# Heavy-Ion Testing of the AD8151 Cross-Point Switch

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#### 1. Introduction

Single Event Effects testing of the AD8151, a fabric-based switch, was carried out using heavy ions at Texas A&M University's Cyclotron Institute. A single part was tested due to the difficulty of changing parts soldered to the evaluation board. SEEs were measured as a function of number of paths through the switch, the data rate and ion LET.

## 2. Device Description

The AD8151 Crosspoint switch manufactured by Analog Devices is designed to connect any (or all) of 33 inputs to any (or all) of 17 outputs with a maximum throughput of 3.2 Gbps. Because of its low power and high speed, it has potential applications in space for optical network switching or for a Giga-bit ethernet.

Fig. 1 shows the functional block diagram of the AD8151. Inputs are connected to outputs by connecting or disconnecting the appropriate switches in a two dimensional array. The state of each switch, whether "on" or "off", is controlled by configuration data stored in a latch. The data are loaded into the latch through a series of programming steps. The first step is to load all the configuration data sequentially into a "first rank" latch. The data are then strobed simultaneously into a "second-rank" latch. The outputs of the second rank latch are decoded and drive the individual switches in the 33 by 17 matrix.



**Figure 1.** Functional Block diagram of the AD8151 showing the first and second rank latches as well as the switch matrix connecting any input to any output.

The latches are manufactured in CMOS technology and the switches in bipolar technology. Figure 2 shows the bipolar components used in the switch. Ion strikes in the latch will cause a SEU that may disrupt communications and manifest itself as a loss of synchronization (LOS). An ion strike in the decoder or the switch itself could cause a temporary change in the state of the switch, interrupting data transmission for a short time. These types of SEUs could cause single bit errors or bursts of errors, depending on how long it takes the switch to recover.



Figure 2. Circuit components used for constructing a switch.

For testing, the manufacturer provided a part mounted on an evaluation board together with software for programming the switch. However, for programmatic control, Labview drivers were developed and used instead. Two lines are required for all input and output ports because the part is a fully differential non-blocking array. The device is packaged in a plastic 184 lead LQFP (leaded quad flat pack) with 16 mil lead pitch. Prior to testing, the plastic over the die was removed by first grinding a depression in the plastic and then filling the depression with acid. Figure 3 shows the die and the bond wires leading into the plastic encapsulant.



Figure 3. Closeup picture of the AD8151 die and bond wires.

# 3. Test Setup

A bit error-rate tester (BERT) was used for SEE testing of the switch. The BERT supplied a serial data stream to a switch input. After passing through the switch, the output was fed back to the BERT and compared with the original data pattern. Any differences were flagged as SETs. The signals supplied by the BERT to the switch were a standard, pseudo-random 127 bit repeating sequence pattern having a peak-to-peak differential from -0.75 V to + 1.5 V. The data rate was varied for different runs. High performance (18 GHz) cables were used for all RF signals.

The switch was programmed using the software drivers written in Labview and incorporated into the test application. Two different matrix configurations were used. In the first the data stream made one pass through the matrix. In the second the data stream passed through the switch five times. This was achieved by connecting four outputs to four inputs and defining the matrix configuration in such a way as to have a continuous path through the AD8151. The rational for this approach was to ascertain whether the BER or the LOS cross-section depended on the switch configuration. Figure 2 shows the switch configurations for both cases. The path is as follows:

### BERTout $\rightarrow$ I10 $\rightarrow$ O0 $\rightarrow$ I13 $\rightarrow$ O2 $\rightarrow$ I8 $\rightarrow$ O6 $\rightarrow$ I28 $\rightarrow$ O16 $\rightarrow$ I18 $\rightarrow$ O10 $\rightarrow$ BERTin,

where the bold arrows  $(\rightarrow)$  are external coaxial cables and the regular arrows  $(\rightarrow)$  are internal paths thru the AD8151. In the single path case the switch configuration is:

### BERTout $\rightarrow$ I10 $\rightarrow$ O0 $\rightarrow$ BERT(in)



Figure 4. Diagram of the internal and external connections for the 5-path and 1-path configurations for the AD8151 crossbar switch.

#### 4. SEE Test Results

Table 1 lists all the pertinent details for each exposure. The standard information, such as ion species, ion LET, angle of incidence, flux, exposure time and fluence are included. Only one device (device #3) was tested with  $I_{Vee} = 3.2$  V. The table also contains information regarding operation of the device, such as data rate and number of paths through the device. In addition, the table lists the three types of errors encountered during the measurements. The first type is single bit errors characterized by a single bit flip in the data stream. There is no long-term disruption to data transmission associated with a single bit error. The second type consists of a burst of errors, which is a continuous series of errors of finite length. Once the burst is over, transmission of correct data resumes. The third type of error is a LOS by the BERT due to a loss of the transmitted signal as a result of a SEU in the latch that changes the configuration. A LOS requires that the configuration data be reloaded into the AD8151 latch. In most cases at least two runs were made for each set of experimental conditions and the average was computed.

