Operation

1. Linac

The linac was in operation for about 5,070 hours in 1999. The failure rate, which corresponds to periods when no 1 GeV beam was available because of trouble etc., was 2.5 % of the total operation time.

The present parameters of the beams injected into the synchrotron and New SUBARU are summarized in Table 1.

Table 1. Beam parameters of SPring-8 linac

	SPring-8		New SUBARU
Width	1ns	40ns	1ns
dE/E	±0.3%	±0.4%	±0.2%
Current	~2A	~80mA	~200mA
ε_x 90%	6.5πnm.rad	3.1πnm.rad	7.1πnm.rad
ε_y 90%	4.3πnm.rad	5.8πnm.rad	8.5πnm.rad

The failure statistics for the year are given in Fig. 1. The event frequency of the vertical axis in the figure means the total failure count during one operation cycle. Most of the failure events are alarms from interlock circuits of devices equipped to the linac.

The majority of failures originate in the RF system of the linac and are mainly caused by deterioration or incorrect adjustment of the thyratrons as well as discharge in the klystrons. Such failures occurred frequently, especially at the startup of the linac after a long maintenance period.

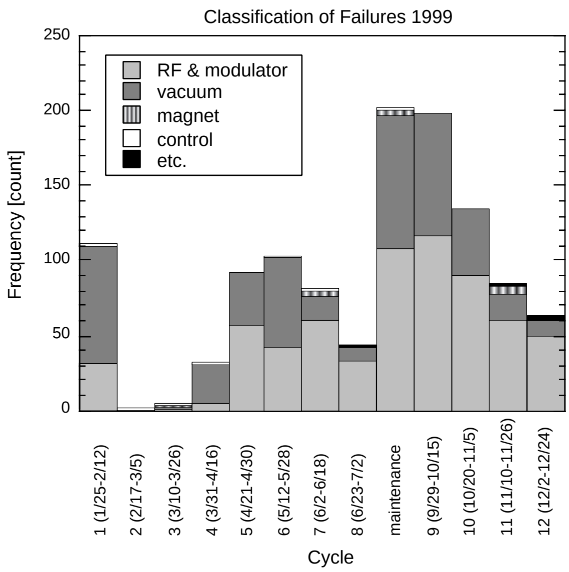

Fig. 1. Linac failure statistics for 1999.

Before the summer maintenance, the vacuum pressure at an injector section of the linac exceeded the alarm level frequently due to deterioration of the ion pumps mounted there. Therefore, six ion pumps were replaced at the summer maintenance. The noticeable vacuum failures after a long maintenance period were actually due to a rise in vacuum pressure in the accelerator guides or the waveguides during RF conditioning.

In February 1999, there was an accident when the electron gun was unable to emit a beam due to a control grid being short-circuited to a cathode of the gun. After replacement of the cathode assembly, the gun was operated without any trouble till the end of 1999. However, we observed the cathode emission decreasing and the grid emission increasing as time elapsed, as mentioned in another report.

The cumulative usage hours of klystrons and the PFN voltages are shown in the following Table 2.

Table 2. Cumulative usage hours of klystrons and PFN voltages as of No. 26, 1999

Name	LV-on time (hours)	HV-on time (hours)	Klystron type	PFN volt. (kV)
Booster	21898	19939	PV2012	25.0
H0	23454	17627	E3712	41.9
H1	23382	17832	E3712	43.3
H3	23574	17766	E3712	43.0
H5	23137	17807	E3712	43.1
M2	23233	17721	E3712	43.4
M4	11281	9728	E3712	43.1
M6	1042	1000	E3712	43.3
M8	23082	17685	E3712	42.0
M10	23578	18007	E3712	43.4
M12	23380	17904	E3712	42.2
M14	23233	16646	E3712	42.0
M16	23037	15947	E3712	20.0
M18	23738	17733	E3712	44.1

We first excluded one 80-MW klystron which was suffering from vacuum deterioration.This klystron was originally unstable and had been kept as a spare. We replaced the klystron leaking water at M6 with this spare, however, it failed in a short time.

We continued measurement of the klystron's perveance, and no klystron showed any decrease in cathode emission current.

The SPring-8 linac adopted a thyratron F351 made by TRITON as a switching tube for a klystron modulator. In 1999, five of them were replaced because of failures. Their operational lives were around 22,000 hours. Four of them had the same trouble of short circuits in their reserver heaters. According to TRITON's investigation, the alumina coating on the heater had gradually evaporated during operations and finally the heater could not be isolated. The engineers reported that these phenomena were inevitable, that is, this was the life of an F351 tube.

A Thyratron CX1937A made by EEV, which has an automatic reserver system, is one of the alternatives. Therefore we replaced some of the malfunctioning F351's with CX1937A's. We will exchange the two models henceforth, then we will be able to compare their performance and operational lives.

2. Synchrotron

We had some trouble with the synchrotron: 1) Some filters of the water cooling system, which are placed at site of the quadrupole magnets, became blocked with copper oxide. 2) The power supply to the klystrons was stopped due to the breakdown of a diode and a rectification controller. These were later repaired.

