郑州大学 ZHENGZHOU UNIVERSITY

Recent progress on heavy meson LCDA

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第二十一届全国重味物理与CP破坏研讨会

Outline

- **HQET and heavy meson LCDA**
- Progress on heavy meson LCDA
- Accessing heavy meson LCDA
- Summary and Outlook

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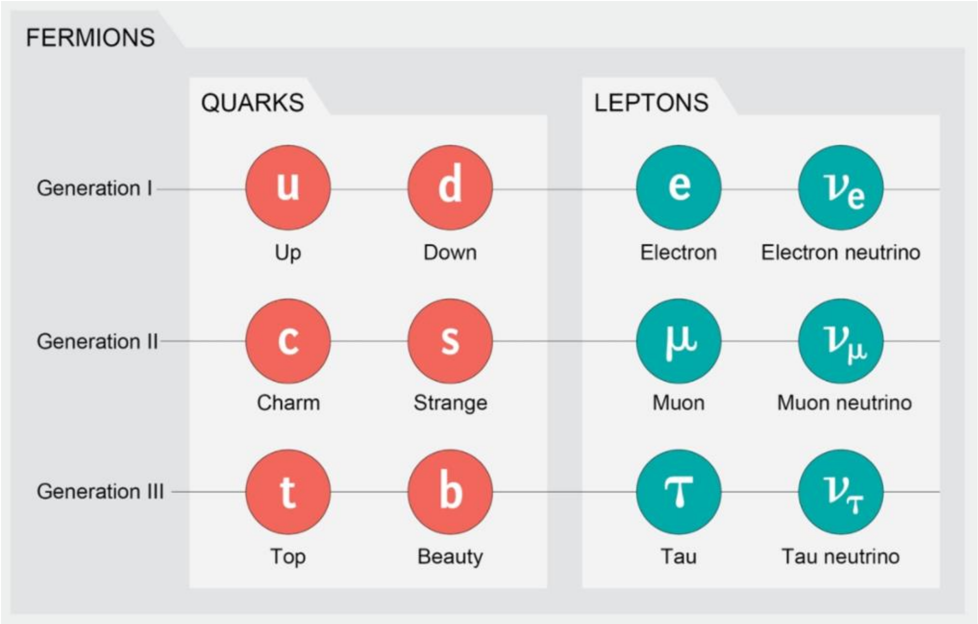
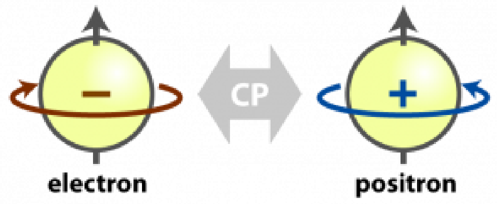
Heavy Flavor Physics

➢ The charm quark was predicted by Glashow, Iliopoulos and Maiani in 1970.





Flavor physics plays a very important role in particle physics

Heavy Flavor Physics

- The charm quark was predicted by Glashow, Iliopoulos and Maiani in 1970.

1976

- The bottom quark was first predicted in 1973 by Kobayashi and Maskawa to explain CP violation.

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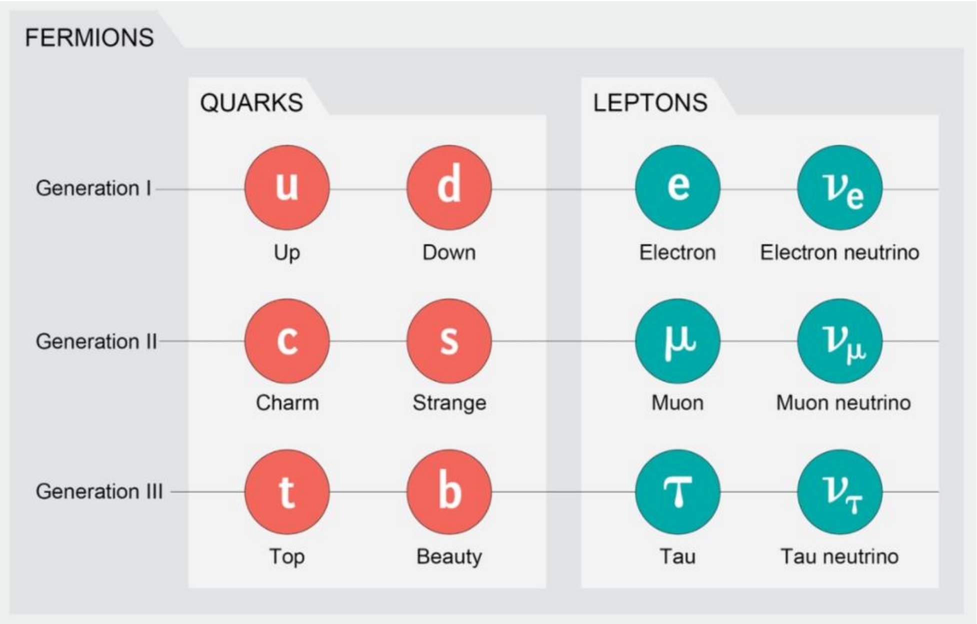

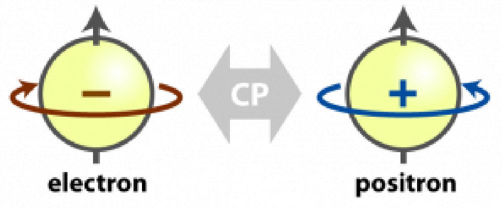

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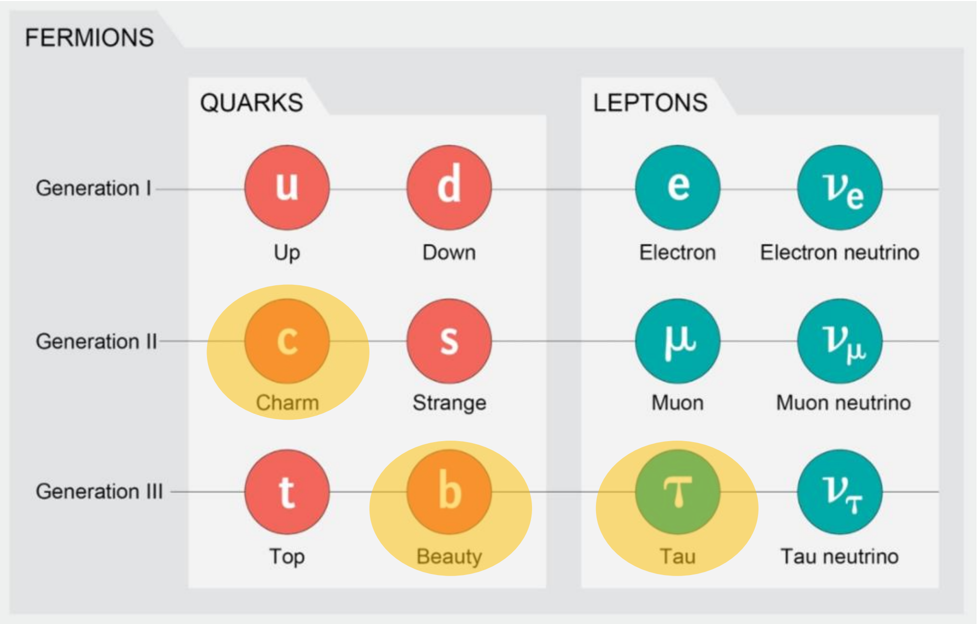
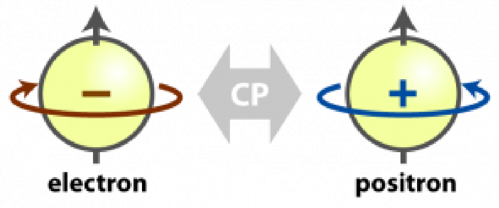
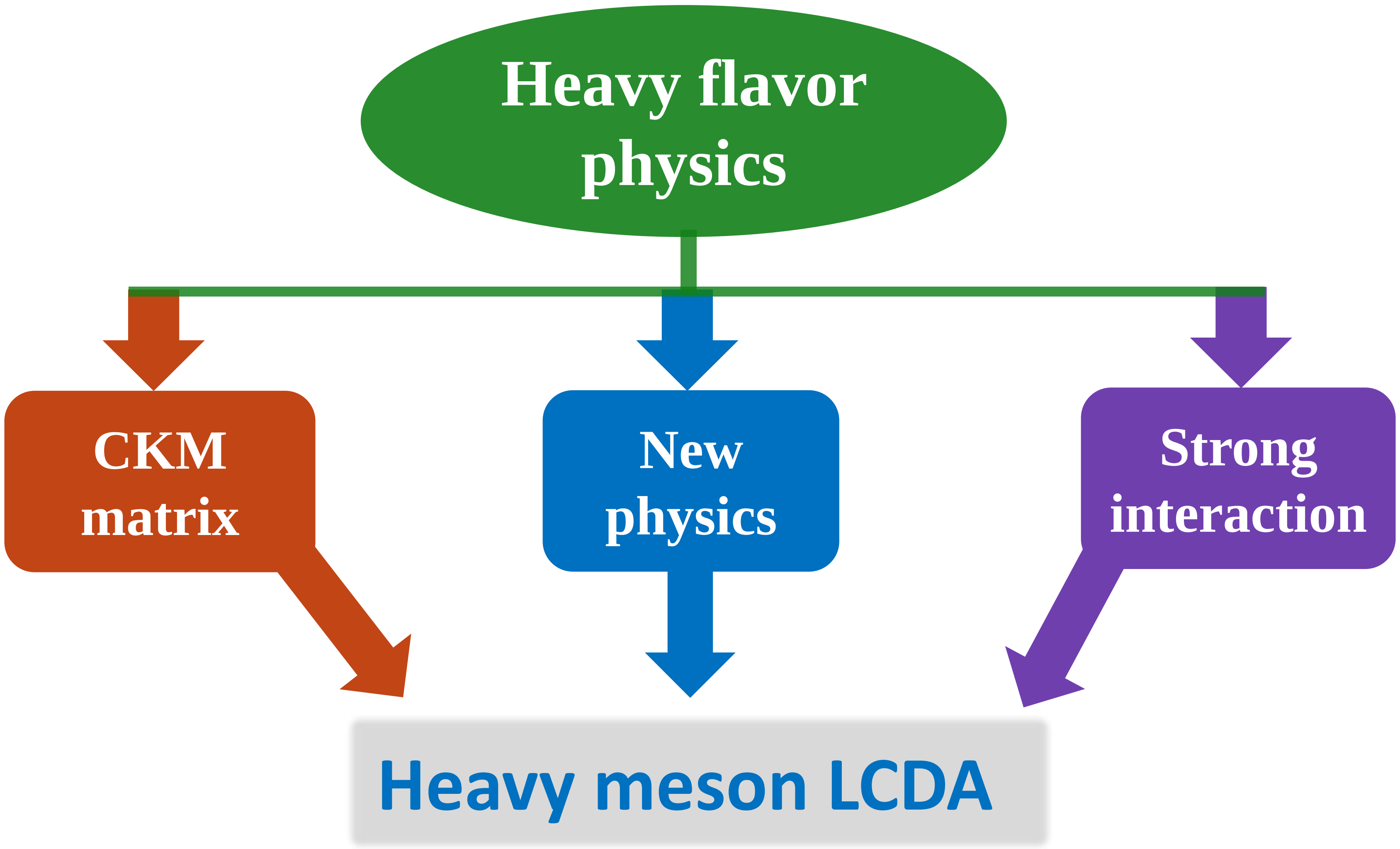
- Heavy Flavor Physics: $b,\ c,\ \tau.$





