NSRL Fault Studies

A.Rusek

This document contains details and summary of the NSRL fault-study carried out in April 2003. The fault studies were part of the commissioning process. We used protons at 2 GeV (K.E.), 6×10^8/spill with 5.6 sec repetition rate.

Table of Contents

Objectives

The fault study goals were to:

i. Verify that the target room can be designated "uncontrolled" while the booster is operating.

ii. Measure the dose at various points outside the radiation area while controlled faults are occurring, and make decisions as to the correct location and trip levels of the chipmunks.

iii. Measure the radiation on the berm above the stub-tunnel, where shielding thickness is smaller than the design called for, to decide whether or not additional shielding is needed.

Method

Create the 5 faults listed below and check doses in corresponding locations:

a. Beam on RD1 and/or RD2. Survey on the berm, near the entrance to the upstream labyrinth and in the power supply building, near the penetrations. Record all chipmunk readings.

b. Beam scraping the beam pipe along the berm penetration to the power supply building. Survey on the berm, in the power supply building near the penetration and at the entrance to the down stream labyrinth. Record all chipmunk settings.

c. Beam on the gate valve about midway between the berm penetration and the target room. Survey on the berm, in the power supply building, near the penetration and at the entrance to the down stream labyrinth. Record all chipmunk readings.

d. Beam on a thick target in the middle of the target room. Survey near entrance to labyrinth from user support building. Record all chipmunk readings.

e. Beam on the beam dump (normal conditions). Survey near both labyrinth entrances, on the berm and in the power supply building, near the penetration. Record all chipmunk readings.

During each of these setups, a survey of the berm, entrances to the two labyrinths, the power supply building and the user support building will be carried out by HP, using calibrated 1010 instruments.

Layout

Figure 1 shows the layout of the NSRL beam line (R line) along with the target room, the labyrinth leading from it to the users' support building, the cable and bus penetrations leading to the power supply building, and the booster magnet which does the extraction into NSRL (D6). Two views are shown: to the left of the figure is the top view, while to the right is a side view looking at the line from beam-right.
The NSRL facility is divided into three zones: Zone 1 is the target room along with the labyrinth leading from it to the users' support building. Zone 2 is the beam line from the end of the stub tunnel to the target room. Zone 3 is the stub tunnel at the exit from the booster (see figure 1).