The exposure time is a critical parameter because it is needed to measure the BER. During the experiment, transmission was started before the beam was turned on and the beam was stopped as quickly as possible following a LOS or after a predetermined fluence. The bit errorrate is determined by dividing the number of errors by the number of bits transmitted, where the number of transmitted bits is obtained by multiplying the data rate by the exposure time. Therefore, the BER is given by:

$$BER = \frac{\# errors}{(time) \bullet (data \_ rate)}$$

The BER was calculated for both single-bit errors and burst errors as a function of ion LET, data rate and number of paths through the switch. The average length of a burst of errors was calculated by taking the ratio of the total number of bit errors in bursts to the total number of bursts. That value was plotted as a function of ion LET for different data rates and number of paths through the switch.

Figure 5 shows the BER for single bit errors for five paths through the switch for different data rates as a function of ion LET. The single BER has a threshold below 2.86 MeV.cm<sup>2</sup>/mg. The single BER initially increases with LET and then shows a sharp decrease above a LET of about 9 MeV.cm<sup>2</sup>/mg. Above an LET of 12 MeV.cm<sup>2</sup>/mg the single BER increases again. There BER also depends on data rate, but the explanation is not obvious.



Figure 5. Single-bit error rate as a function of ion LET for four different frequencies and five paths through the switch.

Figure 6 shows the BER for one path through the switch. It has the same overall behavior and, as expected, is approximately one fifth of the BER for the case of 5 paths through the switch.



Figure 6. Single bit error rate as a function of ion LET for different data rates and for one pass through the switch.

Figure 7 shows the burst event rate as a function of effective LET for one path through the switch. The LET threshold for burst events is below  $2.86 \text{ MeV.cm}^2/\text{mg}$ . The dependence on LET seems to depend on data rate.



Figure 7. Burst event rate as a function of effective LET for 1 path through the switch and for different data rates.

Figure 8 shows the burst event rate as a function of ion LET for 5 paths through the switch. The LET threshold is also below  $2.86 \text{ MeV.cm}^2/\text{mg}$ . There is a general increase in the burst rate with ion LET. but the dependence on data rate is not clear.



Figure 8. Burst event rate as a function of effective LET for five paths through the switch and for different data rates.

Figure 9 shows the average burst length versus ion LET for different data rates for five paths through the switch. Below a LET of 5.72 MeV.cm<sup>2</sup>/mg the average burst length is less than 10 bits. Above, the average burst length increases rapidly with LET. There is no clear dependence on data rate, with the highest data rate having the shortest burst length.



Figure 9. Average number of bits in a burst as a function of LET for 5 paths through the switch and for different bit error rates.

Figure 10 shows the average burst length for 1 path through the switch. The behavior is similar to that observed for five paths.



Figure 10. Average burst error length as a function of effective LET for different data rates and for one path through the switch.

Figure 11 shows the cross-section as a function of effective LET for loss-of-synchronization effects. The LET threshold for loss-of-synchronization is close to 8  $MeV.cm^2/mg$ . There is a general increase in the cross-section with LET but there is no obvious dependence on data rate.



Figure 11. Loss of synchronization cross-section as a function of effective LET for four different data rates and five paths through the switch.

Figure 12 shows the LOS cross section as a function of ion LET for one path through the switch. The general trend is that the cross-section increases with LET but there appears to be no obvious dependence on data rate.



Figure 12. Loss of synchronization cross-section as a function of effective LET for four different data rates and for 1 path through the switch.

### 5. Conclusions

The AD8151 has been tested for SEEs using heavy ions. The part does not latch up but it does suffer from loss of synchronization. Both single bit errors and bursts of errors were observed. Bit error rates were found to depend on ion LET. Although the BERs showed a dependence on data rate, there was no obvious explanation.

