Search for Axion-Like Dark Matter using Cold Neutrons

UNIVERSITÄT BERN

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FOR FUNDAMENTAL PHYSICS

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UNIVERSITÄT BERN

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06. August 2024 - The Axion Quest 2024

University of Bern | Albert Einstein Center for Fundamental Physics

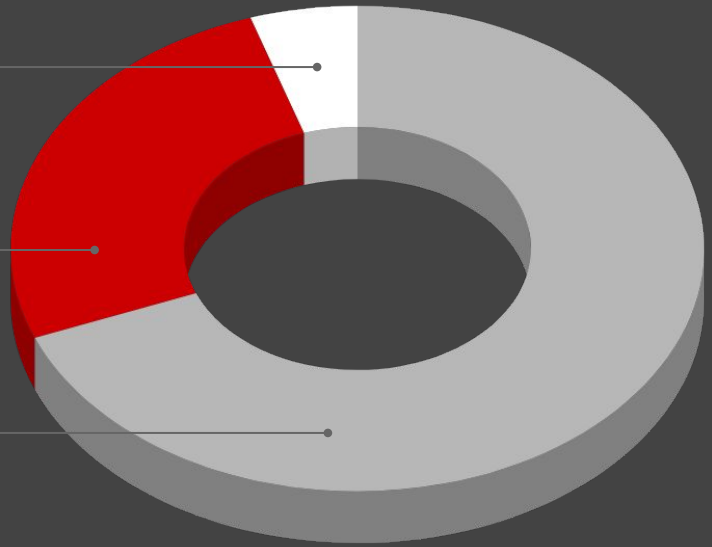
Axion-Like Dark-Matter Search

The Universe and Dark Matter

ordinary matter
5%

dark matter[1]
26%

dark energy
69%



what we know:

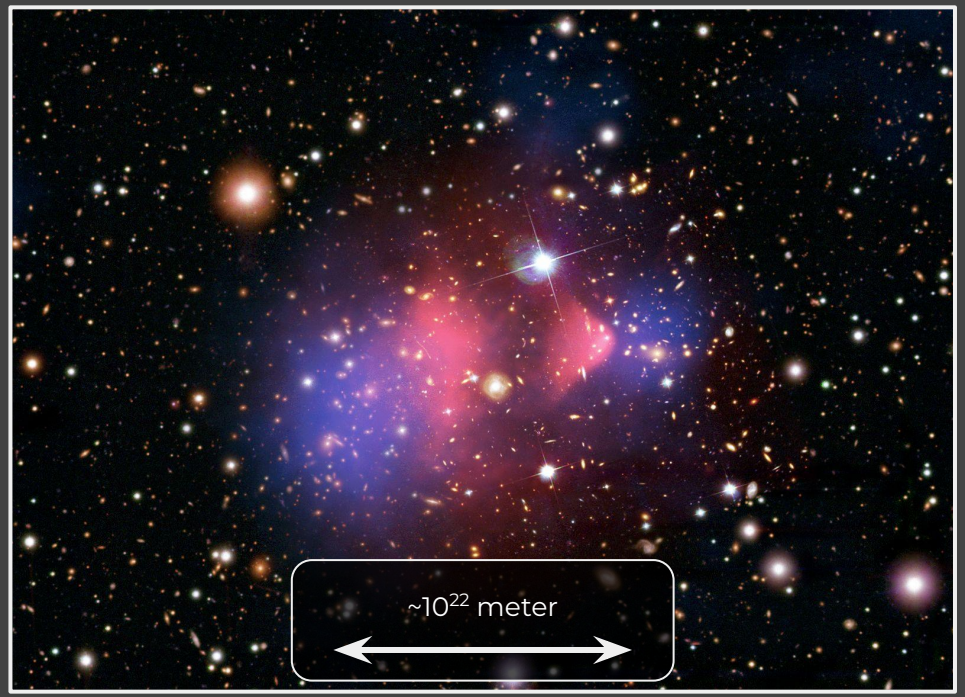
- no interaction with photons
- gravitational interaction
- (no self-interaction)

