

Analysis on axions and dark photon from CDEX experiment

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Outline

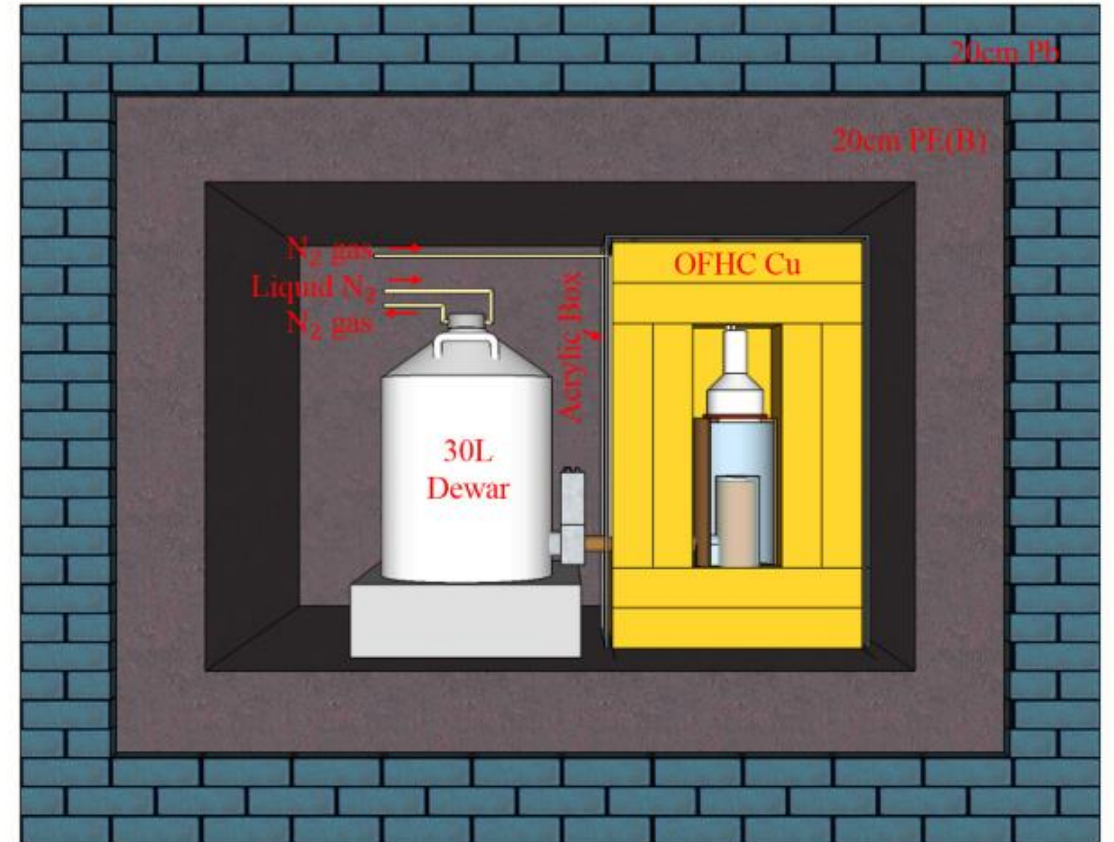
- Background
- Axion & Dark photon
- Analysis
- Summary

Background

Yang, CPC, 42, 23002(2018)

CDEX experiment@CJPL

- Total exposure $> 1000 \text{ kg*days}$
- P-type point contact germanium detector
- $\sim 10\text{kg}$ PPCGe@CJPL-I
- C1B - 737.1 kg*days
- C10 - 449.6 kg*days



C1B system

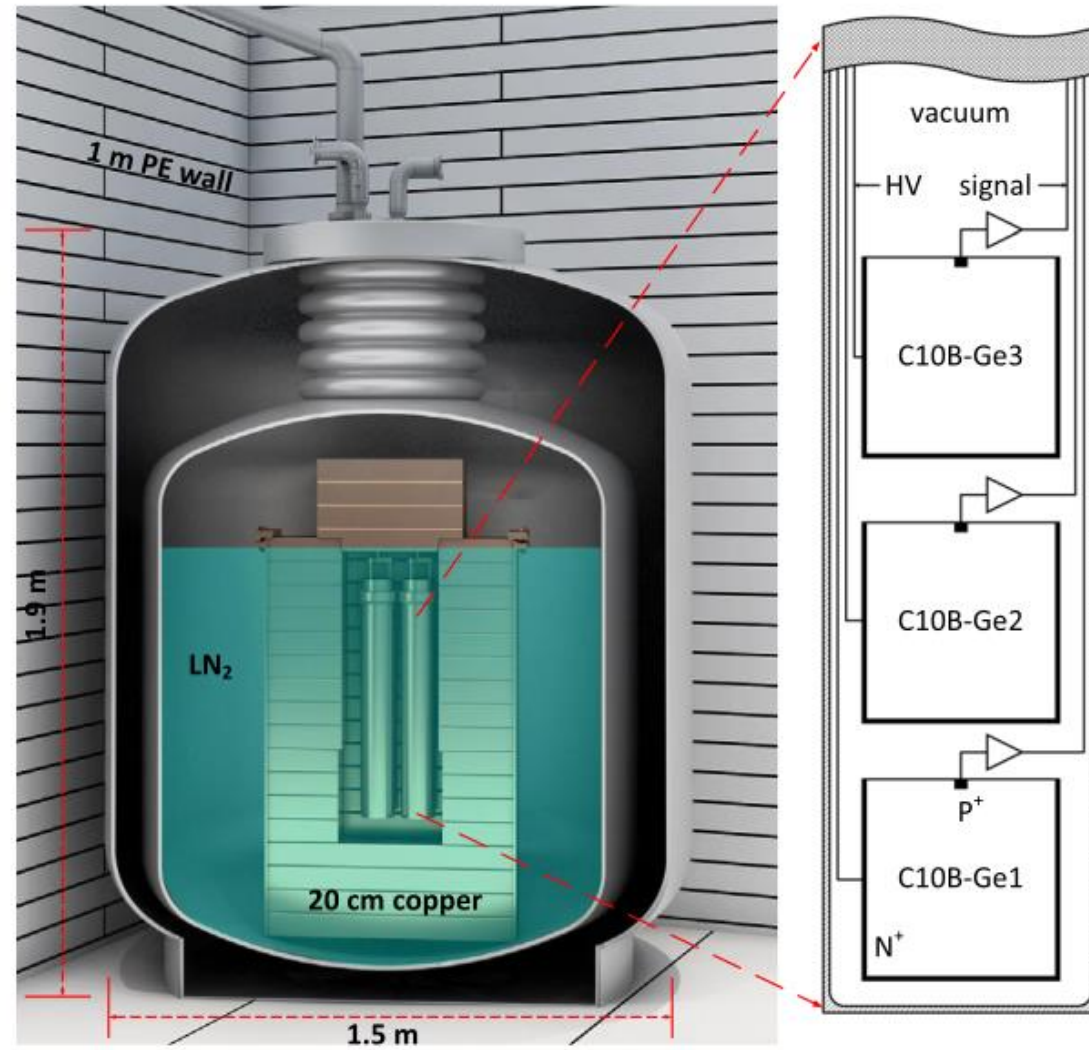
Background

Pros

- Better energy resolution
- Low threshold

Cons

- Expensive : **Home-made**
- Higher background level



C10 system

Axion & Dark photon

Axion

- CP problem in strong interaction
- Coupling with nuclei and electron
- Dark matter candidates
- Small mass $\sim eV$ scale

