CZELTA at Pardubice

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The aim of the CZELTA project is detection of cosmic rays of energies higher than 10^{14} eV. The detectors, manufactured in Canada, are placed on the roof of the building of the Secondary Grammar School in Pardubice and continually detect secondary cosmic ray showers and store gathered information into a computer database. Students of the school created a few computer programs for processing measured data and performed data analyses. This article summarizes the results from the first year of the project.

Project History

In August 2005 the Secondary Grammar School in Pardubice was visited by members of the ÚTEF (Institute Experimental and Applied Physics, Czech Technical University in Prague) and of the Canadian University of Alberta. They took a look at the physics laboratories, were interested by our physics laboratories and right on the roof of the school building we started to discuss the placement of the cosmic ray detectors. Our school was selected for participating in the CZELTA project.

In September 2006 we attended a seminar on the CZELTA project that took place in Prague at the ÚTEF. Besides the lectures we also could see an operating detector.

The crates (envelopes) for the detectors arrived at Pardubice in October 2006 and had to be lifted to the school roof by a crane. In December the detectors themselves were installed and a seminar led by ÚTEF members took place at our school. Some of our students were present at the detector installation and at this seminar.

The station started to measure the secondary cosmic ray showers, impulses were appearing on the monitor, and data were written to the hard disk. However, the data was in hexadecimal format and the software for processing this data had to be written by our students.

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00000000: 4C C0 8D 72 E8 03 00 00|90 A4 FF 1C C1 A1 FF 1C
00000010: C1 A1 FF 1C 06 00 00 00|14 00 00 00 D7 07 00 00
00000020: 11 00 00 00 1D 00 00 00|13 00 00 00 31 00 00 00
00000030: 00 00 00 00 00 00 00 00|00 00 00 00 A3 F1 A7 20
00000040: 59 00 00 00 50 00 00 00|52 00 00 00 40 00 00 00
00000050: 2F 0C D3 09 87 0C A1 09|D0 0C A3 09 4D C0 8D 72
00000060: E8 03 00 00 78 A8 FF 1C|B8 A5 FF 1C B8 A5 FF 1C
00000070: 06 00 00 00 14 00 00 00|D7 07 00 00 11 00 00 00
00000080: 1D 00 00 00 14 00 00 00|24 00 00 00 00 00 00 00
00000090: 00 00 00 00 00 00 00 00|96 CA 9D 26 59 00 00 00
000000A0: 50 00 00 00 52 00 00 00|40 00 00 00 2E 0C D3 09
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Fig. 1: Event record in hexadecimal format

The first programs

The description of each coincidence event (all three detectors have to be hit closely one after another which means that the primary particle had energy of at least 10^{14} eV) has a uniform structure. The first program, **AltaProcessor.exe** was made in C++ by Jakub Čermák, a student of our school. It converted hexadecimal data (fig. 1) into a legible text format (fig. 2).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2006	12	19	08	47	48	344709579.2	1214	3775	3179	547	138	608	40	13	13	54
2006	12	19	08	49	07	447011055.9	2030	3778	3562	367	332	561	39	13	13	54
2006	12	19	08	51	57	560933249.1	967	3765	3274	245	202	336	38	13	13	55
2006	12	19	08	52	31	389660880.8	1749	3784	2783	117	136	85	38	13	13	55
2006	12	19	08	52	34	914462503.3	2357	3683	3775	129	389	302	38	13	13	55
2006	12	19	08	53	06	955924923.4	992	3779	2818	631	335	225	38	13	13	54
2006	12	19	08	53	57	702820486.4	1441	3777	3234	316	916	216	37	13	13	54
2006	12	19	08	54	47	350149874.8	927	3775	2681	1937	142	742	37	13	13	54
2006	12	19	08	55	03	15563523.42	1635	3779	2675	128	162	123	37	13	13	55
2006	12	19	08	55	11	912019927.2	2078	3769	3723	319	1343	107	37	13	13	54
2006	12	19	08	55	47	173339862.8	1611	3788	3068	639	452	348	37	13	13	54
2006	12	19	08	56	17	970051502.3	544	3776	1984	242	438	510	37	13	13	54
2006	12	19	08	56	25	383561538.6	333	4095	1349	295	0	330	36	13	13	54
2006	12	19	08	56	36	443808706.2	2198	3789	3608	766	572	1309	36	13	13	54
2006	12	19	08	57	36	763022120	1962	3727	3768	265	2047	290	36	13	13	55
2006	12	19	09	01	01	252838895.5	908	3776	2534	1718	2047	2047	35	13	13	54
2006	12	19	09	01	24	350464115.3	2033	3789	2894	120	786	727	35	13	13	54
2006	12	19	09	01	55	788981656.8	2247	3784	3464	1781	1419	1256	34	13	13	

