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COLLECTED SVIRCO MULTIPLICITY DATA: 1998

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COLLECTED SVIRCO MULTIPLICITY DATA: 1998

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Abstract. *The multiplicities detected at SVIRCO Observatory in Rome (41.86°N, 12.47°E, height sea level, threshold rigidity 6.27 GV) during the year 1998 have been collected as uncorrected hourly data and reported in tabular format together with the pressure corrected data of the NM-64 neutron monitor and the normalized pressure.*

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1. Introduction

The world-wide network of cosmic ray (CR) detectors provides the continuous registration of the secondary cosmic rays generated in the terrestrial atmosphere by the primary cosmic rays coming from outside the Earth's environment. The secondary CRs were discovered by V. Hess in 1912 by analyzing the ionization recorded at different altitudes. Nowadays, we know that the sources of primary CRs are located both inside and outside the solar system. The Sun ejects into the interplanetary medium low-energy CRs (mainly between 10^6 and 10^{10} eV) during solar flares. Medium and high-energy (probably up to about 10^{21} eV) CRs originate from the Milky Way galaxy, or even from other galaxies. Galactic, extra-galactic or solar CRs, during their travel through the solar system, undergo the influence of the interplanetary medium before reaching the planets and play a significant role in many research topics.
This report briefly describes the standard neutron monitor in use from the sixties and the generation of multiplicity events tied with the energy of the particles arriving to the detector (Sect. 2). Information about multiplicity measurements at SVIRCO Observatory in Rome are given in Section 3. Section 4 introduces the multiplicity data table and provides information about the applied format. Finally the collected multiplicity data of 1998 are reported in tabular form. This report is the first of a series (in preparation) that will cover the period from 1998 up to date.

2. Multiplicity events in the standard NM-64 detector

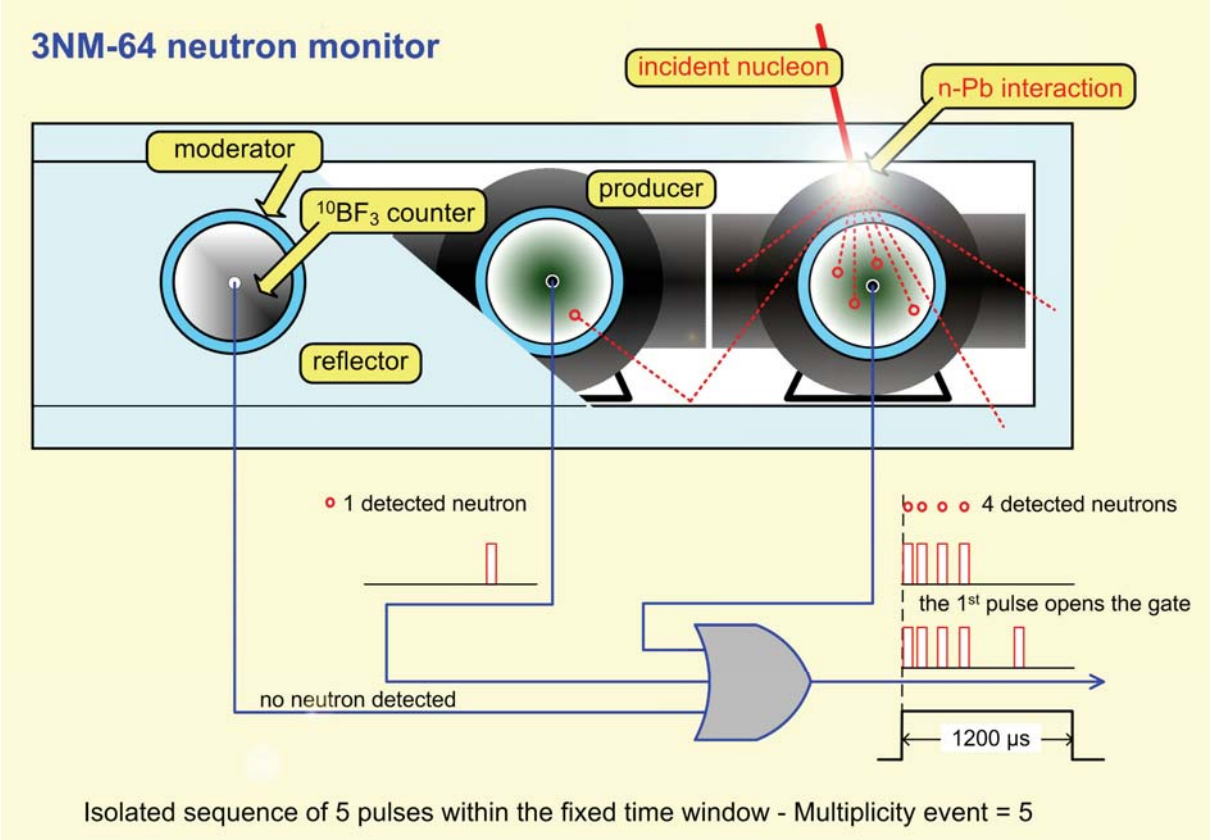
Primary CRs, mostly protons, entering the atmosphere, are involved in multiple interactions resulting in showers of secondary components: nucleonic (protons and neutrons), mesonic (muons) and electromagnetic (photons, electrons, etc.) which may reach the ground and be registered by ground-based detectors. Neutron monitors provide continuous measurements of the nucleonic component intensity that is related to primary CRs not rejected by the Earth's magnetic field.

