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

CEPC NP Potential

--- White paper statues

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On behalf of CEPC NP team

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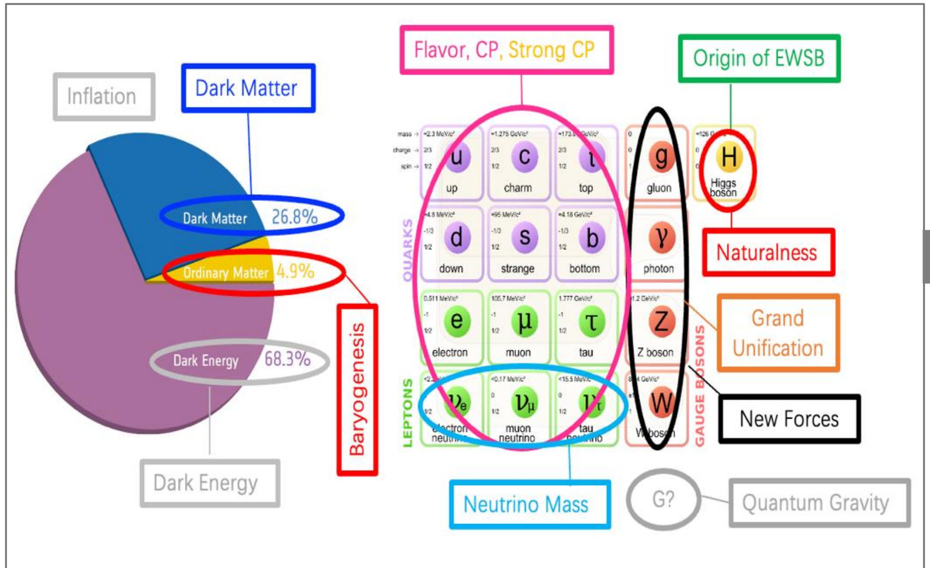
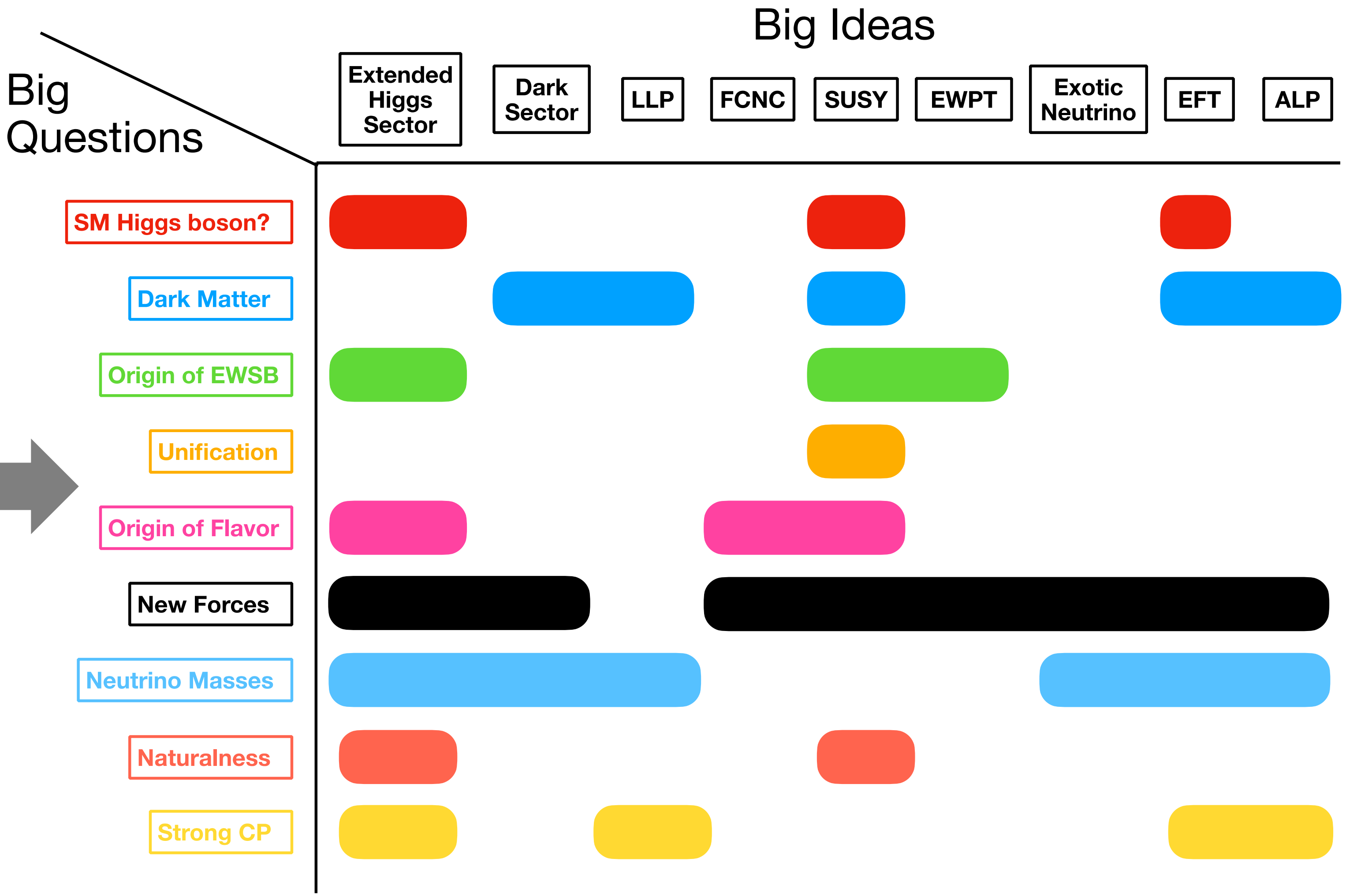
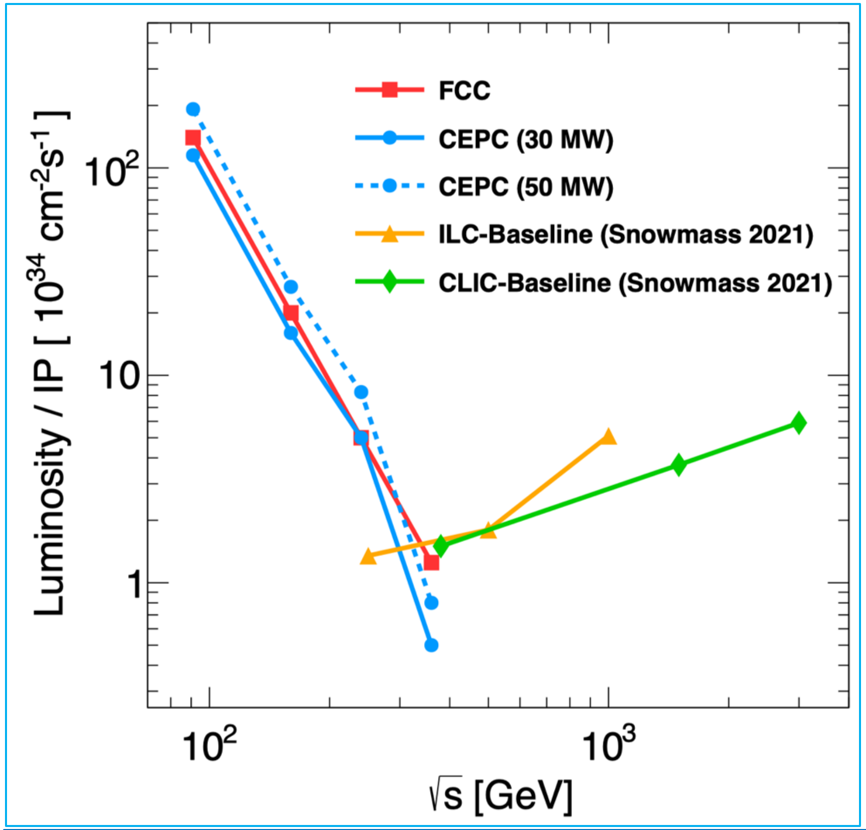
Big Questions and Ideas in particle physics



Picture modified from Jonathan Feng at 2017 ICFA Seminar, gray one not covered by cepc

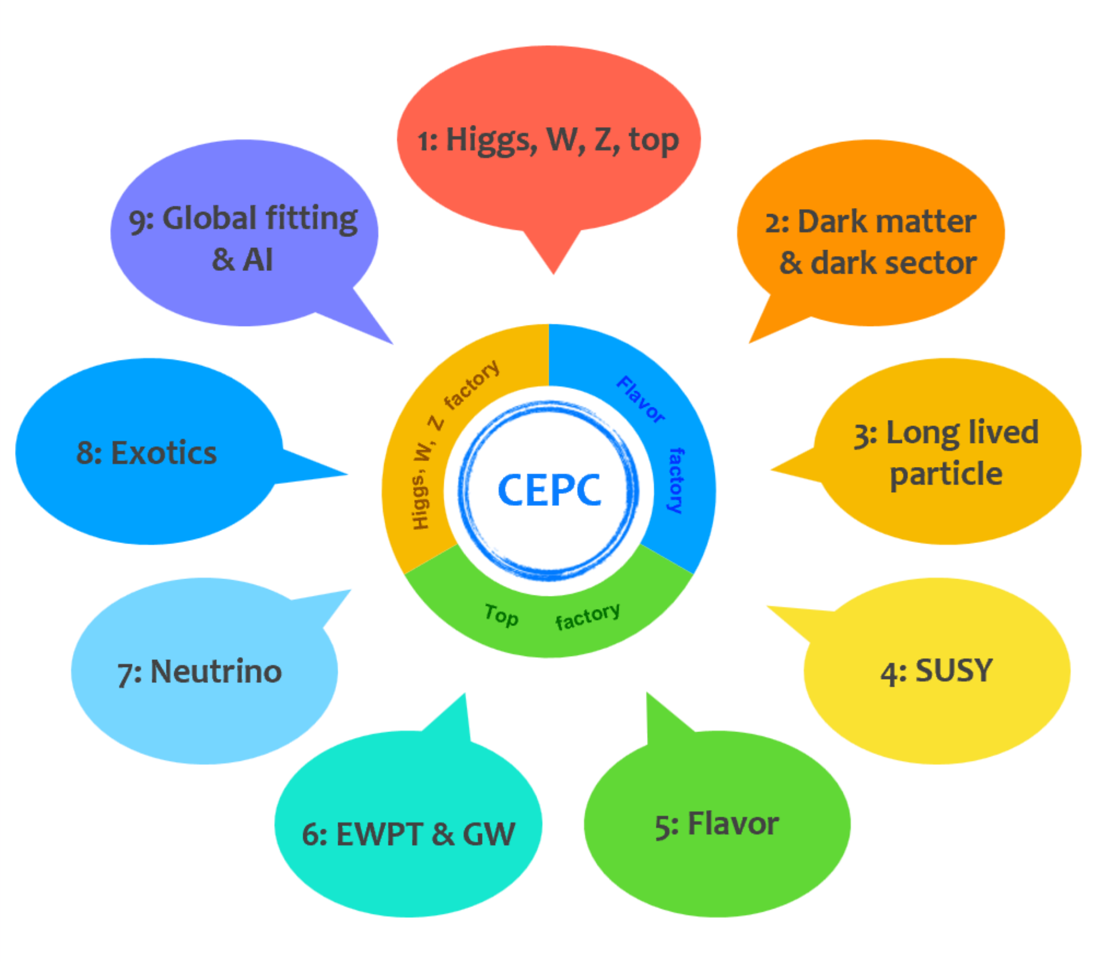


CEPC operation scheme and NP Program



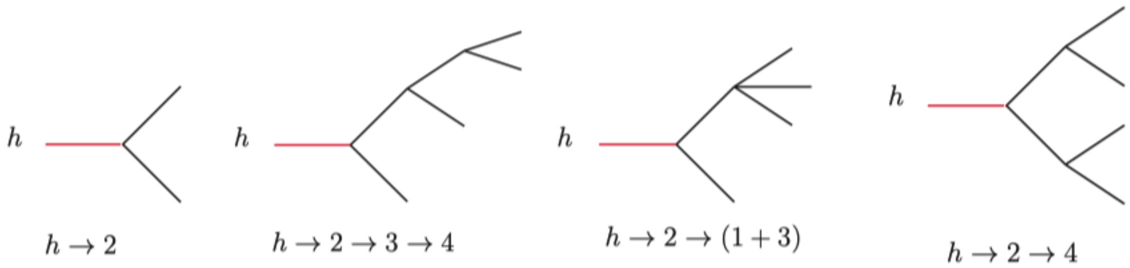
Operation mode	Z factory	WW threshold	Higgs factory	$t\bar{t}$
$\sqrt{s}$ (GeV)	91.2	160	240	360
Run time (year)	2	1	10	5
Instantaneous luminosity ($10^{34} cm^{-2} s^{-1}$, per IP)	191.7	26.6	8.3	0.83
Integrated luminosity (ab^{-1}, 2 IPs)	100	6	20	1
Event yields	3×10^{12}	1×10^{8}	4×10^{6}	5×10^{5}

TABLE I: Nominal CEPC operation scheme, and the physics yield, of four different modes.



1. Exotic Higgs/Z/top decays

- ***Higgs exotic decay*** **motivated by a large class of BSM physics, such as singlet extensions, two Higgs-doublet-models (2HDM), SUSY models, Higgs portals, gauge extensions of the SM …**

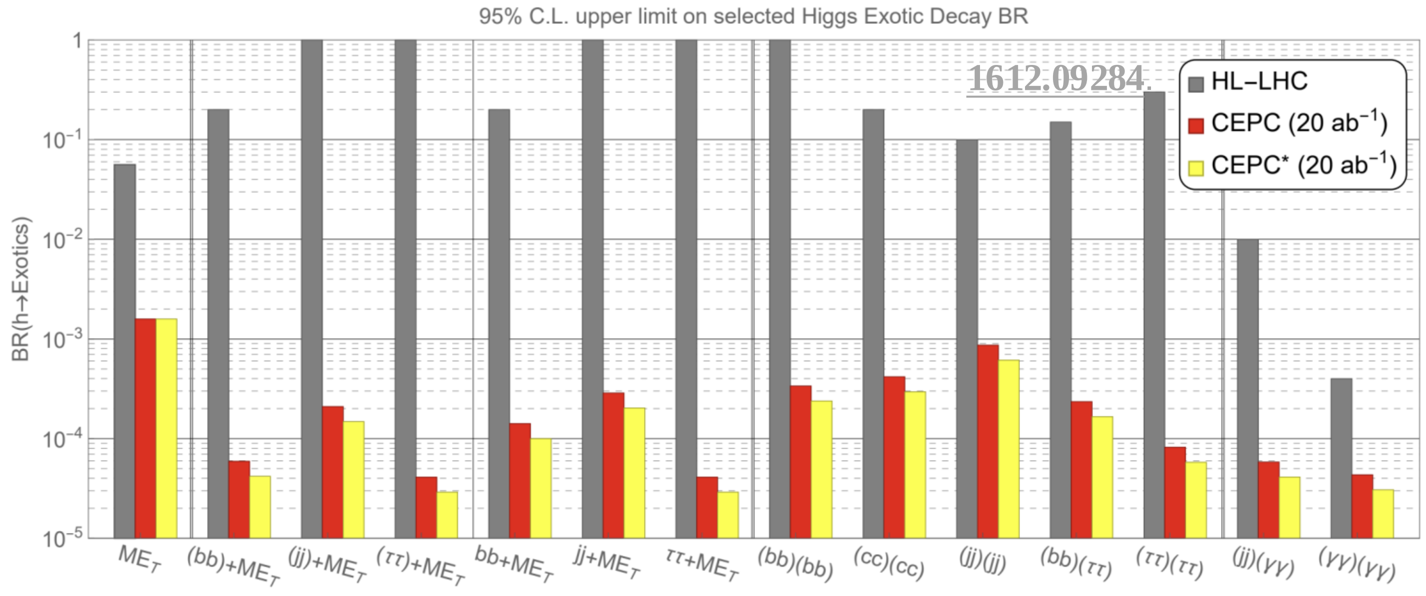


Representative topologies of the Higgs exotic decays

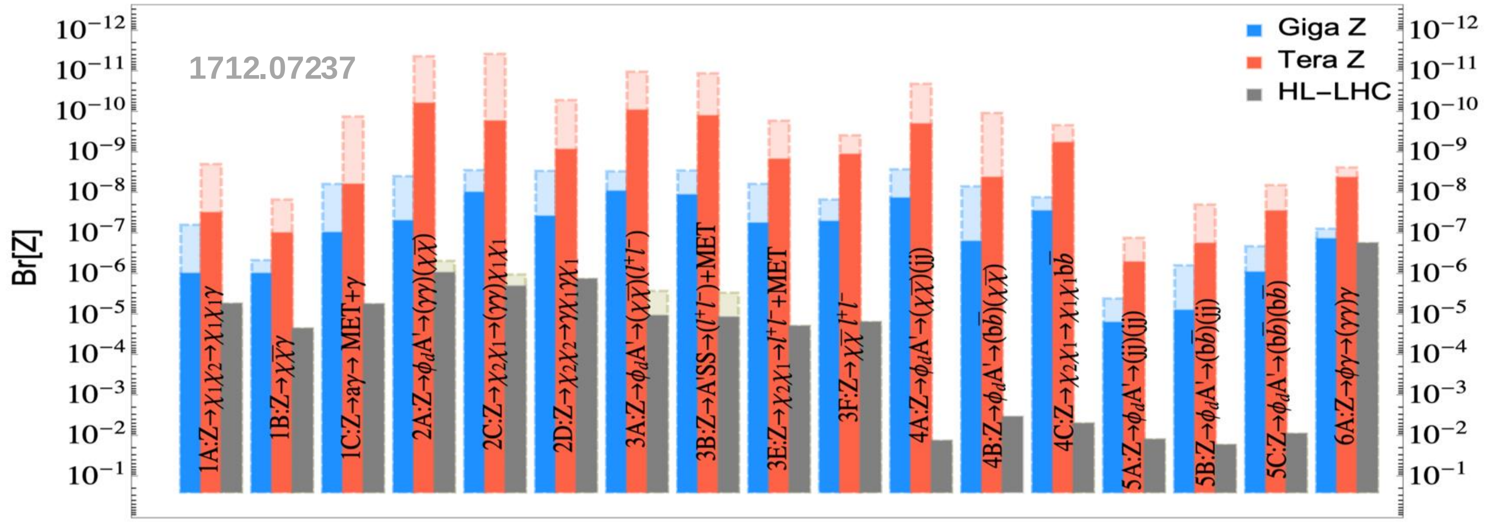
- ***Exotic Z or top decays*** **are also motivated by many BSM models (ED, Heavy Vector Triplet , …) and can also be searched at CEPC**

