合肥工業大學
HEFEI UNIVERSITY OF TECHNOLOGY

Nonstandard neutrino interactions & Neutrino dipole portal at electron colliders

Yu Zhang(张宇)

Hefei University of Technology

Jiajun Liao, YZ, Phys.Rev.D 104 (2021) 3, 035043
YZ, Mao Song, Ran Ding, Liangwen Chen, Phys.Lett.B 829 (2022) 137116
YZ, Wei Liu, Phys.Rev.D 107 (2023) 9, 095031

CEPC味物理-新物理和相关探测技术研讨会，复旦大学，2023/08/18

Introduction

Portal to New Physics

Vector Portal	$F_{\mu\nu}X^{\mu\nu}$
Higgs Portal	$H^\dagger H \phi^\dagger \phi$
Neutrino Portal	HLN_R

Only three *renormalizable* portals in the Standard Model

Ballet, Hostert, Pascoli, 1903.07589

Nonstandard Interactions

$$\mathcal{L}^{eff} = \mathcal{L}_{SM} + \frac{c^{d=5}}{\Lambda} \mathcal{O}^{d=5} + \frac{c^{d=6}}{\Lambda^2} \mathcal{O}^{d=6} + \dots .$$

Neutrino mass

$$\frac{c^{d=5}}{\Lambda}(\overline{L_L^c}\tilde{\phi}^*)(\tilde{\phi}^\dagger L_L)$$

P. Minkowski 1977, T. Yanagida 1979, Weinberg 1979, S.L. Glashow 1980

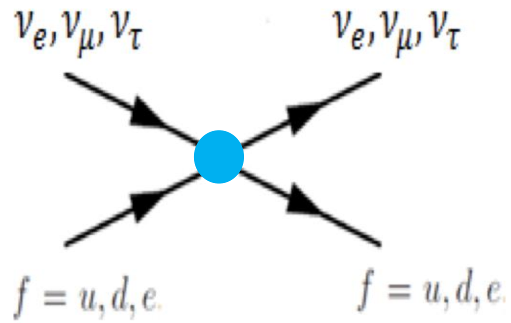
Seesaw mechanism

Nonstandard Interactions (NSI)

$$\mathcal{L}_{\text{NC-NSI}} = -2\sqrt{2}G_F \epsilon_{\alpha\beta}^{fC}[\overline{\nu_\alpha}\gamma^\rho P_L \nu_\beta]\,[\bar{f}\gamma_\rho P_C f]\ ,$$

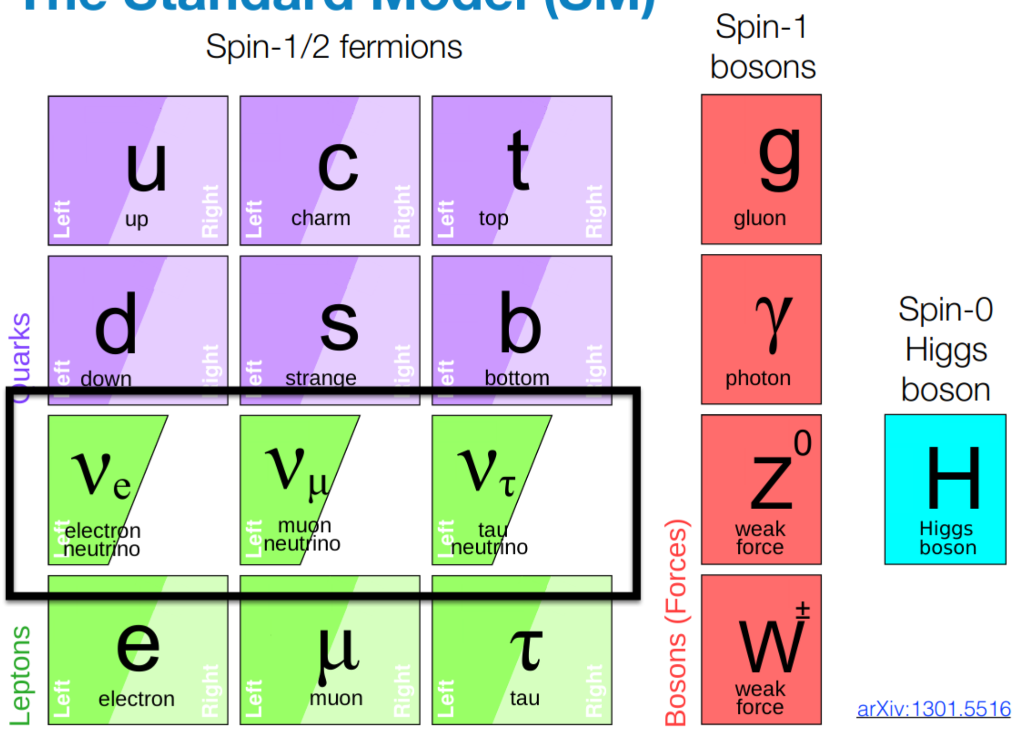
$$\mathcal{L}_{\text{CC-NSI}} = -2\sqrt{2}G_F \epsilon_{\alpha\beta}^{ff'C}[\overline{\nu_\beta}\gamma^\rho P_L \ell_\alpha]\,[\bar{f}'\gamma_\rho P_C f]\ ,$$

Wolfenstein, Phys. Rev., D17, 2369 (1978)

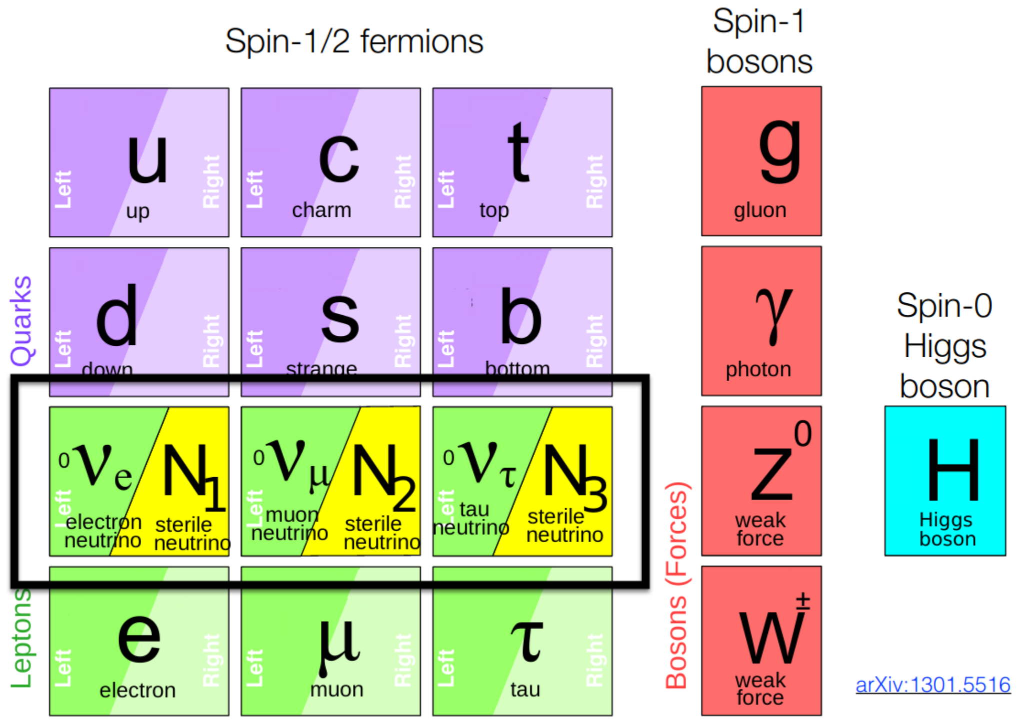


Heavy Neutral Leptons

The Standard Model (SM)



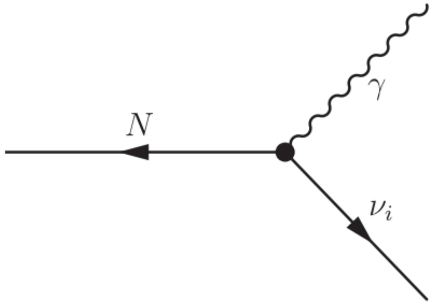
SM Extension with 3 HNLs



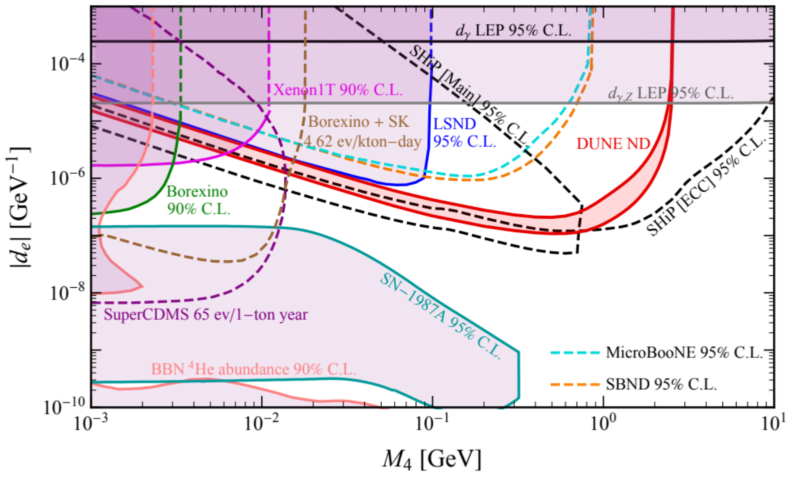
- Best-known description of fundamental particles and their interactions (expect gravity)
- Neutrino oscillations suggest $m_\nu > 0$
- Non-zero neutrino mass is not included in SM

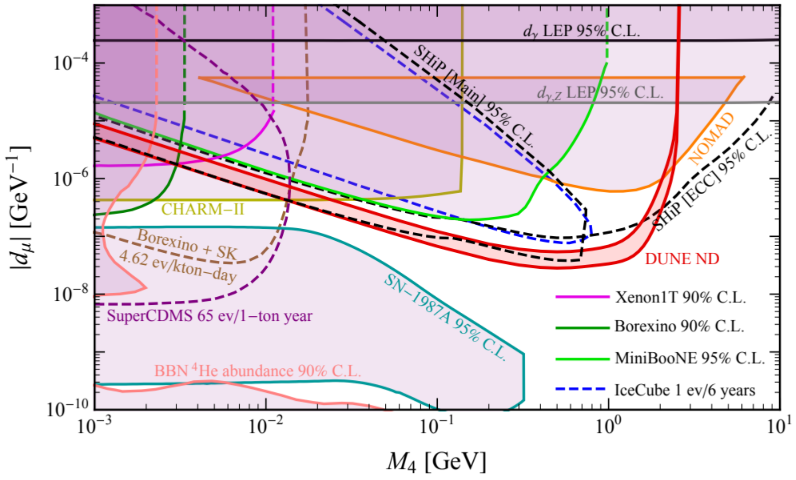
- Introduce right-handed states known as heavy neutral leptons (HNLs)
- Seesaw mechanism explains light neutrino masses

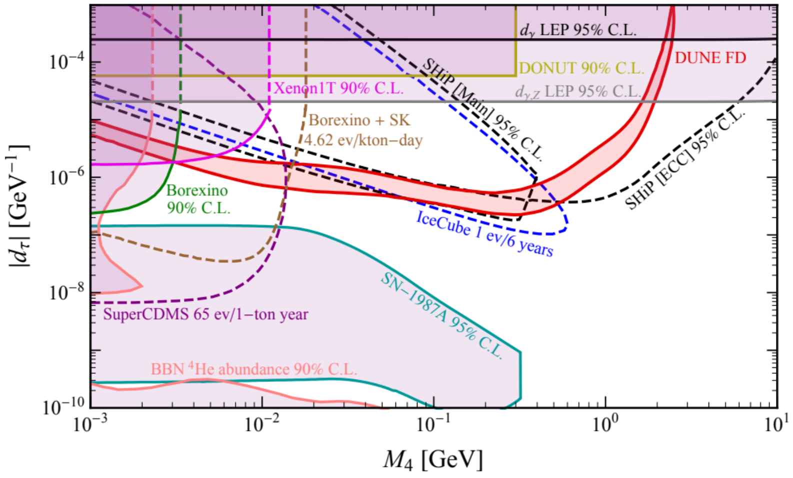
Neutrino dipole portal



$$\mathcal{L} \supset d_k \bar{\nu}_L^k \sigma_{\mu\nu} F^{\mu\nu} N + \text{H.c.},$$



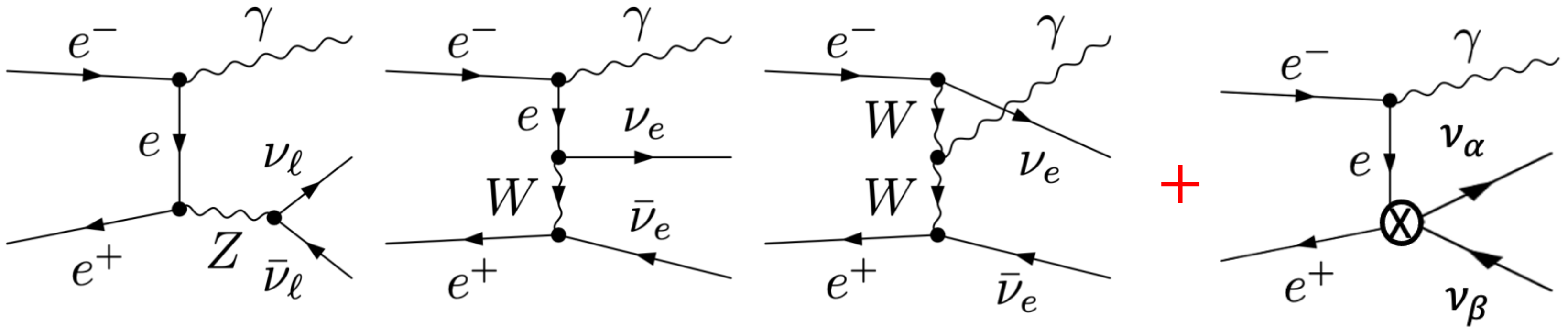




arXiv: 2105.09699

- Collider searches
- Beam-dump experiments
- Neutrino telescope searches
- Dark matter detection
- Astrophysical
- ……

NSI@electron collider



$$e^+e^- \to \nu\bar{\nu}\gamma \qquad \frac{d^2\sigma}{dx_\gamma dz_\gamma} = H\left(x_\gamma, z_\gamma; s\right)\sigma_0(s_\gamma)$$

