NPOD discussion

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Introduction

- NPOD idea was first presented officially towards the end of the CDR
  - We got very good feedback from the PRC committee then

- In the TDR iteration the NPOD was not discussed extensively (only in the executive summary note) but the PRC did comment about it briefly (and positively)

- Now, people are looking into additional signal scenarios (e.g. $G \to \gamma\gamma/e^+e^-$) and followup work(s) are coming

- Several (old and new) institutions working on the NPOD realization itself now

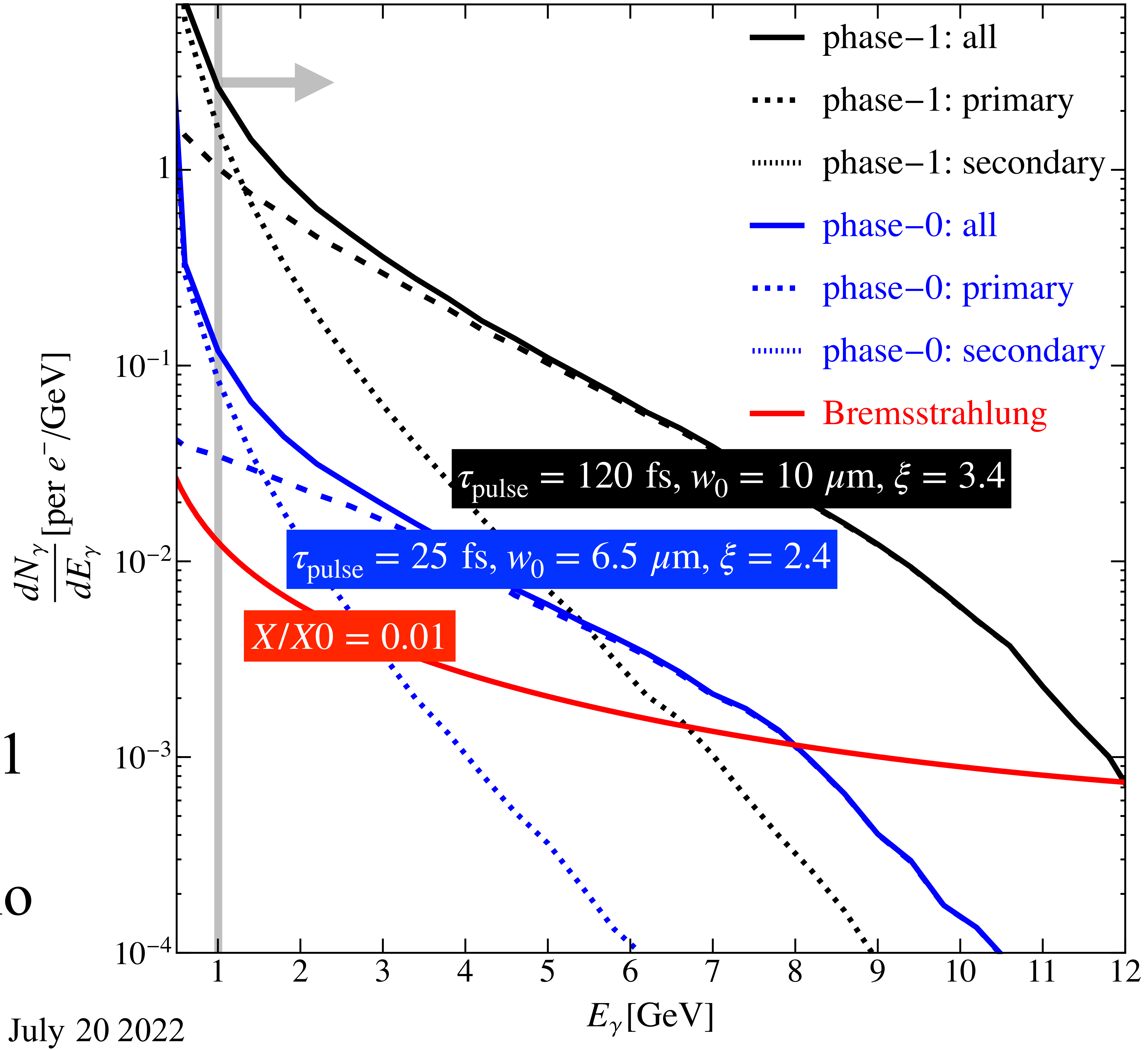
- As you have seen in the SAS meetings, we have space constraints, which affect the NPOD setup - this is the subject of the discussion today

