THUNDERSTORMS & ELEMENTARY PARTICLE ACCELERATION

82 years of cosmic ray monitoring on Aragats, 17 years of TGE observation

Yerevan 2025 TEPA Armenia

International Conference, 22-25 September

September 22-25, 2025

Seminar hall of Cosmic Ray Division
of the Yerevan Physics Institute,
Yerevan, Alikhanyan Brothers 2,
Armenia

PROGRAMME & ABSTRACTS

http://crd.yerphi.am/TEPA_2025

A. ALIKHANYAN National Laboratory

COSMIC RAY DIVISION A. ALIKHANYAN National Laboratory

THUNDERSTORMS & ELEMENTARY PARTICLE ACCELERATION

82 years of cosmic ray monitoring on Aragats, 17 years of TGE observation

TIME FRAME: September 22-25, 2025

LOCATION: Seminar hall of Cosmic Ray Division of the Yerevan Physics Institute,

Yerevan, Alikhanyan Brothers 2, Armenia.

SYMPOSIUM WEBSITE:

http://crd.yerphi.am/TEPA_2025

ORGANIZERS:

Cosmic Ray Division
of Yerevan Physics Institute, Armenia

Yerevan 2025 **TEPA** Armenia

International Conference, 22-25 September

THUNDERSTORMS & ELEMENTARY PARTICLE ACCELERATION

ORGANIZER

Cosmic Ray Division (CRD) of Yerevan Physics Institute, Armenia

INTERNATIONAL ADVISORY COMMITTEE:

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Harufumi Tsuchiya, Cosmic Radiation Laboratory, Riken, Japan

Conference Hall of the Cosmic Ray Division of Yerevan Physics Institute 2 Alikhanyan Brothers Street, Yerevan, Armenia

BACKGROUND:

Thunderstorms generate intense electric fields that extend across large areas within and around the storm system. Charge separation in thunderclouds, driven by updrafts of warm air and interactions among hydrometeors, generates oppositely directed dipoles within the cloud. The fupper dipole consists of the main negative and positive charge layers in the middle and top of a thundercloud (first dipole). The gamma-ray glows, generated in the upper atmosphere, are detected by airborne experiments flying above thunderstorms. The most energetic gamma rays occasionally reach orbiting gamma observatories 400-700 km from the source, registering microsecond bursts of particles known as terrestrial gamma flashes (TGFs). Closer to the ground, the lower dipoles, comprising charge layers in the cloud and their induced counterparts on Earth's surface, accelerate electrons and produce runaway avalanches. The main negative layer and an induced mirror charge in the Earth's surface formed a second dipole. A third dipole forms between the main negative layer and a transient "pocket" of positively charged particles in the lower part of the cloud (LPCR), which is often associated with falling graupel. Electrons accelerated in 2 lower dipoles create electron-gamma ray avalanches detected on the ground as thunderstorm ground enhancements (TGEs), comprising millions of gamma rays, electrons, and neutrons. A fourth dipole between the LPCR and its mirror in the Earth accelerates positrons and positive muons while decelerating electrons and negative muons. Understanding charge structures and their particle acceleration mechanisms provides critical insights into high-energy atmospheric physics (HEPA). These processes affect atmospheric science, space weather forecasting, and even potential global climate change.

Establishing synchronized sensor networks for continuous particle flux monitoring has revolutionized HEPA research. These advancements enable the integration of cosmic ray studies with atmospheric physics, offering practical applications such as predicting geomagnetic storms that threaten satellites and power grids. Moreover, understanding the effects of extreme electric fields during solar flares contributes to mitigating risks associated with natural disasters. The new understanding of thunderclouds as media full of radiation opens up new avenues for research, including developing theories on cloud electrification and its potential impact on climate change.

As the field evolves, the Astroparticle and Atmospheric physics intersection offers unprecedented opportunities. Enhanced understanding of thundercloud electrification, gamma-ray generation, and their potential links to climate systems opens new research frontiers. Collaboration between researchers in solar, astrophysical, and atmospheric physics, combined with technological innovation, will pave the way for groundbreaking discoveries. This conference is a platform for fostering such collaborations, advancing geospace physics, and addressing global challenges like natural disasters and climate change.

STRUCTURE OF THE SYMPOSIUM:

We anticipate the following sessions:

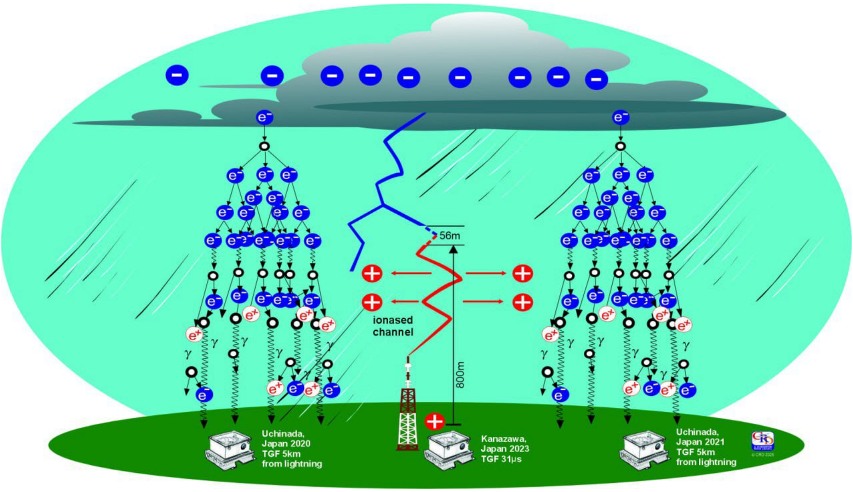
1. Multivariate observations of particles from the Earth's surface, in the atmosphere, and from space (TGEs, gamma glows, and TGFs);
2. Correlated measurements of the atmospheric discharges, lightning flashes, and particle fluxes;
3. Space Weather and Solar physics with SEVAN network;
4. Influence of the atmospheric electric field on experiments using the atmosphere as a target (Surface Arrays and Cherenkov Imaging Telescopes);
5. Remote sensing and modeling of the atmospheric electric fields;
6. Instrumentation;
7. Data organization and correlation analysis of multivariate remote measurements assisted by AI.

