Detecting Dark Matter
Zack Scholl, November 2009

Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

2003: We *know* dark matter exists

We know DM could be explained by….

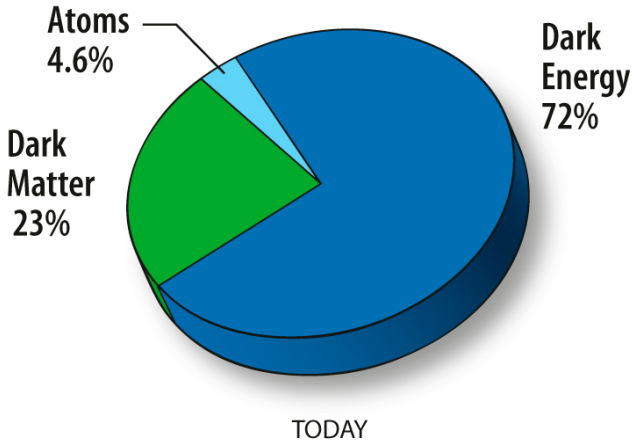
Weakly Interacting Massive Particle (WIMPs)
- Motivated by supersymmetry
- 10-100 GeV

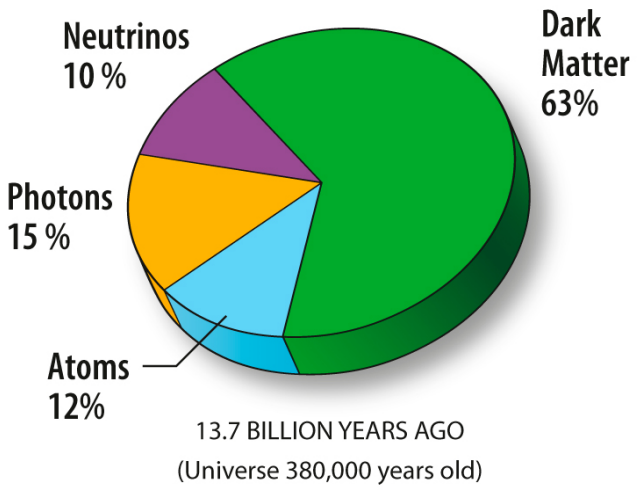
Weakly Interacting Sub-eV Particle (WISPs)
- Motivated by QCD
- 1μeV -1meV

We know DM can *not* be explained by…

Massive Astrophysical Compact Halo Objects (MACHOs)

Modification to Newton's laws





http://map.gsfc.nasa.gov/

How to find WIMPs

Each experiment is $10-20 million

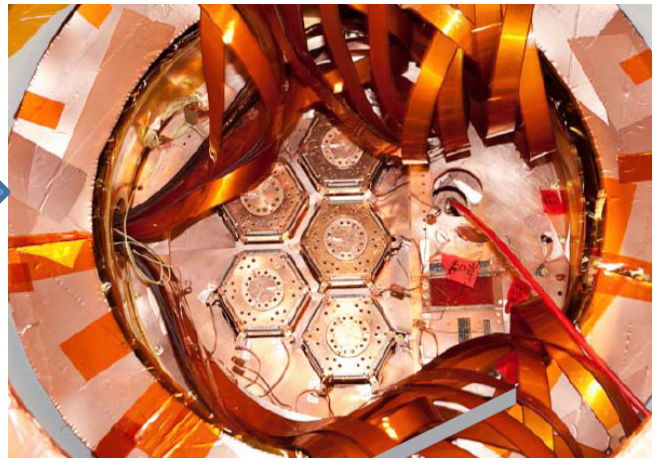
Scintillation (DAMA/LIBRA, KIMs)

- Cheaper, smaller
- Hard to veto particles

http://axion-wimp.desy.de/e30/e52240/e54447/SeungChonKim.pdf

Ionization/Heat (CDMSII)

- Expensive, big
- Can veto particles



Muir, Hazel. (2009, August 04). Let there be light! The search for dark matter. *Wired*.

