Improving the Mass Reach

Light-Shining-Through-Walls Experiments with Phase Shift Plates

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Introduction
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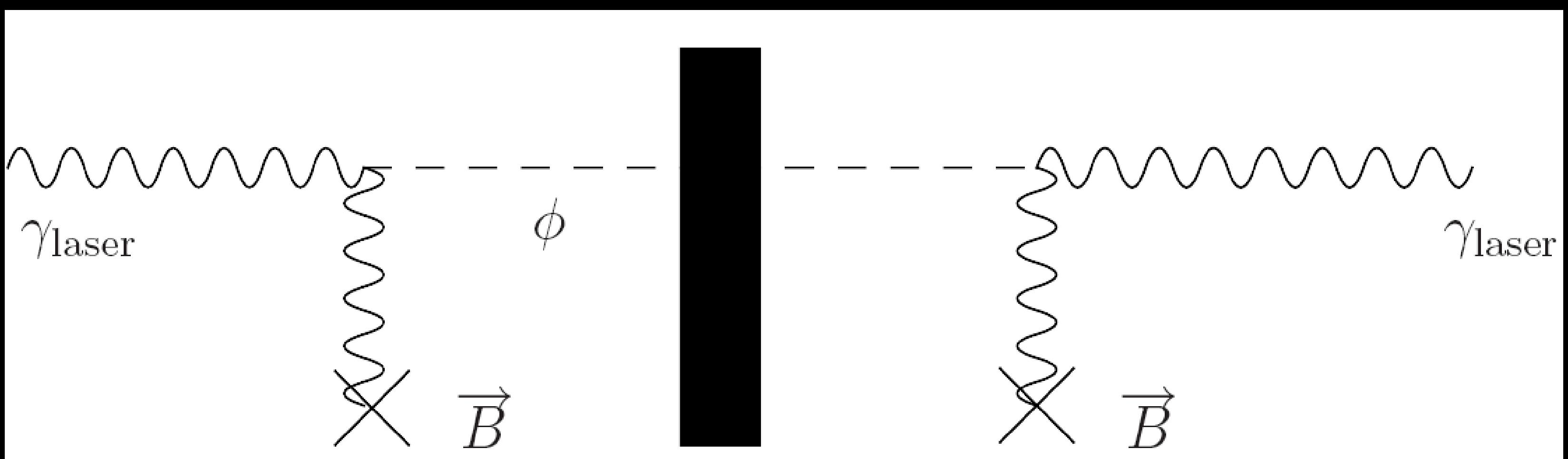
LSW Experiments

Light Shining Through Walls: ALPs

- **Interaction**

$$\mathcal{L} \sim g\phi F^{\mu\nu}\tilde{F}_{\mu\nu} \sim g\phi\vec{E}\cdot\vec{B}$$



