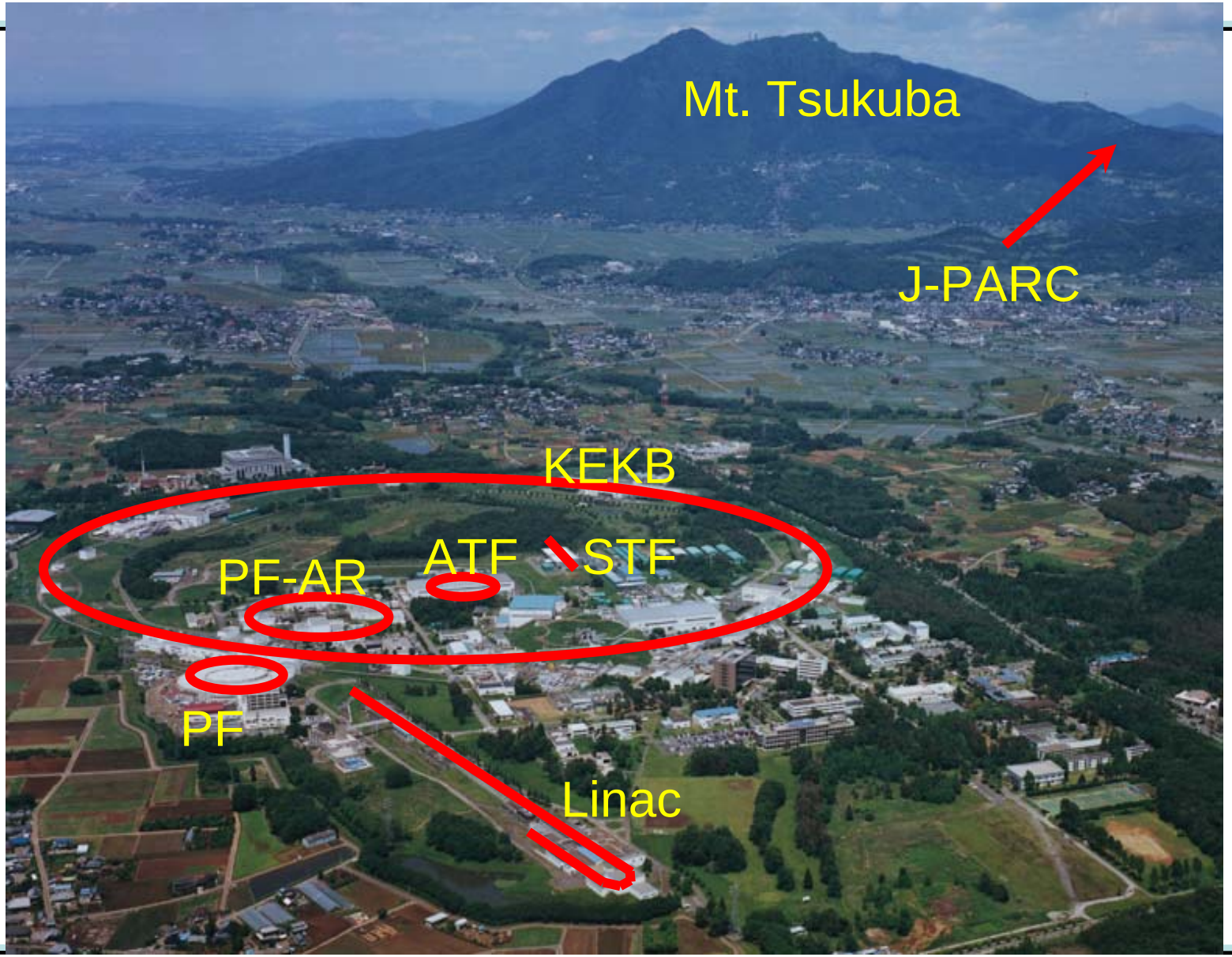
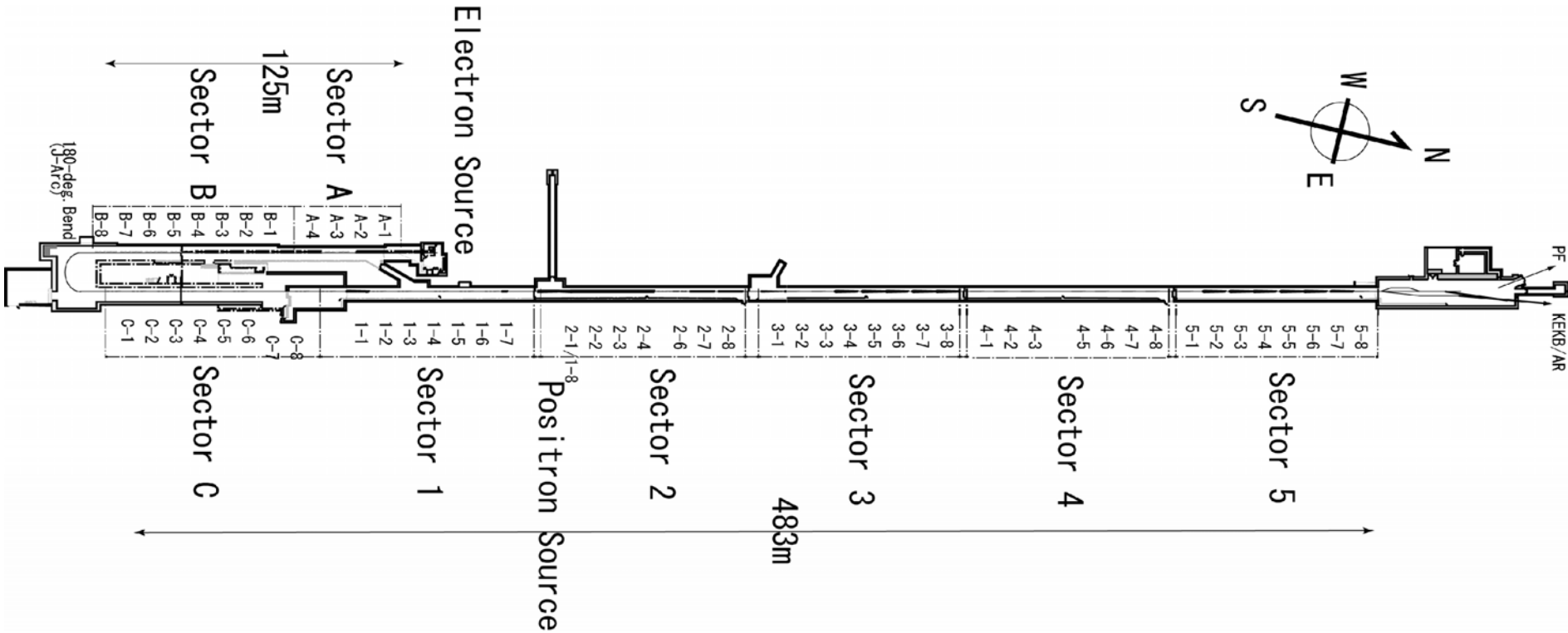
High availability issues and solutions at KEK

