



Progress of the J-PARC Cesium RF-driven Negative Hydrogen Ion Source

K. Shinto, K. Ohkoshi, T. Shibata, K. Nanmo, K.
Ikegami,
A. Takagi, Y. Namekawa*, A. Ueno, H. Oguri

J-PARC Center, Tokai-mura, Ibaraki-ken, Japan

*Nippon Advanced Technology Co., Ltd, Tokai-mura, Ibaraki-ken, Japan

Contents (Digests)



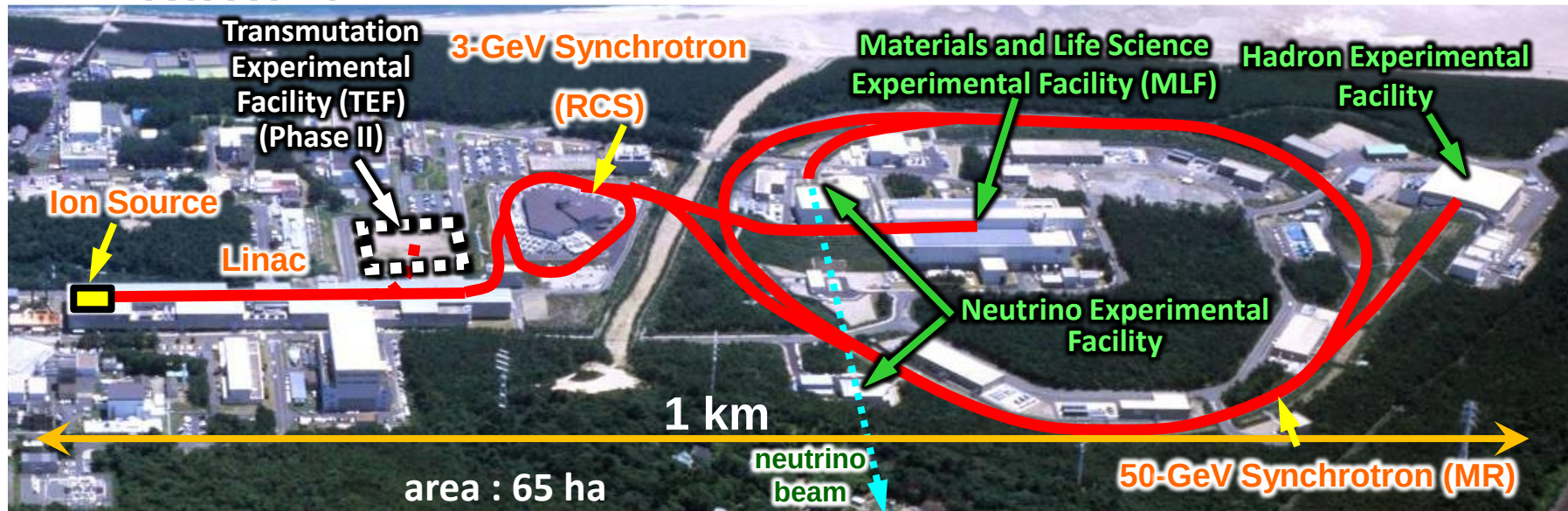
- Introduction –the J-PARC and the H^- ion source
- Operation status of the ion source in 2017/2018 campaign
 - Accomplished **long-term operations more than 2,000 hours** with the H^- beam current of 47 mA
- High-intensity H^- beam operations at the J-PARC linac
 - Produced H^- beam with the current of **72 mA** for demonstration of **60 mA H^- beam at the linac exit**
- Development of J-PARC-made antenna
 - Achieved **total operation time of 1,400 hours**
- Conclusions

Contents (Digests)



- Introduction –the J-PARC and the H^- ion source
- Operation status of the ion source in 2017/2018 campaign
 - Accomplished long-term operations more than 2,000 hours with the H^- beam current of 47 mA
- High-intensity H^- beam operations at the J-PARC linac
 - Produced H^- beam with the current of 72 mA for demonstration of 60 mA H^- beam at the linac exit
- Development of J-PARC-made antenna
 - Achieved total operation time of 1,400 hours
- Conclusions

Overview of the Japan Proton Accelerator Research Complex (J-PARC)



● Linac

- Beam energy : 400 MeV
- Beam current: 40 mA (peak current at exit)
- Pulse length : ≤ 0.5 ms
- Repetition: 25 Hz

● RCS

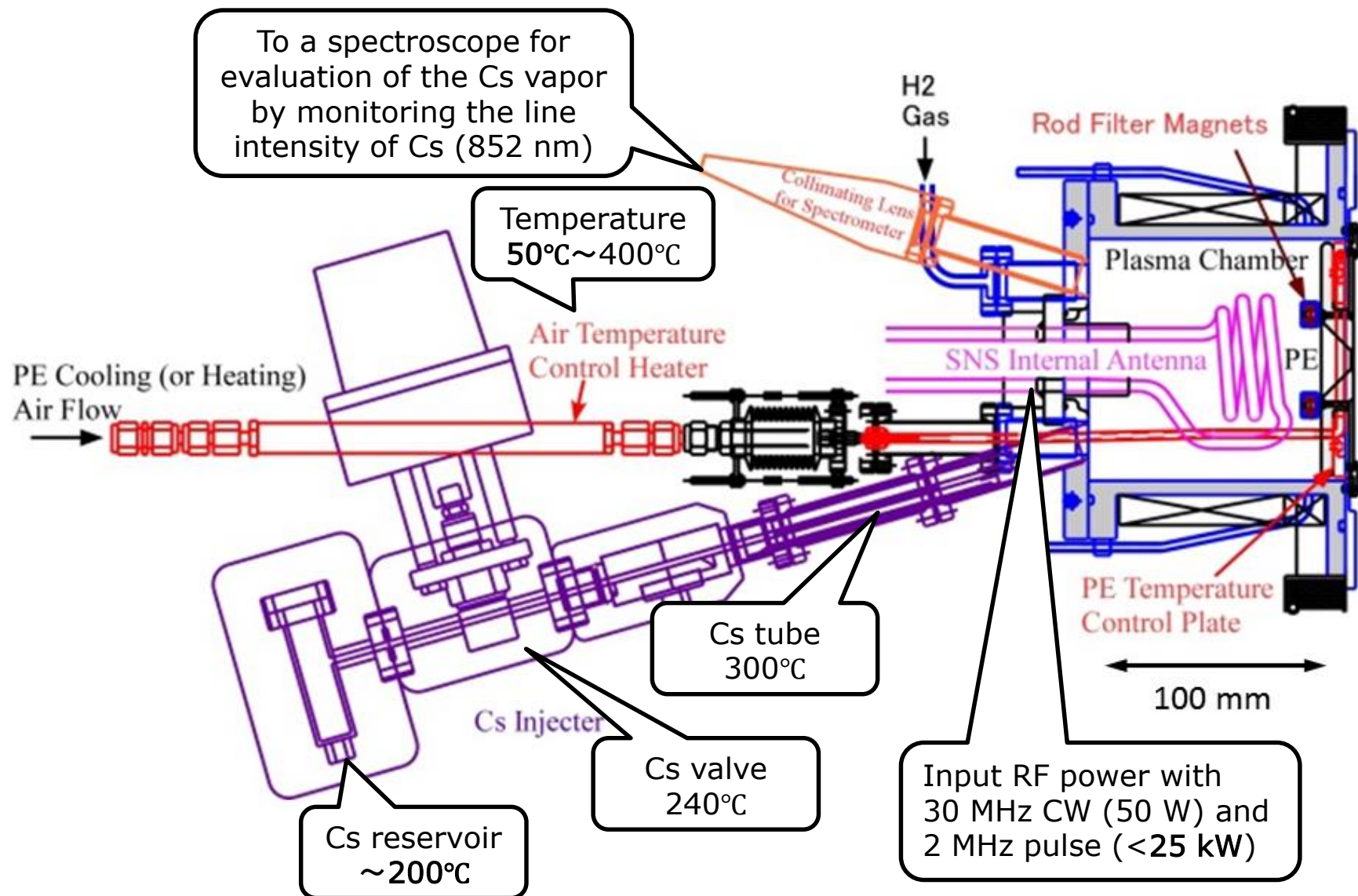
- Beam energy : 3 GeV
- Beam injection into MR and delivered to the Materials and Life Science Experimental Facility (MLF)
- Beam supply to MLF with the beam power of

