GammeV

Gamma to milli-eV particle search
T-969

Installation and Commissioning

Background by
H Murayama

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milli-eV mass scale

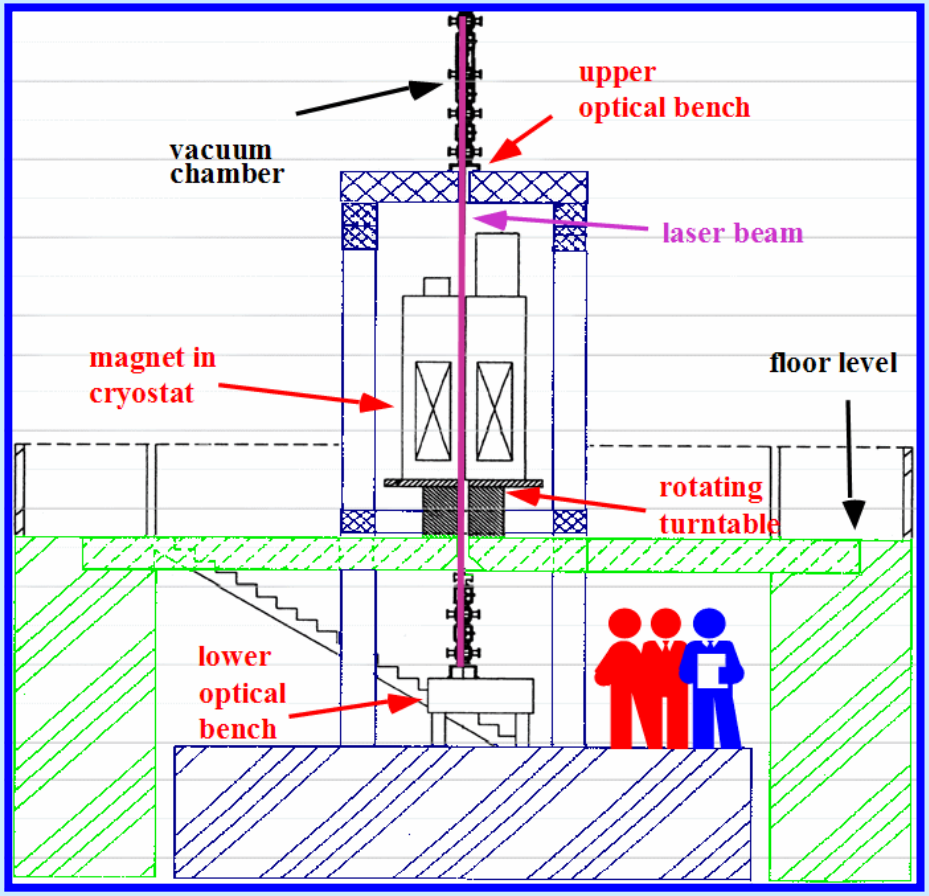
- milli-eV (10^{-3} eV) mass scale arises in various areas in modern particle physics.
  - See-saw with the TeV scale:
    - meV ~ TeV^2/M_{planck}
  - Neutrinos
    - $(\Delta m_{21})^2 = (9\times10^{-3}\ eV)^2$
    - $(\Delta m_{32})^2 = (50\times10^{-3}\ eV)^2$
  - Dark Energy density
    - $\Lambda^4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

Energy frontier
Neutrinos
Astrophysics
all in one!

