probing BSM at LUXE (preliminary study)

Yotam Soreq

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the study group

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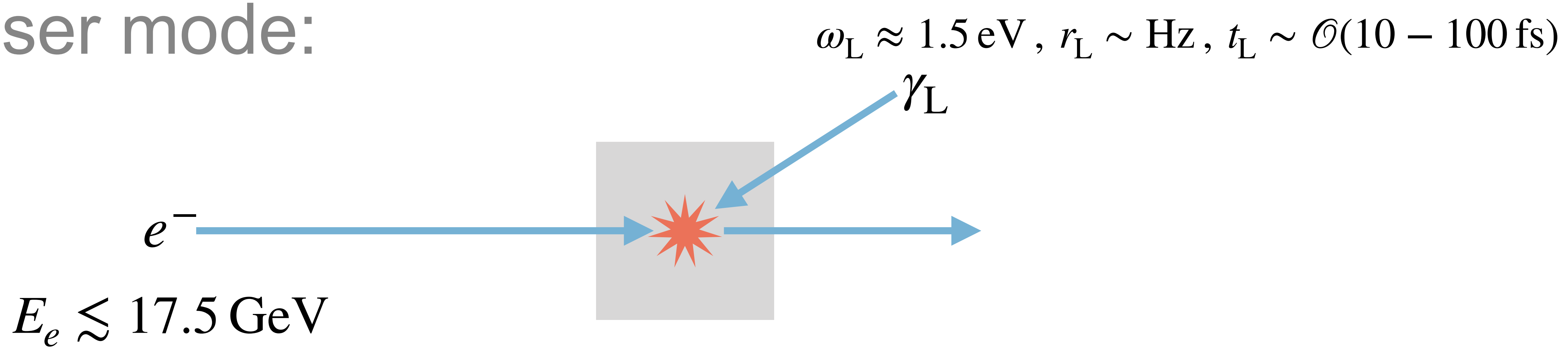
Noam Tal Hod (WIS)

LUXE setup

e^--laser mode:



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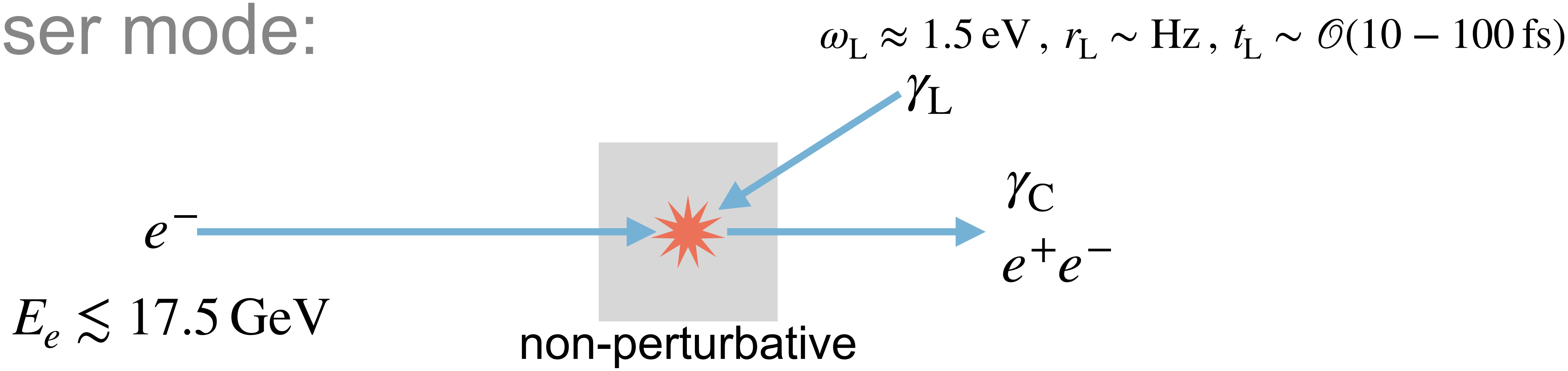
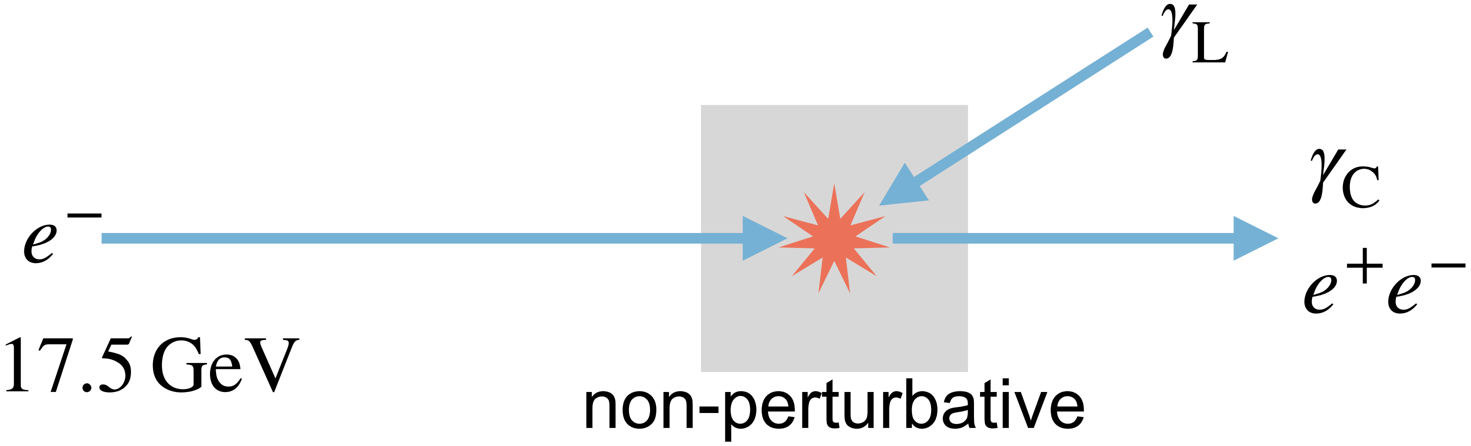


LUXE setup

e^--laser mode:

$\omega_\mathrm{L} \approx 1.5\,\mathrm{eV}\,,\ r_\mathrm{L} \sim \mathrm{Hz}\,,\ t_\mathrm{L} \sim \mathcal{O}(10 - 100\,\mathrm{fs})$



$E_e \lesssim 17.5\,\mathrm{GeV}$

High Intensity Compton Scattering (HICS)

$$e^-\gamma_\mathrm{L} \to e^-\gamma_\mathrm{C},\ \tau_\mathrm{HICS} \sim \mathcal{O}(10\,\mathrm{fs})$$

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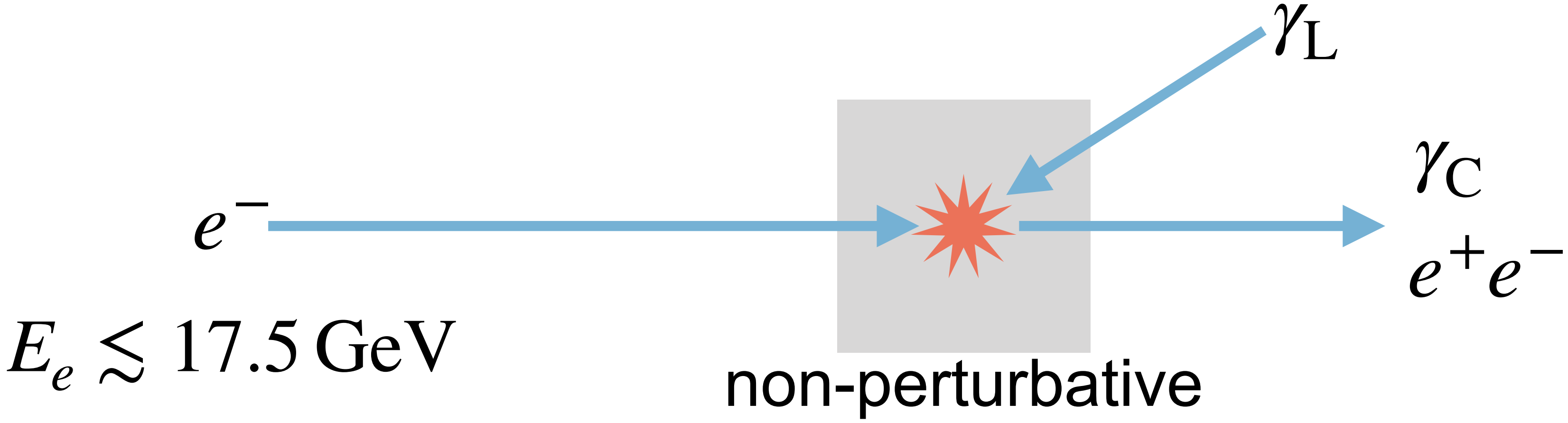

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$\gamma_\mathrm{L}\gamma_\mathrm{C} \to e^+e^-, \tau_\mathrm{OPPP} \sim \mathcal{O}(10^4 - 10^6\,\mathrm{fs})$

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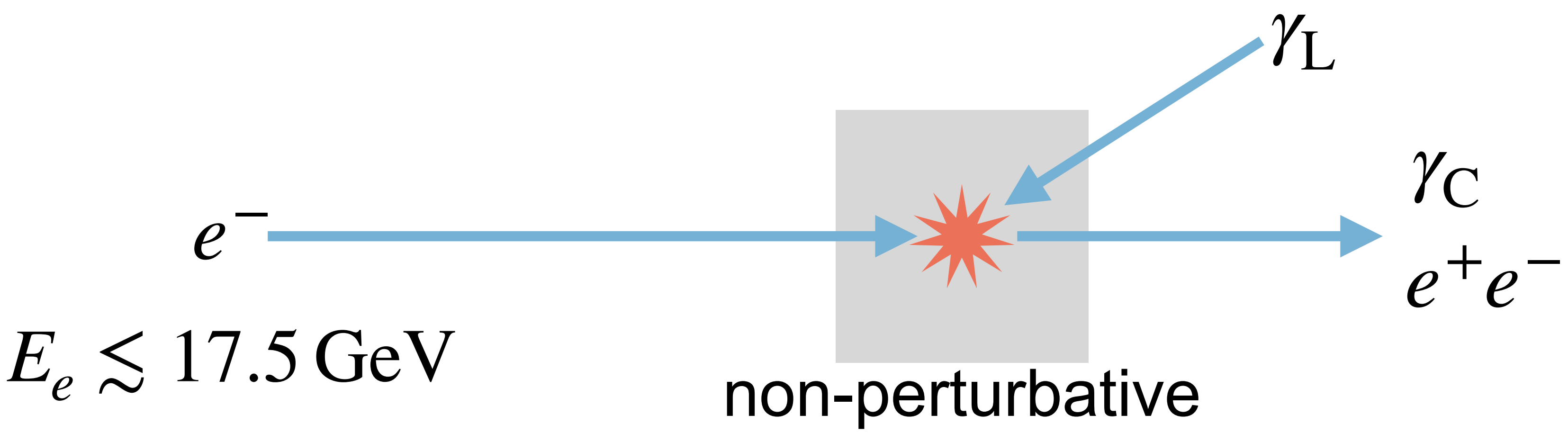

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emitted photons per pulse per e^-

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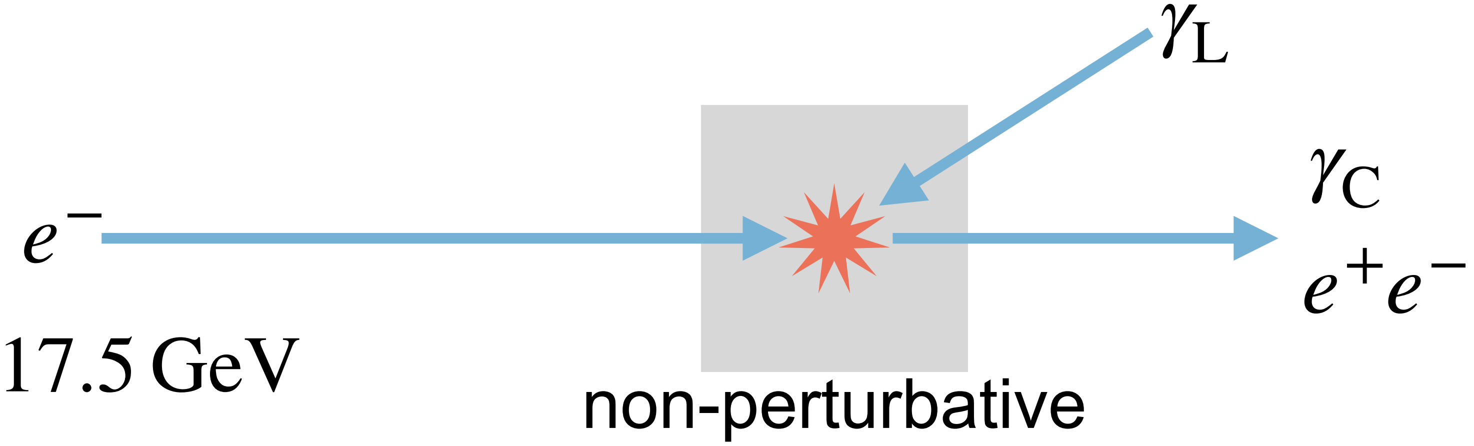