Flavor physics plays a very important role in particle physics

Heavy meson LCDA



Heavy meson LCDA plays a very important role in Flavor physics

Heavy Quark Effective Theory

- The Lagrangian of HQET.

$$\mathcal{L}_{\text{eff}} = \bar{h}_v iv \cdot D h_v + \frac{1}{2m_Q} \sum_{n=0}^{\infty} \bar{h}_v i \not{D}_\perp \left(-\frac{iv \cdot D}{2m_Q} \right)^n i \not{D}_\perp h_v \,.$$

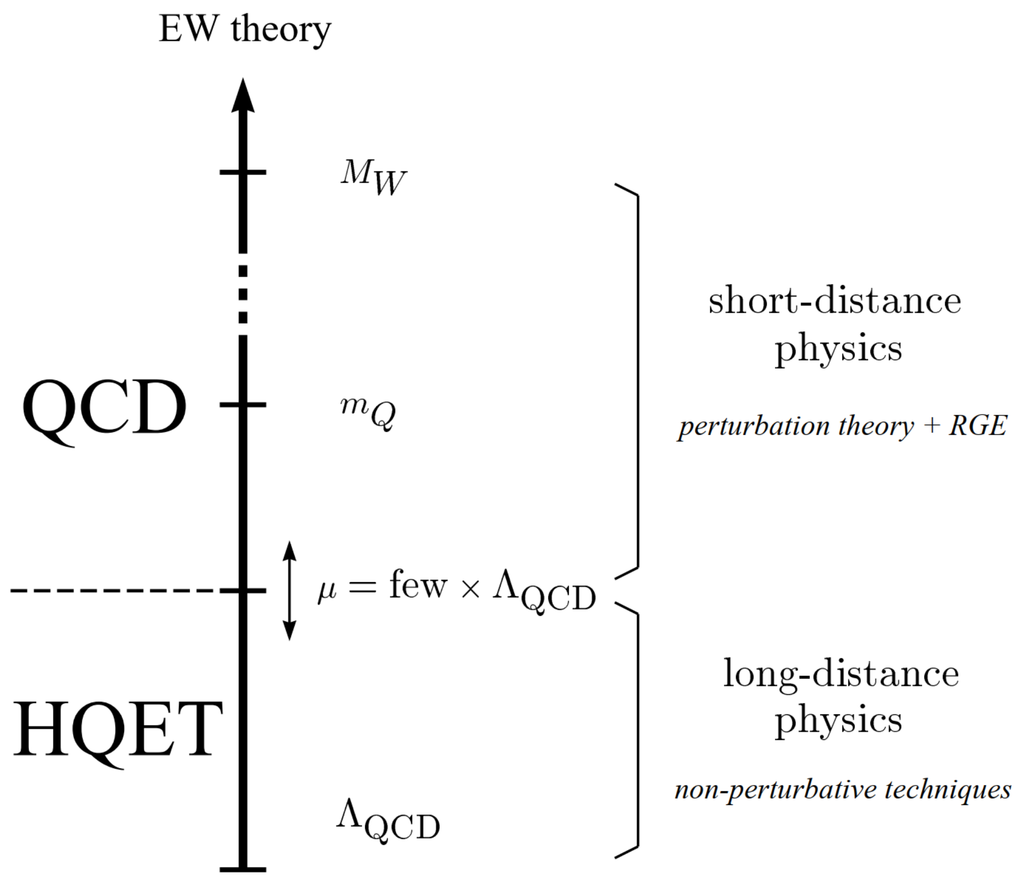


Figure 5: Philosophy of the heavy-quark effective theory.

Neubert, Subnucl.Ser 34, 98-165 (1997)

HQET is constructed to describe heavy flavor physics

Heavy Quark Effective Theory

- Using HQET, observables can be written schematically as series.

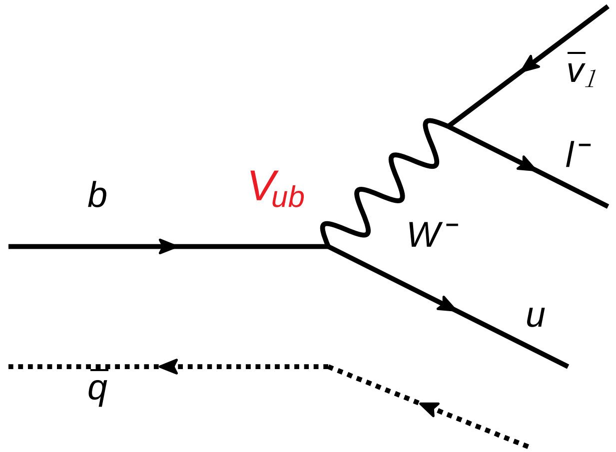
$$\text{Observable} = \sum_{n=0}^{\infty} \sum_{j} c_n^j(\mu) \frac{\langle O_n^j(\mu) \rangle}{m_Q^n} .$$

Wilson coefficients

- **Decay constant**
- **Heavy meson LCDA**
- **Form factor**

LCDA is a crucial nonperturbative quantity

Why heavy meson LCDA important?



$$\Delta F_M(2E,\mu) = T(u,2E,\omega,\mu) \otimes \phi_B^+(\omega,\mu) \otimes \phi_M(u,\mu)\,.$$

B-meson LCDA

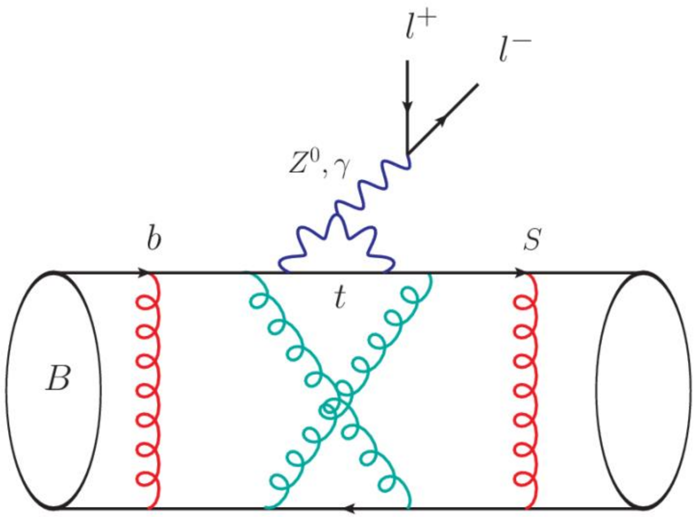
[$B \to \pi\, \ell\, \nu$ Khodjamirian, Mannel, Offen, YMW, PRD 83, 094031 (2011); ZHL, ZGS, YW, NZ, NPB, 900, 198-211 (2015)]

[$B \to D\, \ell\, \nu$ HPQCD Collaboration, PRD 92, 054510 (2015)]

[$B_s \to PP, PV, VV$, Ali, Kramer, YL, CDL, YLS, et.al., PRD, 76, 074018 (2007)]

LCDA is pivotal in determining V_{ub} and V_{cb}

Why heavy meson LCDA important?



$$\langle K_a^* \ell^+ \ell^- | H_{eff} | B \rangle = T_a^I (q^2) \zeta_a (q^2) + \sum_{\pm} \int_0^\infty \frac{d\omega}{\omega} \phi_\pm^B(\omega) \int_0^1 du \phi_{K^*}^a(u) T_{a,\pm}^{II} (\omega, u, q^2) \ .$$

