Development of the beam halo monitor in the J-PARC 3-GeV RCS

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Overview of J-PARC 3GeV RCS

Configuration of the Accelerator Complex of J-PARC

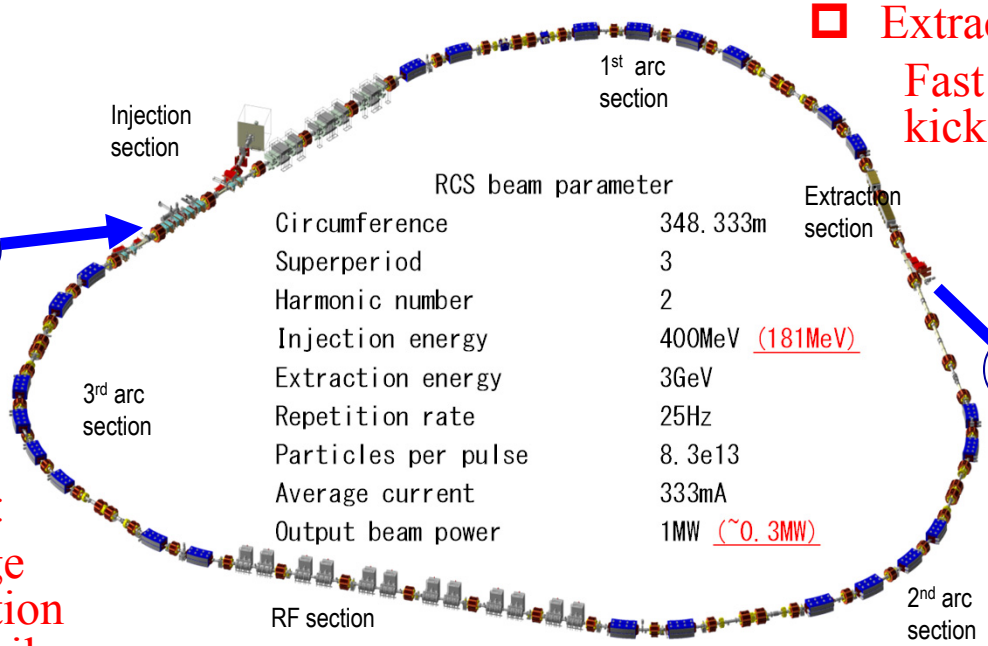
- J-PARC = Japan Proton Accelerator Research Complex
- Three accelerators:
  - 400MeV LINAC / **3GeV RCS** / 50GeV MR
- Multi purpose research facility with high power proton beam
  - Nuclear and Particle Physics
  - Material and Life Science

3GeV - RCS

from LINAC

H^-

multi-intermediate pulse structure formed by the RF chopper



RCS beam parameter

Circumference	348.333m
Superperiod	3
Harmonic number	2
Injection energy	400MeV (181MeV)
Extraction energy	3GeV
Repetition rate	25Hz
Particles per pulse	8.3e13
Average current	333mA
Output beam power	1MW (~0.3MW)

