New Limit on Axion-Like Dark Matter using Cold Neutrons

UNIVERSITÄT BERN

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FOR FUNDAMENTAL PHYSICS

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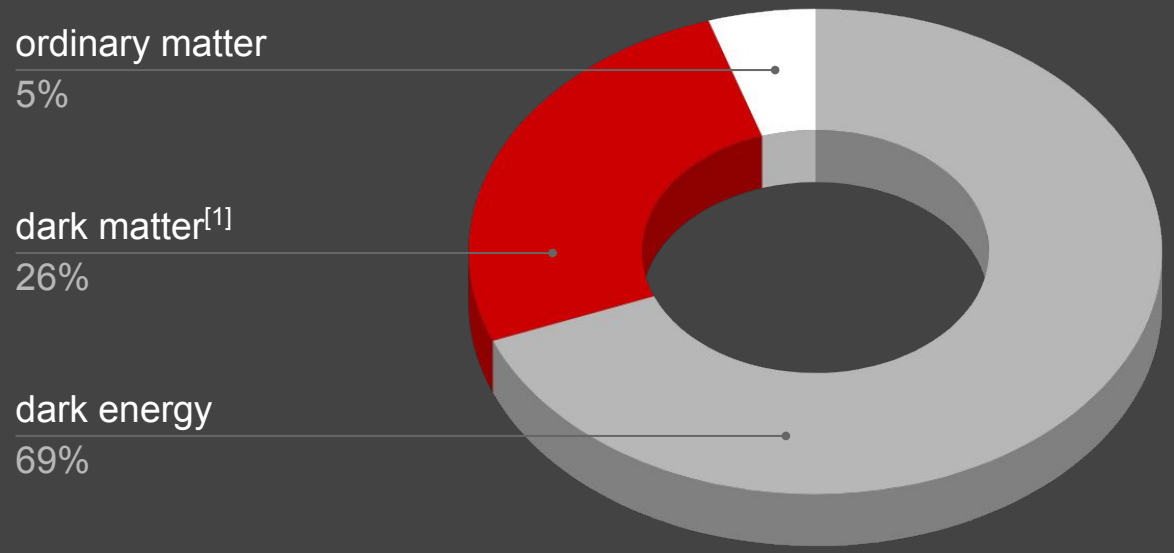
Universität Bern | Albert Einstein Center for Fundamental Physics

photo courtesy: isa_mau (pixabay.com)

Axion-Like Dark-Matter Search

The University and Dark Matter



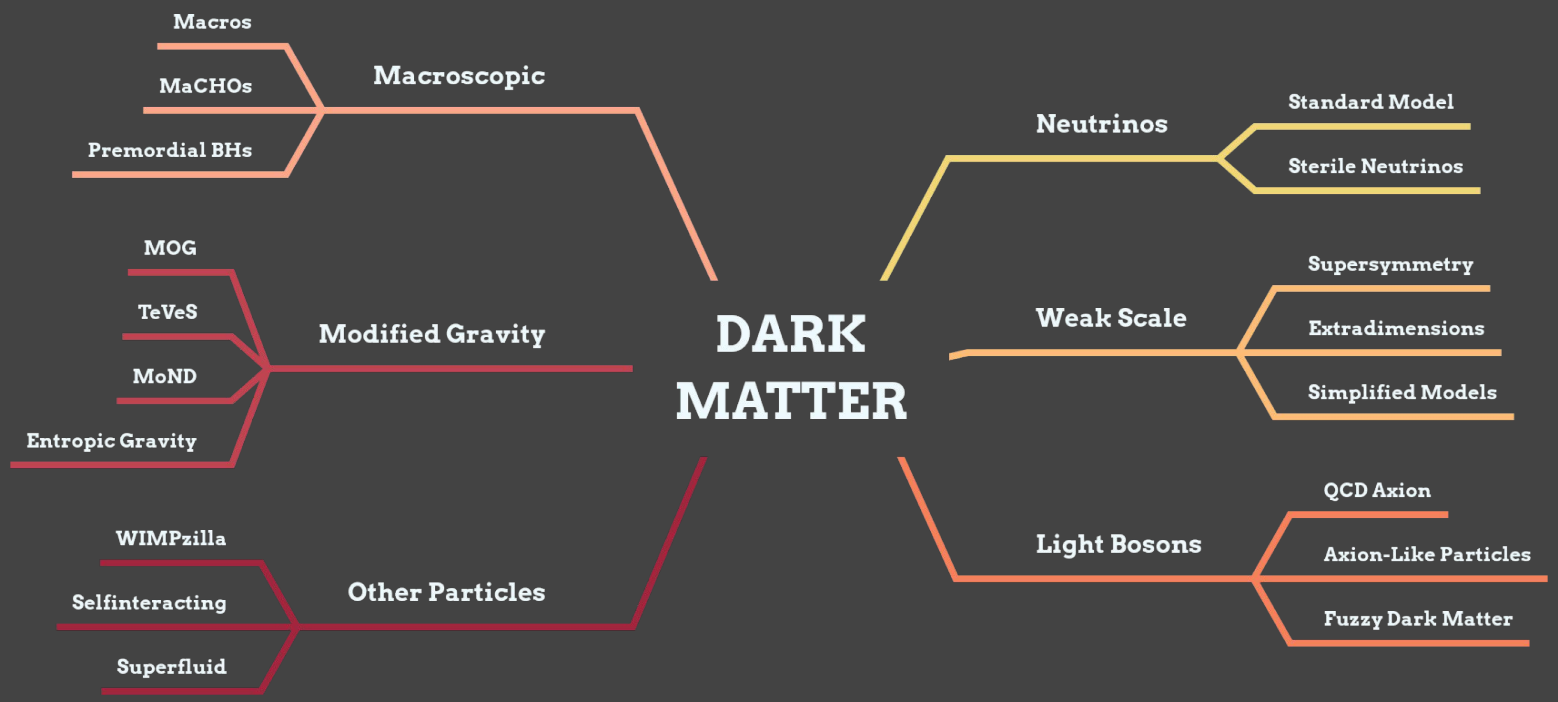
what we know:

- no interaction with photons
- gravitational interaction
- (no self-interaction)

