Spill regulation scheme and status

KEK/J-PARC Center, Japan

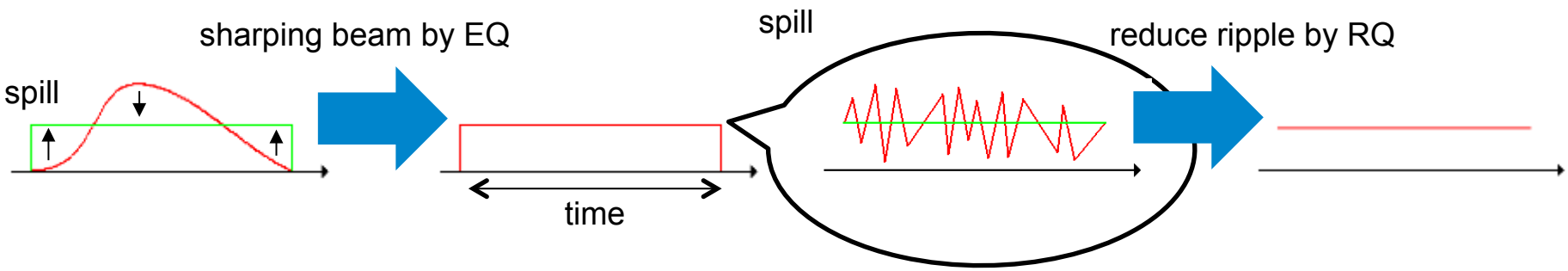
March. 2018

Contents

- Slow Extraction & Spill Structure
- Spill Feedback Control System
- Achievement of Spill Duty 50%

Slow Extraction & Spill Structure

- The slow beam extraction of the J-PARC MR utilizes third integer resonance at Qx = 22.333.
- The flat and small ripple noises are required for extraction beam to prevent pile-up of events in particle detectors or acquisition systems.
- We make amount of extracted beam constant in time structure by using spill feedback control system.



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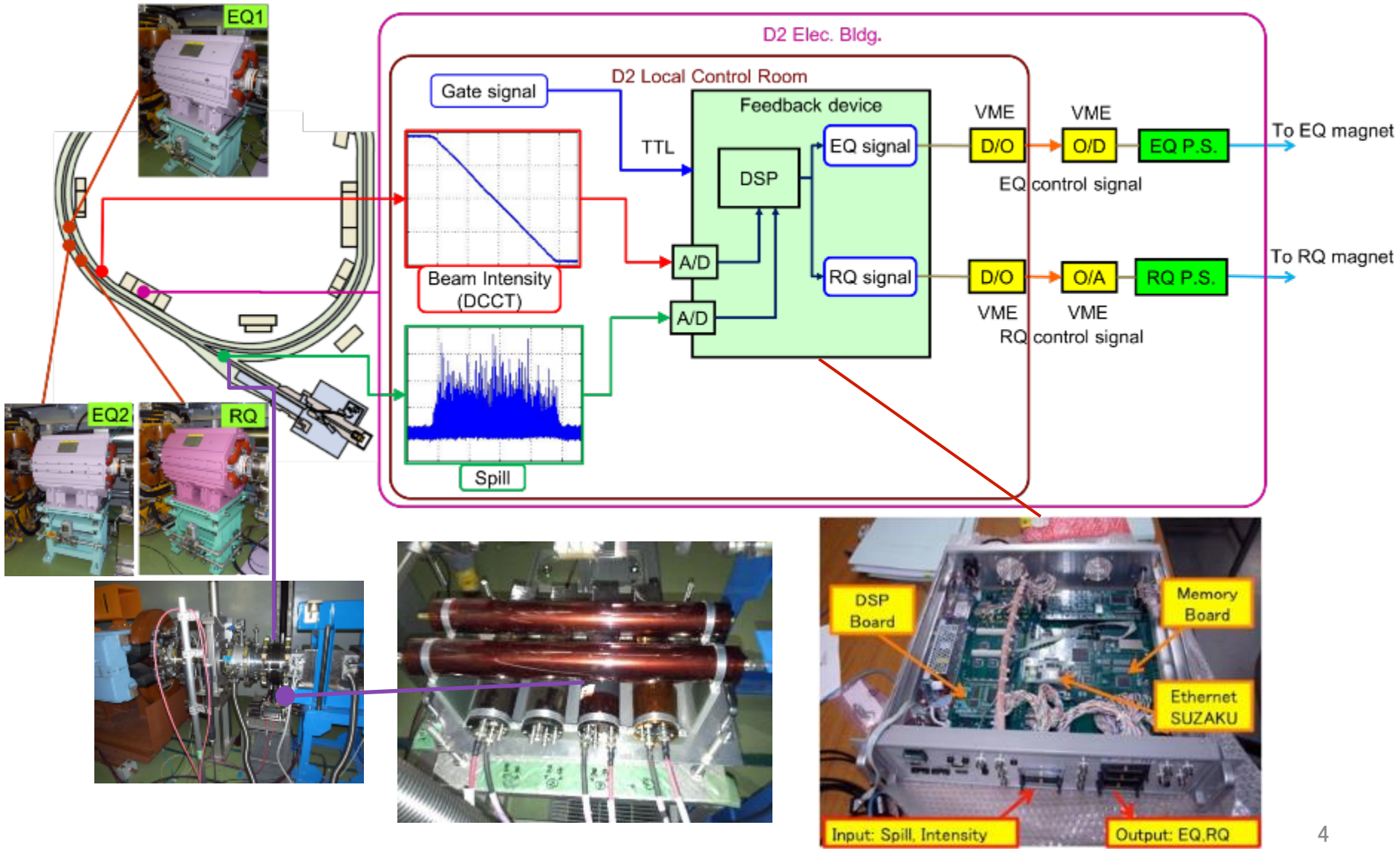
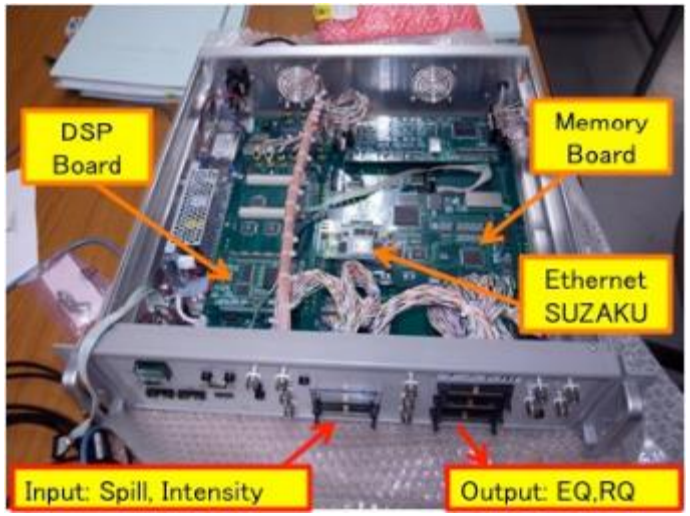
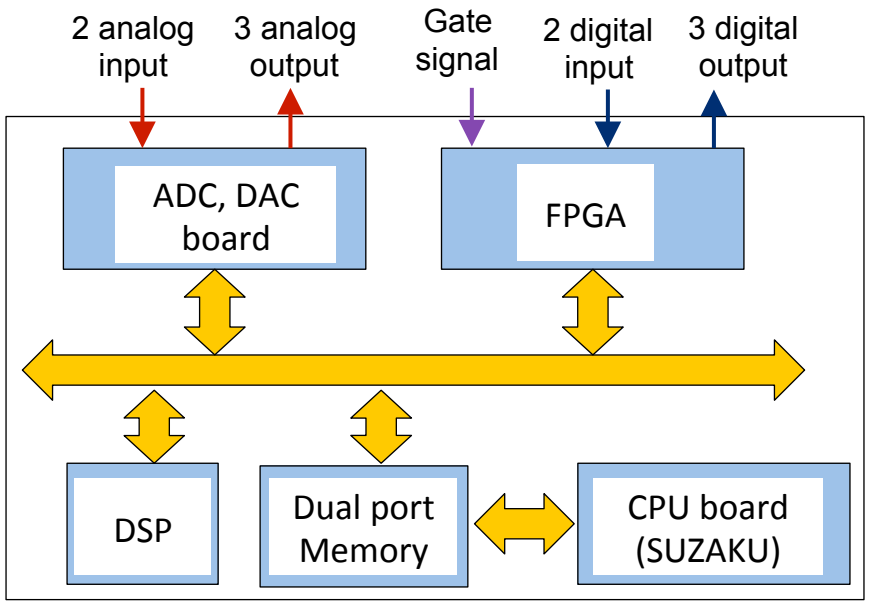
Spill Feedback Control System Overview



