Search for long-lived heavy particles and tachyons in the EAS muons flux on the EAS array of Moscow State University

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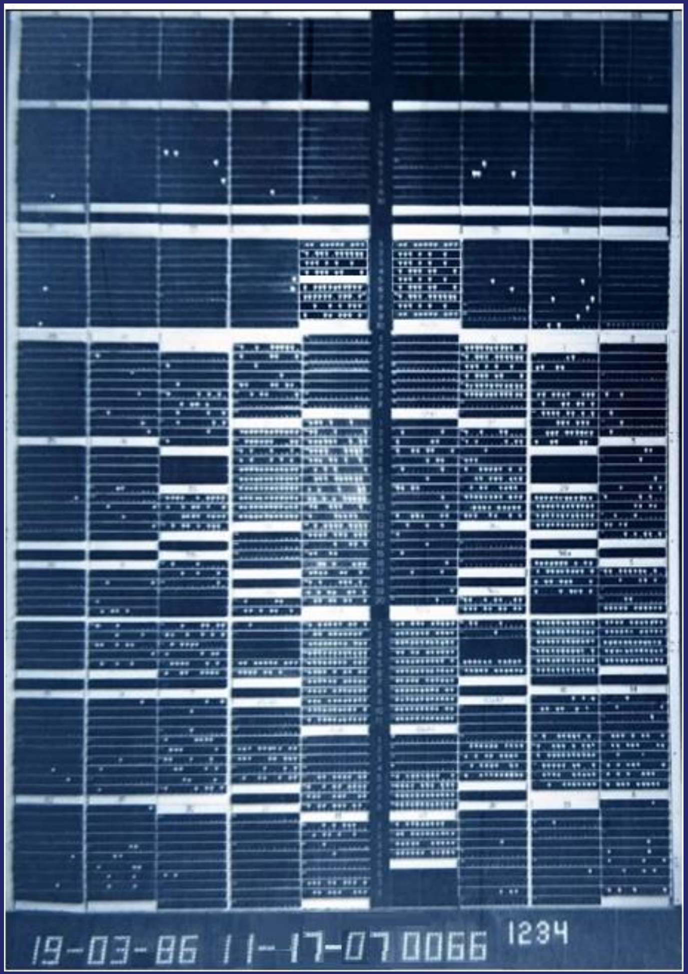
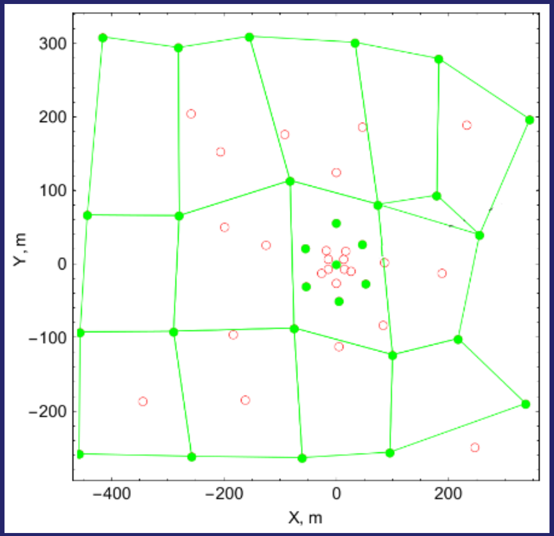




Installation area 0.5 km^2
77 registration points with Geiger-Muller counters
29 points of them have scintillation detectors which are used to find arrival direction of the EAS.
~10000 Geiger-Muller counters with a total area of ~250 m^2
Scintillation detectors for search heavy particles and tachyons are placed in central part of the array

This figure shows the central display of the array when registering EAS. The display consists of neon tubes, each of which is connected to its own Geiger- Muller counter whose are placed in the registration points of the array. The tube lights when the Geiger- Muller counter registers the particle.

The array is started up and the event is registered when arising the coincidence signals of scintillation detectors, and given number of Geiger-Muller counters are triggered.

