Status of beam monitor in J-PARC Linac

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J-PARC Center

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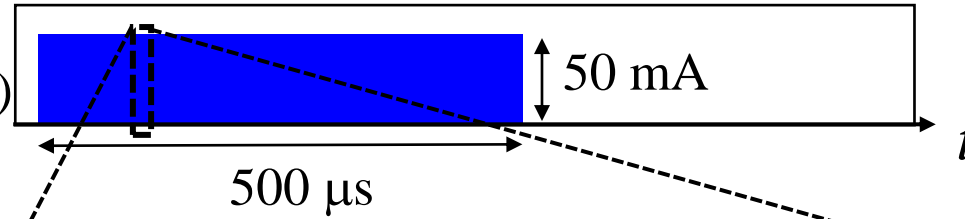
Outline

- Overview of beam monitor in J-PARC Linac

- Diagnosis of beam anomaly

- Beam monitor under development

- Summary
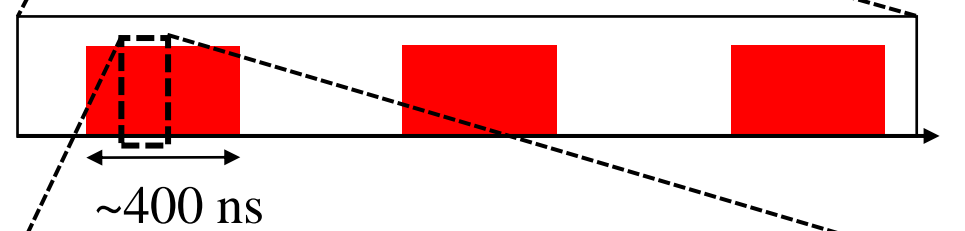
Beam Pulse Structure in J-PARC Linac
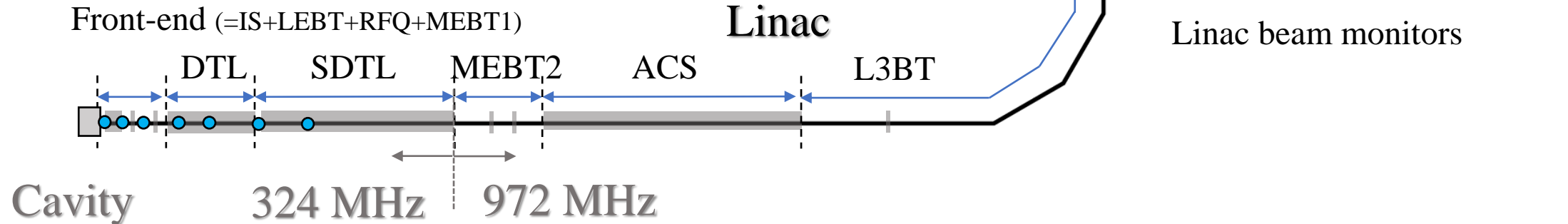

Macro pulse
(made by the Ion Source)

50 mA

500 μs

Intermediate pulse
(made by the choppers)

~400 ns

Micro pulse
(made by the RFQ)

~3 ns

Charge Stripping Foil

3 GeV synchrotron (RCS)

1.2~1.4 MHz

Front-end (=IS+LEBT+RFQ+MEBT1)

Linac

Linac beam monitors

DTL   SDTL   MEBT2   ACS   L3BT

Cavity   324 MHz   972 MHz
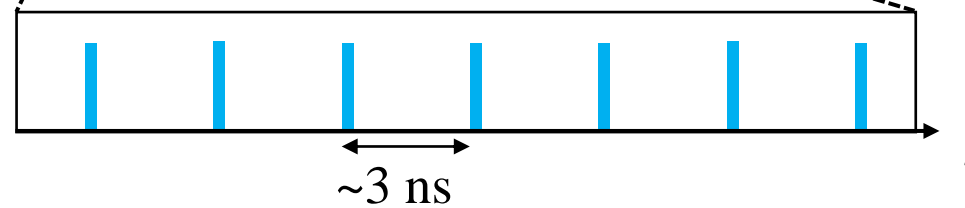
List of Beam Monitors

	Invasive monitor
	Non-invasive monitor

| Beam parameter	J-PARC Linac	ESS
Beam current	SCT	BCM, FC
Centroid position (Trans.)	BPM	BPM
Centroid position (Long.)	FCT	BPM, FC
Profile (Trans.)	WSM	WS, EMU, NPM, IPM
Profile (Long.)	BSM	BSM, LBPM
Beam loss	BLM	BLM

A non-destructive profile monitors are currently under development at J-PARC Linac.
I will introduce the developing monitors at the end of this presentation.

SCT: Slow Current Transfer, FCT: Fast Current Transfer

SCT : Beam current monitor

FCT : Beam phase monitor

Energy measurement using two FCTs (Time of Fright Method)
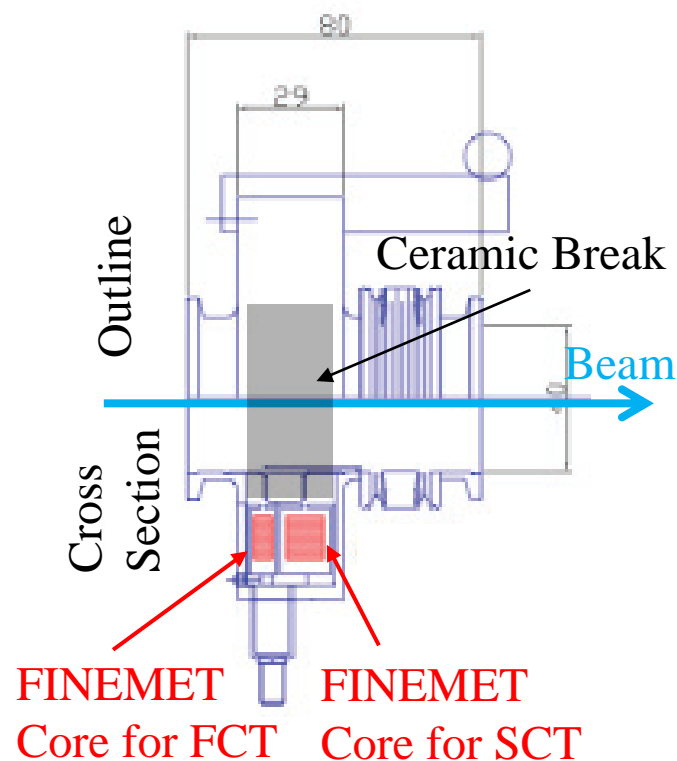
Annular magnet core "FINEMET" is employed for the current transformer.