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

Axion-Like Dark-Matter Search

The Universe and Dark Matter

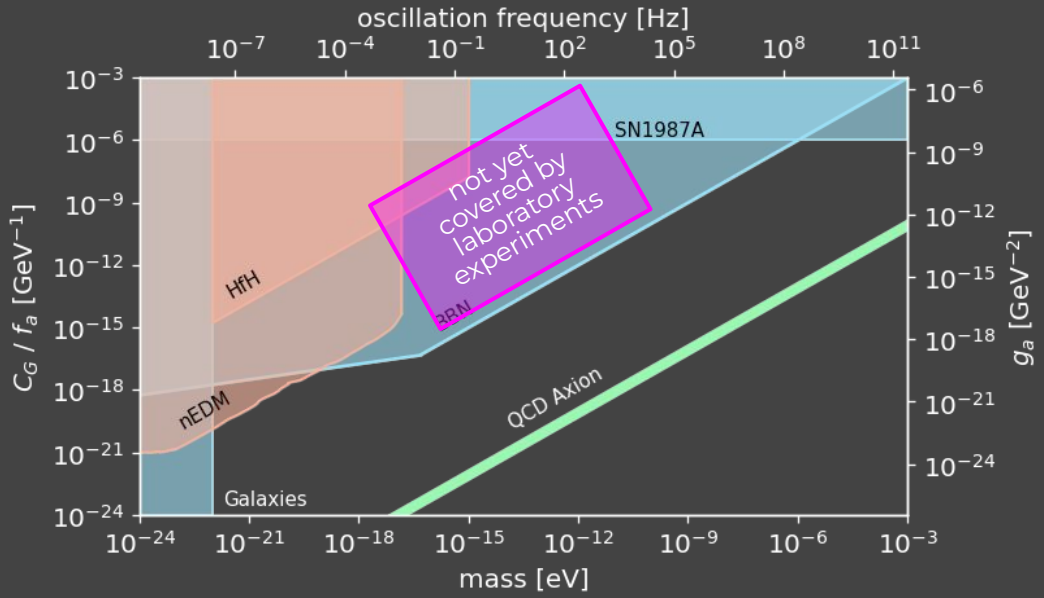
example:
Bullet Cluster
1E 0657-56



picture courtesy of:
Chandra X-Ray Observatory:
1E 0657-56

Axion-Like Dark-Matter Search

Motivation to Search for Axions



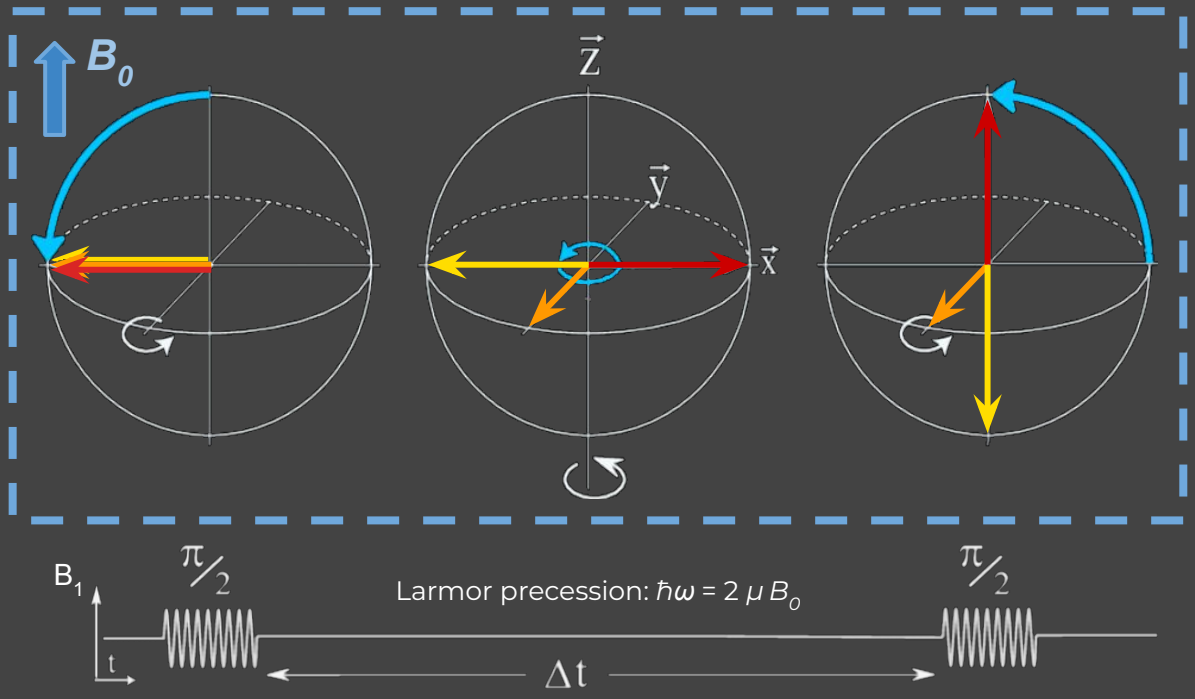
- **axion-gluon coupling**
  ➔ oscillating neutron EDM[2]
- $d_n(t) \approx \frac{C_G}{f_a} a_0 \cos(m_a t) \cdot 2.4 \times 10^{-16} e \cdot \mathrm{cm}$

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



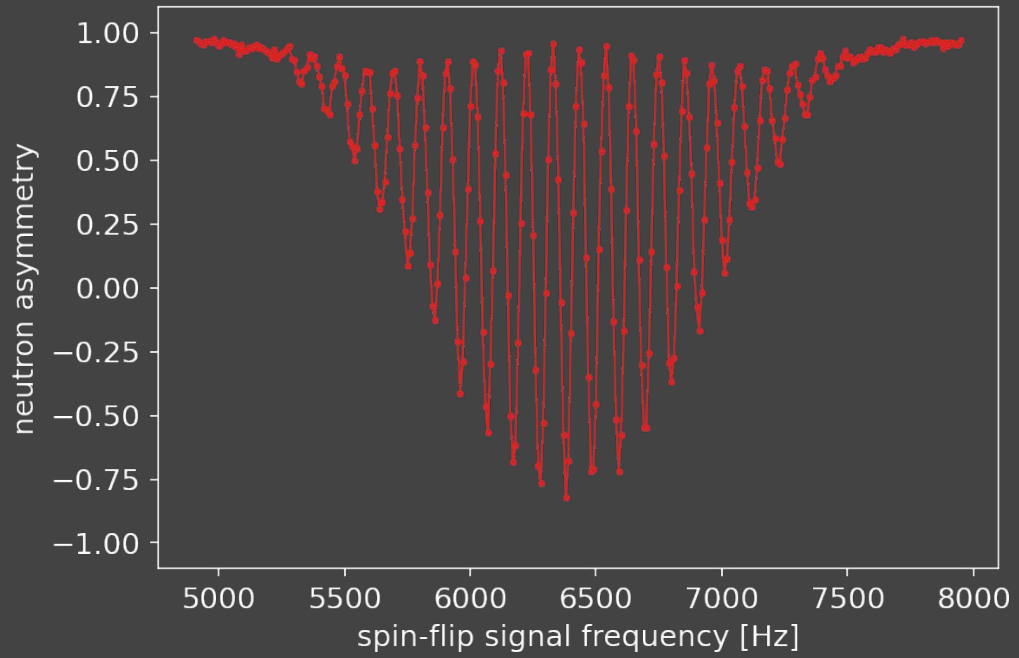
$$A(t) = \frac{N_{\uparrow}(t) - N_{\downarrow}(t)}{N_{\uparrow}(t) + N_{\downarrow}(t)}$$

