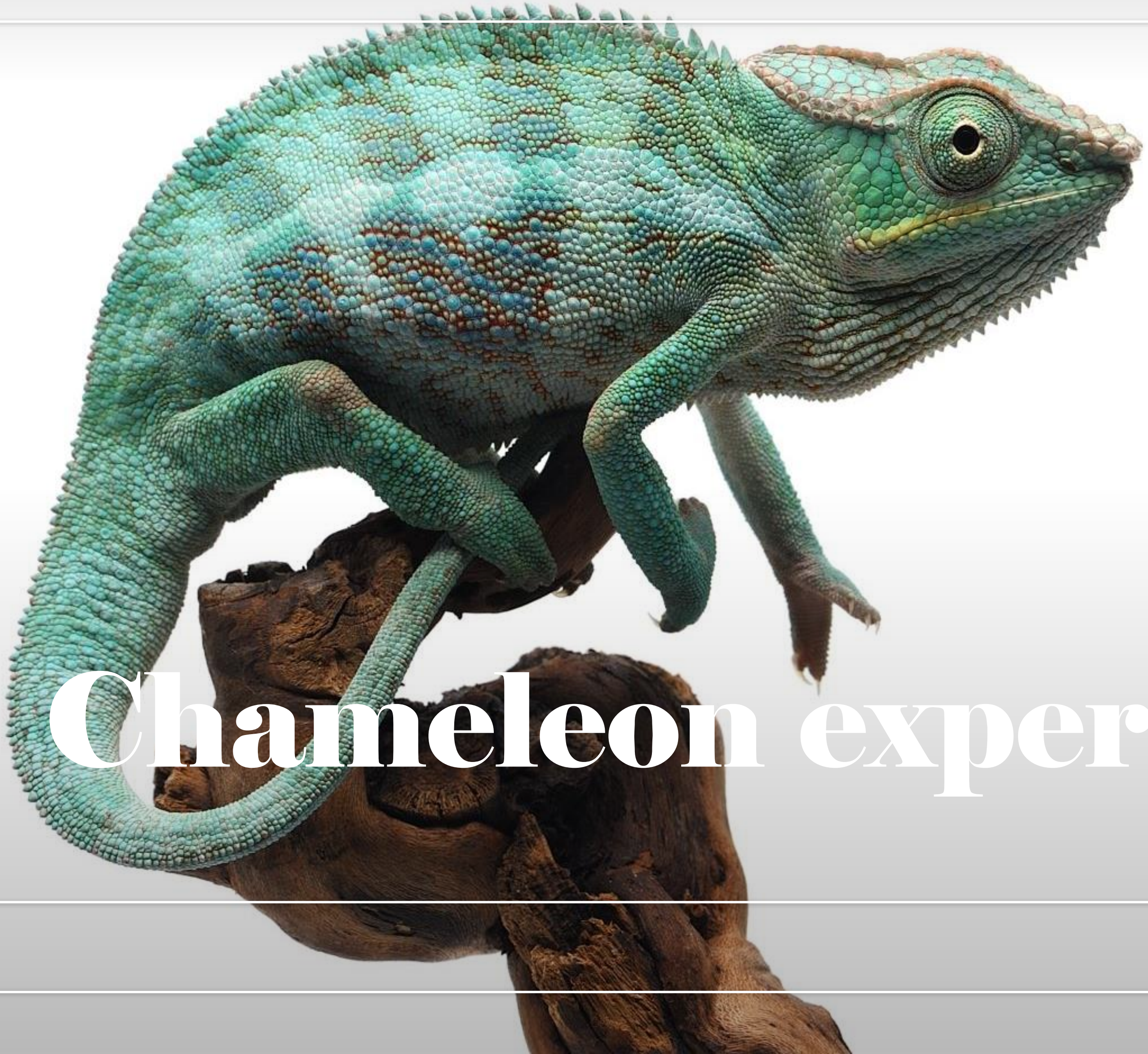
@CAST



Chameleon experiments

MARIN KARUZA, FACULTY OF PHYSICS,
UNIVERSITY OF RIJEKA, COST, NOV. 2023

Chameleons

$$V_{eff}(\phi) = \Lambda^4\left(1 + \frac{\Lambda^n}{\phi^n}\right) + \rho_m e^{\frac{\beta_m \phi}{M_{Pl}}} + \frac{1}{4} F_{\mu\nu} F^{\mu\nu} e^{\frac{\beta_\gamma \phi}{M_{Pl}}}$$

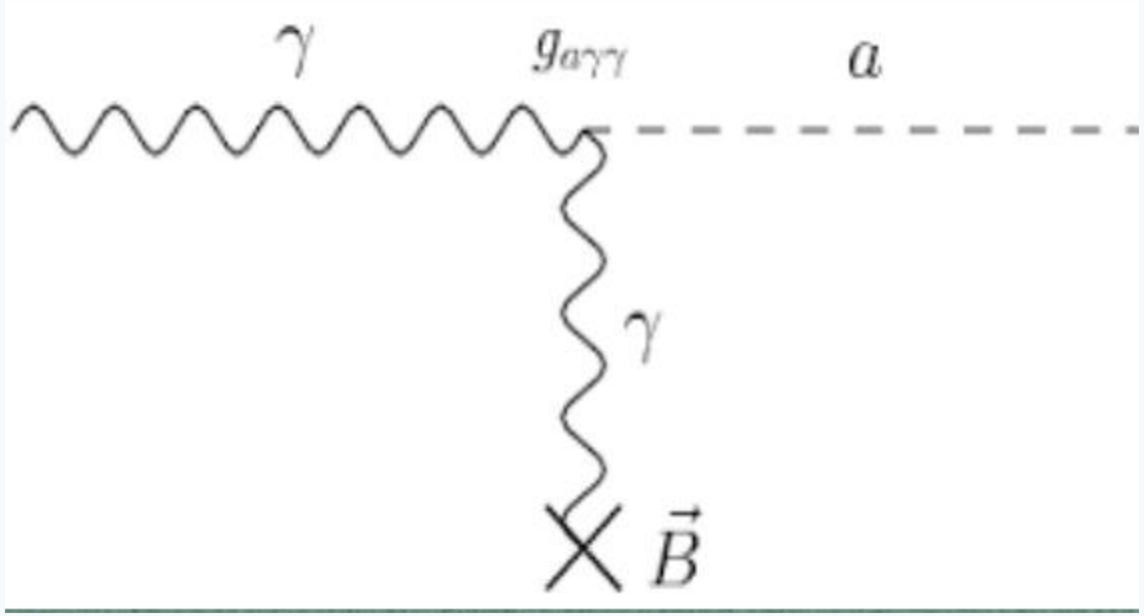
$$m = \left(n(n+1)\frac{\Lambda^{n+4}}{\phi_{min}^{n+2}}\right)^{1/2}$$

$$\phi_{min} = \left(\frac{n\Lambda^{n+4} M_{Pl}}{\rho_m \beta_m}\right)^{1/(n+1)}$$

MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

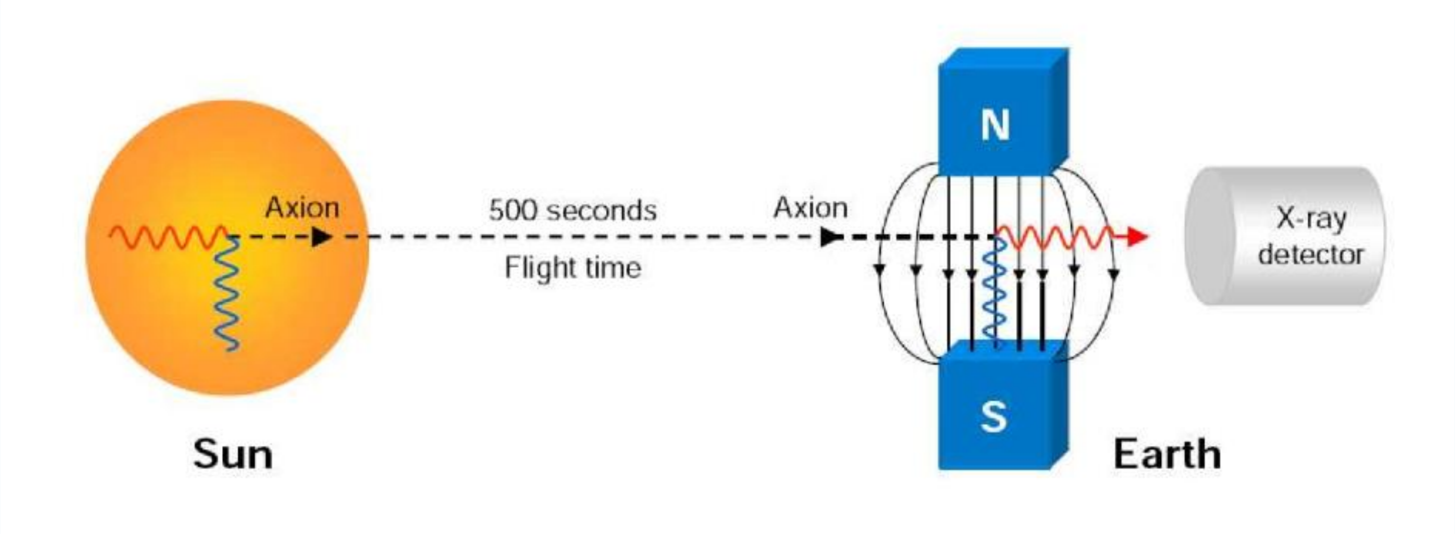
Primakoff effect

- Axion
- Chameleon
- ...



MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

CAST is searching for solar _____ using the inverse Primakoff effect

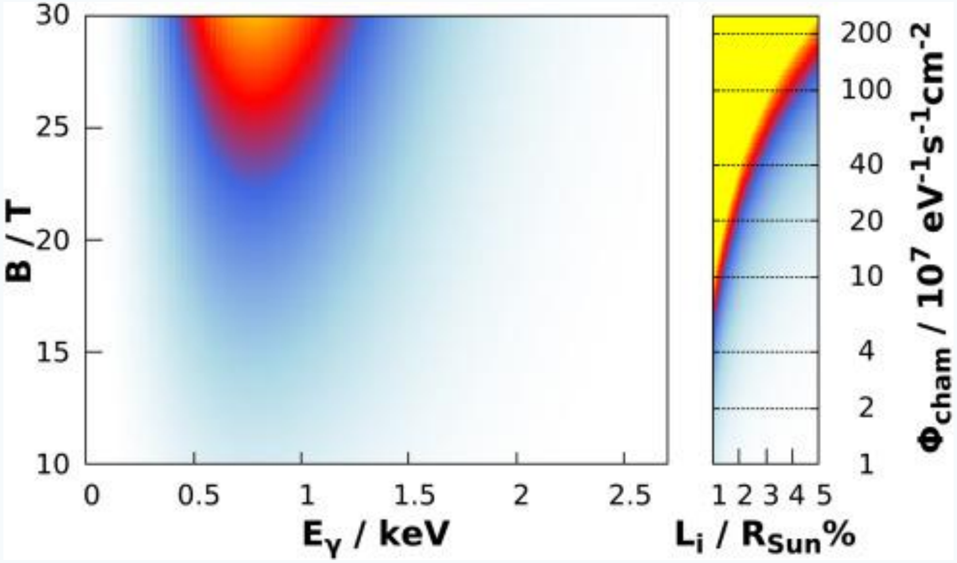


Photons in the sun are converted to ____ via the Primakoff effect

Back-conversion of ____ into x-ray photons in a strong magnetic field via the inverse Primakoff effect

P. Sikivie, PRL 51, 1415-1417 (1983)

Production (in tachocline)



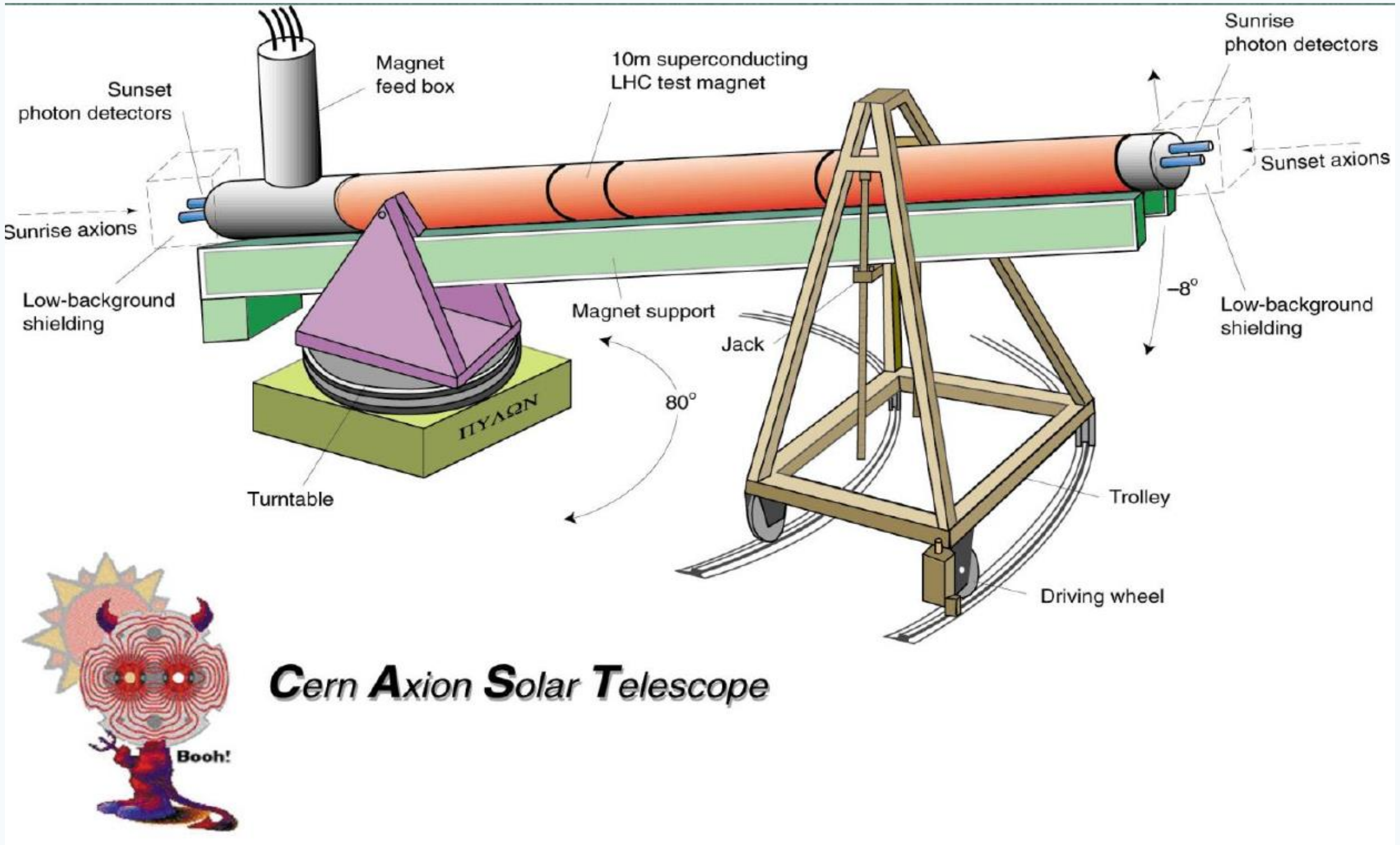
Solar evolution constrains the total exotica flux to less than 10%

Fig. 3. A calculation of the chameleon flux at Earth. The interaction region length is taken in its uncertainty interval from 1% to 5% of solar radius. For a given pair of energy and field values in the left plot, the corresponding colour in the right plot provides the range of fluxes for various interaction region lengths.

Magnet

MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

CAST (-8 to + 8 deg –> 2x5000 s/day)

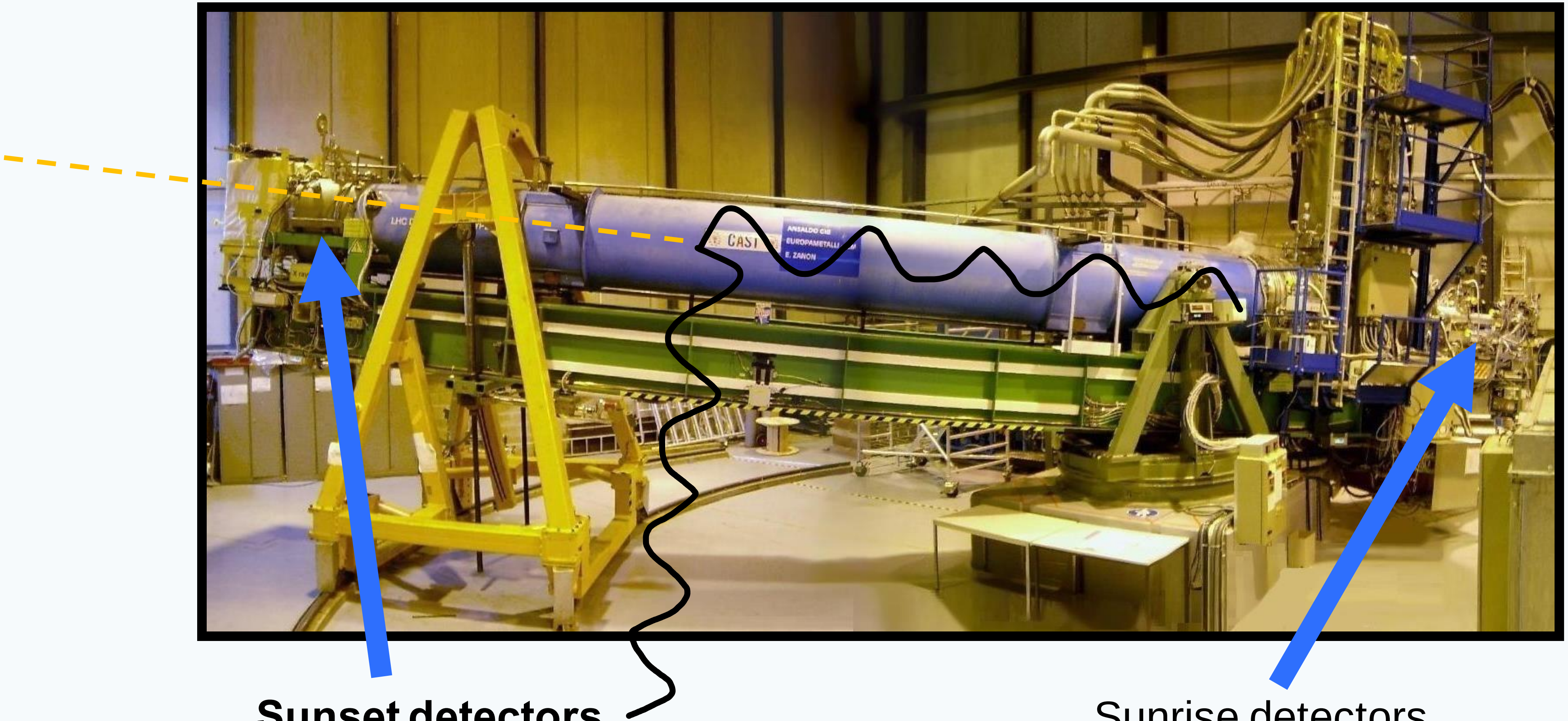


MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

Arrival at Earth

MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

How? The CAST Cern Axion Solar Telescope



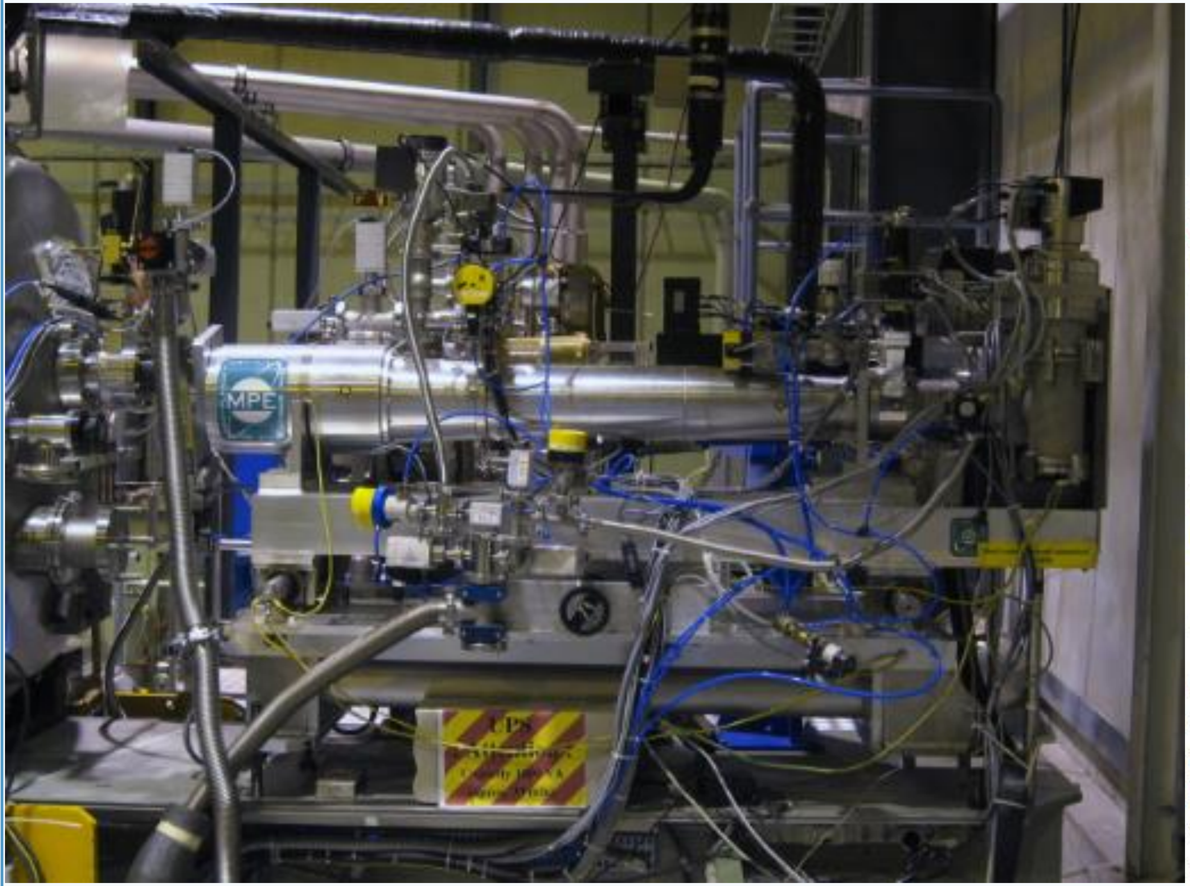
Sunset detectors

Sunrise detectors

2 MicroMegas
Detectors

Up to 2013: MicroMegas, CCD & MPE XRT
Since 2014: MicroMegas & LLNL XRT,
InGrid & MPE XRT , KWISP