- ***Light Higgs*** **are motivated by 2HDM and Axion-like particle models, which can be searched at CEPC well if they exist.**

Exotic Higgs/Z/top decays



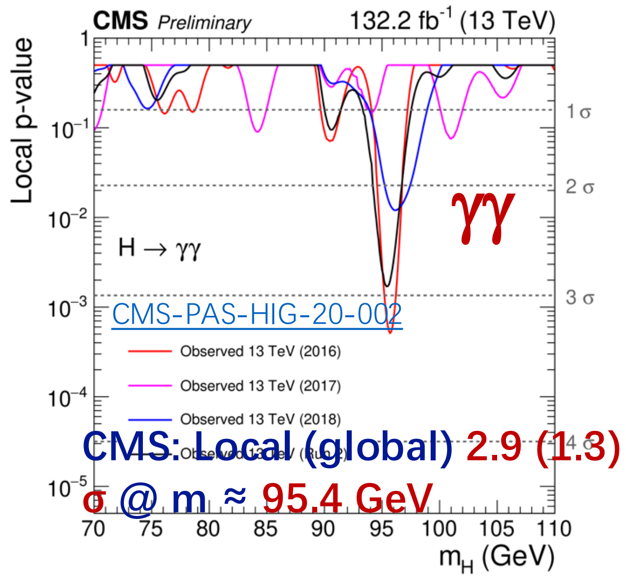
The 95% C.L. upper limit on selected Higgs exotic decay BR



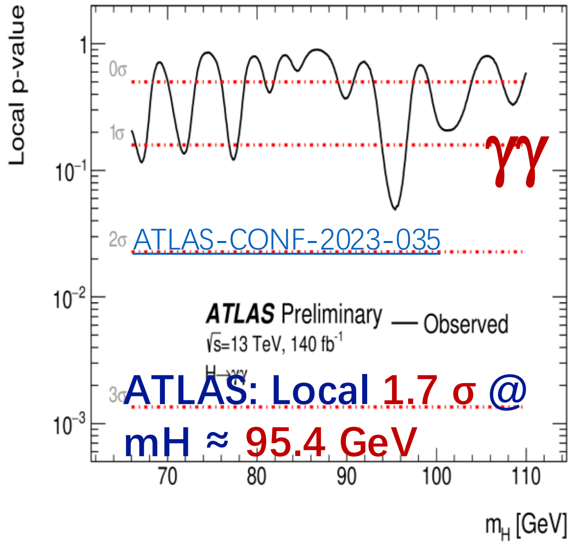
The reach for the branching ratio of various exotic Z decay modes

→ Good sensitivity of exotic Higgs/Z decay from CEPC

Light Higgs

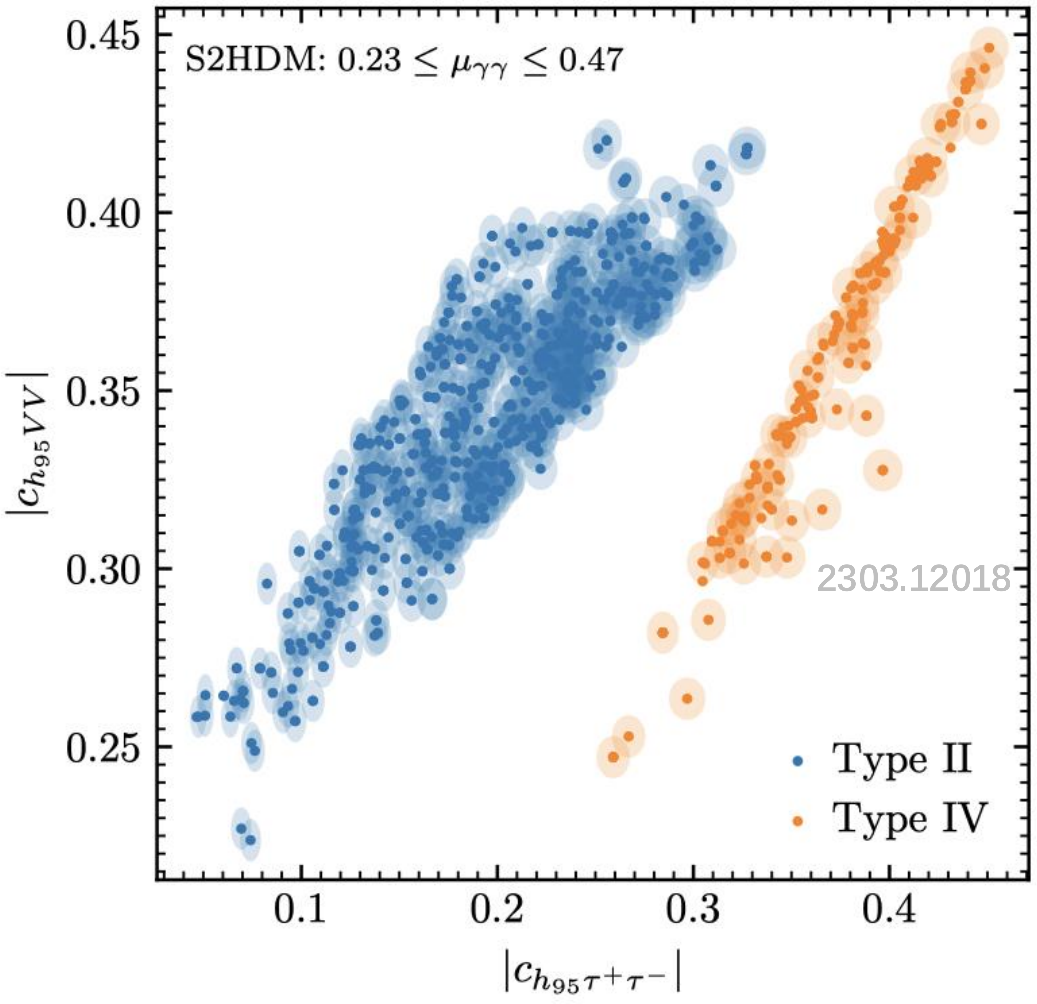


CMS: Local (global) 2.9 (1.3) σ @ m ≈ 95.4 GeV



ATLAS: Local 1.7 σ @ mH ≈ 95.4 GeV

- **Light Higgs are motivated by 2HDM and Axion-like particle models**

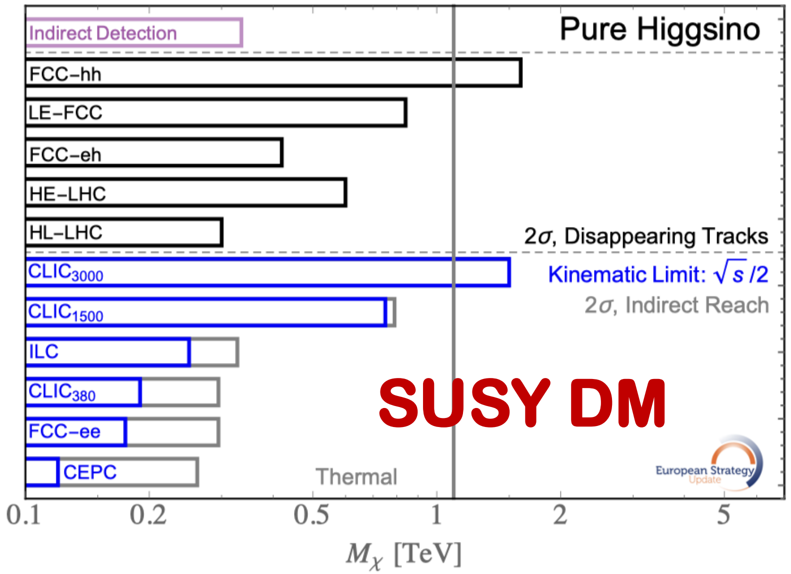


S2HDM parameter points passing the applied constraints for the di-photon signal strengths.

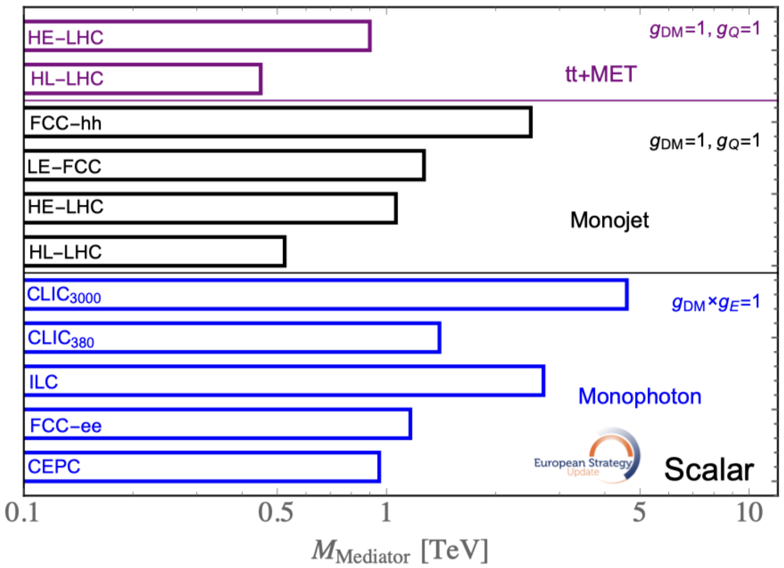
Light higgs can be searched at CEPC very well if exists.

2. Dark Matter and Dark Sector

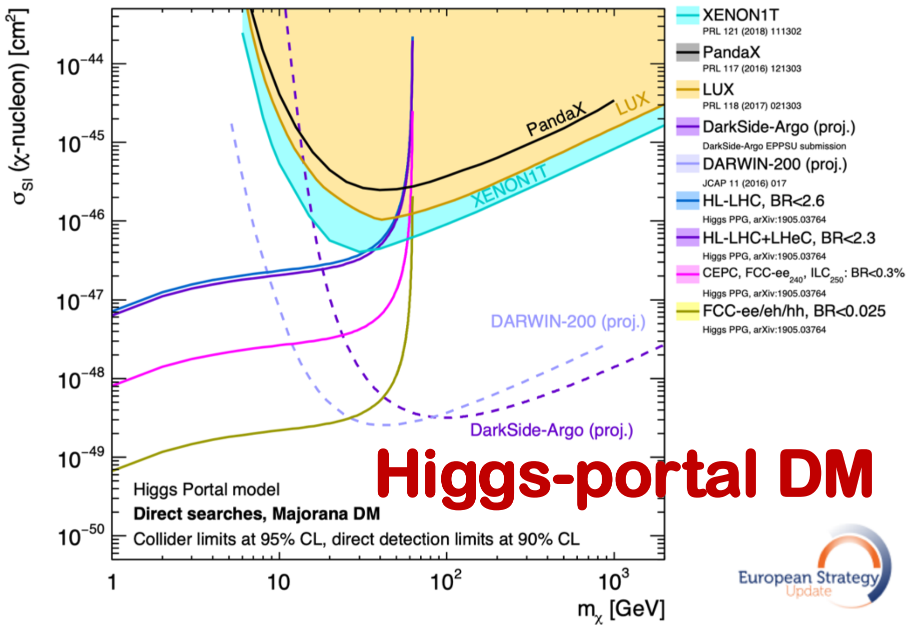
- **UV models DM:**
  - SUSY DM
  - Double dark portal model
  - ……
- **Simplified models DM:**
  - Scalar portal
  - Fermion portal
  - Vector portal
- **EFT DM**



