

The Machine Protection System of the J-PARC Main Ring

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Introduction

- In J-PARC MR, Machine Protection System (MPS) is required for reducing beam loss by immediate beam abort and stopping beam operation.
- In 2017, a high-speed beam abort system (under 1ms) was available in MR.
- For Further speed up of MPS, we have considered to speed up the interlock signal transmission in MR components (Magnet, RF system, Extraction system...).
- Recently, we succeeded in speed-up of MPS in RF system.

Today, I talk about **the outlines of the MPS of J-PARC MR** and **how to speed up the MPS in RF system.**

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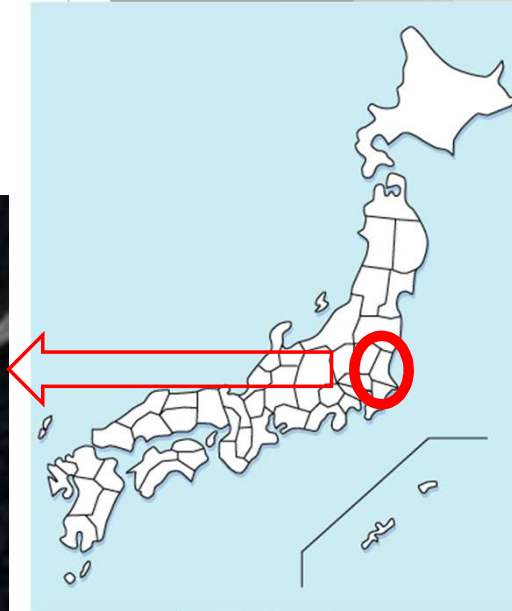
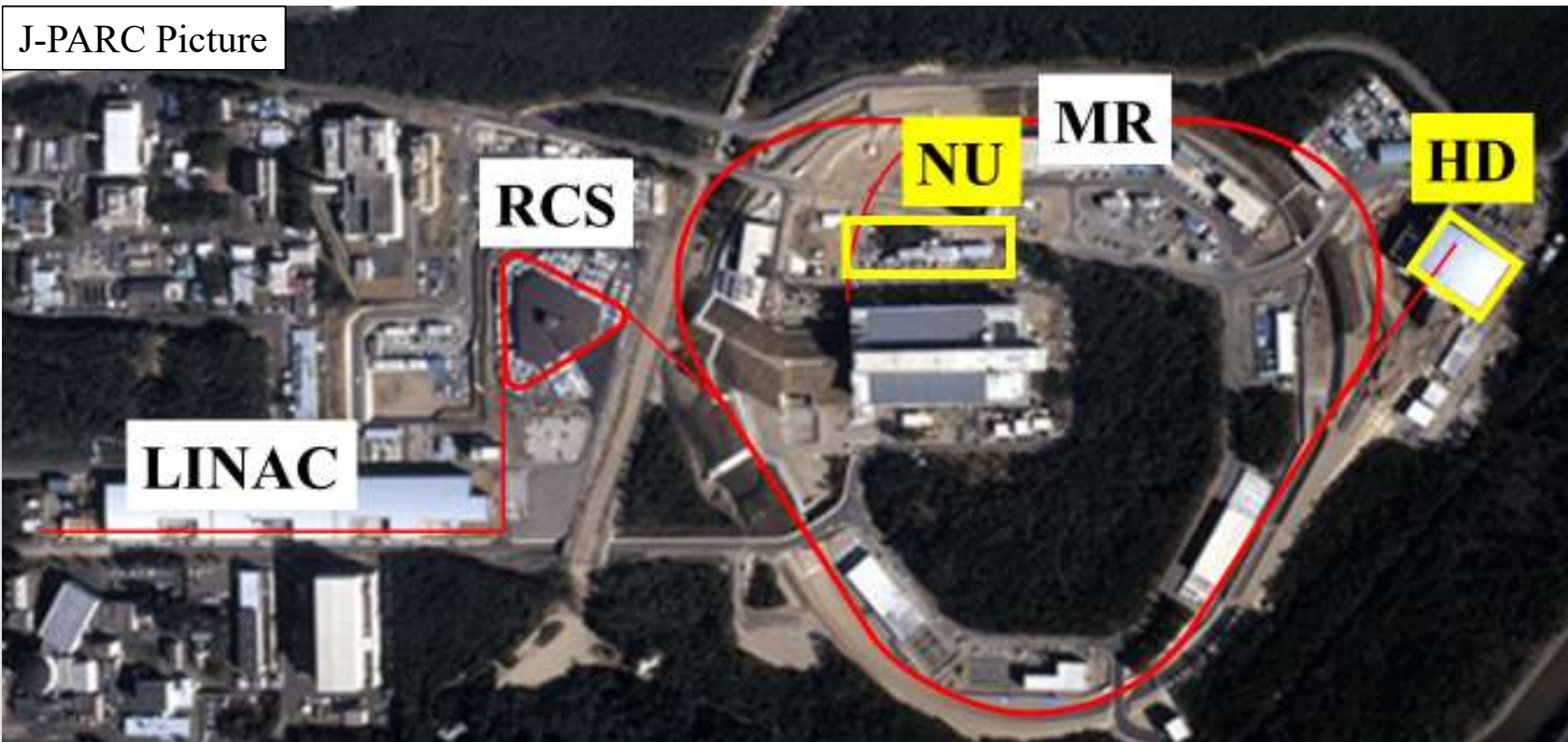
- ▶ J-PARC (Japan Proton Accelerator Research Complex) Main Ring
- ▶ J-PARC MR MPS (Machine Protection System) and Abort Extraction System Outline
- ▶ MPS improvement in MR RF systems
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J-PARC Main Ring (MR)

- ▶ J-PARC is composed of a linac and two synchrotrons.
- ▶ J-PARC MR supplies the proton beam to NU and HD.

