7th workshop on radiation safety of synchrotron radiation source, RadSynch13 (May .08-10, 2013)

# Shielding designs for the electron transport line of XFEL facility, SACLA to SPring-8 storage ring

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# SPring-8 & SACLA

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

- 8GeV electron energy
  - 1GeV LINAC Injector
  - 8GeV Booster synchrotron
  - 1436m circumferential ring
- 61 beamlines
  - (operation:55beamlines )
  - (construction: 2 beamlines)

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

- 8.5 GeV electron energy (max. Sep. 2012)

Accelerator section(414m), Undulator section (234m), Exp. Hall(56m)

- 5 beamlines ( now: two beamlines are operated (XFEL & SR))

# XFEL-Synchrotron Beam Transport-line (XSBT line)

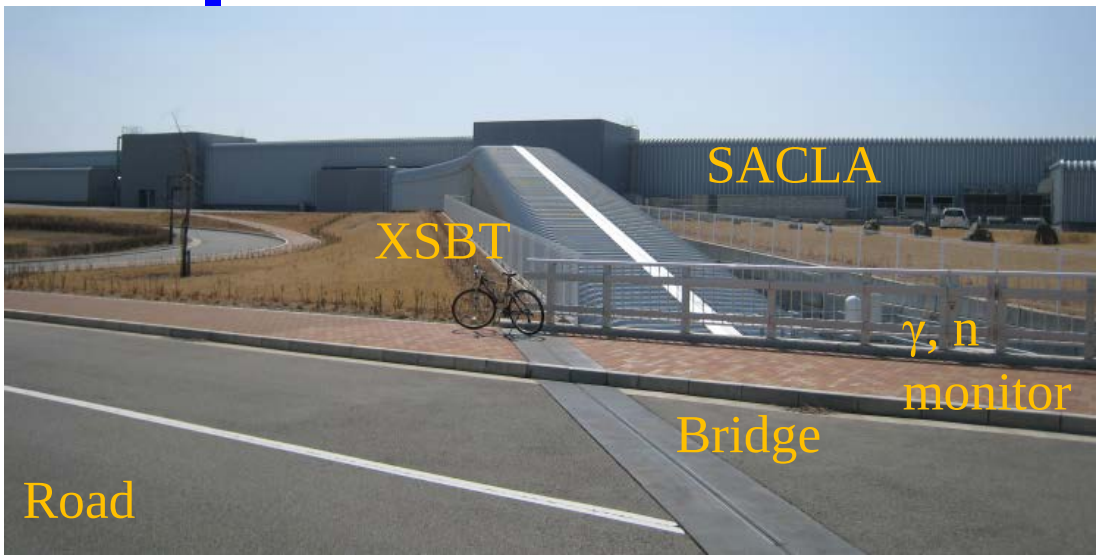
- Purpose: Upgrade of SPring-8 (Plan)
- ( lower emittance, shorter pulse)
- Utilization of high quality electron beam of SACLA (Plan)
- Distance: about 200m
- Vertical interval: about 10m
- First step: Energy 8GeV (fix)

| | SPring-8 ring | SACLA |
|---|---|---|
| **Beam emittance** | **~3.5nm.rad (H)** | **~1.3mm.mrad(norm.)** |
| **Bunch length** | **~38ps (FWHM;1mA/bunch)** | **~30fs(FWHM)** |

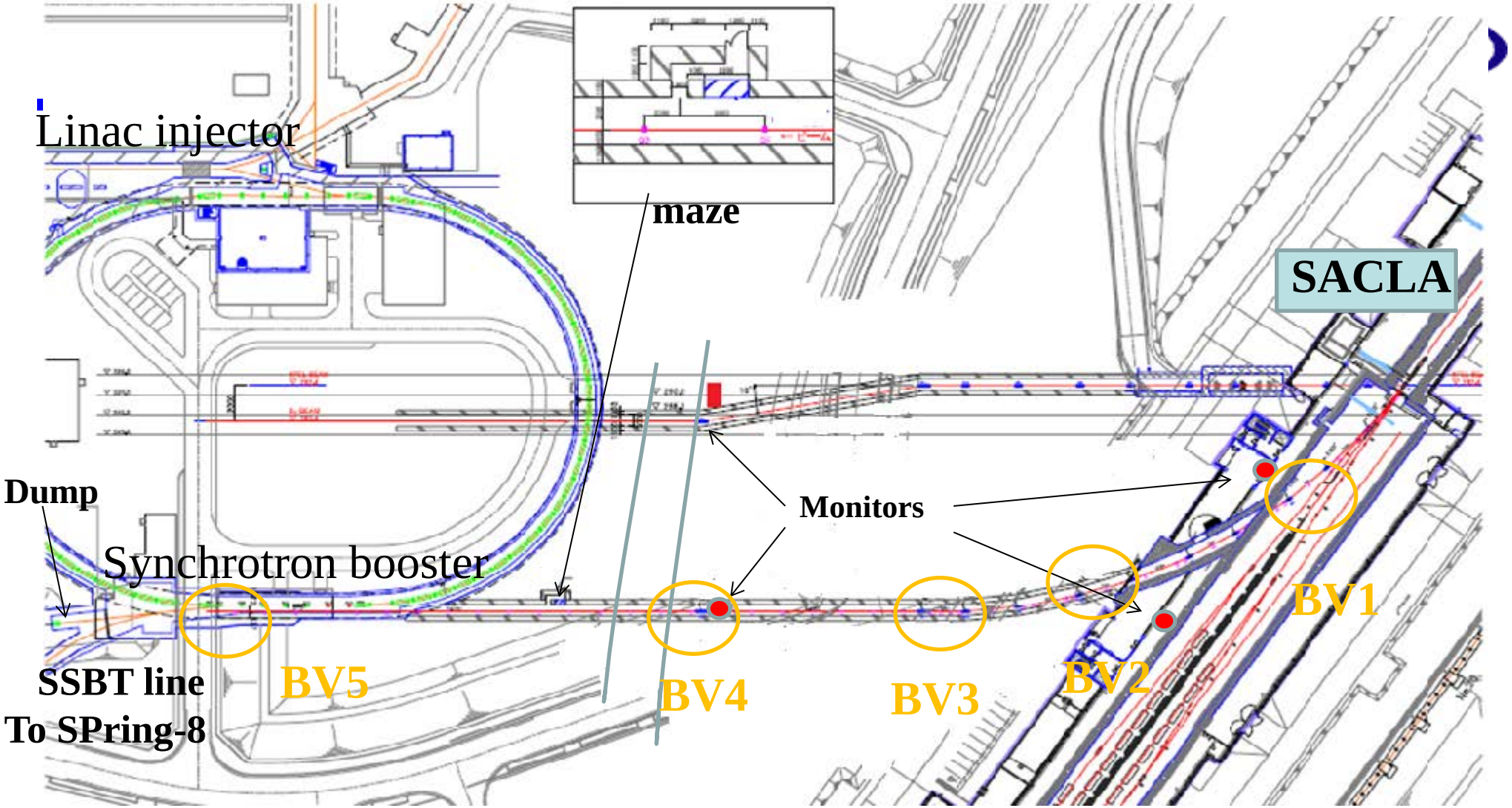
# XFEL-Synchrotron Beam Transport line (XSBT)