Run	I V <sub>EE</sub>	# of	Ion	Tilt	LET	Effect.	Total	Effect.	Expos.	Data Rate	Total bits	Loss of	Non-	Burst	Total	Burst	Total
No.	(mA)	paths				LET	fluence	fluence	Time	(Gbps)		Synch	Burst Errors	Errors	Errors	Events	Events
1	161	5	Ne	0	2.86	2.86	5.34E+06	5.34E+06	128	3	3.84E+11		292	1888	2180	265	557
2	161	5	Ne	0	2.86	2.86	2.00E+06	2.00E+06	44	1.6	7.04E+10		35	366	401	71	106
3	161	5	Ne	0	2.86	2.86	2.00E+06	2.00E+06	44	1.6	7.04E+10		35	286	321	54	89
4	161	5	Ne	0	2.86	2.86	1.99E+06	1.99E+06	42	1	4.20E+10		24	188	212	56	80
5	161	5	Ne	0	2.86	2.86	1.99E+06	1.99E+06	41	1	4.10E+10		29	202	231	53	82
0	161	5	Ne	0	2.86	2.86	2.00E+06	2.00E+06	42	0.32	1.34E+10		35	21	50	10	45
8	71	1	Ne	0	2.80	2.80	2.01E+00	2.01E+00	42	0.52	1.34E+10 1.38E+11		20	20	250	12	47 62
0	71	1	Ne	0	2.80	2.80	2.02E±06	2.02E+06	40	3	1.36E+11		29	221	230	35	61
10	71	1	Ne	0	2.80	2.80	2.02E+00	2.02E+00	42	16	6.72E+10		25 6	87	93	18	24
11	71	1	Ne	Ő	2.86	2.86	2.02E+06	2.02E+06	40	1.6	640E+10		7	29	36	6	13
12	71	1	Ne	Ő	2.86	2.86	2.02E+06	2.02E+06	40	1	4.00E+10		8	46	54	11	19
13	71	1	Ne	0	2.86	2.86	1.99E+06	1.99E+06	38	1	3.80E+10		5	35	40	11	16
14	71	1	Ne	0	2.86	2.86	1.98E+06	1.98E+06	37	0.32	1.18E+10		5	12	17	5	10
15	71	1	Ne	0	2.86	2.86	1.99E+06	1.99E+06	40	0.32	1.28E+10		10	2	12	1	11
16	71	1	Ne	45	2.86	4.04	2.84E+06	2.01E+06	64	3	1.92E+11		29	512	541	62	91
17	71	1	Ne	45	2.86	4.04	2.83E+06	2.00E+06	84	3	2.52E+11		37	835	872	99	136
18	71	1	Ne	45	2.86	4.04	2.84E+06	2.01E+06	37	1.6	5.92E+10		21	119	140	21	42
19	71	1	Ne	45	2.86	4.04	2.81E+06	1.99E+06	38	1.6	6.08E+10		14	203	217	35	49
20	71	1	Ne	45	2.86	4.04	2.80E+06	1.98E+06	34	1	3.40E+10		9	66	75	14	23
21	71	1	Ne	45	2.86	4.04	2.85E+06	2.02E+06	36	1	3.60E+10		16	98	114	21	37
22	71	1	Ne	45	2.86	4.04	2.84E+06	2.01E+06	33	0.32	1.06E+10		7	21	28	9	16
23	71	I	Ne	45	2.86	4.04	2.83E+06	2.00E+06	34	0.32	1.09E+10		12	15	27	6	18
24	161	5	Ne	45	2.86	4.04	2.82E+06	1.99E+06	31	3	9.30E+10		210	1388	1598	190	400
25	101	5	Ne	45	2.80	4.04	2.83E+00	2.00E+06	29	3	8.70E+10		191	1450	1041 549	109	300 140
20	161	5	No	45	2.80	4.04	2.83E+00	2.02E+00	20	1.0	4.60E+10		65	405	502	04 95	149
28	161	5	No	45	2.80	4.04	2.30E+00	1.96E+06	29	1.0	4.04E+10		34	425	450	03	127
20	161	5	Ne	45	2.80	4.04	2.77E+00	1.90E+00	24	1	2.40E+10 2.40E+10		30	273	312	61	100
30	161	5	Ne	45	2.86	4 04	2.82E+06	1.99E+06	26	0.32	8 32E+09		42	70	112	29	71
31	161	5	Ne	45	2.86	4.04	2.87E+06	2.03E+06	27	0.32	8.64E+09		38	65	103	26	64
32	161	5	Ne	60	2.86	5.72	4.02E+06	2.01E+06	39	3	1.17E+11		346	2418	2764	269	615
33	161	5	Ne	60	2.86	5.72	4.02E+06	2.01E+06	43	3	1.29E+11		269	2187	2456	246	515
34	161	5	Ne	60	2.86	5.72	4.02E+06	2.01E+06	49	1.6	7.84E+10		116	1071	1187	149	265
35	161	5	Ne	60	2.86	5.72	3.96E+06	1.98E+06	51	1.6	8.16E+10		97	1032	1129	144	241
36	161	5	Ne	60	2.86	5.72	4.00E+06	2.00E+06	53	1	5.30E+10		76	618	694	115	191
37	161	5	Ne	60	2.86	5.72	3.97E+06	1.99E+06	60	1	6.00E+10		62	526	588	99	161
38	161	5	Ne	60	2.86	5.72	4.03E+06	2.02E+06	59	0.32	1.89E+10		46	165	211	65	111
39	161	5	Ne	60	2.86	5.72	3.97E+06	1.99E+06	53	0.32	1.70E+10		48	150	198	61	109
40	71	1	Ne	60	2.86	5.72	4.04E+06	2.02E+06	53	3	1.59E+11		41	1028	1069	96	137
41	71	1	Ne	60	2.86	5.72	4.04E+06	2.02E+06	48	3	1.44E+11		41	589	630	13	114
42	/1	1	Ne	60	2.86	5.72	3.98E+06	1.99E+06	53	1.6	8.48E+10		33	200	283	65	98
45	71	1	Ne	60 60	2.80	5.72	3.90E+00	1.98E+00	53 52	1.0	8.48E+10 5.20E+10		25	299	324 225	32	57 47
44	71	1	No	60	2.80	5.72	4.01E+00	2.01E+00	53	1	5.30E+10		23	200	223	20	47
46	71	1	Ne	60	2.80	5.72	3.97E+00	1.99E+00	52	0.32	1.66E+10		25	205	37	11	18
40	71	1	Ne	60	2.86	5 72	3.97E+06	1.99E+06	50	0.32	1.60E+10		15	40	55	15	30
48	71	1	Ar	0	8.96	8 96	171E+06	1.77E+06	14	3	4 20E+10	1	28	4704	4732	67	95
49	71	1	Ar	Ő	8.96	8.96	0.00E+00	0.00E+00	0	3	0.00E+00	•	4	386	390	10	14
50	71	1	Ar	Ő	8.96	8.96	1.71E+06	1.71E+06	15	3	4.50E+10	1	49	4794	4843	93	142
51	71	1	Ar	Ő	8.96	8.96	5.26E+05	5.26E+05	5	1.6	8.00E+09	1	6	234743	234749	991	997
52	71	1	Ar	0	8.96	8.96	2.57E+05	2.57E+05	3	1.6	4.80E+09	1	3614	207647	211261	8243	11857
53	71	1	Ar	0	8.96	8.96	2.99E+05	2.99E+05	3	1.6	4.80E+09	1	7	316618	316625	1501	1508
54	71	1	Ar	0	8.96	8.96	2.00E+06	2.00E+06	70	1.6	1.12E+11	0	40	1145	1185	68	108
55	71	1	Ar	0	8.96	8.96	1.64E+05	1.64E+05	6	1.6	9.60E+09	1	6	258603	258609	1381	1387
56	71	1	Ar	0	8.96	8.96	3.17E+05	3.17E+05	12	3	3.60E+10	1	11	3876	3887	22	33
57	71	1	Ar	0	8.96	8.96	5.58E+05	5.58E+05	20	3	6.00E+10	1	47	12911	12958	149	196
58	71	1	Ar	0	8.96	8.96	2.00E+06	2.00E+06	74	1	7.40E+10	0	61	19684	19745	190	251

