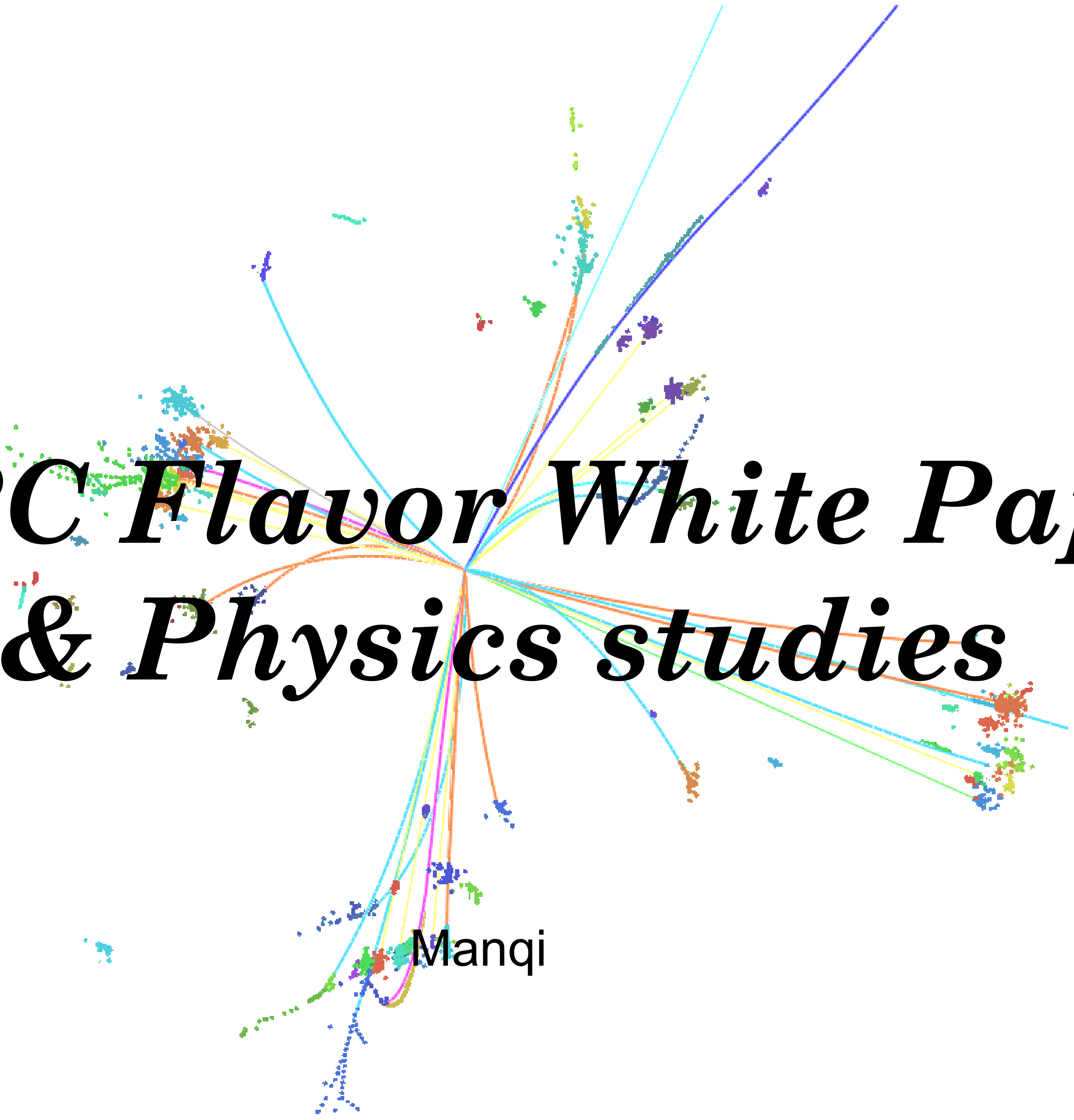
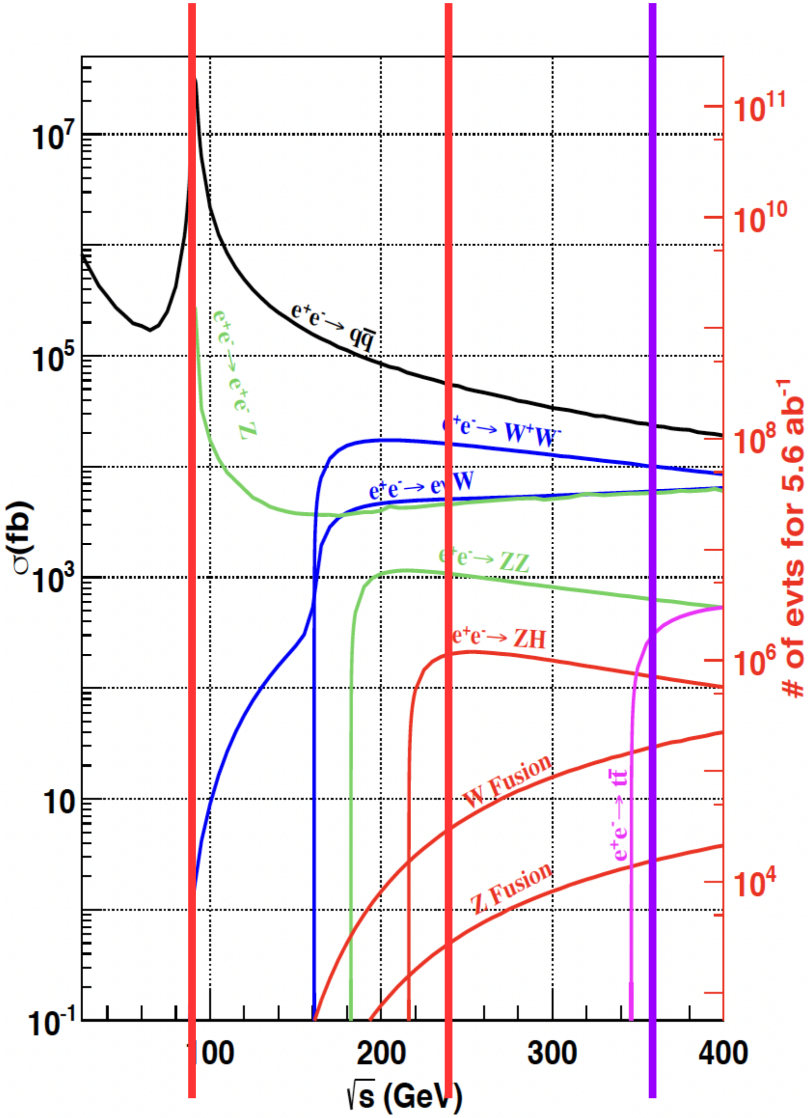
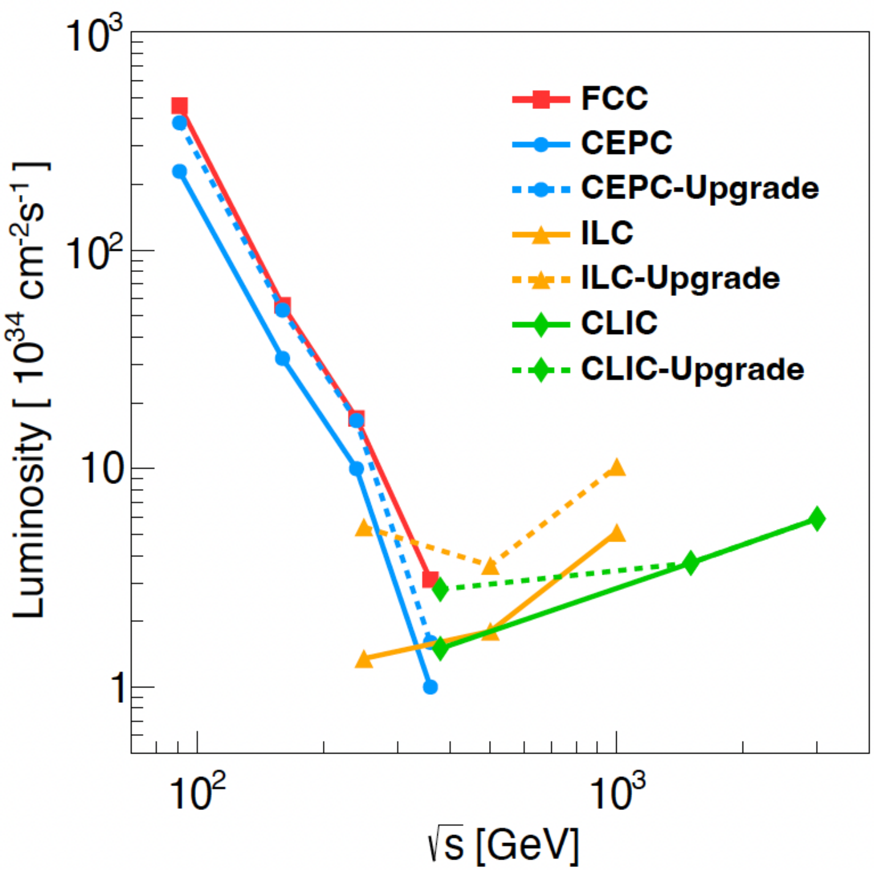


CEPC Flavor White Paper & Physics studies

Manqi

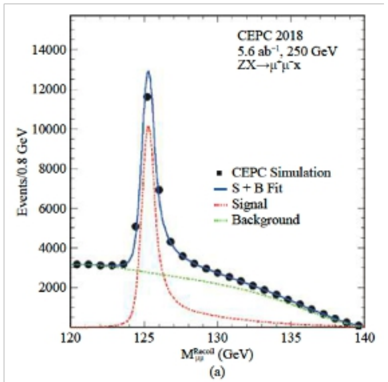
Yields ~ Xsec * Lumi * Time

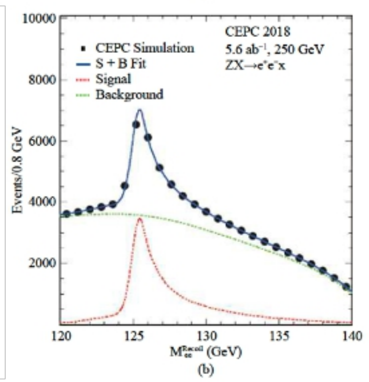


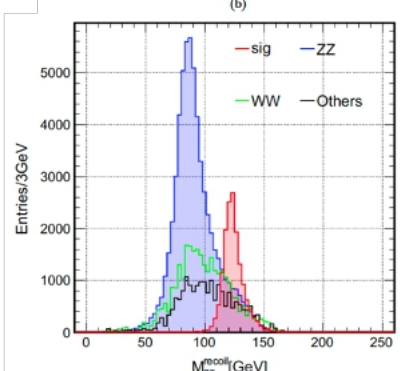


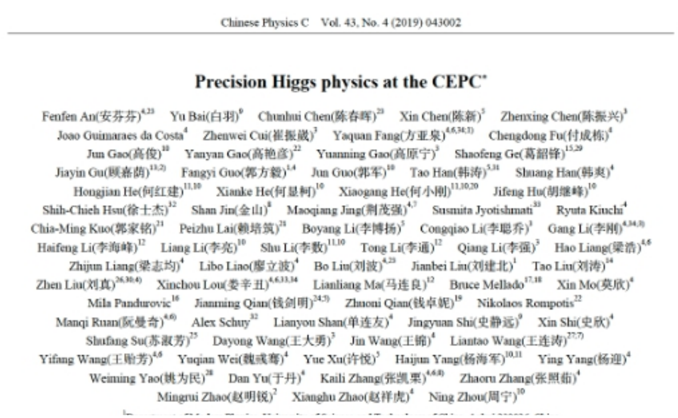
- 4 Million Higgs (10 years)
- ~ 1 Giga W (1 year) + 4 Tera Z (2 years)
- Upgradable: Top factory (500 k ttbar)

Physics reaches...








Chinese Physics C Vol. 43, No. 4 (2019) 043002

Precision Higgs physics at the CEPC*

White papers +

~300 Journal/AxXiv citables


Received 9 November 2018, Revised 21 January 2019, Published online 4 March 2019

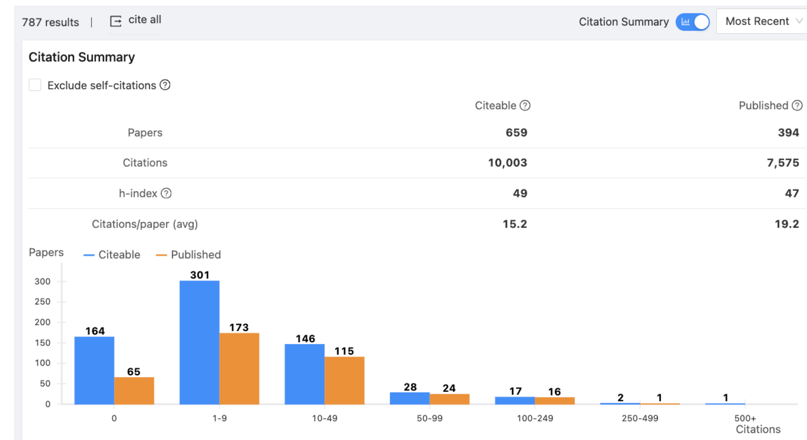


Table 2.1: Precision of the main parameters of interests and observables at the CEPC, from Ref. [1] and the references therein, where the results of Higgs are estimated with a data sample of 20 ab^{-1}. The HL-LHC projections of 3000 fb^{-1} data are used for comparison. [2]

Higgs			W, Z and top		
Observable	HL-LHC projections	CEPC precision	Observable	Current precision	CEPC precision
M_H	20 MeV	3 MeV	M_W	9 MeV	0.5 MeV
Γ_H	20%	1.7%	Γ_W	49 MeV	2 MeV
$\sigma(ZH)$	4.2%	0.26%	M_{top}	760 MeV	$\mathcal{O}(10)$ MeV
$B(H\to bb)$	4.4%	0.14%	M_Z	2.1 MeV	0.1 MeV
$B(H\to cc)$	-	2.0%	Γ_Z	2.3 MeV	0.025 MeV
$B(H\to gg)$	-	0.81%	R_b	3×10^{-3}	2×10^{-4}
$B(H\to WW^*)$	2.8%	0.53%	R_c	1.7×10^{-2}	1×10^{-3}
$B(H\to ZZ^*)$	2.9%	4.2%	R_μ	2×10^{-3}	1×10^{-4}
$B(H\to\tau^+\tau^-)$	2.9%	0.42%	R_τ	1.7×10^{-2}	1×10^{-4}
$B(H\to\gamma\gamma)$	2.6%	3.0%	A_μ	1.5×10^{-2}	3.5×10^{-5}
$B(H\to\mu^+\mu^-)$	8.2%	6.4%	A_τ	4.3×10^{-3}	7×10^{-5}
$B(H\to Z\gamma)$	20%	8.5%	A_b	2×10^{-2}	2×10^{-4}
$Bupper(H\to inv.)$	2.5%	0.07%	N_ν	2.5×10^{-3}	2×10^{-4}

