2000.2.11 KEKB Accelerator Review Committee
Atsushi ENOMOTO (Accelerator Laboratory, Electron/Positron Injector Group)

LINAC

1. Introduction

The KEK 8-GeV electron/ 3.5-GeV positron injector linac was upgraded from the 2.5-GeV linac during 1994-1997; Following commissioning it began routine injection for the KEKB ring in December 1998.

The two main goals of the linac upgrade, an acceleration energy of >8 GeV and a positron intensity of > 0.64 nC (4 x 10^9 e+)/bunch after the energy compression system (ECS) at the end of the linac, were achieved on April 24, 1998 and April 8, 1999, respectively.

Since the last review committee, the primary effort has been to improve the stability of linac, especially the high-current electron beam for positron production, because the above performance of the positron beam was not maintainable after beam tuning and the average performance was about 50%. Related to this, the reproducibility of switching beams was also improved. This report presents the linac improvements, concentrating on the stability issues.

2. Stability of the linac

2-1 Positron beam improvements since 1999.4

The average intensity of positron beam after energy compression has notably been improved since the summer shutdown. It increased by about 50% from 0.32 nC (April to August) to 0.45 nC (October to December), and then again to 0.62 nC (January to February). The best injection rate of 1.8 mA/s was recorded in January 2000. This progress was mainly due to the primary electron beam becoming more stable as a result of hardware improvements and the development of a feedback system.

2-2 Tolerance of the linac parameters

Though many factors were considered possibly resposible for degradation in positron intensity, when the positron beam intensity decreased, we found that the positron orbit had usually changed below the pre-injector most upstream in the linac. This consists of a triode electron gun, a 25th subharmonic buncher (114.24-MHz SHB), a 5th (571.2-MHz) SHB, a fundamental (2856-MHz) prebuncher and a main buncher.

In the linac beam study, the tolerances needed to keep the high-current beam hitting the positron target at more than 90% of the best tuned intensity (9.4 nC/bunch at that time) were studied. Some results were as follows: gun beam timing-- ±45 ps; gun high voltage-- ± 0.38%; SHB1 phase-- ±1.1 deg; SHB2 phase-- ±1.3 deg; buncher phase-- ±1.7 deg. These parameters, except for the gun high-voltage, had not been stabilized before the monitors and the feedback system were installed.

2-3 Hardware improvements

The first thing started was to improve monitors for the rf and beam timing. As for the pre-injector proper, there were some old components such as a 114-MHz, 10-kW main amplifier and a 2856-MHz 1-kW drive amplifier, which had been unstable during operation. The cooling performance of SHB2 was not sufficient. These improvements were undertaken during the summer shutdown in 1999. During the new-year shutdown, the gun-beam timing, which is determined by the gun-grid pulser timing system, which is synchronized with the master frequency (571.2 MHz), became monitored and stabilized. A gun modulator and a high-power klystron modulator for the fundamental bunchers were finely tuned and stabilized.

According to the rf and timing monitors and beam study of linac parameter tolerances, it seems that the linac beam instability was due to multiple factors.

2-4 Feedback system

As of one year ago, using a host computer, we had developed feedback software to stabilize: 1) the beam energy at the linac arc; 2) the beam energy at the end of the linac (e- and e+); 3) the beam orbit at the end of the linac; 4) the gun high-voltage; 5) the 114-MHz SHB power; and 6) the 571-MHz SHB power. Subsequently we have added feedback loops to: 7) the gun grid pulse timing; 8) the 114-MHz SHB rf phase; 9) the 571-MHz SHB rf phase; and 10) the beam orbit before the positron target. These feedback tasks should be run on local hardware or computers, but this has not been done so far. One of reason for not using hardware is noise problems in the klystron gallery. A fast host computer (CPUs: Alpha 21264, 500 MHz x 2) was added for this purpose before the summer shutdown.