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

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

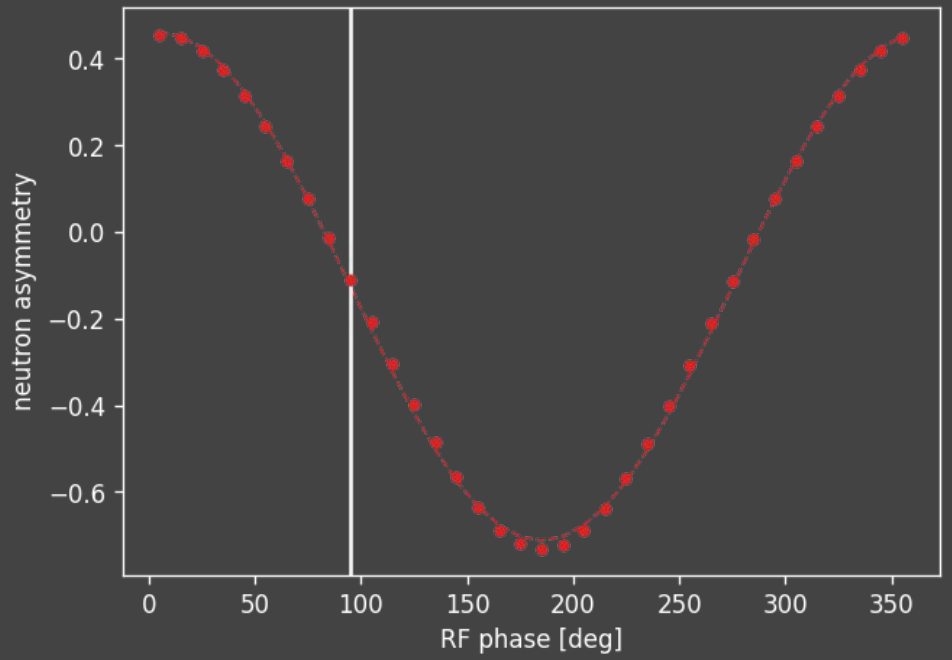
Measurement Technique

Ramsey's Method of Oscillatory Fields



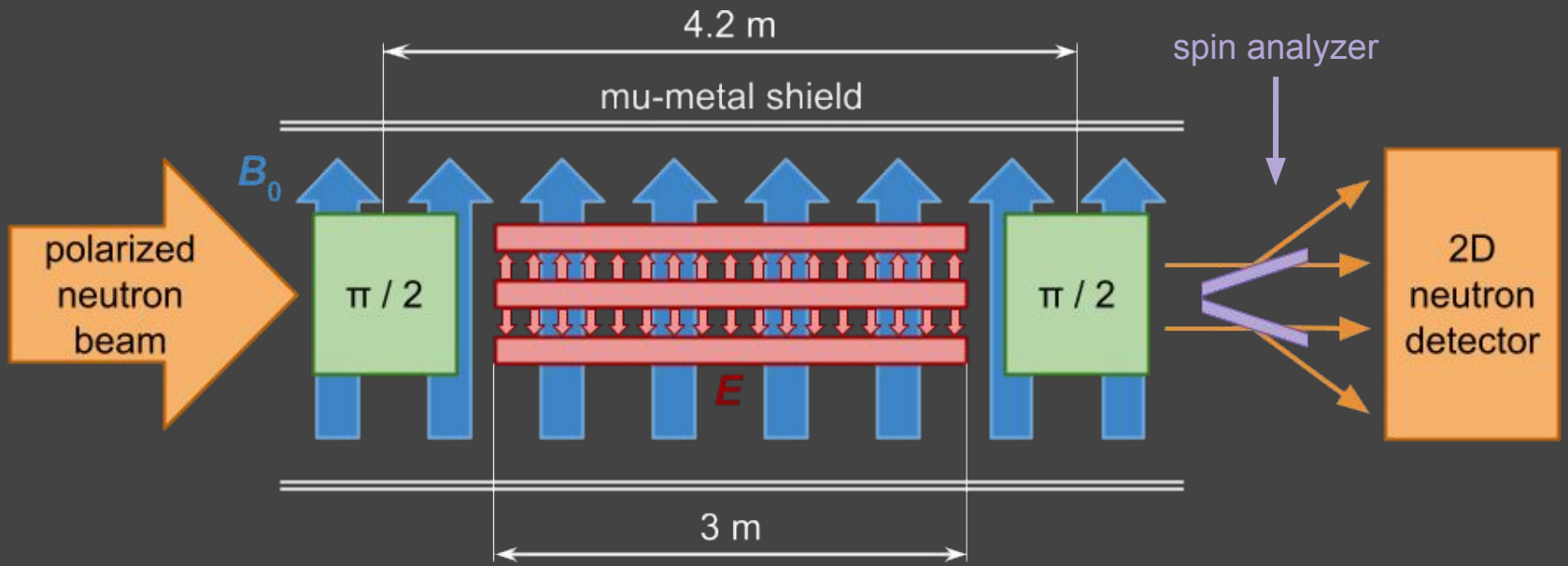
Measurement Technique

Ramsey's Method of Oscillatory Fields



The *Beam EDM* Apparatus