example: KEKB injector linac (whole system including llrf)

Shin MICHIZONO, KEK

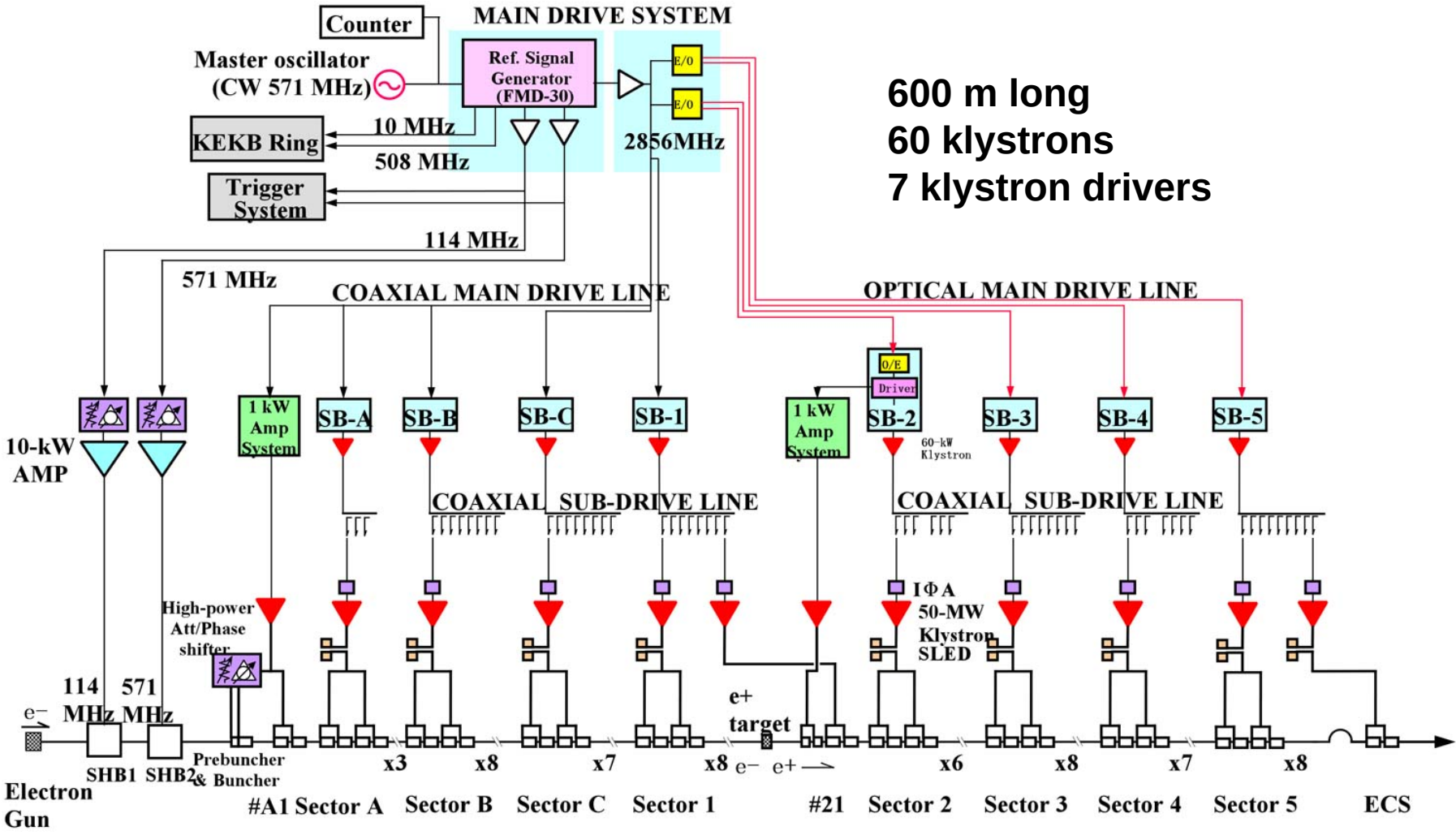

Mt. Tsukuba
J-PARC
KEKB
ATF
STF
PF-AR
PF
Linac

KEKB injector linac

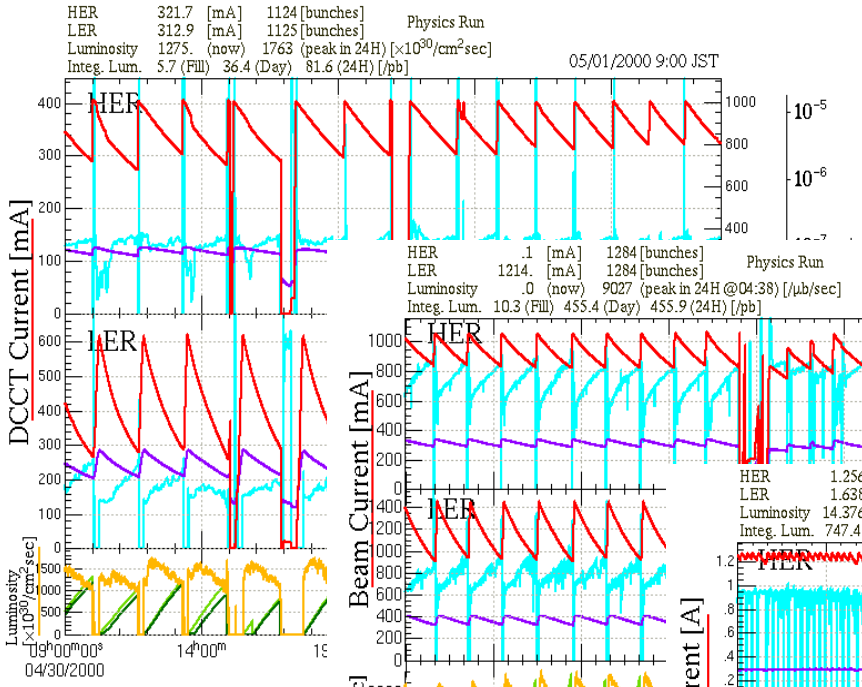


Total 600 m
e-(8GeV)/e+(3.5GeV) injector to KEKB
e- (2.5GeV,3GeV) to PF, PF-AR (light source)