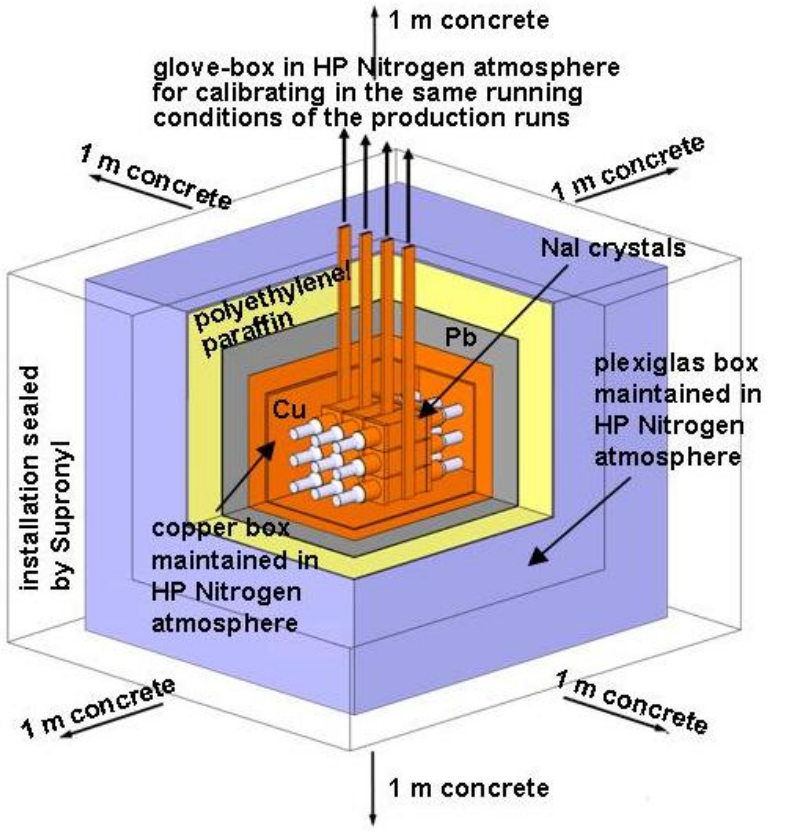
LHC (6$ billion)

- Can detect particles of 100GeV

WIMPs have never been detected (unless you believe DAMA)!