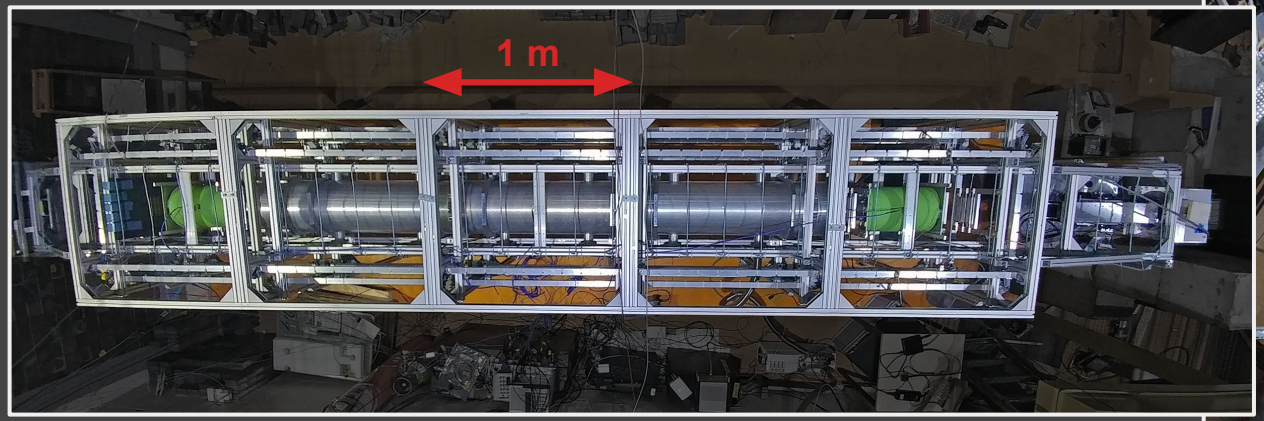
Experiment Schematic

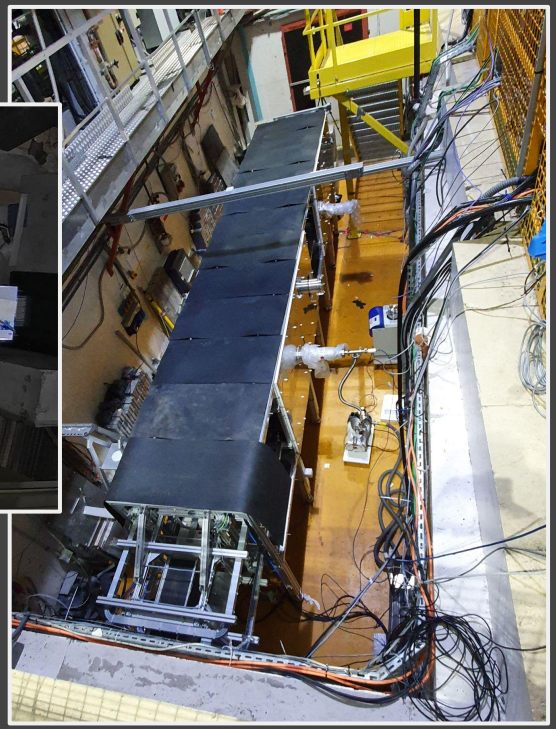


Larmor precession: $\hbar\omega = 2\,\mu\,B_0 \pm 2\,d\,E$

The *Beam EDM* Apparatus

Experimental Setup





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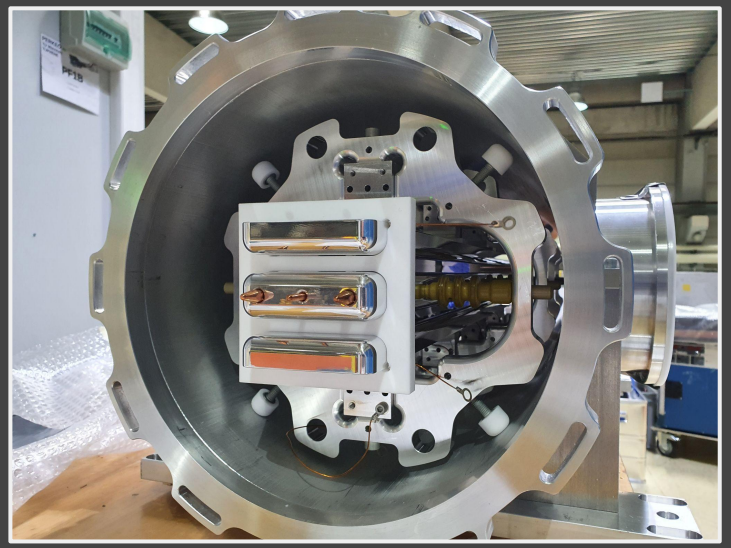
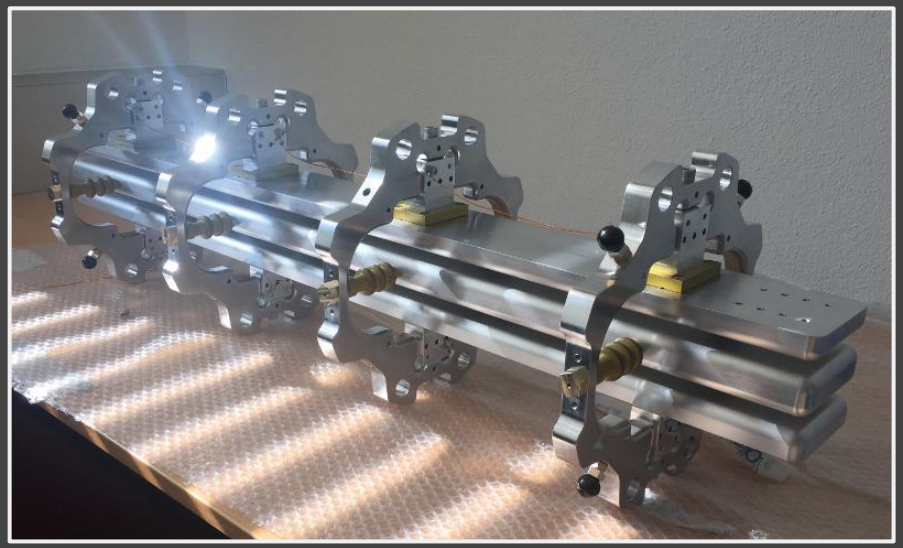
NEUTRONS FOR SOCIETY

