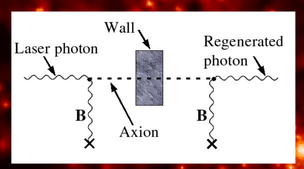
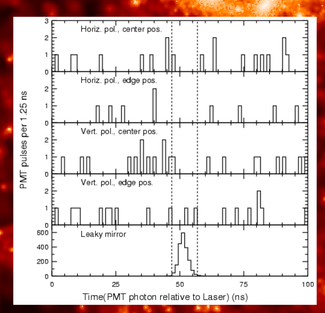
Results from the GammeV Axion-like Particle Search

Axion-like Particle Results

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.

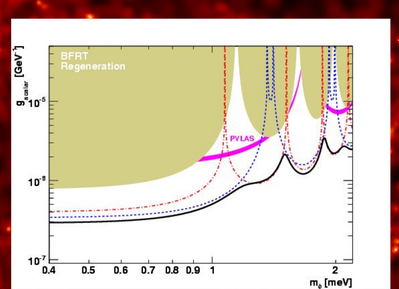


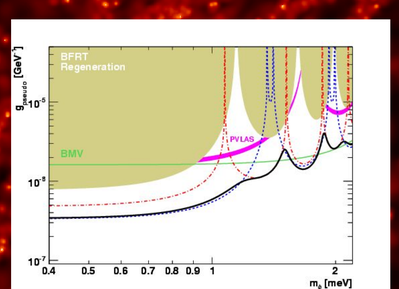
We collected 80 hours of data, 20 hours in each of four configurations, two positions of the plunger and two laser polarizations, which allows us to search for both pseudoscalar (horizontal) and scalar (vertical) particles. The number of photons within our coincidence window are consistent with background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



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



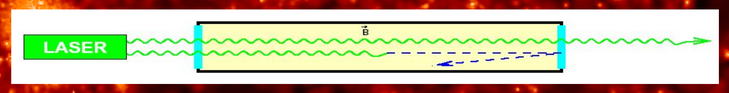


The GammeV Collaboration

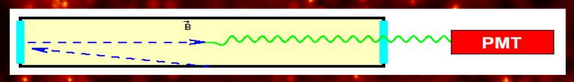
Abstract: We report the results of the GammeV experiment---a light-shining-though-a-wall search for axion-like particles and a particle-trapped-in-a-jar search for chameleon particles. This experiment was motivated to study the reported signal of the PVLAS experiment which was indicative of a new axion-like 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 exclude the particle interpretation of the PVLAS signal with a high level of confidence. With a slight modification to the apparatus (pictured above) we conducted an experiment to probe for chameleon particles, particles which are a candidate for the dark energy. This second phase of the GammeV experiment can exclude many regions of parameter space for cosmologically interesting chameleon models.

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 scalar couplings to two photons and have very strong interactions with matter.

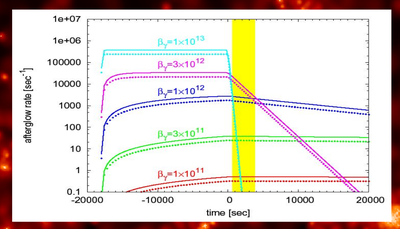


The matter effects cause the walls and windows of the GammeV cavity to act like perfectly reflective mirrors. To detect chameleons, we shine the laser into the magnetic field region for several hours to "fill the jar" (see above). We then turn off the laser and turn on our photo-detector. If chameleons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

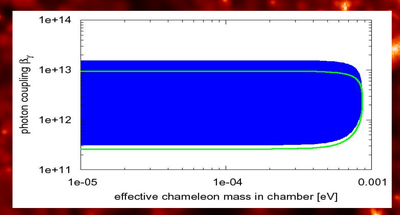


Chameleon Results

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. The yellow region is our observation window for scalar chameleons, the pseudoscalar window is similar.



We compare the mean photon rate in our PMT during the observation window with the mean rate of the PMT when no chameleons are expected. Below is a graph that shows the 3-sigma exclusion region for the chameleon to photon coupling for generic chameleon models as a function of the chameleon particle's effective mass inside the GammeV vacuum chamber, These are the results of the first particle-in-a-jar search for chameleon-like particles.



Acknowledgments

The GammeV Collaboration includes as members:

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