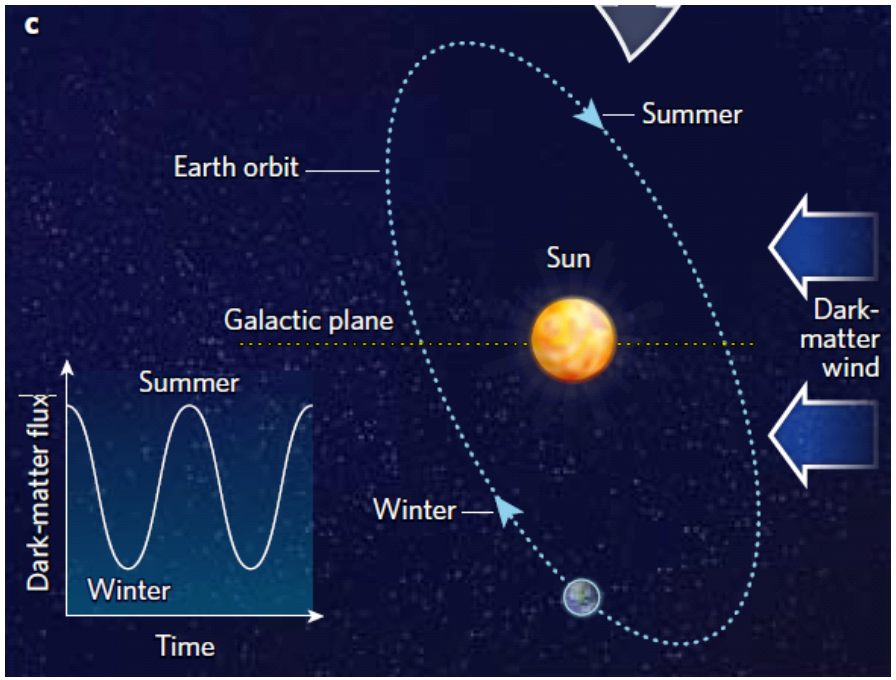
1996: DArk MAtter experiment

Underground scintillating detector in Gran Sasso, Italy



Simplified schema of ~ 100 kg NaI(Tl) set-up

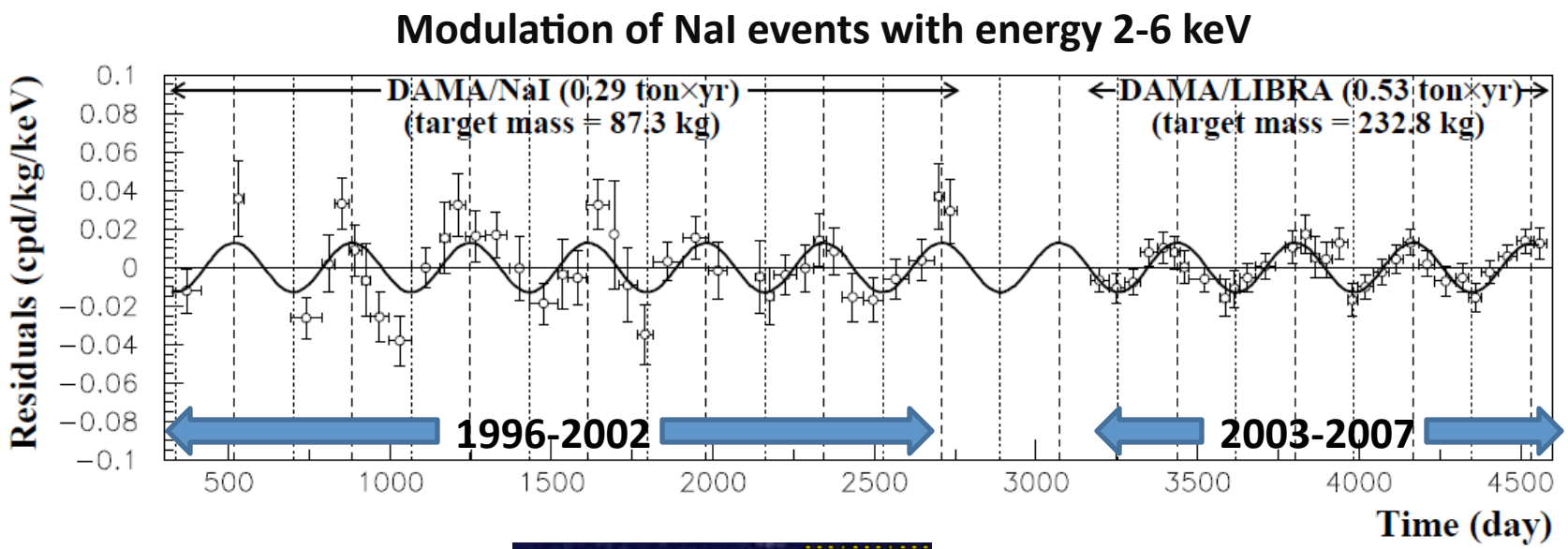
http://people.roma2.infn.it/~dama/web/home.html

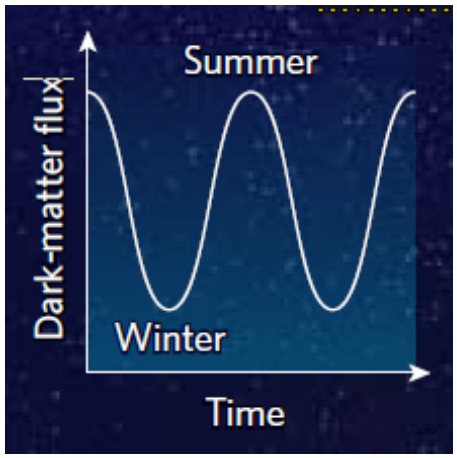


Caldwell, R., & Kamionkowski, M. (2009). Cosmology: Dark matter and dark energy. *Nature.* 458 (7238), 587.

2002: DAMA detects dark matter….

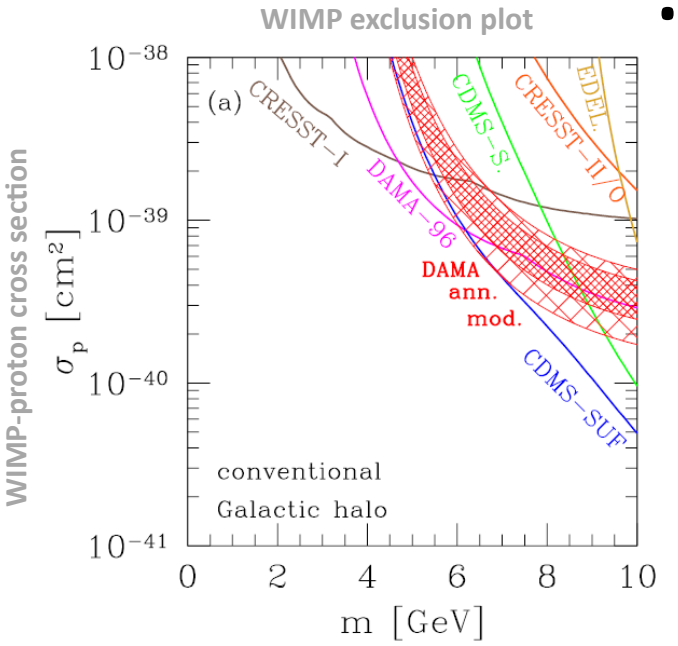
Rate of dark matter events





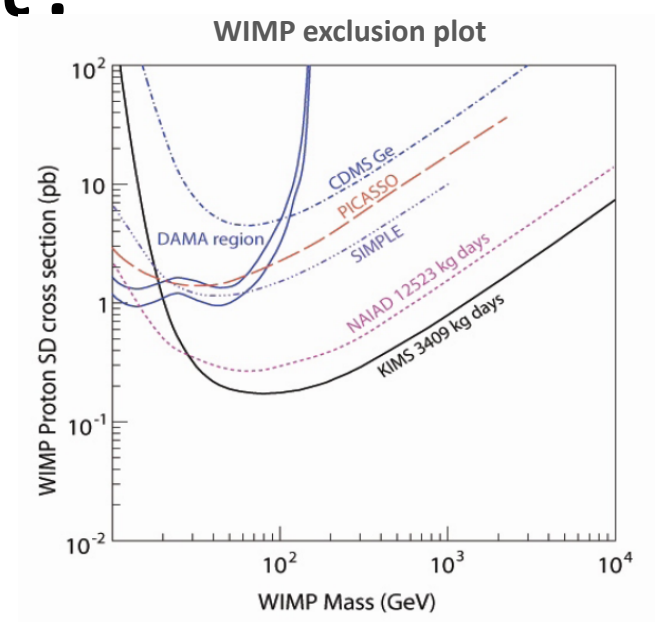
Bernabei, R., Belli, P., Cappella, F., Cerulli, R., Dai, C., d'Angelo, A., et al. (2008). First results from DAMA/LIBRA and the combined results with DAMA/NaI. *The European Physical Journal C - Particles and Fields.* 56 (3), 333-355.