Solar Axion

- CBRD Axion
- Axion from Fe57

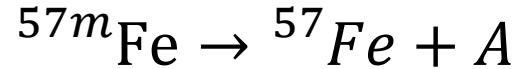
Dark matter

- Pseudo-scalar Axion Like Particles
- Vector Bosonic Dark Matter

Axion & Dark photon

Axion from Fe57

- The magnetic transition of Fe57 in the Sun

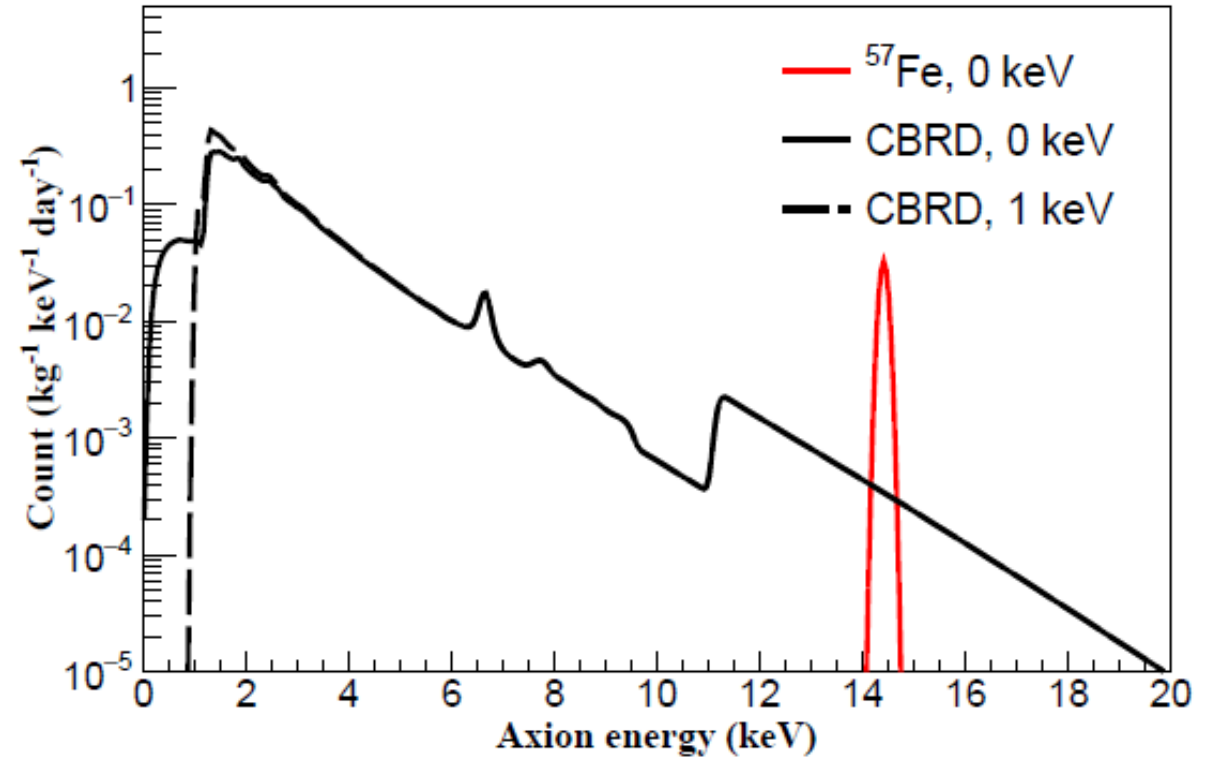


- Gaussian Peaks @ 14.4 keV

$$\Phi_{14.4} = \left(\frac{\kappa_A}{\kappa_\gamma} \right)^3 \times 4.56 \times 10^{23} (g_{AN}^{eff})^2 \text{ cm}^{-2} \text{ s}^{-1}$$

- Compton-like scattering (C)
- Axion-bremsstrahlung (B)
- Atomic-recombination (R)
- Atomic-deexcitation (D)

Andriamonje, JCAP 2009, 002 (2009)
 Redondo, JCAP 2013, 008 (2013)



Expected signal of CBRD Axion and Axion from Fe57

$$\begin{aligned} \frac{d\Phi_{CB}}{dE_A} &= \frac{d\Phi_C}{dE_A} + \frac{d\Phi_B}{dE_A} \\ &= g_{Ae}^2 \times 1.33 \times 10^{33} E_A^{2.987} e^{-0.776E_A} \\ &+ g_{Ae}^2 \times 2.63 \times 10^{35} E_A e^{-0.77E_A} \frac{1}{1 + 0.667E_A^{1.278}} \end{aligned} \quad \sigma_{Ae}(m_A) = \sigma_{pe}(m_A) \frac{g_{Ae}^2}{\beta} \frac{3m_A^2}{16\pi\alpha m_e^2} \left(1 - \frac{\beta^{\frac{2}{3}}}{3} \right)$$

Axion & Dark photon

Wang, ArXiv: 1911.0385

- Dark Matter
- Different interaction
- Dark Matter Halo Assumption
(Local density)

