Longitudinal Beam Diagnosis with RF Chopper System

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Outline

My talk is about the measurement of longitudinal beam size by existing two apparatus: an RF chopper System in the linac and a beam loss monitor in RCS. Therefore, my topics is different from the development of new monitor.

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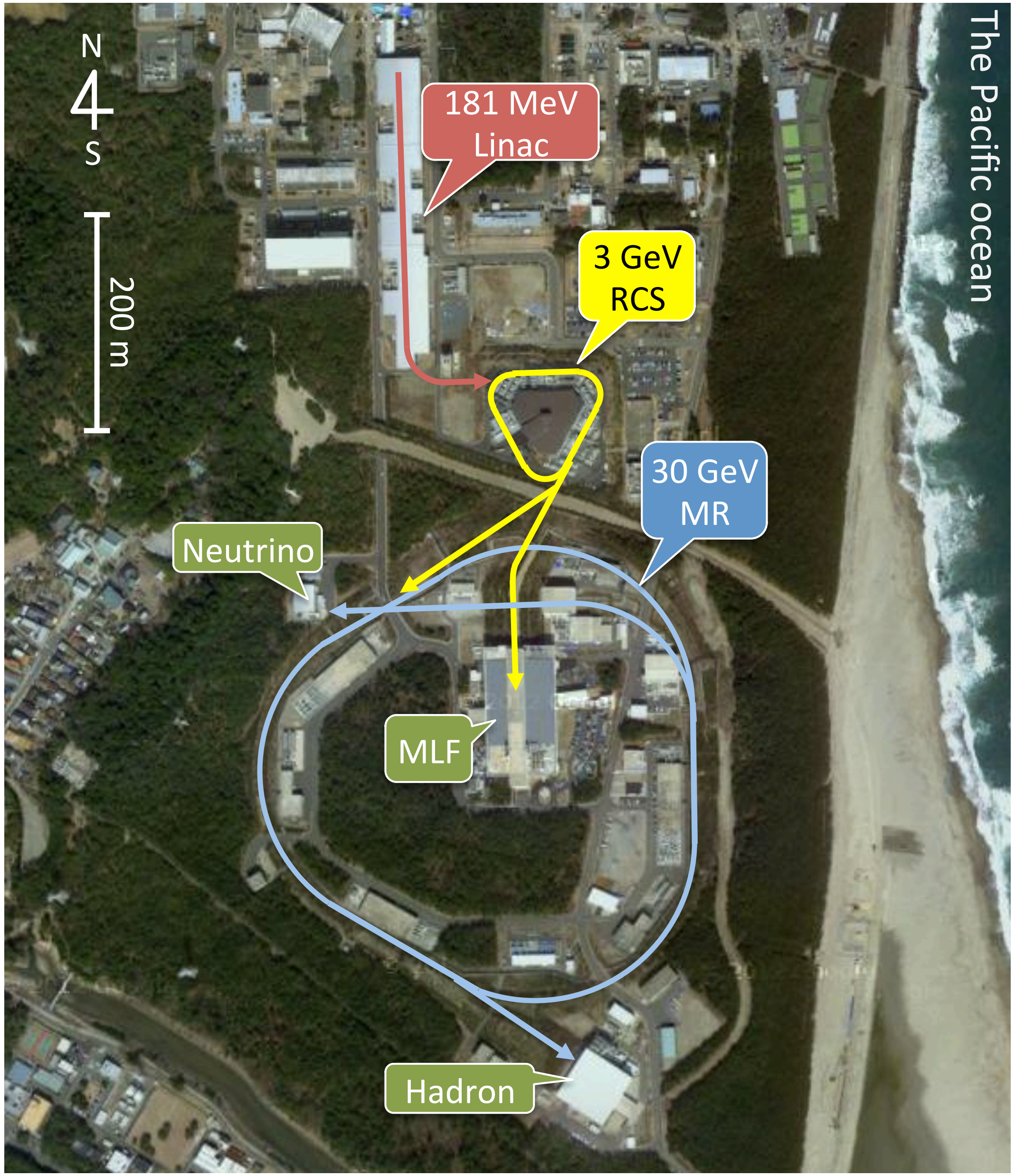
Outline of Japan Proton Accelerator Research Complex



Accelerator Complex

- 181 MeV Linac
- 3 GeV Rapid Cycling Synchrotron (RCS)
- 30 GeV Main Ring (MR)