B-meson LCDA

[$B \to K^+ \ell^+ \ell^-$ Ali, Kramer, GHZ, EPJC 47, 625 (2006)]

[$B \to K^* \ell^+ \ell^-$ QC, XQL, YDY, JHEP 04, 052 (2010)]

Without precise knowledge on LCDAs, it is hard to probe NP

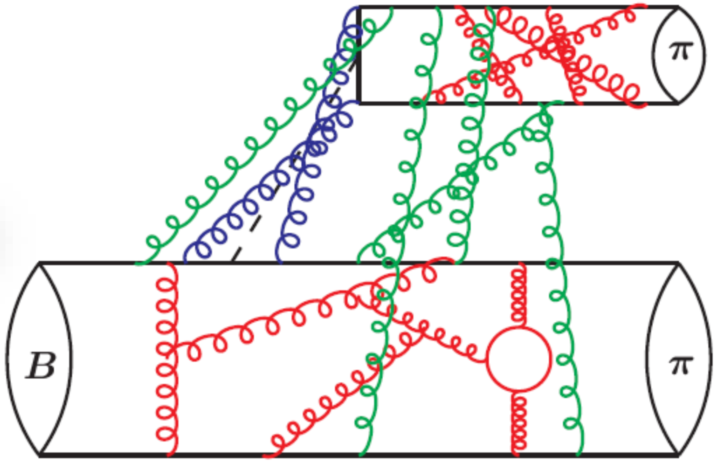
Why heavy meson LCDA important?

$$\langle \pi(p')\,\pi(q)\,|Q_i|\,\bar{B}(p)\rangle = f^{B\to\pi}(q^2)\int_0^1 dx T_i^{\rm I}(x)\phi_\pi(x) + \int_0^1 d\xi dx dy T_i^{\rm II}(\xi,x,y)\varphi_B(\xi)\phi_\pi(x)\phi_\pi(y)$$

***B* → *π* form factor**

Hard kernel

B-meson LCDA



[QCD factorization: Beneke, Buchalla, Neubert, Sachrajda, PRL 83, 1914 (1999); YDY, XQL, Phys.Rev.D 73 (2006) 114027]

[For PQCD, see: Keum, Li, Sanda, PRD 63, 054008 (2001); ZJX, CDL, et.al., PRD 73, 074002 (2006)]

[For TMDF, see: JPM, QW, JHEP, 01, 067 (2006)]

LCDA is an indispensable part of factorization theory

Definition on heavy meson LCDA

➢ The light-ray HQET matrix element [Grozin, Neubert, PRD 55, 272-290 (1997)]

$$\langle 0 \,|\bar{q}_\beta(z)[z,0]h_{v\alpha}(0)|\,\bar{B}(v)\rangle = -\frac{i\tilde{f}_B m_B}{4}\left[\frac{1+\not{v}}{2}\left\{2\tilde{\varphi}_B^+(t,\mu) + \frac{\tilde{\varphi}_B^-(t,\mu) - \tilde{\varphi}_B^+(t,\mu)}{t}\not{z}\right\}\gamma_5\right]_{\alpha\beta} .$$

Leading twist Sub-leading twist

We assume that $z^2 = 0$, define $t = v.z$ and the path-ordered exponential

$$[z,0] = \mathrm{P}\exp\left(ig_s\int_{z_2}^{z_1} dz^\mu A_\mu(z)\right) .$$

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What do we know about heavy meson LCDA?

➢ Equation of motion. [Kawamura, Kodaira, CFQ, Tanaka, PLB 523, 111 (2001)]

$$\tilde{\phi}'_-(t) - \frac{1}{t}\left(\tilde{\phi}_+(t) - \tilde{\phi}_-(t)\right)$$
$$= 2t \int_0^1 du u \left(\widetilde{\Psi}_A(t,u) - \widetilde{\Psi}_V(t,u)\right) .$$
$$\ldots$$

What do we know about heavy meson LCDA?

- Equation of motion. [Kawamura, Kodaira, CFQ, Tanaka, PLB 523, 111 (2001)]

- B-LCDA with contribution from 3-particle Fock States. [TH, CFQ, XGW, PRD 73, 074004 (2006)]

$$\Psi_+(\omega, b) = \frac{\omega}{\omega_0^2} \exp\left(-\frac{\omega}{\omega_0}\right) \left(\Gamma[\delta] J_{\delta-1}[\kappa] + (1-\delta)\Gamma[2-\delta] J_{1-\delta}[\kappa]\right) \left(\frac{\kappa}{2}\right)^{1-\delta} .$$

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- B-LCDA with contribution from 3-particle Fock States. [TH, CFQ, XGW, PRD 73, 074004 (2006)]
- Evolution equations of ϕ_+^B. [Lange, Neubert, PRL 91, 102001 (2003); Bell, Feldmann, JHEP 04, 061 (2008)]

$$\frac{d}{d\ln\mu}\phi_B^+(\omega,\mu) = -\frac{\alpha_s C_F}{4\pi}\int_0^\infty d\omega' \gamma_+^{(1)}(\omega,\omega',\mu)\,\phi_B^+(\omega',\mu) + \mathcal{O}(\alpha_s^2)\ .$$

With

$$\gamma_+^{(1)}(\omega,\omega',\mu) = \left(\Gamma_{\rm cusp}^{(1)}\ \ln\frac{\mu}{\omega} - 2\right)\delta(\omega-\omega') - \Gamma_{\rm cusp}^{(1)}\ \omega\left[\frac{\theta(\omega'-\omega)}{\omega'(\omega'-\omega)} + \frac{\theta(\omega-\omega')}{\omega(\omega-\omega')}\right]_+\ .$$

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- Evolution equations of ϕ_+^B. [Lange, Neubert, PRL 91, 102001 (2003); Bell, Feldmann, JHEP 04, 061 (2008)]
- RG equations of $\phi_B^+(\omega,\mu)$ at two-loops. [Braun, YJ, Manashov, PRD 100, 1, 014023 (2019); ZLL, Neubert, JHEP 06, 060 (2020)]

$$\left(\mu\frac{\partial}{\partial\mu}+\beta(a)\frac{\partial}{\partial a}+\Gamma_{\rm cusp}\,(a)\ln\left(\tilde{\mu}e^{\gamma_E}s\right)+\gamma_\eta(a)\right)\eta_+(s,\mu)$$
$$=4C_Fa^2\int_0^1du\frac{\bar{u}}{u}h(u)\eta_+(\bar{u}s,\mu)\,.$$

What do we know about heavy meson LCDA?

- Solution of evolution equations. [Bell, Feldmann, YMW and Yip, JHEP 11, 191 (2013); Braun, Manashov, PLB 731, 316-319 (2014)]

$$\phi_B^+(\omega,\mu) = e^V \int_0^\infty \frac{d\omega'}{\omega'} \sqrt{\frac{\omega}{\omega'}} J_1\left(2\sqrt{\frac{\omega}{\omega'}}\right) \left(\frac{\mu_0}{\hat{\omega}'}\right)^{-g} \rho_B^+(\omega',\mu_0)$$

What do we know about heavy meson LCDA?

- Solution of evolution equations. [Bell, Feldmann, YMW and Yip, JHEP 11, 191 (2013); Braun, Manashov, PLB 731, 316-319 (2014)]

- Factorization theorem connecting the LCDA in QCD and HQET. [Ishaq, YJ, XNX, DSY, PRL 125, 13, 132001 (2020); Beneke, Finauri, Vos, YBW, JHEP 09, 066 (2023)]

$$\Phi^{\mathrm{QCD}}(x,\mu_Q) = \int_0^\infty d\omega Z(x,\omega,m_b;\mu_Q,\mu_H)\,\Phi_+^{\mathrm{HQET}}(\omega,\mu_H)$$

