



Метод регистрации скрытых фотонов с помощью мультикатодного счетчика

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Наши публикации:

- Kopylov, AV; Orekhov, IV; Petukhov, VV/ *A method to register hidden photons with the aid of a multi-cathode counter*, *TECHNICAL PHYSICS LETTERS*, 2016, v.42, 16, p.102
- Kopylov A.V., Orekhov I.V., Petukhov V.V. / "On a Search for Hidden Photon CDM by a Multicathode Counter" // *ADVANCES IN HIGH ENERGY PHYSICS*, Volume 2016 (2016), Article ID 2058372
- Kopylov A.V., Orekhov I.V., Petukhov V.V./ *A multi-cathode counter in a single-electron counting mode*, *NUCLEAR INSTRUMENTS and METHODS in PHYSICS RESEARCH A*, 2018, Volume 910, pp 164-167
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Author(s): A.Kopylov, I.Orekhov, V.Petukhov

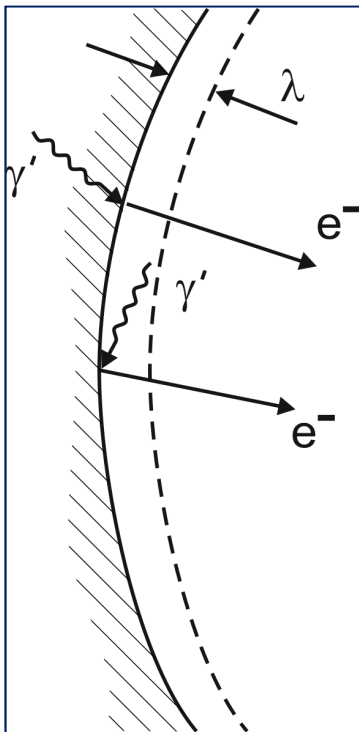
Title: Results from a Hidden Photon Dark Matter
Search Using a Multi-Cathode Counter

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Referee report:

Their experiment is very interesting and their idea has both novelty and originality. I consider that this preprint is acceptable for publication in JCAP

Поиск скрытых фотонов холодной темной материи путем регистрации одиночных электронов, испускаемых с поверхности катода мультикатодного счетчика.



Мощность, поглощаемая антенной

$$P = 2\alpha^2 \chi^2 \rho_{CDM} A_{dish} \quad (1)$$

здесь:

$$\alpha^2 = \cos^2 \theta$$

θ – угол между вектором НР и поверхностью антенны

χ - безразмерный параметр кинетического смещения (1)

(D.Horns, J.Jackel, A.Lindner, A.Lobanov, J.Redondo, A.Ringwald, “Searching for wispy cold dark matter with a dish antenna” *Journal of Cosmology and Astroparticle Physics*, vol.4. article 16, 2013)

В нашем случае:

$$P = R_{MCC} m_{\gamma'} / \eta \quad (2)$$

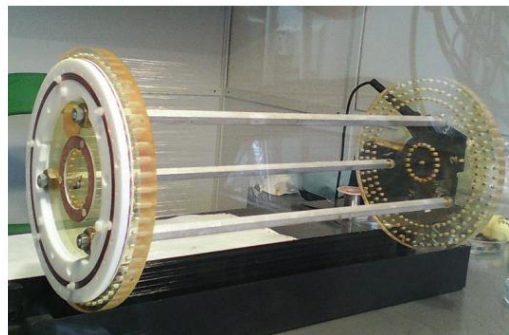
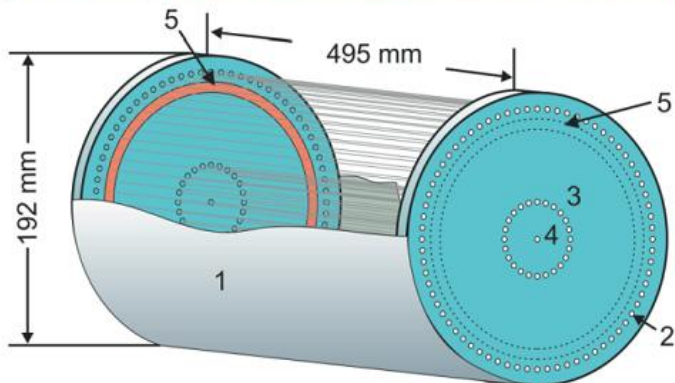
здесь: R_{MCC} – скорость эмиссии одиночных электронов,

