The **GammeV** Search for Chameleon Particles

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GammeV Review
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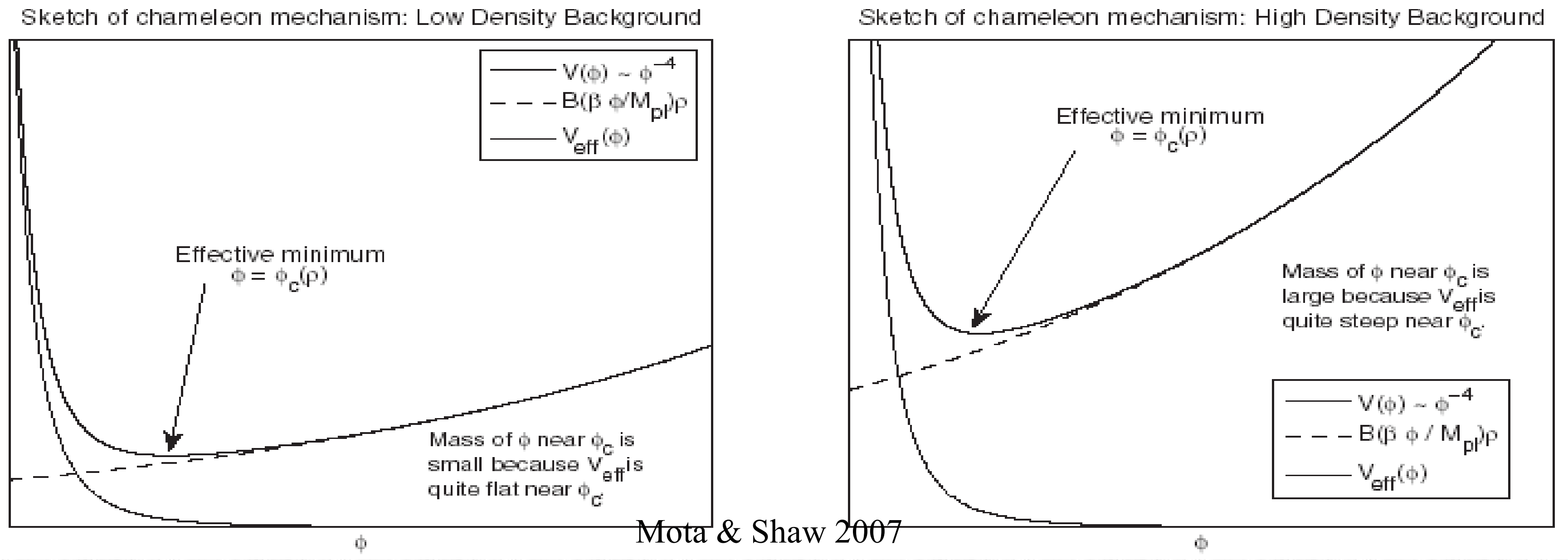
Outline

- Introduction to Chameleon particles
- Design of GammeV search
- Results from GammeV search
- Improvements to the experiment
- Anticipated sensitivity

Chameleon Particles

- New scalar field with nontrivial potential and coupling to the energy–momentum tensor
- Mass is a strong function of the local energy density
- Hides the axions of string theory
- Evades constraints from astrophysics and torsion pendula