	SCT	FCT
Dynamic Range	0.1 - 80 mA	> 30 dB
Resolution	0.1 mA	1 deg.
Winding Coil	50 turns	1 turn

BLM: Beam Loss Monitor

BLM

Gas Proportional BLM, E6876-600
Canon Electron Tubes & Devices Co., Ltd.

Length	600 mm
Diameter	50.8 mm
Enclosed Gas	Ar and additive gas
Gas Pressure	Approx. 1 atm

Realization of a microsecond response time makes it ideal for machine protection systems. (Taken from the website)

Abnormality detection is determined from signal peak value.
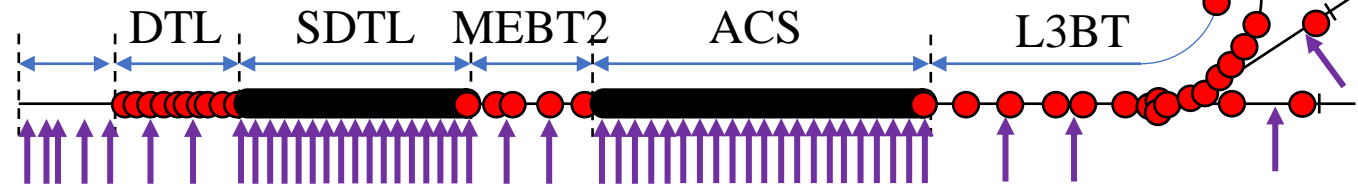The integral value of the BLM signal is recorded as a trend.

Monitor Location (SCT, BLM)

Monitor		MEBT1	DTL	SDTL	MEBT2	ACS	L3BT
SCT	↑	5	3	16	2	21	6
BLM	●	0	10	21	3	21	39

SCT : Beam current

BLM : Beam loss

3 GeV synchrotron (RCS)

Front-end (=IS+LEBT+RFQ+MEBT1)

DTL   SDTL   MEBT2   ACS   L3BT

SCT and BLM are installed everywhere.

Monitor Location (FCT)

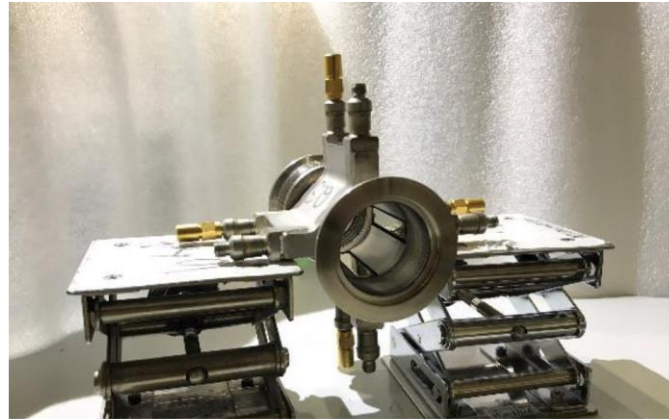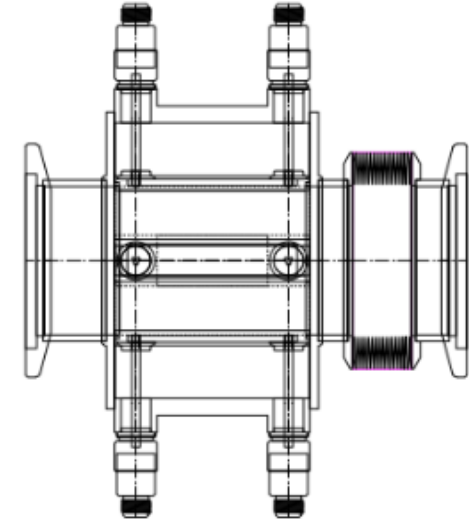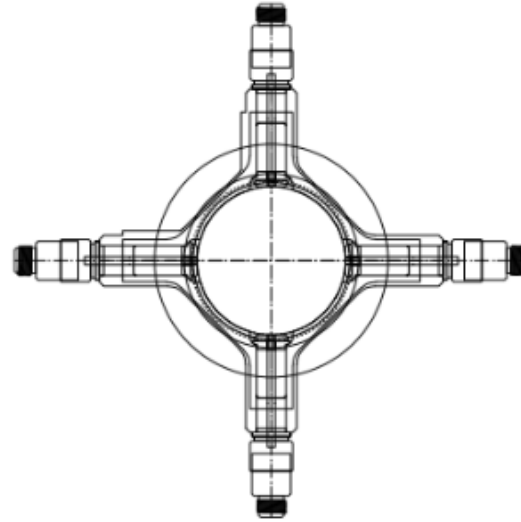| Monitor	MEBT1	DTL	SDTL	MEBT2	ACS	L3BT
FCT ◆	5	3	47	6	21	7

