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III-5-13. Large Bursts under 10.5 cm of Lead in Ionization

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The spectrum, altitude dependence and barometric effects of large bursts frequencies under 10.5 cm of lead in size intervals from 10^3 to 10^4 of cascade particles in lead are considered. The sea level spectrum of power law form with exponent $\gamma'=2.08\pm0.08$ is obtained. The results concerning the spectrum of μ-mesons at sea level and predominate generation scheme of them in energy regions 10^{11}-10^{13} ev.

1. The bursts experimental data (part of which was published) obtained at different stations of continuous observations of cosmic rays hard component intensity variation by spherical ionization chambers of high pressure (10 to 50 atm) with volume 18 to 950 liters[1),2)] in periods of 1942-1946[3)] and 1949-1956.

2. The experimental dependence of expected ionization of argon pressure and of ions recombination was found from comparison (Fig. 1) of observed mean values of ionization intensity I_0 in chambers of different pressures and can be presented in these chambers in form:

$$I_e=N_\mu\times j_1\times p\times V\times(1+a)\times(1-\alpha\times j_1^2\times p^2)$$

where N_μ-intensity of μ-mesons ($\mathrm{cm}^{-2}\,\mathrm{sec}^{-1}$), $j_1=85$ ion pairs cm^{-1} atm^{-1} [4)], p argon pressure (atm) V-volume of chamber (cm^{-3}) $a=0.25$, $\alpha=1.5\times10^{-8}$ cm^2. This means that at $p=50$ atm$\sim27\%$ of produced ionization is lost because of recombination. From these comparisons it is also followed that$\sim25\%$ of total ionization in chambers is produced by soft radiation accompanying the hard component. The lead-walls transition effect was estimated from an assumption of electrons and photons equilibrium spectrum in lead (5) and calculations of the spectra of electrons $q_e(E_0, t_{Fe}, >E)$ and photons $q_\gamma(E_0, t_{Fe}, >E)$ produced by the equilibrium spectrum at depths of 1.5 to 2.1 radiation units of iron (Fig. 2). On the curves the energies are given in ev. In this estimations the calculations[6),7)] of cascade showers of relatively little primary energies

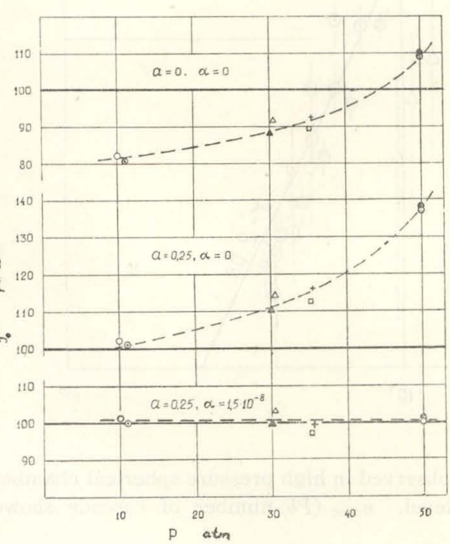

Fig. 1. The comparison of the observed ionization I_0 with expected I_e (under various assumptions) in chambers of high pressure.

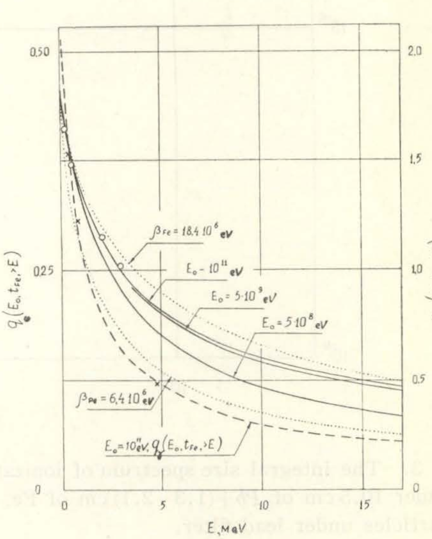

Fig. 2. The calculated integral spectra of electrons $q_e(E_0, t_{Fe}, >E)$ and photons $q_\gamma(E_0, t_{Fe}, >E)$ under chamber walls. $t=1.6$ radiation units.