Topics to be covered during oral and poster sessions:

- Energy spectra of electrons and gamma rays measured on the earth's surface, in the atmosphere, and space; their relation to the strength and location of the electric field;
- Abrupt termination of the particle flux by the lightning flash;
- Registration of neutron and positron fluxes during thunderstorms;
- SEVAN particle detector network as a tool of HEPA research;
- Methods of remote sensing of thundercloud charge structure and atmospheric electric fields;
- Relations to the climate and space weather issues;
- Monitoring of lightning flashes by fast cameras;
- Influence of the atmospheric electric fields on Extensive Air Showers (EASs);
- he possibility of joint observations by aircraft and ground-based facilities.

We plan to discuss the most intriguing problems related to high-energy physics in the atmosphere and explore possible directions for advancing collaborative studies. Additionally, we will report on the results of the international competition for annual projects in high-energy physics in the atmosphere that were performed on Aragats in 2024 and nominated winners of 2025.

RREA originates extended particle fluxes in the upper and lower atmosphere. Surface detectors and detectors on board aircraft register numerous particle bursts over huge areas with durations from seconds to tens of minutes.



DTGF model. Approaching lightning leaders (center) induce non-local reorganization of the atmospheric electric field (AEF), transforming previously subcritical regions into RREA-capable zones. RREA regions are shown at distances of ~5 km from the lightning channel, consistent with observations in Uchinada (2020–2021). Blue – downward negative leader; red – upward positive leader.

Topics to be covered during conference:

- Fluxes of electrons and gamma rays measured on the Earth’s surface, in the atmosphere, and in space; their relation to the strength and location of the electric field;
- Simulation of the RREA in upper and lower atmosphere. Comparisons with experimental spectra.
- Registration of neutron and positron fluxes during thunderstorms;
- SEVAN particle detector network as a tool of HEPA research;
- Methods of remote sensing of thundercloud charge structure and atmospheric electric fields;
- SEVAN network in Solar and space weather physics;
- Relations to the climate and space weather issues;
- Monitoring of lightning flashes by fast cameras;
- Influence of the atmospheric electric fields on Extensive Air Showers (EASs);
- The possibility of joint observations by aircraft and ground-based facilities.

We also plan to discuss the most intriguing problems in high-energy physics and possible directions for advancing collaborative studies in the atmosphere.

PROGRAMME OF TEPA-2024

Monday, 22 September

10:00 – 11:00	***Registration***
11:00 – 11:20	***Opening Ceremony***

Session 1: **High-Energy Physics in the Atmosphere (HEPA)**

Chairperson – ***Johannes Knapp***

11:20 – 12:00	***Ashot Chilingarian,*** *Yerevan Physics Institute* **From TGEs up to gamma glows and TGFs**
12:00 – 12:30	***Coffee break***
12:30 – 13:15	***Mirzoyan Razmik,*** *Max-Planck-Institute for Physics, Garching, Germany,* **A Few Important Scientific Advances Made with the MAGIC Telescopes and Assessment of the Atmosphere by Ancillary Instruments**
13:15 – 15:00	***Lunch***
15:00-15:20	***Zazyan Mary,*** *Yerevan Physics Institute, Armenia*, **Electron multiplication in the upper dipole: contrasts with multiplication in the lower dipole**
15:20-15:40	***Zazyan Mary,*** *Yerevan Physics Institute, Armenia*, **MOS and RREA operation in the upper and lower dipoles: intensities and spectral shapes**
15:40 – 16:00	***Hovhannisyan Liza,*** *Yerevan Physics Institute, Armenia*, **Threshold Atmospheric Electric Fields for Initiating Relativistic Runaway Electron Avalanches: Theoretical Estimates and CORSIKA Simulations**
16:00 – 16:20	***Hovhannisyan Liza,*** *Yerevan Physics Institute, Armenia*, **Estimation of the height of the atmospheric electric field above particle spectrometers on Earth's surface**
16:20 – 16:40	***Coffee break***
16:40 – 17:00	***Sargsyan Balabek,*** *Yerevan Physics Institute, Armenia,* **Classification of GLE and magnetospheric events through energy deposit of muons and neutrons: Observations by the SEVAN light detector**

17:00 – 17:20	***Sargsyan Balabek***, *Yerevan Physics Institute, Armenia,* **Wind-induced Gamma-ray Enhancements (WiGERs)**
17:20 - 17:40	***Piliposyan Qajik,*** *Yerevan Physics Institute, Armenia*, **Thunderstorms on Aragats: simultaneous detection of electric field, cloud height, and count rate enhancements on Aragats and Nor Amberd**
17:40-18:00	***Kozliner Lev,*** *Yerevan Physics Institute, Armenia*, **Influence of strong electric fields on cosmic ray fluxes at an altitude of 800 meters above sea level in Yerevan.**