SUSY DM



Simplified model DM

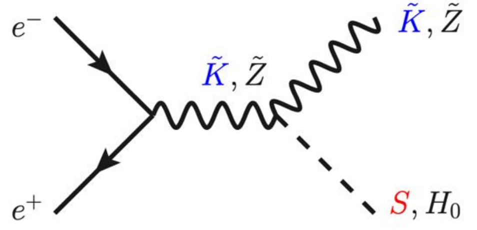


Higgs-portal DM

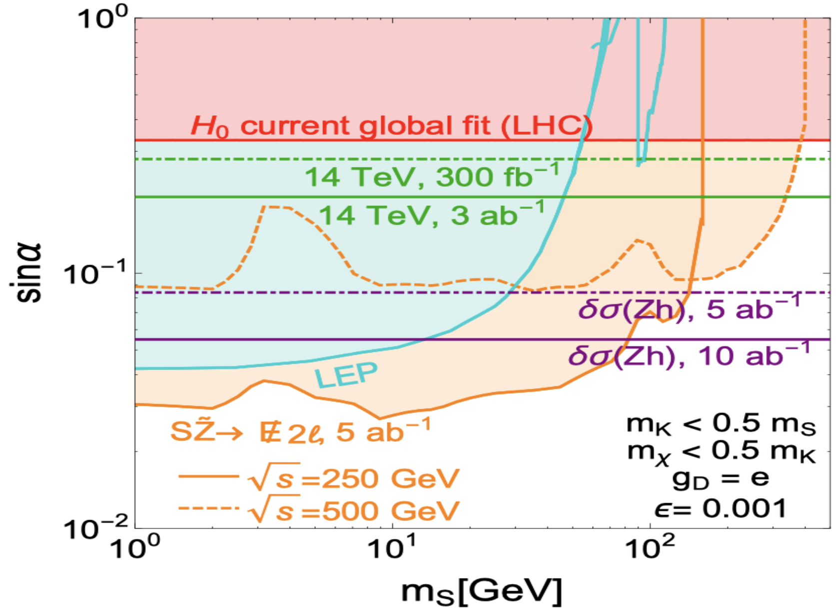
2. Dark Matter and Dark Sector

Portal	Effective operator	$\sqrt{s}$ [GeV]	$\mathcal{L}[ab^{-1}]$	Sensitivity of CEPC (HL-LHC)	Figs.	Ref.
Scalar	$\lambda_{HP}\|H\|^2 S^2 \rightarrow$ scalar mixing $\sin\theta$	250	5	invisible S, $\sin\theta \approx 0.03$ (0.20 global-fits)	22	[108]
Fermion	$y_\ell \bar{\chi}_L S^\dagger \ell_R$ + H.c.	250	5	covering 100 GeV $< m_S <$ 170 GeV	23	[56]
	$\kappa \Phi \overline{q'_L} \ell_R$ + H.c. (dark QCD)	250	5	$m_\Phi \sim$ 10 TeV for $c\tau_{\rm darkpion} \in [1, 10^3]$ cm (Null)	25	[109]
	$y \Phi \bar{F}_L \ell_R$ + H.c.	240	5.6	$y\theta_L \in [10^{-11},\ 10^{-7}]$ ($\lesssim 10^{-8} - 10^{-9}$)	26	[110]
Vector	$A'_\mu \left(e\epsilon J^\mu_{\rm em} + g_D \bar{\chi}\gamma^\mu \chi\right)$	250	5	$\epsilon \sim 10^{-3}$ for $g_D = e$ and $m_{A'} <$ 125 GeV ($\epsilon \sim 0.02$)	27, 28	[108]
	$\varepsilon A_\mu \bar{\chi}\gamma^\mu\chi$, (millicharge DM)	250	5	$\epsilon \sim 0.1$ for $m_\chi \sim$ 50 GeV	29	[111]
		91.2	2.6	$\epsilon \sim 0.02$ for $m_\chi \sim$ 5 GeV		
		160	16	$\epsilon \sim 0.5$ for $m_\chi \sim$ 10 GeV		
	$\frac{1}{2}\mu_\chi \bar{\chi}\sigma^{\mu\nu}\chi F_{\mu\nu} + \frac{i}{2} d_\chi \bar{\chi}\sigma^{\mu\nu}\gamma^5\chi F_{\mu\nu}$	91.2	100	$\mu_\chi, d_\chi \sim 4 \times 10^{-7}$ $(4 \times 10^{-6})\mu_B$ for $m_\chi <$ 25 GeV	30	[112]
	$-a_\chi \bar{\chi}\gamma^\mu\gamma^5\chi\partial^\nu F_{\mu\nu} + b_\chi \bar{\chi}\gamma^\mu\chi\partial^\nu F_{\mu\nu}$	240	20	$a_\chi, b_\chi \sim 10^{-6}$ (2×10^{-6}) GeV^{-2} for $m_\chi <$ 80 GeV		
EFT	$\frac{1}{\Lambda^2}\sum_i \left(\bar{\chi}\gamma_\mu(1-\gamma_5)\chi\right)\left(\bar{\ell}\gamma^\mu(1-\gamma_5)\ell\right)$	250	5	$\Lambda_i \sim$ 2 TeV ($m_\chi = 0$) (Null)	31	[113]
	$\frac{1}{\Lambda_A^2}\bar{\chi}\gamma_\mu\gamma_5\chi\bar{\ell}\gamma^\mu\gamma_5\ell$	250	5	$\Lambda_A \sim$ 1.5 TeV (Null)	32	[111]
	$\sum_i \frac{1}{\Lambda_i^2}\left(\bar{e}\Gamma_\mu e\right)\left(\bar{\nu}_L\Gamma^\mu\chi_L\right)$ + H.c. $\Gamma_\mu = 1, \gamma_5, \gamma_\mu, \gamma_\mu\gamma_5, \sigma_{\mu\nu}$	240	20	$\Lambda_i \sim$ 1 TeV ($m_\chi = 0$) (Null)	33	[114]

Dark Sector from Z/H associate production



Double dark portal model: Scale and Vector-portal DM



See details at Yongchao's talk this Wed.

2. Dark Matter and Dark Sector

Portal	Effective operator	$\sqrt{s}$ [GeV]	$\mathcal{L}[ab^{-1}]$	Sensitivity of CEPC (HL-LHC)	Figs.	Ref.
Scalar	$\lambda_{HP}\lvert H\rvert^2 S^2 \to$ scalar mixing $\sin\theta$	250	5	invisible S, $\sin\theta \approx 0.03$ (0.20 global-fits)	22	[108]
Fermion	$y_\ell \bar{\chi}_L S^\dagger \ell_R$ + H.c.	250	5	covering $100\,\text{GeV} < m_S < 170\,\text{GeV}$	23	[56]
	$\kappa\Phi\overline{q'_L}\ell_R$ + H.c. (dark QCD)	250	5	$m_\Phi \sim 10$ TeV for $c\tau_{\text{darkpion}} \in [1, 10^3]$ cm (Null)	25	[109]
	$y\Phi\bar{F}_L\ell_R$ + H.c.	240	5.6	$y\theta_L \in [10^{-11},\ 10^{-7}]$ ($\lesssim 10^{-8} - 10^{-9}$)	26	[110]
Vector	$A'_\mu\,(e\epsilon J^\mu_{\text{em}} + g_D\bar{\chi}\gamma^\mu\chi)$	250	5	$\epsilon \sim 10^{-3}$ for $g_D = e$ and $m_{A'} < 125$ GeV ($\epsilon \sim 0.02$)	27, 28	[108]
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	$\frac{1}{2}\mu_\chi\bar{\chi}\sigma^{\mu\nu}\chi F_{\mu\nu} + \frac{i}{2}d_\chi\bar{\chi}\sigma^{\mu\nu}\gamma^5\chi F_{\mu\nu}$	91.2	100	$\mu_\chi, d_\chi \sim 4\times10^{-7}$ $(4\times10^{-6})\mu_B$ for $m_\chi < 25\,\text{GeV}$	30	[112]
	$-a_\chi\bar{\chi}\gamma^\mu\gamma^5\chi\partial^\nu F_{\mu\nu} + b_\chi\bar{\chi}\gamma^\mu\chi\partial^\nu F_{\mu\nu}$	240	20	$a_\chi, b_\chi \sim 10^{-6}$ $(2\times10^{-6})\,\text{GeV}^{-2}$ for $m_\chi < 80$ GeV		
EFT	$\frac{1}{\Lambda^2}\sum_i(\bar{\chi}\gamma_\mu(1-\gamma_5)\chi)\,(\bar{\ell}\gamma^\mu(1-\gamma_5)\ell)$	250	5	$\Lambda_i \sim 2$ TeV ($m_\chi = 0$) (Null)	31	[113]
	$\frac{1}{\Lambda_A^2}\bar{\chi}\gamma_\mu\gamma_5\chi\bar{\ell}\gamma^\mu\gamma_5\ell$	250	5	$\Lambda_A \sim 1.5$ TeV (Null)	32	[111]
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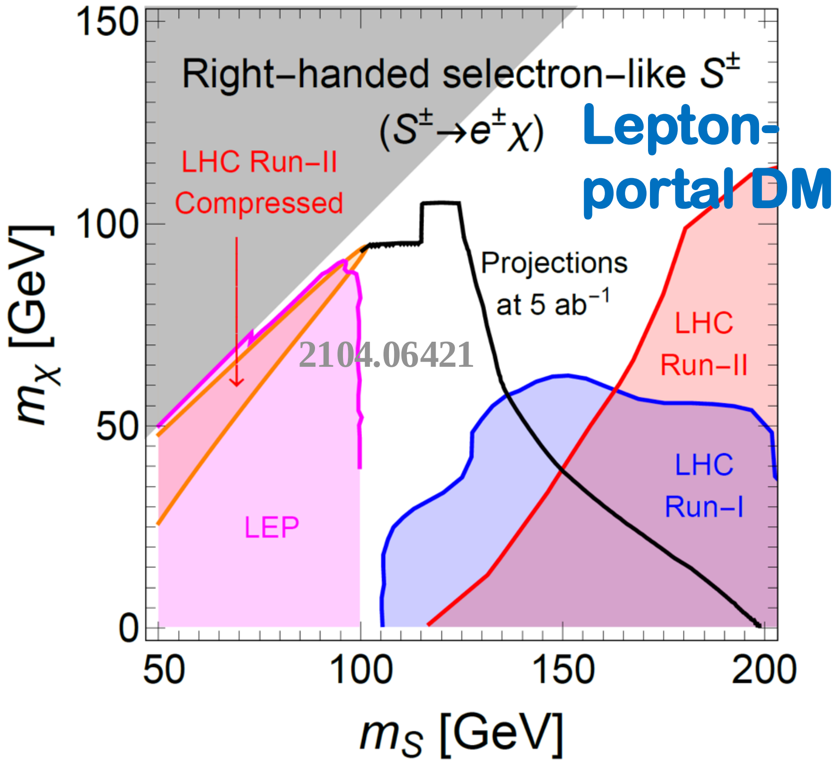
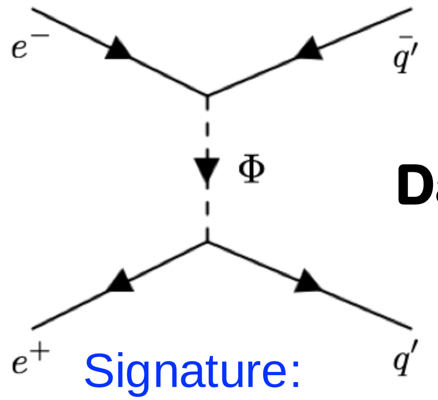
$$e^+e^- \to S^{\pm(*)}S^\mp \to \ell^+\chi\ell'^-\chi$$



Lepton-portal DM

$m_S \sim 100 - 170\ GeV$

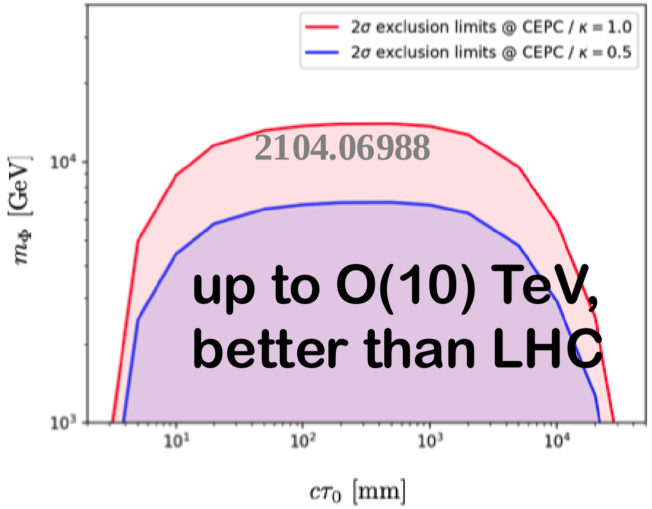
Decay to leptons



Dark quark q‘

Jet-like

Signature:
Lepton + jet + MET



up to O(10) TeV, better than LHC

2. Dark Matter and Dark Sector

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Scalar	$\lambda_{HP}\|H\|^2S^2 \to$ scalar mixing $\sin\theta$	250	5	invisible S, $\sin\theta \approx 0.03$ (0.20 global-fits)	22	[108]
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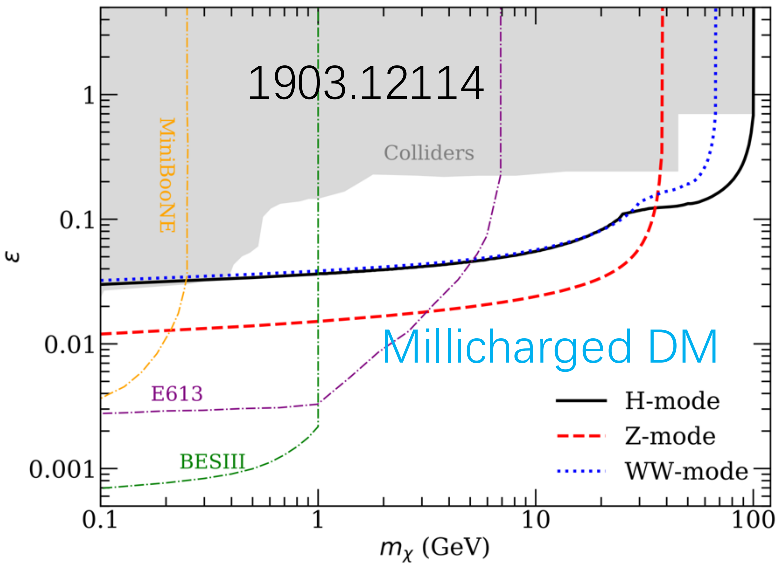
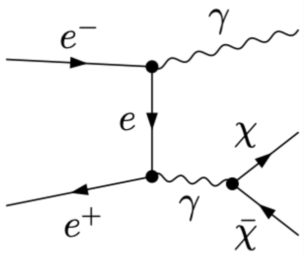
	$y\Phi\bar{F}_L\ell_R$ + H.c.	240	5.6	$y\theta_L \in [10^{-11},\ 10^{-7}]$ ($\lesssim 10^{-8} - 10^{-9}$)	26	[110]
Vector	$A'_\mu\,(e\epsilon J^\mu_{\text{em}} + g_D\bar{\chi}\gamma^\mu\chi)$	250	5	$\epsilon \sim 10^{-3}$ for $g_D = e$ and $m_{A'} < 125$ GeV ($\epsilon \sim 0.02$)	27, 28	[108]
	$\varepsilon A_\mu\bar{\chi}\gamma^\mu\chi$, (millicharge DM)	250	5	$\epsilon \sim 0.1$ for $m_\chi \sim 50$ GeV	29	[111]
		91.2	2.6	$\epsilon \sim 0.02$ for $m_\chi \sim 5$ GeV		
		160	16	$\epsilon \sim 0.5$ for $m_\chi \sim 10$ GeV		
	$\frac{1}{2}\mu_\chi\bar{\chi}\sigma^{\mu\nu}\chi F_{\mu\nu} + \frac{i}{2}d_\chi\bar{\chi}\sigma^{\mu\nu}\gamma^5\chi F_{\mu\nu}$	91.2	100	$\mu_\chi, d_\chi \sim 4\times10^{-7}$ $(4\times10^{-6})\mu_B$ for $m_\chi < 25$ GeV	30	[112]
	$-a_\chi\bar{\chi}\gamma^\mu\gamma^5\chi\partial^\nu F_{\mu\nu} + b_\chi\bar{\chi}\gamma^\mu\chi\partial^\nu F_{\mu\nu}$	240	20	$a_\chi, b_\chi \sim 10^{-6}$ (2×10^{-6}) GeV^{-2} for $m_\chi < 80$ GeV		
EFT	$\frac{1}{\Lambda^2}\sum_i (\bar{\chi}\gamma_\mu(1-\gamma_5)\chi)\,(\bar{\ell}\gamma^\mu(1-\gamma_5)\ell)$	250	5	$\Lambda_i \sim 2$ TeV $(m_\chi = 0)$ (Null)	31	[113]
	$\frac{1}{\Lambda_A^2}\bar{\chi}\gamma_\mu\gamma_5\chi\bar{\ell}\gamma^\mu\gamma_5\ell$	250	5	$\Lambda_A \sim 1.5$ TeV (Null)	32	[111]
	$\sum_i \frac{1}{\Lambda_i^2}\,(\bar{e}\Gamma_\mu e)\,(\bar{\nu}_L\Gamma^\mu\chi_L)$ + H.c. $\Gamma_\mu = 1, \gamma_5, \gamma_\mu, \gamma_\mu\gamma_5, \sigma_{\mu\nu}$	240	20	$\Lambda_i \sim 1$ TeV $(m_\chi = 0)$ (Null)	33	[114]