Scientific Significance quantified by **CEPC physics** studies, via full simulation/phenomenology studies:

- Higgs: Precisions exceed HL-LHC ~ 1 order of magnitude.
- EW: Precision improved from current limit by 1-2 orders.
- Flavor Physics, sensitive to NP of 10 TeV or even higher.
- Sensitive to varies of NP signal.
- …

White papers

- Higgs: 2019 Chinese Phys. C 43 043002: summarization of relevant simulation studies till CDR
- Snowmass Whitepaper:
  - Input to Snowmass, covers Higgs, EW, Flavor, NP, etc, available at ArXiv 2205.08553v1
- Flavor:
  - Main editors: Lingfeng Li (Brown U), Tao Liu (HKUST), Fengkun Guo (ITP), Lorenzo Calibbi (Tianjing U), Xinqiang Li (CCNU), Qin Qin (Huazhong S&T), etc)
  - Submitted to ArXiv at Dec. 2024 (2412.19743v2), submitted to CPC.
- NP:
  - Main editors: Jia Liu (PKU), Liantao Wang(Chicago U), Zhen Liu (Minnesota U), Xuai Zhuang (IHEP), Yu Gao (IHEP), Zhao Li (IHEP), etc
  - Submitted to ArXiv May. 2025 (2505.24810v1)
- EW: In progress
  - Main efforts: Jiayin Gu (Fudan U), Zhijun Liang (IHEP), Yong Du (UCAS) etc
- QCD: Roadmap rather than WP
  - Main efforts: Huaxing Zhu (PKU), Meng Xiao (ZJU), Jun Gao (SJTU), Zhao Li (IHEP), etc
  - Very rich physics: strong coupling constant measurement + Form Factor + Hadron Fragmentation + QCD Phase transition + accurate calculation + interplay to other measurements especially Flavor & Higgs...

Prepared for submission to JHEP

Flavor Physics at CEPC: a General Perspective

Xiaocong Ai[1], Wolfgang Altmannshofer[2], Peter Athron[3], Xiaozhi Bai[4], Lorenzo Calibbi[5,*], Lu Cao[6,7], Yuzhi Che[8,9], Chunhui Chen[10], Ji-Yuan Chen[31], Long Chen[11], Mingshui Chen[8,9,77], Shanzhen Chen[7,8,77,†], Xuan Chen[11], Shan Cheng[12], Cheng-Wei Chiang[13], Andreas Crivellin[14,15], Hanhua Cui[8,9], Olivier Deschamps[16], Sébastien Descotes-Genon[17], Xiaokang Du[18], Shuangshi Fang[8,9], Yu Gao[8,9,77], Li-Sheng Geng[19], Pablo Goldenzweig[20], Jiayin Gu[21,22,23], Fengkun Guo[24,9,25,†], Yuchen Guo[26,27], Zhi-Hui Guo[28,†], Tao Han[29], Hong-Jian He[30,31], Jibo He[9], Miao He[8,9,77], Yanping Huang[8,9,77], Gino Isidori[15], Quan Ji[8,9,77], Jianfeng Jiang[8,9], Xu-Hui Jiang[8,32,33], Jernej F. Kamenik[34,35], Tsz Hong Kwok[33,†], Gang Li[8,9,77], Geng Li[36], Haibo Li[8,9], Haitao Li[11], Hengne Li[37], Honglei Li[38], Liang Li[30,31], Lingfeng Li[39,33,*], Qiang Li[40], Shu Li[30,31], Xiaomei Li[41], Xin-Qiang Li[42,†], Yiming Li[8,9,77], Yubo Li[43], Yuji Li[6], Zhao Li[8,9], Hao Liang[8,9], Zhijun Liang[8,9,77], Libo Liao[44], Zoltan Ligeti[45], Jia Liu[46], Jianbei Liu[75,76], Tao Liu[33,*], Yi Liu[1], Yong Liu[8,9,77], Zhen Liu[47], Xinchou Lou[8,77,78], Peng-Cheng Lu[11], Alberto Lusiani[48], Hong-Hao Ma[49], Kai Ma[50], Yaxian Mao[42], David Marzocca[51], Juan-Juan Niu[49], Soeren Prell[10], Huirong Qi[8,9,77], Sen Qian[8,9,77], Zhuoni Qian[52], Qin Qin[53,†], Ariel Rock[33], Jonathan L. Rosner[54,55], Manqi Ruan[8,9,77,*], Dingyu Shao[6], Chengping Shen[56,23], Xiaoyan Shen[8,9], Haoyu Shi[8,9,77], Liaoshan Shi[57,†], Zong-Guo Si[11], Cristian Sierra[3], Huayang Song[24], Shufang Su[58], Wei Su[44], Michele Tammaro[59], En Wang[1], Fei Wang[1], Hengyu Wang[8,9], Jian Wang[11], Jianchun Wang[8,9,77], Kun Wang[74], Lian-Tao Wang[54], Wei Wang[31,60], Xiaolong Wang[56], Xiaoping Wang[19], Yadi Wang[61], Yifang Wang[8,9], Yuexin Wang[8,62,†], Xing-Gang Wu[63], Yongcheng Wu[3], Rui-Qing Xiao[30,31,64], Ke-Pan Xie[19], Yuehong Xie[42], Zijun Xu[8,9,77], Haijun Yang[30,31,65,66], Hongtao Yang[4], Lin Yang[30], Shuo Yang[26,27], Zhongbao Yin[42], Fusheng Yu[67], Changzheng Yuan[8,9], Xing-Bo Yuan[42], Xuhao Yuan[8,9,77], Chongxing Yue[26,27], Xi-Jie Zhan[68], Kaili Zhang[8,62], Liming Zhang[69], Xiaoming Zhang[42], Yang Zhang[1], Yanxi Zhang[46], Yongchao Zhang[70], Yu Zhang[71], Zhen-Hua Zhang[72], Zhong Zhang[57], Mingrui Zhao[41], Qiang Zhao[8,9], Xu-Chang Zheng[63], Yangheng Zheng[9], Chen Zhou[46], Pengxuan Zhu[24], Yongfeng Zhu[46], Xunwu Zuo[20,†], Jure Zupan[73]

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[†] Primary contributor.

Contents

Flavor Physics White Paper

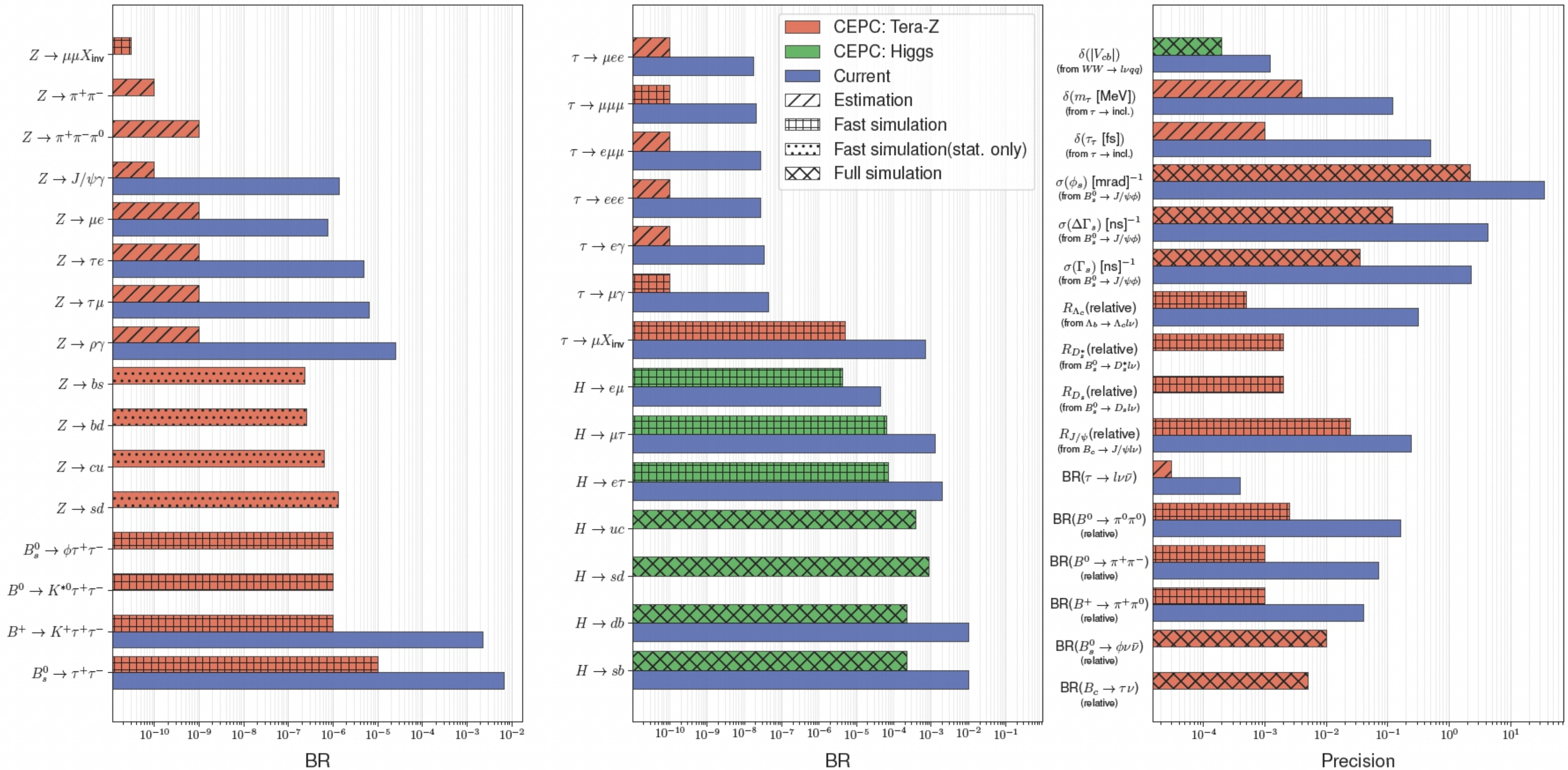


Figure 45: Anticipated upper limits or measurement precisions for the flavor physics benchmarks at the CEPC. It should be remarked that the limits of Z hadronic FCNC decays are statistic w.r.t. current performance of jet origin identification, whose calibration remains challenging. A breakthrough is thus needed to control the relevant systematic uncertainty to a level comparable to their statistic ones.

arXiv:2412.19743v1 [hep-ex] 27 Dec 2024

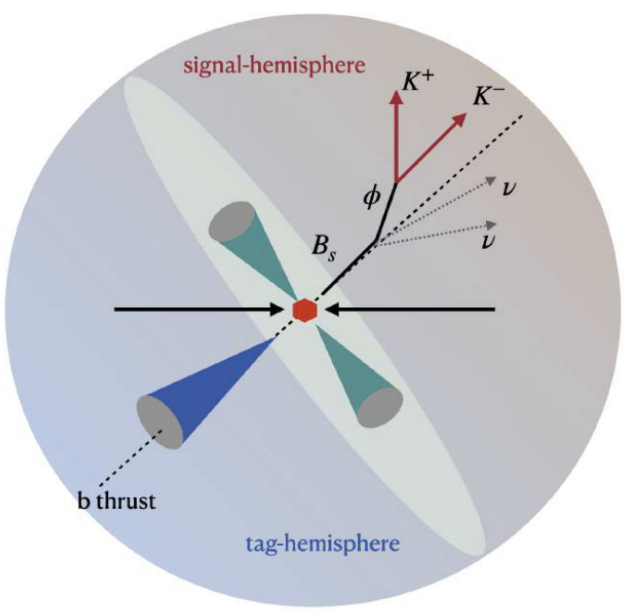
See the Non-Seen

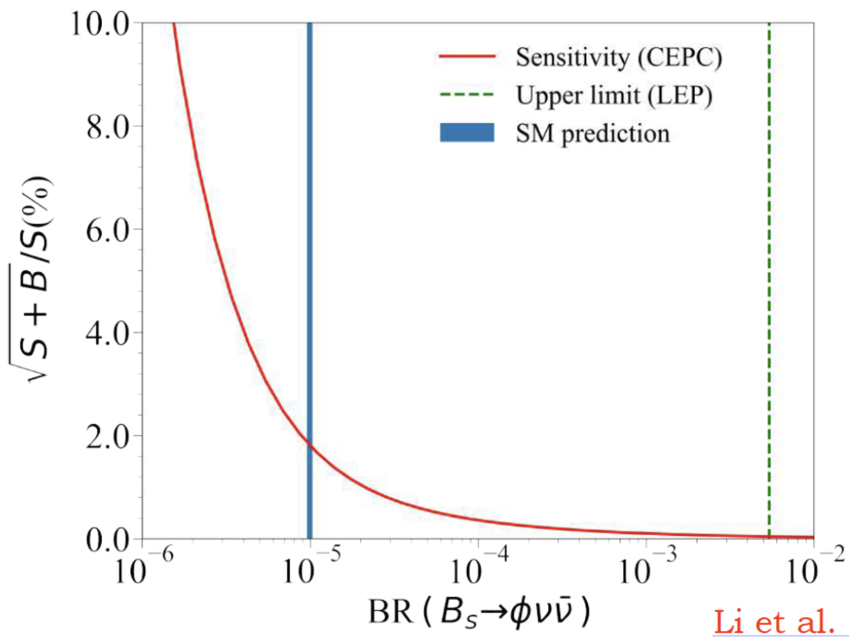
$b \to s\nu\nu$

Li et al. '22

	Current Limit	Detector	SM Prediction
$\mathrm{BR}(B^0 \to K^0 \nu\bar{\nu})$	$< 2.6 \times 10^{-5}$ [3]	BELLE	$(3.69 \pm 0.44) \times 10^{-6}$ [1]
$\mathrm{BR}(B^0 \to K^{*0} \nu\bar{\nu})$	$< 1.8 \times 10^{-5}$ [3]	BELLE	$(9.19 \pm 0.99) \times 10^{-6}$ [1]
$\mathrm{BR}(B^\pm \to K^\pm \nu\bar{\nu})$	$< 1.6 \times 10^{-5}$ [4]	BABAR	$(3.98 \pm 0.47) \times 10^{-6}$ [1]
$\mathrm{BR}(B^\pm \to K^{*\pm} \nu\bar{\nu})$	$< 4.0 \times 10^{-5}$ [5]	BELLE	$(9.83 \pm 1.06) \times 10^{-6}$ [1]
$\mathrm{BR}(B_s \to \phi \nu\bar{\nu})$	$< 5.4 \times 10^{-3}$ [6]	DELPHI	$(9.93 \pm 0.72) \times 10^{-6}$

