


# Flavor physics at CEPC

10000000000000

**As a Tera-**  **Plus**

Lingfeng Li Brown U.

On behalf of the CEPC Flavor Physics Study Group

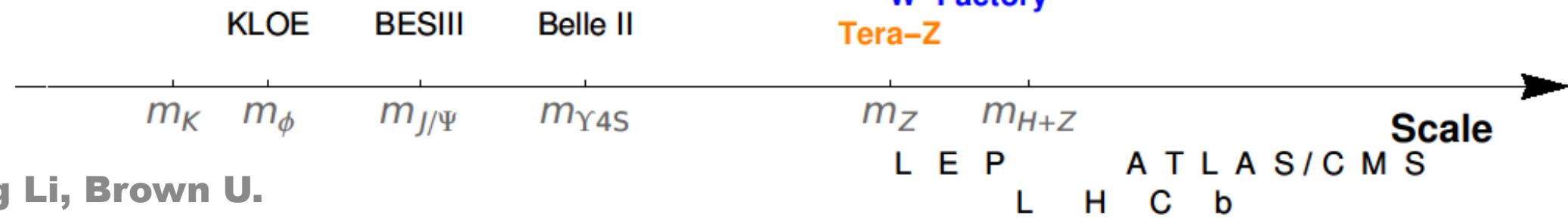
Aug. 11, 2022

11th National Particle Physics Academic Conference



- Clean lepton collider (good for  $\nu$ ,  $\gamma$ ,  $\tau$ ,  $e$  ... Big advantages vs. hadronic ones)
- $O(10^{11+})$  b/c/ $\tau$  ( $>$  B-factory of  $50 \text{ ab}^{-1}$ )
- Generates all kinds of hadrons ( $B_c$ ,  $\Lambda_b$ ,  $T_{bb}$ ...)
- Large energy (20-45 GeV) and boost for precision measurements
- Most advanced tech. infused detectors

~100/ $\pi$  km

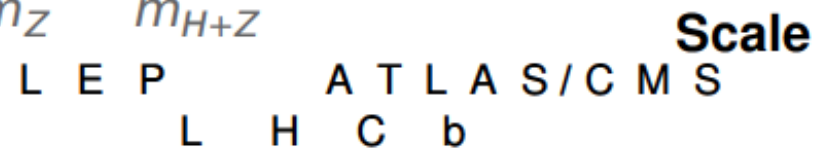
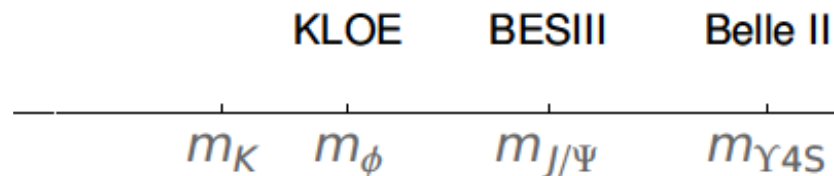




- Higher luminosity as the accelerator design keeps upgrading
- $\geq 2$  interaction points and various detectors

Flavor physics also need energy larger than 91 GeV (e.g.,  $|V_{cb}|$  from W decays)

