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Results of dose control and measurement plans applied for SPEAR3 commissioning year (FY04)

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Abstract

Dose control and measurement plans for the SPEAR3 Booster and storage ring have taken place during the SPEAR3 commissioning. The initial commissioning period (SPEAR3 start-up) covered the time period from the beginning of November 2003 to the early part of March 2004. The period from the beginning of March to the beginning of August 2004 has been mostly dedicated to the scientific program. The initial commissioning period was characterized with frequent injection and significantly higher losses. In comparison, the scientific program period was characterized with more stable beam operation with limited number of injections per day and lower beam losses. Three types of dose measurements, passive, active and special measurements, were implemented around the SPEAR3 Booster and storage ring. Based on the expected radiation hazards, several dose control measures were adopted at several stages of the commissioning. In the early stages of commissioning, areas within 4.5 m from the walls of the Booster and storage ring were designated as Radiation Areas (RA). Areas outside RA were classified as Radiologically Controlled Area (RCA). Access to these areas required less training than the radiation areas. A monthly review of the accelerator operation conditions and radiation measurement results were used to determine the changes needed for the RA classification status and associated dose control measures.

Keywords: SPEAR3; synchrotron radiation; dose measurements

Submitted to Radiation Measurements

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1. Introduction

The dose control requirements established at the beginning of the commissioning period (James Liu et al., 2003) were reexamined several times based on the progress achieved with SPEAR3 operation and improved results of the dose measurements. By the beginning of March 2004, the Radiation Areas (RA) within 4.5 m from the walls of the storage ring as well as B130 were reduced to Radiologically Controlled Area (RCA) except for the following locations where they were maintained as RA with a reduced distance of 1.5 m to the Booster and storage ring walls.

1) Outside the Booster walls.
2) The injection region (except for the 120 cm-thick concrete outer wall area).
3) Area extending from BL7 ratchet wall to the "I" beam located along BL10 lateral wall (located between BL7 and BL10 ratchet walls).
4) Area extending from room 101 up to BL6 ratchet wall.
5) West Pit klystrons area.

The areas described in items 3 and 4 were maintained as RA because of the high dose rates measured at these locations during the Long IONization Chamber (LION) tests that were performed during the year. Finally, area classification around the Booster (item 1) was maintained. A decision was made to review the Booster declassification after SSRL develop an engineering solution to the beam losses observed during the Booster turn-on mode. A map showing the final dose control boundaries is shown in Figure 1.

2. Dose measurement results

Integrated dose monitoring was conducted by using two groups of dosimeters. The first group of dosimeters uses moderated and bare Panasonic Thermo Luminescent Dosimeters (TLD)s around the entire areas (part of the regular SLAC area dose monitoring program, where the area TLDs are exchanged every 6 months). A total of 66 TLDs were used as area monitors. The second group uses 2 sets of Luxel event dosimeters (which use optically stimulated luminescence (OSL) technology). The 1st set was exchanged monthly and the 2nd set was exchanged quarterly. The Luxel dosimeters (were placed at 7 locations along the walls outside the Booster and 32 locations along the walls outside the storage ring (these locations overlap with some of the area monitoring locations). In addition, dosimeters were placed outside two trailers (B-288 and B-294) on the hill overlooking

SPEAR3 to monitor potential doses received by staff occupying the trailers. Figure 1 shows the location of the area monitoring dosimeters.

2.1 Area Monitors

An analysis of the area monitoring results (November 03 – July 04) around SPEAR3 showed that the highest doses associated with operation of the injector (Booster and LINAC) ~ 10 mSv were observed inside B140 which is located in the center of the Booster and also hosts the LINAC and Gun Test Facility (GTF). These locations are associated with monitoring of the continuous operation of the LINAC and GTF as well as their klystrons. On the other hand, doses in the general area of B140 were < 100 μSv. The TLD located in the workstation area where personnel work (SRL-7) only measured 46 μSv. The TLDs inside B130 showed doses ~ 100 μSv during the same nine-month period. Figure 2 shows a summary of the area monitoring doses.

The highest doses associated with operation of the storage ring were observed in the injection section. The dose values ranged from about 400 to 2800 μSv during the nine-month period. On the other hand, an examination of the TLDs located on the experimental floor showed that, in general, TLDs located near beamline ratchet walls measure higher doses than TLDs located outside lateral walls. The TLD outside BL8 ratchet wall (SRL-38) recorded a dose rate of 1910 μSv. On the other hand, Except for BL6 and BL10 lateral walls, all other lateral walls measured doses of < 150 μSv during the nine-month period. TLDs outside BL6 and BL10 lateral wall measured doses due to losses in the BL6 and BL10 wigglers, respectively. The highest doses outside the lateral walls of BL6 and BL10 were 924 and 950 μSv, respectively. The dose fractional contributions at these locations were 60% photons and 40% neutrons. Finally, the TLDs in B120 kitchen (2^{nd} floor) and the SPEAR3 control room (SRL-31 and SRL-67) measured doses of 78 and 60 μSv during the nine-month period, respectively.

2.2 Event Monitors

For Results of 34 event monitors that were collected on December 22, 2003, showed that during the first 12 days of SPEAR3 operation (ring operation started on December 10, 2003), the highest dose values were detected in the vicinity of the injection area. The highest dose (1160 μSv) was measured in the injection region on the outer wall gap near the K3 kicker (SRL-60). On the experimental floor, doses > 100 μSv were detected on the walls close to beamlines 1, 4, 6, 7, 8 and 10. During the month of December 2003, SPEAR3 operation consisted of attempting

to bring beam down the Booster to SPEAR (BTS), injecting into SPEAR3 for the first time, and establishing accumulation in the ring. This stage required frequent injections and required significantly more electrons per day than the rest of the commissioning period. This period of commissioning has been characterized with an average injection current of 0.15 nA at the BTS Average Current Monitor # 3 (BTS-ACM3) and a maximum stored current of 20 mA.

