DEVELOPMENT OF VACUUM PMT’ S BY MELZ AND IHEP

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MELZ is a leading Russian developer and manufacturer of electro-vacuum devices, namely photomultiplier tubes for geophysical and spectrometry purposes and image intensifier tubes of 2, 2+ and 3 generations.
Our devices cover all the spectrums of light emission, starting from deep UV up to visible and even near infrared areas, having applications in numerous detection systems.

OUTLINE

- **The new 3-inch PMT for the KM3Net project.**
- **The PMT's with cylindrical photocathodes of Ø40×200mm^2 and Ø60×200mm^2 sizes.**
- **Three inch and two inch photomultipliers for astrophysical detectors.**
    - The idea and possible applications of the photomultipliers.
    - Construction and characteristics of PMTs.

PHOTOMULTIPLIER FOR KM3NET

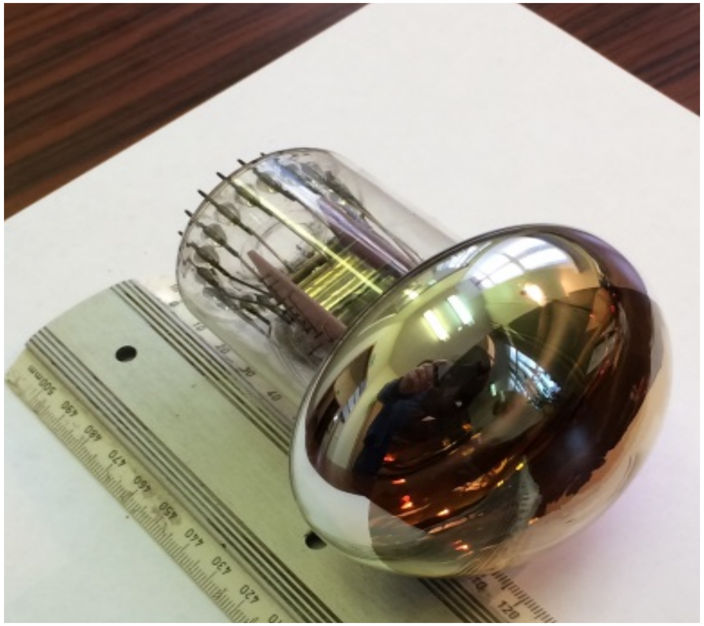
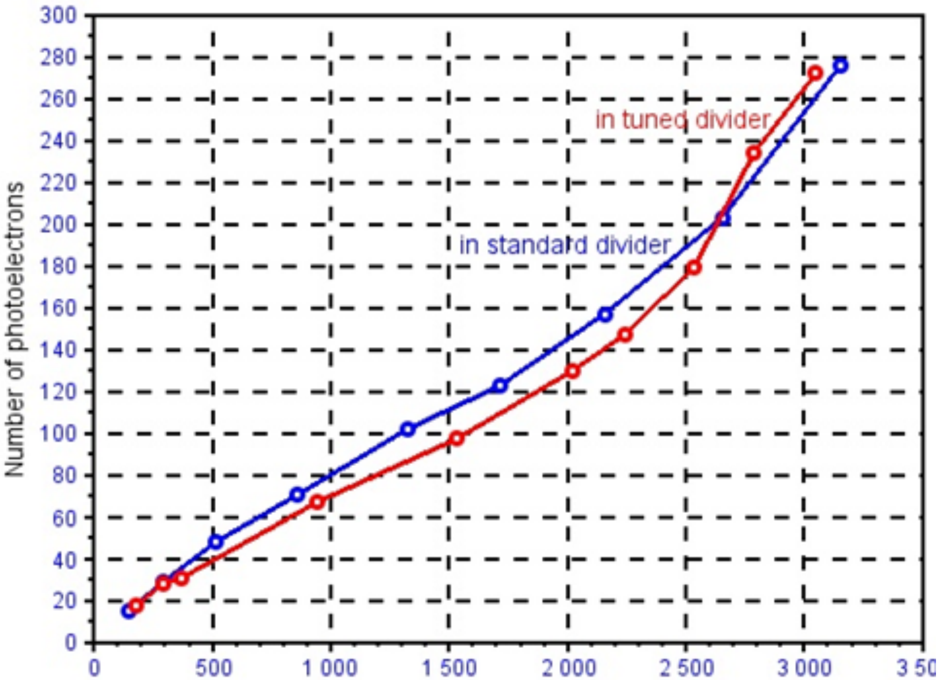


