Safety systems for the pulse by pulse operation at SPring-8 Angstrom Compact free electron LAser facility, SACLA

Yoshihiro Asano

and

The Ad Hoc committee

XFEL/RIKEN SPring-8 Center

asano@spring8.or.jp

SPring-8 & SACLA

SPring-8 (3^{rd} generation SR)
(User operation 1997~)

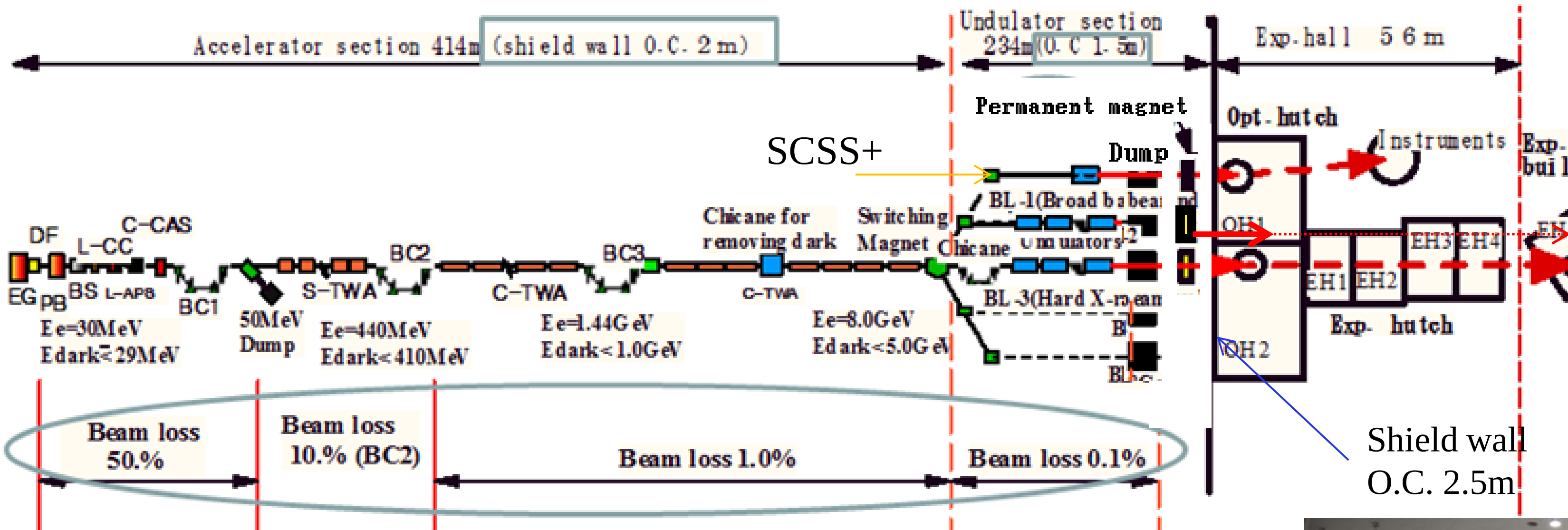
- 8GeV electron energy
  - 1GeV LINAC Injector
  - 8GeV Booster synchrotron
  - 1436m circumferential ring
- 61 beamlines
  (operation:57beamlines)

SACLA(4^{th} generation ; SPring-8 Angstrom Compact x-ray free electron LAser)
(User operation 2012.3~)

- ~10 GeV electron energy (max. licence)
  Accelerator section(414m), Undulator section (234m), Exp. Hall(56m)
- 5 beamlines (now: three beamlines are operated (XFELs & SR))

SACLA

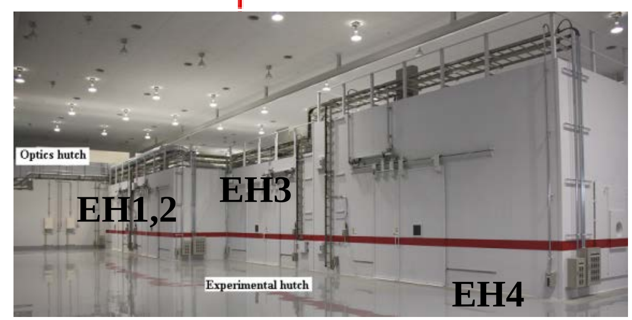
XFEL wave length: less than 0.1nm
10 GeV, 60pps, 0.5nC/pulse (design)



