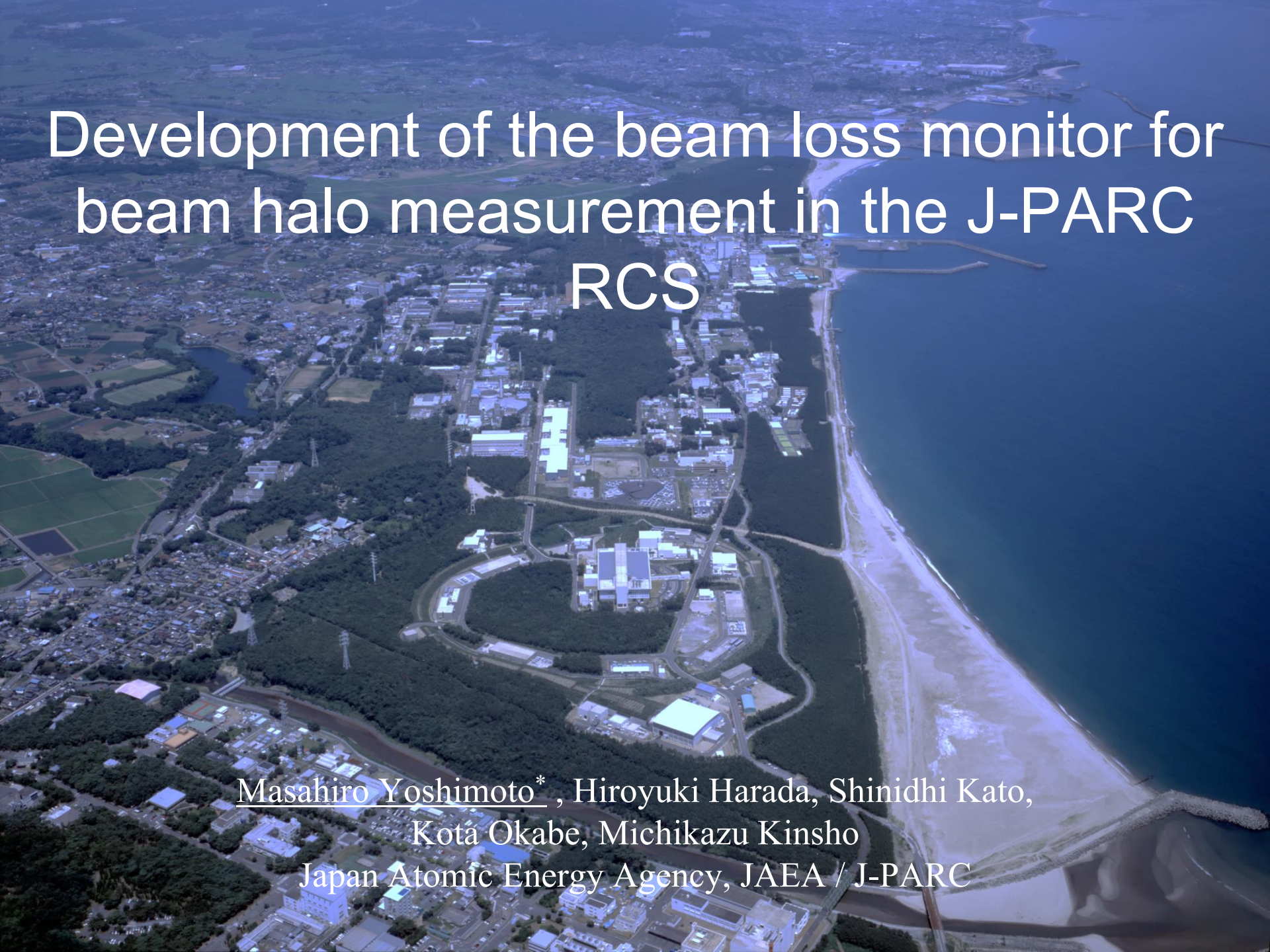
Development of the beam loss monitor for beam halo measurement in the J-PARC RCS



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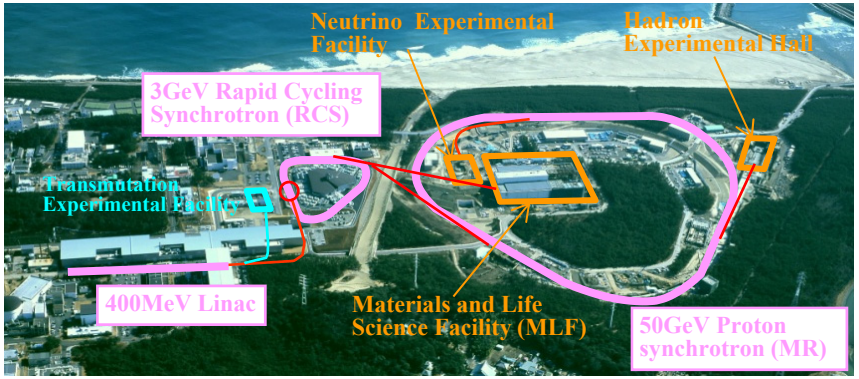
Outline

1. Introduction
2. Transverse beam halo measurement in the RCS.
   - Wire scanner type with beam loss monitors
   - Correction formula
   - Reconstruction of the beam profile
3. New BLM development for the Intra-bunch beam halo measurement
   - Scintillation-type BLM of lead glass
   - Cherenkov-type BLM of quartz or UV acrylic
   - Trial beam test
4. Conclusion

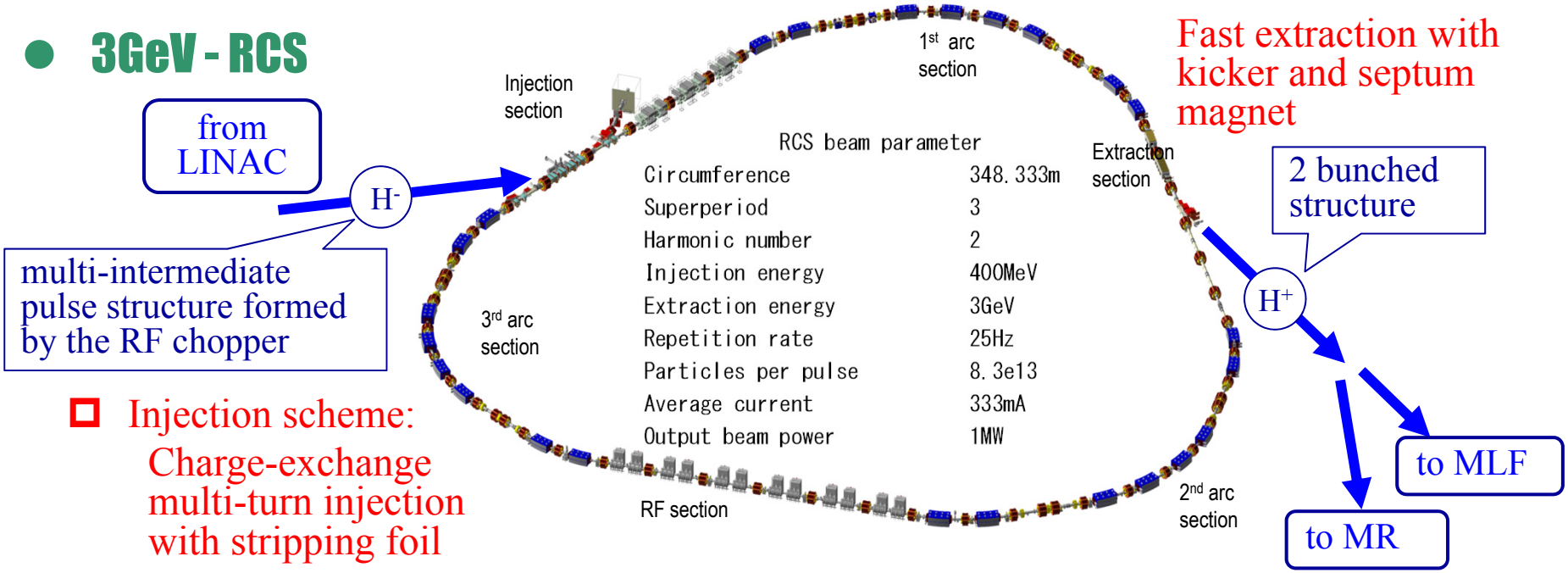
Overview of J-PARC 3GeV RCS

Configuration of the Accelerator Complex of J-PARC



- J-PARC = Japan Proton Accelerator Research Complex
- Three accelerators:
  - 400MeV LINAC / **3GeV RCS** / 50GeV MR
- Multi purpose research facility with high power proton beam
  - Nuclear and Particle Physics
  - Material and Life Science

