PHELEX: Present Status

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The aim of experiment: to search for Dark Matter

Zwicky (1937) – analyses of red shifts of the Coma Cluster of galaxies: surprisingly high mass-to-light ratio

Enigma 1: to-day, according to a combination of all data: the dark matter accounts for about **84 %** of the matter content of the Universe (Planck 2018 results)
Enigma 2: why dark matter is distributed in galaxy by a spherical halo while baryonic matter – in the plane of galaxy ?

→ CDM is not particles but **waves**,

→ $\mathbf{m_{\gamma'} < 100\ eV}$

Lam Hui arXiv:2101.11735v1

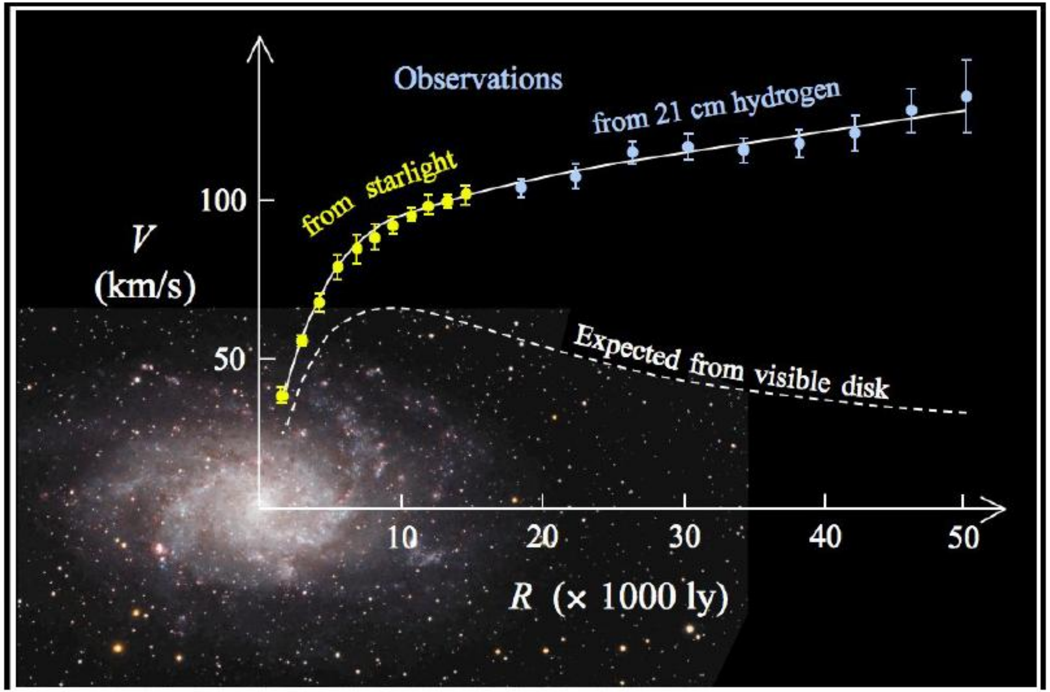
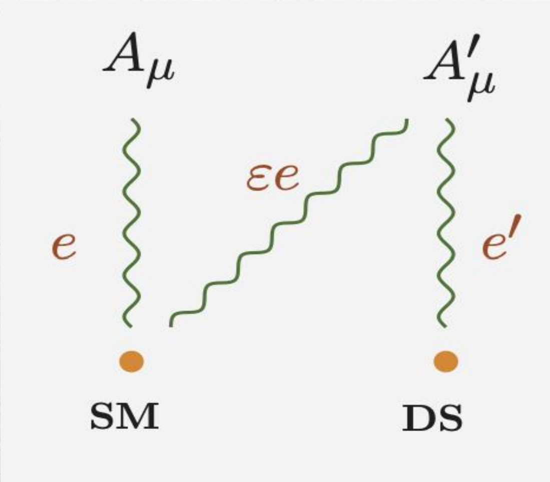


Fig. 1 The image of M33 and the corresponding rotation curve (Corbelli and Salucci 2000). What exactly does this large anomaly of the gravitational field indicate? The presence of *i)* a (new) non-luminous massive component around the stellar disk or *ii)* new physics of a (new) dark constituent?

Why Dark Matter?

P. Salucci arXiv:1811.08843

The dark Photon



Abstract

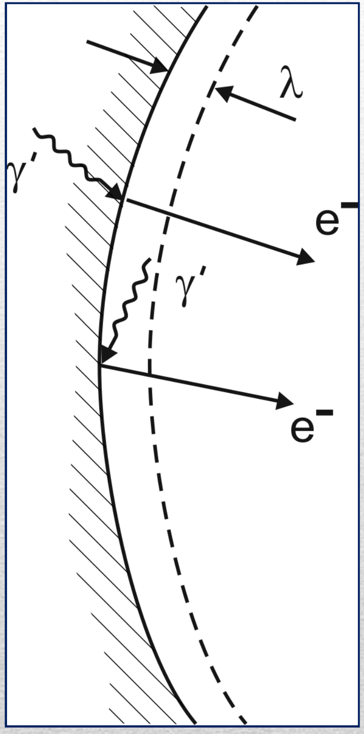
THE DARK PHOTON IS A NEW GAUGE BOSON whose existence has been conjectured. It is dark because it arises from a symmetry of a hypothetical dark sector comprising particles completely neutral under the Standard Model interactions. Dark though it is, this new gauge boson can be detected because of its kinetic mixing with the ordinary, visible photon. We review its physics from the theoretical and the experimental point of view. We discuss the difference between the massive and the massless case. We explain how the dark photon enters laboratory, astrophysical and cosmological observations as well as dark matter physics. We survey the current and future experimental limits on the parameters of the massless and massive dark photons together with the related bounds on milli-charged fermions.

