Beam diagnostics of the J-PARC accelerator and its applications

T. Toyama
J-PARC / KEK

FRIB in Apr. 9-10, 2024

Outline

oduction to J-PARC (Japan Proton Accelerator Research Compl

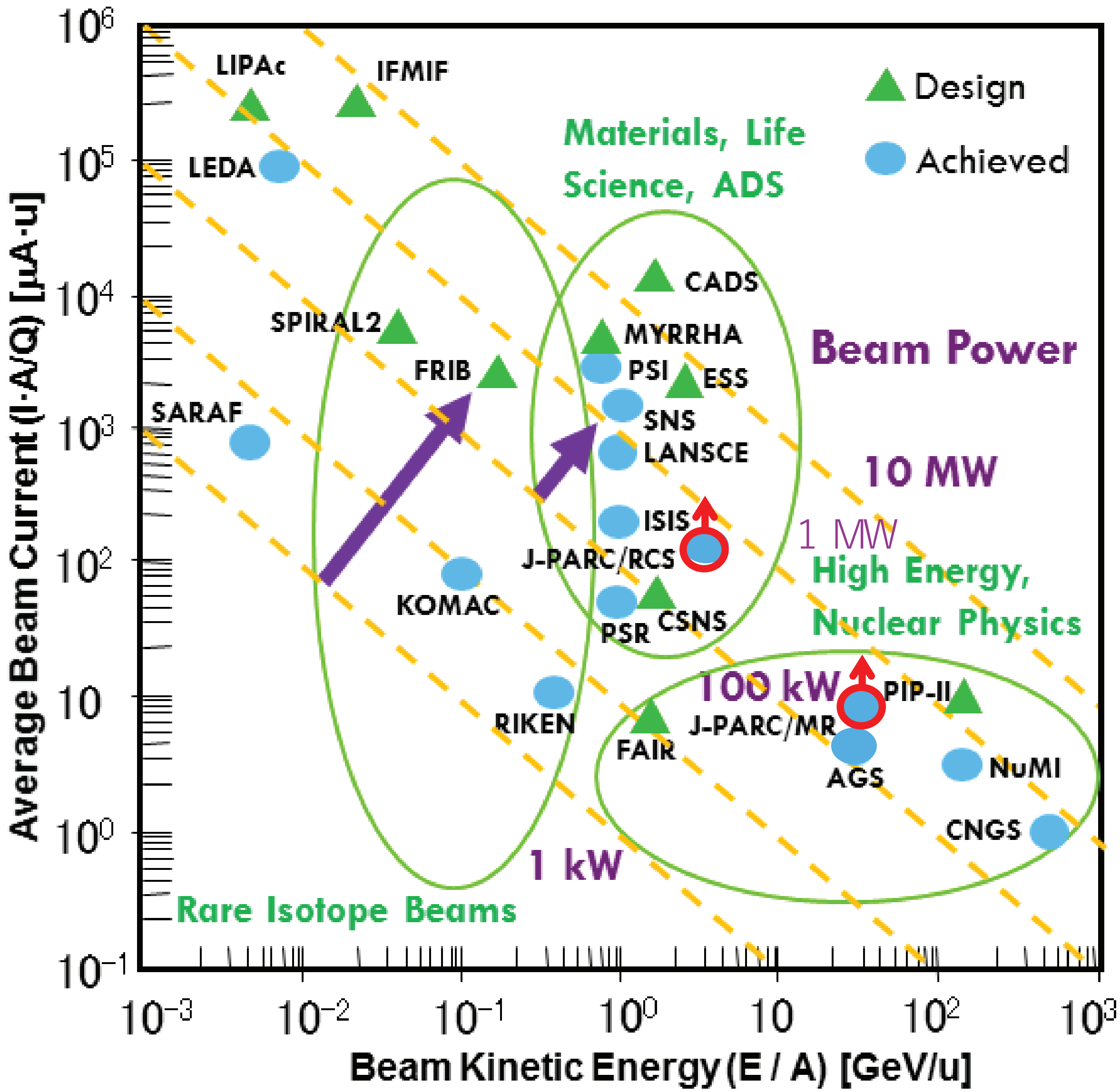
am diagnostic instruments at J-PARC

on-invasive" diagnostics (two examples)

am diagnostics for the MPS (two examples related to targets)

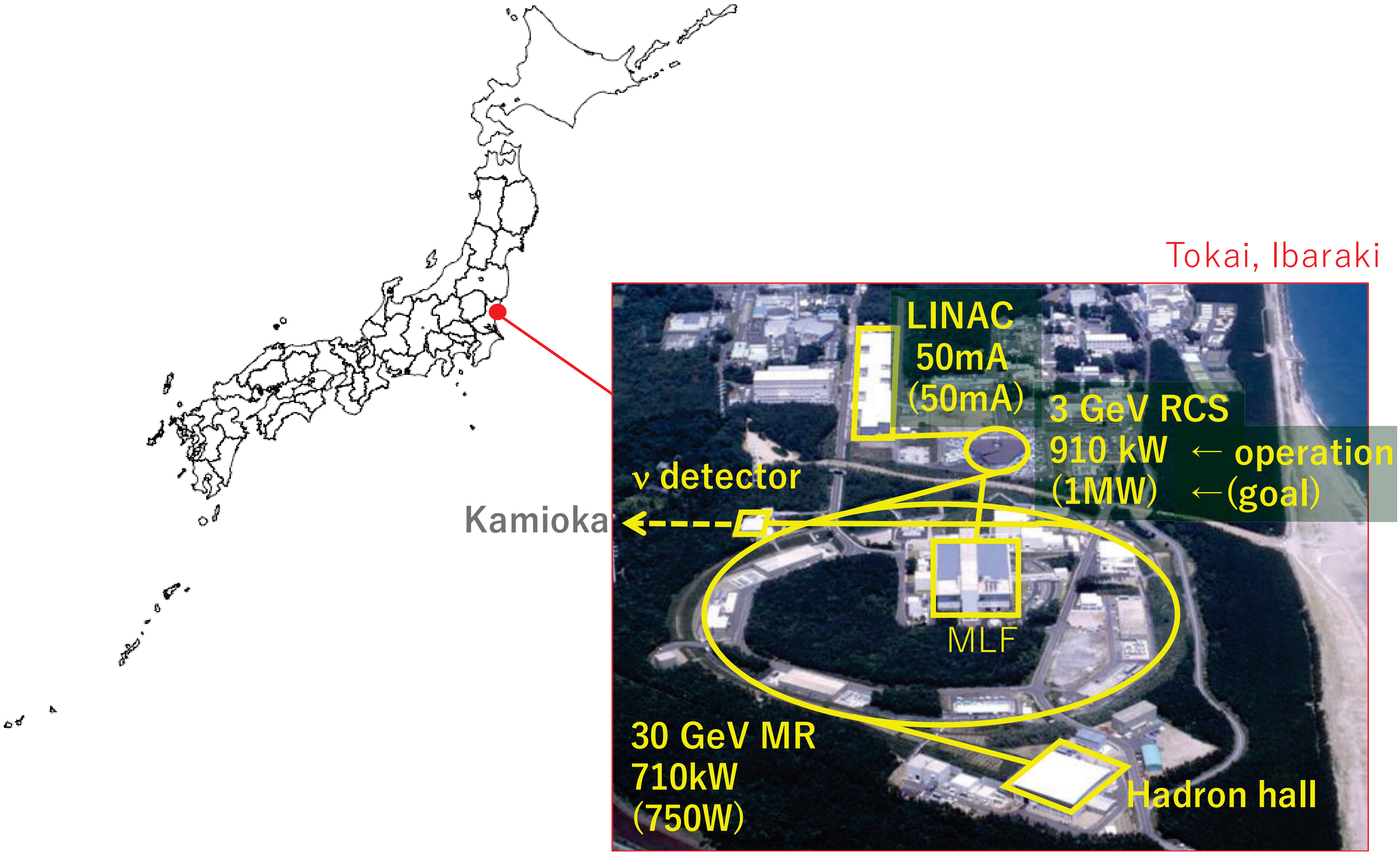
Introduction to J-PARC

High Intensity (Power) Frontier in the world



N. Saito, HINT2016; J.Wei,IPAC2014

J-PARC = Japan Proton Accelerator Research Complex



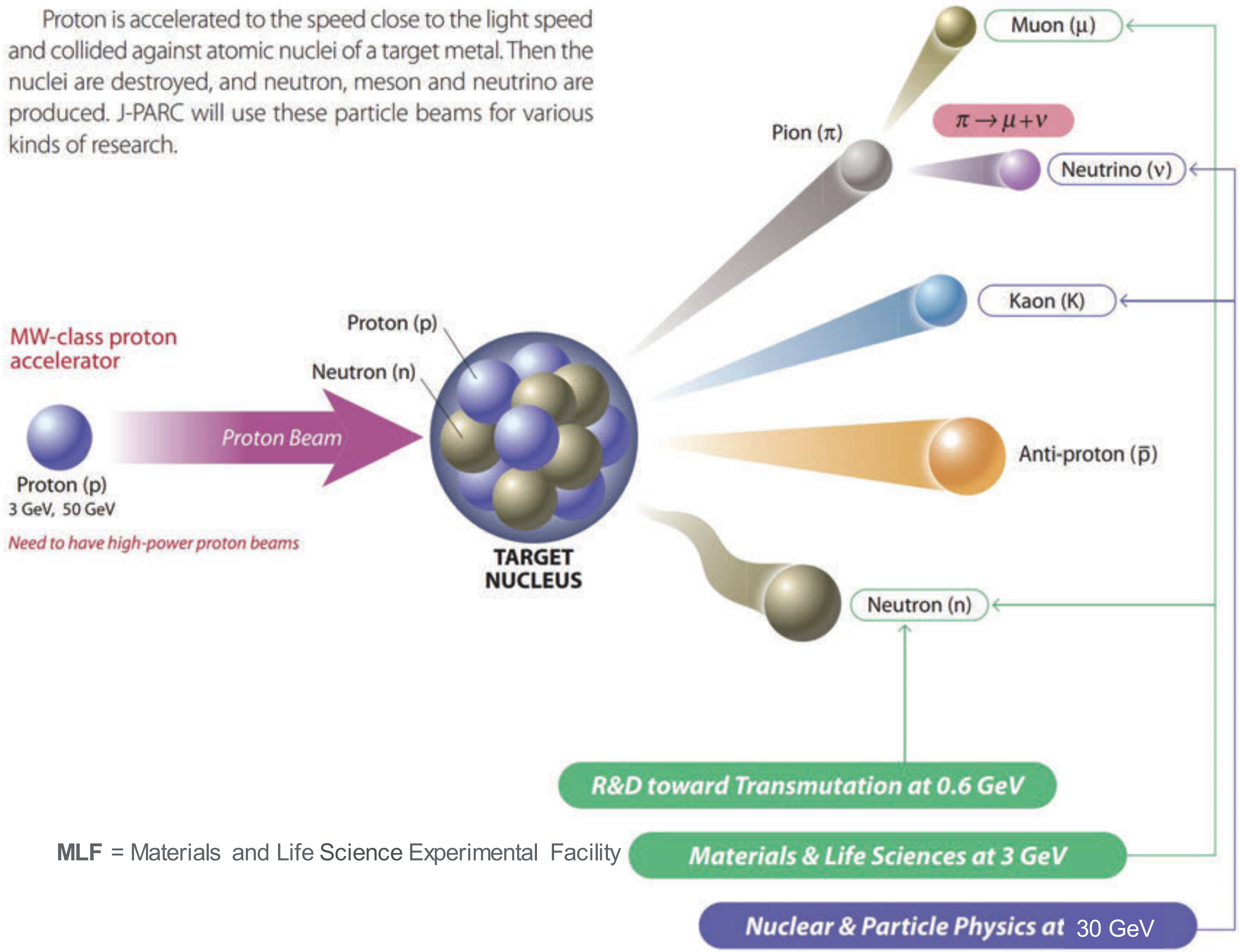
of J-PARC

Construction of J-PARC facilities started.
January Expected energy was achieved at Linac.
October Expected energy was achieved at RCS.
May First beam was successfully received for neutron target at MLF.
September First beam was successfully received for muon target at MLF.
December Initial target energy (30 GeV) was achieved at MR.
December Utilization of the Materials and Life Sciences Facility (MLF) was started.
January Hadron Experimental Facility was completed.
March Neutrino Experimental Facility was completed.
November First neutrino was successfully observed by the T2K near neutrino detector.
December The world's highest intensity of muon generation per pulse was confirmed at MLF.
March Operation was suspended due to the Great East Japan Earthquake.
January Operation resumed and user operation started.
November The world's highest intensity of neutron generation per pulse was confirmed at MLF.
May Incident at the Hadron Experimental Facility occurred.
January Energy upgrade was achieved at Linac.
January Short pulse 1 MW was achieved at MLF.
April User operation resumed at Hadron Experimental Facility.
July Continuous operation with a beam power equivalent to 1 MW was succeeded at MLF.
April Operation and user operation were suspended due to COVID-19.
June 36.5 hours of 1 MW user operation was implemented.
February Hyper-Kamiokande Project started.
April 750 kW beam was achieved for the first time in MR

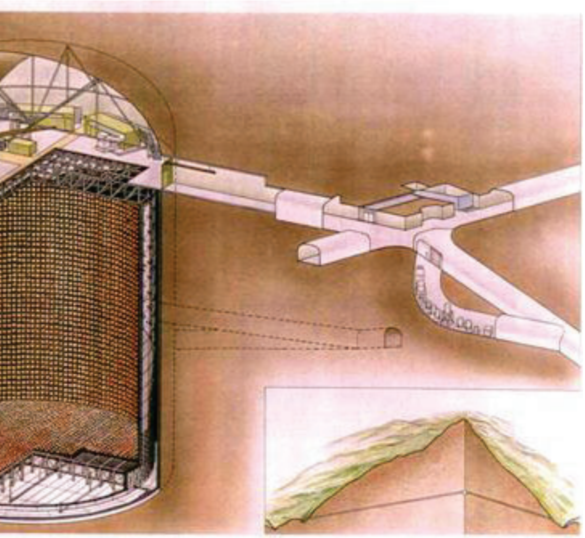
https://j-parc.jp/c/en/about/hi

Secondary beams produced with high-intensity proton beam

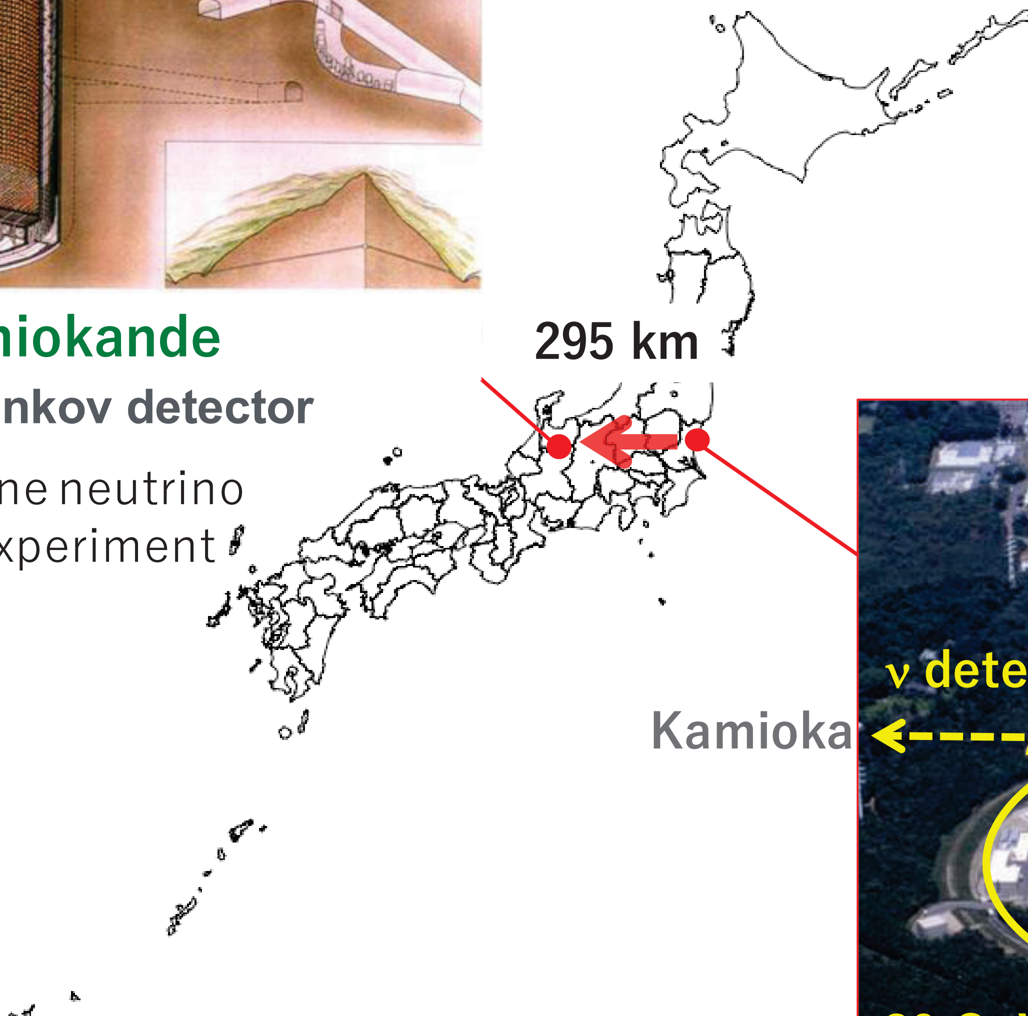
Proton is accelerated to the speed close to the light speed and collided against atomic nuclei of a target metal. Then the nuclei are destroyed, and neutron, meson and neutrino are produced. J-PARC will use these particle beams for various kinds of research.