3GeV - RCS

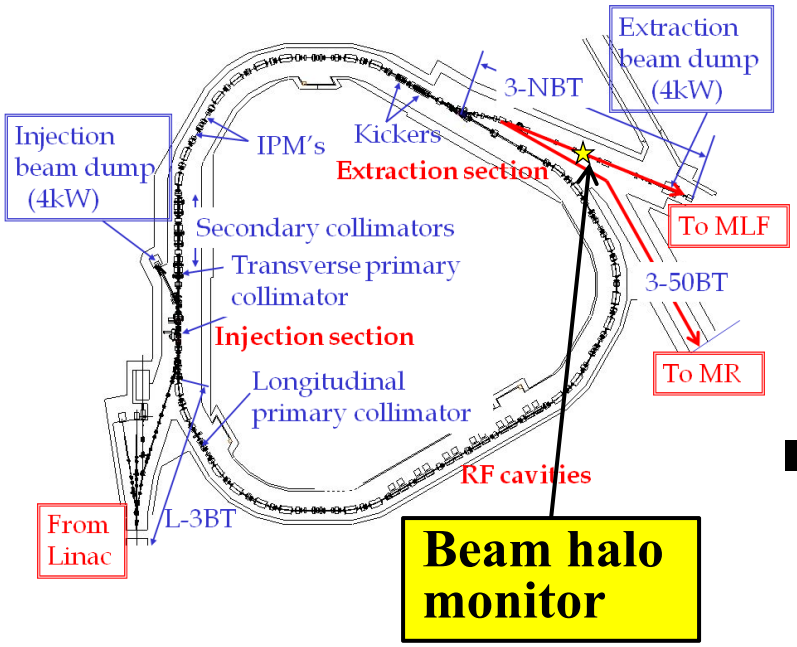


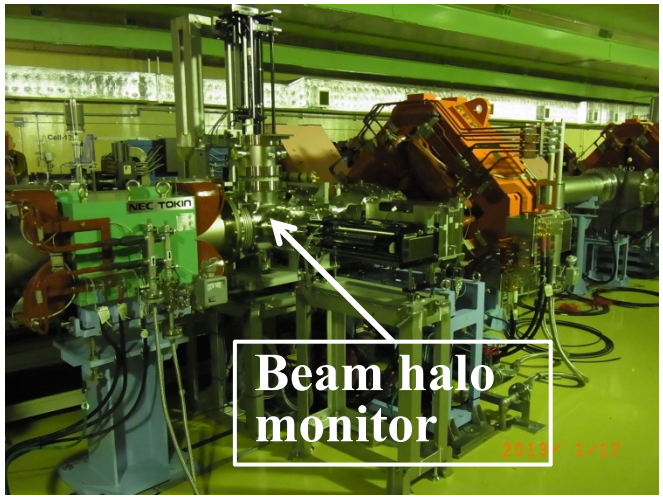
Injection scheme:
Charge-exchange multi-turn injection with stripping foil

Extraction scheme:
Fast extraction with kicker and septum magnet

Beam Halo Measurement

- The J-PARC RCS successfully achieved 1-MW beam acceleration in January 2015.
- To provide such a high power proton beam for the MR and MLF, it is required to improve the extraction beam quality, namely to achieve the **Low-Halo** and **High-Intensity** beam by finer beam tuning in the RCS.
- Therefore the measurement of the transverse beam profile including both of the beam core and the beam halo is one of the key issues for the high power beam operation in the RCS.

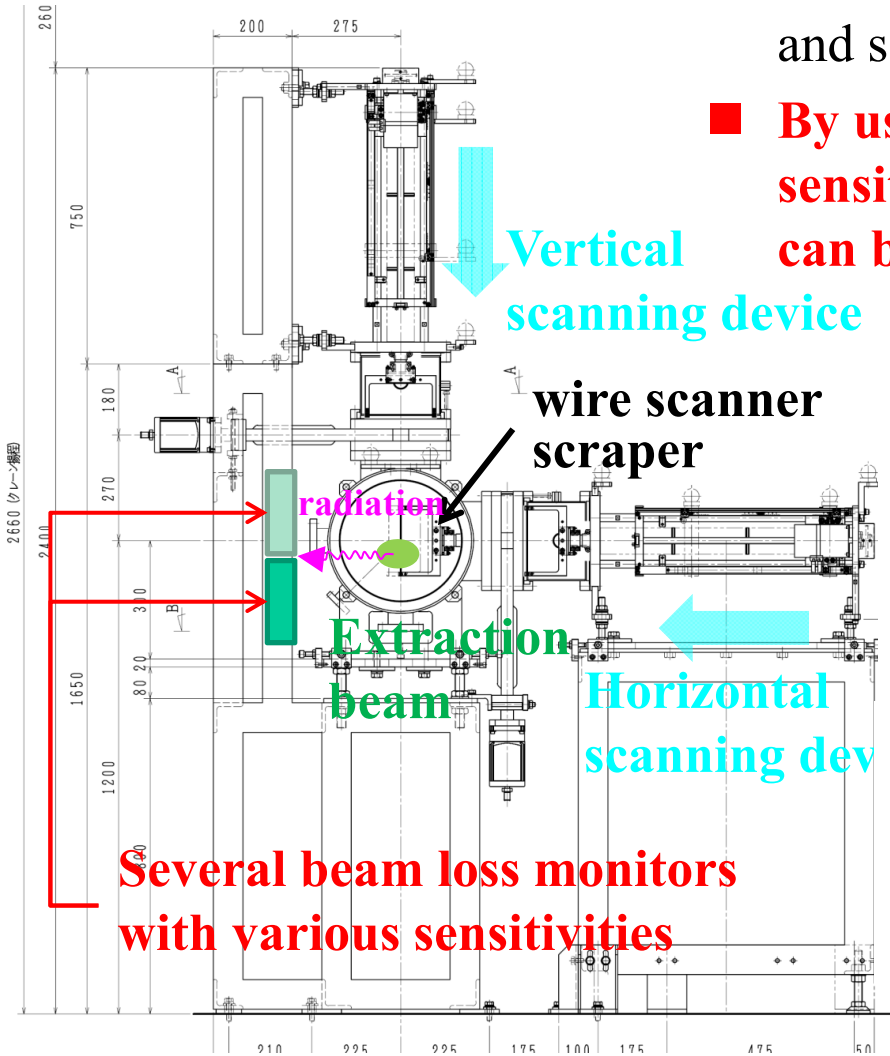


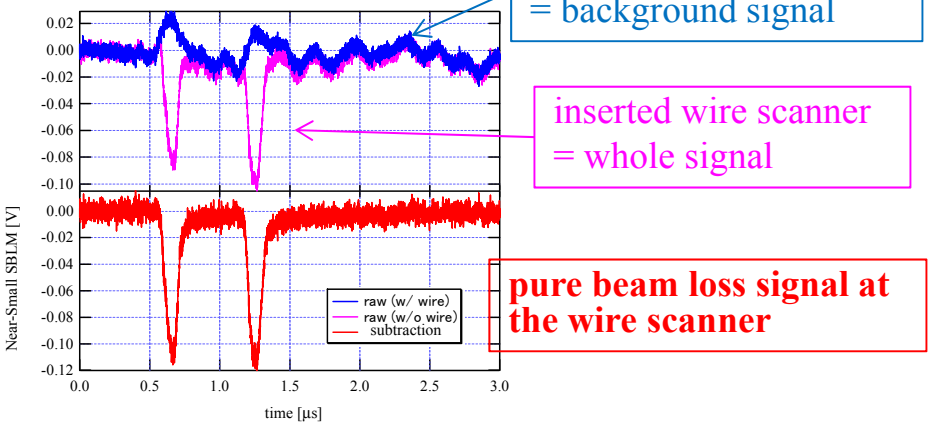


- RCS beam halo monitor is installed at the extraction beam transport line (3NBT).

