

# Towards a Large Scale Axion Photon Regeneration Experiment

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**Workshop on Future Axion Searches  
Axion Academic Training  
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- Many models beyond the Standard Model:

New light pseudoscalar particles, very weakly coupled to ordinary matter

- Would arise if there was a global continuous symmetry in the theory that is spontaneously broken in the vacuum

Example:

**Axion**, arising from the breaking of a U(1) Peccei-Quinn symmetry introduced to explain the absence of strong  $CP$  violation

[Peccei, Quinn (1977); S. Weinberg (1978); Wilczek (1978)]

- Such pseudoscalars couple to two photons via

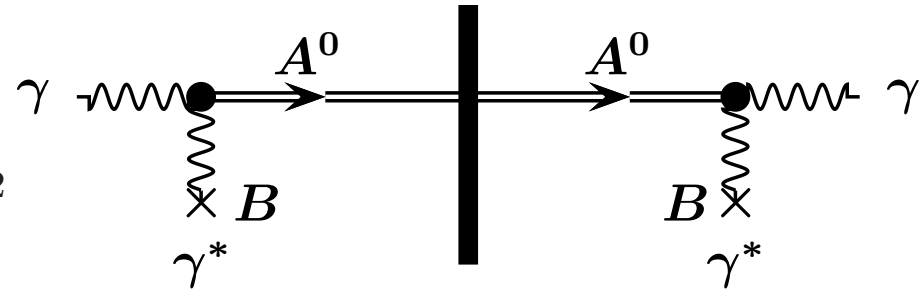
$$\mathcal{L}_{\phi\gamma\gamma} = -\frac{1}{4} g \phi F_{\mu\nu} \tilde{F}^{\mu\nu} = g \phi \vec{E} \cdot \vec{B},$$

⇒ In the presence of a magnetic field  $\vec{B}$ , a photon of frequency  $\omega$  may oscillate into a pseudoscalar particle of mass  $m_\phi < \omega$ , and vice versa

[Sikivie (1983); Ansel'm (1985); van Bibber *et al.* (1987); Raffelt, Stodolsky (1988)]

- **Conversion probability** of photon send along magnetic field:

$$P_{\gamma \leftrightarrow \phi} \approx \frac{1}{4} g^2 B^2 \ell^2 \left( \frac{\sin \left( \frac{m_\phi^2 \ell}{4\omega} \right)}{\frac{m_\phi^2 \ell}{4\omega}} \right)^2$$

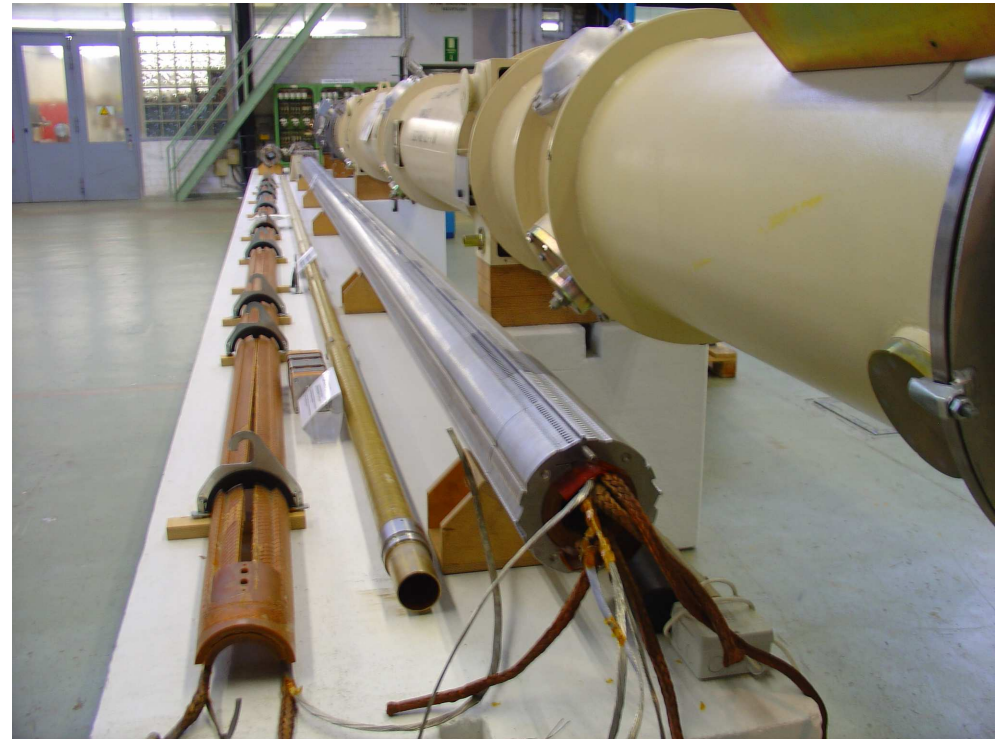


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- ⇒ **Photon regeneration** optimal
- for large  $B\ell$  ⇒ recycle dipole magnets from accelerators

