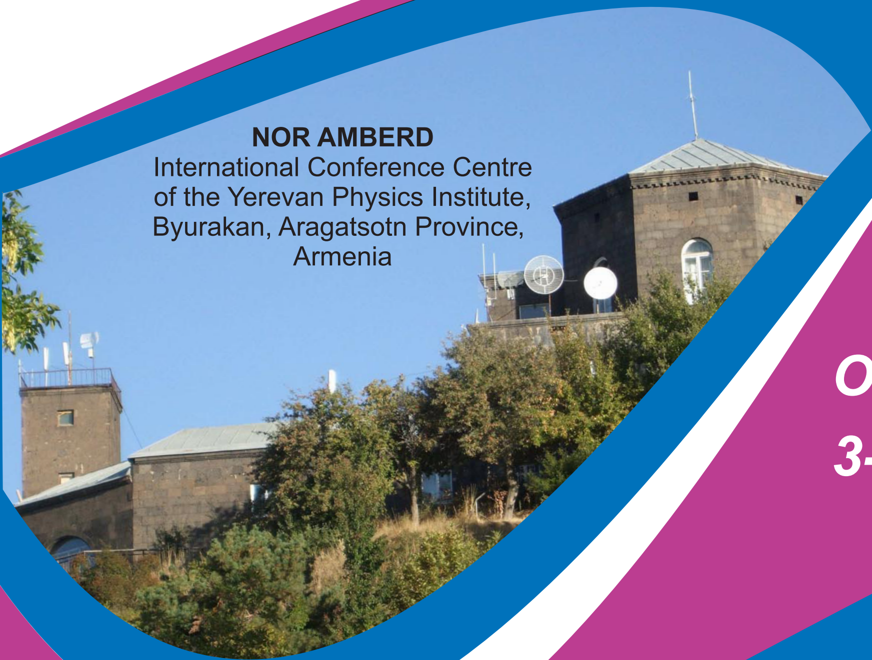
TEPA 2016

COSMIC RAY DIVISION
ALIKHANYAN National Laboratory



October 3-7

Programme & Abstracts

international symposium

THUNDERSTORMS & ELEMENTARY PARTICLE ACCELERATION

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A.ALIKHANYAN National Laboratory

THUNDERSTORMS & ELEMENTARY PARTICLE ACCELERATION

GENERAL INFORMATION:

TIME FRAME: October 3-7 2016

LOCATION: Nor Amberd International Conference Centre of the Yerevan Physics Institute,

Byurakan, Aragatsotn District, Armenia.

SYMPOSIUM WEBSITE:

http://crd.yerphi.am/Conferences/tepa2016/home

ORGANIZERS:

Cosmic Ray Division
of Yerevan Physics Institute, Armenia

Skobeltsyn Institute of Nuclear Physics
of Moscow State University, Russia

INTERNATIONAL ADVISORY COMMITTEE:

INTERNATIONAL ADVISORY COMMITTEE:

- ***Ashot Chilingarian***, Yerevan Physics Institute, Armenia, *co-chair*
- ***Lev Dorman,*** *Israel* Cosmic Ray Center and Emilio Segre' Observatory, Israel
- ***Joe Dwyer*****,** University of New Hampshire, USA
- ***Gerald Fishman*****,** NASA-Marshall Space Flight Center, Huntsville, USA)
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- ***Johannes Knapp,*** *DESY, Zeuten, Germany*
- ***Karel Kudela*****,** Institute of Experimental Physics, Slovakia
- ***Alexandr Lidvanski*****,** Nuclear Physics Institute, Russian Academy of Science, Russian Federation
- ***Jean Lilensten*****,** et d'Astrophysique Institut de Planétologie de Grenoble, France
- ***Evgeny Mareev,*** Institute of Applied Physics, Nizhny Novgorod, Russian Federation
- ***Razmik Mirzoyan,*** MPI, Munich, Germany
- ***Yasushi Muraki*****,** STE laboratory, Nagoya University, Japan
- ***Michail Panasyuk*****,** Moscow State University, Russian Federation, *co-chair*
- ***David Smith*****,** University of California, Berkeley, USA
- ***Marco Tavani*****,** INAF and University of Rome "Tor Vergata", Italy
- ***Tatsuo Torii*****,** Japan Atomic Energy Agency, Tsuruga, Japan
- ***Harufumi Tsuchiya*****,** Cosmic Radiation Laboratory, Riken, Japan.
- ***Lev Zeleny*****,** Space Research Institute, Russian Academy of Sciences, Russian Federation

BACKGROUND:

The problem of the thundercloud electrification and how lightning is initiated inside thunderclouds is one of the biggest unsolved problems in atmospheric sciences. The relationship between thundercloud electrification, lightning activity, wideband radio emission and particle fluxes have not been yet unambiguously established. One of most intriguing opportunities opening by observation of the high-energy processes in the atmosphere is their relation to lightning initiation. C.T.R. Wilson postulated acceleration of electrons in the strong electric fields inside thunderclouds in 1924. In 1992 Gurevich et al. developed the theory of the runaway breakdown, now mostly referred to as relativistic runaway electron avalanches - RREA. The separation of positive and negative charges in thundercloud and existence of a stable ambient population of the cosmic ray MeV electrons in the atmosphere enables acceleration of the electrons in direction of the earth's surface (Thunderstorm ground enhancements, TGEs) and to open space (Terrestrial gamma flashes, TGFs). Thus both TGEs and TGFs precede the lightning activity and can be used for the research of poorly understood lightning initiation processes providing key research instrument – fluxes of electrons, neutrons and gamma rays originated in the thunderclouds. Information acquired from the time series of TGEs and TGFs along with widely used information on the temporal patterns of the radio waveforms will help to develop both reliable model of lightning initiation and detailed mechanism of electron acceleration in thunderclouds.

STRUCTURE OF THE SYMPOSIUM:

After receiving abstract of presentations following sessions were outlined:

1. Research of the Thunderstorm ground enhancements (TGEs);
2. Research of the Terrestrial gamma-ray flashes (TGF);
3. Lightning initiation: multivariate observations from the earth's surface;
4. Instrumentation

We plan as well discussions on the most intriguing problems of high-energy physics and on possible directions for the advancement in research and collaborative studies.