A – year, B – month, C – day, D – hour, E – minute, F – second, G – nanosecond, H, I, J – times of incidence of detectors (the number has to be multiplied by 25 ps), K, L, M – energy absorbed in the detectors, N,O,P,Q – temperatures

Fig. 2: Text file describing 18 events.

Each day a huge number of events is gathered and their manual counting and analysis is impossible. The next program made by J. Čermák enables us to count events, do basic analysis (fig. 3) and later on also to plot graphs (fig. 4 and 5).

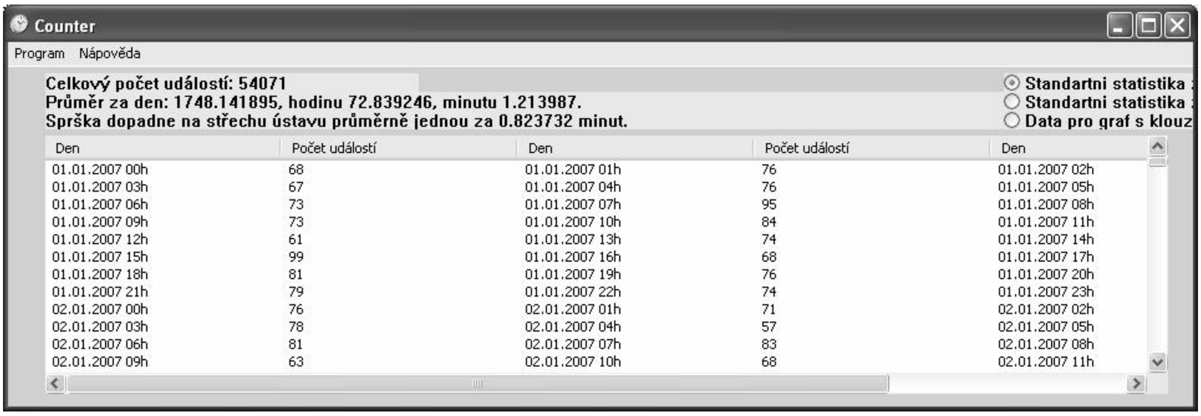


Fig. 3: Hourly counts of events

The example above shows the result of **Counter.exe** being run above the data gathered during the dates between 1.1.2007 and 31.1.2007. It may be seen that the detectors gathered 54 071 events during January. The daily average was 1748 events and the hourly average 73 events.

