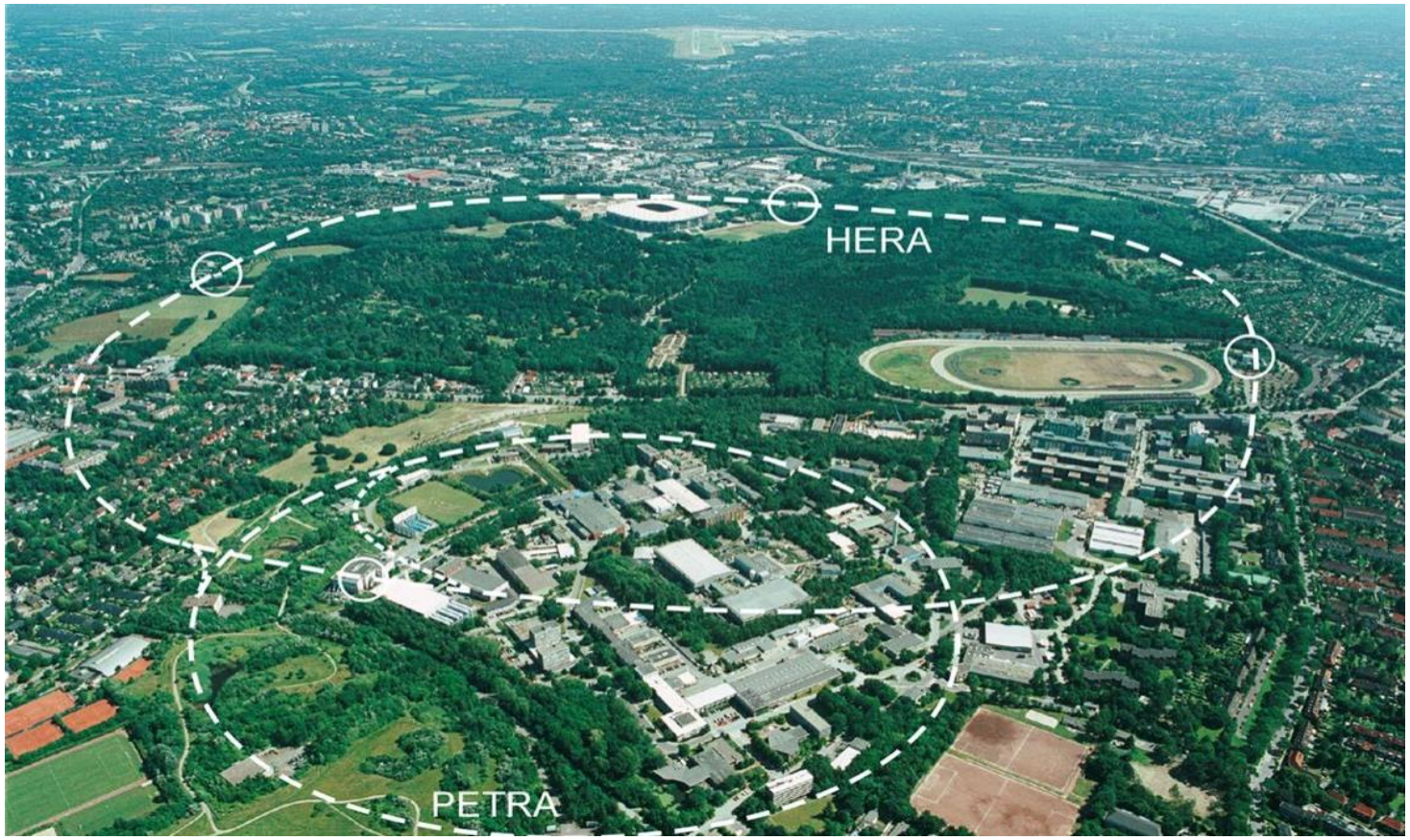
Status of ALPS II

In Search of the Axion



Frädrich, Henry
DESY
Karlsruhe, 14.09.2023

Leibniz Universität Hannover

HELMHOLTZ

UF UNIVERSITY of FLORIDA

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

SDU University of Southern Denmark

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

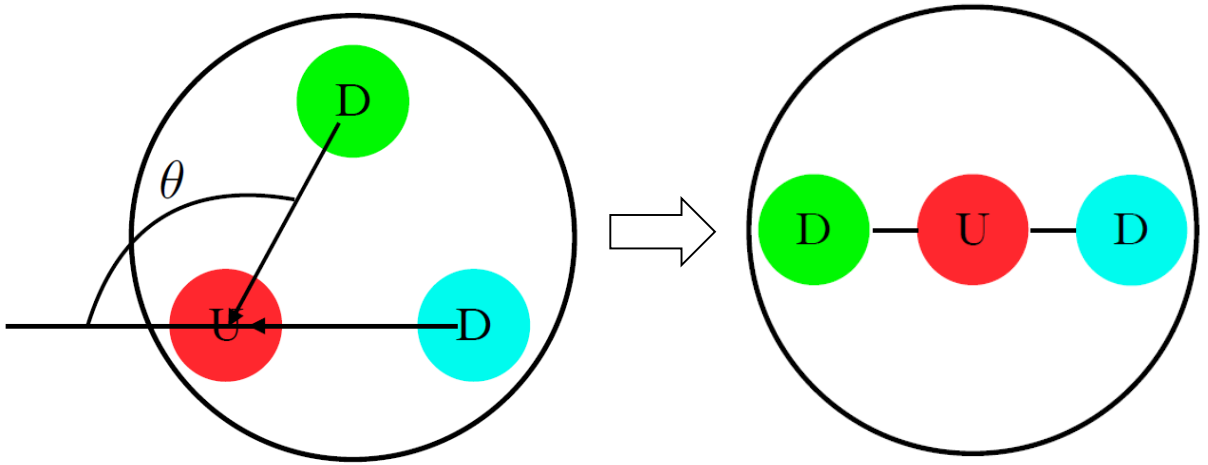
JGU JOHANNES GUTENBERG UNIVERSITÄT MAINZ

DESY.

Why Axion?

Motivation

- Axions solve the Strong CP-Problem
  - CP-Symmetry is conserved at $\theta = 0$
  - θ is arbitrarily close to 0 (Experiments: $\theta < 10^{-10}$)
  - Peccei-Quinn-Symmetry solves this Problem
  - $\rightarrow$ Axion
- Excellent cold dark matter candidate
- Astrophysical Hints

