Quantum interferometry for axion searches

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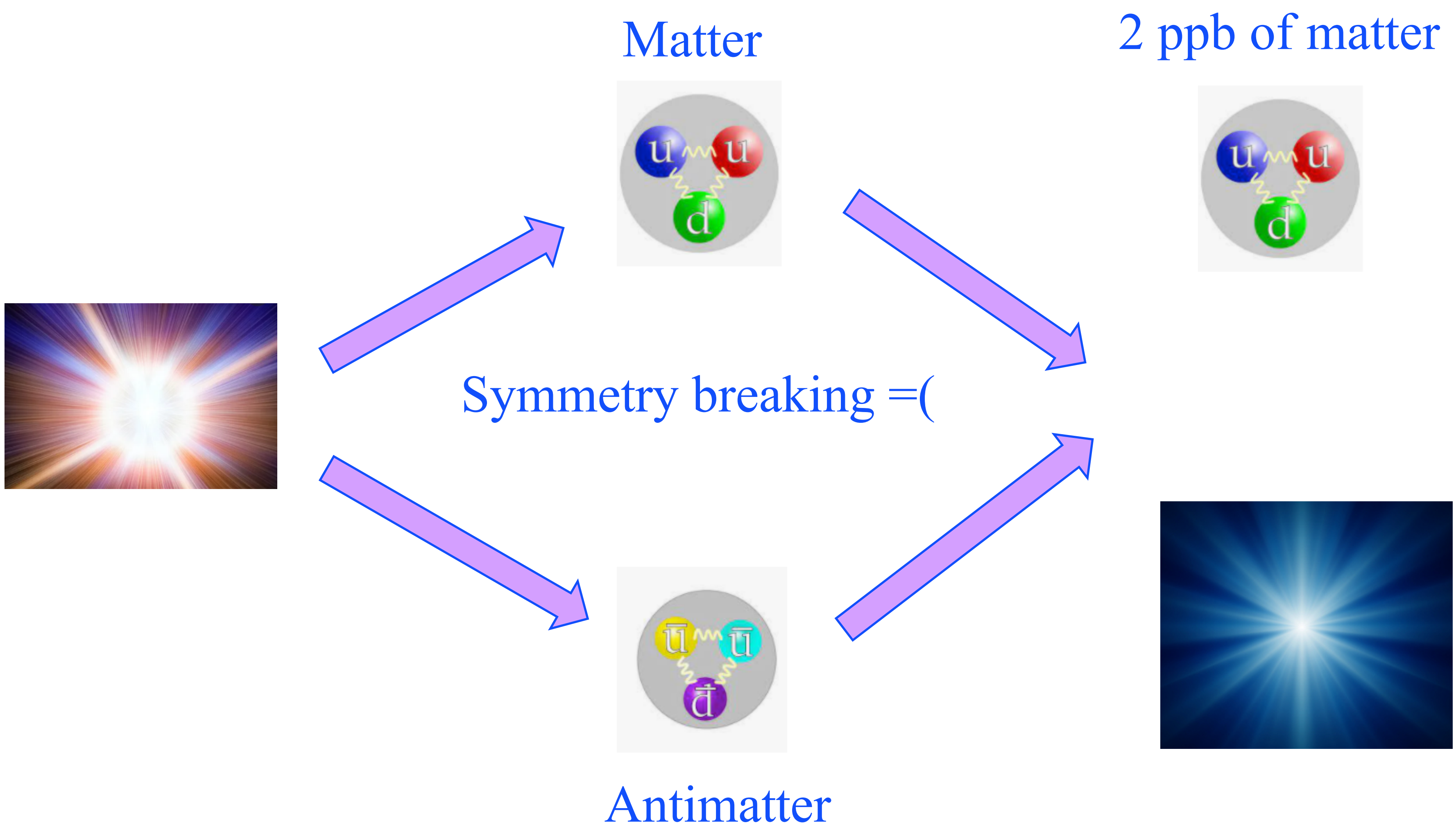
Overview

