Prospects for axion-like particle searches in the meV mass range using a microwave–laser–mixed stimulated resonant photon collider

Kensuke Homma
Hiroshima Univ. / KEK-QUP

arXiv:2405.03577 **[hep-ph]**

KH et al.
Phys. Rev. D 110, 092017, 2024

Guiding principles to design experiments to identify Dark Matter as an extension of particle physics

Long lifetime

decay rate ∝ coupling^2 mass^3 (model independent statement)

Direct production by inverting the decay process

Learn from the history of the discovery of neutrino by Cowan & Reines via the inverse process. Collider in general is the best way.

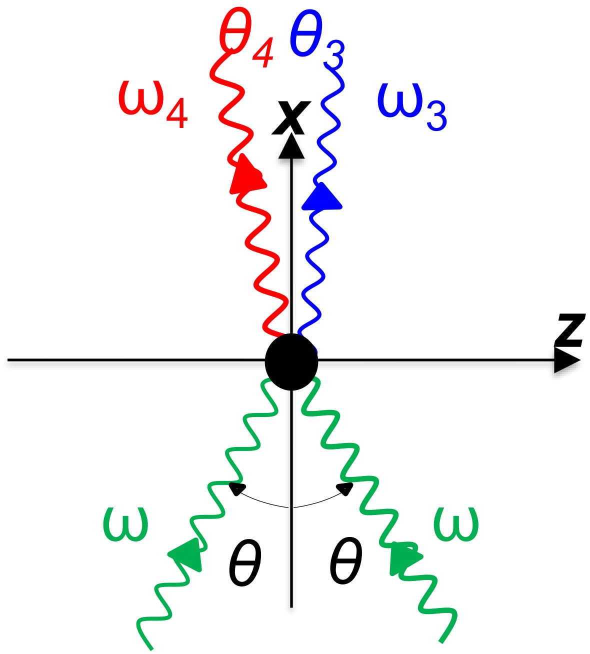
Relevant to symmetry breakings

dilaton (scale symmetry), axion (PQ-symmetry) etc.

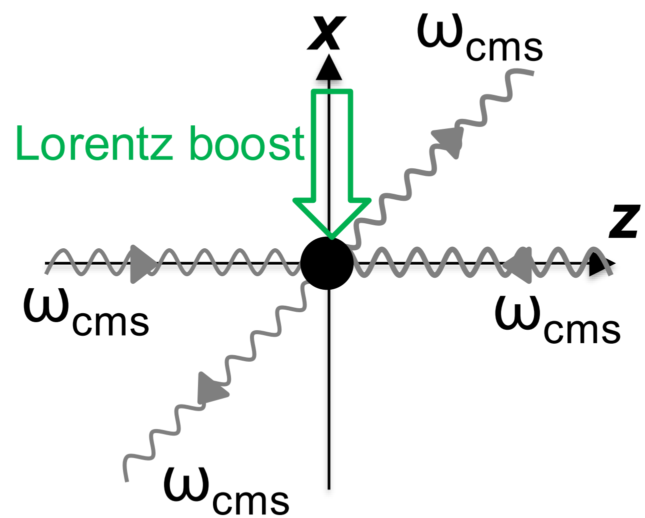
Production of low-mass pseudo Nambu-Goldstone bosons in photon-photon colliders is one of the best approaches !

How to lower collision energies ?