PVLAS Experiment

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

INFN, Legnaro



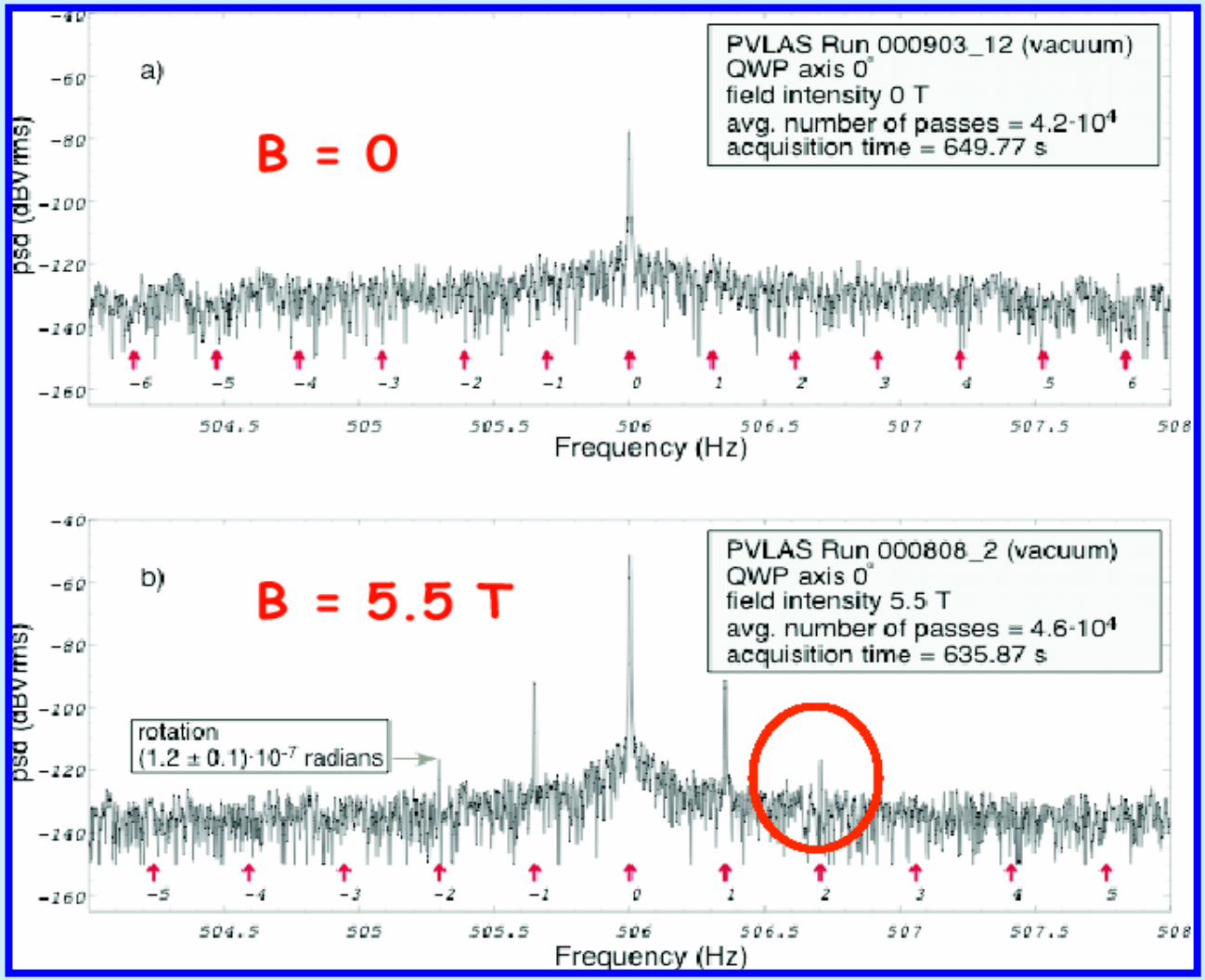
PVLAS Polaraization Rotation Results

Heterodyne techniques
Frequency analysis

Positive results also seen looking at polar-ization elipticity generation

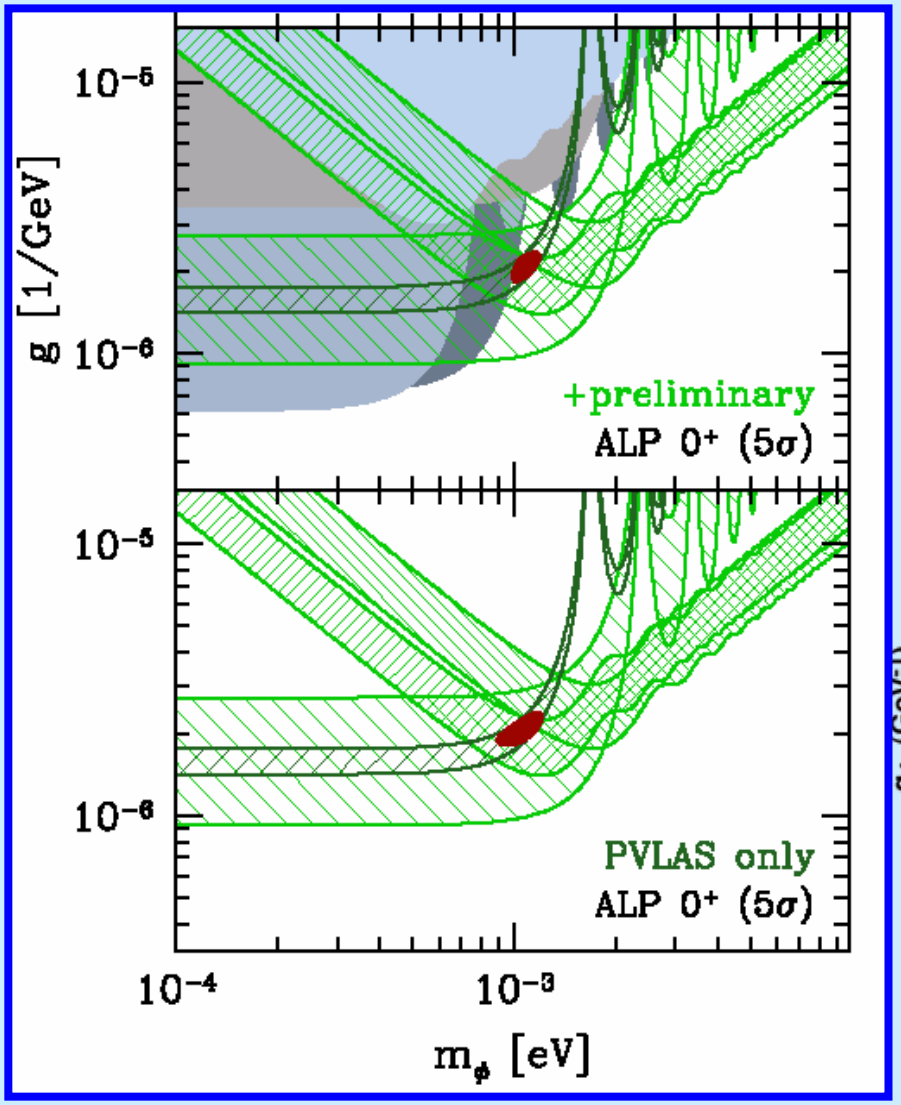
Positive results seen at both 1064nm and 532nm

