



IBIC 2020

 RIKEN

Commissioning of the Beam Energy Position Monitoring System for the Superconducting RIKEN Heavy-Ion Linac

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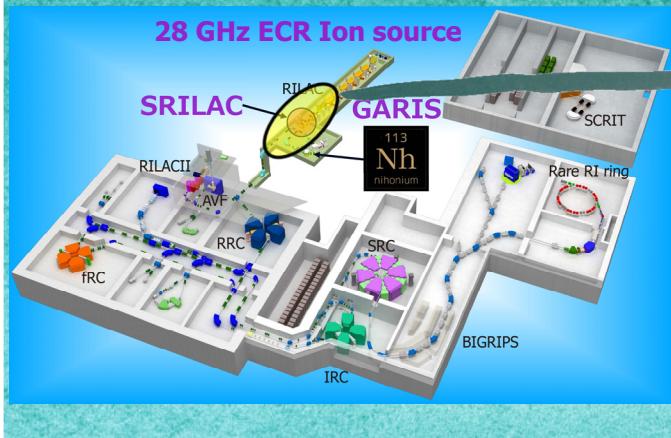
18 September 2020 Brazil

Previews

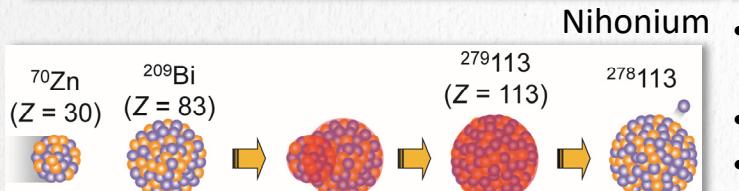
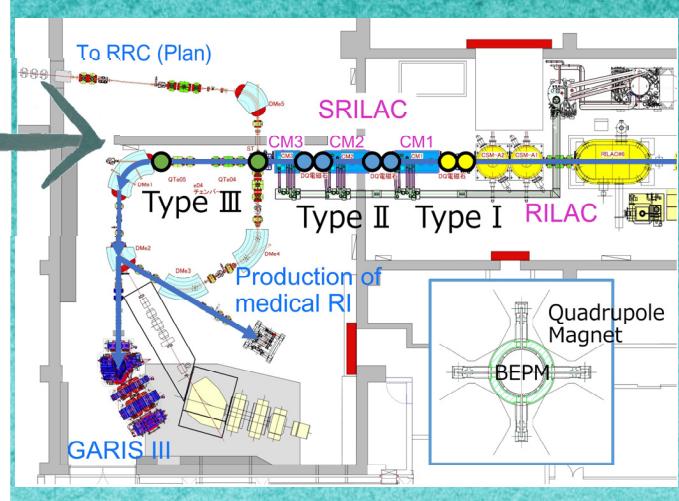
1. RI Beam Factory
2. Successful Beam Commissioning
3. BEPM System
4. BEPM Calibration (Mapping)
5. Commissioning
6. Conclusion