During the month of January 2004 higher stored beam was achieved and the need for frequent injection was lessened. During this month, an average injection current of 0.2 nA at BTS-ACM3 and a maximum stored current of 100 mA were recorded. Results of the event monitors that were collected on January 27, 2004, showed that during the month of January (event monitors were placed on December 22, 2003), the highest dose values were still detected in the vicinity of the injection area. The highest photon dose (260 μSv) was measured on the outer wall gap near the K3 kicker (SRL-60). This is compared to the 1160 μSv measured during the first 12 days of commissioning. This significant drop in measured dose is most probably caused by improvement of the injection efficiency. Except for the event dosimeter attached to the lateral wall of BL6, all other event dosimeters located on the experimental floor showed photon dose rates outside the wall of < 100 μSv. The event dosimeter (SRL-43) attached to the lateral wall of BL6 showed a photon dose rate of 170 μSv during the 35-day measurement period. During the first 12 days of SPEAR3 operation, a photon dose of 50 μSv was detected at the same location.

During the month of February 2004, the dose values measured were very much similar to the dose values detected during the previous month. This is an indication that the amount of losses and level of injection frequencies have leveled off. During this period, an average injection current of 0.2 nA (maximum of 0.38 nA) at BTS-ACM3 and a maximum stored current of 100 mA were recorded. Starting early March 2004, the beam was delivered to the SSRL users and stable beam operation was clearly achieved. The dose values during the months of March, April and May were mostly similar and showed that photon dose rates on the experimental floor were < 50 μSv during each month. These values are within the threshold limit for photons measurement by Luxel dosimeters.

In addition to the use of monthly dosimeters, quarterly dosimeters were placed during the commissioning period. The dose values measured during the first and second quarter were somewhat similar. Except for the injection region, all quarterly dosimeters measured values around the storage ring < 350 μSv. The quarterly dosimeter located outside the ring wall near the K3 kicker continually measured > 1 mSv. Figure 2 shows a summary of the event monitoring doses.

2.3 BF_3/GM Stations

The Continuous active dose monitoring of the SPEAR3 ring was provided by the use of 7 BF_3/GM stations. As shown in Figure 3, these fixed BF_3/GM stations were located at the following locations:

1) Outside B140 (south arc).
2) Trailer 288.
3) Building120 kitchen.
4) BL2 Lateral wall.
5) BL7 ratchet wall/BL10 lateral wall.
6) BL6 lateral wall.
7) BL11 Lateral wall.
8) 1st floor of Building130.

Table 1 shows the average dose rate values detected by the different stations during the period of 12/03 to 4/04. At the start of commissioning, a station located outside B140 south arc was used to monitor the Booster and then was later moved to different locations around the storage ring at different times during the commissioning period. The station outside B140 showed an average dose rate of about 5 μSv/h during the month of December.

As shown in Figsures 4 and 5, the maximum dose rates during Booster turn-on mode (ejection septum off) were about 20 and 2 μSv/h for photons and neutrons, respectively. With the start of the users run in March, the stations were gradually moved one by one from their initial locations to be used in the beamline commissioning surveys. As previously shown from the event dosimeter results, the radiation environment outside the ring became stable from the beginning of March and the dose rate values were somewhat constant. As shown in Table 1, except for BL6 and BL10 stations, the dose rates measured at all locations were < 0.5 μSv/h. Most of the dose was seen during the periods of beam injection to the storage ring which were more frequent in December and January. Other than during injection, dose rates due to stored beam are very close to background values. The higher dose rates in the vicinity of BL6 and BL10 are most probably due to the beam losses in the BL6 and BL10 wigglers, respectively

2.4 BSOICs Monitoring

Continuing active monitoring by the 26 Beam Shut Off Ion Chambers (BSOIC)s placed around the Booster and storage ring provided large amount of information about beam losses around the SPEAR3 ring. Figure 3 shows the location of the BSOICs. BSOICs placed along the ring side walls were set to trip at 100 μSv/h. On the other hand, BSOICs located on the SPEAR3 ring roof were set to trip at 1 mSv/h. The SSRL data collection system recorded average dose rate values every 2 minutes. During the early part of the commissioning period, December and early January, five BSOICs (S9, S13, S16, S20 and S26) regularly recorded dose rates that were 20-30 μSv/h above background (from internal source). These dose rate values were detected during a period when the average injection power was 0.3 W.

However, with the end of the early period of frequent injection and high beam losses, all BSOICs showed dose rates < 10 μSv/h above the internal source background signal. Except for infrequent BSOICs trips due to stored beam loss (millisecond type of event), dose rates measured by the BSOICs remained at the same level for the duration of the commissioning period. This shows that the SPEAR3 ring has achieved its goal of good beam accumulation with limited losses. Figures 6 and 7 show the dose rates measured by the S13 BSOIC during the early period of commissioning (12/10/03 – 1/15/04) and during the users run (3/6/04 – 3/19/04), respectively. While the S13 BSOIC was clearly showing dose rate levels of 20-30 μSv/h (shown on figure as 2-3 mrem/h) for extended period of times, the dose rate measured by the BSOIC during the users run continually stayed below 10 μSv/h (shown on figure as 1 mrem/h) above the internal source.

2.5 Commissioning Survey

The SSRL allocated beam time exclusively to perform radiation measurements under various beam steering conditions. In case of the Booster, only one survey was performed when the ejection kicker was off (Booster turn-on mode). Beam injected into the Booster at 120 MeV and was allowed to accelerate to 3 GeV and then decelerate and lost without ejecting it into the BTS. Booster conditions during the survey indicated an approximate beam power of about 0.5 W. The maximum dose rates were observed in the south arc area. The maximum dose rates were 25, 40 and 164 μSv/h on the outer side, inner side and roof of the Booster ring, respectively. These values would be an order of magnitude higher for the maximum possible 3 GeV beam power of 5.85 W.

In the case of the storage ring, surveys were performed under several beam conditions. A summary of the different beam conditions that were analyzed during these surveys are shown in Table 2. These surveys consisted of creating beam losses that may occur during the ring operation due to failure of hardware or software. The results show that losses due to failure of horizontal or vertical magnets, septum or the 4 screens in the BTS produce their highest doses rates in the injection region. Dose rates measured outside the inner wall were < 40 μSv/h for 0.3 W of injected power. Dose rates outside the outer wall and on the roof were < 20 and 70 μSv/h, respectively. These results indicate that for future SPEAR3 operation, a 4 W injection would produce dose rates that are less than 500, 300 and 1100 μSv/h outside the inner wall, outer wall and the roof, respectively.