The main goal of the MSU EAS array is the study of EAS in the knee region of the spectrum of primary cosmic rays

Additional works carried out at EAS MSU array

one of them was

Search for long-lived heavy particles (delayed particles) and tachyons .

The study of delayed particles in EAS was started more ten 50 years ago (Linsley J., Scarsi L., Phys.Rev.,1962, V. 128, n.5, 2384), and this study devoted a huge number of works

Idea is very simple

When heavy particles are born in EAS, then such a particle, as well as the products of its interaction with the atmosphere, will come to the level of observation with some time delay relative to the EAS disk. These particles come after EAS disc.

When appear particle capable to move at a speed exceeding the speed of light, such a particle, as well as the products of its interaction with the atmosphere will come to the level of observation ahead of the particles of the EAS.
These particles come before EAS disc.

Three main old questions.

In such kind of experiments three main problems have to be solved.

1. Are delayed pulses are caused by a PMT after – pulses ?

John Linsley , Sub - Luminal Pulses from Cosmic Ray Air Shower, 19th ICRC, HE4.7-13, San Diego, California 1985

2. Are delayed pulses are caused by a slow neutrons ?

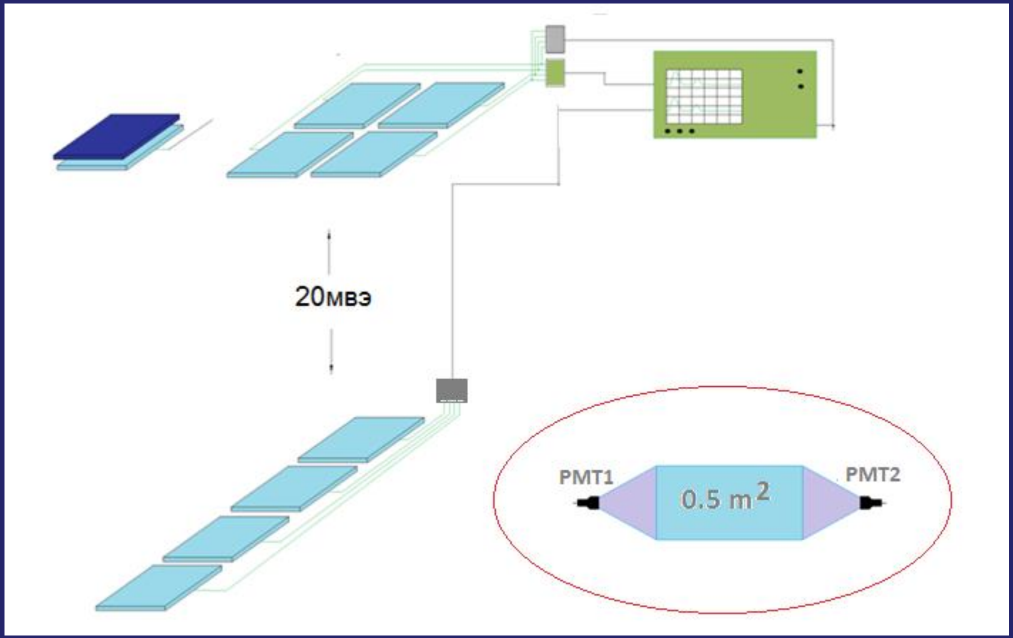
Greisen, K. !962, Proc.5th Interamerican Seminar on Cosmic Rays (Lab. Fisica Cosmica, OMSA, La Paz, Bolivia) 2, XLVII-2 “ some of the delays ... are due to neutron traveling at a speed slightly lower than light”

3. Are delayed pulses caused by long-lived heavy particles with fractional charge ? This question arose together with quark theory.

Why these questions are important ?

Signals from non - relativistic hadrons are difficult to recognize from signals caused by predicted long – lived heavy relativistic particles which can have a fractional charge, exceeded charge of one electron, because , signals from these particles and signals caused by hadrons moving with speed less then light velocity in a scintillation detectors look similar.