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

Extraction scheme:
Fast extraction with kicker magnet

2 bunched structure

H^+

to MLF

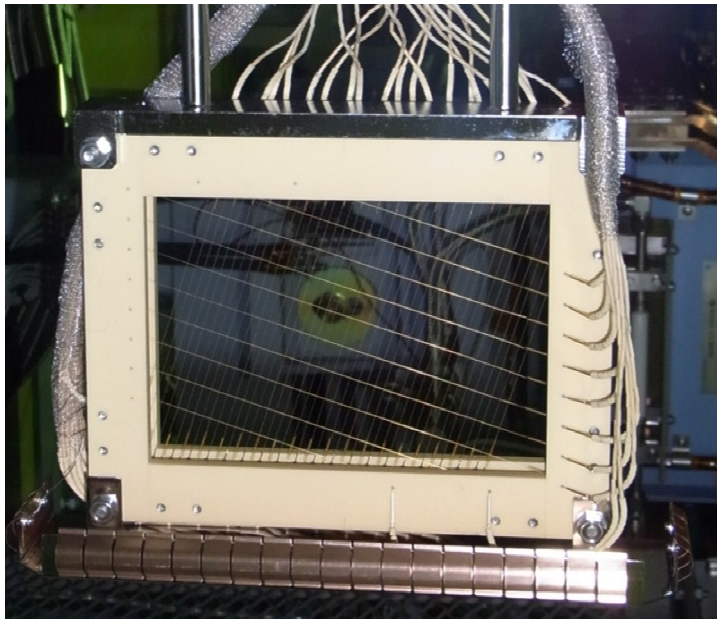
to MR

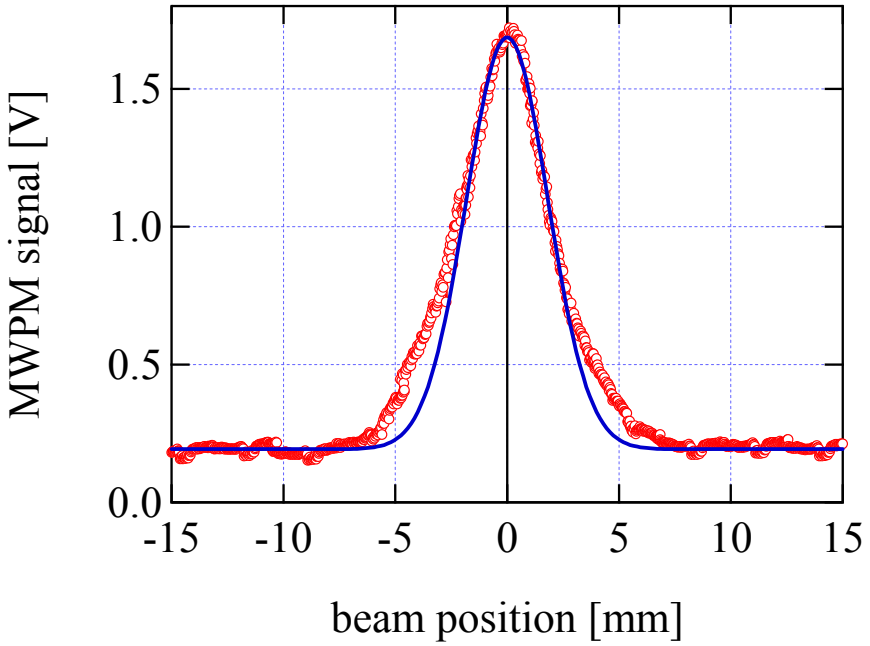
Aim of the beam halo measurement

- Why are the beam halo measurement required in the RCS?
  - Current user operation: 200kW
  - Demonstration: 420kWeq.
  - To provide such a high power proton beam for the MR with small injection beam loss, 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.
- How are the beam halo measured in the RCS?
  - Injection: H- / 181MeV / multi-intermediate pulses
  - Extraction: H+ / 3GeV / 2bunched beam
  - To measure the beam haloes at the injection and extraction respectively**, the various devices and methods are combined.**

Injection beam halo measurement ①

- Multi-Wire Profile Monitor (MWPM)
  - Injected H^- beam profiles are measured

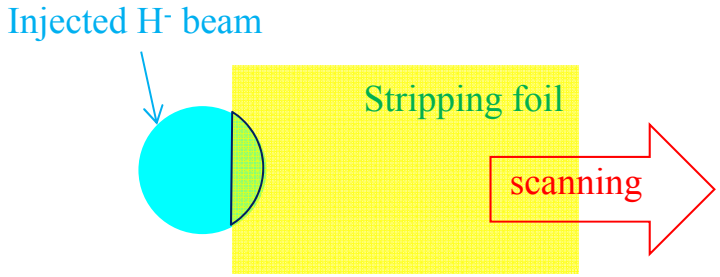




- The beam core and tail can be obtained clearly.
- But it is difficult to distinguish the beam halo from the measured profile.

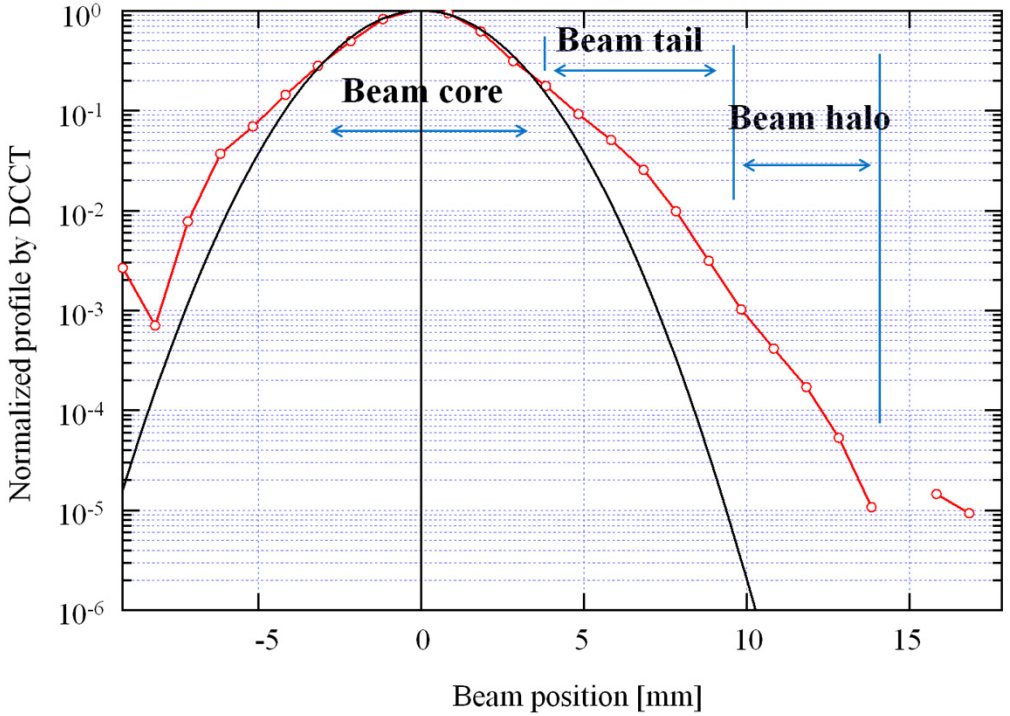
Injection beam halo measurement ②

☐ Foil scanning (stripping foil + DCCT)



