所创新CEPC项目
理论研究报告

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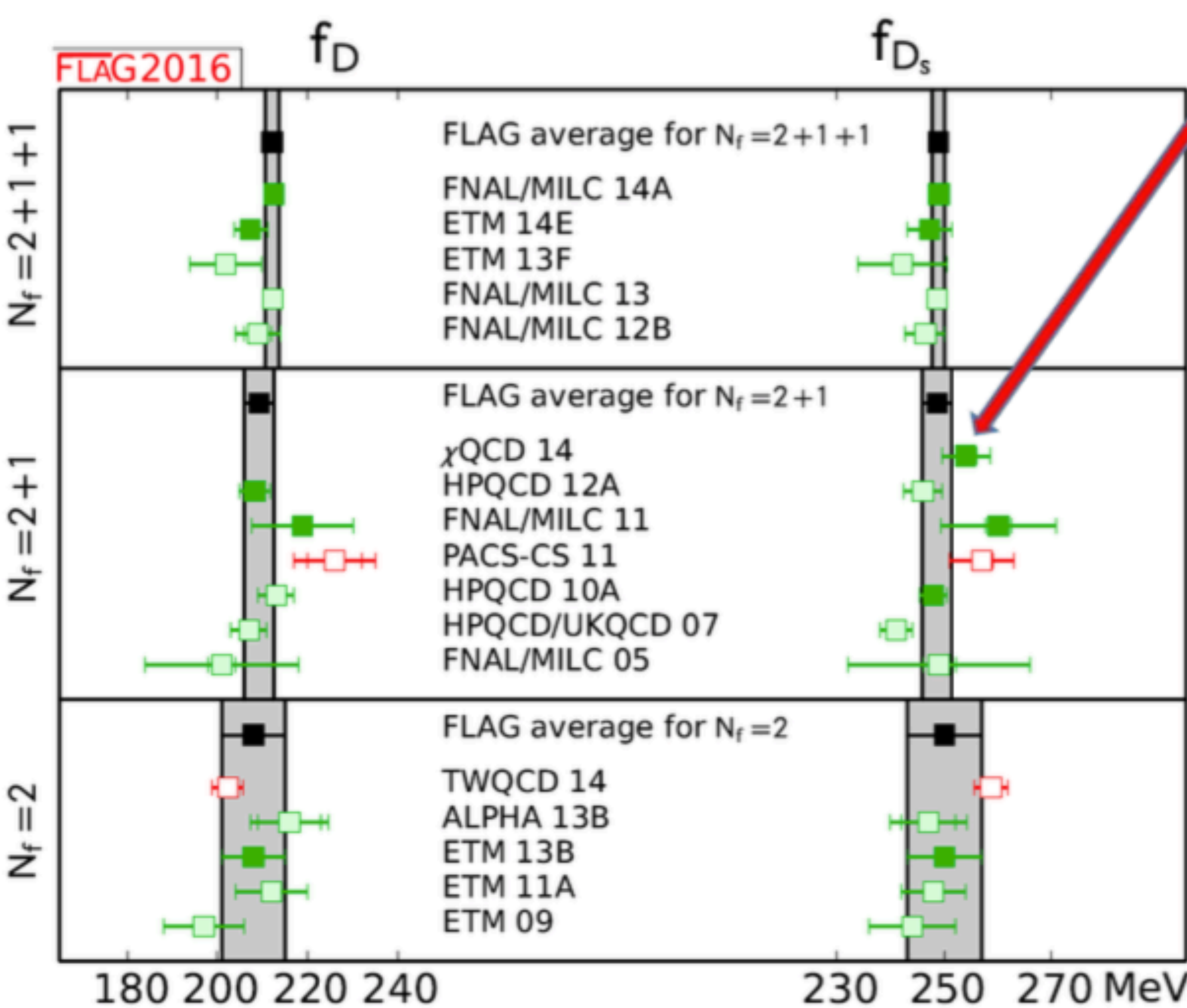
f_{D_s} 和 m_c

- f_{D_s}: 确定CKM矩阵元|Vcs|
- m_c: 标准模型基本参数

◆ $m_c^{\overline{MS}}(2\text{ GeV}) = 1.118(6)(24)$ GeV

Yang,…, ZL et al., PRD92.034517, 2015



FLAG2016, EPJC77 (2017) no.2, 112
[arXiv:1607.00299]

