

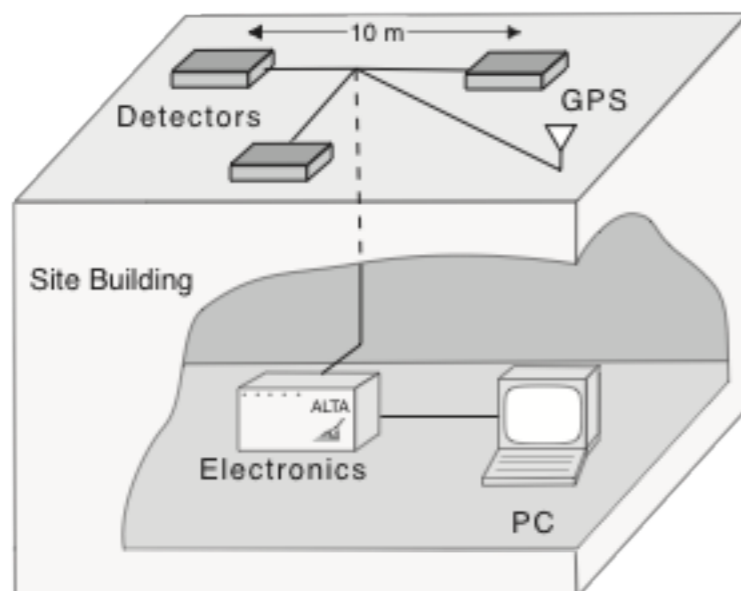
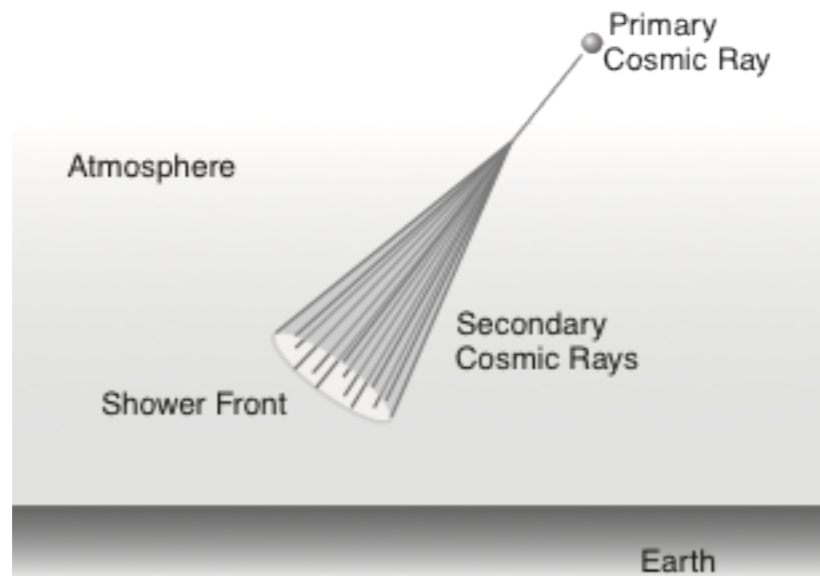
# Masterclasses with Cosmic Rays Košice, Slovakia

One day during Summer Physics School, Kysak, Slovakia, 21. 06. 2011

Coordinator of the day: Marek Bombara (P. J. Šafárik University, Košice, Slovakia)

School organizers: Alexander Dirner (P. J. Šafárik University and Institute of Experimental Physics, Slovak Academy of Sciences, Košice) and Ivan Kimák (Regional Youth Centre, Košice)

# Experiment SKALTA



- SlovaKiAn Large-area Time coincidence Array is the 1st of its kind in Slovakia.
- SKALTA consists of three scintillation detectors, each with the size of 60x60cm, connected in coincidence. Detectors are in the plastic case with the stabilized temperature. They are arranged into an equilateral triangle with the size of 10m.

