



# New physics searches at ILC beam-dump

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(Joined in 2023 Feb.)

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Summer Institute 2023, Sun-Link-Sea Forest and Nature Resort

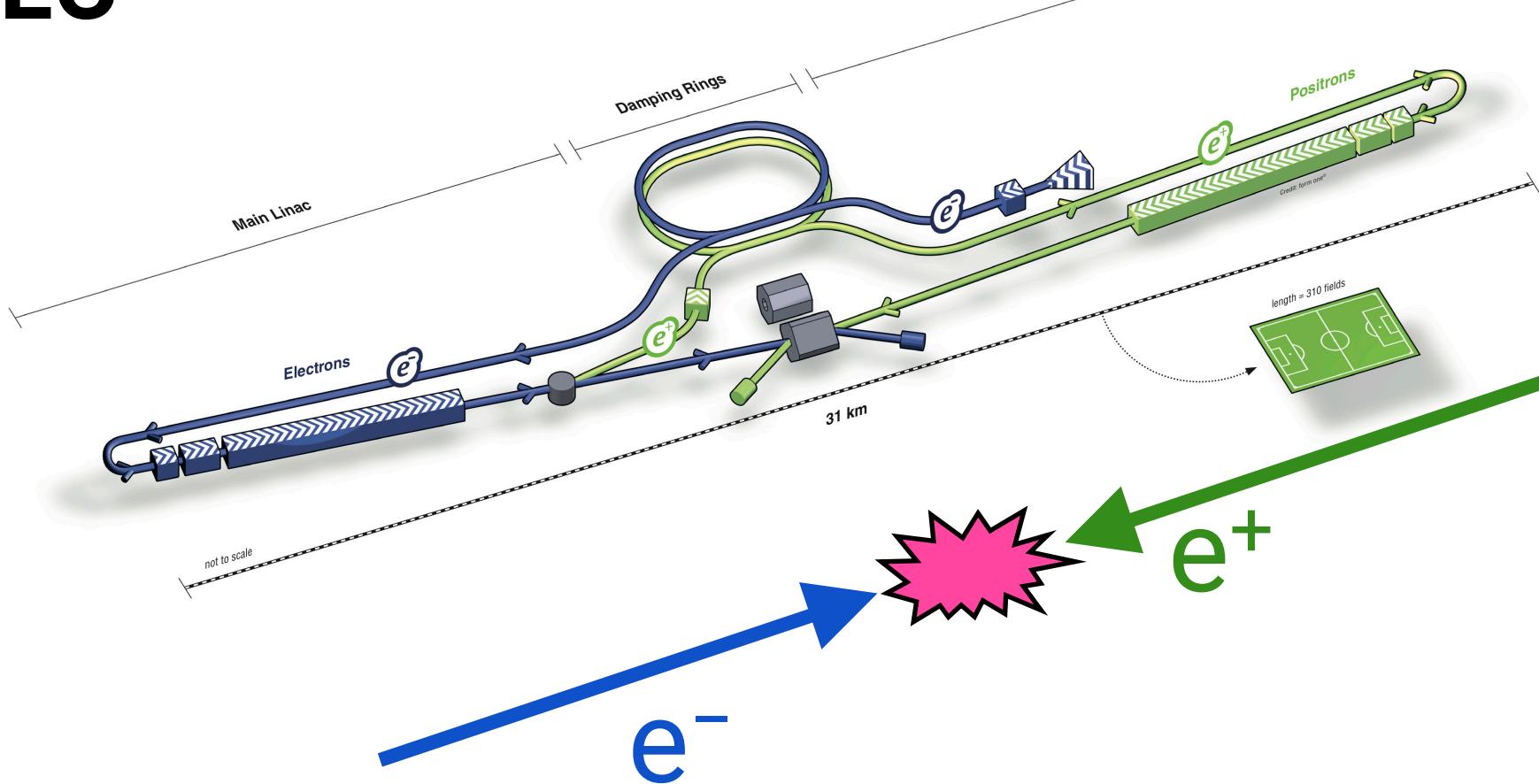
SI2009  
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2012  
2013  
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2019  
2020  
2021  
2022  
2023

Based on [arXiv:2105.13768](#) and [arXiv:2301.03816](#).

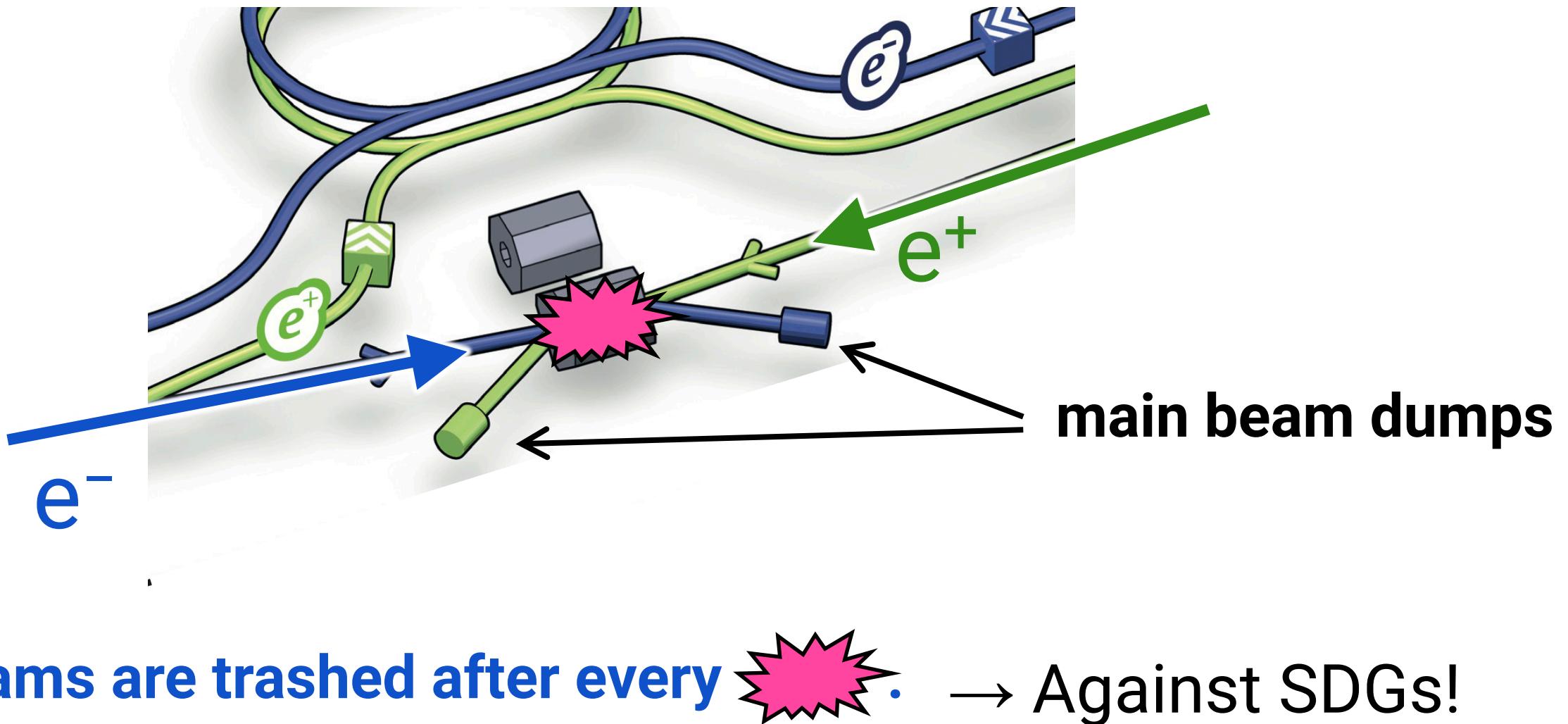
(with Daiki Ueda @ KEK→Technion, Yasuhito Sakaki @ KEK,  
Kento Asai @ Tokyo U. ICRR, Maxim Perelstein @ Cornell)

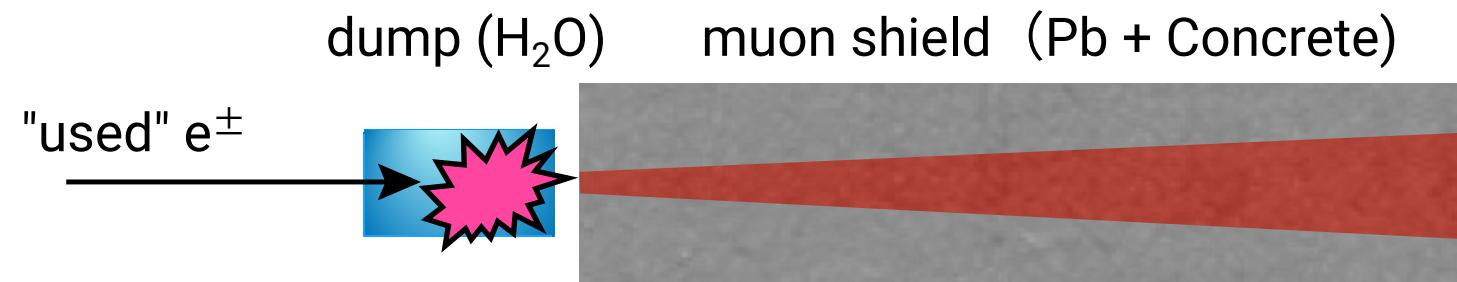
# ILC

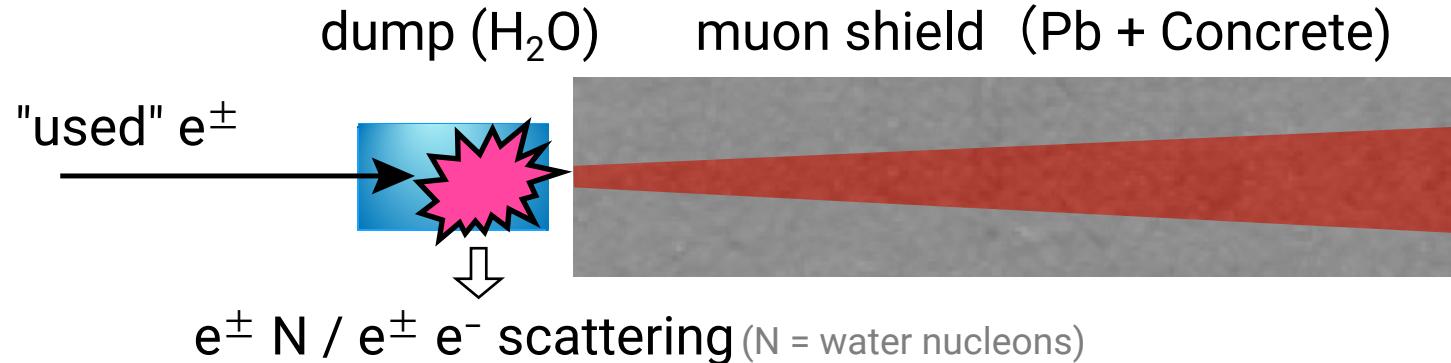
$E_{\text{beam}} = 125 \text{ GeV}$  ( $\rightarrow 250 \text{ GeV}?$   $\rightarrow 500 \text{ GeV}?$ )



# ILC







## Utilizable as a fixed-target experiment @ ILC beam dump !

Kanemura, Moroi, Tanabe [[1507.02809](#)]