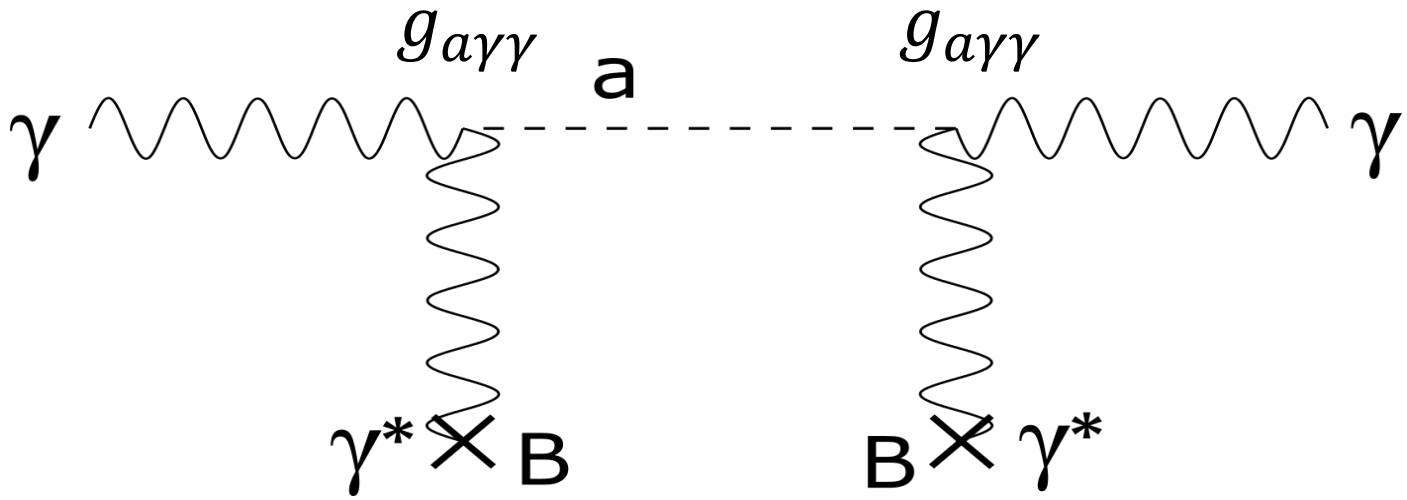


https://arxiv.org/abs/1812.02669

Axion ⇔ Photon Interaction

How to look for the Axion

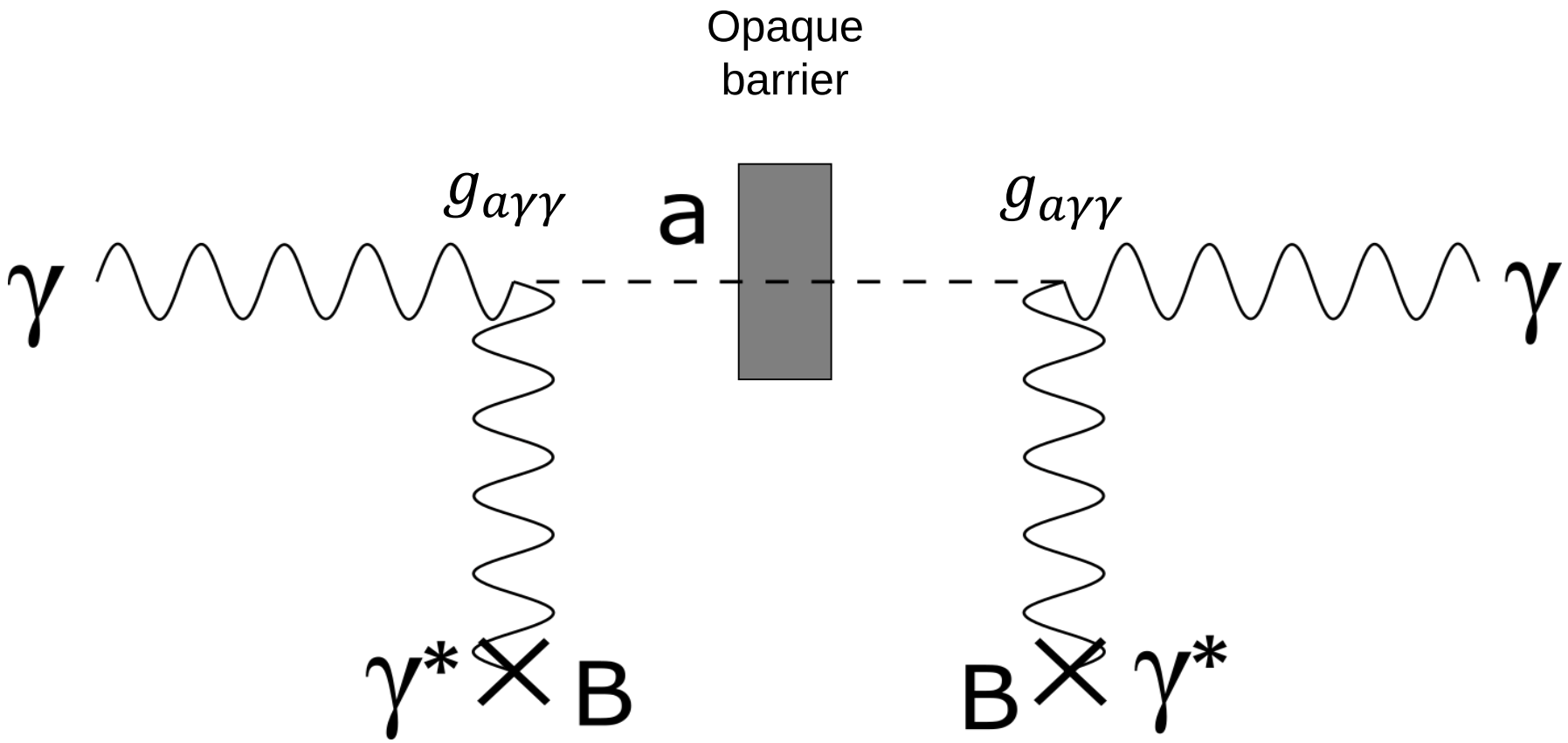
- (Inverse) Sikivie Effect
- Axion ⇔ Photon mixing in background magnetic field
- $g_{a\gamma\gamma}$ and m_a are unknown, but there are models and hints



