# CEPC 理论研究报告

李钊

吕才典，贾宇，刘朝峰，顾嘉荫，毛英男，王科臣，王彦，殷文

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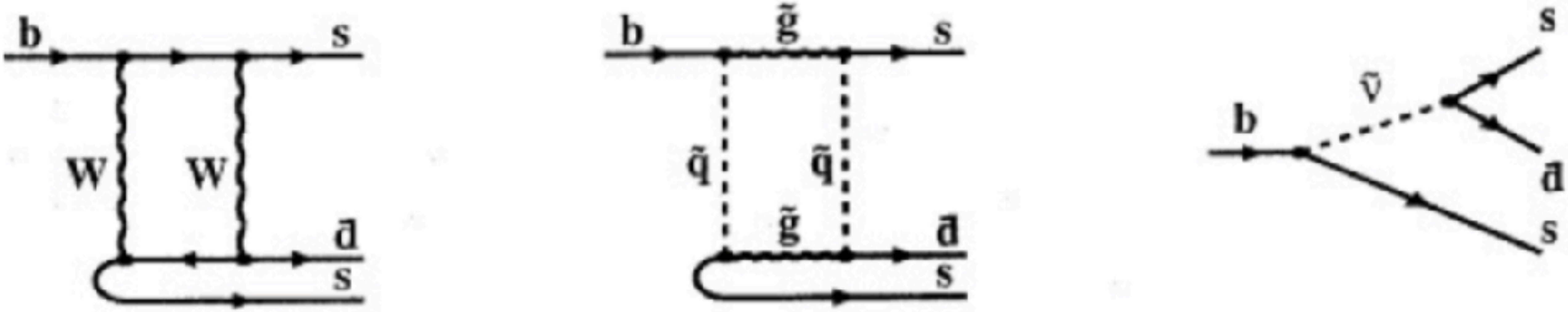
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

INSTITUTE OF HIGH ENERGY PHYSICS · CAS
理論物理
THEORETICAL PHYSICS DIVISION

# Search for new physics in hadronic B decays

K. Huitu, C.D. Lü, P. Singer D.X. Zhang, **Phys. Rev. Lett. 81, 4313 (1998), hep-ph/9809566.**




$b \to ss\bar{d}$ transition (a) SM, (b) MSSM, (c) MSSM with R-parity violating coupling

**SM BRs: ~ $10^{-14}$, Some New physics can reach $10^{-6}$;**

**Recent Study in Randall Sundrum model,**

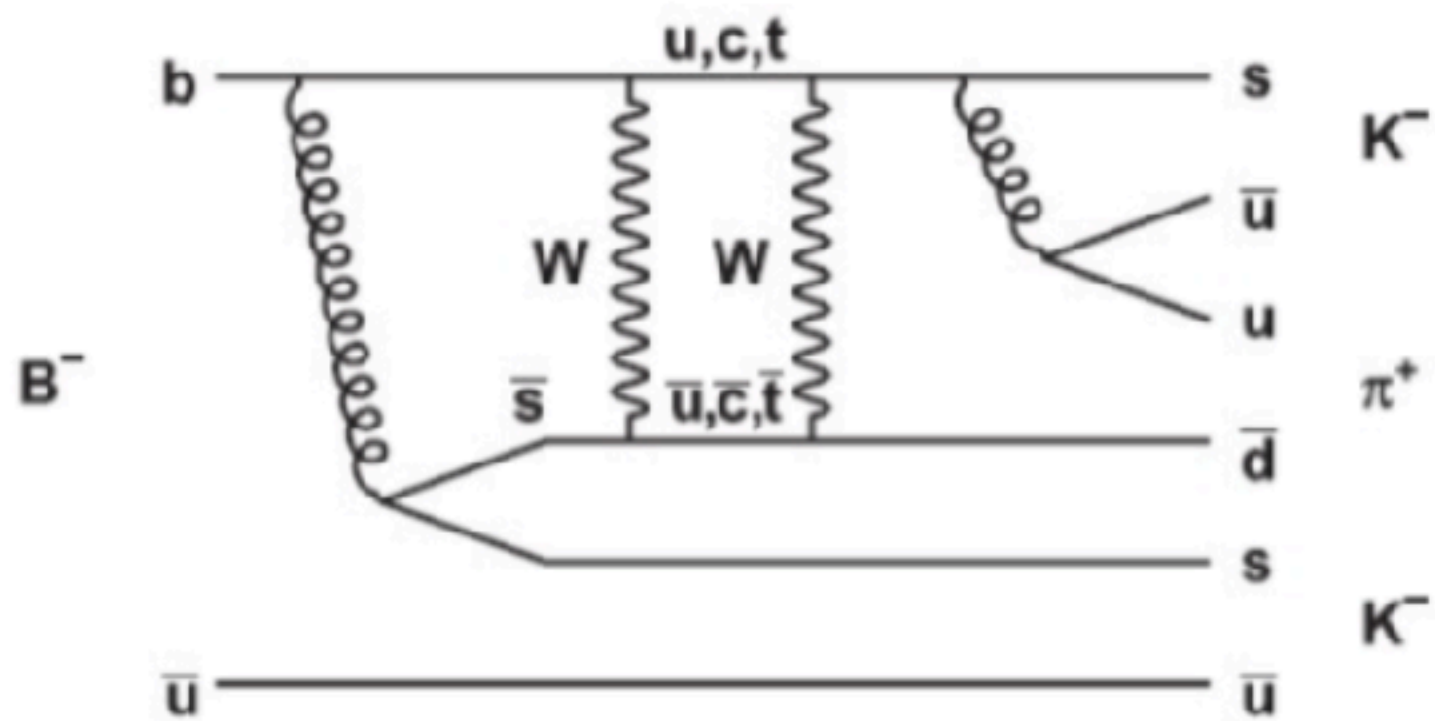
Br($b \to ss$ d-bar) can reach to $10^{-10}$, **Chin. Phys. C41 (2017) 053106**

Experimental search starting from OPAL @ LEP, phys. Lett. B 476 (2000) 233, later searched also by Belle/Babar

BABAR collaboration, Phys. Rev. D 78 (2008) 091102 [arXiv:0808.0900]

A search for the decay $B^- \to K^- K^- \pi^+$, Using a sample of $(467 \pm 5) \times 10^6$ $B\overline{B}$ pairs collected with the BABAR detector.

**Similar channel $B^- \to \pi^- \pi^- K^+$**




Recent LHCb result (Physics Letters B 765 (2017) 307–316) :

$$\mathcal{B}(B^+ \to K^+K^+\pi^-) < 1.1 \times 10^{-8}$$
$$\mathcal{B}(B^+ \to \pi^+\pi^+K^-) < 4.6 \times 10^{-8}.$$

# CEPC as a flavor factory

- Looking for new physics through precision measurements
- LQCD can calculate form factors and meson decay constants appearing in weak decays of hadrons
- Combined with experiments, they give us CKM matrix elements

- $O(10^9)$ $D^0/D^{\pm}$/Ds/$D^{*\pm}$ events
- # of $\Lambda_c$: $\sim 3 \times 10^9$ (PDG2016: $Z^0 \to \Lambda_c X$, 1.54(33)%)

| $b$-hadron species | Fraction in decays of $Z^0 \to b\bar{b}$ | Number of $b$-hadron at $Z^0$ peak |
|---|---|---|
| $B^0$ | $0.404 \pm 0.009$ | $0.6 \times 10^{10}$ |
| $B^+$ | $0.404 \pm 0.009$ | $0.6 \times 10^{10}$ |
| $B_s$ | $0.103 \pm 0.009$ | $0.02 \times 10^{10}$ |
| $b$ baryons | $0.089 \pm 0.015$ | $0.02 \times 10^{10}$ |

