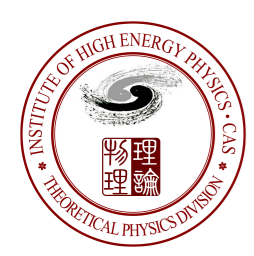


CEPC physics study at the Theoretical Physics Division (TPD)

Hao Zhang

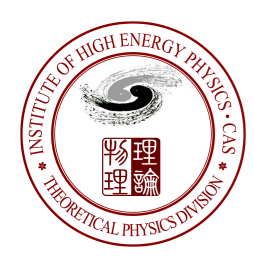
Theoretical Physics Division, Institute of High Energy
Physics, Chinese Academy of Science

Based on materials from Bin Gong, Zhao Li and Bin Yan
For the CEPC Day on May 30th 2023



“Young” staffs in the TPD

- There are 11 staffs born after 1978.
- 4 of them are professor, 7 of them are associate professor.
- Research area:
 - Neutrino physics: 1+1
 - Lattice QCD: 1+1
 - **Perturbative QFT: 2+1**
 - **TeV Physics: 0+2**
 - Gravitational wave physics and cosmology: 0+2



“Young” staffs in the TPD

- Professors



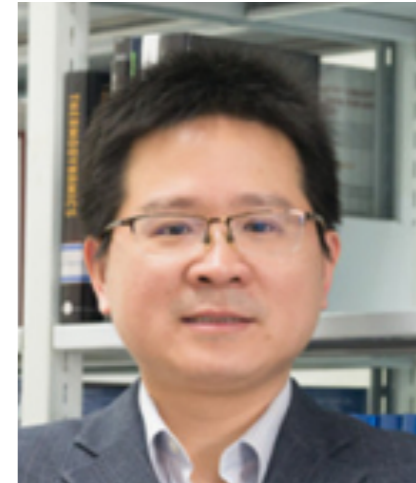
Bin Gong



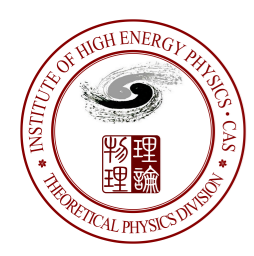
Zhao Li



Zhaofeng Liu



Shun Zhou



“Young” staffs in the TPD

- Associate professors



Ming Gong



Hao Zhang



Cen Zhang



Jing Ren



Sai Wang



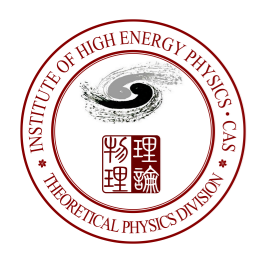
Tao Liu



Xun-Jie Xu

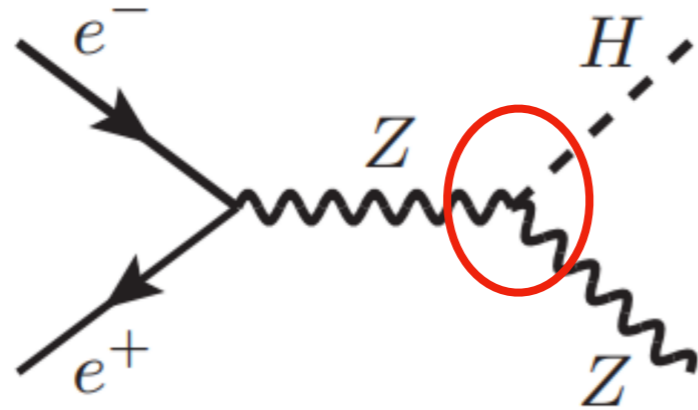


Bin Yan

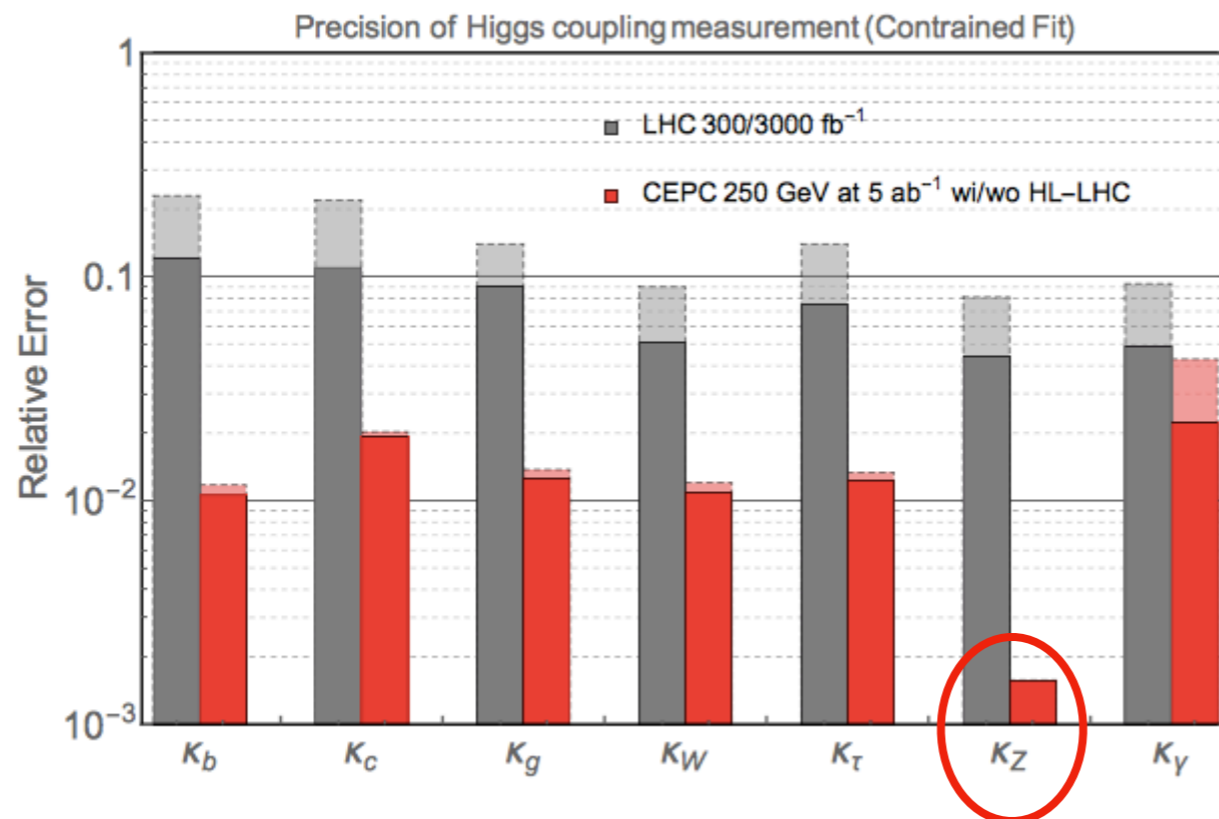


Perturbative QFT group

- Accurate calculation of the Higgs strahlung process



Zhao Li

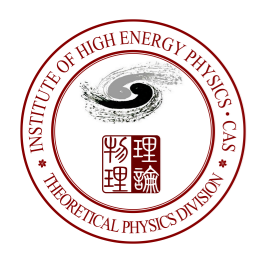


$\delta\sigma_{HZ} < 0.5\%$
with millions of
Higgs bosons

NLO-EW corr.
err. $\sim 6\%$

$\delta\kappa_Z \sim 3\%$

Go beyond
NLO!