~100/ $\pi$  km





Still a lot to understand  
even we can write down  $\mathcal{L}_{SM}$

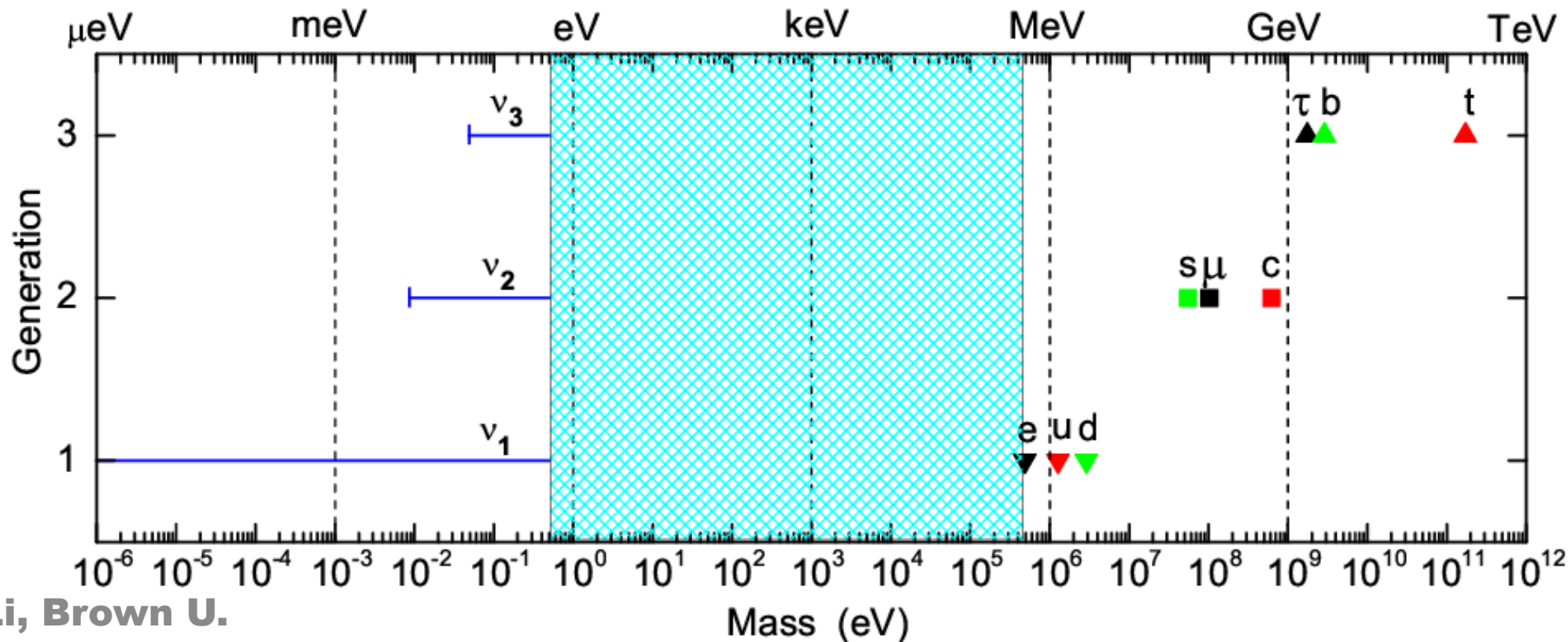
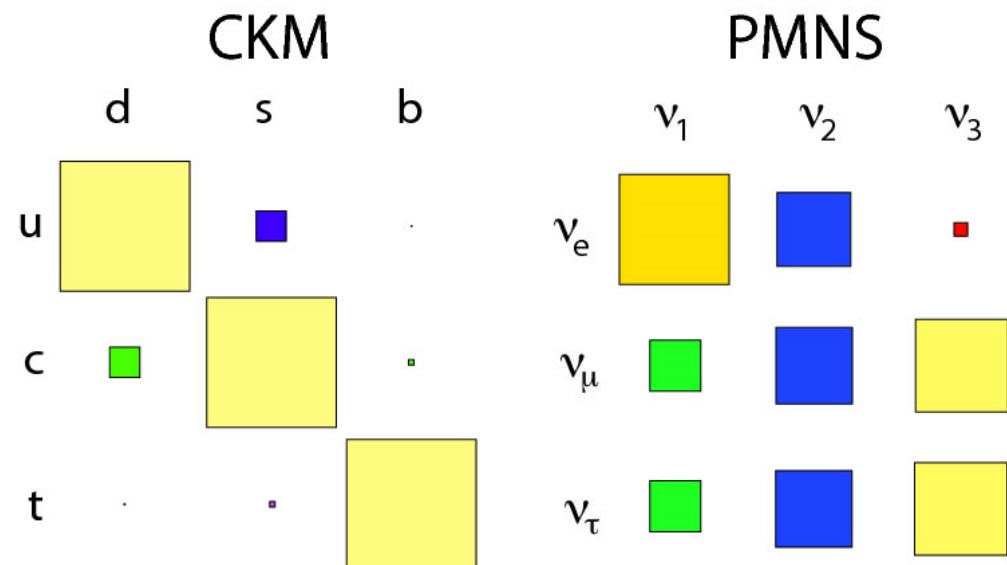
Great ways to probe new physics  
Great prize awaits?



# Who Ordered These?

Flavor mixing and CP violation patterns

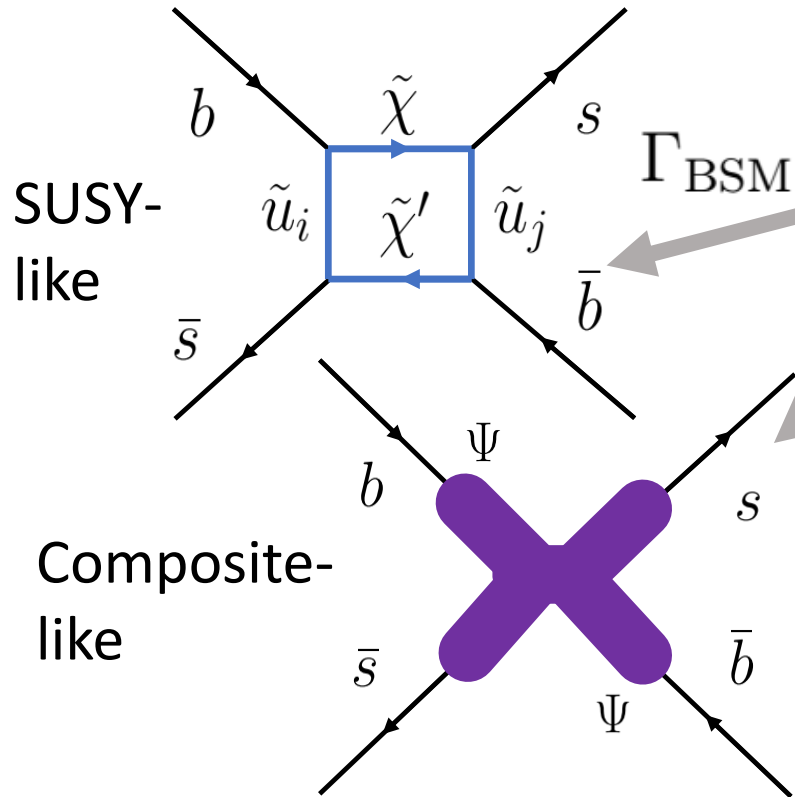
Large flavor hierarchy



# Flavor and New Physics

Heavy flavors (b, c, and  $\tau$ ) are long-lived particles, width  $< 10^{-11}$  GeV  $\ll$  mass:

$$\Gamma_{\text{SM}} \sim \frac{G_F^2 m_f^5}{192\pi^3} \times \text{const} \propto \frac{m_f^5}{m_W^4}.$$

