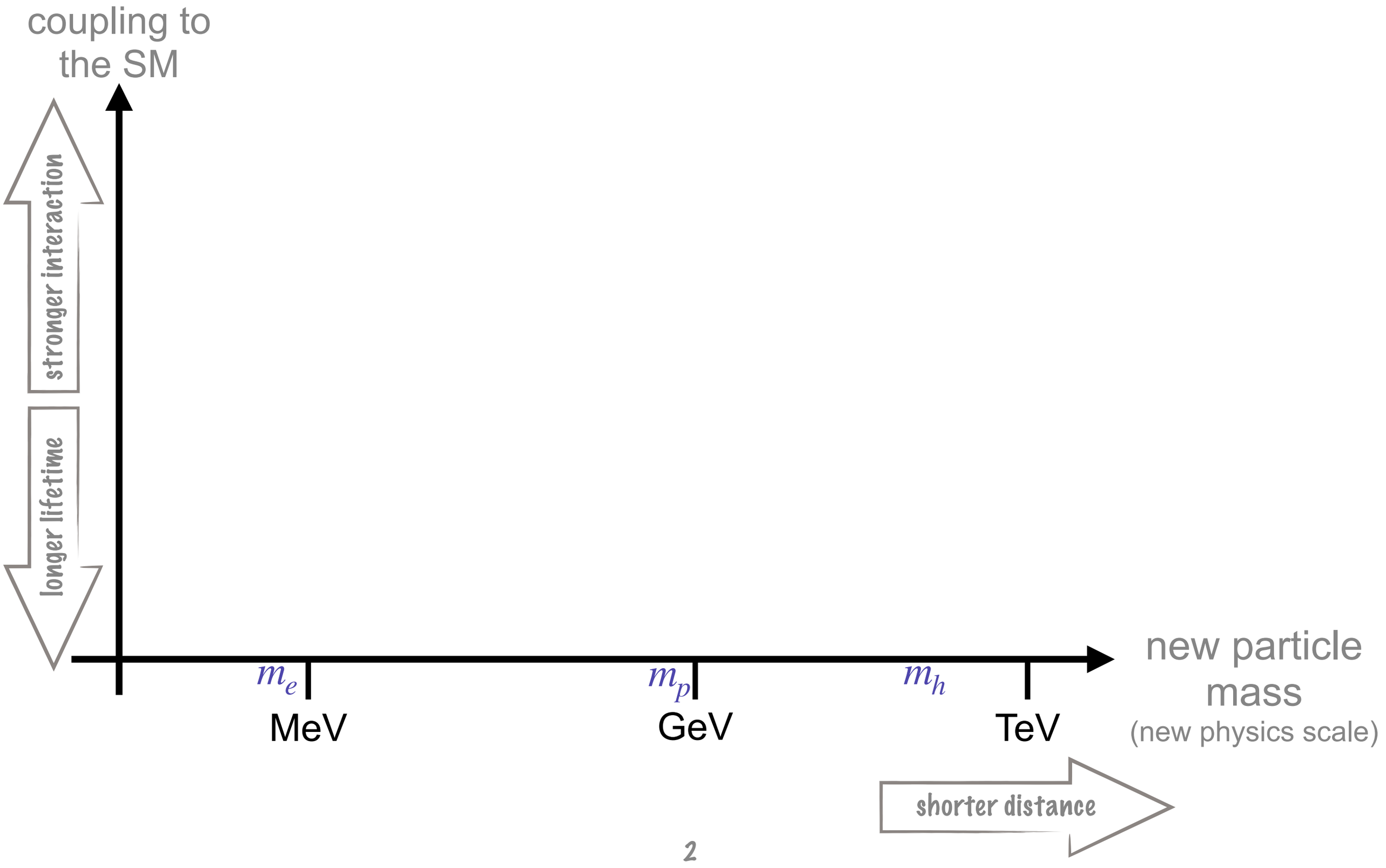
LUXE

probing new physics with the LUXE experiment

Yotam Soreq
Physics Department, Technion
on behalf of the LUXE collaboration

PPC21, May 20, 2021

the quest for new physics



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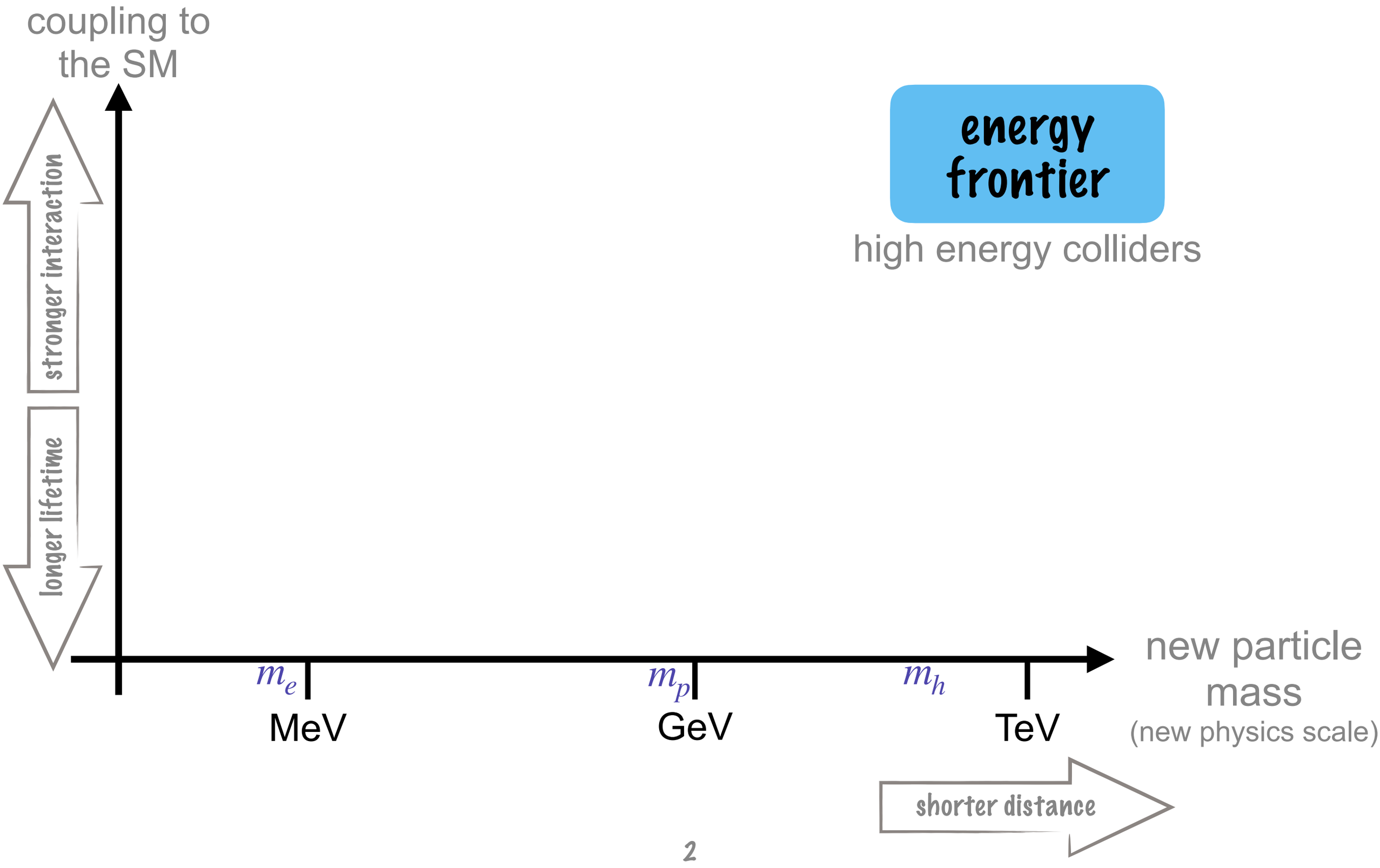

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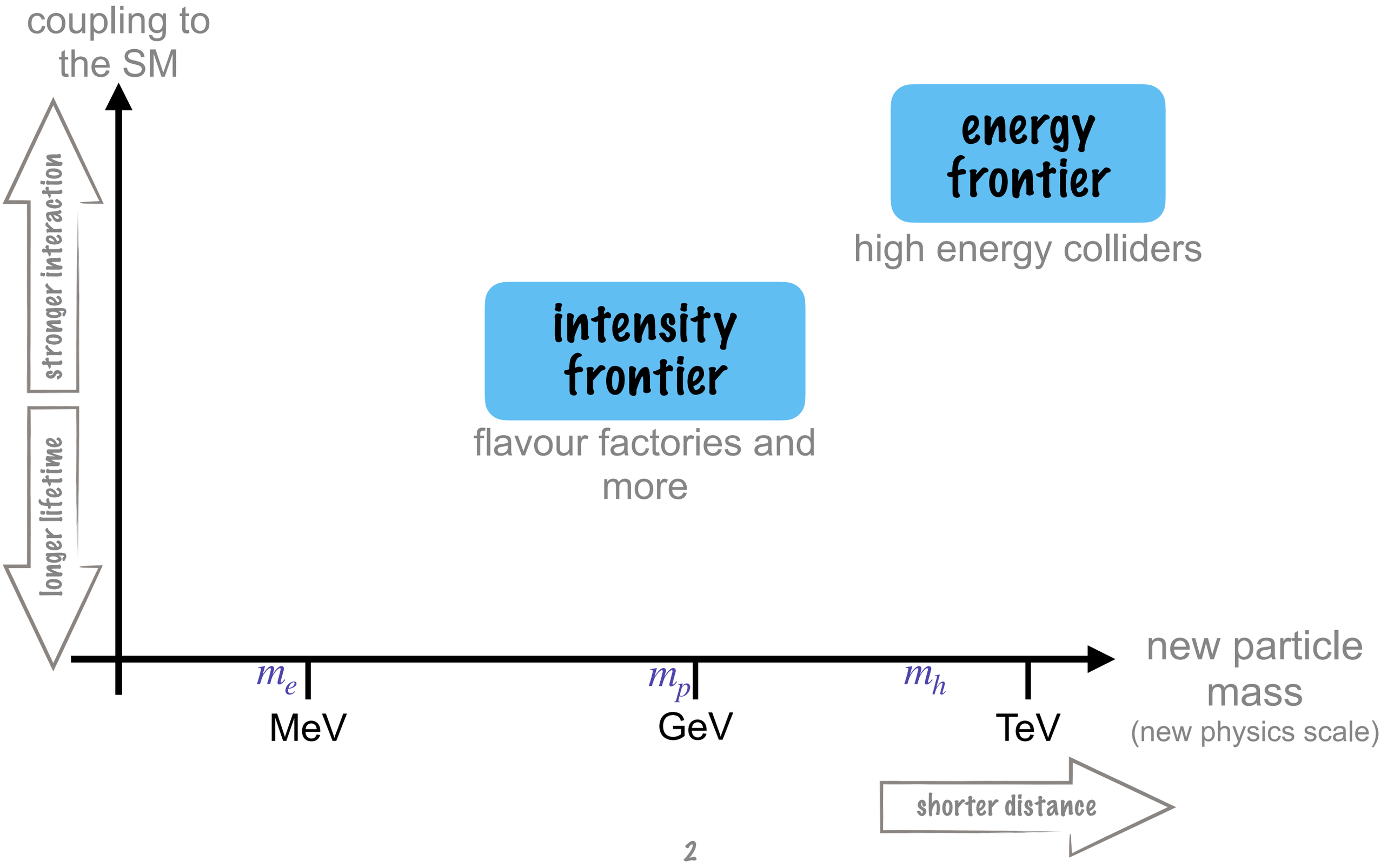

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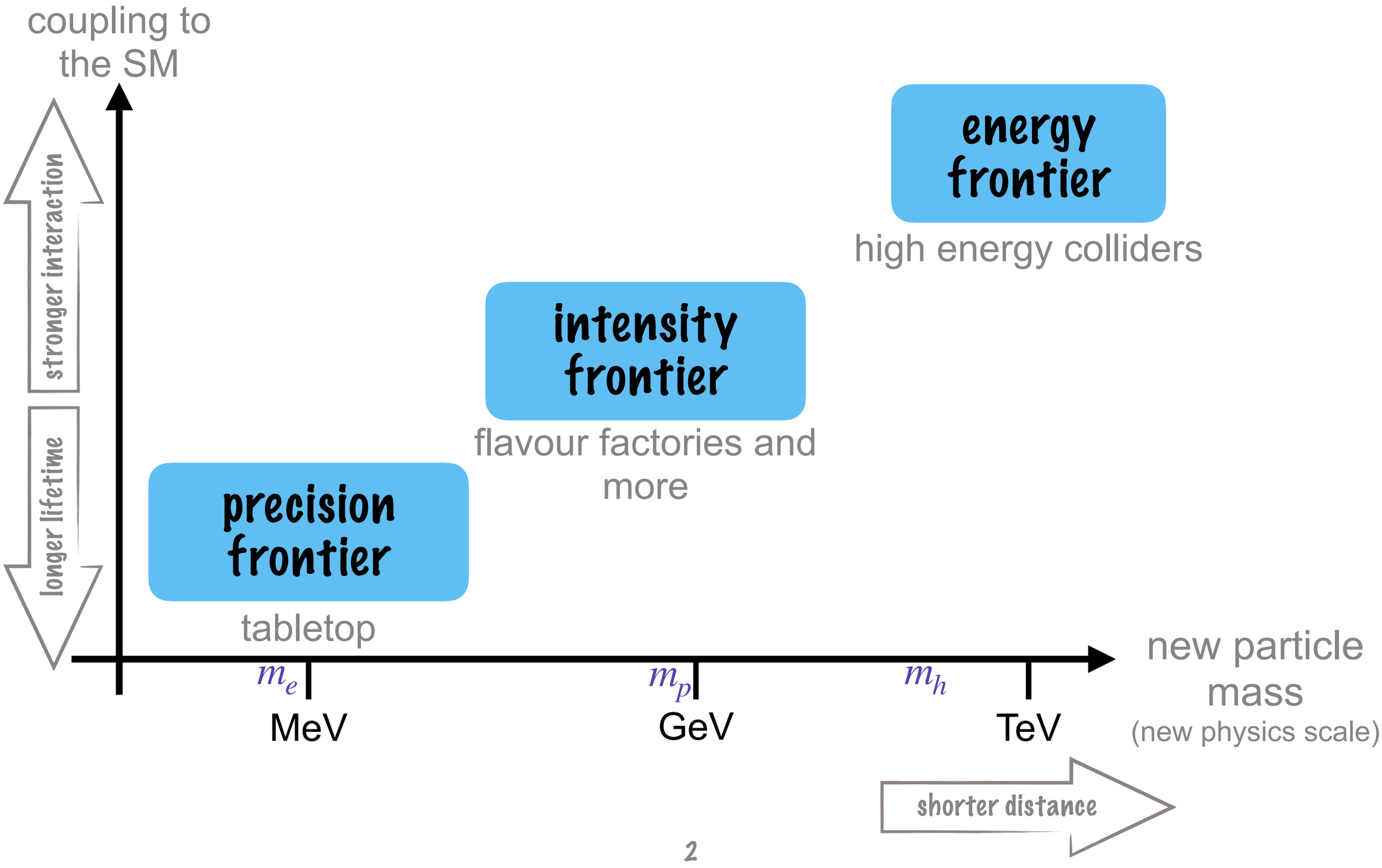