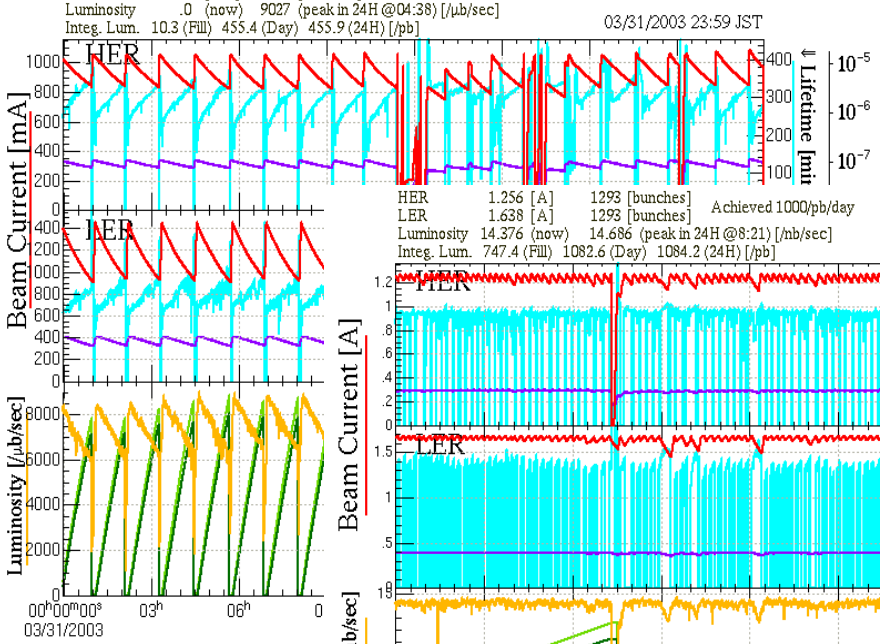
RF system schematic



Increase of the Luminosity

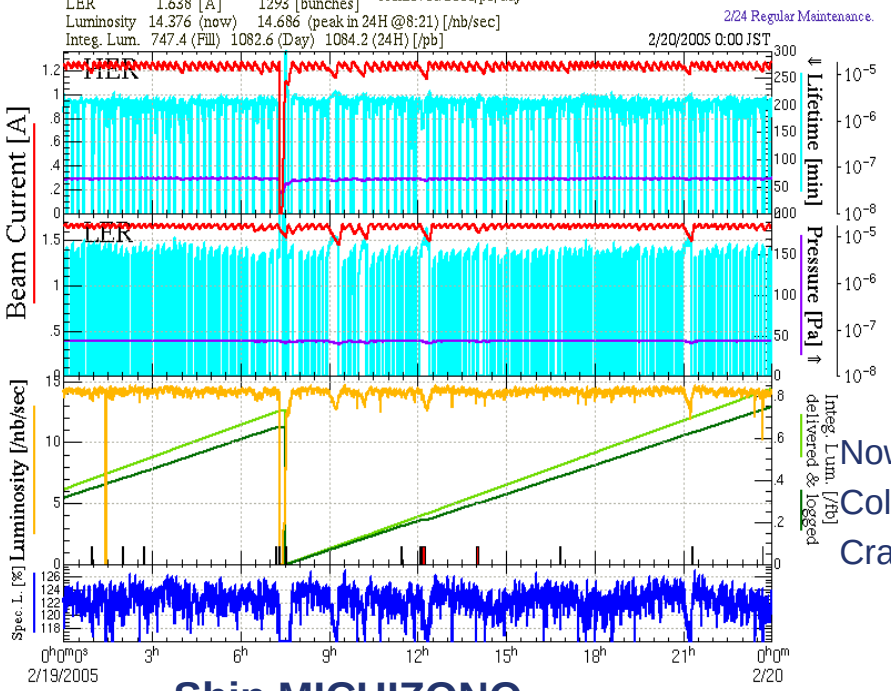


May.2000



