



Probing New Physics at the LUXE experiment

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speaking for the LUXE Collaboration [luxede.desy.de]



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“LUXE”

Laser und XFEL Experiment

- A high power laser beam (40 or 350 TW)
- The XFEL.EU electron beam (16.5 GeV)
... or converted GeV gamma beam

Primary Goal: non-perturbative QED

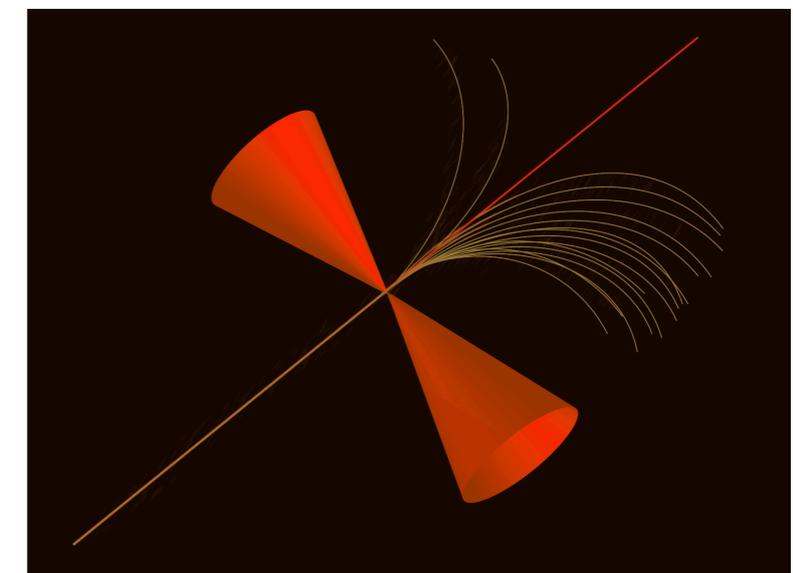
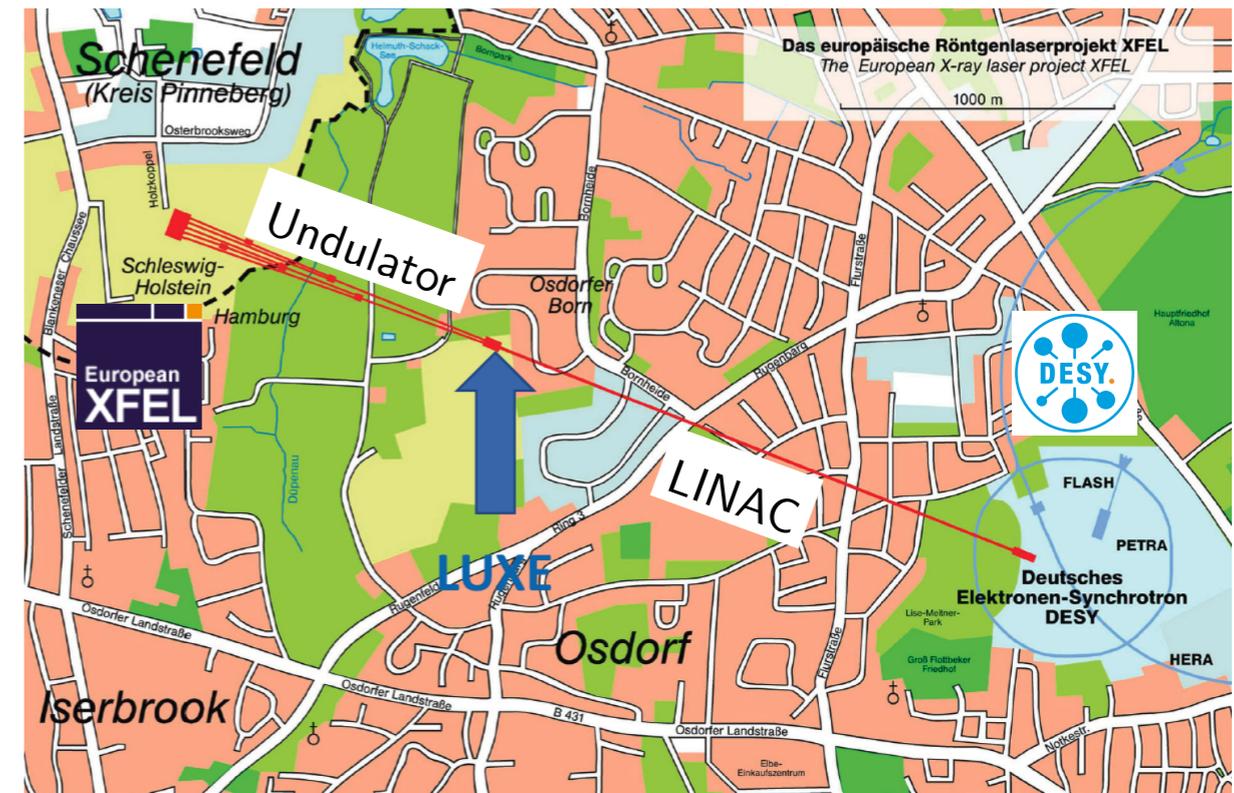
- Physics near/above Schwinger limit
- QED Theory's transition into non-perturbative

An international collaboration

- 91 scientists contribute to the CDR
- Over 20 active collaborating institutes

Y.C. Yap: [Fri. 08 at 17:30](#)

O. Borysov: [Sat. 09 at 18:15](#) (Room 4)



LUXE CDR: [EPJ ST 230 2445 \(2021\)](#)