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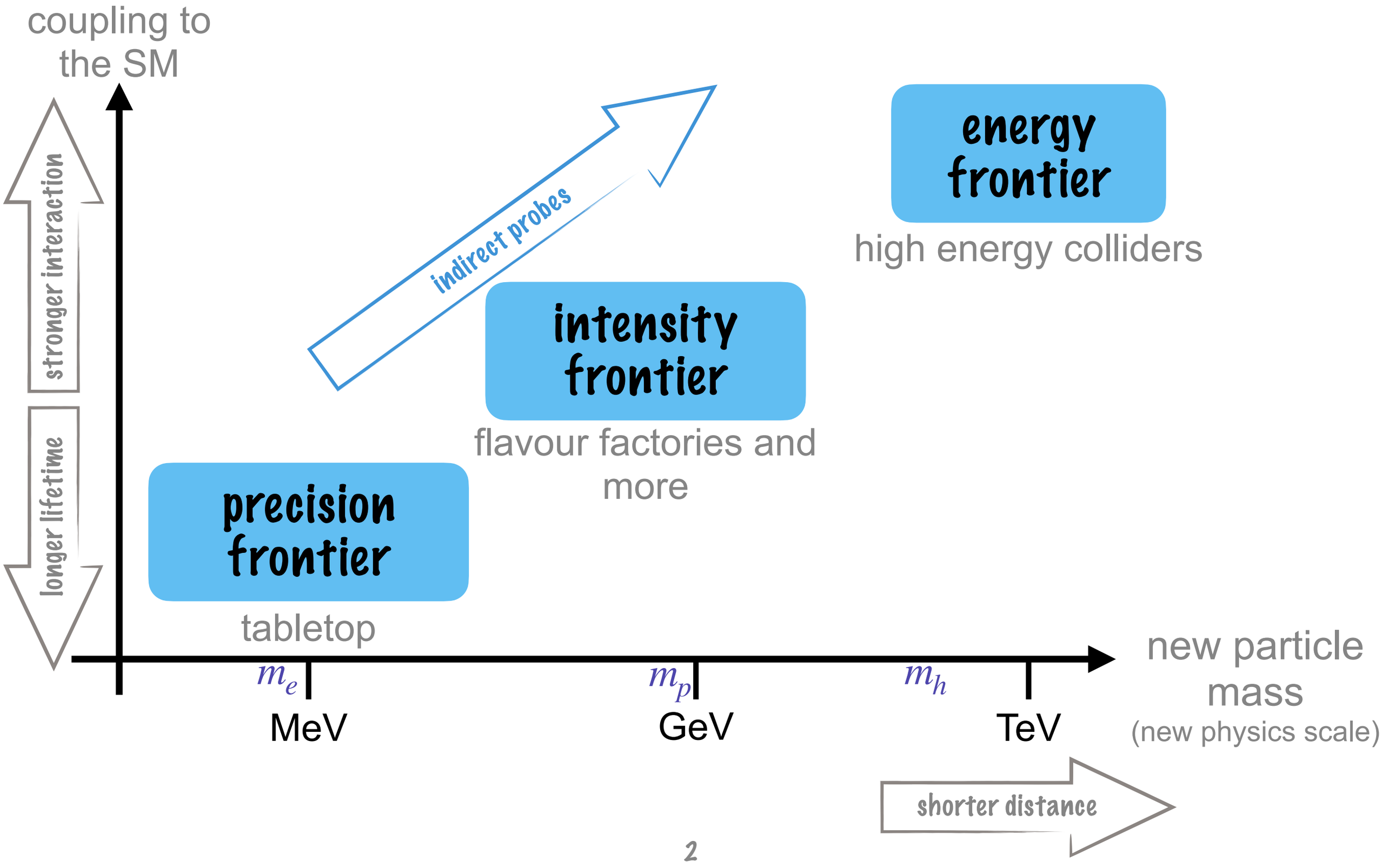

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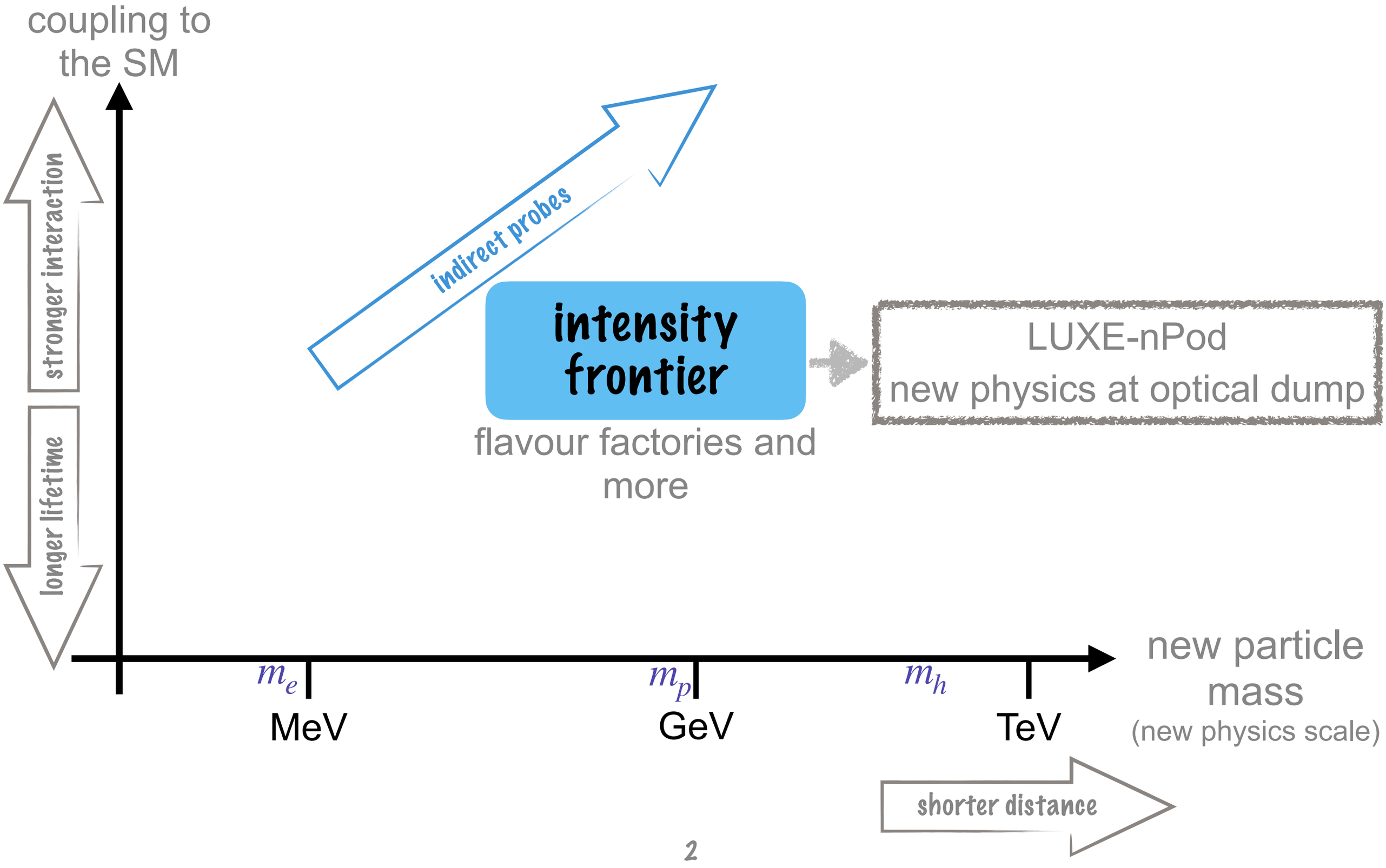

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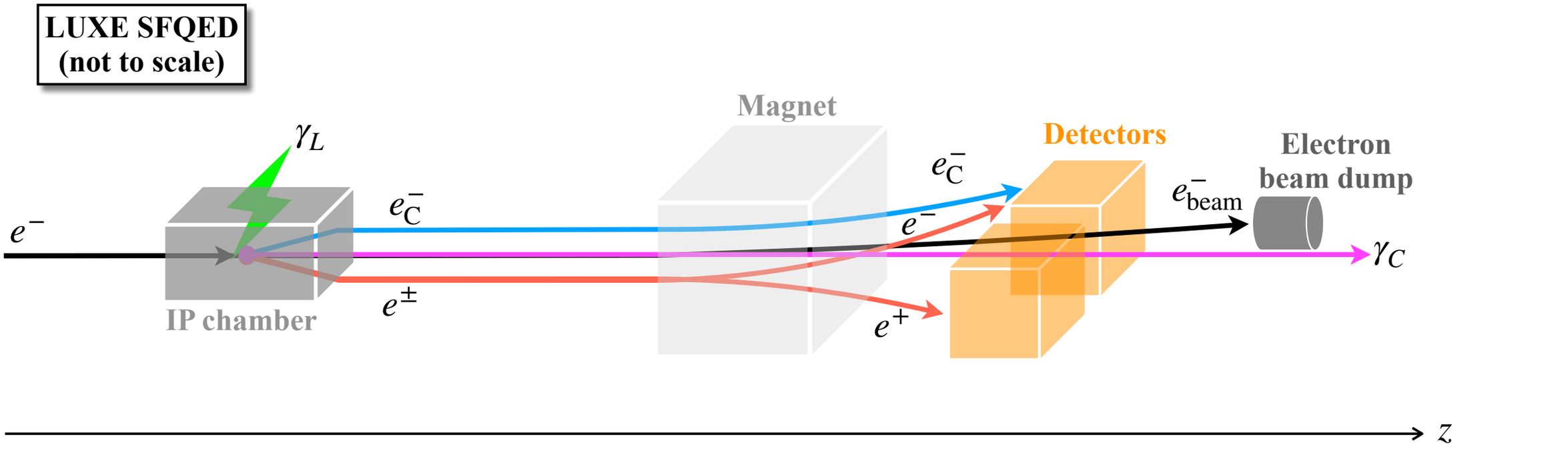

Ritus, 1985
LUXE, 1909.00860, 2102.02032

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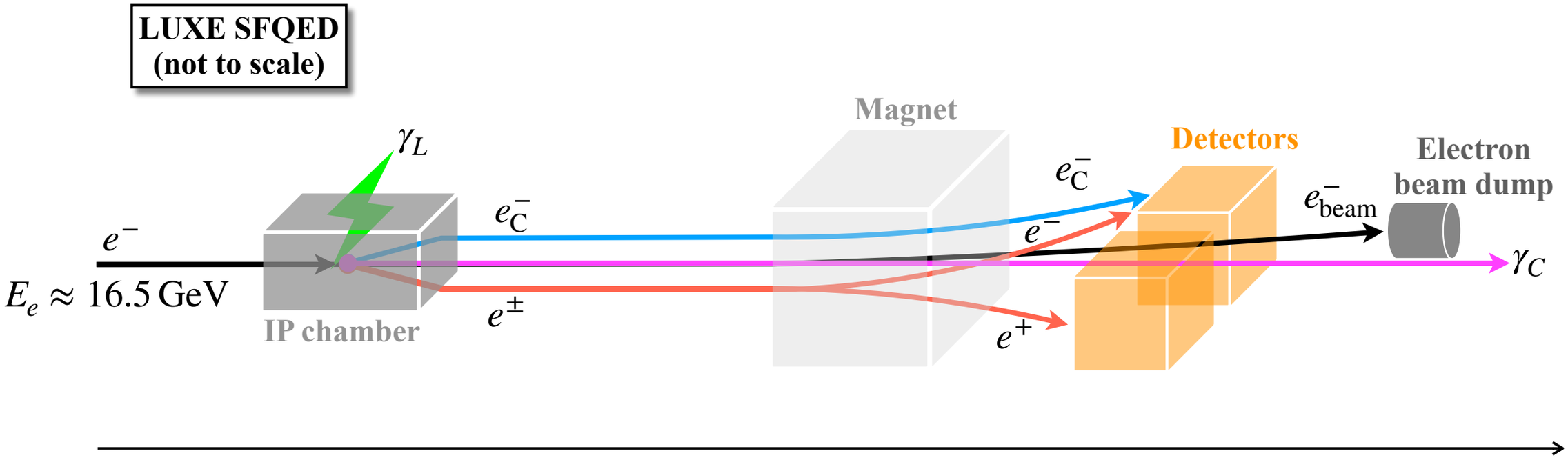

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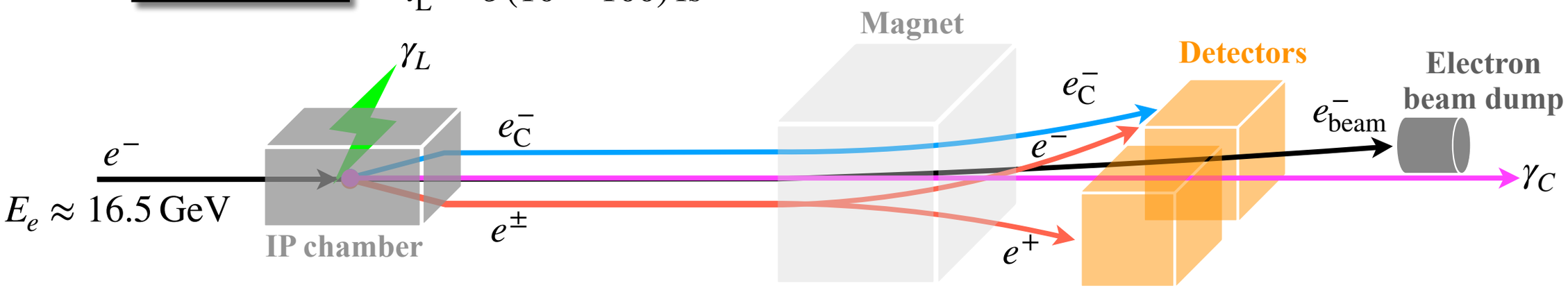
(not to scale)

$\omega_L \approx 1.5\,\text{eV}$
$t_L \sim \mathcal{O}(10-100)\,\text{fs}$



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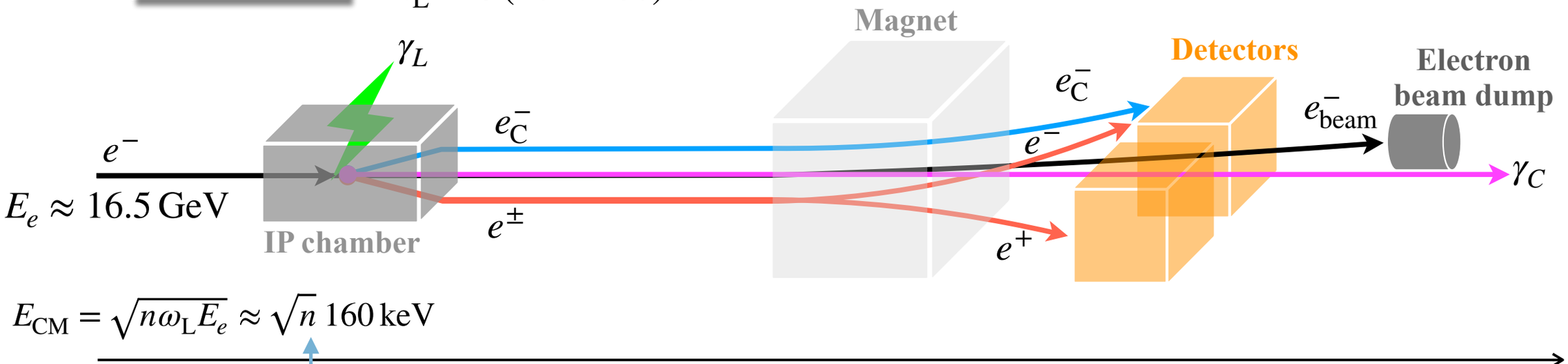

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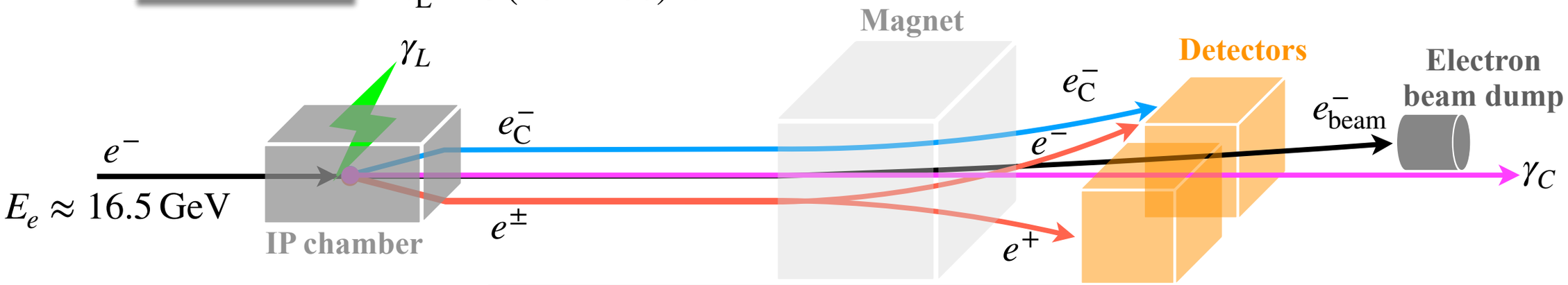

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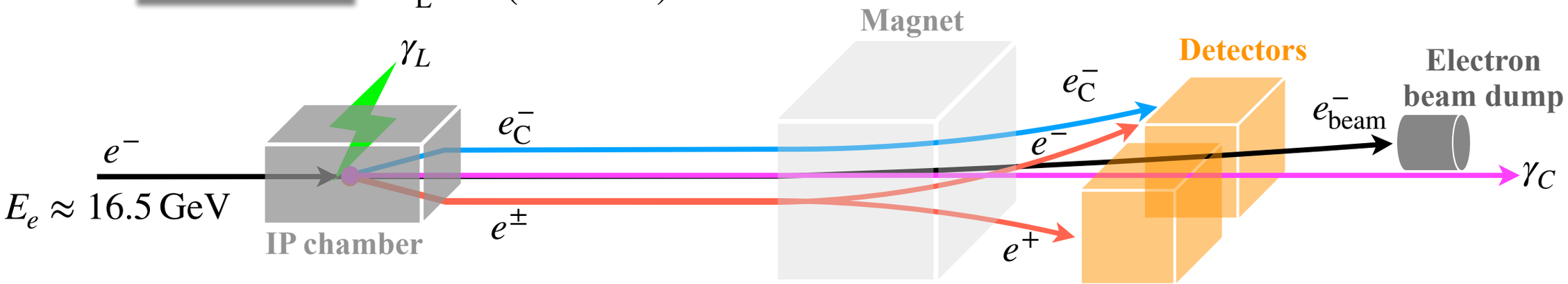