**HERA dipole ( $B\ell = 50 \text{ Tm}$ ):**

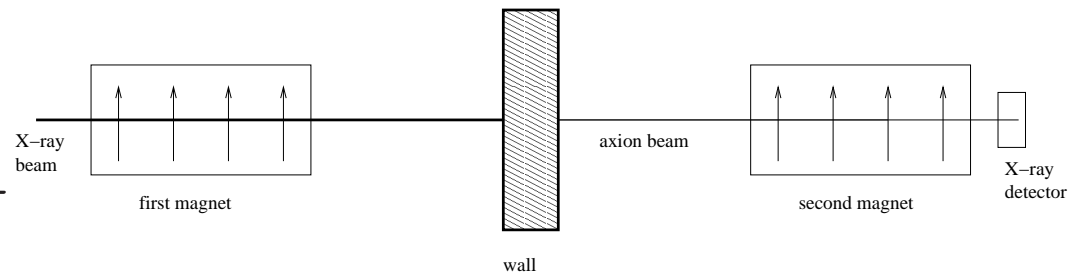


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for  $\omega \gg m_\phi^2 \ell / 2\pi$



[Rabadan,AR,Sigurdson '05]

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  - for large  $\omega \Rightarrow$  exploit VUV or X-ray free-electron lasers

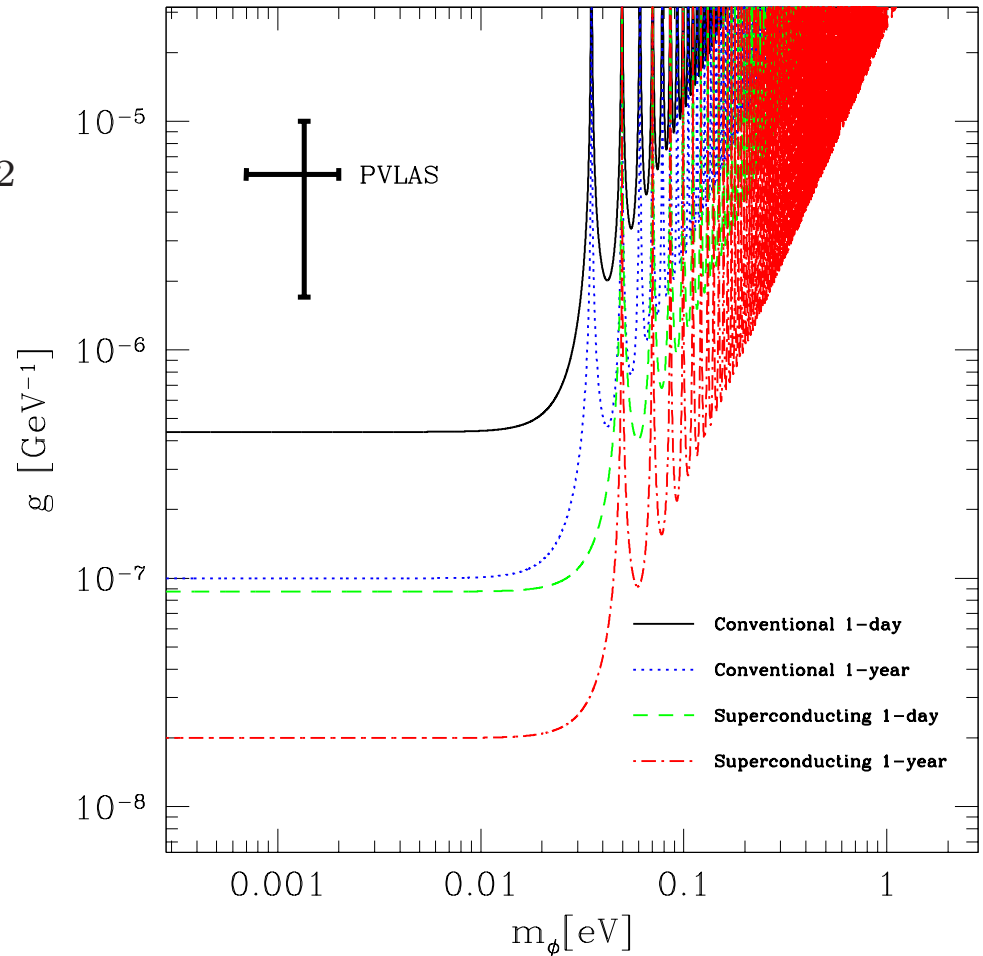
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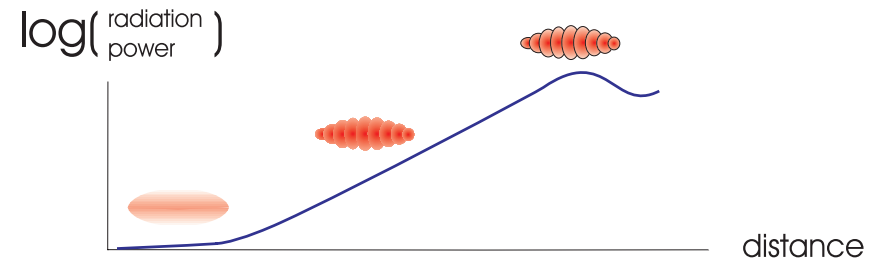
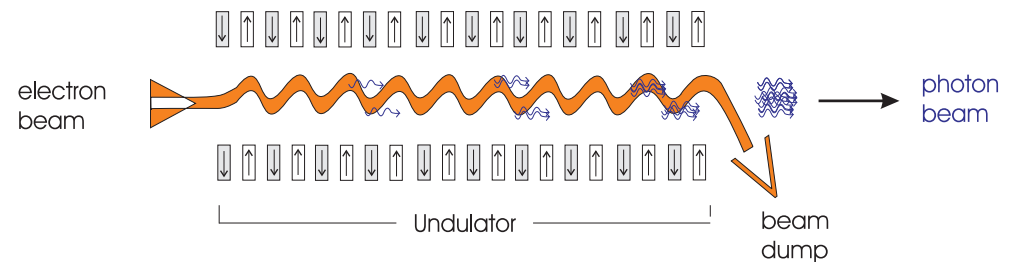
- **Powerful free-electron lasers (FEL)** already/soon available:

name?	$\omega$ [eV]	when?
<b>VUV-FEL</b> at TTF	10–200	2004
<b>LCLS</b>	$10^4$	2005–2008
<b>XFEL</b>	200– $10^4$	2005–2011

**TTF:** TESLA Test Facility (DESY)

**LCLS:** Linac Coherent Light Source (SLAC)

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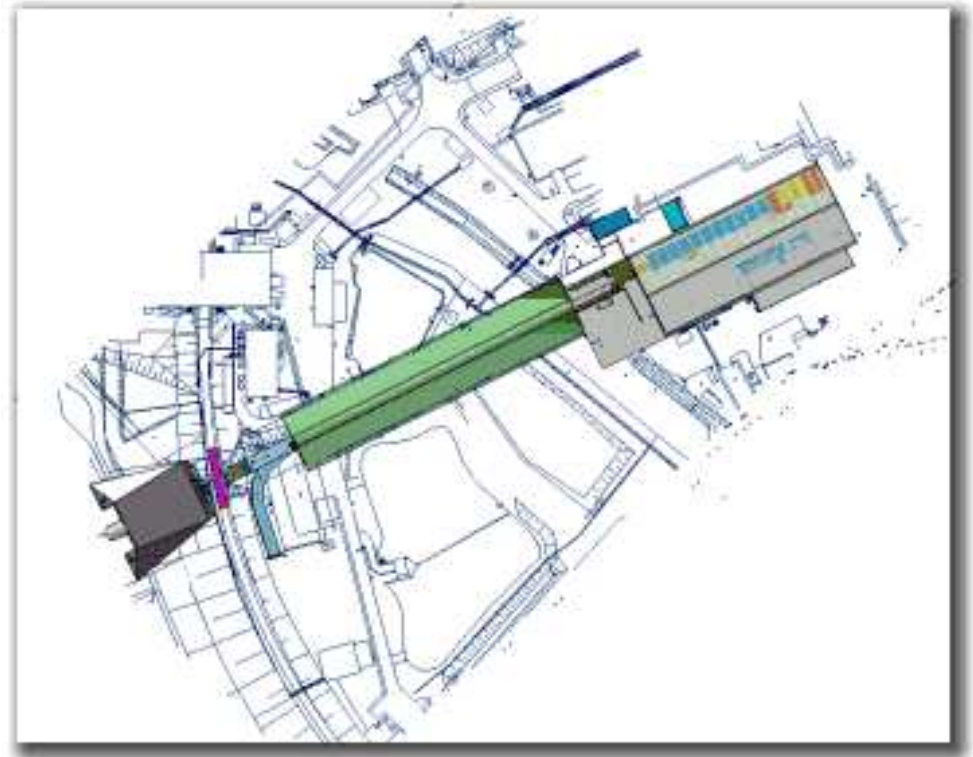
**LCLS:** Linac Coherent Light Source (SLAC)