[1] doi:10.1051/0004-6361/201833880

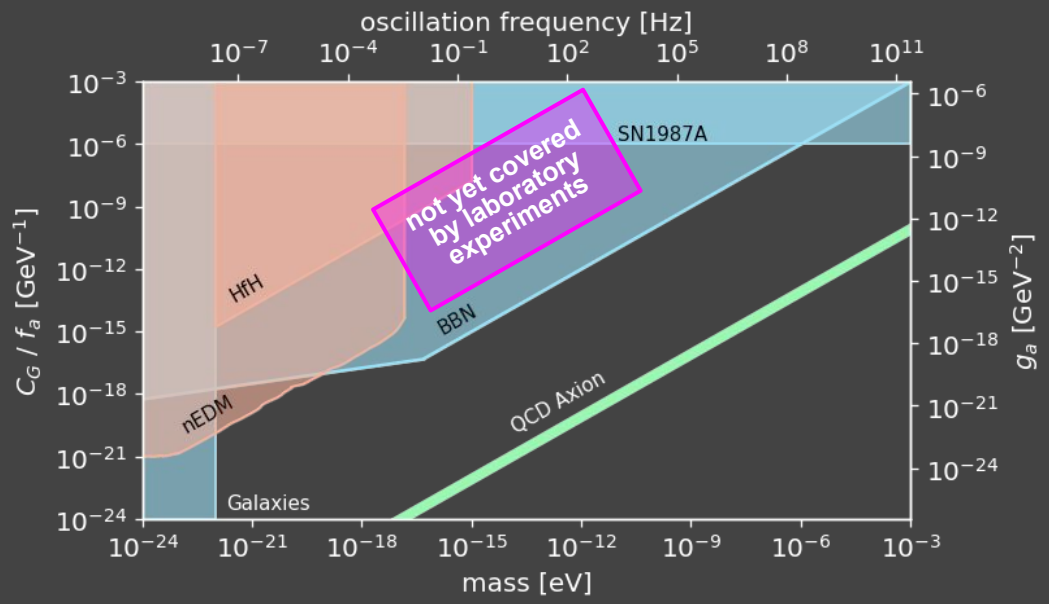
Axion-Like Dark-Matter Search

Dark Matter Candidates



Axion-Like Dark-Matter Search

Motivation to Search for Axions



- **axion-gluon coupling**
  ➔ oscillating neutron EDM[2]

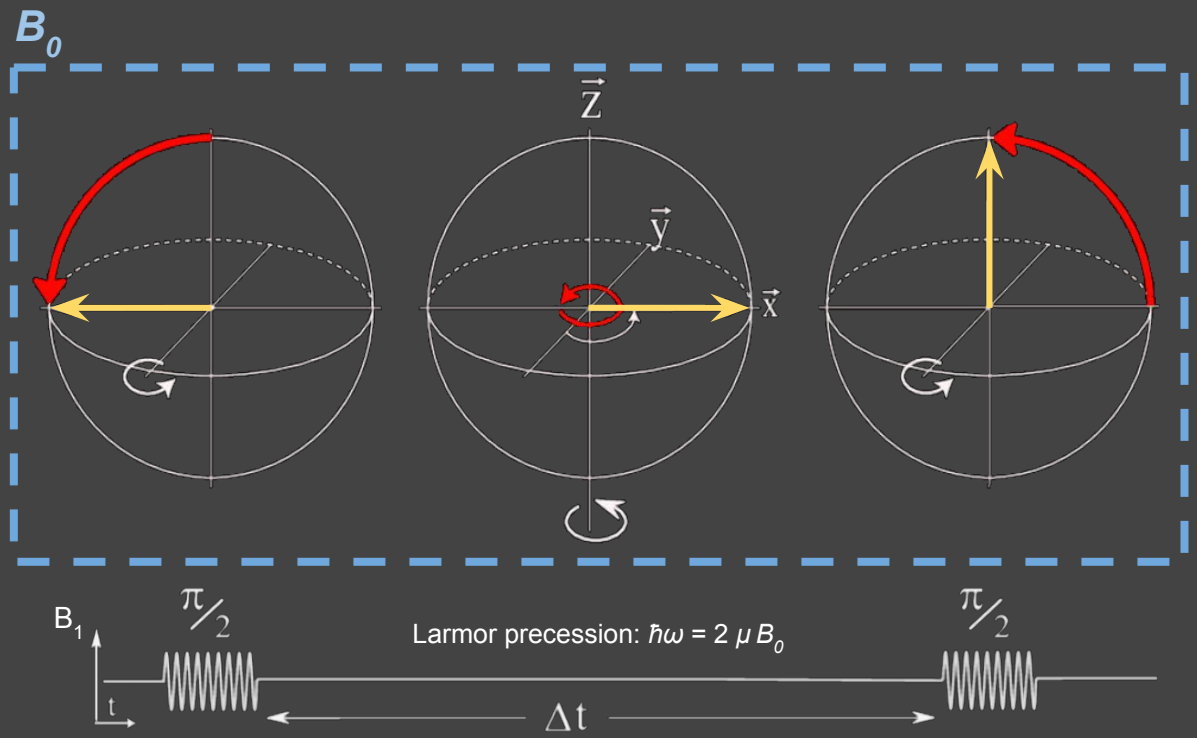
- $d_n(t) \approx \frac{C_G}{f_a} a_0 \cos(m_a t) \cdot 2.4 \times 10^{-16} e \cdot \mathrm{cm}$

  C_G: model dependent parameter
  f_a: axion decay constant
  a_0: axion field amplitude
  m_a: axion mass