$m_{\gamma'}$ – масса скрытого фотона, η – эффективность эмиссии одиночного электрона фотоном с энергией $m_{\gamma'}$;

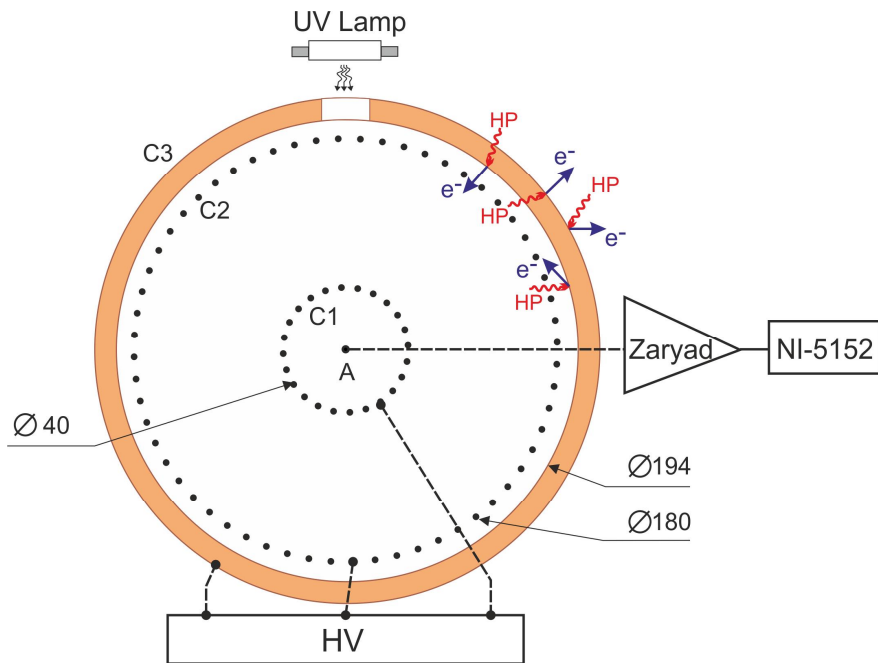
Из (1) и (2) получаем:

$$\chi_{sens} = 2.9 \cdot 10^{-12} \left(\frac{R_{MCC}}{\eta \cdot 1Hz} \right)^{1/2} \left(\frac{m_{\gamma'}}{1eV} \right)^{1/2} \left(\frac{0.3GeV / cm^3}{\rho_{CDM}} \right)^{1/2} \left(\frac{1m^2}{A_{MCC}} \right)^{1/2} \left(\frac{\sqrt{2/3}}{\alpha} \right) \quad (3)$$

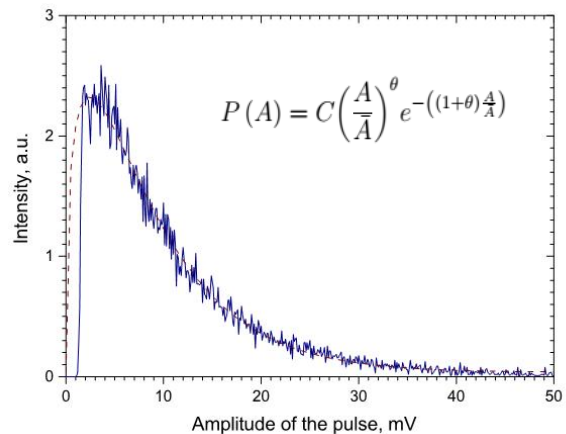
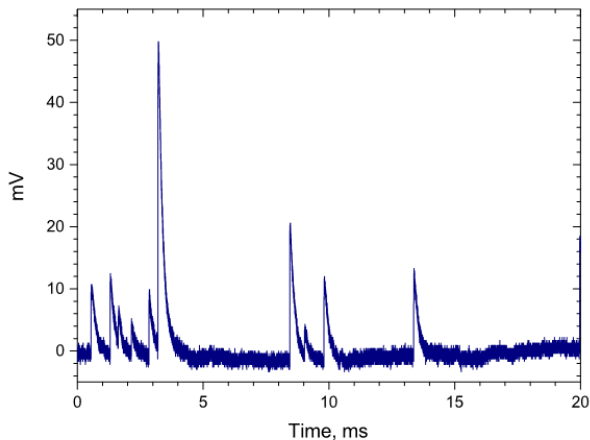
Общий вид и упрощенная схема детектора