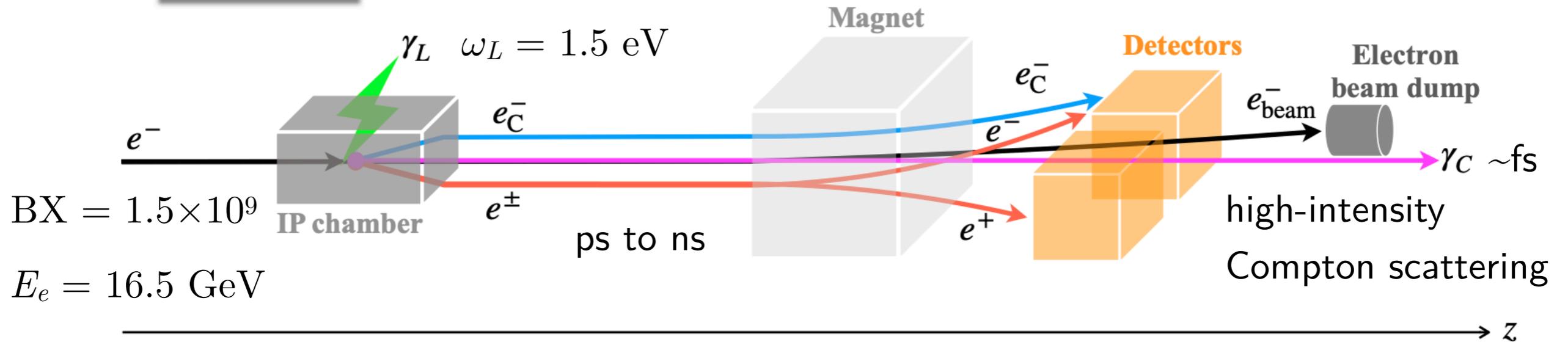
Primary Interaction

**LUXE SFQED
(not to scale)**

electron-laser mode

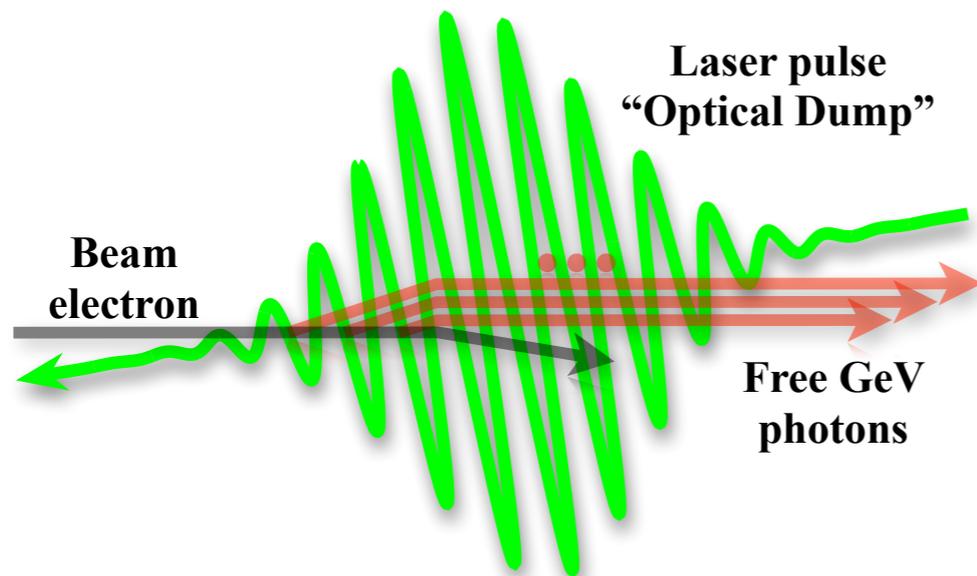
$$I_L \approx 10^{18}-10^{21} \text{ W cm}^{-2}$$

$$\xi = (eI_L^{1/2}) / (m_e \omega_L)$$



$$BX = 1.5 \times 10^9$$

$$E_e = 16.5 \text{ GeV}$$



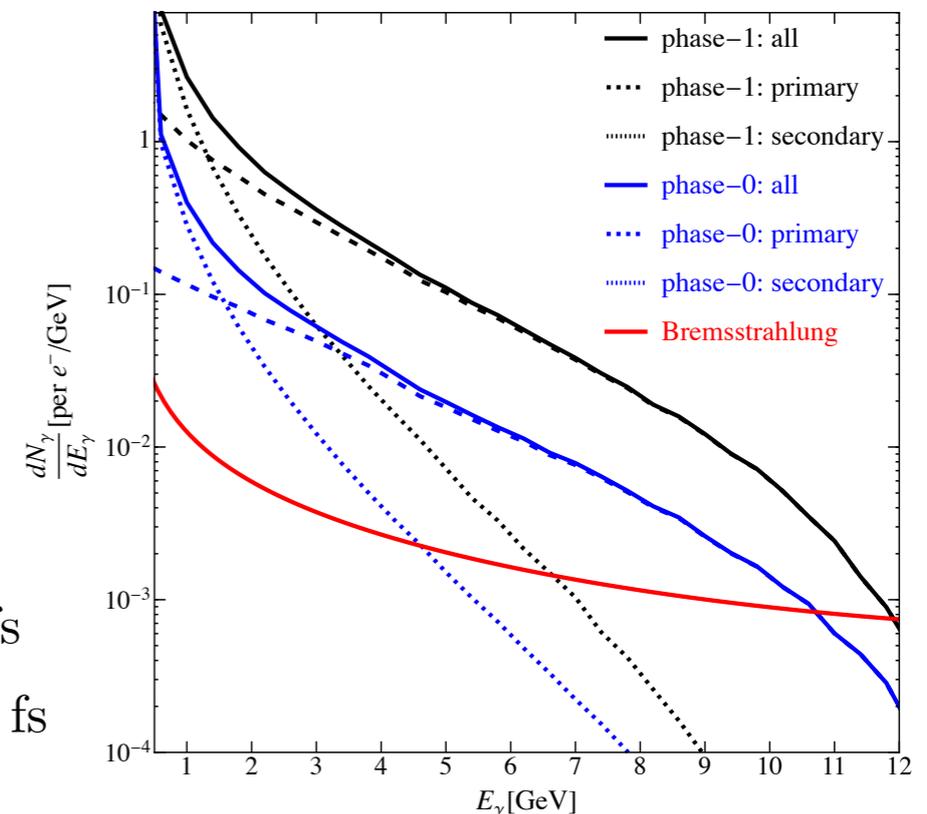
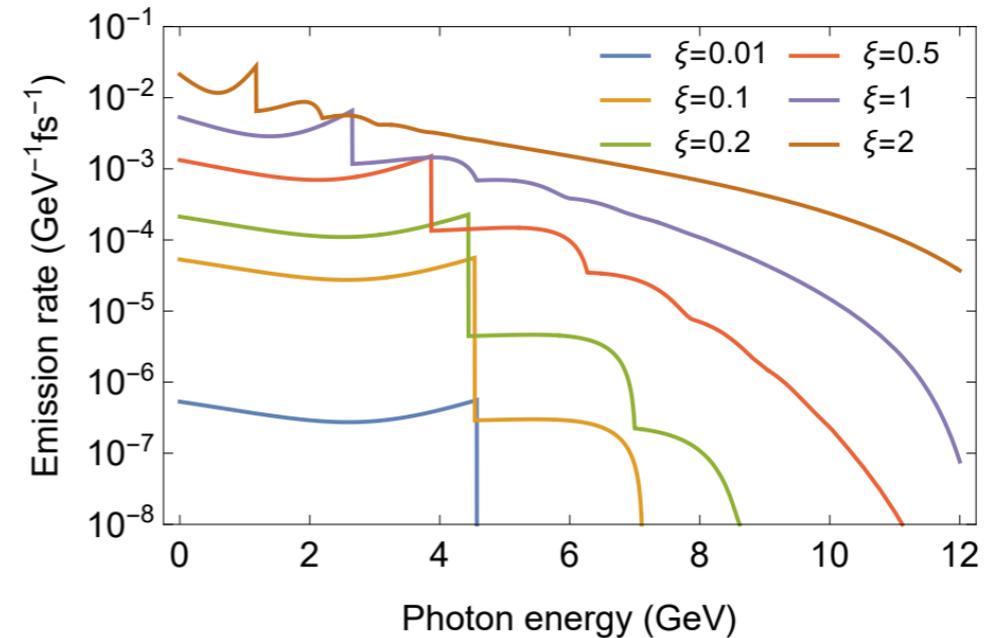
- High-intensity laser converts electrons into GeV photons like a dump
- HICS flux falls into a 5 cm radius (95%) on the photon dump at IP+13 m
- What can we make use of the **free photons?**