- Also these modes can be greatly enhanced by new physics responsible for the B anomalies
  see e.g. LC Crivellin Ota '15
- A Tera Z can measure $B_s \to \phi\nu\nu$ with a percent level precision:





Li et al. '22

FCNC b hadronic decays

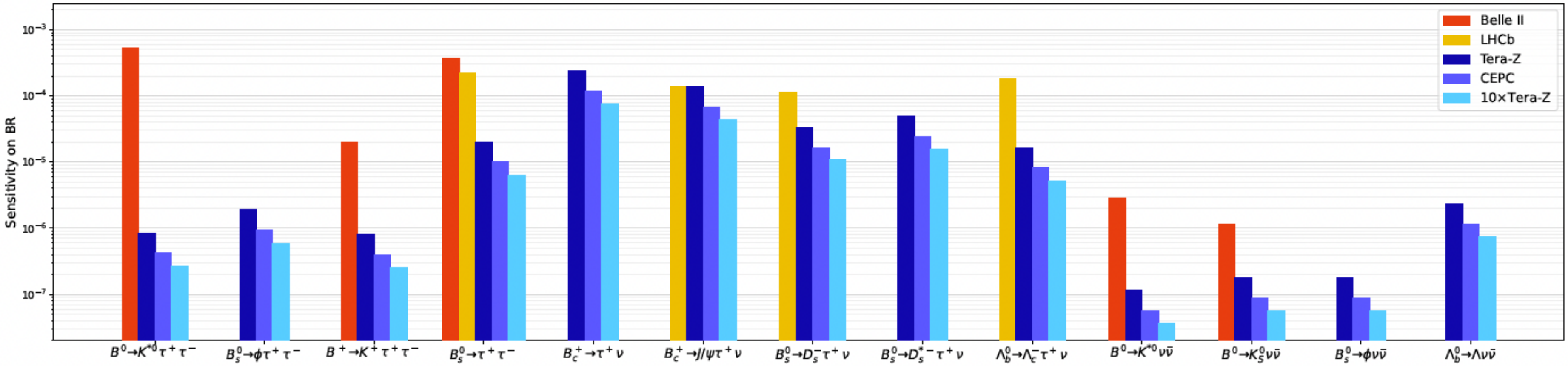
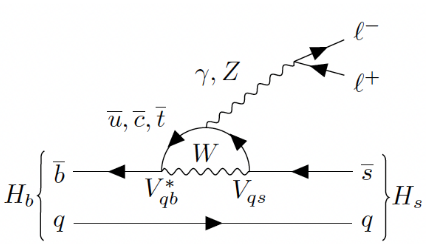
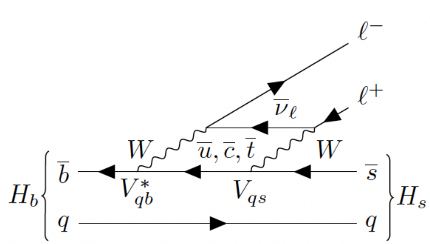
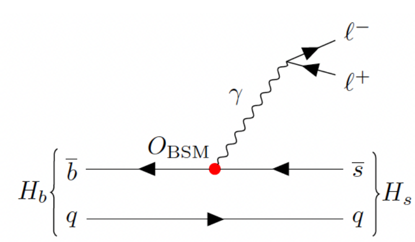
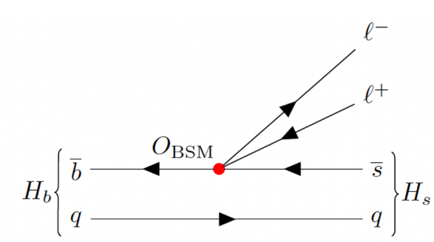


Figure 16: Projected sensitivities of measuring the $b \to s\tau\tau$ [85], $b \to s\nu\bar{\nu}$ [36, 86] and $b \to c\tau\nu$ [39, 68] transitions at the Z pole. The sensitivities at Belle II @ 50 ab^{-1} [7, 87] and LHCb Upgrade II [18, 57] have also been provided as a reference. Note that LHCb sensitivities are generated by combining the analyses of $\tau^+ \to \pi^+\pi^-\pi^-(\pi^0)\nu$ and $\tau \to \mu\nu\bar{\nu}$. This plot is taken from Ref. [39], with additional $b \to s\nu\bar{\nu}$ modes included.

Spectroscopy and exotics

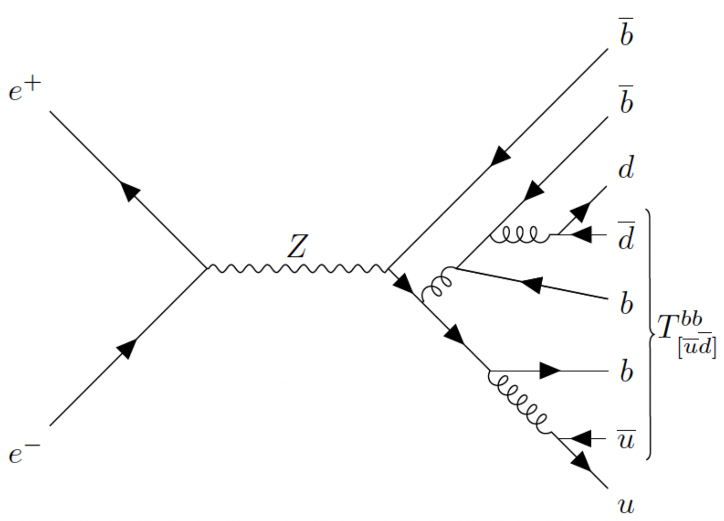


Figure 37: An illustrative Feynman diagram for the production of tetraquark state T from the $Z \to b\bar{b}\bar{b}\bar{b}$ decay.

Very clear signature:

IP->T->B->D...

Anticipate o(1E6) events at Tera-Z, Rele. Accuracy of percentage level anticipated...

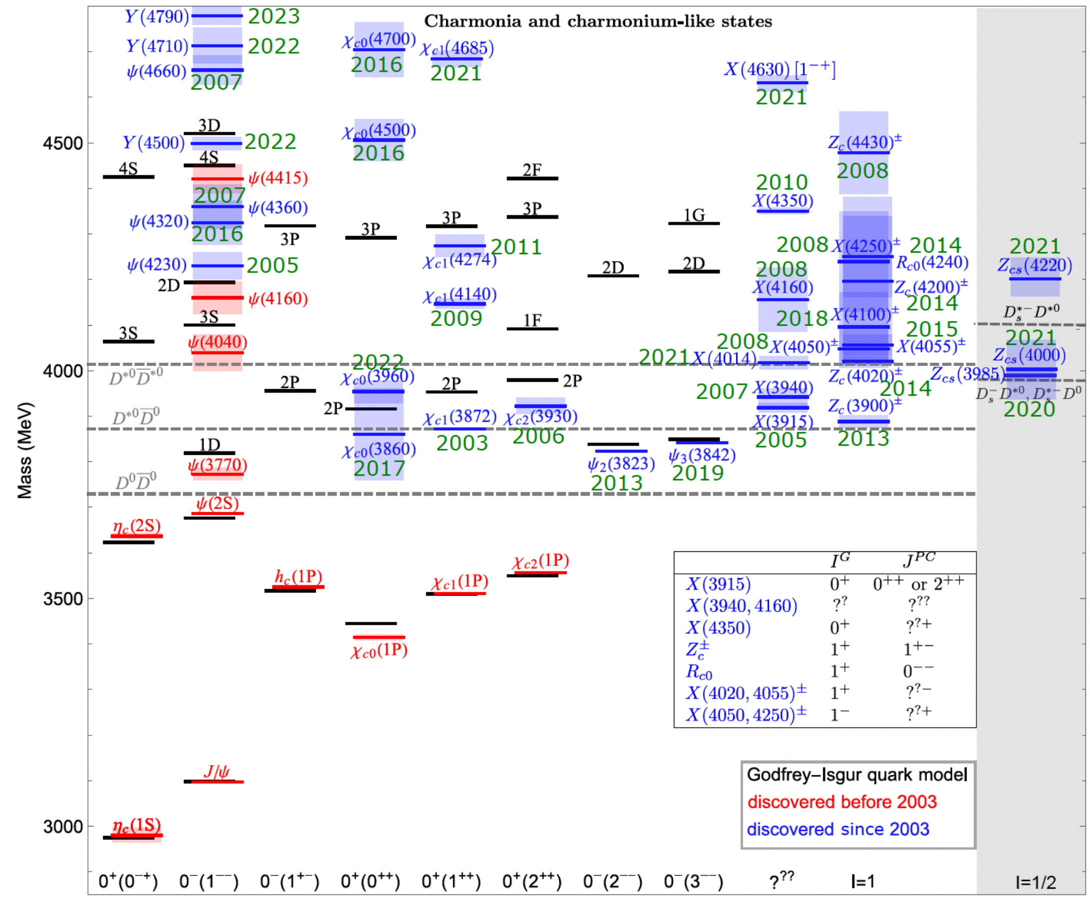


Figure 36: Spectrum of the charmonium and charmonium-like states. Black lines represent the masses in the Godfrey-Isgur quark model [283]. The red and blue lines represent the states observed experimentally before 2003 and since 2003, respectively. For the latter, the years when the states were observed are labeled in green. The height of each shadow indicates the width of the corresponding state. We also show a few two-body open-charm thresholds as dashed lines.

New Particles...

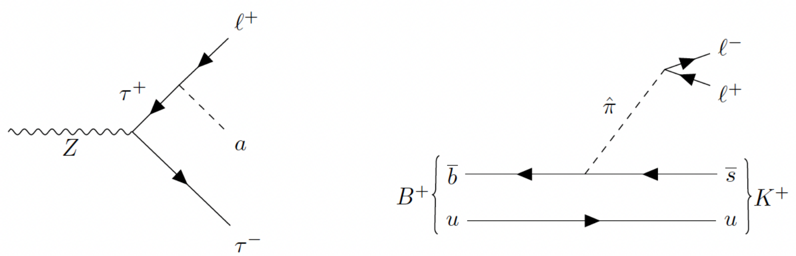


Figure 39: Illustrative Feynman diagrams of light BSM states produced via their couplings with the flavor sector, including the light dark pion $\hat{\pi}$ and the ALP a. **LEFT**: Illustrative Feynman diagrams for the ALP production in $Z \to \tau^-\tau^+$ events via lepton flavor violating couplings. **RIGHT**: $B^+ \to K^+\hat{\pi}(\to \mu^+\mu^-)$. The flavor-changing interaction between the SM quarks and $\hat{\pi}$ can arise either at the tree level or through an EW loop.

Light particles are widely predicted in BSM scenarios involving dark sectors and feebly interacting particles [332], and may couple to lepton and quark sectors. Candidates for such particles include axions and axion-like-particles a [333–336], dark photons A' and light Z' bosons [337], heavy neutral leptons (HNL) [338–340], hidden valley hadrons such as the dark pion $\hat{\pi}$ [341], etc. As a paradigmatic example, let us consider an ALP a that couples with the SM fermions via the dimension-5 operators

$$\mathcal{L} \supset \frac{\partial_\mu a}{2f_a}\left(c^A_{ff'}\,\bar{f}\gamma^\mu\gamma^5 f' + c^V_{ff'}\,\bar{f}\gamma^\mu f'\right) , \qquad (11.1)$$

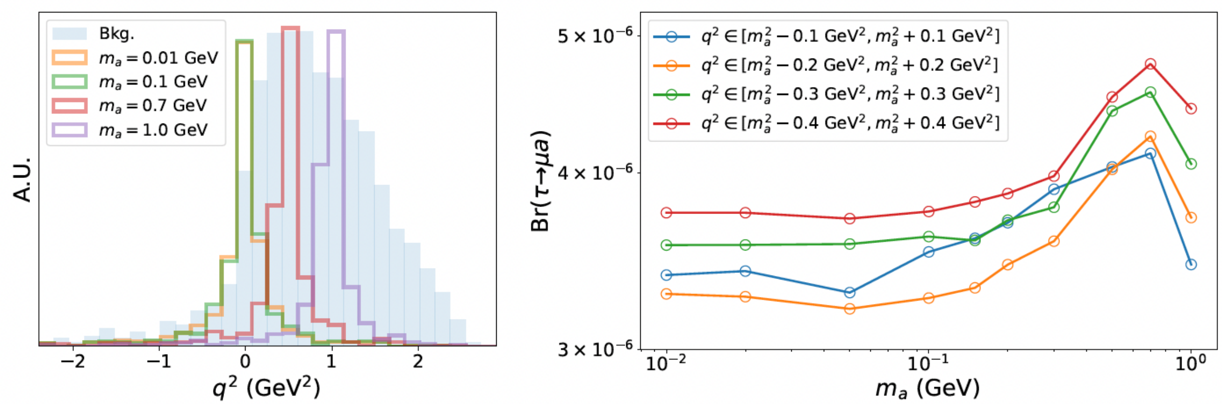


Figure 40: Preliminary sensitivity analysis for searching for an invisible ALP in the $Z \to \tau(\to \mu a)\tau(\to 3\pi\nu)$ events at the CEPC. **LEFT:** Reconstruction of $q^2 \equiv (p_\tau - p_\mu)^2$. **RIGHT:** Upper limits on BR$(\tau \to \mu a)$ with 95% CL, where four q^2 windows have been considered. The plots are taken from [344].

