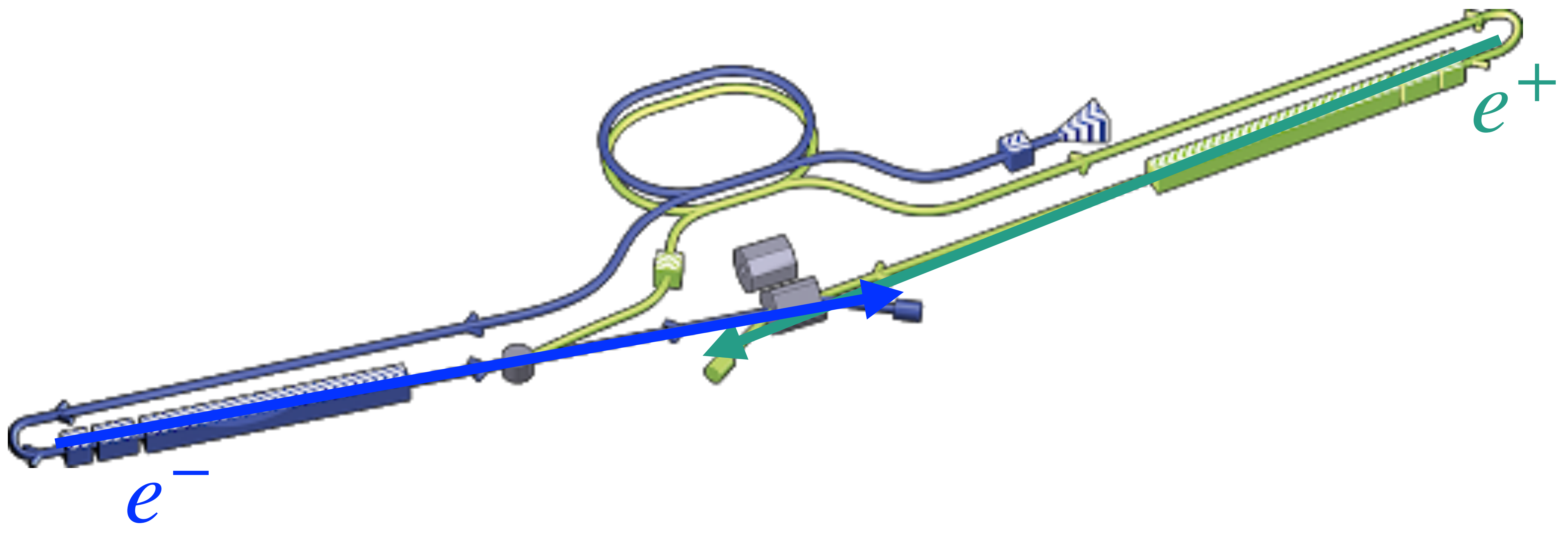
Informal update on ILC-BDX

Daiki Ueda (Peking University) 2021/09/13

Introduction

Proposed fixed-target experiments using main beam dump



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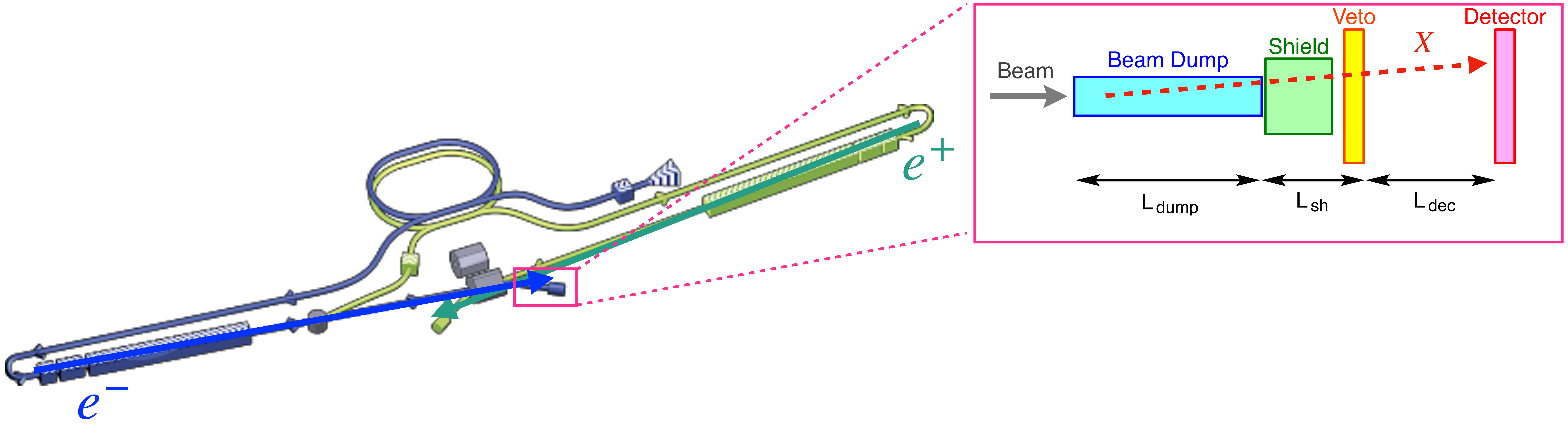
[S. Kanemura, T. Moroi, T. Tanabe. arXiv:1507.02809]



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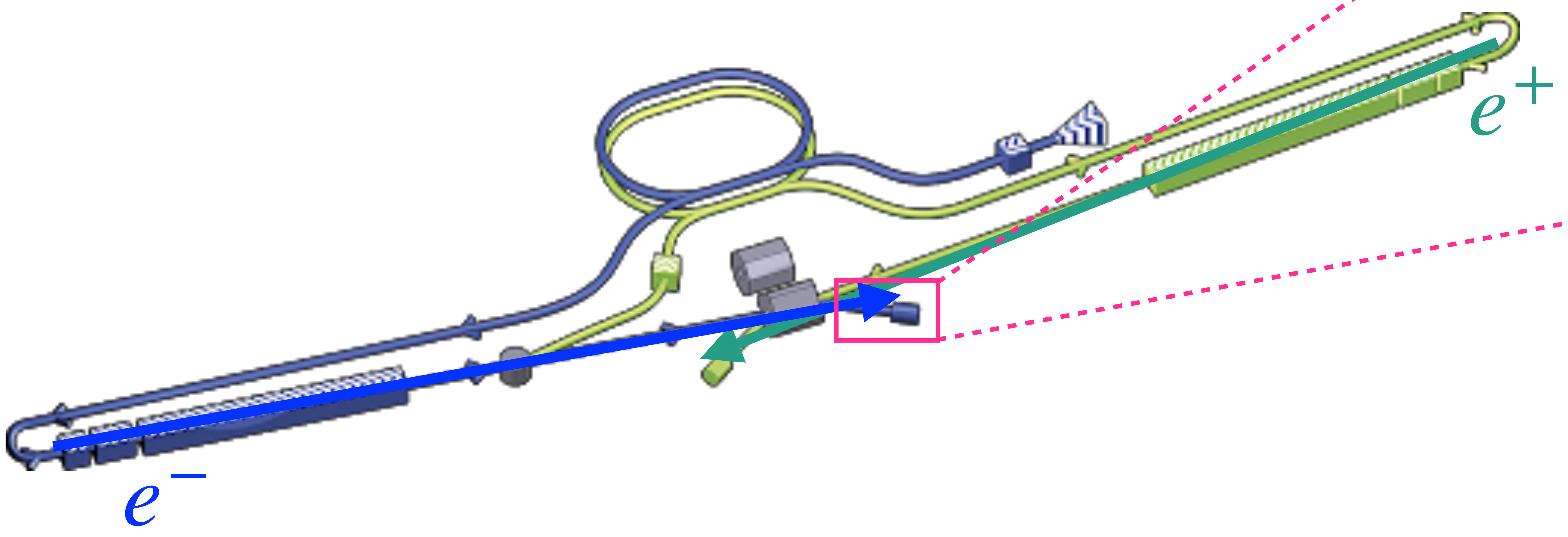

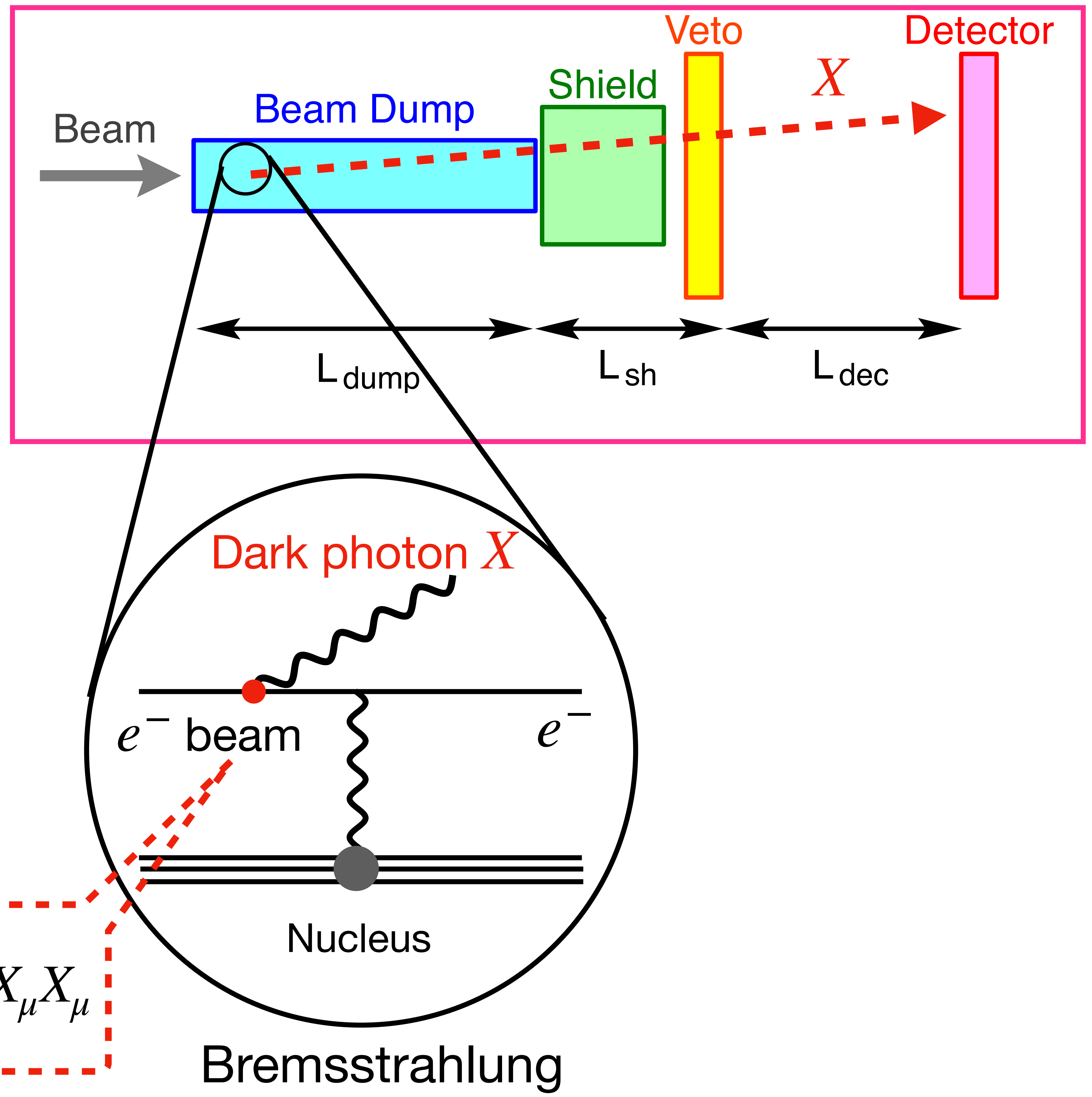

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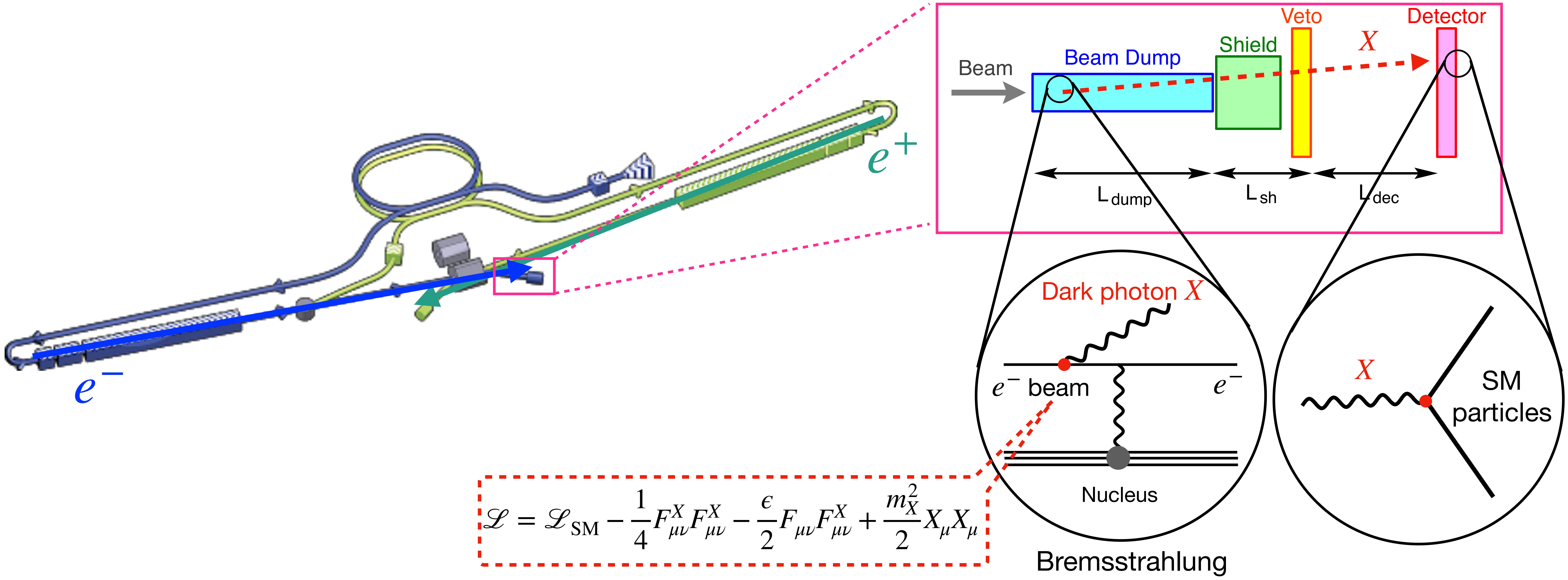

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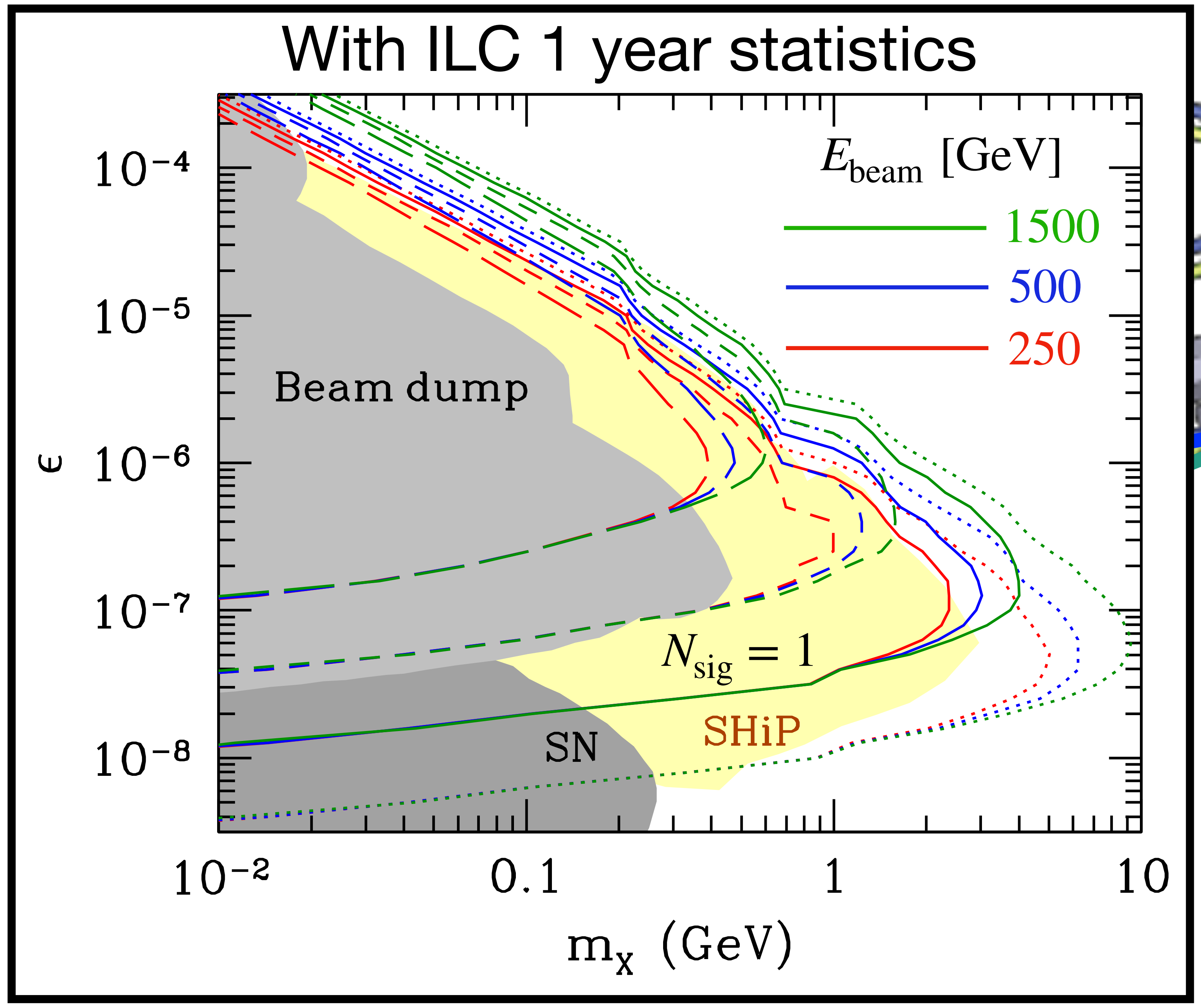
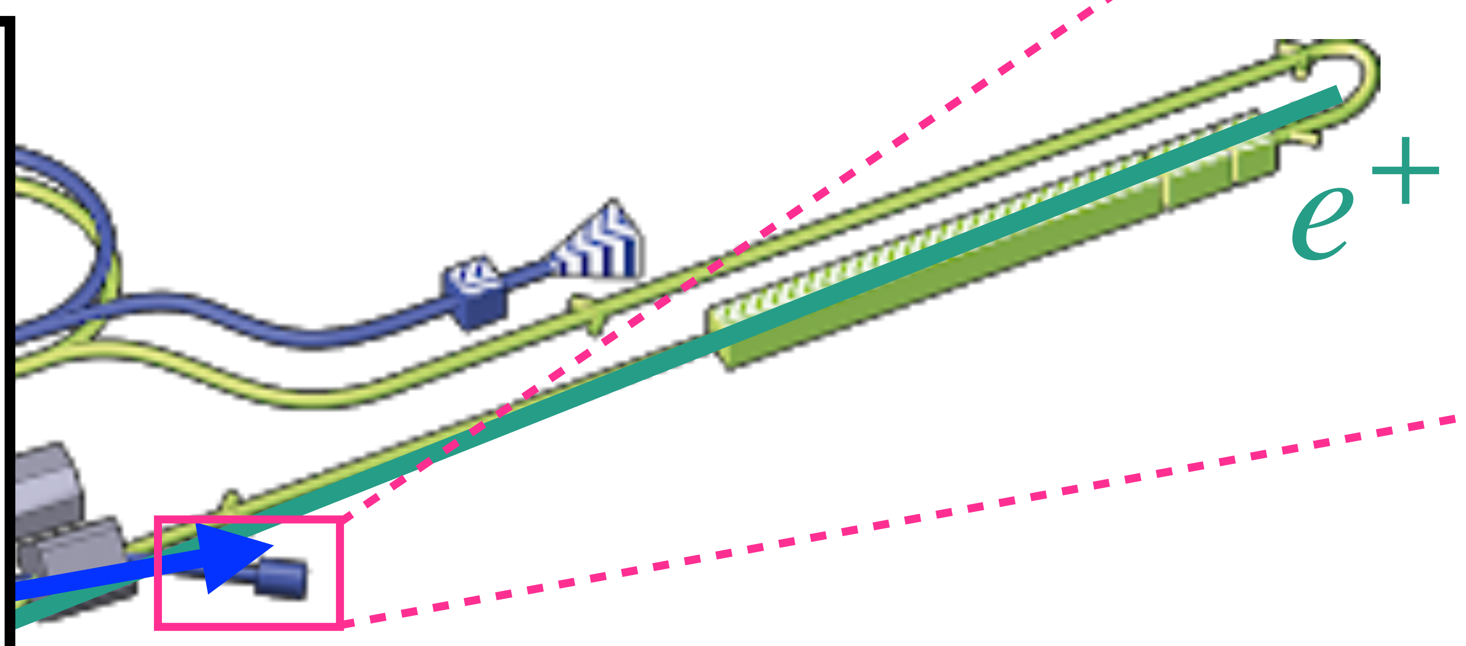
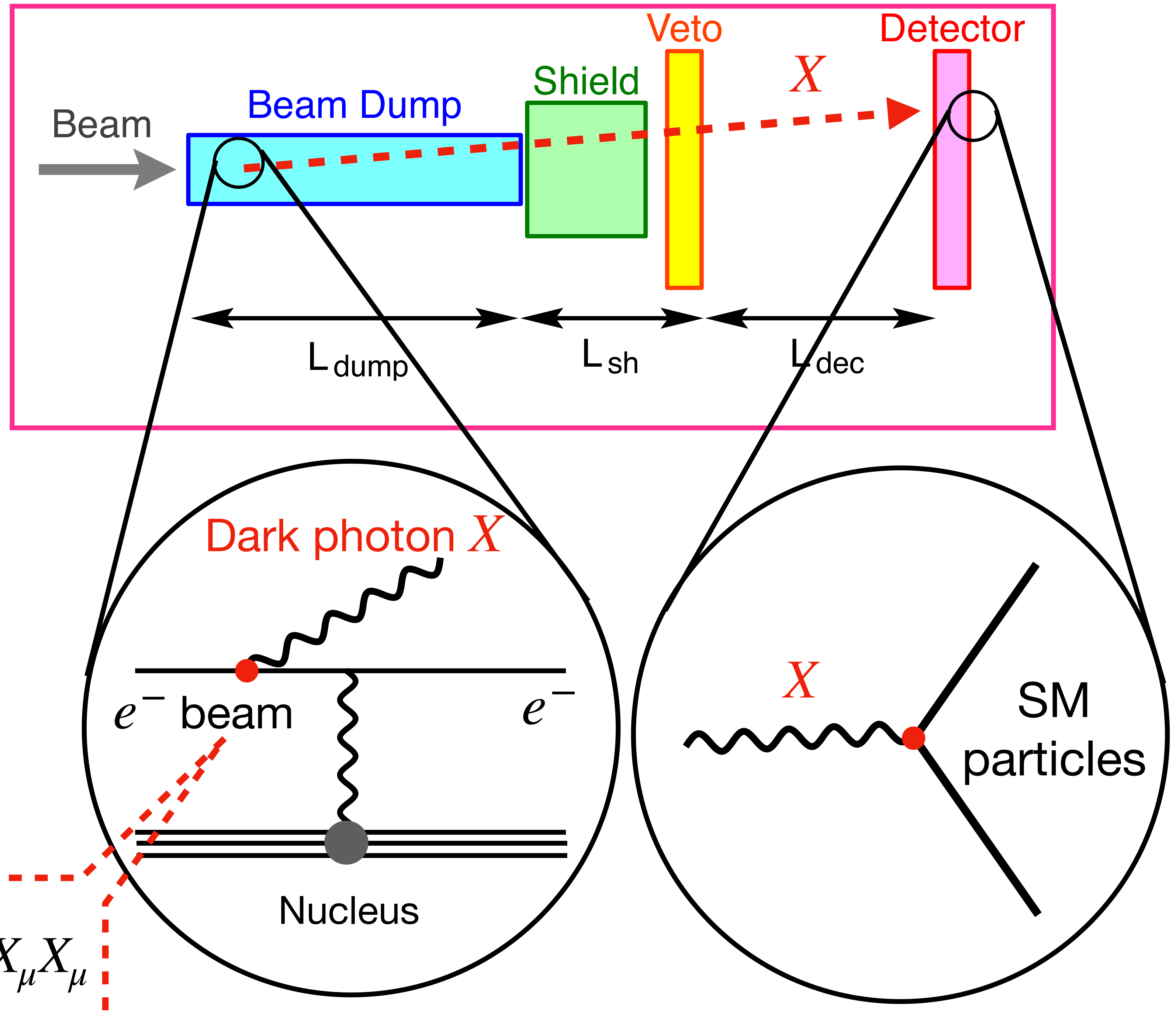






