Current status and future idea of J-PARC accelerator

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Outline

1. Introduction
2. Current status
3. Near future plan for 1.3 MW
4. Future idea for >1.3 MW
5. Summary

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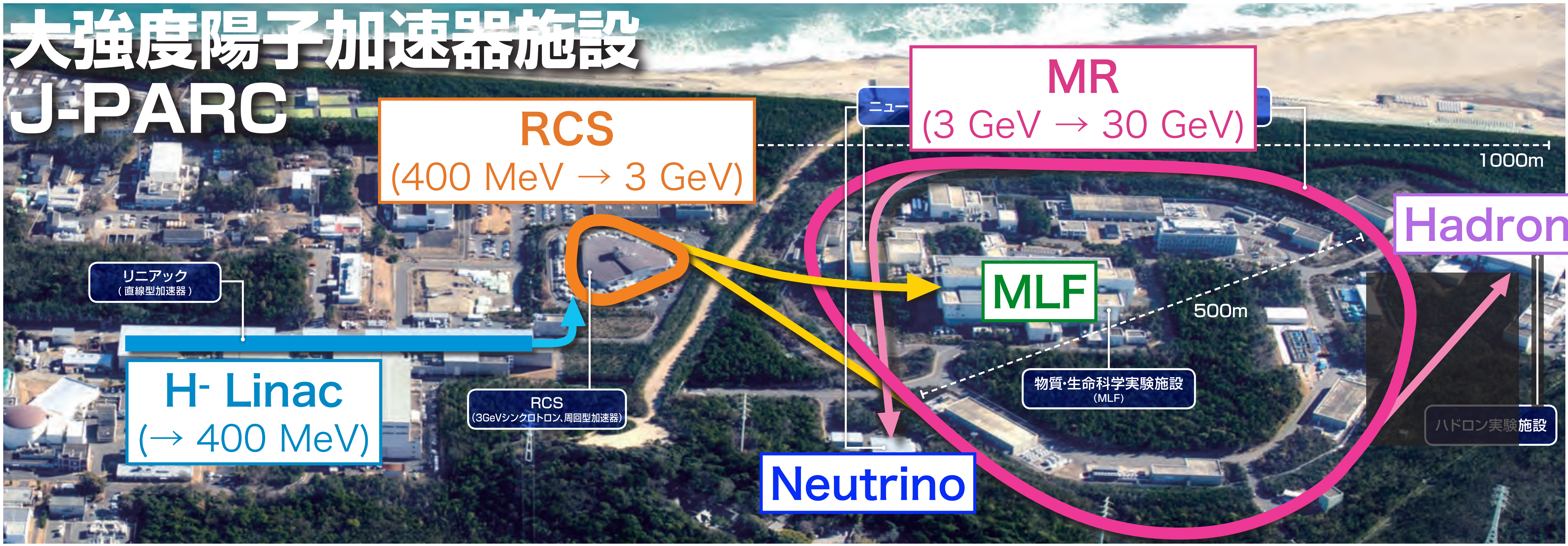
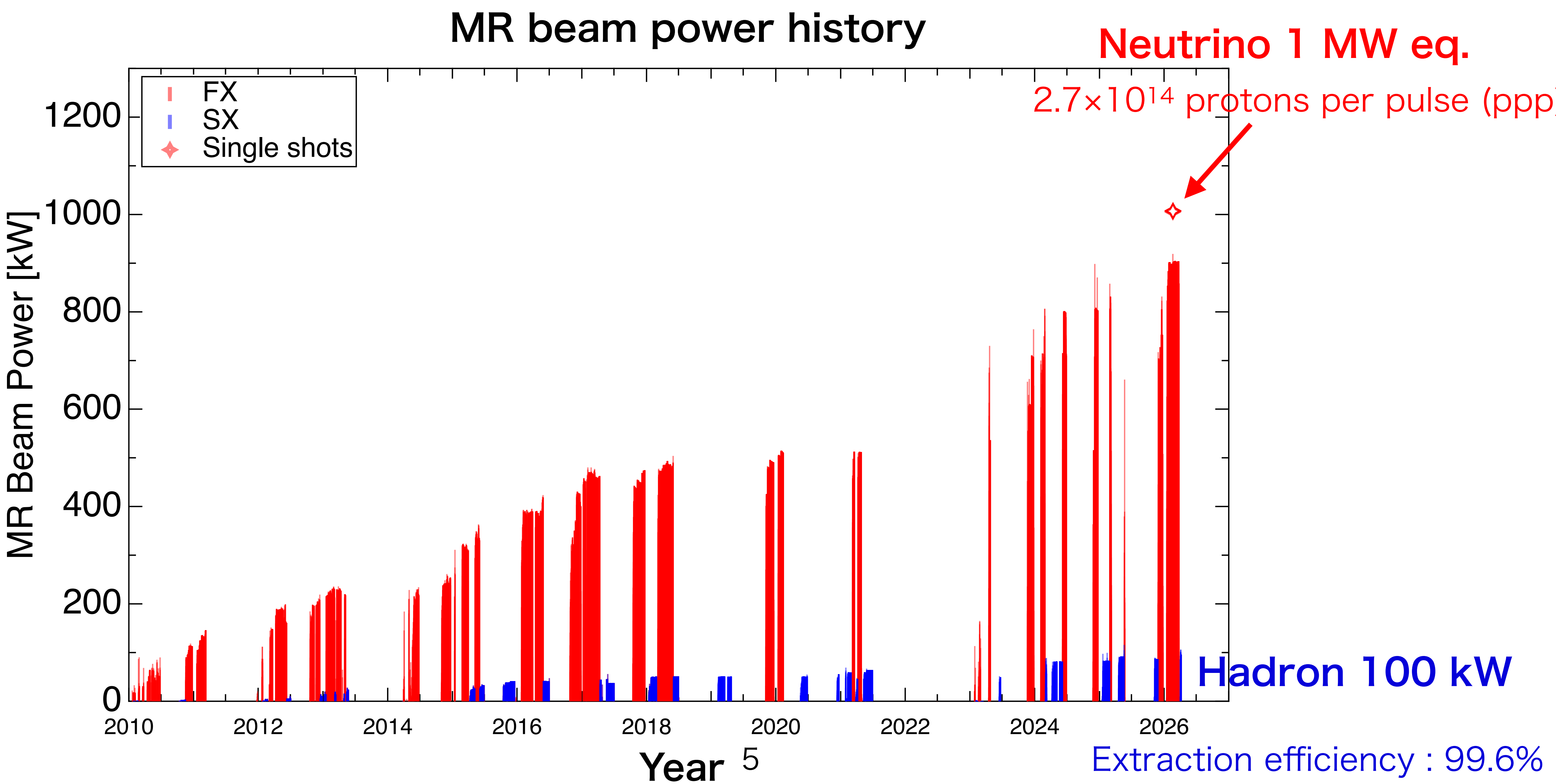
J-PARC



The main ring synchrotron (MR) provides
high power proton beams with a kinetic energy of 30 GeV
to neutrino and hadron experimental facilities.

MR beam power history

To accumulate the statistics of neutrinos and hadrons, stable beam operation with higher power is required.



MR beam power upgrade plan

Power = Energy(30 GeV) × **Number of protons** / **Cycle time**

		Power	Number of protons	Cycle time
JFY2021		515 kW	2.66×10^{14} ppp	2.48 s
Mar. 2025		830 kW	2.36×10^{14} ppp	1.36 s
Feb. 2026	(continuous)	900 kW	2.41×10^{14} ppp	1.28 s
	(1 shot)	1000 kW	2.69×10^{14} ppp	
JFY2028		1300 kW	3.3×10^{14} ppp	1.16 s

ppp ⋯ protons per pulse

MR beam power upgrade plan

Power = Energy(30 GeV) × **Number of protons** / **Cycle time**

		Power	Number of protons	Cycle time	Beam loss
JFY2021		515 kW	2.66×10^{14} ppp	2.48 s	2.1%
Mar. 2025		830 kW	2.36×10^{14} ppp	1.36 s	1.5%
Feb. 2026	(continuous)	900 kW	2.41×10^{14} ppp	1.28 s	0.4%
	(1 shot)	1000 kW	2.69×10^{14} ppp		1.1%
JFY2028		1300 kW	3.3×10^{14} ppp	1.16 s	

ppp … protons per pulse

To realize 1.3 MW operation, we need

- further hardware upgrades
- beam loss reduction

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Recent upgrade (Nov. 2025-)

The following two major upgrades were applied.