Optical Dump

$$\xi \propto I_L^{1/2} \propto (\Delta t_L)^{-1/2} w^{-1}$$

16.5 GeV electron, 800 nm laser, 17.2° crossing angle

- The optical dump creates more photons than actual “dump” of a $0.01X_0$ Bremsstrahlung target
- Photon number over 1 GeV per BX
 - Phase-1: 2.5×10^9
 - Bremsstrahlung: 10^8
- HICS can produce enough amount of photons for the study of new physics e.g. ALP-photon coupling at GeV scale



Bai, et al. LUXE-NPOD, [arXiv 2107.13554](https://arxiv.org/abs/2107.13554).

Optimal laser parameters for NPOD

Phase-0 40 TW laser: $\xi = 2.4$, $\Delta t_L = 25$ fs

Phase-1 350 TW laser: $\xi = 3.4$, $\Delta t_L = 120$ fs

SM particles
+
BSM particles

BSM particles
(and neutrinos)

axion(-like-particles)

scalar ALPs

millicharged particles

dark photons

.....

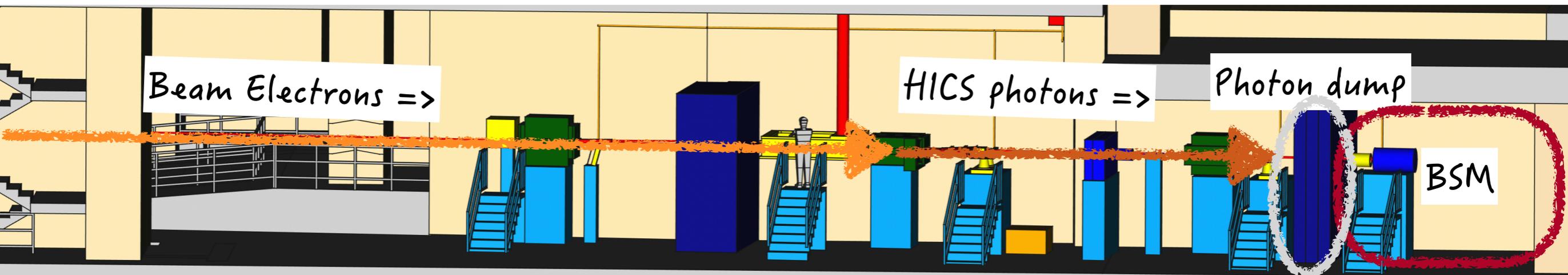
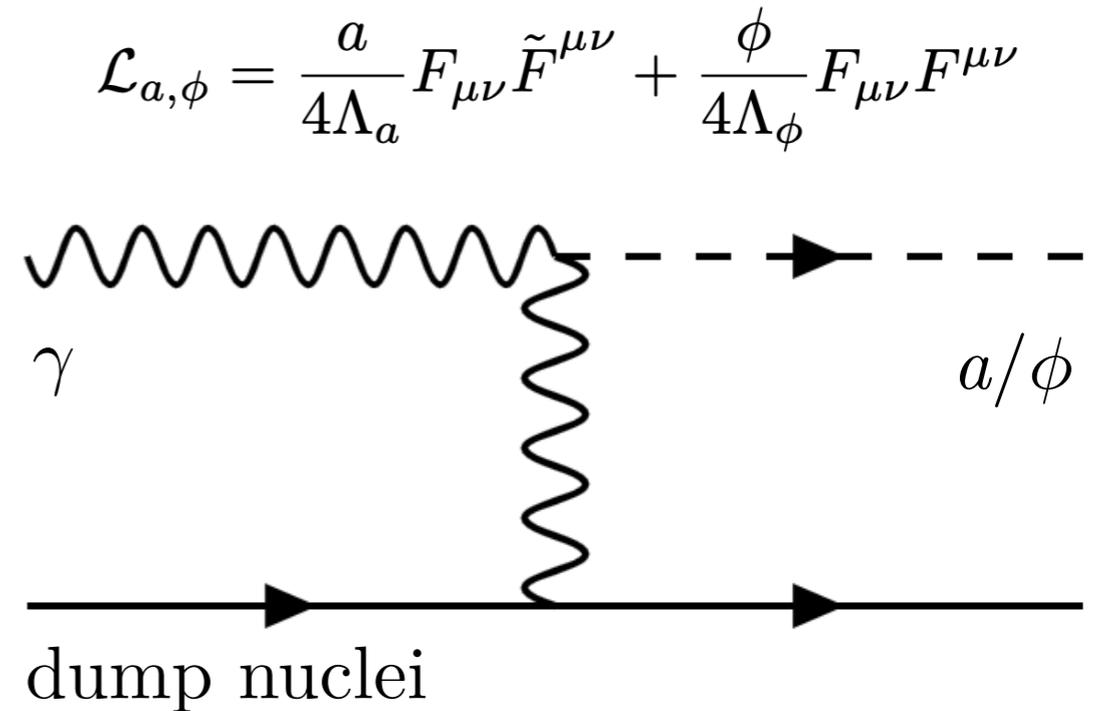
ν

