

Emittance measurement of J-PARC RF ion source after 5-month continuous operation

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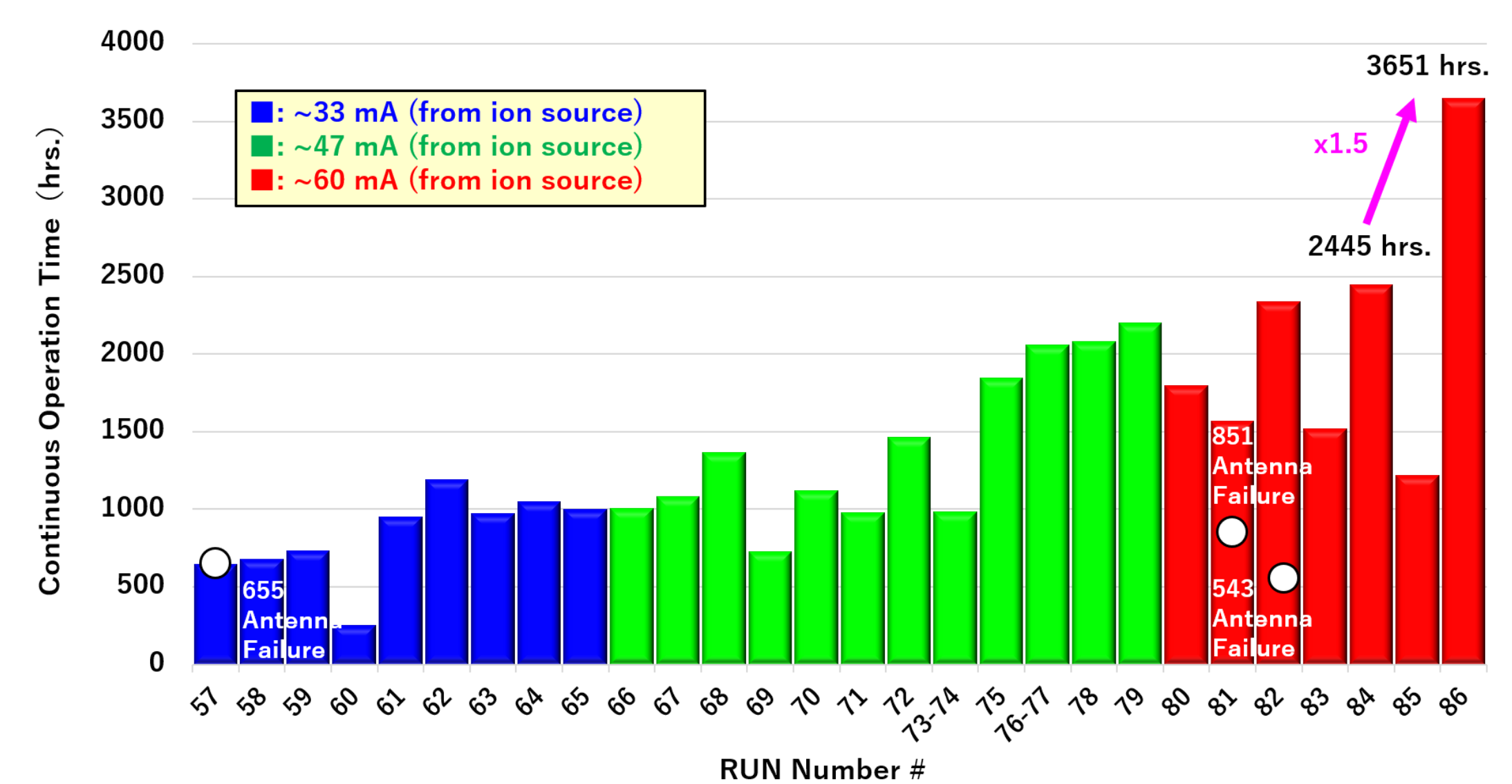