Photon spectra for ALPs search

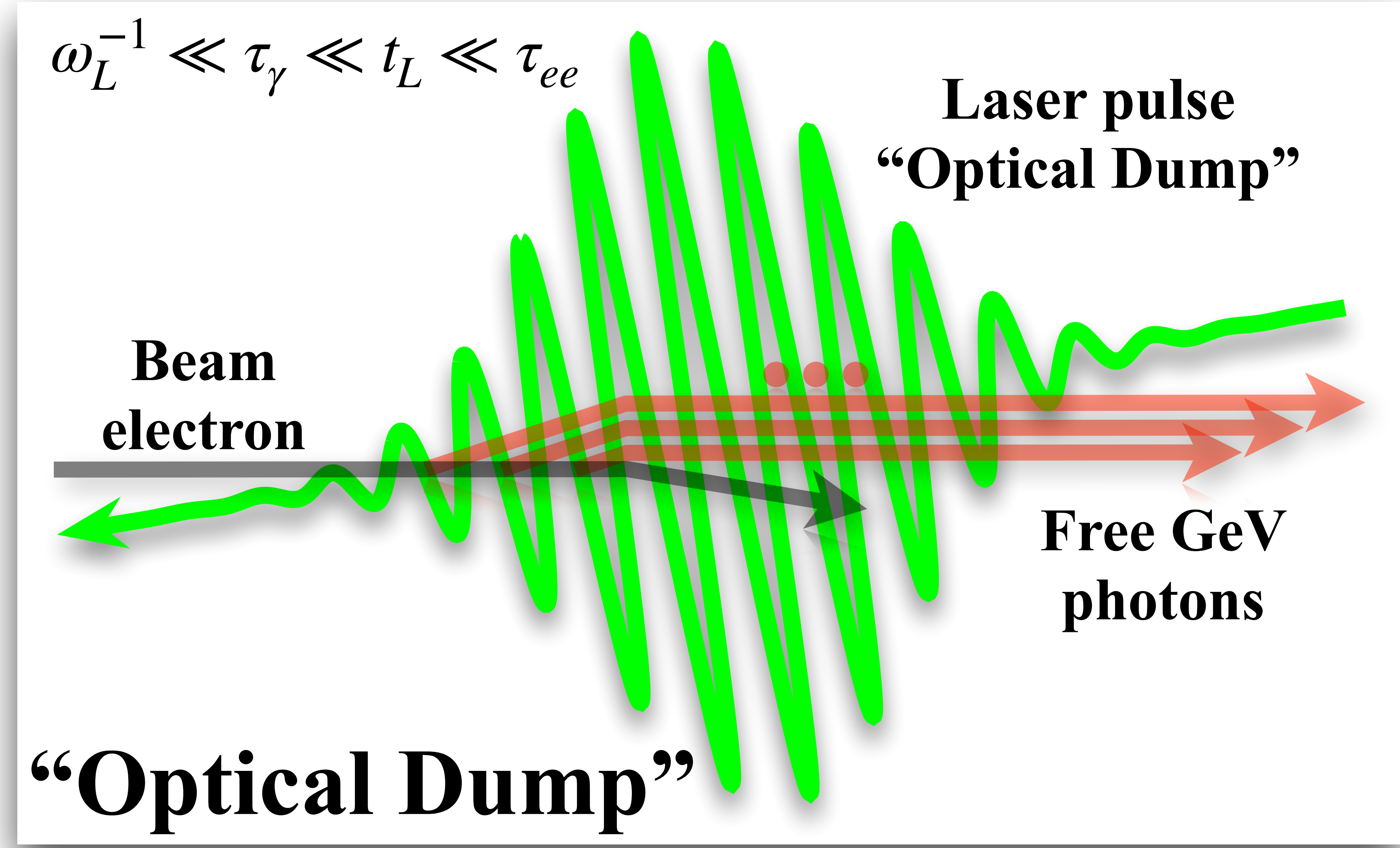
- Showing spectra per primary electron
  - primary: from the IP and
  - secondary: from the dump shower

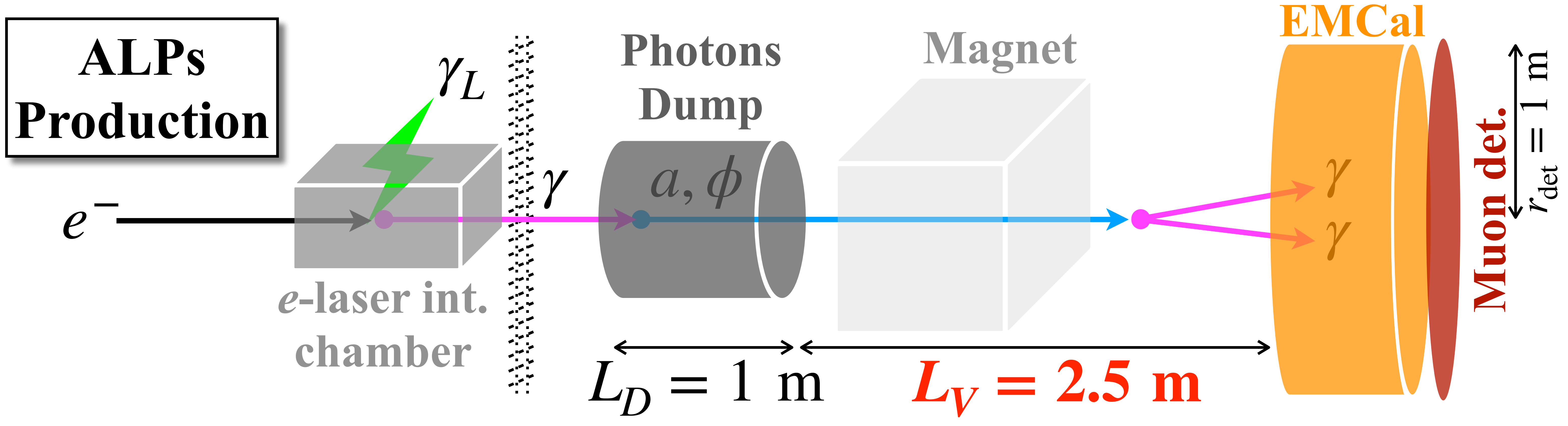
- Many photons per electron (phase-1):
  ~3.5 for $E_\gamma > 0$ GeV
  ~1.7 for $E_\gamma > 1$ GeV