500 kW (in June 2018)

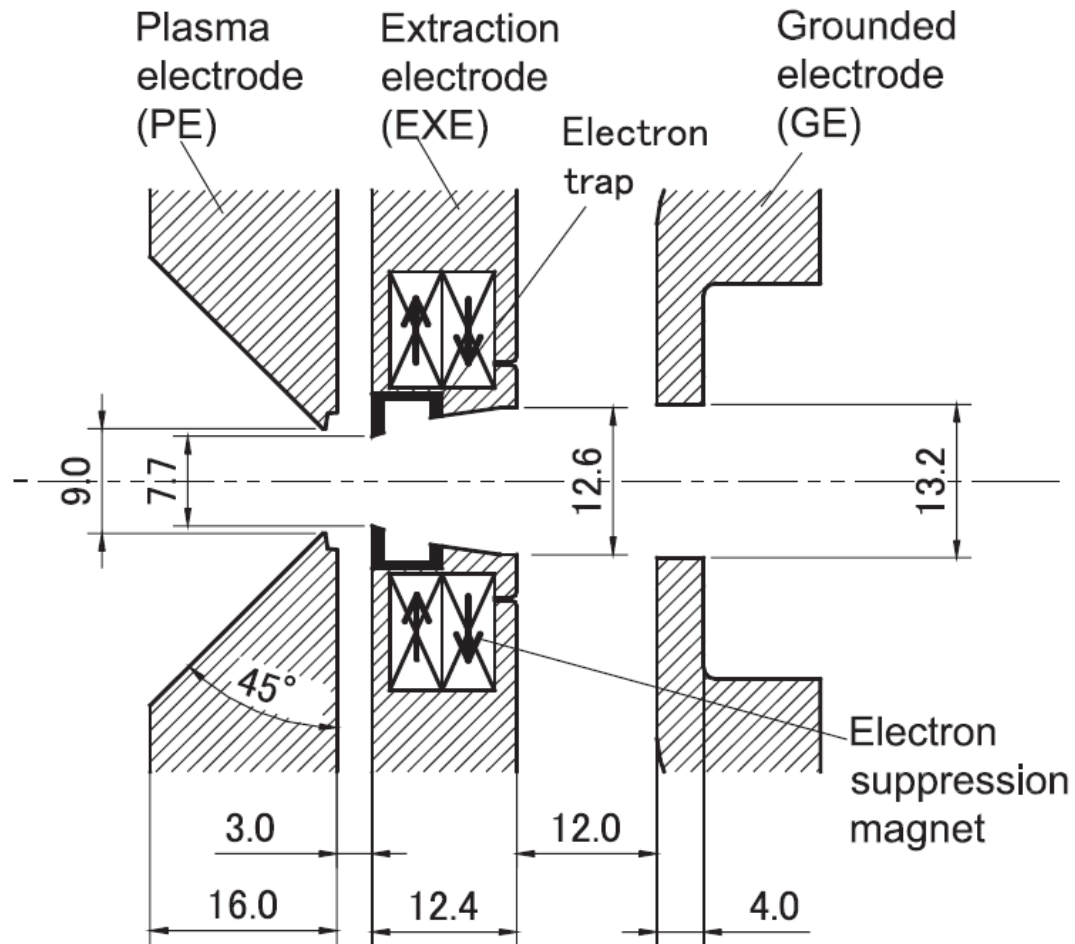
● MR

- Beam energy : 30 GeV (at present)
- Beam power
 - **480 kW** (in May 2018) to the Neutrino Experimental Facility (NU)
 - **50 kW** (in June 2018) to the Hadron Experimental Facility (HD)

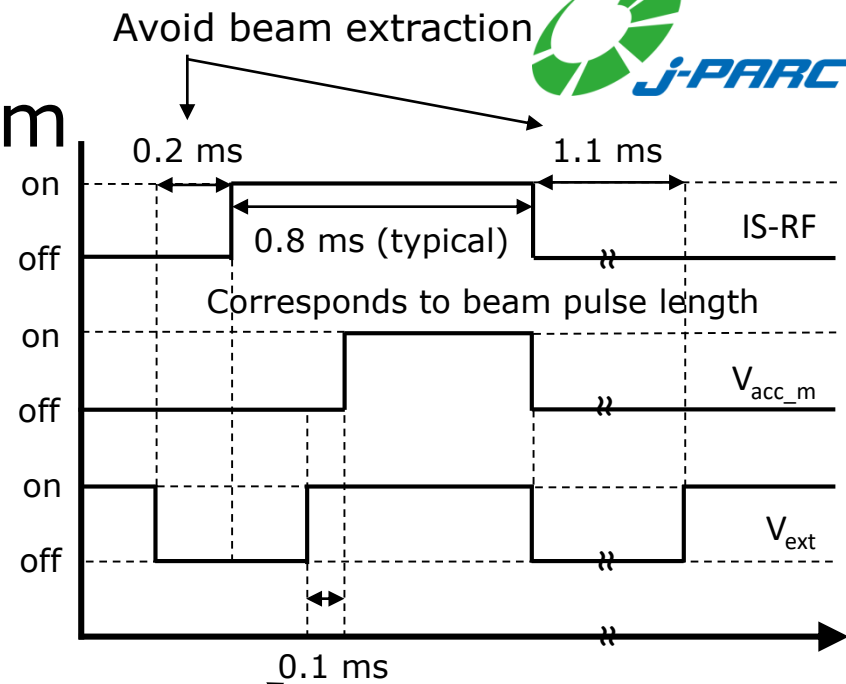
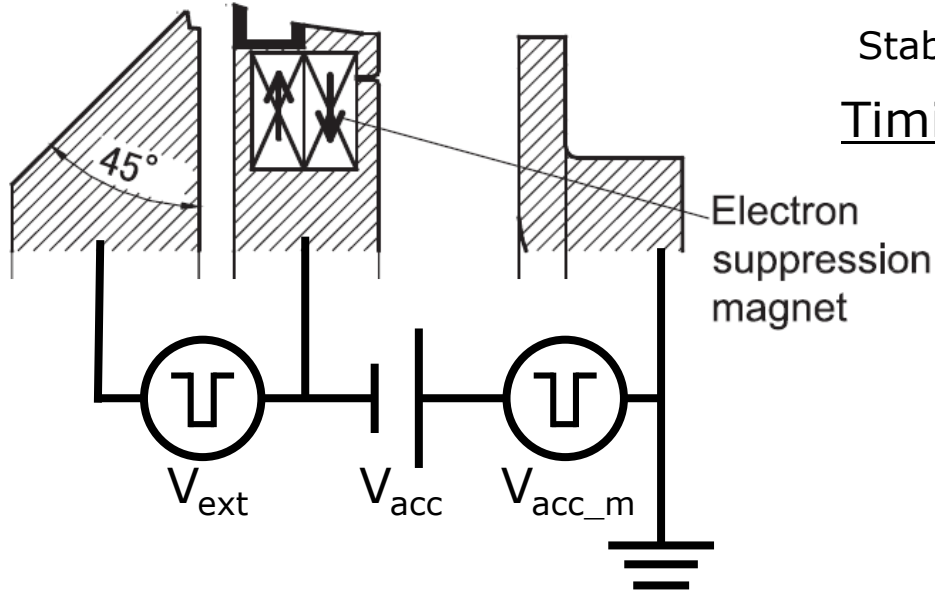
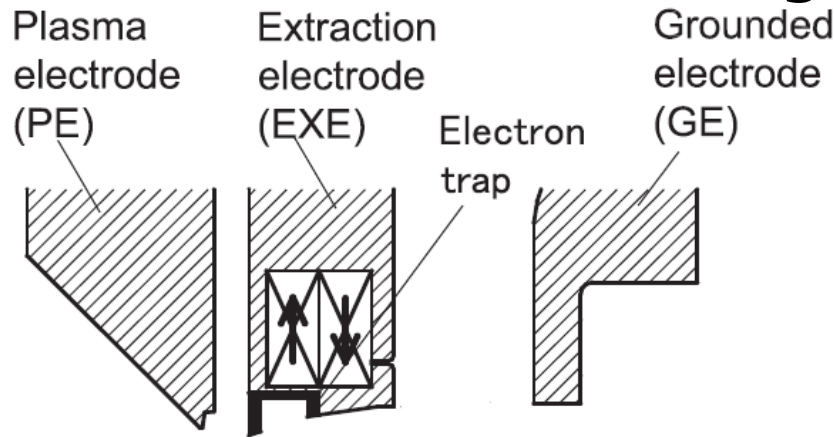
The J-PARC cesiated rf-driven negative hydrogen (H^-) ion source