- The DCCT has three current range; 0.15A, 1.5A, 15A
- And measureable dynamic range of 10^{-2} on each current range.
- **Thus total dynamic range of 10^{-5} can be achieved.**

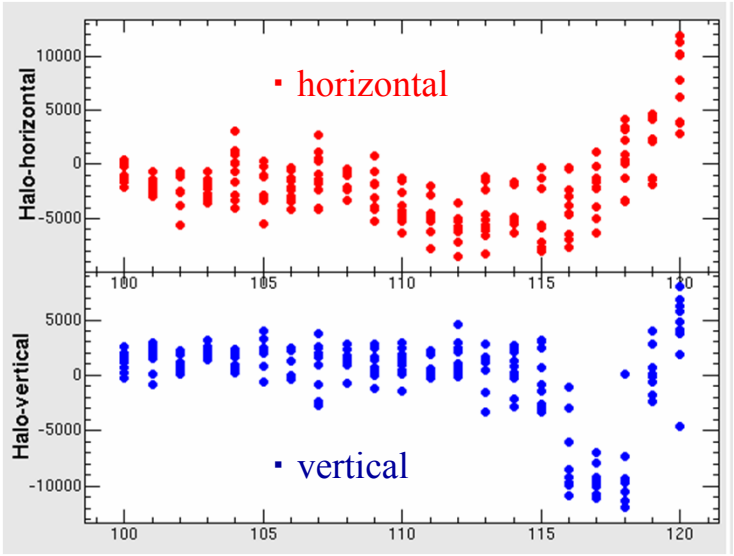
- The stripping foil position is scanning while the DCCT signal data are acquired.
- As a result, we can obtain the beam profile with wide dynamic range.



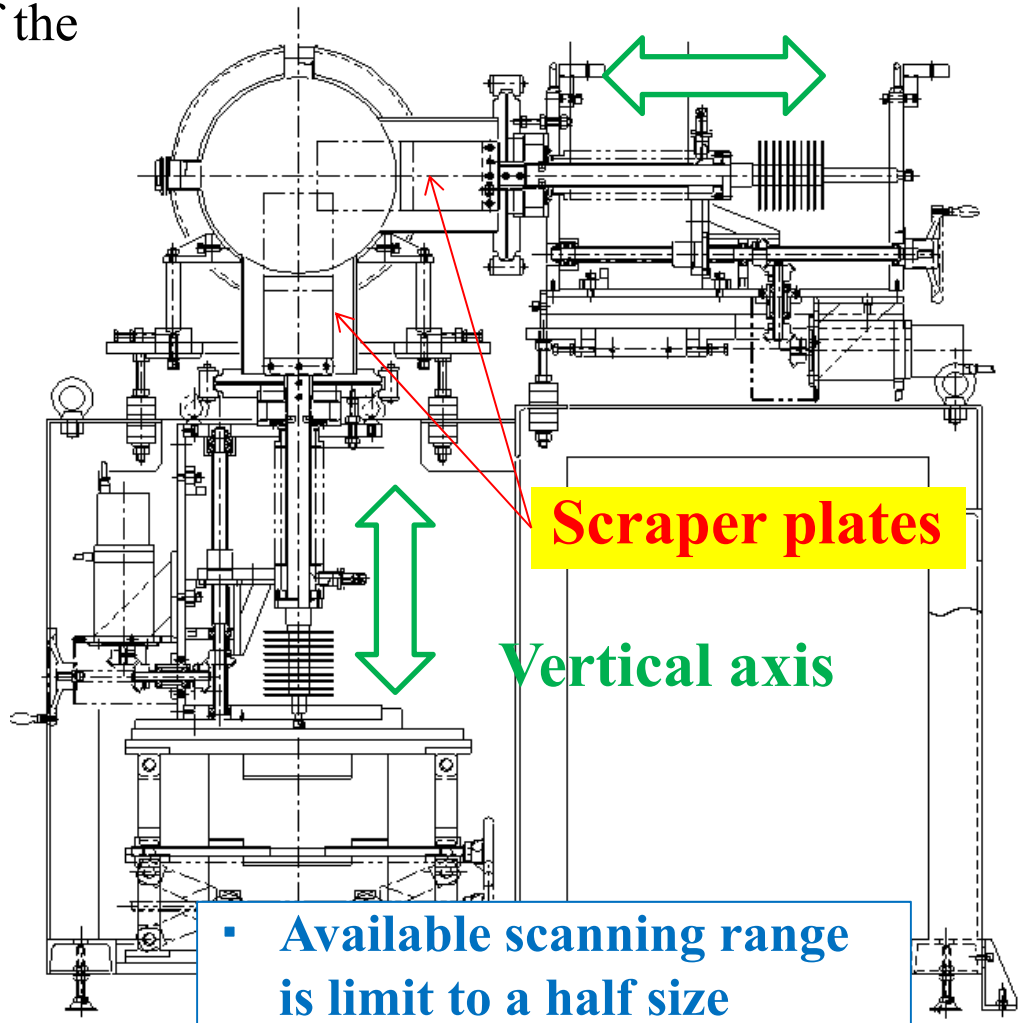
- **Two different slops are measured clearly due to the beam tail and halo.**

Extraction beam halo measurement ①

- Halo monitor with scrapers
  - A secondary emission current of the scraper plate is read out.

