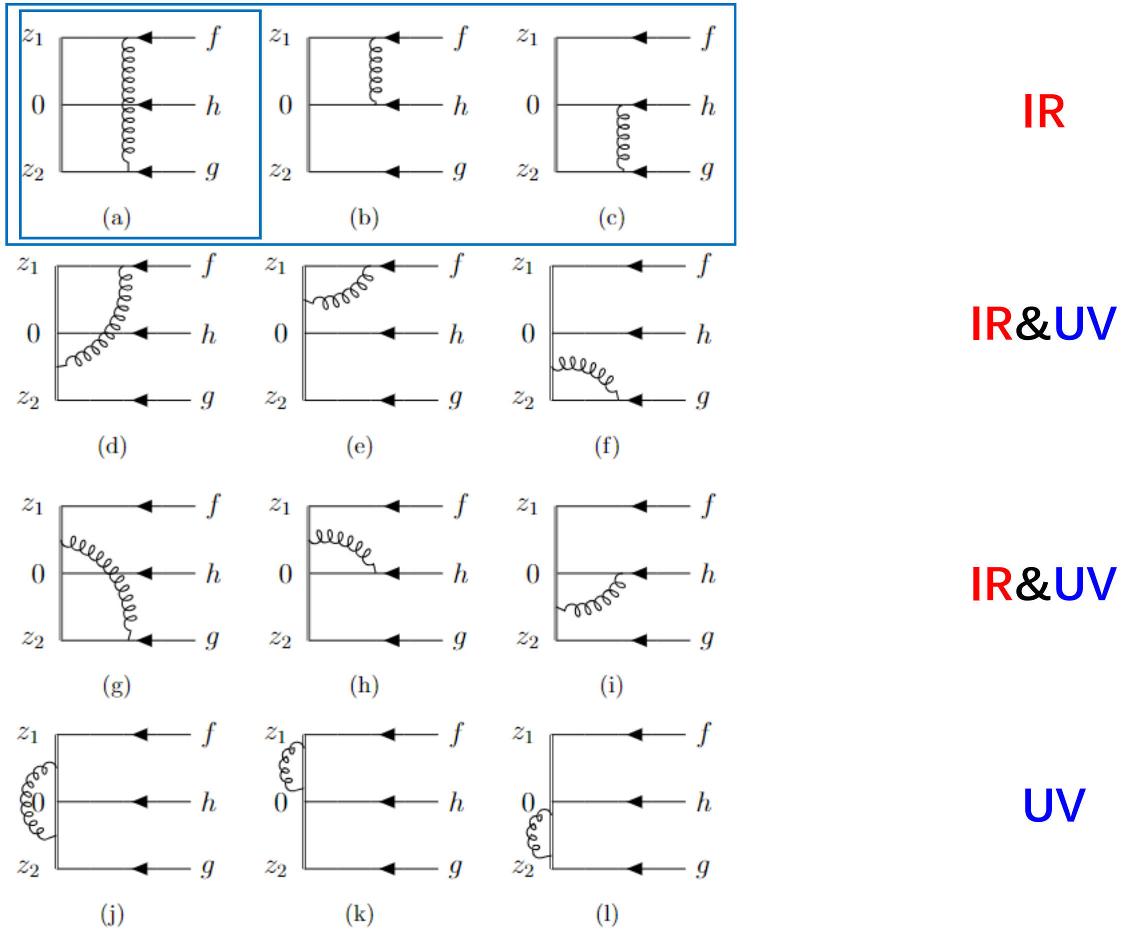
$$\widetilde{M}_\varphi^B(z_1,z_2,z_3,P_B^z)=\left\langle 0\left|\left(f\left(z_1n_z\right)\right)^T\left(\frac{1}{2}C[\gamma^\nu,\gamma^z]\right)g\left(z_2n_z\right)h\left(z_3n_z\right)\right|B(P_B,\lambda=\frac{3}{2})\right\rangle=-\lambda_\varphi\tilde{\varphi}^B\left(z_1,z_2,z_3,P_B^z\right)\Delta^\nu$$