Tuesday, 23 September

Session 2: **Instrumentation and data analysis**

Chairperson – ***Johannes Knapp***

10:00 - 10:20	***Helena Velyčková [1, 2] , Iva Ambrožová [1] , Martin Kákona [1] , Jakub Šlegl [1, 2] , Marek Sommer [1] , Ondřej Ploc [11] ,*** *Nuclear Physics Institute CAS, Řež, Czech Republic 2 Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic*, **Data Analysis of the measurement campaign at Milešovka within the BIOSPHERE Project**
10:20 – 10:40	***P.A. Klimov, V.D. Nikolaeva, A.A. Belov, V.D. Kudryavtsev, K.D. Shchelkanov,*** *Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics, Russia,* **Optical insights into particle acceleration in thunderclouds and near-Earth space**
10:40 – 11:00	***E.P. Volkov,*** *A.N. Dmitrieva, D.M. Gromushkin, A. Yu. Konovalova, P.S. Kuzmenkova, Yu. N. Mishutina, I.A. Izhenko, National Research Nuclear University MEPhI, Moscow,* **Studies of Neutron Background Variations in the NEVOD Experimental Complex**
11:00 – 11:20	***Chilingaryan Suren,*** *Institute for Data Processing and Electronics, Karlsruhe Institute of Technology Managing*, **Data and Infrastructure Challenges in Multi-Decade Monitoring Systems**
11:20 - 11:40	***Coffee break***

11:40 – 12:00 *Karapetyan Tigran, Yerevan Physics Institute, Armenia*, **Forbush decreases observed by the SEVAN particle detector network in the 25th solar activity cycle.**

12:00 – 12:20 ***Abovyan Sergey, Pokhsraryan David, Sargsyan Balabek,*** *Yerevan Physics Institute, Armenia*, **New electronics for the SEVAN network**

12:20 – 12:40 ***Khanikyanc Yeghia,*** *Yerevan Physics Institute, Armenia,* **Measurements of Particle Fluxes, Electric Fields, and Lightning occurrences at the Aragats Space-Environmental Center (ASEC)**

12:40 – 13:00 ***Hovsepyan Gagik,*** *Yerevan Physics Institute, Armenia,* **New software for analyzing MAKET-ANI registered extensive air showers.**

13:00 – 14:00 ***Lunch***

14:30 – 19:00 **Excursion to Yerevan**

Wednesday, September 24

Chairperson – *Karapetyan Tigran*

Discussion: **Future of SEVAN network, collaborations with other projects**

10:00 – 10:30 ***Knapp Johannes,*** *DESY,*

DESY - CRD Collaboration: Results and Perspectives

10:30 – 11:00 **Ondřej Ploc[1], Jakub Kákona[3], Iva Ambrožová[1], Jakub Šlegl[1,2], Helena Velyčková[1,2], Roman Dvořák[1], Lucie Švihrová[1,2], Martina Lužová[1,2], Marek Sommer[1], Aleksandr Kostinskii[1], Martin Kákona[1]**

[1] Nuclear Physics Institute of the CAS, Řež, Czechia
[2] Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czechia
UST – Universal Scientific Technologies, Soběslav, Czechia, **Sustaining High-Energy Atmospheric Research in Czechia: CRREAT Activities and Instrumentation from Mountain Peaks to Flight Altitudes in the Post-Project Era**

11:00 – 11:30	***Barseghyan Anna, Asaturyan Zara,*** *TARME Tech LLC*, **Newark, Delaware, USA, The B.4 System: A Multimodal Wearable Platform for Continuous Physiological and Environmental Monitoring in Industrial Safety Applications**
12:00 – 13:15	***Lunch***
14:00 – 17:00	**Excursion to Aragats Cosmic Ray Station; Introduction to Aragats Space Environmental Center particle monitors**
17:00	**Conference dinner in Nor Amberd**

Thursday, 25 September

11:00 -12:30	**ASEC collaboration board meeting**
12:30 -12:45	**Closing Ceremony**

TEPA 2024 Reports 14-17 October, Yerevan, CRD seminar hall

1. Chilingarian Ashot

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

High-Energy Physics in the Atmosphere: From Thunderstorm Ground Enhancements to Terrestrial Gamma-Ray Flashes

It is widely known that the atmosphere protects the Earth from harmful radiation; however, understanding its active role in particle acceleration is crucial for research in space weather and atmospheric physics. Thunderstorms create strong atmospheric electric fields (AEFs) that cover large areas within and around storm systems. The energy in AEFs mostly converts into radiation energy via relativistic runaway electron avalanches (RREAs, Gurevich et al., 1992), which appear as thunderstorm ground enhancements (TGEs, Chingarian et al., 2010, 2011) when detected on Earth's surface and as gamma glows when observed above intense tropical storms. Variations of these primary radiation sources include short gamma ray bursts recorded by orbiting gamma observatories at 500-700 km altitude, called terrestrial gamma ray flashes (TGFs, Fishman et al., 1994), and downward terrestrial gamma ray flashes (DTGFs, Ortberg et al., 2024), recorded in coincidence with lightning leader propagation.

This work presents a unified conceptual and observational framework that reinterprets these radiation bursts as manifestations of the same runaway processes happening at different atmospheric depths (Dual-stage model, DSM). We review recent results from satellite (ASIM), aircraft (ALOFT), balloon (HELEN), and ground-based (SEVAN and KANAZAWA) experiments to demonstrate the advantages of this integrated approach. This study addresses key contradictions in the field, introduces new classification criteria based on physics rather than detector location, and enhances our understanding of particle acceleration in thunderstorms.