M. Fabbrichesi, E. Gabrielli, G. Lanfranchi

The Physics of the Dark Photon, Springer Briefs in Physics (Springer, 2021)

PHELEX – PHoton-ELectron EXperiment

multicathode counter technique as an extension of a method of a dish antenna to higher masses (energies)



$$P = 2\alpha^2 \chi^2 \rho_{CDM} A_{dish}$$

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

θ – angle between a field of a hidden photon and the surface
χ- dimensionless parameter quantifying a kinetic mixing

(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)

$\rho_{CDM} \approx 0.3$ GeV/cm^3

$\rho_{\odot}$ = (0.43 ± 0.06) GeV/cm3 (Salucci et al 2010)

Galactic dark matter halo.
But locally, near the Sun?
Primordial Solar dark matter halo?
arXiv:2007.11016
(N.B.Anderson, A.Partenheimer, and T.D.Wiser)

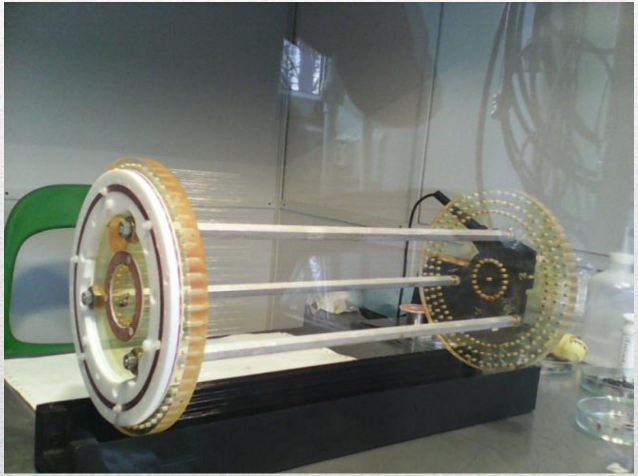
In our case: due to low reflectivity of the surface the photon gets absorbed and emits an electron

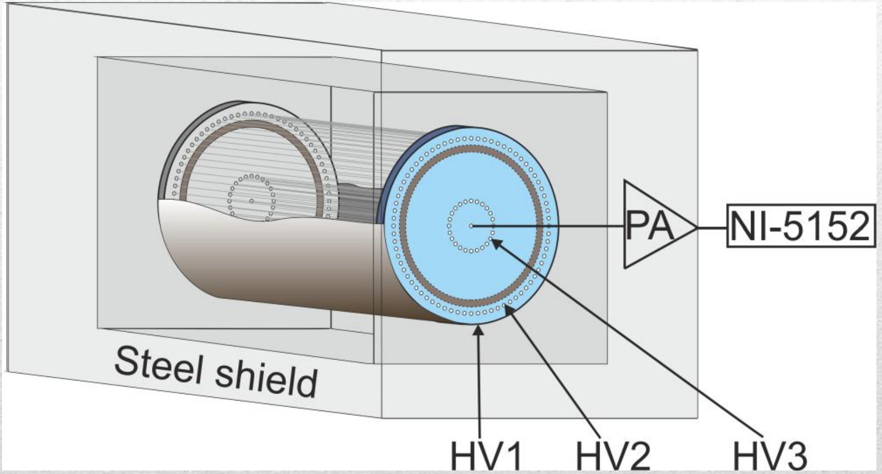
$$P = R_{MCC} m_{\gamma'} / \eta$$

Sensitivity:

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

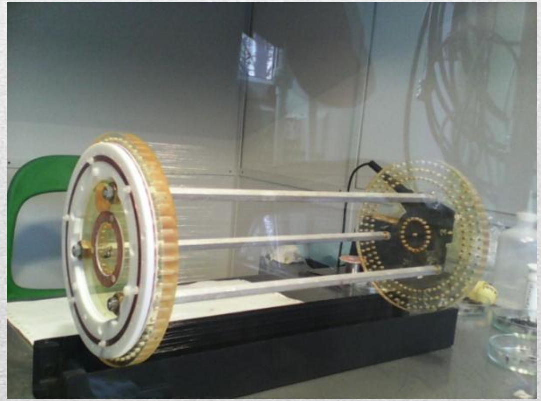
Multicathode counter technique as an extension of a method of dish-antenna





