



IBIC 2020



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

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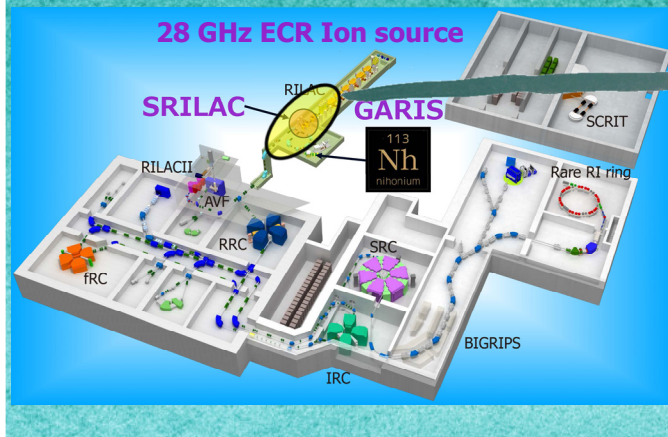
18 September 2020 Brazil

Previews

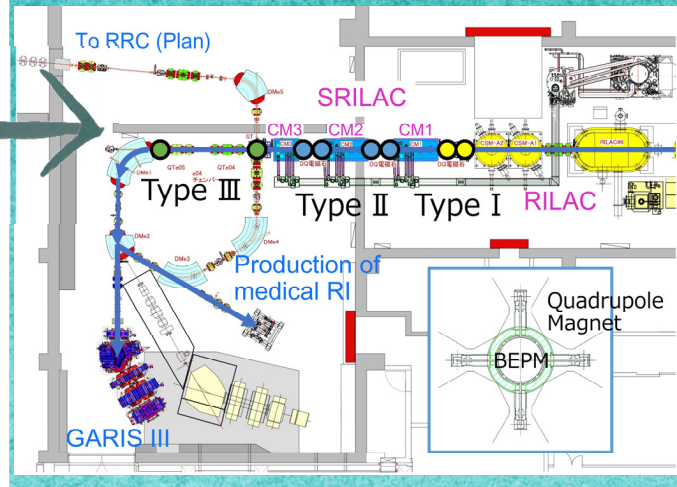
1. RI Beam Factory
2. Successful Beam Commissioning
3. BEPM System
4. BEPM Calibration (Mapping)
5. Commissioning
6. Conclusion

RI Beam Factory

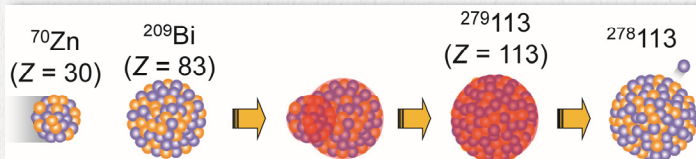
- U beam up to 345 MeV/u in 2007
- Discovered new RI -> **176**