The neutron monitor called NM-64 (Hatton and Carmichael, 1964) was introduced as the standard ground-based CR detector during the International Quiet Sun Year (IQSY-1964) and still remains the state-of-the-art instrumentation for measuring CRs at ground-level, providing a precious tool in the research field of solar-terrestrial relations, space physics and space weather applications. Because of its sensitive to the nucleonic component of CRs penetrating the Earth's atmosphere in a wide energy range (mainly from about 0.5 to 20 GeV), it has been largely adopted in the CR measurement sites of the world-wide network and represents an inexpensive and statistically accurate way to perform continuous measurements of cosmic radiation beyond compare with the ones onboard of spacecraft.
The minimum configuration for a standard neutron monitor (the so-called 3NM-64) consists of 3 large proportional counters ($^{10}BF_3$ gas-filled; Fowler, 1963); each one with an active length of 191 cm and diameter of 14.8 cm. Each tube is surrounded by a polyethylene moderator (thickness 2 cm) and a ring-shaped lead producer (~1610 Kg). The assembly of tubes, moderators, and quite cylindrical producers is enclosed by polyethylene slabs which act as shield against low energy particles produced in the environment surrounding the neutron monitor, gamma-radiation and electrons, moreover they reflect back to the counters the evaporation neutrons emitted by the lead.
When a neutron passes through polyethylene and lead, undergoing only elastic interactions, becomes less energetic and sometime (when its energy is sufficiently reduced) getting into a counter it can be recorded as a single pulse. Otherwise a large part (about 60%) of energetic hadrons (mostly neutrons or protons) hitting the producer causes inelastic interactions with the lead nucleus. They can be split and alongside with nucleus fragmentation several neutrons, called instantaneous, are emitted together with knock-on nucleons, heavy fragments, and mesons. These secondary particles typically escape detection because of their high energy. As another result of non-elastic interaction with energetic particles the lead nucleus becomes excited and during the de-excitation phase additional particles are emitted. Most of these emissions are evaporation neutrons which are characterized by a spectrum peaked near 1.0 MeV and an isotropic angular distribution.

High purity lead (99%) is chosen as producer because its high atomic mass provides a large nucleus target for producing evaporation neutrons. In addition, lead has a relatively low absorption cross-section for thermal neutrons.

Neutrons, produced in the above processes which are triggered by inelastic interactions of a single incident secondary cosmic ray, are called multiple. Having reduced their energy in the producer, these neutrons can be thermalized by the inner moderator and detected by the counters. Actually only a small percentage (5.7%) of these neutrons are caught by the tubes of NM-64 giving a sequence (cluster) of pulses spaced by short time intervals.