Feedback Device



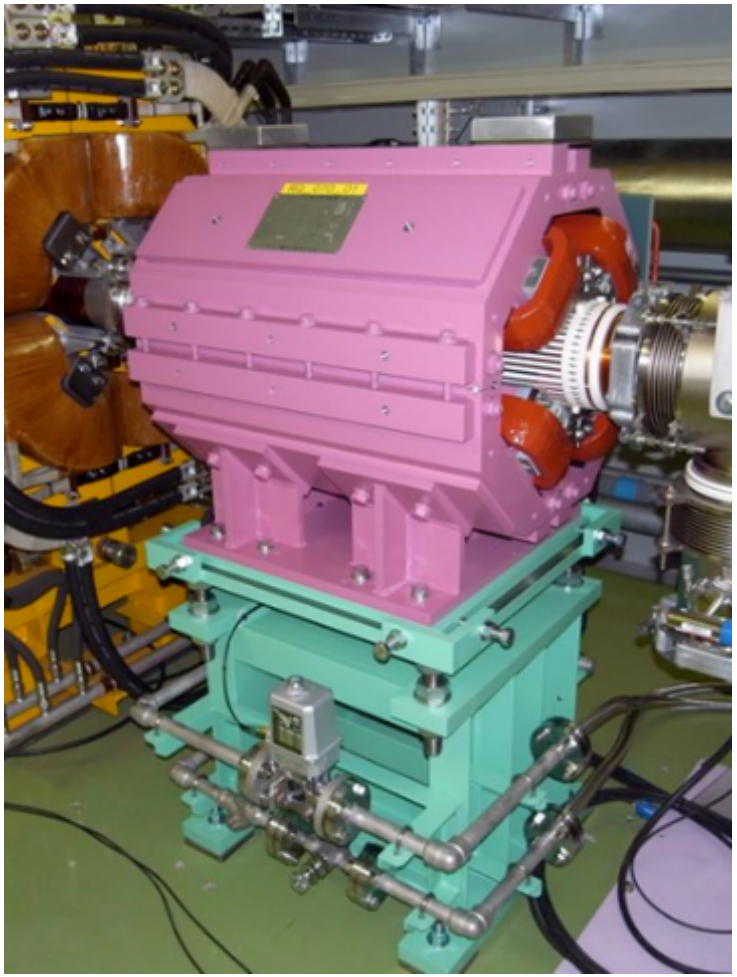


Feedback Device	
DSP board	TMS320C6713 (TEXAS INSTRUMENTS)
ADC, DAC board	C6713DSK (TEXAS INSTRUMENTS)
Sampling Frequency	100kHz
Analog Input/Output	±1V, 10Ω
Digital Input/Output	LVTTL3.3V, 32bit Positive logic

EQ magnet & EQ P.S.

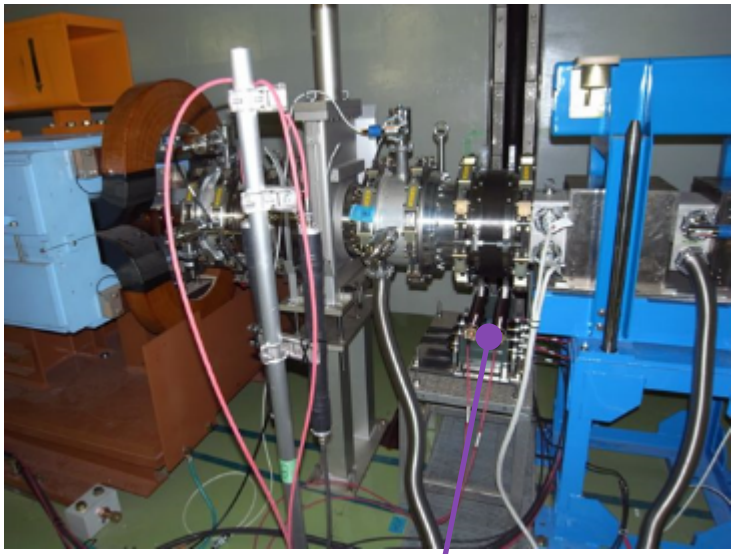
EQ	
Core Material	0.1mm thick lamination steel
Bore Radius	80mm
Magnet Length	0.62m
Coil Turn Number	22
Field Gradient	2.60T/m@301A
Inductance	8.8mH
Resistance	80.3mΩ
Current	110A
Voltage	±250V
Band Frequency	DC~1kHz
ΔH tune	0.0106/100A

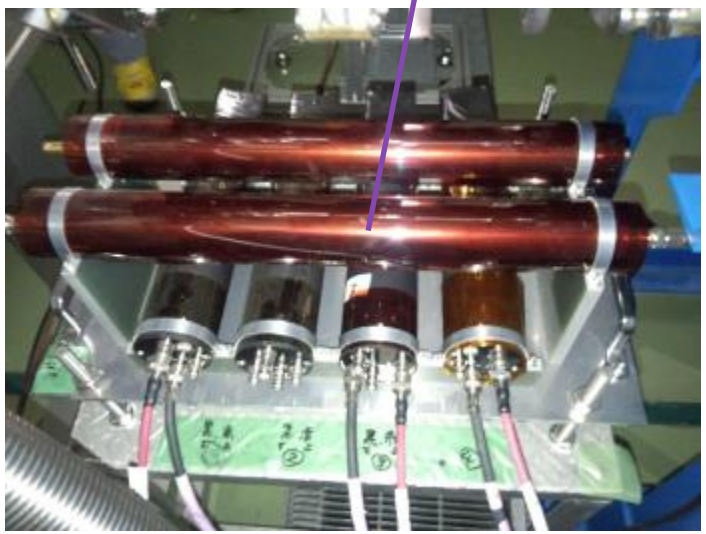
RQ magnet & RQ P.S.



RQ	
Core Material	0.1mm thick lamination steel
Bore Radius	80mm
Magnet Length	0.62m
Coil Turn Number	6
Field Gradient	0.94T/m@400A
Inductance	0.65mH
Resistance	11.25mΩ
Current	75Arms
Voltage	400Vrms
Band Frequency	40Hz~10kHz
ΔH tune	0.001439/100A