- 实心绿色方块: 控制好了各项系统误差; 纳入格点QCD世界平均
- $N_f = 2+1$:
  $f_{D_s} = 249.8(2.3)$ MeV
- $N_f = 2+1+1$:
  $f_{D_s} = 248.83(1.27)$ MeV
- PDG2016 (CPC40):
  $f_{D_s^+}^{exp} = 257.8(4.1)$ MeV
- 格点结果与实验在2σ内一致

f_{D^*} and $f_{D_s^*}$

- f_V也可用于确定CKM矩阵元|Vcq|
- 检验重夸克有效理论的精度
- 检验B介子非轻衰变中因子化方法的精度

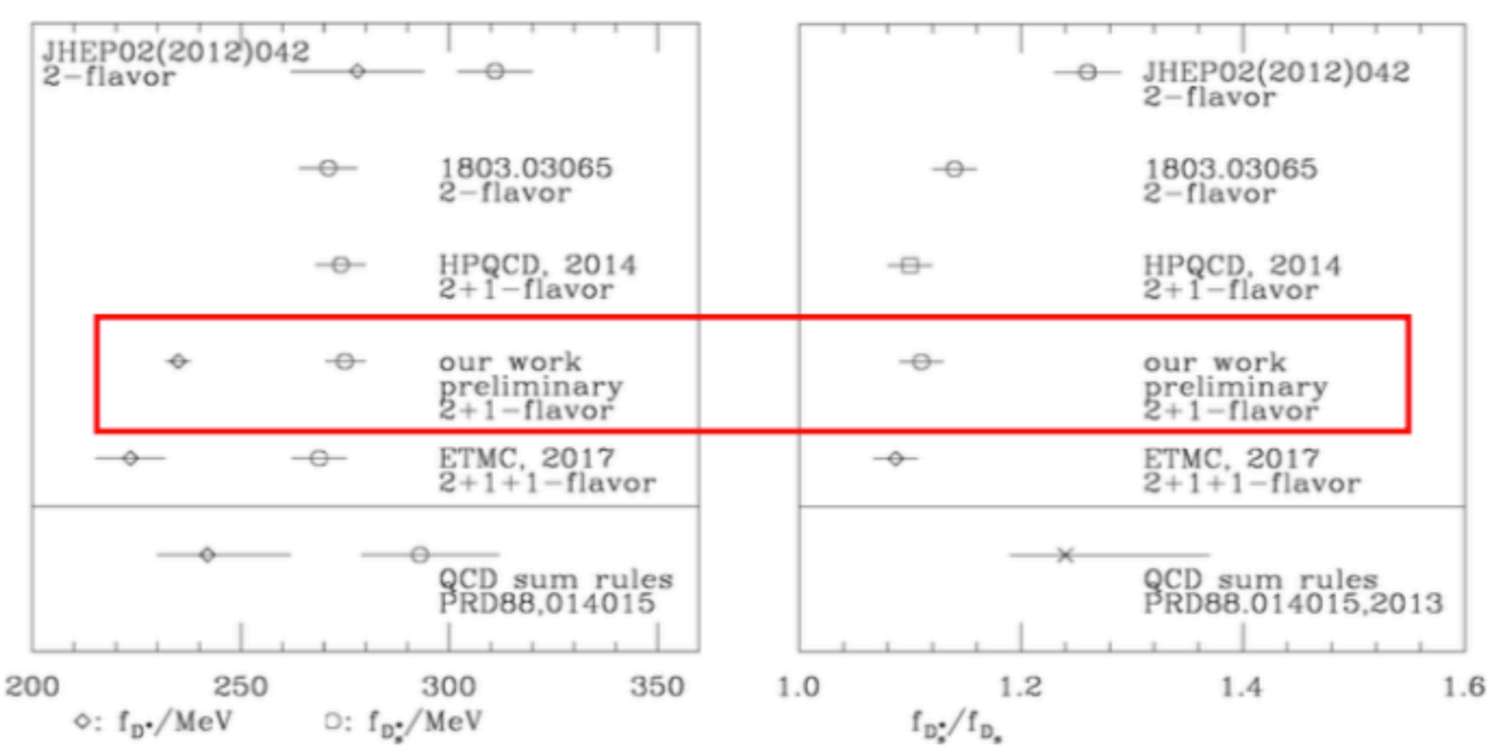
- 2+1-味畴壁费米子组态 (from RBC-UKQCD 合作组), 物理π质量点:

  $M_\pi^{(\text{sea})} = 139.2(4)$ MeV,　格子大小 $L^3 \times T = 48^3 \times 96$, La~5.5 fm

- 算符重正化常数(用于衰变常数的计算, 已完成)

  $\bar{\psi}\Gamma\psi$,　$\Gamma = I, \gamma_5, \gamma_\mu, \gamma_\mu\gamma_5, \sigma_{\mu\nu}$　Bi, ..., ZL et al., PRD97.094501(2018)

