BREAD: Broadband Reflector Experiment for Axion Detection

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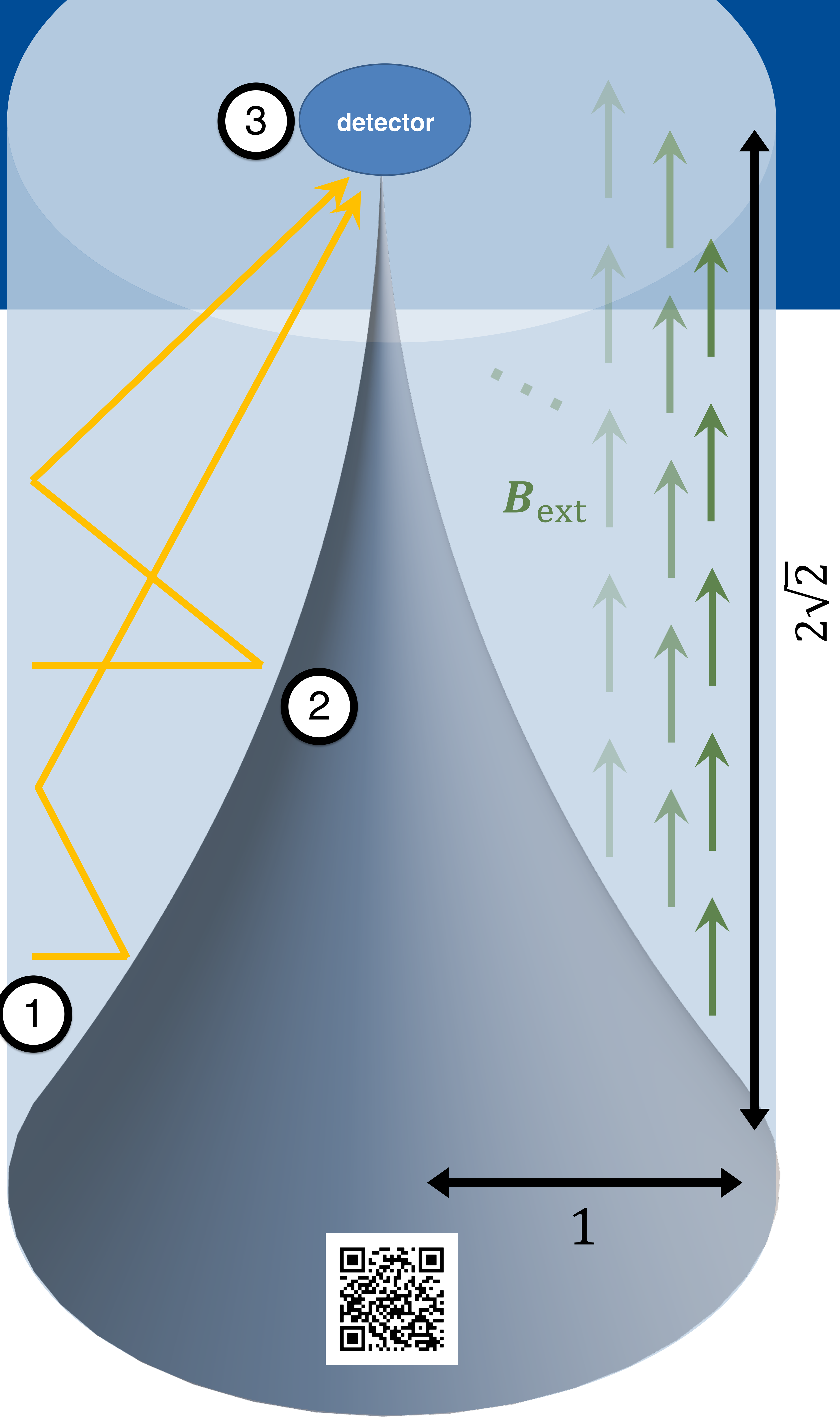
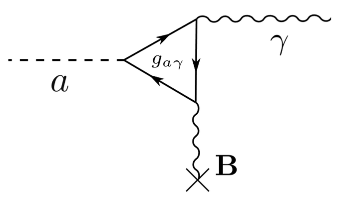


Motivation

Axions are excellent dark matter candidates [36-41], initially introduced to explain the smallness of the neutron electric dipole moment [29-31]. Axion direct detection experiments like ADMX [52] are typically only sensitive to axions of about ~μeV mass but unsuitable around ~meV, favored by a cosmological scenario where most axions are effectively produced after inflation [65-67].