Beam Halo Monitor in the 3GeV-RCS

- Beam halo monitor is combined a wire scanner and several beam loss monitors.
- **By using several BLMs with the various sensitivities, the ultra-wide dynamic range can be achieved.**



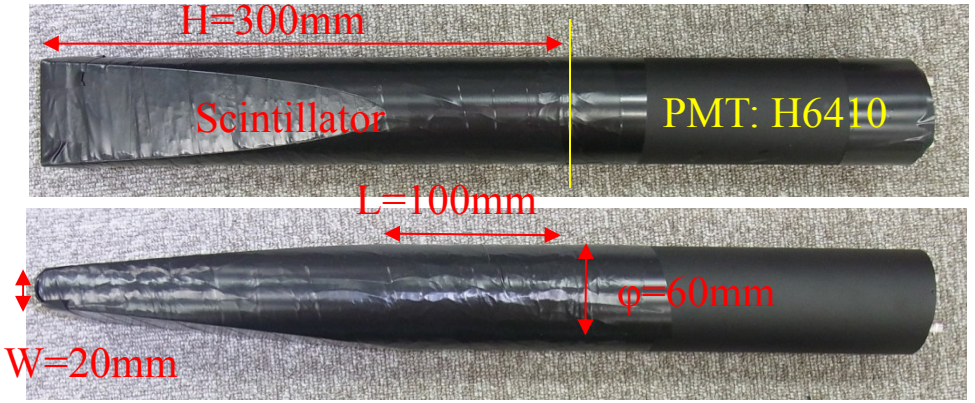


- BLM detects the whole radiations which are generated at the various place around the monitor.
- By subtracting the background signal from the whole signal, pure beam loss signal at the wire scanner can be obtained.

Various sensitivity of BLMs (I)

- **Plastic scintillator** and photomultiplier (PMT) assemblages were adopted as the BLMs with quick time response.

Large scintillator BLM

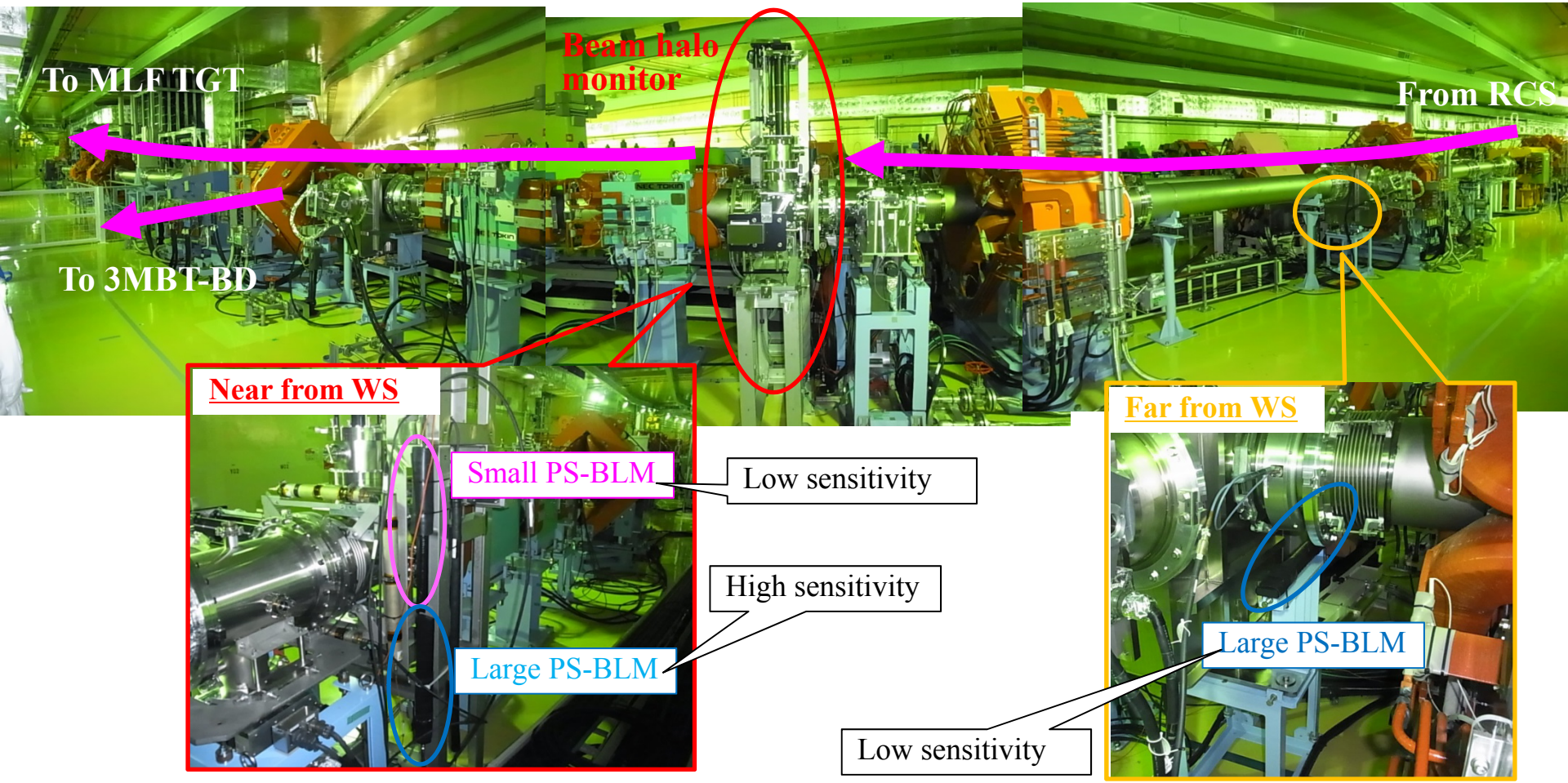


- In order to achieve the ultra-wide dynamic range, we need to control the sensitivities of the BLMs.
- By changing the volume of the plastic scintillator, the sensitivity-difference can be achieved.

Small scintillator BLM

Various sensitivity of BLMs (II)

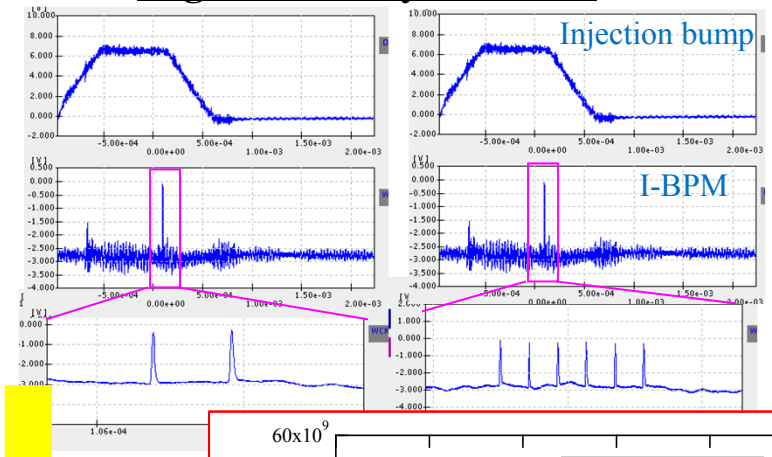
- Another method to achieve the sensitivity difference is changing the distance from the wire scanner to the BLMs.