Block diagram of the installation for search for long-lived heavy particles and tachyons



The installation has several scintillation detectors, the signals from which were recorded with help of an analog storage oscilloscope.

The first detector with an effective area of 4 m^2 was installed on the ground surface in the centre of the installation.

The second detector with an effective area of 5 m^2 was located in the centre of the installation and was installed underground at the depth equivalent to 20 meters of water column

Each detector consisted of cells with an area of 0.5 m^2 each. In a each cell, scintillation flashes are viewed by two PMT. So first detector has 8 cells, second – 10 of them.

To start the oscilloscope sweep, a 4-fold coincidence circuit was used. Signals from 4 equal parts of the first detector with an effective area of 1 m^2 each were used for this.

The third detector with an effective area of 1 m2, was used in additional experiments and has 2 cells

The main advantage of this installation is that the distribution of the arrival times of the EAS particles was studied simultaneously using the unshielded detector located on the surface of the ground and underground detector. Signals from which were registered with help a two-beam analog storage oscilloscope.

A layer of ground is used for cutting off hadrons that can simulate heavy long-lived particles with fractional charge is exceeded one electron charge.

Examples of signals registered by the installation

R<200m

R= 20; n_e =29; Ne =6.9· 10^4

Technical parameters were chosen so that to register as particles arrival ahead EAS disk as well as delayed particles arrival after EAS disk

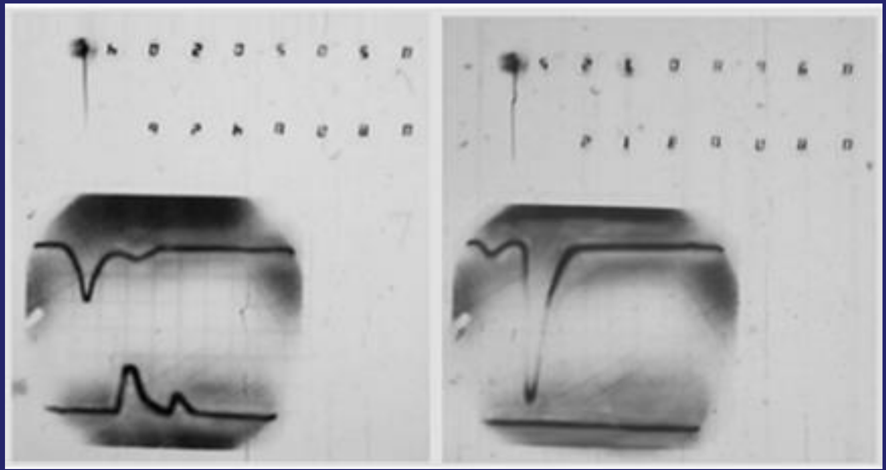
Top beam - signals from the unshielded detector

Bottom beam - signals from the shielded detector

Scale, one division 50ns, duration 500ns

R<200m

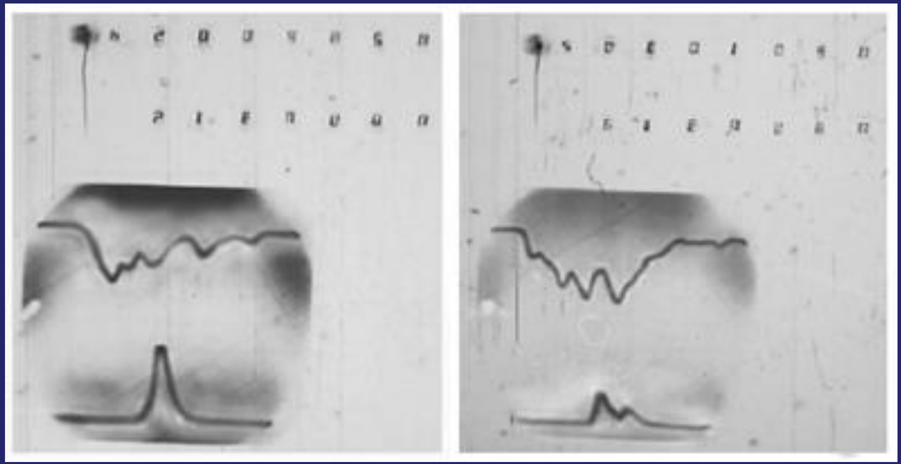
Examples of the registration of delayed and ahead particles.