FCT : Beam position (Long.)
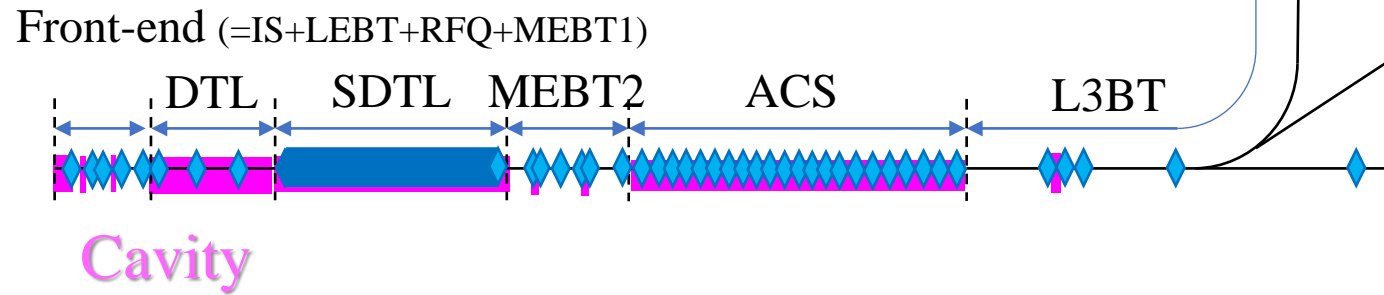
Each FCT is located downstream of each cavity.
These monitors are used only during beam tuning and are rarely used during user operation.

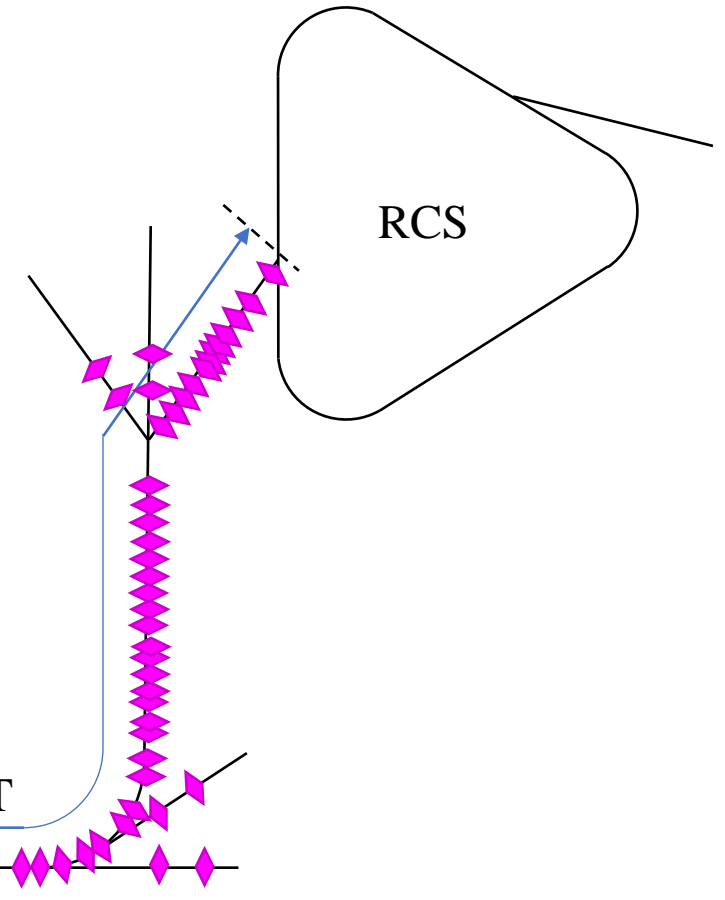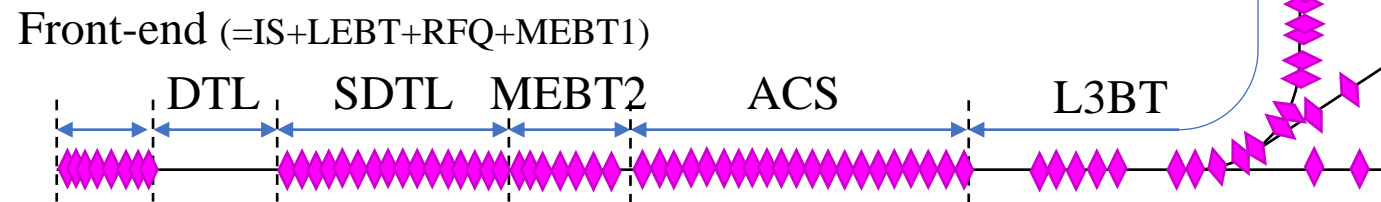# BPM: Beam Position Monitor (Transverse Centroid)

Strip-line type is employed.

Resolution < 0.1 mm

Monitor Location (BPM)

Monitor	MEBT1	DTL	SDTL	MEBT2	ACS	L3BT
BPM ♦	8	0	32	6	21	20

BPM : Beam position (Trans.)

Front-end (=IS+LEBT+RFQ+MEBT1)
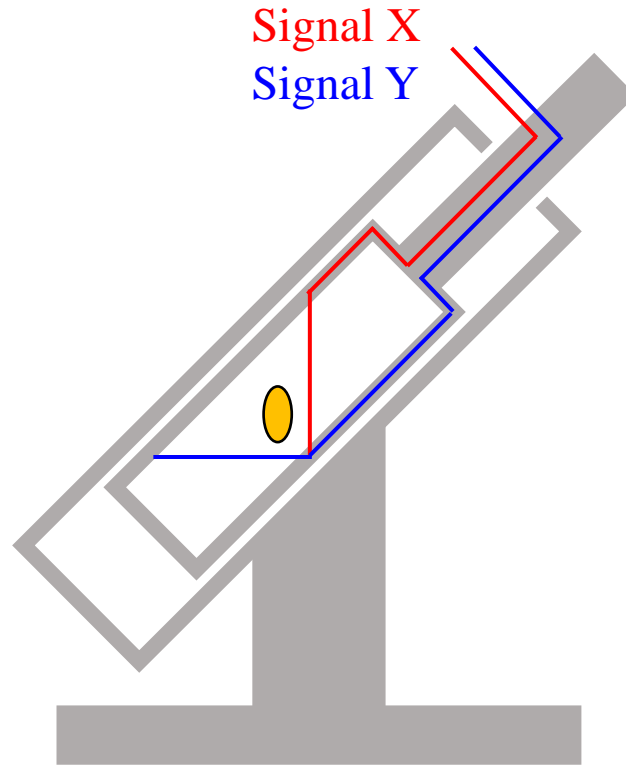
DTL   SDTL   MEBT2   ACS   L3BT

RCS

It is installed in various locations, but no BPM is installed in the DTL section at all.
In DTL section, there is no space for a monitor because the DTQ is installed in the Drift Tube.

