Balloon Direct Measurements of the PCR Charge and Energy in the Range of 10^{13}-10^{15} eV (CROSS)

A.S.Borisov[1], K.A.Kotelnikov[1], S.K.Kotelnikov[1], V.M.Maximenko[1], R.A.Mukhamedshin[2], V.P.Pavluchenko[1], V.S.Puchkov[1], S.E.Pyatovskiy[1], Yu.A.Trubkin[1], A.P.Chubenko[1]

[1] P.N.Lebedev Physical Institute RAS, Moscow, Russia
[2] Institute of Nuclear Research RAS, Moscow, Russia

The project CROSS (Cosmic Rays Over Spectrum Steepening) is intended for direct measurements of mass and energy of PCR in energy range 10^{13}-10^{15} eV near the region of knee in PCR energy spectrum. The experimental technique is balloon-born ionization spectrometer consisting of transition X-ray radiation generators interposed with proportional chambers. Each of three generators consists of 50 Mylar films of 40 microns thick. Total thickness of these generators is about 1 g/cm^2. Number of proportional chambers is 1400 among which 800 chambers are filled with Ar gaseous mixture, while the others – with Xe mixture. The proportional chambers diameter is 2 cm and their length – 200 cm. The array will be exposed during balloon flights mainly from Kamchatka peninsula to the river Volga (5-6 days) at the atmosphere boundary (5-10 g/cm^2). It is expected that during a 5-day flight about 40 PCR-particles with energies above 10^{14}eV will be registered.

Introduction.

As a rule the investigations of PCR chemical composition and energy spectrum near the spectrum knee are fulfilled with the help of EAS and by method of mountain large emulsion chambers [1-2]. However the experimental data, obtained in the depth of atmosphere , are distorted by complicated cascade processes. Because of that at determining atomic masses and PCR particle energies one has to solve inverse problems where as parent data there are used such experimental values as spatial distribution of EAS electrons, high energy gamma-quanta and muons etc. It leads to ambiguous conclusions at the experimental data analysis. Obviously only direct experimental data [3] on the nature of PCR particles with energies near their spectrum knee could clear up the situation. Besides there exists a whole row of other problems in cosmic ray physics and astrophysics which solution makes actual the physical program of the presented project – experimentally determining the PCR particle nature in energy range $\gamma=5\cdot10^3\div5\cdot10^4$.

Parent experimental material is supposed to be received with the help of long duration balloon flights of project CROSS installation at altitudes (3÷10)g/cm^2.The basic experimental method supposed to be used is stratospheric balloon born ionization spectrometer for detecting transition radiation and specific ionization by specially elaborated large proportional chambers, filled by Xe-mixture and Ar-mixture gas.

Experimental installation.

On Fig.1 it is schematically shown the stratospheric installation ,which has a form of rectangular parallelepiped close to cube one, on the platform with area 2×2 m^2. It consist of three identical TRD sections each including a periodic radiation of 50 mylar foils of 40 microns thick, separated by 1.5 cm gaps of air at stratospheric altitudes, and a double row of gas-filled X-ray proportional chambers with Xe-containing gaseous mixture (for example, 0,25 Xe+0,60 He+0,15 CH_4). The sections are alternated with analogous layers of proportional chambers for PCR-particle energy loss measurements, with Ar-based gas mixture (0,75 Ar+0,10 He+0,15CH_4). Geometrical factor of the cube arrangement is equal to G=2.52 m^{2}ster.