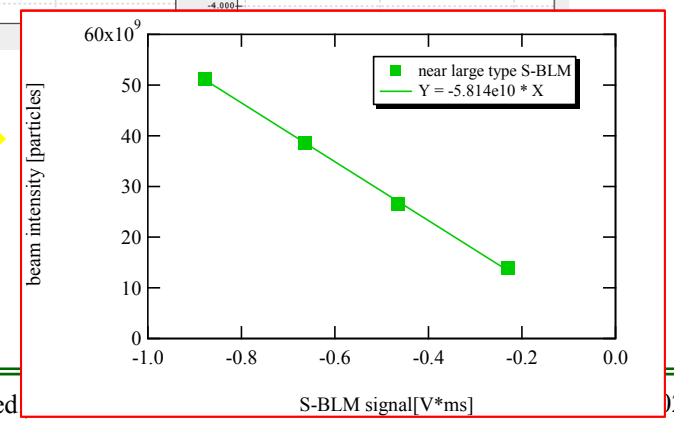


Calibration of Beam Loss Monitors

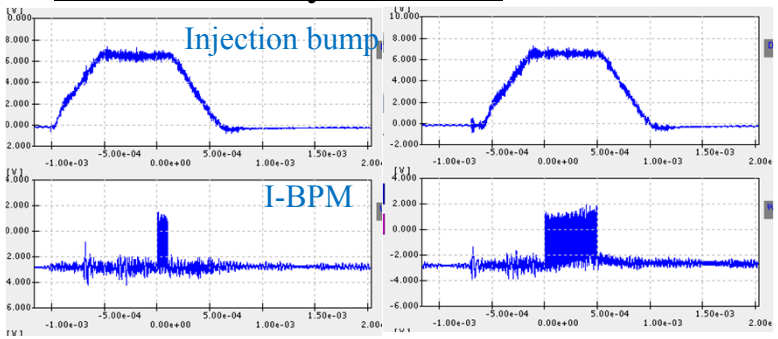
- In this system, BLMs can detect the only radiations caused by hitting the beam into the wire scanner.
- Thus BLMs signal should be proportional to the number of the hitting particles.
- Calibration formula ($N_{particle}$ / S_{BLM}) for each BLM can be obtained by using the matched beam intensity with each sensitivity.

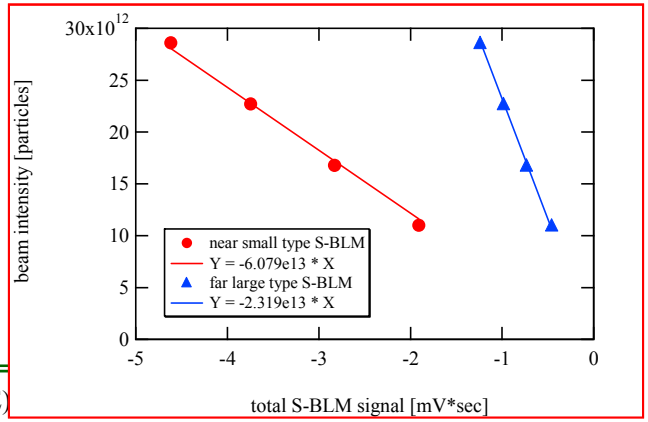
① **High sensitivity detector:**





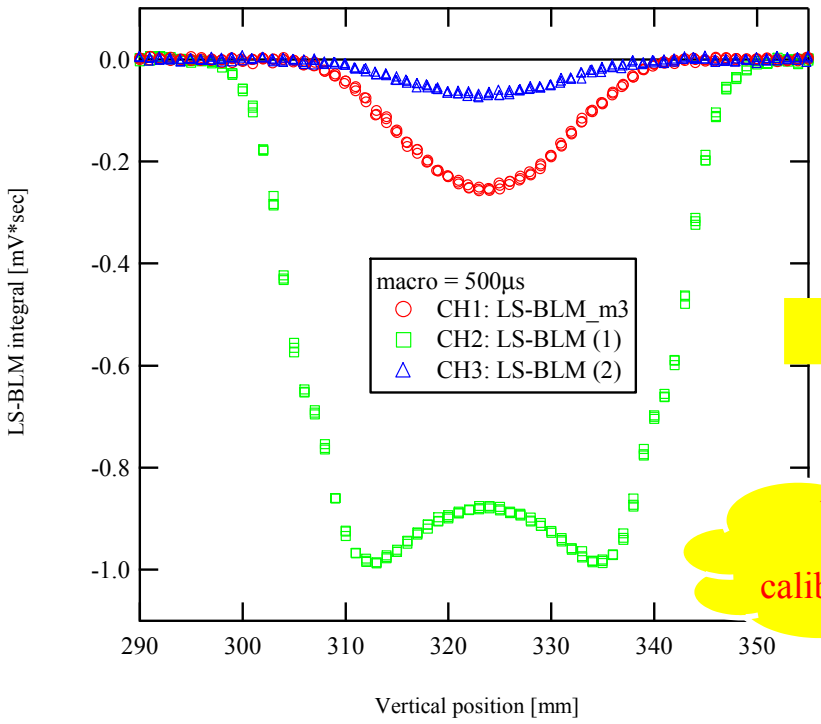
② **Low sensitivity detector:**





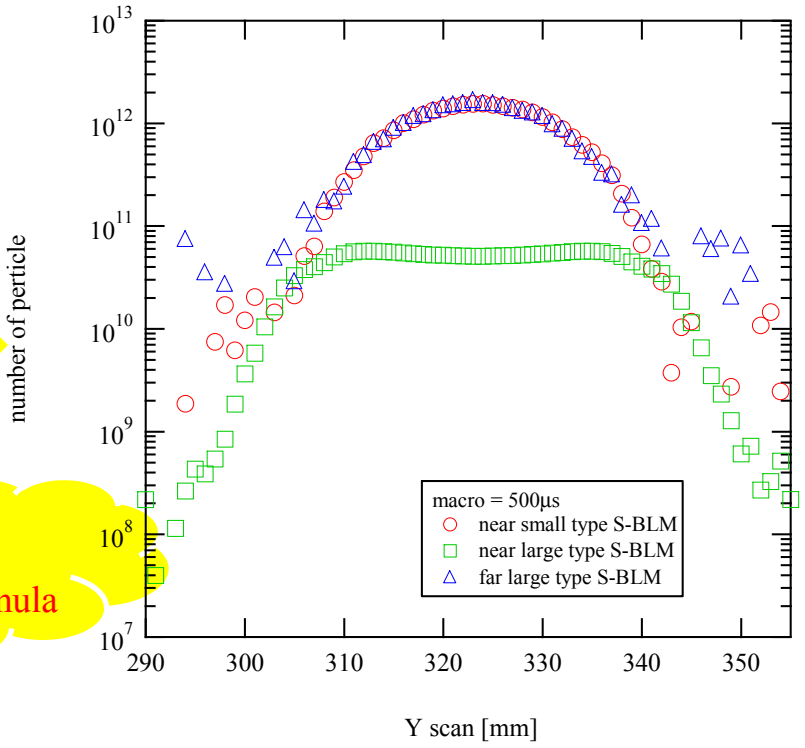
Reconstruction of the transverse profile

Raw data



Using each sensitivity calibration formula

After calibration



- **Only by using sensitivity calibration formula for the each BLM, transverse profile including both the beam core and beam halo can be reconstructed directly**

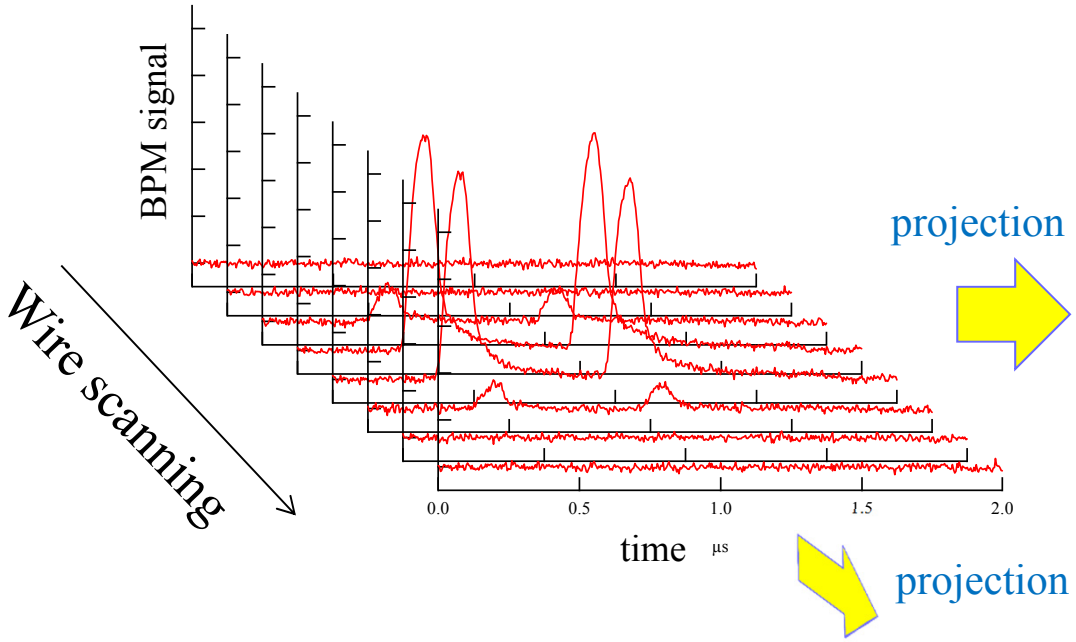
(Any other correction is not necessary to join together all measured plots.)