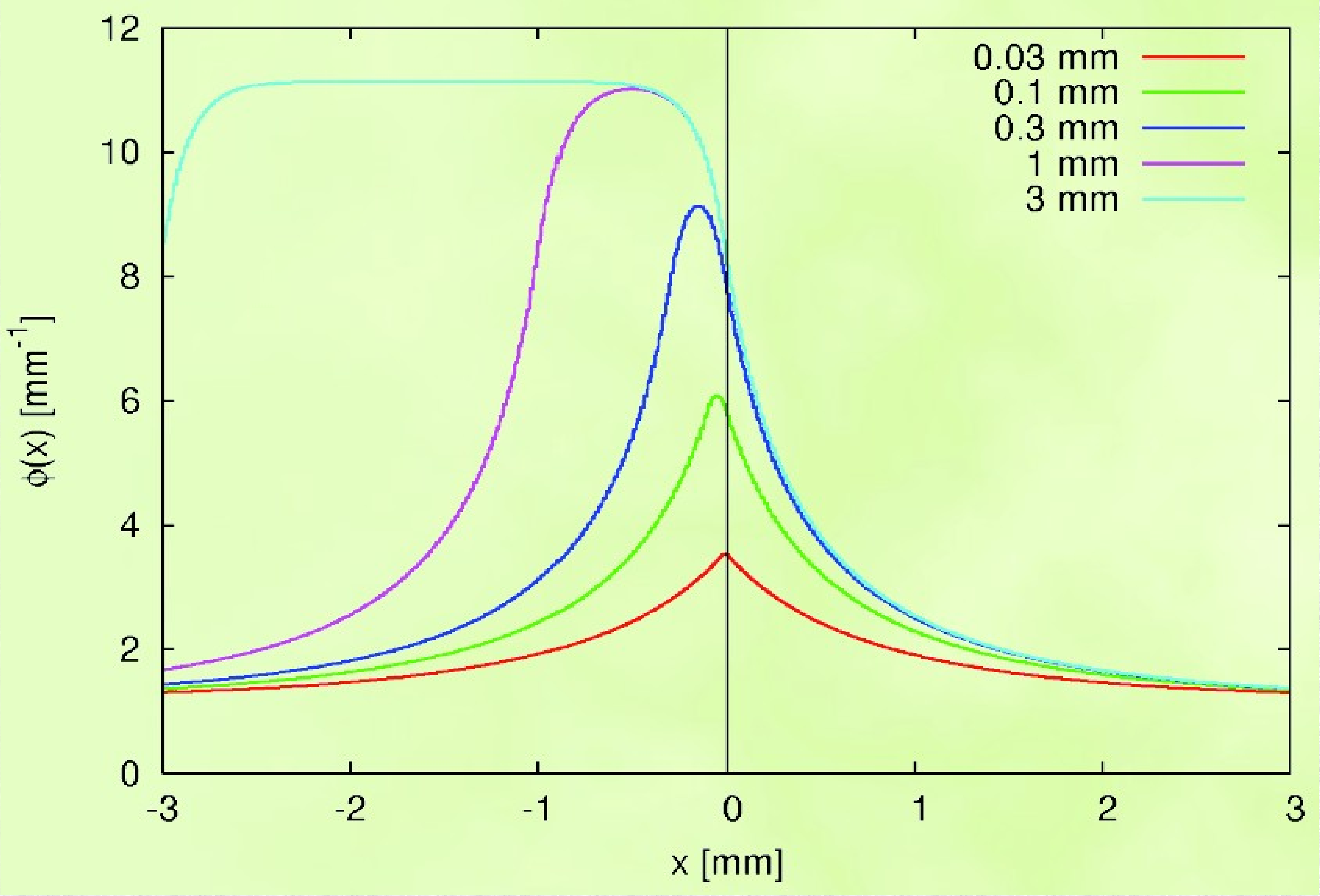


Mota & Shaw 2007

NB: The simplest models predict $m_{\text{eff}} \sim \rho^{\alpha}$.