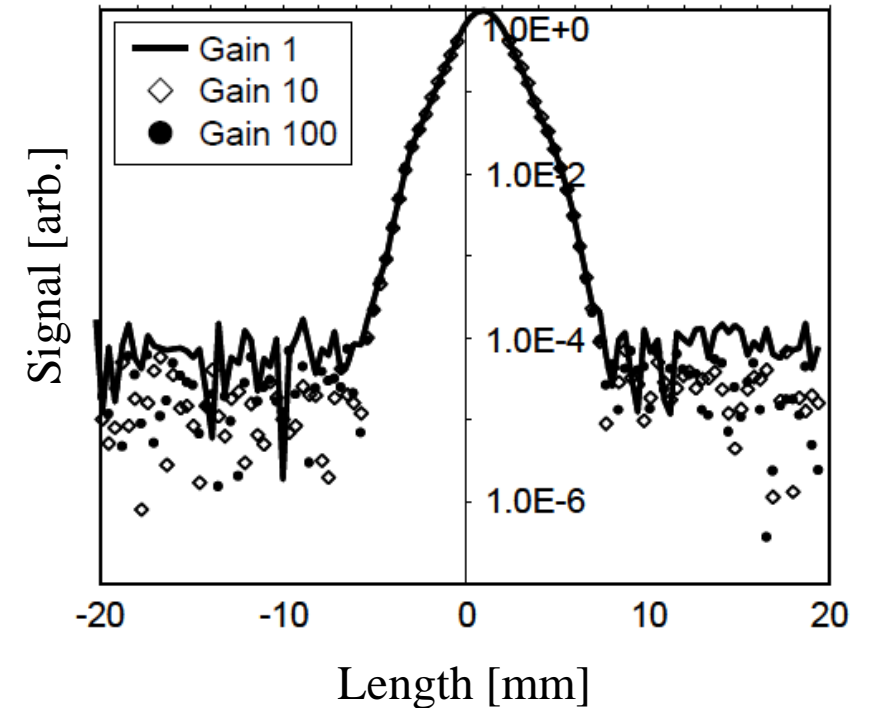# WSM: Wire Scanner Monitor (Transverse Profile)

Signal X
Signal Y
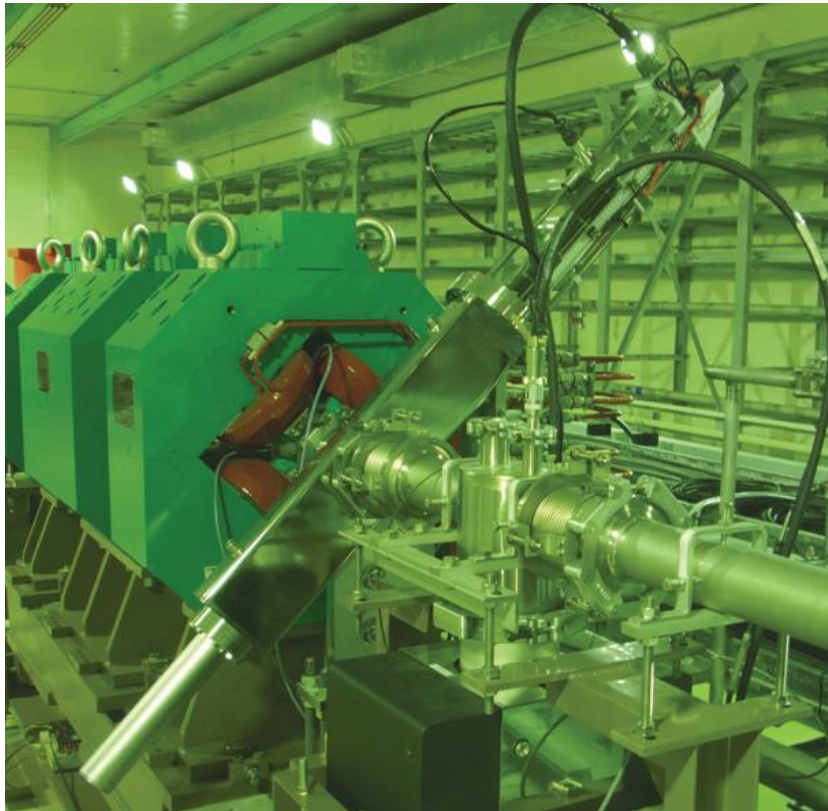
Beam conditions
during beam measurement
- Current 50 mA
- Pulse width 50 μs
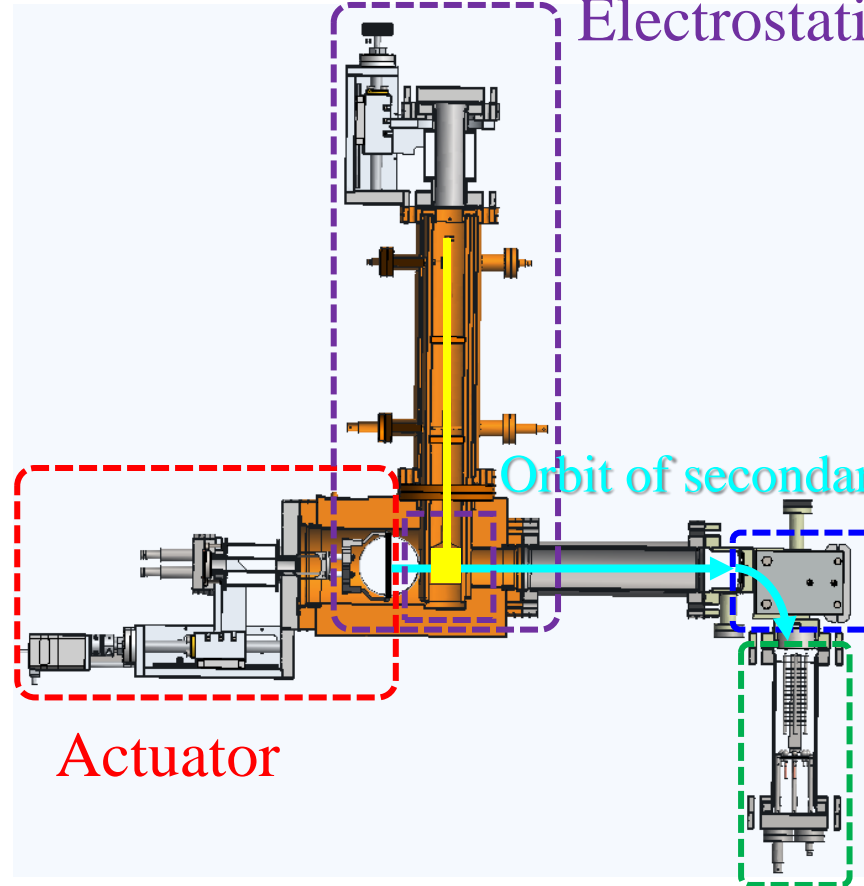
Wire material
- Tungsten (except 3 MeV beam)
- Carbon Nanotune (3 MeV beam)
  product by Hitachi Zosen Corporation