Telescope



New Journal of Physics
The open-access journal for physics

The x-ray telescope of CAST

M Kuster[1,2,13], H Bräuninger[2], S Cebrián[3], M Davenport[4], C Eleftheriadis[5], J Englhauser[2,12], H Fischer[6], J Franz[6], P Friedrich[2], R Hartmann[7,8], F H Heinsius[6,12], D H H Hoffmann[9], G Hoffmeister[1], J N Joux[4], D Kang[6], K Königsmann[6], R Kotthaus[10], T Papaevangelou[4], C Lasseur[4], A Lippitsch[4], G Lutz[8,10], J Morales[3], A Rodríguez[3], L Strüder[8,2], J Vogel[6] and K Zioutas[4,11]

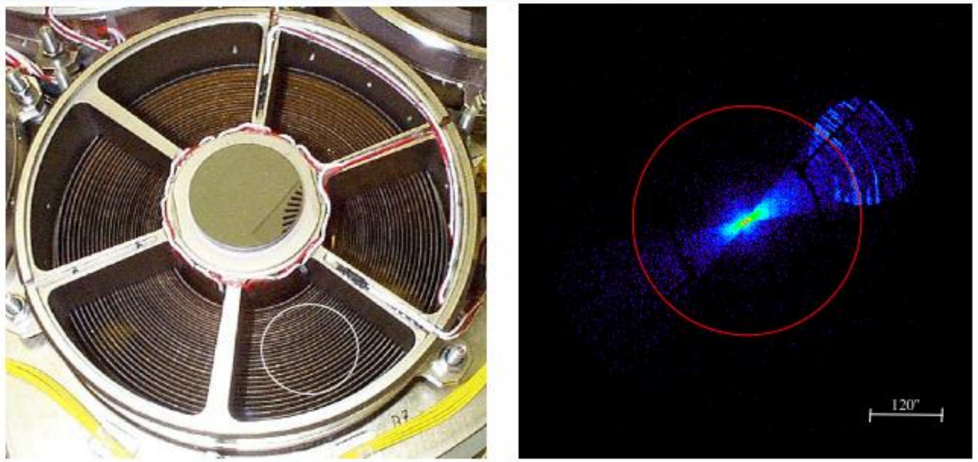
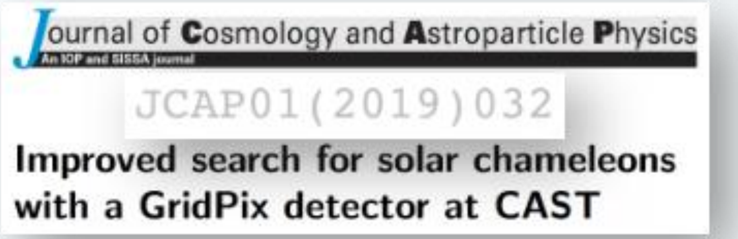
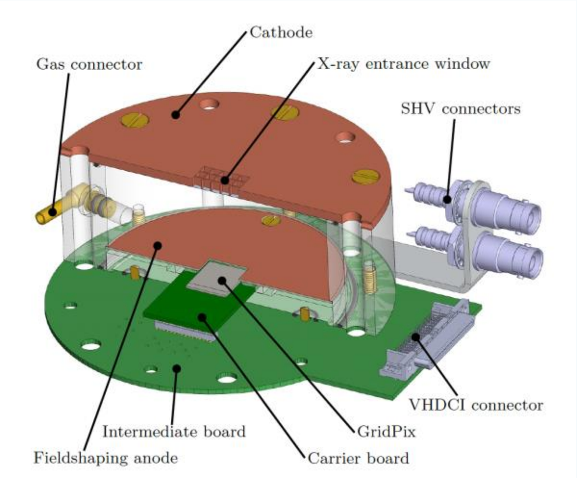
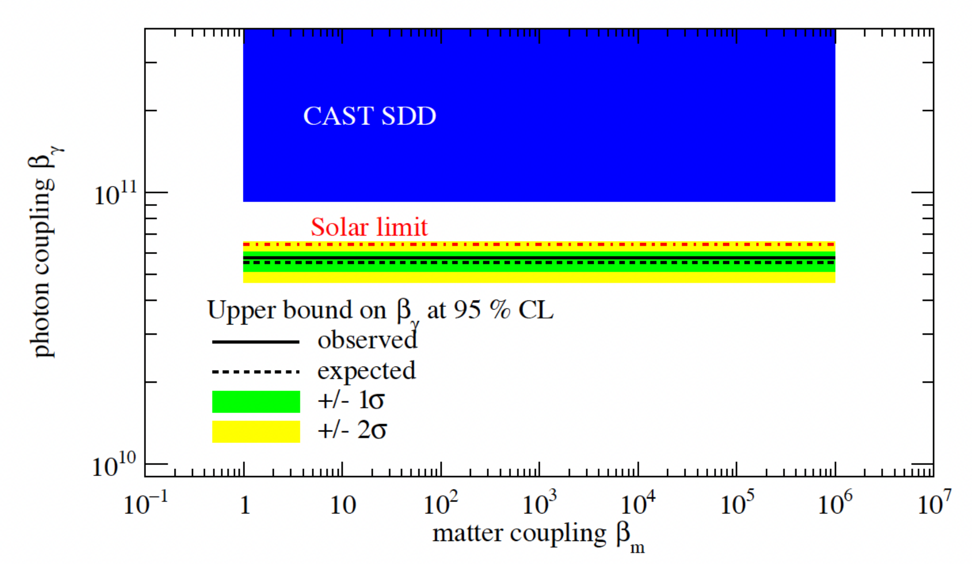


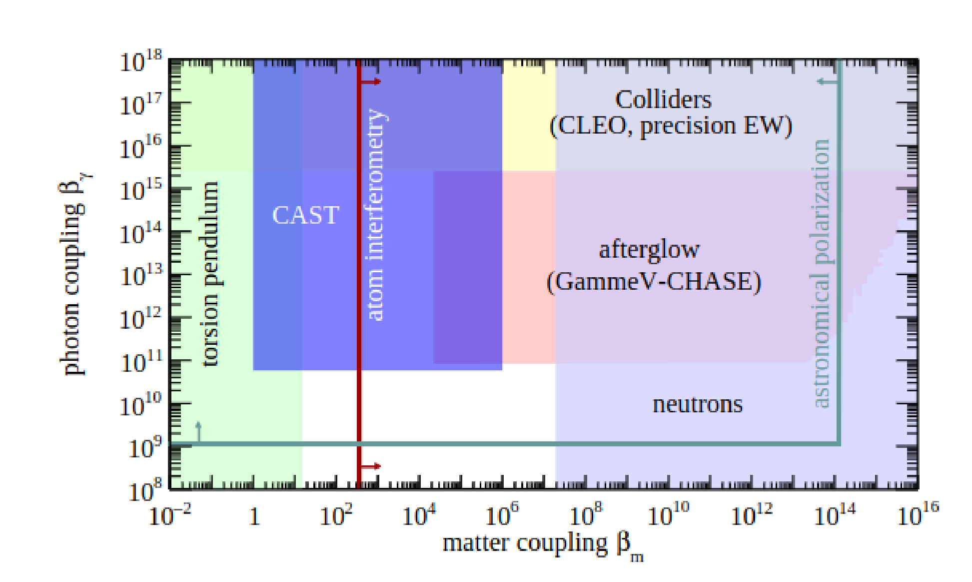
Figure 3. Left panel: front view of the mirror system. The individual mirror shells and the supporting spoke structure are shown. One of the six sectors is illuminated through the magnet bore, the approximate size of the magnet bore is indicated by the white circle. Right panel: logarithmic intensity image of a nearly parallel x-ray beam measured with one mirror sector at the PANTER test facility at an energy of 1.5 keV. For comparison, the red circle indicates the expected spot size of the solar axion signal. Due to the fact that the x-ray source is at a finite distance ($d \approx 130$ m), photons reflected by only one of the parabolic or hyperbolic shaped surfaces are apparent in the image (circular shaped region towards the top right).

Photon coupling


Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal
JCAP01(2019)032
Improved search for solar chameleons with a GridPix detector at CAST







KWISP

Exotic particles

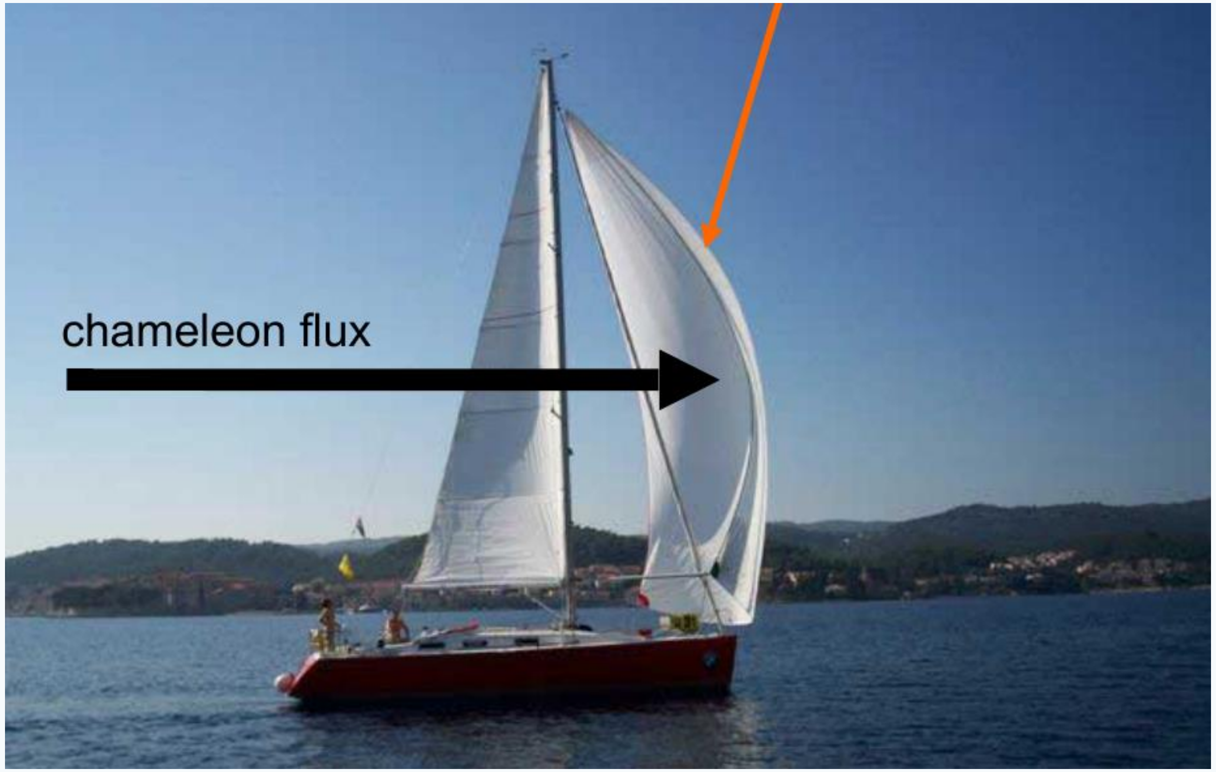
Luca Nagel/CAST

Giovanni Cantatore and Marin Karuza in front of the CAST magnet, holding the heart of the KWISP force sensor: nanomembranes to detect the direct coupling of exotic particles to matter.