Light Shining Through Walls: Paraphotons

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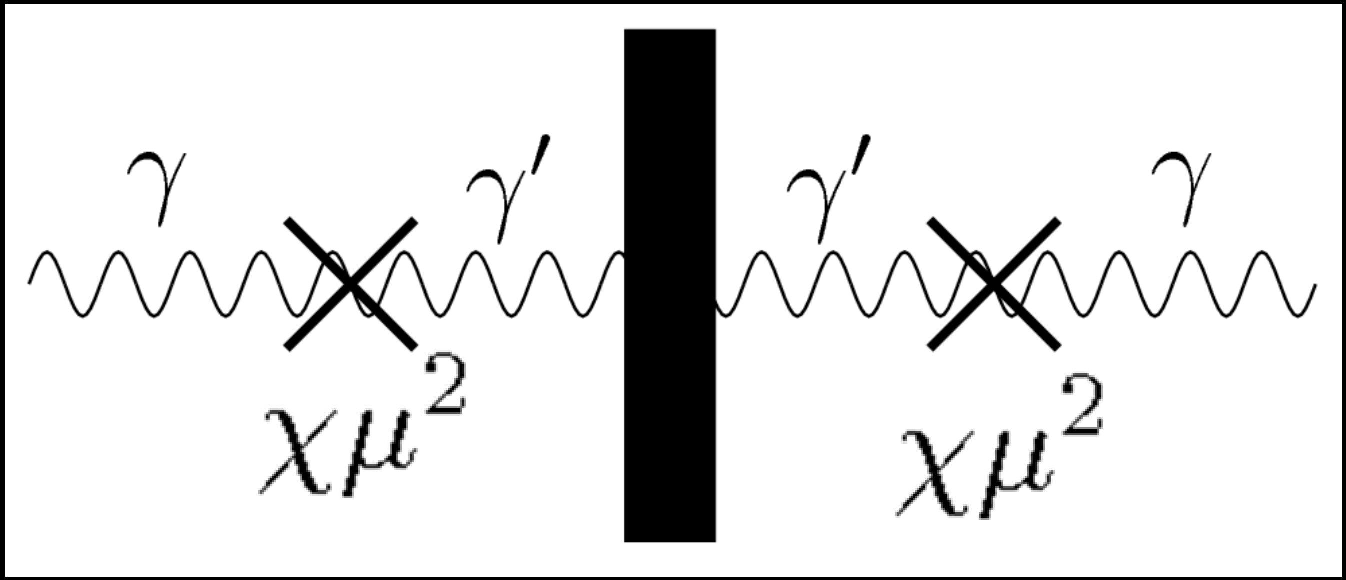
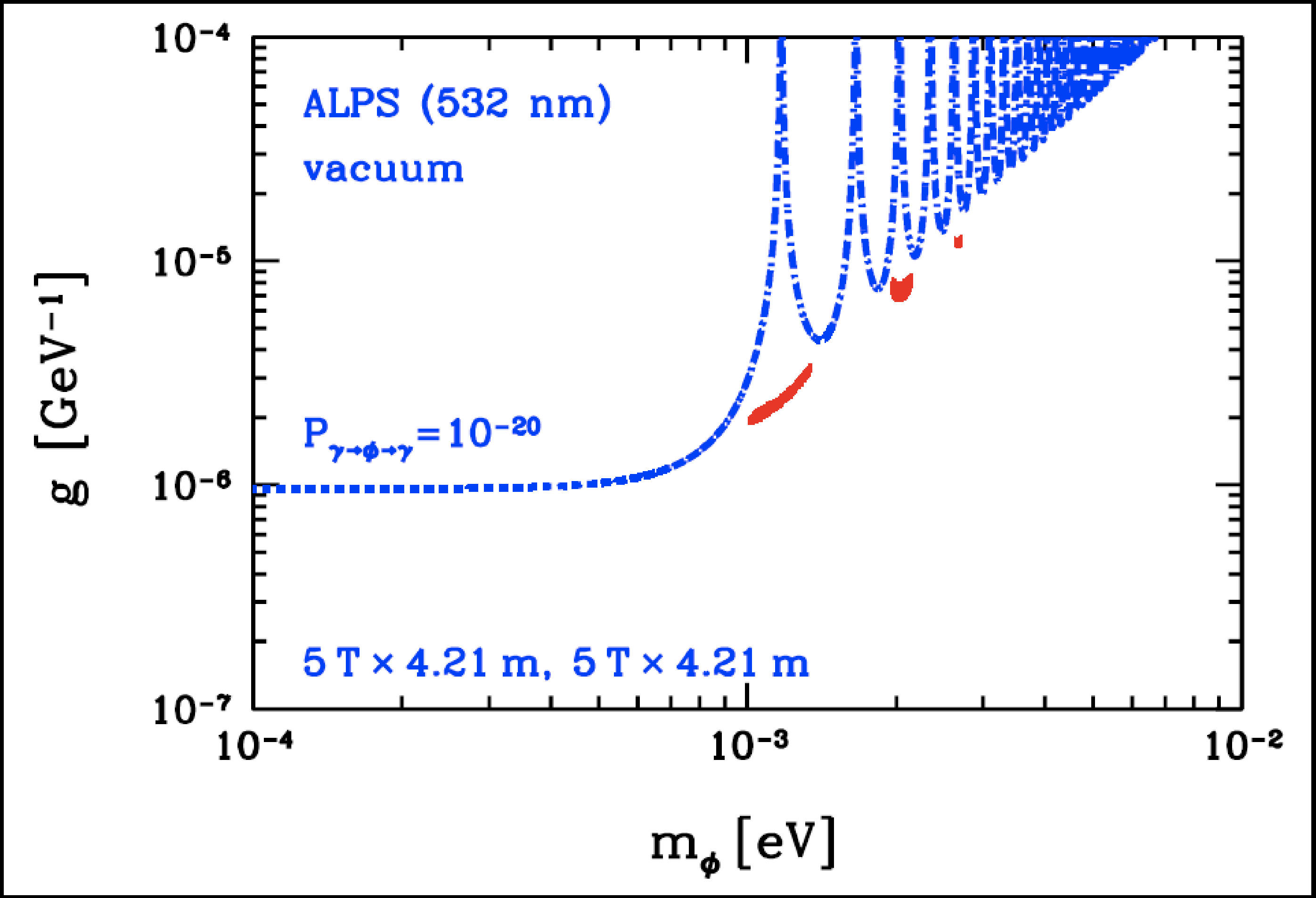
- Two U(1)'s + with mixing term

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} - \frac{1}{4}B^{\mu\nu}B_{\mu\nu} + \frac{1}{2}\mu^2(B^\mu B_\mu - 2\chi A^\mu B_\mu + \chi^2 A^\mu A_\mu)$$