- 衰变常数初步结果及与其他计算的比较



- HPQCD, PRL112, 212002 (2014), 2+1-味
- ETMC, PRD96, 034524 (2017), 2+1+1-味
- Becirevic et al., JHEP02 (2012) 042, 2-味
- Blossier, Heitger, Post (1803.03065), 2-味
- 海夸克效应? 也许

Mixed QCD-EW corrections for Higgs boson production at e+e- colliders

1.3%

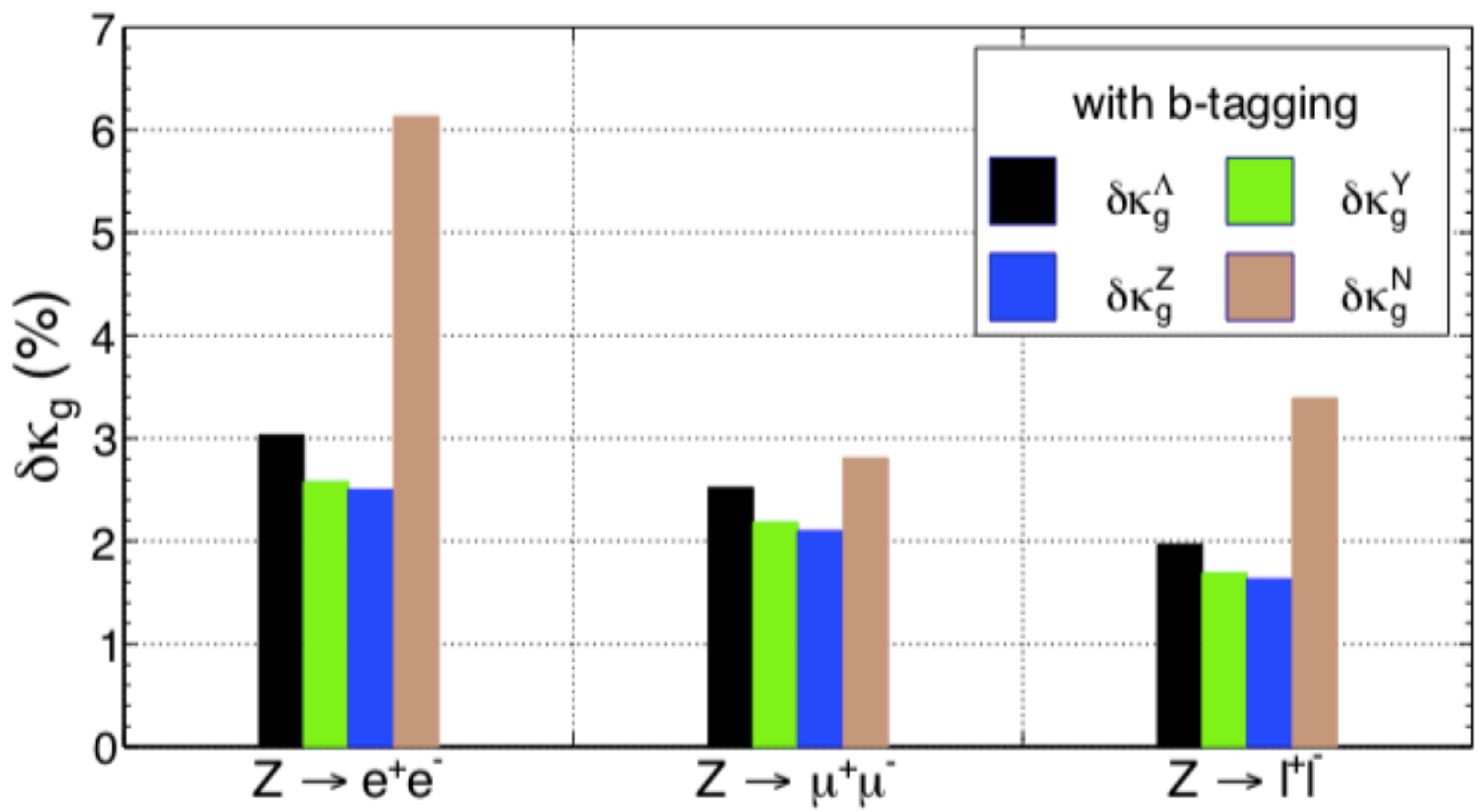
$\sqrt{s}$ (GeV)	σ_{LO} (fb)	σ_{NLO} (fb)	σ_{NNLO} (fb)	$\sigma^{\text{exp.}}_{\text{NNLO}}$ (fb)
240	256.3(9)	228.0(1)	230.9(4)	230.9(4)
250	256.3(9)	227.3(1)	230.2(4)	230.2(4)
300	193.4(7)	170.2(1)	172.4(3)	172.4(3)
350	138.2(5)	122.1(1)	123.9(2)	123.6(2)
500	61.38(22)	53.86(2)	54.24(7)	54.64(10)

TABLE I. The NNLO predictions for the total cross sections at various collider energies.