- Upgraded SRILAC



Nihonium

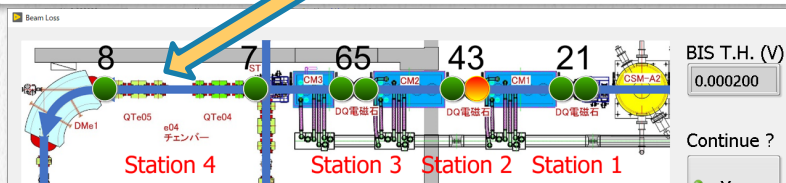
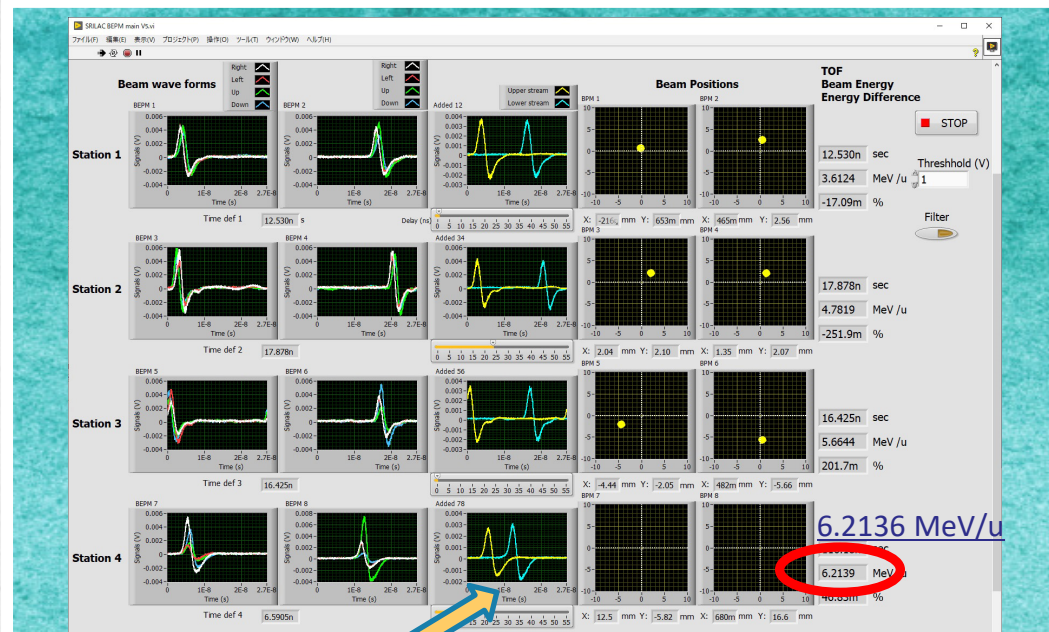


- It is crucial to monitor a **very weak beam (nA)** to accelerate it stably.
- Destructive monitors generate outgassing;
-  Q value and surface resistance of the SRF cavities

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

Successfully Accelerated !

Beam Current
20 enA



Beam is lost at **BEPM3: Up**

BIS T.H. (V)
0.000200

Continue ?

Yes

1. RI Beam Factory

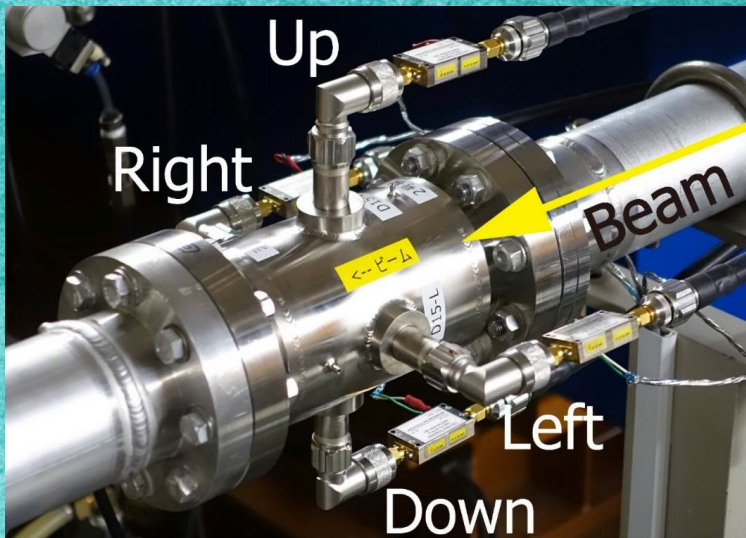
2. Successful Beam Commissioning

3. BEPM System

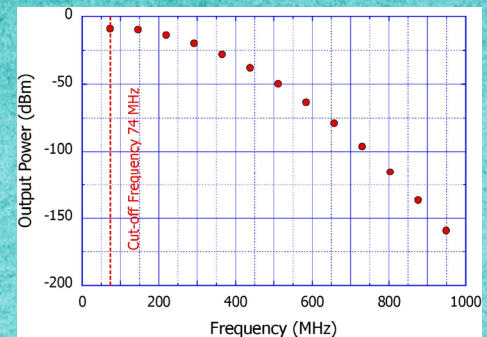
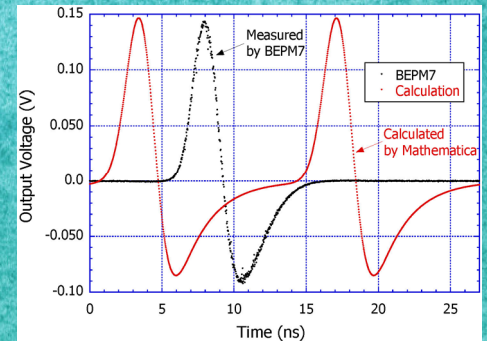