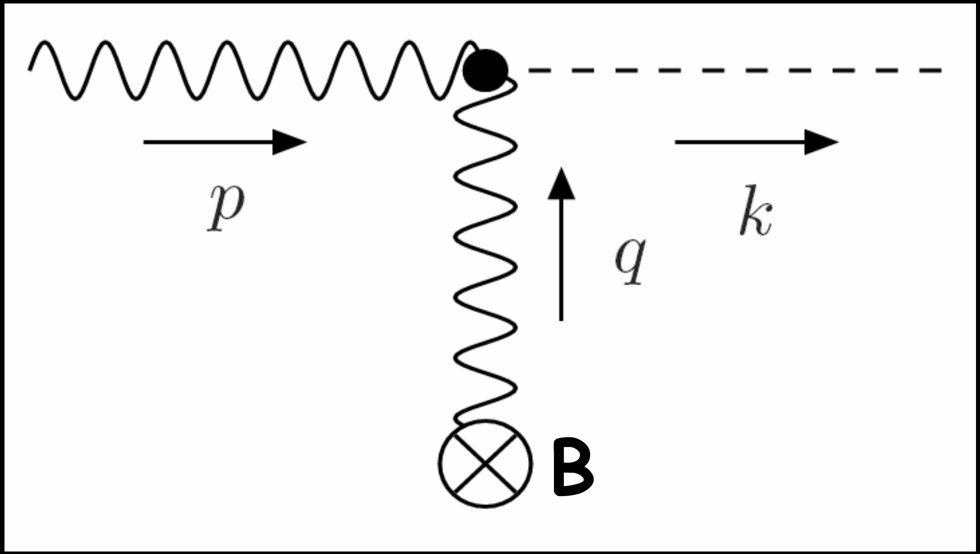
Problem for higher masses

Problem



➡ **Unsensitive regions at larger masses!**

Reason: Version I

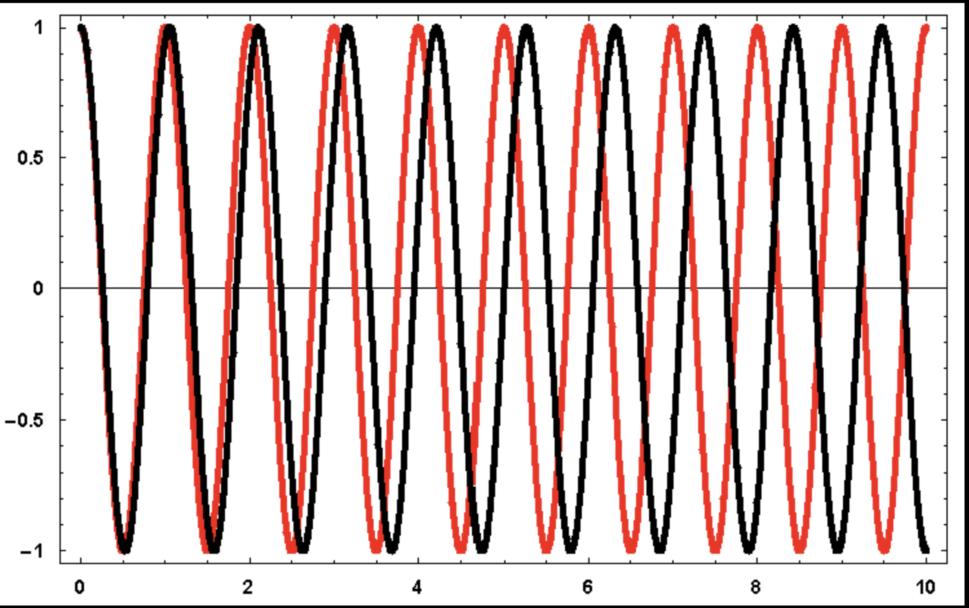


$$|\vec{q}| = |\vec{p}| - |\vec{k}| = \omega - \sqrt{\omega^2 - m^2} \approx \frac{m^2}{2\omega} > 0$$

➡ Need **inhomogeneous** magnetic field with

$$\frac{1}{L} \gtrsim |\vec{q}|$$

Reason: Version II



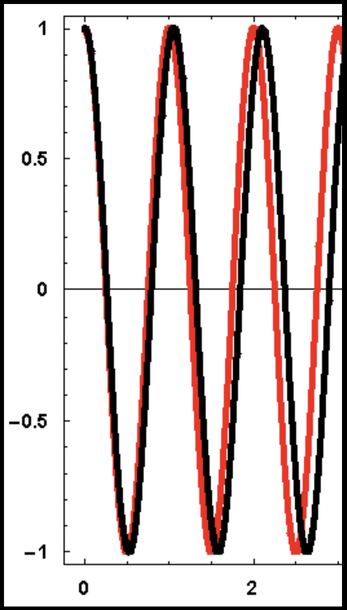
$$\frac{2\pi}{\omega} = \lambda_\gamma < \lambda_{\mathrm{ALP}} = \frac{2\pi}{\sqrt{\omega^2 - m^2}}$$

→ ALP and photon field run out of phase

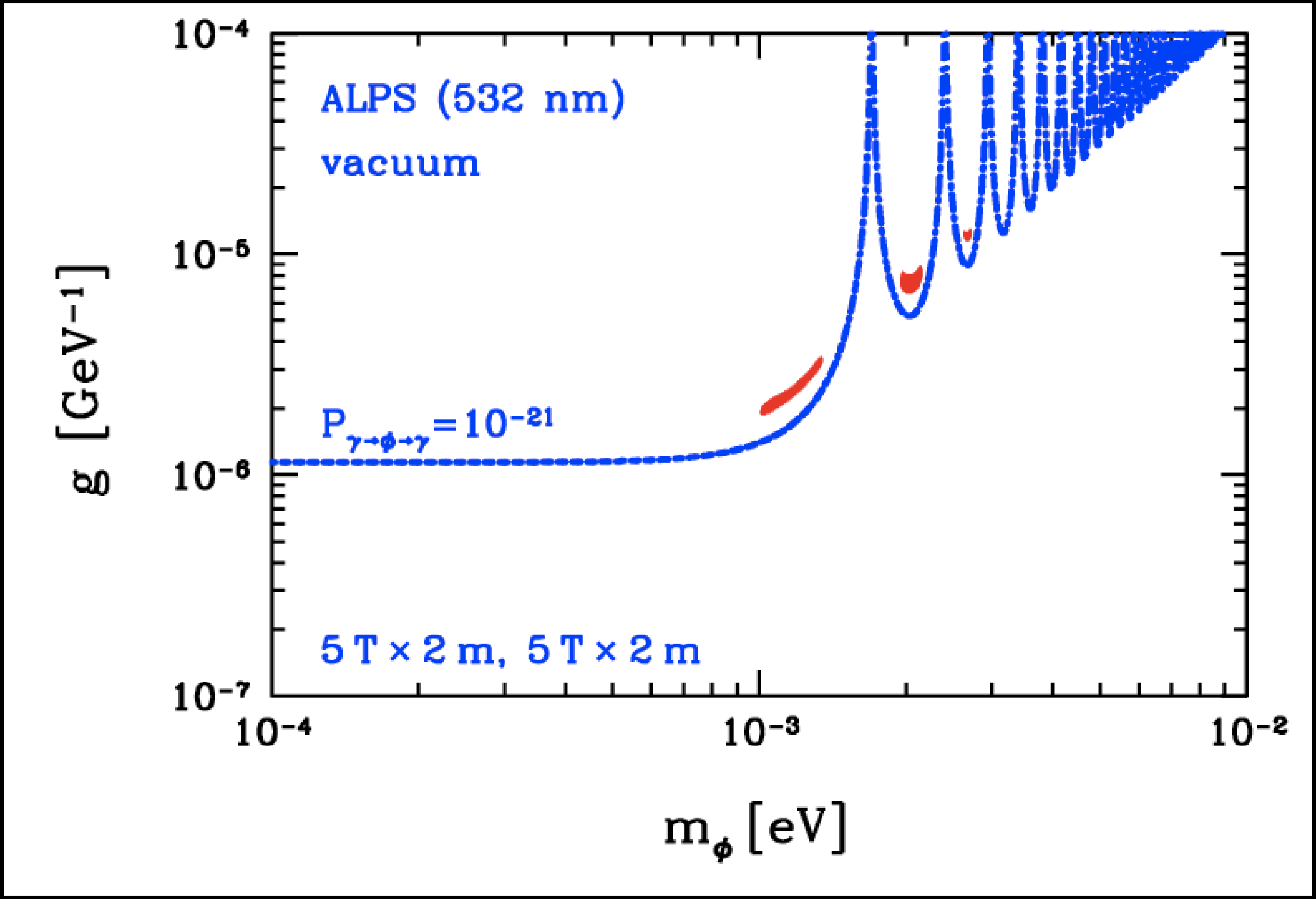
→ "Destruction" of the ALP field!

