Search for new light particles using MeV photon beam at the ILC

Hajime Fukuda (LBL/UC Berkeley)

in collaboration with:

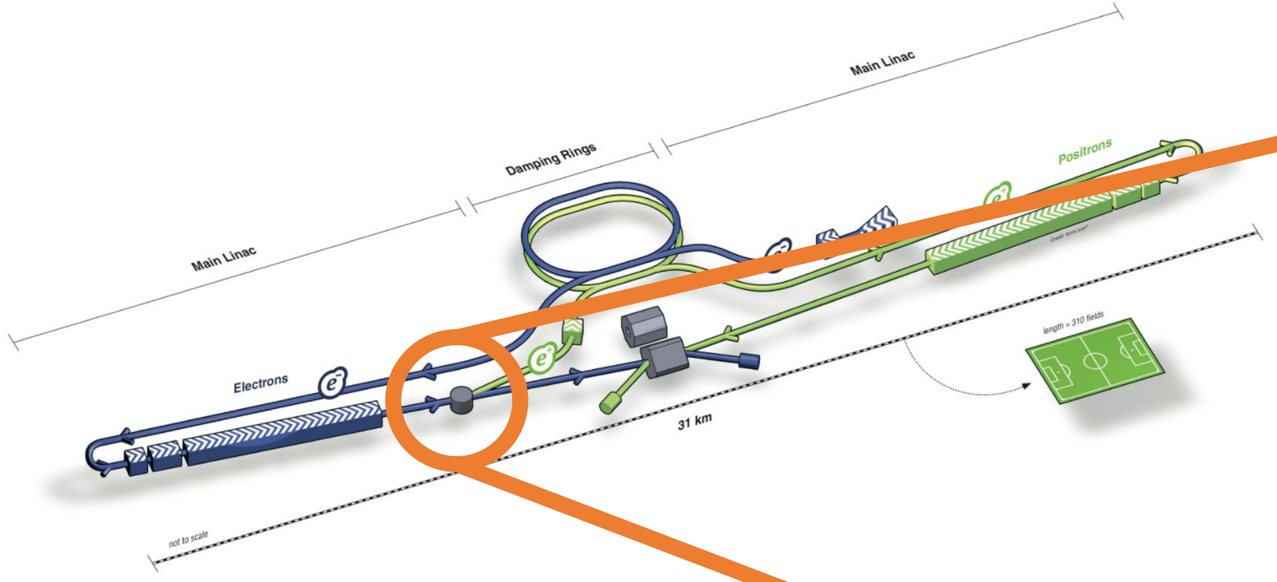
Hidetoshi Otono (Kyushu U.) Satoshi Shirai (Kavli IPMU)

Positron source at the ILC

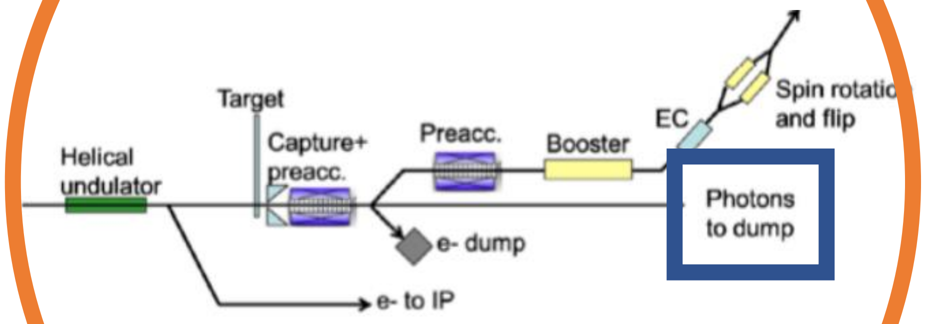
- It is a challenge to generate enough e^+ at the ILC
- Two methods are proposed to create e^+e^- pair:
  - Use a 3 GeV e^- beam created at an independent LINAC
  - **Use a γ beam created from the 125 GeV e^- beam at a undulator**

Let’s focus on this design

Positron from the 125 GeV electron



From ILC collaboration



Riemann et al. 2002.10919

- An oscillating magnetic field is imposed at the undulator and a photon beam is created
- The photon beam then create e+e- pair at a target