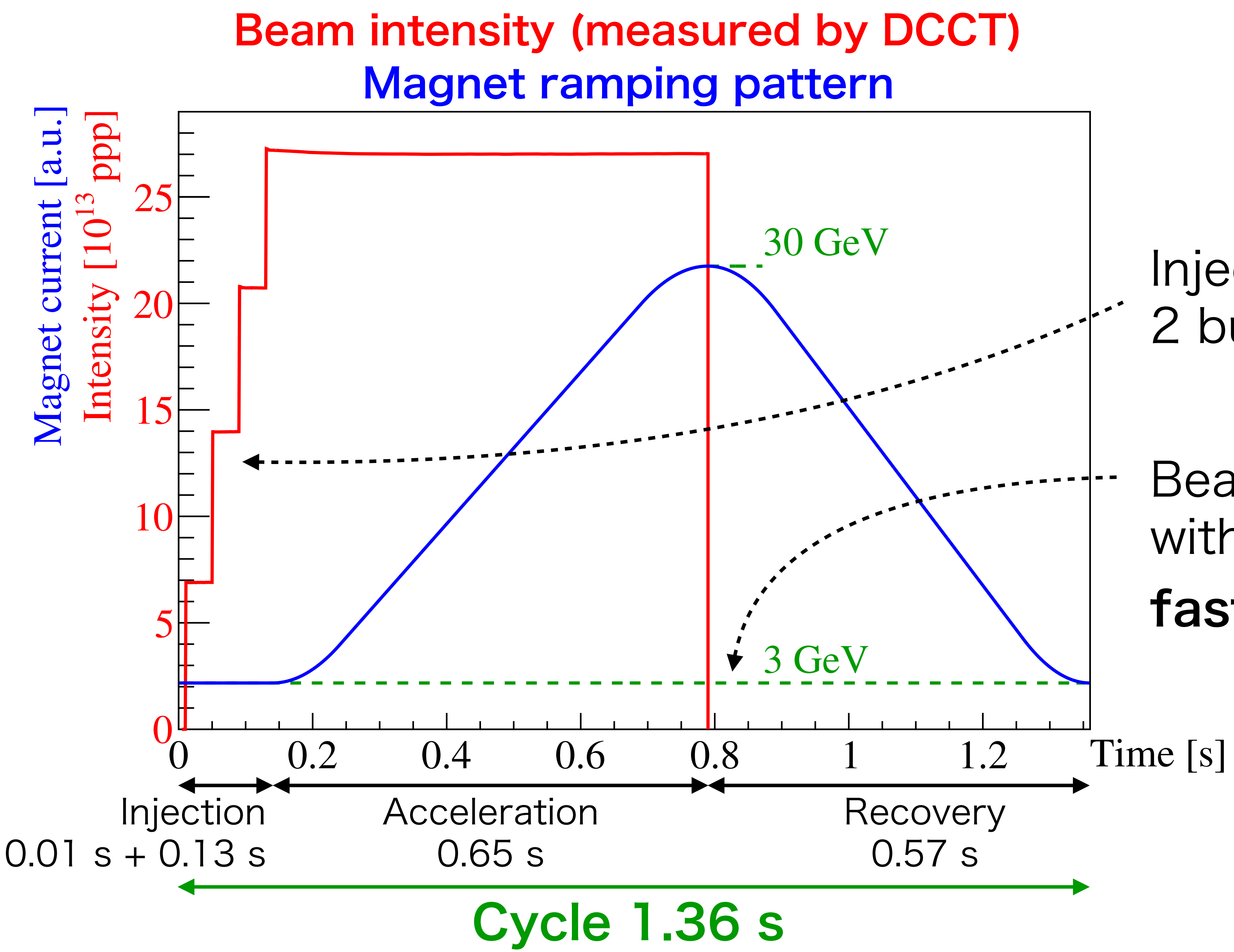
- From Nov. 2025

  Modification of the beam optics to reduce the beam loss

- From Jan. 2026

  Shortening the cycle time from 1.36 s to 1.28 s

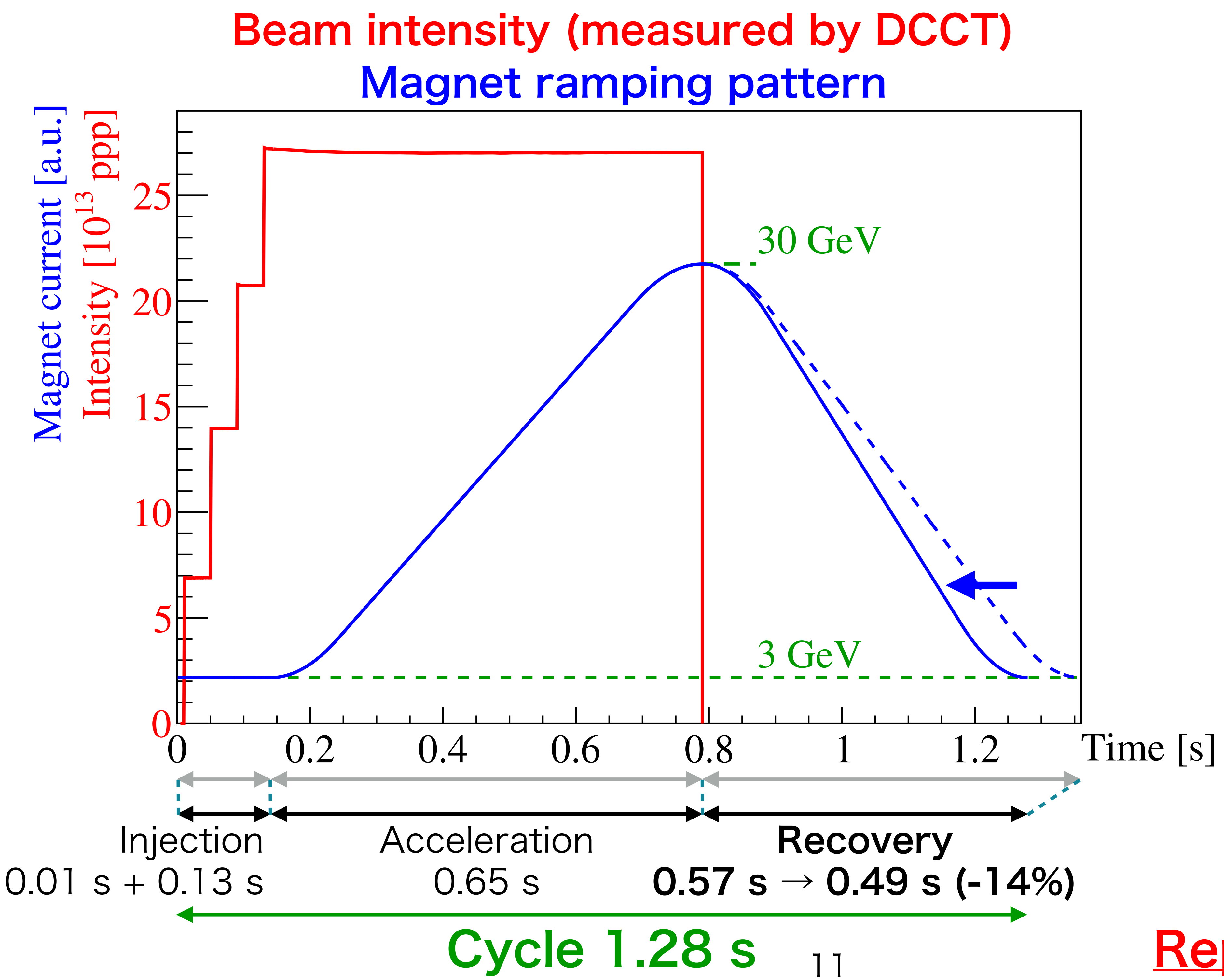
FX operation status by 2025



Injection:
2 bunches × 4 times

Beams are extracted within one turn:
fast extraction (FX)

FX operation status from 2026



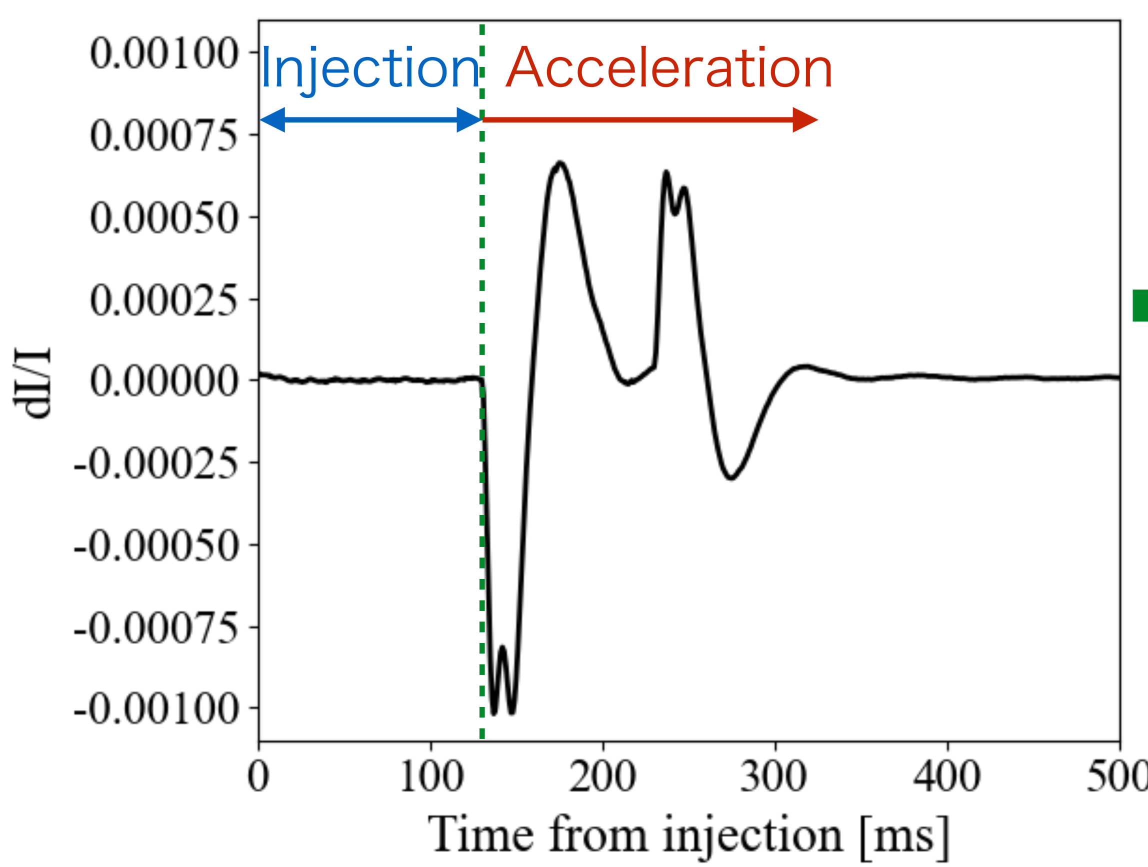
Rep. freq.: +6.25%

Reduction of systematic fluctuations of bend current

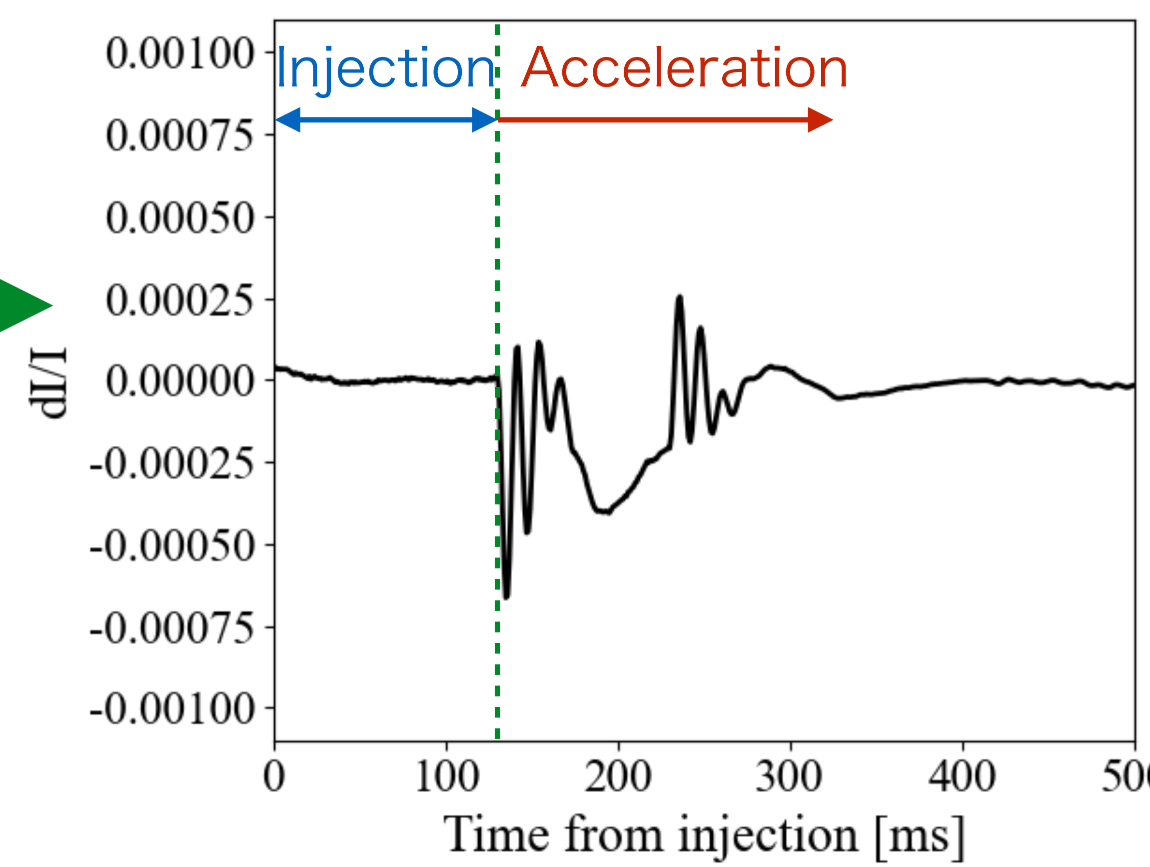
In 1.36 s cycle, the bending magnet current showed a systematic fluctuation at the beginning of acceleration period.