J-PARC Picture



In Ibaraki, Japan

J-PARC MR Parameters

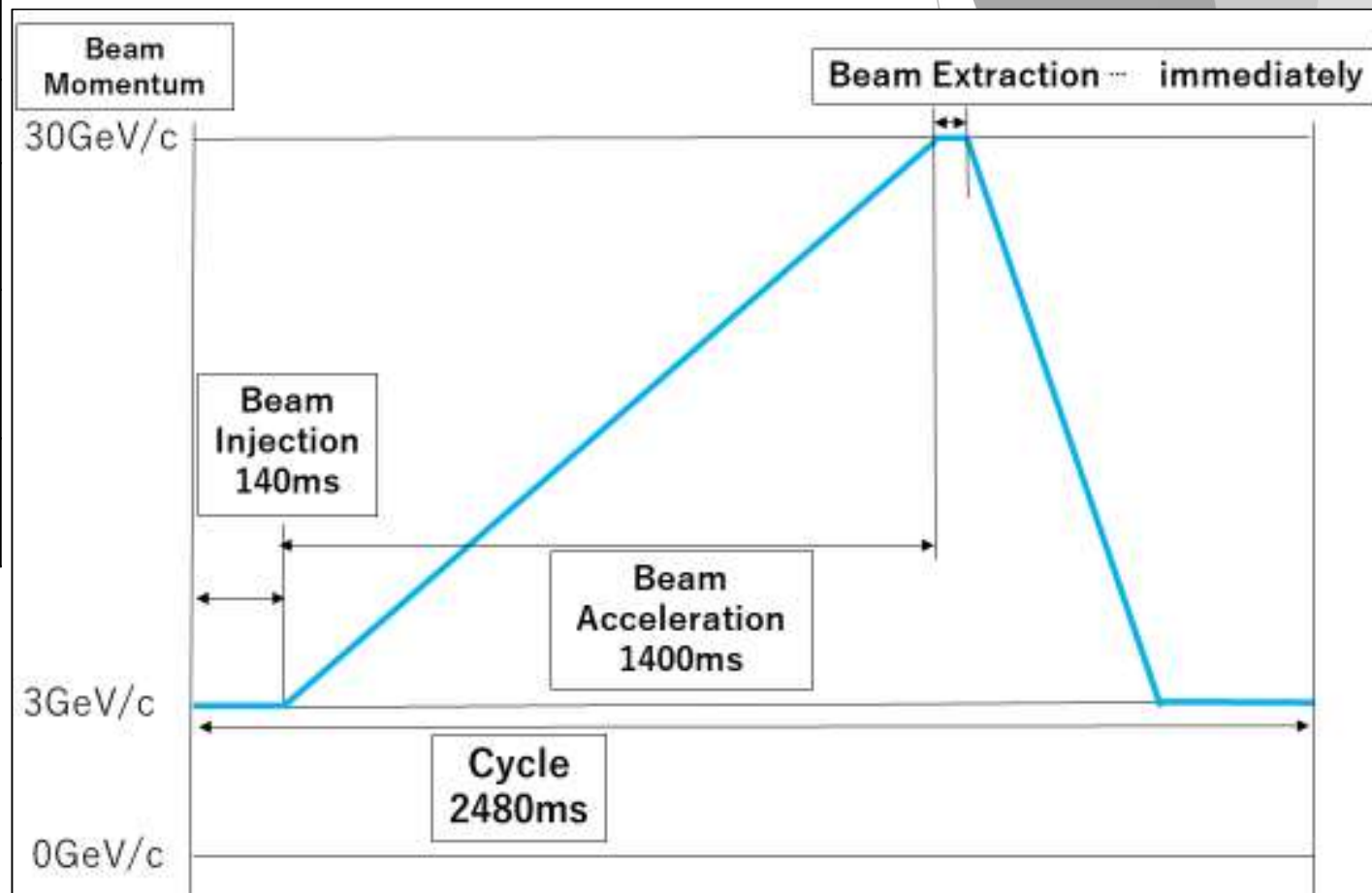
	MR
Particle	Proton (H ⁺)
Circumference	1567.5m
Extraction Energy	30GeV
Repetition	<u>2.48s (FX)</u> 5.20s (SX)
Destination	<u>Nu Experiment (FX)</u> HD Experiment (SX)

There are several destinations of the proton beam.



Acceleration cycle changes according to destinations.

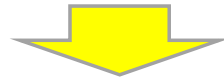
Fast Extraction (FX) …one of the MR acceleration cycles



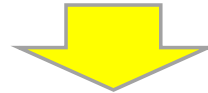
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The Role of MPS in MR

When the MR equipment does not function properly, beam abnormality (Beam loss etc.) occurs.

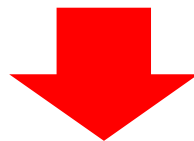


If the beam loss occurs, particles stray away from the orbit and collide with the equipment in MR.



If the beam loss continues, damages to MR components and surrounding facilities by activation are considered.

Therefore, it is necessary to **receive failure signal** of components and **prevent damages to MR components**.



This system is called **MPS**

Type of MPS events

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Components' MPS

- It manages interlock signals from MR components (Magnet, RF components, etc.).
- It transmits signals when abnormality occurs in MR components.

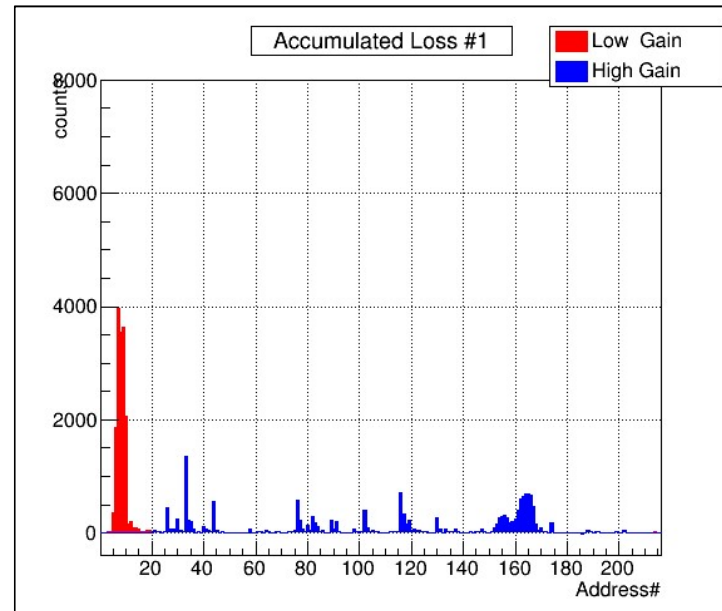
Beam Loss Monitor (BLM) MPS

- It manages interlock of BLM.
- When it exceeds the threshold of beam loss at MR position, it transmits a signal.



MR BLM ... Proportional Counter

- There are 216 BLM in MR.
- Every BLM has a unique address.