On the other hand, turning the K3 kicker off or turning the rf off produced the highest dose rates on the experimental floor near BL6 and BL7. In these two cases, a 4 W loss will produce dose rates of less than 200 μSv/h outside the ring and < 2 mSv on the roof. Reducing the dipole filed to 95% of its nominal strength produced a dose rate of 33 μSv/h outside the outer wall on the experimental floor. Finally reducing the dipole field to 99% of its nominal strength produced the highest dose rates measured during the commissioning. A 0.3 W injected beam loss produced a dose rate of 312 μSv/h on the roof. This is equivalent to a dose rate of 4.16 mrSv/h in case of a 4 W loss (maximum allowed during future SPEAR3 operation). In case of a 4 W loss, the dose rate values at all locations will not exceed the design limits of 4 and 15 mSv/h for mis-steering beam outside the side walls and on the roof of the ring, respectively.

2.6 LION Test Survey

The use of Long IONization Chamber (LION) cables in SPEAR3 ring is required prior to allowing for increasing the injection power from 1.5 W to 4 W. Several LION tests were performed during the commissioning year to select the optimum location and setting of each of the proposed 4 LION cables (one per quadrant). Normal beam losses and beam dumps were measured in each quadrant by using temporary LION cables. During testing of a LION cable installed in quadrant 3, the injected beam was mis-steered at 11S (BL6). Measurements of mis-steered beam outside the lateral wall of BL6 showed a photon dose rate of 200 μSv/h for an estimated beam loss of 1 W. Calculation for a similar power loss at a point resulted in a photon dose rate of 640 μSv/h outside a lateral wall facing an aperture (Khater et al., 2003). Based on results obtained by measurements using BF_3/GM stations as well as calculations showed that the neutrons dose is about 2/3 the photon dose.

A loss of 1.5 W at a point would result in the measurement of 300 μSv/h of photon dose vs. a calculated value of 950 μSv/h. The factor of three differences in the measured and calculated doses is probably because losses may have occurred in the form of a line source rather than a point source.

2.7 Routine Surveys

During the commissioning year, two types of routine radiation surveys took place. Prompt radiation and residual induced activity surveys were performed at varying frequencies depending on SPEAR3 running conditions. The prompt radiation surveys were performed during Booster operation as well as during SPEAR3 injection and covered the inner and outer walls of the Booster, 1st and 2nd floors of B131 (experimental floor building) as well as the kitchen area in B120. All locations around Booster and ring showed photon dose rates < 10 μSv/h and neutron dose rates < 5 μSv/h.

During the early period of Booster commissioning (12/1/03 – 12/20/03), induced activity surveys showed that contact dose rate near the injection septum was 3 μSv/h. Lower dose rates were also measured at different locations. In the BTS line, the stoppers, B-1 magnet, B-5 magnet and ejection septum showed dose rates of 2, 1, 1 and 0.8 μSv/h, respectively. All other locations showed dose rates < 0.2 μSv/h. Except for the ejection septum, surveys throughout the rest of the commissioning period showed dose rates in the injection and BTS regions < 1 μSv/h. The ejection septum showed a maximum dose rate of 3.5 μSv/h.

During the early period of storage ring commissioning (12/10/03 – 1/15/04), induced activity surveys showed that contact dose rate near the septum was 1 μSv/h. BL6, BL9 and BL11 insertion devices showed contact dose rates of 0.3 μSv/h. All other locations showed dose rates < 0.2 μSv/h. During the following month (1/15/04 – 2/15/04), the septum, K3 kicker and Beam Abort Dump (BAD) areas showed contact dose rate of < 4 μSv/h. On the other hand, BL6 insertion device showed a dose rate of 2 μSv/h. All other location remained at < 0.2 μSv/h. Surveys through out the rest of the commissioning period showed dose rates in the injection region < 0.4 μSv/h and dose rates everywhere else < 0.2 μSv/h.

2.8 Personnel Dosimeter Results

Reviewing of personnel dosimeters showed that during the 1st quarter of 2004 a total of 186 Luxel dosimeters were issued to staff and users. Examination of the records showed that none of these dosimeters showed any dose.

Summary

Using a combination of a dose control plan and several types of passive, active and special dose measurements allowed for the successful monitoring of the dose environment outside the SPEAR3 Booster and storage ring during the different stages of SPEAR3 commissioning. Monthly monitoring of the dose environment through the use of the passive event monitors as well as the continuous monitoring through the use of BF_3/GM stations and BSOICs provided valuable information that were used to gradually relax the dose control requirements according to the change in operation conditions. Results from event and area monitors confirmed that the maximum monthly dose detected outside the lateral wall on the experimental floor is in the order of 100-150 μSv. These values were only detected in the vicinity of BL6 and BL10. In the mean time the results also confirmed that most locations in B140, B130 and B120 experimental floor showed monthly dose of only about 10-20 μSv. Since work area of personnel and users is usually located at several feet from the lateral wall, it is estimated that on average personnel and users were exposed to less than 100 μSv/1000 h during the commissioning year

Acknowledgements

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References

James Liu et al., 2003. Control and Measurement Plans for SSRL Booster and Storage Ring during the SPEAR3 Commissioning Year of November 2003 to August 2004, Stanford Linear Accelerator Center (SLAC), RP Note 03-18, Rev. 2.

Hesham Khater et al., 2003. Shielding of High Loss Points in the SPEAR3 Ring, Stanford Linear Accelerator Center (SLAC), RP Note 03-02.

Figure Captions

Figure 1. Map showing the final boundary of the RA area. (RA-purple, RCA-yellow, non RCA-white). Numbers on the map show the area monitoring locations.

Figure 2. Map showing the dose values (μSv) during the first 2 quarters of 2004. Area dose "in black" and event dose "in red".

Figure 3. **.** Locations of BSOICs and BF_3 stations.

Figure 4. Photon dose rates outside B140 (south arc) during early commissioning period (December 2003).

Figure 5. Neutron dose rates outside B140 (south arc) during early commissioning period (December 2003).

Figure 6. Neutron BSOIC S13 reading during early commissioning (12/10/03 – 1/25/04).

