# Broadening the search for Dark Matter with LUX-ZEPLIN (LZ) Experiment

## *Hidden Photons and Axion-Like Particles*

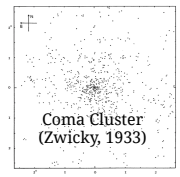
Athoy Nilima[1], Alex Murphy[1] (Supervisor), [1]School of Physics and Astronomy, University of Edinburgh

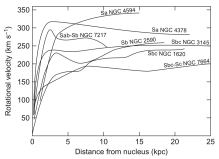
## Overview

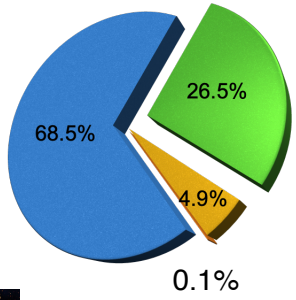
Motivated by possible theoretical extensions to the standard model, hidden photons (HP) are a candidate for the cold dark matter. Their possible masses cover a broad range, from $10^{-12}$ to $10^{6}$ eV/$c^2$. Large scale direct detection experiments such as LUX-ZEPLIN (LZ), built primarily to detect Weakly Interactive Massive Particles (WIMPs), are also sensitive to HP dark matter via the so-called hidden photoelectric effect. This work presents the projected sensitivity of LZ to hidden photons with masses in the range of 2-70 keV/$c^2$. Sensitivity Projections for Axion Like Particles (ALPs) are also discussed.

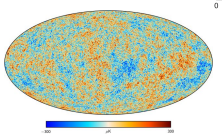
## Dark Matter : A Mystery

### Evidence



Cosmic Microwave Background Anisotropy

Gravitational Lensing observation of Bullet Cluster

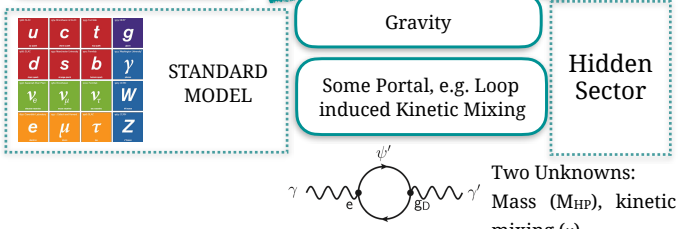
- ☑ We Know that Dark Matter Exists
- ☑ We have estimates for its relic abundance
- ☐ But We don't know what it is made of !

## Hidden Photons (HPs) and Axion Like Particles (ALPs)

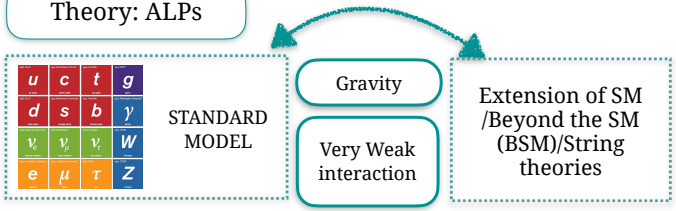
**Candidacy for DM**

- ☑ Non-Baryonic
- ☑ Neutral
- ☑ Feeble interaction strength
- ☑ Can be DM if produced by misalignment

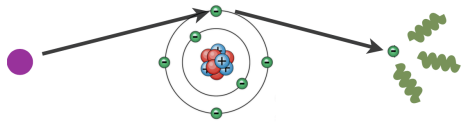
**Theory: HPs**




**Theory: ALPs**



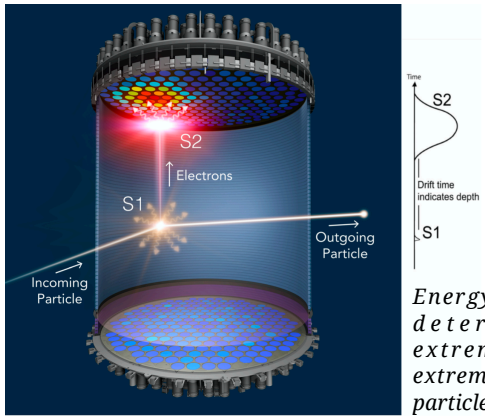

**Interaction Signature: HP/ALP Absorption**



- Analogous to the ordinary photoelectric effect
- Entire rest mass energy is absorbed by an atom, resulting in an electron being ejected. It is this electron that is observed.

