

# GASTRON: Gamma Spectrometry of Thunderstorm Radiation Observatory Network

Ondrej Ploc<sup>1</sup>, Jakub Šlegl<sup>1,2</sup>, Iva Ambrožová<sup>1</sup>, Ronald Langer<sup>1,3</sup>, Martina Lužová<sup>1,2</sup>,  
Martin Kákona<sup>1</sup>, Marek Sommer<sup>1,2</sup>, Olena Velychko<sup>1,2</sup>,

<sup>1</sup>Nuclear Physics Institute of the CAS, v.v.i., Rez, Czechia

<sup>2</sup>Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Czechia

<sup>3</sup>Institute of Experimental Physics of SAV, Kosice, Slovakia

ploc@ujf.cas.cz

**Keywords:** thunderstorm; ionising radiation

## 1. Project description

Thunderclouds can act as the biggest natural particle accelerators in the world. It's because there are differently charged areas between which high voltage exists. If the initial electron reaches energy high enough, electron avalanches called relativistic Runaway Electron Avalanches (RREA) might be triggered. RREAs are large populations of high energetic electrons formed by avalanche growth driven by electric fields in Earth's atmosphere. The electron avalanches propagate through the matter and are decelerated and deflected by particles in the atmosphere. Since the 1990s, two basic thunderstorm radiation phenomena have been recognized: (1) brief and intense high-energy emissions called Terrestrial Gamma-ray Flashes, and (2) seconds to minutes lasting emissions called Gamma-Ray Glows or Thunderstorm Ground Enhancements. Objective is to detect such phenomena, describe their energies, and other characteristics.

### Method

To detect such phenomena, we developed (and participated in the development of) the scintillation counters of three types: (1) GEODOS (or AIRDOS-C, see Velychko et al. 2022) with NaI(Tl) crystal and autonomous system based on solar cells, (2) RT-56 with NaI(Tl) crystal for gamma-ray detection and a compact data acquisition system with GPS for exact time. Collected data on Jungfrauoch can be then compared with neutron monitor and GammaTRACER data.

Detection probability and intensity of the thunderstorm radiation increases with increasing altitude due to a shorter distance to the thundercloud. High-mountain observatories are, therefore, ideal measurement sites. For this purpose, we intended to create a network of gamma spectrometers in Europe called GASTRON (Gamma Spectrometry of Thunderstorm Radiation Observatory Network) in which, to date, we have spectrometers on observatories in Czechia, Slovakia, Bulgaria, Germany, Switzerland and Japan, see Table 1 and Figure 1.

Table 1. Locations of the GASTRON detectors and their types.

Place	Country	Altitude / m	Type of Gamma spectrometer
Milešovka	CZ	837	RT-56
Poledník	CZ	1,315	RT-56, GEODOS
Košetice	CZ	650	GEODOS
Lomnický štít	SK	2,634	RT-56
Musala	BG	2,925	GROWTH
Zugspitze	DE	2,670	GROWTH
Jungfrauoch	CH	3,579	GROWTH
Kanazawa	JP	0 - 5	3x RT-56

### Expected results

First, the thunderstorm radiation event must be identified via the increased measured radiation dose rates coincident with local thunderstorms detected by the custodians or using the lightning networks. Second, the gamma-ray spectra and time structure will be evaluated. Such elementary information is needed to answer remaining questions like life cycle of long bursts, structure of

acceleration regions, and how big radiation risk can pose these radiation phenomena.

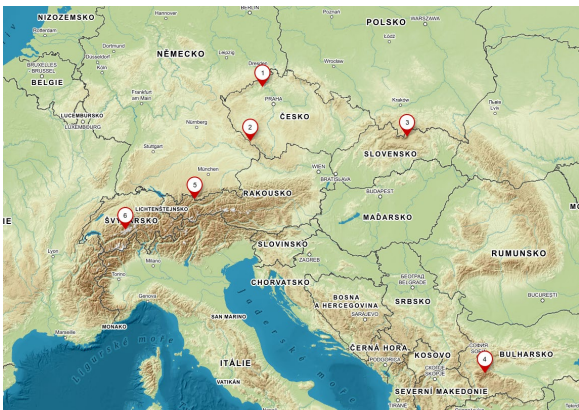


Figure 1. Locations of GASTRON instrumentation in Europe.

**Results**

In 2021, we started with experiments at Jungfrauoch observatory. Our gamma spectrometer (type Growth with NaI(Tl) crystal size 3"x5") has been installed there from August 2021 for continuous measurements.

In 2022, we detected at least 2 TGE events on Jungfrauoch, see Figures 2 and 3. The algorithm for detection of such increase in data was developed.