Apr.2003

Dual Bunch e^+



Feb.2005: Continuous Injections

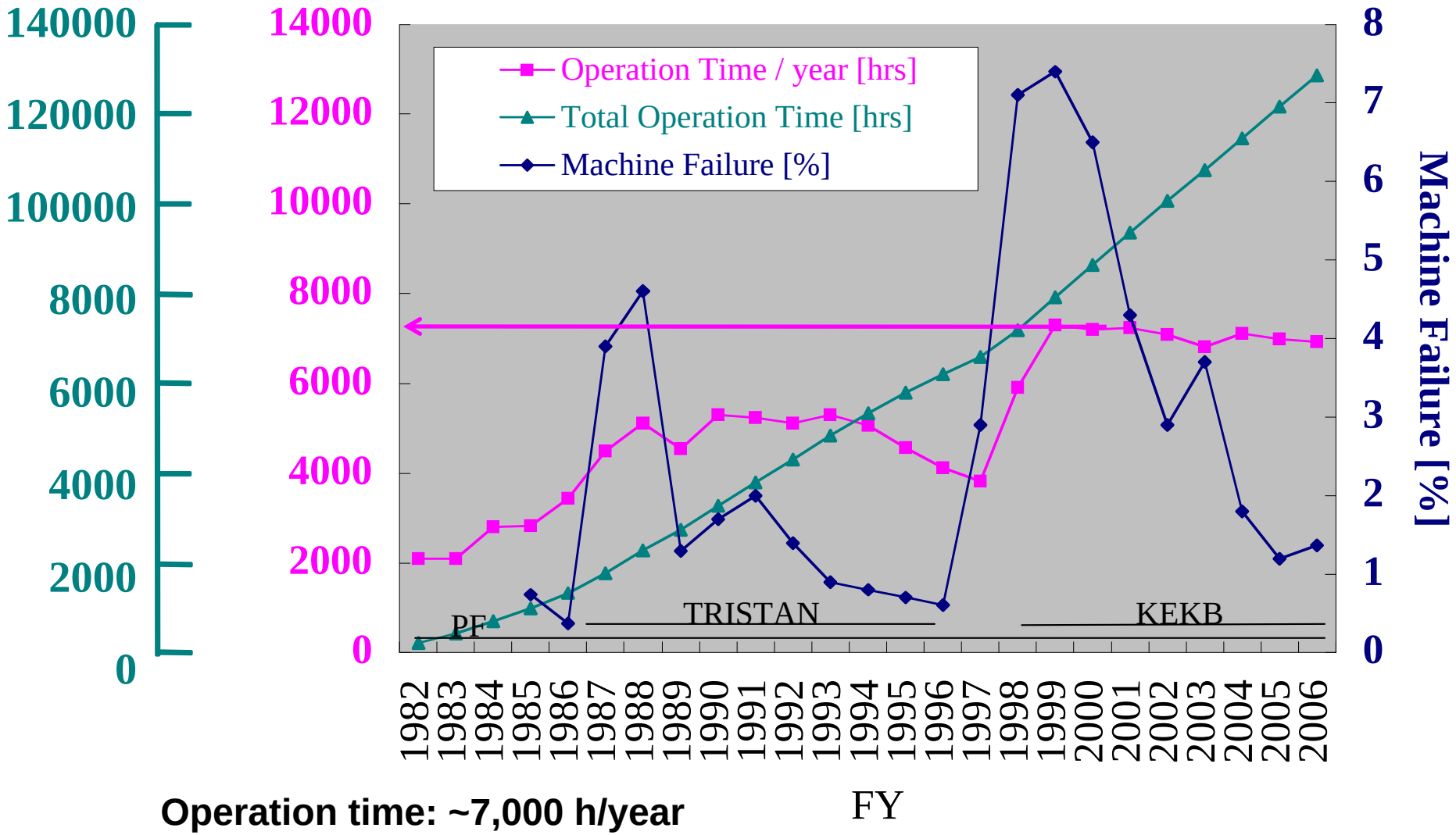
Linac injects almost all time to the rings.