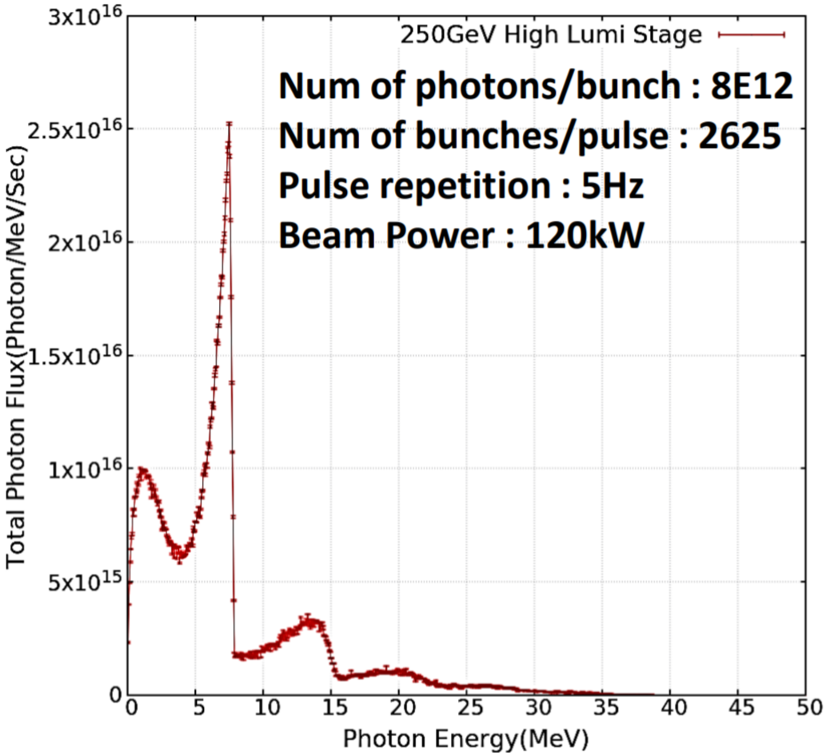
Photon beam

- As a biproduct, an energetic and intense photon beam is obtained
- Energy: $\mathcal{O}(1-10)\ \mathrm{MeV}$
- Intensity: $\mathcal{O}(10^{17})\ \gamma/\mathrm{sec}$

more intense than any other MeV γ source up to the present

→Our motivation

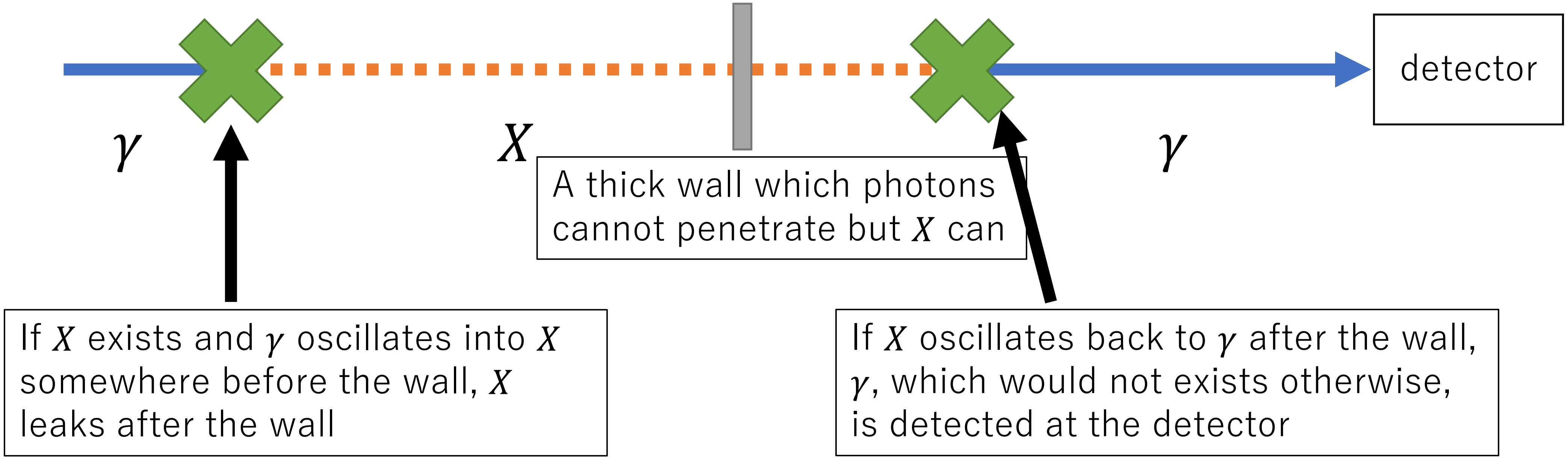
Can we do anything with this photon beam?