Possible interpretation is a new axion-like particle that mediates these effects



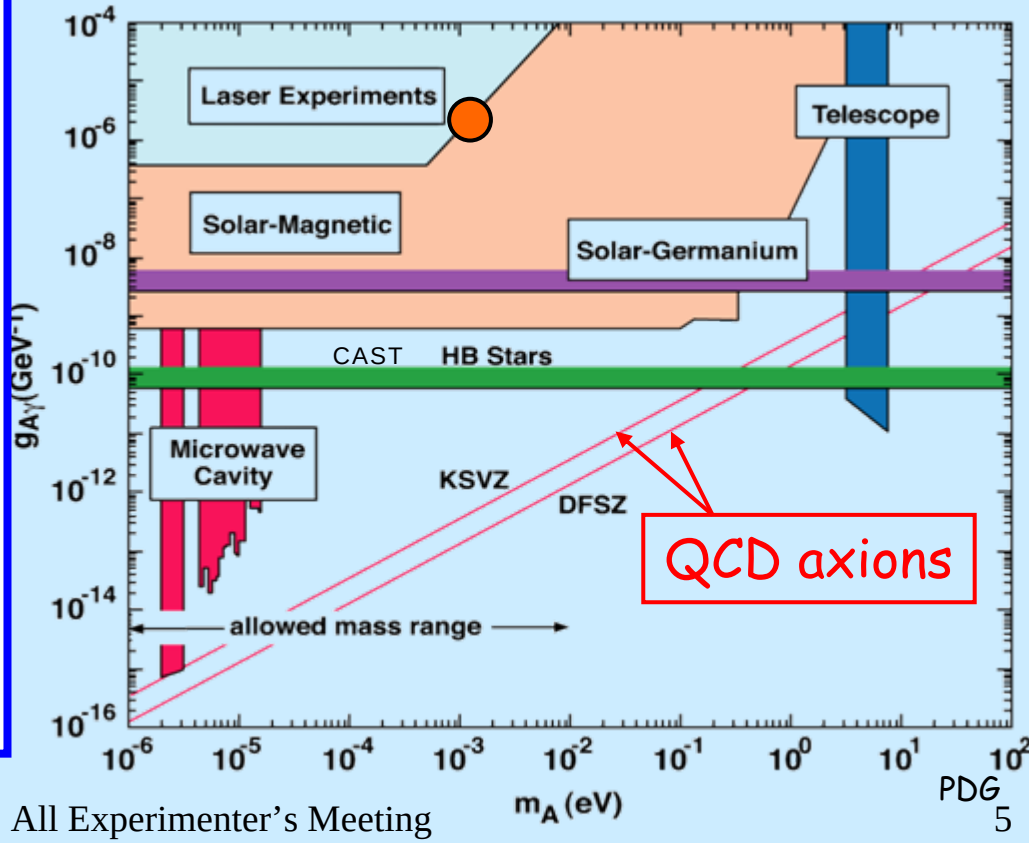
PRL **96**, 110406, (2006)

Axion-like Particle Interpretation



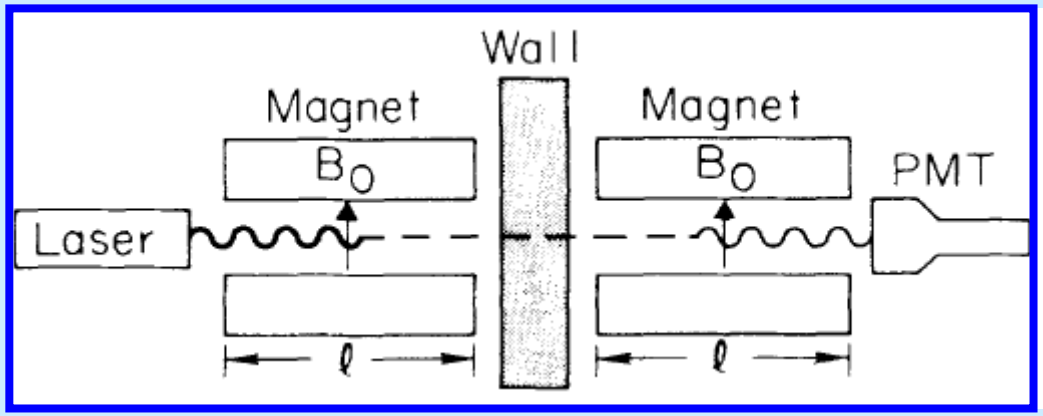
PRD **75**, 035011 (2007)

Scalar particle with mass 1.2 meV and $g \sim 2\times10^{-6}$ GeV^{-1} is consistent with rotation and ellipticity measurements using both green and IR light.

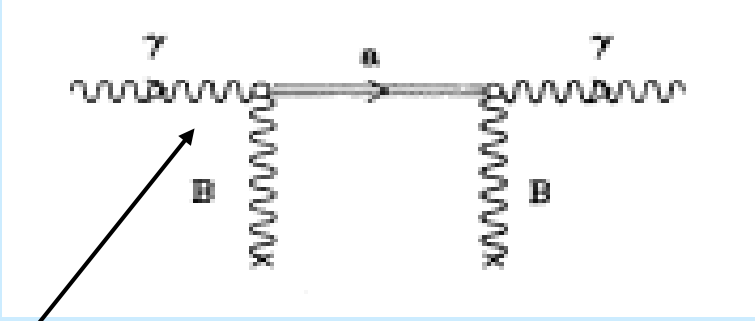


PDG

"Light shining through a wall"



PRL **59**, 759 (1987)



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

scalar

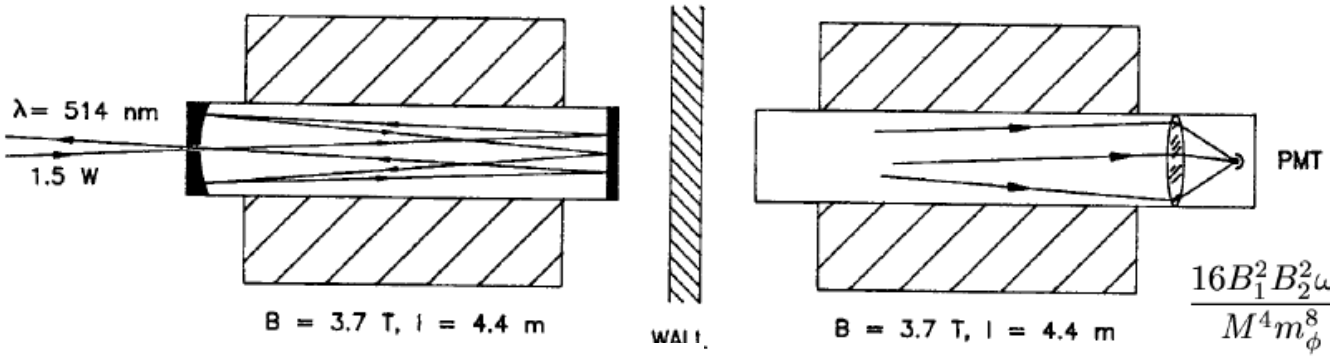
$$P_{regen} = \frac{16B_1^2B_2^2\omega^4}{M^4m_\phi^8}\sin^2\left(\frac{m_\phi^2L_1}{4\omega}\right)\cdot\sin^2\left(\frac{m_\phi^2L_2}{4\omega}\right)$$