Distance:
about 200m
Vertical interval:
about 10m
Bend: about 40 degrees(H)
10 degrees(V)

# XSBT beamline



# XFEL-Synchrotron Beam Transport line



# XSBT electron beam transport line

**Num. of Electron：max $5.67 \times 10^{14}$ e/w**

**（$9.38 \times 10^{8}$e/s）**

**2 shutters (XFEL Und.hall & booster synchrotron)**

**Design criteria**

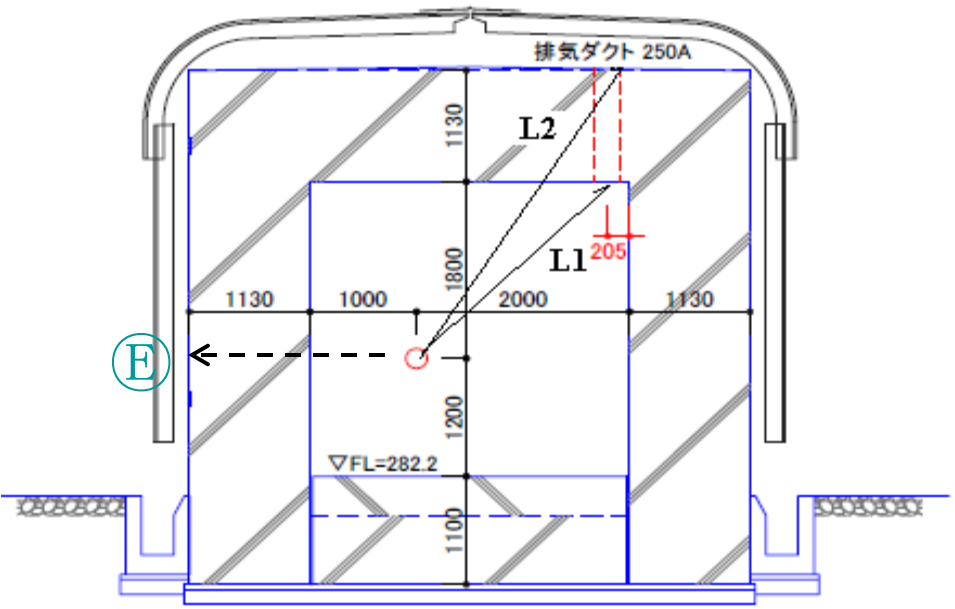
- **boundary of controlled area：1.3mSv/3m (100μSv/w)**
- **1% beam loss at any points (normal operation)**

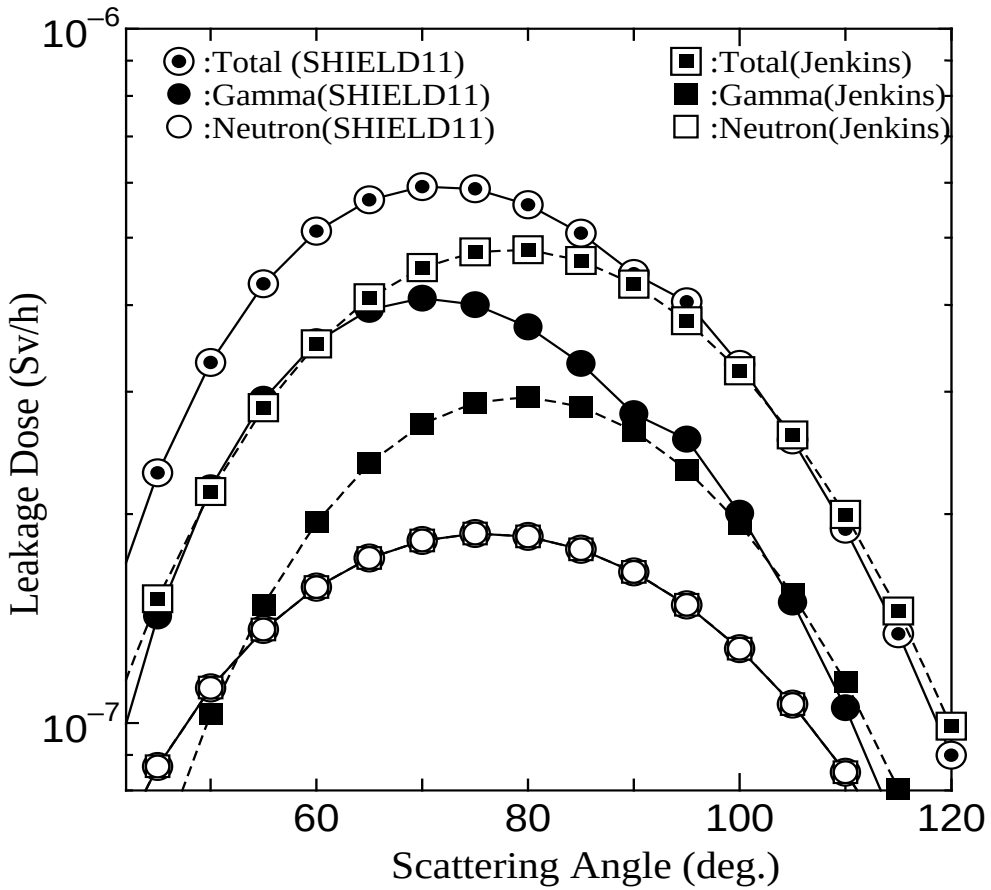
**Bulk shield ：Ord. Concrete 1.1 m（density > 2.2 g/cm$^3$）**

