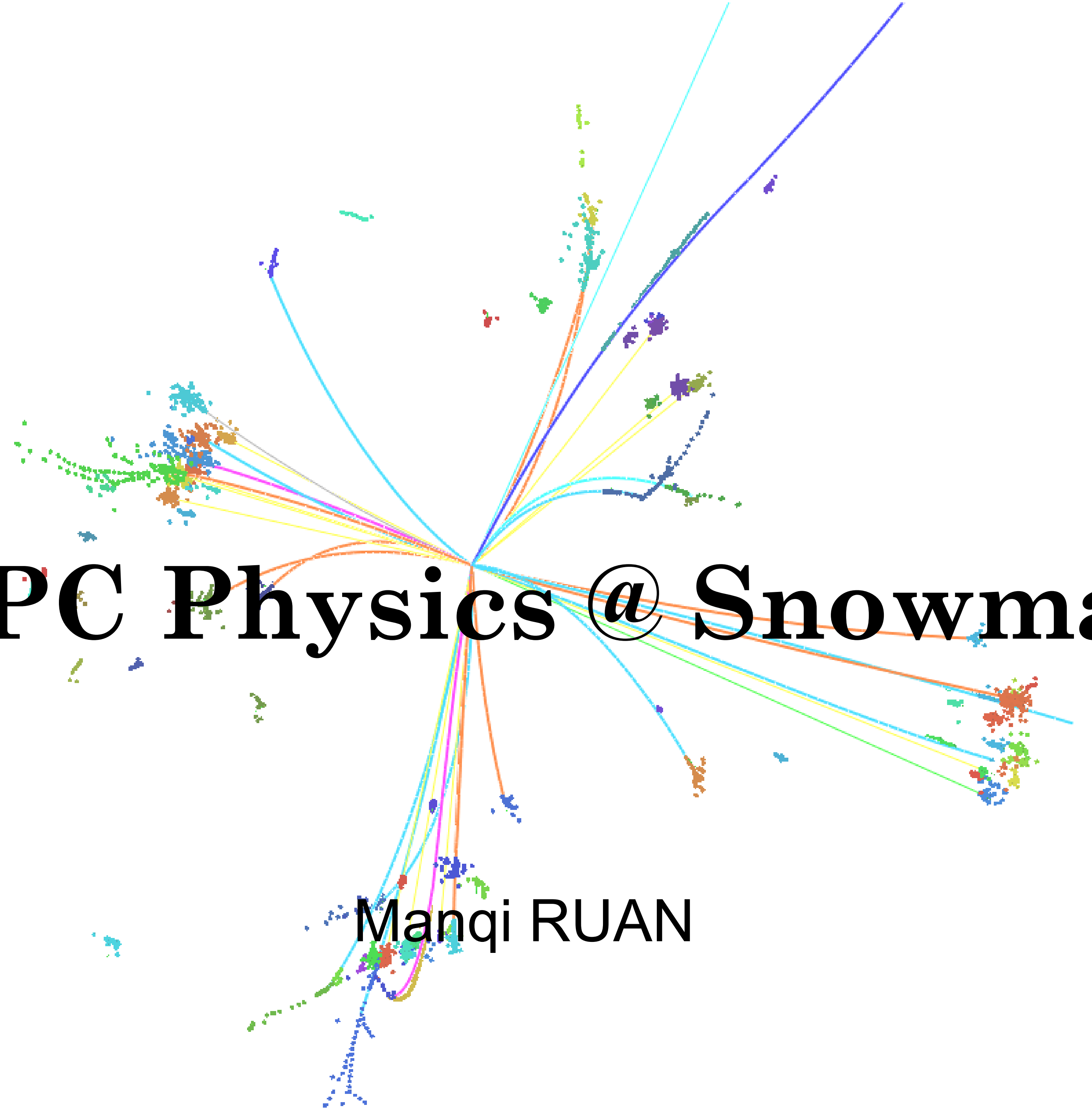
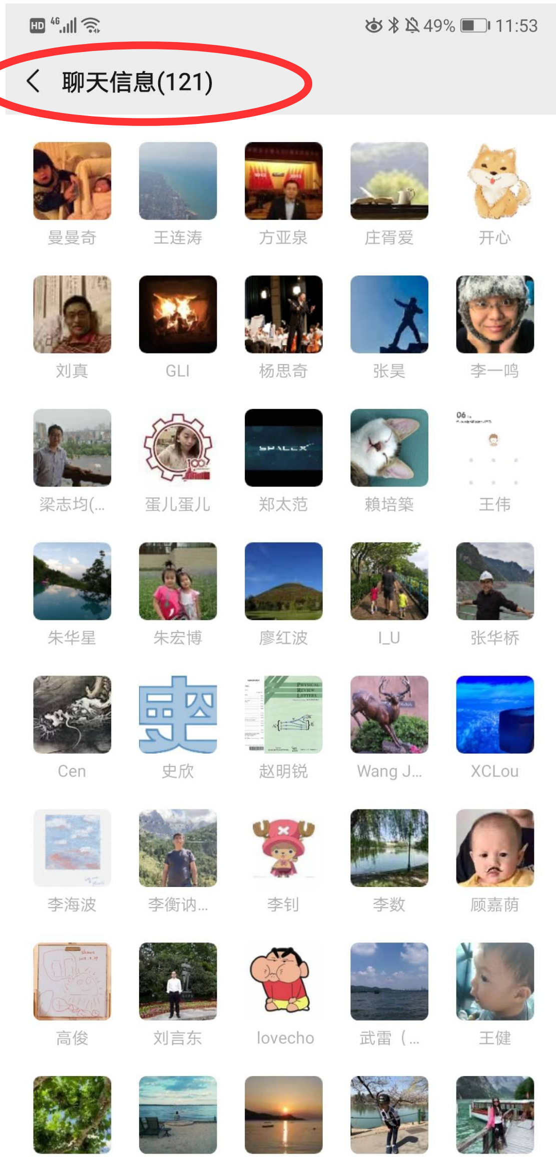