Quasi-Parallel collision System



Center of Mass System



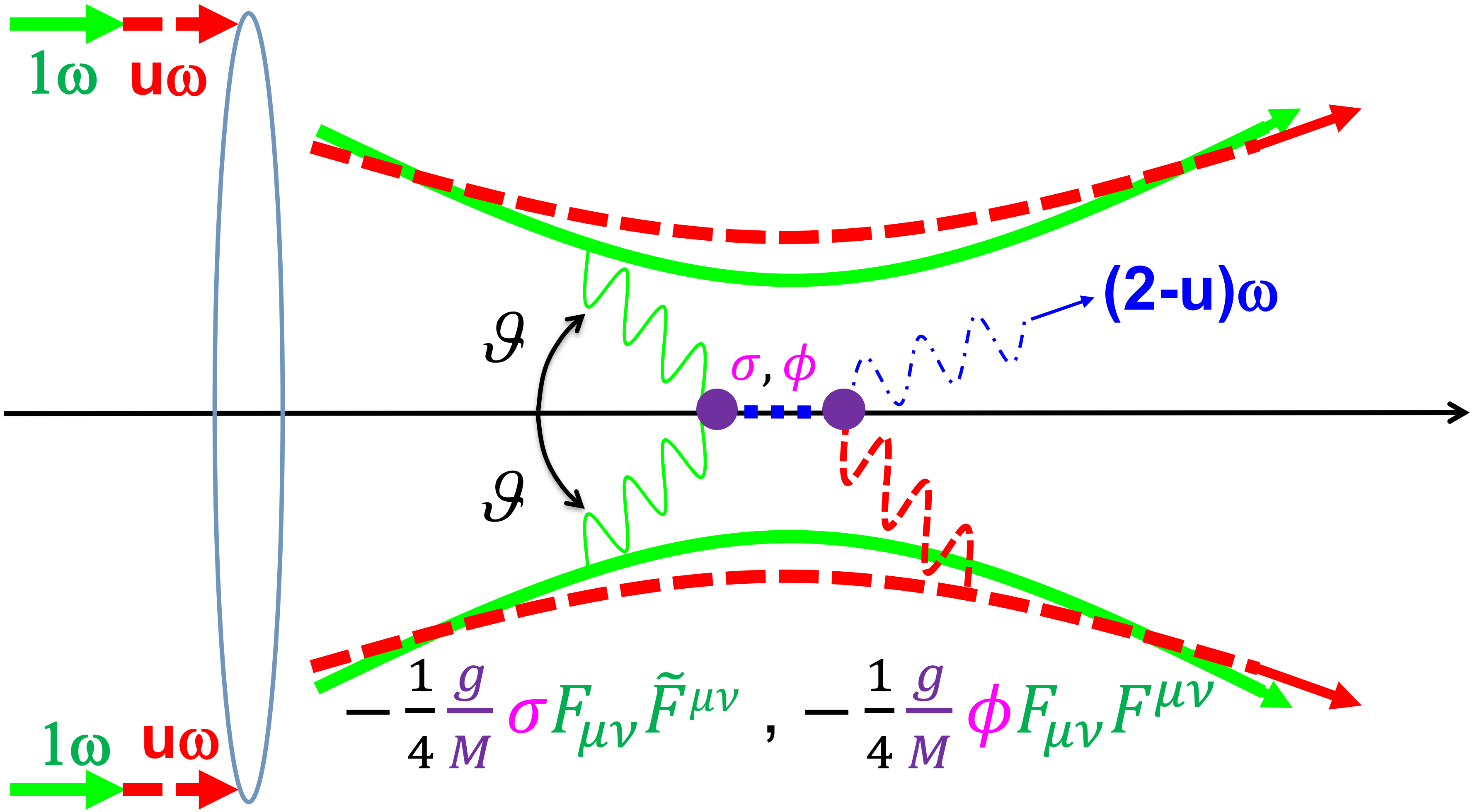
$$E_{cms} = 2\omega \sin\theta$$

Low-mass search

$$E_{cms} = 2\omega_{cms}$$

High-mass search

Stimulated Resonant Photon Collider (with two beams)



$$-\frac{1}{4}\frac{g}{M}\sigma F_{\mu\nu}\tilde{F}^{\mu\nu}\ ,\ -\frac{1}{4}\frac{g}{M}\phi F_{\mu\nu}F^{\mu\nu}$$

Three Beam Stimulated Resonant Photon Collider

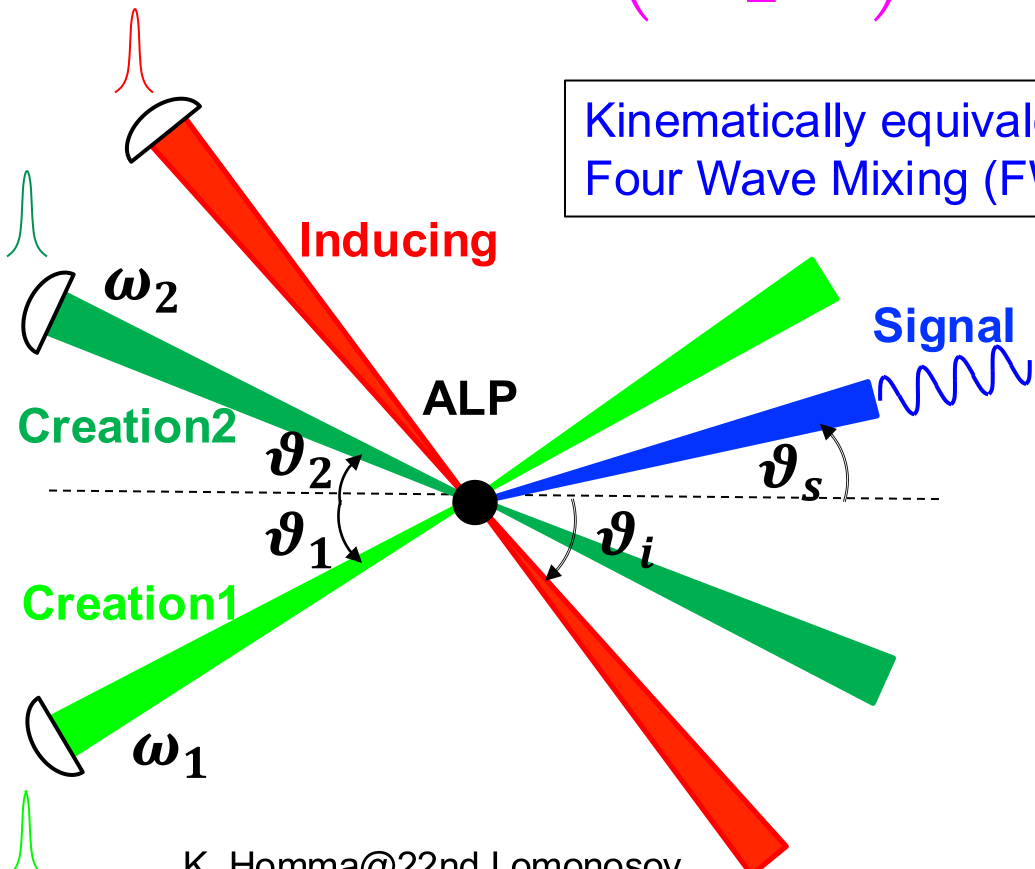
create ALP + stimulate ALP decay

Resonant condition in the s-channel scattering amplitude:

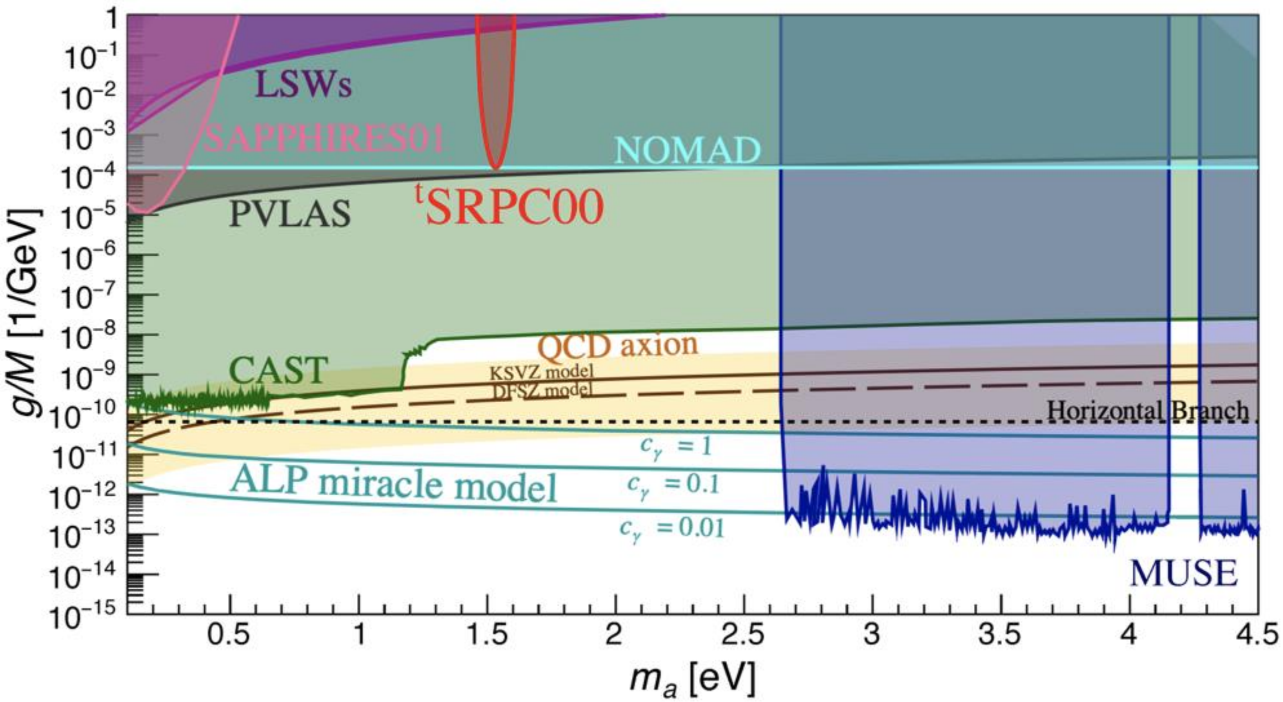
ALP pole mass = E_{cms}

$$E_{cms} = 2\sqrt{\omega_1\omega_2}\sin\left(\frac{\vartheta_1+\vartheta_2}{2}\right)$$