Incident or Accidental condition

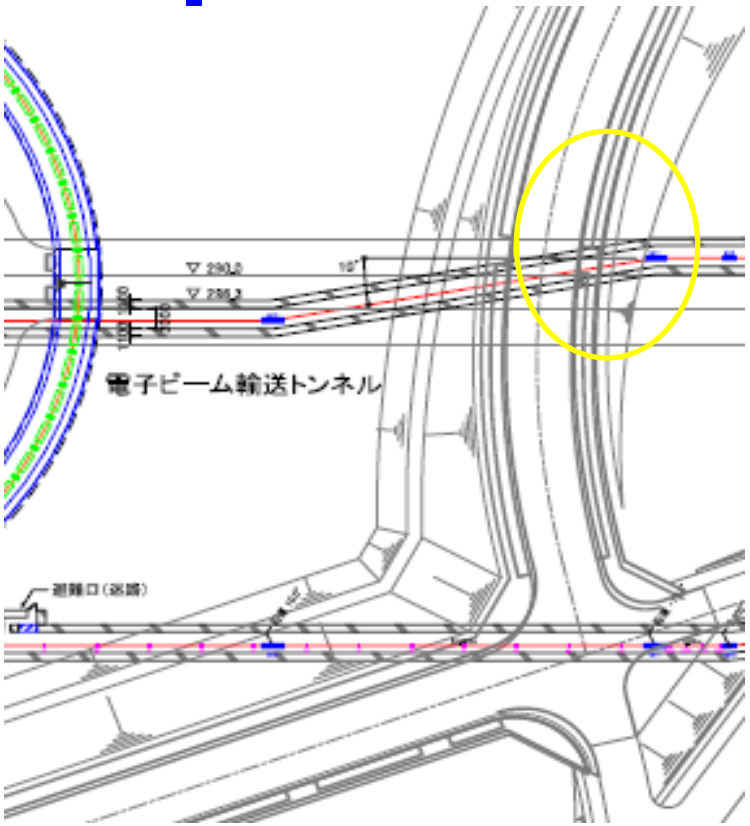
- **local shield**
- **safety interlock system**
- **BM power in series**
- **Area monitor(I.C.,He-3) + ( Cherenkov beam-loss monitor)**

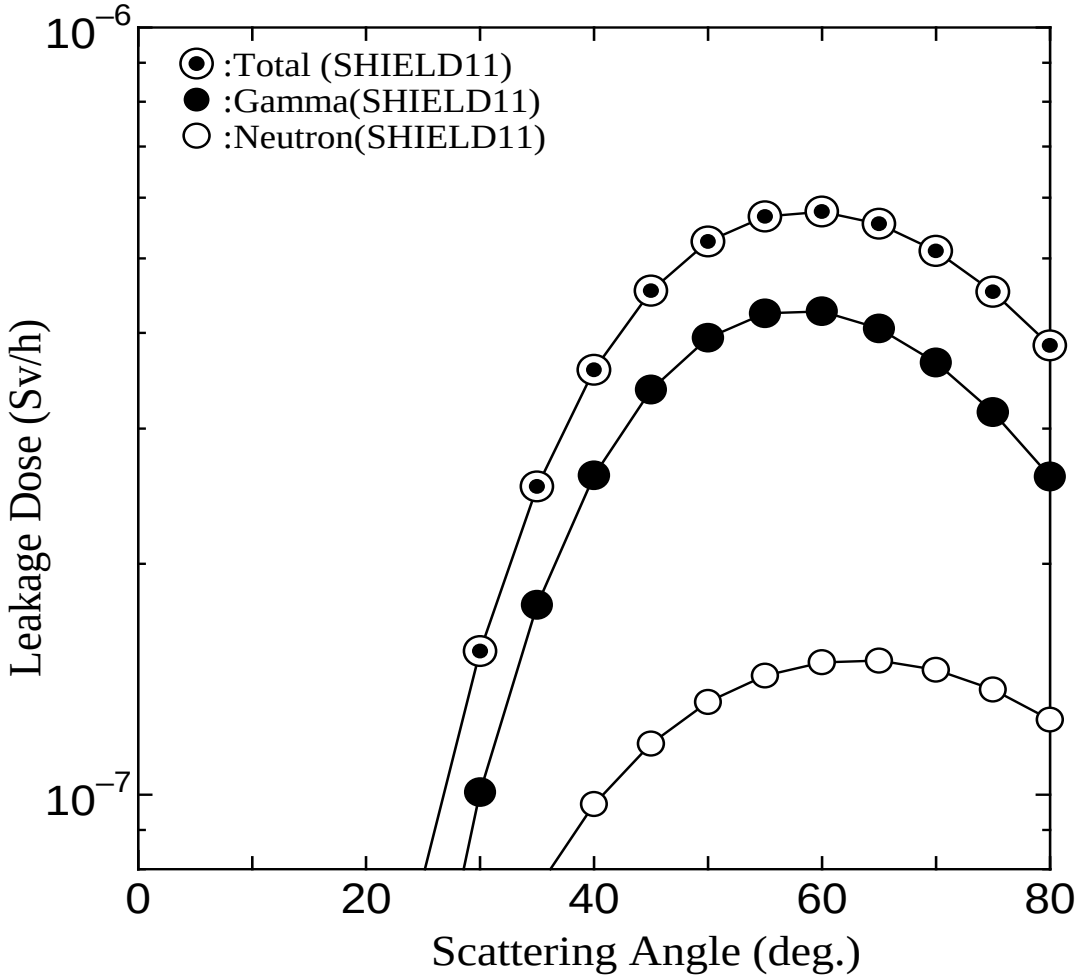
# Leakage dose estimation (side)
# XSBT transport line(normal operation)