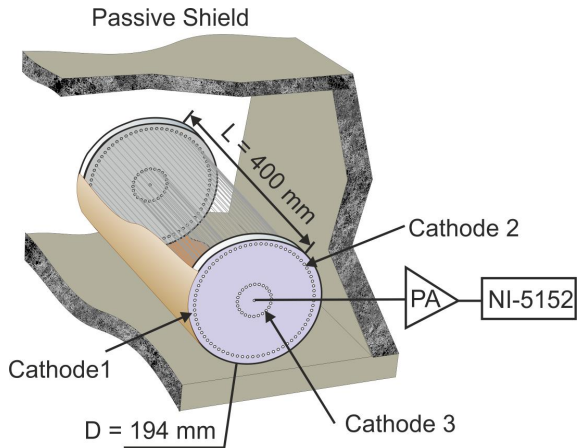
Калибровка детектора с помощью ртутной лампы ДРТ 240.



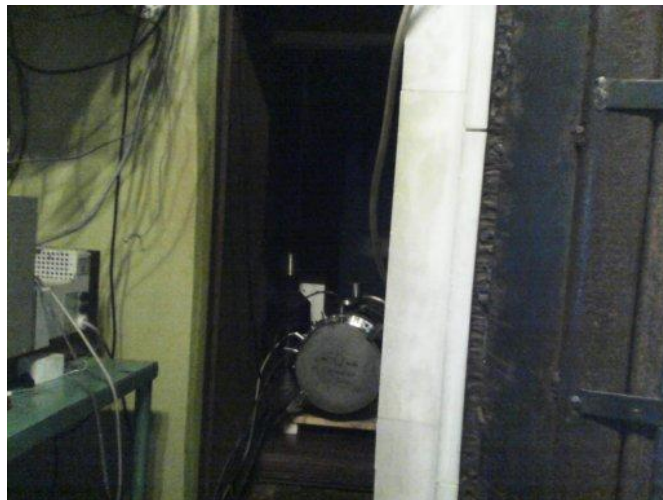
Формы импульсов и распределение Поля



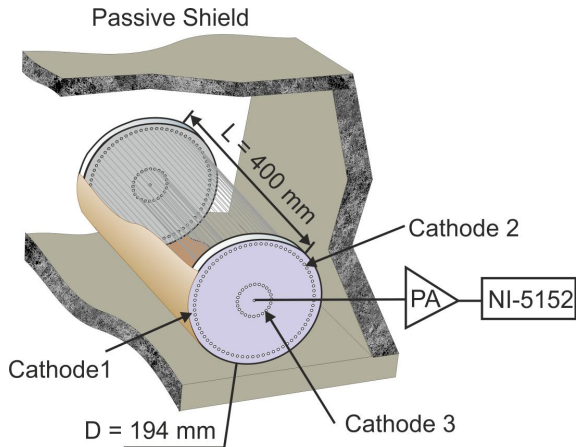
Here A is the amplitude of the pulse, \bar{A} is the mean amplitude and θ – is a parameter which depends on the counting characteristics. For this counter θ was found to be equal ≈ 0.4 . The rate was taken as an integral by the interval of the amplitudes of the pulses from 3 to 30 mV. In this interval Polya distribution is well approximated by exponent [8]. The efficiency calculated from this distribution and interval from 3 to 30 mV was found to be $(77 \pm 2)\%$. The average amplitude of the pulse found from Polya distribution is 9 mV. The sensitivity of CSP was 0.4 V/pC. One can easily find from this that gas



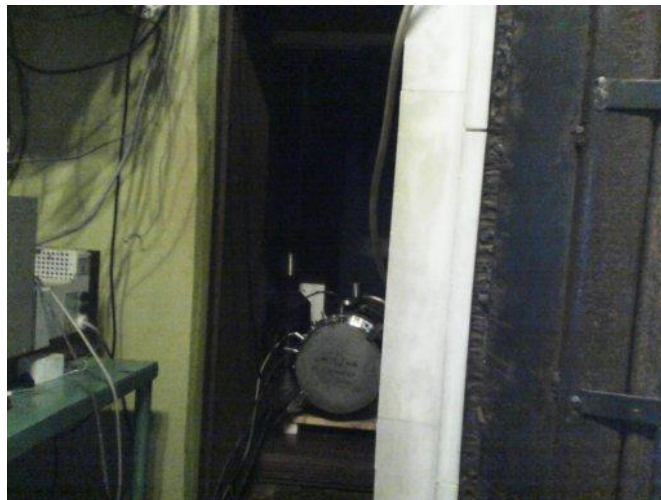
Измерения внутри стального бокса (30 см стали) на 1-м этаже здания в г. Троицк (Москва)