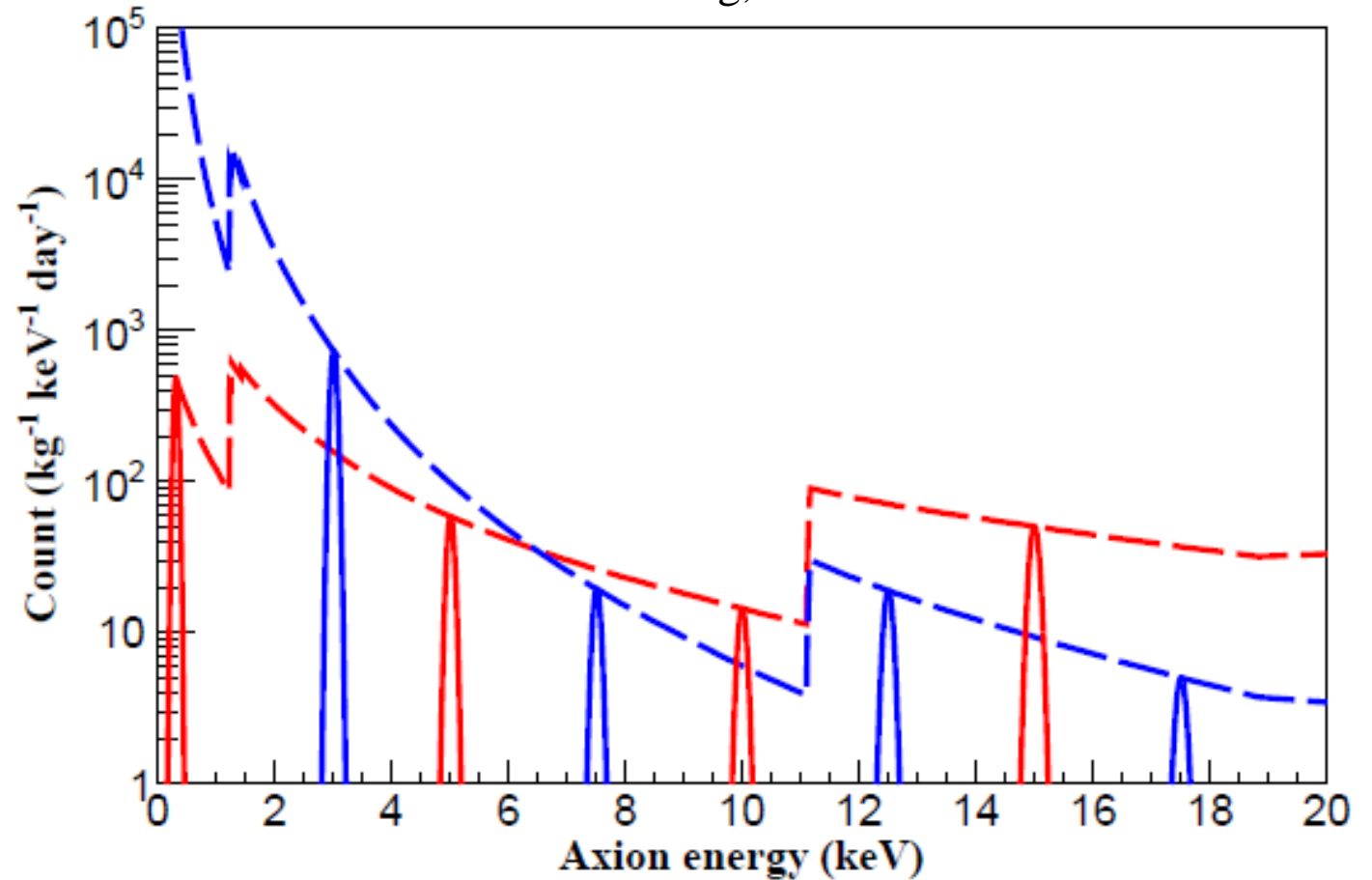
Axion Like Particle Dark Matter

$$R = 4 \times 10^{47} A^{-1} \frac{\alpha'}{\alpha} m_v \sigma_{pe}(m_v)$$

Vector Bosonic Dark Matter

$$R = 1.2 \times 10^{43} A^{-1} g_{Ae}^2 m_A \sigma_{pe}(m_A)$$

An, PLB, 747, 331(2015)



Expected signal of Pseudo-scalar Axion like Particle Dark Matter (red) and Vector Bosonic Dark Matter (blue)

Axion & Dark Photon

Dark Photon

- Mixing parameter
- Dark Matter Candidate
- Small mass $\sim eV$ scale

Experiments

- Cosmological observations
- Rare event searching experiment
- Laser experiments

Interaction

- Oscillation between photon and dark photon
- Similar to photoelectric effect

Dark photon

- Solar dark photon
- Dark photon dark matter

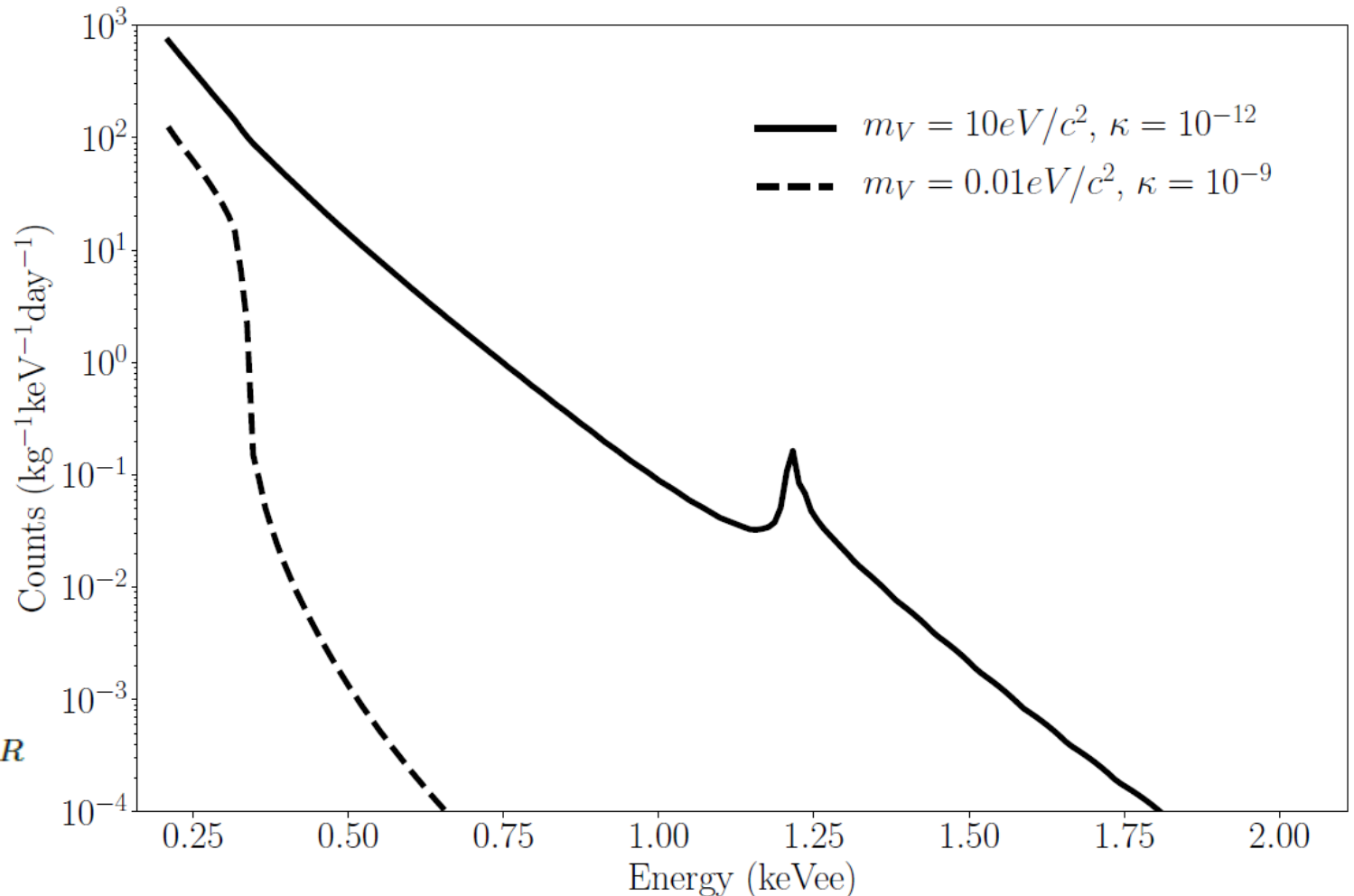
Axion & Dark photon

She, ArXiv:1910.13234

Solar dark photon

- The Sun
- Stuckberg case
- Transverse or Longitudinal
- Do not exceed 10% luminosity
- Tens of eV scale

$$\frac{dR(E)}{dE} = \frac{M}{\rho} \frac{E}{m_V} \left(\frac{d\Phi_T}{dE} \Gamma_T + \frac{d\Phi_L}{dE} \Gamma_L \right) B_R$$