Bremsstrahlung

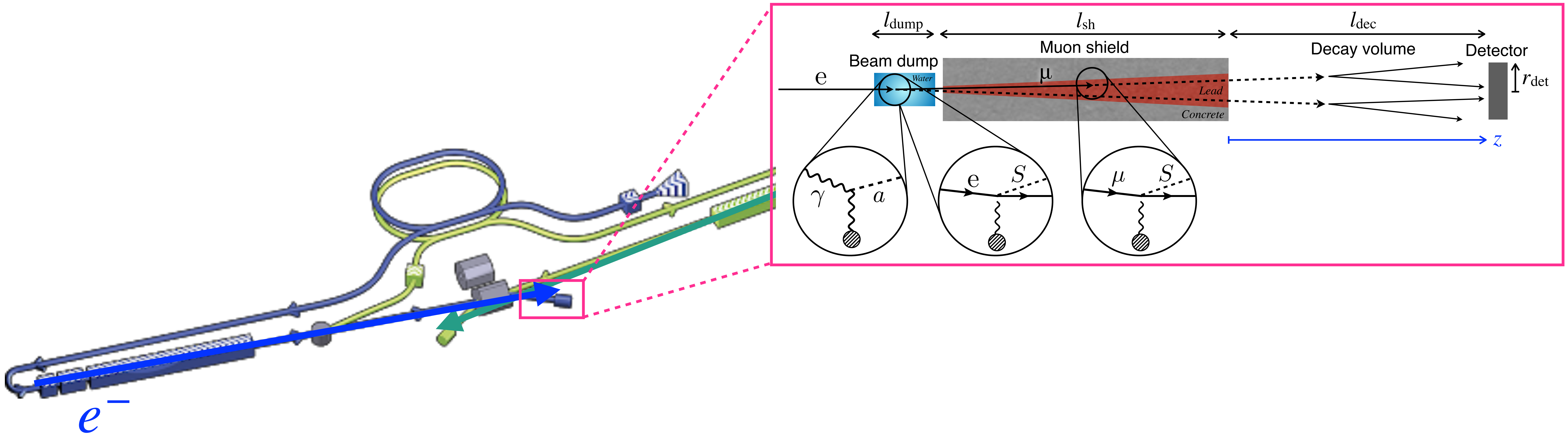
$$\mathscr{L} = \mathscr{L}_{\text{SM}} - \frac{1}{4}F^X_{\mu\nu}F^X_{\mu\nu} - \frac{\epsilon}{2}F_{\mu\nu}F^X_{\mu\nu} + \frac{m_X^2}{2}X_\mu X_\mu$$

ILC beam dump experiment has higher sensitivity than past beam dump experiments

Introduction

Proposed fixed-target experiments using main beam dump

[Y. Sakaki, DU. arXiv:2009.13790]



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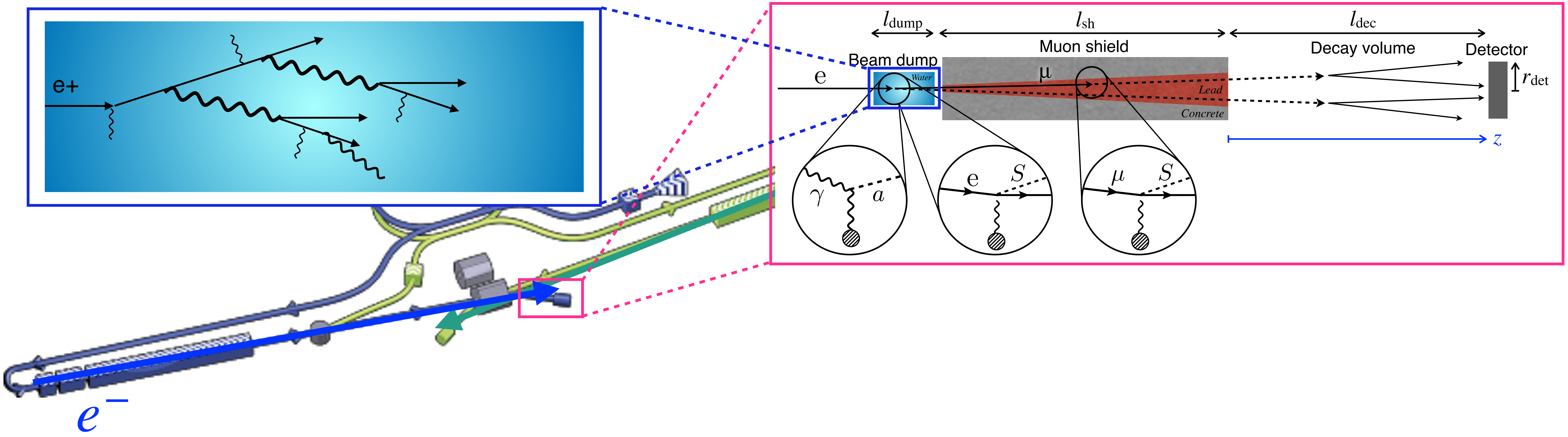
Proposed fixed-target experiments using main beam dump

Many photons, electrons, and positrons are produced

[Y. Sakaki, DU. arXiv:2009.13790]



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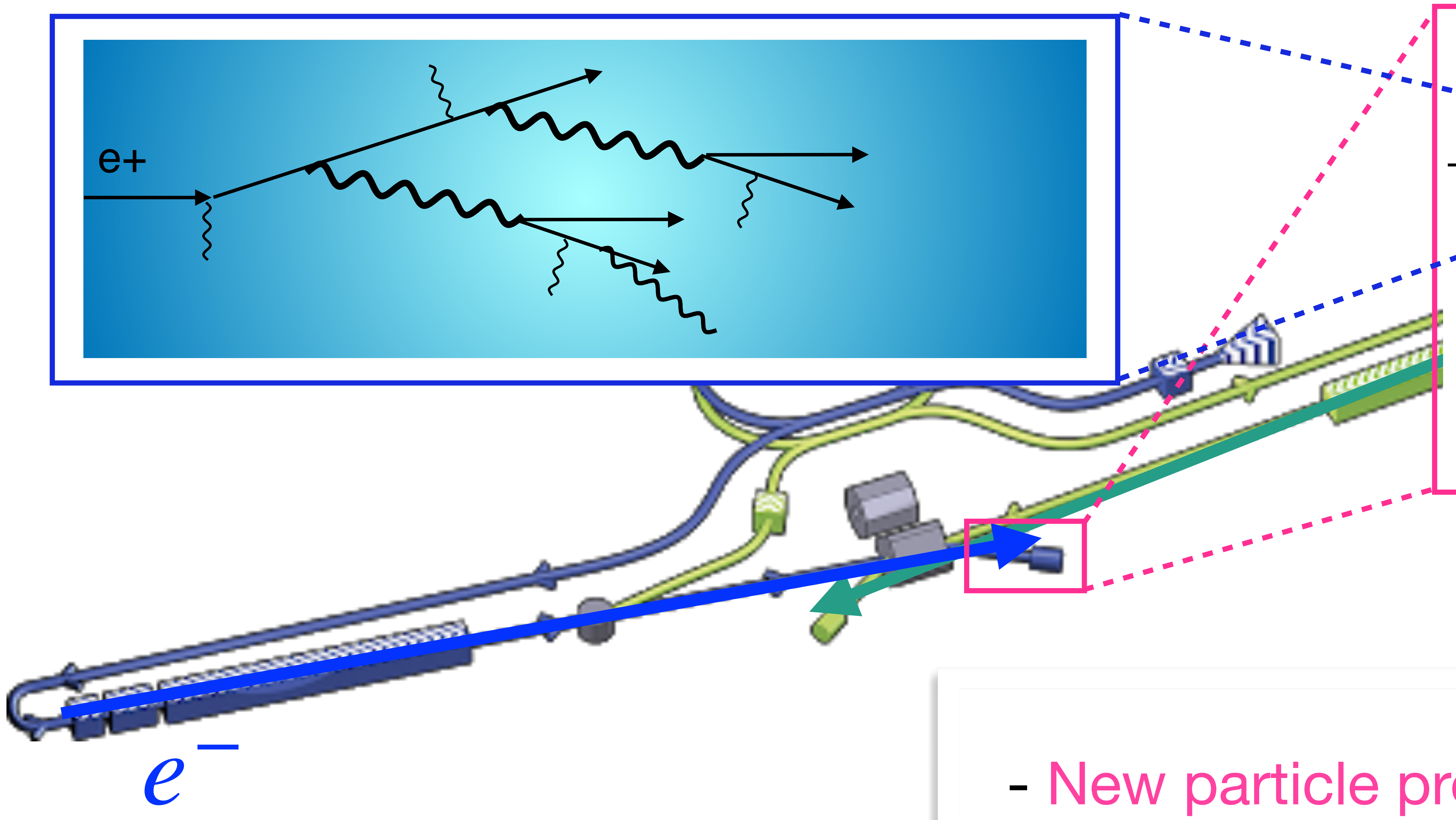

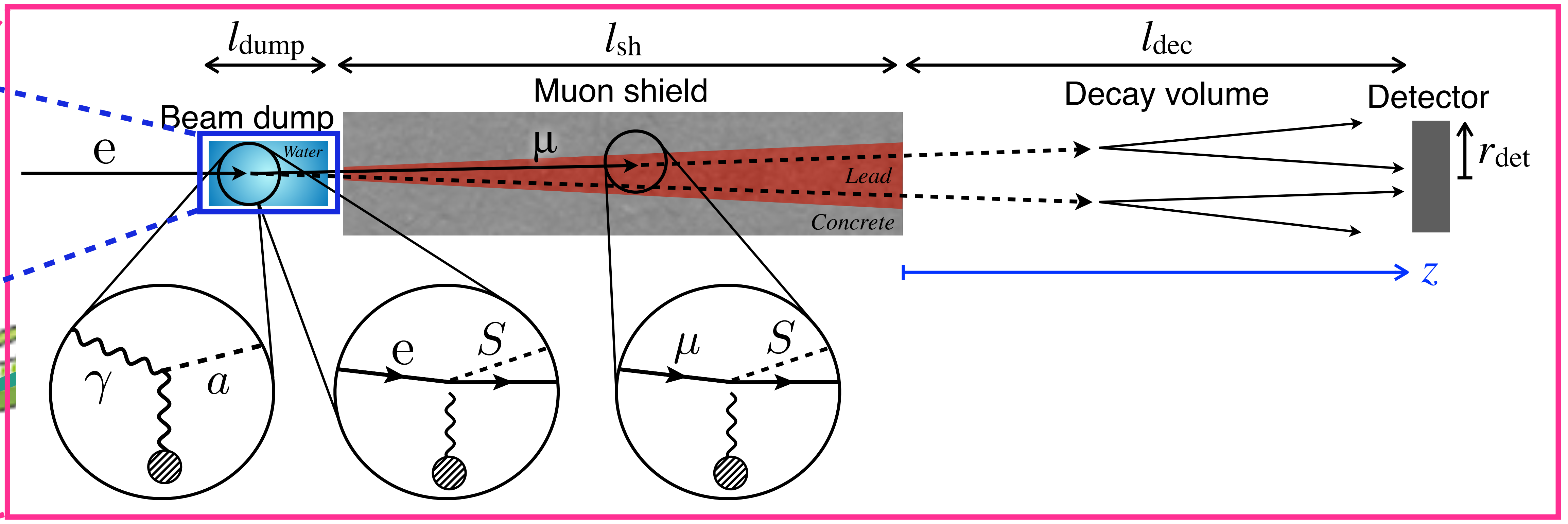

- New particle production by secondary particles such as photon and muon

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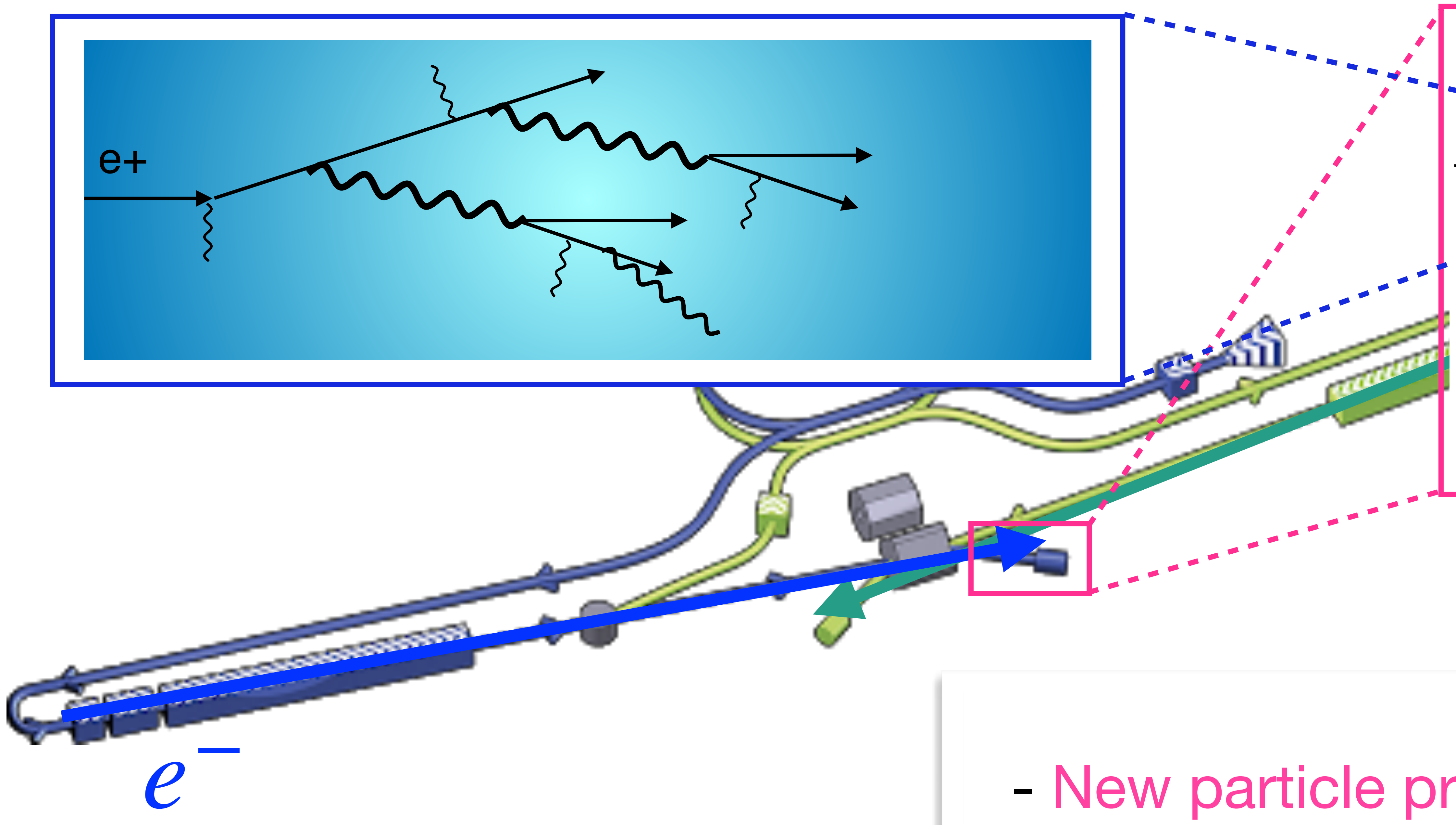

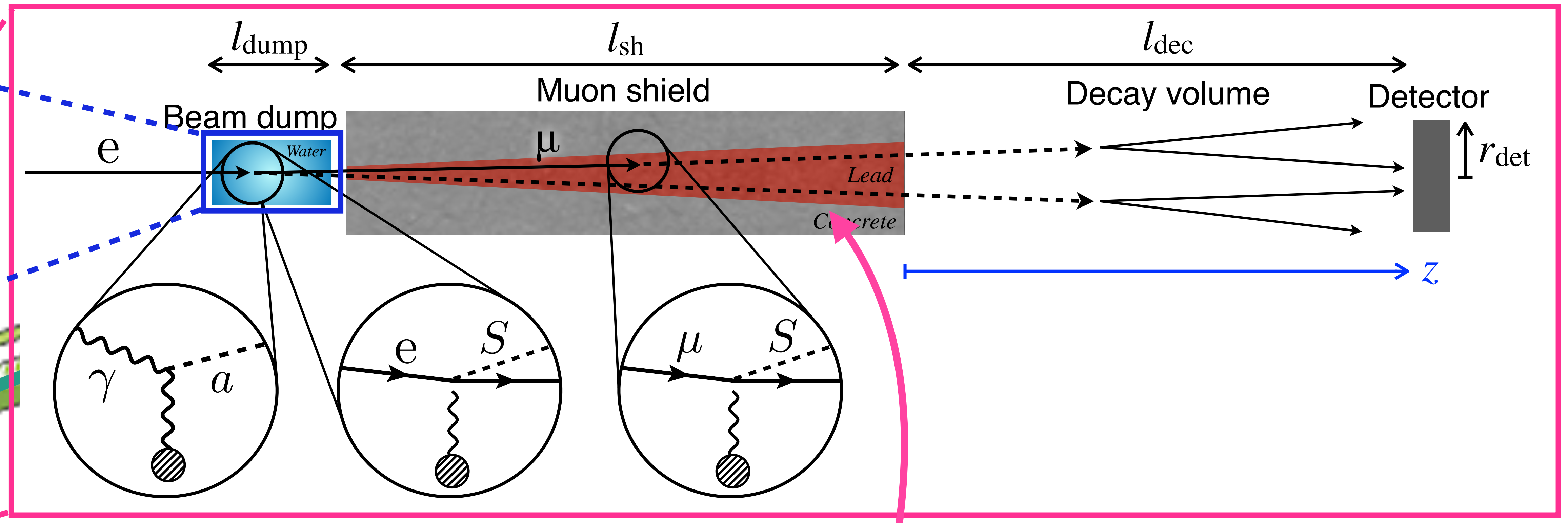

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- Installing cheap muon shield was proposed ⇒ zero background

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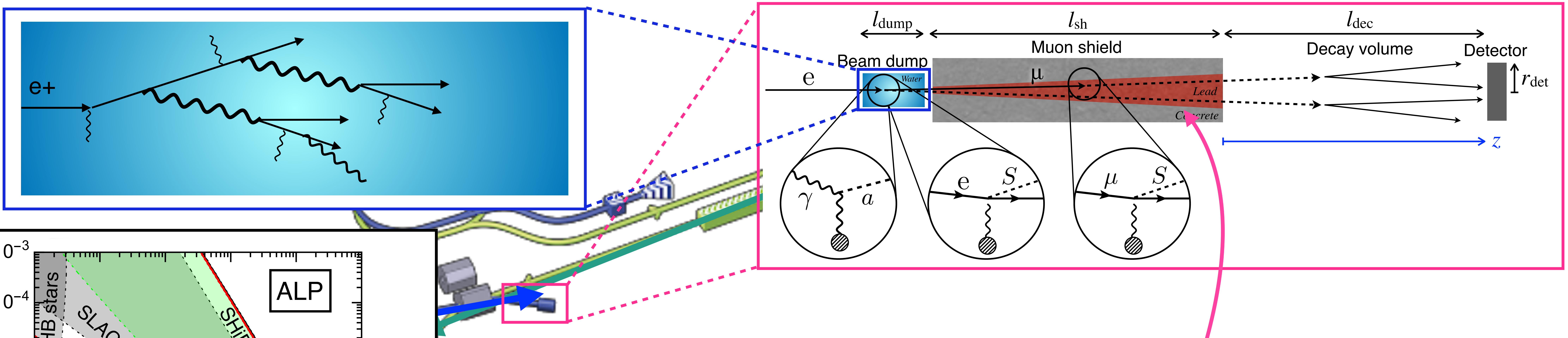

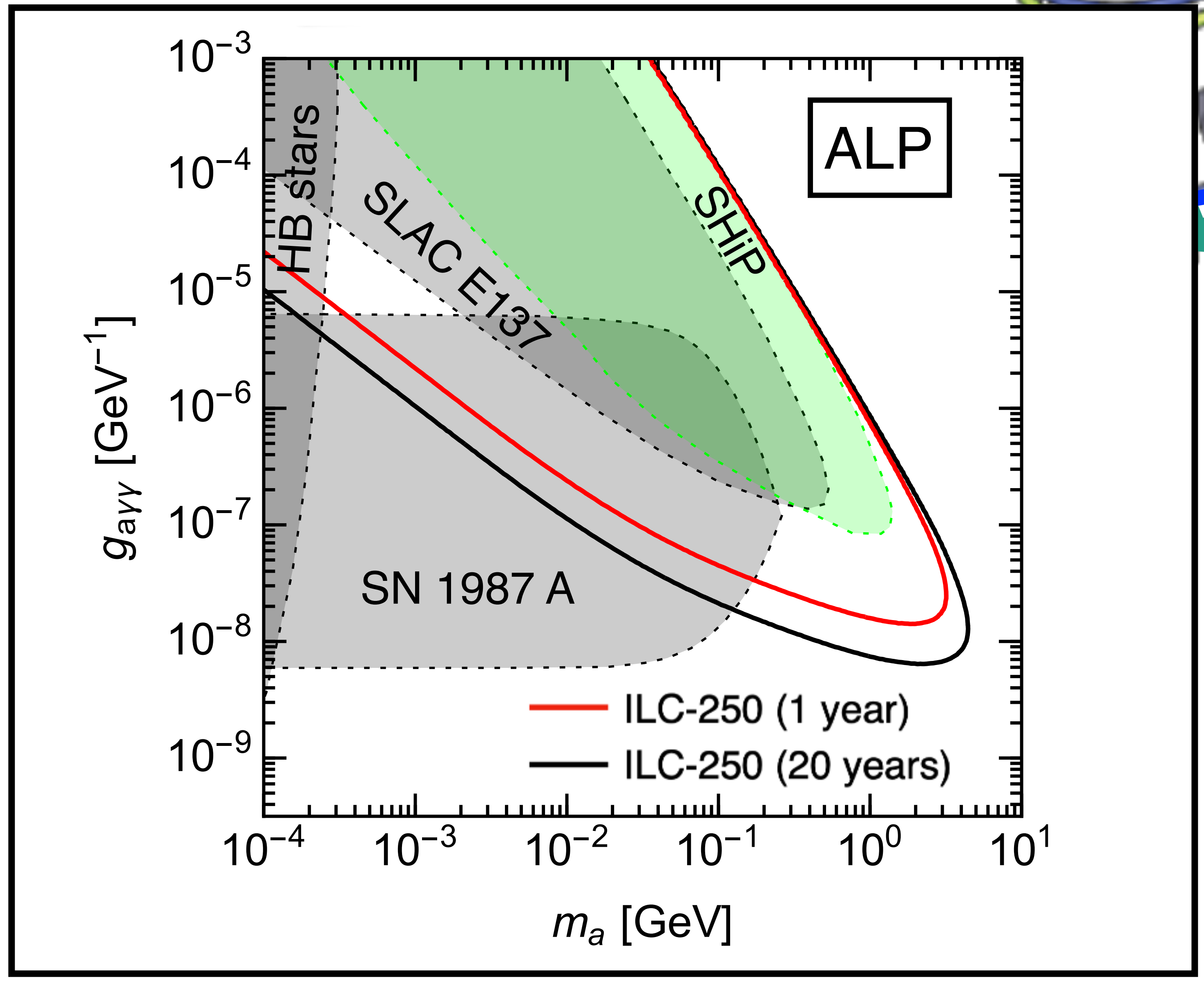

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Contributions of secondary particles are significant