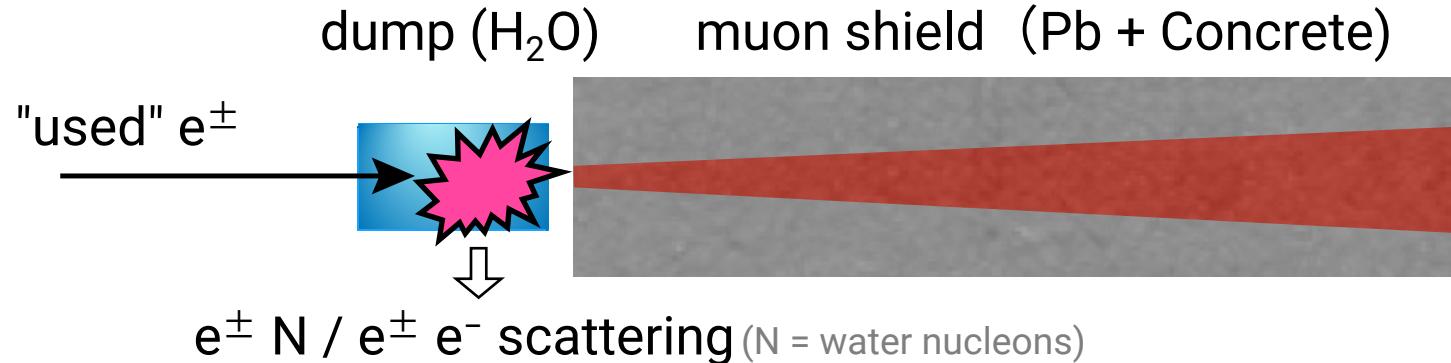
center-of-mass energy		#events	cost
$E_{CM}$ ( $= \sqrt{s}$ )			
beam-beam collision	<b>Higher</b>	less	\$\$\$\$\$
fixed-target collision	lower	<b>more</b>	<b>\$\$</b>

**Money for detector only!**

For  $E_{beam} = 125$  GeV [throughout this talk]

$$E_{CM} = \sqrt{2mE_{beam}} = \begin{cases} 15 \text{ GeV} & (e^\pm N) \\ 0.36 \text{ GeV} & (e^\pm e^-) \end{cases}$$

→ **Searches for  
sub-GeV new particles**



## Utilizable as a fixed-target experiment @ ILC beam dump !

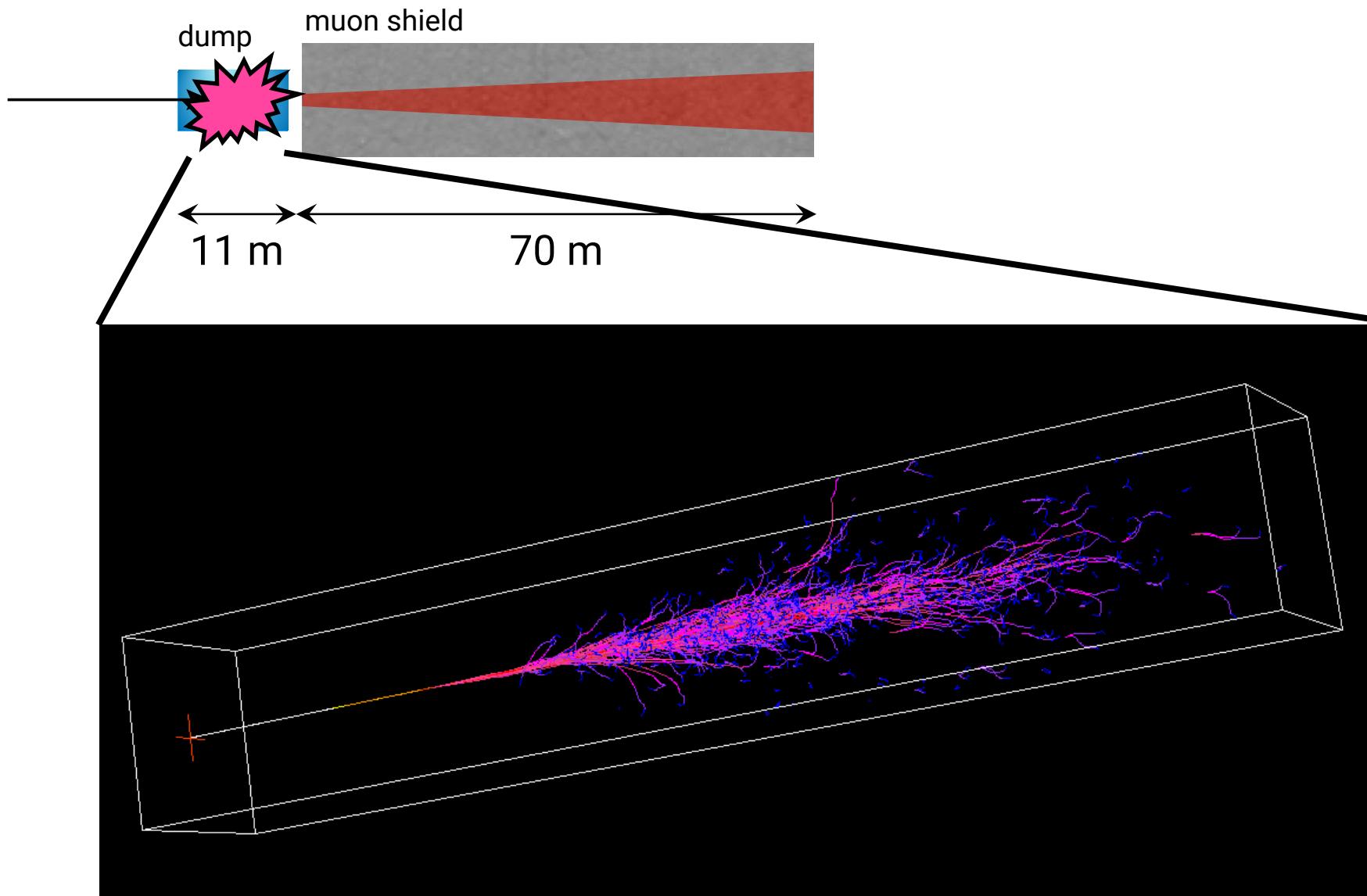
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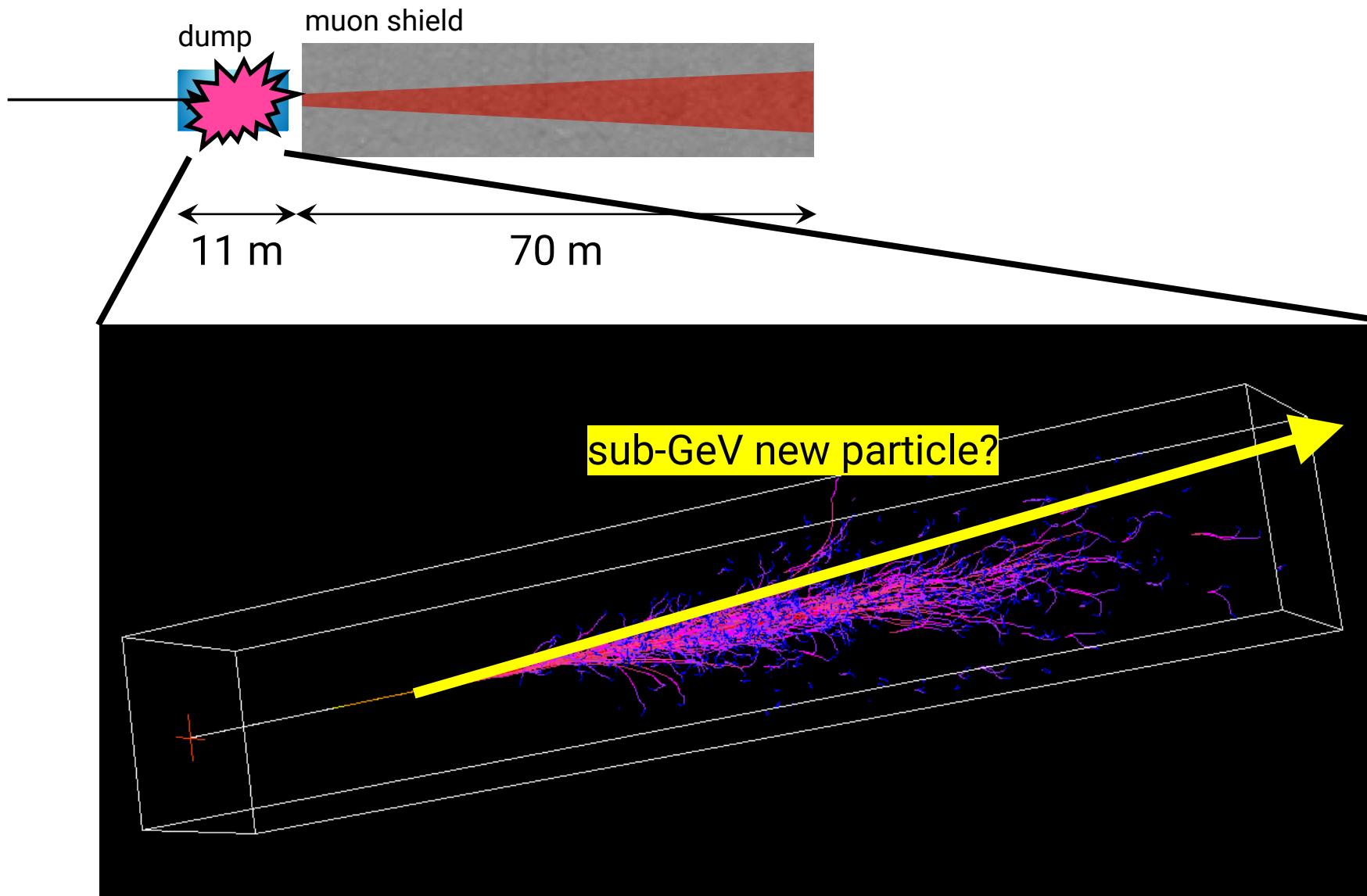
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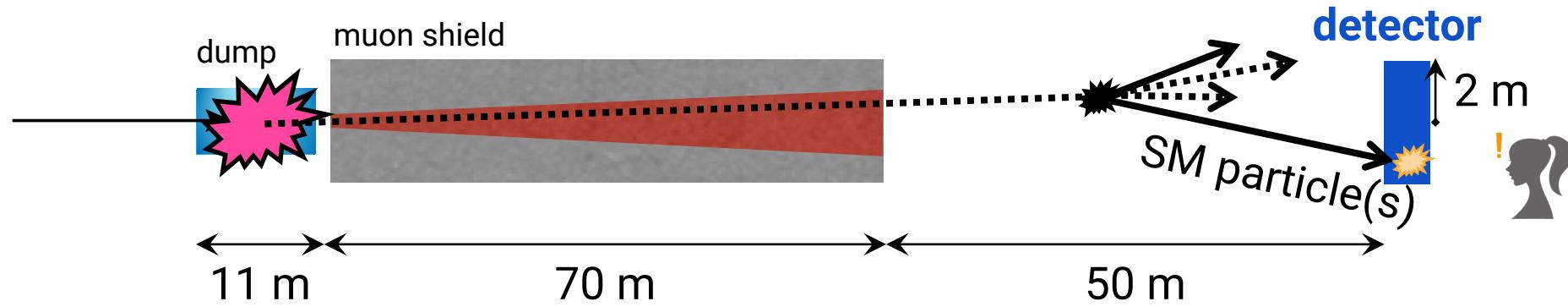
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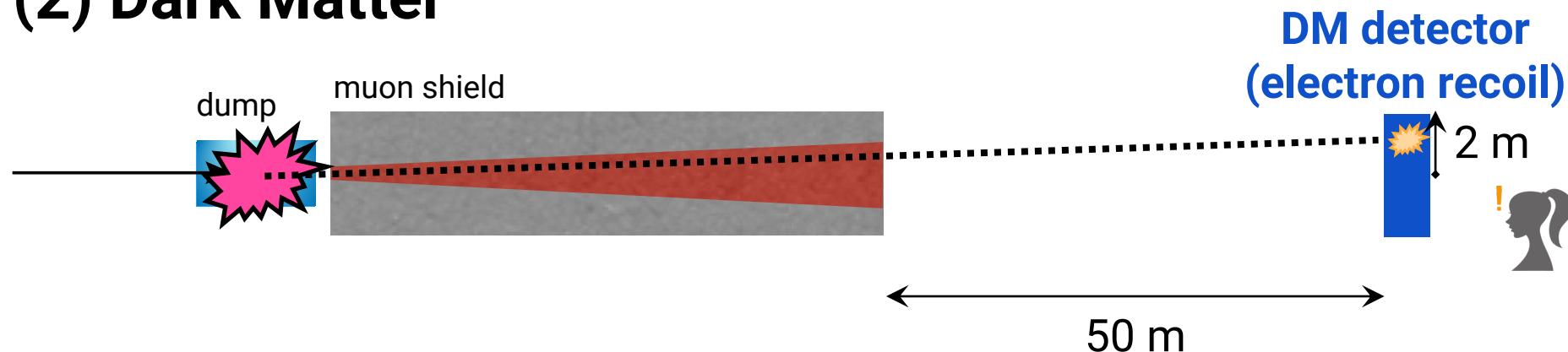
# (1) Meta-stable, decaying into SM (and other) particles