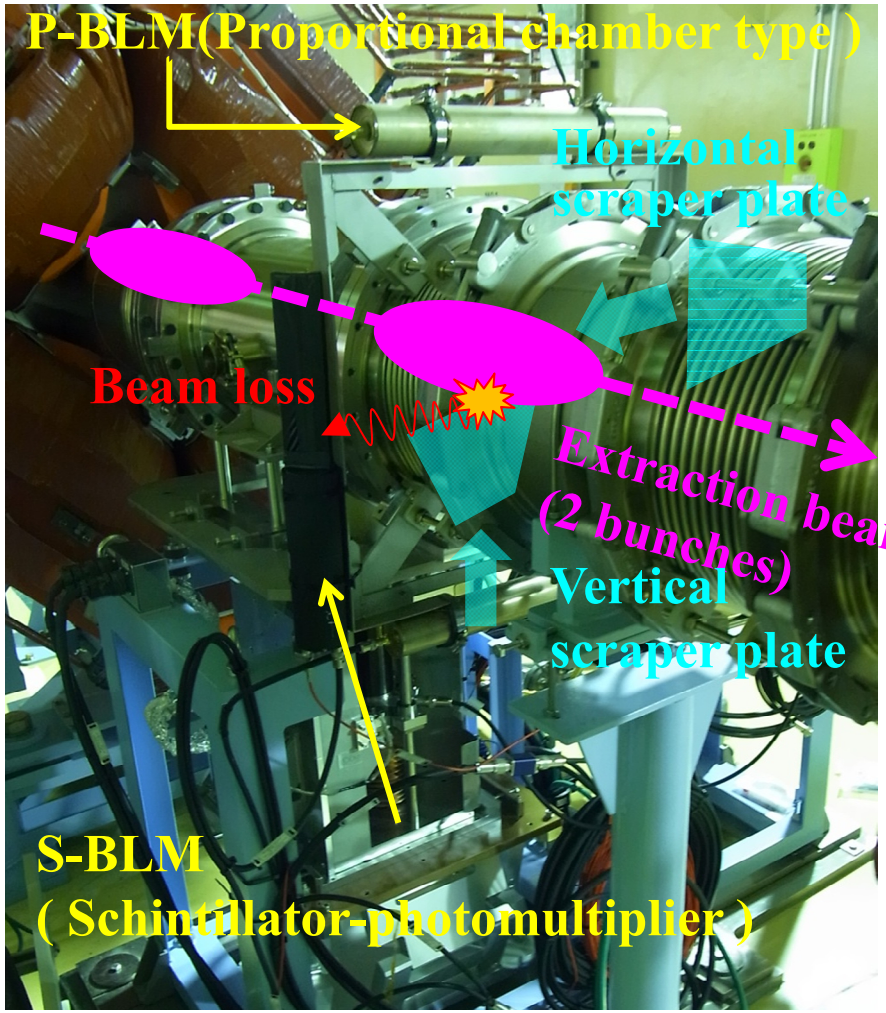


- **The measured signals include some huge noise.**
  - EM noises from AC magnets
  - Residual free electron
- **It is difficult to measure the beam profile and the beam halo.**