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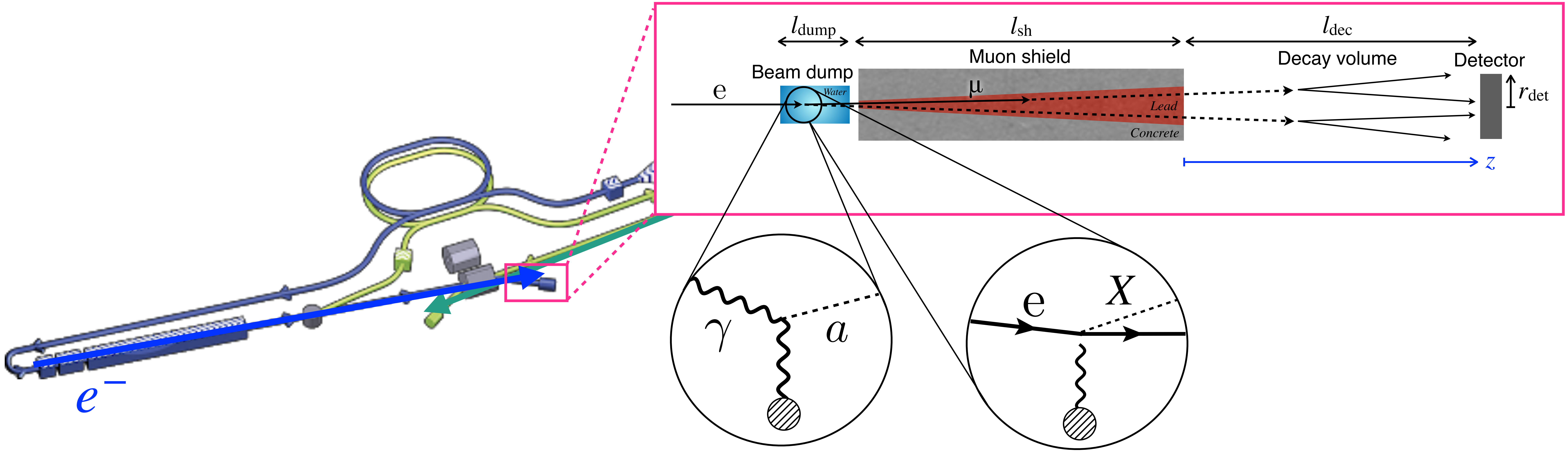

Primakoff process
by photons

Bremsstrahlung process
by electrons and positrons

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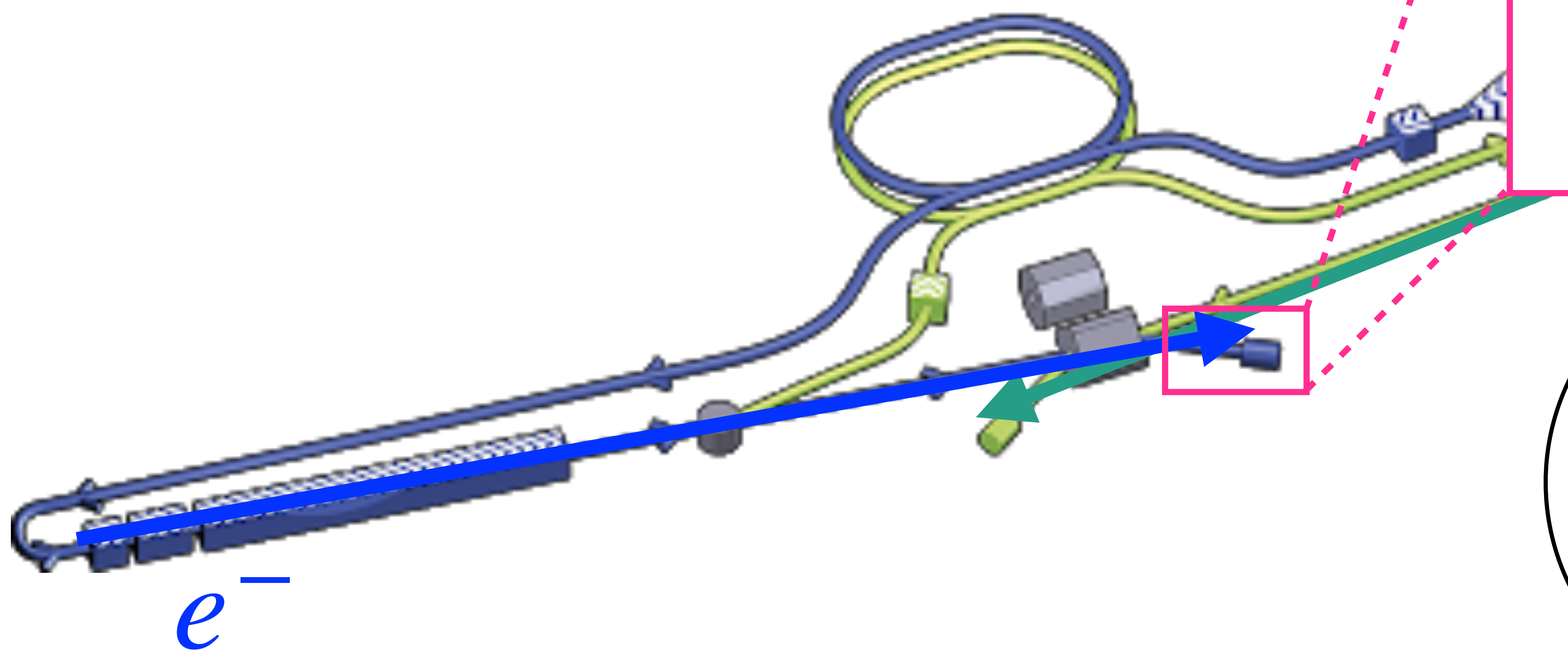

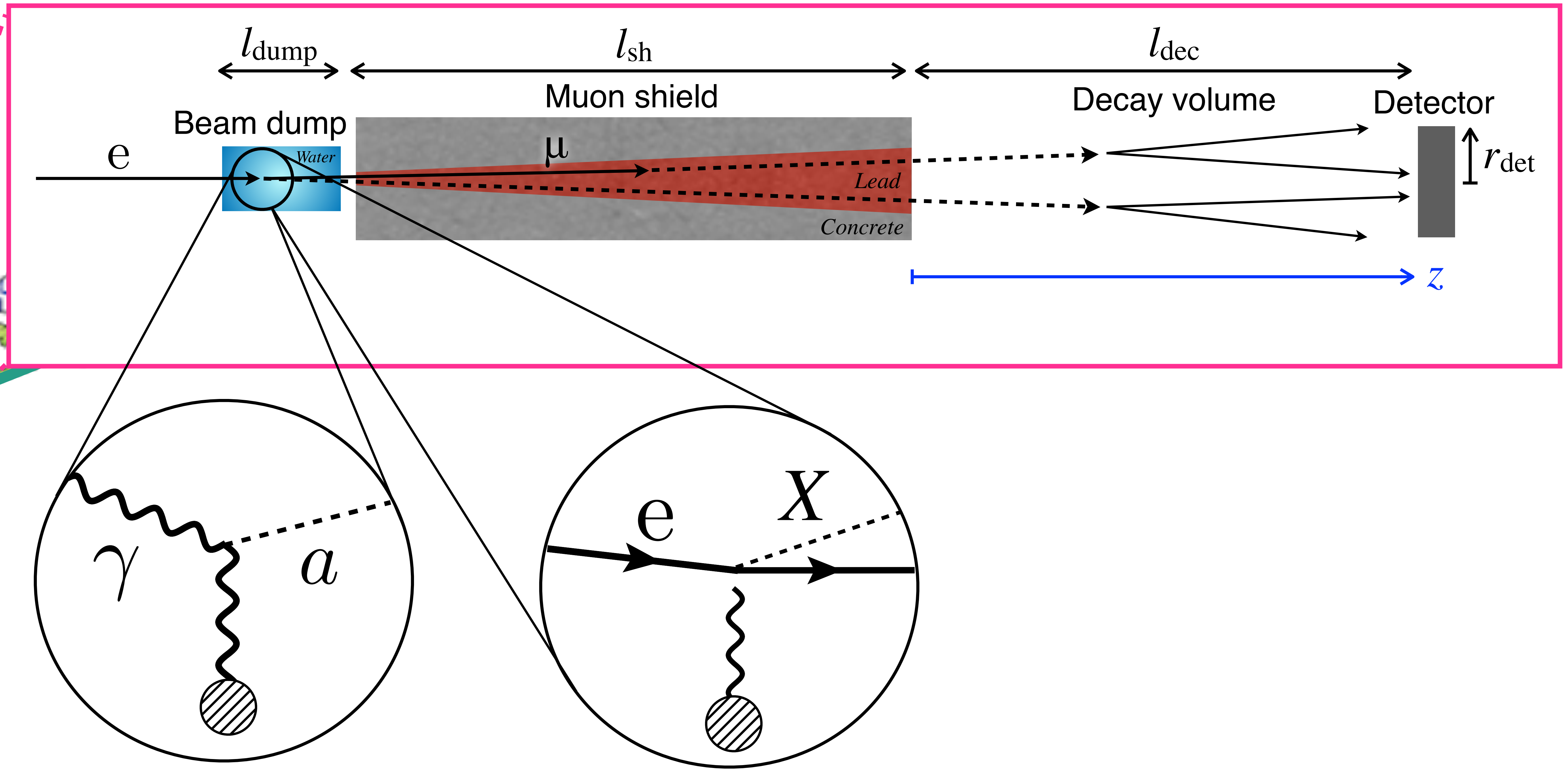

Primakoff process
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Secondary photons are generated in both electron and positron beam dumps

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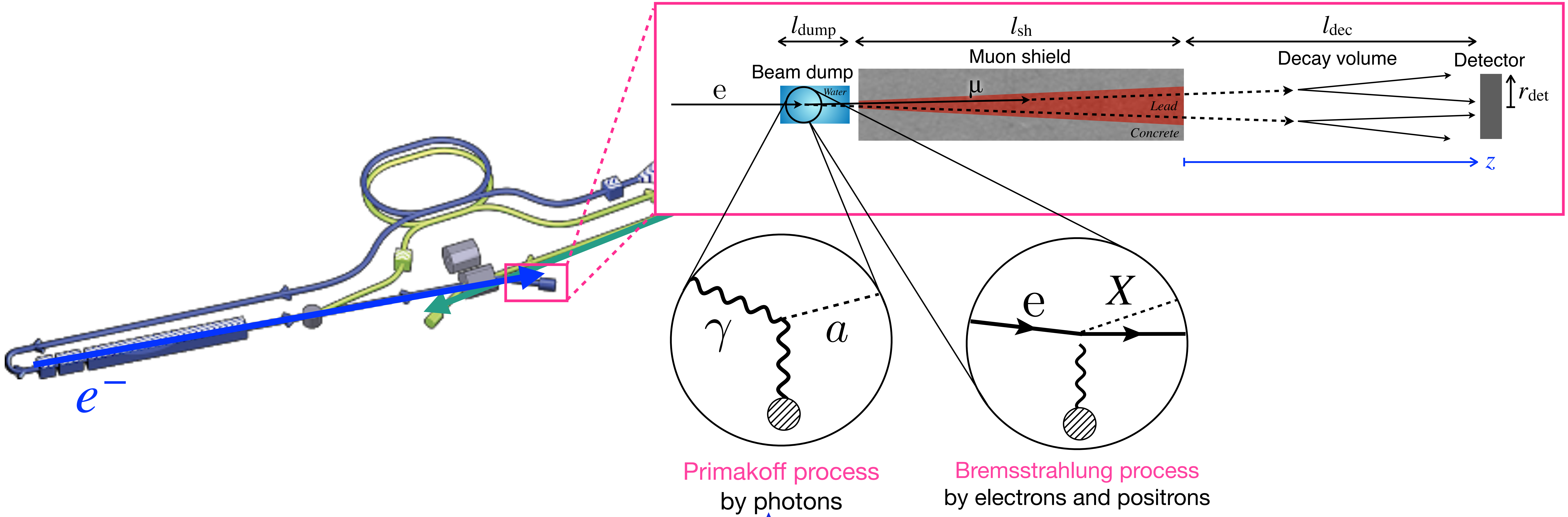

Secondary photons are generated in both electron and positron beam dumps

Bremsstrahlung process occurs in both electron and positron beam dumps

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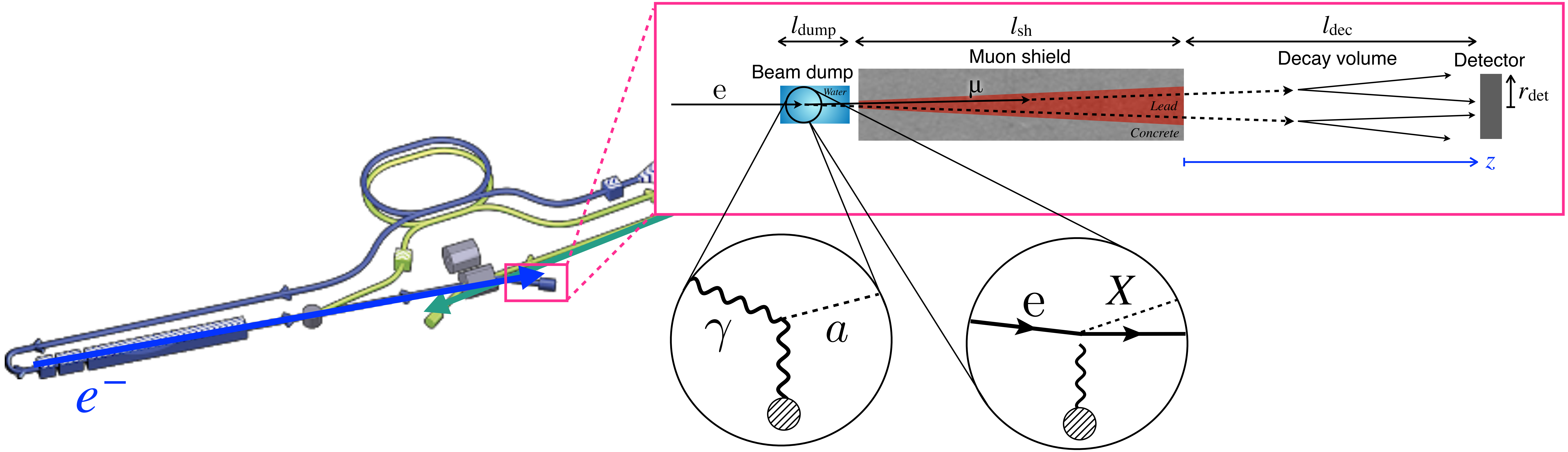

Primakoff process
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Bremsstrahlung process
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Secondary photons are generated in both electron and positron beam dumps

Bremsstrahlung process occurs in both electron and positron beam dumps

These processes occur in the same way for both electron and positron beam dumps

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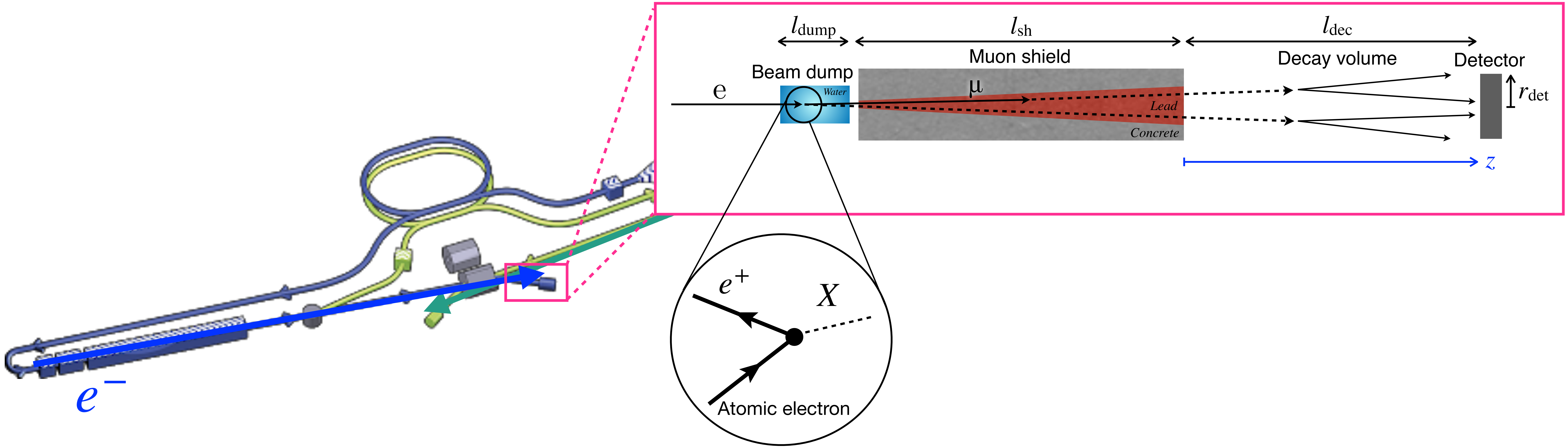

Primary positron beam generates new particles by pair-annihilation, but primary electron beam doesn’t

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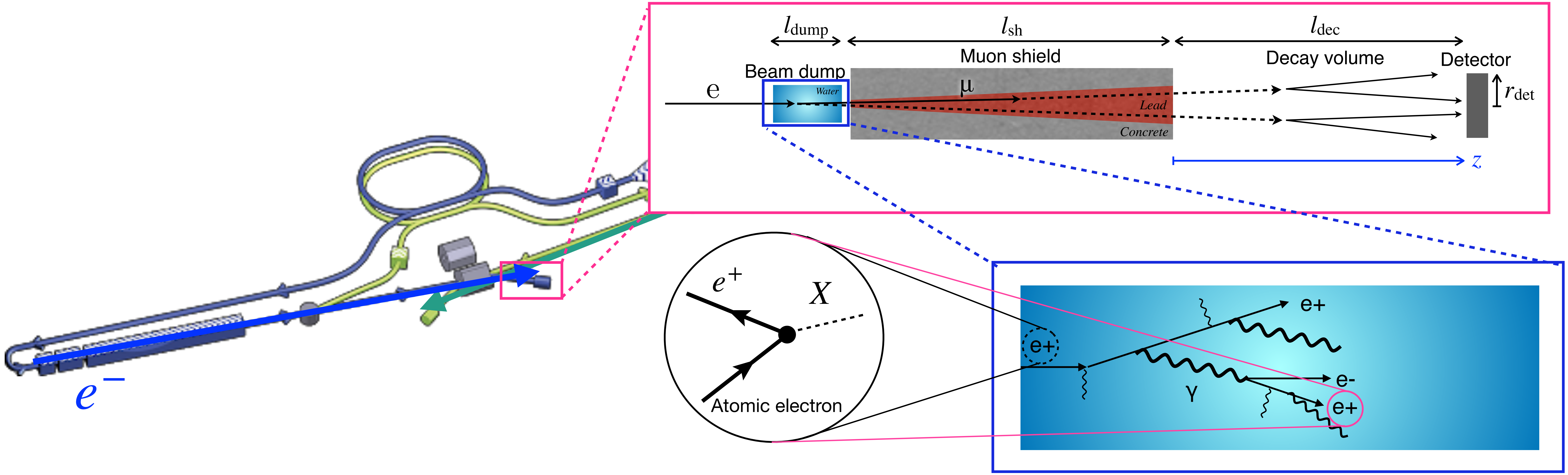

Many positrons are produced in electromagnetic shower, and pair-annihilation process occur even in electron beam dump

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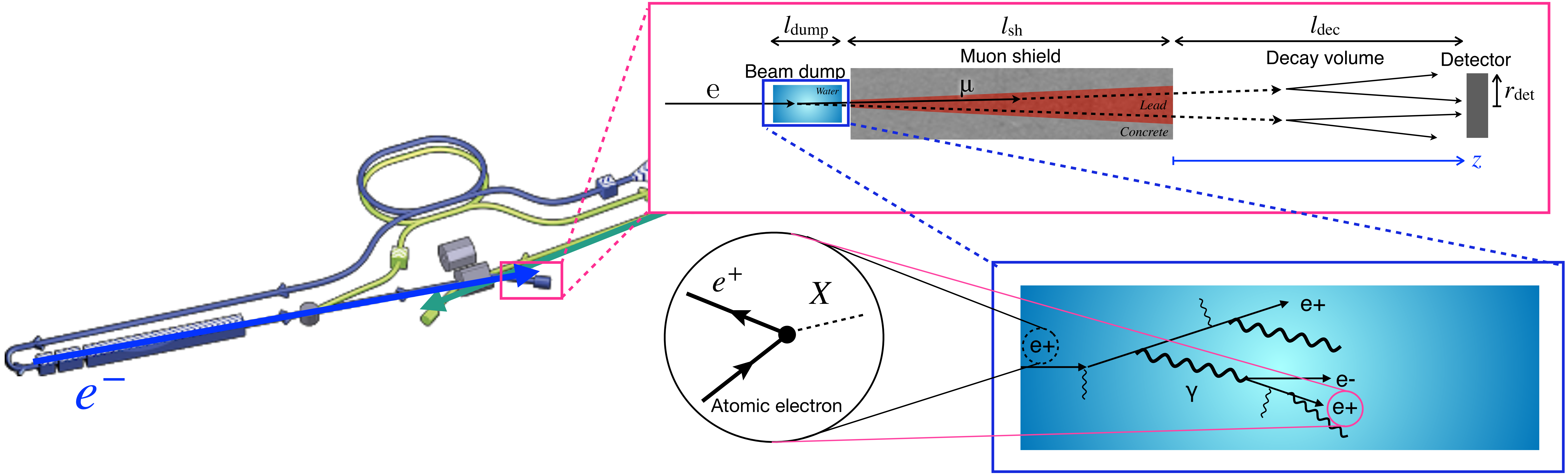

Many positrons are produced in electromagnetic shower, and pair-annihilation process occur even in electron beam dump

How sensitive is positron beam dump experiment to new particles compared to electron beam dump experiment?

