Dark particle production in the ILC beam dumps

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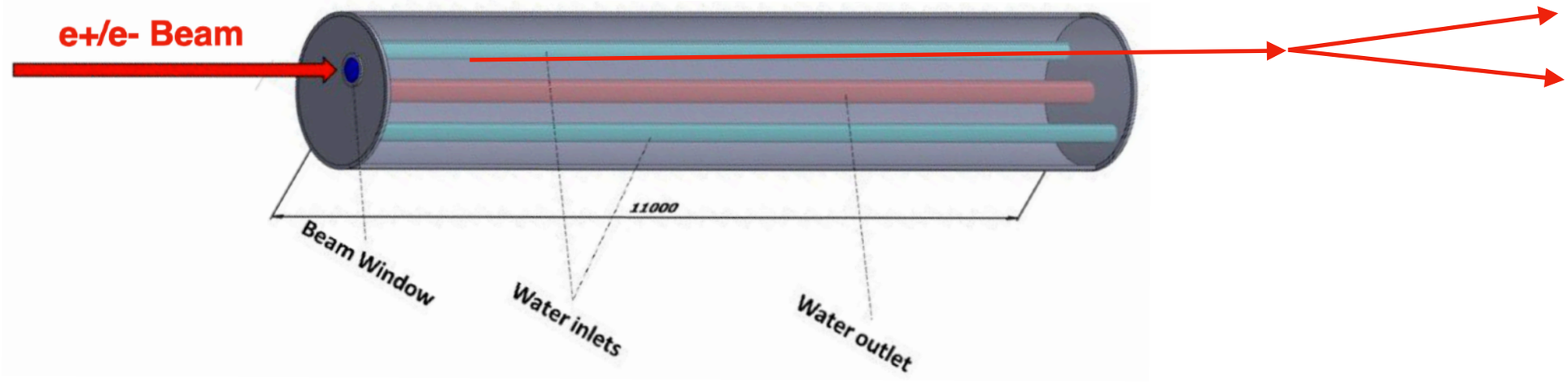
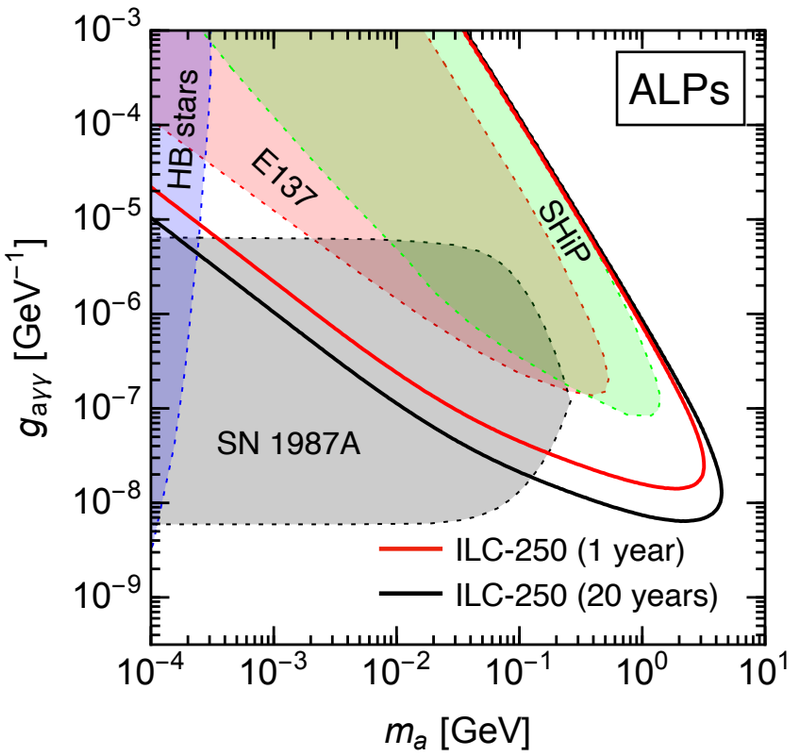
This talk

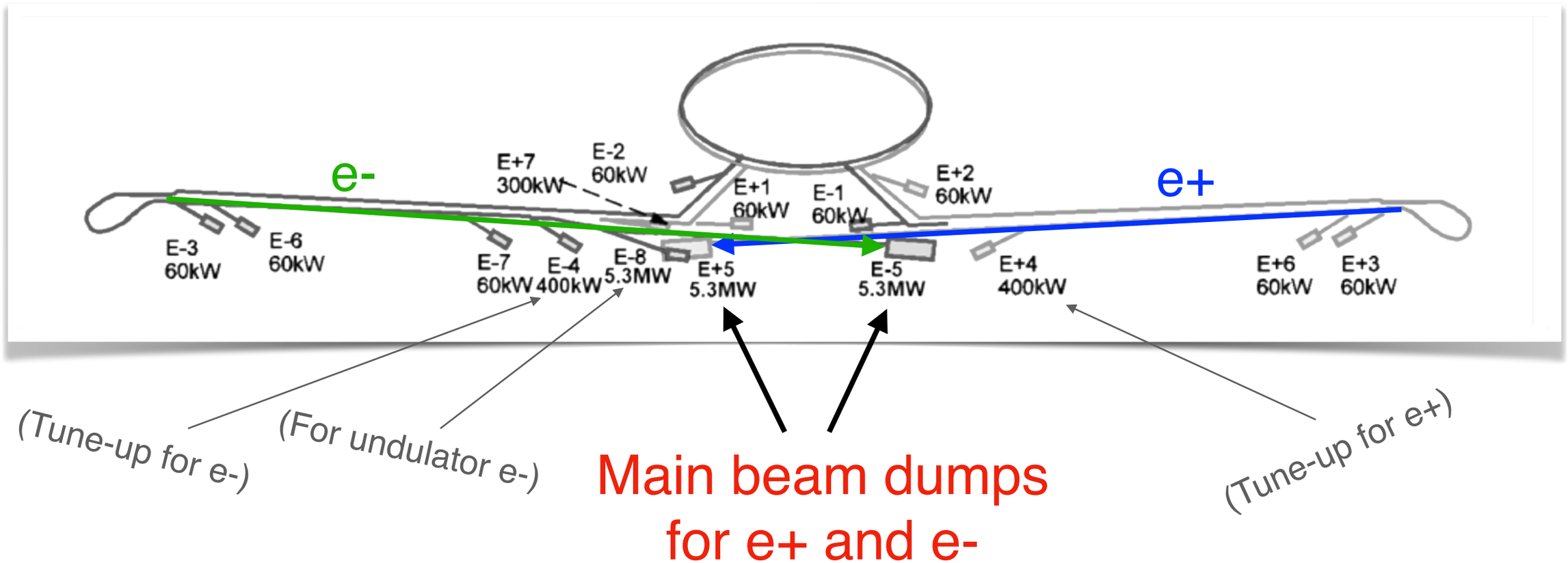
(1) Consider visible decay searches utilizing ILC main beam dumps



(2) Typical sensitivity for the ILC beam dump experiment (with a thick shield setup)