BLM during MR position

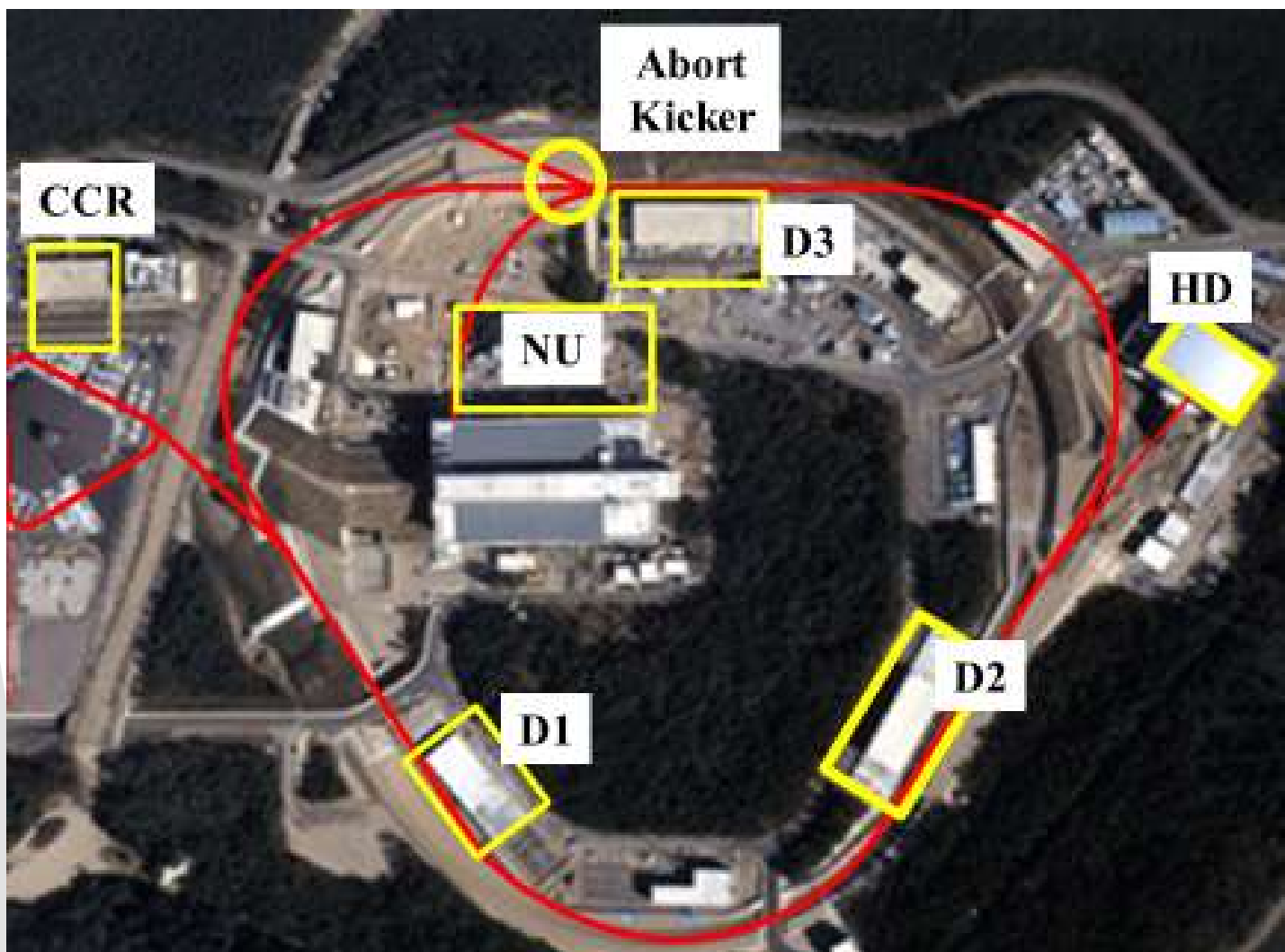
Horizontal axis

⇒ BLM address (1~216)

Vertical axis

⇒ Beam loss amount

The Layout of MR MPS

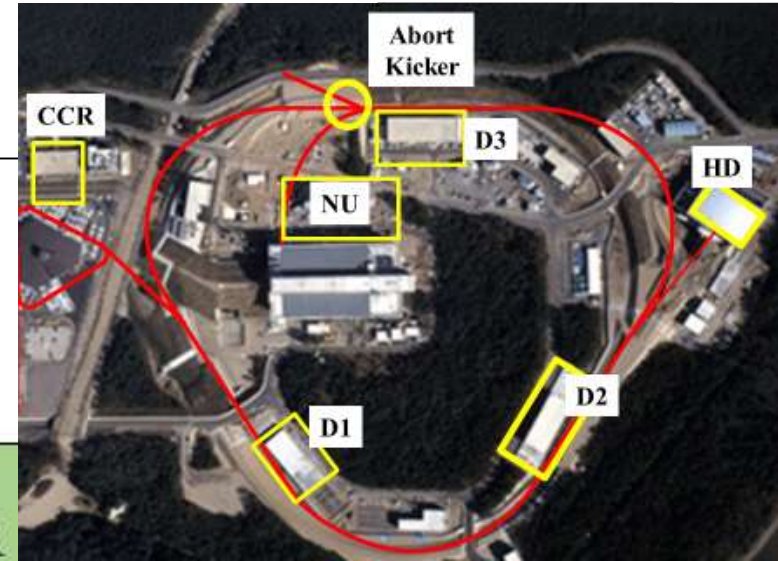
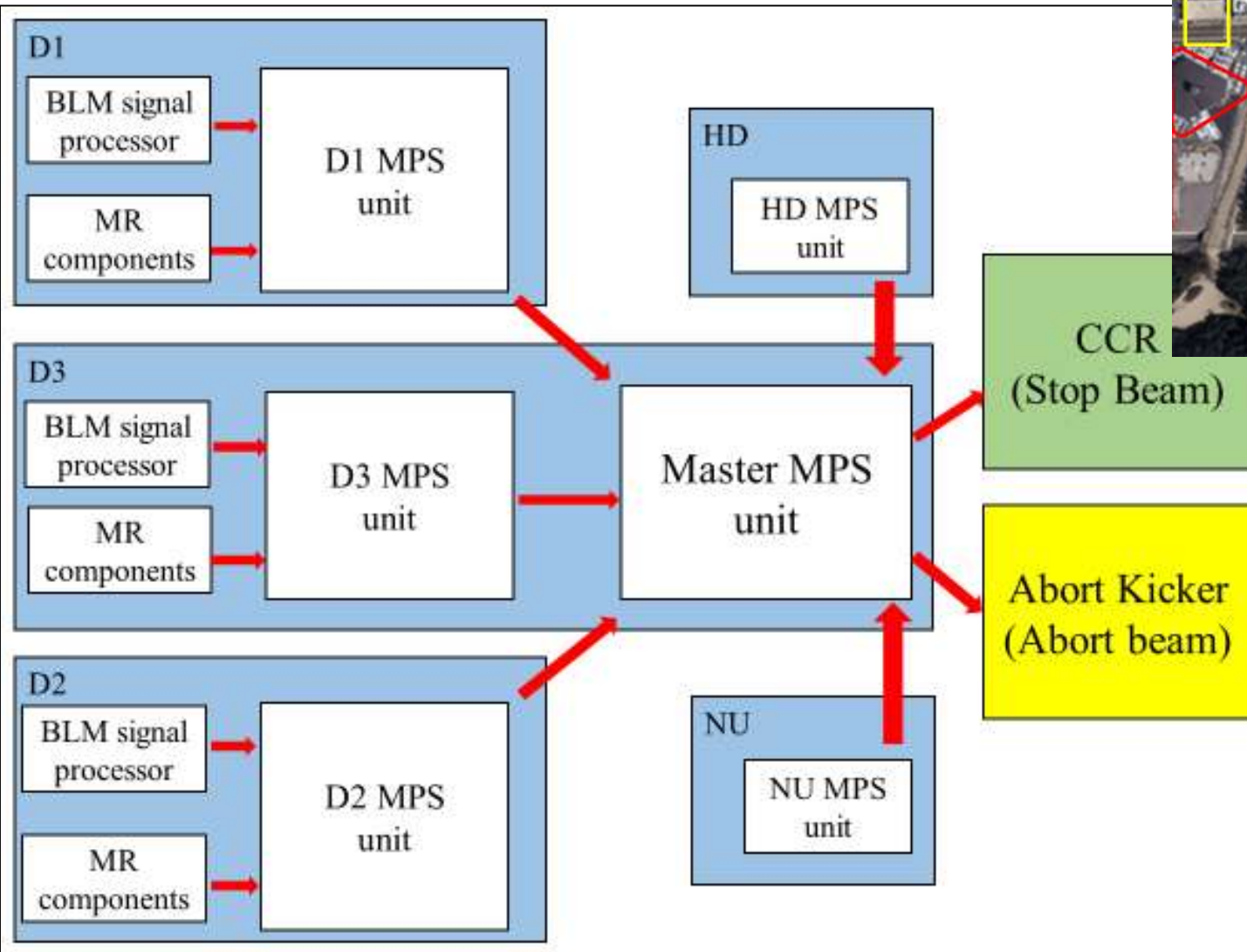


MR is large (1568m), and there are many components.



Interlock signals are received in three power supply buildings (D1, D2, D3), NU and HD.

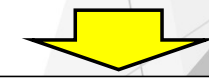
The Signal Flow



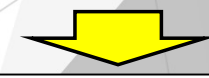
① MR components or/and BLM make an interlock signals.



② D1, D2, D3 MPS units receive signals.