- **In this scheme, it is possible to expand the dynamic range by using the higher sensitivity BLMs.**

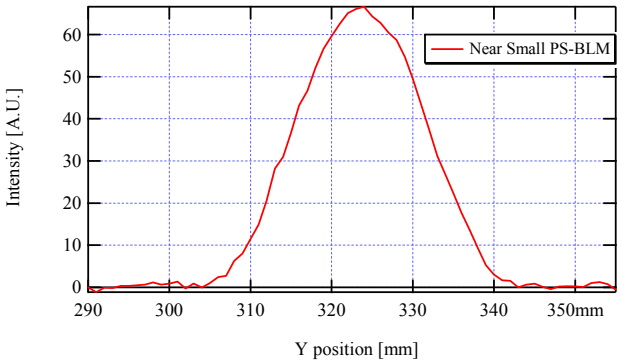
Intra-bunch beam halo measurement

- The beam halo monitor, which is combined with the wire scanner and several BLMs with various sensitivities, can reconstruct the transverse beam profile including both the beam core and halo.

- Our final goal of this halo monitor is also to measure the intra-bunch beam halo of extracted two bunches from the RCS.



Transverse beam profile

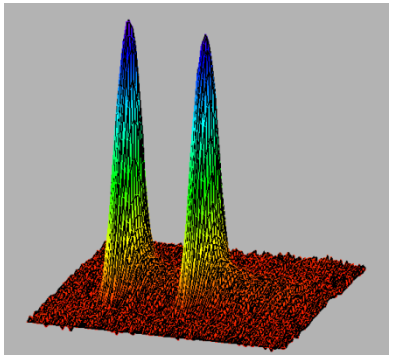


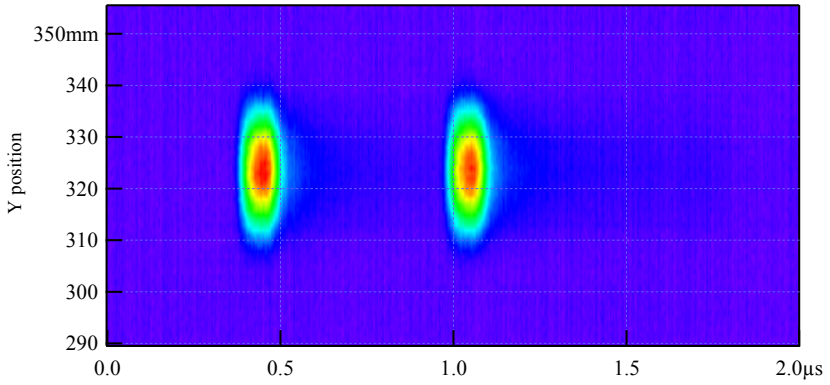
Intra-bunch beam profile

Reconstruction 2D-profile

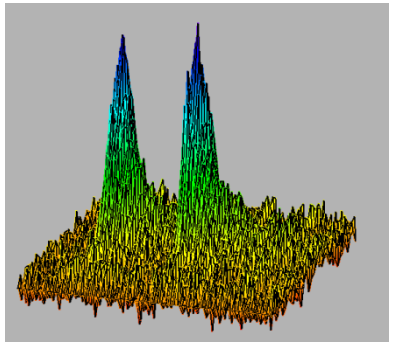
- 2D-profiles (bunch length vs beam size) were reconstructed from the two BLMs with low sensitivity.