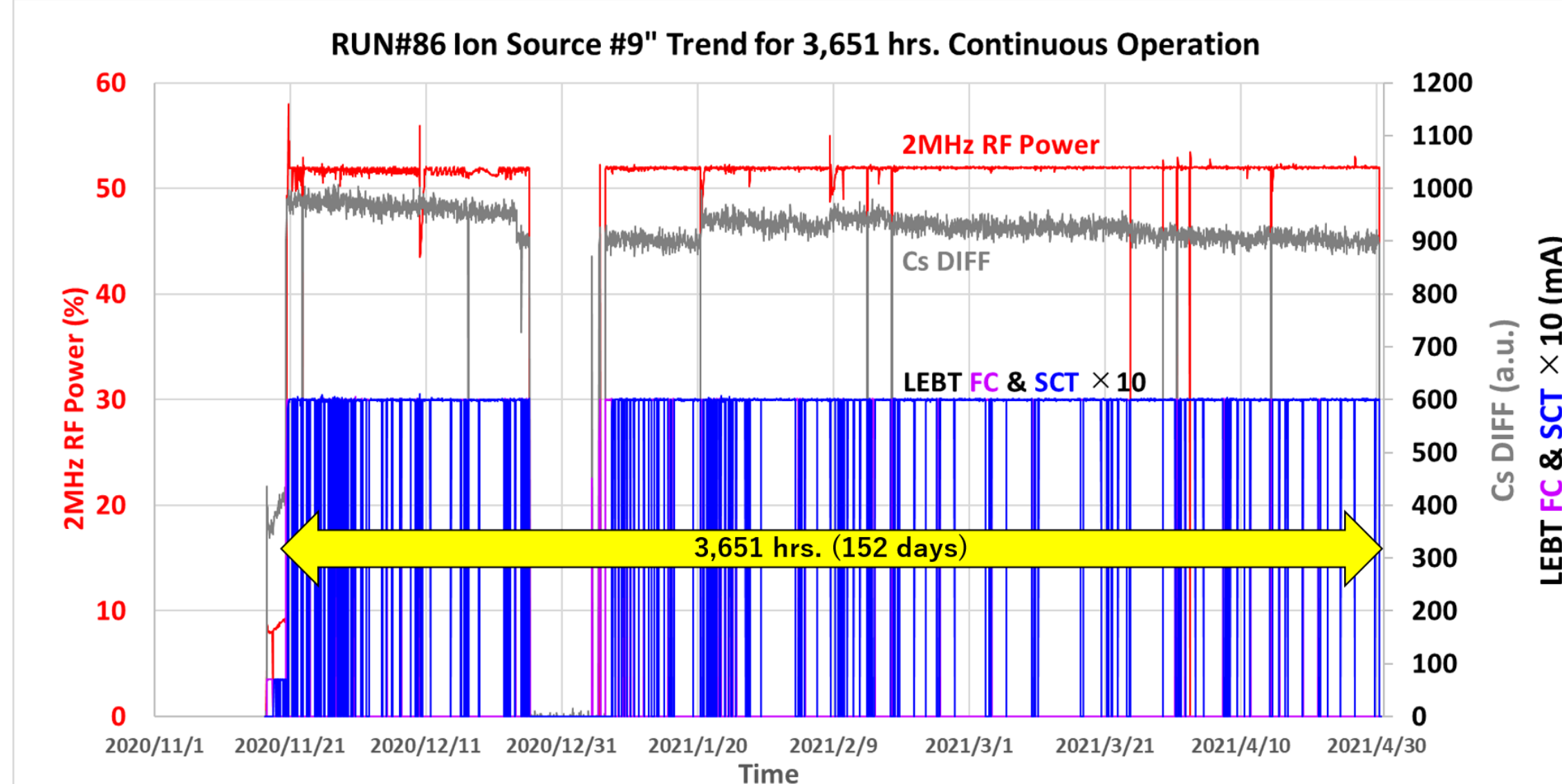
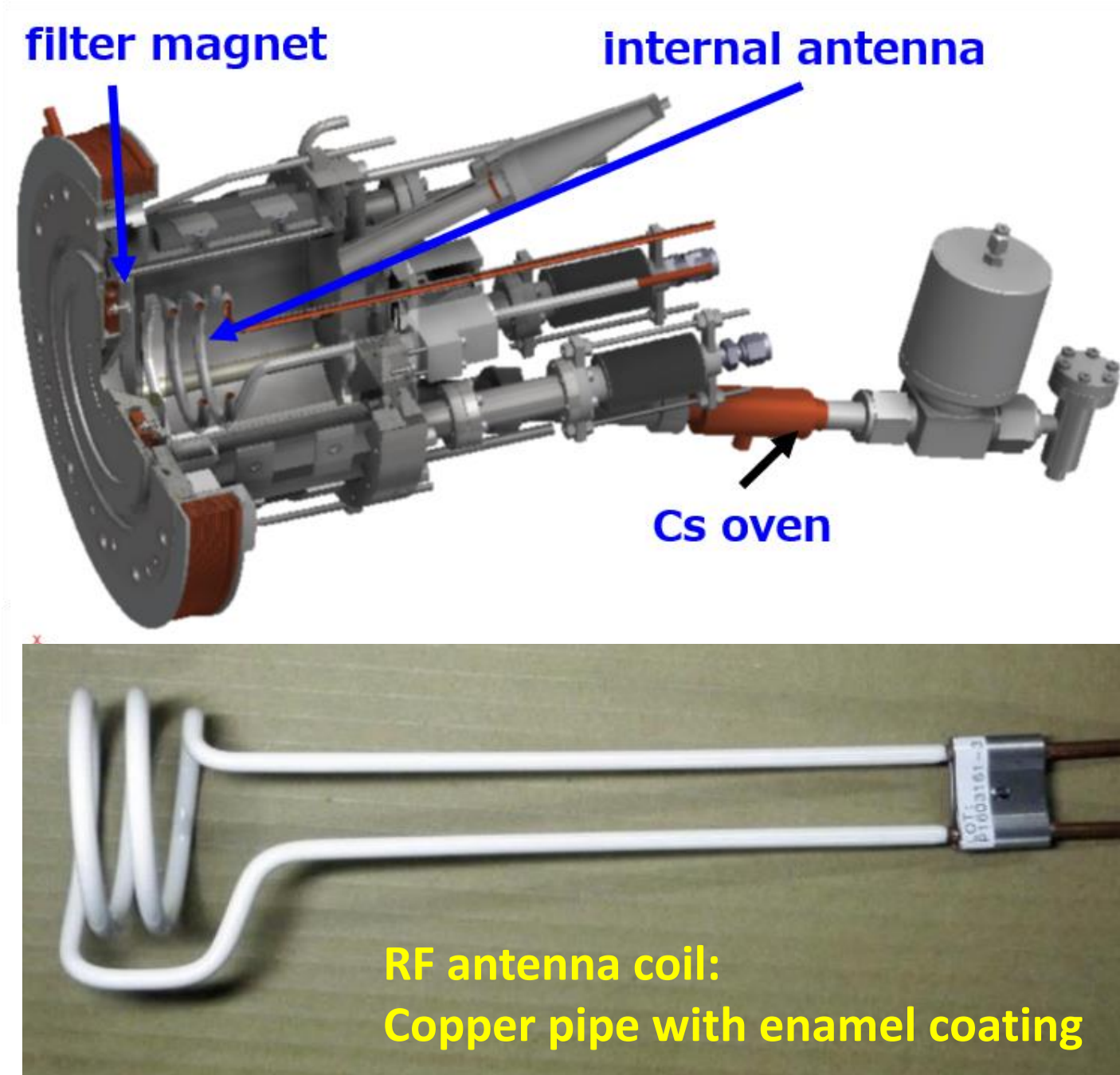
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Abstract