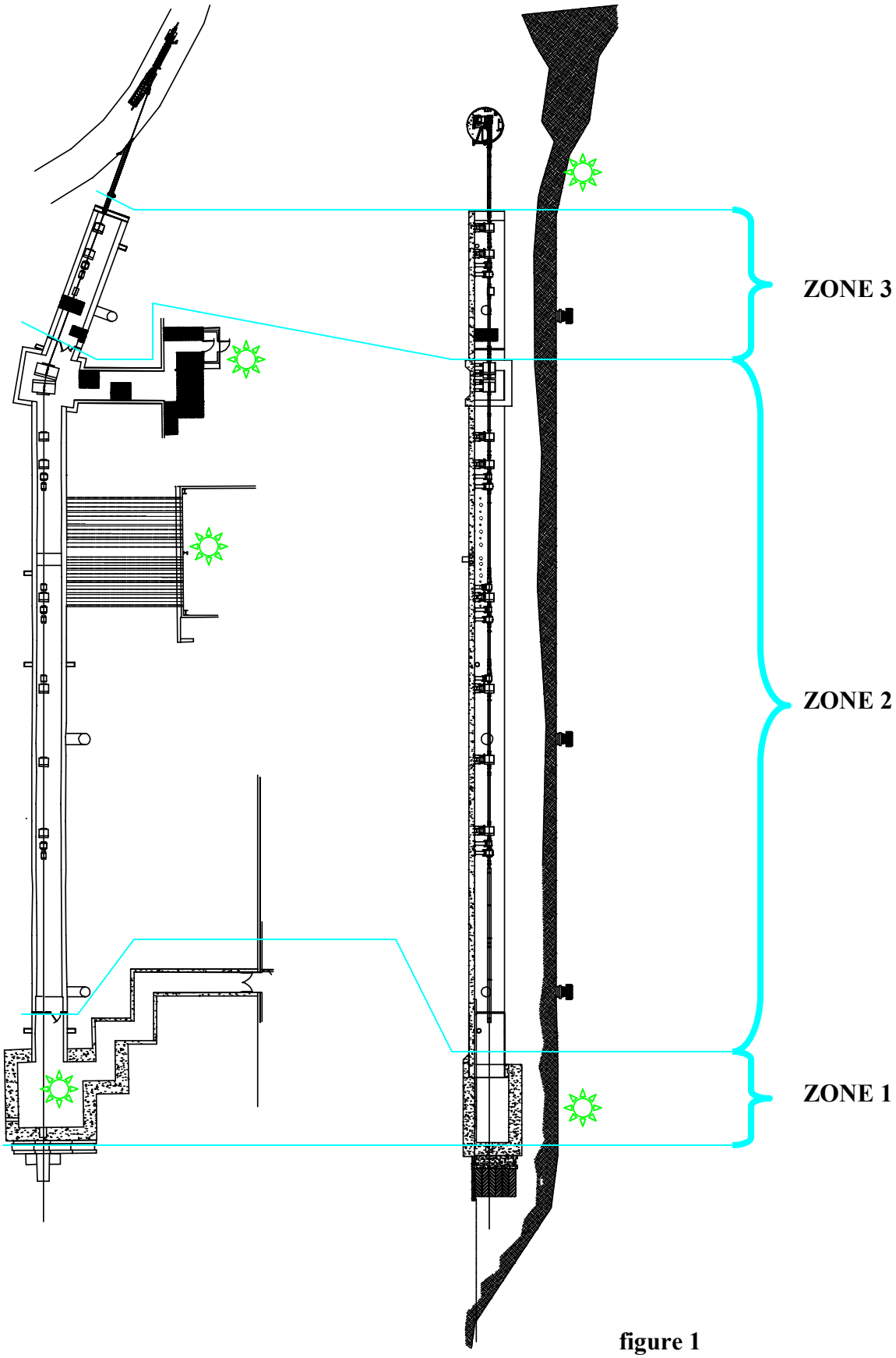


figure 1

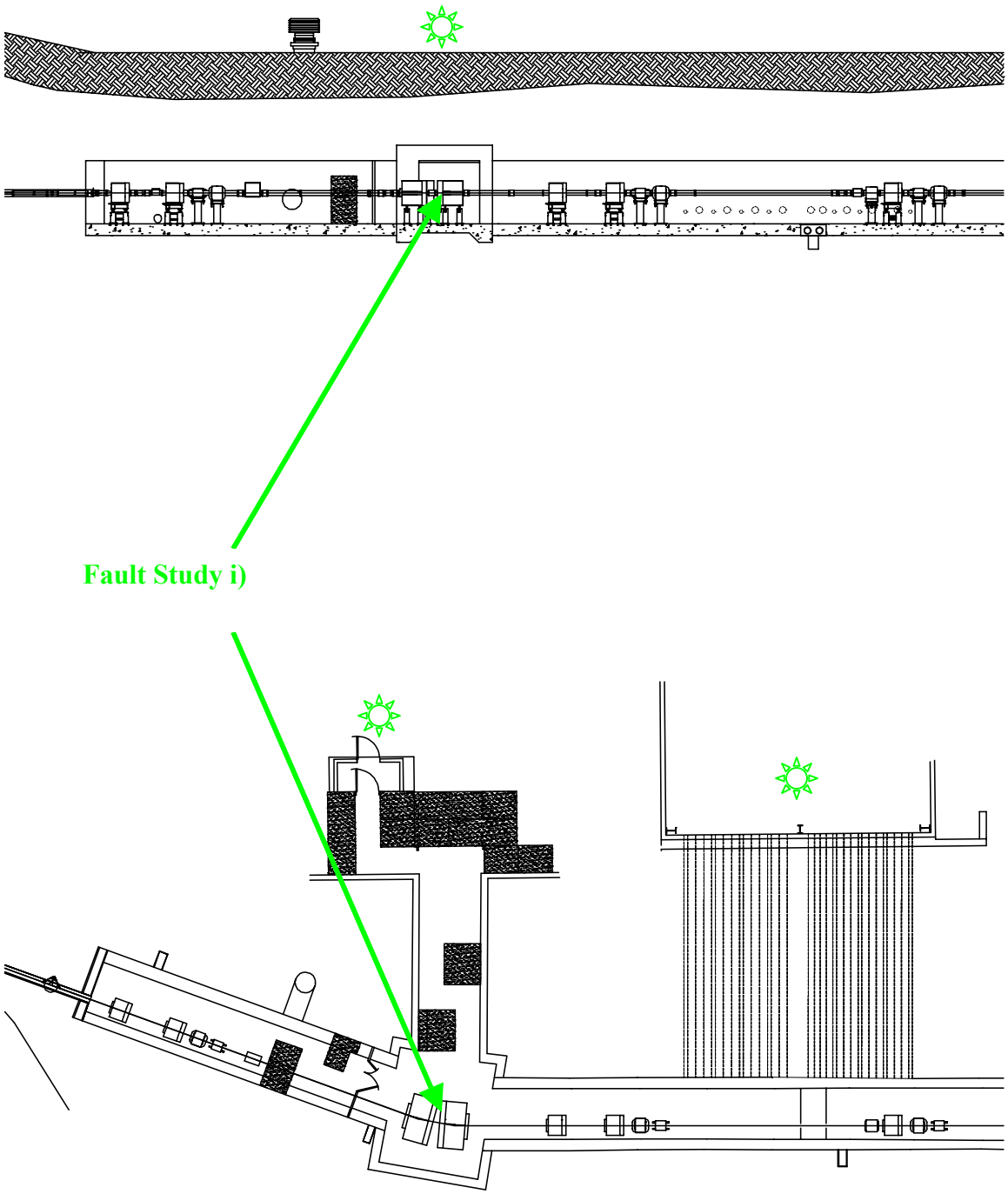


Figure 2

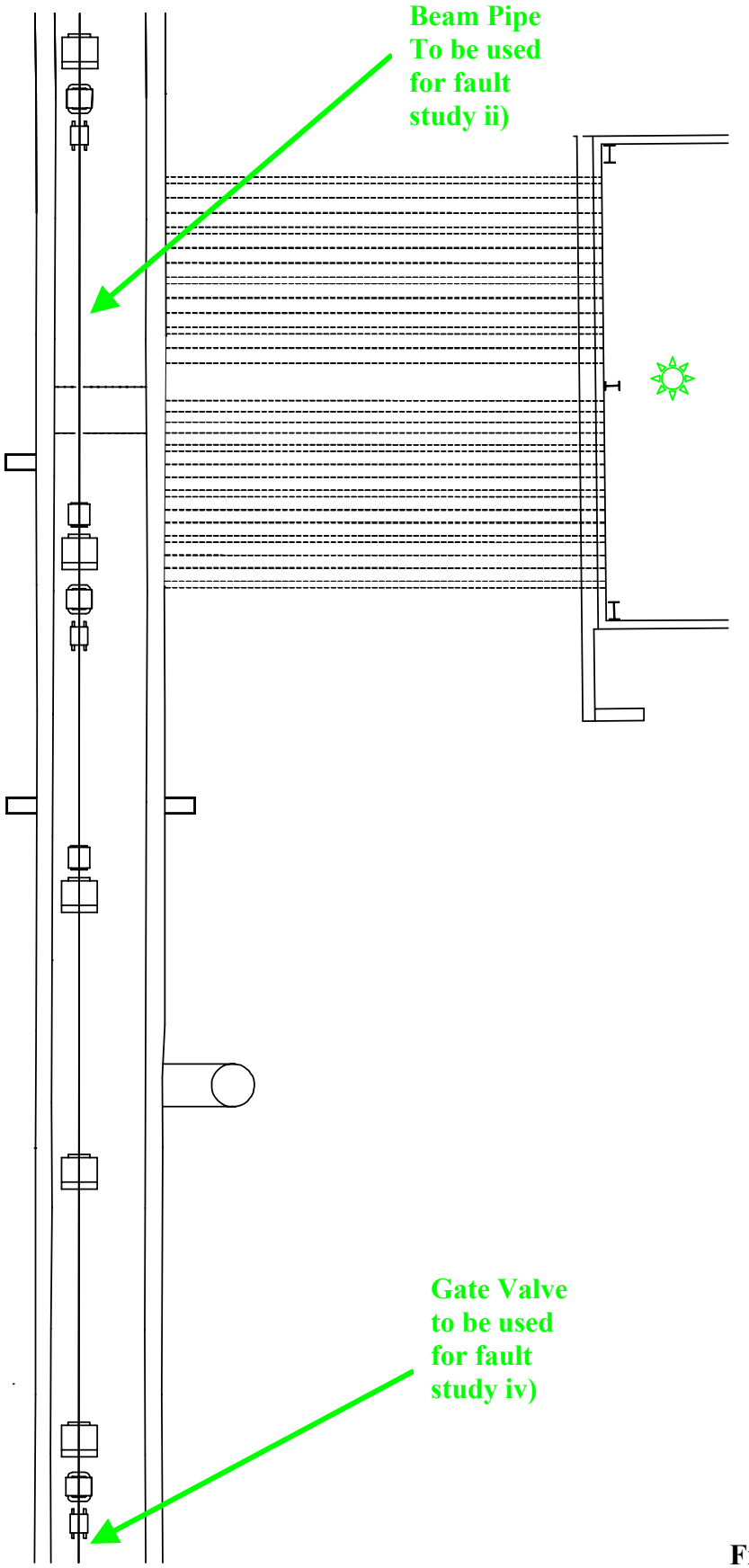

Beam Pipe
To be used
for fault
study ii)
Gate Valve
to be used
for fault
study iv)

Figure 3

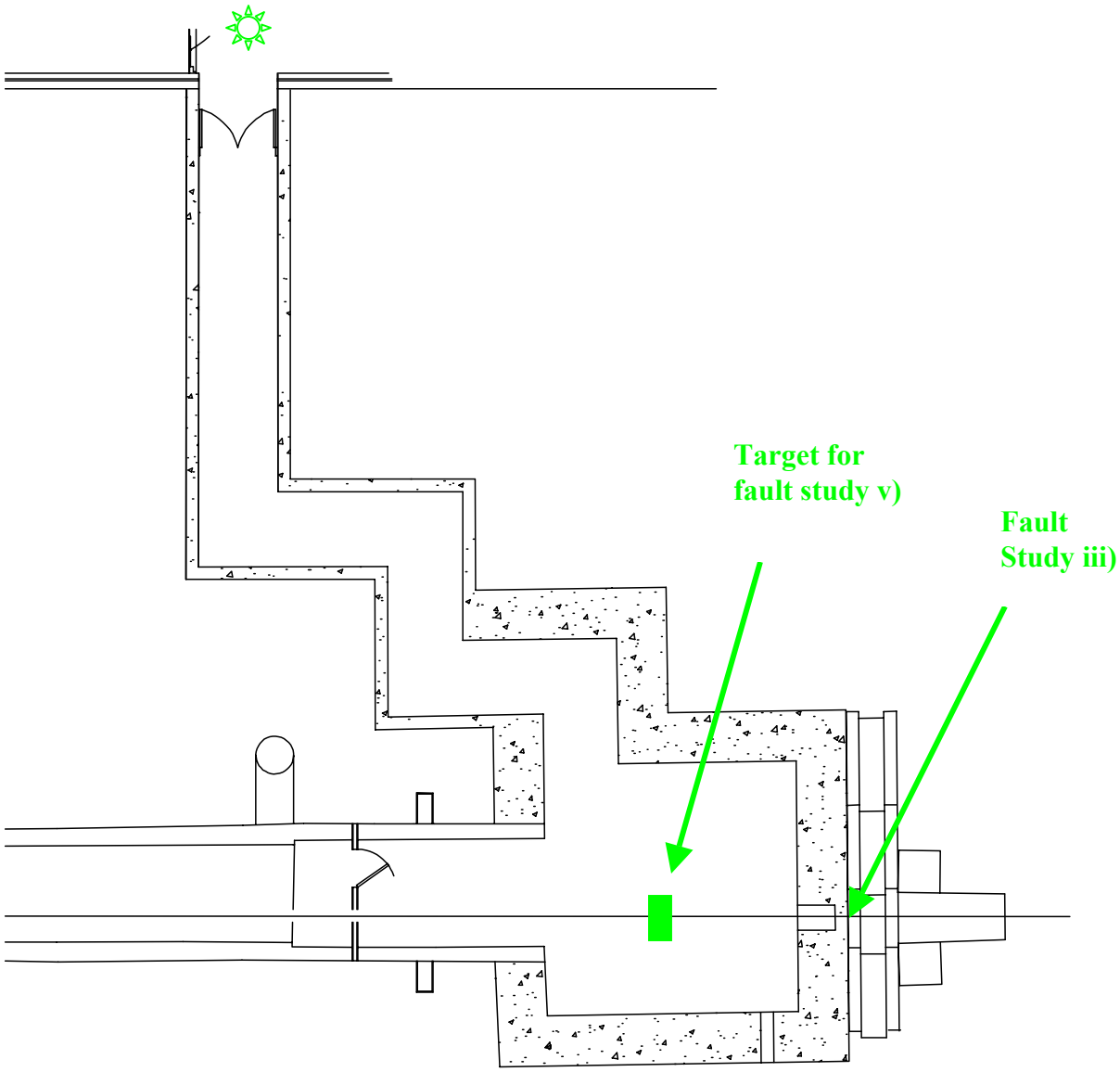


Figure 4

Chipmunks Locations

In addition to the permanent chipmunks, four others were added temporarily to help monitor the radiation in both labyrinths during the fault studies (see figures 5 and 6). In the list below, the temporary chipmunks are marked with a *:

- Up-stream labyrinth (MN138*).
- Up-stream labyrinth (MN137*).
- Target room labyrinth (MN136*).
- Target room labyrinth (MN135*).
- Stub Tunnel, near the exit from the booster (MN134).
- Stub tunnel, near the gate (MN133).
- Up-stream labyrinth, near the personnel entrance (MN132).
- Target room labyrinth, in the bend nearest the entrance gate (MN131).
- On top of the berm, above the beam plug (MN130).