Key Points:

- Unified physical mechanism: TGEs, gamma glows, TGFs, and DTGFs are all outcomes of the RREA process occurring in different atmospheric regions.
- Multi-platform data synthesis: Includes results from ASIM (space), ALOFT (aircraft), Kanazawa (DTGF), and SEVAN (TGE).
- A dual-stage, feed-forward coupling mechanism in which a lower-dipole RREA supplies photons that seed electrons to upward RREA (DSM model).
- A new model for DTGF origination: field reorganization, not leader-gap acceleration

2. Mirzoyan Razmik

Max-Planck-Institute for Physics, Garching, Germany

A Few Important Scientific Advances Made with the MAGIC Telescopes and Assessment of the Atmosphere by Ancillary Instruments

In this report, I focus on some important scientific advances recently achieved with the two 17-meter MAGIC imaging atmospheric Cherenkov telescopes. These include the measurement of the proton spectrum over a wide energy range from the cosmic ray trigger data, which is otherwise suppressed as unwanted background. I also describe advances in stellar intensity interferometry for measuring the diameter and shape of bright celestial objects of various types on a scale of several hundred microarcseconds. Another focus is on atmospheric research using MAGICs and ancillary instruments—the calorimeter for imaging atmospheric Cherenkov telescopes.

3. Karapetyan Tigran

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Forbush decreases observed by the SEVAN particle detector network in the 25th solar activity cycle.

The temporal variations of cosmic-ray intensity, measured by ground-based detectors at various latitudes, longitudes, and altitudes, are linked to geophysical and solar phenomena. These include interplanetary coronal mass ejections and fast solar wind from coronal holes, which cause sudden changes in the interplanetary magnetic field (IMF) near Earth. Interacting with the magnetosphere, they induce abrupt global decreases (Forbush decreases, FDs) followed by gradual recovery. The magnitude of the flux depletion depends on the particle type and energy, which are influenced by geographic location and the detector's energy threshold and selective capability. The SEVAN particle detector network, with nodes in Europe and Armenia, identifies three particle types corresponding to different energy galactic protons interacting with disturbed magnetospheric plasmas, showing consistent depletion and recovery patterns. This report presents measurements of these FDs taken at mountain altitudes on Aragats (Armenia), Lomnicky Stit (Slovakia), Mileshovka (Czechia), and at sea level at DESY (Hamburg, Germany). We compare FD measurements obtained by SEVAN detectors and neutron monitors located on Aragats and Lomnicky Stit, along with a correlation analysis of FD records from different locations.

4. Sargsyan Balabek

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Classification of GLE and magnetospheric events through energy deposit of muons and neutrons: Observations by the SEVAN light detectors

The simultaneous detection of increased neutron and muon fluxes caused by solar energetic protons and interactions of galactic cosmic rays in the magnetosphere represents a major step forward in understanding and characterizing solar events. The new ability to record energy deposit histograms provides a valuable tool for monitoring cosmic ray fluxes at Earth's surface. Currently, the neutron monitor and SEVAN networks only measure particle flux intensities without directly determining the energies of incoming particles. The energies of neutrons and muons produced during Ground Level Enhancements (GLEs) and Magnetospheric effects (MEs) vary significantly. GLEs deposit energy above 100 MeV in detectors, while ME events are limited to 10 MeV. Gaining new insights into the energies of secondary particles helps us better identify the types of solar events and estimate the energies of the primary protons responsible for these events, which is vital for solar physics and space weather forecasting.

5. Sargsyan Balabek

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Wind-induced Gamma-ray Enhancements (WiGERs)

During extreme weather conditions in the fall of 2024 at Mount Aragats, natural gamma radiation (NGR) levels surged by over 1000%, with a total fluence of 2×10^7 gamma/cm^2 recorded over 10 hours. The corresponding dose reached 3.26 mSv—about 120 times higher than the seasonal background level. This unprecedented increase occurred during intense, dry snowstorms at subzero temperatures, without thunderstorm-related electric fields. The observed gamma-ray intensities far exceed those explainable by known atmospheric mechanisms such as relativistic electron avalanches or radon exhalation alone.

We propose that these enhancements, which we call Wind-induced Gamma-ray Enhancements (WiGERs), result from dense radioactive clouds formed when electrified snow and aerosols mobilize radon progeny and keep them suspended near sensitive detectors. These findings suggest that similar radiation surges could occur in high-altitude and polar regions, such as the Arctic and Antarctic, where strong winds and persistent snowstorms are common.

Understanding the origin and duration of WiGERs is crucial for improving radiation background models, refining atmospheric ionization predictions, and assessing environmental and climate impacts during severe winter storms.

6. Zazyan Mary

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Electron multiplication in the upper dipole: contrasts with multiplication in the lower dipole

While it is generally understood that the physical mechanism behind atmospheric radiation is RREA, the source of seed electrons can vary. Historically, TGFs are modeled with highly intense local gamma sources, with fluence reaching up to 10^{19}. In contrast, TGEs are modeled with seed electrons from EAS, providing a stable, altitude-dependent density over large volumes of thundercloud systems. Persistent, upward-directed gamma-ray glows observed by ALOFT and balloon experiments—covering areas greater than or equal to 10,000 km^2 and lasting from tens of minutes to hours—cannot be explained by short, localized discharge scenarios (e.g., classic TGF models). Therefore, we propose a dual-stage, vertically coupled mechanism in which a lower-dipole RREA supplies photons that seed an upper-cloud RREA, naturally producing a sustained gamma flux that extends into space over large areas (~10^4 km^2), spans multiple kilometers vertically, and lasts for several tens of minutes. Upper-dipole multiplication was estimated using Corsika simulations at 8-10 km altitude. The seed population was simulated with an AEF of 1.2–1.7 kV/cm and L = 2 km. The maximum multiplication occurred at a medium field strength of 1.4 kV/cm. In excessively strong fields, electrons gain energy so quickly that they pass through the dipole before undergoing enough interactions to sustain an avalanche, thus reducing overall multiplication. The decline in stronger fields is explained by the combined effects of low atmospheric density at upper altitudes (10–15 km); therefore, the avalanche growth length increases, requiring more time for multiplication. Additionally, excessive acceleration at high fields causes electrons to gain energy so rapidly that they escape the dipole volume before fully developing RREA. In other words, they 'run away too quickly' to multiply effectively.