2-5 Beam switching

The linac must inject four kinds of beam: 1) KEKB 8-GeV electrons, 2) KEKB 3.5-GeV positrons, 3) PF 2.5-GeV electrons, and 4) AR 2.5-GeV electrons. The changed parameters and switched devices are: 1) Gun parameters; 2) Positron devices (target, chicane); 3) BT parameters (using hysteresis loop for Q and B); 4) Rf phase; 5) Standby accelerator; 6) BPM range; and 7) Beam repetition. Since the last review committee, due to the addition of feedback programs, different kinds of software for each beam came under automatic control. Up/down speeds of the magnet currents were controlled to avoid troubles due to abrupt switching damaging the power supplies.

2-6 Fault and rf trip rate

From the beginning of KEKB commissioning in December 1998 untill April 1999, the linac fault rate increased to about 7% of the operation time. Before the upgraded linac began commissioning in 1998, the fault rate had been around 1%. This is because the linac operation load became more severe: the power of the rf source increased four times compared to before and the number of injections and switchings increased. Most components had been considered and improved before the upgraded linac commissioning; nevertheless, during the initial period, the fault rate was notably increased. But following machine maintenance during the BELLE roll-in, the fault rate decreased by 50%, and after the summer shutdown this rate has been maintained and tends to decrease slowly.

The rf trip rate, that is, the rate of momentary stops of klystron, is also an important factor for linac operation. In January 2000, every 8.0 minutes on average an rf trip occurred. 76% of the rf trips were due to by arcing of the accelerator components, and recovered immediately. This was under the condition of an average accelerator gain of 22.2 MeV/m or 167.5 MeV /accelerator module. The rf trip rate needs to be further reduced.

3. Summary

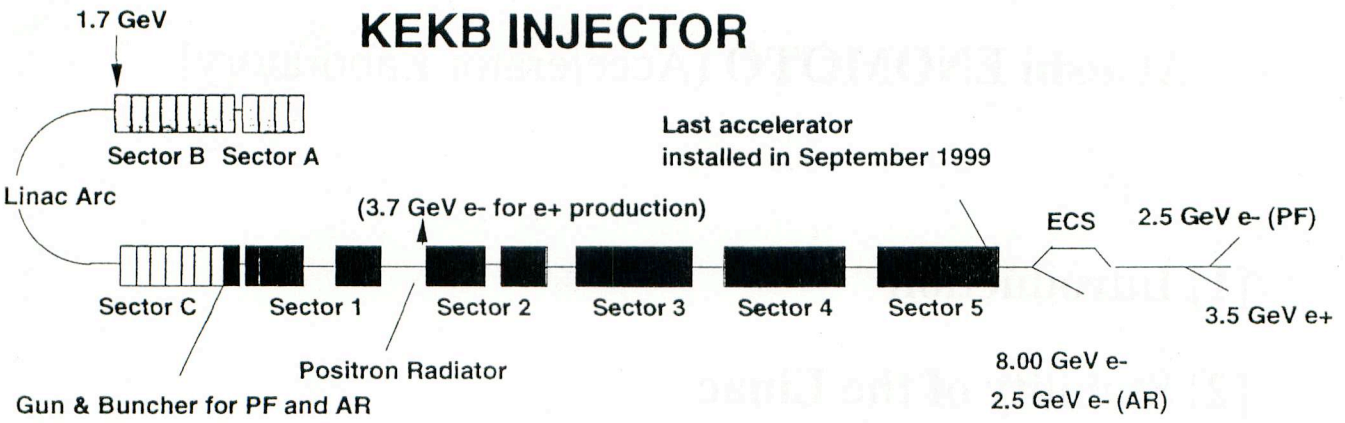
(1) The average intensity of the positron beam and the reproducibility of the different kinds of beam switchings have been improved by the linac stabilizing project since the last review committee.