- **Momentum space**

$$\widetilde{\Phi}^B\left(x_1,x_2,x_3,P_B^z,\mu\right)=\int_{-\infty}^{+\infty}\frac{P_B^z d\,z_1}{2\pi}\frac{P_B^z d\,z_2}{2\pi}\times e^{-ix_1P_B^zz_1-ix_2P_B^zz_2}\times\widetilde{\Phi}_R^B\left(z_1,z_2,0,P_B^z,\mu\right),$$

3.2 perturbative calculation

- replacing the hadron state with the partonic state
- eg, V part of proton $\widetilde{\mathcal{M}}_V(z_1,z_2,z_3,P^z,\mu)=\frac{\epsilon^{ijk}\epsilon^{abc}}{6}\langle 0\left|u_i^T(z_1)C\not{n}_z u_j(z_2)d_k(z_3)\right|u_a(x_1P)u_b(x_2P)d_c(x_3P)\rangle$



3.2 perturbative calculation

$$
\begin{aligned}
&\widetilde{\mathcal{M}}_{V(A)}(z_1,z_2,0,P^z,\mu)= \\
&\left\{1+\frac{\alpha_s C_F}{\pi}\left(\frac{1}{2}L_1^{\mathrm{UV}}+\frac{1}{2}L_2^{\mathrm{UV}}+\frac{1}{2}L_{12}^{\mathrm{UV}}+\frac{3}{2}\right)\right\}\widetilde{\mathcal{M}}_0\left(z_1,z_2,0,P^z,\mu\right) \\
&-\frac{\alpha_s C_F}{8\pi}\int_0^1 d\eta_1\int_0^{1-\eta_1}d\eta_2 \\
&\times\left\{\left(L_1^{\mathrm{IR}}-1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\widetilde{\mathcal{M}}_0\left(\left(1-\eta_1\right)z_1,z_2,\eta_2 z_1,P^z,\mu\right)+\left(L_2^{\mathrm{IR}}-1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\widetilde{\mathcal{M}}_0\left(z_1,\left(1-\eta_1\right)z_2,\eta_2 z_2,P^z,\mu\right)\right. \\
&\left.+2\left(L_{12}^{\mathrm{IR}}-3+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\widetilde{\mathcal{M}}_0\left(\left(1-\eta_1\right)z_1+\eta_1 z_2,\left(1-\eta_2\right)z_2+\eta_2 z_1,0,P^z,\mu\right)\right\} \\
&-\frac{\alpha_s C_F}{4\pi}\int_0^1 d\eta\times\left\{\widetilde{\mathcal{M}}_0\left((1-\eta)z_1+\eta z_2,z_2,0,P^z,\mu\right)\left\{\left(L_{12}^{\mathrm{IR}}+1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\left(\frac{1-\eta}{\eta}\right)_+ +2\left(\frac{\ln\eta}{\eta}\right)_+\right\}\right. \\
&+\widetilde{\mathcal{M}}_0\left(z_1,(1-\eta)z_2+\eta z_1,0,P^z,\mu\right)\left\{\left(L_{12}^{\mathrm{IR}}+1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\left(\frac{1-\eta}{\eta}\right)_+ +2\left(\frac{\ln\eta}{\eta}\right)_+\right\} \\
&+\widetilde{\mathcal{M}}_0\left((1-\eta)z_1,z_2,0,P^z,\mu\right)\left\{\left(L_1^{\mathrm{IR}}+1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\left(\frac{1-\eta}{\eta}\right)_+ +2\left(\frac{\ln\eta}{\eta}\right)_+\right\} \\
&+\widetilde{\mathcal{M}}_0\left(z_1,(1-\eta)z_2,0,P^z,\mu\right)\left\{\left(L_2^{\mathrm{IR}}+1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\left(\frac{1-\eta}{\eta}\right)_+ +2\left(\frac{\ln\eta}{\eta}\right)_+\right\} \\
&-\widetilde{\mathcal{M}}_0\left(z_1,z_2,\eta z_1,P^z,\mu\right)\left\{\left(L_1^{\mathrm{IR}}+1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\left(\frac{1-\eta}{\eta}\right)_+ +2\left(\frac{\ln\eta}{\eta}\right)_+\right\} \\
&\left.-\widetilde{\mathcal{M}}_0\left(z_1,z_2,\eta z_2,P^z,\mu\right)\left\{\left(L_2^{\mathrm{IR}}+1+\frac{1}{\epsilon_{\mathrm{IR}}}\right)\left(\frac{1-\eta}{\eta}\right)_+ +2\left(\frac{\ln\eta}{\eta}\right)_+\right\}\right\}
\end{aligned}
$$