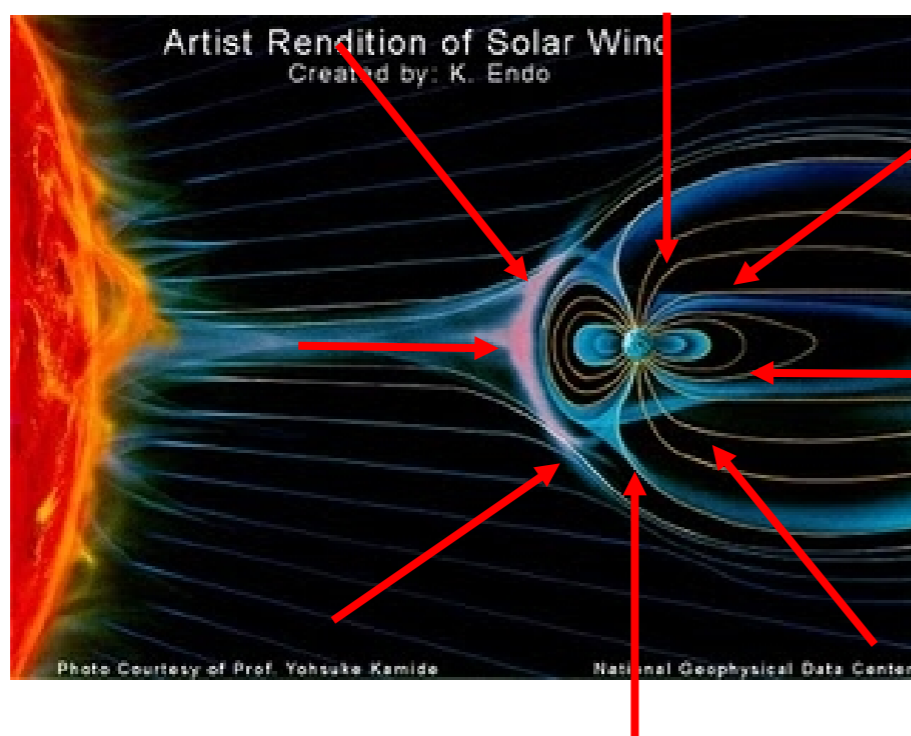
# Programme

- 9:00 - lecture about Cosmic Rays Physics, detection techniques and the SKALTA experiment
- 9:30 - HOWTO for data analysis (lecture with practical info for data accessing from web interface), introduction to exercises
- 10:15 - data analysis
- 12:00-14:00 - lunch
- 14:00 - data analysis + presentation preparation
- 15:10 - presentations of each groups, discussions, interpretations of results
- 16:15 - end of the programme - feedback from the students about the day

# Introductory lecture about Cosmic Rays Physics, detection techniques and the SKALTA experiment



Exercise 1: Is the cosmic ray measured by SKALTA ( $> 10^{14}$  eV) affected by Sun? (Or alternatively, does it come from Sun?)