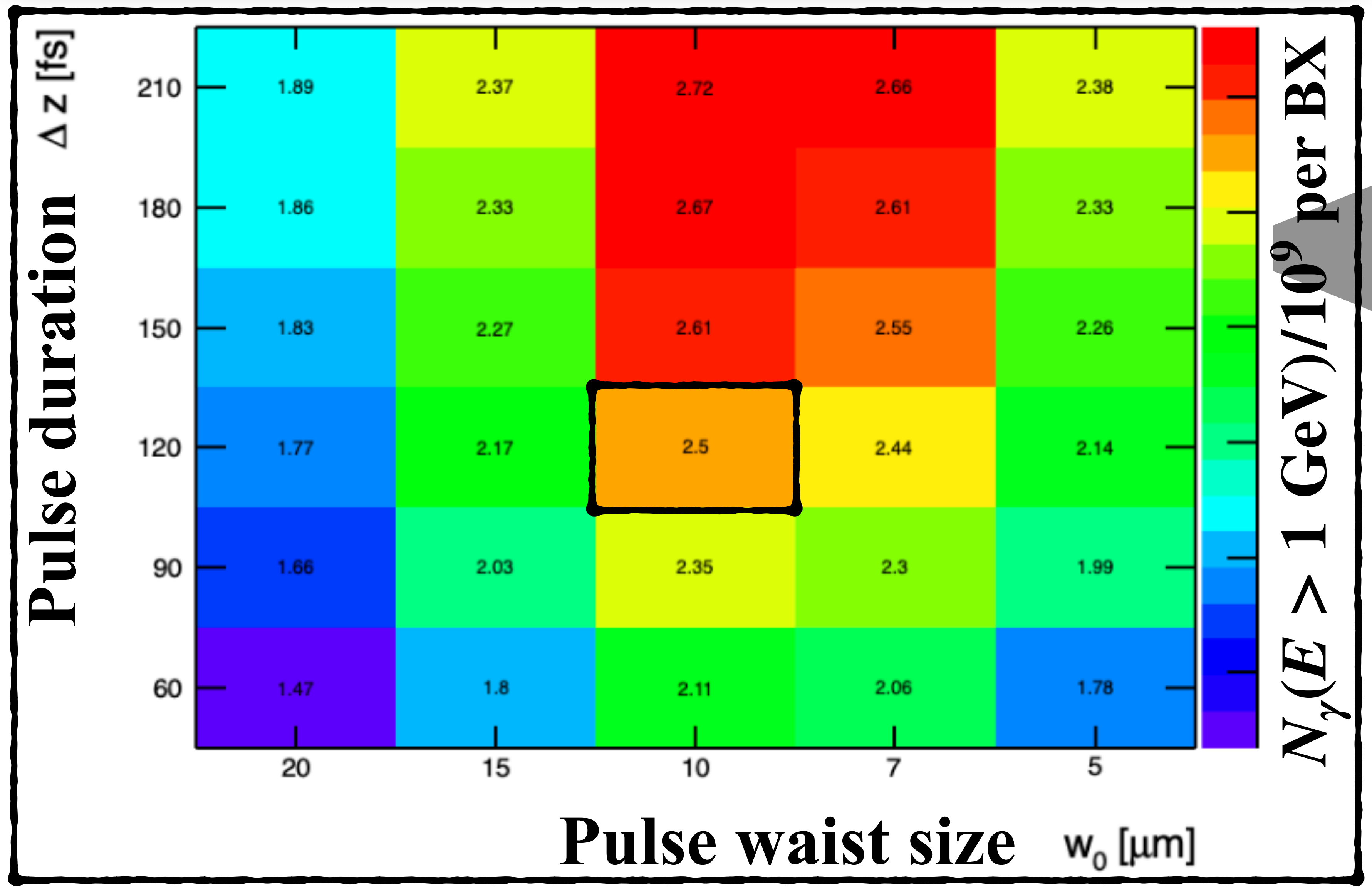
- If we shoot the *e*-beam on the dump
  - about 2 more photons than in phase-1
  - bkg is also higher by
  - completely different analysis scenario