Solution

Idea 0: Cut Magnet



Idea 0: Problem



High price: Loose sensitivity!!

Idea I: Alternating Magnetic Field

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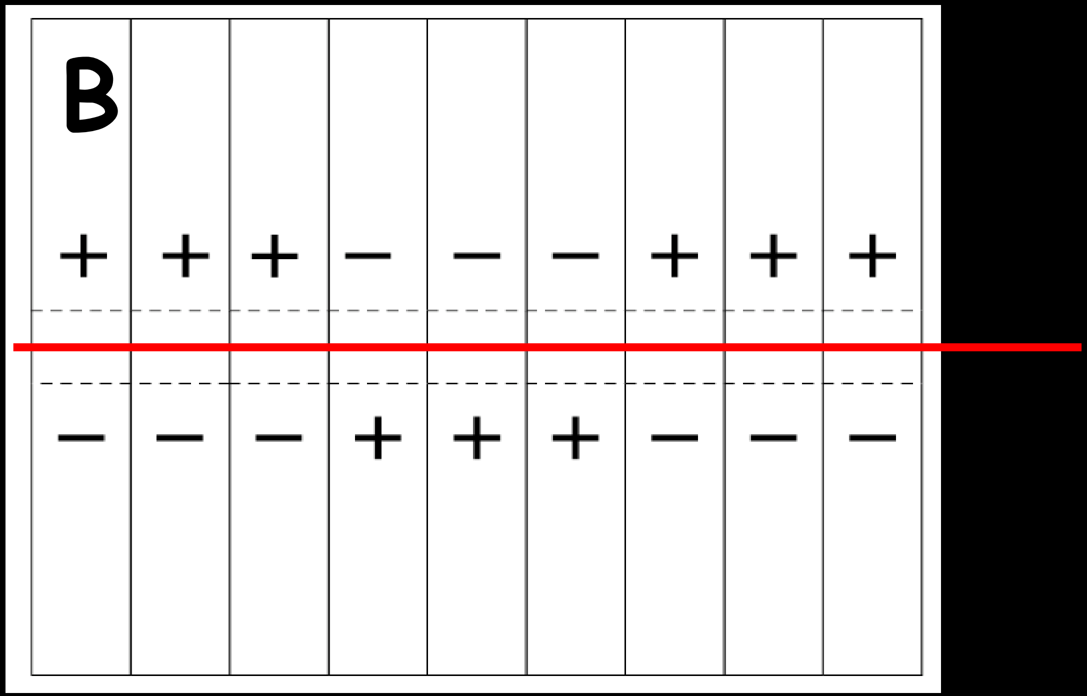
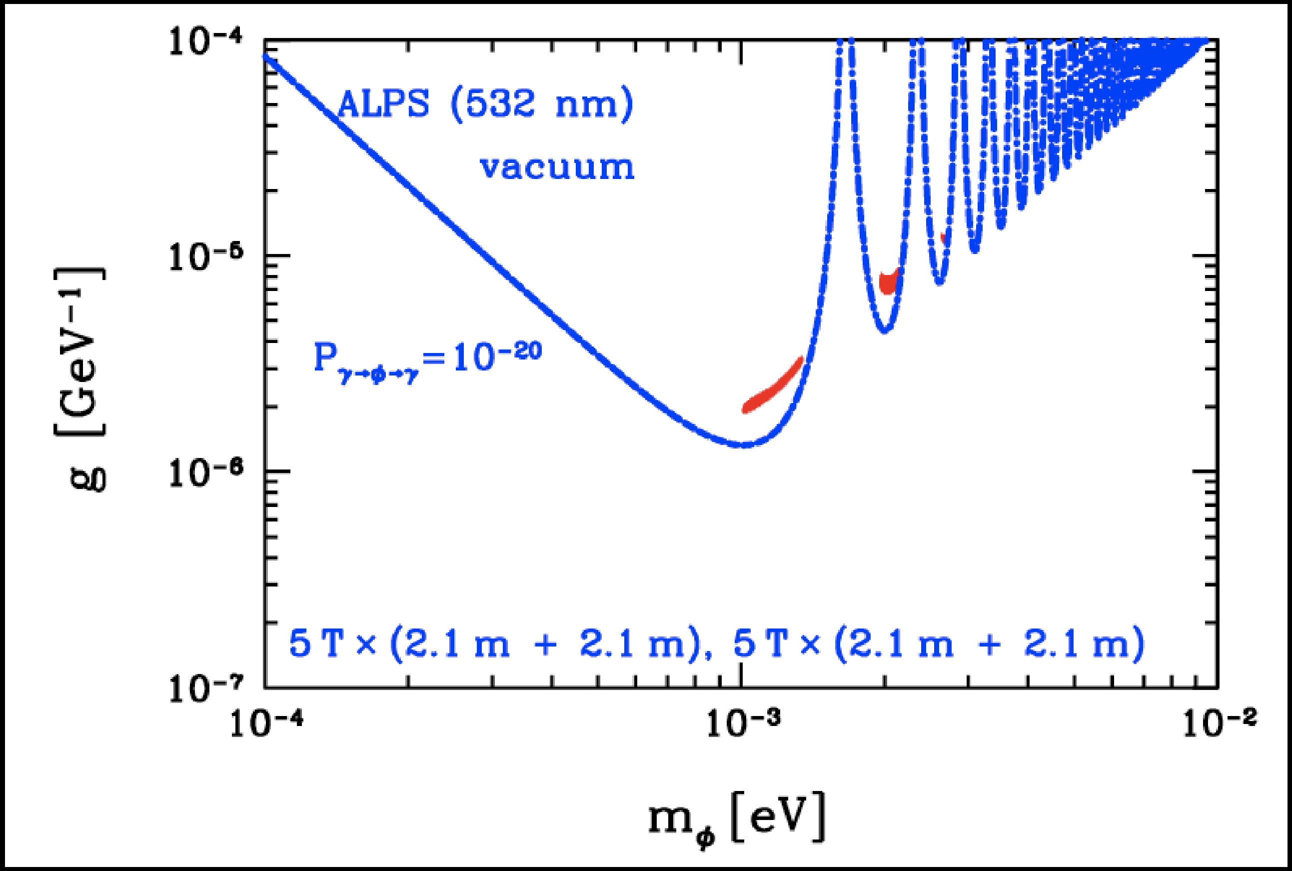