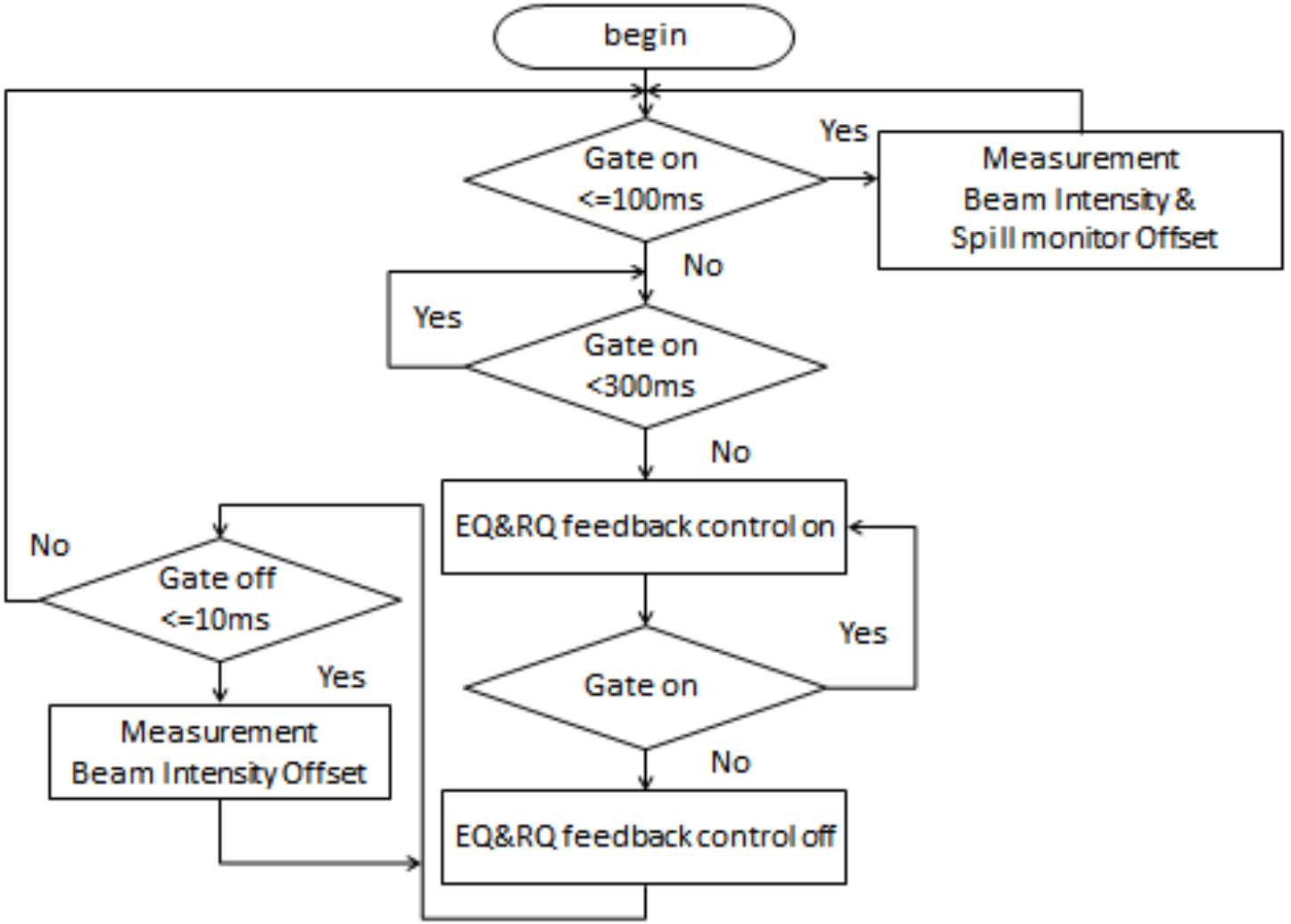
Spill Monitor



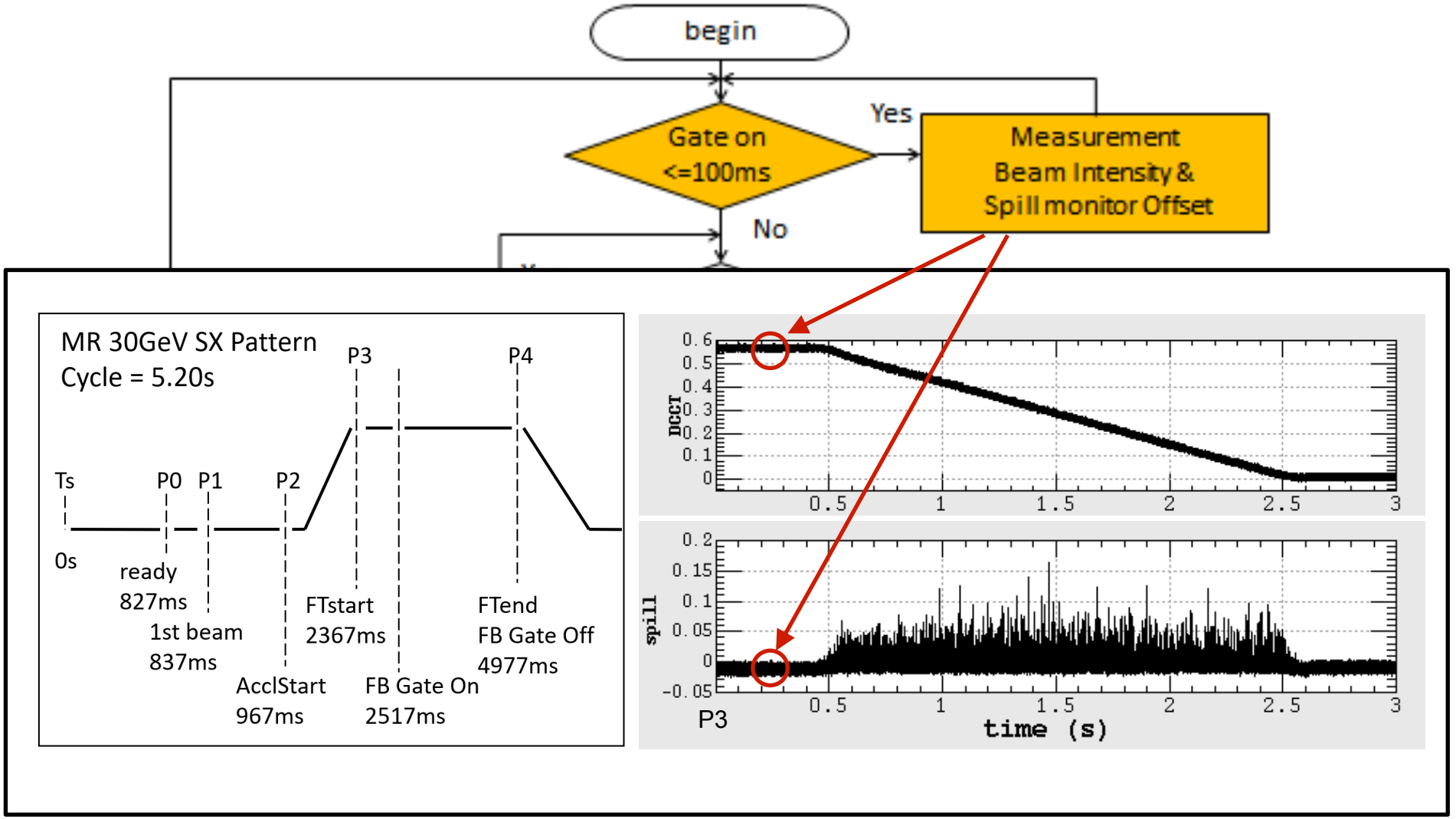


- Beam spill was measured by the photomultiplier with plastic scintillator, where is installed in slow extraction beam line.
- Spill monitor measures secondary particles generated when the beam passes through the vacuum film.

