The troubles caused by the radiation DOSE in KEK-PS

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Abstract

The Operation of KEK-PS has been getting more and more tight, and the beam intensity higher and higher. Fortunately, machine troubles do not increase, but the residual activity has increased according to the machine time and the beam intensity. When a machine trouble happens, users ask us "repair the trouble as fast as possible". So, we must consider "How to decrease the human DOSE".

We have another trouble caused by the radiation, which is the deterioration of the equipments watching in the PS tunnel, like a fire alarm and a TV camera.

1 OPERATION OF KEK-PS

1.1 Fiscal Schedule

The fiscal year of Japan is from April 1 to next March 31. As the typical machine schedule, the fast extraction period for the experiment of neutrino oscillation is operated from April 1 to the end of April. After about two weeks shutdown, the fast extraction mode resumes to the end of June. Then, only the booster operation mode continues for about three weeks, while the beam to main ring is stopped for the cooling down of the main ring. After two months shutdown, fast extraction mode resumes and continues until Christmas season. The operation resumes from the begging of January. It changes to slow extraction mode from middle of February and continues to the end of March. Therefore, there are two short shut downs (for about three weeks) in May and Christmas & New Year, and one long shut down (for about two months) in summer. Almost every three weeks, we change the run number for the reason of publishing the run summary. Almost every Monday noon, we take two hours machine shutdown, when we enter PS tunnel for the small maintenance.

1.2 History of the Beam Condition of KEK-PS

Figure 1 shows the "History of operation times of PS" from Fiscal Year of 1985 to 2001 (17 years). Blue colour shows "Physics group experiment", that is "user time". Green shows "Accelerator group tuning and study". Red shows "Accelerator Failure". Brown shows "Other", which means the scheduled short shut down for small maintenance and the troubles caused by experimental group. Purple shows the Booster mode operation time to neutron and meson laboratory, while the main ring operation stops for cooling down. Comparing with the beginning year of the operation, the present operation time has double increased. The machine time is about 6000 hours (250 days) per year.

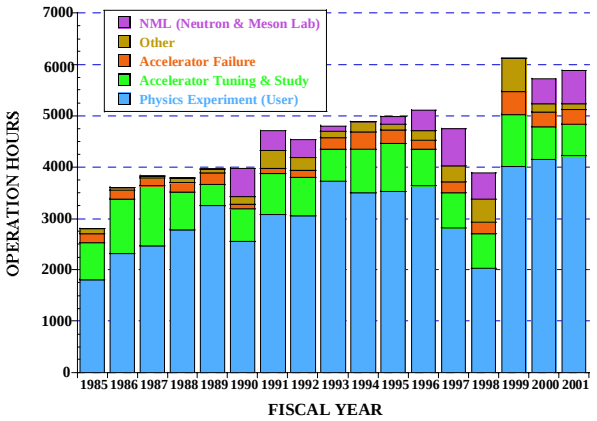


Figure1: History of operation times of PS

There is a compromised decision between user and accelerator group that the total amount of time for accelerator tuning and study should not exceed 15% of the whole machine time.

Figure 2 shows "the history of the averaged intensity of the booster ring from FY1979 to 2002". Every bar shows the averaged intensity of every ran. The present intensity of the booster is almost four times larger than that in the begging of the operation