In the J-PARC user operation from Nov. 2020 – Apr. 2021, continuous operation of J-PARC Radio Frequency (RF) negative hydrogen ion (H⁻) source up to 3,651 hours (5 months) has been achieved. The ion source was operated with the output H⁻ current of 60 mA, the duty factor (for plasma generation) 2% and the input RF power up to 30 kW. After the operation, phase space diagrams at the Radio Frequency Quadrupole (RFQ) entrance were measured by the emittance monitor at the ion source test stand (IS-TS) under the same operation condition as in the J-PARC Linac. Comparison of the phase spaces and the beam emittances between the ion sources in the present and the previous operations shows slight difference. From the direct observation of the antenna coil, no exhaustion or the decrease in the thickness of the enamel coating of the coil have been confirmed. The results indicate the possibility of the next goal of the long-run up to 7 months, which is the same as the full duration of the J-PARC user operation in 1 year.



J-PARC ion source [1,2]

- J-PARC ion source is Radio Frequency (RF) type with **internal RF antenna coil**.
- The antenna coil is a spiral **copper pipe coated by enamel** for the insulation to the plasma which was **developed at SNS [3]**.
- The antenna coils delivered from the factory are checked by the original criterion in J-PARC to omit the ones with crack, pin-hole or uniform thickness of the enamel coating.
- The antenna coil with the highest grade (AA) in the check is applied to the J-PARC long-run operation.

Continuous Operation up to 3,651 hours of J-PARC RF ion source

- The J-PARC user operation RUN#86 started from Nov. 2020 and finished in Apr. 2021.
- Duration of the **continuous operation was 3,651 hours (5 months)**.
- In this duration, the same ion source (#9) was used continuously for the beam supply to the Linac.
- The beam operation suspensions were NOT due to the ion source (e.g., due to earthquake), which were recovered in 0.5 – 2 hours.
- The beam current was kept 60 mA ± 0.3 mA** (LEBT FC&SCT in the trend graph) in the user operation with the **2 MHz RF power input up to 27 kW** (corresponds to 2MHz RF power ~ 52 % in the graph).
- The **total Cs consumption was 88 mg in the 5 months** while the filled amount was 2.49 g.
- This year, the continuous operation time was extended from previous 2,445 hours by a factor of 1.5.

Emittance measurement

- After removed from the J-PARC linac, the ion source is installed to the **ion source test-stand (IS-TS)** for the emittance measurement.
- A **double-slit emittance monitor [4,5]** is located at the end of IS-TS, which corresponds to the entrance position of the Radio Frequency Quadrupole (RFQ) in the linac.
- The **normalized RMS emittance** measured are **0.262 and 0.264 π mm mrad** in horizontal and vertical directions.
- The beam operation condition and the configuration of ISTS are the same as in the J-PARC linac commissioning, which optimizes the RFQ transmission ratio.
- The average emittance** in these two years (including the short-run operations) is **0.262 – 0.266 π mm mrad**.
- The results show that **no emittance increase takes place even after the 5 month continuous operation**.