No.     No.     No.     Lot. 7     Bares     Mode     Time     (Hi)     No.     Spr. 7     Lot. 8     Derus     Events     Zamp       39     71     1     Ar     0     8.96     2.96     3     1     3.06E-10     1     4     679538     2.26     16     5     Ar     0     8.96     2.96     2.06     3     3.03E-10     1     0.8     2.25<	Run	I_V <sub>EE</sub>	# of	Ion	Tilt	LET	Effect.	Total	Effect.	Expos.	Freq.	Total bits	Loss of	Non-	Burst	Total	Burst	Total
L     L     L     L     L     L     L     L     Fronts     L <th>No.</th> <th>(mA)</th> <th>paths</th> <th></th> <th></th> <th></th> <th>LET</th> <th>fluence</th> <th>fluence</th> <th>Time</th> <th>(GHz)</th> <th></th> <th>Synch</th> <th>Burst</th> <th>Errors</th> <th>Errors</th> <th>Events</th> <th>Events</th>	No.	(mA)	paths				LET	fluence	fluence	Time	(GHz)		Synch	Burst	Errors	Errors	Events	Events
99     1     1     Ar     0     8.98     7/94     1/94	-		Ļ			0.07	0.04	5.045.04	<b>5</b> 045.04			2.005.00	L	Errors	(2055)	670550	2404	2400
a     a     b<	59 60	71	1	Ar	0	8.96	8.96	7.94E+04	7.94E+04	3	0.22	3.00E+09	1	20	679554	679558	2486	2490
cc     ci     ci<	61	71	1	Ar	0	8.96	8.96	2.00E+00 1.99E+06	2.00E+00 1.99E+06	74	0.32	2.40E+10 2.37E+10	0	20	171	179	37	45
63     64     161     5     Ar     0     8,96     4,82E+05     4,82E+05     11     1.6     1,76E+10     1     1.0     3     4,650     4,457     1.7 <td< td=""><td>62</td><td>161</td><td>5</td><td>Ar</td><td>0</td><td>8.96</td><td>8.96</td><td>8.88E+05</td><td>8.88E+05</td><td>31</td><td>3</td><td>9.30E+10</td><td>1</td><td>105</td><td>2536</td><td>2641</td><td>102</td><td>207</td></td<>	62	161	5	Ar	0	8.96	8.96	8.88E+05	8.88E+05	31	3	9.30E+10	1	105	2536	2641	102	207
64     61     5     Ar     0     8,96     3,01E:105     3,01E:105     11     1.6     1.70E:10     1     30     4020     4020     4021     121       66     161     5     Ar     0     8,96     402E:105     15     1     5,00E:10     1     12     224158     215771     822     838       66     161     5     Ar     00     8,96     8,96     222E:145     5     1     5,00E:10     1     15     1110     4620     4630     463     4630 <	63	161	5	Ar	0	8.96	8.96	4.82E+05	4.82E+05	17	3	5.10E+10	1	103	32581	32707	252	355
66     161     5     Ar     0     8,96     4,064     105     1     1.0     2.724     10     1     2.915     2.15782     2.15782     2.15782     2.15782     2.15782     2.15782     2.15782     2.15782     1.15783     1.15783<	64	161	5	Ar	0	8.96	8.96	3.01E+05	3.01E+05	11	1.6	1.76E+10	1	30	4620	4650	42	72
	65	161	5	Ar	0	8.96	8.96	4.64E+05	4.64E+05	17	1.6	2.72E+10	1	29	241568	241597	1162	1191
	66	161	5	Ar	0	8.96	8.96	4.02E+05	4.02E+05	15	1	1.50E+10	1	27	255884	255911	1501	1528
$ \begin{array}{c} \mathbf{e}_{8}    \mathbf{e}_{1} \\ \mathbf{e}_{1}  \mathbf{e}_{1} \\ \mathbf{e}_{2}  \mathbf{e}_{1} \\ \mathbf{e}_{1}  \mathbf{e}_{1} \\ \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{1}  \mathbf{e}_{1} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2}  \mathbf{e}_{2} \\ \mathbf{e}_{2}  \mathbf$	67	161	5	Ar	0	8.96	8.96	1.39E+05	1.39E+05	5	0.22	5.00E+09	1	16	157621	15/63/	822	838
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	60 60	161	5	Ar	0	8.90	8.90	5.23E+05	5.25E+05 1.80E±05	21	0.32	0.72E+09	1	15	54580	191044 54615	085 402	/00
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	70	161	5	Ar	45	8.96	12 67	8.01E+03	5.66E+03	1	0.52	3.00E+09	1	43	9612	9655	+02	129
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	71	161	5	Ar	45	8.96	12.67	3.59E+05	2.54E+05	66	3	1.98E+11	1	52	1626	1678	68	120