From Pre-CDR

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

- **Definition (vector meson decay constant):**

$$\langle 0|\bar{q}(0)\gamma^\mu q'(0)|V(p,\lambda)\rangle = f_V m_V e_\lambda^\mu$$

- **Widths of leptonic decay, e.g. $D_s^*$ (no exp. measurements yet), extract $|V_{cs}|$**

$$\Gamma_{(D_s^*\to\ell\nu)} = \frac{G_F^2}{12\pi}|V_{cs}|^2 f_{D_s^*}^2 M_{D_s^*}^3 \left(1-\frac{m_\ell^2}{M_{D_s^*}^2}\right)^2\left(1+\frac{m_\ell^2}{2M_{D_s^*}^2}\right)$$

- **Inputs for studies of nonleptonic $B$ meson decays using factorization (e.g., $f_{D^*}$ for $B \to D^{(*)}M$)**

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

W.-F. Chiu, … Zhaofeng Liu, … et al., in preparation

- Overlap fermions on domain wall fermion configurations

| $1/a$(GeV) | label | $am_{sea}$ | volume |
|---|---|---|---|
| 1.730(4) | 48I | 0.00078/0.0362 | $48^3 \times 96$ |

- Almost physical light quark mass: $m_\pi = 139.2(4)$ MeV
- 2+1-flavors (RBC/UKQCD Collaborations)
- Preliminary results (statistical error only)

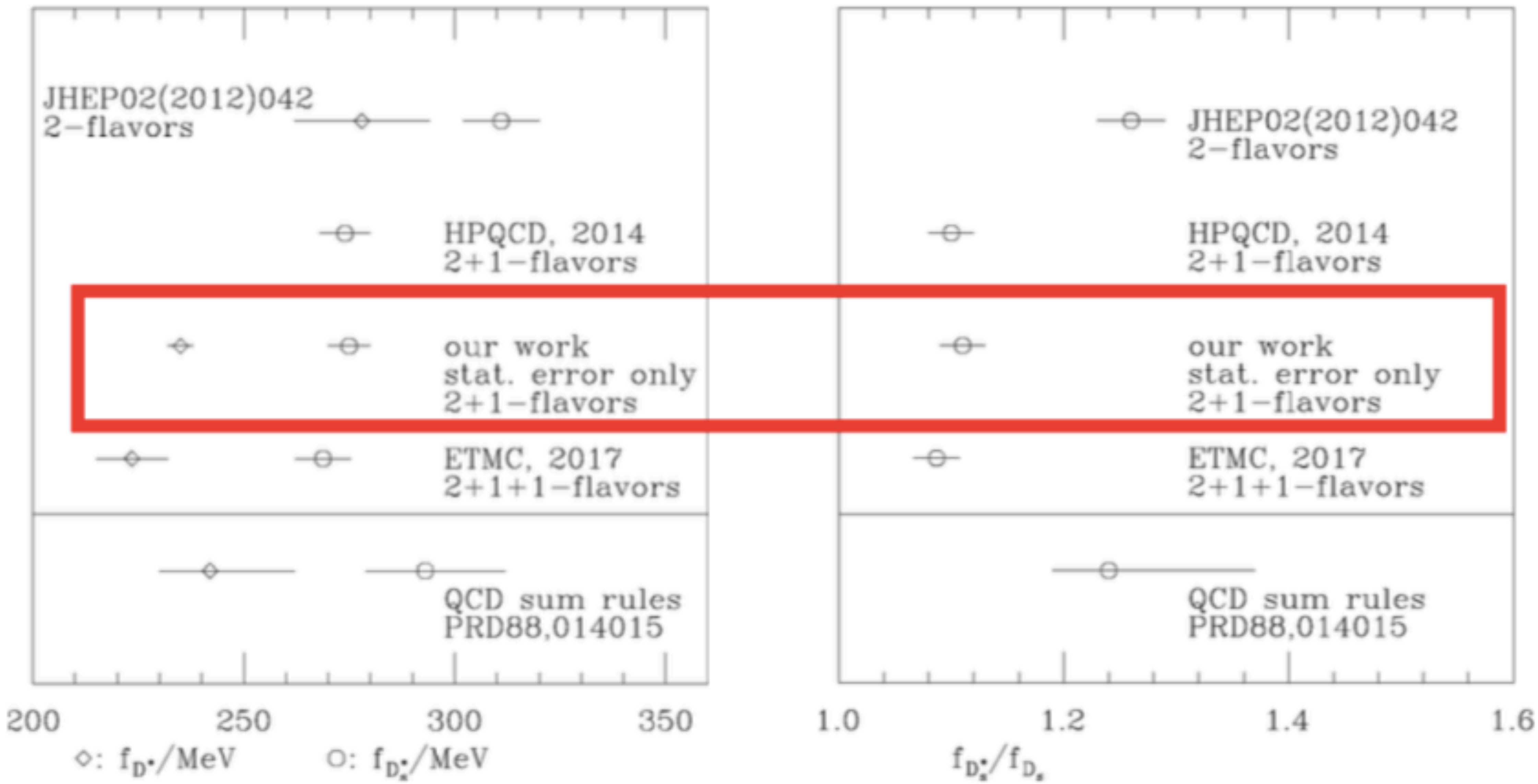
| | $D$ | $D^*$ | $D_s$ | $D_s^*$ |
|---|---|---|---|---|
| $f_M$/MeV | 213(1) | 235(3) | 248(2) | 275(5) |

$f_{D^*}/f_D = 1.10(3)$

$f_{D_s^*}/f_{D_s} = 1.11(2)$

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

W.-F. Chiu, … Zhaofeng Liu, … et al., in preparation




- HPQCD, PRL112, 212002 (2014) — 2 lattice spacings, 2+1-flavors
- ETMC, PRD96, 034524 (2017) — 3 $a$'s, 2+1+1-flavors
- Becirevic et al., JHEP02 (2012) 042 — 4 $a$'s, 2-flavors
- Sea quark effects? Difference between 2-flavor and 2+1-flavor, 2+1+1-flavor results.