Now

Collision with

Crab Cavities

Operation time

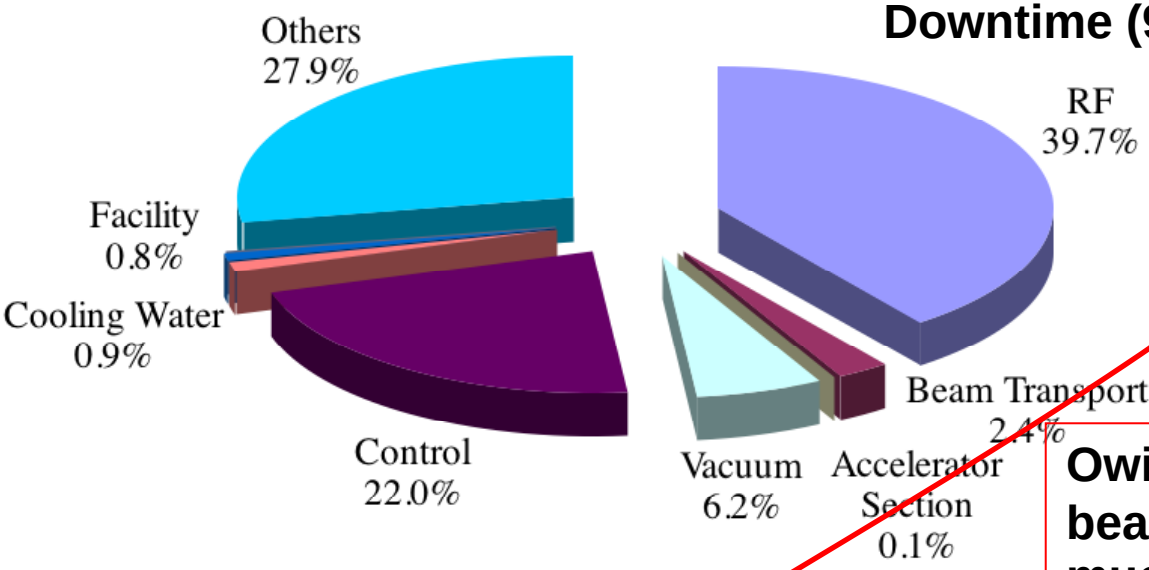


Operation time: ~7,000 h/year

High availability of injection is requested from light sources and KEKB.

Downtime and Injection delay

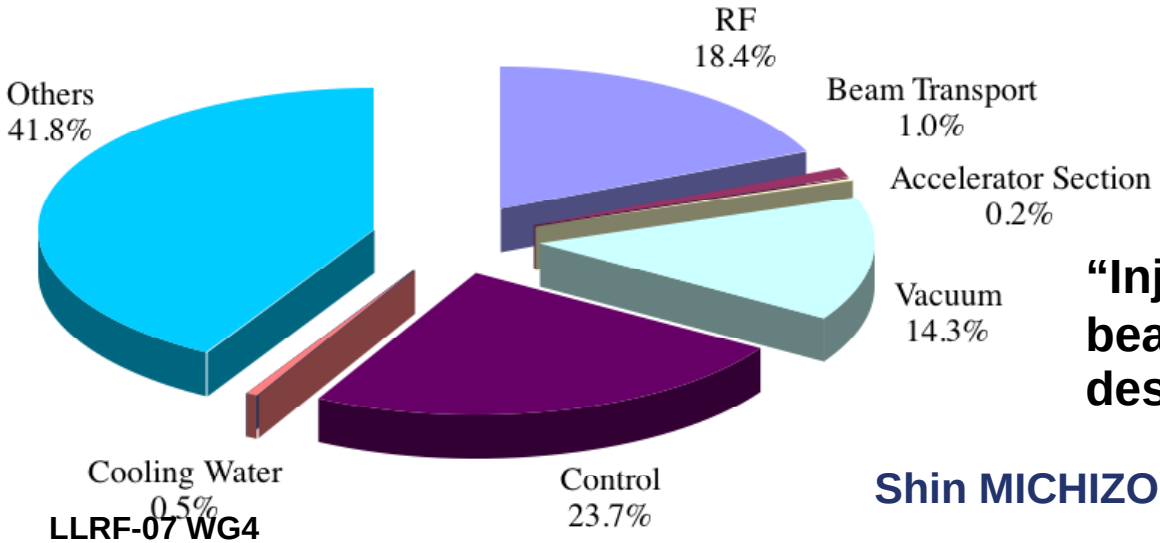
Downtime (95 hours/ ~7000h operation)



"Downtime" means the time necessary for recovering the failures.

Owing to the stand-by units and beam-optics change, delay time is much shorter than down time.