Step size : < 0.1 mm

Dynamic Range: 10^4

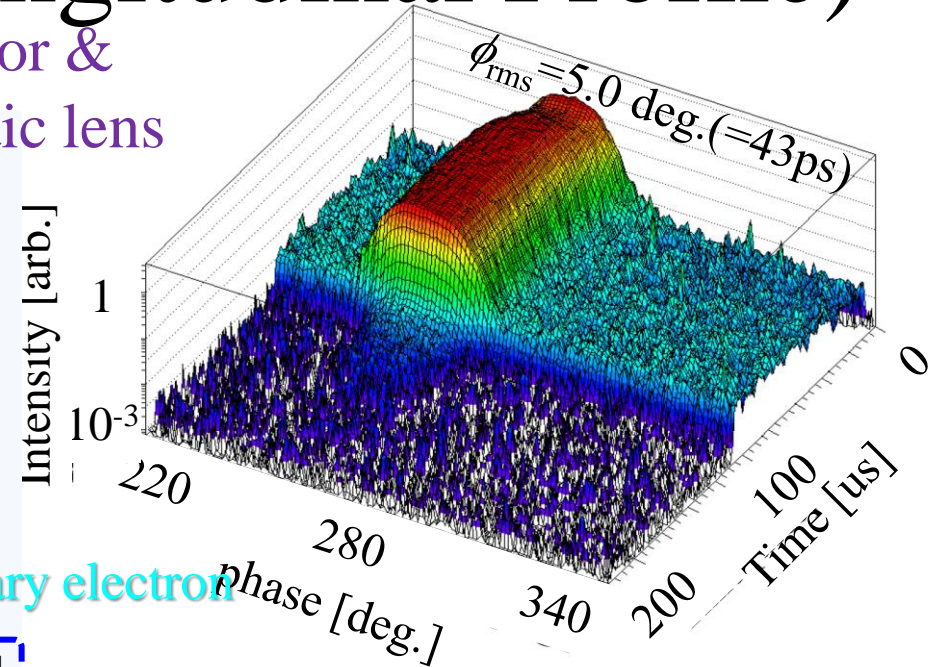# BSM: Bunch Shape Monitor (Longitudinal Profile)

RF deflector & Electrostatic lens

Orbit of secondary electron

Bending Magnet

Actuator

Detector (SEM)

$\phi_{rms} = 5.0$ deg.(=43ps)

Resolution : ~ 0.5 deg. ? (324 MHz)
Dynamic Range: 10^2

BSM: Bunch Shape Monitor (Longitudinal Profile) (cont.)

Monitor	MEBT1	DTL	SDTL	MEBT2	ACS	L3BT
WSM	4	0	4	2	4	22
BSM	1	0	0	1	(3)	1

WSM : Beam profile (Trans.)
BSM : Beam profile (Long.)

Profile monitors for RCS injection are not included.
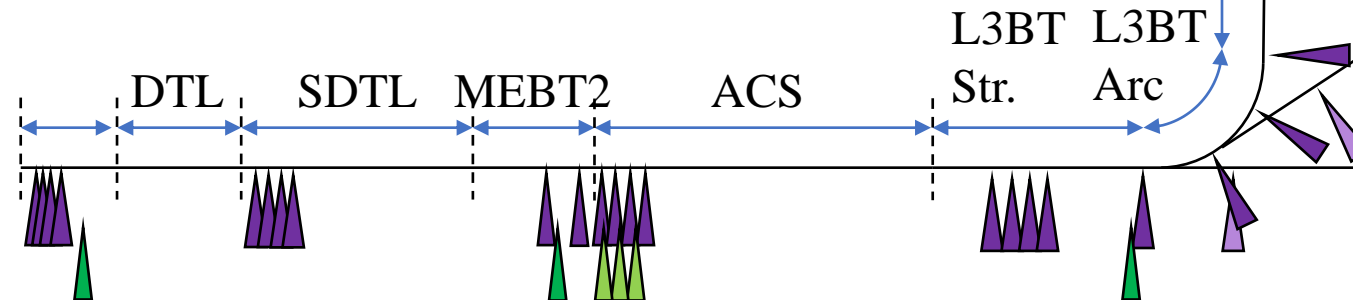
4 WSMs are installed each section.
We are adjusting the BSM to measure the longitudinal distribution at various sections.