- First generation experiment may start next year

⇒ Study of feasibility underway ...

[Tschentscher,AR '05]

## VUV-FEL at TTF:



## Study of feasibility: [Tschentscher,AR]

### ● Benchmarks:

– VUV-FEL:

$$\omega = 30 \text{ eV}, N_0 = 10^{17} \text{ s}^{-1}$$

– HERA type magnet:

$$B = 5 \text{ T}, L = 2\ell = 10 \text{ m}$$

⇒ Flux of regenerated photons:

$$N_f \approx 2 \times 10^{-3} \text{ s}^{-1} \left( \frac{N_0}{10^{17} \text{ s}^{-1}} \right) F^4(q\ell) \left( \frac{g}{10^{-6} \text{ GeV}^{-1}} \right)^4 \left( \frac{B}{5 \text{ T}} \right)^4 \left( \frac{\ell}{5 \text{ m}} \right)^4$$

⇒ Test of PVLAS parameter region within minutes

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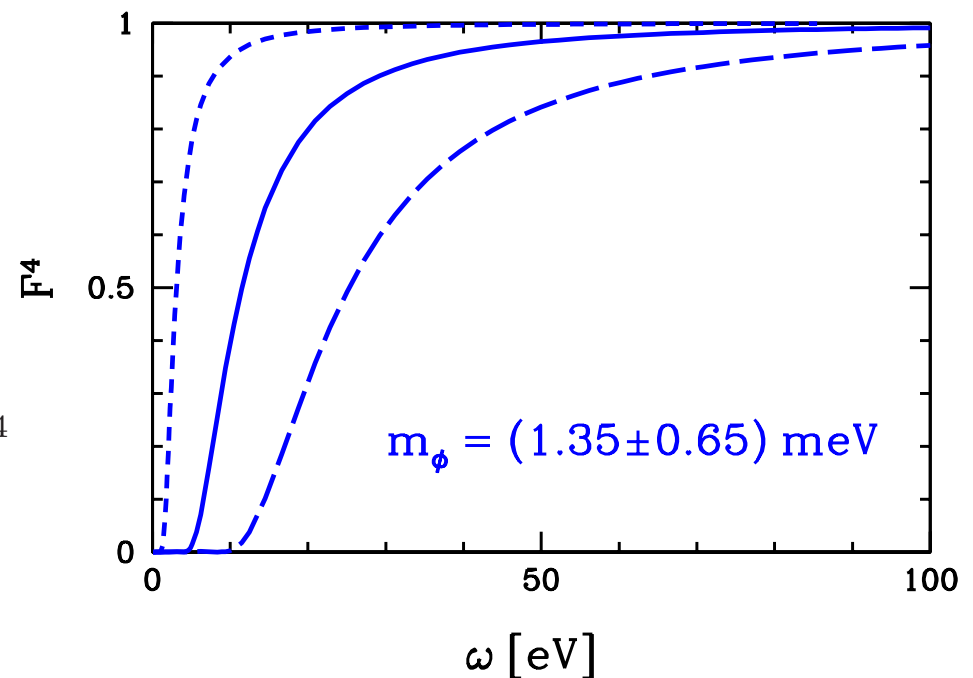
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⇒ Determine mass by tuning  $\omega$