Detectors

ν
.....
(feebly inter.) BSM particles

ALP Generation

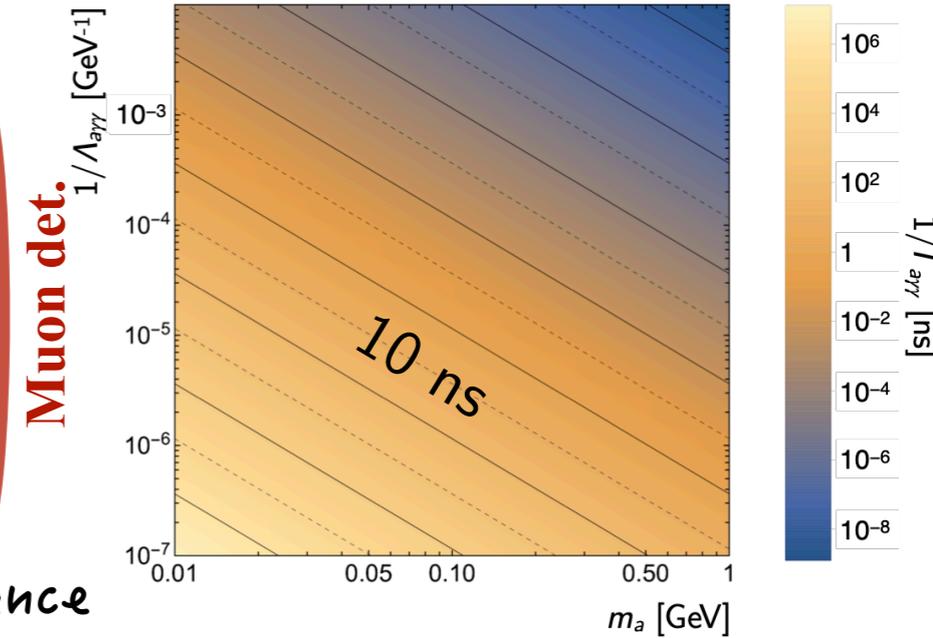
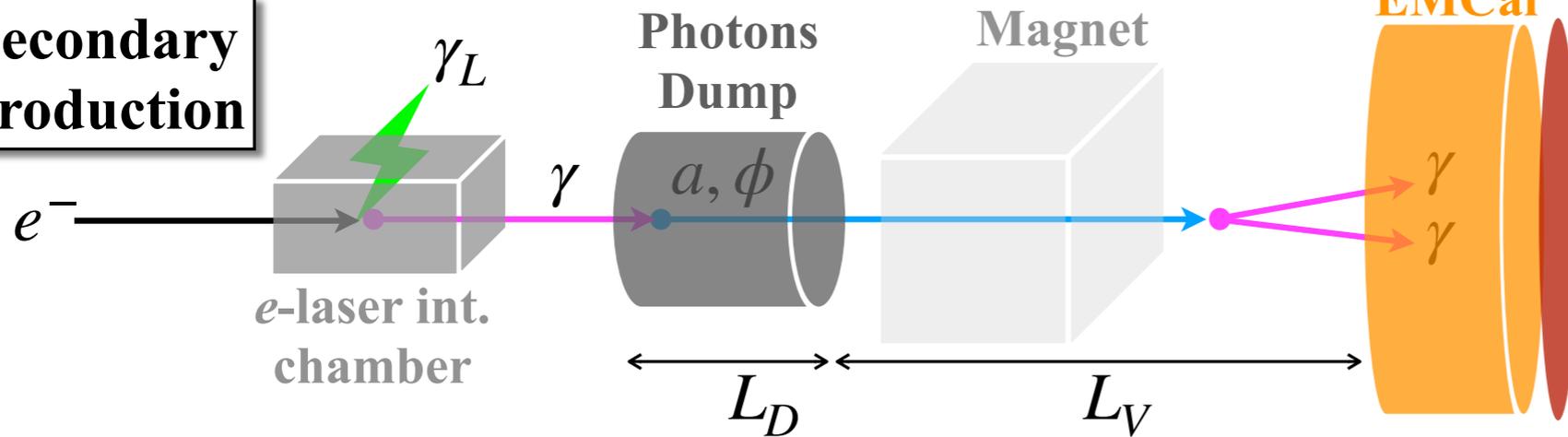
- A secondary interaction point in LUXE at the photon dump
- Secondary photons are created in dump by electromagnetic showers
- Through Primakoff process, pseudo-scalar a or scalar ϕ particles are created



Photon Regeneration

$$\Gamma_{a \rightarrow \gamma\gamma} = \frac{g_{a\gamma\gamma}^2 m_a^3}{64\pi}$$

Secondary Production



Photon spectrum

Detector acceptance

$$N_X \approx \mathcal{L}_{\text{eff}} \int dE_\gamma \frac{dN_\gamma}{dE_\gamma} \sigma_X(E_\gamma) \left(e^{-\frac{L_D}{L_X}} - e^{-\frac{L_V+L_D}{L_X}} \right) A$$