$E_{CM} = \sqrt{n\omega_L E_e} \approx \sqrt{n}\,160\,\text{keV}$

number of laser photons

One Particle Pair Production (OPPP)
$\gamma_L \gamma_C \to e^+ e^-$, $\tau_{OPPP} \sim \mathcal{O}(10^4 - 10^6)\text{fs}$

z

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$N_\gamma \sim \mathcal{O}(t_L/\tau_{HICS})$

emitted photons per pulse per e^-

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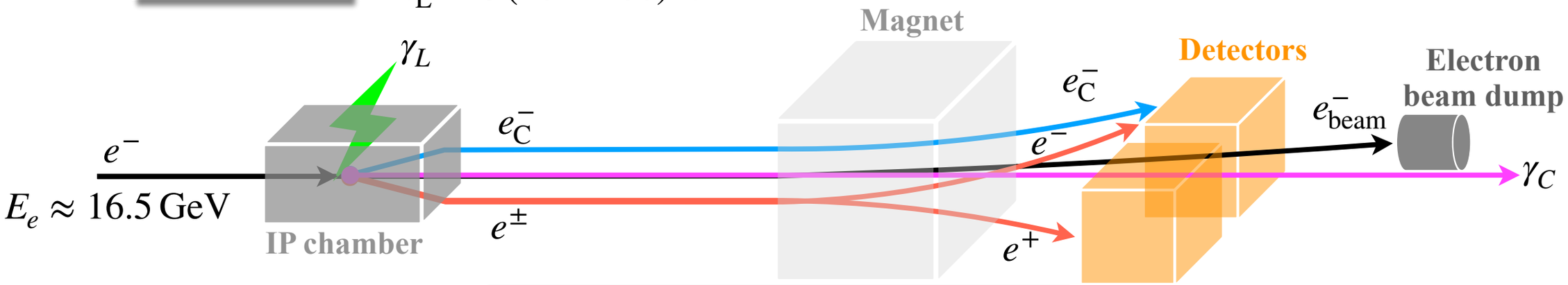

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pair production is suppressed

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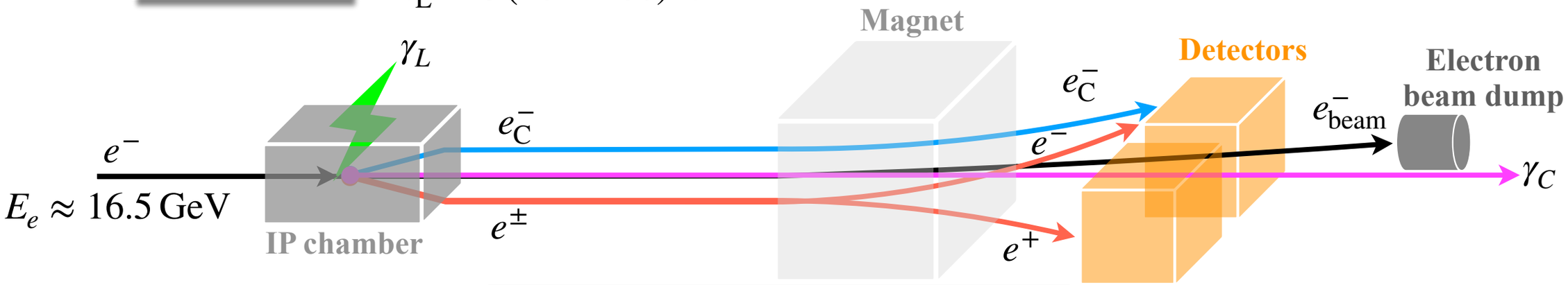

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emitted photons per pulse per e^-

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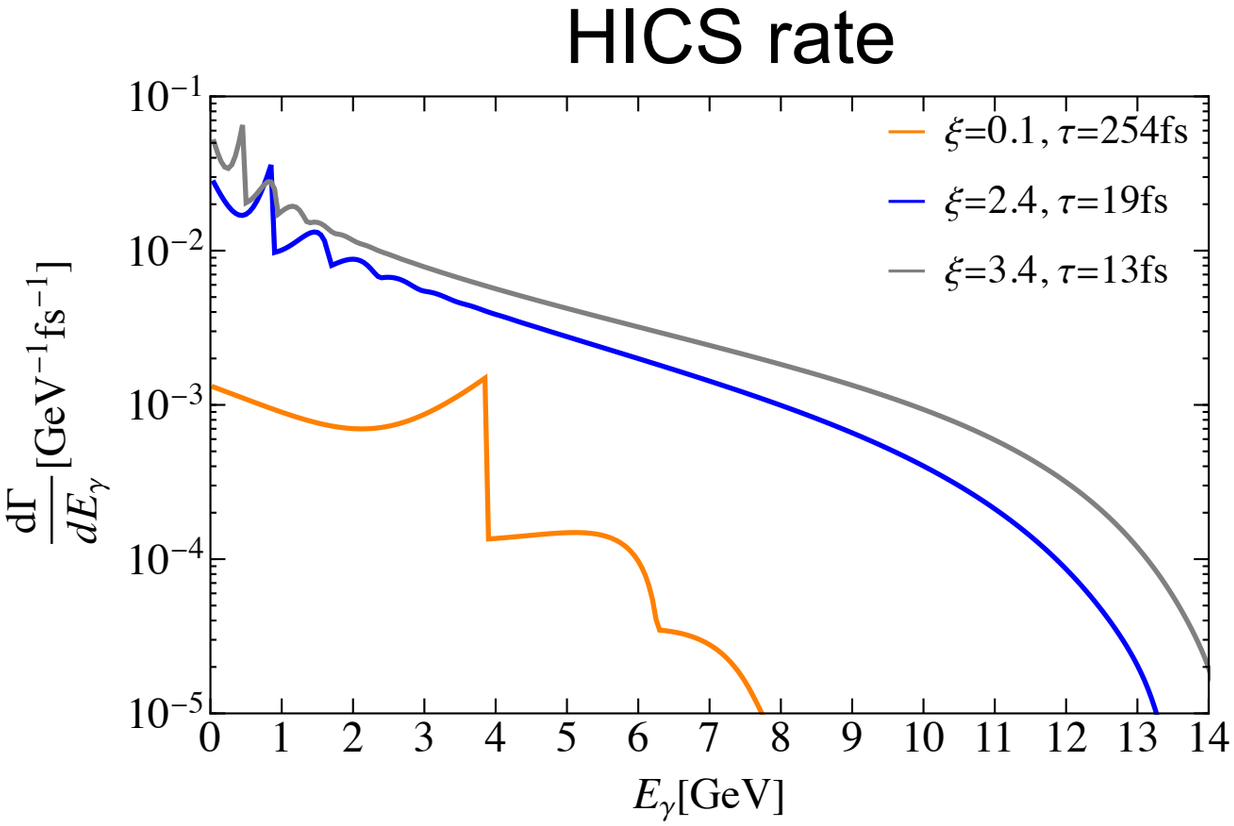
pair production is suppressed

excellent source of GeV scale photons

the photon spectrum



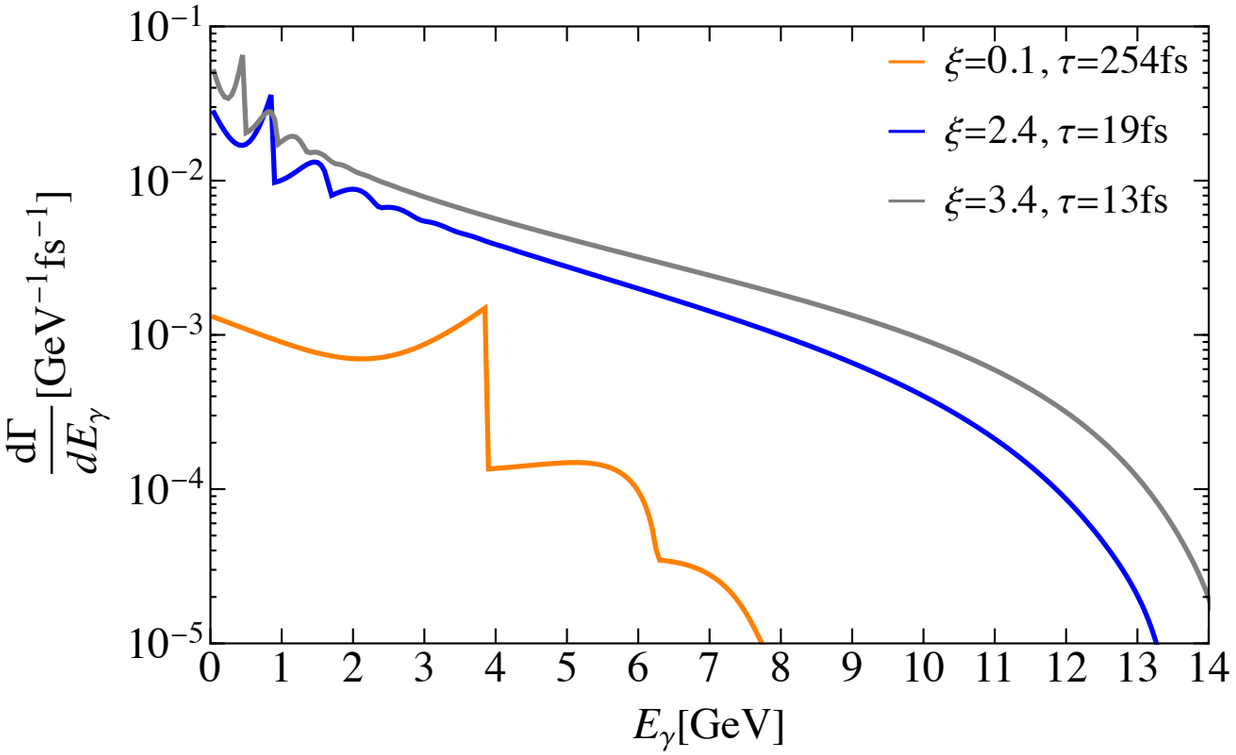
laser electric field

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

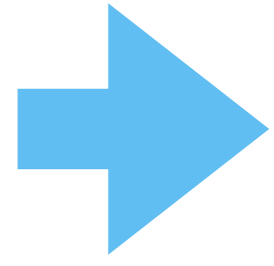
the non perturbative parameter

the photon spectrum

HICS rate



convolution
with the laser



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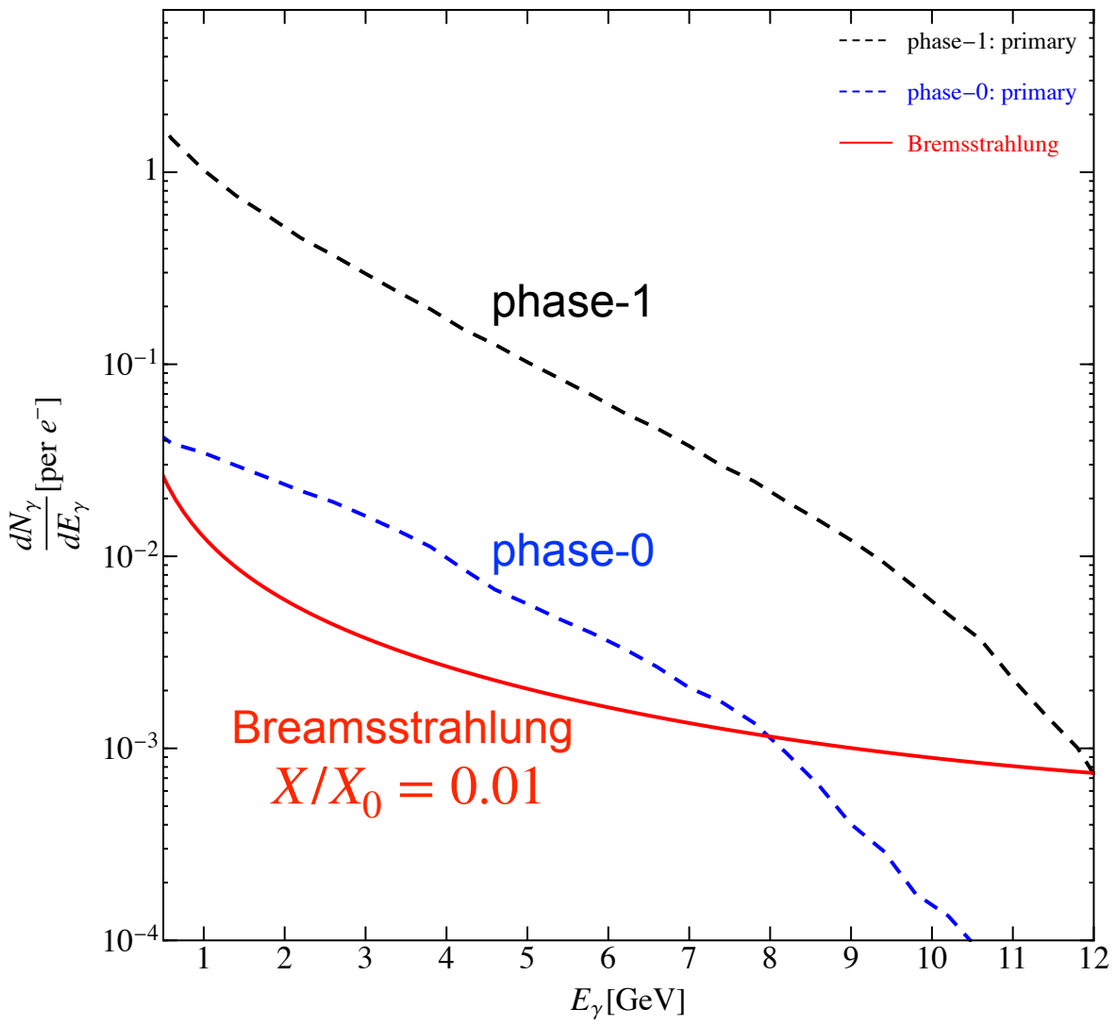
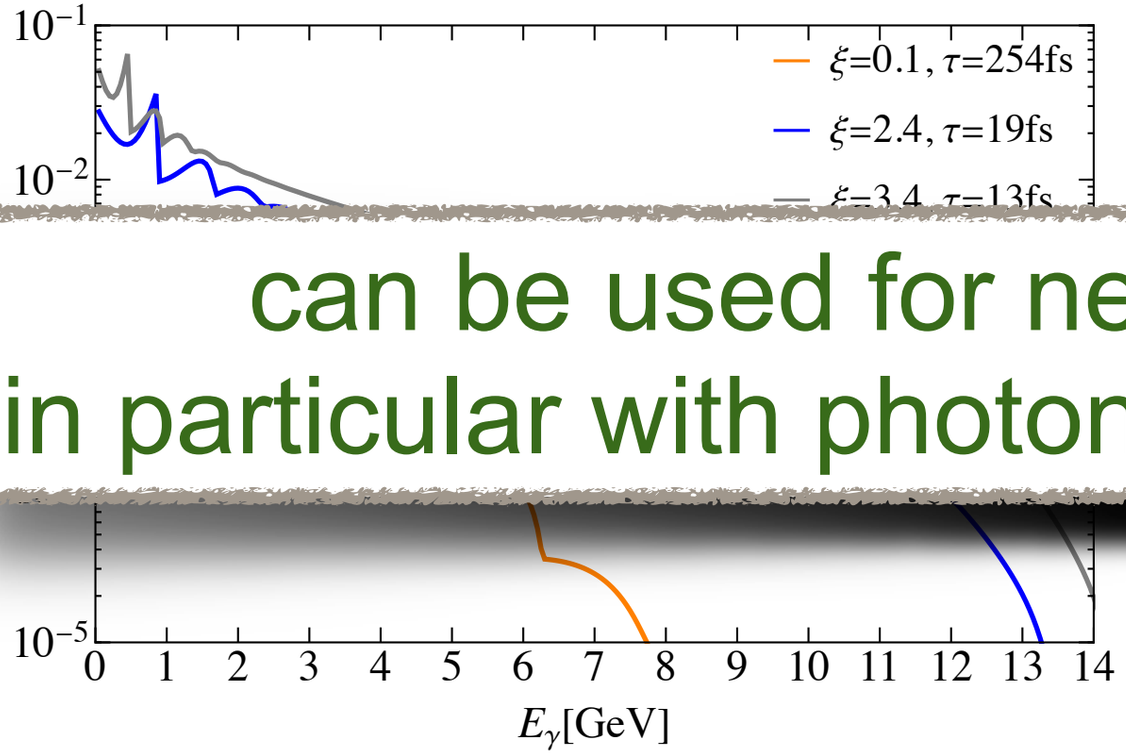
outgoing Compton photon spectrum