Sakaki, Ueda [2009.13790]

Asai, Iwamoto, Sakaki, Ueda [2105.13768]

# (2) Dark Matter



Asai, Iwamoto, Perelstein, Sakaki, Ueda [2301.03816]

# (1) Meta-stable, decaying into SM (and other) particles

Still “Conceptual estimation”

Monte Carlo simulation  
(for fundamental steps)

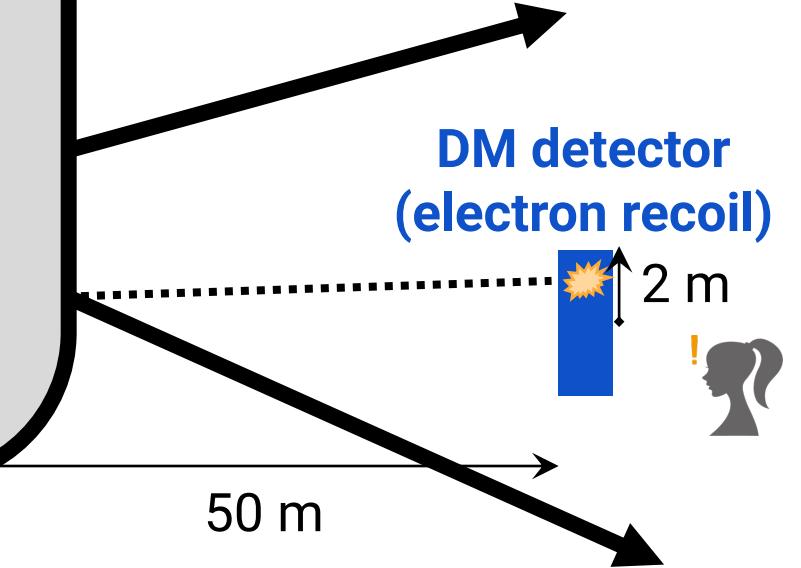
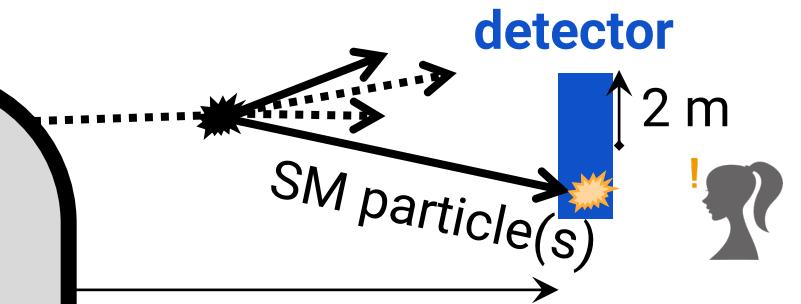
+

Analytic evaluation  
with several approximations

To be done: Full Monte Carlo

(I need to find an easy/doable method...)

dump muon shield



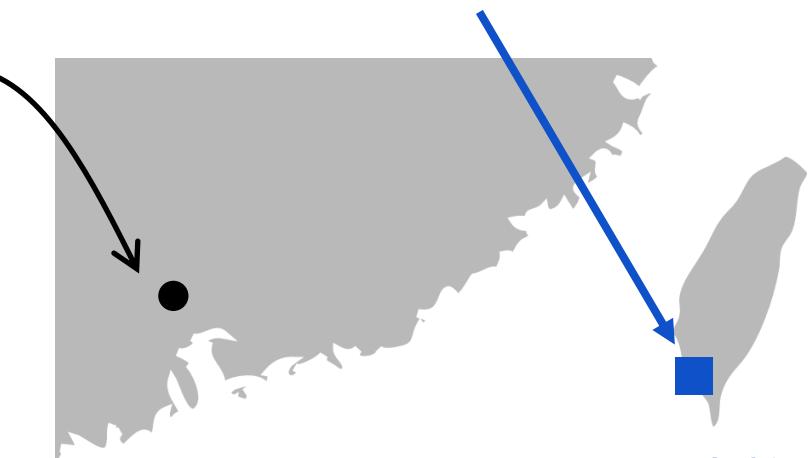
# Advertisement

I've joined  
National Sun Yat-sen U.  
(Feb. 2023)



國立中山大學  
National Sun Yat-sen University

cf. Different from  
“Sun Yat-sen University”  
中山大学 [Enomoto-san]



Kaohsiung 高雄 city

# Advertisement



**Sun Yat-sen** [孫逸仙]

= Sun Wen [孫文]

= 孫**中山**

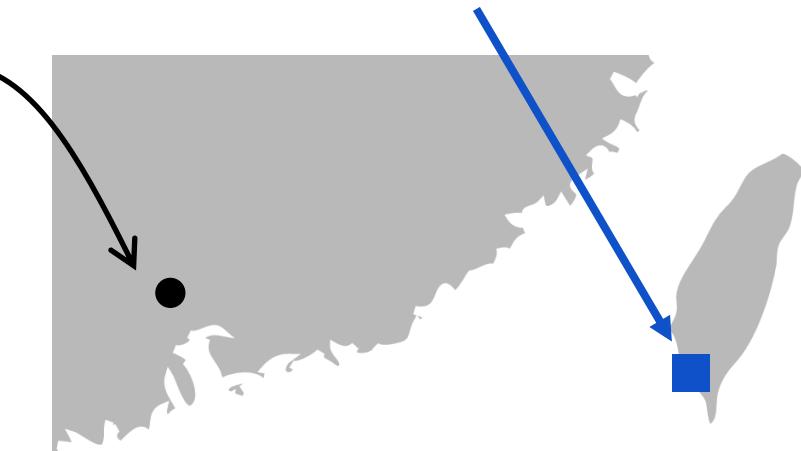
= 高野 長雄

= 中山 樵



國立中山大學  
National Sun Yat-sen University

cf. Different from  
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中山大学                    [Enomoto-san]