~15 beam dumps



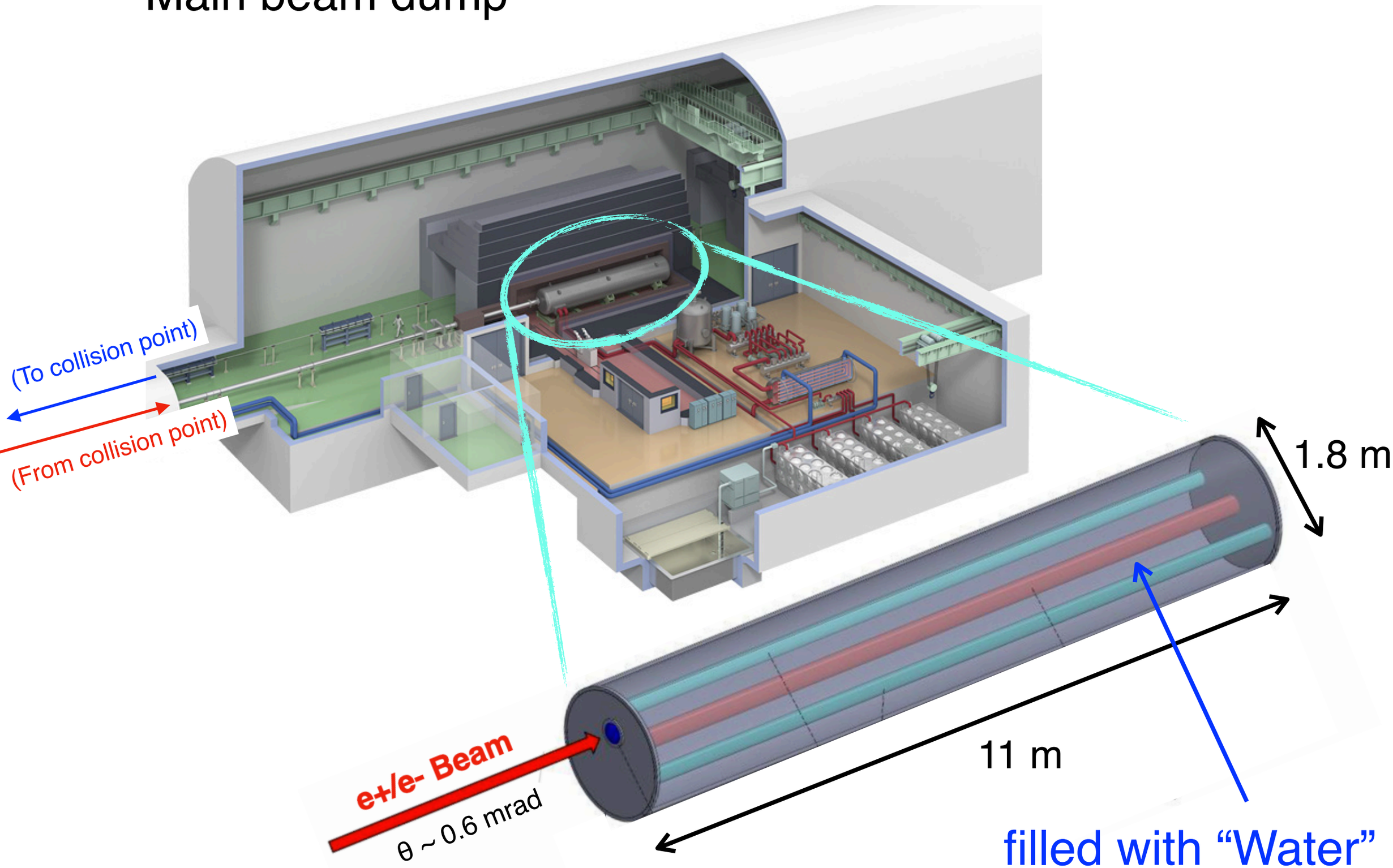
for e+ and e-

- **ILC is a linear collider**

  ➡ ~100% particles are discarded in main beam dumps

- Fixed-Target experiment using the main beam dumps can be performed in parallel with the collider experiment

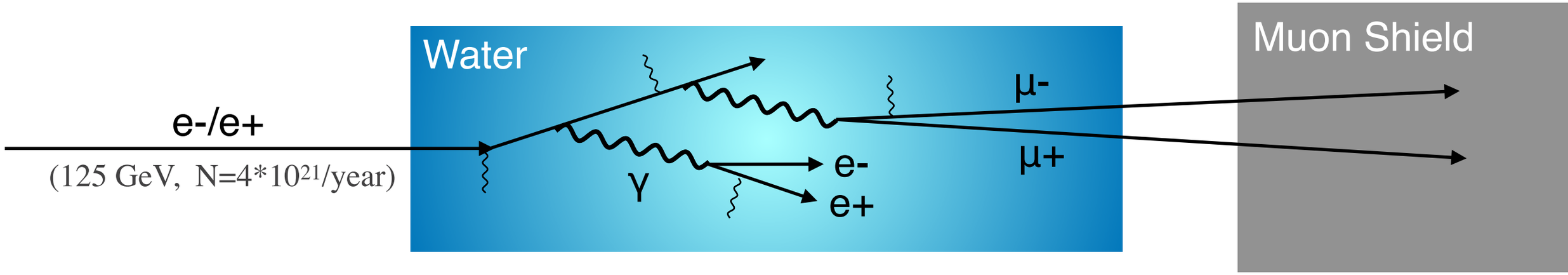
Main beam dump



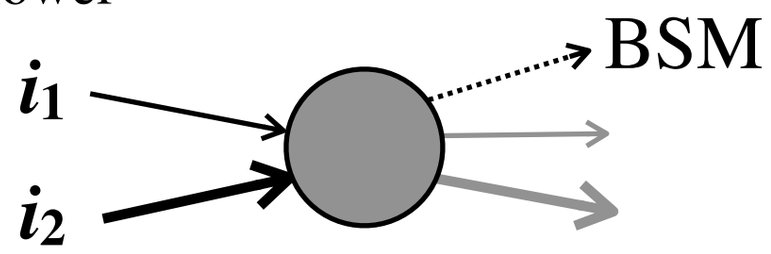
(Base design) P. Satyamurthy, et.al., NIM A 679 (2012)

Being developed by N. Terunuma and Y. Morikawa

Typical processes to generate new particles

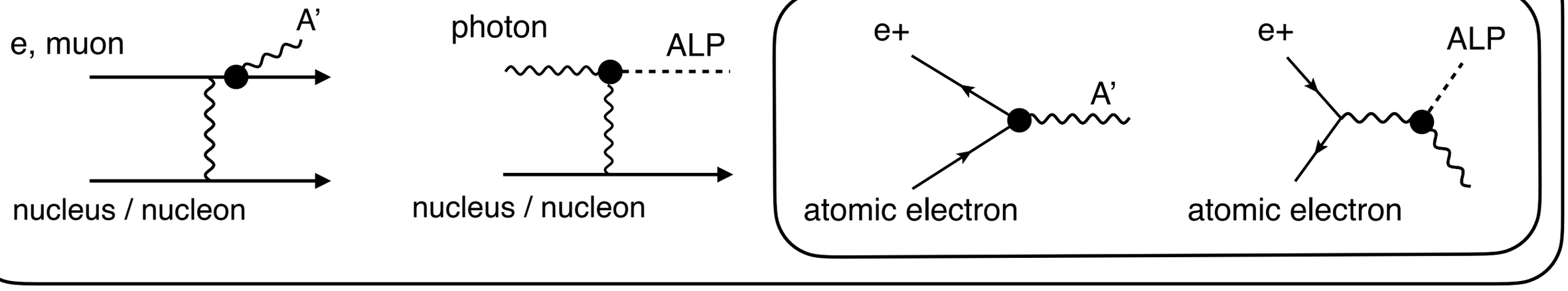


Primary beam or EM shower
(e-, e+, γ, μ, …)

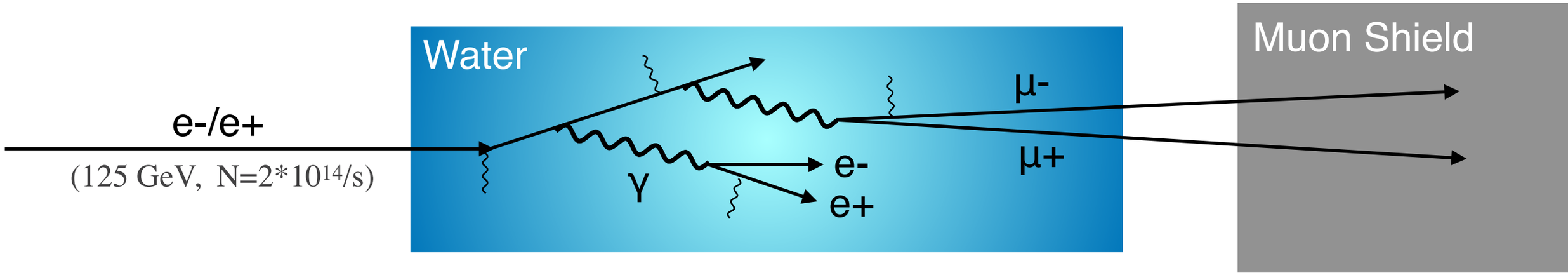


Target particles
(Nucleus / Nucleon / Atomic e⁻)