Experimental facilities

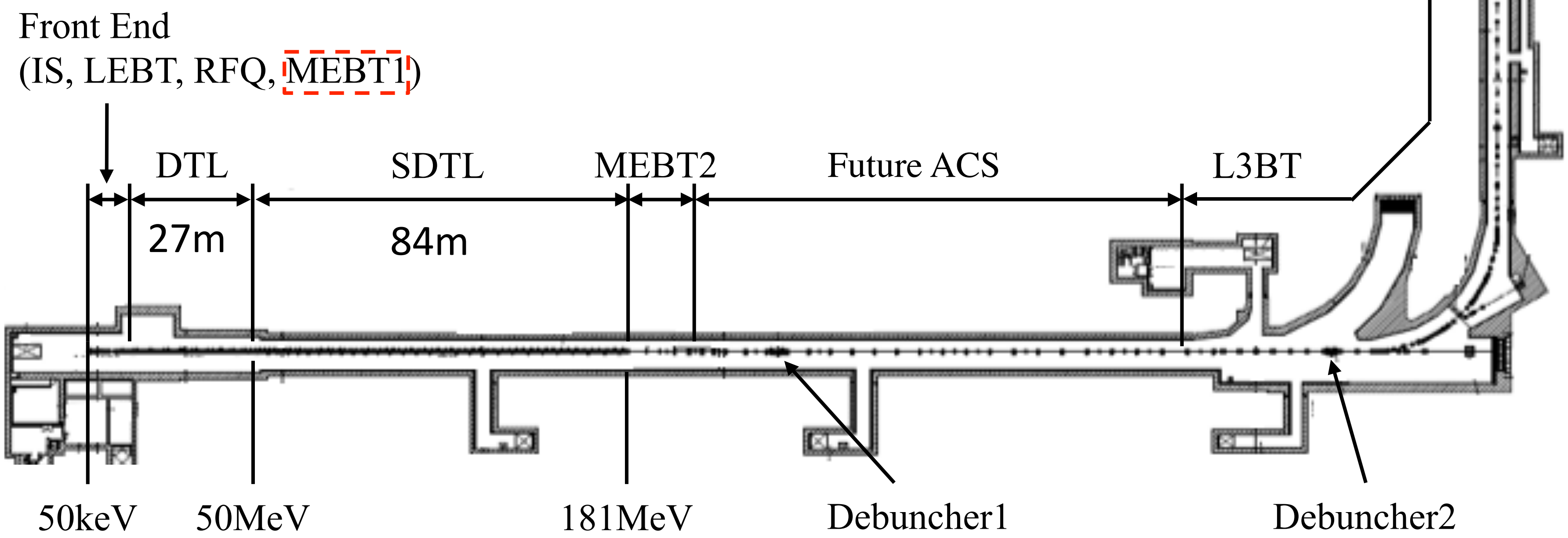
- Materials and Life Science Experimental Facility (MLF)
- Hadron Experimental Facility
- Neutrino Experimental Facility