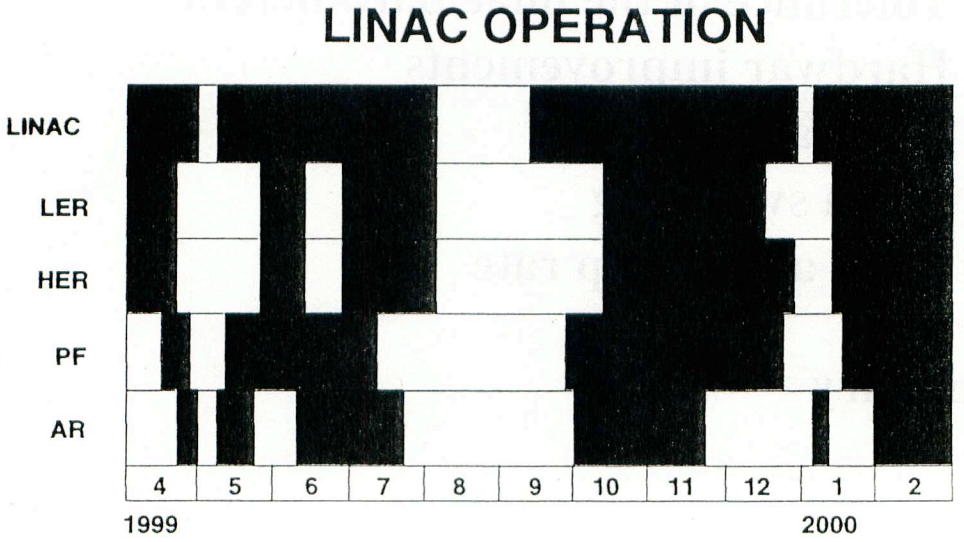
(2) To further decrease the fault and trip rates and to avoid serious problems are the most important goals for the linac at this time.

LINAC

Atsushi ENOMOTO (Accelerator Laboratory)

[1] Introduction





Linac primary effort in FY1999

Stabilizing the linac, especially the high-current beam for positron production, including the reproducibilty of the different kinds of beam switchings.

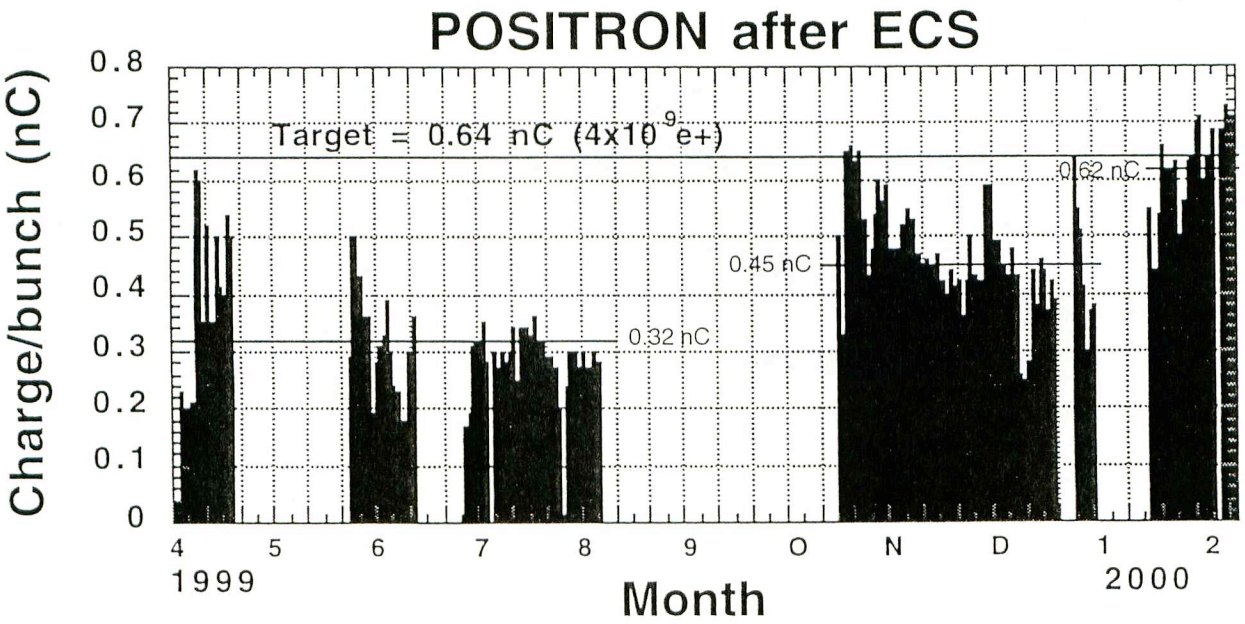
[2]-1 Positron beam progress since 1999.4