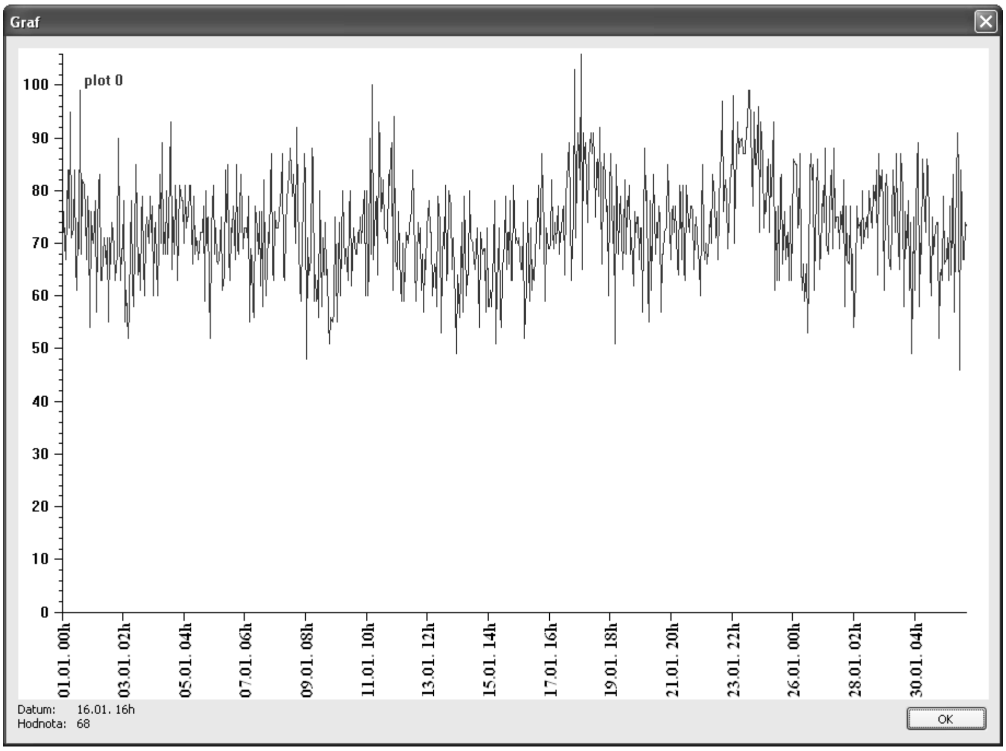


Fig. 4: Hourly counts of events during January 2007

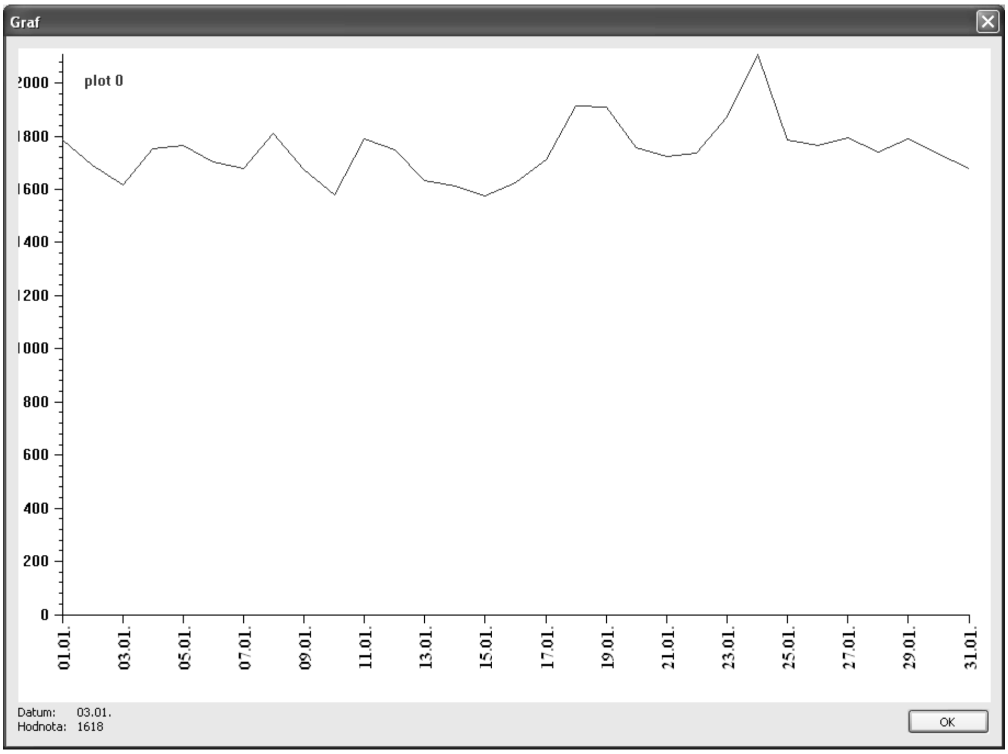


Fig. 5: Daily counts of events during January 2007

We supposed that the fluctuation of data may have been caused by atmospheric pressure changes. Our hypothesis is supported by data obtained from a meteorological station that had been placed near the detectors as part of the experiment.

Nova as a source of cosmic rays?

During the night of 4th February 2007 Yukio Samuraj and Yuji Nakanuta found a very bright nova in the Scorpion constellation [1].