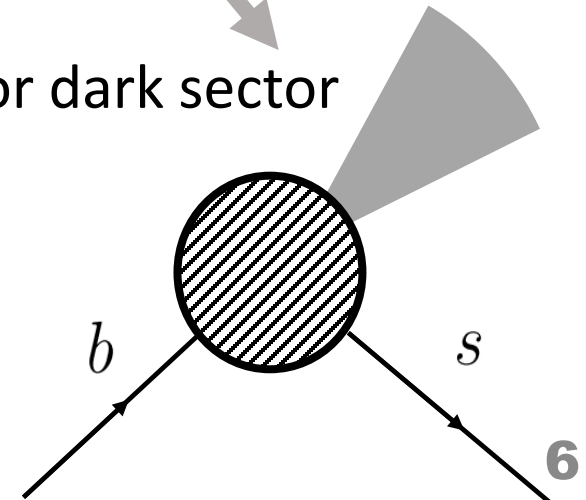


$$\Gamma_{\text{BSM}} \propto \frac{m_f^5}{\Lambda_{\text{NP}}^2 m_W^2} \text{ (w/ interference), or } \frac{m_f^5}{\Lambda_{\text{NP}}^4} \text{ (w/o interference)}$$

$$\left( \frac{m_W^2}{\Lambda_{\text{NP}}^2} \text{ or } \frac{m_W^4}{\Lambda_{\text{NP}}^4} \gg \frac{m_f^4}{\Lambda_{\text{NP}}^4} \right)$$

Large rates with moderate suppression

ALP or dark sector



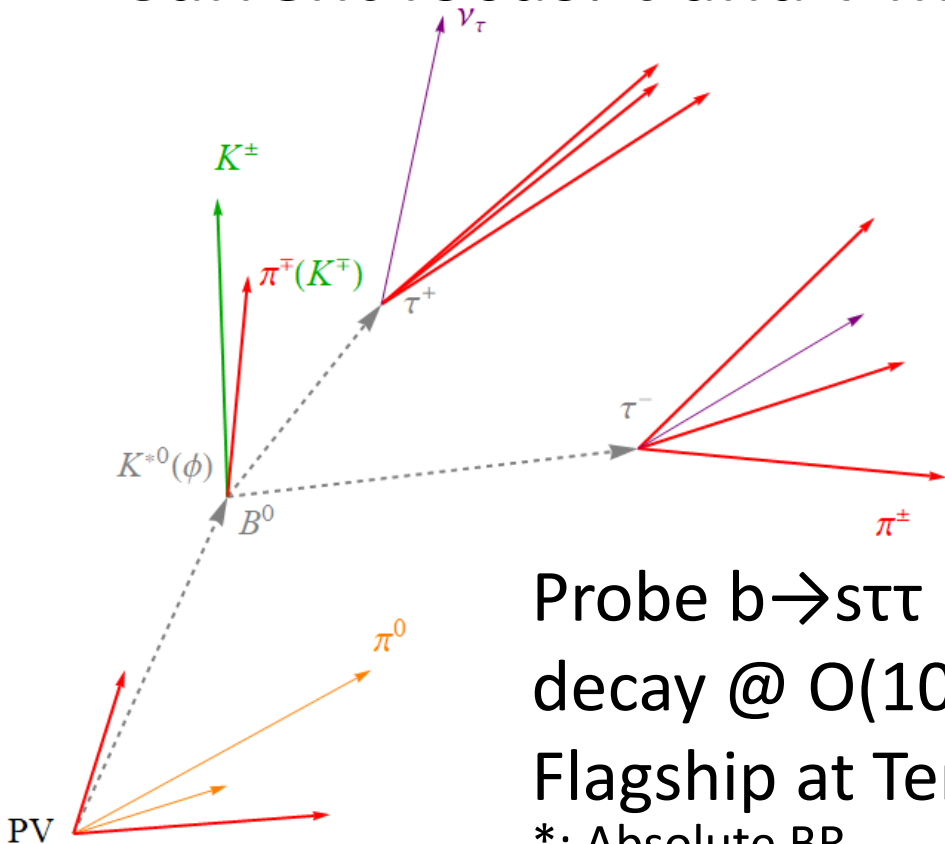
# Recent Progress

2	Description of CEPC facility	1
2.1	Key Collider Features for Flavor Physics	3
2.2	Key Detector Features for Flavor Physics	3
3	Charged Current Semileptonic and Leptonic $b$ Decays	6
4	Rare/Penguin and Forbidden $b$ Decays	7
4.1	Dileptonic Modes	7
4.2	Neutrino Modes	8
4.3	Radiative Modes	9
4.4	Lepton Flavor Violating (LFV), Lepton Number Violating(LNV) and Baryon Number Violating (BNV) Decays	10
5	Hadronic $b$ Decays and $CP$ Violation Measurements	10
6	Spectroscopy and Exotics	11
7	Charm Physics	12
8	$\tau$ Physics	12
9	Flavor Physics at Higher Energies	14
9.1	Flavor Physics from $Z$ Decays	14
9.2	Flavor Physics from $W$ Decays	15
9.3	Flavor Physics from Higgs and Top	15
10	Production of BSM States from Heavy Flavor Decays	15
11	Two Photon and ISR Physics with Heavy Flavors	15

Taken from the flavor physics white paper (in preparation)