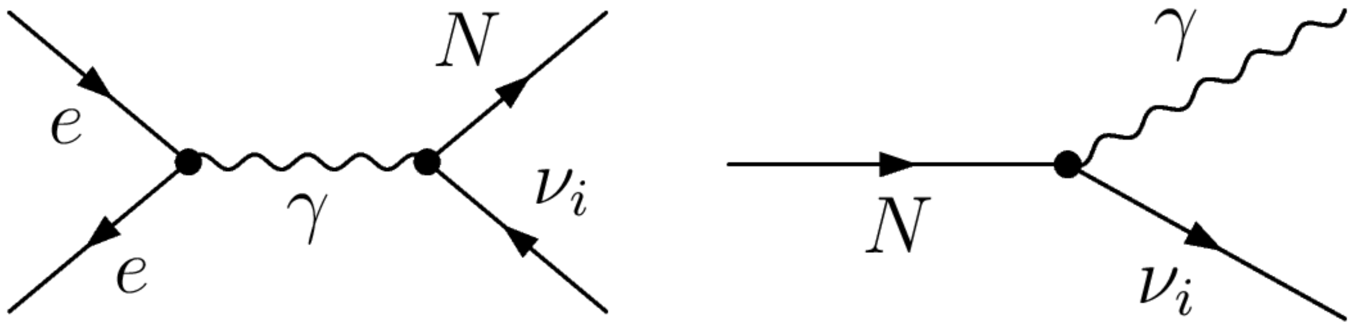
Altarelli-Parisi radiator function

$$H\left(x_\gamma, z_\gamma; s\right) = \frac{\alpha}{\pi}\frac{1}{x_\gamma}\left[\frac{1+(1-x_\gamma)^2}{1-z_\gamma^2} - \frac{x_\gamma^2}{2}\right]$$

$$e^+e^- \to \nu\bar{\nu} \qquad \sigma_0^{\mathrm{SM}}(s) = \frac{N_\nu G_F^2}{6\pi}M_Z^4\left(g_L^2+g_R^2\right)\frac{s}{\left[(s-M_Z^2)^2+(M_Z\Gamma_Z)^2\right]}$$
$$+\frac{G_F^2}{\pi}M_W^2\left\{\frac{s+2M_W^2}{2s} - \frac{M_W^2}{s}\left(\frac{s+M_W^2}{s}\right)\log\left(\frac{s+M_W^2}{M_W^2}\right)\right.$$
$$\left.-\,g_L\frac{M_Z^2\left(s-M_Z^2\right)}{(s-M_Z^2)^2+(M_Z\Gamma_Z)^2}\times\left[\frac{(s+M_W^2)^2}{s^2}\log\left(\frac{s+M_W^2}{M_W^2}\right) - \frac{M_W^2}{s} - \frac{3}{2}\right]\right\}$$

Nicrosini, Trentadue, PLB 231, 487 (1989)

Neutrino dipole portal @electron collider



$$e^+e^- \to \gamma^* \to N(\to \gamma \upsilon)\bar{\upsilon}$$

$$\frac{d\sigma_{N\bar{\nu}}}{dz_N} = \frac{d^2\alpha\left(s - m_N{}^2\right)^2\left((1 - z_N^2)s + \left(1 + z_N^2\right)m_N^2\right)}{4s^3} \qquad z_N \equiv \cos\theta_N$$

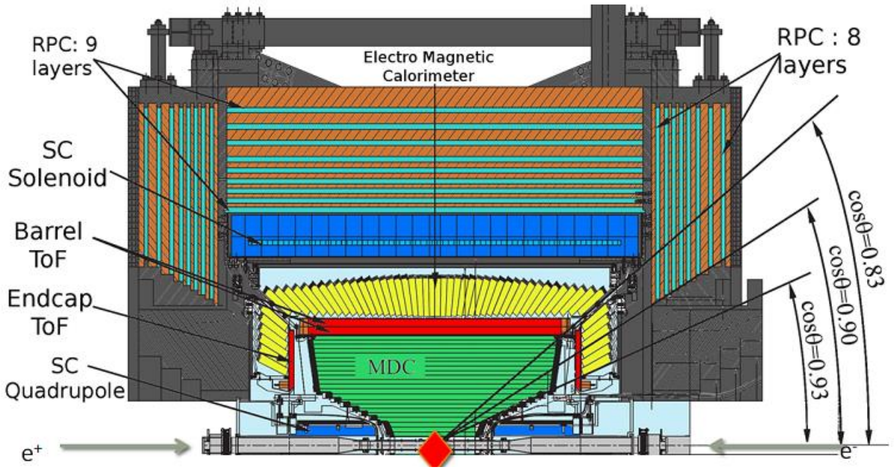
$$\sigma(e^+e^- \to N\bar{\nu}) = \frac{\alpha d^2(s - m_N^2)^2(s + 2m_N^2)}{3s^3}$$