The number of pulses (neutrons) recorded per production event is the so-called multiplicity that increases according to the energy of the incident particle starting the production of multiple neutrons.



Isolated sequence of 5 pulses within the fixed time window - Multiplicity event = 5

The figure illustrates the production of multiplicity events in a 3NM-64 providing a sketch of a multiplicity 5 event detection.

The recorded multiplicity distribution comes from all the particles detected by a neutron monitor, it is weakly dependent on the spectrum of galactic cosmic rays at the top of the atmosphere, but can be used as a peculiar spectrometer to study the nucleonic component of the secondary radiation as it reflects the energy spectrum of cosmic ray at the measurement site.

Of course the interpretation of variations in the multiplicity spectrum (frequency distribution in differential channels) related to primary variations, requires the knowledge of the atmospheric cascade process, depending on the air mass and therefore affected by meteorological changes. Usually the barometric pressure recorded onsite is assumed as a good measure of the air overburden and together with an appropriate barometric or attenuation coefficient (α) it is used to perform the atmospheric corrections on the NM-64 counting rates. Generally the attenuation coefficient is determined in empirical way for each measurement site. It varies with latitude, altitude, rigidity cut-off, primary spectrum shape and also with solar cycle. As result, because of the attenuation coefficient is

energy depending for an adequate correction of multiplicity rates individual coefficients must be estimated for the different energy (multiplicity) channels.

3. Multiplicity measurements at SVIRCO Observatory

The S.V.I.R.CO. (Studio Variazioni Intensità Raggi COsmici) Observatory is managed by the joint collaboration between the Institute of Interplanetary Space Physics of the National Institute for Astrophysics (INAF/IFSI-Rome) and the Roma Tre University.

Since May 1997, the SVIRCO neutron detector has been operating at the Department of Physics "E. Amaldi". The main characteristic parameters of measurement site are: latitude 41.86°N; longitude 12.47°E; height sea level; effective vertical cut-off rigidity (epoch 1995) 6.27 GV.
From May 1997 to December 2004 the standard neutron monitor (IQSY-NM64) was equipped with 17 Boron trifluoride proportional counters (BP-28 type) arranged in four 3-counter sections and a 5-counter one. On January 1, 2005 three counters were added to the detector. After this upgrade, from 17 to 20 NM-64, the SVIRCO neutron monitor has been still composed by 5 sections, but the arrangement varied as follow: three 3-counter, one 5-counter and one 6-counter units, with an improvement of the overall counting rate of 15.6 %.

The one-minute online acquisition of each counter rate, together with the atmospheric pressure, is performed by a GPS-controlled system, meanwhile another instrument (realized by SVIRCO Laboratory) acquires the individual 5-minute counting rate of each detector section. Moreover the continuous flux of pulses from each NM section, a shift register based electronics detects also the multiplicity events. For each pulse cluster a time gate of 1200 microseconds is opened, the pulses of each isolated sequence within the time window are determined and assigned to separated counting channels (from m ≥ 1 to m ≥ 8). Finally the counting rates of the same channels of all the NM sections are added together and the overall multiplicity of the whole neutron detector is sorted in eight differentiated channels: multiplicity m1, m2, m3, m4, m5, m6, m7 and m≥ 8 respectively (where m1 = m ≥ 1 - m ≥ 2; m2 = m ≥ 2 - m ≥ 3 etc.). The events with the highest multiplicity (average value = 10) are collected in the channel m ≥ 8. Notice that a part of these large multiplicities is not generated by a production event but is caused by local atmospheric cascades having dimensions consistent with the neutron monitor ones and a time scale of the same order of the used gate (1200 μs).

4. Data presentation

The hourly counting rates of the multiplicities recorded at SVIRCO Observatory in Rome have been collected and here reported as detected; i.e. they are presented without corrections for atmospheric or instrumental effects (overlapping of events in the same gate, losses due to gate finite length etc.). The collected uncorrected data let the user free to apply the preferred algorithm kits. Nevertheless, the total hourly rate, i.e., the sum of each channel rate multiplied by the corresponding multiplicity number, as recorded by the multiplicity electronics, was cross-checked with the one of the whole neutron monitor.