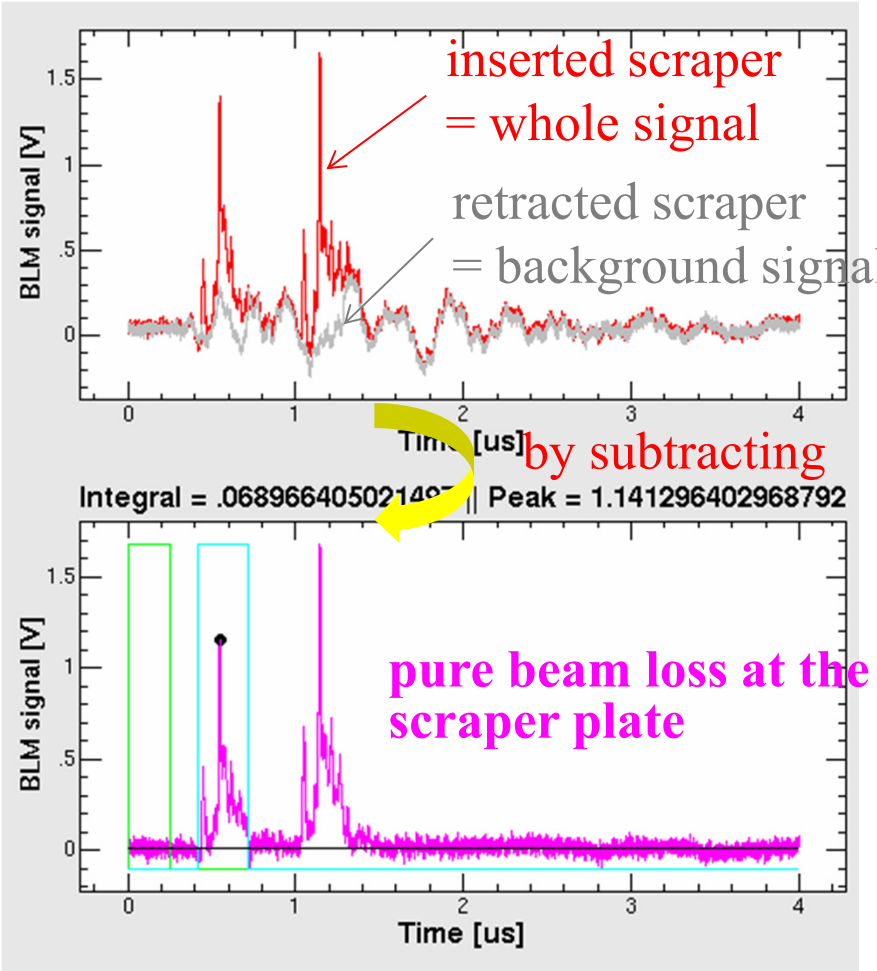


Extraction beam halo measurement ②

- Halo scraper + S-BLM



- This S-BLM has very high sensitivity, thus a few particles in the beam halo can be measured.

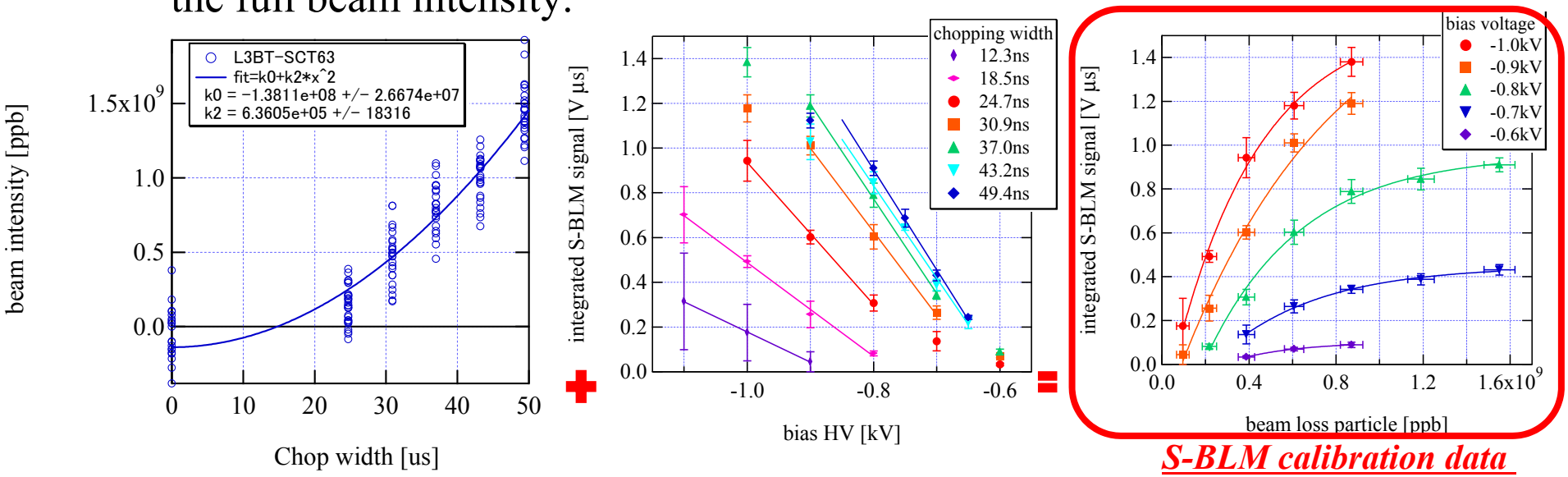


Extraction beam halo measurement ②

Beam halo quantification:

S-BLM need to calibrate with controlled beam losses at the scraper plate.

- Horizontal bump orbit of about 20mm is produced at the 3NBT line because the whole beam particles hit the scraper plate.
- Beam intensity is cut off by the RF chopper and reduced to less than 10^{-5} of the full beam intensity.



S-BLM calibration data

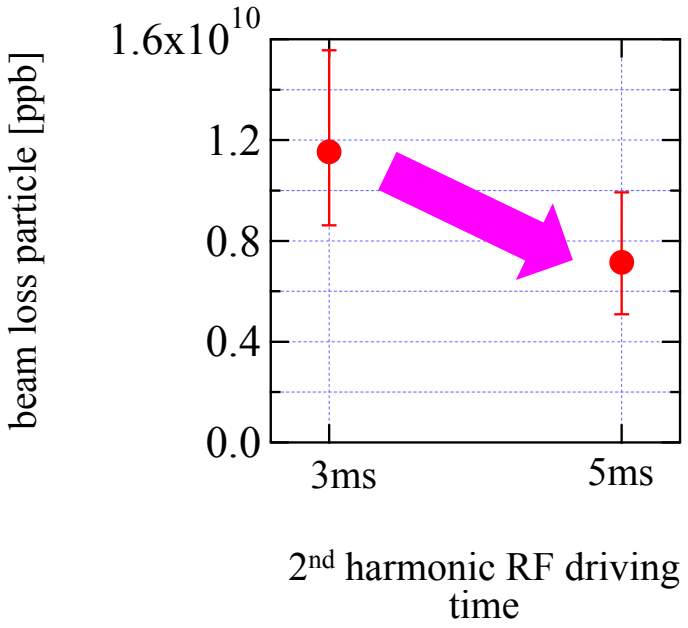
- The beam halo quantification can be available from the S-BLM calibration data.
- And it is useful and powerful tool for finer beam tuning in the RCS.