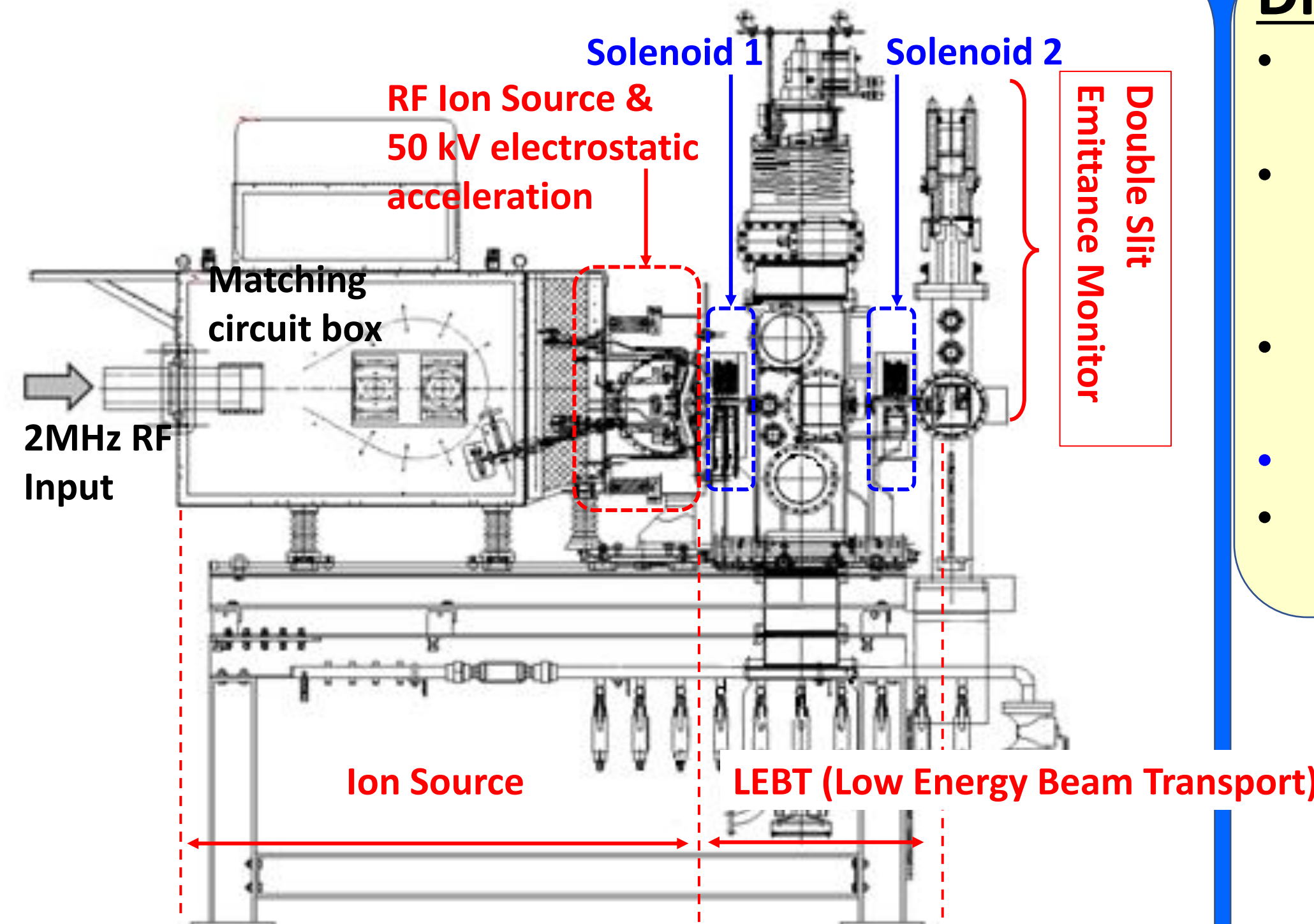
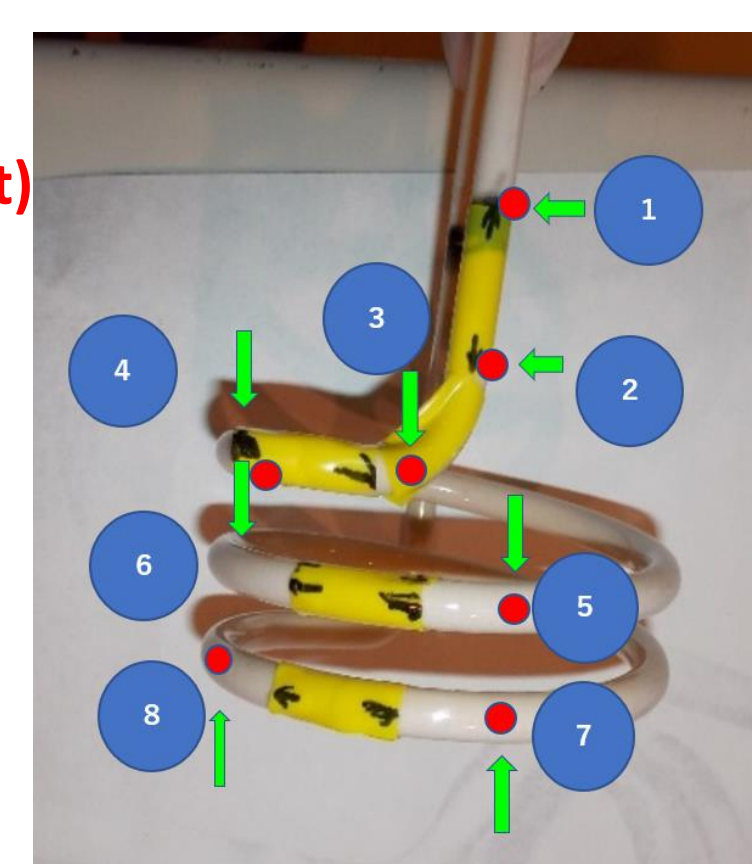


Table 1. Recent history of the beam emittance of the ion source operated in the J-PARC long-run.

RUN # and period	RUN#83: Nov. 2019 – Dec. 2020	RUN#84: Jan. 2020 – Apr. 2020	RUN#85: May. 2020 – Jul. 2020	RUN#86: Nov. 2020 – Apr. 2021
Gas flow rate	23.5 sccm	22.0 sccm	21.0 sccm	21.0 sccm
2MHz RF power input	25.5 kW	31.2 kW	27.2 kW	27.0 kW
Emittance (X/Y)	0.244 / 0.244 π mm mrad	0.277 / 0.273 π mm mrad	0.284 / 0.269 π mm mrad	0.262/0.264 π mm mrad

Direct investigation of the antenna coil

- After the long-run operation, **condition of the ion source was checked** in detail.
- There was deposition of the metal component (seen as gloss) on the enamel coating. On the other hand, **no cracks or pin-holes of the coating** itself was confirmed.
- Also, the **thickness of the coating was 5.92 ± 0.15 and 5.94 ± 0.14 mm before and after operations**.
- No serious damage** in 5 month is seen in the antenna.
- Although slight damage was seen in the **Extraction Electrode**, **no difference in the aperture shape** was confirmed.

