The Sun in the Axion light?

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- Introduction: PVLAS vs. CAST puzzle
- Can CAST tell?
- Use of optical sensors
- Outlook

3rd Joint ILIAS–CERN–DESY Axion–WIMPs Training Workshop

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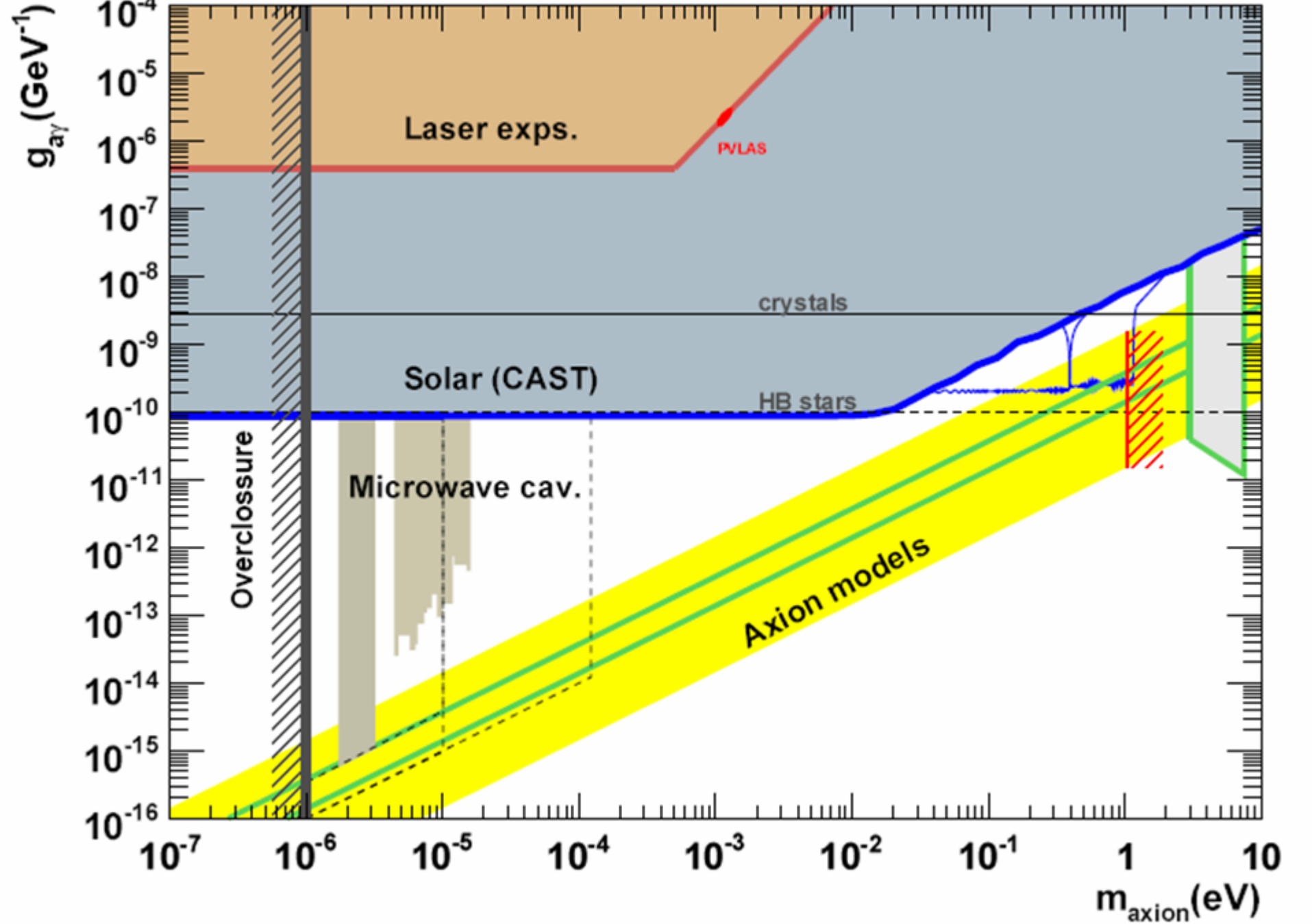
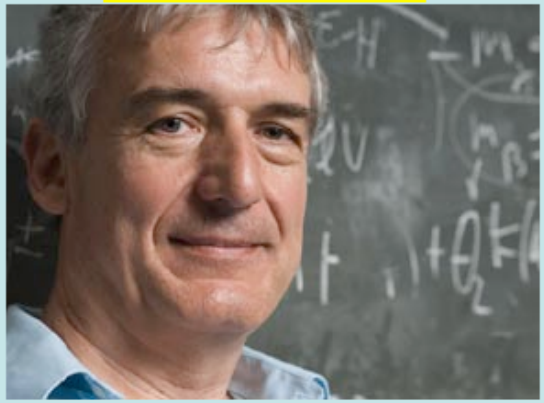
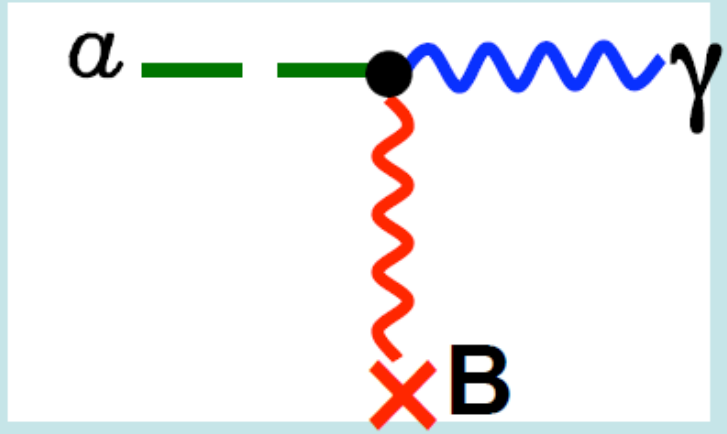