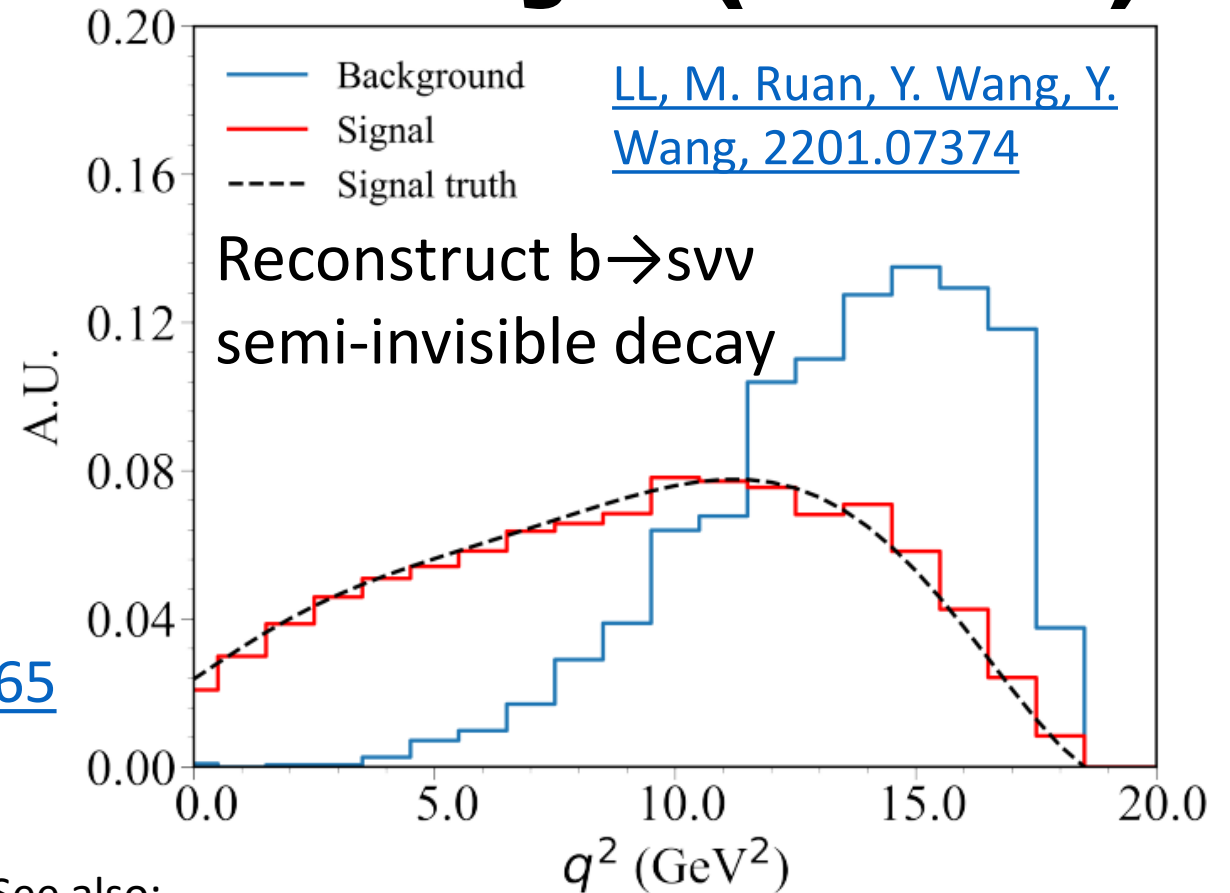
# Heavy Quark Weak Decays (FCNC)

- Rare decays, sensitive to BSM
- $R_K$  and  $R_{K^*}$  anomalies
- Current focus:  $\tau$  and  $\nu$  modes



[LL, T. Liu, 2012.00665](#)

Probe  $b \rightarrow s \tau \tau$  rare decay @  $O(10^{-7})^*$   
 Flagship at Tera-Z  
 \*: Absolute BR



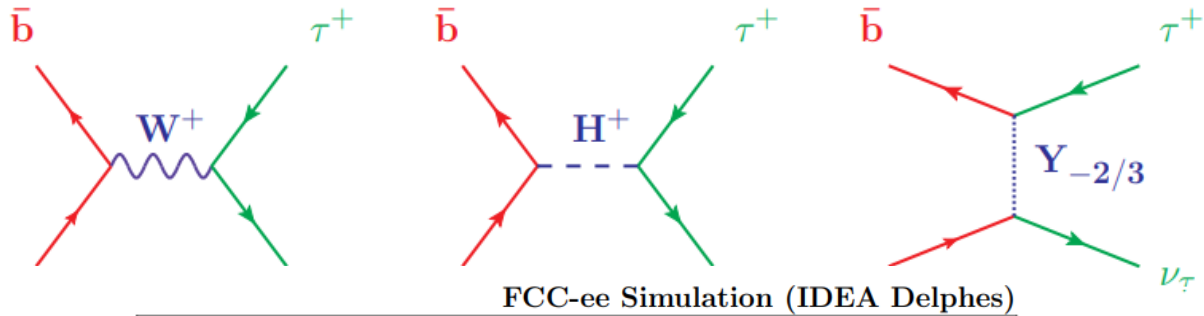
See also:

- [J. F. Kamenik, S. Monteil, A. Semkiv, L. V. Silva 1705. 11106](#)
- [S. Descotes-Genon, S. Fajfer, J. Kamenik, M. Novoa-Brunet, In prep](#)
- [S. Monteil, G. Wilkinson, 2106.01259](#)
- [M. Chrzaszcz, R. Gonzalez Suarez, S. Monteil, 2106.15459](#)
- [T. Miralles et al., In prep](#)