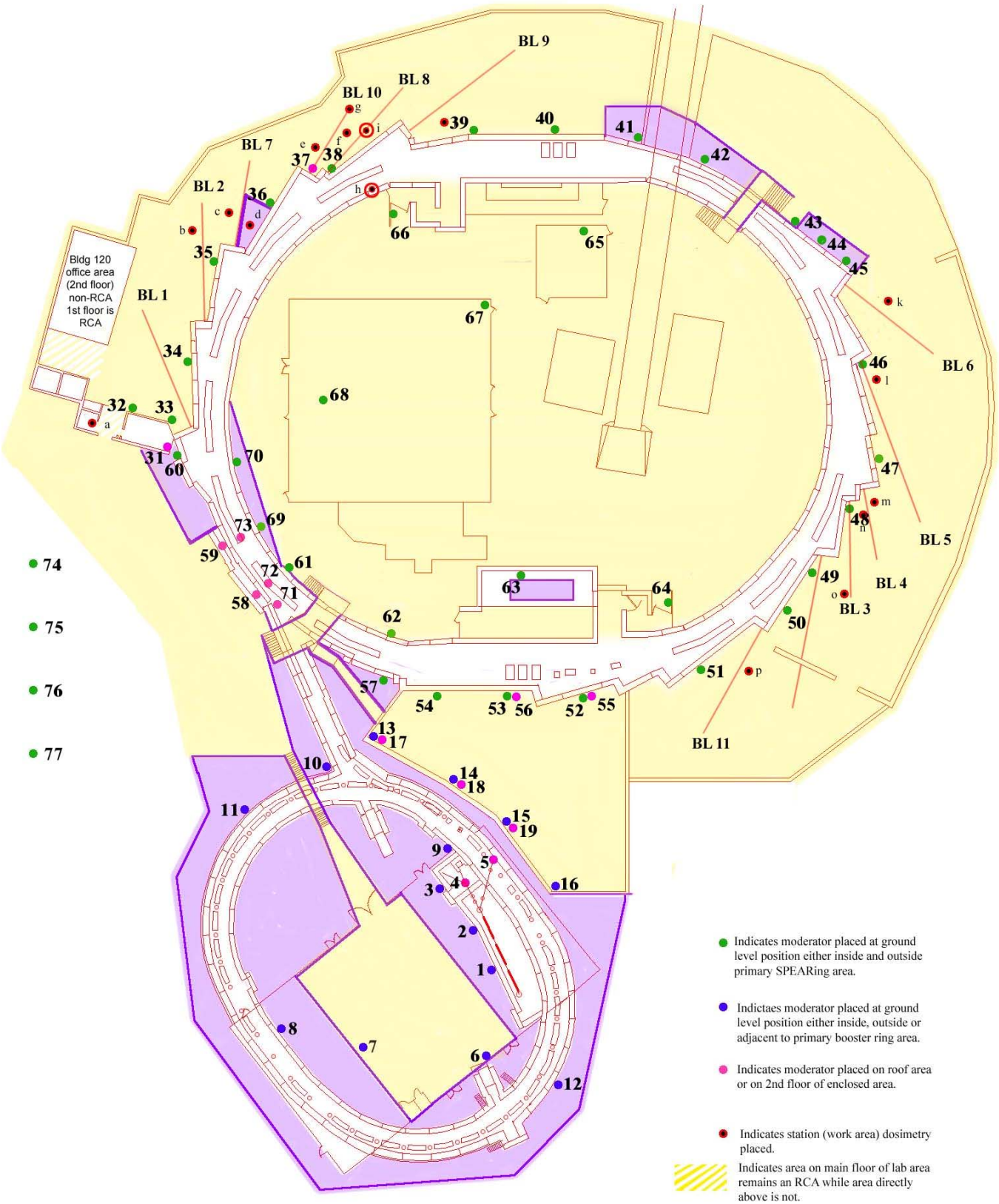
Figure 7. BSOIC S13 reading during late commissioning (3/6/04 – 3/13/04).

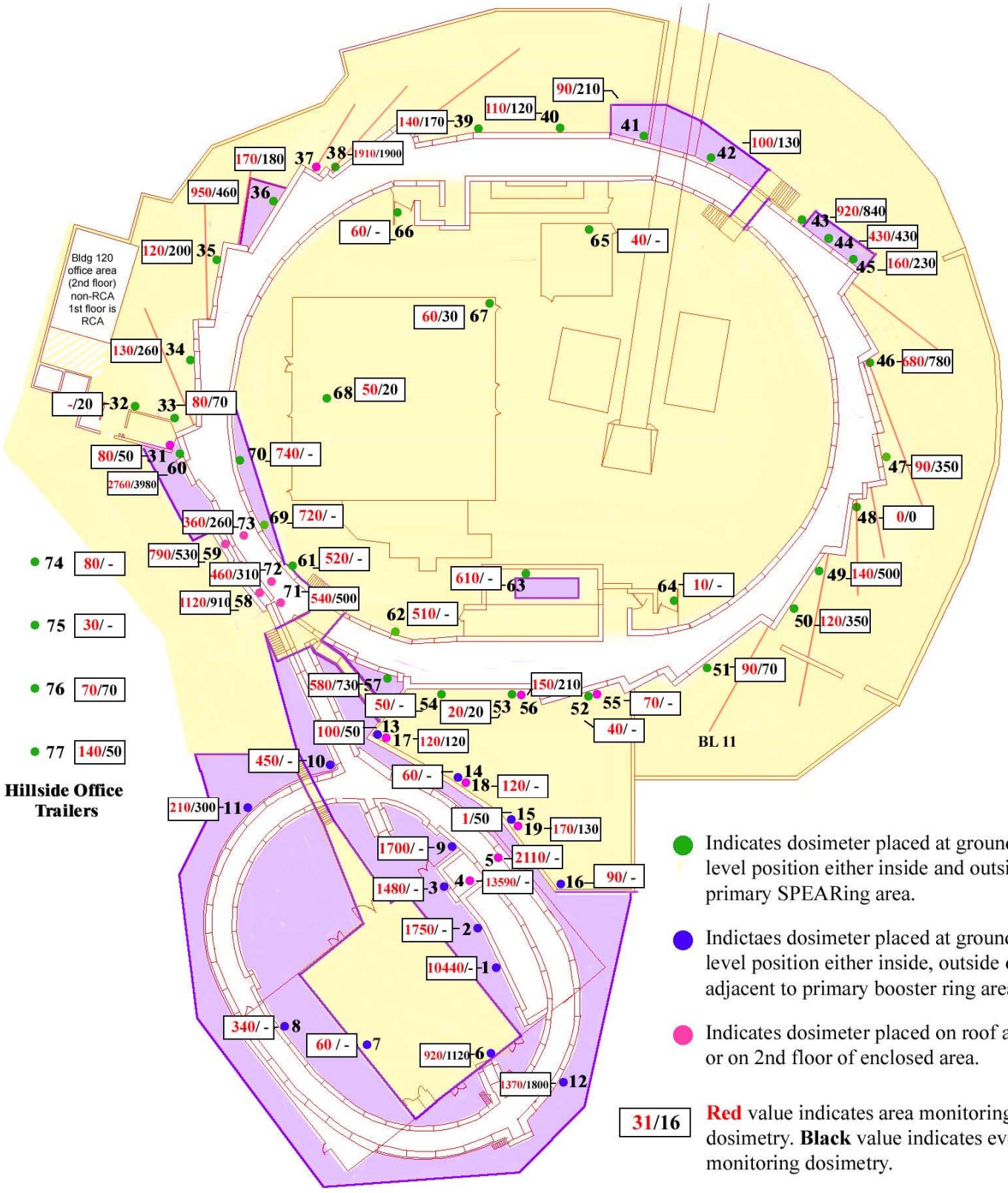
Table 1. Average Dose Rates (μSv/h) Measured by Different BF_3/GM Stations.