CeB_6 thermionic gun

C-band accelerator tube

In-vacuum type undulator
Period 18mm



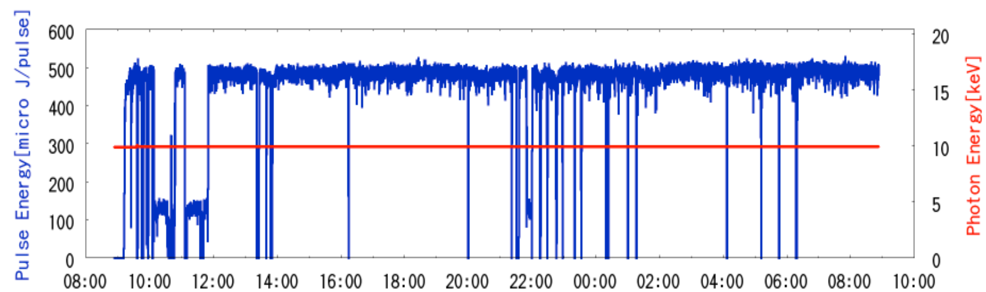
Exp. hall

Present Status of SACLA

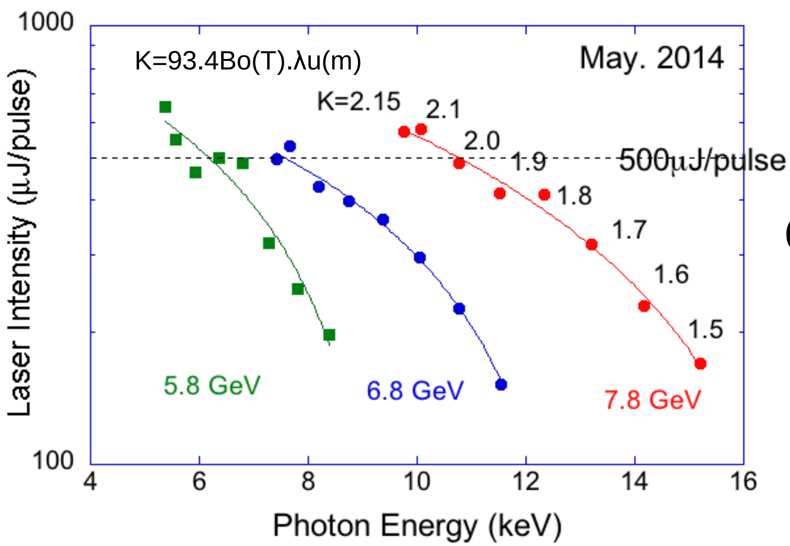
2005.4	Manufacture of a 250MeV test facility (SCSS) begins
'05.12	**XFEL project was started**
'11.2	**Commissioning was started (RF H.V. & Gun H.V. supply)**
'11.3	**Undulator light was observed**
'11.6	**First XFEL was observed**
'12.3	**Operations for users were started**

11 May 2015

Pulse Energy	Photon Energy / Wavelength
482.5 micro J/pulse	9.9 keV / 0.124 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
30 Hz	10.9 %



