GammeV

Gamma to milli-eV particle search
T-969

Light shining through a wall

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Motivation

① milli-eV mass scale is interesting in it's own right

② PVLAS reports anomalous polarization results that can be interpreted as a new axion-like particle. Now, new data doesn't reproduce older result.

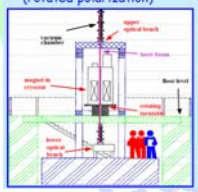
① milli-eV (10^{-3} eV) mass scale arises in various areas in modern particle physics.

- See-saw with the TeV scale:
  - meV ~ TeV^2/M_{planck}
- Neutrinos
  - $(\Delta m_{21})^2 = (9\times10^{-3}\ eV)^2$
  - $(\Delta m_{32})^2 = (50\times10^{-3}\ eV)^2$
- Dark Energy density
  - $\Lambda^4 = 7 \times 10^{-30}\ g/cm^3 \sim (2\times10^{-3}\ eV)^4$
- Dark Matter Candidates
  - Certain SUSY sparticles (low mass gravitino)
  - Axions and axion-like particles / other scalars

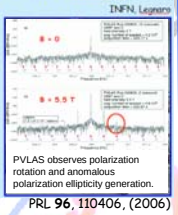
Energy frontier
Neutrinos
Astrophysics
all in one!

② PVLAS: Polarizzazione del Vuoto con LASer

- Designed to study the vacuum by optical means: birefringence (generated ellipticity) and dichroism (rotated polarization)



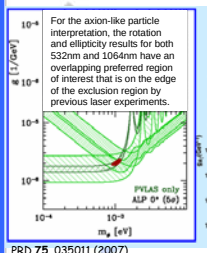
PVLAS



PVLAS observes polarization rotation and anomalous polarization ellipticity generation.

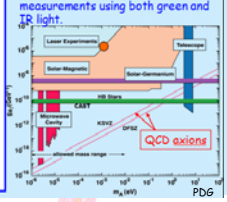
PRL **96**, 110406, (2006)

Axion-like particle interpretation

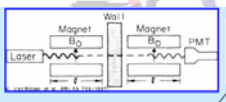


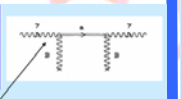
PRD **75**, 035011 (2007)

Scalar particle with mass 1.2 meV and g~2x10⁻⁶ GeV⁻¹ is consistent with rotation and ellipticity measurements using both green and IR light.



PDG





$$\mathcal{L}_{int}^{scalar} = -\frac{1}{4}\frac{\phi}{M}F_{\mu\nu}F^{\mu\nu} = \frac{\phi}{M}(\vec{E}\cdot\vec{E} - \vec{B}\cdot\vec{B})$$

$$P_{regen} = \frac{16B_1^2B_2^2\omega^4}{M^4m_\phi^8}\sin^2\left(\frac{m_\phi^2L_1}{4\omega}\right)\cdot\sin^2\left(\frac{m_\phi^2L_2}{4\omega}\right)$$

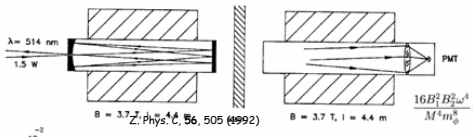
Assuming 5T magnet, the PVLAS "signal", and 532nm laser light

$$P_{regen}^{GammeV} = (3.9\times10^{-21})\times\frac{(B_1/5\ T)^2(B_2/5\ T)^2(\omega/2.33\ eV)^4}{(M/4\times10^5\ GeV)^4(m_\phi/1.2\times10^{-3}\ eV)^8}$$
$$\times\sin^2\left(\frac{\pi}{2}\frac{(m_\phi/1.2\times10^{-3}\ eV)^2(L_1/2.0\ m)}{(\omega/2.33\ eV)}\right)\sin^2\left(\frac{\pi}{2}\frac{(m_\phi/1.2\times10^{-3}\ eV)^2(L_2/2.0\ m)}{(\omega/2.33\ eV)}\right)$$

Light shining through a wall

Laser shines into a magnetic field, there is a small probability that some of the photons can convert into an axion-like particle which is weakly interacting and goes through the "wall." On the other side, there again is a small probability for regenerating back into a photon, which is something that can be detected.