The NM/m ratio is reported in the table as a control parameter for each data line provided to verify that all the neutrons detected by the NM64 were detected also by multiplicity and vice-versa.

$$NM/m = ((NM/m)-1)*1000,$$

where NM is the total uncorrected rate of the neutron monitor and m is the multiplicity total rate

$$m = (m1)+(m2*2)+(m3*3)+(m4*4)+(m5*5)+(m6*6)+(m7*7)+(m\geq 8*10)$$

In the table headline it is reported the year and the arrangement of the neutron monitor:

- 17 NM-64 from 1 January 1998 to 31 December 2004
- 20 NM-64 since 1 January 2005 (the overall counting rate has been increased of 15.6%).

The first three columns are relative to month, day, and hour (UT) respectively. In the fourth column is indicated the NM/m ratio in ‰. From the fifth to the twelfth column it is reported the hourly counting

rate of the multiplicity channels from m1 to m≥8. The last two columns contain the pressure corrected counts per hour (CCPH) of the NM64 detector and the normalized average pressure in hPa.

The atmospheric correction for the total intensity was estimated with a barometric coefficient α = 0.70% / hPa and a pressure reference level = 1009.25 hPa (level used to maintain data continuity from 1957).

Data reported in this paper are available as text files upon request from Fabrizio Signoretti at signoretti@fis.uniroma3.it

References

Fowler, I. L.: Very large boron trifluoride proportional counters, Rev. of Scientific Instruments, 34(7), 731-739, 1963.

Hatton, C. J., and Carmichael, H.: Experimental investigation of the NM-64 neutron monitor, Can. J. Phys., 42, 2443-2472, 1964.