CEPC Physics @ Snowmass

Manqi RUAN

CEPC Snowmass LoIs



WG	LoI
EF01	Higgs boson CP properties at CEPC
	Measurement of branching fractions of Higgs hadronic decays
EF02	Study of Electroweak Phase Transition in Exotic Higgs Decays with CEPC Detector Simulation
	Complementary Heavy neutrino search in Rare Higgs Decays
EF03	Feasibility study of CP-violating Phase ϕs measurement via $Bs \to J/\Psi\phi$ channel at CEPC
	Probing top quark FCNC couplings tq\gamma, tqZ at future e+e- collider
	Searching for $Bs \to \phi$ vv and other $b \to$ svv processes at CEPC
EF04	Measurement of the leptonic effective weak mixing angle at CEPC
	Probing new physics with the measurements of $e+e- \to W+W-$ at CEPC with optimal observables
	NNLO electroweak correction to Higgs and Z associated production at future Higgs factory
EF05-07	Exlusive Z decays
EF08	SUSY global fits with future colliders using GAMBIT
	Probing Supersymmetry and Dark Matter at the CEPC, FCCee, and ILC
EF09-10	Search for t + j + MET signals from dark matter models at future e+e- collider
	Search for Asymmetric Dark Matter model at CEPC by displaced lepton jets
	Dark Matter via Higgs portal at CEPC
	Lepton portal dark matter, gravitational waves and collider phenomenology

Topics

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Higgs Physics: 4

Flavor Physics: 3

EW: 3

QCD: 1

BSM: 5

Tool: 1 (GAMBIT)

Multiple Working Group

indico.ihep.ac.cn/category/715/

Apps | Admin | CEPC | ILC | FCC | Software | PhysEr

December 2020

- 18 Dec CEPC Snowmass Progress New!

November 2020

- 27 Nov CEPC Snowmass Progress

September 2020

- 25 Sep CEPC Snowmass Bi-week Meeting

August 2020

- 26 Aug CEPC Snowmass LoIs: General Status Discussion
- 19 Aug LoI status chat

June 2020

- 28 Jun Snowmass General - 01

Friday, 27 November 2020

09:00 - 09:10 News & Updates

09:10 - 10:50 Individual Talks

09:10 **EF01:Higgs CP in e+e- -->Z(mumu)H with optimal variable method** *20'*
Qiyu, Sha
Material: Slides

09:30 **EF08: SUSY Search at the CEPC** *20'*
Jiarong Yuan
Material: Slides

09:50 **Update on Higgs CP measurement via ZH->ZZZ* Channel** *20'*
Xin Shi
Material: Slides

10:10 **Afb_b measurements at CEPC Z pole** *20'*
Zhenyu Zhao
Material: Slides

10:30 **Measurement of Bs->2 pi0 at the CEPC** *20'*
Yuexin Wang
Material: Slides

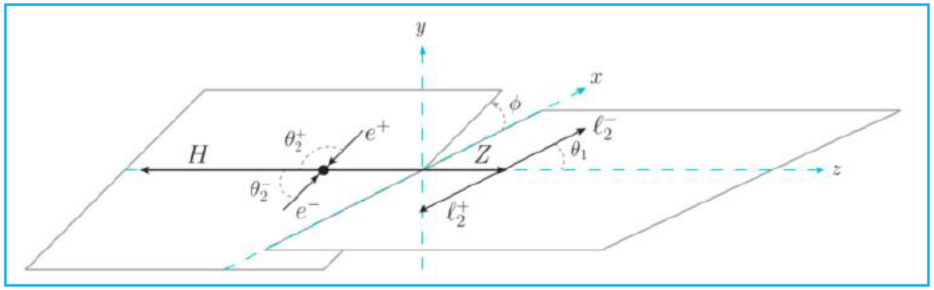
Communicate with Snowmass Conveners, Discussions/Presentations organized Accordingly.

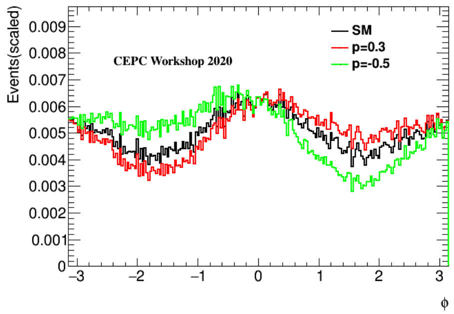
Higgs: CP measurements with llH & H->ZZ final states

Differential cross section for $ee \to ZH \to llH$

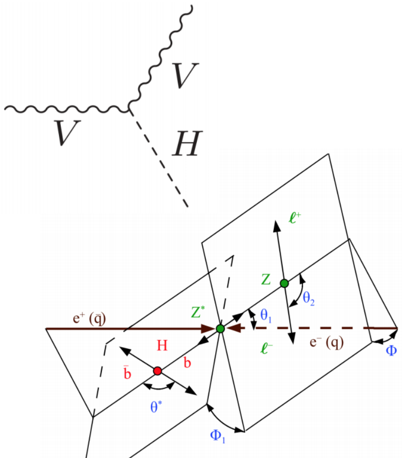
$$\frac{d\sigma}{dcos\theta_1 dcos\theta_2 d\phi} = \frac{\mathcal{N}_\sigma(q^2)}{m_H^2}\mathcal{J}(q^2,\theta_1,\theta_2,\phi),$$

$$\mathcal{N}_\sigma(q^2) = \frac{1}{2^{10}(2\pi)^3}\cdot\frac{1}{\sqrt{r}\gamma_Z}\cdot\frac{\sqrt{\lambda(1,s,r)}}{s^2}$$





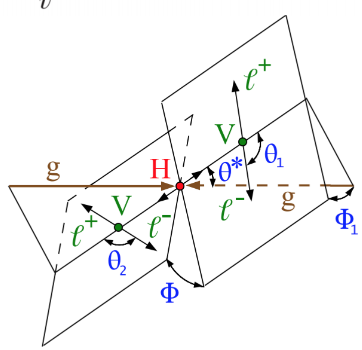
Angular Distributions

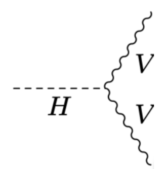


CPC43 (2019) 043002

PRD 89, 035007 (2014)

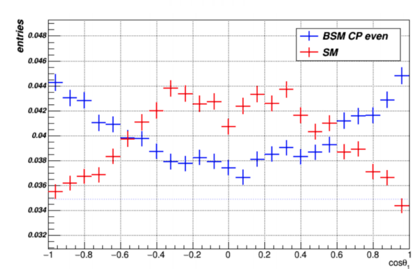
$$A(X_{J=0} \to VV) = \frac{1}{v}(g_1 m_V^2 \epsilon_1^* \epsilon_2^* + g_2 f_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + g_4 f_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu}$$



