Search for Dark Matter in the Hidden-Photon Sector with a Large Spherical Mirror

The FUNK Experiment

Hidden Photons

most prominent candidate DM are weakly interacting massive particles (WIMP)
ALP & HP are good alternative: weakly interacting slim particles (WISP)
HP as SM extension: light extra U(1) gauge bosons $X$, kinetic mixing with EM bosons $F$

$$\mathcal{L} = -\frac{1}{4} (F_{\mu\nu} F^{\mu\nu} + X_{\mu\nu} X^{\mu\nu}) + J^\mu A_\mu + \frac{m^2}{2} X_\mu X^\mu - \frac{\chi}{2} F_{\mu\nu} X^{\mu\nu}$$

Arias et al., JCAP 06 (2012) 013
Horns et al., JCAP 04 (2013) 016

boundary condition for E-field on conducting surface
tiny EM component emitted almost perpendicularly, photon energy $\sim m$
reduce background: spherical mirror

Jaeckel & Redondo, JCAP 11 (2013) 016
Spherical Mirror

almost perpendicular emission

relative DM movement: $\psi \sim p/m$

power from spherical mirror with area $A$

$$P = \langle \alpha^2 \rangle \chi^2 \rho_{\text{cdm}} A \approx 2 \times 10^5 \text{ W} \chi^2$$

Jaeckel & Redondo, JCAP 11 (2013) 016
FUNK Mirror

dimensions:
~ 4 x 4 m

6 x 6 segments

only 3 unique shapes for simpler production

\[ R = 340 \text{ cm} \]
\[ A = 14.56 \text{ m}^2 \]
Pierre Auger Observatory

Schmidt telescope: corrector ring, 440 PMT camera, mirror

remaining spare segments
strict curvature quality controls <1 cm

massively produced in early 2000
Observatory completed in 2008

four Fluorescence Detector sites;
6 telescopes each

Abraham et al., NIMA 620 (2010) 227
Experimental Hall
Optical Quality

frosted-glass screen scan
LED
linear stage
Raspberry Pi
controller

initial assembly
Fine Realignment
New alignment
New alignment

spot size ~6 mm

spot size ~2 mm
Preliminary Results

PCO Sensicam VGA
640x480 pixel CCD
internally Peltier-cooled –15°C

no lens, exposed CCD
total image intensity
Preliminary Results

motorized flipper
open/closed images

temperature dependence
of image intensity

![Image of motorized flipper with open and closed images]

![Graph showing temperature dependence of image intensity]
Preliminary Results

- Example 6 day run
- 1000 s exposure

- Temperature correction

- Measured difference

- Distribution
Preliminary Results

Suzuki et al., arXiv:1504.00118

Mixing parameter

Hidden photon mass [eV]

allowed DM

not allowed as DM

Solar lifetime

Test result

Tokyo mirror

HBS

Haloscope

CAST

Sumico

Coulomb

CMB

FIRAS
Outlook and Future Plans

Low-noise PMT

far-UV extended sensitivity (Q)

![Graph showing quantum efficiency vs. wavelength (nm)]

- 0 %
- 10 %
- 20 %
- 30 %

% quantum efficiency

- wavelength (nm)

100 300 500 700 900

Q B

cooled encasing

$T = -50^\circ C$
Outlook and Future Plans

Hidden photon mass [eV]

Mixing parameter

- CMB
- Coulomb
- LSW
- CAST
- Sumico
- Test result
- Solar lifetime
- not allowed as DM
- allowed DM
- Haloscope
- PMT

Suzuki et al., arXiv:1504.00118
Outlook and Future Plans

1 – 20 GHz (UHF-SHF band)

CROME experiment
PRL 113 (2014) 221101
Outlook and Future Plans

[Graph depicting the mixing parameter versus hidden photon mass in eV, with regions for allowed DM and not allowed as DM, and notes on various experiments.]
Thank you!
Backup Slides
Alignment Quality
New Center Point

side beam

mirror axis
Image Entropy

\[ S = - \sum_i p_i \ln p_i \]

sharp segments

old center

new center

+ old setup

+ new setup

entropy

longitudinal distance [mm]
Outlook and Future Plans