# Renormalization of bilinear quark operators

Y. Bi, …, Zhaofeng Liu, arXiv:1710.08678

- Matching hadronic matrix elements calculated on the lattice to the continuum

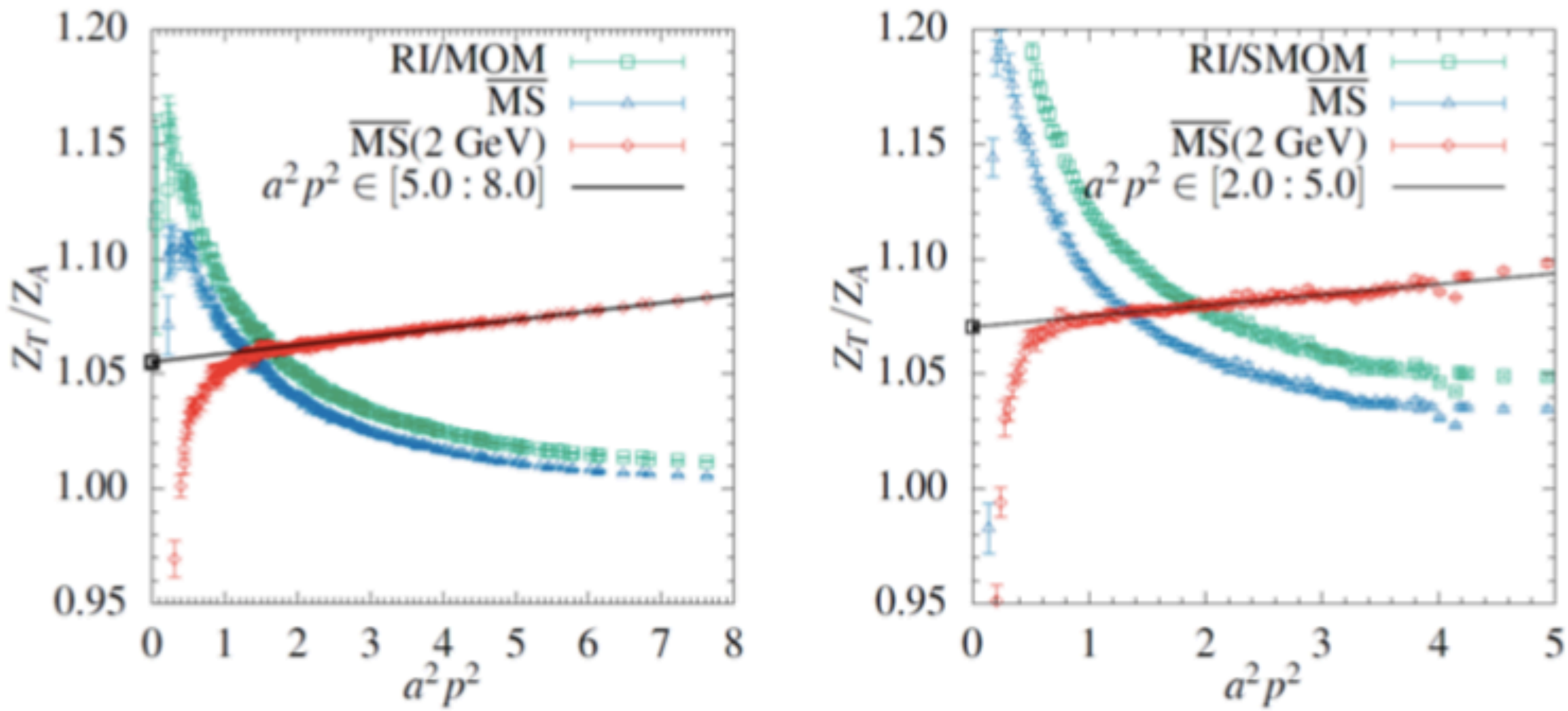
$$\bar{\psi}\Gamma\psi, \quad \Gamma = I, \gamma_5, \gamma_\mu, \gamma_\mu\gamma_5, \sigma_{\mu\nu}$$

- For example, $Z_T$ for $f_V^T$ (coupling of a vector meson to the tensor current/tensor decay constant) , $Z_V$ for $f_{D^*}$
- Configurations (from RBC-UKQCD Collab.) with almost physical pion mass: $M_\pi^{(\mathrm{sea})} = 139.2(4)$ MeV

| $1/a$(GeV) | label | $am_l^{sea}/am_s^{sea}$ | volume | $N_{\mathrm{conf}}$ |
|---|---|---|---|---|
| 1.730(4) | 48I | 0.00078/0.0362 | $48^3 \times 96$ | 81 |

# Renormalization of bilinear quark operators

Y. Bi, ..., Zhaofeng Liu, arXiv:1710.08678




- (Above) $Z_T$ in the RI/MOM, RI/SMOM and $\overline{\text{MS}}$ schemes
- (Below) Final results for all renormalization constants

Matching factors to the $\overline{\text{MS}}$ scheme for the quark field and bilinear quark operators

| $Z_A$ | $Z_q$(2 GeV) | $Z_T$(2 GeV) | $Z_S$(2 GeV) | $Z_P$(2 GeV) |
|---|---|---|---|---|
| 1.1025(9) | 1.2157(54) | 1.1631(24) | 1.118(18) | 1.123(19) |

Cosmology and Particle Physics from simple set-ups,

Wen Yin

# ALP miracle

arXiv: 1702.03284 (JCAP05(2017)044)
arXiv: 1710.XXXX

set up: **Successful Axion Inflation + Up-Side Down Symmetry**

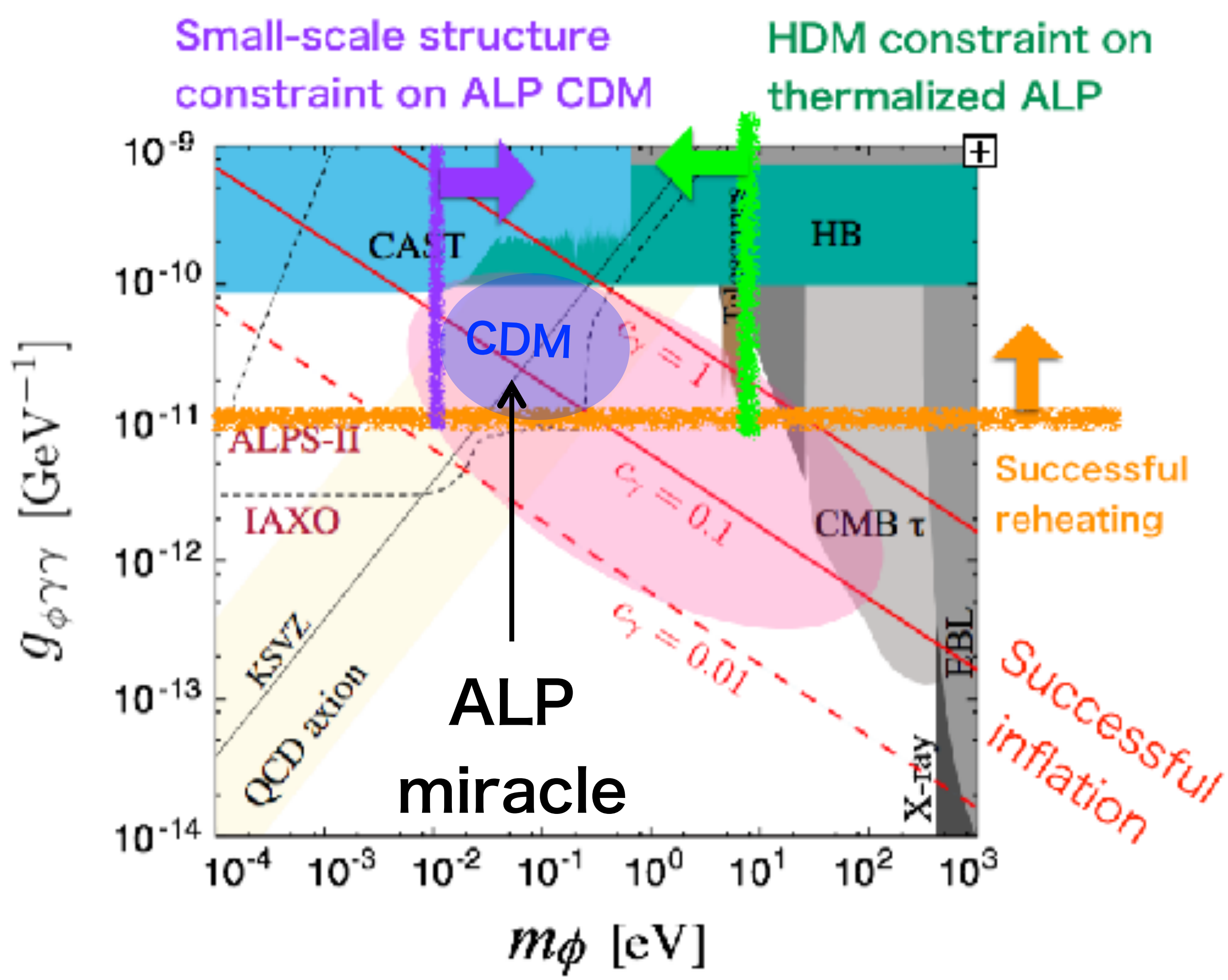
we get: **=Longevity and Dark Matter(=axion) abundance.**