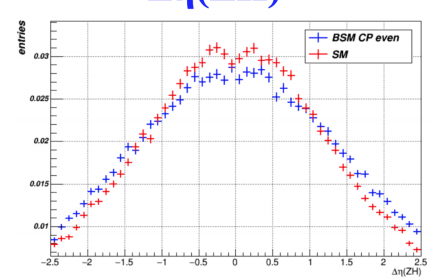


Angulars distribution

$\cos\theta_1$



$\Delta\eta(ZH)$



EW: Afb(b) measurement & TGC

1. AFB method — theory

- In theory, $A_{FB} = A_{FB}(\sin^2\theta_{eff})$, so one can derive $\sin^2\theta_{eff}$ by measuring A_{FB}(software ZFITTER can be used for calculation)
- Error propagation:

$$sensitivity = S_{phy} \coloneqq \frac{\Delta A_{FB}}{\Delta \sin^2\theta_{eff}}$$

- Error estimation for stw

$$\Delta sin^2\theta_{eff}(stat.) = \sqrt{\frac{1-(A_{FB}^{measure})^2}{N\cdot\epsilon_{tagging}}}\cdot\frac{\sqrt{1-2f+2f^2}}{1-2f}\cdot\frac{1}{S_{phy}}$$

Tagging efficiency

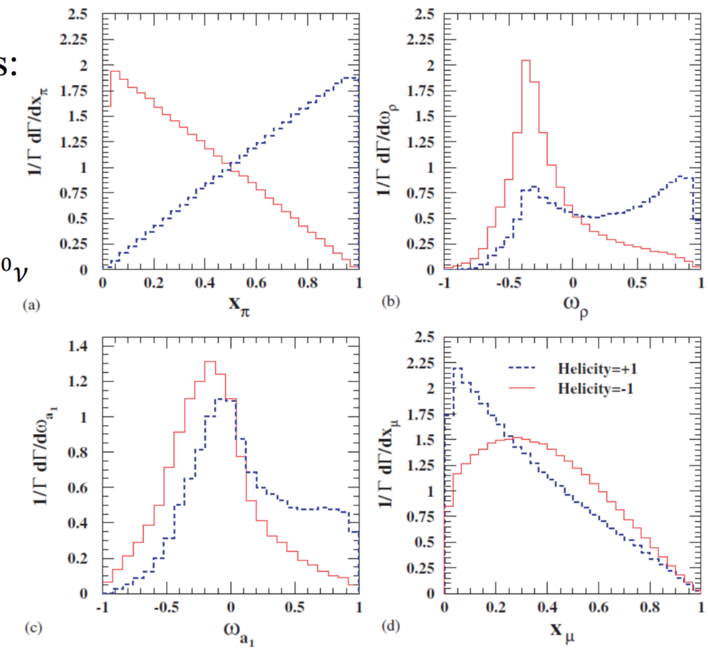
Charge mis-id rate

2020/11/27 Effective mixing angle measurement at CEPC

2.How to get P_τ — kinematic spectrum

- 5 leading τ decay modes:
  - $\tau \to \pi\nu$
  - $\tau \to \rho\nu$,
    - $\rho \to \pi\pi^0$
  - $\tau \to a_1\nu$,
    - $a_1 \to \pi\pi\pi\nu$ or $\pi\pi^0\pi^0\nu$
  - $\tau \to \mu\nu\bar{\nu}$
  - $\tau \to e\nu\bar{\nu}$
- Kinematic variable ω

mode1	mode2
mode3	mode4/5

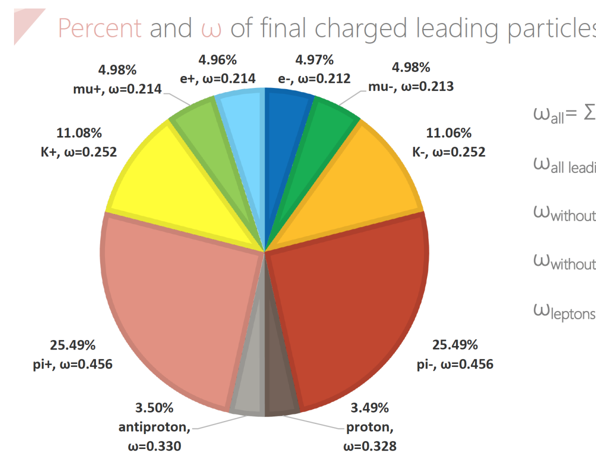


2020/11/27 Effective mixing angle measurement at CEPC 7

Afb(b) measurement & Performance

What we further need

- AFB method:
  - Hope for further results of b quark tagging performance
    - Tagging efficiency $\epsilon_{tagging}$
    - Charge mis-id rate f and error of f
- P_τ method:
  - Need:
    - ECAL: error of 4-momentum of: $\pi^{\pm}; \pi^0; e; \mu; \tau$
    - Efficiency: ϵ and $\Delta\epsilon$ of: $\pi^{\pm}; \pi^0$
  - Plan:
    - Study systematic error and get final results
    - Study the energy running effect of P_τ method



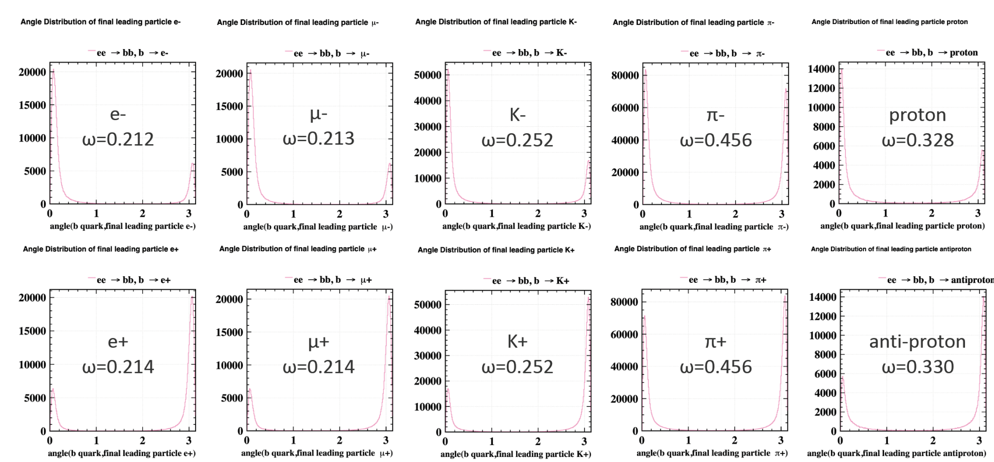
$\omega_{all} = \Sigma(\omega_i * \text{Probability}^{N(statistics)}{}_i)$