Introduction

Sensitivity comparison of positron and electron beam dump experiment

[K. Asai, S. Iwamoto, Y. Sakaki, DU. arXiv:2105.13768]

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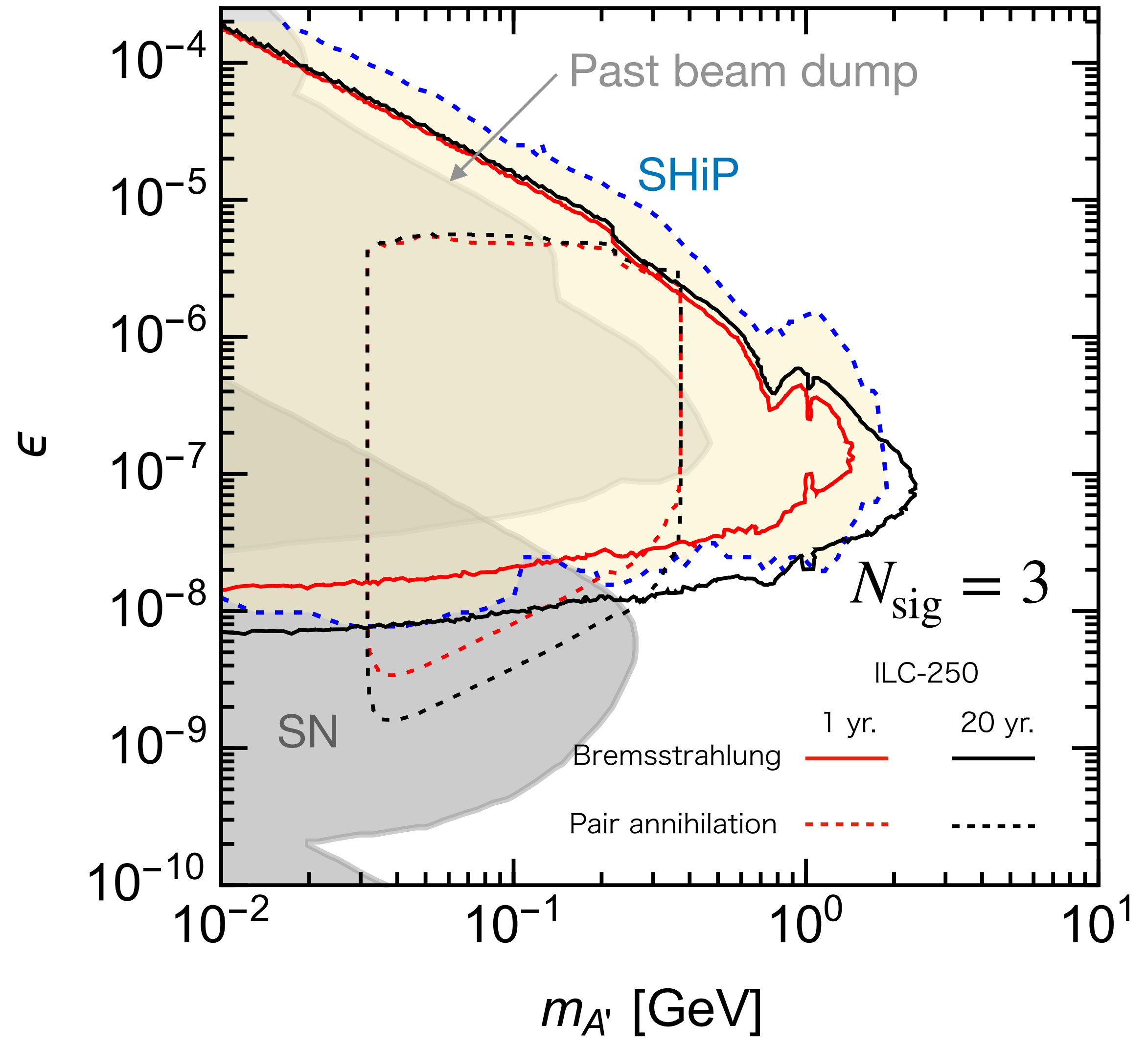
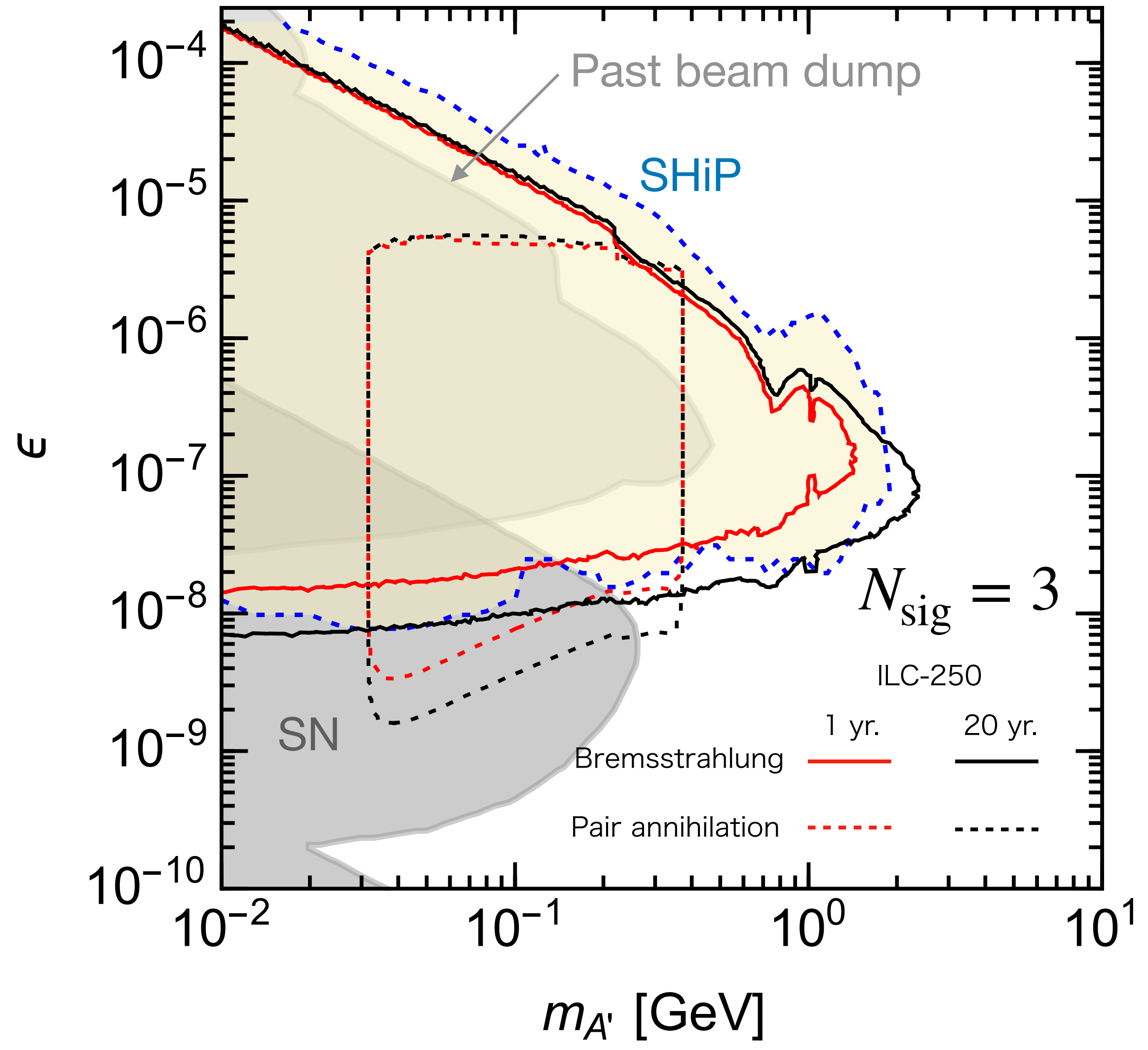


Positron beam dump



Dark photon: $-\frac{1}{4}F^{(A')}_{\mu\nu}F^{(A')\mu\nu} - \frac{\epsilon}{2}F^{(\rm em)}_{\mu\nu}F^{(A')\mu\nu} + \frac{m^2_{A'}}{2}A'_{\mu}A'^{\mu}$

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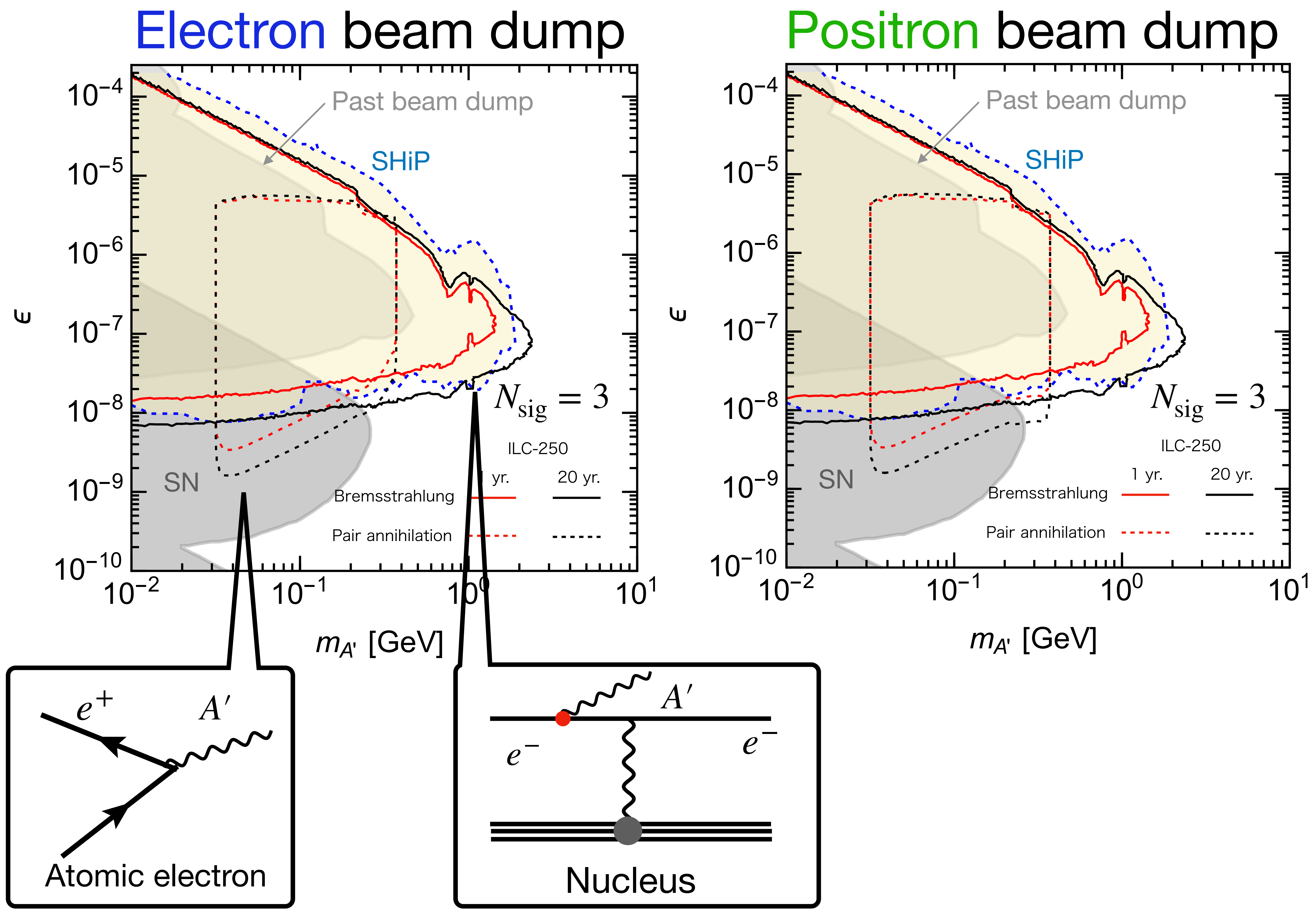

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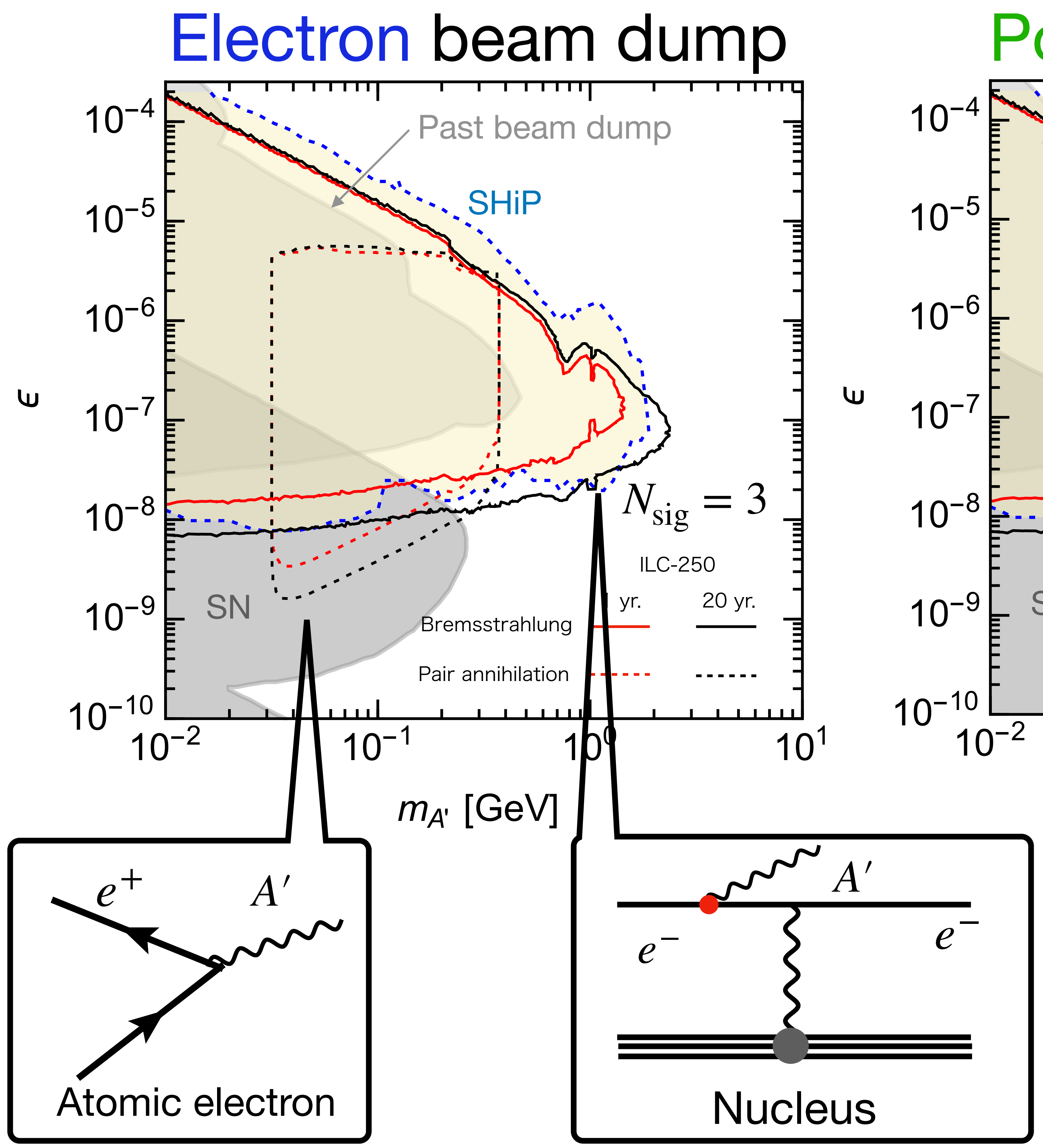

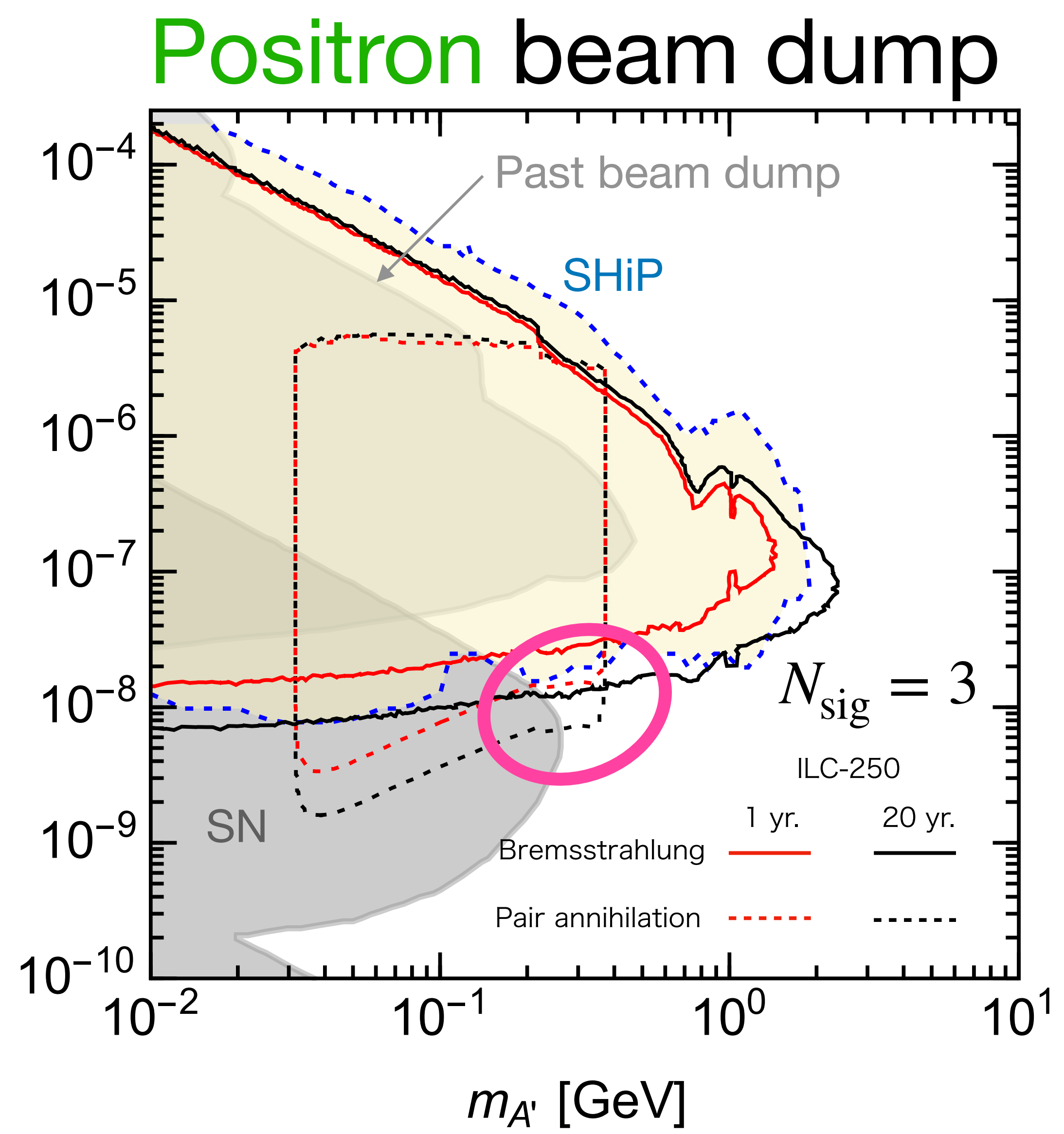

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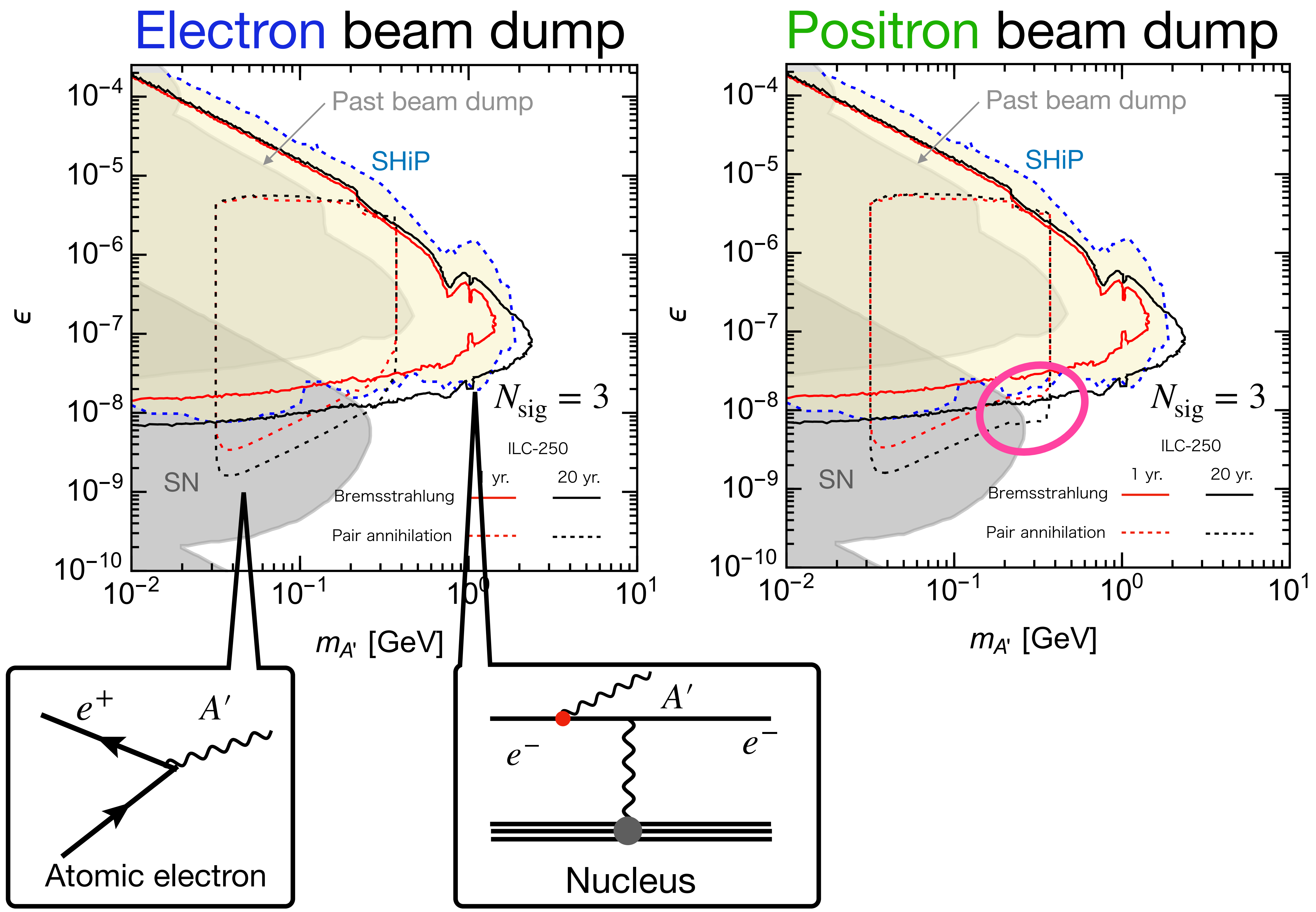