Pickup Signal Analysis for SRILAC

$^{51}_{23}\text{V}^{13}$ Beam	
β	0.082
N	5.5×10^6 (2.5 μA)
σ	1.00 ns
G	36.5 dB

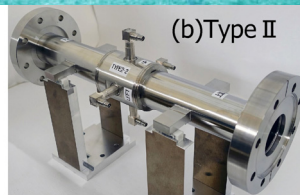
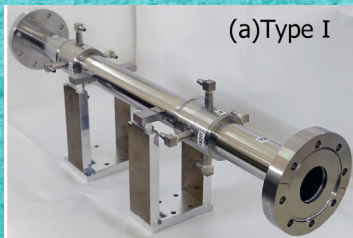


Prototype BEPM
installed at the RIBF

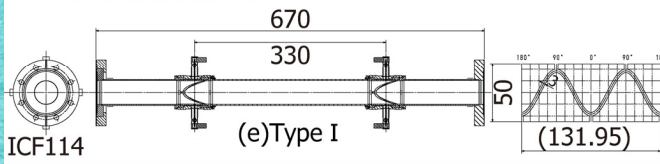
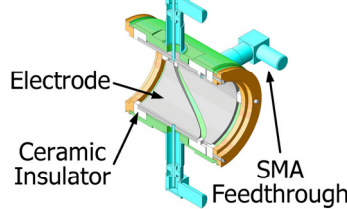
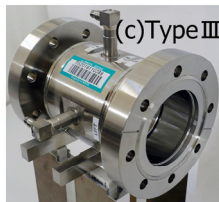


3 Types of BEPM

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



(d) Cross Section

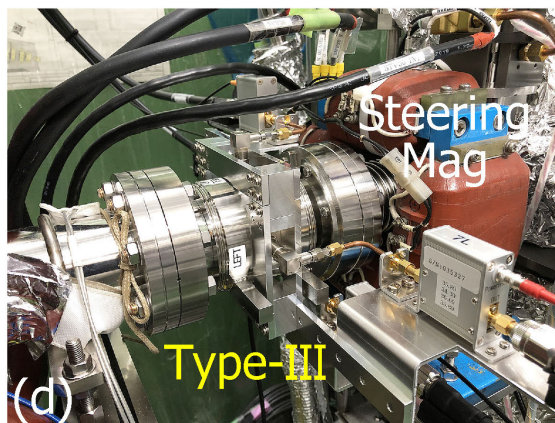
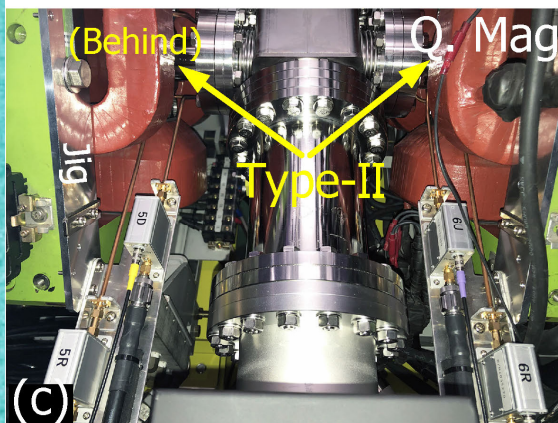
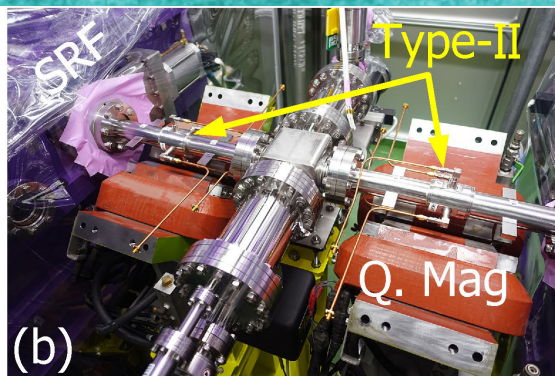
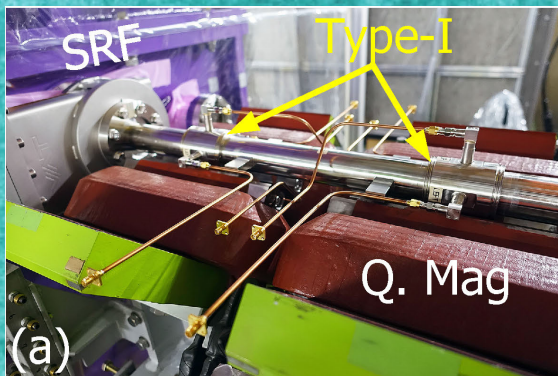