Beam Halo Experiment (a typical example)

- Recent RCS effort is to suppress the beam loss at 3-50BT collimator (aperture < 54π) to increase the injected beam intensity in the MR.

- **Thus we try finer beam tuning in the RCS to reduce the beam halo components defined by the outside of the 54π emittance.**

- **Finer beam tuning procedure:**
  - ① Halo scraper is set at 54π emittance.
  - ② 2nd harmonic RF driving time is extended from 3ms to 5ms.
  - ③ Beam halo quantities are measured.

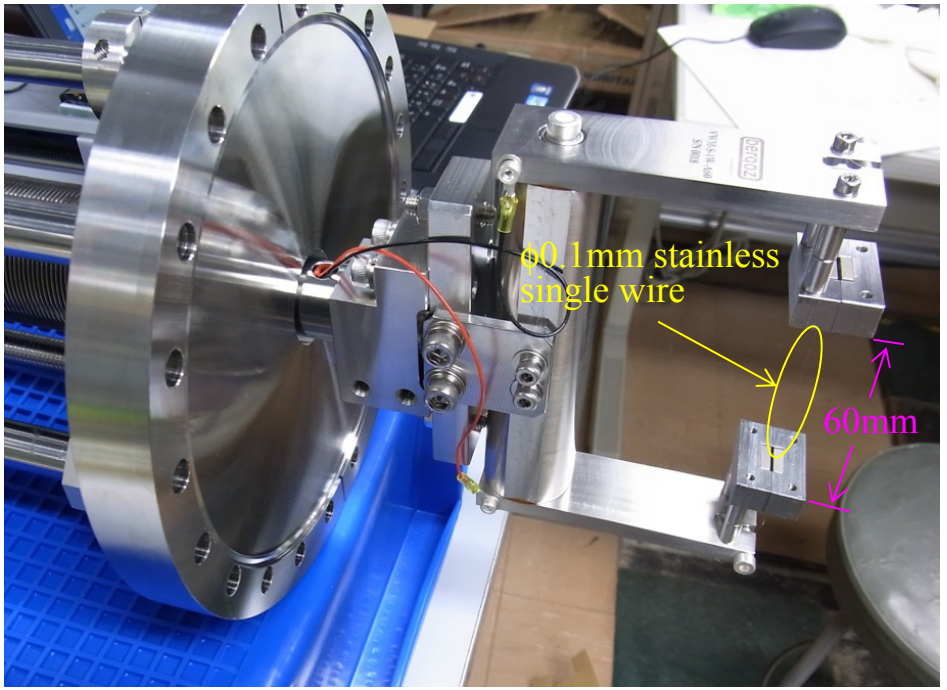


- **Experimental result:**
  - Beam halo components can be reduced in almost half.