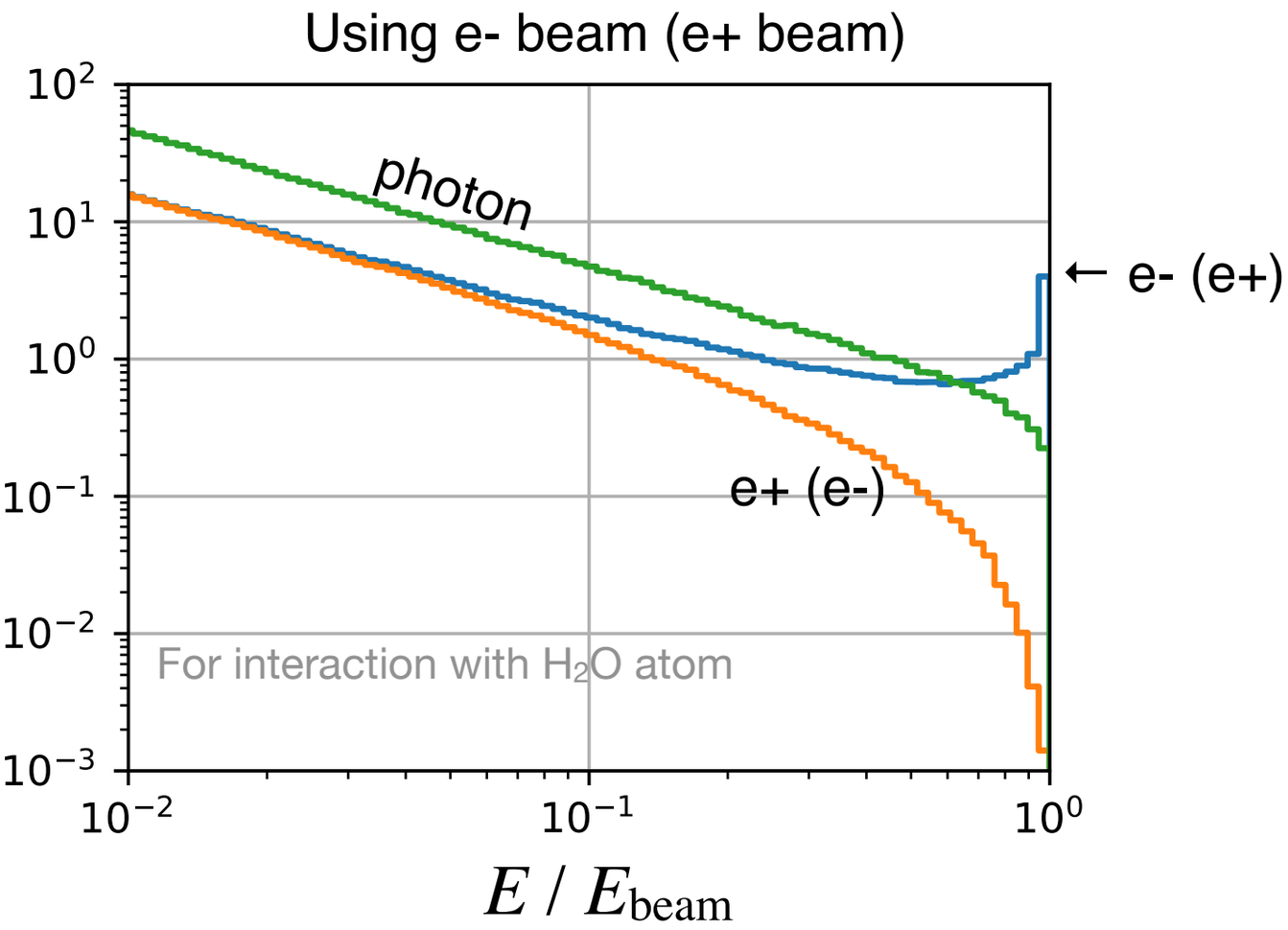
(Examples)



Luminosity for Main beam dump experiments

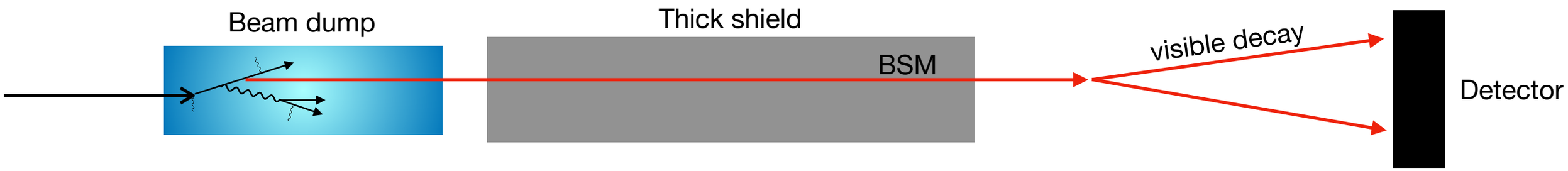


$$\frac{d(\text{Luminosity})}{d\log_{10}(E/E_{\text{beam}})}\ [\text{fb}^{-1}/\text{s}]$$