Overview of the J-PARC Linac

Major parameters

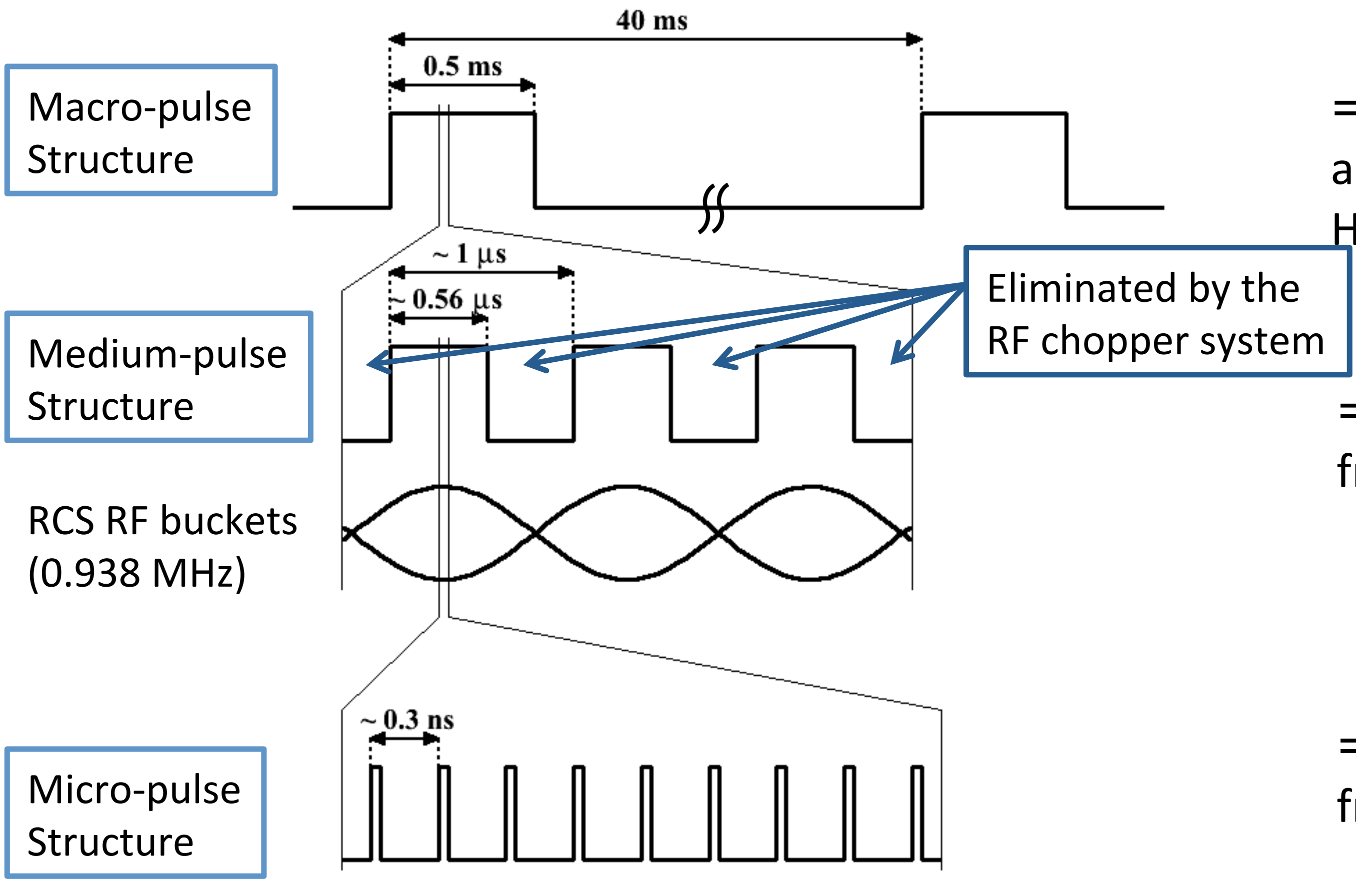
Particles	H^-
Output energy	181 MeV
Peak current	30 mA
Pulse width	0.5 ms
Chopper duty factor	56%
Repetition rate	25 Hz
Output power	36 kW

- Present beam power is 16 kW (current: 15mA, pulse width: 0.5ms).
- The RF chopper system is placed at MEBT1 between RFQ and DTL.



Function of RF Chopper System

The J-PARC linac has three kinds of pulse structure.



⇒ Equivalent to the one acceleration cycle in RCS (25 Hz).

⇒ Equivalent to the RCS RF frequency (0.938 MHz).

⇒ Equivalent to the linac RF frequency (324 MHz).

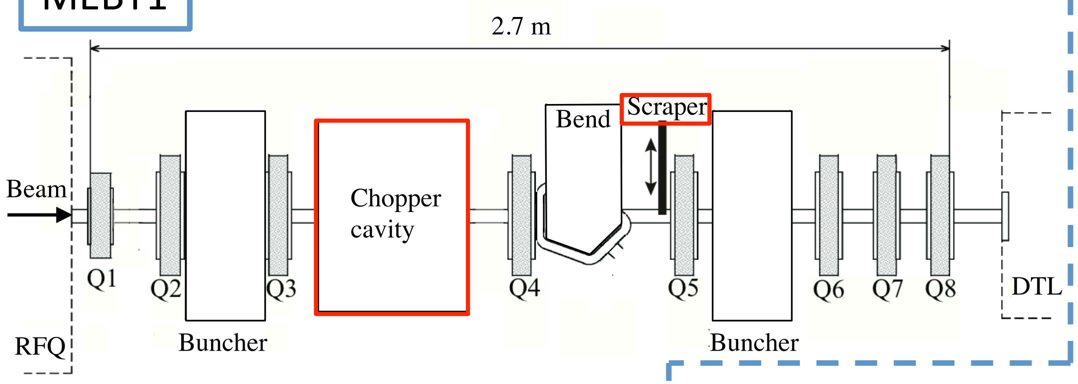
Medium-pulse is for the mitigation of a beam loss in RCS.
⇒ Insufficient beam rejection power causes beam loss in RCS.