Внутри защиты: медный счетчик
 Поток гамма-излучения (в пике при ≈ 200 keV) подавлен на два порядка.
 Скорость счета снизилась на 20%.
 Следовательно, внутри защиты вклад от гамма-излучения $< 0.2\%$.
 Не наблюдалось событий в совпадении с мюонами.



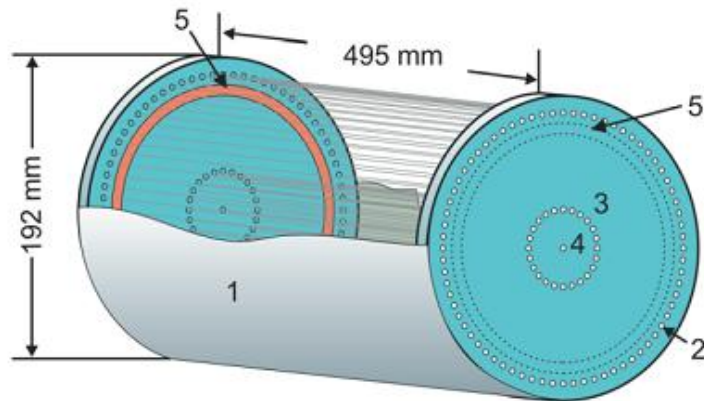
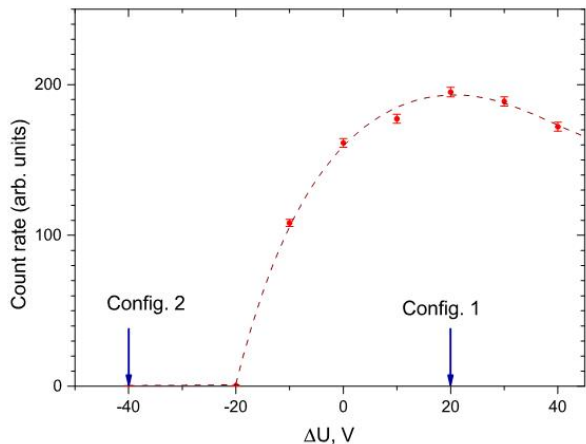
Измерения внутри стального бокса (30 см стали) на 1-м этаже здания в г. Троицк (Москва)



Внутри защиты:
 алюминиевый счетчик
 Поток гамма-излучения (в пике при ≈ 200 keV) подавлен на два порядка.
 Скорость счета снизилась на порядок.
 Следовательно, внутри защиты вклад от гамма-излучения $< 10\%$.
 Не наблюдалось событий в совпадении с мюонами.