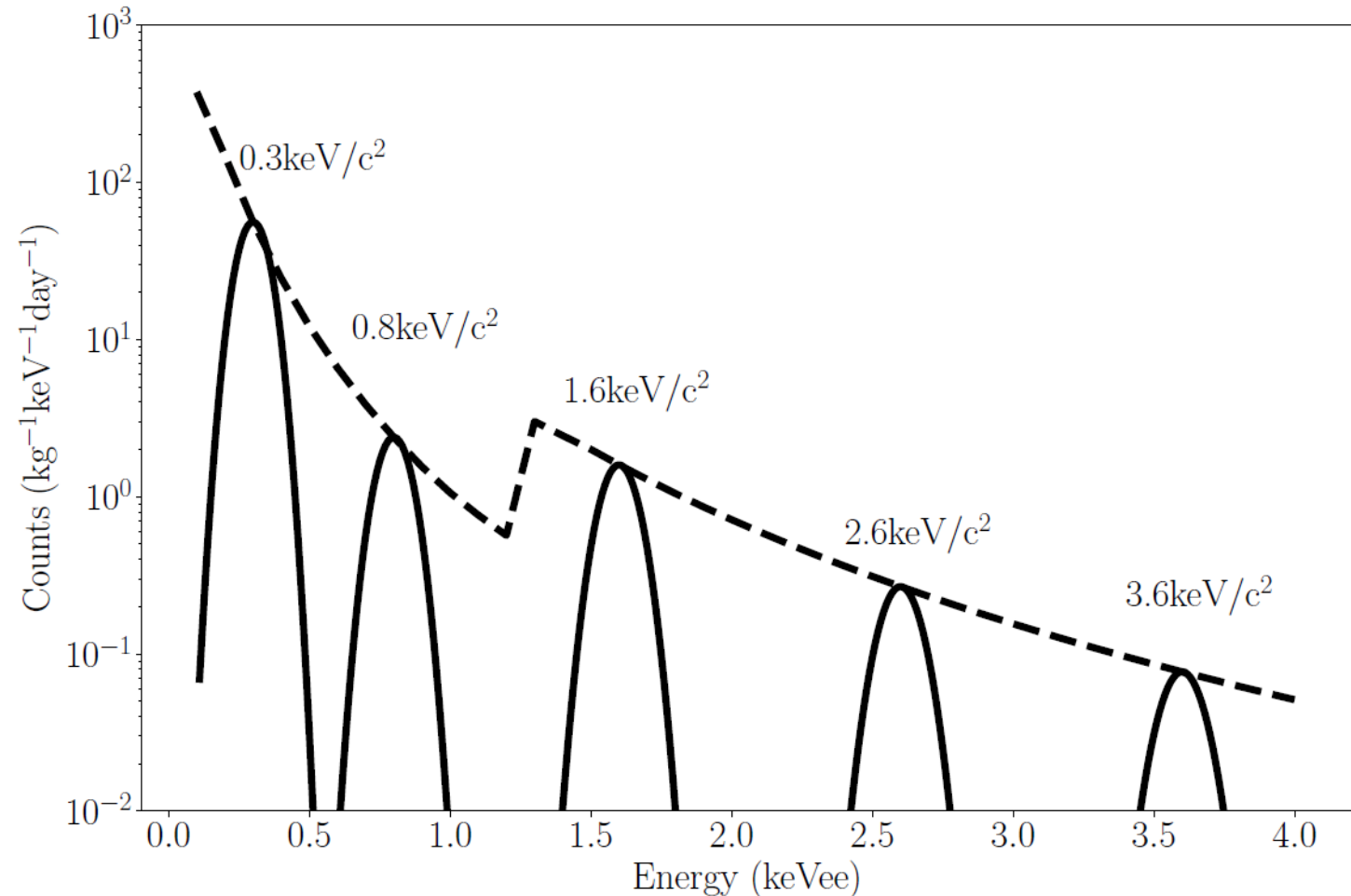
Axion & Dark photon

She, ArXiv:1910.13234

Dark photon Dark matter

- ~keV scale
- Dark Matter Halo assumption
(Local density)

$$\frac{dR}{dE} = V \rho_\chi \kappa^2 I_r$$



An, PLB, 725, 190 (2013)

Signal of dark photon dark mater (C10-B1)

Analysis

Analysis on axion

- Dataset: Exposure of 737.1kg*days from CDEX-1B
- During time : Mar, 2014 ~ Jul, 2017
- Analysis threshold : 160eV
- Statistic method: Profile Likelihood Ratio

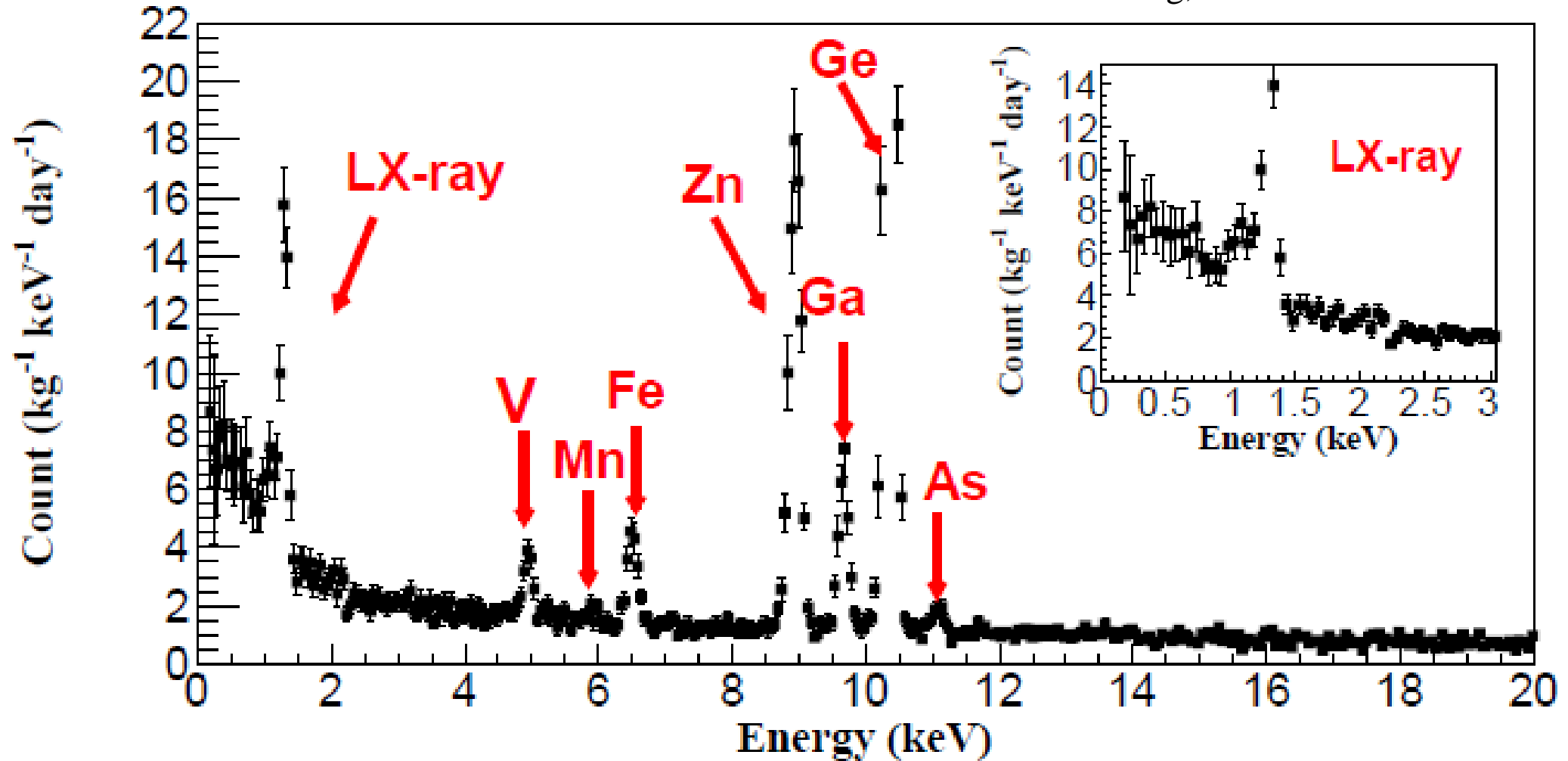
Bulk/Surface selection, data selection and system uncertainties are included in likelihood function.