Orders of magnitude improvements

Summary of the tau and Z prospects

Measurement	Current [126]	FCC [115]	Tera-Z Prelim. [127]	Comments
Lifetime [sec]	$\pm 5 \times 10^{-16}$	$\pm 1 \times 10^{-18}$		from 3-prong decays, stat. limited
$\mathrm{BR}(\tau \to \ell\nu\bar{\nu})$	$\pm 4 \times 10^{-4}$	$\pm 3 \times 10^{-5}$		$0.1\times$ the ALEPH systematics
$\mathrm{m}(\tau)$ [MeV]	± 0.12	$\pm 0.004 \pm 0.1$		$\sigma(p_{\mathrm{track}})$ limited
$\mathrm{BR}(\tau \to 3\mu)$	$< 2.1 \times 10^{-8}$	$\mathcal{O}(10^{-10})$	same	bkg free
$\mathrm{BR}(\tau \to 3e)$	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
$\mathrm{BR}(\tau^\pm \to e\mu\mu)$	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
$\mathrm{BR}(\tau^\pm \to \mu ee)$	$< 1.8 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
$\mathrm{BR}(\tau \to \mu\gamma)$	$< 4.4 \times 10^{-8}$	$\sim 2 \times 10^{-9}$	$\mathcal{O}(10^{-10})$	$Z \to \tau\tau\gamma$ bkg , $\sigma(p_\gamma)$ limited
$\mathrm{BR}(\tau \to e\gamma)$	$< 3.3 \times 10^{-8}$	$\sim 2 \times 10^{-9}$		$Z \to \tau\tau\gamma$ bkg, $\sigma(p_\gamma)$ limited
$\mathrm{BR}(Z \to \tau\mu)$	$< 1.2 \times 10^{-5}$	$\mathcal{O}(10^{-9})$	same	$\tau\tau$ bkg, $\sigma(p_{\mathrm{track}})$ & $\sigma(E_{\mathrm{beam}})$ limited
$\mathrm{BR}(Z \to \tau e)$	$< 9.8 \times 10^{-6}$	$\mathcal{O}(10^{-9})$		$\tau\tau$ bkg, $\sigma(p_{\mathrm{track}})$ & $\sigma(E_{\mathrm{beam}})$ limited
$\mathrm{BR}(Z \to \mu e)$	$< 7.5 \times 10^{-7}$	$10^{-8} - 10^{-10}$	$\mathcal{O}(10^{-9})$	PID limited
$\mathrm{BR}(Z \to \pi^+\pi^-)$			$\mathcal{O}(10^{-10})$	$\sigma(\vec{p}_{\mathrm{track}})$ limited, good PID
$\mathrm{BR}(Z \to \pi^+\pi^-\pi^0)$			$\mathcal{O}(10^{-9})$	$\tau\tau$ bkg
$\mathrm{BR}(Z \to J/\psi\gamma)$	$< 1.4 \times 10^{-6}$		$10^{-9} - 10^{-10}$	$\ell\ell\gamma$+$\tau\tau\gamma$ bkg
$\mathrm{BR}(Z \to \rho\gamma)$	$< 2.5 \times 10^{-5}$		$\mathcal{O}(10^{-9})$	$\tau\tau\gamma$ bkg, $\sigma(p_{\mathrm{track}})$ limited

From the Snowmass report: The Physics potential of the CEPC

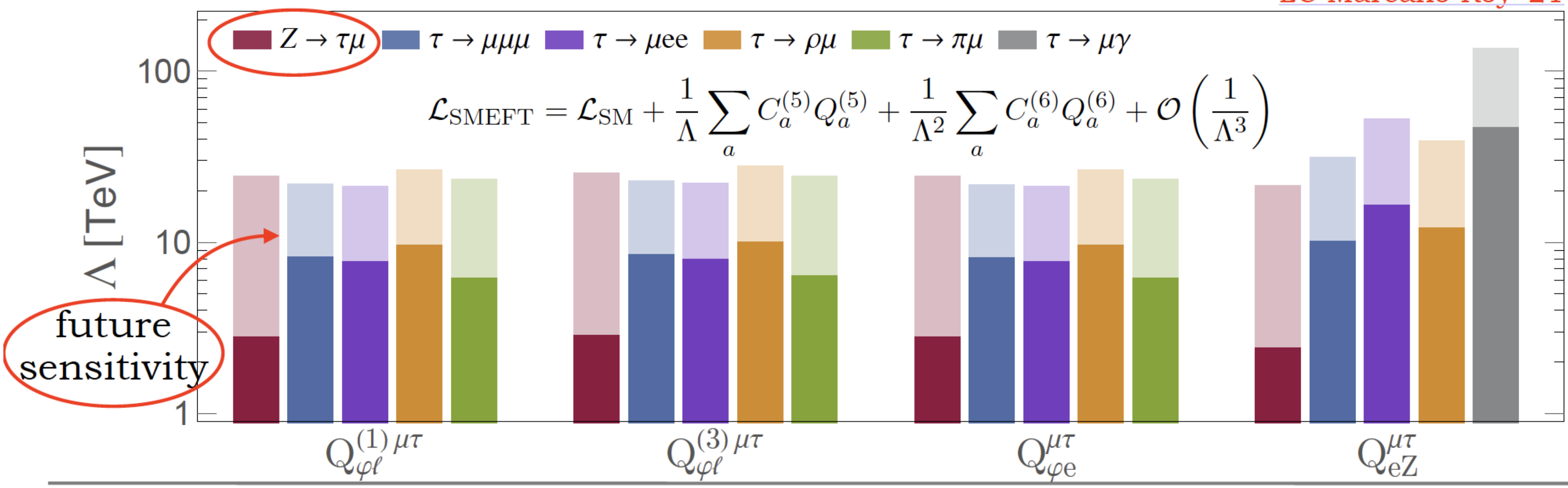
Lepton Flavour Violation in Z decays

Mode	LEP bound (95% CL)	LHC bound (95% CL)	CEPC/FCC-ee exp.
$\mathrm{BR}(Z \to \mu e)$	1.7×10^{-6} [2]	7.5×10^{-7} [3]	$10^{-8} - 10^{-10}$
$\mathrm{BR}(Z \to \tau e)$	9.8×10^{-6} [2]	5.0×10^{-6} [4, 5]	10^{-9}
$\mathrm{BR}(Z \to \tau \mu)$	1.2×10^{-5} [6]	6.5×10^{-6} [4, 5]	10^{-9}

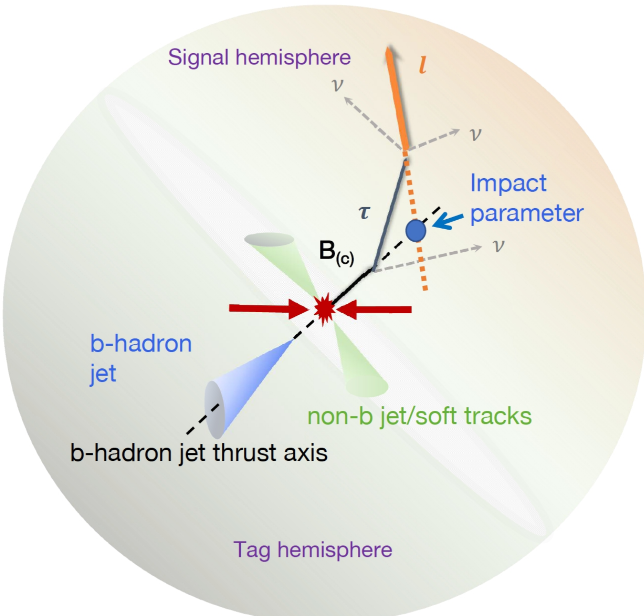
M. Dam '18

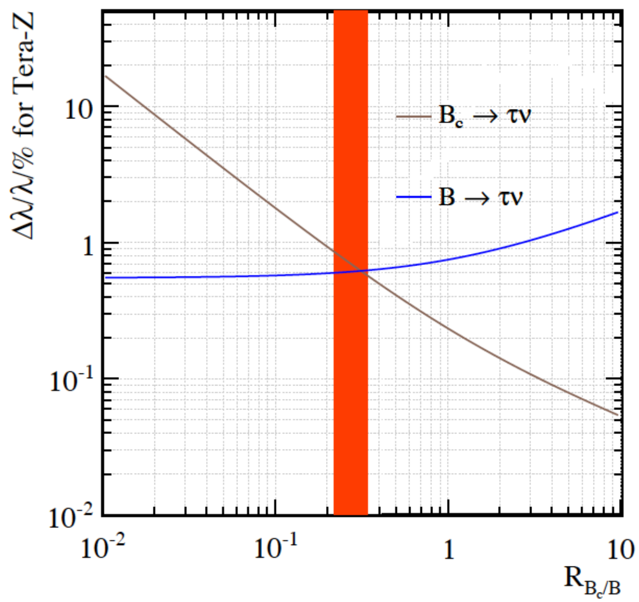
- LHC searches limited by backgrounds (in particular $Z \to \tau\tau$): max ~10 improvement can be expected at HL-LHC (3000/fb)
- A Tera Z can test LFV new physics searching for $Z \to \tau\, \ell$ at the level of what Belle II (50/ab) will do through LFV tau decays (or better)

LC Marcano Roy '21



Bc → τν





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Analysis of $B_c \to \tau\nu_\tau$ at CEPC*

Taifan Zheng(郑太范)[1] Ji Xu(徐吉)[2] Lu Cao(曹璐)[3] Dan Yu(于丹)[4] Wei Wang(王伟)[2] Soeren Prell[5] Yeuk-Kwan E. Cheung(张若筠)[1] Manqi Ruan(阮曼奇)[4†]

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[5]Department of Physics and Astronomy, Iowa State University, Ames, IA, USA

Abstract: Precise determination of the $B_c \to \tau\nu_\tau$ branching ratio provides an advantageous opportunity for understanding the electroweak structure of the Standard Model, measuring the CKM matrix element $|V_{cb}|$, and probing new physics models. In this paper, we discuss the potential of measuring the process $B_c \to \tau\nu_\tau$ with τ decaying leptonically at the proposed Circular Electron Positron Collider (CEPC). We conclude that during the Z pole operation, the channel signal can achieve five-σ significance with $\sim 10^9$ Z decays, and the signal strength accuracies for $B_c \to \tau\nu_\tau$ can reach around 1% level at the nominal CEPC Z pole statistics of one trillion Z decays, assuming the total $B_c \to \tau\nu_\tau$ yield is 3.6×10^6. Our theoretical analysis indicates the accuracy could provide a strong constraint on the general effective Hamiltonian for the $b \to c\tau\nu$ transition. If the total B_c yield can be determined to $O(1\%)$ level of accuracy in the future, these results also imply $|V_{cb}|$ could be measured up to $O(1\%)$ level of accuracy.

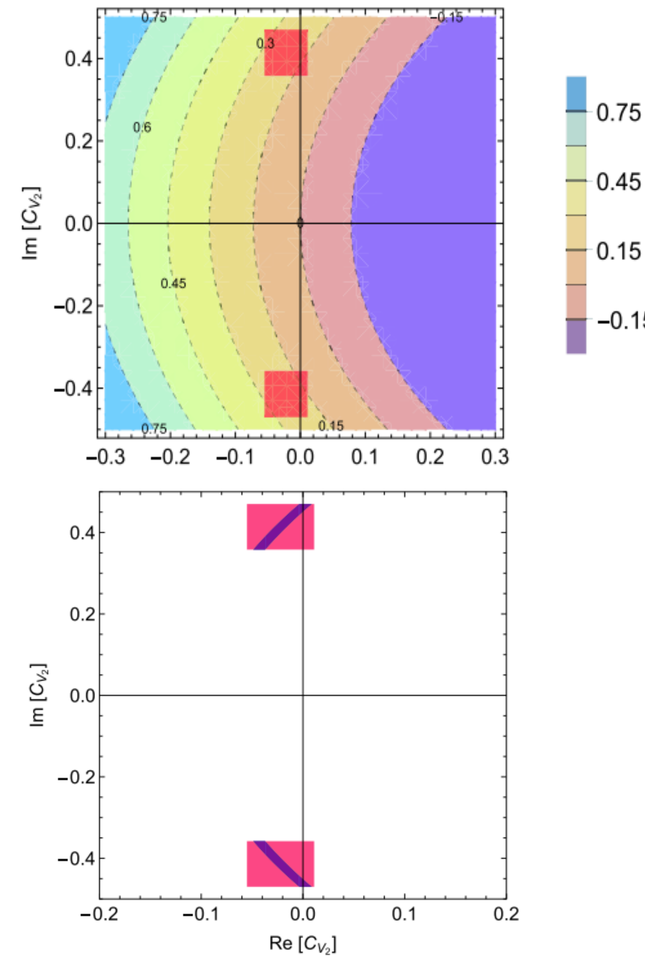


Fig. 10. (color online) Constraints on the real and imaginary parts of C_{V_2}. The red shaded area corresponds to the current constraints using available data on $b \to c\tau\nu$ decays. If the central values in Eq. (9) remain while the uncertainty in $\Gamma(B_c^+ \to \tau^+\nu_\tau)$ is reduced to 1%, the allowed region for C_{V_2} shrinks to the dark-blue regions.