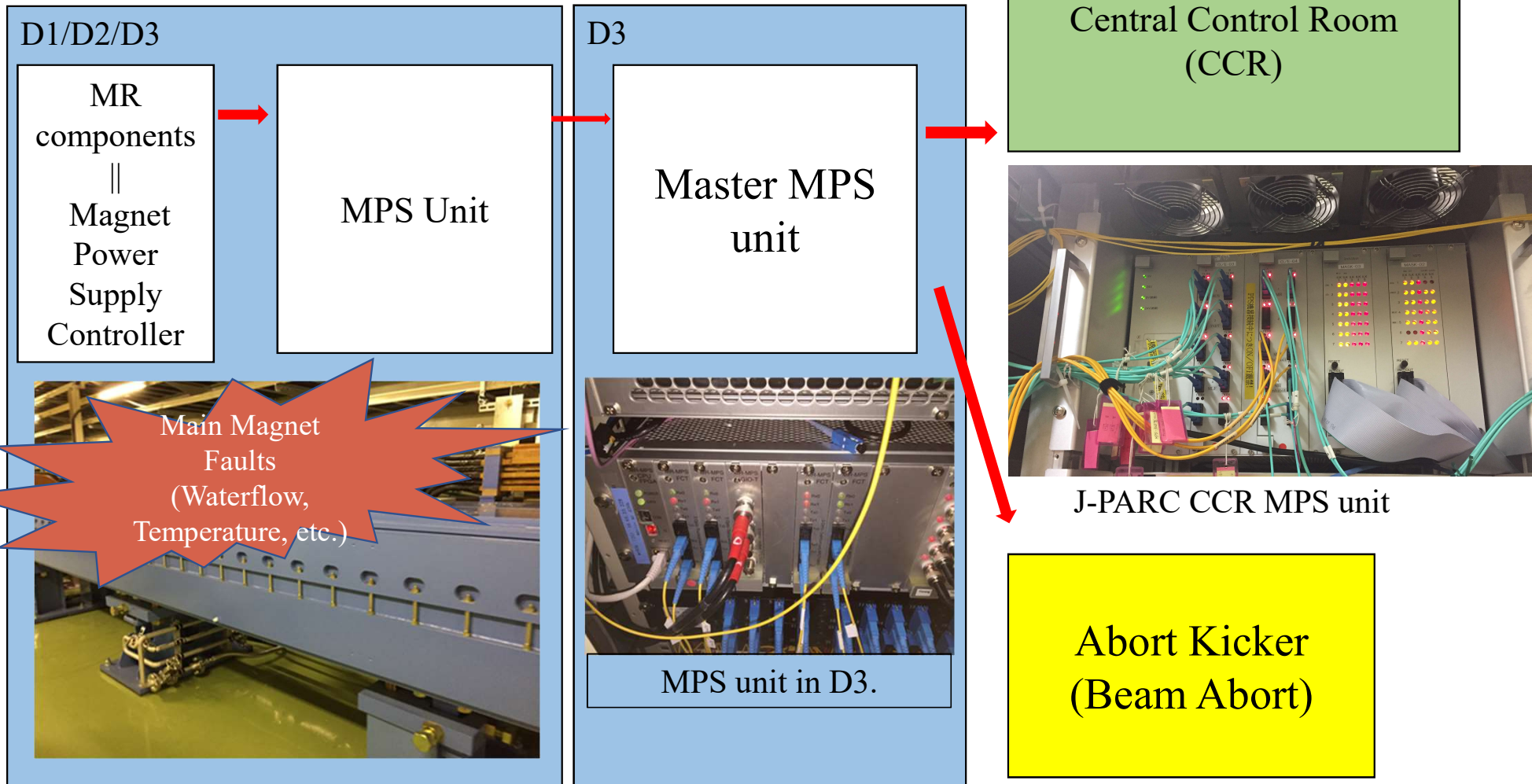


③ The Master MPS unit collects signals.



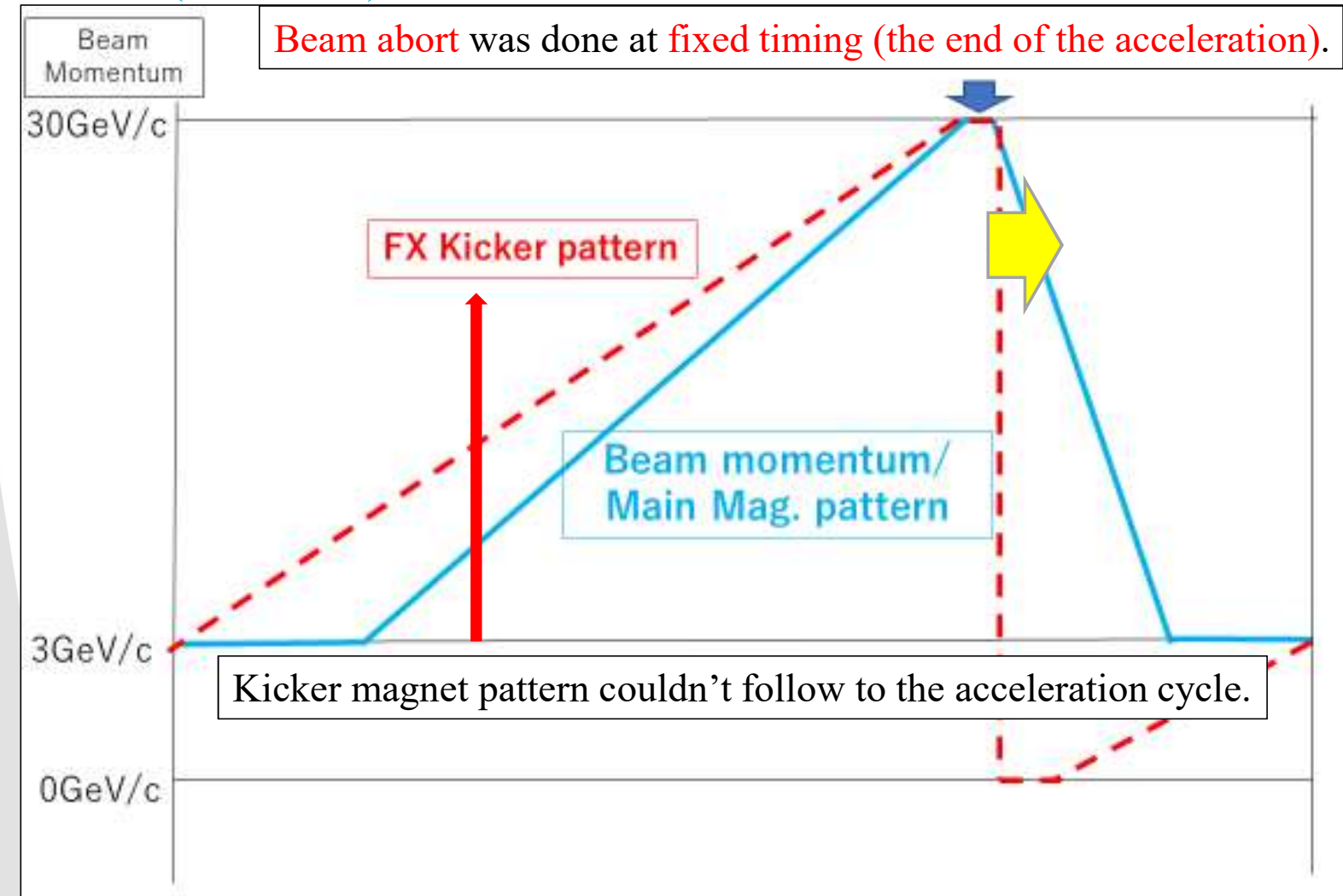
④ CCR receives signals to stop beam operation and abort kicker receives it to abort beam.

