# Results from the GammeV Axion-like Particle Search

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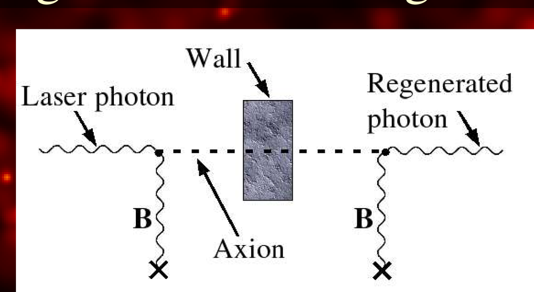
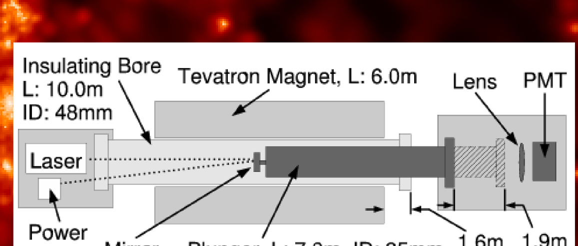
**Abstract:** I report on the results of the GammeV experiment---a light-shining-though-a-wall search for axion-like particles. This experiment was motivated to study the reported signal of the PVLAS experiment which was indicative of a new axion-like particle with a mass of ~1meV---a possible dark matter candidate. Using spare parts from the Tevatron particle accelerator and a novel, variable-baseline experimental approach we were able to probe the PVLAS region of interest with a high sensitivity.

## Experimental Apparatus

We detect axions by shining a laser into a region with a large magnetic field. A fraction of the photons oscillate into axions. Since axions interact weakly with matter, they can penetrate a barrier that would otherwise block all the incident photons (see below). After passing through the barrier, a fraction of the axions oscillate back into detectable photons. The two salient features of GammeV are its pulsed laser, which allows for a large reduction in noise, and its variable baseline, which allows us to change the length of the two magnetic field regions.



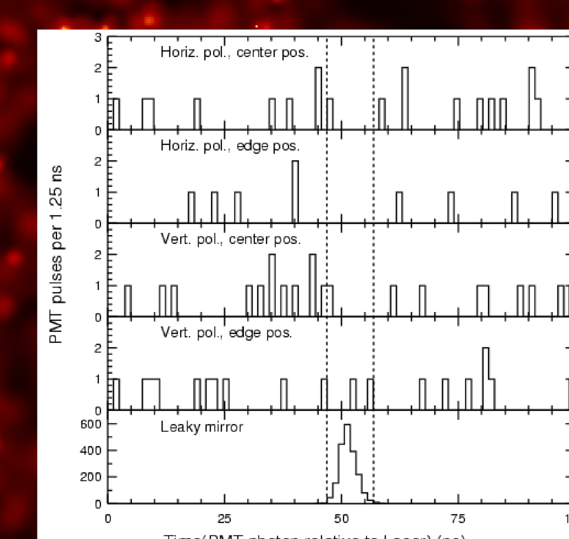

Our 3.2W laser (top) is pulsed at a rate of 20Hz. The width of each pulse is 5ns. When we analyze our data, we require that the detected photons lie within a 10ns window that is coincident with the laser pulses. Since the photo-detector (bottom) has a background rate of only 100Hz this gives us a signal-to-noise ratio of over 100 for the PVLAS region of interest.




Our "wall" is a mirror mounted to a stainless steel cap. This is located at the end of a long plunger which can be inserted into and retracted from a superconducting, Tevatron dipole magnet that provides a 5T magnetic field. With the wall at a fixed position there are certain particle masses that the instrument is not sensitive to because the various distances correspond to an integer number of oscillation lengths. By having a movable barrier, we can be sensitive to particles of all masses.

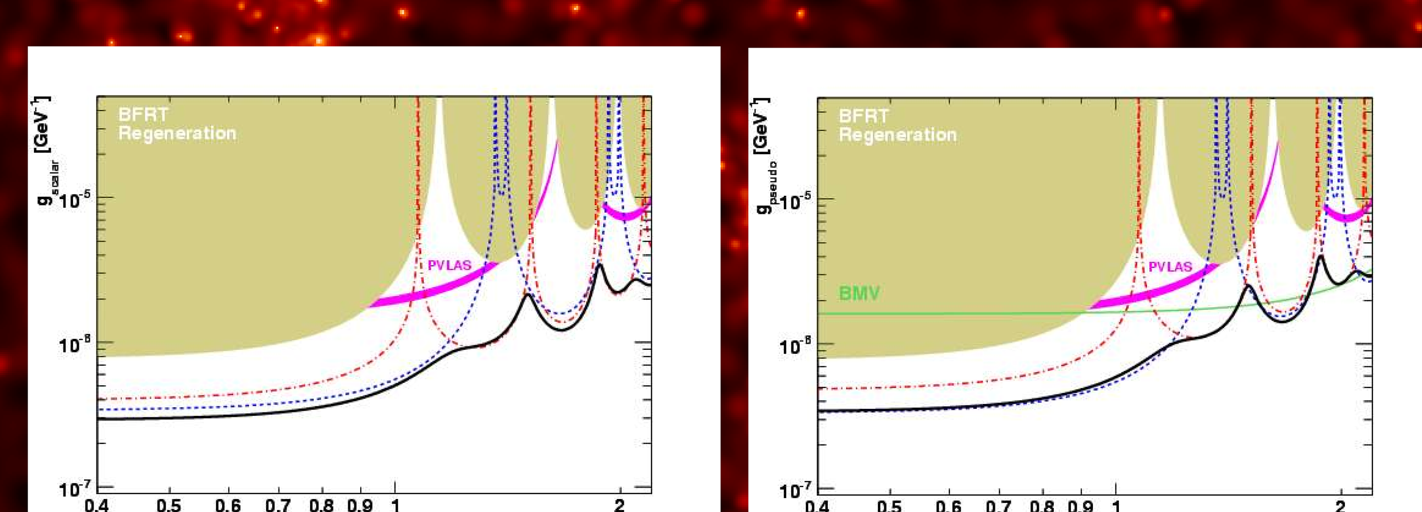
## Axion-like Particle Results

We collected 80 hours of data, 20 hours in each of four configurations, two plunger positions and two laser polarizations, which allows us to search for both pseudoscalar (horizontal) and scalar (vertical) particles. The number of photons that lie within our coincidence window (see figure) are consistent with our background. A summary of the data is given below.



