HP CDM Search in Tokyo

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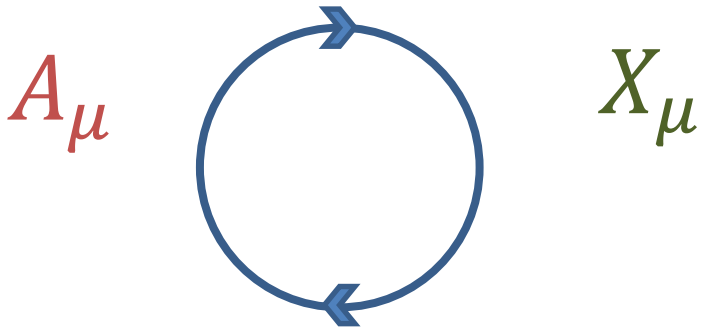
Hidden photon

$$\mathcal{L} \supset -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} - \frac{\chi}{2}F_{\mu\nu}X^{\mu\nu} + \frac{m_{\gamma'}^2}{2}X_\mu X^\mu + J^\mu A_\mu$$

- Beyond SM physics
- Kinetic mixing
- Mass term



Weakly Interacting Slim Particles (**WISP**)

HP Cold Dark Matter

DM candidate (like axions) via **misalignment mechanism**

$$L \supset -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} - \frac{\chi}{2}F_{\mu\nu}X^{\mu\nu} + \frac{m_{\gamma'}^2}{2}X_\mu X^\mu + J^\mu A_\mu$$

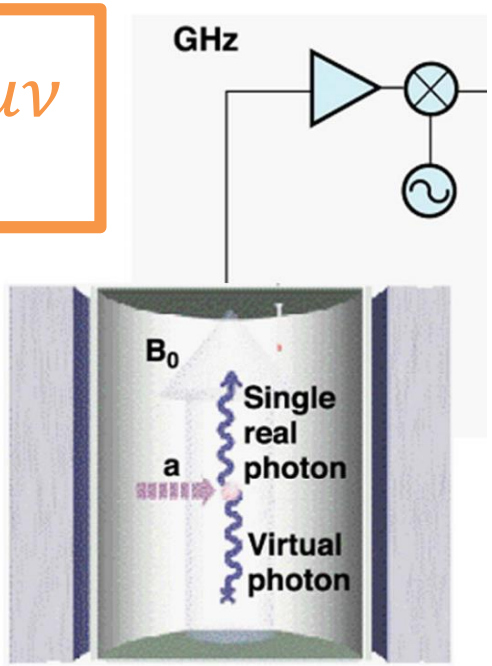
$$= \rho_{\mathrm{CDM}}$$

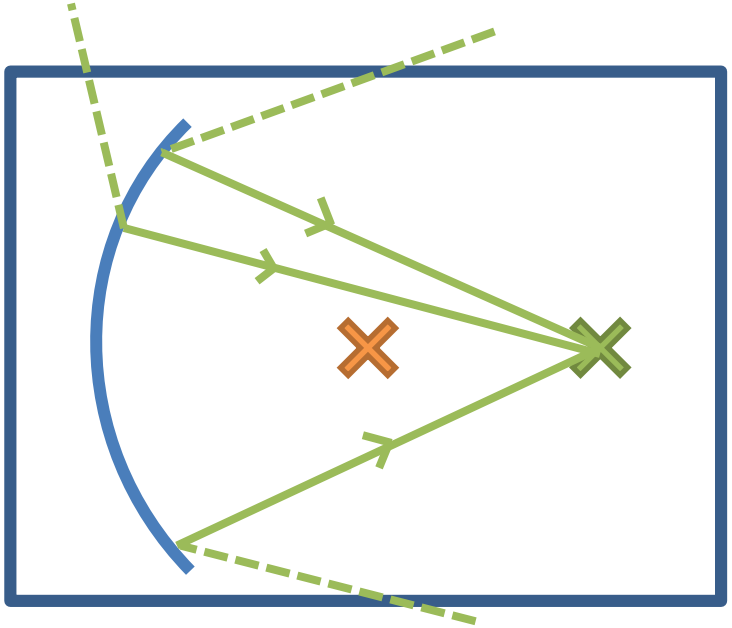
Misalignment mechanism
(non-thermal production of HP)

(like Axion DM scenario)

How to search

$$-\frac{\chi}{2}F_{\mu\nu}X^{\mu\nu}$$



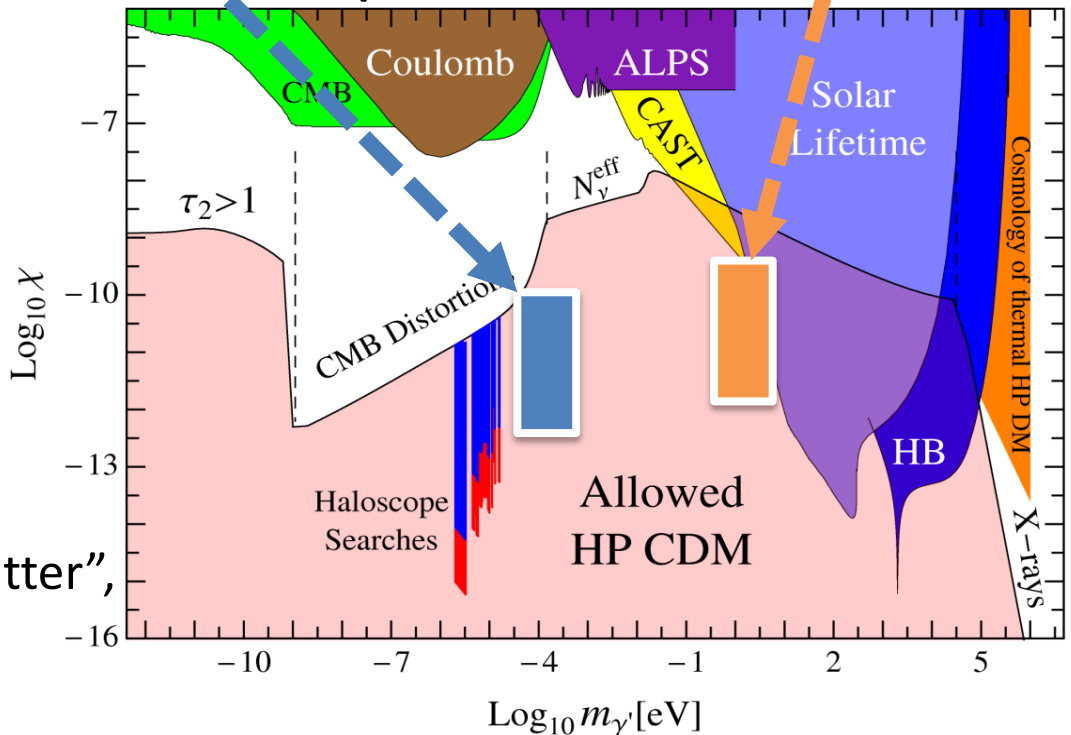


- Faint interaction (χ…very small) → **Amplify**!
- Amplification by a cavity (ex. ADMX)
- Dish antenna

Horns et al.
JCAP04(2013)016

Experimental search

- Using optical equipments ($m_{\gamma'} \sim$ eV)
  - Spherical mirror + PMT, CCD
- Using equipments for CS ($m_{\gamma'} \sim \mu$eV)
  - Dish antenna