R ≈30; n_e ≈23; Ne≈3.5 · 10^4 R≈ 15; n_e ≈40; Ne ≈ 1.3 · 10^5

R>200m

Examples of registration of the time distribution of particles in EAS

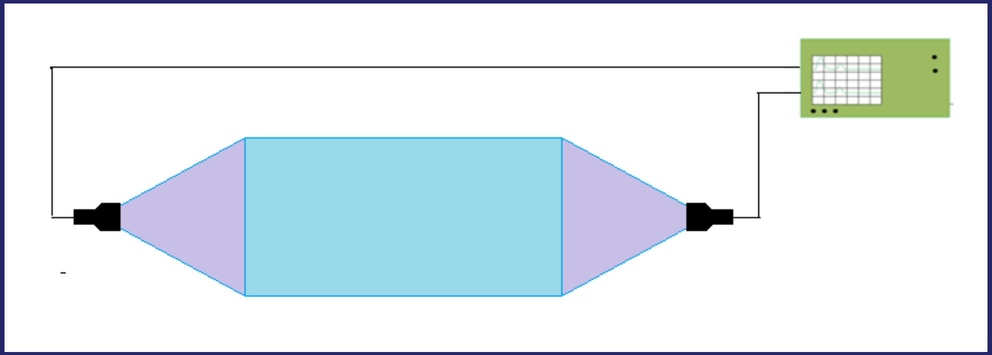


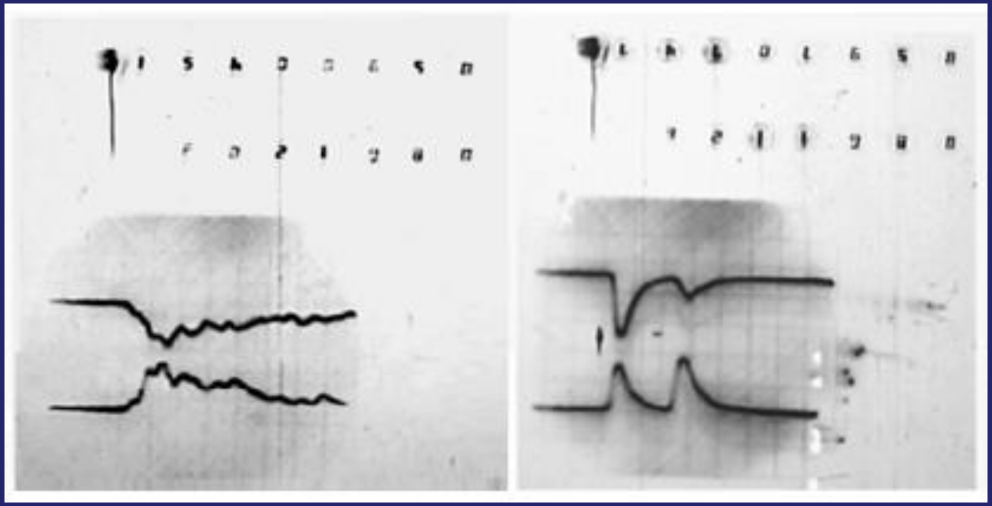
R =275; n_e =30; Ne =6.2· 10^6 R =220; n_e =28; Ne =1.7· 10^8

Main results : *During ~ 1000 hours ~ 35000 EAS were registered, in ~ 1200 of them delayed particles were observed in unshielded detector, in 36 of them were observed delayed penetrating particles with delay time from 30 to 300 ns relative to the front of the EAS disc .*

Penetrating particles moving before EAS disc were not registered in this experiment.