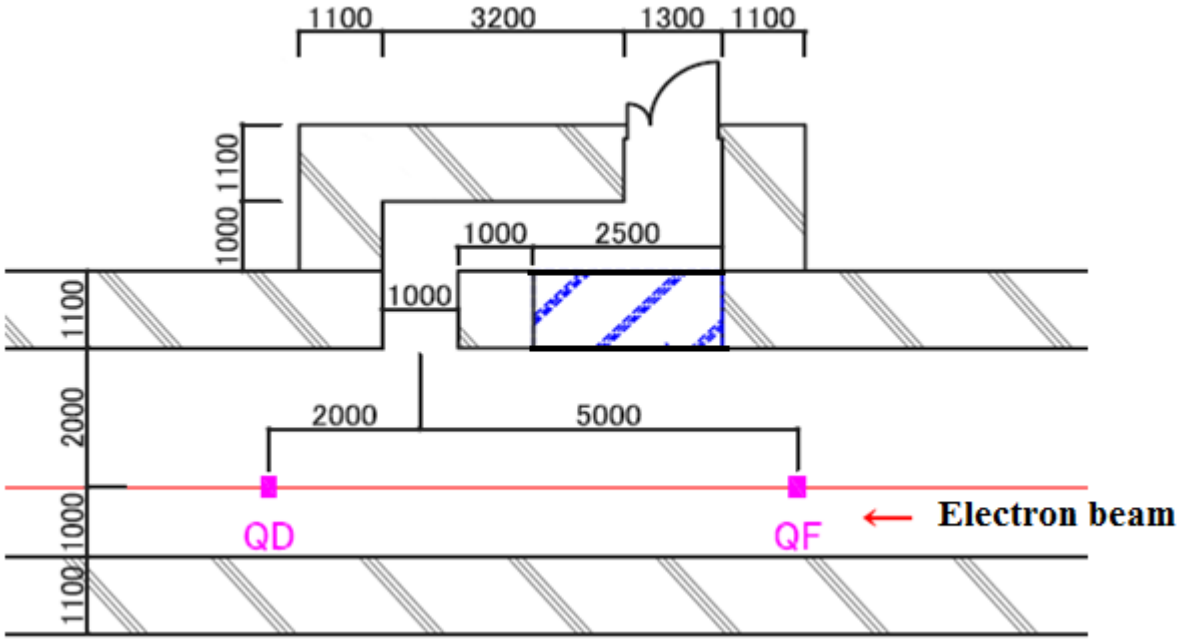



# Dose estimation outside the inclined roof (normal operation)



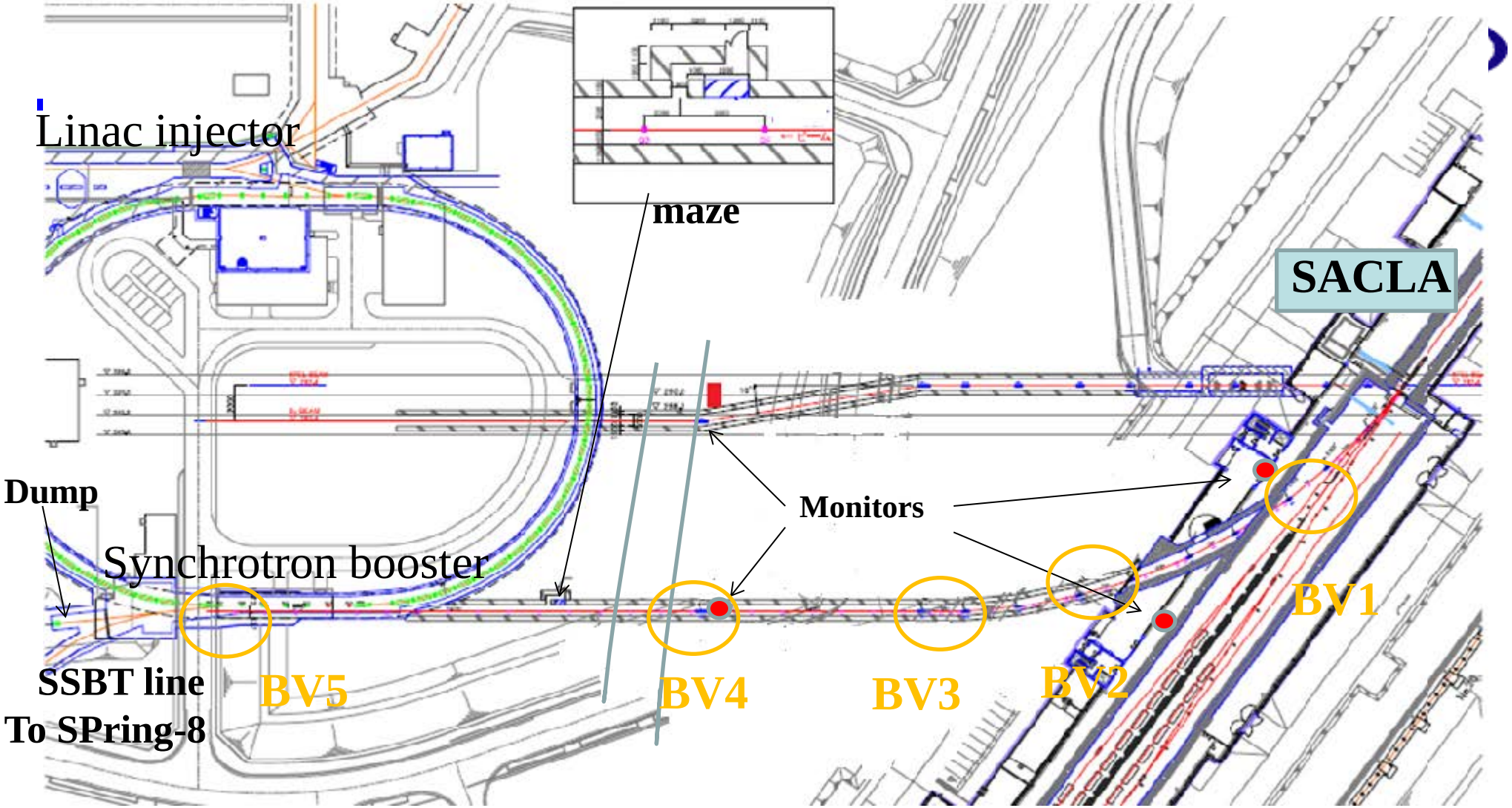
# XSBT line maze (normal operation)




SHIELD11
+ Tesch's Formula

| | Length (m) | Width ＊0.5 (m) | Cross section ($m^2$) | Inlet dose ($\mu$Sv/h) | Outlet dose ($\mu$Sv/h) |
|---|---|---|---|---|---|
| Second labyrinth | 3.45 | 0.5 | 2.0 | $\gamma$:28.0 | $\gamma$:0.17 |
| | | | | N: 11.0 | N: 0.19 |
| Third labyrinth | 1.60 | 0.65 | 2.6 | $\gamma$:0.17 | $\gamma$:0.0046 |
| | | | | N: 0.19 | N: 0.015 |