…or does it?

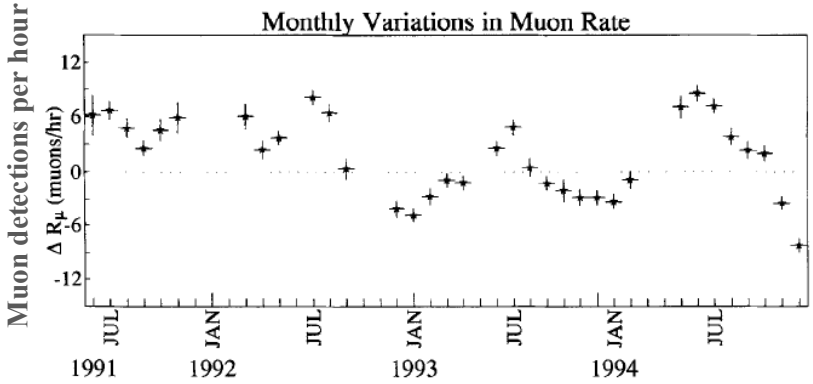


Gondolo, P., & Gelmini, G. (2005). Compatibility of DAMA dark matter detection with other searches (10 pages). *Physical Review. D, Particles and Fields.* 71 (12), 123520.

DAMA result occupies area excluded by Korean Invisible Matter Search (KIMS) and Cryogenic Dark Matter Search (CDMS)



http://stacks.iop.org/1742-6596/120/042021



Ambrosio, M et. Al.*Seasonal Variations in the Underground Muon Intensity As Seen by MACRO*. 1997.

Maybe DAMA sees something other than WIMPs….

Will the future bring WIMP detection?

~20 experiments worldwide working on this problem today.

"Hopefully we'll have a first result by early 2010" – *Elena Aprile (XENON100 team leader)*

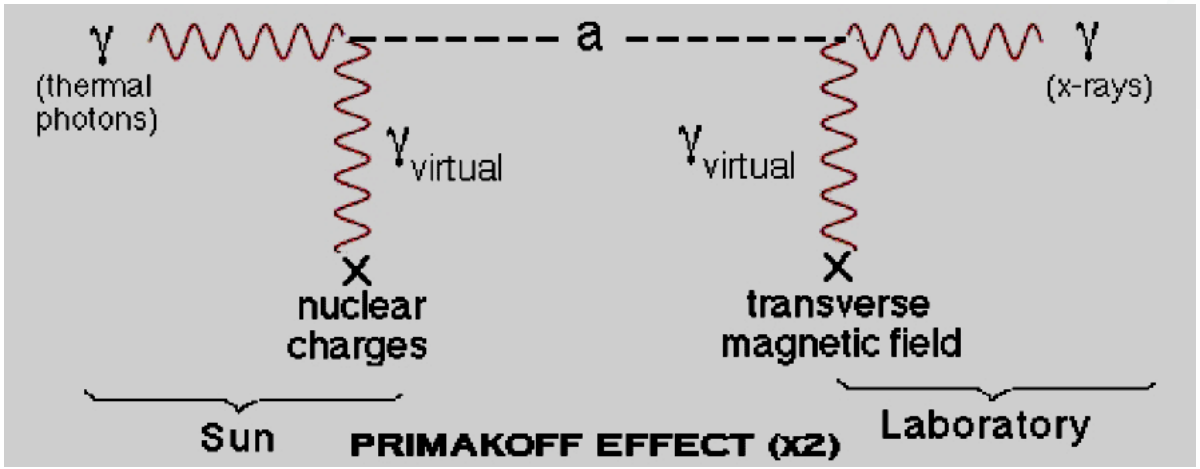
"We'll find them within five years." – *Rick Gaitskell (LUX team)*

"I have no idea. [Greeks] knew that there were fundamental particles….but it took 2,000 years before we figured out what atoms are." – *Jeremiah Ostriker (Dark matter expert)*

Muir, Hazel. (2009, August 04). Let there be light! The search for dark matter. *Wired*. Retrieved November 1, 2009, from http://www.wired.co.uk/wired-magazine/archive/2009/09/features/let-there-be-light!-the-search-for-dark-matter.aspx.

Switch gears to WISPs (Axions)

How to find them? Use Primakoff effect!