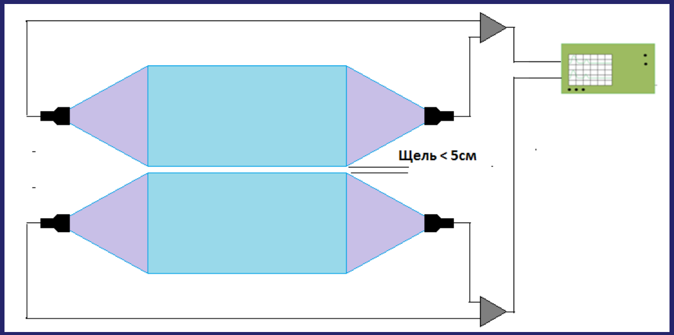
Verification of imitation of delayed particles by PMT after - pulses and confirmation of the existence of the delayed particles.

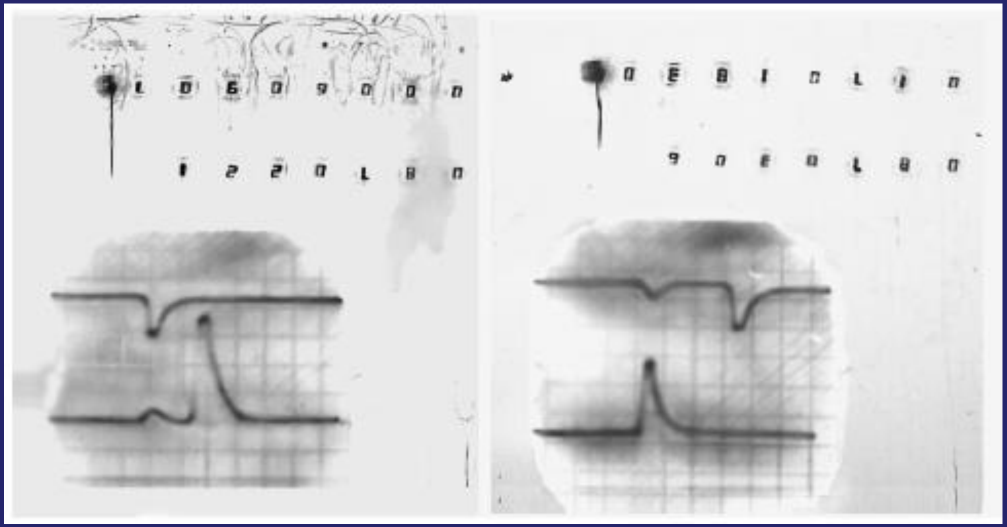




An example of signal registration by two PMT registering signals from a single scintillation plastic. Observation of the delayed signal by two PMT indicates on the existence of the delayed particles and absents of PMT after – pulses.