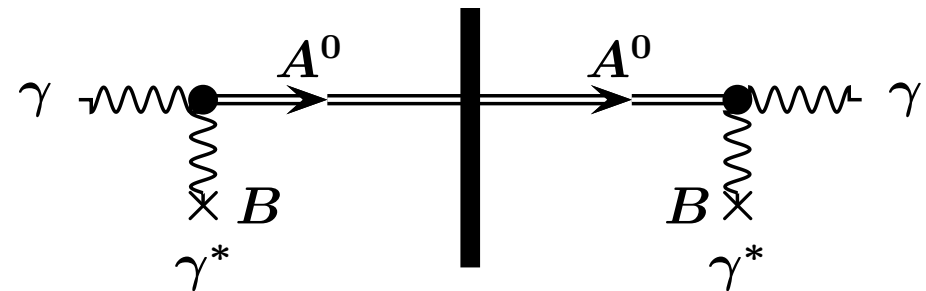


## Study of feasibility: [Tschentscher,AR]

- Use magnet available at DESY or build new, dedicated one?

available space (8 m × 2 m) in experimental hall too small for HERA dipole (10 m)

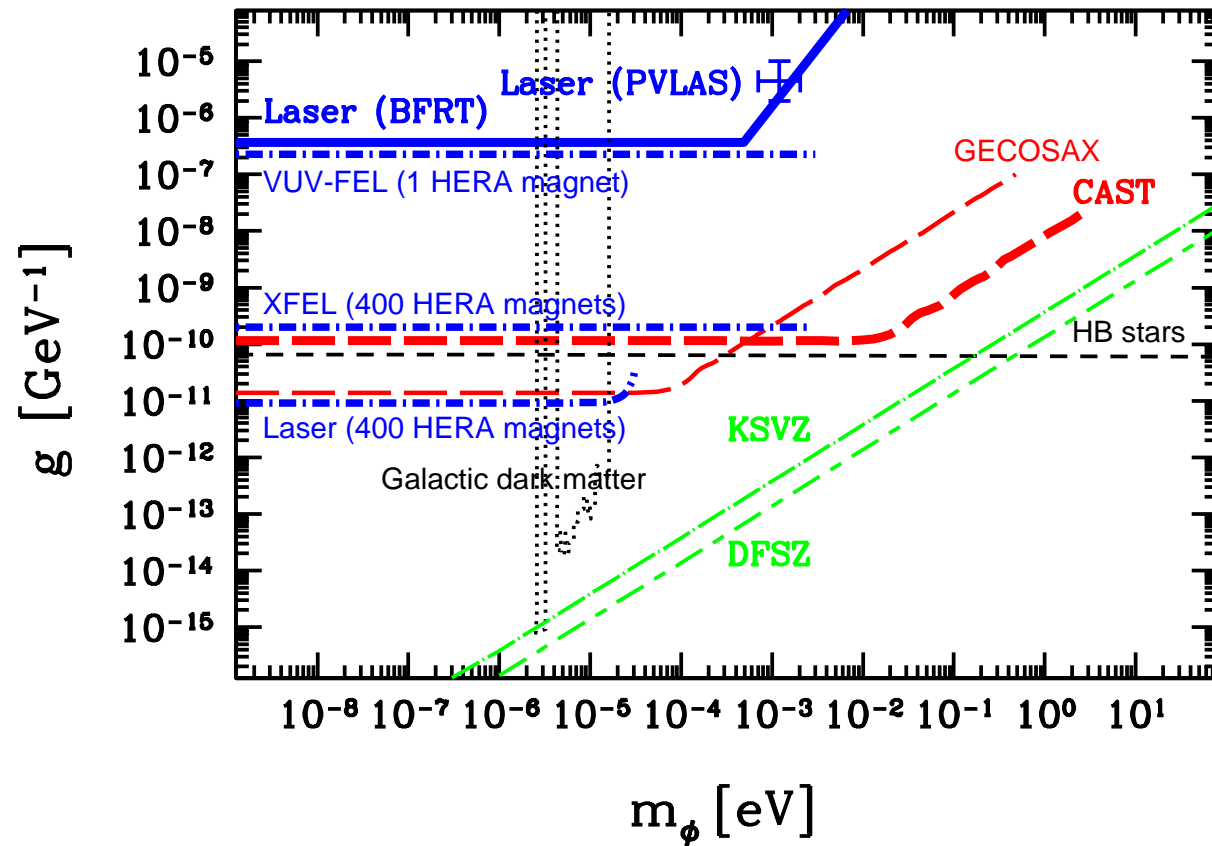
- Two photon detectors, one at entrance ( $\rightarrow N_0$ ) and one at exit ( $\rightarrow N_f$ ). Latter should have very high efficiency and low background for  $\omega > 10$  eV