Kinematically equivalent to
Four Wave Mixing (FWM) in vacuum

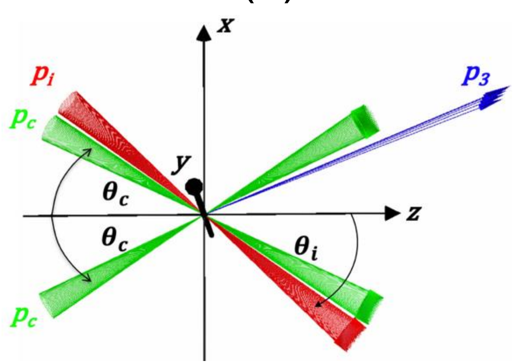


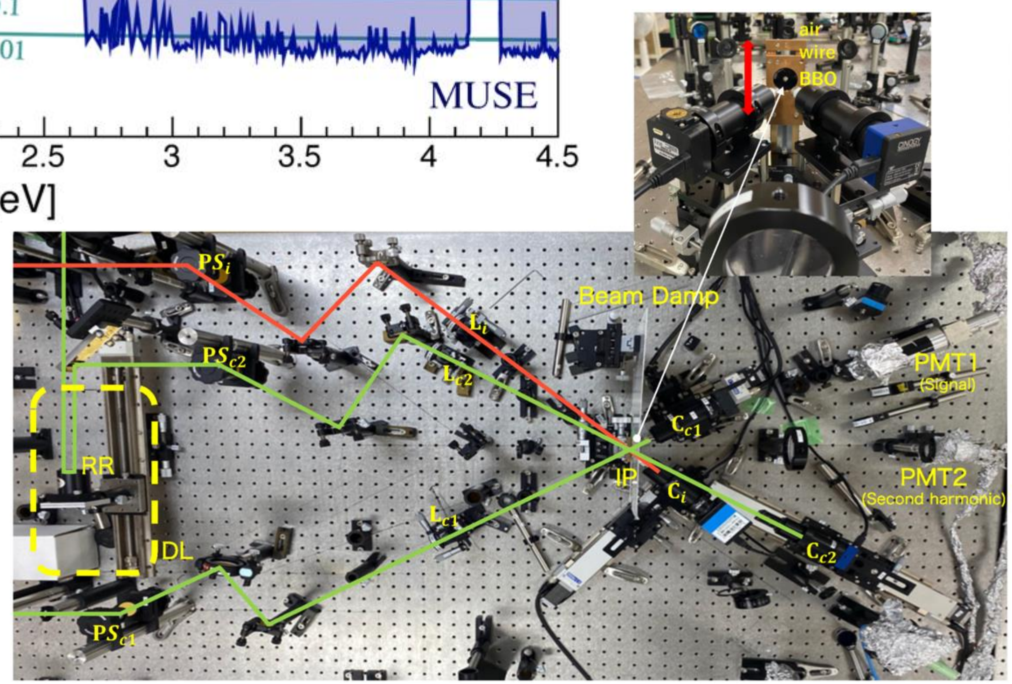
Pilot search in the eV mass range

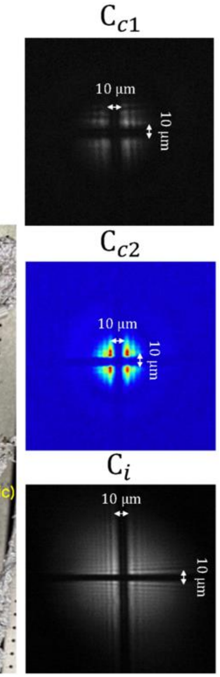


$$-\mathcal{L} = \frac{1}{4}\frac{g}{M}F_{\mu\nu}\tilde{F}^{\mu\nu}\phi_a$$

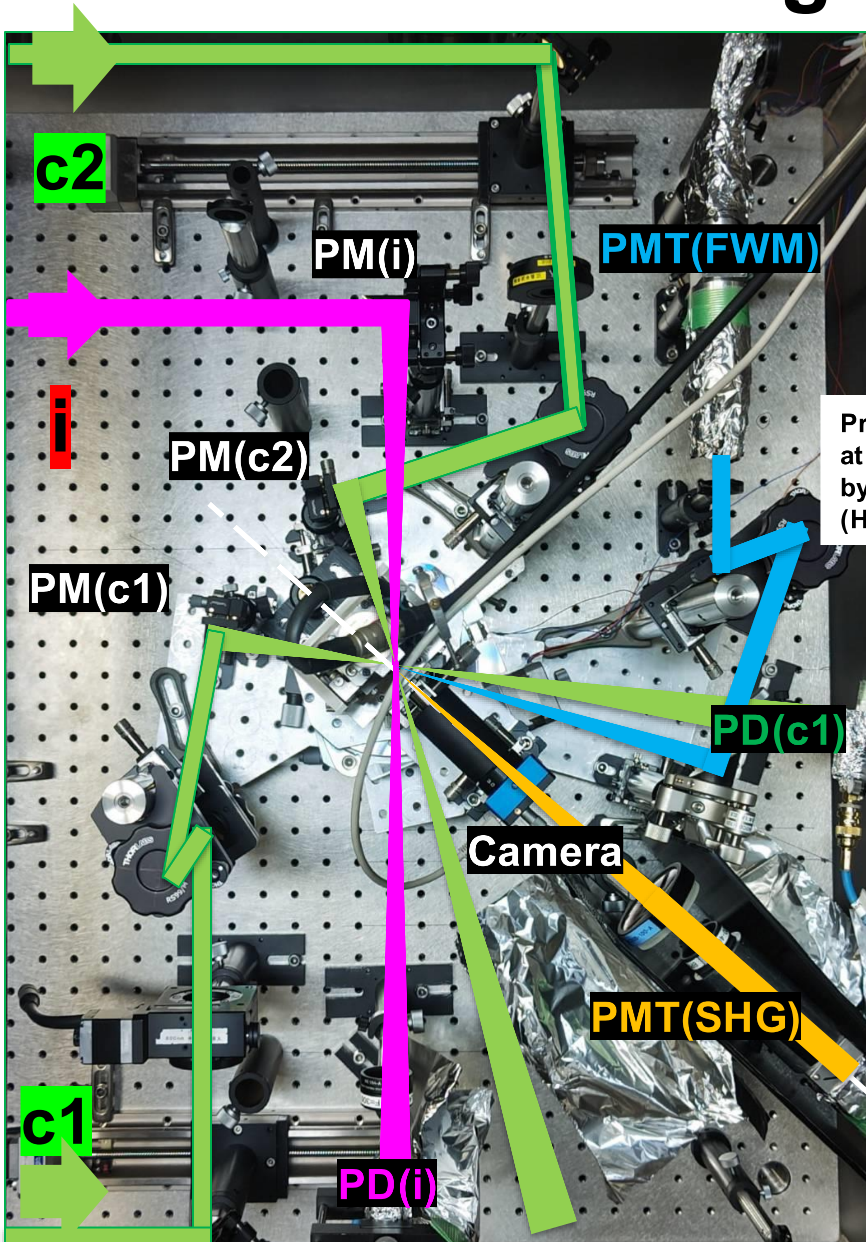
F. Ishibashi, T. Hasada, KH et al.
Universe **2023**, *9*(3), 123





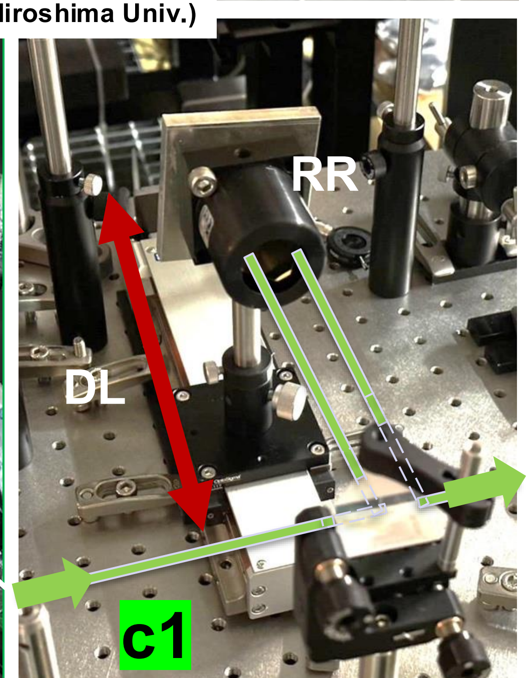


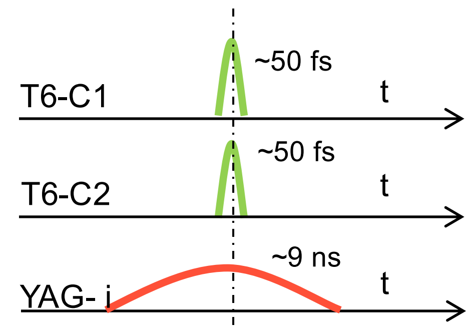
Design and Construction of a Variable-Angle Three-Beam SRPC

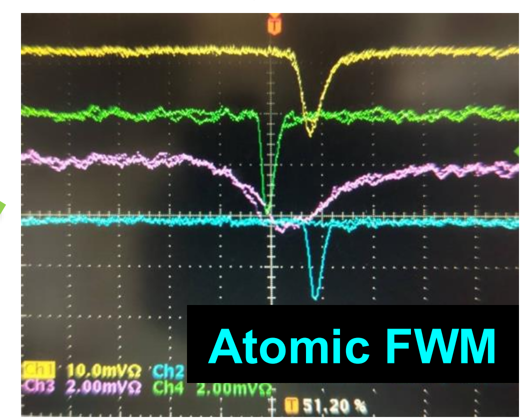


T. Hasada, KH, Y. Kirita, *Universe* **2023**, *9*(8), 355

Presented at JPS 2023.9.17 by T. Hasada (Hiroshima Univ.)