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pair production is suppressed

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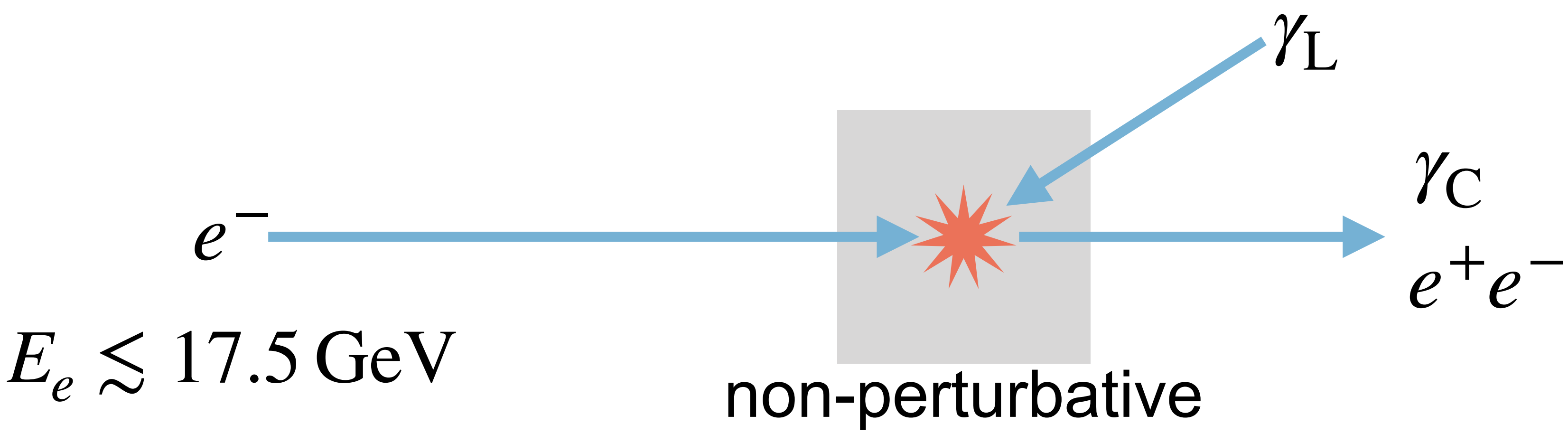

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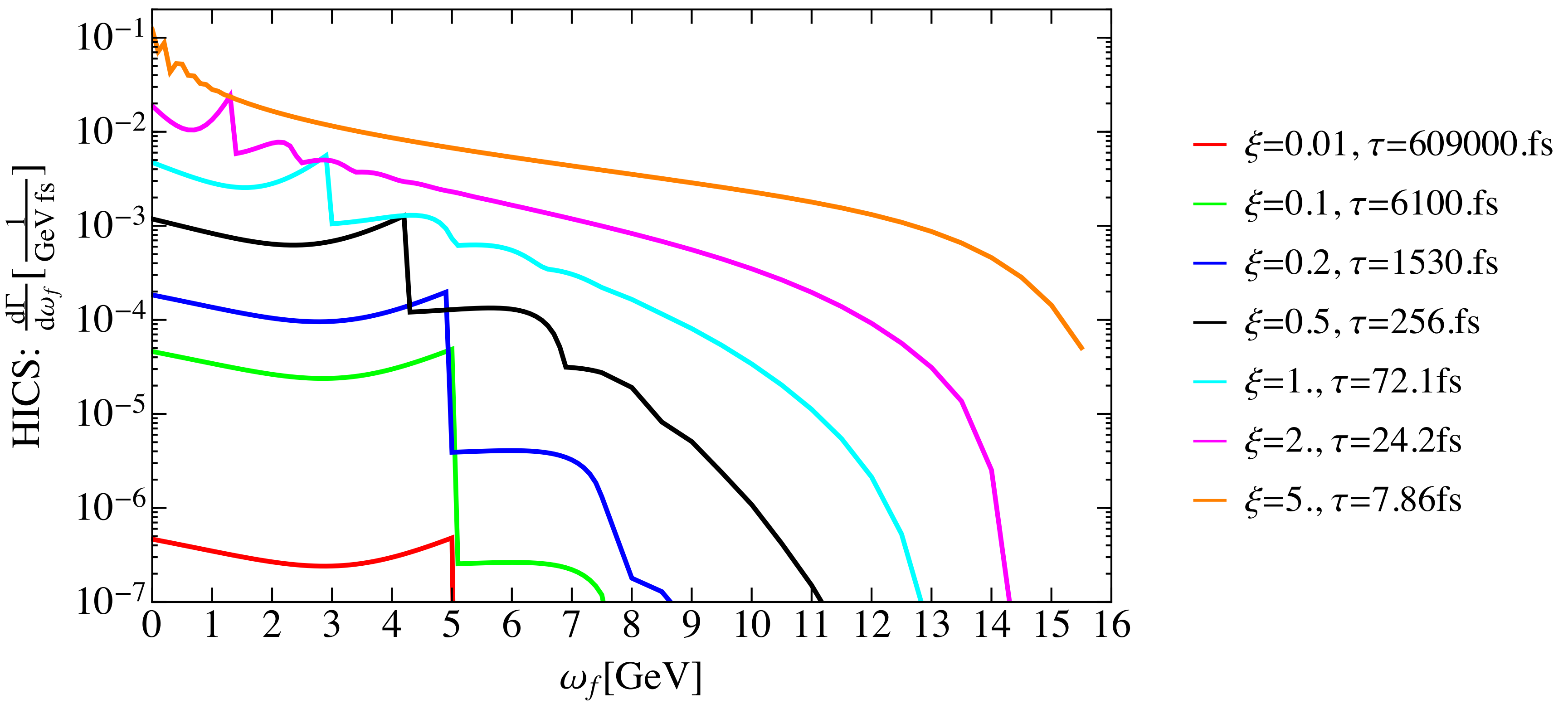
excellent source of GeV scale photons

the photon spectrum

$$E_e = 17.5\,\mathrm{GeV}$$



laser electric field

$$\xi = \frac{e\mathscr{E}_{\mathrm{L}}}{m_e \omega_{\mathrm{L}}}$$

the non perturbative parameter

the photon spectrum

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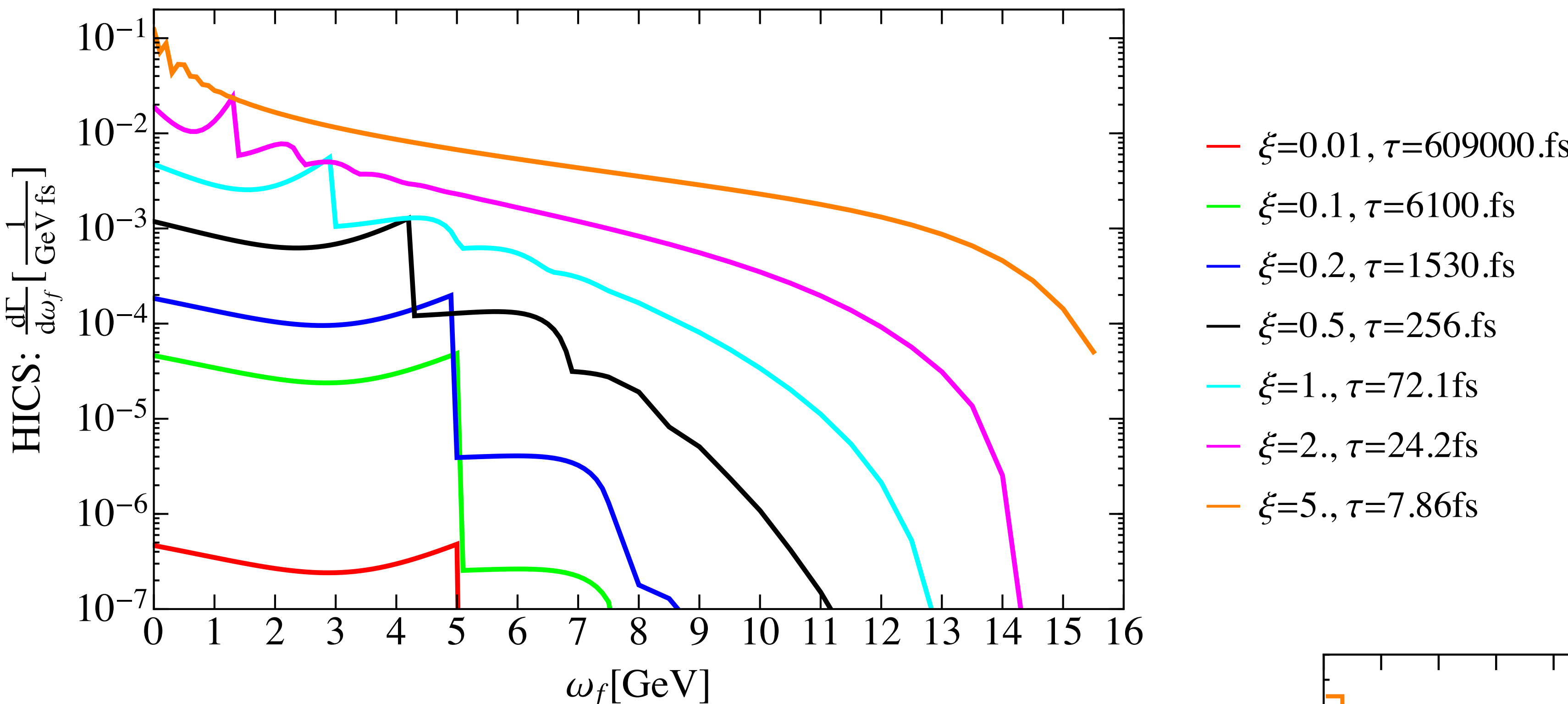

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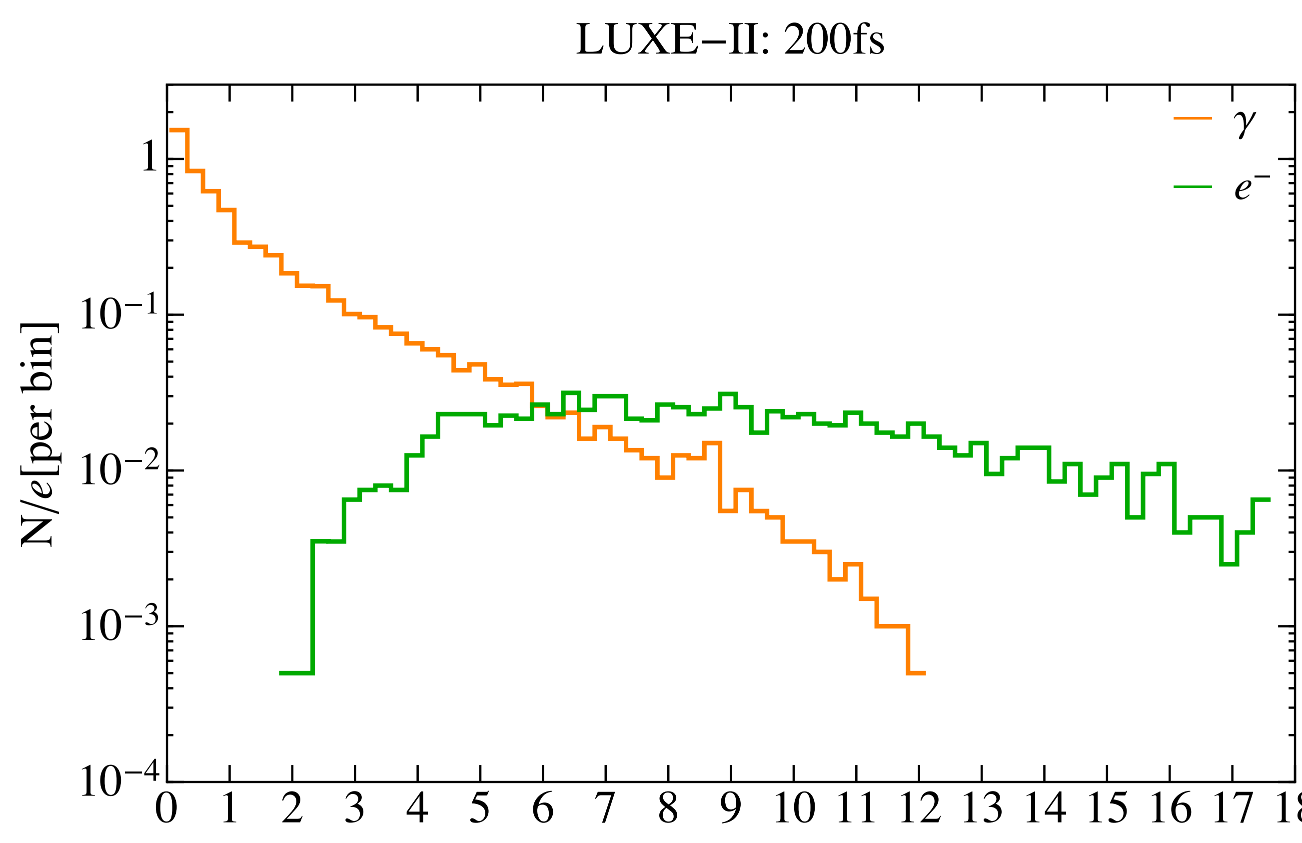