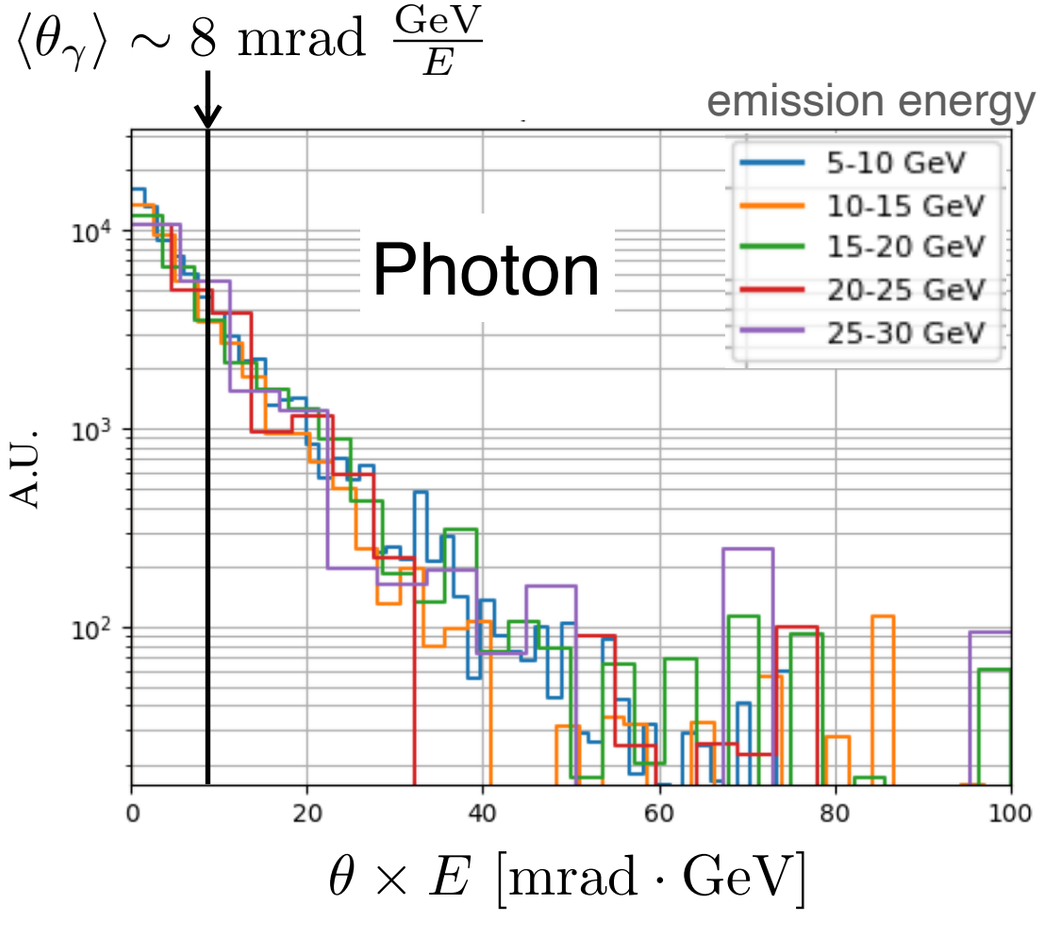
We can utilize the huge Luminosity

A feature of e+/e- beam dump experiments

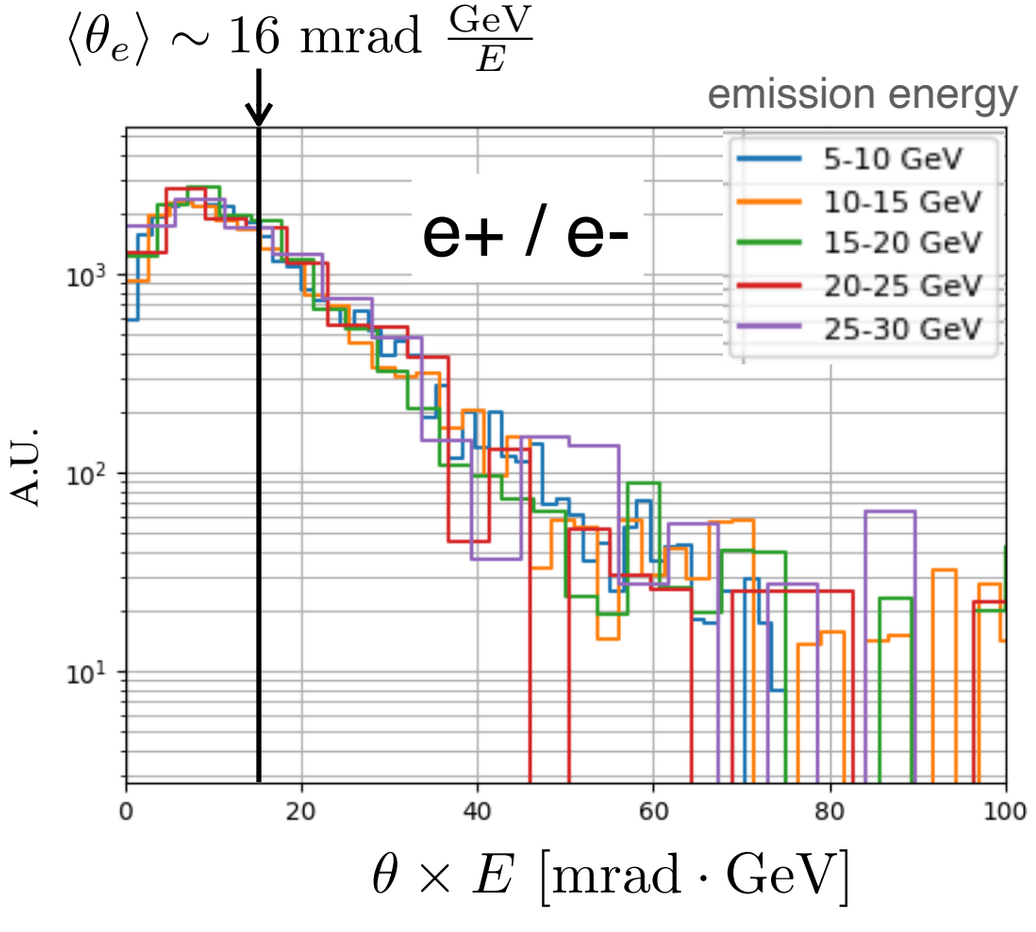


Electromagnetic shower develops very forward

- ➡ New particles are emitted in forward direction
- ➡ Good angular acceptance
- ➡ Detectors can be manufactured at relatively low cost



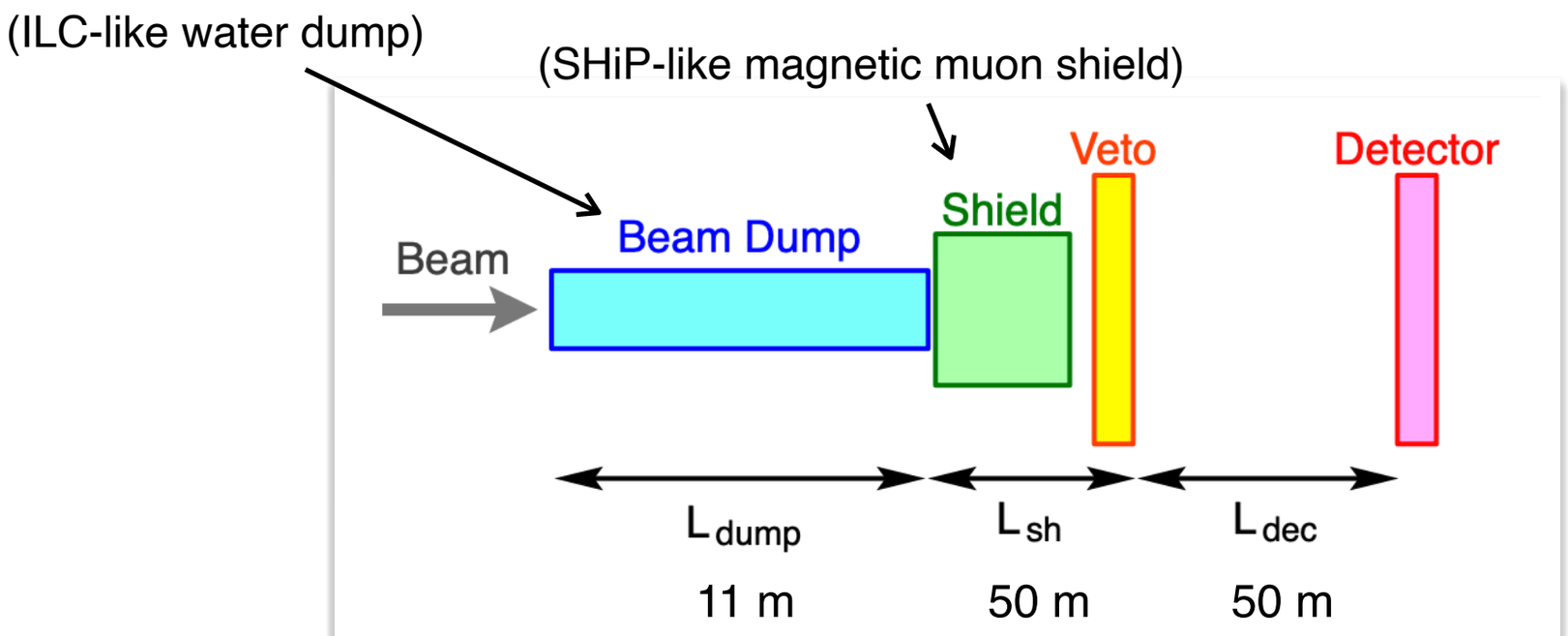
(emission angle) x (emission energy)

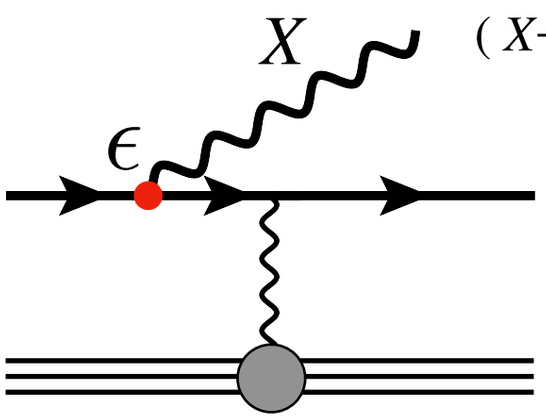


(emission angle) x (emission energy)

[1] A benchmark setup (for future e+e- beam dump)

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





Dark photon

$$\mathcal{L} = \mathcal{L}_{\rm SM} - \frac{1}{4} F^{(X)}_{\mu\nu} F^{(X)}_{\mu\nu} - \frac{\epsilon}{2} F^{(\rm em)}_{\mu\nu} F^{(X)}_{\mu\nu} + \frac{m_X^2}{2} X_\mu X_\mu$$

[1] A benchmark setup (for future e+e- beam dump)