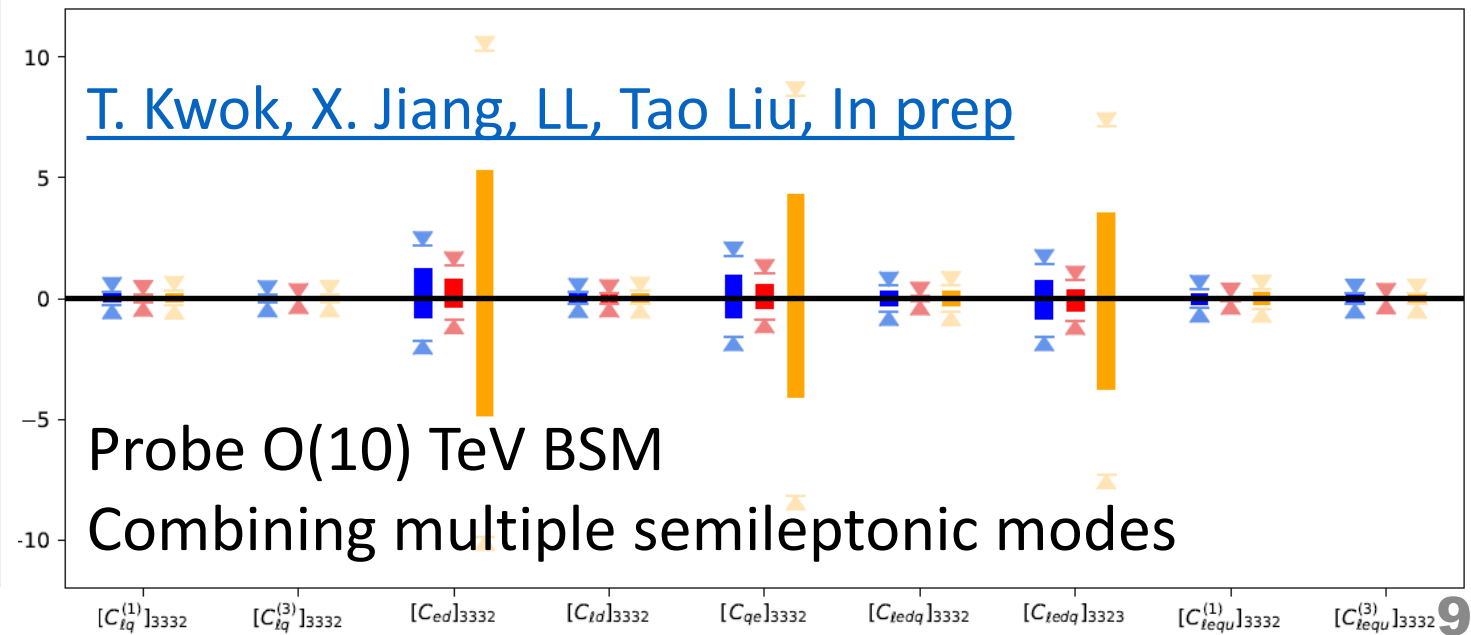
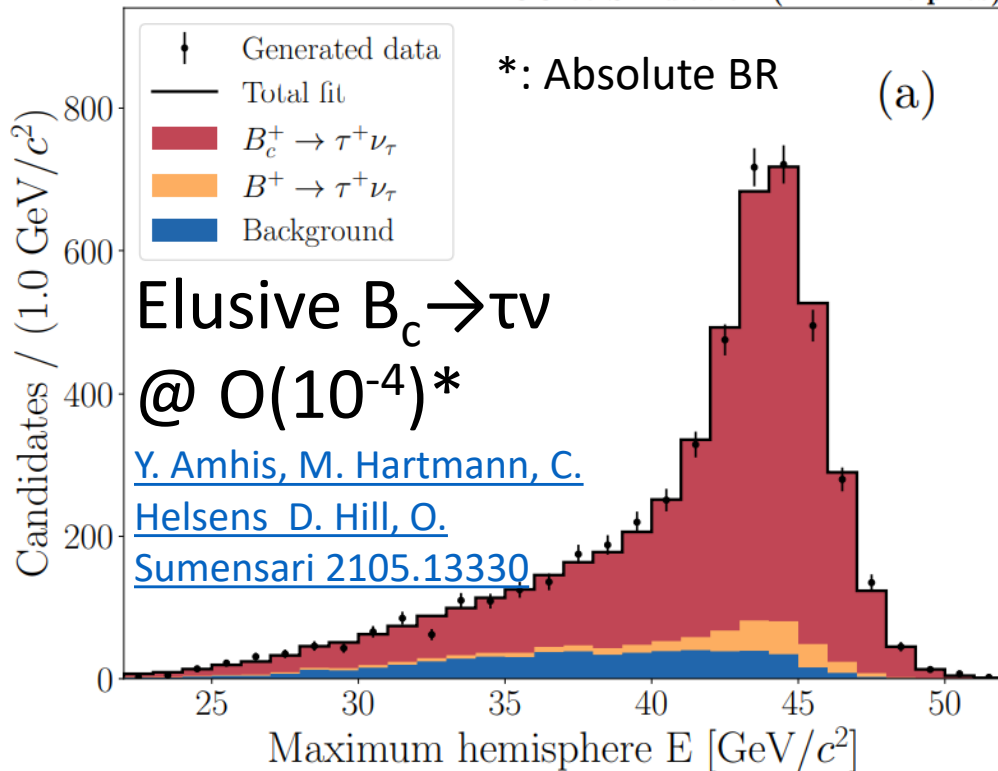


# Heavy Quark Weak Decays (FCC)

[T. Zheng, J. Xu, L. Cao, D. Yu, W. Wang et al., 2007.08234](#)