[2] doi:10.1103/PhysRevD.89.043522

Measurement Technique

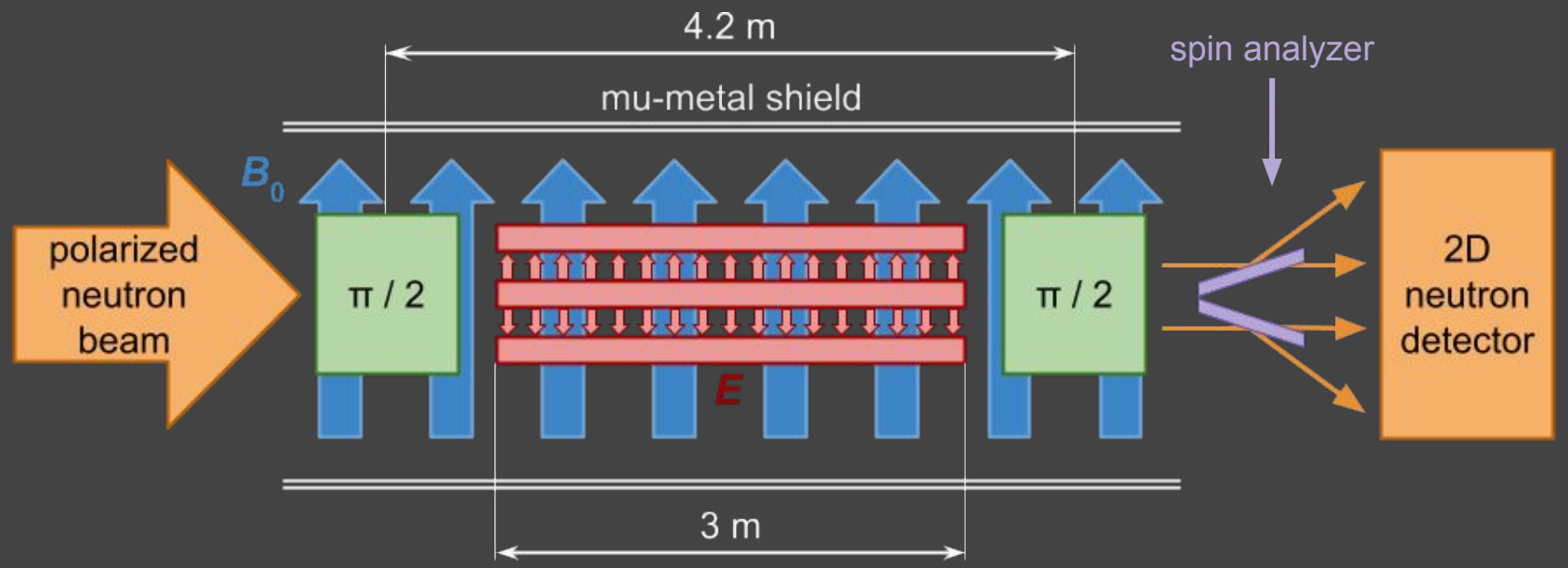
Ramsey's Method of Oscillatory Fields



picture adapted from:
J. Lisenfeld thesis - Fig. 4.25

The Beam EDM Apparatus

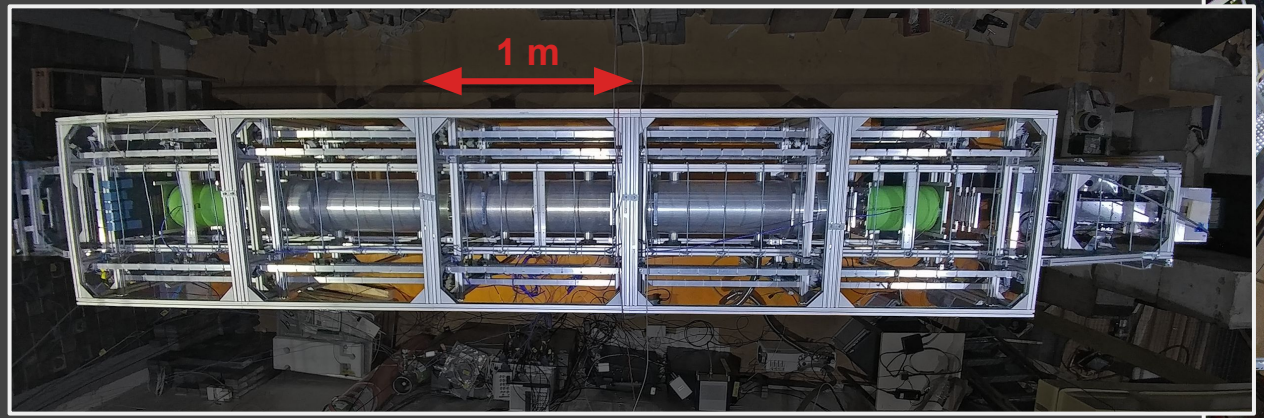
Experiment Schematic

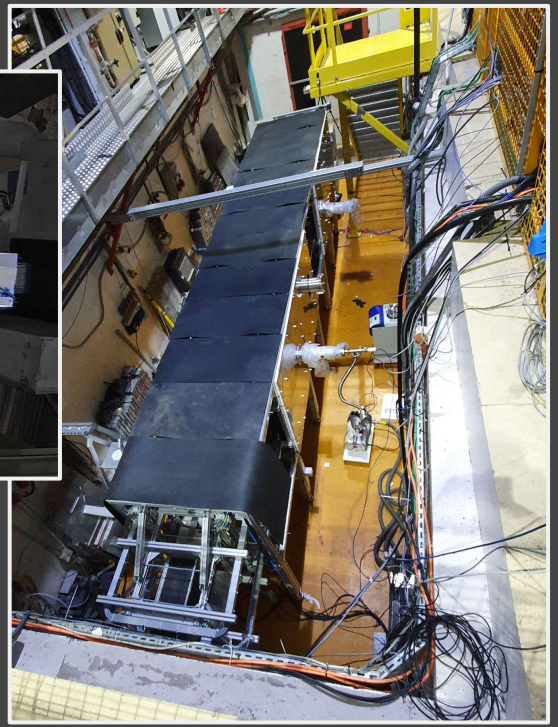


Larmor precession: $\hbar\omega = 2\,\mu\,B_0 \pm 2\,d\,E$

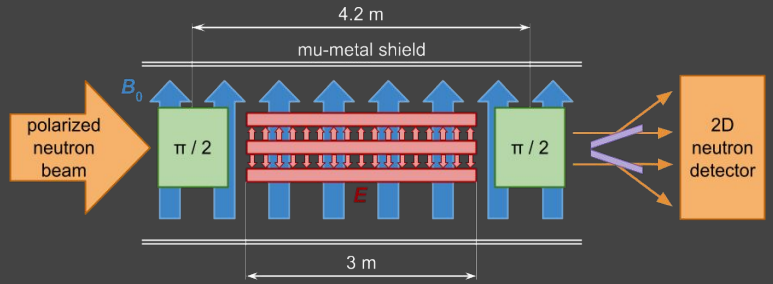
The Beam EDM Apparatus

Experimental Setup (I)