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

Multicathode counter: assembling and testing

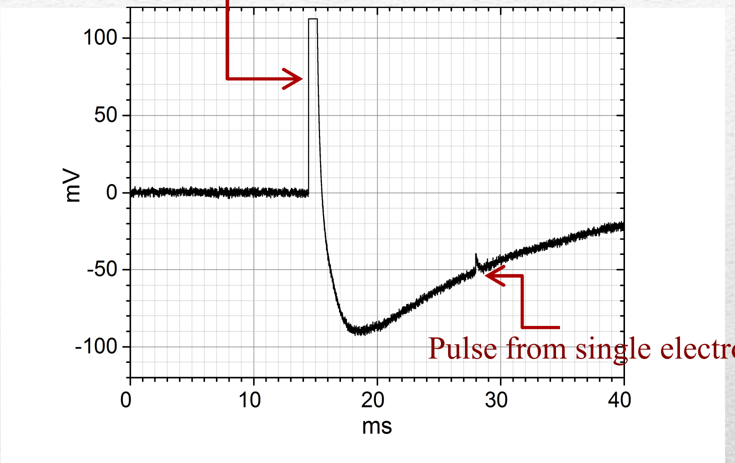


Single-electron pulses

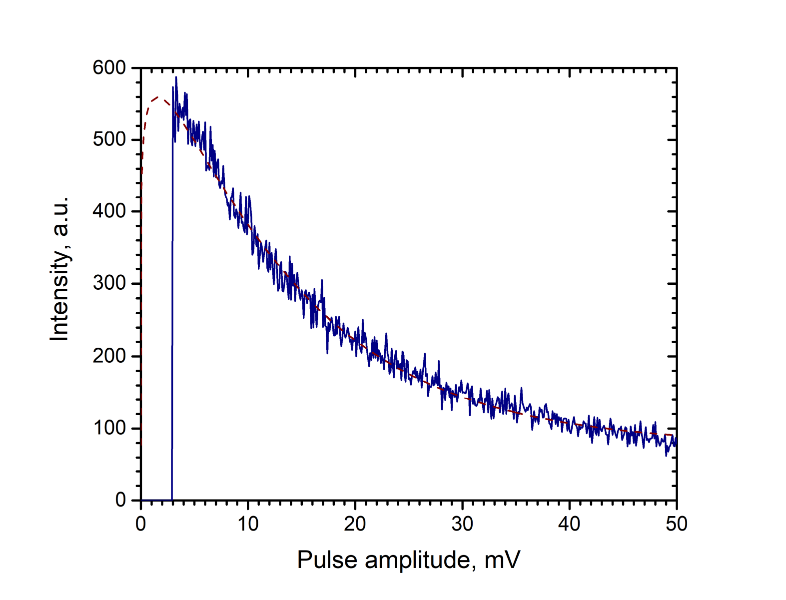
Polya distribution

$$P(A) = C\left(\frac{A}{\bar{A}}\right)^{\theta} e^{-\left((1+\theta)\frac{A}{\bar{A}}\right)}$$

Pulse from muon crossing the counter



Pulse from single electron

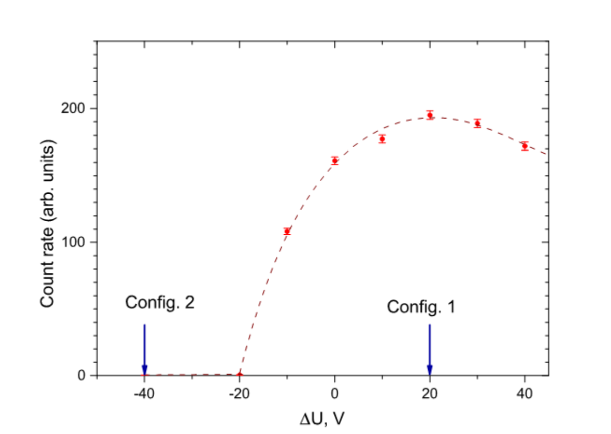


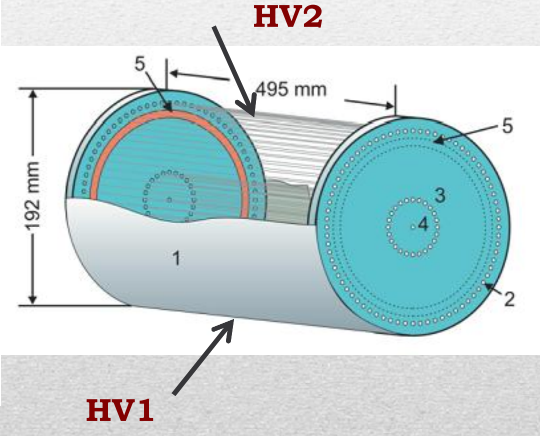
From muons at sea level: ≈ 15 pulses per second → ≈ 15% dead time (10 ms per each pulse)

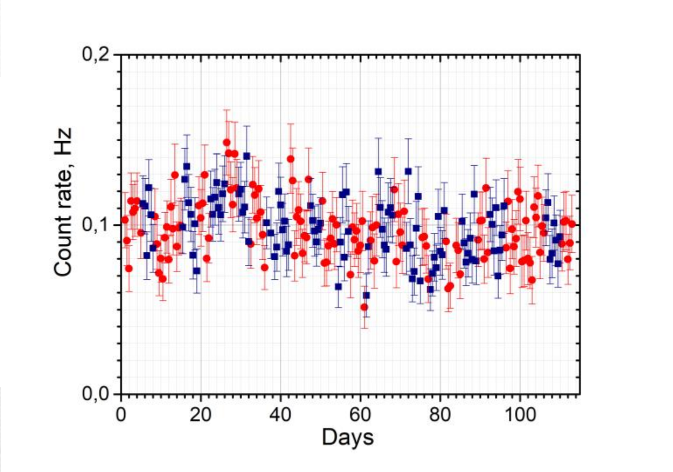
Principle of a multicathode counter:

Retarding potential of the second cathode in configuration 2

The effect: $r_{MCC} = R_1 - R_2$







ΔU = HV2 – HV1

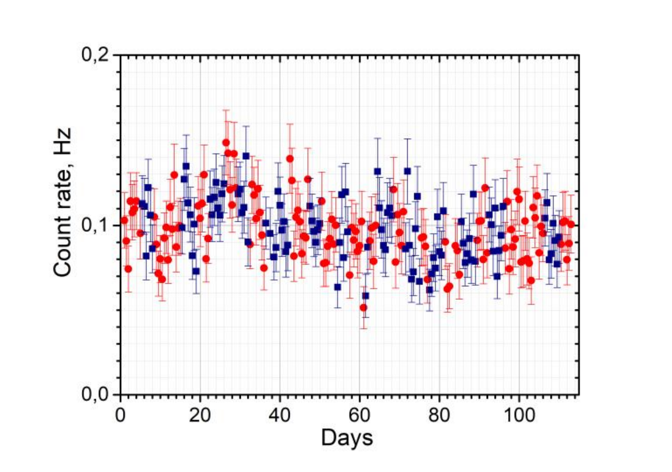
R_1 – red, R_2 - blue

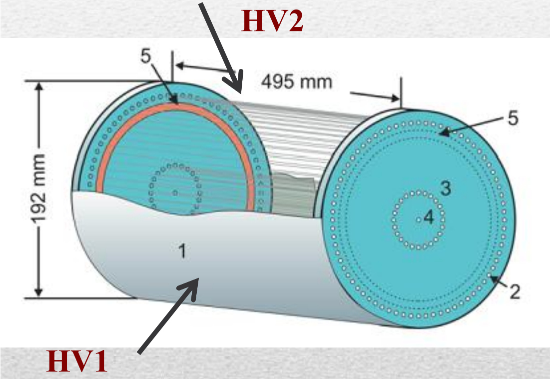
Results of measurements

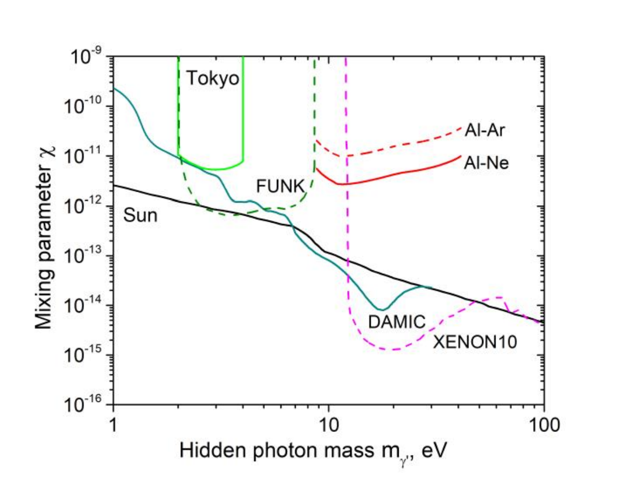
with Ar + CH_4(10%) and Ne + CH_4(10%) gas mixtures

The target – free electrons of a degenerate electron gas of a metal

Result is included in compilation of the data
Review of Particle Physics in Prog. Theor. Exp. Phys. 2020, 083C01 (2020).







R_1 – red, R_2 - blue

- ***Target – valence electrons***

$$r_{MCC} = (-\ 0.33 \pm 0.7) \cdot 10^{-6}\ \mathrm{Hz/cm^2}$$

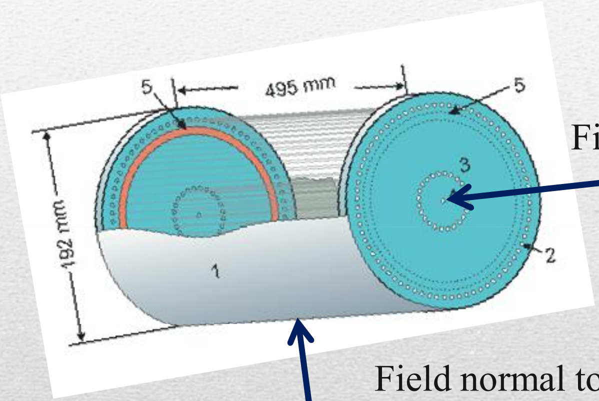
Directionality of the counting

$$P = 2\alpha^2 \chi^2 \rho_{CDM} A_{dish}$$

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

θ – angle between a field of a hidden photon and the surface

χ- dimensionless parameter quantifying a kinetic mixing



Field along the axes of the counter

$$< \cos^2\theta >= 0$$

Field normal to the axes of the counter

$$< \cos^2\theta >= \frac{1}{2}$$

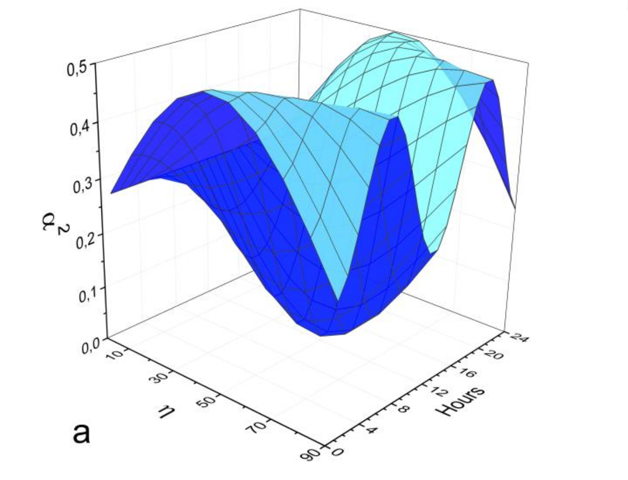
(D.Horns, J.Jackel, A.Lindner, A.Lobanov, J.Redondo, A.Ringwald , “Searching for wispy cold dark matter with a dish antenna” *Journal of Cosmology and Astroparticle Physics*, vol.4. article 16, 2013)