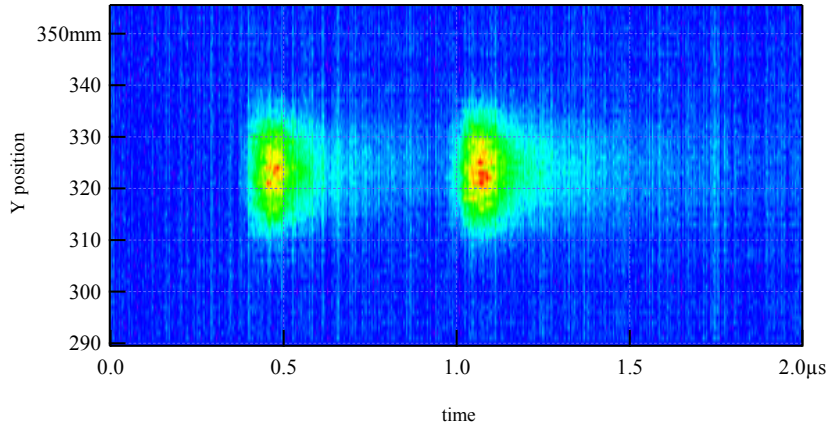
Near Small PS-BLM





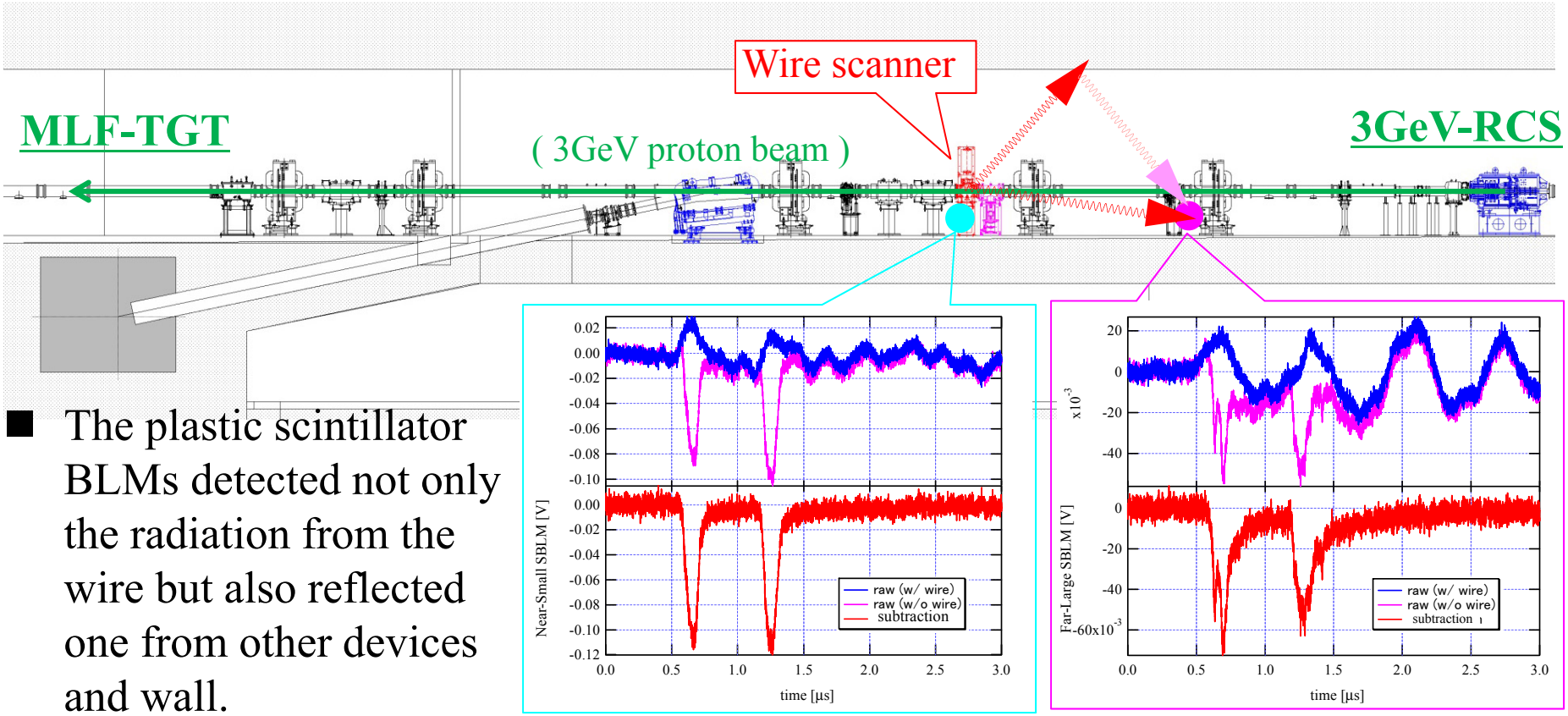
Far Large PS-BLM





- Two 2D-profiles differ in the time distribution. ⇒ **why ?**

Distortion of the bunch signal

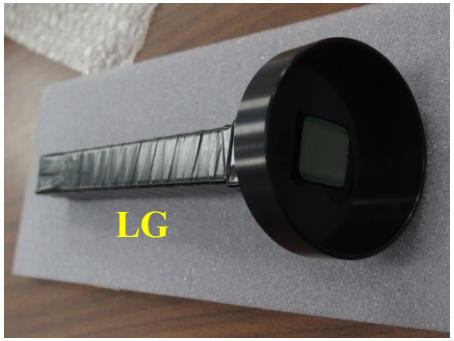


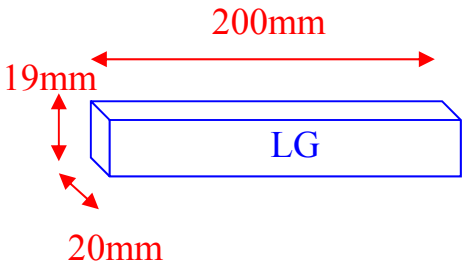
- The plastic scintillator BLMs detected not only the radiation from the wire but also reflected one from other devices and wall.

- To obtain the bunched beam structure from the BLM clearly, it is necessary to suppress these reflected radiation.
- Therefore we develop new-type BLMs, which are scintillation-type BLM of lead glass and Cherenkov-type BLM of quartz or UV acrylic.

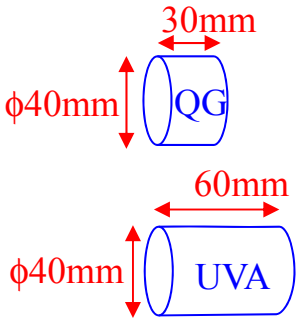
new-type BLMs

① Scintillation-type BLM of lead glass





② Cherenkov-type BLM of quartz or UV acrylic

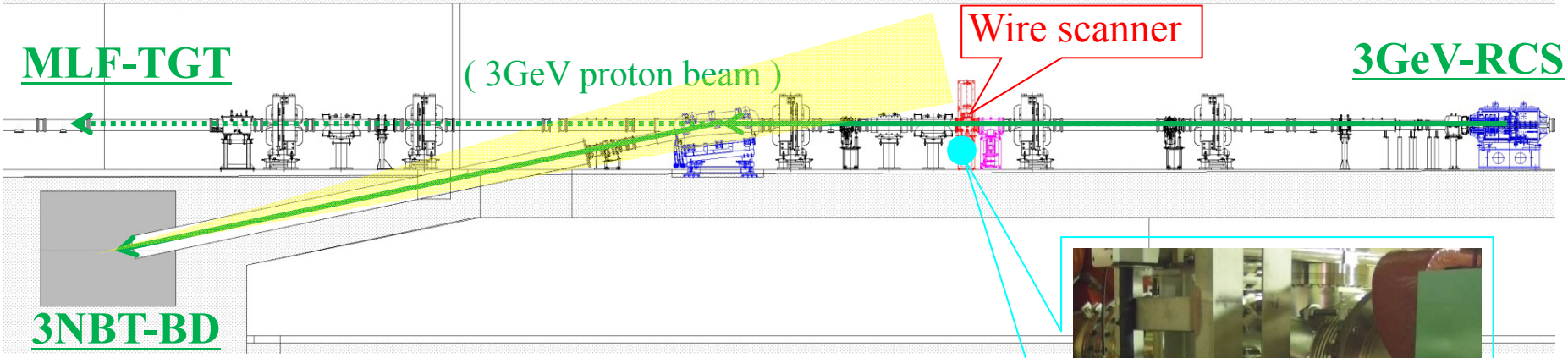


- These new-type of BLMs have high sensitivity toward the faster gamma-ray or electron.
- Thus the suppression of the reflected radiations may be expected.

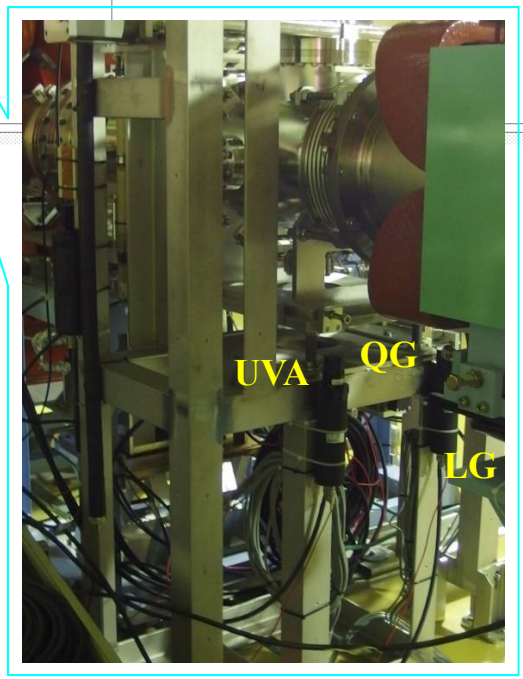
Trial beam test with new-type BLM

- To see if the new-type BLMs work as they were expected to, they were installed near the wire scanner and trial beam tests were carried out.

(Particle simulation with GEANT4 is starting now.)

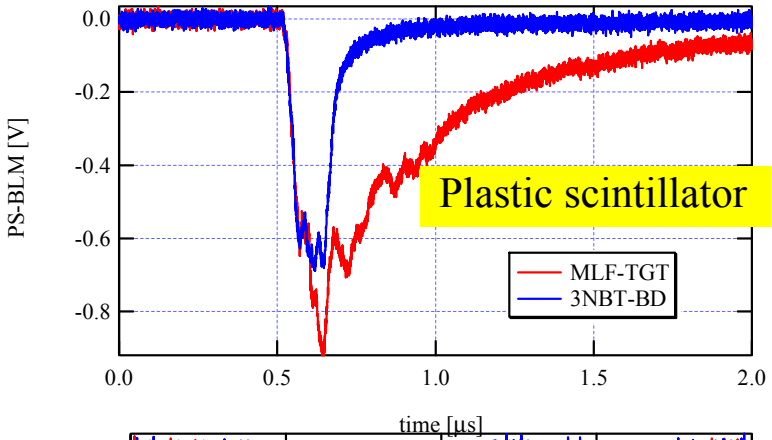


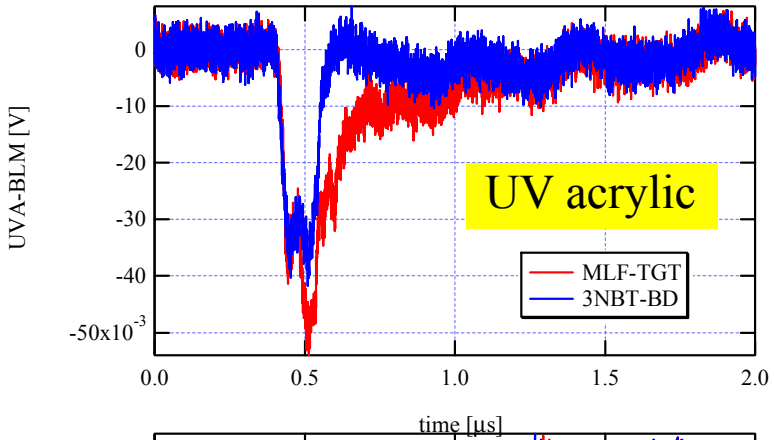
- To enhance the effect of the reflected radiation, the beam destination from the RCS switched from MLF-Target to 3NBT-Beam Dump.
- At first, the ultra-low intensity beam was used to prevent the saturation of the BLM.
- Next, the high intensity beam was used for the high power beam commissioning.