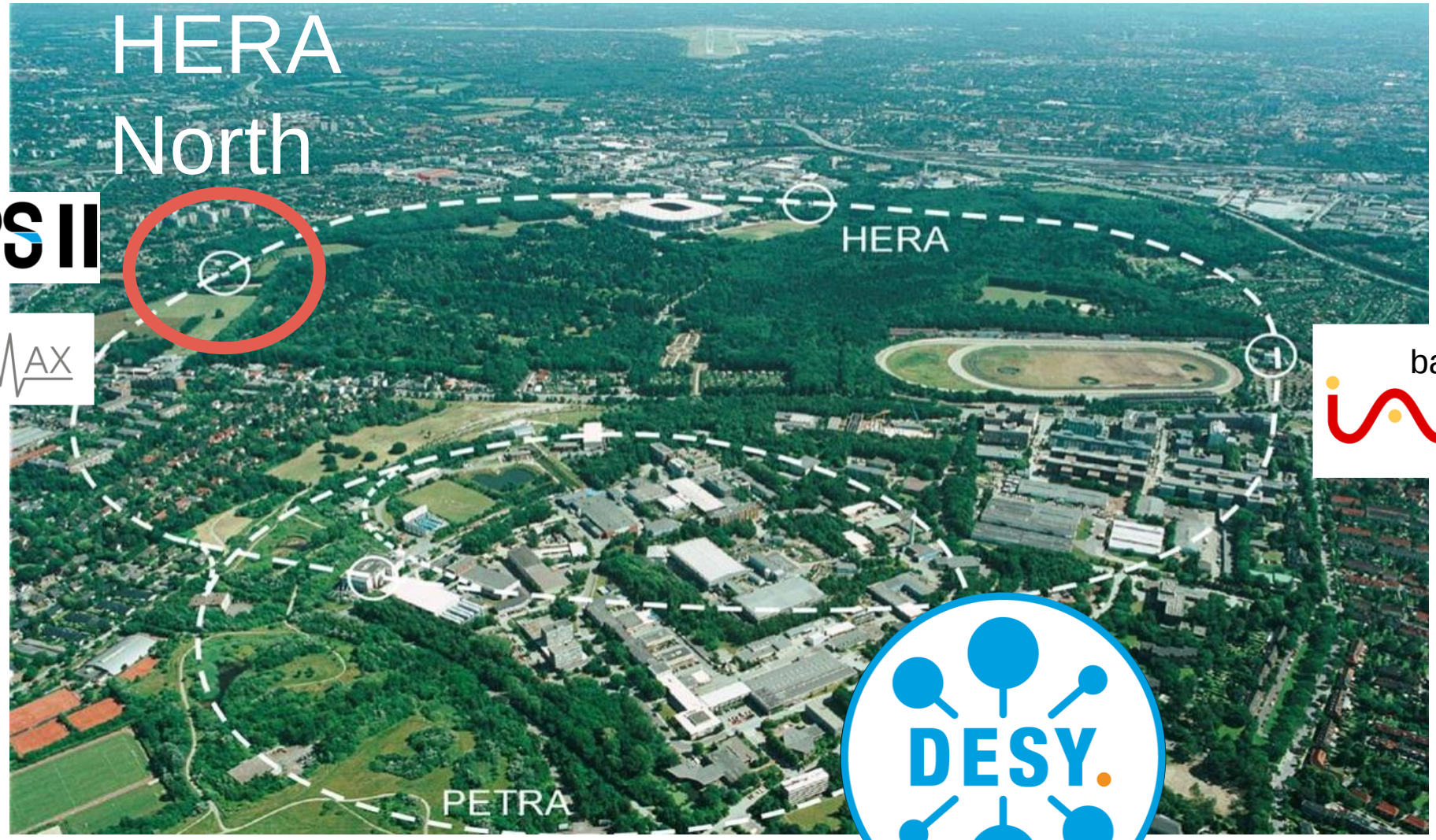
P. Sikivie
Phys. Rev. Lett. **51**, 1415 (1983)

$$\mathcal{L}_{a\gamma} = g_{a\gamma\gamma} a \mathbf{E} \cdot \mathbf{B}$$

Light Shining Through a Wall



Desy - Hamburg



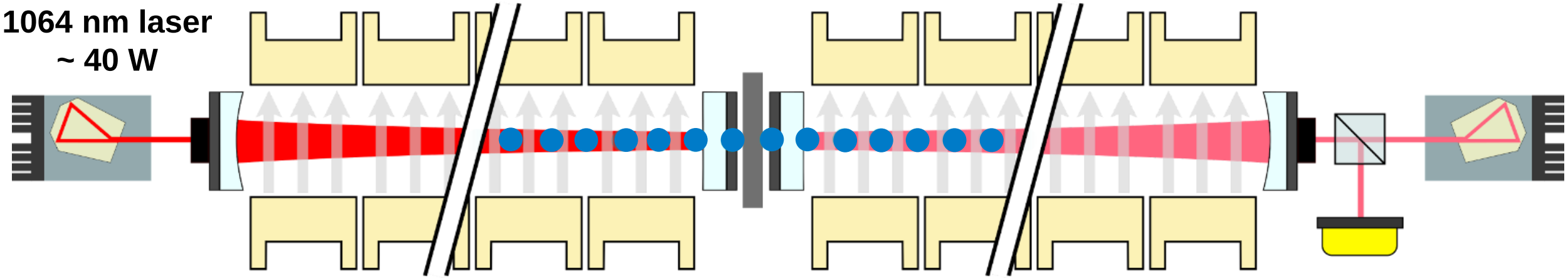
ALPS II

MADMAX

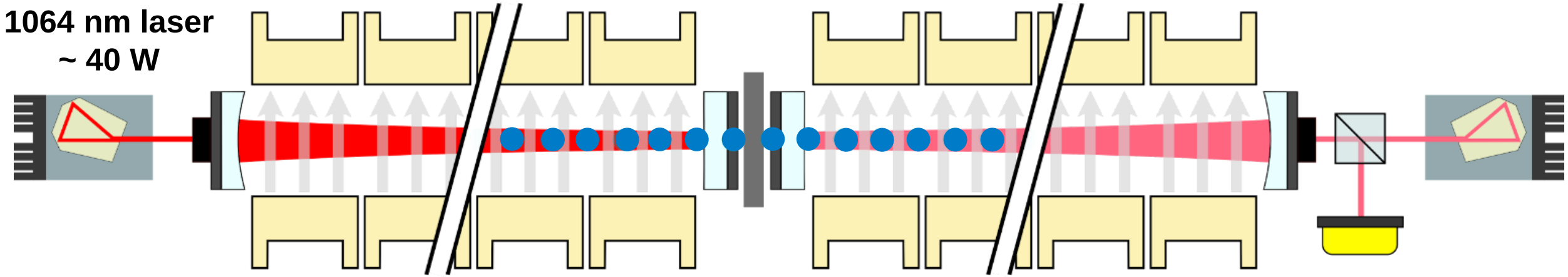
baby IAXO

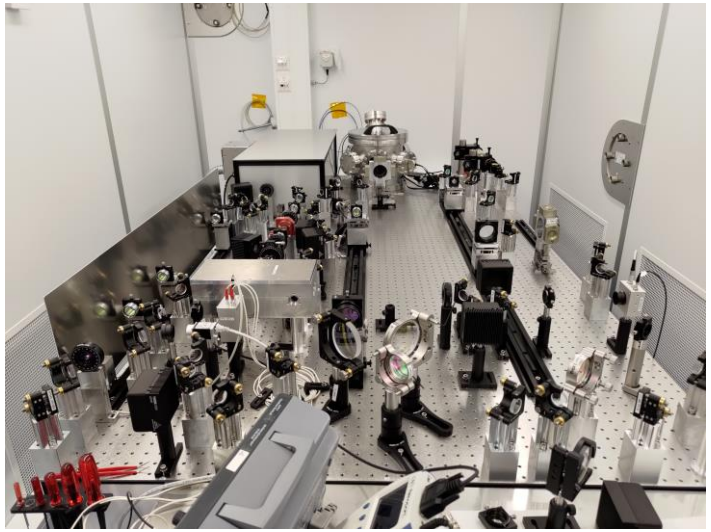
DESY.