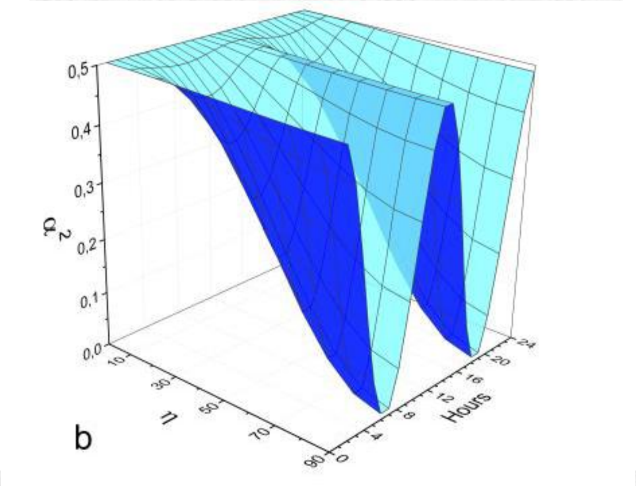
- **By rotation of the counter – variation of the count rate**

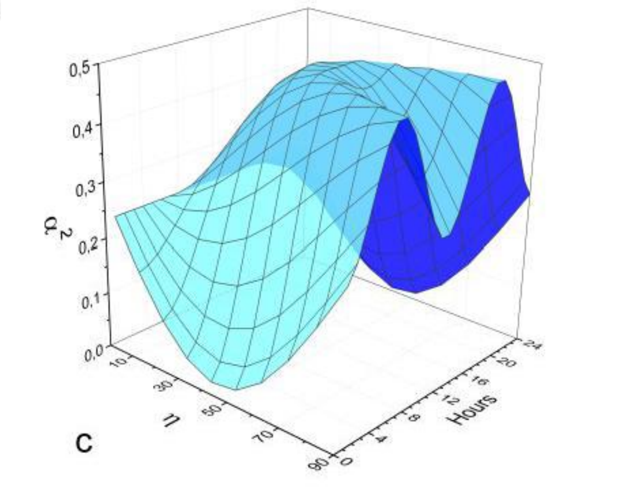
If the surface is mirror-like!
The counter with a matt surface – for the control measurements