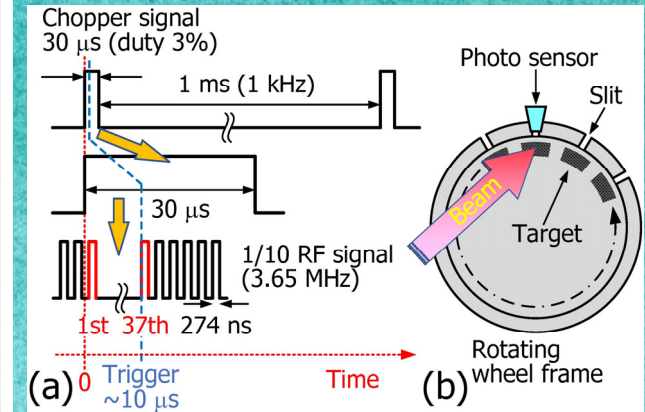
- Vacuum oven (70°C for 5 days)

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

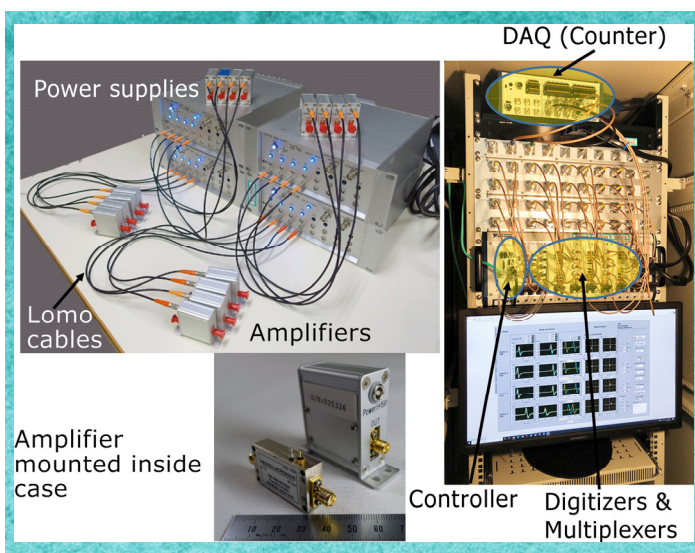
Installation

- (c),(d)
After installation





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

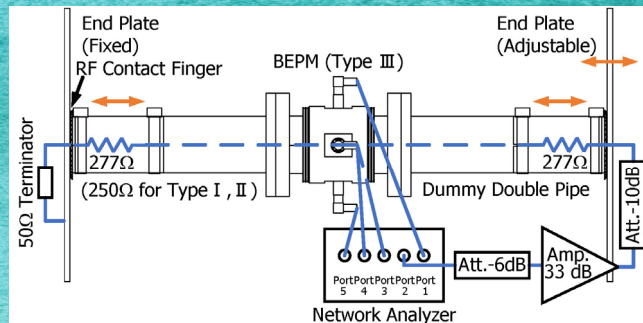
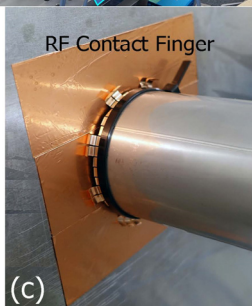
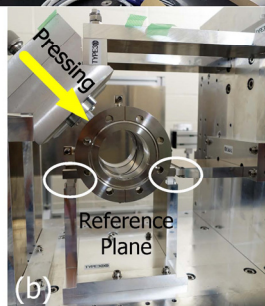
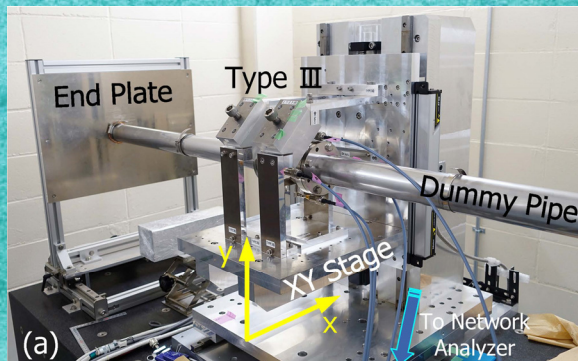
for measurements of weak beams.

3. BEPM System

4. BEPM Calibration (Mapping)

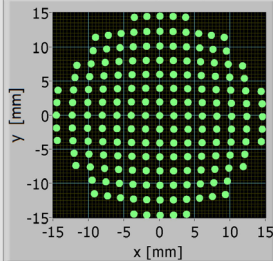