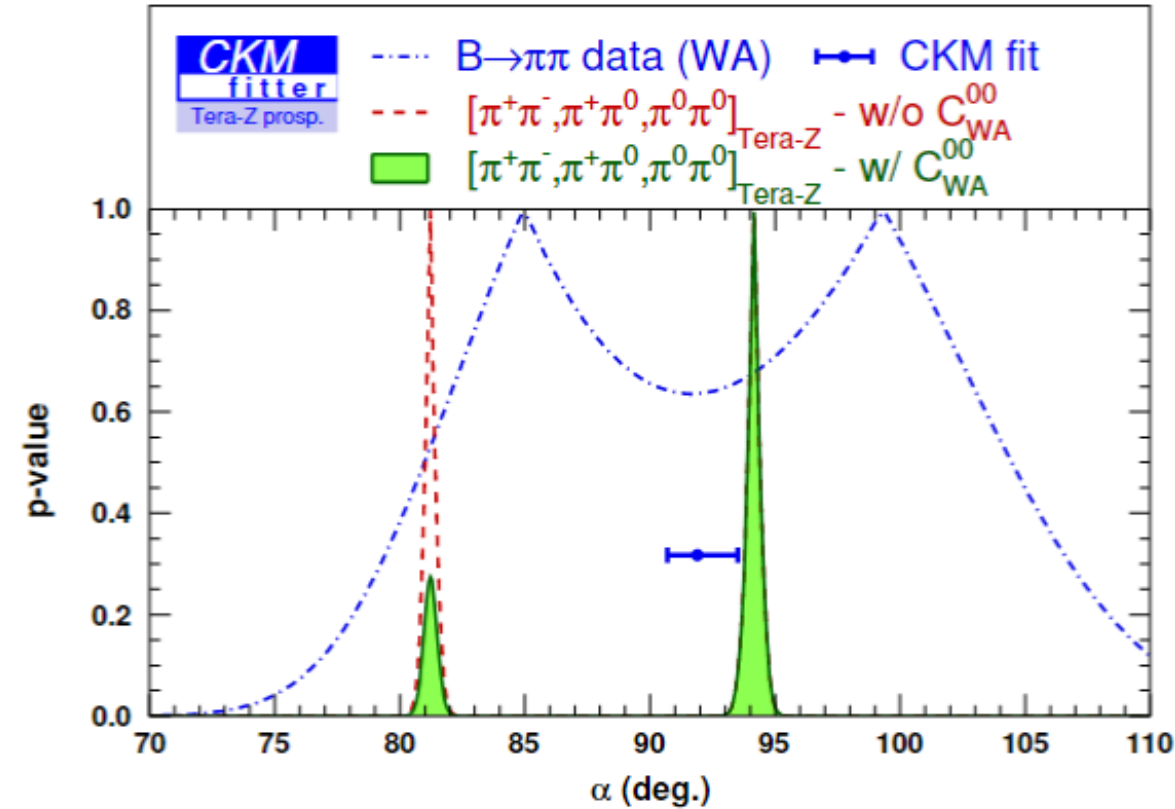
- Anomalies indicating lepton flavor universality violation
- Potential for  $|V_{cb}|$  &  $|V_{ub}|$  extraction
- Current focus: (Semi)leptonic modes



# CPV

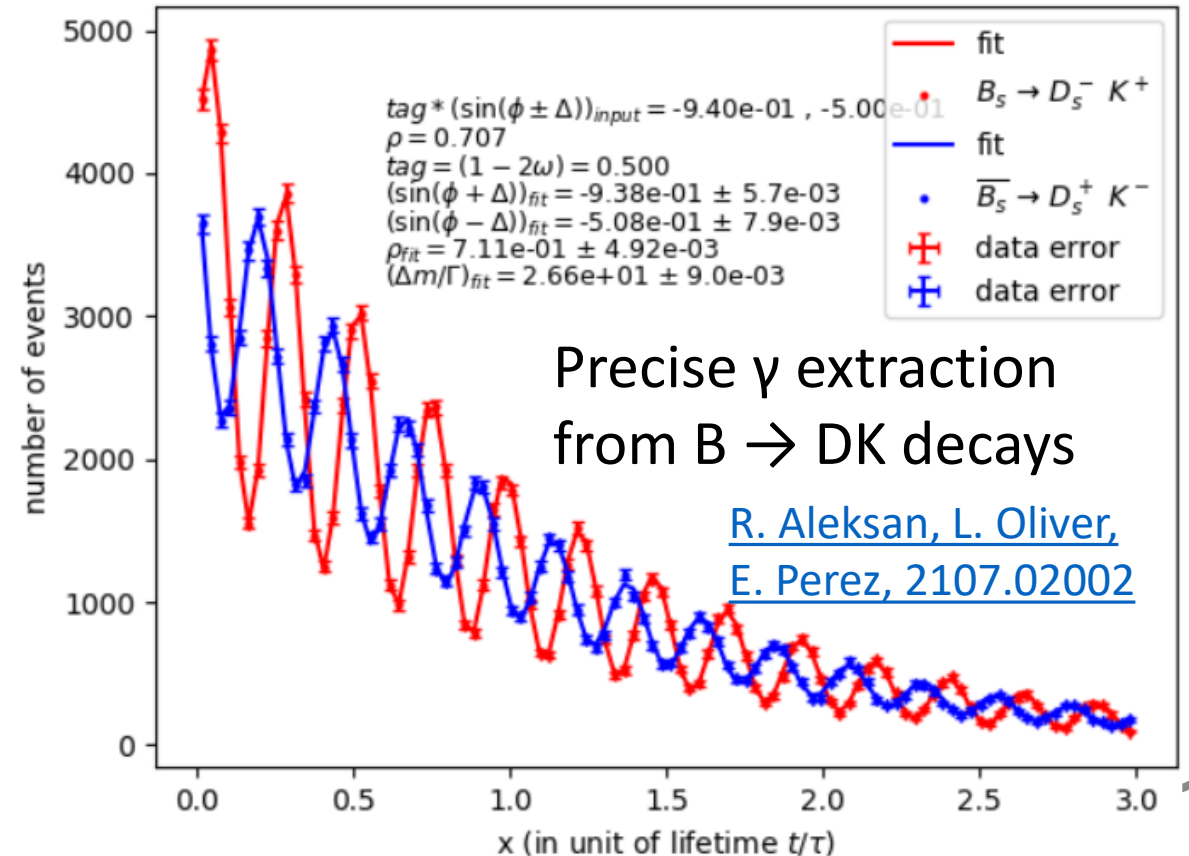
- Multiple new ways of measurement
- Current focus: B decays