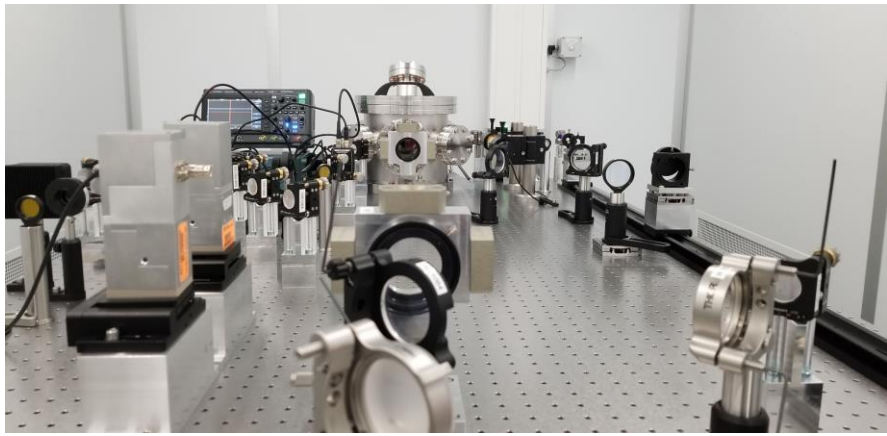
ALPS II



ALPS II

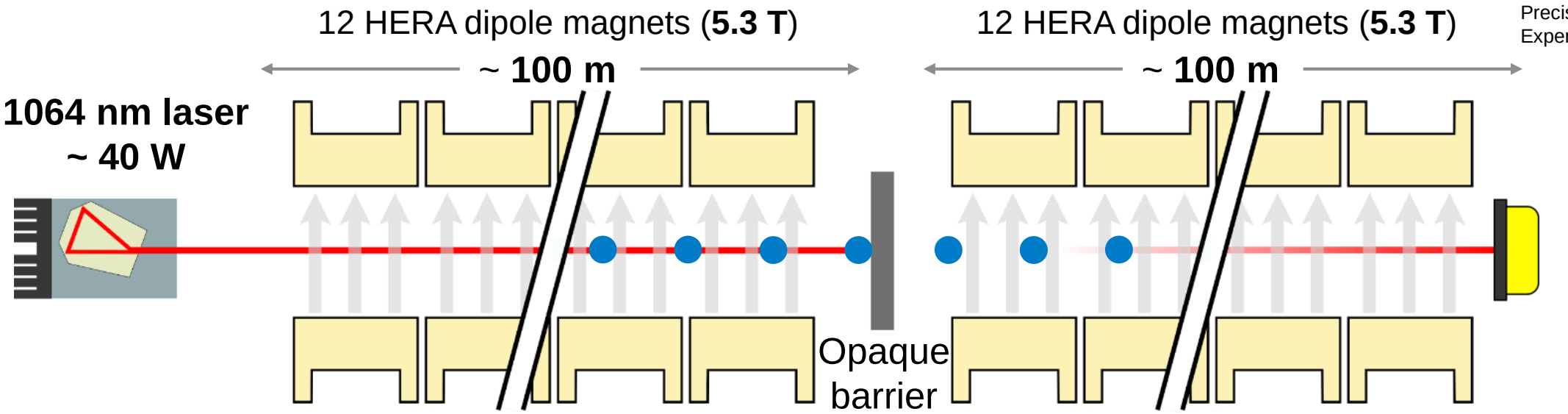






Light Shining Through a Wall

Todd Kozlovski
Precision Optical Techniques in ALPS Experiment, (2023)



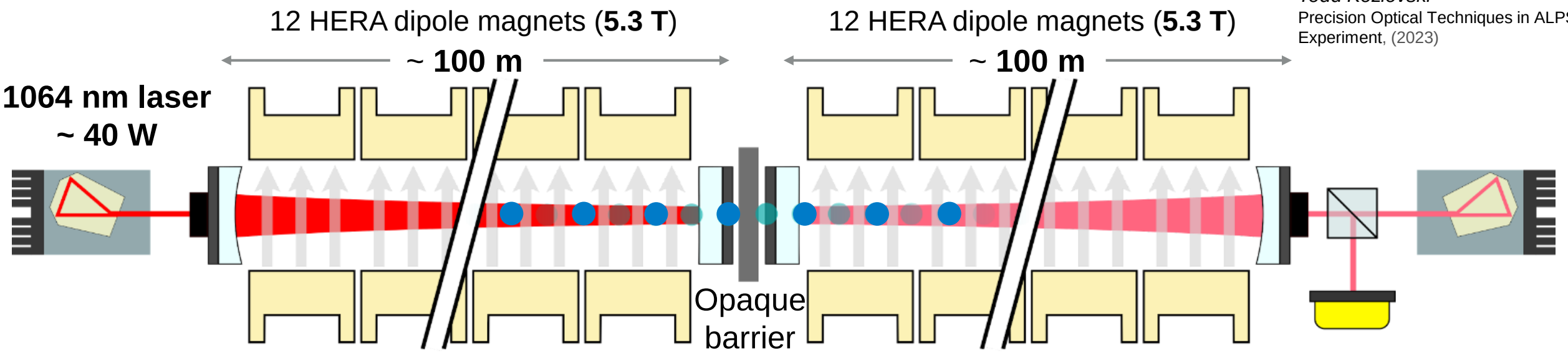
without optical cavities:

$$N_s = \frac{1}{16}\left(g_{\alpha\gamma\gamma} B_0 L_B\right)^4 \frac{P_{laser}}{h\nu}$$

for $g_{a\gamma\gamma} = 2 \times 10^{-11}$ GeV^{-1}

~photon / 150,000 yrs

Light Shining Through a Wall with Optical Cavities



Todd Kozlovski
Precision Optical Techniques in ALPS Experiment, (2023)

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without optical cavities:

$$N_s = \frac{1}{16}\left(g_{\alpha\gamma\gamma} B_0 L_B\right)^4 \frac{P_{laser}}{h\nu}$$