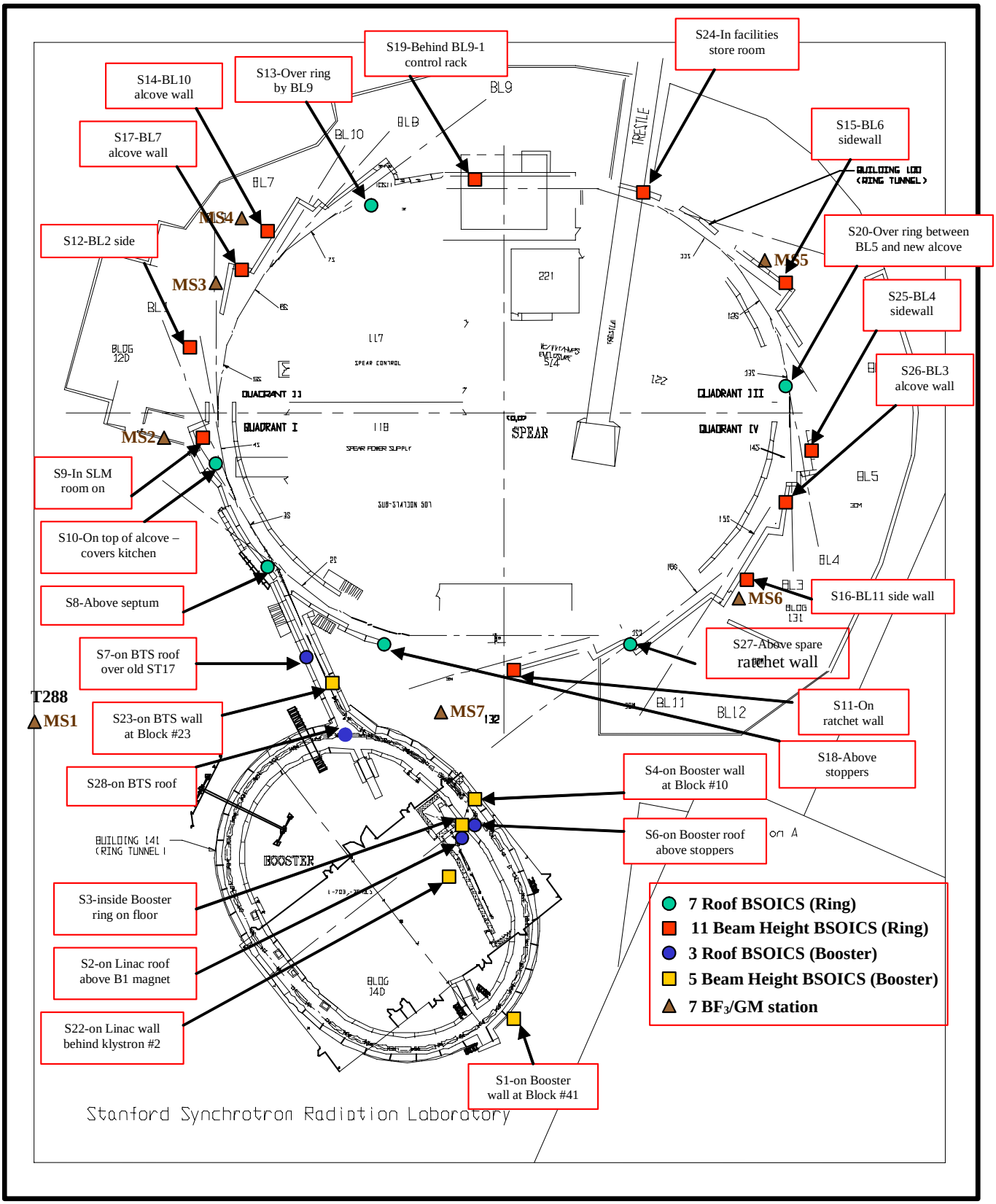
Location	**12/03**	**1/04**	**2/04**	**3/04**
B-140	5	---	---	---
B-288	0.5	0.1	0.1	0.1
B-120 Kitchen	0.3	0.1	0.1	---
BL2 Lateral Wall	0.2	0.5	0.5	0.1
BL6 Lateral Wall	---	---	5	3
BL7 Ratchet Wall/ BL10 Lateral Wall	0.3	0.4	5	2
BL11 Lateral Wall	---	0.1	0.8	0.4
1st Floor B-130	---	0.05	---	---