new physics process: $e^+e^- \to \bar{\chi}\chi\gamma$

Vector-portal DM

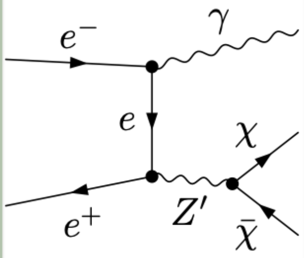


millicharged DM



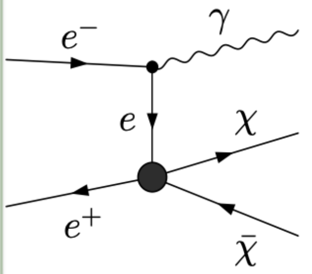
photon mediator

vector-portal DM



Z' mediator

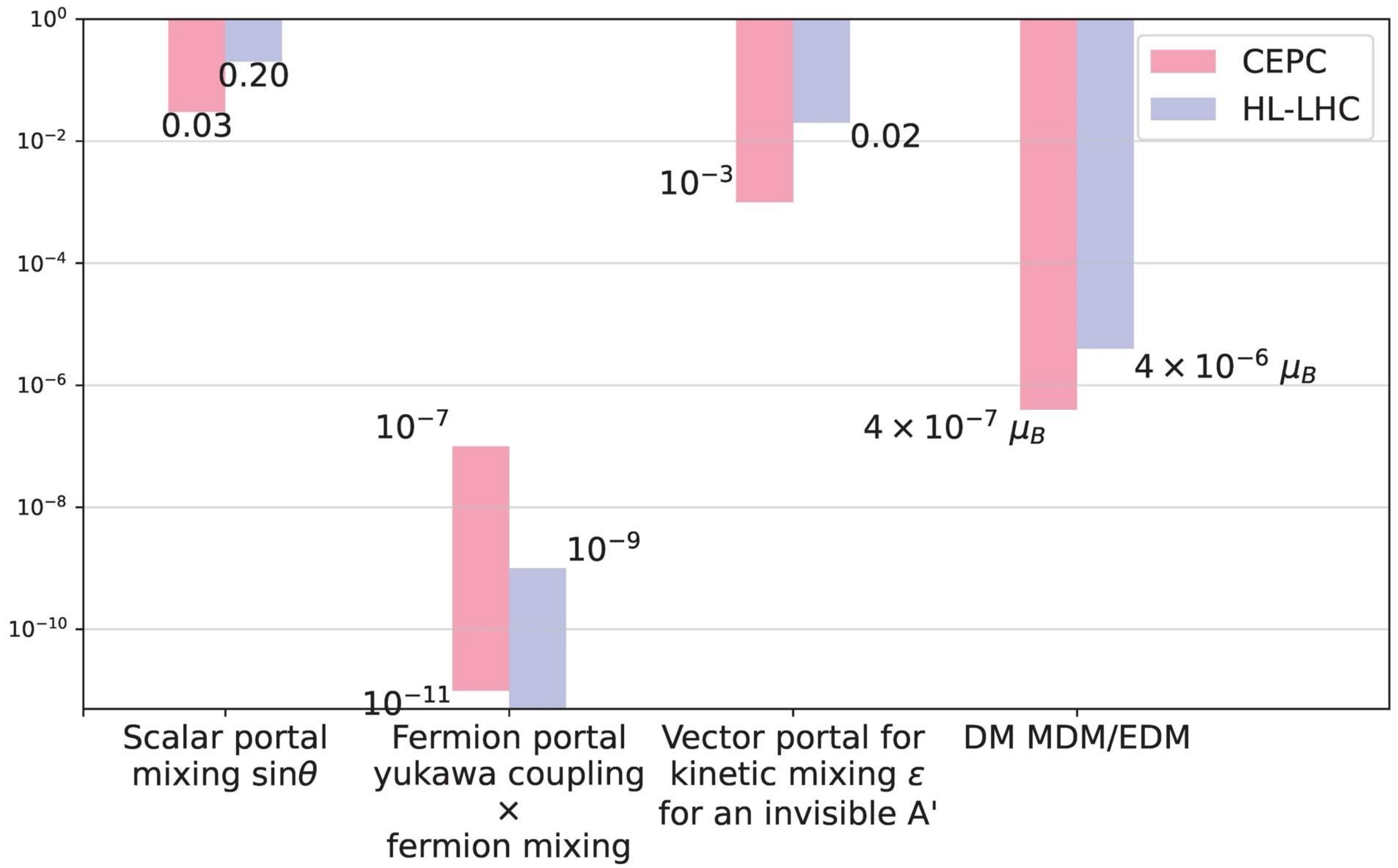
EFT DM



4-F interaction

→ **CEPC can probe low-mass light dark states.**

2. Dark Matter and Dark Sector

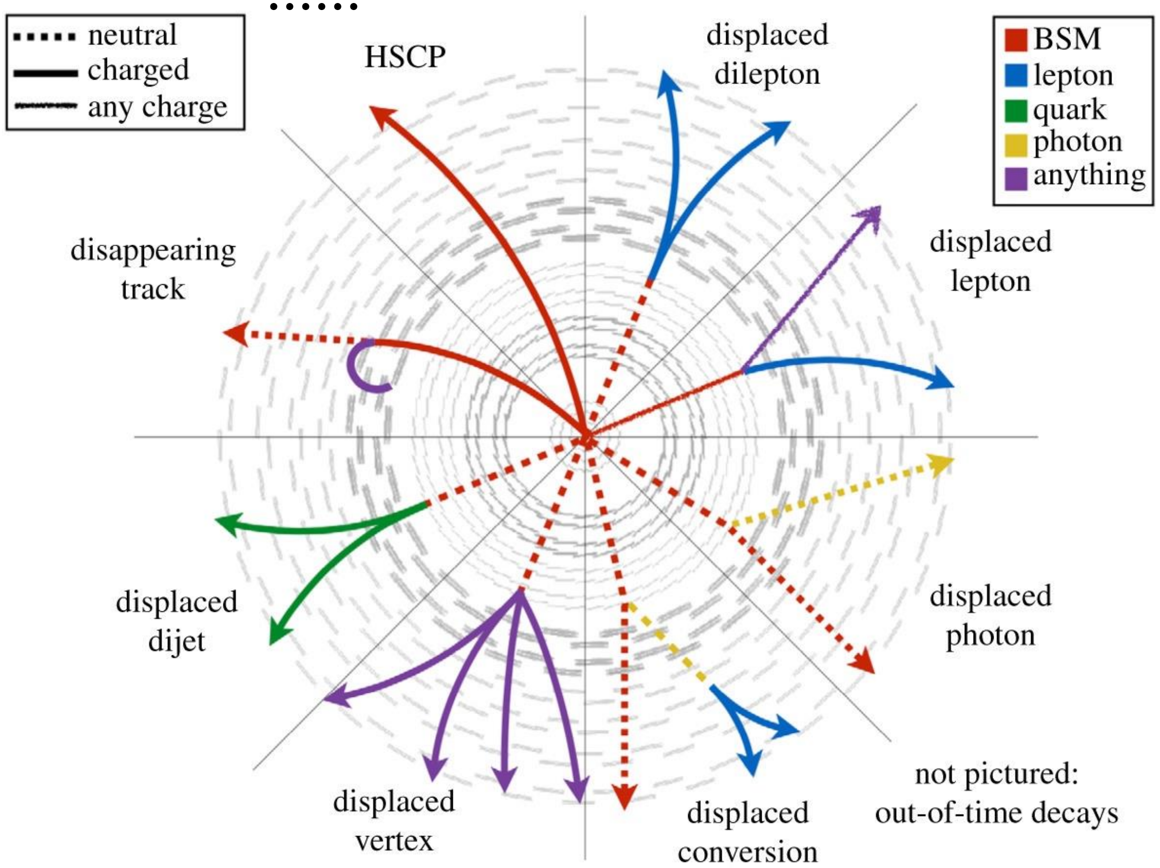


CEPC can improve the sensitivities by roughly one order of magnitude (vs LHC), for some cases.

3. Long-lived particles (LLP)

Long lifetimes result from a few simple physical mechanisms:

- Small couplings (ex. RPV SUSY)
- Limited phase space: small mass splitting (ex. compressed SUSY, …)
- Heavy intermediate states
- ……

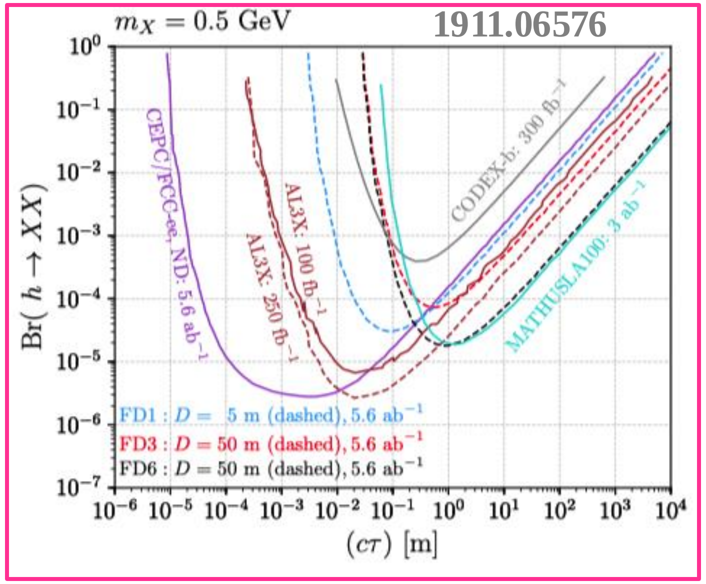


- New scale particles from higgs decay
- SUSY RPV N1 from Z-boson decays
- ALP
- Dark photons
- …

→ Far Detector can help a lot!

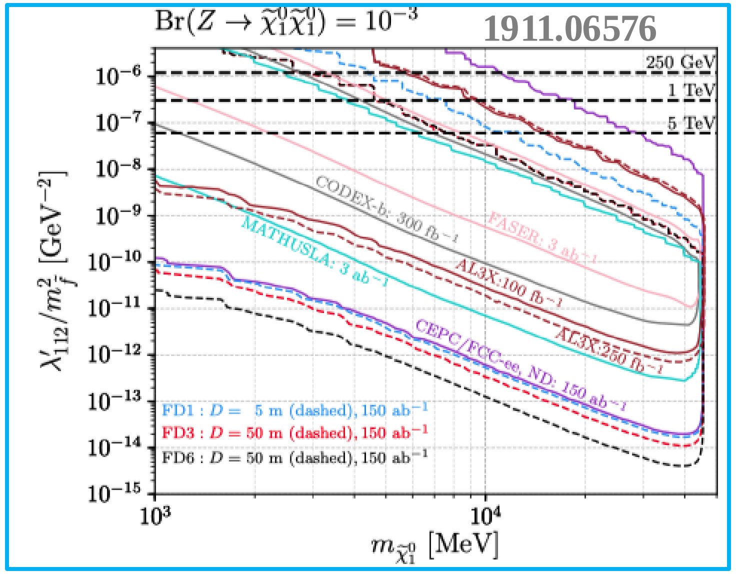
3. Long-lived particles (LLP)

LLP Type	Signal Signature	$\sqrt{s}$ [GeV]	$\mathcal{L}$ [ab^{-1}]	Detector	Sensitivities on parameters [Assumptions]	Figs.	Refs.
New scalar particles (X)	$Z(\to \text{incl.})\, h(\to XX)$, $X \to q\bar{q}/\nu\bar{\nu}$	240	20	ND	$\mathrm{Br}(h \to XX) \sim 10^{-6}$ [$m \in (1, 50)$ GeV, $\tau \in (10^{-3}, 10^{-1})$ ns]	37	[80]
	$Z(\to \text{incl.})\, h(\to XX)$, $X \to \text{incl.}$	240	5.6	ND	$\mathrm{Br}(h \to XX) \sim 3 \times 10^{-6}$ [$m = 0.5$ GeV, $c\tau \sim 5 \times 10^{-3}$ m]	49	[86]
				FD3	$\mathrm{Br}(h \to XX) \sim 7 \times 10^{-5}$ [$m = 0.5$ GeV, $c\tau \sim 1$ m]	49	[86]
				LAYCAST	$\mathrm{Br}(h \to XX) \sim 5 \times 10^{-6}$ [$m = 0.5$ GeV, $c\tau \sim 10^{-1}$ m]	49	[241]
RPV-SUSY neutralinos ($\tilde{\chi}_1^0$)	$Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \to \text{incl.}$	91.2	150	ND	$\lambda'_{112}/m_{\tilde{f}}^2 \in (2 \times 10^{-14}, 10^{-8})$ GeV^{-2} [$m \sim 40$ GeV, $\mathrm{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	43	[86]
				FD3	$\lambda'_{112}/m_{\tilde{f}}^2 \in (10^{-14}, 10^{-9})$ GeV^{-2} [$m \sim 40$ GeV, $\mathrm{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	50	[86]
				LAYCAST	$\lambda'_{112}/m_{\tilde{f}}^2 \in (7 \times 10^{-15}, 10^{-9})$ GeV^{-2} [$m \sim 40$ GeV, $\mathrm{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	50	[241]
ALPs (a)	$Z^{(*)} \to \mu^-\mu^+ a$	91	150	ND	$f_a/C^A_{\mu\mu} \lesssim 950$ GeV	44	[85]
	$\gamma\, a$, $a \to \gamma\gamma$	91.2	150	ND	$C_{\gamma\gamma}/\Lambda \sim 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 2$ GeV]	51	[241]
				FD3	$C_{\gamma\gamma}/\Lambda \sim 6 \times 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 0.3$ GeV]	51	[242]
				LAYCAST	$C_{\gamma\gamma}/\Lambda \sim 2 \times 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 0.7$ GeV]	51	[241]
Hidden valley particles (π_V^0)	$Z\, h(\to \pi_V^0\pi_V^0)$, $\pi_V^0 \to b\bar{b}$	350	1.0	ND	$\sigma(h) \times \mathrm{BR}(h \to \pi_v^0\pi_v^0) \sim 10^{-4}$ pb [$m \in (25, 50)$ GeV, $\tau \sim 10^2$ ps]	41	[243]
Dark photons (γ_D)	$Z(\to q\bar{q})\, h(\to \gamma_D\gamma_D)$, $\gamma_D \to \ell^-\ell^+/q\bar{q}$	250	2.0	ND	$\mathrm{Br}(h \to \gamma_D\gamma_D) \sim 10^{-5}$, [$m \in (5, 10)$ GeV, $\tau \sim 10^2$ ps, $\epsilon \in (10^{-6}, 10^{-7})$]	42	[83]



Light Scalars from Exotic Higgs Decays

FD can extend and complement the sensitivity to the LLPs compared with Near Detector

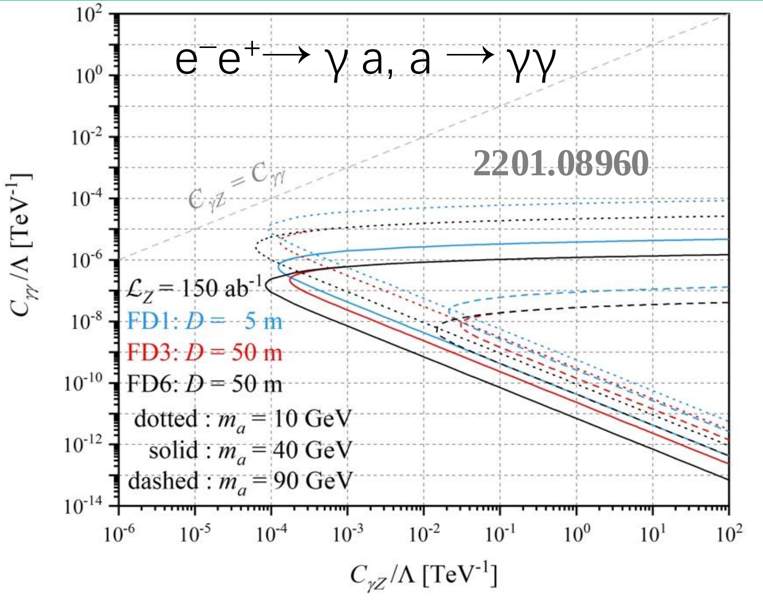


SUSY RPV Neutralino1 from Z Decays

3. Long-lived particles (LLP)

LLP Type	Signal Signature	$\sqrt{s}$ [GeV]	$\mathcal{L}$ [ab^{-1}]	Detector	Sensitivities on parameters [Assumptions]	Figs.	Refs.
New scalar particles (X)	$Z(\to \text{incl.})\, h(\to XX)$, $X \to q\bar{q}/\nu\bar{\nu}$	240	20	ND	$\text{Br}(h \to XX) \sim 10^{-6}$ [$m \in (1, 50)$ GeV, $\tau \in (10^{-3}, 10^{-1})$ ns]	37	[80]
	$Z(\to \text{incl.})\, h(\to XX)$, $X \to \text{incl.}$	240	5.6	ND	$\text{Br}(h \to XX) \sim 3 \times 10^{-6}$ [$m = 0.5$ GeV, $c\tau \sim 5 \times 10^{-3}$ m]	49	[86]
				FD3	$\text{Br}(h \to XX) \sim 7 \times 10^{-5}$ [$m = 0.5$ GeV, $c\tau \sim 1$ m]	49	[86]
				LAYCAST	$\text{Br}(h \to XX) \sim 5 \times 10^{-6}$ [$m = 0.5$ GeV, $c\tau \sim 10^{-1}$ m]	49	[241]
RPV-SUSY neutralinos ($\tilde{\chi}_1^0$)	$Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \to \text{incl.}$	91.2	150	ND	$\lambda'_{112}/m_{\tilde{f}}^2 \in (2 \times 10^{-14}, 10^{-8})$ GeV^{-2} [$m \sim 40$ GeV, $\text{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	43	[86]
				FD3	$\lambda'_{112}/m_{\tilde{f}}^2 \in (10^{-14},\ 10^{-9})$ GeV^{-2} [$m \sim 40$ GeV, $\text{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	50	[86]
				LAYCAST	$\lambda'_{112}/m_{\tilde{f}}^2 \in (7 \times 10^{-15},\ 10^{-9})$ GeV^{-2} [$m \sim 40$ GeV, $\text{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	50	[241]
ALPs (a)	$Z^{(*)} \to \mu^-\mu^+ a$	91	150	ND	$f_a/C^A_{\mu\mu} \lesssim 950$ GeV	44	[85]
	$\gamma\, a$, $a \to \gamma\gamma$	91.2	150	ND	$C_{\gamma\gamma}/\Lambda \sim 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 2$ GeV]	51	[241]
				FD3	$C_{\gamma\gamma}/\Lambda \sim 6 \times 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 0.3$ GeV]	51	[242]
				LAYCAST	$C_{\gamma\gamma}/\Lambda \sim 2 \times 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 0.7$ GeV]	51	[241]
Hidden valley particles (π_V^0)	$Z\, h(\to \pi_V^0\pi_V^0)$, $\pi_V^0 \to b\bar{b}$	350	1.0	ND	$\sigma(h) \times \text{BR}(h \to \pi_v^0\pi_v^0) \sim 10^{-4}$ pb [$m \in (25, 50)$ GeV, $\tau \sim 10^2$ ps]	41	[243]
Dark photons (γ_D)	$Z(\to q\bar{q})\, h(\to \gamma_D\gamma_D)$, $\gamma_D \to \ell^-\ell^+/q\bar{q}$	250	2.0	ND	$\text{Br}(h \to \gamma_D\gamma_D) \sim 10^{-5}$, [$m \in (5, 10)$ GeV, $\tau \sim 10^2$ ps, $\epsilon \in (10^{-6}, 10^{-7})$]	42	[83]