Not only Z!
From H, W, ... and top

Higgs LFV decay

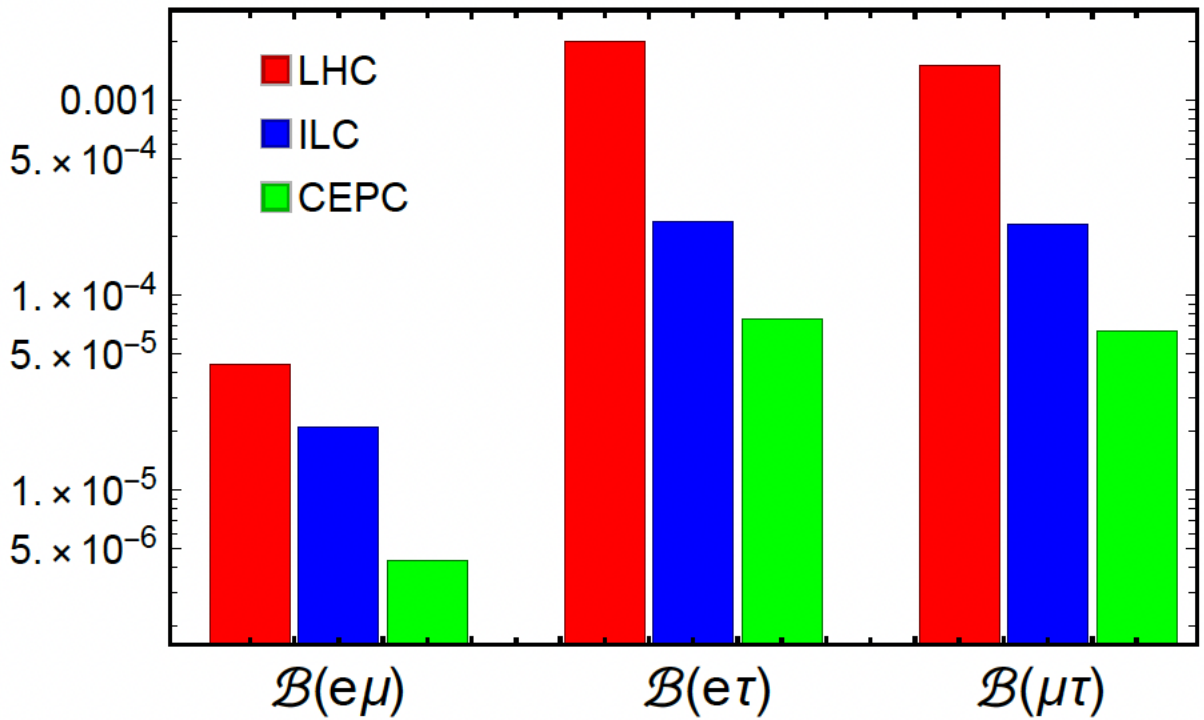
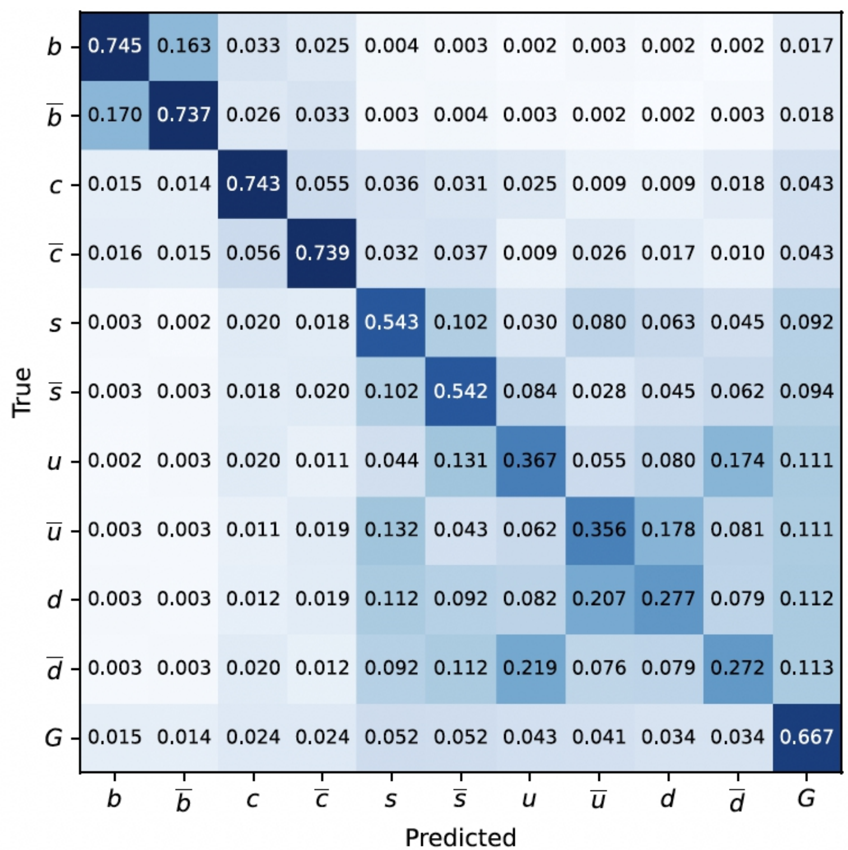
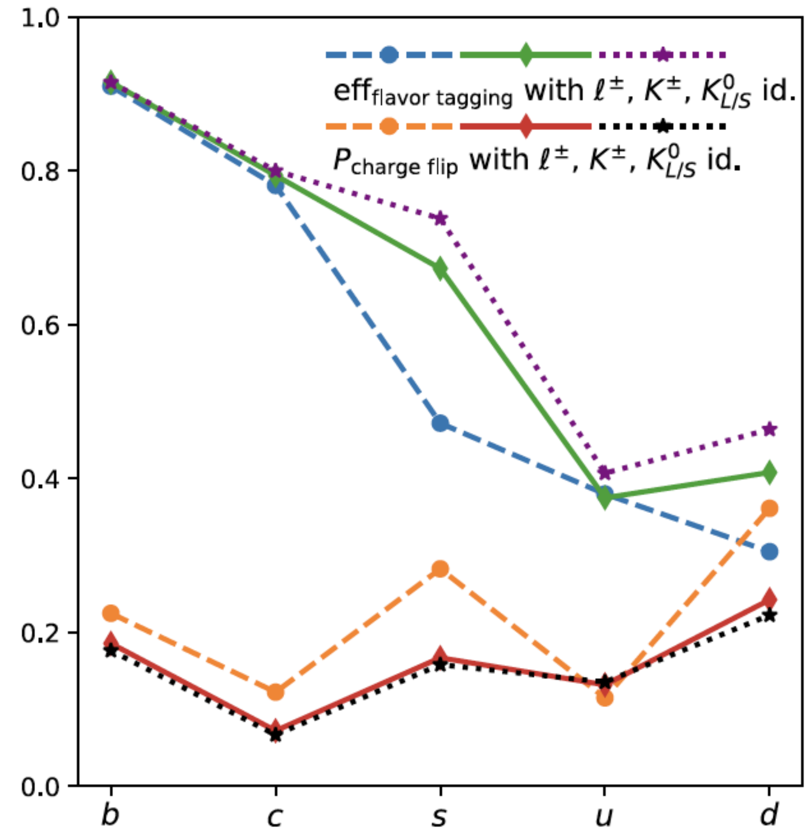


Figure 33: Projected upper limits on the LFV Higgs decays at the LHC, ILC and CEPC. The figure is updated from [250].

Jet origin id

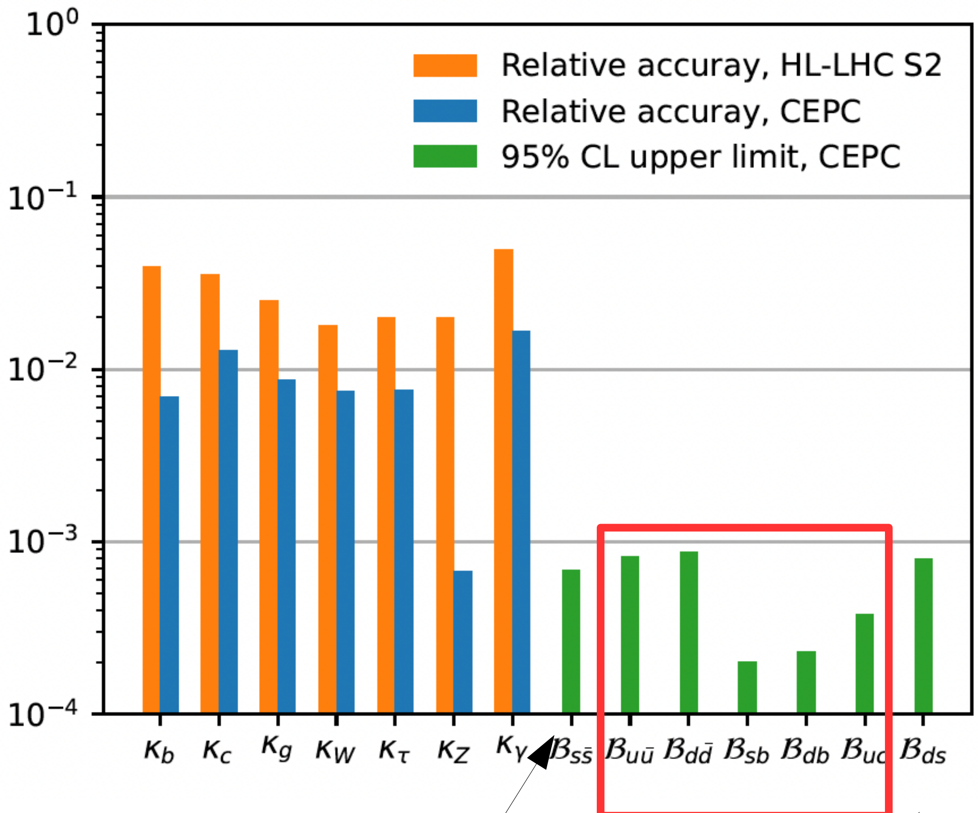


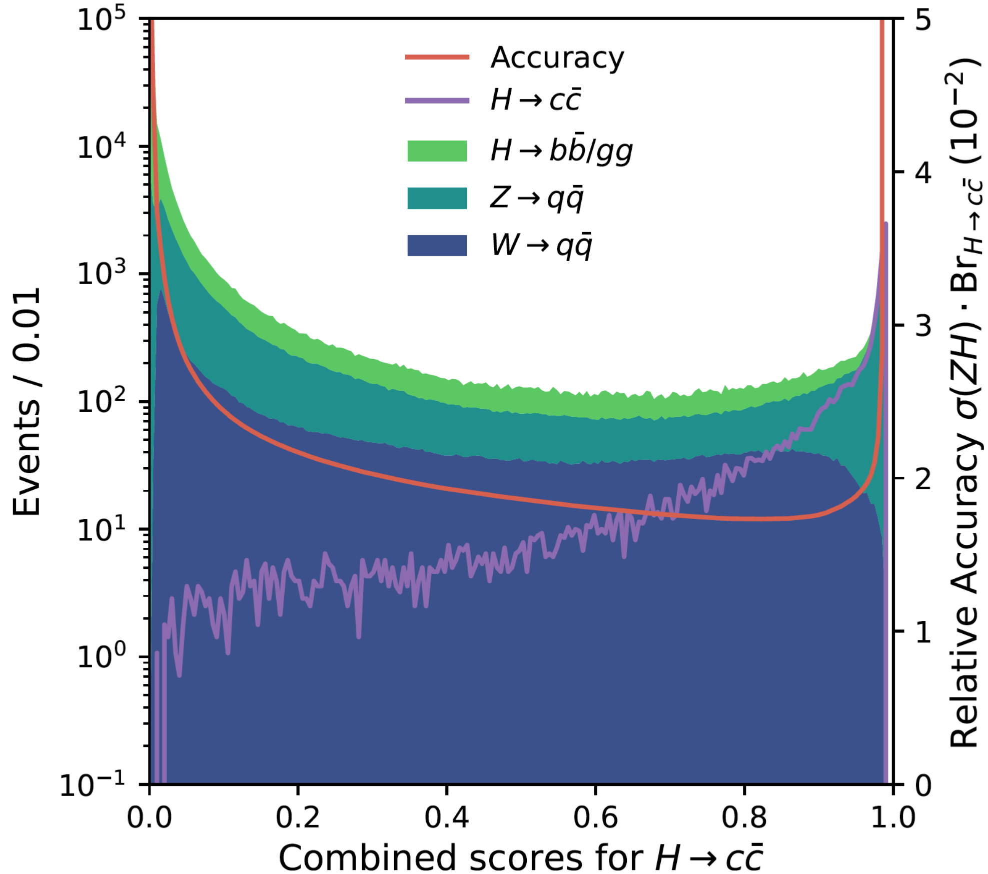


- 11 categories (5 quarks + 5 anti quarks + gluon) identification, realized at Full Simulated di-jet events at CEPC CDR baseline with Arbor + ParticleNet
- Published in PRL *132, 221802 (2024)*. Comment from the referee: *"demonstrate the world-leading performance of tagger", "a "game changer" and opens new horizons for precision flavor studies at all future experiments."*