Despite the shorter cycle and the increased difficulty of tuning, the systematic fluctuation was successfully reduced.

1.36 s cycle



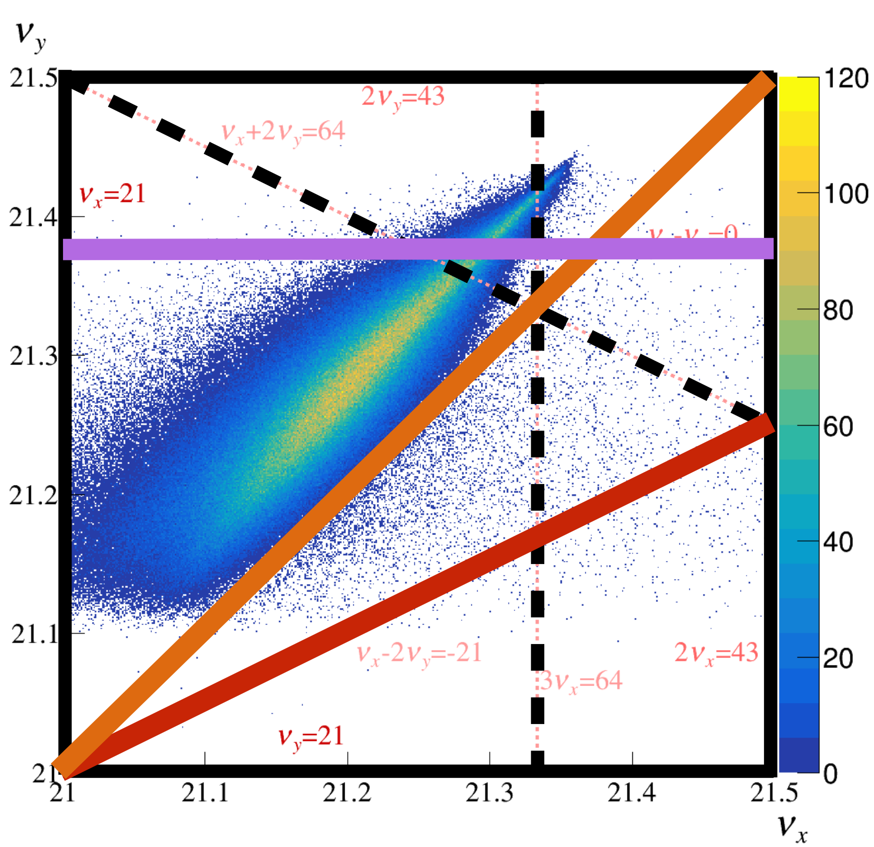
1.28 s cycle



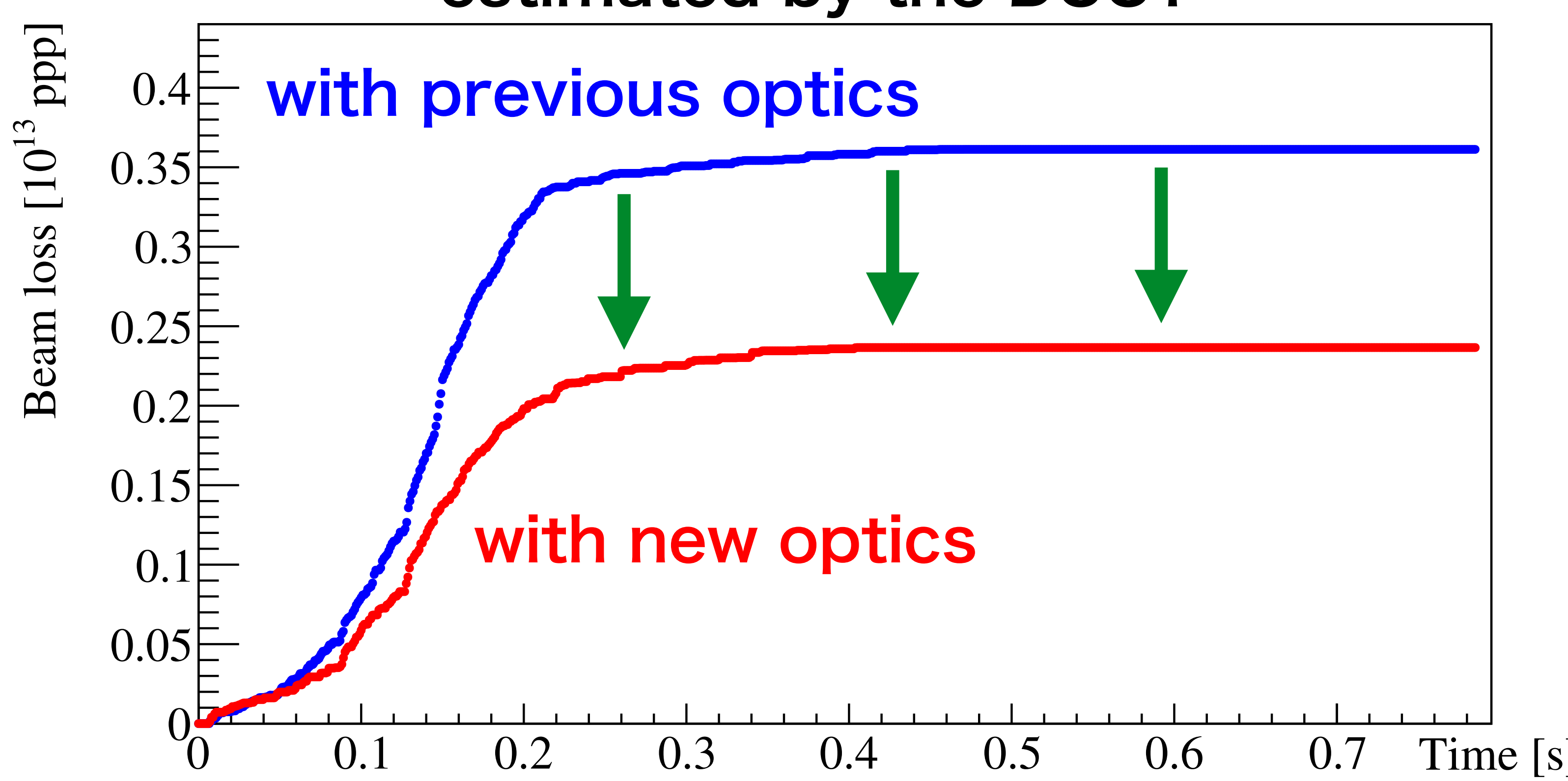
New beam optics

We developed a new beam optics to weaken structure resonances.

- $\nu_x - 2\nu_y = -21$ (driven by sext. field) T. Yasui *et al.*, PTEP **2022**, 013G01 (2022)
- $2\nu_x - 2\nu_y = 0$ (driven by space charge)
- $8\nu_y = 171$ (driven by space charge) T. Yasui and Y. Kurimoto, PRAB **25**, 121001 (2022)

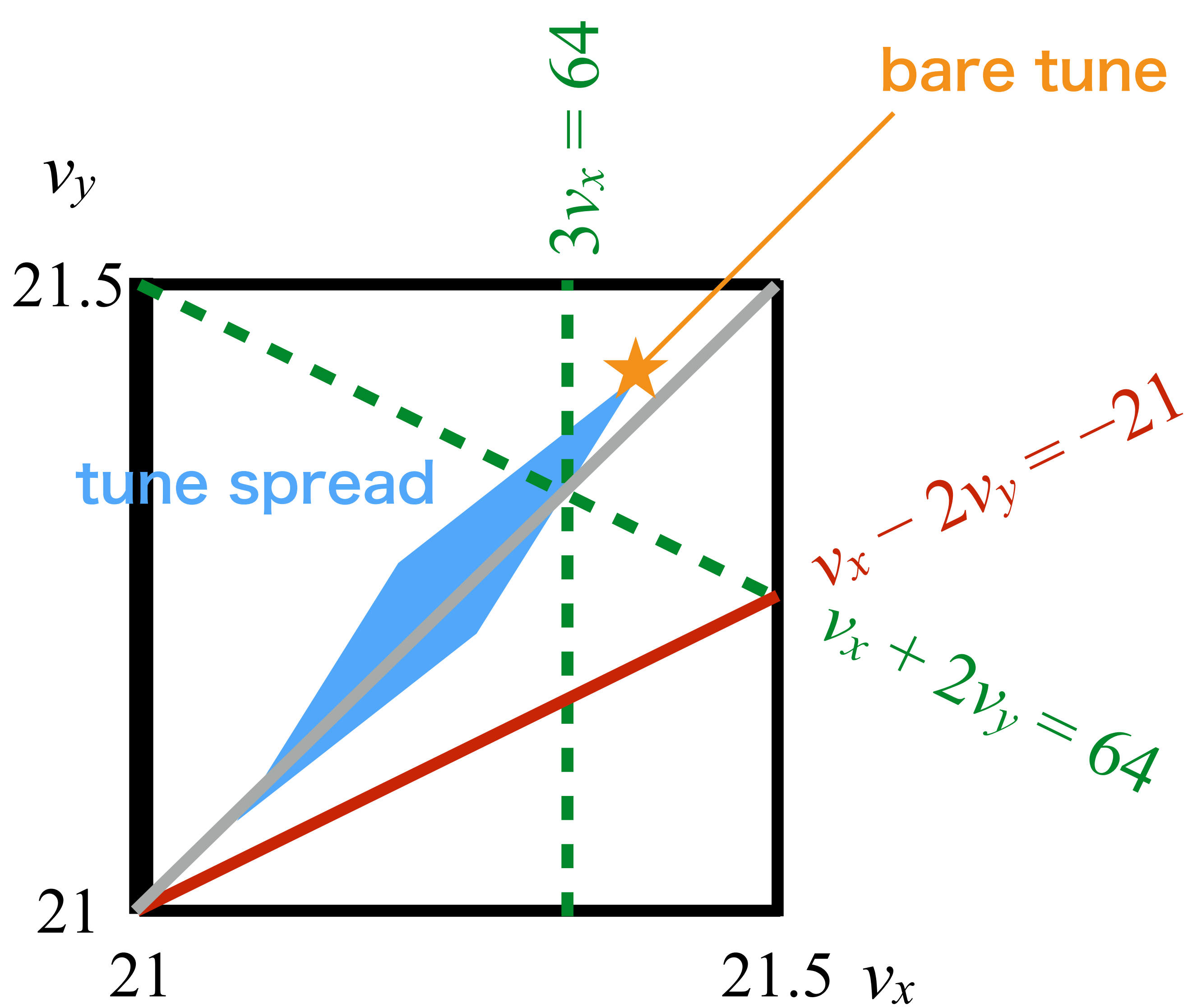


Beam loss of 830 kW beams estimated by the DCCT



Tune scan with the new optics

Taking advantage of the resonance $\nu_x - 2\nu_y = -21$ correction, we significantly changed the tune.