RF Chopper System

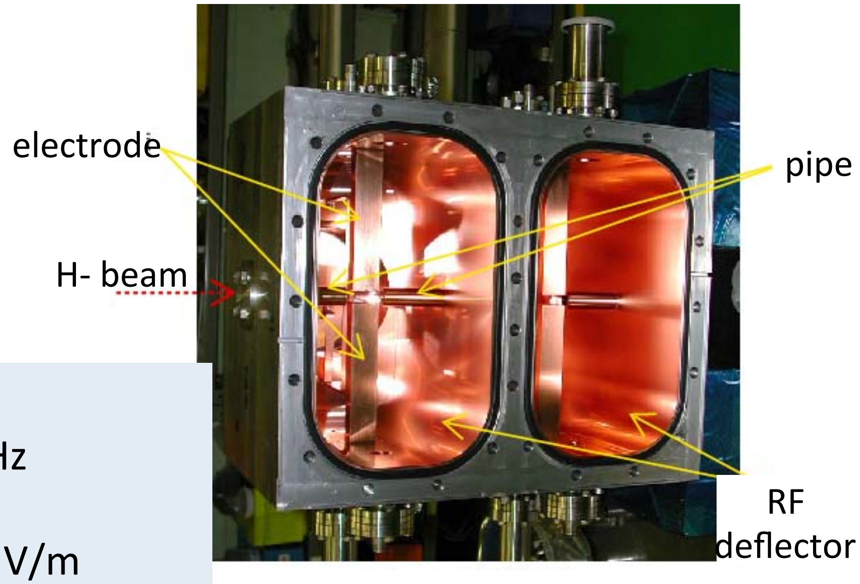
- The system is placed in MEBT1.
- An RF chopper cavity and a scraper.
- The cavity is **not a slow-wave kicker** but an **RF deflector**.
- Beam is horizontally deflected, and then the beam is absorbed in the Scraper
- The beam extinction: 10^{-7} ($\Delta\phi$ < +/-20 deg) ⟺ Requirement: 10^{-4}

  ⇒ Achieved our requirement with 3 order higher level.

MEBT1



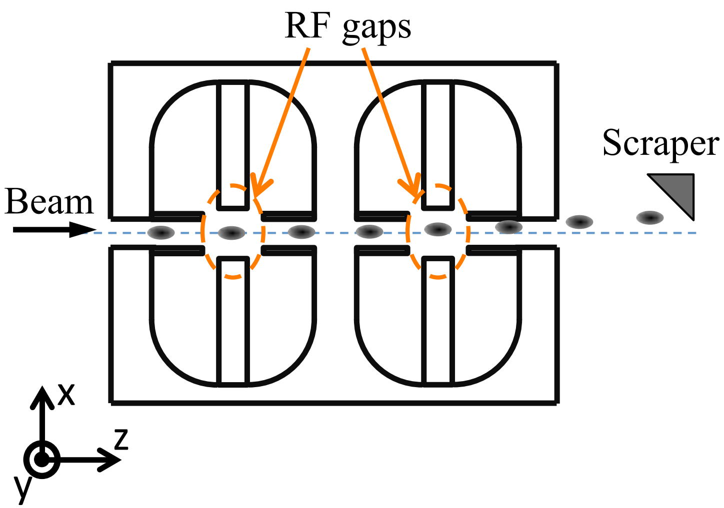
Top view of RF chopper cavity



- Beam: H^-
- Energy: 3 MeV
- Length: 2.7 m
- 8 x Quads, 2 x Bunchers
- RF Chopper System
  (RF chopper cavity + Scraper)

- TE-11 like mode
- Frequency: 324 MHz
- Rise time: 11ns
- Electric field: 1.6 MV/m
- Deflection angle : 6 mrad/gap
- Amplifier: 35 kW max.
  (2.0 MV/m)