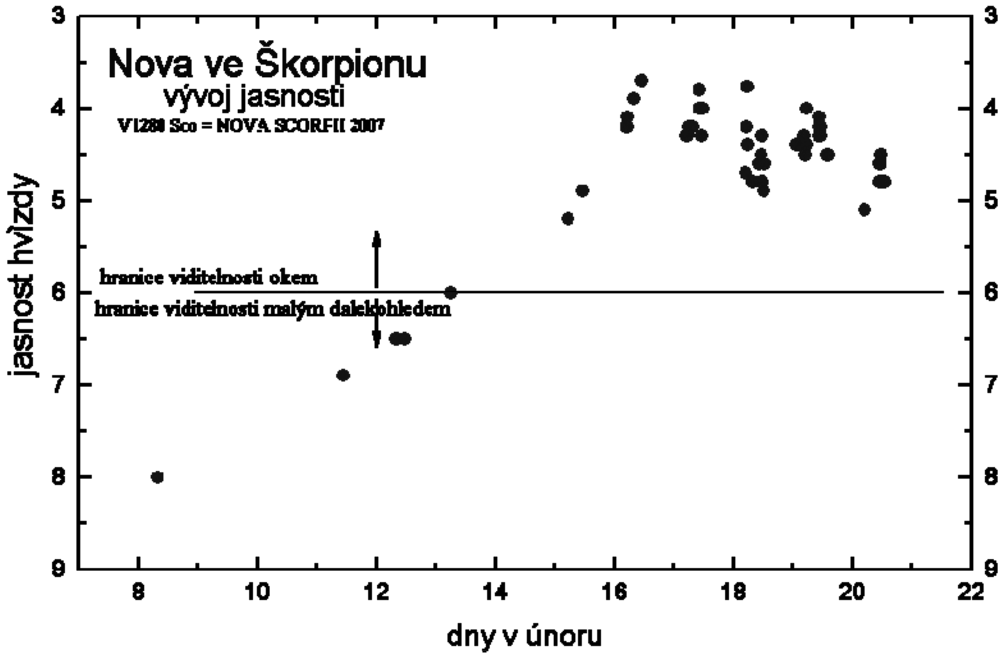


Fig. 6: The rise of the nova's magnitude in February 2007.

In the graph, the steep rise of the nova brightness may be observed around February 16th. We thought of this event as of a great opportunity to test our detectors. Would they detect an increased intensity of the cosmic rays?

However, unfortunately Murphy's Law's validity has been verified. A failure of the detector station occurred and because there was a spring holiday at this time, we found it out late. Therefore, the data from the days before February 20th are missing.

Nevertheless, Petr Drábek, one of our students, analyzed at least the data from the days when the station was operational and compared it to similar times in January and March.