73     161     5     Ar.     45     8.96     12.67     199E.05     1.4     1.6     6.24E.10     1     1     3066     3977     72     23       75     161     5     Ar.     45     8.96     1.2.67     2.97E+05     3.0     3.2     1.38E+10     1     1.939915     399915     399915     399915     399915     399915     399915     399915     399915     399915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39915     39916     30016     34814     1     10     3785     3781     31     39915     39937     62.3     340016     34144     33     32415     14154     1.44514     33     324171     1.1     1.4     33     324727     234727     234727     234727     234727     234727     234727     234727     234727     234727     234727     234727     234727	72	161	5	Ar	45	8.96	12.67	6.79E+05	4.80E+05	137	1.6	2.19E+11	1	54	33393	34199	173	227
74   161   5   Ar   45   8.96   12.67   32281+05   2.281+05   54   1   5.106+10   1   25   163984   163994   163994   1911   1913   545     76   161   5   Ar   45   8.96   12.67   2.378+05   1.381+06   45   0.32   1.484+10   1   70   395934   1911   1910   395915   395934   1911   1910   395916   228282   22809   2005   70   71   1   Ar   45   8.96   12.67   1.484444   1   3   3.581+11   1   12   4702   4724   68   90     80   71   1   Ar   45   8.96   12.67   3.0824+05   91   1.0918+10   1   1   13   52473   97   70   75   71   1   Ar   45   8.96   12.67   1.2694+11   0   13   15974   1.292472   2.261740   2.3524   39   700   743   1.35295   613   71   1.36174   1.35295 <td< td=""><td>73</td><td>161</td><td>5</td><td>Ar</td><td>45</td><td>8.96</td><td>12.67</td><td>1.99E+05</td><td>1.41E+05</td><td>39</td><td>1.6</td><td>6.24E+10</td><td>1</td><td>11</td><td>3966</td><td>3977</td><td>22</td><td>33</td></td<>	73	161	5	Ar	45	8.96	12.67	1.99E+05	1.41E+05	39	1.6	6.24E+10	1	11	3966	3977	22	33
75   161   5   Ar   45   8.96   12.67   2.07E+05   2.10E+05   51   1   5.10E+10   1   12   163984   164011   518   545     77   161   5   Ar   45   8.96   12.67   2.36E+05   1.81E+05   45   0.32   1.38E+11   1   7   528289   2050   2057     78   71   1   Ar   45   8.96   12.67   630E+05   3.63E+11   1   12   2.4702   4724   68   90     80   71   1   Ar   45   8.96   12.67   5.00E+05   3.82E+05   99   1.6   1.58E+11   1   1.3   2.3277   2.34740   925   9383   3   3.152945   1.52957   6.30   6.33   3.33   3.02   9.00E+10   1   3.152945   1.52957   6.30   6.33   3.34   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64   3.64<	74	161	5	Ar	45	8.96	12.67	3.23E+05	2.28E+05	54	1	5.40E+10	1	25	164982	165007	760	785
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	75	161	5	Ar	45	8.96	12.67	2.97E+05	2.10E+05	51	1	5.10E+10	1	27	163984	164011	518	545
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	76	161	5	Ar	45	8.96	12.67	2.47E+05	1.75E+05	43	0.32	1.38E+10	1	19	395915	395934	1911	1930
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	79	161	5	Ar	45	8.96	12.67	2.56E+05	1.81E+05	45	0.32	1.44E+10	1	10	528282 2785	528289 2705	2050	2057
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	70	71	1	Ar	45	8.90	12.07	1.49E+03	1.03E+03 4.81E±05	121	3	0.90E+10	1	22	3783	5795 4724	10	20
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	80	71	1	Ar	45	8.96	12.67	3.96E+05	2.80E+05	74	16	1.18E+11	1	15	146490	146505	720	735
82   71   1   Ar   45   8.96   12.67   1.26E+05   8.91E+04   19   1   1.90E+10   1   3   152954   152957   65.0   978     84   71   1   Ar   45   8.96   12.67   1.01E+06   997E+05   2.09E+11   0   0.1   14   1316421   1E+06   6103   6117     85   71   1   Ar   45   8.96   1.2.67   1.07E+06   1.00E+06   22   3   3.96E+11   0   15   74051   74051   74053   711   3   3.71   1   Ar   60   8.96   1.792   1.00E+06   502E+05   1.32   3   3.96E+11   1   302   30233   2.3023   2.3233   2.3023   2.3233   2.3233   2.326   3.396E+11   1   302   3023   2.302E+11   1   302   3.349   3.349   3.349   3.349   3.349   3.349   3.349   3.349   3.349   3.349   3.341   3.348   3.466   3.353   3.1848   3.3654   3.458   3	81	71	1	Ar	45	8.96	12.67	5.40E+05	3.82E+05	99	1.6	1.58E+11	1	13	234727	234740	925	938