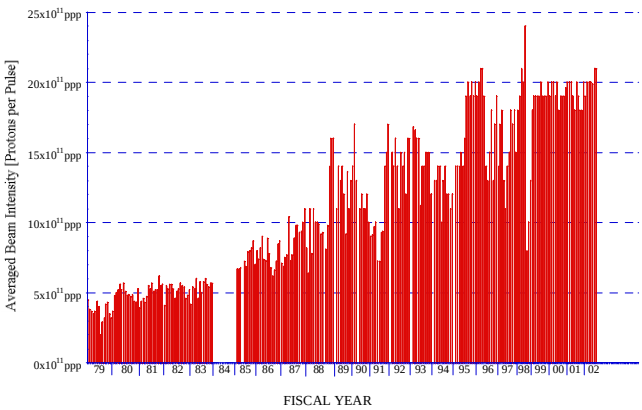


Figure2: The history of the averaged intensity of the booster ring

Figure 3 shows "the history of the averaged intensity of the main ring from FY1979 to 2002". Until February 1999, there was only slow extraction system from the main ring. But at 1999, we made the fast extraction system by the request of the neutrino oscillation experimental group. As the beam loss at the fast extraction period is about half in the case of slow extraction, we can increase the beam intensity to the double.

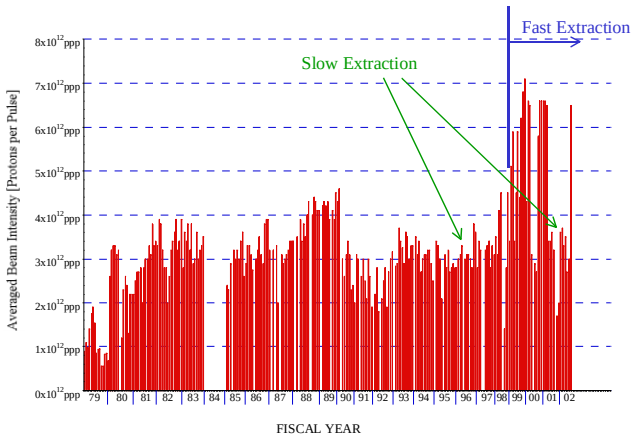


Figure3: The history of the averaged intensity of the main ring

1.3 Residual Activity[1]

Figure 4 shows the plan of Booster ring. The 40MeV H- beam is injected from Linac and accelerated to 500MeV. At the middle of 500MeV-BT, there is a blanching point to the booster user line of Neutron & Meson group and to the main ring.

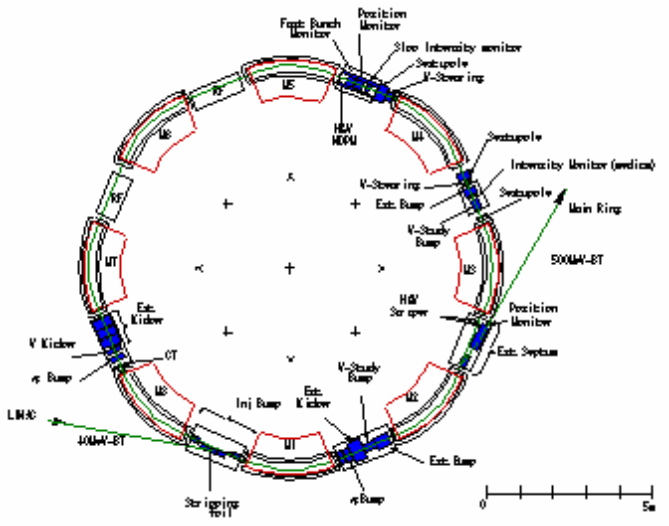


Figure 4: Plan of booster ring

Figure 5 shows the typical residual activity in the booster ring. In this case, the operation was stopped at July 12, and after four days, the measurement was done. These values are on the surface of the beam duct. Green circles show 1 and 10 mSv/h. Especially at the extraction point, the activity is very high, 50mSv/h.