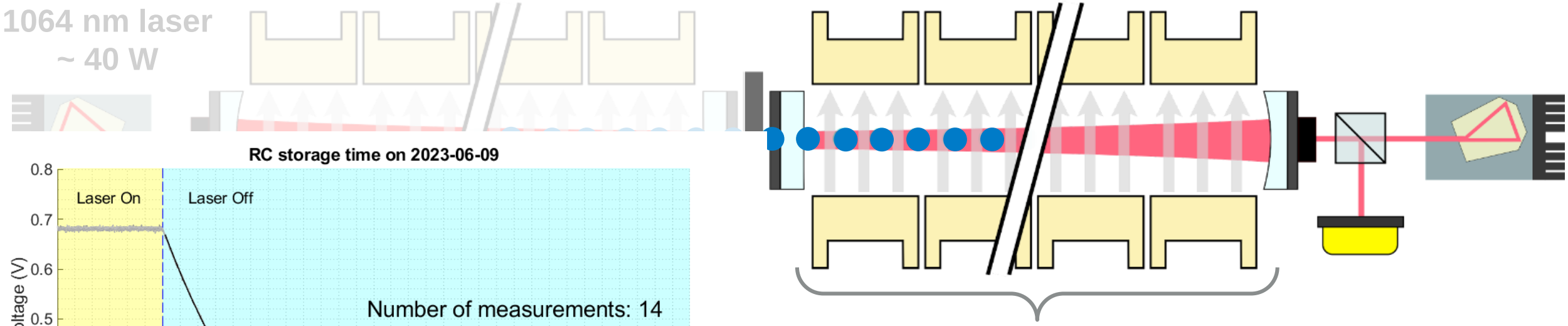
~photon / 150,000 yrs

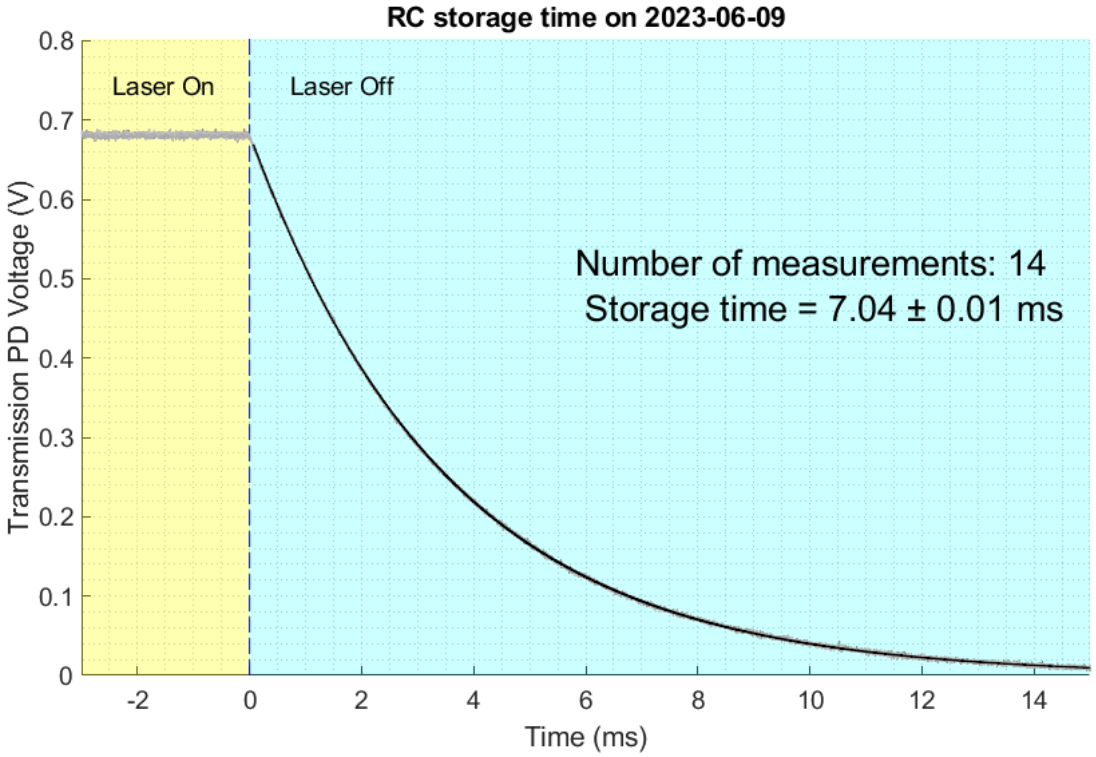
with optical cavities:

$$N_s = \frac{\eta}{16}\left(g_{\alpha\gamma\gamma} B_0 L_B\right)^4 \frac{P_{PC}}{h\nu}\beta_{RC}$$

~2 photons/day

Optical Cavities in ALPS II

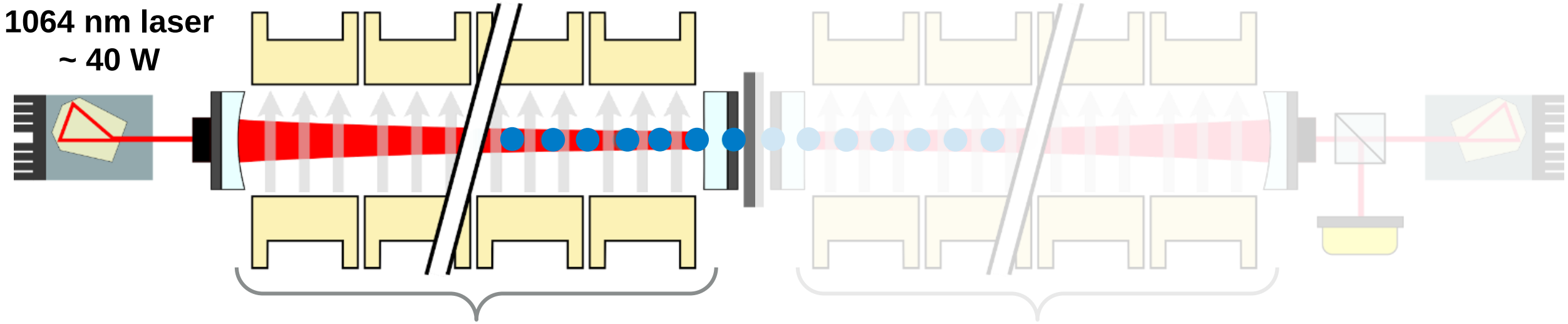




Regeneration Cavity (RC)

- Bulids up regenerated axion field.
- High resonant enhancement **β > 7,000** over a long baseline (120 m) cavity
- World record light storage time

Optical Cavities in ALPS II



Production Cavity (PC)