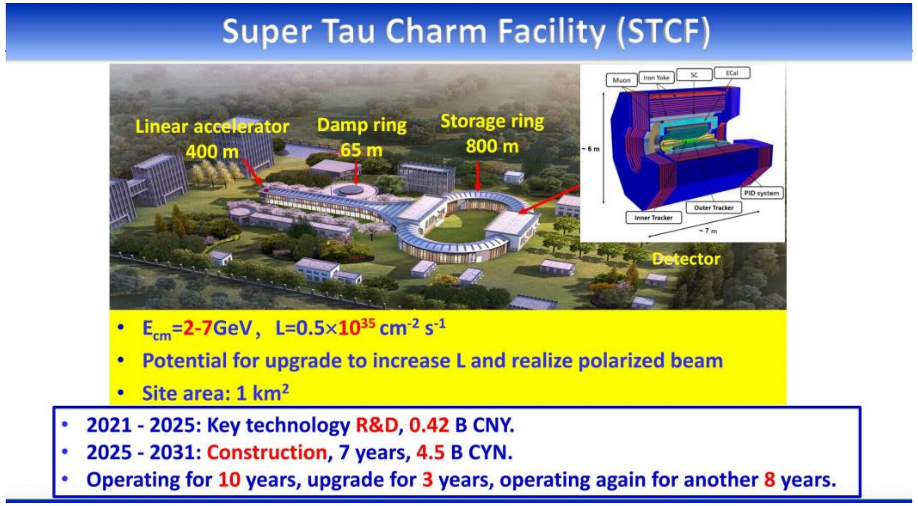
合肥工業大學
HEFEI UNIVERSITY OF TECHNOLOGY

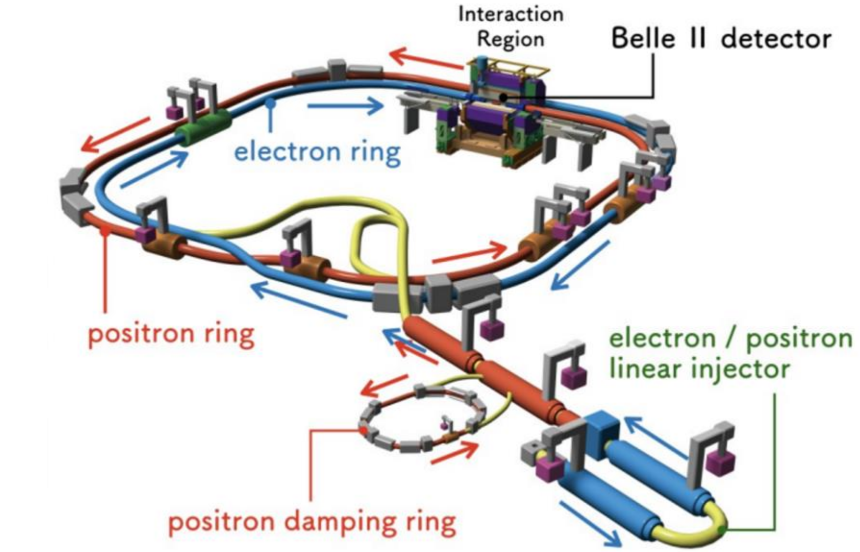
Mono-γ signature at electron colliders

$e^+ e^-$ colliders

BESIII detector

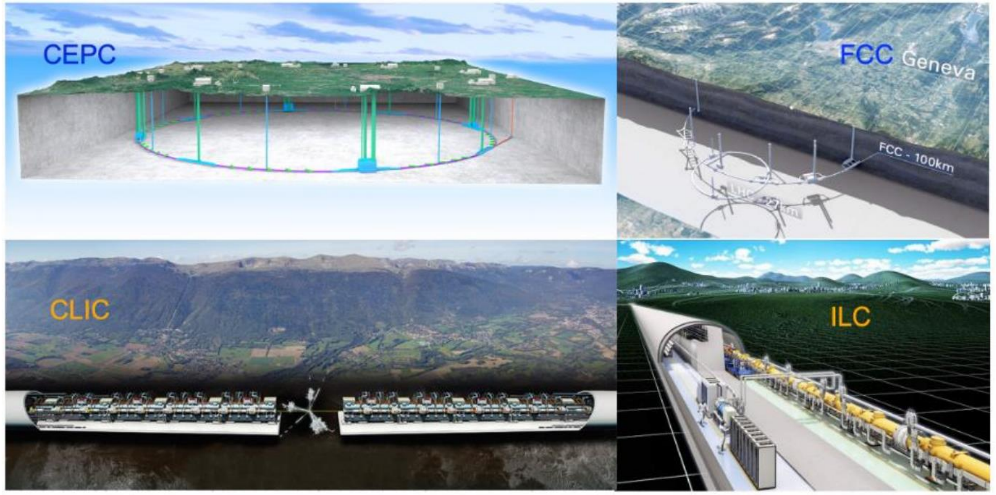




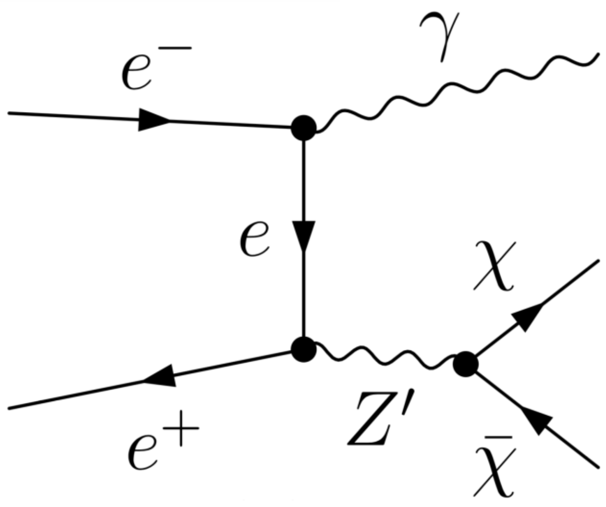


$$\sqrt{s} \ll M_Z$$

$$\sqrt{s} \geq M_Z$$



Mono-γ @ $e^+ e^-$ colliders



Monophoton

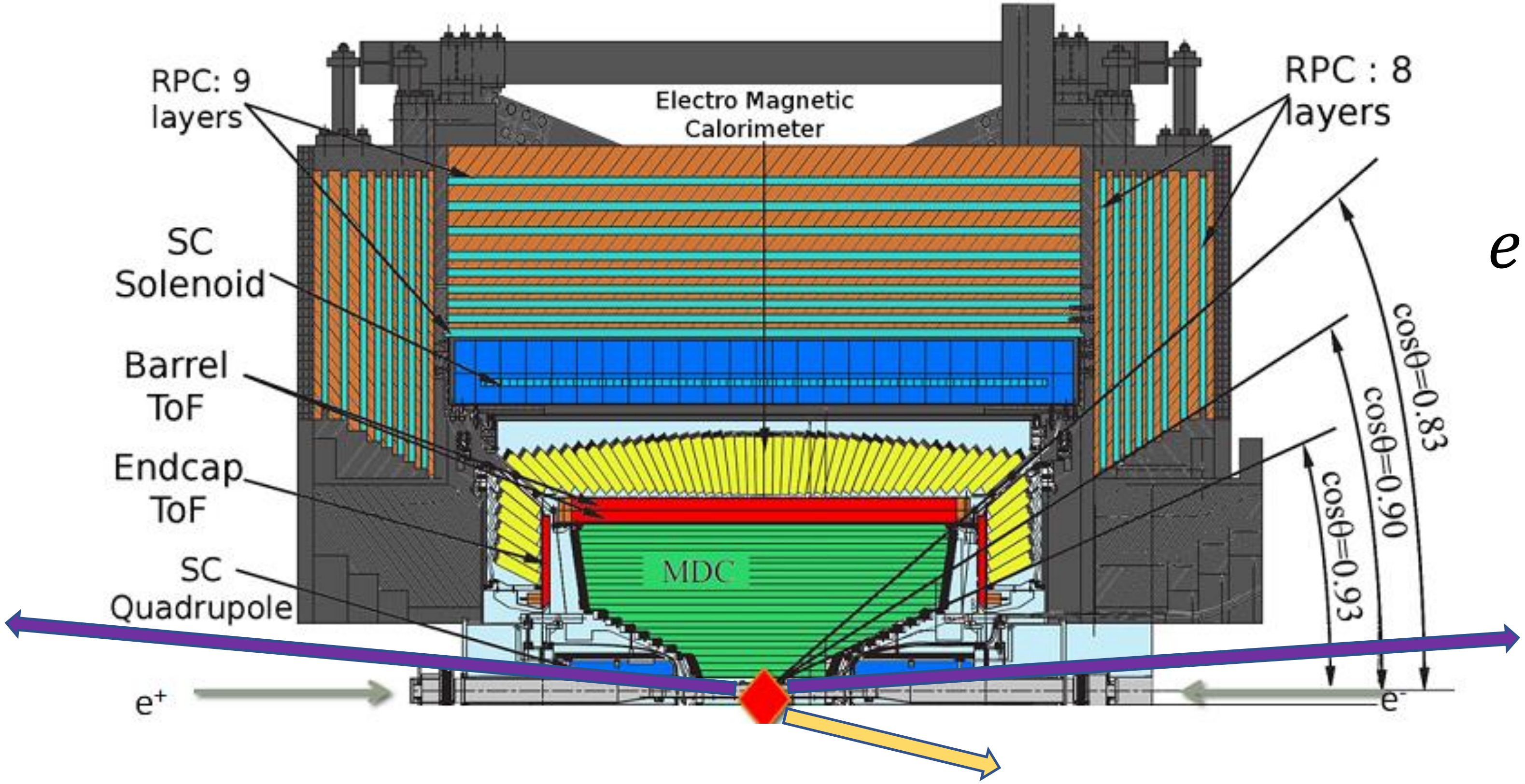
Undetected

Irreducible Backgrounds $e^+e^- \to \nu\bar{\nu}\gamma$

Reducible Backgrounds $e^+e^- \to \not{e}^+\not{e}^-\gamma$

$e^+e^- \to \gamma\not{\gamma}(\not{\gamma})$

Reducible Backgrounds



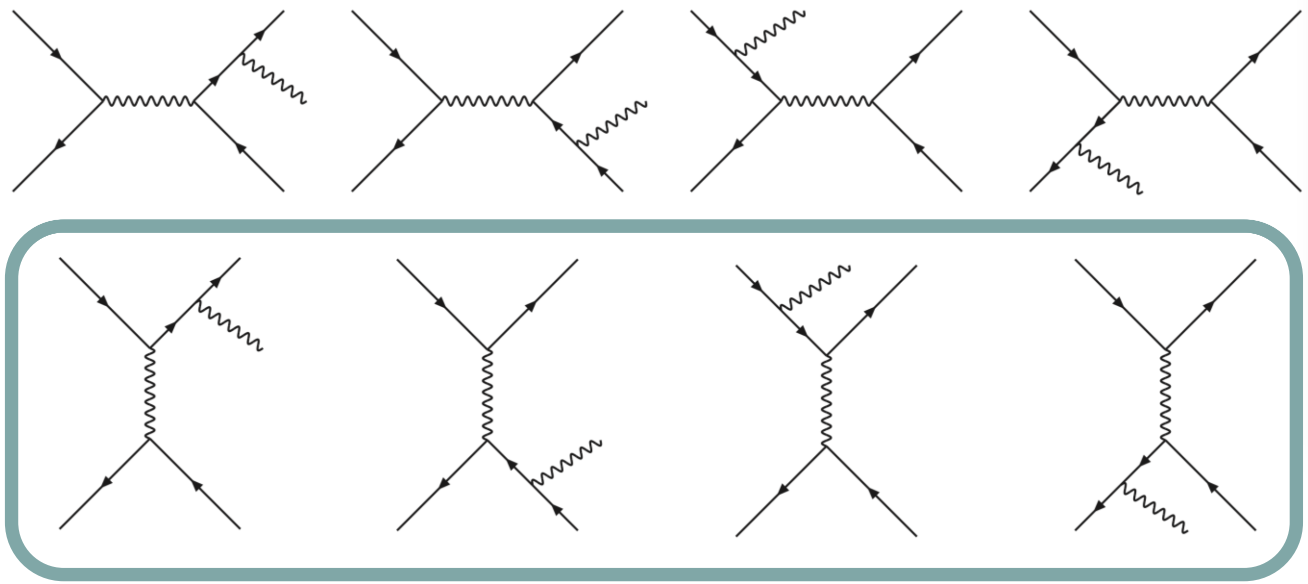
$$e^+e^- \to e^+e^-\gamma$$

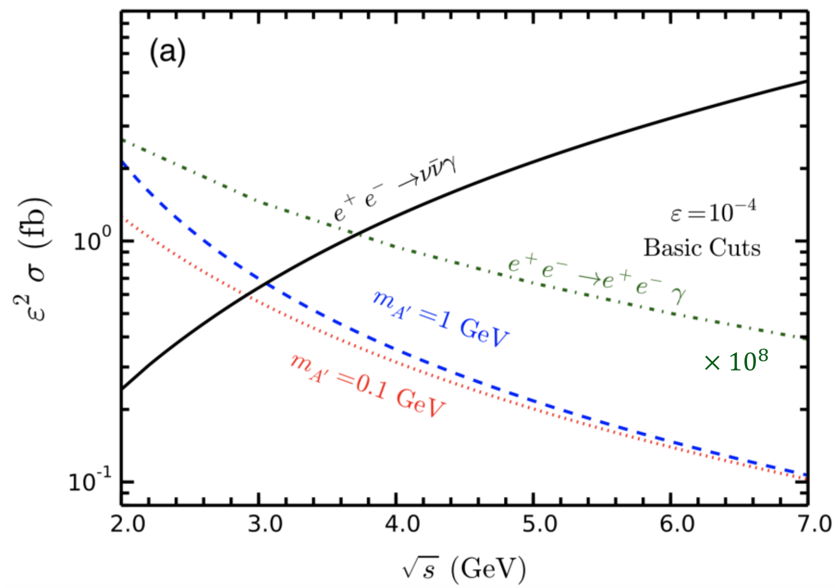
主漂移室（MDC）： $|\cos\theta| < 0.93$

飞行时间计数器（TOF）： $|\cos\theta| < 0.83$ $0.85 < |\cos\theta| < 0.95$

电磁量能器（EMC）： $|\cos\theta| < 0.83$ $0.85 < |\cos\theta| < 0.93$

$e^+e^- \to e^+e^-\gamma$

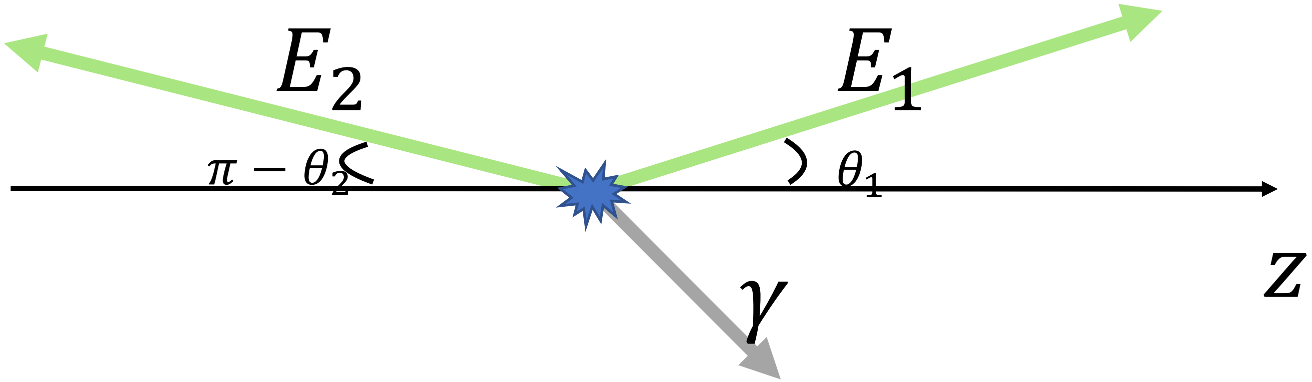


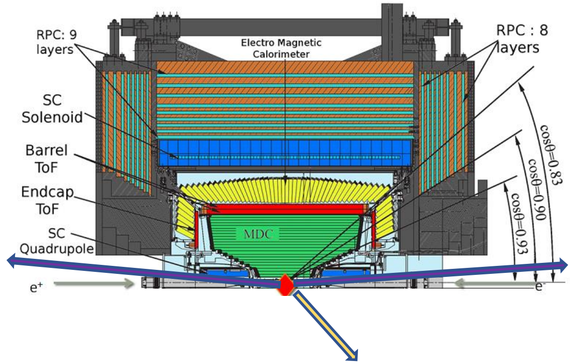


$$\overline{|\mathcal{M}|^2} \propto \frac{1}{t_{13}t_{24}} \sim \frac{1}{\theta_{13}^2 t_{24}} \quad \text{for} \quad \theta_{13} \ll 1 \;\&\; m_e \to 0$$

collinear singularity in the t-channel

Reducible Backgrounds





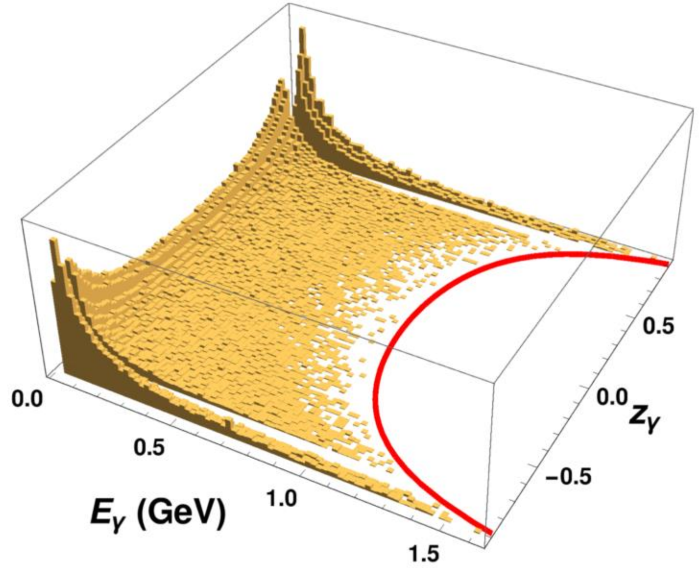
$$\begin{cases} E_\gamma^m \sin\theta_\gamma - E_1 \sin\theta_1 - E_2 \sin\theta_2 = 0 \\ E_\gamma^m \cos\theta_\gamma + E_1 \cos\theta_1 + E_2 \cos\theta_2 = 0 \\ E_\gamma^m + E_1 + E_2 = \sqrt{s}, \end{cases}$$

$$E_\gamma^m(\theta_\gamma) = \frac{\sqrt{s}(A\cos\theta_1 - \sin\theta_1)}{A(\cos\theta_1 - \cos\theta_\gamma) - (\sin\theta_\gamma + \sin\theta_1)}$$

$$A = (\sin\theta_1 - \sin\theta_2)/(\cos\theta_1 - \cos\theta_2)$$

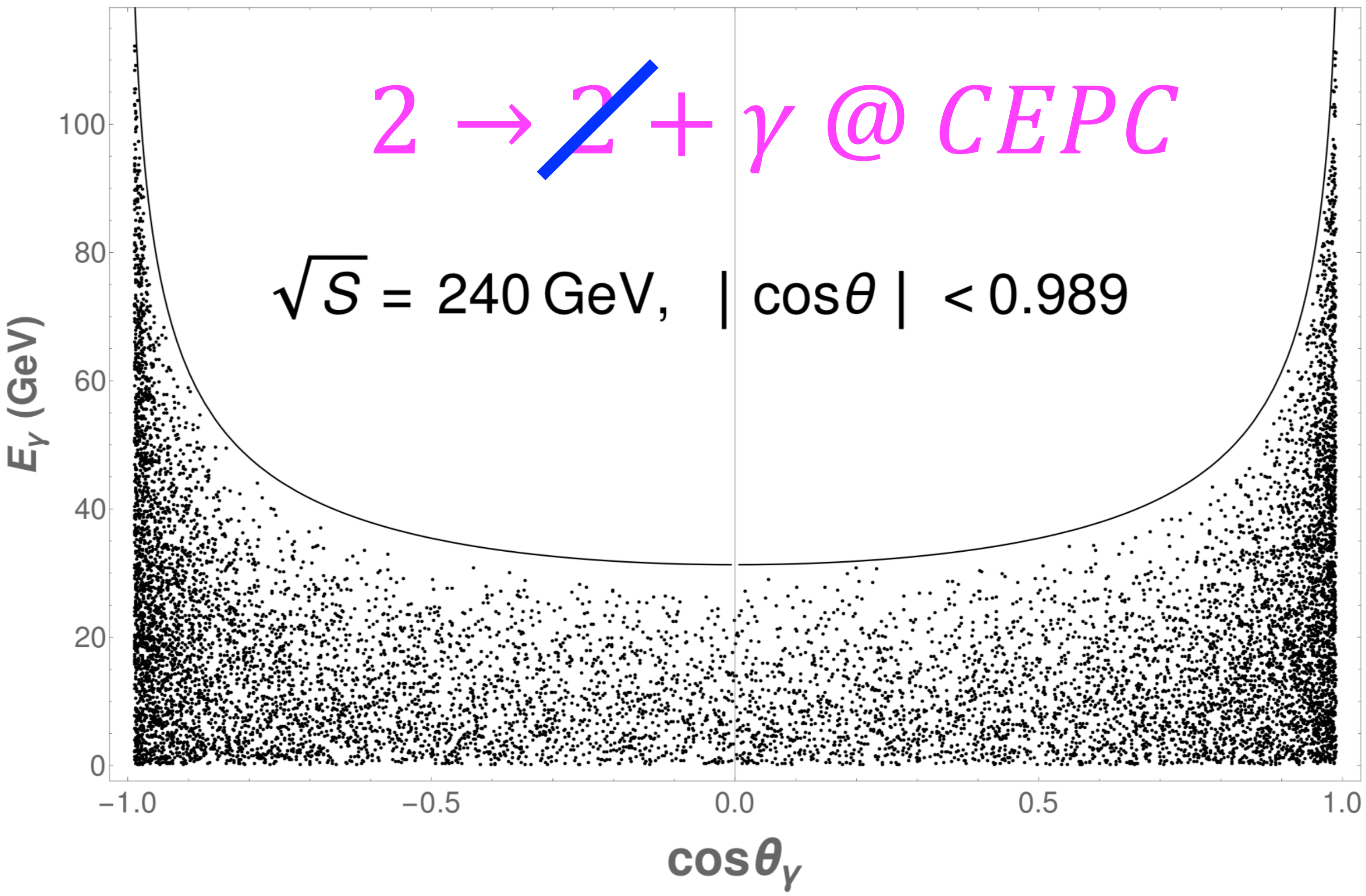
$$\sin\theta_1 = \sin\theta_2 = \sin\theta_b$$

$$E_\gamma^m(\theta_\gamma) = \sqrt{s}\left(1 + \frac{\sin\theta_\gamma}{\sin\theta_b}\right)^{-1}$$