Diurnal variations, Baksan, Russia 43°

$\langle \alpha^2 \rangle$ averaged for 1 hour





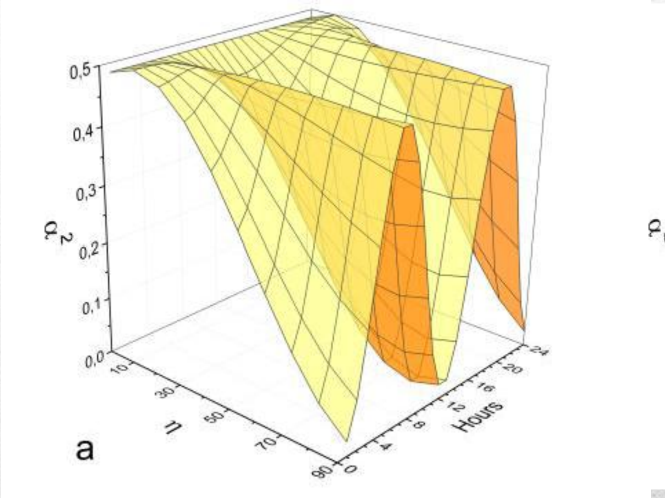


Vertical orientation

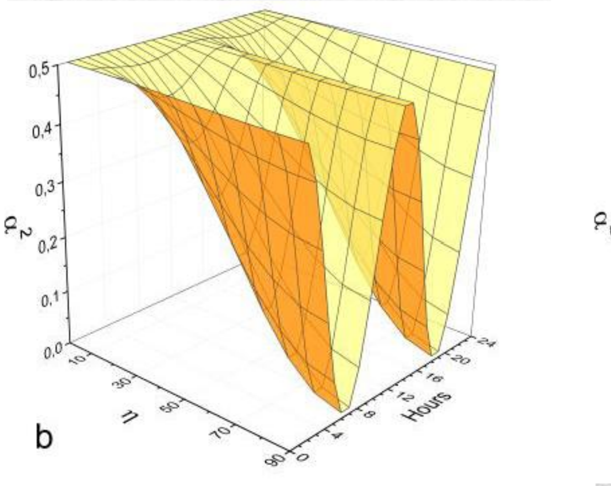
East-West orientation

North-South orientation

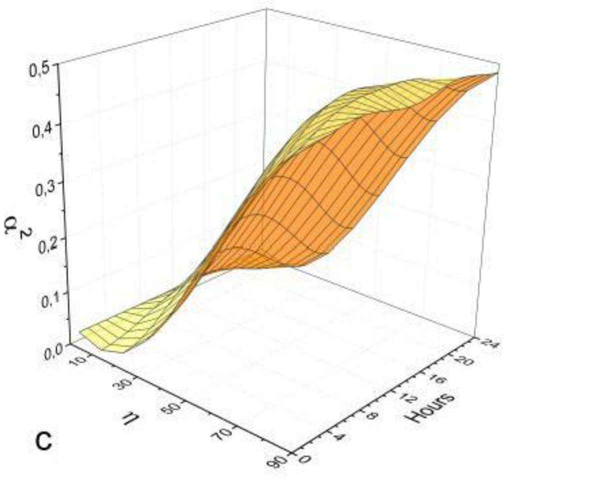
Diurnal variations, INO, India 10º



Vertical orientation

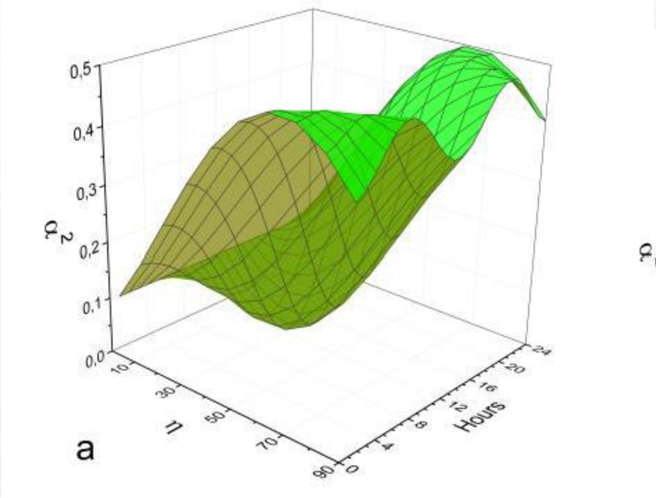


East-West orientation

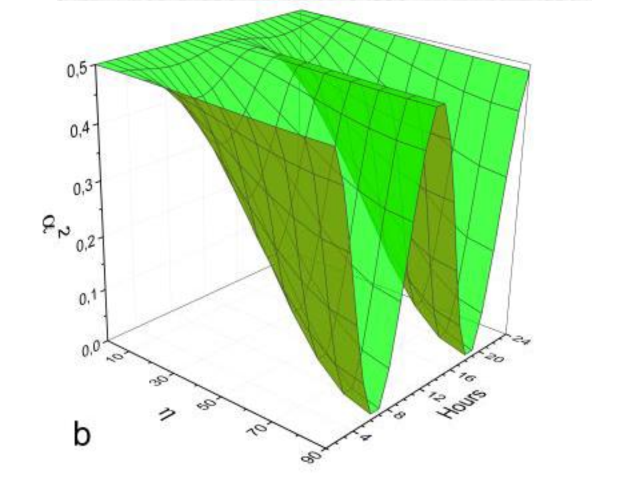


North-South orientation

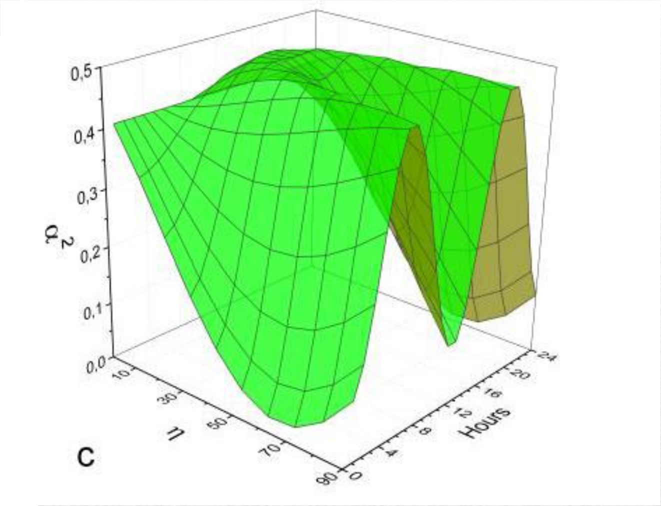
Diurnal variations, Pyhäsalmi, Finnland 64º