Following topics will be covered during oral and poster sessions and during discussions:

- *Research of the Thunderstorm ground enhancements (TGEs), measurements of electrons, gamma rays and neutrons by networks of particle detectors located on Earth's surface;*
- *Research of the Terrestrial gamma-ray flashes (TGFs) observed by the orbiting gamma-ray observatories;*
- *Radio emissions produced by atmospheric discharges and particle fluxes;*
- *Lightning initiation and its relation to the TGE and TGF;*
- *Large Extensive air showers and ambient population of the cosmic ray electrons – influence on lightning initiation and unleashing of the RREA;*
- *Neutron production during thunderstorms (lightning bolt or photonuclear reactions?)*
- *Ultraviolet and infrared emissions during thunderstorms;*
- *Monitoring of thunderclouds from orbit;*
- *Monitoring of the thunderstorms by high speed cameras from the earth's surface;*
- *Monitoring of thunderclouds from orbit;*
- *Methods of the remote sensing of the thundercloud structure and electric field;*
- *Relation of the lightning occurrences to the TGE and TGF initiation;*
- *X-ray emissions from the lightning;*
- *Relations to the climate and space weather issues;*

PROGRAMME OF TEPA-2016

Sunday, 2 October

Meeting of participants at the Zvartnots airport, transportation to the Nor Amberd, Registration at Nor Amberd International Conference Center

Monday, 3 October

9:00 – 11:00 ***Registration***

11:00 – 11:15 ***Opening Ceremony***

***Session:* Research of the Thunderstorm ground enhancements (TGEs), *Chairperson* – Johannes Knapp**

11:15 – 12:00 Ashot Chilingarian*, Yerevan Physics Institute, Armenia*, **Particle fluxes from thunderclouds: measurements and myths.**

12:00 – 12:45 ***Coffee break and poster session***

***Session*: Research of the Terrestrial gamma-ray flashes (TGFs) observed by the orbiting gamma-ray observatories*. Chairperson* – Johannes Knapp**

12:45 – 13:30 *Bagrat Mailyan, The University of Alabama, Huntsville, USA,* **Constraining the source properties of individual Terrestrial Gamma-ray Flashes.**

14:00 – 15:00 ***Lunch***

***Session:* Relation of Lightning to the TGE and TGF;**
Chairperson - Bagrat Mailyan

16:00 – 16:40 *Suren Soghomonyan, Yerevan Physics Institute, Armenia,* **Electric field changes produced by lightnings that abruptly terminate the Thunderstorm Ground Enhancements (TGEs)**

16:40 – 17:20 *Shaolin Xiong, Fan Li, Institute of High Energy Physics, Chinese Academy of Sciences,* **On the TGF - lightning relation based on the Fermi GBM and ENTLN data**

18:00 – 18:30	***Coffee break and poster session***
19:00 - 20:00	*Tigran Karapetyan and Karen Avagyan, Yerevan Physics Institute, Armenia,* **Presentation how to access the data bases of Cosmic ray Division**
20:00	***Special Event:*** **Icebreaker, Nor Amberd Conference Center Restaurant**

Tuesday, 4 October

09:00	***Breakfast***

Session: **Research of the Thunderstorm ground enhancements (TGEs),**
Chairperson **– Mirzoyan Razmik**

10:00 - 10:40	*Alexander Shepetov, P. N. Lebedev Physical Institute of RAS, RF,* **The search for neutron signal from lightning discharges at Tien Shan.**
10:40-11:20	*Anatoly Petrukhin, National Research Nuclear University MEPhI, RF,* **Possibilities of atmospheric disturbance investigations in muon flux.**
11:20 - 12:00	***Coffee break and poster session***
12:00 – 12:40	*Donald Pleshinger, Louisiana State University, USA,* **Terrestrial Gamma Flashes at Ground Level--TETRA II.**
12:40 – 13:20	*Vitaly Bogomolov, Physical Department of Skobeltsyn Institute of Nuclear Physics, MSU, RF,* **Results of TGE Study in 0.03-10 MeV Energy Range in Ground Experiments near Moscow and Aragats**
14:00 – 15:00	***Lunch***

Session: Monitoring of TLEs and thunderstorms from the orbit,
Chairperson Suren Sogomonyan

16:00 – 16:40	*Maxim Dolgonosov, Space Research Institute of RAS, RF,* **Investigation of atmospheric high-energy phenomena on-board International Space Station: microsatellite.**

16:40 – 17:20 *Pavel Klimov, Skobeltsyn Institute of Nuclear Physics, MSU, RF,* **First results on transient atmospheric events from Tracking Ultraviolet Set-up (TUS) on board of Lomonosov satellite**

17:20 – 18:00 *Sergey Svertilov, Skobeltsyn Institute of Nuclear Physics, MSU, RF,* **Gamma-Ray and Relativistic Electron Flux Short-time Variations Observed in Vernov and Lomonosov Mission.**

19:00 - 20:00 *Razmik Mirzoyan, Max-Planck-Institute for Physics, Munich, Germany*
Expanding the Observational Limits of the Ground-Based Atmospheric Cherenkov Technique at Very High Energies

20:00 ***Supper***

Wednesday, 5 October

09:00 ***Breakfast***

Session: Cloud electrification and atmospheric discharges: measurements and applications, Chirperson Sergey Svertilov

10:00 – 10:30 *Leonid Sorokin, People's Friendship University of Russia,* **Mapping of Microwave radiation associated with propagating High Energy Particles in the Atmosphere.**

10:30 – 11:00 *Igor Yashin, National Research Nuclear University MEPhI, RF,* **Muon hodoscope as a new meteorological tool**

11:00 – 11:30 *Roy Yaniv, Department of Geosciences, Tel Aviv University, Israel,* **Ground measurements of the vertical E-field in Israel and Armenia**

11:30 – 12:00 ***Coffee break and poster session***

12:00 - 12:30	*Natalia Barbashina, National Research Nuclear University MEPhI, RF,* **Investigation thunderstorms according to muon hodoscope URAGAN**
12:30 - 13:00	*Hripsime Mkrtchyan, Yerevan Physics Institute, Armenia,* **Relation between flash rate and wind speed.**
13:00 – 14:00	***Lunch***
14:00 – 18:00	***Excursion to Aragats Cosmic Ray Station; Introduction to Aragats Space Environmental Center particle monitors***
18:00 – 19:00	**Evening Lecture** *Johannes Knapp, DESY Zeuthen, Germany,* **A new era of Gamma Ray Astronomy with the Cherenkov Telescope Array.**
20:00	***Conference dinner***

Thursday, 6 October

09:00	***Breakfast***

Session: **Research of the Terrestrial gamma-ray flashes (TGFs)*,* *Chairperson - Donald* Pleshinger.**

10:00 - 10:30	*Alexei Pozanenko, Space Research Institute, RAS, RF,* **Typical properties of TGFs registered by RHESSI experiment**
10:30-11:00	*Anton Chernenko, Space Research Institute, RAS, RF,* **On the connection of TGFs and atmospheric pollution.**
11:00 – 12:00	***Poster session***
12:30 – 13:00	***Lunch***
13:00 – 19:00	***Excursion to Yerevan and Echmiadzin***
20:00	***Supper***

Friday, October 7

09:00	***Breakfast***
10:00 – 11:00	***Discussion:*** **Do lightning discharges produce relativistic particles?**
11:00-11:30	***Closing Ceremony***
12:00 – 12:30	***Lunch***
13:00 – 17:30	***Excursion to Garni (pagan temple) and Geghard (church from 4th century)***
20:00	***Supper***

Transport participants to Zvartnots airport Breakfast

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POSTER SESSION

Alexander Shepetov, Olga Kryakunova, Nazyf Salikhov P.N. Lebedev Physical Institute, **RAS, RF, The compact, microcontroller based data acquisition system for reliable operation under thunderstorm conditions.**

Leonid Sorokin, People's Friendship University of Russia, **Space-time analysis of the Seismic Waves and WWLLN data associated with the third Fermi GBM Gamma-ray Burst Catalog.**