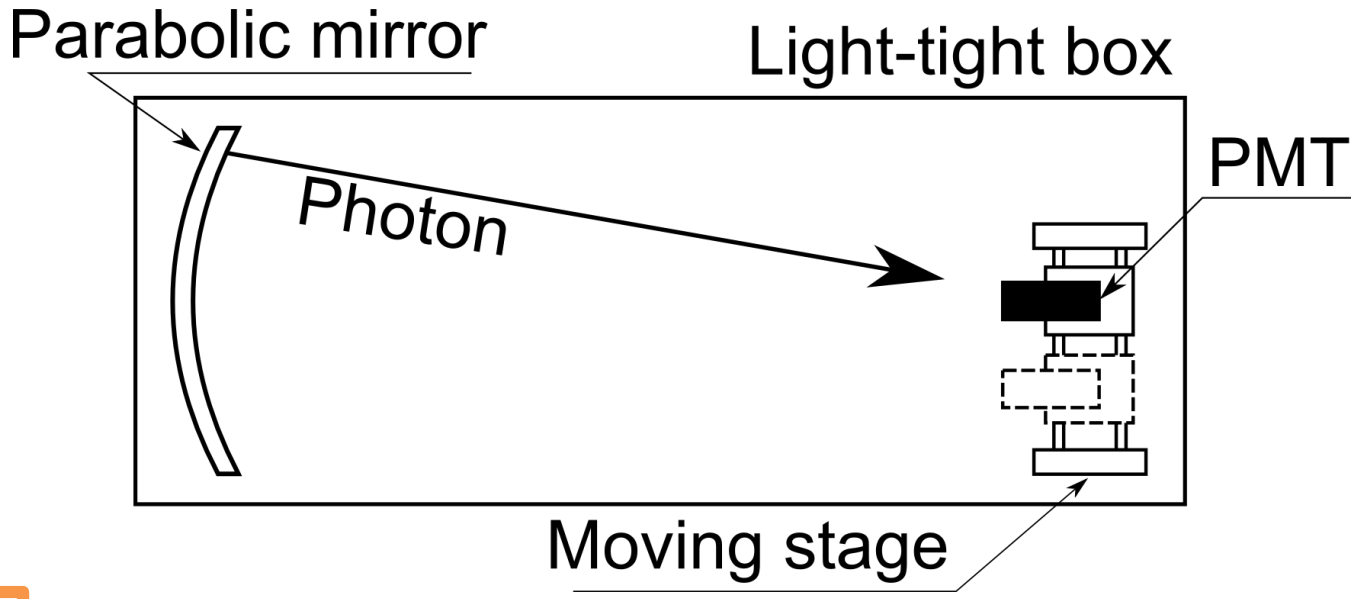
P. Arias et al, "WISPy cold dark matter", JCAP 06(2012)013

HPDM search in $m_{\gamma'} \sim$ eV

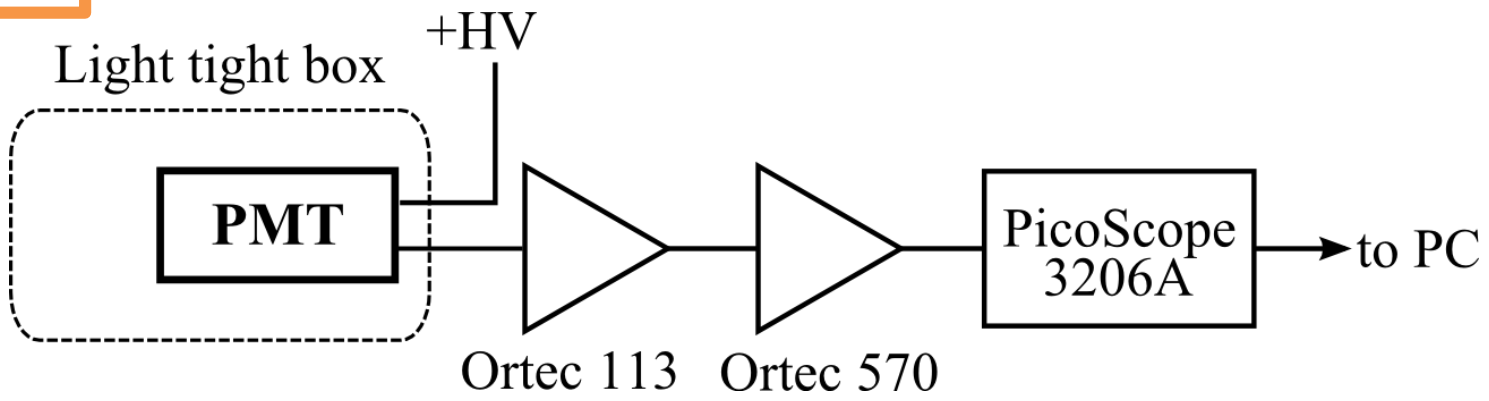
- Parabolic mirror (d: 50 cm → Area: 0.2 m^2)
- PMT (Hamamatsu R3550P, d: 1 inch)
  - Dark count rate ~ 5 Hz (@ room temperature)