The *Beam EDM* Apparatus

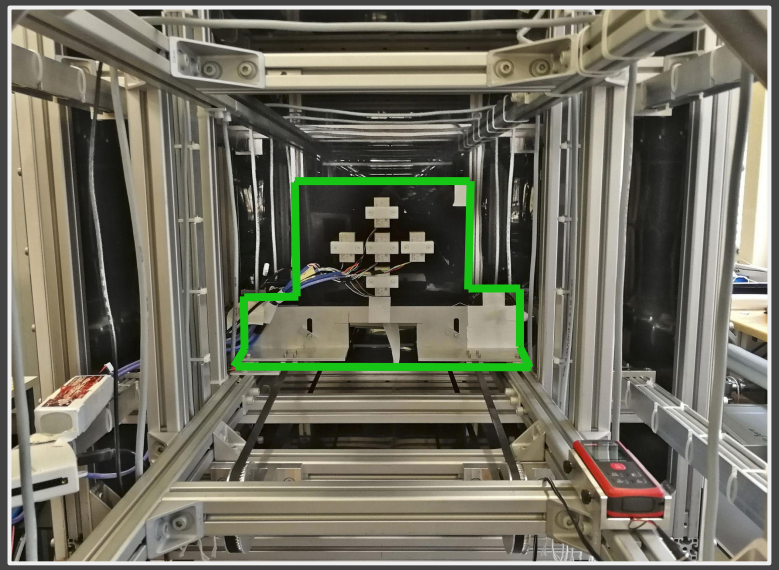
Experimental Setup

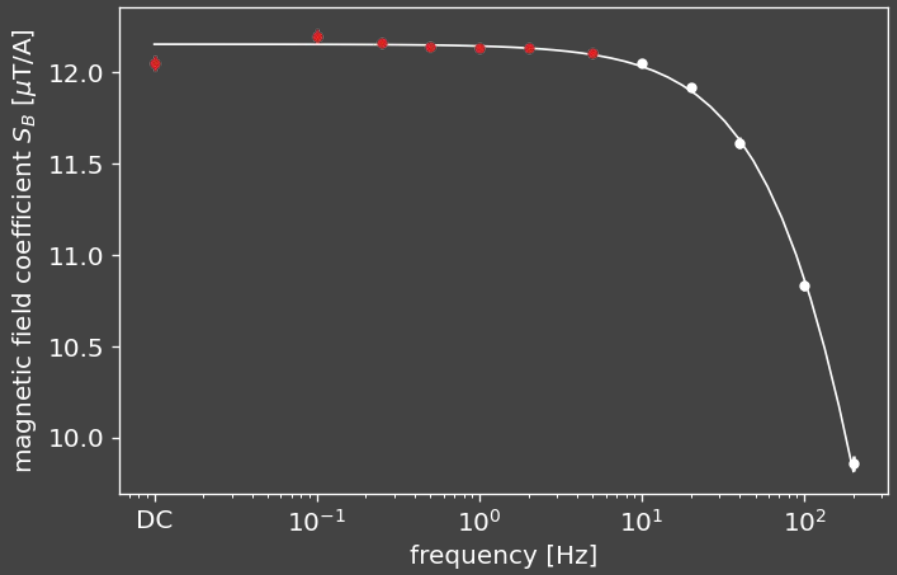




Axion-Like Dark-Matter Search

Characterization of the Experimental Apparatus





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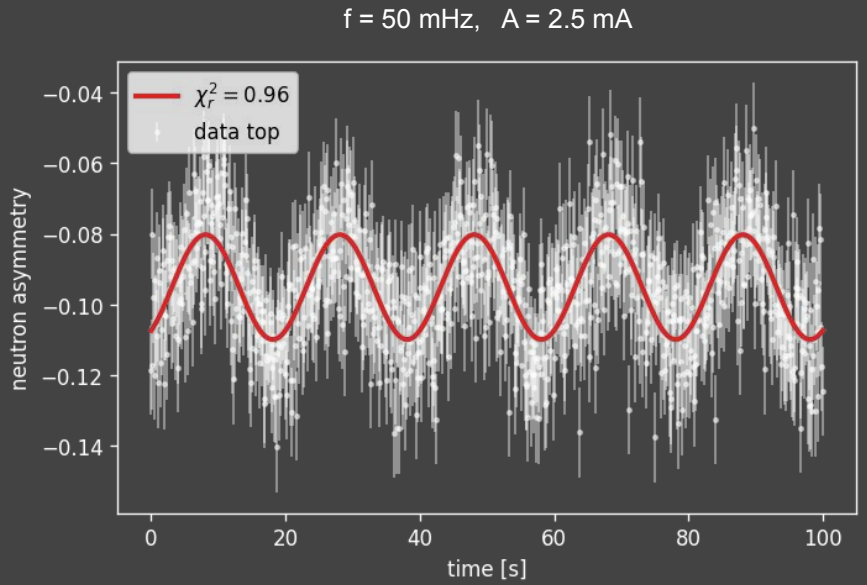