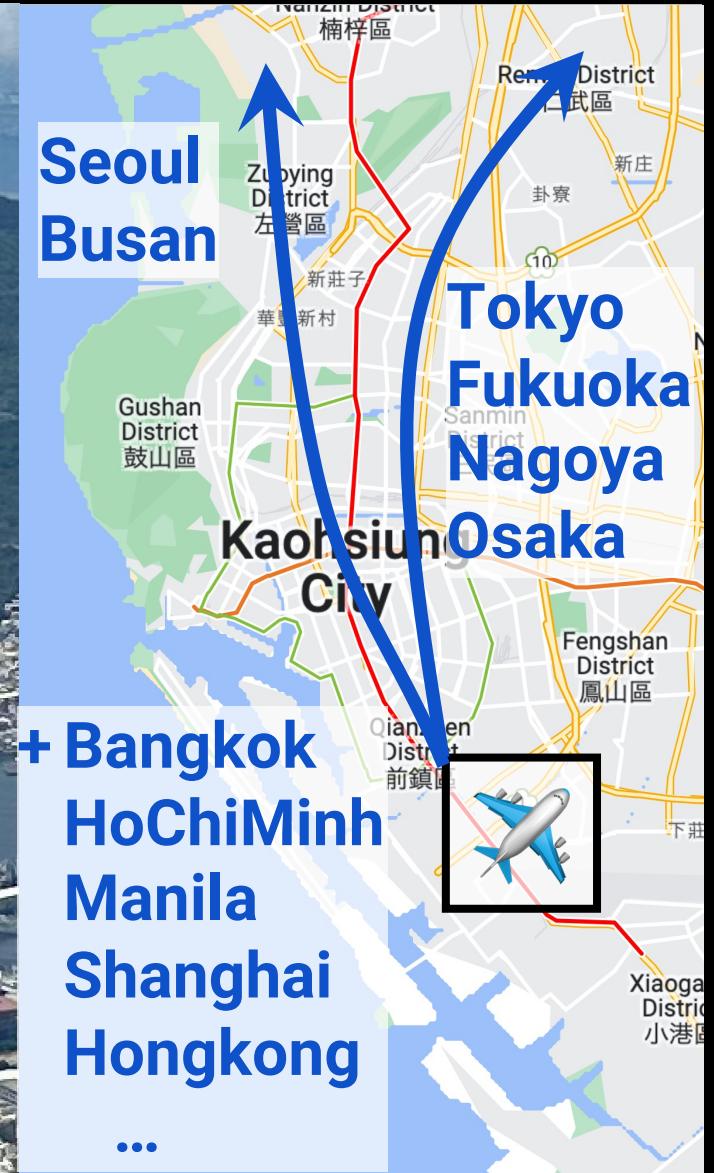


Kaohsiung 高雄 city

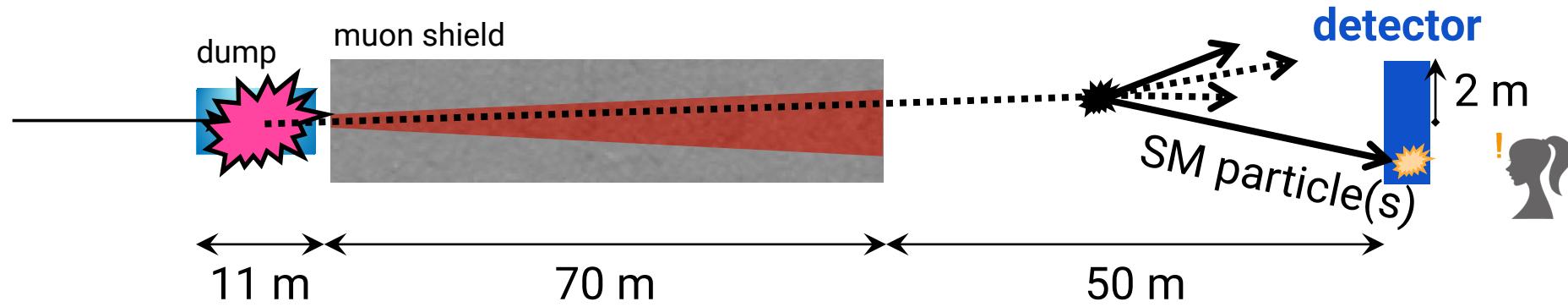
# Advertisement



# Advertisement



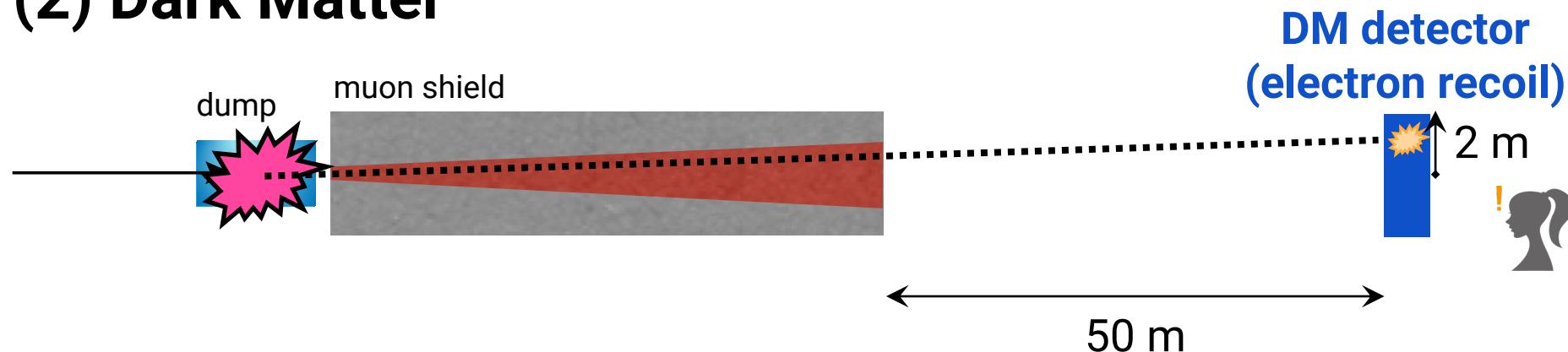
# (1) Meta-stable, decaying into SM (and other) particles



Sakaki, Ueda [[2009.13790](#)]

Asai, Iwamoto, Sakaki, Ueda [[2105.13768](#)]

# (2) Dark Matter



Asai, Iwamoto, Perelstein, Sakaki, Ueda [[2301.03816](#)]

# Benchmark Hypotheses:

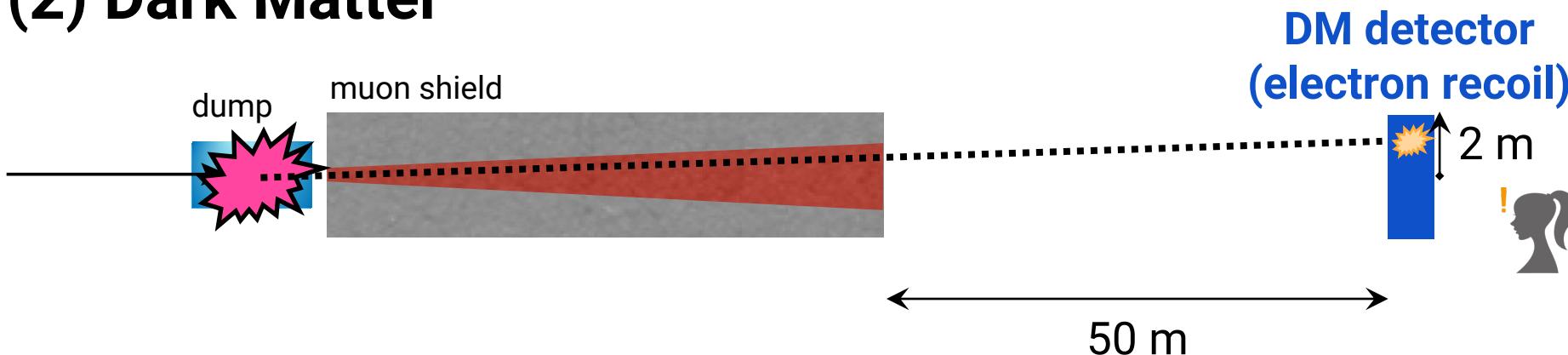
Dark-photon mediator +

- Scalar elastic DM
- Scalar inelastic DM
- Majorana DM
- pseudo-Dirac DM

$(m_{DM} < 1 \text{ GeV})$

**→ electron recoil**  
= DM signal.

## (2) Dark Matter



Asai, Iwamoto, Perelstein, Sakaki, Ueda [2301.03816]

$$\mathcal{L}_{\text{int}} = -ig_D A'_\mu (\chi^* \partial^\mu \chi - \chi \partial^\mu \chi^*)$$

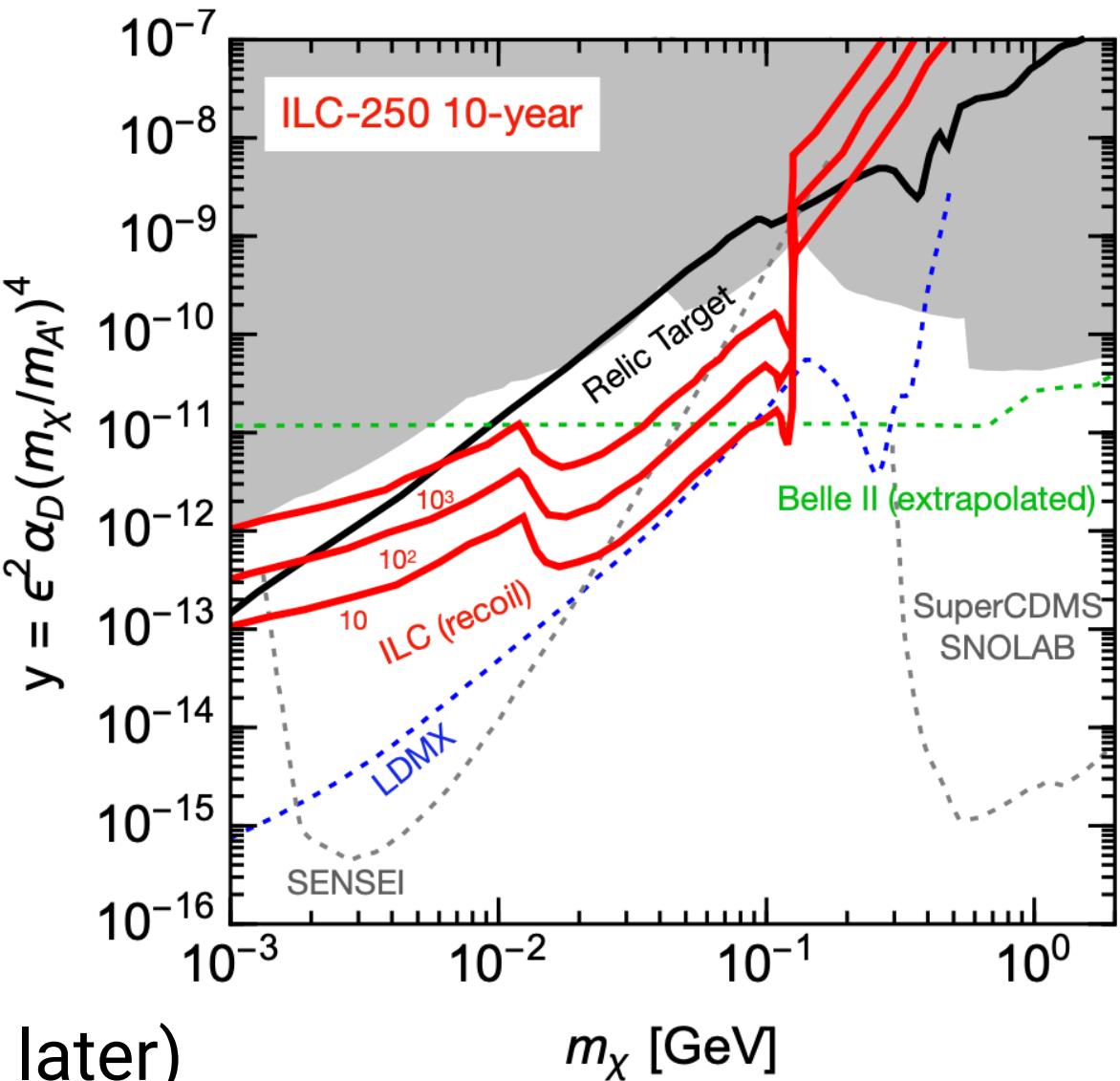
$$\alpha_D = 0.5,$$

$$m_{A'} = 3m_{\text{DM}}$$

**#(signal events) = 1000**

1000  
100  
10

vs. #(BKG)  $\sim O(10)$   
(our crude estimation  $\rightarrow$  later)