- $\widetilde{M}_0$
- Abbreviation

$$
\begin{aligned}
L_1^{\mathrm{IR,UV}}&=\ln\left(\frac{1}{4}\mu_{\mathrm{IR,UV}}z_1^2 e^{2\gamma_E}\right), \\
L_2^{\mathrm{IR,UV}}&=\ln\left(\frac{1}{4}\mu_{\mathrm{IR,UV}}^2 z_2^2 e^{2\gamma_E}\right), \\
L_{12}^{\mathrm{IR,UV}}&=\ln\left(\frac{1}{4}\mu_{\mathrm{IR,UV}}^2\left(z_1-z_2\right)^2 e^{2\gamma_E}\right).
\end{aligned}
$$

- $\ln(z_1^2)$, $\ln(z_2^2)$, $\ln(z_1-z_2)^2$

4. Hybrid renormalization scheme

4.1 Renormalization

4.2 Self-renormalization

4.3 Ratio scheme

4.4 Procedure

4.1 renormalization

- Challenge
  - $\ln(z^2)$, $\overline{\text{MS}}$
  - Baryon LCDA, dim-2 distribution
- Renormalization scheme
  - Remove UV divergence
  - No new non-perturbative effects
- Hybrid scheme: self-renormalization + ratio

4.2 Self-renormalization $\widetilde{M} \to \widetilde{M}_R$

- Lattice version $\overline{\mathrm{MS}}$: $\widetilde{M} = Z_R \widetilde{M}_R$
- Z_R parameterization [LPC '21]

$$Z_R(z_1, z_2, a, \mu) = \exp\left[\underbrace{\left(\frac{k}{a\ln[a\Lambda_{\mathrm{QCD}}]} - m_0\right)}_{\text{Linear divergence}}\tilde{z} + \underbrace{\frac{\gamma_0}{b_0}\ln\left[\frac{\ln[1/(a\Lambda_{\mathrm{QCD}})]}{\ln[\mu/\Lambda_{\overline{\mathrm{MS}}}]}\right] + \ln\left[1 + \frac{d}{\ln(a\Lambda_{\mathrm{QCD}})}\right]}_{\text{Log divergence}} + \underbrace{f(z_1, z_2)a}_{\text{Discrete divergence}}\right]$$

- convert lattice to continuous matrix element without new IR
- Singular logarithms
- lattice effect at short distance

4.3 Ratio scheme

$$\widetilde{M}^{\mathrm{ratio}}\left(z_1, z_2, P, \epsilon\right)=\frac{Z_R \widetilde{M}\left(z_1, z_2, P, \epsilon\right)}{Z_R \widetilde{M}\left(z_1, z_2, 0, \epsilon\right)}=\frac{\widetilde{M}\left(z_1, z_2, P, \epsilon\right)}{\widetilde{M}\left(z_1, z_2, 0, \epsilon\right)}$$