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

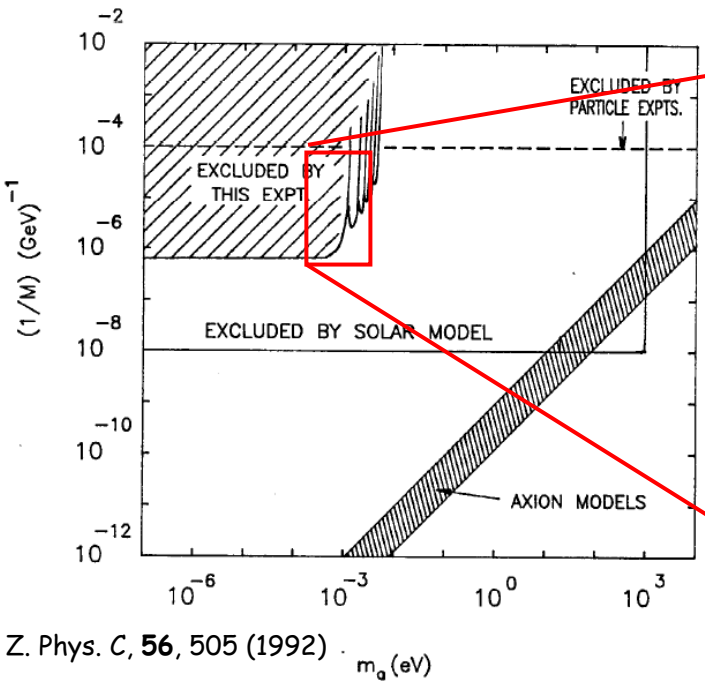
$$P_{regen}^{GammeV} = (3.8\times10^{-21})\times\frac{(B_1/5\ \mathrm{T})^2(B_2/5\ \mathrm{T})^2(\omega/2.33\ \mathrm{eV})^4}{(M/4\times10^5\ \mathrm{GeV})^4(m_\phi/1.2\times10^{-3}\ \mathrm{eV})^8}$$
$$\times\sin^2\left(\frac{\pi}{2}\frac{(m_\phi/1.2\times10^{-3}\ \mathrm{eV})^2(L_1/2.5\ \mathrm{m})}{(\omega/2.33\ \mathrm{eV})}\right)\sin^2\left(\frac{\pi}{2}\frac{(m_\phi/1.2\times10^{-3}\ \mathrm{eV})^2(L_2/2.5\ \mathrm{m})}{(\omega/2.33\ \mathrm{eV})}\right)$$

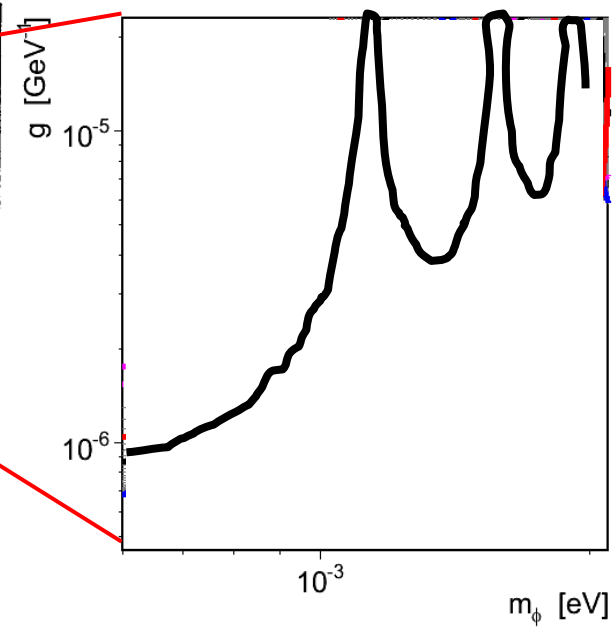
BFRT Experiment

- Brookhaven, Fermilab, Rochester, Trieste (1992)