# XFEL-Synchrotron Beam Transport line



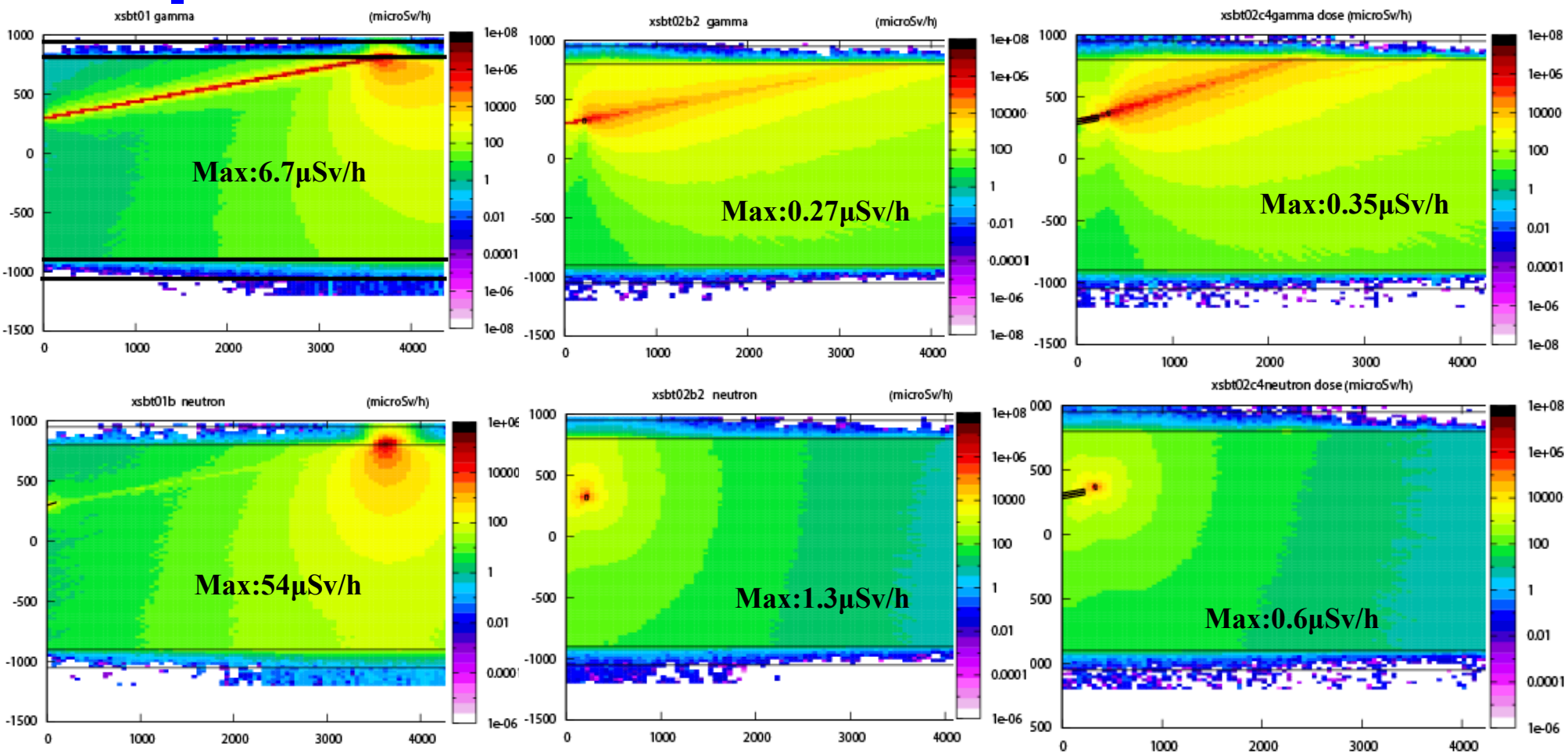
# XSBT line accidental condition analyses

## BV1:BM power in series (6 BMs)

- BM=0; E=8GeV
- Without local shield

- BM=0; E=8GeV
- With local shield（Fe40x20x20）

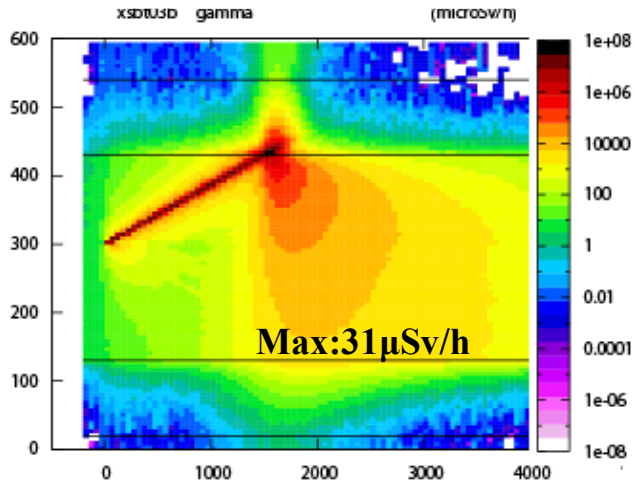
- BM=8GeV; E=4GeV
- With local shield(Fe20cm)

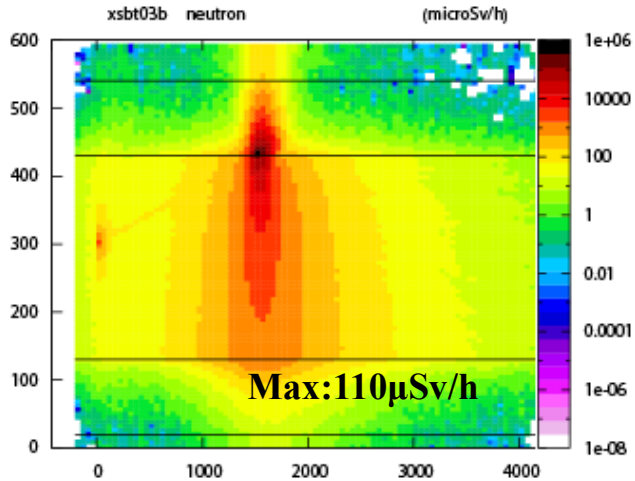


# XSBT line accidental condition analyses

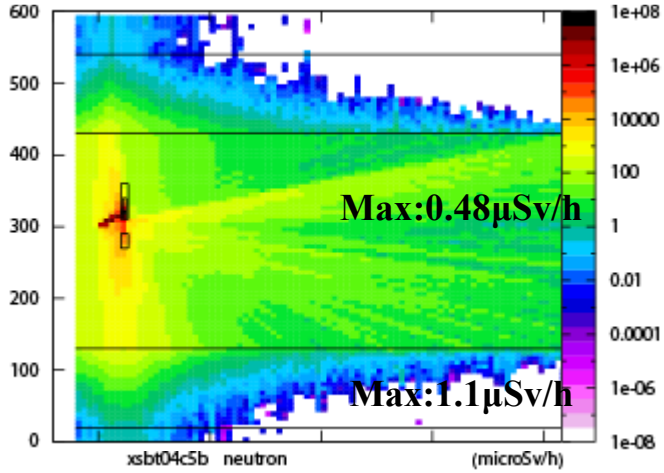
## BV2:BM power in series (2 BMs)

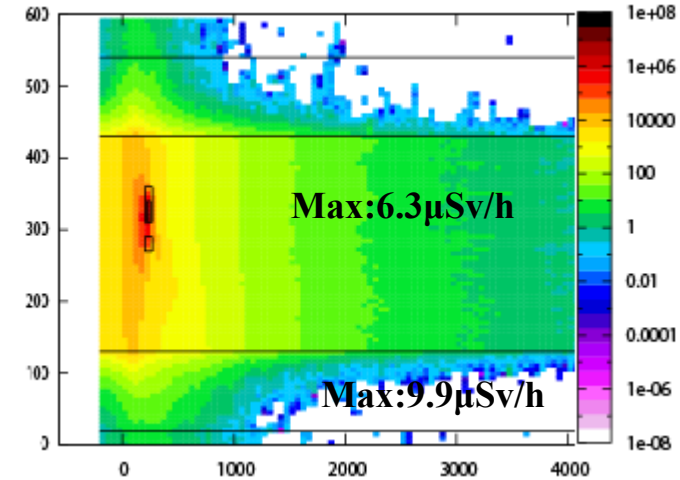
- BM=0,E=8GeV
- Without local shield




- BM=0,E=8GeV
- With local shield(OC20cm,Pb30cm)