Beam extractor



Beam extractor and the electrical circuit diagram

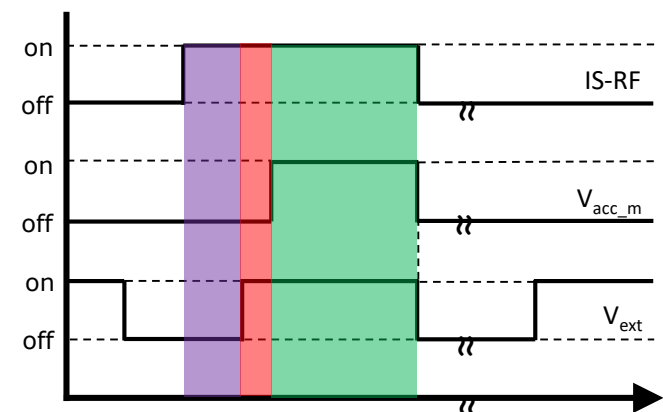
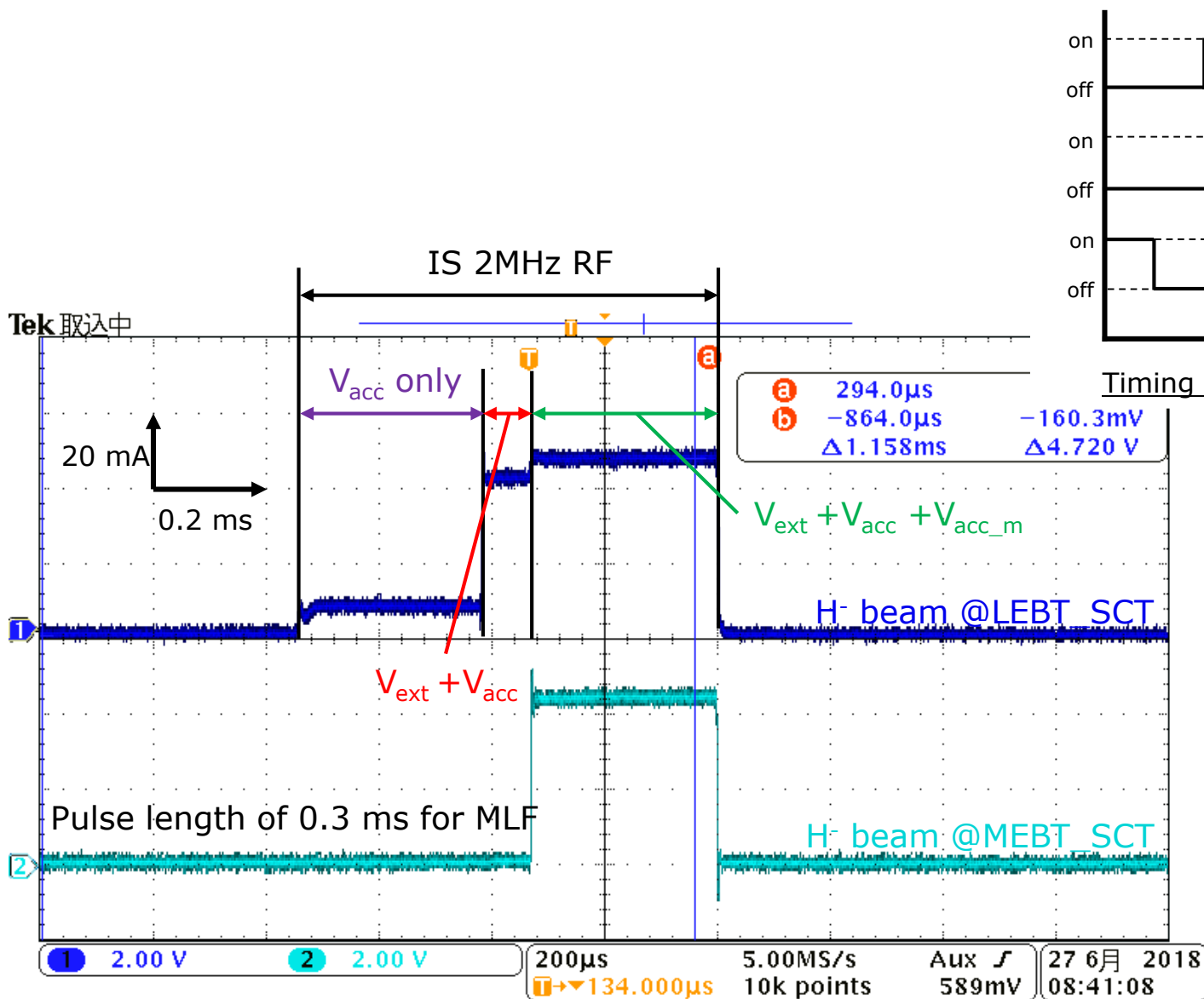


Stabilize space-charge neutralization in LEBT
Timing scheme of the power supplies

Typical parameters for user operation mode

V_{ext}	= - 9.8 kV (Pulse)
V_{acc}	= -30.0 kV (DC)
V_{acc_m}	= -12.5 kV (Pulse)

Example of the H⁻ beam waveform



Timing scheme of the power supplies

Contents (Digests)



- Introduction –the J-PARC and the H^- ion source
- Operation status of the ion source in 2017/2018 campaign
 - Accomplished **long-term operations more than 2,000 hours** with the H^- beam current of 47 mA
- High-intensity H^- beam operations at the J-PARC linac
 - Produced H^- beam with the current of **72 mA** for demonstration of 60 mA H^- beam at the linac exit
- Development of J-PARC-made antenna
 - Achieved total operation time of **1,400 hours**
- Conclusions