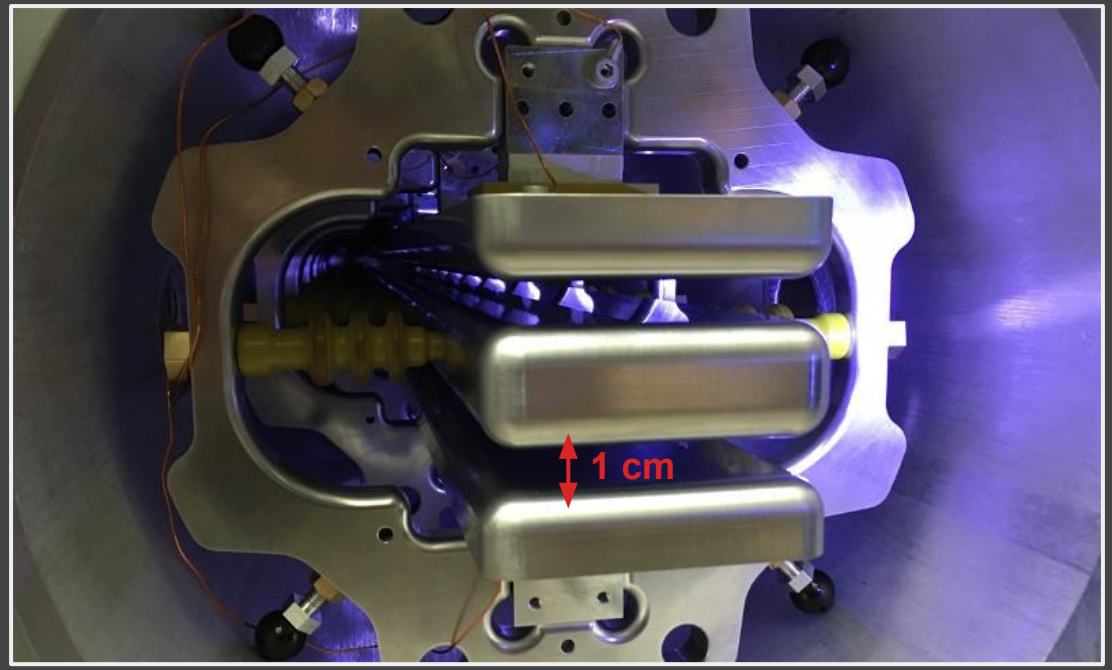


Poster by A. Fratangelo:
online available



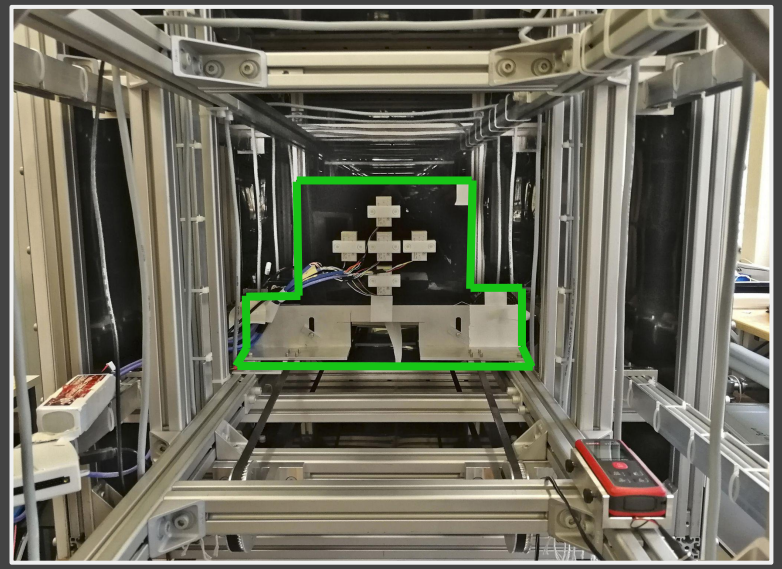
The Beam EDM Apparatus

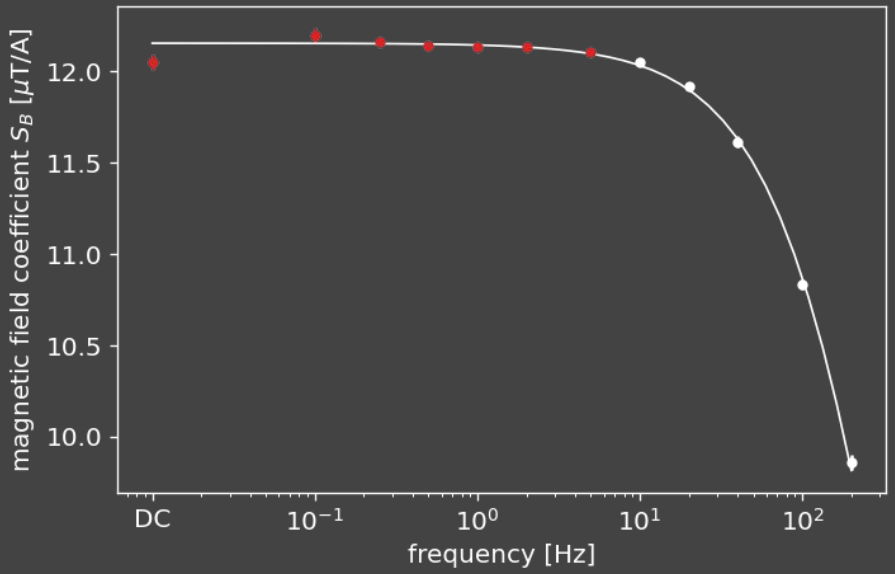
Experimental Setup (II)