BSM scenarios

BSM scenarios

axion-like-particles
(ALPs)

$$\mathscr{L}_{\text{int}} = \frac{a}{4\Lambda} F_{\mu\nu}\tilde{F}^{\mu\nu} + g_{ae} a \bar{e} \gamma^5 a$$

mass - m_a

photon coupling - $1/\Lambda$

electron coupling - g_{ae}

for scalars, ϕ, $\tilde{F} \to F$, $\gamma^5 \to 1$

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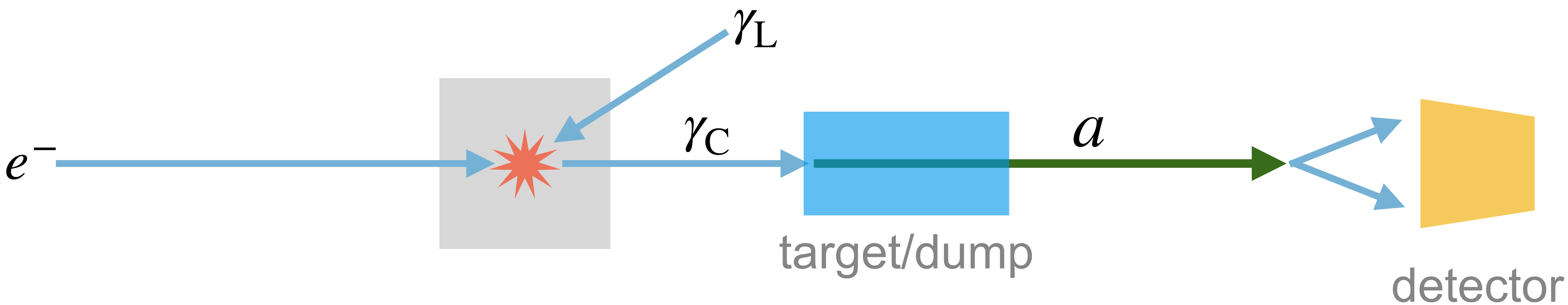
new physics production at LUXE

secondary new physics production
leverage LUXE as GeV photons source



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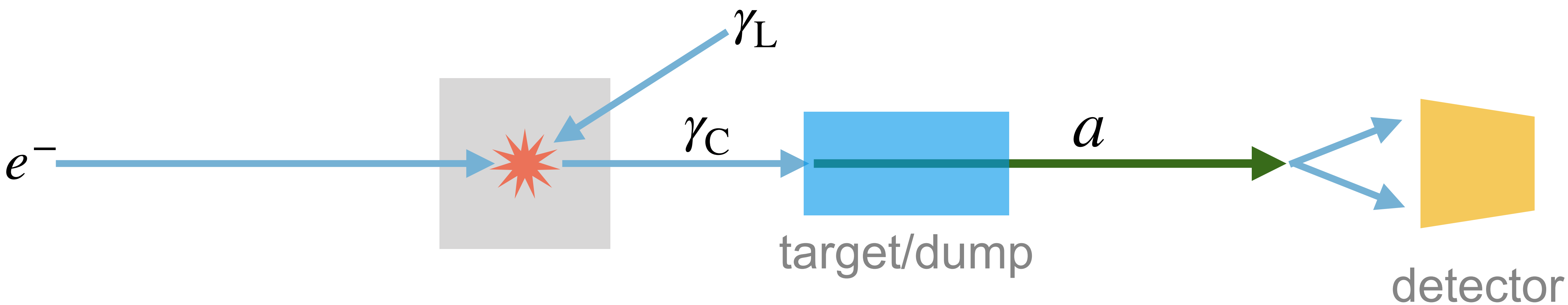
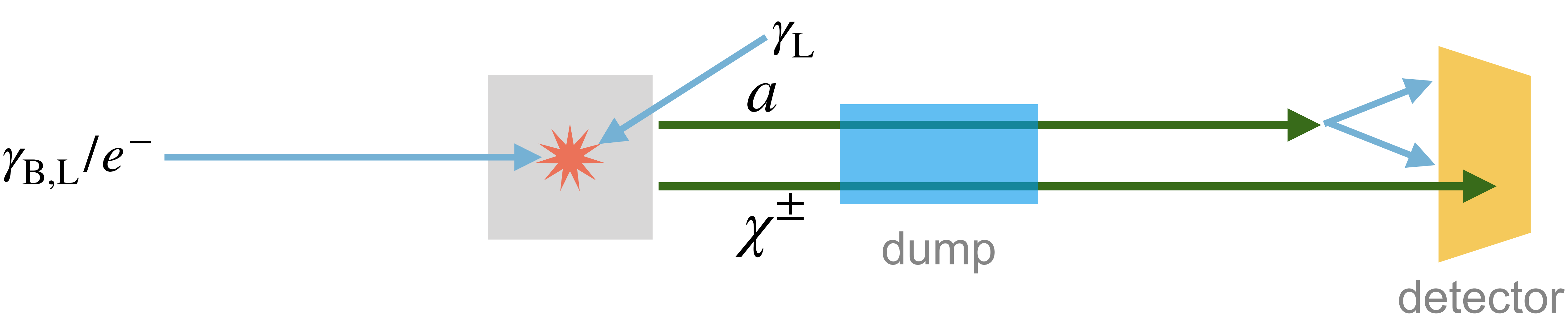


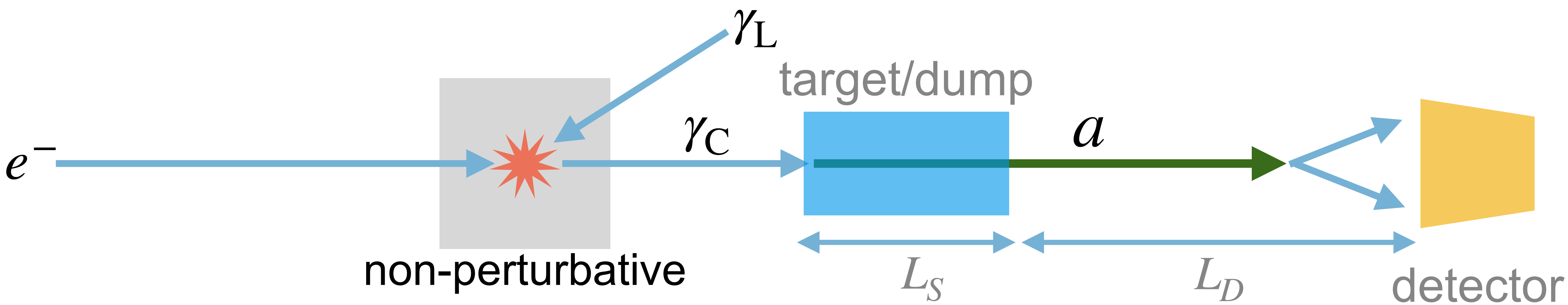
primary new physics production
new physics production at the interaction point

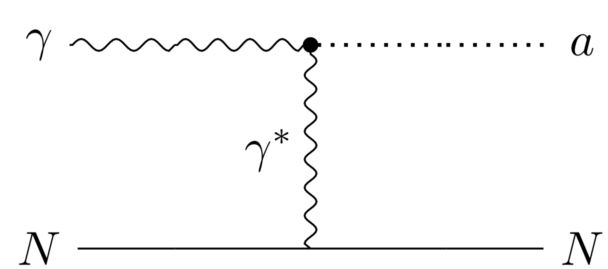


ALPs at the MeV to the GeV scale secondary production

secondary ALPs production

secondary ALP production at LUXE





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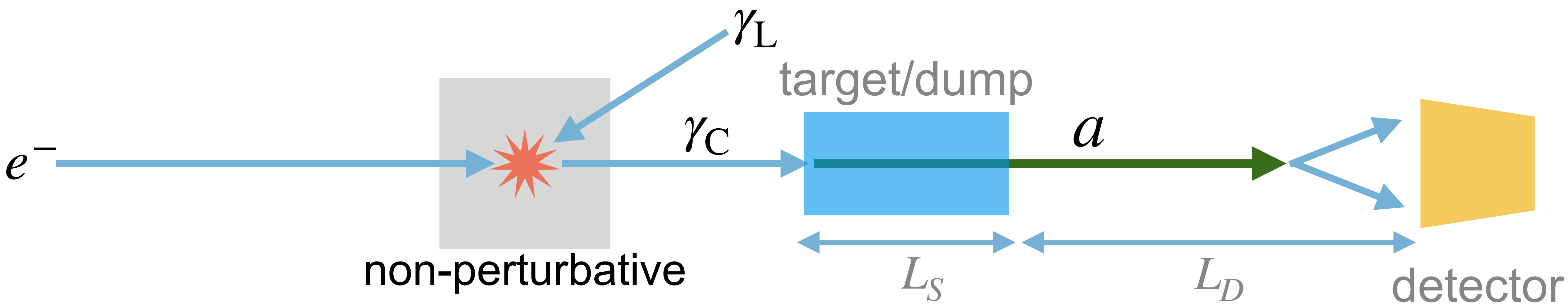
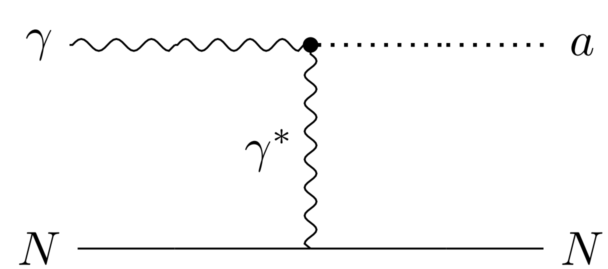
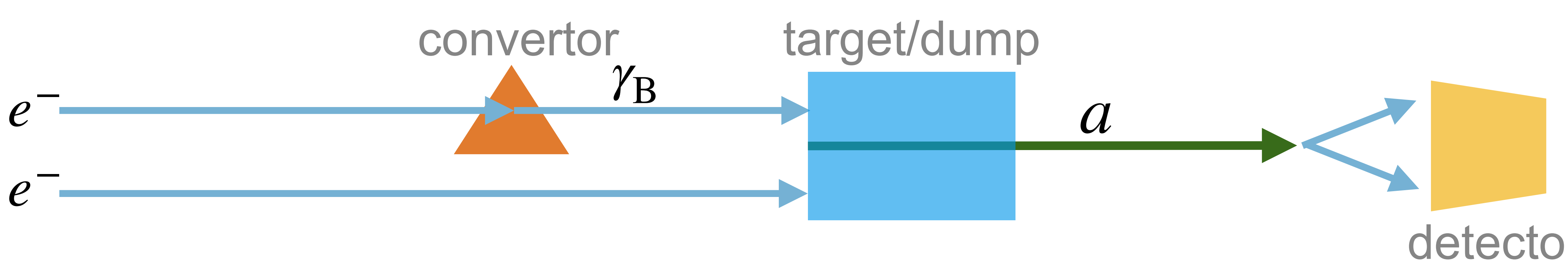