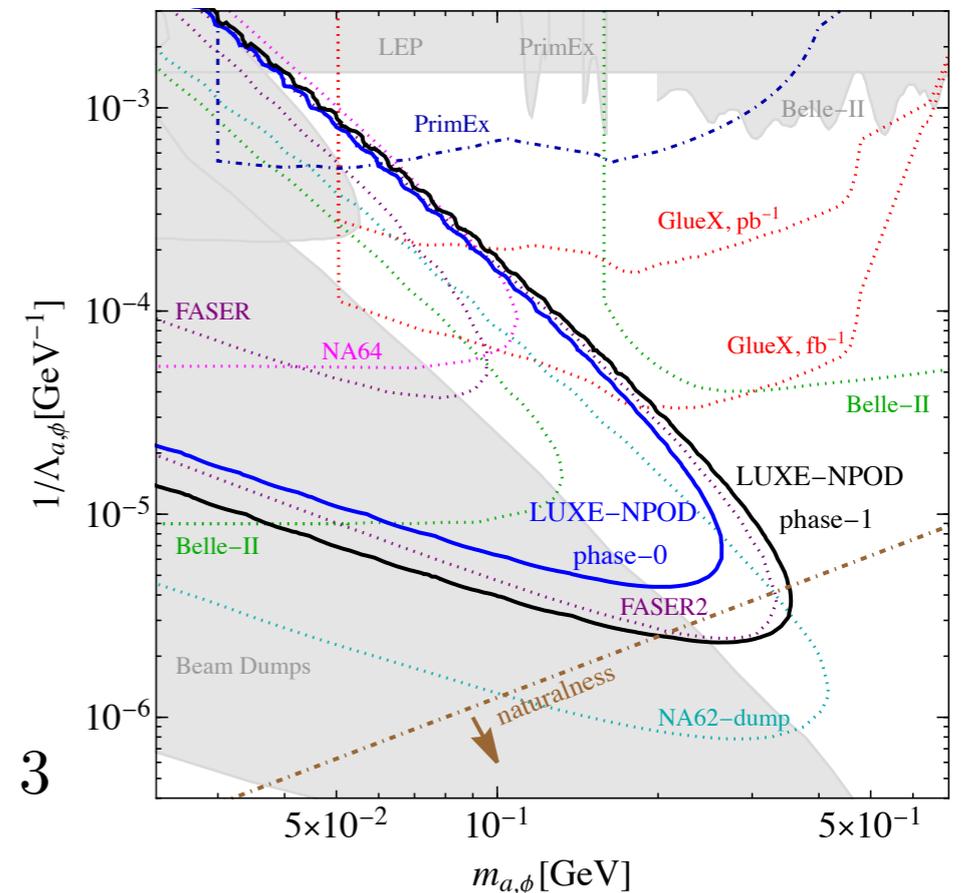
Luminosity

cross-section

Decay

- Effective luminosity relates to the dump material (density, radiation length)
- ALP decays inside the dump will not reach the detector
- Agrees with MADGRAPH simulation