Two operation modes

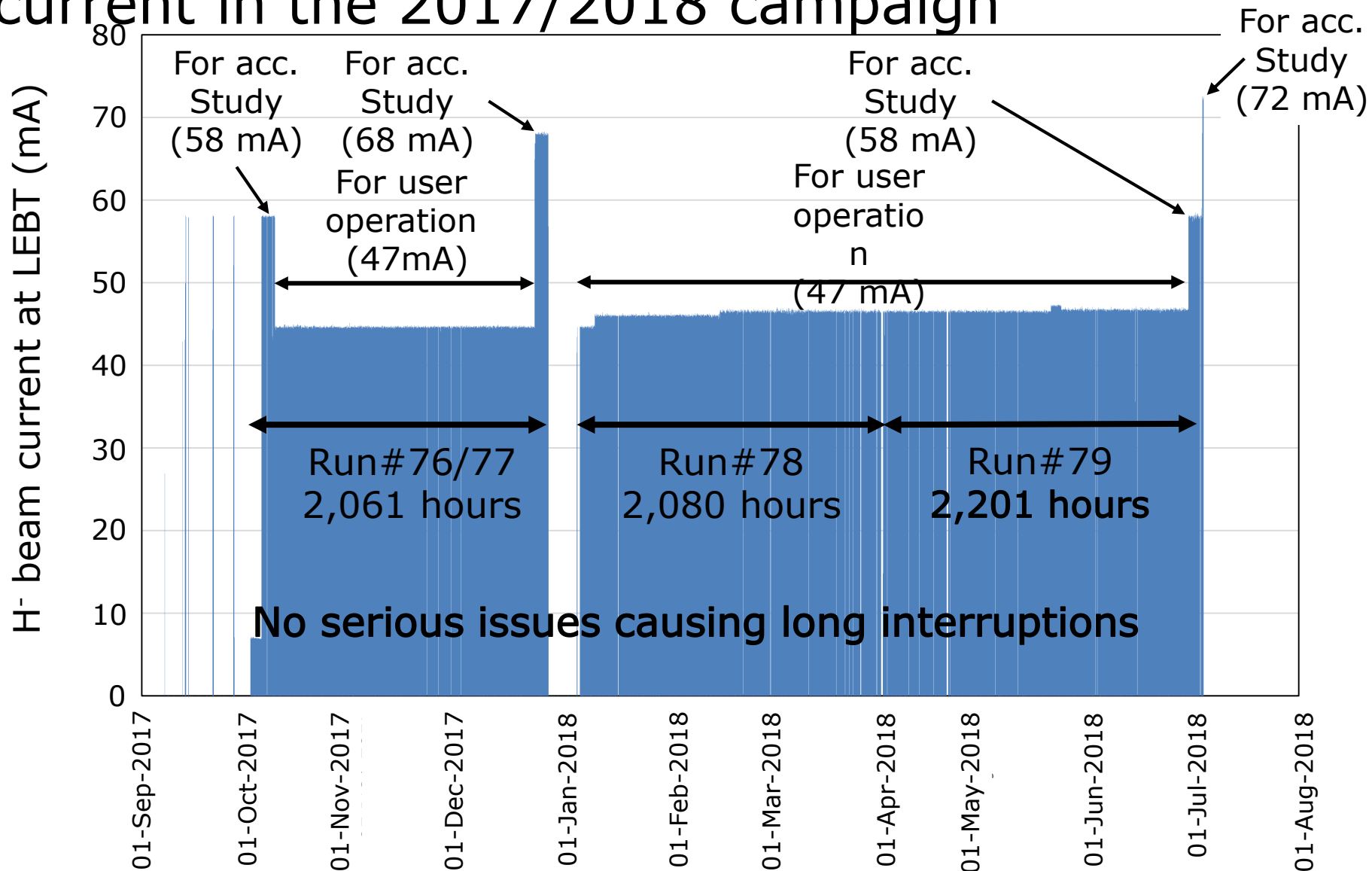
● User operation mode

- H⁻ beam current: 45 mA (40 mA @linac exit)
- RF pulse length: 0.8 ms
- Beam pulse length: 0.3 ~ 0.5 ms (depends upon user's requests)

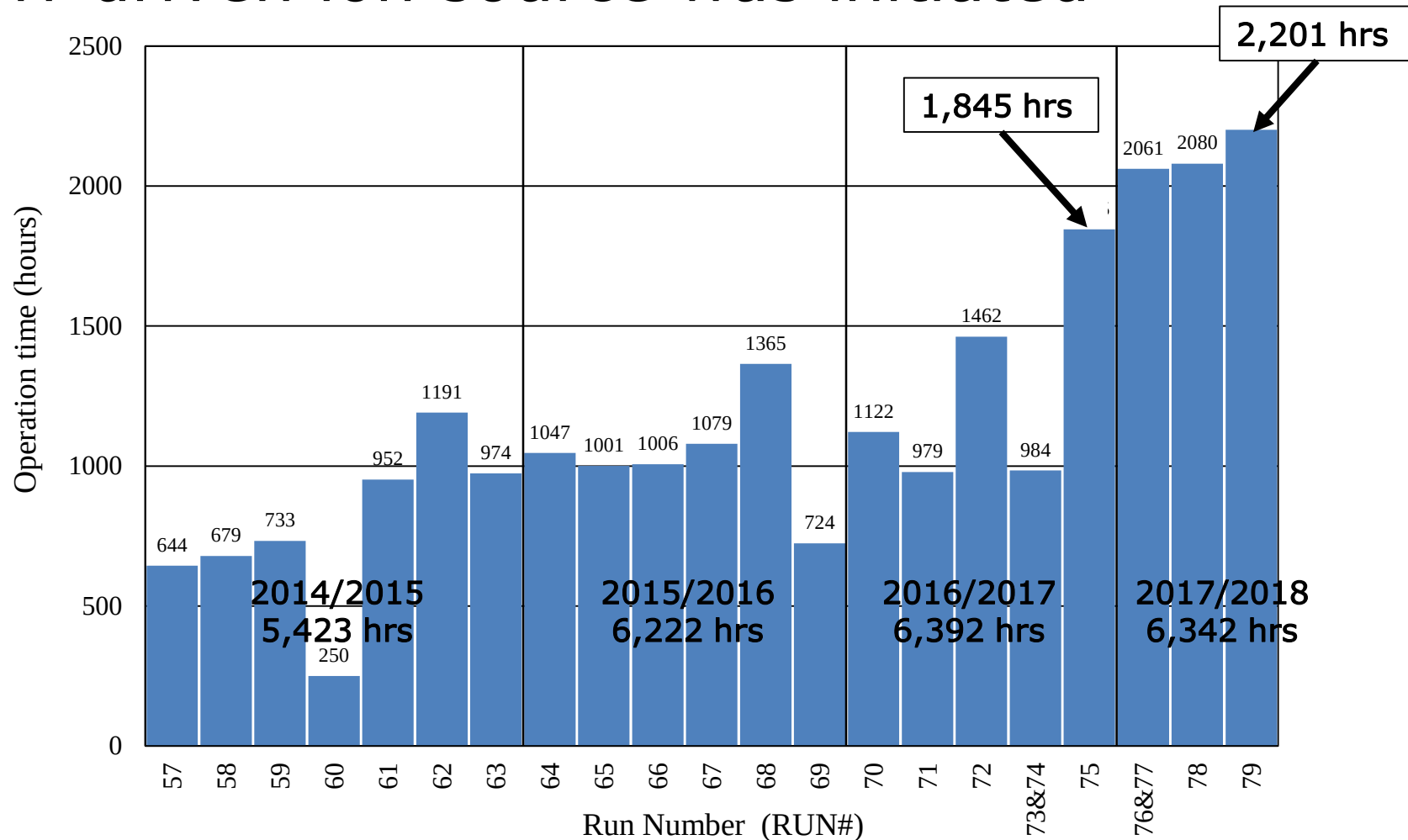
● Accelerator study mode

- H⁻ beam current : 58 mA (50 mA @linac exit)
(depends upon acc. study contents)
- RF pulse length: 0.8 ms
- Beam pulse length: 0.05 ~ 0.5 ms
(depends upon acc. study contents)

Operational history of the H⁻ beam current in the 2017/2018 campaign



Operational history since the rf-driven ion source was initiated



~1.5 months → 2.5 months (Run#75) → 3 months (2017 Autumn~)

The operation time has **become longer**.