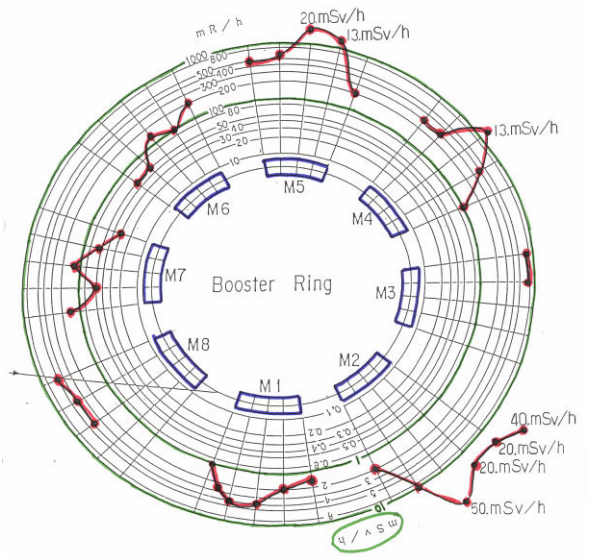


Figure5: typical residual activity in the booster ring (4 days after beam stop)

Figure 6 is the plan of main ring. 500MeV beam is injected from the booster ring, accelerated to 12GeV, and extracted from EP1 or EP2. There is another extraction line from the internal target. There are slow extraction systems for both EP1 and EP2 line, but fast extraction system is installed only for EP1 line. Usually we use the fast extraction system of EP1 line for the neutrino oscillation measurement, but we also use the slow extraction system of EP1 or EP2. In rare cases, we use simultaneous extraction using EP2 mainly, EP1 and internal target line additionally.

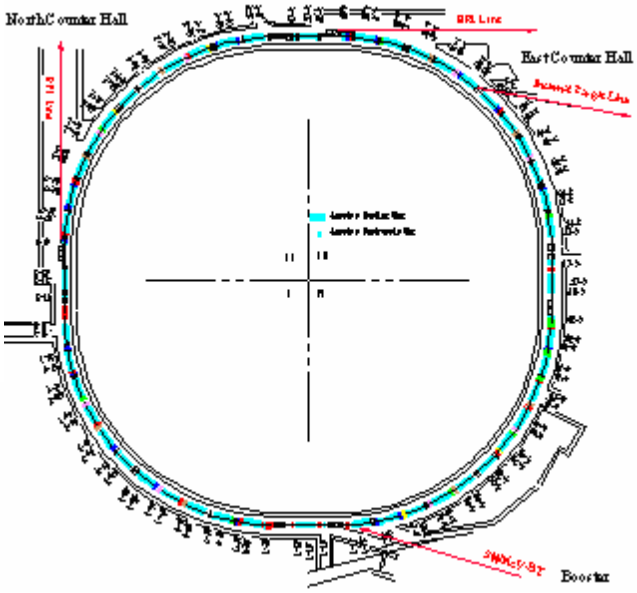


Figure 6: Plan of main ring

Figure 7 shows the typical residual activity in the main ring 4 days after beam stop. Green circles show 10 and 100mSv/h. Especially near the extraction point, the activity is very high, from 10 to 50mSv/h.

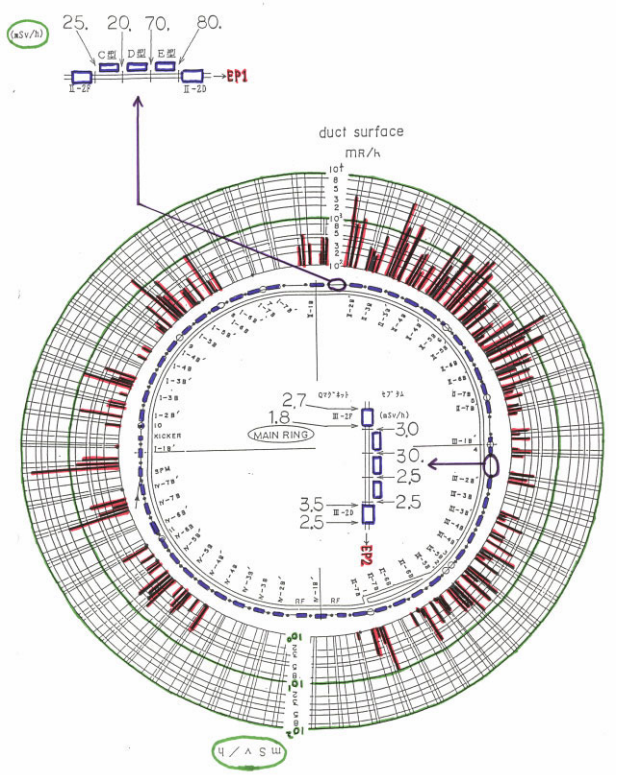


Figure7: typical residual activity in the main ring (4 days after beam stop)