Example...The Case of MR Main Magnet



MR Abort Extraction System

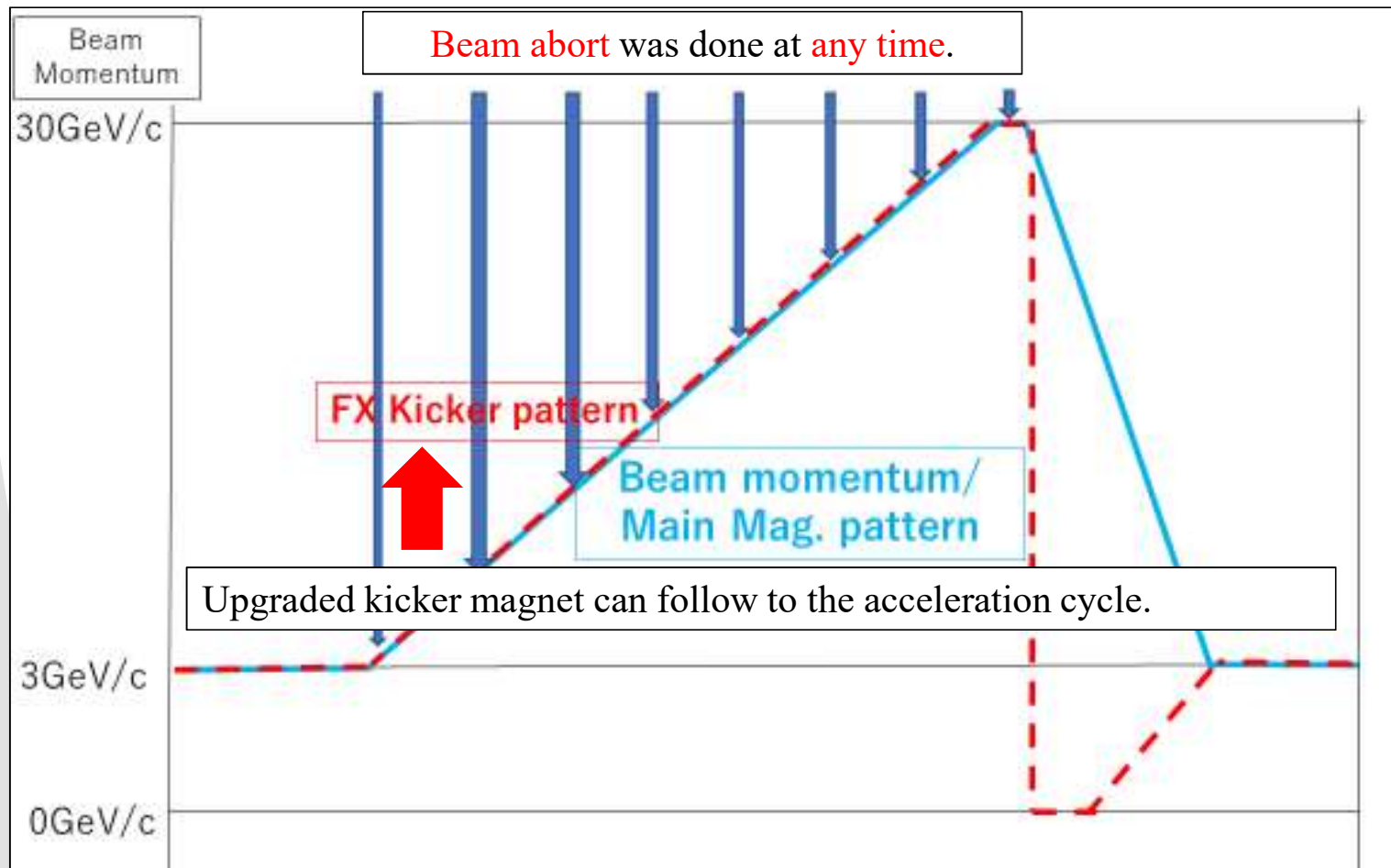
Before (~2017/10)



Depending on the fault timing, it was necessary to wait long time.

Upgraded (~2017/10)

Since last October, the so-called “The millisecond abort system =the ms abort” has been available. (it takes under 1 ms from receiving signals to start aborting) .

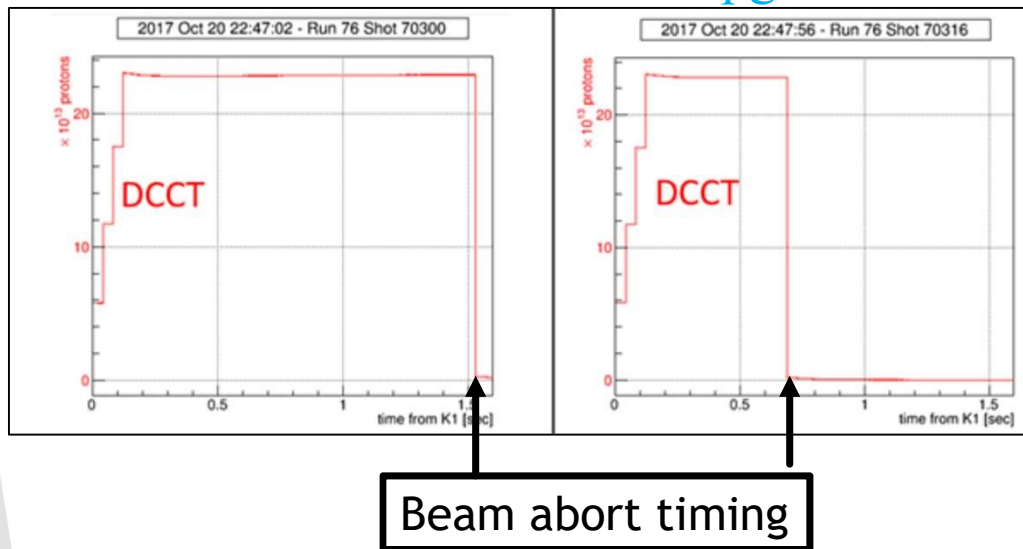


The ms abort system enabled high-speed aborting.