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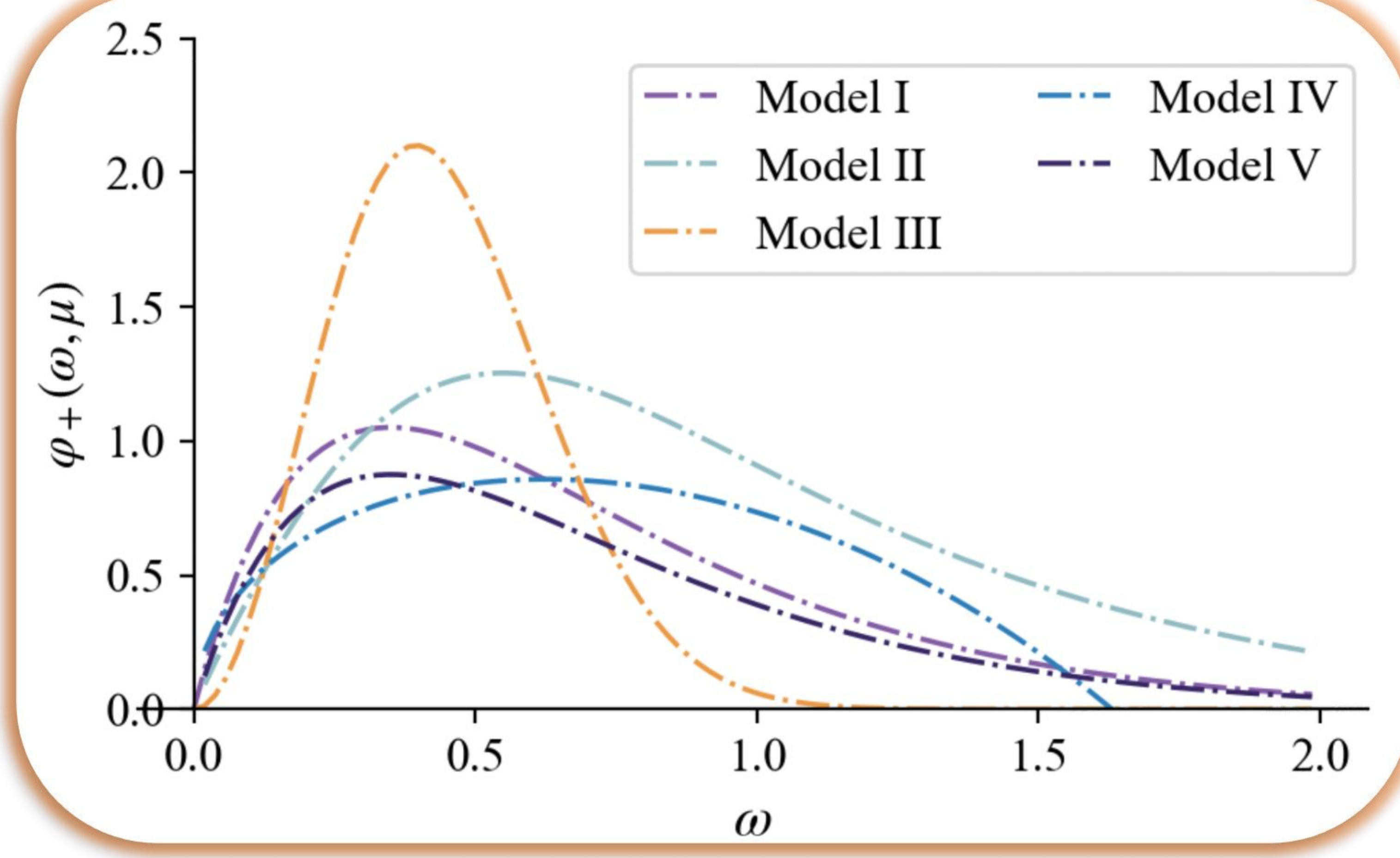
- Perturbative constraint for large ω. [Lee, Neubert, PRD 72, 094028 (2005)]

$$\phi_+^B(\omega,\mu) = \frac{C_F\alpha_s}{\pi\omega}\left[\left(\frac{1}{2}-\ln\frac{\omega}{\mu}\right)+\frac{4\bar{\Lambda}}{3\omega}\left(2-\ln\frac{\omega}{\mu}\right)+\dots\right]$$

But…

- Compare with several phenomenological models.



There are considerable differences between various models.

But…

- Recent studies have utilized these models to calculate the form factors for $B \to K^*$ and $B \to \pi$.

[JG, CDL, YLS, YMW, YBW, PRD 101,7, 074035 (2020); BYC, YKH, YLS, CW, YMW, JHEP 03, 014 (2023)]

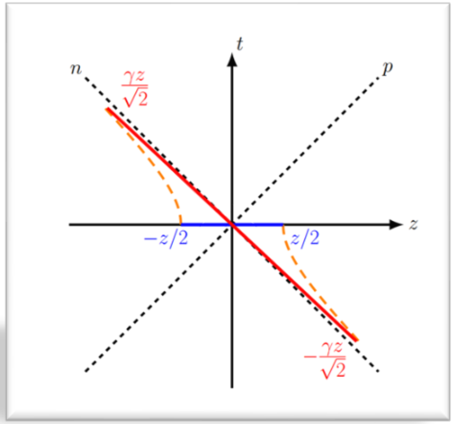
$$\mathcal{V}_{B\to K^*}(0) = 0.359^{+0.141}_{-0.085}\Big|_{\lambda_B}{}^{+0.019}_{-0.019}\Big|_{\sigma_1}{}^{+0.001}_{-0.062}\Big|_{\mu}{}^{+0.010}_{-0.004}\Big|_{M^2}{}^{+0.016}_{-0.017}\Big|_{s_0}{}^{+0.153}_{-0.079}\Big|_{\varphi_\pm(\omega)},$$

$$f^+_{B\to\pi}(0) = 0.122 \times \Big[1 \pm 0.07\Big|_{S_0^\pi} \pm 0.11\Big|_{\Lambda_q} \pm 0.02\Big|_{\lambda_E^2/\lambda_H^2}{}^{+0.05}_{-0.06}\Big|_{M^2} \pm 0.05\Big|_{2\lambda_E^2+\lambda_H^2}{}^{+0.06}_{-0.10}\Big|_{\mu_h} \pm 0.04\Big|_{\mu}{}^{+1.36}_{-0.56}\Big|_{\lambda_B}{}^{+0.25}_{-0.43}\Big|_{\sigma_1,\sigma_2}\Big].$$

Uncertainties from heavy meson LCDAs are dominant

Difficulties in first-principle determinations

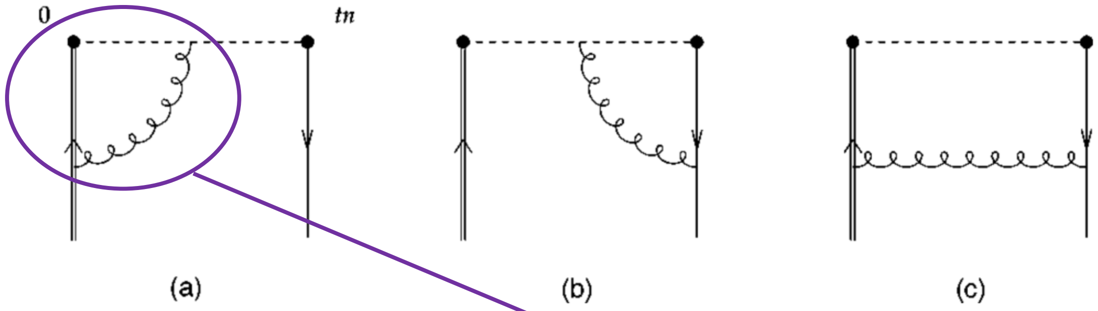
- The LCDAs are defined on the light-cone. [Grozin, Neubert, PRD 55, 272-290 (1997)]



They cannot be directly simulated on the lattice

Difficulties in first-principle determinations

- The LCDAs are defined on the light-cone. [Grozin, Neubert, PRD 55, 272-290 (1997)]
- Non-negative moments $\int dk\, k^n \varphi_B^+(k)$ for $n = 0, 1, 2$ ... are not related to matrix elements of local operators.



[Braun, Ivanov, Korchemsky, PRD 69, 034014 (2004)]

$$O_+^{\rm ren}(t,\mu) = O_+^{\rm bare}(t) + \frac{\alpha_s C_F}{4\pi}\left\{\left(\frac{4}{\hat{\epsilon}^2} + \frac{4}{\hat{\epsilon}}\ln(it\mu)\right) O_+^{\rm bare}(t) - \frac{4}{\hat{\epsilon}}\int_0^1 du\, \frac{u}{1-u}\left[O_+^{\rm bare}(ut) - O_+^{\rm bare}(t)\right] - \frac{1}{\hat{\epsilon}} O_+^{\rm bare}(t)\right\},$$

$$[\bar{q}(tn)\not{n}[tn,0]\Gamma h_v(0)]_R \neq \sum_{p=0}^{\infty} \frac{t^p}{p!}\left[\bar{q}(0)(\overleftarrow{D}\cdot n)^p h_v(0)\right]_R .$$

Cannot get φ_B^+ by their moments

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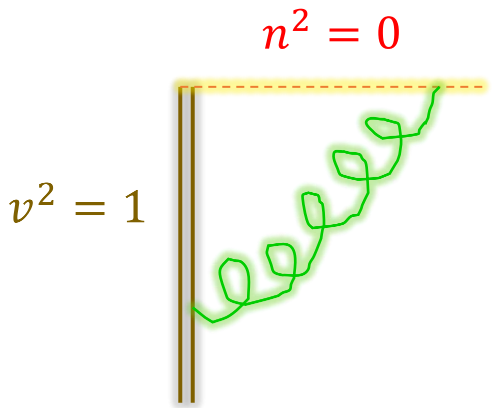
How to solve this problem?

$$\langle H(p_H)|\,\bar{h}_v(0)\not{n}_+\gamma_5\,[0,tn_+]\,q_s(tn_+)\,|0\rangle = -i\tilde{f}_H m_H n_+\cdot v\int_0^\infty d\omega e^{i\omega t n_+\cdot v}\varphi_+(\omega;\mu)\,.$$

Cusp divergence:



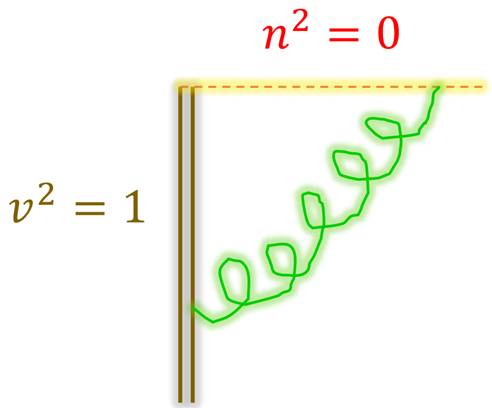
$$\cosh\theta = \frac{n\cdot v}{\sqrt{n^2}\sqrt{v^2}}$$