2 TROUBLES OF KEK-PS

2.1 Machine Trouble[2]

From now, we will introduce the typical repair working for the trouble of magnet with high radiation. The run schedule was simultaneous extraction mode of EP2 main and EP1 additional, and the run would continue to July 26, 1999. But, at July 10, septum magnet D and E at EP2 line broke down. As there were no spare of septum magnets, we stopped the simultaneous extraction, but continue the single extraction of EP1 line. Fortunately, there was no schedule to use EP2 line until next April 4th, while we only used the EP1 line. Just a few days before resuming the extraction of EP2, we removed the broken septum D and E from EP2 line. Next day, we moved septum D and E from EP1 to EP2 line because we had no spare magnets and did not have enough time to make new ones.

2.2 History of DOSE of PS Members

Nevertheless the long cooling time at EP2, the maximum residual activity on the surface of the magnets was about 20mSv/h, and one at EP1 is 150mSv/h because of short cooling time.

Figure 8 shows the DOSE of individual person from 1997 to 2001. Every section surrounded by green bars shows the DOSE of same group members. In the KEK rule, the limit DOSE per year for man is 20mSv/year, but, when you are exposed to near 7mSv/year (as blue dotted lines show in the figure), you will get the alarm card that warns not to exceed 7mSv/year. The maximum DOSE is near 10mSv/year in the case of the main ring group in 1999, which is much higher than 7mSv/year. The members of main ring group and vacuum group suffer much higher radiation than another group. The bar at the right end shows the averaged DOSE of all PS members.

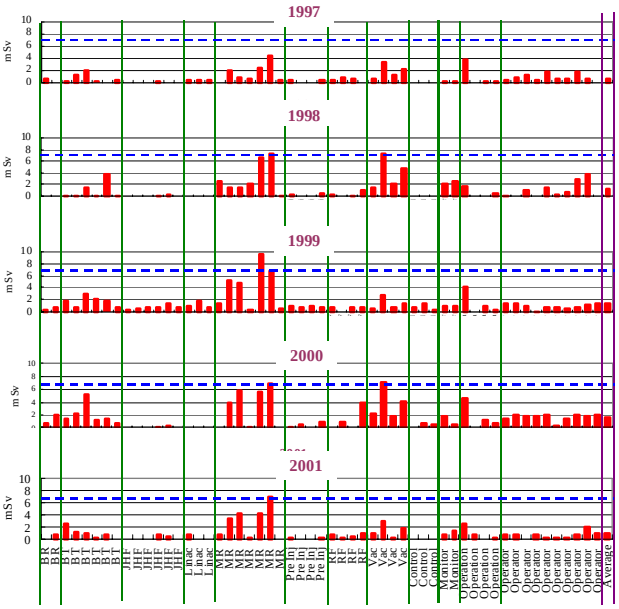


Figure 8: DOSE of individual person separated by PS maintenance group

2.3 Supporting List

Therefore, another group should support the main ring group for repairing the magnet. At first, we made the order list for supporting work, which was proportional to the total DOSE. It is shown in Table 1. Actually there are 56 members in PS group, but we simplify the number to 20 in these lists. For instance, the person suffered low total DOSE is listed on upper order. But we do not want that young man not having a baby exposes to high radiation. And there was a complain that the man of low DOSE must use his valuable time to another group work for long hours. So, we took another formula as Table 2. This formula depends on not only the total DOSE (S), but also man's age (Y) and his working time (H). For example, supposing two men with same DOSE, one is 20 years old and another 60. In the case of 20, the value of the term of (-Y/20+5) is 4, on the other side, in the case of 60, its value is 2. So, even if two men suffer the same radiation, young man suffers twice radiation effectively.