RI Beam Factory

- U beam up to 345 MeV/u in 2007
- Discovered new RI \rightarrow **176**



- Upgraded SRILAC

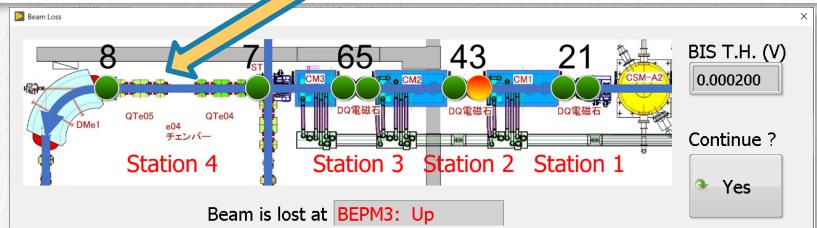
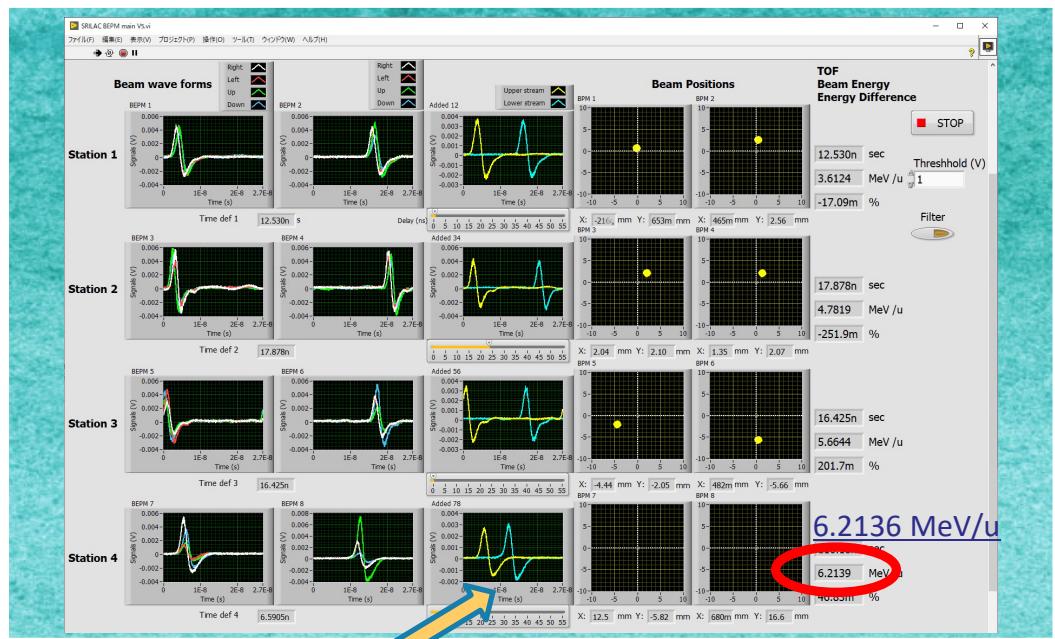


- It is crucial to monitor a **very weak beam** (**nA**) to accelerate it stably.
- Destructive monitors generate outgassing;
- → **X** Q value and surface resistance of the SRF cavities

$^{40}\text{Ar}^{13+}$ beam
(2020/01/28 21:02)

Successfully Accelerated !

Beam Current
20 enA



1. RI Beam Factory

2. Successful Beam Commissioning

3. BEPM System



Pickup Signal Analysis for SRILAC

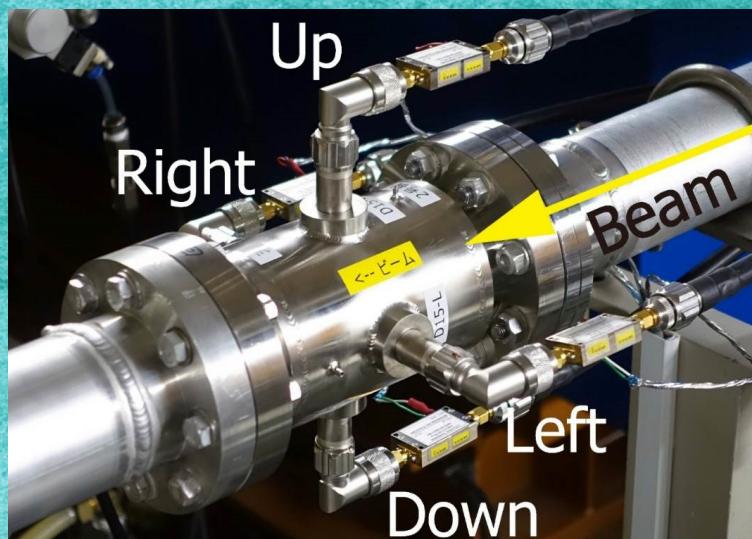
$^{51}V^{13}$ Beam
23

β 0.082

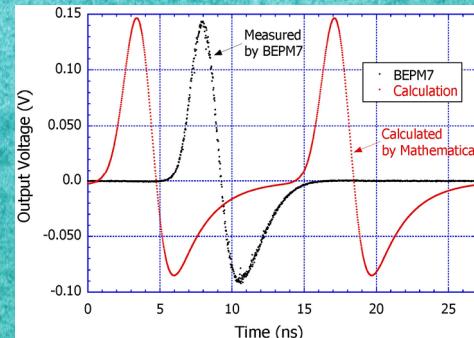
N 5.5×10^6 (2.5 p μ A)