7. Zazyan Mary

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia, AM0036

MOS and RREA operation in the upper and lower dipoles: intensities and spectral shapes

The main mechanism for increasing electron and gamma-ray flux in the atmosphere is relativistic runaway electron avalanches (RREA). It is a threshold process triggered when the atmospheric electric field surpasses a certain value related to air density, such as at a specific altitude above sea level. However, another mechanism discovered in 2012, called the Modification of the electron energy spectrum (MOS), also affects gamma-ray production. If the electric field is not strong enough for RREA, electrons still gain energy from the electric field, causing their energy spectrum to shift to the right, which raises the likelihood of bremsstrahlung. Unlike RREA, this effect is not threshold-dependent; it influences and enhances gamma-ray flux across all energies, though to a lesser degree. The MOS effect becomes significant at high energies, when RREA activity diminishes but particle detectors continue to record gamma rays exceeding 80 MeV, the upper limit for RREA particles. In this study, we simulate gamma rays from MOS and compare their impact on the RREA energy spectrum. We present and analyze estimates of how spectral shapes change due to RREA and MOS. Our simulations are conducted at the Aragats level and at altitudes of 15-20 km, where the recent ALOFT mission observed high fluxes of gamma rays persisting for hours. We hypothesize that the MOS mechanism can locally boost background flux significantly, but only RREA can increase flux enough to offset attenuation from a source within the cloud up to aircraft altitude at 20 km.

8. Liza Hovhannisyan

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Threshold Atmospheric Electric Fields for Initiating Relativistic Runaway Electron Avalanches: Theoretical Estimates and CORSIKA Simulations

We examine the threshold Atmospheric Electric Field (Eth) needed to initiate a runaway avalanche process in Earth's atmosphere. We compare the traditional, thirty-year-old theoretical threshold value with its recently updated value, along with the threshold derived from CORSIKA-simulated avalanches (Ez). The altitude dependence of these threshold values is analyzed, considering changes in air density and their effects on avalanche development. This study is vital for understanding high-energy atmospheric phenomena in both the lower and upper atmosphere, including thunderstorm ground enhancements (TGEs) and gamma glows, as well as for refining AEF models based on particle flux measurements.

Highlights

- Introduces a refined framework for determining threshold atmospheric electric fields (Eth) needed to initiate relativistic runaway electron avalanches (RREAs) and thunderstorm ground enhancements (TGEs).
- Compares classical (Eth ≈ 2.80 × n) and updated (Eth ≈ 2.67 × n) theoretical thresholds with altitude-dependent thresholds derived from CORSIKA simulations.
- Demonstrates that realistic avalanche development requires fields 15–22% stronger than theoretical values, depending on altitude and air density.
- Provides a reproducible simulation methodology for integrating experimental particle flux measurements into atmospheric electricity models across multiple research stations.

9. Liza Hovhannisyan

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan 36, Armenia

Estimation of the height of the atmospheric electric field above particle spectrometers on Earth's surface

The electron energy spectrum is a crucial measurement that confirms the source of increased particle fluxes detected on Earth's surface. At Aragats station, the electron energy spectrum was measured during the largest thunderstorm ground enhancements (TGEs) using spectrometers that distinguish between electron and gamma-ray fluxes. These TGEs occurred when the atmospheric electric field (AEF) was weak above Earth, since electrons are quickly attenuated in dense air. However, directly measuring the height of the AEF is very challenging. In 2002, we proposed an empirical method to estimate h, based on analyzing electron and gamma-ray energy spectra. The distance where the strong accelerating field ends—called the free passage distance (FPD)—is determined using CORSIKA simulations with an empirical equation calibrated on available electron spectra (Spread, 2025): FPD (meters) = (C1*Emax – Eemax)/C2. Coefficients C1 and C2 are 1.2 and 0.2, respectively. This allows us to estimate the maximum energy of electrons leaving the field as C1*Emax. Additionally, we assume that the maximum energy of gamma rays remains roughly unchanged when they travel 100 meters or less in the atmosphere. We also assume that electrons lose about 0.2 MeV per meter at an altitude of approximately 3000 meters. We present the results of multiple simulations of electron-gamma ray avalanches to verify the accuracy of our assumptions and to identify any potential methodological errors.

10. Piliposyan Qajik

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Thunderstorms on Aragats: simultaneous detection of electric field, cloud height, and count rate enhancements on Aragats and Nor Amberd

Thunderstorm ground enhancements (TGE) observed in remote sites on the slopes of Mt. Aragats shed light on the horizontal and vertical profiles of atmospheric electric fields. The atmospheric electric field fills many thousands of km^3 in thunderclouds, and electron accelerators operate over large areas of surface. If clouds are low, both particle detectors and electrons, along with gamma rays, reach the surface and are detected as thunderstorm ground enhancements. If they are high (as in the case of Nor Amberd), nonetheless, electric fields lift positively and negatively charged aerosols with attached Radon progeny into the atmosphere, where they radiate and enhance the natural gamma radiation background. The network of SEVAN detectors at three stations on the slopes of Mt. Aragats has monitored secondary particle fluxes 24/7, greatly advancing our understanding of how RREAs develop in the atmosphere. We found that previous estimates of the regions in the atmosphere where RREA occurs were significantly underestimated. This report describes observations from the SEVAN and NaI particle detector networks, demonstrating that particle fluxes from atmospheric electron accelerators can cover many cubic kilometers and produce particle showers over large areas on the Earth's surface.