But there was another complain. The DOSE of the man who just becomes PS member is very small. But actually, all people suffer about 1mSv from nature every year. So, we decided to add 14mSv to the total DOSE from 1989 to 2002 (14 years). The Table 3 is made by the final formula.

Now we compare the position in these lists in the case of Mr.E, J, S and T. Mr.E is old and low DOSE, Mr.J is young and low DOSE, Mr.S is middle age and high DOSE, Mr.T is old and high DOSE. In the second list, Mr.E's position becomes lower because of long working time. Although the working time of Mr.J is short, his position also becomes lower because of his young age. In the third list, we are sorry that Mr.E comes to the first position and Mr.J's position becomes lower because of the bias DOSE. But, if you have suffered high DOSE, your position dose not move in spite of your age, like Mr.S and T.

Order	Name	Age (year) Y	Total Dose 89 - 02 (mSv) S
1	A	41	1.18
2	B	40	1.58
3	C	52	2.44
4	D	50	2.71
5	E	63	3.55
6	F	51	3.57
7	G	37	3.66
8	H	48	4.79
9	I	56	4.79
10	J	26	5.20
11	K	41	6.02
12	L	49	6.80
13	M	50	7.24
14	N	42	8.98
15	O	37	9.70
16	P	57	24.48
17	Q	35	32.98
18	R	59	36.00
19	S	40	57.53
20	T	55	66.91

N=S

Table 1: (proportional to total DOSE)

Order	Name	Age (year) Y	Total Dose 89 - 02 (mSv) S	Working Time (hour) H	Point N
1	B	40	1.58	9.5	9
2	A	41	1.18	15.9	11
3	D	50	2.71	14.0	14
4	H	48	4.79	2.8	14
5	C	52	2.44	16.6	14
6	I	56	4.79	7.4	14
7	F	51	3.57	12.4	15
8	G	37	3.66	6.9	15
9	E	63	3.55	16.9	15
10	L	49	6.80	1.6	18
11	K	41	6.02	4.1	20
12	J	26	5.20	2.3	20
13	M	50	7.24	7.3	22
14	N	42	8.98	4.1	28
15	O	37	9.70	1.0	31
16	P	57	24.48	0.0	53
17	R	59	36.00	0.0	74
18	Q	35	32.98	0.0	107
19	T	55	66.91	1.00	151
20	S	40	57.53	0.0	173

N=S(-Y/20+5)+H/2

Table 2: (depends on age & supporting hour)

Order	Name	Age (year) Y	Total Dose 89 - 02 (mSv) S	Working Time (hour) H	Point N
20	E	63	3.55	16.9	41
14	I	56	4.79	7.4	45
19	C	52	2.44	16.6	48
17	D	50	2.71	14.0	49
16	F	51	3.57	12.4	49
9	H	48	4.79	2.8	50
15	B	40	1.58	9.5	51
18	A	41	1.18	15.9	53
7	L	49	6.80	1.6	54
13	M	50	7.24	7.3	57
12	G	37	3.66	6.9	59
10	K	41	6.02	4.1	61
11	N	42	8.98	4.1	69
8	J	26	5.20	2.3	72
5	O	37	9.70	1.0	75
1	P	57	24.48	0.0	83
2	R	59	36.00	0.0	103
3	Q	35	32.98	0.0	153
6	T	55	66.91	1.00	183
4	S	40	57.53	0.0	215

N=(S+14)*(-Y/20+5)+H/2

Table 3: (bias DOSE of 1mSv/year)

2.4 DOSE Caused by the Supporting Work

Therefore we asked PS members to support changing magnets along the final supporting list. Two of the supporting members worked at the same time by the instruction of one of the main ring group who stayed in the weak radiation area. The limit of exposure DOSE per day is 0.5mSv, but the alarm level is set 0.35mSv. Therefore, when the supporting member's DOSE was close to 0.35mSv, we asked the man at next position of the list to join the supporting work.