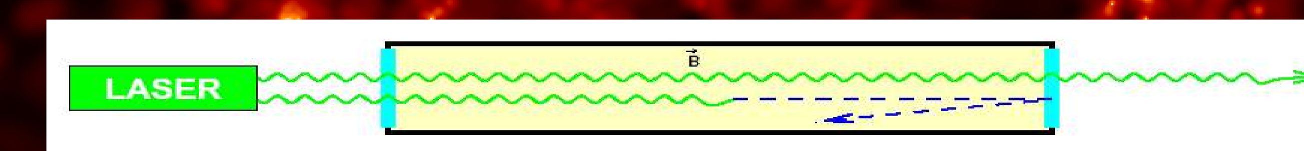

| Configuration | # photons | Est.Bkgd | Candidates | g[GeV$^{-1}$] |
|---|---|---|---|---|
| Horiz.,center | $6.3 \times 10^{23}$ | 1.6 | 1 | $3.4 \times 10^{-7}$ |
| Horiz.,edge | $6.4 \times 10^{23}$ | 1.7 | 0 | $4.0 \times 10^{-7}$ |
| Vert.,center | $6.6 \times 10^{23}$ | 1.6 | 1 | $3.3 \times 10^{-7}$ |
| Vert.,edge | $7.1 \times 10^{23}$ | 1.5 | 2 | $4.8 \times 10^{-7}$ |

With these data we rule out the axion-like particle interpretation of the PVLAS signal at greater than 5 sigma. Below are the 3-sigma exclusion curves for both scalar (left) and pseudoscalar (right) particles from GammeV. The tan regions are excluded by the BFRT experiment, the cyan is the PVLAS signal region, the green is the limit from the BMV experiment, the red and blue curves are the individual limits from the two plunger positions, and the black curve is a combined analysis of the data from both positions.

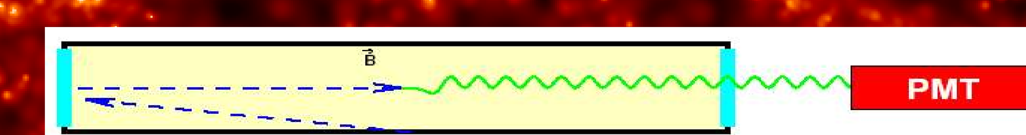



## Chameleon Particle Search

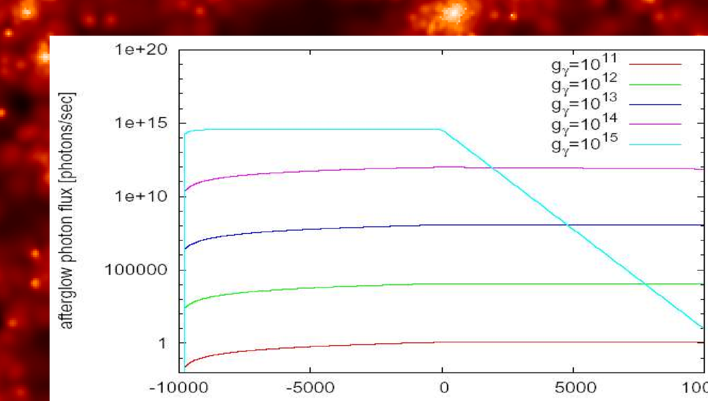
A second aspect of the GammeV experiment, and part of its original design, is a search for chameleon particles. These particles have very strong interactions with matter and can have interactions with photons that are identical to axions.




Matter effects cause the walls and windows of the GammeV cavity to act like perfectly reflective mirrors. To detect chameleons, we shine the laser into the magnetic field region for several hours to "fill the jar" (see above). We then turn off the laser and turn on our photo-detector. If chameleons exist we should see an exponentially decaying afterglow as they reconvert into photons and exit the chamber (see below).




Below is a graph that shows the expected Chameleon afterglow rate as a function of time for various couplings to photons. Time t = 0 corresponds to the moment that the laser is turned off and the photo-detector is turned on. Large couplings would reach equilibrium quickly and result in an afterglow that is as bright as the laser used to fill the cavity. Smaller couplings cannot reach equilibrium but still produce a detectable signal.




## Acknowledgements

The GammeV Collaboration includes as members:

A. S. Chou (NYU), A. Baumbaugh (FNAL), H. R. Gustafson (Michigan), Y. Irizarry-Valle (FNAL), P. O. Mazur (FNAL), J. H. Steffen (FNAL), R. Tomlin (FNAL), A. Upadhye (KICP), A. Weltman (Cambridge), W. Wester (FNAL), X. Yang (BNL), and J. Yoo (FNAL).

This work is supported by the U.S. Department of Energy under contract No. DE-AC02-07CH11359. A. Chou is also supported by NSF-PHY-0401232, J. Steffen is supported by the Brinson Postdoctoral Fellowship.