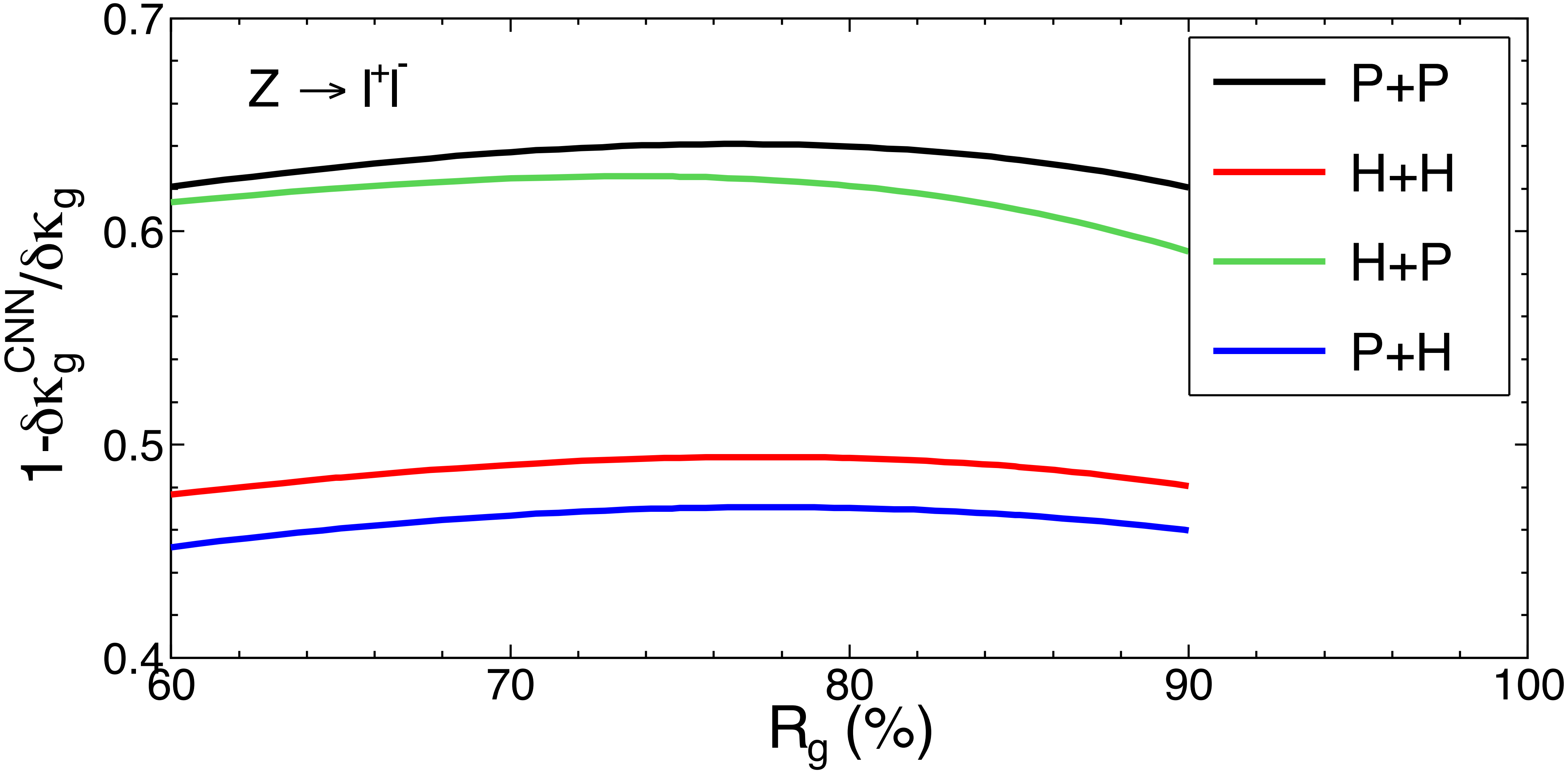
Y.Gong, Z.Li, X.Xu, L.Yang and X.Zhao
Phys.Rev. D95 (2017) no.9, 093003

Probing the Higgs boson-gluon coupling via the jet energy profile at e^+e^- colliders

Gexing Li, Zhao Li, Yandong Liu, Yan Wang, and Xiaoran Zhao
Phys. Rev. D **98**, 076010 – Published 17 October 2018



Great improvement via CNN



NNLO correction to $\gamma\gamma^* \rightarrow \eta_c$ form factor

Feng, Jia, Sang, PRL 117, 222001 (2015)

PRL 115, 222001 (2015) PHYSICAL REVIEW LETTERS week ending 27 NOVEMBER 2015

Can Nonrelativistic QCD Explain the $\gamma\gamma^* \rightarrow \eta_c$ Transition Form Factor Data?