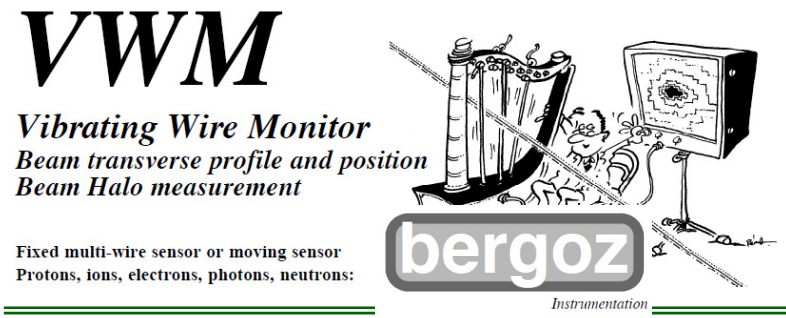
More detail => THPPP080

Future Plan: Vibrating Wire Monitor

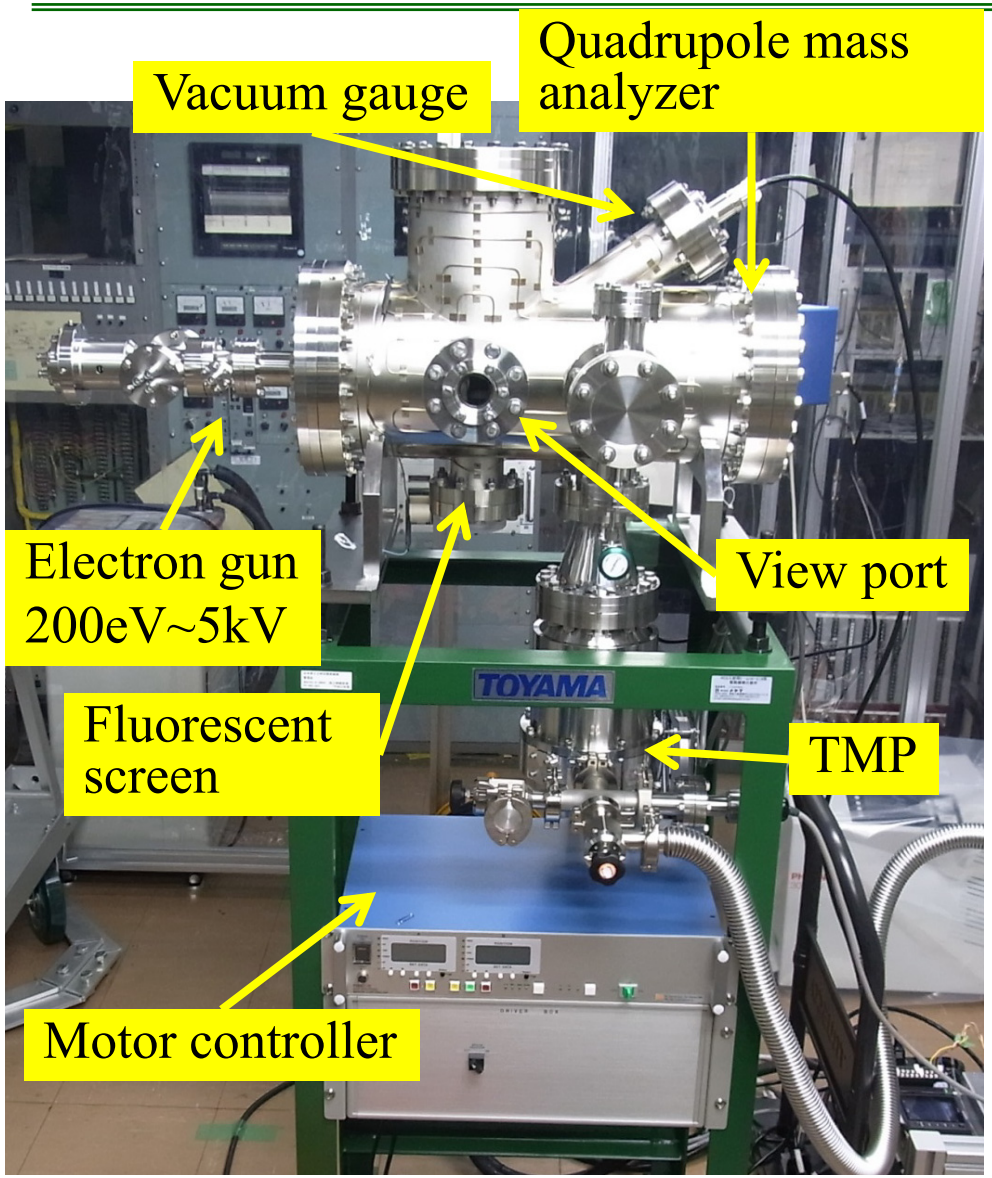
- Through beam halo measurements, we found some **technical issues**.
- Then we develop the new halo monitors, and one option is the **vibrating wire monitor**.
- The VWM is based on the **wire resonant frequency** depending on its **temperature**. Particle heats up the wire by hitting it, and resonant freq. is shifted.
- It is a strong advantage that the VWM is not affected with any EM noise or residual free electron.



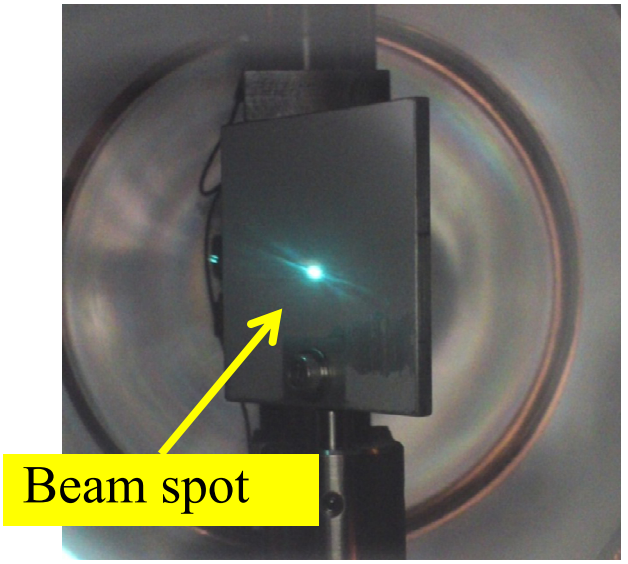
- Check items before its installation
  - ① Acquisition time …. freq. ramp up/down time
  - ② Dynamic range …. beam profile
- **At first, we try some offline studies at a test stand with a low energy electron gun.**