Hinted by

- cooling of HB stars
- missing satellite

Predictions

- $g_{\phi\gamma\gamma} \propto m_\phi^{-1/2}$
- will appear in IAXO and TASTE.
- running of spectral index
- $\Delta N_{eff} \simeq 0.03$



Cosmology and Particle Physics from simple set-ups,

Wen Yin

# Higgs-Anomaly Mediation

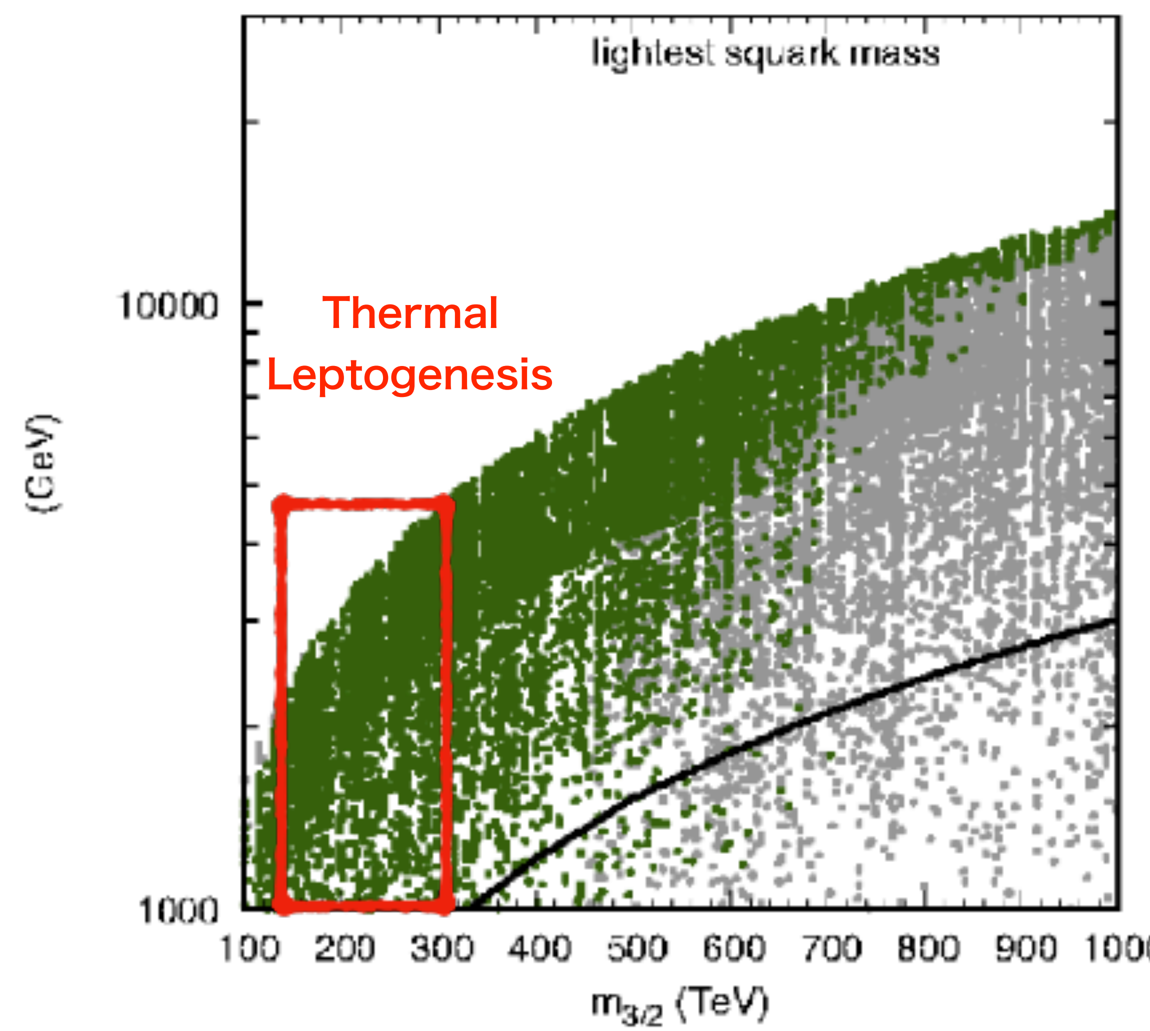
arXiv:1606.04953,
Phys.Lett. B762 (2016) 72-79,
JHEP 1609 (2016) 086

set up: SUSY breaking only in Higgs sector + Anomaly Mediation

we get: =Higgs boson mass, light sfermions and Yukawa Unification.

Hinted by
- Muon g-2 anomaly
- GUT
- Baryon Asymmetry of Universe
- Origin of Flavor.

Predictions
- Light sfermions in LHC and future colliders
- Typical mass patterns of gaugino



Cosmology and Particle Physics from simple set-ups,

Wen Yin

# Simplest Neutrino-Portal WIMP model

arXiv:1706.07028

set up:

SM+WIMPs with O(10)MeV-O(10)GeV
+Neutrino Portal Interaction

we get:

=Neutrino mass, Higgs Invisible Decay,
Cutoff for Cosmic Ray Neutrino, DM

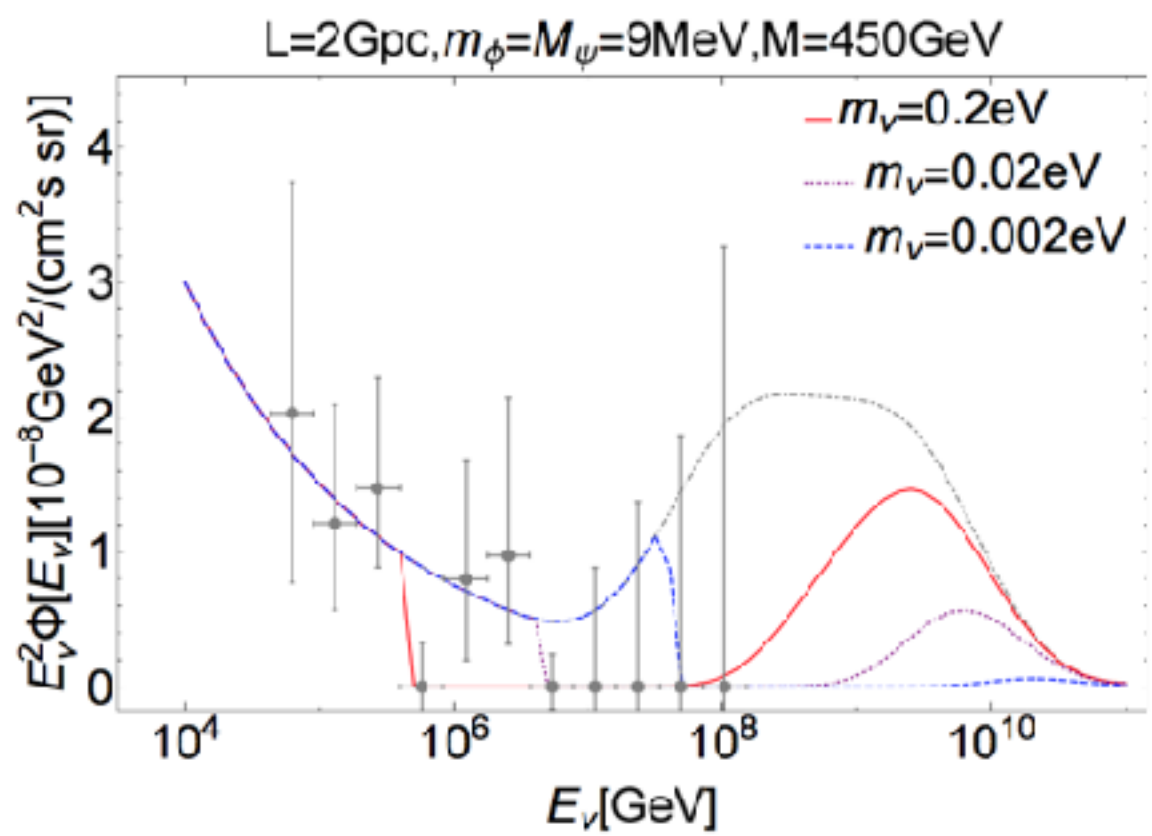
Hinted by

- No signal in Direct Detections(DD)
- No signal for >PeVs Neutrino event in ICECUBE

Predictions

- If the DM is found in DD,

  Higgs anomalous decay is within reach of CEPC etc.