CAST: enlightening the dark

MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

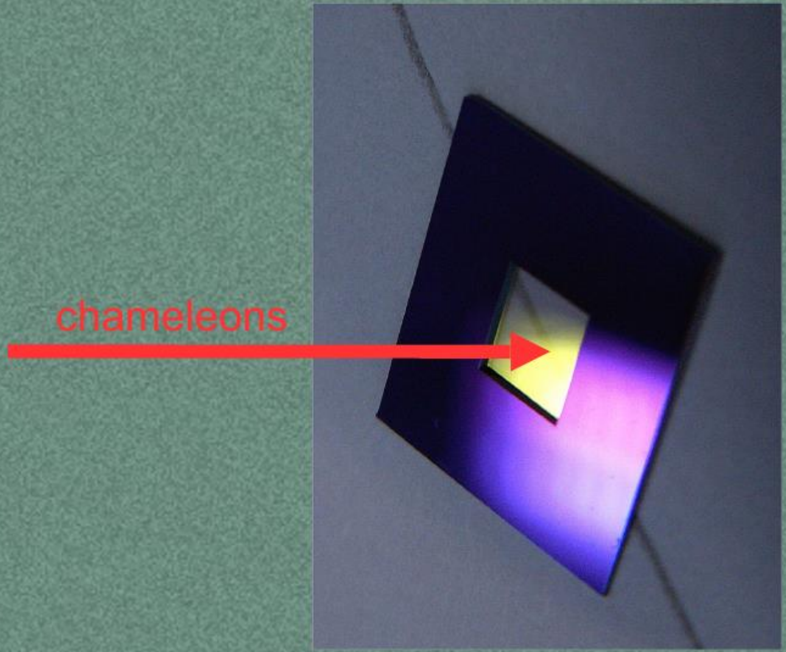
Detection



$$m = \left(n(n+1)\frac{\Lambda^{n+4}}{\phi_{min}^{n+2}}\right)^{1/2}$$

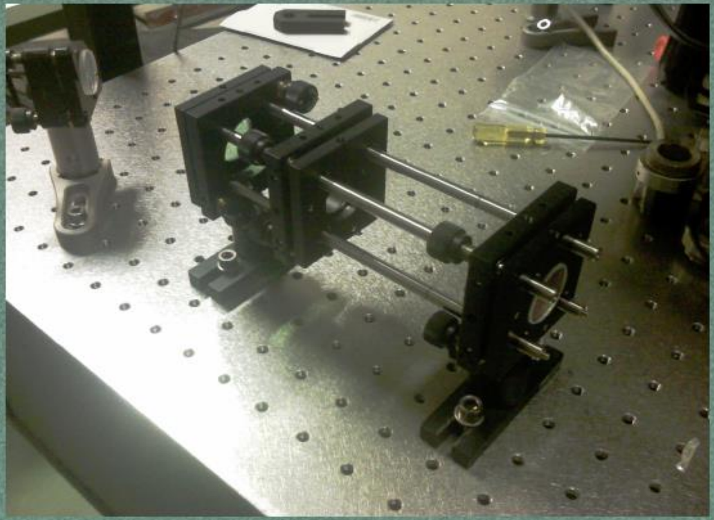
$$\phi_{min} = \left(\frac{n\Lambda^{n+4}M_{Pl}}{\rho_m\beta_m}\right)^{1/(n+1)}$$

Sensing element



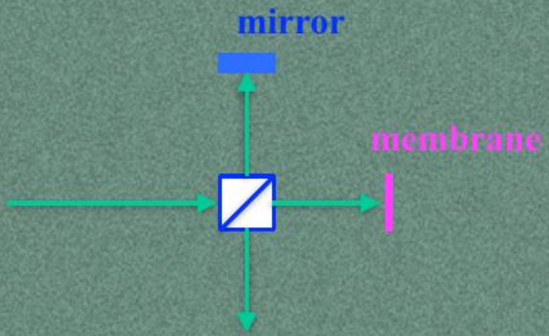
- Use thin stoichiometric silicon nitride membrane as a sensing element
- Commercially available
- "large" area, up to 5x5 mm
- Transparent @1064 nm
- Density ~ 3 g/cm^3
- Can be coated with metal
- High stress
- High resonant frequency
- High mechanical Q ~ 10^6