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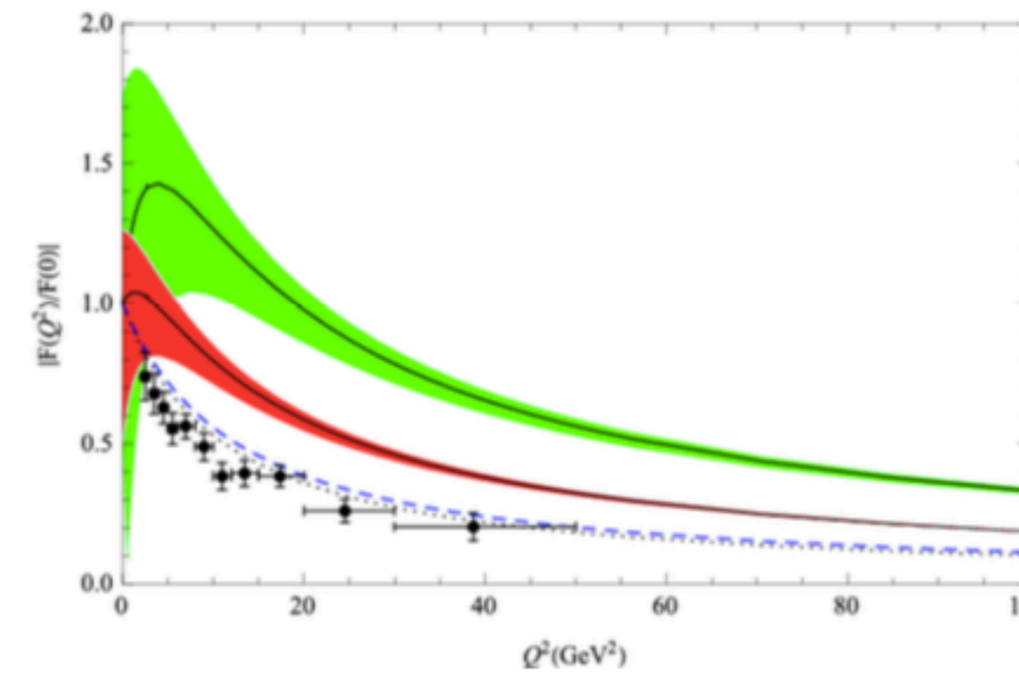
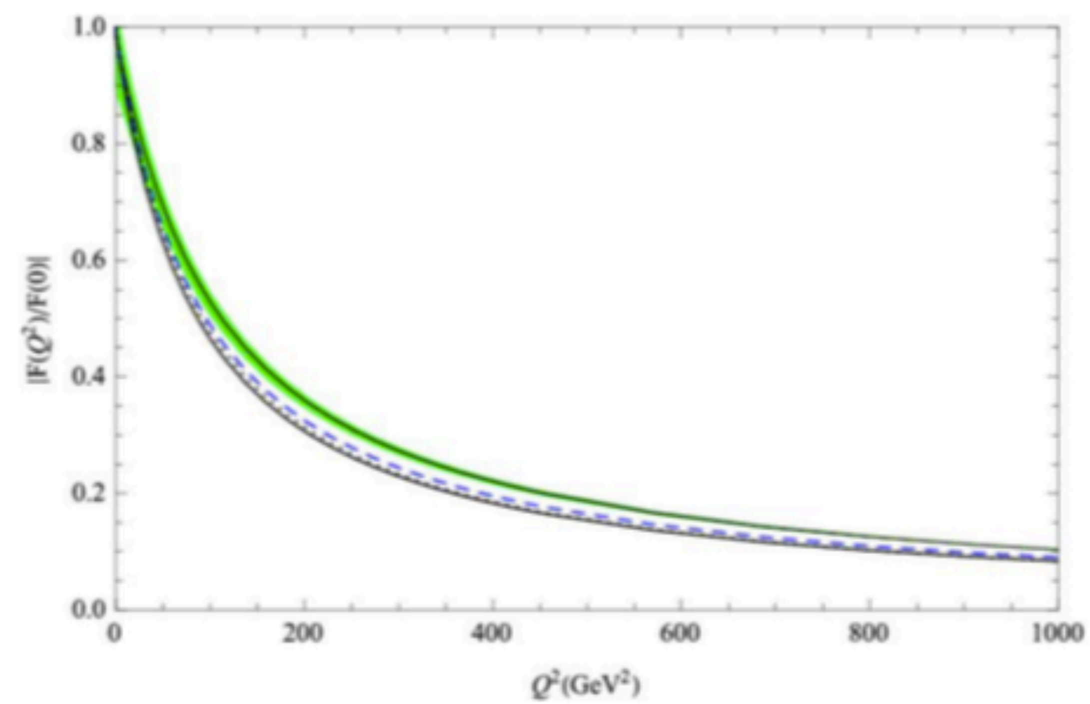
Unlike the bewildering situation in the $\gamma\gamma^* \rightarrow \pi$ form factor, a widespread view is that perturbative QCD can decently account for the recent *BABAR* measurement of the $\gamma\gamma^* \rightarrow \eta_c$ transition form factor. The next-to-next-to-leading-order perturbative correction to the $\gamma\gamma^* \rightarrow \eta_{c,b}$ form factor, is investigated in the nonrelativistic QCD (NRQCD) factorization framework for the first time. As a byproduct, we obtain, by far, the most precise order-α_s^2 NRQCD matching coefficient for the $\eta_{c,b} \rightarrow \gamma\gamma$ process. After including the substantial negative order-α_s^2 correction, the good agreement between NRQCD prediction and the measured $\gamma\gamma^* \rightarrow \eta_c$ form factor is completely ruined over a wide range of momentum transfer squared. This eminent discrepancy casts some doubts on the applicability of the NRQCD approach to hard exclusive reactions involving charmonium.