Benefit of The ms Abort

Before

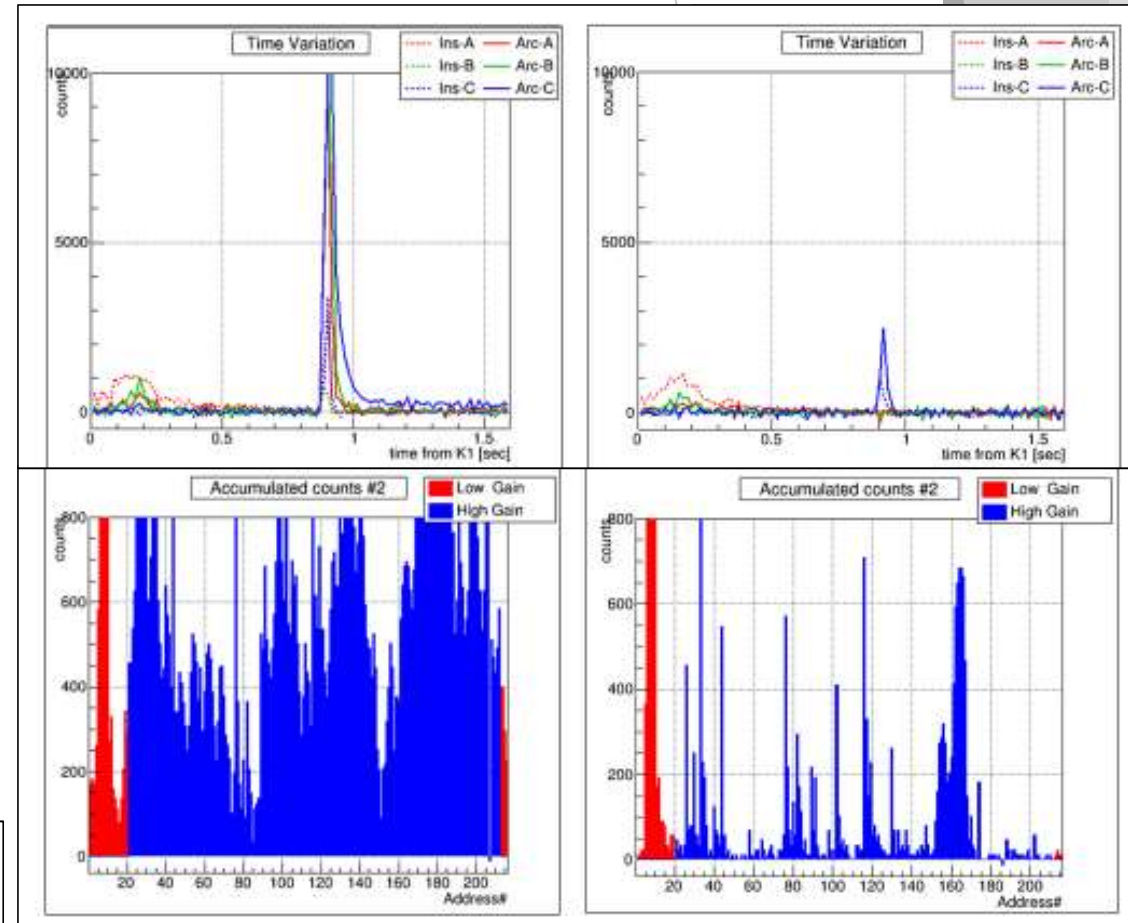
Upgraded



The ms abort enables beam-abort at early timing during FX cycle.

Before

Upgraded



The ms abort enables to reduce beam loss .

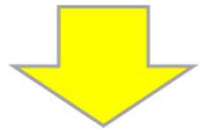
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Further speed up of MPS

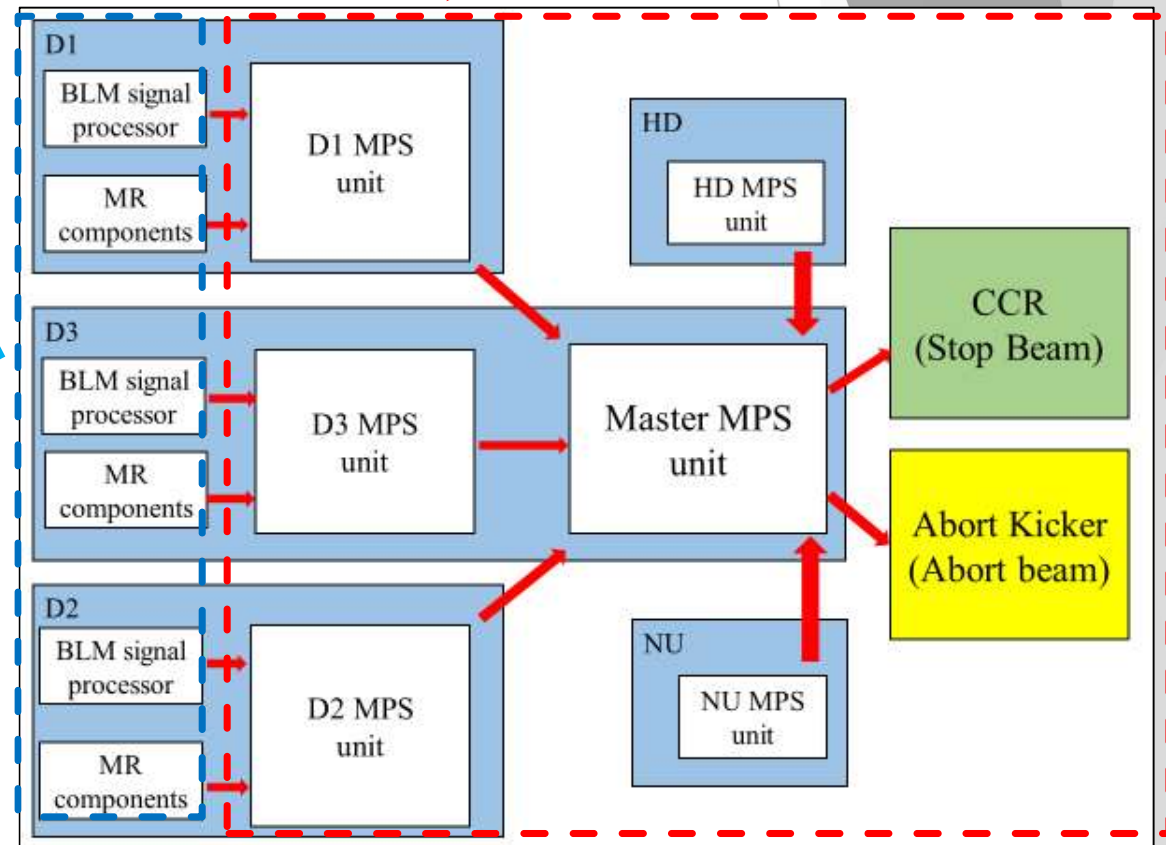
By introducing the ms-abort, the unwanted beam pulse became to be aborted within 1 ms after MPS unit received an interlock signal.



MPS's rate limiting is the components side. Therefore, we considered to speed up MPS of MR components for further MPS speed-up.



In MR-RF system, we upgraded speed of MPS.



The MPS of Radio Frequency (RF) system

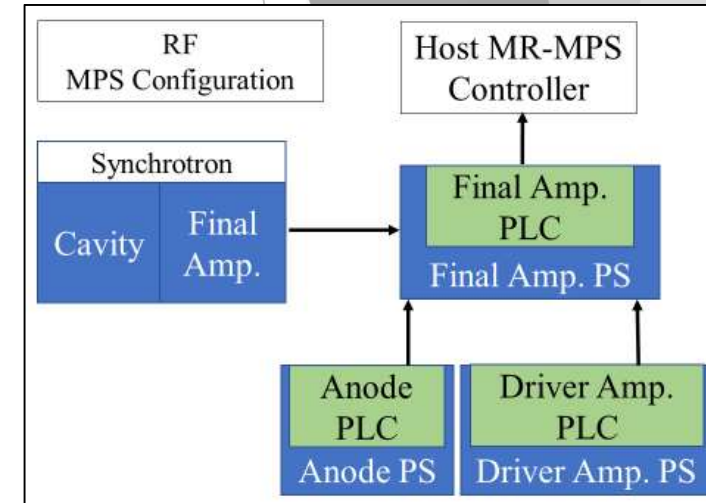
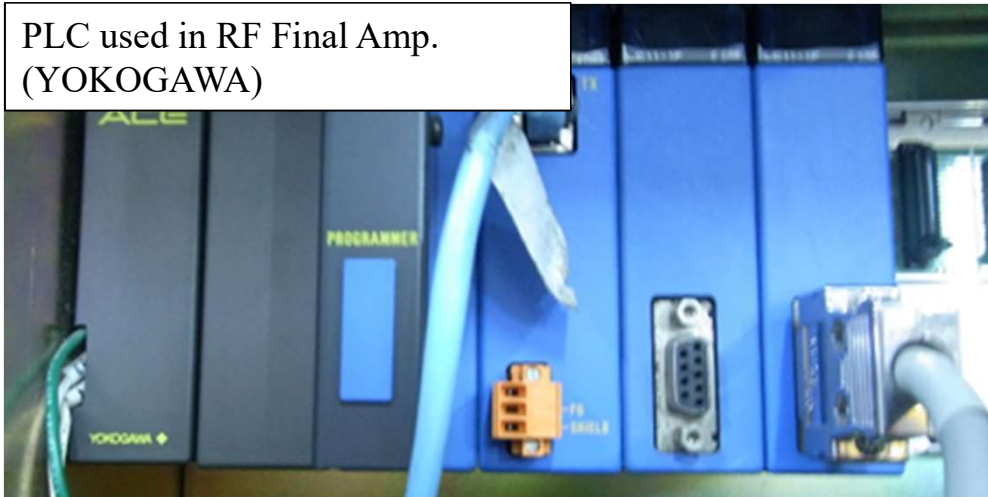
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- The RF System is controlled by the Programmable Logic Controller (PLC).