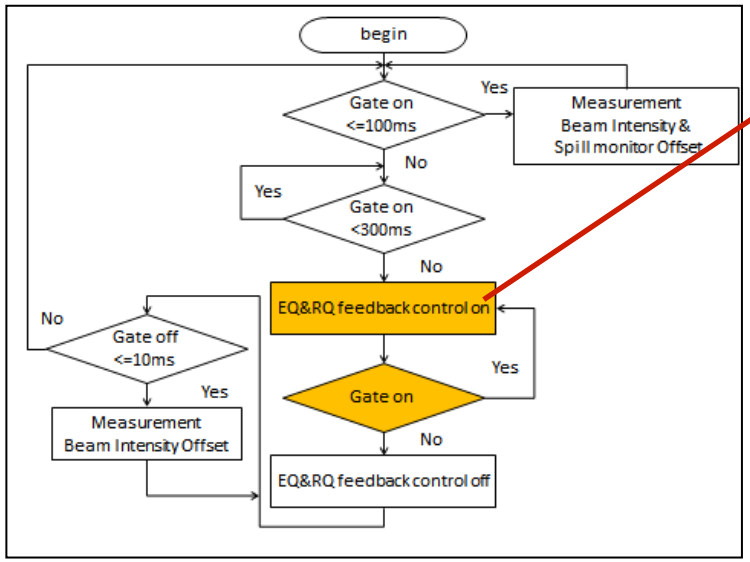
Feedback program flow

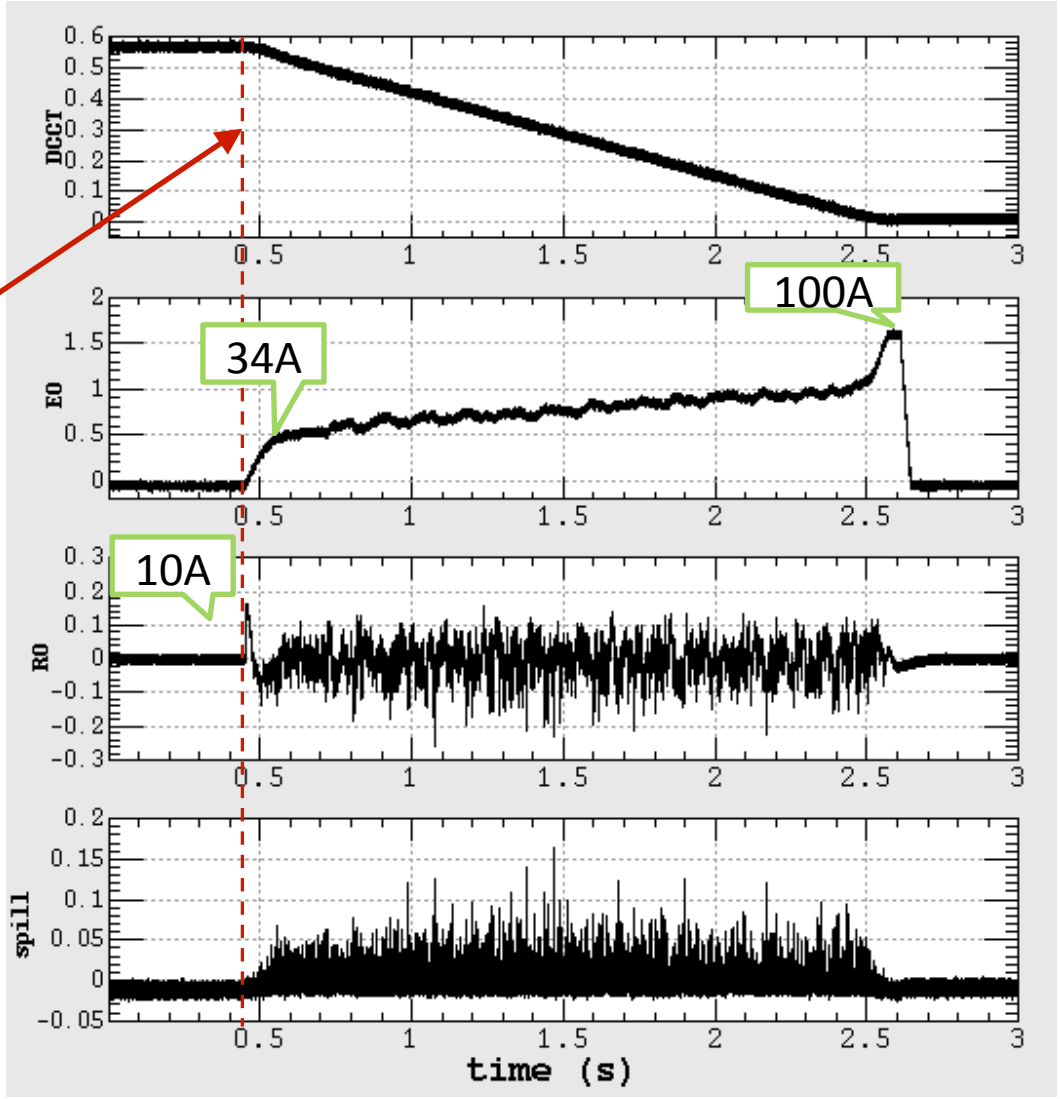


Feedback program flow

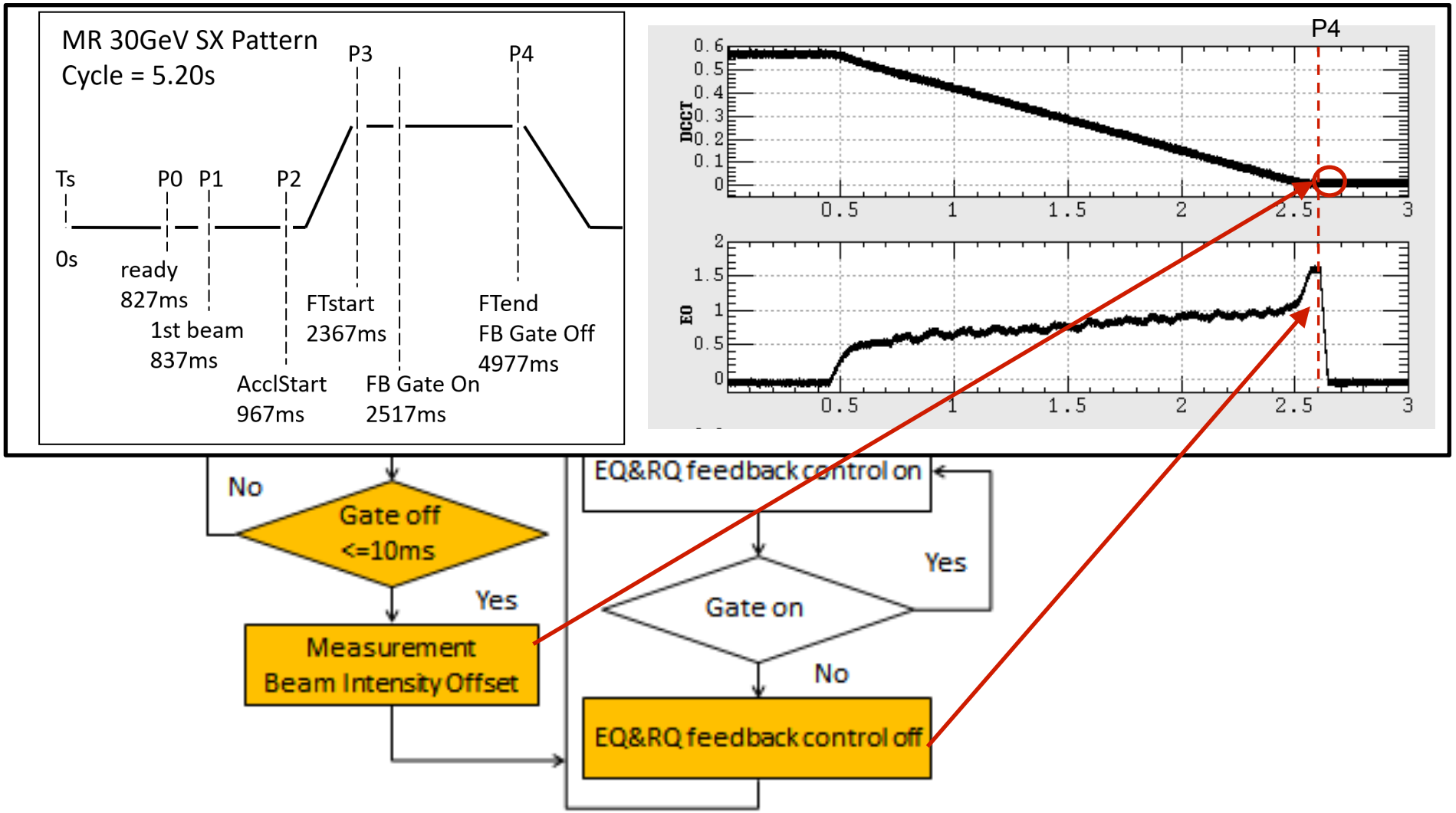


Feedback program flow