BEPM Calibration (Mapping)

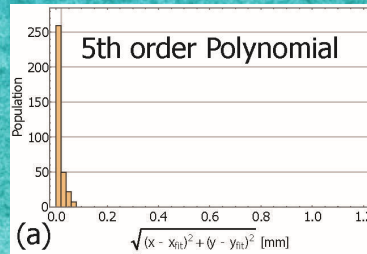
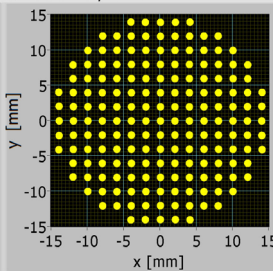


Hard Ware & Synchronized Timing

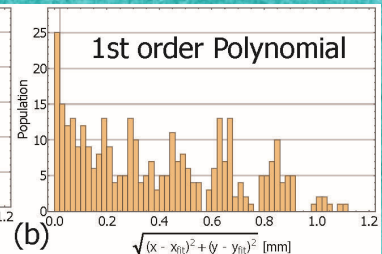
1st-order Polynomial (Linear)



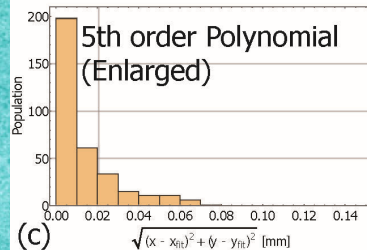
5th-order Polynomial



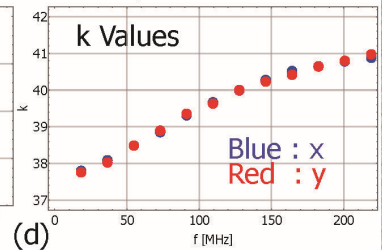
(a)



(b)



(c)



(d)

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

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

Resolution of the beam position

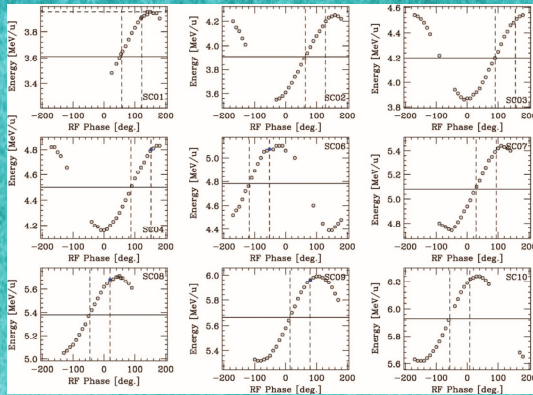
- 0.1 mm (Absolute)
- 0.003 mm (Relative)

