Search for hidden-photon Dark Matter with FUNK

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It has been proposed that an additional U(1) sector of hidden photons could account for the Dark Matter observed in the Universe. When passing through an interface of materials with different dielectric properties, hidden photons can give rise to photons whose wavelengths are related to the mass of the hidden photons. In this contribution we report on measurements covering the visible and near-UV spectrum that were done with a large, 14 m^2 spherical metallic mirror and discuss future dark-matter searches in the eV and sub-eV range by application of different electromagnetic radiation detectors.

For the introduction to the hidden-photon physics and related extension of the Standard Model see [1, 2]. For results of a similar experiment, although with a smaller mirror see [3, 4].

1 Experimental setup

For this experiment a mirror composed of 36 segments is used. For more details on the setup see [5, 6]. The experiment is set-up in a light-tight window-less room with concrete walls of at least 2 m thickness. The inner area (see Fig. 1), encompassing the camera and the mirror, is additionally light insulated with a thick black curtain and a 120 µm layer of opaque polyethylene foil.

As the light detector a 29 mm diameter photomultiplier (PMT) ET 9107BQ with very low dark-current properties was chosen. The PMT has a blue-green sensitive bialkali photocathode with the quantum efficiency extended into the ultra-violet range with the peak quantum efficiency of around 28% and excellent single electron and pulse-height resolution, suitable for the photon counting. The PMT camera is placed on a motorized linear-stage that can drive it (perpendicularly to the mirror axis) in and out of the center of the spherical mirror. The PMT front is additionally equipped with a motorized shutter that can obscure the entrance of photons.

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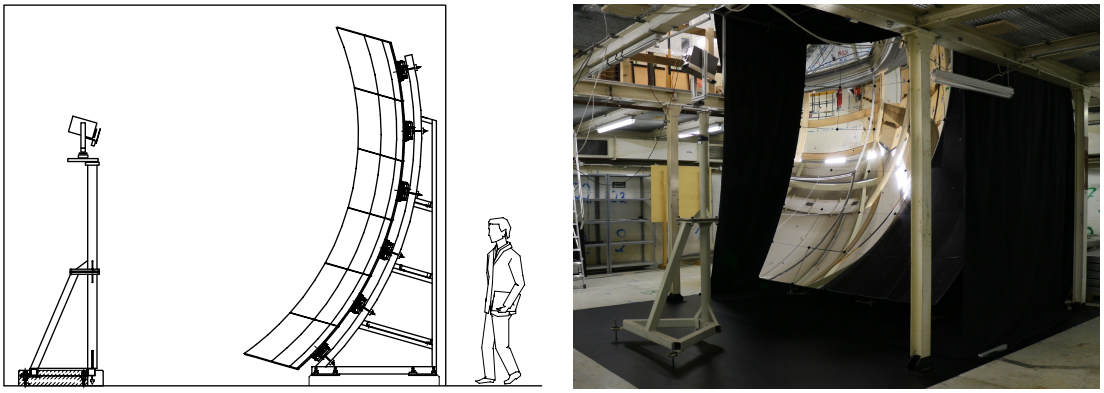

Figure 1: Schematic (left) and photo (right) of the experimental setup.