- If CosmicRay neutrino obtains a cutoff,

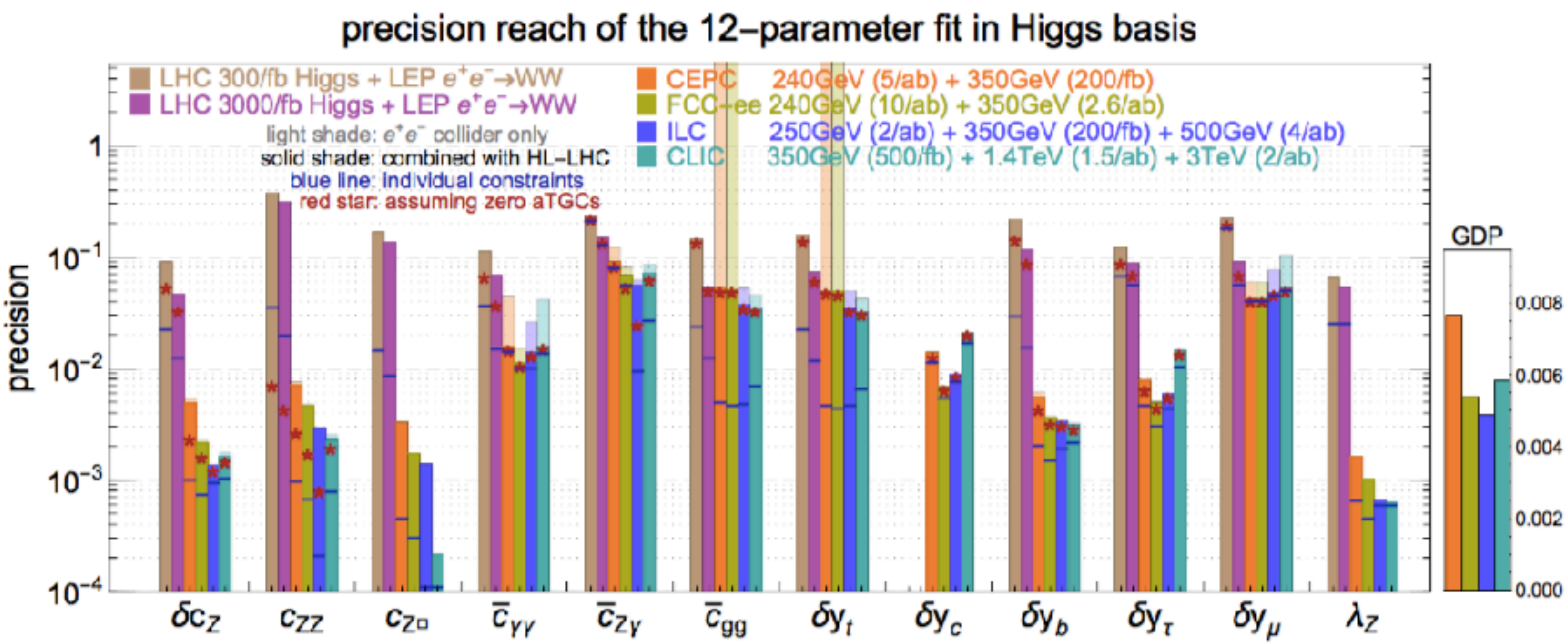
  Higgs anomalous decay is within reach of CEPC etc.

  \+ Neutrino mass range is predicted

- J. Gu and Y. Y. Li, Optimizing Higgs factories by modifying the recoil mass, arXiv:1709.08645 [hep-ph].
- J. Gu, H. Li, Z. Liu, S. Su and W. Su, Learning from Higgs Physics at Future Higgs Factories, arXiv:1709.06103 [hep-ph].
- G. Durieux, C. Grojean, J. Gu and K. Wang, The leptonic future of the Higgs, JHEP 1709, 014 (2017) doi:10.1007/JHEP09(2017)014 [arXiv:1704.02333 [hep- ph]].
- H. An, J. Gu and L. T. Wang, Exploring the nearly degenerate stop region with sbottom decays, JHEP 1704, 084 (2017) doi:10.1007/JHEP04(2017)084 [arXiv:1611.09868 [hep-ph]].

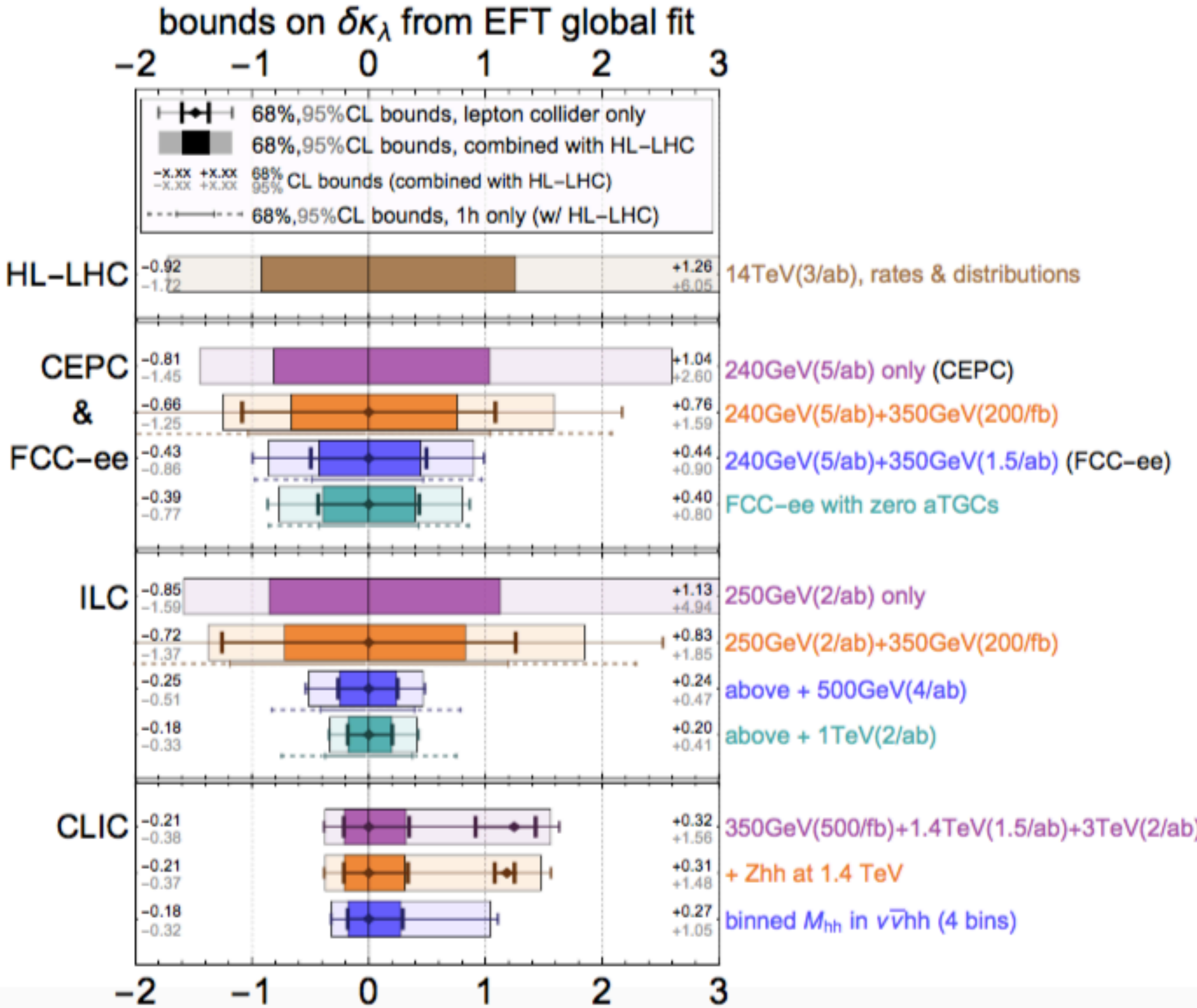
# The "12-parameter" EFT fit of Higgs couplings

