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Skyshine Dose Estimation from Large Storage Ring of Electrons

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Abstract

For high energy and large-scale accelerator, dose estimation of skyshine at the facility boundary is very important to achieve the dose limit to the public. Here skyshine dose estimation was done by using calculation to obtain a design concept of the synchrotron facility which had a linear accelerator and a large scale storage ring of 1-2 GeV electrons. Through the detailed consideration a basic ideas are obtained under several operation modes.

1 Introduction

We are promoting the project of Synchrotron Radiation Facility in Kashiwa New Campus of the University of Tokyo. For the accelerator building construction, shielding designs and their radiation dose estimations are requested. Shielding calculations are categorised into two parts: bulk shielding and skyshine. Here we would like to discuss about the skyshine dose from this accelerator facility.

There are several accelerator designs. One is a 400 MeV linear accelerator (LINAC) and a 2 GeV storage ring(SR), another is a 1 GeV linear accelerator and a 1 GeV storage ring. These situations may change depending on the final decision of the plan. Here several discussions are done for the base of design by performing a typical calculation of skysine phenomena to these designs.

So we did a setting of typical case as: Phase I, having 400 MeV LINAC [on the ground] and 2 GeV SR [on the ground] (see Fig.1), Phase II, having 1 GeV LINAC [in the underground] and 1 GeV SR [on the ground] (see Fig.2).

2 Method of Shielding Calculation

For the estimation of skyshine dose, the equation of Stevenson-Thomas[2,3,4] was applied.

$$H = 3.0 \times 10^{-15} \exp(-r/\lambda) / r^2 \times S \times 3600$$

Here,

H : skysine dose (Sv/h)

λ : attenuation length in air of high energy neutrons (m)

r : distance from a source to a considering point

S : total neutron source intensity on the surface of building ceiling (n/s)

Point neutron source was assumed in the skyshine dose calculation.

For Phase I: source points were 4 at LINAC (e^-/e^+ converter and 3 slits), and 33 at Storage Ring (32 bending magnets and one beam injection point).

For Phase II: Source points were set only for the storage ring because the linear accelerator was set under the ground and caused less dose contribution to the skyshine. The 24 point sources distributed on the race track storage ring.

The procedure of source term neutron intensity estimation on the ceiling is as follows.

① Bulk shielding estimation on the ceiling by the Jenkins formula[1].
② Neutron flux estimation based on the obtained dose by assuming 1/E spectrum.
③ Total neutron intensity, S, estimation by multiplying total ceiling surface.
④ Skyshine estimation by Stevenson-Thomas formula to each point source.
⑤ Total skyshine estimation by summing up each dose component from each source points.

This method gives conservative dose estimation because the assumption of 1/E is a safety side discussion and the Stevenson-Thomas formula is overestimation within about 100 m distance.

3 Accelerator Operation Mode and Beam Loss

Operation modes are 5 pattern to LINAC and 10 pattern to Synchrotron Storage Ring. LINAC has an energy of 0.3-1 GeV to electron or positron and its modes are ①electron short pulse ② electron semi-long pulse ③ electron long pulse ④positron short pulse ⑤positron semi-long pulse. Storage ring has a maximum energy of 2 GeV and its modes are ①multi bunch operation (accumulation) ②multi bunch operation (injection) ③ single bunch operation (accumulation) ④single bunch operation (injection) ⑤start up adjustment ⑥operation under baking ⑦machine study ⑧ machine study for injector ⑨ start up adjustment for injector ⑩stand by. The beam parameters like beam energy, peak current, pulse width, duty cycle, duty factor, average current, beam intensity, beam loss rate and beam loss, were given to each parameter and to each region.

Beam loss rate is a very important parameter and was given by an empirically estimated value based on experiments. The used values are listed in Table 1.1 and 1.2. It is noted that these values are safe side values to keep the conservative shielding result.

4 Dose Estimated Result

4.1 Result of Phase I

The estimated annual dose to each facility were shown in Table 2.1 and 2.2 to LINAC and SR respectively. By adding skyshine dose and direct dose, we could obtain the total dose to each points (see Table 3). The nearness of the site boundary gives a little higher value. The marking point is a value at the 5th floor of control building (in Table 3). At that point a little high value was obtained for the reasons of reaching a little more direct arrival of radiation (not so much skyshine).