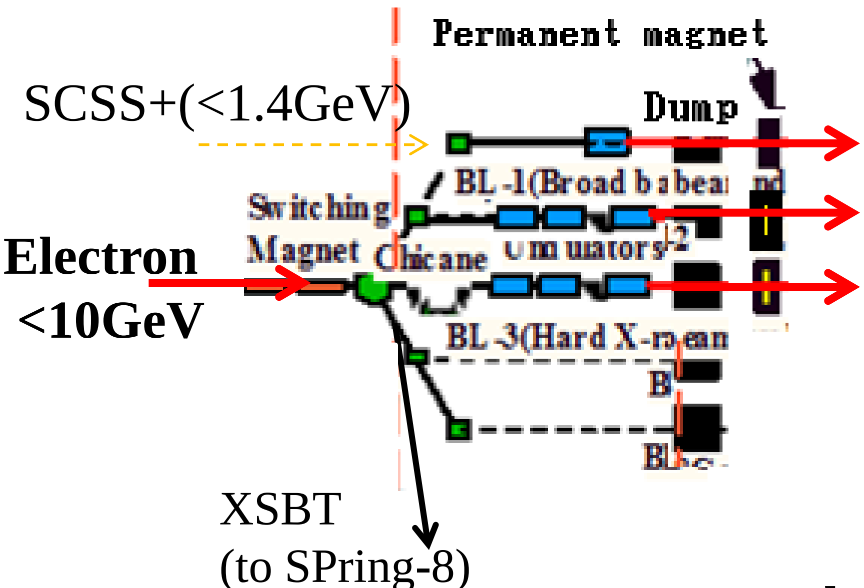
Stability of SACLA/XFEL

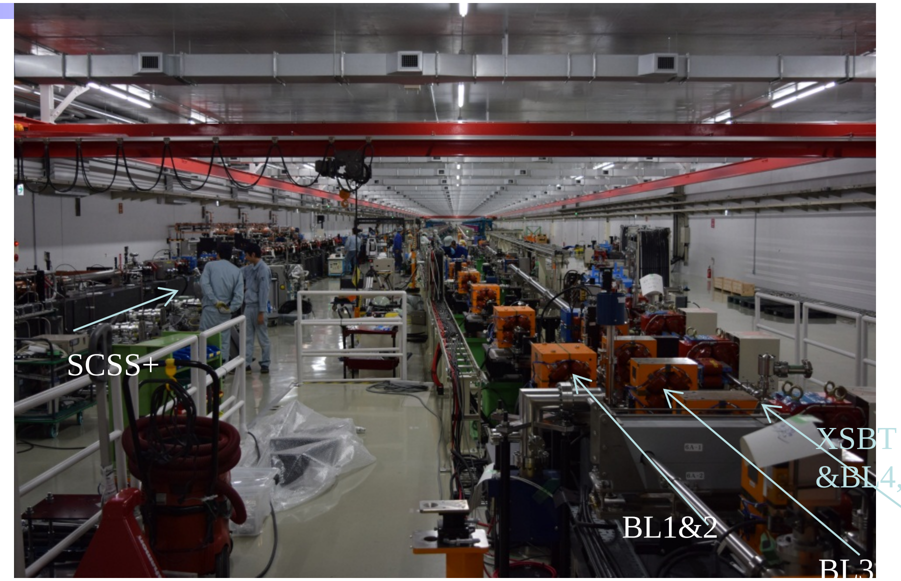


Operation time from Apr.2014 to Mar.2015; 6258hours
Average interval of the operation faults : 52 min.

Next step: To pulse by pulse operation with different energy for each beamline.

Safety design and concept for high speed pulse by pulse switching system



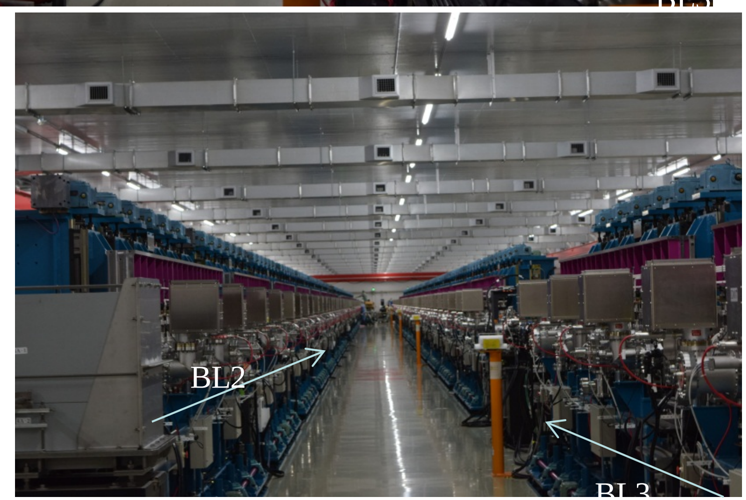


For example

60Hz,~8GeV(BL3) ⇨ **20Hz, 7GeV(BL2)**
40Hz, 8GeV(BL3)

⇩ **Future plan**

6 paths with different energy including XSBT line to SPring8



Undulator hall

Safety design and concept for high speed pulse by pulse switching system

●Pulse by pulse operation with different energy will be caused severe conditions such as high leakage dose, because energy mismatching due to such as shift of the kicker magnet timing or inconsistent the energy between the accelerated electrons and the swing or swing back magnets are occurred .

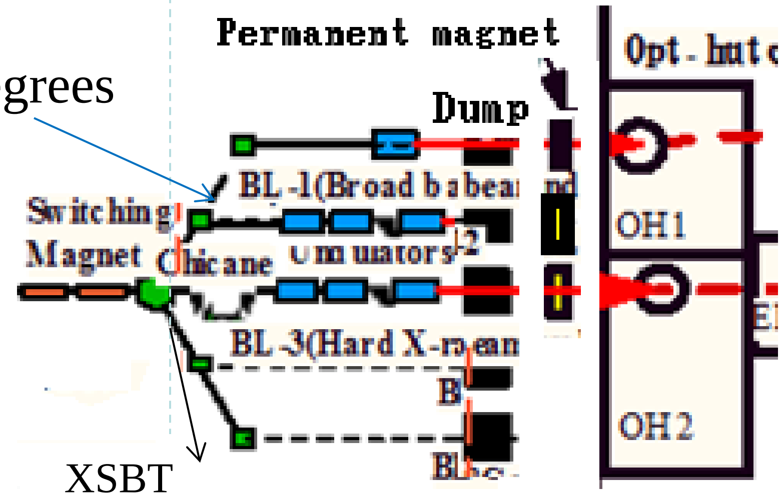
●LINAC accelerators cause unexpected electron energy change frequently, for example, by miss-fired the one of many klystrons (64 units for our case).