- $\ln(z^2)$
- multiplicative renormalizability
- Only small z

4.4-Procedure

$$\widetilde{M}$$

Self renormalization

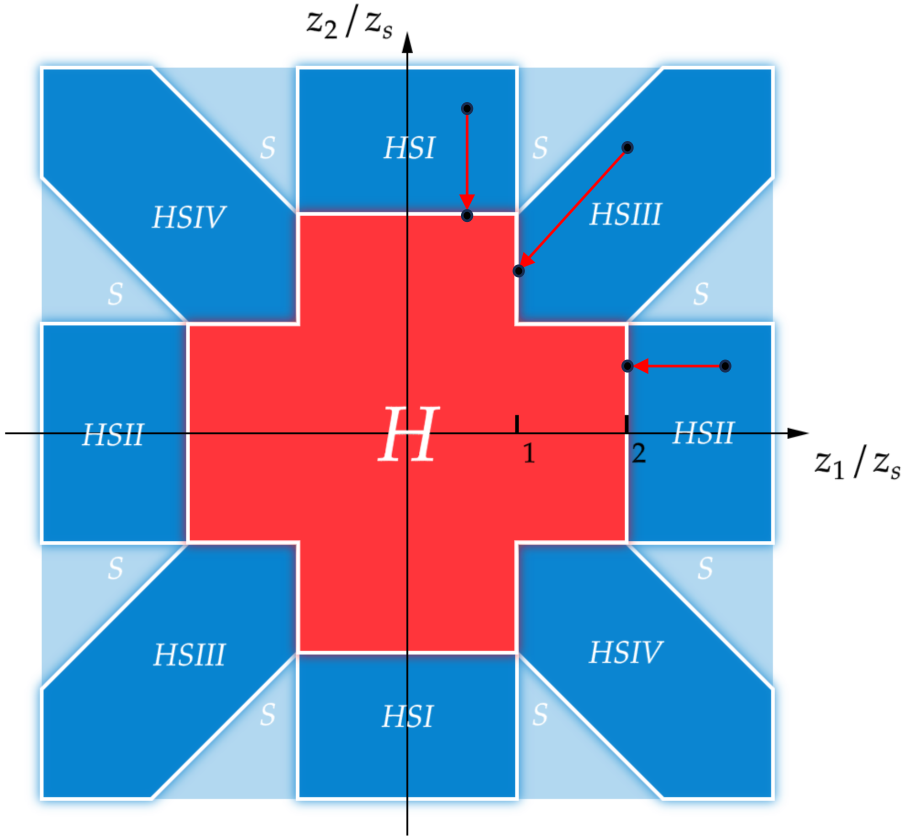
$$\widetilde{M}_R\left(z_1, z_2, P^z\right)=\frac{\widetilde{M}\left(z_1, z_2, a, P^z\right)}{Z_R\left(z_1, z_2, a\right)}$$

$$\widetilde{M}_R$$

ratio

$$\widetilde{M}_{\mathrm{H}}\left(z_1, z_2, P^z\right)=\frac{\widetilde{M}_R\left(z_1, z_2, P\right)}{\widetilde{M}_R\left(z_1'\left(z_1, z_2\right), z_2'\left(z_1, z_2\right), P=0\right)}$$

$$\widetilde{M}_H$$



5. matching kernel

5.1 matching formula

- **Partonic state**

$$\widetilde{\Psi}_H^{V,A,T,\varphi}(x_1,x_2,P^z,\mu)=\int dy_1 dy_2 \mathcal{C}_{V,A,T,\varphi}(x_1,x_2,y_1,y_2,P^z,\mu)\Psi_{\overline{\mathrm{MS}}}^{V,A,T,\varphi}(y_1,y_2,\mu)$$

  - $\widetilde{\Psi}_H(x_1,x_2,P^z,\mu)$
  - $\Psi_{\overline{MS}}(y_1,y_2,\mu)$
  - $C(x_1,x_2,y_1,y_2,P^z,\mu)$

- **Hadron state**

$$\tilde{\Phi}_H^B(x_1,x_2,P^z,\mu)=\int dy_1 dy_2 \mathcal{C}_{V,A,T,\varphi}(x_1,x_2,y_1,y_2,P^z,\mu)\Phi_{\overline{\mathrm{MS}}}^B(y_1,y_2,\mu)$$

5.2 matching kernel

$$\mathcal{C}_{V,A}\left(x_1,x_2,y_1,y_2,P^z,\mu\right)=\delta\left(x_1-y_1\right)\delta\left(x_2-y_2\right)+\frac{\alpha_s C_F}{4\pi}C_{1V,A}\left(x_1,x_2,y_1,y_2,P^z,\mu\right)$$
$$+\frac{\alpha_s C_F}{4\pi}\times\left[C_2\left(x_1,x_2,y_1,y_2,P^z,\mu\right)\delta\left(x_2-y_2\right)\right.$$
$$\left.+C_3\left(x_1,x_2,y_1,y_2,P^z,\mu\right)\delta\left(x_3-y_3\right)+\left\{x_1\leftrightarrow x_2,y_1\leftrightarrow y_2\right\}\right]_\oplus$$