4. BEPM Calibration (Mapping)

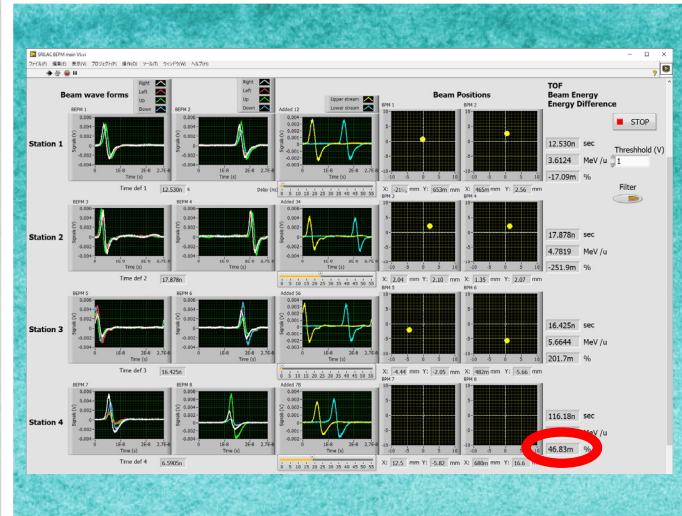
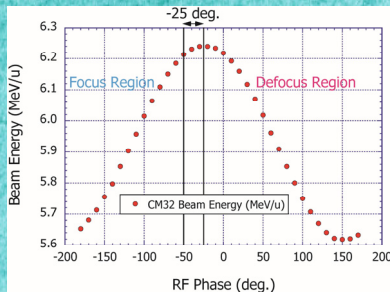
5. Commissioning



Commissioning I

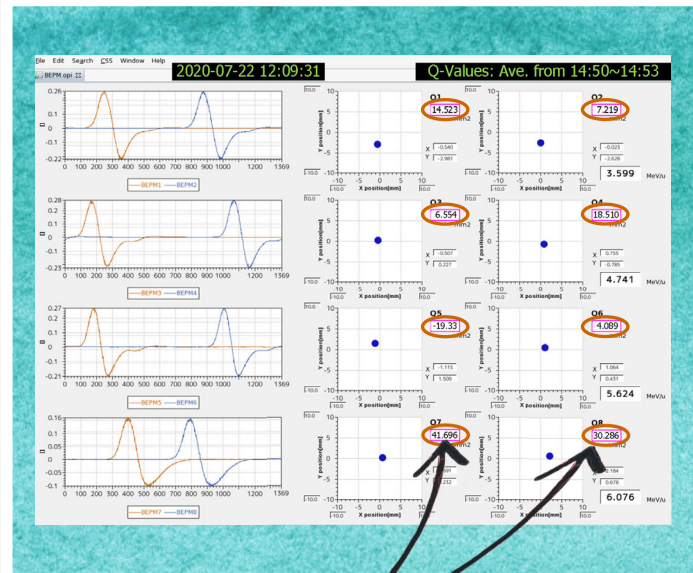
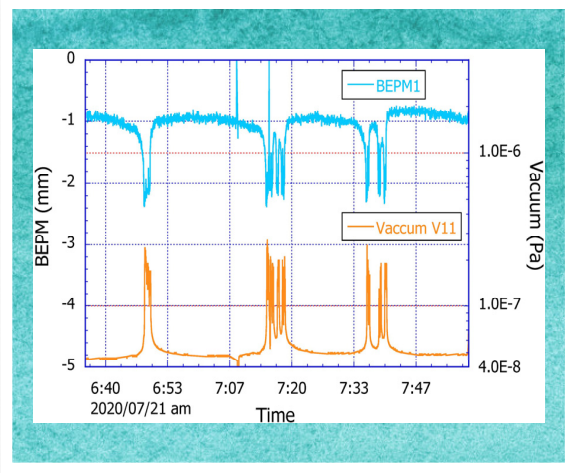


N. Sakamoto, Journal of Particle Accel. Society of Japan,
Vol. 17, No.2, 2020, pp. 70-79



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

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!