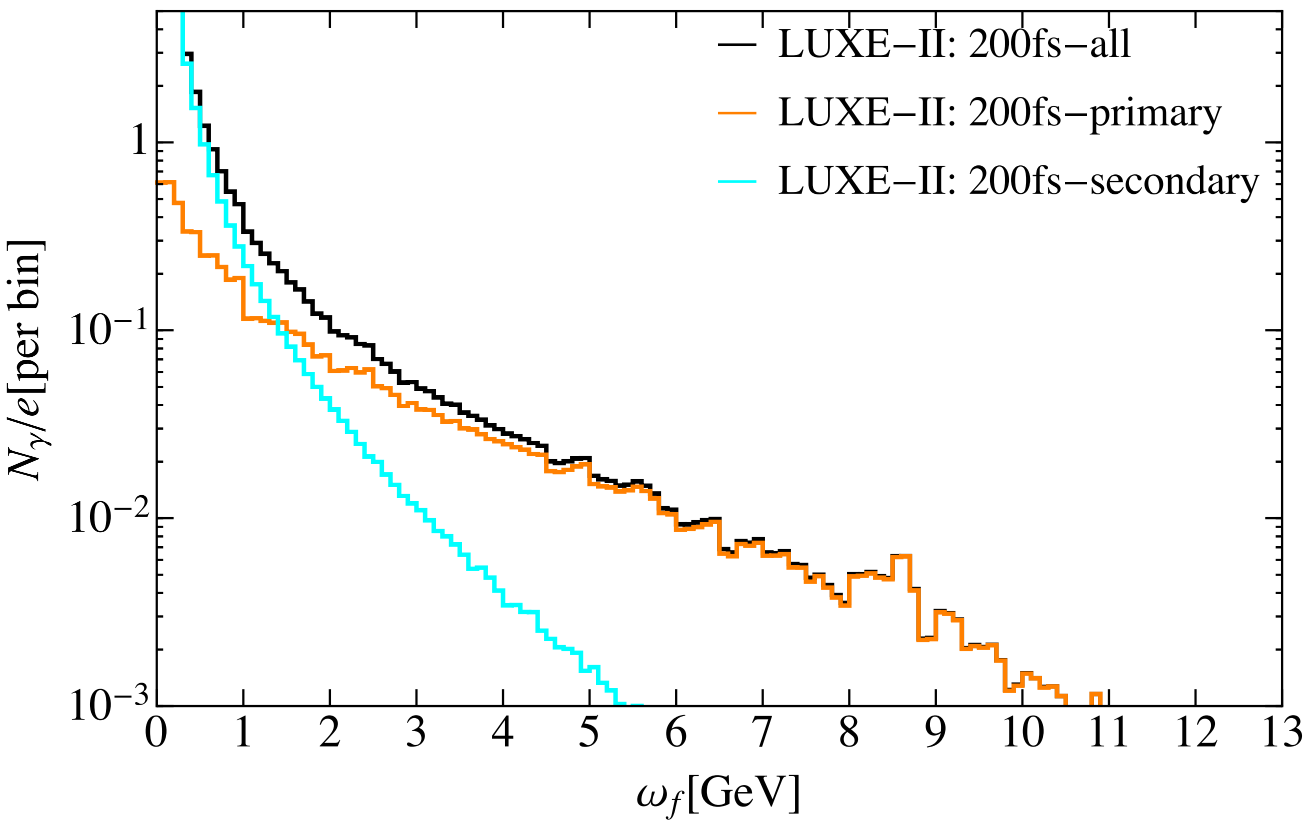


ALP production from bremsstrahlung photons (perturbative)



the photon spectrum

$$E_e = 17.5\,\mathrm{GeV}\,,\ \langle\omega_f\rangle \approx 2.5\,\mathrm{GeV}$$



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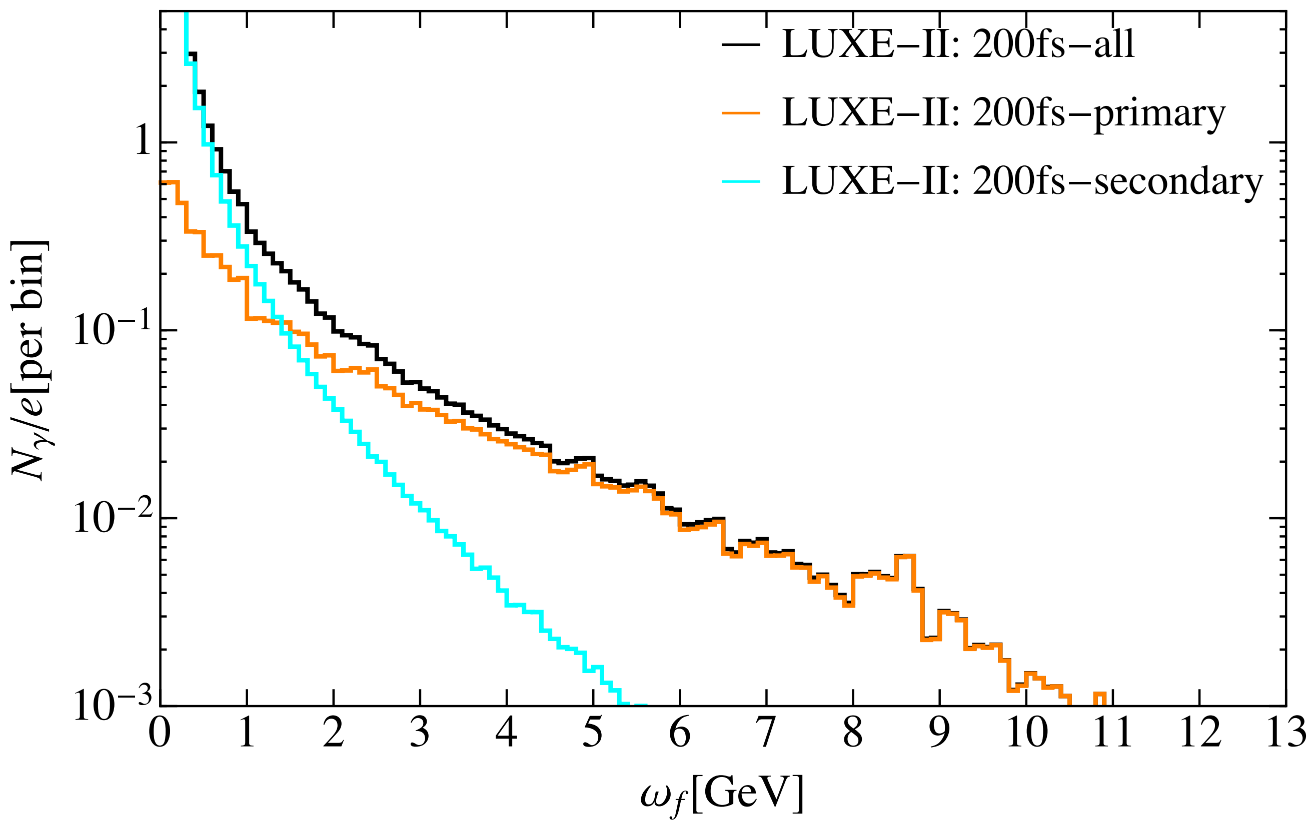

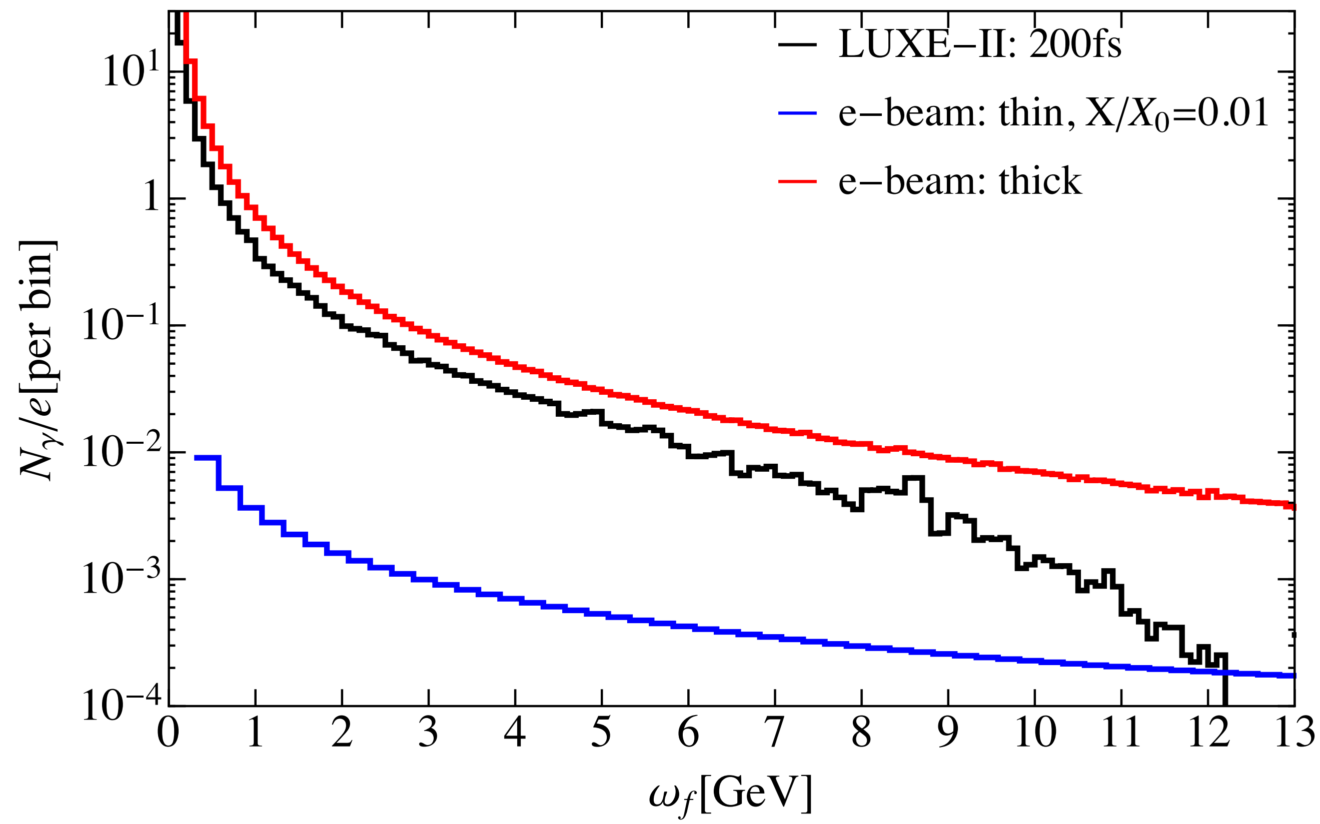

source	# photons, E>1 GeV
LUXEII	3.8
e-beam thin	0.03
e-beam thick	7.2

ALP reach estimation

number of ALPs

$$E_a \approx \omega_f\,,\ L_{\max} = L_D + L_S$$

$$N_a = \frac{\rho_T \Delta x}{A_T m_0} \int dE_\gamma \frac{dN_\gamma}{dE_\gamma} \int dp_a \frac{d\sigma_a}{dp_a} \left(e^{-\frac{\Gamma_a L_S}{p_a/m_a}} - e^{-\frac{\Gamma_a L_{\max}}{p_a/m_a}} \right) \approx \frac{\rho_T \Delta x}{A_T m_0} \int dE_\gamma \frac{dN_\gamma}{dE_\gamma} \sigma_a \left(e^{-\frac{\Gamma_a L_S}{p_a/m_a}} - e^{-\frac{\Gamma_a L_{\max}}{p_a/m_a}} \right)$$