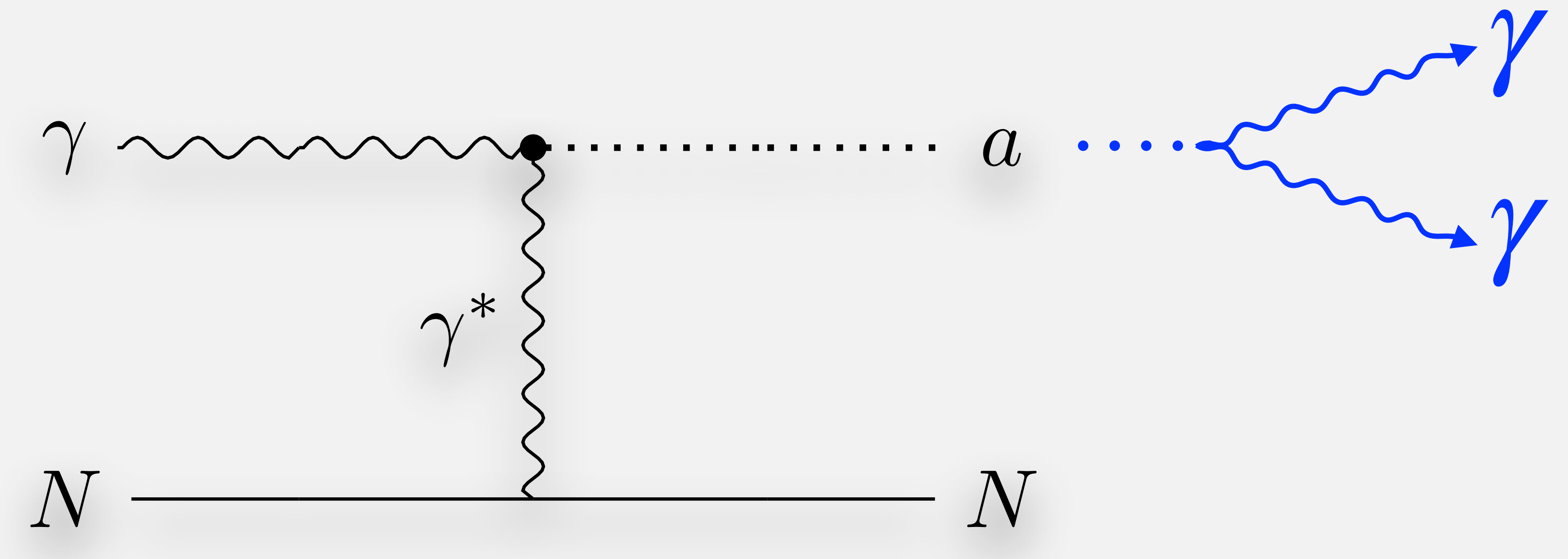
New Physics @ Optical Dump







~1.7 photons above 1 GeV per primary electron for 120 fs and 10 μm pulse

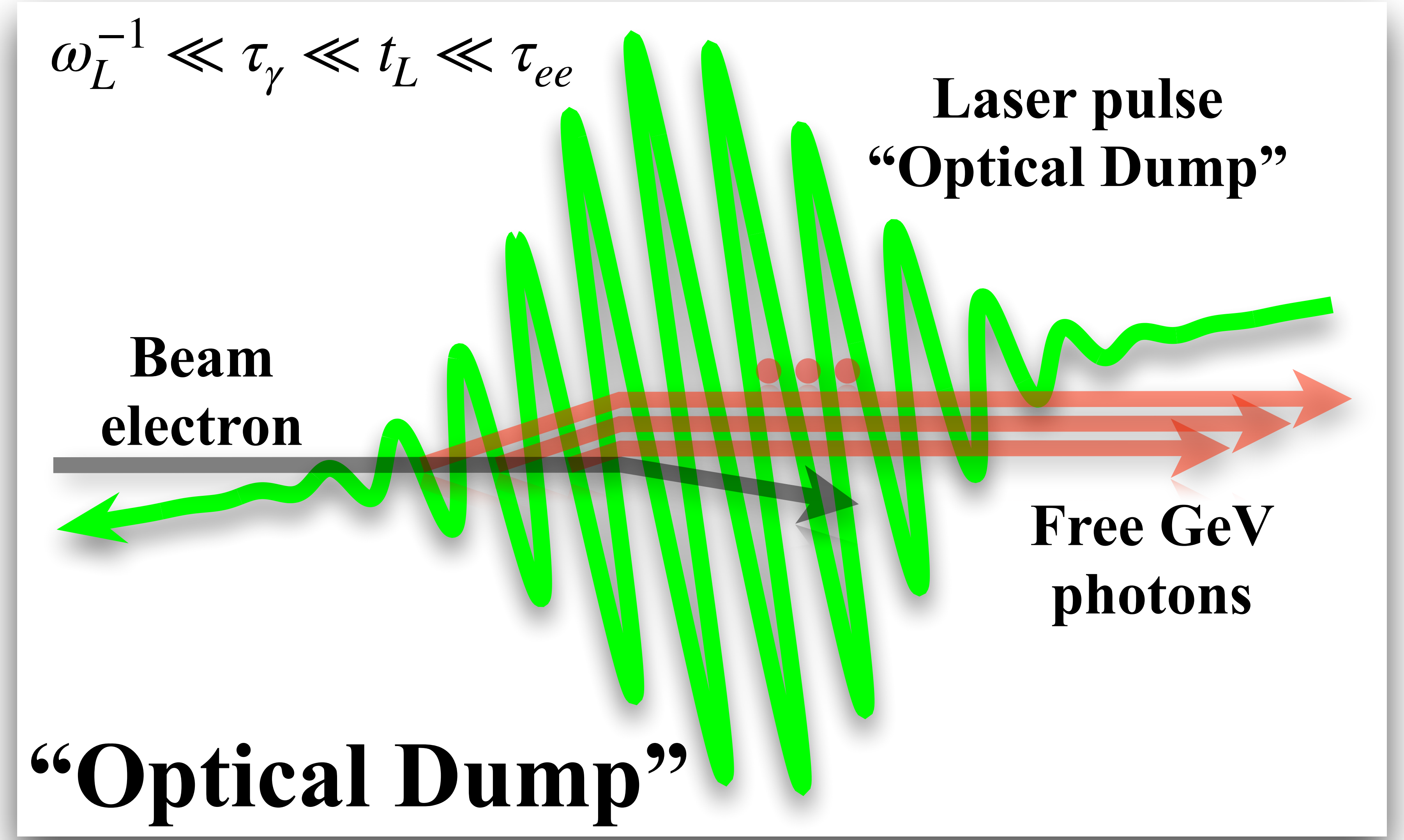