11. Kozliner LeV

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Influence of strong electric fields on cosmic ray fluxes at an altitude of 800 meters above sea level in Yerevan.

Continuous monitoring of secondary cosmic rays with a ground-based network of detectors allows us to draw conclusions about their connection with atmospheric electric fields and the state of thunderstorm clouds that trigger increases in these fluxes. One of the most intriguing issues is the observed rise in electron, gamma-ray, and neutron fluxes during thunderstorms (TGE). This spike in cosmic ray fluxes indicates the presence of strong electric fields in thunderstorm clouds, which initiate relativistic electron avalanches (runaway electrons) and trigger TGE phenomena in the thunderstorm atmosphere. Analyzing cosmic ray fluxes at different altitudes (Yerevan – 800 m; Burakan 1500 m, Nor Amberd – 2000 m; Aragats – 3200 m) helps reconstruct their energy spectra and addresses fundamental problems in solar, magnetospheric, and atmospheric physics. The experimental setups developed in our department, along with devices for measuring electric and magnetic fields, lightning direction finders, and weather stations, enable us not only to determine cosmic ray parameters but also to assess atmospheric conditions during events. This creates unique opportunities to study TGE and explore connections between particle fluxes, electric fields, and lightning activity.

12. Barseghyan Anna, Asaturyan Zara

TARME Tech LLC, Newark, Delaware, USA

The B.4 System: A Multimodal Wearable Platform for Continuous Physiological and Environmental Monitoring in Industrial Safety Applications

The **B.4 system** is a compact chest-mounted wearable developed by TARME Tech LLC for continuous monitoring of workers in hazardous industrial environments. Integrating multi-sensor modules, the device tracks cardiovascular, respiratory, and environmental parameters in real time, transmitting data securely to enterprise dashboards for occupational health teams. Its low-power circular PCB design and ruggedized casing ensure reliability under dust, vibration, and thermal extremes. Field validation in mining environments demonstrates robust performance, while upcoming iterations will incorporate AI-driven anomaly detection and predictive safety modeling. By combining health and environmental data streams into a scalable platform, the B.4 system enables a shift from reactive incident response to proactive worker safety and operational risk management.

13. Hovsepyan Gagik

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

New software for analyzing MAKET-ANI registered extensive air showers**.**

The energy spectrum of light nuclei was first measured by the MAKET-ANI detector, located at 3200m (40°25'N, 44°15'E). The compact array consisted of nearly a hundred plastic scintillators that selected showers from approximately 1000 m² with an efficiency of more than 95% (see details in Chilingarian et al., 2007). The data analysis scheme employs non-parametric multivariate methods, along with Bayesian and neural network techniques. This approach allowed event-by-event classification of EAS to be verified using both methods and under different models of strong interaction. MAKET-ANI was decommissioned over 20 years ago; however, the raw data was preserved. With the recent increase in interest in proton energy spectra due to LHAASO measurements, we have revived the data analysis software, updating from old CRN libraries and FORTRAN code to Python. We present comparisons between the old and new results and discuss further implementation of MAKET-ANI data.

14.Abovyan Sergej, Pokhsraryan David

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

New electronics for the SEVAN network

We present a new design and implementation of a modernized frontend, the logarithmic amplitude-to-digital converter (LogADC) board, developed for the Aragats Space Environment Center (ASEC) particle detection system. The upgrade addresses several limitations of the previous LogADC version, including relatively long dead time caused by reading out event data from the 8LADC board to the C32USB MCU board, as well as complex circuitry and high component costs. The proposed solution utilizes a new generation of fast (600 MHz), low-power digital microcontrollers with integrated high-resolution timer systems. Signal processing—which was previously handled by CPLD—is now transferred to the MCU, enabling flexible counting mechanisms, spectrum accumulation, threshold adjustments, coincidence logic, and event selection via software. This approach offers three main advantages: (i) minimizing overall system dead time for particle events, limited only by the LogADC's working principle; (ii) simplifying hardware layout by removing the CPLD from the 8LADC board and completely eliminating the C32USB board; and (iii) significantly reducing costs by replacing circuitry with a commercially available digital MCU. The modernized LogADC board maintains backward compatibility with the ASEC Data Acquisition System (ADAS) while providing improved calibration stability, online programmability, and easier mass production. These improvements enhance the long-term reliability, ease of maintenance, and scalability of the ASEC particle detector network for studies of solar and atmospheric cosmic rays.

15. Khanikyanc Yegia

Yerevan Physics Institute, Alikhanyan Brothers 2, Yerevan, Armenia AM0036

Measurements of Particle Fluxes, Electric Fields, and Lightning occurrences at the Aragats Space-Environmental Center (ASEC)

The Aragats Space-Environmental Center (ASEC) has measurement tools for different kinds of cosmic rays, near-surface electric fields, and lightning events, all located at the high-mountain research station on the slopes of Mt. Aragats. These measurements aim to improve models of particle acceleration, charge distribution, and lightning initiation in the lower atmosphere, including inverted -IC and -CG flashes.

Despite the significance of these atmospheric processes, the complex interaction between thundercloud electrification, lightning activity, wideband radio emissions, and particle fluxes remains poorly understood. An especially intriguing area of research is the connection between high-energy atmospheric phenomena, intracloud electric fields, and lightning initiation. Additionally, studying accelerated structures within geospace plasmas can provide valuable insights into particle acceleration, which may extend to higher energies in similar structures found in cosmic plasmas.

Additionally, we evaluate the usefulness of wideband field and interferometer antenna signals in this context, offering valuable opportunities for further research. Through these efforts, we aim to improve our understanding of high-energy atmospheric processes and their wider implications for lightning phenomena.