Axion-Like Dark-Matter Search

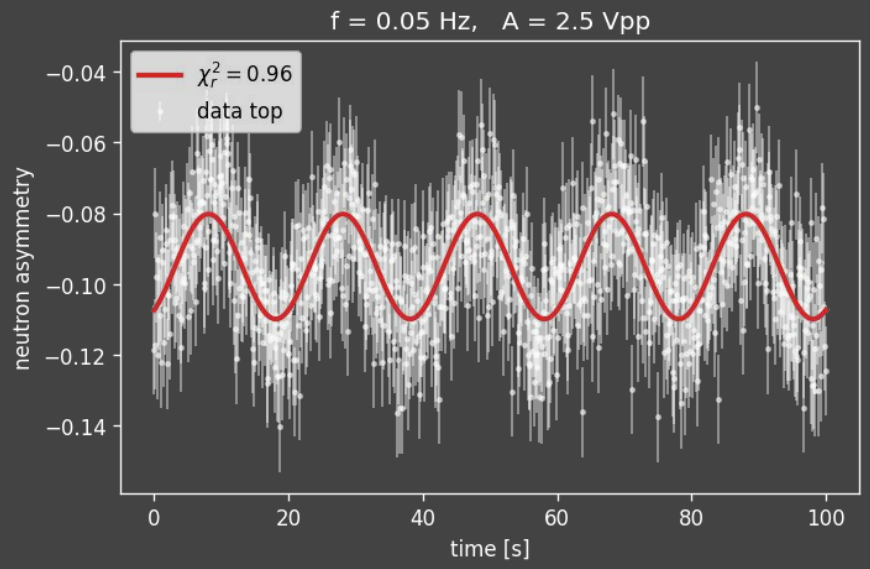
Characterization of the Experimental Apparatus (I)

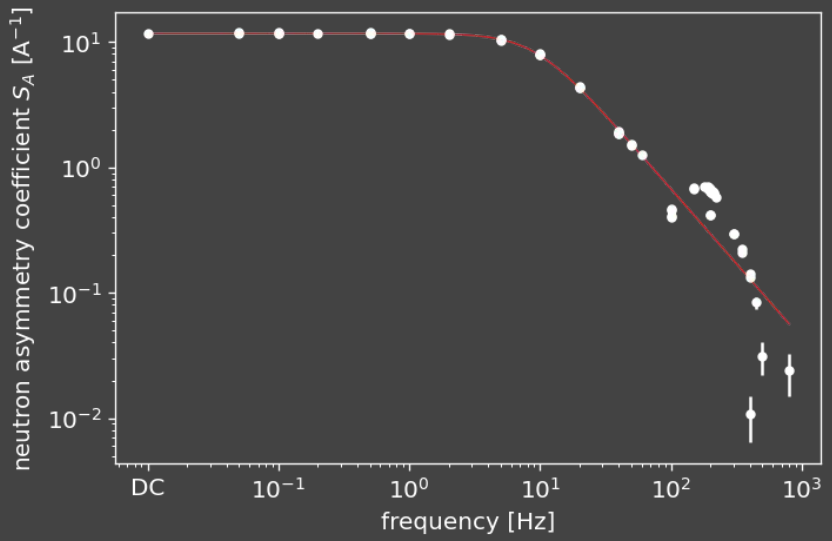




Axion-Like Dark-Matter Search

Characterization of the Experimental Apparatus (II)

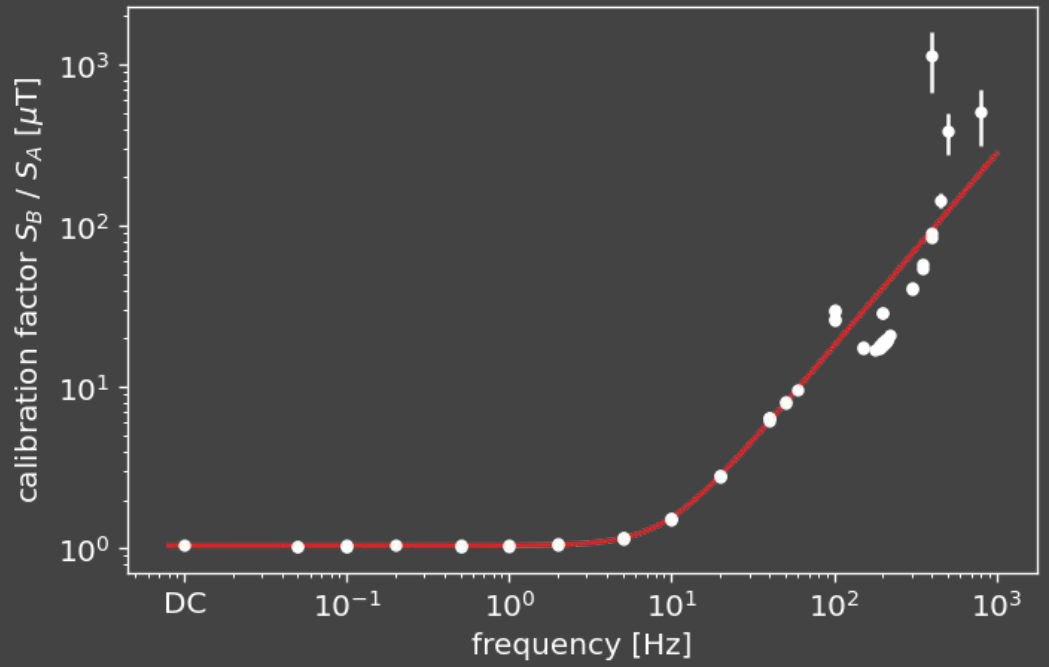




$$A(t) = \frac{N_\uparrow(t) - N_\downarrow(t)}{N_\uparrow(t) + N_\downarrow(t)}$$