Sensing strategy

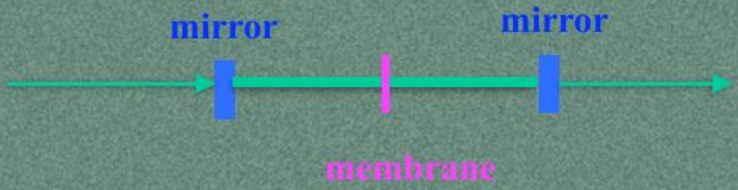


Information on membrane position

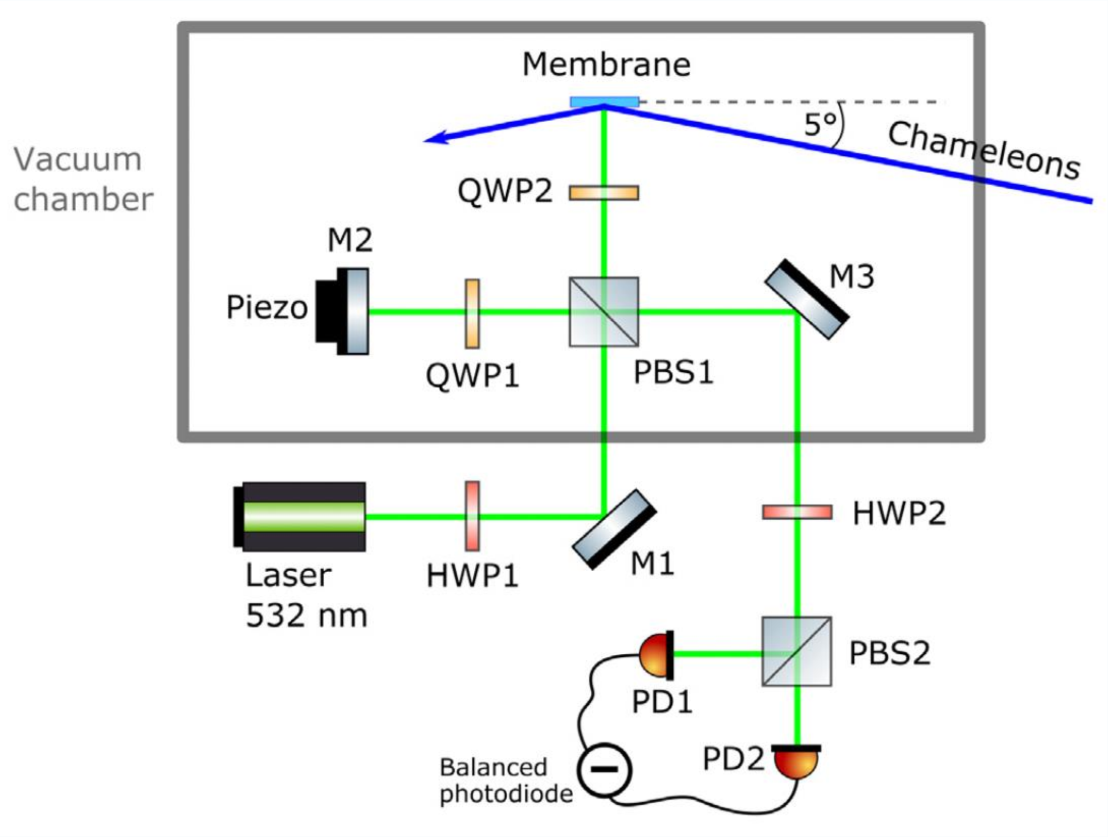
- Michelson interferometer

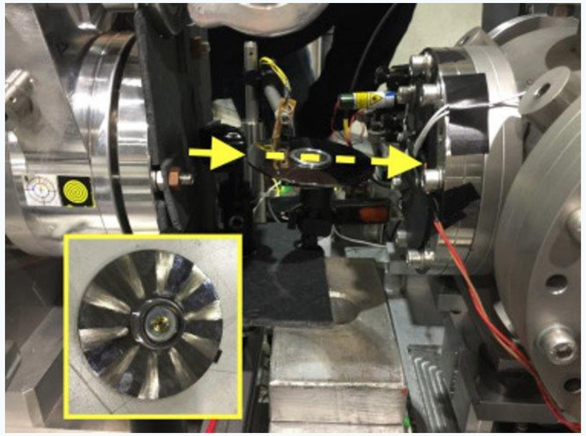


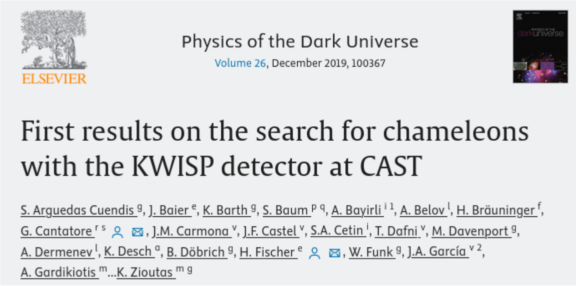
- Fabry – Perot cavity



KWISP @ CAST



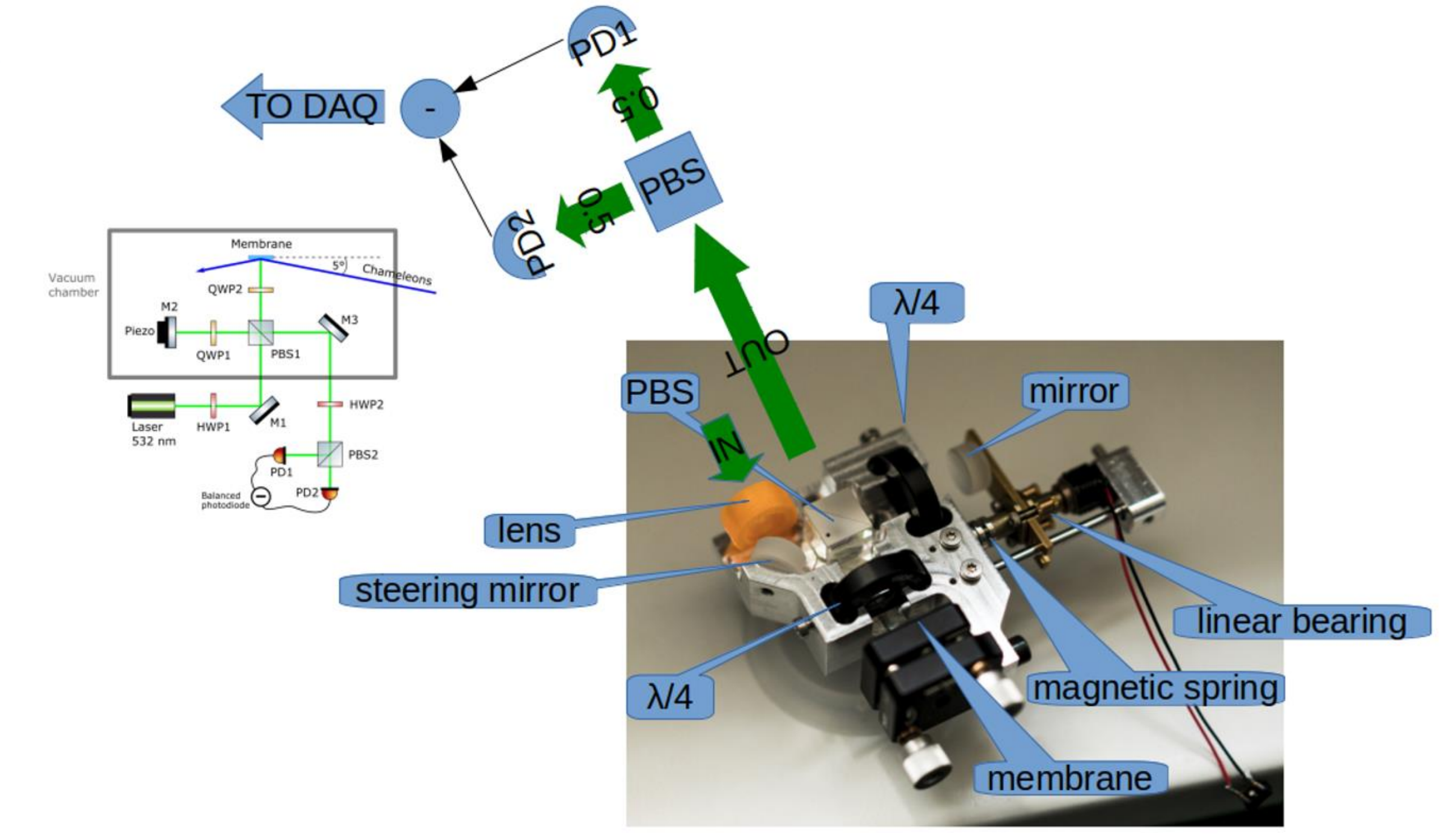




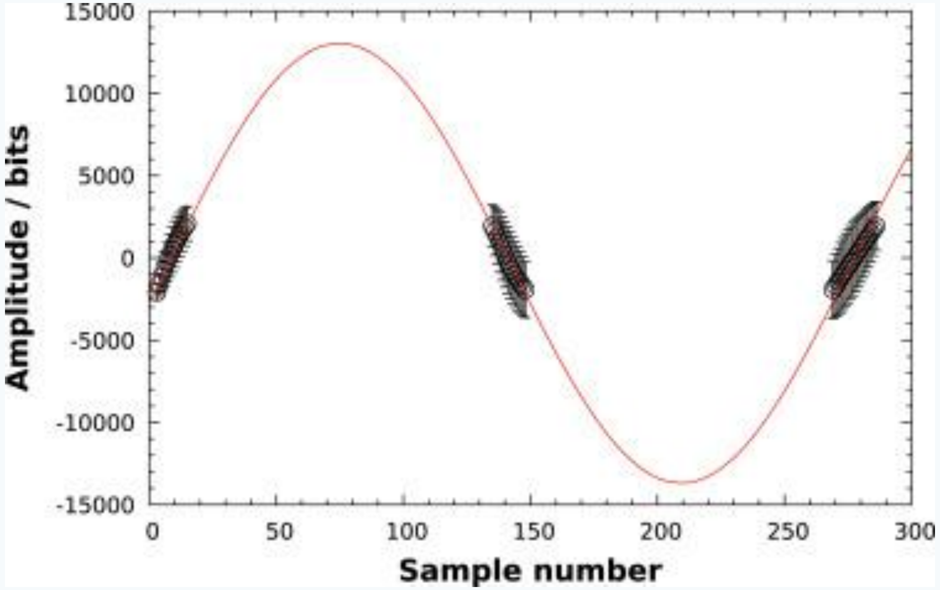
ELSEVIER
Physics of the Dark Universe
Volume 26, December 2019, 100367

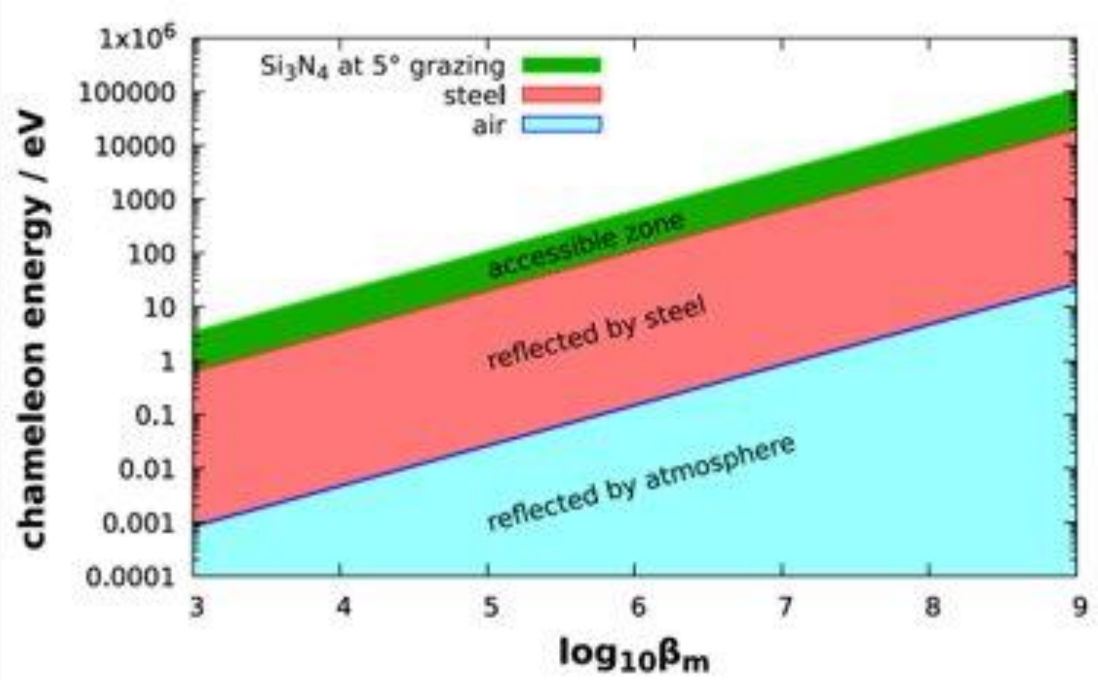
First results on the search for chameleons with the KWISP detector at CAST

S. Arguedas Cuendis [g], J. Baier [e], K. Barth [g], S. Baum [p q], A. Bayirli [i 1], A. Belov [l], H. Bräuninger [f], G. Cantatore [r s], J.M. Carmona [v], J.F. Castel [v], S.A. Cetin [i], T. Dafni [v], M. Davenport [g], A. Dermenev [l], K. Desch [a], B. Döbrich [g], H. Fischer [e], W. Funk [g], J.A. García [v 2], A. Gardikiotis [m]…K. Zioutas [m g]


TO DAQ
-
PD1
0.5
PBS
PD2
0.5
OUT
IN
Membrane
Vacuum chamber
5°
Chameleons
QWP2
M2
Piezo
QWP1
PBS1
M3
Laser 532 nm
HWP1
M1
HWP2
PBS2
PD1
PD2
Balanced photodiode
λ/4
mirror
PBS
lens
steering mirror
linear bearing
λ/4
magnetic spring
membrane