SVIRCO-ROME 17NM-64 YEAR 1998

MTH	DAY	UT	NM/m	m1	m2	m3	m4	m5	m6	m7	m≥8	CCPH	PRESS
1	1	1	1.301	227250	52450	16430	6015	2655	1242	644	1114	473050	1018.79
		2	1.508	226350	52870	16450	5920	2552	1230	672	1156	474202	1019.22
		3	0.991	226900	51980	16260	6040	2644	1242	636	1098	471481	1018.99
		4	1.460	226800	52460	16370	5960	2526	1218	694	1172	471984	1018.66
		5	1.523	226900	52320	16310	6050	2554	1202	698	1166	472046	1018.67
		6	1.652	227650	52450	16220	6020	2516	1318	686	1140	473786	1018.92
		7	1.906	226500	52240	16360	6080	2580	1272	644	1124	473555	1019.24
		8	1.256	225850	52090	16310	5850	2560	1212	654	1074	472630	1020.00
		9	1.418	224250	52010	16230	5800	2528	1242	640	1100	472262	1020.53
		10	1.330	224450	52150	16300	5830	2530	1200	660	1080	474033	1020.91
		11	1.740	224300	51700	16150	5900	2444	1156	654	1096	472028	1020.83
		12	1.320	225350	51370	16270	5850	2574	1214	640	1132	472162	1020.34
		13	1.515	225150	52170	16390	6030	2576	1178	698	1208	474275	1019.83
		14	1.975	226300	52200	16530	6010	2506	1206	702	1146	473642	1019.32
		15	0.992	225450	52070	16520	5920	2516	1290	672	1162	471426	1019.12
		16	2.090	225800	52000	16340	5930	2530	1248	648	1104	470631	1019.12
		17	1.353	225800	51720	16390	6050	2482	1238	650	1070	470548	1019.38
		18	1.955	225250	52050	16220	5980	2616	1268	652	1164	472925	1019.64
		19	1.263	224700	51780	16380	6020	2532	1244	642	1102	471272	1019.80
		20	2.343	224950	51810	16300	5860	2566	1208	698	1208	473035	1019.90
		21	1.740	225000	52000	16240	5930	2606	1254	602	1168	471947	1019.68
		22	1.411	225450	51990	16170	6120	2508	1218	612	1132	471400	1019.57
		23	1.226	225750	52130	16350	6120	2502	1182	670	1096	471433	1019.31
		24	1.060	226000	52100	16260	5990	2488	1330	662	1170	470476	1018.75
1	2	1	1.278	227150	52190	16320	5925	2579	1244	684	1108	469934	1018.32
		2	1.352	227700	52220	16590	6070	2592	1254	684	1090	471513	1018.16
		3	1.000	229300	52680	16790	6190	2678	1226	604	1132	473618	1017.65
		4	1.745	229950	53070	16670	6220	2640	1310	718	1222	474694	1016.85
		5	1.159	230100	52960	16740	6150	2706	1278	716	1150	473197	1016.71
		6	1.656	230150	52950	16800	6210	2598	1266	676	1150	472324	1016.52
		7	1.718	231650	53550	16650	6200	2644	1260	708	1138	473199	1015.98
		8	1.768	231150	53770	16990	6250	2690	1292	684	1174	473713	1015.57
		9	1.394	231550	53710	16930	6230	2744	1308	740	1188	474370	1015.53
		10	2.047	232300	53800	17130	6150	2710	1278	682	1150	474017	1015.31
		11	1.746	232150	54690	16930	6160	2836	1338	718	1178	475035	1014.84
		12	2.010	234700	54620	17170	6250	2698	1378	754	1230	473756	1013.23