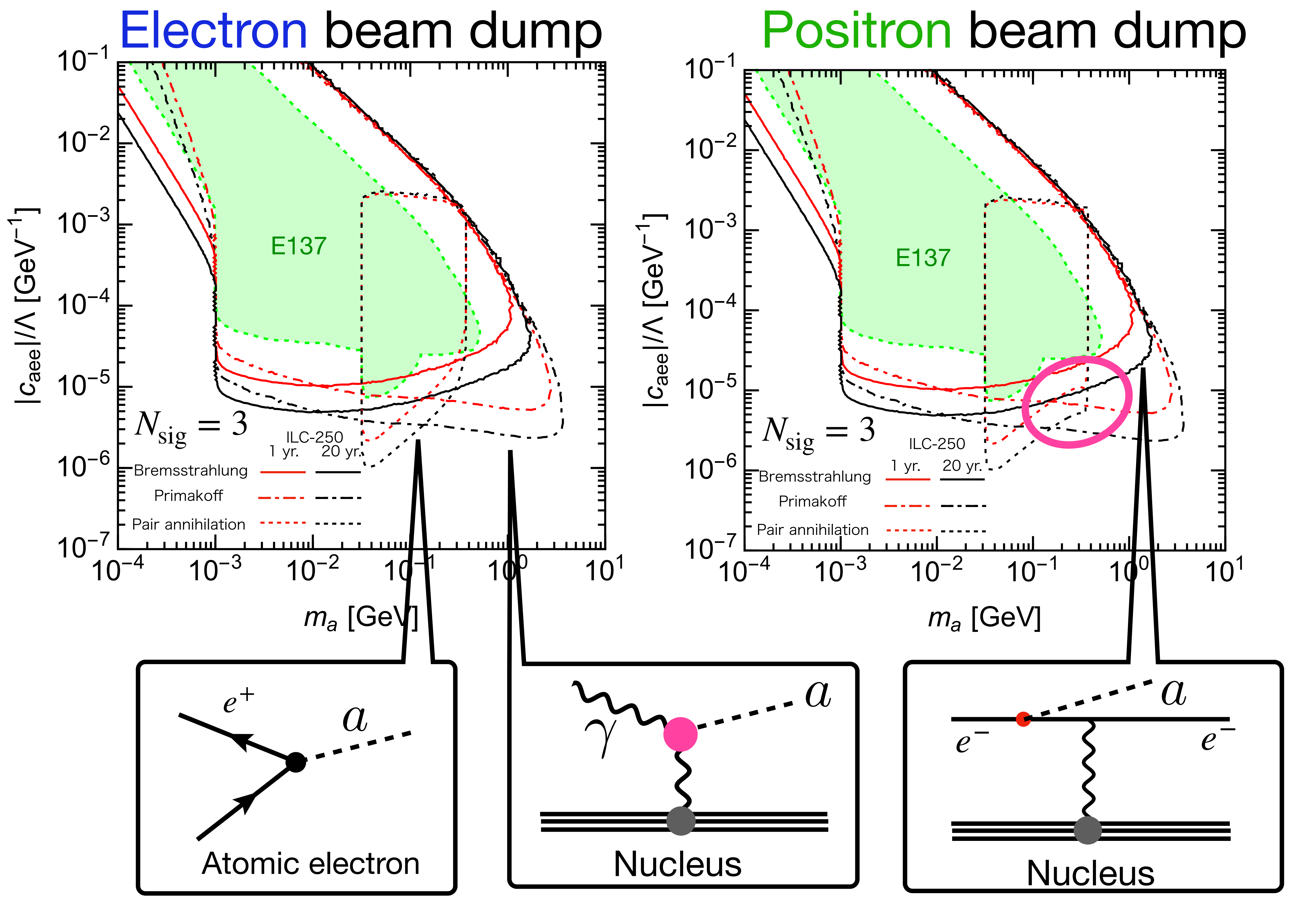

Loop induced

Dark photon: $-\frac{1}{4}F^{(A')}_{\mu\nu}F^{(A')\mu\nu} - \frac{\epsilon}{2}F^{(\mathrm{em})}_{\mu\nu}F^{(A')\mu\nu} + \frac{m_{A'}^2}{2}A'_{\mu}A'^{\mu}$

ALPs: $\mathcal{L} \supset \frac{1}{2}\partial_\mu a \partial^\mu a - \frac{1}{2}m_a^2 a^2 + \frac{1}{2}c_{aee}\frac{\partial_\mu a}{\Lambda}\bar{e}\gamma^\mu\gamma_5 e \boxed{- \frac{1}{4}g_{a\gamma\gamma}aF_{\mu\nu}\tilde{F}^{\mu\nu}}$

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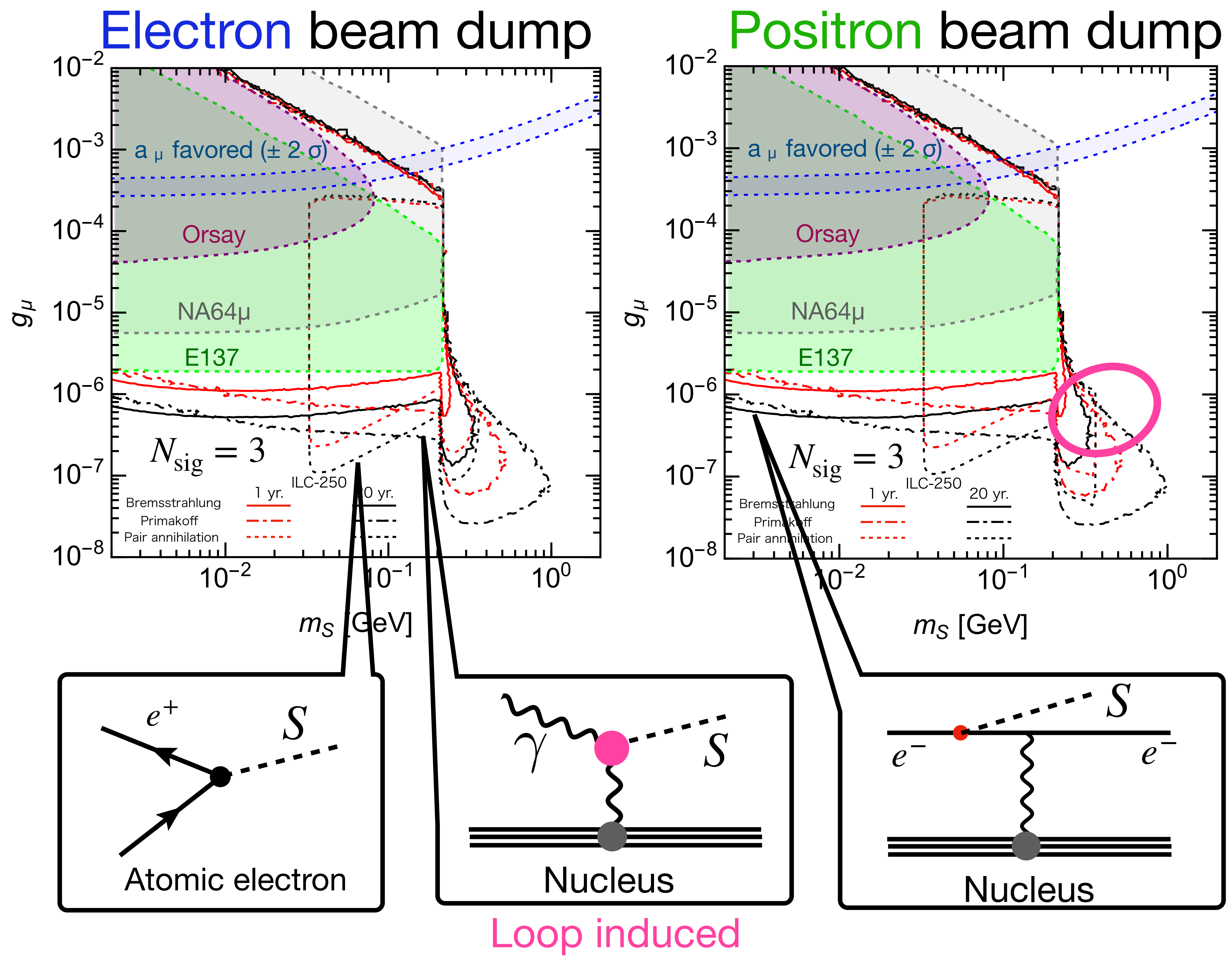

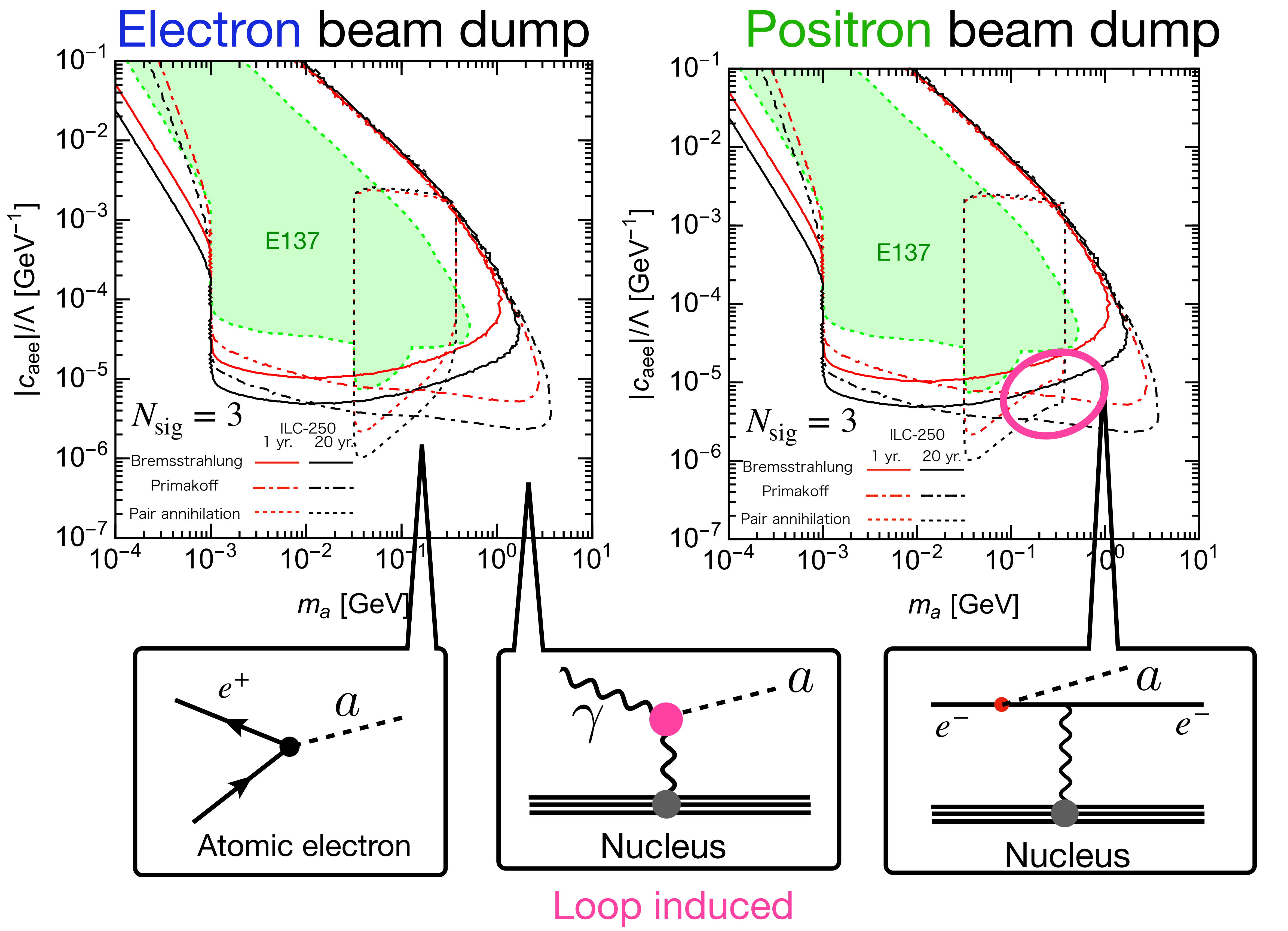

Light scalar: $\mathcal{L} = \frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2}m_S^2 S^2 - \sum_{\ell=e,\mu,\tau} g_\ell S\bar{\ell}\ell \boxed{- \frac{1}{4} g_{S\gamma\gamma} S F_{\mu\nu}F^{\mu\nu}}$

$g_e/m_e = g_\mu/m_\mu = g_\tau/m_\tau$

Loop induced

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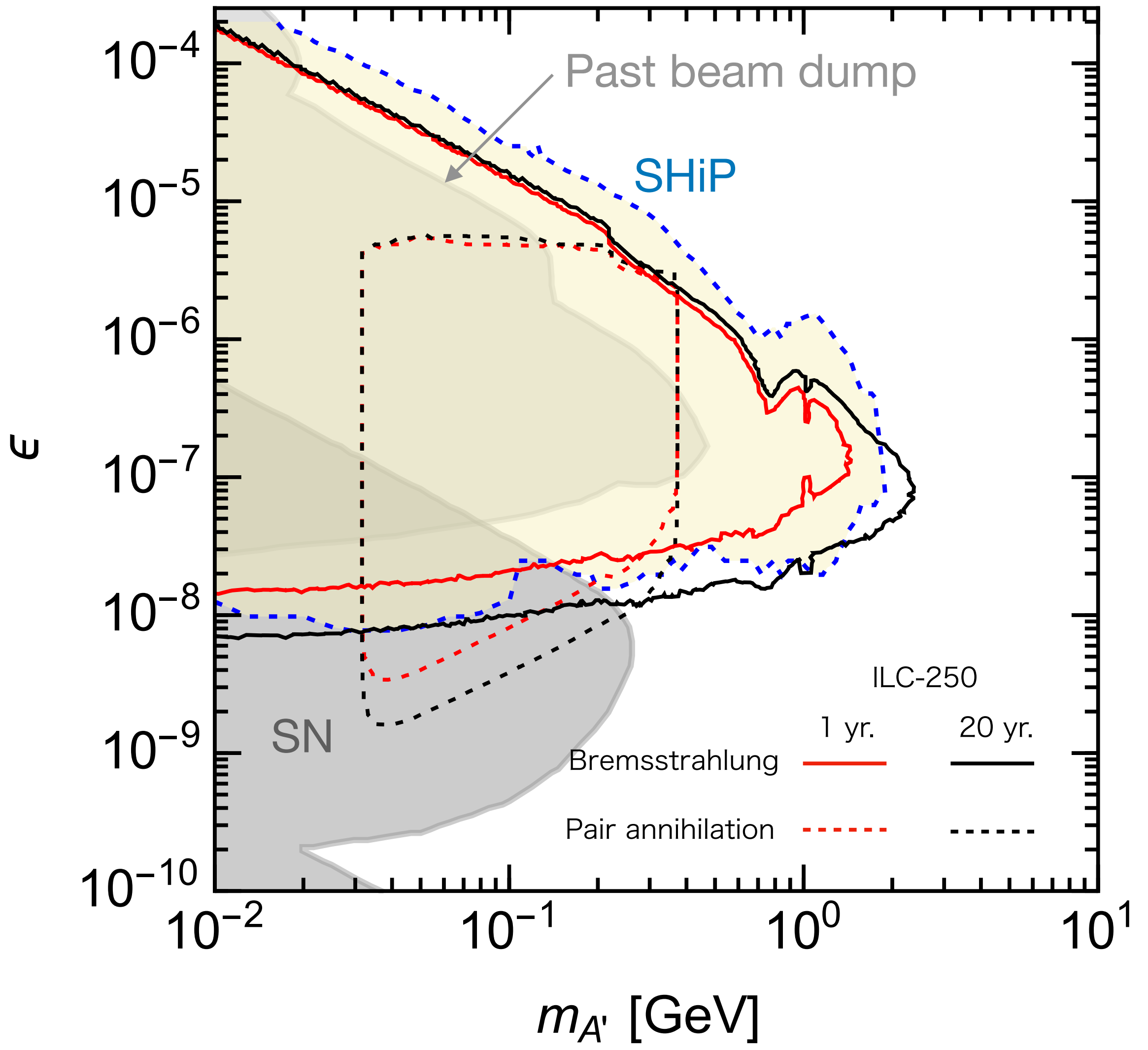
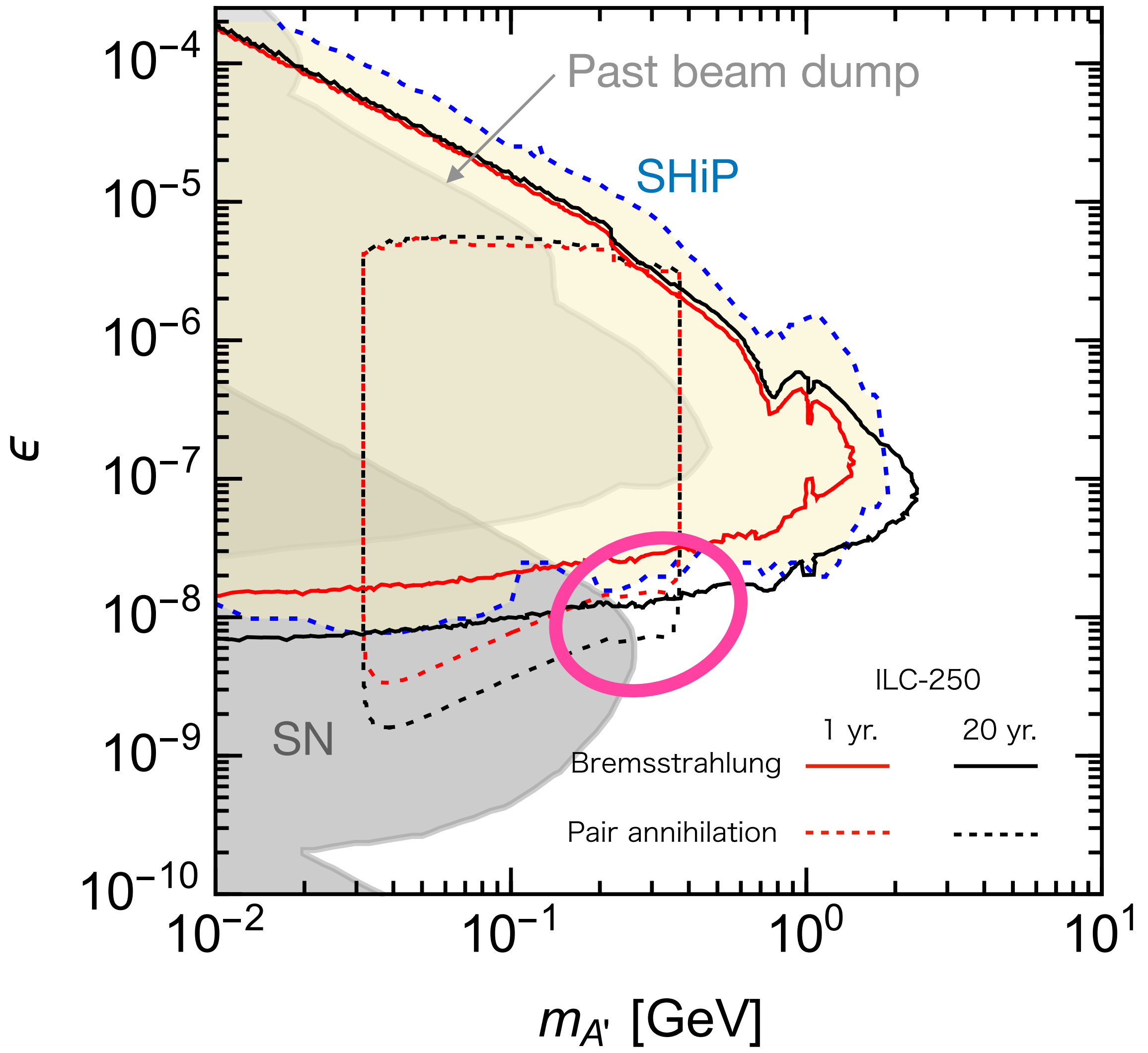


Positron beam dump



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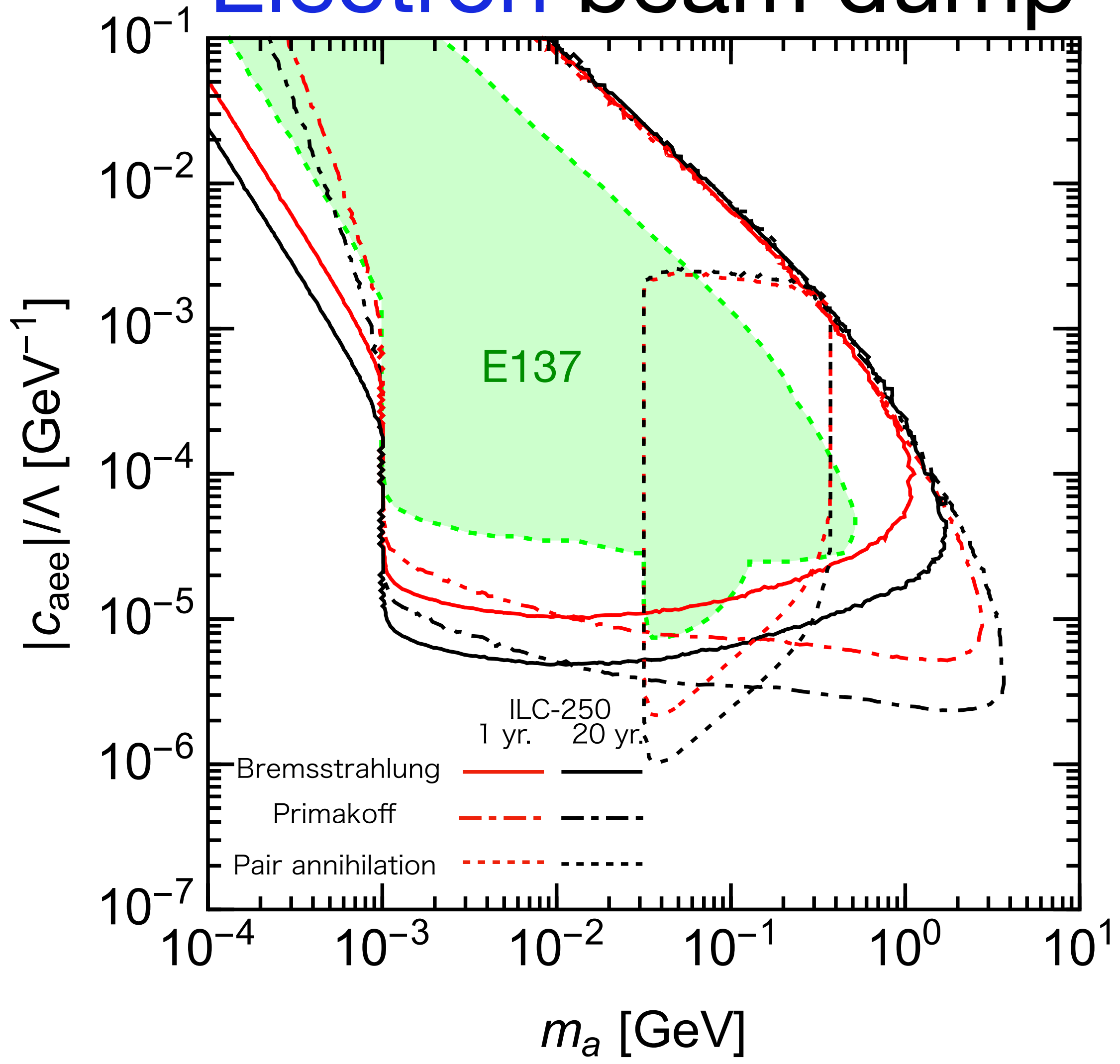