Principle of the RF Chopper System

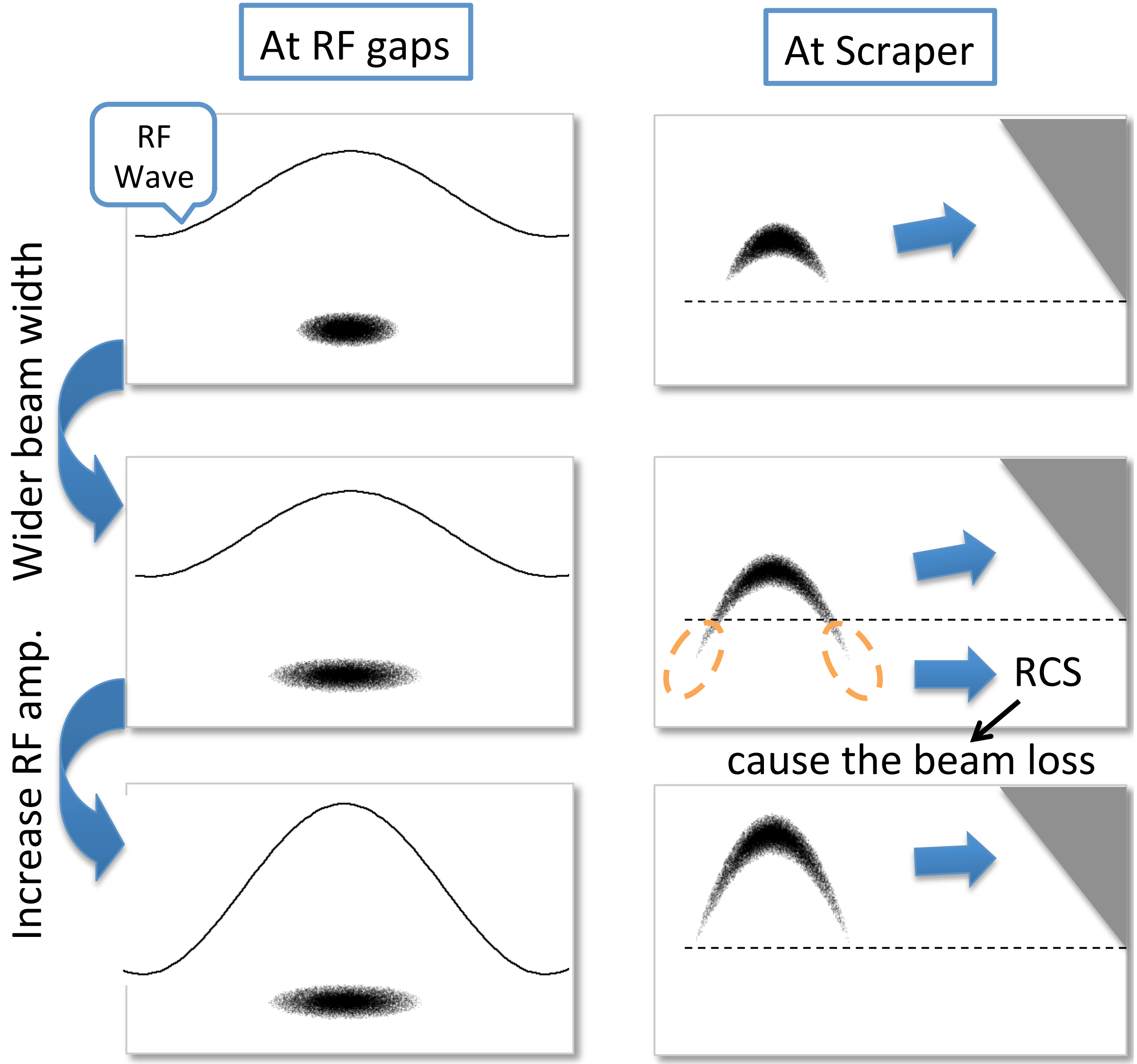


Beam is horizontally deflected by two RF gaps.

Deflection angle depends on

- RF amplitude
- (Inversely) Beam width on phase axis

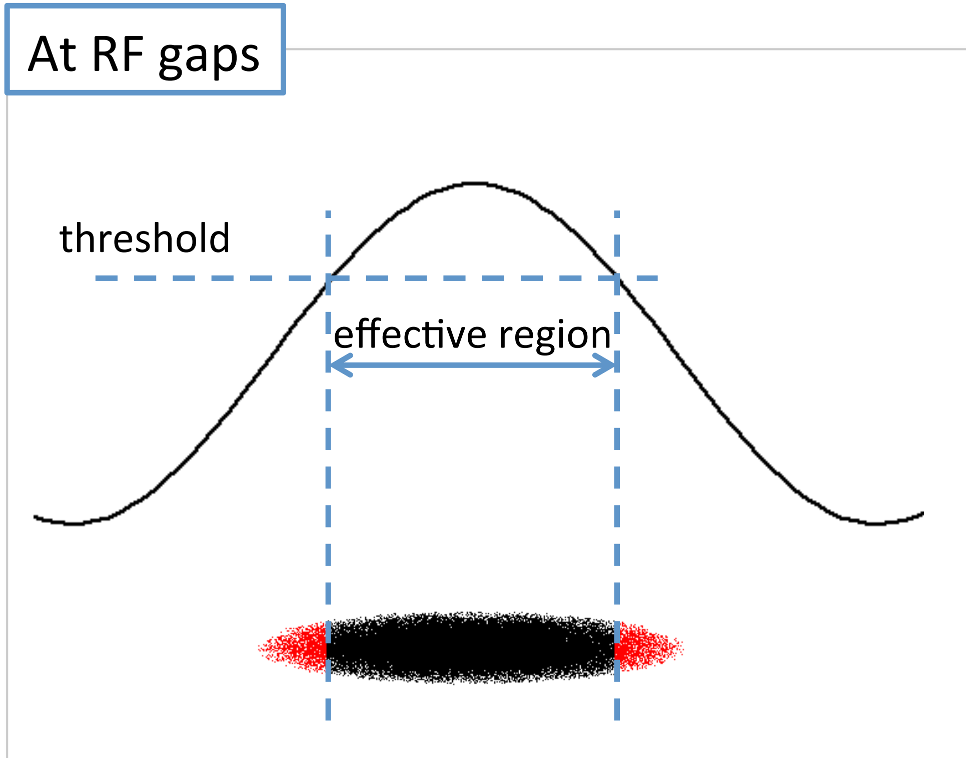
If beam becomes wider, higher RF amplitude is required to eliminate them.