$g_{a\gamma}$ (GeV^{-1})
Laser exps.
PVLAS
crystals
Solar (CAST)
HB stars
Overclossure
Microwave cav.
Axion models
m_{axion}(eV)

CAST

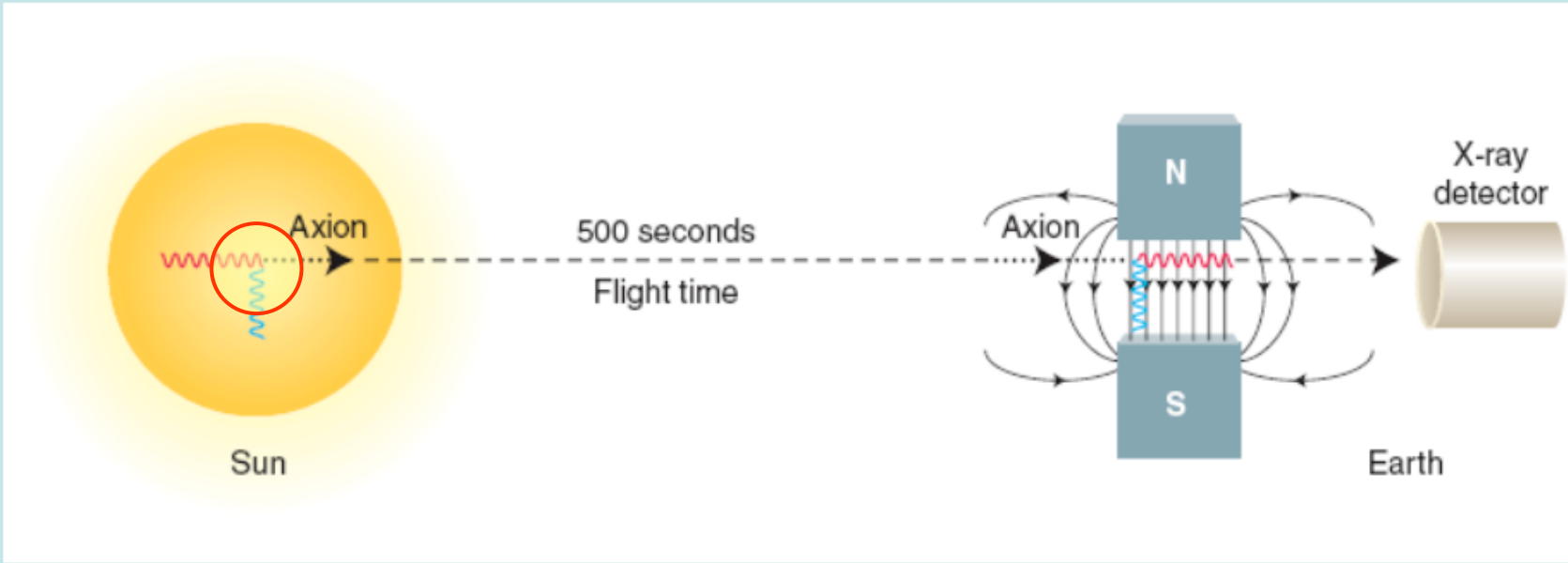
P. Sikivie



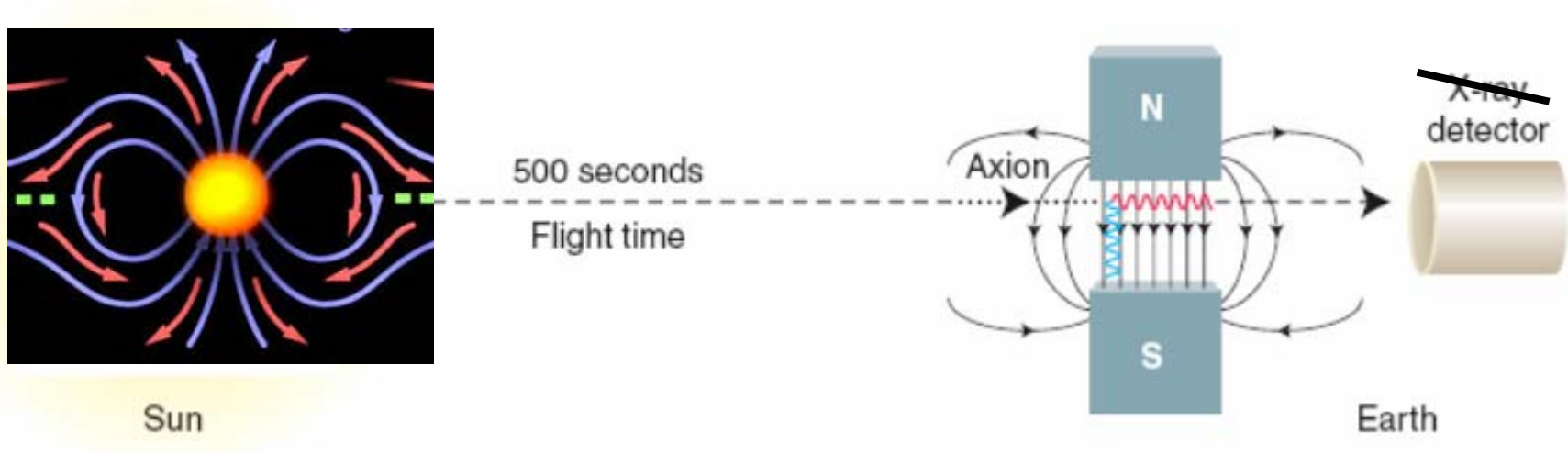


Axion - source

Axion - detection



Can one use CAST to test PVLAS more directly?

