Cosmic Ray Measurements at Lomnický Štít Observatory

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1. Introduction.

Lomnický Štít measurements of the laboratories of the institutes of Slovak Academy of Sciences comprise cosmic ray and solar observations. In additon to that the dosimetric observations are done by the Department of Dosimetry, Institute of Nuclear Physics, Acad. Sci. of Czech Republic, Prague. Regarding the solar observations, there exist a very long series of solar coronal indices (e.g. Rybanský et al, 2001). The dosimetric measurements are mentioned e.g. in paper by Spurný et al (this volume). Slovak Hydrometeorological Institute (www.shmu.sk) has one of its observatories on the top of that mountain.

Fig.1 . *The top of Lomnický Štít in High Tatras mountains, 2634 m above sea level, 49.40 N and 20.22 E is a suitable place for high altitude cosmic ray, solar, dosimetric and atmospheric observations.*

2. Experimental devices and data

Measurements of the cosmic ray intensity on Lomnický Štít commenced in January 1958 as part of the Czechoslovak scientific program associated with the International Geophysical Year (Dubinský et al, 1960). The initial data were recorded in bi-hourly intervals in accordance with the guidelines of IGY Committee. Experience gained during the IGY and later years illustrated that smaller recording intervals were necessary for many transient

studies. Therefore hourly data were routinely archived starting on February 1, 1968. The average counting rate of IGY neutron monitor was ~ 9.10^4 per hour.
From January 1972 a 4-tube IQSY (International Quiet Sun Year) monitor with an hourly counting rate of ~ 8.10^5 replaced the UGY monitor. This monitor was subsequently replaced in December 1981 by an 8-tube NM64 installed in the small house on the roof of the main building at Lomnický Štít. The average counting rate of the NM is now ~ $1.6.10^6$. At each of these changes, both monitors were kept in concurrent operation for several months so that the recorded cosmic ray intensity could be normalized back to the initial measurements in 1958. The increasing statistical accuracy from December 1981 allowed to observe short time variations. Thus, from 1982 5 min data and from 1984 1 min data resolution are available. The description of the existing measurements can be found in preprint (Kudela et al, 2000a). Checking of the simultaneous temporal profile in 4 sections by 2 tubes is done routinely. In addition, the barometric pressure is measured automatically and pressure corrected data are constructed. From 2001 the preliminary data are routinely put on the web (http://neutronmonitor.ta3.sk) where past 6 hours of 1 min data, past 24 hours of 5 min and past 30 days of hourly cosmic ray intensity can be found both in graphical and digital data mode. The data are continually updated. Along with the current measurements the archive at the same web page includes hourly data from January 1982 and each monthly set is put to the archive at the beginning of next month. The construction of the NM 64 instrument is seen in Figure 2. Cutoff rigidity is ~ 4 GV and their changes due to external geomagnetic field are presented in paper (Bobik et al, 2001).

Fig.2. *The detail of the neutron monitor placed in the small measurement building on the roof of the main one at Lomnický Štít. There are used 8 proportional counters of the type SNM-15.*

3. Cosmic Rays in relations to Space Weather effects.

There are two types of relations between cosmic ray observations and space weather effects: the direct and indirect ones. The summaries on the topic can be found e.g. in papers (Kudela et al, 2000b; Kudela and Storini, 2002). For both aspects of the relations the measurements of cosmic rays at high mountains altitudes are of importance.
Regarding the direct relations, the most important are irregular effects of solar relativistic particle emissions during some of the solar flares. A table with the largest increases during GLE (ground level events) observed at Lomnický Štít is presented below. More details of the GLE observed at Lomnický Štít before 1993 can be found e.g. in paper (Kudela et al, 1993).

Table 1 Solar acceleration events observed at 4 GV (increases >3 % at LŠ from 1966, numbers from GLE data base).

GLE Nr	YYMMDD	T OF MAX	INCR (%)
17	670128	1000-1015	5.0
29	770924	0940-0955	3.9
30	771122	1035-1040	4.2
31	780507	0340-0345	32.9
36	811012	0755-0810	3.6
38	821207	0000-0005	9.1
39	840216	0910-0915	3.7
42	890929	1240-1245	179.5
45	891024	1915-1920	22.2
47	900521	2310-2315	5.3
48	900524	2115-2120	6.5
49	900528	1040-1045	3.8
52	910615	0925-0930	4.1
60	010415	1418-1419	13.5

Protons accelerated in solar flares can induce the nuclear reactions with the nuclei of solar atmosphere. One of the consequences is the production of neutral high energy emissions. Their observation is very important since they carry the information about the acceleration which is not affected by interplanetary and geomagnetic field as it is in the case of GLE proton emissions. In the flare of June 3, 1982, the first ground level response from solar neutrons was observed at Lomnický Štít NM (Fig. 3, Efimov et al, 1983).

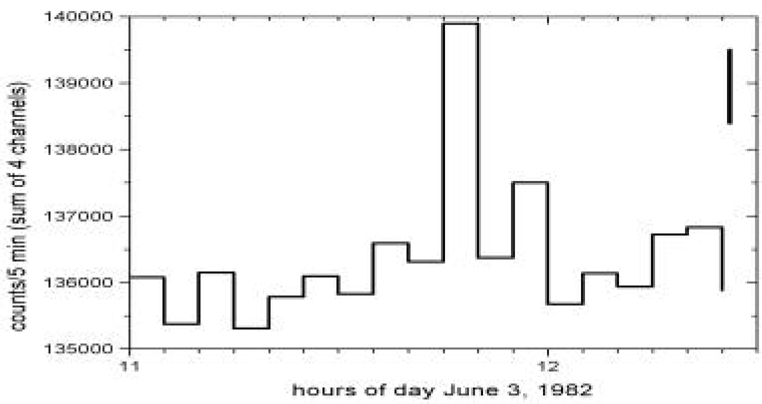

Fig. 3. Lomnický Štít solar neutron response during the first ground level event observed as a consequence of solar neutron emissions. High statistical accuracy confirmed other observations during that event by Jungfraujoch, Switzerland (Debrunner et al, 1983).