		13	1.351	235350	54830	17130	6190	2786	1358	760	1196	474098	1013.20
		14	1.758	235600	55140	17640	6410	2796	1374	696	1144	474018	1012.36
		15	1.233	236200	54860	17310	6430	2804	1300	690	1206	471375	1011.85
		16	0.976	237550	55710	17330	6440	2734	1334	696	1206	472601	1011.32
		17	1.817	236100	55240	17460	6380	2638	1274	708	1200	469999	1011.36
		18	1.557	237000	55260	17390	6420	2642	1366	726	1196	470814	1011.16
		19	0.892	238350	55590	17400	6410	2724	1400	752	1174	470047	1010.24
		20	1.782	239000	56140	17930	6430	2614	1350	742	1194	471323	1009.67
		21	1.880	239700	56160	17590	6510	2866	1358	738	1278	471921	1009.18
		22	1.152	240900	56440	17710	6390	2842	1332	732	1254	470527	1008.54
		23	2.093	242350	56130	17820	6550	2814	1380	744	1212	470470	1007.90
		24	2.022	243650	57430	17790	6740	2860	1360	756	1214	472075	1006.97
1	3	1	0.794	243800	56860	18060	6515	2891	1342	712	1220	470197	1006.95
		2	1.310	244300	56740	18050	6610	2780	1396	724	1200	470882	1007.01
		3	1.302	243800	57040	18100	6640	2766	1432	762	1260	471509	1006.79
		4	1.687	243950	57270	18310	6730	2934	1376	766	1264	473332	1006.64
		5	1.585	244450	56790	18010	6740	2838	1322	754	1296	471688	1006.72
		6	1.507	243250	56970	17880	6570	2856	1312	770	1192	471864	1007.62
		7	1.121	242750	56690	17990	6600	2858	1350	718	1244	473919	1008.36
		8	1.459	241600	57060	17610	6620	2802	1376	736	1196	474101	1008.95
		9	1.513	239450	56210	17700	6440	2838	1278	706	1178	474576	1010.63
		10	1.264	238000	55560	17510	6360	2814	1410	730	1216	476262	1011.90
		11	1.113	238100	54880	17290	6330	2796	1320	712	1172	474490	1012.39
		12	1.928	236600	55220	17290	6350	2746	1300	694	1200	474508	1012.57
		13	1.087	236450	55070	17380	6480	2772	1374	676	1198	474904	1012.57
		14	1.204	235000	54920	17210	6380	2716	1296	690	1188	472900	1013.00
		15	1.740	233800	54740	17180	6290	2798	1314	694	1184	474200	1013.79
		16	1.049	234650	54010	17130	6080	2616	1256	658	1200	473230	1014.51
		17	1.640	231700	53720	17040	6160	2594	1294	712	1180	473725	1015.58
		18	1.030	230250	53650	16840	6300	2638	1234	736	1152	473406	1016.16
		19	1.408	229800	53520	16790	6160	2644	1272	638	1176	472835	1016.45
		20	1.258	228700	53080	16500	6030	2598	1300	690	1102	469959	1016.81
		21	1.196	228400	52800	16640	6080	2612	1262	678	1128	470523	1017.06
		22	0.970	228250	52670	16510	6180	2616	1310	704	1160	471010	1017.11
		23	1.220	228700	53280	16690	6080	2572	1320	678	1080	472458	1017.30
		24	1.477	228850	53210	16760	6040	2604	1286	682	1168	472702	1017.04
1	4	1	0.907	228150	52830	16760	6105	2541	1232	690	1092	470705	1017.33
		2	1.550	229300	53120	16600	6040	2624	1260	724	1132	473704	1017.44