Table 4 is the individual DOSE caused by changing magnets at March 29 and 30, 1999. As shown in Table 5, total number joining the work is 46, and the averaging DOSE is 0.28mSv/person. Nevertheless the members of the main ring group stays in low radiation area, they suffered a lot of radiation as shown in pink colour column because of their long stay in tunnel.

Fortunately, it is unusual that the severe trouble happens to need the supporting work.

Date (March)	Total Number	Personal Name	Time Start	Time End	Time Difference	DOSE (mSv)
29	1	A	9:38	10:59	1:21	0.208
	2	B	9:38	11:00	1:22	0.218
	3	C	10:55	11:45	0:50	0.29
	4	D	10:55	11:25	0:30	0.3
	5	E	11:22	11:54	0:32	0.18
	6	F	11:25	11:54	0:29	0.16
	7	G	13:04	14:22	1:18	0.31
	8	H	13:04	13:24	0:20	0.33
	9	I	13:04	13:30	0:26	0.36
	10	J	13:04	14:17	1:13	0.33
	11	K	13:25	15:10	1:45	0.31
	12	L	14:45	15:52	1:07	0.27
	13	M	15:10	15:52	0:42	0.2
	14	N	9:40	11:51	2:11	0.213
	15	O	9:38	9:57	0:19	0.124
	15	O	13:29	14:10	0:41	0
	16	P	9:58	16:20	6:22	0.161
	17	Q	13:04	15:50	2:46	0.32
30	18	R	9:34	10:10	0:36	0.313
	19	S	9:35	10:13	0:38	0.341
	20	T	9:55	10:30	0:35	0.34
	21	U	10:02	10:37	0:35	0.35
	22	V	10:30	11:38	1:08	0.42
	23	W	10:30	11:39	1:09	0.37
	24	X	11:25	11:50	0:25	0.33
	25	Y	13:00	13:37	0:37	0.32
	26	Z	13:00	13:45	0:45	0.31
	27	a	13:35	14:09	0:34	0.32
	28	b	13:55	15:13	1:18	0.32
	29	c	14:09	15:15	1:06	0.33
	30	d	14:52	15:14	0:22	0.15
	31	N	9:35	11:22	1:47	0.318
	32	O	9:51	11:03	1:12	0.35
	33	P	10:12	15:40	5:28	0.24
	34	Q	11:10	15:03	3:53	0.34

Table 4: Individual DOSE caused by the supporting work

Date	Total number of People	Total DOSE [mSv*men]	Averaged DOSE [mSv/men]
29/3/99	23	5.694	0.25
30/3/99	23	7.392	0.32
SUM	46	13.086	0.28

Table 5: Total DOSE caused by the supporting work

3 DETERIORATION OF EQUPMENTS

3.1 Fire Alarm and TV Camera

Fire alarm measuring smoke and CCD camera are very important equipments for watching the operating condition in PS tunnel. But, they are very weak for radiation. As shown in Figure 9, the lifetime of the fire alarm set near the extraction places of the booster ring is few days, and one in other places is few months. A CCD camera is set at the corner of the ceiling of booster room where the radiation is supposed to be weak. But, the lifetime of the camera is few months.