Injection delay (22 hours/ ~7000h operation)

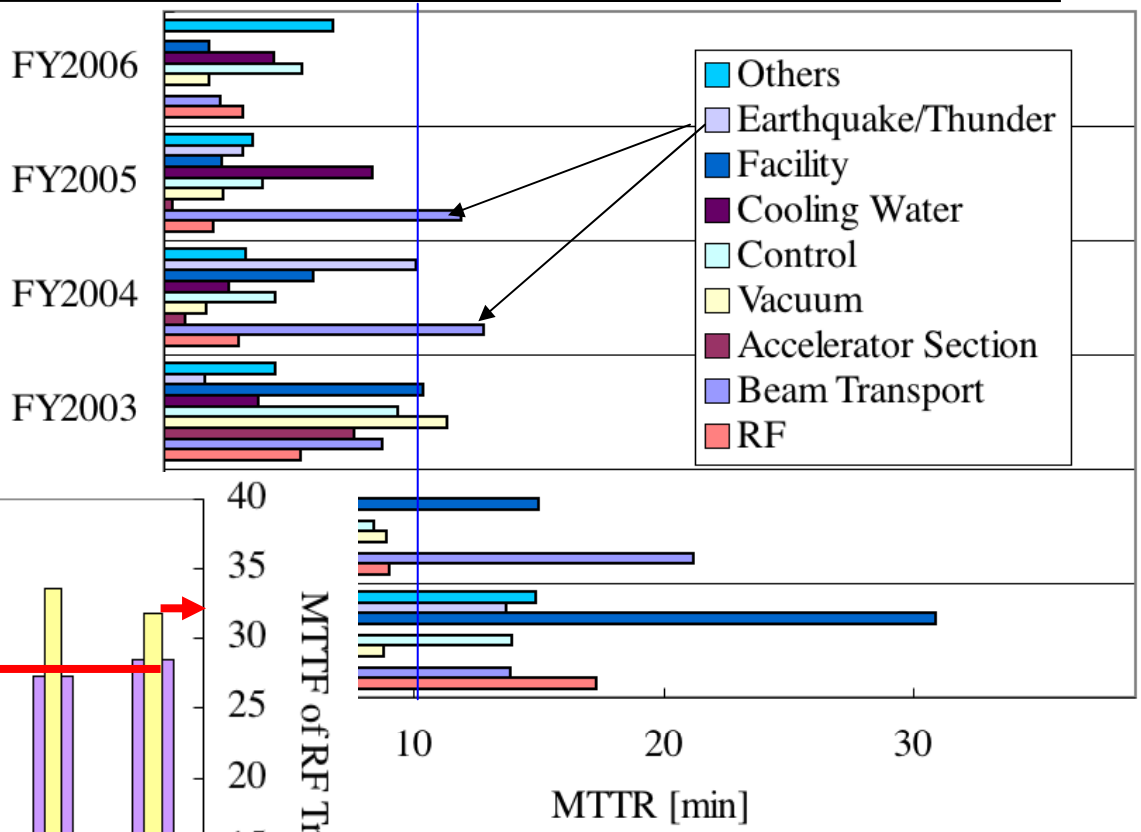


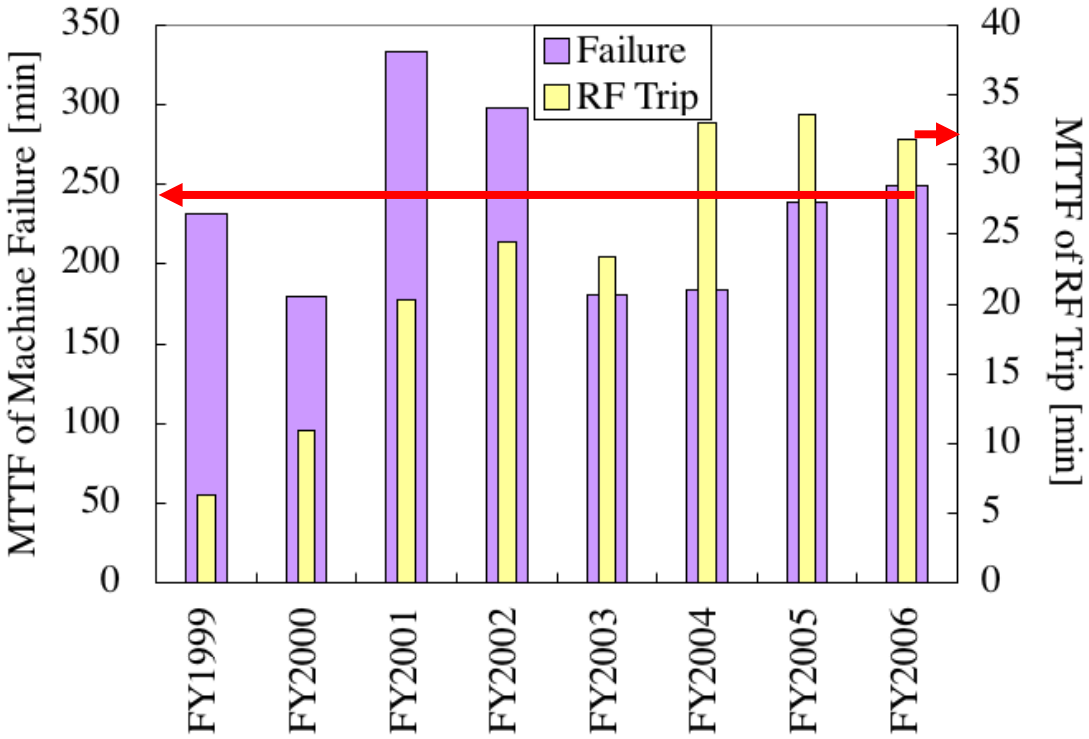
"Injection delay" means beam unavailable time despite of beam request.

MTTR and MTTF

MTTR (Mean time to repair): Necessary time for recovery

In the case of an earthquake, we sometimes check the whole beam tunnel for safety.