$\omega_{\text{all leading particles}} = 0.354$

$\omega_{\text{without } \pi} = 0.247$

$\omega_{\text{without } \pi\&\text{proton}} = 0.234$

$\omega_{\text{leptons}} = 0.213$

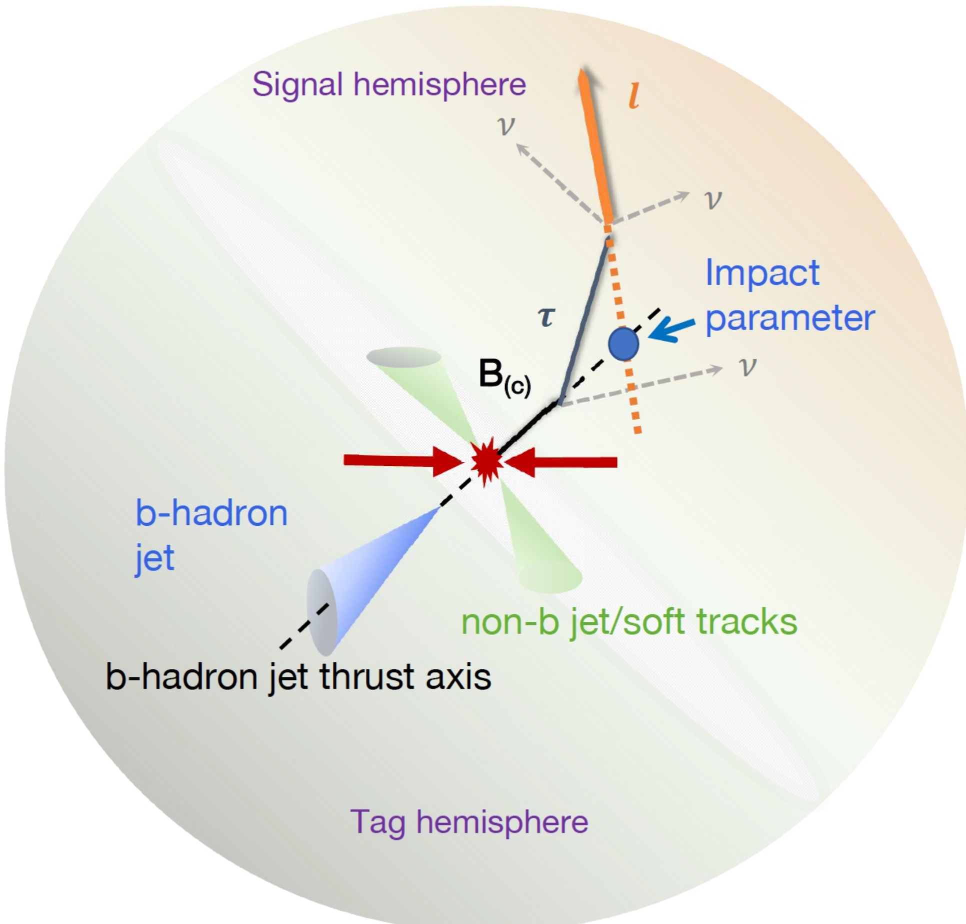


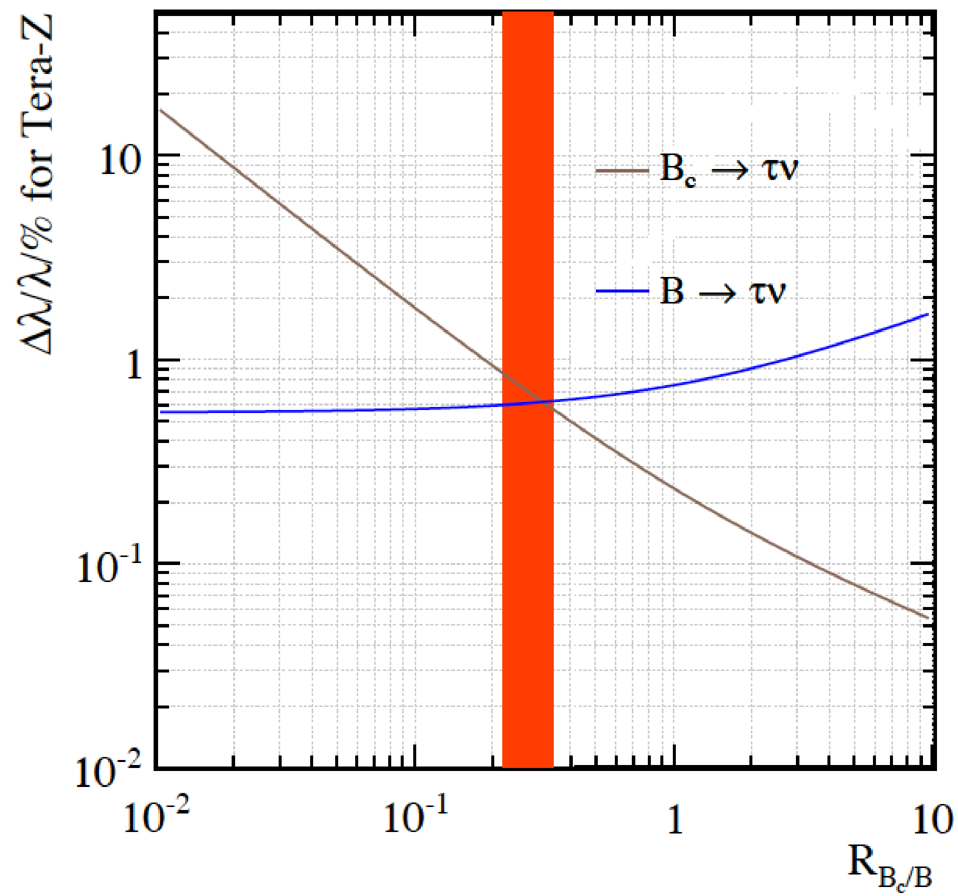
Health interactions with the Performance study... and lots of work ahead!