Needs **Background Subtraction**

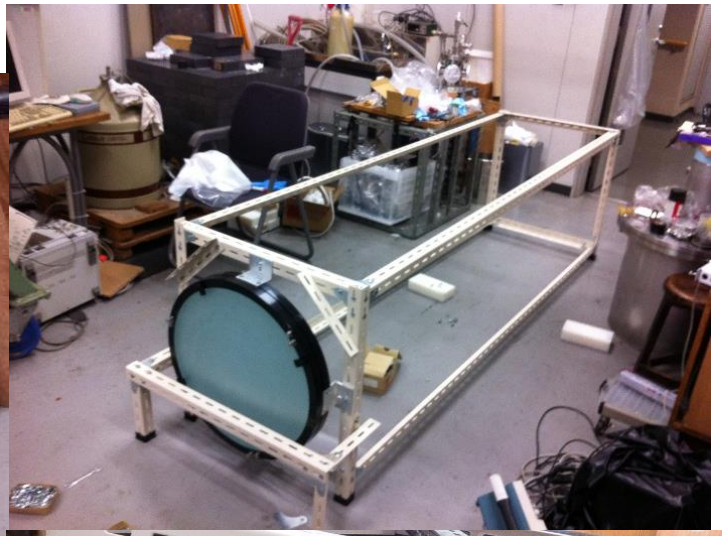
Instruments

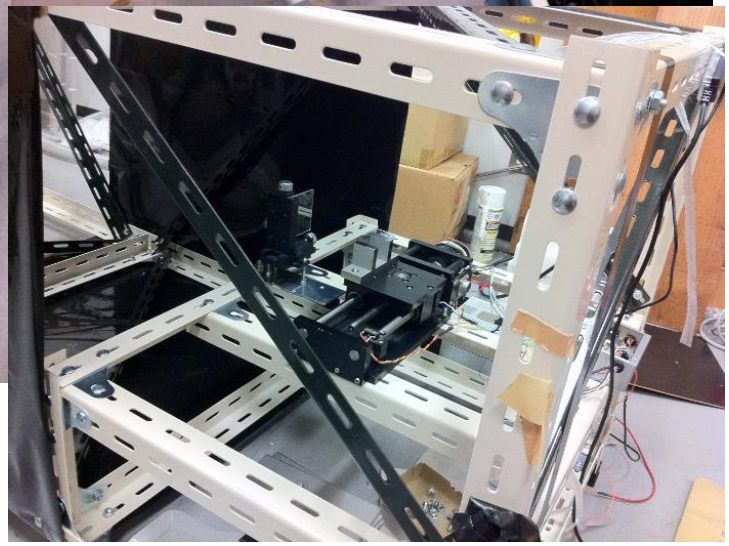


DAQ

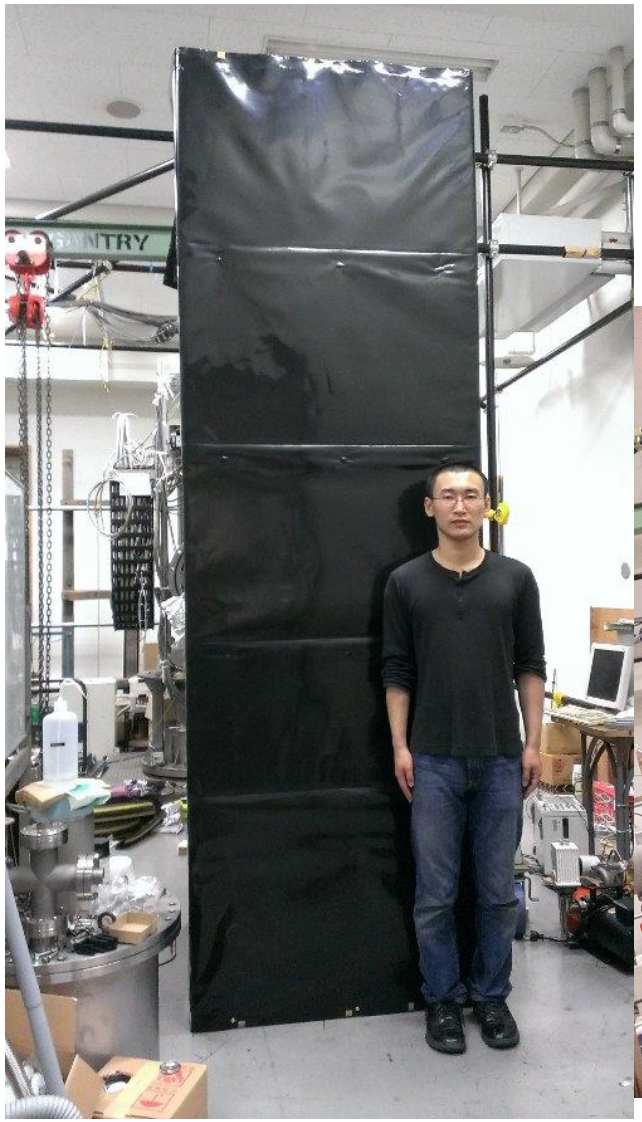


Apparatus



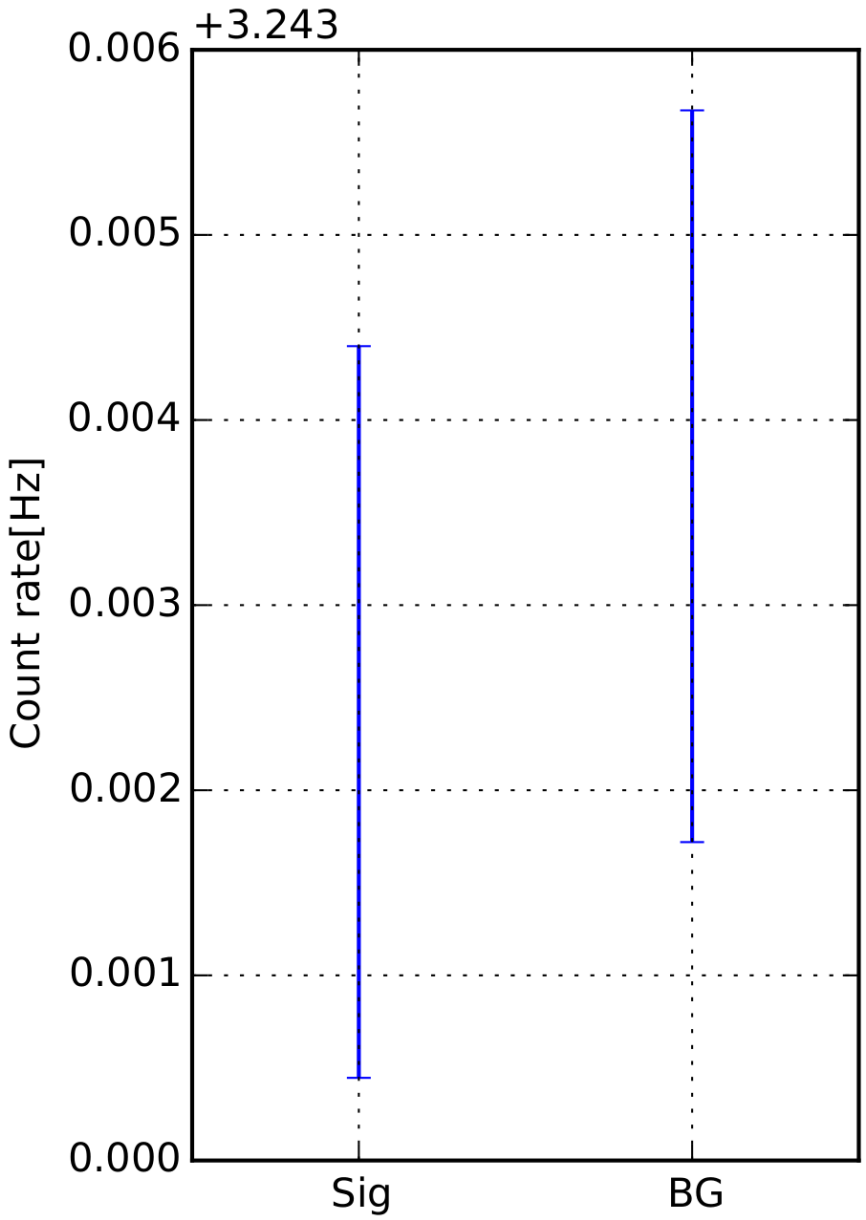


Light-tight box



$1\text{m} \times 1\text{m} \times 3\text{m}$

Result



Duration: 8×10^5 sec

(each Sig & BG)

Sig – BG =

$(-1.9 \pm 3.8) \times 10^{-3}$ Hz

$< 6.4 \times 10^{-3}$ Hz

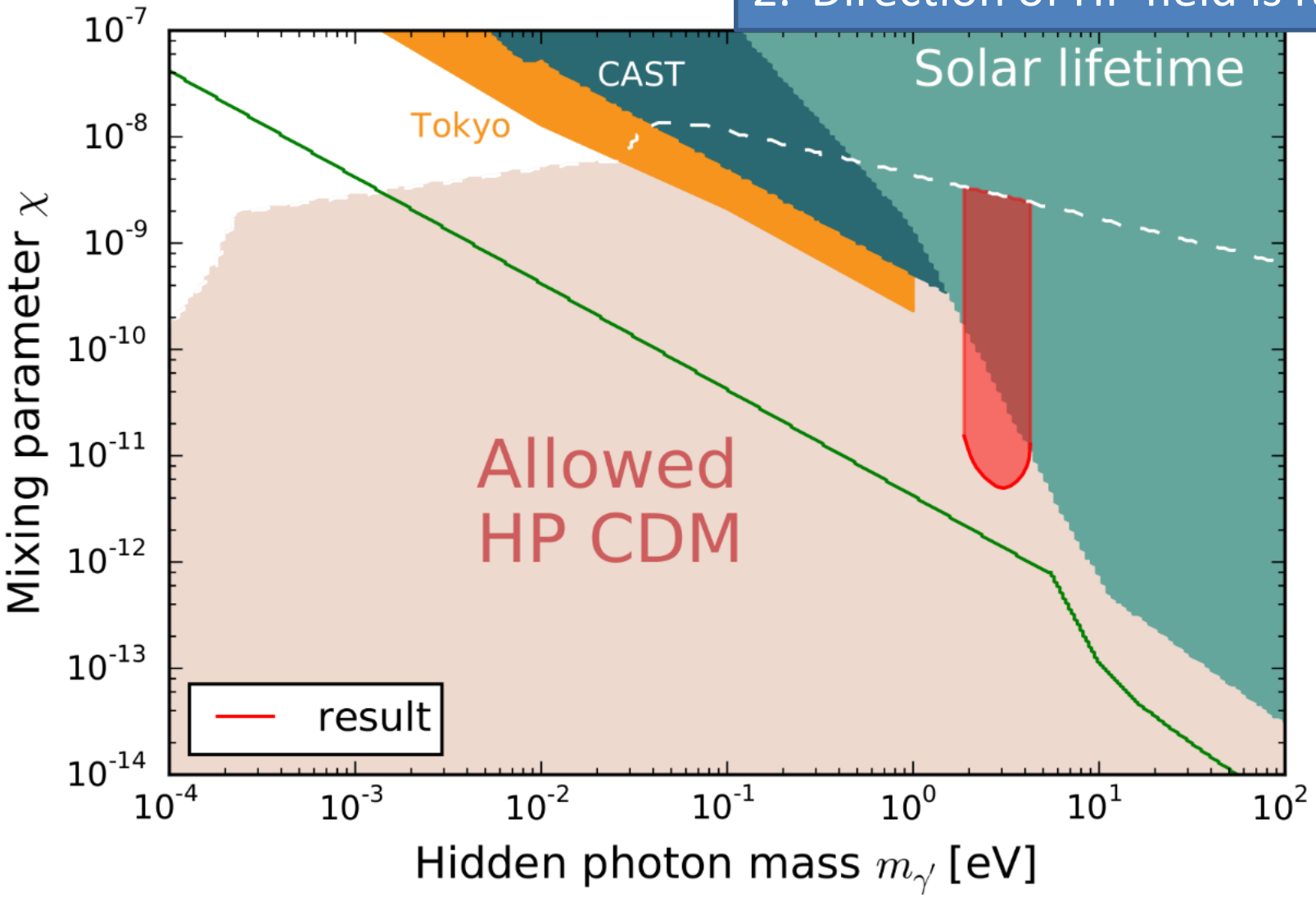
(95%CL)