MLF = Materials and Life Science Experimental Facility

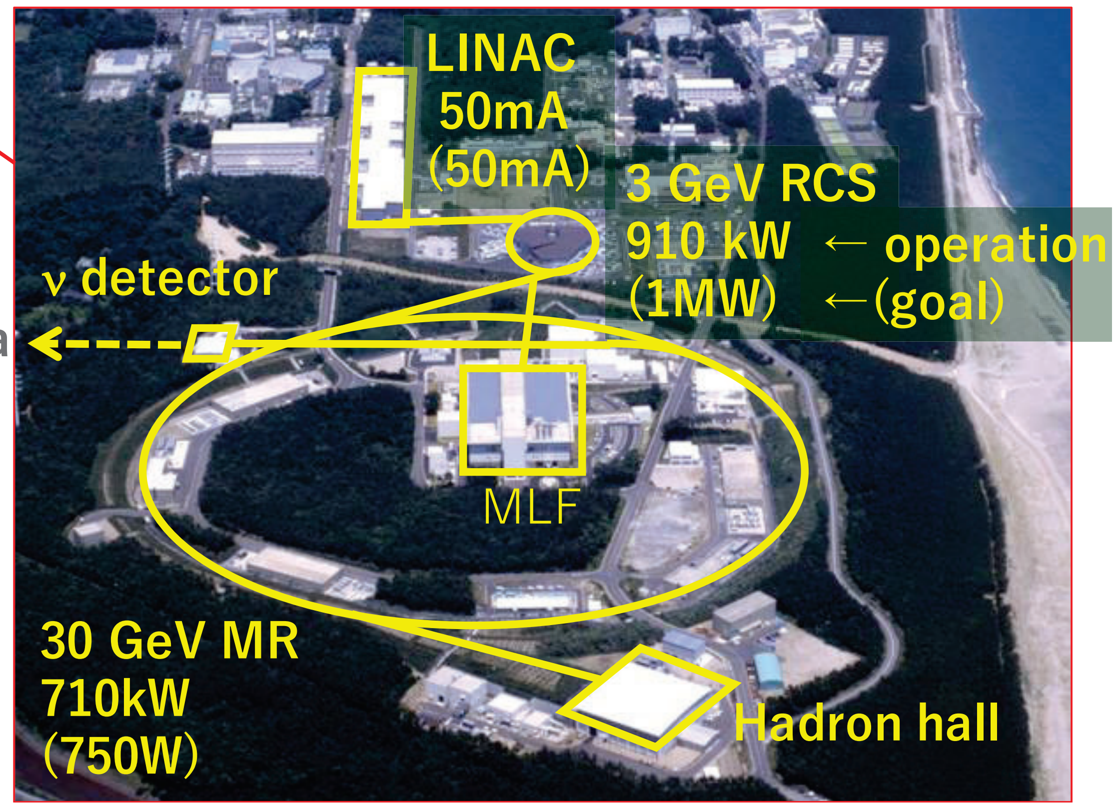


Kamiokande
herenkov detector
aseline neutrino
on experiment

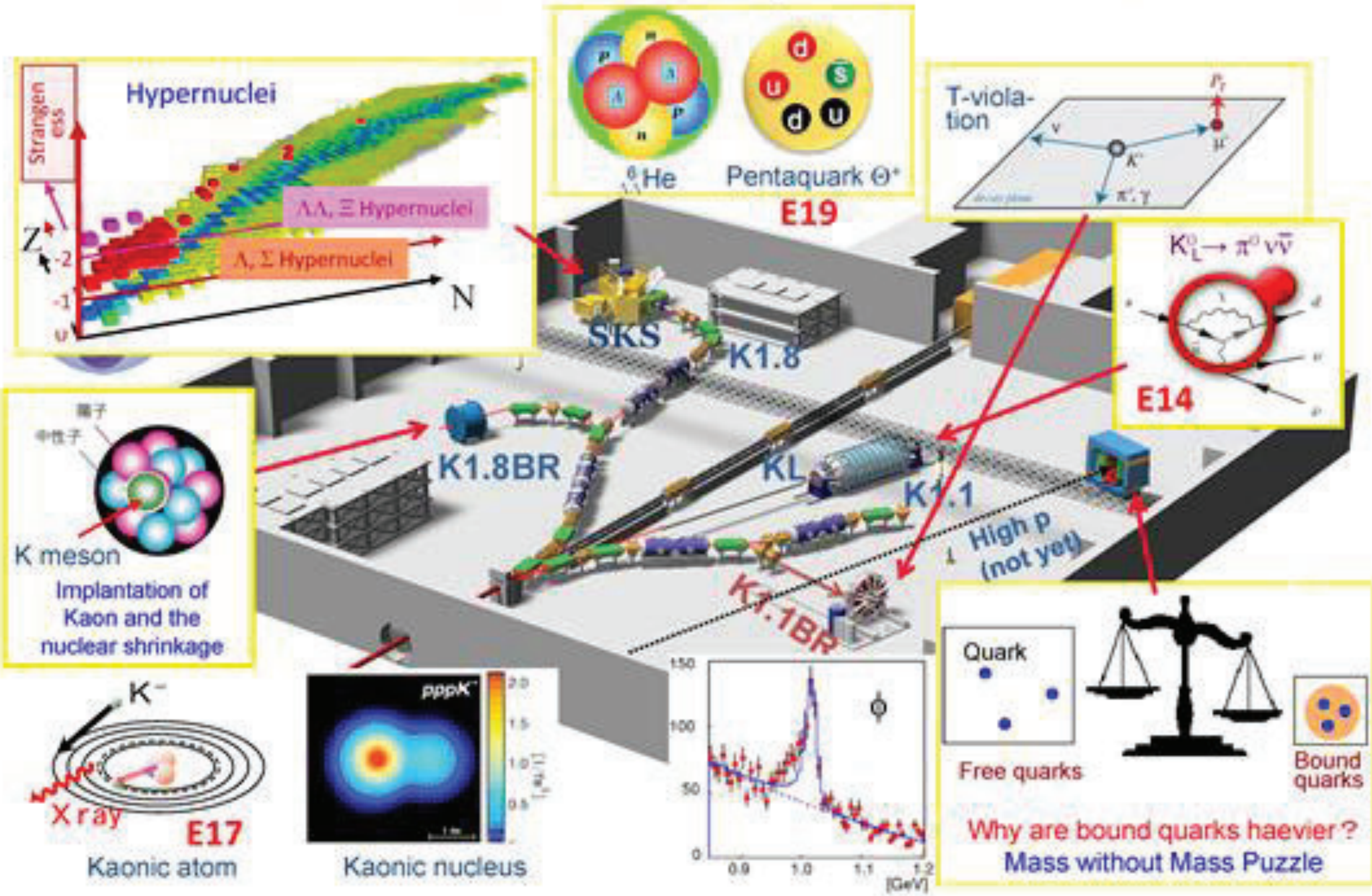


J -PARC

Tokai, Ibaraki



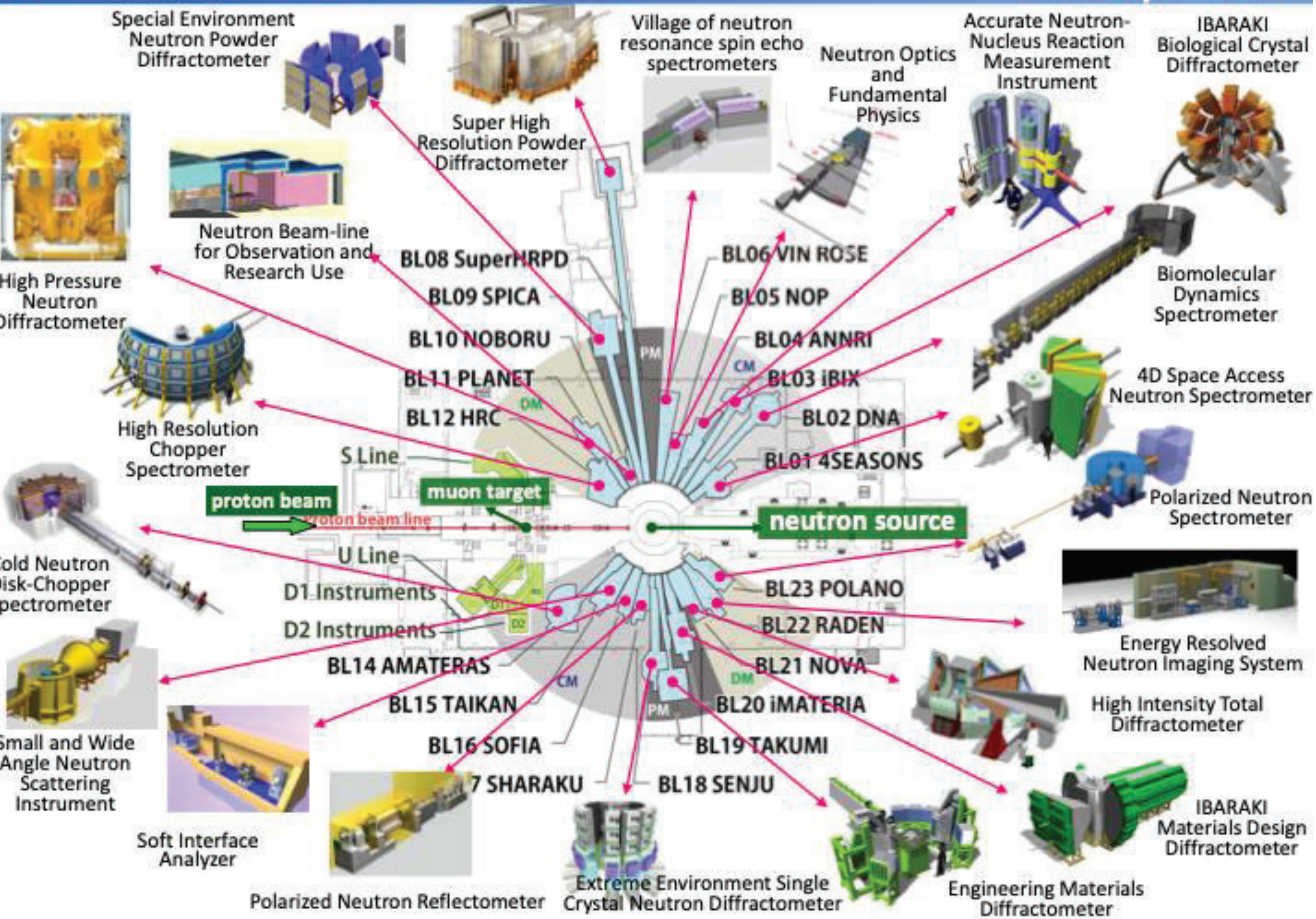
Nuclear & Particle Physics Program at J-PARC Hadron Experimental Hall



https://j-parc.jp/Hadron/

Neutron Instruments in MLF

23 beam ports
21 in operation



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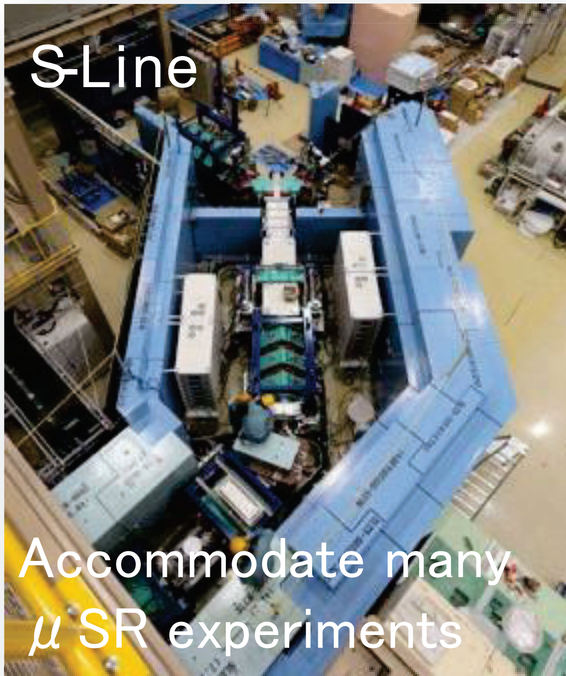
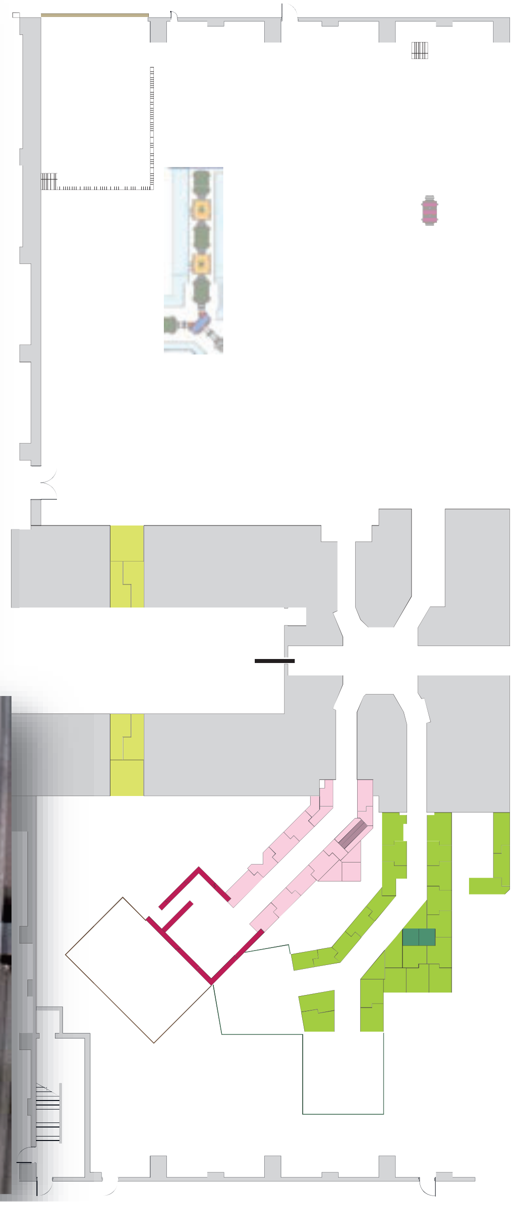
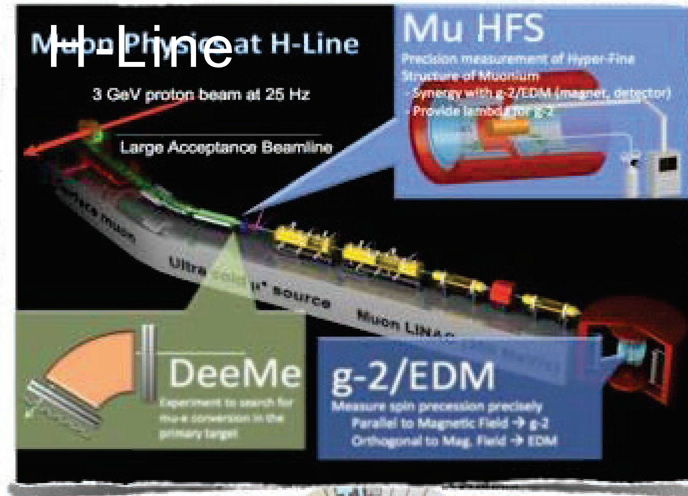
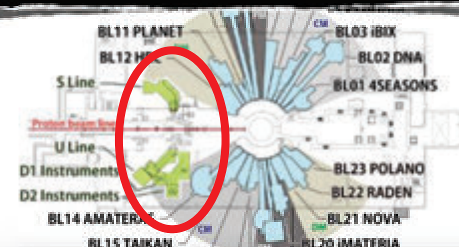
Muon Facility MUSE @ MLF









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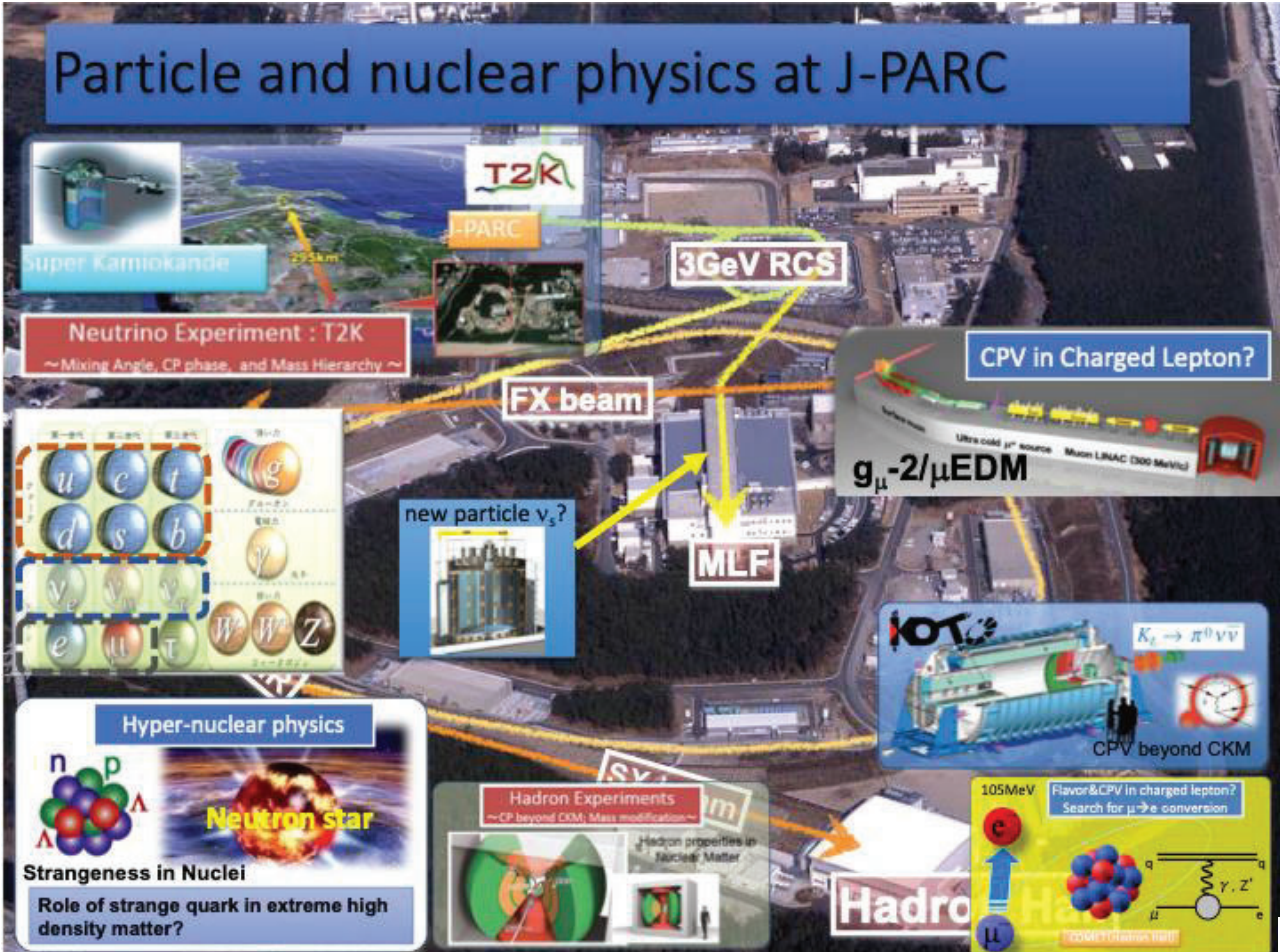
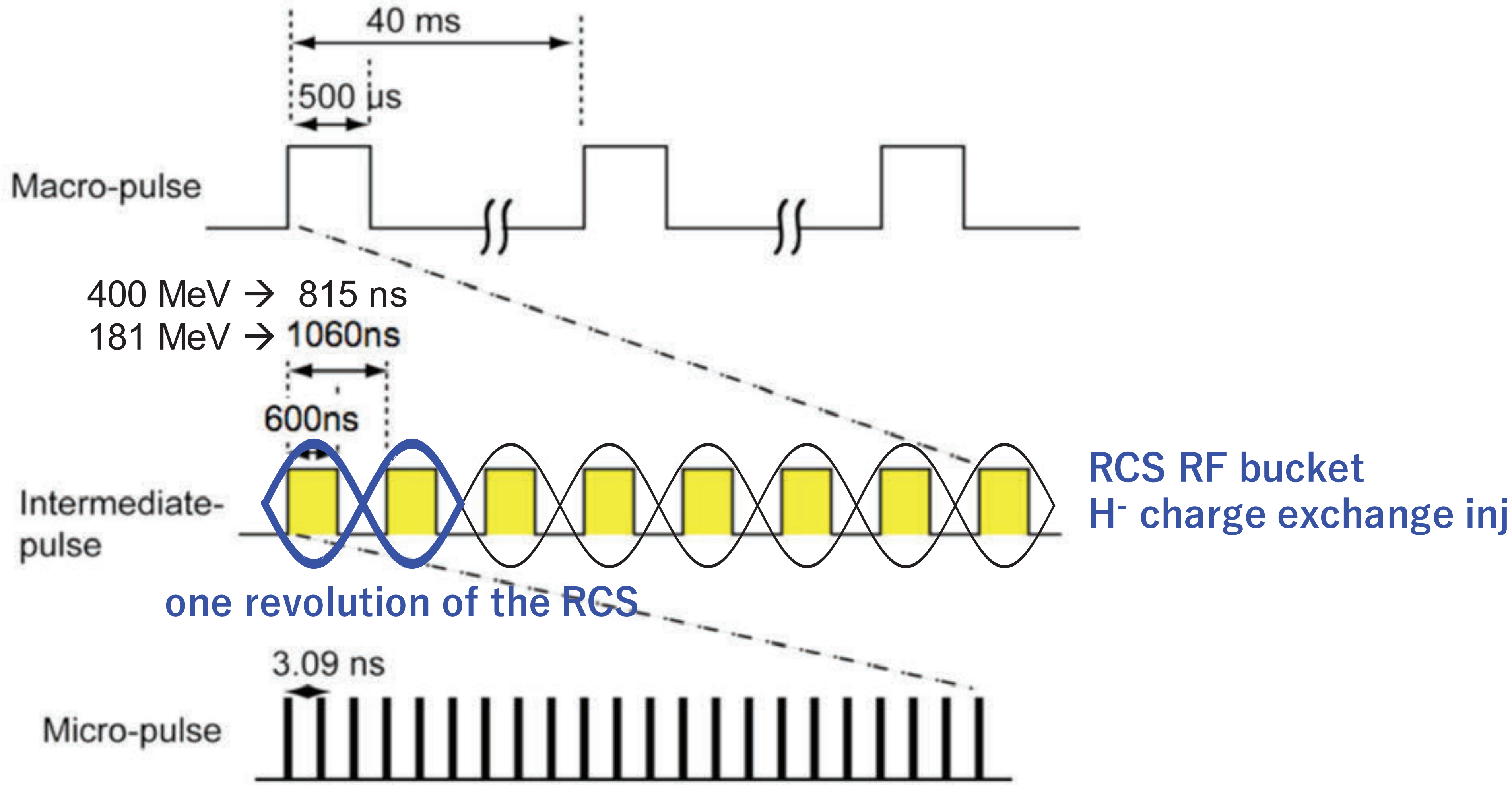