the photon spectrum

HICS rate



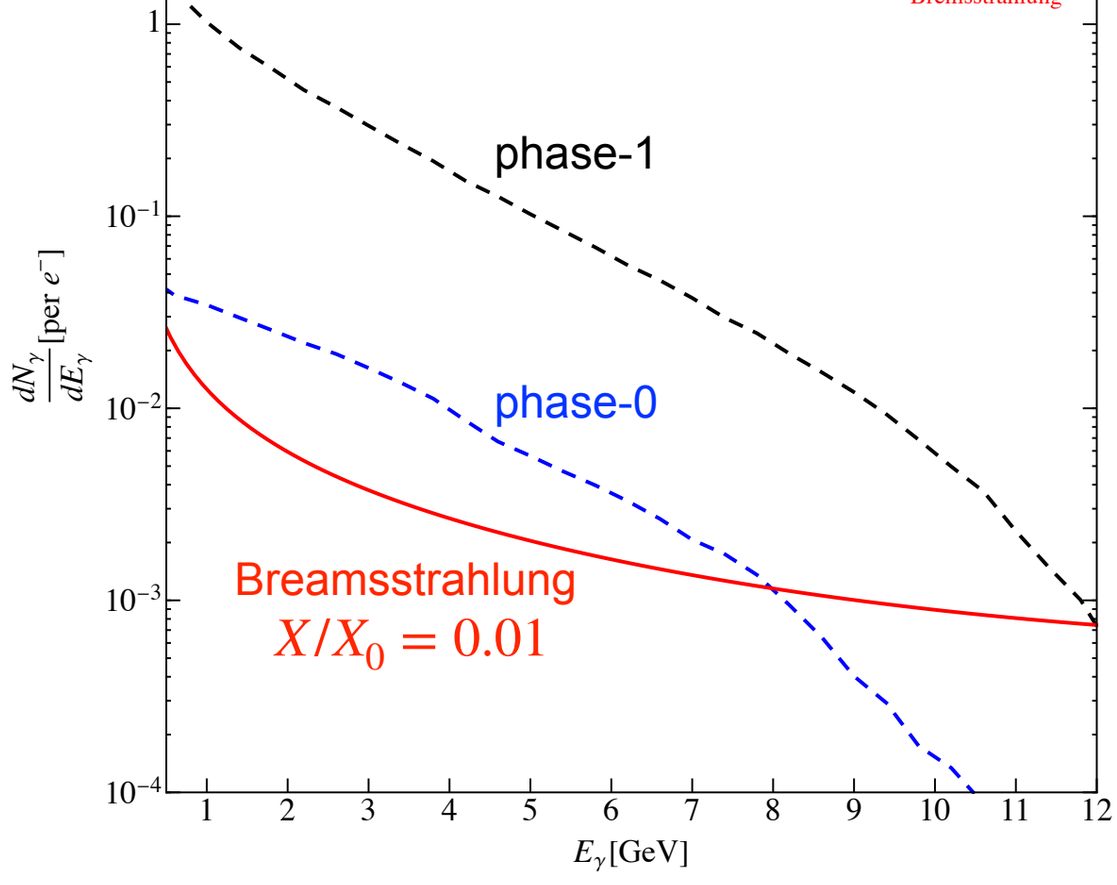
laser electric field

$e\mathscr{E}_L$

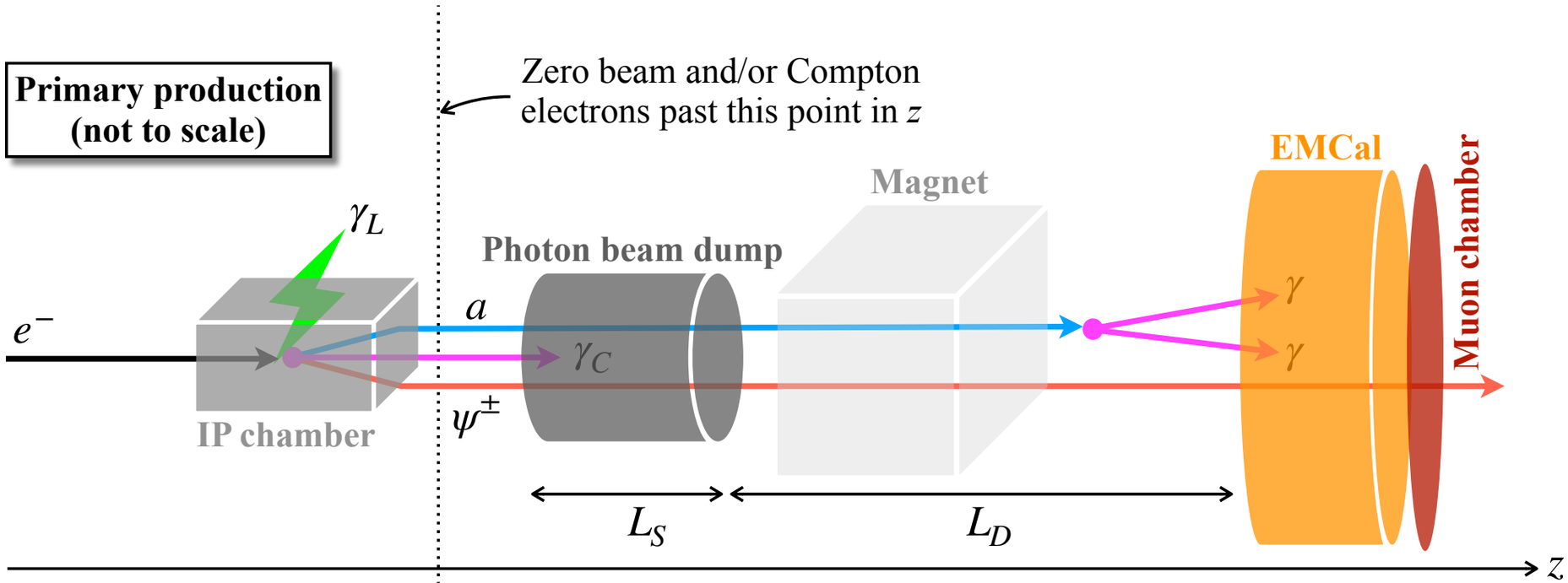
ξ =

can be used for new physics searches
in particular with photon and/or electron coupling

convolution with the laser



new physics production at LUXE



Bai, Blackburn, Borysov, Davidi, Hartin, Heinemann, Ma, Perez, Santra, YS, Tal Hod, to appear

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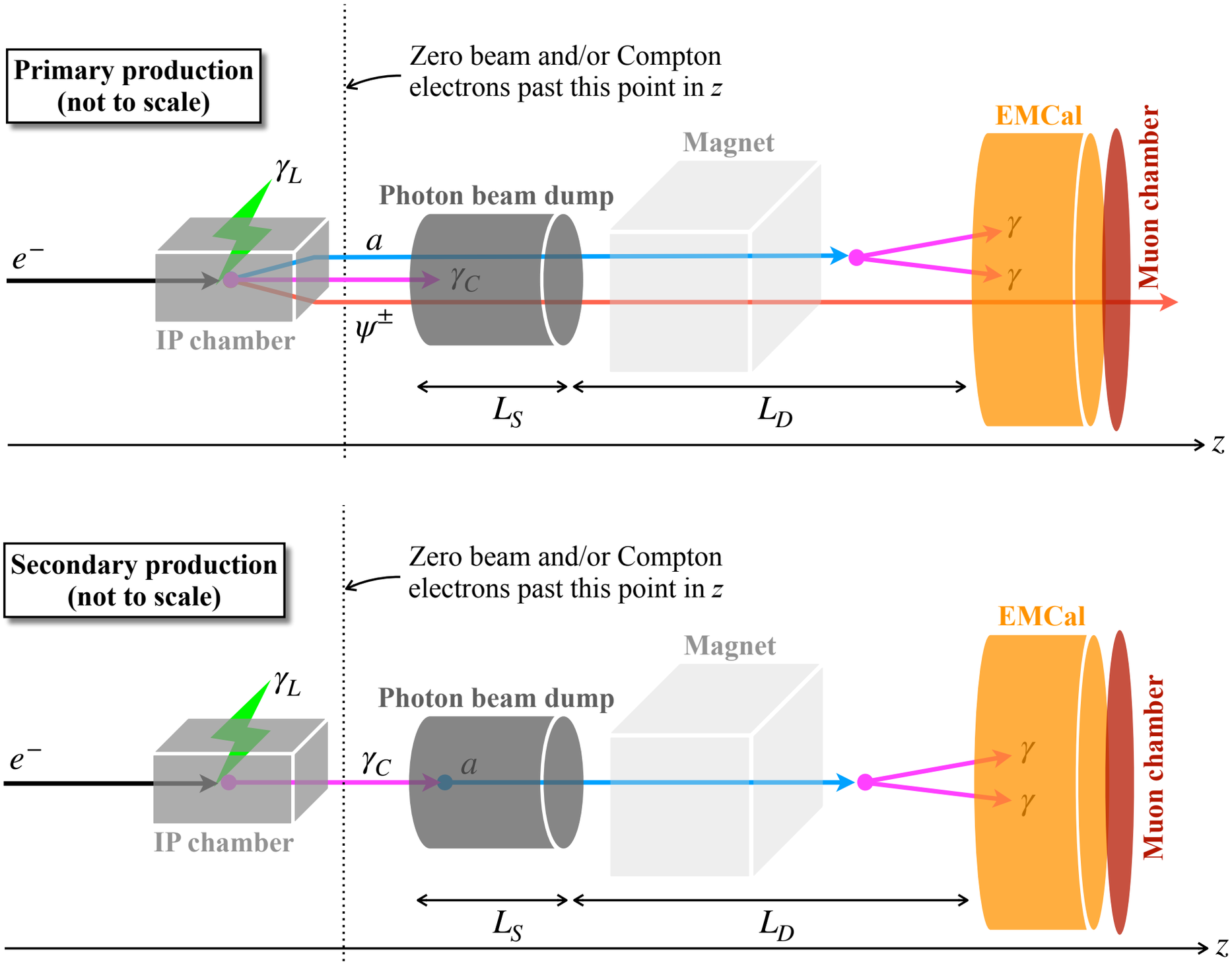

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axion like particles - ALPs

* originally - the Axion, part of a solution to the strong CP problem (PC)
* portal to dark matter and/or dark sector
* if very light, it is a dark matter candidate
* predicted by string theory

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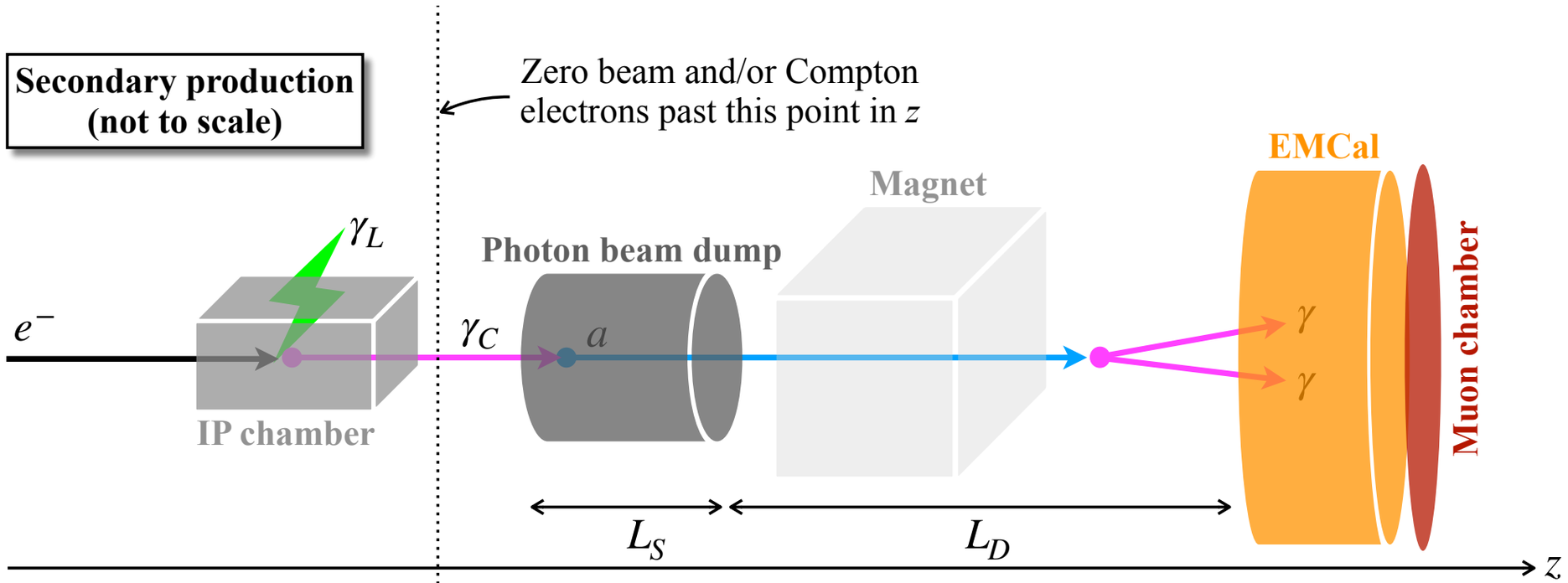
focus the effective ALP photon and electron interaction and mass range, m_a, of MeV-to-GeV

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

well motivated BSM scenario

secondary ALPs production



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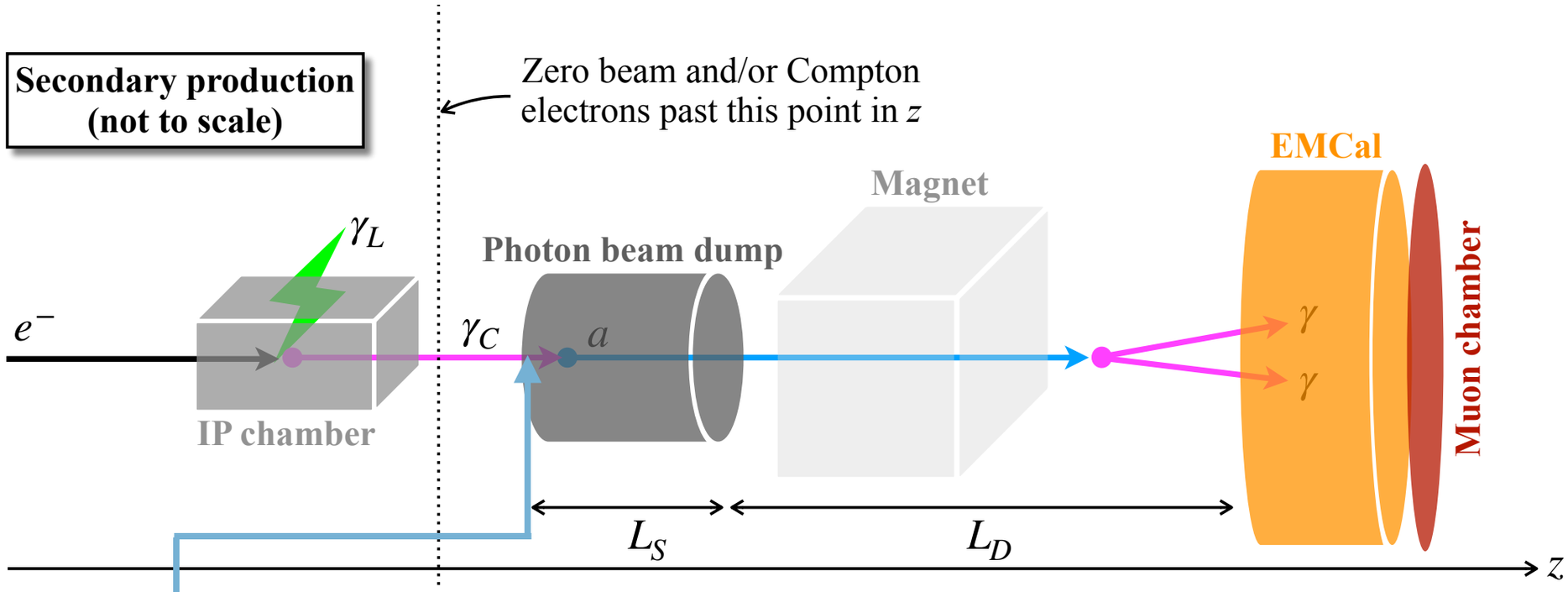