Fig.1

Tube diameter	52 mm
Tube length	105 mm
Photocathode sizes (spherical form)	Ø3 inch
Photocathode type	K2CsSb
Spectral response	350 – 600 nm
Spectral sensitivity, В т 405 nm	up to 130 m A /
Dynode type	trough-shaped
Number of dynodes	10
Multiplication at maximum voltage (1500 V)	≥ 5×10^{6}
Single photoelectron pulse width at 10% level	≤ 5 ns
Single photoelectron time jitter	3,5 ns (FWHM)

One of the last development of MELZ is PMT with the 3 inch spherical photocathode designed for registration of nanosecond light signals (Cherenkov emission). Such PMT's are to be used in 17 inches diameter spherical optical module of deep-water neutrino telescope for the KM3Net project. In this particular PMT we applied an electron-optical system of linear type from PMT-115 with 10 trough-shaped sprayed dynodes fixed on ceramic supporting plates. The mesh anode located between two last dynodes is used to increase the linearity of output signals. Dimensional length of this PMT without pins states 105 mm, the external diameter of a mouth - 52 mm. Optimal radius of a curvature (43,2 mm) of the photocathode was calculated by means of computer modeling in order to increase efficiency of photoelectrons' collection at the minimum jitter of photoelectrons flight time.

KM3Net PMT.
Linearity of anode current at the impulse with 20 ns width



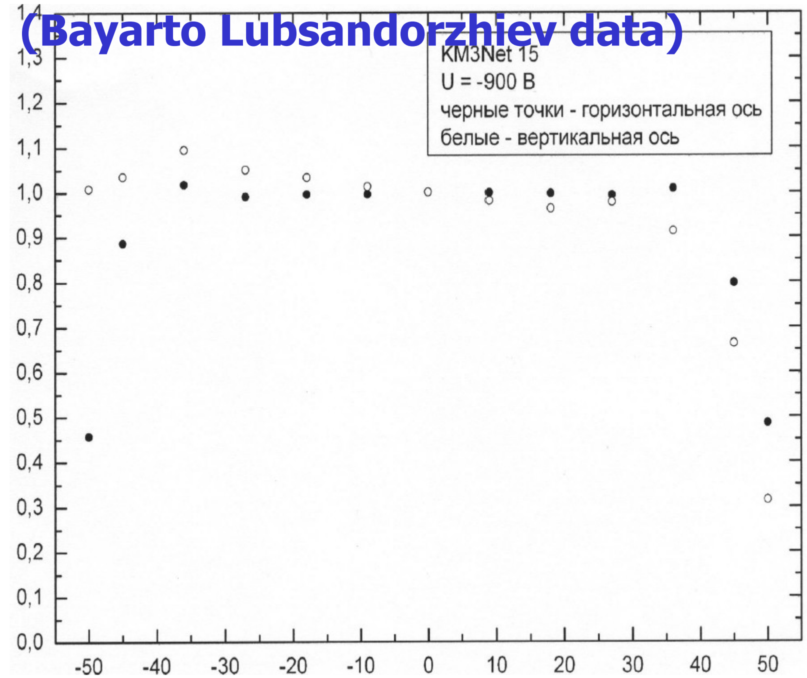
Charge /pulse

0 10 20 30 40 50 mA pulse amplitude

Fig.2 Blue circles – the standard divider, red circle – specially adjusted divider.