Particle and nuclear physics at J-PARC
T2K
J-PARC
Super Kamiokande
295km
Neutrino Experiment : T2K
~Mixing Angle, CP phase, and Mass Hierarchy~
3GeV RCS
FX beam
CPV in Charged Lepton?
g_μ-2/μEDM
new particle ν_s?
MLF
KOTO
CPV beyond CKM
Hyper-nuclear physics
Neutron star
Strangeness in Nuclei
Role of strange quark in extreme high density matter?
Hadron Experiments
~CP beyond CKM; Mass modification~
Hadron properties in Nuclear Matter
105MeV
Flavor&CPV in charged lepton?
Search for μ→e conversion
Hadro

Kob

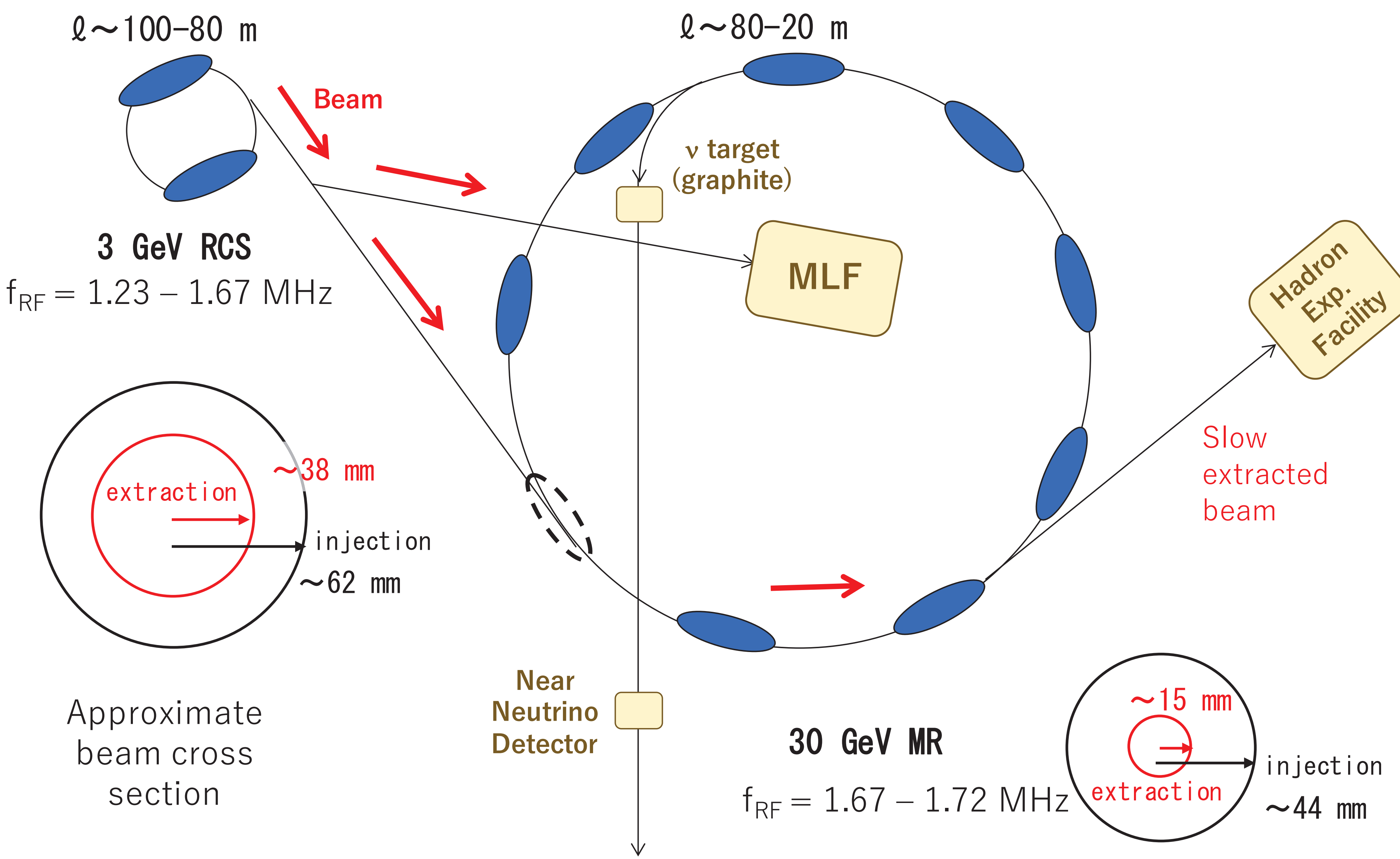
Beam from LINAC to RCS



Beam current ~ 5 mA - 50 mA

Beam pulse width ~ 200 ns – 500 μs

RCS (Rapid Cycling Synchrotron) & MR (Main Ring Synchrotron)



S. Igarashi, Y. Sato, R. Mu

MR Beam Power

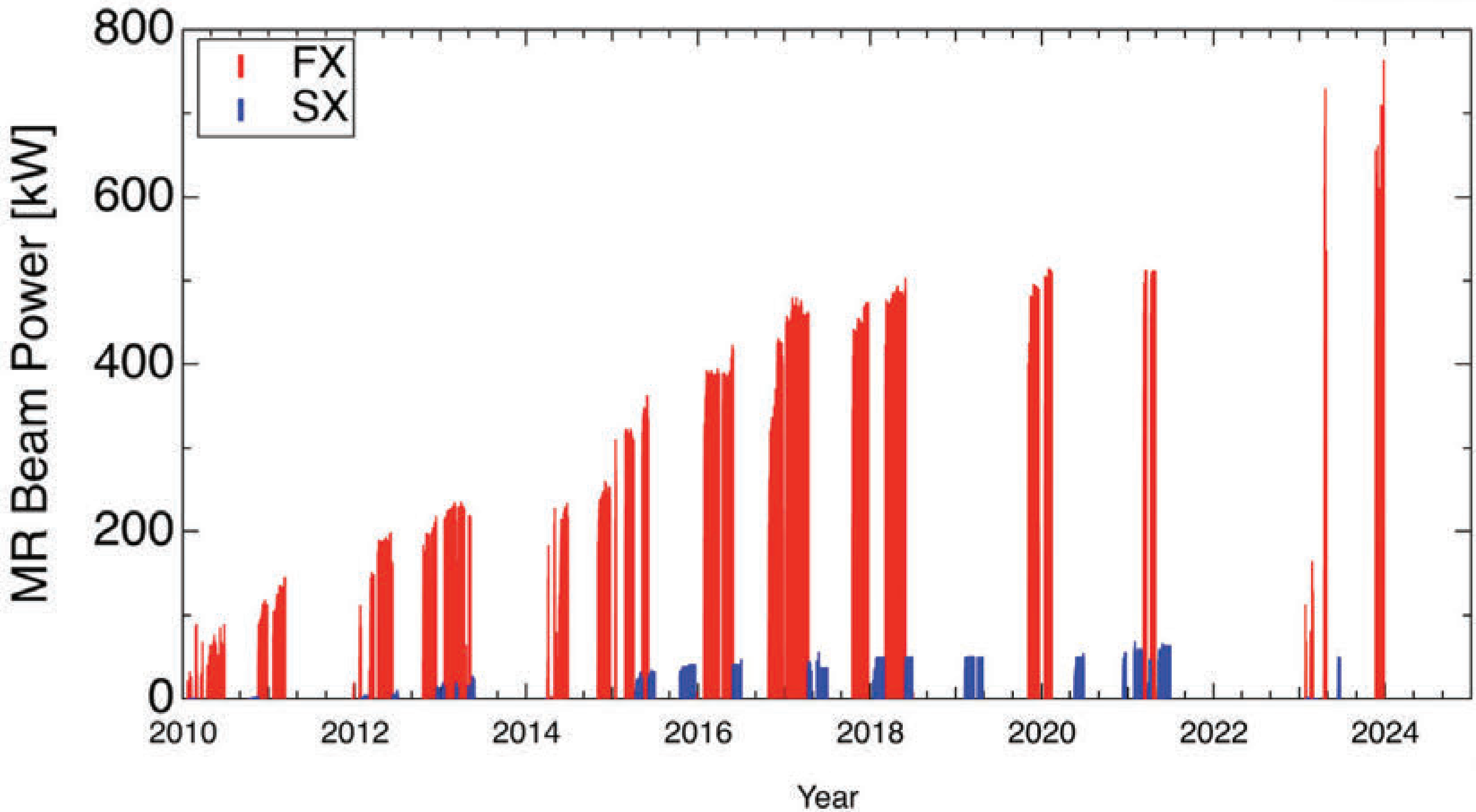
FX operation (Apr. 15 – 25 and Nov. 20 – Dec. 27, 2023) with the cycle time of 1.36 s

- Beam power (max.) : 760 kW   stable user operation 710 kW

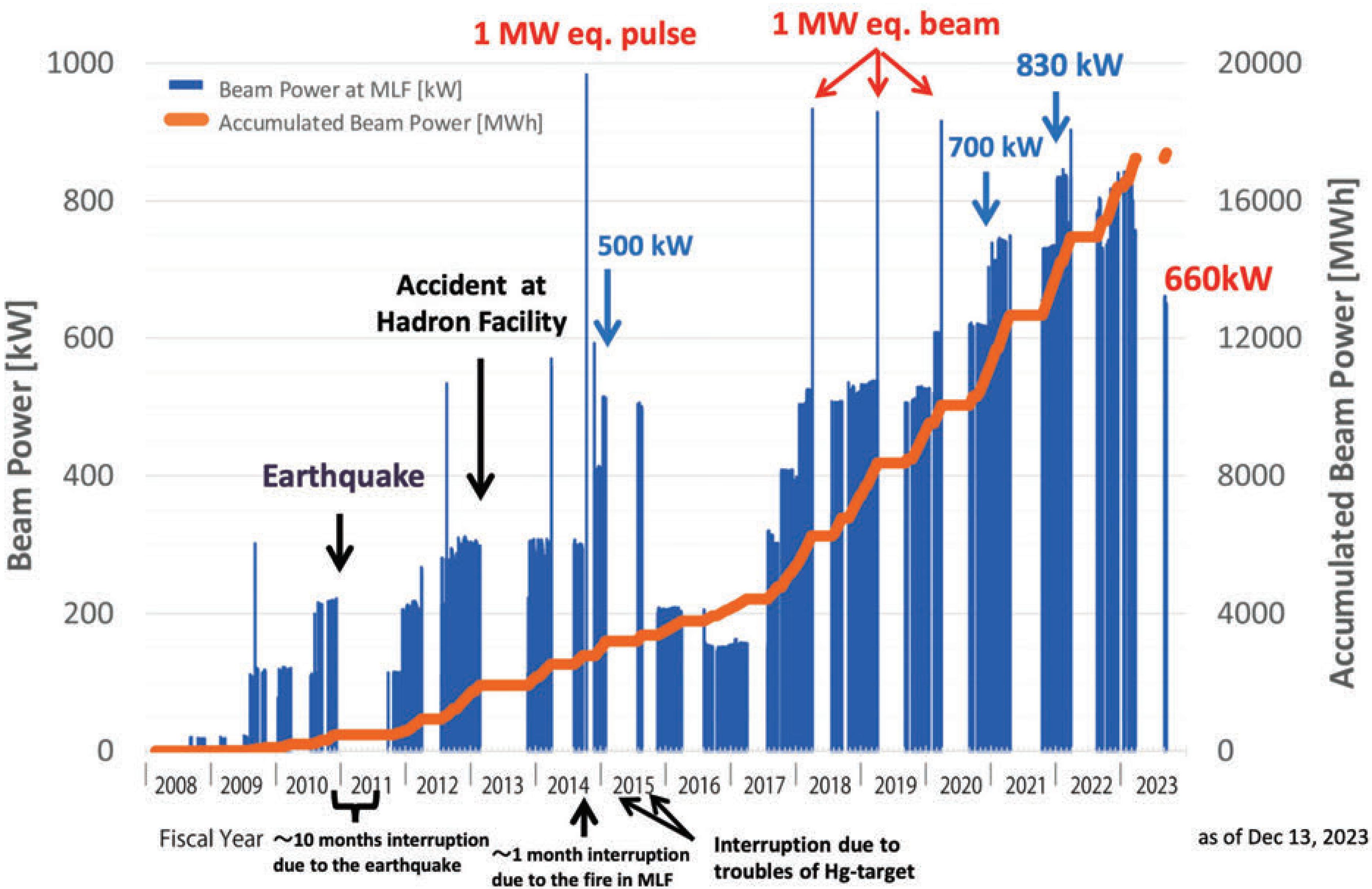
SX operation

- 8 GeV (Feb. 10 – 14, March 1 – 14, 2023) with cycle time of 4.8 s × 2 = 9.6 s
- 30 GeV (June 13 – 22, 2023) with cycle time of 5.2 s

As of Dec. 26, 2023



Beam Power History at MLF



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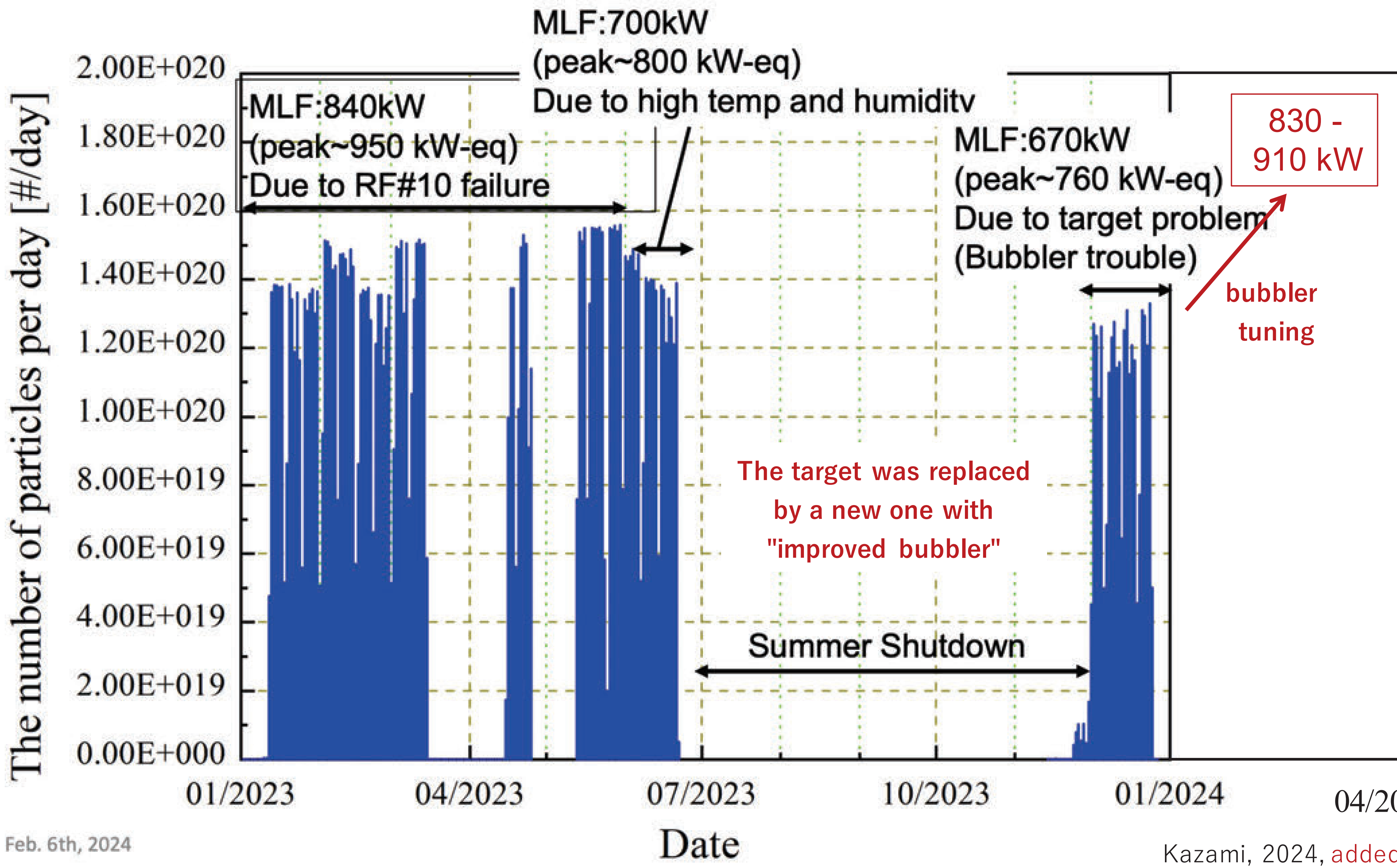
Output beam power



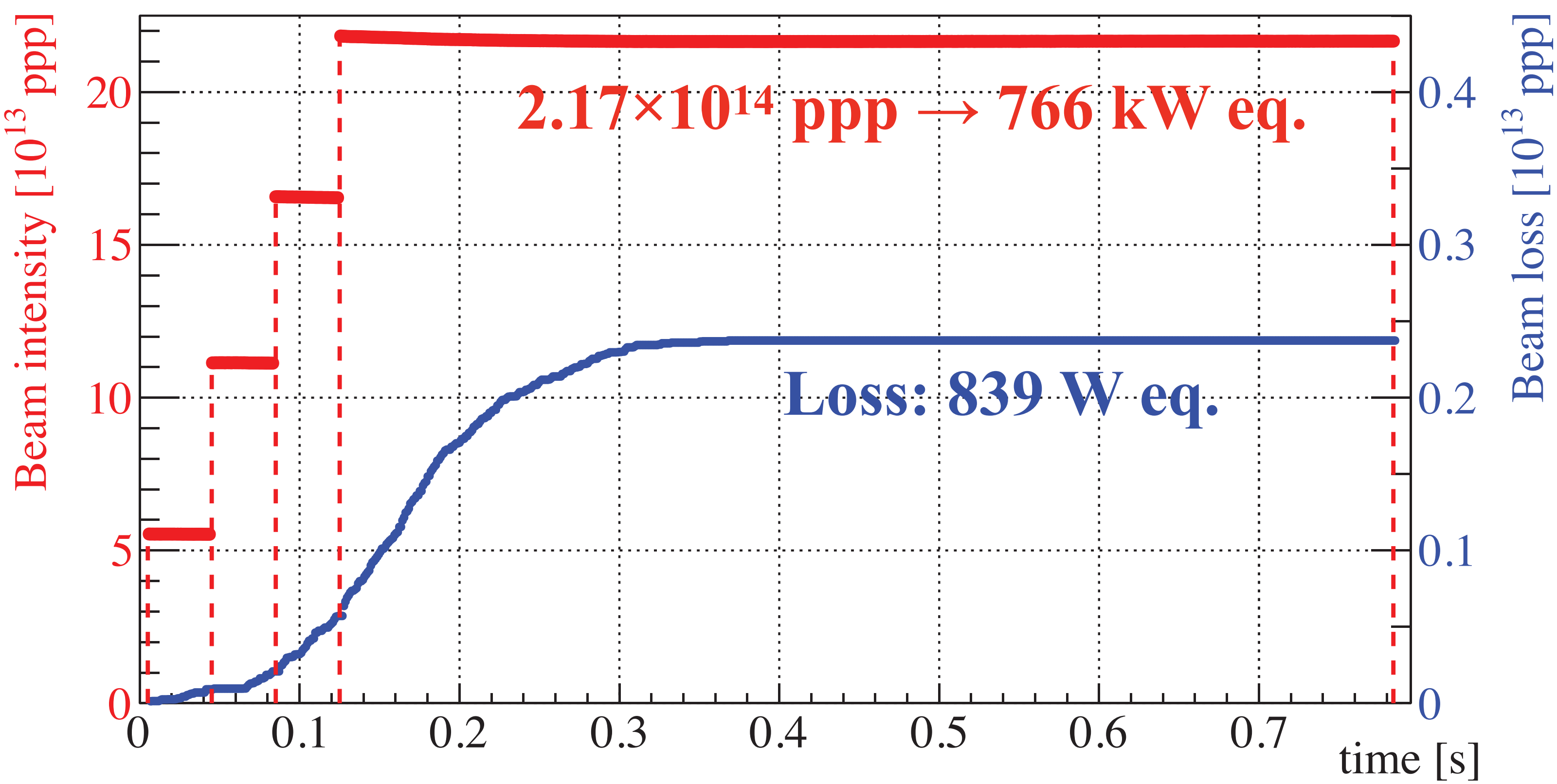
Feb. 6th, 2024

Kazami, 2024, added

Achievement of FX 750 kW (design param. of the MR)

'e have successfully demonstrated the conditions for the FX user operat
ith the beam power of 750 kW.