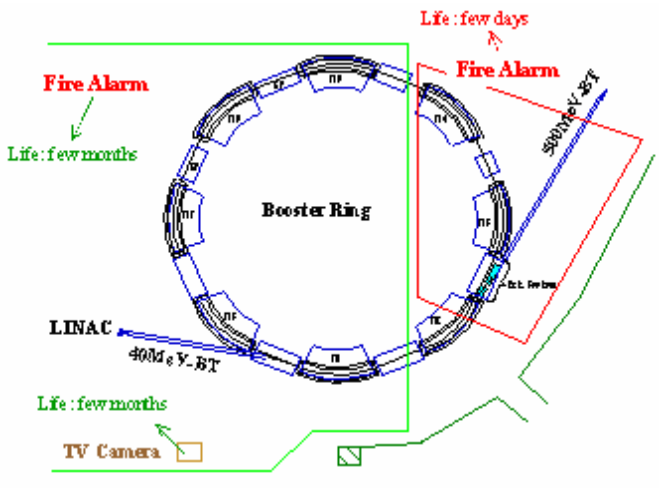


Figure 9: The lifetime of fire alarm and TV camera in the booster ring

Figure 10 shows the case of the main ring. The lifetime of fire alarm set near extraction place is few days. But, the lifetime set other place is few months. On the other side, the lifetime set in the neutron and meson line is few years.

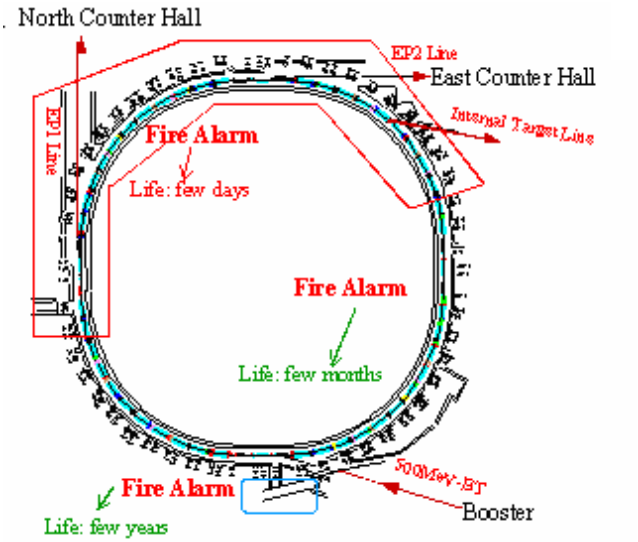


Figure 10: The lifetime of fire alarm in the main ring

We suppose that the lifetime depends on the radiation during operation. Therefore, we measured the radiation field near extraction of the booster ring. We also measured in some places of the neutron and meson line, and near EP1 line. As shown in Figure 11 and Picture 1, we stretched ropes tight along red lines and hung plastic bags containing radiation monitors at red numbers. Near extraction point, we also stretched a rope from the ceiling to the floor to measure the vertical mapping.

Table 6 is the typical measured result. These values show that how much mGy is irradiated to the places by accelerating $1*10^{14}$ protons. Aranine dosemeter measures the radical of amino acid by ESR. Aluminium thin plate measures gamma ray from Na-24, which tells you the quantity of high-energy neutron more than 6MeV. Gold thin plate tells you the quantity of thermal neutron by using imaging plate. There are big difference between the place of long life (A3) and the place of short life (M3,B13 and M1). But it is strange that there is not so big difference between the place of few months (B23) and few days (B1 and B17).