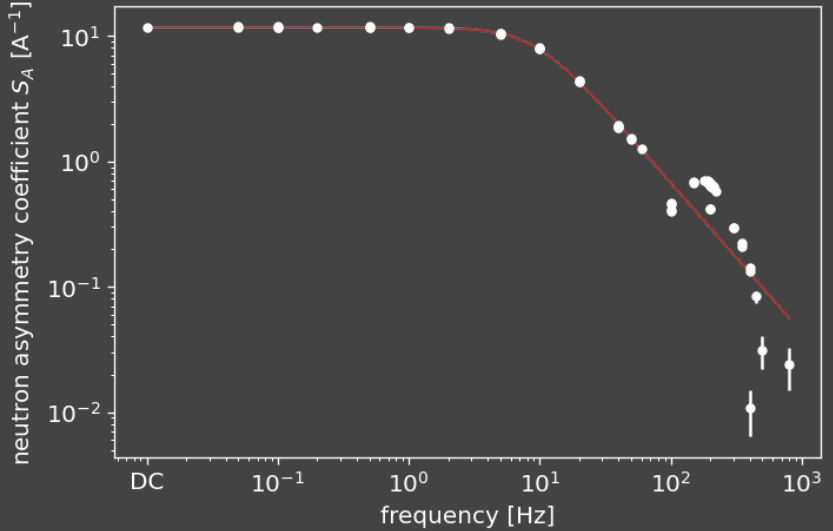

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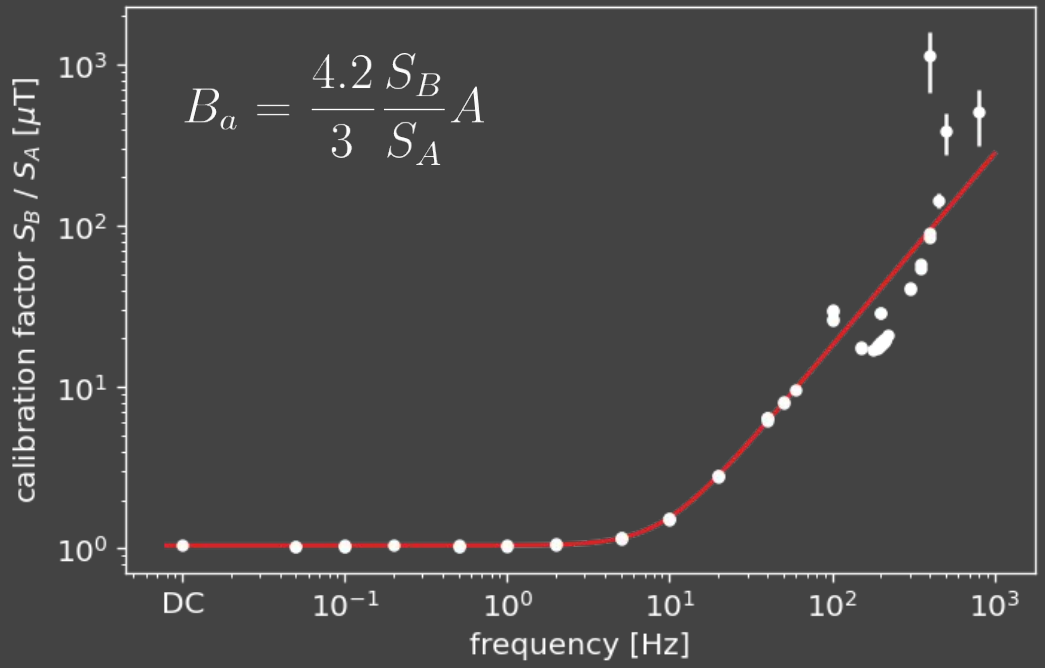


Axion-Like Dark-Matter Search

Excursion: Resonant Cancellation Effect

$$\varphi_n = -\gamma_n B t$$

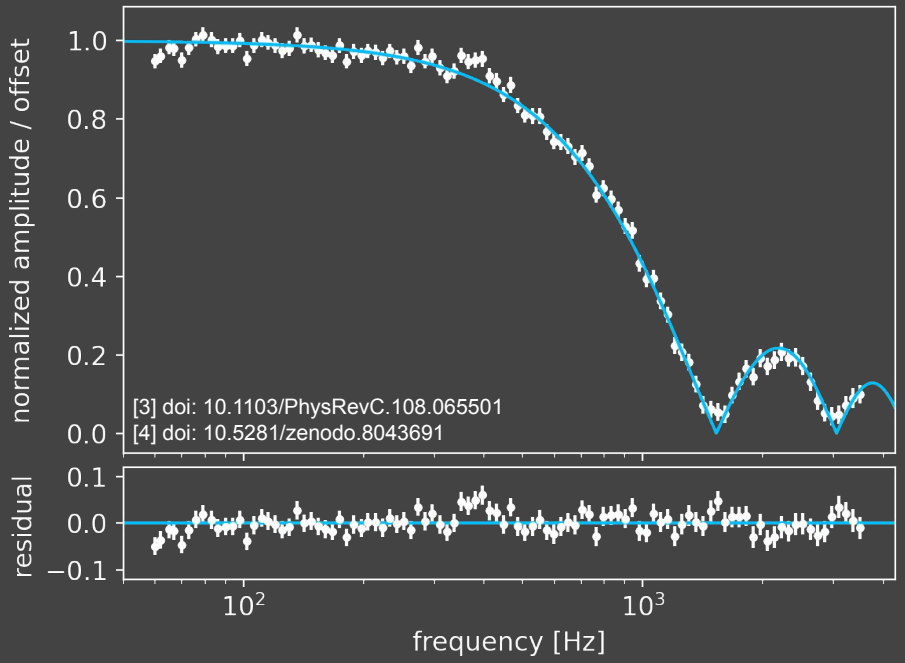
$$\varphi_n = -\gamma_n \int B_a(t)\,\mathrm{d}t \qquad B_a(t) = B_a \cos\left(2\pi\nu_a t\right)$$

$$\varphi_n^{\max} = \frac{\gamma_n B_a}{\pi\nu_a} \sin\left(\pi\nu_a t_{\mathrm{int}}\right)$$

