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HIGH RESOLUTION GAMMA-TELESCOPE WITH MONOCRYSTAL CONVERTER

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It is proposed a high angular resolution gamma-telescope for energies above I GeV based on the experimental evidence obtained as a result of the investigation of the electromagnetic showers initiated by gamma-rays in the aligned single crystal.The main telescope feature is the assembled mozaic converter made of aligned silicon crystals.The telescope angular resolution determined by the width of the shower development orientation dependence is about 3 mrad which is many times better than that of the telescope available.It takes the 0.25 m^2 space telescope of this type from several days to dozens of days to locelize with above accuracy a doscovered discrete source of cosmic gamma-radiation (e.g. Geminga) by identifying it with one of the peculiar objects in its error box.

When high-energy electrons or γ-rays pass through a crystal at a small angle to the crystallographic axis the probability of their interaction with matter becomes higher which promotes the intensive development of electromagnetic showers /I,2/.The charged component of the shower leaving the crystal can be registered and evaluated by the signal amplitude of a scintillation or Cherenkov counter placed behind the crystal.The smaller the angle θ between the crystallographic axis and the incoming particle momentum the greater the signal amplitude.This orientation dependence has its maximum at $\theta = 0$ for all particle energies (in contrast to that of e^+e^--pair production cross-section with the maximum at $\theta \approx m/E$ /3/).

Taking into account that the shower orientation dependence width is much smaller than that of the pair production cross-section we find it reasonable to develop a new method of localization of discrete γ-ray sources /4/.

In order to verify the idea and to find more simple solution (i.e. lower energy γ-rays,more available and cheaper crystals) we undertook the measurements of the charged component of the electromagnetic showers generated by γ-rays with energies $E=0.5 \div 25$ GeV in a silicon single crystal.We used a tagged γ-ray beam created by primary 28 GeV electrons on the CASCADE set of the Serpuchov accelerator /5/.The γ-ray track was measured with the accuracy of no worse than 0.I mrad by means of beam proportional chambers.The γ-ray beam divergence was less than 0.5 mrad in the base.

The 20 mm thick silicon crystal was <IIO> axis oriented.Fig.I

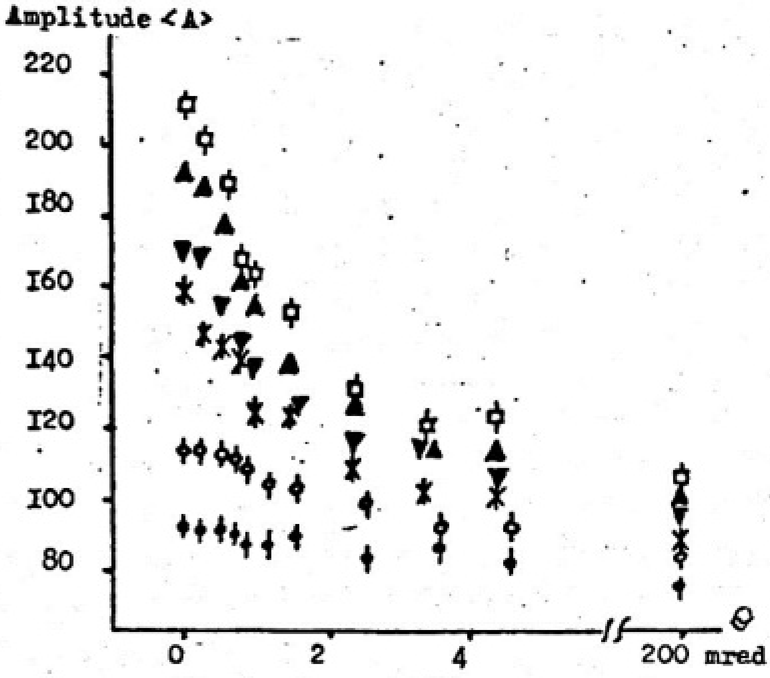

Fig.I Orientation dependence of the average amplitude Cherenkov counter signals for γ-ray energy ranges: ● 0.5-3 GeV, ○ 3-5 GeV, ▼ IO-I5 GeV, × 5-IO GeV, ▲ I5-20 GeV, □ 20-25 GeV.