Contents (Digests)



- Introduction –the J-PARC and the H^- ion source
- Operation status of the ion source in 2017/2018 campaign
 - Accomplished long-term operations more than 2,000 hours with the H^- beam current of 47 mA
- High-intensity H^- beam operations at the J-PARC linac
 - Produced H^- beam with the current of **72 mA** for demonstration of **60 mA H^- beam at the linac exit**
- Development of J-PARC-made antenna
 - Achieved total operation time of **1,400 hours**
- Conclusions

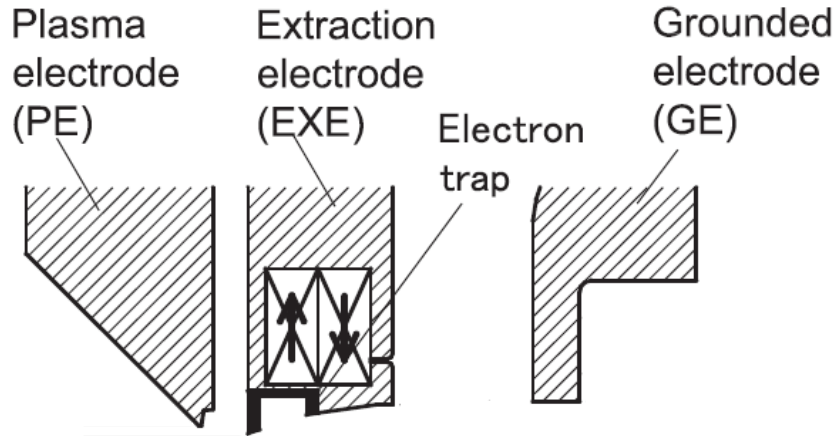
Motivation

- Demonstration of the proton **beam power of 1.5 MW-equivalent** at the RCS in future (Target year: 2020)
 - The RCS commissioning group has found that the RCS has potential to output the proton beam power of 1.5 MW by accelerator studies and beam dynamics studies during these four years.

- Required the H⁻ beam at the linac exit with
 - the beam current of **60 mA**, and
 - the pulse length of **0.6 ms**.

- The ion source needs to produce the H⁻ beam with **the beam current more than 70 mA**.

Beam extractor and the electrical circuit diagram



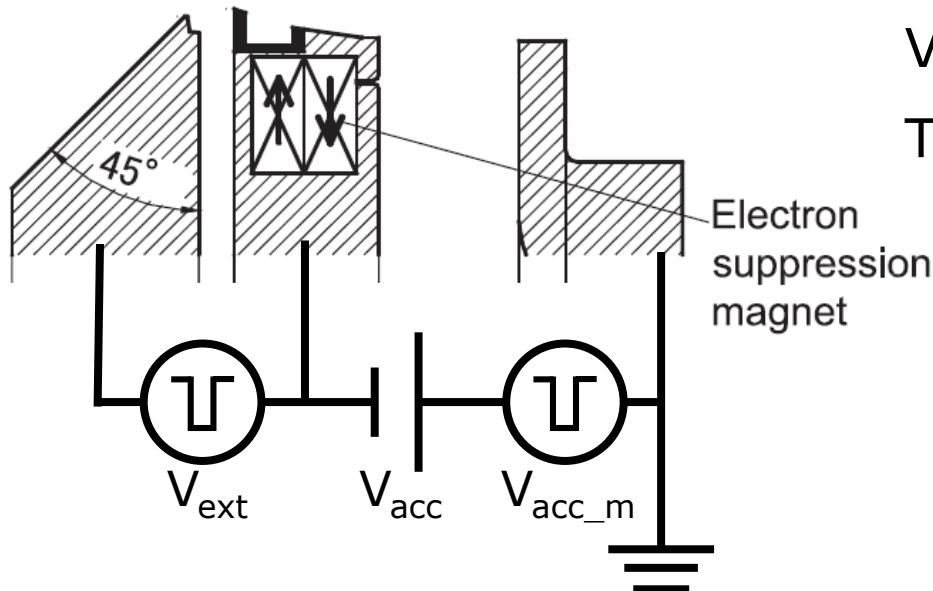
Typical parameters for
72 mA H⁻ beam extraction

$$V_{\text{ext}} = -\mathbf{10.3} \text{ kV (Pulse)}$$

$$V_{\text{acc}} = -30.0 \text{ kV (DC)}$$

$$V_{\text{acc_m}} = -12.5 \text{ kV (Pulse)}$$

$$\text{Total} = -\mathbf{52.8} \text{ kV}$$



Typical parameters for user
operation mode

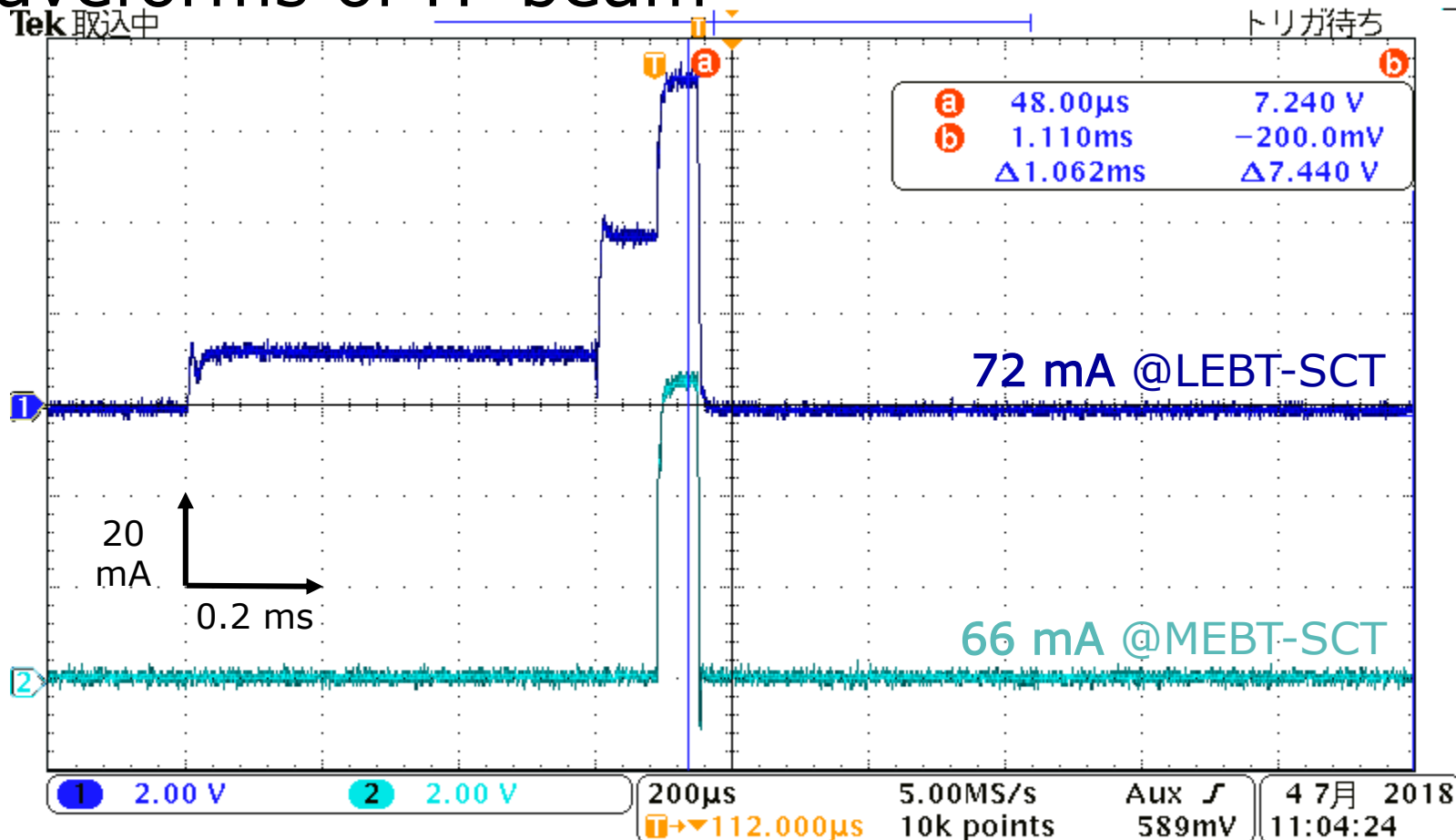
$$V_{\text{ext}} = -9.8 \text{ kV (Pulse)}$$

$$V_{\text{acc}} = -30.0 \text{ kV (DC)}$$

$$V_{\text{acc_m}} = -12.5 \text{ kV (Pulse)}$$

$$\text{Total} = -52.3 \text{ kV}$$

Waveforms of H⁻ beam



- The linac commissioning group could **demonstrate the H⁻ beam with 60 mA** at the linac exit with some optimizations.
- The **pulse length was limited** due to the beam dump capacity in the linac tunnel. →Need to check the flatness of the beam by using other beam dumps in the RCS.