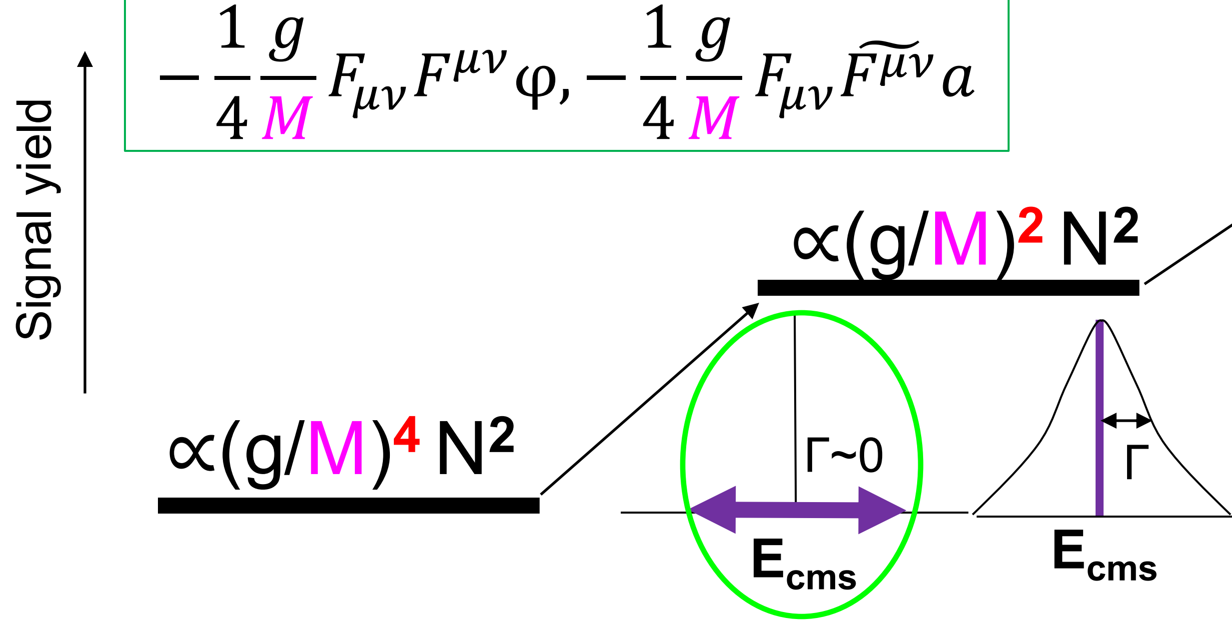






SRPC, a game changer in particle physics

$$-\frac{1}{4}\frac{g}{M}F_{\mu\nu}F^{\mu\nu}\varphi, -\frac{1}{4}\frac{g}{M}F_{\mu\nu}\widetilde{F^{\mu\nu}}a$$



100J laser photons
~ $(10^{20})^3$ / collision
100J S-band photons
~ $(10^{25})^3$ / collision

u,t-channel spontaneous decay

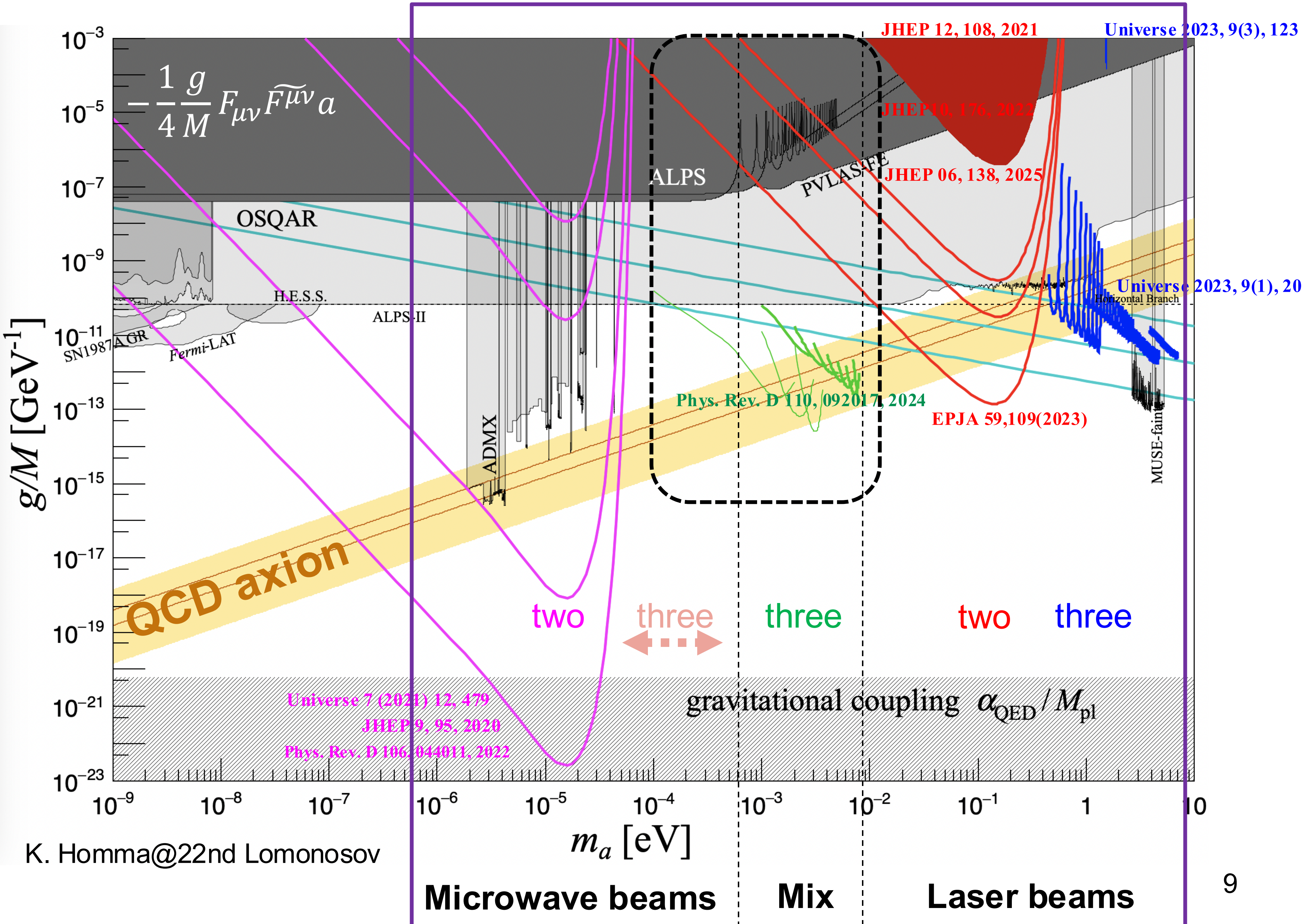
s-channel pole integral spontaneous decay

KH et al. JHEP 9, 95, 2020
KH et al. Universe 7 (2021) 12, 479

LHC p-p collider for Higgs hunting M~246 GeV
~ $(10^{11}$ protons$)^2$ / collision