$$\text{roots at: } \nu_a = \frac{v_n}{l_{\mathrm{int}}}$$

Axion-Like Dark-Matter Search

Excursion: Resonant Cancellation Effect



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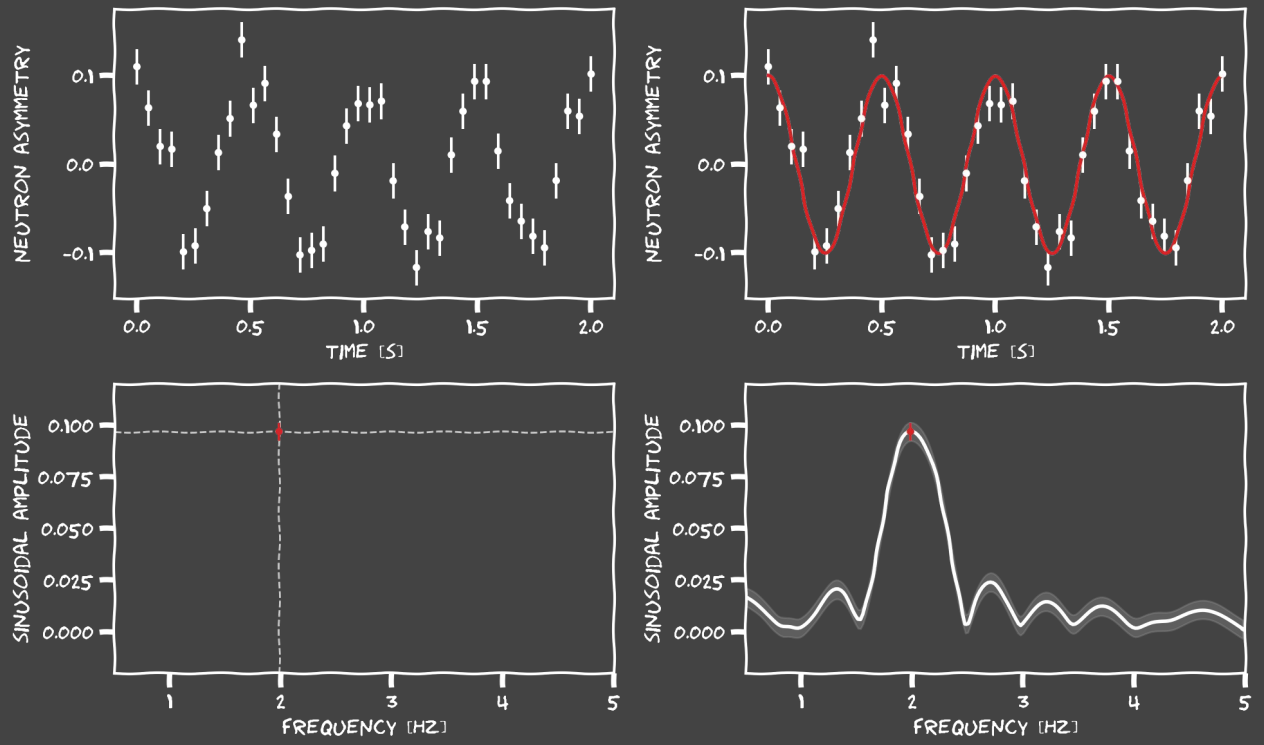
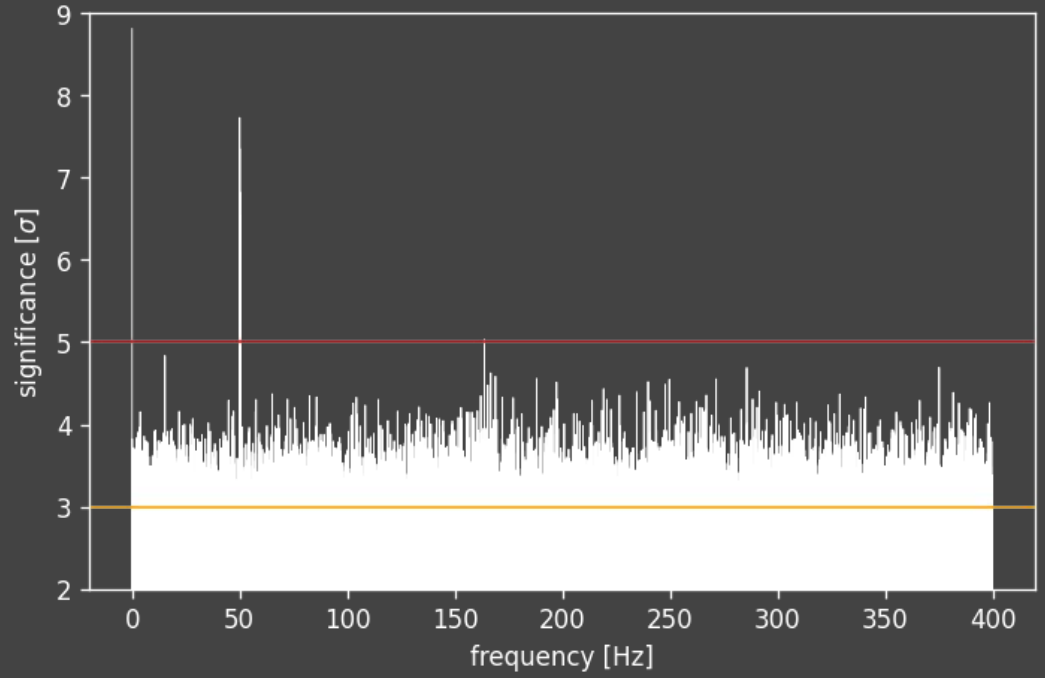
Axion-Like Dark-Matter Search

Data Processing



Axion-Like Dark-Matter Search

Data Processing

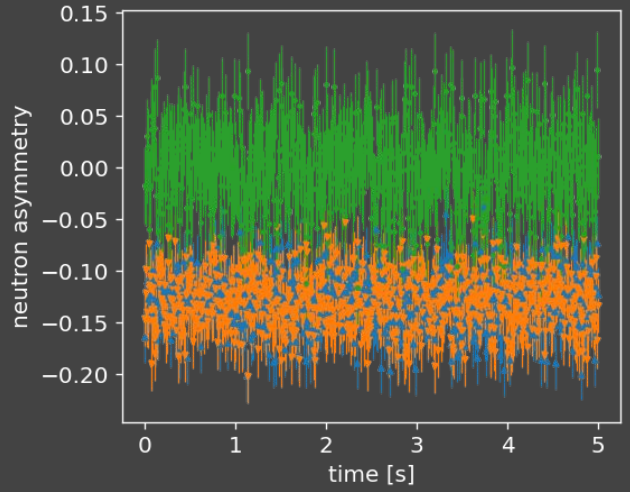


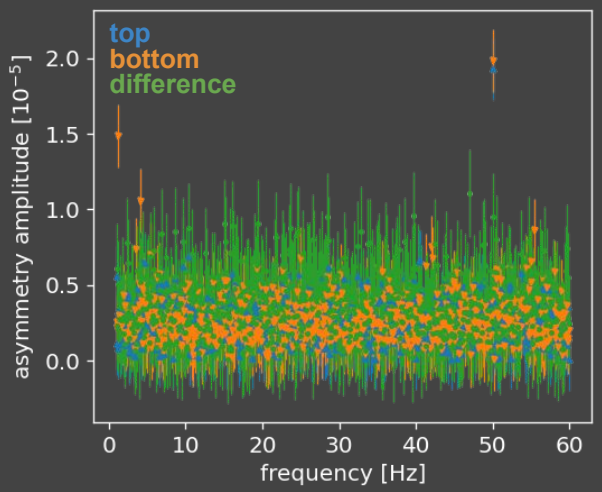
conditions for an axion signal:

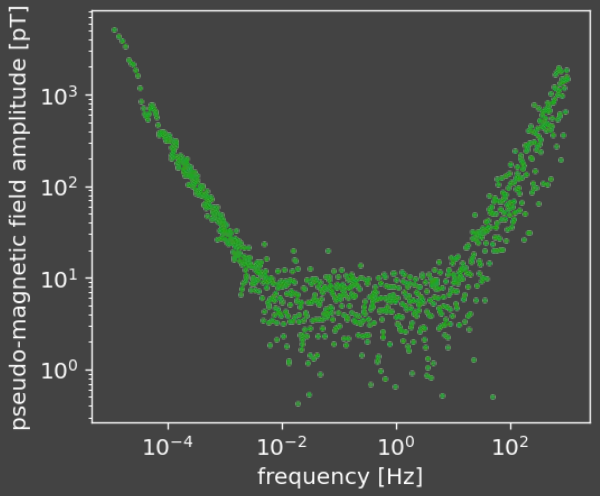
1. no signal for E = 0
2. peak with same amplitude for B↑↑E and B↑↓E
3. 180° phase shift for B↑↑E compared to B↑↓E

Axion-Like Dark-Matter Search

Data Processing

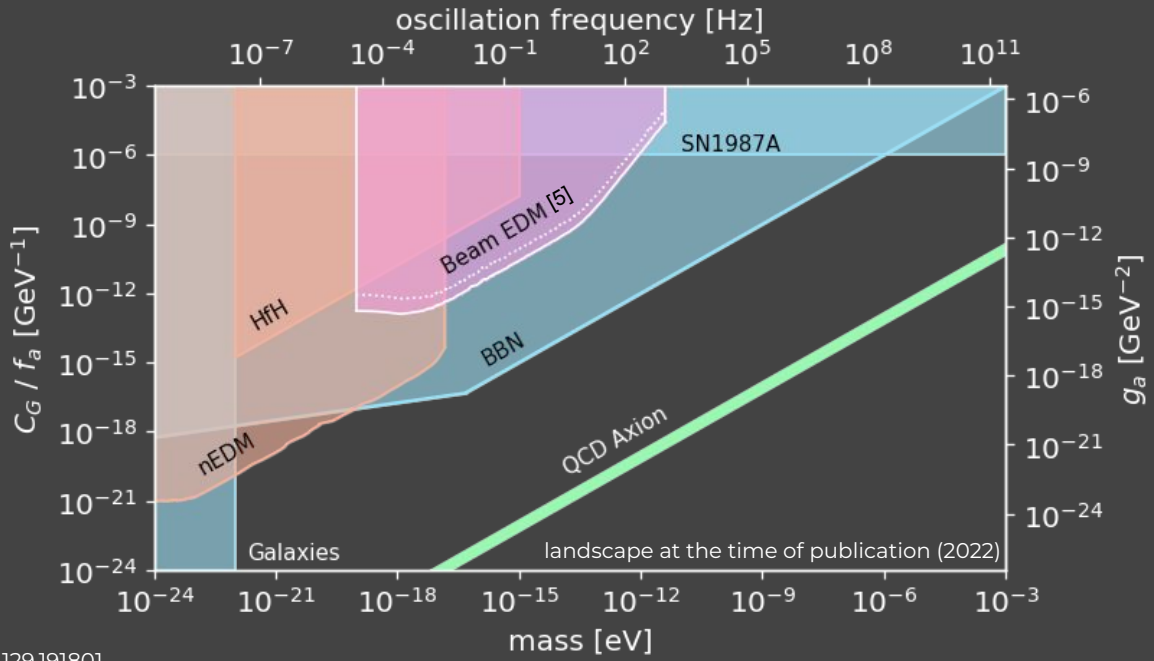






Axion-Like Dark-Matter Search

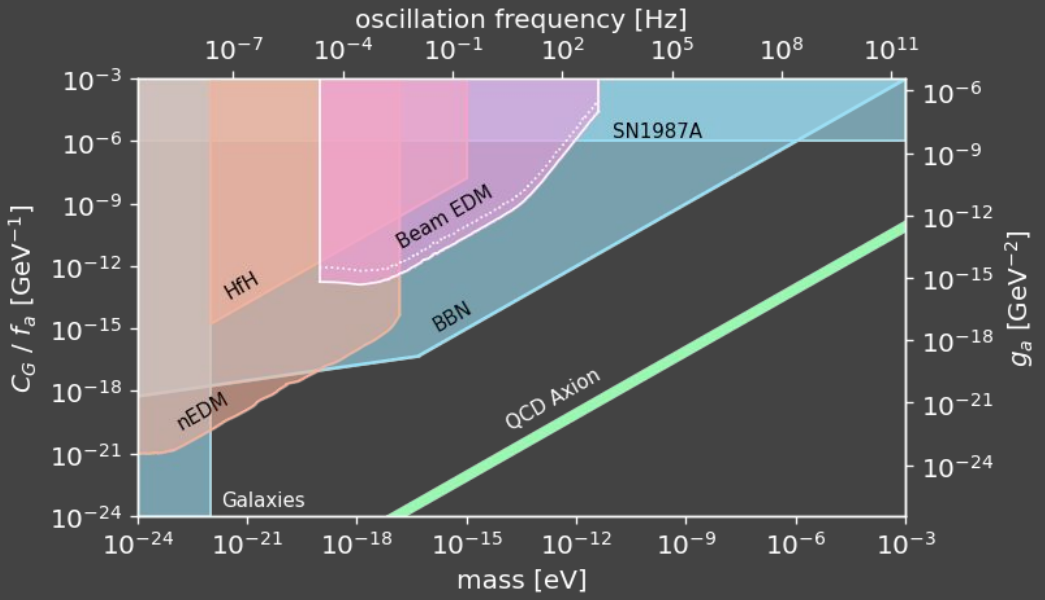
Results



[5] doi:10.1103/PhysRevLett.129.191801

Axion-Like Dark-Matter Search

Conclusion



- set a new limit on the existence of axion-like dark matter in a yet unexplored mass range[5]
- benefits from existing *Beam EDM* apparatus
- only 24 hours
  ➔ 8 orders of magnitude in m_a

[5] doi:10.1103/PhysRevLett.129.191801

Fundamental Neutron and Precision Physics

Acknowledgments