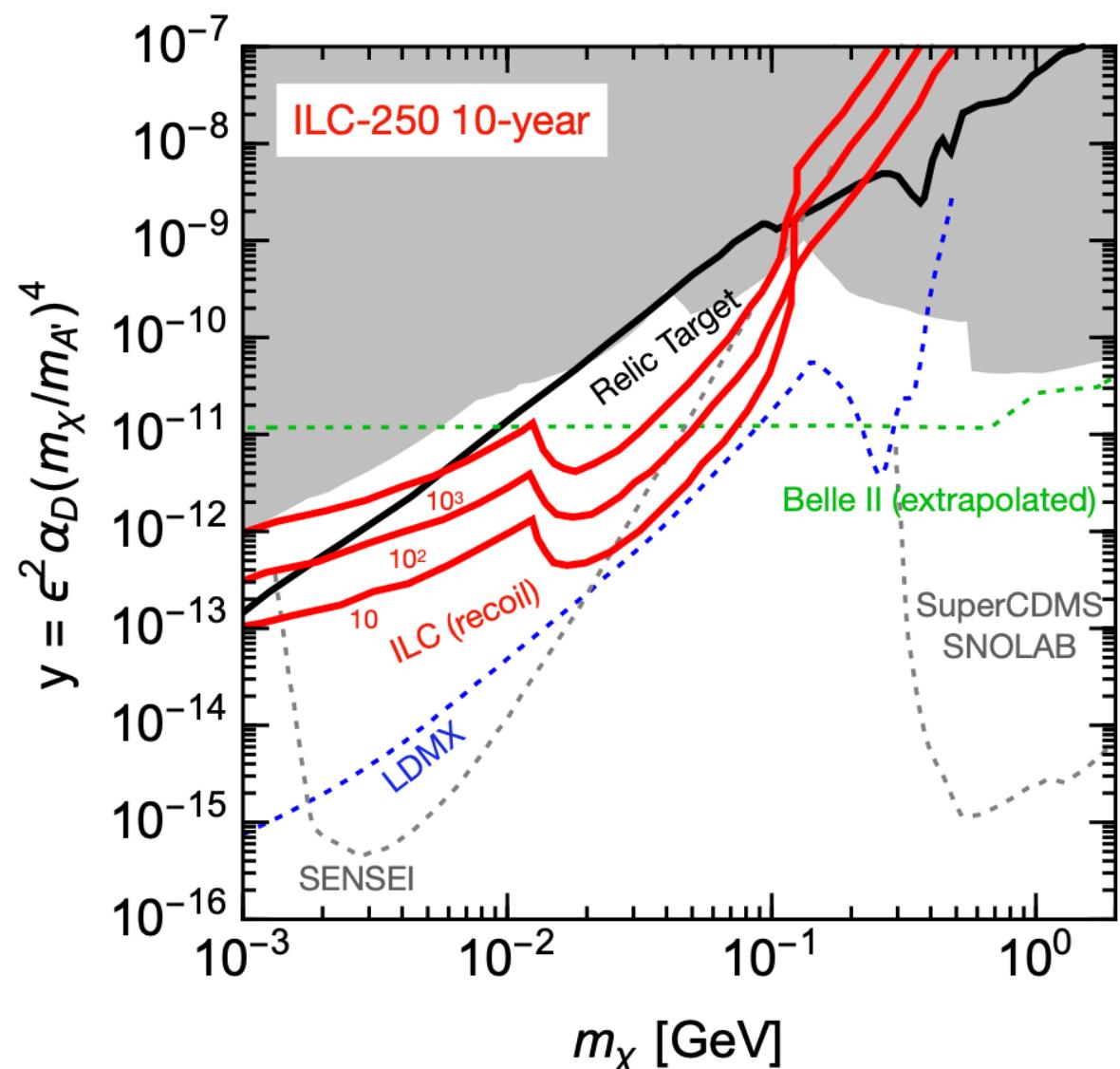


## Benchmark Hypotheses:

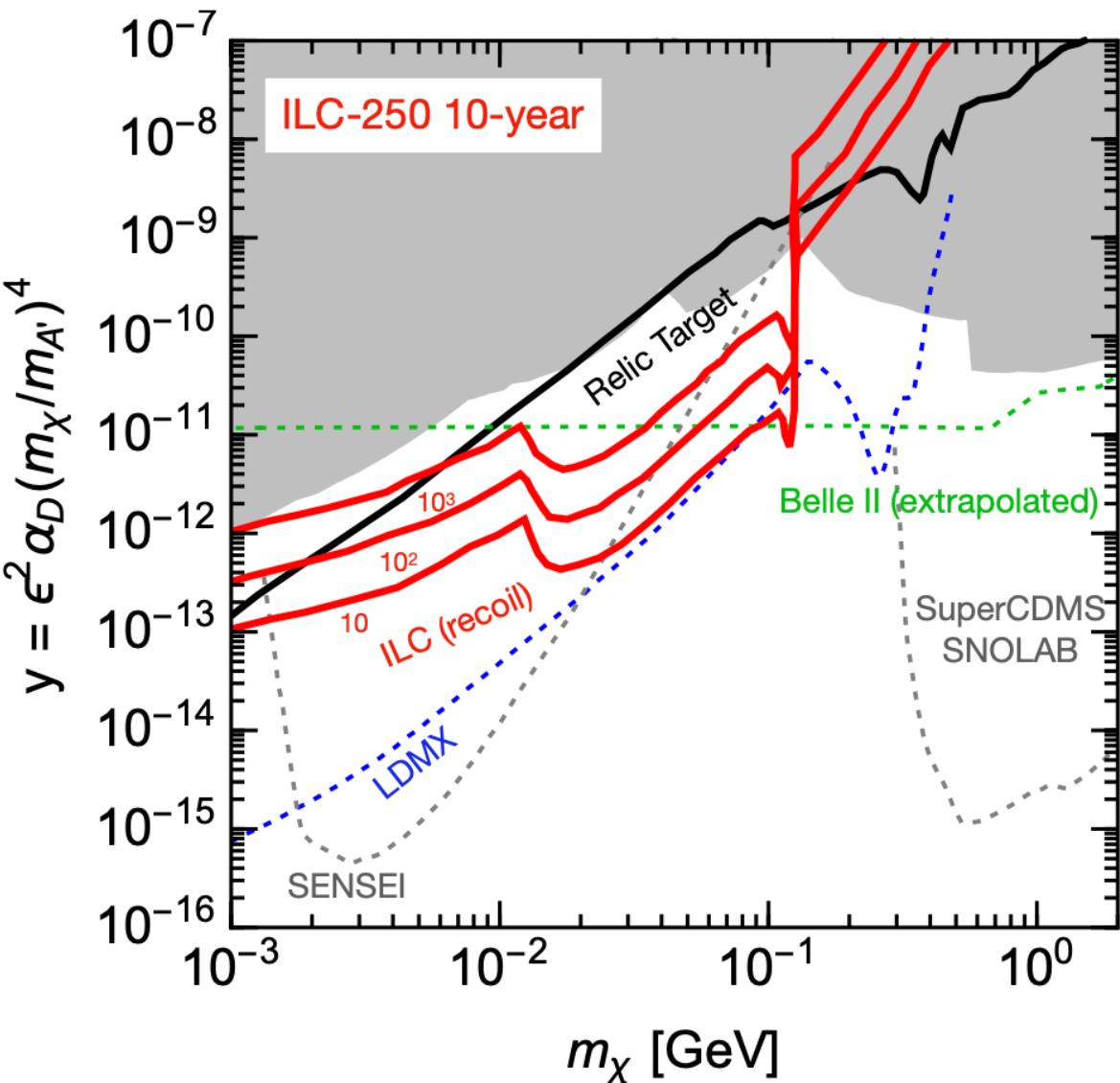
- Dark-photon mediator +
- Scalar elastic DM
  - Scalar inelastic DM
  - Majorana DM
  - pseudo-Dirac DM
- ( $m_{DM} < 1 \text{ GeV}$ )
- **electron recoil**  
= DM signal.
- V.S.
- neutrinos: Beam oriented → background events
  - neutrinos: Cosmic-ray oriented

## Benchmark Hypotheses:

- Dark-photon mediator +
- Scalar elastic DM
  - Scalar inelastic DM
  - Majorana DM
  - pseudo-Dirac DM
- hard work** → **electron recoil**  
= DM signal.
- by Sakaki- & Ueda-sans**
- neutrinos: Beam oriented** → background events
- neutrinos: Cosmic ray oriented**
- by Ueda- & Asai-sans**
- ( $m_{DM} < 1 \text{ GeV}$ )
- V.S.



(a) electron beam dump



(b) positron beam dump

- DM searches at ILC beam dump **seems** nice!
  - cost/performance.

... a bit deeper on  
“background”

**■ Beam into water dump**

→ neutrinos

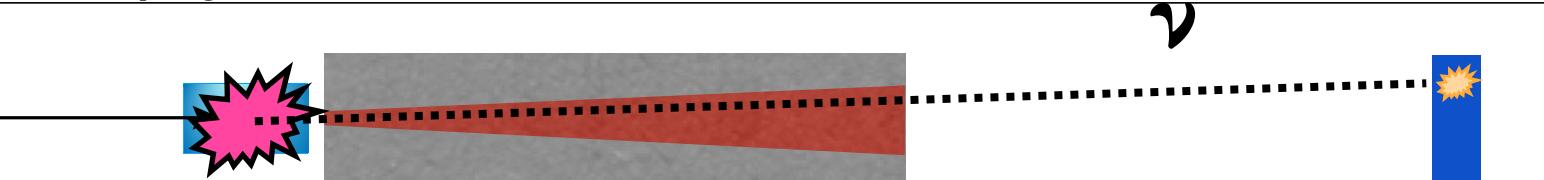
→ background events.

**■  $\nu$ -flux by Monte Carlo simulation**

(PYTHIA 8.3 + PHITS 3.25)

**■ Event selection:**

$$E_{\text{recoil}} > 1 \text{ GeV}$$

**electron recoil by neutrinos**

$$\nu e^- \rightarrow \nu e^-, \quad \bar{\nu} e^- \rightarrow \bar{\nu} e^-$$

**Nuclear recoil by neutrinos : mis-ID**

$$\nu_\ell n \rightarrow \ell^- p, \quad \bar{\nu}_\ell p \rightarrow \ell^+ n,$$

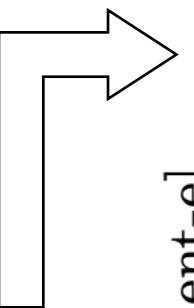
$$\nu p \rightarrow \nu p, \quad \bar{\nu} p \rightarrow \bar{\nu} p, \quad \nu n \rightarrow \nu n, \quad \bar{\nu} n \rightarrow \bar{\nu} n,$$

$$\nu_\mu n \rightarrow \mu^- p \pi^0, \quad \bar{\nu}_\mu p \rightarrow \mu^+ n \pi^0,$$

$$\nu_\mu p \rightarrow \nu_\mu p \pi^0, \quad \bar{\nu}_\mu p \rightarrow \bar{\nu}_\mu p \pi^0,$$

$$\nu_\mu n \rightarrow \nu_\mu n \pi^0, \quad \bar{\nu}_\mu n \rightarrow \bar{\nu}_\mu n \pi^0.$$

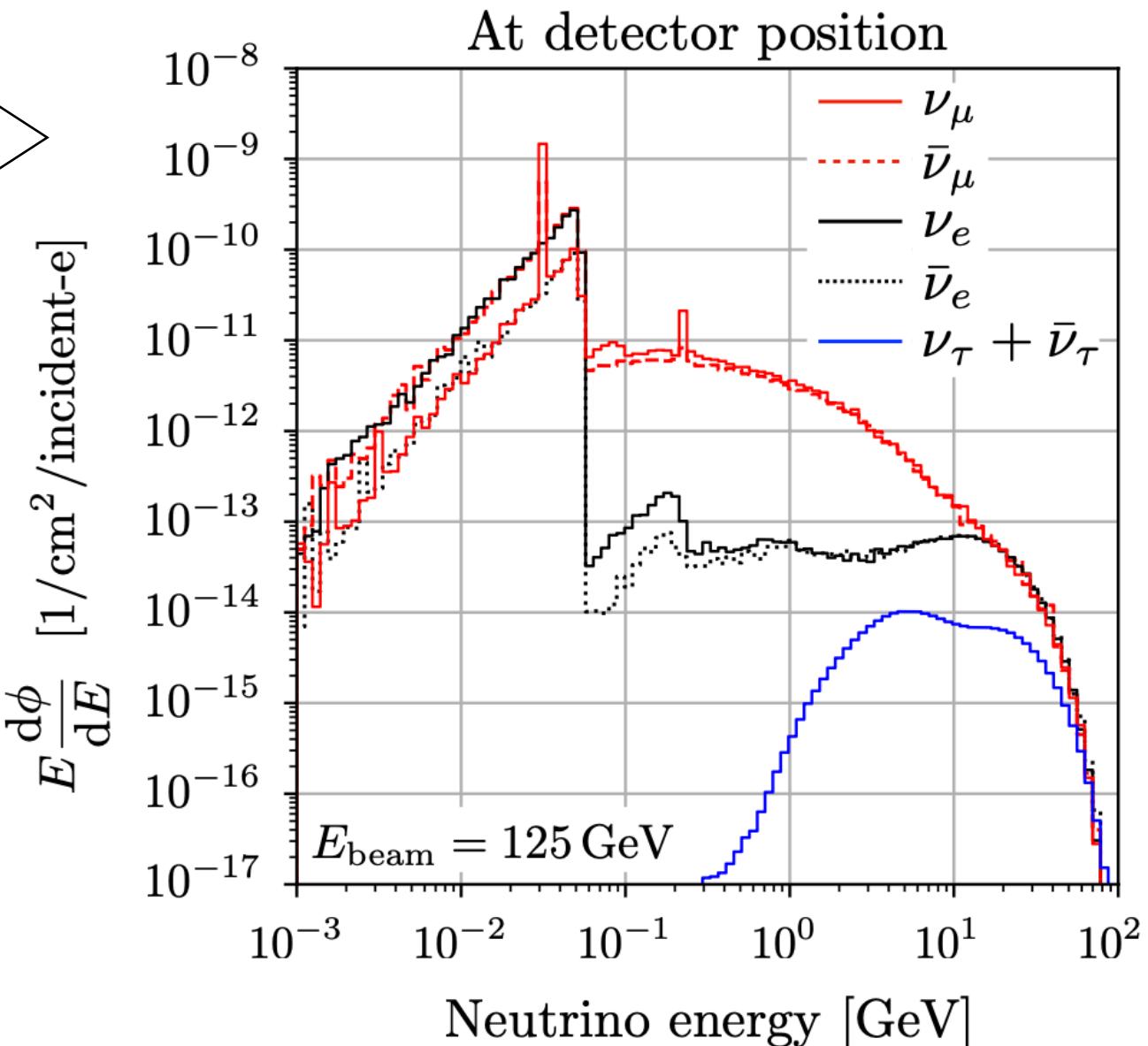
- Beam into water dump
  - neutrinos
  - background events.