No Excess

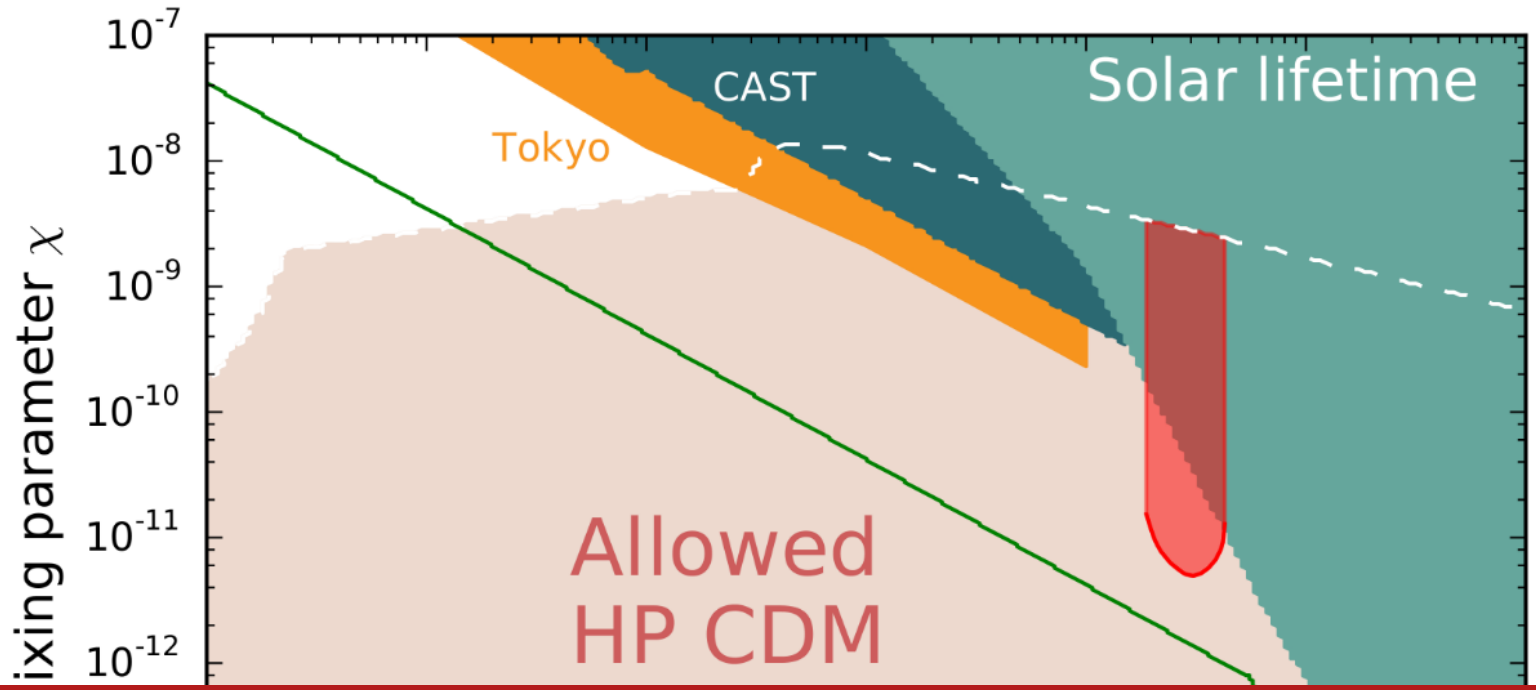
→ Limit for χ

Result

Assumptions:
1. DM is totally composed of HPs
   $\rho_{\mathrm{HP}} = 0.3\ \mathrm{GeV/cm^3}$
2. Direction of HP field is random



Result



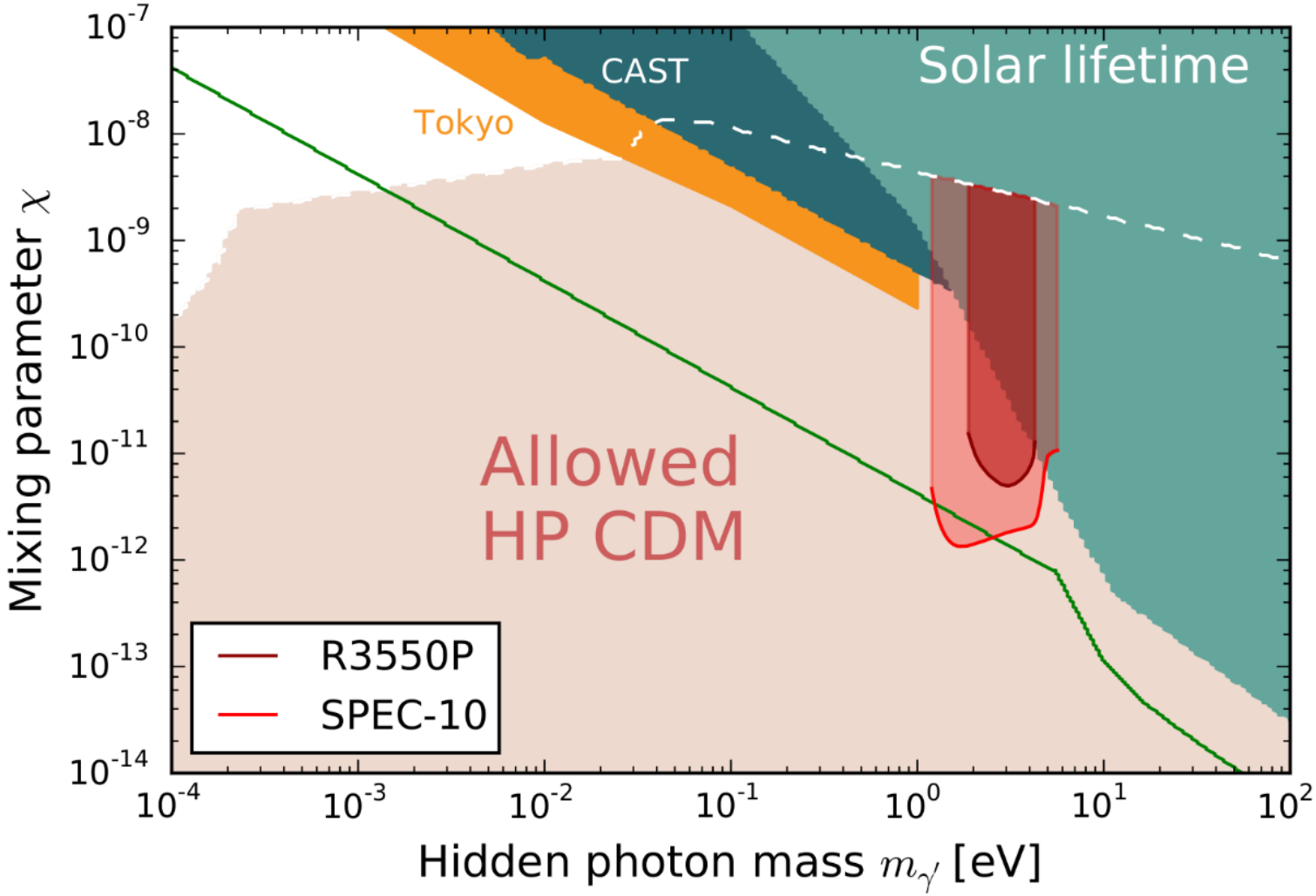
Experimental Search for Hidden Photon CDM in the eV mass range with a Dish Antenna

J. Suzuki, T. Horie, Y. Inoue, M. Minowa

(Submitted on 1 Apr 2015)