DOI: 10.1103/PhysRevLett.115.222001 PACS numbers: 13.60.Le, 12.38.Bx, 14.40.Pq





NNLO QCD corrections to $\eta_{c,b} \to$ light hadrons

Feng, Jia, Sang, PRL 119, 252001 (2017)

PRL **119,** 252001 (2017) PHYSICAL REVIEW LETTERS week ending 22 DECEMBER 2017

Next-to-Next-to-Leading-Order QCD Corrections to the Hadronic Width of Pseudoscalar Quarkonium

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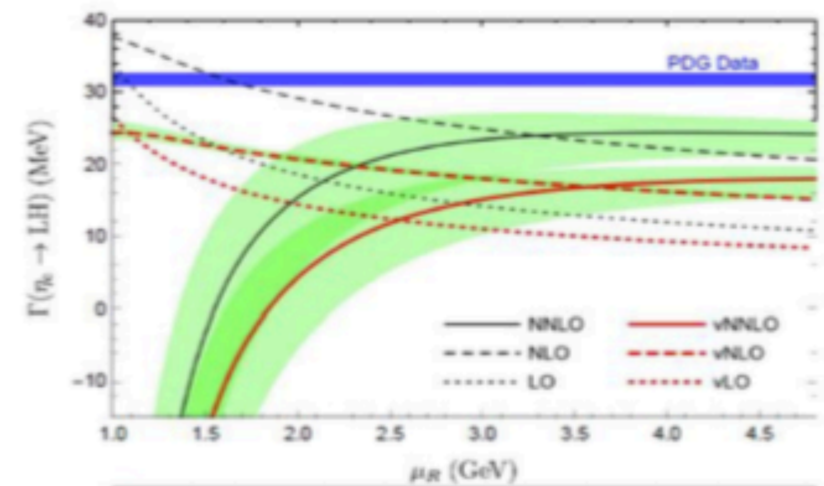
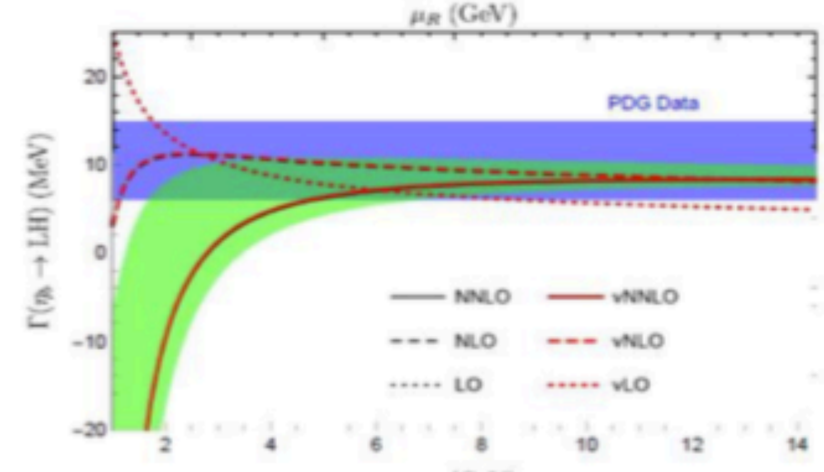
We compute the next-to-next-to-leading-order QCD corrections to the hadronic decay rates of the pseudoscalar quarkonia, at the lowest order in velocity expansion. The validity of nonrelativistic QCD (NRQCD) factorization for inclusive quarkonium decay process, for the first time, is verified to relative order α_s^2. As a by-product, the renormalization group equation of the leading NRQCD four-fermion operator $\mathcal{O}_1(^1S_0)$ is also deduced to this perturbative order. By incorporating this new piece of correction together with available relativistic corrections, we find that there exists severe tension between the state-of-the-art NRQCD predictions and the measured η_c hadronic width and, in particular, the branching fraction of $\eta_c \to \gamma\gamma$. NRQCD appears to be capable of accounting for η_b hadronic decay to a satisfactory degree, and our most refined prediction is $\mathrm{Br}(\eta_b \to \gamma\gamma) = (4.8 \pm 0.7) \times 10^{-5}$.