Flavor Benchmark analyses: status

- Bc -> tau+v -> e + 3v (In finalization, by Taifan Zhen, Fenfen An, Lu. Cao)
  - *Rely on the flavor tagging (Z->bb), jet lepton identification*
  - *Percentage level accuracy could be achieved at the CEPC*
  - *Current identification of jet lepton is good enough for this channel*
- B0 -> J/psi + Phi -> mumu KK (by Mingrui Zhao of 401)
  - *Rely on the Jet Charge measurement,*
  - *MCTruth level study, to mount/Xcheck corresponding performance study*
- Tau -> muon + photon (by Yudong Wang, etc)
  - *Photon energy resolution, lepton id*
  - *MCTruth + Smearing level.*
- b -> stautau (by Linfeng Li of HKUST)
  - *Reducible background might strongly limit the final accuracy*
- *Bs->Phi + vv (by Yudong Wang); Truth + Full Simulation analyses*
- *B0/Bs->2 pi0 (by Yuexin Wang); Truth level analyses*

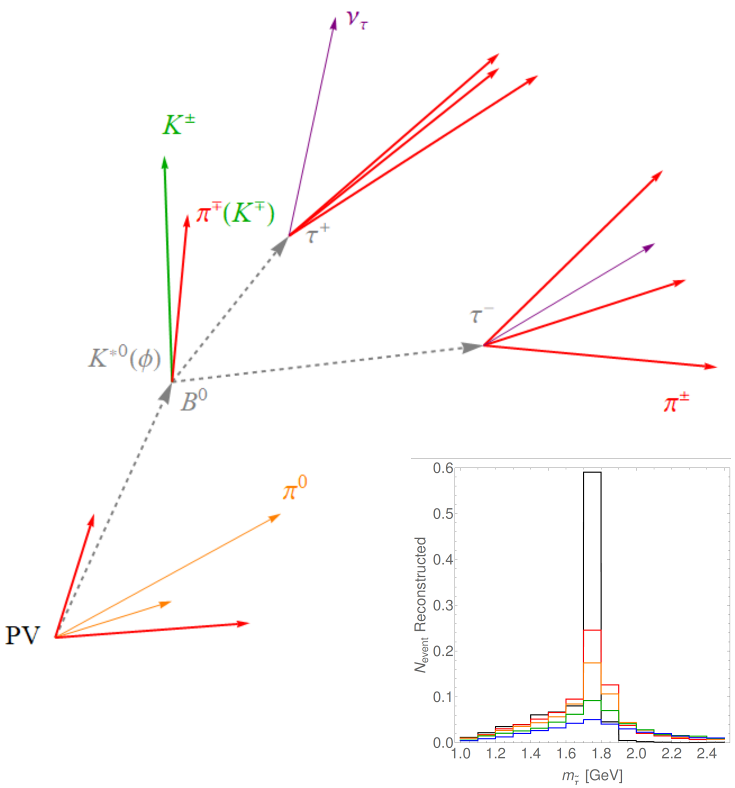
Bc->Tauv

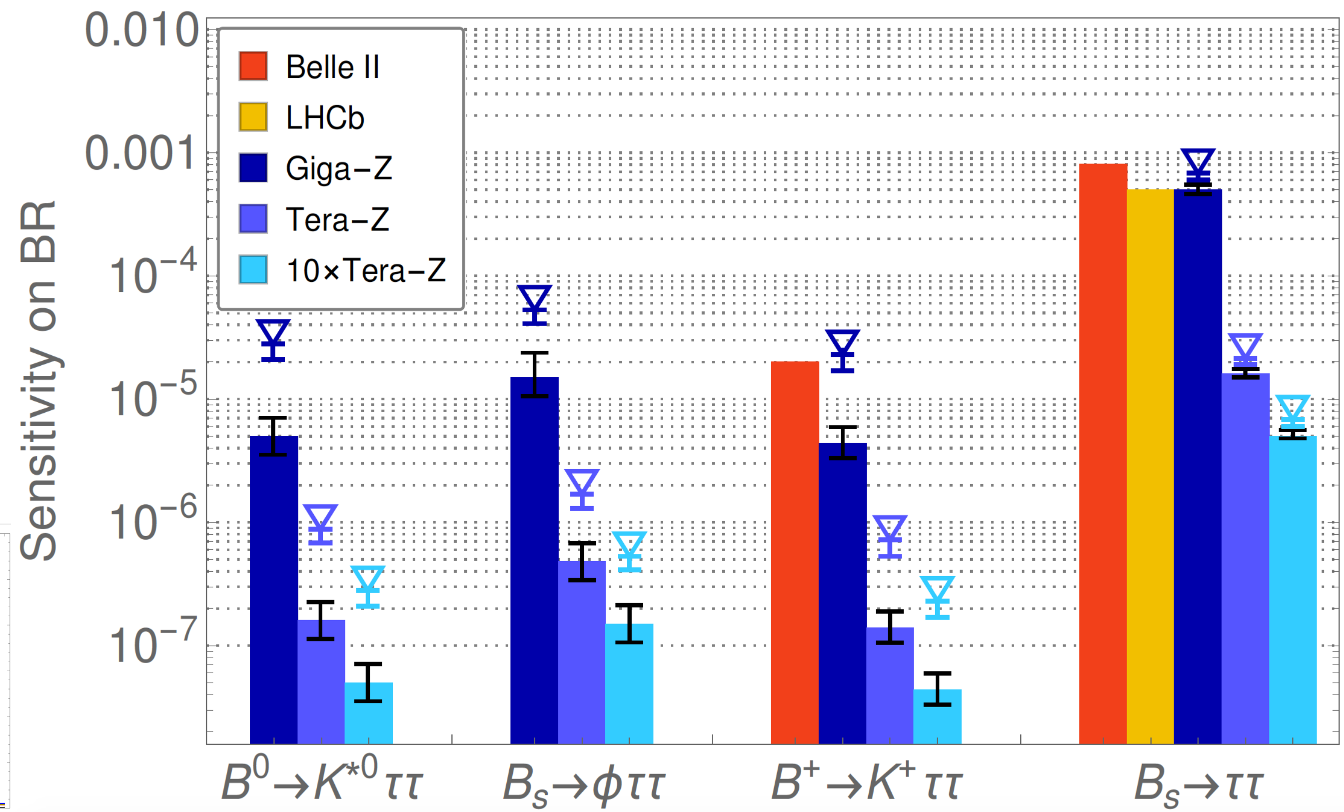




Taifan, etc, Accepted by CPC.
Collaborate with Wei Wang, et.al.