$$\mathcal{C}_{T}\left(x_1,x_2,y_1,y_2,P^z,\mu\right)=\delta\left(x_1-y_1\right)\delta\left(x_2-y_2\right)+\frac{\alpha_s C_F}{4\pi}C_{1T}\left(x_1,x_2,y_1,y_2,P^z,\mu\right)$$
$$+\frac{\alpha_s C_F}{4\pi}\times\left[C_2\left(x_1,x_2,y_1,y_2,P^z,\mu\right)\delta\left(x_2-y_2\right)\right.$$
$$\left.+\left(C_3-C_5\right)\left(x_1,x_2,y_1,y_2,P^z,\mu\right)\delta\left(x_3-y_3\right)+\left\{x_1\leftrightarrow x_2,y_1\leftrightarrow y_2\right\}\right]_\oplus$$

$$\mathcal{C}_{\varphi}\left(x_1,x_2,y_1,y_2,P^z,\mu\right)=\delta\left(x_1-y_1\right)\delta\left(x_2-y_2\right)+\frac{\alpha_s C_F}{4\pi}C_{1\varphi}\left(x_1,x_2,y_1,y_2,P^z,\mu\right)$$
$$+\frac{\alpha_s C_F}{4\pi}\times\left[\left(C_2-C_4\right)\left(x_1,x_2,y_1,y_2,P^z,\mu\right)\delta\left(x_2-y_2\right)\right.$$
$$\left.+\left(C_3-C_5\right)\left(x_1,x_2,y_1,y_2,P^z,\mu\right)\delta\left(x_3-y_3\right)+\left\{x_1\leftrightarrow x_2,y_1\leftrightarrow y_2\right\}\right]_\oplus$$

5.2 matching kernel

$$\mathcal{C}_{1V,A}(x_1,x_2,y_1,y_2,P^z,\mu)=2(P^z)^2\Bigg[I_{\rm H}^{V/A}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSI}^{V/A}[(x_1-y_1)P^z,(x_2-y_2)P^z]$$

$$+I_{\rm HSII}^{V/A}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSIII}^{V/A}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSIV}^{V/A}[(x_1-y_1)P^z,(x_2-y_2)P^z]$$

$$+I_{\rm S}^{V/A}[(x_1-y_1)P^z,(x_2-y_2)P^z]+\delta[(x_1-y_1)P^z]\delta[(x_2-y_2)P^z]\left(\frac{5}{2}\ln\left(\frac{\mu^2e^{2\gamma_E}}{4}\right)+4\right)\Bigg]$$

$$\mathcal{C}_{1T}(x_1,x_2,y_1,y_2,P^z,\mu)=2(P^z)^2\Bigg[I_{\rm H}^{T}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSI}^{T}[(x_1-y_1)P^z,(x_2-y_2)P^z]$$

$$+I_{\rm HSII}^{T}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSIII}^{T}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSIV}^{T}[(x_1-y_1)P^z,(x_2-y_2)P^z]$$

$$+I_{\rm S}^{T}[(x_1-y_1)P^z,(x_2-y_2)P^z]+\delta[(x_1-y_1)P^z]\delta[(x_2-y_2)P^z]\left(\frac{9}{4}\ln\left(\frac{\mu^2e^{2\gamma_E}}{4}\right)+\frac{13}{4}\right)\Bigg]$$

$$\mathcal{C}_{1\varphi}(x_1,x_2,y_1,y_2,P^z,\mu)=2(P^z)^2\Bigg[I_{\rm H}^{\varphi}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSI}^{\varphi}[(x_1-y_1)P^z,(x_2-y_2)P^z]$$

$$+I_{\rm HSII}^{\varphi}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSIII}^{\varphi}[(x_1-y_1)P^z,(x_2-y_2)P^z]+I_{\rm HSIV}^{\varphi}[(x_1-y_1)P^z,(x_2-y_2)P^z]$$

$$+I_{\rm S}^{\varphi}[(x_1-y_1)P^z,(x_2-y_2)P^z]+\delta[(x_1-y_1)P^z]\delta[(x_2-y_2)P^z]\left(\frac{9}{4}\ln\left(\frac{\mu^2e^{2\gamma_E}}{4}\right)+3\right)\Bigg]$$

Conclusion

- Light baryon LCDA
- LaMET
  - Quasi-DA
  - Renormalization: Hybrid scheme
  - Matching kernel
- Outlook

Thanks