Contents (Digests)



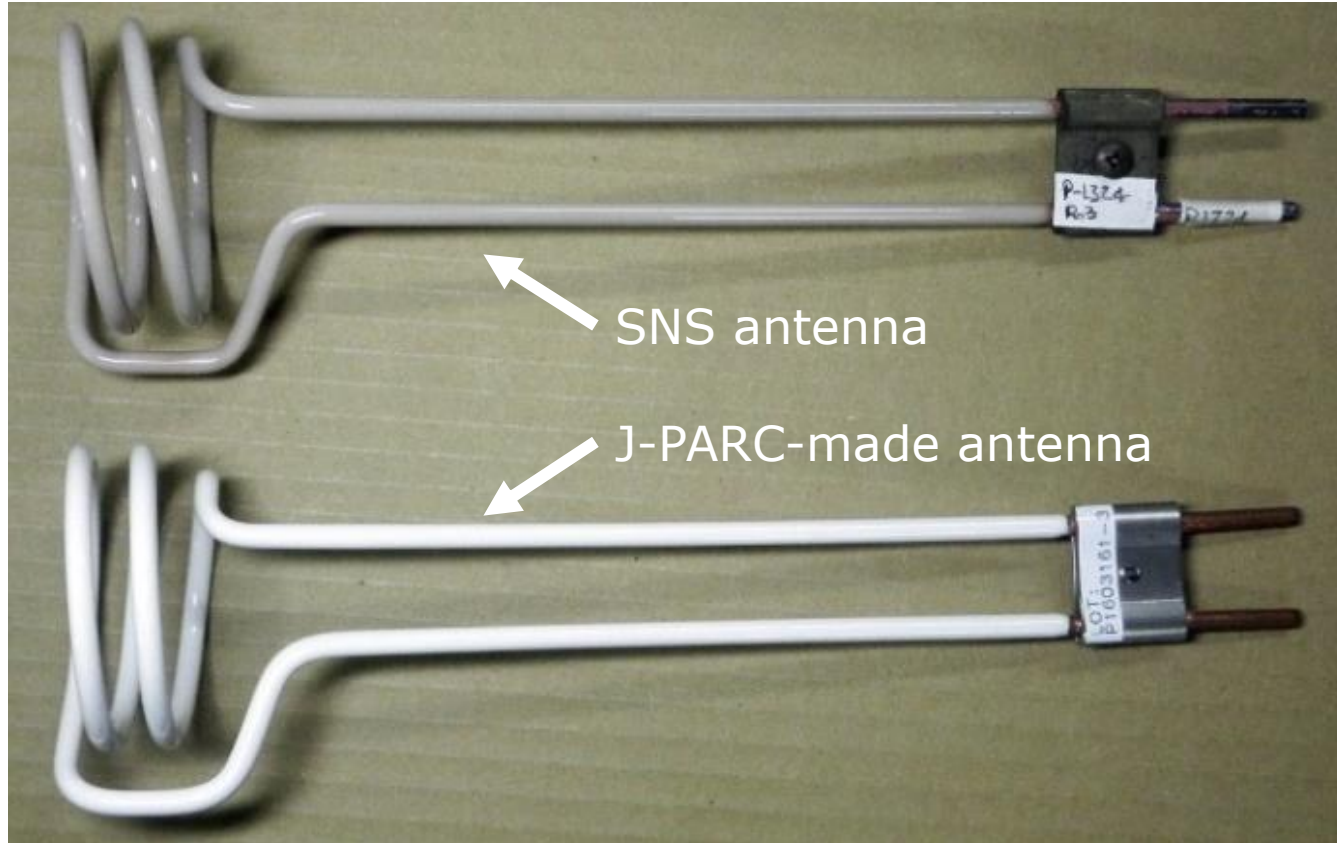
- Introduction –the J-PARC and the H^- ion source
- Operation status of the ion source in 2017/2018 campaign
 - Accomplished long-term operations more than **2,000 hours** with the H^- beam current of 47 mA
- High-intensity H^- beam operations at the J-PARC linac
 - Produced H^- beam with the current of **72 mA** for demonstration of 60 mA H^- beam at the linac exit
- Development of J-PARC-made antenna
 - Achieved **total operation time of 1,400 hours**
- Conclusions

Motivation

- At present, J-PARC ion source uses the SNS antennas.
- To deeply understand the characteristics of the antenna, and
- To establish the manufacturing procedure

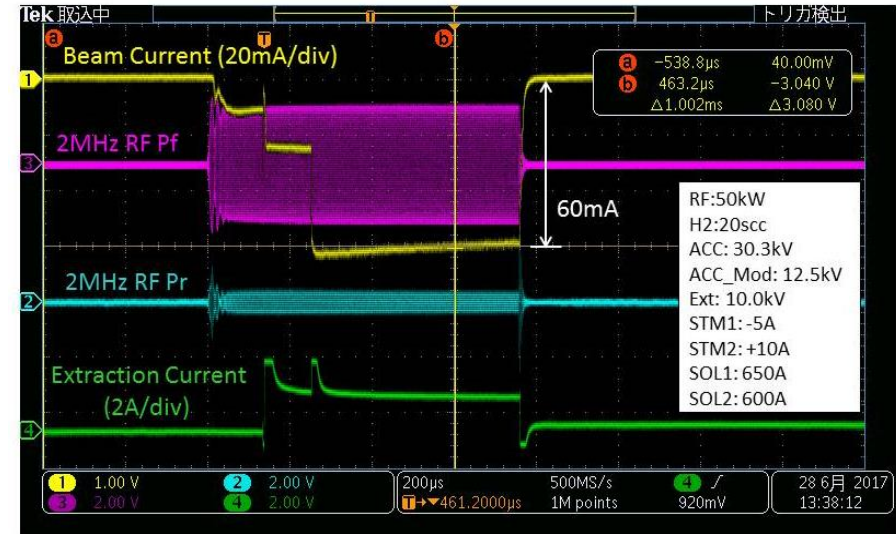
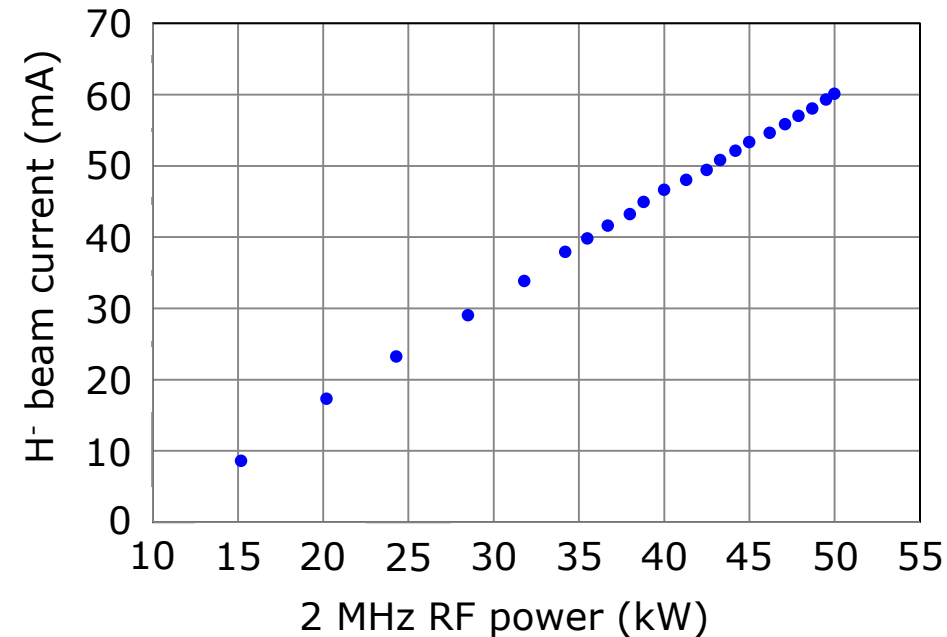
We initiated development of an prototype antenna (J-PARC-made antenna).