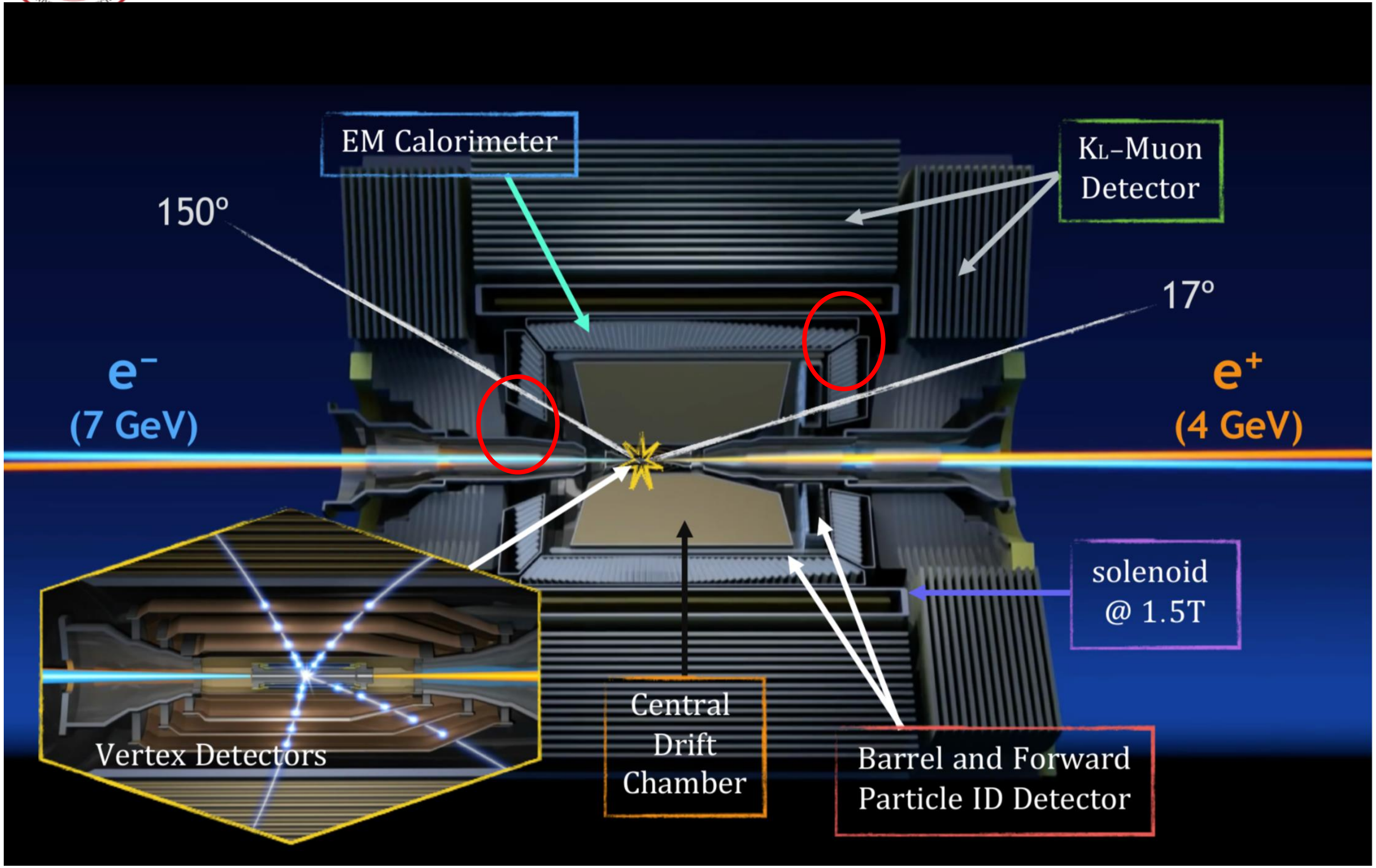


YZ, et. al., arXiv: 1907.07046

$e^+e^- \to e^+e^-\gamma, |\cos\theta_{e^\pm}| > 0.95$


$2 \to \not{2} + \gamma$ @ CEPC
$\sqrt{S} = 240\,\text{GeV}, \quad |\cos\theta| < 0.989$
100
80
60
40
20
0
E_γ (GeV)
−1.0
−0.5
0.0
0.5
1.0
$\cos\theta_\gamma$

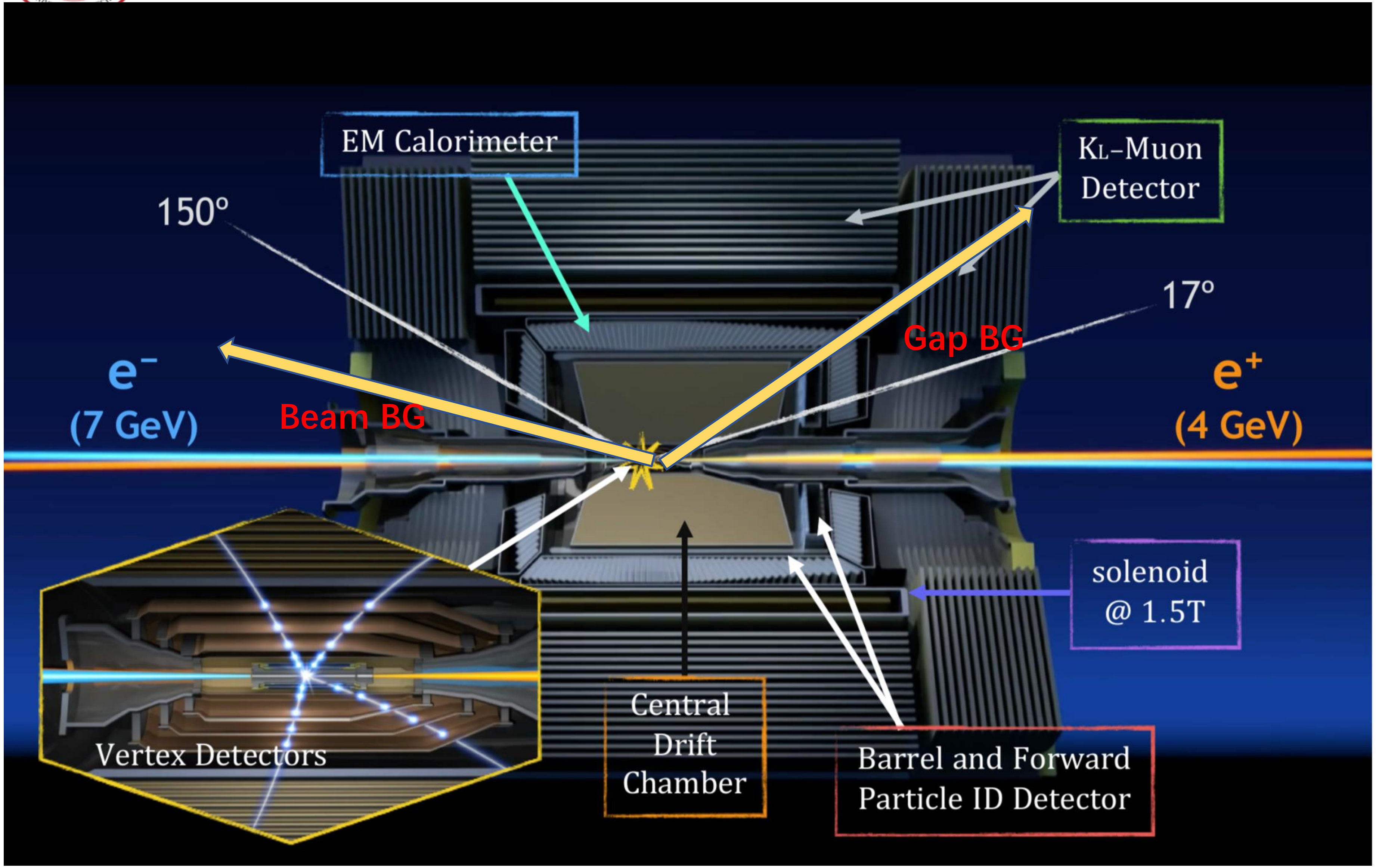
不对称的正负电子对撞机实验



$$e^+e^- \to e^+e^-\gamma$$

$$e^+e^- \to \gamma\gamma(\gamma)$$

不对称的正负电子对撞机实验

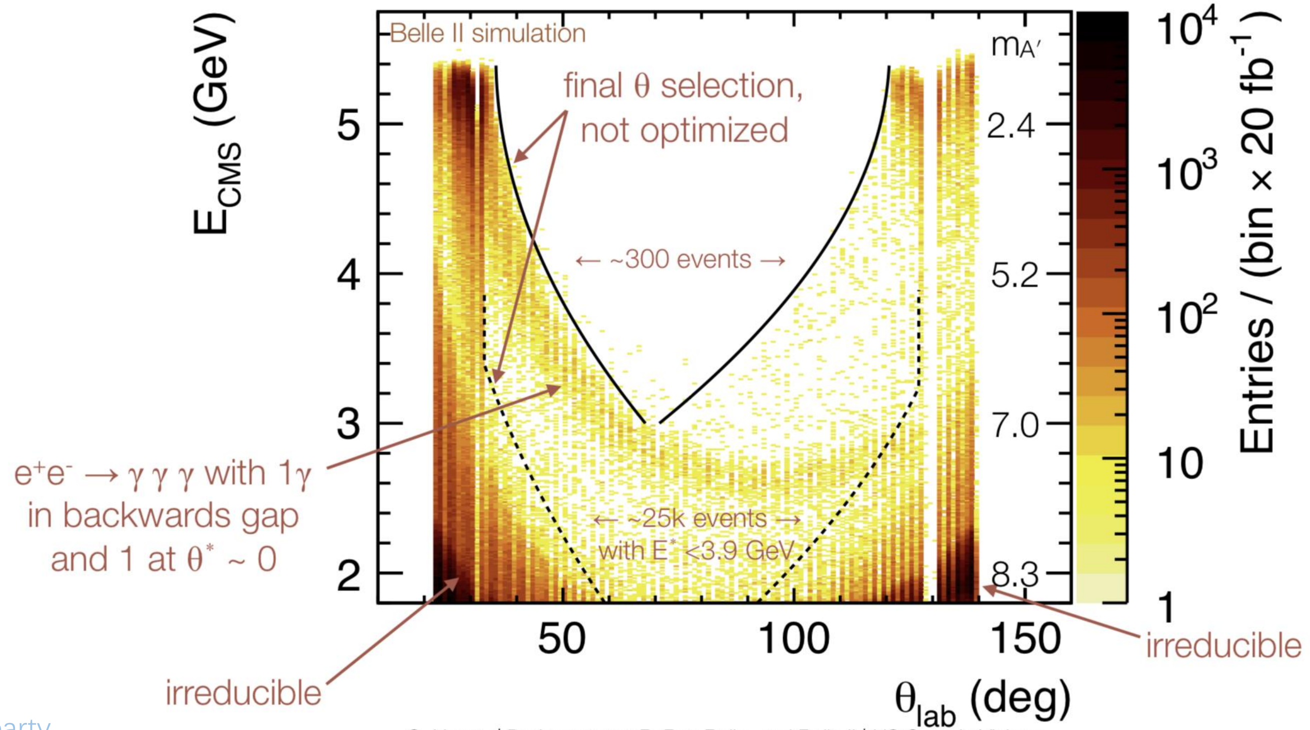


$$e^+e^- \to e^+e^-\gamma$$

$$e^+e^- \to \gamma\gamma(\gamma)$$

Predicted backgrounds in Belle II single photon analysis for 20 fb^{-1}. Loose selection, not optimized.

- Final sample is almost entirely $e^+e^- \to \gamma\,\gamma\,(\gamma)$ with $\geq 3\gamma$



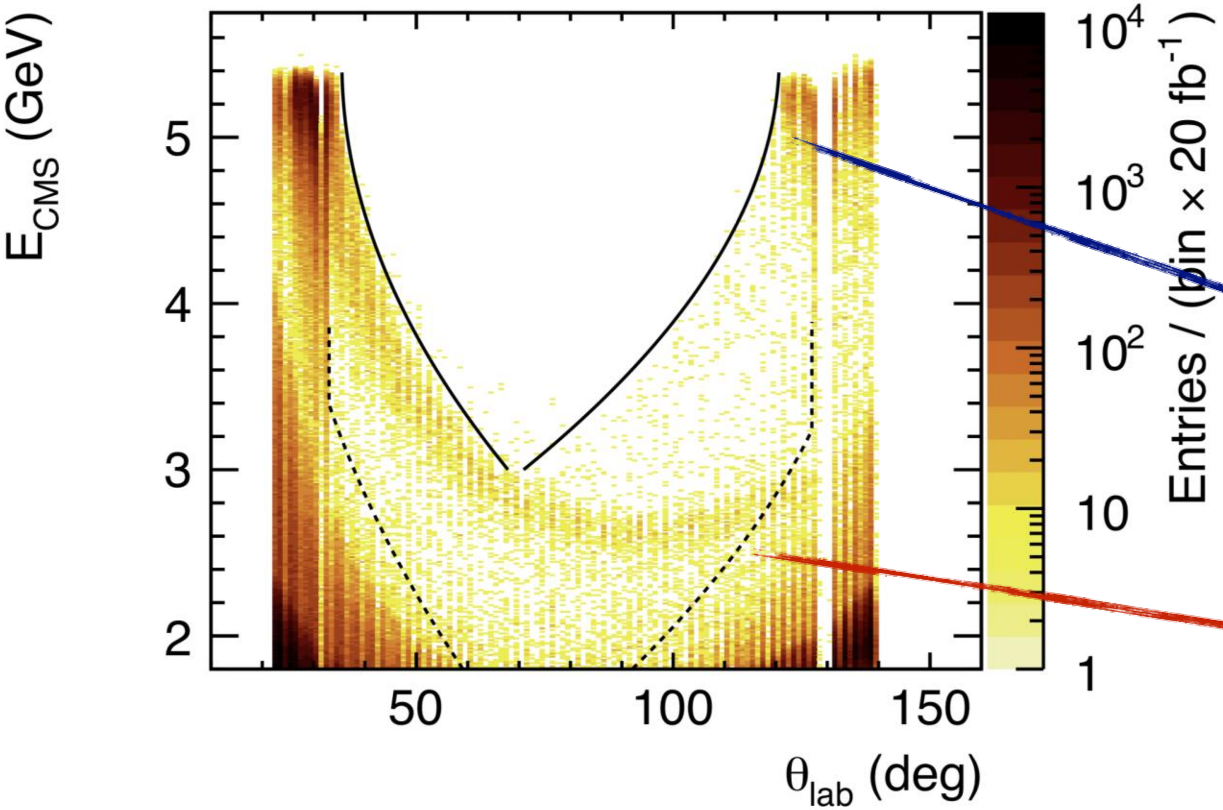
C. Hearty | Dark sector at BaBar, Belle, and Belle II | US Cosmic Visions