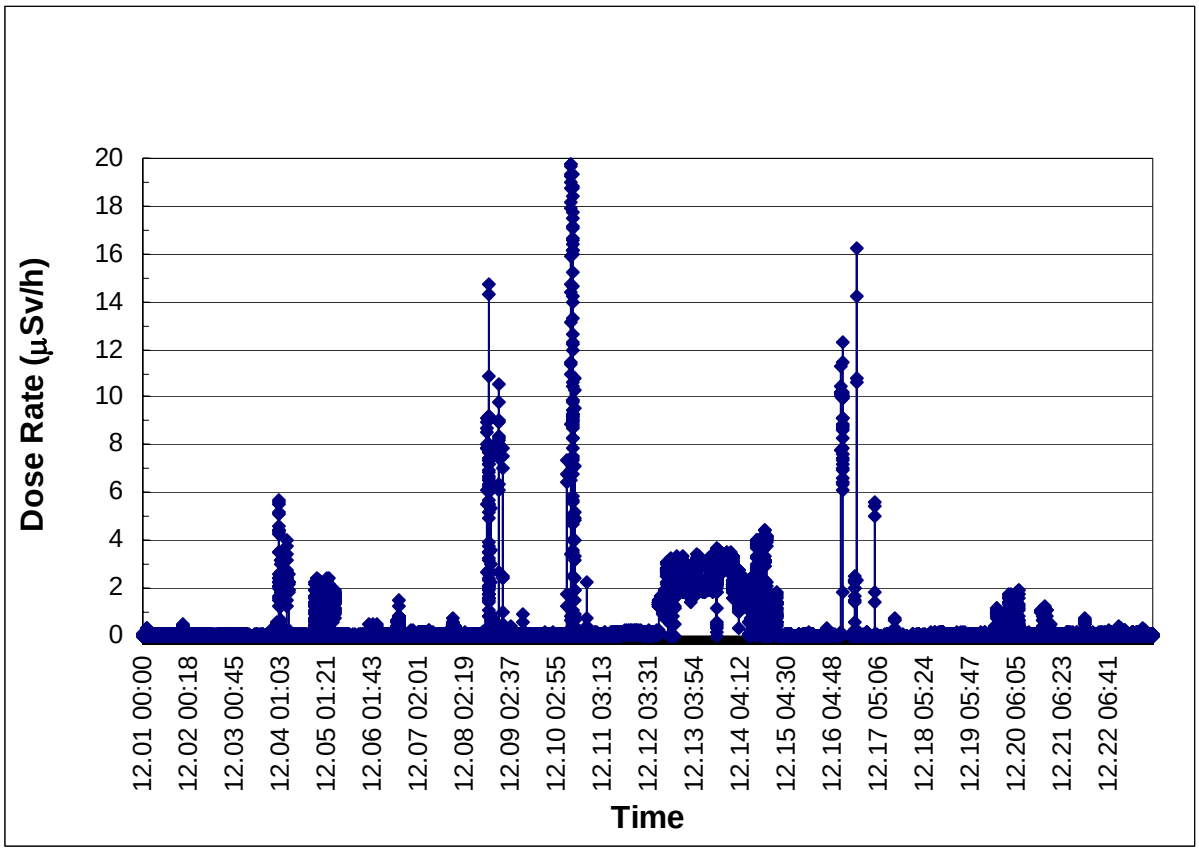
Table 2. Beam Conditions during the SPEAR3 Ring Commissioning Surveys.

Type of Survey (@ P_{inj} = 0.3 W)	**Region of Maximum Dose**	**Maximum Dose Rate (μSv/h)**		
		Inner Wall	**Outer Wall**	**Roof**
B7H magnet off	Injection region	9	5	68
B7H magnet @ max.	Injection region	11	3	67
B8V magnet off	Injection region	11	3	30
B8V magnet @ max.	Injection region	10	4	9
PR1 screen in	Injection region	6	5	4
PR2 screen in	Injection region	18	6	6
PR3 screen in	Injection region	13.5	9	7
PR4 screen in	Injection region	4	14	5
Septum off	Injection region	39	0.5	2
Septum max.	Injection region	37	21	3
K3 kicker off	Exp. Floor (BL6)	13	10	143
K3 kicker @ ½ field	Ring Stoppers	6	14	<5
Dipoles @ 99% field	Exp. Floor (BL1 & BL6)	2.5	14	312
Dipoles @ 95% field	Exp. Floor (SLM & BL5)	6	33	58
rf off	Exp. Floor (BL6 & BL7)	0.6	0.8	13.7


BL 9
BL 8
BL 10
BL 7
BL 2
BL 1
BL 6
BL 5
BL 4
BL 3
BL 11
Bldg 120 office area (2nd floor) non-RCA 1st floor is RCA
74
75
76
77
Indicates moderator placed at ground level position either inside and outside primary SPEARing area.
Indictaes moderator placed at ground level position either inside, outside or adjacent to primary booster ring area.
Indicates moderator placed on roof area or on 2nd floor of enclosed area.
Indicates station (work area) dosimetry placed.
Indicates area on main floor of lab area remains an RCA while area directly above is not.


Bldg 120 office area (2nd floor) non-RCA 1st floor is RCA
Hillside Office Trailers
BL 11
74 80/ -
75 30/ -
76 70/70
77 140/50
90/210
110/120
140/170
39
40
41
42
100/130
170/180
37
38
1910/1900
950/460
36
120/200
35
60/ -
66
65
40/ -
43
920/840
44
430/430
45
160/230
60/30
67
130/260
34
46
680/780
-/20
32
33
80/70
68
50/20
80/50
31
60
2760/3980
70
740/ -
47
90/350
360/260
73
69
720/ -
48
0/0
790/530
59
460/310
72
61
520/ -
610/ -
63
64
10/ -
49
140/500
1120/910
58
71
540/500
62
510/ -
50
120/350
51
90/70
580/730
57
150/210
50/ -
54
20/20
53
56
52
55
70/ -
40/ -
100/50
13
17
120/120
450/ -
10
60/ -
14
18
120/ -
210/300
11
1/50
15
19
170/130
1700/ -
9
5
2110/ -
1480/ -
3
4
13590/ -
16
90/ -
1750/ -
2
10440/-
1
340/ -
8
60 / -
7
920/1120
6
1370/1800
12
Indicates dosimeter placed at ground level position either inside and outside primary SPEARing area.
Indictaes dosimeter placed at ground level position either inside, outside or adjacent to primary booster ring area.
Indicates dosimeter placed on roof area or on 2nd floor of enclosed area.
31/16
Red value indicates area monitoring dosimetry. Black value indicates event monitoring dosimetry.