Beam intensity and beam loss estimated by the DCCT

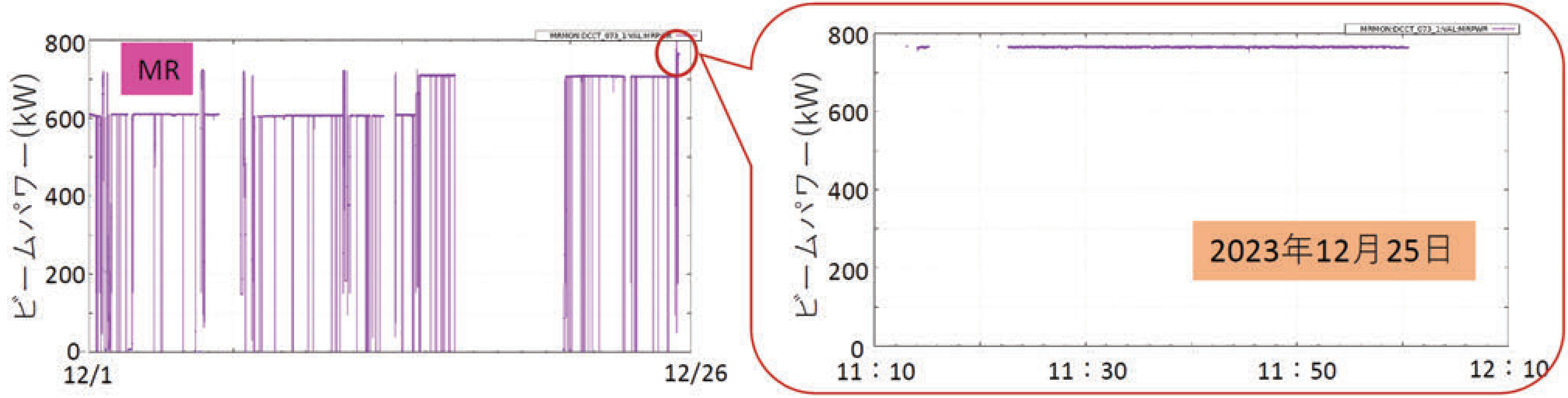


Yasui,

inally, MR/NU succeeded continuous peration at 760kW

MR Power 763.97 kW

2023/12/25 11:22 – 12:00; **Stable operation during 38 min**



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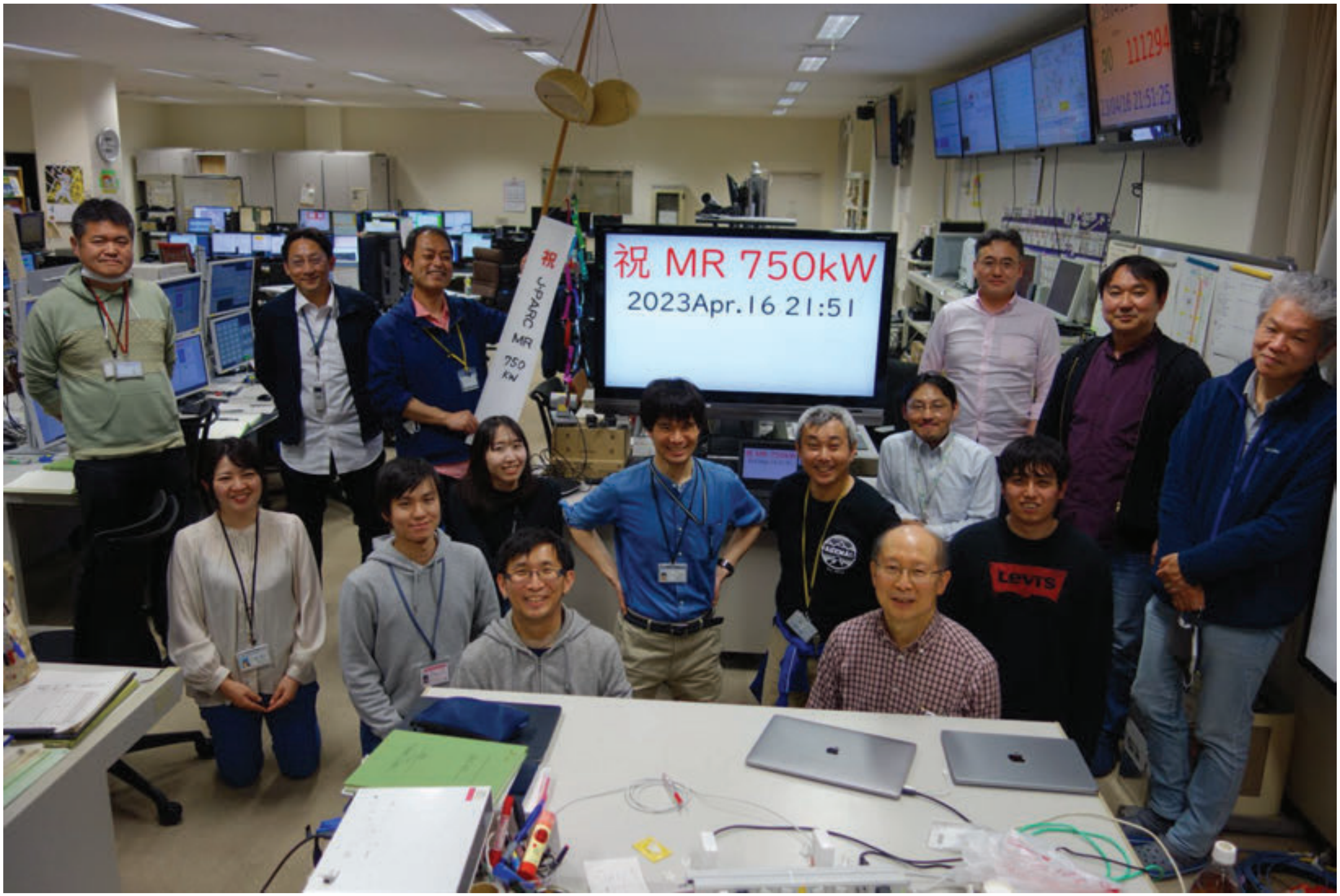
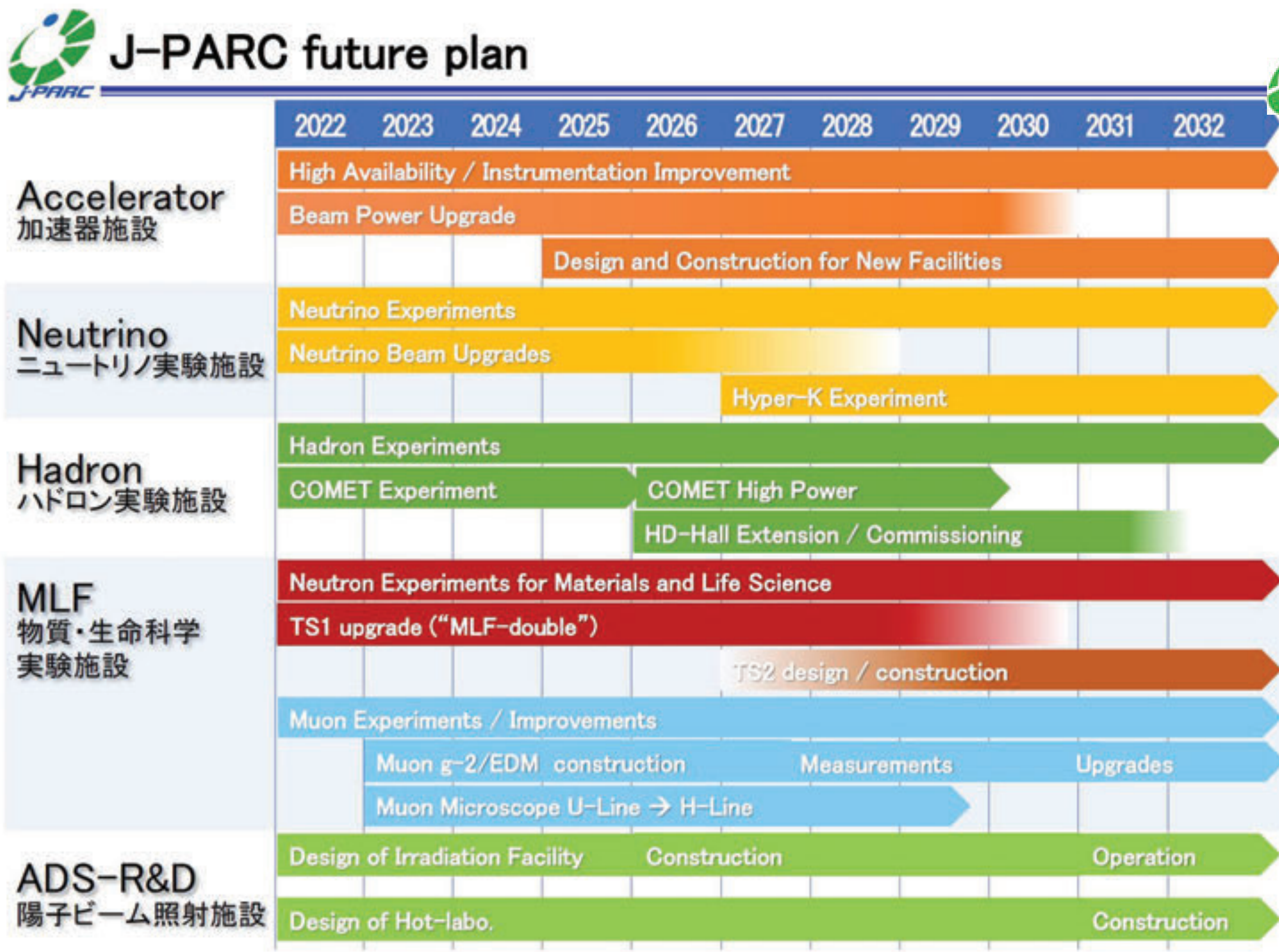
First 750 kW beam



Yasui,

ATAC2024



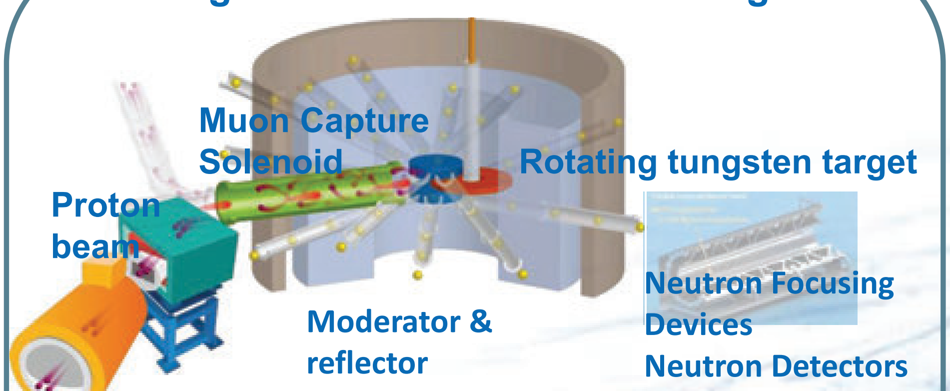
- **J-PARC future plan**
  - Neutrino: Hyper-Kamiokande experiment
    - ➢ Beam power 1.3MW
  - Hadron Facility:
    - Hadron Facility Expansion
      - ➢ Beam power □ 100kW as soon as possible
    - COMET experiment
      - ➢ 8GeV slow bunched extraction
  - MLF: TS2
    - ➢ Beam Power >1.5MW from RCS with 25Hz
  - Transmutation Experimental Facility: Irradiation Facility
    - ➢ Beam energy 400MeV,Beam power 250kW with 25Hz from linac

K

Target Station - 2

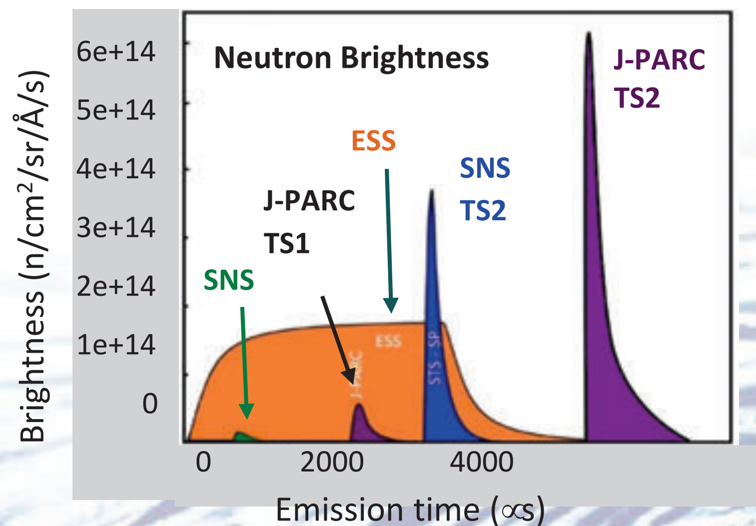
- Integration of neutron and muon sources (world's first)
- J-PARC proton accelerator intensity (1 MW) increased to 1.5 MW
- 1 MW (17 Hz) for TS1 and 0.5 MW (8 Hz) for TS2

Integrated neutron and muon target



Neutron:
10 (target) x 2 (device) → 20 times gain of brightness

Muon:
10 (target) x 5~10 (Muon capture solenoid) → 50 ~100 times gain of flux



Brightness of MLF TS2 will be the world's highest compared to the next plan of overseas facilities

Koba

Beam diagnostic instruments at J-PARC

Overview classified by the detectors

Miura, Kazami, Toyama 2021

	IS & LINAC	3 GeV RCS	30 GeV MR	MLF (3NBT)	HD (A-,B-line)
nsity	FCT, SCT	FCT, WCM,DCCT, MCT, SCT	FCT,ICT, WCM, DCCT	ICT	Scintillator IPM, IC
on	Stripline	Stripline, ESM	Stripline, ESM	Stripline, ESM	= profile
	Scintillator, Prop. chamber, IC	Scintillator, Prop. chamber	Scintillator Prop. chamber, IC, Semiconductor	Scintillator Prop. chamber	Prop. chamber, IC
o	Wire Scanner, (Gas-sheet PM), Bunch shape monitor	MWPM, IPM, (Halo)SEM+Wire Scanner	SCM, MRPM, IPM, Gas-sheet PM, (Halo)OTR/FL	MWPM (Halo)SEM+ Thermocouple	OTR, IPM, IC, SCM
	Slit/Collector (off-line)				
y /	Mom. analyzer				
		Stripline kicker/BPM	Stripline kicker/BPM		
k			Stripline kicker/PU		
back		RF cavity/FCT	RF cavity/WCM		
tector			retarding field analyzer		
					Scintillator, Prop. chamber

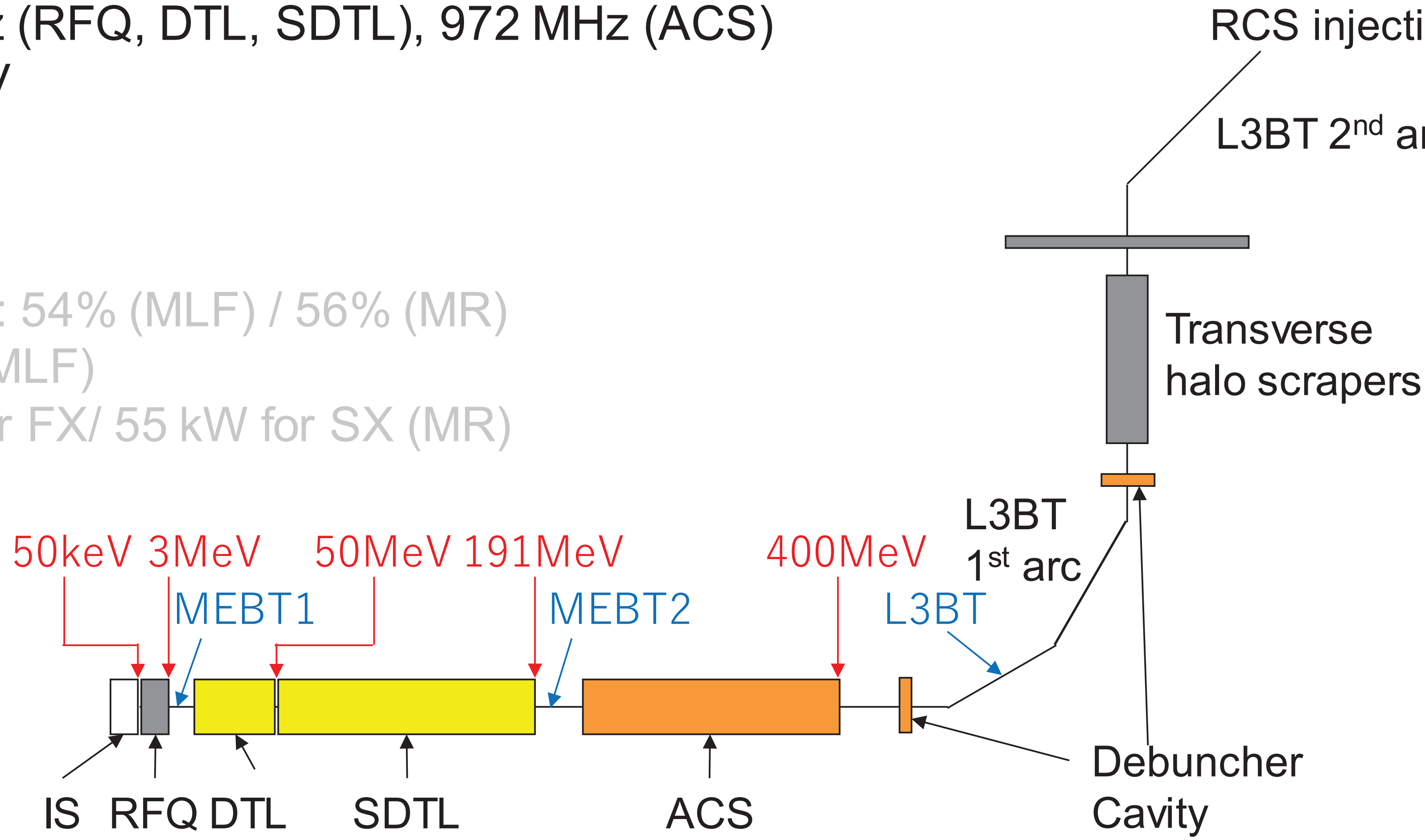
e

FCT	"Fast" Current Transformer (passive CT)
MCT	"Medium" Current Transformer
SCT	"Slow" Current Transformer (Active CT)
ICT	"Integrating" Current Transformer
ESM	ElectroStatic Monitor
MWPM	Multi-wire Profile Monitor
MRPM	Multi-Ribbon Profile Monitor
SSEM	Segmented Secondary Emission Monitor
WSEM	Wire Secondary Emission Monitor
SCM	Screen Monitor
Stripline kicker	same device as an "exciter"
IC	Ionization chamber
Proportional chamber	same device as the proportional counter but acquire the curr

1. LINAC

ain Parameters of Linac

- **species**: Negative hydrogen ion
- **frequency**: 324 MHz (RFQ, DTL, SDTL), 972 MHz (ACS)
- **tput energy**: 400 MeV
- **ak current**: 50 mA
- **se width**: 0.5 msec
- **petition rate**: 25 Hz
- **opper beam-on ratio**: 54% (MLF) / 56% (MR)
- **am power**: 600 kW (MLF)
  515 kW for FX/ 55 kW for SX (MR)



List of IS & LINAC regular monitors

Type	IS	MEBT1	DTL/SDTL	MEBT2	ACS	L3BT & dumps	Spec.
Stripline		8	32	6	21	20	
FCT		5	50	6	21	7	
SCT	1	5	19	2	21	6	
Proportional chamber		0	31	3	21	39	
Scintillator							
WS		4	4	2	4	22	
BSM		1*	0	1	3*	1*	MEBT2: INR dev *: under develop