JHEP 1709, 014 (2017) [arXiv:1704.02333]



# Triple Higgs coupling in the EFT framework

current work, S. Di Vita, G. Durieux, C. Grojean, JG, Z. Liu, G. Panico, M. Riembau, T. Vantalon, to appear soon



### A. Testing CP-violation in the Scalar Sector at CEPC

G. Li, **Y.-N. Mao**, C. Zhang, and S.-H. Zhu, **Phys. Rev. D 95, 035015 (2017)**.

- Assuming a new scalar $h_2$ discovered ($h_1$ is the X(125)), CP properties analysis:

$$\text{Tree level vertices :} \qquad \underset{+}{h_i} VV, \qquad \underset{+}{h_j} VV, \qquad \underset{\substack{+? \\ -?}}{h_i}\, \underset{\substack{-? \\ +?}}{h_j}\, Z$$

- Effective interaction:

$$\mathcal{L} = (c_1 h_1 + c_2 h_2)\, v \left( \frac{g^2}{2} W^{+\mu} W^-_\mu + \frac{g^2}{4c_W^2} Z^\mu Z_\mu \right) + \frac{g c_{12}}{2 c_W} Z^\mu \left( h_1 \partial_\mu h_2 - h_2 \partial_\mu h_1 \right)$$

- $K \equiv c_1 c_2 c_{12} \neq 0$ means CP-violation in scalar sector
- Choose $m_2 = 40$ GeV as an example

Test at CEPC: $e^+e^- \to Z^* \to Zh_1, Zh_2, h_1h_2$ associated productions

- Process simulation: $e^+e^- \to Z(\ell^+\ell^-)h_2(\text{anything}), h_1(b\bar{b})h_2(\text{anything})$

- "Recoil mass technique" and "$p_T$-balance cut" help
  (peak at $h_2$ mass) (tagging the most energetic photon)

- Results summary: sensitivities on $c_2$ (left table) and $c_{12}$ (right table)

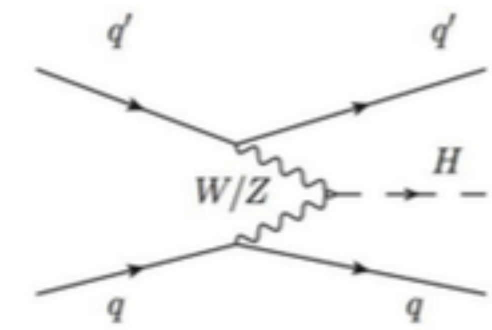
| | 95% U.L. | $3\sigma$ Disc. | $5\sigma$ Disc. |
|---|---|---|---|
| before | $< 0.087$ | $> 0.118$ | $> 0.152$ |
| after | $< 0.061$ | $> 0.083$ | $> 0.107$ |

| | 95% U.L. | $3\sigma$ Disc. | $5\sigma$ Disc. |
|---|---|---|---|
| before | $< 0.092$ | $> 0.125$ | $> 0.161$ |
| after | $< 0.088$ | $> 0.119$ | $> 0.153$ |

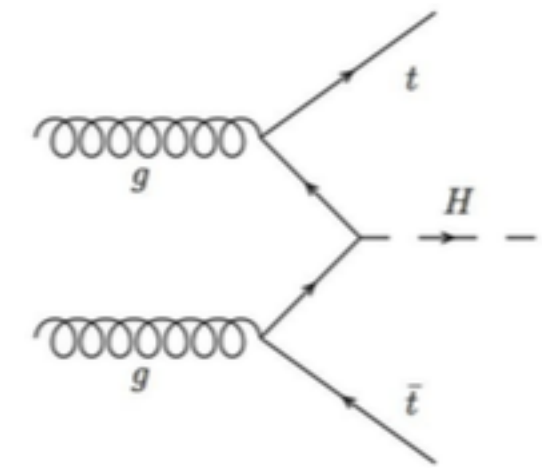
## B. Improved Formalism of SLH model and the $Zh\eta$ Vertex

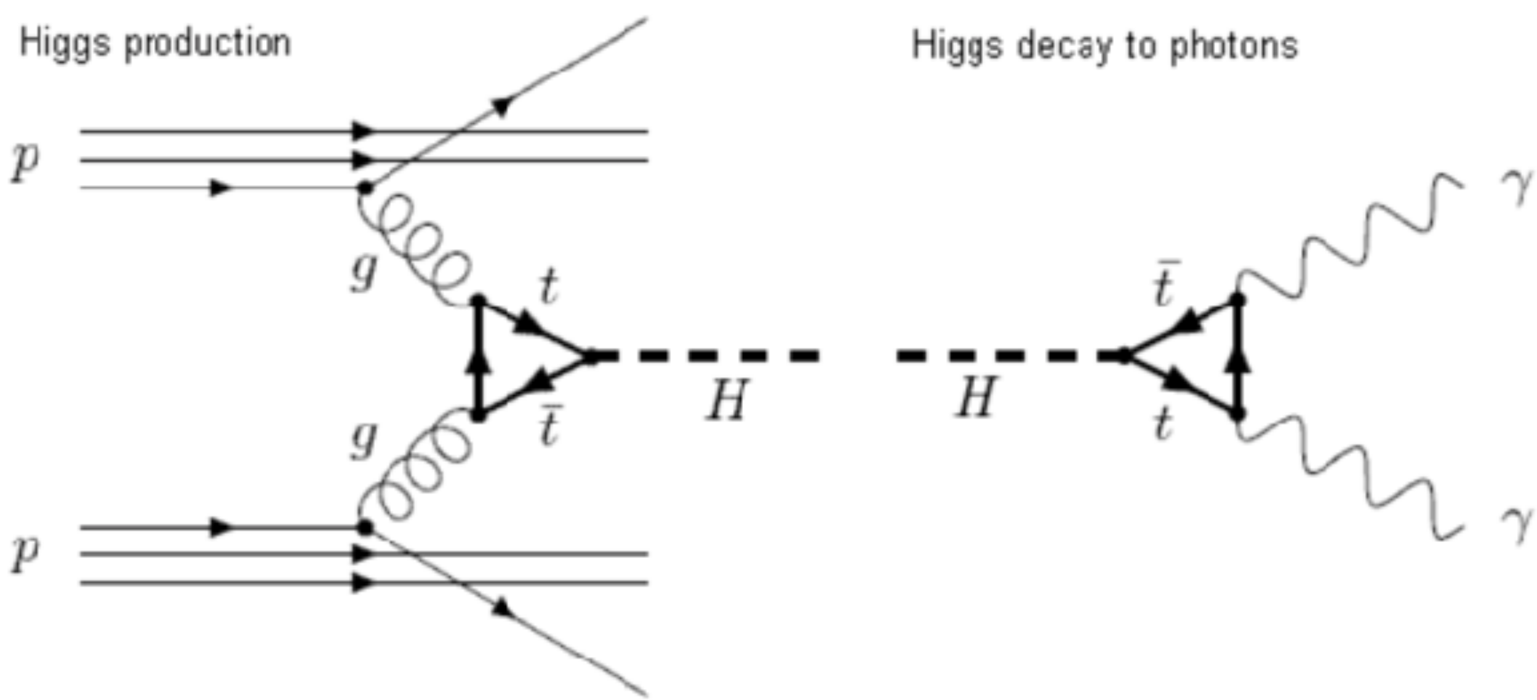
S.-P He, **Y.-N. Mao**, C. Zhang, and S.-H. Zhu, **arXiv: 1709.08929**.