Kozliner L., Pustylnik L., Shtivelman D., Tel-Aviv university, **Electronics designed for a system of Neutron monitor and muon telescope for the Space Weather research on Mt. Hermon (altitude of 2000m) on Holland heights, Israel.**

A.Chilingarian, G. Hovsepyan, A.Badalyan, A.Grigoryan, A. Manukyan, M. Mantashyan, T. Sargsyan, Yerevan Physics Institute, Armenia, **Extensive Air Showers Detected by Aragats Neutron Monitor.**

K.Avagyan, A.Chilingarian, T. Karapetyan, L.Kozliner, Yerevan Physics Institute, Armenia, **Energy spectra of the near horizontal muons**

Avakyan K., Chilingarian A., Hovsepyan G., Kozliner L., Mnatsakanyan E., Yerevan Physics Institute, Armenia, **Calibration of the Log ADCs for NaI spectrometers network on Aragats.**

John Belz, University of Utah, USA, **Study of High- Energy Particles Correlated with Lightning at The Telescope Array Cosmic Ray Observatory.**

Karel Kudela, Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovakia, **Cosmic ray short time increases during intervals with strong electric field at Lomnický štít: first experience.**

Ashot Chilingarian, David Pokhsraryan, Yerevan Physics Institute, Armenia, **First results of the implementation of the fast Data Acquisition system based on NI-myRIO**

*Inna Gubenko, Hydrometeorological Research Centre of Russian Federation***,** **Electric structure of the simulated thunderclouds**

1. Research of the Thunderstorm ground enhancements (TGEs), measurements of electron, gamma ray and neutron fluxes by the networks of particle detectors located on the Earth's surface

Ashot Chilingarian
Yerevan Physics Institute, Armenia

Particle fluxes from thunderclouds: measurements and myths

We present the observational data on detection of atmospheric discharges simultaneously with elementary particles performed at 3200 m altitudes above sea level on Mt. Aragats in Armenia during thunderstorms. Throughout 2016 summer campaign on Aragats we monitor lightning occurrences and signals from NaI spectrometer and Neutron Monitor counter tube. Particle detector signals were synchronized with lightning occurrences on nanosecond time scales and all were Electromagnetic interferences (EMI) and not signals from charged or neutral elementary particles. Thus, based on *in situ* measurements of atmospheric discharges and signals from particle detectors we conclude that relativistic elementary particle do not born in the lightning bolt. We analyze also models based on the concept of "runaway" electrons used for explaining Terrestrial gamma ray flashes (TGFs), observed by orbiting gamma ray observatories and thunderstorm ground enhancements (TGEs) particle fluxes from the thunderclouds detected on the earth's surface. We show that for explaining the TGE it is not necessary to invoke the relativistic feedback discharge scheme (RFDM) used for modeling TGF.

Vitaly Bogomolov, Sergey Svertilov, Ivan Maksimov
Physical Department of Skobeltsyn Institute of Nuclear Physics, MSU, RF

Results of TGE Study in 0.03-10 MeV Energy Range in Ground Experiments near Moscow and on Aragats

Ground-based experiments with scintillator gamma-spectrometers were conducted to study the spectral, temporal and spatial characteristics of TGEs as well, as to search the fast hard X-ray and gamma-ray possibly appearing at the moment of lightning. The time of each gamma-quantum interaction was recorded with ~15 μs accuracy together with detailed spectral data. The measurements are similar to ones reported at TEPA-2015 but some important improvement of the instruments was done for summer, 2016 season. First, GPS module was used to synchronize the instrument time. The accuracy of such synchronization allows one to look at the gamma-ray data at the moment of lightning fixed by radio-wave detector or any other instrument. Second, the energy range of gamma-spectrometers was shifted to higher energies where the radiation of natural isotopes is absent. In this case one can see background changes connected with particles accelerated in thundercloud together with the background increases during the rain caused by Rn-222 daughters.

Long-term measurements with two instruments placed in different points of Moscow region were done in 2016 season. First one based on CsI(Tl) 80x80 mm has energy range 0.03-6 MeV. The range of the second one based on CsI(Tl) 100x100 mm is 0.05-10 MeV. A dozen of thunderstorms with increase of Rn-222 radiation were detected but no significant increase of gamma-ray flux above 3.2 MeV was observed at these periods. The result of the search for short bursts at the moment of lightning fixed by radio-wave detector working in MSU will be discussed as well as the results of the study of slow variations.

A lot of data was obtained from the experiment with small gamma-ray spectrometer (40x40 mm NaI(Tl) at mountain altitude in Armenia at Aragats station. The analysis of readings during the TGE periods indicates on the presence of Rn-222 radiation in low-energy range (E<1 MeV). The use of larger detector with good spectrometric characteristics is necessary for more significant conclusion.

Alexander Shepetov, Alexander Gurevich
P. N. Lebedev Physical Institute of RAS, RF

The search for neutron signal from lightning discharges at Tien Shan

Current status of the Tien Shan detector complex destined for the search of short time increase of neutron flux intensity associated with thunderstorm passages is discussed. At present time, a number of neutron detectors are used sensitive in different ranges of neutron energy: from thermal energies and up to some GeV. Efficiency of neutron registration for all detector types was defined through complete Geant4 simulation of the process of neutron production and propagation inside the detector. The measurements of neutron intensity are held with enhanced time resolution (of a 100-200 microsecond order) with a strict binding to discharge moment. Especial attention is paid to the issues of electromagnetic shielding of detector system, and to the control of correctness of the measurements data being obtained immediately at the time of lightning discharges.

Experimental results on typical duration (tens of milliseconds), neutron energy (0.1-10^4 eV), and integral fluence (0.01-1cm^2) of transient neutron enhancements observed so far are presented.

Donald Pleshinger, Michael Cherry
Louisiana State University, USA

Terrestrial Gamma Flashes at Ground Level--TETRA II

An upgraded version of the TGF and Energetic Thunderstorm Rooftop Array (TETRA-II) consists of an array of BGO scintillators located on the campus of the University of Puerto Rico at Utuado. TETRA-II began operation in May 2016. When it is fully operational, TETRA-II will have approximately an order of magnitude larger sensitivity of the original TETRA array of NaI scintillators at Louisiana State University that detected 37 millisecond bursts of gamma rays at energies 50 keV-2 MeV associated with nearby (< 8 km) thunderstorms. The ability to observe ground-level Terrestrial Gamma Flashes from close to the source allows a unique analysis of the storm cells producing these events. A brief description of the TETRA observations, a description of TETRA-II, and preliminary results will be presented.

John Belz
University of Utah, USA

Study of High- Energy Particles Correlated with Lightning at The Telescope Array Cosmic Ray Observatory

It is known that x-ray and gamma radiation is emitted by lightning. This phenomenon has been observed by both ground- and spaced-based detectors. Recently, cosmic ray physicists studying data collected by the 700 square-kilometer Telescope Array (TA) Surface Detector (TASD) have observed energetic elementary particles in coincidence with lightning strikes. A subset of these events contain reconstructable "showers" which point back to the particles' origin in the Earth's atmosphere. This implies that the TASD may be utilized to trace energetic radiation to its source within the lightning event. The Lightning Mapping Array (LMA) pioneered at Langmuir Laboratories is the ideal instrument to couple with the TASD in order to perform these studies. These LMA's consist of roughly ten VHF detectors spread over hundreds of square kilometers, sensitive to impulsive radiation from lightning. The sources of these impulses may be reconstructed and used to create a 3-dimensional GPS-timed reconstruction of a lightning strike. The merger of TA and LMA is also the ideal instrument to search for evidence of a more speculative connection between particle astrophysics and climate, namely seeding of lightning strikes by cosmic ray air showers. We present the Telescope Array observations and preliminary results from the TA/LMA merger.