List of I & LINAC monitors under development

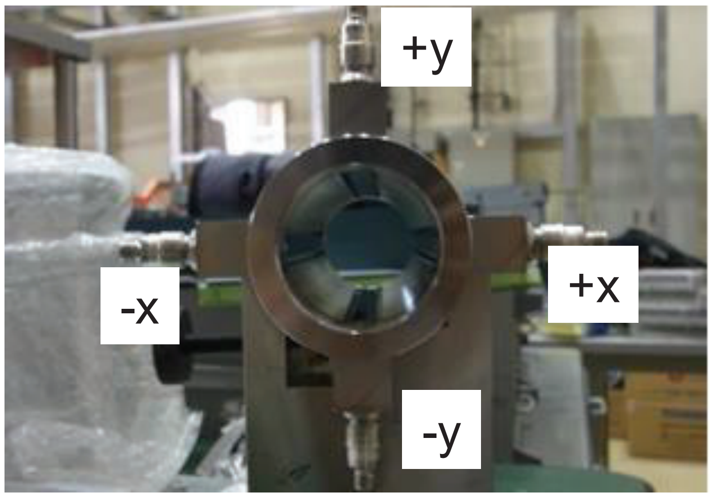
itor Type	Number	Spec.
le	1	Gas-sheet profile monitor; IOP Conf. Series: Journal Physics: Conf. Series 1067 (2018) 072006
ch shape monitor	5	

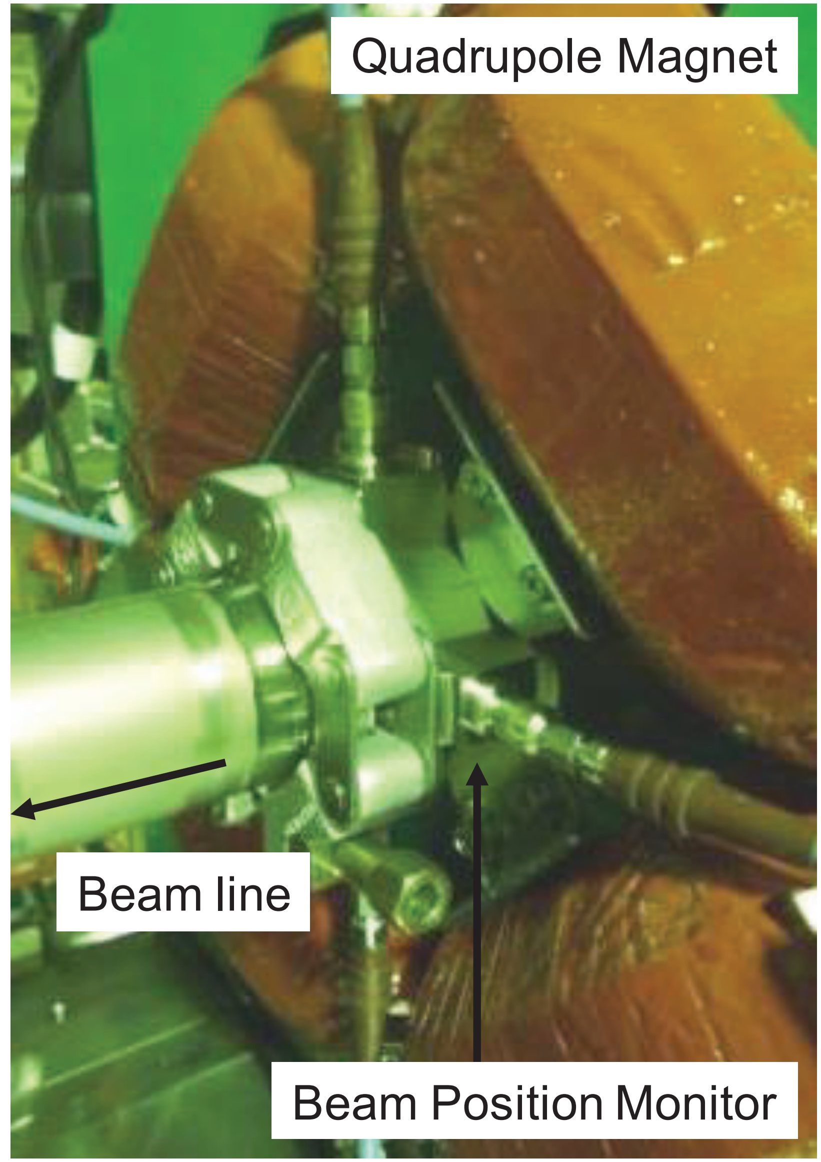
2. Commissioning Tools

Beam Position Monitor (BPM)

Strip-line type is employed.

Resolution
$\Delta x \lesssim 0.1$ mm
$\Delta y \lesssim 0.1$ mm





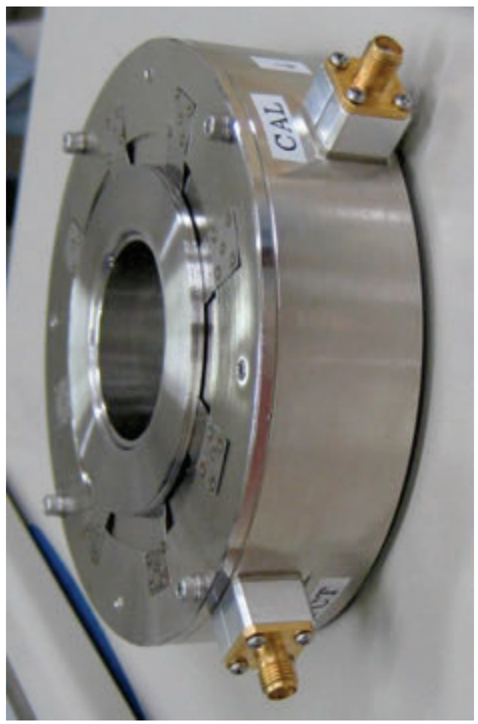
Beam Current (SCT: Slow Current Transformer)
Phase Monitor (FCT: Fast Current Transformer)

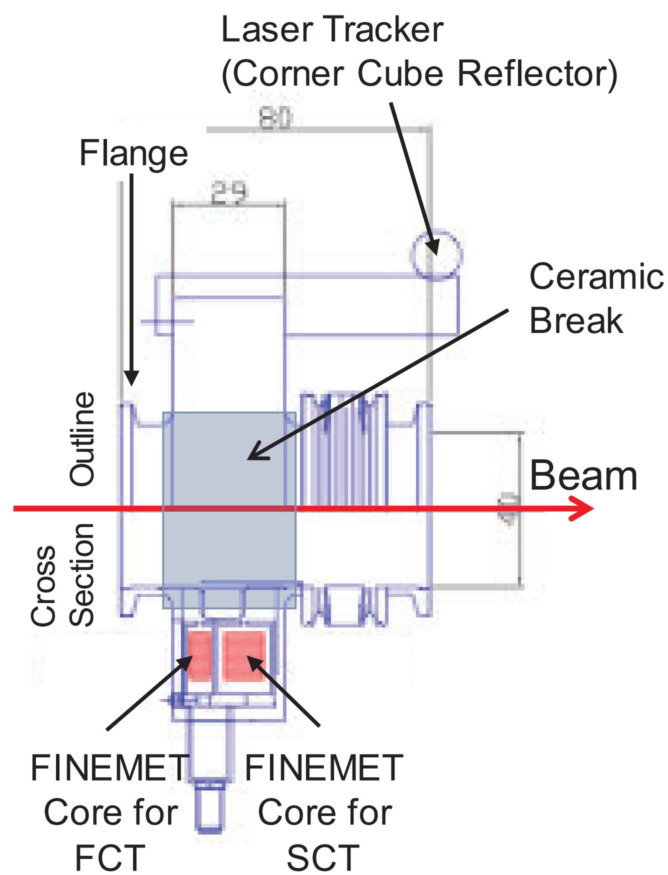
Annular magnet core "FINEMET" is employed for the current transformer.

Dynamic Range
- SCT: 0.1 – 80 mA
- FCT: > 30dB

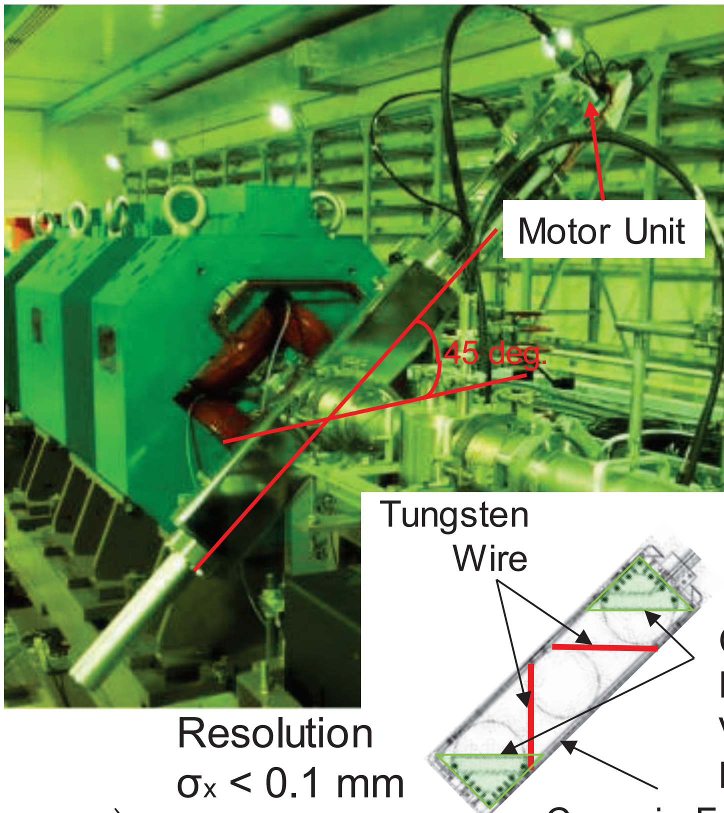
Winding coil,
- SCT: Fifty turns
- FCT: Single turn

Resolution,
- SCT: ΔIbeam < 1.0 %,
  ΔI (resolution) ~ 0.1 mA
- FCT: Δφbeam < 1.0 deg.
  Energy: < 0.1 %



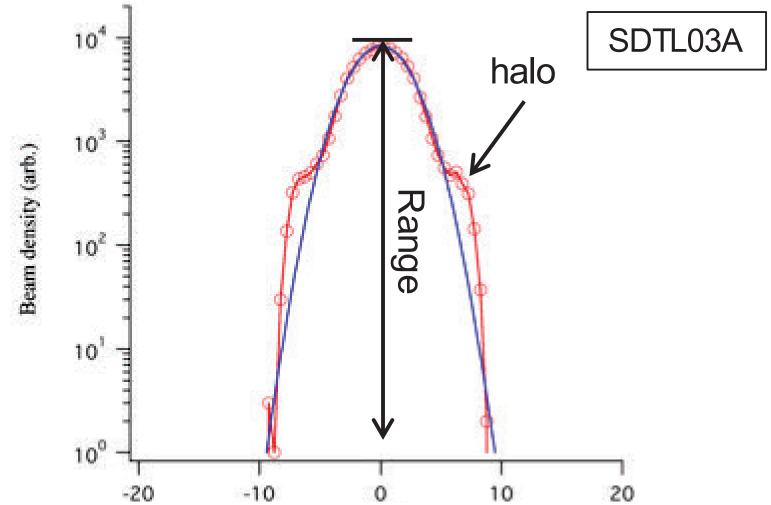


Beam Profile Monitor
(WS: Wire Scanner)

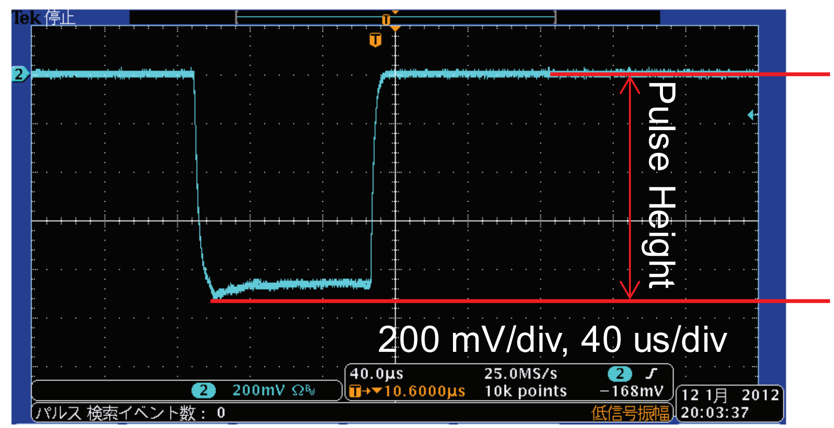


Resolution
(step size) $\sigma_x < 0.1$ mm
$\sigma_y < 0.1$ mm

Four WSs are located in each matching section periodically.
Dynamic range reaches four orders.



Example of Transverse Profile



Signal Obtained at the Peak of Beam Pulse

Carbon nanotube target (100 μm) is used at **MEBT1 (3 MeV)**

A Miura *et al* 2018 *J. Phys.: Conf. Ser.* **1067** 072020

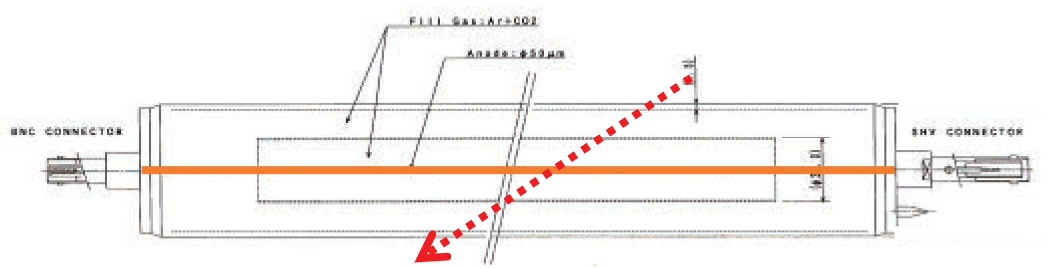
Beam Loss Monitor (BLM)

Gas Proportional BLM, E6876 - 600
Toshiba Electron Tubes & Devices Co. Ltd.,

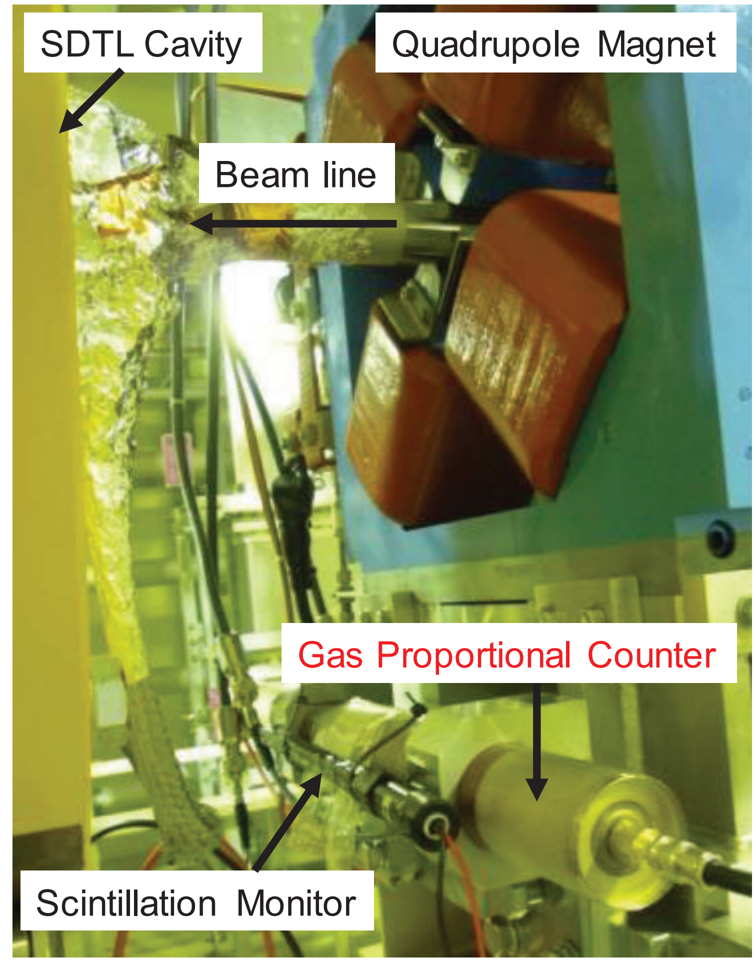
Sensitive for charged particle, X-ray and gamma-ray

Fast time response
It is enough fast to alarm the protection system.
$\tau < 1.0\ \mu s$

Length: 600mm
Diameter: 50.8 mm
Gas pressure: 1 atm



Anode Pt Wire, Φ50um
(Gas: Ar+CO_2)



Utilities of bunch shape monitor

- Optimization of buncher settings based on the amplitude scan.

nplitude tuning using scan curve and Twiss rameters is trying.

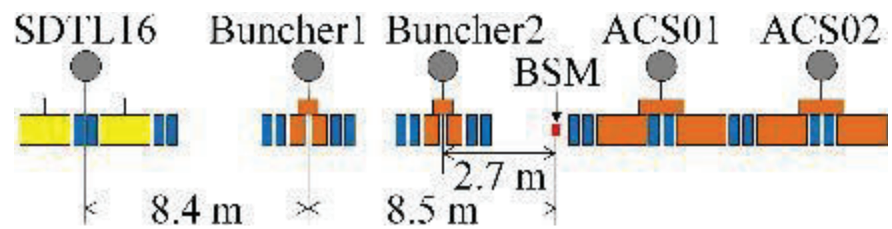
$$\sigma^2_{BSM} = \varepsilon_z[(1+Lk)^2\beta_B - 2L(1+Lk)\alpha_B + L^2\gamma_B]$$

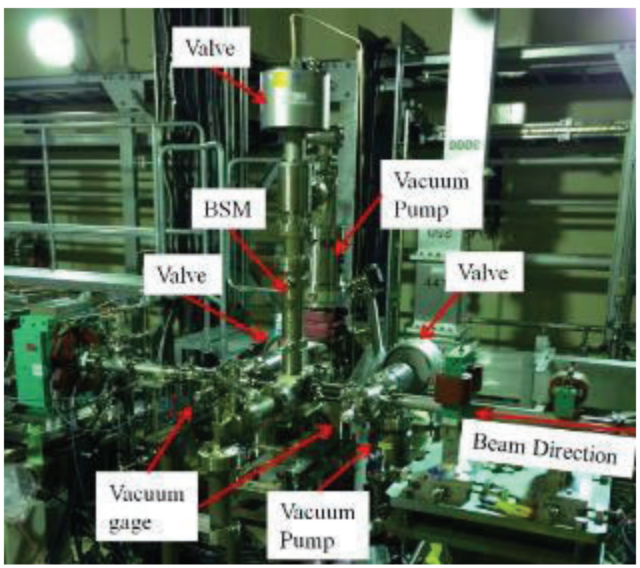
s emittance,

s drift length,

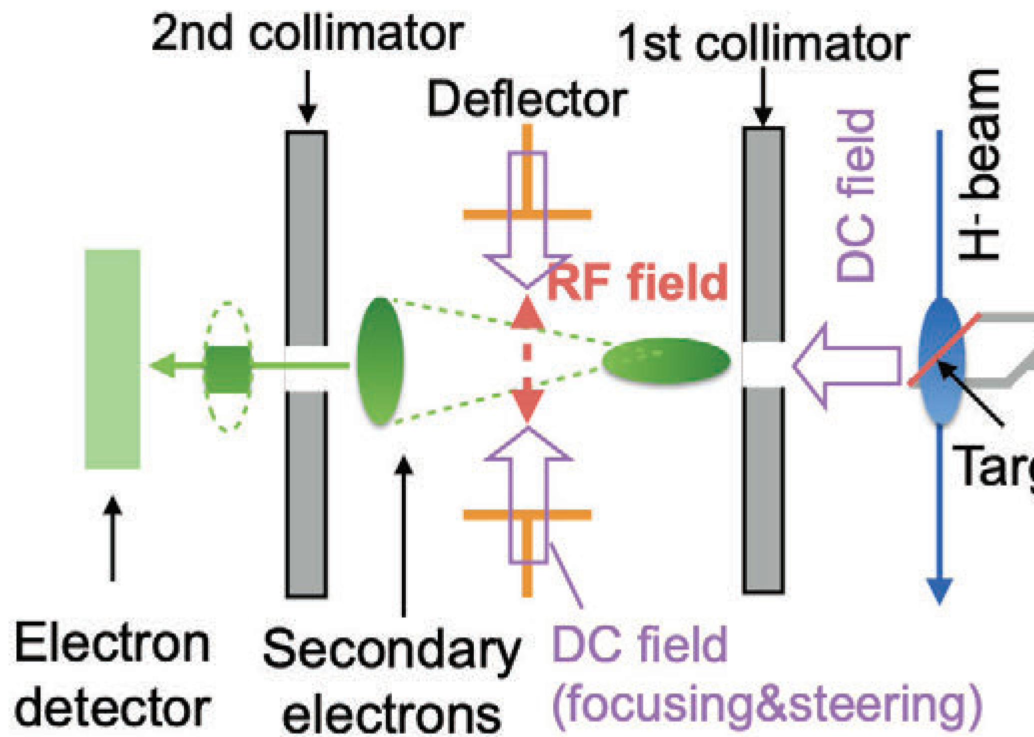
β_B, γ_B are Twiss parameter at BSM position,

s longitudinal focusing force (variable).