Feedback program flow



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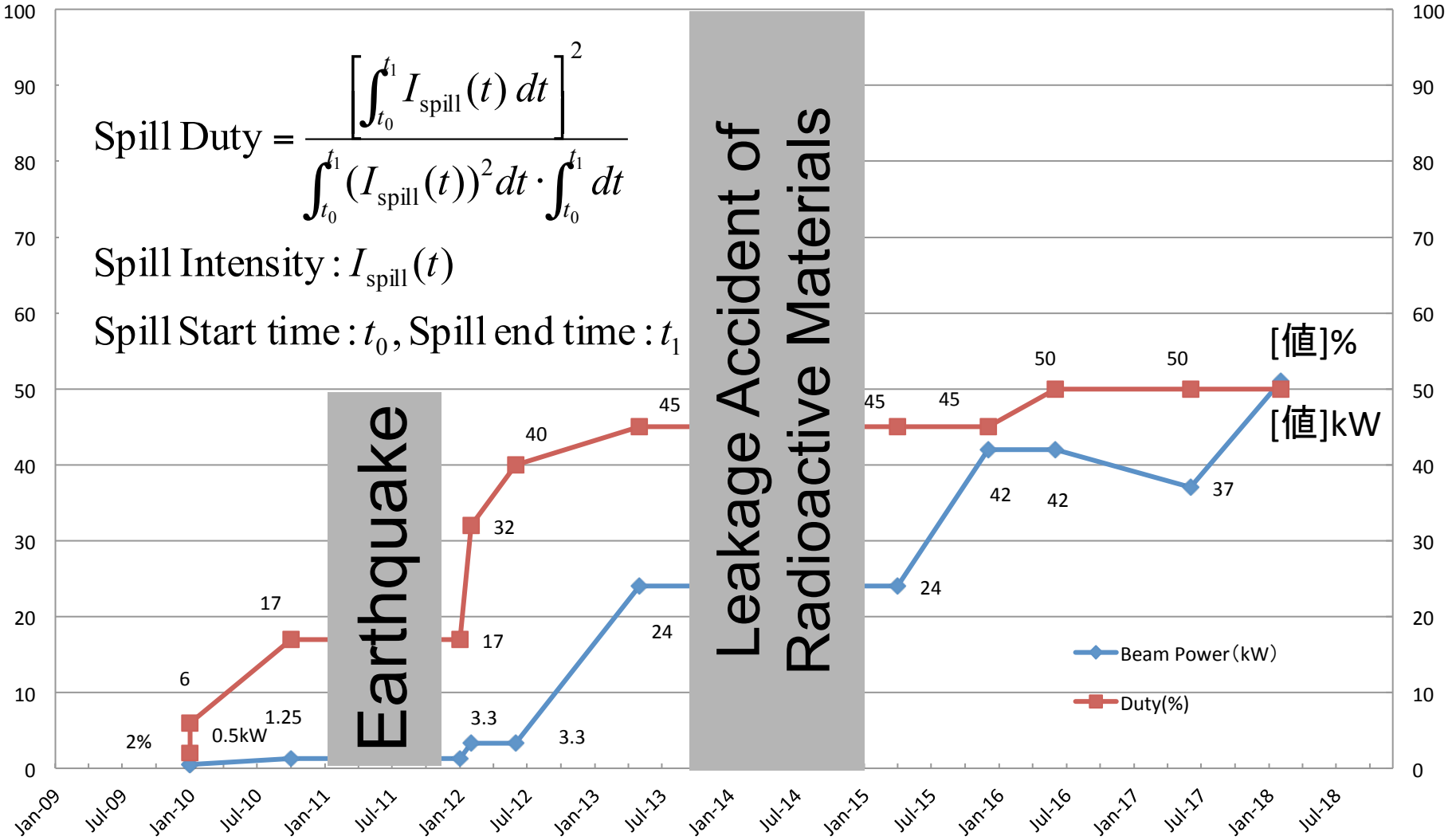
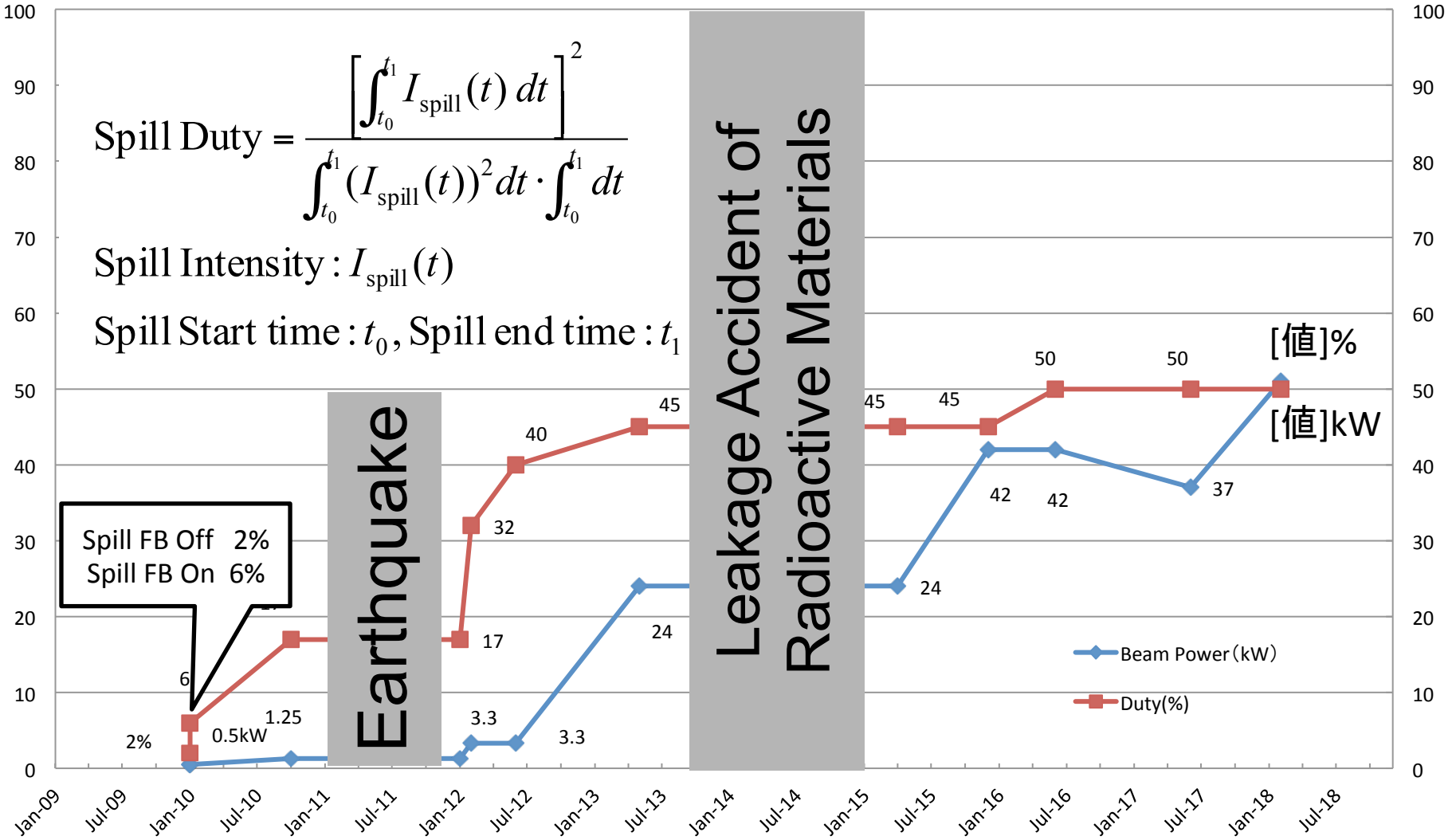
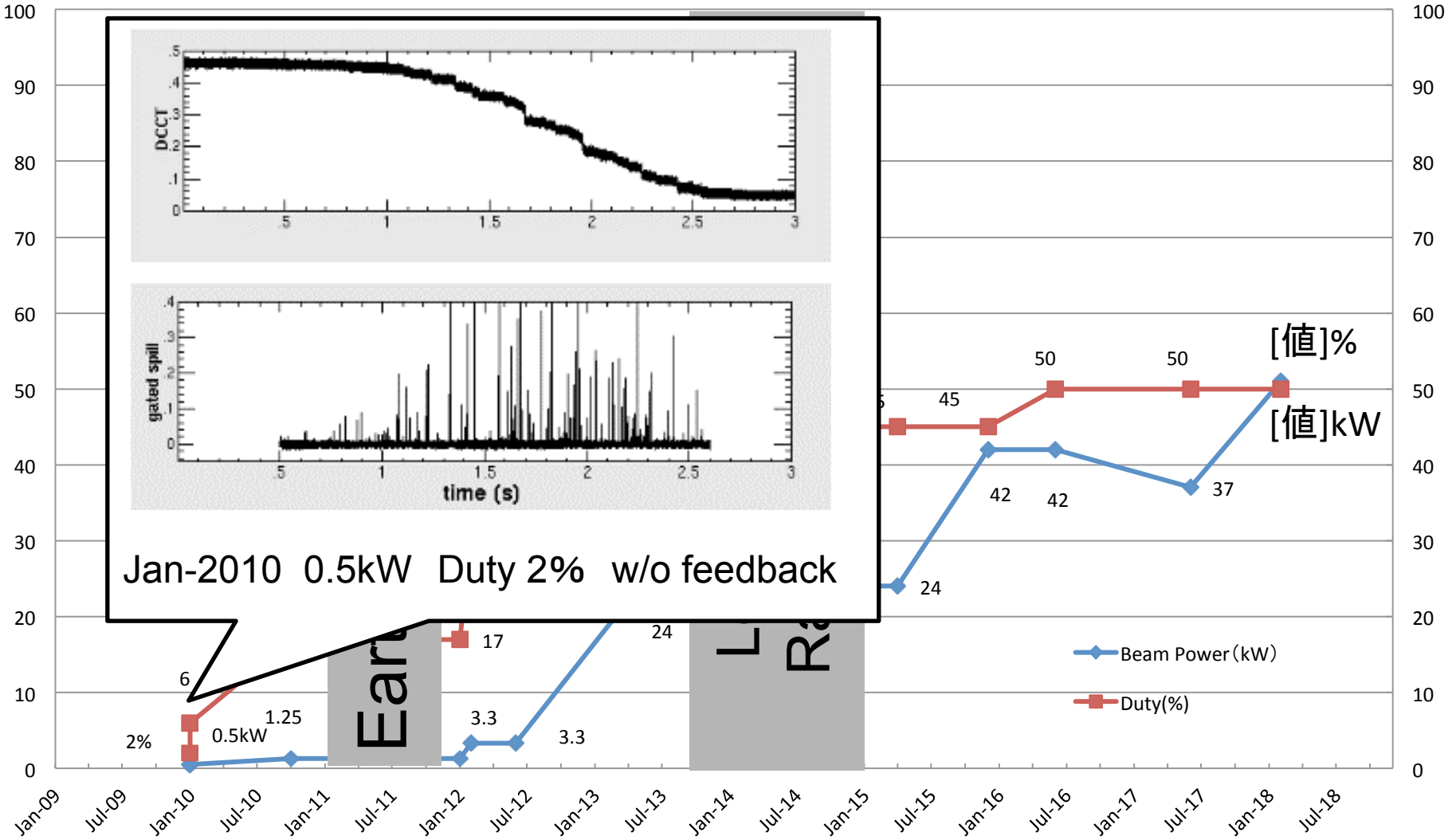
Spill Duty History