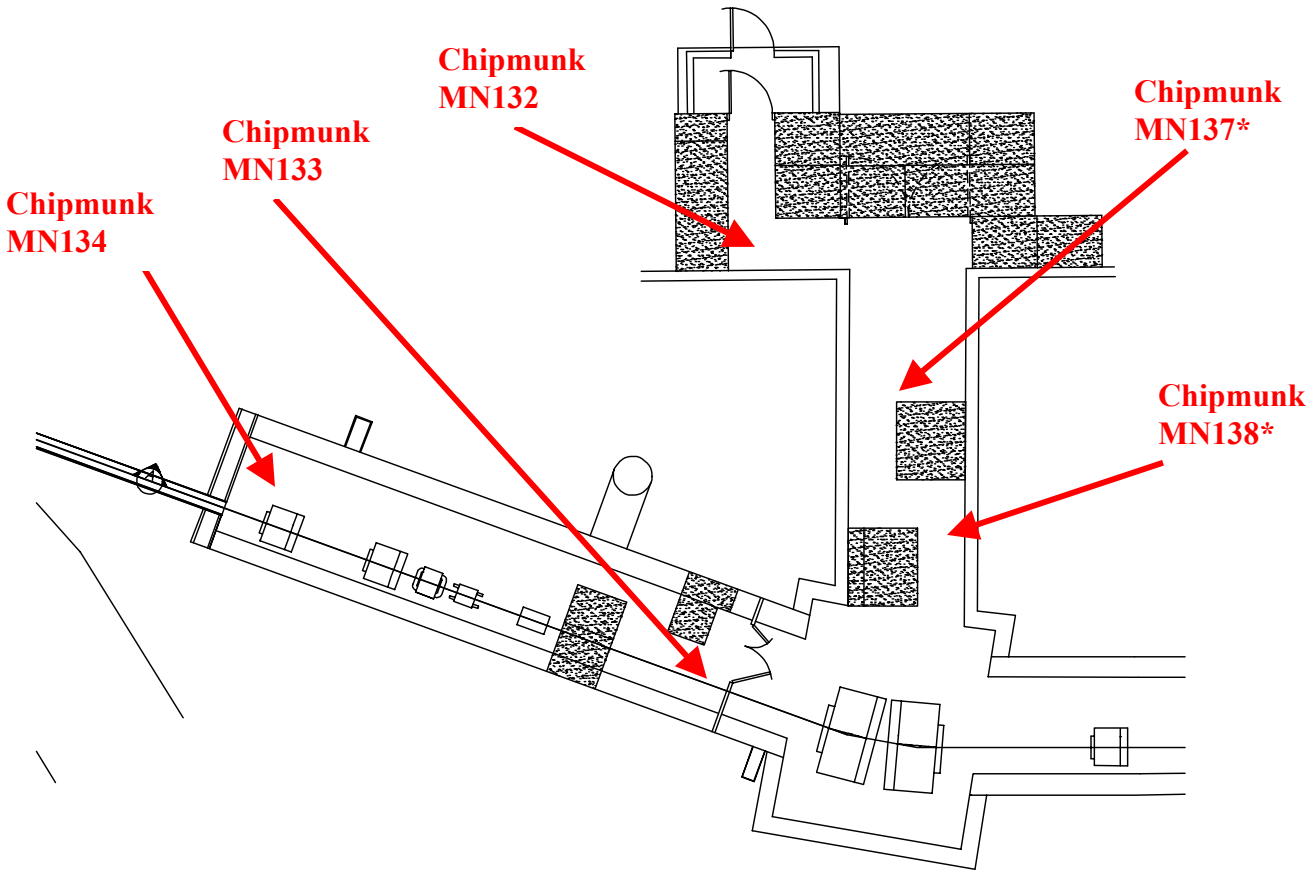


Figure 5

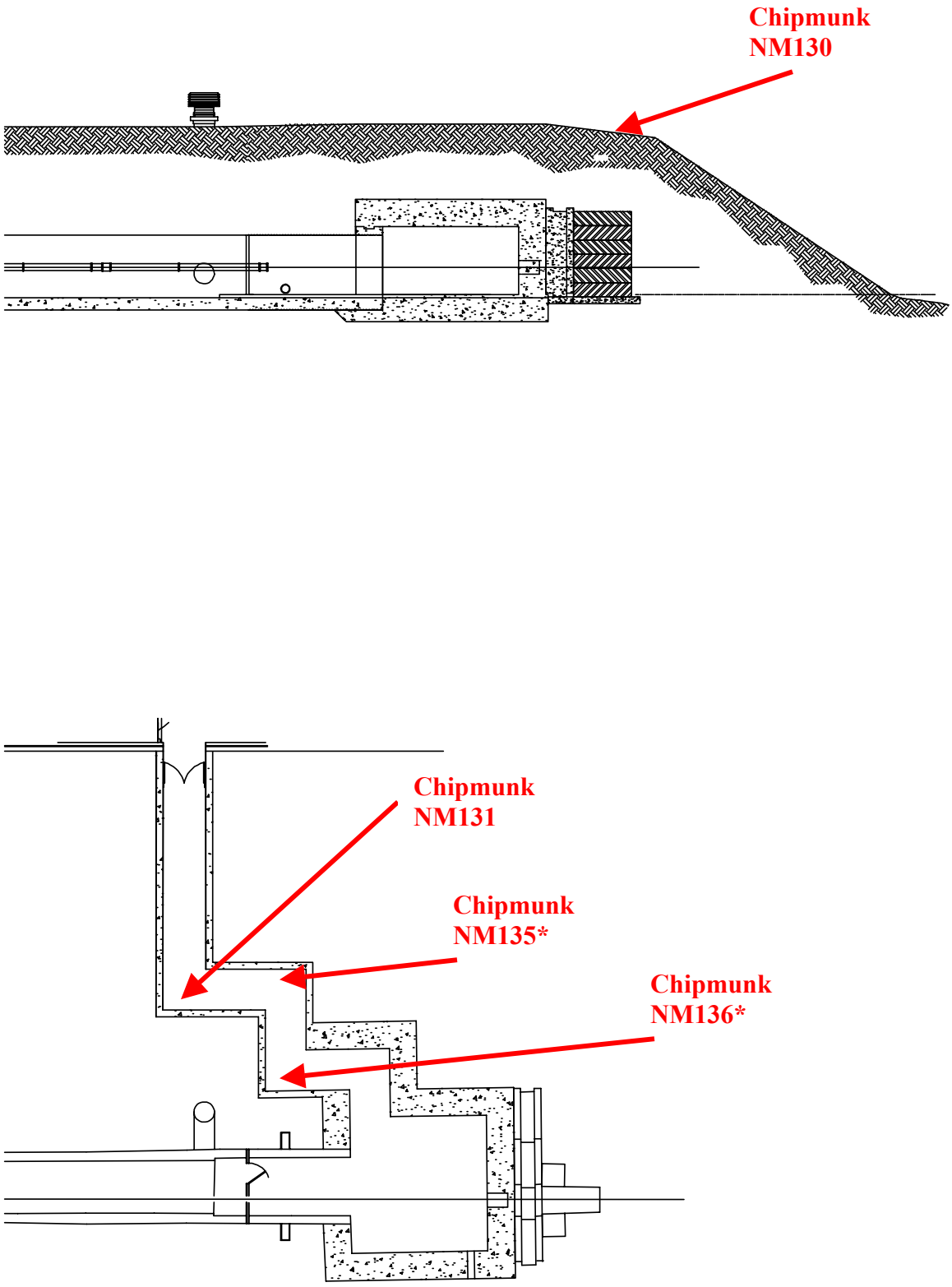

Chipmunk
NM130
Chipmunk
NM131
Chipmunk
NM135*
Chipmunk
NM136*

Figure 6

Fault Studies

The fault studies were carried out with the following beam conditions:

Species: protons
Beam energy: 2 GeV
Intensity: $2-6\times10^{10}$/spill
Spill Length: 0.25 sec.
Repetition rate: 5.4 sec.

Chronology

The fault studies on all but the D6 septum took plce on the evening of April 16th, 2003, starting around 19:30.

20:00 : Taking beam in NSRL at 6×10^{10}/spill. Turned RD1/RD2 off to record chipmunk response.

20:20 : Turned RD1/RD2 back on

20:25 : Retract the 63 instrumentation package

21:15 : In an attempt to steer the beam on to the beam pipe near the power supply penetration, we used the wrong trim magnet and ended up with beam on RD1/RD2 again. This was corrected a few minutes later and the beam was successfully steered onto the beam pipe at the desired location (see figure 9). We looked for radiation in the following locations, and recorded the corresponding readings:

1. Just outside the upstream labyrinth: <0.025 mrem/hour
2. In the power-supply building, near the penetration: 0.200 mrem/hour
3. On the berm, above the fault: <0.025 mrem/hour
4. On the berm, above the beam dump: <0.025 mrem/hour
5. At the entrance to the target room labyrinth: <0.025 mrem/hour
6. At the berm fence, between 957 and 958: <0.025 mrem/hour

22:10 : Established clean transport to beam dump. Looked for radiation in the following locations, and recorded the corresponding readings:

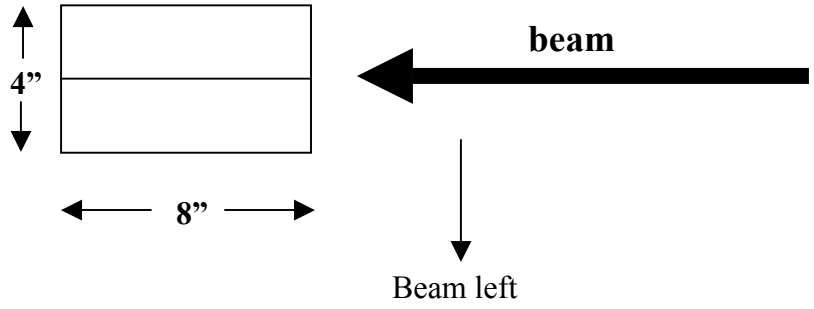
1. At the entrance to the target room labyrinth: 0.030 mrem/hour
2. On the berm, above the beam dump: <0.025 mrem/hour

22:20 : Closed the gate valve located about half way between the berm penetration and the target room. Looked for radiation in the following locations, and recorded the corresponding readings:

1. On the berm, above the fault: <0.025 mrem/hour
2. At the berm fence between 957 and 958: <0.025 mrem/hour
3. In the power-supply building, near penetration: <0.025 mrem/hour

22:35 : Retract the gate valve.

22:45 : Beam off. We went in to the target room to place Iron bricks in the beam. The bricks were arranged as shown below:



23:15 : Beam back at 5×10^{10}/spill.

23:35 : Reducing beam size to ensure all of it hits the target.

23:45 : Looked for radiation in the following locations, and recorded the corresponding readings:

1. At the entrance to the target room labyrinth: 0.050 mrem/hour
2. On the berm, above the target : <0.025 mrem/hour

24:00 : Fault study done.

Chipmunk data

Figures 7-9 display the chipmunk logs, with the horizontal axes in time (5 minute bins) and the vertical axes in mrem/hour. These are grouped according to their locations in NSRL. The two chipmunks in the stub-tunnel are in figure 7, the three in the target room labyrinth in figure 8 and the three in the upstream labyrinth in figure 9. The times at which different events listed above took place are marked on these figures with green vertical lines. In figures 7 and 9, one can see the levels reached during the fault on RD1/RD2 early in the study. In figure 8, the levels reached at each of the chipmunks during the thick target fault, late in the study. I analyzed these in groups:

The Upstream Labyrinth (NM132, NM137, NM138):

Around 20:00, RD1/RD2 was turned off so beam was faulting on its downstream end. The chipmunks read:

NM138: 1430 mrem/hour
NM137: 5.2 mrem/hour
NM132: 0.32 mrem/hour

Around 21:20, we steered the beam onto the beam pipe by the berm penetration. The chipmunks read:

NM138: 530 mrem/hour
NM137: 3.2 mrem/hour
NM132: 0.15 mrem/hour

The ratio of NM138 readings to those of NM137 are very different for the two faults, but this is likely due to the fact that NM138 is in direct line with the RD1/RD2 magnets, and saw direct charged products during the first fault. During the second fault it was shielded from direct exposure.
Using the scaling from the beam pipe fault, and the numbers given above, and given the current trip level on NM132, it will trip at the following instantaneous rates:

- 2×10^{12} /second during a fault on RD1/RD2.
- 4×10^{12} /second during a fault on the beam pipe.
- 9×10^{13} /second during clean transport to the dump.

During clean transport, at the said rate, the level at the target room gate would be ~1.5 mrem/hour.