https://arxiv.org/abs/2310.03440
https://arxiv.org/abs/2309.13231

Impact on Higgs FCNC & rare





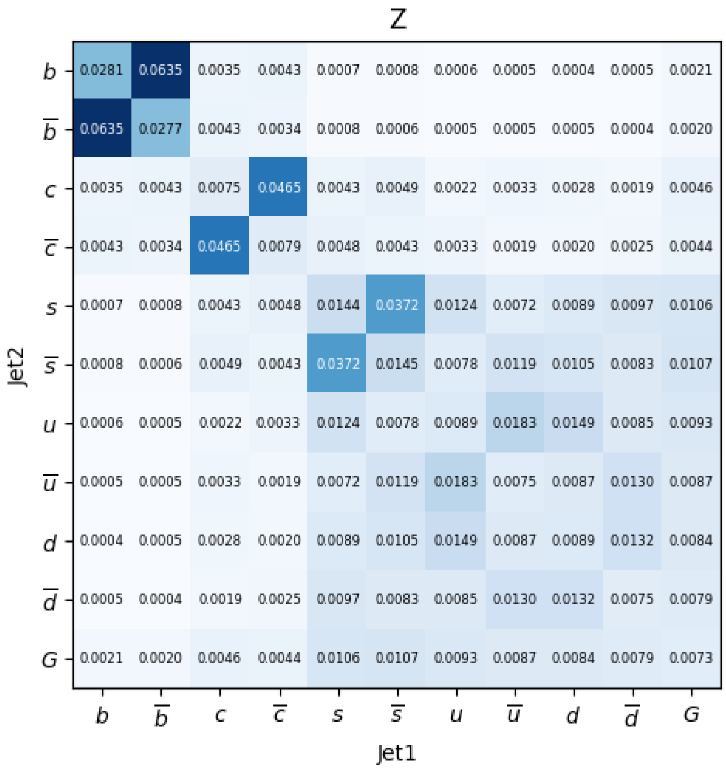
Improved by ~3 times

Improved by 1-2 orders of magnitudes

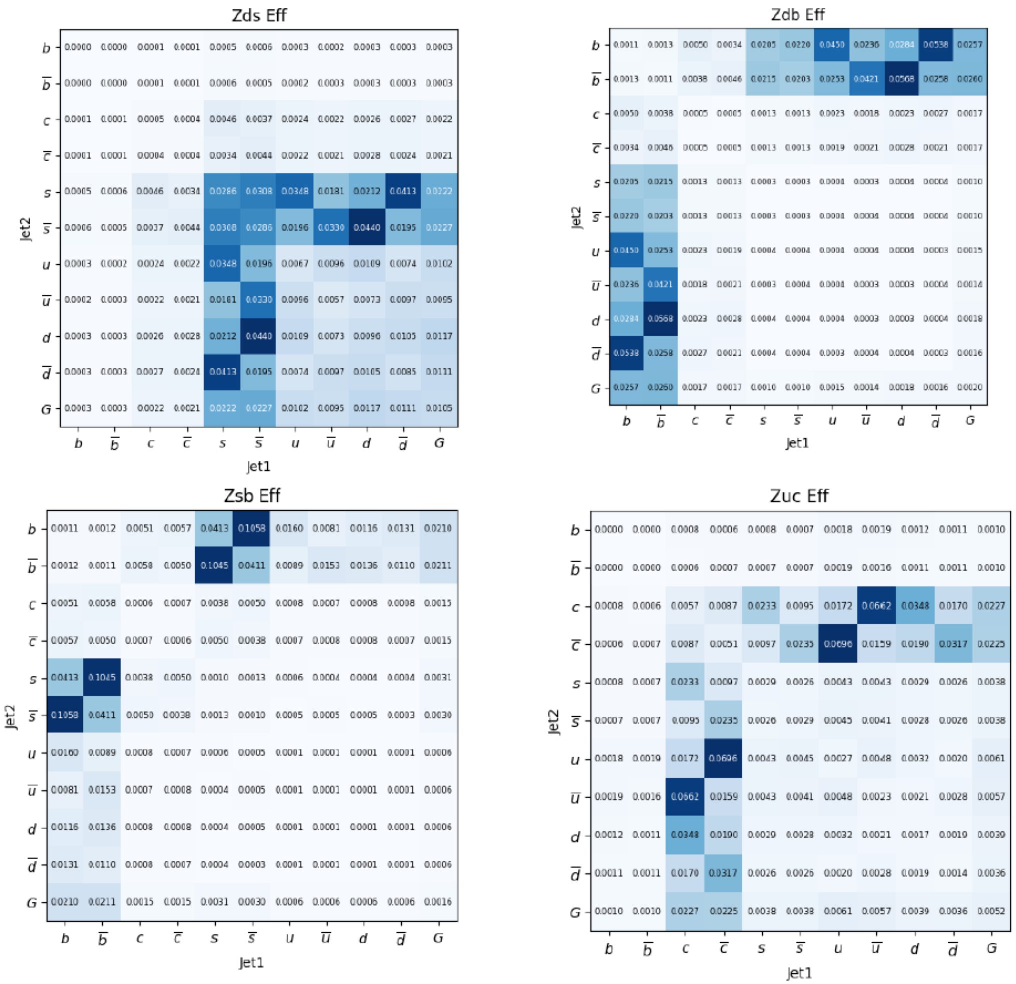
Presumably... firstly quantified

- Compared to Conventional :
  - vvH, H→cc: 3% → 1.7%

Applied to Z FCNC

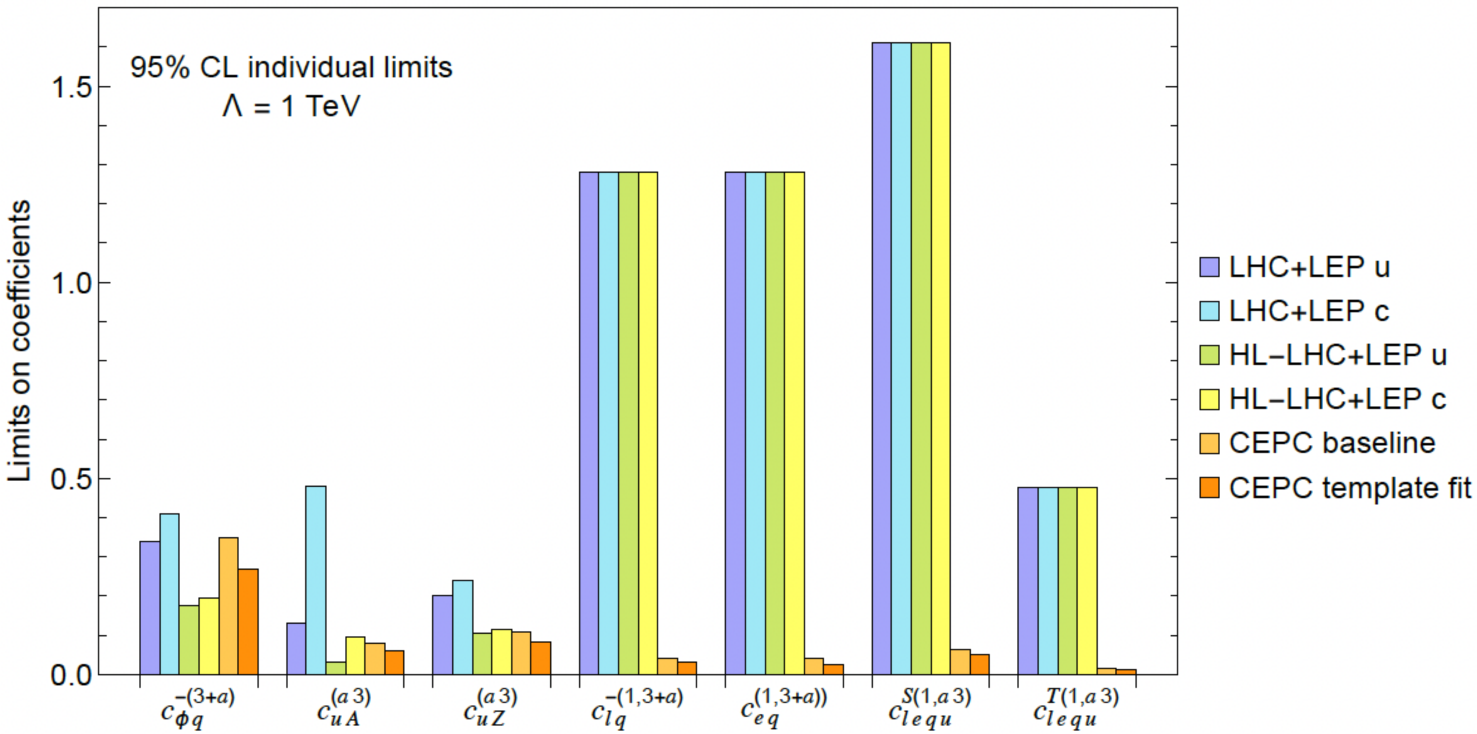


	SM Br	95% Upper limit on Br (statistical only)
Z->bs	8.9E-8	2.3e-07
Z->bd	3.8E-9	2.5e-07
Z->cu	2.7E-20	6.3e-07
Z->sd	-	1.3e-06



- @ Tera Z using template fit
- **Calibration & Systematic control is critical**

Top FCNC decays



$$O_{lq}^{1(ijkl)} = \left(\bar{L}_i\gamma_\mu L_j\right)\left(\bar{Q}_k\gamma^\mu Q_l\right), \quad O_{lq}^{3(ijkl)} = \left(\bar{L}_i\gamma_\mu\tau^I L_j\right)\left(\bar{Q}_k\gamma^\mu\tau^I Q_l\right),$$
$$O_{lu}^{(ijkl)} = \left(\bar{L}_i\gamma_\mu L_j\right)\left(\bar{U}_k\gamma^\mu U_l\right),$$
$$O_{eq}^{(ijkl)} = \left(\bar{E}_i\gamma_\mu E_j\right)\left(\bar{Q}_k\gamma^\mu Q_l\right), \quad O_{eu}^{(ijkl)} = \left(\bar{E}_i\gamma_\mu E_j\right)\left(\bar{U}_k\gamma^\mu U_l\right),$$
$$O_{lequ}^{1(ijkl)} = \left(\bar{L}_i E_j\right)\varepsilon\left(\bar{Q}_k U_l\right), \quad O_{lequ}^{3(ijkl)} = \left(\bar{L}_i\sigma_{\mu\nu}E_j\right)\varepsilon\left(\bar{Q}_k\sigma^{\mu\nu}U_l\right). \tag{9.3}$$

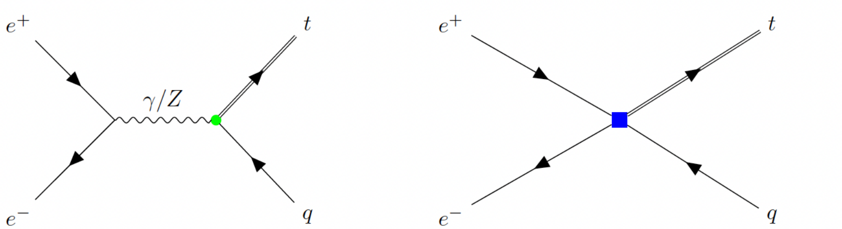


Figure 34: Illustrative Feynman diagrams for the FCNC single top production $e^-e^+ \to t(\bar{t})j$. The green dot and blue square represent two-fermion FCNC and four-fermion (two-lepton two-quark) contact operators, respectively.

CKM element from W decay

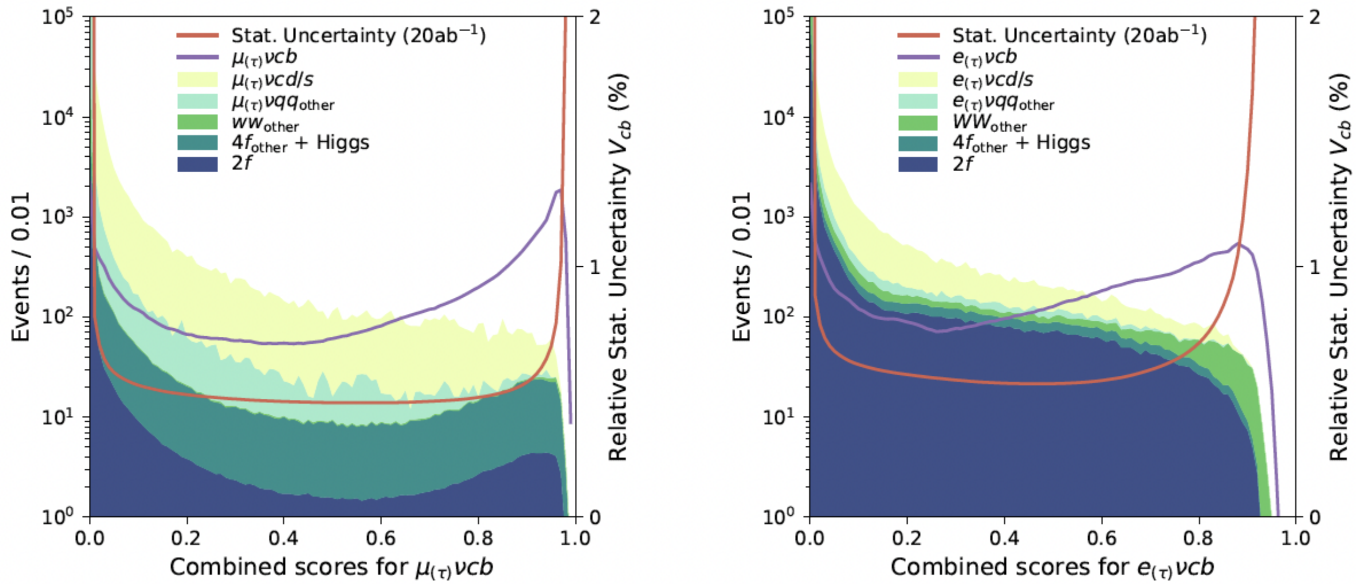
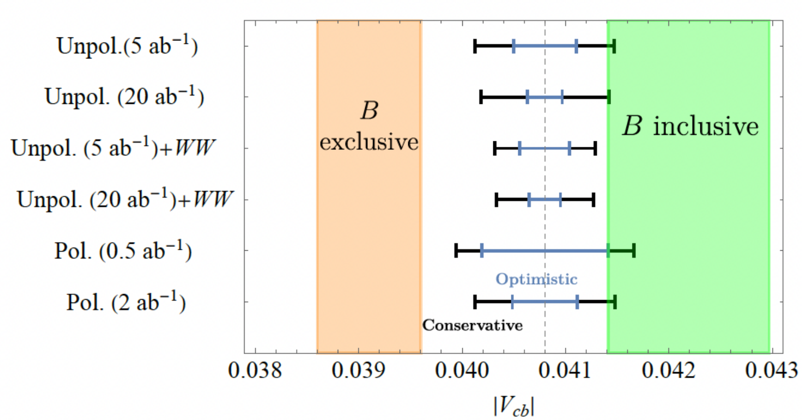


Figure 4. The BDT score distribution of signal and backgrounds in: the muon channel (left) and electron channel (right). The red curve indicates the projected statistical relative sensitivity estimated from eq. (4.1) assuming a luminosity of 20 ab^{-1}.



CEPC V

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Measurement of CKM element $|V_{cb}|$ from W boson decays at the future Higgs factories

Hao Liang[a,b,e], LingFeng Li[c,*] Yongfeng Zhu[a,b,d] Xiaoyan Shen[a,b] and Manqi Ruan[a,b,*]

CKM angle measurements...

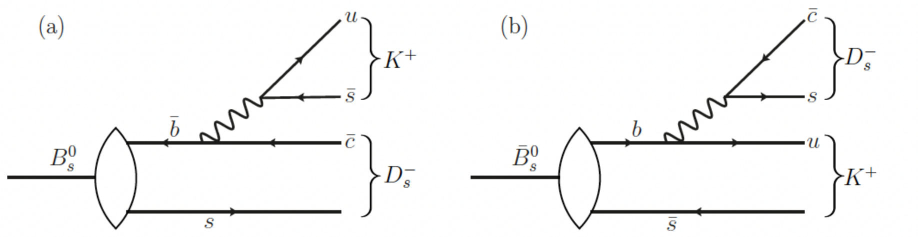


Figure 1. Feynman diagrams for (a) $B_s^0 \to D_s^- K^+$ and (b) $\overline{B}_s^0 \to D_s^- K^+$ decays. Time-dependent fits to these two decay channels and their charge conjugate decays allow to determine the angle γ.

ABSTRACT: A precise determination of the CKM angle γ from B_s^0 oscillations in $B_s^0 \to D_s^{\mp} K^{\pm}$ decays offers a critical test of the Standard Model and probes for new physics. We present a comprehensive study on the prospects of measuring γ at a future Tera-Z factory, utilizing the baseline detector concept of the Circular Electron Positron Collider (CEPC). A two-dimensional simultaneous fit framework, incorporating flavor tagging, decay time resolution modeling, and acceptance corrections, is developed using full Monte Carlo simulations of $B_s^0 \to D_s^{\mp} (\to K^{\mp} K^{\pm} \pi^{\mp}) K^{\pm}$ decays and inclusive background processes. The effective flavor tagging power reaches 23.6%, while the decay time resolution is determined to be 26 fs. Projecting to full statistics of signal events across three dominant D_s^- decay channels, we estimate a statistical precision of $\sigma(\gamma) = 0.69°$, which is corresponding to 4.1 Tera-Z boson equivalent data. This study has established the feasibility of sub-degree level γ measurements at a Z factory, highlighting its unique advantages in time-dependent CP violation studies through ultra-precise vertexing and background suppression capabilities.