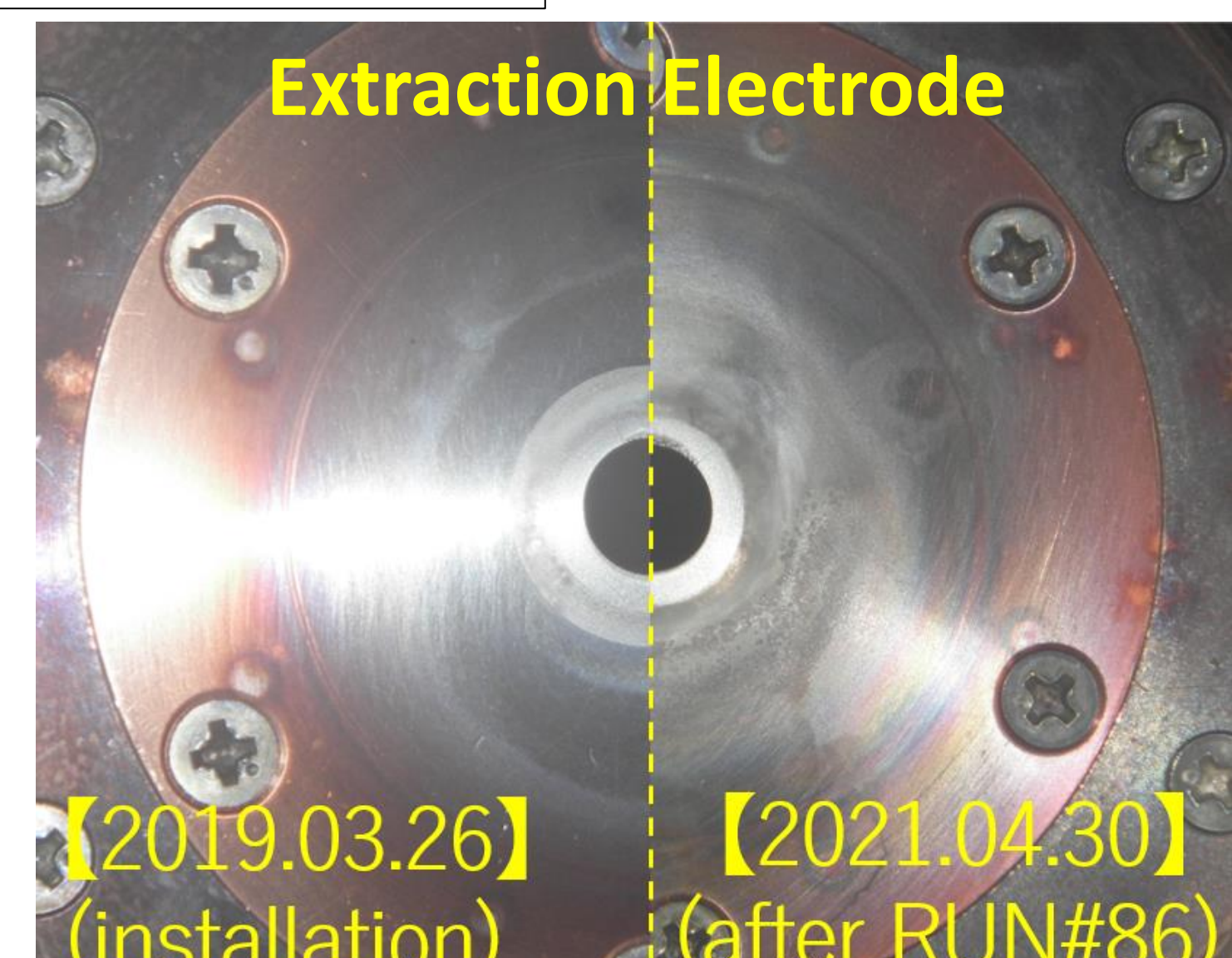
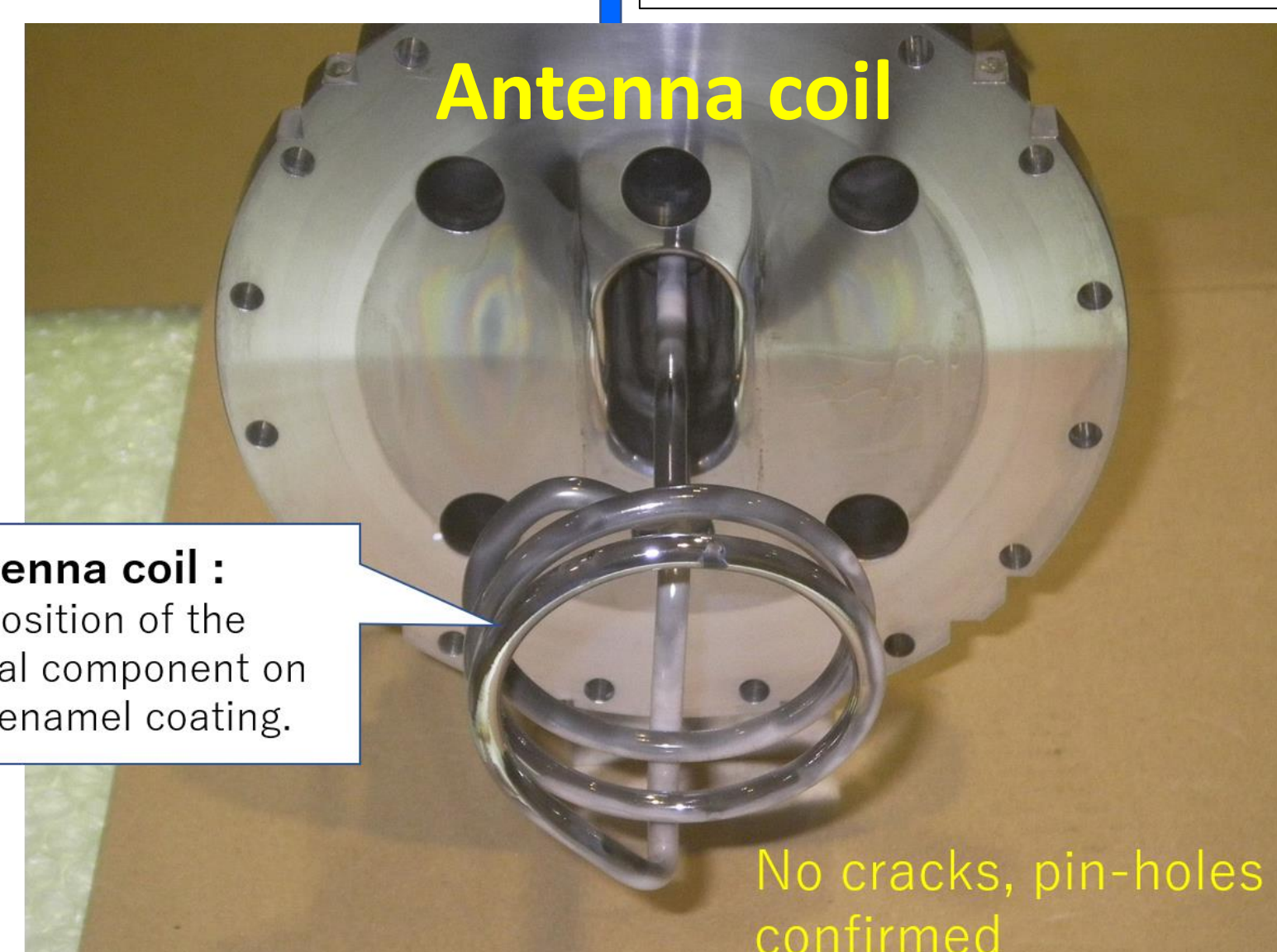