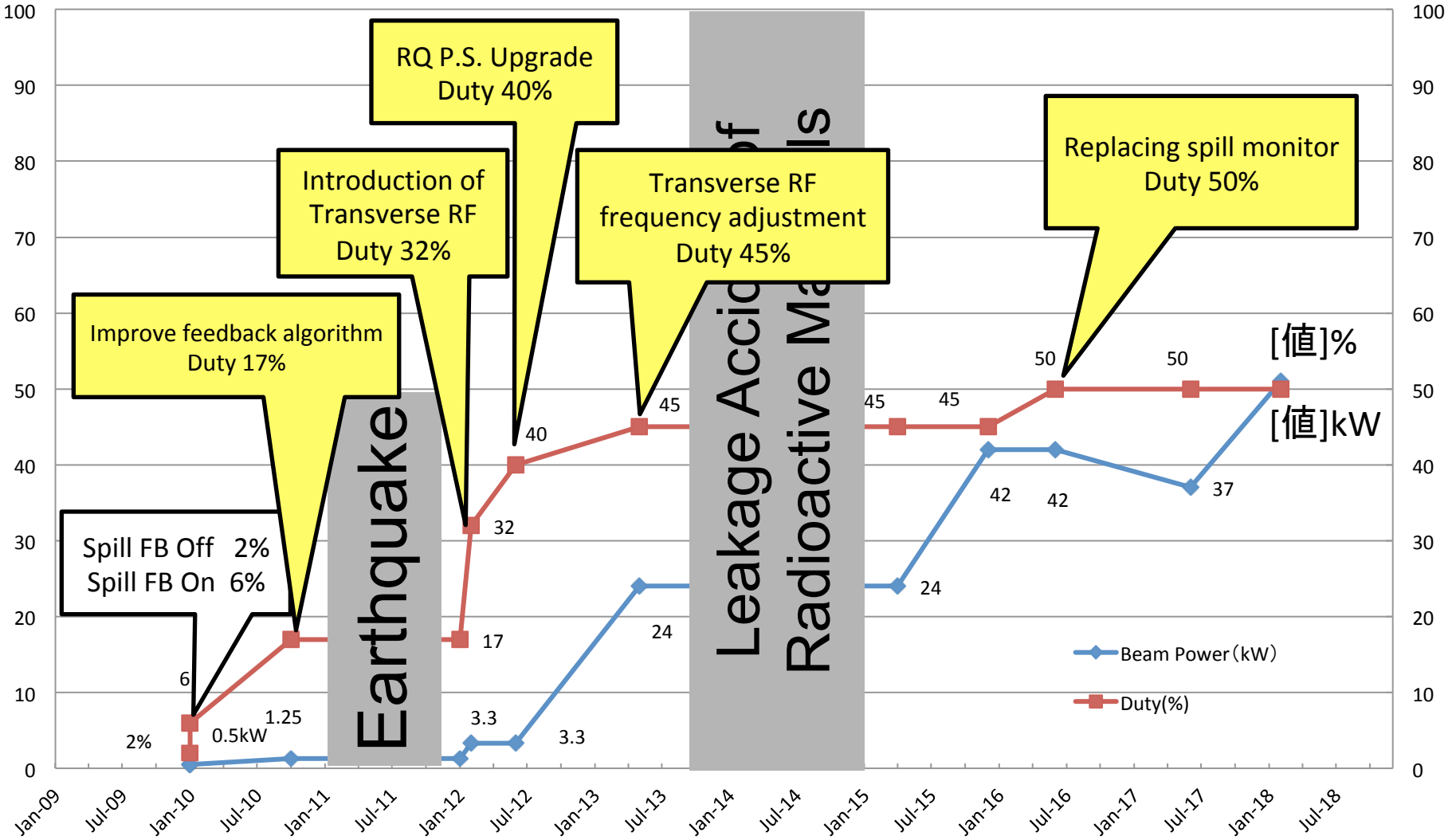
Spill Duty History



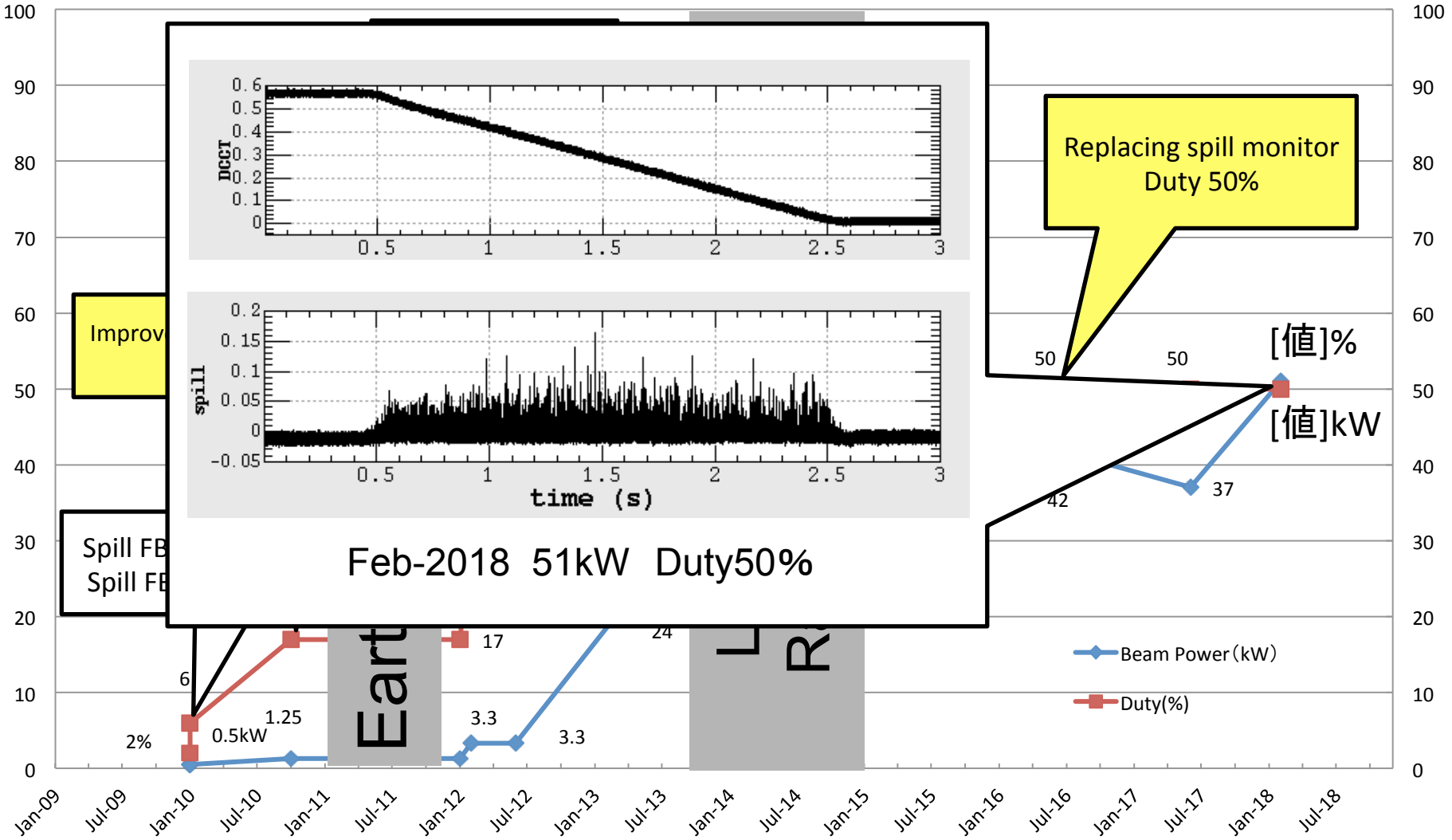
Spill Duty History



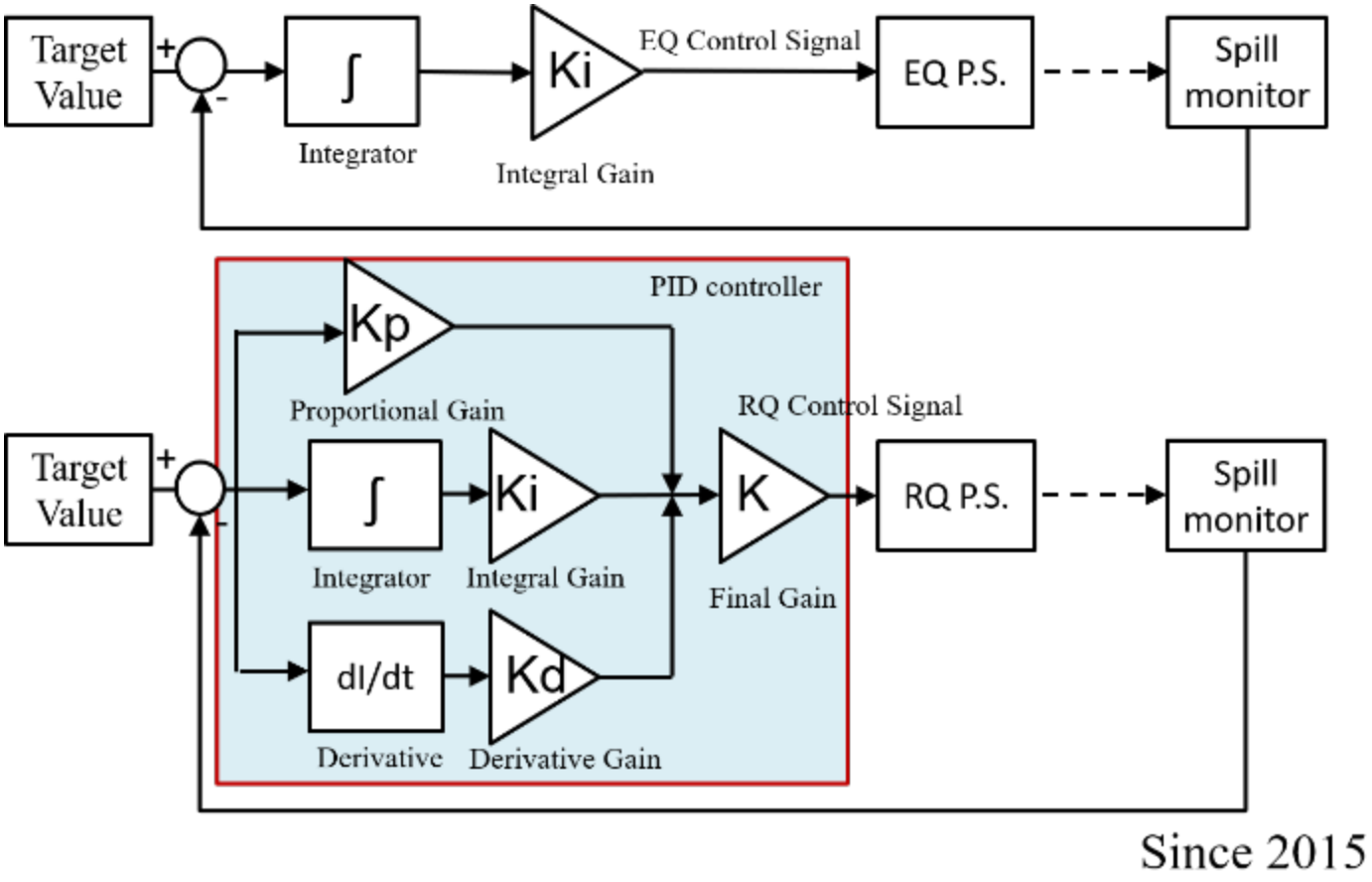
Spill Duty History



Spill Duty History



Improve Feedback Algorithm

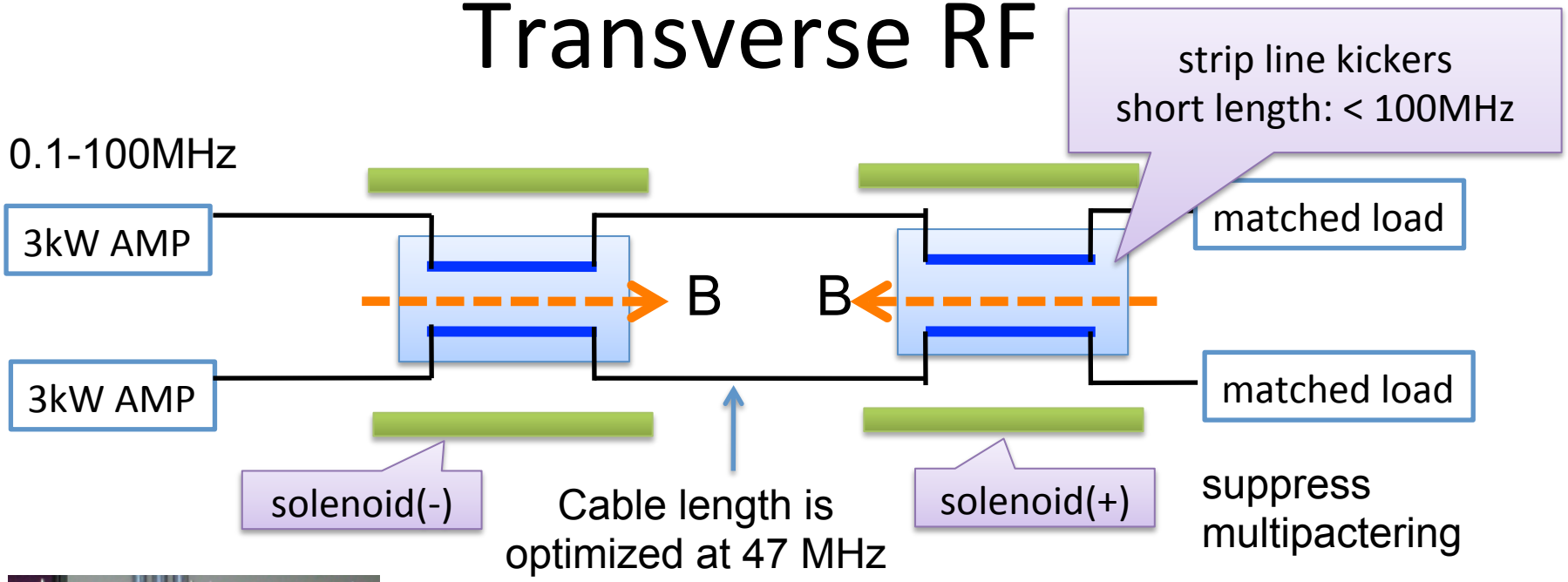


- Feedback Gain (Feb. 2018)
  - EQ: Ki=50
  - RQ: Kp=1.0, Ki=0.05, Kd=2.0, K=2.0

Upgrade of RQ P.S.

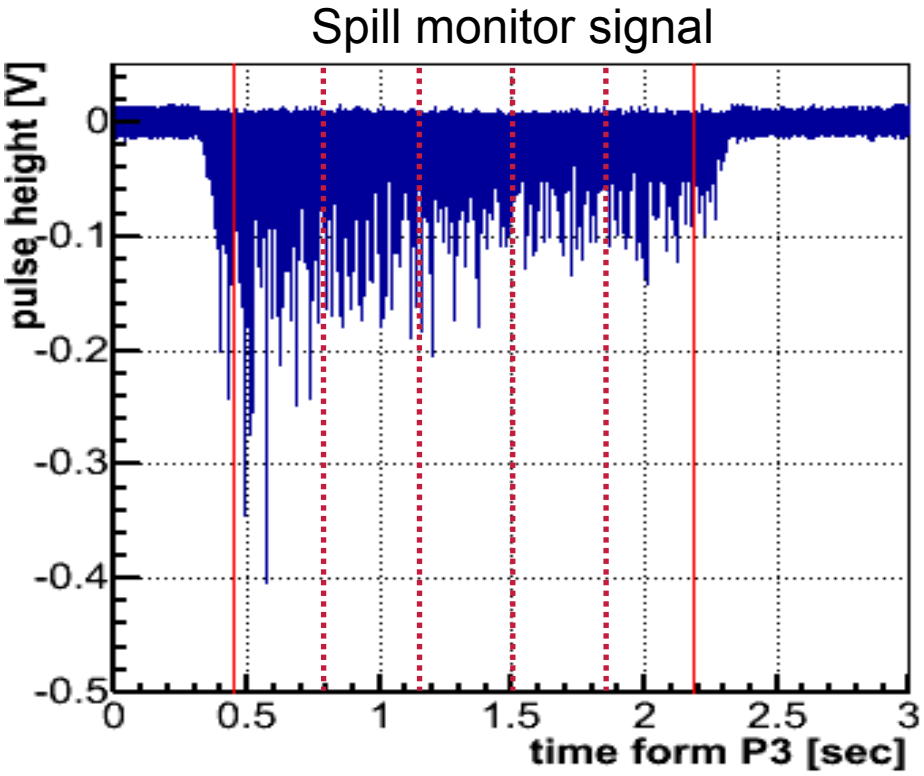
	Old RQ P.S.	New RQ P.S.
Current	175Arms	75Arms
Voltage	180Vrms	400Vrms
Band Frequency	10Hz~10kHz	40Hz~10kHz
Step Response delay	100μs	60μs
Control Input	Current	Voltage

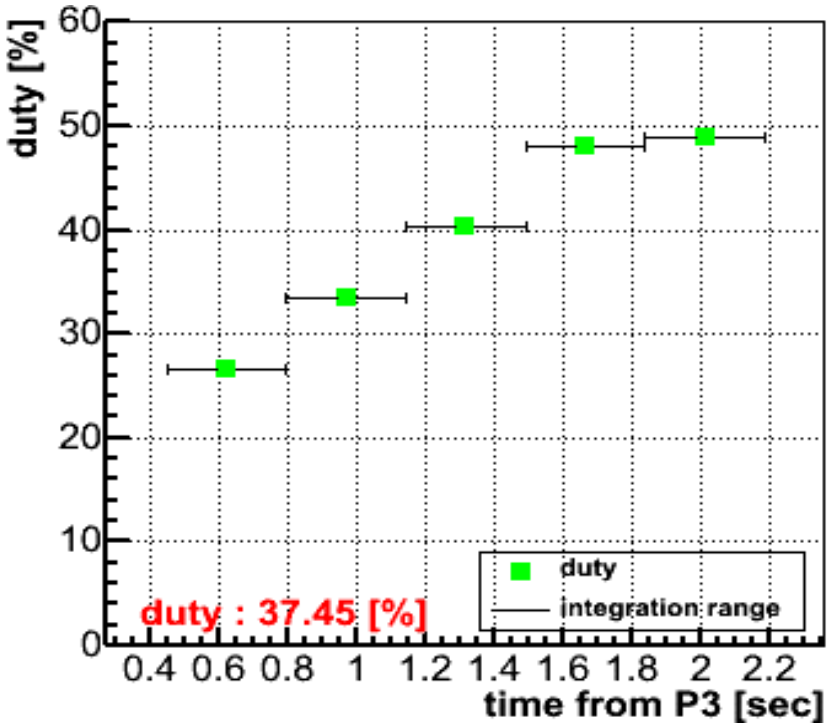
Transverse RF