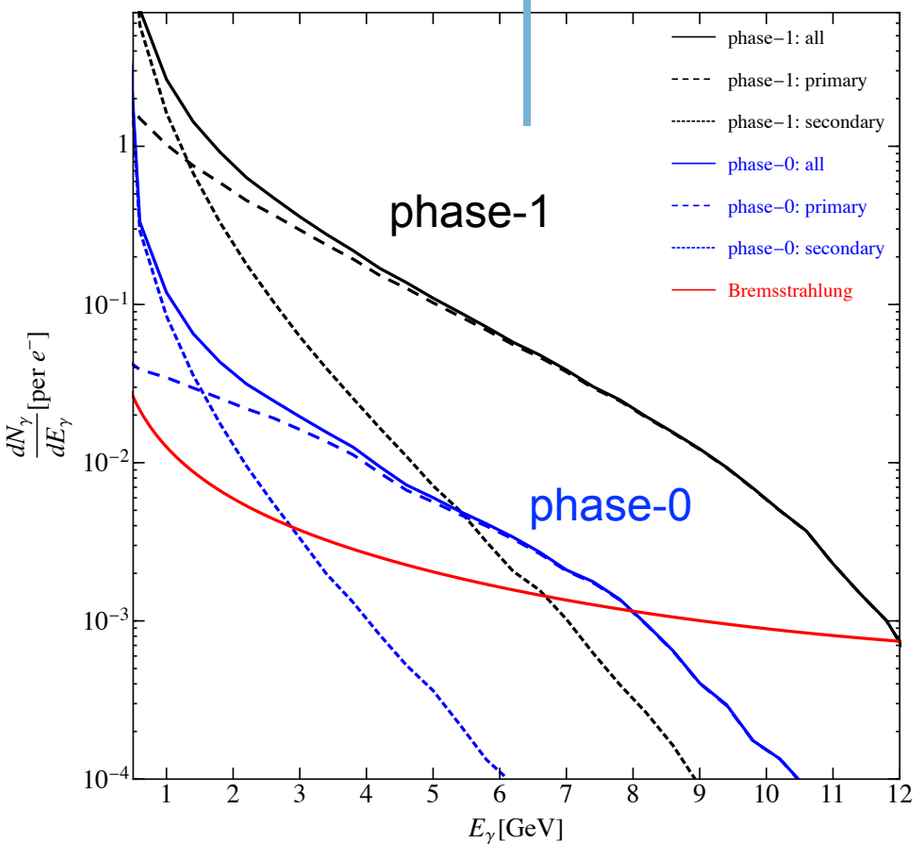

source	# photons, E>1 GeV	backgrounds
LUXE-0/1	0.12 / 2.5	effectively free
e-beam thin	0.03	effectively free
e-beam thick	6.7	O(100) larger

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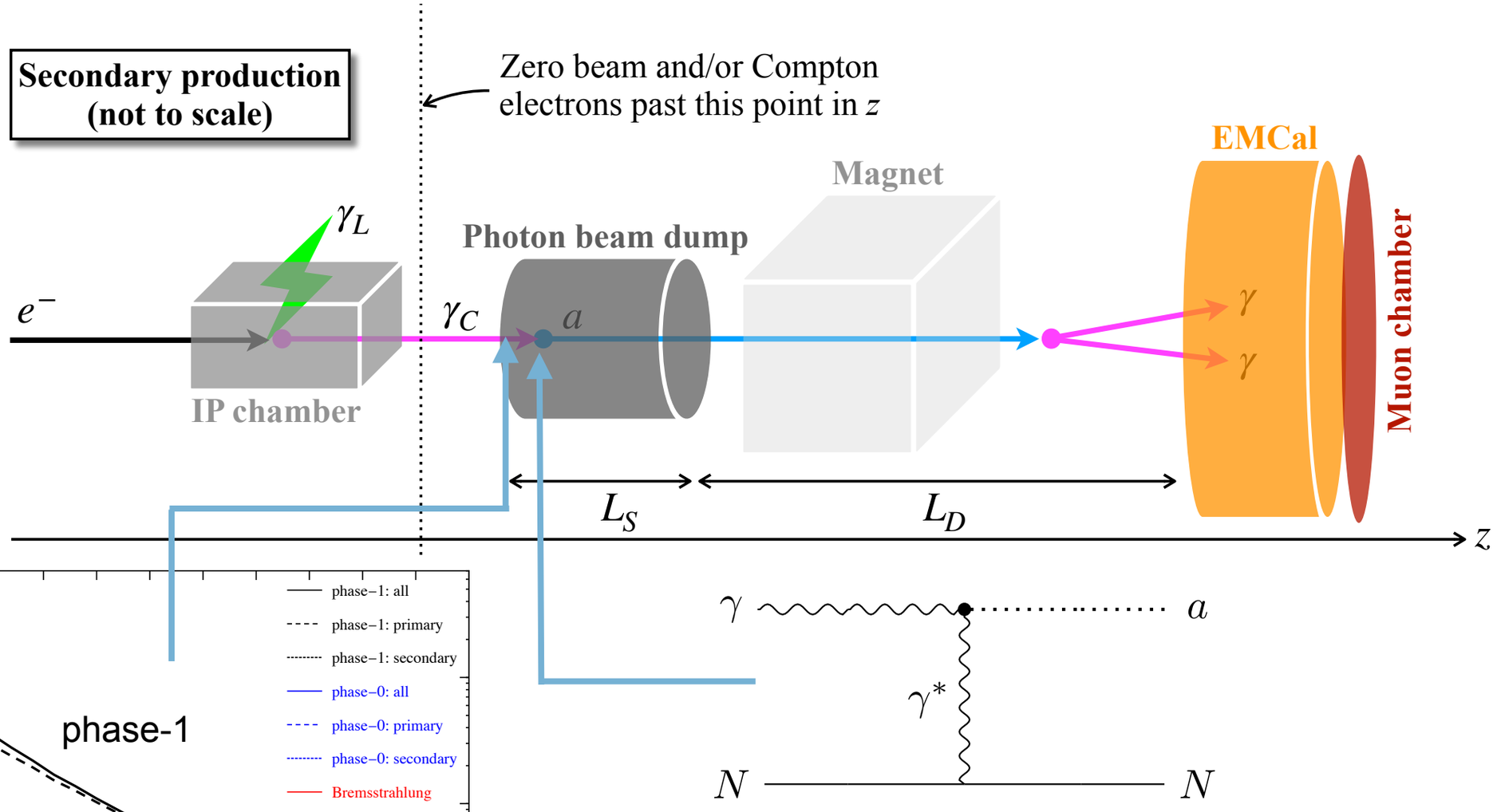

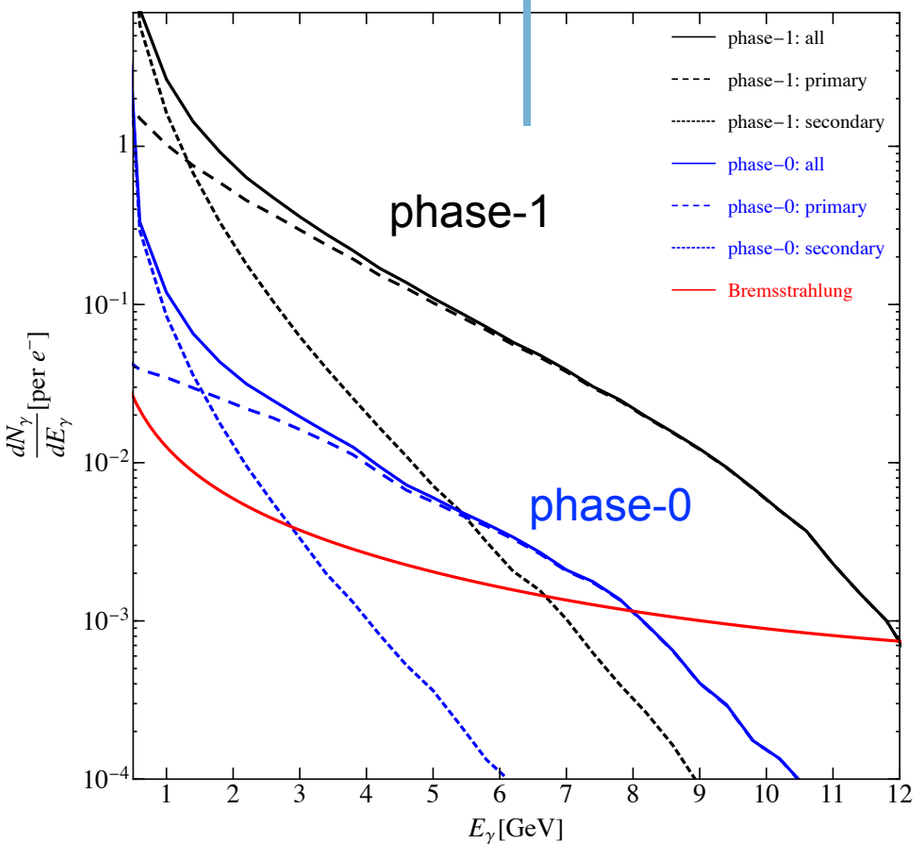

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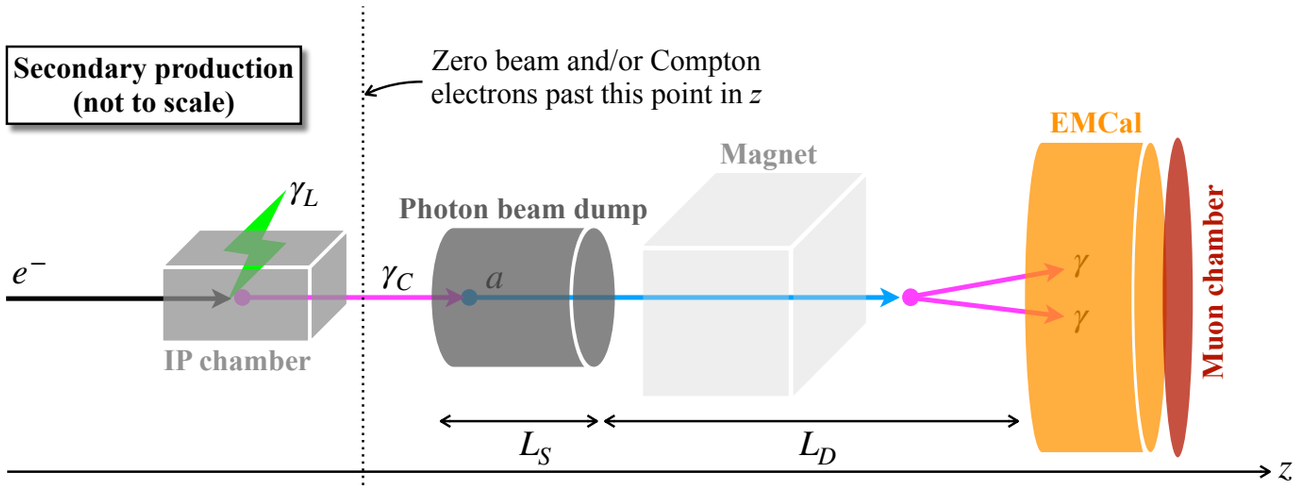

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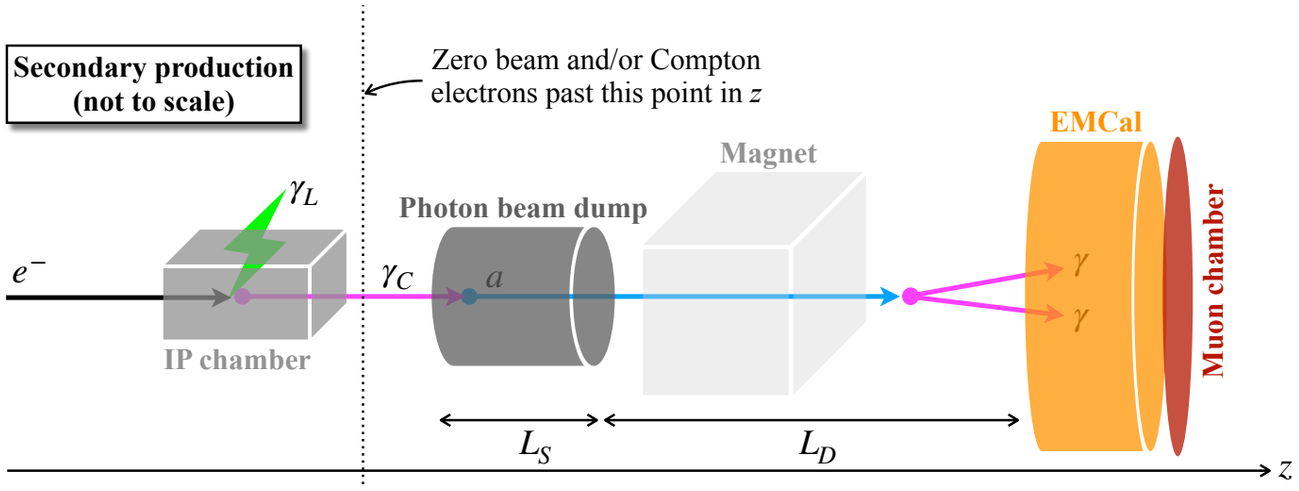

number of ALPs

$$N_a\Big|_{E_a\approx E_\gamma} \approx \mathscr{L}_{\text{eff}} \int dE_\gamma \frac{dN_\gamma}{dE_\gamma}\sigma_a \left(e^{-\frac{L_S}{L_a}} - e^{-\frac{L_S+L_D}{L_a}} \right) \mathscr{A}$$

$$\frac{9}{7} N_e N_{\text{BX}} \frac{\rho_W X_0}{A_W m_0}$$

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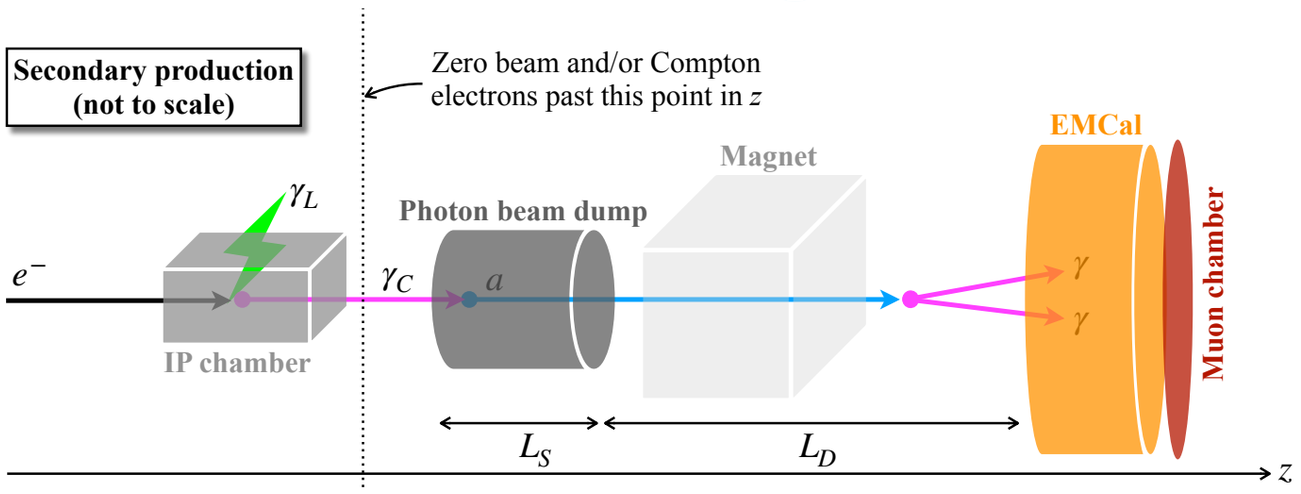

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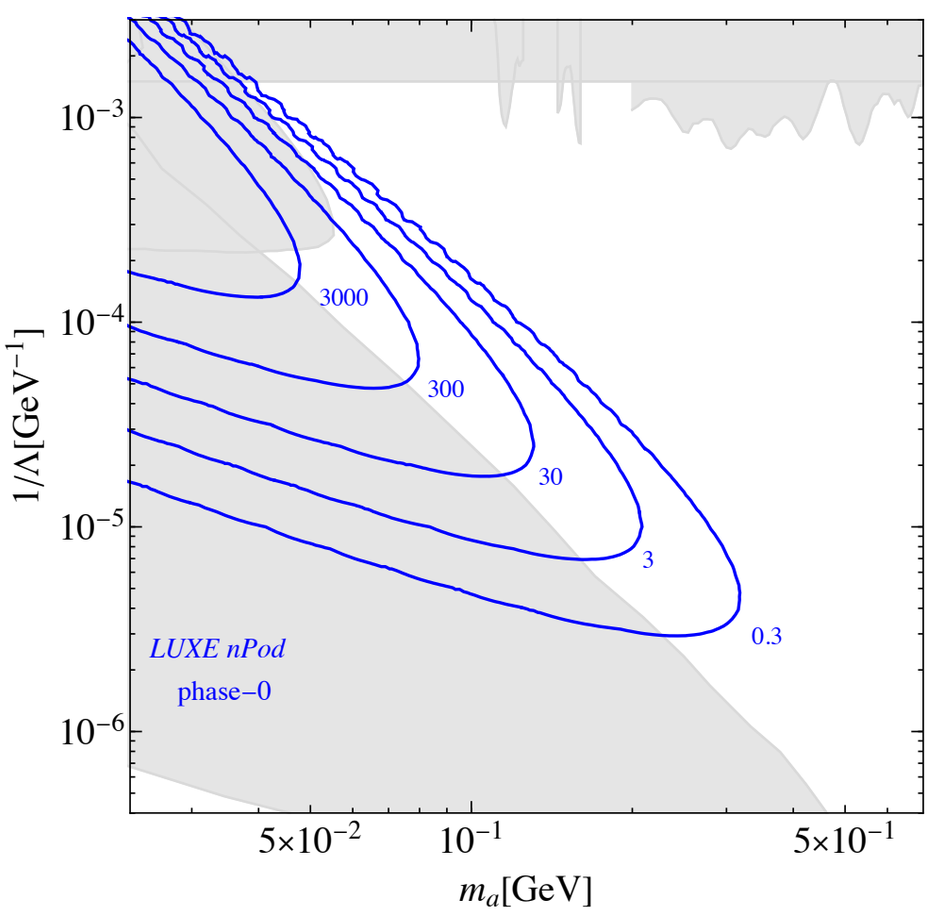