From Morikawa-san's slide at POSIPOL-2018

Search for new light particles

- A new light particle X may mix with the photon



Called the light-shining-through-the-wall (LSW) experiment

Light particle models

- QCD axion
- Dark photon

- Today, we focus on the QCD axion

QCD Axion

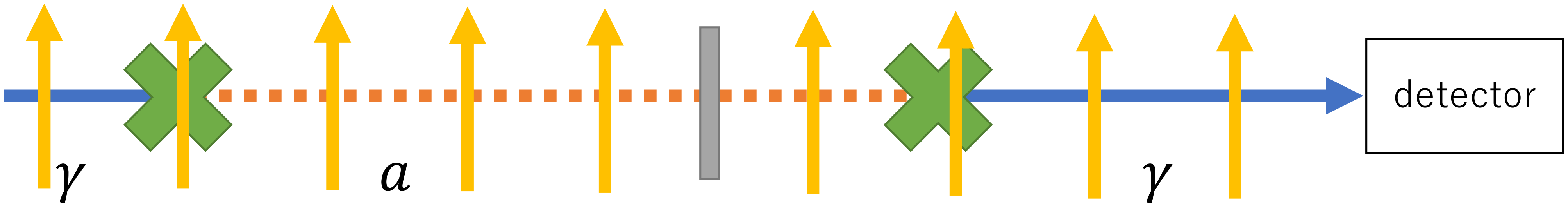
- A hypothetical particle to solve the strong CP problem
- Lagrangian

$$\mathcal{L} = \frac{1}{2}\partial_\mu a \partial^\mu a - \frac{N_{DW}\alpha_s}{8\pi f_a} a G^a_{\mu\nu}\tilde{G}^{a\mu\nu} - \frac{c\alpha}{4\pi f_a} a F_{\mu\nu}\tilde{F}^{\mu\nu}$$

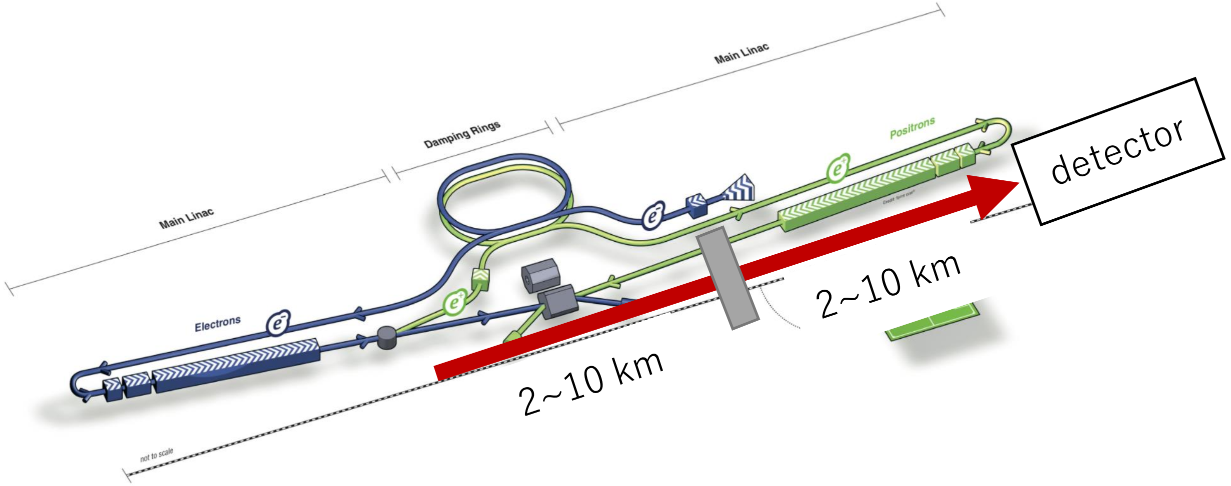
- Very light
  - $m_a \simeq 10^{-2} \left(\frac{10^9 \text{ GeV}}{f_a}\right) \text{ eV}$
- Mix with photon in the presence of a magnetic field
  - $aF_{\mu\nu}\tilde{F}^{\mu\nu} \to B_0(a\,\partial A)$