## LUX-ZEPLIN (LZ) Experiment

- Dual phase xenon Time Projection Chamber
- 7 tonnes of liquid Xe
- constructed from ultra low radioactivity materials
- deployed over a km underground
- can measure energy depositions as small as 1 keV




*Energy and position determination of extremely rare and extremely low energy particle interactions*

## Sensitivity Projection: Analysis Steps

- ☑ Calculate energy depositions of HP/ALP in liquid xenon
- ☑ Model detector response, i.e. convert energy depositions into detector observables
- ☑ Build Probability Density Functions (PDFs) for signal and backgrounds
- ☑ Run statistical analysis using Probability Likelihood Ratio (PLR) method to project sensitivities

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Acknowledgements SUPA COMMONWEALTH SCHOLARSHIPS

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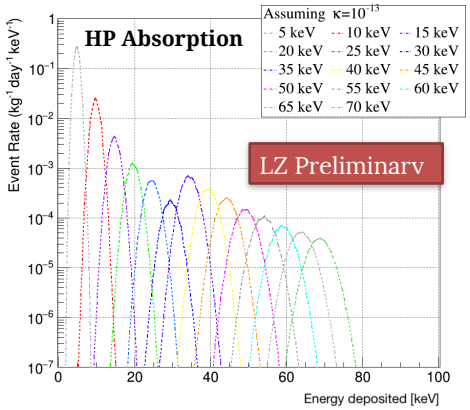
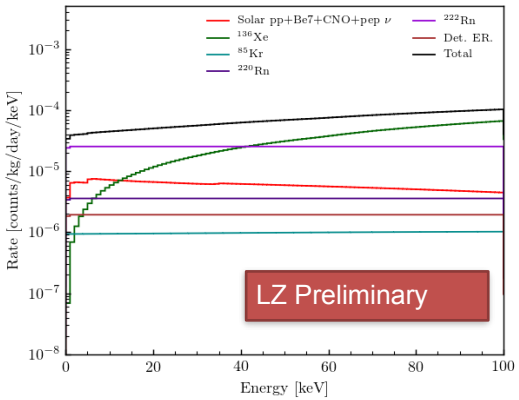
## Signal Models

- Signal: mono-energetic peak centred at the value of the incident mass, smeared by the detector resolution
- Only HP signal models (2-70 keV/c²) are shown here.




## Background Model

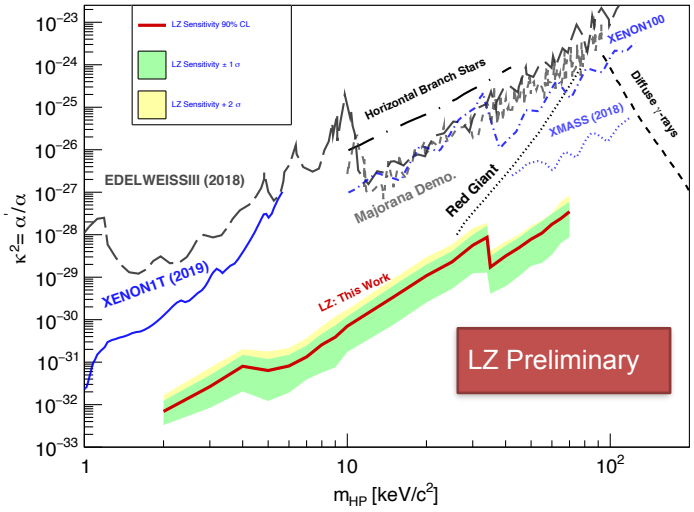
- Despite the use of ultra low radioactivity materials, and the experiment being located deep underground, we still expect some events from known sources.
- Our expectation for this is known as the background model.



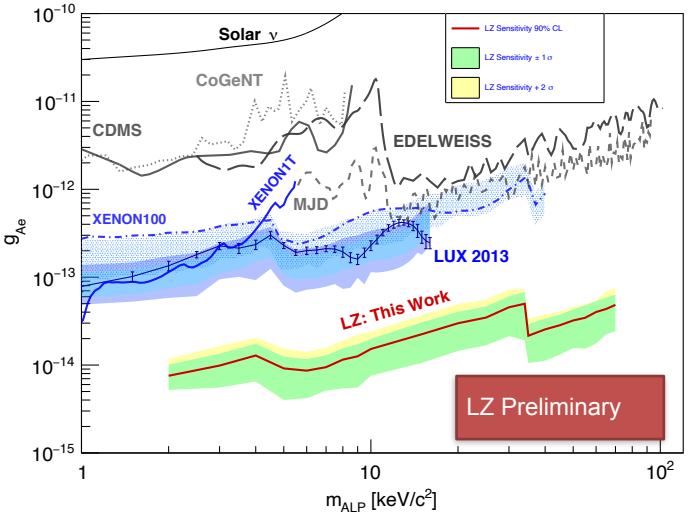

## LZ Projected Sensitivities: Results

(results for ~1000 days of running)

### HP Sensitivity




### ALP Sensitivity




Red curve: 90% C.L. sensitivity on kinetic mixing squared for hidden photons. ±1σ and +2σ bands are also shown.

## Discussion and Conclusion

1. A wide range of HP/ALP mass (2 – 70 keV/c²) was investigated
2. LZ is expected to give a better limit on $\kappa^2$ at intermediate energies, i.e 15-70 keV. (Outside the range, astrophysical bounds are stronger)
3. For ALPs, LZ is expected to give more stringent limit than the published results to date.
4. Overall, projected upper limits of $\kappa^2$ (for HPs) and $g_{Ae}$ (for ALPs), showed nice improvements over existing experimental bounds.

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