The targeting dose level is 50 μSv/y for skysine at the site boundary. The dose limitation to the public given by ICRP (International Commission on Radiological Protection) is 1 mSv/y. In this meaning the obtained value is sufficient.

4.2 Result of Phase II

Next, the phase II situation was estimated. In this case 1 GeV LINAC locate in the underground. That means no estimation was needed for the environment dose at he boundary. 1 GeV racetrack type storage ring was considered for skyshine source.

The same procedure was used for the skyshine dose estimation as Phase I. Skyshine point sources in the storage ring are 24. These skyshine component and direct component of neutrons were summing up and the tabulated (see Table 4). These values are smaller than the phase I. This is because the following reasons: ①energy is smaller ②small size of storage ring gives a large distance to a boundary ③change of the distribution of sources.

6 Conclusion

By using the calculation we could estimate skyshine neutron dose estimation around high-energy electron storage ring used for synchrotron orbit radiation. The detailed discussion of source term was done by introducing several operation modes and segmentation of radiation generation points. The obtained typical results of Phase I and Phase II will be effectively used for the efficient designing of this facility.

References

[1] T.M. Jenkins, Nucl. Instrum. Meth., 159, 265 (1979).
[2] R.H.Thomas et al., NIRL/M/30, Rutherford Laboratory, Cambridge University (1962).
[3] R.H.Thomas, in Engineering Compendium on Radiation Shielding, 1, 56, Splinger-Verlag, Berlin (1968).
[4] G.R.Stevenson et al., Health Physics 46, 115 81985).

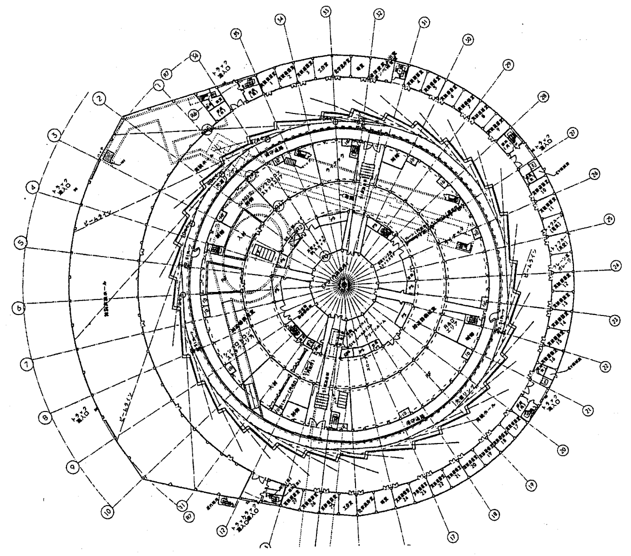

Fig.1 Disposition of LINAC and SR (Phase I)

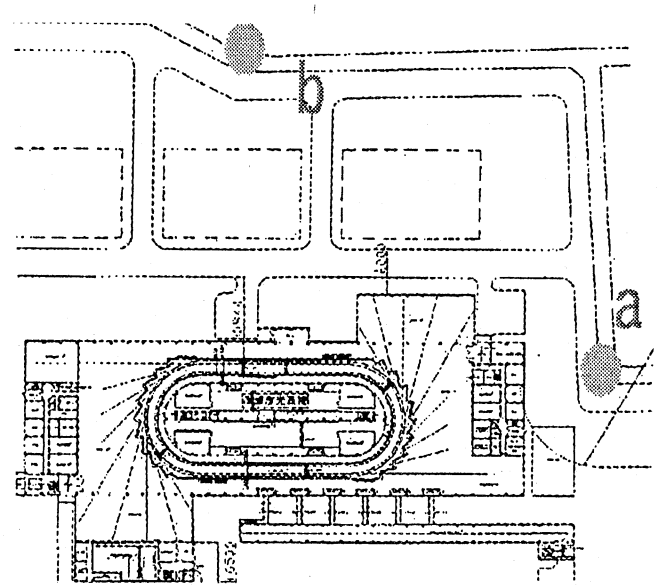

Fig.2 Disposition of LINAC and SR (Phase II)

Table 1.1 Beam Loss Ratio of Lineac

input	30%
first slit	10%
second & third slits	2%
beam dump	100%
e−/e+ converter	100%
line accelerator	1%