High variability of cosmic ray intensity is observed around the intervals of solar activity maxima. Figure 4 shows the variations during 50 days which are only by a factor 1.6 smaller than those from solar minima to solar maxima .

Since cosmic ray particles have large gyroradius and mean free path for scattering in interplanetary magnetic field (IMF), they are sensitive to large scale structure of IMF. These structures are changed e.g. during propagation of CMEs in interplanetary space. Due to the high speed of cosmic rays the information about the change of IMF distribution is transferred to large distances very fast. Thus, the anisotropy of cosmic rays observed from Earth is expected to start several hours before CME is crossing the Earth's orbit and geomagnetic disturbance is initiated. A simplified measure of the anisotropy is the variability observed by a single station at frequencies at which the cosmic ray intensity can be affected in interplanetary space by changing IMF. Figure 5 illustrates this for Lomnický Štít and period around solar maximum intensity. At present there are several studies checking the potential possibilities of cosmic rays for the predictions of geomagnetic activity.

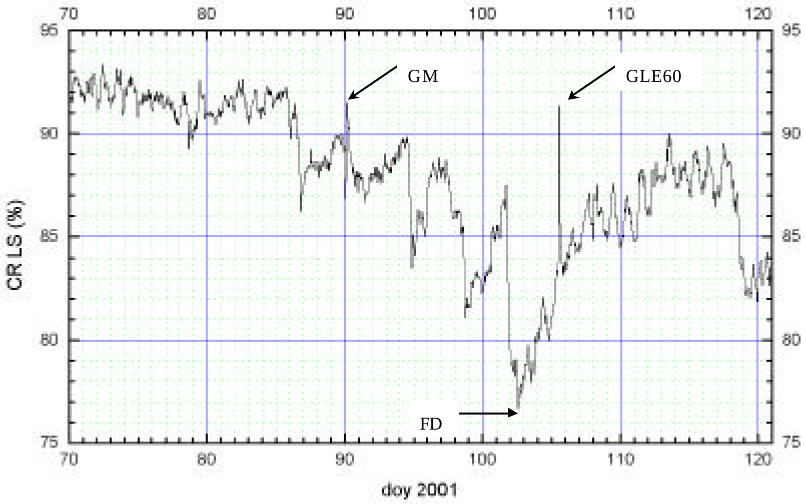

Fig.4. Lomnický Štít neutron monitor hourly data during the disturbed period in 2001. A series of Forbush decreases (the largest one FD), a geomagnetic cutoff change (GM) and the response from high energy solar flare particles accelerated at least up to 4GV (GLE60) is seen. The effects are relevant for Space Weather studies. 100 % is adjusted to the mean value in September 1986 ($1.67.10^6$ counts per hour).The GLE 60 was observed also as an increase of dose on the airplane (Spurný et al, 2001).

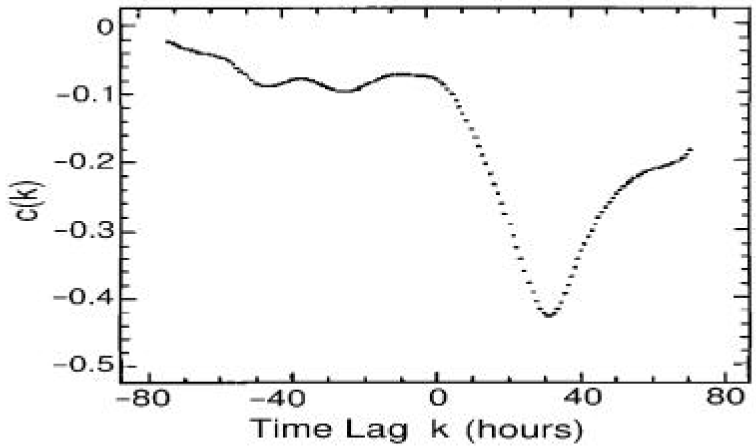

Fig.5. The crosscorelation of cosmic ray variability during (t,t+24h) (X_t) and Dst at t (Y_{t+k}) during 1991-92.Cosmic ray variability is a simplified measure of large scale anisotropy (Kudela et al, 1997). The cosmic ray anisotropy is sometimes evolved several hours before the geomagnetic storm onset. The asymmetry indicates better relation of Dst depressions with „prehistory“ of CR than with its current value. The dependence was obtained from time series of measurements at Lomnický Štít.

4. Concluding remarks.

Long term stable and continuous measurements of cosmic rays at Lomnický Štít brought several results important for cosmic ray physics. They are of potential relevance for space weather monitoring and eventual predictions. These measurements in extreme conditions, however, require much effort. High mountain cosmic ray measurements have high statistical accuracy which allows to study short time variations. Lomnický Štít position is among the European high altitude cosmic ray laboratories situated at the highest geomagnetic latitude (lowest vertical cutoff rigidity) and thus it may be useful point for the European networking. In addition, the solar, dosimetric and atmospheric measurements may be of relevance in such context. Permanent staff of IEP SAS having experience in electronics and running the device in high mountain conditions may contribute to the European projects oriented to high mountain research and applications.

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