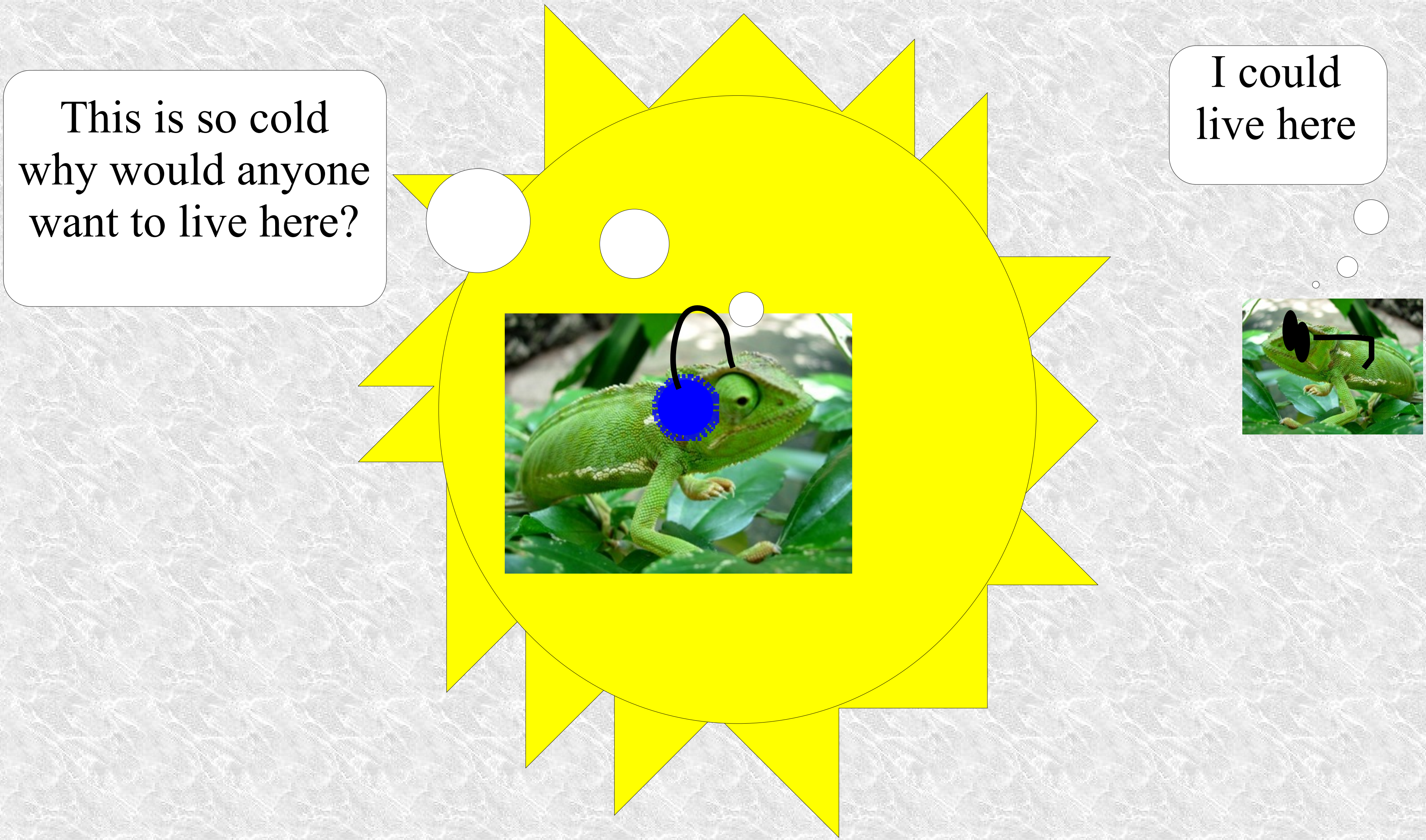
Chameleon Particles

Evades short-range tests of gravity via “thin shell” mechanism



Chameleon Particles

Evades star cooling limits due to large mass in stellar environment



Gamme**V** – Chameleon: Design

Strong matter effects cause the warm bore walls and vacuum windows to act like fully reflective mirrors.

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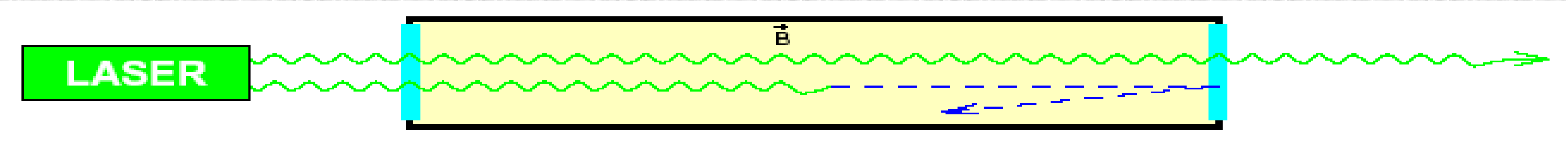

The laser shining into the cavity will fill the “jar” with chameleons.