Outline

- Overview of beam monitor in J-PARC Linac

- **Diagnosis of beam anomaly**

- Beam monitor under development

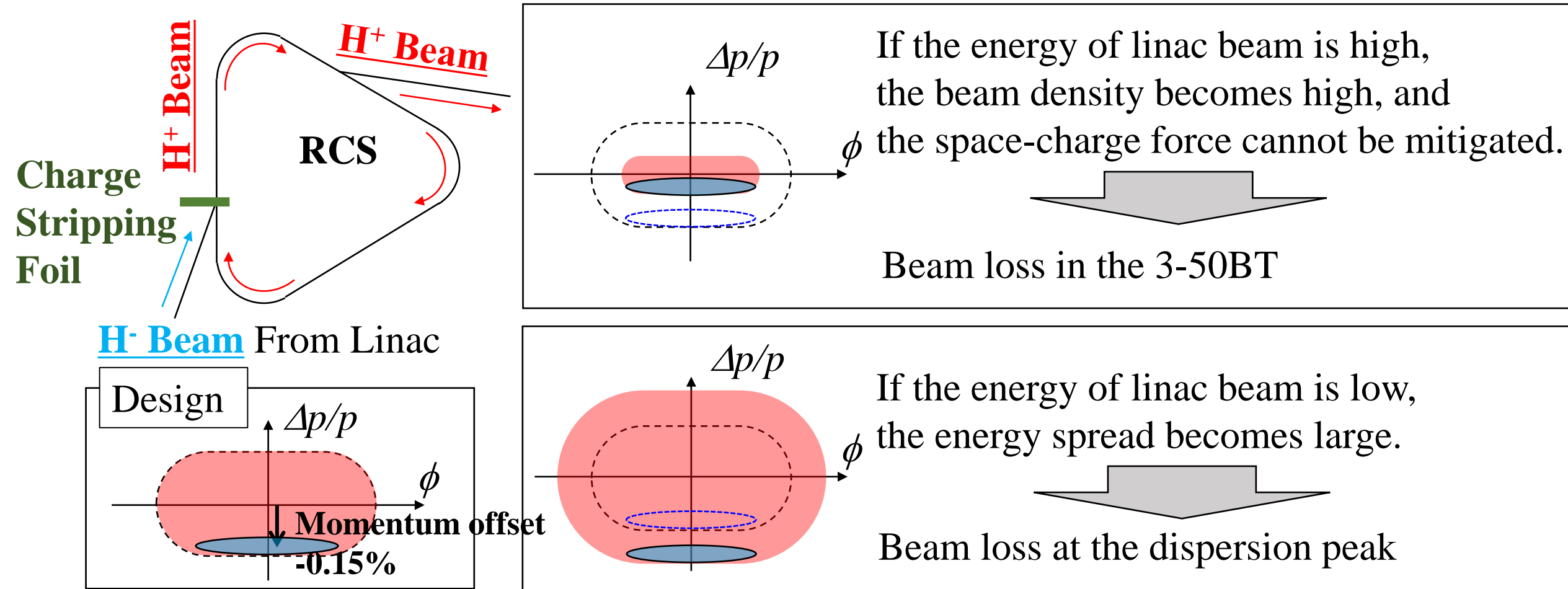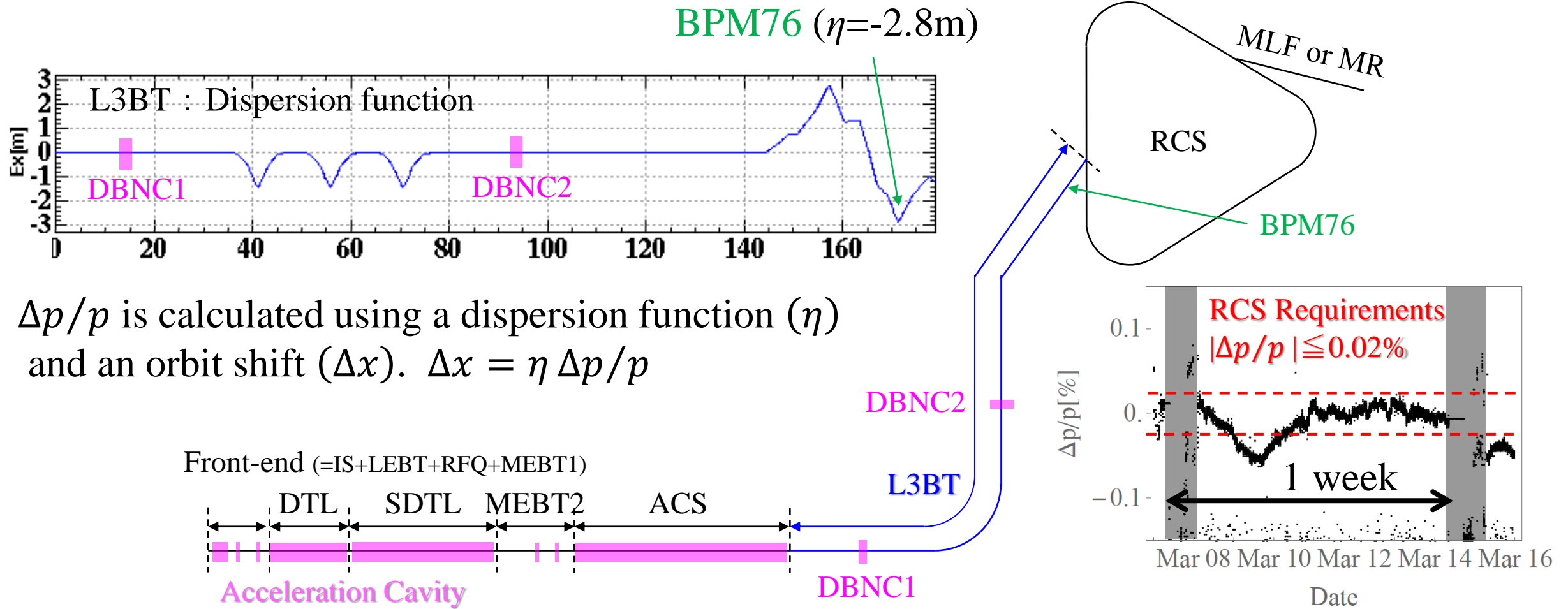- Summary