Запирающий потенциал на втором катоде

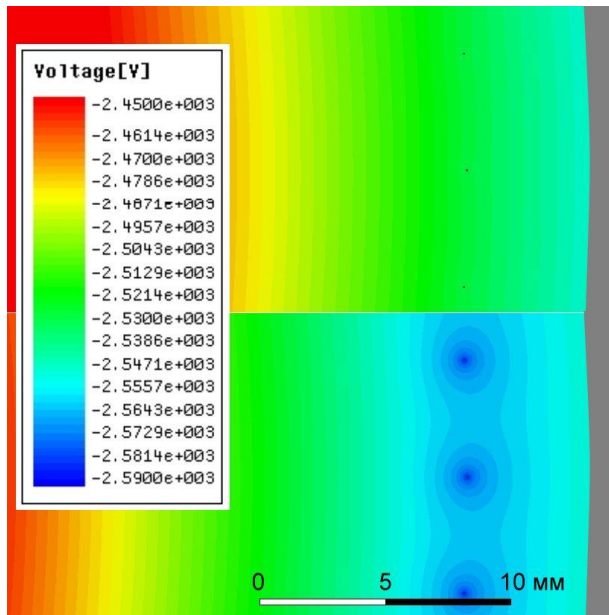
Измеряемый эффект = $R_1 - R_2$



$$\Delta U = U_2 - U_1$$

Потенциалы в конфигурации 1 и 2

Configuration 1



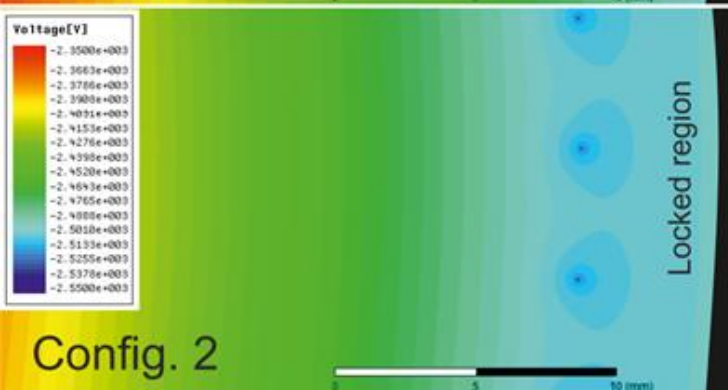
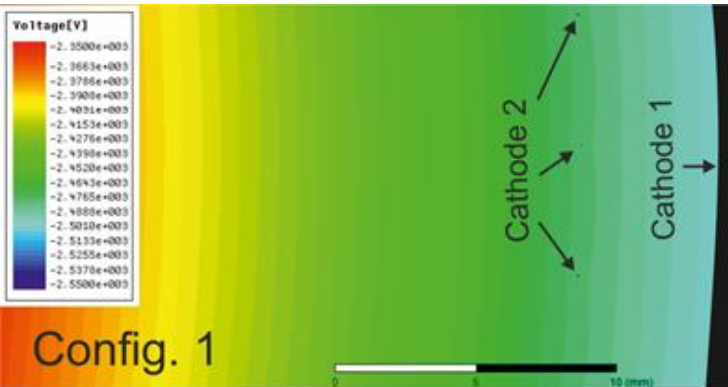
Configuration 2

Измеряемый эффект = R1 - R2

Согласно расчетам потери электронов за счет влияния электроотрицательных примесей в счетном газе в полях, представленных на рисунках, не превышали 1%.

A.K., I.Orekhov, V.Petukhov,
arXiv:1804.00870

Источник систематической ошибки измерений!



Измеряемый эффект

$$R_{MCC} = R_1 - R_2$$

Если скорость счета R_2 определяется нитями, Измеряемый эффект будет

$$R_{MCC} = R_1 - \frac{n_3 + n_2}{n_3 + n_2 / 2} R_2$$

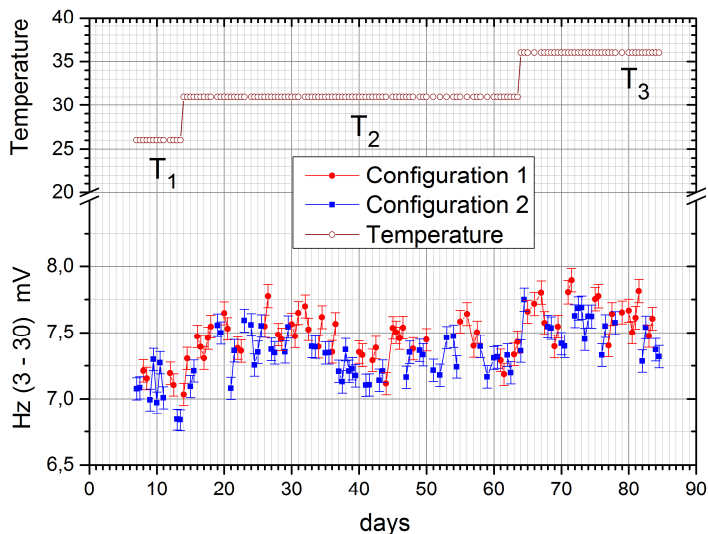
Для $n_2=100$, $n_3=20$

$$R_{MCC} = R_1 - 1.7R_2$$

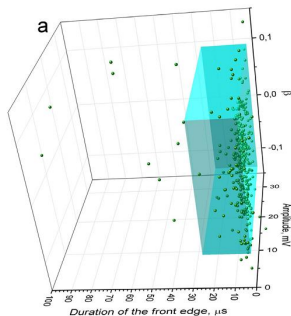
Более низкий предел!