Positron beam after energy compression:

Target:	0.64 nC/bunch
Max:	0.82 nC/bunch (2000.2.3)
Average:	0.62 nC/bunch (2000.1.12-2.6)

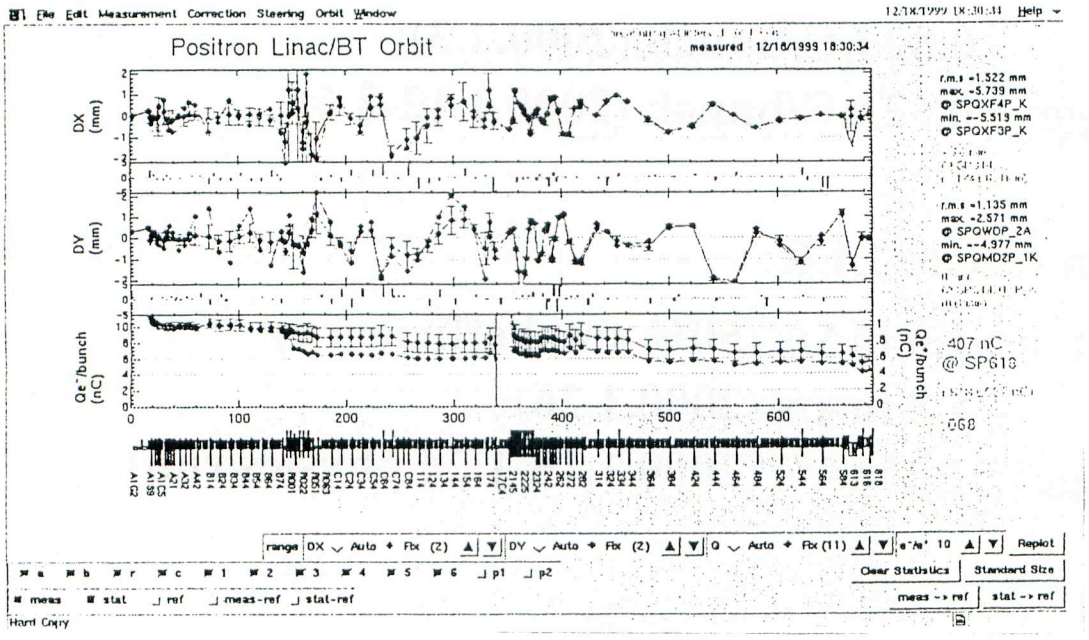
Injection rate to LER:

Target:	>1.6 mA/s (50% total efficiency)
Max:	1.8 mA/s (2000.1.26)
Average:	1.2 mA/s (2000.1.15-1.24 physics run)