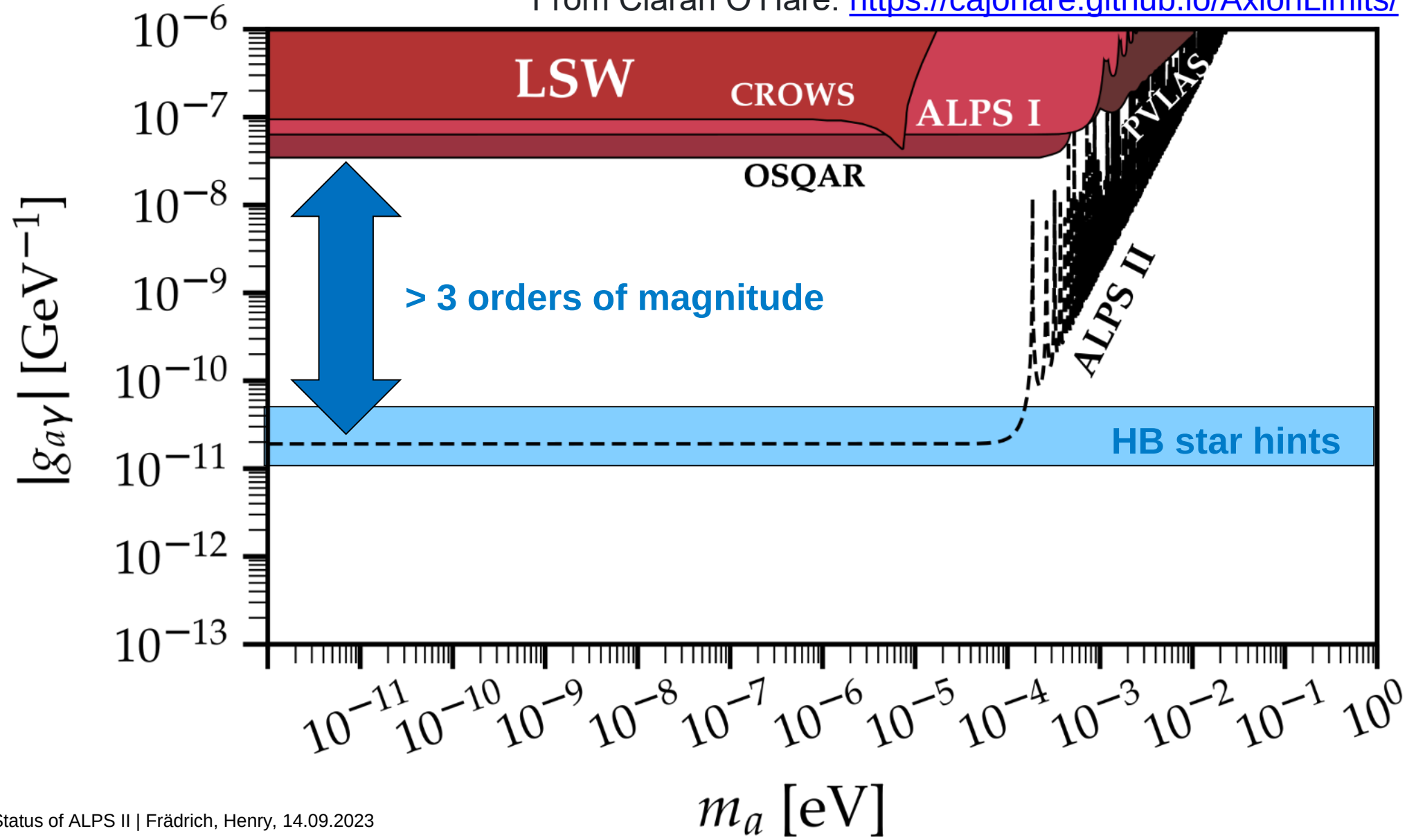
- Builds up the power of stored light circulating in the magnetic field
- Increases axion particle flux
- Will be built after reaching background goals

Regeneration Cavity (RC)

- Bulids up regenerated axion field.
- High resonant enhancement **β > 7,000** over a long baseline (120 m) cavity
- World record light storage time

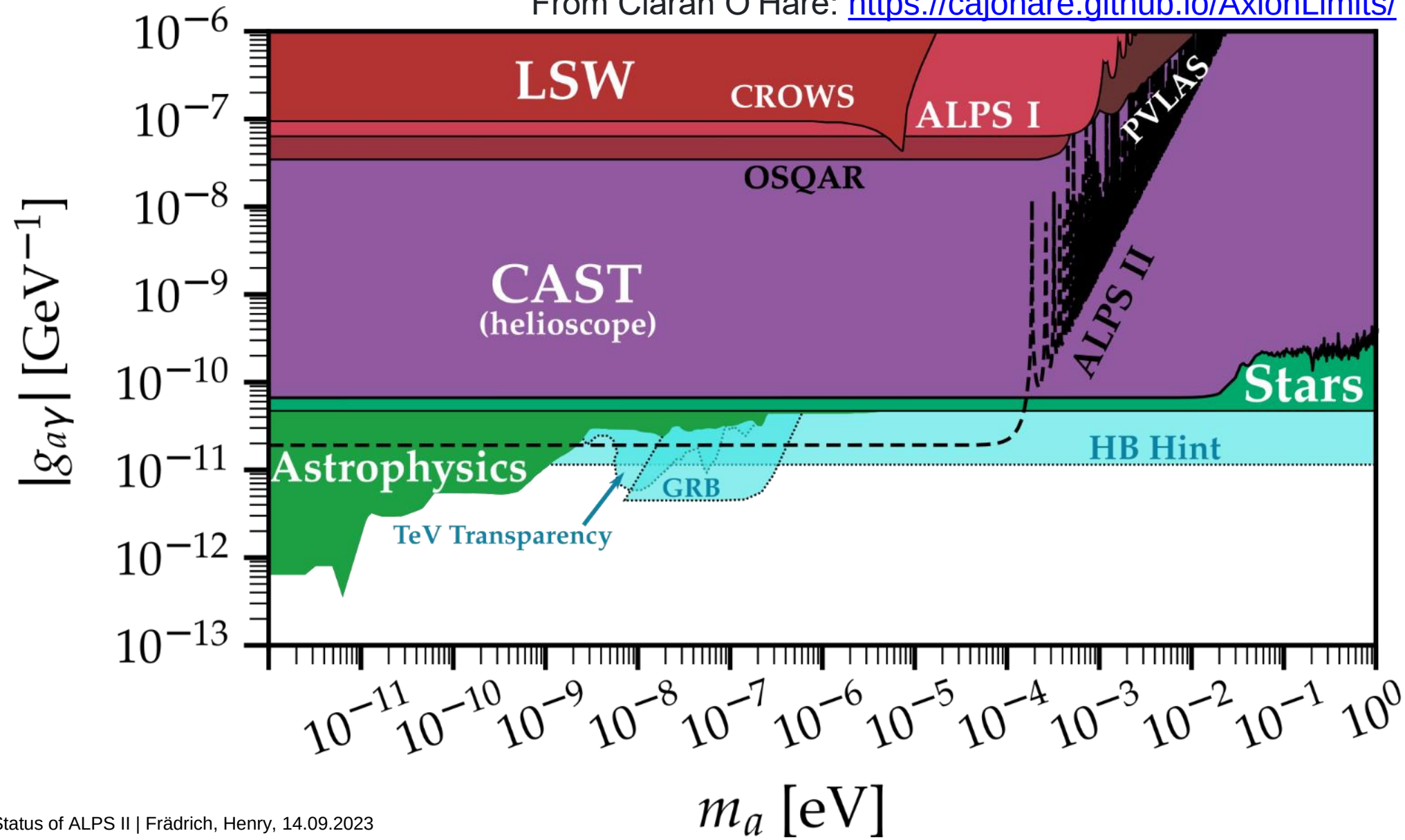
Model Independent Experiments

From Ciaran O'Hare: https://cajohare.github.io/AxionLimits/



Axion Search Overview

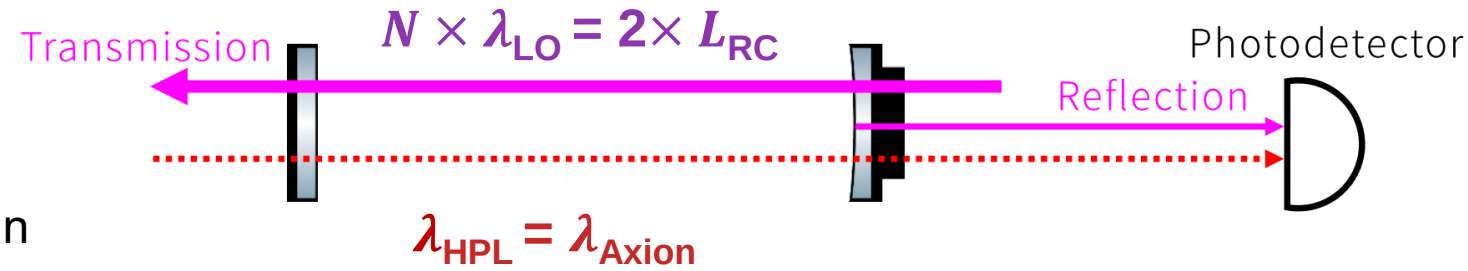
From Ciaran O'Hare: https://cajohare.github.io/AxionLimits/