presents the orientation dependences of a Cherenkov counter with a lead glass I radiation length thick radiator set behind the crystal.The measurements were carried out for 6 energy ranges from 0.5 GeV to 25 GeV.All distributions show maximum at θ =0.As the energy increases the maximum excess rises from $\sim$ 20% at E=0.5-3 GeV to $\sim$ I00% at E=20-25 GeV.This indicates that the method becomes more effective with the increase of γ-ray energy.At energies about I GeV the excess is small,therefore,the search may involve difficulties.At these energies,however,one can make use of the amplitude spectrum transformation coefficient instead of the average amplitude <A> .Fig.2 shows Cherenkov counter amplitude spectra of γ-rays with energies of 3-5 GeV for two extreme cases: a) the crystal is disoriented (θ =200 mrad) b) the crystal <IIO>axis is γ -ray beam oriented (θ =0).When γ -rays pass through the oriented crystal the number of large amplitude events increa-

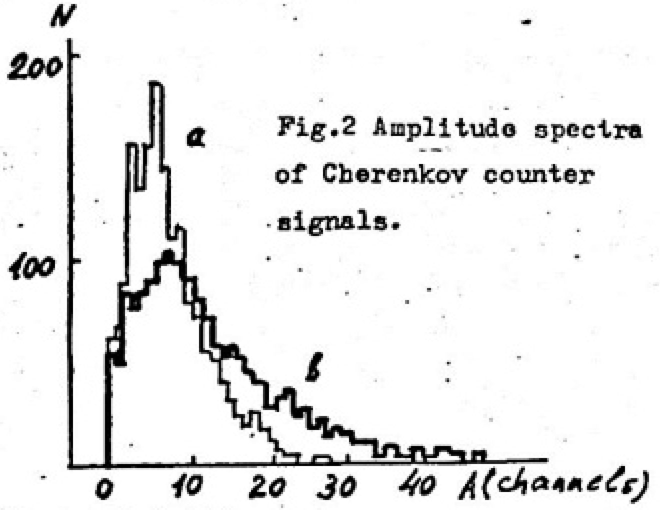

Fig.2 Amplitude spectra of Cherenkov counter signals.

ses due to the decrease of those with small amplitude.The transformation coefficient is $\alpha = N_r/N_l$, where N_r and N_l denote the numbers of events in the right and left parts of the spectrum with respect to a particular (in this case IOth) channel.Fig.3 shows the orientation dependence of the ratio $\frac{\alpha(\theta)}{\alpha_d}$ (α_d is the transformation coefficient for the disoriented crystal) for γ -rays with energies of 0.5-3 GeV, the maximum excess being ~ IOO%.

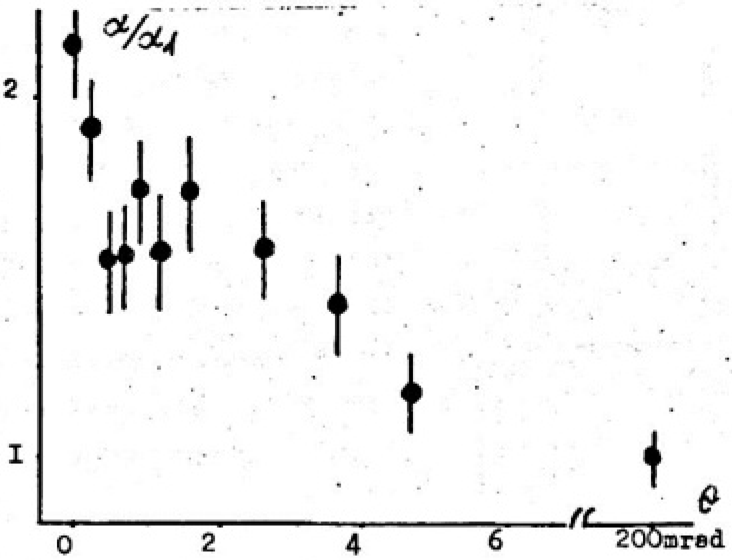

Fig.3

Thus, the use of the amplitude spectrum transformation coefficient considerably facilitates the search of γ-ray sources at low energies.