Baše, J., Chum, J., Kollárik, M., Kudela, K., Langer, R., Strhárský, I, Štefánik

Institute of Atmospheric Physics, Czech Academy of Sciences, Prague, Czech Republic, Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovakia

Cosmic ray short time increases during intervals with strong electric field at Lomnický štít: first experience

Since March 2014 there is a continuous measurement of secondary cosmic rays with use of detector system SEVAN (Space Environmental Viewing and Analysis Network) at Lomnický štít, altitude 2634 m asl. Starting from June 2016 the count rates (1s resolution) obtained from the three detectors and from their coincidences is available, along with selected meteorological characteristics as barometric pressure, temperature, humidity, strength and direction of the wind measured locally. Since May 30 2016 the electric field measurements at the same site have been installed. Until July 31 several events with clear increase of the count rate of the upper detector of SEVAN during the thunderstorms (TGE events) are observed and discussed. It is shown that the increases of count rates measured by SEVAN usually correspond with periods of high electric field rather than with individual discharges (lightning). *Work is supported by the grant project APVV-15-0194.*

2. Research of the Terrestrial gamma-ray flashes (TGFs) observed by the orbiting gamma-ray observatories

Bagrat Mailyan

The University of Alabama, Huntsville, USA

Constraining the source properties of individual Terrestrial Gamma-ray Flashes

We report on the spectral analysis of individual Terrestrial Gamma-ray Flashes (TGFs) observed with the Fermi Gamma-ray Burst Monitor (GBM). The large GBM TGF sample provides 46 events suitable for individual spectral analysis: sufficiently bright, localized by ground-based radio, and with the gamma rays reaching a detector unobstructed. These TGFs exhibit diverse spectral characteristics that are hidden when using summed analysis methods. We account for the low counts in individual TGFs by using Poisson likelihood, and we also consider instrumental effects. The data are fit with models obtained from Monte Carlo simulations of the large-scale Relativistic Runaway Electron Avalanche (RREA) model, including propagation through the atmosphere. Source altitudes ranging from 11.6 to 20.2 km are simulated. Two beaming geometries were considered: In one, the photons retain the intrinsic distribution from scattering (narrow), and in the other, the photons are smeared into a wider beam (wide). Several TGFs are well fit only by narrow models, while others favor wide models. Large-scale RREA models can accommodate both narrow and wide beams; with narrow beams suggest large-scale RREA in organized electric fields while wide beams may imply converging or diverging electric fields. Wide beams are also consistent with acceleration in the electric fields of lightning leaders, but the TGFs that favor narrow beam models appear inconsistent with some lightning leader models.

Alexei Pozanenko, Pavel Minaev, Vadim Vybornov
Space Research Institute of RAS, RF

Typical properties of TGFs registered by RHESSI experiment

We discuss typical properties of TGF light curve registered by RHESSI. In particular we calculate parameters of a time profile of single pulsed TGFs and compare it with pulse parameters deduced from TGF registered by GBM/Fermi. To estimate parameters we use stacking individual TGF events. We also use Monte-Calo simulations for recovering light curve of stacked data of all single pulsed TGFs. We also discuss statistics of multi-pulsed TGFs registered by RHESSI.

Anton Chernenko
Space Research Institute of RAS, RF

On the connection of TGFs and atmospheric pollution

The idea that atmospheric pollutants are tightly linked to properties of lightnings has been around for quite a while (Westcott, 1995, Kar and Liou, 2014), and specifically that the pollution tends to increase the absolute rate of CG lightnings, driving down the percentage of IC lightnings.

In this paper, I check if the excess/deficiency of TGFs correlates with areas of tropospheric pollution. As a measure of the pollution I use OMI instrument (KNMI/NASA) data on tropospheric NO2 column.

The analysis, based on RHESSI data, reveals that the geographical locations where TGFs are in deficit from the number expected from lightning production, have significantly more, by the factor of 2, concentration of tropospheric NO^2 compared to the locations, where TGFs are in excess to the expected number.

Further investigation with high spatial resolution, based on GBM TGFs with WWLLN locations, indicates that the excess/deficiency of TGFs is not related to NO2 distribution at surface.

3. Monitoring of TLEs and thunderstorms from the orbit

Maxim Dolgonosov, Vladimir Gotlib

Space Research Institute of RAS, RF

Investigation of atmospheric high-energy phenomena on-board of International Space Station

Space Research Institute of the RAS (IKI) in cooperation with JSC RSC Energia is gradually developing its own program of the space-born experiments to study high-energy process in our atmosphere. TGFs and CIDs are among principal goals of the scientific research of the program. To conduct research is supposed to produce new ‚instrumentsЃ: microsatellite Chibis-AI and VHF interferometer Kite.

Microsatellite Chibis-AI will be constructed on the platform originally designed at the Special Engineering Department of Space Research Institute of Russian Academy of Sciences in 2011. It's forerunner Chibis-MB was successfully launched in 2012. Expected date of Chibis-AI launch is 2019. The principal idea underlying design of the scientific payload of the microsatellite Chibis-AI is the joint observations of the TGF and CID emissions by different detectors installed onboard: Radio Frequency Analyzer (RFA) and Neutron and Gamma spectrometer (NGS). The microsatellite orbit will be circular with inclination 51B′ with initial elevation above sea level around 550 km. The total mass of the satellite should be around 50 kg.

RFA contained two passbands in the range 15-26 and 26-48 MHz with a digitization at 96 MS/s. The radio channel is connected to a simple passive dipole-like antenna with total length 4 m. The antenna is mounted at the bottom of the platform. Initial footprint of the antenna will about 2300 km along longitude and latitude, or ˝max68′ from the plumb line at the equatorial region. NGS is based on LaBr3(Ce3+) crystal with the maximum achievable today spectral resolution and efficiency of gamma rays in the energy range 100 Kev - 10 MeV among scintillation crystals.

Next useful instrumentation used in the research is mentioned above VHF interferometer Kite to be installed in 2019-2020 aboard ISS. To implement interferometry scheme 4 antennas will be installed on the ISS surface. The passband of the instrument will be ~ -50-100 MHz.

Technical details of both experiments, its current stage and features as well results of the previous experiment Chibis-MB will be discussed.