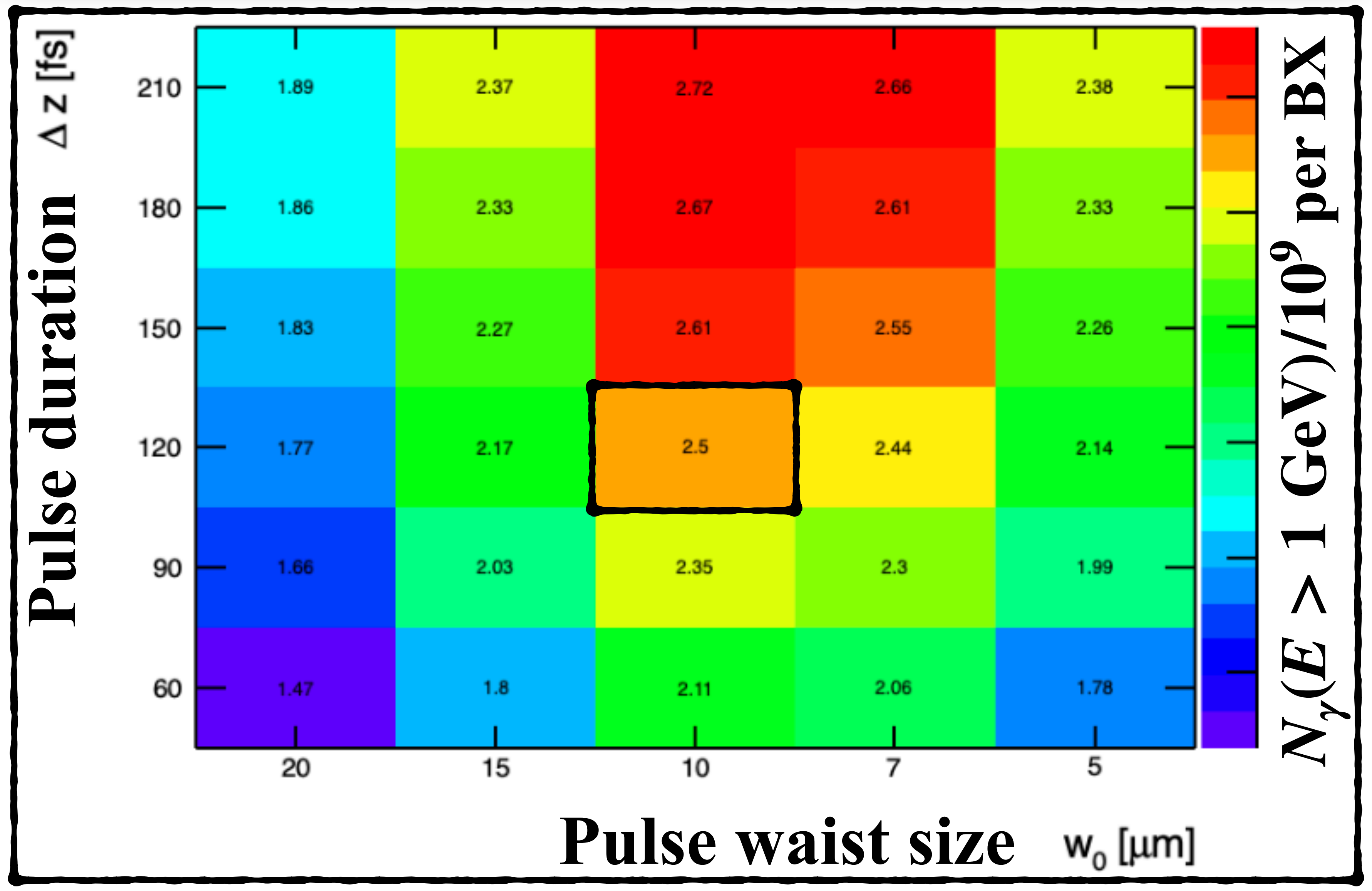
ignore today

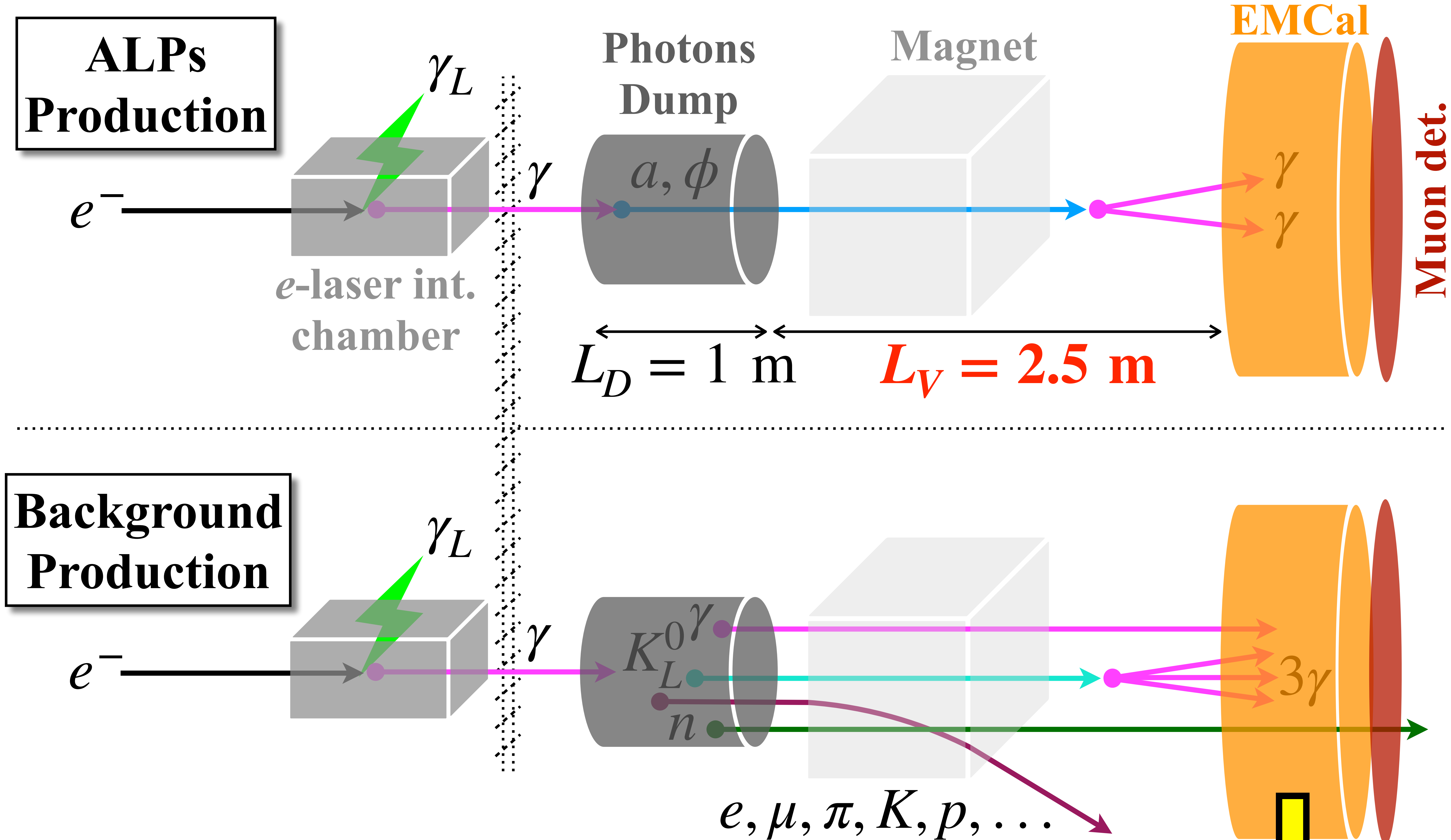
$$\mathscr{L}_a = \frac{a}{4\Lambda_a} F_{\mu\nu}\tilde{F}^{\mu\nu} + i g_{ae} a \bar{e}\gamma^5 e$$