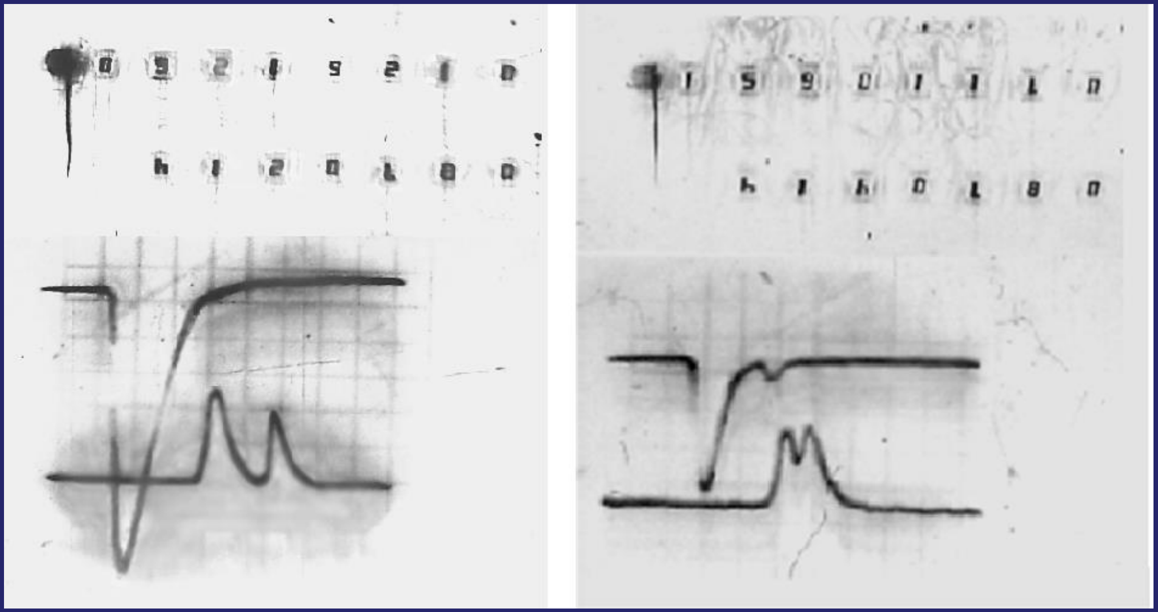
Verification of ionization property of delayed particles and confirmation of the absence of micro showers coursed delayed





An example of registration of delayed particles using two detectors separated by a narrow slit. Observation of the delayed pulse with an amplitude correspondent to several particles in one detector indicates that delayed particles do not produce micro showers and have a higher ionization ability.

Examples of registration of delayed penetrating particles with energy of more than 5 GeV and their increased ionization ability.



Example of registration of penetrating delayed particles. One horizontal division is 50 nc.
Top beam - signal from one relativistic muon correspondent to 0.14 part of one vertical division.
Bottom beam - signal from one relativistic muon correspondent to 0.6 part of one vertical division

Some properties of delayed penetrating particles observed in this experiment

1. *E> 5GeV*
2. *The delayed particles do not form micro showers and lose their energy on ionization, they are not nuclear - active particles.*
3. *Ionization ability of delayed particles exceed one relativistic particle.*
4. *The flow of such particles is attenuated by a layer of ground equivalent to 20 meters of water column about 30 time.*

E> 5GeV

Assumption that delayed particles mass like muons mass

$$E > 5\,\text{ГэВ} \quad m_\mu \cong 100\,\text{МэВ} = 0{,}1\,\text{ГэВ};\ \gamma \cong 50$$

$$\tau = \frac{h}{v} - \frac{h}{c} \Rightarrow \tau \cong \frac{h}{2\gamma^2 c} \Rightarrow \frac{1667\,h}{\gamma^2}\ \text{мсек}$$

$$h \cong \frac{\gamma^2 \cdot \tau}{1667}$$

$$h = \frac{2500 \cdot 166}{1667} \geq 250\,\text{км};\ \Delta t = \frac{250}{c} \gtrsim 750\,\text{мsec}$$

$$\tau_\mu = 2\,\mu\text{sec};\ \gamma = 50;\ \tau_\gamma = 100\,\text{мsec}$$

$$\Delta t \gg \tau_\gamma$$

therefore this assumption are not suitable

E< 50 MeV

2. The fact that there were not observed delayed micro showers caused by delayed hadrons, this can be explained by the fact that the energy of such hadrons is less than 50 MeV. Or the secondary particles of their nuclear interactions have energy less then 10 MeV why they do not recognized by the detector. In any case such charged particles cannot reach underground detector.

3. As for neutrons of such energies , the attenuation of their flux in the ground thickness which is equivalent to 20 meter of water column is more than 10^5 time

In both cases these particles are not suitable for explanation of data of this experiment

Conclusion.

Thus,

Muons and hadrons including neutrons can not explain the data of observation.

Results of this experiment are not enough for full explanation delayed particles properties.

Further studies are required.

Thanks!