Perturbative QFT group

- Accurate calculation of the Higgs strahlung process

PHYSICAL REVIEW D **95**, 093003 (2017)

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

Yinqiang Gong,^{1,*} Zhao Li,^{2,†} Xiaofeng Xu,^{1,‡} Li Lin Yang,^{1,3,4,§} and Xiaoran Zhao^{5,||}



Zhao Li

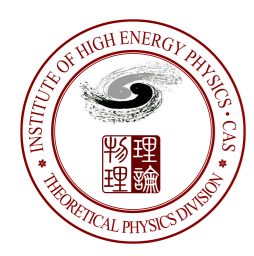
PHYSICAL REVIEW D **96**, 051301(R) (2017)

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

Qing-Feng Sun,^{1,2} Feng Feng,^{3,2} Yu Jia,^{2,4,5} and Wen-Long Sang^{6,*}

\sqrt{s}	Schemes	σ_{LO} (fb)	σ_{NLO} (fb)	σ_{NNLO} (fb)
240	$\alpha(0)$	223.14 ± 0.47	229.78 ± 0.77	$232.21^{+0.75+0.10}_{-0.75-0.21}$
	$\alpha(M_Z)$	252.03 ± 0.60	$228.36^{+0.82}_{-0.81}$	$231.28^{+0.80+0.12}_{-0.79-0.25}$
	G_μ	239.64 ± 0.06	$232.46^{+0.07}_{-0.07}$	$233.29^{+0.07+0.03}_{-0.06-0.07}$
250	$\alpha(0)$	223.12 ± 0.47	229.20 ± 0.77	$231.63^{+0.75+0.12}_{-0.75-0.21}$
	$\alpha(M_Z)$	252.01 ± 0.60	$227.67^{+0.82}_{-0.81}$	$230.58^{+0.80+0.14}_{-0.79-0.25}$
	G_μ	239.62 ± 0.06	231.82 ± 0.07	$232.65^{+0.07+0.04}_{-0.07-0.07}$

$$\delta\sigma_{HZ}^{\text{mixed}} > 1\%$$



Perturbative QFT group

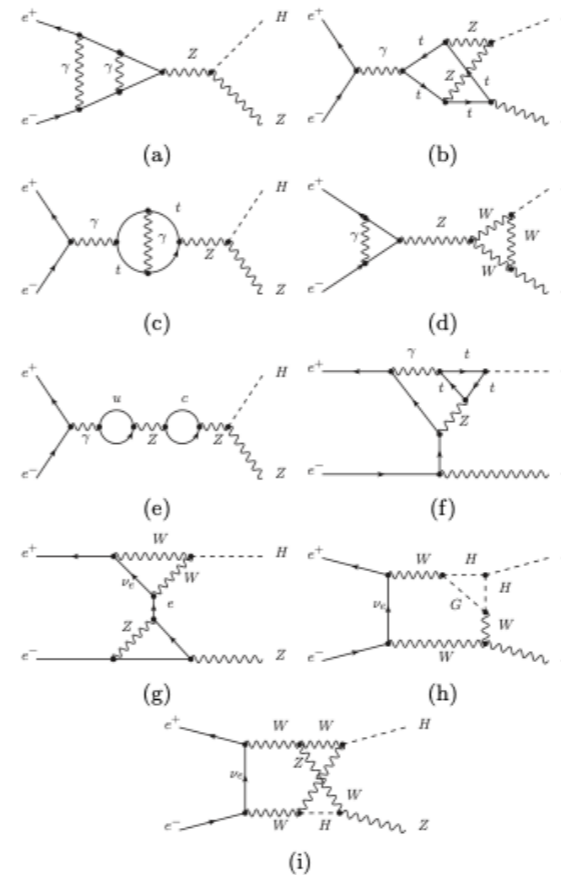
- Accurate calculation of the Higgs strahlung process

Complete two-loop electroweak corrections to $e^+e^- \rightarrow HZ$

Xiang Chen,^{1,*} Xin Guan,^{1,†} Chuan-Qi He,^{1,‡} Zhao Li,^{2,3,4,§} Xiao Liu,^{5,¶} and Yan-Qing Ma^{1,4,**}

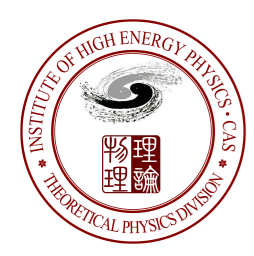
arXiv:2209.14953v1 [hep-ph]

$$\begin{aligned} \mathcal{A}^{(2)} = & \alpha^4 (75548.083 \epsilon^{-4} \\ & - 3.1962821 \times 10^6 \epsilon^{-3} \\ & + 1.1548893 \times 10^7 \epsilon^{-2} \\ & + 2.6990603 \times 10^8 \epsilon^{-1} \\ & + 1.5608903 \times 10^9 + \mathcal{O}(\epsilon)), \end{aligned}$$



Zhao Li

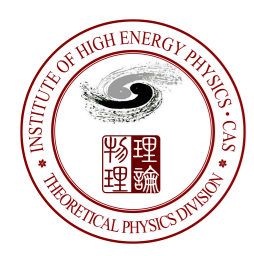
Complete analysis on theoretical uncertainty is upcoming!



Perturbative QFT group

- **Numerical approaches**, e.g. AMFlow, will be the practical key to the calculation of higher order effects.
- EW corrections at higher orders involves **more loops**, **more scales**, **more amplitudes**, **more integrals** etc.
- NNLO EW for $e^+e^- \rightarrow Z$ and $e^+e^- \rightarrow W^+W^-$ could be critical.
- More technique improvements will be needed. (automatic tools, parallel computation, AI?)

Phys.Rev.D 95 (2017) 9, 093003;
Phys.Rev.D 98 (2018) 7, 076010;
Phys.Rev.D 100 (2019) 11, 116013;
Chin.Phys.C 45 (2021) 5, 053102;
JHEP 08 (2022) 211;
Phys.Rev.D 106 (2022) 9, 096029.