Photograph of the SNS and J-PARC-made antennas



J-PARC-made antenna seems to be **whiter** than the SNS antenna. The reason is apparently that **milky glass** containing antimony compounds is used as a coating material for the J-PARC-made.

Performance evaluation of the J-PARC-made antenna



Waveforms of the H⁻ beam current, 2 MHz RF forward (P_f) and reflect power (P_r) and extraction current (I_{ext}).

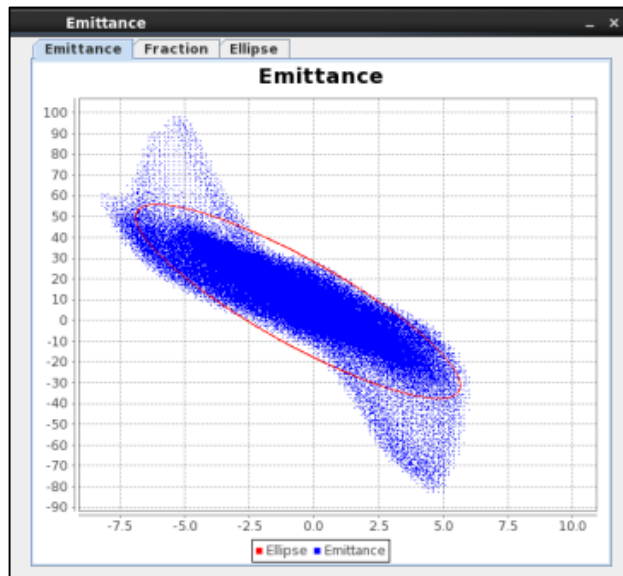
Results similar to those in case of using the SNS antenna were obtained.

K. Ohkoshi *et al.*, Pro. of 14th Annual Meeting of Particle Accel. Soc. Jpn., p. 651 (2017) (in Japanese).

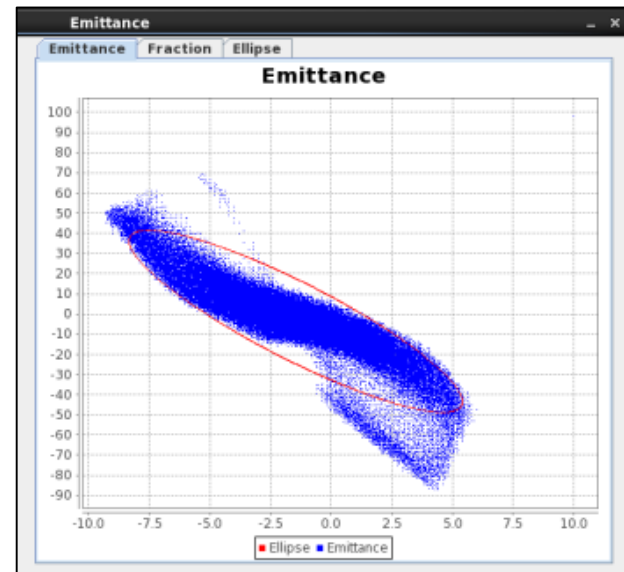
Performance evaluation of the J-PARC-made antenna (cont'd)

95%-beam normalized rms emittance

Beam condition
H⁺ current: 55 mA
RF power: 46.6 kW



Horizontal: 0.261 pi mm mrad

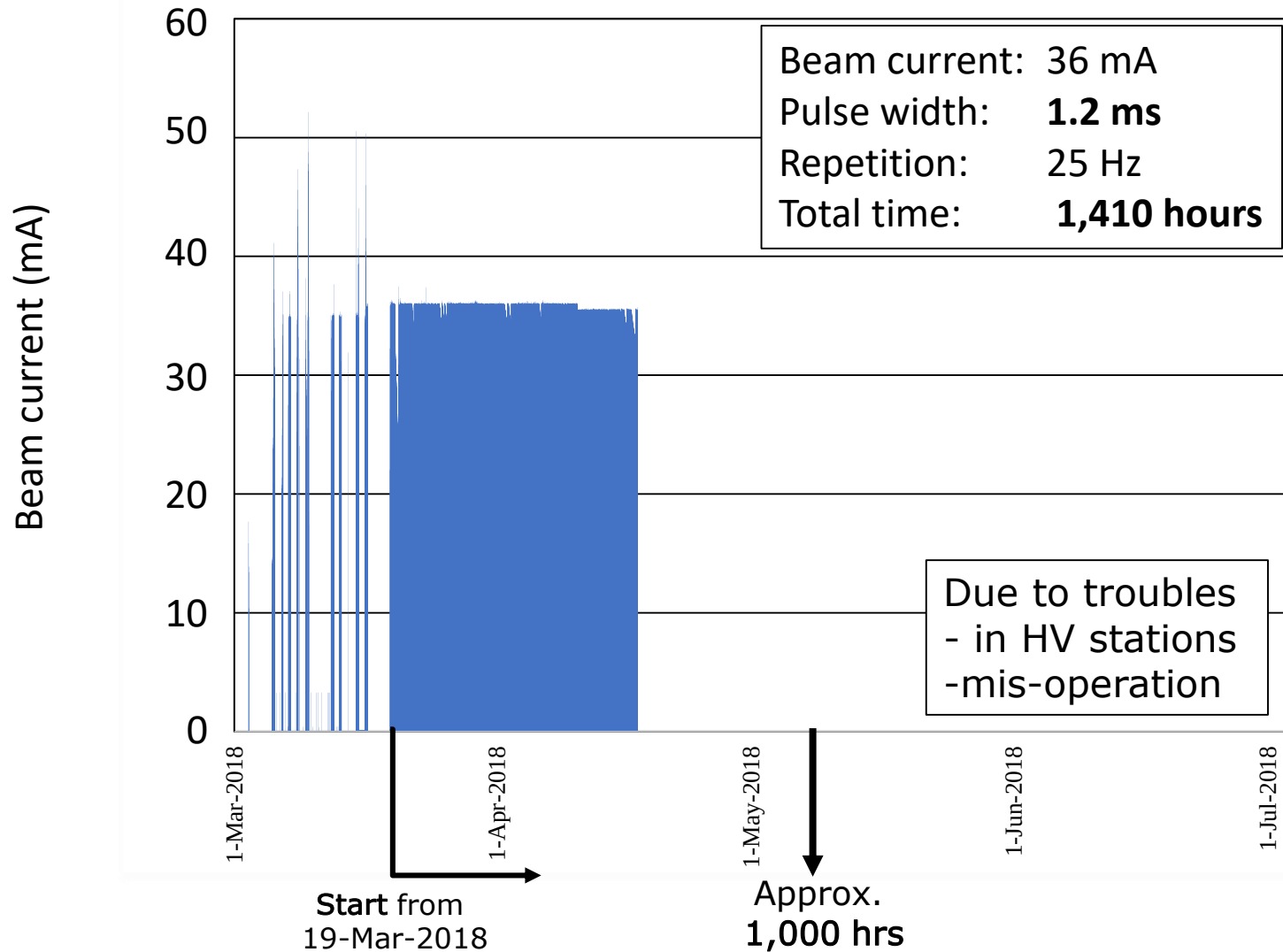


Vertical: 0.302 pi mm mrad

Results similar to those in case of using the SNS antenna were obtained.