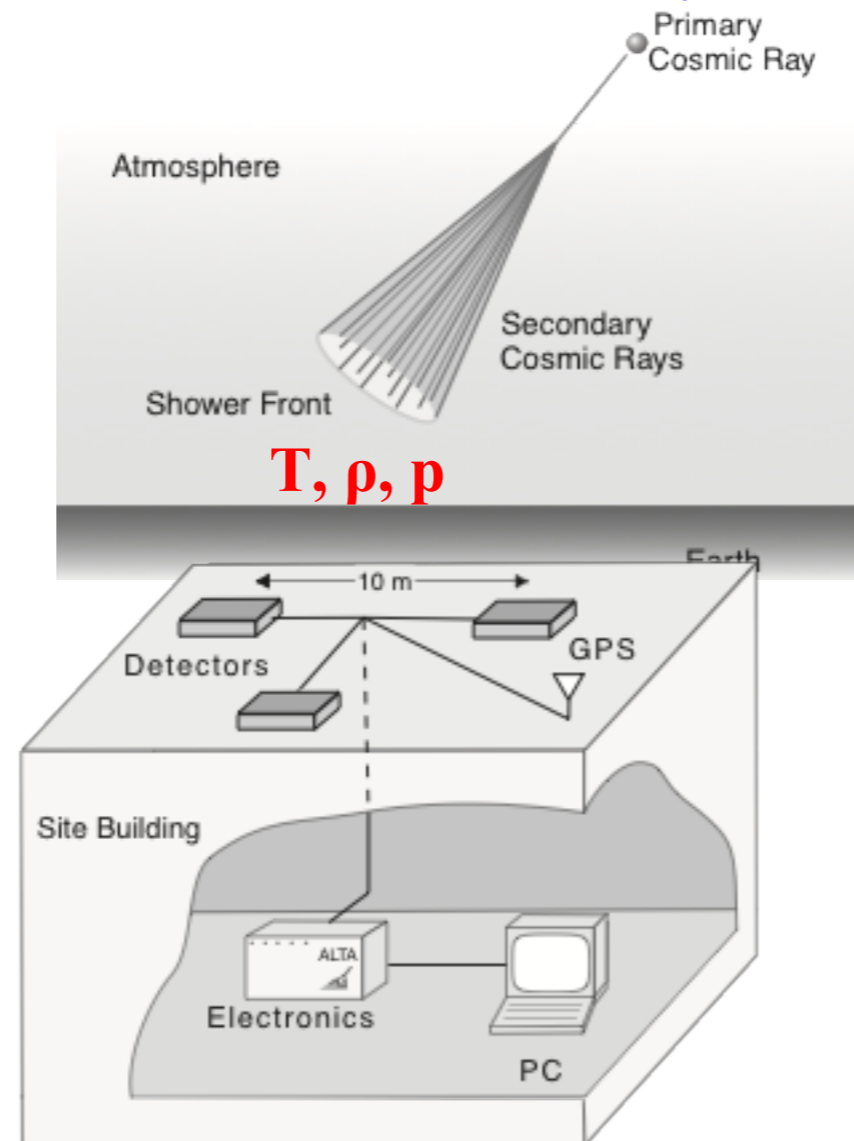


Are the arrival directions of high-energy cosmic rays isotropic?

Proposed analysis method:

Compare numbers of events (showers of secondary cosmic rays) measured by SKALTA during the day and during the night. The outcome of the analysis should be a plot with (day and night) event number as a function of time.