# Measurement @ LHC

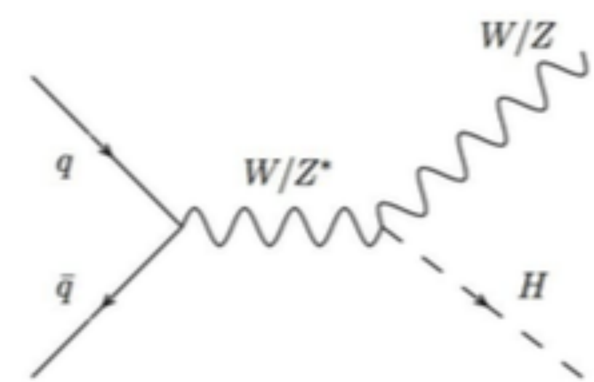



**Different production rate**
**Different decay BR**




$\kappa_g$




**New Physics in fermion loop???**

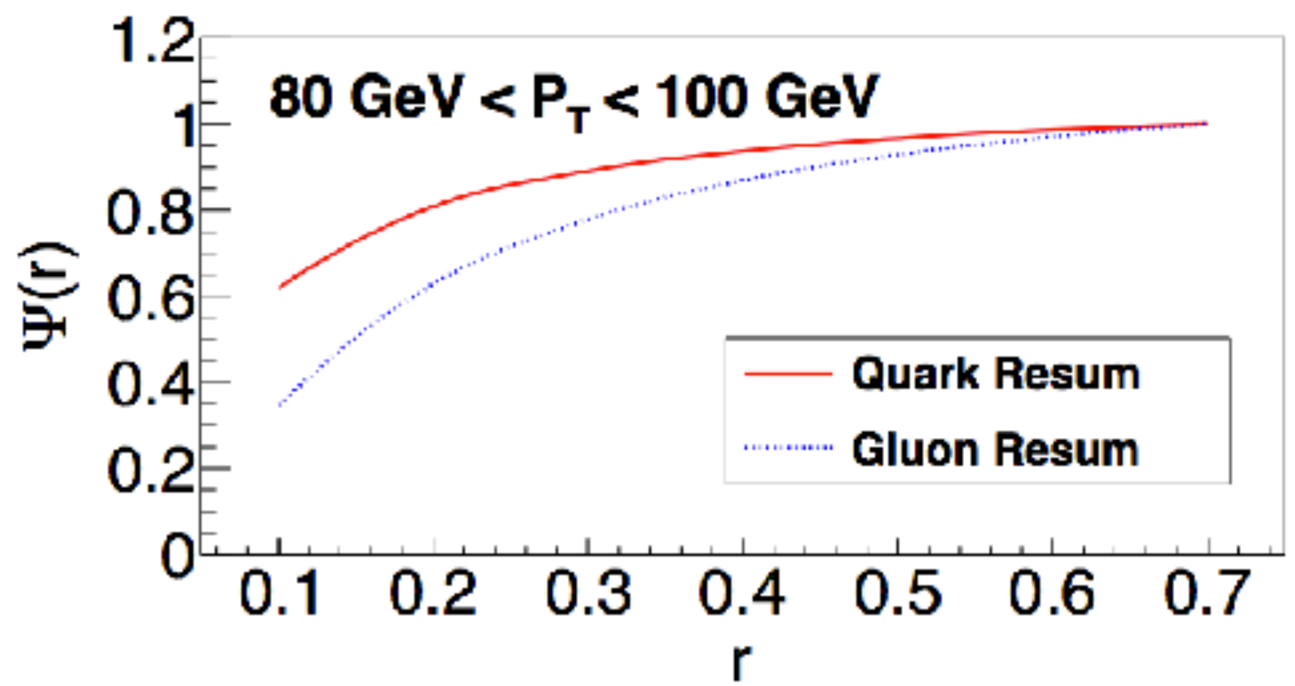
**Probe Higgs-gluon coupling via jet energy profile at $e^+e^-$ colliders**

Gexing Li,[1,*] Zhao Li,[1,2,†] Yandong Liu,[3,‡] Yan Wang,[1,§] and Xiaoran Zhao[4,¶]

$$gg(8.18\%),\ c\bar{c}(2.884\%)\ \text{and}\ b\bar{b}(58.09\%)$$

$$\mathcal{L}_{hgg} = \kappa_g c^g_{\rm SM} \frac{\alpha_s}{12\pi v} h G^a_{\mu\nu} G^{a\mu\nu},$$

$$\psi(r) = \frac{1}{N_j}\sum_j \psi_j(r) = \frac{1}{N_j}\sum_j \frac{\sum_{r_i<r} p_{{\rm T},i}(r_i)}{\sum_{r_i<R} p_{{\rm T},i}(r_i)},$$




$$\psi(0.3)^{p^i_T} = \frac{{\rm Br}(\bar{\rm b}{\rm b})(1-2\varepsilon_{\rm b}+\varepsilon_{\rm b}^2)\psi(0.3)_{\rm b}^{\rm p^i_T} + \kappa_{\rm g}^2{\rm Br}({\rm gg})\psi(0.3)_{\rm g}^{\rm p^i_T} + {\rm Br}(\bar{\rm c}{\rm c})(1-2\varepsilon_{\rm c}+\varepsilon_{\rm c}^2)\psi(0.3)_{\rm c}^{\rm p^i_T}}{{\rm Br}(\bar{\rm b}{\rm b})(1-2\varepsilon_{\rm b}+\varepsilon_{\rm b}^2) + {\rm Br}(\bar{\rm c}{\rm c})(1-2\varepsilon_{\rm c}+\varepsilon_{\rm c}^2) + \kappa_{\rm g}^2{\rm Br}({\rm gg})}$$

$$\Lambda^N(r) = \frac{\sum_j \psi_j(r)}{\sum_j \psi_j^{\mathrm{SM}}(r)}.$$

$$X^N(r) = \frac{\sum_j \psi_{j-q}(r)}{\sum_j \psi_{j-q}^{\mathrm{SM}}(r)},$$

# SG+BG Simulation @ CEPC 5 ab^-1

$$\psi_{j-q}(r) \equiv \psi_j(r) - \tilde{\psi}_q(r),$$

$$\psi_{j-q}^{\mathrm{SM}}(r) \equiv \psi_j^{\mathrm{SM}}(r) - \tilde{\psi}_q(r).$$

$$Y^N(r) = \frac{\sum_j (1-\psi_j)}{\sum_j (1-\psi_j^{\mathrm{SM}})}.$$

$$Z^N(r) = \frac{\sum_j (\psi_j + b)}{\sum_j (\psi_j^{\mathrm{SM}} + b)},$$

| | $Z \to e^+e^-$ | $Z \to \mu^+\mu^-$ | $Z \to \nu\bar{\nu}$ | $Z \to jj$ | Combined |
|---|---|---|---|---|---|
| $\delta\kappa_g^\Lambda$ | | 0.057 | | | |
| $\delta\kappa_g^X$ | | | | | |
| $\delta\kappa_g^Y$ | | 0.066 | | | |
| $\delta\kappa_g^Z$ | | 0.046 | | | |

$$b = \frac{\sigma^2(r) N^{\mathrm{SM}} + N_{\mathrm{BG}}^{\mathrm{SM}}(\psi_g - \psi_{\mathrm{BG}})(\psi_g - \psi_{\mathrm{BG}})}{(N_b^{\mathrm{SM}} + N_c^{\mathrm{SM}})(\psi_g - \psi_q) + N_{\mathrm{BG}}^{\mathrm{SM}}(\psi_g - \psi_{\mathrm{BG}})} - \psi_q.$$