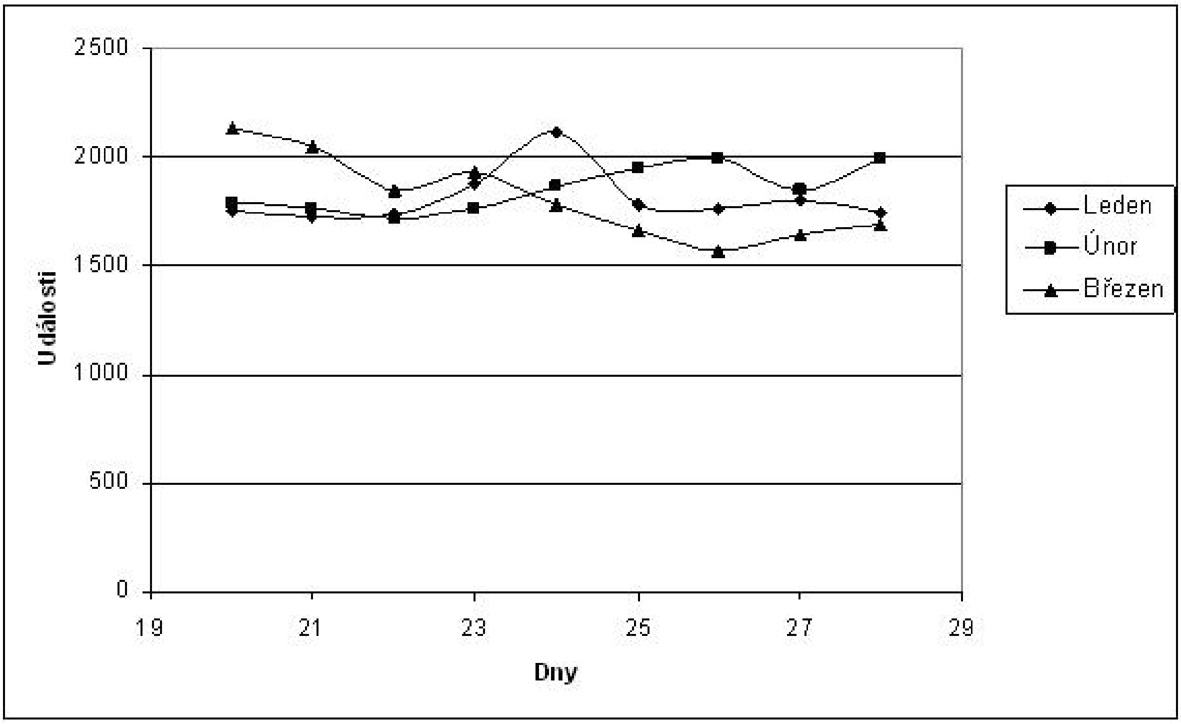


Fig. 7: Daily event counts in selected days in January, February and March.

From the graphs in fig. 7 it may be seen that no significant increase in cosmic rays intensity has been detected.

We took a lesson from this inconvenience and Jakub Čermák developed another program called **AltaWatcher.exe** that watches whether the station is operating. When the measurement is interrupted, it tries to restart the measurement and sends an email to servicing person. After the installation of **AltaWatcher.exe** we never had such a long failure.

The direction of a shower

The data in columns H, I and J (fig. 2) enable us to find out what the delay was between the single detectors that were hit by the shower. So, from these numbers it is possible to determine what the direction of each shower has been.

This has been a job for a student – theoretician. Marek Scholle solved the problem: his ideas suppose that the particles in the shower (mostly muons and electrons) propagate with the speed of light c and the front of the shower is flat. The detectors are positioned in the vertices of an isosceles triangle having one side a = 10 m.

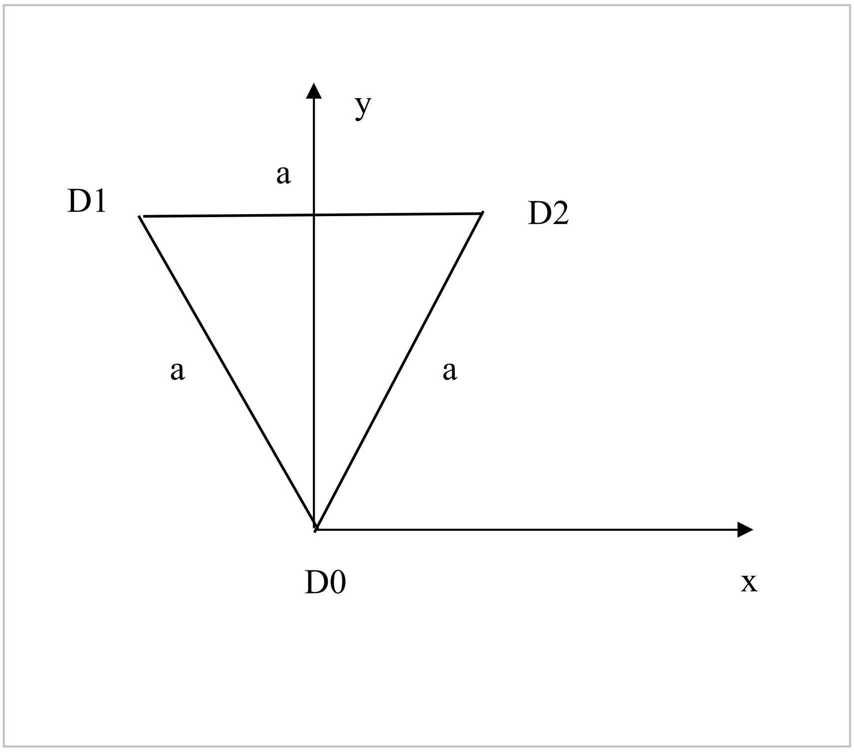


Fig. 8: The placement of detectors (D0, D1, D2) in coordinate system. The *z*-axis aims upwards, perpendicularly to the plane of triangle.