## Exercise 2: What is the relation between secondary cosmic ray flux and air temperature and density?

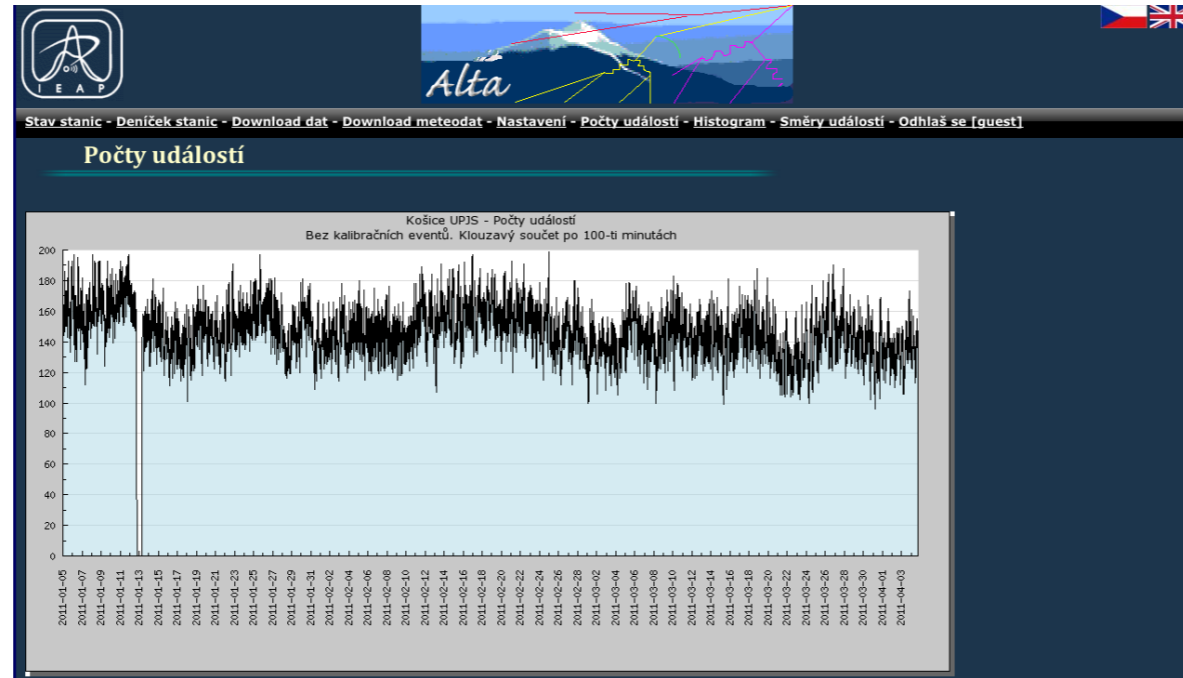


Proposed analysis method:

The outcome of the analysis should be 3 plots with SKALTA event number, air temperature and air density as a function of time. The measurement of the air temperature and air density were obtained from Hydrometeorological Institute of Slovak Academy of Sciences in Košice (In fact, air density was calculated by students from atmospheric pressure measurement.).

# Data analysis: two ways

1. way: by web interface using for example MS Excel, or paper, pen and calculator...



2. way: by raw data using some programming language (for example C/C++, Python, Pascal, etc.).

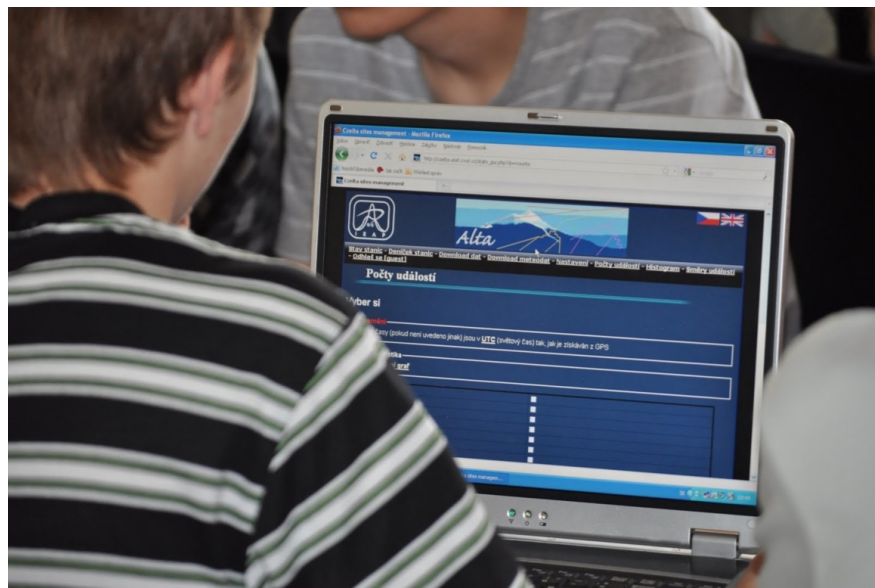
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x 0 0 0 0 0 0 0.0 0 0 0 0 0 0 0.0 0.0 0.0 0.0
a 2011 03 24 15 05 45 645281133.9 2430 3164 4000 433 200 142 29.5 25.5 31.0 46.5
c 2011 03 24 15 05 51 673260.5 0 2322 3961 712 991 941 29.5 25.5 31.0 46.5
a 2011 03 24 15 05 55 854942857.6 1295 3119 4008 189 204 410 29.5 26.0 31.0 46.5
a 2011 03 24 15 05 56 657416869.7 1263 3118 4025 544 480 548 29.5 25.5 31.0 46.5
c 2011 03 24 15 06 51 674999.5 4095 2076 4017 776 1095 1006 29.5 25.5 31.0 46.5
a 2011 03 24 15 07 16 96301373.2 2140 3231 4007 576 213 125 29.5 25.5 30.5 46.5
a 2011 03 24 15 07 38 803003570.3 1634 3012 4000 1019 502 434 29.5 25.5 30.5 46.5
a 2011 03 24 15 07 44 893916939.4 2037 3279 4011 546 190 132 29.5 25.5 30.5 46.5
c 2011 03 24 15 07 51 674080.6 0 2082 3969 673 1062 1008 29.5 25.0 30.5 46.5
c 2011 03 24 15 08 51 670025.5 4095 2052 4012 793 1001 944 29.5 25.0 30.5 46.5
c 2011 03 24 15 09 51 670322.6 0 1908 3984 782 1077 977 29.5 25.0 30.5 46.5
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# Some notes