σ 1.00 ns

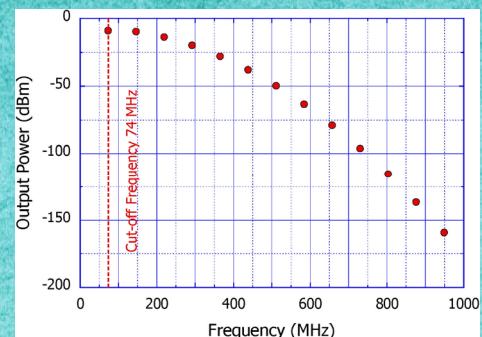
G 36.5 dB



Prototype BEPM
installed at the RIBF



Time domain

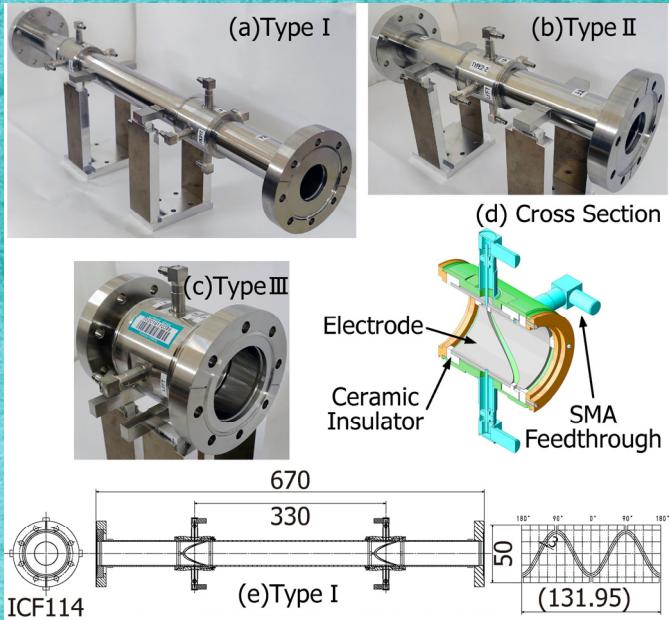


Frequency domain

- ISO class 1 clean room
- Blow-dried with an ionizing gun
- < 10 particles/s

- ISO class 1 clean room
- Blow-dried with an ionizing gun
- < 10 particles/s

3 Types of BEPM

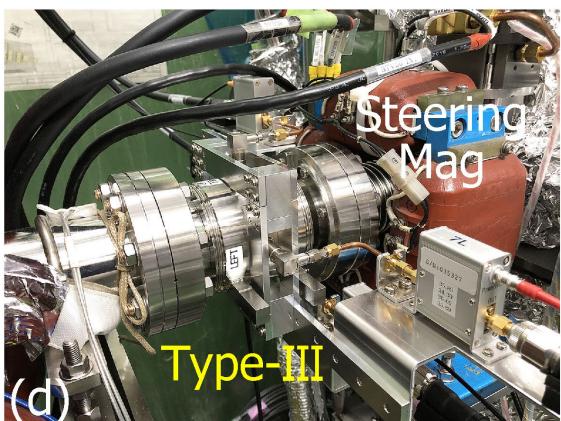
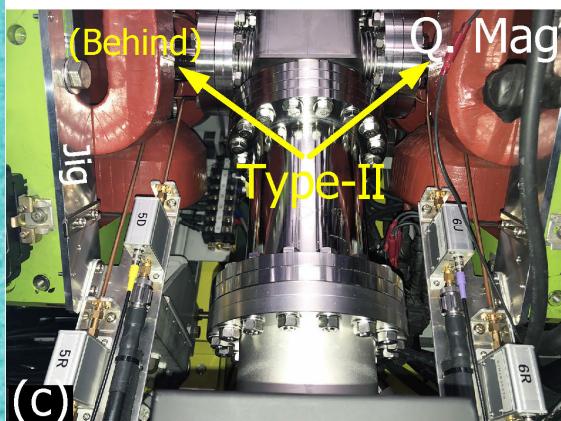
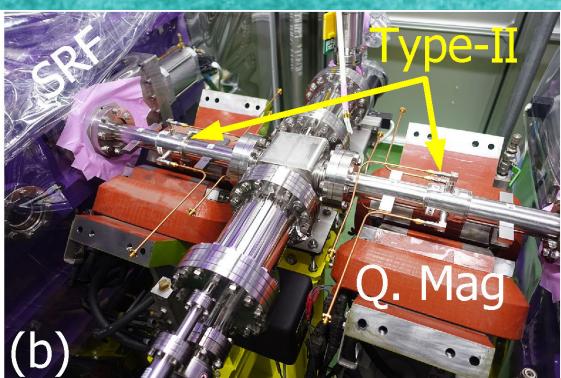
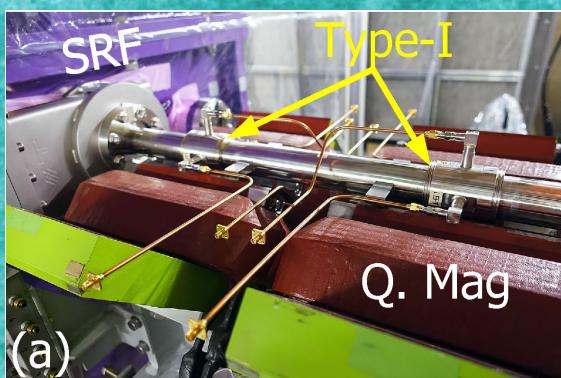