CLs Method

Read, J. Phys. G: Nucl. Part. Phys. 28, 2693(2002)

Analysis

Wang, ArXiv: 1911.0385



Analysis

Wang, ArXiv: 1911.0385

$$\mathcal{L} = \mathcal{L}_1 \times \mathcal{L}_2 \times \mathcal{L}_3$$

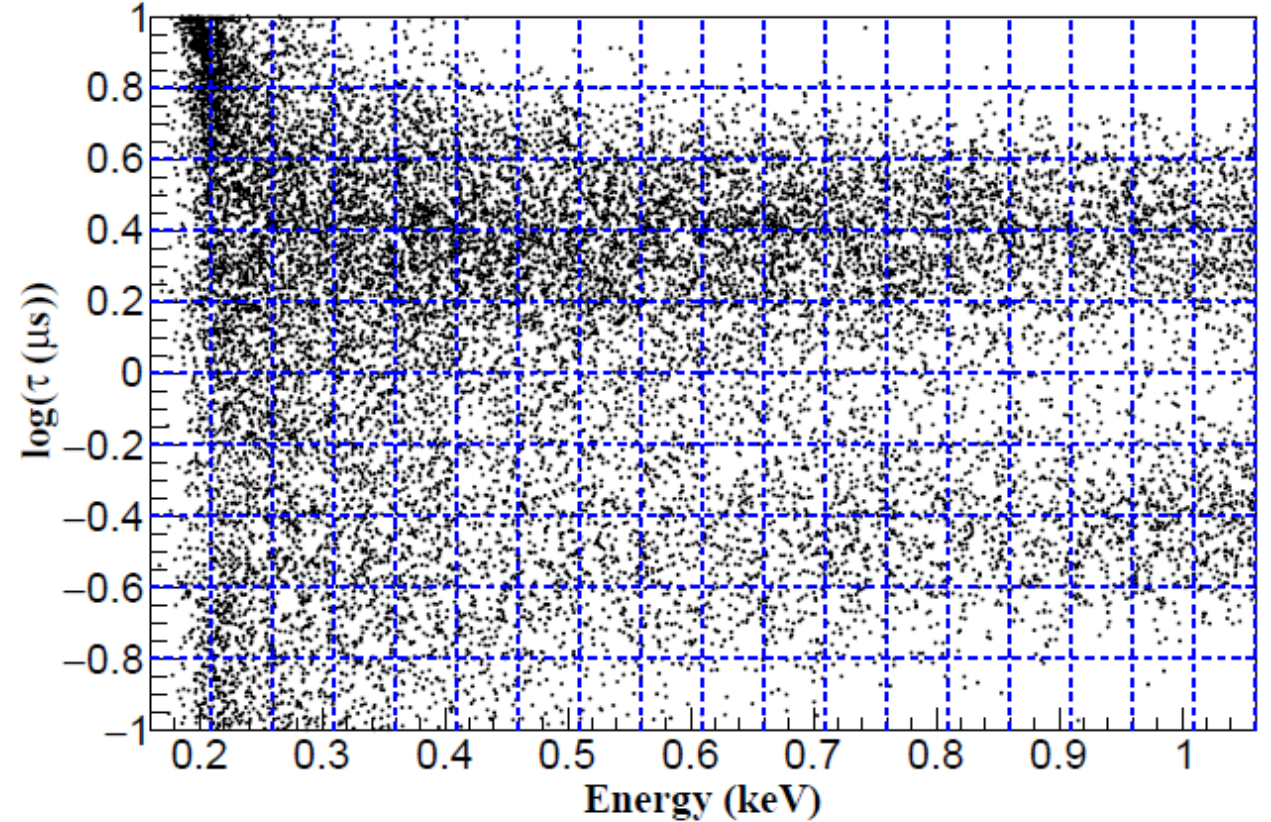
$$\mathcal{L}_1 = \prod_{j=1}^{N_\tau} \prod_{i=1}^{N_E} \text{Poisson}(n_{ij} | (g_{b,j}(E_i) + t_b \cdot \sigma_{b,j}(E_i))N_{i,\text{bulk}} + (g_{s,j}(E_i) + t_s \cdot \sigma_{s,j}(E_i))N_{i,\text{surf}})$$

$$N_{i,\text{bulk}} = (N_{\text{bulk}} - N_A)f_b(E_i, e) + N_A f_A(E_i, e)$$

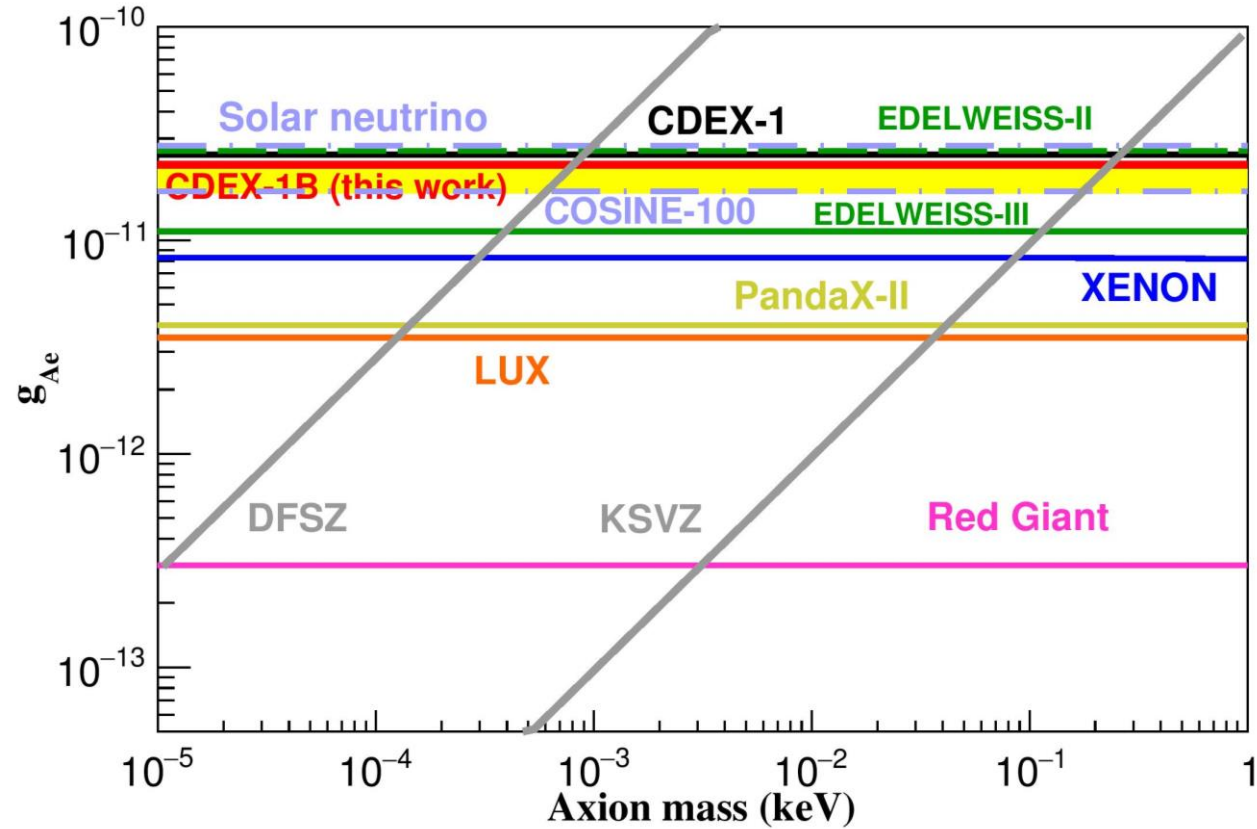
$$N_{i,\text{surf}} = N_{\text{surf}} \cdot f_s(E_i, e)$$