KM3Net PMT.
Efficiency of photoelectrons collection depending on rotation angle

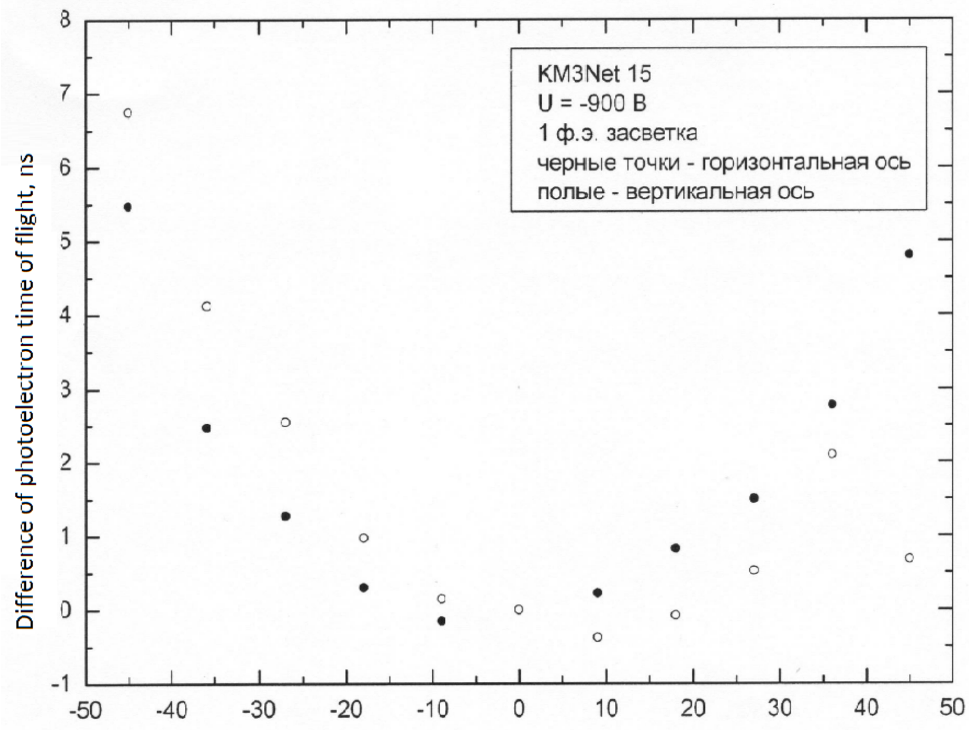
(Bayarto Lubsandorzhiev data)



Angle, degree

Fig.3 Black points – the dependence corresponded to a line of the cross section in parallel to a direction of the first dynode length, circles – the dependence corresponded to a line of the cross section in perpendicular to this direction.

KM3NET PMT. PHOTOELECTRON FLIGHT TIME DEPENDING ON ROTATION ANGLE



Angle, degree

Fig.4 **Black points – the dependence corresponded to a line of the cross section in parallel to a direction of the first dynode length, circles – corresponded to a line of the cross section in perpendicular to this direction.**

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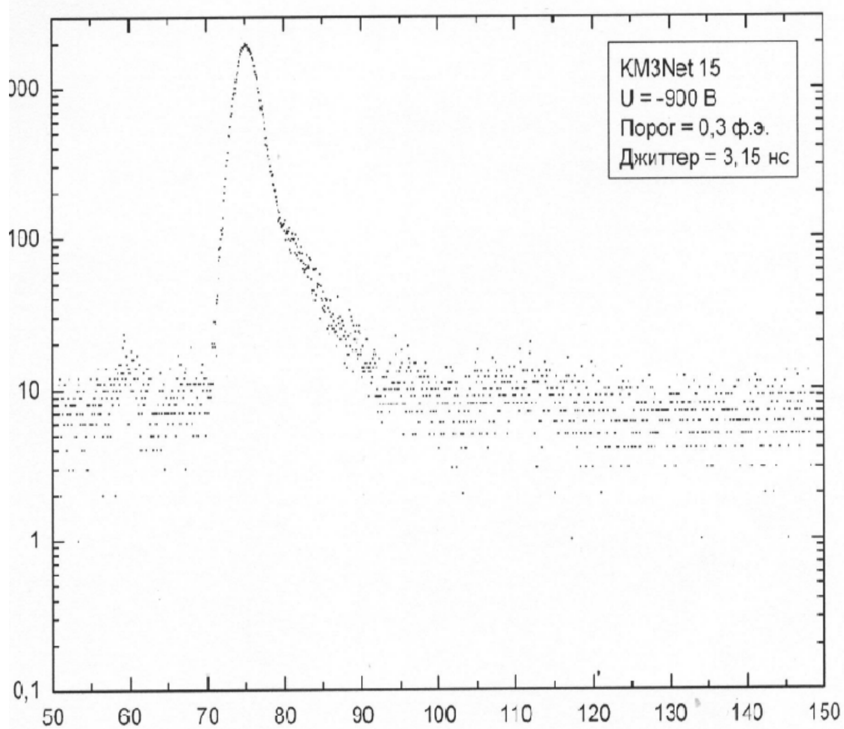
KM3Net PMT. SINGLE PHOTOELECTRON JITTER TIME.