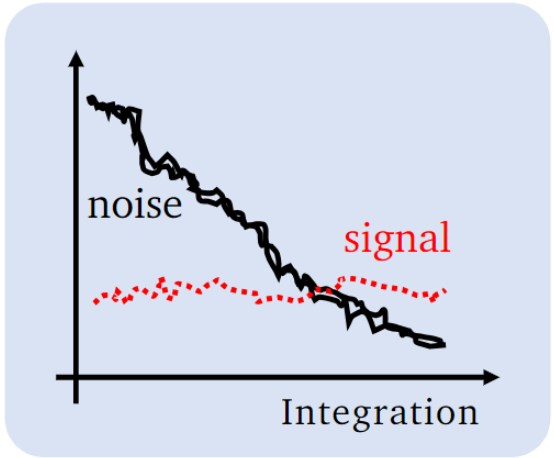
Heterodyne Detection

Graphic courtesy of Li-Wei Li

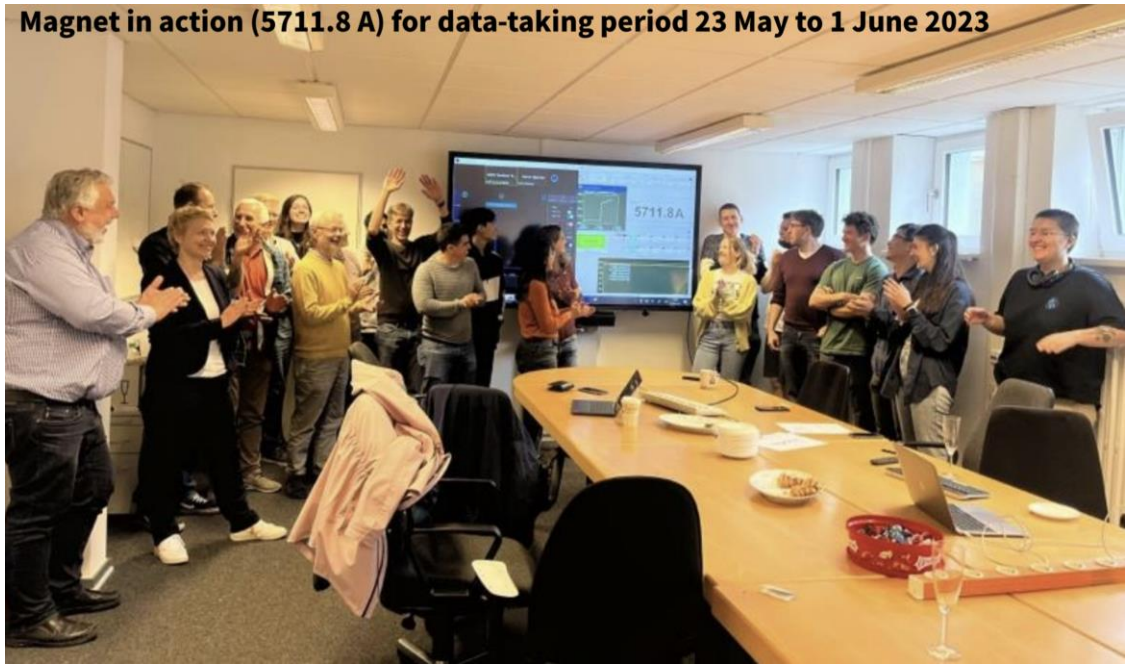
- Overlay the local oscillator (LO) and the regenerated photons in the cavity
- Photodetector detects “beatnote” (peak in frequency space)
- Averaging over long periods of time
  → Shot noise averages out
  → Signal sums up
- Limiting factors
  - Optical shot noise
  - Backgrounds