● The beam transportation was normally monitored by using CTs of the operation control system.

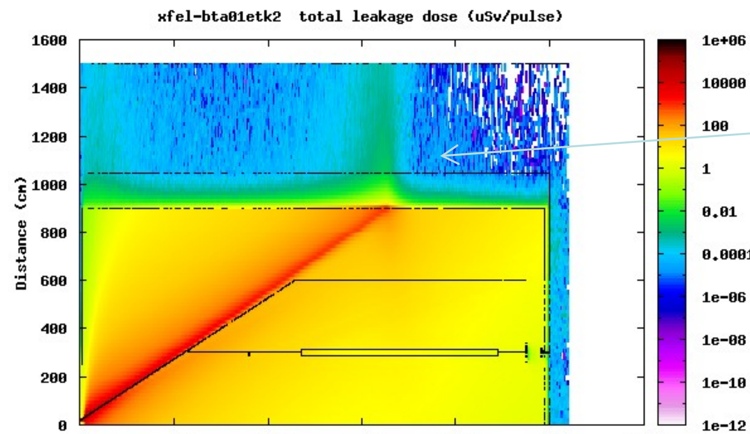
●It is difficult for safety interlock system to check the discrepancy of the energy and the magnet power, in advance.

●To keep the smooth users' operation, leakage dose has to be constrained as low as reasonably achievable.

Safety design and concept for high speed pulse by pulse switching system (Simulation)

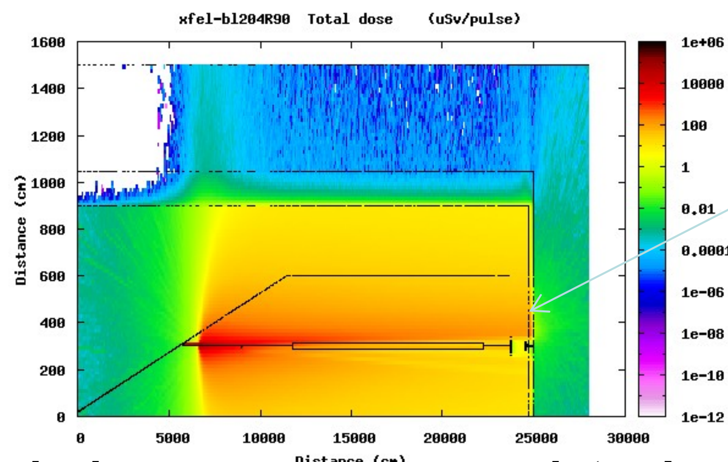


FLUKA simulations (uSv/pulse)



Max. 0.0034 μSv/pulse

Switching magnet power miss-match (over 0.1 degrees)



Max. 0.12 μSv/pulse

Swing back magnet power miss-match (0.1degrees less)

Simulation conditions
Pulse by pulse (max. 60Hz, 0.5nC/pulse)
Energy (8.5 GeV)
1.5m and 2.5m O.C for side and end shield wall

0.1μSv/pulse ⇨ 21.6mSv/h(60Hz)

Safety design and concept for high speed pulse by pulse switching system

- High leakage dose will be risen even though 0.1% discrepancy of switching magnet power or swing back bending magnet power.
- Safety interlock system cannot detect easily these discrepancies under the 60 Hz pulse by pulse operation with changing the energy.
- In addition to the safety interlock system, these methods were employed for the pulse by pulse operation.

Installation of local shields (6 local shields)

→ ● Reduction of leakage dose &
● specified production area of radiation

Many simulations (size, position)