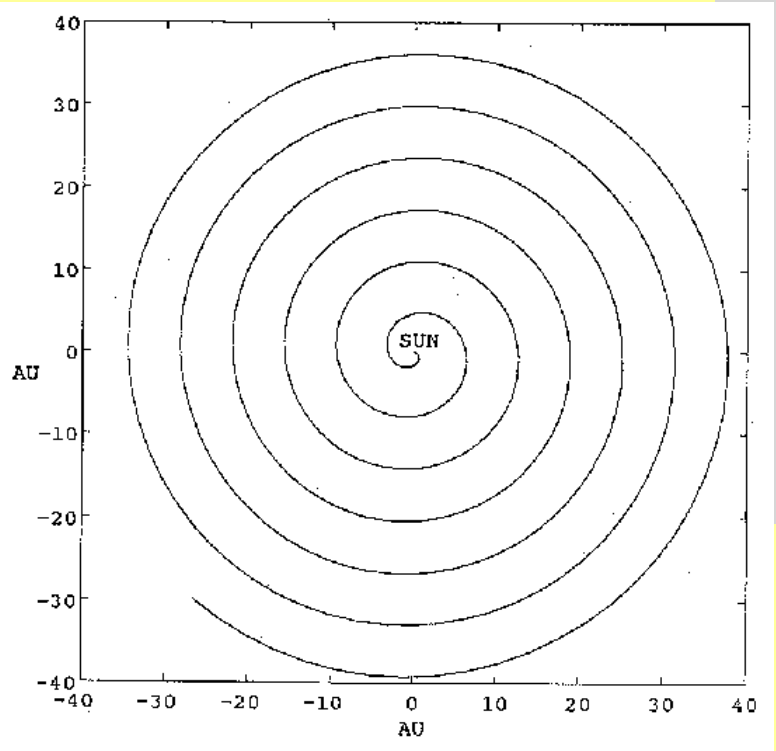


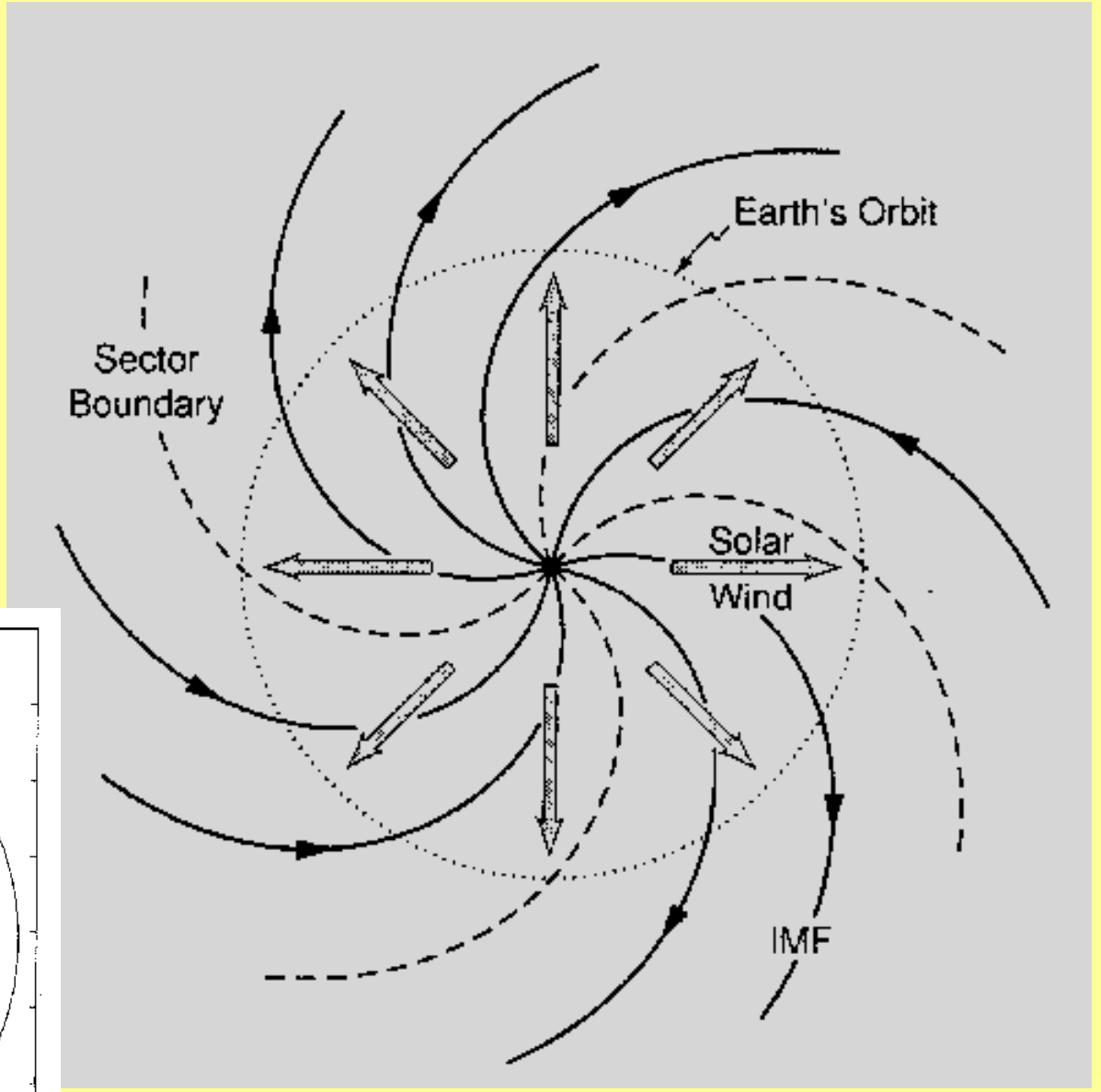
Proposal: Use the Sun light conversion in its own external magnetic field