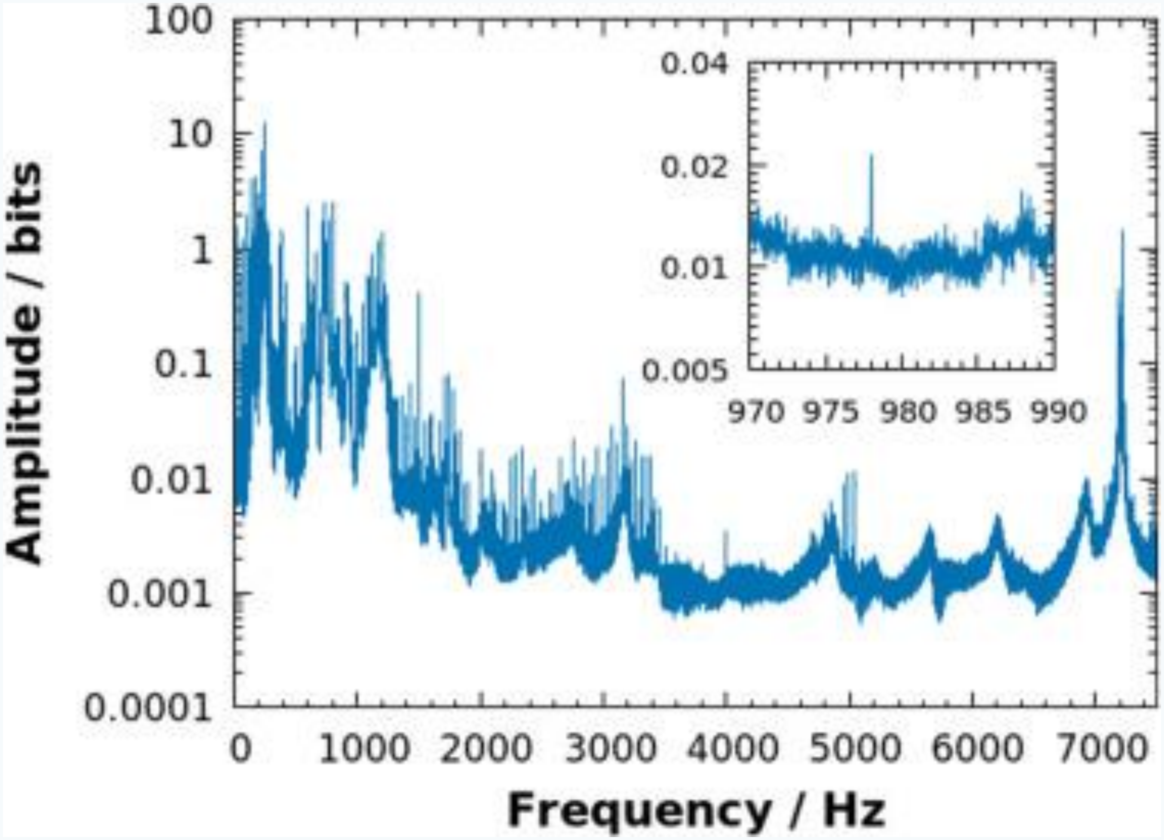
Calibration





MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

Measurements



Force sensitivity

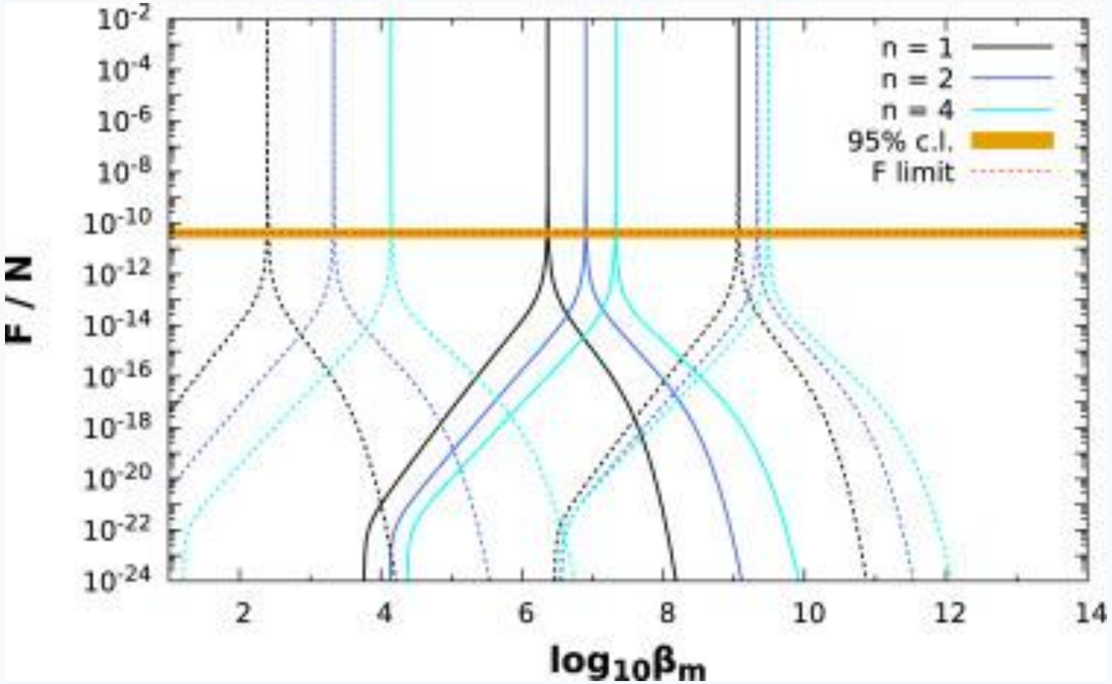
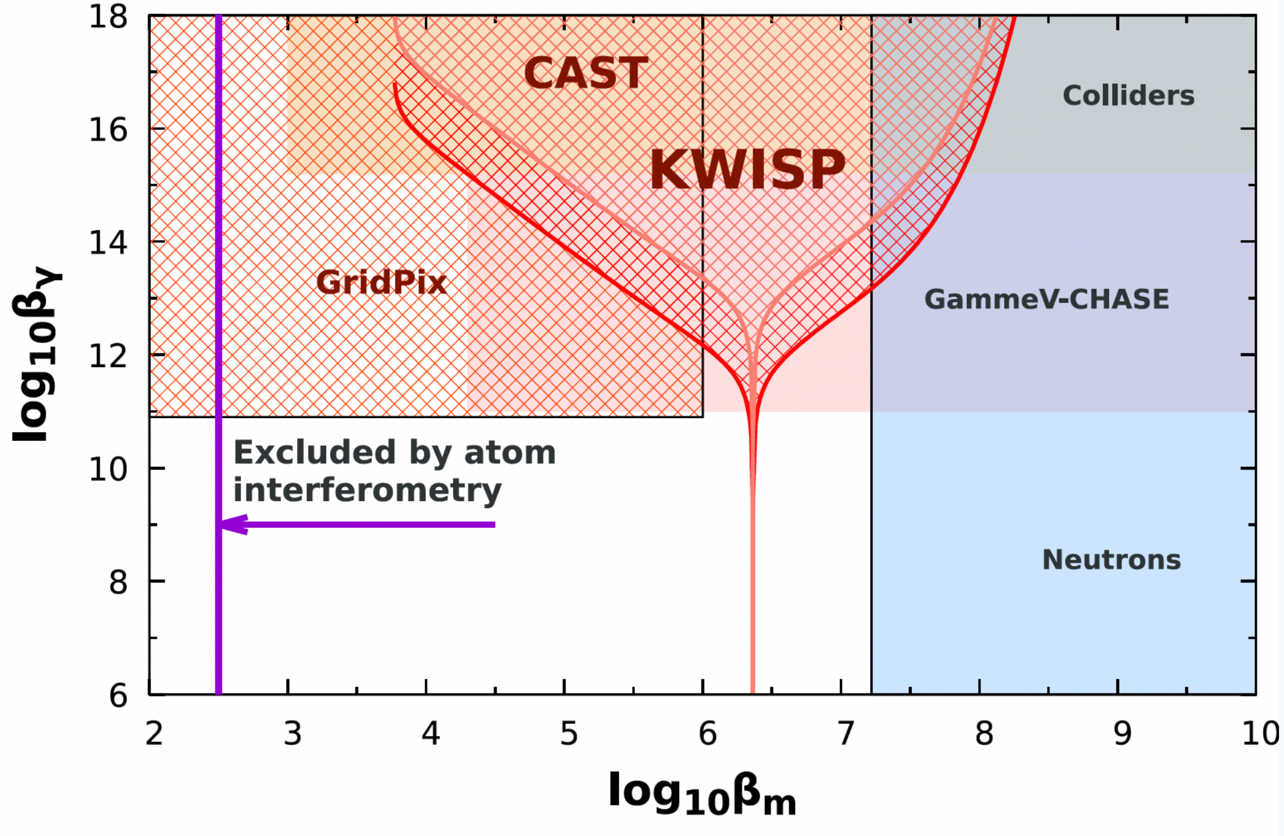
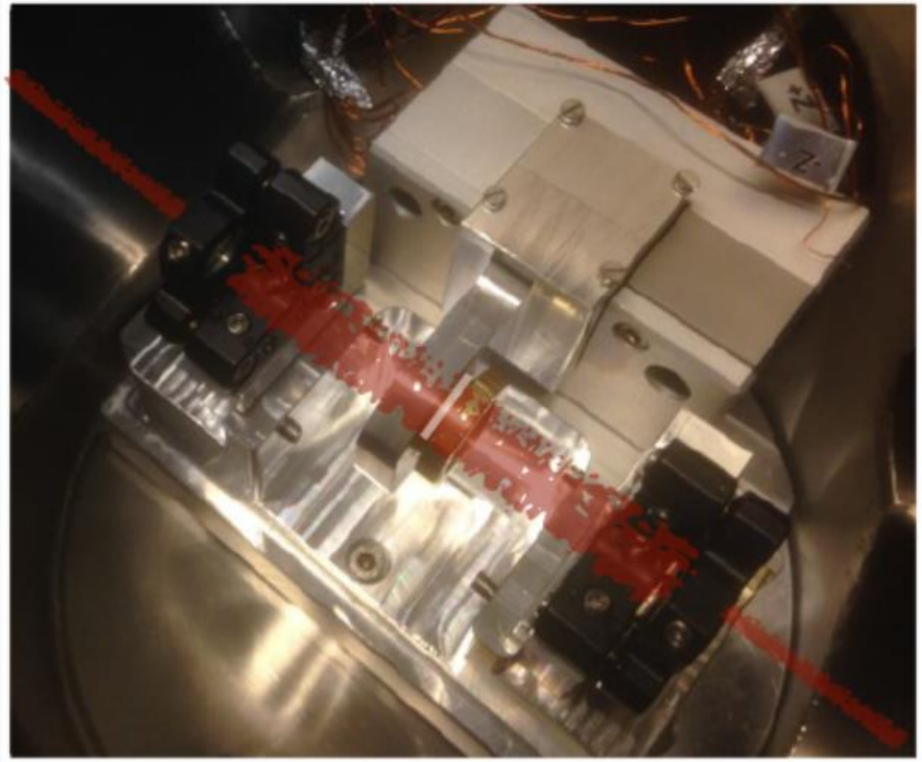


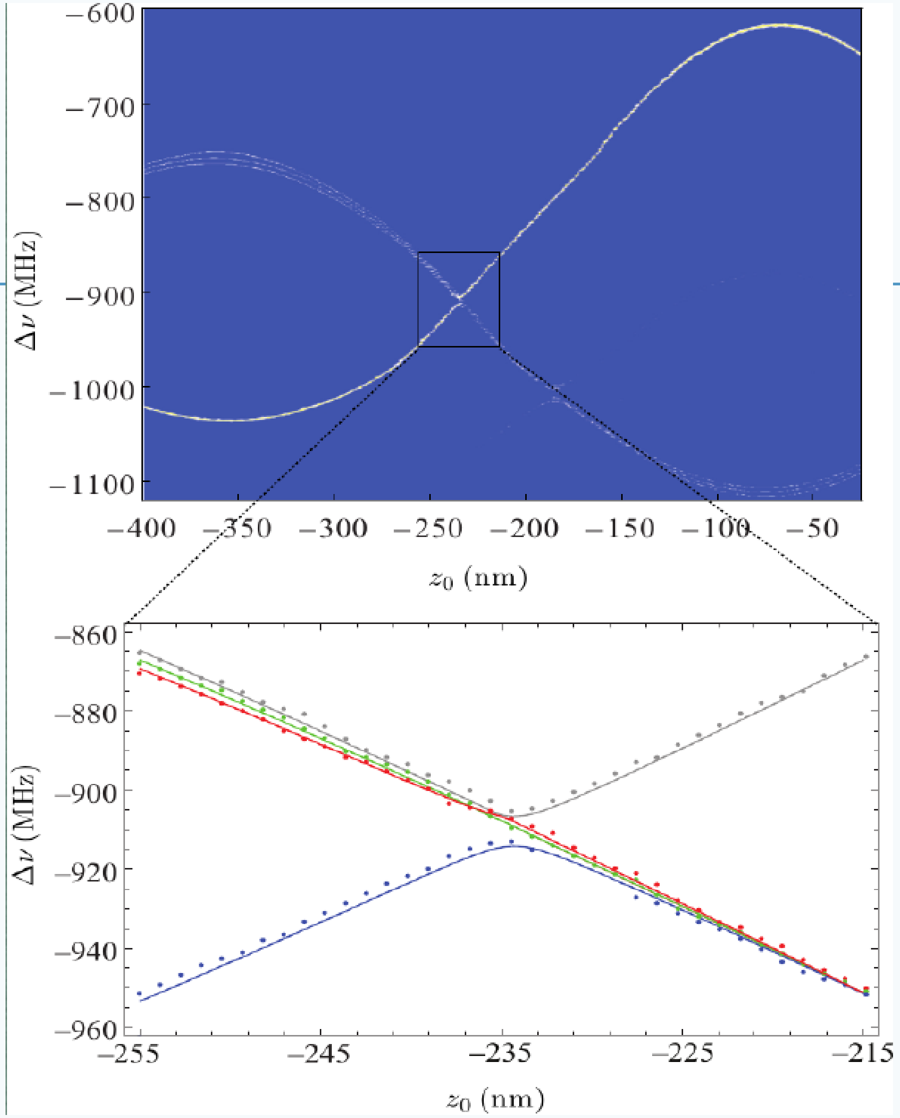
Fig. 11. Expected force at the sensor calculated from the solar chameleon flux assuming $\beta_\gamma = 10^{10.32}$, interaction zone length $L_i = 0.05 \cdot R_{Sun}$ and detector parameters. Solid lines correspond to a dark energy scale $\Lambda = 2.4 \cdot 10^{-3}$ eV, dashed ones to $\Lambda = 1 \cdot 10^{-5}$ eV, and dotted lines to $\Lambda = 0.1$ eV. The interaction zone length is an upper limit according to current Solar models. The flux and consequently the expected force are scaled accordingly for values down to $L_i = 0.01 \cdot R_{Sun}$ while the resonance peak is arbitrarily limited to $F = 10^{-2}$ N by the axis scale. The orange band represents 95% confidence interval centred at the average force value shown by the red dashed line.