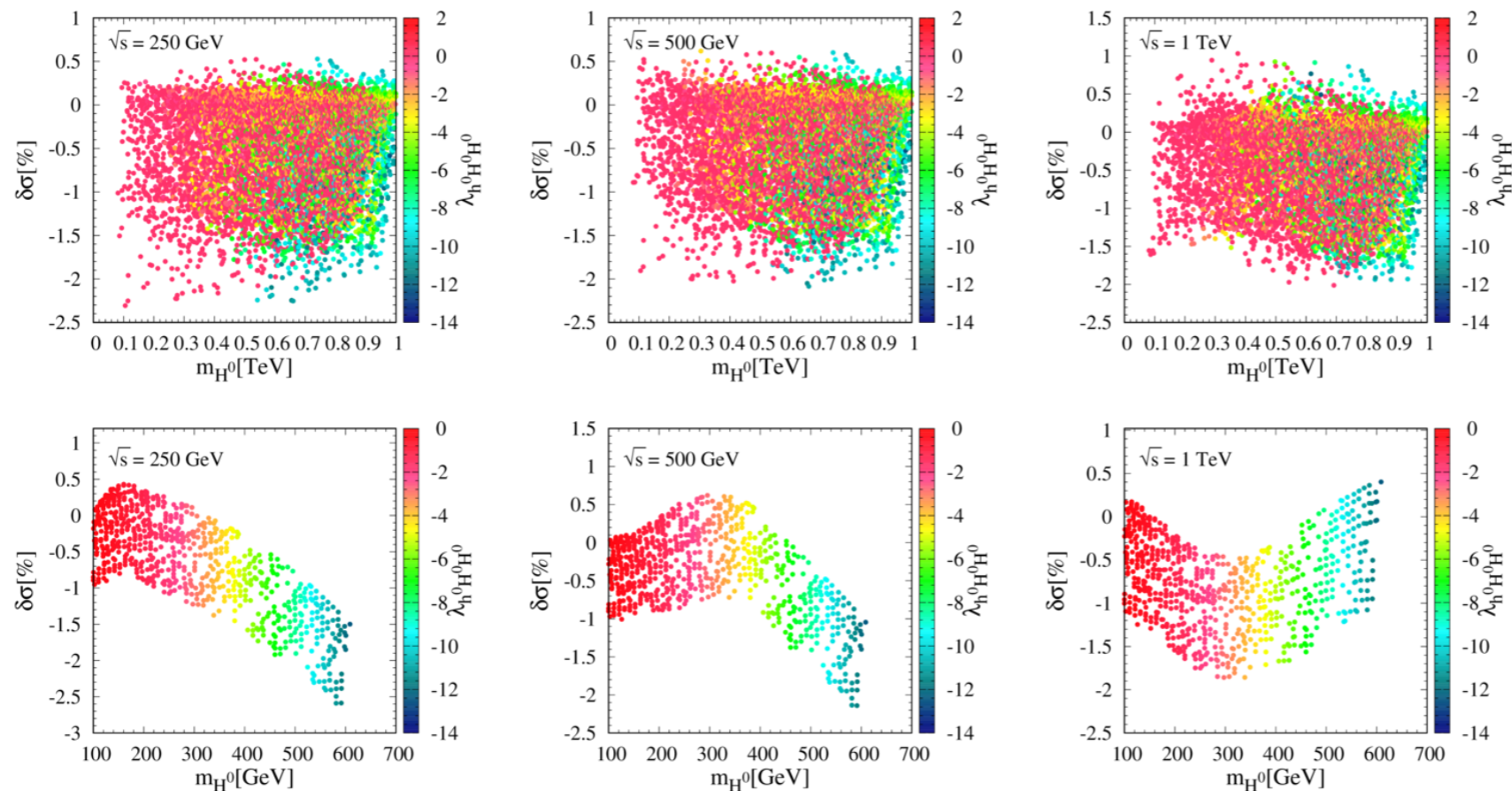


Perturbative QFT group

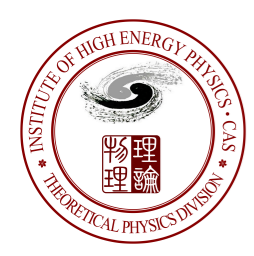
- Accurate calculation in New Physics models
- NP corrections to the Higgs strahlung process in IDM and 2HDM



Bin Gong



NP effects in $e^+e^- \rightarrow Zh^0$ (in IDM) when Higgs invisible decay is closed (upper) or open (lower).

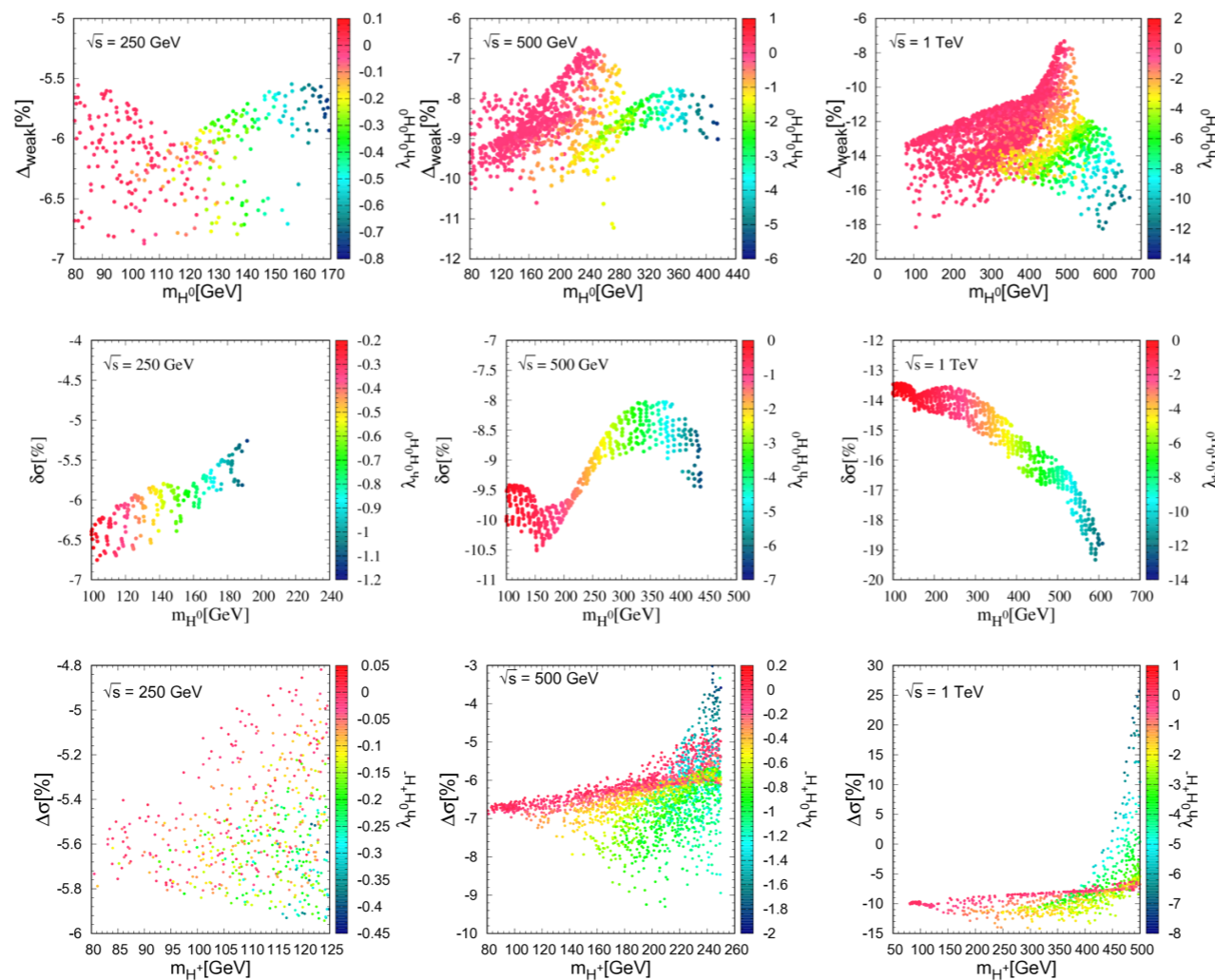


Perturbative QFT group

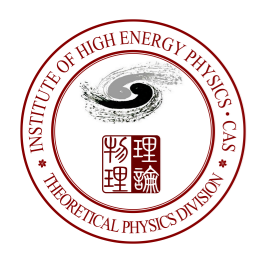
- Accurate calculation in New Physics models
- NP corrections to heavy scalar boson pair production processes in IDM and 2HDM



Bin Gong



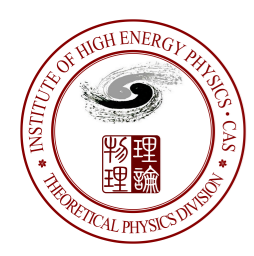
Relative weak corrections in scalar pair production



Perturbative QFT group

- Model-independent calculation
- Radiative corrections in SM
- Radiative corrections in SMEFT

JHEP 05 (2021) 100;
arXiv: 2204.05237 [hep-ph].