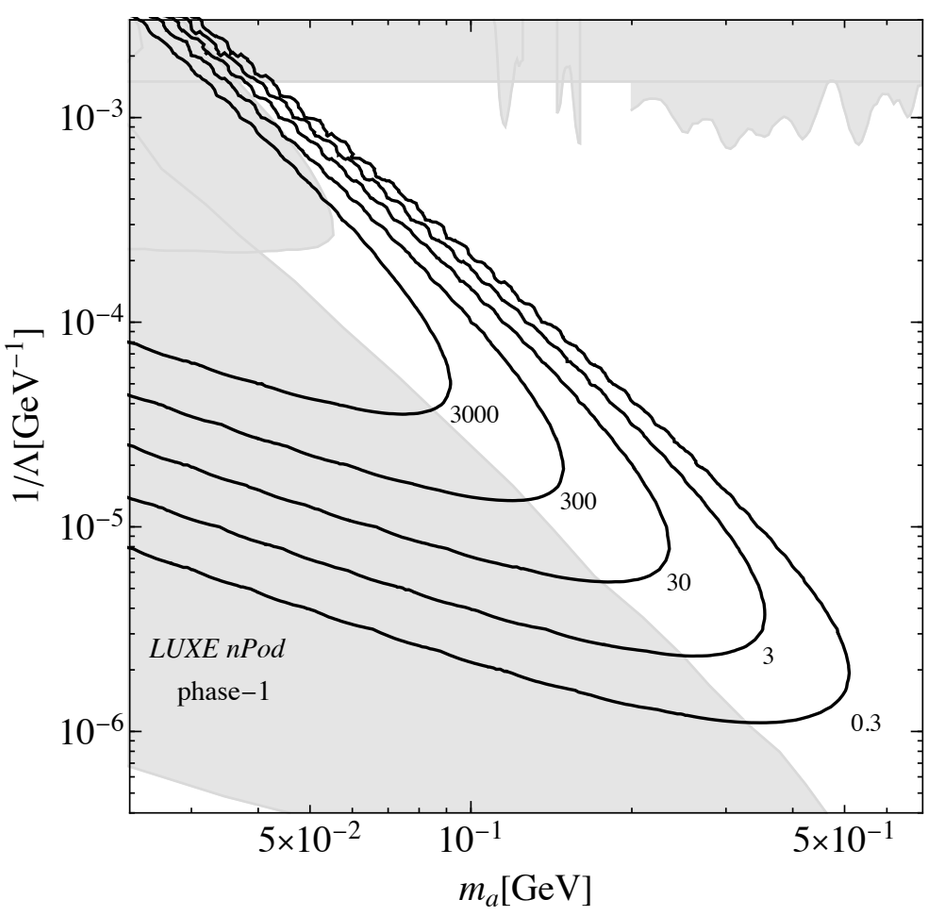

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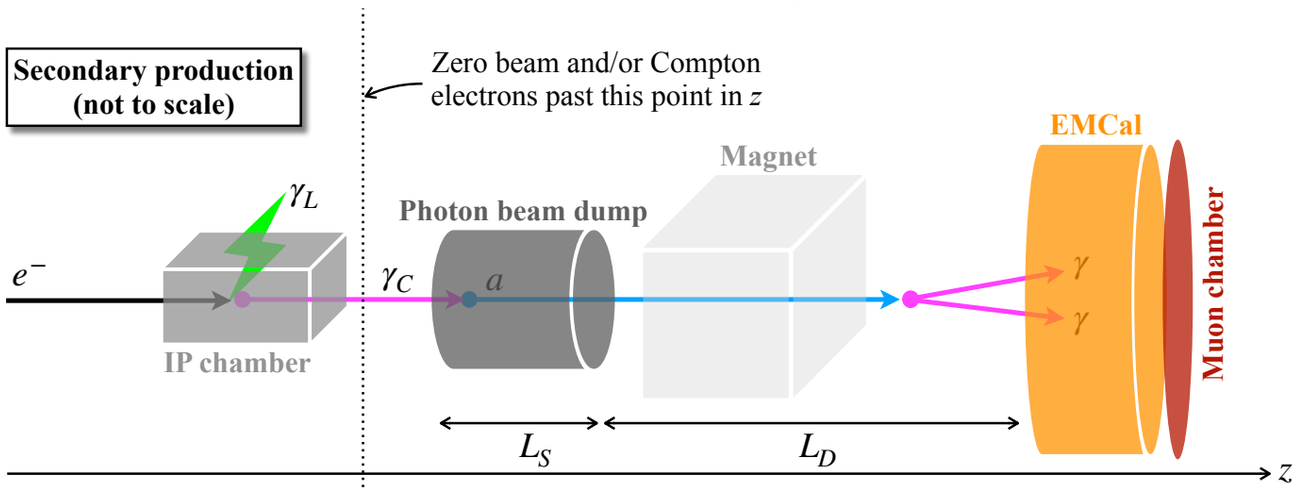

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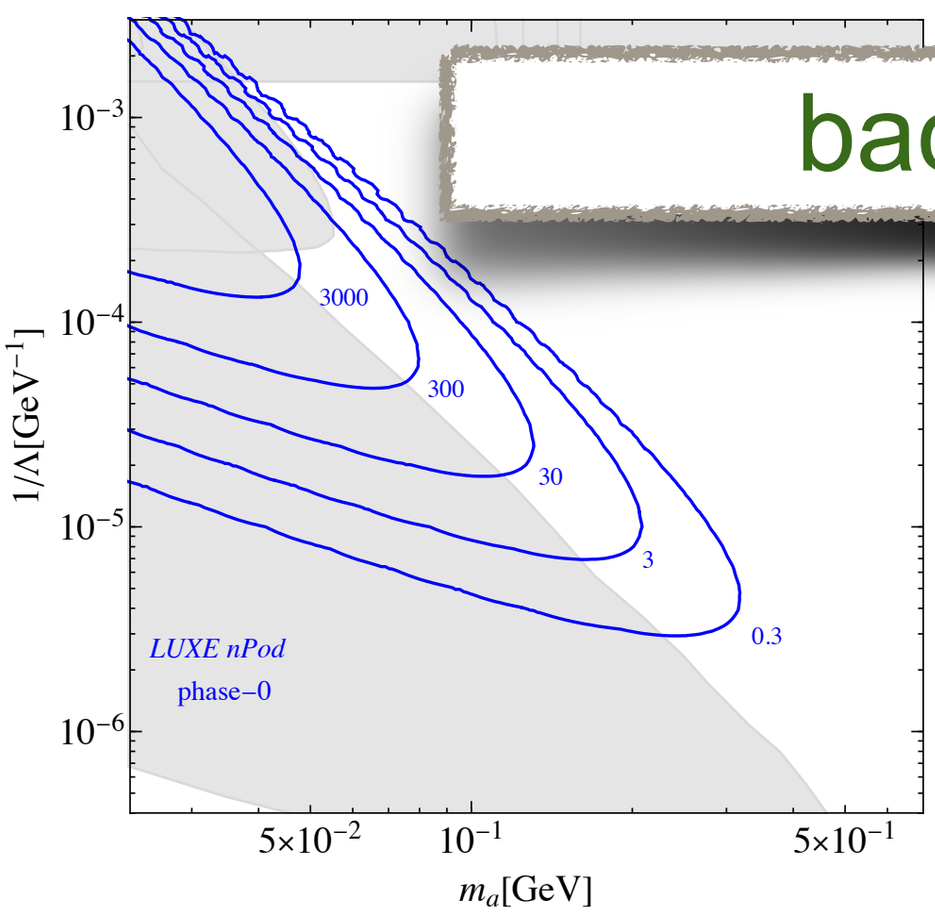
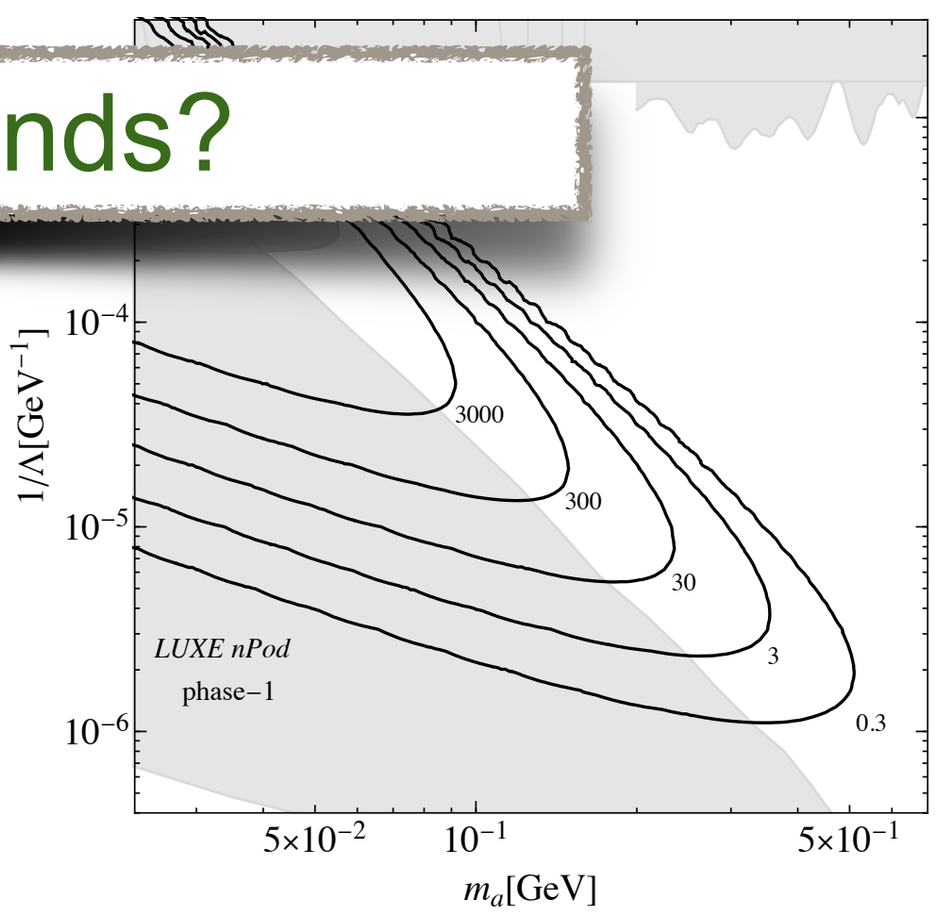
backgrounds?





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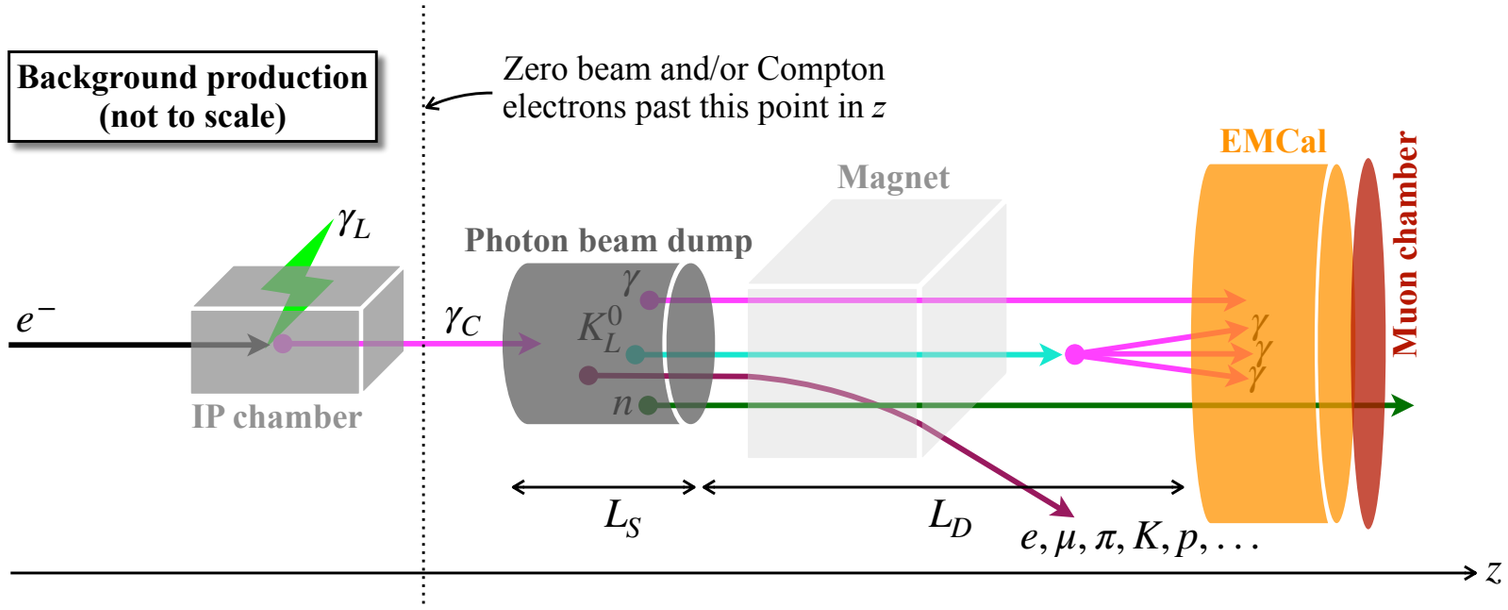

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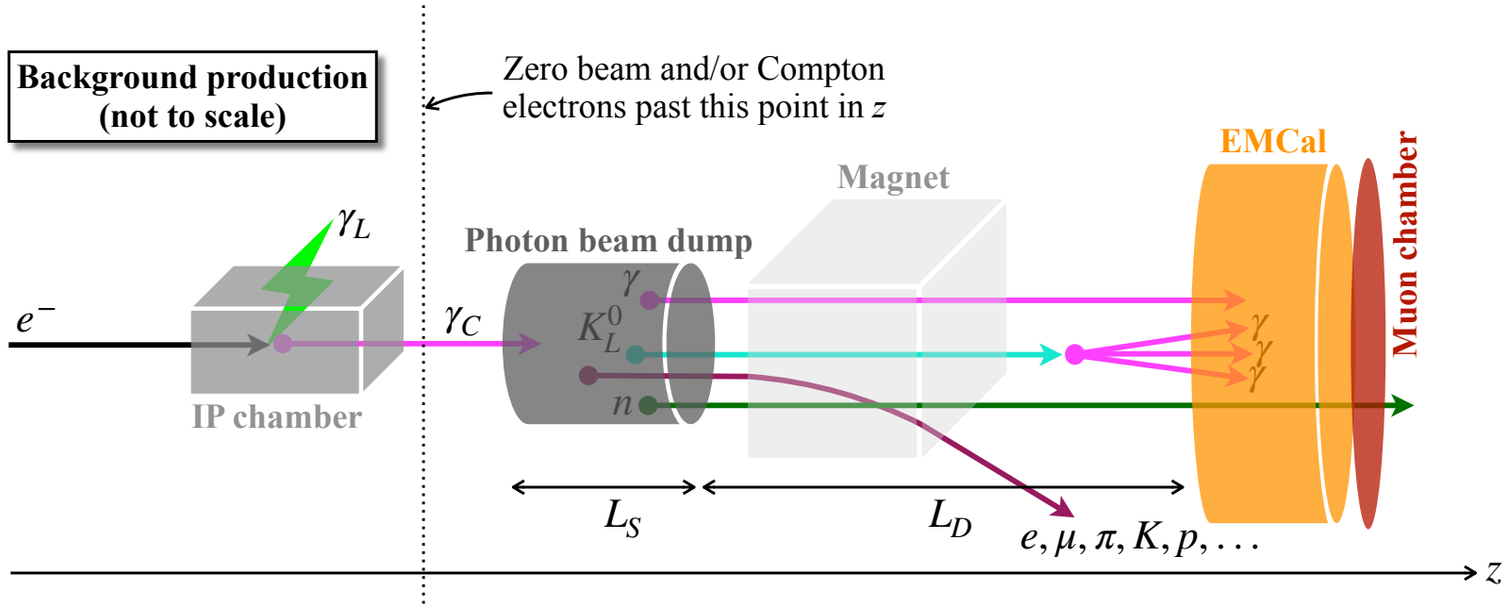


backgrounds (based on GEANT 4 simulation):

1. **charged particles** - bended by a magnetic field (1.5T of 1m)
2. **fake photons** - $N_{2n\to 2\gamma} \approx 5\times 10^{8} f_{n\to\gamma}^{2} e^{-10 f_{n\to\gamma}} R_{\mathrm{sel}}$