Time, ns

Fig.5 **Shows the whole spectrum of photoelectron jitter.**

KM3Net PMT.
Single photoelectron spectrum.

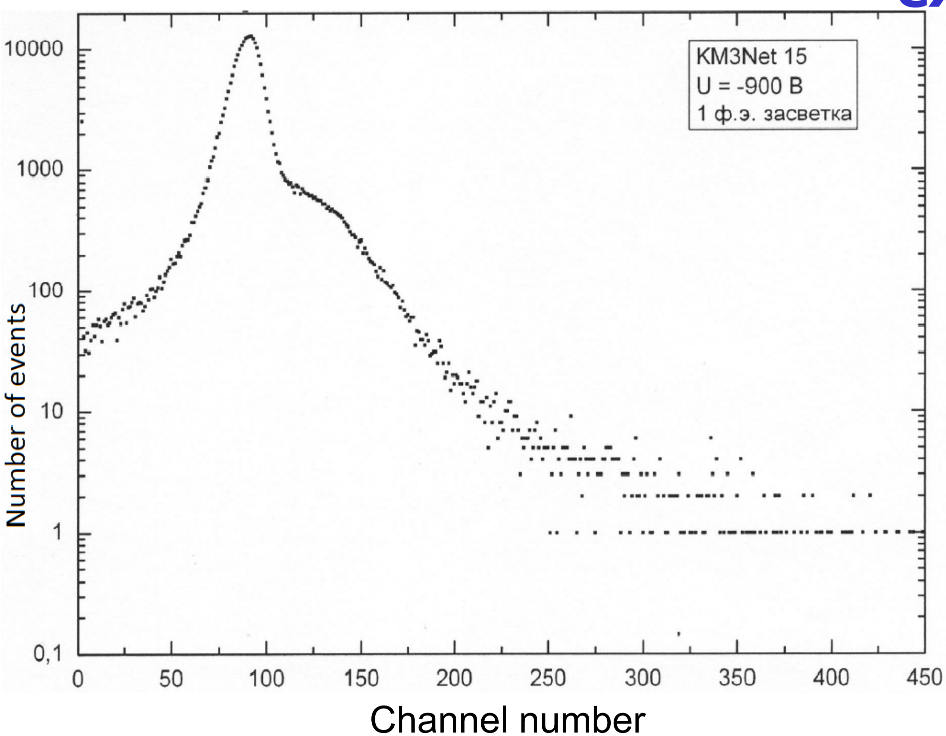


Fig.6 **Shows the whole spectrum of single photoelectron impulse**

CONCLUSION:

Designed KM3Net PMT suits to the requirements of the experiment.

TASKS FOR THE NEAR FUTURE:

1. To improve single photoelectron spectrum.
2. To increase the yield rate of PMT's with the required photocathode sensitivity.

The PMT's with cylindrical photocathodes of Ø40×200mm² and Ø60×200mm² sizes.

- The idea and possible applications of the photomultipliers.
- Construction and characteristics of the PMT's.

Usually the sizes of plastic scintillators of gamma radiation monitors for portal detectors are around meter length and 50 mm thickness. Scintillators are looked through by the two-inch PMT (Fig.7). Photocathode square of that PMT is less than 20 cm^2 thus is light collection efficiency is sufficiently small.