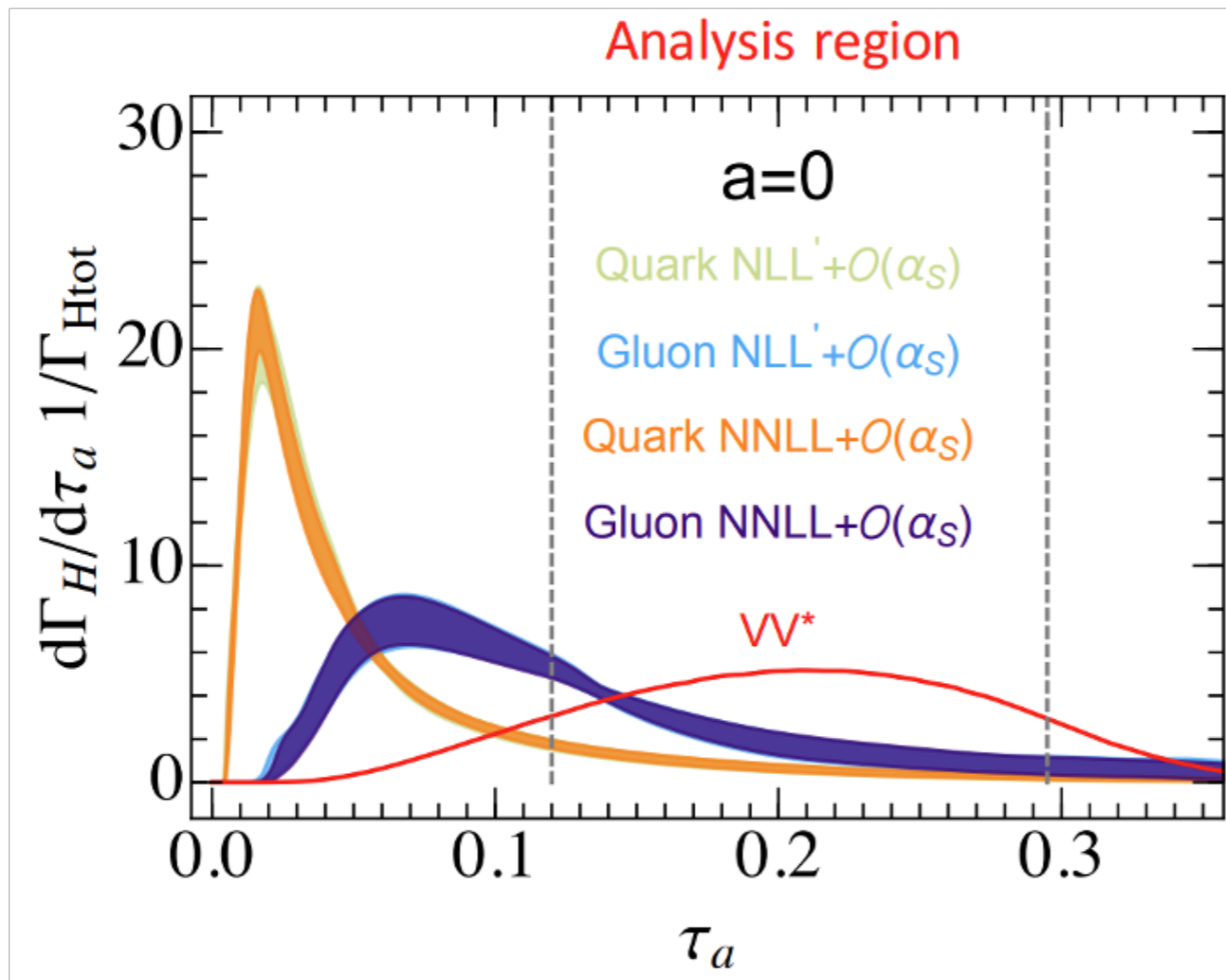
TeV Physics group

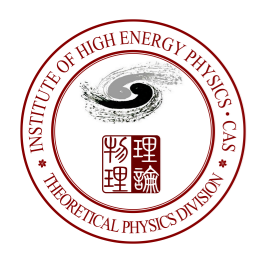
- Probing the light quark Yukawa coupling constant

$$e(X) = \frac{1}{Q} \sum_{i \in X} |p_{\perp}^i| f_e(\eta_i)$$



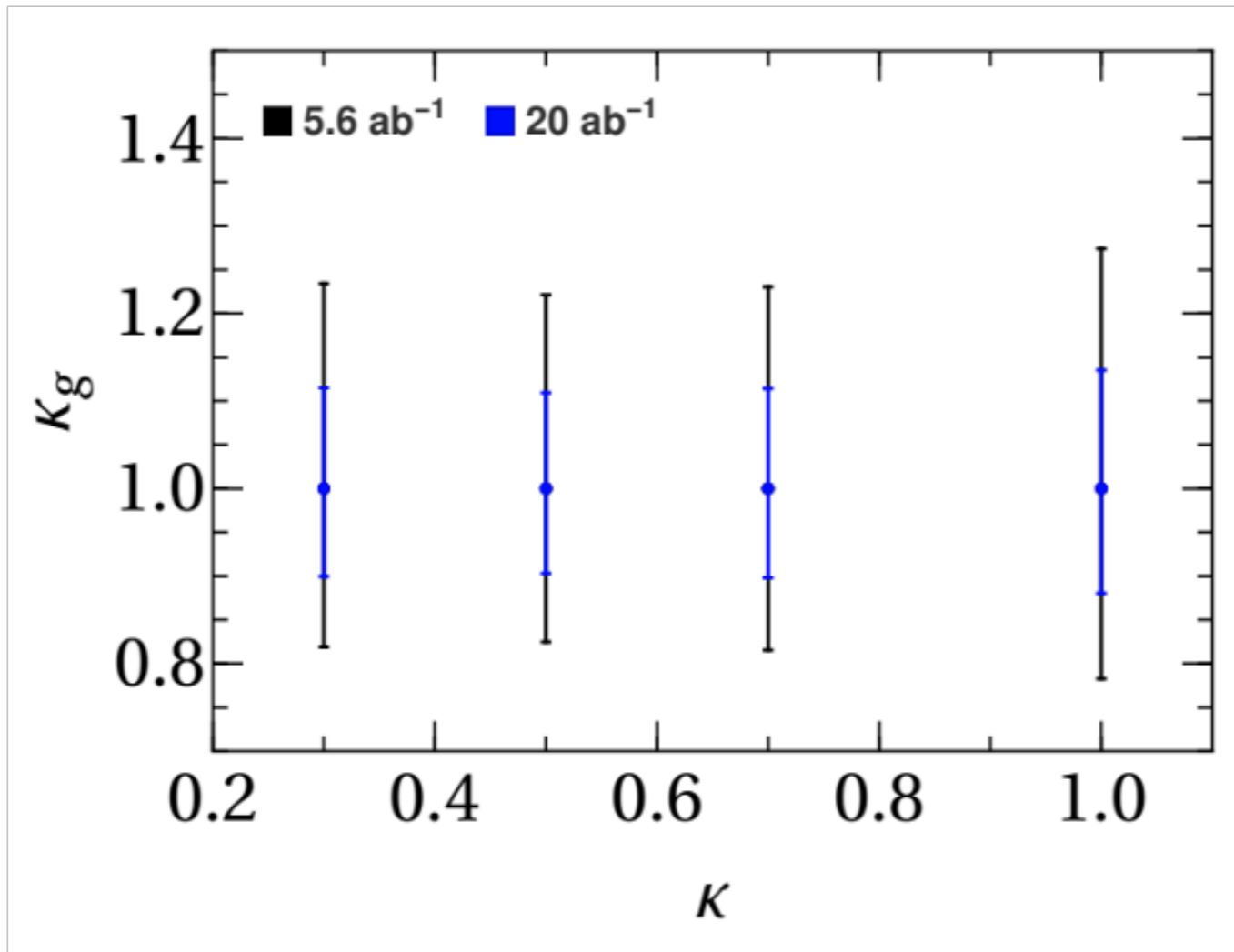
Bin Yan





TeV Physics group

- Probing the Higgs-gluon coupling

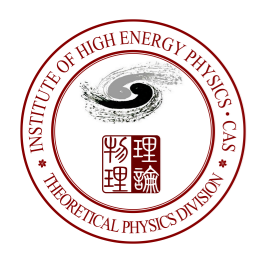


Bin Yan

$$Q_J = \frac{1}{(p_T^j)^\kappa} \sum_{i \in \text{jet}} Q_i (p_T^i)^\kappa, \quad \kappa > 0$$