VTX: reconstruction accuracy V.S final accuracy: ideal, 1, 2, 5, 10μm resolution





LINGFENG @ HKIAS

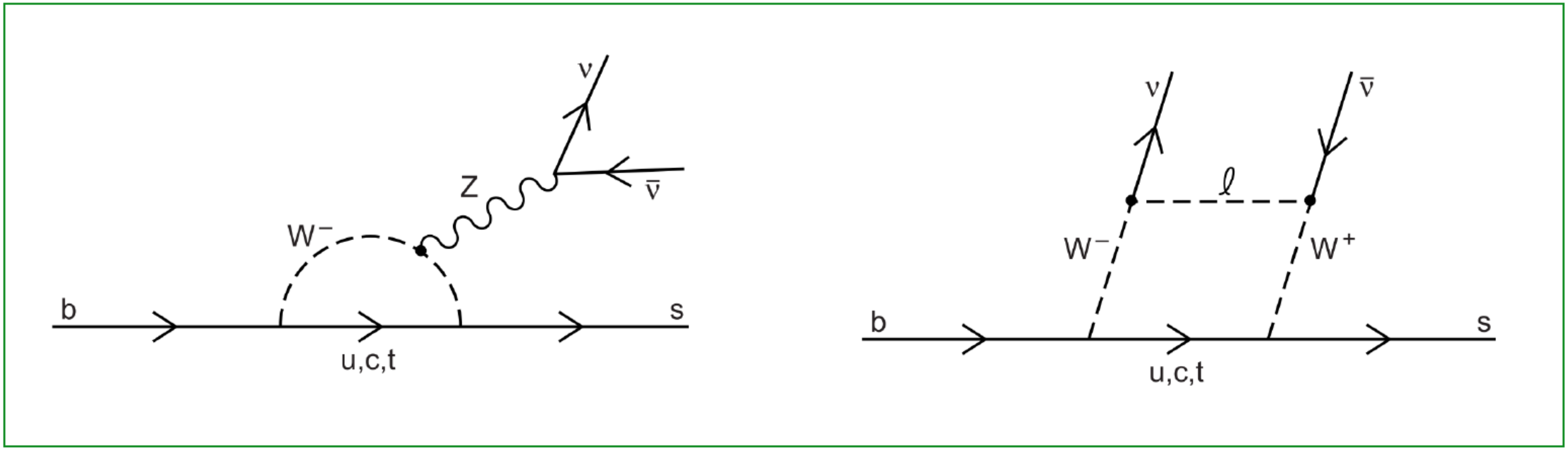
...

Contamination of D decay that mimics tau 3-prong decay;

...

$b \to s\nu\bar{\nu}$

Flavor-change-neutral-current(FCNC) process. Be suppressed by the loop factor and heavy weak boson mass .



One-loop level in the Standard Model (SM) via "penguin" and "box" diagrams.

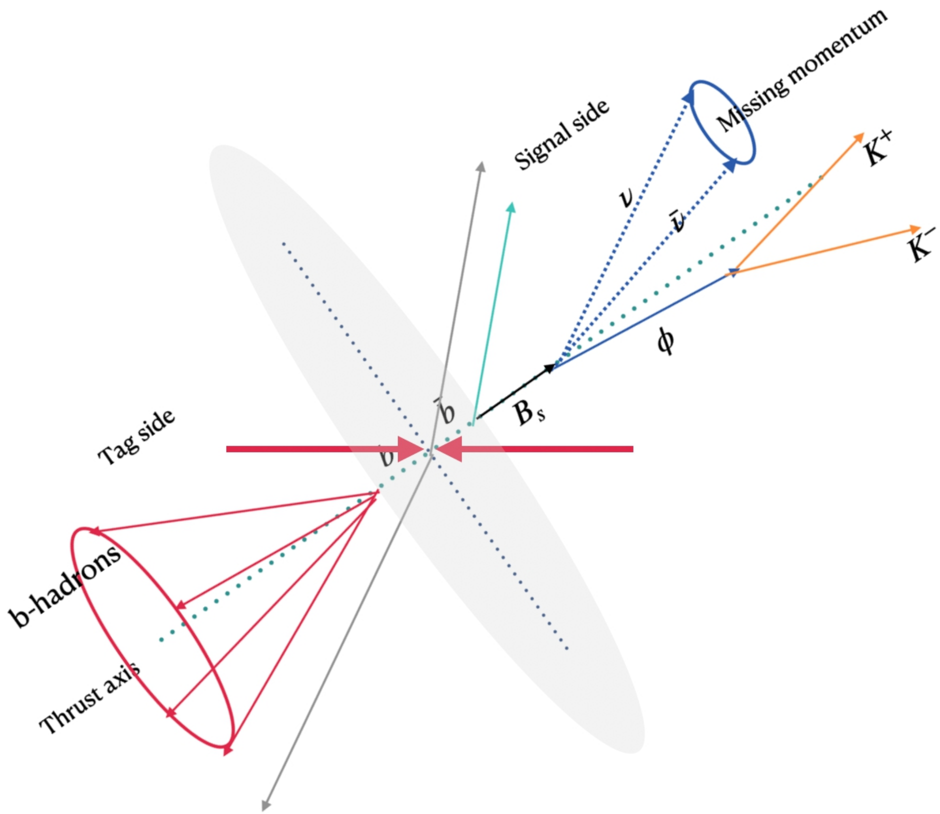
	Experimental [1]	SM Prediction [2]
$\mathrm{BR}(B^0 \to K^0\nu\bar{\nu})$	$< 2.6 \times 10^{-5}$	$(2.17 \pm 0.30) \times 10^{-6}$
$\mathrm{BR}(B^0 \to K^{*0}\nu\bar{\nu})$	$< 1.8 \times 10^{-5}$	$(9.48 \pm 1.10) \times 10^{-6}$
$\mathrm{BR}(B^\pm \to K^\pm\nu\bar{\nu})$	$< 1.6 \times 10^{-5}$	$(4.68 \pm 0.64) \times 10^{-6}$
$\mathrm{BR}(B^\pm \to K^{*\pm}\nu\bar{\nu})$	$< 4.0 \times 10^{-5}$	$(10.22 \pm 1.19) \times 10^{-6}$
$\mathrm{BR}(B_s \to \phi\nu\bar{\nu})$	$< 5.4 \times 10^{-3}$	$(11.84 \pm 0.19) \times 10^{-6}$

Table 1: Constraints and predictions for various $b \to s\nu\bar{\nu}$ decays.

Yudong

[1] M. Tanabashi *et al.*, "Review of Particle Physics," *Phys. Rev.*, vol. D98, no. 3, p. 030001, 2018.

[2] D. M. Straub, "$b \to k^{(*)}\nu\bar{\nu}$ sm predictions," Dec 2015.