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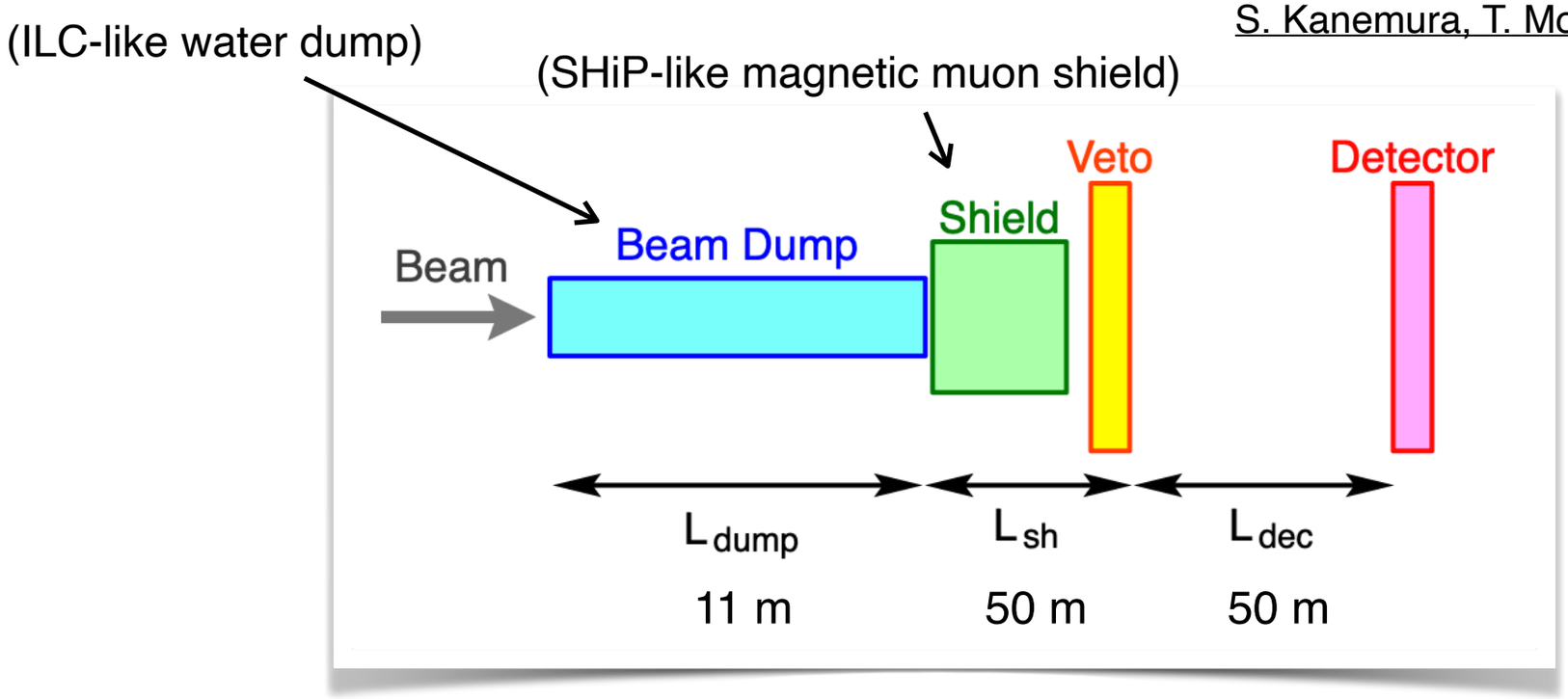
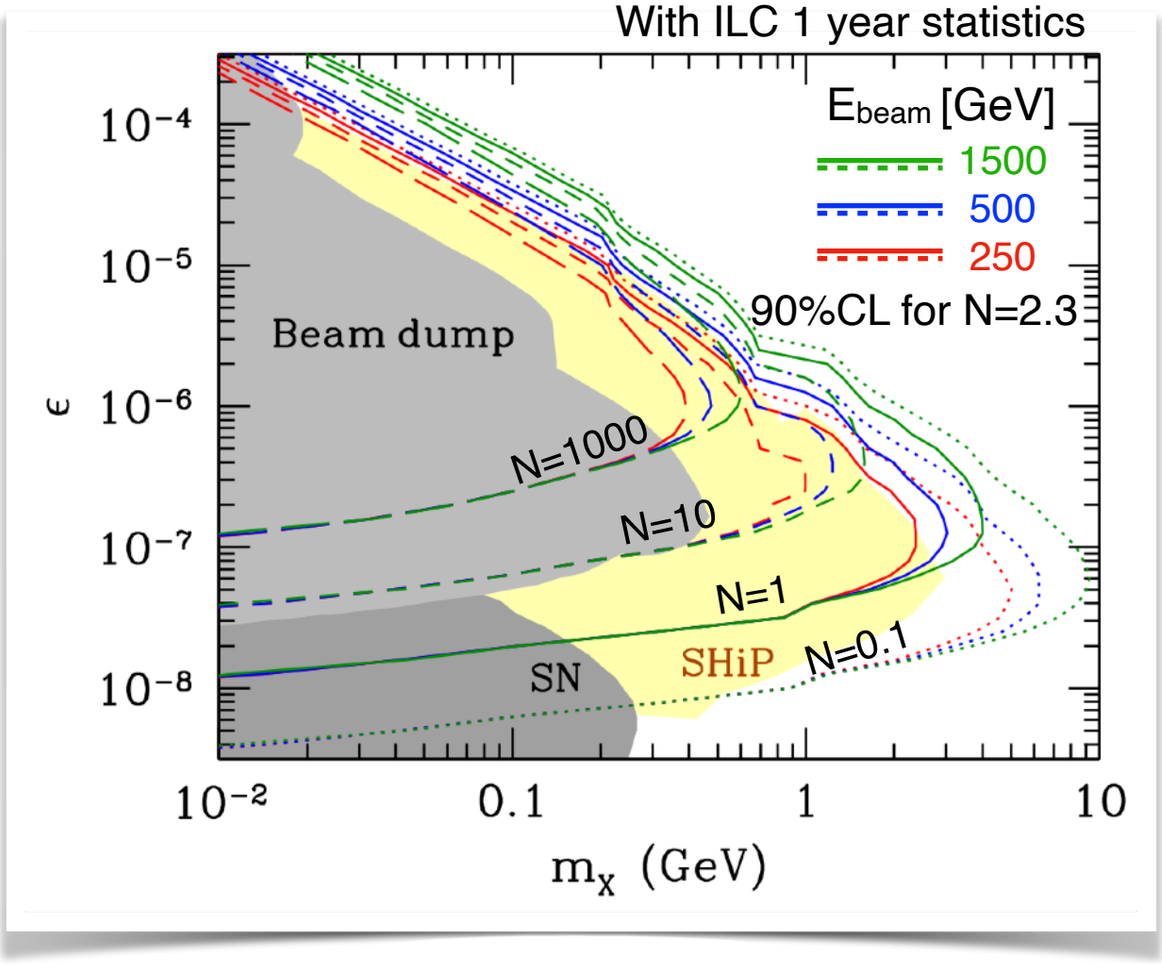
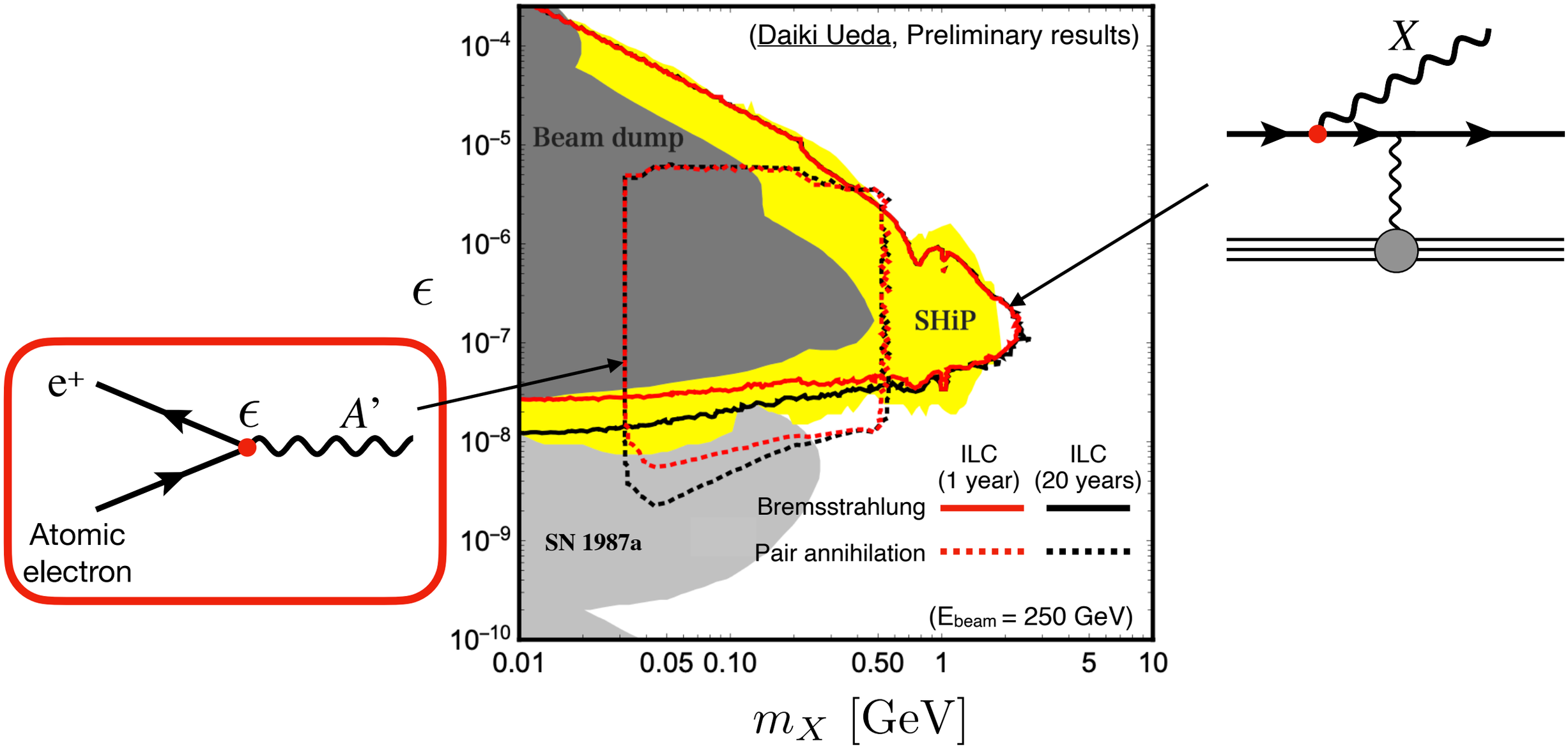


- ✓ Main beam dump experiments can search on the large unexplored region.
- ✓ If SHiP will not be realized due to high-cost issues, ILC will be the only experiment that can access the small-coupling and high-mass region.