Experimental setup

- Magnetic fields are imposed on the entire path



- We assume the path is of the similar length as the ILC itself



- The photon beam is very collimated
- In the current design, the distance from the photon source and the photon dump is ~2km
- We may put the reconversion facility on the ground

Advantage to use energetic photons

- Conversion probability

$$P(\gamma \to a) = g_{a\gamma\gamma}^2 \left| \int^L dz\ e^{iqz}\, B(z) \right|^2$$

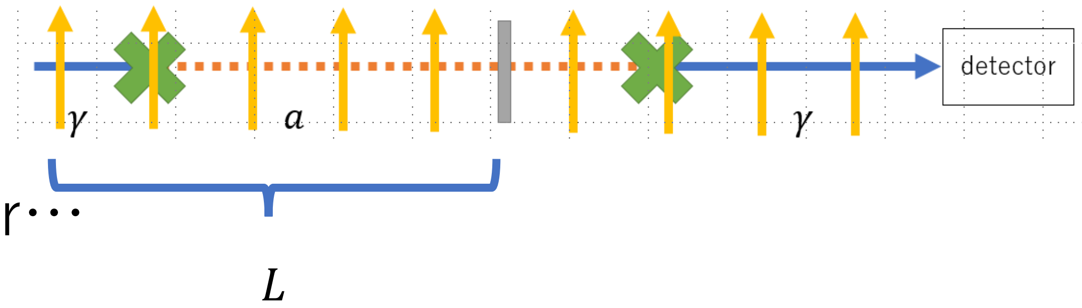
ld configuration

where

For the longer L to maximize P, we need larger E!

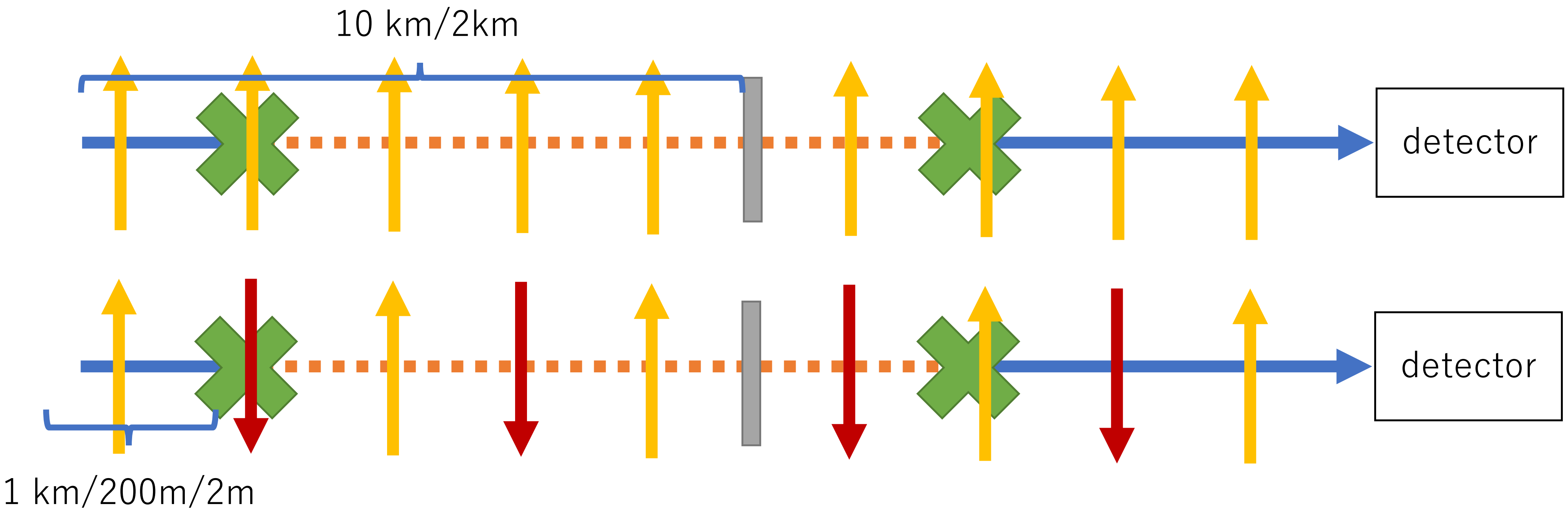
$$q = E - \sqrt{E^2 - m_a^2} \simeq \frac{m_a}{2E} \sim (10\ \text{km})^{-1} \left(\frac{m_a}{10^{-2}\ \text{eV}}\right) \left(\frac{2.5\ \text{MeV}}{E}\right)$$