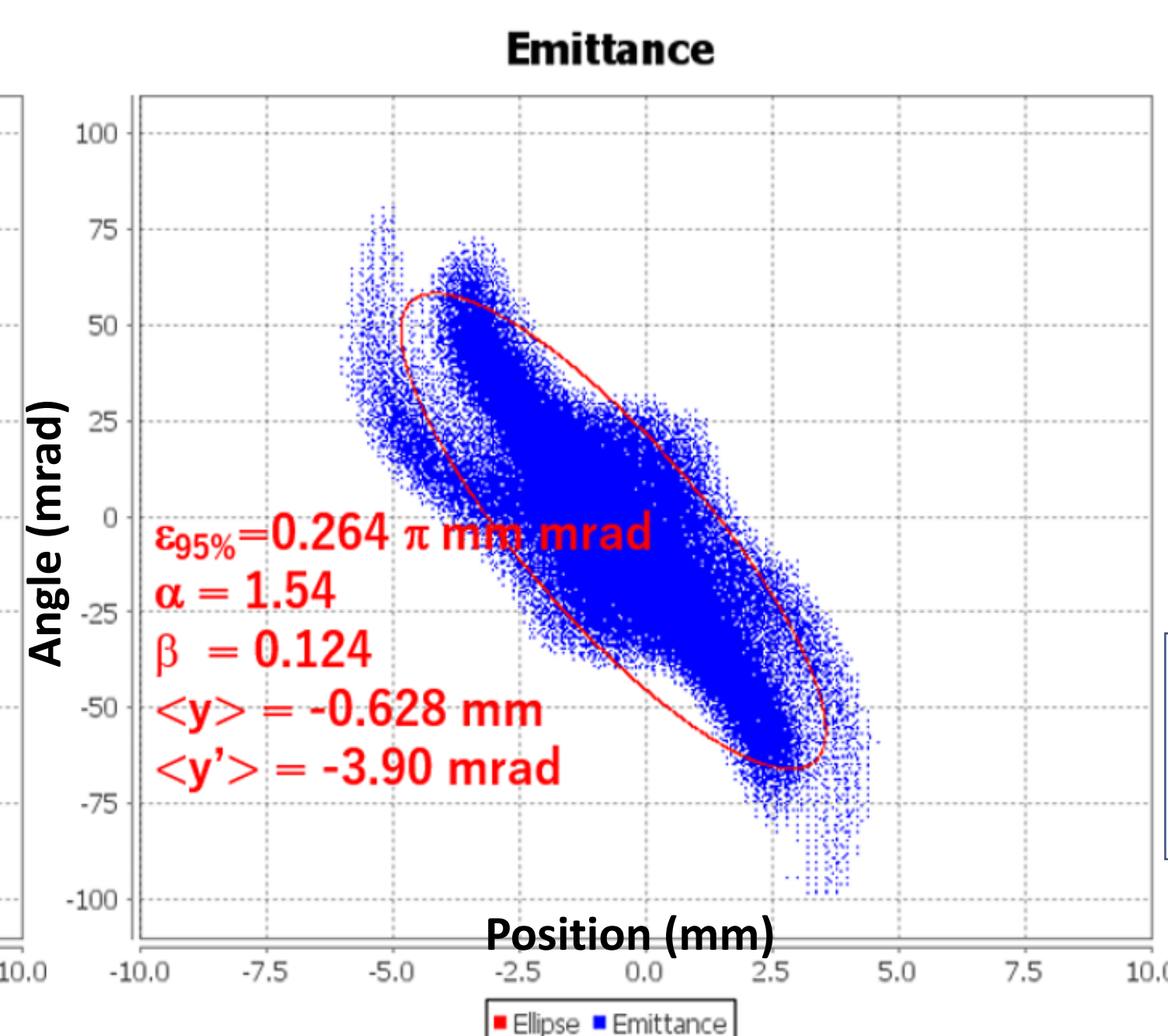