MTTF (Mean time to failure): Time duration between failures

RF trip: mainly due to the discharge at acceleration structure.
It happens 300/week/60-units.

Example of injection down

1. **Rf reflection (due to discharge): ~30 sec.**
2. **Klystron discharge: ~30 sec.**
3. **Magnet interlock: ~5 min.**
4. **Vacuum (due to discharge): ~5 min.**
5. **Water: ~10 min.**
6. **Board or PS (electronics): ~30 min.**
7. **Master oscillator: ~2 hours**
8. **Thyratron replacement: ~2 hours**
9. **Klystron replacement: ~3 days (including conditioning)**

Most of downtime is due to 1. to 5.
In the case of 8. and 9. we change the unit to stand-by.

High availability (comparison with ILC)

(from ILC RDR available from web)

2.9.2 Availability

2.9.2.1 Importance of Availability

The important figure of merit for the ILC is not the peak luminosity but the *integrated* luminosity. The integrated luminosity is the average luminosity multiplied by the uptime. Having surveyed the uptime fraction (availability) of previous accelerators, a goal of 75% availability has been chosen for the ILC. This is comparable to HEP accelerators whose average complexity is much less than that of the ILC. As such it should be a challenging, but achievable goal. This goal is made even more challenging by the fact that all ILC subsystems must be performing well to generate luminosity. In contrast, a storage ring has an injector complex that can be offline between fills without impacting performance.

Because it has more components and all systems must be working all the time, attaining the target availability for the ILC requires higher availability components and more redundancy than previous accelerator designs. High availability must be an essential part of the design from the very beginning. A methodology is in place to apportion the allowed downtime among various components and arrive at availability requirements for the components.

KEKB injector (99.7% injection availability):

60 units (1/10 of ILC)	**(ILC scaled):99.7%^10=96.9%**
600 m in length (1/50 of ILC)	**(ILC scaled):99.7%^50=85.3%**
8 GeV in energy (1/60 of ILC)	**(ILC scaled):99.7%^60=82.6%**

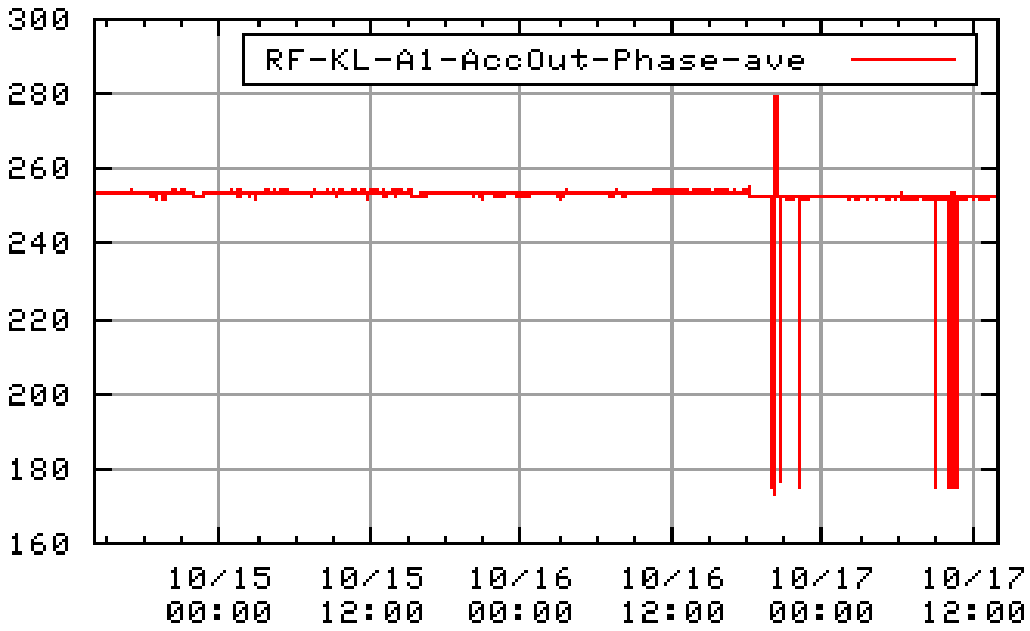
Scaled availability suggests KEKB injector linac satisfies ILC requirements (although this linac is rather old machine.)

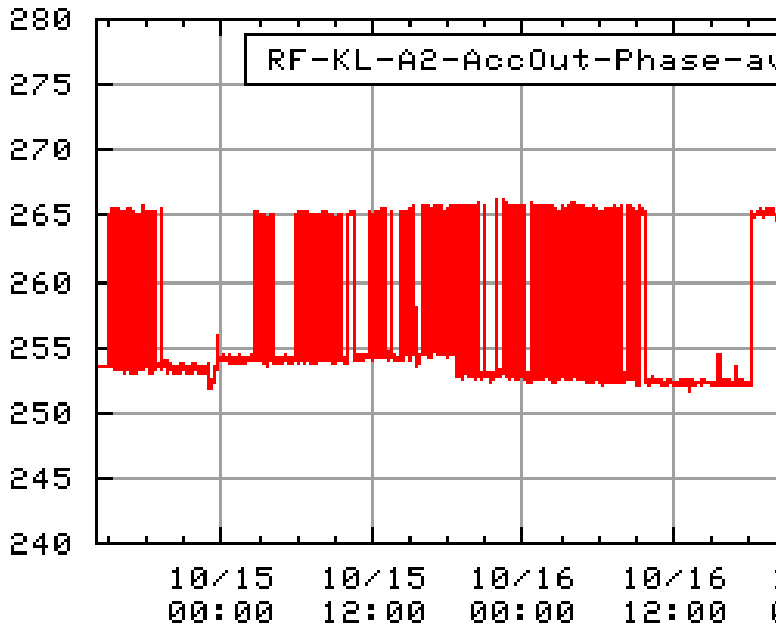
Efforts to suppress MTTR and to prolong MTTF