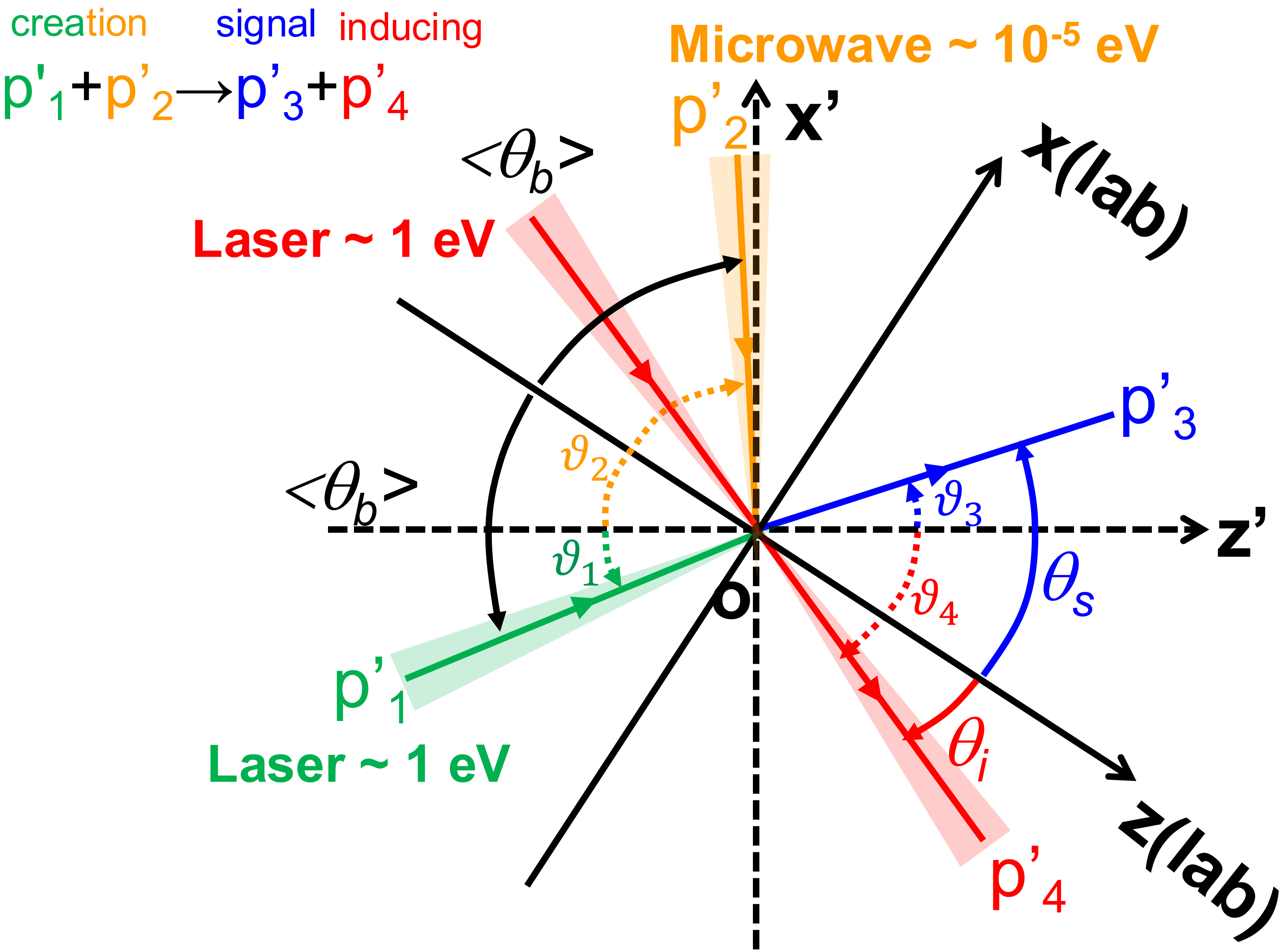
Hyper-Kamiokande M~GUT scale
~10^{34} protons