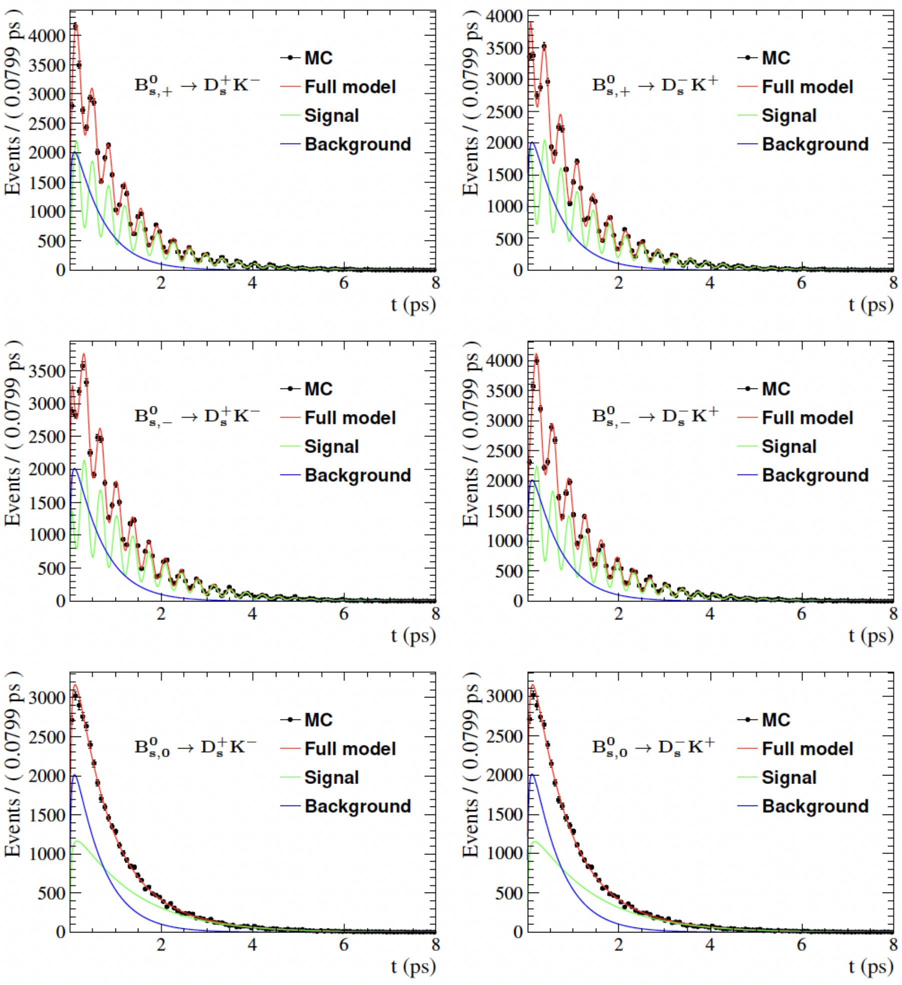
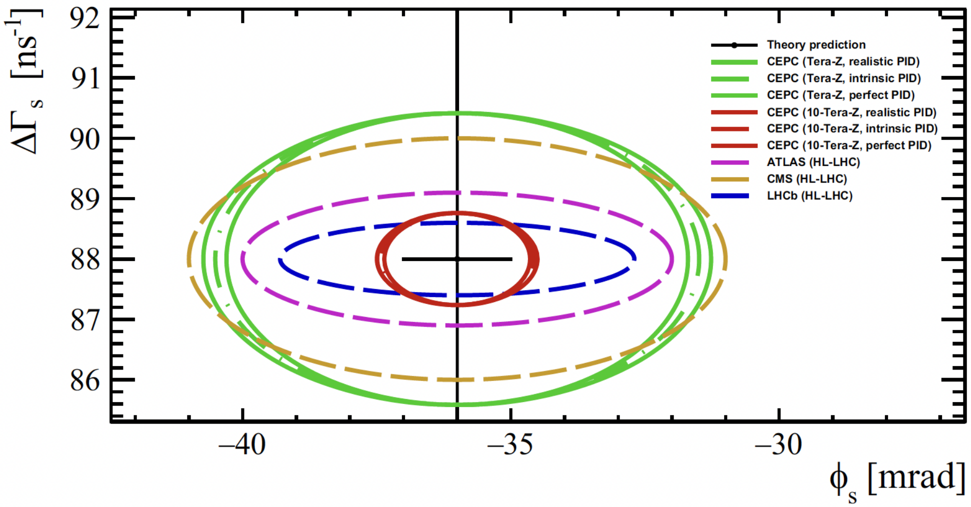


Figure 7. Time distribution projections from the two-dimensional simultaneous fit illustrating the signal and background components. The decay time distribution for the signal is derived from the distributions defined in eq. (4.1), while the background is modeled with a distorted exponential function.

Bs→J/ψϕ



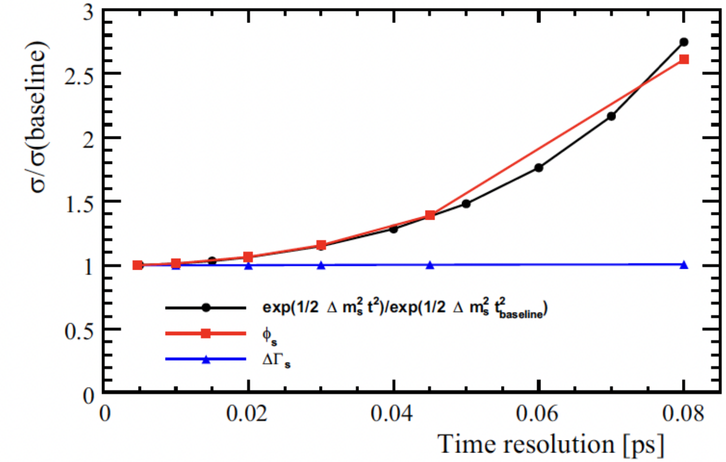


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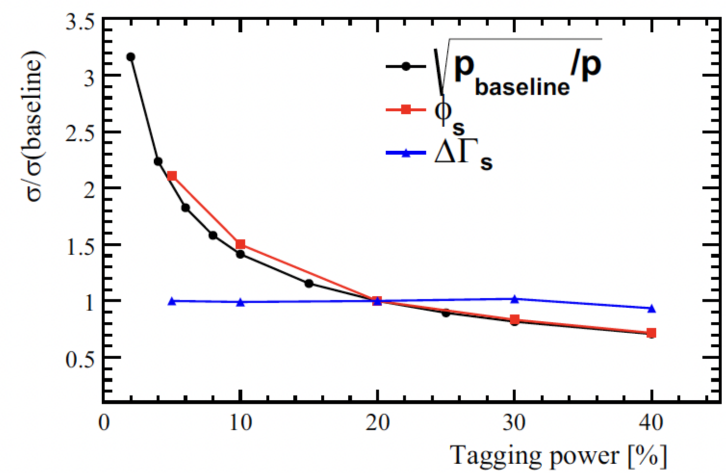
Table 1 Parameters table of factors to calculate the precision of ϕ_s, Γ_s and $\Delta\Gamma_s$. The terms with ∗ means that the factor is insensitive to the resolution of Γ_s and $\Delta\Gamma_s$

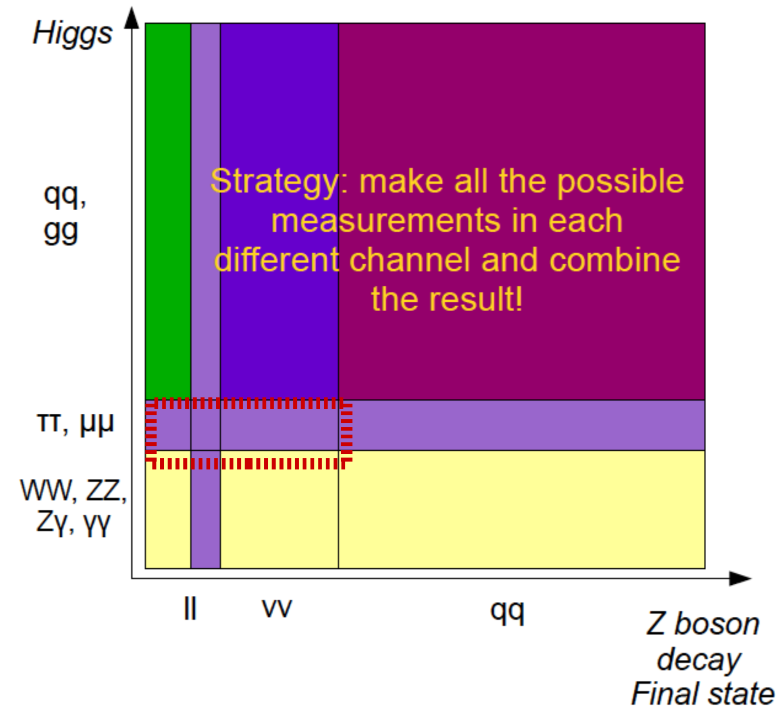
	LHCb (HL-LHC)	CEPC (Tera-Z)	CEPC/LHCb
$b\bar{b}$ statics	43.2×10^{12}	0.152×10^{12}	1/284
Acceptance × efficiency	7%	75%	10.7
Br	6×10^{-6}	12×10^{-6}	2
Flavor tagging*	4.7%	17.3%	3.7
Time resolution* $(\exp(-\frac{1}{2}\Delta m_s^2\sigma_t^2)^2)$	0.52	1	1.92
σ_t (fs)*	45	4.7	
Scaling factor ξ	0.0015	0.0021	1.4
$\sigma(\phi_s)$	3.3 mrad	4.6 mrad	

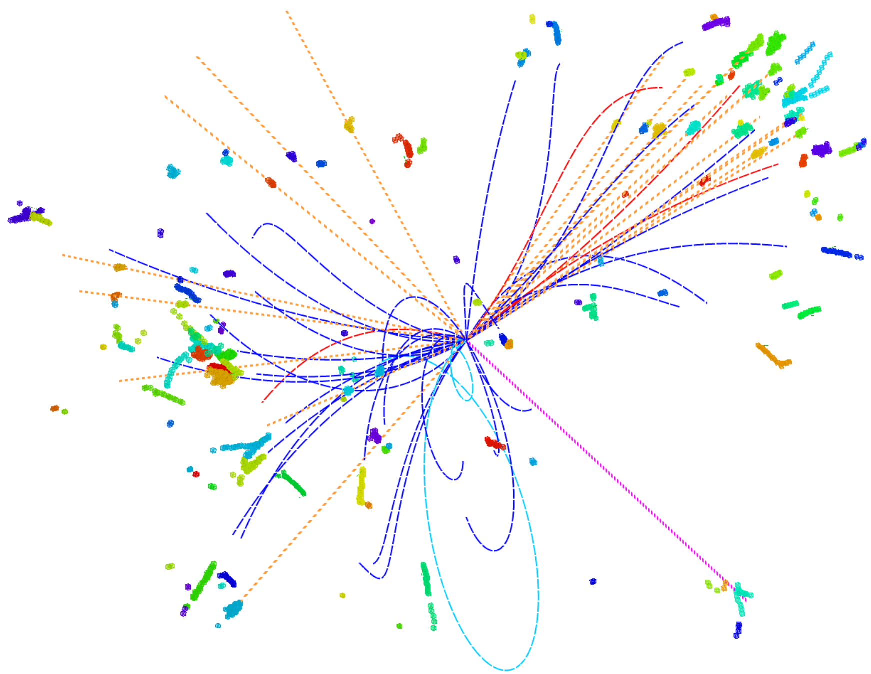


Time resolution ~ o(10) fs

Performance requirements

- To reconstruct all Physics Object, especially Jets
  - Z & W: ~ 70% goes to a pair of jets
  - Higgs: ~97% final state with jets (ZH events)
  - Top: t → W + b
  - Missing energy & Momentum reco...





- Look inside the jet: **1-1 correspondence reco.**
  - ~ confusion free PFA + Excellent Pid
  - Larger acceptance...
  - Excellent intrinsic resolutions (P, E, Pid...)
  - Extremely stable...
- Be addressed by state-of-the-art detector design, technology, and reconstruction algorithm!

Summary

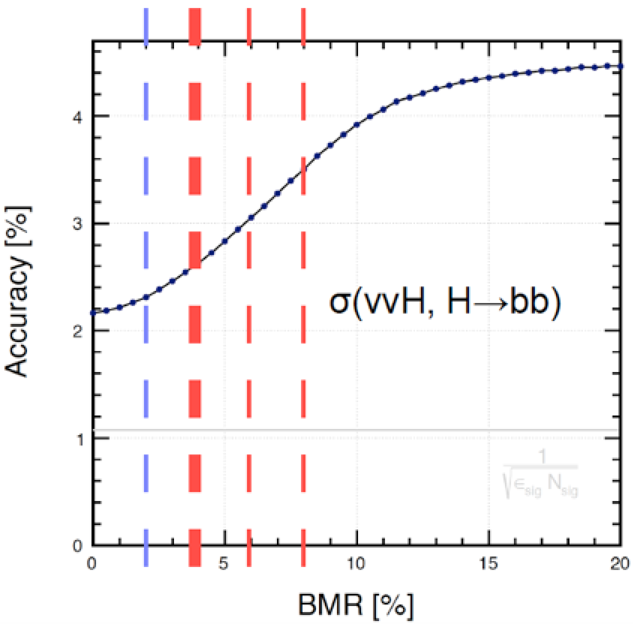
- Electron Positron Higgs factories: a gigantic boost
- CEPC physics studies: composed of physics reach/pheno and detector requirement optimization, aims at White papers to be released according to the project paces
- Flavor Physics at CEPC: strong comparative advantages, a windows to access NP of 10 TeV or even higher
  - White paper with ~ 50 benchmarks summarized: Accesses to Un-seen, orders of magnitudes improvements
  - Next Phase:
    - CKM & CPV, Origin of matter...
    - Interplay with Higgs & QCD...
- Extremely rich physics program results in stringent requirements on the detector performance, to be addressed by intensive study on detector design, key tech R&D, and algorithms development