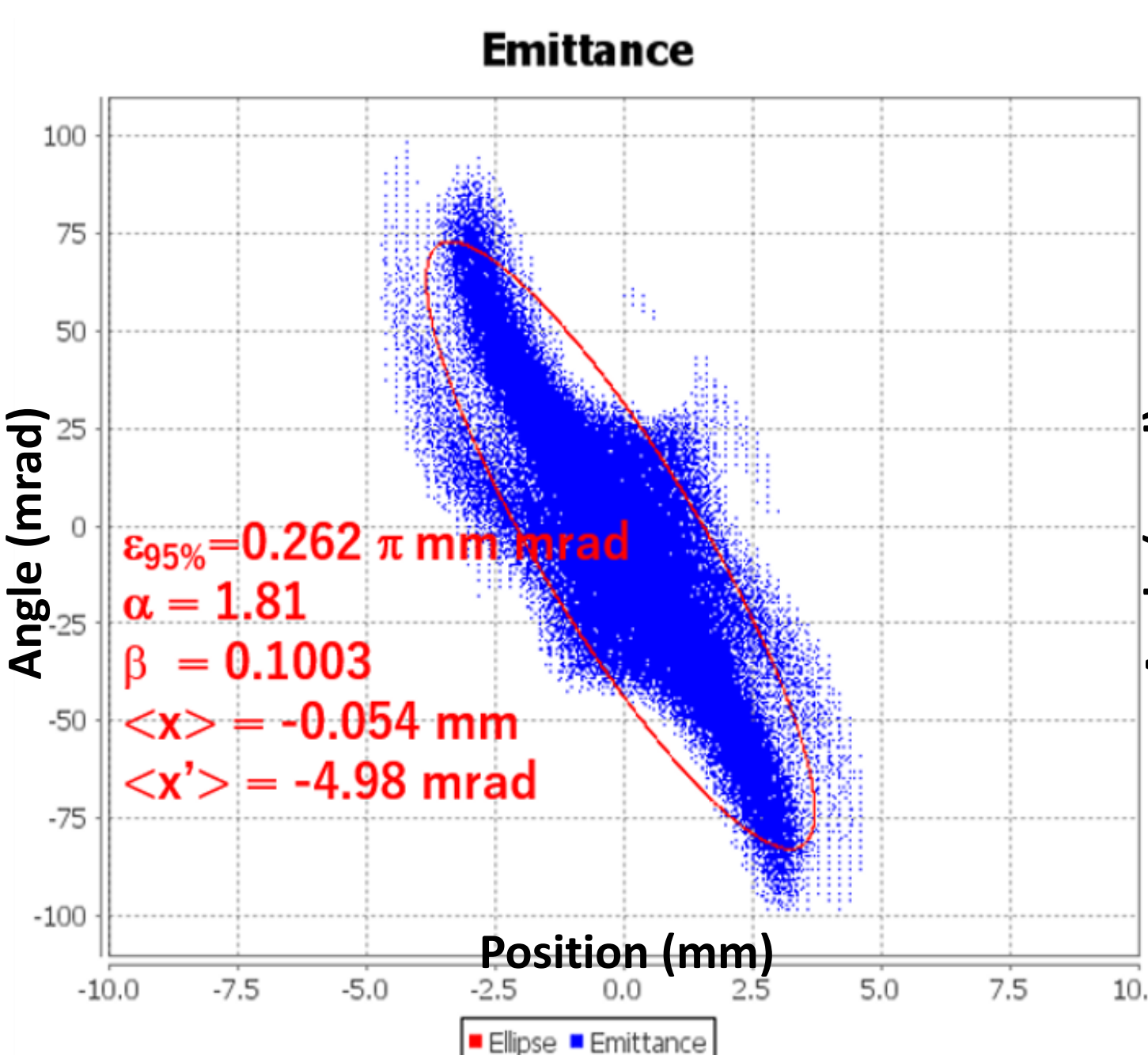
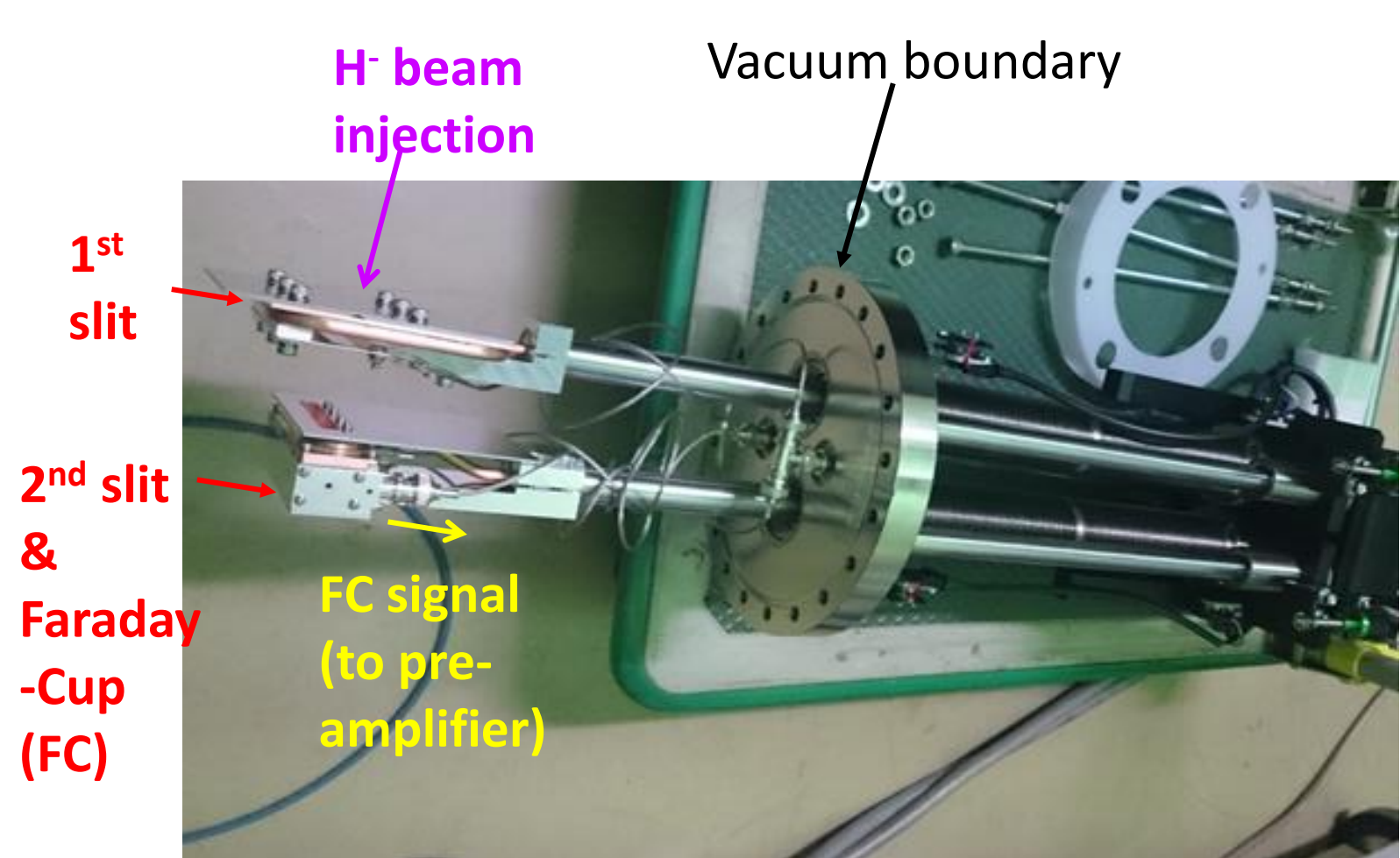