- Vacuum oven (70°C for 5 days)

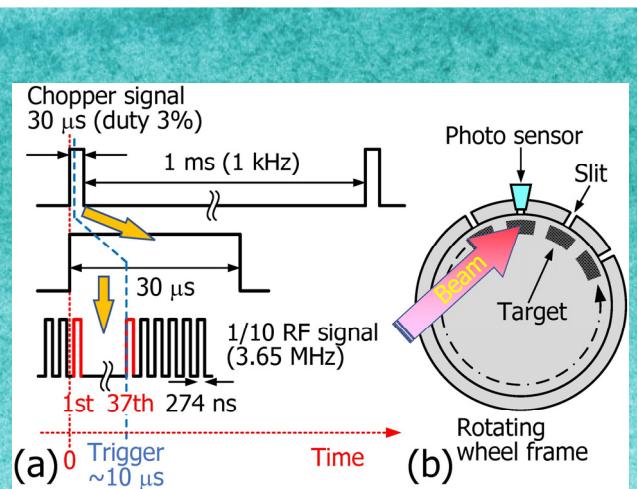
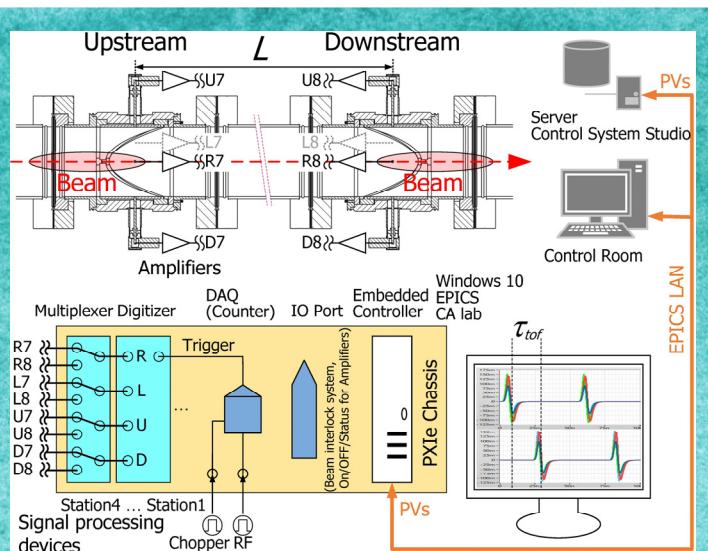
Installation