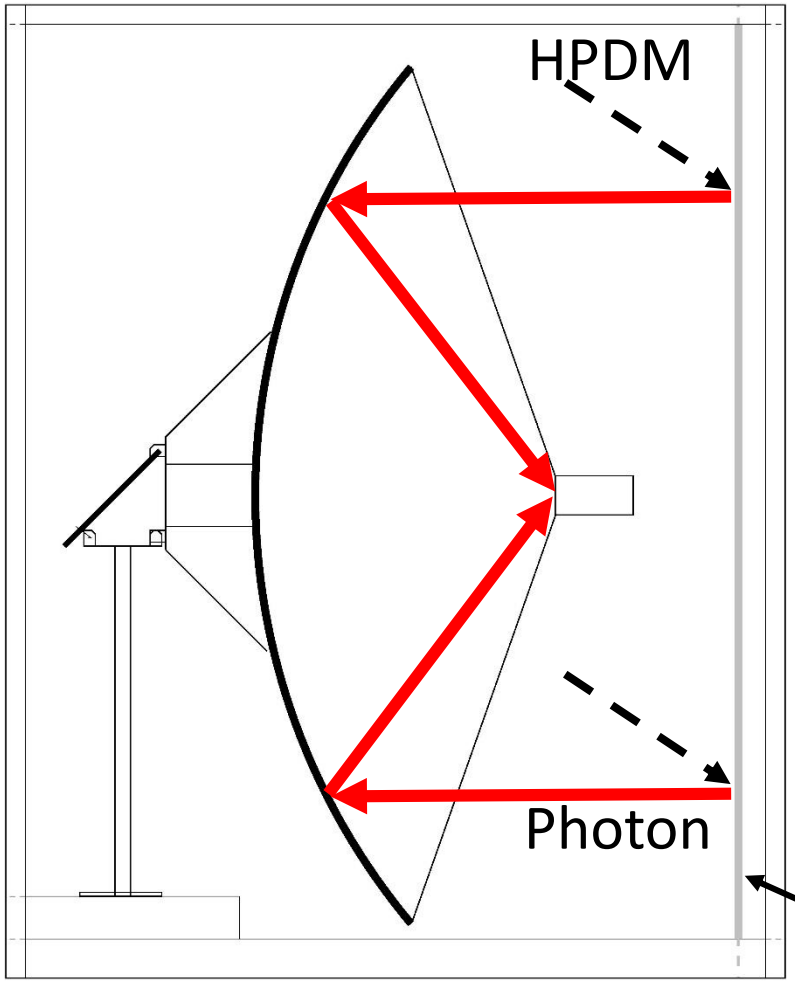
A search for hidden photon cold dark matter (HP CDM) using a new technique with a dish antenna is reported. From the result of the measurement, we found no evidence for the existence of HP CDM and set an upper limit on the photon-HP mixing parameter χ of $\sim 6 \times 10^{-12}$ for the hidden photon mass $m_\gamma = 3.1 \pm 1.2$ eV.

Future



CCD camera → high Q. E. → high sensitivity

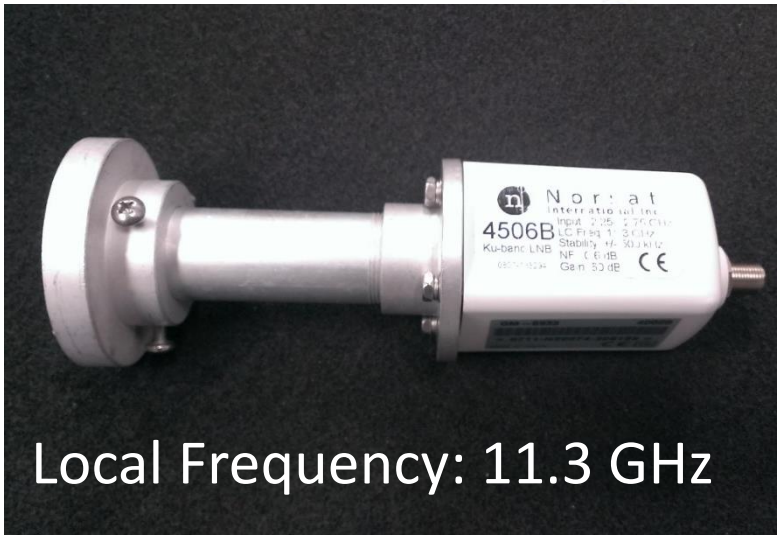
HPDM Search in K_u band ($\sim 12\mathrm{GHz}$)



- Parabolic dish
  → Commercially available
  → Cost reduction
- But:
  parabolic ↔ spherical

⇒ Let the dish face a plane reflector


2.2 m


Norsat
4506B
Ku-band LNB
Local Frequency: 11.3 GHz


2.4 m

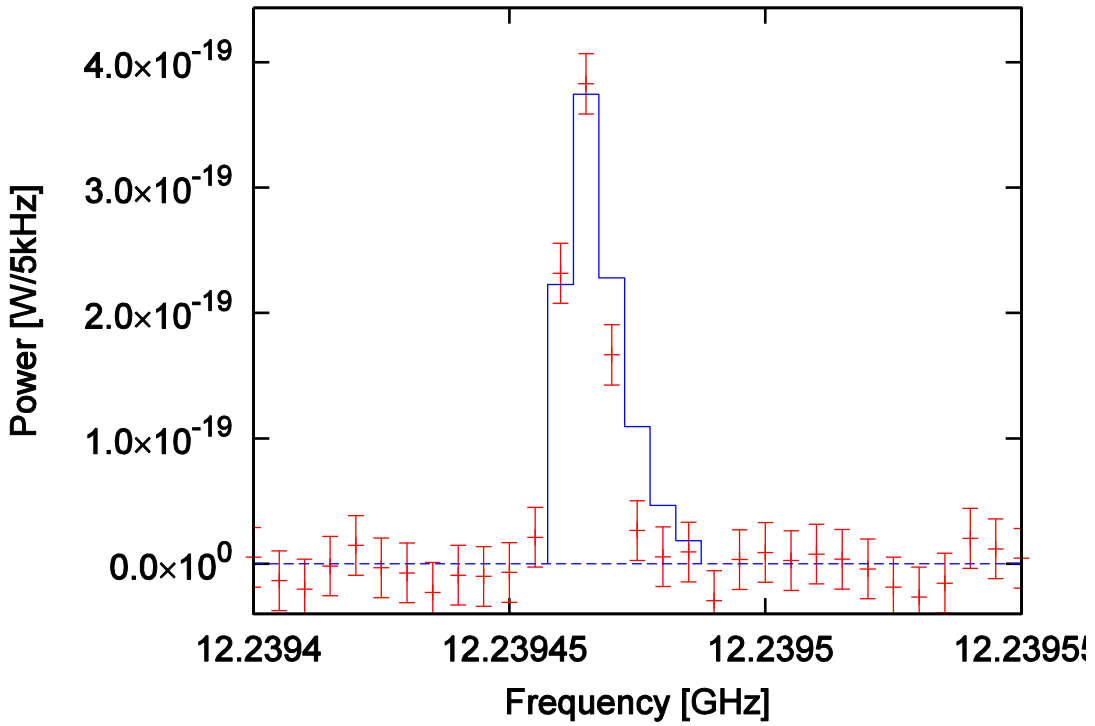
Search for the signal

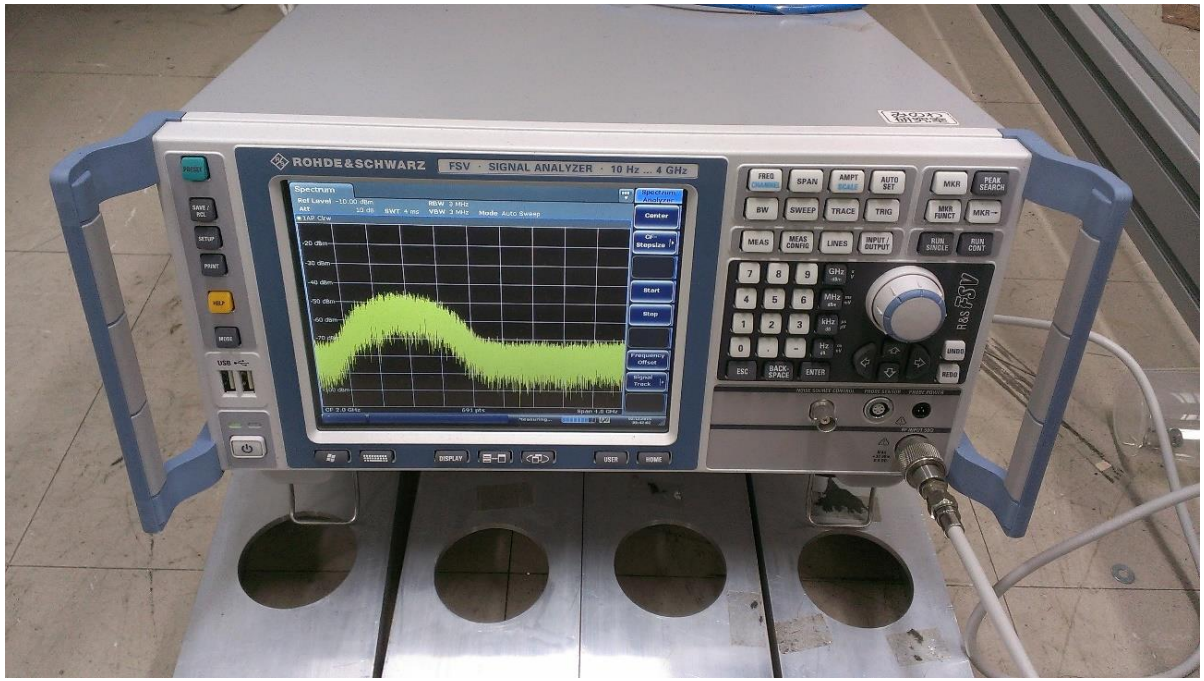
DM signal → a sharp spectral line

- Dispersion: $f(\vec{v}) = \frac{1}{\pi^{3/2} v_0^3} e^{-|\vec{v}|^2/v_0^2}$

$$\frac{\Delta f}{f} \sim 10^{-6}$$

(assuming Isothermal halo model)