Time structure of Spill

- Time structure of spill when Transverse RF frequency is constant

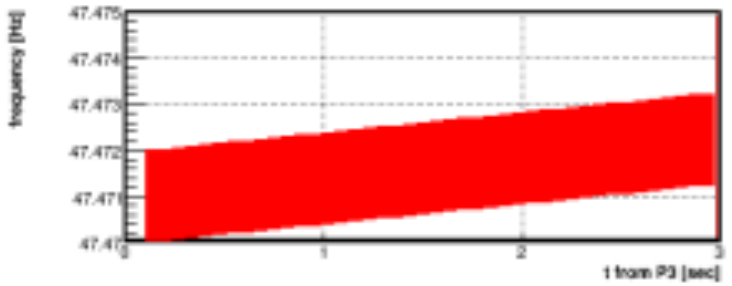


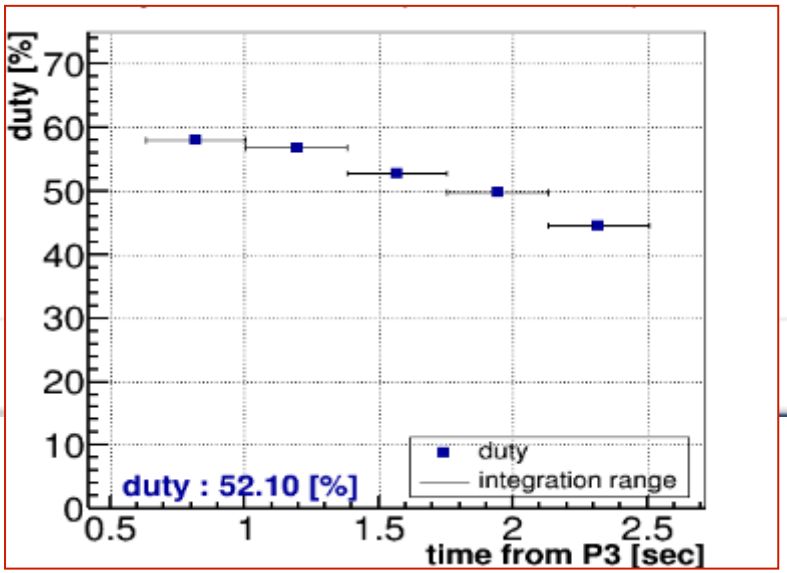


Transverse RF frequency adjustment

Application for control of Transeverse RF S.G. (Rev 0.1, Transeverse RF control)
Run# : 69, Shot# : 0263128 (2016.June.27 09:17:27)

frev [kHz]			
Apply	191.167410714	191.167410714	[kHz]
#. of step			
Apply	42	42	[steps]
POWER [dBm]			
Apply	-4.0	-4.0	[dBm]
edge frequency [MHz]			
Apply	47.46999057	47.46999057	[MHz]
step of frequency [Hz]			
Apply	30	30	[Hz]
noise width			
Apply	2000	2000	[Hz]
period of dwell [sec]			
Apply	0.0685	0.0685	[sec]