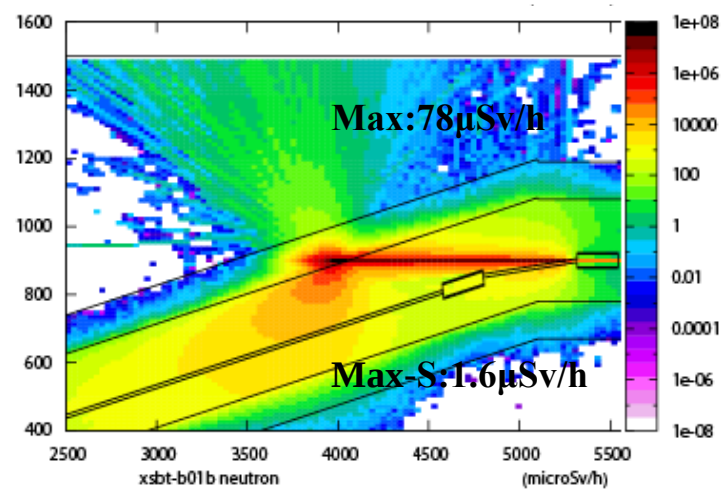



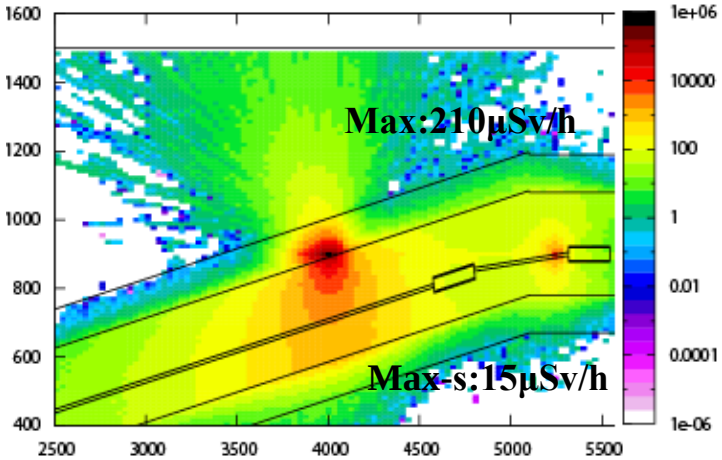

+O.C. 20cm
(opposite side)

# XSBT line accidental condition analyses

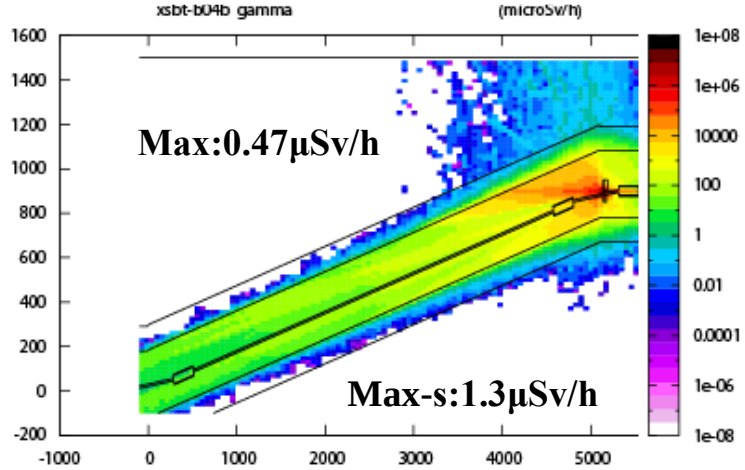
## BV3:BM power in series (2 BMs)

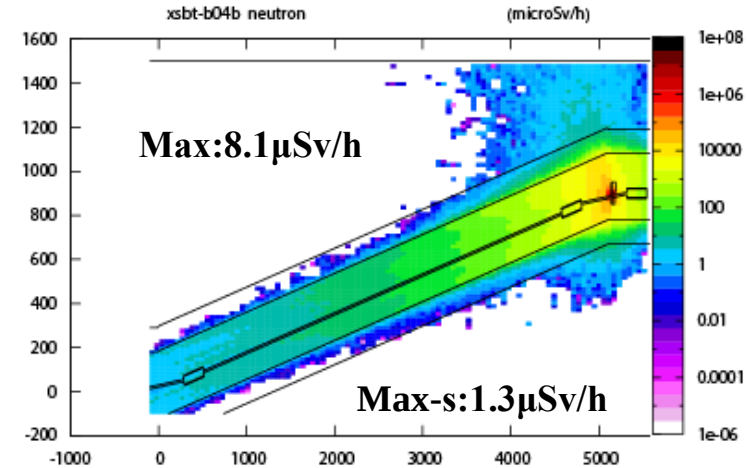
- BM=0,E=8GeV
- Without local shield




- BM=0,E=8GeV
- With local shield(O.C.40cm,Pb20cm)