- (a),(b)
Before installation
• Center of the Q magnets

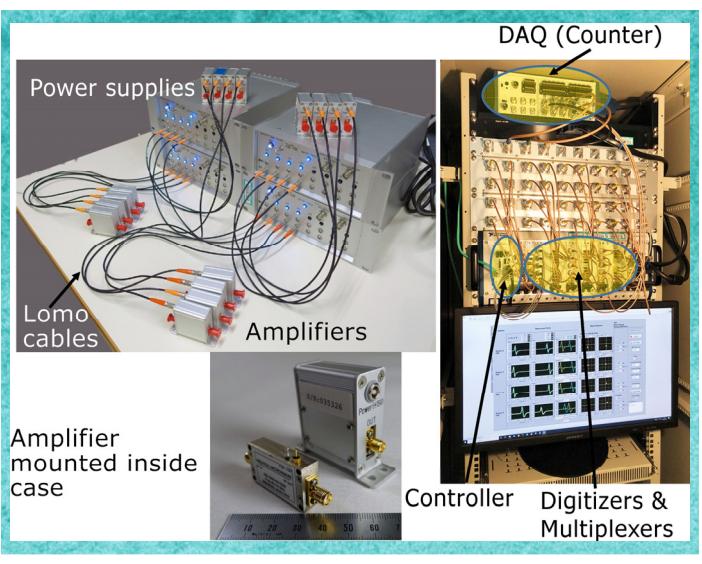
- (c),(d)
After installation



Block Diagram Synchronized Timing



Amplifiers & DAQ system



Amplifier	
Bandwidth	9 kHz - 3.0 GHz
Noise Figure	2.5dB typical
Gain	36.5 dB

Digitizer	
Bandwidth	DC - 500 MHz
Sampling rates (GS/s)	1.25, 50* (4 ch)
Resolution	10-bit
Transfer rates (GB/s)	0.6, 8(Controller), 4 (Chassis)

*(random interleave mode)

Noise figure

$$F = \frac{S_i/N_i}{S_o/N_o}$$

$$F_T = F_1 + \frac{F_2-1}{G_1} + \dots + \frac{F_n-1}{G_1 \cdot G_2 \cdots G_n}$$

} Improvement **35 dB/Hz**
Great advantage
for measurements of weak beams.

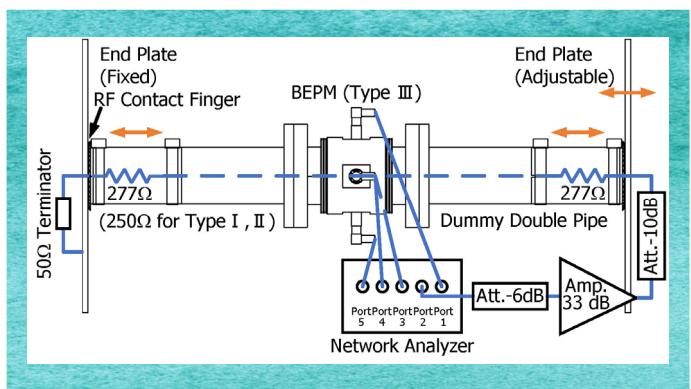
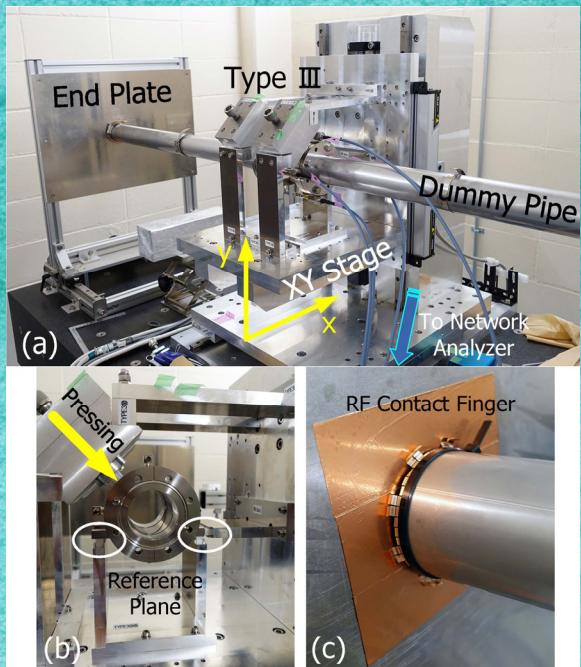
3. BEPM System