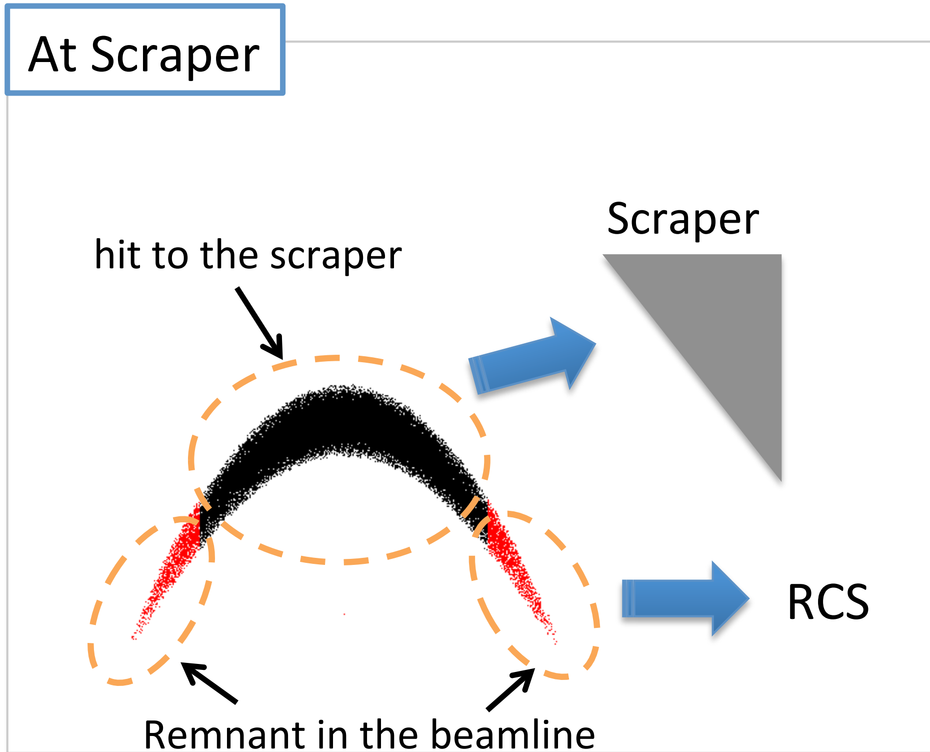


Measurement Method

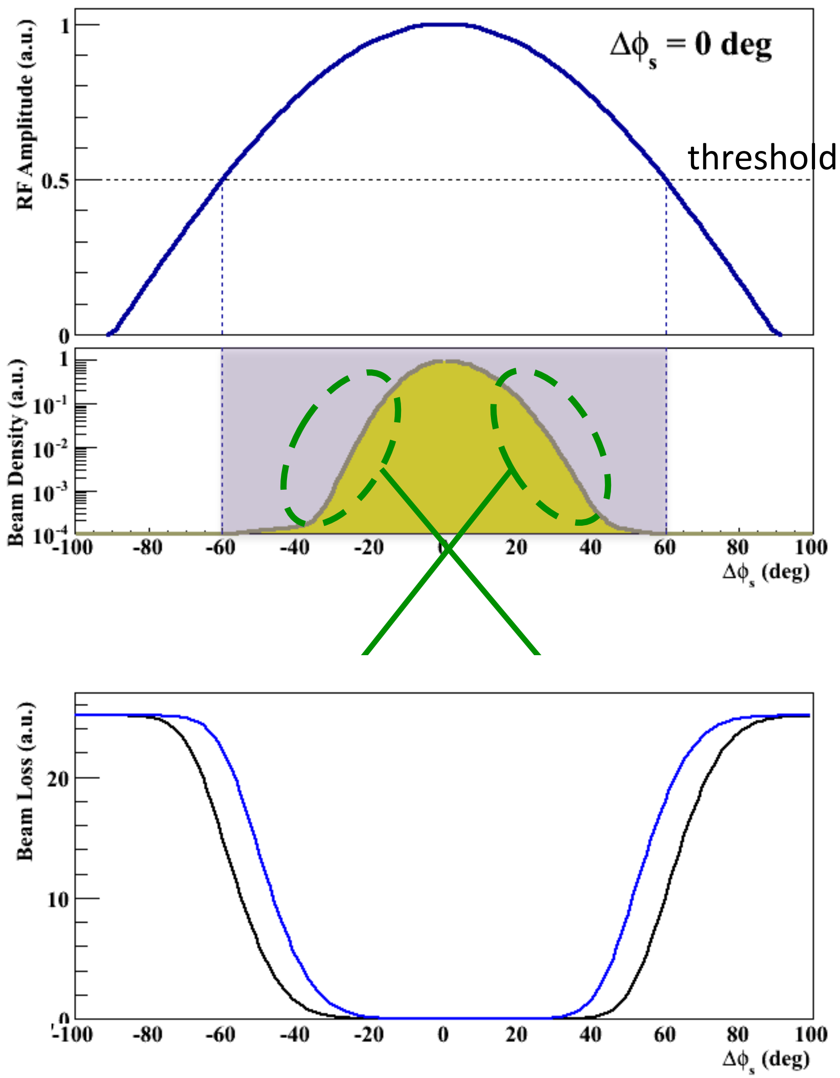
Effective Region

- A certain RF amplitude (threshold) is required for beam to hit the scraper.
- We call the as the phase in which RF amplitude is higher than the threshold as `` effective region''.





RF Amplitude and Phase Scan



- Scan the correlation of the synchronous phase ($\Delta\phi_s$) with Beam loss.
- Effective region shifts as the $\Delta\phi_s$ varies.
- Calculate the correlation of $\Delta\phi_s$ and beam loss.
  - Asymmetric distribution assumed.
  - Negative side beam loss show the positive side beam profile and vice versa.