1983: Pierre Sikivie proposed magnetic field would convert solar axions into x-rays.

CERN Axion Solar Telescope (CAST) experiment

1986: Emilio Zavattini proposed magnetic field would convert photons into axions, causing small rotation in polarization of photons.

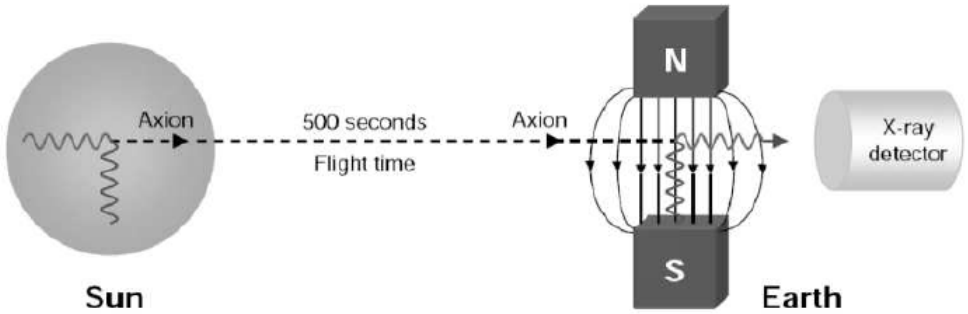
Polarizzazione del Vuoto con LASer (PVLAS) experiment

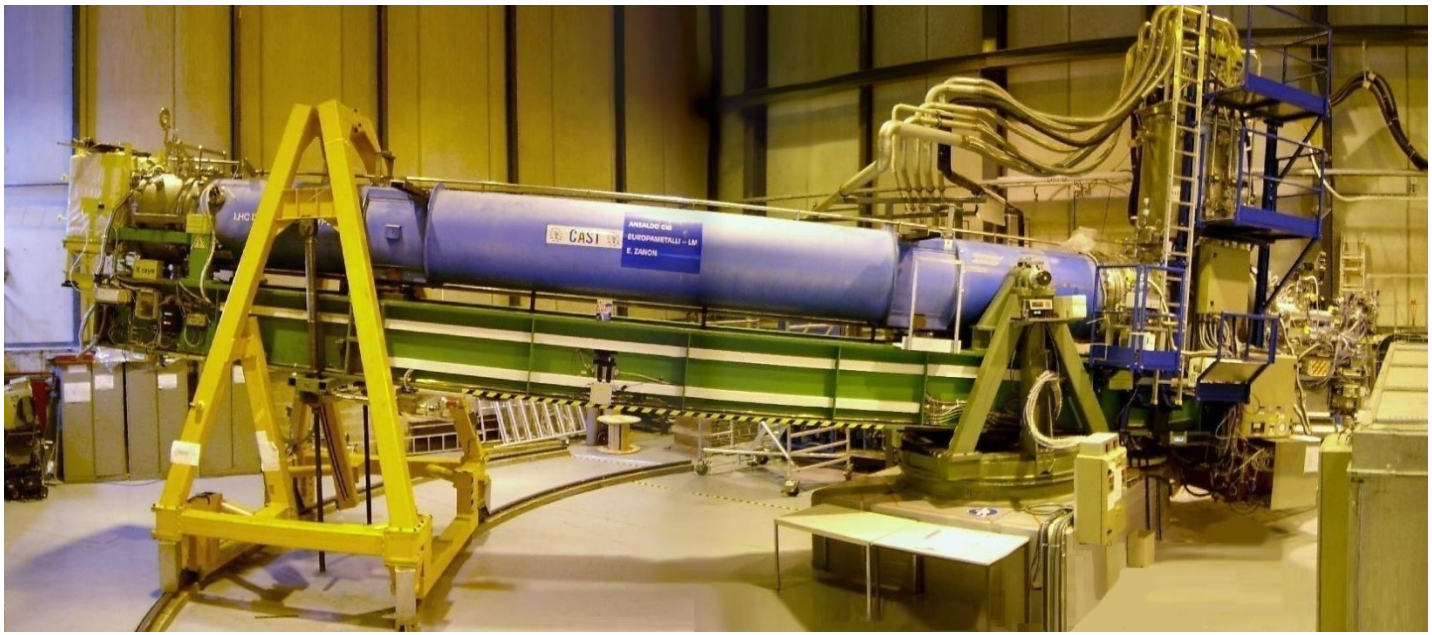
Axions have never been detected!

http://collargroup.uchicago.edu/projects/axion/index.html

2002: CERN Axion Solar Telescope (CAST)

CAST is a X-ray detector behind a 10m, 9 Tesla magnet, that points at the sun 3 hr/day.