Dump material, N, here is Tungsten (high Z, but could be optimized)

New Physics @ Optical Dump







- $E_\gamma > 0.5$ GeV
- $\sigma_t \sim \mathcal{O}(100\ \mathrm{ps})$
- $\sigma_r \sim \mathcal{O}(100\ \mu\mathrm{m})$
- $\sigma_\theta \sim \mathcal{O}(10\ \mathrm{mrad})$

Can it be bkg-free?

Signal production

$$N_a \approx \underbrace{\mathscr{L}_{\text{eff}}}_{} \int dE_\gamma \underbrace{\frac{dN_\gamma}{dE_\gamma}}_{} \underbrace{\sigma_a(E_\gamma, Z)}_{} \left(\underbrace{e^{-\frac{L_D}{L_a}} - e^{-\frac{L_V + L_D}{L_a}}}_{} \right) \underbrace{\mathscr{A}}_{}$$

$10^{14\text{-}16}$ electrons on target

Incoming photons spectrum from previous slides

Production x-sec

Ensures the decay happens in a volume between L_D and L_V

need to ~minimize L_D and ~maximize L_V

Acceptance times efficiency

$$\mathscr{L}_{\text{eff}} = N_e N_{\text{BX}} \frac{9\rho_W X_0}{7A_W m_0} \qquad L_a = c\tau_a \frac{p_a}{m_a} \qquad p_a = \sqrt{E_\gamma^2 - m_a^2}$$

Background and Projections

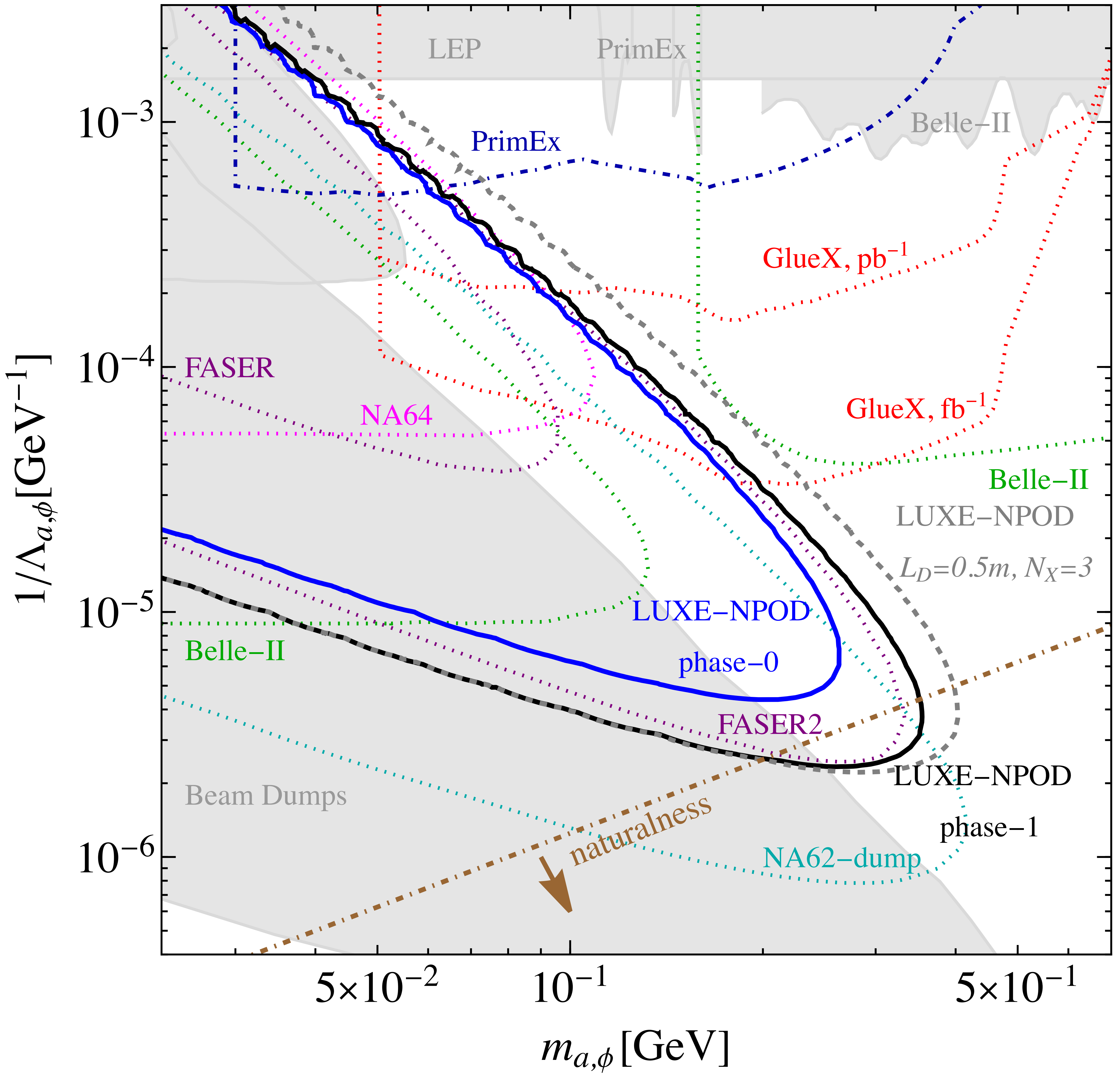
- **Benchmark assumptions**
  - one year of phase-1 running with $T_{op} \sim 10^7$ BXs
  - rejection (kinematics, timing,…): $R_{sel} \lesssim 10^{-3} - 10^{-4}$
  - neutron-to-photon fake rate: $f_{n\to\gamma} \lesssim 10^{-3} - 10^{-4}$