Измерения при различных температурах

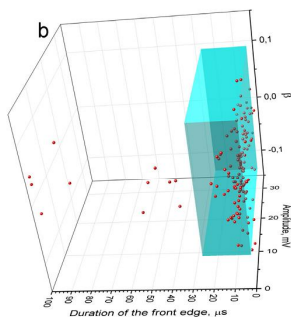
Каждая точка - результат обработки
 ≈ 100 Gb данных измерений
(10 Gs (2 Ms x 5000 snapshots), 8 bit 100 mV 10 MHz ADC)



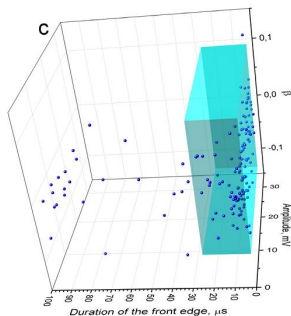
Калибровка



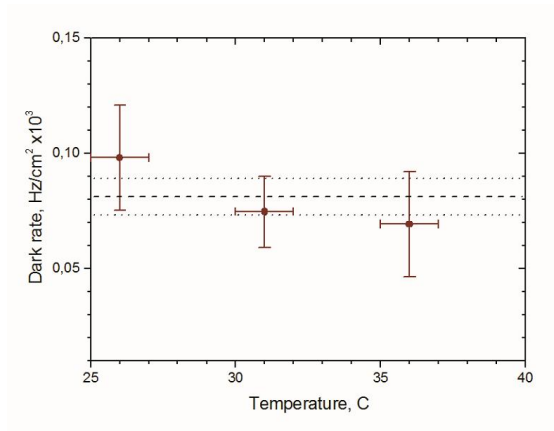
Измерение
Конфигурация 1



Измерение
Конфигурация 2



Измерения на медном счетчике

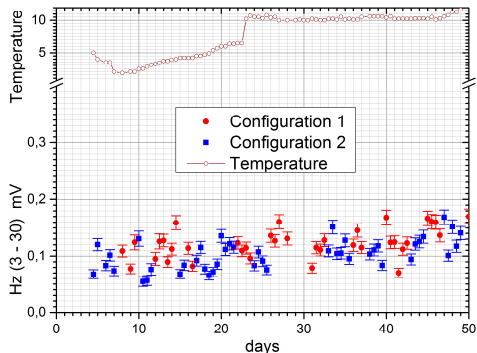


ROI was selected from data of calibration

$$R_{MCC} = \Delta R / A_{\text{cath}} = (0.81 \pm 0.08) \cdot 10^{-4} \text{ Hz/cm}^2$$

Fig. 6. Determination of ROI upon the 3-D events, obtained during calibration by UV lamp. The shaded area is the ROI used for the data analysis: (a) the 3-D distribution of the real events, obtained in measurements during 30 min for configurations 1(b) and 2(c).

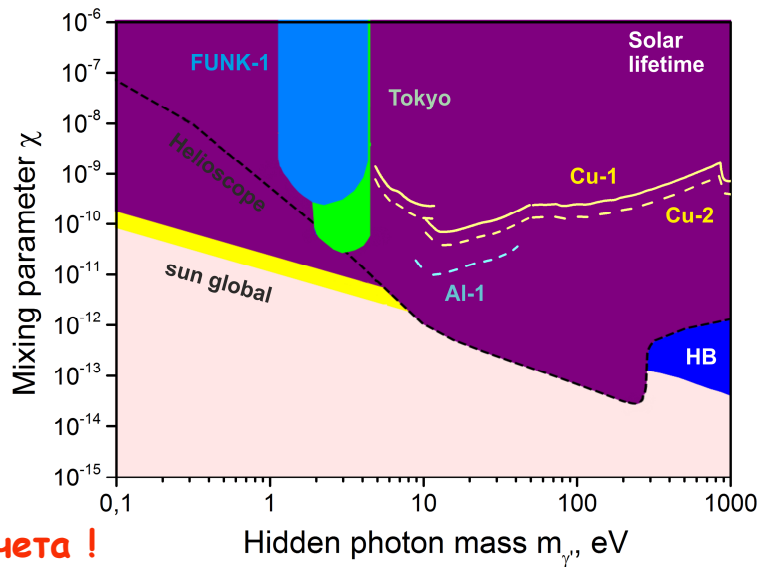
Измерения на счетчике с алюминиевым катодом