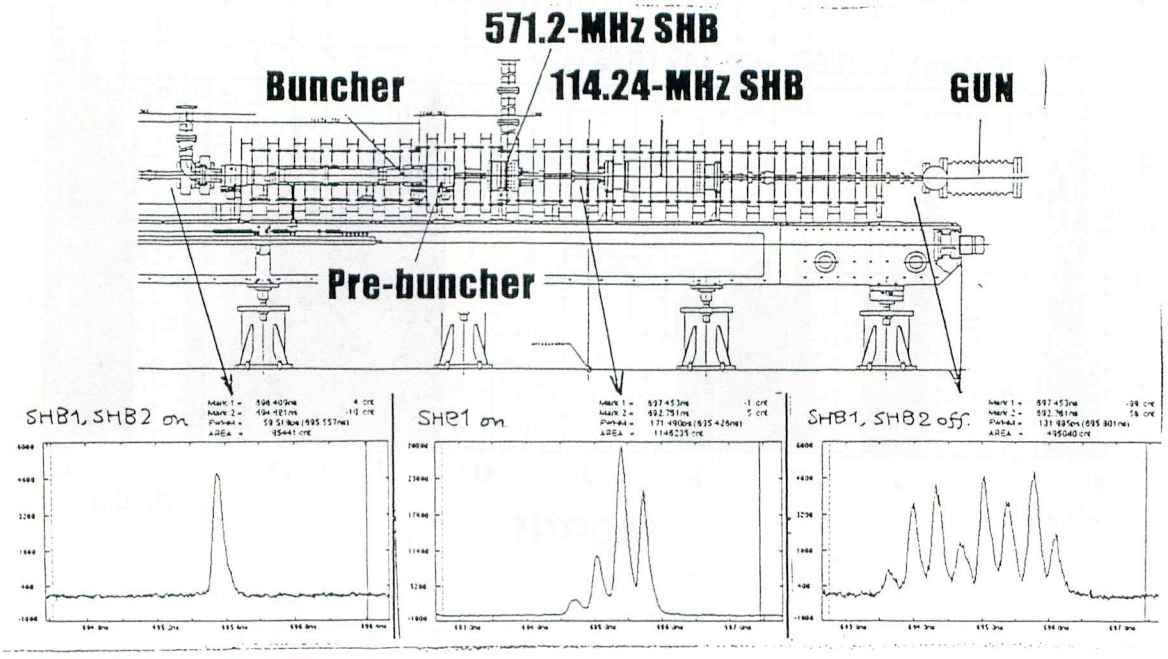


[2]-2 Tolerance of the linac parameters (1)

Beam orbit and current distribution

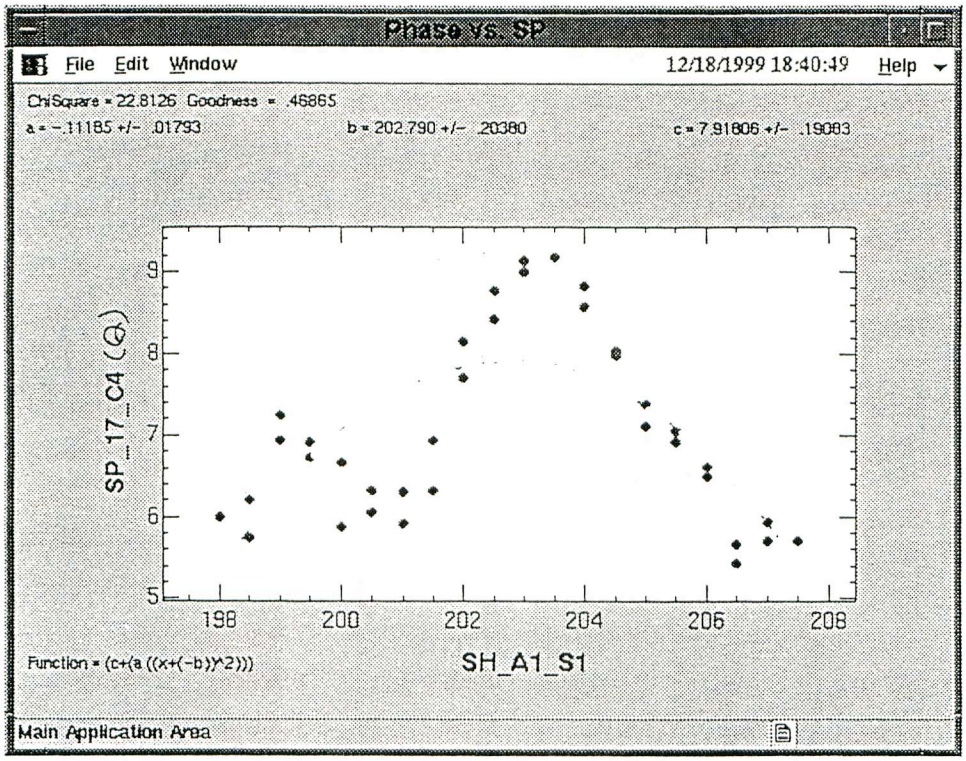


Pre-injector



[2]-2 Tolerance of the linac parameters (2)