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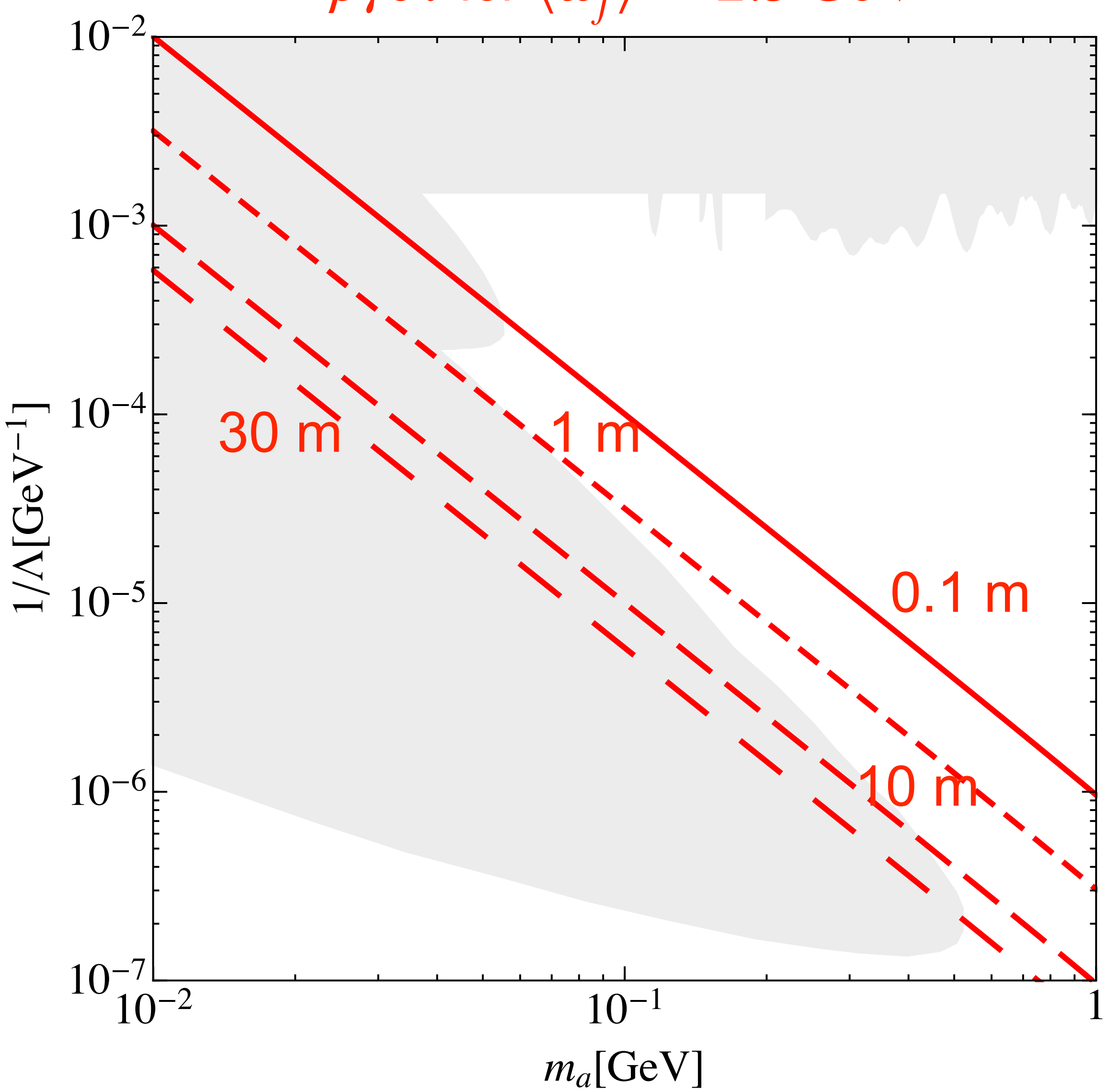
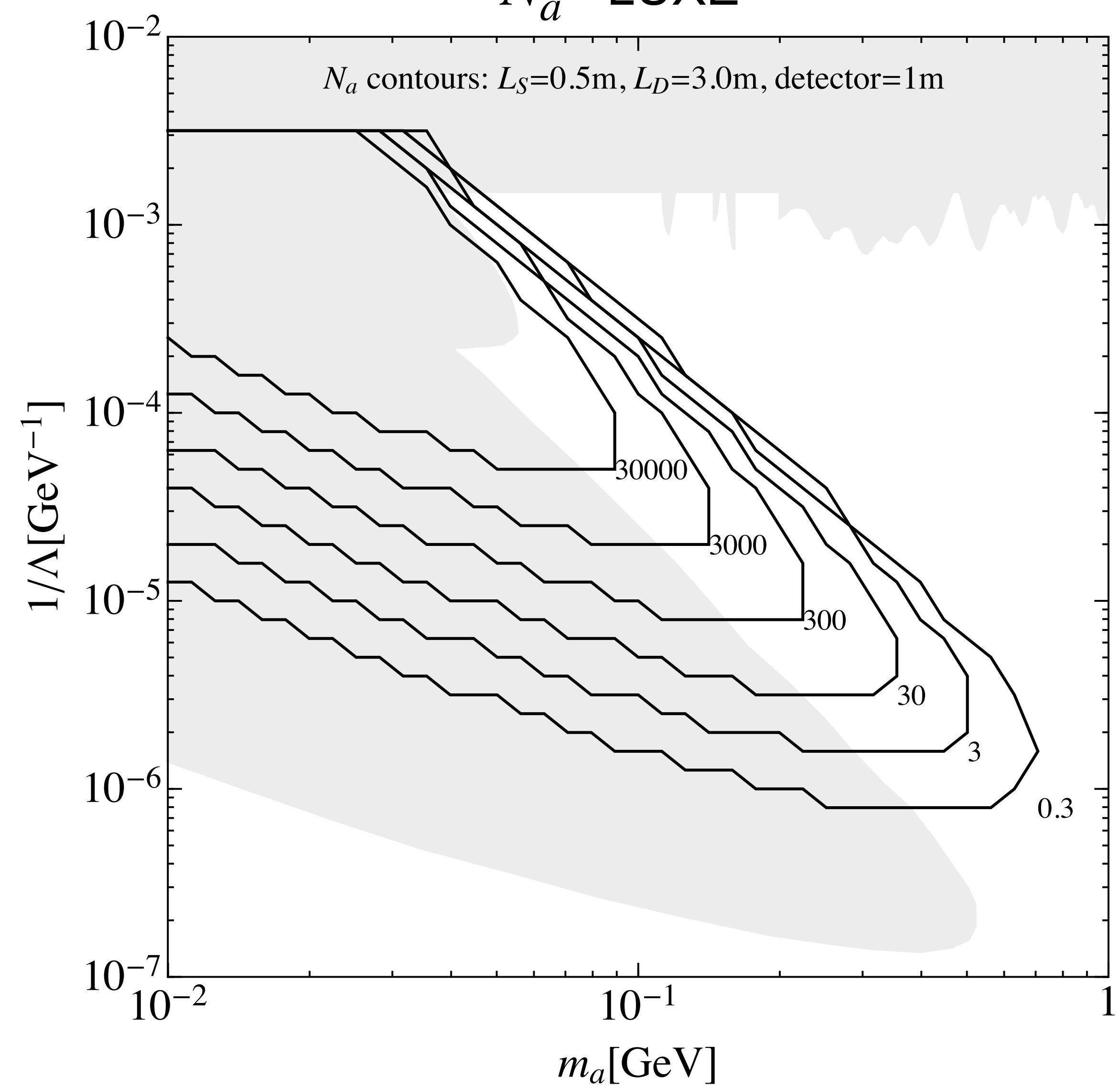
$$E_e = 17.5\,\mathrm{GeV} \quad N_e = 6\times 10^9 \quad t_\mathrm{L} = 200\,\mathrm{fs} \quad \xi = 2.43 \quad t_\mathrm{op} = 10^7\,\mathrm{s} \quad R_\mathrm{L} = 1\,\mathrm{Hz}$$

$\beta\gamma c\tau$ for $\langle\omega_f\rangle \approx 2.5\,\mathrm{GeV}$



N_a - LUXE



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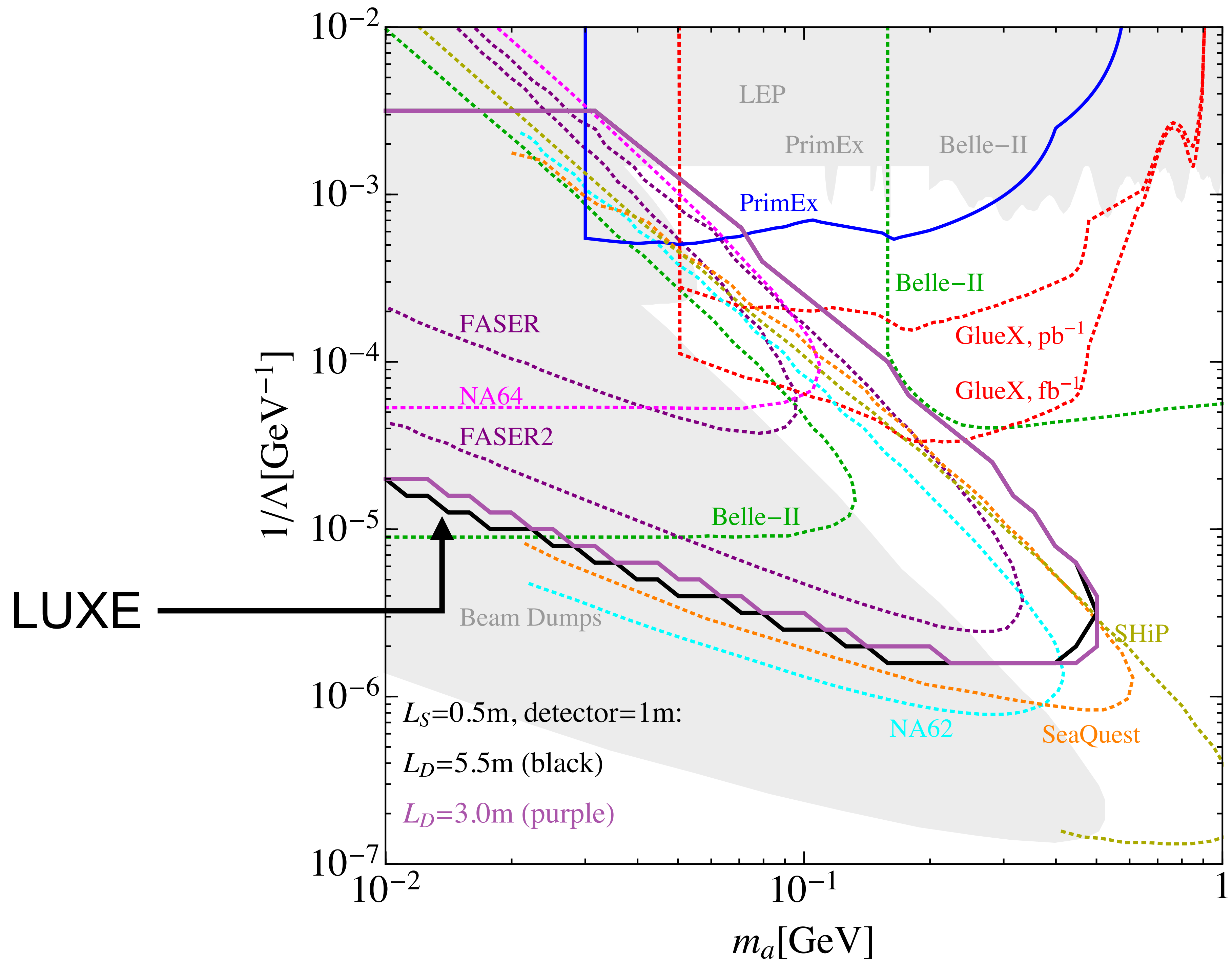

μ pair background is under study

based on Aloni et al, 1903.03586

Primary ALP/scalar production

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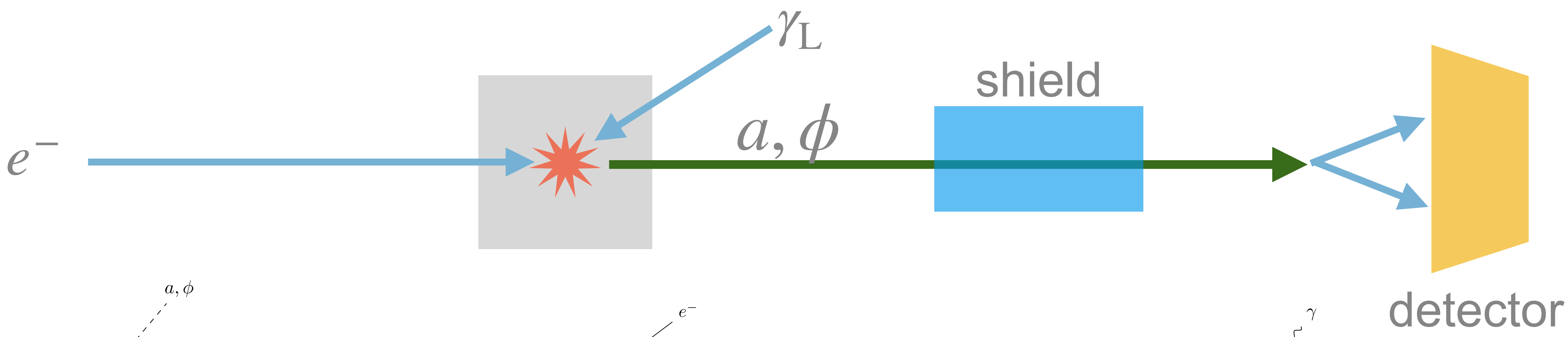
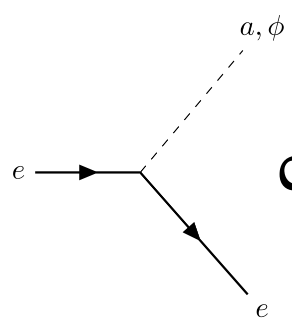
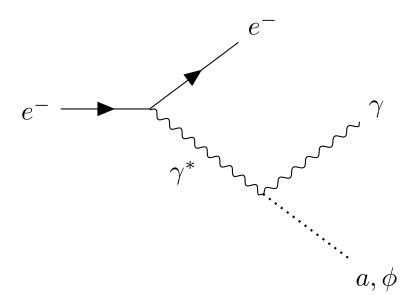
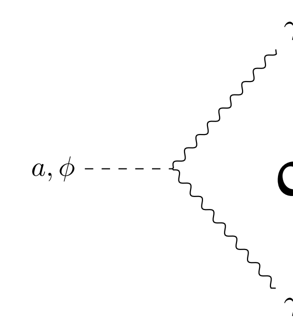