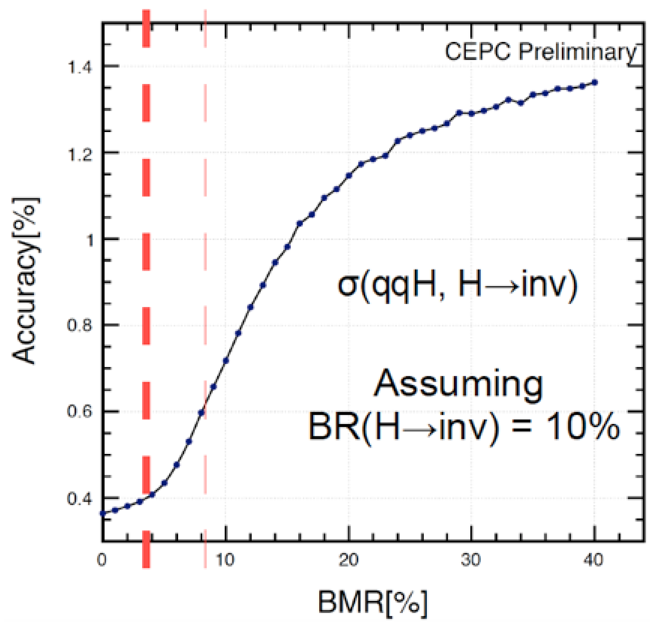
Back up

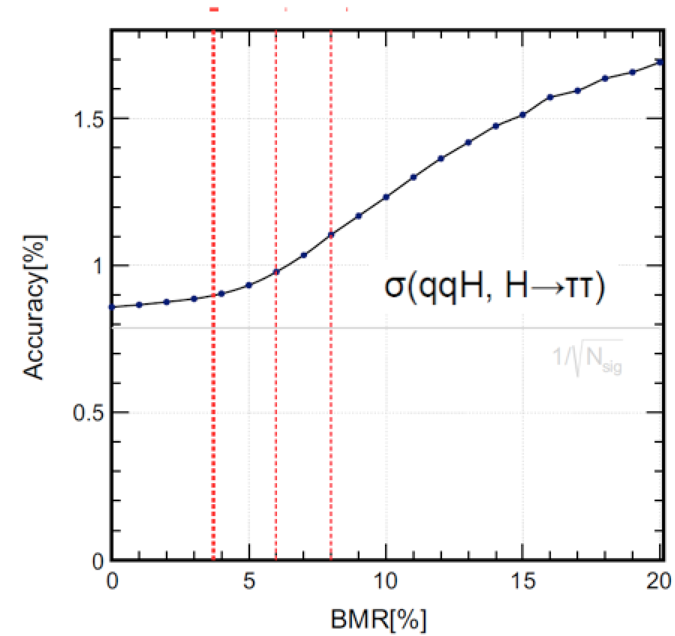
Summary

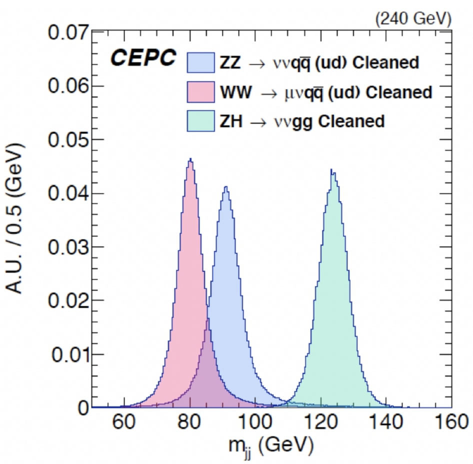
- Electron Positron Higgs factories: a gigantic boost from LHC
- CEPC physics studies: composed of physics reach/pheno and detector requirement optimization, aims at White papers to be released according to the project paces
  - Community activated, results in multiple new ideas/results
  - Good international communication/collaboration
  - Lots of raw material available, visionary summarization/interpretation is needed
- Flavor Physics at CEPC: strong comparative advantages, a windows to access NP of 10 TeV or even higher
  - Accesses to Un-seen, plus orders of magnitudes improvements
- Extremely rich physics program results in stringent requirements on the detector performance, to be addressed by intensive study on detector design, key tech R&D, and algorithms development
  - Significant efforts towards the RDR (reference detector design TDR)
- New tools, especially AI, could significantly alter the physics study/detector design.

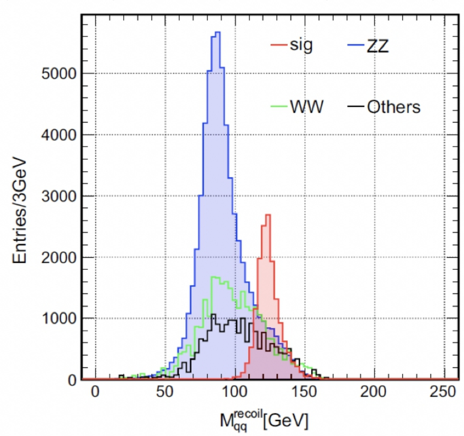
BMR < 4% for Higgs physics











	BMR = 2%	4%	6%	8%
σ(vvH, H→bb)	2.3%	2.6%	3.0%	3.4%
σ(vvH, H→inv)	0.38%	0.4%	0.5%	0.6%
σ(qqH, H→ττ)	0.85%	0.9%	1.0%	1.1%

Bs→Φvv

https://arxiv.org/pdf/2201.07374.pdf

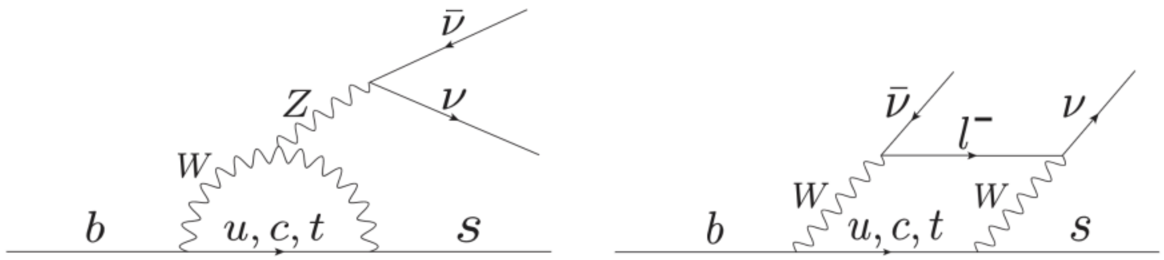
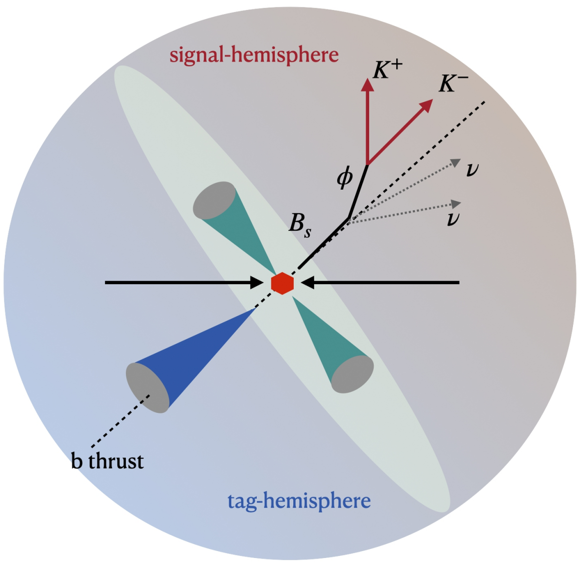
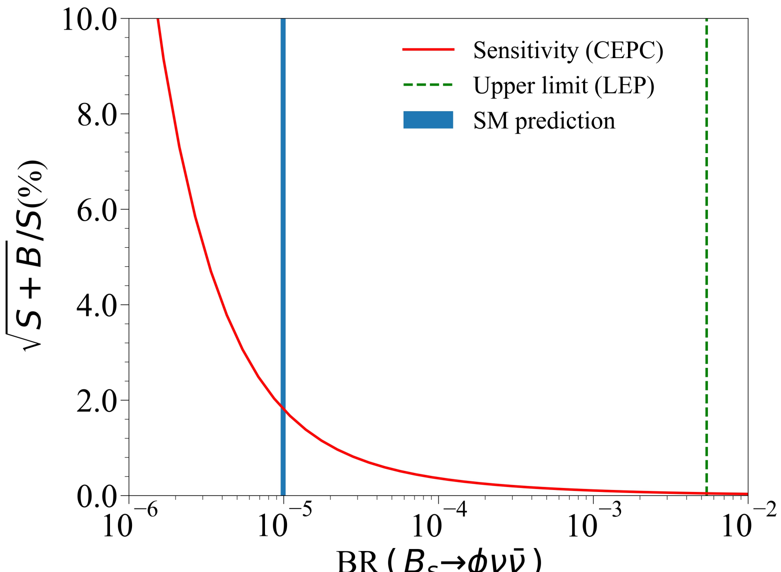


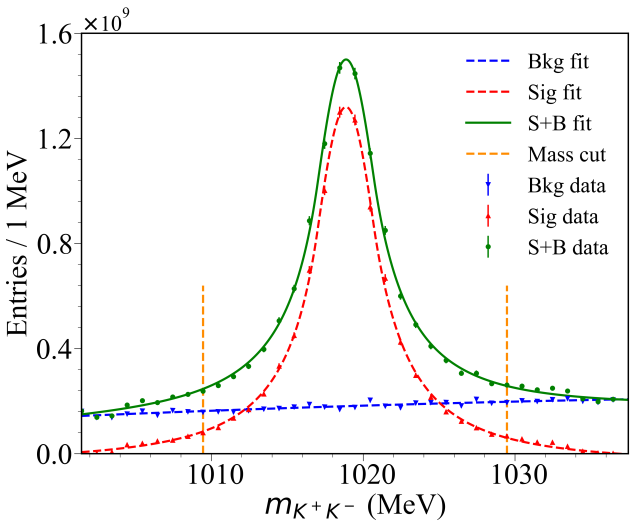
FIG. 1. The penguin and box diagrams of $b \to s\nu\bar{\nu}$ transition at the leading order.

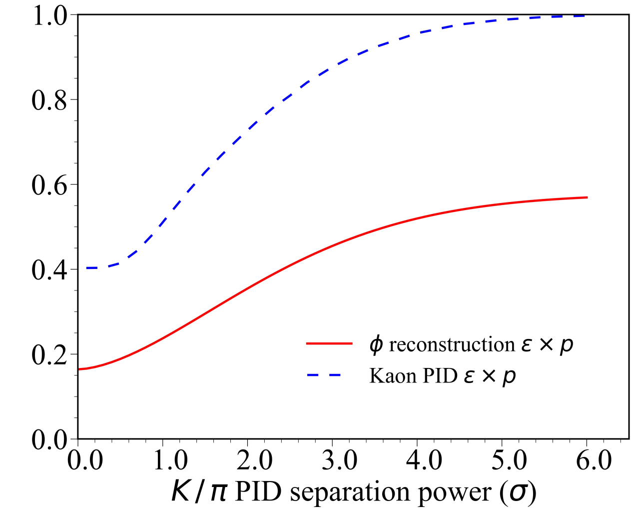


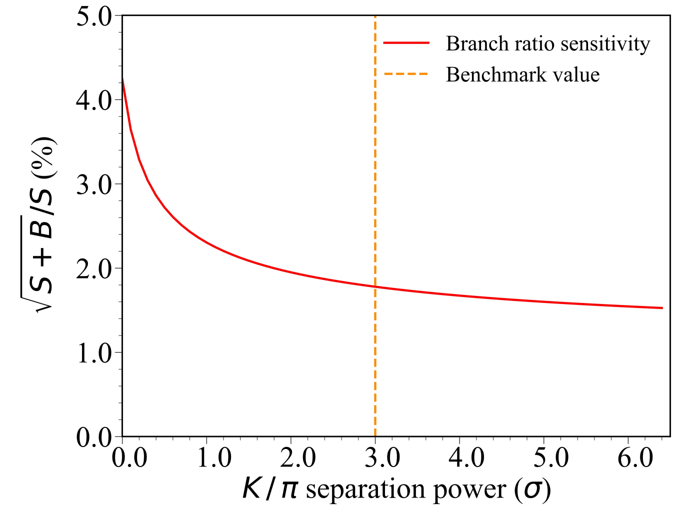
- Key ingredient to understand FCNC anomaly...
- Critical Physics Objects: Phi (and charged Kaon), 2nd VTX, Missing E/P, b-jet at opposite side
- Percentage level accuracy anticipated at Tera-Z

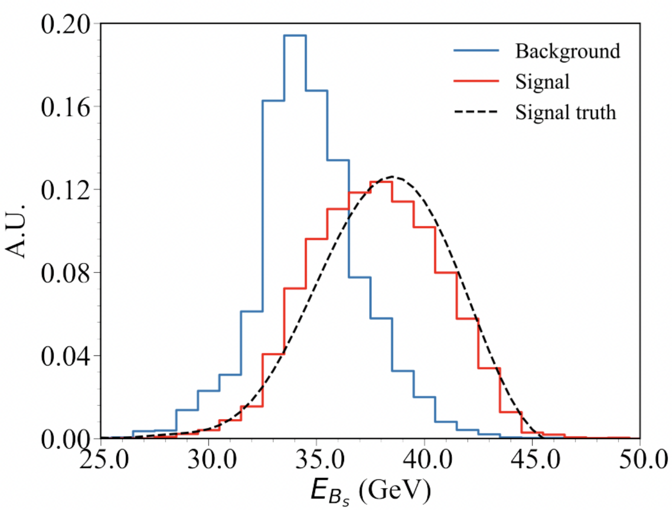


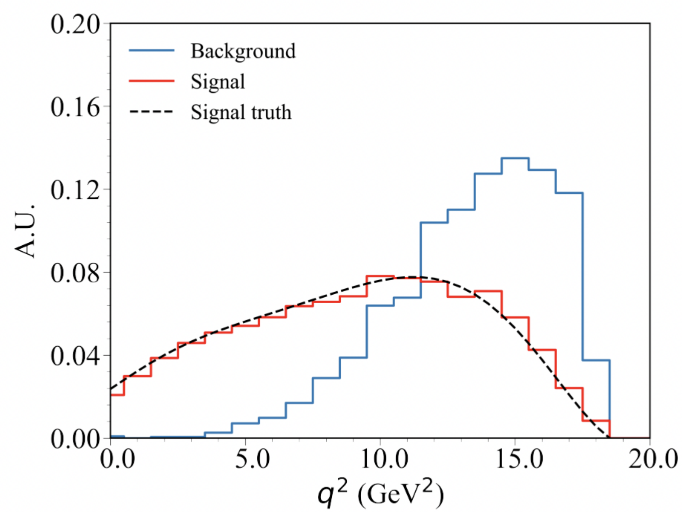
Requirements: Pid & MET











$$M_{\rm tag} = \sqrt{\left(\sum p_{\rm tag}^{\rm vis}\right)^2},$$

$$M_{\rm sig}^{(i)} = \sqrt{\left(\sum p_{\rm sig}^{\rm vis} + p_{B_s}^{(i-1)} - p_\phi\right)^2},$$

$$E_{B_s}^{(i)} = \frac{s + (M_{\rm sig}^{(i-1)})^2 - M_{\rm tag}^2}{2\sqrt{s}} - E_{\rm sig} + E_\phi\,,$$

$$(q^2)^{(i)} = (p_{B_s}^{(i-1)} - p_\phi)^2\,,$$

3σ Pion-Kaon separation + Good missing Energy/Momentum (~ BMR) resolution

$B_c \to \tau\nu$

- Key observable to test the LFU anomalies in charged-current B decays

  Alonso et al. '16

- SM prediction for the BR ~ 2%, beyond the reach of LHCb

- Tera Z could measure with percent level accuracy (thus providing also a percent level accurate measurement of V_{cb})

  Zheng et al. '20