SVIRCO-ROME 17NM-64 YEAR 1998

MTH	DAY	UT	NM/m	m1	m2	m3	m4	m5	m6	m7	m≥8	CCPH	PRESS
		3	1.158	229650	53410	16640	6070	2546	1278	642	1164	472729	1017.00
		4	1.660	229550	53010	16510	6150	2648	1298	710	1124	472437	1016.93
		5	1.222	228750	53370	16650	6070	2618	1326	674	1142	472340	1016.97
		6	1.507	228500	53240	16780	6080	2620	1342	682	1156	474755	1017.58
		7	1.646	229150	53070	16660	6230	2584	1256	674	1176	474668	1017.54
		8	1.239	228550	53110	16530	6170	2576	1254	672	1138	473930	1017.89
		9	1.297	227500	52240	16280	5930	2594	1270	684	1102	472112	1018.81
		10	1.668	226150	51890	16510	6050	2564	1226	650	1160	473285	1019.42
		11	1.136	226150	53010	16470	5850	2618	1220	734	1148	475242	1019.43
		12	1.934	226750	52090	16340	6010	2498	1252	688	1172	472567	1018.99
		13	1.197	228000	52960	16600	5930	2604	1260	704	1142	473749	1018.21
		14	1.773	228700	53200	16710	6040	2522	1196	682	1150	473731	1017.77
		15	0.783	228300	52860	16590	5950	2600	1302	670	1128	471615	1017.62
		16	1.615	228450	53090	16620	6100	2680	1256	692	1112	473972	1017.76
		17	1.988	228500	52520	16380	6220	2546	1260	634	1140	471760	1017.71
		18	1.301	227400	52700	16390	6010	2640	1234	660	1166	471386	1017.95
		19	1.272	227300	52400	16570	6000	2524	1192	668	1146	469805	1017.86
		20	1.459	227400	52300	16650	5980	2556	1290	662	1162	471125	1017.93
		21	1.154	228450	53090	16470	6080	2620	1250	638	1202	474268	1018.03
		22	1.798	227300	52720	16580	5890	2574	1228	594	1114	471918	1018.47
		23	1.542	228150	52790	16750	6150	2502	1220	682	1156	474472	1018.26
		24	1.424	229450	53130	16700	6040	2614	1284	640	1142	475451	1017.96
1	5	1	1.993	228100	52540	16490	6135	2687	1274	638	1136	472709	1017.87
		2	1.511	228650	52770	16740	6050	2596	1350	688	1156	473577	1017.57
		3	1.571	229500	53120	16520	6050	2614	1250	650	1096	472012	1017.24
		4	1.498	230500	53360	16630	6230	2610	1246	696	1128	473872	1016.82
		5	1.323	231250	53770	16760	6170	2596	1320	686	1248	476334	1016.56
		6	1.935	231000	53400	16720	6230	2680	1288	700	1182	476936	1017.03
		7	1.585	230150	53310	16830	6030	2592	1296	672	1120	475292	1017.45
		8	1.971	228800	53000	16700	6180	2622	1294	668	1136	475533	1017.94
		9	2.036	229450	53010	16380	6040	2560	1262	690	1208	476676	1018.43
		10										477570	1019.06
		11	2.318	227650	53250	16580	6120	2594	1268	734	1204	478109	1018.79
		12	0.964	229600	52760	16690	6140	2514	1276	662	1158	475813	1018.28
		13	1.220	229950	53370	16760	6070	2596	1258	698	1098	475107	1017.57
		14	1.962	230250	53350	16790	6130	2620	1270	660	1130	475027	1017.17
		15	1.106	229750	53370	16950	5970	2562	1290	732	1176	474491	1017.08
		16	1.412	230100	53200	16720	6230	2586	1292	692	1180	475352	1017.21
		17	1.562	230900	52880	16720	6300	2564	1262	664	1110	475371	1017.43
		18	1.300	229600	53040	16540	6220	2622	1304	692	1182	475673	1017.68
		19	1.260	229050	53410	16680	6110	2654	1246	680	1170	475355	1017.66
		20	2.640	229950	53190	16830	6090	2614	1286	640	1200	476976	1017.67
		21	1.442	229000	53320	16460	6110	2592	1258	674	1186	474737	1017.77
		22	1.445	229450	52830	16560	6090	2624	1258	664	1124	473857	1017.78
		23	1.737	228800	53320	16690	6130	2568	1260	672	1160	474989	1017.75
		24	1.252	230150	53530	16650	6110	2580	1340	694	1146	475569	1017.31
1	6	1	1.439	230550	53410	16950	6295	2593	1232	648	1122	475352	1017.01
		2	1.993	231200	53340	16530	6140	2674	1218	698	1200	475188	1016.86
		3	1.858	231850	53410	16820	6260	2660	1282	724	1194	476938	1016.59
		4	1.327	232350	53850	16860	6230	2642	1250	710	1108	475421	1016.17
		5	1.602	232600	53440	17150	6260	2608	1300	692	1150	476736	1016.26
		6	1.576	232200	53860	16900	6150	2582	1310	724	1074	476292	1016.55
		7	1.680	231450	53090	17000	6190	2610	1266	654	1140	476006	1017.02
		8	1.107	230300	53440	17000	6090	2658	1280	696	1136	476302	1017.27
		9	1.354	228600	53580	16750	6200	2580	1252	676	1162	476657	1018.03
		10	1.780	227950	52590	16440	6080	2658	1284	678	1120	474844	1018.67
		11	1.072	228300	52700	16470	6130	2544	1264	670	1122	474439	1018.60
		12	1.475	229200	52660	16590	6150	2586	1262	676	1076	474238	1018.15
		13	1.015	229100	53040	16780	6120	2698	1222	662	1178	475490	1017.84
		14	0.677	229350	52730	16770	6090	2622	1258	670	1110	474017	1017.86
		15	0.937	229150	52930	16490	6070	2662	1276	638	1184	475190	1018.15
		16	1.609	227900	52620	16540	6060	2602	1252	692	1134	474337	1018.54
		17	1.169	228150	52510	16480	5970	2622	1290	646	1132	475035	1018.98
		18	1.592	228300	53080	16530	6080	2672	1248	686	1204	479244	1019.26
		19	1.262	228050	52630	16640	6090	2538	1254	658	1140	477279	1019.44
		20	1.255	226650	52010	16480	6220	2618	1222	692	1108	475548	1019.72
		21	1.721	226700	52400	16280	6150	2616	1216	712	1126	476762	1019.94
		22	0.765	226900	52280	16550	6010	2620	1258	682	1100	477868	1020.40
		23	1.361	226000	52060	16290	5970	2634	1276	638	1132	477572	1020.91
		24	1.567	226150	52090	16520	6000	2634	1218	646	1142	478723	1020.95
1	7	1	0.782	226450	51790	16500	5945	2607	1166	638	1104	477250	1021.10
		2	1.781	226000	52280	16290	5860	2522	1222	678	1148	478537	1021.28
		3	1.233	225000	51860	16180	5910	2518	1124	674	1134	474928	1021.17
		4	1.538	226350	52090	16430	6140	2524	1238	652	1176	480336	1021.29