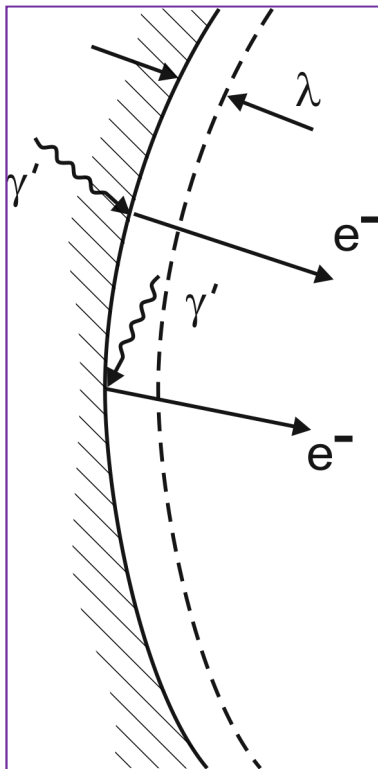
$$R_{MCC} = (0.8 \pm 0.25) \cdot 10^{-5} \text{ Hz/сн}$$

Рекордно низкая скорость счета !

Результаты измерений



Планы на будущее: Photon-Electron Experiment (ΦELEX)



Показано, что метод работает.

Метод обладает высокой чувствительностью в области вакуумного ультрафиолета.

Для дальнейшего продвижения необходимо:

- Применить технологию высокой очистки поверхности катода и нитей.
- Использовать по возможности материалы с низкой удельной активностью по U(Ra), Th, K
- Обеспечить дальнейшее снижение гамма-фона внутри пассивной защиты.
- Оптимизировать конструкцию детектора и состав газовой смеси для снижения темновой скорости счета.
- Разработать и изготовить систему охлаждения детектора.
- Минимизировать систематическую ошибку.

Цель эксперимента - «увидеть» темную материю (если DM действительно есть скрытые фотоны с массой (энергией) в области вакуумного ультрафиолета).

'The new guiding principle should be "no stone left unturned": we should look for dark matter not only where theoretical prejudice dictates that we "must", but wherever we can.

G. Bertone and T.M.P. Tait A New Era in the Quest for Dark Matter
arXiv:1810.01668

Спасибо



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journal homepage: www.elsevier.com/locate/nima

A multi-cathode counter in a single-electron counting mode

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ARTICLE INFO

Keywords:

Proportional counter
Single-electron counting
Low threshold detector

ABSTRACT

We describe the operation of the multi-cathode counter developed by us. It has an aluminum alloy cathode and operates in single-electron counting mode. The calibration results are given. The gas gain was found from the calibration spectra. The electric fields and the operation of this detector in two configurations are described. Our original idea was to measure the effect of electrons emitted from the cathode surface according to the difference in count rates in two configurations. We found the optimal potential difference between the first and second cathodes in the two configurations using the calibration measurements of the count rates. In addition, the advantage of using a multi-cathode counter for measuring the intensity of single-electron emission from a metal is explained.

Experimental Search for Hidden Photon CDM in the eV mass range with a Dish Antenna

J. Suzuki,^a T. Horie,^a Y. Inoue,^b and M. Minowa^{a,c}

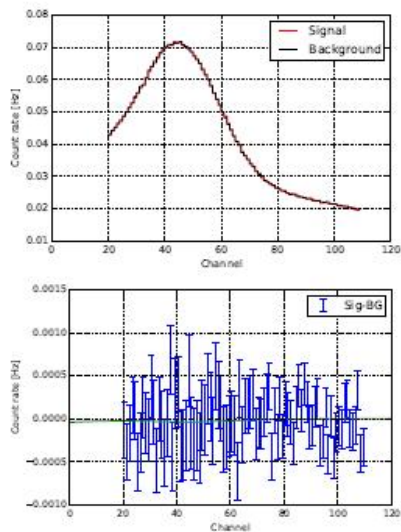


Figure 3. (top) Pulse height spectra taken at S (red) and at B (black) normalized by the live times. (bottom) Difference between spectra taken at S and at B (blue), fitted with the template function obtained in the calibration utilizing LED light (green).

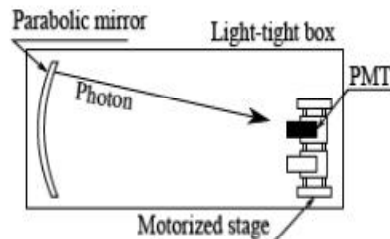


Figure 1. Schematic diagram of the apparatus. Photons from non-relativistic HPs are emitted from the surface of the mirror and converge to a small region at twice the focal length of the mirror. A photon-counting PMT was placed at the point of convergence and detects emitted photons. The PMT is mounted on a motorized stage, which shifts the position of the detector to measure background noise. Device described above are installed in a light-tight box to shield from the ambient light.