➡ Inhomogeneities of size $\sim \frac{L}{N}$

magnetic field can supply N times more momentum

➡ Can reach higher masses!

Improvement I

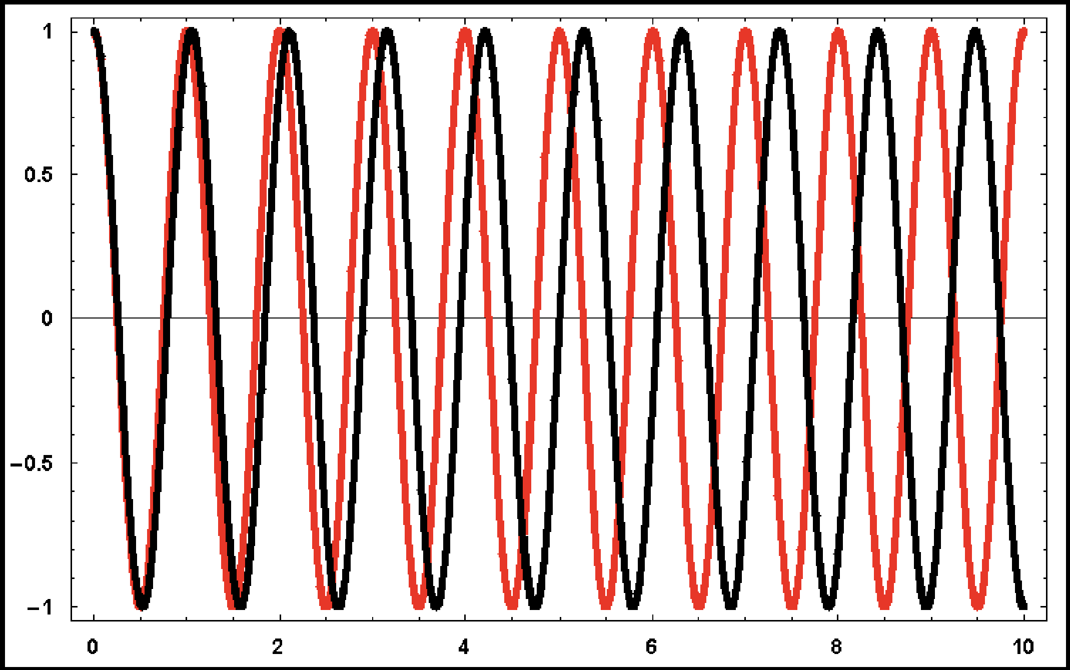


- Sensitive at higher masses!
- But, reduced sensitivity at small masses!

Difficulties I

- Need more than one magnet.
- Sensitivity at small masses is reduced.
- Difficult to change the # of segments.

Idea IIa: Gas Filling



➡ **Wavelength of Photon and ALP differ**

We can modify the wavelegth of the photon!

$$\lambda = \frac{\lambda_{\mathrm{vac}}}{n}$$

Difficulties IIa

$$\frac{2\pi}{\omega} = \lambda_\gamma < \lambda_{\mathrm{ALP}} = \frac{2\pi}{\sqrt{\omega^2 - m^2}}$$

$$\lambda_\gamma = \frac{\lambda_{\mathrm{vac}}}{n}$$ ➡ **We need n<1!**

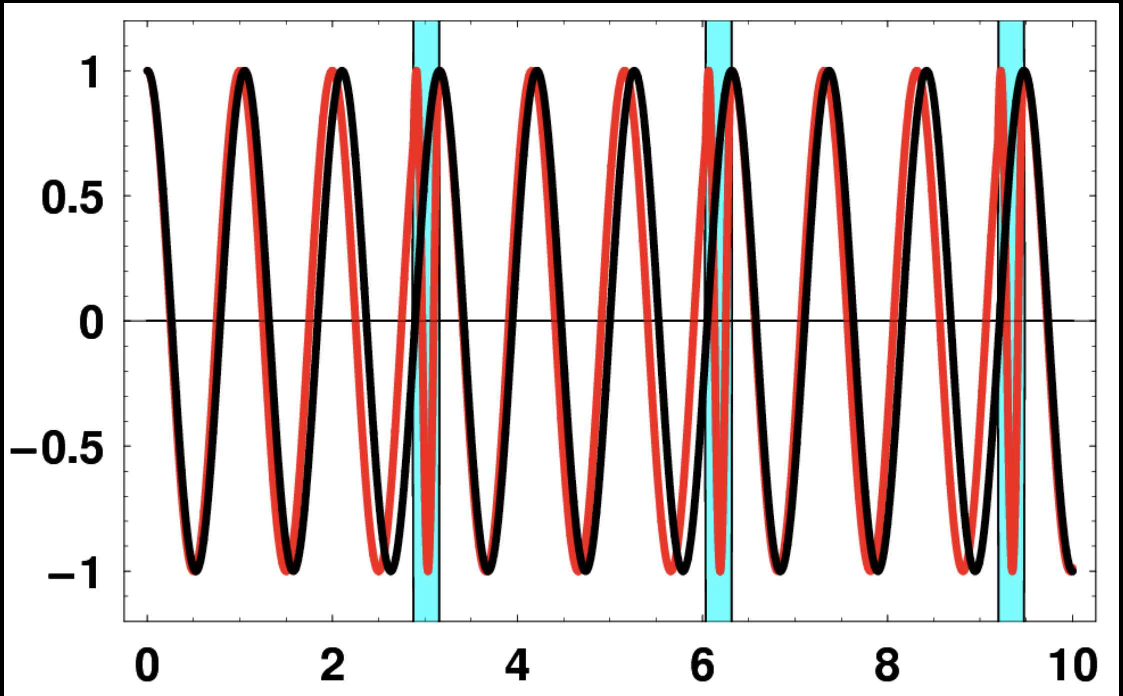
Difficult for low energy photons!