From Christopher Hearty

Belle II, 1808.10567

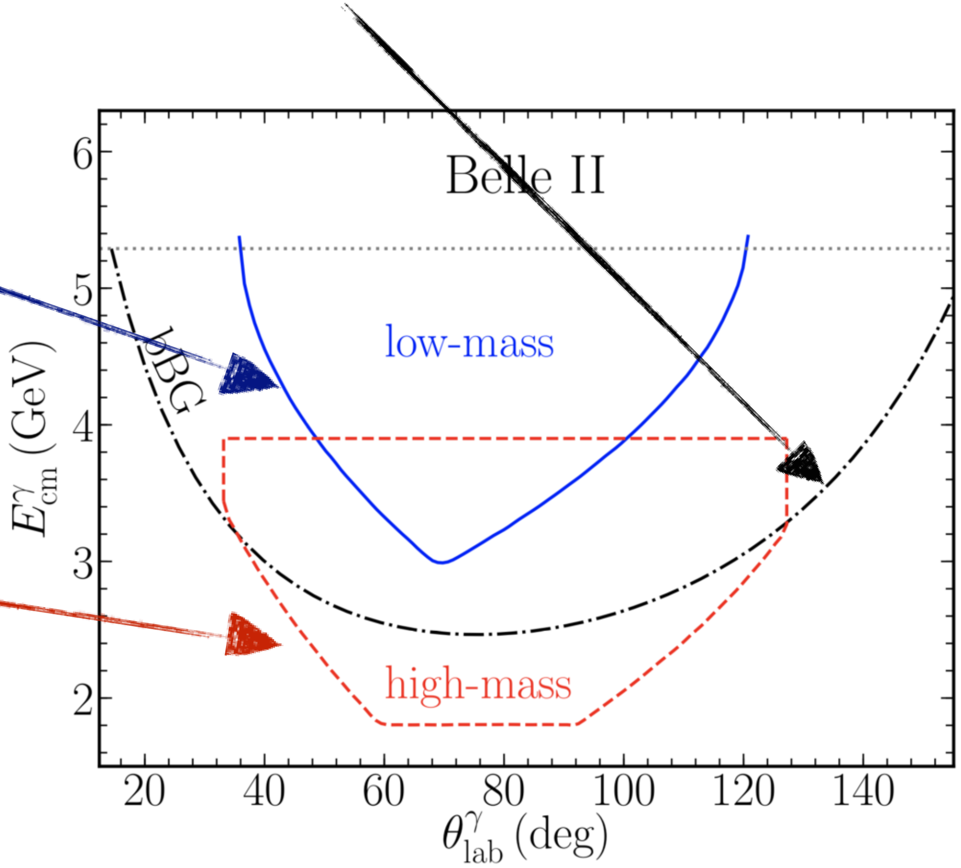
Cuts at Belle-II

Belle II, 1808.10567



$$E^m_\gamma(\theta_\gamma) = \frac{\sqrt{s}(A\cos\theta_1 - \sin\theta_1)}{A(\cos\theta_1 - \cos\theta_\gamma) - (\sin\theta_\gamma + \sin\theta_1)}$$

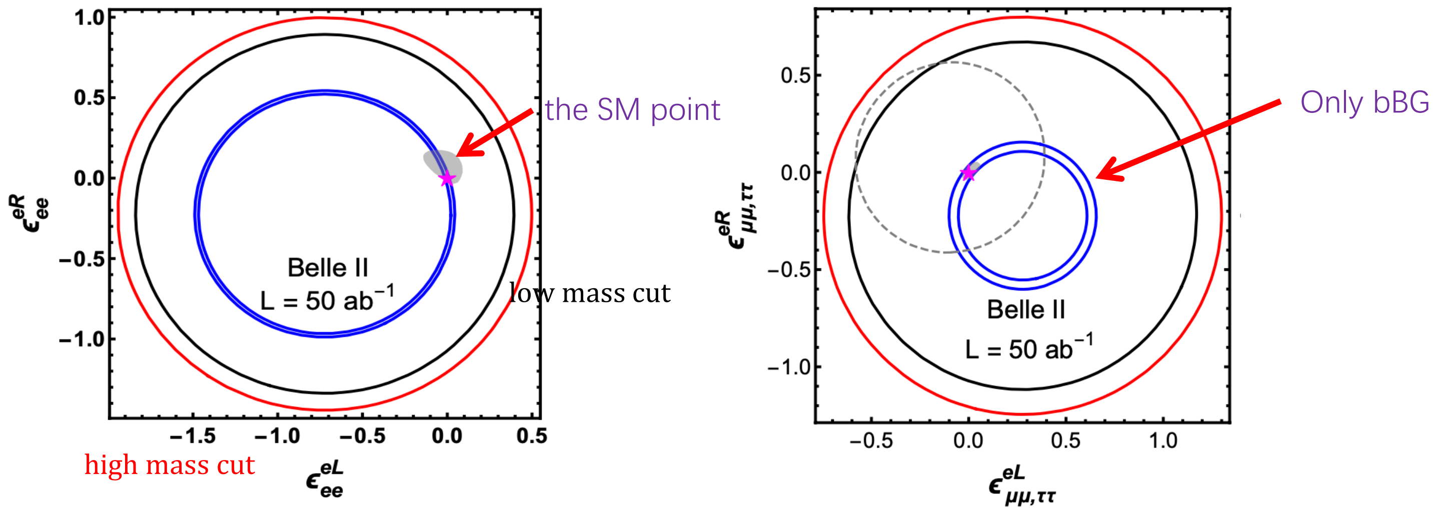
$$A = (\sin\theta_1 - \sin\theta_2)/(\cos\theta_1 - \cos\theta_2)$$

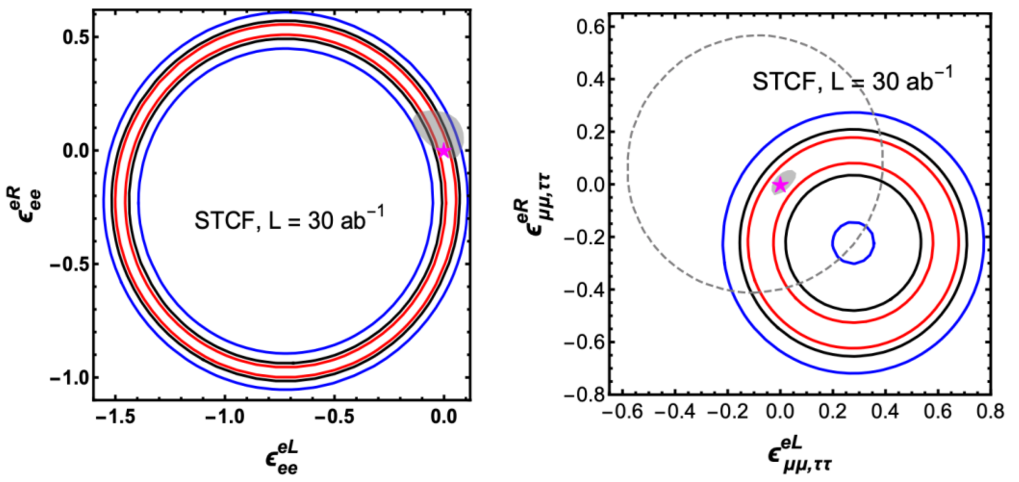


J. Liang, Z. Liu, Y. Ma and **YZ**, Phys.Rev.D 102 (2020), 015002.

NSI at electron colliders

NSI@Belle II&STCF





$$e^+e^- \to \nu\bar{\nu}\gamma \qquad \text{with } \sqrt{s} \ll M_Z$$

$$\frac{d\sigma^{\rm SM}}{dx_\gamma dz_\gamma} = H(x_\gamma, z_\gamma, s)\frac{G_F^2 s_\gamma}{2\pi} C^{\rm SM} \qquad C^{\rm SM} \equiv g_L^2 + g_R^2 + \frac{2}{3}g_L + \frac{1}{3}$$

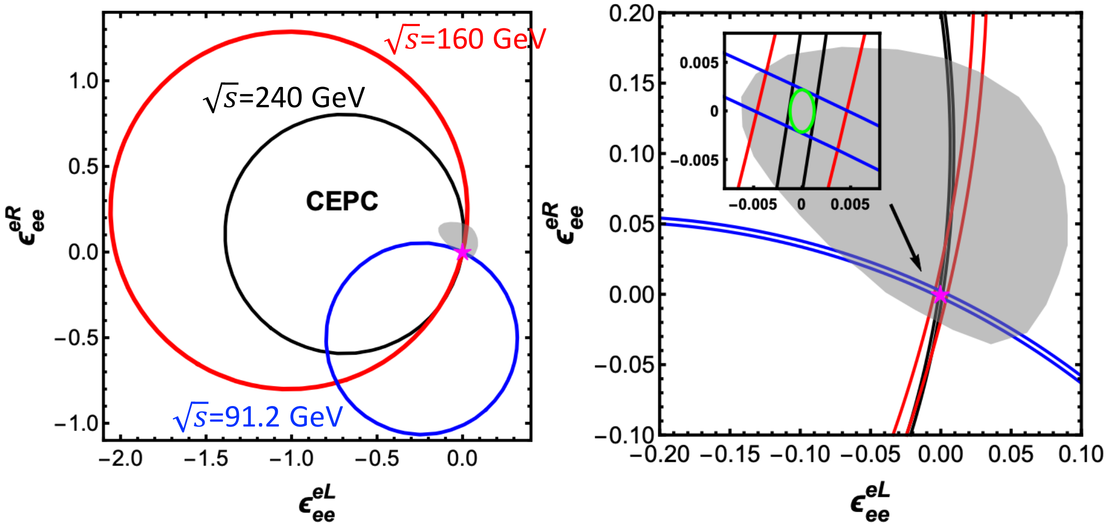
$$\frac{d\sigma^{\rm NSI}}{dx_\gamma dz_\gamma} = H(x_\gamma, z_\gamma, s)\frac{G_F^2 s_\gamma}{2\pi} C^{\rm NSI} \qquad C^{\rm NSI} \equiv \frac{1}{3}\sum_{\alpha,\beta=e,\mu,\tau}\left[(\epsilon^{eL}_{\alpha\beta})^2 + (\epsilon^{eR}_{\alpha\beta})^2 + 2(g_L\epsilon^{eL}_{\alpha\beta} + g_R\epsilon^{eR}_{\alpha\beta})\right] + \frac{2}{3}\epsilon^{eL}_{ee}$$

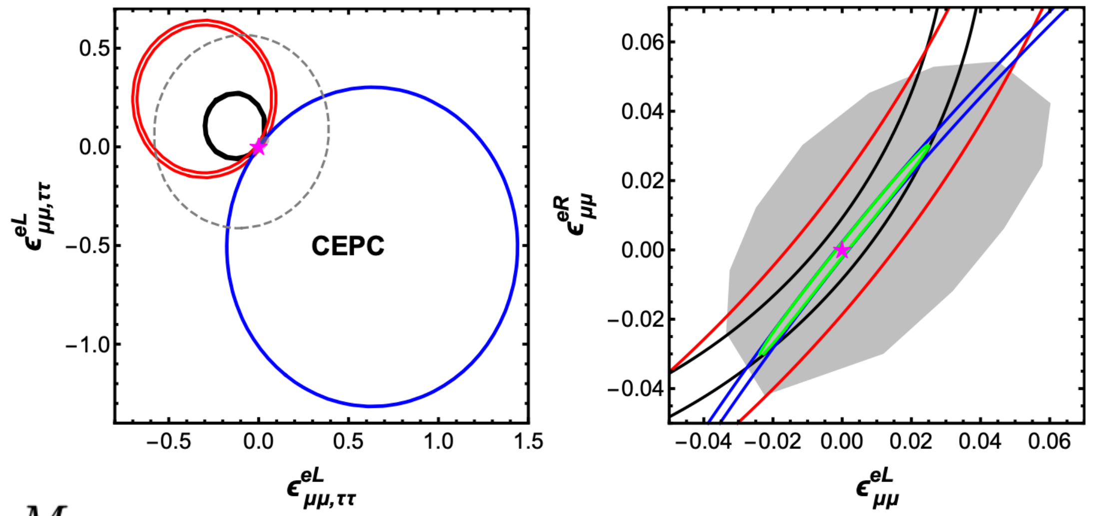
$$\chi^2 = \delta^2\sigma^{SM} L \qquad \delta \equiv C^{\rm NSI}/C^{\rm SM}$$

	STCF-2 $L = 30$ ab^{-1}	STCF-4 $L = 30$ ab^{-1}	STCF-7 $L = 30$ ab^{-1}	Belle II $L = 50$ ab^{-1}	Previous Limit 90% Allowed [45]
ϵ^{eL}_{ee}	[-0.067,0.061]	[-0.033,0.031]	[-0.018,0.018]	[-0.0091,0.0089]	[-0.03,0.08]
ϵ^{eR}_{ee}	[-0.60,0.15]	[-0.163,0.087]	[-0.070,0.053]	[-0.031,0.028]	[0.004,0.15]
$\epsilon^{eL}_{\mu\mu/\tau\tau}$	[-0.13,0.69]	[-0.073,0.101]	[-0.044,0.052]	[-0.023,0.025]	[-0.03,0.03]/[-0.5,0.2]
$\epsilon^{eR}_{\mu\mu/\tau\tau}$	[-0.60,0.15]	[-0.163,0.087]	[-0.070,0.053]	[-0.031,0.028]	[-0.03,0.03]/[-0.3,0.4]

Iso-σ contours form concentric circles with center at

$$(\epsilon^{eL}_{\alpha\alpha}, \epsilon^{eR}_{\alpha\alpha}) = (-g_L - \delta_{\alpha e}, -g_R)$$





$$\sqrt{s} \geq M_Z$$

$$\sigma^{\rm NSI}\left(\epsilon_{ee}^{eL},\epsilon_{ee}^{eR}\right) = I_1\left(\left(\epsilon_{ee}^{eL}\right)^2+\left(\epsilon_{ee}^{eR}\right)^2\right)+(I_2+I_3)\epsilon_{ee}^{eL}+I_2\frac{g_R}{g_L}\epsilon_{ee}^{eR}$$

$$\sigma^{\rm NSI}\left(\epsilon_{\mu\mu/\tau\tau}^{eL},\epsilon_{\mu\mu/\tau\tau}^{eR}\right) = I_1\left(\left(\epsilon_{\mu\mu/\tau\tau}^{eL}\right)^2+\left(\epsilon_{\mu\mu/\tau\tau}^{eR}\right)^2\right)+I_2\epsilon_{\mu\mu/\tau\tau}^{eL}+I_2\frac{g_R}{g_L}\epsilon_{\mu\mu/\tau\tau}^{eR}$$