S19-Behind BL9-1 control rack
S24-In facilities store room
S14-BL10 alcove wall
S13-Over ring by BL9
S15-BL6 sidewall
S17-BL7 alcove wall
MS4
S12-BL2 side
S20-Over ring between BL5 and new alcove
MS3
MS5
S25-BL4 sidewall
S26-BL3 alcove wall
MS2
S9-In SLM room on
S10-On top of alcove – covers kitchen
S8-Above septum
MS6
S16-BL11 side wall
S27-Above spare ratchet wall
S7-on BTS roof over old ST17
T288
MS1
S23-on BTS wall at Block #23
MS7
S11-On ratchet wall
S18-Above stoppers
S28-on BTS roof
S4-on Booster wall at Block #10
S6-on Booster roof above stoppers
S3-inside Booster ring on floor
S2-on Linac roof above B1 magnet
S22-on Linac wall behind klystron #2
S1-on Booster wall at Block #41
7 Roof BSOICS (Ring)
11 Beam Height BSOICS (Ring)
3 Roof BSOICS (Booster)
5 Beam Height BSOICS (Booster)
7 BF3/GM station
Stanford Synchrotron Radiation Laboratory


Dose Rate (μSv/h)
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18
16
14
12
10
8
6
4
2
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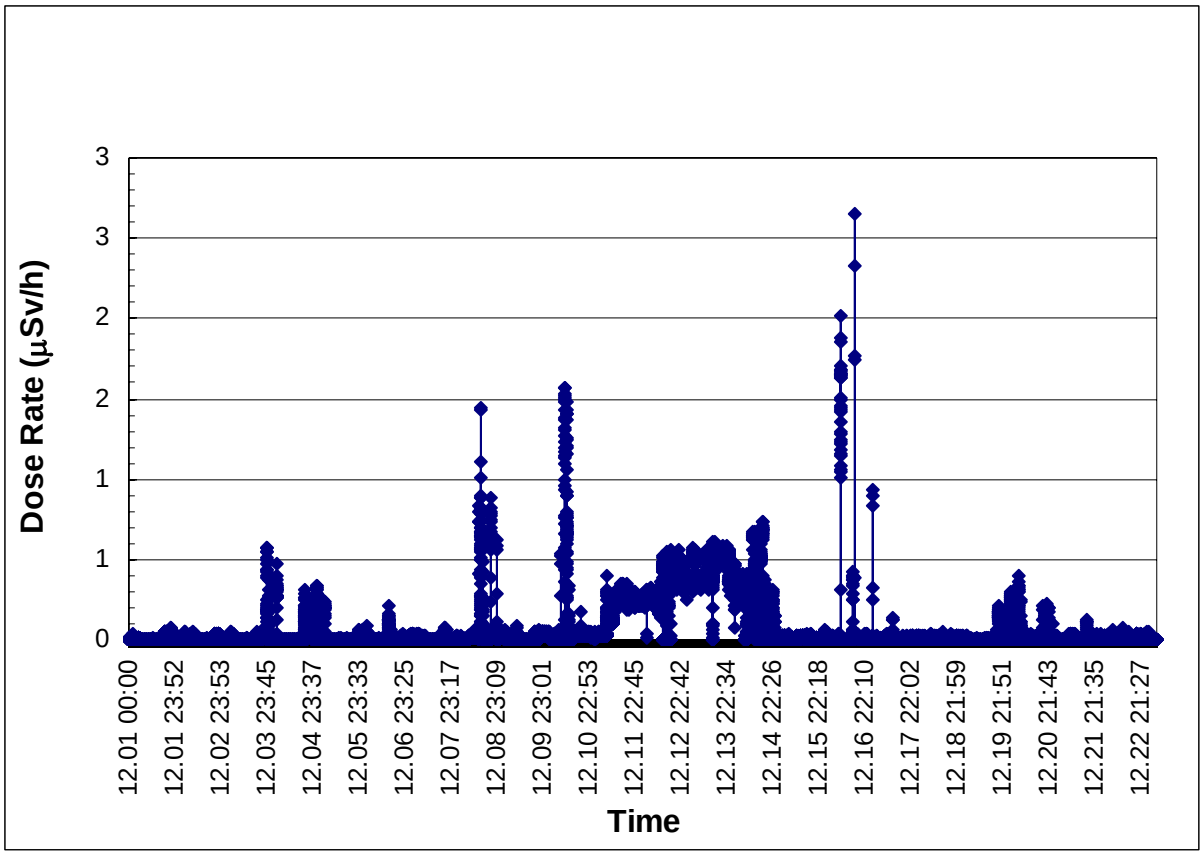
12.02 00:18
12.03 00:45
12.04 01:03
12.05 01:21
12.06 01:43
12.07 02:01
12.08 02:19
12.09 02:37
12.10 02:55
12.11 03:13
12.12 03:31
12.13 03:54
12.14 04:12
12.15 04:30
12.16 04:48
12.17 05:06
12.18 05:24
12.19 05:47
12.20 06:05
12.21 06:23
12.22 06:41
Time