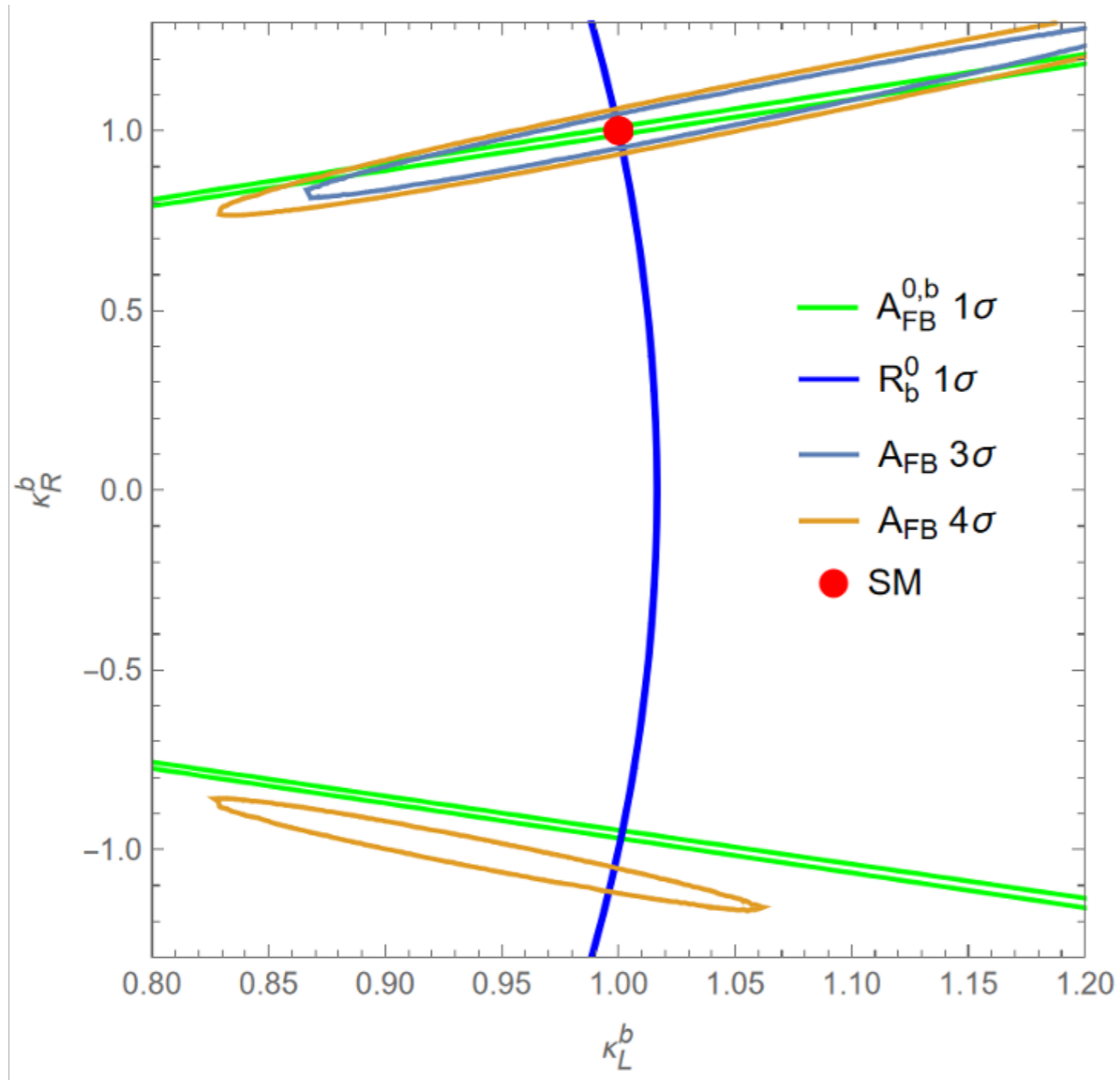
$$\bar{A}_Q \equiv \frac{\langle |Q_J^1 - Q_J^2| \rangle}{\langle |Q_J^1 + Q_J^2| \rangle} \equiv \frac{\langle Q^{(-)} \rangle}{\langle Q^{(+)} \rangle}$$

Xiaorui Wong and **Bin Yan**, arxiv:2302.02084

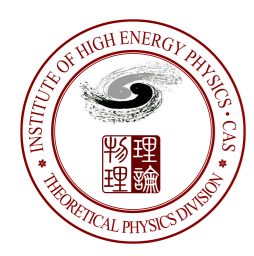


TeV Physics group

- Zbb anomalous coupling

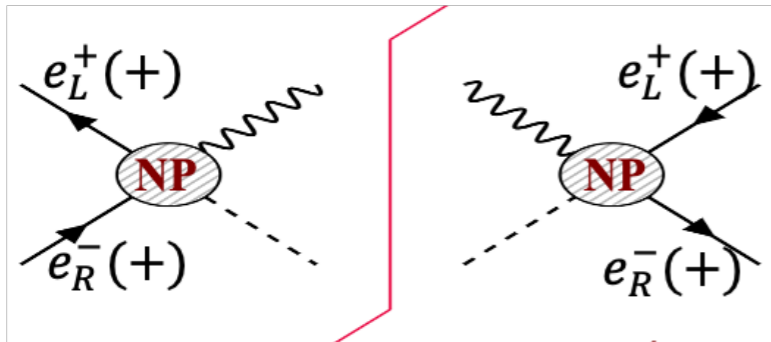


Bin Yan

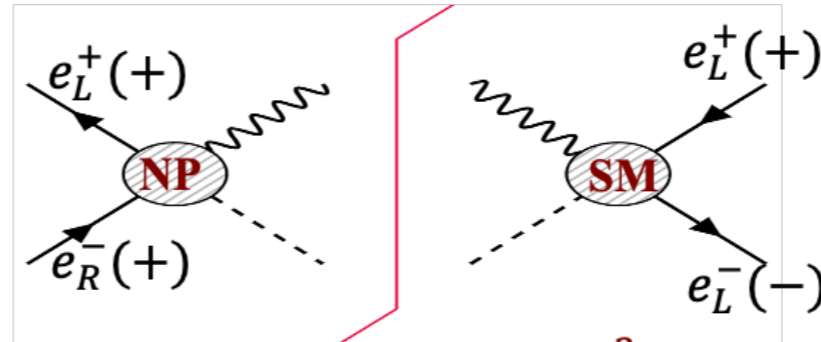


TeV Physics group

- Transverse spin asymmetry



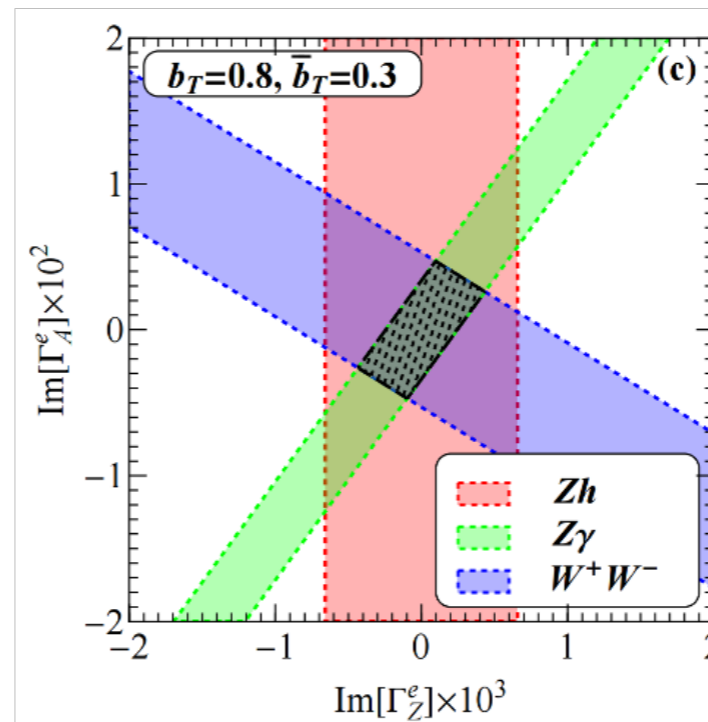
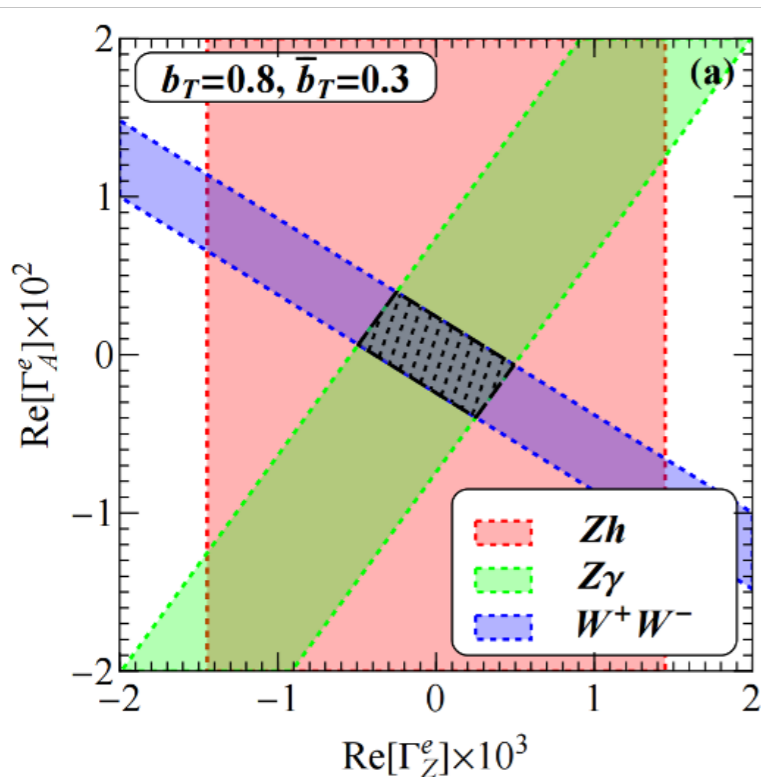
Traditional method: $O(1/\Lambda^4)$