SRPC can test axion in the μev-1eV range

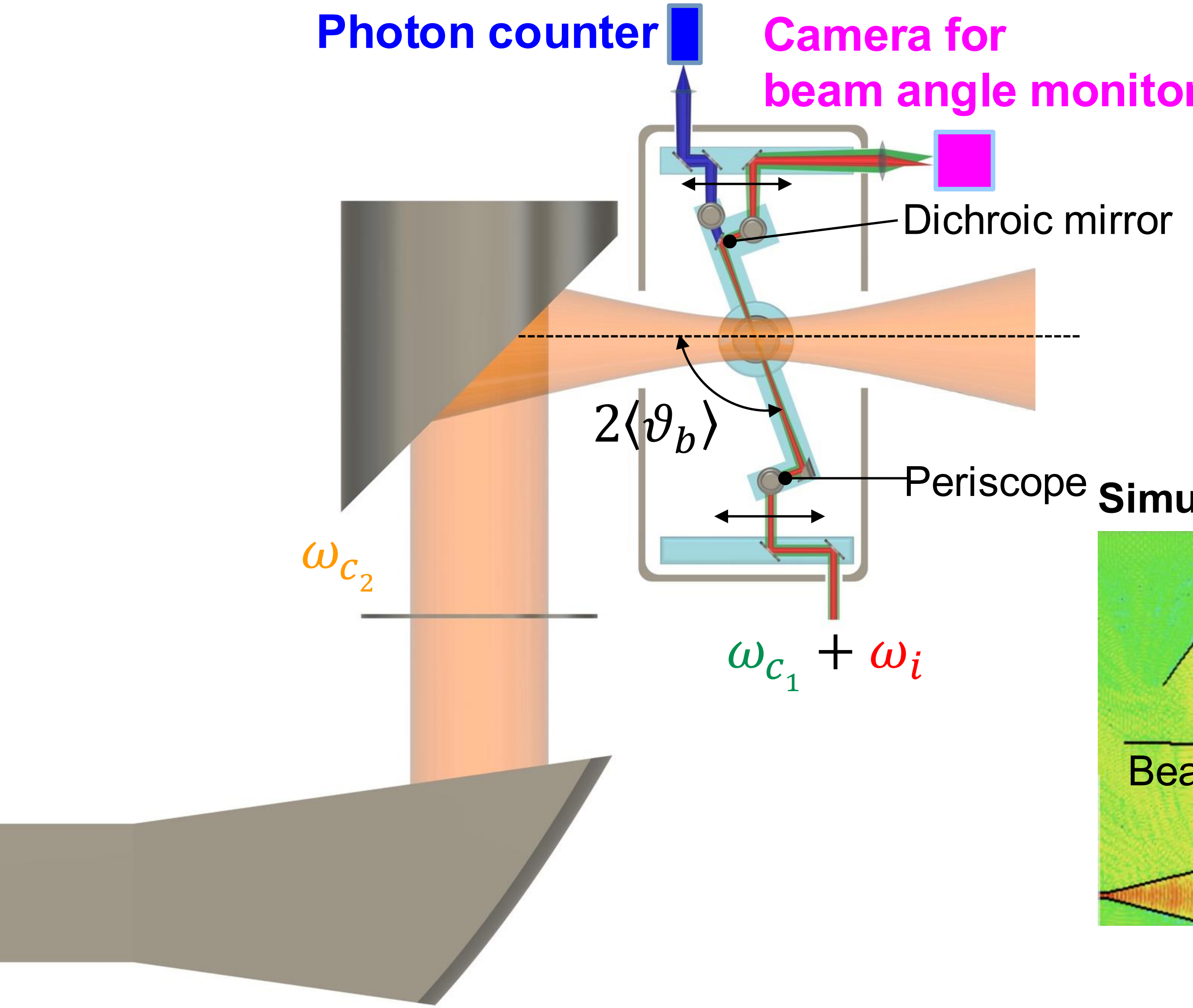


K. Homma@22nd Lomonosov

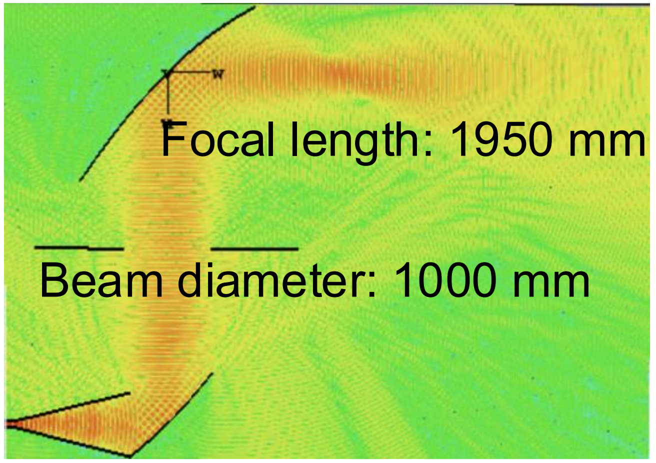
Extremely asymmetric ^{t}SRPC



Concept of experimental setup

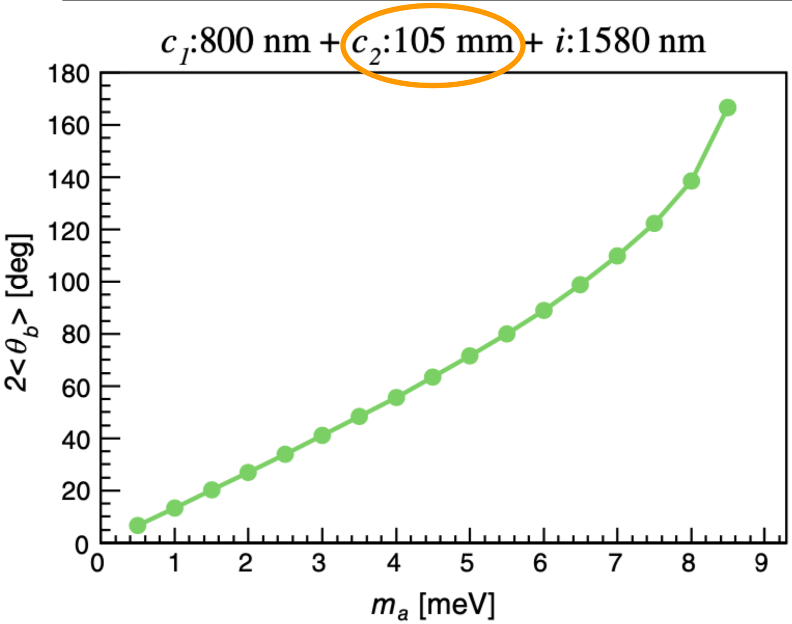


Simulation (CST studio suit)