However,

➡ Gas can have n<1 for X-Ray photons

➡ Works for CAST!

Idea II: Phase Shift Plates



- Phase Correction by 2π-x
- Photon and ALP "remain" in phase!
- Can reach higher masses!

Improvement Formula

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Before:

$$P_{\gamma\to\mathrm{ALP}} \sim g^2 B^2 \frac{2\sin\left(q\frac{L}{2}\right)}{q}$$

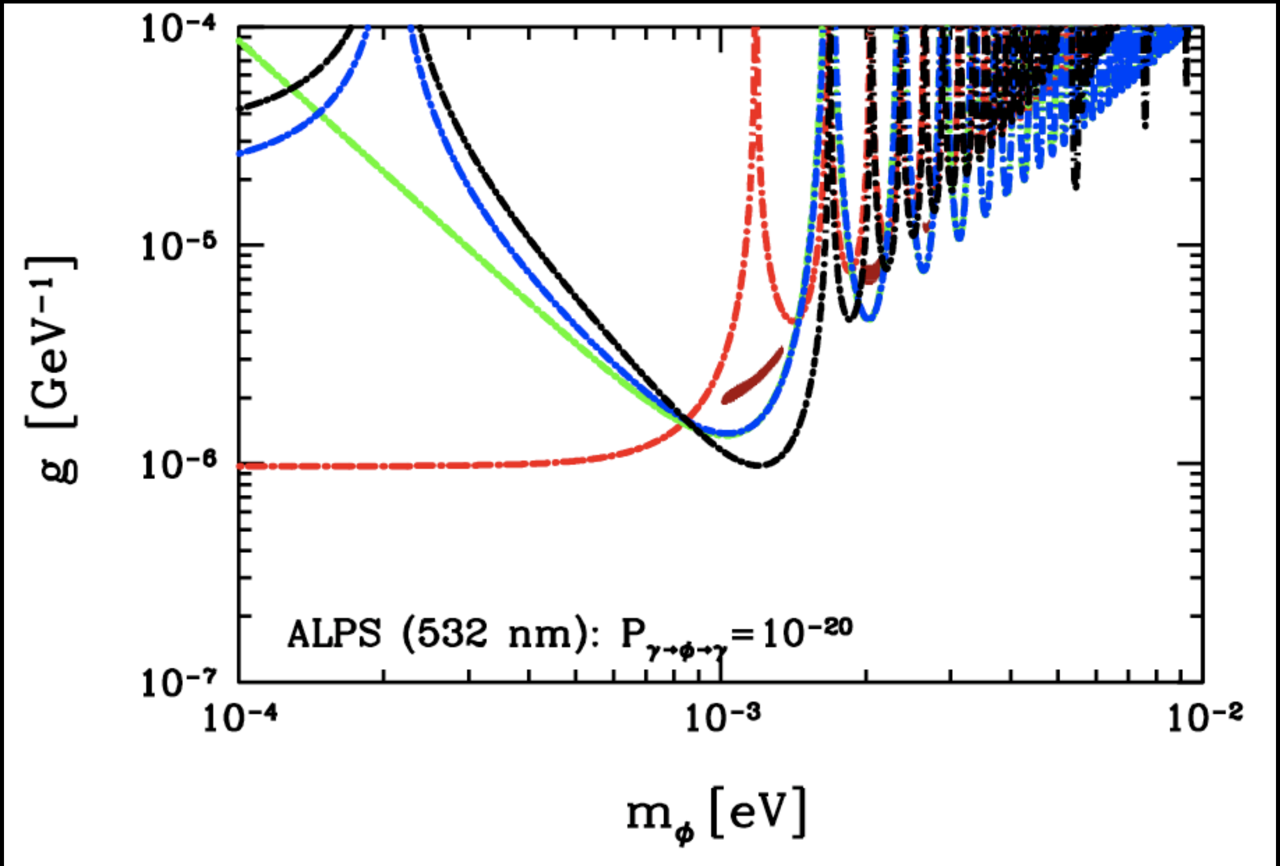
After:

$$P_{\gamma\to\mathrm{ALP}} \sim g^2 B^2 \left[\frac{2\sin\left(q\frac{L}{2N}\right)}{q}\frac{\sin\left(\frac{N}{2}\left[q\frac{L}{N}+x\right]\right)}{\sin\left(\frac{1}{2}\left[q\frac{L}{N}+x\right]\right)}\right]^2$$

$$\approx g^2 B^2 L^2$$

Coherent production over whole length!

Improvement II



Sensitive at higher masses!

Advantages

- Easy to install.