[1] A benchmark setup (for future e+e- beam dump)

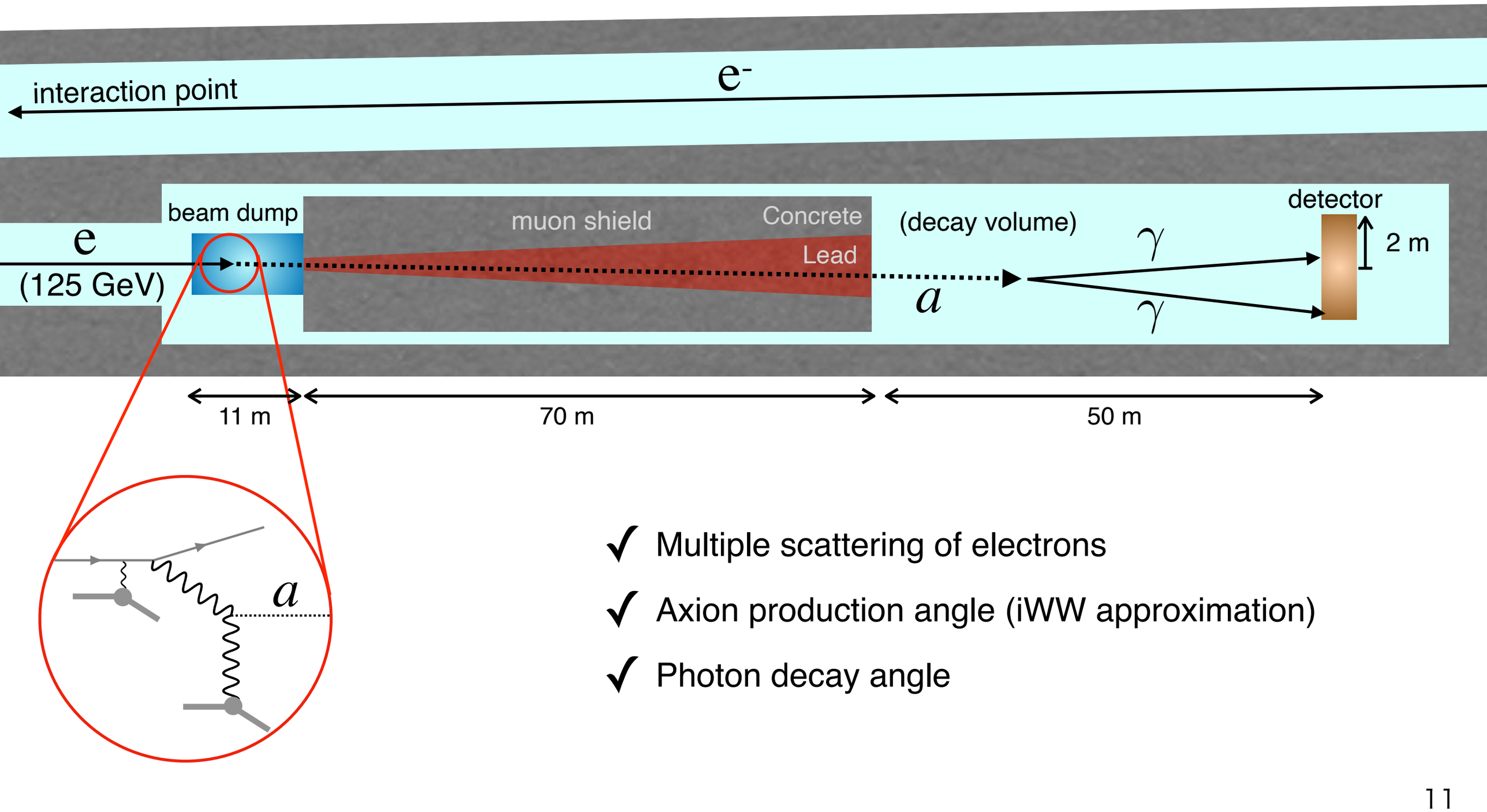
Positron beams can be used to increase sensitivity to small coupling regions.



[2] A benchmark setup (for √s=250 GeV, with passive muon shield)

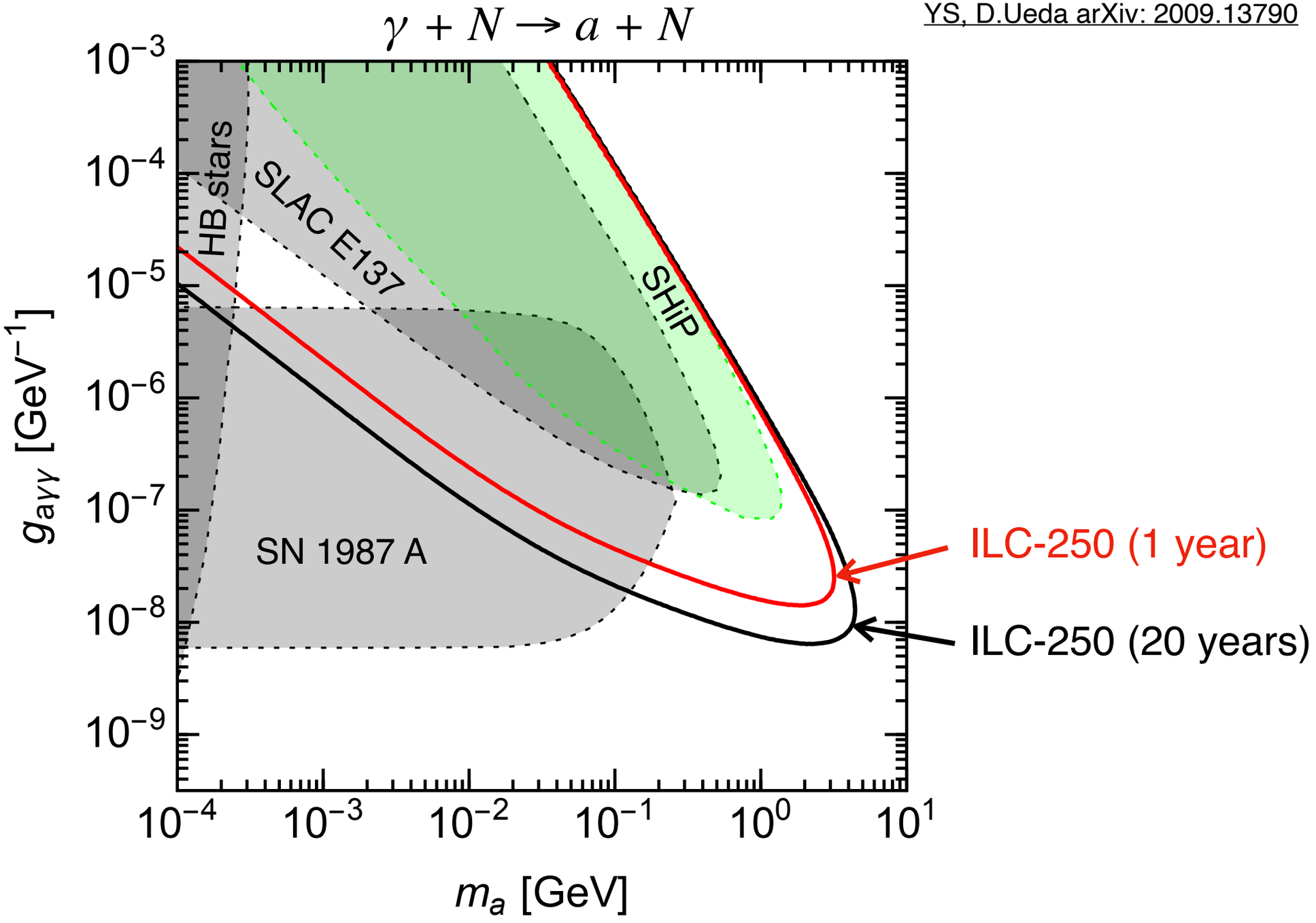
YS, D.Ueda arXiv: 2009.13790

(Axion-like particles) $\mathcal{L} \supset -\frac{1}{4} g_{a\gamma\gamma} a F_{\mu\nu} \tilde{F}^{\mu\nu} + \frac{1}{2}(\partial_\mu a)^2 - \frac{1}{2} m_a^2 a^2$



- ✓ Multiple scattering of electrons
- ✓ Axion production angle (iWW approximation)
- ✓ Photon decay angle