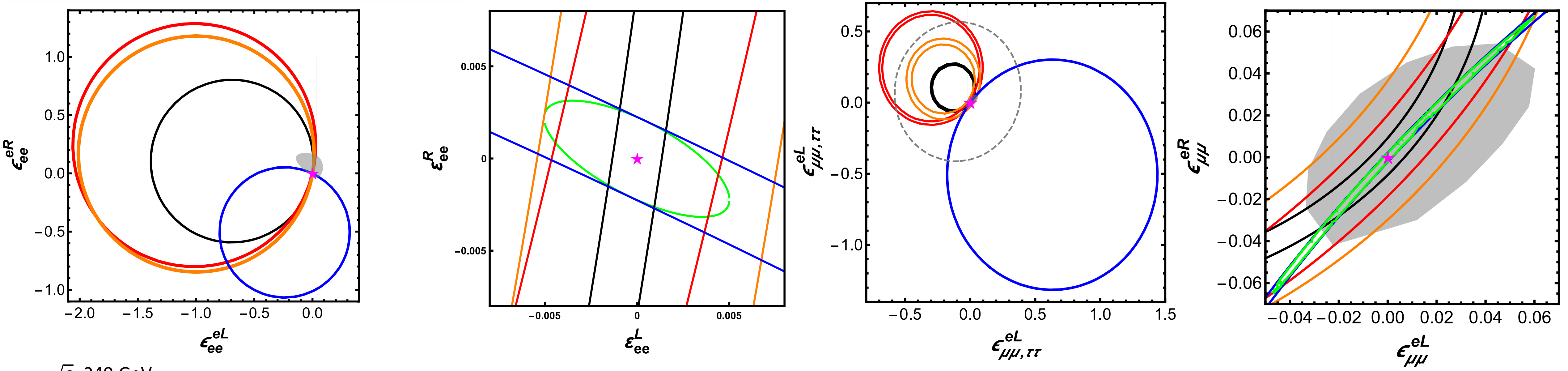
$$I_i \equiv \int dx \int dz_\gamma H(x_\gamma,z_\gamma,s)\left[\sigma_0^{\rm NSI}((s_\gamma)\right]_i$$ is a function of $\sqrt{s}$

Allowed regions lie between two concentric circles with the center:

$$(\epsilon_{ee}^{eL},\ \epsilon_{ee}^{eR}) = (-\frac{I_2+I_3}{2I_1},-\frac{I_2 g_R}{2I_1 g_L})$$

$$(\epsilon_{\mu\mu/\tau\tau}^{eL},\epsilon_{\mu\mu/\tau\tau}^{eR}) = (-\frac{I_2}{2I_1},-\frac{I_2 g_R}{2I_1 g_L})$$

Include 125 GeV



$\sqrt{s}$=240 GeV

$\sqrt{s}$=160 GeV

$\sqrt{s}$=125 GeV

$\sqrt{s}$=91.2 GeV

	CEPC-91.2 $L = 16\ ab^{-1}$	CEPC-160 $L = 2.6\ ab^{-1}$	CEPC-240 $L = 5.6\ ab^{-1}$	CEPC-combine $L = (16+2.6+5.6)\ ab^{-1}$	Previous Limit 90% Allowed	FCC-ee 125 GeV $L = 10\ ab^{-1}$
ε_{ee}^{L}	[-0.0037,0.0037]	[-0.0036,0.0035]	[-0.0010,0.0010]	[-0.00095,0.00095]	[-0.03,0.08]	[-0.0042,0.0041]
ε_{ee}^{R}	[-0.0017,0.0017]	[-0.014,0.015]	[-0.0065,0.0070]	[-0.0017,-0.0017]	[0.004,0.15]	[-0.023,0.027]
$\varepsilon_{\mu\mu/\tau\tau}^{L}$	[-0.0014,0.0014]	[-0.012,0.012]	[-0.0055,0.0053]	[-0.0013,0.0013]	[-0.03,0.03]/[-0.5,0.3]	[-0.021,0.019]
$\varepsilon_{\mu\mu/\tau\tau}^{R}$	[-0.0017,0.0017]	[-0.014,0.015]	[-0.0065,0.0070]	[-0.0017,0.0017]	[-0.03,0.03]/[-0.3,0.4]	[-0.023,0.027]

Constraints of NSI parameters by varying only one parameter at a time.

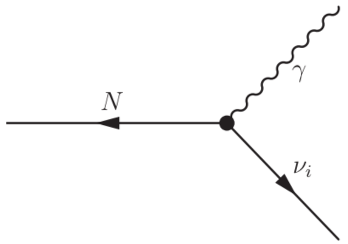
Neutrino dipole portal at electron colliders

Neutrino dipole portal

$$\mathcal{L} \supset \bar{L}(d_{\mathcal{W}} \mathcal{W}^a_{\mu\nu}\tau^a + d_B B_{\mu\nu})\tilde{H}\sigma_{\mu\nu}N_D + \text{H.c.}$$

SSB

$$\mathcal{L} \supset d_W(\bar{\ell}_L W^-_{\mu\nu}\sigma^{\mu\nu}N_D) + \bar{\nu}_L[d_\gamma F_{\mu\nu} - d_Z Z_{\mu\nu}]\sigma^{\mu\nu}N_D + \text{H.c.}$$



$$\mathcal{L} \supset d_k \bar{\nu}^k_L \sigma_{\mu\nu} F^{\mu\nu} N + \text{H.c.},$$

$$d_\gamma = \frac{v}{\sqrt{2}}\left(d_B \cos\theta_w + \frac{d_{\mathcal{W}}}{2}\sin\theta_w\right)$$
$$d_Z = \frac{v}{\sqrt{2}}\left(\frac{d_{\mathcal{W}}}{2}\cos\theta_w - d_B \sin\theta_w\right)$$
$$d_W = \frac{v}{\sqrt{2}}\frac{d_{\mathcal{W}}}{2}\sqrt{2}.$$

$$\{m_N, d_{\mathcal{W}}, d_B\}$$

$$d_{\mathcal{W}} = a \times d_B$$

$$d_Z = \frac{d_\gamma(a\cos\theta_w - 2\sin\theta_w)}{2\cos\theta_w + a\sin\theta_w}$$
$$d_W = \frac{\sqrt{2}a d_\gamma}{2\cos\theta_w + a\sin\theta_w}.$$

$$\{m_N, d_\gamma, a\}$$

$$a = -2\cot\theta_w$$

HNL Decays

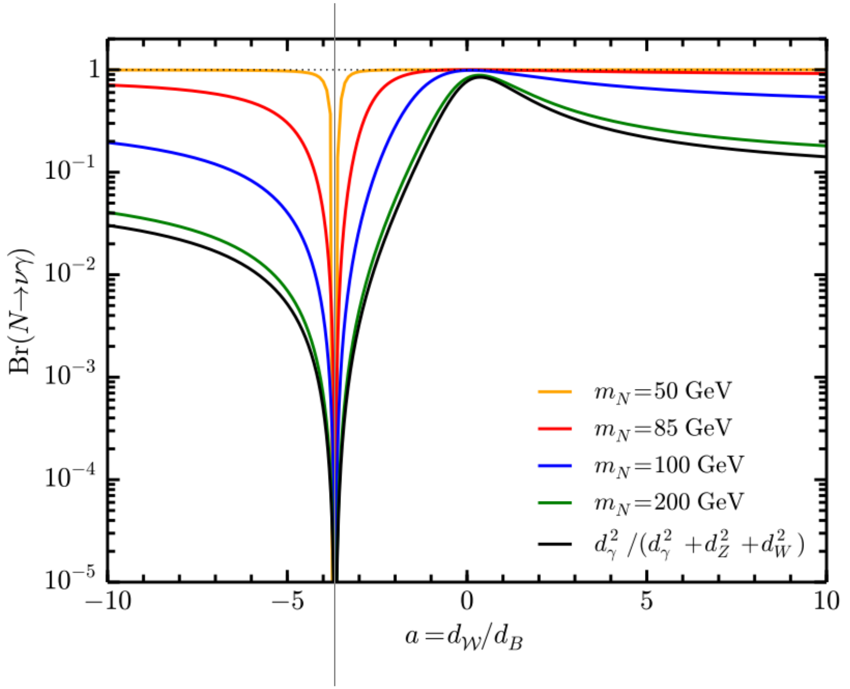
$$\Gamma_{N\to\nu\gamma} = \frac{d_\gamma^2 m_N^3}{4\pi},$$

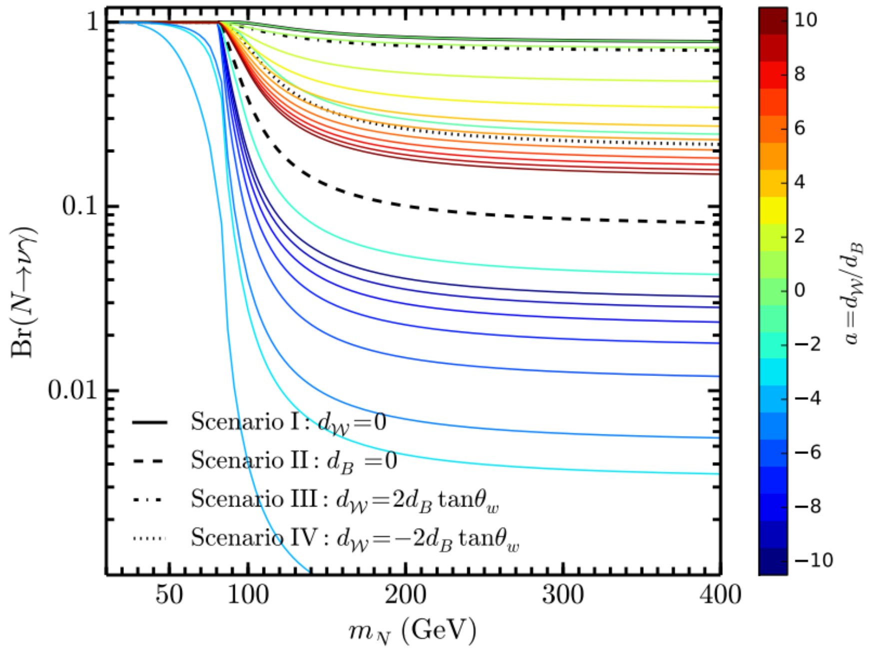
$$\Gamma_{N\to\nu Z} = \frac{d_Z^2 (m_N^2 - M_Z^2)^2 (2m_N^2 + M_Z^2)}{8\pi m_N^3}\Theta(m_N > M_Z),$$

$$\Gamma_{N\to W\ell} = \frac{d_W^2}{8\pi m_N^3}\sqrt{(m_N^2 - (M_W - m_\ell)^2)(m_N^2 + (M_W - m_\ell)^2)}$$
$$\times \left(2m_\ell^2(2m_\ell^2 - 4m_N^2 - M_W^2) + (m_N^2 - M_W^2)(2m_N^2 + M_W^2)\right)\Theta(m_N > M_W + m_\ell).$$

$$N \to \nu Z^* \to \nu f\bar{f}$$

$$N \to W^*\ell \to \ell + ff'$$

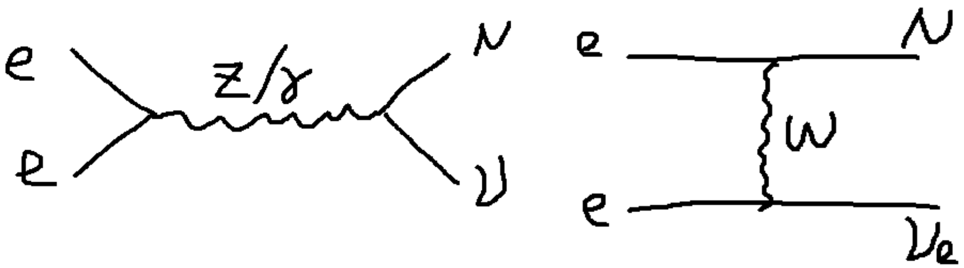




$$a = -2\cot\theta_w$$

$$\mathrm{Br}(N\to\nu\gamma) \equiv \frac{\Gamma_{N\to\nu\gamma}}{\Gamma_{N\to\nu\gamma} + \Gamma_{N\to\nu Z} + \Gamma_{N\to W\ell} + \Gamma_{N\to\text{3-body}}}$$

Production at electron colliders

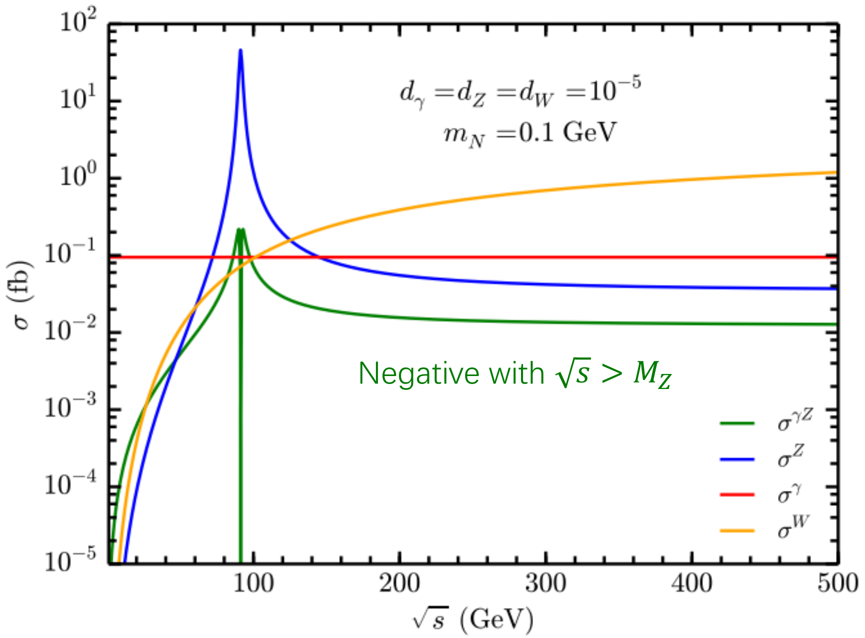


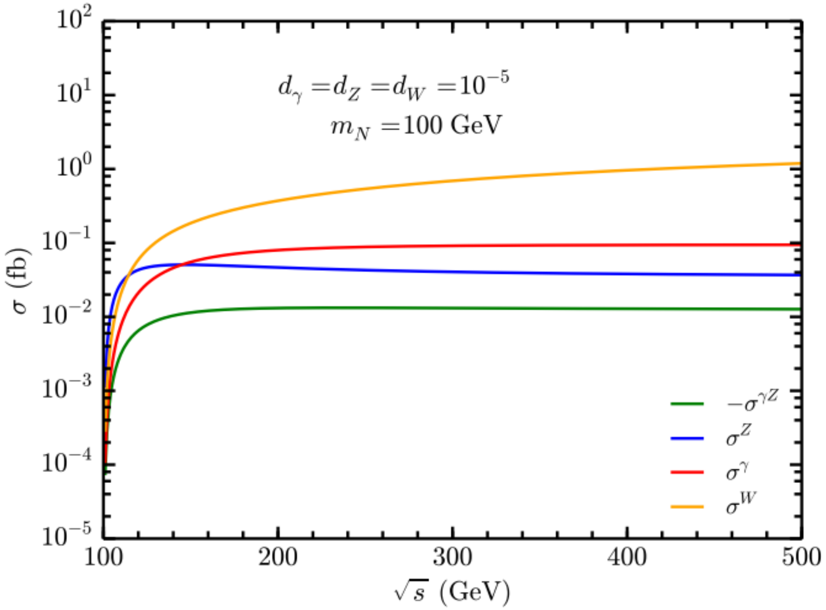
$$\sigma^{\gamma}(e^+e^- \to N\bar{\nu}) = \frac{\alpha d_\gamma^2 (s-m_N^2)^2(s+2m_N^2)}{3s^3},$$

$$\sigma^{Z}(e^+e^- \to N\bar{\nu}) = \frac{\alpha d_Z^2 (s-m_N^2)^2(s+2m_N^2)}{24 c_w^2 s_w^2 s \left(\Gamma_Z^2 M_Z^2 + (M_Z^2-s)^2\right)}\left[(8s_w^2-4s_w+1)\right],$$

$$\sigma^{\gamma Z}(e^+e^- \to N\bar{\nu}) = \frac{\alpha d_\gamma d_Z (s-m_N^2)^2(s+2m_N^2)}{6 c_w s_w s^2 \left(\Gamma_Z^2 M_Z^2 + (M_Z^2-s)^2\right)}\left[(-4s_w+1)(M_Z^2-s)\right],$$