✓ $n^2 \neq 0$, still heavy quark field h_v

How to solve this problem?

$$\langle H(p_H)|\bar{h}_v(0)\not{n}_+\gamma_5[0,tn_+]q_s(tn_+)|0\rangle = -i\tilde{f}_H m_H n_+\cdot v\int_0^\infty d\omega e^{i\omega t n_+\cdot v}\varphi_+(\omega;\mu)\,.$$

Cusp divergence:

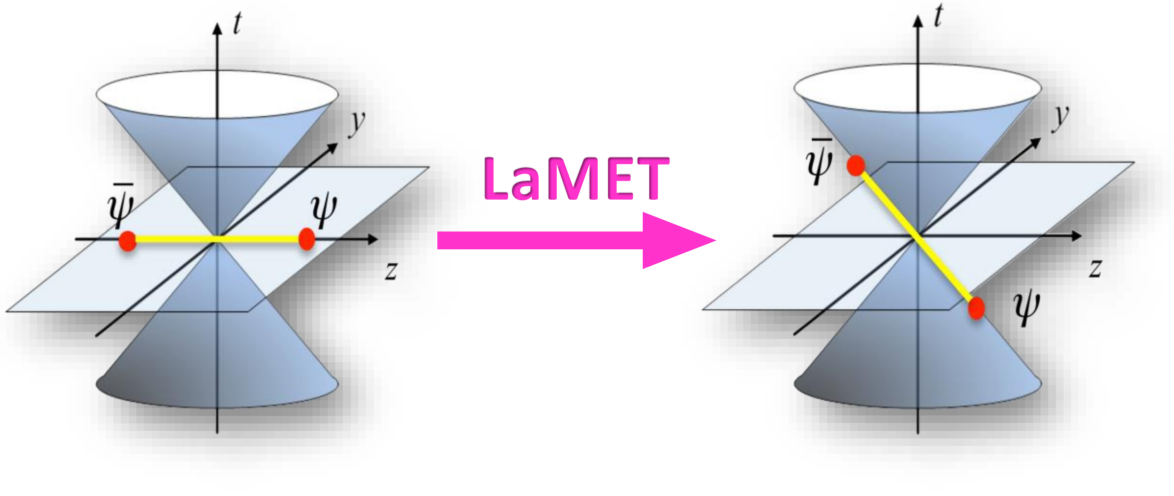


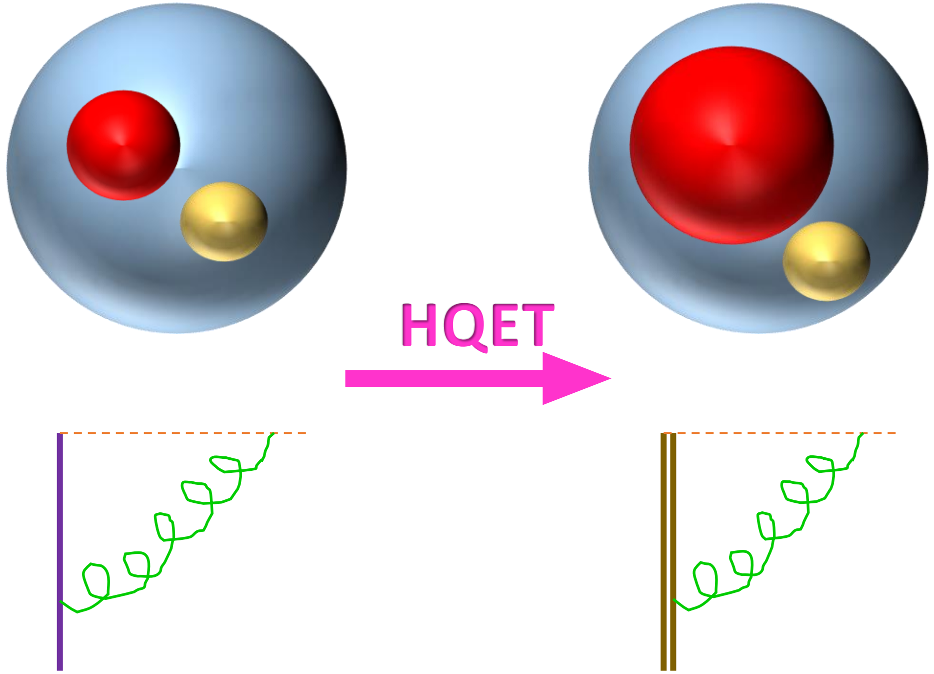
$$\cosh\theta = \frac{n\cdot v}{\sqrt{n^2}\sqrt{v^2}}$$

✓ $n^2 \neq 0$, still heavy quark field h_v

✓ $n^2 \neq 0$, and No h_v: QCD heavy quark

How to solve this problem?

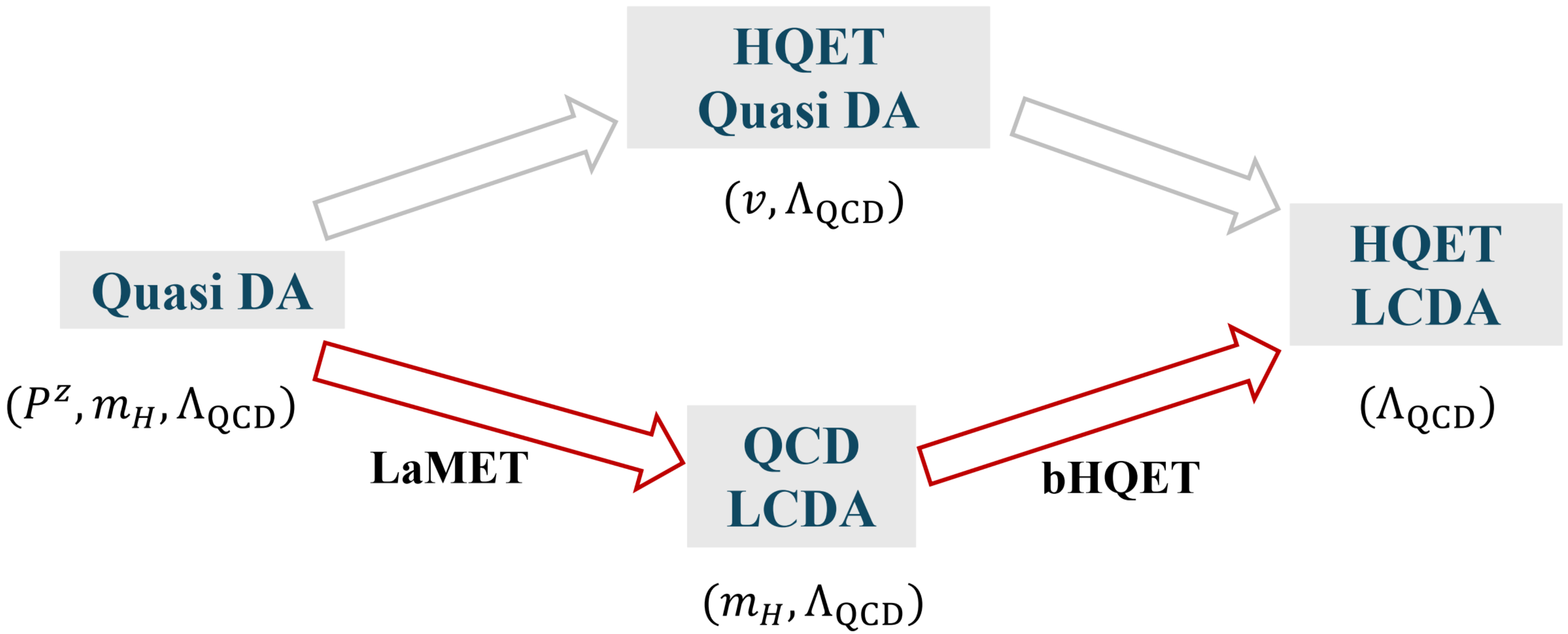




- Light-cone can be accessed by simulating correlation functions with a large but finite P^z. [XDJ, PRL 110 (2013)]

- HQET can be accessed by simulating correlation functions with a large but finite m_Q. [Isgur, Wise, PLB 232, 113-117 (1989)]

How to solve this problem?