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





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

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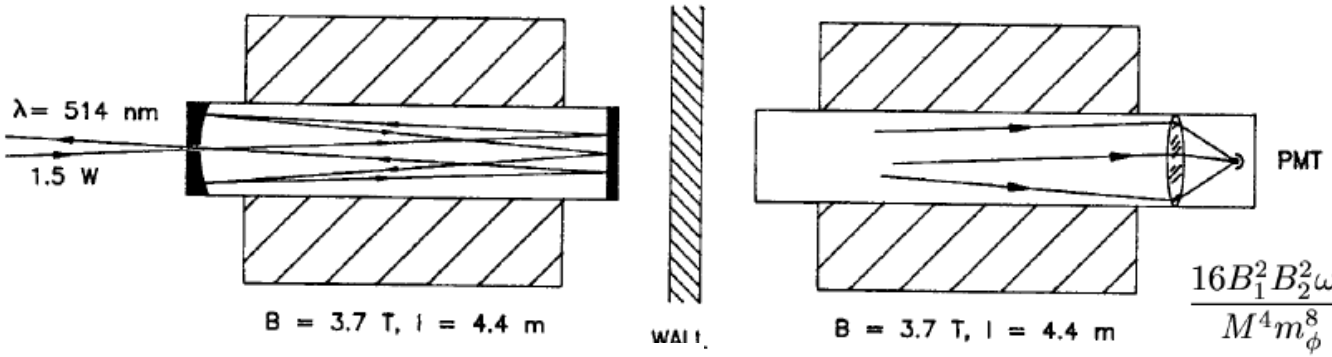
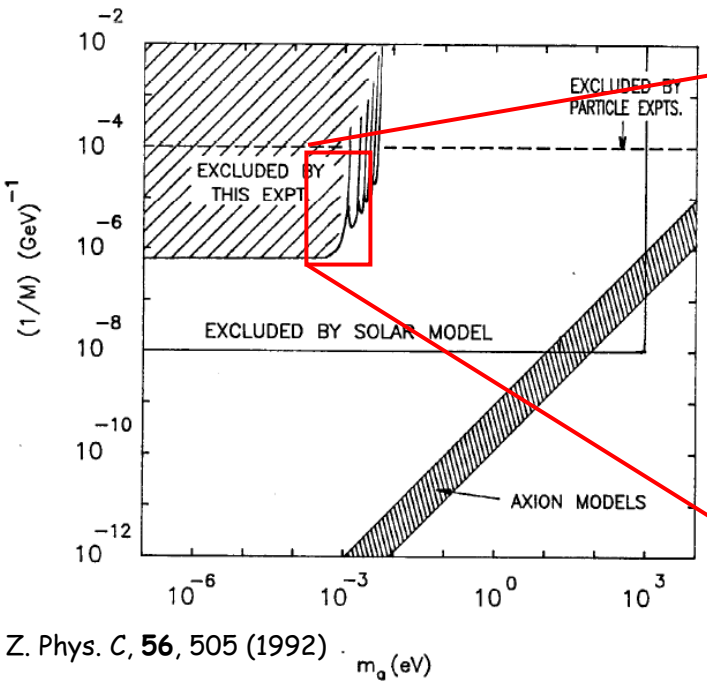


$$\frac{16B_1^2B_2^2\omega^4}{M^4m_\phi^8}\sin^2\left(\frac{m_\phi^2L_1}{4\omega}\right)\cdot\sin^2\left(\frac{m_\phi^2L_2}{4\omega}\right)$$



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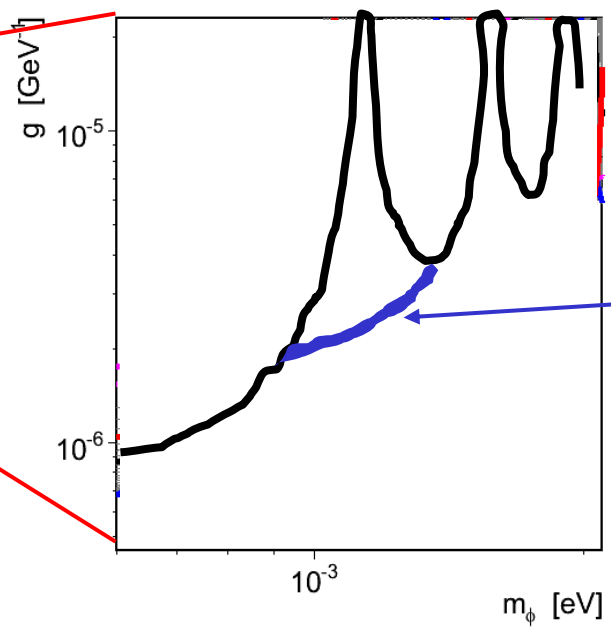
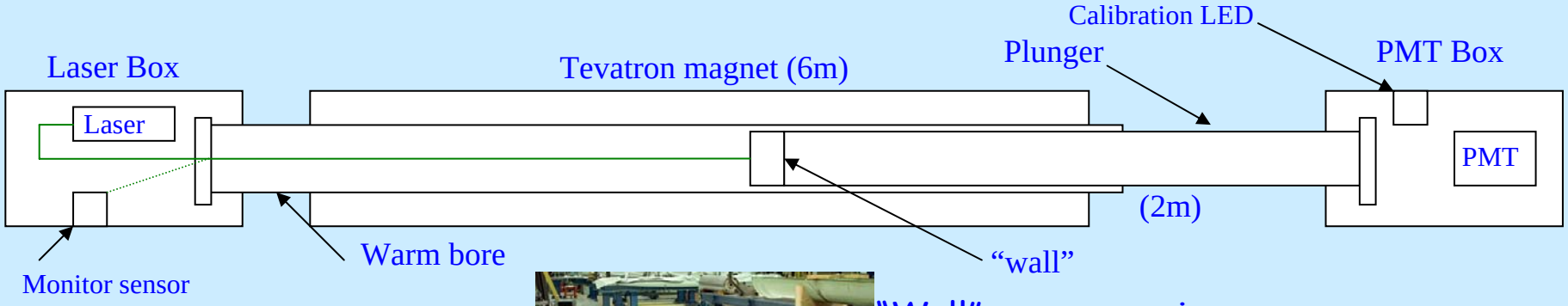
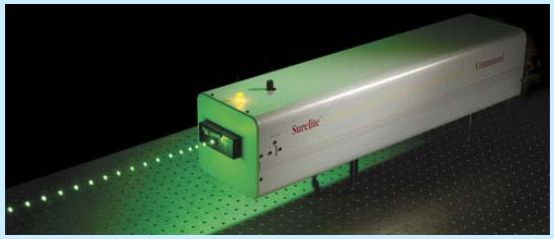


BFRT is not sensitive in the PVLAS region of interest because the 4.4 m baseline is near the oscillation minimum of 5 m for milli-eV mass.