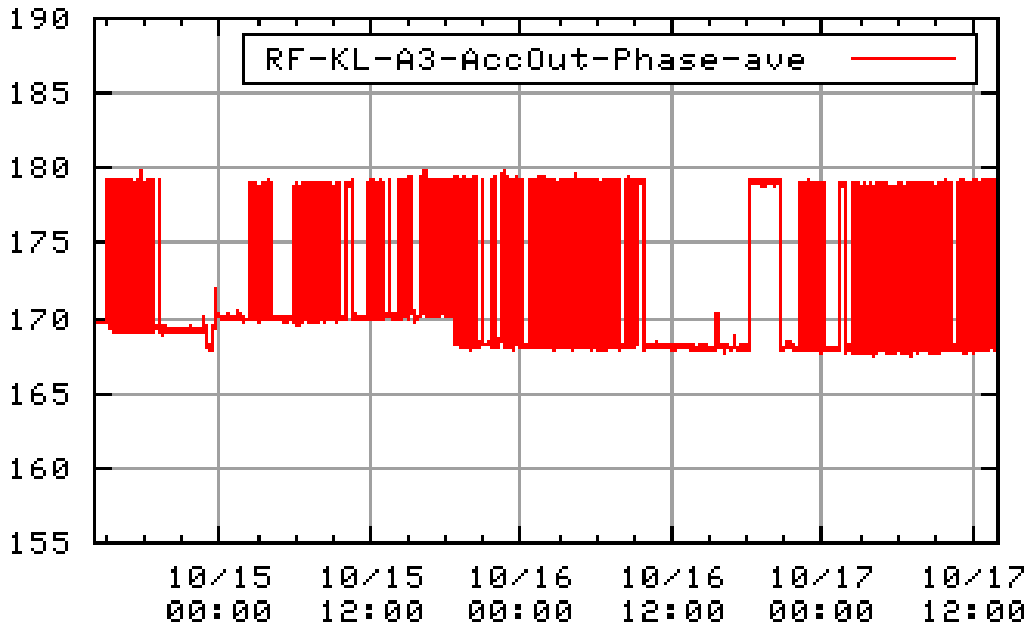
1. **Hardware diagnostics (: enable to find problema in a short time)**
   - **RF amplitude/phase trend**
   - **Water temperature (with warning)**
   - **RF power meter**
   - **Interlock status**
   - **Experienced operators -> Automation?**

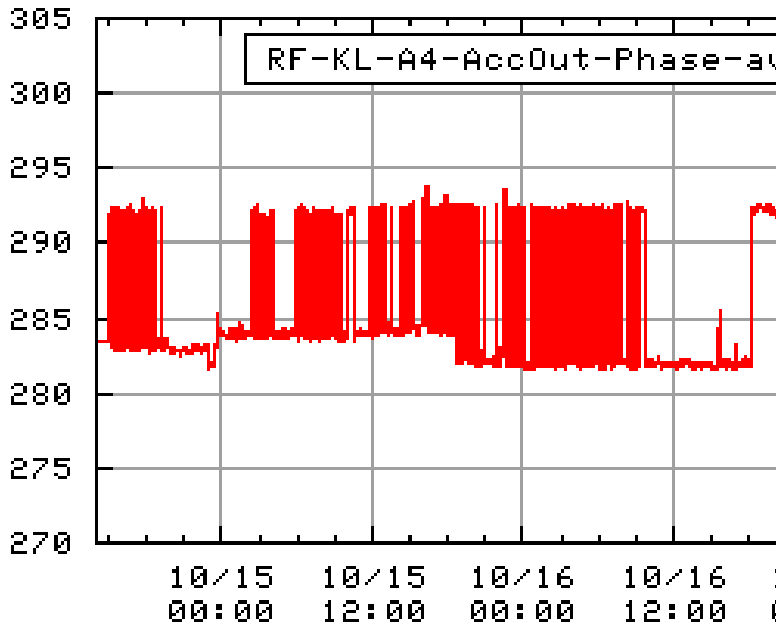
2. **Biweekly regular maintenance (8-hour)**
   - **Regular Checkup**
   - **Optimal tuning (: enables to prolong MTTF)**

2007/10/14 14:00:00 - 2007/10/17 14:00:00









Summary

1. **KEKB injector linac operates ~7,000 hours/year and deliver 4 kinds of beam to light sources and KEKB.**
2. **High availability is required from both light sources and KEKB.**
3. **The downtime is ~97% and injection availability is >99.5% (owing to stand-by units).**
4. **This number can satisfy ILC-HA requirements (although our linac is old.)**
5. **Hardware diagnostics, biweekly regular maintenance, and especially experienced operators contribute to suppress MTTR and prolong MTBF.**
6. **Intelligent automation (including experiences of skilled operators) will be important for next generation HA accelerator.**