- We had 48 students and asked them to form groups. We did not specify a size of a group. The biggest group consisted of 11 students and there were two “groups” made up of one person. Usually, the measurement was split up inside the group: 1 month for 1 student .
- Exercise 1 was more attractive for them - 7 groups chose this option. Only 2 groups went for exercise 2.
- Only two groups chose to do measurement by method number 2 (using programming language).
- Of course, we did not tell the students how the results should look.
- Two groups did not finish the measurement (one with using programming language) due to the lack of time.

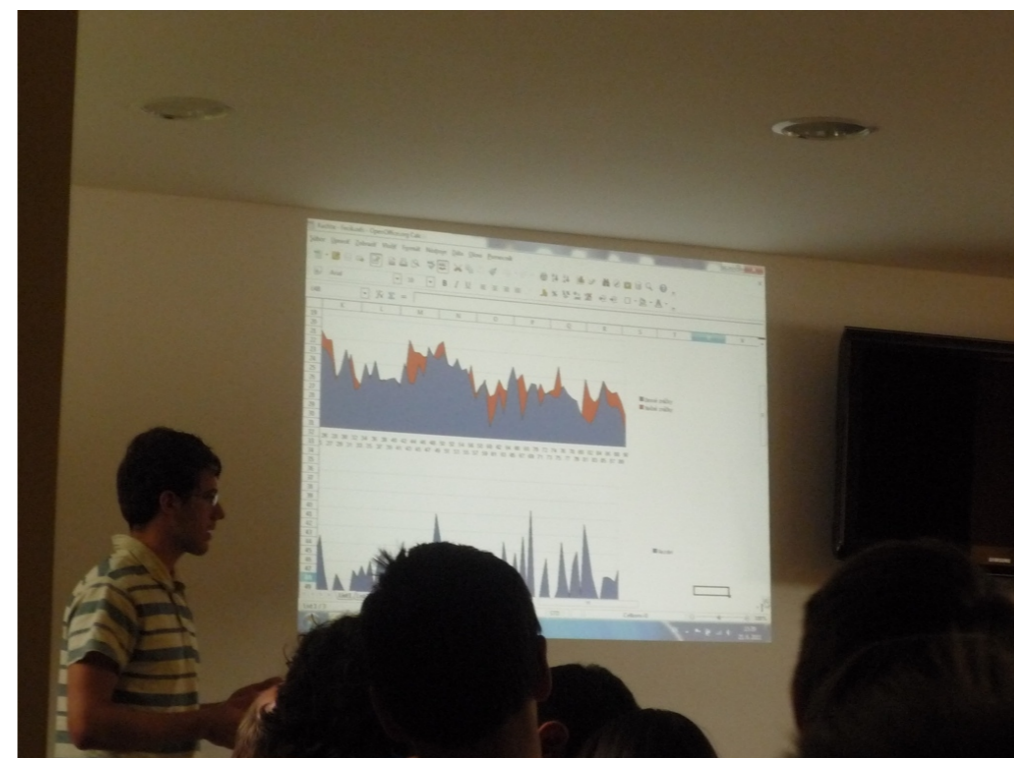
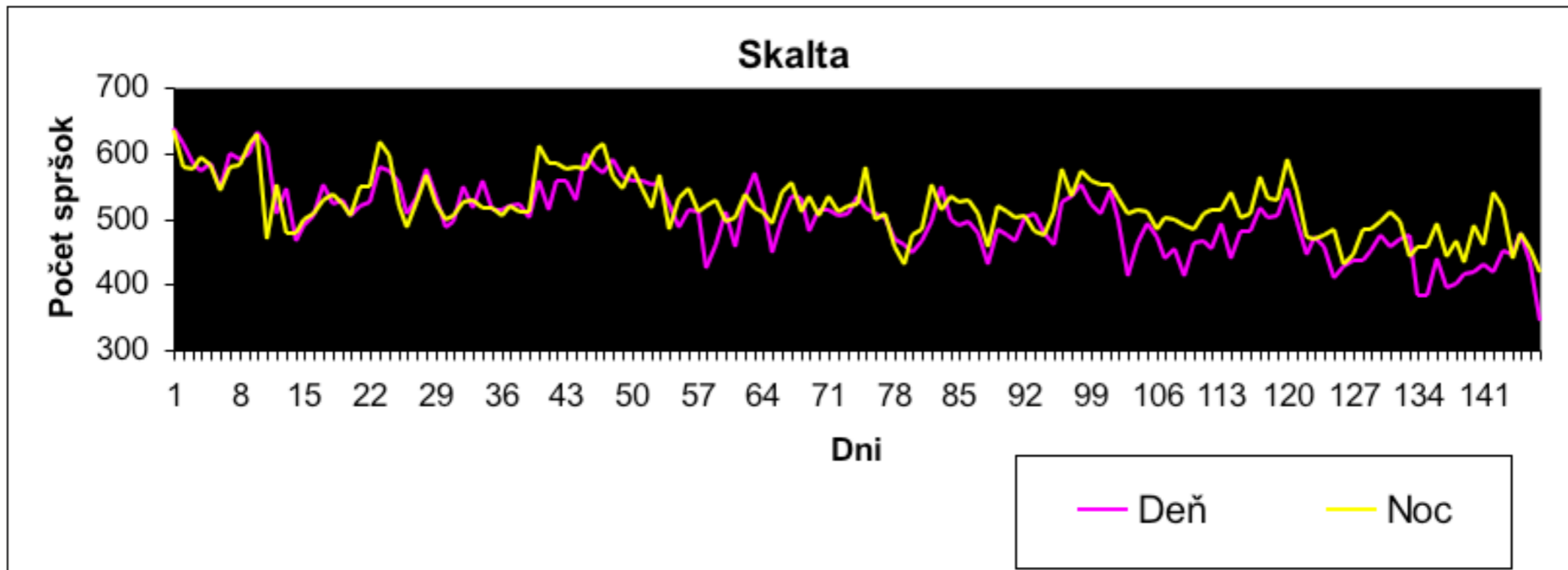