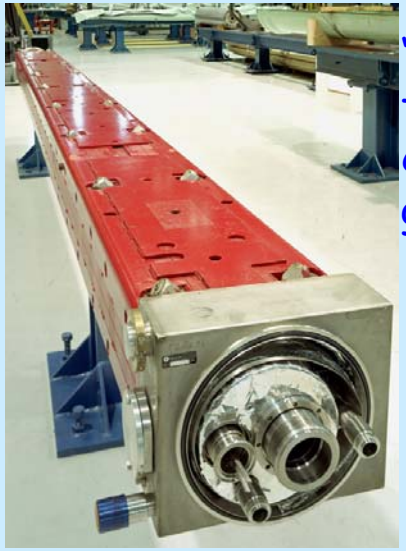
GammeV Experiment

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

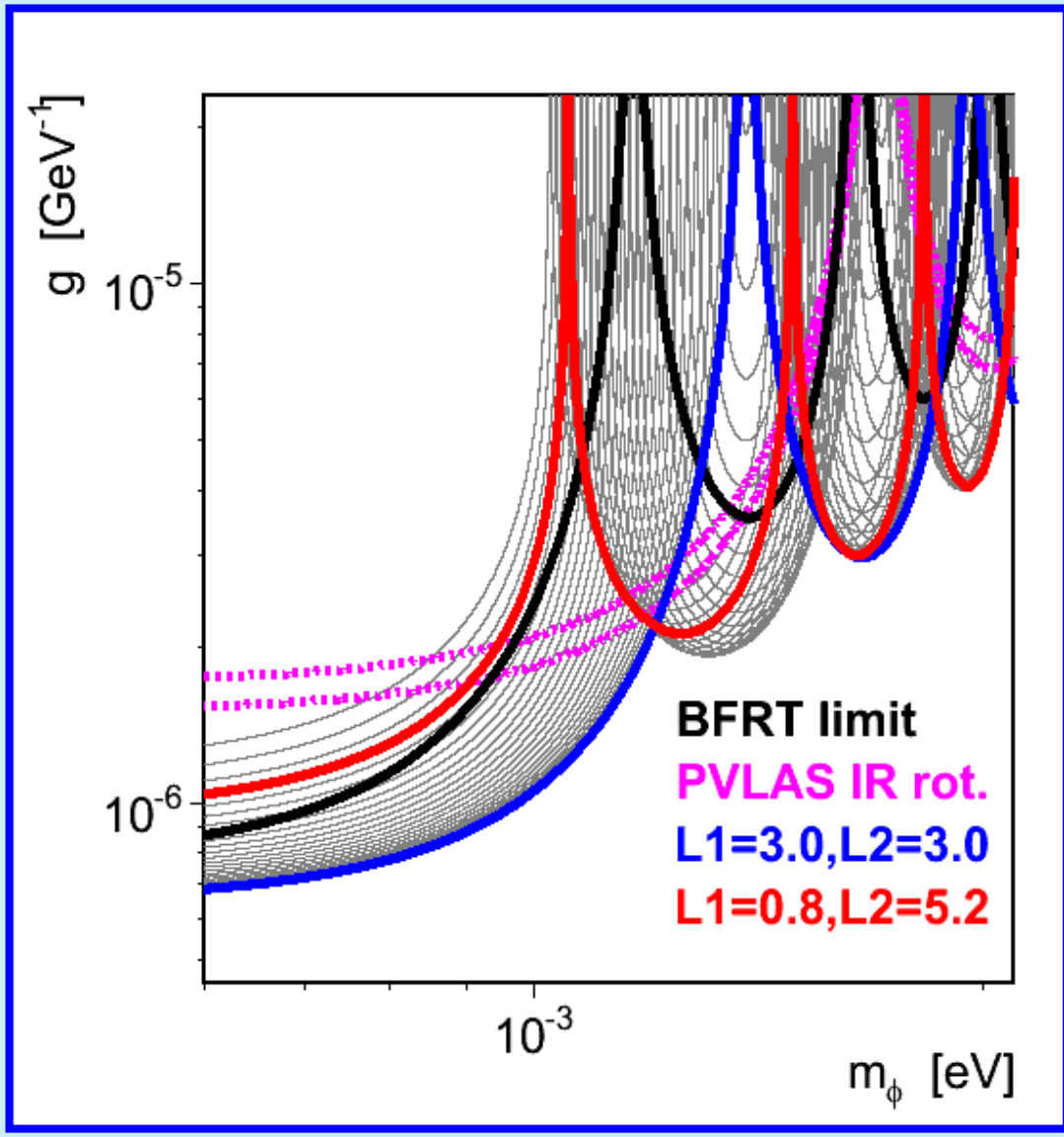


"Wall": concave mirror to control divergence + coated for high power green laser light

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

Expected Sensitivity

- Black = BFRT 3 sigma upper bound
- Pink = PVLAS 3 sigma signal region
- Grey = GammeV 3 sigma exclusion with 5 hours running at each beam dump position
  - Blue = center of magnet
  - Red = 0.8m from end
- **By changing the baseline, we cover the entire PVLAS signal region**



Sensitivity of proposed expts, using M=4e5 GeV, m=1.2meV

Name	Place	Magnet	Laser	P_{regen}	photons /s	R_{signal} (Hz)	Eff	R_{noise} (Hz)
BFRT (1993)	BNL	3.7 T*4.4m	514nm 1.5W*200 pass	2e-24	1e21	2e-3	0.1	6e-1 PMT
ALPS	DESY	5 T*4.2m	1064nm 200W welder	2e-24	1e21	2e-3	???	???
PVLAS (6/07)	LNL Italy	5 T*1m 2.2 T*0.4m	1064nm 0.06W*1e5 pass	2e-23	3e22	7e-1	0.5	1e-3 TES
LIPSS	JLab	1.7 T*1m	900nm 10kW cw FEL	6e-24	5e22	3e-1	0.3	1e-1/pixel CCD
OSQAR	CERN	9.5 T*3m 9.5 T*11m	514nm 100W	2e-20	3e20	5e0	0.5	1e-3/pixel CCD
BMV (9/07)	LULI France	10 T*0.4m	1053nm, 5e-5Hz 5 ns pulse 0.07W avg	7e-22	4e17 (1e22/pulse)	2e-4 (4/pulse)	0.2	1e-8 InGaAs APD
APFEL	DESY	2.2 T*6m	32 nm, 1e4 Hz 10 ns pulse 0.4 W avg	7e-20	6e16 (1e13/pulse)	5e-3	0.1	??? EMT, MCP, APD?
FNAL	FNAL	5 T*3m	532nm, 20 Hz 5 ns pulse 3W avg	1e-21	5e18 (2e17/pulse)	5e-3	0.4	1e-5 PMT
HERA SR	DESY	4.3 T*4.2m	SR: 50 kHz 100 ps timing	2e-19	1e17	3e-2	0.1	5e-5 MCP