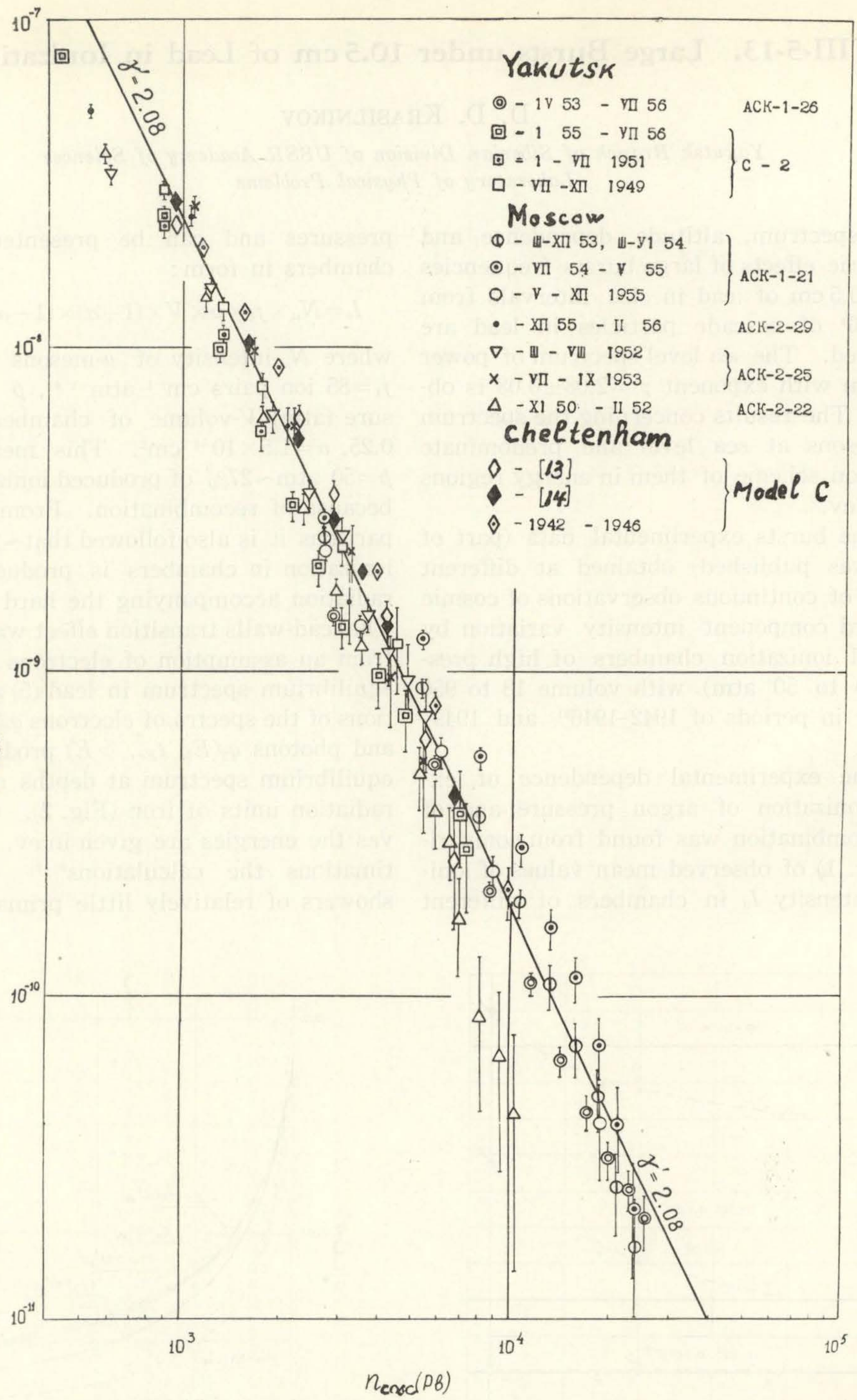

Fig. 3. The integral size spectrum of ionization bursts observed in high pressure spherical chambers under 10.5 cm of Pb+(1.3−2.1) cm of Fe, near sea level. n_{casc} (Pb)-number of cascade shower particles under lead filter.