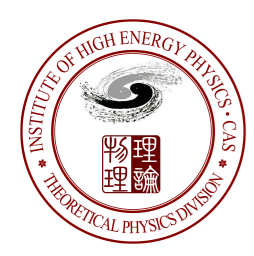


Our proposal: $O(1/\Lambda^2)$



Bin Yan

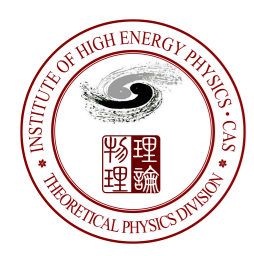




TeV Physics group

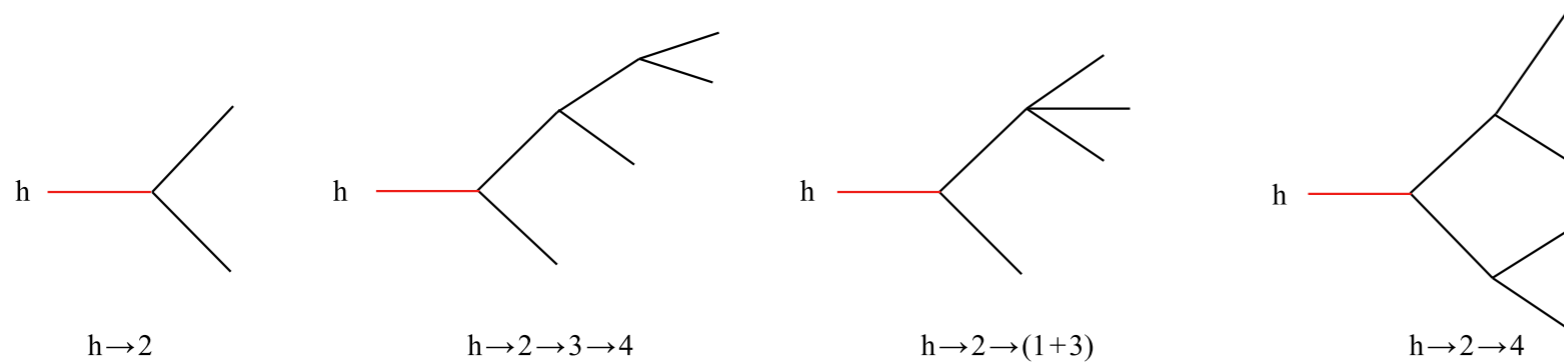
- Precisely testing the Higgs couplings with new methods
- Probing the new physics effects via the electroweak correction
- Utilizing the polarization of the particles to probe the new physics effects

Nucl.Phys.B 909 (2016) 197-217;
Phys.Rev.Lett. 127 (2021) 5, 051801;
Phys.Lett.B 822 (2021) 136709;
Phys.Lett.B 829 (2022) 137076;
arXiv:2302.02084 [hep-ph];
to be published.



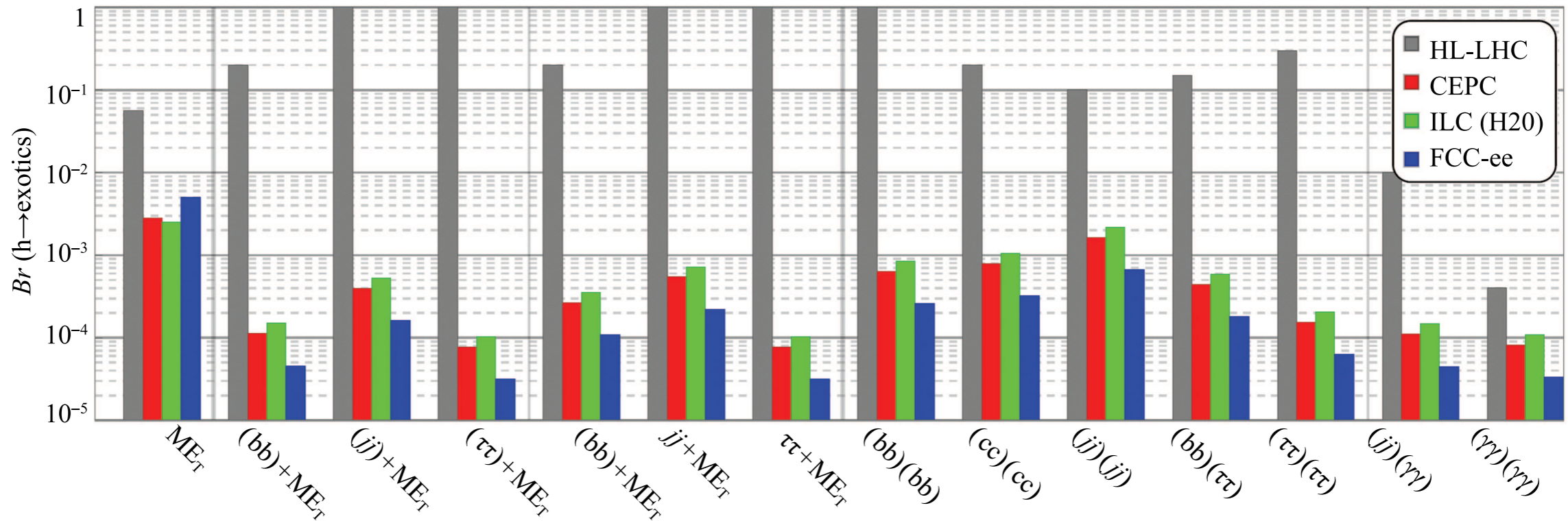
TeV Physics group

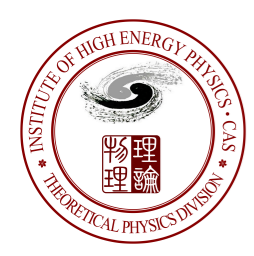
- Exotic decays of the 125 GeV Higgs boson



Hao Zhang

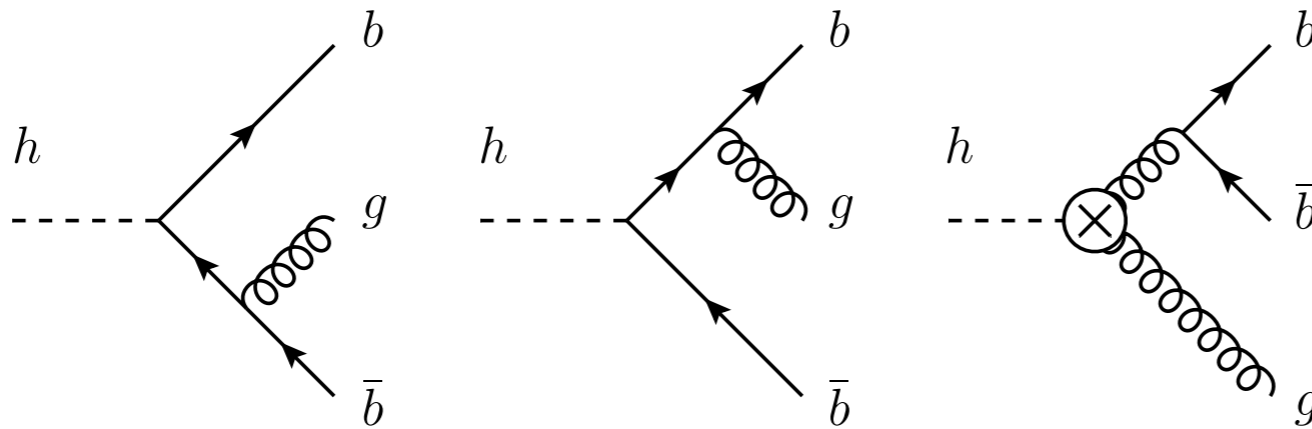
95%C.L. upper limit on selected Higgs exotic decay BR