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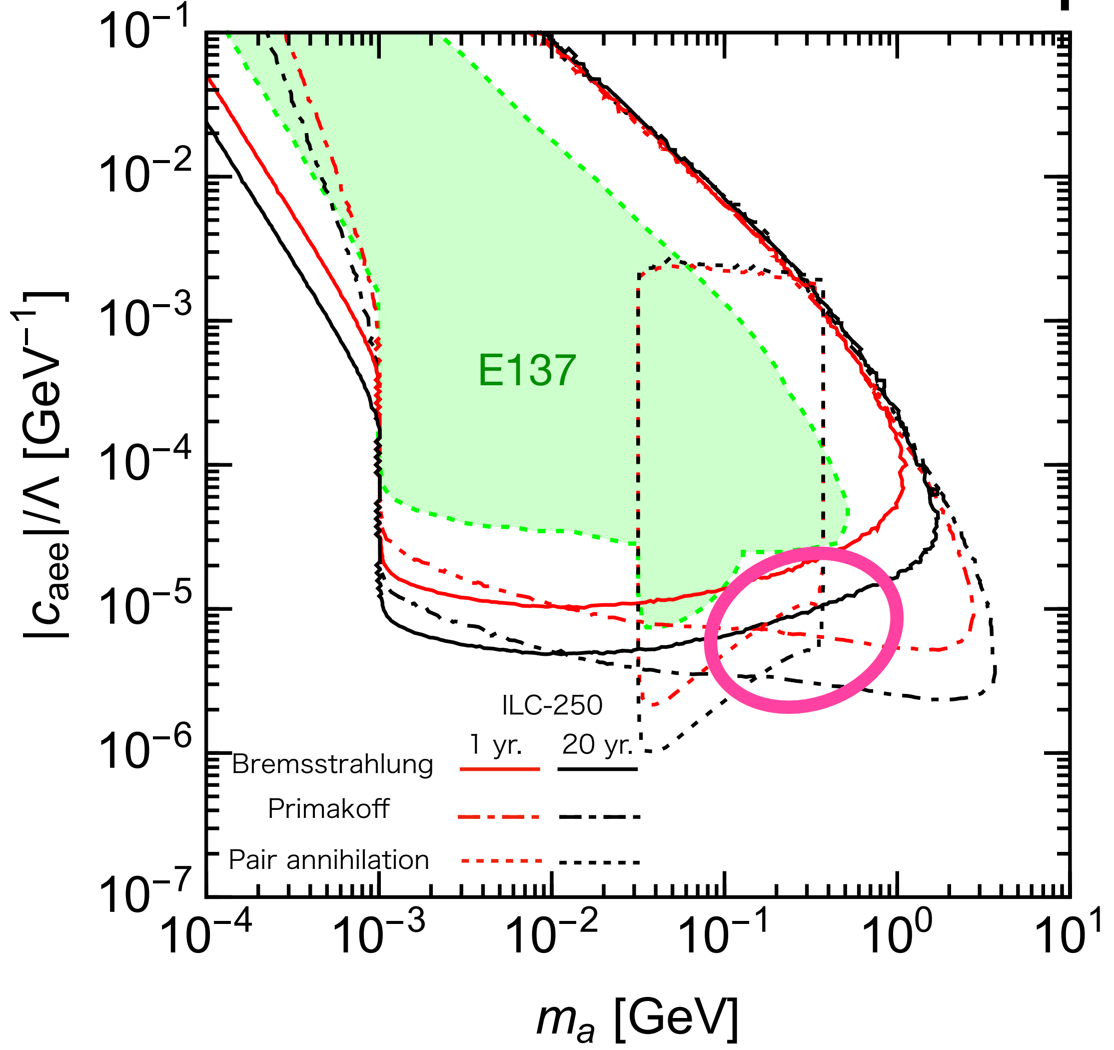

- Sensitivity of ILC main beam dump to visibly-decaying LLP have been studied
- How about invisibly-decaying particle searches using ILC main beam dump?

Invisible-decaying particles search at ILC

- “Normal” bunch charge of ILC beam is very large
    - Buch charge (density) at ILC: 3.2nC ($2*10^{10}$ e/bunch)

Invisible-decaying particles search at ILC

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- Because of pileup, active beam-dump experiment using active target is challenging

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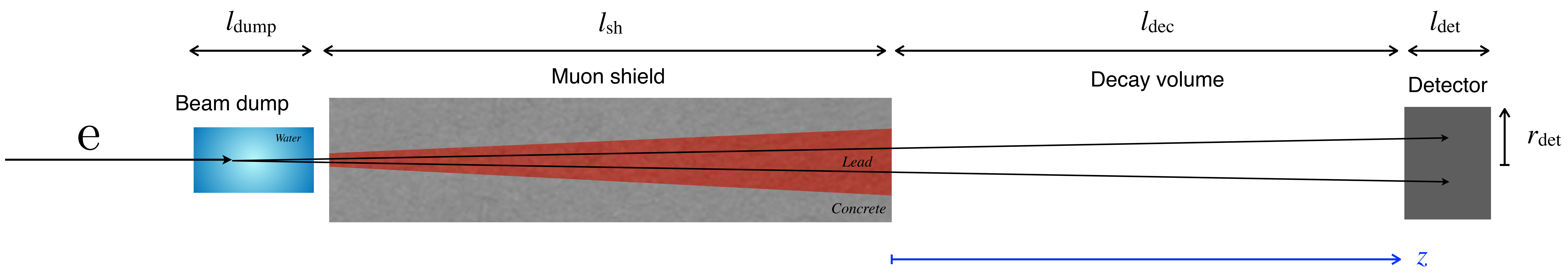
We started to evaluate sensitivity of ILC-BDX experiment

ILC-BDX setup

- Setup similar to visibly-decaying LLP searches



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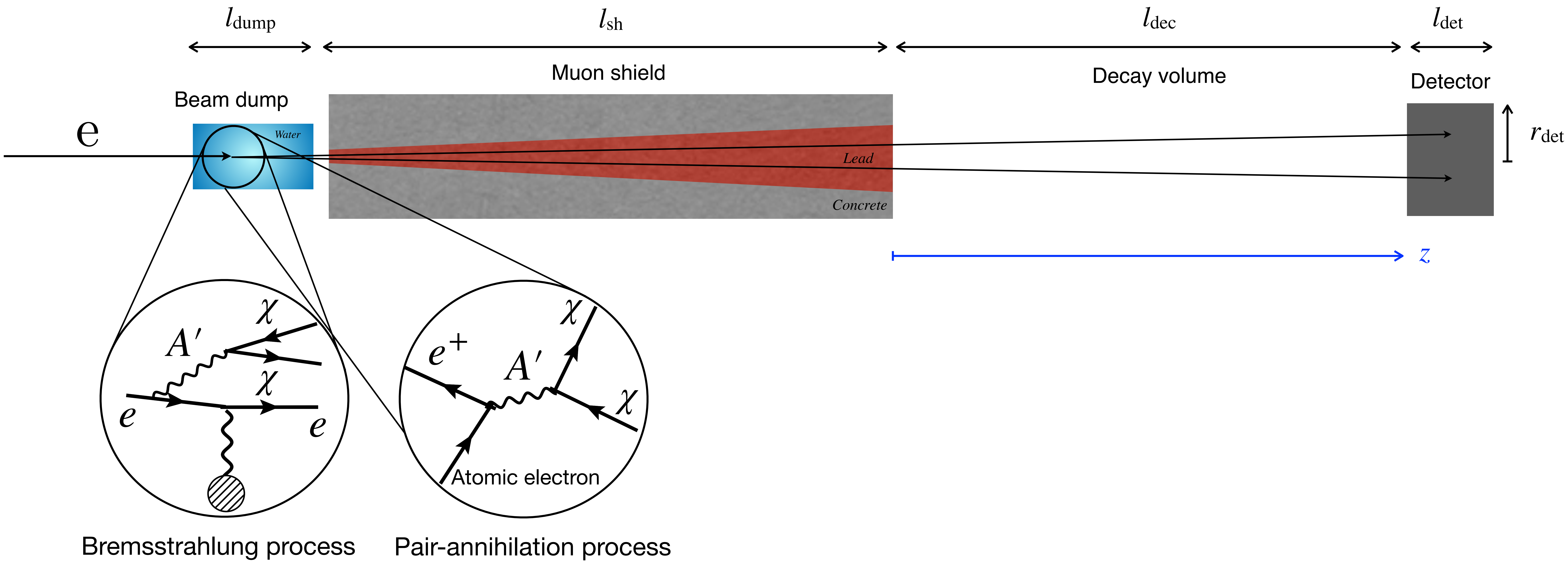

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ILC-BDX setup

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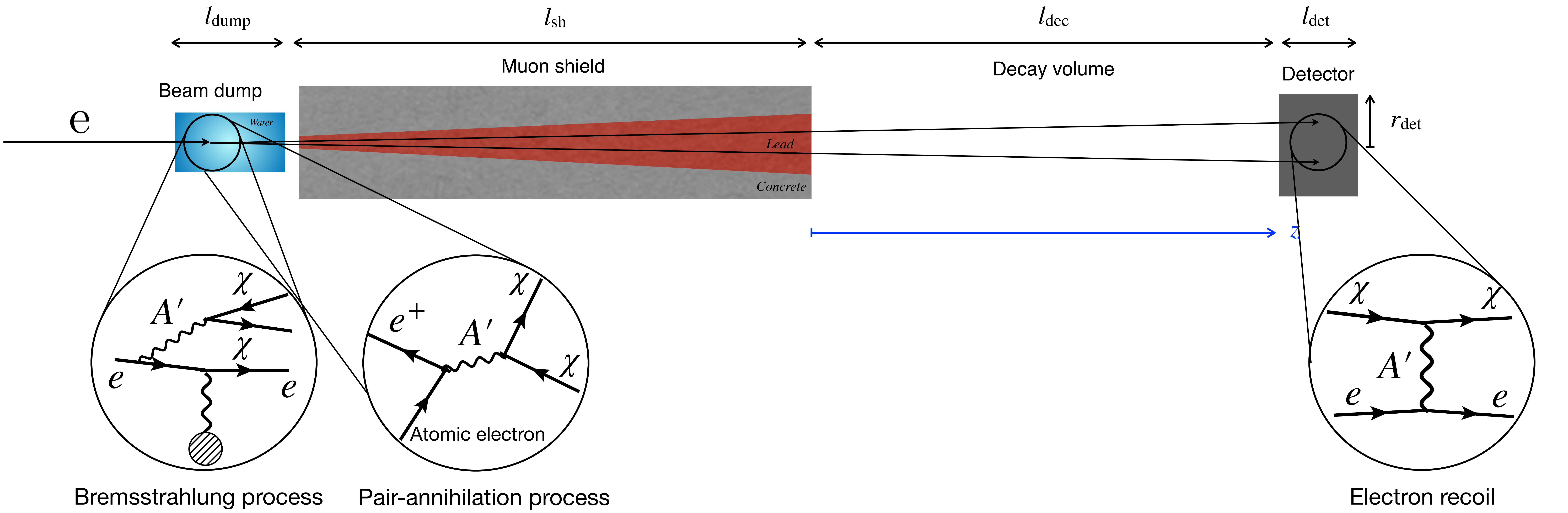

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signal events in calorimeter

ILC-BDX setup

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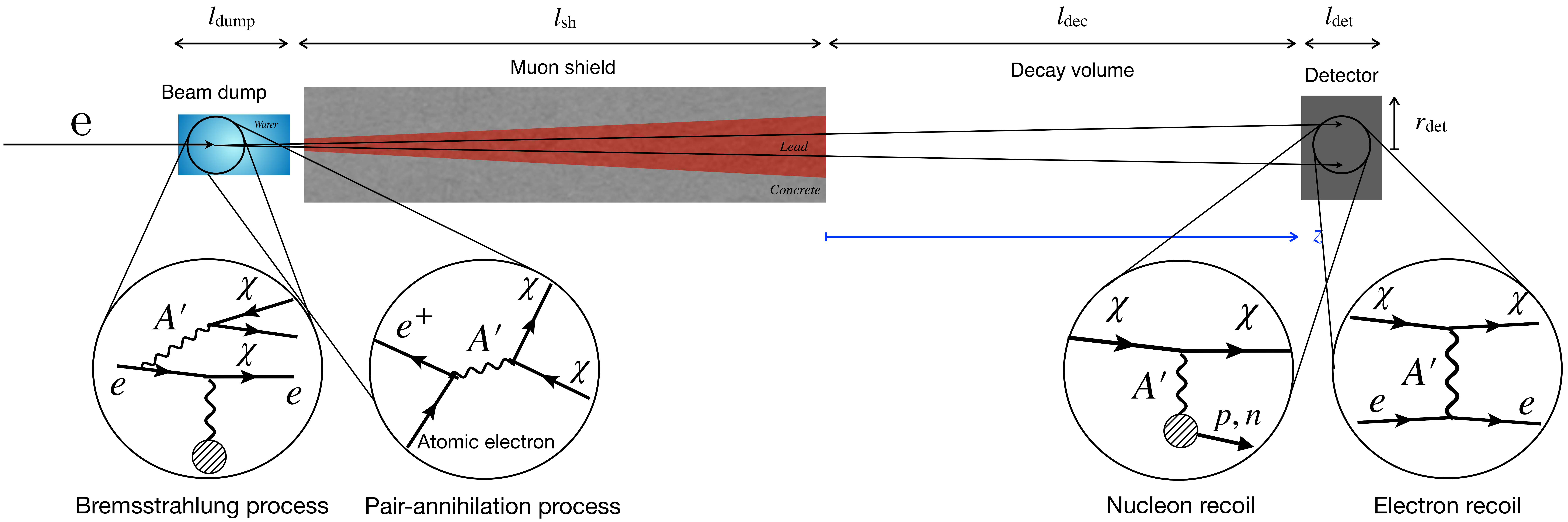

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signal events in mineral oil detector used by MiniBooNE

signal events in calorimeter

ILC-BDX setup

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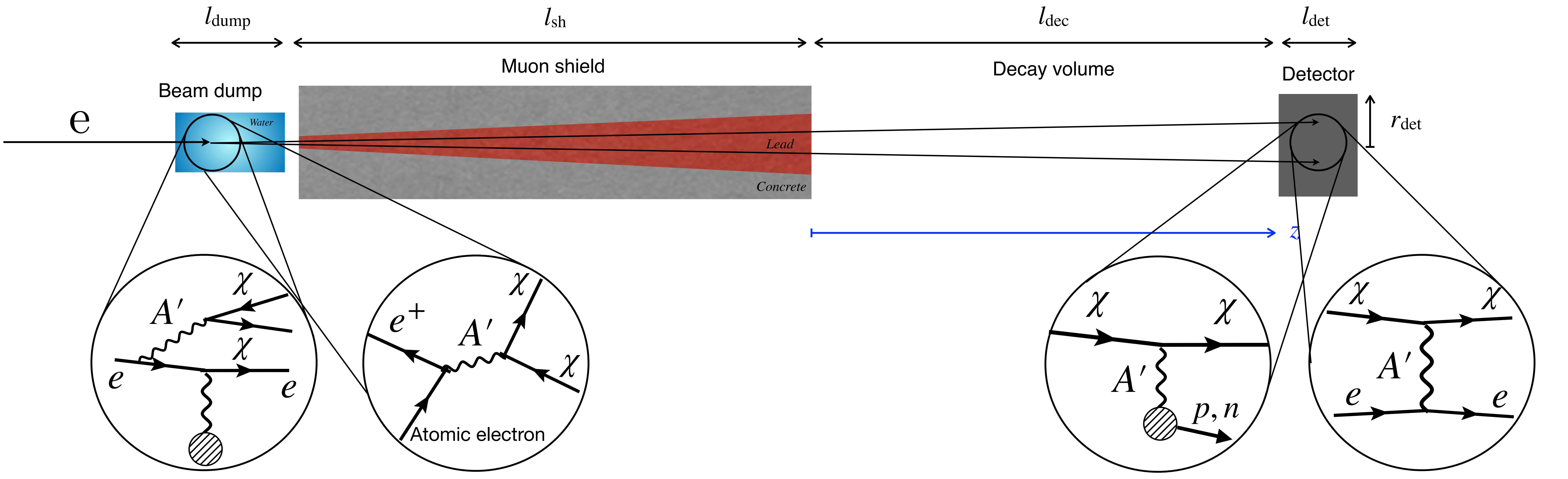

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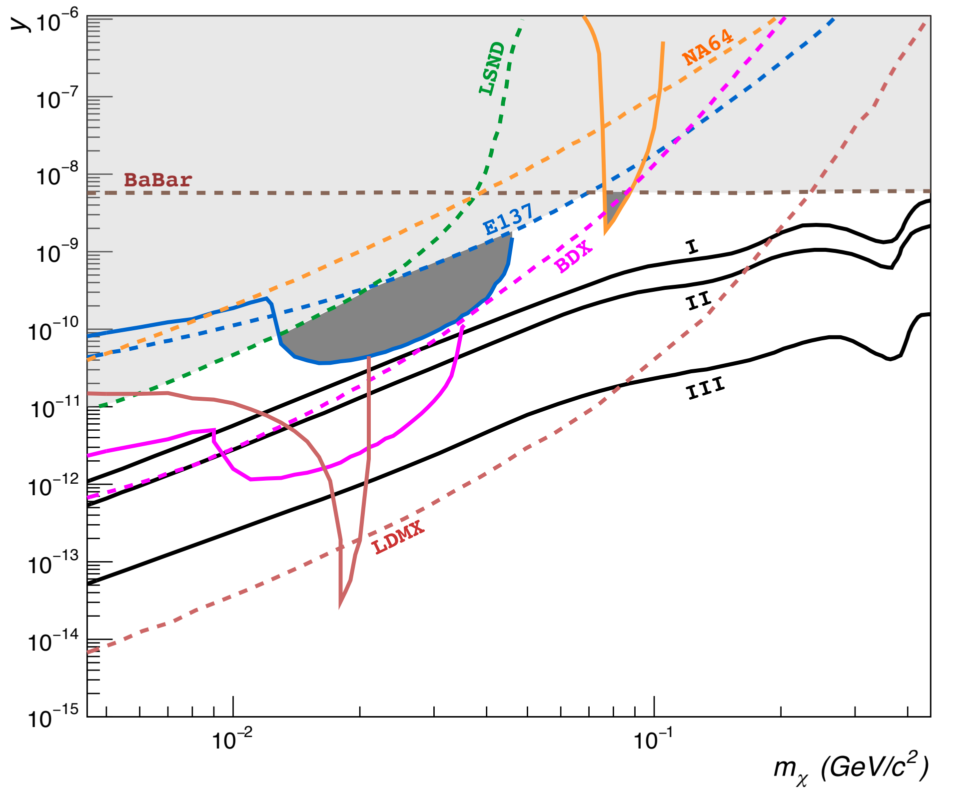
signal events if mineral oil detector used by MiniBooNE is set

signal events in calorimeter

We assume that detector is mineral oil detector or calorimeter

Numerical results of electron recoil

- We calculated the sensitivity of ILC-BDX and reproduced results of [1807.05884]