The Target Room Labyrinth (NM131, NM135, NM136):

Around 20:40, there is a spike in the chipmunk readings during transport to the dump. The chipmunks read:

NM136: 6.2 mrem/hour
NM135: 1.0 mrem/hour
NM131: 0.15 mrem/hour

During the thick target fault, from 23:30 to 00:00, the chipmunks read:

NM136: 30 mrem/hour
NM135: 4.2 mrem/hour
NM131: 0.7 mrem/hour

During the fault on the beam pipe, around 22:00, the chipmunks read:

NM136:	2.5 mrem/hour
NM135:	0.45 mrem/hour
NM131:	0 mrem/hour

Using the scaling from the first two faults, and the numbers given above, and given the current trip level on NM131, it will trip at the following instantaneous rates:

- 8×10^{11} /second during a thick target exposure.
- 9×10^{12} /second during a fault on the gate valve.
- 1×10^{13} /second during clean transport to the dump.

Under these conditions, the rate at the gate would be ~0.2 mrem/hour.

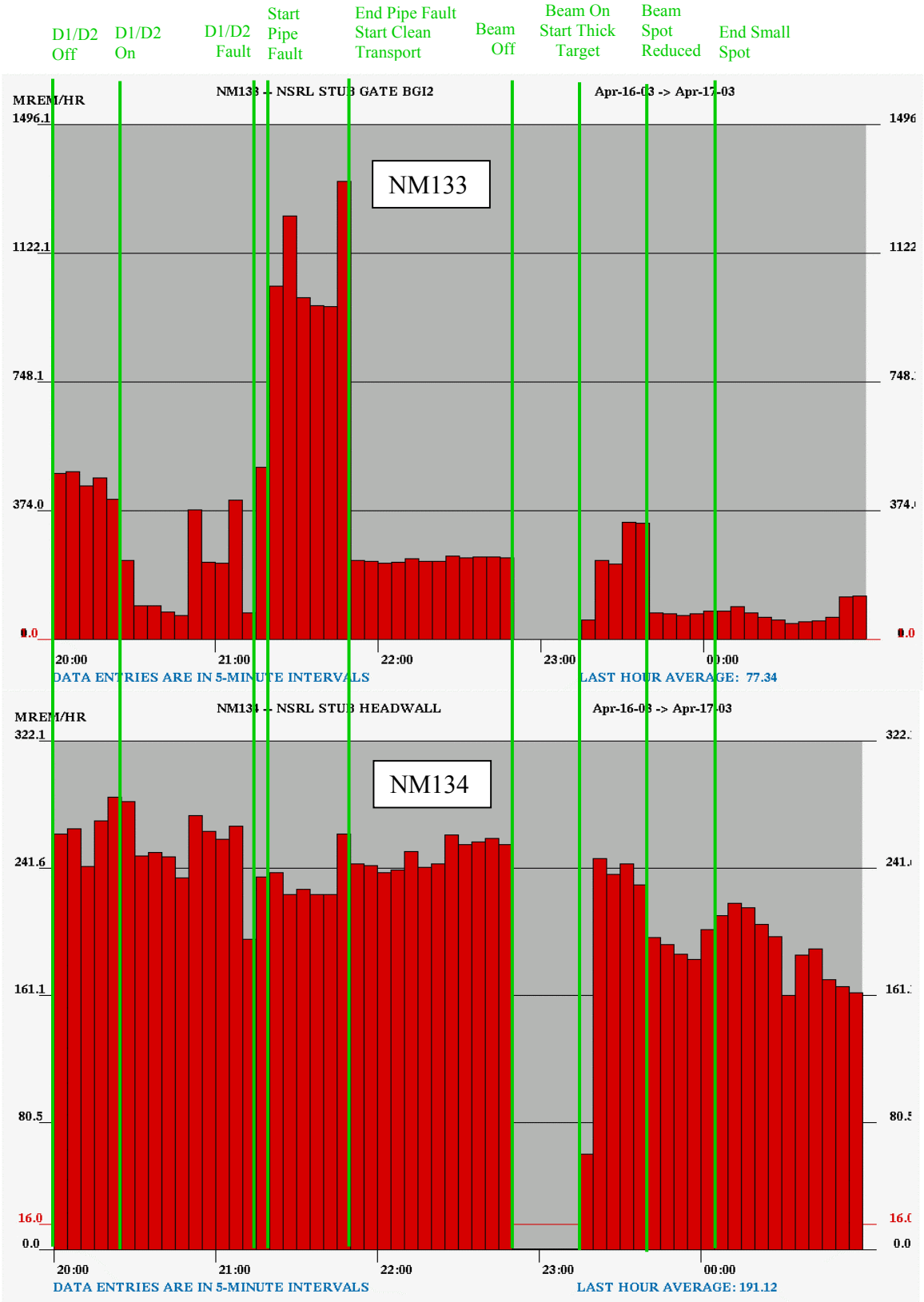

D1/D2 Off
D1/D2 On
D1/D2 Fault
Start Pipe Fault
End Pipe Fault Start Clean Transport
Beam Off
Beam On Start Thick Target
Beam Spot Reduced
End Small Spot
MREM/HR
NM133 -- NSRL STUB GATE BGI2
Apr-16-03 -> Apr-17-03
1496.1
1122.1
748.1
374.0
0.0
NM133
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 77.34
MREM/HR
NM134 -- NSRL STUB HEADWALL
Apr-16-03 -> Apr-17-03
322.1
241.6
161.1
80.5
16.0
0.0
NM134
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 191.12