3. Storage Ring

3.1 Operation Statistics

The SPring-8 storage ring is usually operated in three-week mode for one cycle, with 38×8 hour shifts for user service mode, another 6×8 hour shifts for machine studies, and about 48 hours for tuning. Up to now the storage ring completed three years operation for user time. Over this period the storage ring was operated for more than 13,000 hours of which more than 9,000 hours were dedicated to user time. During the year 1999, the total operation time of the storage ring was 4,864 hours, and 3,364 hours (69.2%) was delivered to the users. The downtime was 61 hours, 1.3% of the operation time for the users. The remaining 1,439 hours (29.6%) were used for machine tuning, for beamline tuning and for the commissioning of new photon beamlines. The failure statistics of the storage ring in 1999 are shown in Fig. 2.

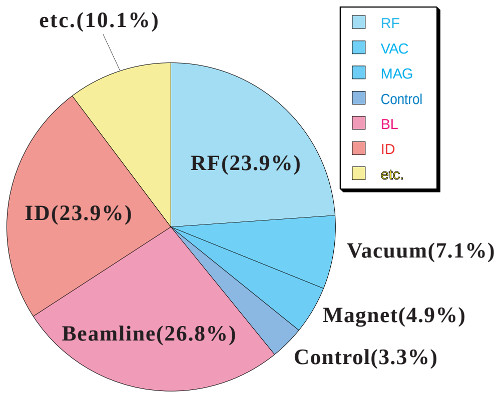

Fig. 2. The failure statistics of the storage ring in 1999.

3.2 Filling Modes

In 1999, 47.5% of the total user time was delivered in the multi-bunch mode operation. In the first half of 1999, a 2/3-filling mode was used for the user time operation. After the summer shutdown of 1999, a 24/29-filling mode began to be used for the user time operation, where 24/29 of the 2,436 available RF buckets were filled continuously with electrons. In the storage ring, the beam lifetime depends strongly on these filling modes. The beam lifetime became longer in the filling more than 24/29. It seems that the electron beam size grows as a result of instability due to an ion-trapping effect.

Recently the operations of the several bunch and hybrid filling modes with isolated bunches have increased. In 1999, the several bunch modes amounted to 1,148 hours (34.1% of user time) and the hybrid filling modes were 617 hours (18.3%). As an example of a several bunch mode and a hybrid filling mode, the 21-bunch train mode (21 equally spaced 3- or 7-bunch trains) and 1/12-partially filled multi-bunch with 10-isolated bunches were used. Since we can select an arbitrary RF bucket among 2,436 ones at each injection, the filling pattern in the storage ring can be controlled easily. In the case of isolated bunches, 1 or 1.5 mA/bunch were stored, and impurities in the low 10^{-6} range were routinely achieved in the user time operation. The maximum current per bunch is about 16mA in machine study.

3.3 Performance of the Storage Ring

The overall performance characteristics are listed in Table 3.

Table 3. Performance of the SPring-8 Storage Ring.

	Designed value	Achieved value	
	Hybrid / HHLV	Hybrid	HHLV
Energy	8GeV	8GeV	8GeV
Circumference	1436m	-	-
Number of bucket	2436	-	-
Revolution time	4.79µs	-	-
Symmetry	24 / 48	24	48
(β_x/β_y) at ID section		(24/10),(1/8)	(25/4)
Current			
single bunch	5mA	16mA	
multi bunch	10mA	10mA	10mA
Bunch length (FWHM)	36ps	36ps[$1]	36ps[$2]
Emittance	6.99 / 6.0nm.rad	6.8±0.5nm.rad	6nm.rad
Tunes(ν_x/ν_y)		51.16 / 16.36	43.16/21.36
Chromaticities(ξ_x/ξ_y)			
natural	(-115.9/-40.0) / (-105.9/51.2)		
operation		(3.2/3.9)	(7.0 / 4.0)
Momentum acceptance	~2%[$1]	1.3%[$1]	1.9%[$1]
			2.8%[$2]
Energy spread ($\Delta E/E$)	0.0011	0.0012	0.001
Coupling	less than 10%	≤0.06%	≤0.04%
Lifetime			
100mA (multi bunch)	24hr	~70hr[$3]	~140hr[$4]
1mA (single bunch)	~5hr[$1]	~11hr[$1]	~25hr[$2]
COD			
horizontal (rms)	-	<0.1mm	<0.1mm
vertical (rms)	-	<0.1mm	<0.1mm
Beam size at ID section			
horizontal (rms)	-	400µm / 86µm	390µm
vertical (rms)	-	6.7µm / 6µm	3µm
Residual dispersion at non-dispersive section			
horizontal (rms)	0	9.8mm	7.0mm
vertical (rms)	0	2.7mm	4.5mm (1.1mm[$5])

[$1] Vrf=12MV
[$2] Vrf=16MV
[$3] 2/3-filling, Vrf=12MV
[$4] 24/29-filling, Vrf=16MV
[$5] with correction by 24 skew Q's

At the normal operation of the storage ring for user time operation, 'Hybrid optics' had been used until the summer shutdown of 1999. Since the summer shutdown of 1999, the new optics have been used in user time operation. The new optics is called a 'HHLV optics' which means 'High Horizontal and Low Vertical betatron functions'.

In order to stabilize the orbit of the storage ring, periodic and global orbit correction is now routinely used in user time operation.

An integrated beam dose of 425Ah was achieved at the end of 1999. In the summer shutdown of 1999, the fourth RF station was installed. With this fourth RF station the total accelerating voltage increased from 12 to 16MV and beam lifetime increased from 100 to 140 hours in user time operation of the 24/29-filling multi-bunch mode at 100mA.