Dose Rate (μSv/h)
3
3
2
2
1
1
0
12.01 00:00
12.01 23:52
12.02 23:53
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12.04 23:37
12.05 23:33
12.06 23:25
12.07 23:17
12.08 23:09
12.09 23:01
12.10 22:53
12.11 22:45
12.12 22:42
12.13 22:34
12.14 22:26
12.15 22:18
12.16 22:10
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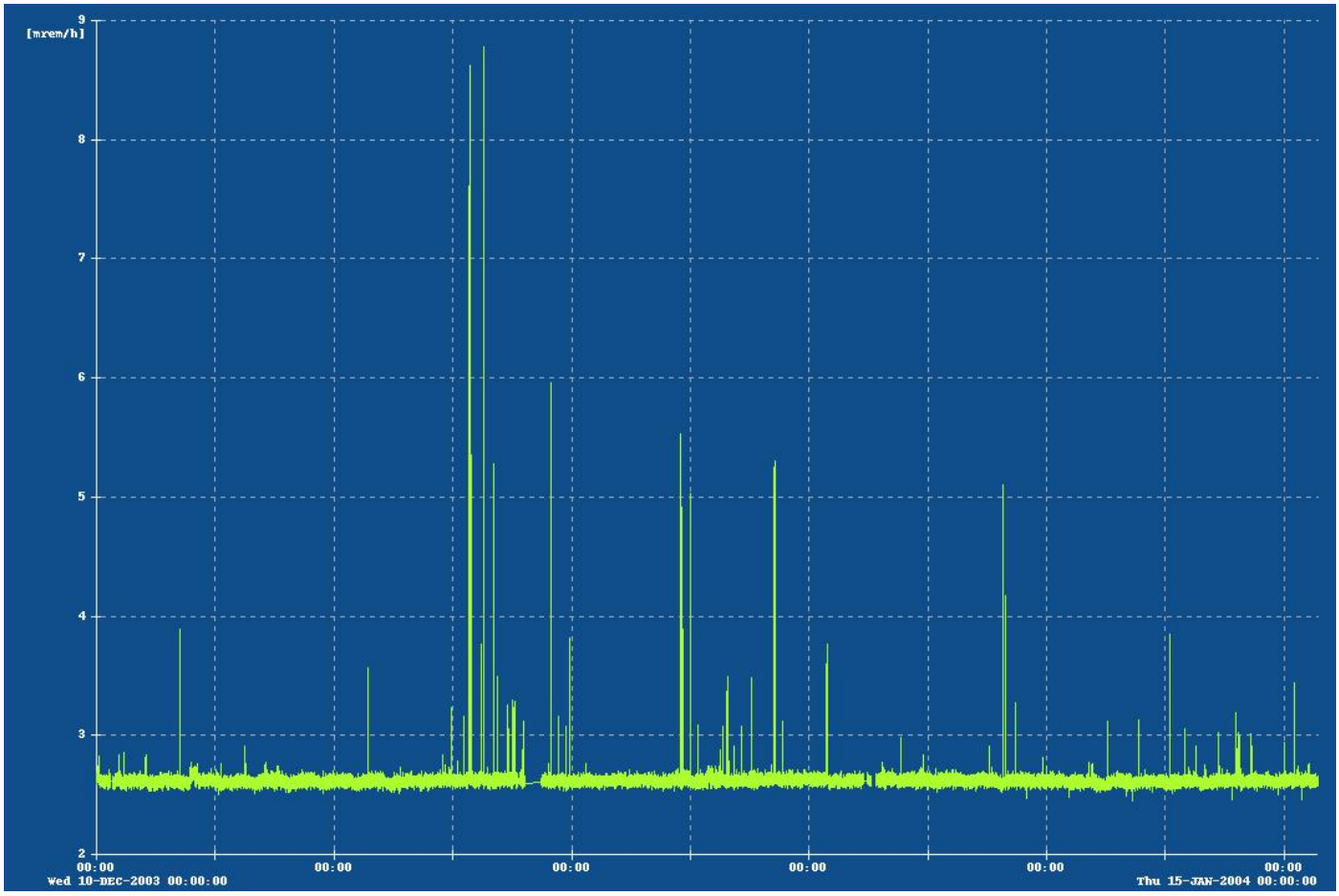
Time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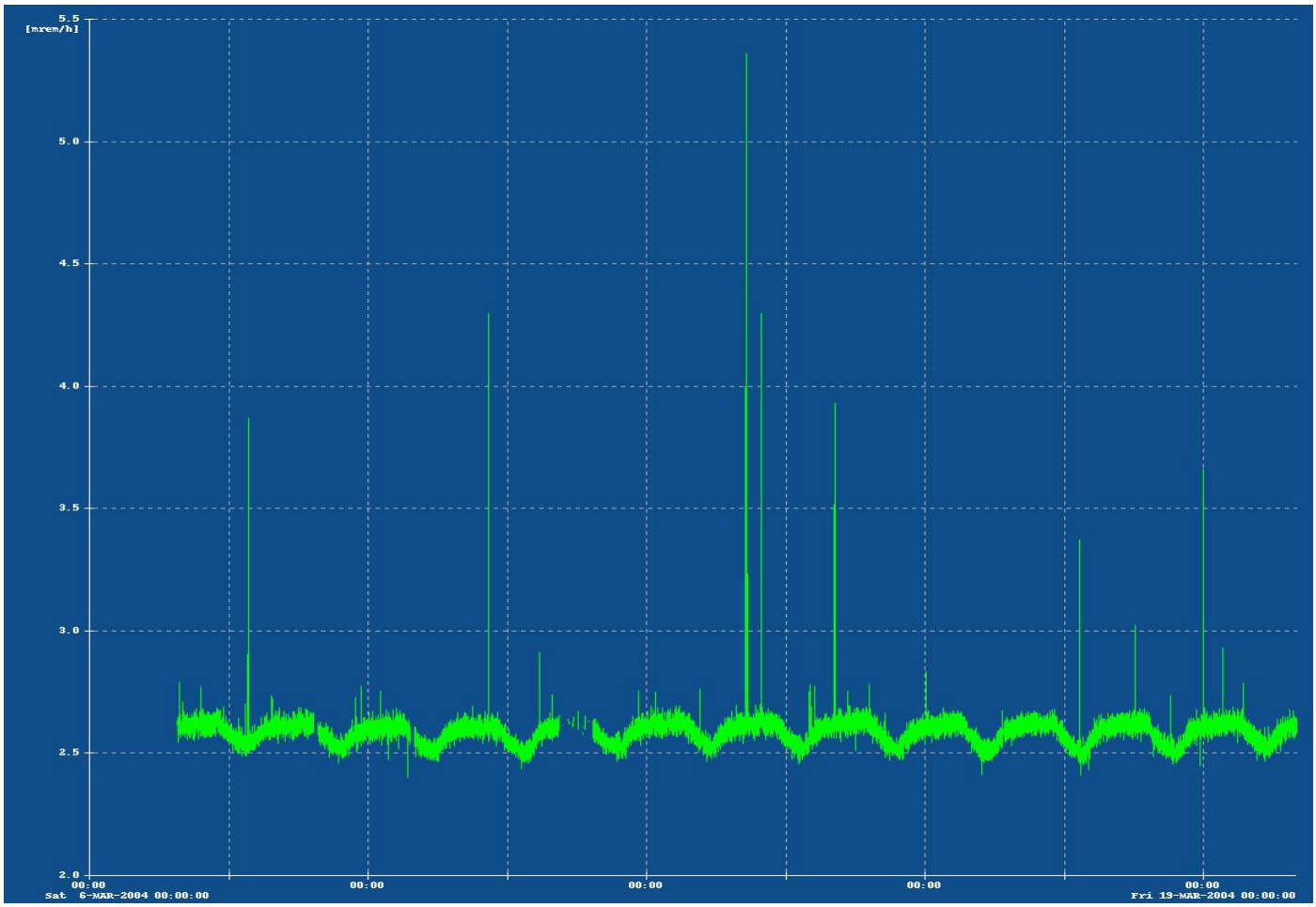
Thu 15-JAN-2004 00:00:00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Sat 6-MAR-2004 00:00:00
Fri 19-MAR-2004 00:00:00