    ➡ Beam profile can be obtained from the slope shape.
- Phase scan by other RF amplitude
  - Equivalent to measure beam profile with different edge position.
    ➡ possible to obtain the threshold and edge.

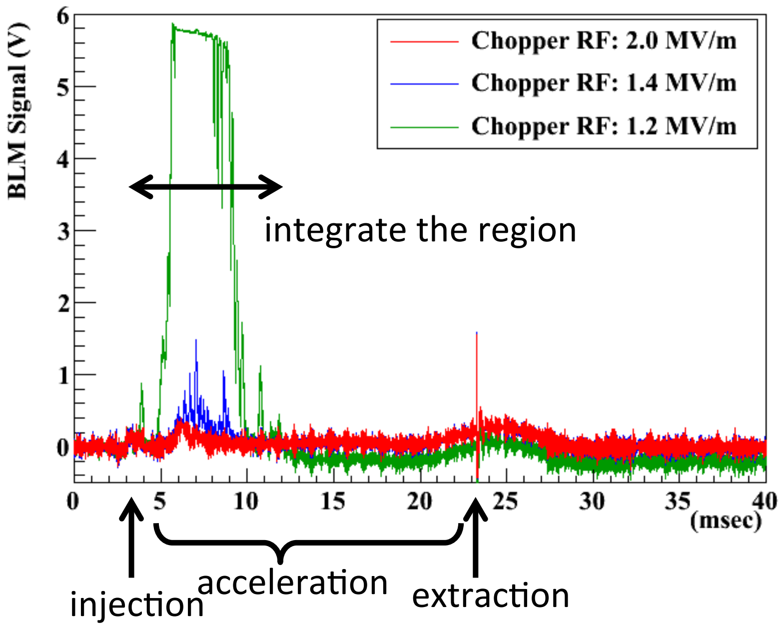
Experimental Results

Monitor ： RCS beam loss monitor signal at arc section

Knob ： RF amplitude and synchronous phase of the RF chopper cavity

RF Phase Scan Result

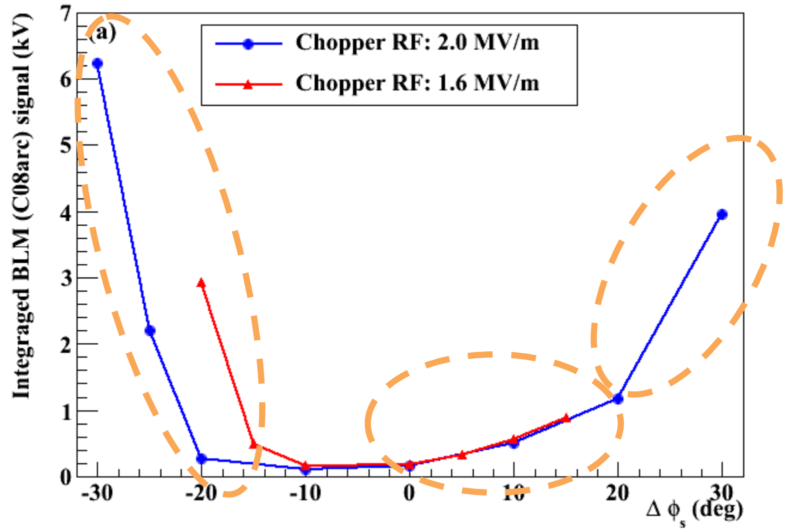
Time evolution of the BLM signal



- RF amplitude: 2.0, 1.4 and 1.2 MV/m.
- Significant Beam loss at the beginning of acceleration.
- Signal saturation at 1.2 MV/m.
- Undershoot after 12 ms at 1.2 MV/m.