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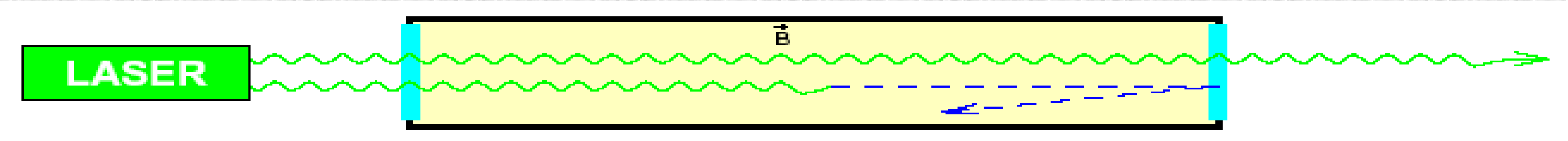

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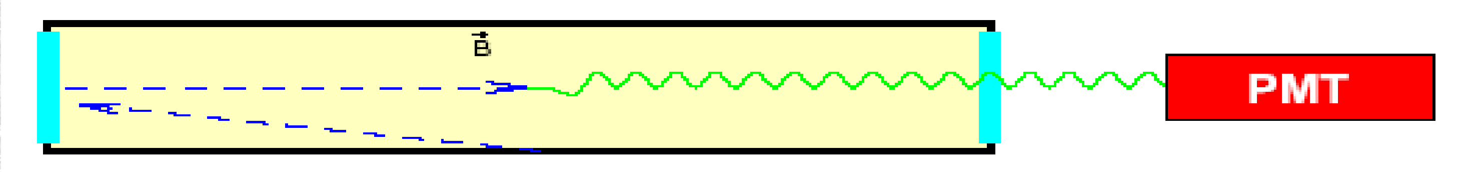
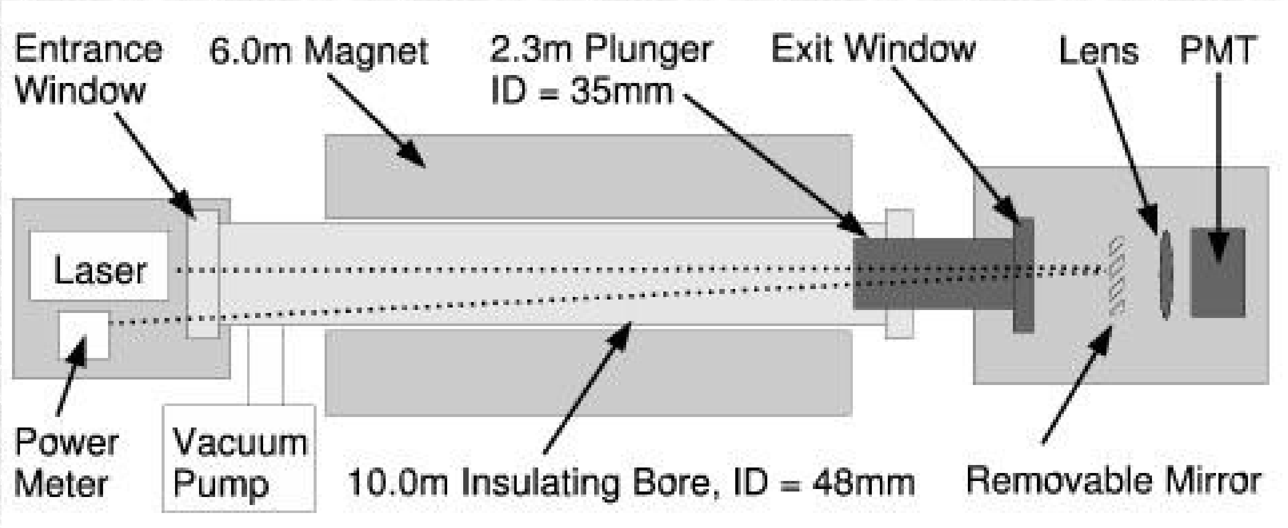
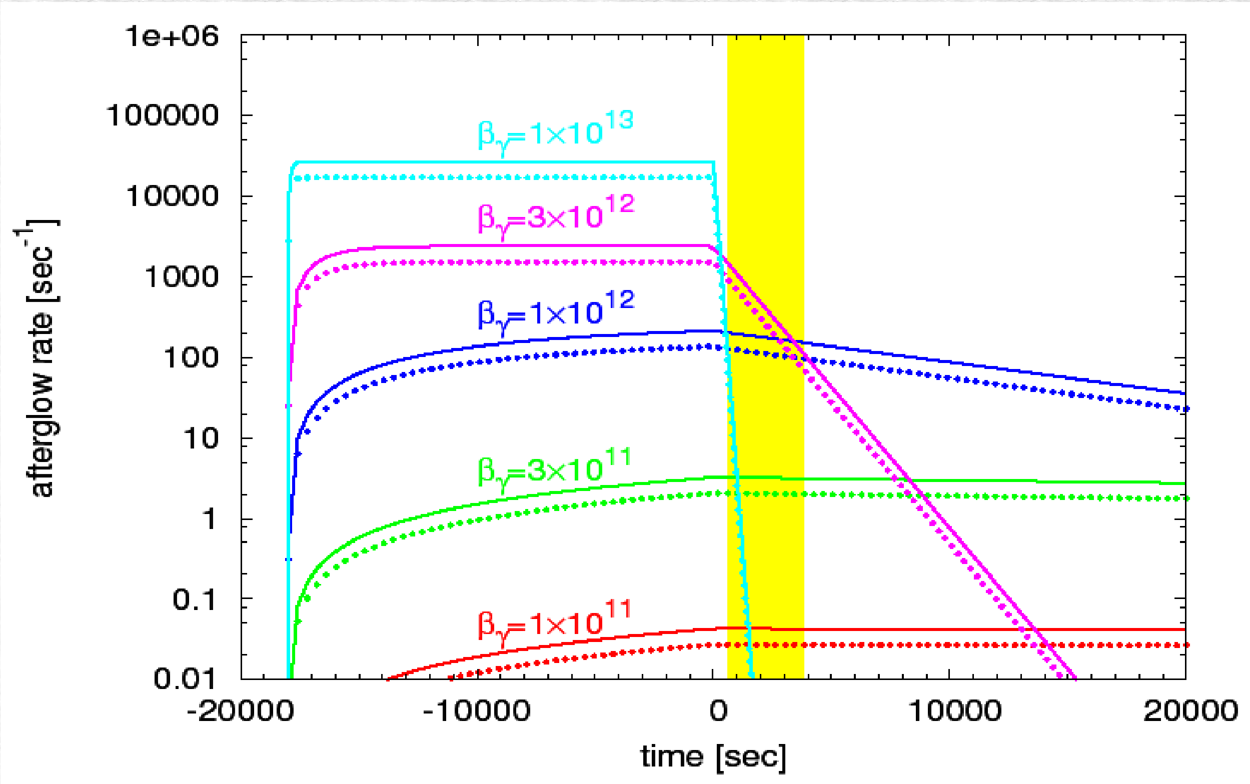