- Dark matter
- Current status of the experiment
- Future plans

Thank you to STFC/EPSRC "Quantum Technologies for Fundamental Physics" programme

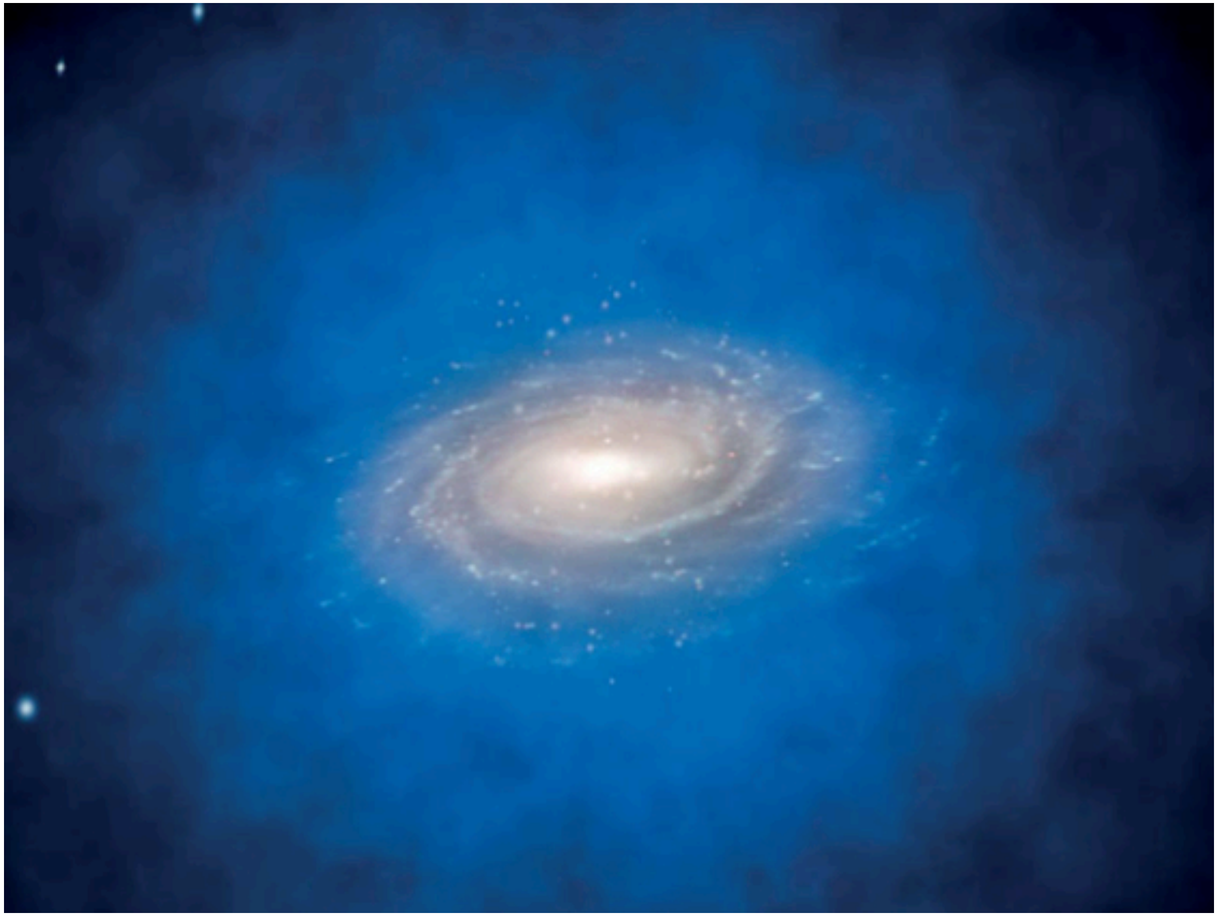
Matter – antimatter annihilation



No symmetry breaking =(

- CP-symmetry: Physics is the same if
  - Particles < = > antiparticles
  - Left handed < = > right handed particles
- Broken in weak interactions
- Expected to be broken in strong interactions
- Peccei-Quinn solution: introduce a new particle (axion)

Dark matter halo: axion-like-particle?