$$N_X \geq 3$$



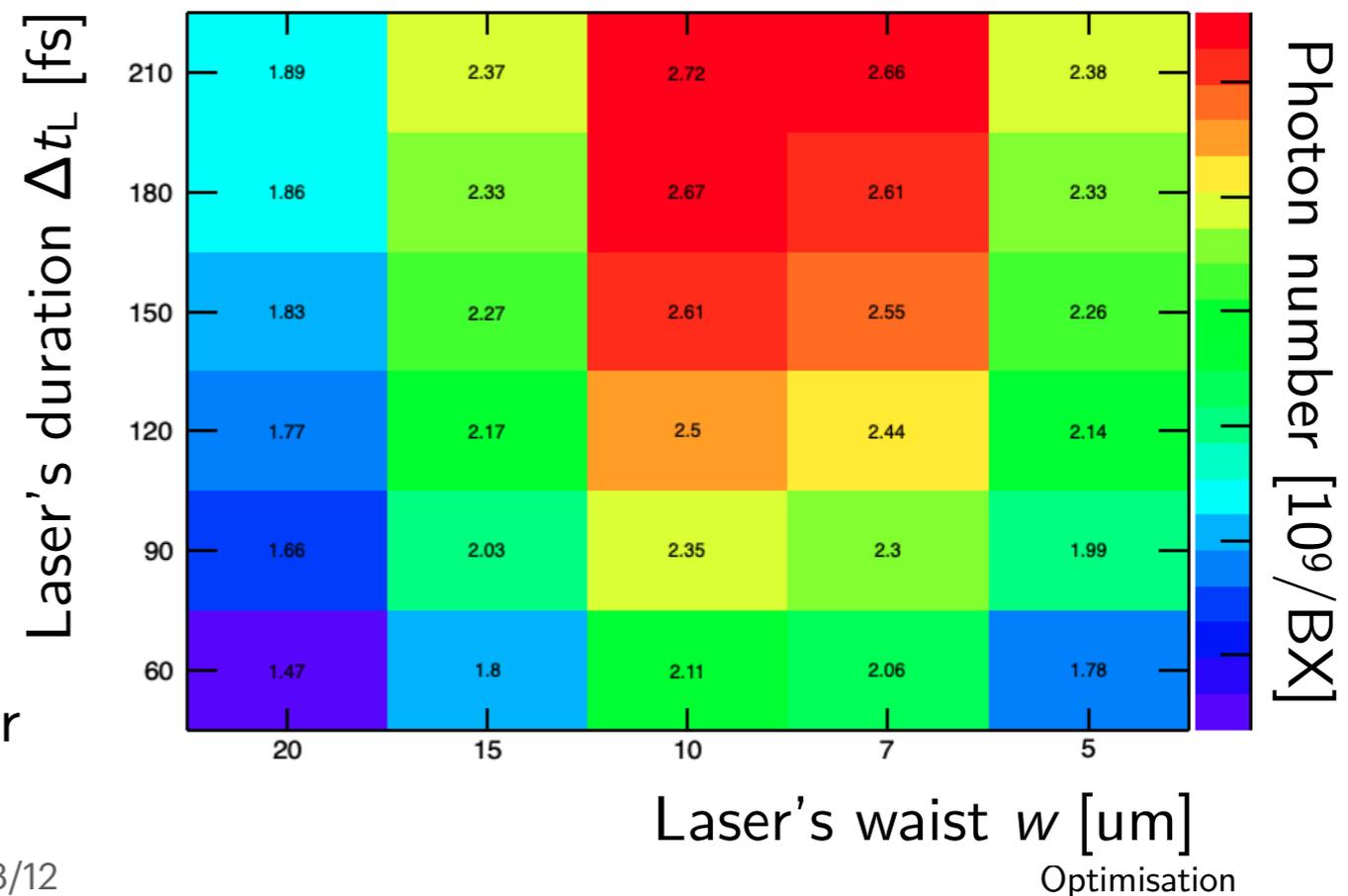
Luminosity

- A year's run will produce 10^7 BXs
@ 1 Hz x 8 hours per day
- To create as many HICS photons as possible, laser's parameters needs to match electron beam's characters
- The LUXE primary goal requires a short and narrow laser beam
 - Phase-1: 2.5×10^9
- Benchmarked with a W disk dump
 - 1 m in length
 - > 10 cm in radius

Phase-1 350 TW laser

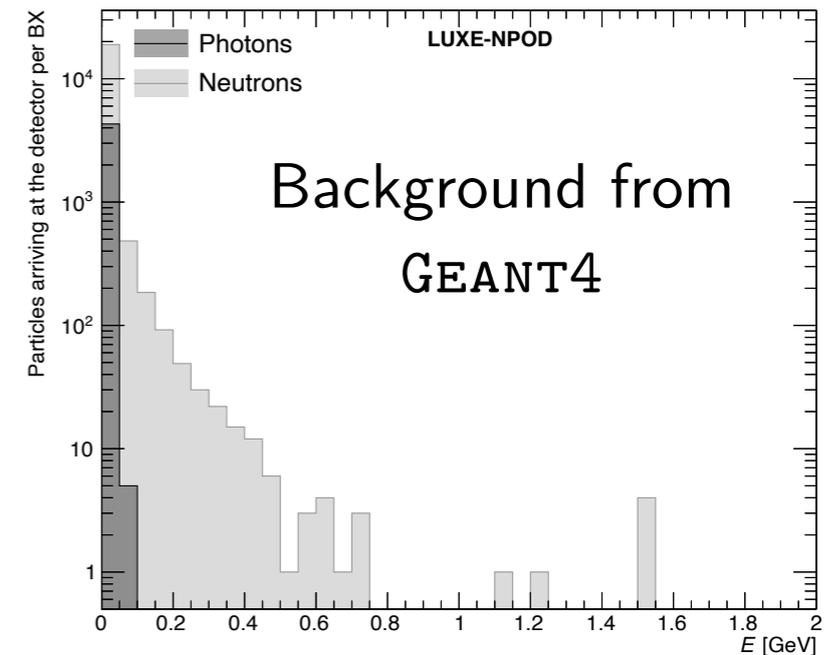
LUXE Electrons from XFEL.EU

Energy	16.5 GeV
Charge	0.25 nC
Spotsize (IP)	5 μm
Bunch length	30-50 μm = 100-130 fs
Norm. emittance	1.4 mm mrad

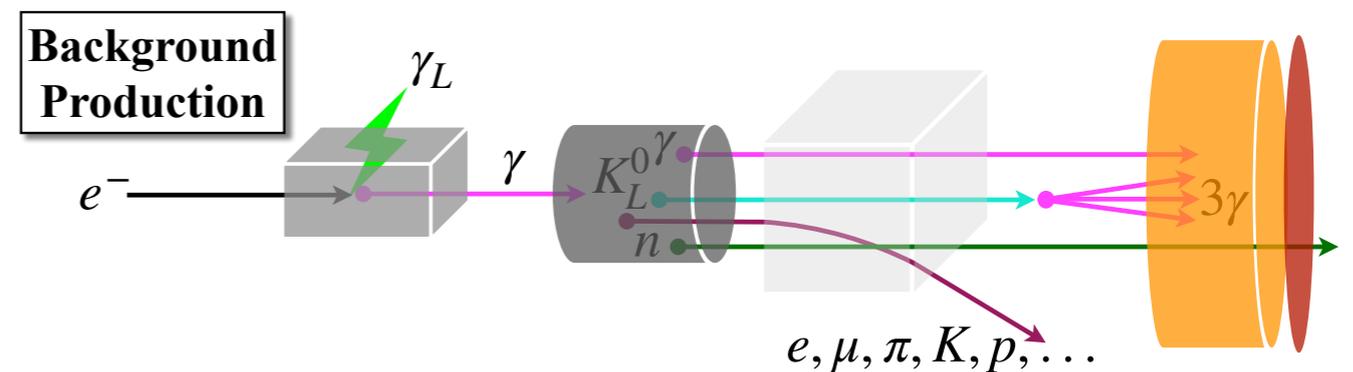
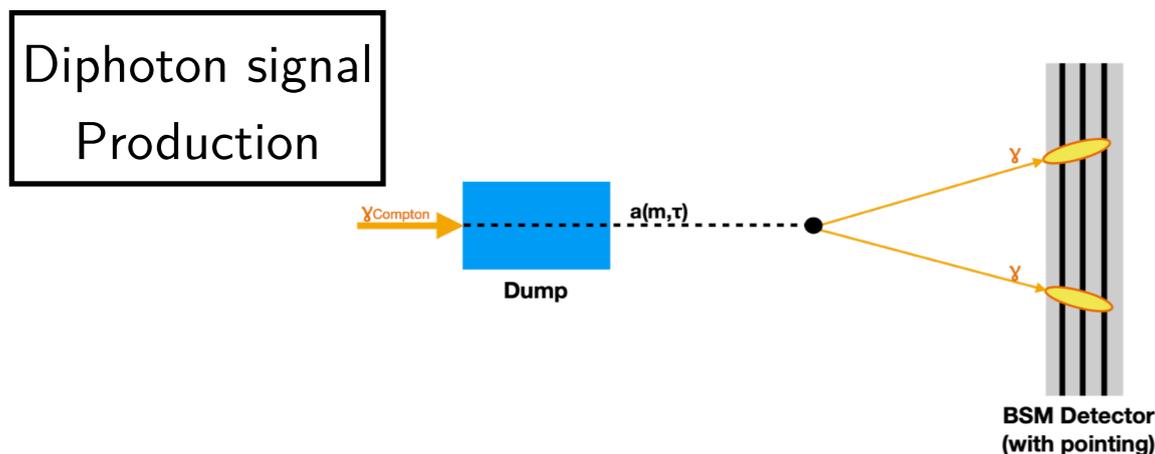