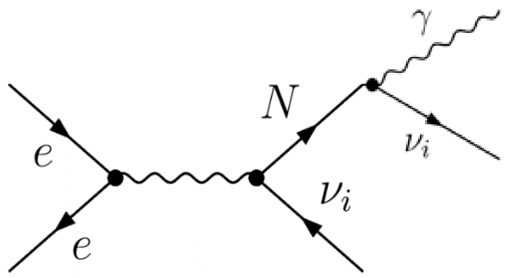
$$\sigma^{W}(e^+e^- \to N\bar{\nu}_e) = \frac{\alpha (d_W^e)^2}{2 s_w^2 s}\left[-2s - (2M_W^2+s)\log\left(\frac{M_W^2}{-m_N^2+M_W^2+s}\right) + m_N^2\left(\frac{M_W^2}{-m_N^2+M_W^2+s}+1\right)\right],$$

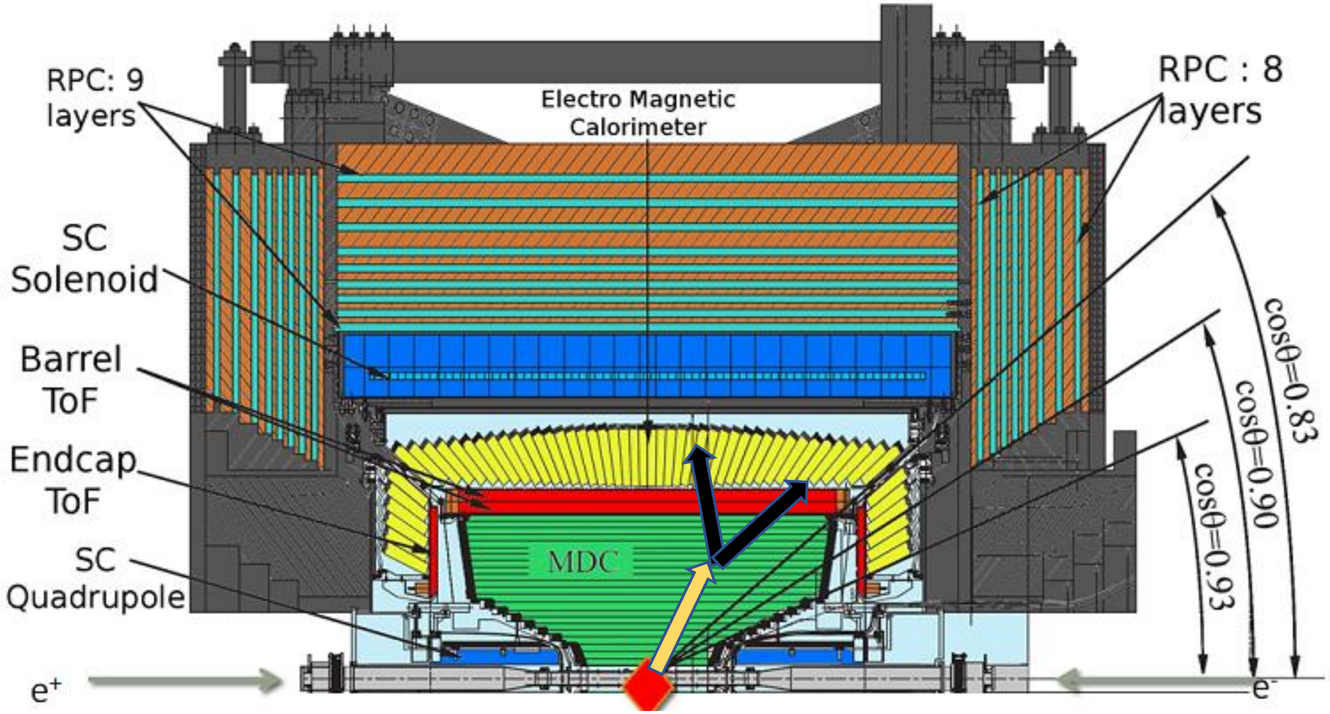




- With $\sqrt{s} \ll M_Z$ the contribution from Z or W can be neglected comparing with γ.
- σ^{γ} has little to do with the CM energy when $m_N \ll \sqrt{s}$.
- σ^{W} dominants when $\sqrt{s} \gg M_Z$ while can be ignored around Z-pole

Decay Length





$$\Gamma_{N\to\nu\gamma} = \frac{|d|^2 m_N^3}{4\pi}$$

$$l_{dec} = c\tau\beta\gamma = \frac{4\pi}{|d|^2 m_N^4}\sqrt{E_N^2 - m_N^2},$$

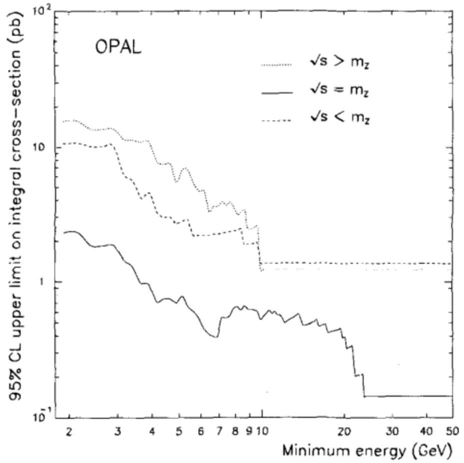
$$P_{dec}(l) = (1 - e^{-l/l_{dec}})\mathrm{Br}(N \to \nu\gamma).$$

$$N_s = L\sigma(e^+e^- \to N\nu)\mathrm{Br}(N \to \nu\gamma)\epsilon_{cuts}\epsilon_{det}P_{dec}(l_D)$$

Searches at LEP

OPAL collaboration, Z. Phys. C 65 (1995) 47

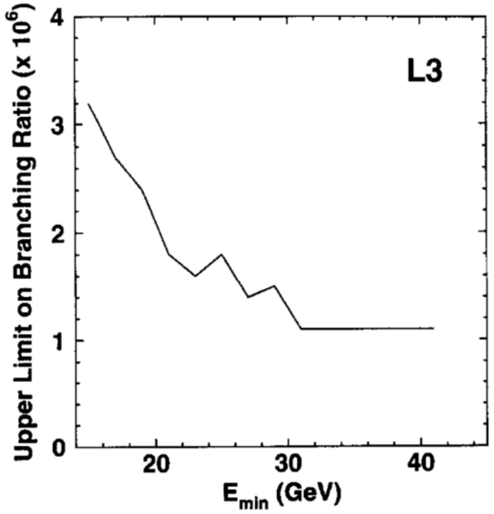
LEP1



scan-points. The 95 % CL upper limit on the cross-section at the Z^0 peak for production of a single photon with energy exceeding 23 GeV is found to be 0.15 pb. For models in

$Z \to \gamma$+invisible

L3 collaboration, Phys. Lett. B 412 (1997) 201



95% C.L. upper limit of 3.2×10^{-6} with $E_\gamma > 15$ GeV

LEP2

DELPHI collaboration, Eur. Phys. J. C 38 (2005) 395

	$\sqrt{s}$	200–209 GeV
	$<\sqrt{s}>$	205.4 GeV
	$N_{\rm observed}$	190
HPC	$N_{\rm background}$	0.1
$0.06 < x_\gamma < 1.1$	$N_{e^+e^-\to\nu\bar{\nu}\gamma}$	198.1±2.0
$45^\circ < \theta_\gamma < 135^\circ$	$\sigma_{\rm meas}$ (pb)	1.50±0.11
	$\sigma_{\nu\bar{\nu}\gamma(\gamma)}$ (pb)	1.61
	N_ν	2.71±0.30

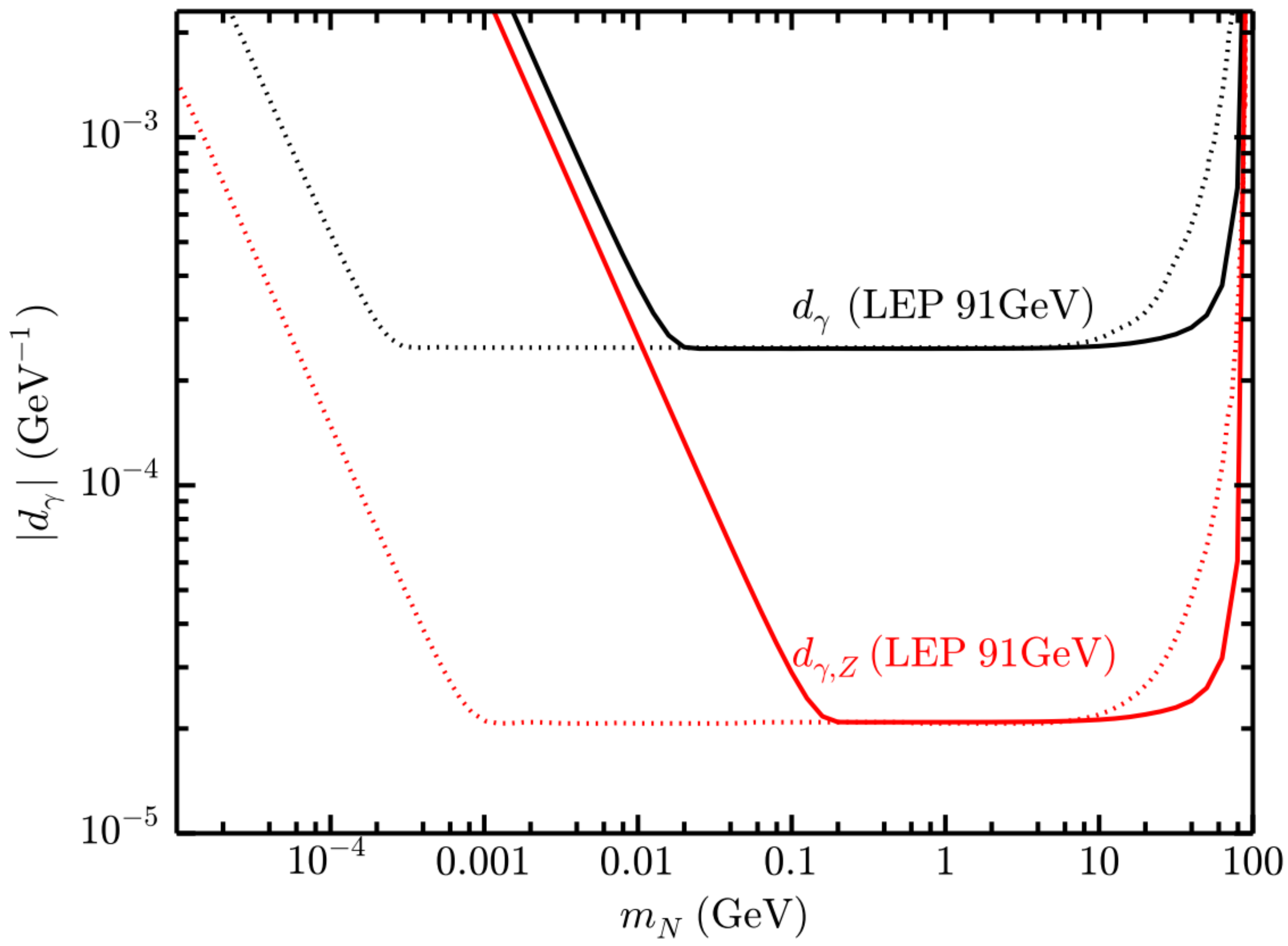
$$\chi^2 = \left(\frac{\sigma^{\rm SM} + \sigma^{N\nu} - \sigma^{\rm exp}}{\delta\sigma^{\rm exp}}\right)^2$$

$Z \to$invisible

Phys.Rept. 427 (2006) 257

new physics contributions $\Gamma^{\rm NP}_{Z\to{\rm invisible}} < 2.0$ MeV at 95% C.L.

Comments



Comparison between our results (solid lines) and that of [arXiv:1803.03262] for the 95% CL upper bounds at LEP.