The times are measured from the incidence of the shower front and detector D0. This means that the time t_1 is the delay between D1 and D0 signals and t_2 is delay between D2 and D0 signals.

The velocity vector length is *c* and its components are:

$$v_x = \frac{c^2(t_2 - t_1)}{a} \qquad v_y = \frac{c^2(t_1 + t_2)}{a\sqrt{3}} \qquad v_z = \sqrt{c^2 - v_x^2 - v_y^2}$$

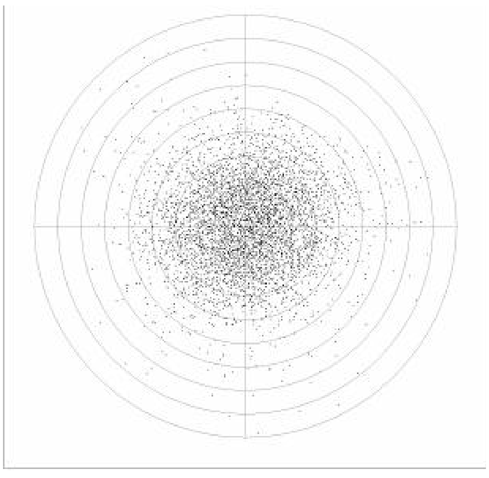


Fig 9: Point representing directions from which the showers came

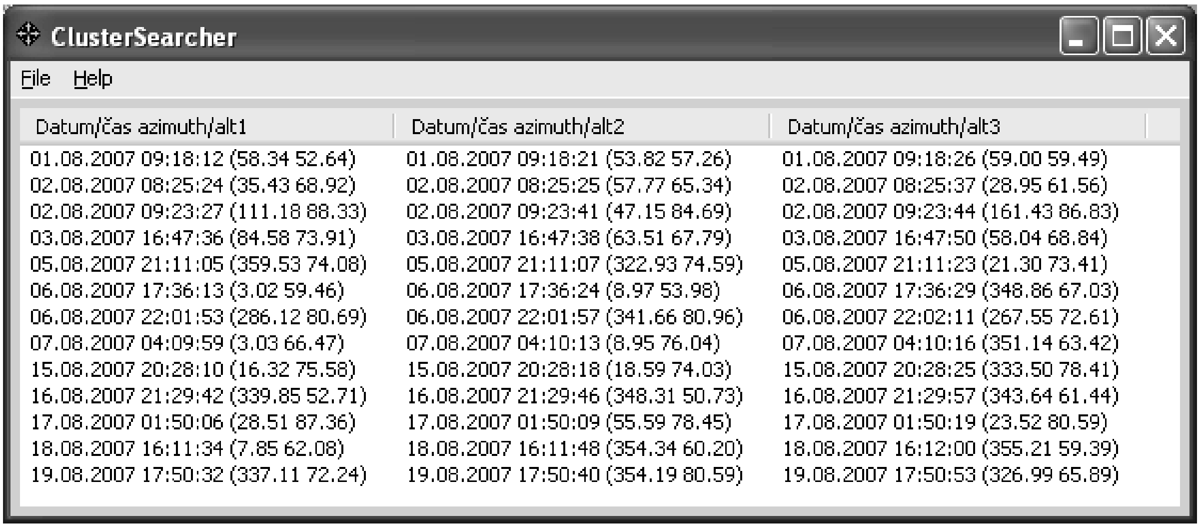
A program created by Marek Scholle calculated the directions from which the showers came and plotted them into a circle representing the sky above the detectors. The zenith is in the centre of all circles, and the distance between each two neighbouring circles means 10°.

From fig. 9 we realized that the detectors are able to detect rays coming from angles up to 40° from the zenith and almost incapable of detecting rays from directions near to the horizon.