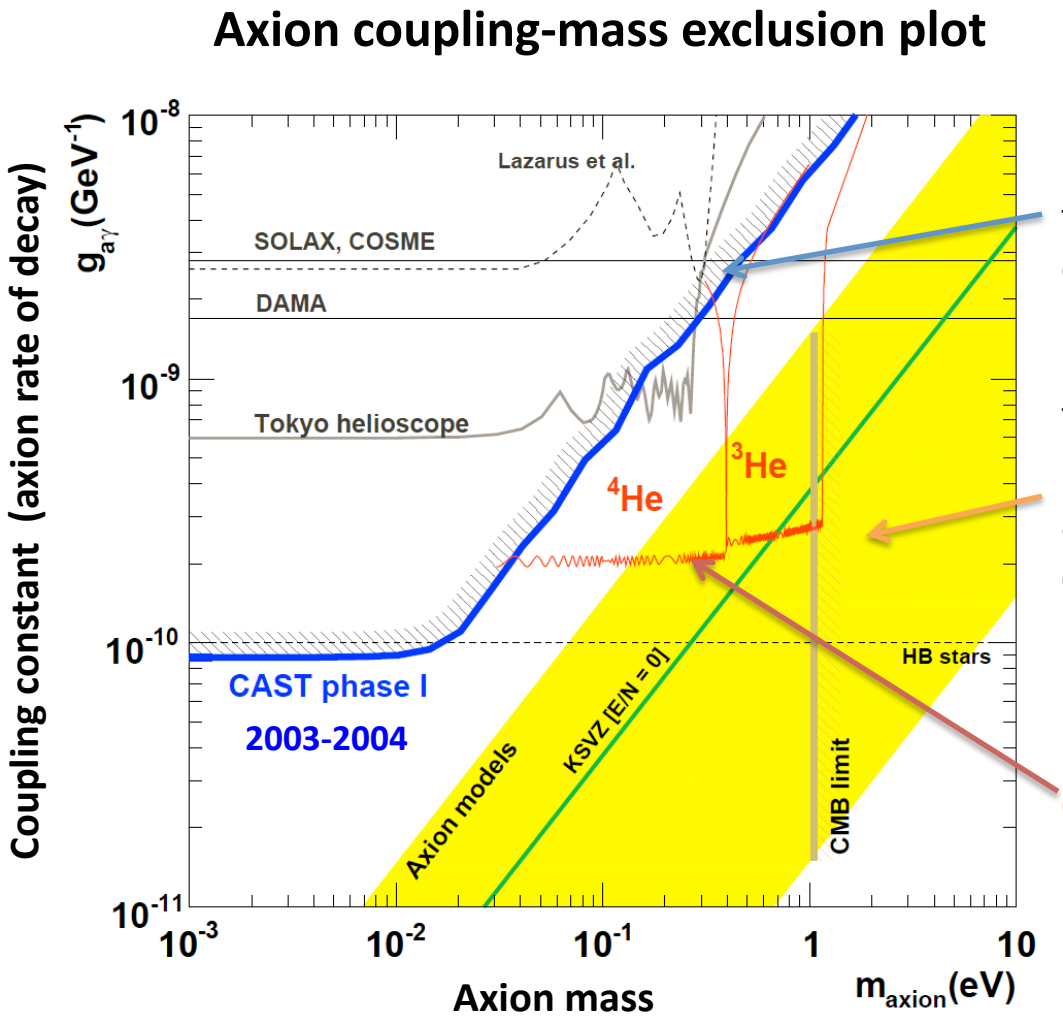




Battesti R., Beltran B., Davoudiasl H., et al. (2008). Axion searches in the past, at present, and in the near future. *Lecture Notes in Physics.* 741, 199-237.

http://cast.web.cern.ch/CAST/

2005: CAST does not find axions



Lines represent upper bounds to the axion-photon coupling constant

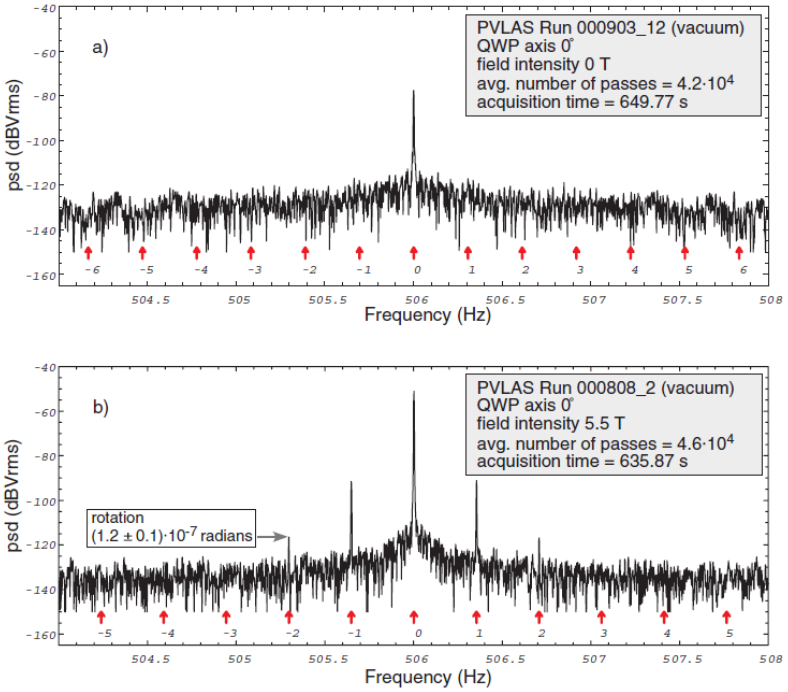
Yellow area represents where model predicts axion mass and axion-photon coupling constant