Measurement

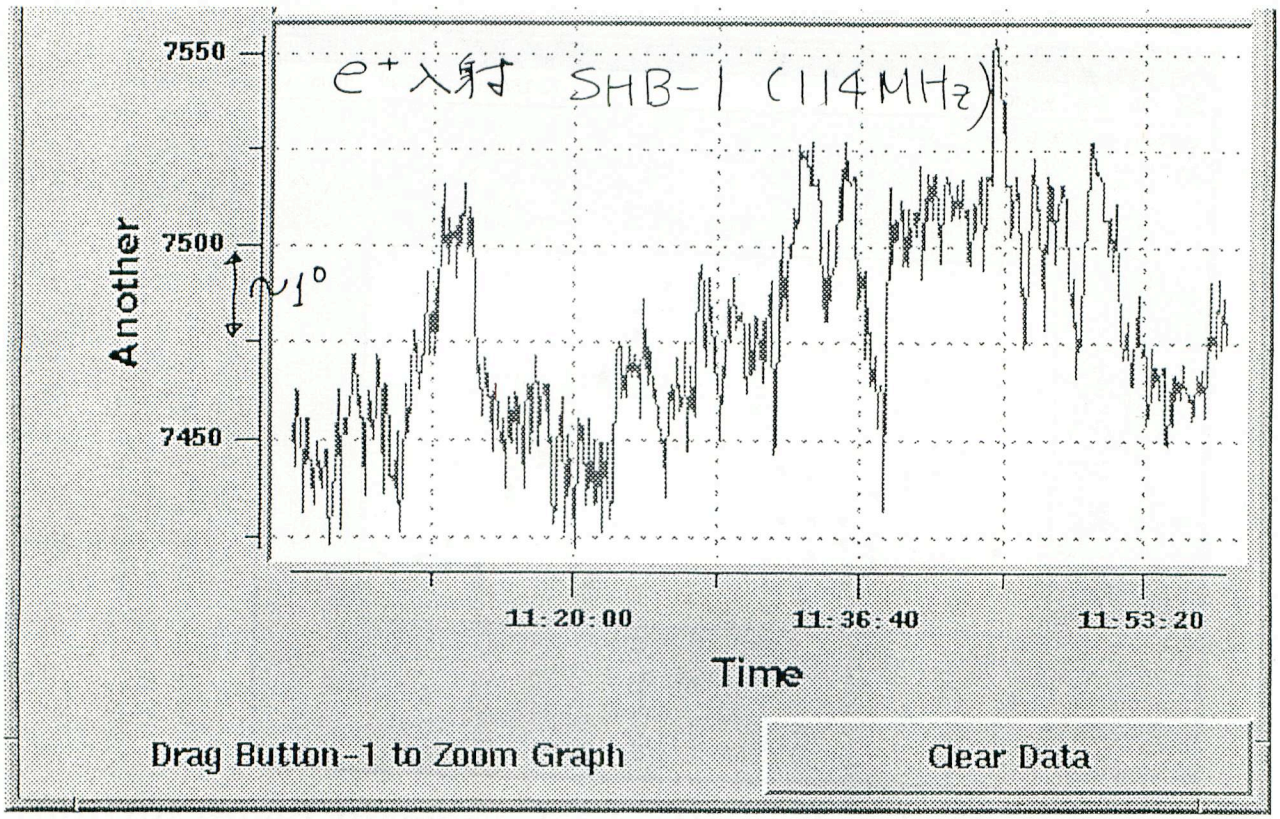


Tolerances needed to keep the high-current beam hitting the positron target at more than 90% of the best tuned intensity (9.4 nC/bunch at that time)

Gun beam timing,	±45 ps
Gun high voltage,	± 0.38%
SHB1 phase,	±1.1 deg
SHB2 phase,	±1.3 deg
Buncher phase;	±1.7 deg

[2]-3 Hardware improvements

Ex) Phase stability before improved.



During the summer shutdown in 1999

- Monitors for the rf
- Some old components
  - ex.114-MHz, 10-kW main amplifier
    - 2856-MHz 1-kW drive amplifier
    - SHB2 (cooling performance not sufficient)

During the new-year shutdown

- Gun-beam timing monitored and stabilized

[2]-4 Feedback system

As of one year ago:

1) Beam energy at the linac arc
2) Beam energy at the end of the linac (e- and e+)
3) Beam orbit at the end of the linac
4) Gun high-voltage
5) 114-MHz SHB power
6) 571-MHz SHB power

Subsequently added:

7) Gun grid pulse timing
8) 114-MHz SHB rf phase
9) 571-MHz SHB rf phase
10) Beam orbit before the positron target

Before the summer shutdown,

A fast host computer was added for the feedback
(CPUs: Alpha 21264, 500 MHz x 2)

[2]-5 Beam switching

Switching four kinds of beam:

1) KEKB 8-GeV electrons
2) KEKB 3.5-GeV positrons
3) PF 2.5-GeV electrons
4) AR 2.5-GeV electrons

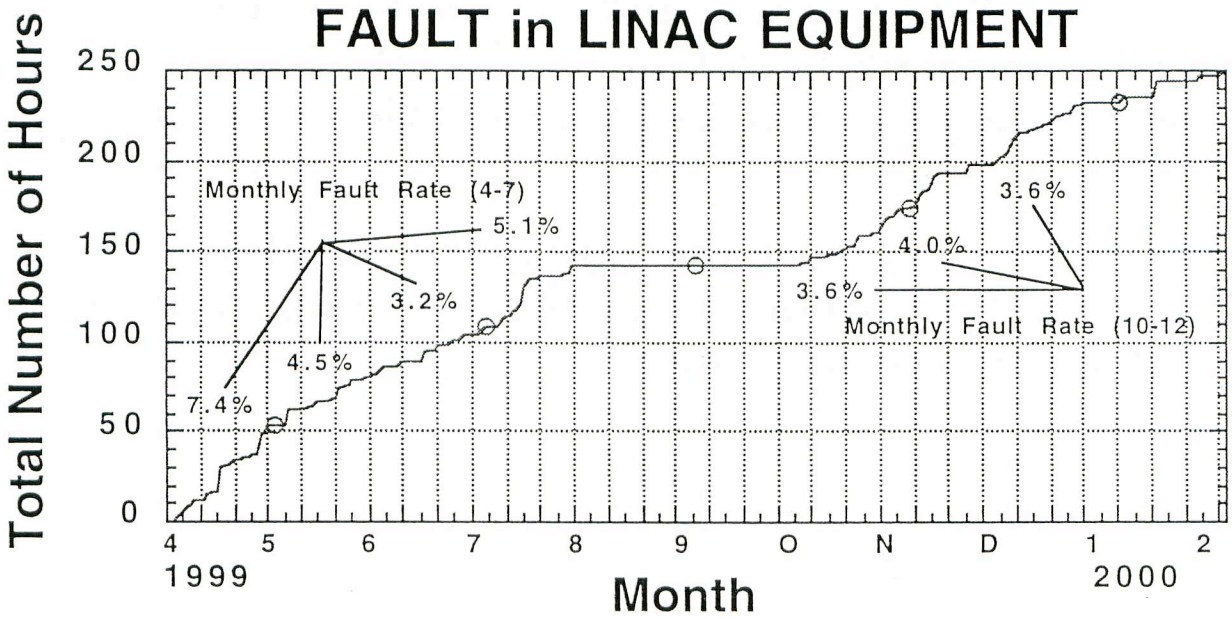
Changed parameters and switched devices:

1) Gun parameters
2) Positron devices (target, chicane)
3) BT parameters (using hysteresis loop for Q and B)
4) Rf phase
5) Standby accelerator
6) BPM range
7) Beam repetition.

Since the last review committee,

1) Different kinds of feedback programs for each beam came under automatic control.
2) Up/down speeds of the magnet currents were controlled to avoid damaging the power supplies.

[2]-6 Fault and rf trip rate



Histry (fault rate)

FY1999	4%	
FY1998	7%	KEKB started
FY1997	2.9%	
FY1996	0.6%	
FY1995	0.7%	
FY1994	0.8%	
FY1993	0.9%	
FY1992	1.4%	
FY1991	2.0%	
FY1990	1.7%	
FY1989	1.3%	
FY1988	4.6%	
FY1987	3.9%	TRISTAN started
FY1986	0.7%	

3. Summary

(1) The average intensity of the positron beam and the reproducibility of the different kinds of beam switchings have been improved by the linac stabilizing project since the last review committee.

(2) To further decrease the fault and trip rates and to avoid serious problems are the most important goals for the linac at this time.