Pavel Klimov, Boris Khrenov, Gali Garipov
Skobeltsyn Institute of Nuclear Physics, MSU, RF

First results on transient atmospheric events from Tracking Ultraviolet Set-up (TUS) on board of Lomonosov satellite

Study of Transient Atmospheric Events (TAE) is started by new space instrument TUS -an imaging detector with large area mirror concentrator (2 m^2) and 256 pixels-photo multipliers in its focal plane. Its covering area in the atmosphere is 80x80=6400 km^2. TAE in range of wavelengths 240-420 nm is registered by trigger command selecting several “hited” pixels with signals over a threshold. To compare with visual cameras used in previous experiments for measurement of bright transients called TLE (Transient Luminous Events) TUS instrument measures orders of magnitude less bright transients due to large optical aperture. Detector has several modes of operation with different temporal resolution (0.8 µs, 25.6 µs, 0.4 ms and 6.6 ms) which allow to measure TAE in various time scales. Lomonosov satellite was launched on 28 April 2016 and during first months of its operation several hundreds of TAE were measured. In comparison with previous MSU experiments on board Tatiana and Vernov satellite TUS detector has a spatial resolution, which gives the opportunity for more reliable classification of the TAE types based on their temporal development and spatial structure. In this talk preliminary data on TAE measurements are presented. Results on background atmosphere UV radiation and various classes of TAE from new detector are discussed. The work is partially supported by RFBR grants в–15-35-21038 and 16-29-13065.

Svertilov Sergey, Panasyuk Michail, Bogomolov Vitaly
MSU, Physical Department of Skobeltsyn Institute of Nuclear Physics

Gamma-Ray and Relativistic Electron Flux Short-time Variations Observed in Vernov and Lomonosov Missions

The short-time (10^{-4} -10^{-2}s) variations of gamma-quantum (0.02 -3.0 MeV) and relativistic (0.3 -10.0 MeV) electron fluxes were observed during Vernov and Lomonosov missions. The similar detectors based on NaI(Tl)/CsI(Tl) crystals of 13.0 cm diameter and 2.0 cm total thickness (0.3 cm NaI(Tl) + 1.7 cm CsI(Tl)) were used in both missions for study different kinds of transient phenomena, such as GRBs, TGFs, Solar Flares and magnetosphere electron precipitation.

Four gamma-ray detectors on-board of the Vernov satellite had a total area of about 480 cm^2, and were directed toward the Earth atmosphere (in local Nadir). They were used especially for TGF observations. These detectors were also able to detect precipitated and quasi-trapped sub-relativistic and relativistic electrons. The several dozens of TGF candidates were selected as satisfied the trigger condition, i.e. more than 5 gamma-quanta detected for a 400 ms exposure time in one detector with 120 cm^2 area. Possible connection of these events with TLEs detected by DUV instrument and lightning observed by WWLN is discussed. Quasi-trapped and precipitated electron flux short-time variations (burst-like) were observed regularly in different areas of the near-Earth space. The time and energy spectrum parameters of such events observed in Vernov mission are presented.

The first results of Lomonosov mission on TGF-like events and electron flux short-time variations are also discussed.

4. Relation of Lightning to the TGE and TGF

Chilingarian, Y. Khanikyants, L. Kozliner, S. Soghomonyan
Yerevan Physics Institute Armenia

Electric field changes produced by lightnings that abruptly terminate the Thunderstorm Ground Enhancements (TGEs)

We present measurements of the near-surface electrostatic field changes and wideband fast *electric field waveforms* produced by lightning discharges that abruptly terminate the TGEs observed at an altitude of 3200 m above sea level on Mt. Aragats. Electrostatic field changes are measured by a network of five field mills, three of which are placed in Aragats station, one in Nor Amberd station (12.8km from Aragats), and another one in Yerevan station (39km from Aragats). We consider examples of lightning flashes for which the electrostatic field changes reverse or do not reverse polarity with distance, and discuss the possibility to distinguish between cloud-to-ground and intracloud flashes by virtue of their polarity. Analysis of fast electric field waveforms and their comparison to the corresponding electrostatic field change patterns is performed. Some characteristic features of fast electric field *waveforms show correlation with* polarity reversal properties of electrostatic field. *We compare our results of lightning detection* with the data from the World Wide Lightning Location

Shaolin Xiong, Fan Li
Institute of High Energy Physics, Chinese Academy of Sciences

On the TGF-lightning relation based on the Fermi GBM and ENTLN data

Previous studies have suggested that Terrestrial Gamma-ray Flashes (TGFs) occur at the initial stage of +IC lightning. However, it is unclear if this statement is valid for all TGFs, because previous studies were solely based on a small sample of TGFs. Here we matched >3000 TGFs detected by Fermi Gamma-Ray Burst Monitor (GBM) to radio sferics measured by the Earth Networks Total Lightning Network (ENTLN), obtaining >1000 TGF-sferics associations, which is the largest sample to date. With this sample, we clearly identified that the TGF-associated sferics span from ~10 ms to 10 ~800 ms relative to TGF time, consisting of three distinct components: TGF-produced radio signal within ~˜0.2 ms, adjacent sferics within ~˜5 ms and sub-sequent lightning sferics from 5 ms to ~800 ms. Based on this large sample of TGFs, we conclude that all TGFs happen in the first 10 ms of lightning process.

D. I. Iudin[1], V. A. Rakov[2], E. A. Mareev[1], S. S. Davydenko[1], F. D. Iudin[3], and A. A. Syssoev[1]

[1] Institute of Applied Physics of Russian Academy of Science, Nizhny Novgorod, RF
[2] University of Florida, Gainesville, USA
[3] Lobachevski State University, Nizhniy Novgorod, RF

Advanced numerical model of lightning development: Application to studying the role of LPCR in determining lightning type

An advanced 3D numerical model of lightning development is presented. The key features of the model include probabilistic branching, streamer-to-leader transition, bidirectional propagation, non-zero internal electric field, simultaneous growth of multiple branches, physical timing, and, for the first time, probabilistic propagation field threshold and channel decay. The model was applied to studying the occurrence of lightning flashes of different type depending on the cloud charge structure, with emphasis on the lower positive charge region (LPCR). We demonstrated with the new model that the presence of relatively large (excessive) LPCR prevents the occurrence of negative CG flashes by "blocking" the progression of descending negative leader from reaching ground. This "blocking" effect occurs when a negative potential well at the cloud bottom is present and the vertical component of electric field at the cloud bottom is negative. Additionally, we showed that significant reduction or absence of LPCR can eliminate the possibility of negative CG flashes and lead to IC flashes between the main positive and main negative charge regions instead.

5. Cloud electrification and atmospheric discharges: measurements and applications

A.Chilingarian, T.Karapetyan, D.Pokhsraryan
Yerevan Physics Institute, Armenia

Research of the Thundercloud Electrification by facilities of Aragats Space Environmental Center

The problem of the thundercloud electrification is one of most difficult ones in the atmospheric physics. Structure of electric fields in the cloud escape from the detailed *in situ* measurements; few balloon flights recognize rather complicated structure much more sophisticated than a simple dipole or tripole. To get insight into problem of charge structure of thundercloud we use new key evidence – the fluxes of particles from thundercloud, so called, Thunderstorm Ground Enhancements – TGEs. TGEs originate from electron acceleration, multiplication processes in the strong electric fields in the thundercloud and the intensity and energy spectra of electrons, and gamma rays as observed at the Earth's surface are directly connected with the charge structure of the cloud.