This, when we return back to the nova in Scorpion, tells us that it had been undetectable by our detectors.

Cluster detection

A cluster is a group of a few events that come closely one after another.



Datum/čas azimuth/alt1	Datum/čas azimuth/alt2	Datum/čas azimuth/alt3
01.08.2007 09:18:12 (58.34 52.64)	01.08.2007 09:18:21 (53.82 57.26)	01.08.2007 09:18:26 (59.00 59.49)
02.08.2007 08:25:24 (35.43 68.92)	02.08.2007 08:25:25 (57.77 65.34)	02.08.2007 08:25:37 (28.95 61.56)
02.08.2007 09:23:27 (111.18 88.33)	02.08.2007 09:23:41 (47.15 84.69)	02.08.2007 09:23:44 (161.43 86.83)
03.08.2007 16:47:36 (84.58 73.91)	03.08.2007 16:47:38 (63.51 67.79)	03.08.2007 16:47:50 (58.04 68.84)
05.08.2007 21:11:05 (359.53 74.08)	05.08.2007 21:11:07 (322.93 74.59)	05.08.2007 21:11:23 (21.30 73.41)
06.08.2007 17:36:13 (3.02 59.46)	06.08.2007 17:36:24 (8.97 53.98)	06.08.2007 17:36:29 (348.86 67.03)
06.08.2007 22:01:53 (286.12 80.69)	06.08.2007 22:01:57 (341.66 80.96)	06.08.2007 22:02:11 (267.55 72.61)
07.08.2007 04:09:59 (3.03 66.47)	07.08.2007 04:10:13 (8.95 76.04)	07.08.2007 04:10:16 (351.14 63.42)
15.08.2007 20:28:10 (16.32 75.58)	15.08.2007 20:28:18 (18.59 74.03)	15.08.2007 20:28:25 (333.50 78.41)
16.08.2007 21:29:42 (339.85 52.71)	16.08.2007 21:29:46 (348.31 50.73)	16.08.2007 21:29:57 (343.64 61.44)
17.08.2007 01:50:06 (28.51 87.36)	17.08.2007 01:50:09 (55.59 78.45)	17.08.2007 01:50:19 (23.52 80.59)
18.08.2007 16:11:34 (7.85 62.08)	18.08.2007 16:11:48 (354.34 60.20)	18.08.2007 16:12:00 (355.21 59.39)
19.08.2007 17:50:32 (337.11 72.24)	19.08.2007 17:50:40 (354.19 80.59)	19.08.2007 17:50:53 (326.99 65.89)

Fig. 10: A record of a few clusters taken in August 2007

The program **ClusterSearcher.exe** for cluster detection was created by Jakub Čermák. Fig 10 shows a typical set of search results. In this case we asked the program to look for clusters between 1st and 20th August 2007. The cluster should consist of at least three events that came less than 10 s one after another and the incoming direction should not differ by more than 10°. Similar clusters could lead to future discovery of a strong source of cosmic rays.

Current state of the project

On 4th April 2007 a second CZELTA seminar took place in Pardubice. The seminar was attended by members of the UTEF as well as students and teachers from schools that would like to participate in the project or have the detectors already installed (like Silesian University or Secondary Grammar School in Opava). The main topics were speeches and presentations of our students Jakub Čermák, Petr Drábek and Marek Scholle who did most work on the project.

Jakub Čermák and Petr Drábek entered the contest of scientific projects organised by the Amavet association. They placed 7th and were awarded the prize of the American Meteorological Society and in May represented the Czech Republic at the EXPO Sciences in Brussels.

The above mentioned students finished their studies at our school and left for universities; however they have successors who will continue in their work. CZELTA has to be a long-term project and we would like to improve the data analysis and cooperate with other schools – Czech as well as abroad.

Our thanks for all know-how as well as technical support belong to members of the UTEF in Prague.

We have information about the CZELTA project at the web pages of the Secondary Grammar School in Pardubice http://www.gypce.cz .

References

[1] http://www2.jpl.nasa.gov/calendar/2007.html
[2] http://www.utef.cvut.cz/cz/vyzkum/czelta.html
[3] http://csr.phys.ualberta.ca/alta