Concept

① **Axions can convert to photons on metallic surfaces** of area $A_{\rm dish}$ under a strong parallel magnetic field $B_{\rm ext}$ ("dish antenna" concept [68]) giving a signal power of

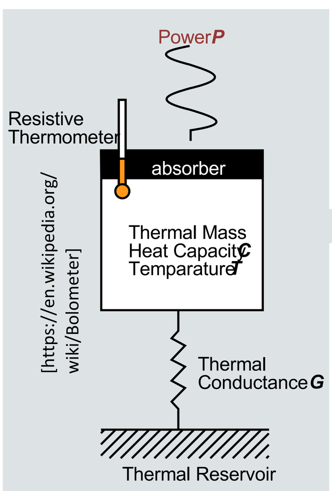


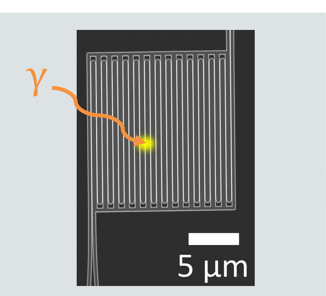
$$P_{\rm sig} = 1 \cdot 10^{-25}\,{\rm W} \cdot \left(\frac{A_{\rm dish}}{10\,{\rm m}^2}\right)\left(\frac{B_{\rm ext}}{10\,{\rm T}}\right)^2 \times \left(\frac{\rho_{\rm DM}}{0.45\,{\rm GeV\,cm^{-3}}}\right)\left(\frac{g_{a\gamma\gamma}}{3.9\cdot 10^{-16}\,{\rm GeV}^{-1}}\right)^2\left(\frac{1\,\mu{\rm eV}}{m_a}\right)^2$$

ρ_{DM}: Local Dark Matter Density, $g_{a\gamma\gamma}$: Axion-Photon-Coupling, m_a: Axion Mass

② Our design uses a cylindrical metallic surface and a **parabolic surface of revolution (reflector)** to focus the generated radiation. This allows using a **solenoid magnet**, drastically simplifying magnet design and reducing cost compared to other designs [68-73].

③ A **photosensor** is placed at the focus. Candidates for different photon energy ranges E are