83   71   1   Ar   45   8.96   12.67   1.41E-06   907E+05   20.960E+08   1   1   41516421   1E-06   6103   6117     85   71   1   Ar   45   8.96   12.67   1.47E+06   1.04E+06   202   3   8.46E+11   0   15   74051   74066   311   326     86   71   1   Ar   60   8.96   1.792   1.00E+06   5.00E+05   122   3   3.96E+11   0   18   1060   1078   53   71     88   71   1   Ar   60   8.96   1.792   1.24E+06   6.20E+05   120   1.6   2.36E+11   1   302   230233   230263   1448   1449     90   71   1   Ar   60   8.96   1.792   1.30E+06   5.20E+05   2.1   1.2.36E+11   1   46   272683   272729   1303   1349   142     91   71   1   Ar   60   8.96   1.792   1.30E+05   512   0.	82	71	1	Ar	45	8.96	12.67	1.26E+05	8.91E+04	19	1	1.90E+10	1	3	152954	152957	630	633
84   71   1   Ar   45   8,96   12.67   2.03E+04   1.4E+04   3   0.32   9.60E+08   1   14   1316421   1E+066   6103   6111   326     85   71   1   Ar   60   8.96   17.92   2.00E+06   100E+06   282   3   8.46E+11   0   50   2073   2123   127   177     87   71   1   Ar   60   8.96   17.92   1.3E+06   6.20E+05   180   1.6   2.88E+11   0   1060   1078   5.3   71     88   71   1   Ar   60   8.96   17.92   1.3E+06   6.20E+05   16   2.06E+11   1   300   230233   230263   1448   1449     90   71   1   Ar   60   8.96   17.92   3.0E+05   2.30E+05   2.36E+11   1   46   22683   272729   1.333   184   94   161   5   Ar   60   8.96   17.92   3.0E+05   5.12   0.32   7.80E+10   1 </td <td>83</td> <td>71</td> <td>1</td> <td>Ar</td> <td>45</td> <td>8.96</td> <td>12.67</td> <td>1.41E+06</td> <td>9.97E+05</td> <td>209</td> <td>1</td> <td>2.09E+11</td> <td>0</td> <td>31</td> <td>495</td> <td>526</td> <td>39</td> <td>70</td>	83	71	1	Ar	45	8.96	12.67	1.41E+06	9.97E+05	209	1	2.09E+11	0	31	495	526	39	70
85   71   1   Ar   45   89.6   12.67   1.47E+06   1.04E+06   2007   0.22   66.2E+10   0   15   74056   311   326     86   71   1   Ar   60   89.6   17.92   1.04E+06   500E+05   132   3   3.846E+11   0   50   2073   320233   320433   460010   106   90   1211   147   4001   1211   400   4229   93   11   Ar   60   8.96   17.92   1.05E+06   50E+05   152   4023   7.81E+10   0   12   84538   406	84	71	1	Ar	45	8.96	12.67	2.03E+04	1.44E+04	3	0.32	9.60E+08	1	14	1316421	1E+06	6103	6117
86   71   1   Ar   60   8.96   17.92   2.00E+06   1.00E+06   282   3   8.96E+11   0   50   2073   2.123   127   177     87   71   1   Ar   60   8.96   17.92   1.24E+06   5.02E+05   180   1.6   2.88E+11   1   30   2.30233   2.30263   1.468   1498     89   71   1   Ar   60   8.96   17.92   3.18E+06   9.05E+05   2.36   1   2.36E+11   1   46   2.22633   2.27279   1.303   1.349     91   71   1   Ar   60   8.96   1.792   2.00E+06   1.00E+06   2.42   2.3   3.6   1.28   8.47937   850812   4901   4929   3.3   46   1.82   3.3   4.6   1.82   3.3   4.6   1.82   3.3   4.6   1.82   3.3   4.8   4.06   4.18   4.93   7.8   1.43   4.93   5.7   3.6   4.18   4.93   5.7   3.20E+10   1.2   8.4534	85	71	1	Ar	45	8.96	12.67	1.47E+06	1.04E+06	207	0.32	6.62E+10	0	15	74051	74066	311	326
	86	71	1	Ar	60	8.96	17.92	2.00E+06	1.00E+06	282	3	8.46E+11	0	50	2073	2123	127	177
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	87	71	1	Ar	60	8.96	17.92	1.00E+06	5.00E+05	132	3	3.96E+11	0	18	1060	10/8	53	1409
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	00 89	71	1	Ar Ar	60	8.90	17.92	1.24E+00 9.37E±05	0.20E+03	120	1.0	2.00E+11 2.06E+11	1	3602	250255 456408	250205 460010	1408	1498
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	90	71	1	Ar	60	8.96	17.92	1.81E+06	9.05E+05	236	1.0	2.00E+11	1	46	272683	272729	1303	1349
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	91	71	1	Ar	60	8.96	17.92	7.80E+05	3.90E+05	91	1	9.10E+10	1	28	847937	850812	4901	4929
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	92	71	1	Ar	60	8.96	17.92	2.00E+06	1.00E+06	244	0.32	7.81E+10	0	13	169	182	33	46