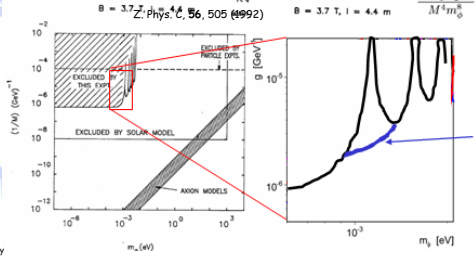
The experiment, BFRT, was performed in the early 1990's but had regions of minimum sensitivity right around the milli-eV mass scale due to their particular choice of a magnet.



Z. Phys. C, **56**, 505 (1992)

Like ν oscillations

$$\frac{16B_1^2B_2^2\omega^4}{M^4m_\phi^8}\sin^2\left(\frac{m_\phi^2L_1}{4\omega}\right)\cdot\sin^2\left(\frac{m_\phi^2L_2}{4\omega}\right)$$

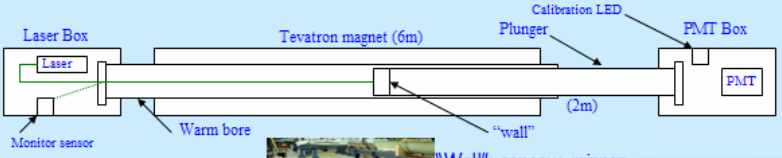


BFRT is not sensitive in the PVLAS region of interest because the 4.4 m baseline is near the oscillation minimum of 5 m for milli-eV mass.

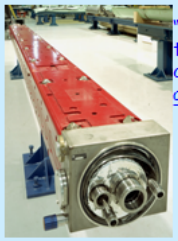
Background by H Murayama

The GammeV Experiment

Search for evidence of a milli-eV particle in a light shining through a wall experiment to unambiguously test the PVLAS interpretation of an axion-like (pseudo-)scalar



Existing laser in Acc. Div. nearly identical with PPD's laser last used by KTeV



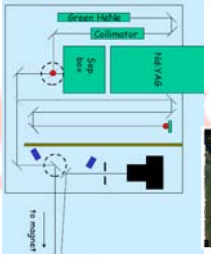
"Wall": concave mirror to control divergence + coated for high power green laser light

High-QE, low noise, fast PMT module (purchased)

Installation and commissioning

- Mechanical assembly is completing in Lab 8

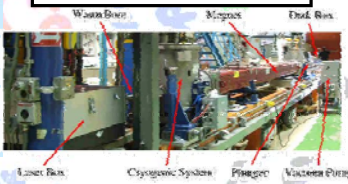
- DAQ system using QuarkNet boards



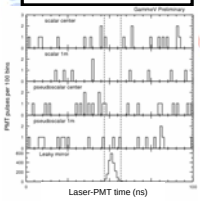
Comparison with other expt's

CERN Courier

Magnet Test Facility (IB1)



"Leaky Mirror"

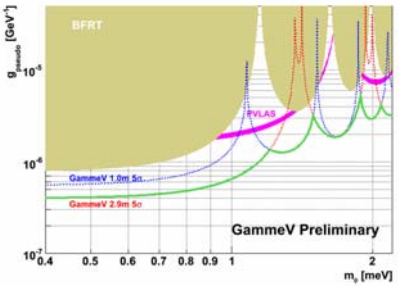


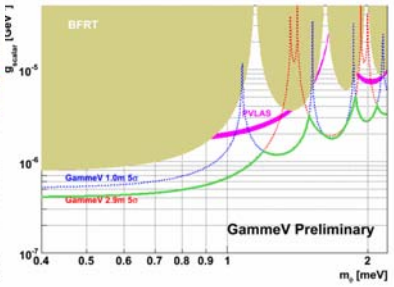
We attenuate the Nd:YAG laser down to single photons and measure the exact arrival time and set a 10ns search window for our signal. If there were a signal, we'd see it!

Preliminary Results (new on 9/25/07)

In order to be sensitive to the entire PVLAS region of interest vs mass of the axion-like particle, we move our "wall" mounted on a movable plunger either in the center of the magnet or 1m from the end. We insert a ½-wave plate to rotate the laser polarization to change sensitivity from pseuoscalar to scalar. We estimate our efficiency at (36 +/- 9)% and use Feldman-Cousins to set limits.

Spin	Position	# Laser pulse	# photon / pulse	Expected Background	Signal
Scalar	Center	1.34 M	0.41e18	1.56±0.04	1
Scalar	1 m	1.47M	0.38e18	1.67±0.04	0
Pseudo	Center	1.43M	0.41e18	1.59±0.04	1
Pseudo	1m	1.47M	0.42e18	1.50±0.04	2





ALP interpretation of PVLAS excluded by >5σ!