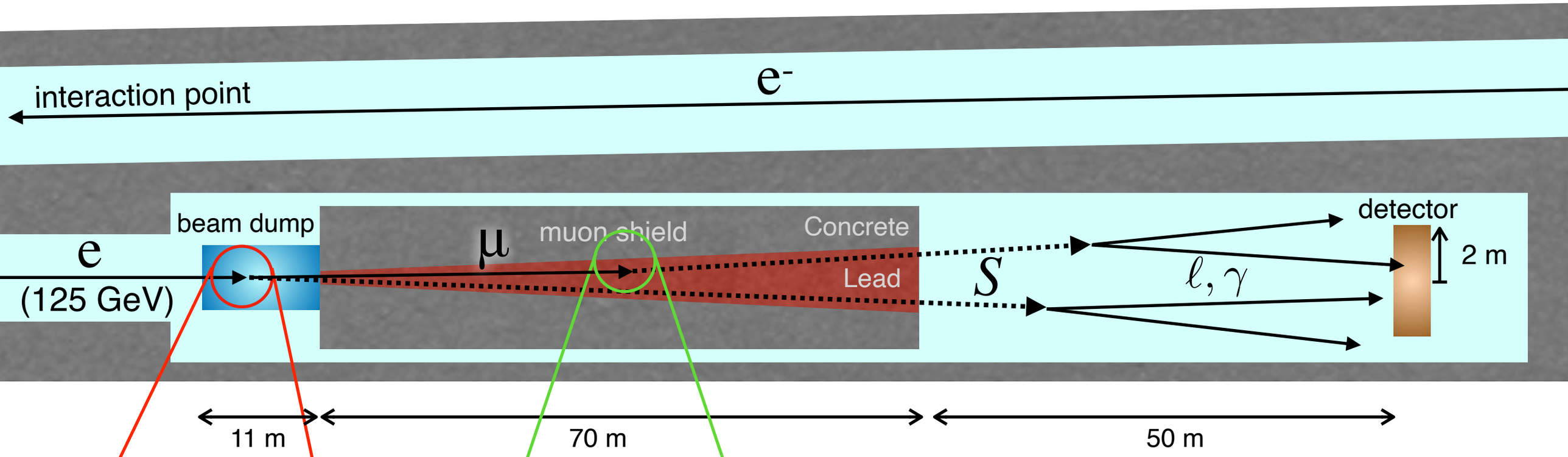
YS, D.Ueda arXiv: 2009.13790



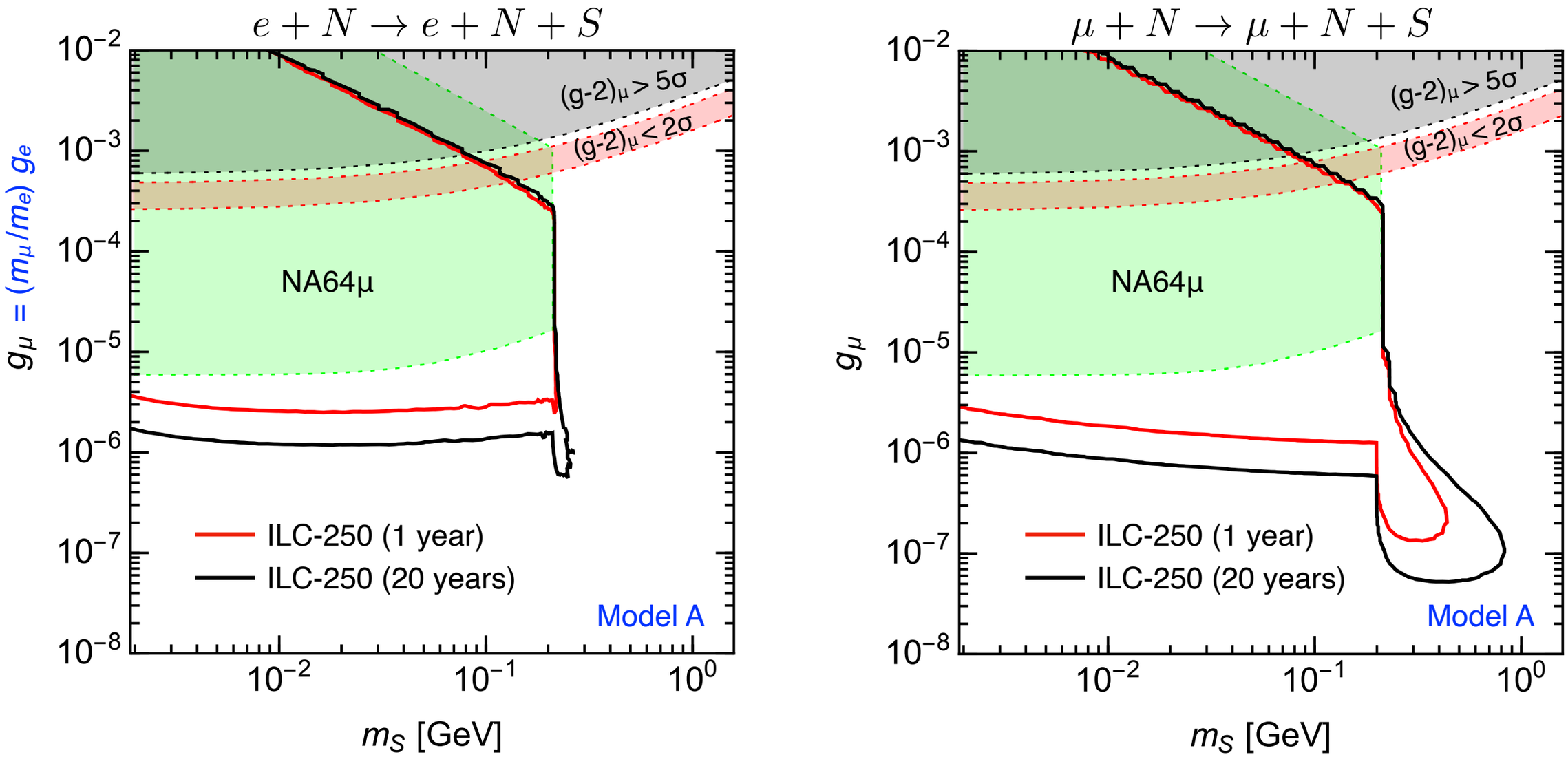
✓ An order of magnitude better sensitivity than other beam dump experiments

[2] A benchmark setup (for √s=250GeV, with passive muon shield)

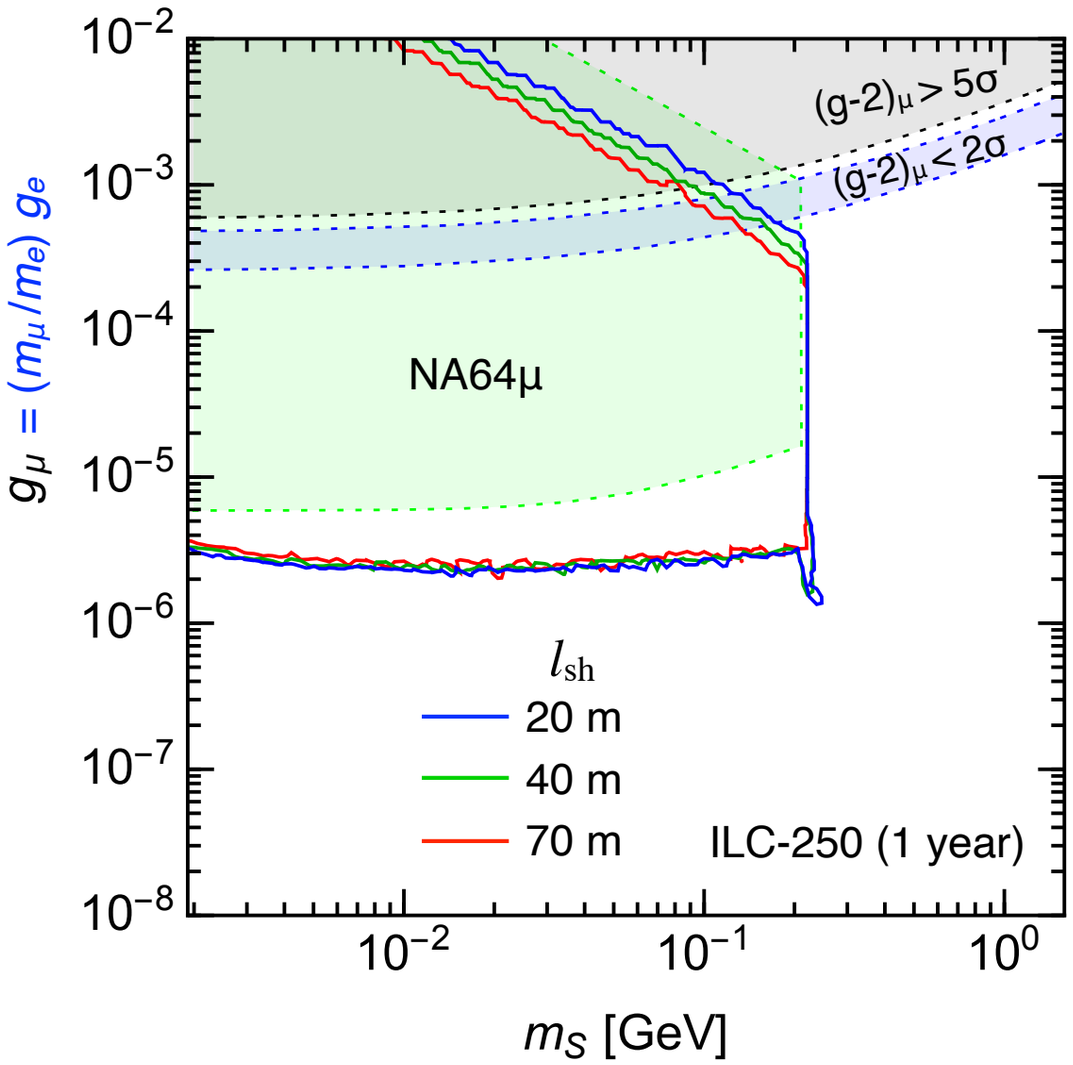
(Light-scalar particle) $\delta\mathcal{L}_{\rm eff} = \frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2}m_S^2 S^2 - \sum_{\ell=e,\mu,\tau} g_\ell S\bar{\ell}\ell, \quad (g_\ell \propto m_\ell/\Lambda)$