## Data analysis (7 groups chose exercise 1, 2 groups chose exercise 2)





# The results for exercise 1

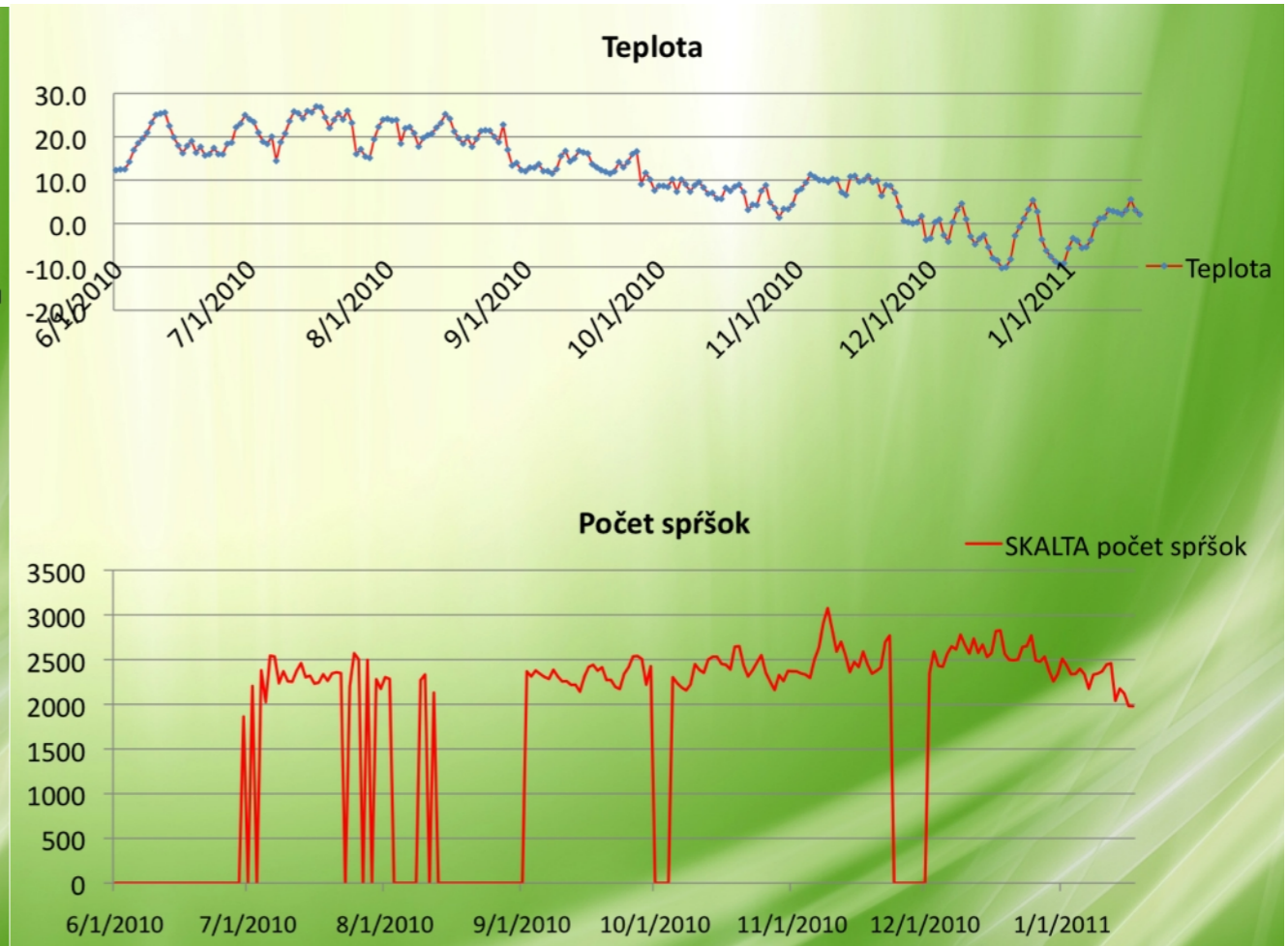
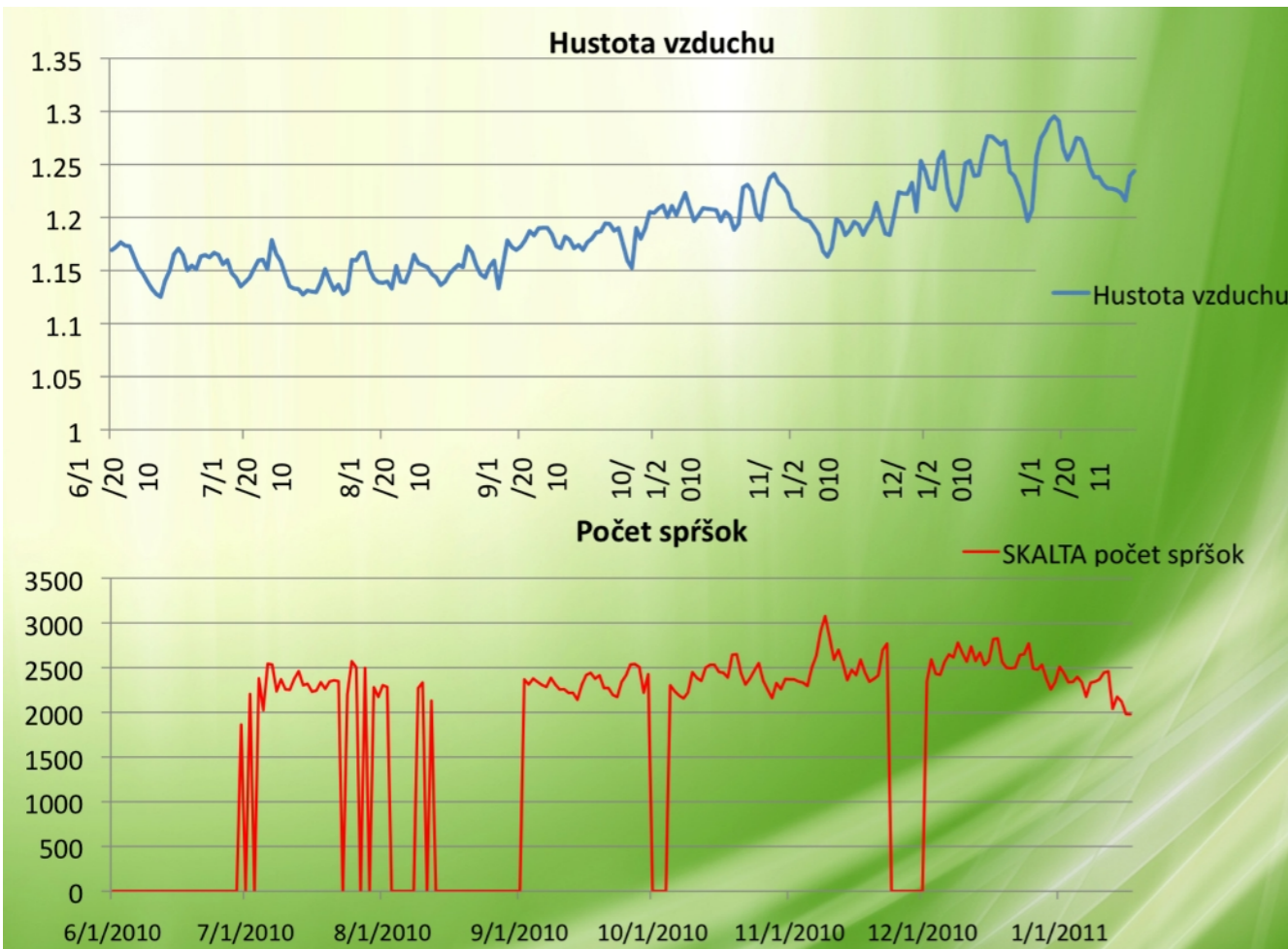