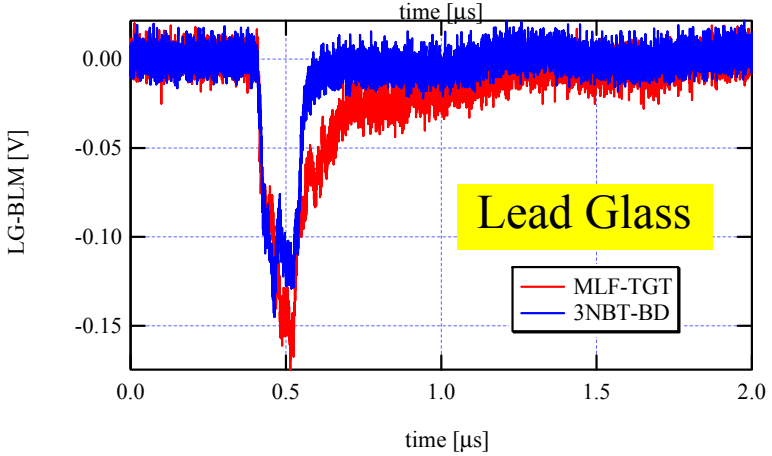


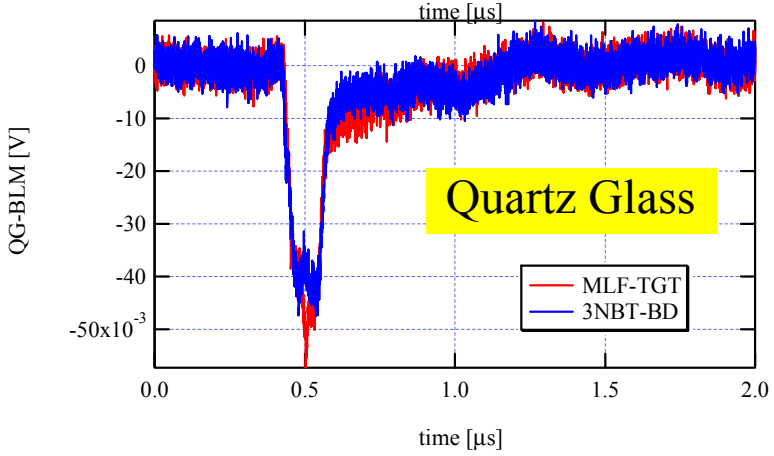
Ultra-low intensity beam test

- Ultra-low intensity beam (1-intermediate bunch with thin chopped width)
- By switching the beam destination from MLF-TGT to 3NBT-BD





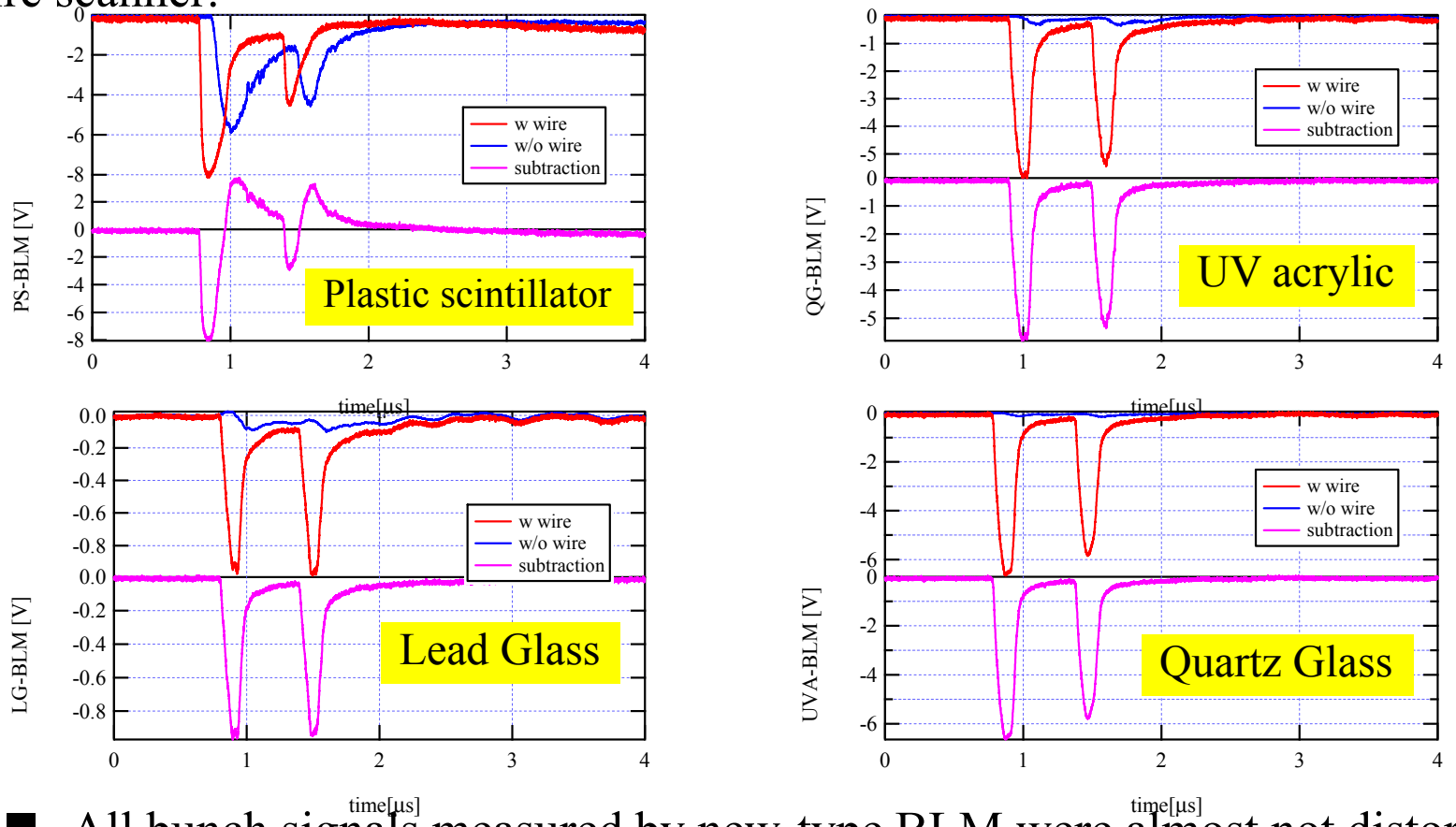




- All new-type BLMs can suppress the reflected radiation drastically.

High intensity beam test (I)

- High intensity beam test (747kW-eq.)
- Bema destination is fixed to 3NBT-BD, compare between inserted and retracted the wire scanner.

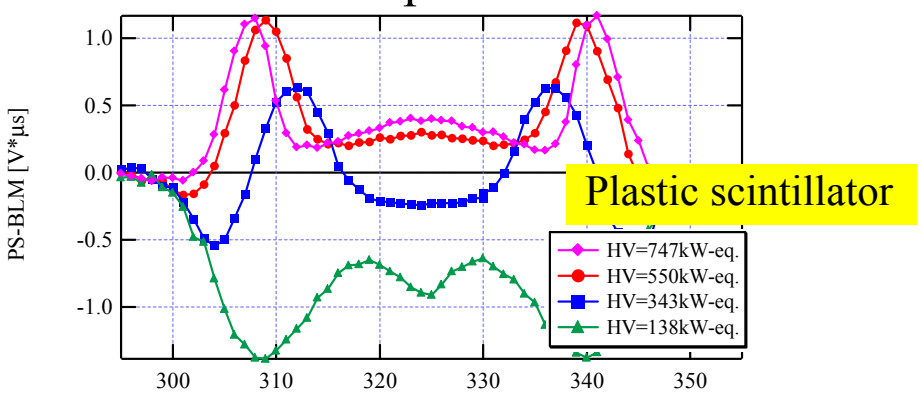


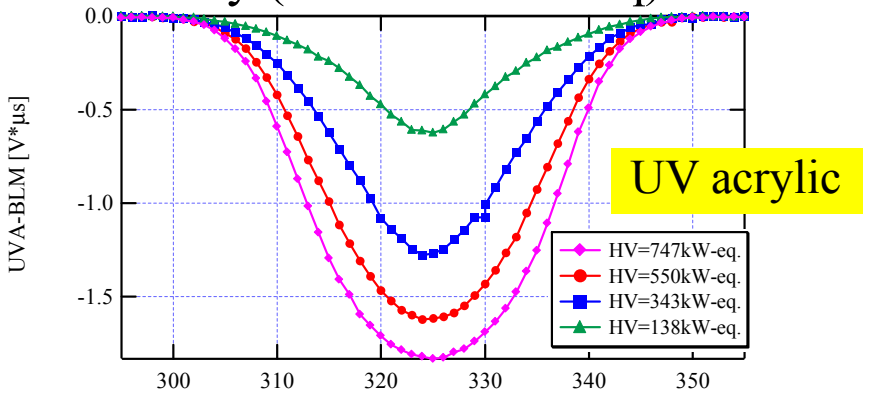
- All bunch signals measured by new-type BLM were almost not distorted.