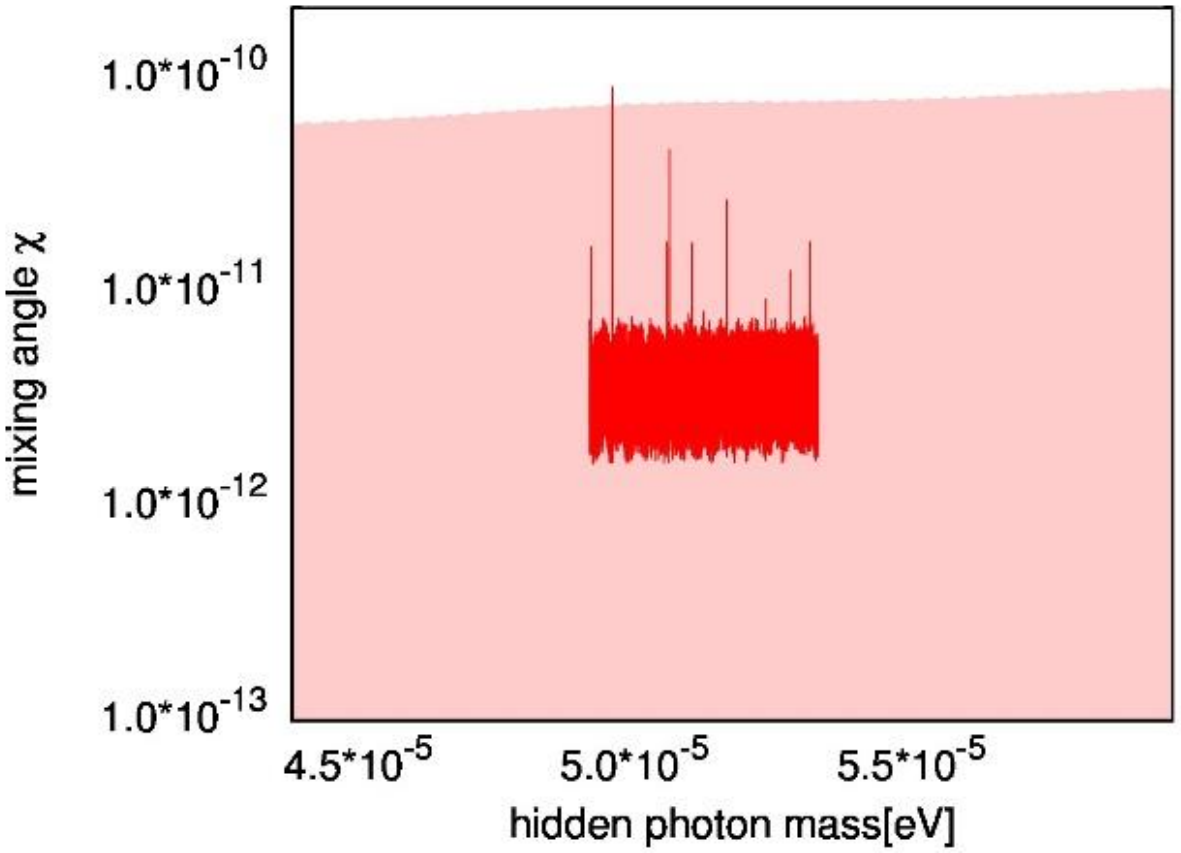
FFT analyzer
(FSV-4, R&S)
High-speed
data accumulation

Signal generator

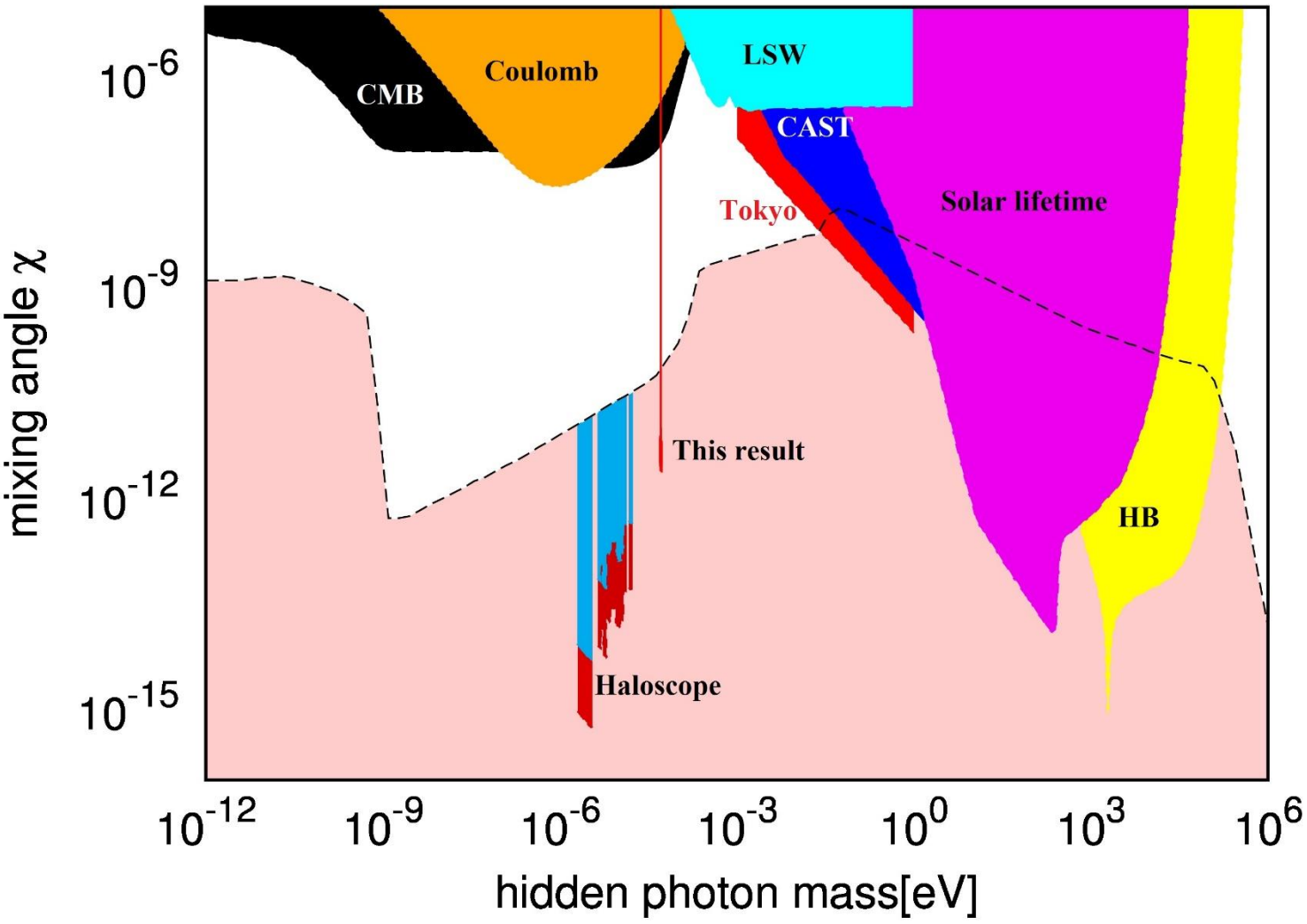
Fluctuation of
local frequency
→Need for calibration