In the presented paper, we demonstrate that experimentally measured patterns of the near-surface electrostatic field during TGEs are consistent with tripole structure of the cloud electrification. The maximal particle flux and energy spectra extended above 4 MeV coincide with special pattern of the disturbances of the near surface electrostatic field – the "bumps" arising from deep negative electrostatic field domain. These features we identify with development of mature Lower Positively Charge Region (LPCR), with development of which the electric field in the cloud get enough strength to unleash the Runaway Breakdown (RB) process accelerated electrons downward in the direction of earth.

Leonid Sorokin
People's Friendship University of Russia

Mapping of Microwave radiation associated with propagating High Energy Particles in the Atmosphere

The powerful radio-physical methods of Microwave radiation sources passive direction-finding are highly effective for mapping High Energy Particles beams. This instrument can be used for obtaining time and spatial information on the propagating High Energy Particles in the Atmosphere together with particle detectors and facilities of A. Alikhanyan National Lab (Yerevan Physics Institute). The visualization of the High Energy Particles beams can be useful for studying the high-energy physics in the atmosphere: Thunderstorm ground Enhancements (TGEs), Relativistic Ranaway Electron Avalanches (RREAs), Extensive air showers, Terrestrial Gamma-ray Flashes (TGFs) and propagation of High Energy Particles from Space and Solar.

Leonid Sorokin

People's Friendship University of Russia

Space-time analysis of the Seismic Waves and WWLLN data associated with the third Fermi GBM Gamma-ray Burst Catalog

The natural high intensity sub-millisecond electromagnetic pulses associated with seismic waves from earthquakes can trigger +CG lightning discharges and transient luminous events. The +CG lightning discharges with higher peak currents are more probable during the moments when seismic waves from earthquakes pass through a place of +CG lightning. Huge peak currents of triggered +CG lightning discharges can radiate powerful electromagnetic emission. Space-time analysis of the seismic waves propagation and WWLLN data was done. The Third Fermi GBM Gamma-ray Burst Catalog have been studied together with earthquake USGS NEIC catalog, and space-time coupling of positive cloud-to-ground discharges (+CG) with exact seismic waves from the earthquakes has been described. Electromagnetic pulses related to seismic waves can provoke positive lightning discharges (+CG), transient luminous events (TLEs) and non-luminous events (TGFs).

Inna Gubenko

Hydrometeorological Research Centre of Russian Federation

Electric structure of the simulated thunderclouds

The objectives of this study are:

1. Physical and mathematical description of the cumulonimbus clouds electrification model. The model uses the forecasts of numerical predictive meso-scale model WRF-ARW (Weather Re-search and Forecast) and allows predicting the parameters of the atmospheric electric field (total volume charge, potential and electric field intensity) including specific to thunderstorm activity.

2. Analysis of simulated parameters of the atmospheric electric field for the cases when the simulated thunderstorm cells coincide with observed thunderstorm cells.

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A.A. Petrukhin,

National Research Nuclear University MEPhI, RF

Possibilities of atmospheric disturbance investigations in muon flux

Muons of cosmic rays are widely used for investigations of near terrestrial space including the atmosphere. However, dependence of the muon flux on conditions in the heliosphere and in the atmosphere requires specific approaches for the separation of their influence. In this talk some problems of atmospheric processes investigations and their possible solutions are discussed.

N.S. Barbashina[a], I.I. Astapov[a], T.A. Belyakova[b], Y.B. Pavluokov[b], A.A. Petrukhin[a], N.I. Serebryannik[b], V.V. Shutenko[a], I.I. Yashin[a]

[a] *National Research Nuclear University MEPhI, RF*

[b] *Federal State Budget Institution "Central Aerological Observatory", Roshydromet, Dolgoprudny, RF*

Investigation thunderstorms according to muon hodoscope URAGAN

Thunderstorms are a clear manifestation of non-stationary processes in the atmosphere and a good material for the development and validation of the main approaches to the study of these processes on the basis of muon flux variations, detected on the Earth's surface. The results of the analysis of spatial and angular characteristics of muon flux registered by means of muon hodoscope URAGAN (MEPhI) during 47 storm events in Moscow region in 2014 – 2015 are presented. Identification of thunderstorms and tracking of their development was carried out on the basis of information received with Doppler weather radar DMRL-C (Central Aerological Observatory, Russia).

I.I. Yashin, I.I. Astapov, N.S. Barbashina, A.N. Dmitrieva, A.A. Petrukhin, V.V. Shutenko

National Research Nuclear University MEPhI

Muon hodoscope as a new meteorological tool

Muon diagnostics is a new direction in the development of the world environmental observation system based on penetrative ability of cosmic ray muons. Muon flux is formed in the atmosphere at altitudes 15 – 20 km and is sensitive to the changes of main thermodynamic atmospheric parameters as well as to the processes in the near-heliosphere and the magnetosphere of the Earth, related with the activity of the Sun.

The approach is based on simultaneous detection of cosmic ray muons coming from all directions of the upper hemisphere (hodoscopic mode). It makes possible to obtain an overall picture of the conditions of the upper layers of the troposphere, and to trace the dynamics of changes, in particular, to identify disturbed areas, determine the direction and speed of their movement, and to estimate the time of appearance at a given point.

This method is sensitive to large-scale atmospheric processes, as well as to rapidly changing local phenomena, and, in addition, allows you to explore the characteristics of wave processes generated by powerful turbulent phenomena, including those of a potentially hazardous nature (storms, squalls, tornadoes, hurricanes, etc.).

The muon diagnostic technique was realized in the multi-directional muon hodoscope URAGAN with large acceptance and high angular accuracy, which was designed and constructed in Moscow Engineering Physics Institute. In the talk, results of a study of the ability of URAGAN to detect various atmospheric processes are presented and discussed.

Roy Yaniv[a], Hripsime Mkrtchyan[b], Yoav Yair[c], Colin Price[a], Barry Lynn[d] and Shai Katz[a]

a) Department of Geosciences, Tel Aviv University, Israel.

b) Cosmic Ray Division, Yerevan Physics Institute, Armenia.

c) School of Sustainability, Interdisciplinary Center (IDC) Herzliya, Israel.

d) Weather It Is, LTD, Efrat, Israel

Ground measurements of the vertical E-field in Israel and Armenia

The global electric circuit (GEC) on earth is driven by electrified shower clouds and thunderstorms that act as current generators. The current flows up to the ionosphere and returns back to earth in areas known as fair weather regions. One of the GEC parameters that is routinely measured is the vertical electrical field (Ez) with a typical fair weather value between 100-300 V/m near ground. The Ez was found to correlate with the diurnal global thunderstorm activity in what is known as the Carnegie curve (Rycroft et al., 2012).

Four ground based stations that measure the daily mean variations of the Ez during fair weather are currently operational in Israel and Armenia. The Israeli stations are located in the arid region of Mitzpe Ramon, Negev desert in southern Israel (30.6N, 34.76E, altitude 860 a.s.l) [Yaniv et al 2015] and at the Tel-Aviv University Cosmic Ray Observatory on Mount Hermon, in northern Israel (33.3N 35.78E, 2100 a.s.l). The Armenian stations are located on Mount Aragats: Nor Amberd (40.37N, 44.26E, 2000m a.s.l.) and Aragats (40.47N, 44.18E, 3200m a.s.l.).