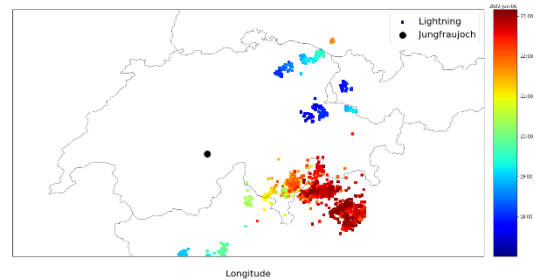
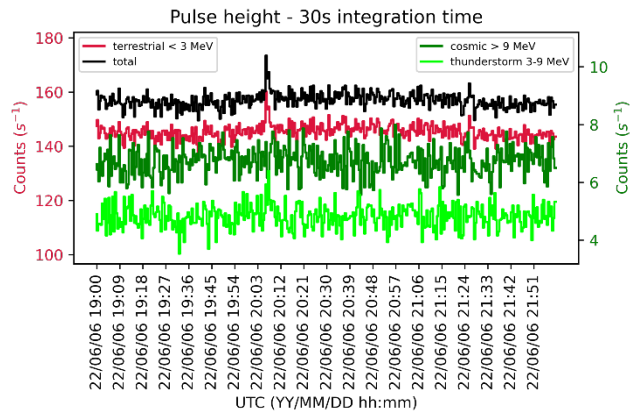


Figure 3. TGE event detected by the GROWTH detector on Jungfrauoch (up) during the thunderstorm on June 6th, 2022, and lightning map from Blitzortung.com (bottom).

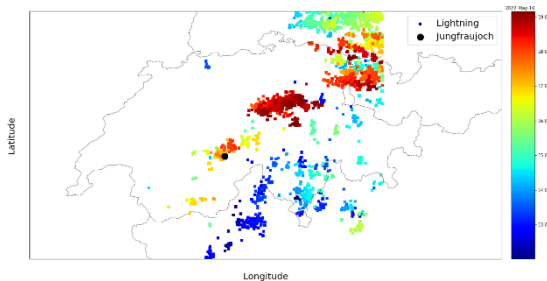
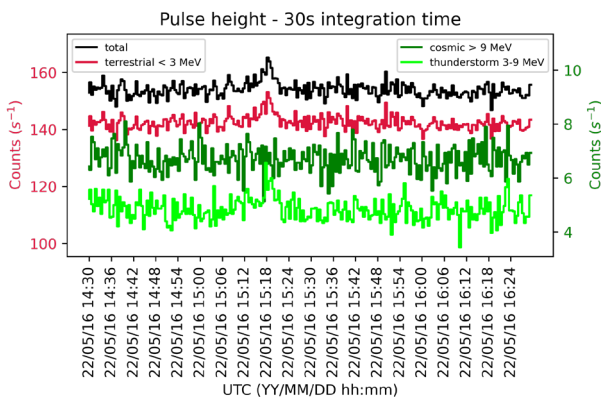


Figure 2. TGE event detected by the GROWTH detector on Jungfrauoch (up) during the thunderstorm on May 16th, 2022, and lightning map from Blitzortung.com (bottom).

**Internet data bases**

- <http://adei.crd.yerphi.am/>
- <https://www.blitzortung.org/>

**Collaborating partners / networks**

- Dr. Vladimír Mareš, Helmholtz Zentrum Munchen, Observatory on Zugspitze mountain (partner in GASTRON)
- Dr. Nina Nikolova, BEO Moussala, Bulgaria (partner in GASTRON)
- Prof. Teruaki Enoto, RIKEN and Kyoto University, Japan (partner in GASTRON)
- Prof. Ashot Chilingarian, Yerevan Physics Institute, Armenia, Aragats mountain observatory (partner in GASTRON)