- Accuracy: ~o(1%).
- Depends on
  - *Lepton id (to veto background from B/D leptonic decay)*
  - *Missing energy/momentum reco.*
  - *Phi reco (Pid)*

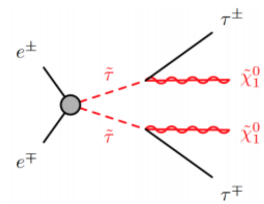
	N_S	N_B	S/sqrt(B)	sqrt(S+B)/S
Total	180000	1.5e+11	0.46	2.15
$N_\phi > 0$	6.78e4	4.82e+09	0.98	1.02
$E_l < 1$ GeV	5.55e4	2.05e9	1.22	0.85
$E_{Neutral} < 2.7$ GeV	1.20e4	6.9e8	1.75	0.0543
$\alpha < 0.8$	1.73e4	7.5e+4	20.08	0.0503
Efficiency	0.0966	5e-06		

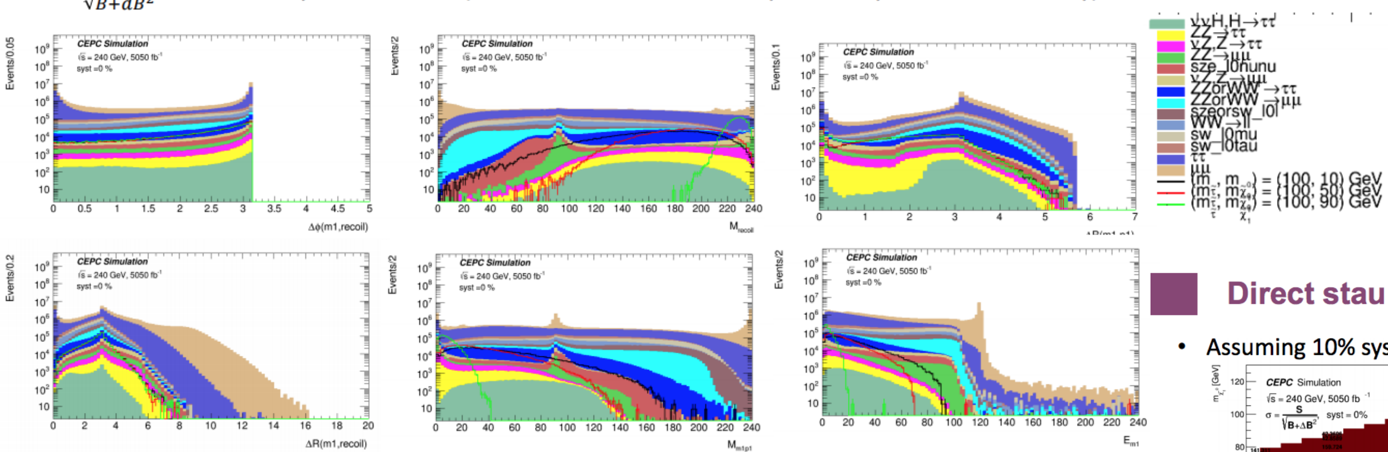
...Preliminary!!...

BSM: SUSY

Direct stau: Optimization Strategy

- Use the leading track with minus(positive) charge to represent the $\tau^-(\tau^+)$ for simplicity.
- Select events with 2 OS τ with energy > 0.5GeV.
- Perform a multi-dimension optimization, considering variables:
$$\Delta R(\tau,\tau), \Delta R(\tau,recoil), \Delta\varphi(\tau,\tau\ ), \Delta\varphi(\tau,recoil), M_{\tau\tau}, M_{recoil}, E_\tau$$
- Check for both upper cut and down cut for each variable.
- Use $\frac{S}{\sqrt{B+dB^2}}$ as a sensitivity measurement (consider statistical uncertainty and 5% systematic uncertainty).

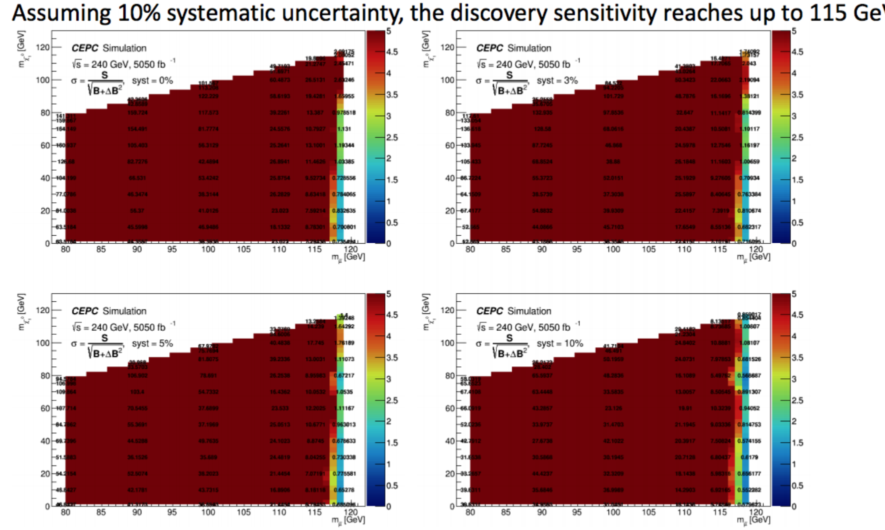




With relatively simple Final states & Covers many different models (Bino, Chargino, ...)