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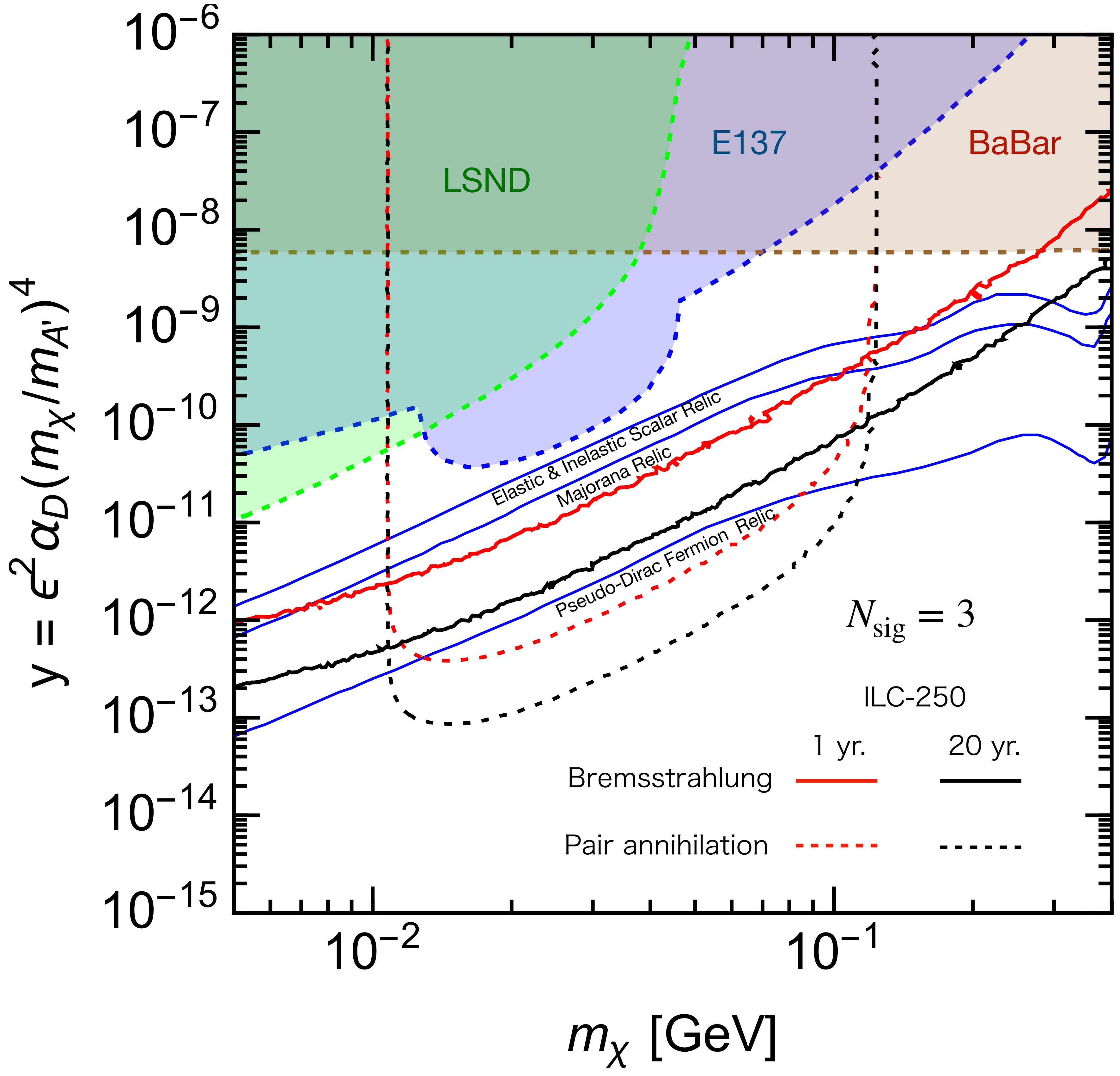
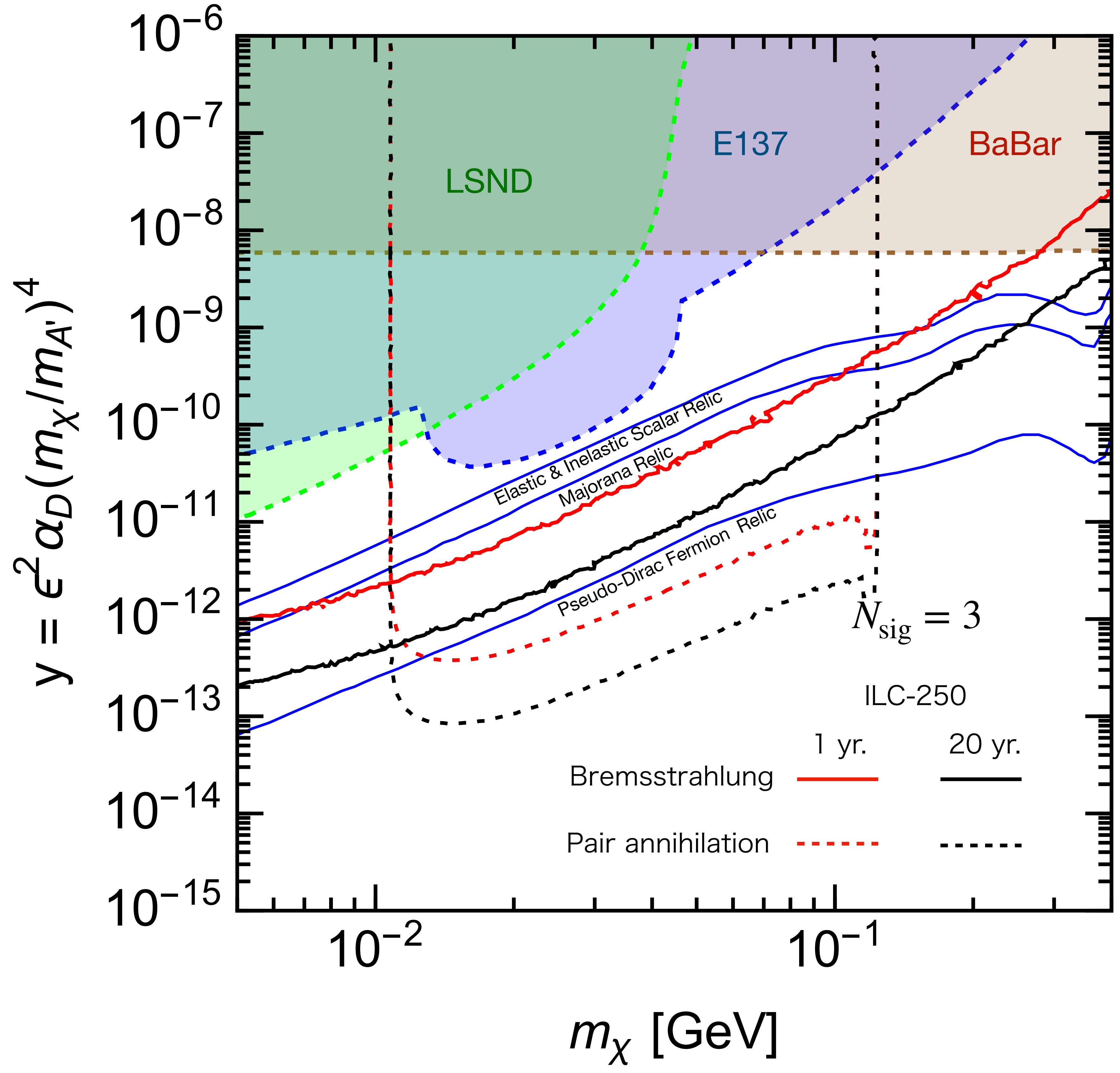
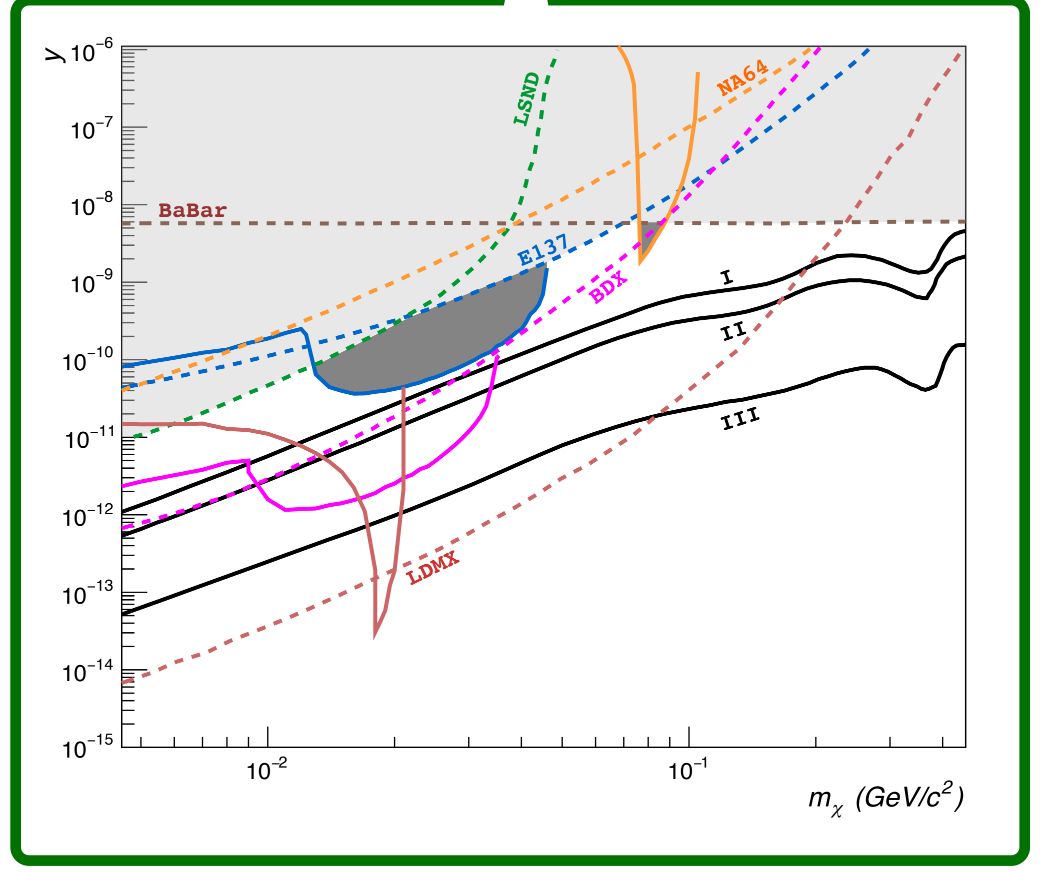
Electron beam dump



Positron beam dump





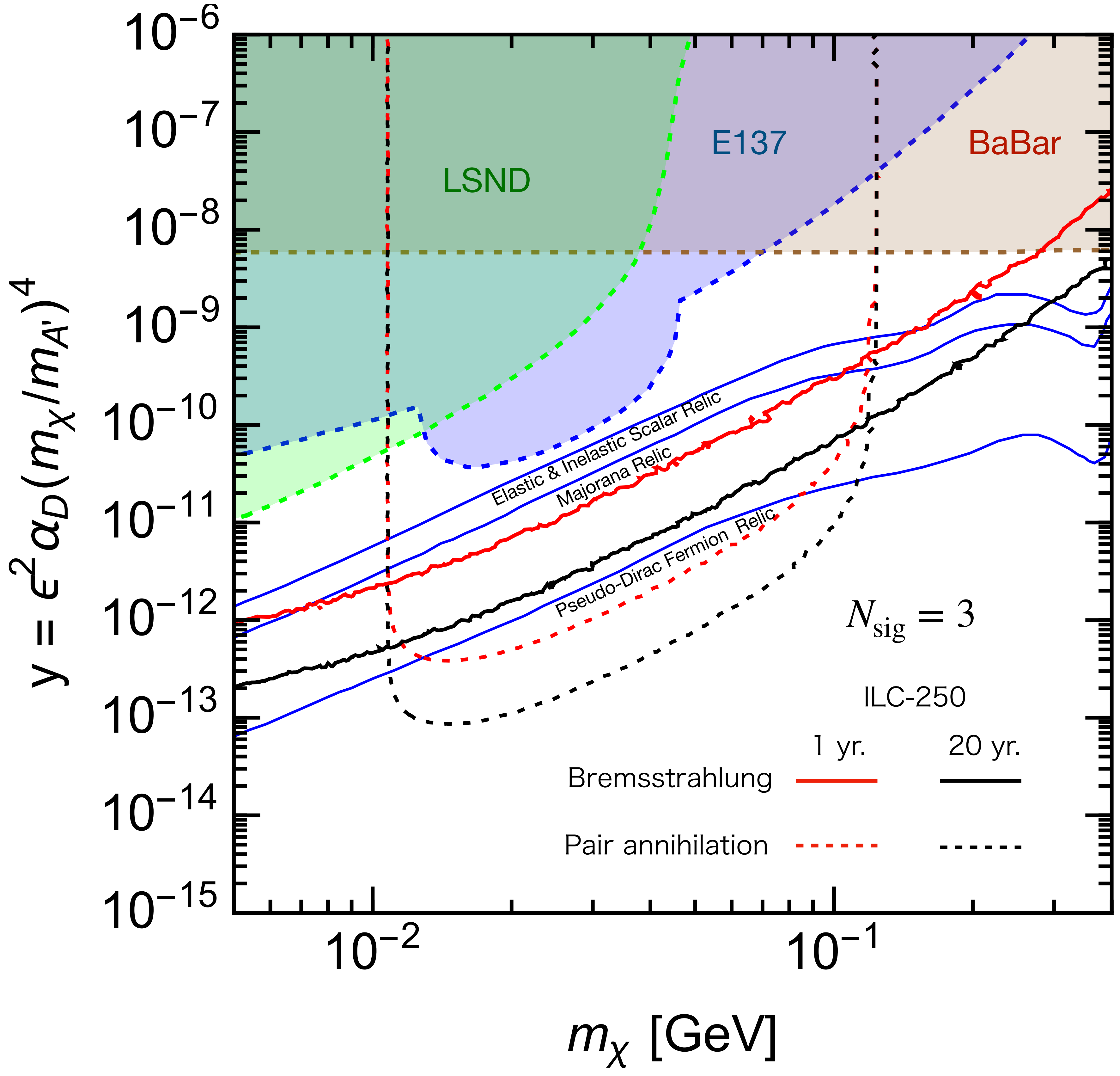
※ $\alpha_D \equiv g_D^2/4\pi = 0.5, \quad m_{A'} = 3m_\chi$

Model: $\mathscr{L} \supset -\frac{1}{4}F^{A'}_{\mu\nu}F^{A'}_{\mu\nu} - \frac{\epsilon}{2}F_{\mu\nu}F^{A'}_{\mu\nu} + \frac{m_{A'}^2}{2}A'_\mu A'_\mu + \bar{\chi}(iD_\mu\gamma^\mu - m_\chi)\chi, \quad D_\mu = \partial_\mu + ig_D A'_\mu$

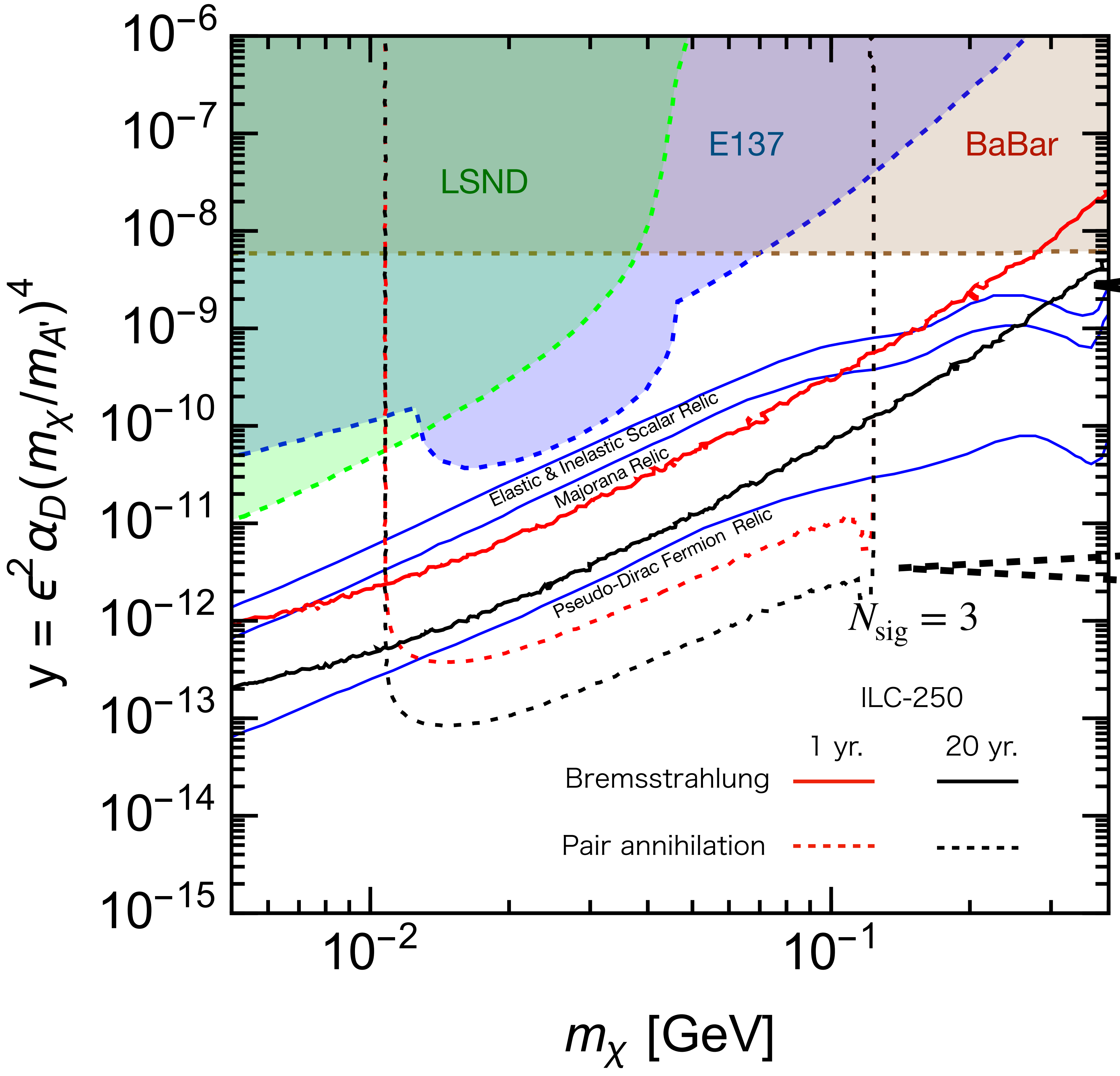
Numerical results of electron recoil

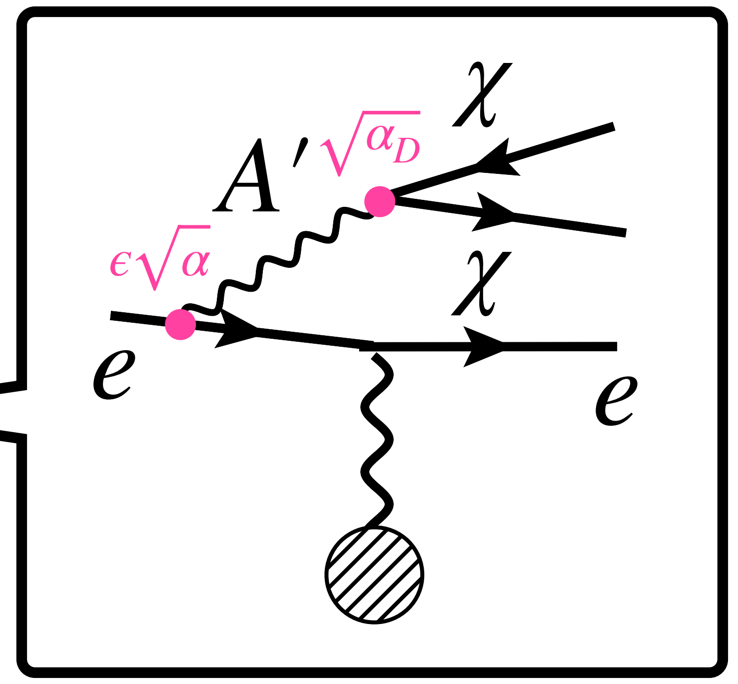
- We calculated the sensitivity of ILC-BDX and reproduced results of [1807.05884]