16.E.P. Volkov, A.N. Dmitrieva, D.M. Gromushkin, A. Yu. Konovalova, P.S. Kuzmenkova, Yu. N. Mishutina, I.A. Shulzhenko

National Research Nuclear University MEPhI, Moscow, Russia
sstimakov@mephi.ru

Studies of Neutron Background Variations in the NEVOD Experimental Complex

The Experimental Complex NEVOD operates the «Neutron» and PRISMA-36 facilities, which include unshielded thermal neutron detectors based on ZnS (Ag) + 6LiF scintillators. The «Neutron» facility, designed to measure the neutron background at various locations, consists of four detectors positioned on different floors with varying absorber thicknesses. It has been in operation since 2010. The PRISMA-36 array is designed to study the hadron component of EAS and changes in the neutron background near Earth's surface simultaneously. Data collection for this run began in 2024.

In this talk, the design of neutron detectors, methods of data selection and processing, and the influence of meteorological parameters are demonstrated. The results of recording Forbush decreases and the solar-diurnal anisotropy are discussed.

17.Knapp Johannes
DESY

DESY - CRD Collaboration: Results and Perspectives

Since the 1990s, DESY and YerPhI have engaged in numerous scientific and technological collaborations across various departments. A key player has been the Cosmic Ray Department (CRD, a founding depart ment of YerPhI), which focuses on cosmic particle fluxes, astrophysics, and thriving research in cosmic ray physics, gamma-ray, and neutrino astronomy. These efforts are supported by major institutions in Germany, including the Karlsruhe Institute of Technology, Max Planck Institutes in Heidelberg and Munich, and notably DESY in Hamburg and Zeuthen (near Berlin).

CRD's expertise in measuring particle fluxes, operating large facilities at mountain peaks, and multivariate analysis has been vital for the development of European facilities such as KASCADE, Auger, HESS, and MAGIC.

A recent priority has been maintaining research infrastructures on Mt Aragats (located at 2000 and 3200 meters), which had fallen into disrepair during financially challenging times. Various European grants, along with close cooperation with DESY, have helped refurbish laboratories and living spaces, allowing scientific activity to continue in Yerevan and on the slopes of Aragats. It was recognized that local scientific activities are crucial for sustaining vibrant research in Armenia.

Recently, research efforts have shifted toward studying lower energy particle fluxes originating from cosmic rays, solar activity, and atmospheric phenomena, using a network of relatively simple detectors placed on mountain peaks across Europe. One of these detectors was initially installed at DESY in 2020 and was relocated to the Zugspitze, Germany’s highest mountain, in April 2023. It is now operating successfully and contributes data to a public database that covers all detectors in the network, resulting in a steady stream of publications.

The evolution of this cooperation, current challenges, and future prospects will be discussed.

18. P.A. Klimov, *V.D. Nikolaeva, A.A. Belov, V.D. Kudryavtsev, K.D. Shchelkanov*

M.V.Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics, Russia

Optical insights into particle acceleration in thunderclouds and near-Earth space

Radiation of the Earth's atmosphere, including the near UV range (300–400 nm), is an important manifestation of various processes occurring in the atmosphere. These are processes of both an internal nature, such as thunderstorm phenomena (lightning, transient luminous events, terrestrial gamma-ray bursts), and the result of an external impact on the Earth's atmosphere: penetration of energetic ionizing radiation, cosmic rays in a wide range of energies, the passage of meteors, etc. In the auroral zone, optical emission is caused by energetic particle precipitation from the magnetosphere. Measurements of the spatiotemporal structure of the near-UV emission make it possible to study the physical mechanisms of various processes in the Earth's atmosphere and the sources of their origin. Thus, an imaging photometer can be an effective instrument for research in various fields of physics. A pair of imaging photometers were developed in the frame of the PAIPS project and provided stereoscopic measurements of pulsating aurora in the Murmansk region. One of these detectors was installed at Aragats station in June 2024 to measure near-UV emissions of thunderstorms and extensive air showers.

The results of the photometer measurements in the auroral region, the first data from the Aragats station, and the possible application of compact imaging photometers for EAS measurements are presented.

This research was supported by Russian Science Foundation grant number 22-62-00010. (https://rscf.ru/project/22-62-00010/).

19. S.Chilingaryan

Institute for Data Processing and Electronics, Karlsruhe Institute of Technology

Managing Data and Infrastructure Challenges in Multi-Decade Monitoring Systems

Research in fields like meteorology and cosmic ray physics often relies on continuous, long-term monitoring of environmental parameters and particle fluxes. Similar monitoring systems are integral components of many control frameworks that operate complex scientific facilities and experiments. Once set up, these systems usually operate for decades. Meanwhile, the broader computing environment is changing rapidly, but limited budgets and resources make it challenging to keep pace with these changes. For example, the Aragats Space Environmental Center (ASEC) has been providing monitoring data since 2001, with most of its software dating back to the late 1990s. The Karlsruhe Tritium Neutrino (KATRIN) experiment began collecting data in 2007, and its last major software update occurred around the same time. Over the years, system operation has been passed down through multiple groups of maintainers, and eventually, no one had a complete understanding of the original design or the decisions behind it. This creates serious issues for security and reliability, especially when adding newer detectors that generate data much faster than the original system was designed for. Poor-quality code, often written by students or non-experts as quick fixes, makes the problem worse. In this talk, we will share our experience managing the ASEC and KATRIN monitoring systems as they begin their third decade of operation. We will highlight the technical and organizational challenges we encountered and discuss recent technologies designed to simplify maintenance, including our efforts to outsource parts of system upkeep to external companies.