The bare tune must be placed so that the tune spread can avoid the black and red lines.

↓

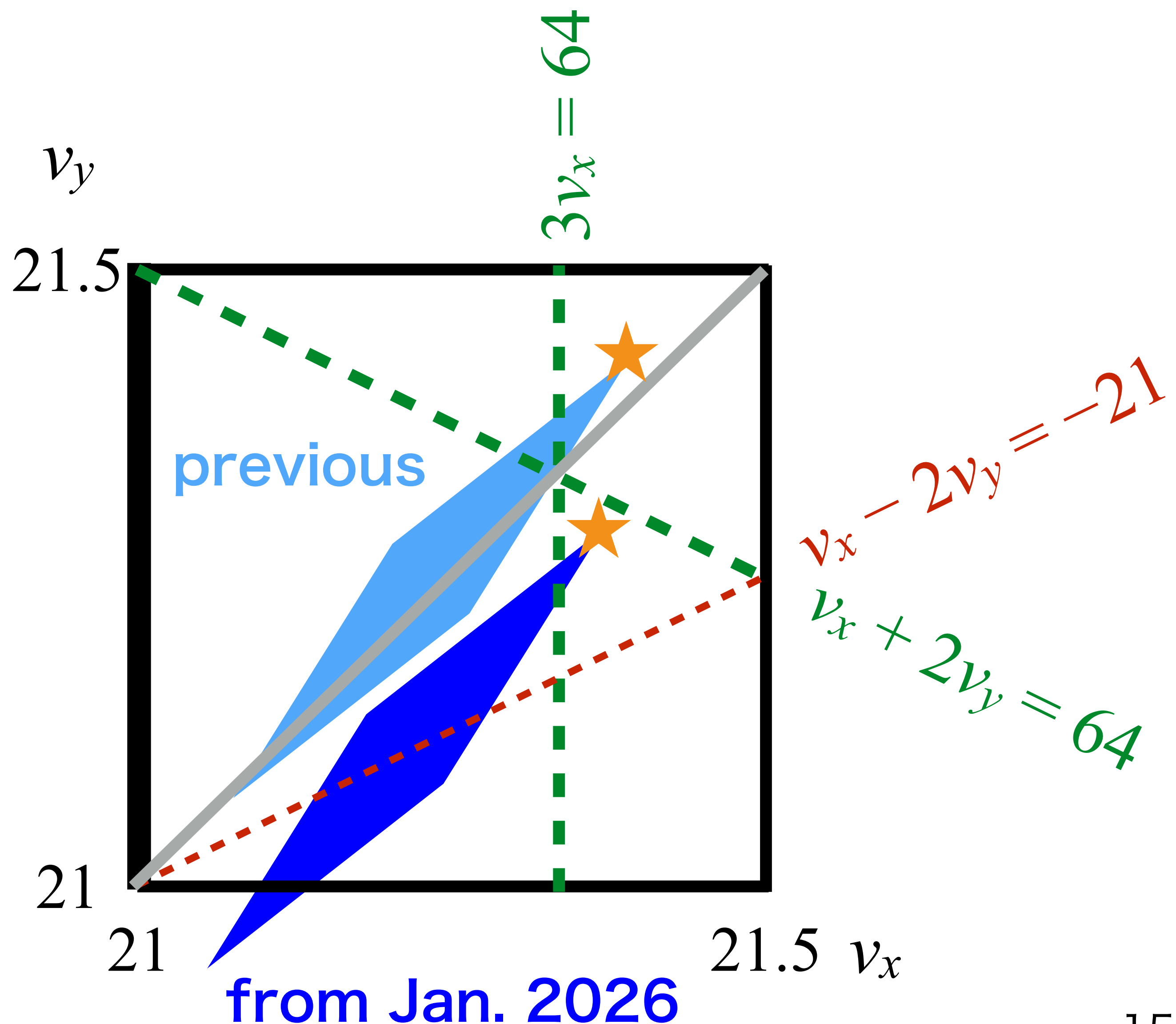
Impossible to avoid two green dashed lines.

↓

Two green dashed lines are the main source of beam loss.

Tune scan with the new optics

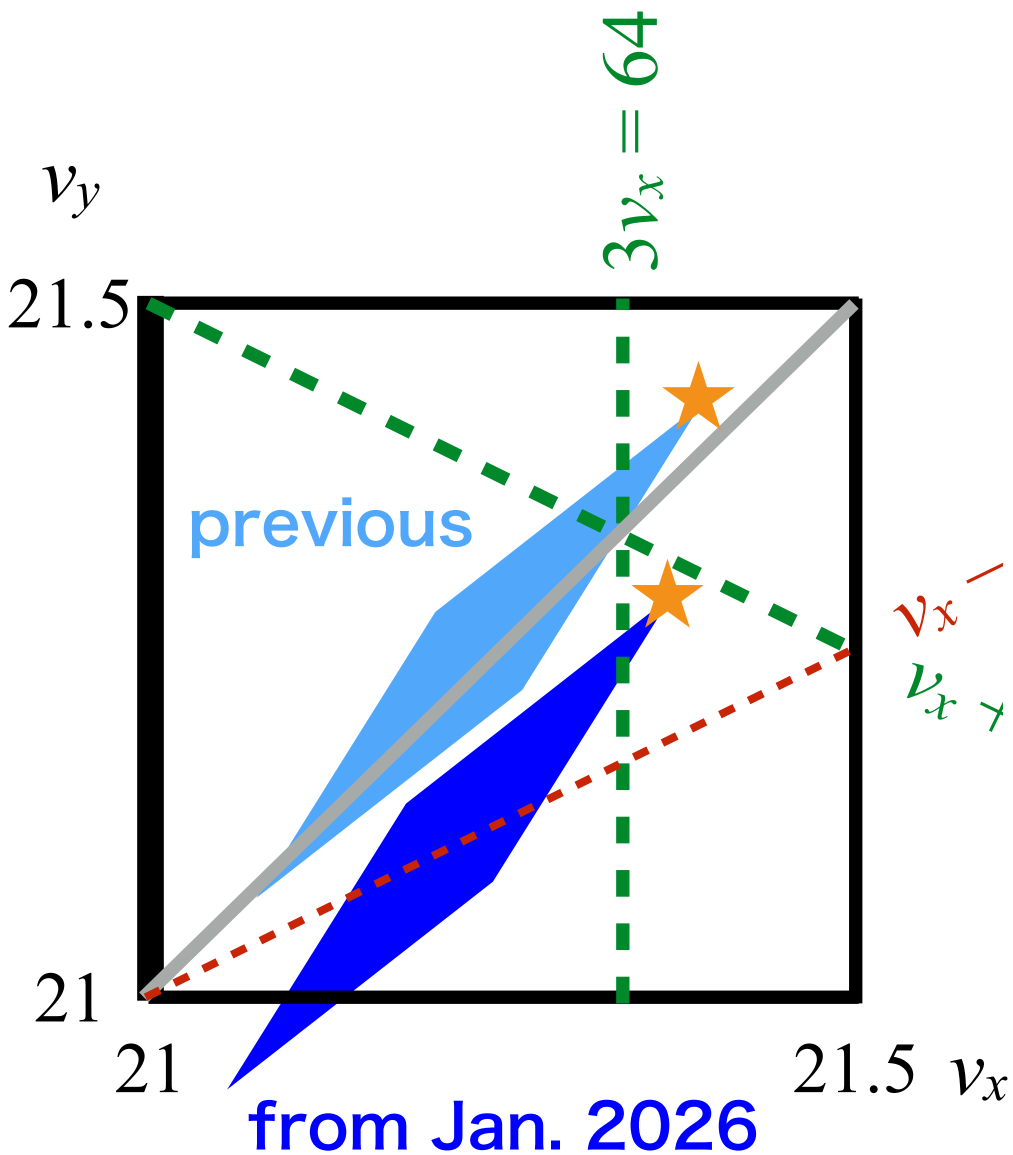
Taking advantage of the resonance $\nu_x - 2\nu_y = -21$ correction, we significantly changed the tune.

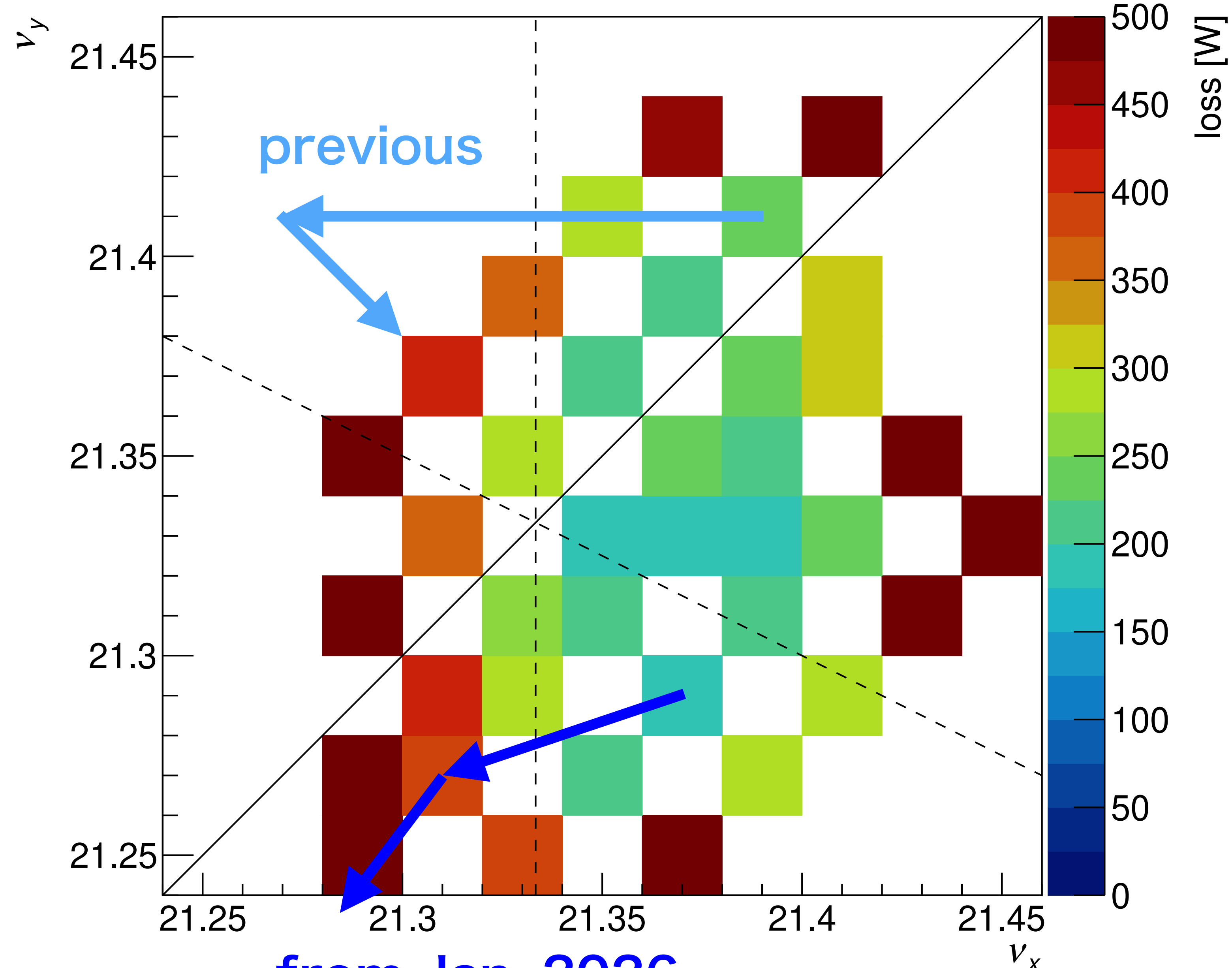


By significantly lowering the tune, we can avoid one of the green dashed lines.