4. BEPM Calibration

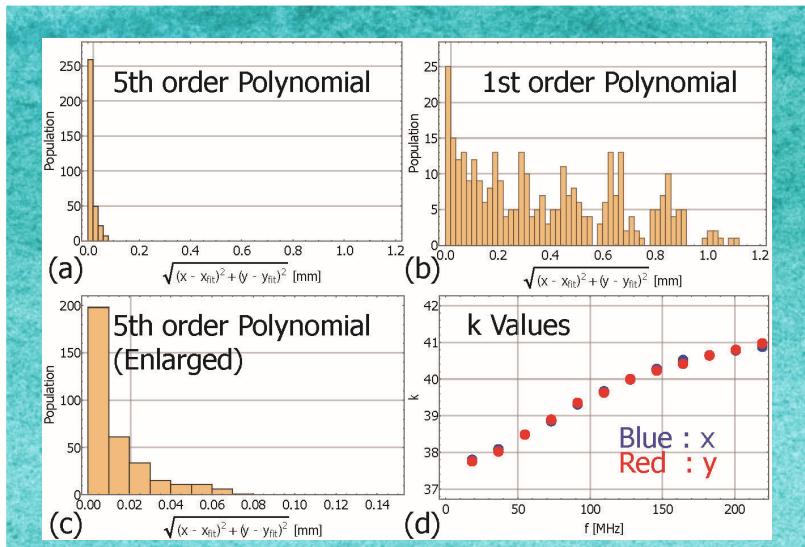
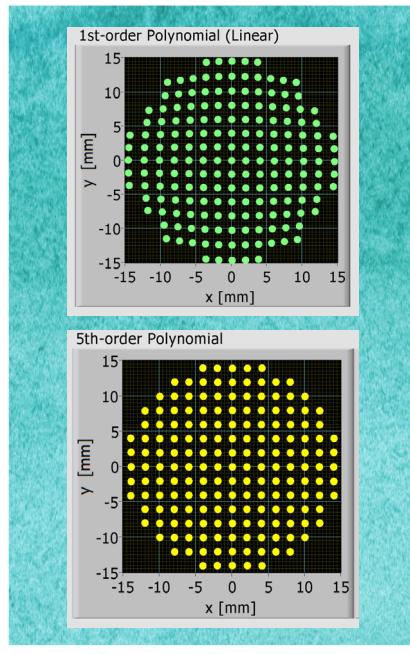
(Mapping)



BEPM Calibration (Mapping)



Hard Ware & Synchronized Timing



$$\frac{V_R - V_L}{V_R + V_L + V_U + V_D} = \frac{\Delta_x}{\Sigma} \cong f_x(x, y) \cong k_x x,$$

$$\frac{V_U - V_D}{V_R + V_L + V_U + V_D} = \frac{\Delta_y}{\Sigma} \cong f_y(x, y) \cong k_y x$$

Resolution of the beam position

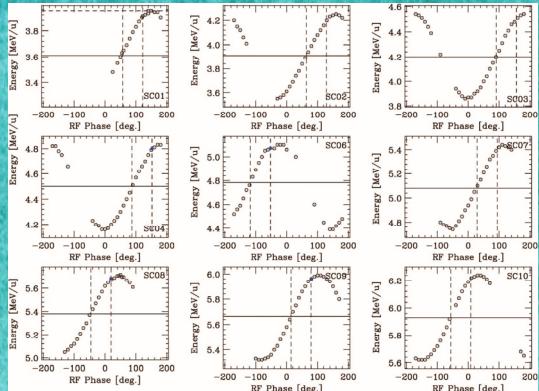
- 0.1 mm (Absolute)
- 0.003 mm (Relative)