Magnetic field near Sun $B_0 \sim 10^{-4}$ T, and drops with distance roughly like $1/r^2$ → calculate effective BL for photon-axion conversions

(Parker) Spiral Interplanetary Magnetic Field

$\mathrm{rot}(\mathbf{E}) = \mathrm{rot}(\mathbf{V} \times \mathbf{B}) = 0$





Borrowed from S. Solanki

Note: Sunlight photon spectrum peaks at about 0.5 eV – OK for production of ~ 1 meV ALPs suggested by PVLAS!

Problem: Oscillation length $l = 2E/m_A^2$ is only about 0.2 m for $m_A = 1$ meV

Conversion power for PVLAS ALPs is very limited in Sun's external field: effective BL < 10^{-4} Tm; however magnetic fields close to Sun's surface (photosphere) can be much stronger, so assuming tens of Tesla in average, effective BL ~ 10 Tm might be expected

Note: In optical domain full Sun's angular size is visible by CAST; and same conditions are for scalar and pseudo-scalar case…

Assuming effective BL = 10 Tm, event rate at CAST for E = 0.5 eV and $g_{a\gamma\gamma} = 2.10^{-6}$ GeV^{-1} can be estimated:

$$N \approx 0.6\ 2^4\ N_\gamma^{17}\ 10^{-2}\ 0.02^2 \approx 0.8 \text{ events/min},$$

where number of photons was obtained assuming 1.4 kW/m^2 power of sunlight + 100% efficient detector of 20 cm^2

CAST might see PVLAS ALPs if equipped with (single photon sensitive) photodetectors!

Using thin mirrors one can make it parasitically, and focus regenerated light on single, small (and low-noise) photosensor.

Note: Coherence condition prefer higher photon energies – rate increases (initially) like E^4 so UV photons get much higher weight

Good reason to get CAST sensitive in optical/UV

Axion search in general:

Coherence length increases like m_A^{-2} so for very light axions rates are strongly enhanced and Sun's external field becomes relevant…

For example, if m_A ~ 1 μeV CAST rate grows about 2.10^9 times → sensitivity to axion-photon coupling increases by about 200…

Finally, for even smaller axion masses like 0.02 μeV, sensitivity could reach interesting values $g_{a\gamma\gamma} = 2.10^{-10}$ GeV^{-1}

Another, strong reason to get CAST sensitive in optical

Final remark:

- **It might be possible to do PVLAS test all in lab, in one step – it is enough to divide CAST optically in two halves and use some bright light source as a 'sun'…**

- **For white light source, it requires only about 70 W (optical) power to get equivalent event rates:**

$$N \approx 0.6\ 2^4\ N_\gamma^{17}\ 0.02^2\ 0.02^2 \approx\ 0.8 \text{ events/min}$$

…and one can still increase rate by using UV source, or/and higher power, and can modulate it to suppress/subtract backgrounds…

Summary/Outlook

• It is possible to test directly PVLAS ALPs interpretation using CAST, by equipping it with sensors sensitive in optical wavelengths, either by looking at the Sun, or by using a bright light source in ‘lab-only setup’

• More importantly, if CAST is sensitive in optical domain, axion search can be extended by independent search using Sun’s external magnetic field for conversion of sunlight, reaching effective BL ≈ 500 Tm (for m_A = 0.2 μeV)!

CAST future is bright