Tune scan with the new optics

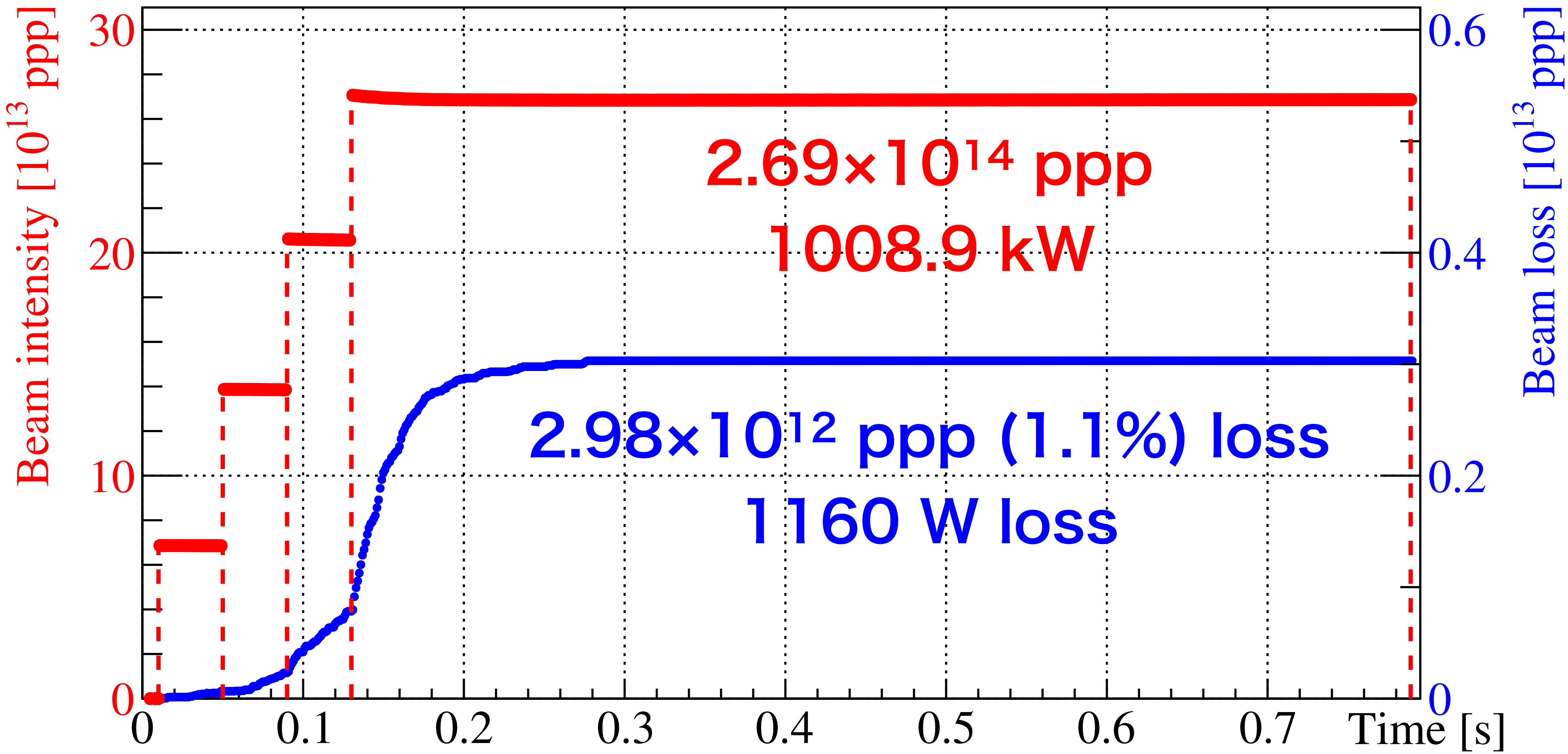
Taking advantage of the resonance $\nu_x - 2\nu_y = -21$ correction, we significantly changed the tune.





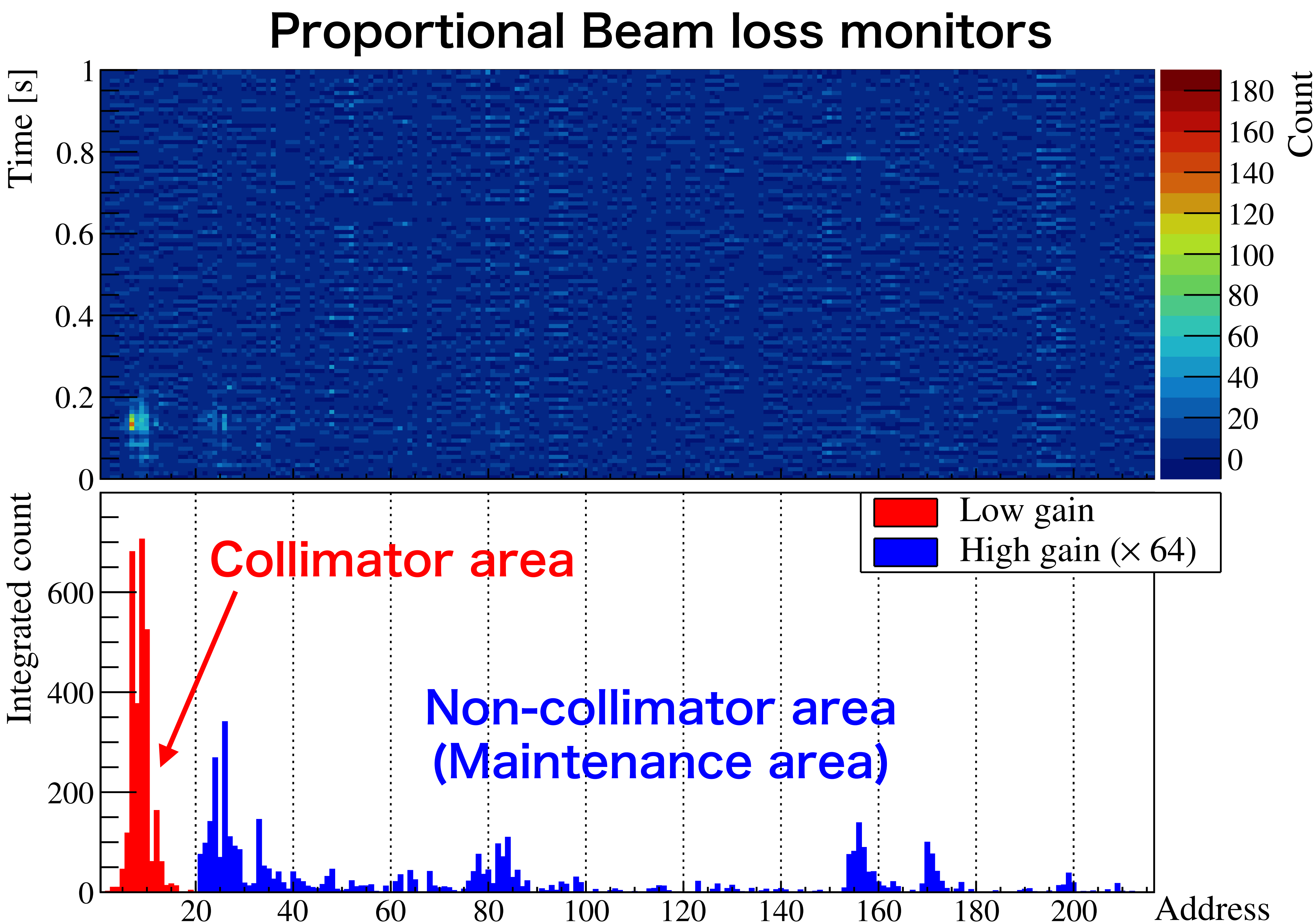
1 MW demonstration

Beam intensity and **beam loss** estimated by the DCCT



Beam loss at the neutrino beamline was also acceptable.