Background

- Few SM particles can still leak through the dump
 - Charged particles: bent out by magnet
 - Neutral particles: neutrons and photons
- Background has been studied with GEANT4
 - 10 neutrons per BX (>0.5 GeV)
 - photon number estimated as 10^{-2}
- Neutrons fly slower (a few ns) than signal
- Diphoton event matching
- Background free during 10^7 data taking

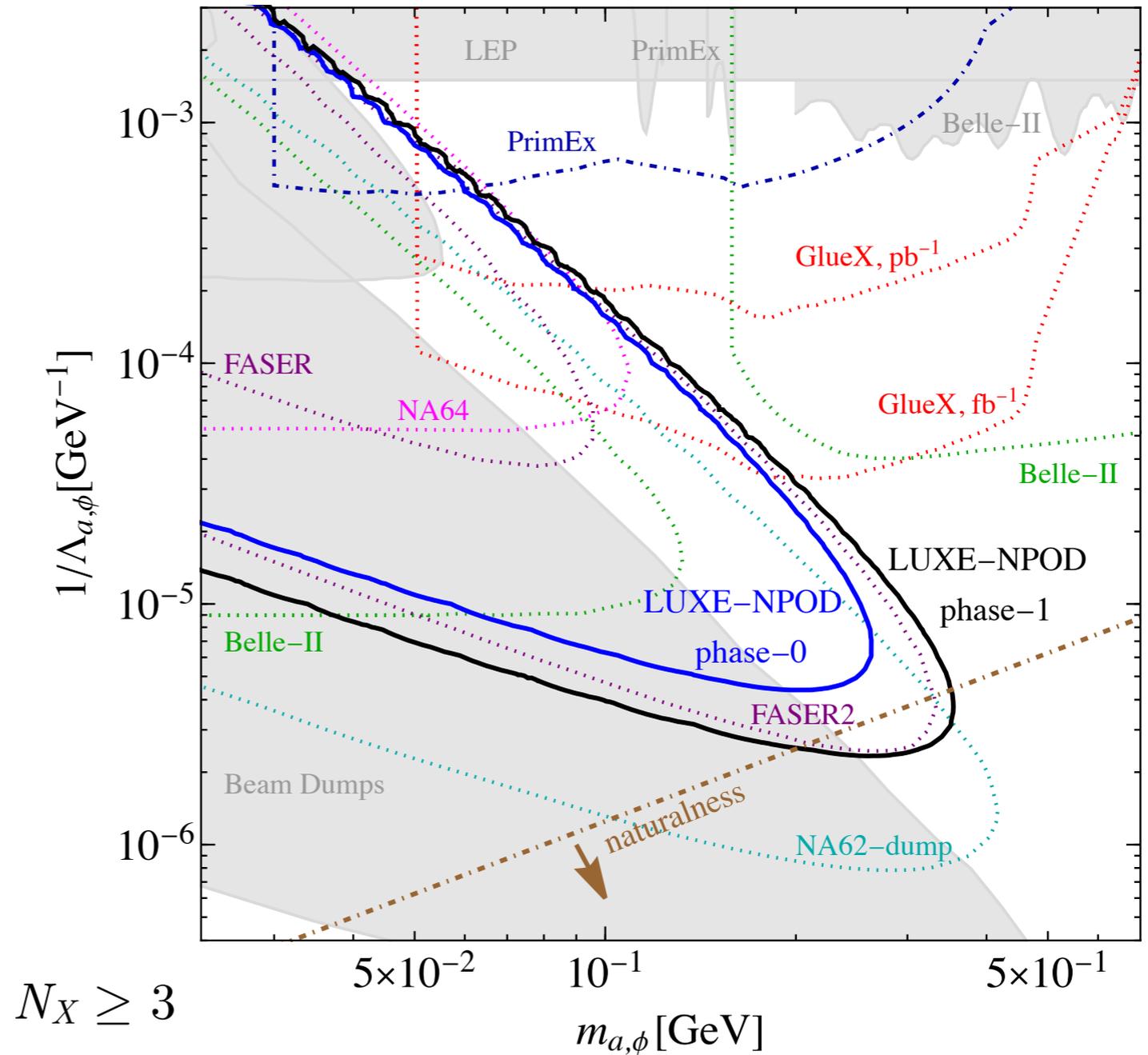


Δt [ns]	Background rejection ~[%]				Signal efficiency [%] for $m_a:1/\Lambda_a$		
	γ	n	p	K_L	130:1e-4	200:e-5	416:e-5
0.1	57	99.9	99.9	87	99.6	84	46
0.5	16	96	94	52	100	100	99
1.0	0	80	70	13	100	100	100