$$\mathcal{L}_2 = e^{-\frac{1}{2} \sum_{1,2} (e_i - \mu_{ei}) V_{ij}^{-1} (e_j - \mu_{ej})} \times e^{-\frac{1}{2} \sum_{3,4} (e_i - \mu_{ei}) V_{ij}^{-1} (e_j - \mu_{ej})}$$

$$\mathcal{L}_3 = e^{-\frac{t_b^2}{2}} \times e^{-\frac{t_s^2}{2}}$$

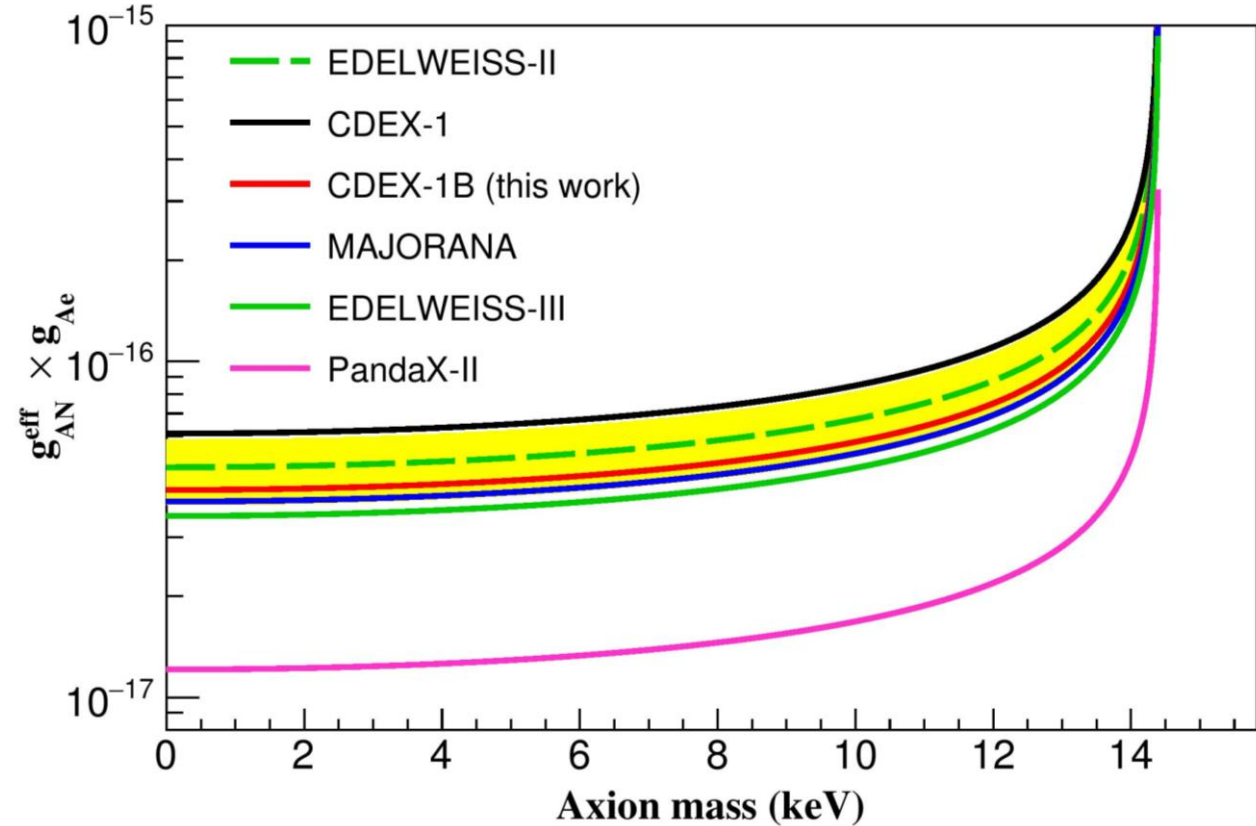


Analysis



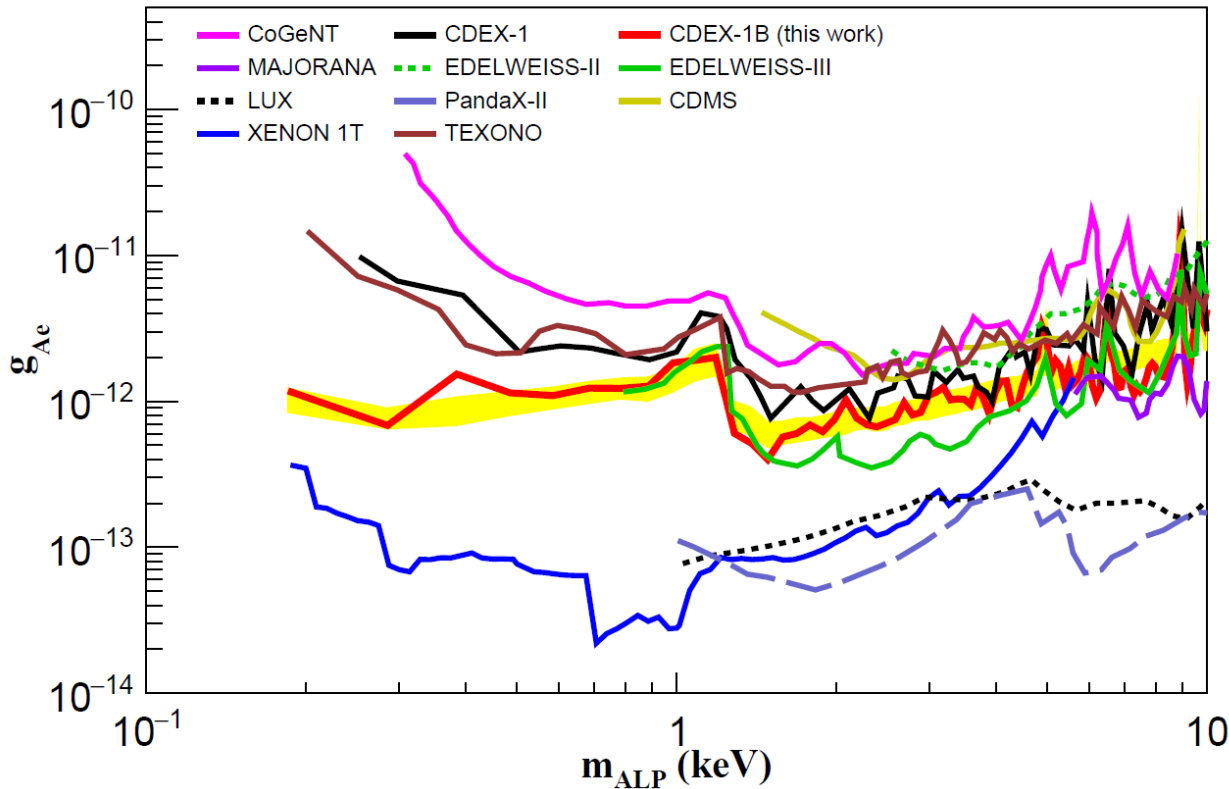
Exclusive plot of CBRD solar Axion @ 90% C.L.