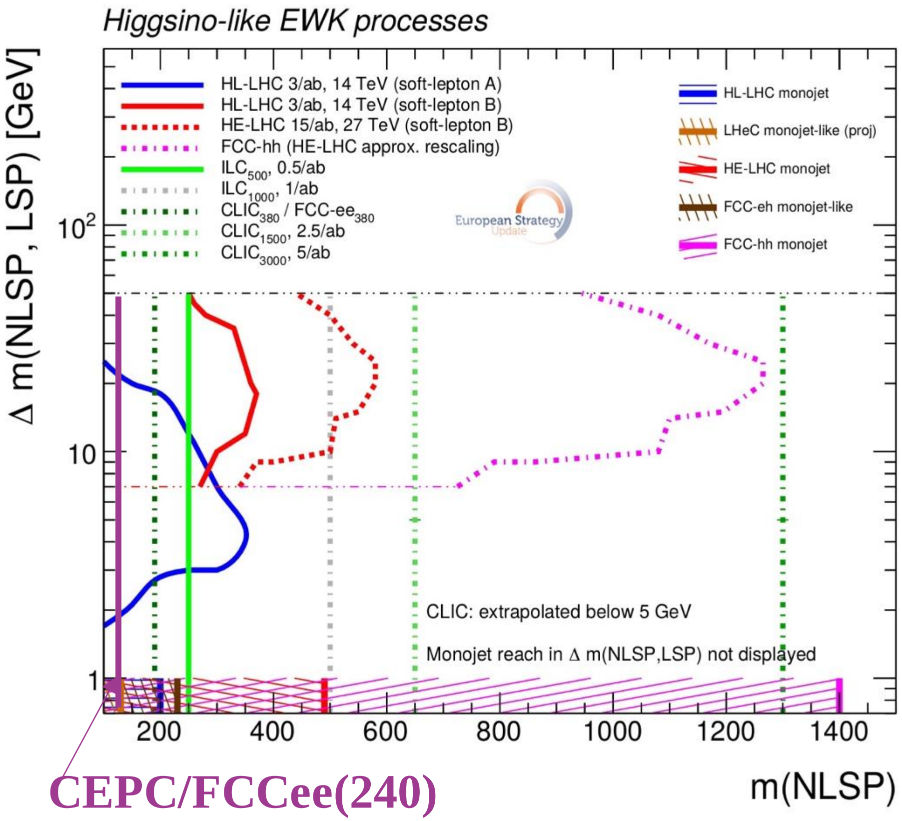
Good sensitivity for ALP

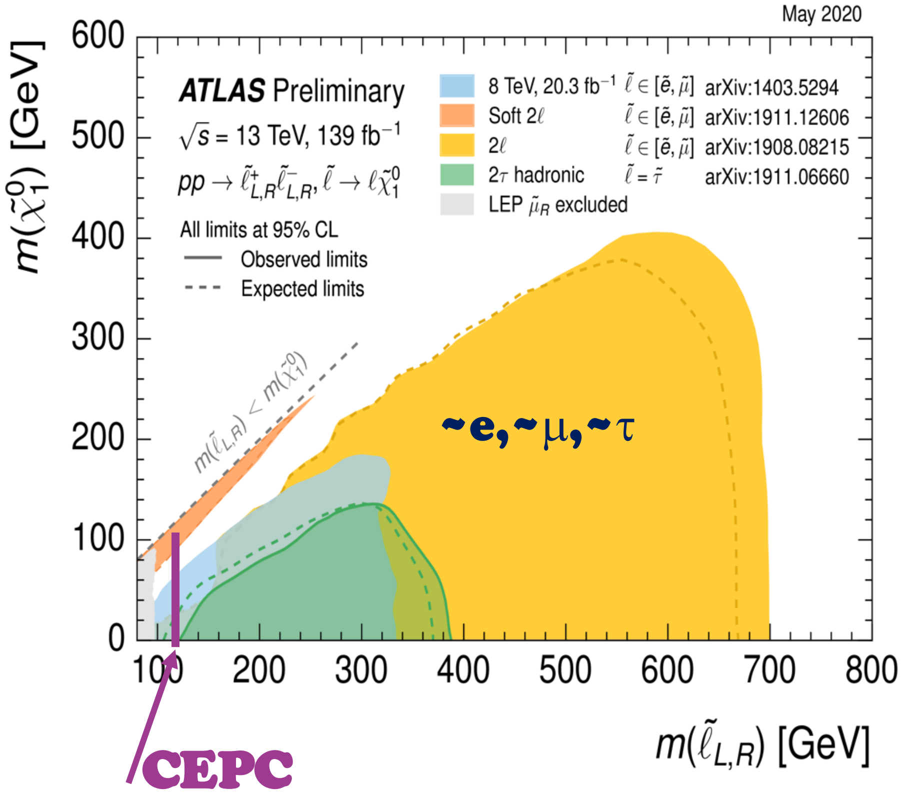


Axion-like Particles

4. SUSY Searches at CEPC

- SUSY: establishes a symmetry between fermions and bosons, solve many big questions: unification, DM, Hierarchy, ……
- Complementary with LHC: lower mass/soft energy region
  - ✓ Mainly light EWKino and slepton for CEPC

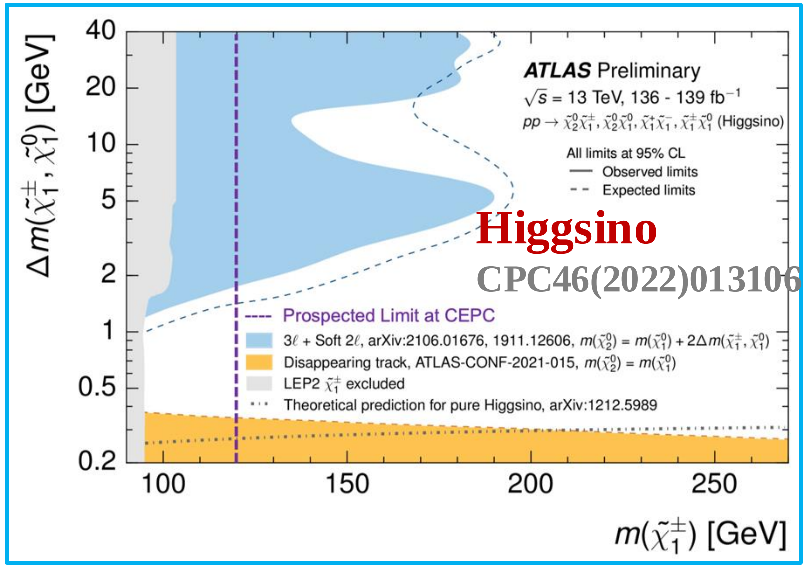




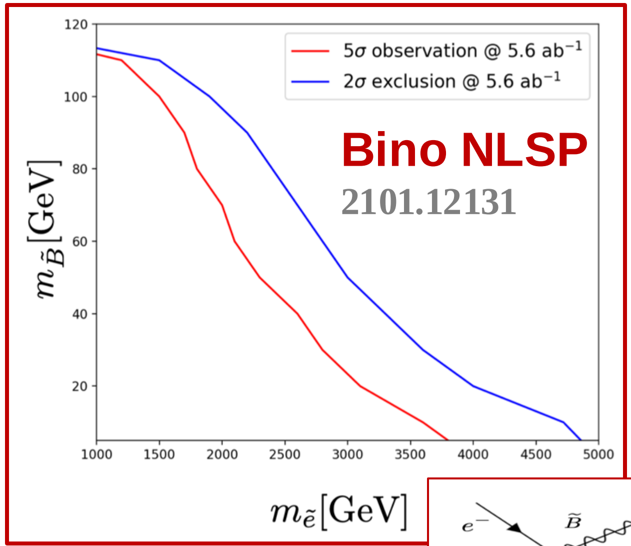
Lepton collider: discovery in all scenarios up to kinematic limit: $\sqrt{s}/2$

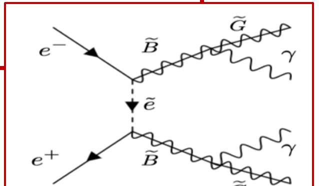
4. SUSY Searches at CEPC

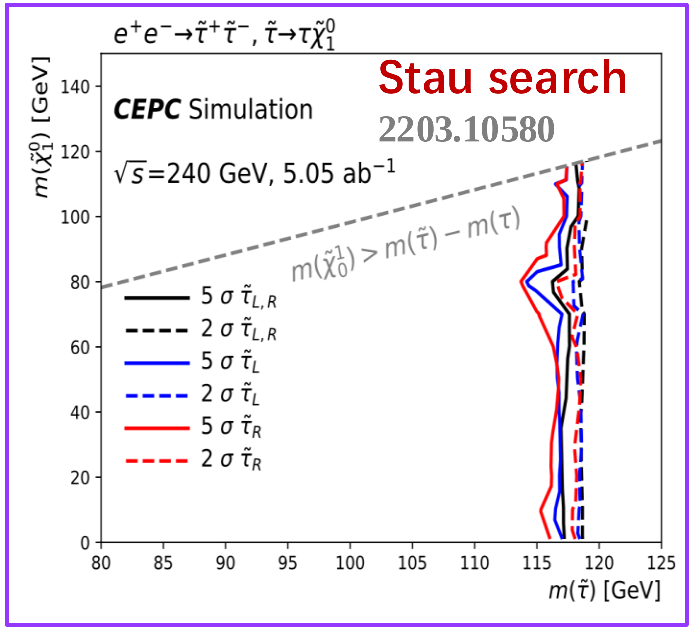
Search	Production	$\sqrt{s}$ [GeV]	$\mathcal{L}[ab^{-1}]$	Sensitivity	Figs.	Ref.
Light electroweakino	chargino pair	240	5.05	chargino excluded up to 120 GeV	57	[339]
	$e^+e^- \to \tilde{B}\tilde{B} \to \gamma\gamma\tilde{G}\tilde{G}$.	240	5.6	selectron excluded up to 4.5 TeV	58	[341]
Light slepton	smuon pair	240	5.05	smuon excluded up 118 GeV	59	[342]
	stau pair	240	5.05	stau excluded up 117 GeV	59	[342]
	smuon pair	360	1	smuon excluded up 178 GeV	59	[]
	stau pair	360	1	stau excluded up 175 GeV	59	[]
	off-shell smuon pair	240	5	smuon excluded up 126 GeV	61	[344]
	$e_R^+e_R^- \to \tilde{\chi}_1^0(\text{bino}) + \tilde{\chi}_1^0(\text{bino}) + \gamma$	240	3	right-handed selectron excluded up to 210 GeV	60	[343]
	$\mathcal{F}$-$SU(5)$	-	-	upper limits on $\tilde{\tau}_1$ up to 115 GeV	62	[345]
	$\mathcal{F}$-$SU(5)$	-	-	upper limits on $\tilde{e}_R$ up to 150 GeV	62	[345]

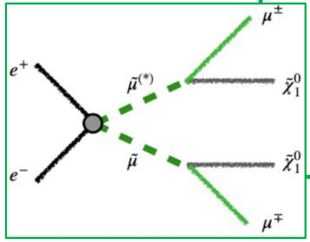


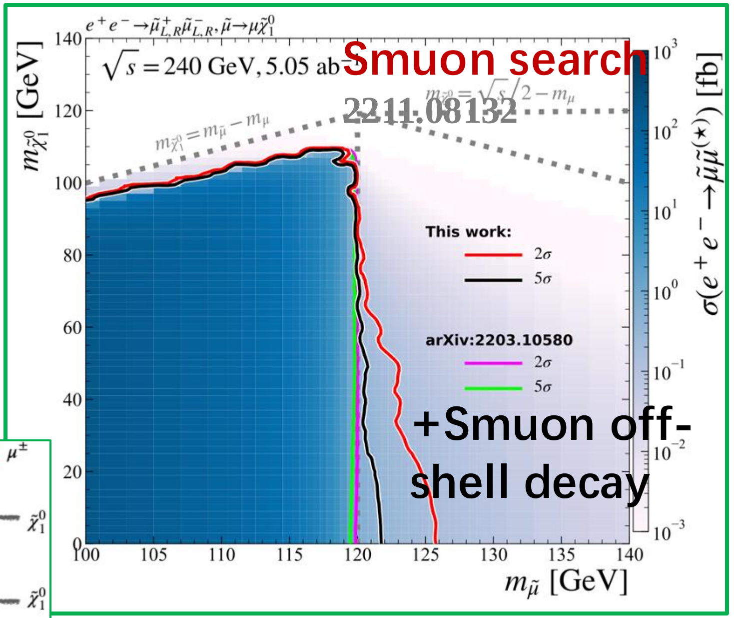
$$\tilde{B} \to \tilde{G}/\tilde{a} + \gamma$$



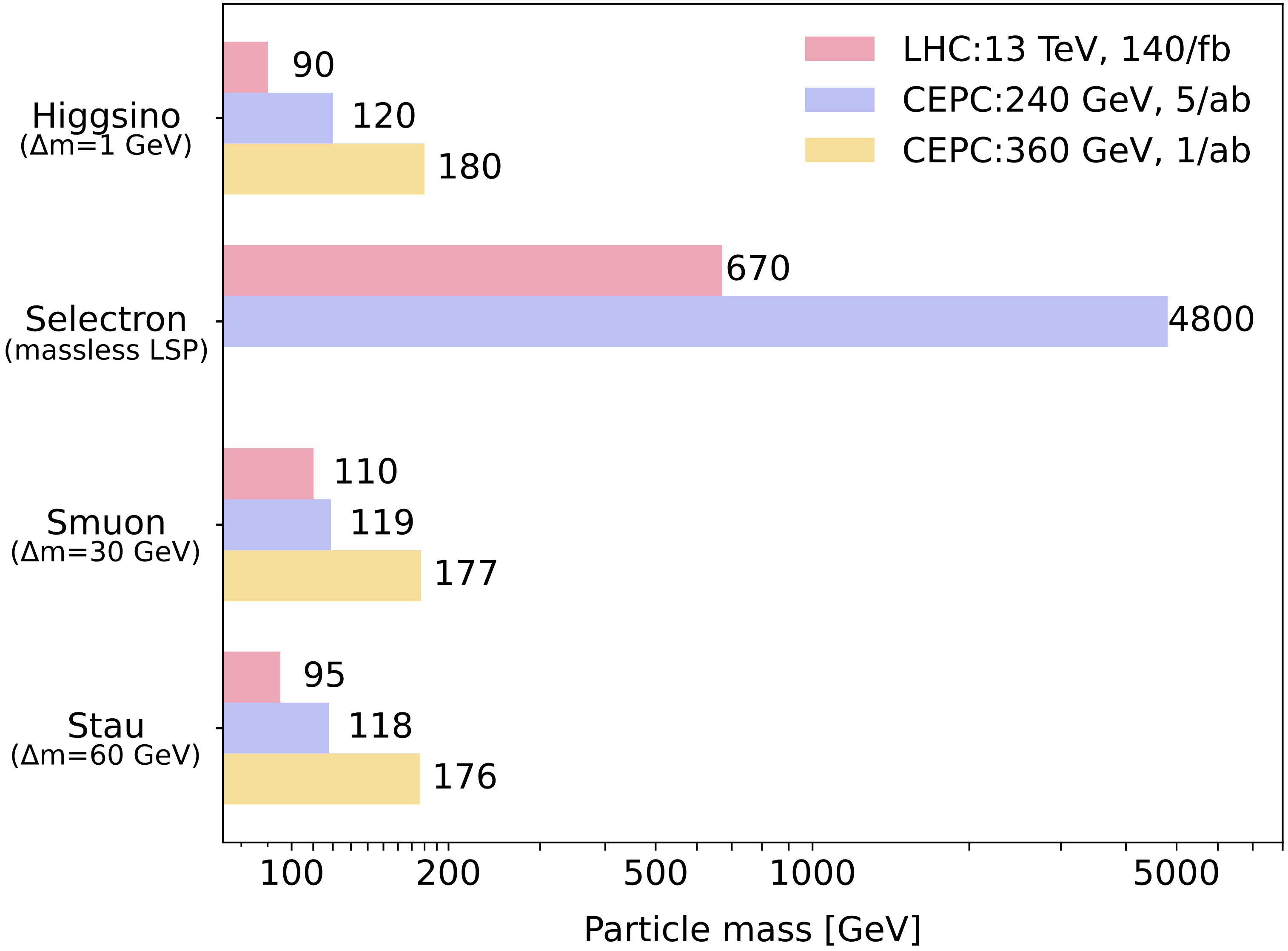




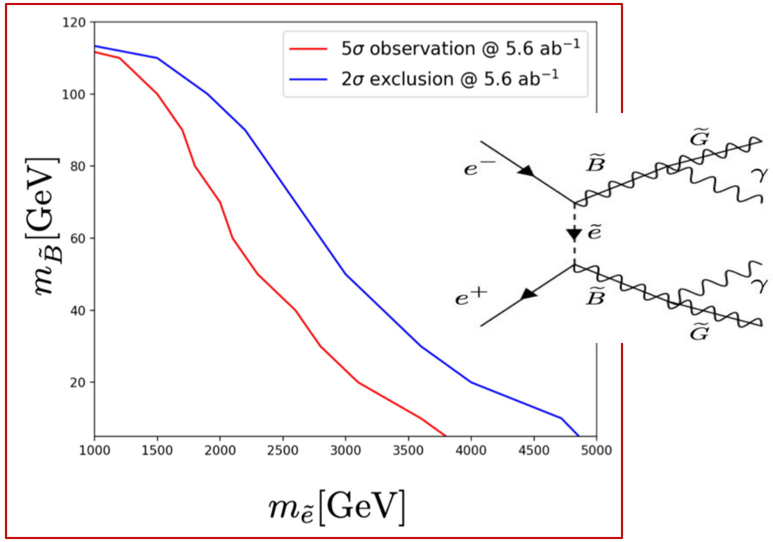




4. SUSY Searches at CEPC



- **Light EWKinos/sleptons: discovery in all scenarios up to kinematic limit √s/2**
- **Heavy selectron from t-channel**