$\propto g_{ae}\,,\, g_{\phi e}$



$\propto 1/\Lambda$



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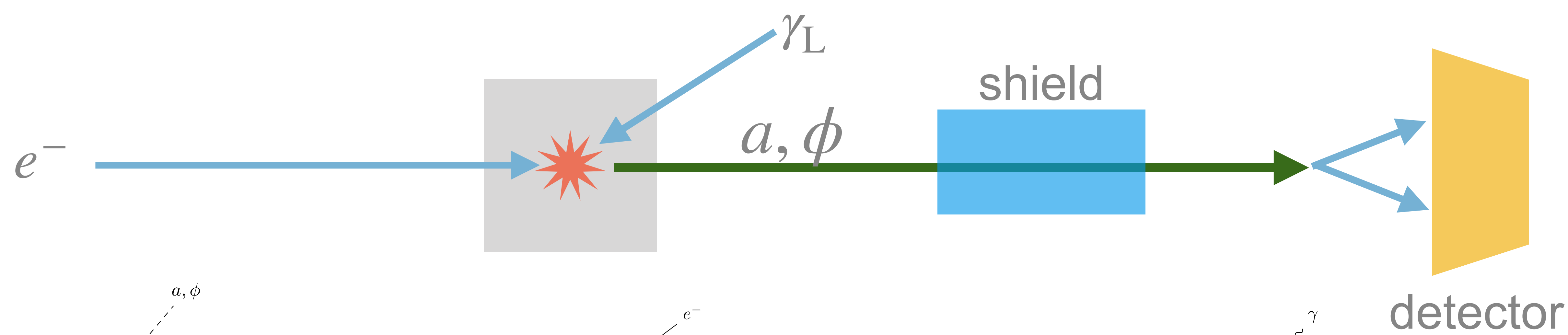

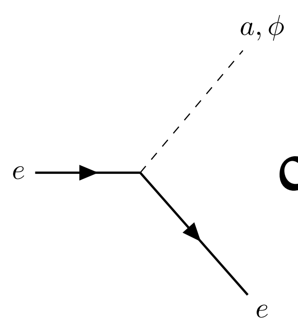

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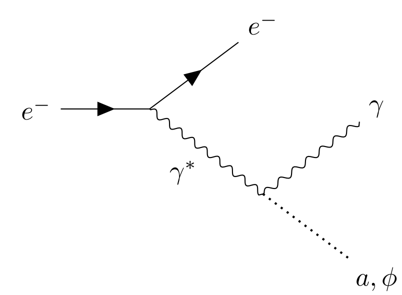

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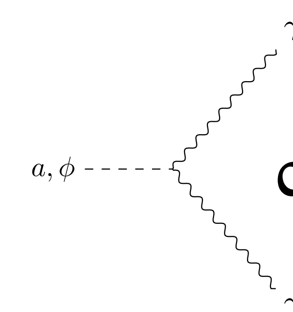


$\propto 1/\Lambda$

normalize to Compton photons

$$\frac{\sigma(e \to e\phi)}{\sigma(e \to e\gamma_{\rm C})} \approx \frac{g_{\phi e}^2 \beta_\phi}{4\pi\alpha_{\rm EM}} \qquad \frac{\sigma(e \to ea)}{\sigma(e \to e\gamma_{\rm C})} \approx \frac{g_{ae}^2 \beta_a}{4\pi\alpha_{\rm EM}} \left(\frac{E_a}{m_e}\right)^2$$

$$\frac{\sigma(e \to e\phi)}{\sigma(e \to e\gamma_{\rm C})} \approx \frac{m_{a,\phi}^2}{16\pi^2\Lambda^2}$$

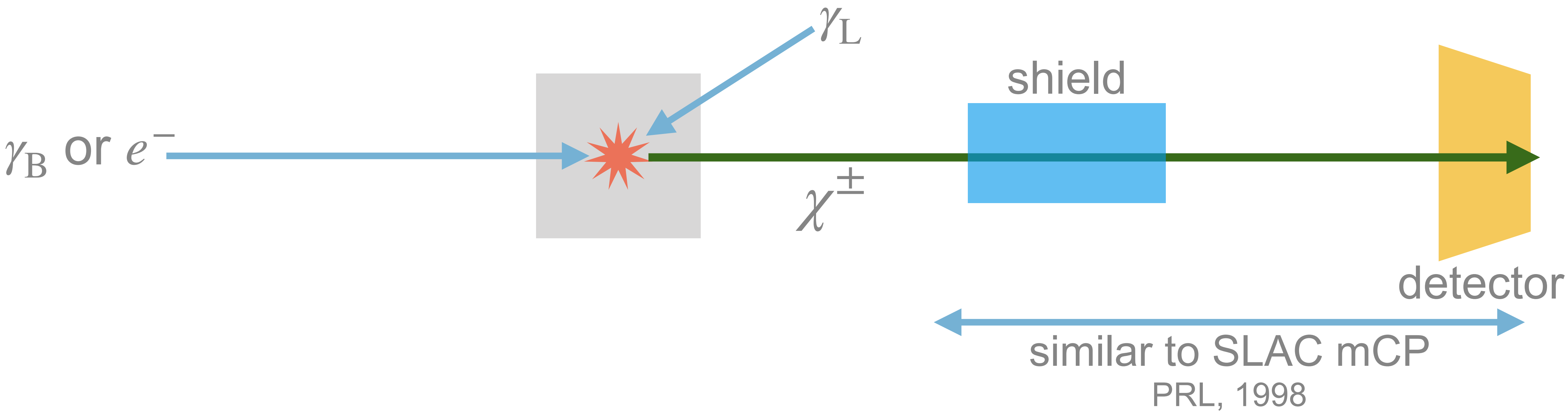
$\beta_{a,\phi}$ = velocity

milli-charged particle (mCP)

primary mCP production

$$\mathscr{L}_{\text{int}} = eq\bar{\chi}\gamma^{\mu}\chi A_{\mu}$$

mass - m_χ, fractional charge - q



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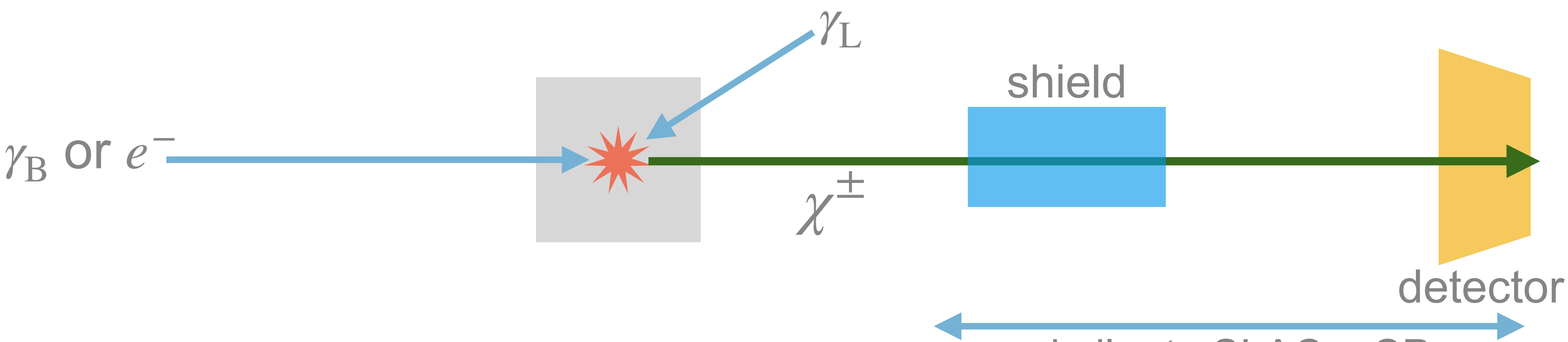


similar to SLAC mCP
PRL, 1998

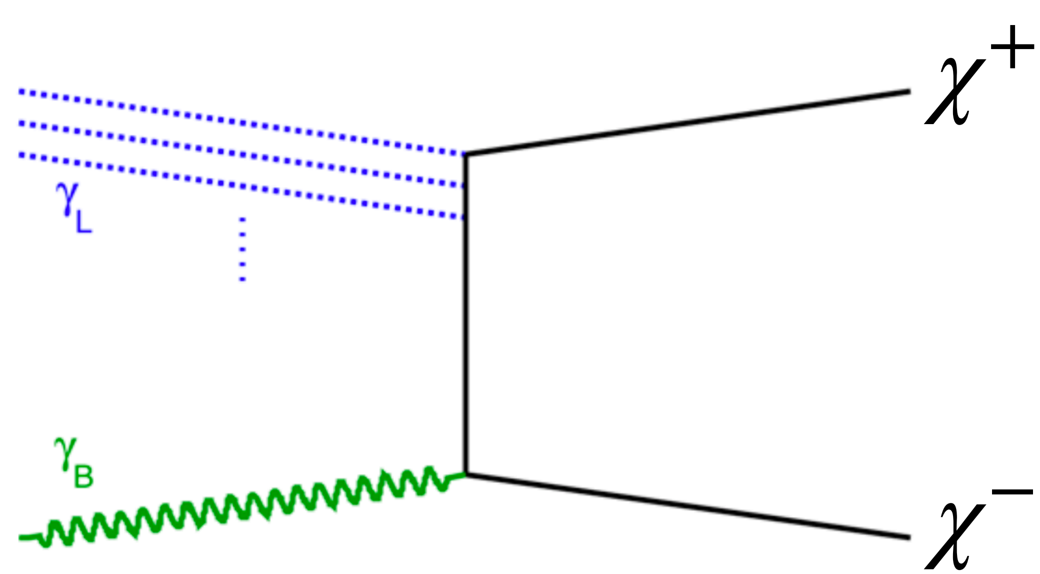
similar production as e^+e^-

$$m_e \to m_\chi \,,\; e \to qe$$

Schwinger critical field

$$\frac{\mathscr{E}^{\chi}_{\text{cr}}}{\mathscr{E}^{e}_{\text{cr}}} = \frac{10^{-6}}{q}\left(\frac{m_\chi}{0.5\,\text{keV}}\right)^2$$

$$\mathscr{E}^{e/\chi}_{\text{cr}} = m^2_{e/\chi}/eq$$



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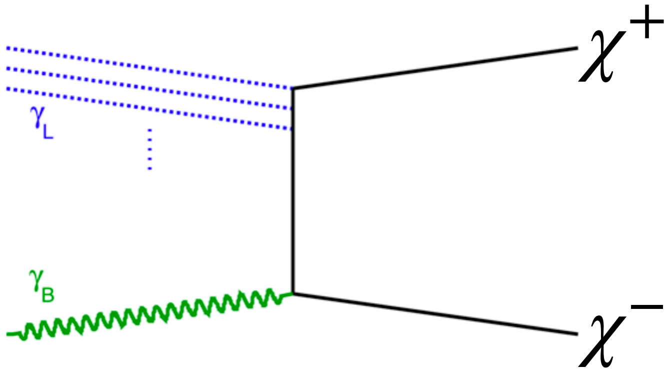

$$\sigma(\gamma_L\gamma_B \to \chi^+\chi^-) \propto q^4$$

$$10^{-5} < m_\chi/m_e < 10^{-3}$$

(weak mass dependence)

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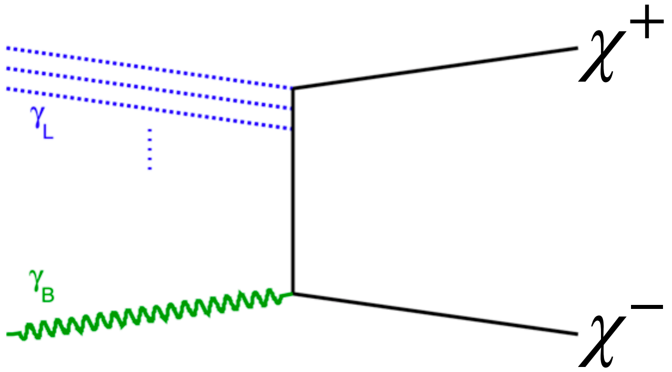