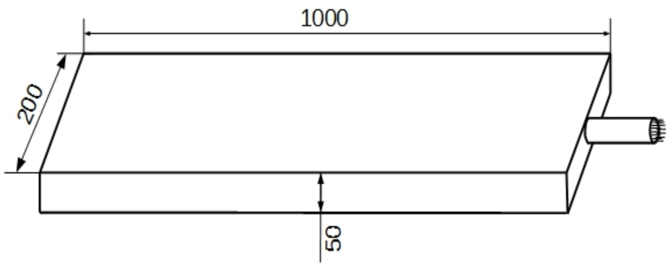


Fig.7

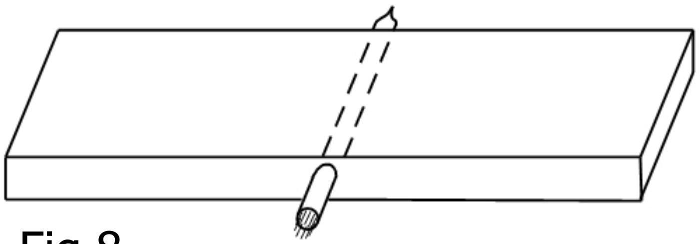


Fig.8

In turn it results in low efficiency of gamma quanta registration in the energy field lower than100 кeV. As a result of it we came up to the idea of development of PMT with the extended cylindrical photocathode (Fig.8) that allows to improve a light collection significantly. With a length of photocathode of 200 mm and its diameter of 40 mm the active square of the photocathode exceeds the square of the photocathode of two-inch PMT more, than by 10 times. Maximum distance passed by photons decreases twice in comparison to the basic PMT and, besides, the photons falling on PMT can pass through the photocathode twice.

The PMT's with cylindrical photocathodes.

(sketch)

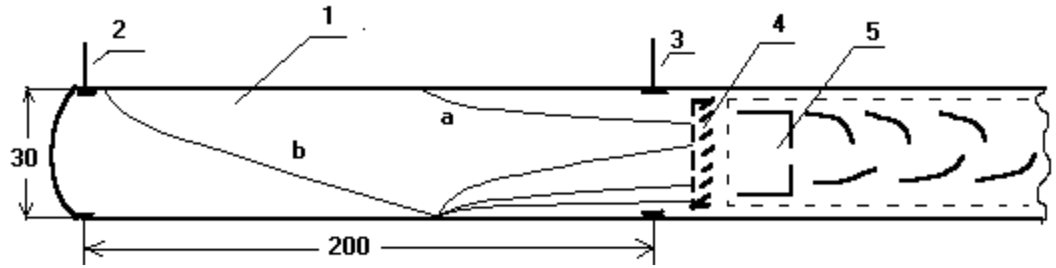


Fig.9 1 - glass cylindrical photocathode window. 2 - photocathode beginning. . a, b - photoelectron trajectories. 3 - photocathode end. 4 - venetian blend dynode. 5 - cathode camera.