94   161   5   Ar   60   8.96   17.92   3.82E+05   1.91E+05   67   3   2.01E+11   1   65   1853   1918   78   143     95   161   5   Ar   60   8.96   17.92   5.52E+04   2.76E+04   9   1.6   1.44E+10   1   4   223011   223015   888   892     97   161   5   Ar   60   8.96   17.92   5.67E+04   2.84E+04   9   1.6   1.44E+10   1   7   297086   297093   1225   1332     98   161   5   Ar   60   8.96   17.92   2.84E+04   24   2.40E+10   1   13   280604   280617   1225   1332     101   161   5   Ar   60   8.96   17.92   2.84E+04   14   0.32   3.52E+09   1   6   183160   183166   866   872     101   161   5   Kr   0   30   30.00   7.5E+04   1.33   3.90E+10   1	93	71	1	Ar	60	8.96	17.92	1.00E+06	5.00E+05	152	0.32	4.86E+10	0	12	84536	84548	406	418
95   161   5   Ar   60   8.96   17.92   1.75E+05   8.75E+04   26   3   7.80E+10   1   33   534   567   36   69   96   161   5   Ar   60   8.96   17.92   5.52E+04   2.84E+04   9   1.6   1.44E+10   1   7   297086   297093   1225   1232     98   161   5   Ar   60   8.96   17.92   5.47E+04   2.84E+04   9   1.6   1.44E+10   1   7   297086   297093   1225   1232     98   161   5   Ar   60   8.96   17.92   2.84E+04   1.42E+04   5   1   5.00E+09   1   1   280604   2280617   1293   1306     101   161   5   Ar   60   8.96   17.92   6.72E+04   3.36E+04   11   0.32   2.53E+10   1   293   348284   348313   1264   1293     102   161   5   Kr   0   30   30.00   7.57E+04   1.3 <td>94</td> <td>161</td> <td>5</td> <td>Ar</td> <td>60</td> <td>8.96</td> <td>17.92</td> <td>3.82E+05</td> <td>1.91E+05</td> <td>67</td> <td>3</td> <td>2.01E+11</td> <td>1</td> <td>65</td> <td>1853</td> <td>1918</td> <td>78</td> <td>143</td>	94	161	5	Ar	60	8.96	17.92	3.82E+05	1.91E+05	67	3	2.01E+11	1	65	1853	1918	78	143
96   161   5   Ar   60   8.96   17.92   5.52E+04   2.76E+04   9   1.6   1.44E+10   1   4   223011   223015   888   882     97   161   5   Ar   60   8.96   17.92   5.67E+04   2.84E+04   9   1.6   1.44E+10   1   7   297086   297093   1225   1232     98   161   5   Ar   60   8.96   17.92   2.84E+04   1.42E+04   5   1   5.00E+09   1   1   262440   1420   1421     100   161   5   Ar   60   8.96   17.92   6.72E+04   3.05E+04   11   0.32   2.53E+10   1   29   348284   348313   1264   1293     102   161   5   Kr   0   30   30.00   7.57E+04   1.3   3   3.90E+10   1   38   5101   5139   60   98   105   161   5   Kr   0   30   30.00   7.57E+04   1.3   3<.300E+10	95	161	5	Ar	60	8.96	17.92	1.75E+05	8.75E+04	26	3	7.80E+10	1	33	534	567	36	69
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	96	161	5	Ar	60	8.96	17.92	5.52E+04	2.76E+04	9	1.6	1.44E+10	1	4	223011	223015	888	892
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	97	161	5	Ar	60	8.90	17.92	5.6/E+04	2.84E+04	24	1.0	1.44E+10 2.40E+10	1	12	297080	297093	1225	1232
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	90	161	5	Ar Ar	60	8.90	17.92	1.47E+0.03 2.84E+0.04	1.55E+04	24	1	2.40E+10 5.00E±09	1	15	260004	260017	1420	1421
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	100	161	5	Ar	60	8.96	17.92	672E+04	3 36E+04	11	0.32	3.52E+09	1	6	183160	183166	866	872
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	101	161	5	Ar	60	8.96	17.92	4.48E+05	2.24E+05	79	0.32	2.53E+10	1	29	348284	348313	1264	1293
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	102	161	5	Kr	0	30	30.00	4.47E+04	4.47E+04	0	3	0.00E+00		51	363883	363934	1610	1661
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	103	161	5	Kr	0	30	30.00	7.57E+04	7.57E+04	13	3	3.90E+10	1	38	5101	5139	60	98
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	104	161	5	Kr	0	30	30.00	5.82E+04	5.82E+04	10	3	3.00E+10	1	35	29271	29306	258	293
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	105	161	5	Kr	0	30	30.00	4.15E+04	4.15E+04	7	1.6	1.12E+10	1	7	183313	183320	616	623