K. Ohkoshi *et al.*, Pro. of 14th Annual Meeting of Particle Accel. Soc. Jpn., p. 651 (2017) (in Japanese).

H⁻ beam current from the ion source with J-PARC-made antenna



Conclusions

- The J-PARC cesiated rf-driven H^- ion source producing H^- beam with the beam current of 47 mA accomplished three **long-term operations more than 2,000 hours** without any serious issues.
- The ion source produced an H^- beam current of **72 mA** so that the linac commissioning group could demonstrate the H^- beam current of 60 mA at the J-PARC linac exit.
- An endurance test of the **J-PARC-made antenna** was carried out and the antenna achieved the operation time of **approximately 1,400 hours**.



Thank you so much
for your kind attention.
Большое вам спасибо
за ваше внимание.

BACK-UP SLIDES

Demonstration of beam power of 1 MW at MLF



Succeed continuous operation with 1 MW-equivalent beam power at J-PARC MLF

Approx.
1 hour

J-PARC MLFでの1MW相当の連続運転に成功

J-PARCセンターでは、7月3日にMLFにおいて1MW相当となるビーム出力の連続運転に成功しました。

MLFでは4月19日からビーム出力を500kWに上げて運転していましたが、稼働率が93%と非常に安定した運転を6月30日早朝まで継続することができました。引き続き、夏季メンテナンス前に運転出力を増大させる試験運転を実施し、時間平均で約935kWを超えるビームで連続運転に成功しました。これは、中性子生成水銀標的及びミュオン生成回転標的で受けるビーム出力換算で、設計値である1MWのバルスビーム出力に相当します(図1参照)。

水銀標的については、夏季メンテナンス中にこれまでのビームにより標的容器が受けた影響を評価し、その結果を基に標的容器の改良を行う予定です。その後、さらに運転経験を蓄積しつつMLFにおける1MWでの利用運転を目指します。

Beam power (kW)

ビーム出力 (kW)

On 03 July 2018

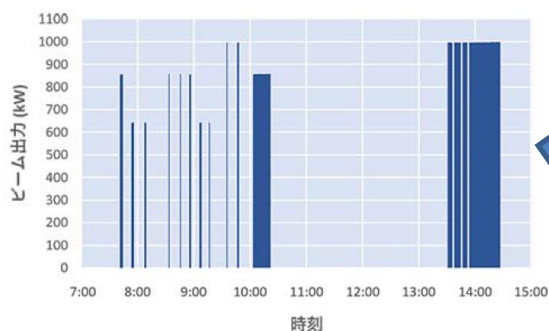
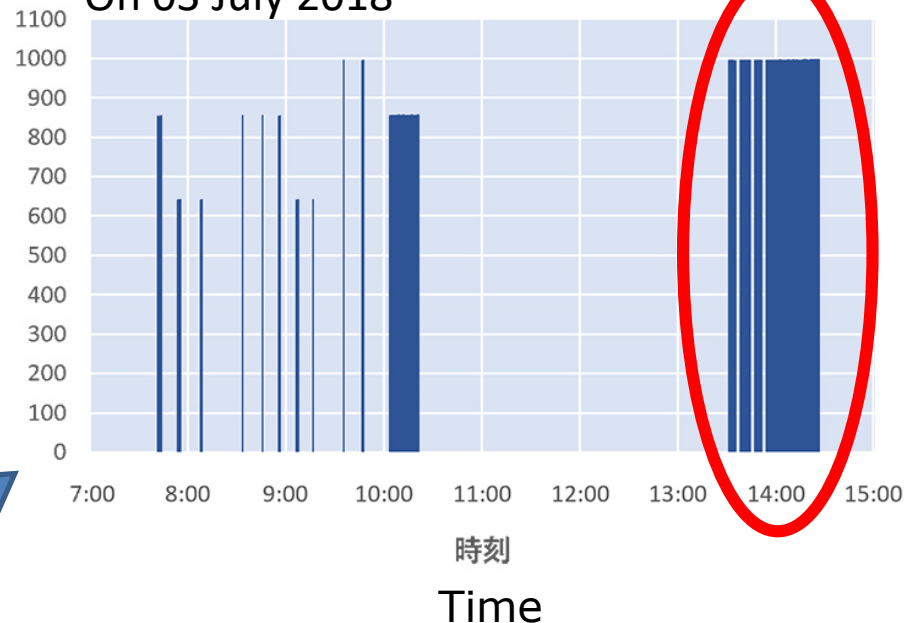


図1 MLFにおける7月3日のビーム出力

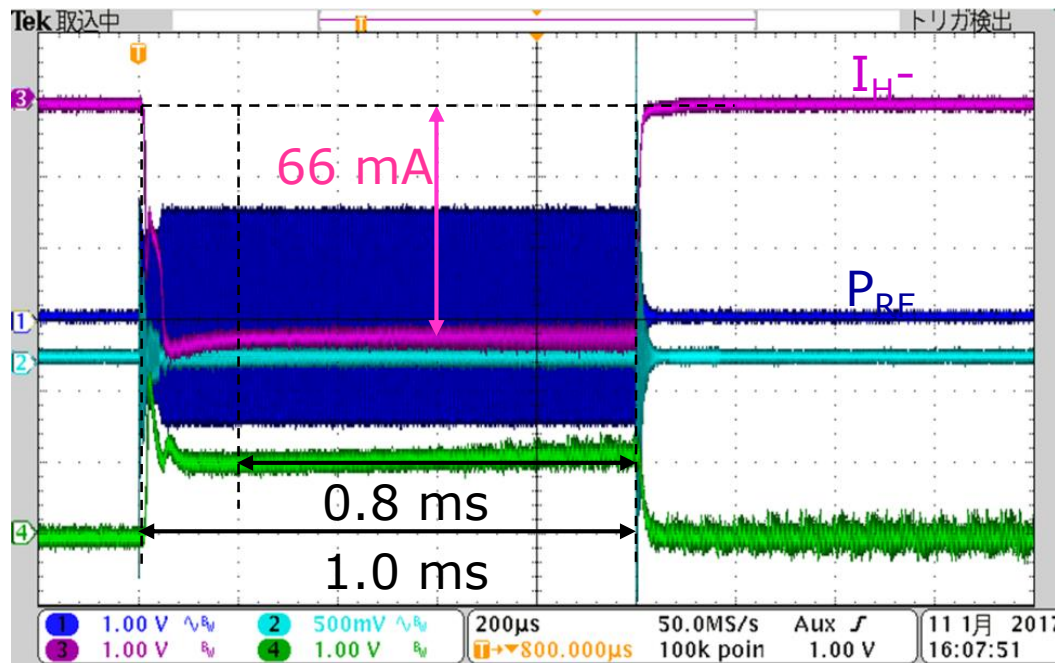
*クリックすると、大きく表示されます。

Beam power at MLF on 03 July 2018

J-PARC topics (Sorry, but only in Japanese language)

H⁻ beam waveform with long pulse at a test bench

Jan. 2017



- H⁻ beam current of 66 mA with RF input power of 26.4 kW
- Pulse length of 0.8 ms
- Beam emittance of $\epsilon_{nrmsy} = 0.27 \pi \text{mm} \cdot \text{mrad}$

M. Kinsho, H. Oguri and K. Yamamoto,
“Linac and RCS upgrade”, presented at J-PARC
Accelerator Technical Advisory Committee
(ATAC) 2017 (on 23rd – 25th Feb 2017).