1 MW demonstration



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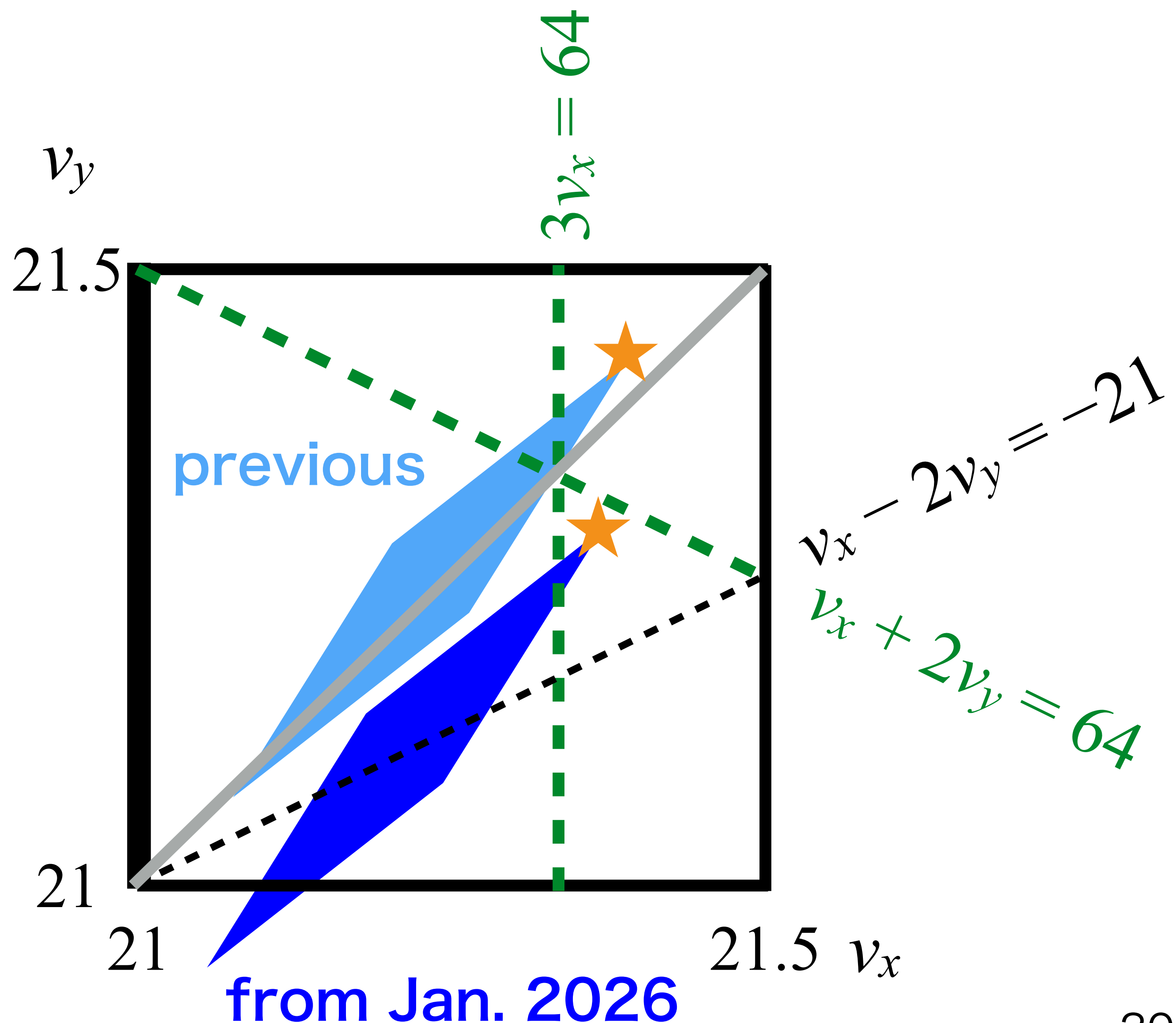
3rd nonstructure resonance

The main sources of the beam loss are the resonances $3\nu_x = 64$ and $\nu_x + 2\nu_y = 64$. They are simultaneously corrected by 4 trim coils of sextupoles, but the correction is still insufficient



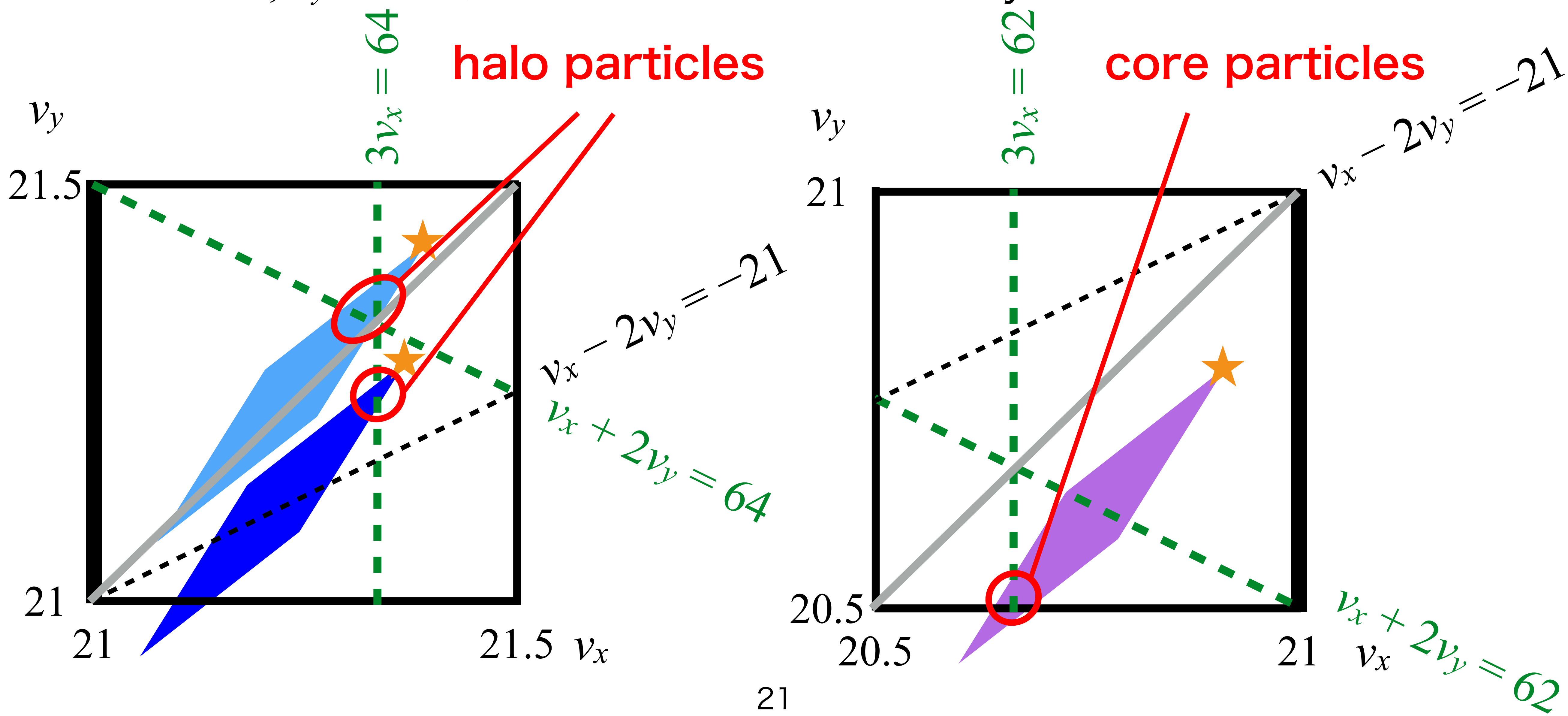
because ⋯

- Resonances are uncorrected during the acceleration period in practice.
- Resonances are not fully corrected for off-momentum particles.

Idea 1: Under 21 optics

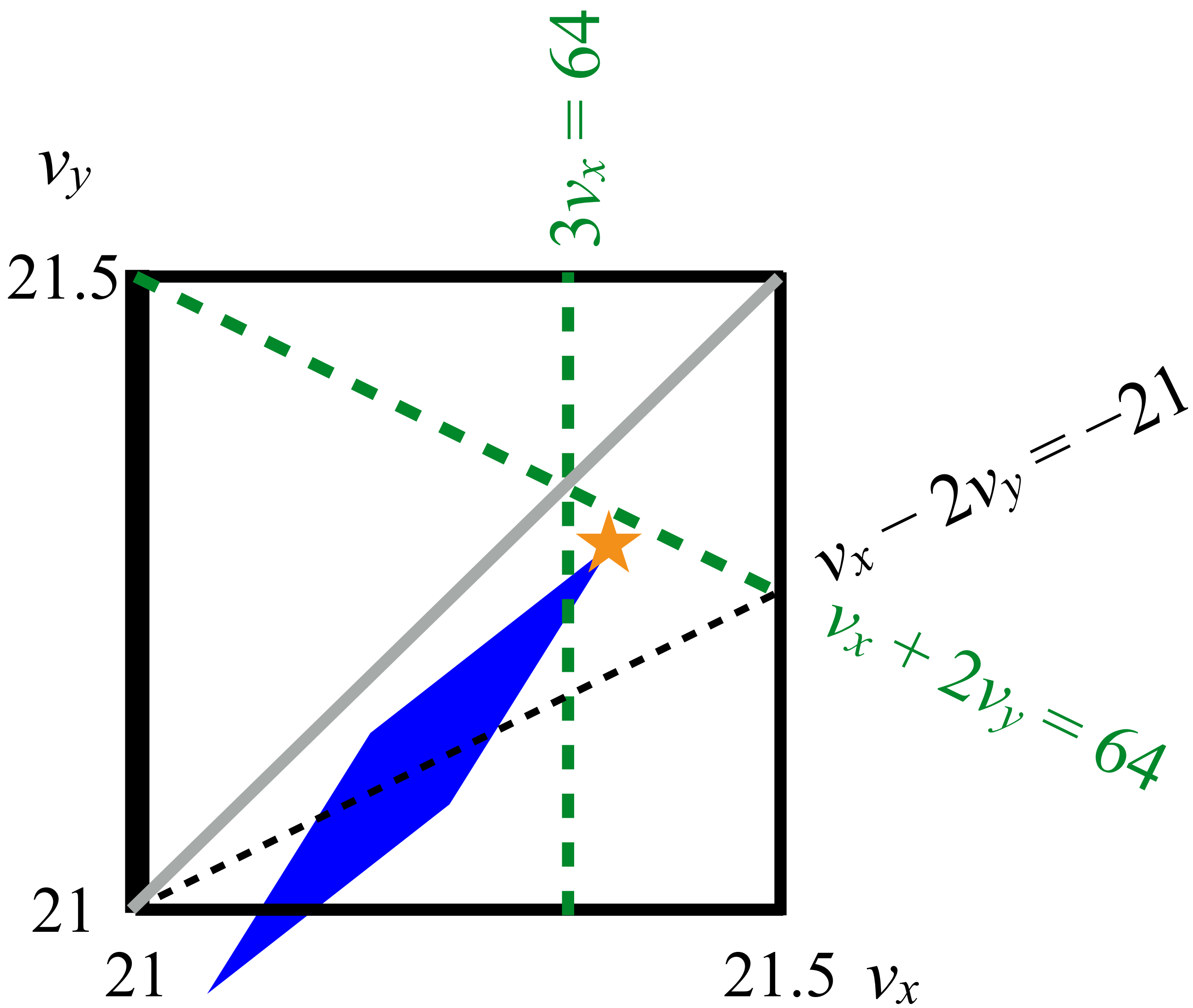
The effect of resonances on the halo particles is much larger than that on the core particles.

In $20.5 < \nu_x, \nu_y < 21.0$, the tune can be set away from 3rd resonances.