Search for hidden-photon dark matter with the FUNK experiment

arXiv://1711.02958;1711.02961

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J. Jaeckel^c, M. Kowalski^{de}, A. Lindner^d, H.-J. Mathes^a, J. Redondo^f, M. Roth^a,
T. Schwetz-Mangold^a, C.M. Schäfer^a, R. Ulrich^a
[The FUNK Experiment]

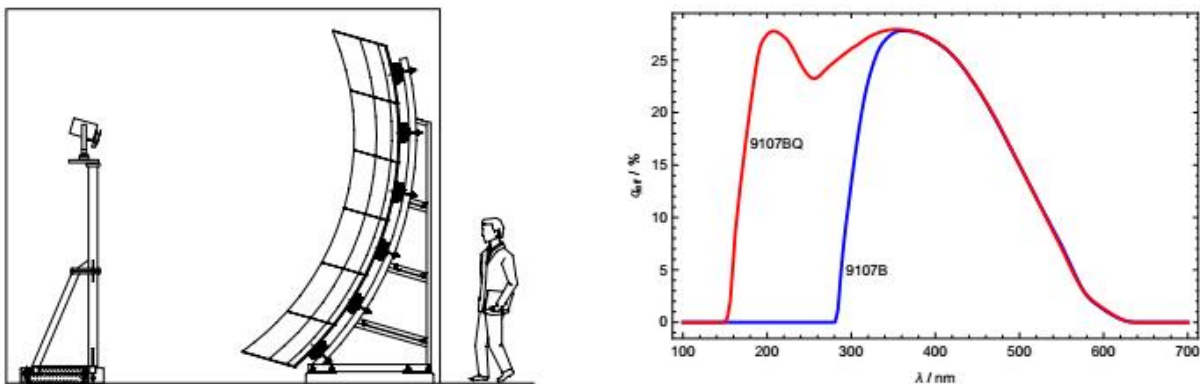


Figure 1: *Left:* Schematic view of the FUNK experiment with a pillar supporting the PMT camera in the center of the spherical mirror consisting of 6×6 segments. The box outlines a $495 \times 431 \times 435 \text{ cm}^3$ experimental volume. *Right:* The quantum efficiency of the PMT used as photon sensor [19]. The UV-extended sensitivity of the used PMT 9107BQ is shown in red.

First results from a hidden photon dark matter search in the meV sector using a plane-parabolic mirror system

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Abstract. We report on the first results from a new dish antenna search for hidden photon dark matter (HPDM) in the meV mass region. A double mirror system composed of a plane and a parabolic mirror is designed to convert HPDMs into photons focused on a receiver. In this phase 1 experiment we obtain an upper limit on the photon-HP kinetic mixing $\chi \lesssim 10^{-8}$ for the mass range of 0.67 – 0.92 meV using conventional mm-wave technology with a room-temperature receiver and a small-sized mirror system.

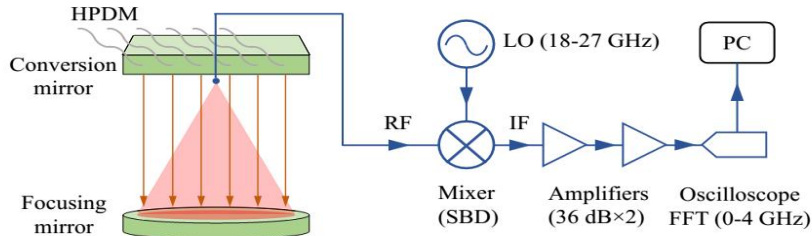


Figure 1: Schematic of the setup and the receiver chain. Dark matter hidden photons are converted into ordinary photons at the surface of the plane aluminum mirror. They are emitted in perpendicular direction to the surface and focused by the parabolic mirror. A horn antenna is placed at the focal point to receive the mm-wave power. The RF frequency is down-converted by an even harmonic mixer (Schottky barrier diode) fed with a local oscillator signal at a frequency of 18–27 GHz. The output IF power is amplified by two low-noise amplifiers, and the waveform is Fourier-transformed by an oscilloscope. The power spectrum is stored after the linear average of 10^3 spectra.