- $\nu$ -flux by Monte Carlo simulation  
(PYTHIA 8.3 + PHITS 3.25)

- Event selection:

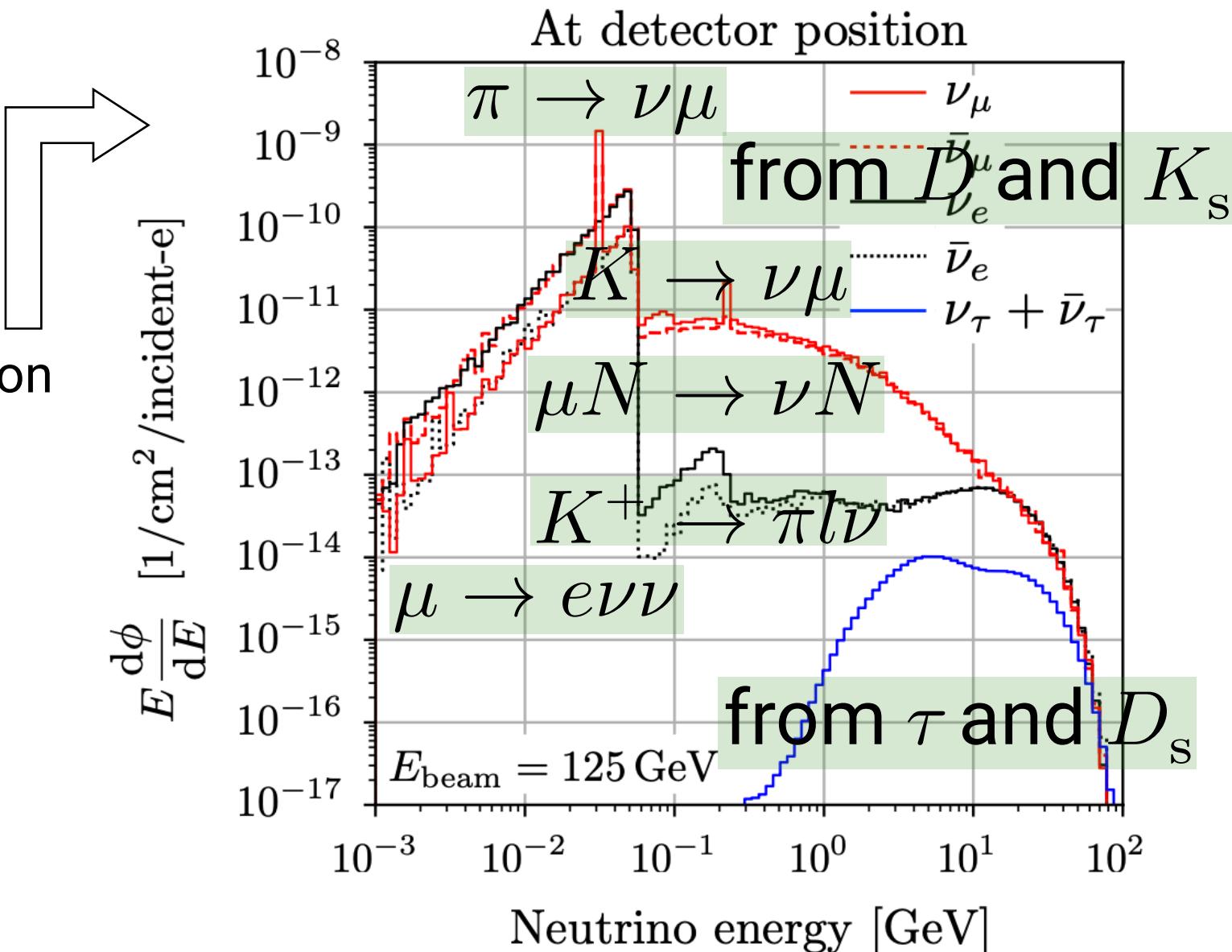
$$E_{\text{recoil}} > 1 \text{ GeV}$$



- Beam into water dump
  - neutrinos
  - background events.

- $\nu$ -flux by Monte Carlo simulation  
(PYTHIA 8.3 + PHITS 3.25)

- Event selection:  
 $E_{\text{recoil}} > 1 \text{ GeV}$



**■ Beam into water dump**

→ neutrinos

→ background events.

**■  $\nu$ -flux by Monte Carlo simulation**

(PYTHIA 8.3 + PHITS 3.25)

**■ Event selection:**

$$E_{\text{recoil}} > 1 \text{ GeV}$$

$\sim 1 \text{ ev/year}$

**electron recoil by neutrinos**

$$\nu e^- \rightarrow \nu e^-, \quad \bar{\nu} e^- \rightarrow \bar{\nu} e^-$$

**nuclear recoil by neutrinos : mis-ID**

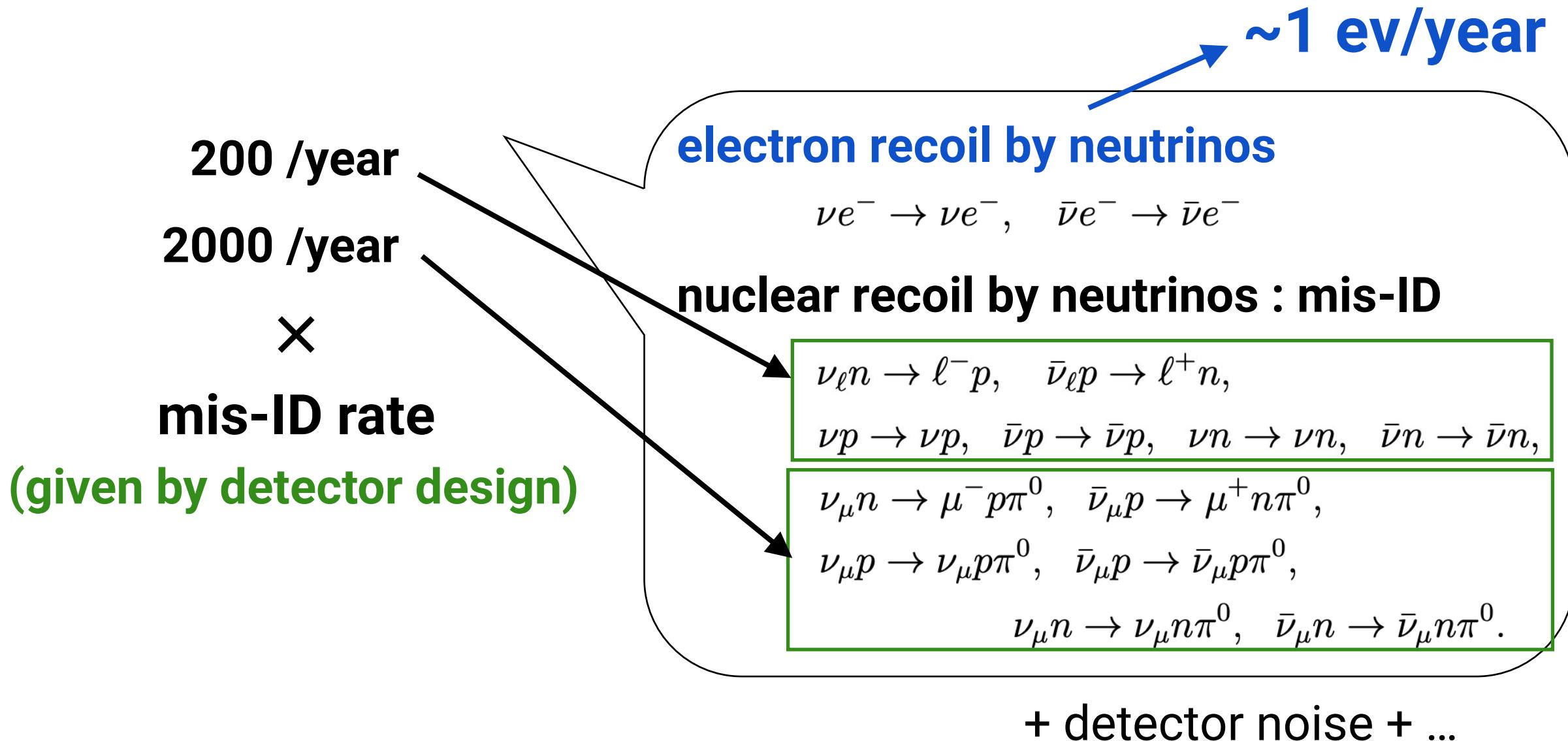
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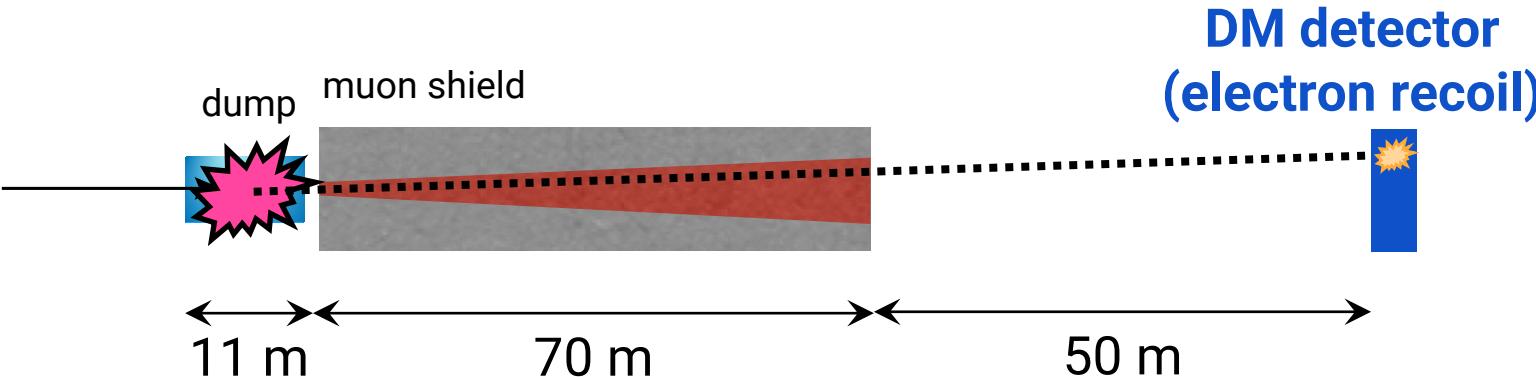
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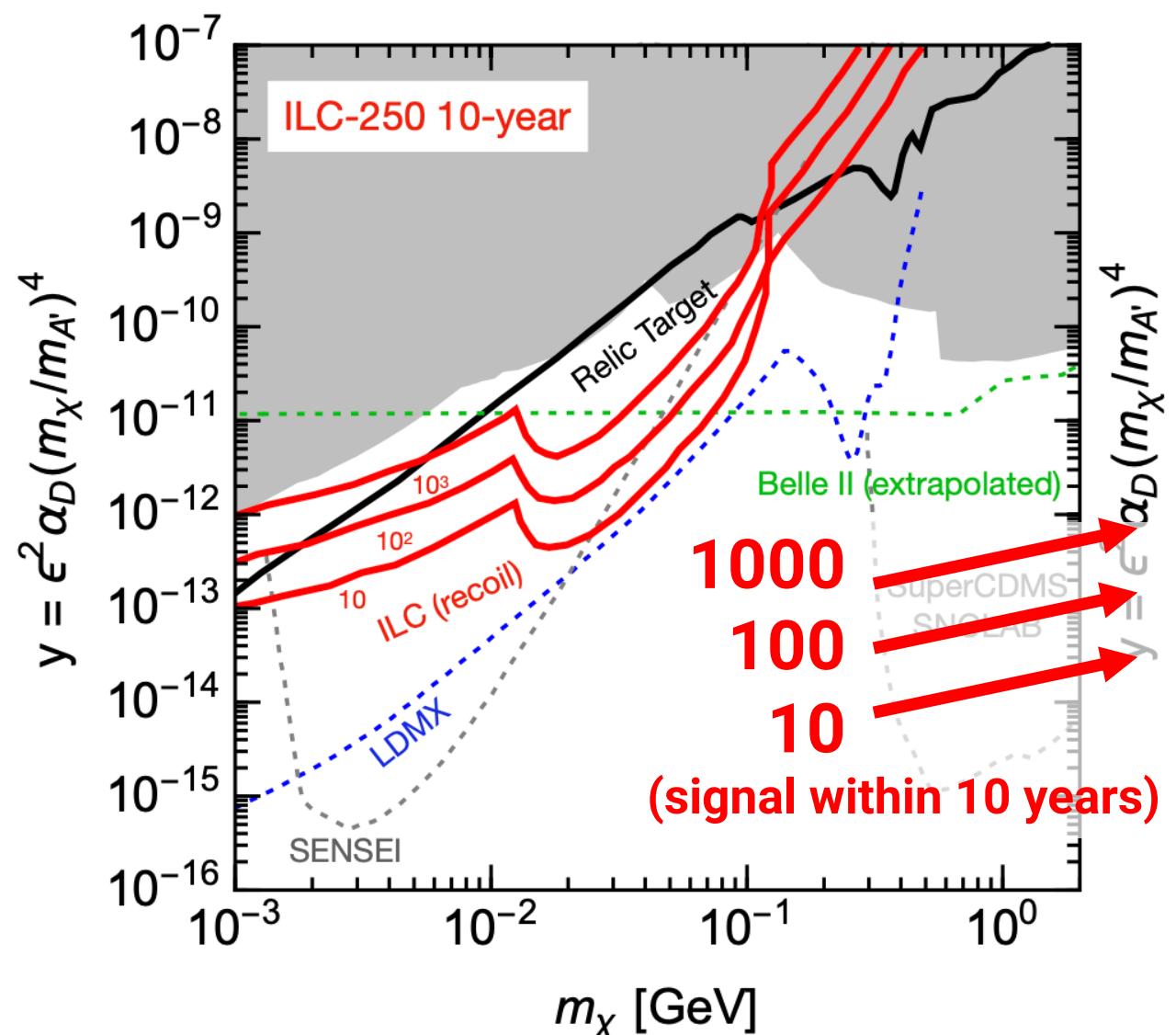