We present results of the mean daily variations of Ez recorded in these stations, showing a strong mid-day effect in the mountainous stations (Hermon, Aragatz and Nor Amberd) and a local morning effect of aerosols in the arid station that is absent from the famous oceanic Carnegie curve. This strong mid-day local effect in mountainous regions were previously observed by several authors and referred to as “Austausch” – The rising of a charged aerosol layer due to solar morning heating of the ground. The transport of electrical charge results in an increase of the local Ez [Chalmers 1965, Cobb et al 1967, Israul 1970].

Hripsime Mkrtchyan
Yerevan Physics Institute, Armenia

Relation between flash rate and wind speed

Many experiments have been done to find connections between lightning activity and severity of weather. For our analysis we have used data from various kinds of equipment installed on Aragats Space Environmental Center (ASEC). Near surface electric field, lightning discharges, meteo parameters are registered during thunderstorms incessantly.

As it is reported previously features of lightning activity can serve for classifying thunderstorms and be a key for forecasting their severity. Violence of storm directly coupled with lightning activity. In the current work we will discuss connections between wind speed and lightning flash rate behavior during different storms in different season of year. According to the first results there is strong connection between near surface wind speed and lightning activity.

6. Instrumentation

Alexander Shepetov, Olga Kryakunova, Nazyf Salikhov
P.N. Lebedev Physical Institute RAS, RF

The compact, microcontroller based data acquisition system for reliable operation under thunderstorm conditions

New compact system of data acquisition is created at Tien~Shan mountain station. The system is based on a modern 32-bit microcontroller unit of STM32F407 type, and its embedded program code ensures the following operation functionality: (1) continuous monitoring of the intensity of digital pulse signals and the amplitude measurements of a quasi-potential input signal with a low time resolution (1s-100s); (2) the measurement of the high-resolution (typically, 10-50μs) time series of input signals with its sum duration up to a few seconds; (3) synchronization of the registered time series both with external trigger signal which can come from outside, and with a local casual trigger generated internally on the basis of momentary distribution of input signal; (4) possibility of an on-the-fly change of the configuration of informational system (both the combination and type of input signals, time resolution and sum duration of time series measurements, and so on) immediately in the time of measurements. Due to its compactness and low power consumption, the system of such a type can be applied in a number of mobile experimental set-ups; and in particular, in autonomous detector points of the Thunderstorm experiment at Tien~Shan.

Kozliner L., Pustylnik L., Shtivelman D.
Tel-Aviv University, Israel

Electronics designed for a system of Neutron monitor and muon telescope for the Space Weather research on Mt. Hermon (altitude of 2000m) on Holland heights, Israel

Variations of the different components of the cosmic ray (CR) flux are source of uniqueinformation on space state and open ways for space weather forecasting. The main instruments for CR study are neutron monitors measuring a temporary variation of the CR flux and muon telescope allowed to study CR anisotropy. These two approaches applied simultaneously increase efficiency of CR monitoring and forecasting of severe space weather impacts. For operation of the hybrid NM-telescope system we have developed and manufactured cheap electronics consisted of standard analog-to-digital converter at 250 kHz per channel(NI PCI-6221V) and a special expander-module allowing effectively register pulses from the scintillation detectors having amplitude of 0.02 - 4 V, and duration of 30 -200 nsec. Thus designed electronics can operate 4 channels of particle detectors at frequencies of 5 MHz instead of 125 kHz possible with NI PCI-6221V. Using the NI PCIe 6535b module we design a system for identification of the channel number (one of 16) and precise incidence time of muon (~1µs).

A.Chilingarian, G. Hovsepyan, A.Badalyan, A.Grigoryan, A. Manukyan, M. Mantashyan, T. Sargsyan

Yerevan Physics Institute, Armenia

Extensive Air Showers Detected by Aragats Neutron Monitor.

Extensive Air Shower (EAS) duration as registered by the surface particle detectors does not exceed a few tens of nanoseconds. However, several detectors containing plenty of absorbing matter can prolong the “life” of EAS to approximately 1 ms. In the neutron monitor’s 5-cm lead producer, the EAS hadrons generate several hundreds of neutrons and in the polyethylene moderator they slow the neutrons down to thermal energies before entering the proportional counters. Thus, the time distribution of the pulses from the proportional counters of the neutron monitor after EAS propagation extends to approximately 1 ms, several orders of magnitude larger than the EAS passing time. The Aragats Neutron Monitor (ArNM) has a special option for the EAS detection. In general, the dead time of NM is set to approximately 1 ms for one-to-one relation of incident hadrons and detector counts. Thus, all neutrons entering the proportional chamber after the first one will be neglected. In ArNM, we use several dead times, and the shortest one, 400 ns, can count almost all the secondary neutrons that enter the proportional chambers. If ArNM one-second time series corresponding to the shortest dead time contain much more signals (burst multiplicity) than with 1-ms dead time, then we conclude that the EAS core hits the detector.

The distribution of registered burst multiplicities reflects the energy spectrum of the primary hadrons. The primary cosmic ray energy spectrum was obtained by the frequency analysis through the counting intensities of multiplicities of different magnitudes and relating them to the integral energy spectrum measured by the MAKET array at the same place several years ago.

K.Avagyan, A.Chilingarian, T. Karapetyan, L.Kozliner
Yerevan Physics Institute, Armenia

Energy spectra of the near horizontal muons

Software triggers of the Aragats Solar Neutron Telescope (ASNT) select the events with energy releases above preselected threshold ensuring the horizontal transport of muons. Trigger is selected events intersecting two scintillators in a row and releasing energy equivalent to energy release of a muon in 1 m of scintillator.

ASNT comprises of four 5 cm thick plastic scintillators with area of 1 m^2 each detecting particles coming from opposite directions. Because axes of ASNT are near to directions to Poles we denote these directions as West-East (WE), East-West (WE), North-South (NS) and South-North (SN). 3 from 4 directions (WE, EW, SN) are open for incoming particles; NS direction is obscured by the Aragats Mountain (30 km of mountain rock). Analogical consideration is related to the four 60 cm scintillators located below 5-cm thick scintillators.

Based on 8-year statistics (2,200,000 muons) we estimate near-horizontal muon energy spectra. Assuming that the intensity from the open horizon directions, i.e. WE, EW, SN is identical we can estimate the intensities from these directions and from suppressed by rock NS direction. Muons coming from the Aragats direction have higher energies (as minimum 25-30GeV), comparing with muons coming from the "free" horizon.

Avakyan K., Chilingarian A., Hovsepyan G., Kozliner L., Mnatsakanyan E.
Yerevan Physics Institute, Armenia

Calibration of the Log ADCs for NaI spectrometers network on Aragats

A detector network measuring energy of electrons and photons originated in the thunderstorm atmospheres consists of seven NaI crystal scintillators packed in a sealed 3-mm- thick aluminum housing. The NaI crystals are coated by 0.5 cm of magnesium (MgO) by all sides (because the crystal is hygroscopic) with a transparent window directed to the photo-cathode of a FEU-49 PM. The large cathode of FEU-49 (15-cm diameter) provides a good light collection. The spectral sensitivity range of FEU-49 is 300–850 nm, which covers the spectrum of the light emitted by NaI(Tl). The sensitive area of each NaI crystal is ~0.0348 m^2 and the gamma-ray detection efficiency is ~80%. A logarithmic analog-digit converter (LADC) is used for the coding of PM signals. Calibration of LADC and code-energy conversion was made by detecting the peak from exposed ^{137}Cs isotope emitting 662 keV gamma rays and by the high-energy muon peak (~50 MeV) in the histogram of energy releases in the NaI crystal. The PM high voltage was tuned to contain both structures (peaks) in the histogram of LADC output signals (codes) and to ensure linearity of LADC in the energy region of 0.4–100 MeV.