Theorists and "easy" experiments…

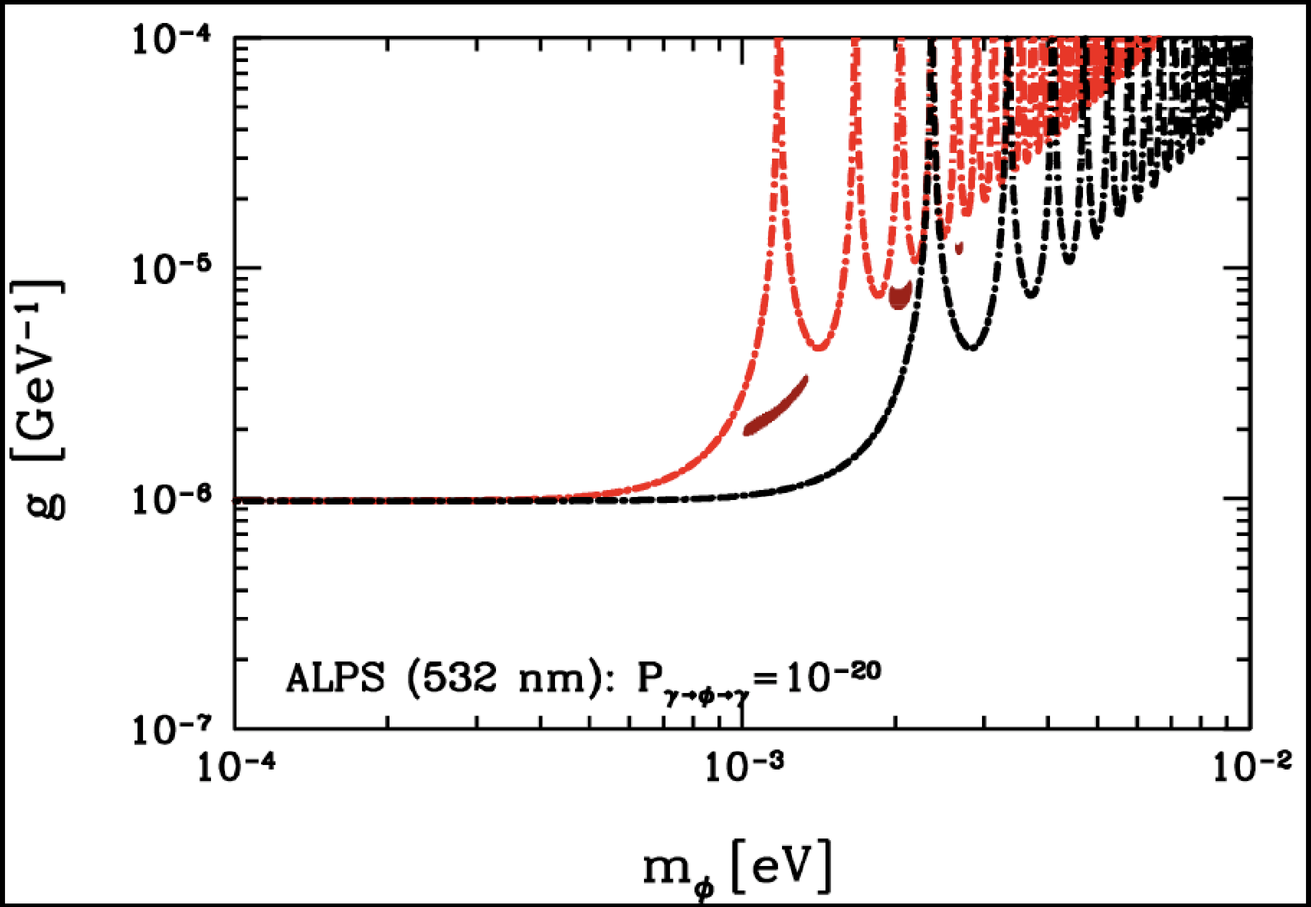
Experiments

Advantages

- Easy to install.
- Can adapt for different masses.

➡ Allows to scan a mass range!

Improvement II:… scanning



➡ **Significant gain in sensitivity!**

Advantages

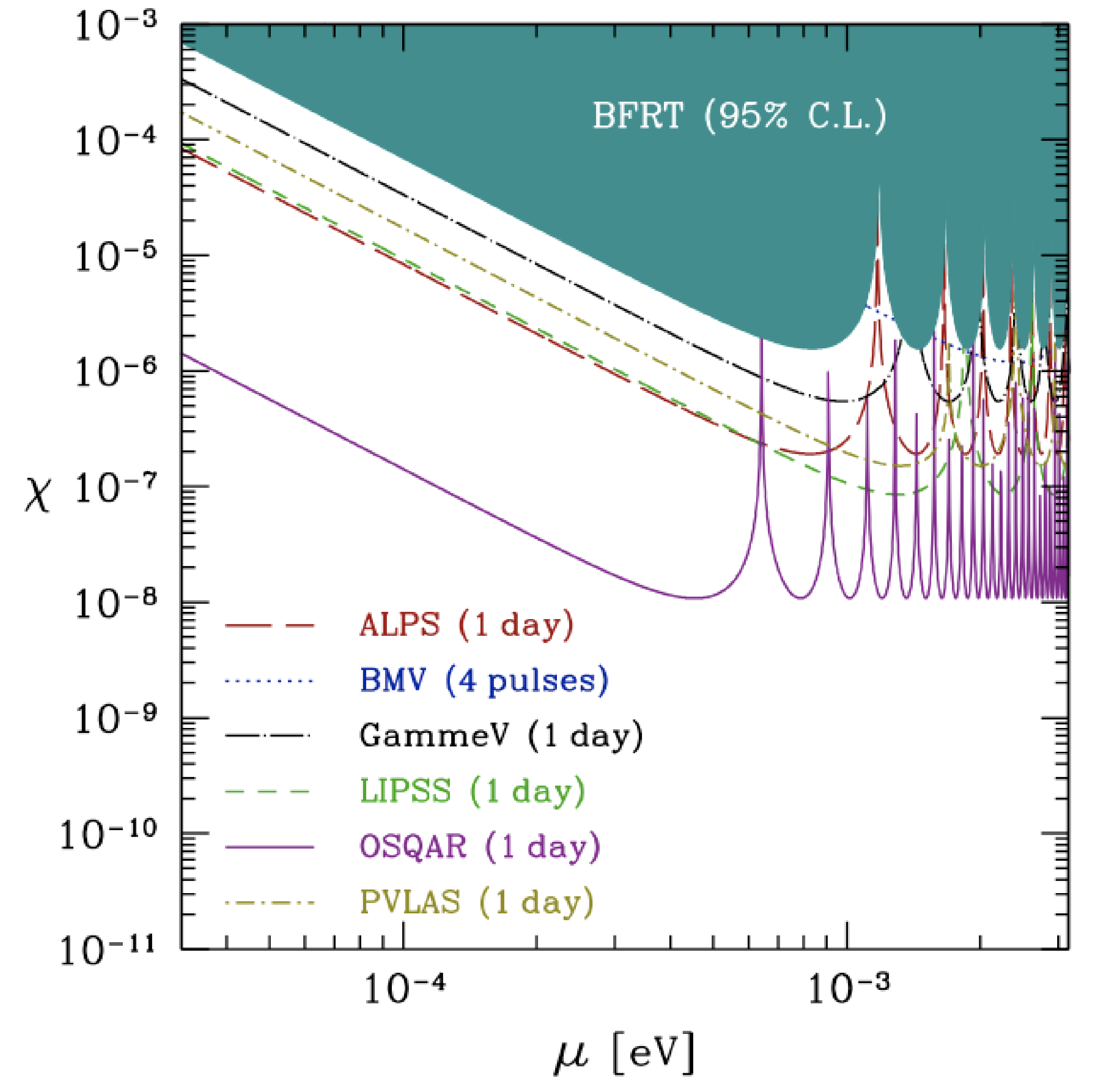
- Easy to install.