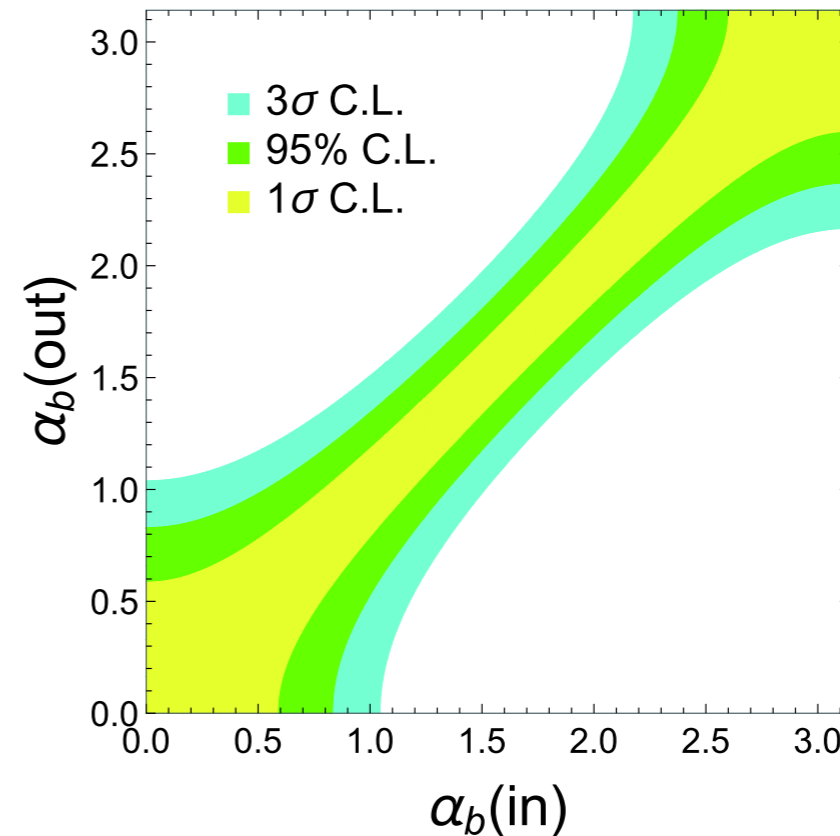
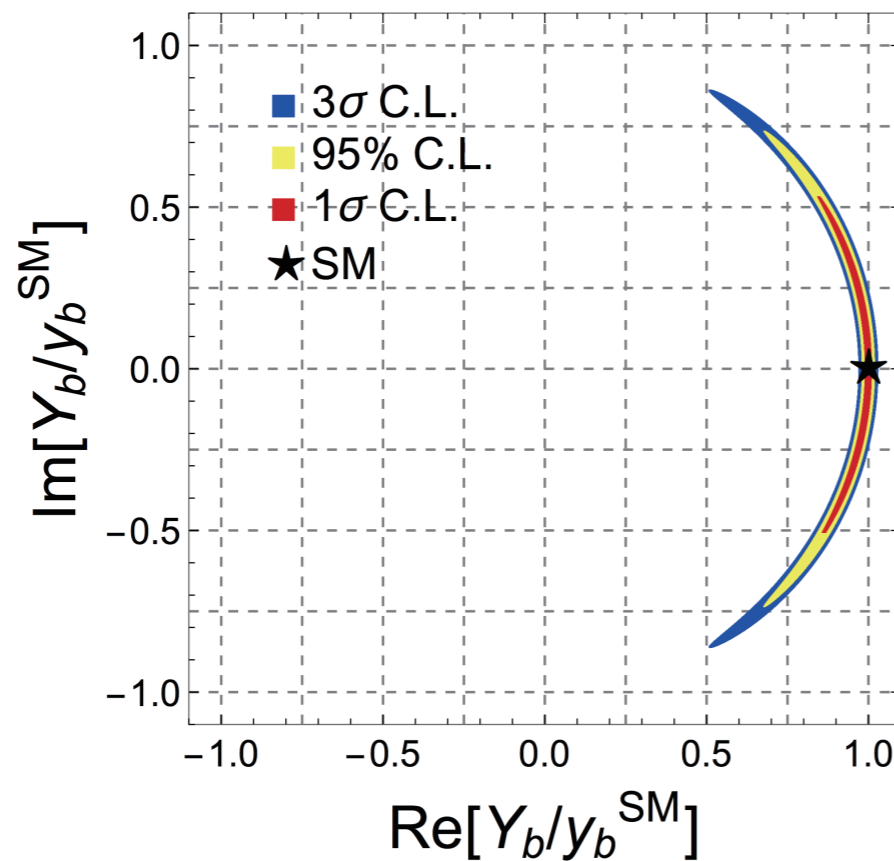


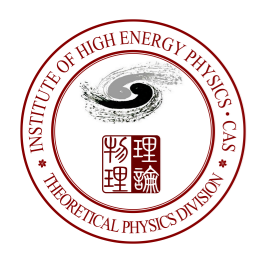
TeV Physics group

- The CP property of the bottom Yukawa interaction



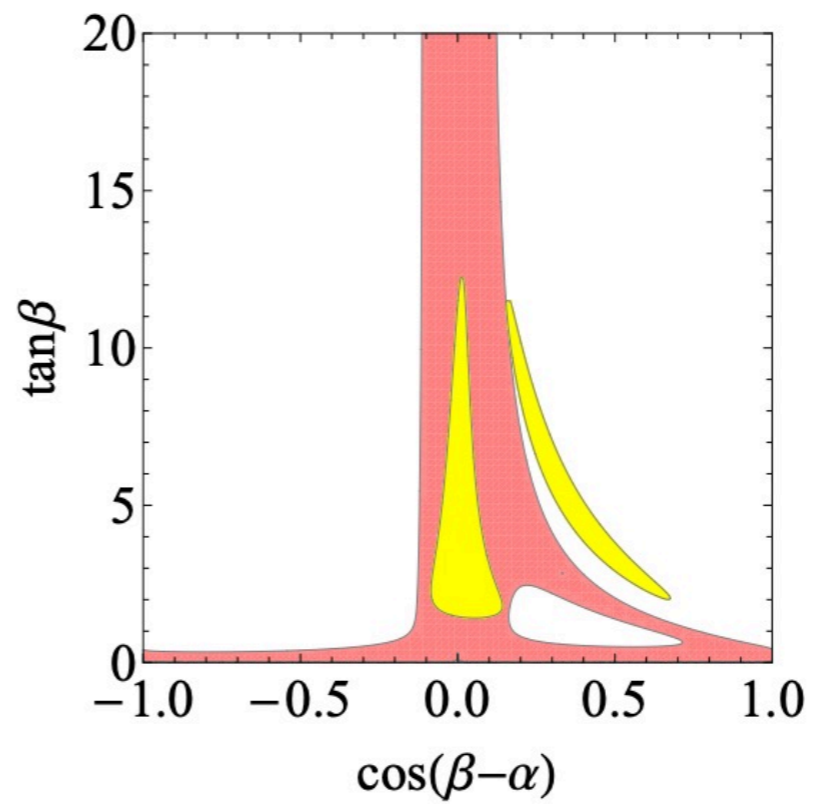
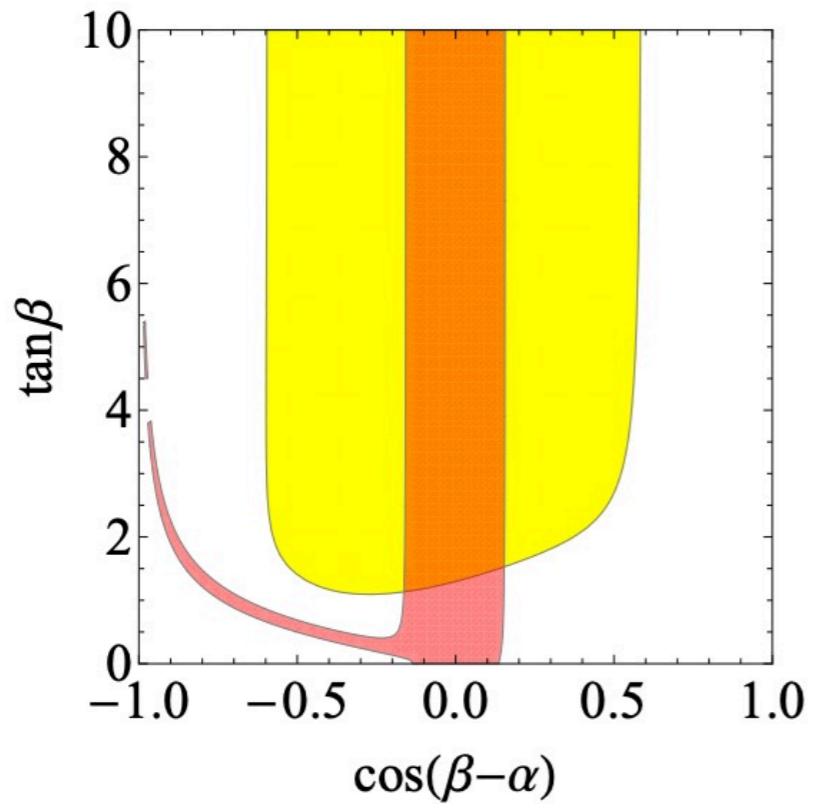
Hao Zhang