The first road

- **Can we utilize the heavy meson quasi-DA in HQET to obtain LCDA in HQET ?**

- Our first attempts.
  [WW, YMW, JX, SZ, PRD 102, 011502 (2020)]

Quasi-DA in HQET

LCDA in HQET

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Quasi-DA in HQET

LCDA in HQET

$$\tilde{\varphi}_B^+(\xi,\mu) = \int_0^\infty d\omega\, H(\xi,\omega,n_z\cdot v,\mu)\,\varphi_B^+(\omega,\mu) + O\left(\frac{\Lambda_{\rm QCD}}{n_z\cdot v\,\xi}\right)$$

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  [WW, YMW, JX, SZ, PRD 102, 011502 (2020)]
  [JX, XRZ, PRD 106, 114019 (2022)]
  [JX, XRZ, SZ, PRD 106, L011503 (2022)]
  [SMH, WW, JX, SZ, PRD 109, 034001 (2024)]

Quasi-DA in HQET

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  [SMH, WW, JX, SZ, PRD 109, 034001 (2024)]

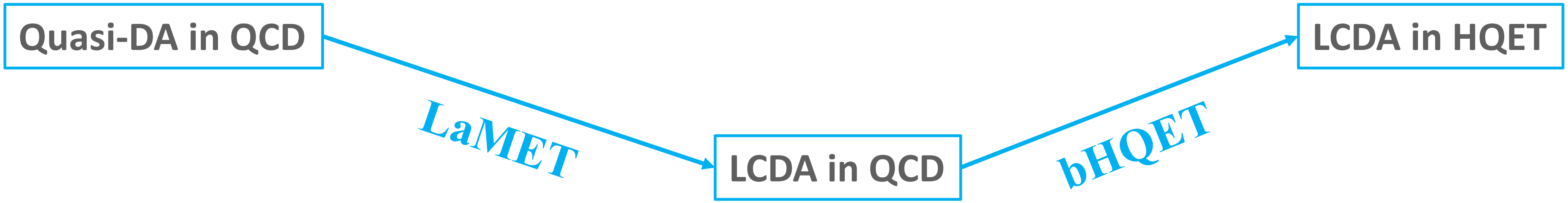
Quasi-DA in HQET

LCDA in HQET

- **Difficult to realize the boosted HQET field on lattice QCD.**

The second road

- **Two-step factorization to access heavy meson LCDA.**

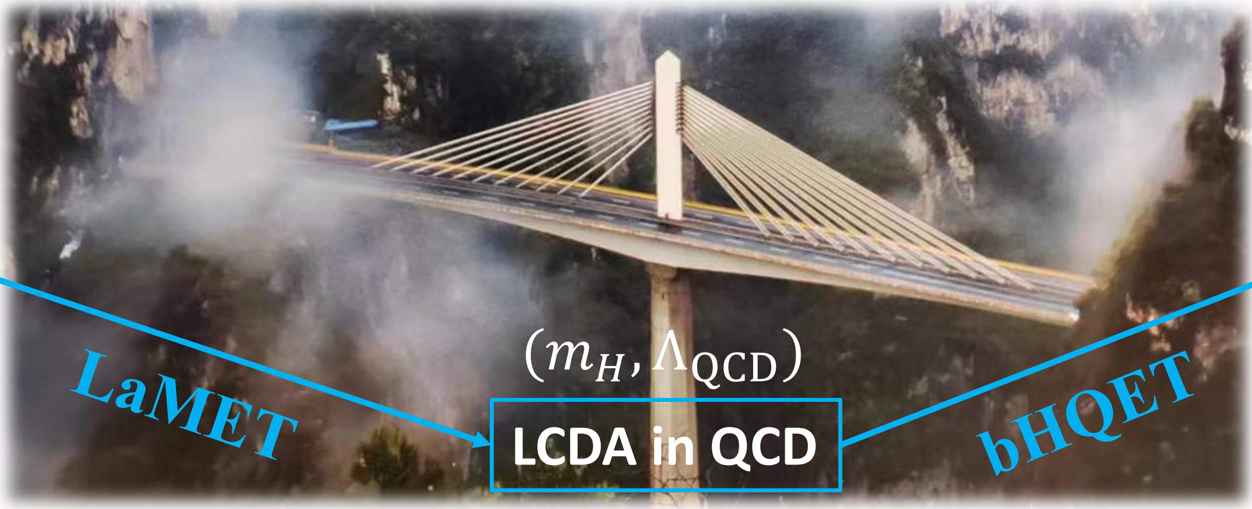


The second road

- Two-step factorization to access heavy meson LCDA.

$(P_z, m_H, \Lambda_{\text{QCD}})$

Quasi-DA in QCD



(Λ_{QCD})

LCDA in HQET

$\Rightarrow$ **Hierarchy $\Lambda_{\text{QCD}} \ll m_H \ll P_z$:**

Λ_{QCD}~ hundreds MeV $\ll$ **m_H** **$\ll P^z$ can achieve 4 GeV currently**

1 GeV m_D $\cdots$ $1.6 m_D$ 5 GeV

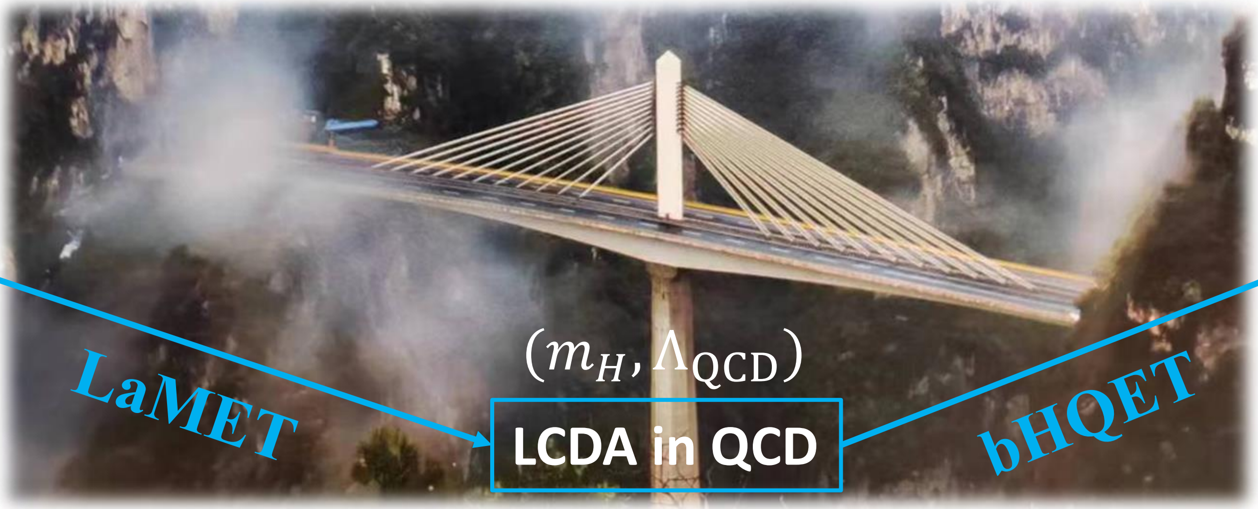
A big challenge for lattice simulation but still calculable on the lattice

The second road

➢ **Two-step factorization to access heavy meson LCDA.**

$(P_z, m_H, \Lambda_{\rm QCD})$

Quasi-DA in QCD



$(\Lambda_{\rm QCD})$

LCDA in HQET

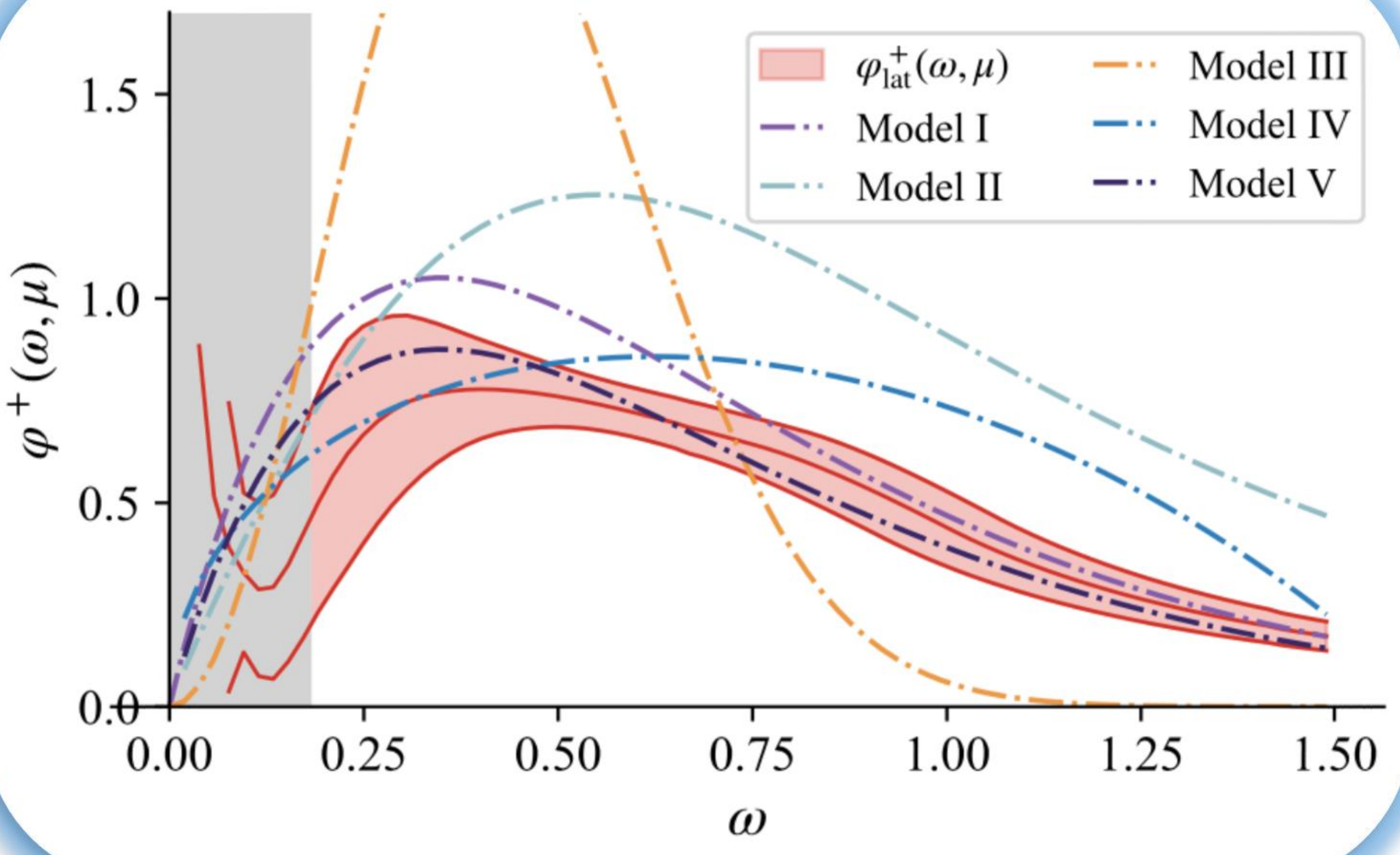
For more details, please refer to SZ's report:
Heavy quark mass dependence of heavy meson LCDAs in QCD

For more details, please refer to QAZ's report:
Determining heavy meson LCDAs from lattice QCD

For more details, please refer to YBW's report:
QCD LCDAs of heavy mesons from boosted HQET

Final results for HQET LCDAs

➢ **Compare with several phenomenological models**



The first step towards heavy meson LCDAs

➢ First inverse moment (IM)

$$\lambda_B^{-1}(\mu) \equiv \int_{-\infty}^{\infty} d\omega \frac{\phi_B^+(\omega,\mu)}{\omega}\,.$$

- ✓ The IM is a crucial quantity in LCSR and QCD factorization theorems in heavy flavor physics.
- ✓ We determine the IM by employing a model-independent parametrization formula.