## ■ Neutrinos from dumped beam

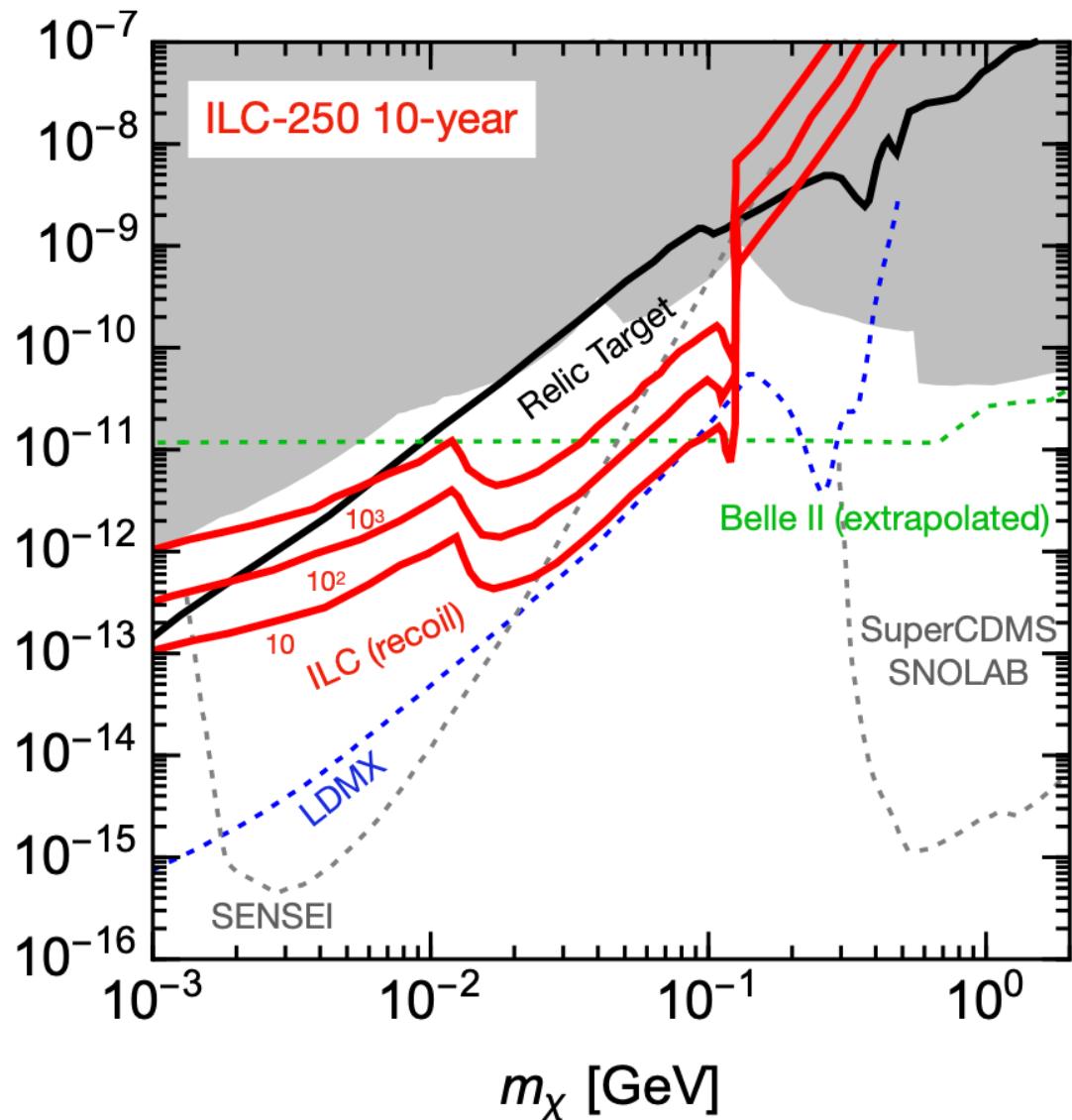
- electron recoil                               $\sim 10$     / 10 years
- nuclear recoil  $\rightarrow$  mis-ID     $\sim 20000 \times$  mis-ID rate      / 10 years