4. BEPM Calibration (Mapping)

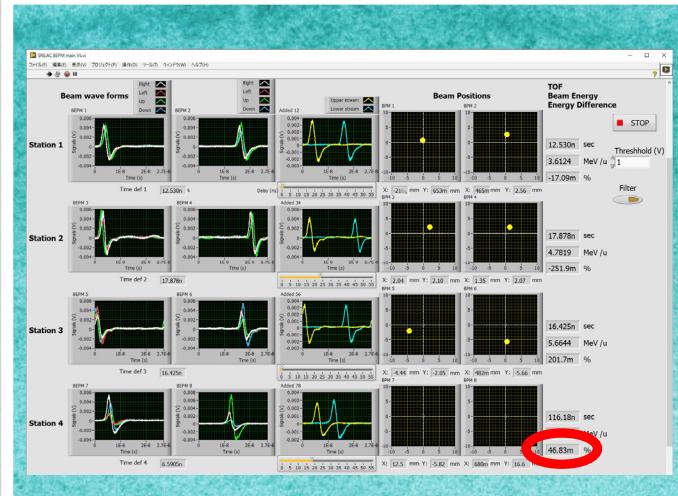
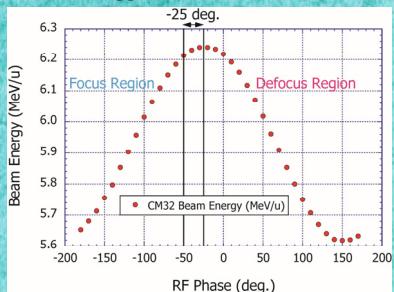
5. Commissioning



Commissioning I



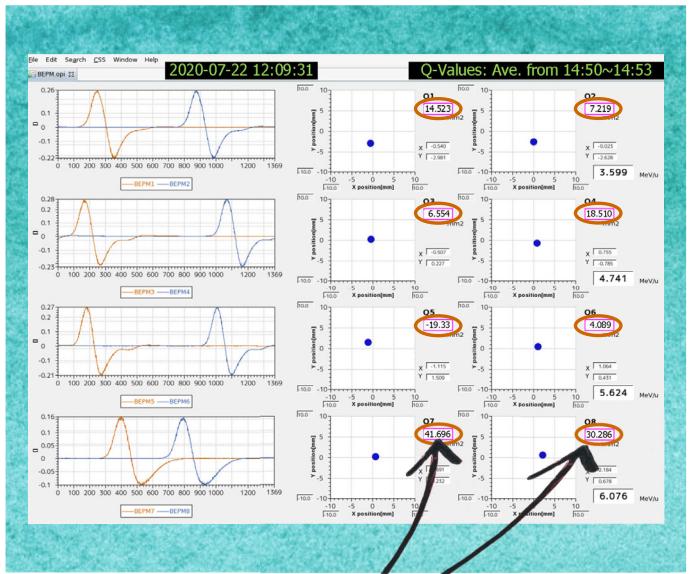
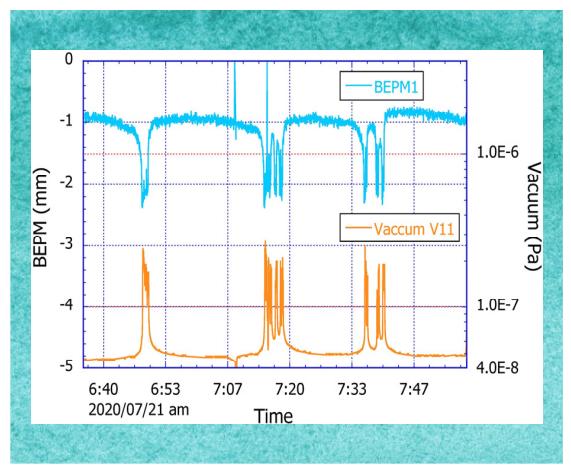
N. Sakamoto, Journal of Particle Accl. Society of Japan,
Vol. 17, No.2, 2020. pp. 70-79



- Electrical lengths of the 8 coaxial cable sets < 3 ps
(Totally 64 cables)
- Absolute resolution of the beam energy -> 5.1×10^{-4}

Commissioning II

Future Outlook



1. Quadrupole moments

$$Q = k_q \times \frac{(V_R + V_L) - (V_U + V_D)}{V_R + V_L + V_U + V_D} - \langle x^2 \rangle + \langle y^2 \rangle$$

2. Beam intensity from the bunched signal
3. TOF using a lock-in amp technique.

Conclusion

1. RI Beam Factory
2. Successful Beam Commissioning
3. BEPM System works well
4. BEPM Calibration (Mapping)
5. Commissioning

Thank you for
your kind attention!