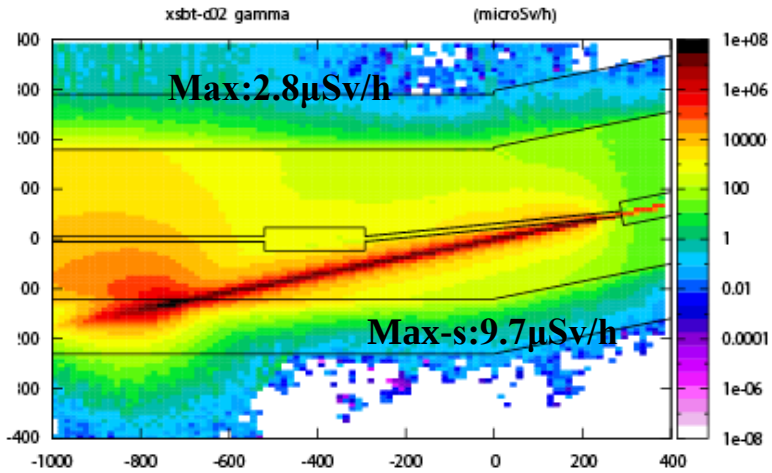


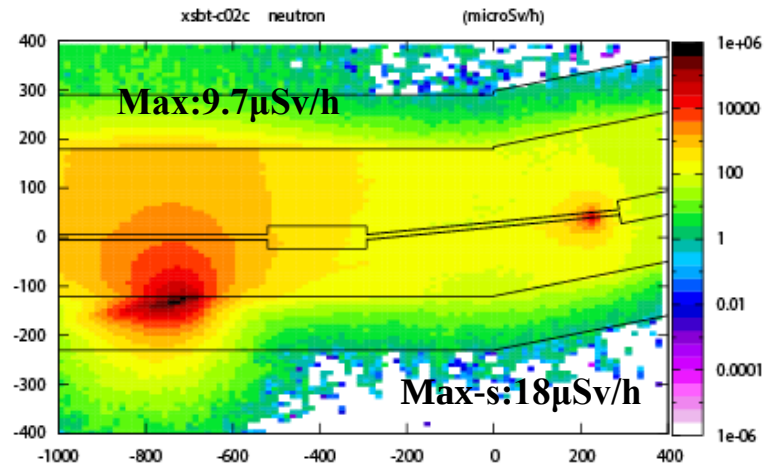



# XSBT line accidental condition analyses

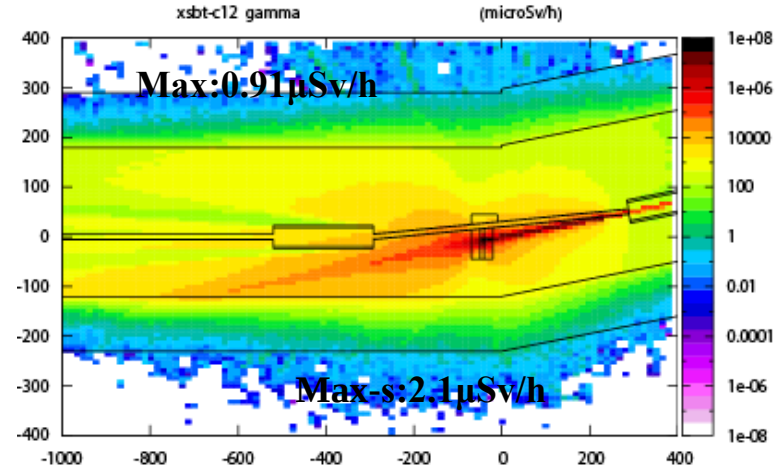
## BV4:BM power in series (2 BMs)

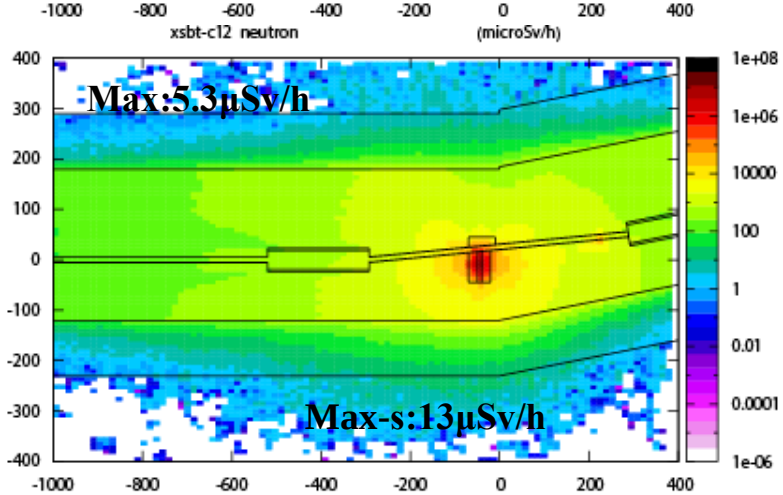
- BM=0,E=8GeV
- Without local shield




- BM=0,E=8GeV
- With local shield(O.C.40cm,Pb10cm)



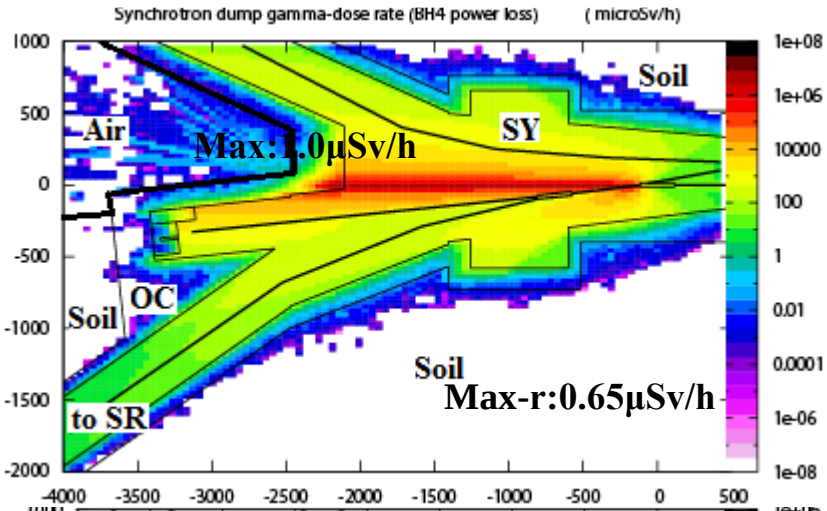



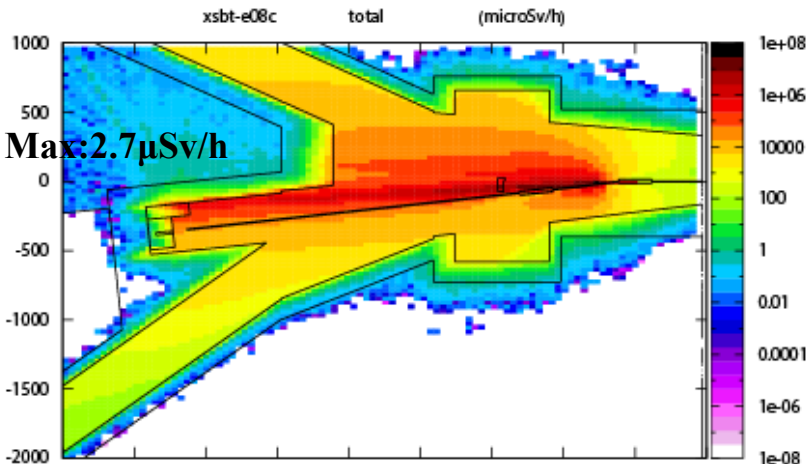
# XSBT line accidental condition analyses BV5:BM