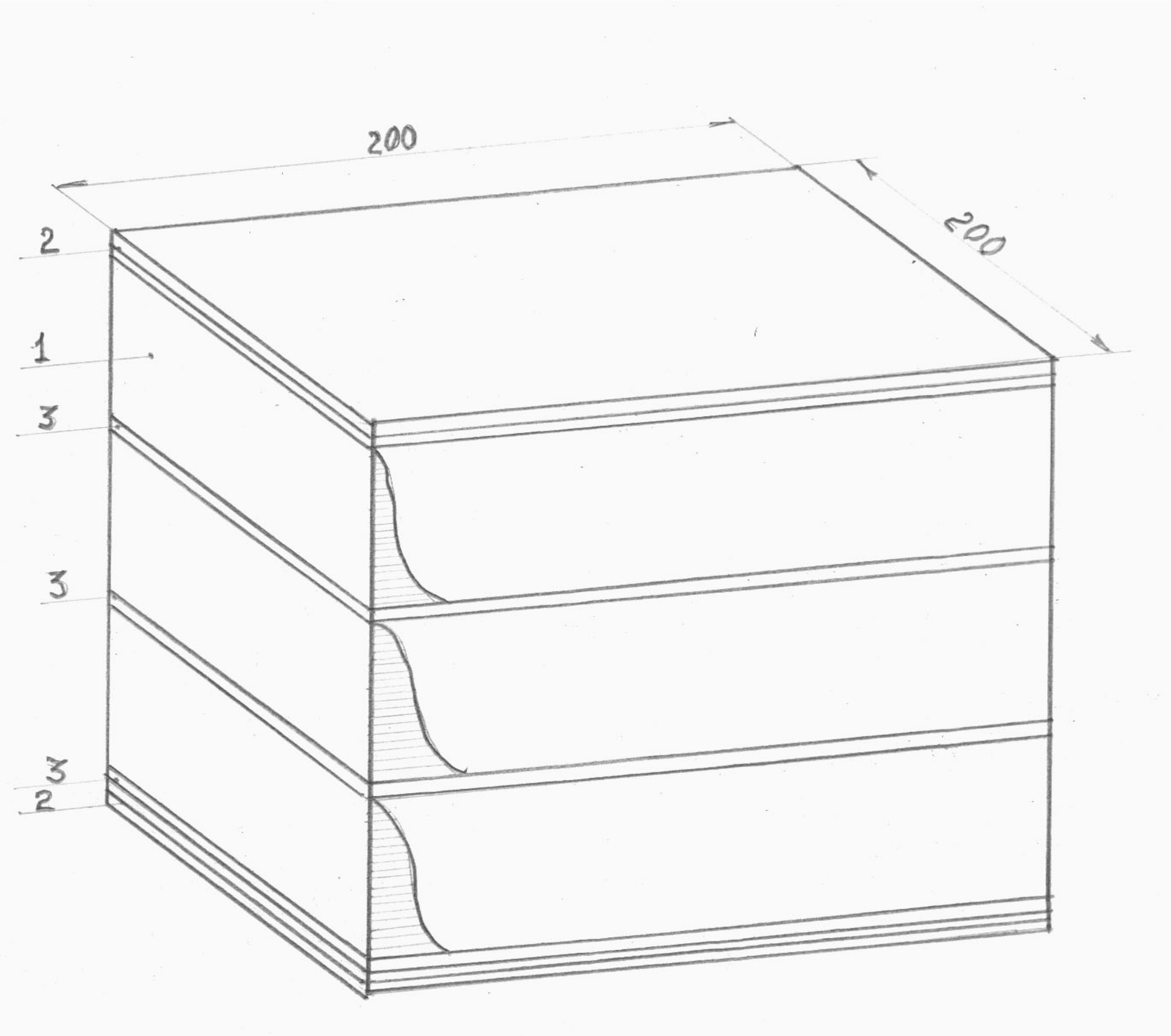

Fig.1. Scheme of experimental installation : 1-TR-radiators; 2-two layers of double rows of Ar-mixture filled chambers for specific ionization measurement and track coordinates; 3- double rows of Xe-filled proportional chambers.

All the cylindrical proportional chambers of 2-cm diameter and 200 cm long are performed from aluminum backed mylar of 150 microns thick. As an anode there is used a gilded 25-60 micron of diameter tungsten filament. The full number of the chambers is 1400, among them 800 chambers are filled with Ar gas mixture and 600 – with Xe mixture.

To estimate experimental characteristics of the array we used the theoretical results of the following works: a)for transition radiation – the mathematical expressions, presented in [4], b)for ionization energy losses and their fluctruations in superthin gaseous layers – results of theoretical consideration and numerical calculations of [5].