Table 1.2 Beam Loss Ratio of Storage Ring

adjustment period	incidence area	95%
	others	5%
beam input period	incidence area	95%
	others	5%
storage period	incidence area	80%
	others	20%

Tabe2.1 Annual Dose around LINAC (Phase I)

site ID	area	machine room (up side) bulk shield thickness cm	point shielding cm	annual dose mSv/y	klystron room (side) bulk shield thickness cm	wall side mSv/y	1m apart mSv/y	3m apart mSv/y
1	lineac	OC 250		3.6	OC 200	116.5	70.5	33.8
2	slit	OC 250		0.8	OC 200	27.2	16.5	7.9
3	lineac	OC 250		2.7	OC 200	48.8	29.5	14.2
4	slit	OC 250		5.3	OC 200	96.6	58.4	28.0
5	lineac	OC 250		2.6	OC 200	47.3	28.6	13.7
6	converter	OC 250	Fe 25	6.6	OC 200	42.5	25.7	12.3
7	lineac	OC 250	Fe 5	19.7	OC 200	223.8	135.4	64.9
8	slit	OC 250	Fe 20	18.3	OC 200	443.6	268.3	128.6
9	lineac	OC 250	Fe 5	19.2	OC 200	217.5	131.6	63.1

Tabe2.2 Annual Dose around SR (Phase I)

Beam incidence area

source	annual oparation period	estimated site ID and Sv				unit
		A-1	A-2	B-1	B-2	
	forward	S2,S3	S2,S3	S3, S0	S0, S4, S5	
	side	S0	S0	S4		
forward shielding	OC	65	65	65	65	cm
	Pb	15	20	40	15	cm
side shielding	OC	60	60	60	60	cm
	Pb	0	15	0	0	cm
forward distance to source		10.3, 3.0	16.5, 8.2	13.5, 6.5	17.5,10.3,3.0	m
side distanse to source		5.8	4.8	3.0		m
annual dose		17.3	9.6	11.1	9.3	mSv/y
multi-banti-mode(input)	4000h	0.703	0.386	0.480	0.771	μSv/h
multi-banti-mode(store)	320h	23.838	13.180	14.176	10.253	μSv/h
single-banti-mode(input)	500h	0.031	0.017	0.021	0.034	μSv/h
single-banti-mode (store)	80h	0.532	0.294	0.338	0.229	μSv/h
preparation 1	150h	5.036	2.784	3.206	2.160	μSv/h
preparation 2	200h	15.107	8.353	9.618	6.479	μSv/h
machine study	400h	7.553	4.176	4.809	3.239	μSv/h

Other than beam incidence area *forward bulk shielding 80cm (OC65+Pb15)* *side bulk shielding 60cm (OC)*

	annual oparation period	estimated site ID and Sv					unit
		C-0	C-1	C-2	C-3	C-4	
forward distance to source			9.8	15.0	10.3	14.5	m
side distanse to source		1.5	3.0	1.5	3.0	1.5	m
annual dose		1.74	0.20	1.75	0.20	1.75	mSv/y
multi-banti-mode(input)	4000h	0.205	0.024	0.206	0.024	0.207	μSv/h
multi-banti-mode(store)	320h	1.500	0.175	1.508	0.175	1.507	μSv/h
single-banti-mode(input)	500h	0.009	0.001	0.009	0.001	0.009	μSv/h
single-banti-mode (store)	80h	0.033	0.004	0.034	0.004	0.034	μSv/h
preparation 1	150h	0.317	0.037	0.318	0.037	0.319	μSv/h
preparation 2	200h	0.950	0.111	0.955	0.111	0.956	μSv/h
machine study	400h	0.475	0.055	0.478	0.055	0.478	μSv/h

Tabe3 Total Dose at the Boundary (Phase I)

site ID	Border direction	Distance(m)	Annual dose(μSv/y)
1	NE	63	33.4
2	NW	57	38.3
3	5th floor of control building*	50	72.5

*directly arrival dose, not skyshine

Tabe4 Total Dose at the Boundary (Phase II)

Site ID	Border direction	Annual dose(μSv/y)
Point A	NE	3.8(Direct) + 10.2(skyshine) = 14.0
Point B	NW	0.03(Direct) + 5.1(skyshine) = 5.1