RF cavity



PLC used in RF Final Amp.
(YOKOGAWA)



- In RF System, the PLC logic program amount is large.
Therefore, the sequence scan time takes 3.5ms at most.
⇒It is possible to **speed up the MPS** by **improving the program**.

Upgrade of MPS in RF

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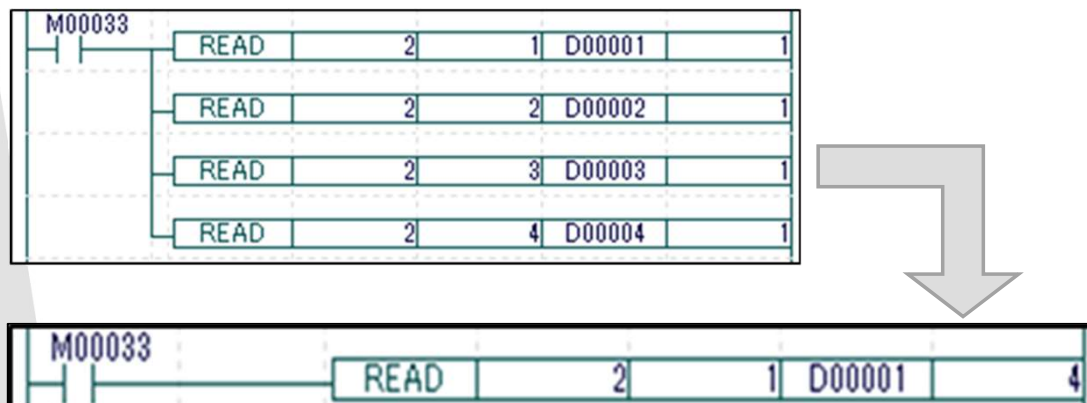
A, PLC-CPU replacement

PLC-CPU (YOKOGAWA) original and upgraded

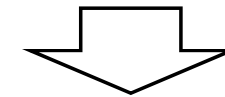
CPU	Original	Program time (ms)	Upgraded	Program time (ms)
Final Amp.	F3SP53-4S	1.5	F3SP71-4	1.0
Driver Amp.	F3SP21-0N	2.0	F3SP22-0S	0.5
Anode PS	F3SP58-6S	0.4	F3SP71-4S	0.1

- We could save time in Driver amplifier and anode PS.
- Final amplifier still has room for saving times.

B, PLC program investigation and improvement in Final Amp.

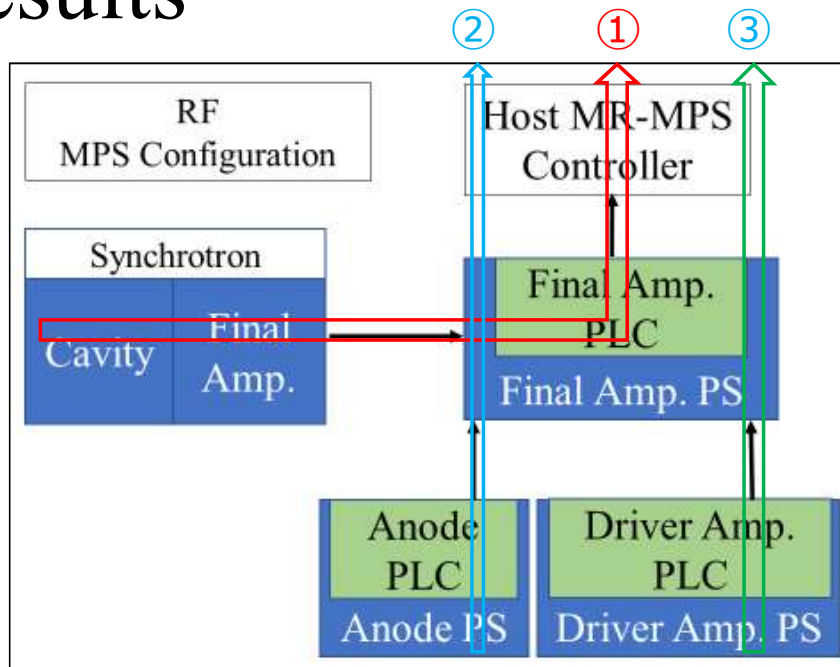


We gathered several programs to read values



Program time was reduced by 0.1ms.

Results



There are three MPS Signal transition Routes in RF System.

The Summary of the Change in the RF MPS Scan-time

The Signal Transition Route	Before [ms]	After [ms]
① Cavity⇒Final Amp.	1.5	0.9
② Anode PS⇒Final Amp.	1.9	1.0
③ Driver Amp. ⇒Final Amp.	3.5	1.4

We reduced the signal transition time.
(Max 2.1ms reducing)

We could **upgrade MPS** by improving PLC program.

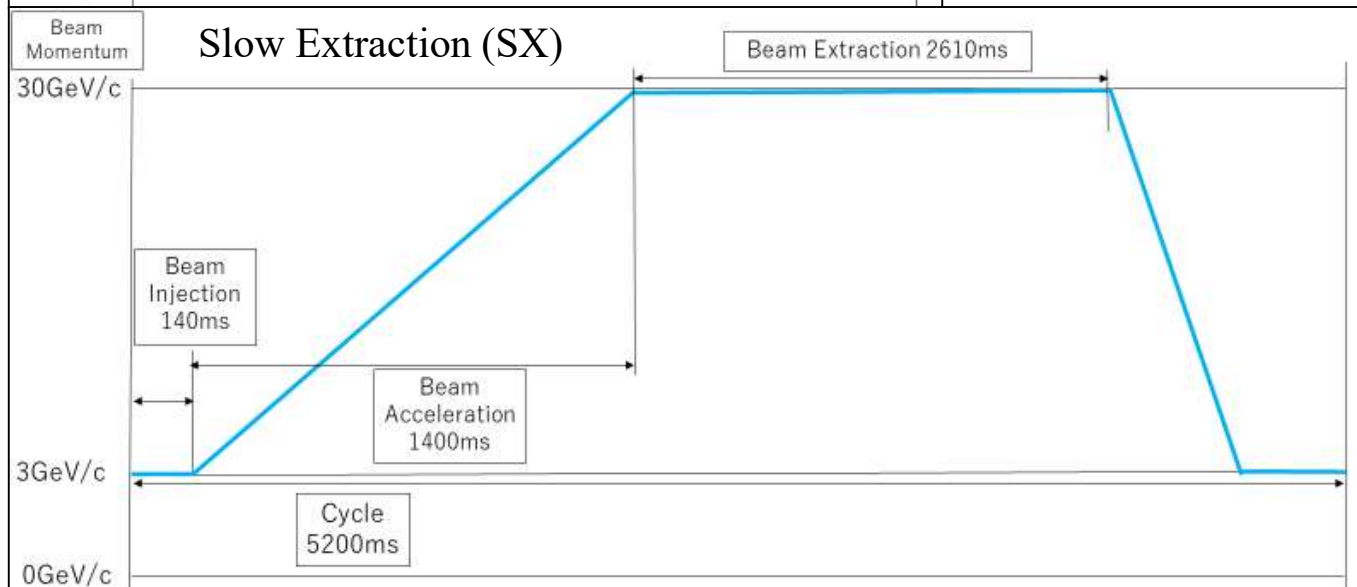
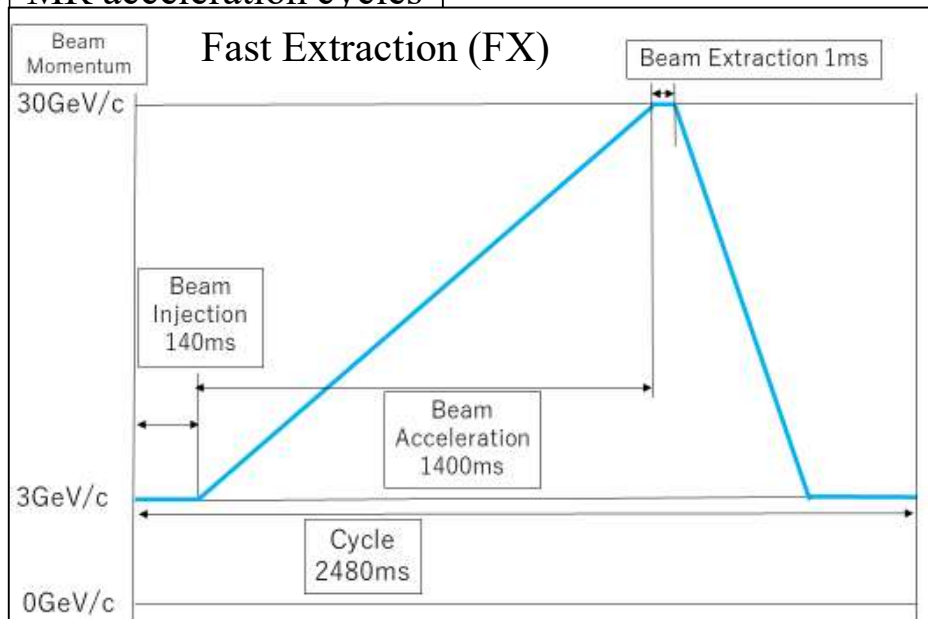
Summary