+

Arrangements of area monitors

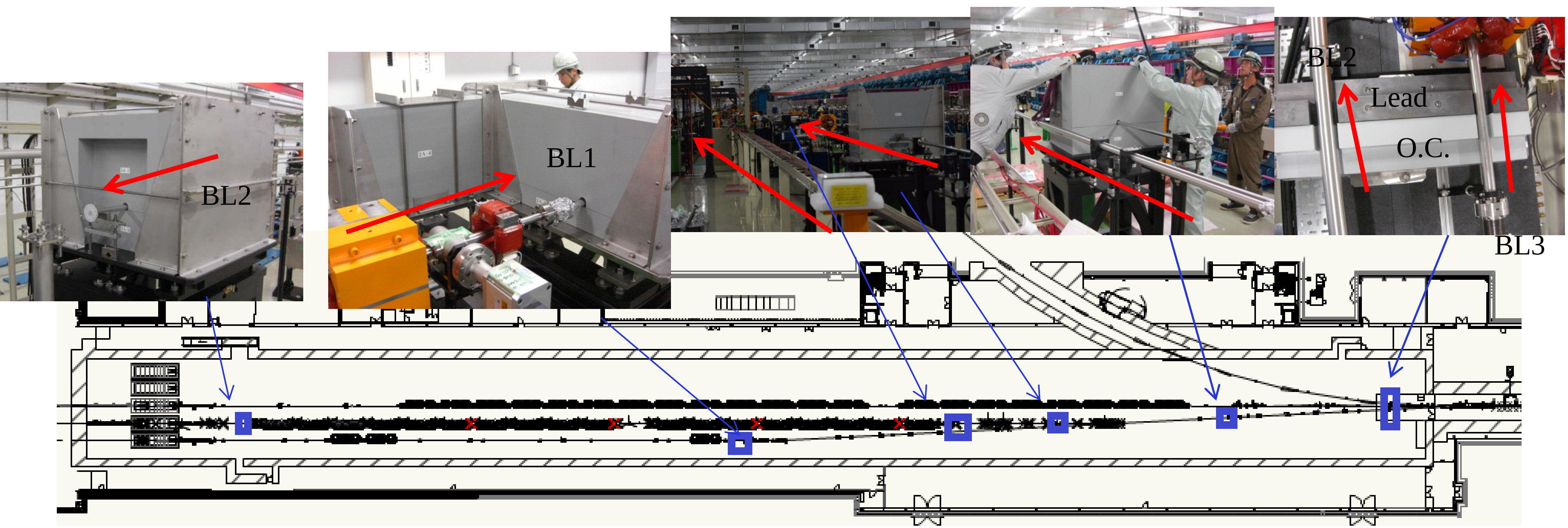
Cherenkov beam loss monitors

→ Alarm & Beam stop

→ **Leakage dose (ALARA)**

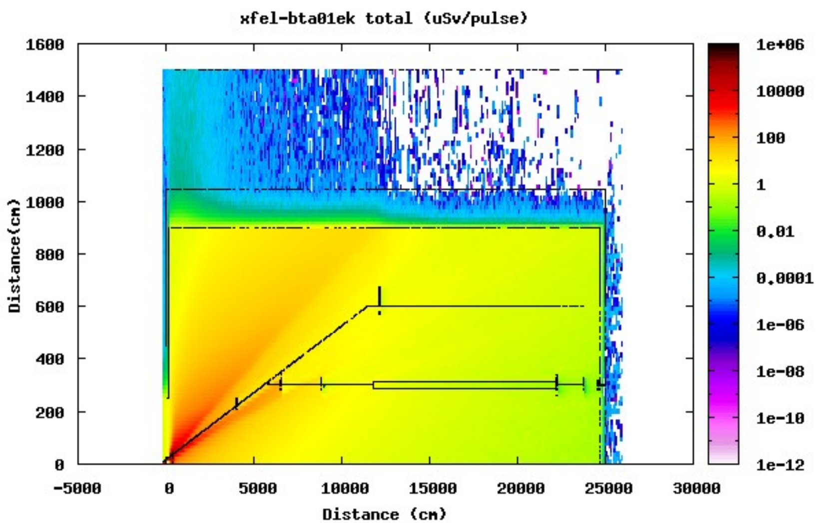
Safety design and concept for high speed pulse by pulse switching system (local shield)

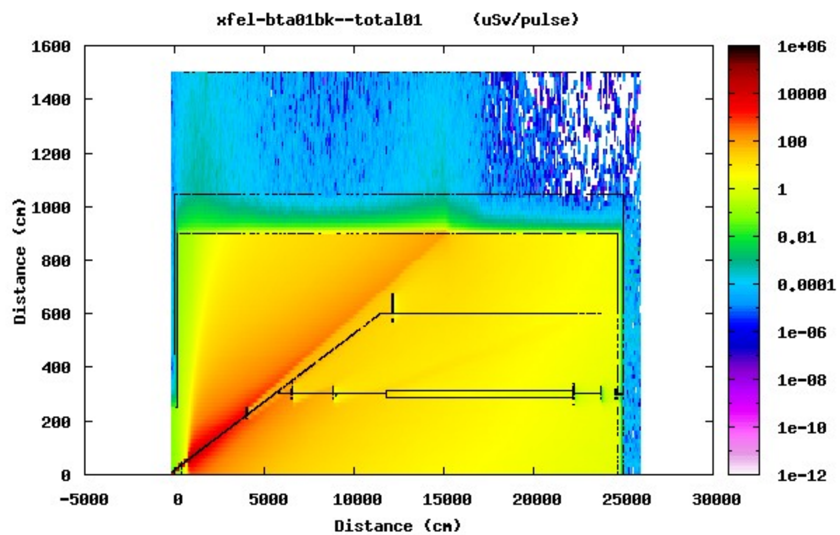
●To reduce the high leakage doses as low as reasonably achievable, and localize the production of the high dose due to unwanted beam losses, the local shields made of O.C. and lead were installed into beam transport lines. The size and positions were decided based on the simulations.