Wang, ArXiv: 1911.0385



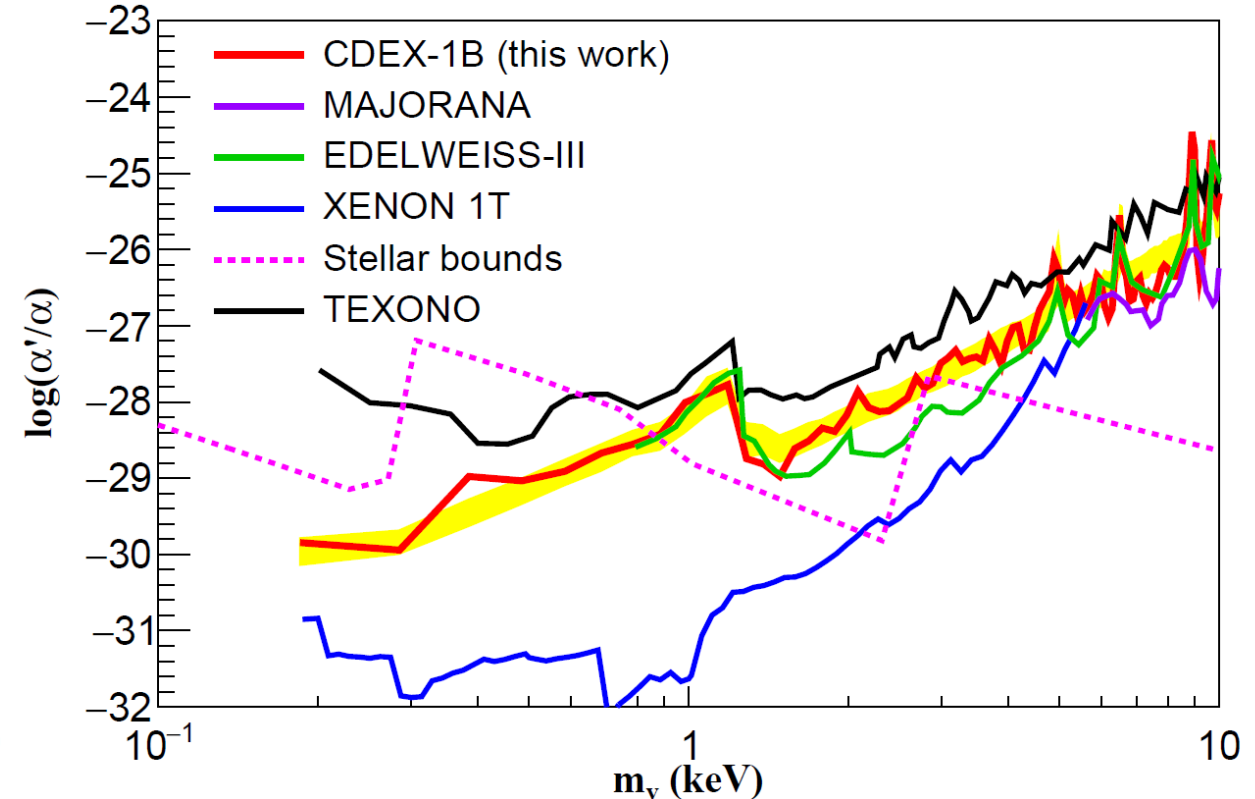
Exclusive plot of 14.4 keV solar axion from ^{57}Fe @ 90% C.L.

Analysis



Exclusive plot of pseudo-scalar axion like particle dark matter @ 90% C.L.

Wang, ArXiv: 1911.0385



Exclusive plot of vector bosonic dark matter @ 90% C.L.

Analysis

Dark photon

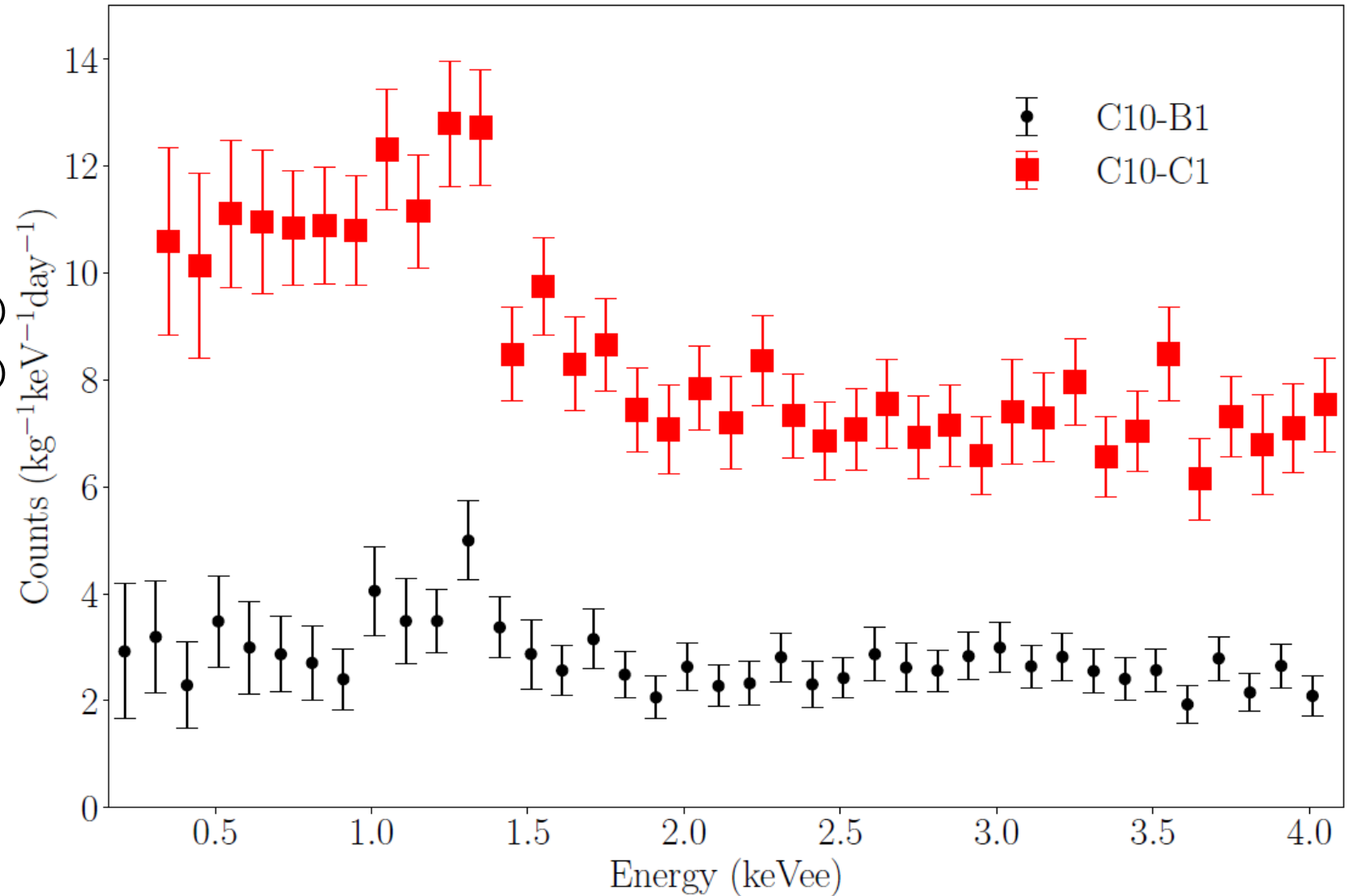
- Dataset: C10-B1 (205.4kg*days) February 2017 to August 2018
C10-C1 (244.2kg*days)
- Analysis threshold: C10-B1(160 eV)
C10-C1(300 eV)
- Statistic Method: Minimal- χ^2 + Feldman-Cousins Method
Combined analysis