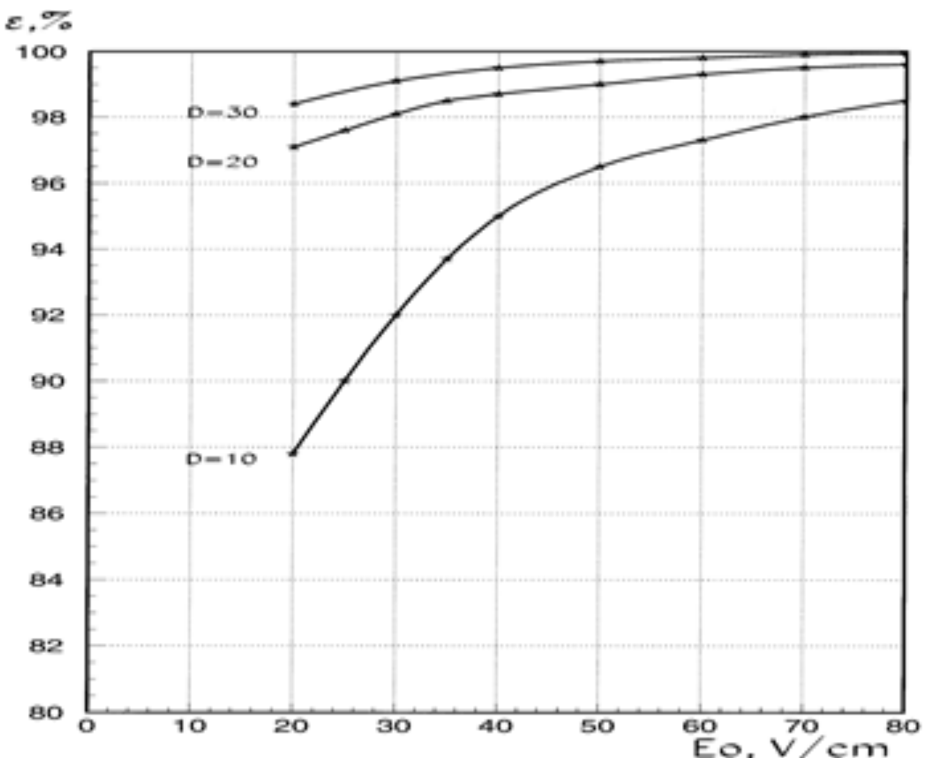


Fig.10 Efficiency of photoelectron transportation to venetian blinded dynode in dependence with diameter of glass cylindrical flask D and value of longitudinal electric field E_0 inside flask. E_0 is defined by a difference of electric potentials between contacts 2 and 3.

The PMT's with cylindrical photocathodes.

Fig.10 Photo of PMT (PMT KF) with sizes of photocathode Ø40×200mm^2 , evaporated aluminum corbels are intended for leveling electric potential along the photocathode.

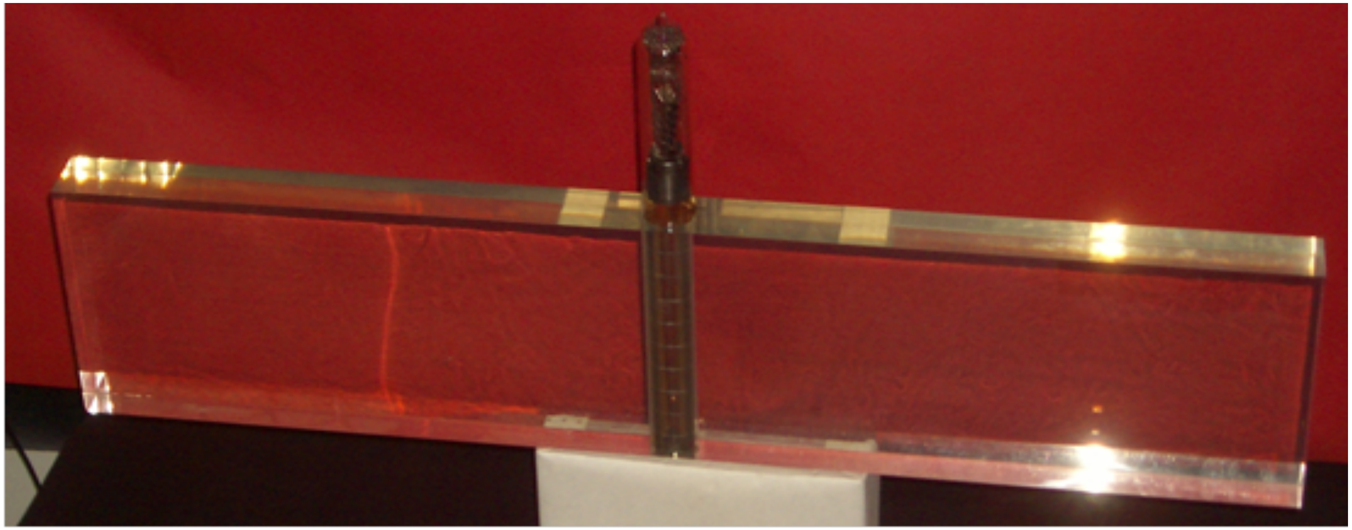


Fig.11 Photo of scintillator of 50×200×1000mm^3 with the PMT KF introduced inside the scintillator body.

The PMT's with cylindrical photocathodes.

A few samples of PMT KF were made before a termination of the ISTC project. Average on perimeter photocathode blue sensitivity of one from first samples is shown below.