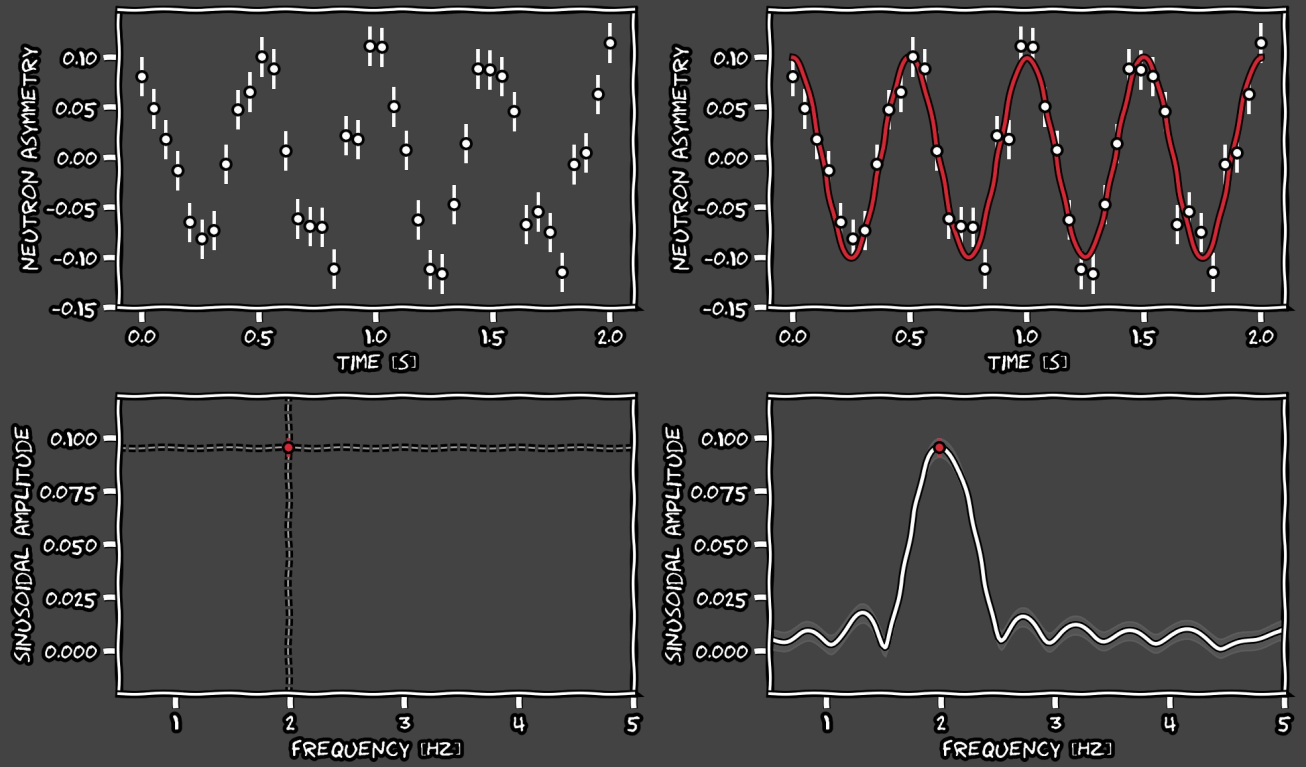
Axion-Like Dark-Matter Search

Characterization of the Experimental Apparatus (III)



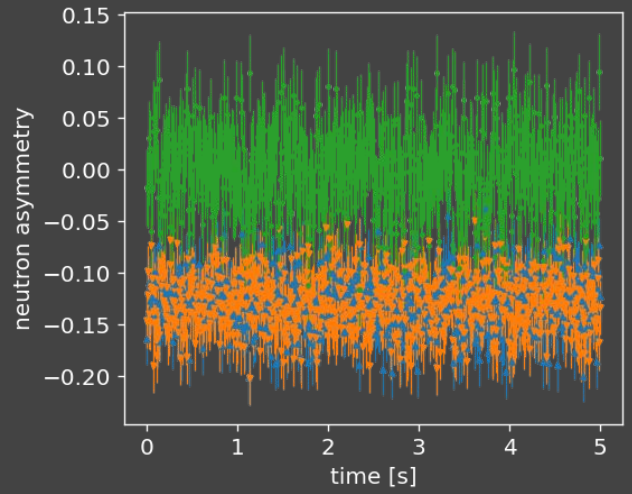
Axion-Like Dark-Matter Search

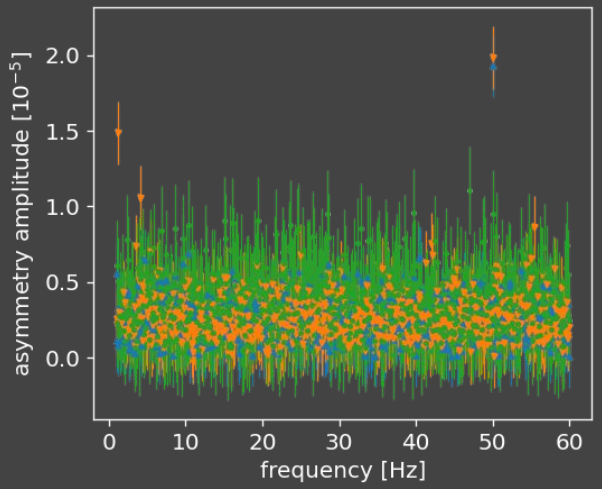
Data Processing (I)

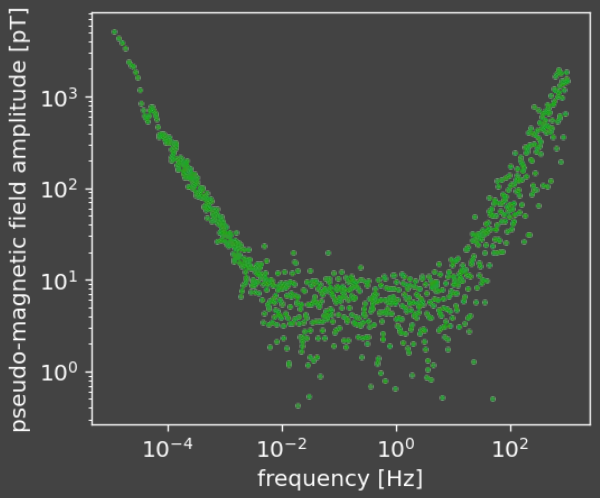


Axion-Like Dark-Matter Search

Data Processing (II)