Figure 7

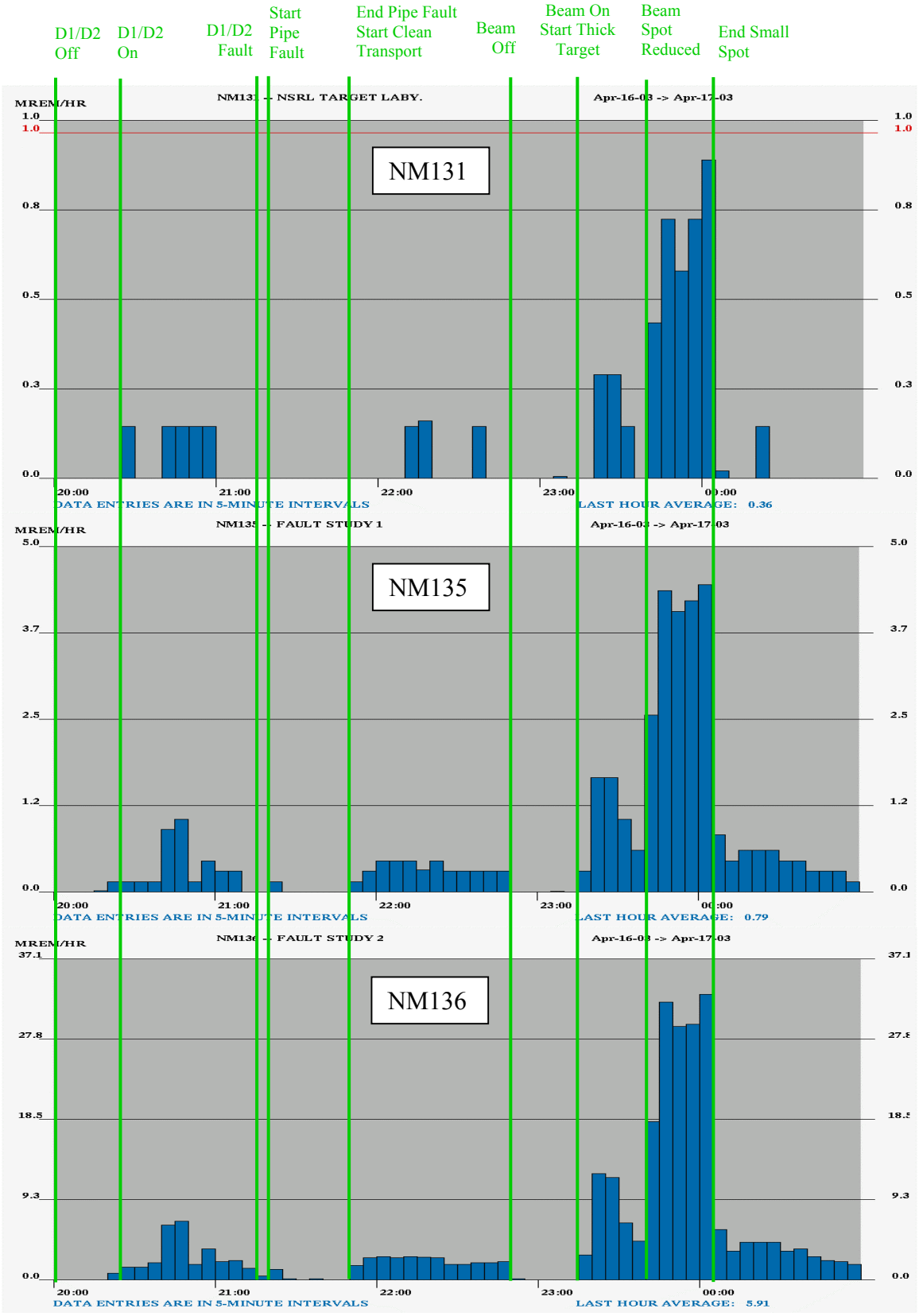

D1/D2 Off
D1/D2 On
D1/D2 Fault
Start Pipe Fault
End Pipe Fault Start Clean Transport
Beam Off
Beam On Start Thick Target
Beam Spot Reduced
End Small Spot
NM131
MREM/HR
1.0
0.8
0.5
0.3
0.0
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 0.36
NM135
MREM/HR
5.0
3.7
2.5
1.2
0.0
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 0.79
NM136
MREM/HR
37.1
27.8
18.5
9.3
0.0
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 5.91