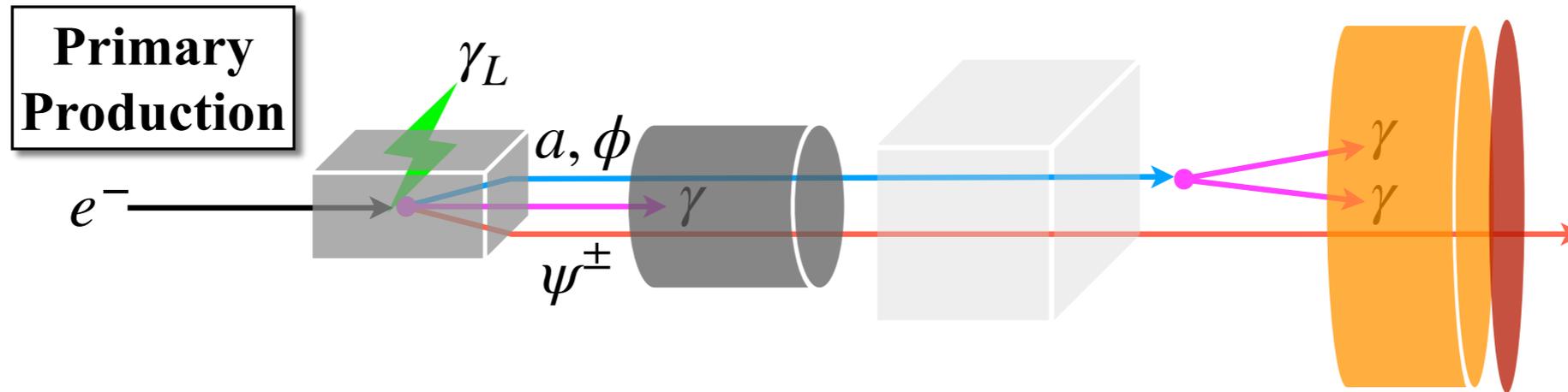


LUXE NPOD bounds

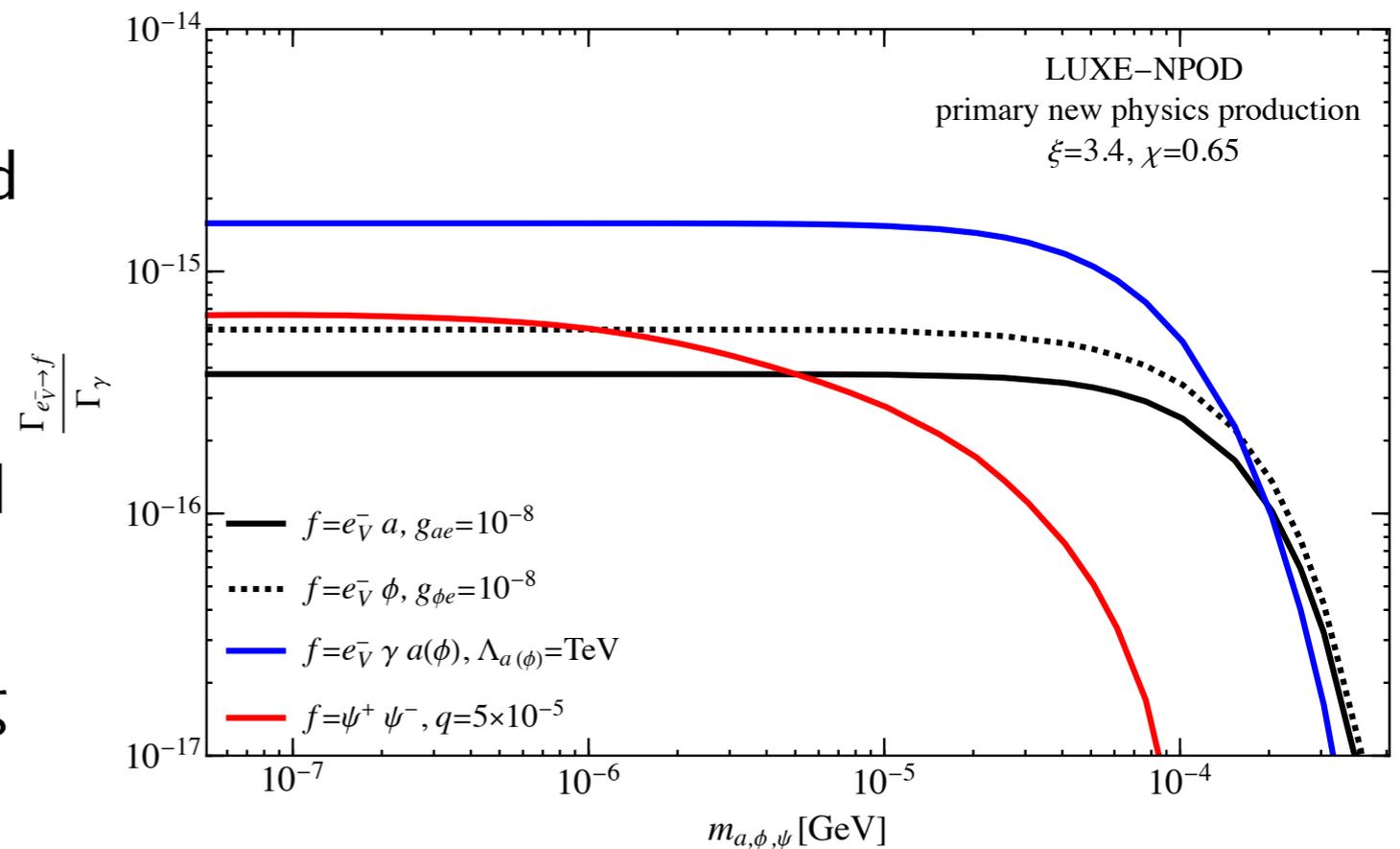
- Parameter bounds
 - m_a : 50-350 MeV
 - $1/\Lambda_a$: 6×10^{-6} - 10^{-3} GeV $^{-1}$
- For both pseudoscalar and scalar ALPs
- In LUXE Phase 1, NPOD bound could reach the scalar ALP's naturalness bound
- Comparable to NA62 and FASER2



Production at the IP



- Three types of processes have been calculated at eV scale:
 - ALP-electron under laser field
 - ALP-electron-photon
 - Photons into mCP pairs
- Production rates are normalised by HICS rates
- Further estimations are ongoing



Summary

- LUXE: A groundbreaking experiment for non-perturbative QED
- Data taking is set to start at 2026
- LUXE studies a collision between (in its electron-laser mode)
16.5 GeV electron and a 40 or 350 TW laser beams



- High-intensity Compton scattering provides a GeV photon flux
 - for BSM physics
 - ... and maybe more
- LUXE-NPOD search can reach the uncharted ALP parameter space for ALP-photon interaction
- ALP/mCP-electron(-photon) studies at the IP

THANKS FOR YOUR ATTENTION!