Safety design and concept for high speed pulse by pulse switching system (Simulation with local shield)

Switching (Kicker and pulse Bending magnet) angle mismatch (μSv/pulse)





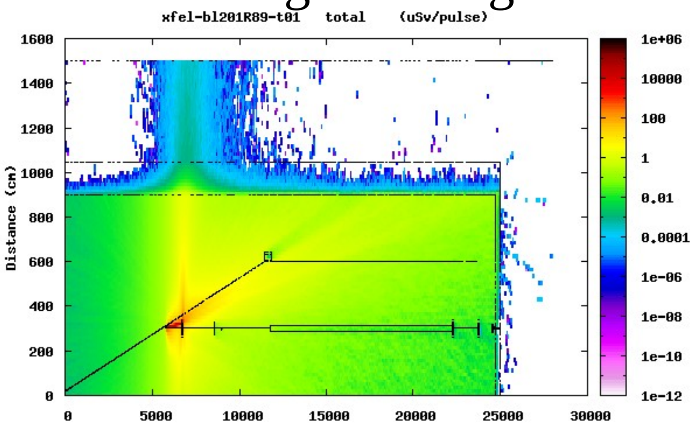
0.1 degrees over
(Max. 0.001 μSv/pulse)

0.004 degrees over
(Max. 0.00077 μSv/pulse)

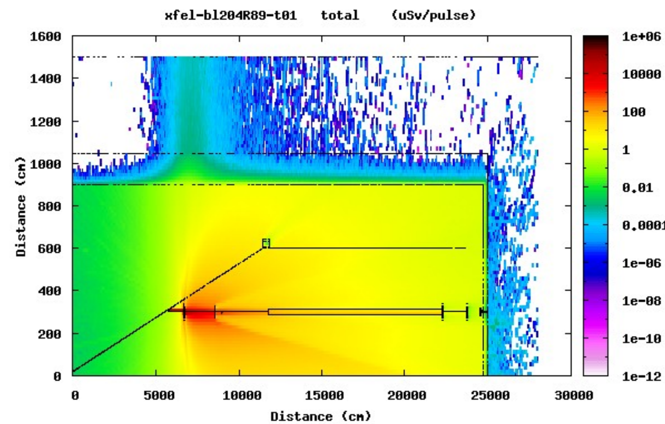
- The thicknesses of the local shields are almost 20cm O.C. + 20cm Lead.
- Max. leakage doses are almost less than 0.001 μSv/pulse .

Safety design and concept for high speed pulse by pulse switching system (Simulation with with local shield)

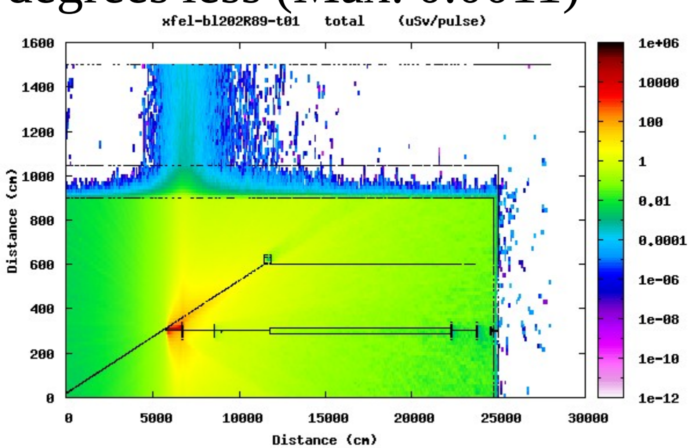
Swing back angle mismatch (μSv/pulse)