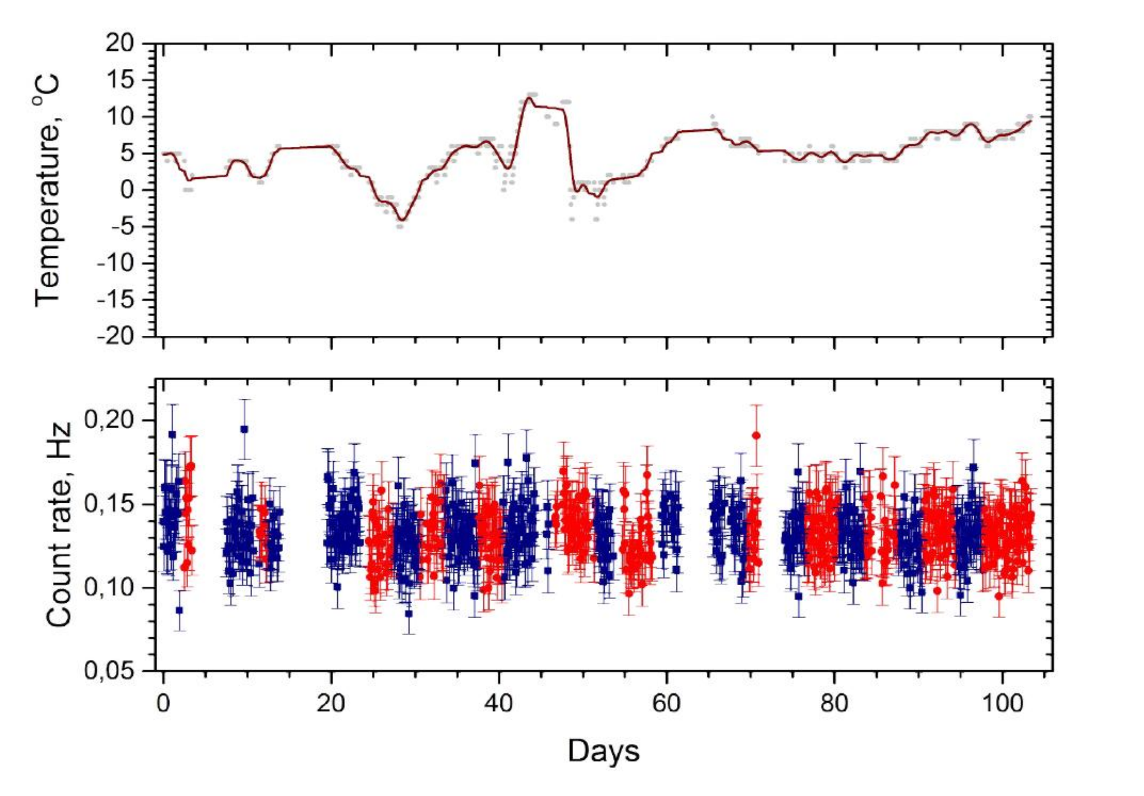
Vertical orientation



East-West orientation



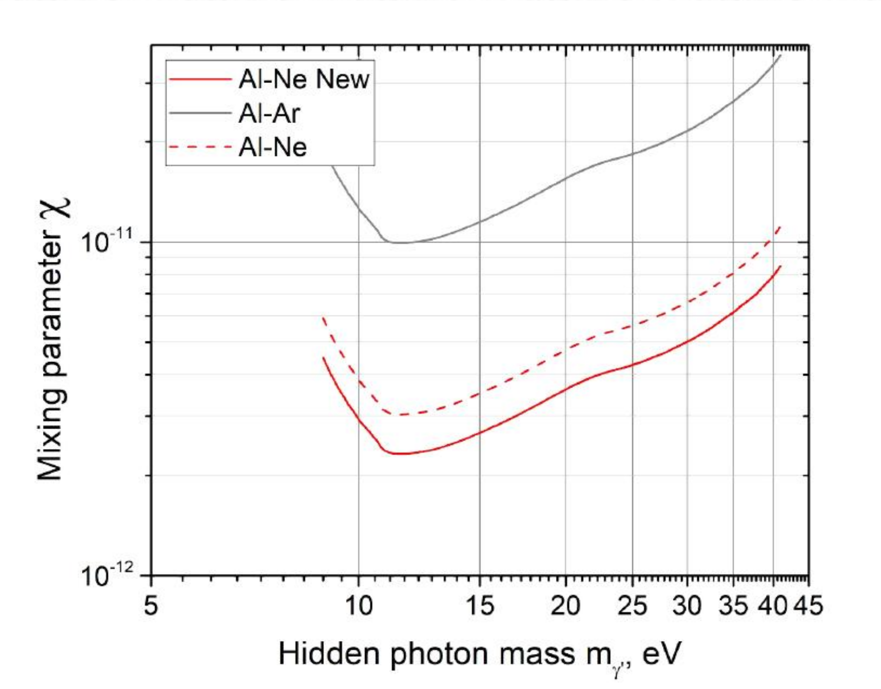
North-South orientation



Red – configuration 1
Blue – configuration 2

871 points;
In previous measurements – 200 points

New measurements Al – (Ne + CH_4(10%) 1 Bar)



preliminary !

C1-C2 = - 0.00018 ± 0.00101 (2σ)

R_{MCC} = (C1 –C2 + 2σ)/ε = 0.00184/0.608

ε – efficiency of counting

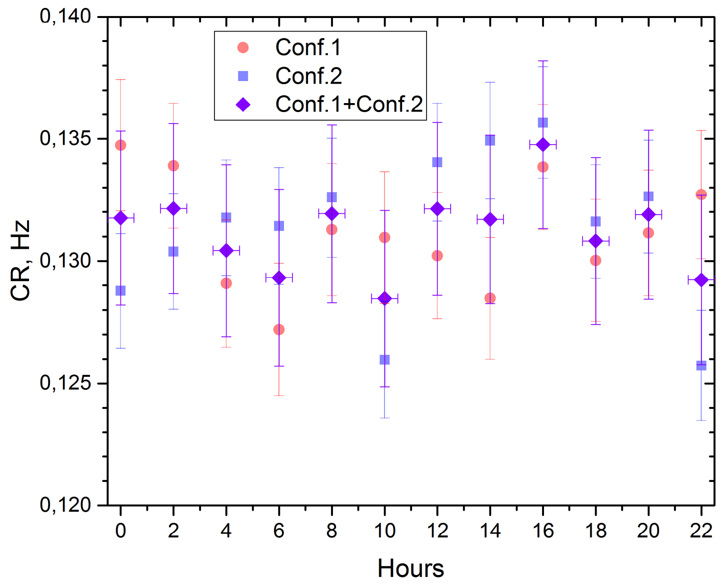
Previous measurements:

C1-C2 = - 0.00098 ± 0.00211 (2σ)