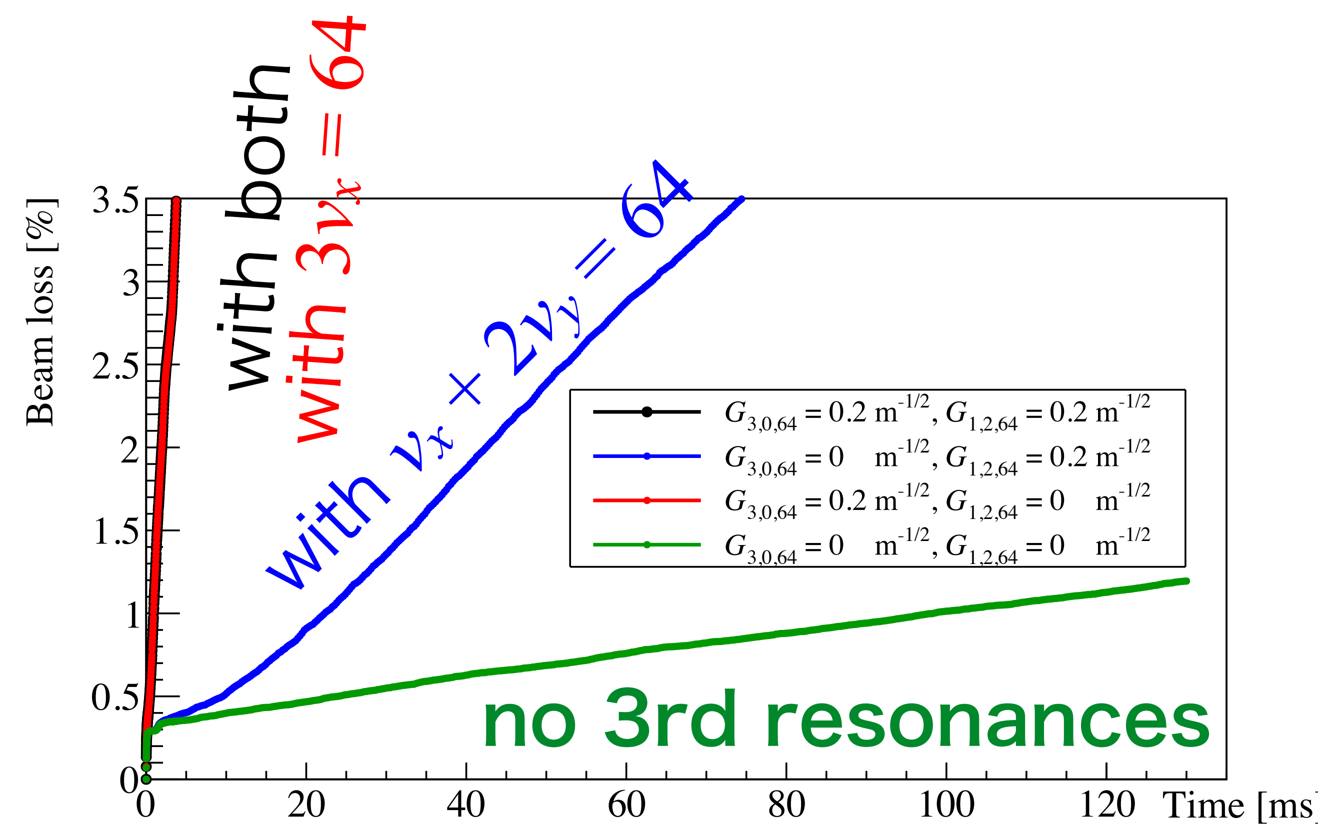


Idea 1: Under 21 optics

Resonance $\nu_x + 2\nu_y = 64$ has a significant impact on beam loss.
The impact of resonance $3\nu_x = 64$ is even larger.

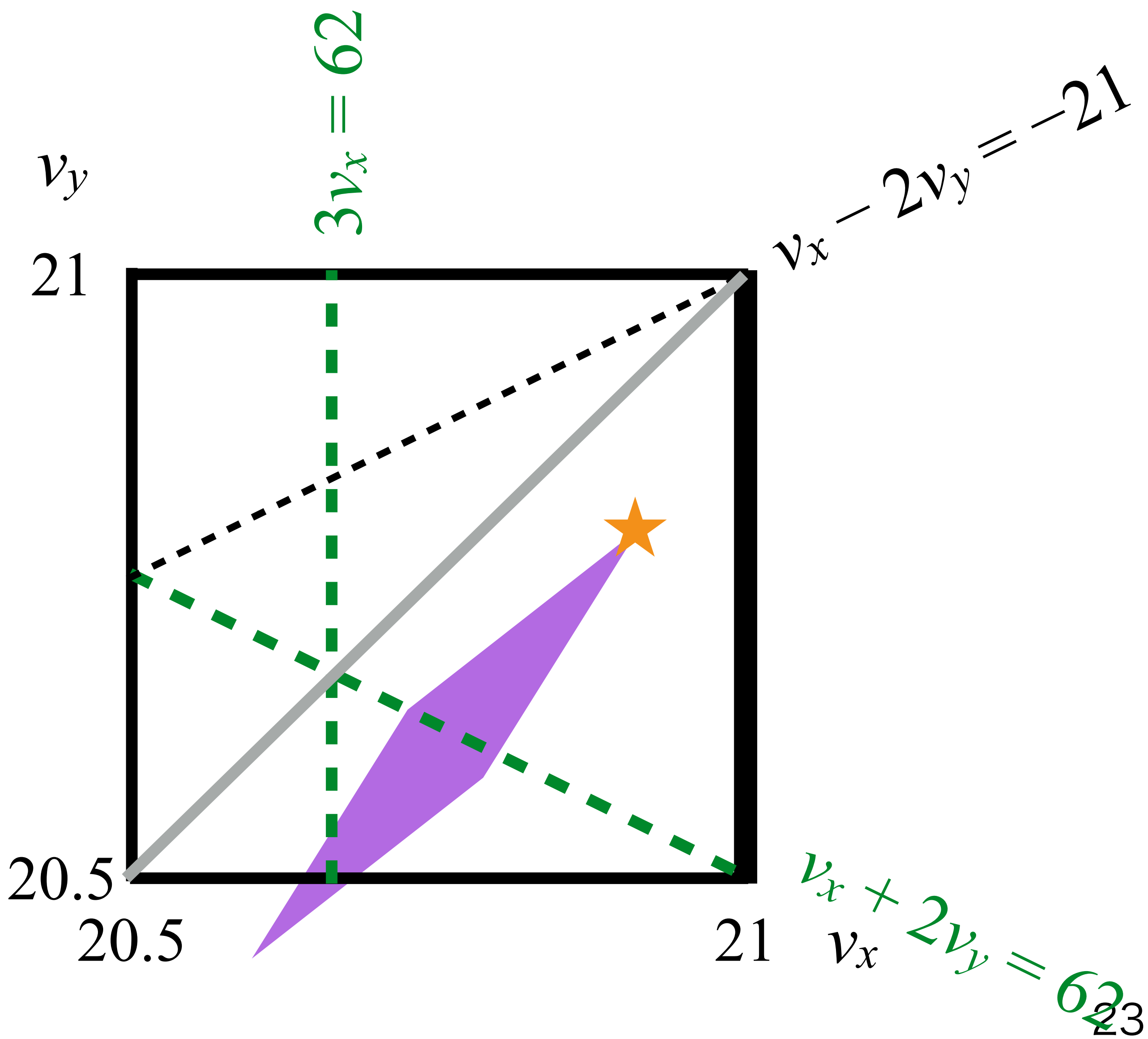


Beam loss (simulation)

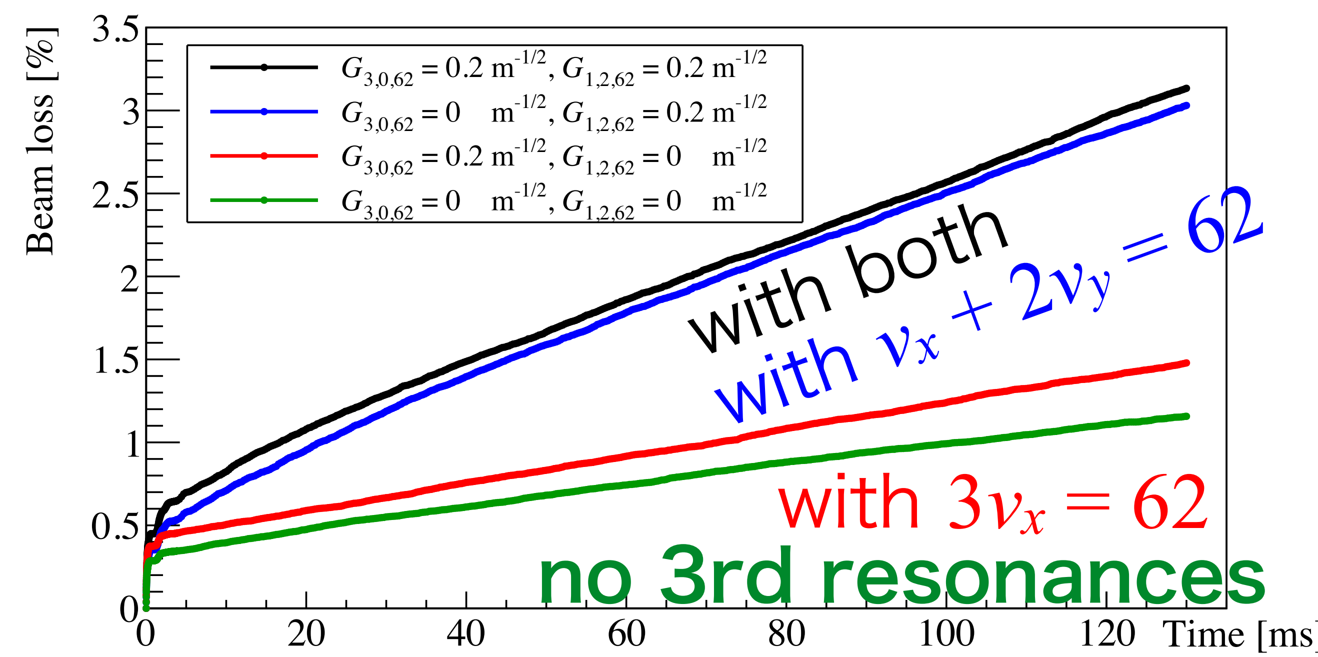


Idea 1: Under 21 optics

Resonances $3\nu_x = 62$ has little effect on the beam loss.
The effect of resonances $\nu_x + 2\nu_y = 62$ is also limited.