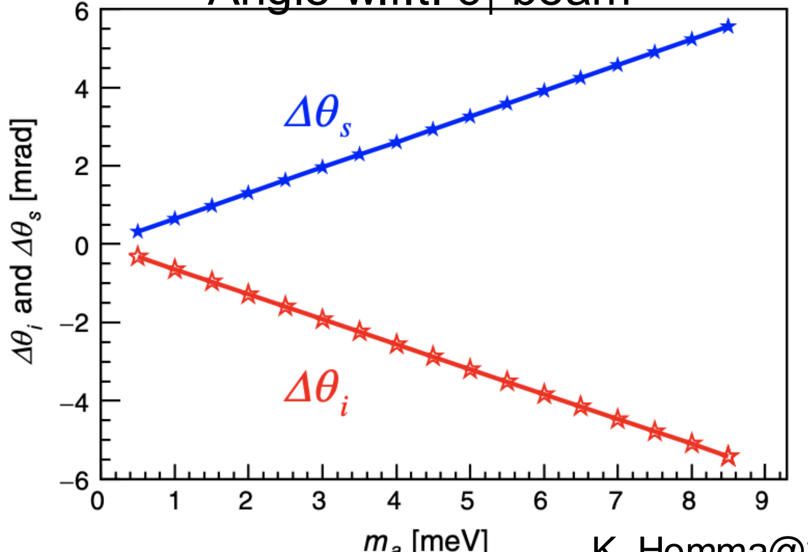


Relative angles of beams and signal

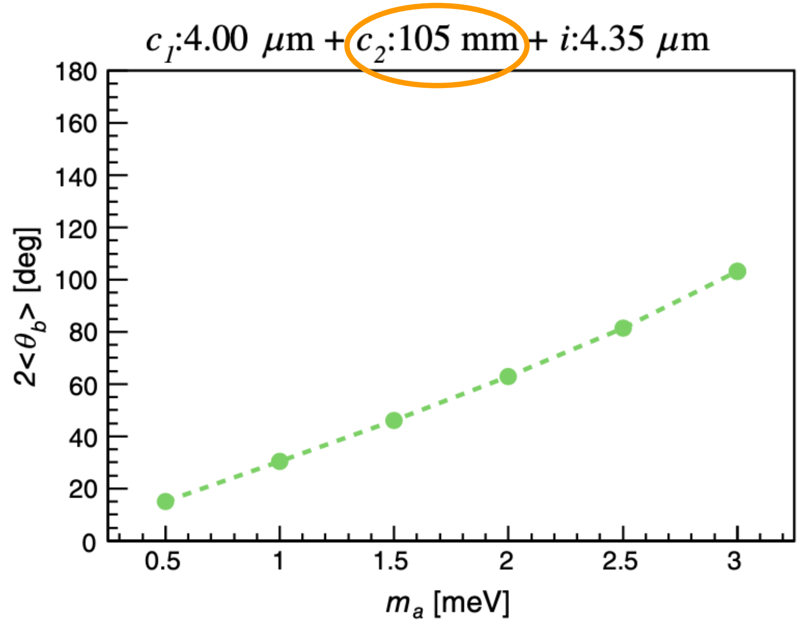
Higher mass: IR lasers + S-band



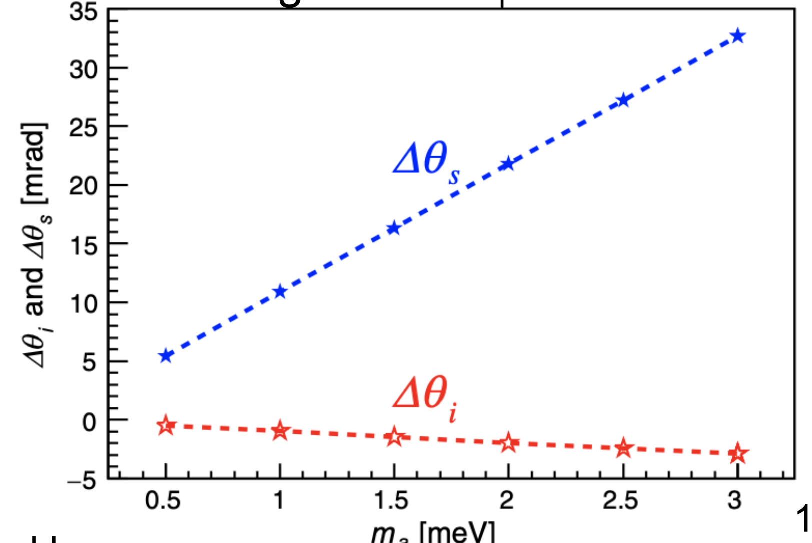
Angle w.r.t. c_1 beam



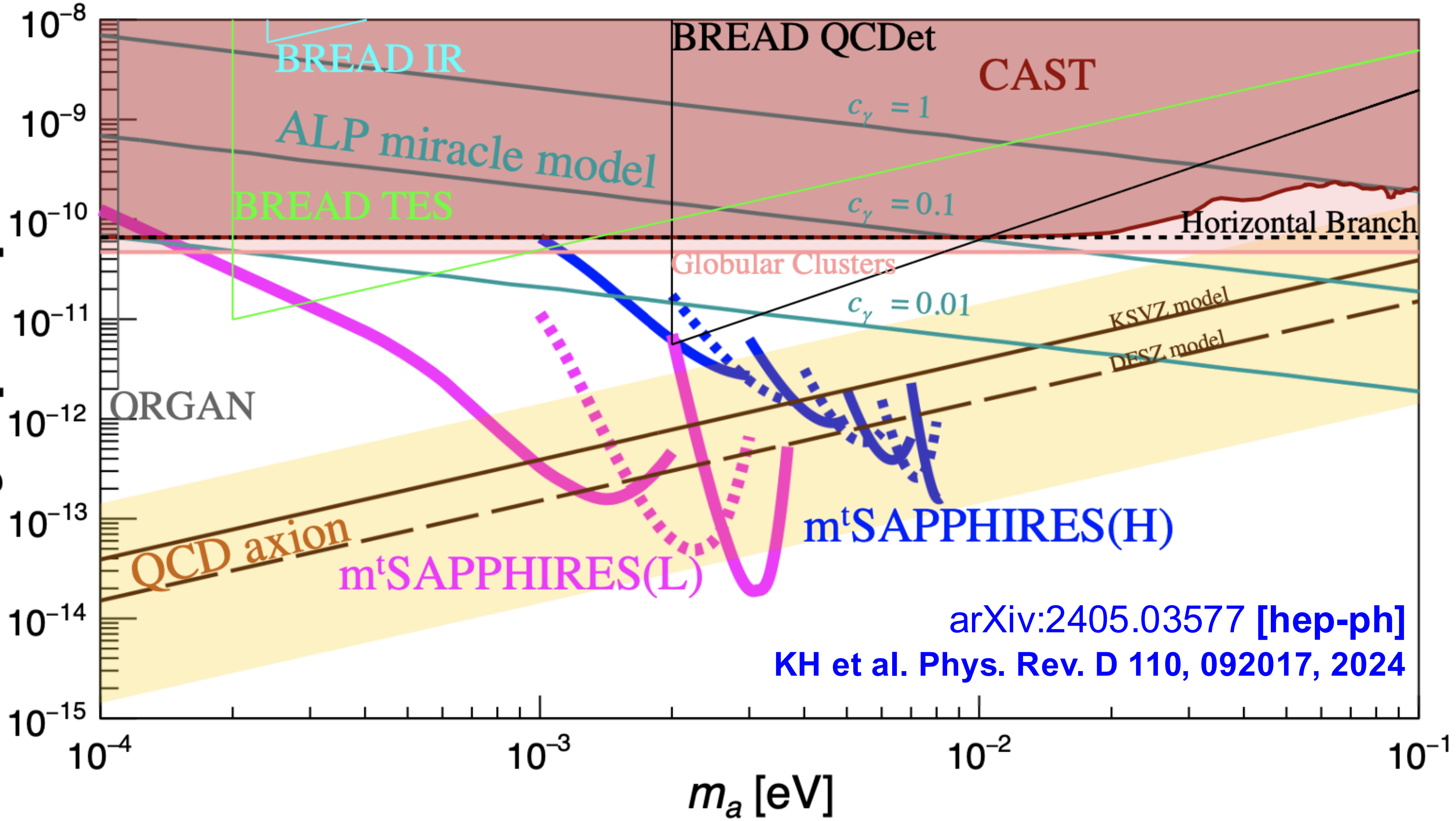
Lower mass: MIR lasers + S-band



Angle w.r.t. c_1 beam



Sensitivity projection



Summary

We have developed the concept of Stimulated Resonant Photon Collider (SRPC), which can be a game changer in particle physics.

SRPC is independent of any cosmological and astrophysical models, which thus would be able to give most stringent upper limits to the coupling-mass parameter space in the near future.

We have launched search experiments with both two and three beam configurations with pulsed lasers.

It is feasible to combine a microwave and lasers to access to the meV ALP window.