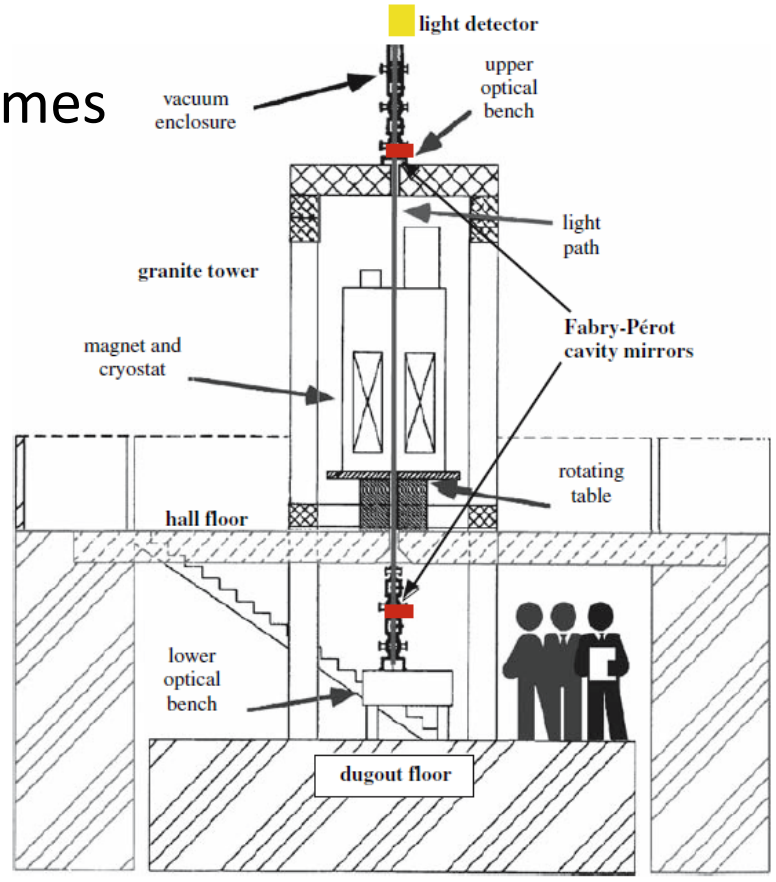
Coming soon! Running 2007-2010

Beltran, B., & CAST Collaboration. (2007). Search for Solar Axions: The CAST Experiment. *AIP Conference Proceedings.* 878, 395-404.

2006: PVLAS experiment finds axions

- Linearly polarized light passed through 1m 5T magnet in vacuum.
- Mirrors reflect the light ~50,000 times
- Change in polarization = Axions!