Installation and Commissioning

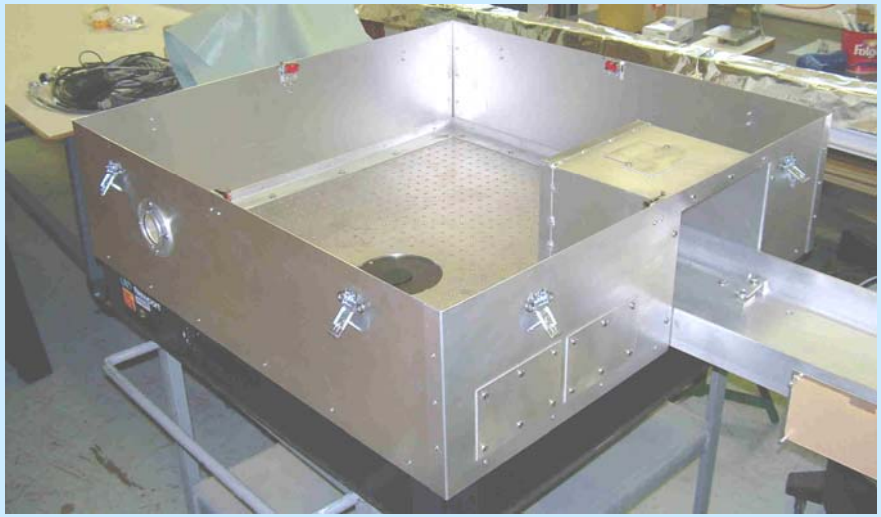
- Nov 2006: Aaron gives a theory seminar, William attends
- Feb 20: Ideas presented at food for thought seminar
- March 23: Review for funding within PPD
- April/May: Start putting systems together
- June 1: start installation and commissioning

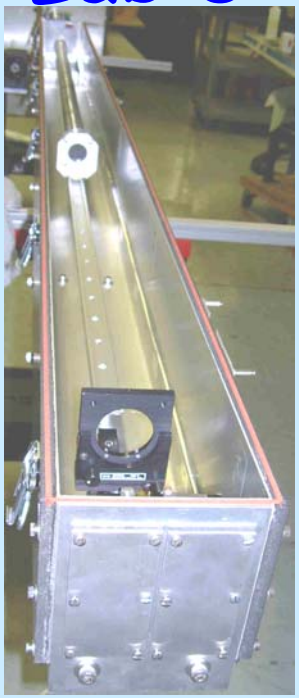
- Mechanical: Lab 8 within PPD
- Magnet: Technical Division, Magnet Test Facility
- Laser/Optics: Accelerator Division Linac Laser Lab
- Electronics: WH14 Electrical Engineering Dept.

- June 15: goal is to start data taking

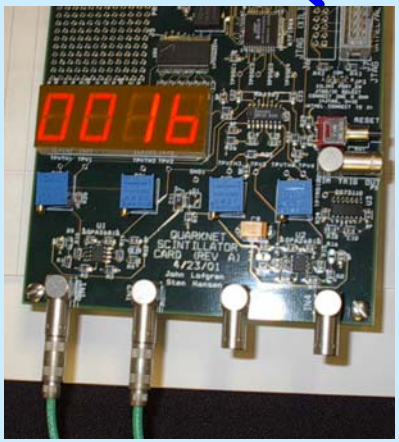
Mechanical and DAQ

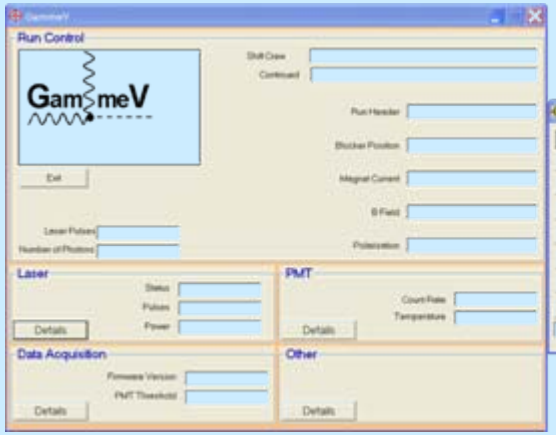
- Mechanical assembly is completing in Lab 8