Upper limit for χ

$$\chi_{95\%} = 4.5 \times 10^{-14} \left(\frac{2 \times P_{95\%}}{10^{-23}\mathrm{W}}\right)^{\frac{1}{2}} \left(\frac{0.3\mathrm{GeV/cm^3}}{\rho_{\mathrm{HP}}}\right)^{\frac{1}{2}} \left(\frac{1\mathrm{m^2}}{A_{\mathrm{eff}}}\right)^{\frac{1}{2}} \left(\frac{\sqrt{2/3}}{\alpha}\right)$$



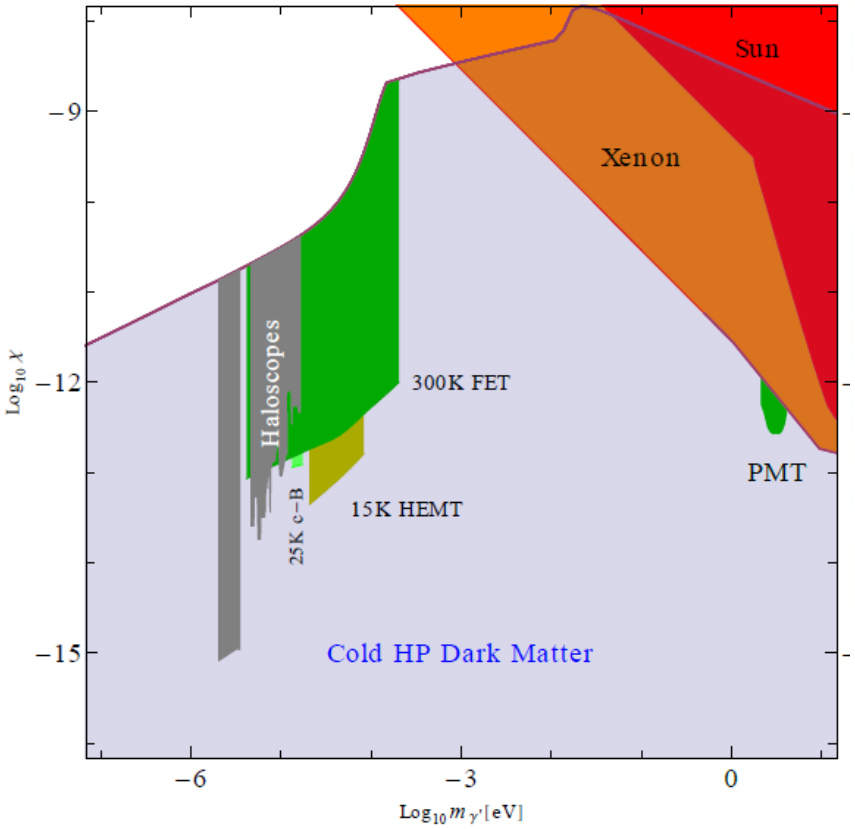
Upper limit for χ



Other experiment

$A \sim 13\mathrm{m}^2$!

FUNK (talk on Mon.)



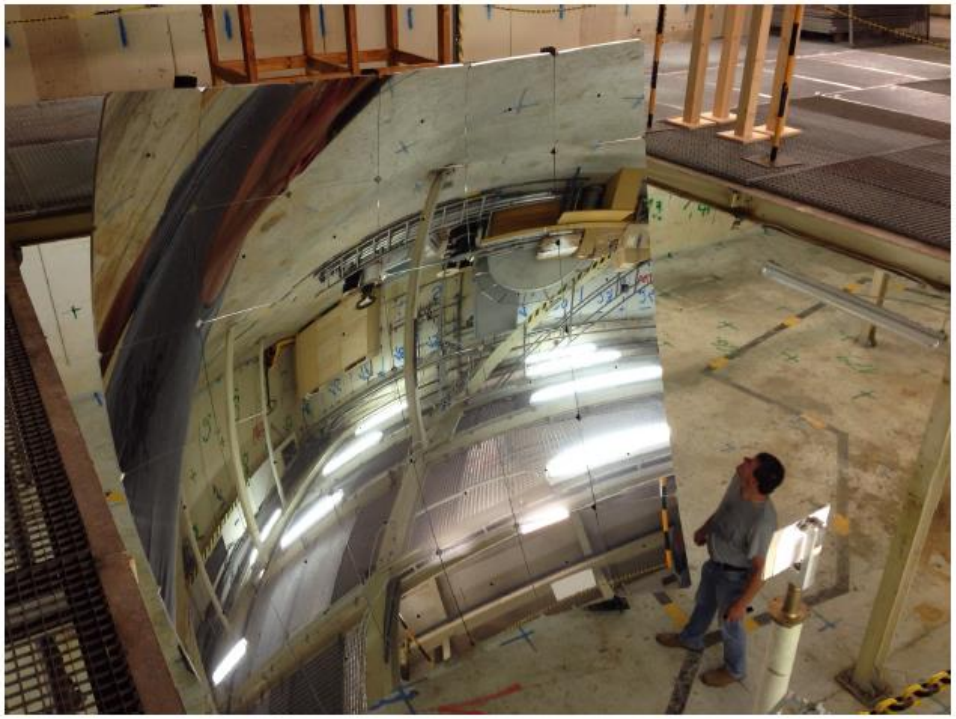
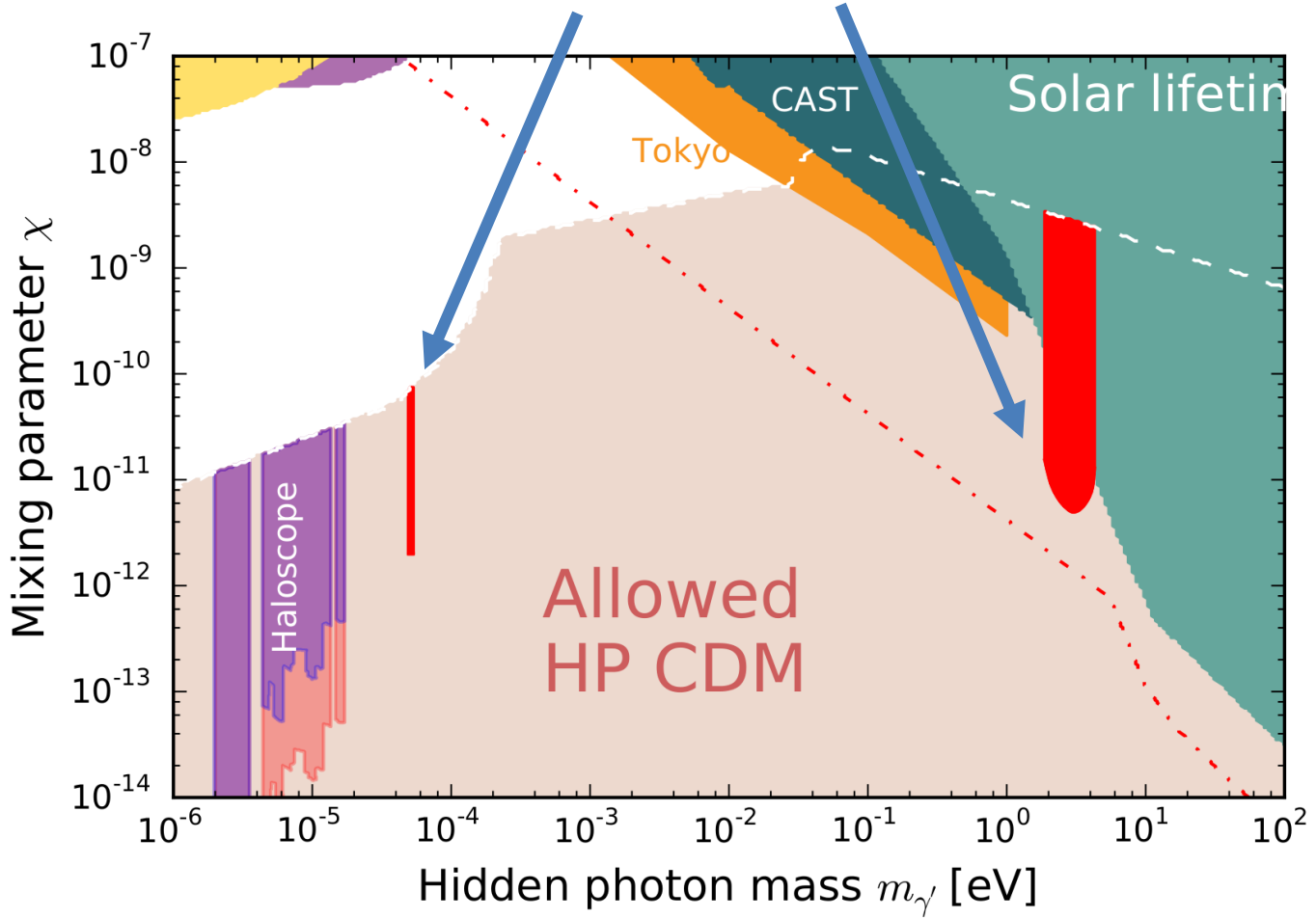


Figure 2: Spherical prototype mirror for AUGER housed at KIT (campus north). The grey post at the lower right hand side is the detector mount located in the center of curvature.