KWISP - results

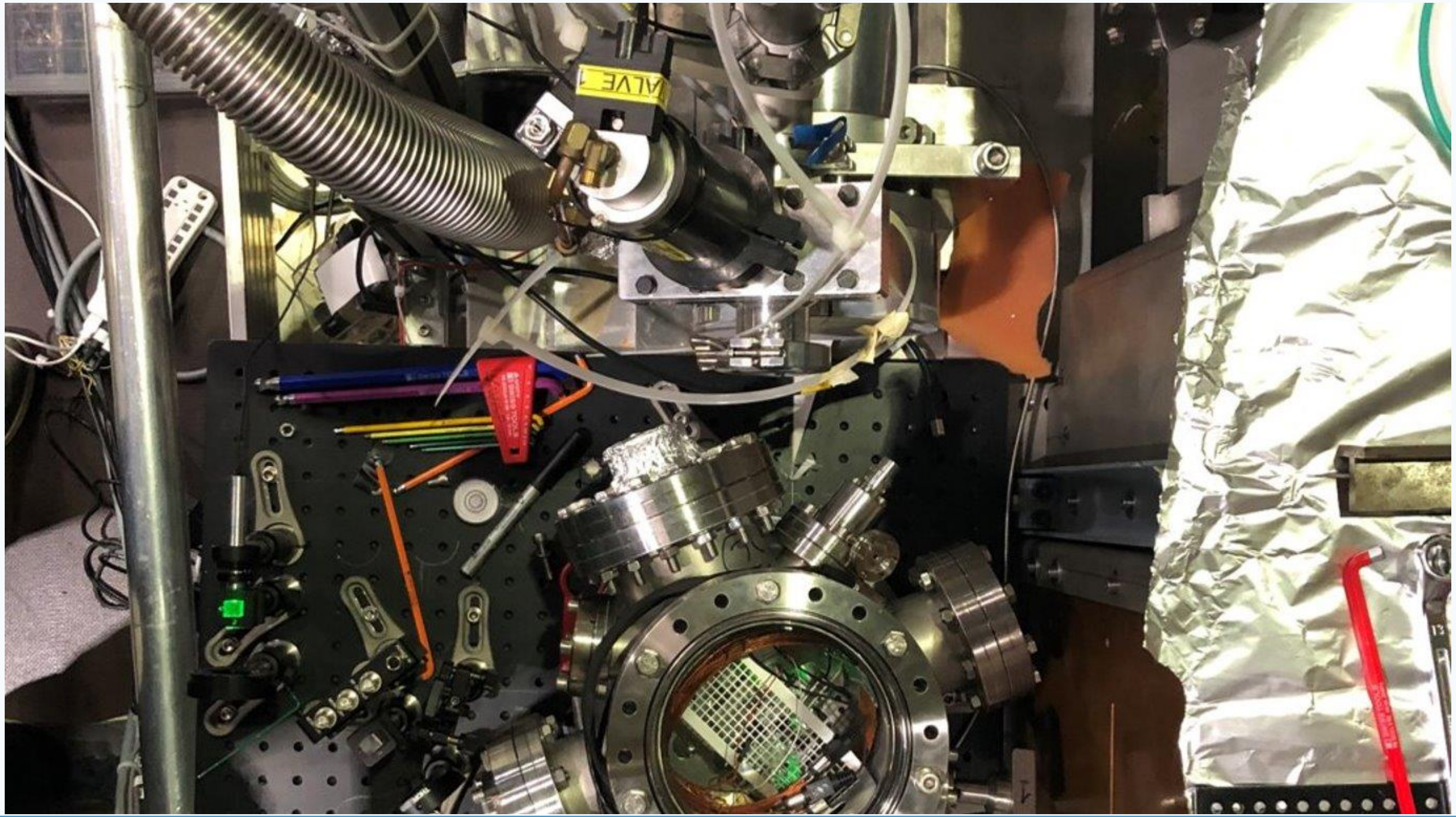


Sensing strategy



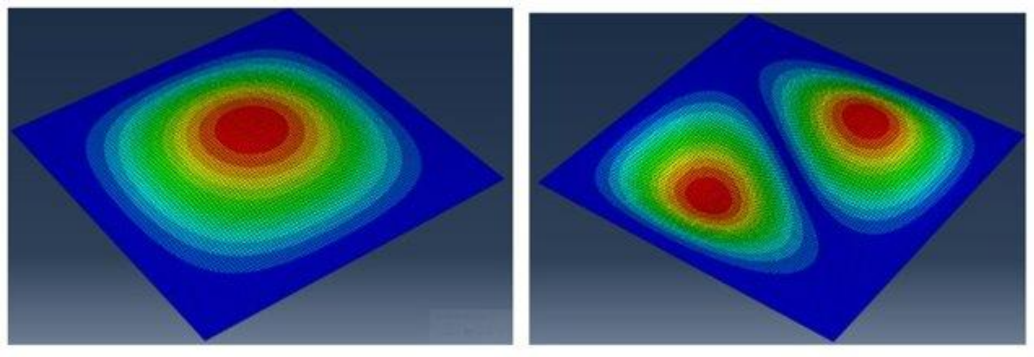


KWISP@CAST



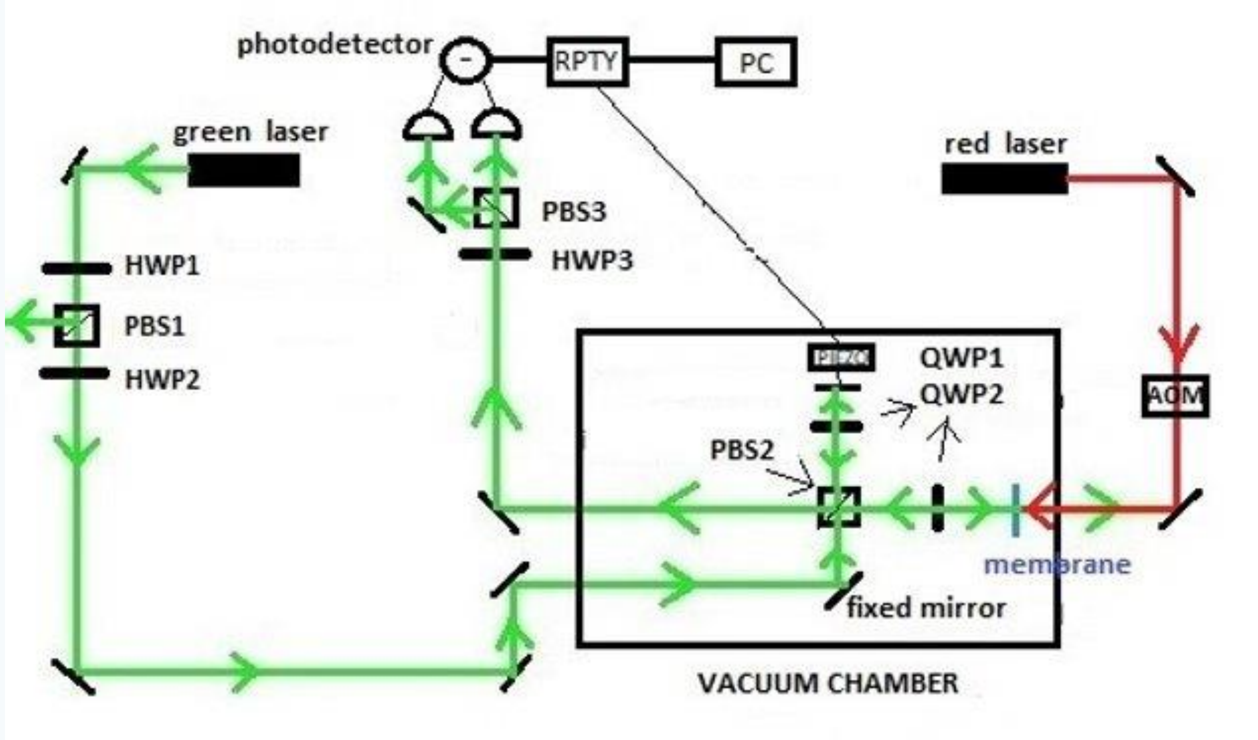
MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