Direct stau: Sensitivity map

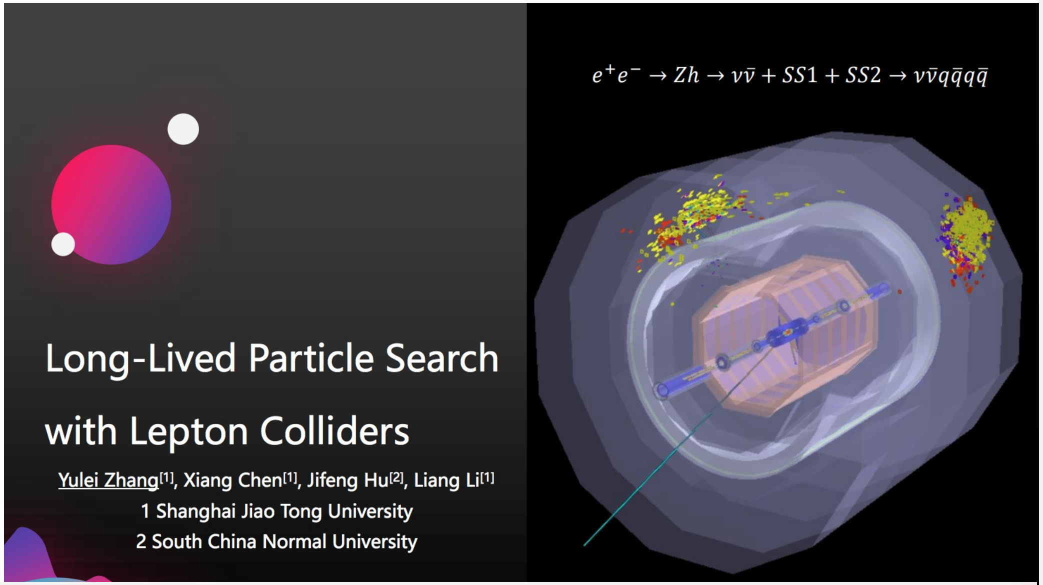
- Assuming 10% systematic uncertainty, the discovery sensitivity reaches up to 115 GeV.



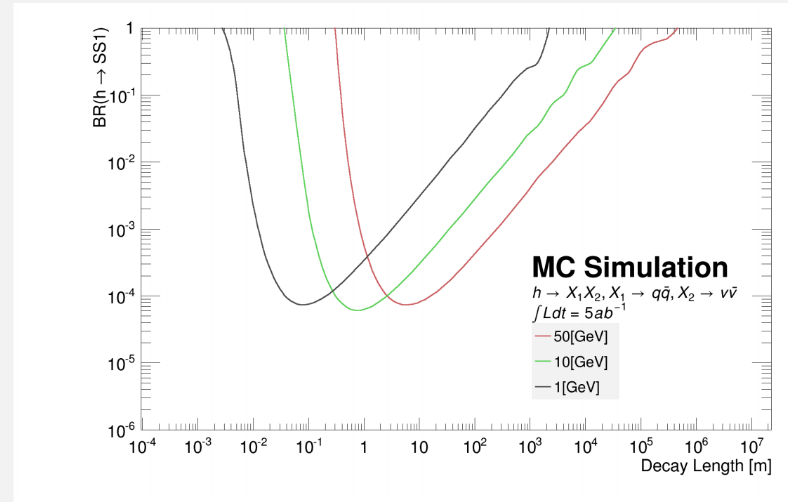
Summary

- A preliminary SUSY sensitivity study has been performed to direct stau production, direct smuon production and chargino pair production (Bino LSP and Higgsino LSP) in CEPC, which is promising. With assuming 10% systematic uncertainty:
  - For direct stau production, the discovery sensitivity reaches up to 115 GeV.
  - For direct smuon production, the discovery sensitivity reaches up to 115 GeV.
  - For chargino pair production (Bino LSP), the discovery sensitivity can still reach up all the mass phase space.
  - For chargino pair production (Higgsino LSP), the discovery sensitivity can reach up to 118 GeV.

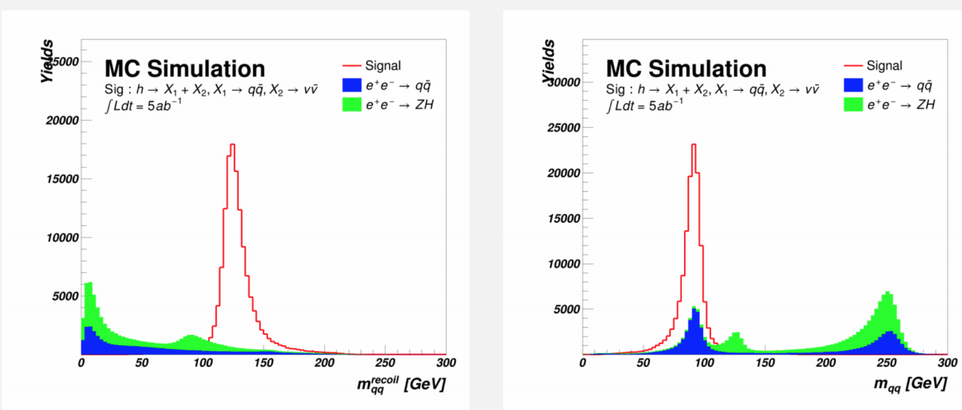
BSM: Long Lived Particle



Sensitivity (2 jets)

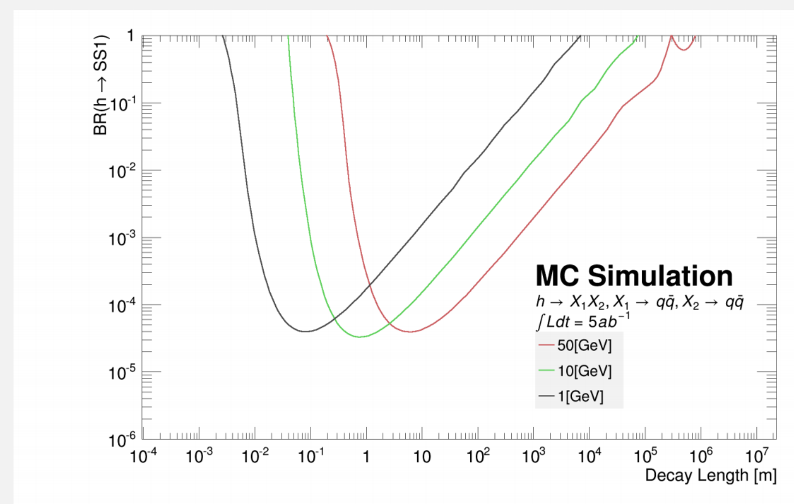


Mass of 2 prompt jets



- qq is reconstructed by $e^+e^- - k_T$ algorithm, which represents for the jets from primary vertex
- Background is normalized to the scale of signal.

Sensitivity (4 jets)



update anticipated this Friday

Conclusion

- Snowmass: awaiting for mature results by July 2021
- 17 LoIs submitted from CEPC.
  - Many original ideas
  - ~ 4 LoIs reaches the needed maturity now
    - Bc->tau v;
    - B->stautau;
    - SUSY;
    - LLP
    - ...
  - ~Half of the LoIs presented at CEPC Snowmass LoI meetings (bi-weekly based, hope to).
- Health interaction/collaborations between Performance & Physics
- Health & Helpful interactions with Snowmass community.
- Note: There are also many Physics Studies Not included in these Snowmass LoIs.