## ■ Neutrinos from cosmic rays    $\sim 0(10)$    / 10 years

## ■ Noise    $\sim ??$

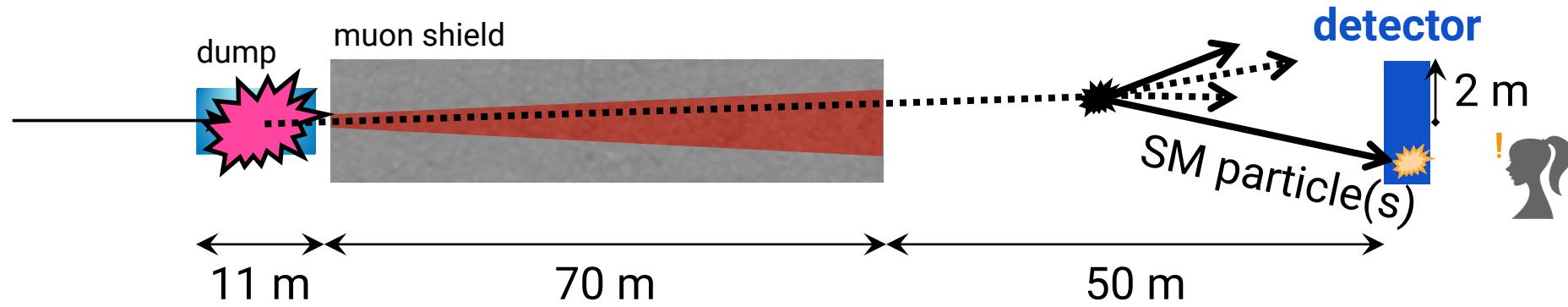


(a) electron beam dump



(b) positron beam dump

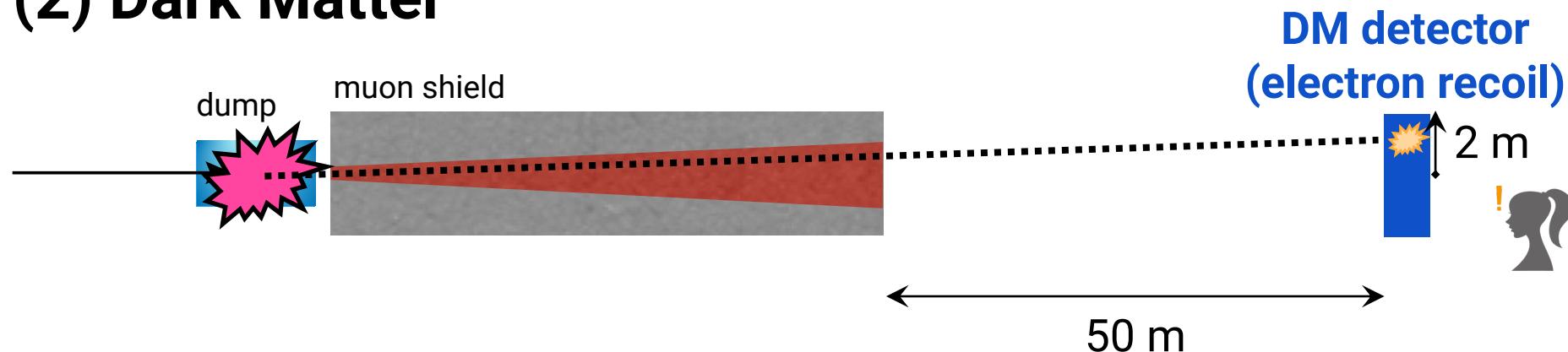
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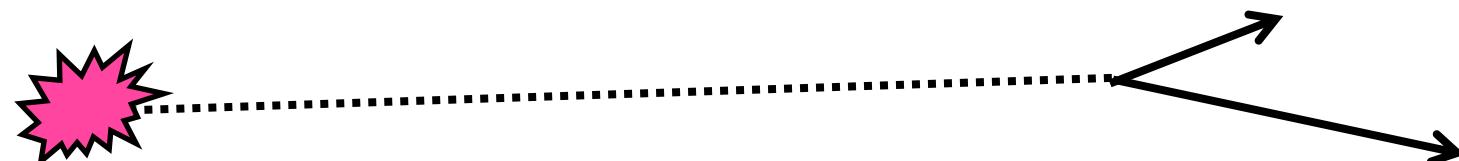
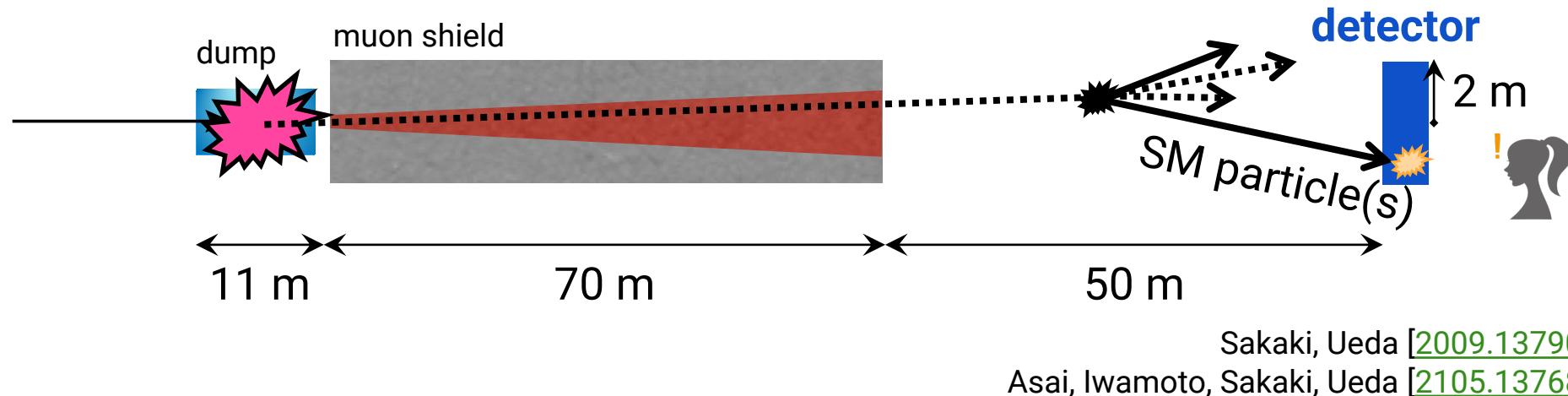
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Asai, Iwamoto, Perelstein, Sakaki, Ueda [2301.03816]

**if time allows...**

# (1) Meta-stable, decaying into SM (and other) particles

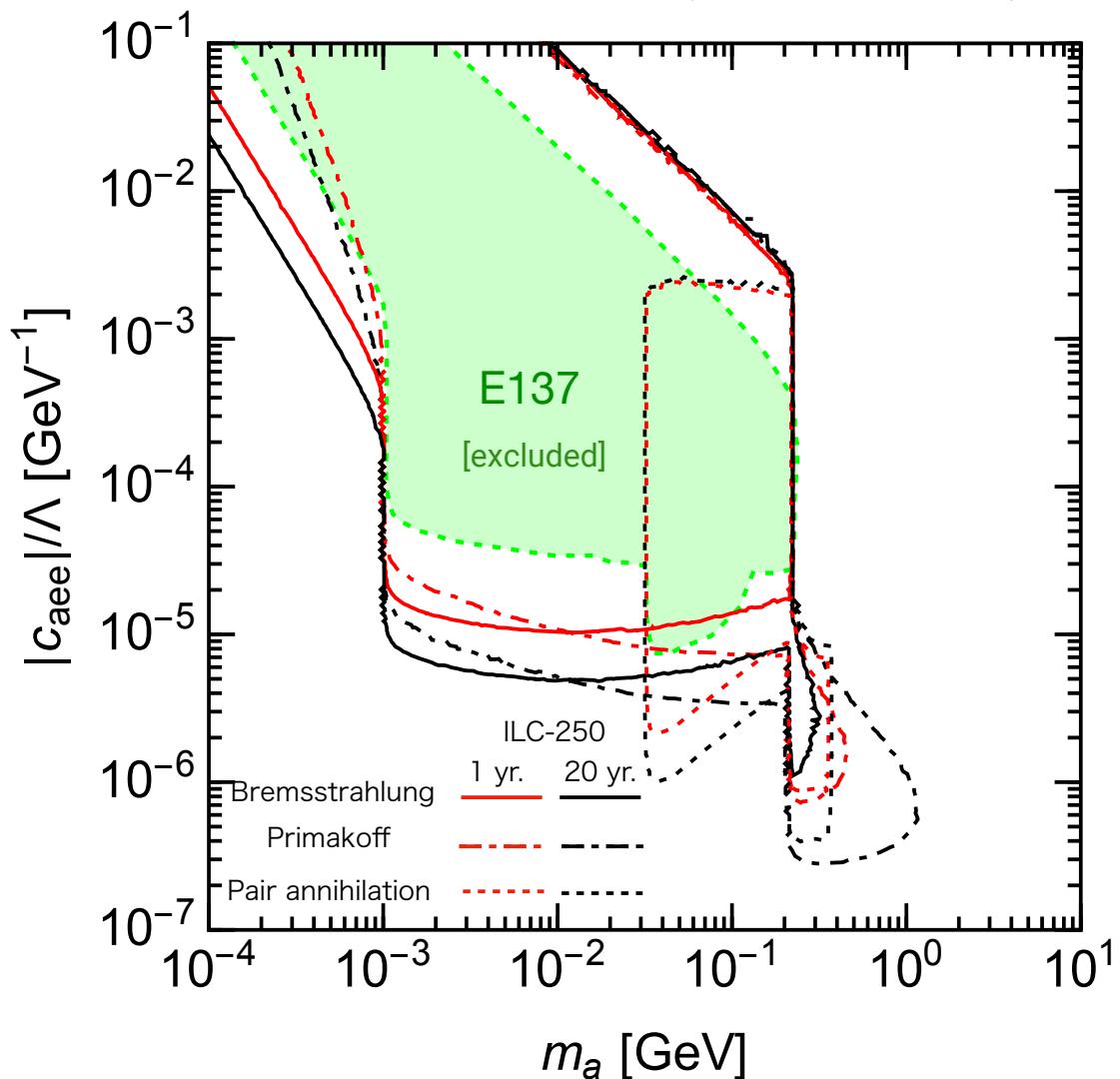


dark photon  $\rightarrow l^+l^-$

axion-like particle  $\rightarrow l^+l^-, \gamma\gamma, \dots$

extra scalar boson  $\rightarrow l^+l^-, \gamma\gamma, \dots$

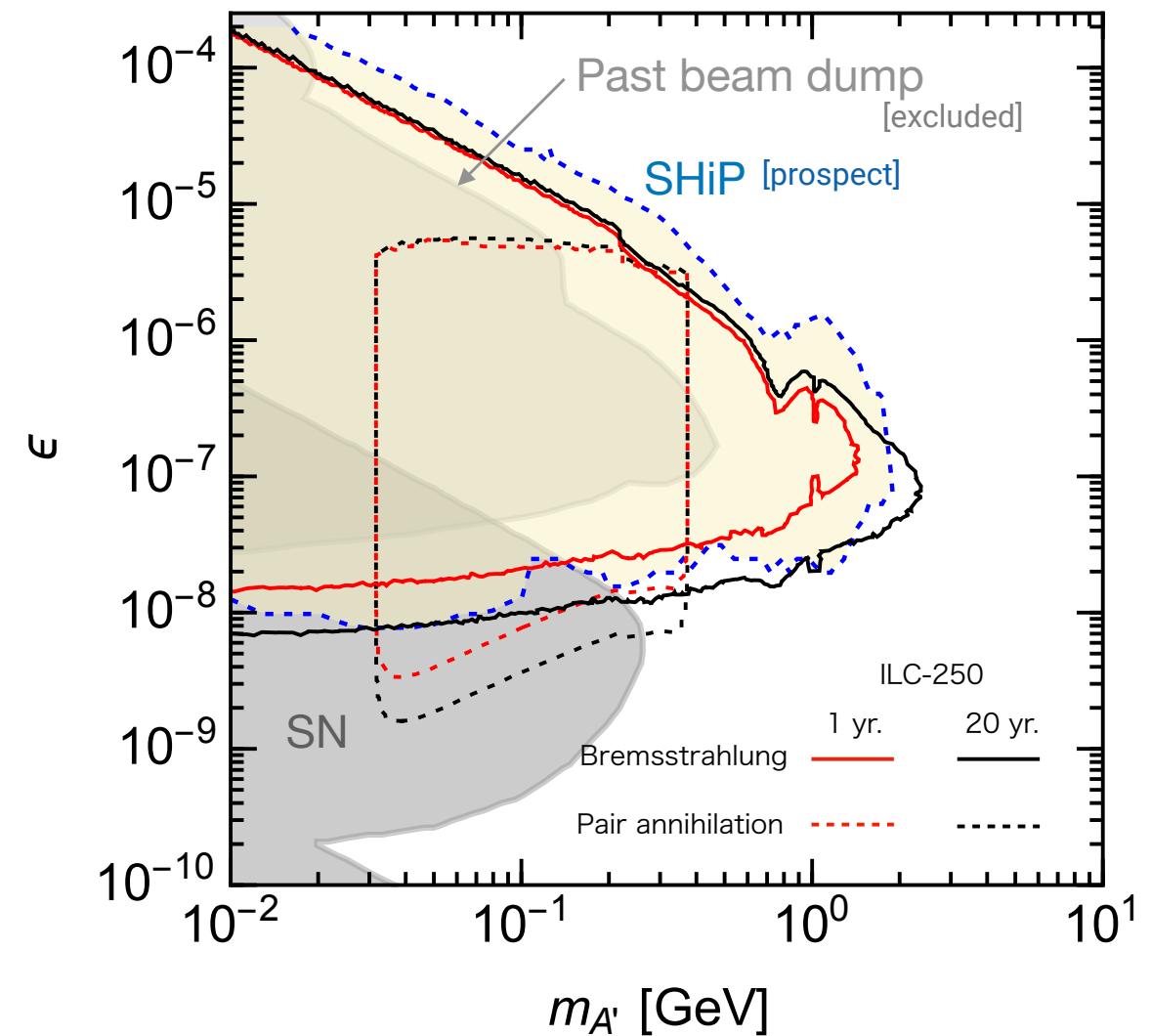
## axion-like particles (positron dump)



$$\mathcal{L} \supset \frac{1}{2}\partial_\mu a\partial^\mu a - \frac{1}{2}m_a^2 a^2 + \sum_{\ell=e,\mu,\tau} \frac{1}{2}\frac{c_{\text{all}}}{\Lambda} \partial_\mu a \bar{\ell} \gamma^\mu \gamma_5 \ell - \frac{1}{4}g_{a\gamma\gamma} a F_{\mu\nu} \tilde{F}^{\mu\nu},$$

$$c_{aee} = c_{a\mu\mu} = c_{a\tau\tau}$$

## dark photon (positron dump)



$$\mathcal{L} \supset -\frac{1}{4}F'^{\mu\nu}F'_{\mu\nu} + \frac{m_{A'}^2}{2}A'^\mu A'_\mu - \frac{\epsilon}{2}F^{\mu\nu}F'_{\mu\nu}$$