After the jar is filled and the laser is turned off, you should see an afterglow as the chameleons reconvert to photons and escape.

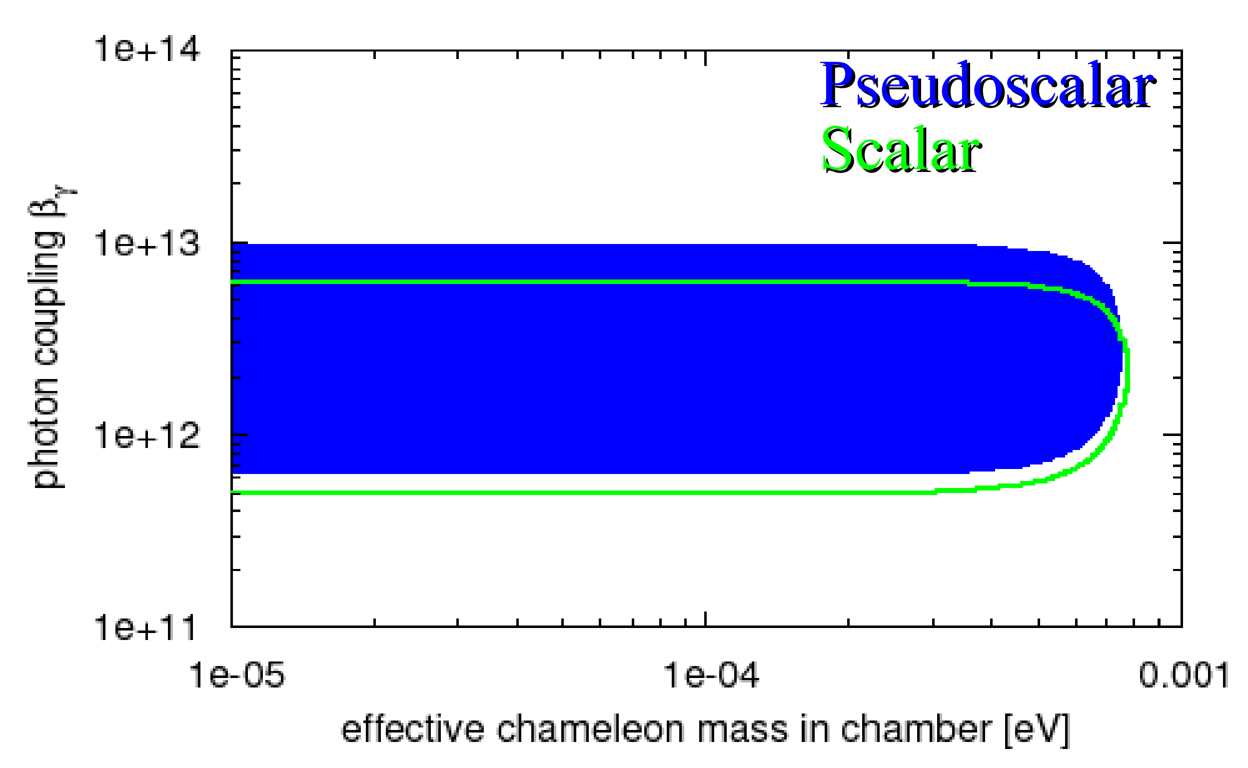
GammeV – Chameleon: Design





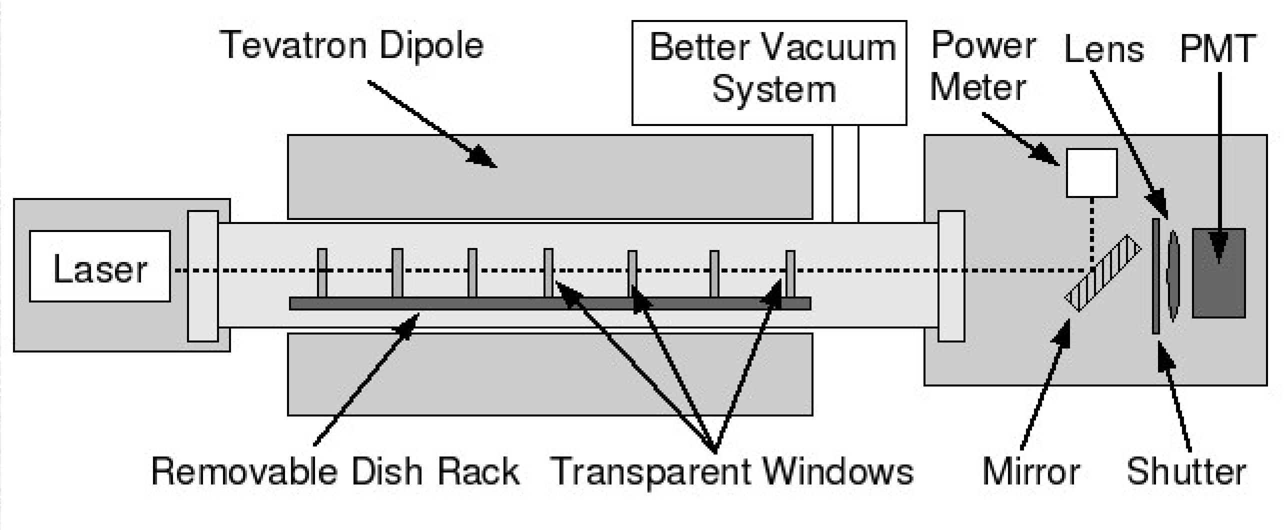
GammeV – Chameleon: Results

Configuration	Fill Time (s)	# photons	Vacuum (Torr)	Observation (s)	Offset (s)	Mean Rate (Hz)
Pseudoscalar	18324	2.39e23	2e-7	3602	319	123
Scalar	19128	2.60e23	1e-7	3616	1006	101



Detector systematic uncertainty dominates; we exclude models which would produce signals larger than 36Hz for $\alpha \gtrsim 0.8$.