Axion-photon interaction

- Dark matter density ~10^{-21} kg/m^3

- Axion mass ~10^{-47} kg, wavelength ~10^8 m

- Axion field behaves classically

$$a(t) = a_0 \sin(\Omega_a t + \delta(t))$$

amplitude of the field — axion mass — phase of the field

- Coherence time is ~10^6 periods

Axion-photon interaction

- Maxwell's equations

$$\nabla \cdot \vec{E} = -\frac{1}{f}\nabla a \cdot \vec{B}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0$$

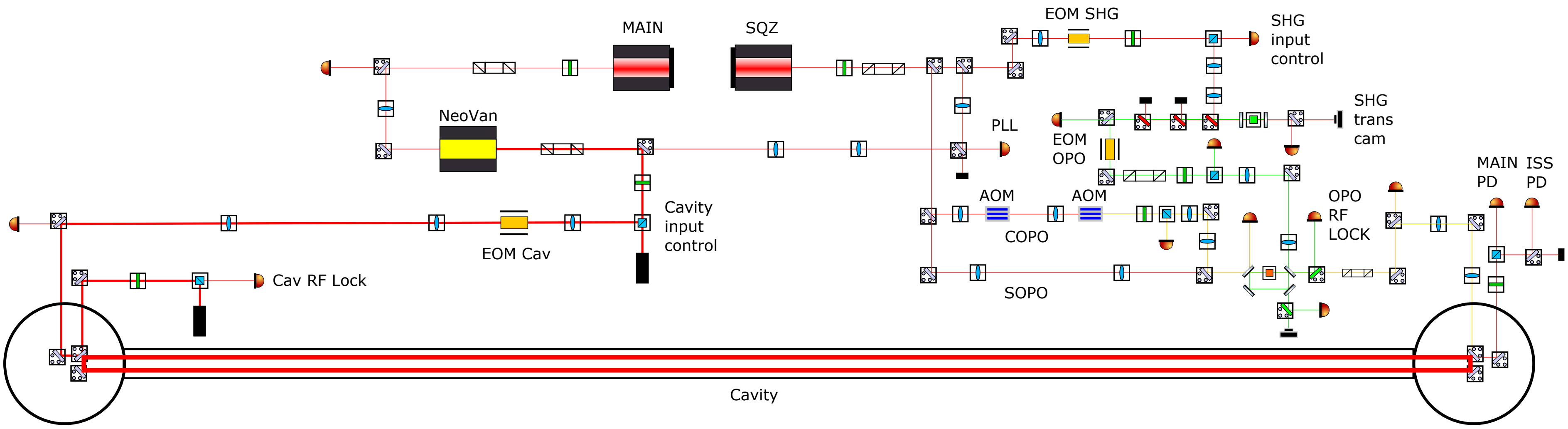
$$\nabla \times \vec{B} = \frac{\partial \vec{E}}{\partial t} + \frac{1}{f}(\dot{a}\,\vec{B} + \nabla a \times \vec{E})$$

- Plane-wave solution

$$v_{\rm phase} \approx 1 \pm \frac{\dot{a}}{2kf}$$

Optical interferometer

- Resonate the pump and signal fields in the cavity
- Apply squeezed states of light to improve the shot noise



The sensitivity scaling

Input coupler transmissivity

Squeezing factor

Cavity pole

$$g_{a\gamma} = \sqrt{\frac{2\pi T_p}{P_{\mathrm{cav}}\rho_{\mathrm{DM}}\lambda}}\,\frac{e^{-r}}{\tau c^2 (T_{\mathrm{int}}\tau_{\mathrm{bw}})^{1/4}}\sqrt{1+\left(\frac{f}{f_p}\right)^2}$$