Also methodical errors of the TGE particle energy recovering due to fluctuations of the background are considered.

Ashot Chilingarian, David Pokhsraryan
Yerevan Physics Institute, Armenia

First results of the implementation of the fast Data Acquisition system based on NI-myRIO

For deciding on atmospheric particle origin, we perform experiments with pulse shape recording from particle detectors and simultaneously from atmospheric discharges. Direct comparisons of synchronized patterns of lightning discharges and particle detector outputs along with examining the typical response of detectors to particle traversal will answer the question of "thunderstorm" particle origin. Signals from the lightning detecting system (commercial MFJ-1022 active whip antenna) triggered digital oscilloscope (Picoscope 5244B with 25MS/s sampling rate) that records fast electric field waveforms along with particle signals. Thus, along with spectrograms of atmospheric discharges we measure synchronized signals from particle detector. National Instruments myRio board provides an absolute timing for TGE-lightning relation that well coincide with measurements provided by Worldwide lightning location network (WWLLN). We prove that bipolar pulses registered by particle detectors are triggered by the strong atmospheric discharge and not by particle flux from the lightning bolt. Signals from charged or neutral particles detected by NaI spectrometer or by neutron monitor, or plastic scintillator are always unipolar. After monitoring 2016 summer storms we did not observe even one lightning producing particles in any of tested detectors.

EVENING LECTURES

Razmik Mirzoyan
Max-Planck-Institute for Physics, Munich, Germany

Expanding the Observational Limits of the Ground-Based Atmospheric Cherenkov Technique at Very High Energies

We are further improving the Atmospheric Cherenkov Telescope (IACT) observational technique for ground-based very high energy gamma-ray astrophysics. For this we are developing a diversity of methods and techniques, which allow observing under non-optimal conditions like, for example, under largely varying lighting and weather conditions. These allow us to observe during nearly full-moon conditions. Also, atmospheric transmission corrections obtained from the LIDAR and other auxiliary instruments allow us to analyze data taken during cloudy and/or dusty conditions. Observations at large zenith angles allow us not only to significantly increase our effective detector area for very high energies, but also enable accessing sources from the other hemisphere. In this talk we will present some selected recent results that we achieved by expanding the observational limits of the IACT technique.

Johannes Knapp
DESY, Zeuthen, Germany

A new era of Gamma Ray Astronomy with the Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) is a new and powerful observatory for gamma rays from 20 GeV to 300 TeV.

The sources of this radiation are the most powerful objects in the universe.

CTA will discover about 1000 new sources of gamma rays and measure their emission with unprecedented precision. As a world-wide next-generation experiment, CTA will revolutionise the field. The science case of CTA will be discussed and the status will be presented.

List of Partisipants

1.	Donald Pleshinger, University of Louisiana, USA	djpleshinger@gmail.com
2.	Bagrat Mailyan, The University of Alabama, Huntsville, USA	bagrat.mailyan@uah.edu
3.	Shaolin Xiong, Institute of High Energy Physics, Chinese Academy of Sciences	xiongsl@ihep.ac.cn
4.	Roy Yaniv, Department of Geosciences, Tel Aviv University, Israel	
5.	Razmik Mirzoyan, Max-Planck-Institute for Physics, Munich, Germany	mirzoyan.razmik@gmail.com
6.	Johannes Knapp, DESY, Zeuten	johannes.knapp@desy.de
7.	Leonid Sorokin, People’s Friendship University of Russia	leonid.plasma@gmail.com
8.	Vitaly Bogomolov, Physical Department of Skobeltsyn Institute of Nuclear Physics, MSU, RF	bogovit@gmail.com
9.	Pavel Klimov, Skobeltsyn Institute of Nuclear Physics, MSU, RF	pavel.klimov@gmail.com
10.	Svertilov Sergey, Skobeltsyn Institute of Nuclear Physics, MSU, RF	sis@coronas.ru
11.	Gali Garipov, Skobeltsyn Institute of Nuclear Physics, MSU, RF	ggkmsu@yandex.ru
12.	Anton Chernenko, Space Research Institute, RAS, RF	anton.chernenko@gmail.com
13.	Maxim Dolgonosov, Space Research Institute of RAS, RF	russia.on.mars@gmail.com
14.	Vladimir Gotlib, Space Research Institute of RAS, RF	gotlib@iki.rssi.ru
15.	Alexei Pozanenko, Space Research Institute, RAS, RF	grb123@mail.ru
16.	Alexander Shepetev, P. N. Lebedev Physical Institute of RAS, RF	ashep@tien-shen.org
17.	Inna Gubenko, Hydrometeorological Research Centre of Russian Federation (Hydrometcentre of Russia)	img0504@yandex.ru
18.	Anatoliy Petrukhin, National Research Nuclear University MEPhI, RF	AAPetrukhin@mephi.ru
19.	Igor Yashin, National Research Nuclear University MEPhI, RF	iiyashin@mephi.ru

20.	Natalia Barbashina, National Research Nuclear University MEPhI, RF	nsbarbashina@mephi.ru
21.	Dmitry Iudin, Institute of Applied Physics of Russian Academy of Science, Nizhny Novgorod, RF	Idiot64@gmail.com
22	Stanislav Davidenko, Institute of Applied Physics of Russian Academy of Science, Nizhny Novgorod, RF	chili@aragats.am
23.	Ashot Chilingarian, Yerevan Physics Institute, Yerevan, Armenia	chili@aragats.am
24.	Tigran Karapetyan , Yerevan Physics Institute, Yerevan, Armenia	ktigran79@gmail.com
25.	Karen Avagyan, Yerevan Physics Institute, Yerevan, Armenia	avagyan.karen@gmail.com
26.	Gagik Hovsepyan, Yerevan Physics Institute, Yerevan, Armenia	hgg@yerphi.am
27.	David Pokhsraryan, Yerevan Physics Institute, Yerevan, Armenia	davitpo@gmail.com
28.	Eduard Mnatsakanyan, Yerevan Physics Institute, Yerevan, Armenia	eduardmnats@gmail.com
29.	Lev Kozliner, Yerevan Physics Institute, Yerevan, Armenia	kozliner@yerphi.am
30.	Hripsime Mkrtchyan, Yerevan Physics Institute, Yerevan, Armenia	hripsime@yerphi.am
31.	Suren Soghomonyan, Yerevan Physics Institute, Yerevan, Armenia	surensog@gmail.com
33.	Yeghia Khanikyants, Yerevan Physics Institute, Yerevan, Armenia	khanikync@yerphi.am
34	Zaruhi Asaturyan, Yerevan Physics Institute - Yerevan, Armenia	zara@mail.yerphi.am