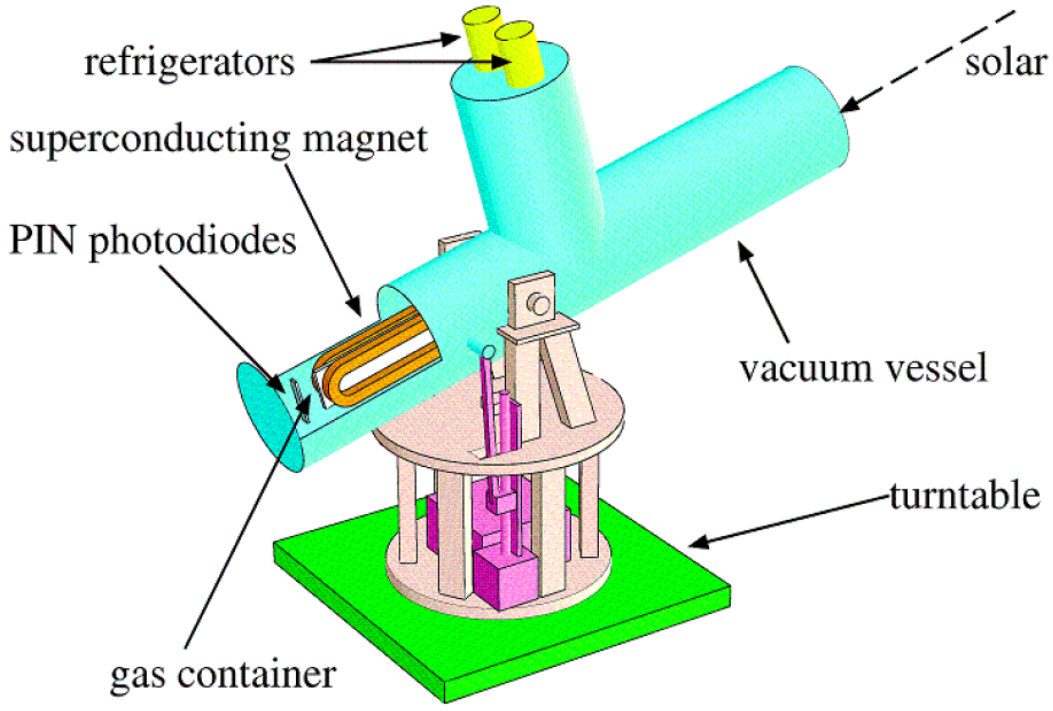
B. Dobrich et al.,
Hidden Photon Dark Matter Search with a Large Metallic Mirror arXiv:1410.0200

Conclusion

We actually conducted the search for HP CDM using Dish method in two frequency ranges

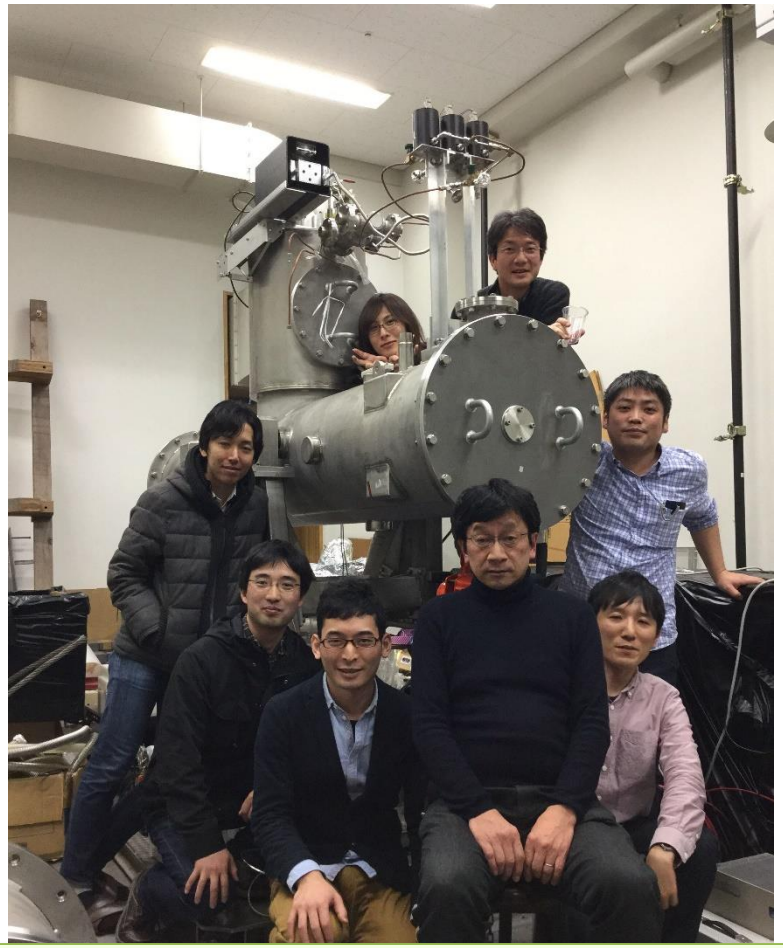


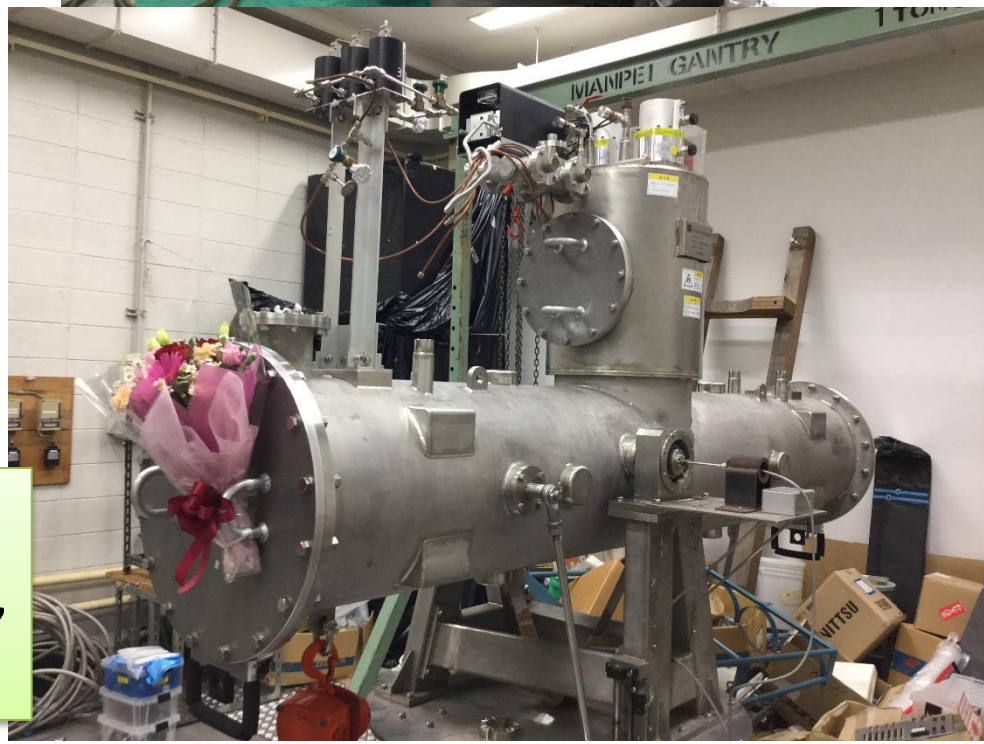
Tokyo Axion Helioscope aka Sumico



- No Liq. He
- B=4T, L=2.3m
- 268A persistent current
- 16 PIN photodiodes
- Altazimuth:
  Horiz. 360°, vert. ±28°

Decommissioning





Constructed by
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T. Namba, Y. Takasu, A. Yamamoto

Thank you for listening!