See also: [J. Charles, S. Descotes-Genon, Zoltan Ligeti, S. Monteil, M. Papucci, K. Trabelsi, L. Silva, 2006.04824](#)  
[R. Aleksan, L. Oliver, E. Perez, 2107.05311](#)  
[X. Li, M Ruan, M. Zhao, 2205.10565](#)



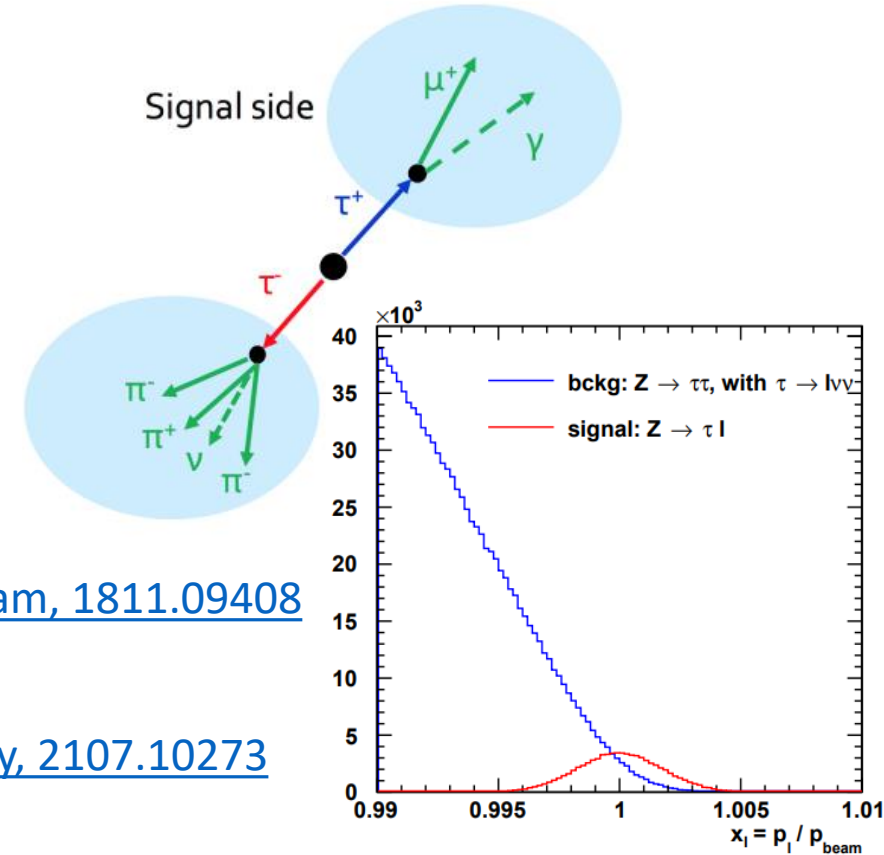
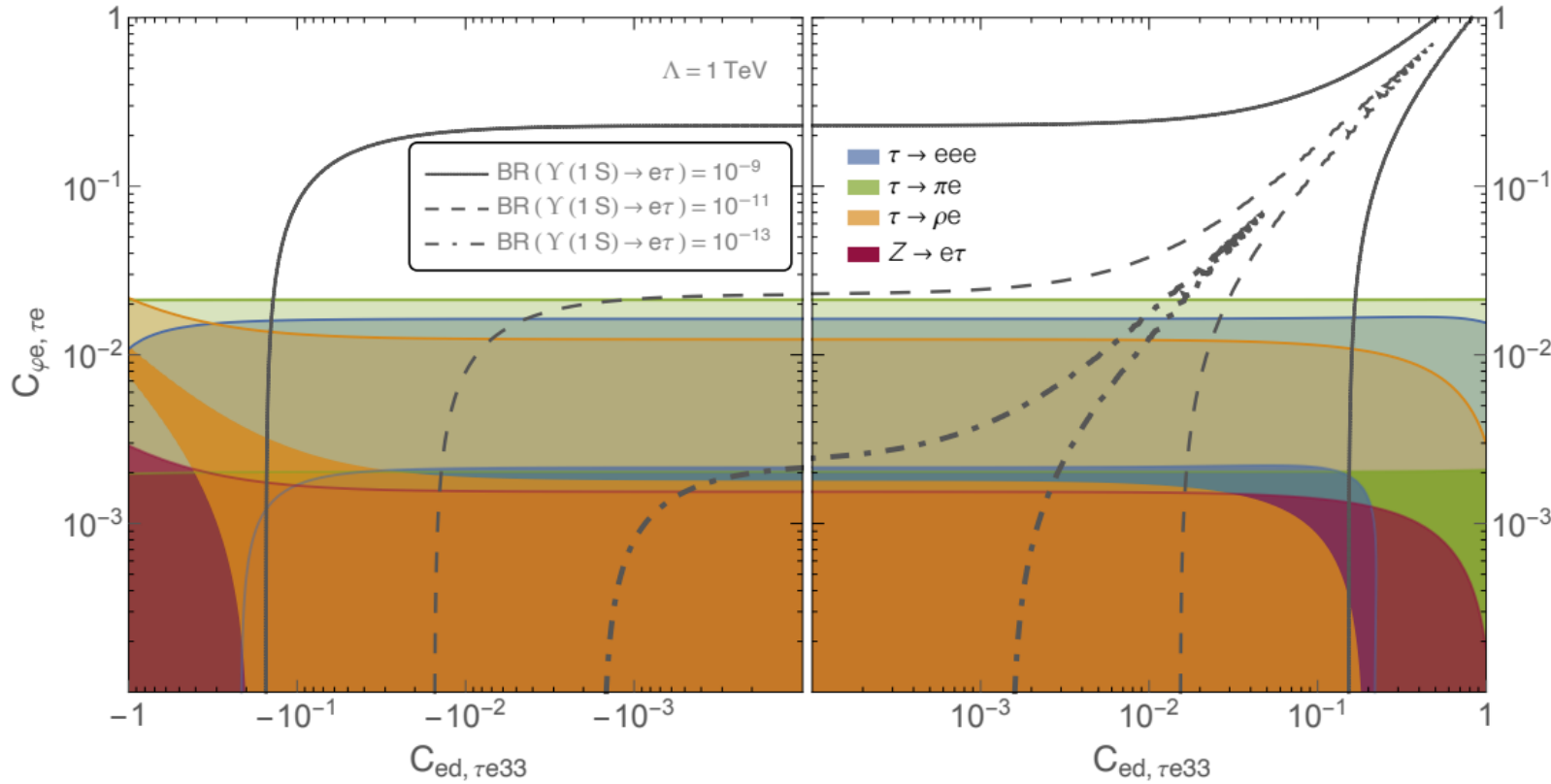
[Y. Wang, S. Descotes-Genon, O. Deschamps, LL, S. Chen, Y. Zhu, M. Ruan, In prep](#)