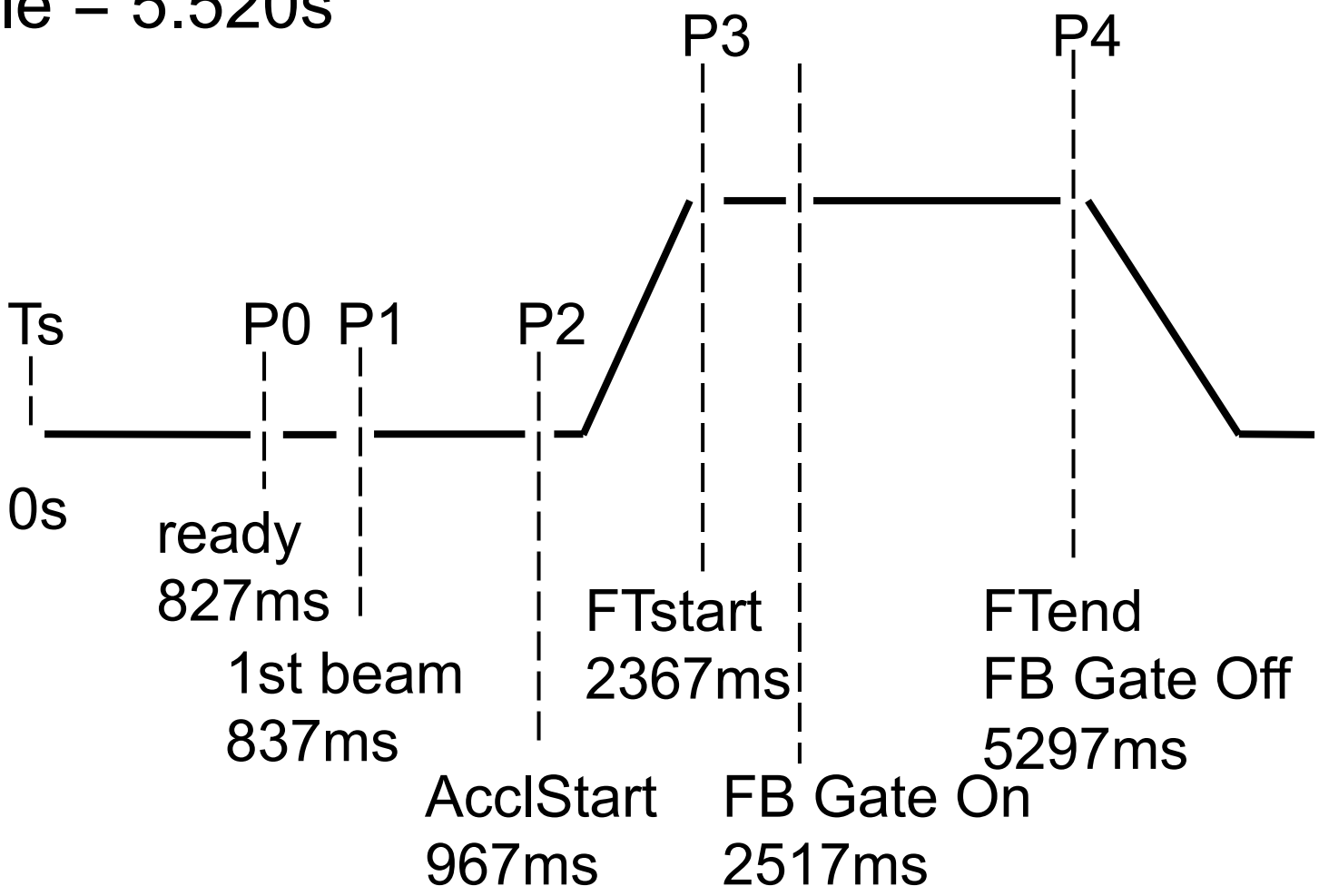


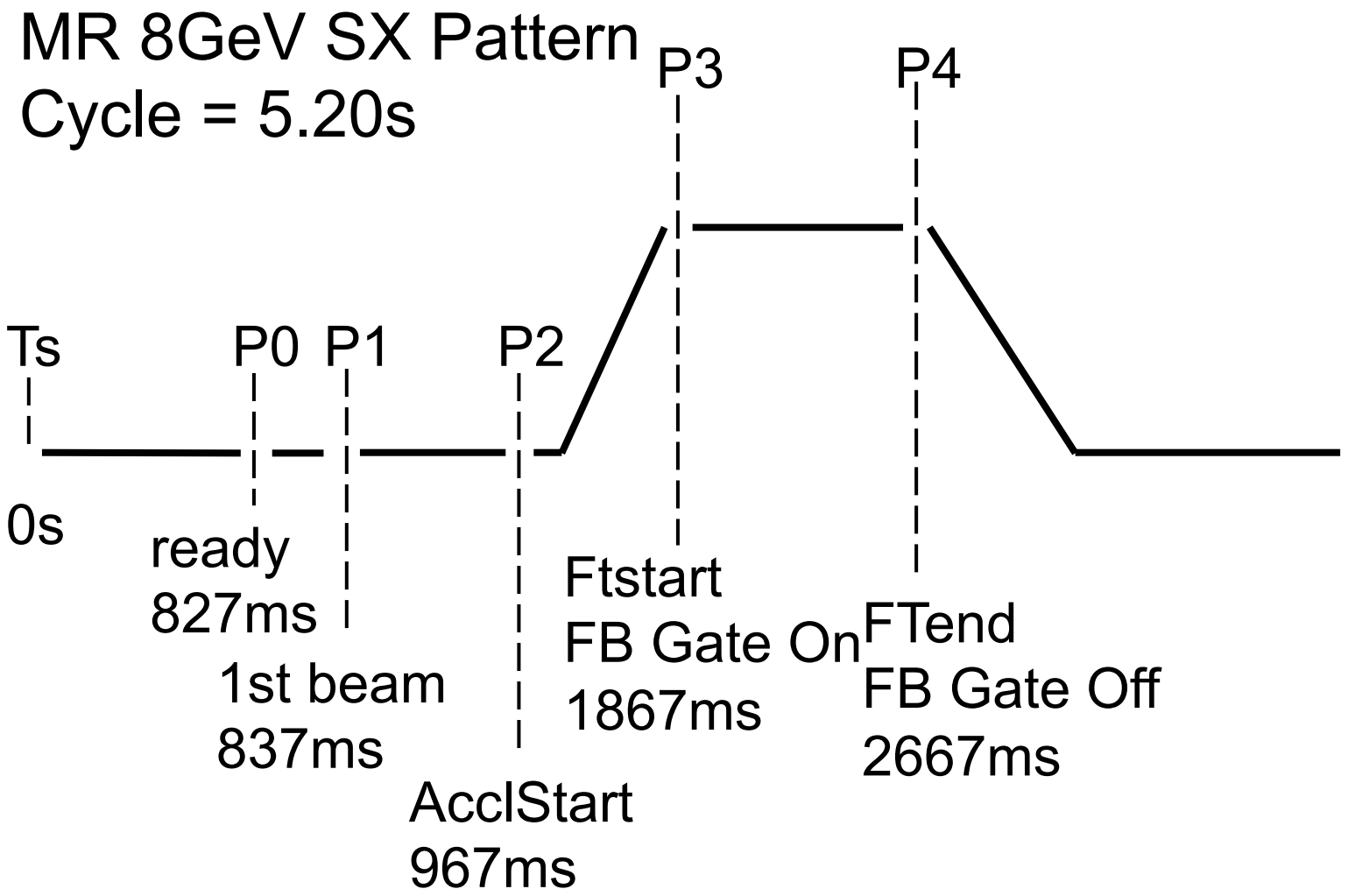
Decreased response of Spill monitor

- Effect of high intensity beam
  - Decreased response by 10% in one week (51kW operation)
  - HV adjustment of spill monitor is necessary every week
- Replacing spill monitor
  - Improvement of adverse effect on feedback control
  - Duty 45% → 50%
- Countermeasure
  - Add spill monitor at distance of 1 m (Normal: 30 cm)
  - Introduction of Diamond Detector (Future plan)

buckup

# MR 30GeV SX Pattern
Cycle = 5.520s




MR 8GeV SX Pattern
Cycle = 5.20s
P3
P4
Ts
P0
P1
P2
0s
ready
827ms
1st beam
837ms
AcclStart
967ms
Ftstart
FB Gate On
1867ms
FTend
FB Gate Off
2667ms