μ		λ_B (GeV)	$\sigma_B^{(1)}$	
1GeV	$N=1$	0.389(35)	1.63(8)	[e-Print: 2403.17492]
1GeV	Ref. [31]	>0.24		[PRD 98, 112016 (2018)]
	Ref. [18]	0.383(153)		[JHEP 10, 043 (2020)]
	Ref. [7]	0.48(11)	1.6(2)	[PRD 72, 094082 (2005)]
	Ref. [15]	0.46(11)	1.4(4)	[PRD 69, 034014 (2004)]
	Ref. [1]	0.35(15)		[PRD 55, 272 (1997)]
	Ref. [21]	$0.343^{+0.064}_{-0.079}$		[PRD 101, 7, 074035 (2020)]
	Ref. [73]	0.338(68)		[PLB 848, 138345 (2024)]

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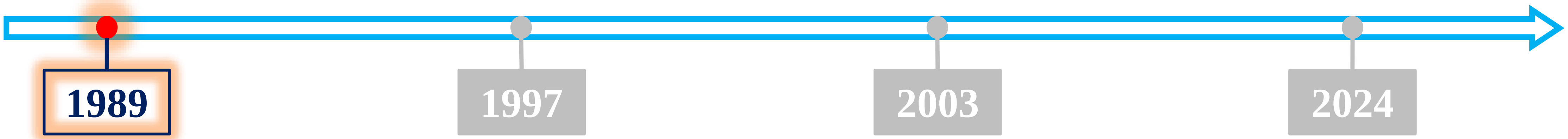
Weak Decays of Heavy Mesons in the Static Quark Approximation

Nathan Isgur (Toronto U.), Mark B. Wise (Caltech) (Oct 30, 1989)

Published in: *Phys.Lett.B* 232 (1989) 113-117



[Isgur, Wise, PLB 232, 113-117 (1989)]

2448 citations

Asymptotics of heavy meson form-factors

A.G. Grozin (Novosibirsk, IYF), M. Neubert (CERN) (Jul, 1996)

Published in: *Phys.Rev.D* 55 (1997) 272-290 • e-Print: hep-ph/9607366 [hep-ph]

[Grozin, Neubert, PRD 55, 272-290 (1997)]

389 citations

Renormalization group evolution of the B meson light cone distribution amplitude

Bjorn O. Lange (Cornell U., LNS), Matthias Neubert (Cornell U., LNS) (Mar, 2003)

Published in: *Phys.Rev.Lett.* 91 (2003) 102001 • e-Print: hep-ph/0303082 [hep-ph]

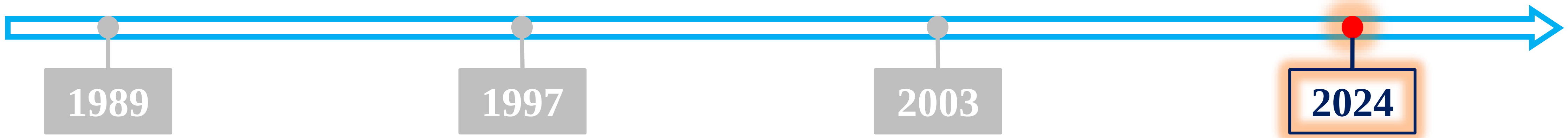
[Lange, Neubert, PRL 91, 102001 (2003)]

181 citations

A new method to access heavy meson lightcone distribution amplitudes from first-principle

Xue-Ying Han, Jun Hua, Xiangdong Ji, Cai-Dian Lü, Wei Wang et al. (Mar 26, 2024)

e-Print: 2403.17492 [hep-ph]



[XYH, WW et.al, e-Print: 2403.17492 (2024)]

9 citations

Summary

- Two-step effective theories to calculate the heavy meson LCDA in HQET.
- CLQCD ensembles (0.05 fm) to simulate heavy meson quai-DAs.
- The first (preliminary) results for LCDAs are consistent with models.

Mass dependence of heavy meson LCDA

$\Lambda^2/(x\,P^z)^2$ corrections

Heavy quark spin symmetry

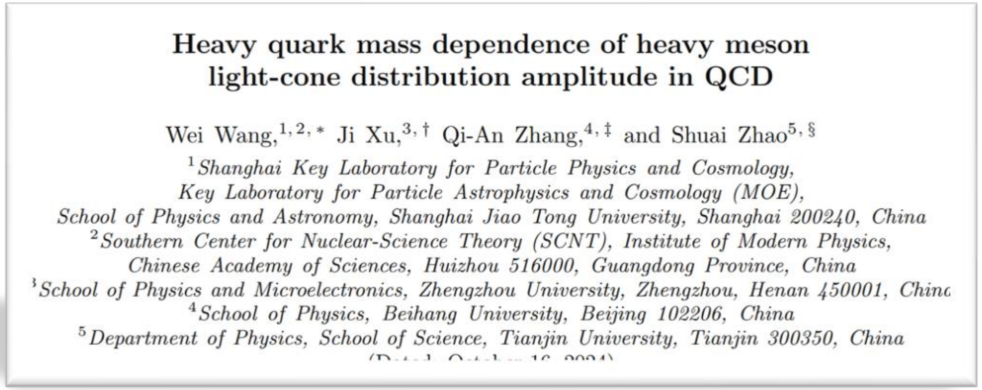
Resum infrared-renormalon

Finer lattice spacing

Hybrid-ratio renormalization

……

Precise Heavy meson LCDA


Heavy quark mass dependence of heavy meson light-cone distribution amplitude in QCD

Wei Wang,[1,2,*] Ji Xu,[3,†] Qi-An Zhang,[4,‡] and Shuai Zhao[5,§]

[1] Shanghai Key Laboratory for Particle Physics and Cosmology, Key Laboratory for Particle Astrophysics and Cosmology (MOE), School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China
[2] Southern Center for Nuclear-Science Theory (SCNT), Institute of Modern Physics, Chinese Academy of Sciences, Huizhou 516000, Guangdong Province, China
[3] School of Physics and Microelectronics, Zhengzhou University, Zhengzhou, Henan 450001, China
[4] School of Physics, Beihang University, Beijing 102206, China
[5] Department of Physics, School of Science, Tianjin University, Tianjin 300350, China

[SZ et.al, accomplished]

Report: Heavy quark mass dependence of heavy meson LCDAs in QCD

Mass dependence of heavy meson LCDA

$\Lambda^2/(x\,P^z)^2$ corrections

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……

Precise Heavy meson LCDA

Power corrections to quasi-distribution amplitudes of a heavy meson

Chao Han,[1] Wei Wang,[1,2,*] Jia-Lu Zhang,[1,†] and Jian-Hui Zhang[3,‡]

[1] *INPAC, Key Laboratory for Particle Astrophysics and Cosmology (MOE), Shanghai Key Laboratory for Particle Physics and Cosmology, School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China*

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[3] *School of Science and Engineering, The Chinese University of Hong Kong, Shenzhen 518172, China*

[CH, WW, JLZ, JHZ, e-Print: 2408.13486]

Report: Power corrections to quasi-DA of a heavy meson

Mass dependence of heavy meson LCDA

$\Lambda^2/(x P^z)^2$ corrections

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Precise Heavy meson LCDA

Probing heavy meson lightcone distribution amplitudes with heavy quark spin symmetry

Zhi-Fu Deng,[1,2] Wei Wang,[1,3,*] Yan-Bing Wei,[4,†] and Jun Zeng[1,‡]

[1]*Shanghai Key Laboratory for Particle Physics and Cosmology, Key Laboratory for Particle Astrophysics and Cosmology (MOE), School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, P.R. China*

[2]*School of Science and Engineering, The Chinese University of Hong Kong, Shenzhen (CUHK-Shenzhen), Guangdong, 518172, P.R. China*

[3]*Southern Center for Nuclear-Science Theory (SCNT), Institute of Modern Physics, Chinese Academy of Sciences, Huizhou 516000, Guangdong Province, P.R. China*

[4]*School of Physics and Optoelectronic Engineering, Beijing University of Technology, Beijing 100124, P.R. China*

[ZFD, WW, YBW, JZ, e-Print: 2409.00632]