- **Number of bkg 2γ events is $N_{bkg} = T_{op}R_{sel}P_{bkg}$**
  - Backgrounds: 2γ, $2n \to 2\gamma$ and $\gamma + n \to 2\gamma$
  - Probabilities given by Poisson and Binomial laws

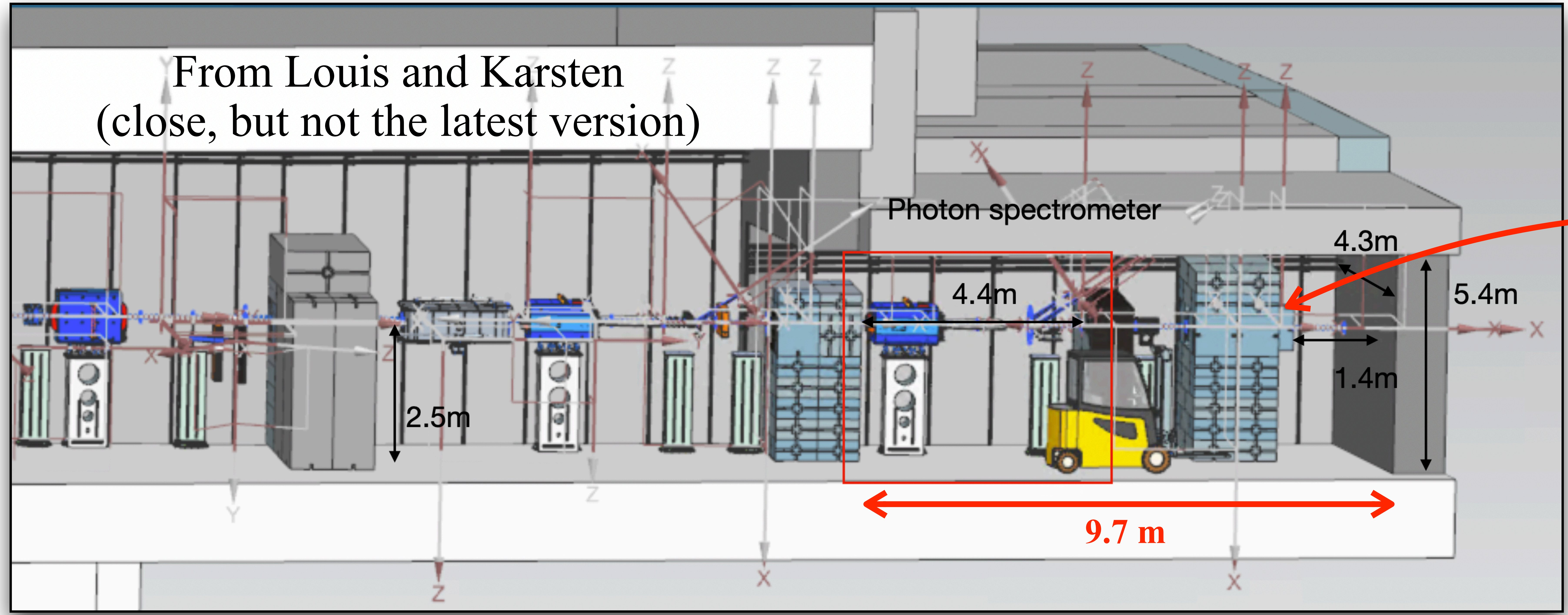
- Phase-1 expected background under these assumptions is 0.4+0.1+0.3 respectively, i.e. effectively bkg-free.
  - this depends strongly on the detector technology
  - phase-0 background will be much lower so the detector requirements on R_{sel} and on $f_{n\to\gamma}$ can be relaxed by an order of magnitude at least, while still staying bkg-free