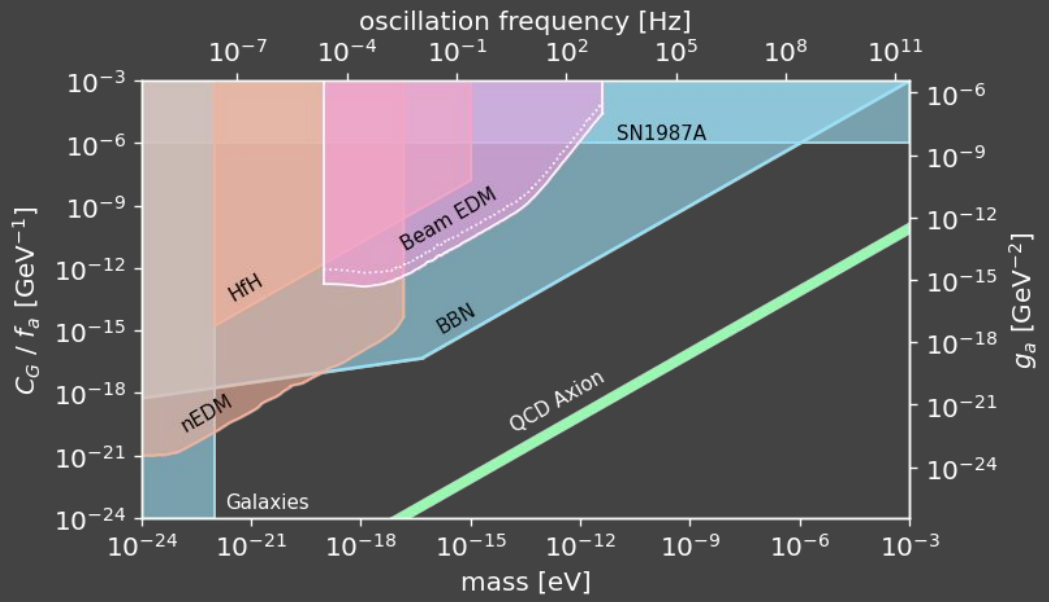






Axion-Like Dark-Matter Search

Results and Conclusion

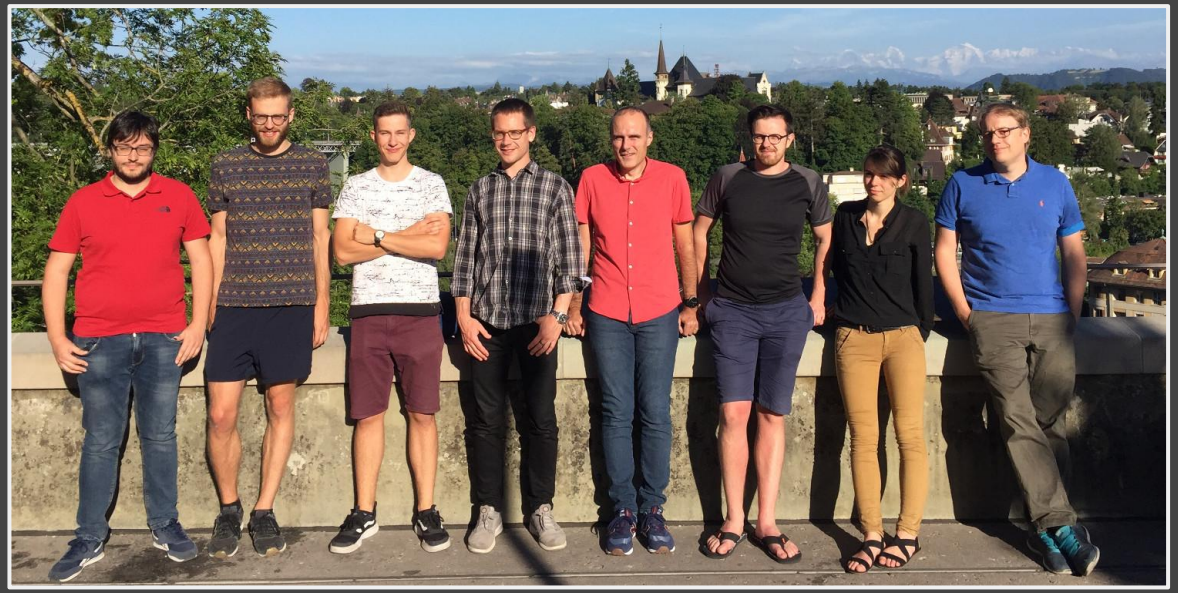


- excluded ALP-gluon coupling in a yet unexplored mass range
- benefits from existing Beam EDM apparatus
- only 24 hours ➔ 8 orders of magnitude in m_a
- potential of finding the QCD axion
- applicable to any EDM measurement