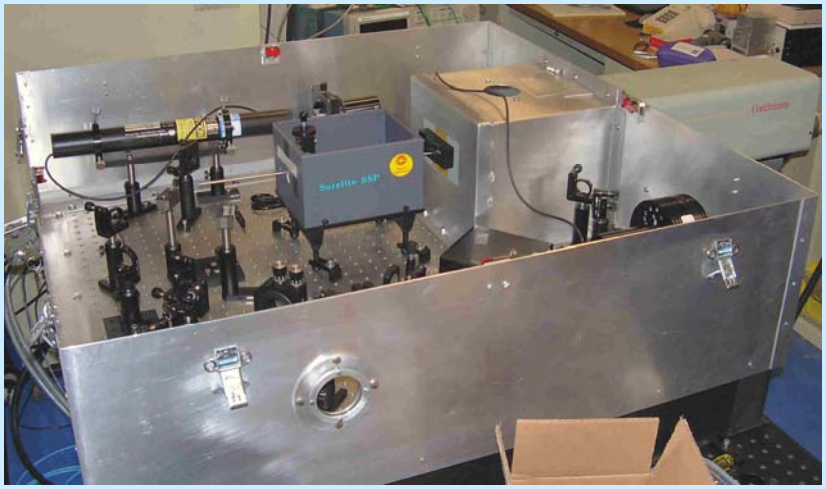
- DAQ system using QuarkNet boards

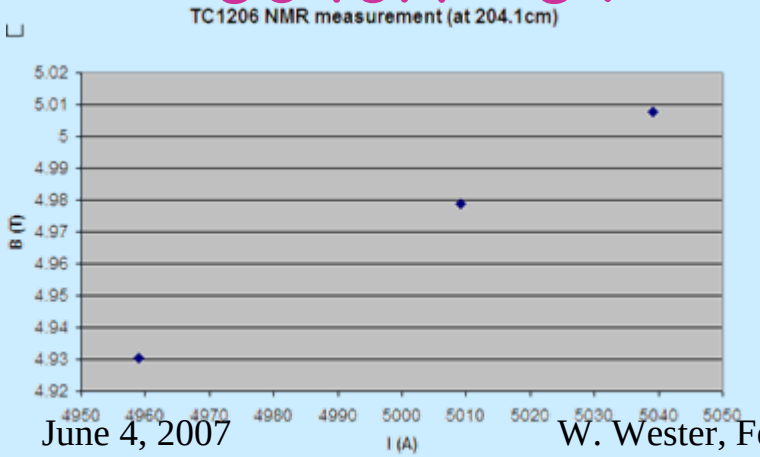


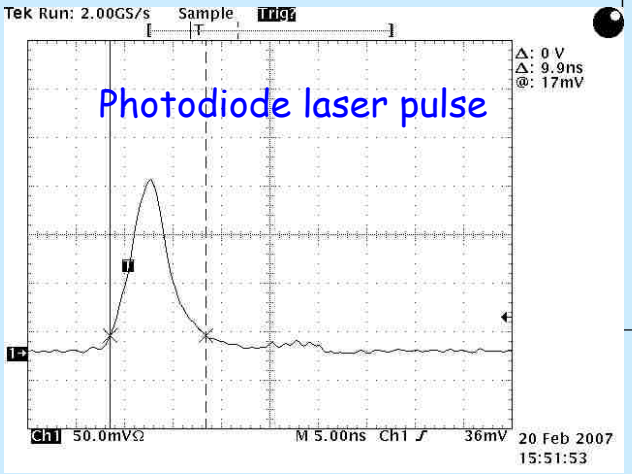


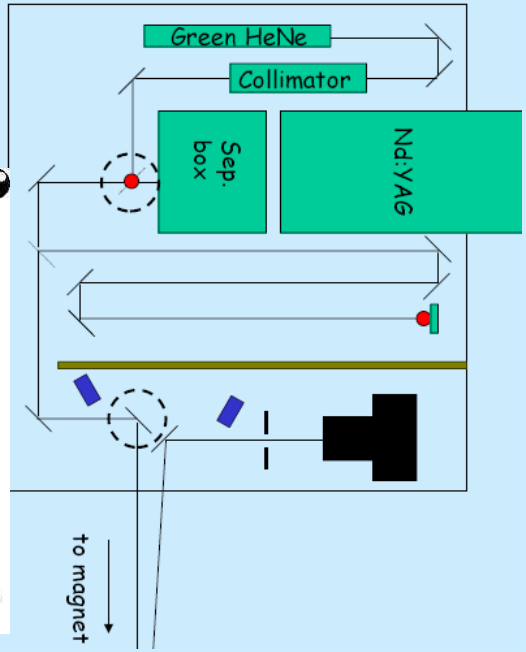
Laser, Optics, and Magnet

- Laser and Optics
  - 3.2W measured in green
  - multi-hour operation
  - Optical layout designed
- Magnet
  - Alignment of warm bore
  - 5040A = 5T









Conclusion

- **G**amme**V** is a search for a milli-eV particle in the PVLAS region of interest.
- This experiment is modest in scope and cost. It will be done within a few months.
- **2007 may be the year of the milli-eV dark particle and just maybe light does shine through walls!**

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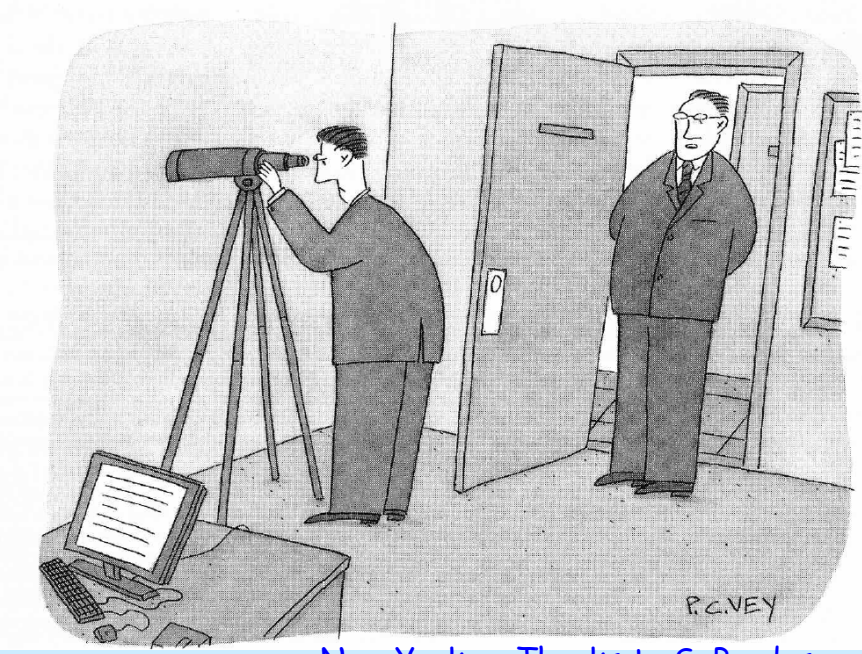

New Yorker. Thanks to S. Pordes