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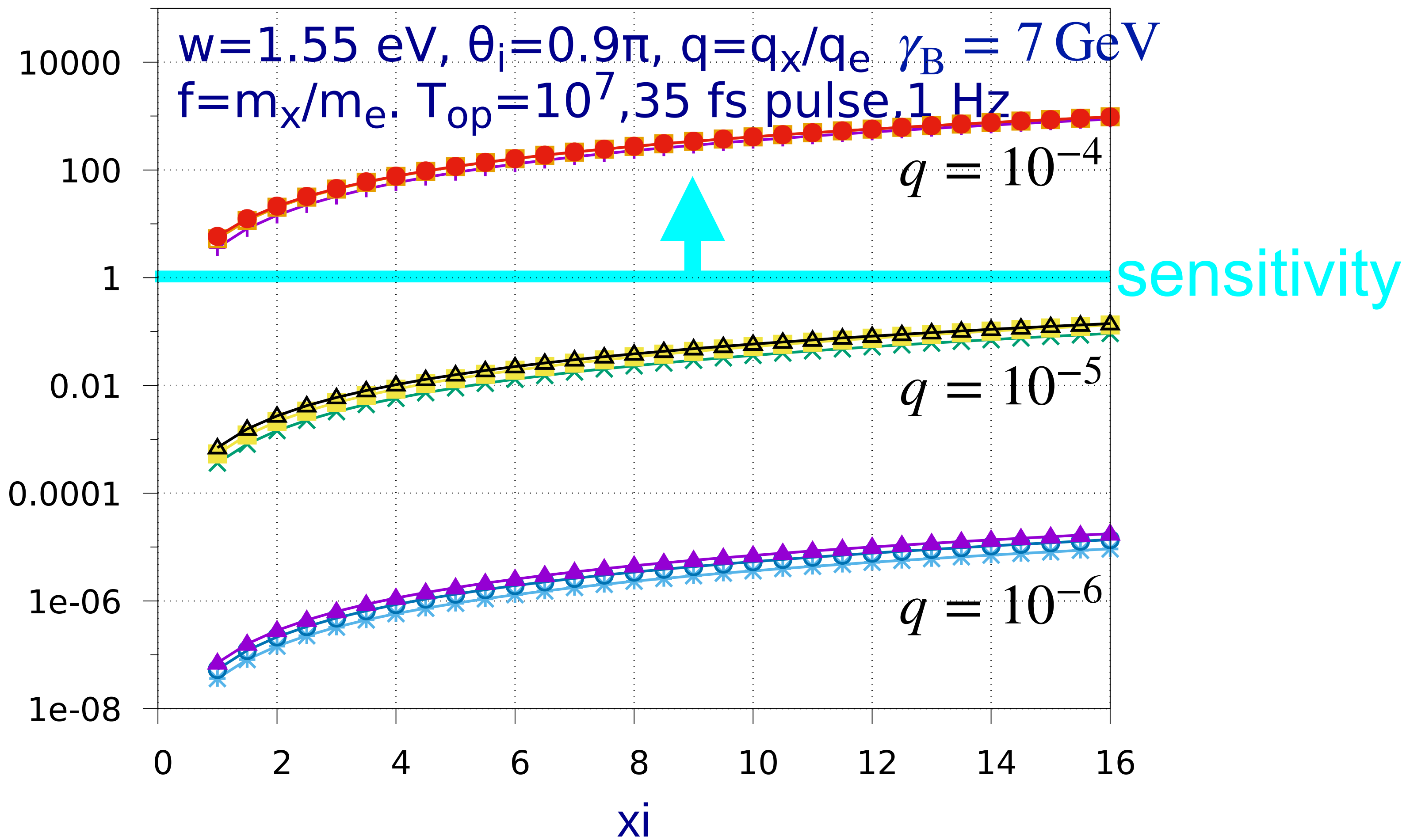
Putative mCP (m_x,q_x) production at LUXE



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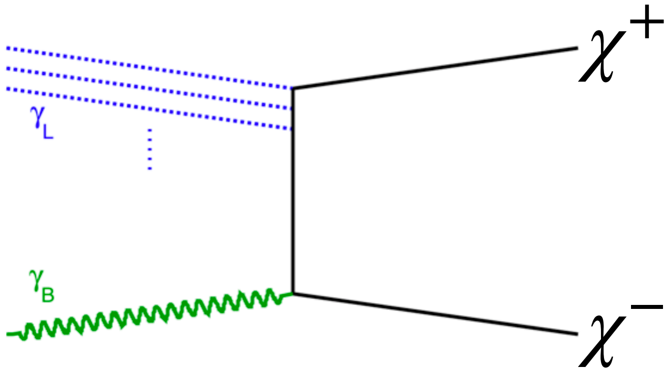

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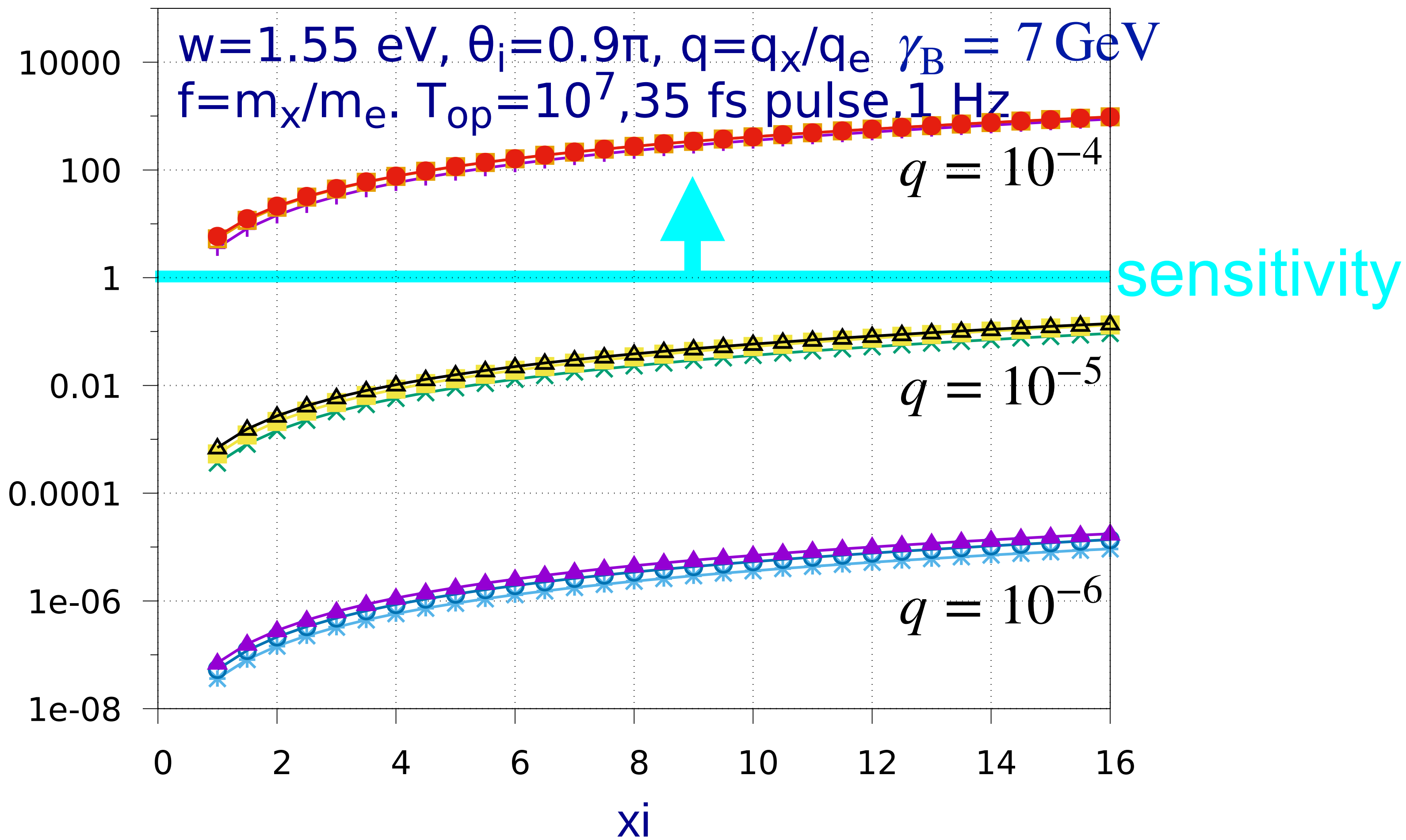


additional productions

(on progress)

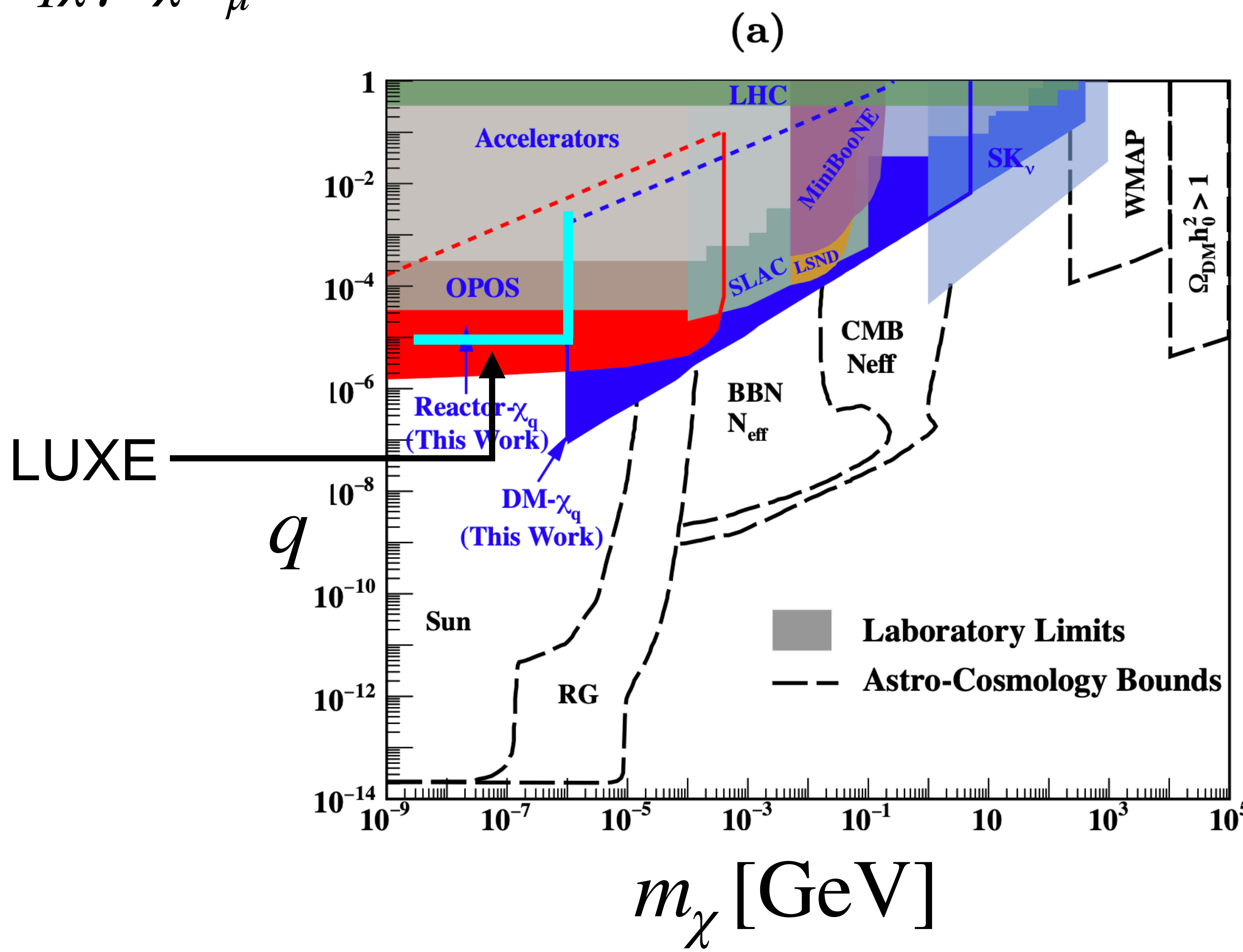
$$\frac{\sigma(e^-\gamma_L \to \chi^+\chi^-)}{\sigma(\gamma_L\gamma_B \to \chi^+\chi^-)} \sim 10$$

off-shell trident

for $m_\chi \lesssim \mathrm{keV}$ the best case sensitivity is for $q \gtrsim 10^{-5}$

mCP projections

$$\mathcal{L}_{\text{int}} = eq\bar{\chi}\gamma^{\mu}\chi A_{\mu}$$



plot from TEXONO, 1808.02719

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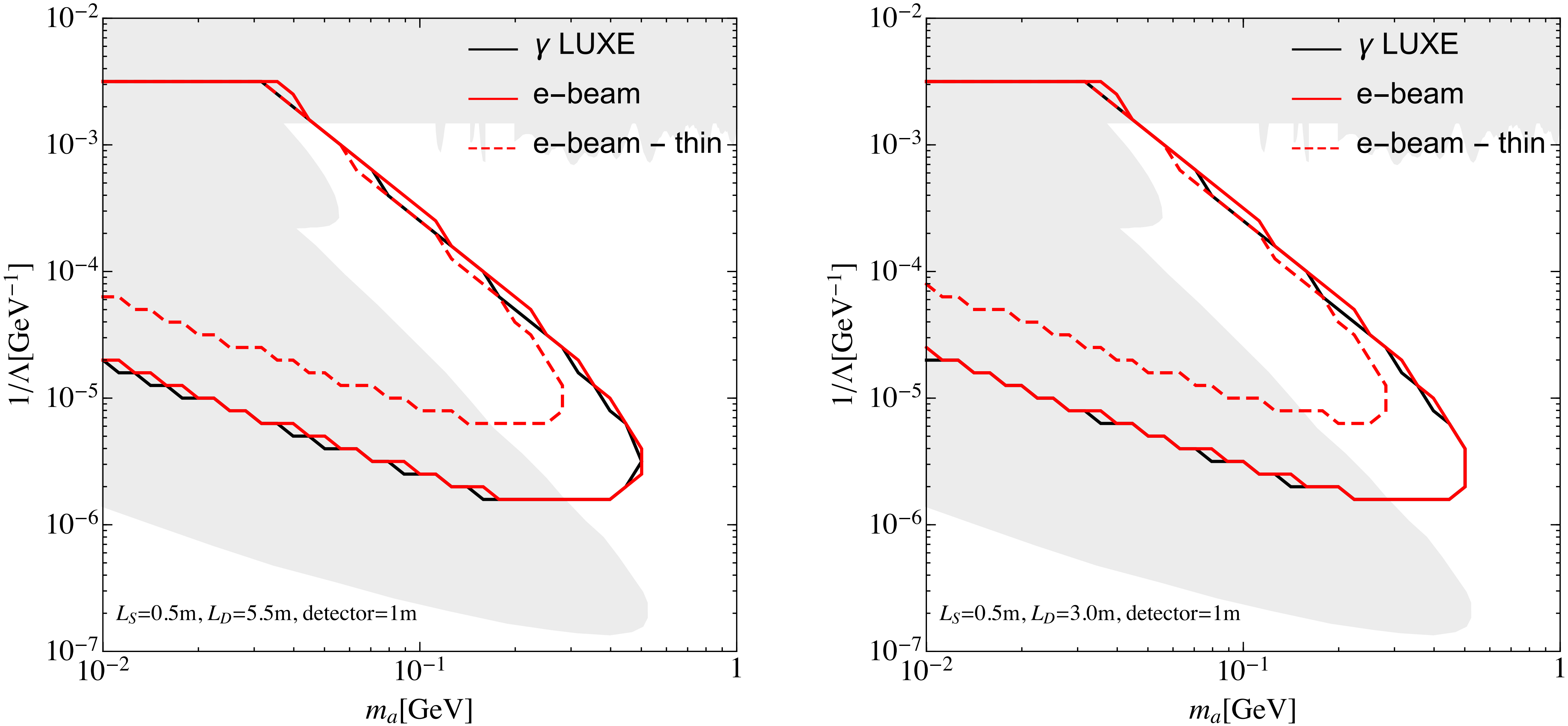
outlook