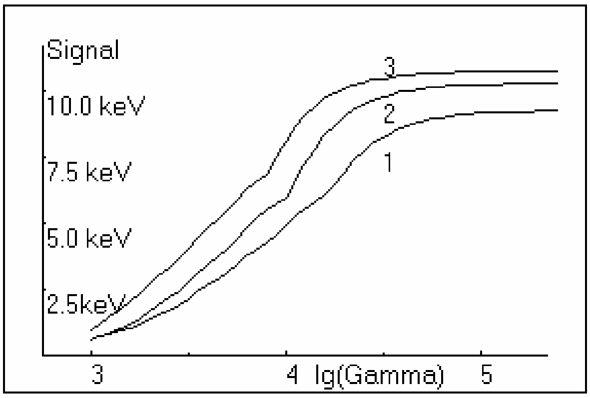

Fig.2. TR energy response S of a section to the fact of an upright passing singly charged particle. Curve "1" corresponds to L_1=40 microns, L_2=1,5 cm, N=50 (main variant). For comparison curves "2" and "3" present variants L_1=25 microns, L_2=1.0cm, N=50 and L_1=15 microns, L_2=1.0 cm, N=50 respectively.

Fig.2 shows the calculated response S of a TRD section (energy of TR-photons detected in the corresponding double row of Xe chambers) to the fact of an upright passing ultra-relativistic singly charged particle, as a function of its Lorentz-factor value γ. At the first look the dependence seems somewhat disappointing: apparent "saturation" occurs long before the value of $\gamma_{sat}= 1.47\cdot10^5$ in our case and insufficient number of registered TR-photons($N_{ph}\leq1$). It is true, but only for a singly charged particles.

For Z-charged PCR-nuclei the situation is shown in the following Table, where there are presented possible uncertainties $\Delta(\lg\gamma)$ in identification of registered particle Lorentz-factor. The uncertainties were estimated as

$$\Delta(\lg\gamma)=[N_{ph}(\eta\varpi)^2+(2060)^2(z^2)^{-0,4}((n_1+n_2)/n_2)]^{0.5}/((dS/d(\lg\gamma)[Z^2n_1]^{0.5}),$$

where N_{ph} - number of registered TR-photons from a singly charged particle,
$(\eta\varpi)$ – photon mean energy in the theoretically calculated TR-photon spectrum,
2060(eV) – rms deviation (theoretical) of ionization energy losses in the layer of 0.8 cm of Xe at atmospheric pressure,
Z – particle charge,
$dS/d(\lg\gamma)$- the derivative of the dependence in Fig2,
n_1 and n_2 – numbers of TR-registering sections and ionization-registering layers correspondingly.

Table. Estimation of possible uncertainties $\Delta(\lg\gamma)$ in identification of Lorentz factor for particles with different Z^2 for the variant L_1=40 microns, L_2=1,5cm, N=50 .

γ	$N_{ph(Z=1)}$	$(\eta\varpi)$,eV	Z^2=12.5	Z^2=25	Z^2=50	Z^2=100	Z^2=200	Z^2=400	Z^2=800
10^3	0.0835	8150	0.24	0.16	0,11	0.07	0.05	0.04	0.03
3.10^3	0.2232	9496	0.17	0.12	0,08	0.06	0.04	0.03	0.02
10^4	0.4414	11104	0.18	0.13	0.09	0.06	0.04	0.03	0.02
3.10^4	0.6760	12178	0.37	0.26	0.18	0.13	0.09	0,07	0.05
5.10^4	0.7161	12318	0.93	0.66	0.46	0.33	0.23	0.16	0.12
7.10^7	0.730	12359	1.86	1,31	0.93	0,65	0.47	0.33	0.23
10^5	0.7368	12379	3.72	2.62	1.85	1.31	0.92	0.65	0.46

Now the CROSS project is in the stage of elaboration of proportional chambers, triggering system, channels of electronics and others blocks of the installation. .

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