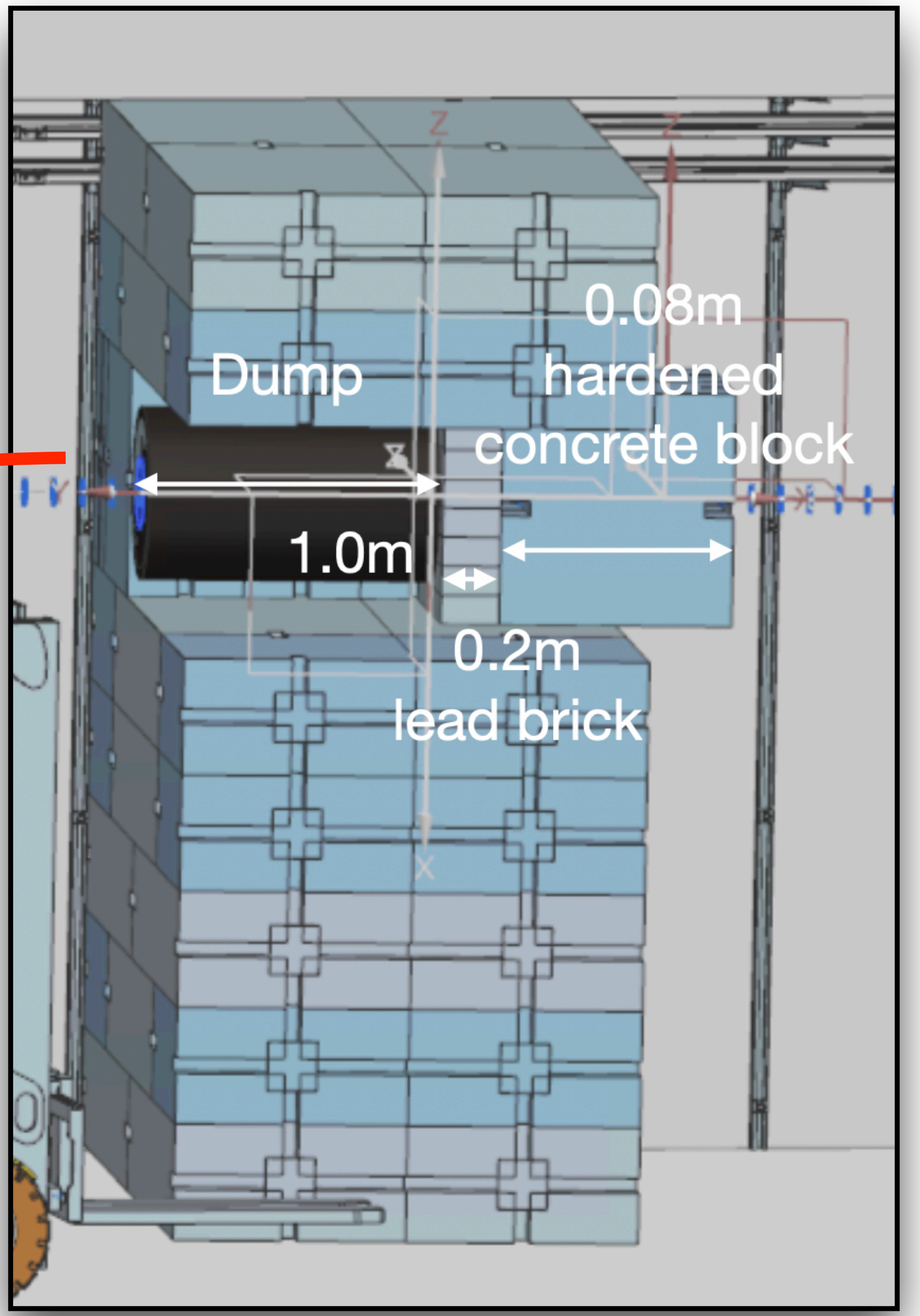
- Parameters that matter are L_D, L_V, r_{det}, R_{sel} and $f_{n\to\gamma}$, T_{op} and the dump material

Setting the number of observed signal-like events to $N_a = 3$, which is the 95 % CL equivalent for background free search



Problems…





- Space between back wall and dump (currently ranging 0.6-1.4 m), but this is not final:
  - IP chamber will move downstream, quadrupoles may move upstream, vacuum elements to be inserted,…
  - whatever change in the model, we probably cannot buy more than ~1-0.5 m
- Dump design (material, length, diameter)
  - Radio-protection: it needs to be enclosed
  - Phase-0 dump can be much smaller, but we don't want to have 2 dumps (way too complicated)

How to proceed

- Exploiting the phase-0 run:
  - study with MadGraph the signal behavior in several new geometries to see (1) how to optimize things, and (2) what physics can be squeezed - **easy**
  - proper re-estimation of the background in every modified scenario - **very difficult**
  - some detector needs to be installed in the 2025 shutdown
    - can probably find a realistic scenario that will allow us to put at least a prototype (a la CALICE/HGCal or the old SpaCal) and gain some invaluable insight for phase-1
    - no space for magnet probably

- **Proposal** for special setup for the NPOD run in phase-1 (see sketches in the next 2 slides):
  - **only** towards the end of phase-1, after the edges measurements are done:
    - "give up" the fwd spectrometer
    - "swap" between the fwd dipole and the photons dump
  - still need photons measurement, so profiler stays (potentially also backscattering calo)
  - need to design elements to be "as movable as possible" (possible to place elements on air cushions)
  - need to find **now** the minimal dump that works for phase-0 and is good enough for phase-1 in terms of radio-protection (easy) and background stopping (difficult)

Proposal for special NPOD run in phase-1

Proposal for special NPOD run in phase-1

Proposal for special NPOD run in phase-1

Questions

- Can we give up the spectrometer for these runs?
  - if not, how much can we compactify it actually in terms of length (along the beam-line)?
  - need to answer the question whether or not the measurement of the Compton e’s (by the IP screen and Cherenkov systems) would give us sufficient confidence in the photon spectra that goes to the dump
  - recall: we can measure the spectrum also in the spectrometer with the same run parameters just before doing the shuffling of the setup, but of course, it won’t be an in-situ measurement after we shuffle.
  - in case the spectrometer stays, there is a need to have another dipole magnet after the photon dump.

- Can the profiler station be swapped with the conversion target station after the IP?
  - option B: the concern is the backscattered flux from the IP dump (inc. the high rate Compton e’s)
  - option A: move the profiler and its back-shielding wall together.

- Do we need more shielding somewhere behind the photon dump from the radio-protection point of view?
  - Kyle et al are checking now the radiation levels and fluxes with the worst case scenario
  - this will also be useful for the radiation considerations for the profiler electronics etc.