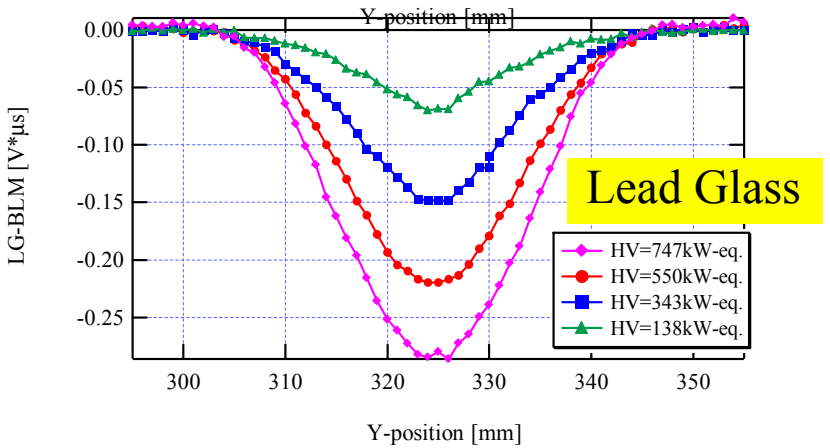
⇒ The transverse profile can be measured in the 3NBT-BD operation.

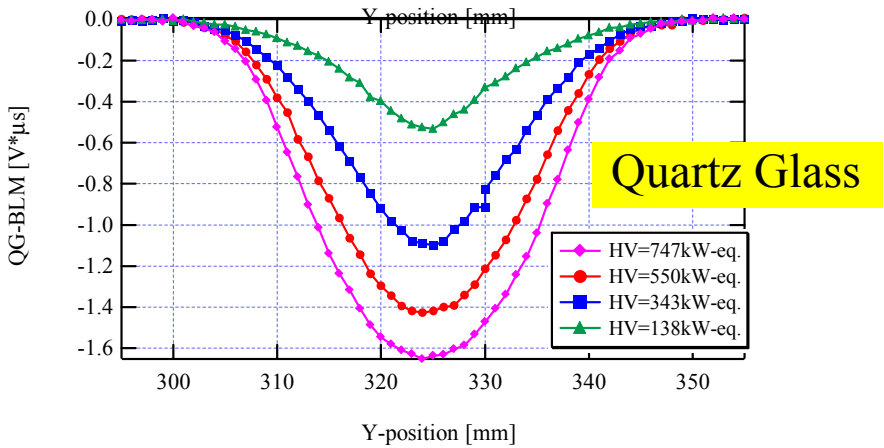
High intensity beam test (II)

- Transverse beam profiles were measured with new-type BLM in the 3NBT-BD operation with various beam intensity (138 ~ 747kW-eq).







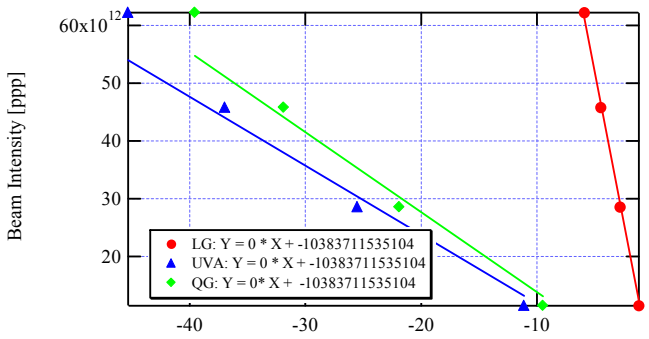


- The Plastic scintillator signal was saturated due to the reflected radiation from the 3NBT-BD, and transverse profile was distorted.
- New BLM signals can obtained the beam profiled.

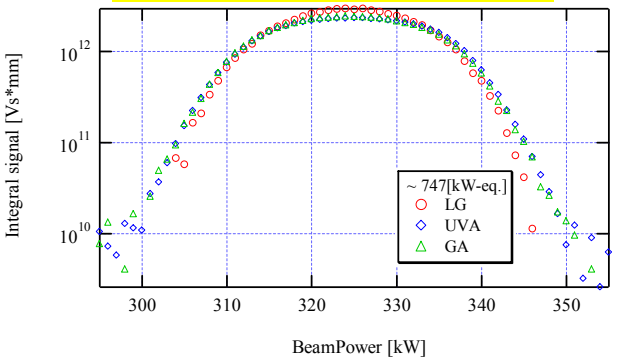
Trial of the reconstruction

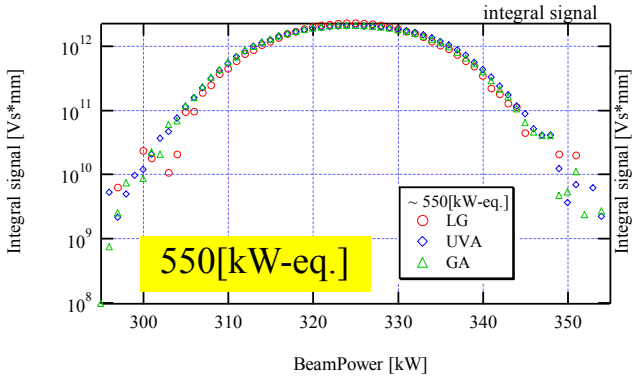
- Calibration formula of the each new-type BLM were calculated roughly
- The transverse beam profiles were reconstructed .

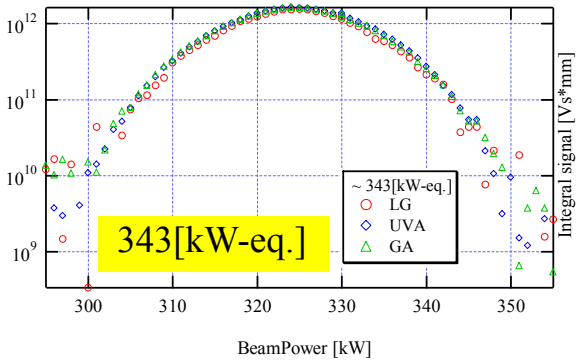
Rough calibration formulas

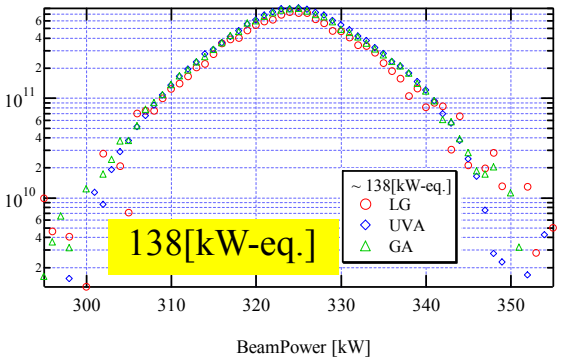


Beam power: 747[kW-eq.]









- Transverse beam profile can be obtained in the 3NBT-BD operation.

⇒ It is good advantage for beam commissioning in the RCS.

conclusion

- The transverse beam profile including both the beam core and beam halo can be reconstructed by using the several BLMs with the various sensitivities.
- Only by using sensitivity calibration formula for the each BLM, transverse profile including both the beam core and beam halo can be reconstructed directly.
- In this scheme, it is possible to expand the dynamic range by using the higher sensitivity BLMs.

- The time structure of the bunch signal measured by the plastic scintillator was distorted, because of the reflected the radiation.
- The new-type BLMs, which are scintillation-type BLM of lead glass and Cherenkov-type BLM of quartz or UV acrylic, can be reduced the reflected radiation drastically.
- In order to achieve the intra-bunch beam halo measurement, the new-type BLMs have to progress.

Thank you for your attention !