5. Flavor portal NP

- CEPC is also a flavor factory (b,c,tau) when running at Z pole, which has a unique sensitivity for some rare processes due to suppression in SM
- The sensitivity of the flavor sector to new physics is underscored by several factors:
  - cLFV processes
  - Decays of b and c hadrons
  - Light BSM degrees of freedom from flavor transitions (cLFV or quark FCNC processes) with inv. BSM states or LLP

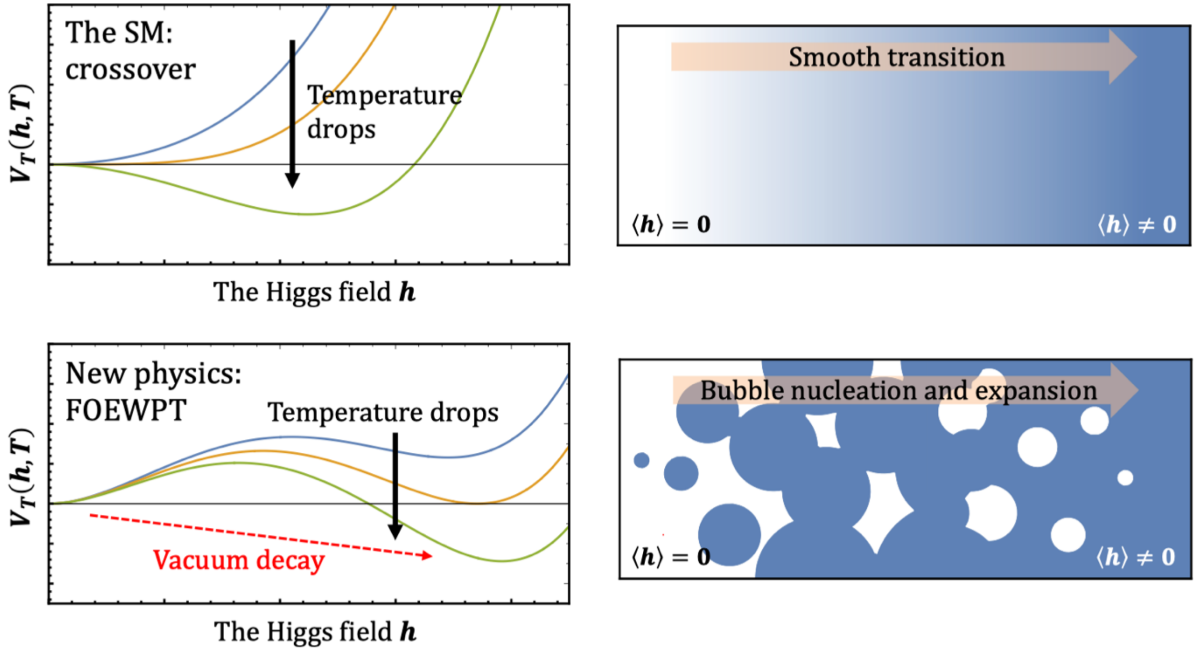
Measurement	Current Limit	CEPC [373]
$\mathrm{BR}(Z \to \tau\mu)$	$< 6.5 \times 10^{-6}$	$\mathcal{O}(10^{-9})$
$\mathrm{BR}(Z \to \tau e)$	$< 5.0 \times 10^{-6}$	$\mathcal{O}(10^{-9})$
$\mathrm{BR}(Z \to \mu e)$	$< 7.5 \times 10^{-7}$	$10^{-8} - 10^{-10}$
$\mathrm{BR}(\tau \to \mu\mu\mu)$	$< 2.1 \times 10^{-8}$	$\mathcal{O}(10^{-10})$
$\mathrm{BR}(\tau \to eee)$	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$
$\mathrm{BR}(\tau \to e\mu\mu)$	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$
$\mathrm{BR}(\tau \to \mu ee)$	$< 1.8 \times 10^{-8}$	$\mathcal{O}(10^{-10})$
$\mathrm{BR}(\tau \to \mu\gamma)$	$< 4.4 \times 10^{-8}$	$\mathcal{O}(10^{-10})$
$\mathrm{BR}(\tau \to e\gamma)$	$< 3.3 \times 10^{-8}$	$\mathcal{O}(10^{-10})$
$\mathrm{BR}(B_s \to \phi\nu\bar{\nu})$	$< 5.4 \times 10^{-3}$	$\lesssim 1\%$ (relative)
$\mathrm{BR}(B^0 \to K^{*0}\tau^+\tau^-)$	-	$\lesssim \mathcal{O}(10^{-6})$
$\mathrm{BR}(B_s \to \phi\tau^+\tau^-)$	-	$\lesssim \mathcal{O}(10^{-6})$
$\mathrm{BR}(B^+ \to K^+\tau^+\tau^-)$	$< 2.25 \times 10^{-3}$	$\lesssim \mathcal{O}(10^{-6})$
$\mathrm{BR}(B_s \to \tau^+\tau^-)$	$< 6.8 \times 10^{-3}$	$\lesssim \mathcal{O}(10^{-5})$
$\mathrm{BR}(B^0 \to 2\pi^0)$	$\pm 16\%$ (relative)	$\pm 0.25\%$ (relative)
$C_{CP}(B^0 \to 2\pi^0)$	± 0.22 (relative)	± 0.01 (relative)
$\mathrm{BR}(B_c \to \tau\nu)$	$\lesssim 30\%$	$\pm 0.5\%$ (relative)
$\mathrm{BR}(B_c \to J/\psi\tau\nu)/\mathrm{BR}(B_c \to J/\psi\mu\nu)$	$\pm 0.17 \pm 0.18$	$\pm 2.5\%$ (relative)
$\mathrm{BR}(B_s \to D_s^{(*)}\tau\nu)/\mathrm{BR}(B_s \to D_s^{(*)}\mu\nu)$	-	$\pm 0.2\%$ (relative)
$\mathrm{BR}(\Lambda_b \to \Lambda_c\tau\nu)/\mathrm{BR}(B_c \to \Lambda_c\mu\nu)$	± 0.076	$\pm 0.05\%$ (relative)
$\mathrm{BR}(\tau \to \mu X_{\mathrm{inv.}})$	7×10^{-4}	(3-5)$\times 10^{-6}$
$\mathrm{BR}(B \to \mu X_{\mathrm{LLP}}(\to \mu\mu))$	-	$\mathcal{O}(10^{-10})$ (optimal)

Preliminary sensitivities of BSM flavor physics probes at CEPC

> two orders of magnitude improv.

6. EWPT at CEPC

- **The nature of Electroweak Phase Transition (EWPT) deeply impacts the thermal history of the Universe, closely linked to puzzles of DM, matter-antimatter asymmetry**
  - **Probing the nature of EWPT at colliders**

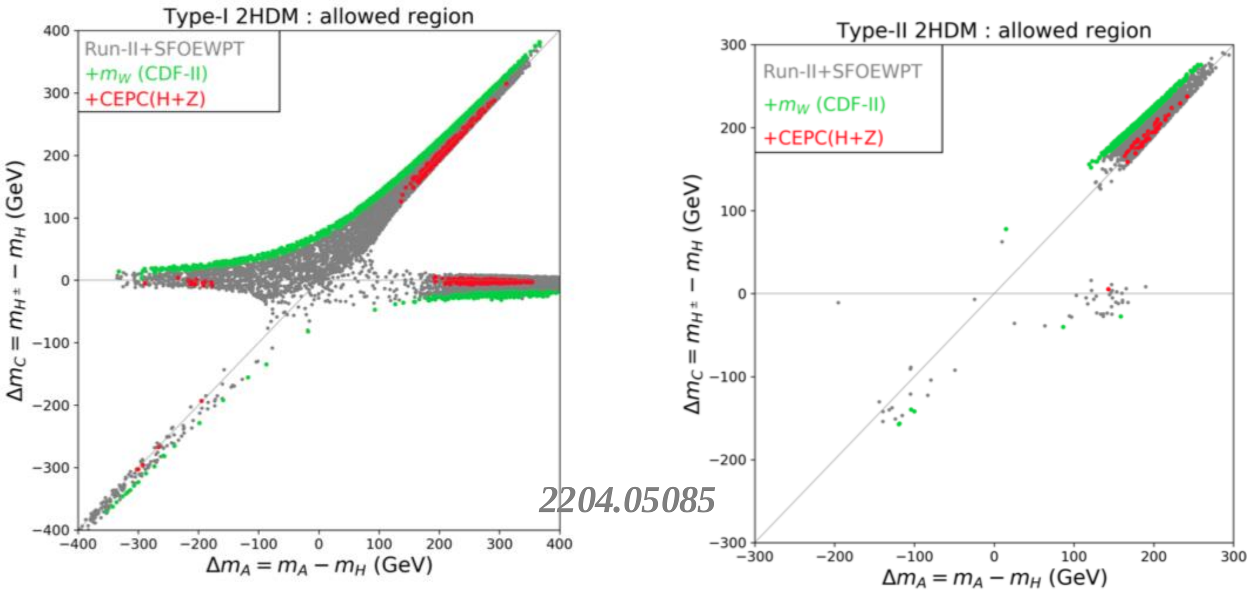


In the SM, the transition is a smooth crossover

In NP, the scalar potential exhibits a barrier, allowing for a FOEWPT with bubble nucleation and expansion

  - **Higgs precision measurements**
  - **Higgs exotic decay**

6. EWPT at CEPC



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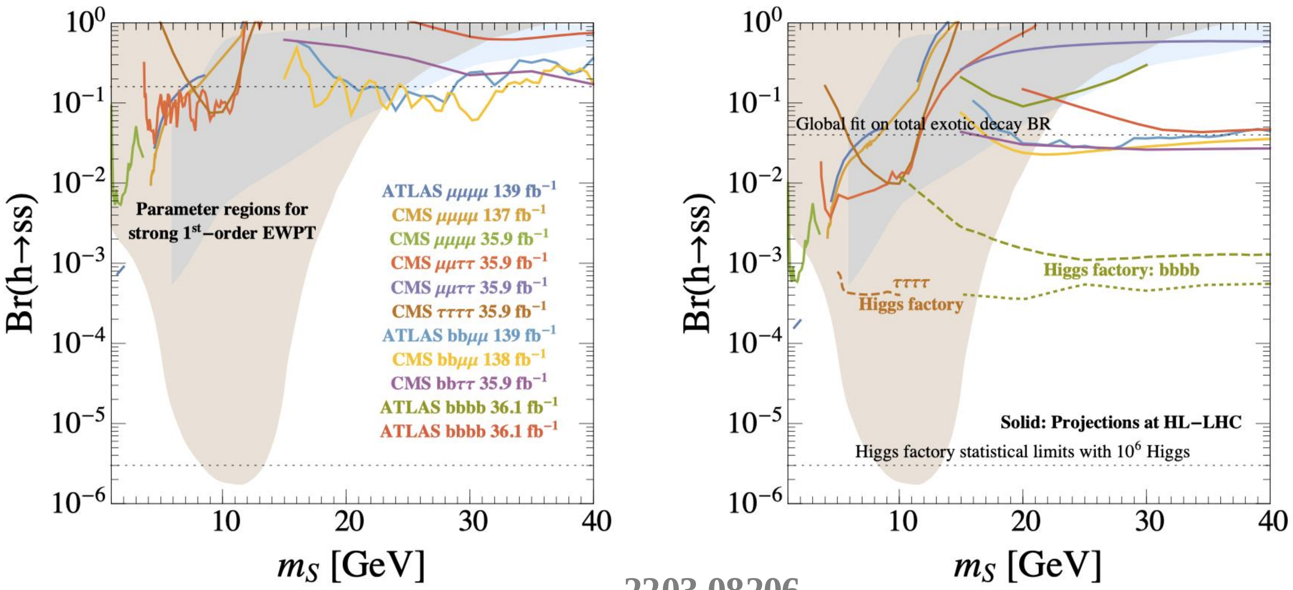
Under current constraints, both Type-I and Type-II 2HDM can explain the SFOEWPT, Z-pole, **Higgs precision measurements** and mW precision measurement of CDF-II at same time.



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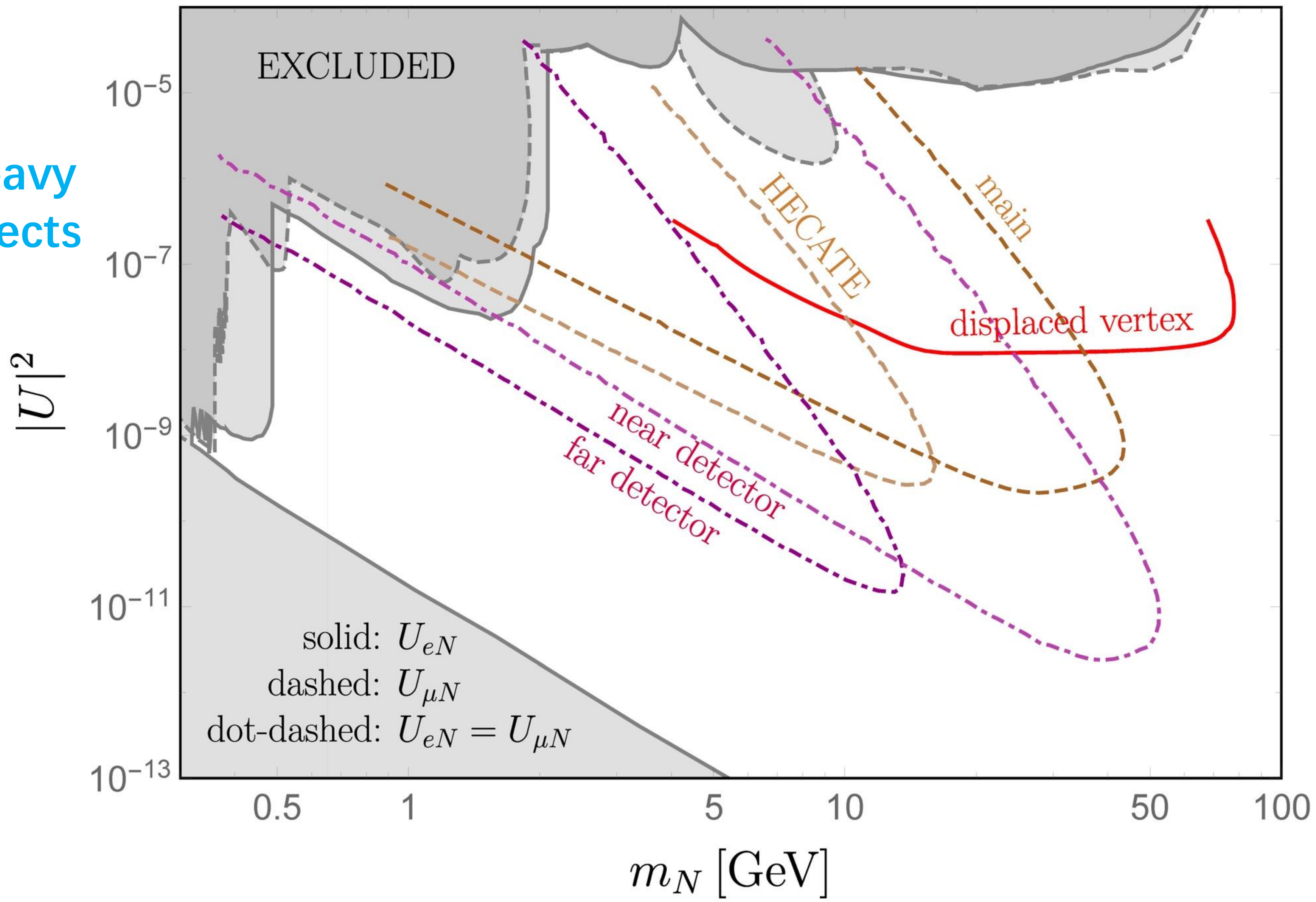
Higgs exotic decay h→ss→XXYY as a probe for the FOEWPT:

CEPC has the potential to probe almost the entire FOEWPT parameter space for 4b and 4tau channels

7. Neutrino physics

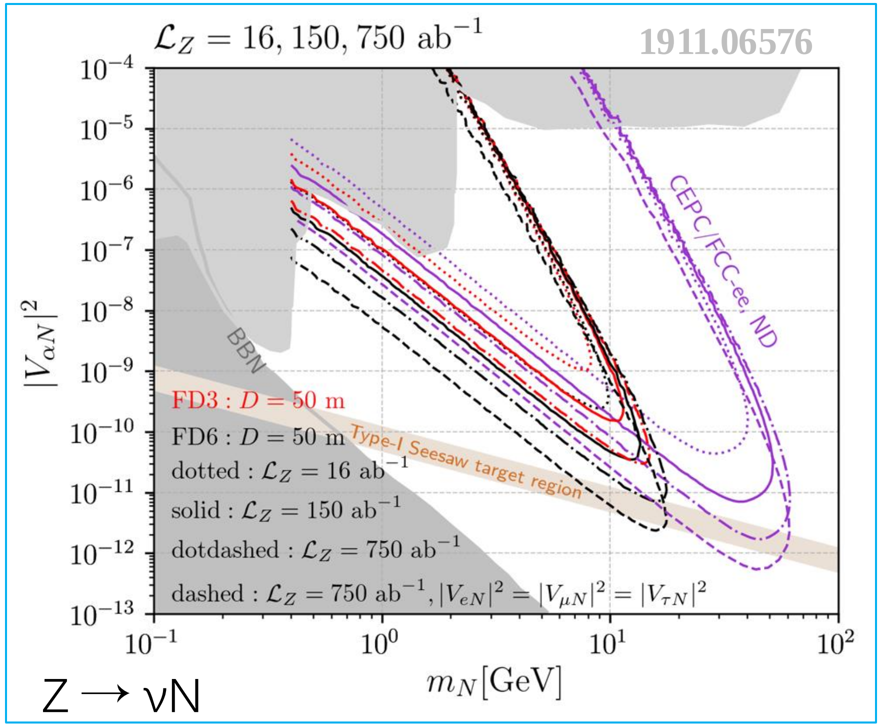
Summary of heavy neutrino prospects @ CEPC

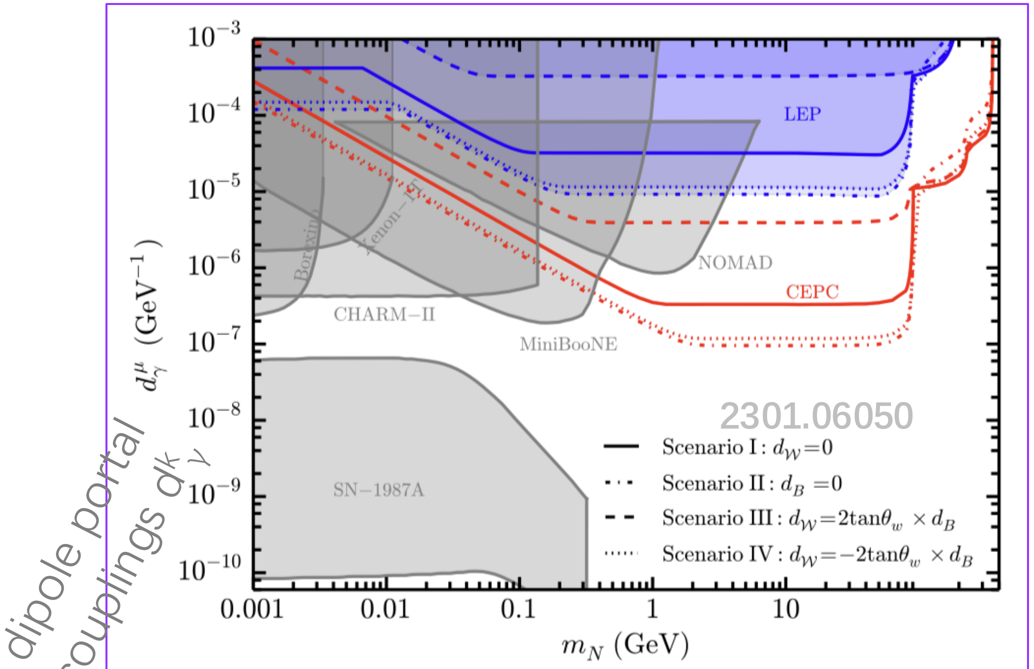


7. Neutrino physics

BSM related neutrino physics from neutrino mass mechanism, new messengers and interactions at EW scale:

- Heavy neutrino (@ND, FD)
- Non-standard neutrino interactions
- Active-sterile neutrino transition magnetic moments
- **Neutral and doubly-charged scalars in seesaw models**
- Connection to leptogenesis (collider probes) and dark matter (sterile neutrino in the νMSM)





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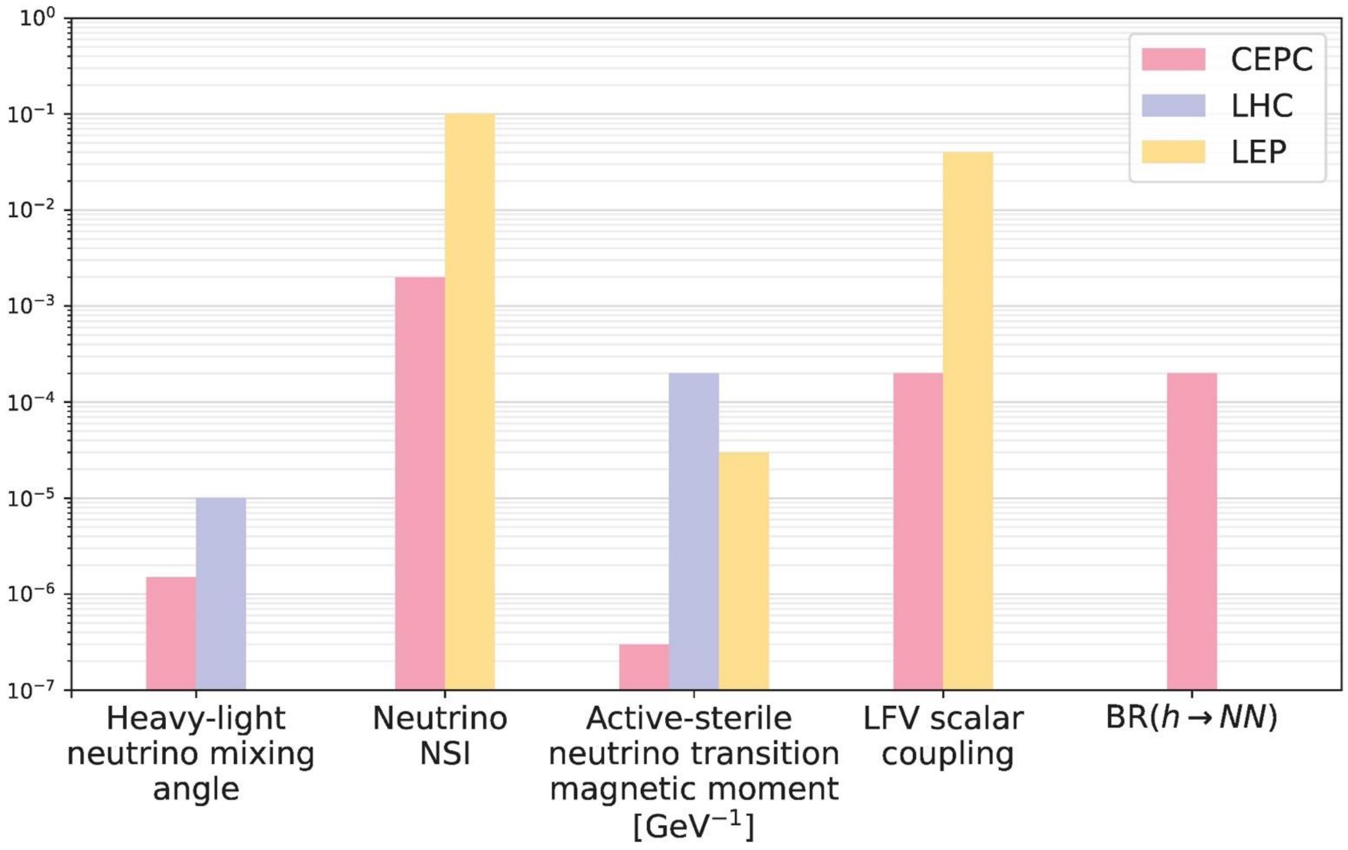
Summary plot of neutrino relevant models

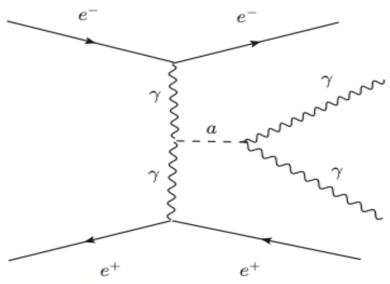


The sensitivities can be improved by roughly 1 to 2 (or more) orders of magnitude (vs LHC & LEP), for some cases.

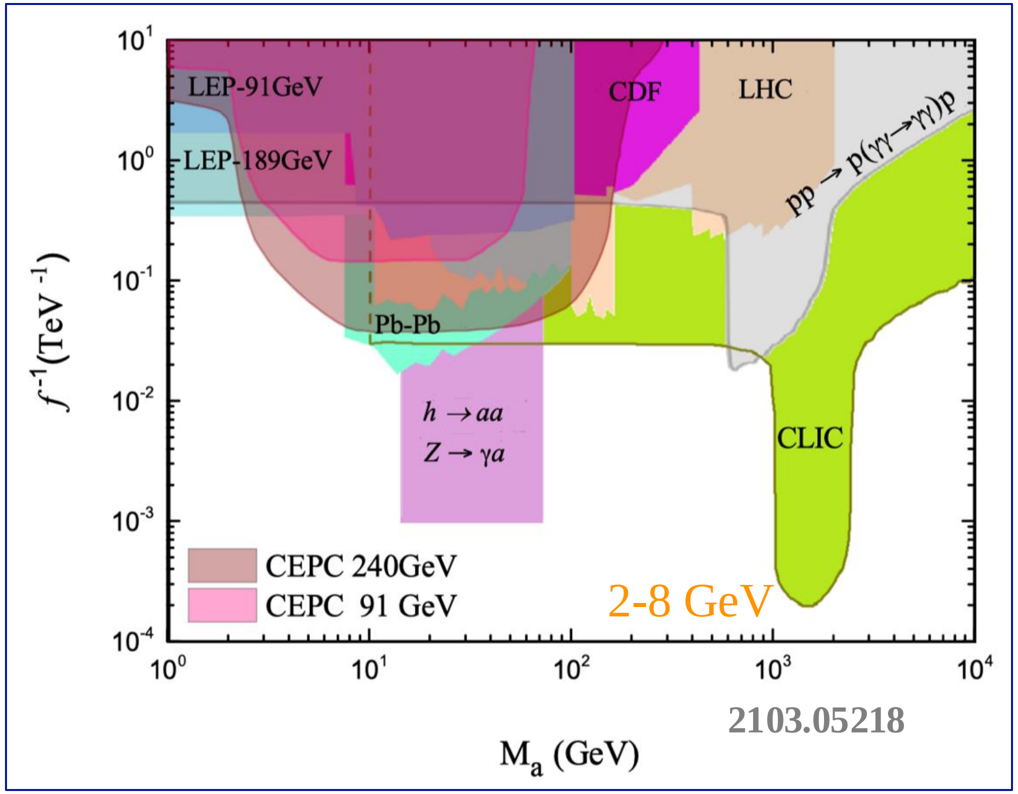
8. More exotics

High precision of Z, h width offers power test of exotics process of
Lepton number/flavor violation, Sterile states, Axion-like particles …

- Axion-like particles (solve "strong-CP" problem)
- Lepton form factors (μ /e g-2, μ /e dipole moments in SUSY, τ weak-electric dipole moments)
- Emergent Hadron Mass
- Exotic lepton mass models
- Spin entanglement
- ……



$e^+e^- \rightarrow \gamma\gamma e^+e^-$



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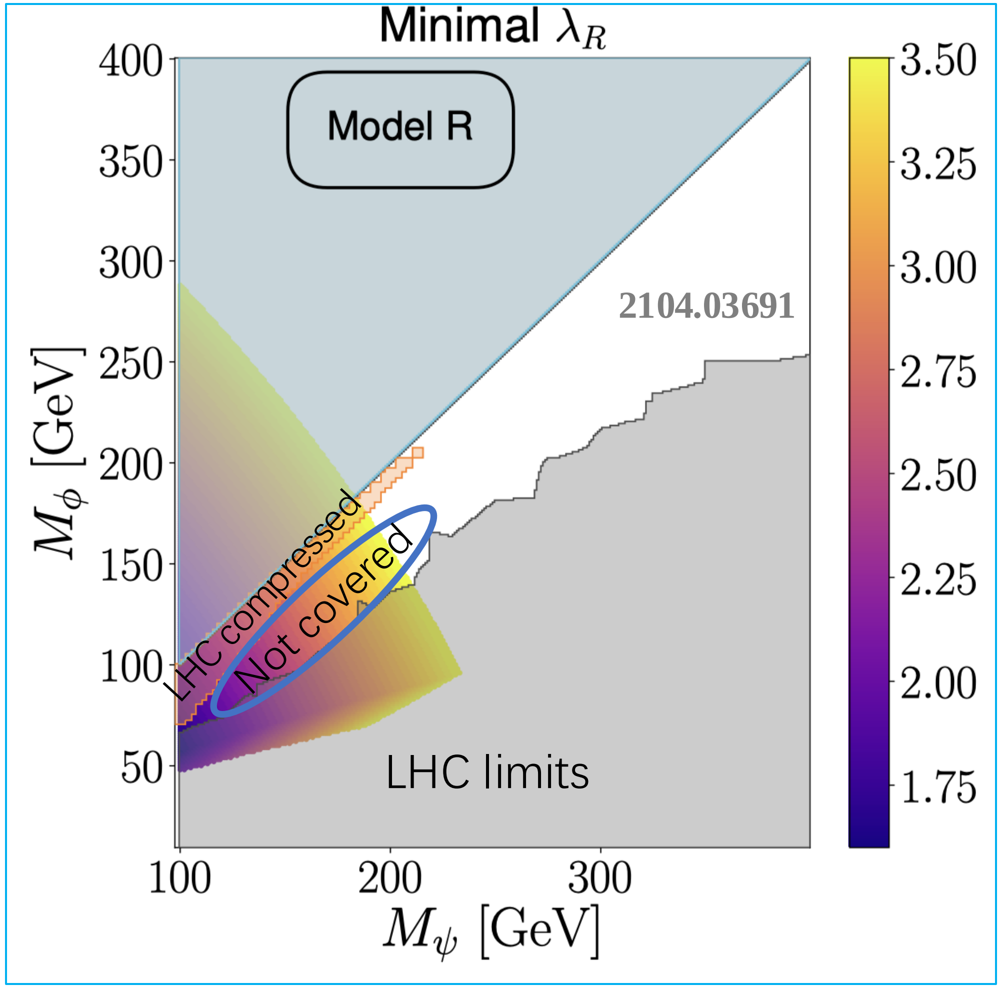
- **Lepton form factors (μ /e g-2, μ /e dipole moments in SUSY, τ weak-electric dipole moments)**
- **Emergent Hadron Mass**
- **Exotic lepton mass models**
- **Spin entanglement**
- **……**