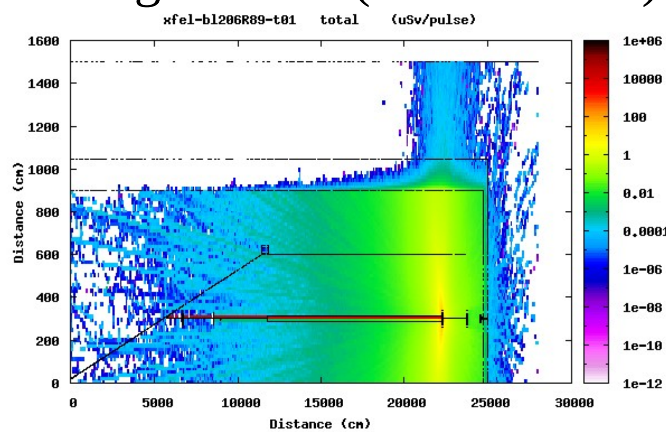
1.5 degrees less (Max. 0.0011)



0.1 degrees less (Max. 0.0012)



1.0 degrees less (Max. 0.00057)

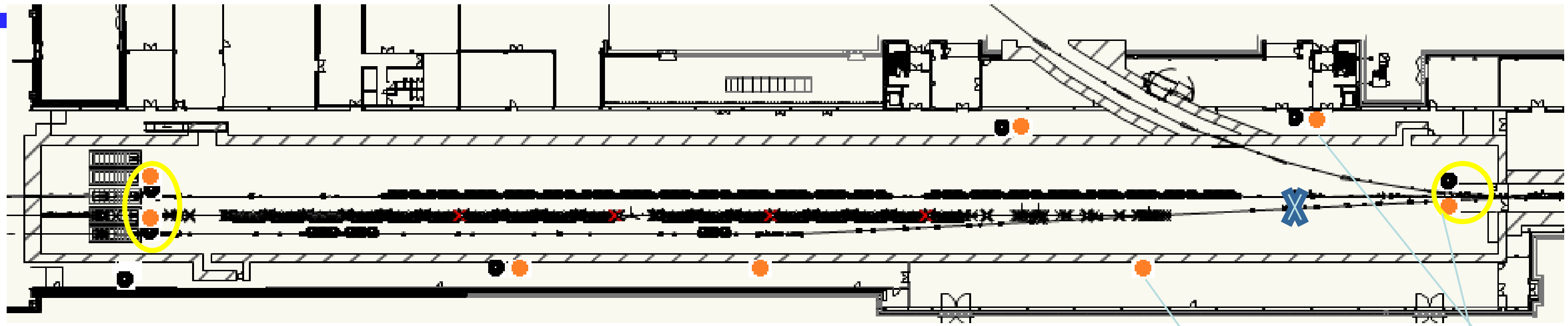


0.008 degrees less (Max. 0.00037)

- The thicknesses of the local shields are almost 20cm O.C. + 20cm Lead.

- the position of the max. leakage doses are specified.
- Max. leakage doses are almost less than 0.001 μSv/pulse .