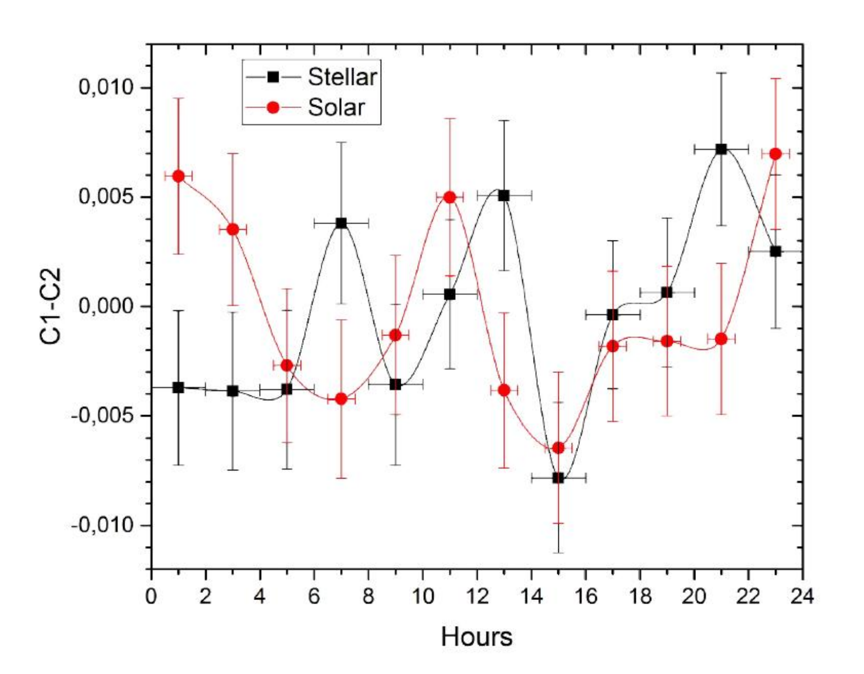
R_{MCC} = (C1 –C2 + 2σ)/ε = 0.00323/0.616

New upper limit

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



Diurnal variations of the count rates in config.1, config.2 and (config.1 + config.2)



preliminary !

Diurnal variations in solar (red) and stellar (blue) frames

one solar day = 24 hours, one sidereal day = 23 hours 56 minutes

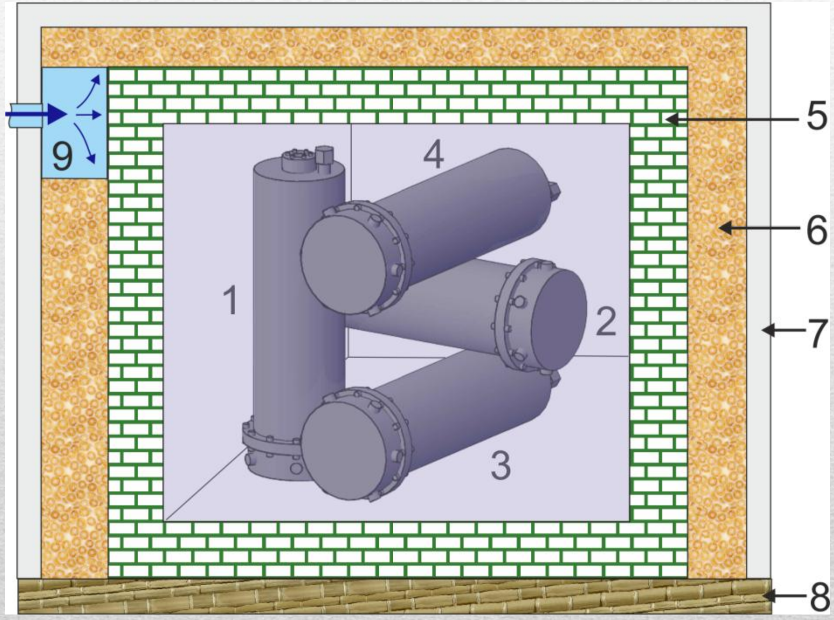
Substantial difference of the diurnal run for three detectors

at each latitude that will enable for sufficiently large samples of data to determine the absolute phase of the diurnal run and thus to find the absolute direction of the vector of the E-field.

Installation with 4 multicathode counters

1,2,3 – counters with the mirror cathodes,
4 – counter with a matt cathode

5 – lead bricks
6 – thermal insulation
7 – metallic housing
8 – impregnated wood
9 – cooling by air



Summary

The method is working and first results are encouraging

The observation (if any) of diurnal variations promises a discovery and will enable to determine a direction of a vector of E-field in Solar or Stellar frame

The study can be performed by independent groups in different mines at different geographical latitudes what will increase the reliability of the results

Our publications:

1. A.K., I.Orekhov, V.Petukhov, On the possibility of observing diurnal variations in the count rate of dark photons using a multicathode counters, Physics of Particles and Nuclei, 2021, Vol.52, No.1, pp. 31 - 38
2. A.K., I.Orekhov, V.Petukhov, First results and future prospects with PHELEX, Journal of Physics, Conference Series, 1690 (2020) 012002, doi:10.1088/1742-6596/1690/1/012002
3. A.K., I.Orekhov, V.Petukhov, Results from a hidden photon dark matter search using a multi-cathode counter, JCAP, 07, 008 (2019)
4. A.K., I.Orekhov, V.Petukhov, Method of search for hidden photons of Cold Dark Matter using a multi-cathode counter, Physics of Atomic Nuclei, Vol.82, No. 9, pp 1-8, (2019)
5. A.K., I.Orekhov, V.Petukhov, Search for Hidden Photon Dark Matter using a Multi-Cathode Counter. Proceedings of the 4th International Conference on Particle Physics and Astrophysics (ICPPA-2018), Journal of Physics: Conference Series, 1390 (2019) 012066
6. A.K., I.Orekhov, V.Petukhov, A multi-cathode counter in a single-electron counting mode, NIM A, 910, 164 (2018)
7. A.K., I.Orekhov, V.Petukhov, Tech. Phys. Lett 42, 102 (2016)
8. A.K., I.Orekhov, V.Petukhov, Adv. High Energy Phys., 2058372 (2016)

Thank you