- Light EWKinos, smuon, stau co-annihilation can explain mu g-2 excess
- Gaps from LHC, can cover by CEPC



A simple model with a new scalar and and a new fermion

8. More exotics

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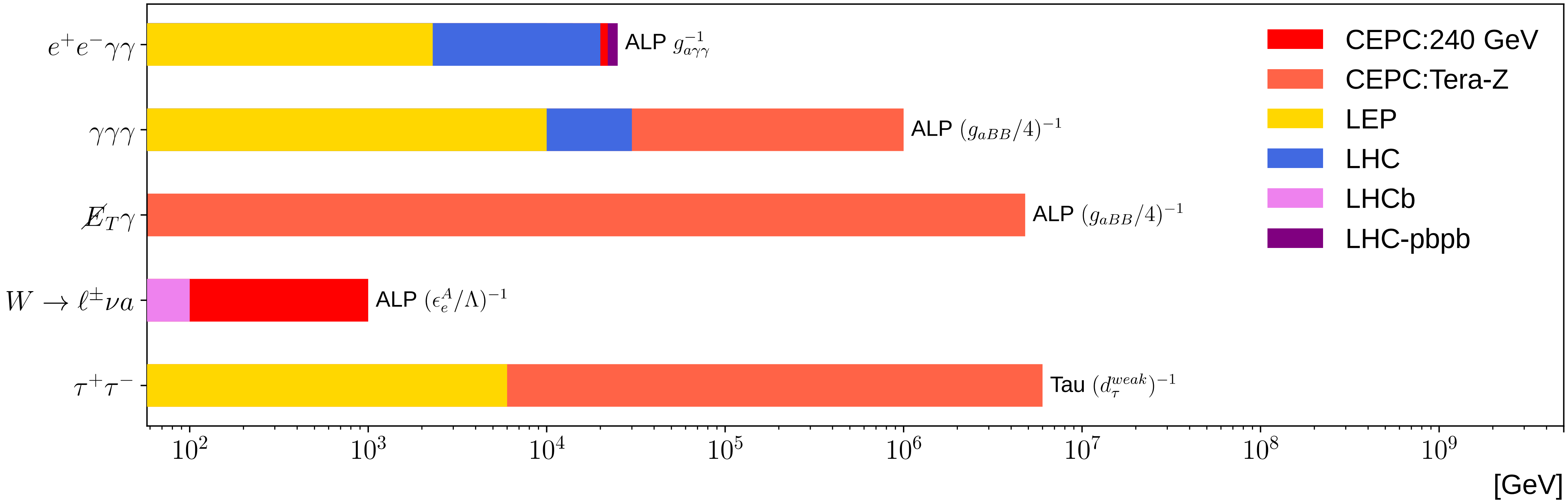
- Emergent Hadron Mass
- Exotic lepton mass models
- Spin entanglement
- ……

Projected energy scale sensitivities via exotic searches at the CEPC

Quantity	Channel	Sensitivity scale (GeV)	CEPC Run
ALP $g_{a\gamma\gamma}^{-1}$	$e^+e^-\gamma\gamma$	6.7×10^3 [637]	Tera-Z
	$e^+e^-\gamma\gamma$	2.2×10^4 [637]	240 GeV
	$\bar{f}fa$	6.5×10^3 [637]	250 GeV
ALP $(g_{aBB}/4)^{-1}$	3γ	10^6 [72]	Tera-Z
	$\not{E}_T\gamma$	4.8×10^6 [72]	Tera-Z
ALP $(\epsilon_e^A/\Lambda)^{-1}$	$W\to\ell^\pm\nu a$	10^3 [639]	240 GeV
Tau $(d_\tau^{weak})^{-1}$	$\tau^+\tau^-$	6×10^6 [667]	Tera-Z
Bell Inequality	$Z,h\to\tau^+\tau^-$	1σ [694]	240 GeV

8. More exotics



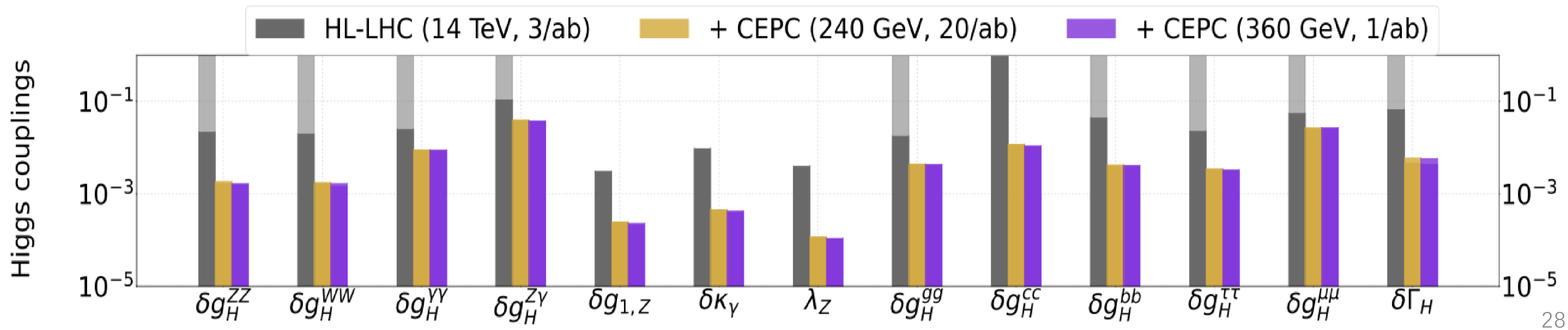
Energy reach in representative exotic search channels at the CEPC. Note the maximal energy reach may apply to different model parameter regions between experiments.

9. Global fits

Global fits: an essential tool to obtaining a thorough understanding of a NP model, and the implications and predictions of the models for future searches and experiments.

- **SMEFT**
- **2HDM**
- **SUSY global fits**

- **Global fit for SMEFT operators at future colliders**
- CEPC can improve the Higgs couplings by a factor of a few, or even orders of magnitude ($\delta g_{1,Z}$, $\delta\kappa_{\gamma}$, and λ_Z.)



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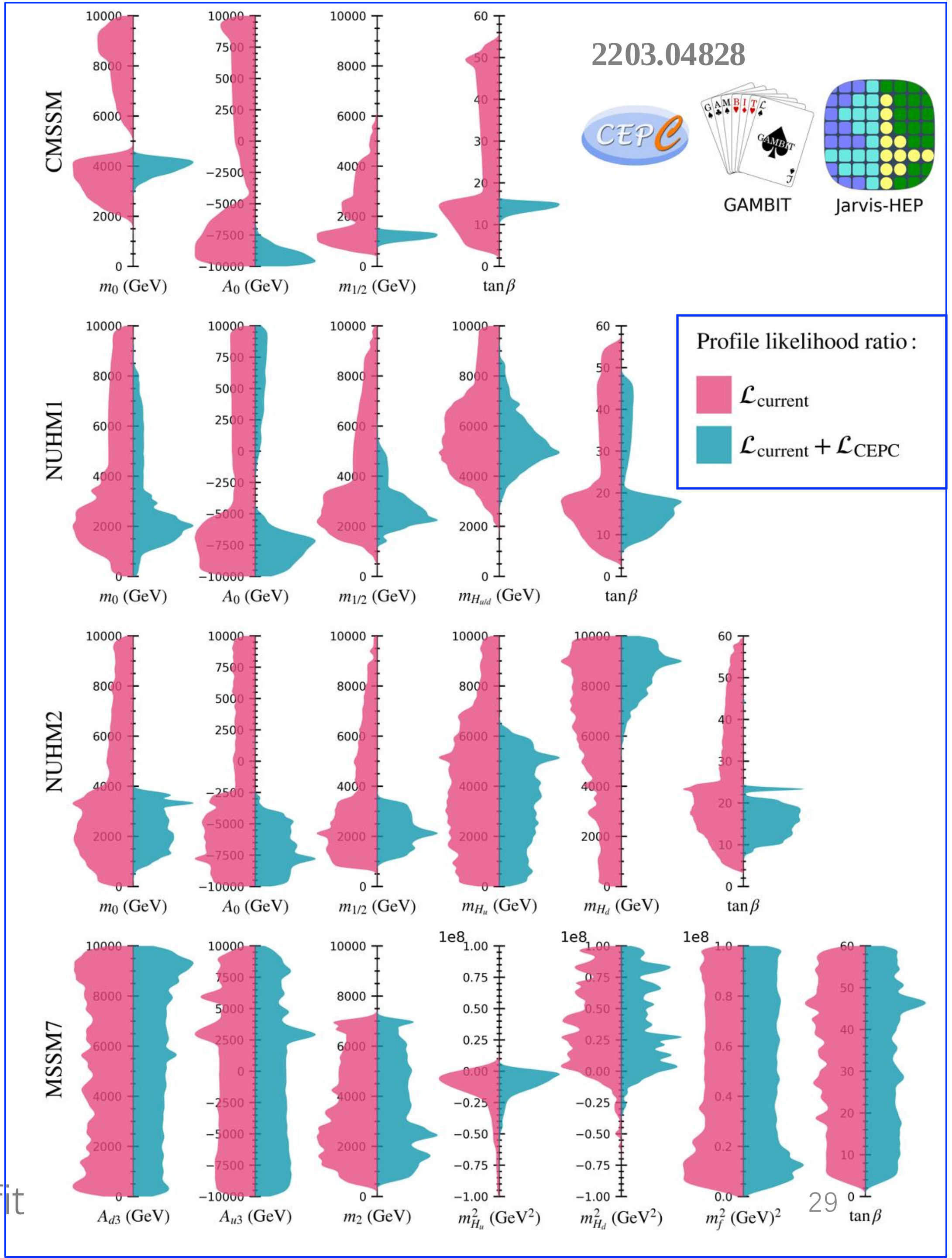
- **SUSY global fits**

CEPC has the potential to greatly enhance our understanding of the parameter space and mass spectrum in the MSSM.



One-dimensional profiled likelihood ratio for the global fit

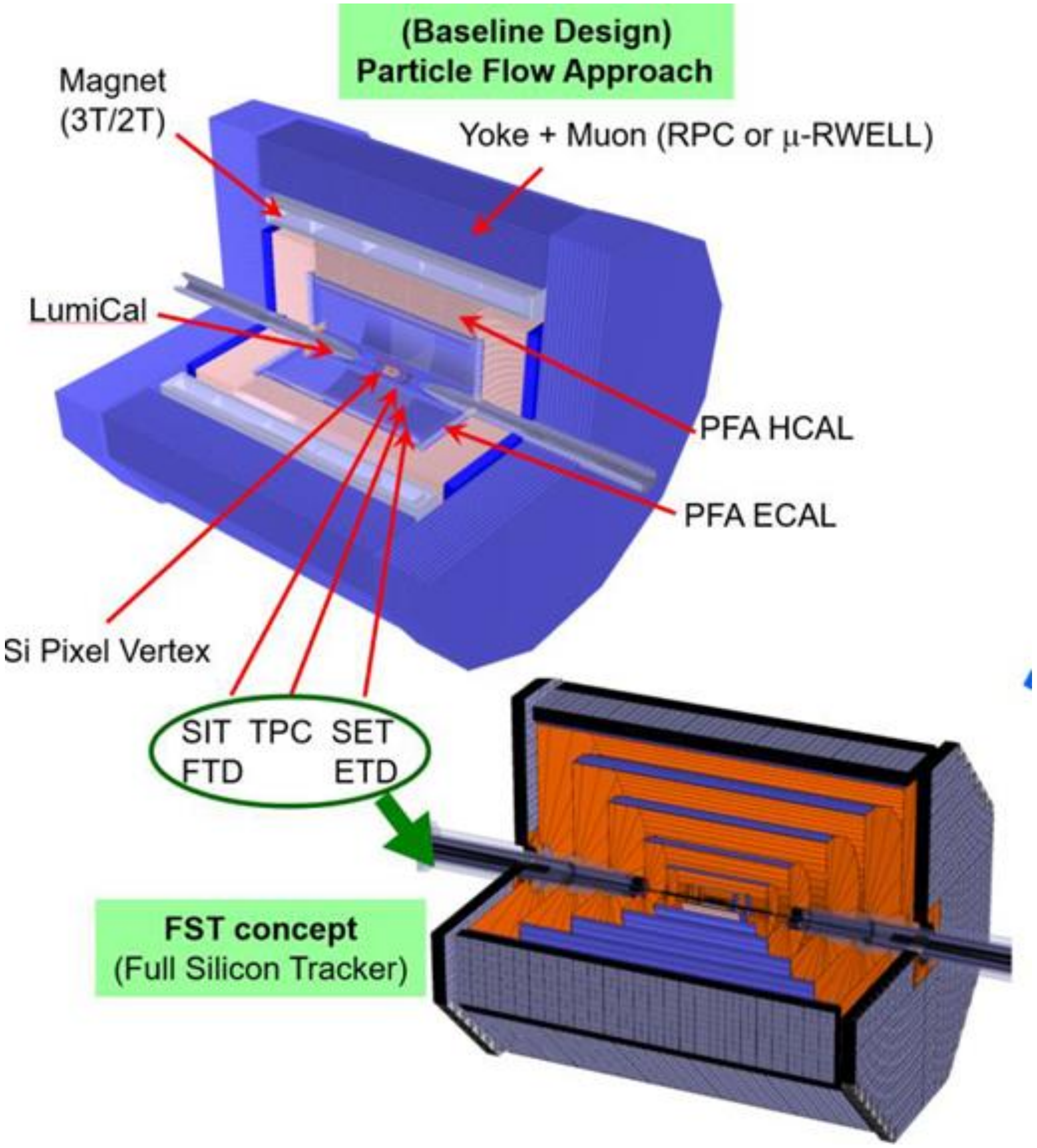
Summary and Outlook

- CEPC has good discovery potential for NP, which is complementary to LHC and has big advantage at low energy/mass scale
- CEPC BSM white paper is preparing and to be ready for review by this year
- Please let us know if you would like to help to polish and review the BSM white paper !

Thanks for your attention!

Backup

CEPC



- About CEPC

ECM=240GeV, higgs factory, 100 km circumference, 2 interaction points.

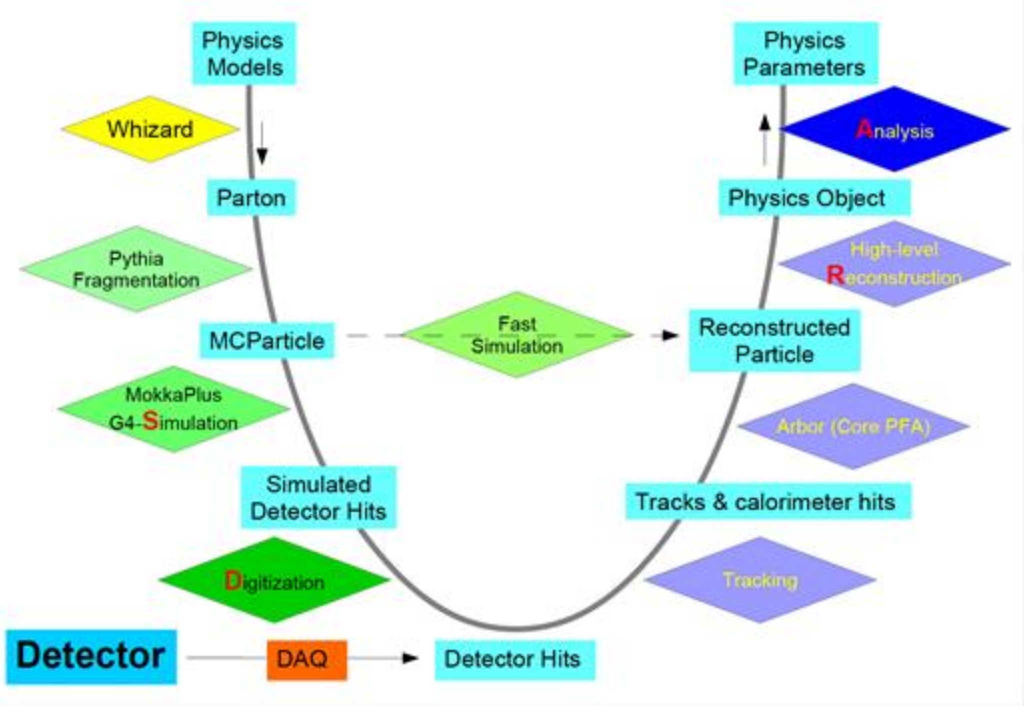
ILD-like detector

- Software

Signal samples: **MadGraph+Pythia8**

Simulation: Mokka

Reconstruction: Marlin



Full simulation reconstruction Chain with Arbor, iterating/validation with hardware studies