Test stand for offline studies of the VWM

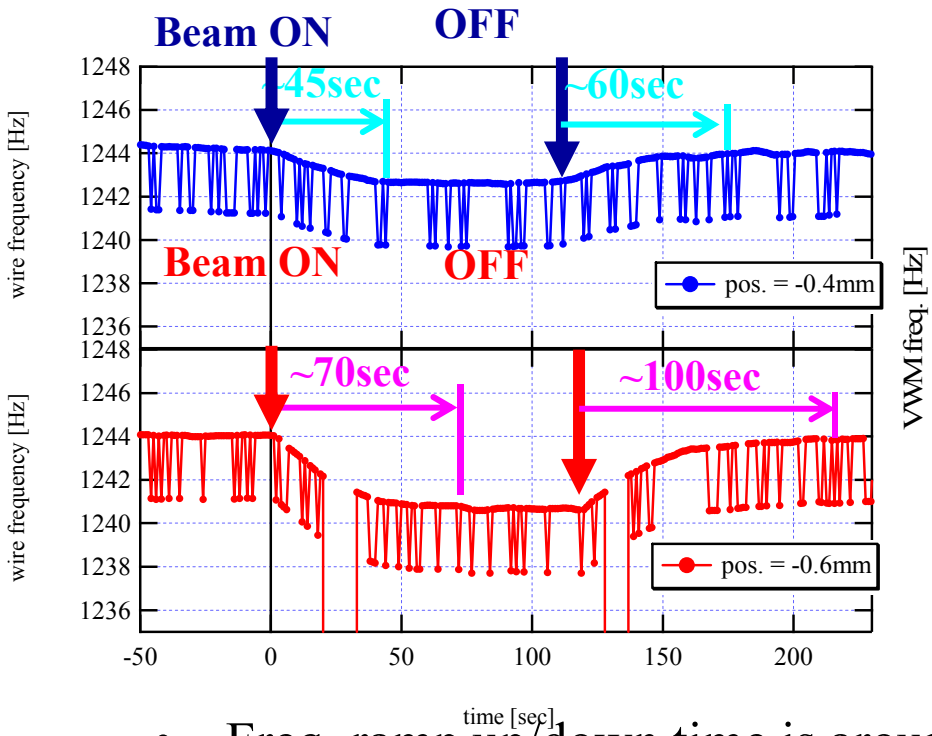


- Test stand for offline studies
  - Electron Gun :
    - energy: 200eV~5kV
    - Current: ~10nA
    - Spot size: ϕ1~5mm
  - Vacuum chamber
    - Base pressure: ~1E-6 Pa
    - Vacuum gauge + Q-mass analyzer
    - Available to bake out

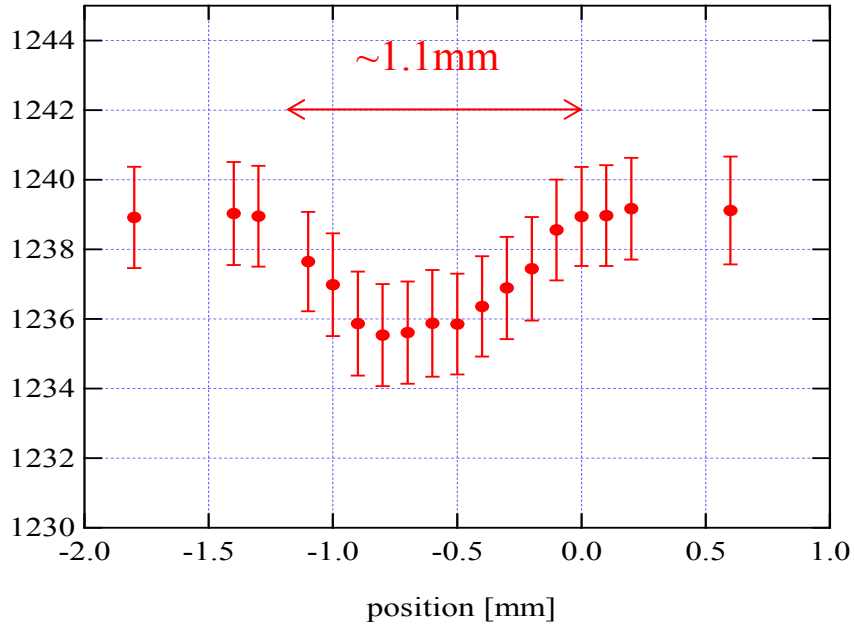


Recent experimental results

① Freq. ramp up/down measurement



② Beam profile measurement



- Freq. ramp up/down time is around one minute.
  ⇒ We need to estimate 181MeV/3GeV proton beam irradiation case
- Profile is noisy due to the freq. jumping is often occurred.
  ⇒ We need to research the cause of freq. jumping

The VWM will be installed in this summer.

Summary

- The injection and extraction beam haloes are measured by combining various devices and methods.
  - The injection beam halo which is less than 10^{-4} of the beam core can be measured by combining the DCCT with the stripping foil.
  - The extraction beam halo quantification can be achieved by the S-BLM with the halo scraper. This method can measure the beam halo components with ultra low intensity of about $1x10^{8}$ ppp.

- In our future plan, new beam halo monitors are developed.
  - In one option, we develop the VWM and some offline studies at the test stand are started.
  - And the VWM will be installed in this summer.