In terms of the obtained data analysis we designed a high resolution gamma-telescope (Fig.4) which consists of an anticoincident shield A, a crystal converter C, registering counters C_I, C_2 , a series of scintillation or Cherenkov detectors S measuring the electromagnetic shower leaving the converter, a series of hodoscopic counters H for preliminary γ-ray selection and a shower detector SD evaluating the energy of the registered γ-ray.

The converter is a mozaic of aligned silicon crystals 5 cm thick and of the most available dimensions (e.g.IO x IO cm^2). The angular resolution of the converter and of the telescope as a

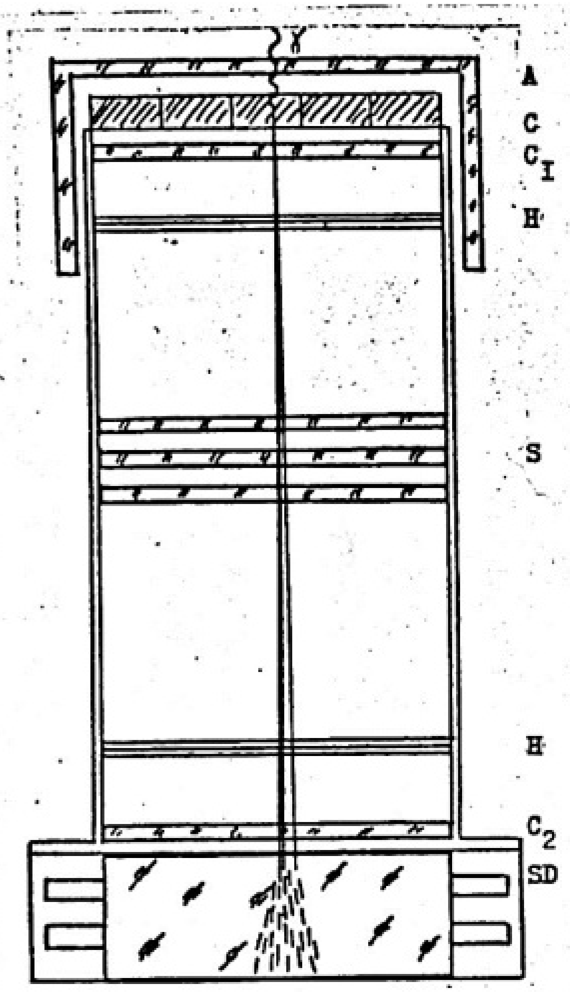

Fig.4

whole depends on the width of the shower orientation dependence which is 2-5 mrad for different γ-ray energy intervals (that of the conventional spark chamber gamma-telescope is of an order lower).To diminish the contribution of the isotropic background γ-radiation the telescope must have a small entrance aperture which can be limited by means of spaced hodoscopic systems (crossed scintillation bands, silicon strip detectors etc.) recording the coordinates of the shower.The measurements showed that the shower core diameter is of I-3 mm.The hodoscope of counters with the coordinate accuracy of 5 mm and spacing of 20 cm makes it possible to determine the γ-ray entrance angle with the precision of I.5° ,while a microprocessor selects the γ-rays coming from the fixed direction within this angle.The isotropic background can be lowered in such a way as to extract a point source flux.

The main function of the shower detector is to set up the energy threshold and to cut off low energy γ-rays.Its energy resolution must be no worse than $\Delta E/E=40\%$ at E=I GeV with the thickness of 5 radiation lengths.The thickness increase is at the present moment undesirable since it makes the telescope much heavier.