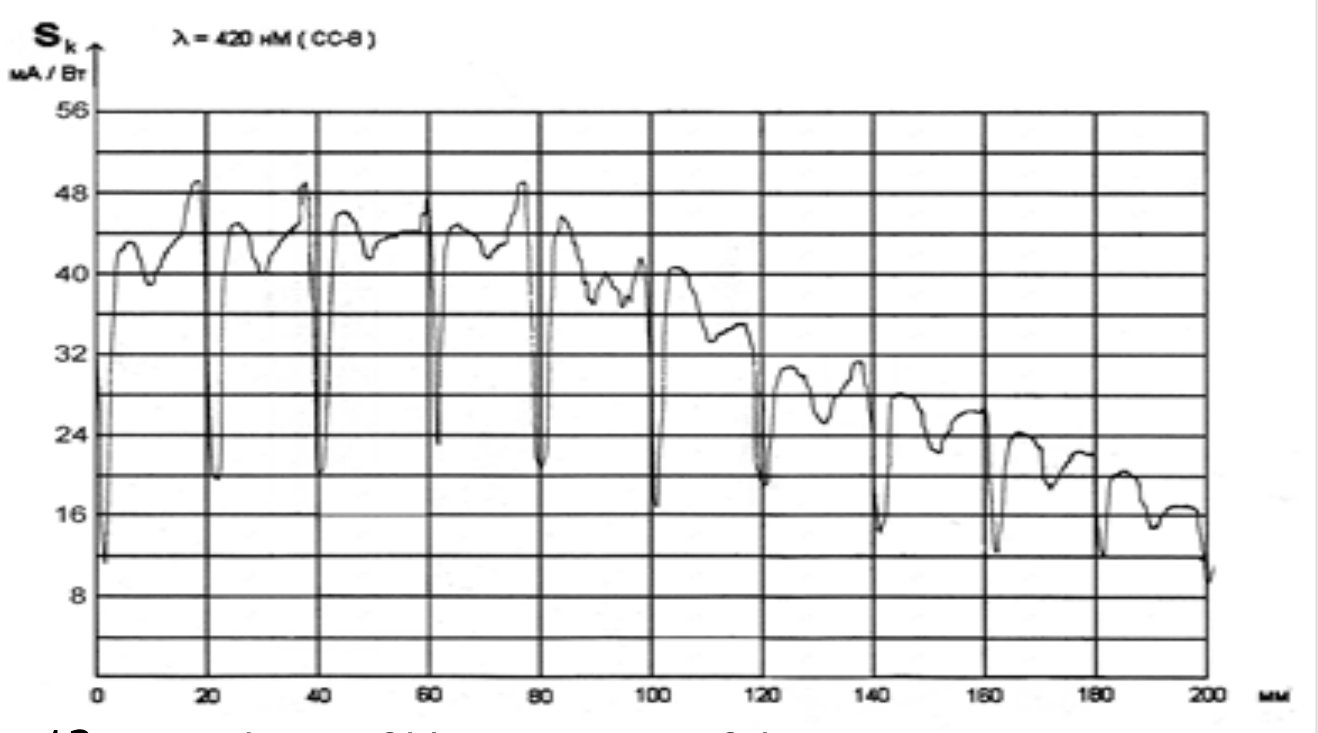


Fig.12 Dependence of blue sensitivity of the PMT KF photocathode on longitudinal coordinate.

At average on all square of photocathode blue sensitivity was near 30mA/W, Registration efficiency of gamma quanta by scintillating counter of 50×200×1000mm^3 with that PMT and PMT 184 (blue sensitivity 120mA/W) was practically equal. Therefore, at an increase of the blue sensitivity of PMT KF to 120mA/W it is necessary to expect at least the fivefold increase in a quantity of photoelectrons at registration of gamma quanta.

The PMT's with cylindrical photocathodes.

In the last time a interest to that PMT appears again. It is connected with creation of the big neutrino liquid scintillating detectors with axial symmetry. Length of these detectors is a few meter, diameter – more one meter. The arrangement with a chain of that PMT along an axis of symmetry of the detector is optimum by efficiency and uniformity of a light collection. Up to now we developed a new design of venetian blend dynodes, produced some models and the first prototype of the new PMT with photocathode sizes of Ø60×200mm^2 (Fig.13). The reached level of blue sensitivity is 30-40 mA/W, multiplication gain – 10^6 as with 13 venetian blend dynodes.