Bunch shape monitor installed at beginning of ACS section



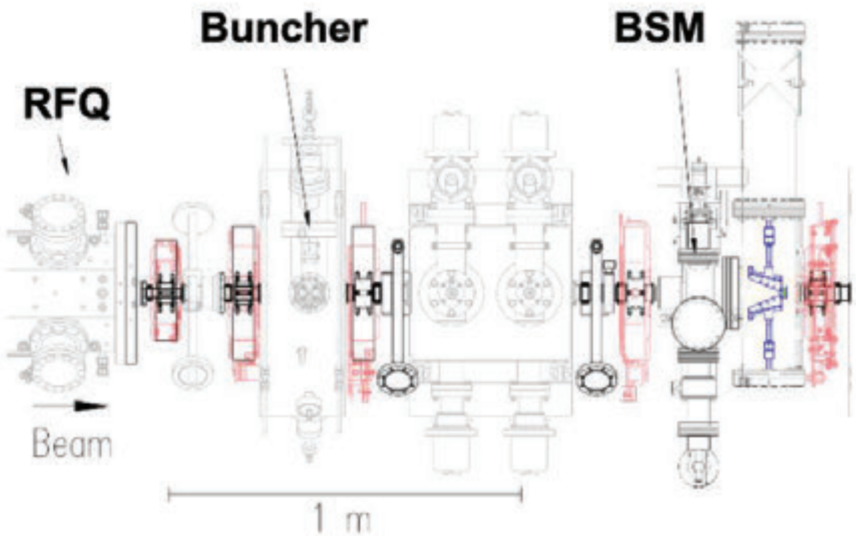
SM has been developed to measure the high-power beam in MEBT1 Kitamur

on nanotube): Field emission was serious for the BSM

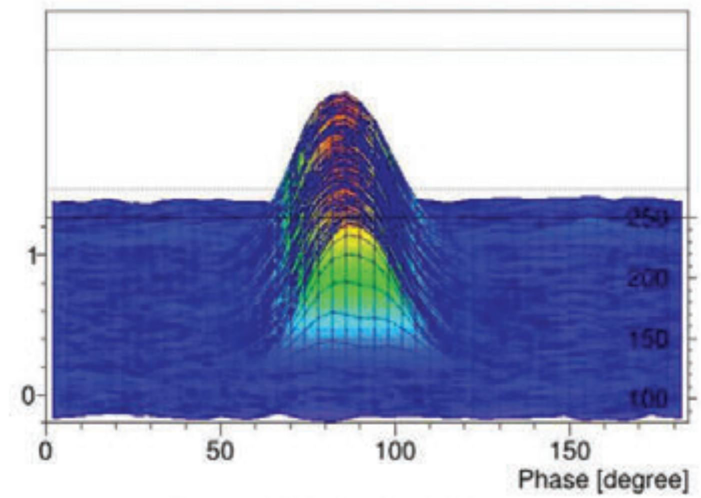
ghly Oriented Pyrolytic Graphite):

Its high thermal conductivity is suitable to mitigate the heat loading

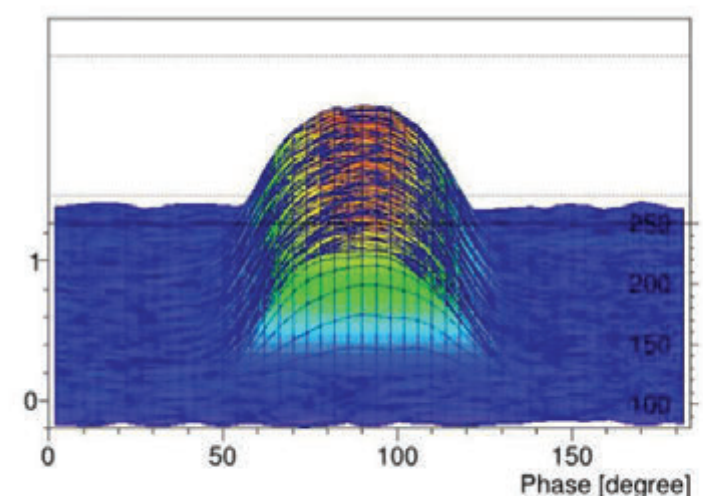
Setup of MEBT1 (upstream)



Waveform of BSM with strong focusing



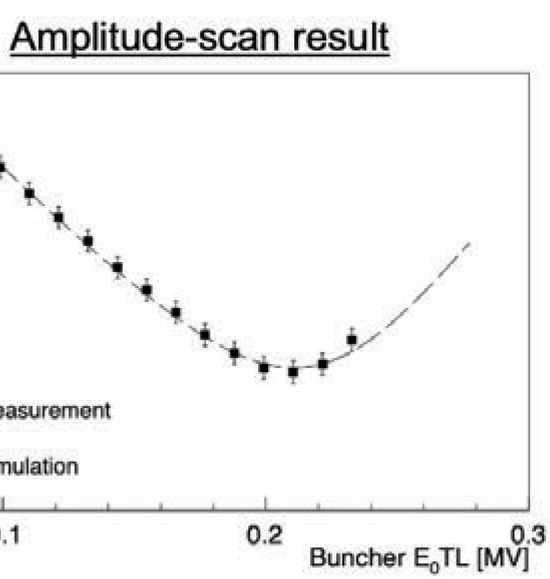
Waveform of BSM with weak focusing

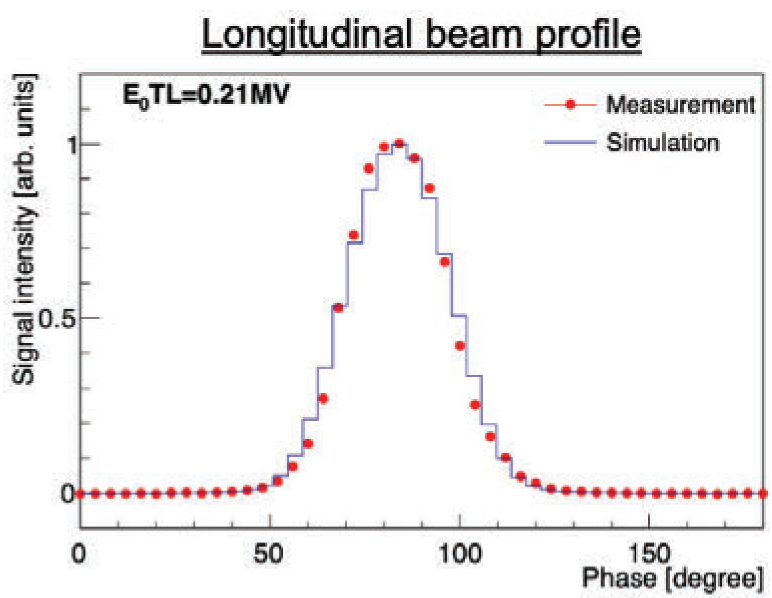


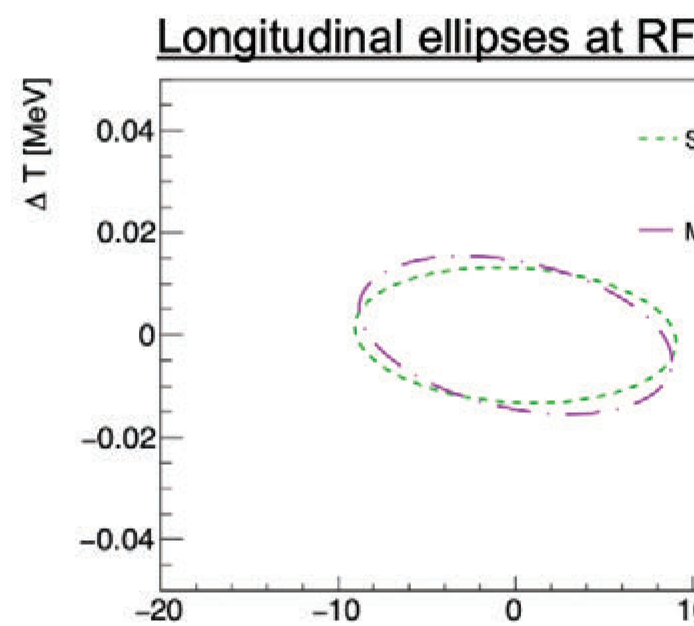
- Longitudinal beam parameters (Twiss and emittance) were measured using the BSM.
  - Amplitude scan method with buncher.
  - Required time ~ 1 hour/scan
- When the amplitude of the buncher was scanned, the dependence of longitudinal profiles was observed as expected.

Fitting result using simulation

l initial parameters are estimated with 3D Particle-In-Cell code (IMPAC

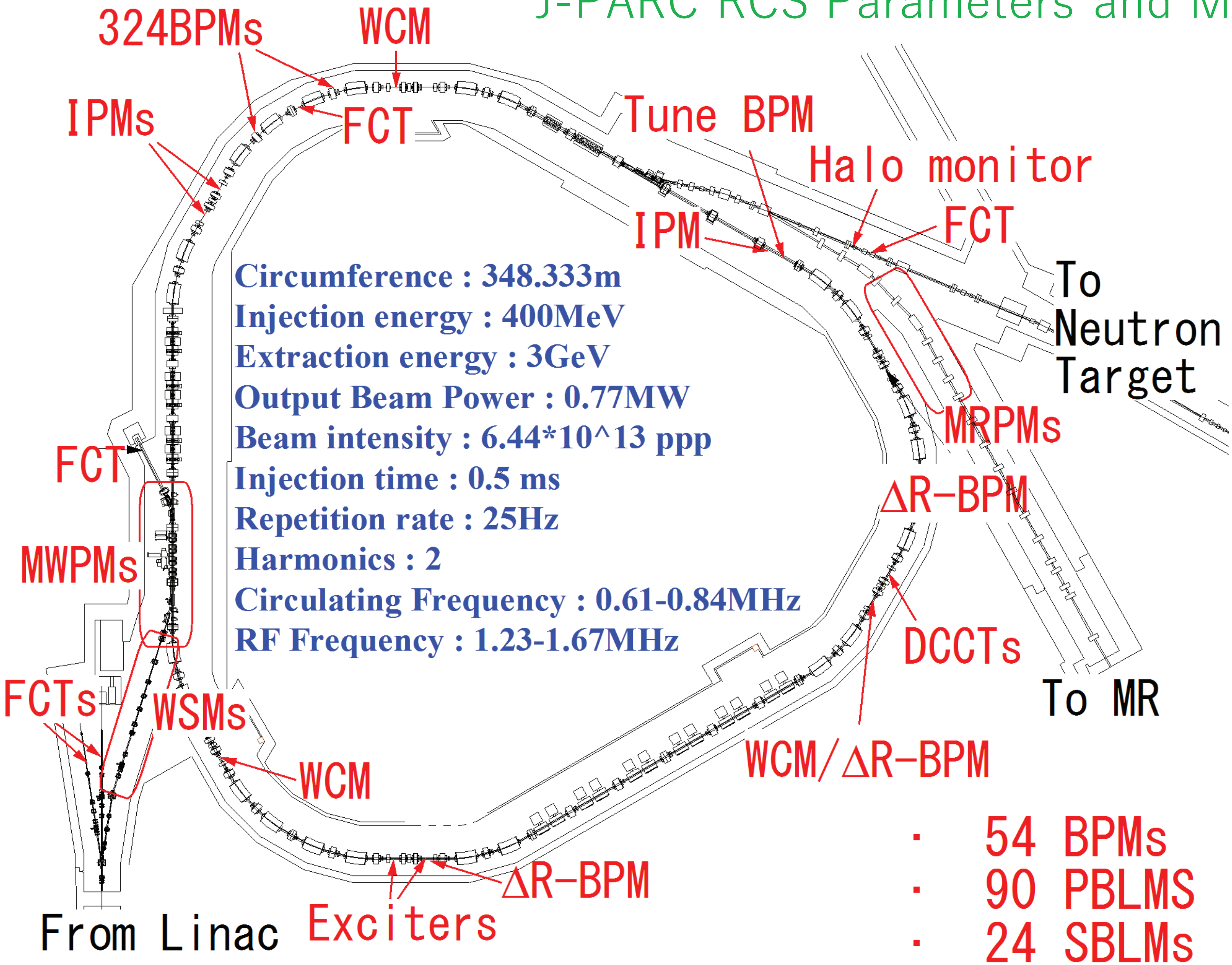






2. RCS

J-PARC RCS Parameters and Monitors



- Circumference : 348.333m
- Injection energy : 400MeV
- Extraction energy : 3GeV
- Output Beam Power : 0.77MW
- Beam intensity : 6.44*10^13 ppp
- Injection time : 0.5 ms
- Repetition rate : 25Hz
- Harmonics : 2
- Circulating Frequency : 0.61-0.84MHz
- RF Frequency : 1.23-1.67MHz

- 54 BPMs
- 90 PBLMS
- 24 SBLMs

N. Hayashi et. al., “BEAM INSTRUMENTATIONS FOR THE J-PARC RCS COMMISSIONING”, Proc. EPAC2008, TUPC03
K. Yamamoto et al., **“BEAM INSTRUMENTATIONS AT THE 1 MW PROTON BEAM OF J-PARC RCS”,** Proc. HB2014, WE

List of RCS regular monitors

Kazami, 2021

or Type	Number	Spec.
	54	2 measurement mode(COD or turn-by-turn), resolution ~ 20 μm (averaged), 0.3 mm (turn- uncertainty ≲ 0.5 mm (BBA)
& Tune BPM	2 (1 for horizontal, 1 for vertical)	Exciter AMP: Freq:100 kHz-7 MHz, Power:1 k
	1 DCCT / 1 SCT 1 MCT 3 WCMs 3 FCTs in the ring 3 FCTs at dump line	DCCT: Range:150mA-15A, Bandwidt: DC-20k FCT: Coil:20turn, Bandwidth:2kHz-10MHz WCM:Shunt impedances 0.1 ohm(10 ohm*100
	90 Proportional counters(PBLM) 22 Plastic scintillation counters(SBLM)	PBLM for MPS SBLM for study
	3 (2 for horizontal, 1 for vertical)	Signal range : single to multi turn injection Pitch : 2.5 mm (core:±40 mm) and 10 mm (ha to +120 mm and -40 to -120 mm)
M	8	Wire material : Au-coated W, Wire diameter : (MWPM1~5 for H-), 1mm (MWPM6~8 for H+ measurement pitch:0.03mm
	1	Large dynamic range : 10^{-6} Halo can be meas

Beam Position Monitor(BPM)

Inner diameter of the BPM detectors is larger than 250 mm
-> Diagonal cut chosen to ensure linear response

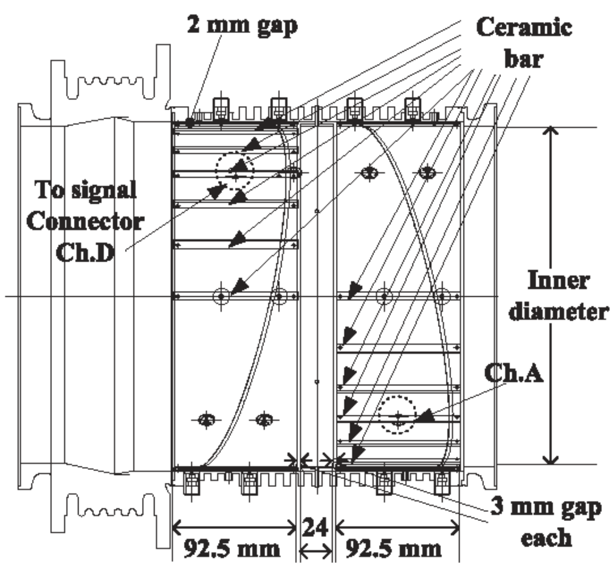
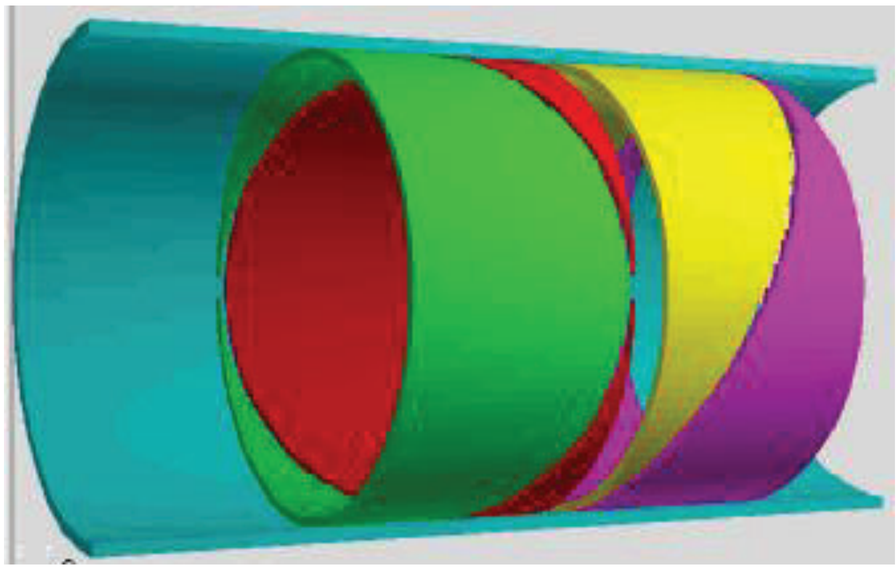


Fig. 7. Inside view of the BPM detector from the top.



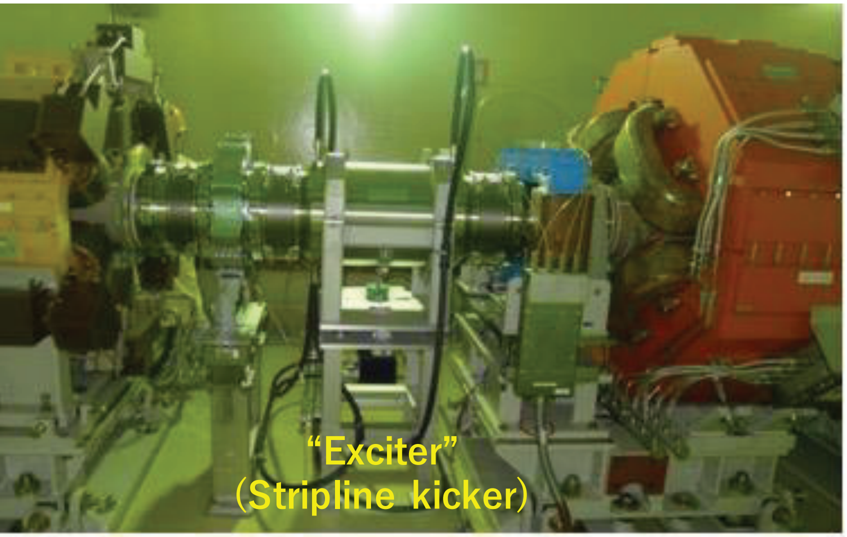
Diagonal cut

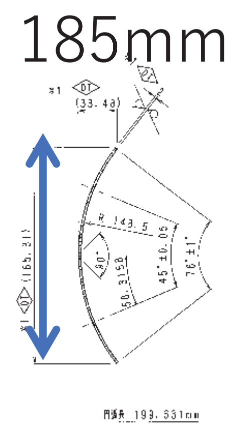
- record the full 25 Hz pulse data for the so-called "COD mode" (averaged beam position calculation)
- it can also store the whole waveform data for further analysis, like turn- by-turn position calculation(not 25Hz but 1 shot per several seconds).