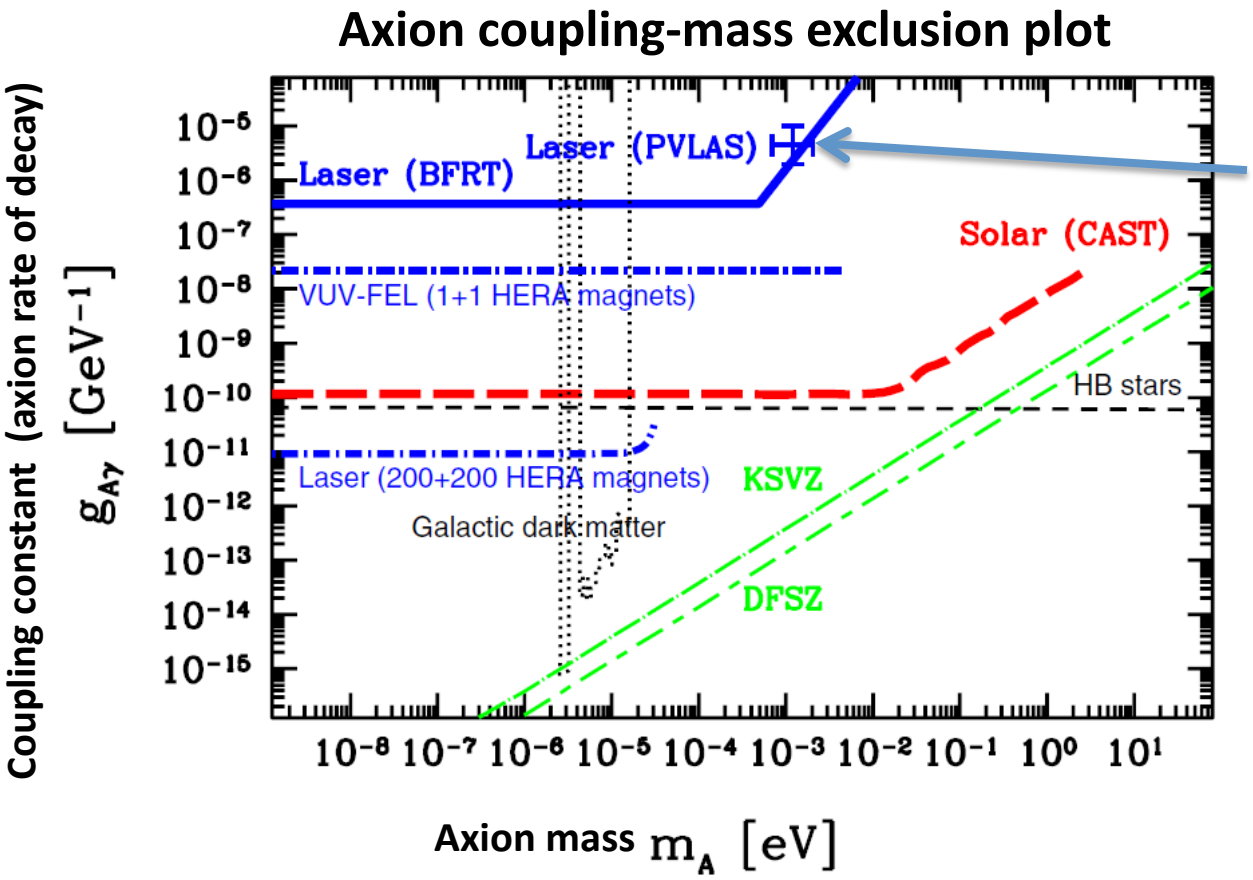




Cantatore, G., & PVLAS Collaboration. (2008). Recent Results from the PVLAS Experiment on the Magnetized Vacuum. *Lecture Notes in Physics.* (741), 157-198.

2007: PVLAS retracts results

Results are not reproducible!

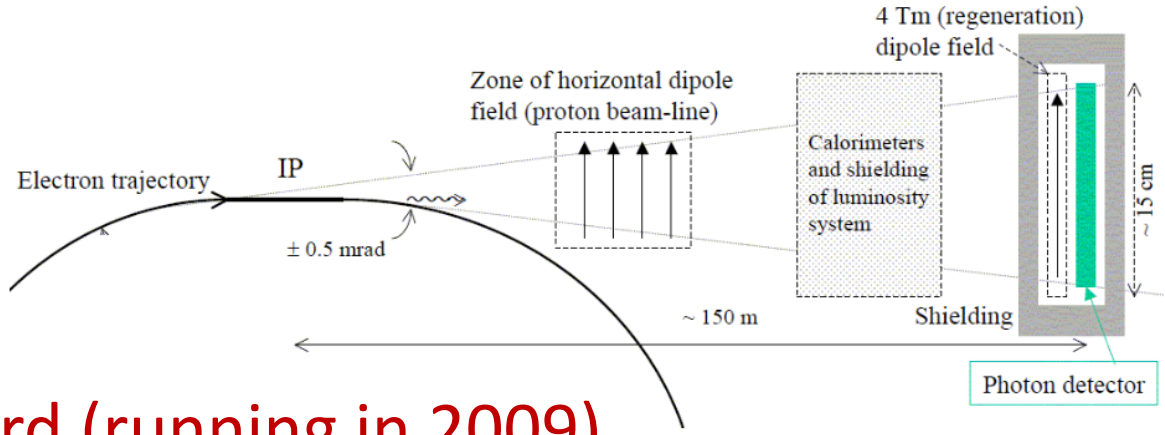


PVLAS results are in conflict with many experiments!

Ringwald, A. (2005). *Axion interpretation of the PVLAS data?* DESY, 05,229. Hamburg: DESY.

Will the future bring WISP detection?

"Shining light through a wall"



Stanford (running in 2009)

DESY, German (running in 2012)

arXiv:hep-ph/0701059v1

Helioscopes

CAST experiment (running in 2010)

Works cited

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Woo, Marcus. (2007, August 23). *Dark matter.* Retrieved October 23, 2009, from NASA website: http://www.nasa.gov/mission_pages/GLAST/science/dark_matter.html.

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Zioutas, K., Aalseth, C. E., Abriola, D., Avignone Iii, F. T., Brodzinski, R. L., Collar, J. I., et al. (1999). A decommissioned LHC model magnet as an axion telescope. *Nuclear Instruments & Methods in Physics Research. Section A, Accelerators, Spectrometers, Detectors and Associated Equipment.* 425 (3), 480.

Zioutas, K. et. Al. (2008). The CAST Experiment. *Journal of Physics: Conference Series*. 110, 06023.