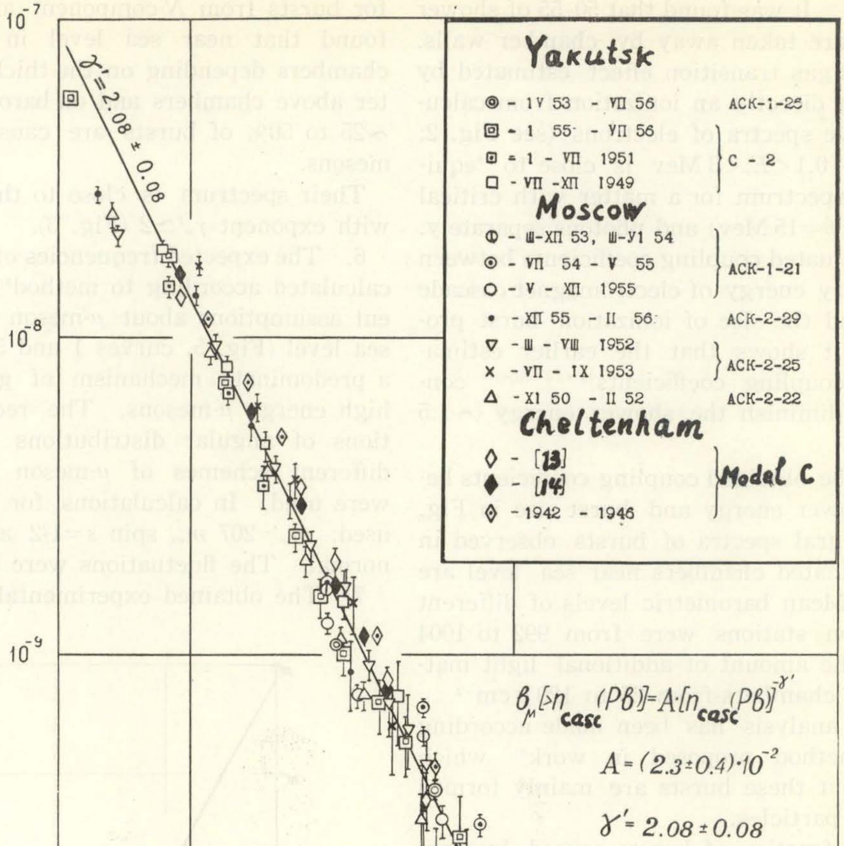

Fig. 4. The observed integral size spectrum of ionization bursts of μ-meson origin in high pressure ionization chambers at sea level. n_{casc} (Pb)-number of cassade shower particles nuder lead filter.

were used. It was found that 50-55 of shower particles are taken away by chamber walls. The walls-gas transition effect estimated by evaluating directly an ionization from calculated above spectra of electrons (see Fig. 2: in region $0.1<E_e<3$ Mev is close to "equilibrium" spectrum for a matter with critical energy of $\beta=15$ Mev) and photons separately.

The evaluated coupling coefficients between the primary energy of electromagnet cascade shower and the size of ionization burst produced by it shows that the earlier estimations of coupling coefficients[9 and others] considerably diminish the shower energy ($\sim$1.5 times).

Using the obtained coupling coefficients between shower energy and burst size in Fig. 3 the integral spectra of bursts observed in the examinated chambers near sea level are plotted. Mean barometric levels of different observation stations were from 992 to 1004 mb and the amount of additional light matter above chambers-from 25 to 120 g cm^{-2}.

4. An analysis has been made according to the method proposed in work[8] which showes that these bursts are mainly formed by single particles.

5. The fraction of bursts caused by neuclear active component[11] and by extensive air showers (EAS) is estimated from altitude dependence according to observations[3] and from consideration of burst frequencies barometer effect. Systematical errors in bursts readings have been taken into consideration while determining of the barometer effect. The errors are connected with changes of total ionization curves slope when barometer changes.

If the bursts from N-component and EAS have absorption length of $\lambda=130$ g/cm^2 and produce half of all observed bursts then the barometric coefficient would be equal to$\sim$6% per cm of Hg. Averaged according to the data of 4 chambers mounted near sea level the experimental coefficient is (-7 ± 2.5)% per cm of Hg for the bursts with sizes $n_{\rm casc}(p_e)\gtrsim10^3$.