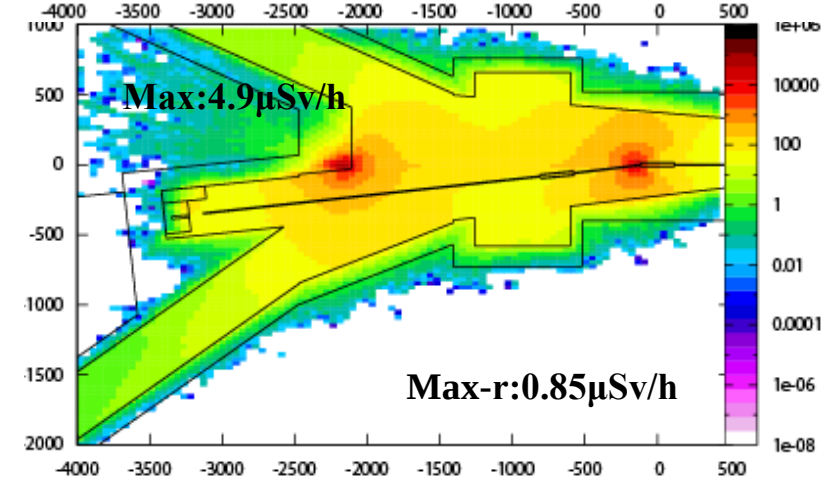
- BM=0,E=8GeV
- Without local shield

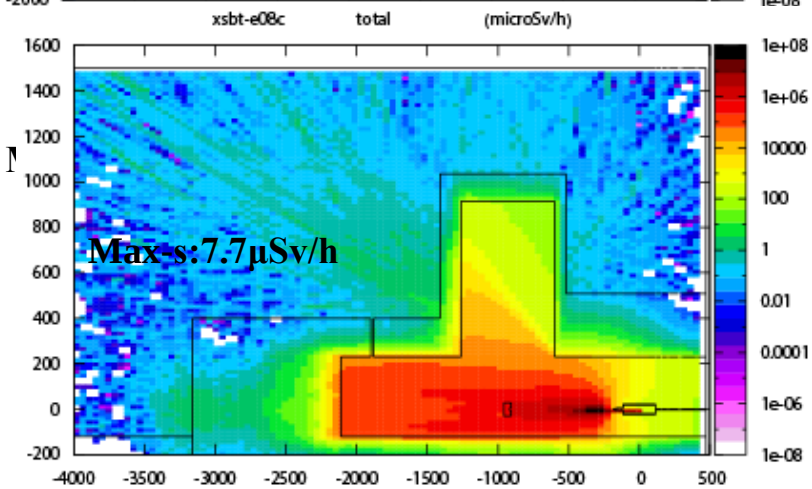
- BM=0.42E(2.5◦),E=8GeV
- With local shield(O.C.40cm)

Total dose rate

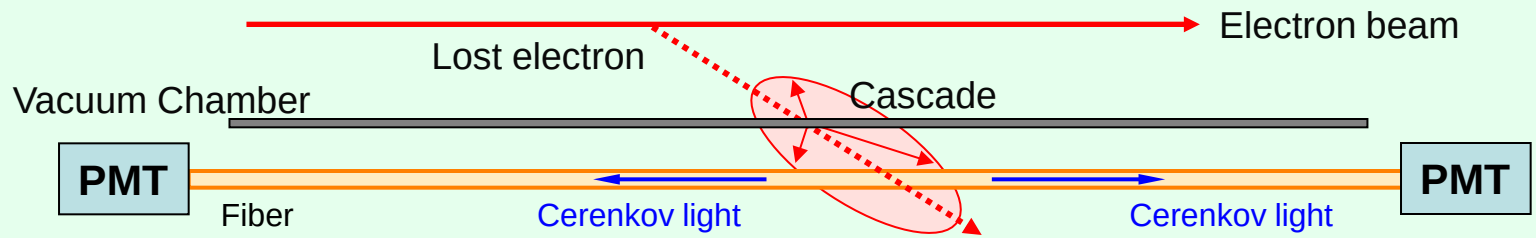


# Cherenkov beam loss monitor




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

mV

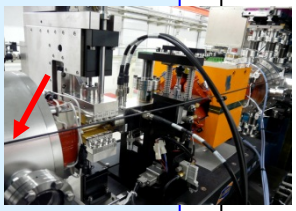
## XFEL TARGET

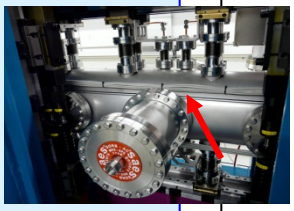
Detect beam losses over a wide area (> 100 m )
Measure their position
Evaluate their amount

## SPECIFICATIONS

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

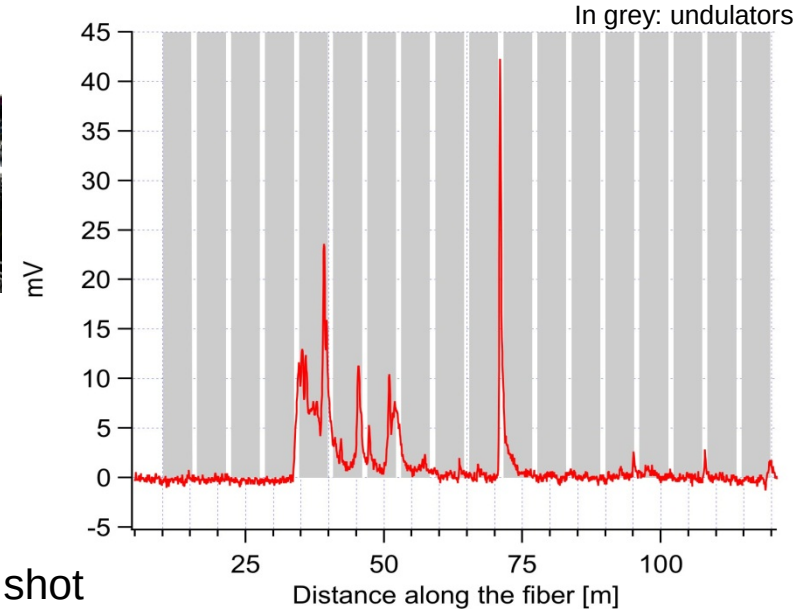
Large core fiber (D=400µm)





110519_movie.gif

## FIRST OPERATION AT THE XFEL




1 shot

# Shielding designs for the electron transport line of XFEL facility, SACLA to SPring-8 storage ring (summary)

- In order to using high performance SACLA electron beam, XFEL-Synchrotron beam transfer line was designed by using empirical formula, SHIELD11, and FLUKA under these fundamental concepts.
- (1) The bulk shield is designed under the normal operation.
- (2) For accidental conditions, we make full use of so called local shield to prevent serious conditions.
- (3) In addition to safety interlock system to connect the bending magnets, Cherenkov beam loss monitors are employed to reduce the unwanted beam loss.
- As the results,
- (1) Leakage dose is less than 0.6μ Sv/h during normal operation under the 1% beam loss rate at any points.
- (2) Using local shields, we can get the leakage dose under control to be less than 20μSv even the 1 hours operation under the accidental conditions.