Search for Axions with the CDMS-II Experiment

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The CDMS Experiment

CDMS operates 19 Ge and 11 Si detectors at mk (~40mk) temperatures.

The detectors stacked in 5 towers with 6 detectors each.

The direction of each crystal axis for each detector is known from installation.



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Axions from the Sun

The axion has been postulated to solve the strong CP problem in QCD.

Stars are expected to be a strong source of axions if they couple to photons.

The strong EM field in the stars interior may convert photons into axions.



A well known source would be the Sun.

From the standard solar model we can calculate the flux of solar axions at the Earth.



Primakov effect in crystals



Coupling to the coulomb field of the nucleus converts axions back into photons.

Bragg condition for momentum transfer in a crystal :

coherent amplification of the Primakov effect.



The conversion rate will depend on the incident beam direction.

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Expected conversion rate

The changing position of the Sun with respect to the crystal axes changes the incident beam direction throughout a day.

Solar axion conversions show an unique pattern in time and energy.



Solar axion fingerprints

The Sun's changing zenith angle in a year causes monthly changing patterns.

Different detector alignments cause different patterns.



Where to search for a signal ?

CDMS ZIP detectors allow discrimination of nuclear recoil events from electron recoil events.

Electron and nuclear recoil band are determined from in-situ calibrations.



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WIMP search analysis looks for the detection of nuclear recoil events.

Electron recoil events are background events.



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WIMP search analysis looks for the detection of nuclear recoil events.

Electron recoil events are background events.

Photons from solar axion conversion are detected as electron recoil events.



- A possible signal will show up in the electron recoil distribution.
- Use background to perform different physics analyses.

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Low energy spectrum

The analysis window (2-8.5 keV) is determined by:

Expected signal



Background

Detection efficiency

Excess rate at ~6.5 keV is likely caused by remnant ⁵⁵Fe decays (6.54 keV) from cosmogenic activation.



Likelihood analysis

Maximise the unbinned log likelihood function.

Consider time, energy and detector of each detected event.





 $\lambda = (1.0 \pm 1.5) \times 10^{-3}$

No indication of solar axion conversions to photons is observed.

Solar axion result

First upper limit with precise knowledge of all crystal orientations.

Future large crystal detector arrays may become competitive to helioscopes.



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Conclusions

- First demonstration of new physics analyses with the CDMS experiment.
 - Sets an upper limit on the axion-photon coupling of $g_{a\gamma\gamma} < 2.4 \times 10^{-9} \text{ GeV}^{-1} @ 95 \% \text{ CL}$
- First result on the axion-photo coupling from a crystal experiment with precise knowledge of all crystal axes orientations.
- Future large crystal detector arrays may provide competitive sensitivity to helioscopes.

Solar physics underground





Relic axion-like particles in the local halo

As dark matter candidates axions may be distributed in the local halo.

May materialize in the detectors via an axio-electric coupling:

→ Axio-electric effect

Energy of the electron is given by the mass of the axion.

Conversion results in a gaussian distribution with width given by the detector's energy resolution.



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Likelihood analysis II

Take possible contribution from Fe decays into account by modeling the background.

Due not subtract this contribution while approaching this energy range.

Maximise the unbinned log likelihood function for each energy/axion mass.

$$Log(\mathcal{L}) = -R_T + \sum_{i,j} Log(\lambda \cdot \mathcal{R}(E_i, d_j) + B(E_i, d_j))$$

3 3.5 4



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Relic axion result

Excludes the relic axion interpretation of the DAMA signal claim. World-leading experimental upper limit on the axio-electric coupling.



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Conclusions

Solar axion search:

First demonstration of new physics analyses with the CDMS experiment.
Sets an upper limit on the axion-photon coupling of gaYY < 2.4 x 10⁻⁹ GeV⁻¹ @ 95 % CL
First result on the axion-photo coupling from a crystal experiment with precise knowledge of all crystal axes orientations.
Future large crystal detector arrays may provide competitive sensitivity to helioscopes.

Relic axion search:

- Excludes the axio-electric interpretation of the DAMA signal claim in the mass range of 1.4 - 6 keV.
- Sets a world-leading experimental upper limit on the axio-electric coupling.