In bursts size intervals $10^3<n_{\rm casc}(p_e)<10^4$ the integral distribution of bursts frequencies at altitude 3350 m (692 g cm^{-2}) is 7.0 ± 0.5 times that near sea level (1025 gcm^{-2}).

Both estimates are not in contradiction.

From the bursts frequencies altitude dependance using absorption length $\lambda=130$g/cm^2 for bursts from N-component and EAS it is found that near sea level in considering chambers depending on the thickness of matter above chambers and on barometric level, $\sim$25 to 50% of bursts are caused not by μ-mesons.

Their spectrum is close to the power law with exponent $\gamma_n'\simeq2$ (Fig. 3).

6. The expected frequencies of bursts were calculated according to method[5] with different assumptions about μ-meson spectrum at sea level (Fig. 5, curves 1 and 5) and about a predominate mechanism of generation of high energy μ-mesons. The recent calculations of angular distributions expected for different schemes of μ-meson generation[12] were used. In calculations for μ-meson are used: $m_\mu=207\ m_e$, spin $s=1/2$ and magnetic normal. The fluctuations were not counted.

7. The obtained experimental spectrum of

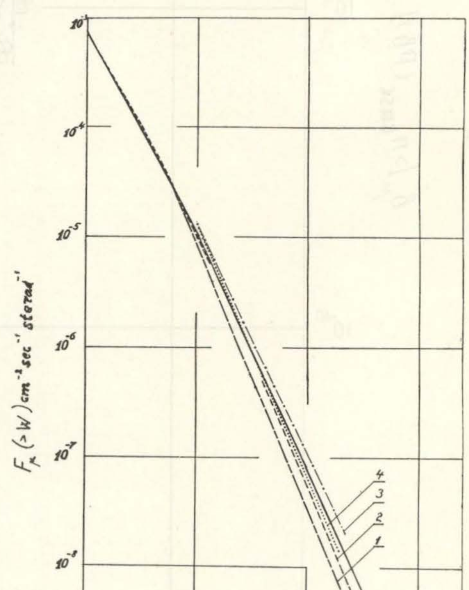

Fig. 5. The integral energy spectrum of μ-mesons at sea level. 1-according to [5], 2-[10], 3, and 4-[11]. 5-spectrum, supposed in this work for the one version of calculation of bursts of μ-meson origin.