Legend:  
Deň ≡ day  
Noc ≡ night

# Some notes to presentations for exercise 1

- We expected no difference between day and night measurements.
- The student results confirmed this expectation. The energy of cosmic ray measured by SKALTA has too big energy to be affected by Sun (solar wind) and has origin beyond the solar system.
- The discussion after each presentation was mostly about errors of the measurement (how to decrease statistical errors by increasing statistics and possible sources of systematic errors).

# The results for exercise 2



Legend:

Hustota vzduchu  $\equiv$  Air density

Teplota  $\equiv$  Air temperature

Počet spřšok  $\equiv$  SKALTA event numbers

# Some notes to presentations for exercise 2

- we expected no visible correlation between SKALTA event numbers and air temperature and anti-correlation between SKALTA event number and air density
- The student results confirmed this expectation. The atmosphere acts as a huge calorimeter with respect to the shower of secondary cosmic ray. The more dense the air is the less probability of shower reaching SKALTA detectors.
- The discussion after each presentation was also mostly about errors of the measurement (how to decrease statistical errors by increasing statistics and possible sources of systematic errors)

# Summary

- The student feedback was very positive. I would say it was successful event comparable with Masterclasses in Particle Physics.
- The students during the analysis were very enthusiastic, they had a lots of questions, they enjoyed it and had a fun - and this was the biggest reward for us.
- We were not sure before if it will work. Apparently, it worked great and this encourages us to continue in this activity, especially because the next year is an anniversary of cosmic ray discovery by Victor Hess in 1912.