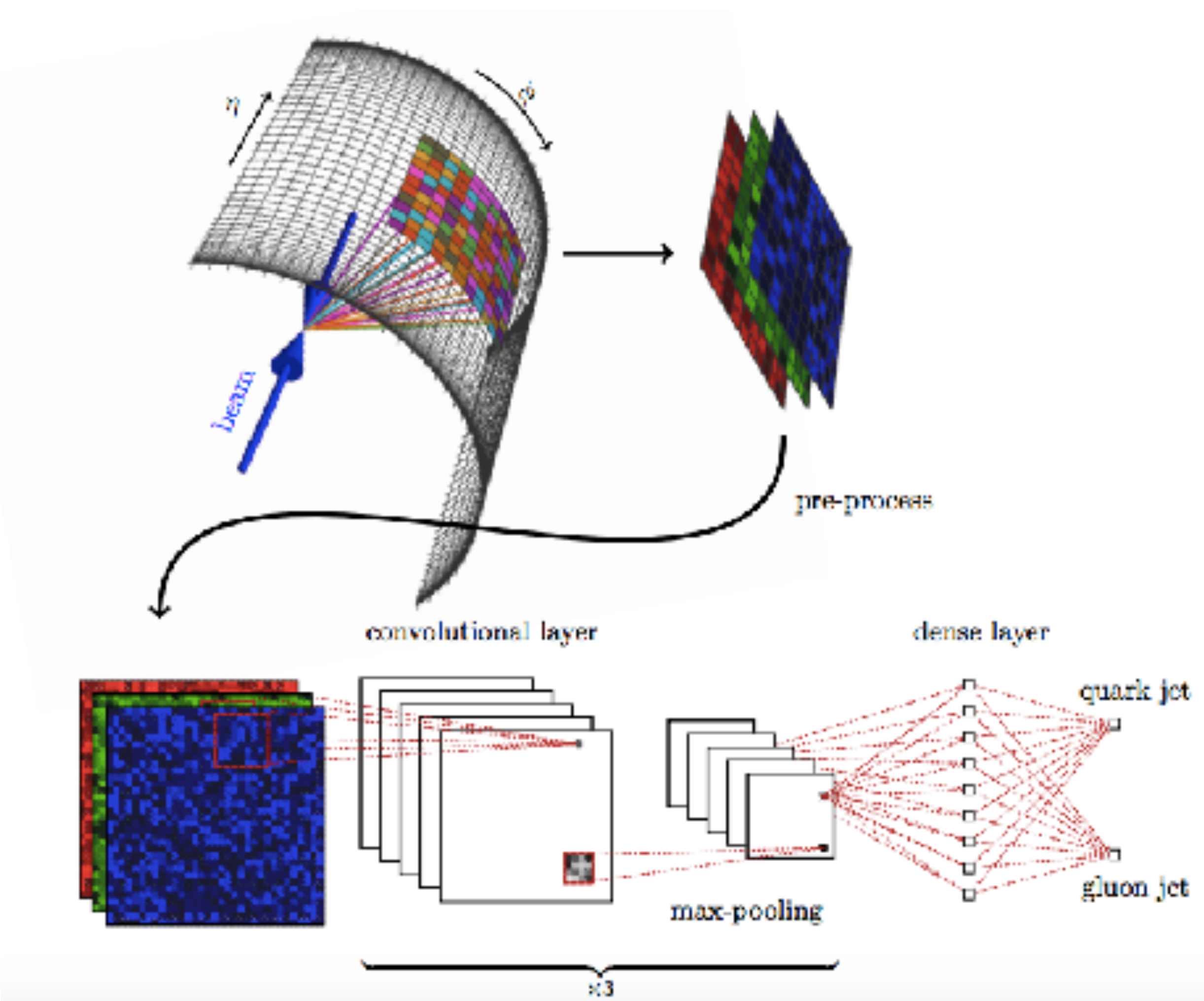
# Deep learning for jet identification @ CEPC

Yefan Wang,[1,*] Gexing Li,[1,†] and Zhao Li[1,2,‡]

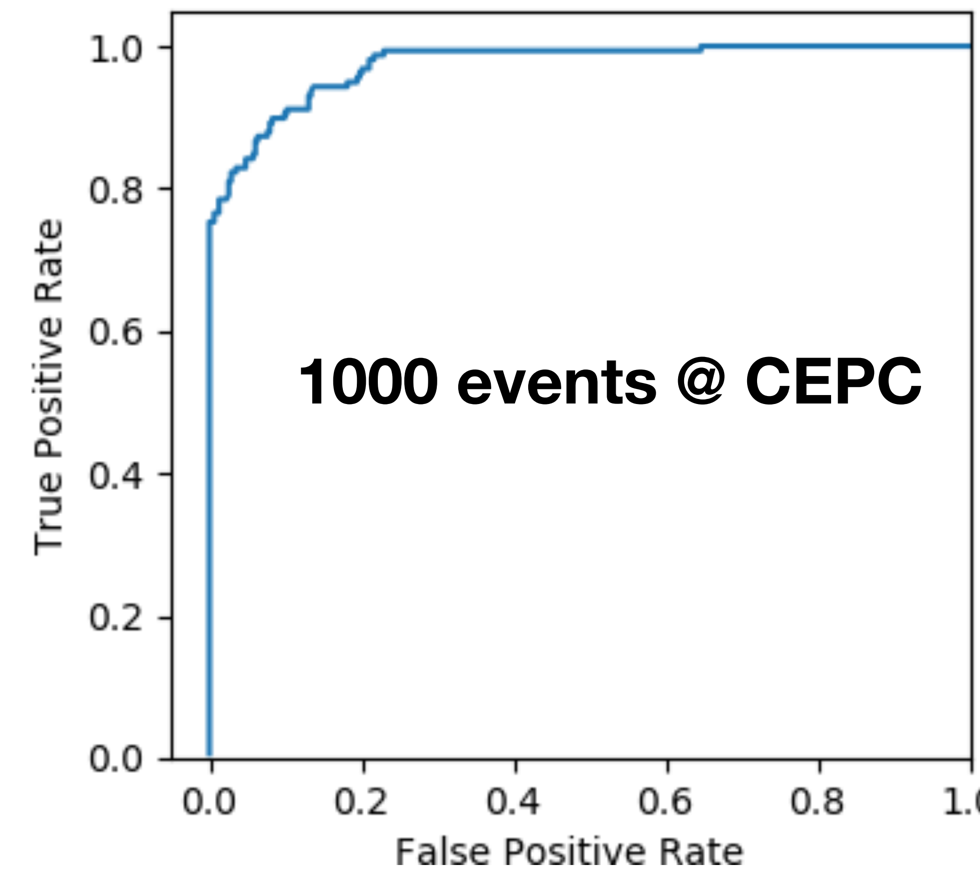
red = transverse momenta of charged particles

green = the transverse momenta of neutral particles

blue = charged particle multiplicity




**Duhram jet is different from jet@LHC**




**Deep learning in color: towards automated quark/gluon jet discrimination**

Patrick T. Komiske, Eric M. Metodiev (MIT, Cambridge, CTP), Matthew D. Schwartz (Harvard U., Phys. Dept. & Harvard U.)

Dec 5, 2016 - 23 pages

JHEP 1701 (2017) 110

**@LHC**

# Thank you!