Report: Probing heavy meson LCDAs with heavy quark spin symmetry

Mass dependence of heavy meson LCDA

$\Lambda^2/(x P^z)^2$ corrections

Heavy quark spin symmetry

Resum infrared-renormalon

Finer lattice spacing

Hybrid-ratio renormalization

……

Precise Heavy meson LCDA

Leading Power Accuracy in Lattice Calculations of Parton Distributions

Rui Zhang,[1,*] Jack Holligan,[2,†] Xiangdong Ji,[1,‡] and Yushan Su[1,3,§]

[1]*Department of Physics, University of Maryland, College Park, MD 20742, USA*
[2]*Biomedical and Physical Sciences Building, Michigan State University, East Lansing, MI, 48824, USA*
[3]*Physics Division, Argonne National Laboratory, Lemont, Illinois 60439, USA*

[RZ, Holligan, XDJ, YSS, PLB, 844, 138081 (2023)]

Mass dependence of heavy meson LCDA

$\Lambda^2/(x\,P^z)^2$ corrections

Heavy quark spin symmetry

Resum infrared-renormalon

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Hybrid-ratio renormalization

……

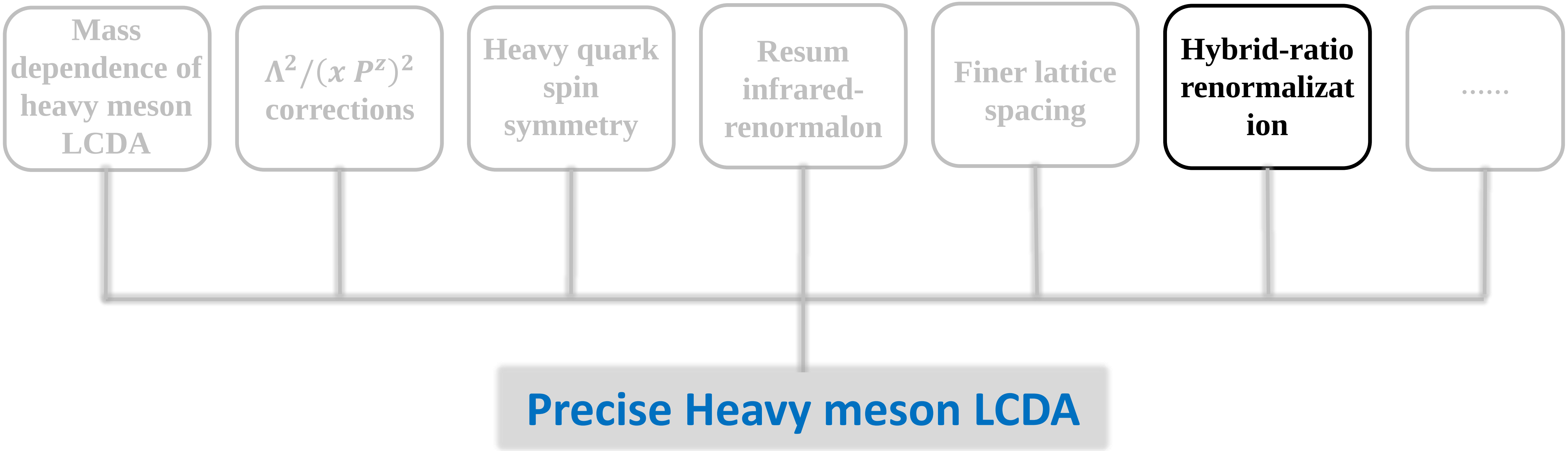
Precise Heavy meson LCDA

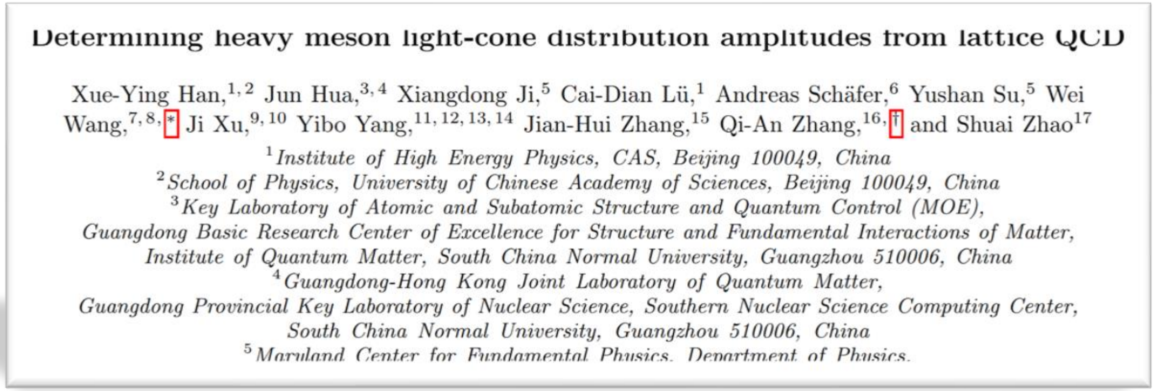
Quark masses and low energy constants in the continuum from the tadpole improved clover ensembles

CLQCD

Zhi-Cheng Hu,[1,2] Bo-Lun Hu,[3] Ji-Hao Wang,[3,2] Ming Gong,[4] Guoming Liu,[5,6] Liuming Liu,[1,7,*] Peng Sun,[1,†] Wei Sun,[4] Wei Wang,[8,9] Yi-Bo Yang,[2,3,10,11,‡] and Dian-Jun Zhao[2,3]

[CLQCD Collaboration, PRD, 109, 5, 054507 (2024)]





Determining heavy meson light-cone distribution amplitudes from lattice QCD

Xue-Ying Han,[1,2] Jun Hua,[3,4] Xiangdong Ji,[5] Cai-Dian Lü,[1] Andreas Schäfer,[6] Yushan Su,[5] Wei Wang,[7,8,*] Ji Xu,[9,10] Yibo Yang,[11,12,13,14] Jian-Hui Zhang,[15] Qi-An Zhang,[16,†] and Shuai Zhao[17]

[1] *Institute of High Energy Physics, CAS, Beijing 100049, China*
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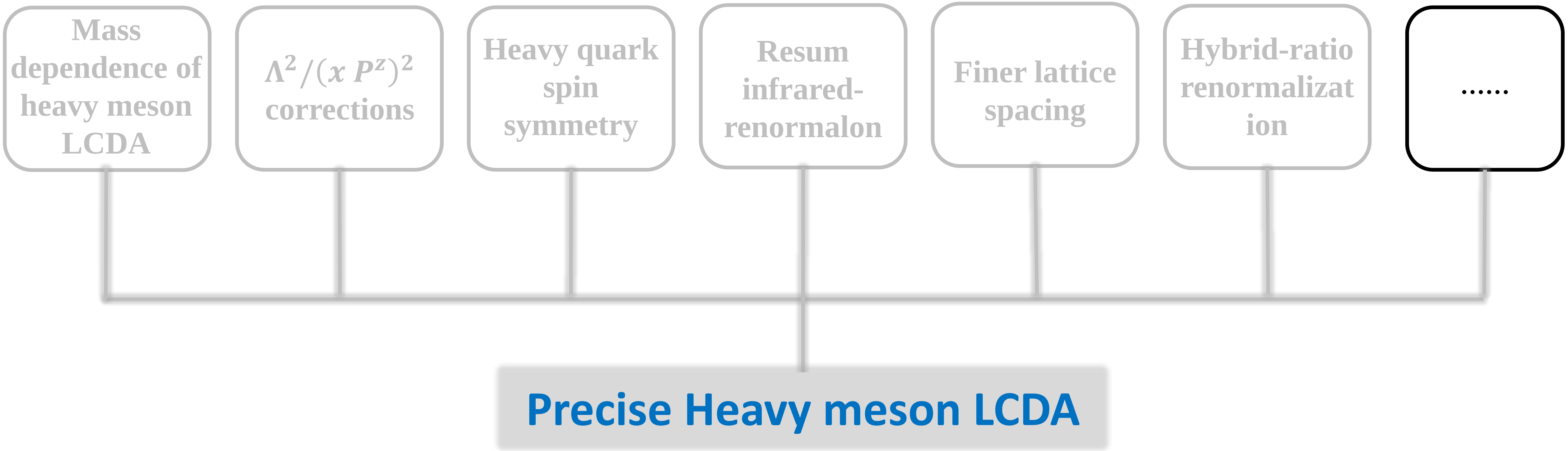
[3] *Key Laboratory of Atomic and Subatomic Structure and Quantum Control (MOE), Guangdong Basic Research Center of Excellence for Structure and Fundamental Interactions of Matter, Institute of Quantum Matter, South China Normal University, Guangzhou 510006, China*
[4] *Guangdong-Hong Kong Joint Laboratory of Quantum Matter, Guangdong Provincial Key Laboratory of Nuclear Science, Southern Nuclear Science Computing Center, South China Normal University, Guangzhou 510006, China*
[5] *Maryland Center for Fundamental Physics, Department of Physics,*

[QAZ et.al, e-Print: 2410.18654]

Report: Determining heavy meson LCDAs from lattice QCD



- Two-loop calculation;
- Λ/m_Q corrections;
- Other theoretical approaches;

……

- Need support of computational resources;
- Need support of new minds;

……

Mass dependence of heavy meson LCDA

$\Lambda^2/(x\,P^z)^2$ corrections

Heavy quark spin symmetry

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Finer lattice spacing

Hybrid-ratio renormalization

……

Precise Heavy meson LCDA

CKM matrix

New physics

Strong interaction

Please stay tuned for precise result of LCDA

Thanks！