Injection Paining in J-PARC RCS

H⁺ Beam

H⁺ Beam

RCS

Charge Stripping Foil

H⁻ Beam From Linac

Design

$\Delta p/p$

ϕ

Momentum offset -0.15%

$\Delta p/p$

ϕ

If the energy of linac beam is high, the beam density becomes high, and the space-charge force cannot be mitigated.

Beam loss in the 3-50BT

$\Delta p/p$

ϕ

If the energy of linac beam is low, the energy spread becomes large.

Beam loss at the dispersion peak

The J-PARC RCS adopts the multiturn injection painting scheme to mitigate space-charge force. If we don't know what kind of beam is coming from the linac, this method can't work properly.
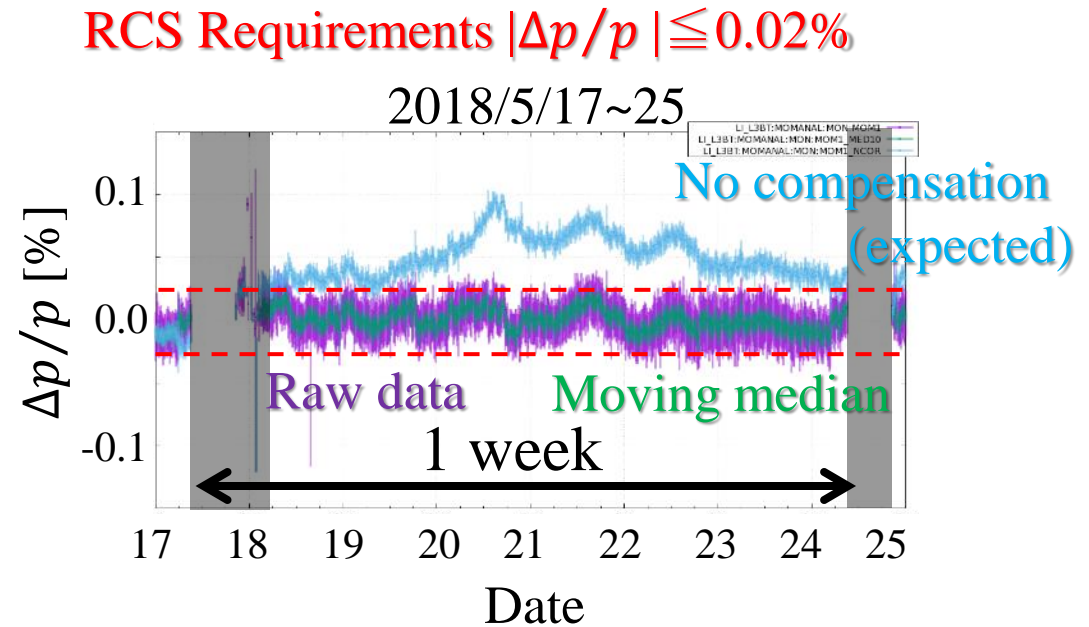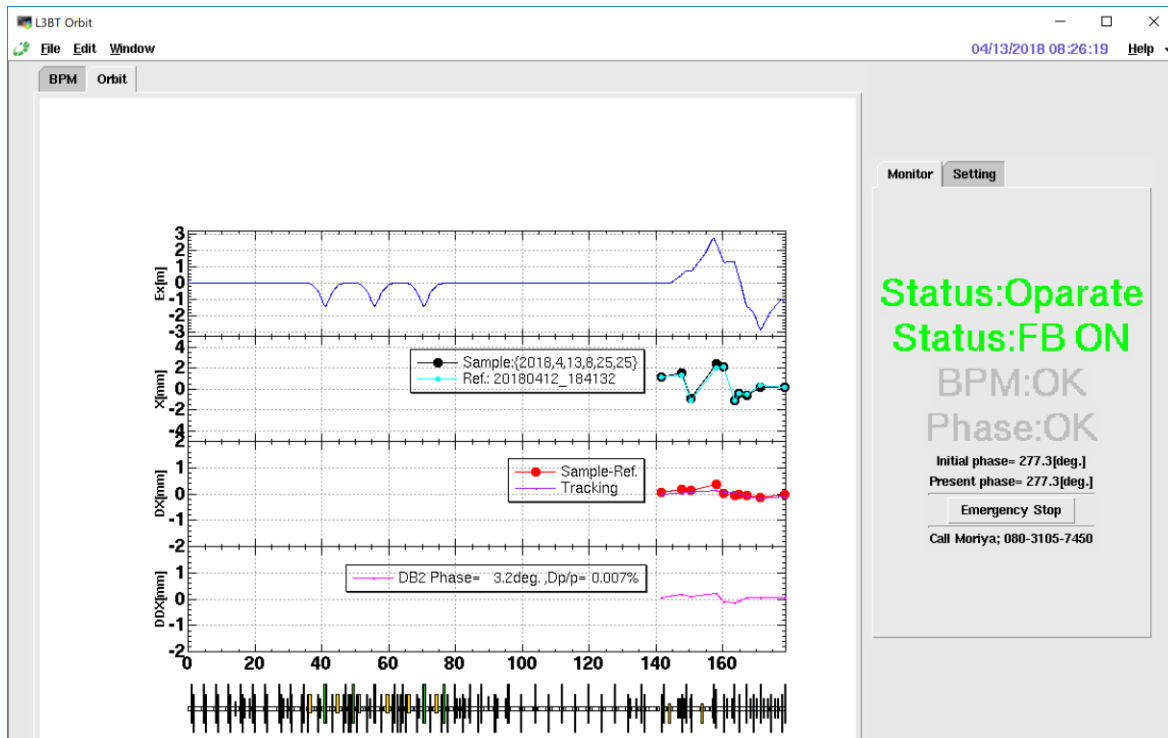
Energy Measurement of Linac Beam Extraction