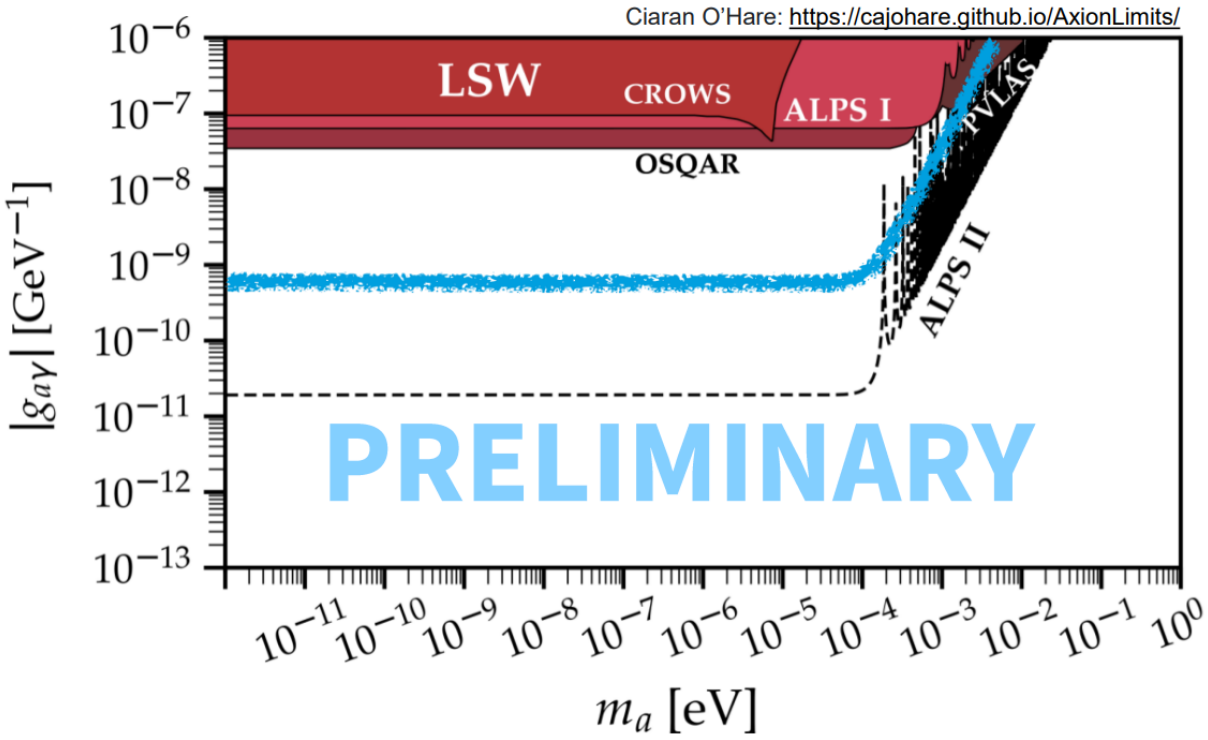


$$P_{LO} + P_a + 2\sqrt{P_{LO}P_a}\cos[2\pi(\nu_a - \nu_{LO})t]$$



Initial Science Run





~150 000 seconds of data above the calibration requirement

Outlook

Currently worked on

- Automatic run procedure + autolocking

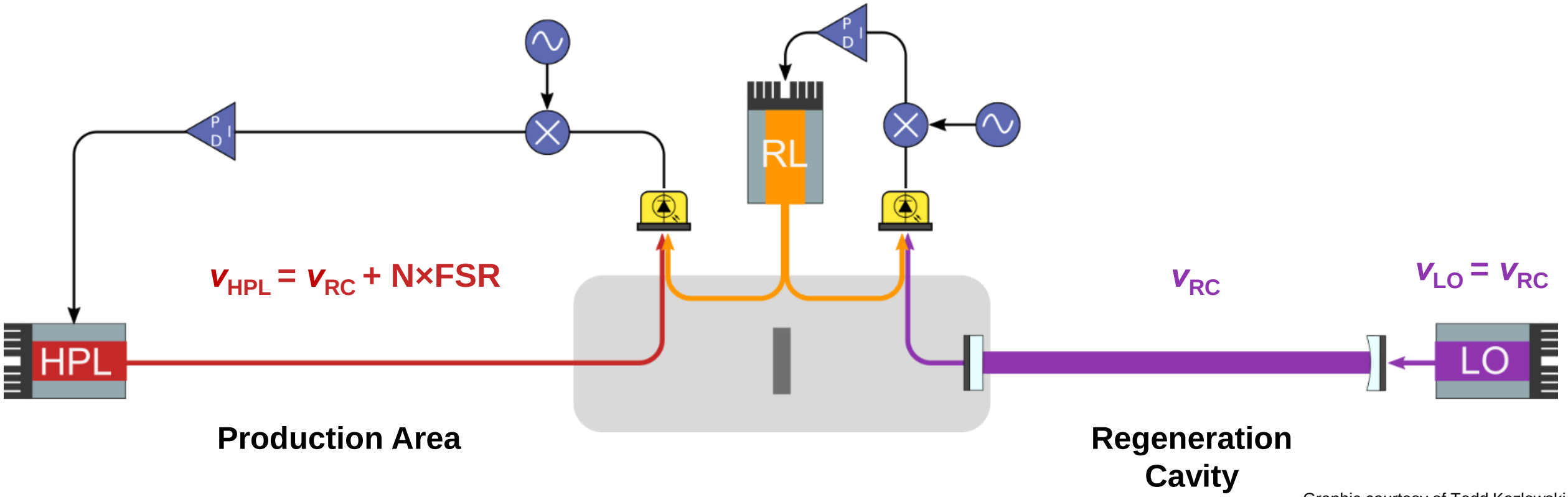
  → 1 Million Second Run

Near Future

- Production Cavity
- Upgrade optics
- → reaching design sensitivity

Thanks for Listening

Control System in ALPS II



Graphic courtesy of Todd Kozlowski

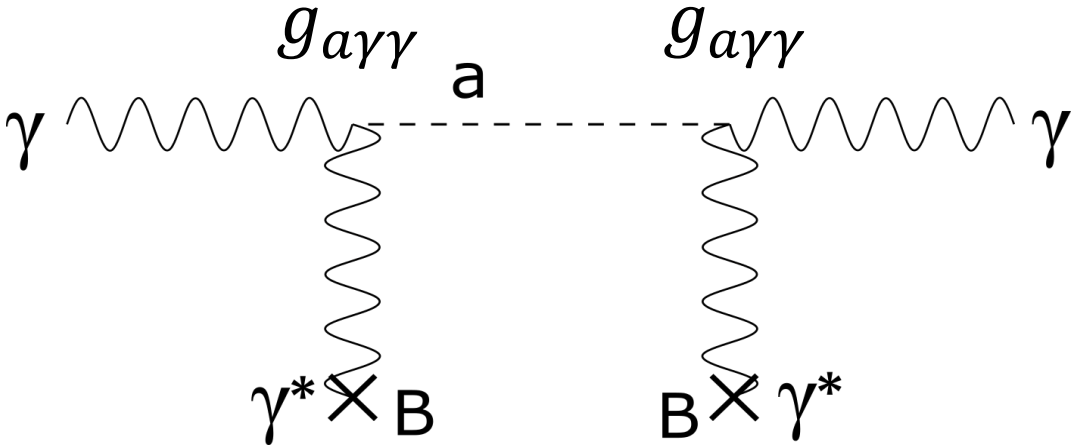
Challenges

- Get the HPL resonant with the RC cavity
- Don’t get any of the HPL light into the cavity

Axion Experiments at Desy

Experiments using Sikivie Effect:

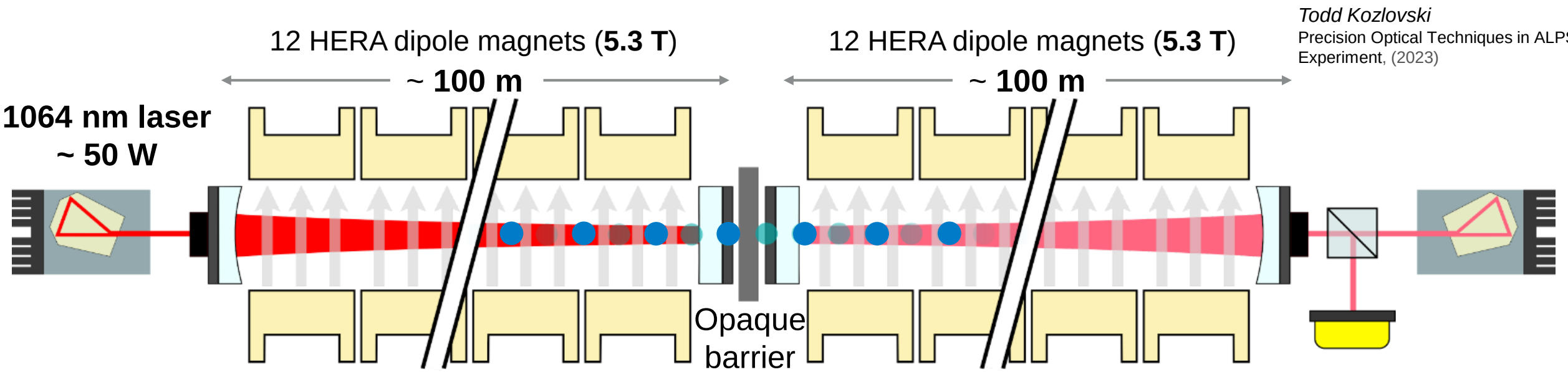
- Haloscopes
- Helioscopes
- Light Shining throught Wall



P. Sikivie
Phys. Rev. Lett. **51**, 1415 (1983)

Source	Experiments	Model dependence
 **Relic CDM axions**	MADMAX	**High**
 **Solar axions**	(baby) IAXO	**Low**
 **Laboratory-prepared axions**	ALPS II	**Very Low**

Backgrounds



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Stray Light

- Light from the HPL falls onto detector
- Currently ~1/300 $\frac{Photons}{Second}$
- Reason Production Cavity is not installed yet