Position arrangements of area monitors and the beam energy miss-matching test

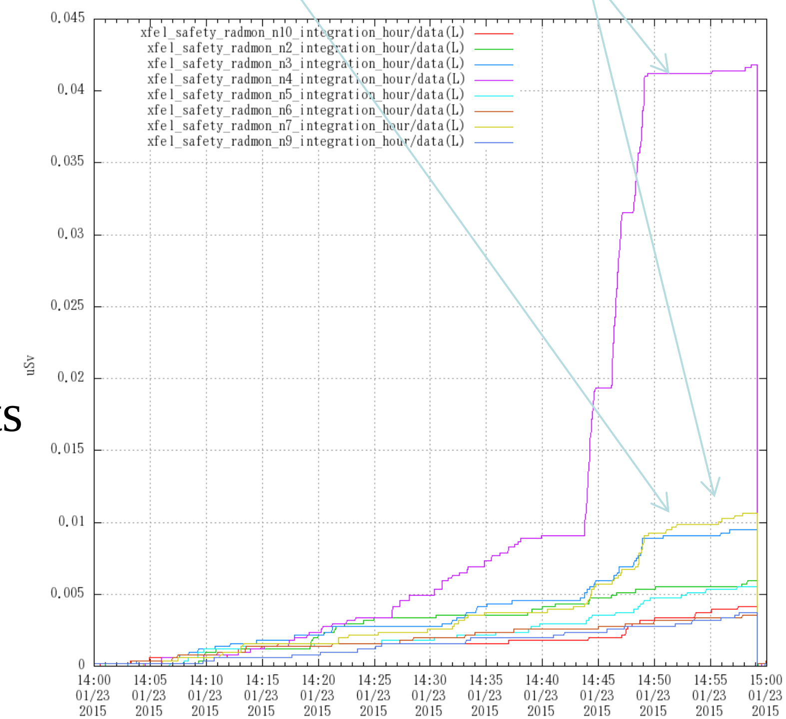


Neutron monitor

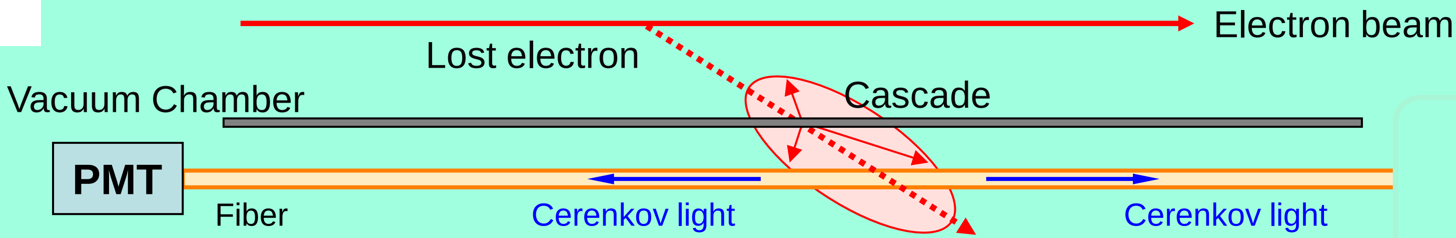
Gamma monitor

On the roof

- To detect leakage dose smoothly, the positions of area monitors were arranged in a related position of the beam loss points as the above figure.
- The right hand side figure shows the outputs of the area monitors during the beam miss-matching test that is due to miss-fired of one unit of klystron. In this case, about 0.01 μSv/min of the leakage dose was detected.



CHERENKOV BEAM LOSS MONITOR



Only parts of the Cerenkov photons are detected (Fiber acceptance).
Fiber length is limited by the attenuation of the Cerenkov signal (Fiber attenuation)

mV

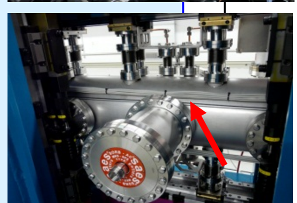
CBLM

Detect beam losses over a wide area (> 100 m)
Measure their position
Evaluate their amount

SPECIFICATIONS

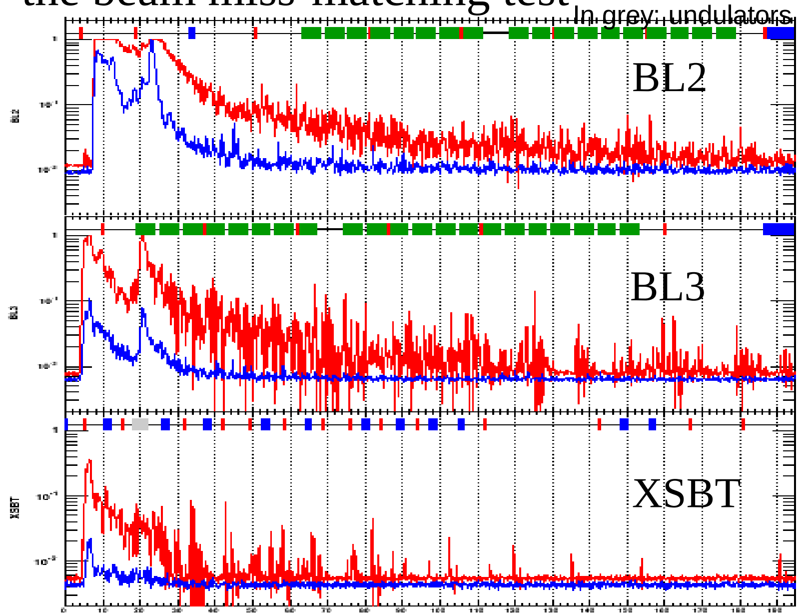
1.Sensitivity: < 1 pC (0.1% beam loss)
2.Span: 150 m
3.Position accuracy: < 1 m
4.Online

Large core fiber (D=400µm)



110519_movie.gif

Outputs of the Cherenkov monitor during the beam miss-matching test



Summary

- In order to operate pulse by pulse with different energy and different beamline safely, additional countermeasures with the safety system of the normal static operation were taken to reduce leakage doses as low as reasonably achievable as follows,
- Local shields based on the simulations were installed to reduce the leakage dose and specify the position of the maximum dose.
- Area monitors outside the shield tunnel were rearranged on the basis of the simulations and linked to the safety interlock system.
- Cherenkov beam loss monitors were installed into all beam transport lines to detect the loss points and announce the alarm to call operators' attention.
- The safety systems for pulse by pulse operation was confirmed to perform effectively through the test operation with misfiring the klystrons.