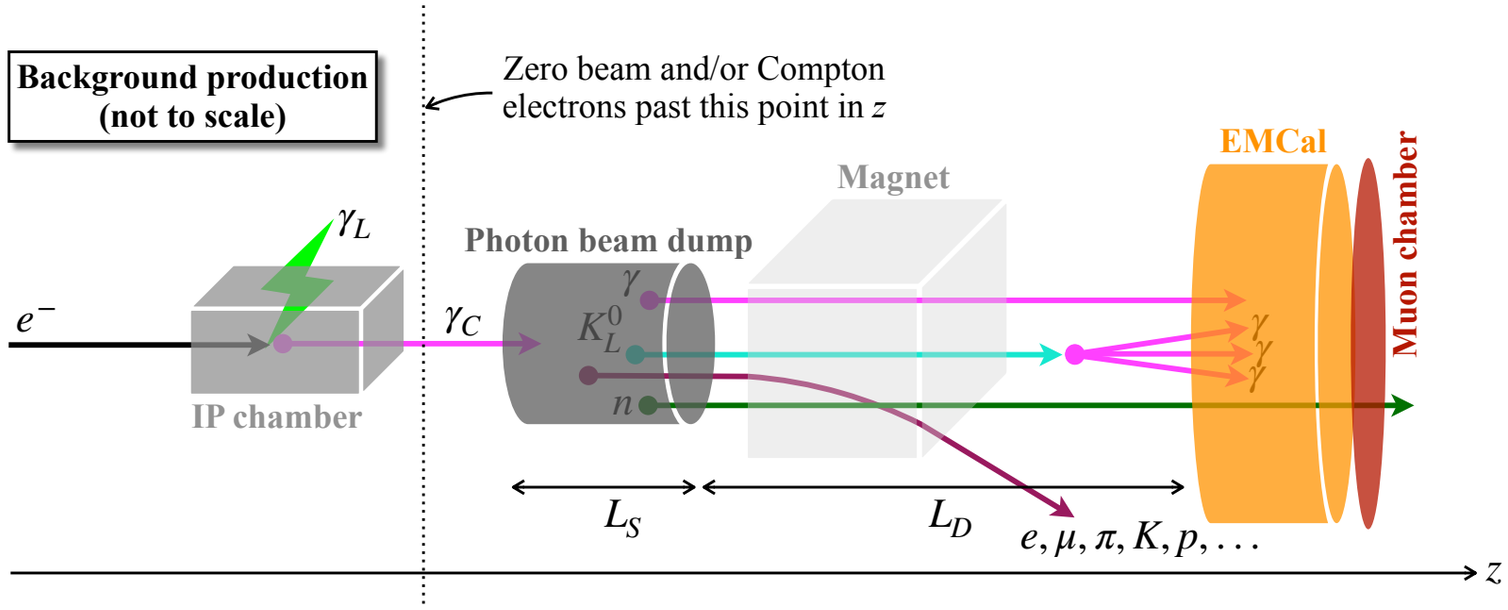
   $N_{n\gamma\to 2\gamma} \approx 1\times 10^{6} f_{n\to\gamma} e^{-10 f_{n\to\gamma}} R_{\mathrm{sel}}$
3. **real photons** - $N_{2\gamma} \approx 8\times 10^{2} R_{\mathrm{sel}}$ dominant

R_{sel} - event selection rejection

$f_{n\to\gamma}$ - neutron fake rate

depend on detector technology
(energy, pointing and timing resolutions)

background estimation



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2. **fake photons** - $N_{2n\to 2\gamma} \approx 5\times 10^{8} f_{n\to\gamma}^{2} e^{-10 f_{n\to\gamma}} R_{\mathrm{sel}}$

   $N_{n\gamma\to 2\gamma} \approx 1\times 10^{6} f_{n\to\gamma} e^{-10 f_{n\to\gamma}} R_{\mathrm{sel}}$
3. **real photons** - $N_{2\gamma} \approx 8\times 10^{2} R_{\mathrm{sel}}$ dominant

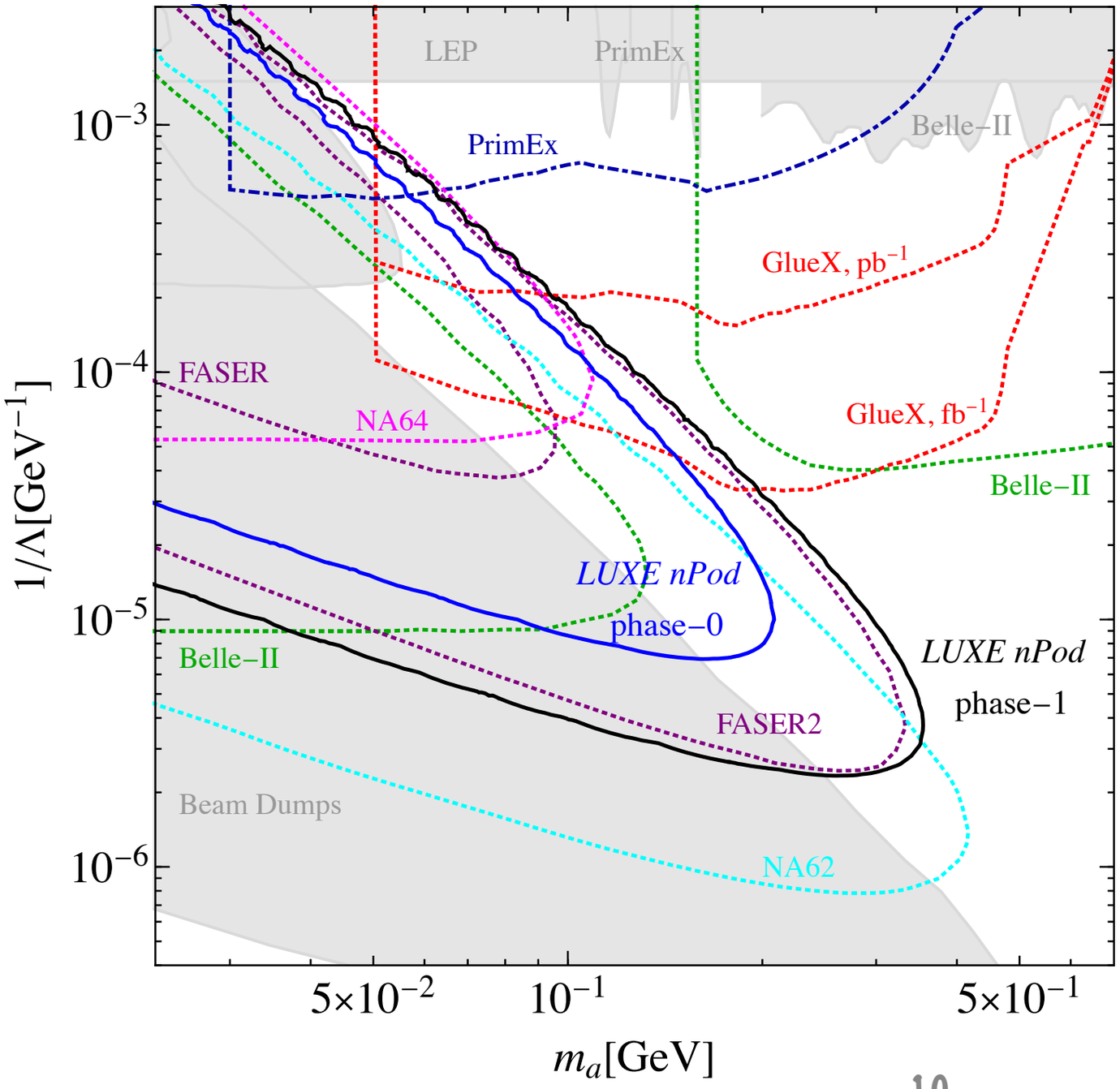
$R_{\mathrm{sel}}, f_{n\to\gamma} \lesssim 10^{-3}$
for background free
achievable with current technologies
(CMS/LHCb/SHiP)

R_{sel} - event selection rejection
$f_{n\to\gamma}$ - neutron fake rate

depend on detector technology
(energy, pointing and timing resolutions)

ALP reach estimation

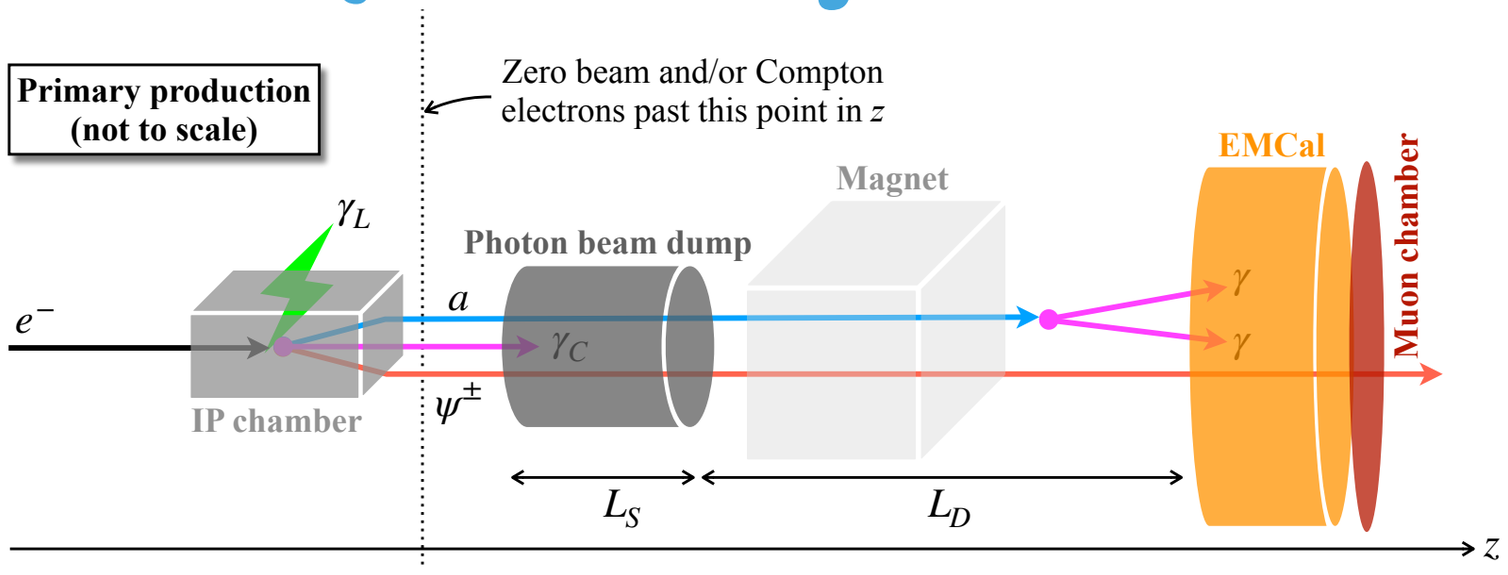
$E_e = 16.5\,\mathrm{GeV}$ $N_e = 1.5 \times 10^9$ $N_{\mathrm{BX}} = 10^7$ $L_S = 1.0\,\mathrm{m}$ $L_D = 2.5\,\mathrm{m}$ $R_D = 1.0\,\mathrm{m}$ $E_{\gamma,\mathrm{min}} = 0.5\,\mathrm{GeV}$



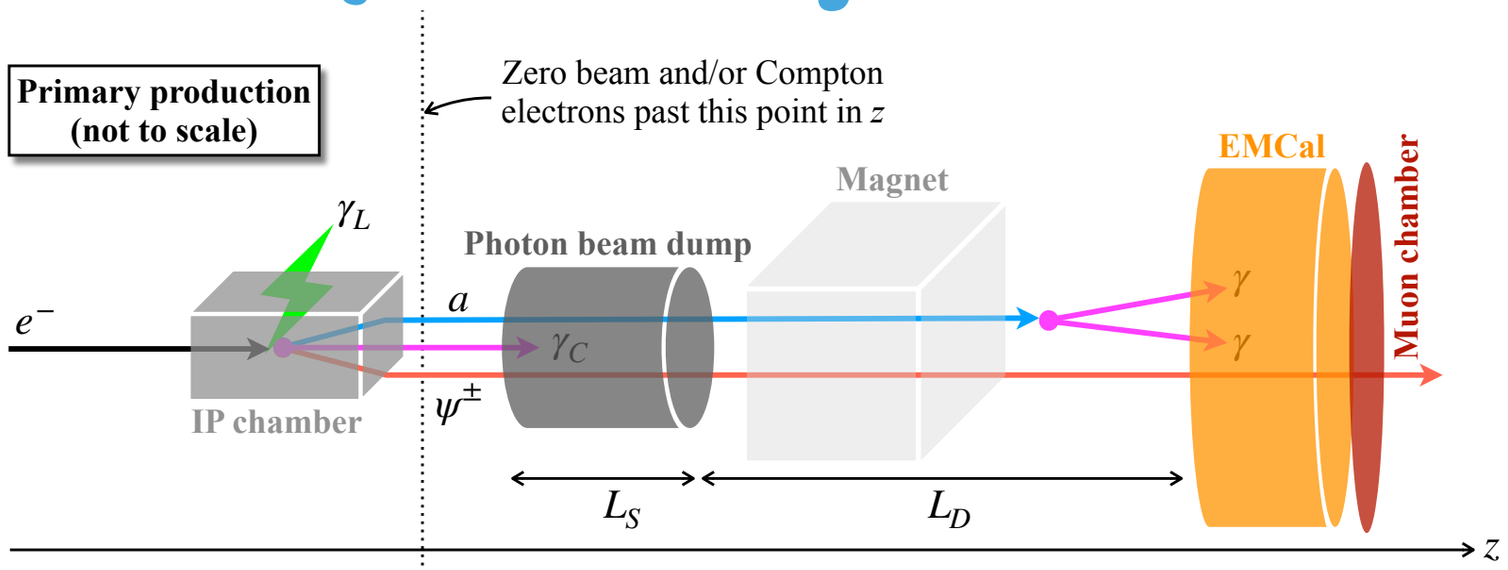
new Physics optical dump (*nPod*)