- **Wrong numerical results.**
- **Unreasonable experiment limits of LEP used.**

Four typical scenarios

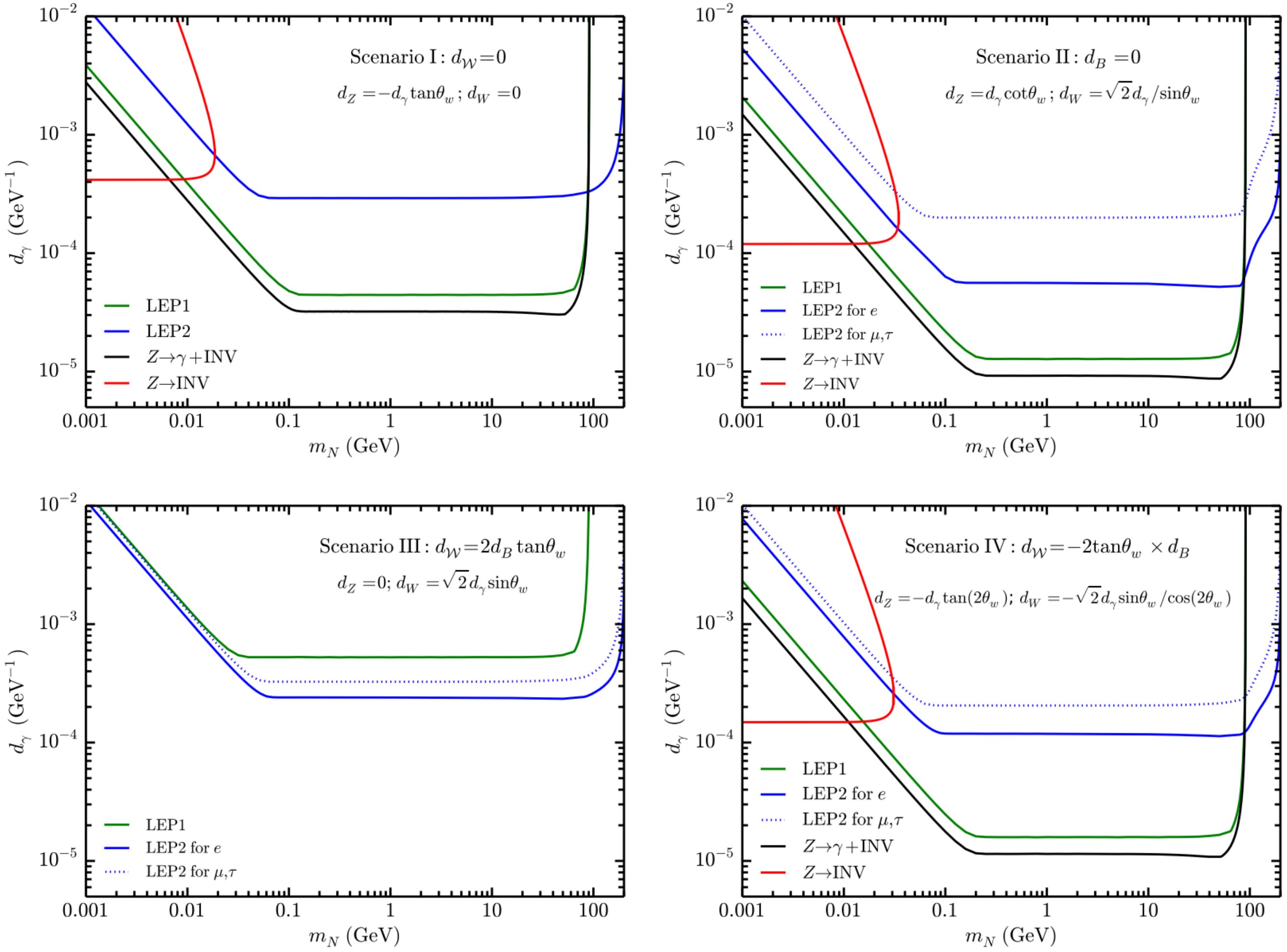
Scenario	Assumptions	Relations
I	$d_{\mathcal{W}} = 0$	$d_Z = -d_\gamma \tan\theta_w;\ d_W = 0$
II	$d_B = 0$ $a \to \infty$	$d_Z = d_\gamma \cot\theta_w;\ d_W = \sqrt{2}d_\gamma / \sin\theta_w$
III	$d_{\mathcal{W}} = 2\tan\theta_w \times d_B$	$d_Z = 0;\ d_W = \sqrt{2}d_\gamma \sin\theta_w$
IV	$d_{\mathcal{W}} = -2\tan\theta_w \times d_B$	$d_Z = -d_\gamma \tan(2\theta_w);\ d_W = -\sqrt{2}d_\gamma \sin\theta_w / \cos(2\theta_w)$

$$d_{\mathcal{W}} = a \times d_B$$

$$d_Z = \frac{d_\gamma(a\cos\theta_w - 2\sin\theta_w)}{2\cos\theta_w + a\sin\theta_w}$$

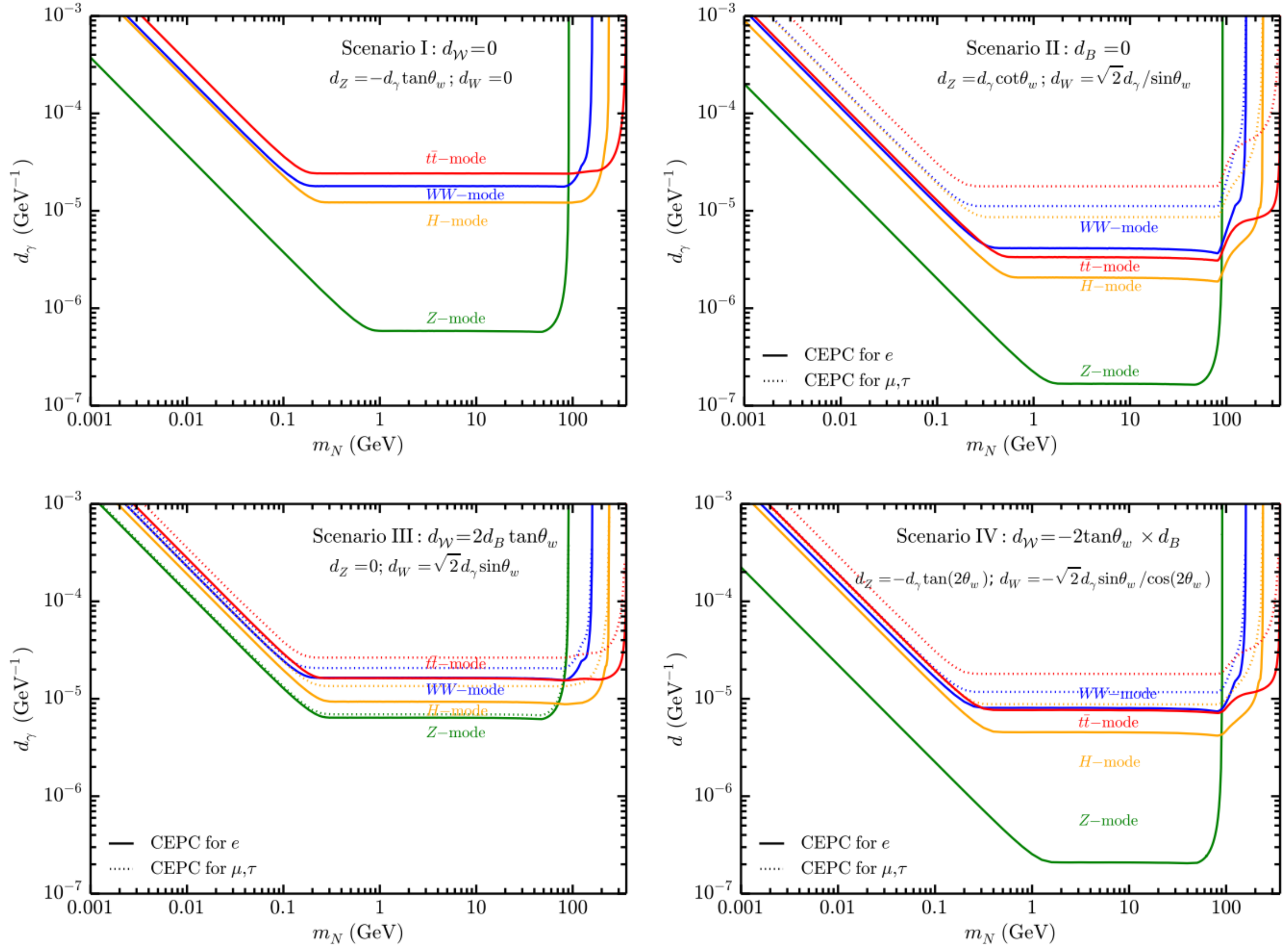
$$d_W = \frac{\sqrt{2}ad_\gamma}{2\cos\theta_w + a\sin\theta_w}.$$

Results at LEP



- A characteristic "U" shape.
- The measurements of Z decay will derive same sensitivity for all the three lepton flavors, so almost do the monophoton searches at LEP1.
- the constraints on electron will be stricter than mu or tau from monophoton searches at LEP2.
- The constraints from the measurement of the branching ratio for Z → γ + invisible are always found to be most stringent.

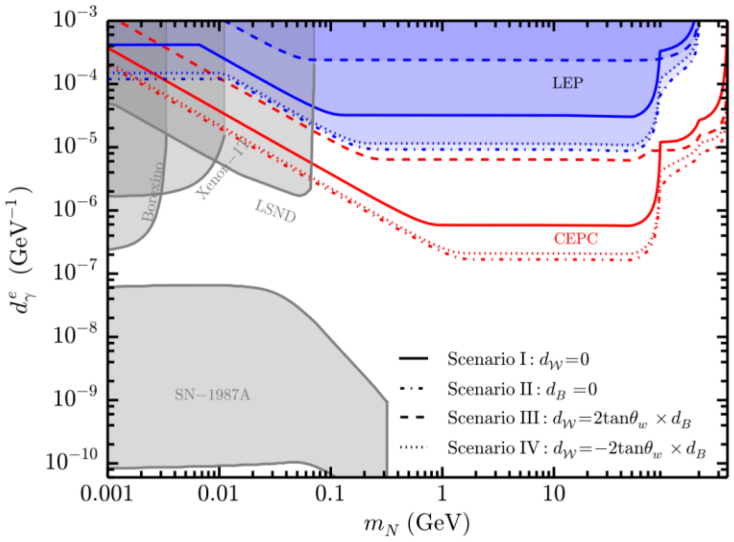
Results at CEPC

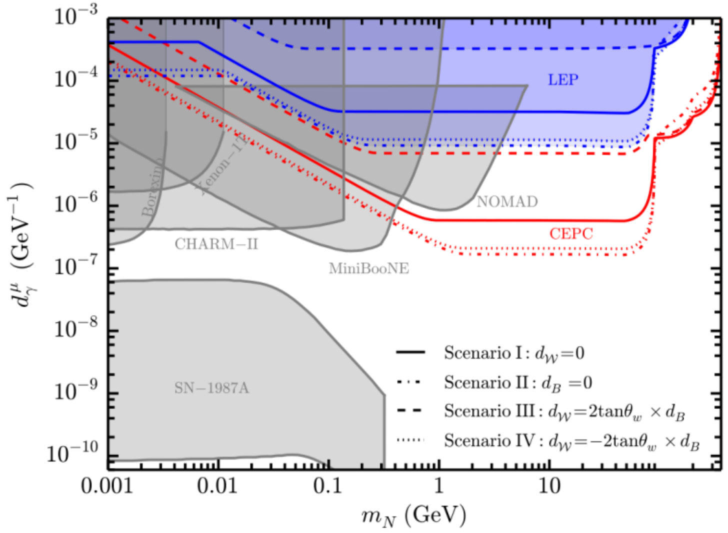


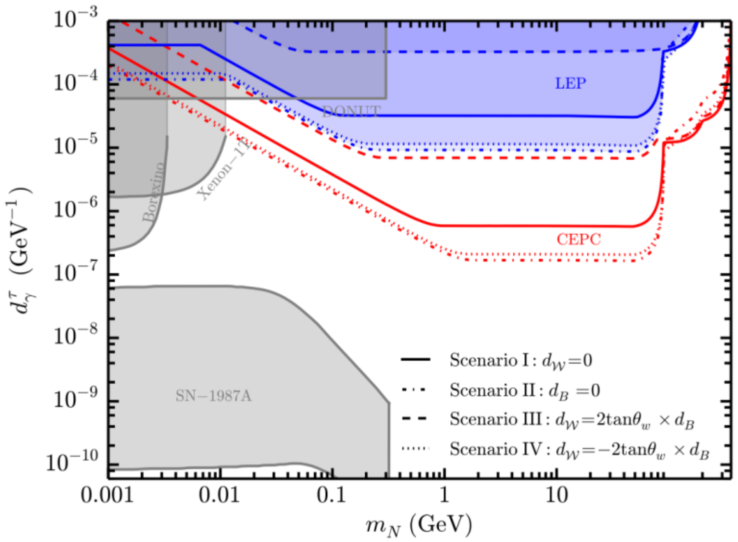
Operation mode	Z factory	WW threshold	Higgs factory	$t\bar{t}$
$\sqrt{s}$ (GeV)	91.2	160	240	360
Run time (year)	2	1	10	5
Instantaneous luminosity ($10^{34} cm^{-2} s^{-1}$, per IP)	191.7	26.6	8.3	0.83
Integrated luminosity (ab^{-1}, 2 IPs)	100	6	20	1
Event yields	3×10^{12}	1×10^{8}	4×10^{6}	5×10^{5}

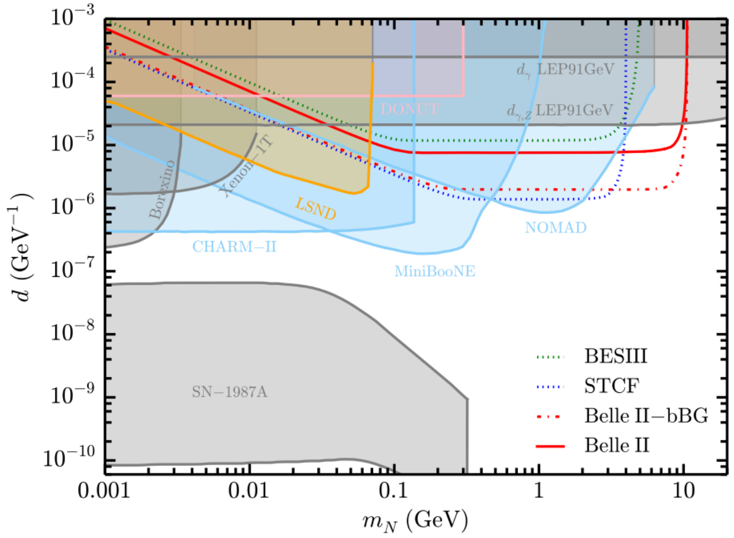
- Z-mode has the best sensitivity in all four scenarios for the HNL with small mass.
- Z-mode can give about two orders of magnitude of improvement over the other three running modes at CEPC in the sensitivity on d_mu/tau.

Results at electron colliders









- The current constraints basically do not dependent on the ratio a, since the typical scattering energies are far less than the electroweak scale.

● Gray regions for all 3 lepton flavors
● Orange regions only for electron-neutrino (d_e)
● Skyblue regions only for muon-neutrino (d_μ)
● Pink regions only for tau-neutrino (d_τ)

Summary

Summary

- Both Belle II and STCF can provide competitive and complementary bounds on $\varepsilon_{ee}^{eL,R}$ as compared to current global analysis, and strong improvements in the constraints on $\varepsilon_{\tau\tau}^{eL,R}$.
- Electron colliers running with three CM energies $\sqrt{s} = 240, 160, 91.2$ GeV will break the degeneracy between the left- and right-handed NSI, and can reach a sub-percent level sensitivity for all electron NSI.

◆ The more general dipole couplings to HNL which respect the full gauge symmetries of the SM are considering.

◆ The constraints on active-sterile neutrino transition magnetic moments dependent on the model at high energy colliders.

HFUT

谢谢观看

Thank you!

合肥工业大学
HEFEI UNIVERSITY OF TECHNOLOGY