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- March 2006: Proposal should be send to HASYLAB at DESY
- End of 2006: Run experiment for  $12 \times 12\text{ h}$

A. Ringwald (DESY)



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## A large scale experiment: [AR '03]

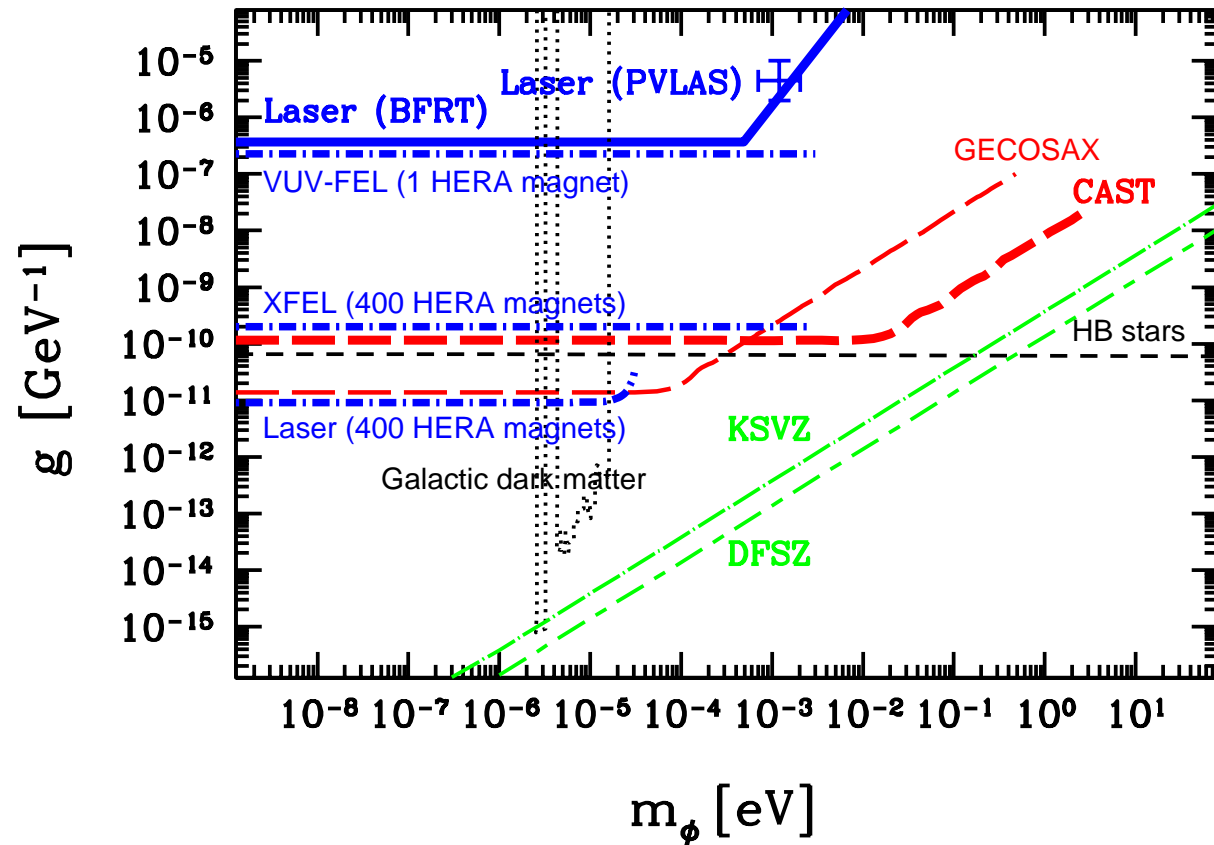
- Mid 2007: decommissioning of **HERA**

⇒ Photon regeneration with  $\approx 400$  superconducting dipole magnets ( $B = 5 \text{ T}$ ,  $\ell = 2000 \text{ m}$ )

- sensitivity comparable to limits involving astrophysical considerations (HB stars; su)
- $B\ell$  still not large enough to be sensitive to the region where the axion qualifies as a cold dark matter candidate

- We need the **(V)LHC** magnets!

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## Conclusions

- Powerful VUV and X-ray FEL's, combined with recycled dipole magnets from accelerators, offer unique possibility for photon regeneration experiments
  - sensitivity towards larger  $m_\phi$  as compared to optical lasers
  - detection efficiency of order unity
  - mass determination through tuning of  $\omega$
- PVLAS indication can be tested already next year with modest experiment
- Scheme can be expanded towards a large scale experiment