- To maximize P,
  - Longer BL is better
  - But then, a momentum $\sim L^{-1}$ is smaller…

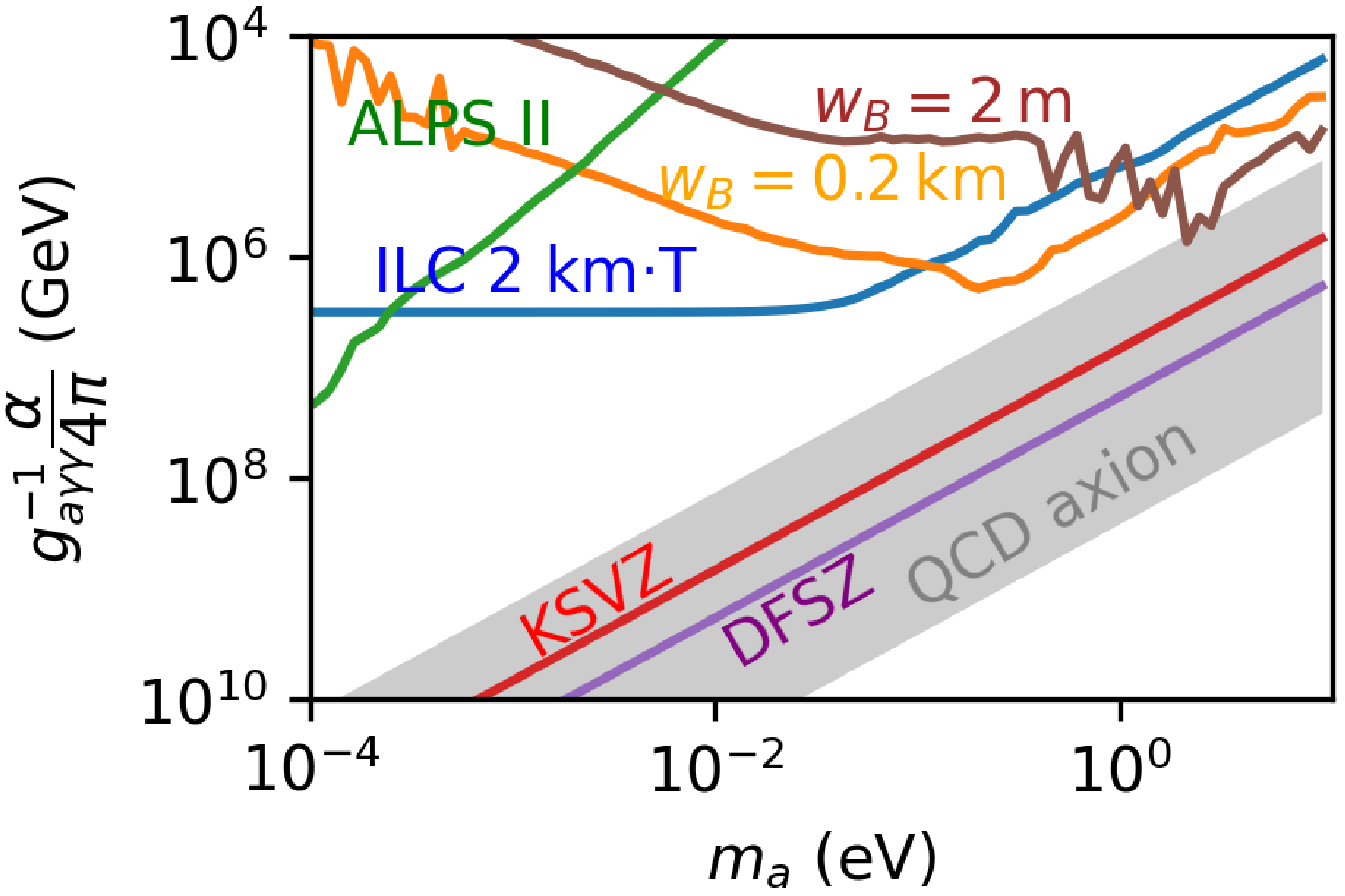


Magnetic field configuration

- If we flip magnetic fields over shorter scale w, the "momentum" can be larger



Result (1-year), conservative

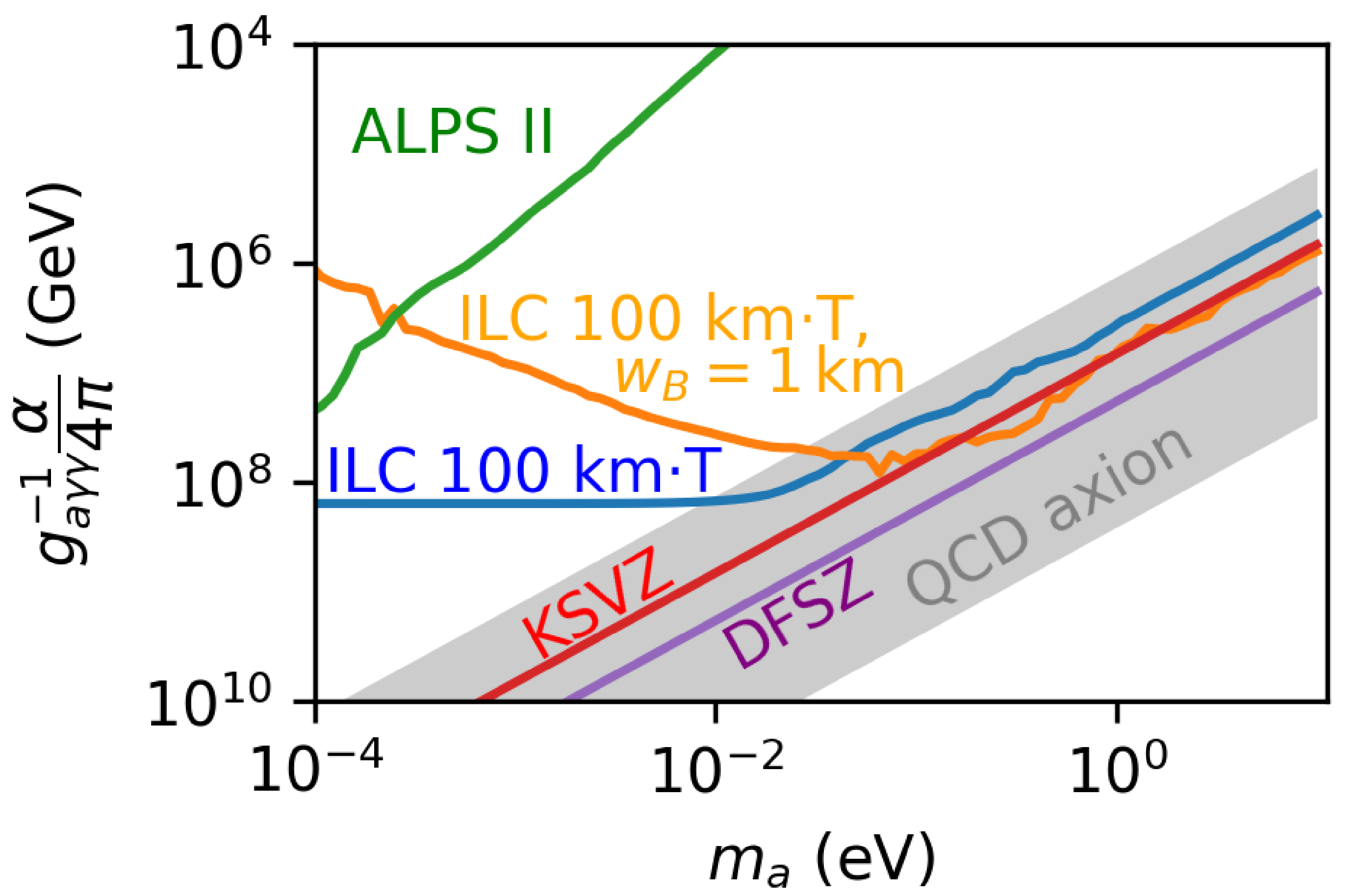


L = 2 km

- The distance between γ source and dump in the current design

B = 1 T

Result (1-year)



L = 10 km
B = 10 T

Summary

- It is proposed to generate MeV photon beam as the positron source at the ILC
- The high intensity and large energy are advantageous for light particle search by the LSW experiment
- For the QCD axion, this may constrain the KSVZ model, where no other ground experiments are expected to do.