assuming background free

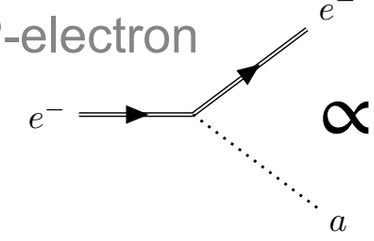
primary ALP production



primary ALP production

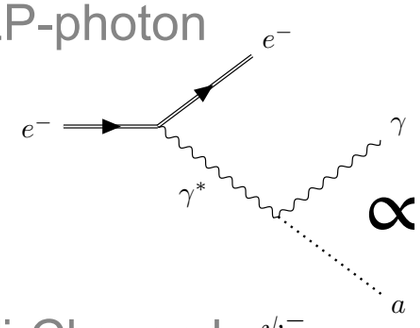


ALP-electron



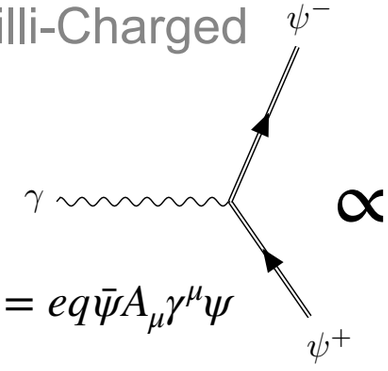
$\propto g_{ae}^2$

ALP-photon



$\propto 1/\Lambda^2$

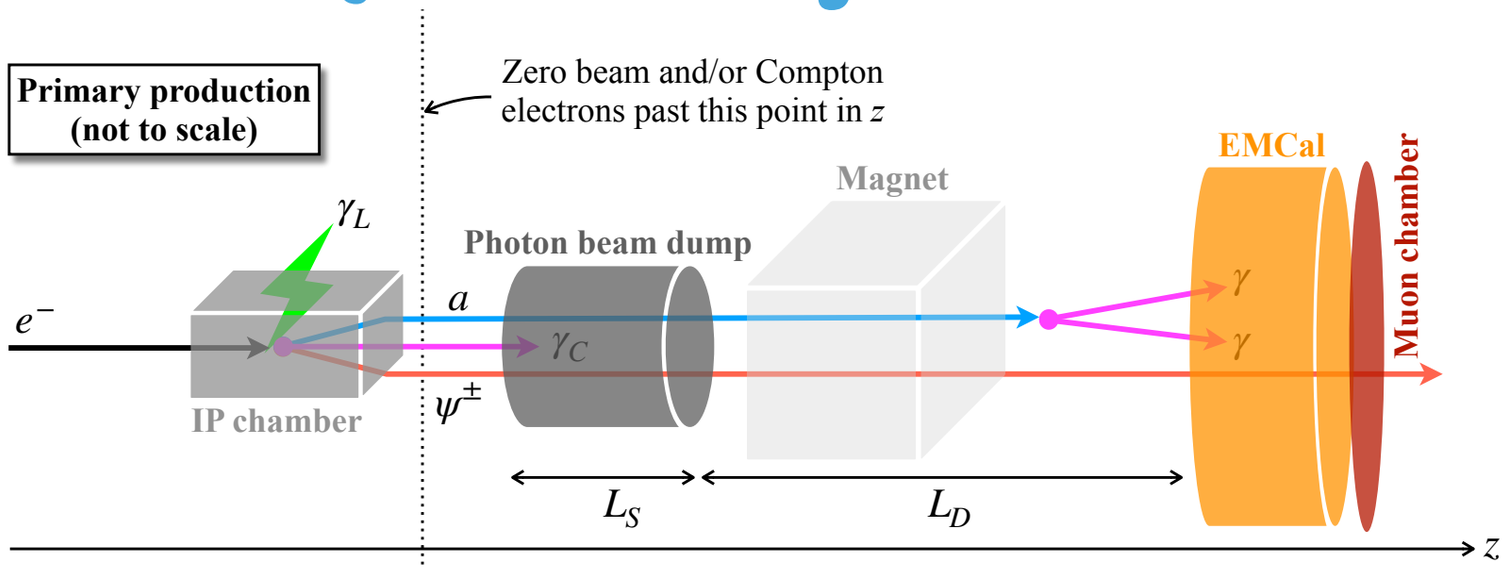
milli-Charged



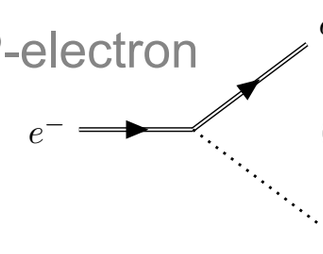
$\propto q^4$

$\mathscr{L}_\psi = eq\bar{\psi}A_\mu\gamma^\mu\psi$

primary ALP production

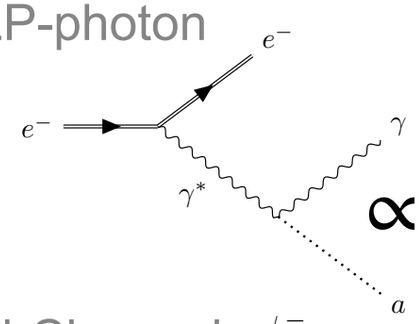


ALP-electron



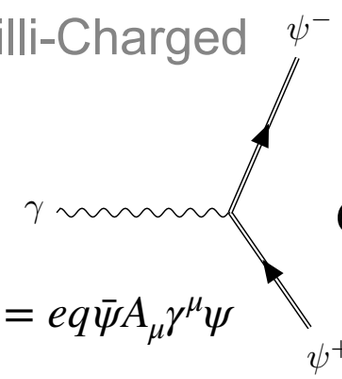
$\propto g_{ae}^2$

ALP-photon



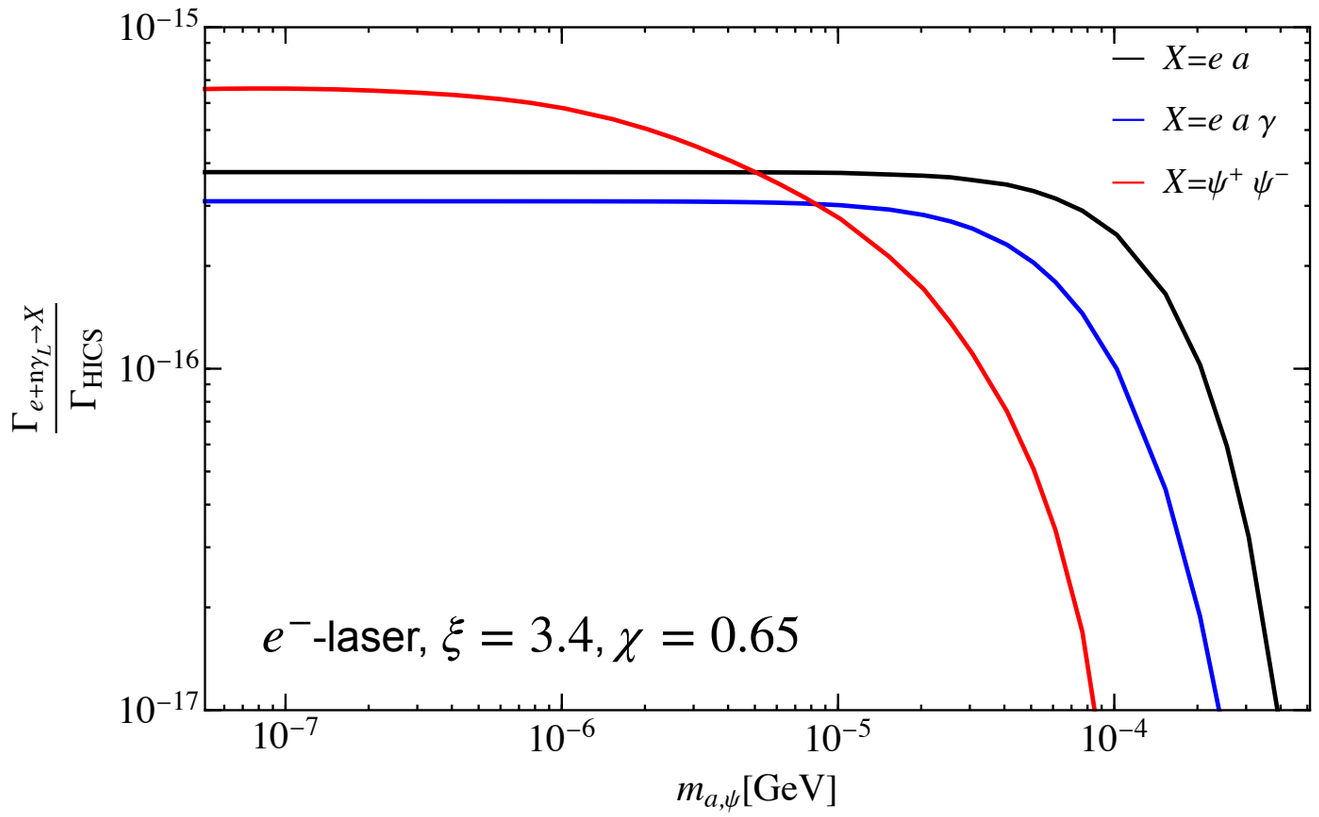
$\propto 1/\Lambda^2$

milli-Charged



$\propto q^4$

$\mathscr{L}_\psi = eq\bar{\psi}A_\mu\gamma^\mu\psi$



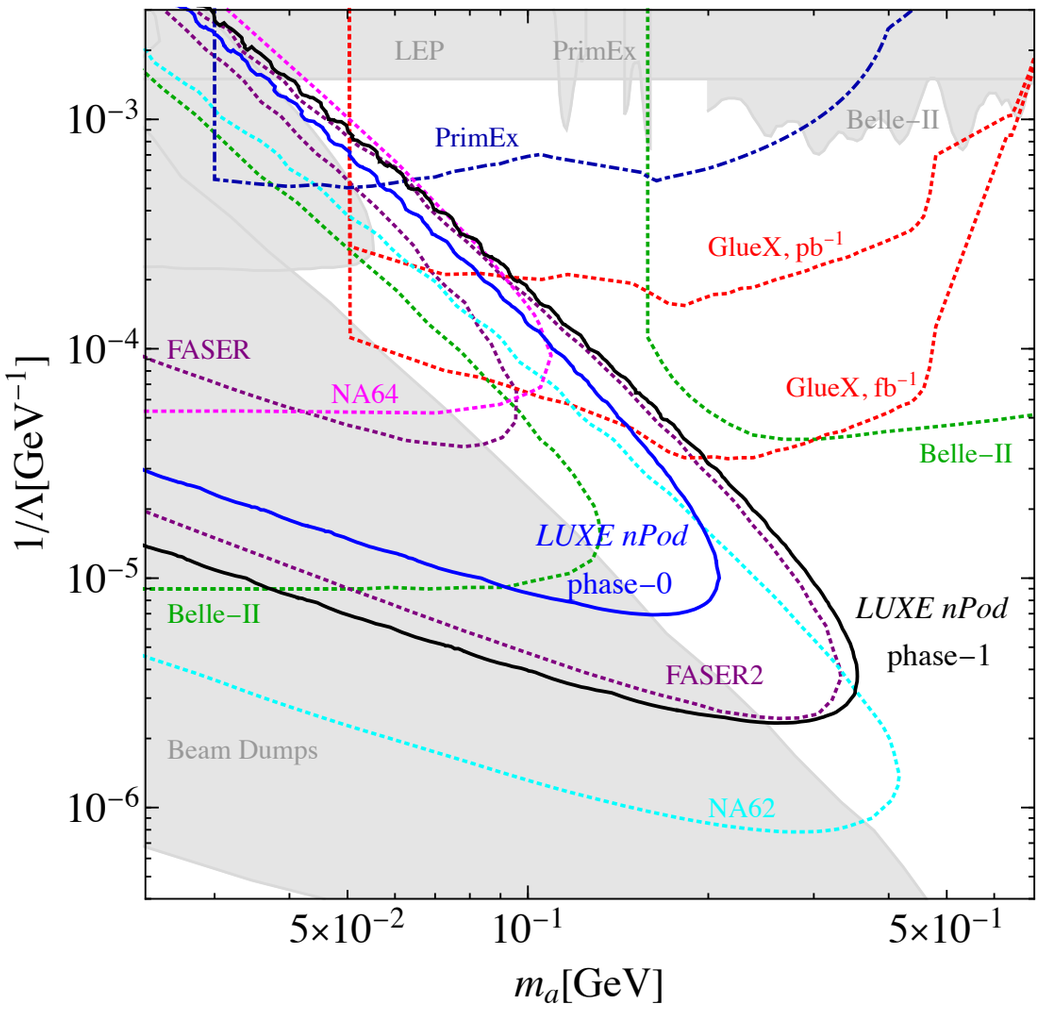
$q = 5 \times 10^{-4},\ g_{ae} = 10^{-8},\ \Lambda = 3\ \text{TeV}$

Outlook

* LUXE is a proposed new experiment at DESY and Eu.XFEL in Schenefeld & Hamburg, Germany. It aims to test QED at its non perturbative regime

* in addition, it can be used to probe unexplored ALP parameter space and open the door to new novel type of beam dump experiments

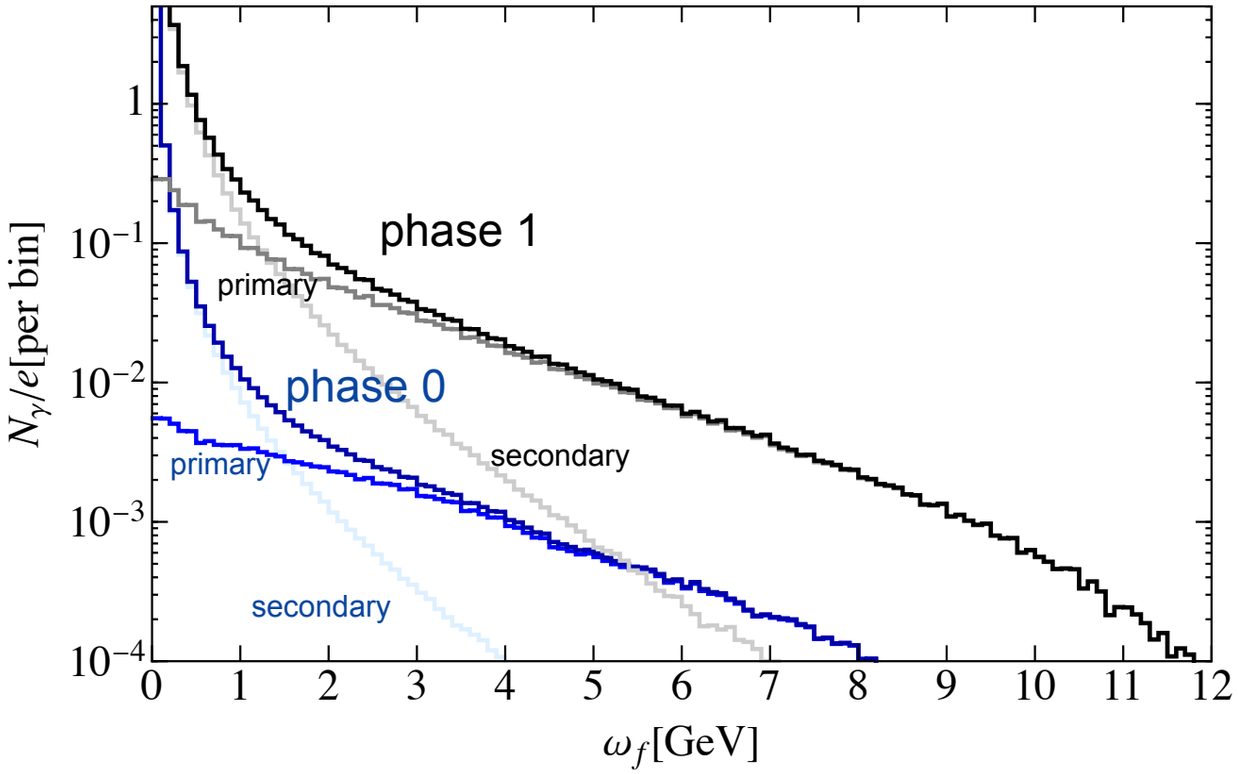
* timeline (on going approval):
2024 - expected installation
operate for at least 5 years

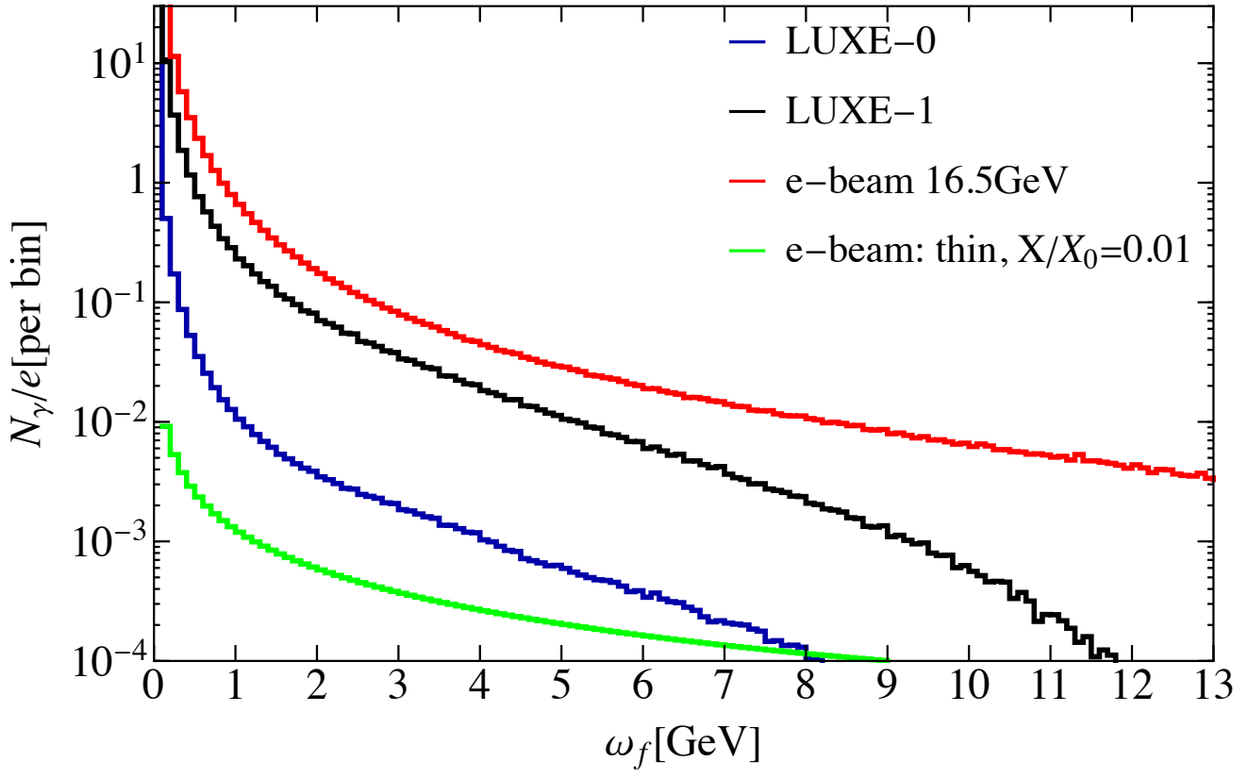


Backups

the photon spectrum

$$E_e = 16.5\,\mathrm{GeV}\,,\ \langle\omega_f\rangle \approx 2.4\,\mathrm{GeV}$$





source	# photons, E>1
LUXE-0/1	0.12 / 2.5
e-beam thin	0.03
e-beam thick	6.7

→ much larger background O(100) and not feasible technically

LUXE Laser

phase-0: $t_{\mathrm{L}} = 20\,\mathrm{fs}$, $\xi_{\mathrm{max}} = 2.4$, transverse spot size $6.5\,\mu\mathrm{m}$

phase-1: $t_{\mathrm{L}} = 120\,\mathrm{fs}$, $\xi_{\mathrm{max}} = 3.4$, transverse spot size $10\,\mu\mathrm{m}$