Beam loss (simulation)



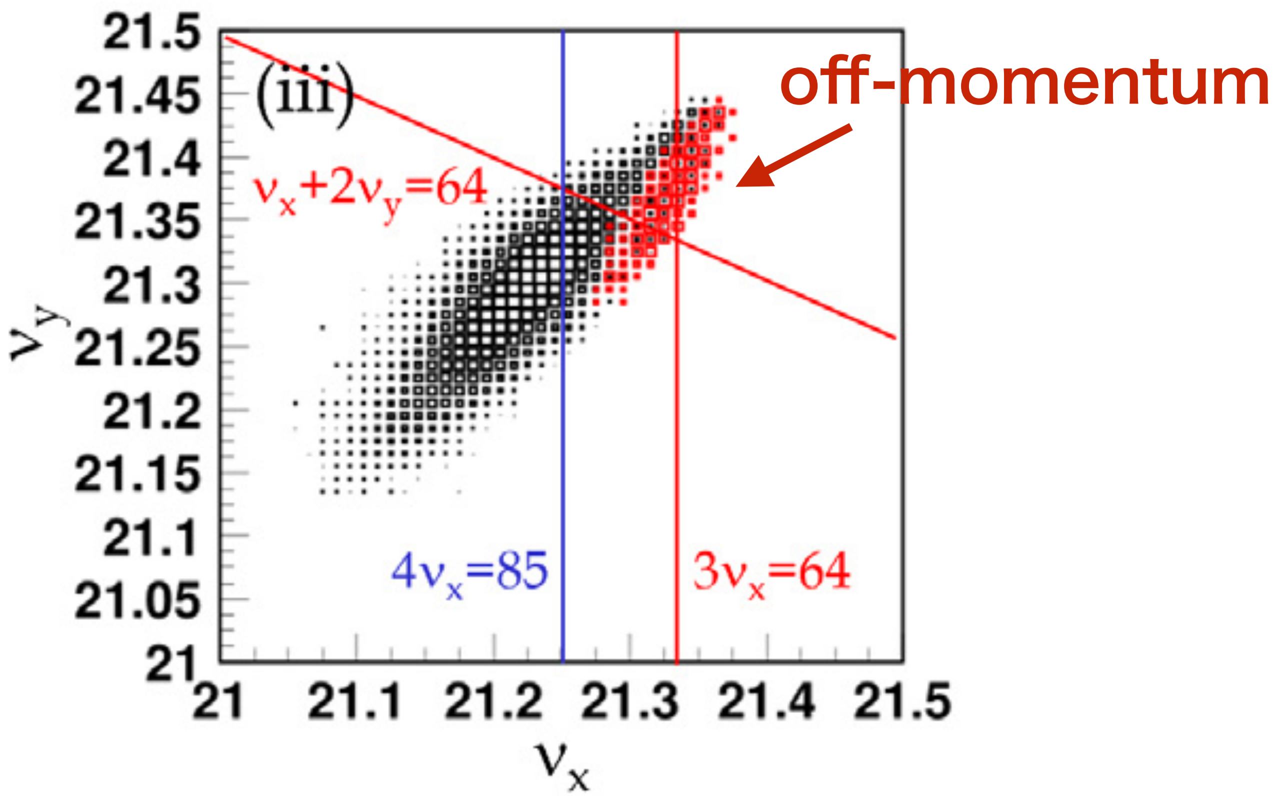
Idea 2: upgrade trim sext.

We are currently using trim coils of 4 sextupole magnets.

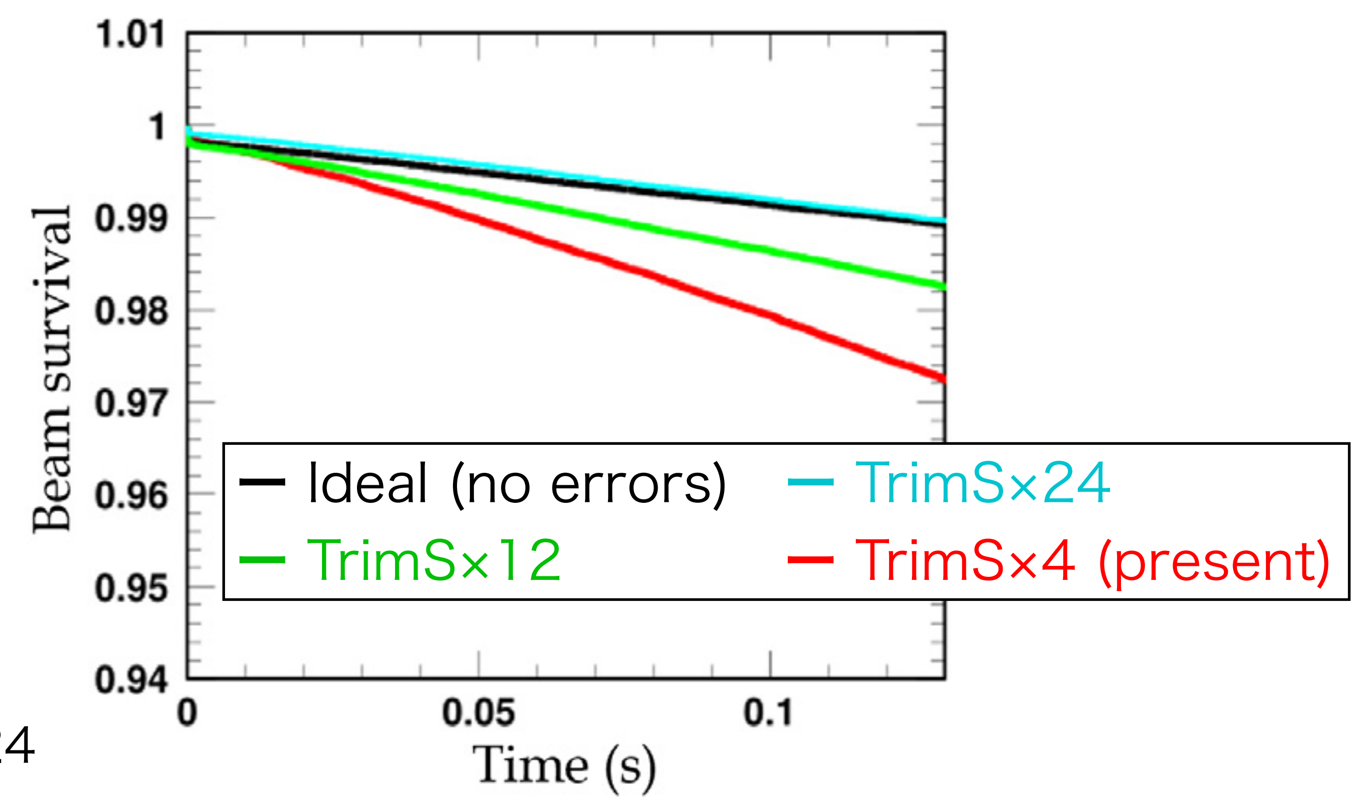
In principle, by increasing the number of trim coils, it is possible to extend the correction to off-momentum particles.

Tracking simulations suggest that the beam loss can be reduced by increasing the number of trim coils to 24.

Simulations of tune spread



Simulations of beam survivals



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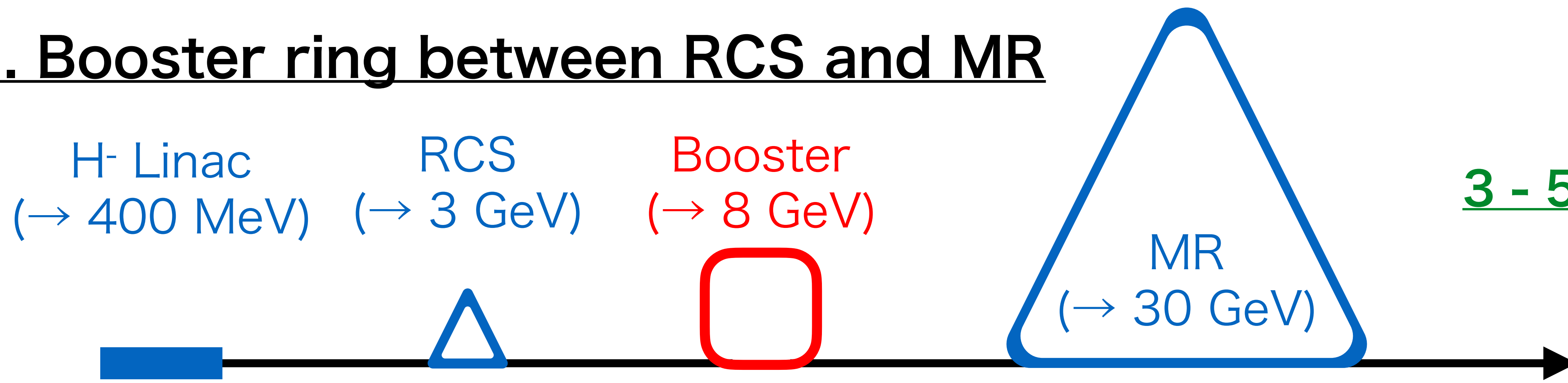
Over 1.3-MW plan

Plan 0. RCS beam power upgrade

RCS beam power is planned to be upgraded to 1.5 MW.
In MR, we are studying how to receive RCS-1.5 MW beams.

>1.3 MW

Plan 1. Booster ring between RCS and MR

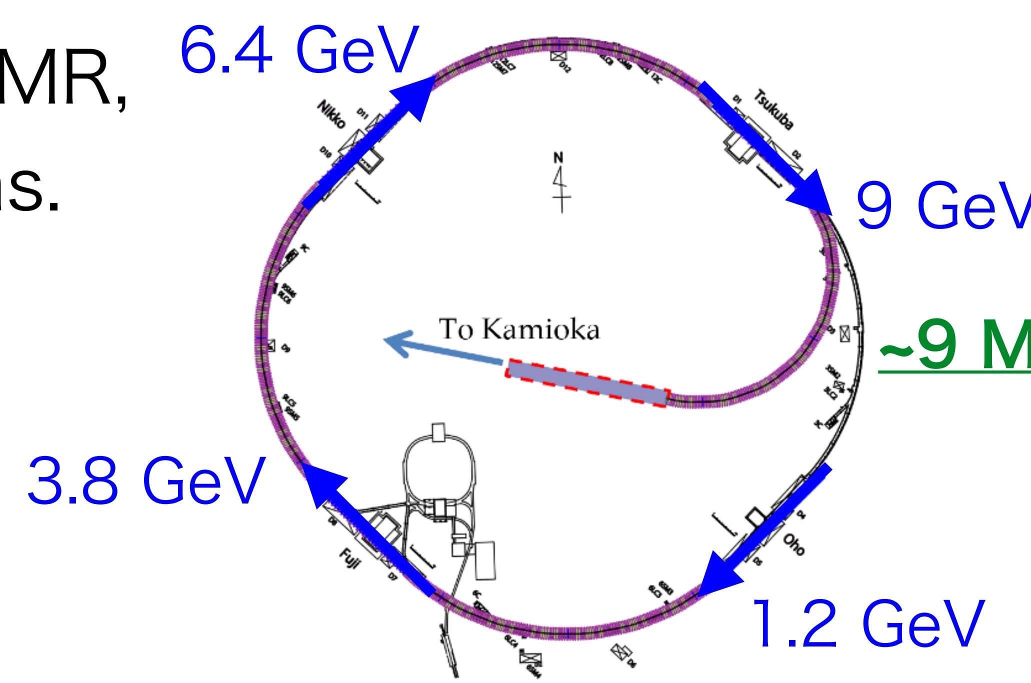


3 - 5 MW

By increasing the injection energy to MR, MR can receive higher intensity beams.

Plan 2. Reuse Super-KEKB tunnel

Use the tunnel as a proton linac.



~9 MW

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Summary

Since Nov. 2025, we have adopted a new beam optics that can suppress the structure resonances.

In Jan. 2026, the cycle time was shortened to 1.28 s.

In Feb. 2026, we successfully demonstrated a 1 MW beam. The beam loss was about 1.1 kW, which is acceptable for continuous operation.

Further reduction of beam loss requires addressing the third-order resonances. One approach is to lower the tune below 21 to avoid the resonances. Another approach is to increase the number of trim coils.