* the LUXE setup gives new opportunities to probe physics beyond the SM.
* preliminary studies show that there is a potential to probe unexplored parameter space of ALPs
* the scalar/axion-electric production is under investigation
* the reach for milli-charge particles (mCP) is under investigation and limited

backups

LUXE vs e-beam

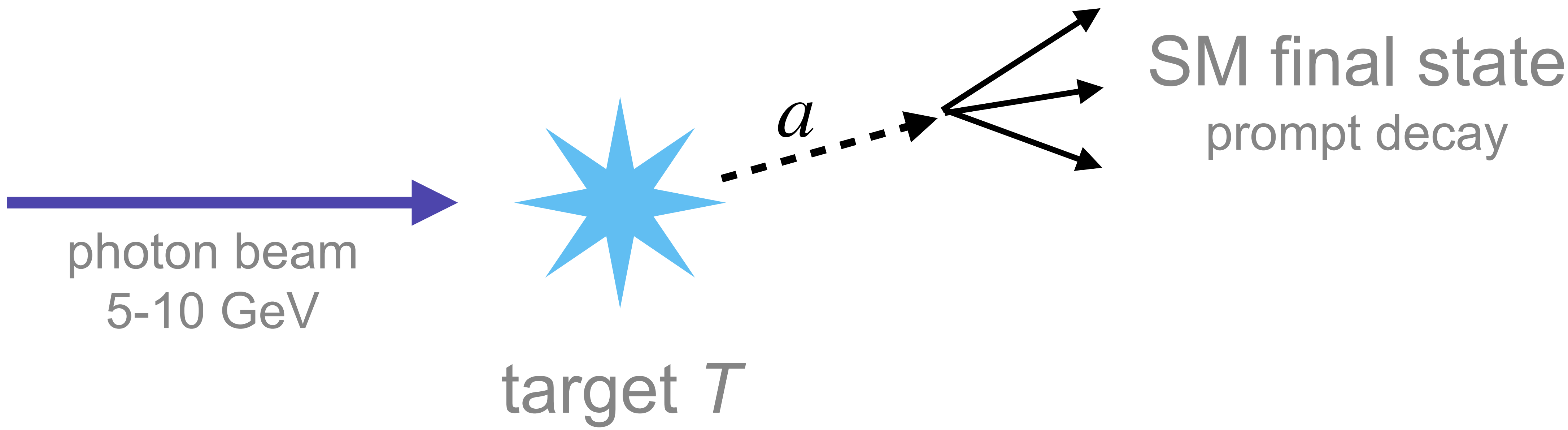


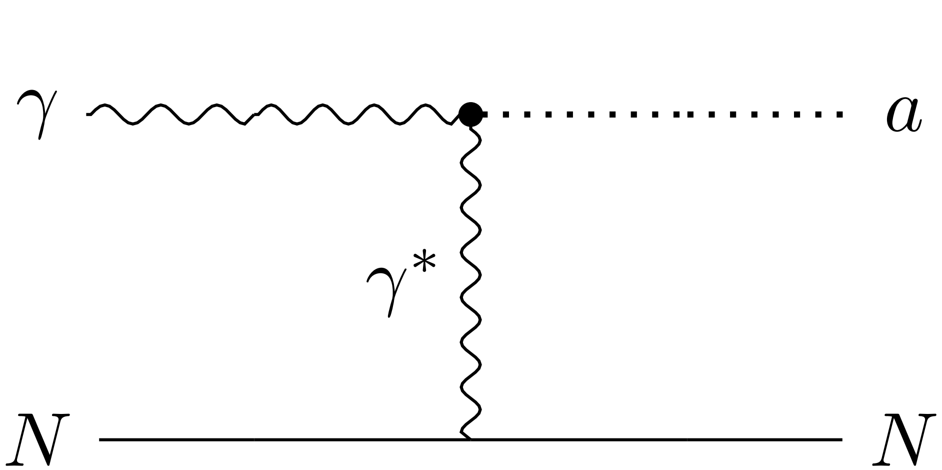
axion like particles

* originally - the Axion propose as a solution to the strong CP problem
* appear in many BSM scenarios
* portal to dark matter and/or dark sector
* if very light, it is a dark matter candidate
* predicted by string theory

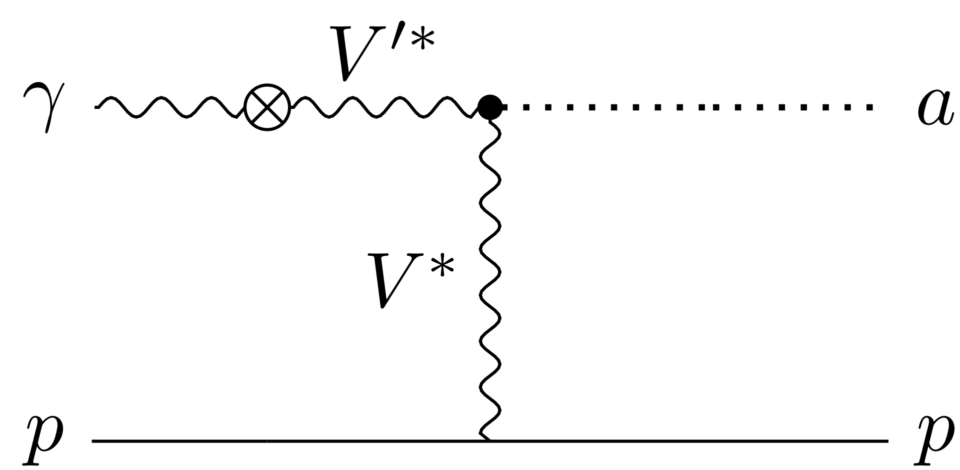
⇒ $\boxed{\text{well motivated BSM scenario}}$

ALPs at Primakoff like experiments





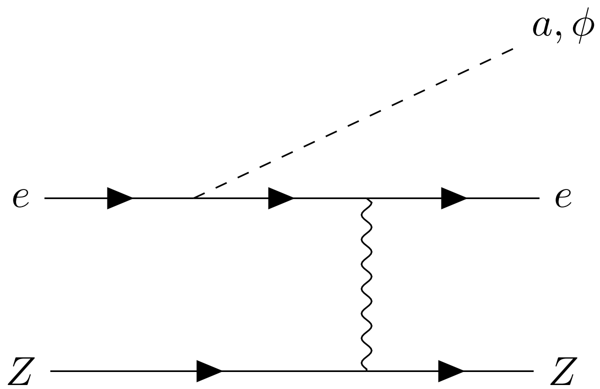
$$\frac{c_\gamma}{4\Lambda}\, a\, F^{\mu\nu}\tilde{F}_{\mu\nu}$$



$$-\frac{4\pi\alpha_s c_g}{\Lambda}\, a\, G^{\mu\nu}\tilde{G}_{\mu\nu}$$

primary ALP/scalar production

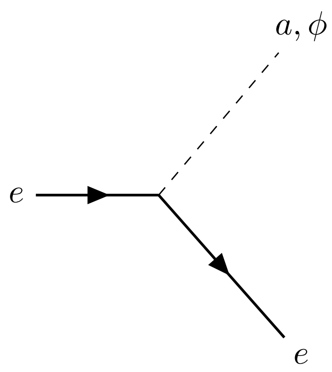
e beam dump (E137)



$$N_{a,\phi} \propto N_{\gamma_C} \frac{g^2_{a,\phi\ e}}{\Lambda^2}$$

$$N_{\gamma_C} \propto N_e$$

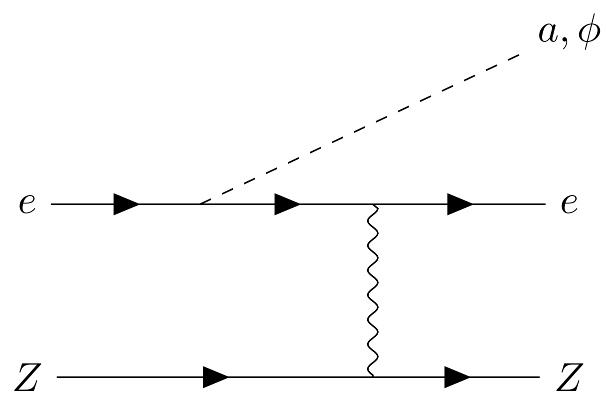
non-perturbative (LUXE)



primary ALP/scalar production

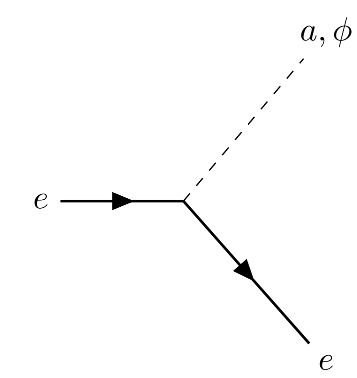
e beam dump (E137)

non-perturbative (LUXE)



$$N_{a,\phi} \propto N_{\gamma_C} \frac{g^2_{a,\phi\ e}}{\Lambda^2}$$

$$N_{\gamma_C} \propto N_e$$



$$N_e^{\mathrm{E137}} \sim 10^{20}$$

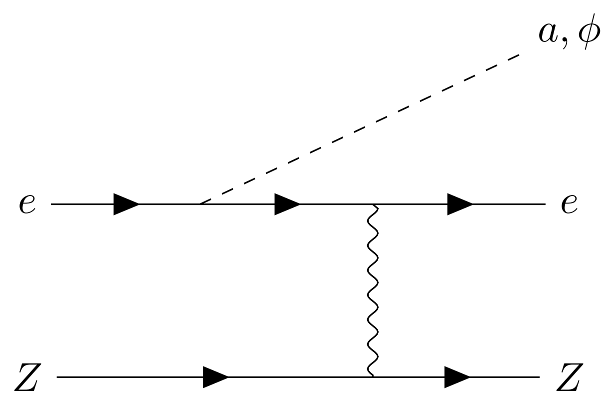
$$N_e^{\mathrm{LUXE}} \sim 10^{18}$$

$$\frac{[N_{\gamma_C}/N_e]_{\mathrm{LUXE}}}{[N_{\gamma_C}/N_e]_{\mathrm{E137}}} \sim 10^2 - 10^3$$

non-perturbative
enhancement

primary ALP/scalar production

e beam dump (E137)

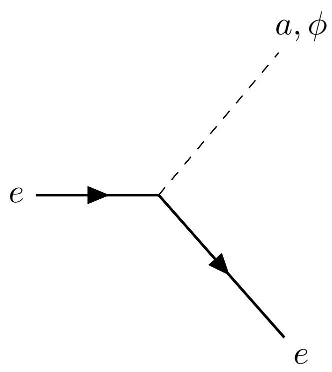


$N_e^{\mathrm{E137}} \sim 10^{20}$

$$N_{a,\phi} \propto N_{\gamma_{\mathrm{C}}} \frac{g^2_{a,\phi\, e}}{\Lambda^2}$$

$$N_{\gamma_{\mathrm{C}}} \propto N_e$$

non-perturbative (LUXE)



$N_e^{\mathrm{LUXE}} \sim 10^{18}$

$$\frac{[N_{\gamma_{\mathrm{C}}}/N_e]_{\mathrm{LUXE}}}{[N_{\gamma_{\mathrm{C}}}/N_e]_{\mathrm{E137}}} \sim 10^2 - 10^3$$

non-perturbative enhancement

possible better sensitivity - in progress