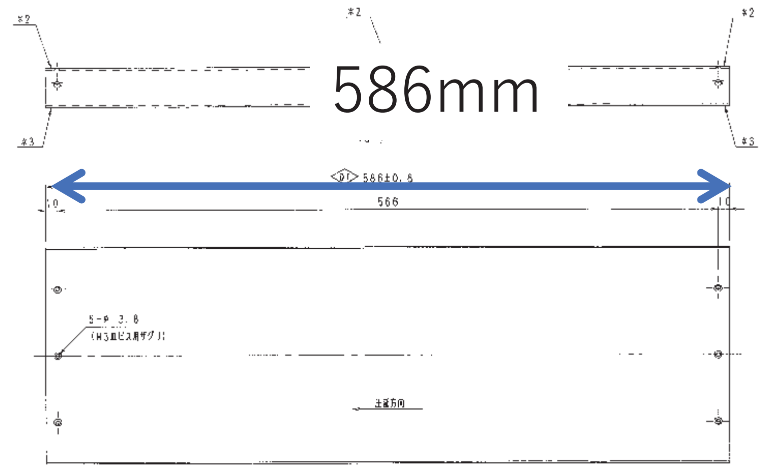
The position uncertainty is estimated to be $\lesssim$ 0.5 mm(COD mode) using a newly developed Beam Based Alignment method. (resolution ~ 20 μm)

N. Hayashi et. al., "Beam position monitor system of J-PARC RCS", NIM A, Volume 677, p. 94-106

Tune measurement

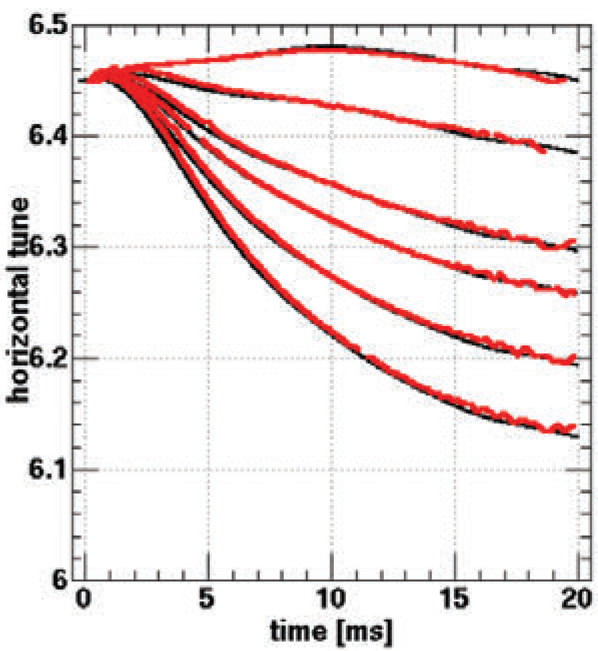


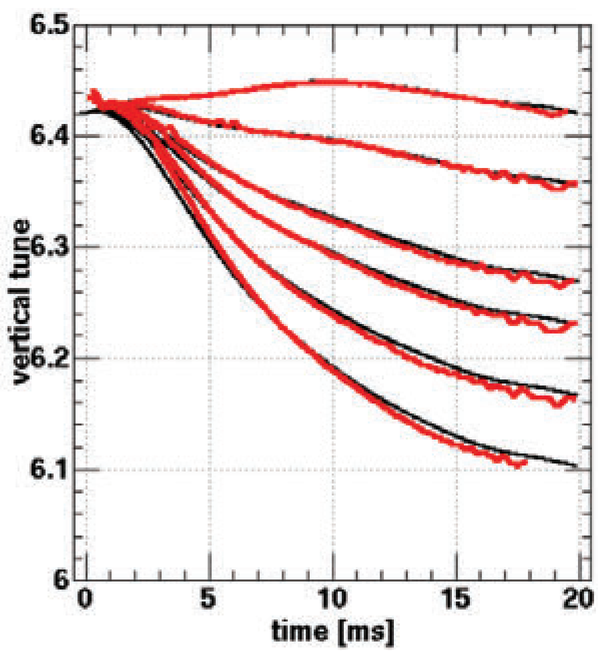




Exciter AMP
Freq:100 kHz-7
Power:1 kW

ulation
suremei





Current Transformer(CT)

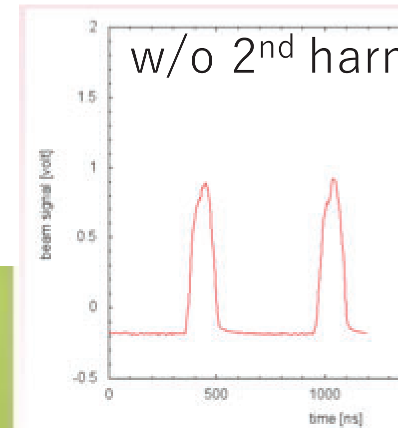
T: purchased from Bergoz (BDCCT-S-380-H)
T: made by the FINMET(FT3M)
ge:150mA-15A
dwidth:DC-20kHz
er Diameter:380mm
DCCT Coil:1000turn

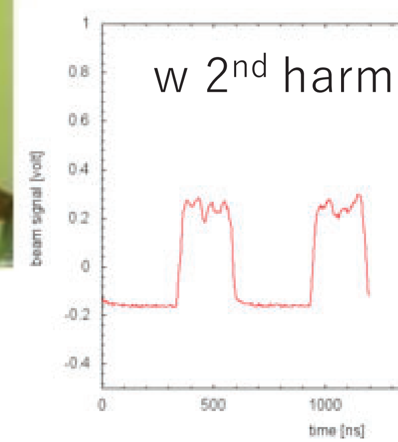
: made by the FINMET(FT3M)
:20turn
dwidth:2kHz-10MHz

hunt impedances 0.1 ohm(10 ohm*100 para)

Some FCT: limit beam
current to dump

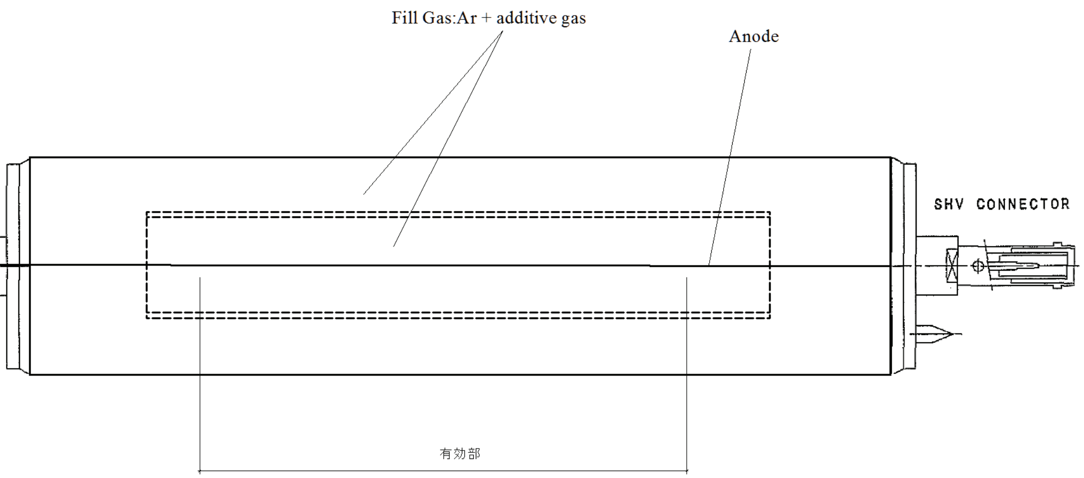
Longitudinal profil

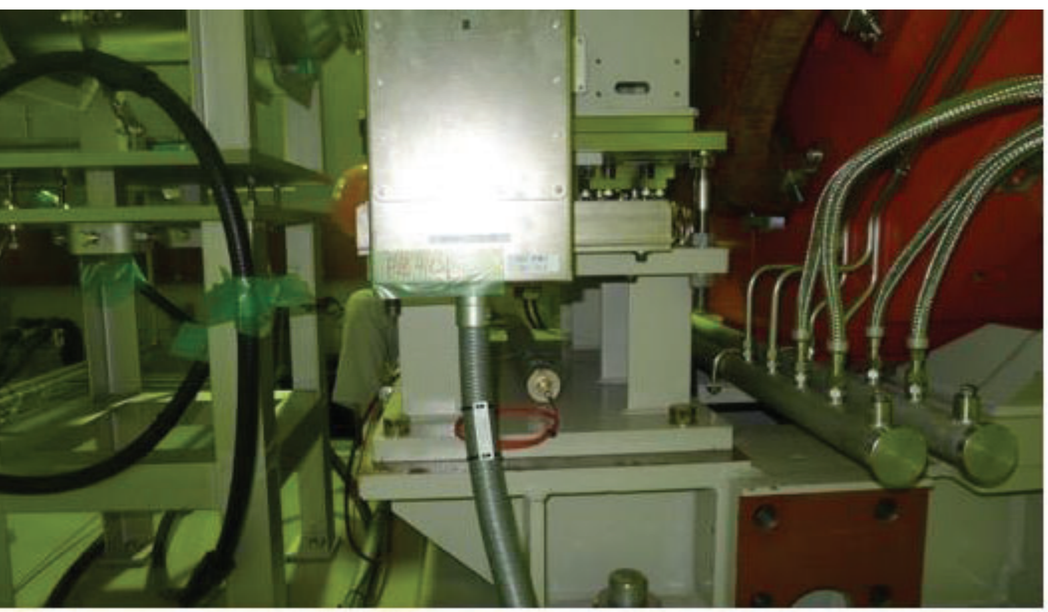




Beam Loss Monitor

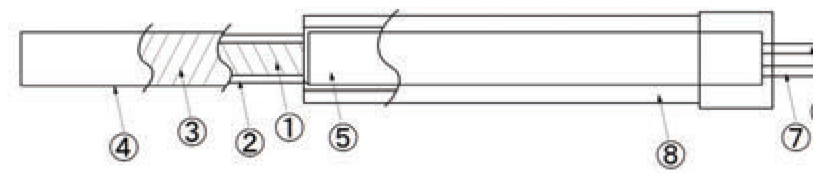
Proportional counter(PBLM)

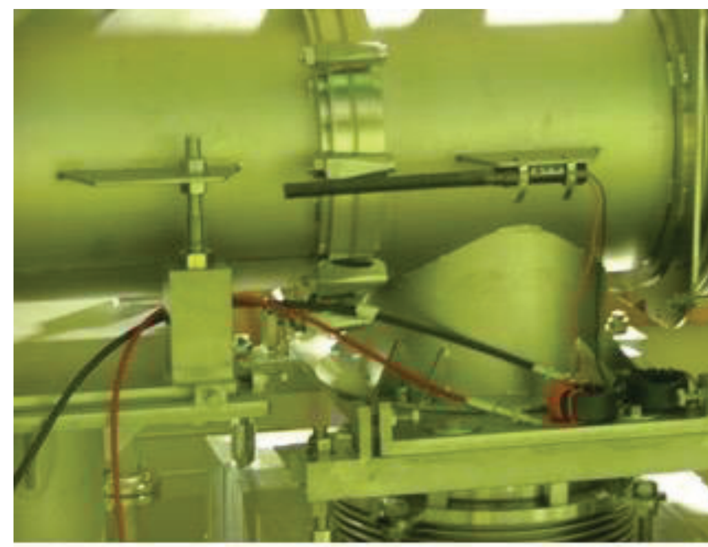




Scintillation counter(SBLM)

①Plastic Scintillator
(BC-400)
②Reflector
③Blind tape
④Kapton Tape
⑤PMT
⑥PMT HV　Cable
⑦PMT signal cable
⑧Magnetic shield c

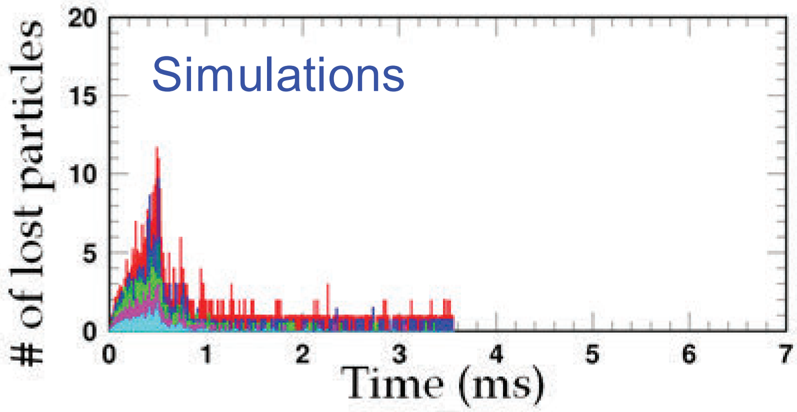




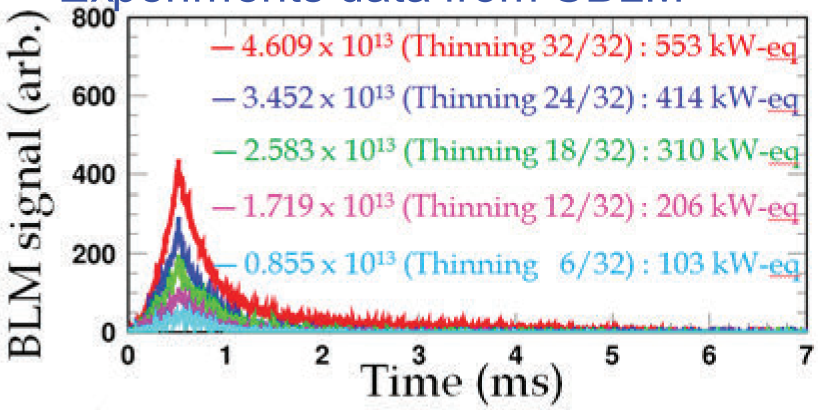
PBLM: Integration for MPS
SBLM: Wave form data analys

Beam Loss Monitor

SBLM signal comparison

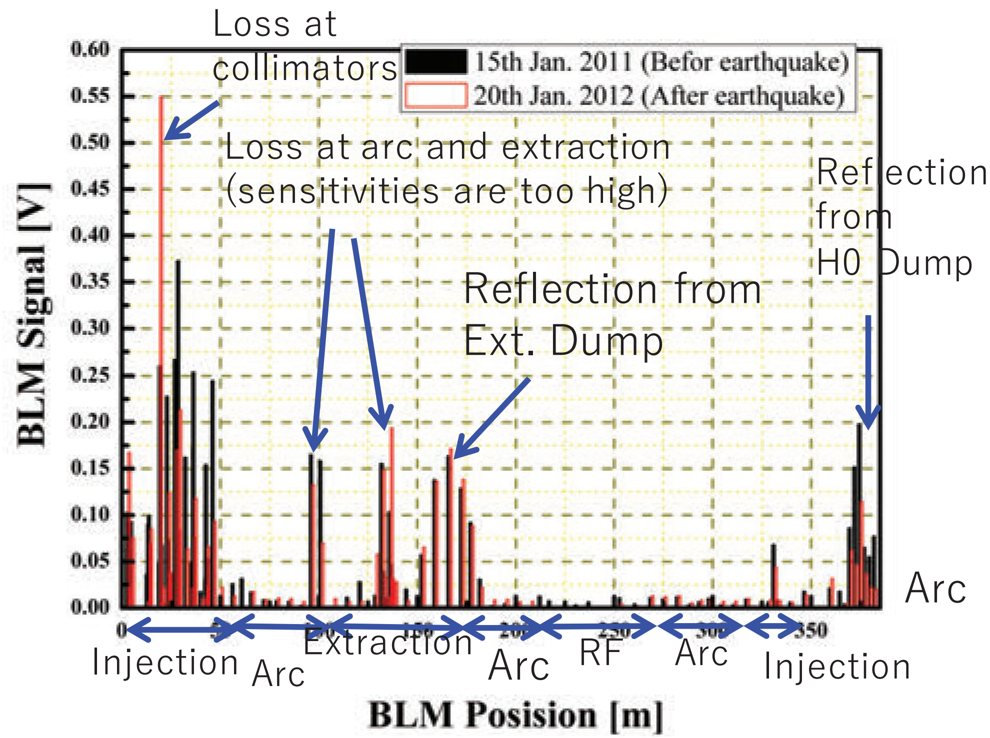


Experiments data from SBLM



The time structure and the amount of the beam loss are well in agreement with the simulation.

PBLM signals around the RCS

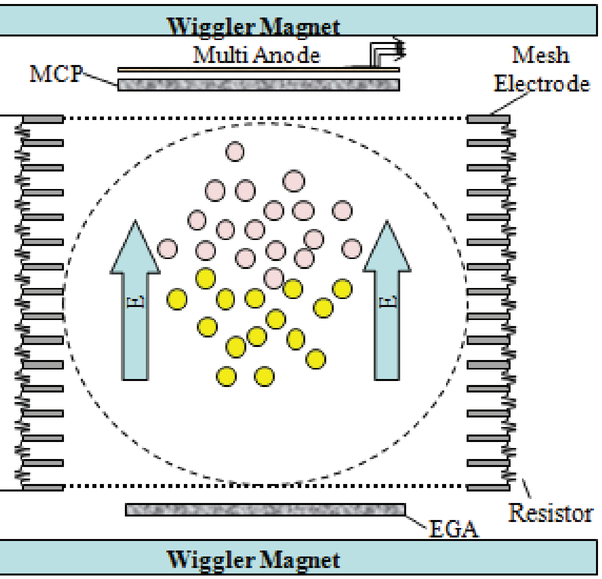


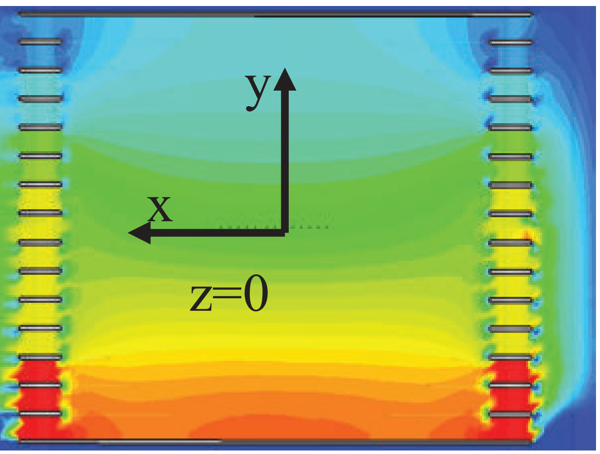
Integrations of PBLM signal are archived at all times.
PBLM signals are also compared with the limit value at every shot.