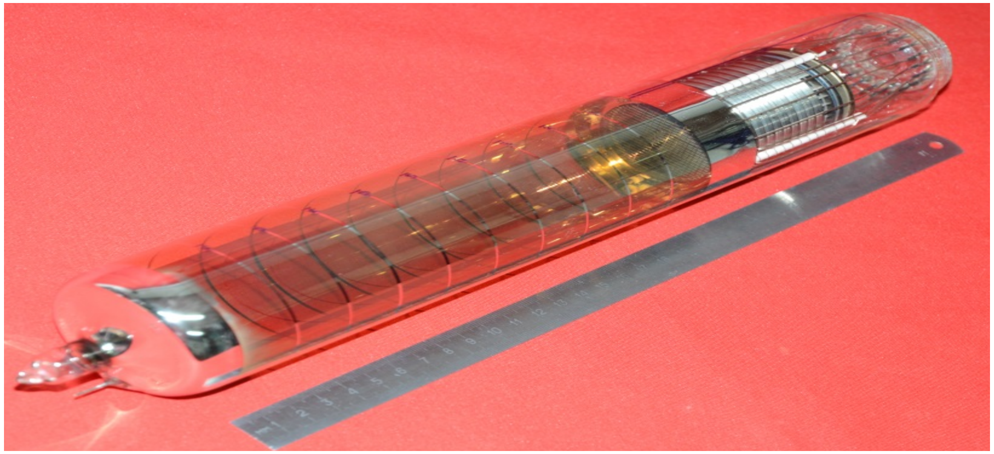


Fig.13

Conclusion, plans.

1. We hope that this type of the PMT's can find application in a number of R&D tasks.
2. First of all it is supposed to make samples of devices with **increased sensitivity** for radiation monitors.
3. It is planned also to make samples of the PMT with high, more than 100 mA/W, blue **photocathode** sensitivity and photocathode diameter of 60(100) mm for neutrino detectors.

MELZ FEU

Photomultiplier Tubes Manufacturer

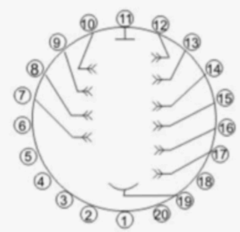
Photomultiplier Tube

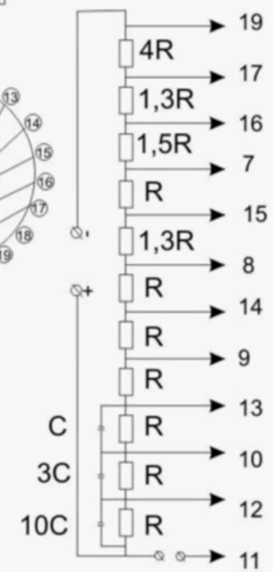
FEU – 184

Photomultiplier Tube with 52 mm diameter, 10-stage Box-&-line-Focusing Type, Head-on Bi-alkali Photocathode, γ-ray Detector.

GENERAL

Application: *scintillation counter, especially for γ-ray chambers*	
Photocathode material	Sb-K- Cs
Photocathode diameter, mm	46
Window material	C-52-1 glass
Optical input	Head-on
Dynode assembly	Box 3 & line 7
Dynode material	Sb-Cs
Number of dynodes	10
Spectral response, nm	300-650
Wavelength of maximum response, nm	420
Design	glass, with rigid pins
Working position	any
Bulb diameter, mm, max	52
Bulb height without pins, mm, max	110
Weight, g, max	120





C= 33 pF R<= 1MOm

MAIN PARAMETERS at 25 °C

	Min.	Typ.	Max.
Luminous photocathode sensitivity, μA/lm	70	100	-
Spectral photocathode sensitivity of photocathode at 410 nm, mA/W	70	90	-
Luminous anode sensitivity, A/lm	8	10	30
Supply voltage, V, max at anode sensitivity 10 A/lm	-	800	1350
Dark anode current after 30 min storage in darkness, nA, at voltage corresponding to anode sensitivity 10 A/lm	-	2	20
Gain	-	$2x10^5$	-
Anode pulse rise time, ns	-	7	-
Electron transit time, ns	-	50	-
Energy resolution for ^{137}Cs,NaJ(Tl)Ø40x40, %	-	6	7
^{57}Co,NaJ(Tl)Ø40x40,%	-	8	9,6
Energy equivalent of inherent noise, keV	-	0,7	3
MTBF, hours	1000		

*Dimensions in millimeters

LIMITING VALUES

Maximum supply voltage with the reference to U_{SA} at sensitivity 10 A/lm	1.1* U_{SA}	
Anode current, mA	0.002	
Operating temperature, °C	-60	60

VOLTAGE DISTRIBUTION RATIO

THANK YOU FOR YOUR ATTENTION!