- Accepted by PRL and preprint on arXiv: 2204.01454

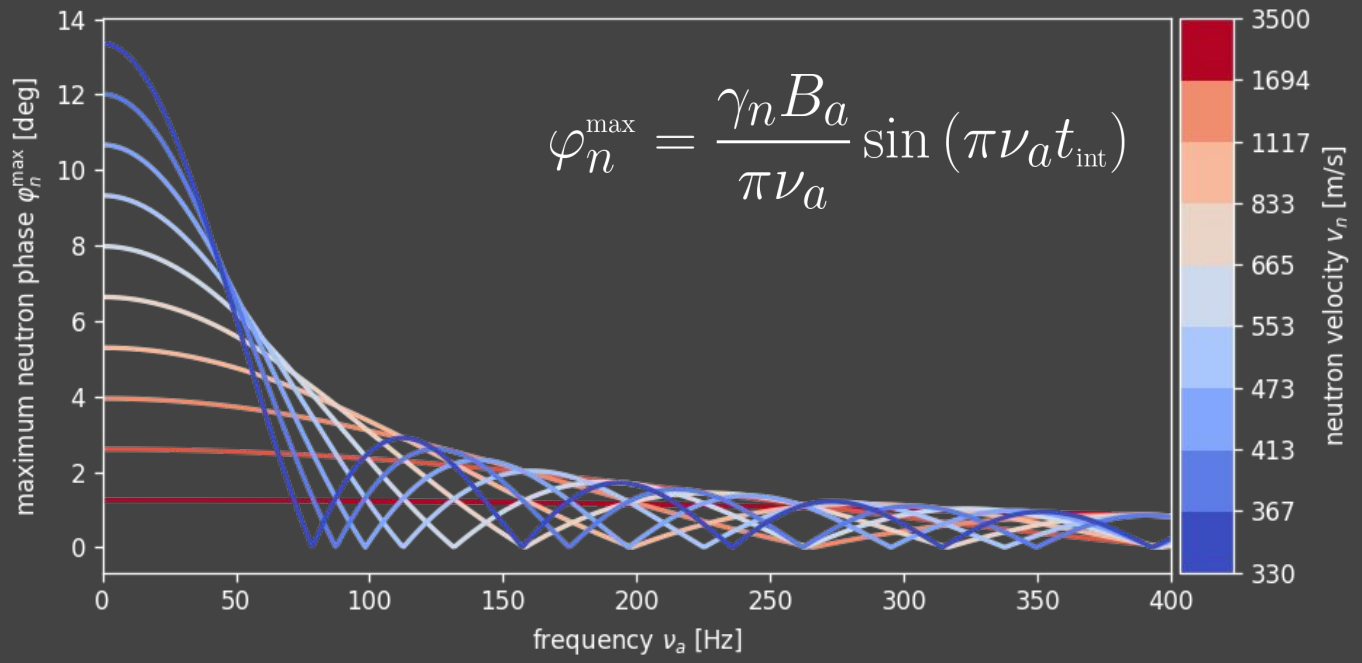
Axion-Like Dark-Matter Search

Acknowledgments



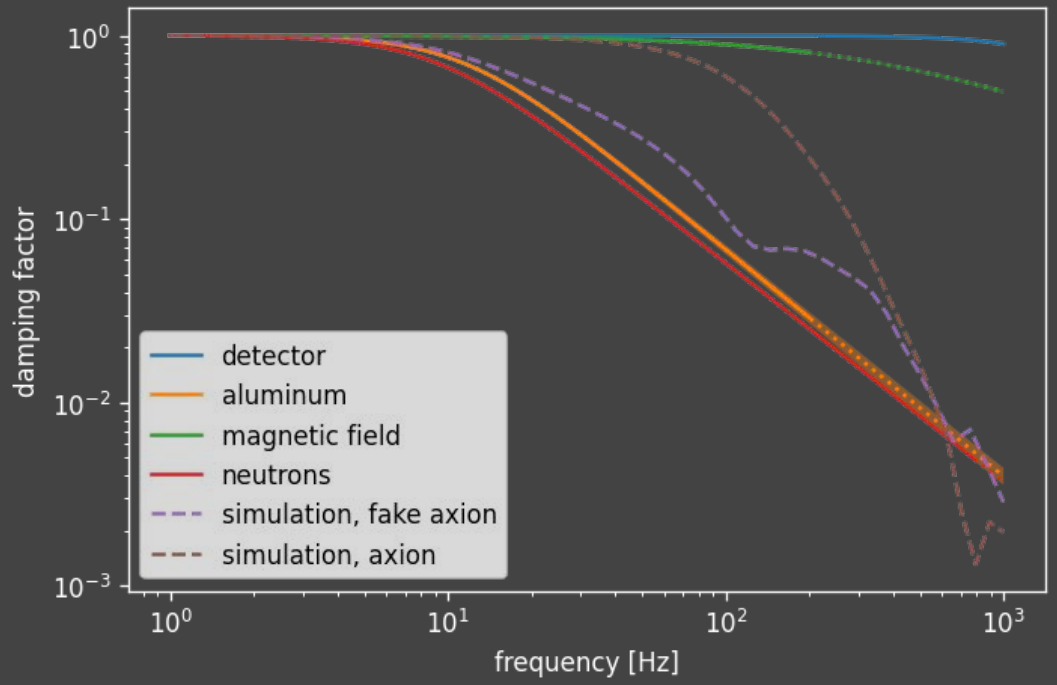
Axion-Like Dark-Matter Search

Backup (I)



Axion-Like Dark-Matter Search

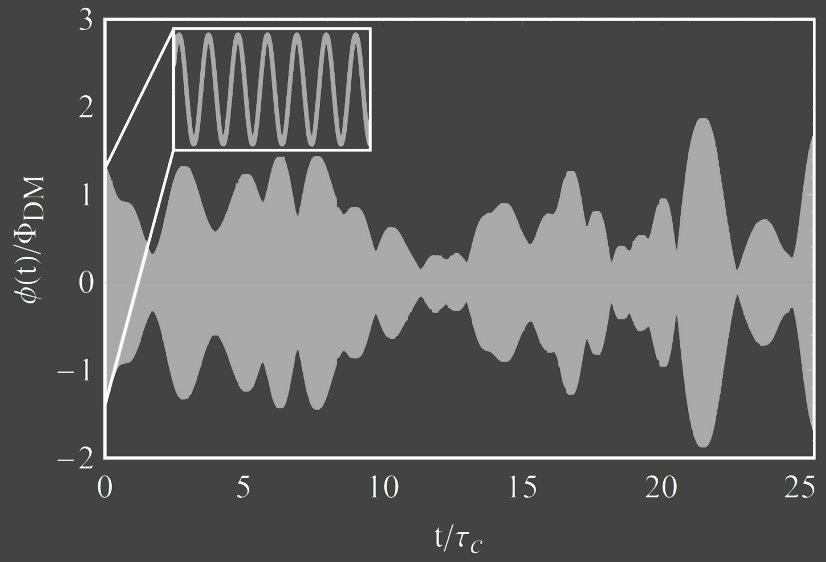
Backup (II)



Axion-Like Dark-Matter Search

Backup (III)

- deterministic DM
  $T \gg \tau_c$
- stochastic DM[3]
  $T \ll \tau_c$
  $$p(\Phi_0) = \frac{2\Phi_0}{\Phi_{DM}^2}\exp\left(-\frac{\Phi_0}{\Phi_{DM}^2}\right)$$
  ➔ $p(\Phi_0 < \Phi_{DM}) = 63\%$



graphic from:
arXiv:1905.13650 Fig. 1

[3]: Centers, G. P. *et al*. Stochastic fluctuations of bosonic dark matter. *arXiv:1905.13650* (2020).