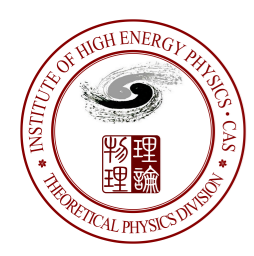
TeV Physics group

- Resolving a degenerate CP-odd 125GeV scalar in 2HDM



Hao Zhang

- 1 ab^{-1} e^+e^- collider
- Current allowed region



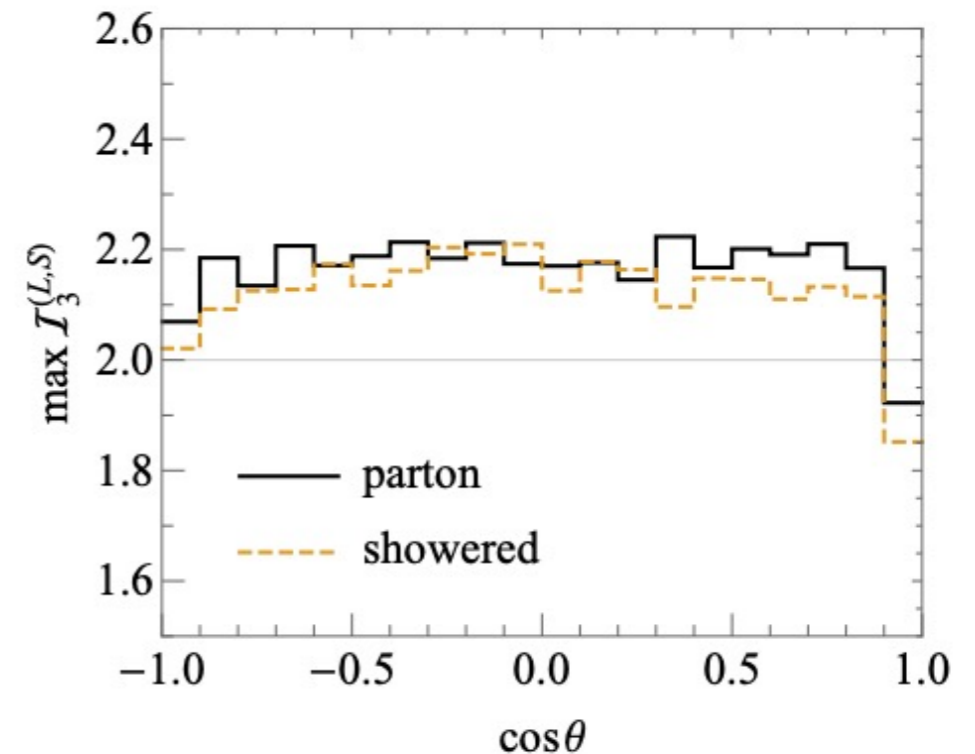
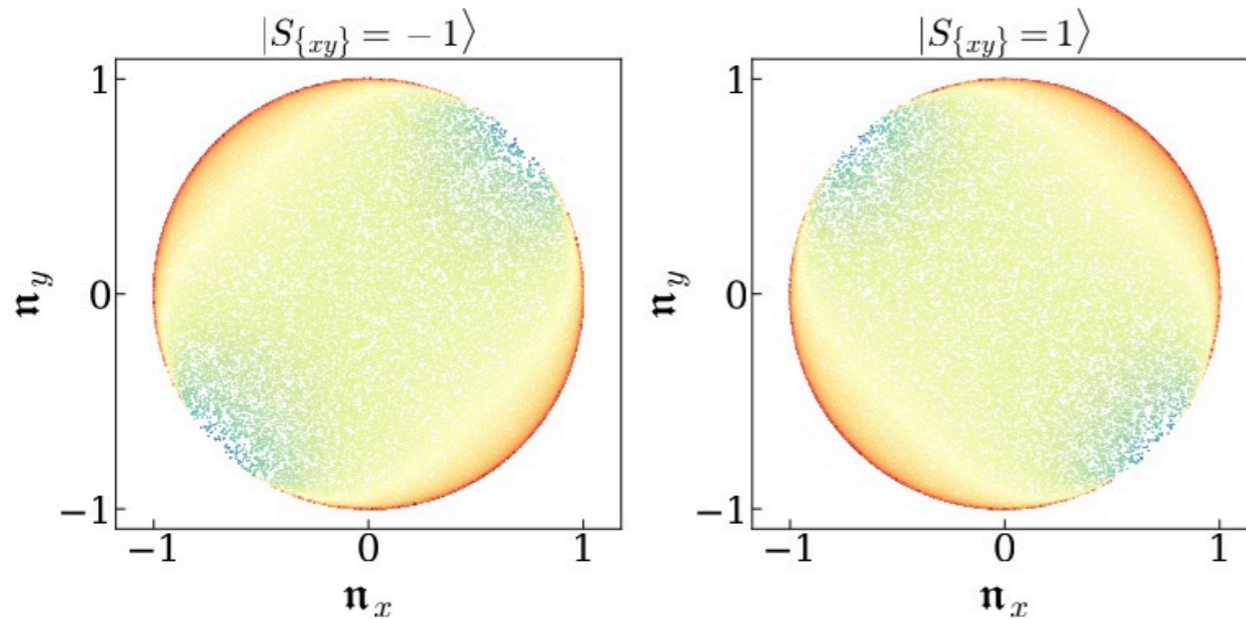
TeV Physics group

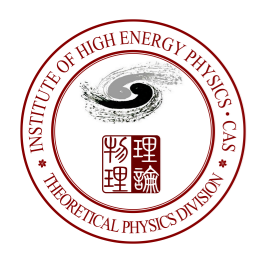
- Verifying the quantum entanglement effect in WW production

$$\begin{aligned} \mathcal{I}_3 \equiv & + [P(A_1 = B_1) + P(B_1 = A_2 + 1) \\ & + P(A_2 = B_2) + P(B_2 = A_1)] \\ & - [P(A_1 = B_1 - 1) + P(B_1 = A_2) \\ & + P(A_2 = B_2 - 1) + P(B_2 = A_1 - 1)] \end{aligned}$$



Hao Zhang





TeV Physics group

- Studying the CP properties of the 125GeV Higgs boson via different channels and methods
- Studying the possibility of investigating the basic properties of QFT at CEPC

Chin.Phys.C 41 (2017) 6, 063102;
Chin.Phys.C 45 (2021) 2, 023105;
Eur.Phys.J.C 83 (2023) 4, 269;
Phys.Rev.D 107 (2023) 5, 055040;
to be published.

Thank you!