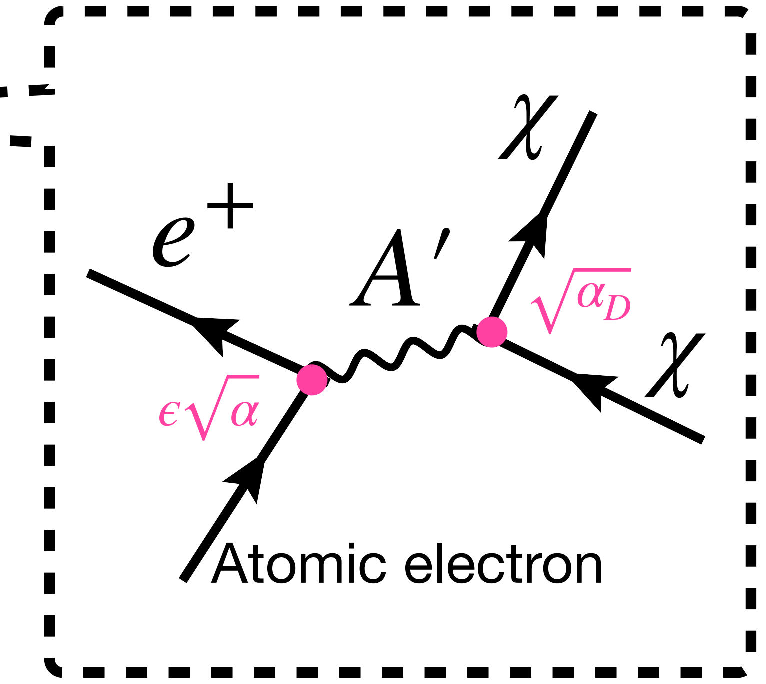
Electron beam dump



Positron beam dump







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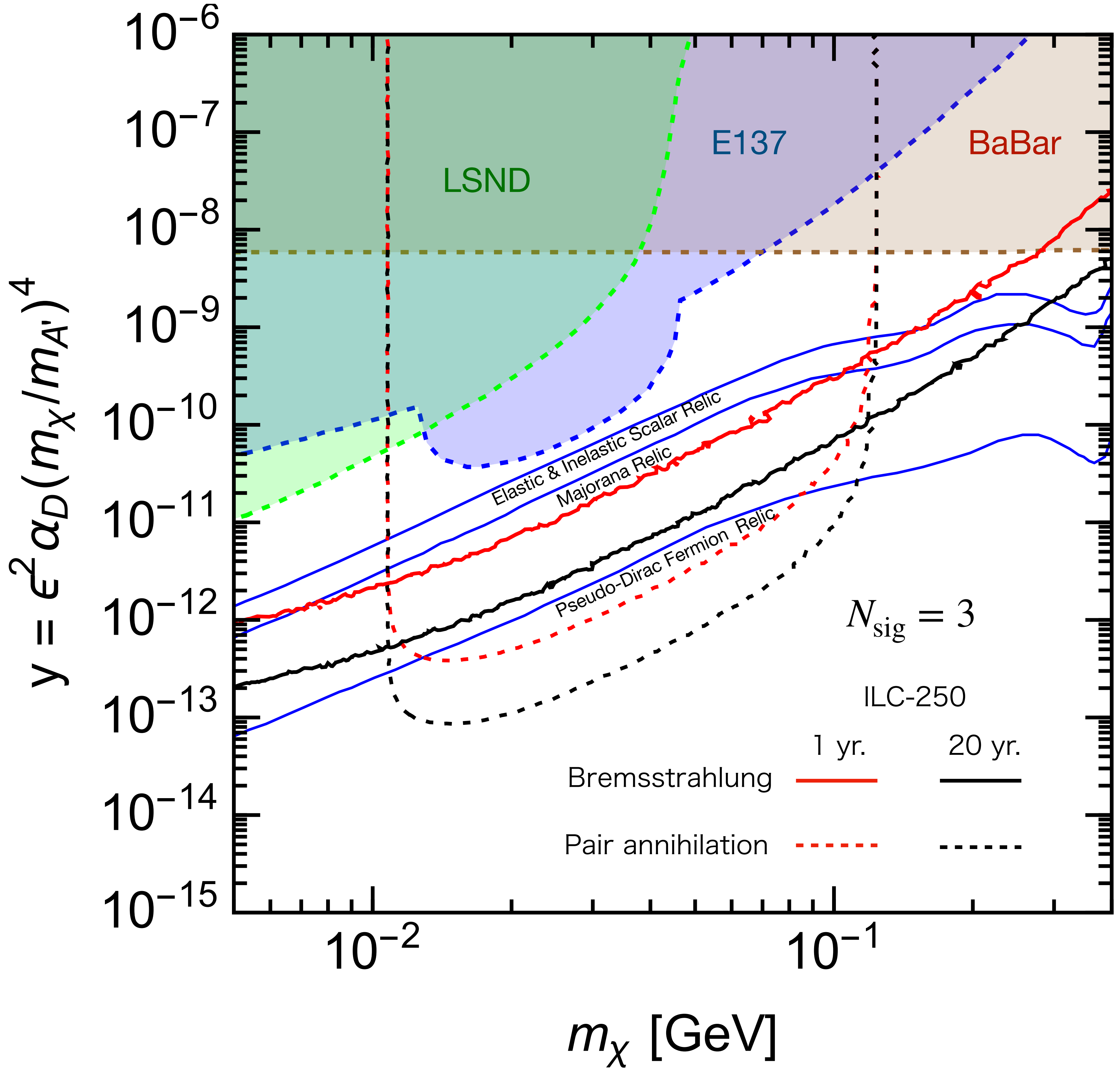
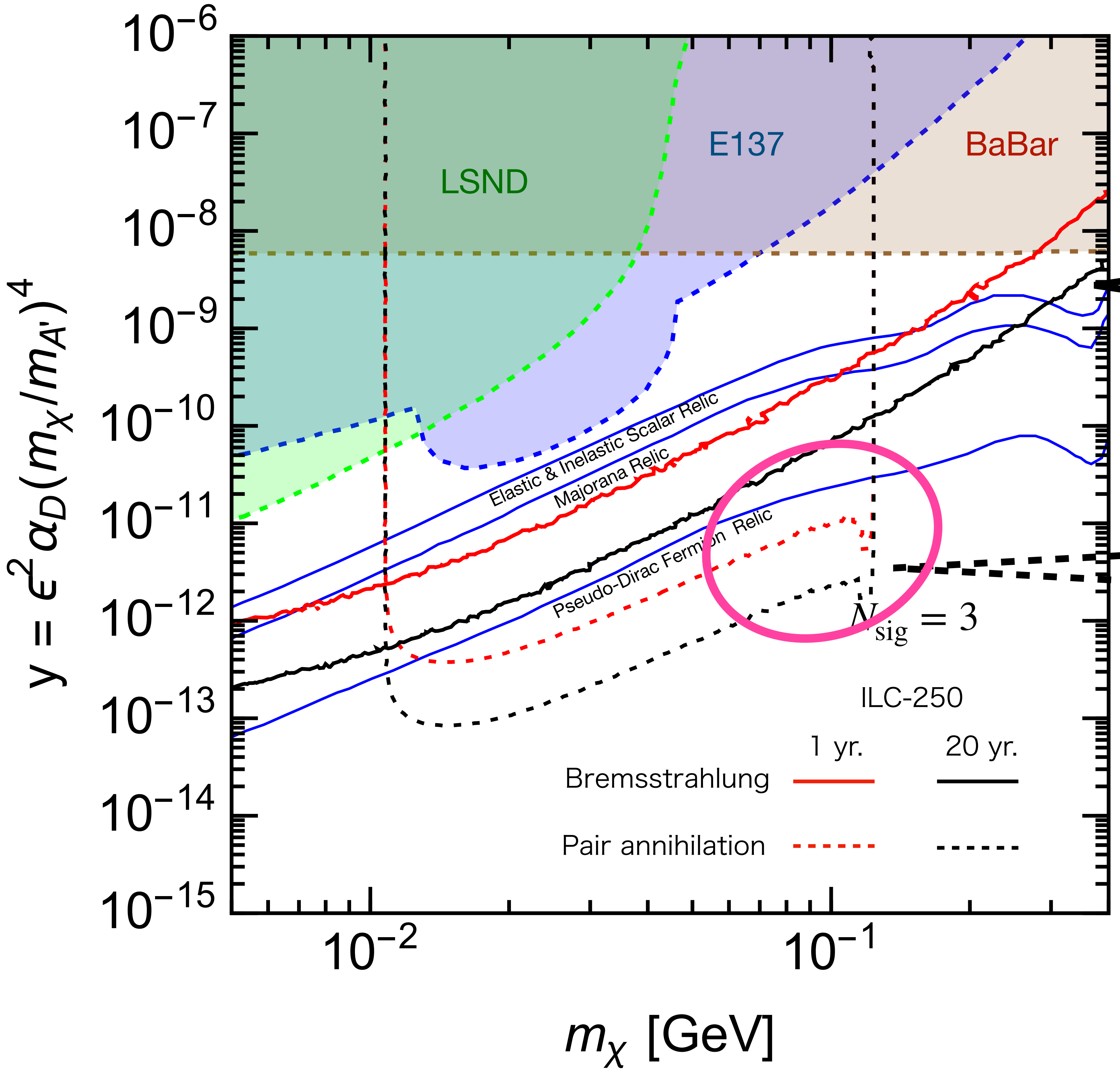
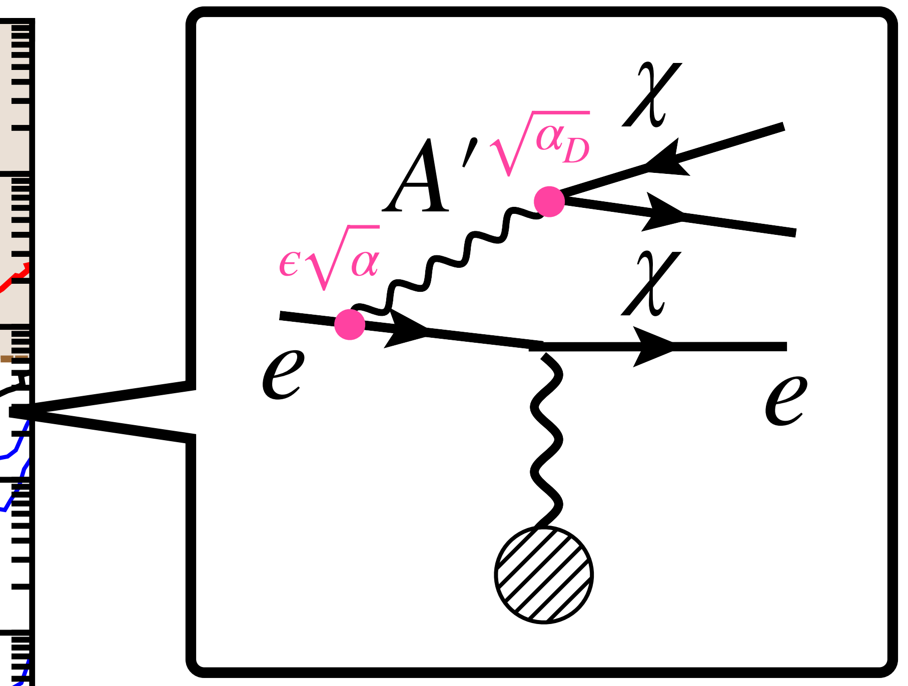
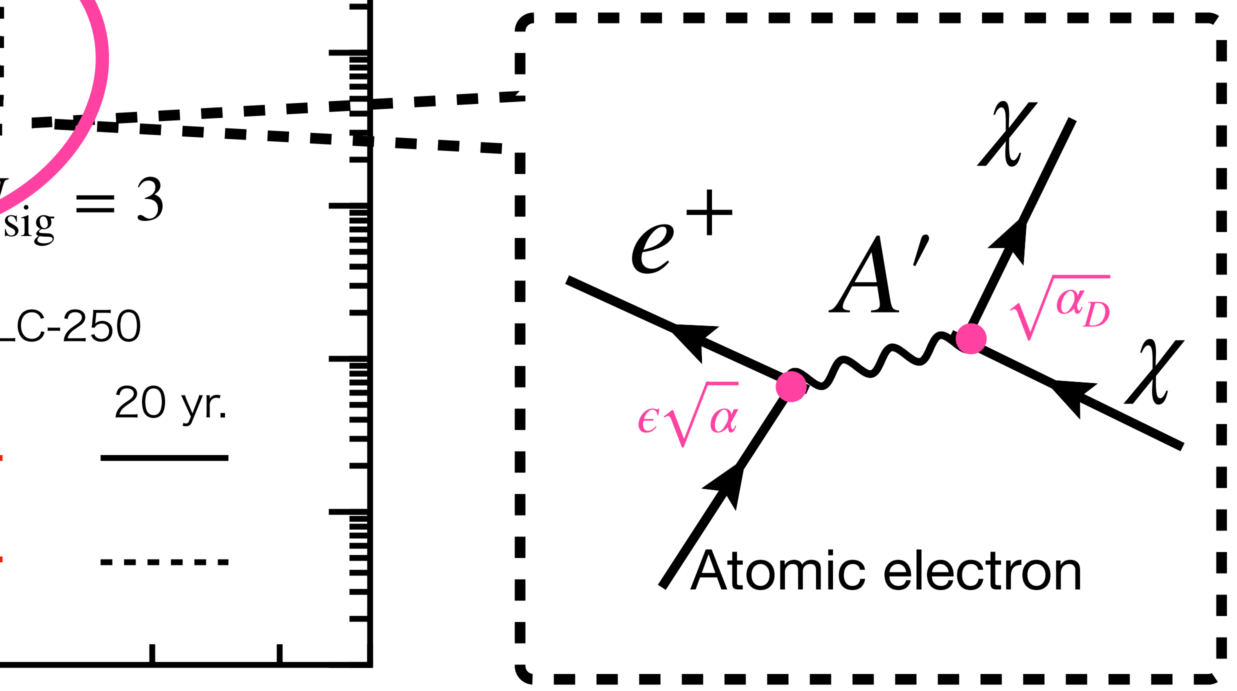


Positron beam dump







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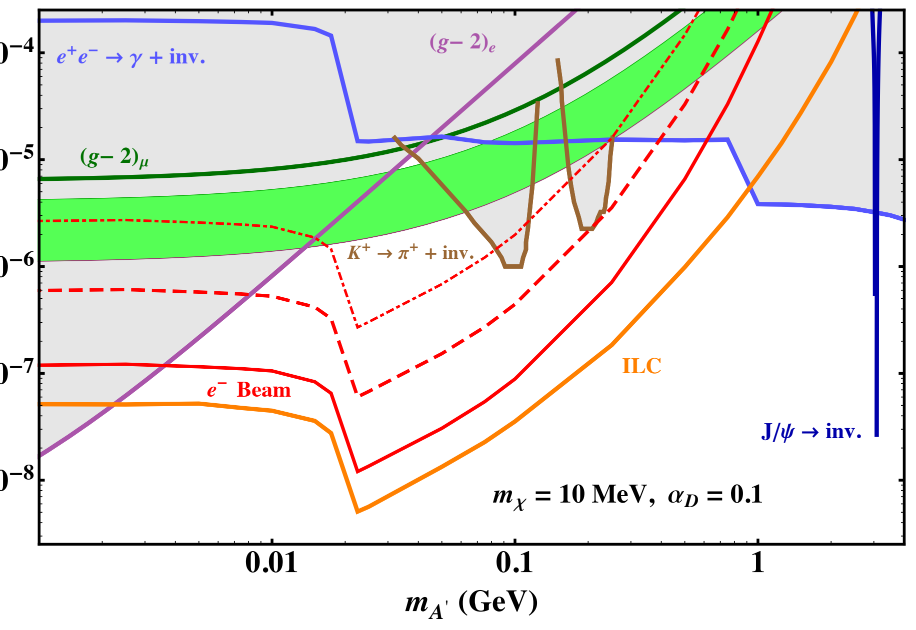

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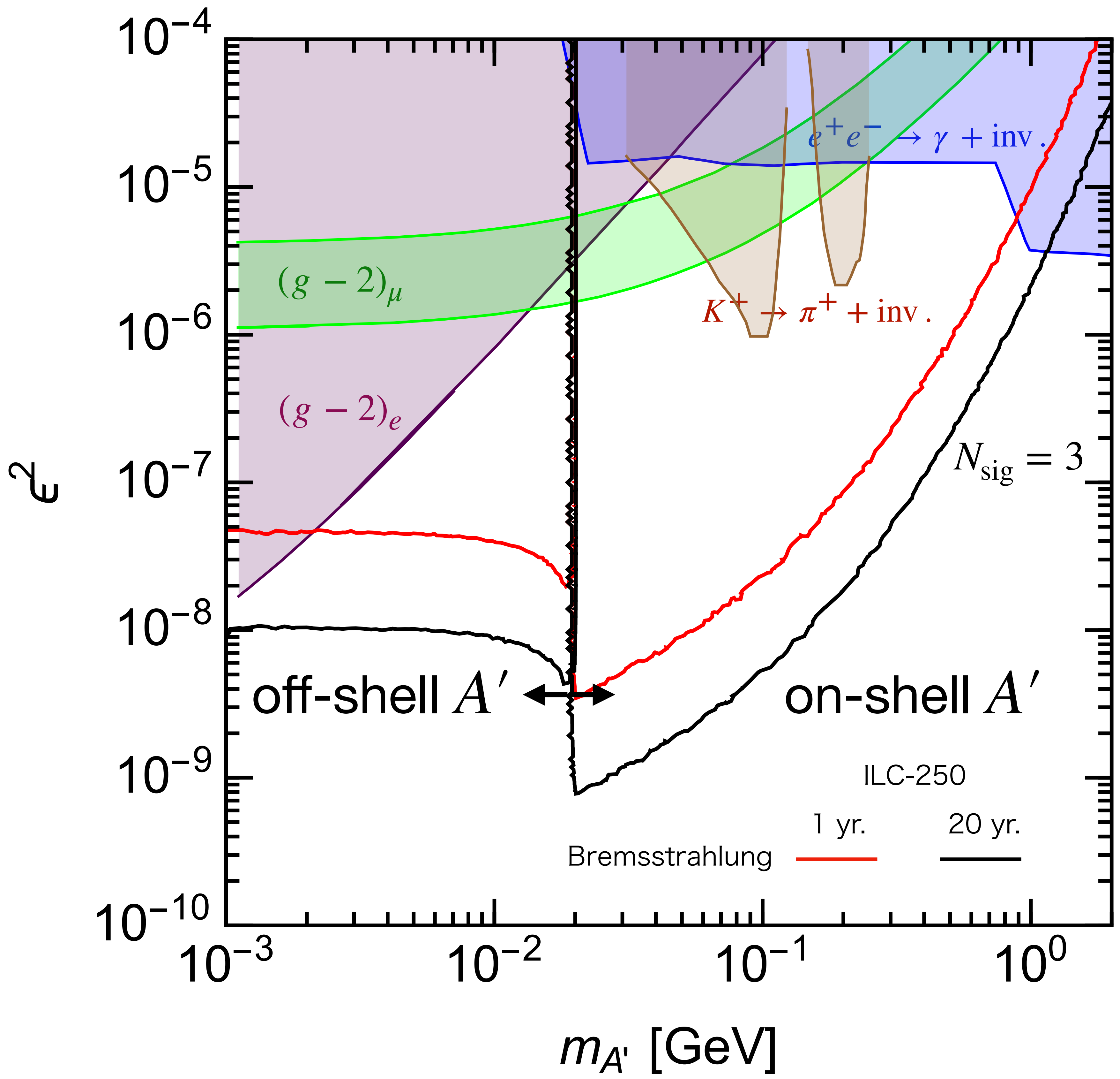

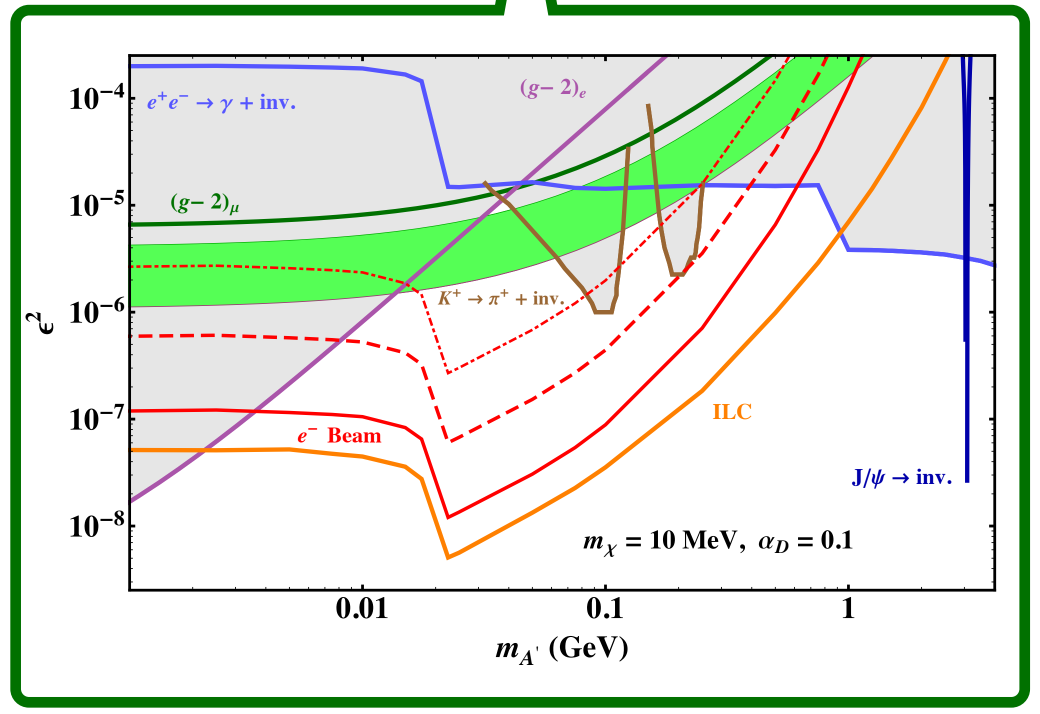

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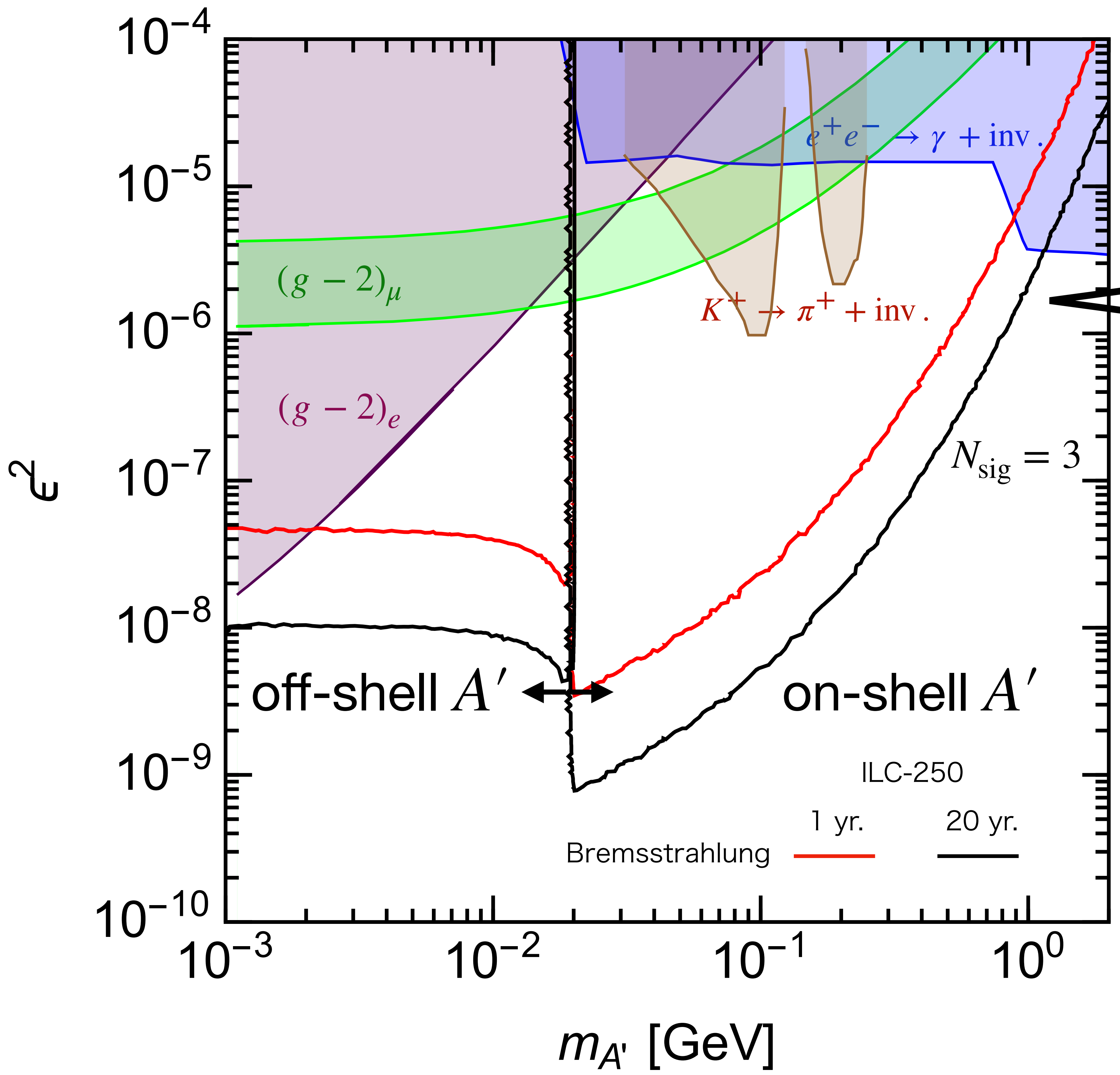

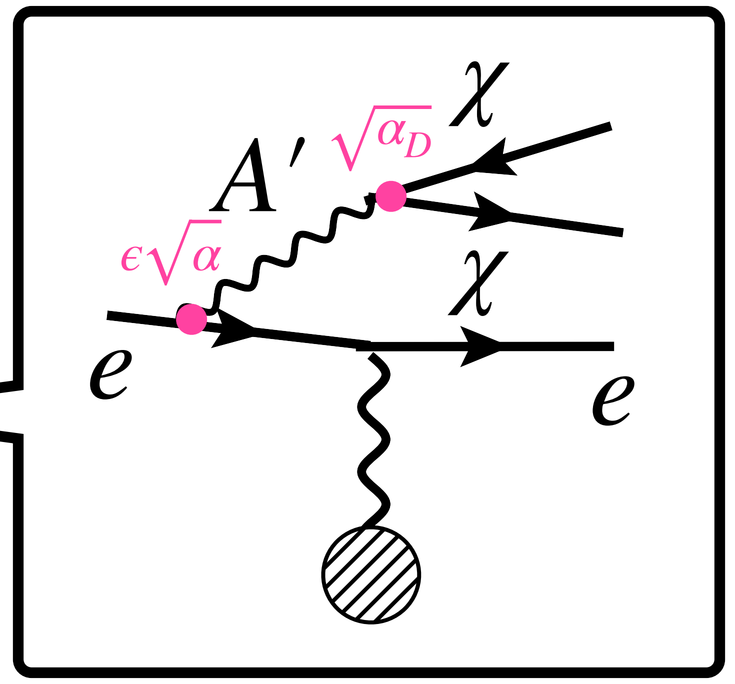

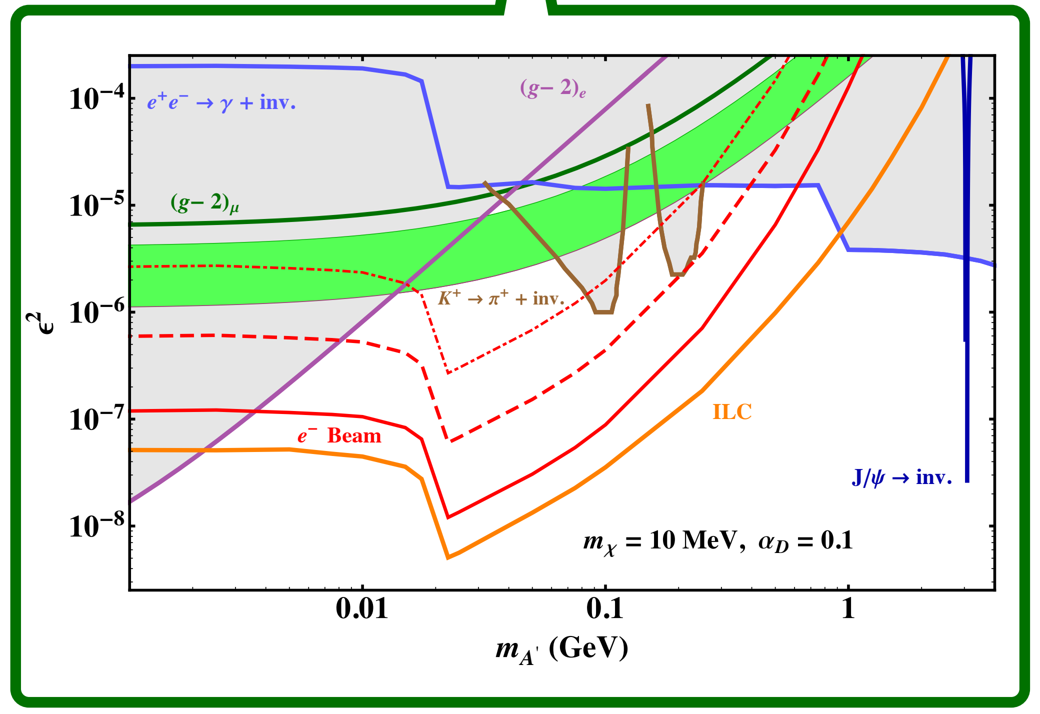

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Things to study

- Background estimations:

  - beam-related background coming from neutrinos produced in the beam dump and muon shield

  - We have already obtained neutrino fluxes by Monte Carlo simulation

- Comparison between electron and nucleon recoils:

  - Using same parameters for electron and nucleon recoil we'll calculate the sensitivities again

- Complementarity of visibly-decaying LLP search and DM search:

  - In $m_{A'} < 2m_\chi$ on-shell dark photon is LLP and visibly-decaying LLP search becomes important