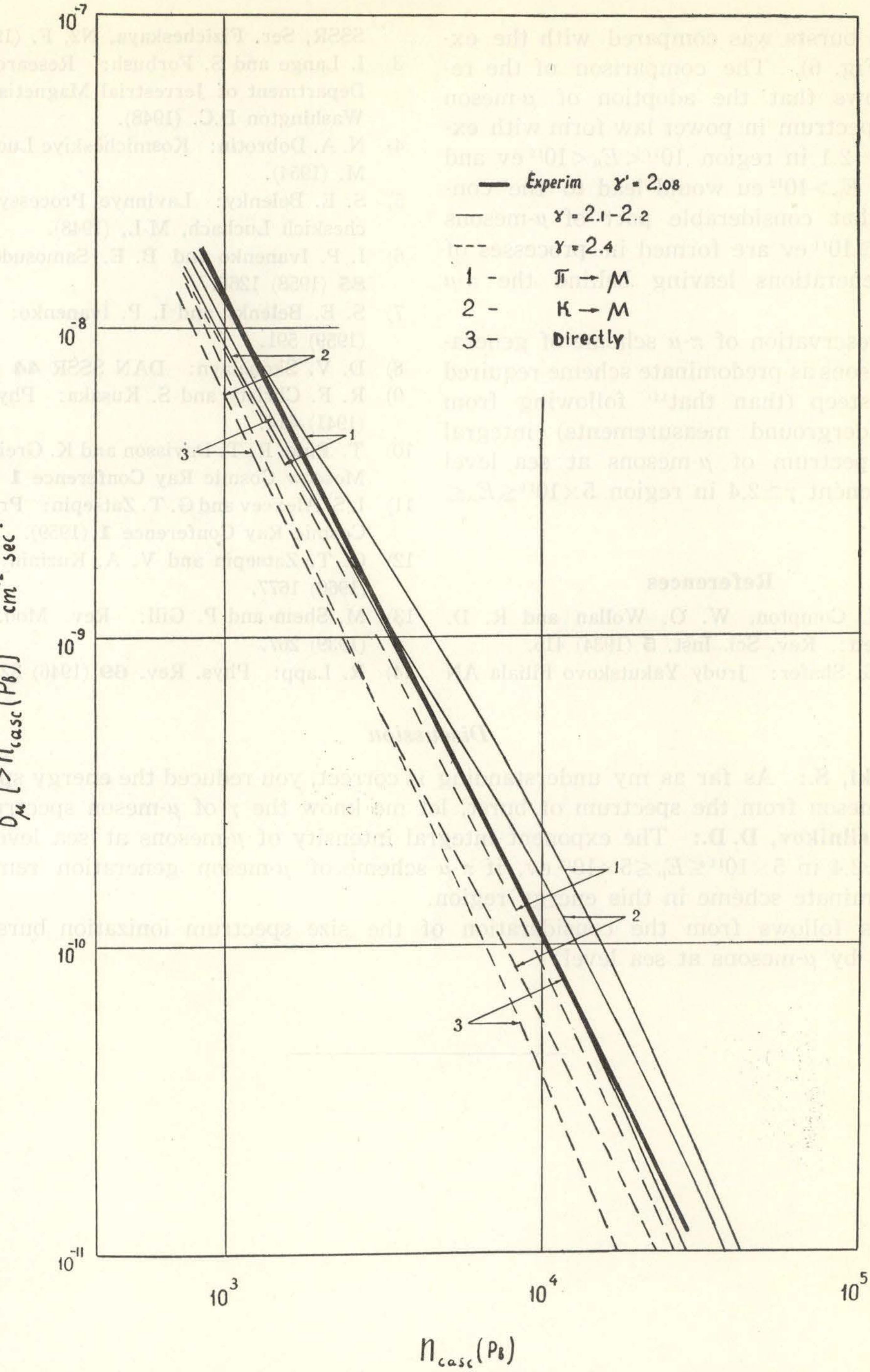

Fig. 6. The comparison of observed integral size spectrum of burst of μ-meson origin with those expected under different assumptions about sea level energy spectrum and generation scheme of high energy μ-mesons n_{casc} (*Pb*)-number of cascade shower particles under lead filter. Full solid line-experimental spectrum of μ-meson bursts with slope $\gamma'=2.08$. Thin solid lines-spectrum of μ-meson bursts, expected for the integral energy spectrum of μ-mesons with exponent $\gamma=2.1-2.2$ (see Fig. 5) in $E_\mu>10^{11}$ ev dashed line-spectrum of μ-meson burst expected for the integral energy spectrum of μ-mesons with exponent $\gamma=2.4$ in $E_\mu>6.10^{10}$ ev. 1, 2 and 3 at curves signify correspondingly the assumptions mainly $\pi-\mu$ or $\kappa-\mu$ and or direct generation (in nuclear interaction) schemes for production of μ-mesons.

μ-mesons bursts was compared with the expected (Fig. 6). The comparison of the results shows that the adoption of μ-meson energy spectrum in power law form with exponent $\gamma=2.1$ in region $10^{11}<E_\mu<10^{12}$ ev and $\gamma=2.2$ at $E_\mu>10^{12}$ eu would lead to the conclusion that considerable part of μ-mesons with $E_\mu \lesssim 10^{11}$ ev are formed in processes of direct generations leaving behind the π-μ process.

The preservation of π-μ scheme of generation μ-mesons as predominate scheme required a more steep (than that[11] following from early underground measurements) integral energy spectrum of μ-mesons at sea level with exponent $\gamma \simeq 2.4$ in region $5\times10^{11} \lesssim E_\mu \lesssim 5\times10^{12}$ ev.

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Discussion

Ozaki, S.: As far as my understanding is correct, you reduced the energy spectrum of μ-meson from the spectrum of burst, let me know the γ of μ-meson spectrum.

Krasilnikov, D. D.: The exponent integral intensity of μ-mesons at sea level must be $\gamma \simeq 2.4$ in $5\times10^{11} \lesssim E_\mu \lesssim 5\times10^{12}$ ev, if π-μ scheme of μ-meson generation remains a predominate scheme in this energy region.

This follows from the consideration of the size spectrum ionization bursts produced by μ-mesons at sea level.