Analysis

She, ArXiv:1910.13234

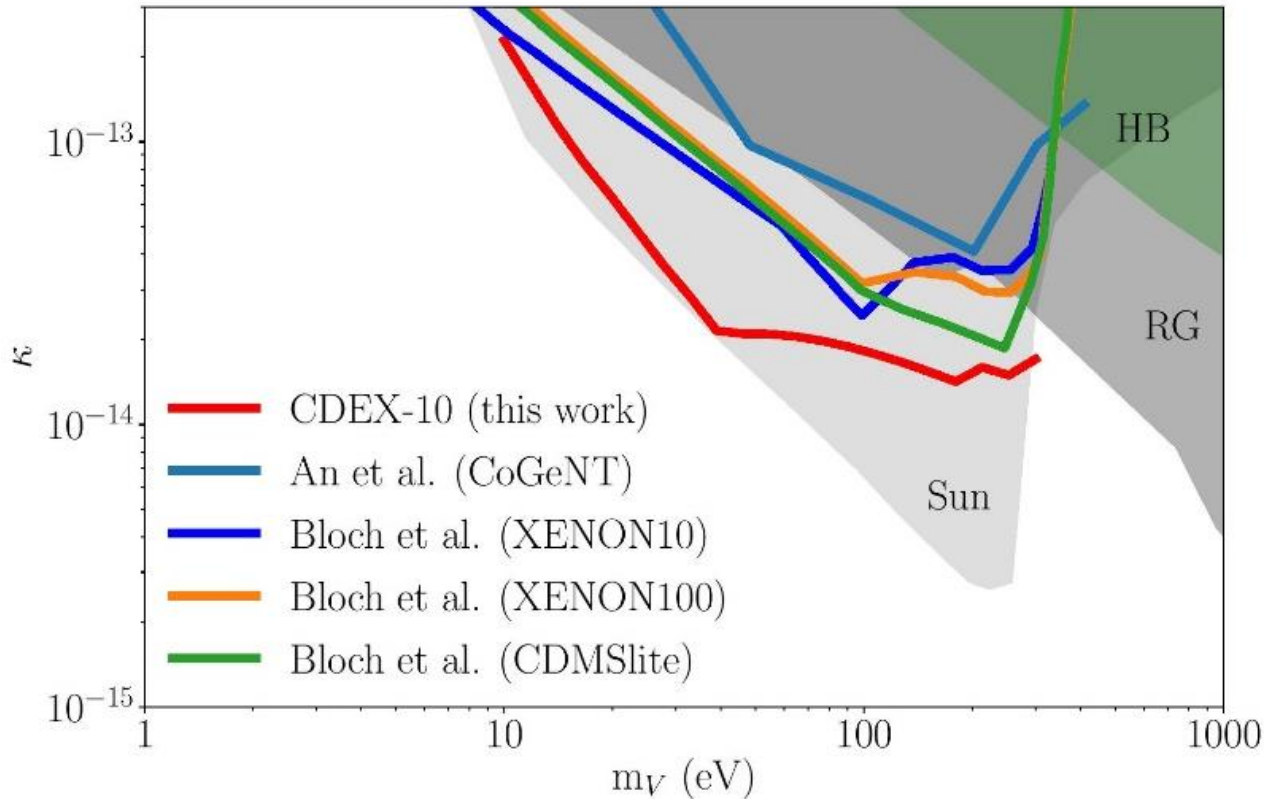
C10-B1 (205.4kg*days)

C10-C1 (244.2kg*days)

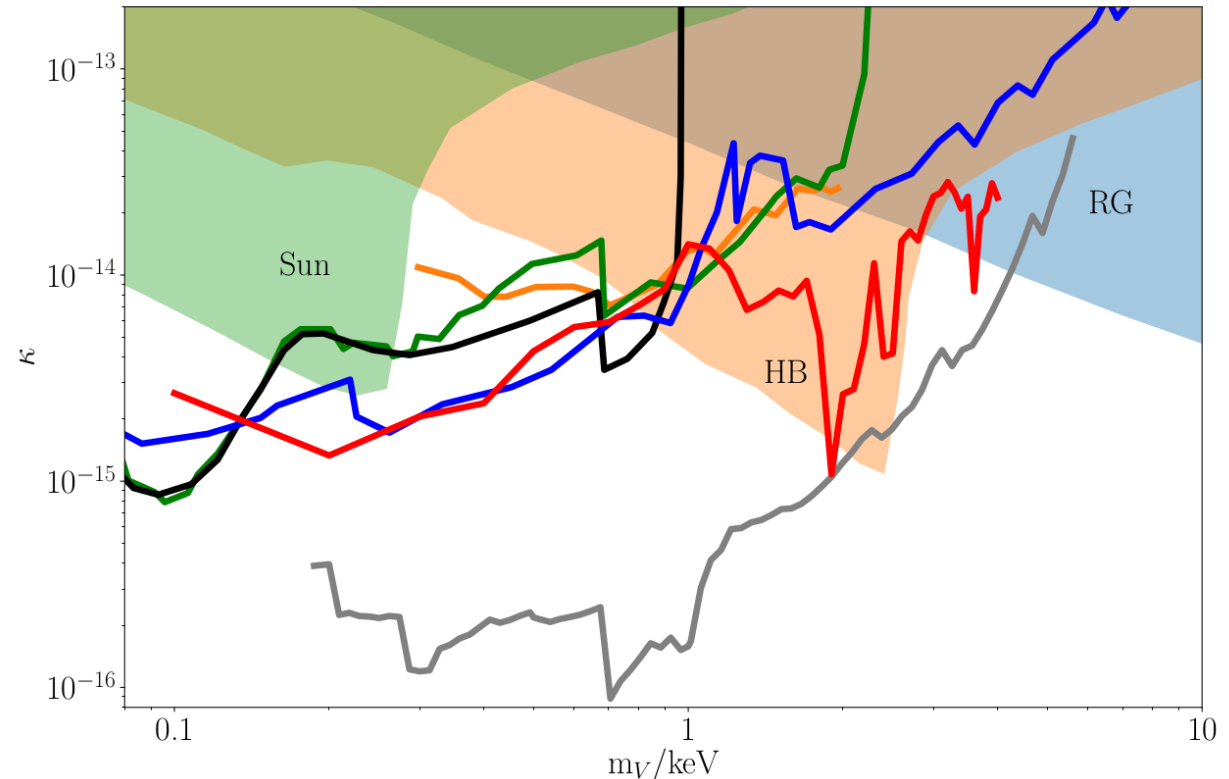


Analysis

She, ArXiv:1910.13234



Exclusive plot of solar dark photon @90% C.L.



Exclusive plot of dark photon dark matter @90% C.L.,
CDEX (red), CRESST-II (orange), XENON-100 (black), XENON-10 (green), CDMSlite (blue),
XENON-1T (grey)

Summary

- Constraints on the parameter space of solar axion, both on axions from Fe-57 and CBRD interactions with data from CDEX-1B experiment.
- Constraints on the parameter space of ALP dark matter and vector bosonic dark matter with data from CDEX-1B experiment.
- Constraints on the parameter space of solar dark photon originated from stuckberg case with data from CDEX-10 experiment.
- Constraints on the parameter space of dark photon dark matter with data from CDEX-10 experiment.

Thanks for your attention!