DOI: 10.1103/PhysRevLett.119.252001

To date most refined prediction for $\eta_b \to \gamma\gamma$

$$\mathrm{Br}(\eta_b \to \gamma\gamma) = (4.8 \pm 0.7) \times 10^{-5},$$





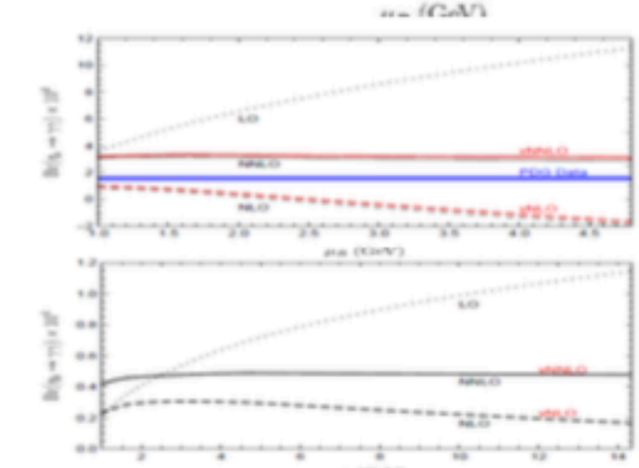


FIG. 3: The predicted branching fractions of $\eta_c \to \gamma\gamma$ (top) and $\eta_b \to \gamma\gamma$ (bottom) as functions of μ_R, at various level of accuracy in α_s and v. The blue band corresponds to the measured branching ratio for $\eta_c \to \gamma\gamma$ taken from PDG 2016 [4], with $\mathrm{Br}(\eta_c \to \gamma\gamma) = (1.59 \pm 0.13) \times 10^{-4}$. The labels characterizing different curves are the same as in Fig. 2.

NNLO mixed EW-QCD correction to e+e- -> H+ Z (mu+mu-) at CEPC

Sun, Feng, Jia and Sang, PRD 96 (2017)051301 (RC)
Chen, Feng, Jia and Sang, CPC 2019 January

RAPID COMMUNICATIONS

PHYSICAL REVIEW D 96, 051301(R) (2017)

Mixed electroweak-QCD corrections to $e^+e^- \to HZ$ at Higgs factories

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The prospective Higgs factories, exemplified by ILC, FCC-ee and CEPC, plan to conduct precision Higgs measurements at the e^+e^- center-of-mass energy around 250 GeV. The cross sections for the dominant Higgs production channel, the Higgsstrahlung process, can be measured to a (sub)percent accuracy. Merely incorporating the well-known next-to-leading-order (NLO) electroweak corrections appears to be far from sufficient to match the unprecedented experimental precision. In this work, we make an important advancement toward this direction by investigating the mixed electroweak-QCD corrections to $e^+e^- \to HZ$ at next-to-next-to-leading order (NNLO) for both unpolarized and polarized Z bosons. The corrections turn out to reach the 1% level of the Born order results, and thereby must be incorporated in future confrontations with the data.

Numerics: NNLO correction has a size about **1%**, relevant for future CEPC measurements

Table 1. Differential cross section with respect to the $\mu^+\mu^-$ invariant mass at $\sqrt{s}$=240 GeV. Note the upper bound for $M_{\mu\mu}$ equals $\sqrt{s}-M_H$.