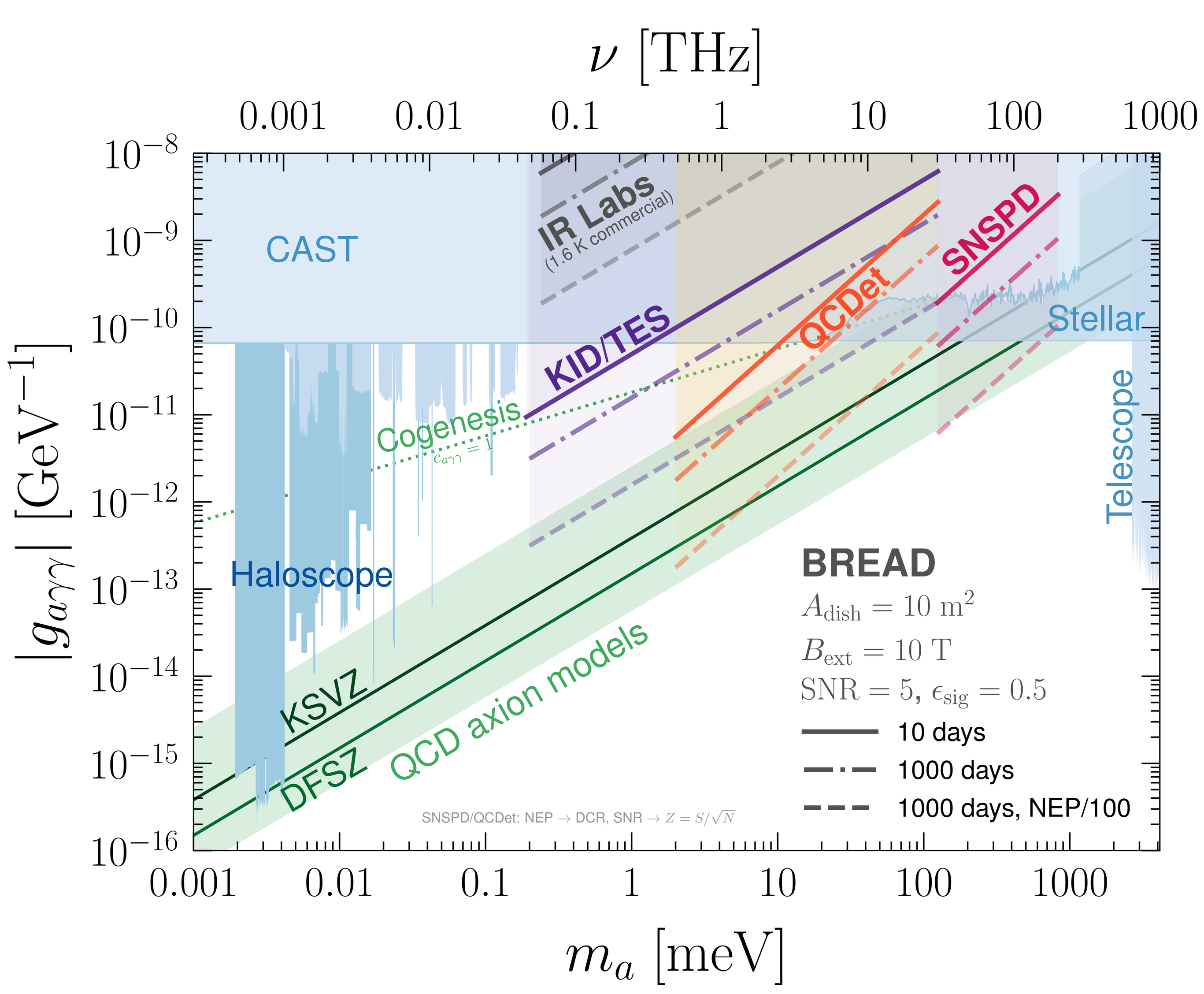




Photosensor	E meV	$T_{\rm op}$ K	NEP W/$\sqrt{\rm Hz}$	$A_{\rm sens}$ mm^2
Bolometers				
GENTEC [97]	[0.4, 120]	293	$1 \cdot 10^{-8}$	$\pi 2.5^2$
IR LABS [98]	[0.24, 248]	1.6	$5 \cdot 10^{-14}$	1.5^2
KID/TES [99, 100]	[0.2, 125]	0.3	$2 \cdot 10^{-19}$	0.2^2
Single Photon Counters				
QCDet [101, 102]	[2, 125]	0.015	$\frac{\rm DCR}{\rm Hz} = 4$	0.06^2
SNSPD [103, 104]	[124, 830]	0.3	$\frac{\rm DCR}{\rm Hz} = 10^{-4}$	0.4^2

$T_{\rm op}$: Operating Temperature, NEP: Noise Equivalent Power, $A_{\rm sens}$: Sensor Area, DCR: Dark Count Rate

For a 3-year experiment with a signal-to-noise ratio (SNR) of 5 and 50% efficiency the single photon detectors are **sensitive to QCD axions above ~meV.**



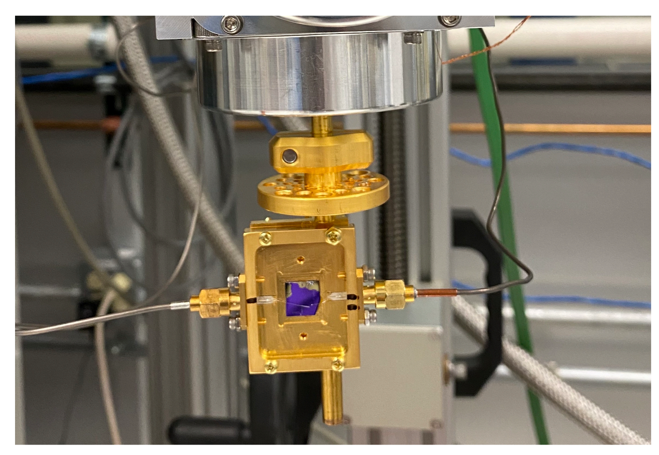
Full-wave simulation of GigaBREAD featured on the 2022 April issue of Physical Review Letters.

Pilot Experiments

Pilot Experiments in the microwave (**GigaBREAD**) and infrared (**InfraBREAD**) ranges are in preparation at the University of Chicago and Fermilab.

GigaBREAD antenna horn:

InfraBREAD SNSPD:



Conclusions

BREAD is a promising concept to discover **axions** in a **broad mass range around ~meV** within the next decade. First pilot experiments are in preparation.

Acknowledgements & References: For detailed authorlist and references please see https://doi.org/10.1103/PhysRevLett.128.131801 or https://arxiv.org/abs/2111.12103.