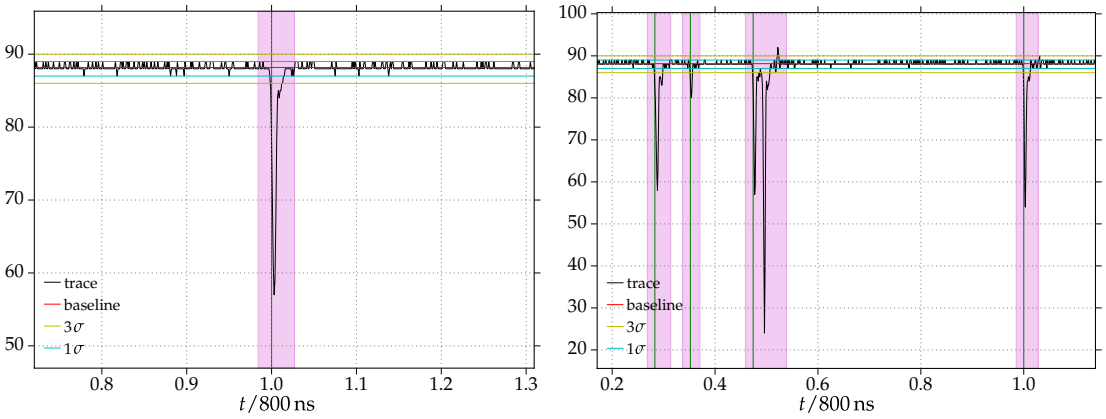

Figure 2: Typical examples of captured traces with single pulse (left) and many pulses within a short time span (right).

Signals from the PMT were digitized with the PicoScope 6404D digital oscilloscope. In Fig. 2 two examples of triggered traces are given. A single-photon (SP) pulse can be observed on the left and a trace containing several pulses in the 1.6 µs trigger window is shown on the right. Traces with multiple pulses were discarded since they can be produced only by cosmic-ray showers. Based on measurements of the SP charge spectrum with an LED flasher, Fig. 3-left, a cut on the allowed range of observed charges was also applied, as seen in Fig. 3-right. The efficiency of the latter cut on SP traces is estimated to be 75%.

2 Preliminary limit on mixing parameter

The selected photon counts for a 30-day run performed in February and March 2017 can be seen in Fig. 4-left. The data was taken in cycles of four 60 s measurements performed in all four possible combinations of the two positions of the PMT camera (*in* and 8 cm *out* of the center), and the two positions of the shutter (*open* and *close*), as schematically shown in Fig. 4-right.

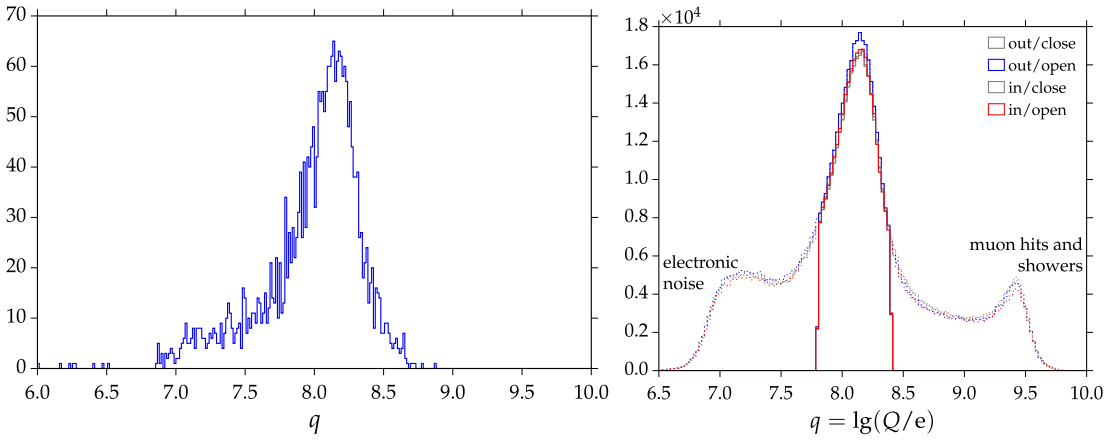

Figure 3: *Left:* Charge distribution for a flasher run with very low power setting and, therefore, composed mostly by single photo-electrons. *Right:* Charge distribution observed in one of the measurement runs. Note that in both cases $q = \lg(Q/\mathrm{e})$ where Q is the charge of a pulse.

The average rate of the whole run is $R = 0.535\,\mathrm{Hz}$ and the relative differences ΔR in the four different configurations are shown in Fig. 4-right.