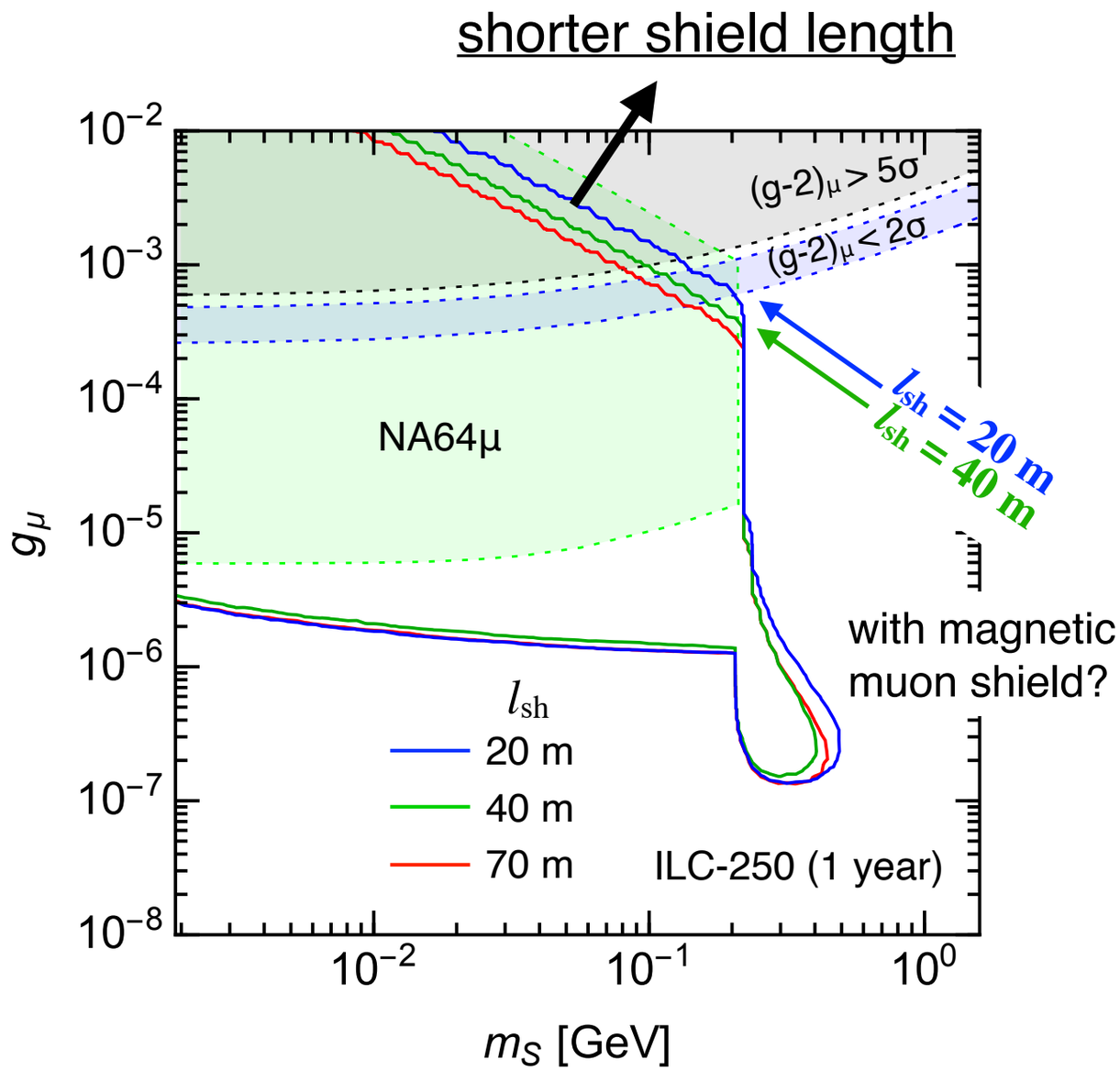


- ✓ Multiple scattering of electrons
- ✓ Muon production angle
- ✓ Multiple scattering of muons
- ✓ S production DDX (WW approximation)
- ✓ Decay angle



- Good sensitivity to small coupling
- The *"hot spot"* relating muon g-2 can be explored
- Shorter shield setup widen the search area in the upward direction





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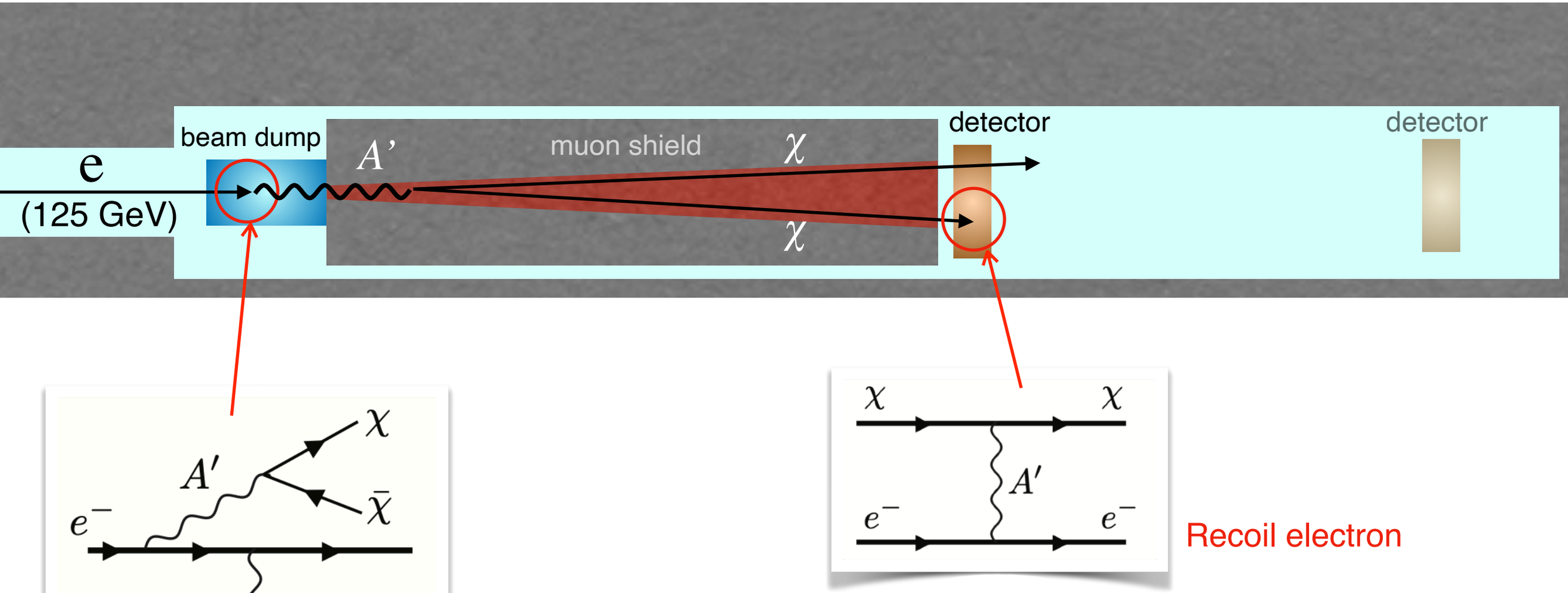
Dark matter search

It can be possible with BDX-like setup



Recoil electron

Plots from arXiv:1406.2698

Summary

- Almost 100% beam power is dumped in the ILC, and we can reuse it for BSM searches at the main beam dump experiment.

- Due to its extremely high luminosity, it is particularly sensitive to small coupling and high mass region.

- Behind the main beam dump is the best place for visible decay search.

- Dark matter search will be possible by catching recoil electron.