20. *Ondřej Ploc[1], Jakub Kákona[3], Iva Ambrožová[1], Jakub Šlegl[1,2], Helena Velyčková[1,2], Roman Dvořák[1], Lucie Švihrová[1,2], Martina Lužová[1,2], Marek Sommer[1], Aleksandr Kostinskii[1], Martin Kákona[1]*

[1] Nuclear Physics Institute of the CAS, Řež, Czechia
[2] Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czechia
[3] UST – Universal Scientific Technologies, Soběslav, Czechia

Sustaining High-Energy Atmospheric Research in Czechia: CRREAT Activities and Instrumentation from Mountain Peaks to Flight Altitudes in the Post-Project Era

The CRREAT project (Research Centre for Cosmic Rays and Radiation Events in the Atmosphere), originally funded from 2016 to 2023, has successfully transitioned into its sustainability phase and continues to deliver impactful scientific output in high-energy atmospheric physics (HEAP). With three institutional partners – the Nuclear Physics Institute (ÚJF), the Institute of Atmospheric Physics (ÚFA), and the Faculty of Electrical Engineering at CTU Prague – the consortium maintains and expands a unique research infrastructure, combining mountain-based observatories, airborne and mobile measurements, and laboratory testing.

At the Milešovka mountain observatory, the CRREAT team operates a suite of detectors, now extended by the directional Large-Area Mosaic Array (LAMA), capable of identifying the incoming direction of secondary cosmic particles (muons) and electrons from thunderstorm ground enhancements (TGEs) or relativistic runaway electron avalanches (RREA). This complements long-term operation of the SEVAN particle detector, broad-band antennas, and Ka-band cloud radar. Recently, Mini Neutron Monitor has also been added, reinforcing the observatory’s role in international networks SEVAN and GASTRON.

In parallel, CRREAT researchers are active in airborne dosimetry. A new instrument, AIRDOS04 – a compact active dosimeter based on a semiconductor PIN diode – has been deployed on commercial aircraft operated by Smartwings as well as on Czech government aircraft as part of the NATO Military Space Weather Panel (MILSWx) activities. This operational deployment contributes real-time measurements of ionizing radiation at flight altitudes and complements existing model-based exposure estimations. These activities are further supported by the ESA-funded ESADOS (ESA Support for Aircrew Dosimetry Services) project, conducted jointly with the Slovak Academy of Sciences. The goal is to improve the accuracy of aircrew exposure assessments by integrating real-time cosmic ray data from neutron monitors and in-flight measurements, contributing to the long-term vision of a pan-European dosimetry service.

Despite the conclusion of its original funding, CRREAT continues to thrive through follow-up projects (e.g., BIOSPHERE, ADVADOSE, CZPAD, MERIT), resulting in peer-reviewed publications, the preservation and extension of infrastructure, and integration into new international initiatives. This presentation will outline the strategic path CRREAT has taken to remain a vibrant and productive research hub, offering scalable models for sustaining scientific excellence in the field of thunderstorm-related radiation and space weather effects.

21. Helena Velyčková[1, 2], Iva Ambrožová[1], Martin Kákona[1], Jakub Šlegl[1, 2], Marek Sommer[1], Ondřej Ploc[1]

[1]Nuclear Physics Institute CAS, Řež, Czech Republic
[2] Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic
velyckova@ujf.cas.cz

Data Analysis of measurement campaign at Milešovka within the BIOSPHERE Project

Enhancing the quality of analysis of observed cosmic radiation and atmospheric phenomena is achievable through the simultaneous use of multiple instruments and methods, enabling the detection and study of rare and extreme events. Within the EURAMET "BIOSPHERE" project, measurements of cosmic radiation, solar cosmic rays, ultraviolet radiation, ozone column, and atmospheric parameters were taken.

One of the locations where this project's research was conducted is Milešovka Mountain (Czech Republic, 837 m). The choice of this site is due to the lack of large enterprises and dense human settlements nearby. The company's goal on Milešovka was also to carry out field tests of detectors developed and designed by our team.

As examples, the presentation will discuss October 2024 data, when SEVAN recorded bursts associated with increased solar activity and a rare winter thunderstorm with γ-radiation, where the proximity of the discharge area allowed the detection of a record flux of high-energy particles.

Acknowledgements:

The project 21GRD02 BIOSPHERE has received funding from the European Partnership on Metrology, co-financed by the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

List of Participants

Full Name	E-mail	Country
Ondřej Ploc	ploc@ujf.cas.cz	Czechia
Mary Zazyan	mary@yerphi.am	Armenia
Razmik Mirzoyan	Mirzoyan.Razmik@gmail.com	Deutschland
Tigran Karapetyan	ktigran79@gmail.com	Armenia
Liza Hovhannisyan	liza.hovhannisyan@aanl.am	Armenia
Pavel Klimov	pavel.klimov@gmail.com	Russia
E.Volkov	Eugenvolk00@gmail.com	Russia
Johannes Knapp	johannes.knapp@desy.de	Germany
Ashot Chilingarian	chili@aragats.am	Armenia
Lev Kozliner	lkozliner@mail.ru	Armenia
Zara Asaturyan	z.asaturyan@yerphi.am	Armenia
Khanikyanc Yegia	khanikyants@yerphi.am	Armenia
Anna Barsegyan	annabarseghyan.arch@gmail.com	USA
Suren Chilingaryan	csa@suren.me	Germany
Balabek Sargsyan	balabeksargsyan@gmail.com	Armenia
Qajik Piliposyan	qajikpiliposyan1@gmail.com	Armenia
Hovsepyan Gagik	hgg@yerphi.am	Armenia
Abovyan Sergei	sergey.abovyan@gmail.com	Armenia
Pokhsraryan David	davitpo@gmail.com	Armenia