$M_{\mu\mu}$/GeV \ $sd\sigma/ds_{12}$/fb		50	70	80	85	90	91	92	95	100	110	σ
LO/fb		0.66	2.39	8.03	24.45	309.02	570.98	407.45	53.27	9.66	1.31	6.9828
$\mathcal{O}(\alpha)$	resonant/fb	0.04	0.14	0.47	1.42	17.78	32.82	23.39	3.05	0.55	0.07	0.4015
	nonresonant (10^{-4}/fb)	65	39	22	12	1	0	-0	-7	-16	-24	8.5
$\mathcal{O}(\alpha\alpha_s)$/fb		0.01	0.04	0.13	0.35	4.54	8.37	5.97	0.79	0.15	0.02	0.103

Table 2. The total cross section for $e^+e^-\to\mu^+\mu^-H$ at $\sqrt{s}$=240(250) GeV. The LO, NLO, and NNLO predecitions are presented with three renormalization sub-schemes. To estimate the parametric uncertainty, we take M_W = 80.385±0.015 GeV, m_t=174.2±1.4 GeV, and $\Delta\alpha^{(5)}_{\rm had}$=0.02764±0.00013. We also vary the QCD coupling constant from $\alpha_s(M_Z)$ to $\alpha_s(\sqrt{s})$, with the central value taken as $\alpha_s(\sqrt{s}/2)$.

$\sqrt{s}$/GeV	schemes	$\sigma_{\rm LO}$/fb	$\sigma_{\rm NLO}$/fb	$\sigma_{\rm NNLO}$/fb
240	$\alpha(0)$	$6.983^{+0.023}_{-0.023}$	$7.385^{+0.037}_{-0.037}$	$7.488^{+0.036+0.004}_{-0.036-0.009}$
	$\alpha(M_Z)$	$8.382^{+0.028}_{-0.027}$	$7.317^{+0.037}_{-0.036}$	$7.448^{+0.036+0.005}_{-0.035-0.011}$
	G_μ	$7.772^{+0.004}_{-0.004}$	$7.527^{+0.016}_{-0.017}$	$7.554^{+0.017+0.001}_{-0.017-0.002}$
250	$\alpha(0)$	$7.036^{+0.023}_{-0.023}$	$7.424^{+0.037}_{-0.037}$	$7.527^{+0.037+0.005}_{-0.037-0.009}$
	$\alpha(M_Z)$	$8.446^{+0.028}_{-0.028}$	$7.350^{+0.037}_{-0.036}$	$7.481^{+0.037+0.006}_{-0.037-0.011}$
	G_μ	$7.831^{+0.004}_{-0.004}$	$7.564^{+0.017}_{-0.017}$	$7.591^{+0.017+0.001}_{-0.016-0.002}$

1. Y.-B. Yang et al., Phys. Rev. D92, 034517 (2015)
2. Jian Liang et al., Phys. Rev. D 91, 054513 (2015)
3. Yi-Bo Yang et al., Phys. Rev. D 91, 074516 (2015)
4. Ying Chen et al., Phys. Rev. D 92, 054507 (2015)
5. Ying Chen et al., Chin. Phys. C40 (2016) no.8, 081002
6. Ting Chen et al., Phys. Rev. D93 (2016) no.11, 114501
7. Ting Chen et al., Eur. Phys. J. C76 (2016) no.7, 358
8. Zhao Li, et al., Phys. Rev. D92 (2015) 014015
9. F. Feng, Y. Jia and W.L.Sang, PRL 115,222001 (2015)
10. R. Zhou, et. al., Eur. Phys. J. C75 (2015) 6, 293
11. W.-F. Wang, et. al., Phys. Rev. D91 (2015) 9, 094024
12. Si-Hong Zhou, et. al., Phys. Rev. D92 (2015) 094016
13. Gexing Li, et. al., Phys.Rev. D98 (2018) no.7, 076010.
14. Yinqiang Gong, et. al., Phys.Rev. D95 (2017) no.9, 093003.
15. Dong H R, Feng F, Jia Y., Phys. Rev. D, 2018, 98(3): 034005.
16. Jia Y, Xiong X. Phys. Rev. D, 2016, 94(9): 094005.
17. Sang W L, Feng F, Jia Y, et al. Phys. Rev. D, 2016, 94(11): 111501.
18. Gao X, Jia Y, Li L, et al. Chin. Phys. C, 2017, 41(2): 023103.
19. Sun Q F, Feng F, Jia Y, et al. Phys. Rev. D, 2017, 96(5): 051301.
20. Sang W L, Chen W, Feng F, et al., PLB, 2017, 775: 152-159.
21. Feng F, Jia Y, Sang W L. PRL 2017, 119(25): 252001.
22. Jia Y, Liang S, Li L J, et al. JHEP 2017, 2017(11): 151.
23. Brambilla N, Chen W, Jia Y, et al. Phys. Rev. D, 2018, 97(9): 096001.
24. Sun Q F, Jia Y, Liu X, et al. Phys.Rev. D98 (2018) no.1, 014039
25. Jia Y, Liang S, Xiong X, et al. Phys.Rev. D98 (2018) no.5, 054011