	Before Operation		After Operation	
	A	B	A	B
①	6.07	6.06	5.99	6.07
②	6.09	6.00	6.15	6.03
③	5.93	6.04	6.23	6.12
④	5.92	5.93	5.98	5.94
⑤	5.88	5.93	5.89	5.94
⑥	-	5.87	-	5.92
⑦	5.78	6.04	5.86	6.03
⑧	5.76	5.96	5.80	6.01
W/O ②③	5.88	5.97	5.90	5.99
W/O ②③ (A+B)/2	5.92		5.94	

Cs consumption in 5 months

- filled Cs amount : 2.49g
- estimation of Cs consumption in RUN#86
 - Cs consumption rate : 4mg/h @180°C
 - Cs VLV open duration : 79,074 sec = 22 hrs.
 - Total Cs consumption : 88 mg
- Cs remain : 2.40 g
- Almost full amount of remaining Cs was confirmed directly by open Cs reservoir after the operations.

Cs oven (RUN#86)



Summary

- In the user operation from Nov. 2020 – Apr. 2021, continuous operation of the ion source up to 3,651 hours was achieved.
- The emittance measurement at the test-stand shows that the no emittance increase has been observed. The normalized RMS emittance is 0.262 and 0.264 π mm mrad in X and Y directions.
- From the direct investigation of the antenna coil, no crack, pin-holes and the thickness variation of the enamel coating has been observed.
- Also, no difference of aperture shape was found on the extraction electrode. This results in the stable emittance for 5 months.
- From the results, ability of J-PARC RF ion source for the 5-month continuous operation has been confirmed.
- The next goal is to achieve 7-month long-run, which corresponds to the full duration of J-PARC user operation in 1 year.

Reference

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