The difference of the count rates between *open* and *close* for the PMT being *in* the radius point is proxy for the dark-matter signal. With the shutter *open* there are $\Delta R = 0.0032 \pm 0.0014\,\mathrm{Hz}$ more counts registered than with *closed*. Ignoring for a moment any possible systematic effects, we obtain the limit shown in Fig. 5 denoted with *FUNK sensitivity*. To determine possible systematic uncertainties that might be related to temperature changes or the limited accuracy of the measurement time, we also compare the rates with the *closed* PMT *in* and *out* of the radius point. The two count rates agree within the statistical uncertainty ($\Delta R = 0.0007 \pm 0.0014\,\mathrm{Hz}$). Nevertheless, the comparison of the count rates for the *open* PMT *in* and *out* of the radius point we found significantly larger count rate for the PMT *open* and *out* of the radius point, possibly related to the different imaging properties of the setup in the two positions. Additional measurements are in progress to better understand this systematic behavior. For now we treat this difference ($\Delta R \approx 0.025\,\mathrm{Hz}$) as an upper limit of the overall systematic uncertainty of the measurement and use it to derive a preliminary upper limit [1] on the magnitude of the mixing parameter χ in the sensitivity range of the PMT, see the line denoted *FUNK preliminary (sys)* in Fig. 5.

Summary. No significant signal was found. The detailed analysis of the data is still ongoing, thus here we are reporting only preliminary results with a maximally conservative estimate of possible systematic uncertainties.

Future plans. We are planning further searches for possible hidden-photon dark matter with measurements extended into the MHz, GHz, and THz range.

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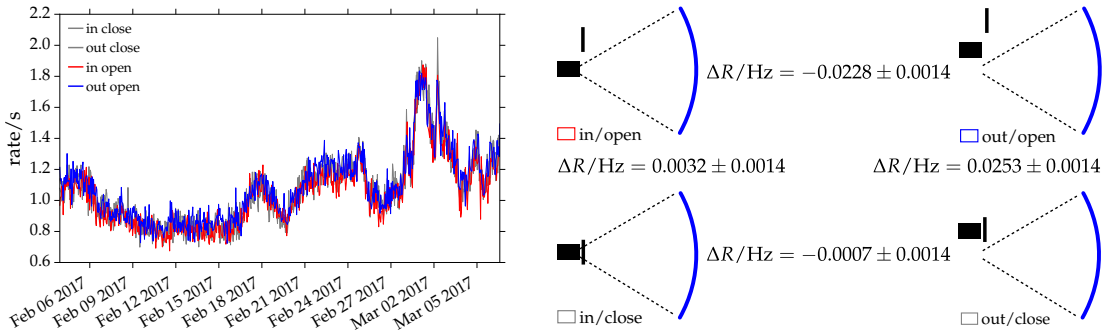

Figure 4: *Left:* observed pulse rate in one of the measurement runs. *Right:* A measurement is composed of many event cycles, where in each cycle four different 60-second measurements are performed. The schematic show these four different combinations obtained with open/closed shutter and with camera in/out.

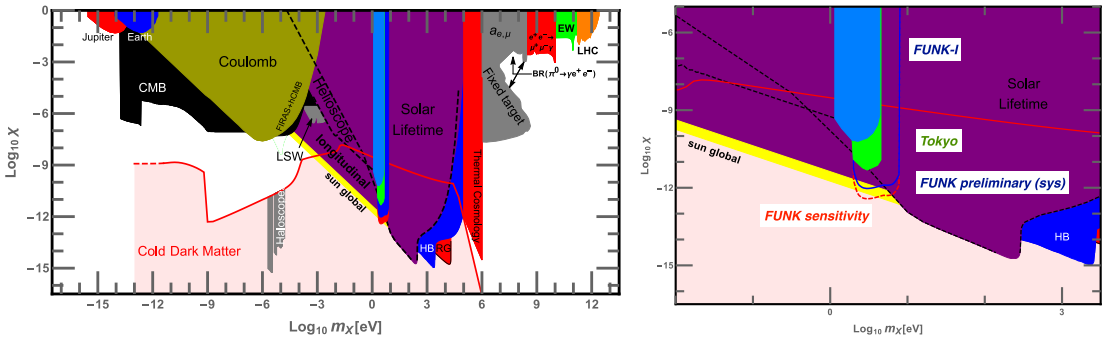

Figure 5: Preliminary limits on the mixing parameter χ derived from systematic dominated (blue) and statistics dominated (red) assumptions. The right figure is an enlargement of the right plot around the dark-matter mass window corresponding to the optical emission of the visible photons. The previous result obtained with a CCD camera [5] is also shown (light-blue).

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