- Can adapt for different masses.

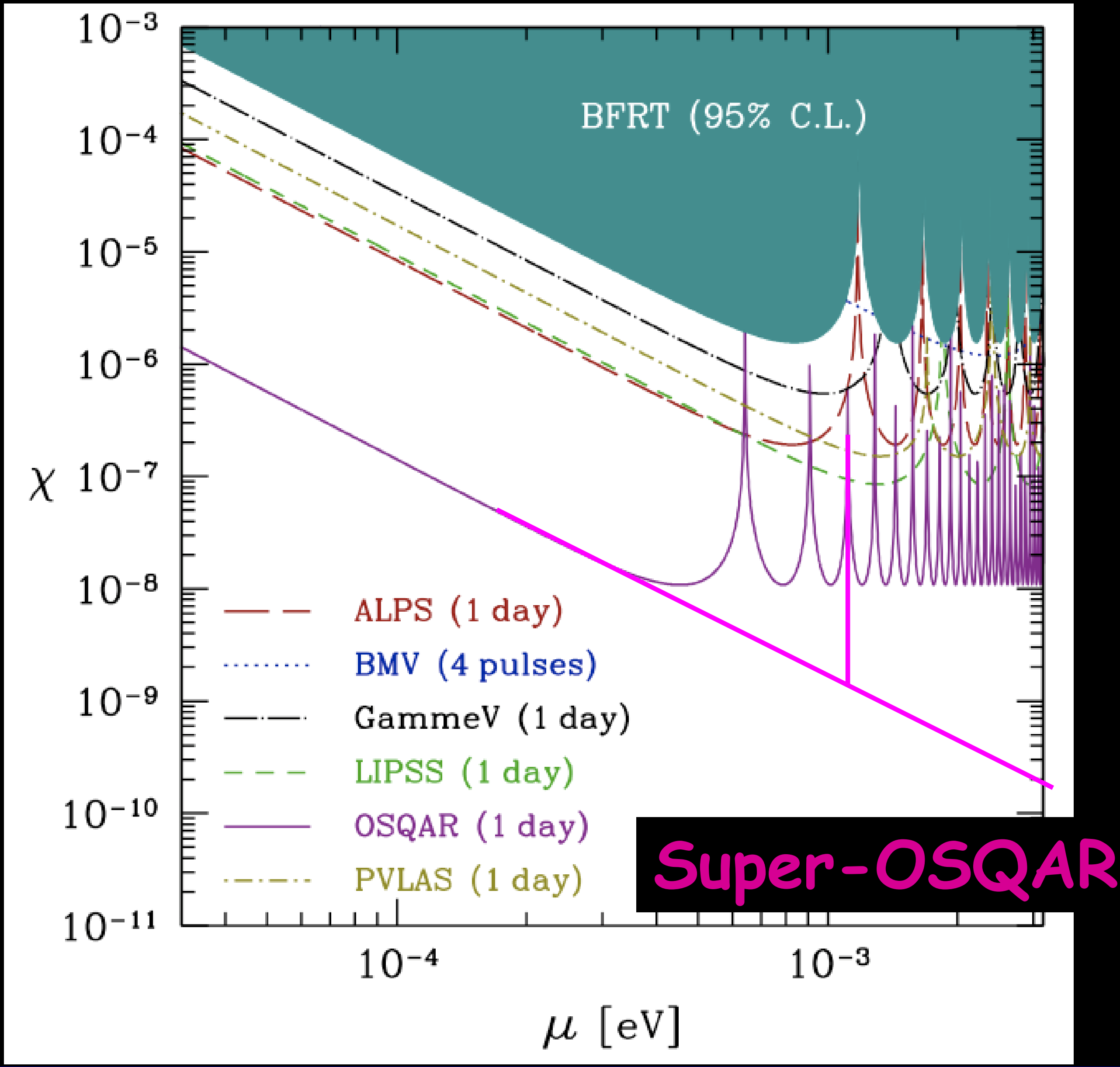
  ➡ **Allows to scan a mass range!**

- Works also for Paraphotons!

Paraphotons



Paraphotons



Conclusions

Conclusions

- Phase shift plates can improve sensitivity of LSW experiments to higher masses
- Allows to scan mass range
- Works for ALPs and Paraphotons


Reach higher masses
with
phase shift plates!