Because a crystal converter gamma-telescope has a high angle resolution it can not be used for searching new sources.Its function as that of any narrow-angled telescope is to verify the position of the discrete sources already known within their error box (about I square degree for COS-B sources /6/).As a rule the error box contains some precisely localized peculiar objects (X-ray and radio sources, active variable objects, etc.) which are the likely candidates for γ-ray counterparts. The crystal converter telescope would make the final choice. The telescope axis coinciding with that of a monocrystal is to be oriented step by step to the candidate objects. Every orientation exposure covers 50–I00 γ-ray events sufficient to make a shower amplitude spectrum. The source would be identified provided the measured spectrum is identical to the expected one for the showers produced by γ-rays following the crystal axis. Its size and the exact position could be proved by measuring the additional spectra as the telescope axis is going away from the source.

The gamma-telescope with the 0.25 m^2 mozaic crystal converter would weigh 300 kg with a I00 kg shower detector and an about 50 kg converter. Its angular resolution could be ~ 3 mrad in the effective energy interval of I-50 GeV which is many times better than that of SAS-2, COS-B and that of functioning now GRO space telescope and which is sufficient for the localization of the γ-ray counterparts. Installed aboard an orbital station this telescope is able to distinguish a true γ-ray source among some peculiar objects within the error box.

Geminga, one of the brightest but so far unidentified γ-ray sources (2CG I95+04 in COS-B cataloque /6/), is considered to be the first object to be observed. Fig.5 shows the Geminga region.

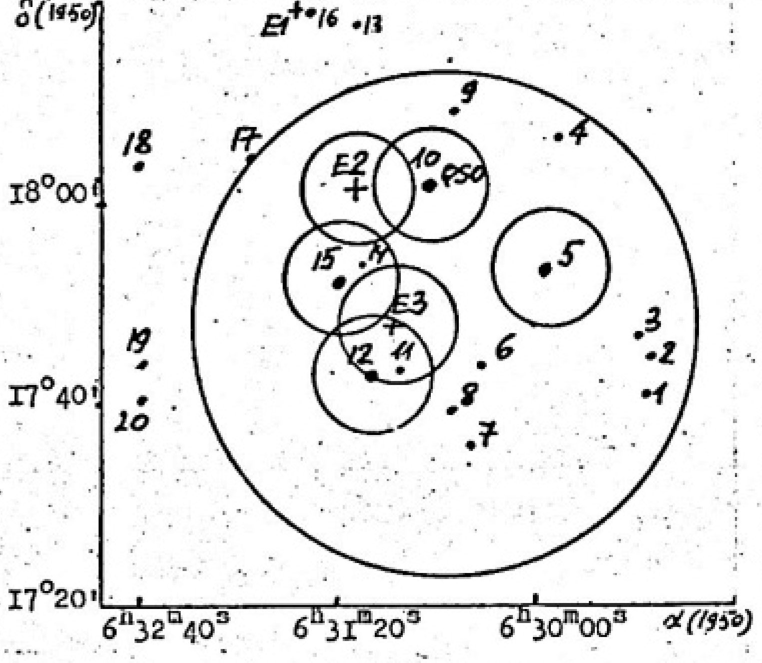

Fig.5

The large circle with 30 arcmin radius is the source error box according to COS-B data (the probability of the source location inside the circle is 68%). The numbered points and crosses indicate the peculiar objects, i.e. discrete radio and X-ray sources discovered as a result of the deep survey of the region. The six brightest ones are circled with the radius equal to the telescope angular resolution. They are the targets the telescope axis is to be oriented. With the Geminga flux being $F(>1\ \mathrm{GeV})=6\ 10^{-7}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, the exposure time of each target (the time needed to register 50 γ-ray events) is $7\ 10^{4}$s, the exposure time for the six brightest objects is 4 d, that for all inner objects being 10 d.

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