<u>Integrate from 3 ms to 12 ms.</u>

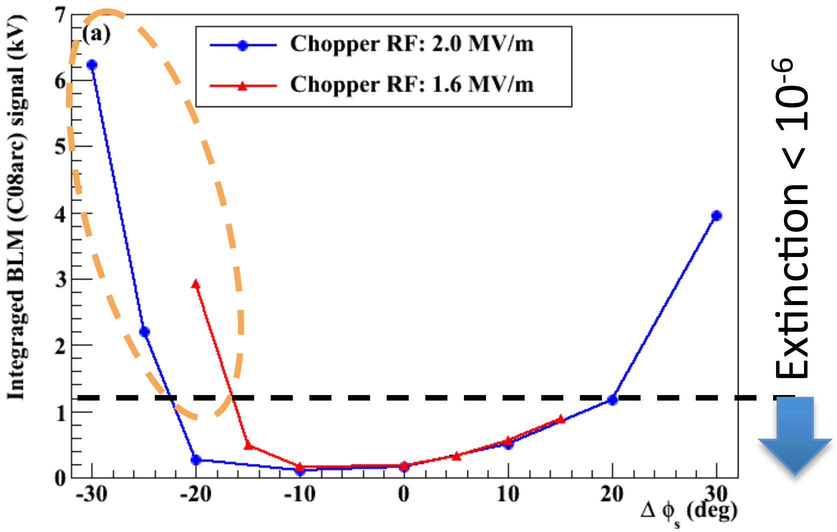
RF Phase Scan Result

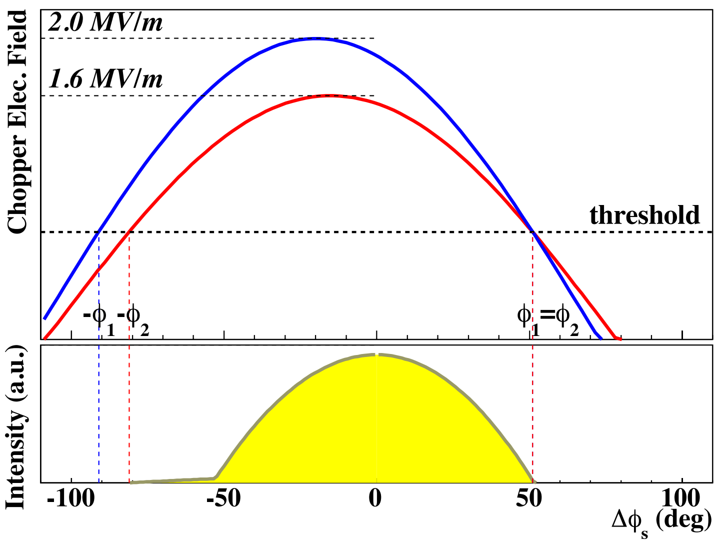


- RF amplitude: 2.0 and 1.6 MV/m.
- $\Delta\phi_s$ = 0 to +20:Gradually increase.
  - beam halo distributes in negative phase.
- Outside of 20 deg in 2.0 MV/m, $\Delta\phi_s < -15$ in 1.6 MV/m: rapid increase.
  - Edge of effective region reach to beam tail.
  - Phase margin is about +/- 20 deg.

Beam Size

Evaluate the longitudinal beam size from the phase and amp. scan result.





- Beam tail (fraction > 10^{-6}) is near to the edge of effective region at
  - 2.0 MV/m, -20 deg
  - 1.6 MV/m, -15 deg
- Threshold is same for 2.0 and 1.6 MV/m, intersection point is equivalent to threshold.
- beam width ($\delta\phi$) satisfies the equation,

$$2.0\cos(-20+\delta\phi) = 1.6\cos(-15+\delta\phi)$$

- The $\delta\phi$ is obtained to be 50 deg.

Summary

- We investigate beam profile in phase direction by using RF chopper system.
- The beam loss in RCS is sensitive to mischopped beam.
- We measure the beam loss in RCS with varying RF amplitude and driving phase.
- We performed RF phase scan to obtain the beam size:
  - Beam halo distributes in negative phase side
  - Beam width is obtained to be 50 deg.