- J-PARC MR delivers the high intensity proton beam for NU experiment, HD experiment.
- In J-PARC MR, it is required for MPS to abort and stop the high intensity beam immediately.
- In 2017, it became possible to abort beam at any time of acceleration (the ms Abort).
- For further speed-up beam-abort, we have considered to improve the MPS signal transmission in MR components.
- Recently, we upgraded MPS by improving the PLC-CPU program in RF system.

Thank You.

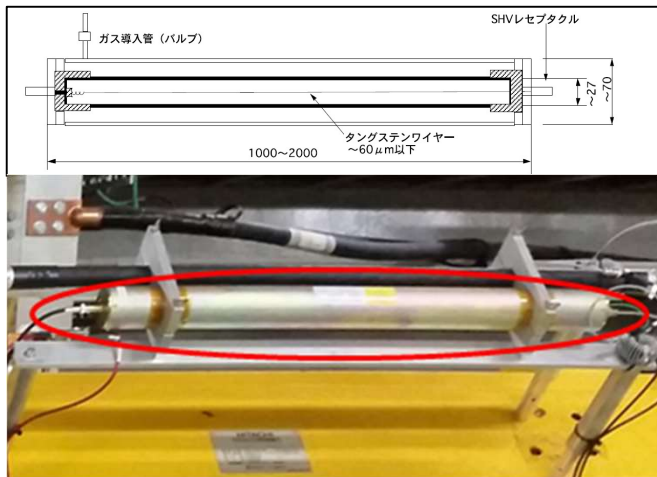
MR cycle

MR acceleration cycles



J-PARC MR BLM

Proportional Counter(Ar+CH₄,3He)



Detects beam anomalies by measurement of ions obtained by collision with radiation.



Now, it is used as MR MPS

Ion Chamber(in air)



Same function as Proportional Counter but uses air for inside gas

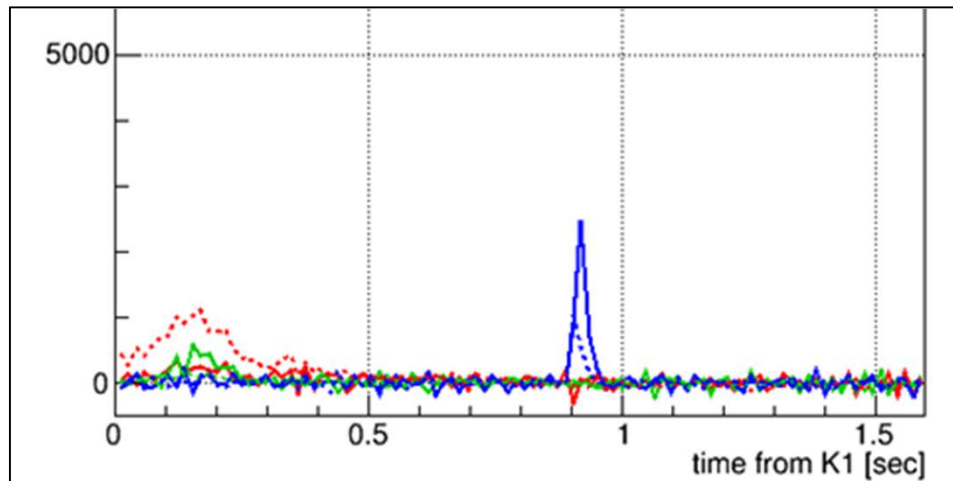


In future, it will be used
as MR MPS

Detail of BLM figures

Vertical axis

⇒ Beam loss (instant)

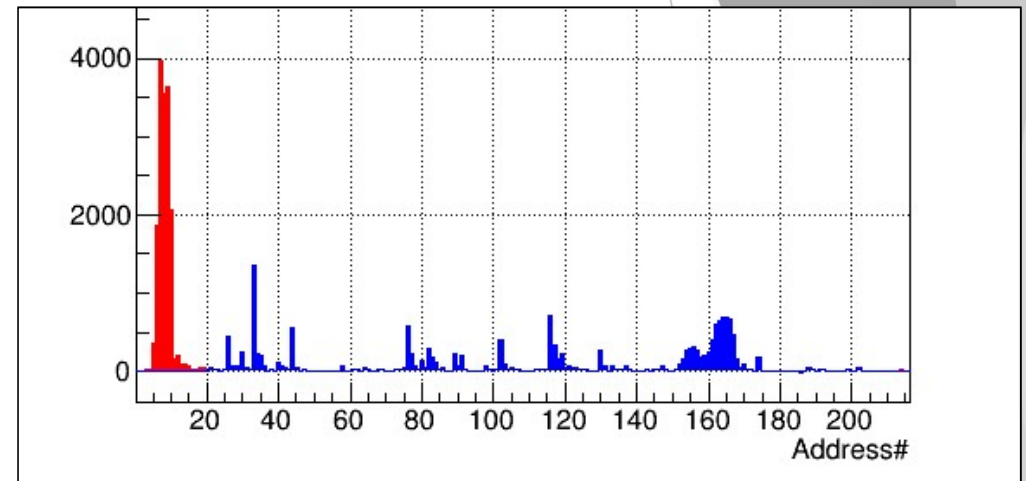


Horizontal axis

⇒ Time from beam injection

Vertical axis

⇒ Beam loss amount (Time integral)



Horizontal axis

⇒ BLM address (1~216)

※ There are 216 BLM used to MPS in MR

※ Estimate Beam power 500kW

⇒ Beam Loss around 800W

Characters of PLC

Merit of using PLC

- PLC enables to execute control and interlock (=MPS) in one PLC module unit.
⇒ There is no need to use separate devices for each system.
- The operation of PLC is determined by the program written to PLC-CPU.
⇒ By understanding and describing the program, it enables complicated operation.
- Expansion of the unit is easy.
⇒ Even if the number of control points is large, it is possible to operate.

Demerit of using PLC

- If the amount of the program in PLC is large, the response is delayed.
⇒ It is possible to **speed up the MPS** by improving the program.