107   161   5   Kr   0   30   30.00   5.96E+04   7   1   7.00E+09   1   4   7106   7110   30   34     108   161   5   Kr   0   30   30.00   1.81E+04   1.81E+04   3   1   3.00E+09   1   5   760664   760669   2811   2816     109   161   5   Kr   0   30   30.00   7.14E+04   7.14E+04   14   0.32   4.48E+09   1   34   6186   6220   101   135     110   161   5   Kr   0   30   30.00   8.75E+04   8.75E+04   20   0.32   6.40E+09   1   17   304282   304299   1084   1101     111   71   1   Kr   0   30   30.00   5.00E+05   5.03E+05   122   3   3.66E+11   0   55   2143   2198   133   188     113   71   1   Kr   0   30   30.00   3.01E+05   108   1.6   <	106	161	5	Kr	0	30	30.00	2.55E+05	2.55E+05	45	1.6	7.20E+10	1	59	249163	249222	891	950
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	107	161	5	Kr	0	30	30.00	3.96E+04	3.90E+04	3	1	7.00E+09	1	4	760664	760660	2811	2816
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	108	161	5	Kr	0	30	30.00	7.14E+04	7.14E±04	14	0.32	3.00E+09 4.48E±09	1	34	6186	6220	101	135
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	110	161	5	Kr	ő	30	30.00	8.75E+04	8.75E+04	20	0.32	6.40E+09	1	17	304282	304299	101	1101
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	111	71	1	Kr	0	30	30.00	5.03E+05	5.03E+05	122	3	3.66E+11	0	55	2143	2198	133	188
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	112	71	1	Kr	0	30	30.00	5.00E+05	5.00E+05	133	3	3.99E+11	1	33	2387	2420	106	139
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	113	71	1	Kr	0	30	30.00	9.46E+04	9.46E+04	28	1.6	4.48E+10	1	8	228970	228978	1130	1138
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	114	71	1	Kr	0	30	30.00	3.01E+05	3.01E+05	108	1.6	1.73E+11	1	44	230607	230651	875	919
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	115	71	1	Kr	0	30	30.00	5.59E+05	5.59E+05	166	1	1.66E+11	0	28	633	661	62	90
117   71   1   Kr   0   50   50.00   5.68E+0.5   2   0.32   6.40E+08   1   2   457/71   457/73   2240   2242     118   71   1   Kr   0   30   30.00   2.27E+05   2.66   0.32   2.11E+10   1   7   4495   4502   12   19     119   71   1   Kr   60   30   60.00   1.22E+05   6.10E+04   33   3   9.90E+10   1   23   270601   270624   980   1003     120   71   1   Kr   60   30   60.00   5.85E+04   2.93E+04   17   3   5.10E+10   1   11   229575   229586   998   1003     120   71   1   Kr   60   20   5.5EE+04   2.93E+04   17   3   5.10E+10   1   11   229575   229586   998   1009     121   71   1   Kr   60   20   5.5EE+04   2.92E+04   17   3   5.10E+10   1	116	71	1	Kr	0	30	30.00	4.00E+05	4.00E+05	115	1	1.15E+11	0	30	794	824	58	88
116   /1   1   Ki   0   50   50.00   2.27E+05   200   0.32   2.11E+10   1   /   4495   4502   12   19     119   71   1   Kr   60   30   60.00   1.22E+05   6.10E+04   33   3   9.90E+10   1   23   270601   270624   980   1003     120   71   1   Kr   60   30   60.00   5.85E+04   2.92E+04   17   3   5.10E+10   1   11   229575   229586   998   1003     121   71   1   Kr   60   30   60.00   5.85E+04   2.92E+04   17   3   5.10E+10   1   11   229575   229586   998   1009     121   71   1   Kr   60   20   5.5EE+04   2.92E+04   17   3   5.10E+10   1   11   229575   229586   998   1009	11/	/1	1	Kľ Vr	0	30 20	30.00	3.08E+03	3.08E+03	2	0.32	0.40E+08	1	2	45///1	45///3	2240	2242
112     71     1     Kr     60     30     60.00     1.221+05     0.102+04     35     5     9.502+10     1     2.5     2/0001     2/0024     980     1003     1003       120     71     1     Kr     60     30     60.00     5.852+04     17     3     5.102+10     1     11     229575     229586     998     1009       201     71     1     Kr     60     30     60.00     5.852+04     17     3     5.102+10     1     11     229575     229586     998     1009       201     71     Kr     60     30     60.00     5.852+04     2.92571     1     10     210575     229586     998     1009	118	/1 71	1	Kr Kr	60	30 30	50.00 60.00	2.27E+05 1.22E±05	2.27E+05 6.10E±04	33	0.52	2.11E+10 9.90E±10	1	23	4495 270601	4502	980	1003
	120	71	1	Kr	60	30	60.00	5.85E+03	2.93E+04	. 17	3	$5.500 \pm 10$ $5.10F \pm 10$	1	23 11	229575	229586	900	1005
121 /1 1 Kr 60 30 60.00 1.13E+06 5.65E+05 284 3 8.52E+11 1 8 4296 4304 27 35	121	71	1	Kr	60	30	60.00	1.13E+06	5.65E+05	284	3	8.52E+11	1	8	4296	4304	27	35