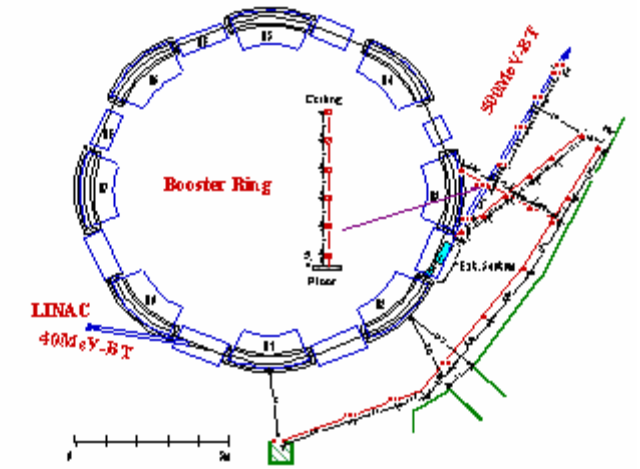
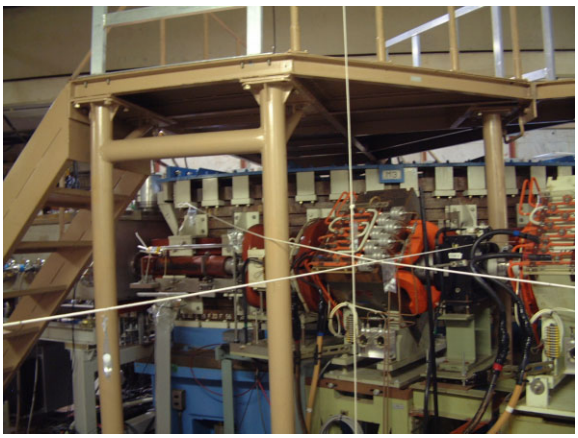


Figure 11: Measuring points of radiation field near booster extraction



Picture 1: Horizontal and vertical ropes hanging plastic bags containing radiation monitors

Place Name	Aranine radical (ESR)	Al γ (Na-24) n>6MeV	Au Imaging Plate n (thermal)	Life of Fire Alarm	Note
	mGy/10^{14}protons				
B1	0.03	0.08	0.62	Few Days	Ceiling (near BR Ex.)
B17	0.05	0.07	0.51	Few Days	Wall (5m from BR Ex.)
B23	0.02	0.06	0.39	Few Months	Wall (2m from BR In.)
A3	0.02	0.03	0.04	Few Years	NML Line
M3	0.71	1.10	25.00	Few Days	Ceiling (near EP1)
B13	3.50	1.30	0.75	Very Short	Beam Duct (BR Ex.)
M1	26.00	60.00	150.00	Very Short	near EP1 Septum

Table 6: Radiation (mGy) irradiated by accelerating $1*10^{14}$ protons at various places in PS tunnel

4 SUMMARIES

4.1 DOSE caused by working in PS tunnel

In the most severe case, the residual activity at working area is 1mSv/h. As the KEK rule, the limit of radiation DOSE is 0.5mSv/day. So, the working time should be about 30min. There was a record that shortest working time was 5min. The list of supporting work under high radiation is made by some formula, which consists of accumulated DOSE, age and supporting time. For the accumulated DOSE, we add 1mSv every year. Fortunately, the number of using the supporting list is small, averages once per two years.

From the fiscal year of 1997 to 2001, the highest DOSE of PS members was 9.7mSv/year. This value is lower than the limit of KEK rule, 20mSv/year, but higher than the alarm level of 7mSv/year. In the same period, the averaged DOSE of PS members was 1.1mSv/year.

4.2 Deterioration of Equipments

There is the deterioration of equipments watching PS tunnel. The lifetime of the fire alarm measuring smoke is few days. On the other side, the lifetime of one measuring temperature is long, but the response is no good, because it is the mechanical type. So, we want a company to make a fire alarm using a photo-multiplier. But, they do not want to make new type, but they try to shield the fire alarm by thick iron, lead and polyethylene.

The lifetime of CCD camera is very short (few months). We use phototube camera to watch H^- stripping foil. The camera's life is long (few years), but it is not colour, and now out of making. We have no good idea on TV camera.

5 ACKNOWLEDGEMENTS

We would like to express our gratitude to Mr.Kouji.Okazaki for his help collecting data.

REFERENCE

[1] Takenori SUZUKI, "Practical Radiation Control at KEK", Presented in this workshop

[2] Hikaru SATO, et al., "Status of the Maintenance for the KEK 12GeV-PS main ring and power supply", Presented in this workshop