Measure CKM  $\alpha$  down to O(0.4) degree,  
 Removing mirror solutions



# Tau and Lepton Sector

- A most powerful tau machine
- Current focus: charged lepton flavor violation (cLFV)



[L. Calibbi, T. Li, X. Marcano, M.A. Schmidt, 2207.10913](#)

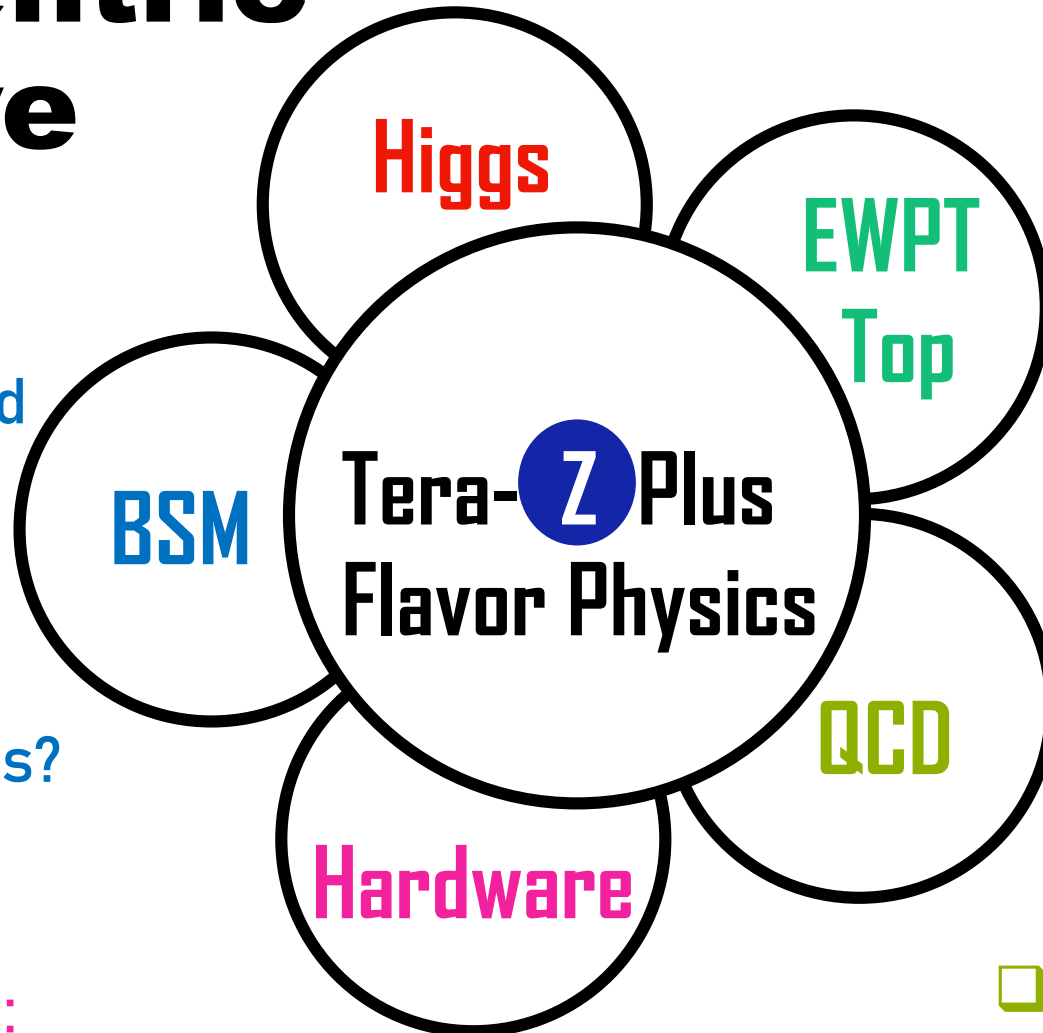
[M. Dam, 1811.09408](#)

Complementarity between Z pole, quarkonia, and lepton cLFV decays

See also: [L. Calibbi, X. Marcano, J. Roy, 2107.10273](#)  
[M. Dam, 2107.12832](#)

# Summary: A flavor-centric perspective

- ❑ Origin of matter?  
understand lepton and  
baryon numbers
- ❑ Light dark matter?
- ❑ Lepton Flavor  
Universality anomalies?



- ❑ Origin of flavor hierarchy?
- ❑ CP violation phases from Yukawa?

- ❑ Flavor physics beyond  
the Tera-Z phase?
- ❑ Common need in  $\tau$  phys.

- ❑ How does asymptotic  
freedom work with  
flavor?
- ❑ New formalism beyond  
the conventional  
meson-baryon picture?

- ❑ Use a plethora of data to  
improve hadronization

❑ Most demanding field:  
We need better tracker, E(H)CAL, electronics... everything!