BPM76 (η=-2.8m)

L3BT : Dispersion function

MLF or MR

RCS

BPM76

$\Delta p/p$ is calculated using a dispersion function (η)
and an orbit shift (Δx). $\Delta x = \eta \, \Delta p/p$

RCS Requirements
$|\Delta p/p| \leqq 0.02\%$

1 week

Mar 08 Mar 10 Mar 12 Mar 14 Mar 16
Date

DBNC2

L3BT

Front-end (=IS+LEBT+RFQ+MEBT1)

DTL   SDTL   MEBT2   ACS

Acceleration Cavity

DBNC1

To measure RCS-Injection beam-energy ($\Delta p/p$), we use BPMs in the L3BT.

Energy Compensation in Linac Beam Extraction

Energy measurement using 10 BPMs at dispersion area
Energy compensation using Cavity at the downstream end of the Linac

RCS Requirements $|\Delta p/p| \leqq 0.02\%$

2018/5/17~25

Energy compensation improves linac beam quality.

With the introduction of the correction, beam loss due to energy fluctuations has not occurred. Recently, the LLRF group has identified the cause and the energy keeps stable.
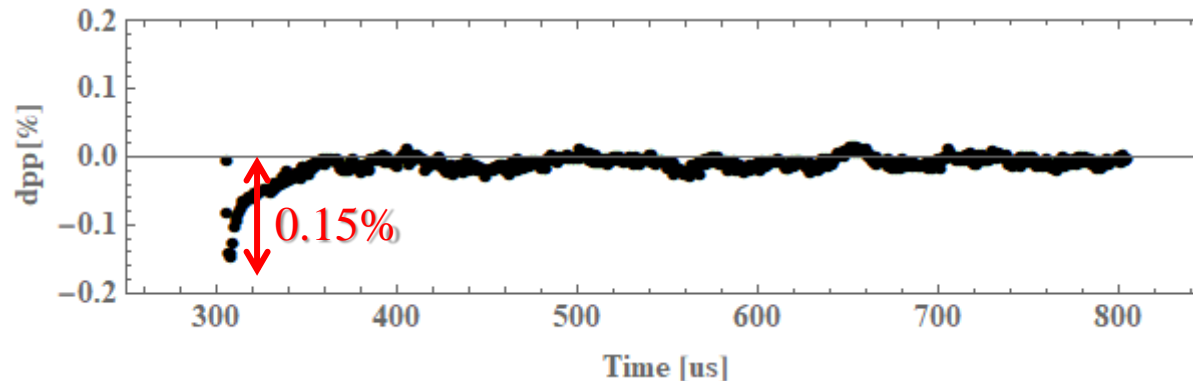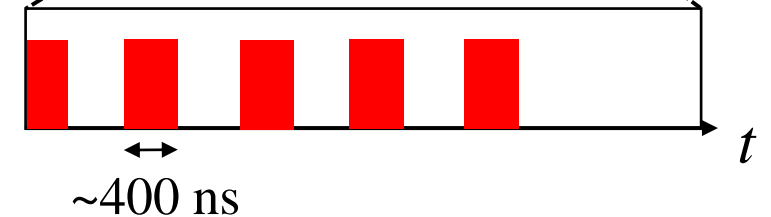
Energy Fluctuation in the macro bunch

Actually, previous J-PARC Linac beam monitors had only measured the last intermediate bunch.

Macro pulse
(made by the Ion Source)

50 mA

500 µs

Intermediate pulse
(made by the choppers)

~400 ns

0.15%
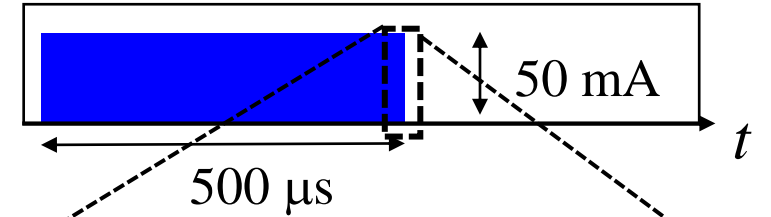
Measurement of all intermediate bunches using BPM at L3BT

FCT will also be utilized to investigate where anomalies occurred.

Beam monitor under development

<u>\<Invasive monitor \></u>
Bunch shape monitor for low energy measurement (R. Kitamura)

<u>\<Non-invasive monitor\></u>
Gas sheet monitor (I. Yamada)
Non-invasive bunch shape monitor (K. Moriya)
Laser diagnostics (H. Harada and P. K. Saha)

<u>\<Analysis\></u>
Calculation of beam parameters from BSM measurements (K. Moriya)

Summary

Beam parameter	J-PARC Linac	ESS
Beam current	SCT	BCM, FC
Centroid position (Trans.)	BPM	BPM
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Profile (Trans.)	WSM	WS, EMU, NPM, IPM
Profile (Long.)	BSM	BSM, LBPM
Beam loss	BLM	BLM

A non-destructive profile monitors are currently under development at J-PARC Linac.

Energy measurement and correction of the RCS injection beam were performed.
To improve beam quality during user operation, we will monitor the beam using not only BPM but also FCT.