Figure 8

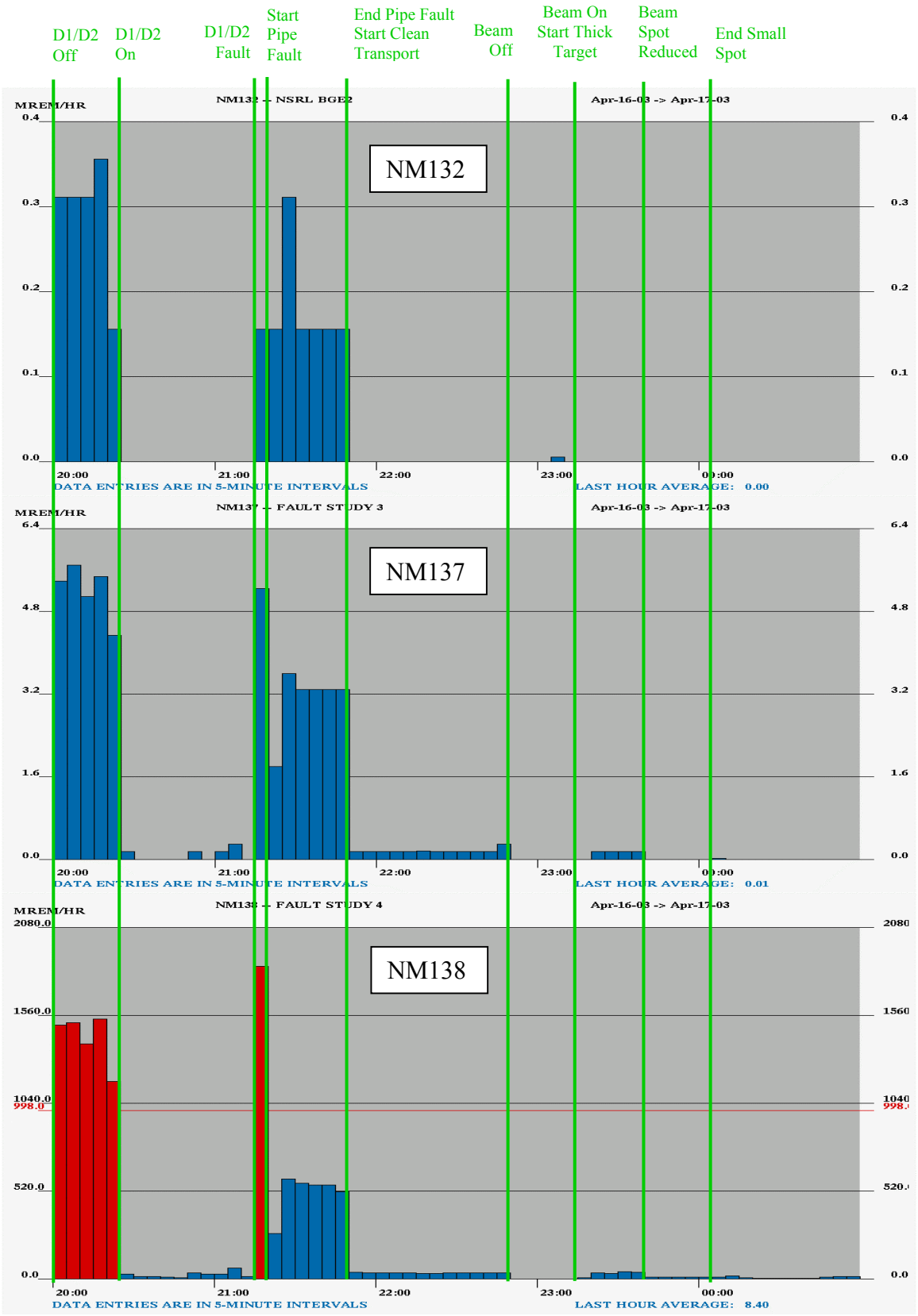

D1/D2 Off
D1/D2 On
D1/D2 Fault
Start Pipe Fault
End Pipe Fault Start Clean Transport
Beam Off
Beam On Start Thick Target
Beam Spot Reduced
End Small Spot
NM132
NM137
NM138
MREM/HR
Apr-16-03 -> Apr-17-03
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 0.00
LAST HOUR AVERAGE: 0.01
LAST HOUR AVERAGE: 8.40

Figure 9

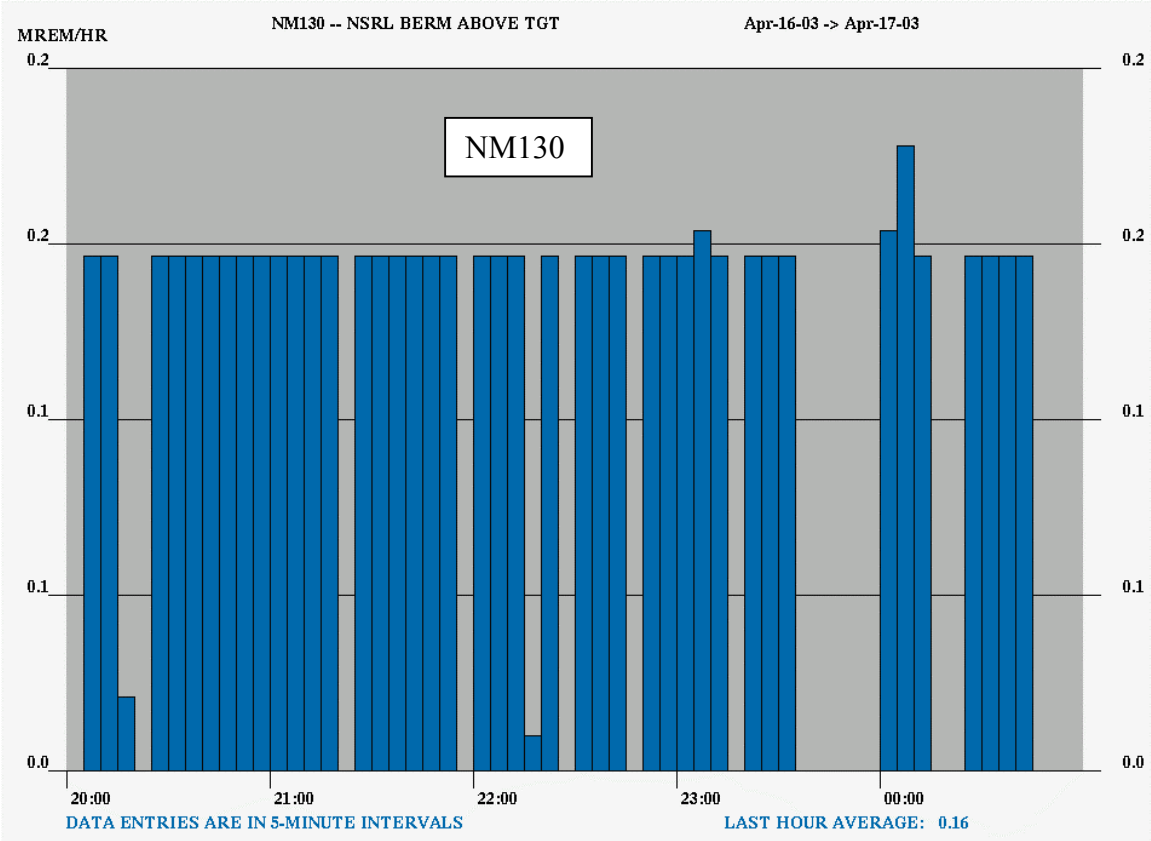

NM130 -- NSRL BERM ABOVE TGT
Apr-16-03 -> Apr-17-03
MREM/HR
0.2
0.1
0.0
NM130
20:00
21:00
22:00
23:00
00:00
DATA ENTRIES ARE IN 5-MINUTE INTERVALS
LAST HOUR AVERAGE: 0.16

Figure 10

Results Summarized

The tables below summarize the results of the fault studies. The first lists the expected dose rate at the three permanent chipmunk locations during a high-intensity, high-energy proton faults. The second lists the dose received at key locations during 5-second faults with the same beam.

Dose rates during high intensity fault (3.07 GeV protons at 10^{14}/sec)

Fault on:	D1/D2	Beam Pipe	Gate Valve	Thick Target	Beam Dump
NM130				5.0 rem/h*	5.0 rem/hr*
NM131			1.0 rem/h	11.4 rem/h	2.5 rem/h
NM132	5.2 rem/h	2.5 rem/h	63 mrem/h	63 mrem/h	63 mrem/h

* Based on calculation, not measurement

Dose during a 5 second high intensity fault

Fault on:	D1/D2	Beam Pipe	Gate Valve	Thick Target	Beam Dump
Upstream Labyrinth	7.2 mrem	3.5 mrem	0.1 mrem	0.1 mrem	0.1 mrem
Building 957		1.18 mrem			
Fence	1.6* mrem	1.6* mrem	1.6* mrem	1.6* mrem	1.6* mrem
Berm	25.7* mrem	25.7* mrem	25.7* mrem	25.7* mrem	25.7* mrem
Downstream Labyrinth	0.8 mrem	0.8 mrem	0.8 mrem	15.8 mrem	0.05 mrem

* Based on calculation, not measurement