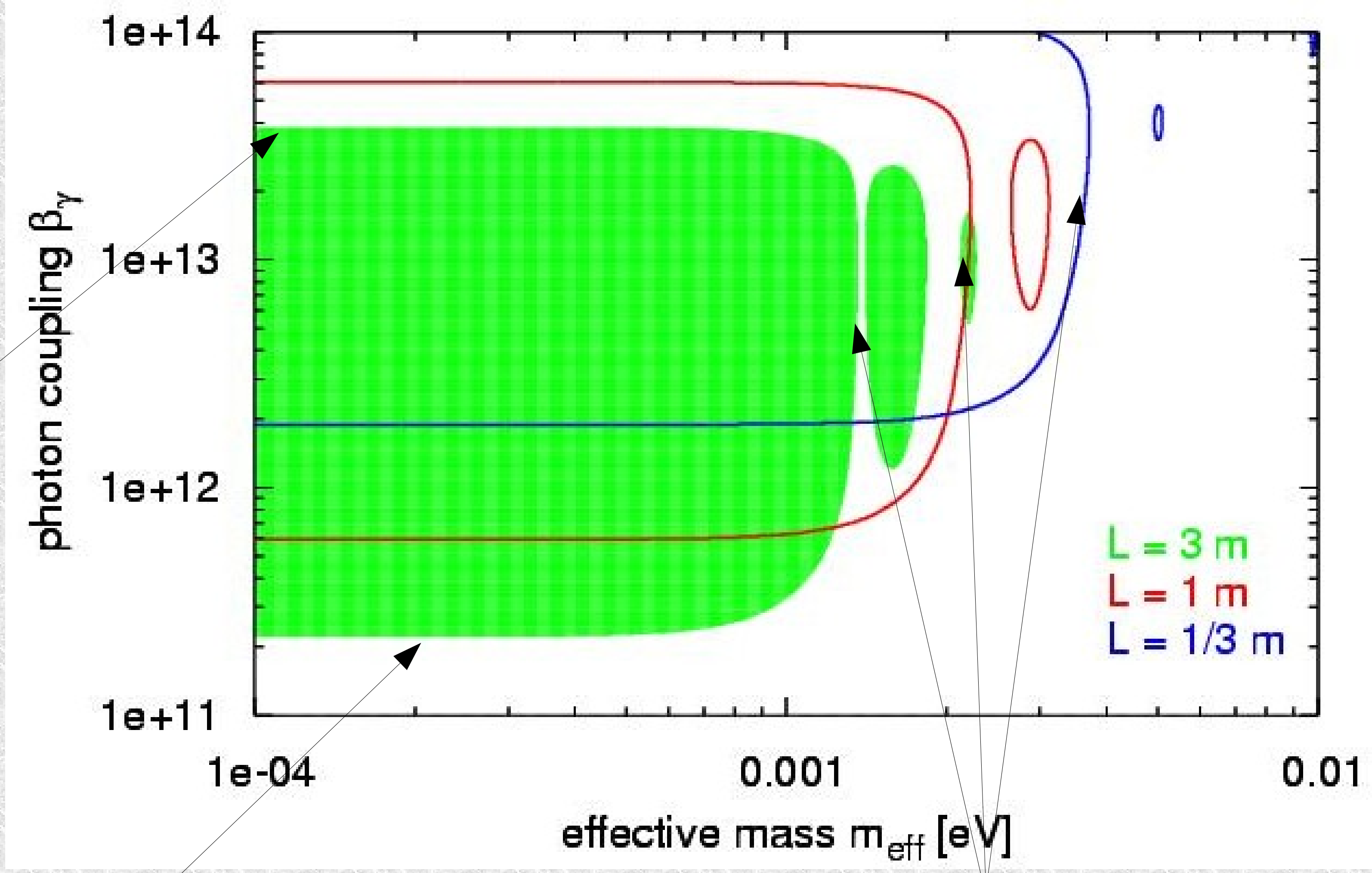
Improvements to Chameleon Search



- Use cold bore as a means to improve vacuum. While the number density of the gas will increase, only the lighter elements will live in the magnetic field region.
- Use a "dish rack" to partition the cavity. This allows us to probe for larger masses and increases the signal since each partition will contribute. No need for separate vacua.
- Use different magnetic field strengths to probe for larger couplings. Stop when we run into existing limits.
- Use a shutter to reduce PMT systematic errors.

The Future of Chameleons

Using different magnetic fields allows us to push to higher couplings.



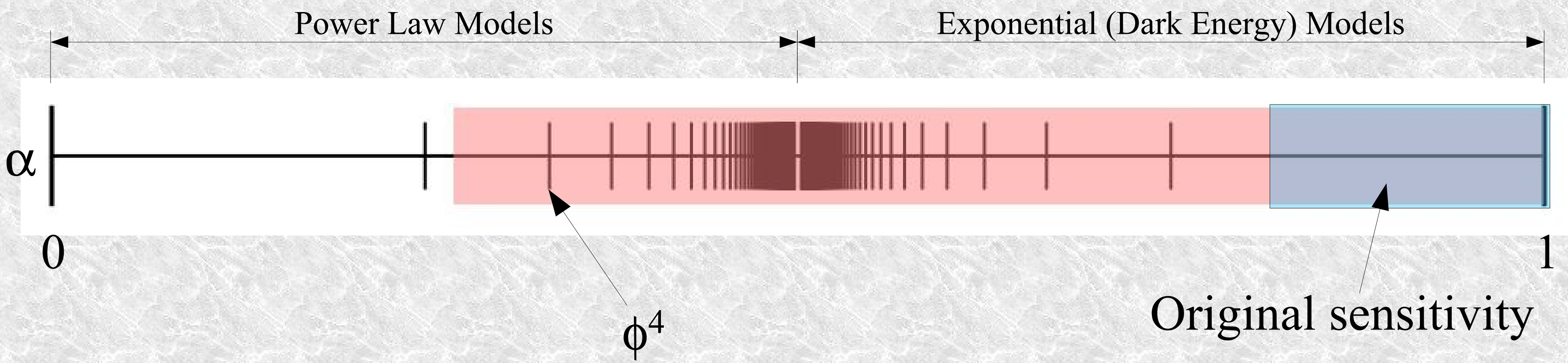
Using the shutter improves our sensitivity to smaller couplings.

Partitioning the magnetic field into smaller pieces allows us to probe for larger masses.

The Future of Chameleons

$$V(\phi) = \frac{\xi}{N!}\phi^N$$

$$V(\phi) = \Lambda^4 \exp\left(\frac{\Lambda^n}{\phi^n}\right)$$



Improved vacuum system allows us to probe for smaller values of α. This probes for a larger variety of chameleon models.

Conclusions

- Original chameleon search was the first application of the particle-in-a-jar detection method
  - Used the GammeV axion apparatus with virtually no additional cost
- Next generation chameleon experiment will be able to probe a wide variety of chameleon models
  - In particular, all dark energy models and power-law models including ϕ^4
  - Improvements in the vacuum design, the shutter, and the "dish rack" are the primary upgrades to the experiment
- Chameleons are one of the few dark energy models with known laboratory signatures
  - With little investment the GammeV collaboration can make a significant breakthrough in the new field of particle cosmology