**Scientific publications and public outreach 2022**

**Refereed journal articles and their internet access**

- Velychko, O., I. Ambrožová, M. Kákona, & O. Ploc, Characterisation of AIRDOS-C detector for measurement of high-energy events in the atmosphere, *Radiation Protection Dosimetry*, **198**, 9-11, 604-610, doi: 10.1093/rpd/ncac105, 2022. <https://academic.oup.com/rpd/article/198/9-11/604/6672998>
- Šlegl, J., R. Langer, T. Brunclík, P. Mašek, I. Strhářský, I. Ambrožová, & O. Ploc, Spectrometry of High-Energy Photons on High Mountain Observatory Lomnický Štít During Thunderstorms, *Radiation Protection Dosimetry*, **198**, 9-11, 623-627, doi: 10.1093/rpd/ncac108, 2022. <https://academic.oup.com/rpd/article-abstract/198/9-11/623/6673012?redirectedFrom=fulltext>
- Kákona, J., J. Mikeš, I. Ambrožová, O. Ploc, O. Velychko, L. Sihver, & M. Kákona, In situ ground-based mobile measurement of lightning events above central Europe, Preprint *egusphere*, 2022. <https://doi.org/10.5194/egusphere-2022-379>
- Kolmašová, I., O. Santolík, J. Šlegl, J. Popová, Z. Sokol, P. Zacharov, ... & I. Strhářský, Continental thunderstorm ground enhancement observed at an exceptionally low altitude, *Atmospheric Chemistry and Physics*, **22**, 12, 7959-7973, 2022. <https://acp.copernicus.org/articles/22/7959/2022/>

**Conference Papers**

Šlegl, J., Z. Sokol, J. Minářová, P. Pešice, R. Langer, I. Strhárský, M. Kákona, I. Ambrožová, O. Ploc, Winter Thunderstorm Ground Enhancement on Milesovka hill, Book of abstracts, TEPA-2022, Prague, Czechia, October 17-20, 2022.

Sommer, M., I. Ambrožová, J. Šlegl, O. Ploc, Neutron detector based on liquid scintillator for measurement of neutrons generated by photonuclear reactions during Terrestrial Gamma Ray Flashes, Book of abstracts, TEPA-2022, Prague, Czechia, October 17-20, 2022.

Ambrožová, I., M. Kákona, H. Kyznarová, P. Novák, O. Ploc, J. Šlegl, M. Tesař, O. Velychko, Monitoring of ionizing radiation during thunderstorms in forests in Sumava using standalone device GEODOS, Book of abstracts, TEPA-2022, Prague, Czechia, October 17-20, 2022.

Kákona, M., J. Kákona, R. Dvořák, M. Sommer, I. Ambrožová, R. Langer, J. Šlegl, O. Velychko, O. Ploc, Thunderstorm chasing using measuring cars equipped with multiple sensors, Book of abstracts, TEPA-2022, Prague, Czechia, October 17-20, 2022.

Dvořák, R., M. Kákona, J. Kákona, M. Sommer, I. Ambrožová, R. Langer, J. Šlegl, O. Velychko, O. Ploc, Three-dimensional reconstruction of a lightning strike from multiple high-speed cameras, Book of abstracts, TEPA-2022, Prague, Czechia, October 17-20, 2022.

Sihver, L., O. Ploc, J. Šlegl, I. Ambrožová, M. Sommer, M. Kákona, Ionizing Radiation Dose Levels from TGFs and TGEs at Aviation Altitudes, Book of abstracts, TEPA-2022, Prague, Czechia, October 17-20, 2022.

Velychko, O., M. Kákona, I. Ambrožová, J. Šlegl, O. Ploc, Použití detektoru GEODOS01 a jeho srovnání s AIRDOS-C, XLIII, Dni radiační ochrany, Stará Lesná, Slovakia, September, 2022.

Šlegl, J., Z. Sokol, J. Popová, P. Pešice, R. Langer, I. Strhárský, M. Kákona, I. Ambrožová, O. Ploc, Zimní Thunderstorm Ground Enhancement na Milešovce, XLIII, Dni radiační ochrany, Stará Lesná, Slovakia, September, 2022.

Sommer, M., I. Ambrožová, P. Alexa, R. Uhlář, O. Ploc, Optimization of a new neutron detector based on liquid scintillator for neutron bursts related to thunderstorms, Neutron and Ion Dosimetry Symposium (NEUDOS-14), Kraków, Poland, April 25-29, 2022.

Sihver, L., O. Ploc, K. Turek, M. Kákona, J. Kákona, J. Šlegl, I. Ambrožová, M. Lužová, O. Velychko, M. Sommer, R. Langer, Measurements of Ionizing Radiation Generated in Thunderstorms, Accepted for IEEE Aerospace conference 2023, peer-reviewed proceedings, 2023.

**Theses**

Sommer, Marek, PhD Thesis, "Detection of Cosmic Radiation in the Atmosphere and Radiation Induced in Thunderclouds" submitted in December 2022, Czech Technical University in Prague, Czechia.

**Address**

Nuclear Physics Institute of the CAS, v.v.i.  
Department of Radiation Dosimetry  
Na Truhlářce 39/64  
180 00 Praha 8  
Czech Republic

**Contacts**

Dr. Ondrej Ploc  
Tel.: +420 774 405 222  
e-mail: ploc@ujf.cas.cz