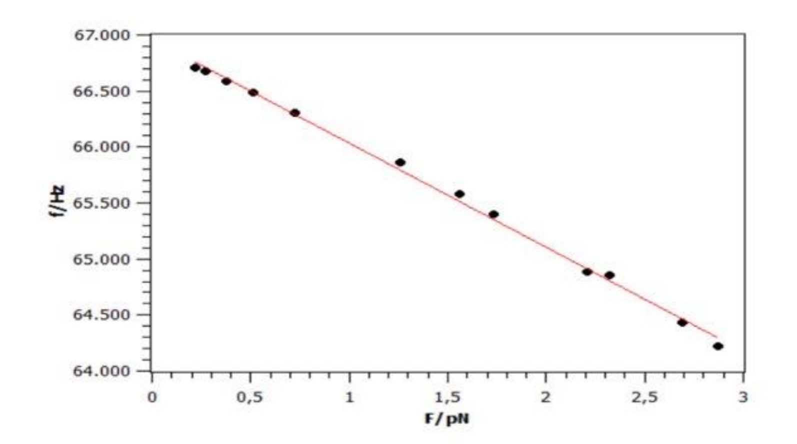
Membranes are special

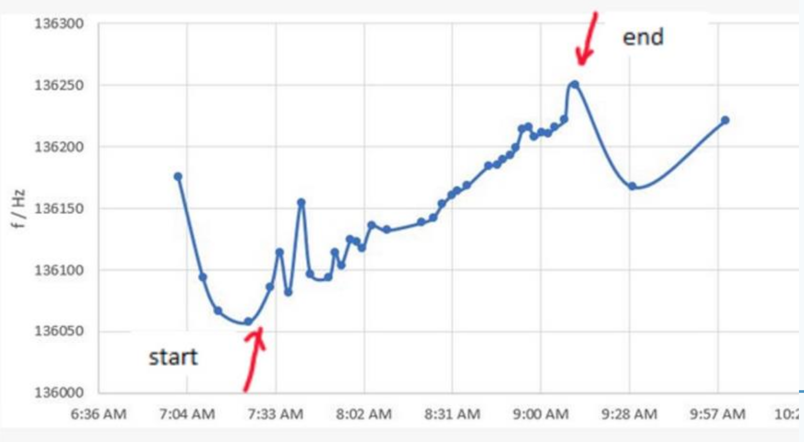


- oscillations thermally excited (F – white noise)
-Brownian motion

Sensing element







MARIN KARUZA, FACULTY OF PHYSICS, UNIVERSITY OF RIJEKA, COST, NOV. 2023

Alternative strategy

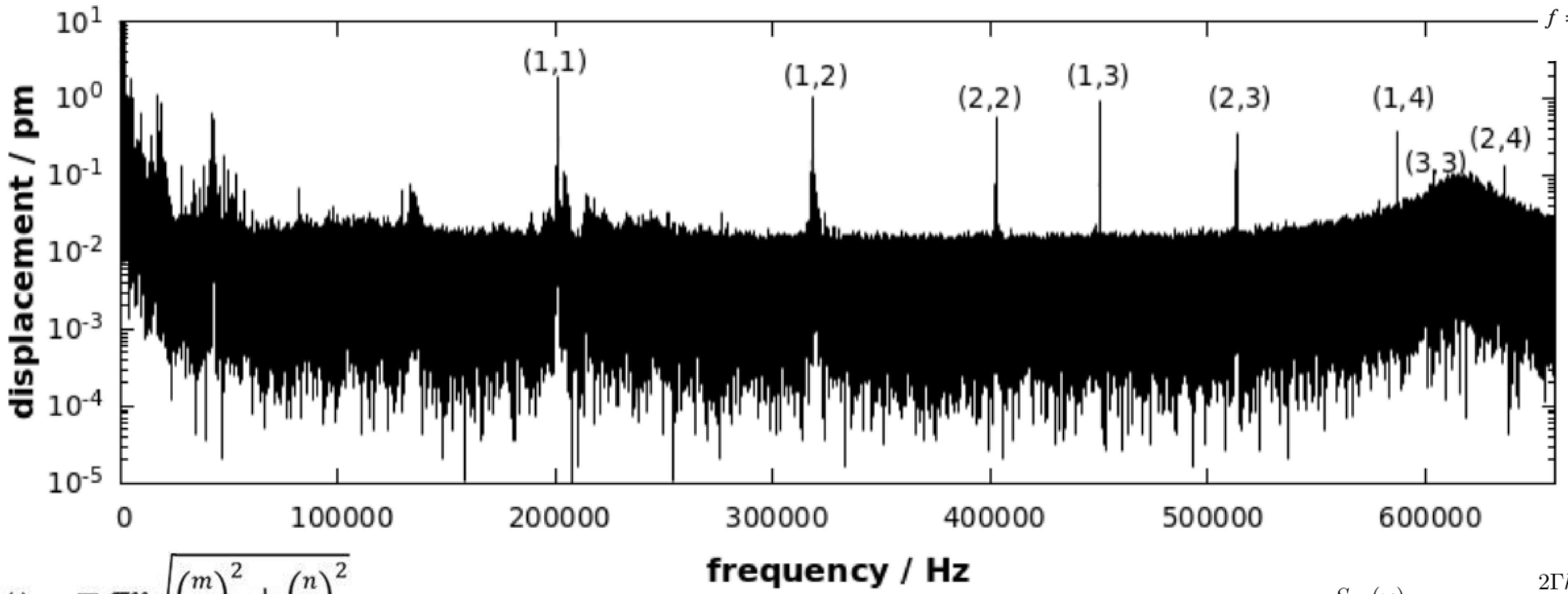
Home > The European Physical Journal C > Article

Dark matter induced Brownian motion

Regular Article – Theoretical Physics | Open access | Published: 10 June 2020 | **80**, Article number: 519 (2020)

$$m\ddot{x} + D\dot{x} + kx = F\ \sin(\omega t)$$

$$f = \frac{\sqrt{2}}{2L}\sqrt{\frac{T}{\rho t}}$$

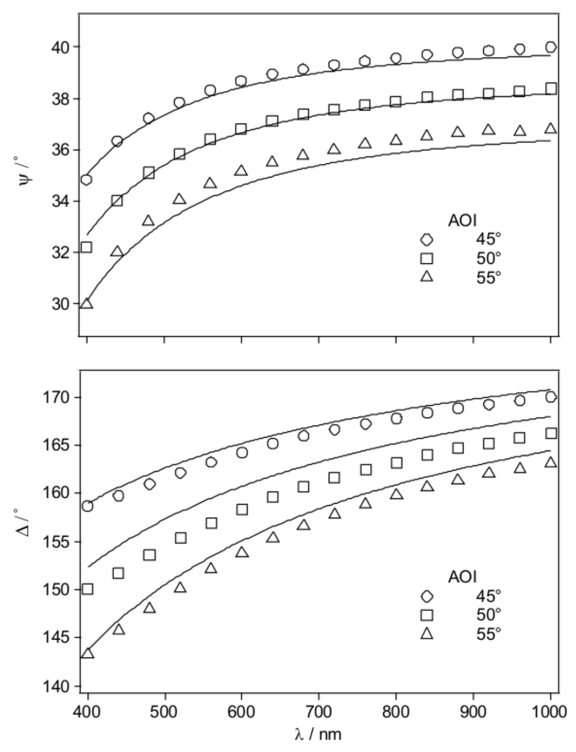


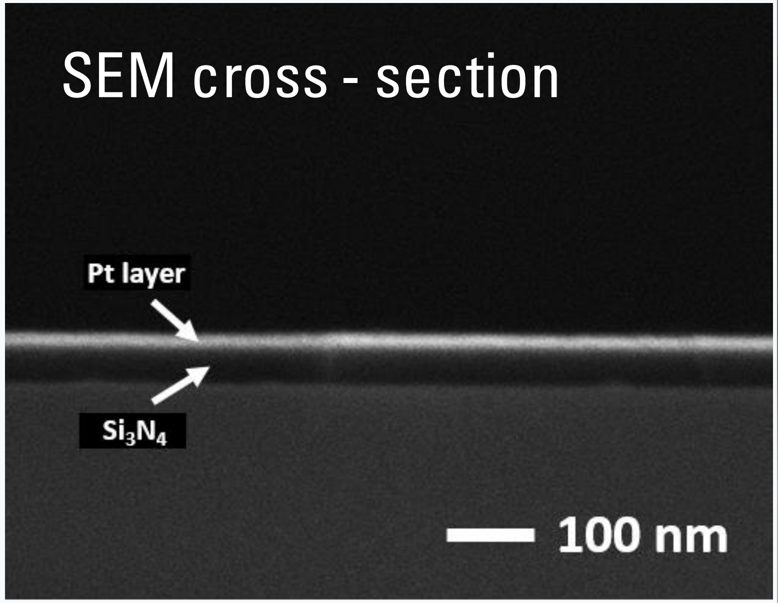
$$\omega_{mn} = \pi v\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$S_{xx}(\omega) = \frac{2\Gamma k_B T}{m\left[(\omega^2_{(n,m)} - \omega^2) + (\Gamma\omega)^2\right]}$$

Step ahead

Ellipsometry 45 nm + 13 Pt





- different thickness from nominal

Experiments

nature physics

LETTERS

https://doi.org/10.1038/s41567-022-01706-9

Check for updates

Experiments with levitated force sensor challenge theories of dark energy

Peiran Yin[1,2,7], Rui Li[2,3,7], Chengjiang Yin[4,5,7], Xiangyu Xu[4,5], Xiang Bian[1], Han Xie[1], Chang-Kui Duan[2,3], Pu Huang[1] ✉, Jian-hua He[4,5] ✉ and Jiangfeng Du[2,3,6] ✉

PHYSICAL REVIEW LETTERS

Highlights Recent Accepted Collections Authors Referees Search Press About Editorial Team

Open Access

Search for Composite Dark Matter with Optically Levitated Sensors

Fernando Monteiro, Gadi Afek, Daniel Carney, Gordan Krnjaic, Jiaxiang Wang, and David C. Moore

Phys. Rev. Lett. **125**, 181102 – Published 28 October 2020

PHYSICAL REVIEW LETTERS

Highlights Recent Accepted Collections Authors Referees Search Press About Editorial Team

Open Access

Search for Composite Dark Matter with Optically Levitated Sensors

Fernando Monteiro, Gadi Afek, Daniel Carney, Gordan Krnjaic, Jiaxiang Wang, and David C. Moore

Phys. Rev. Lett. 125, 181102 – Published 28 October 2020

35

More

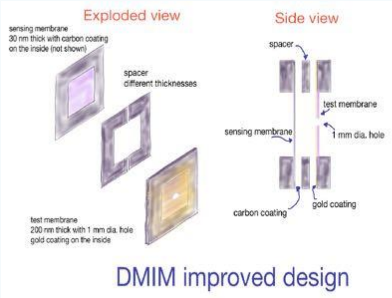
Conclusion and outlook

DARK MATTER DETECTOR

Dark matter induced Brownian motion

Ting Cheng, Reinard Primulando & Martin Spinrath

The European Physical Journal C **80**, Article number: 519 (2020) | Cite this article

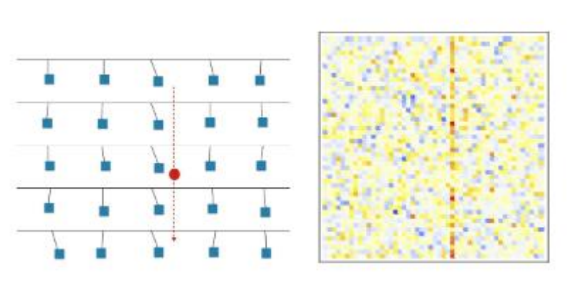


GRAVITATIONAL

PHYSICAL REVIEW D **102,** 072003 (2020)

Proposal for gravitational direct detection of dark matter

Daniel Carney,[1,2,*] Sohitri Ghosh,[1] Gordan Krnjaic,[2] and Jacob M. Taylor[1,†]



QUANTUM COMMUNICATION

QUANTUM OPTOMECHANICAL MEMORY WITH MEMBRANE IN THE MIDDLE