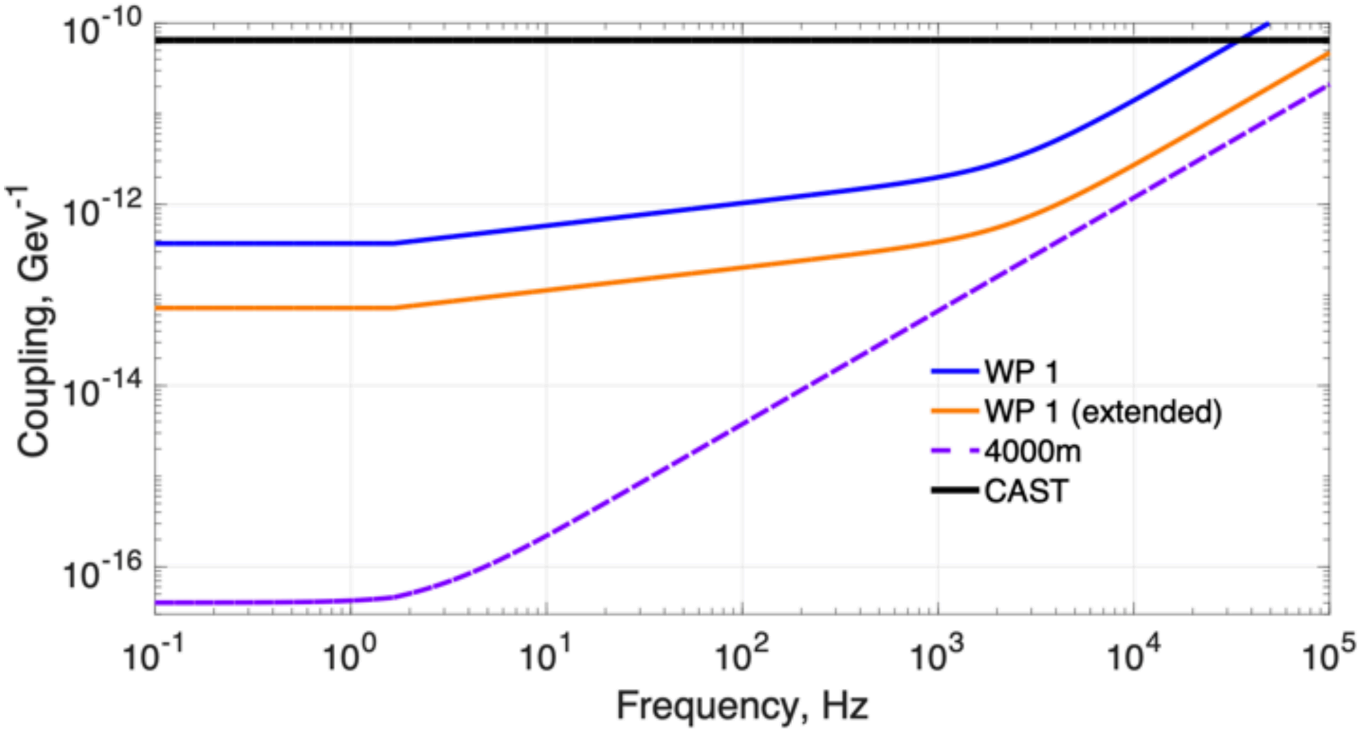
Pump power

Round trip time

Integration time

Sensitivity of the detector

- Table top setups can provide new limits
- The layout can be potentially scaled to km lengths



Phys. Rev. D **101**, 095034

Current status:

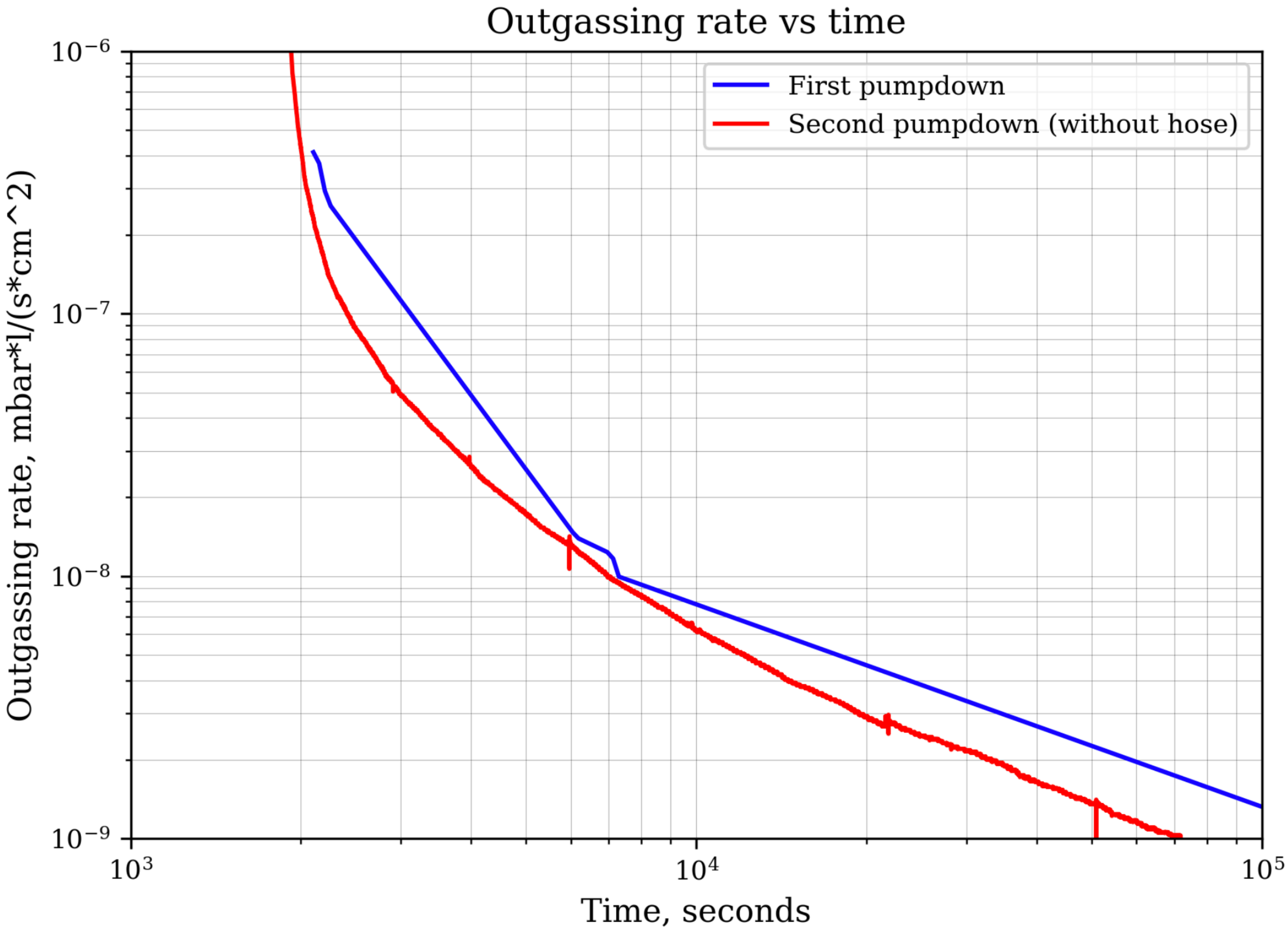
- Laboratory
- Major equipment
- Vacuum tests

Laboratory: March 2021

Laboratory: Sep 2021

Laboratory: Dec 2021

Vacuum measurements



Experimental timeline

Laboratory renovation

Major equipment

Design of the optical coatings

Electronics and data acquisition

Procurement of consumables

Development of the data analysis pipeline

Production of the optical coatings

Installation of the setup

First run

Assembly of the source of squeezed states of light

Second run

Final word

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