Ionization Profile Monitor(IPM)

Three IPMs were insta
2: Dispersive Arc
1: Ext-straight (Dispe

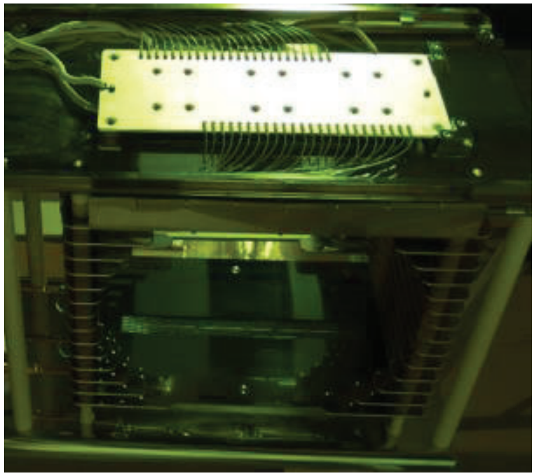
Ion collection mode

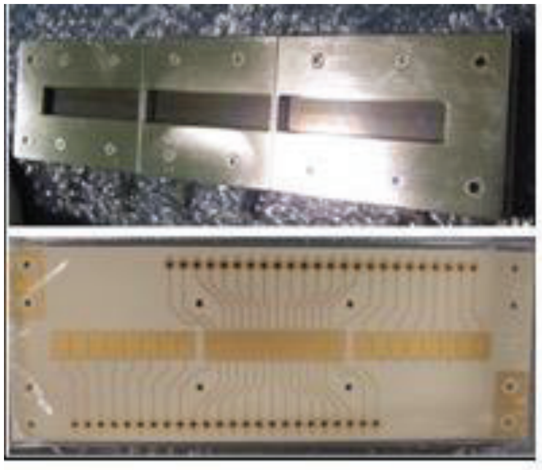


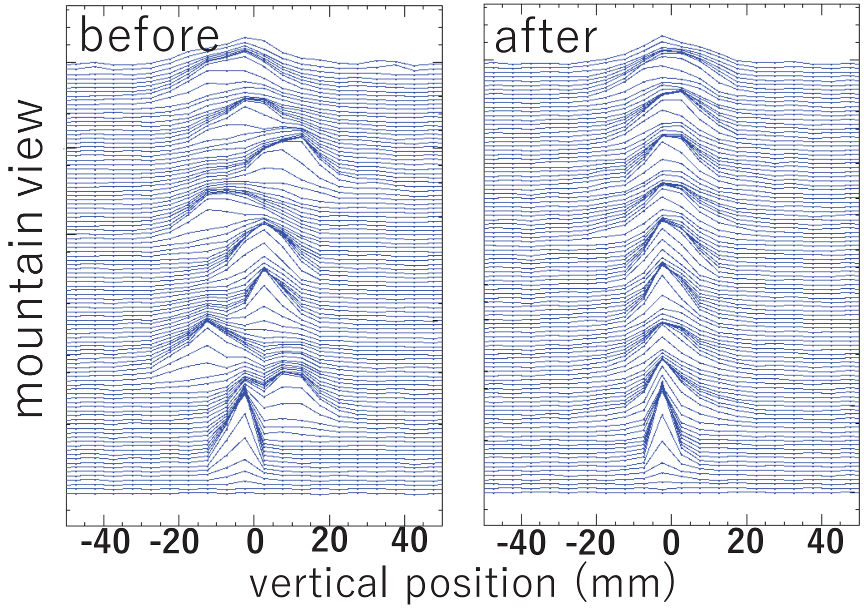


Electric field calculation

Anode structure



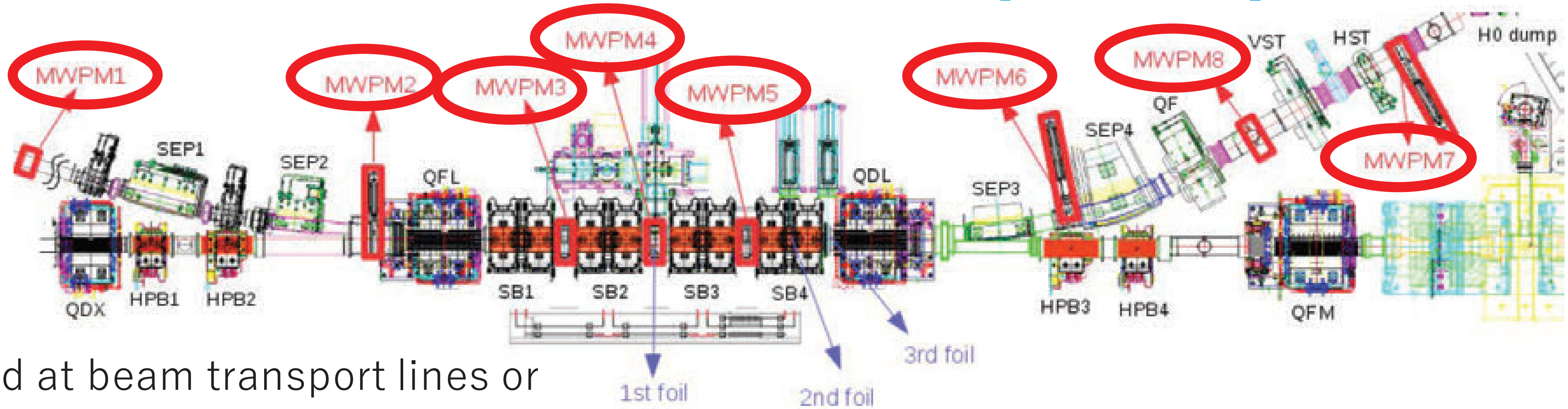




Results of injection beam orbit correction

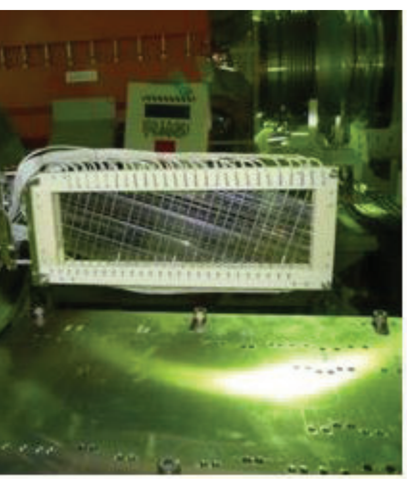
larada et al., "The Residual Gas Ionization Profile Monitor in the J-PARC 3-GeV Rapid Cycling Synchrotron", JPS Conf. Proc. 8, 012011 (2015)

Multi Wire Profile Monitor(MWPM)



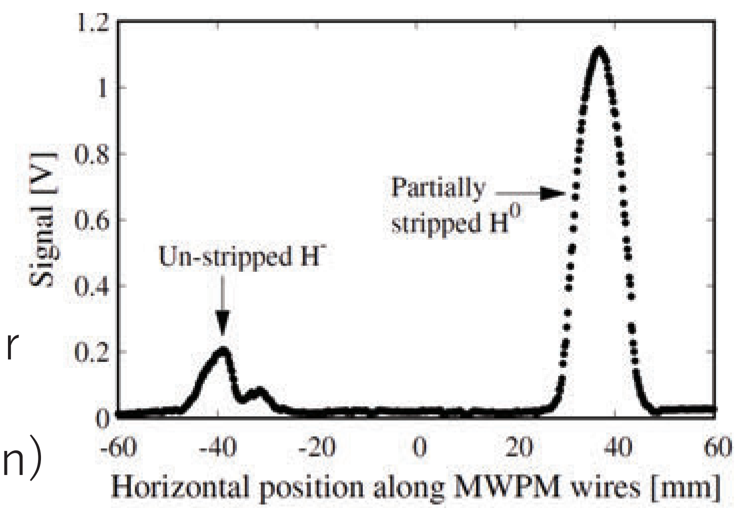
- Used at beam transport lines or one-pass operation
(L3BT and injection line correction)

- Wire material : W
- Wire diameter : 0.1 mm (MWPM1~5 for H^-)
  1 mm (MWPM6~8 for H^+)



MWPM head

- Used at beam transport lines or one-pass operation
(L3BT and injection line correction)
- MWPM7 (installed in the injection dump line) was used not only to measure the profile, but to measure the amount of H^0 and H^- unstripped particles

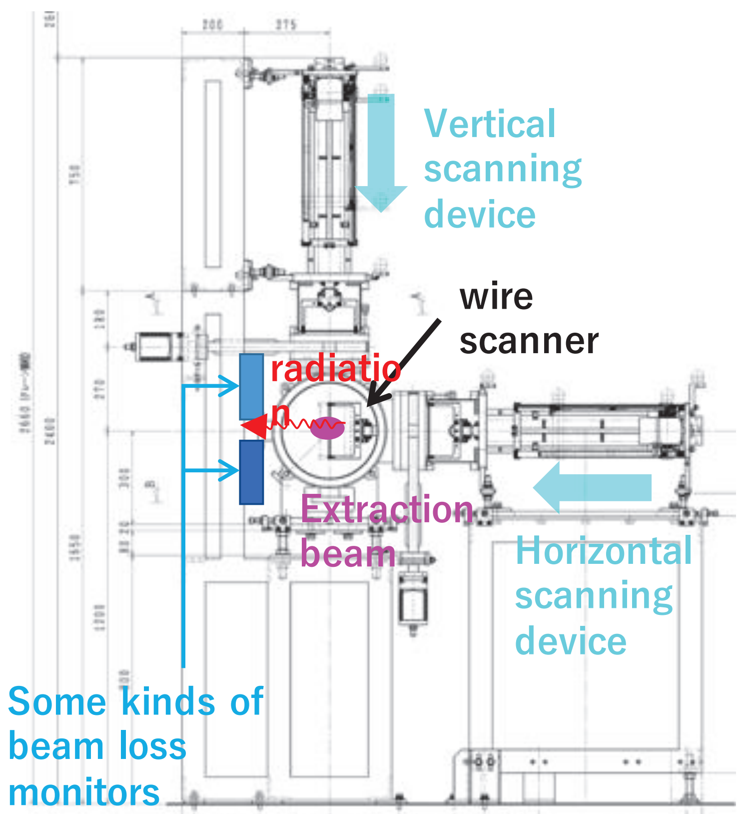


P. K. Saha et. al., "First measurement and online monitoring of the stripper foil thinning and pinhole formation to ensure proper uses and achieving a longer foil lifetime in high intensity accelerators", Phys. Rev. Accel. Beams **23**, 082801 (2020)

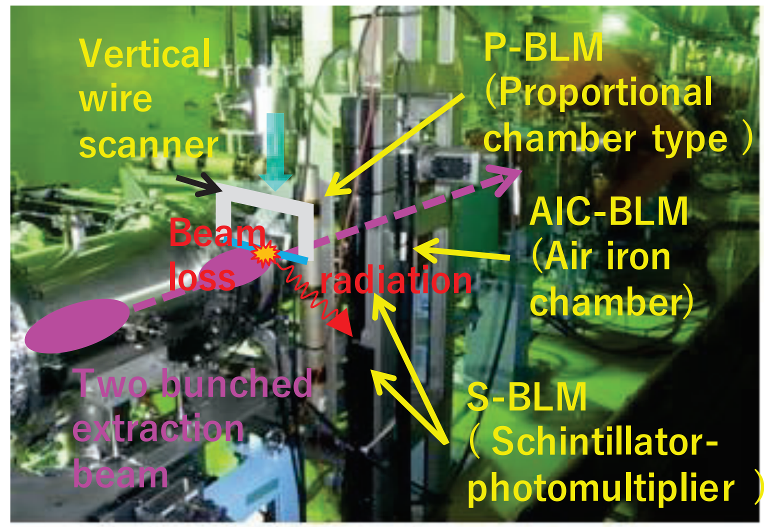
Extraction beam halo monitor
WSM & BLM

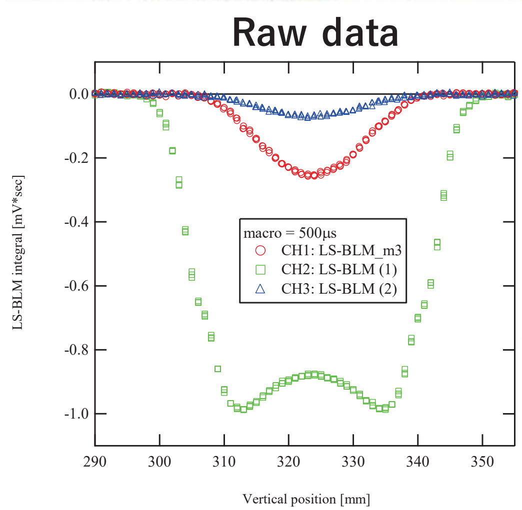
halo monitor is combined a wire type beam scraper and some beam loss monitors.

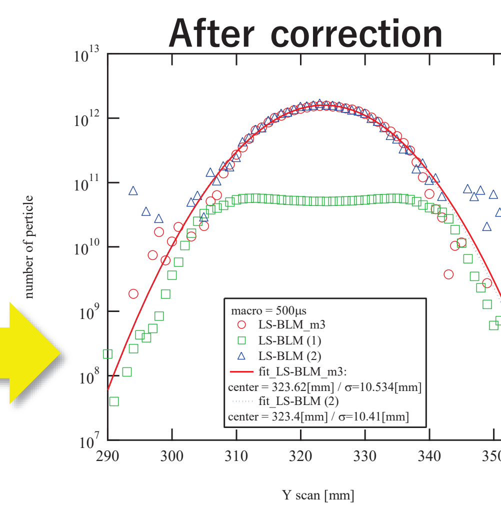
e the scintillation counters with different sensitivities, it has wide dynamic range. Beam profile i
of the beam core and halo can be measured.



M. Yoshimto, et. al., "Beam halo measurement using a combination of a wire scanner type beam scraper and some beam loss monitors in J-PARC 3-GeV RCS.", HB2014, MOPAB44

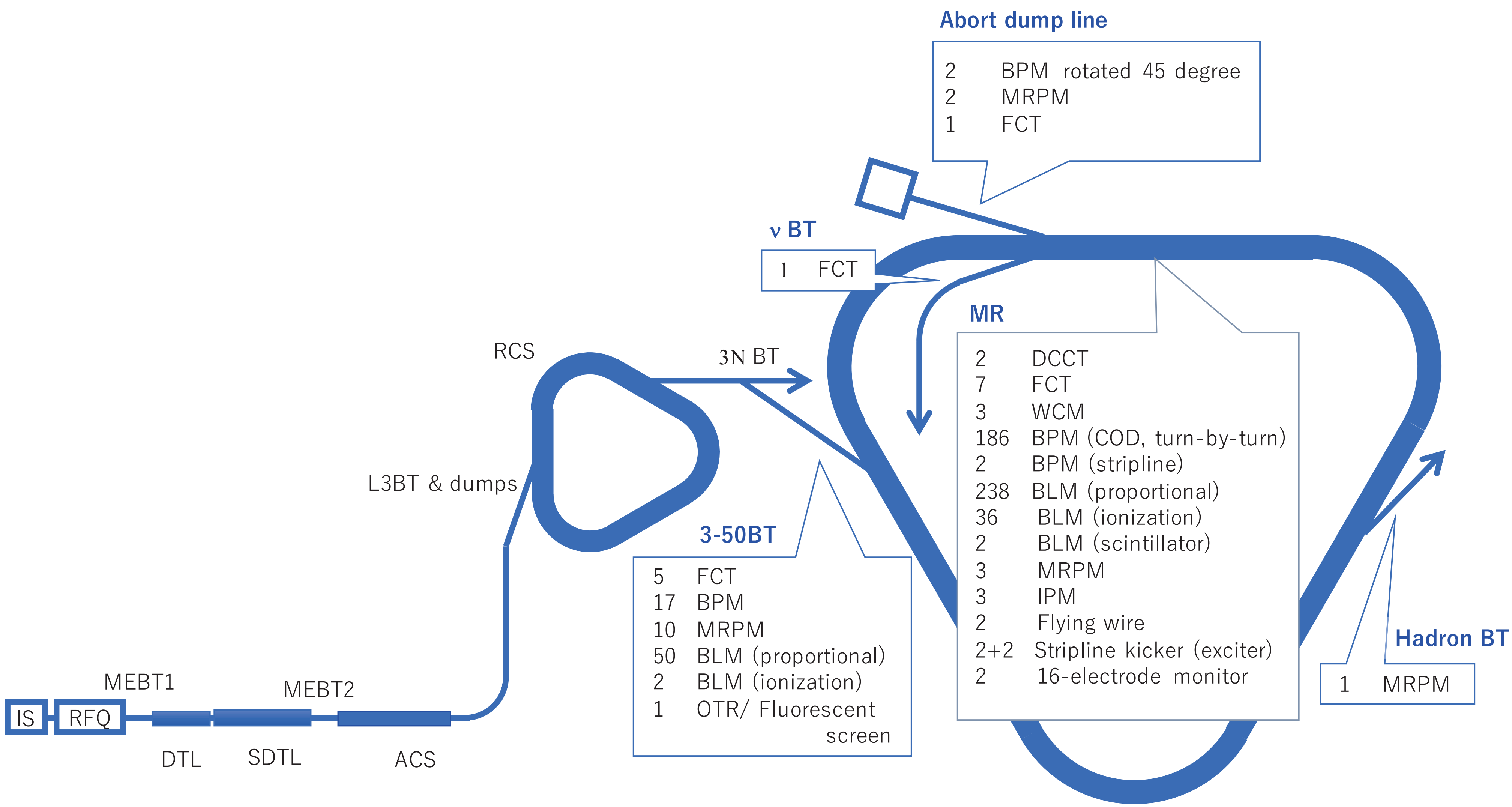






3. MR

Beam Monitors in MR



List of 3-50BT regular monitors

itor Type	Number	Spec.
l	17	bunch-by-bunch mode, resolution < 0.3 mm
	5 FCTs	FCT: Coil: 25 turns, bandwidth: 200 Hz-17 MHz $\|\Delta N_B/N_B\| < 1$ % @ $N_B < 8E+13/2$ bunches 3 FCTs for MPS, 2 FCTs for PPS
	50 Proportional counters(PBLM) 2 long air-filled Ion Chamber (ABLM)	PBLM for MPS ABLM for study
PM	10 Multi-Ribbon Profile Monitors 4: Ti target 6: graphite target	Material: graphite, thickness: ~ 1.1-3 μm, width 2.5 mm, pitch: 2.5-4 mm, Material: Ti, thickness: ~ 1.2 μm, width: 1.5-3 m pitch: 2.5-4.5 mm
/FL	1	Large dynamic range : 10^{-6} Halo can be measur

List of MR and abort-dump BT regular monitors

ype	Number	Spec.
ESM	186	2 measurement mode(COD or bunch-by-bunch), accuracy: ~0.0 mm(COD mode)
Stripline	2	
	2 systems / 4 kickers (1 system = horizontal / vertical)	Exciter AMP: (1) Freq:100 kHz - 250 MHz, Power: 500 W x 4, (2) Freq:100 kHz - 100 MHz, Power:3 kW x 2
FCT	4 for Acc. RF 2 for observation 1 for abort-bump BT	Coil: 50 turns, Bandwidth: ~20 Hz - 180MHz
WCM	2 for Acc. RF 1 for observation	Shunt impedances 0.1 ohm(13 ohm*130 para) f > a few 100 Hz
DCCT	2	Range:150mA-15A, Bandwidth: DC-20kHz
	238 Proportional counters (PBLM)	for MPS
	36 air ionization chamber	
	3 (2 for horizontal, 1 for vertical)	Signal range : bunch-by-bunch Relative measurements
	1 in MR (graphite), 2 in SX line 2 in Abort-BT (Ti) 1 in HD BT (graphite)	Material: graphite, thickness: 1.1-3 μm, width: 1-3 mm, pitch: 2 Material: Ti, thickness: 1.2-10 μm, width: 1.5-~40 mm, pitch: 2.5
	1	Large dynamic range : 10^{-6} Halo can be measured

List of MR monitors under development

itor Type	Number	Spec.
l	~ 200 signal processing circuits upgrade	$\lesssim$ 1/3 of the present position uncertainties
file)	Two 16-electrode monitors	$\Delta\varepsilon/\varepsilon < 5$ %
le	2 Gated IPMs (1 for horizontal, 1 for vertical)	
le	1 OTR/FL	
le	1 Gas-jet profile monitor	

DCCT (MR)

uency bandwidth DC – 20 kHz

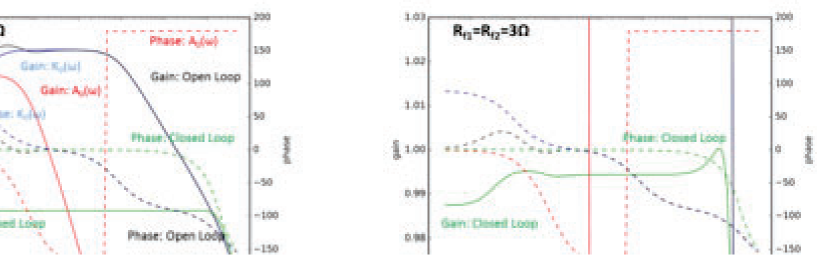
mic range 0.2 / 2 / 20 A (6.5E+14ppp)

racy (uncertainty)

design goal 1%

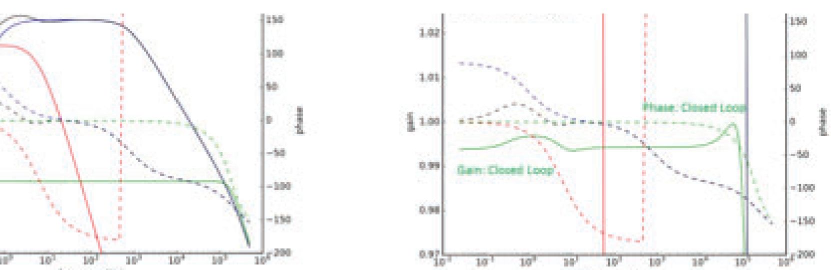
present performance ~ 0.6 %

sion present performance 0.1 %

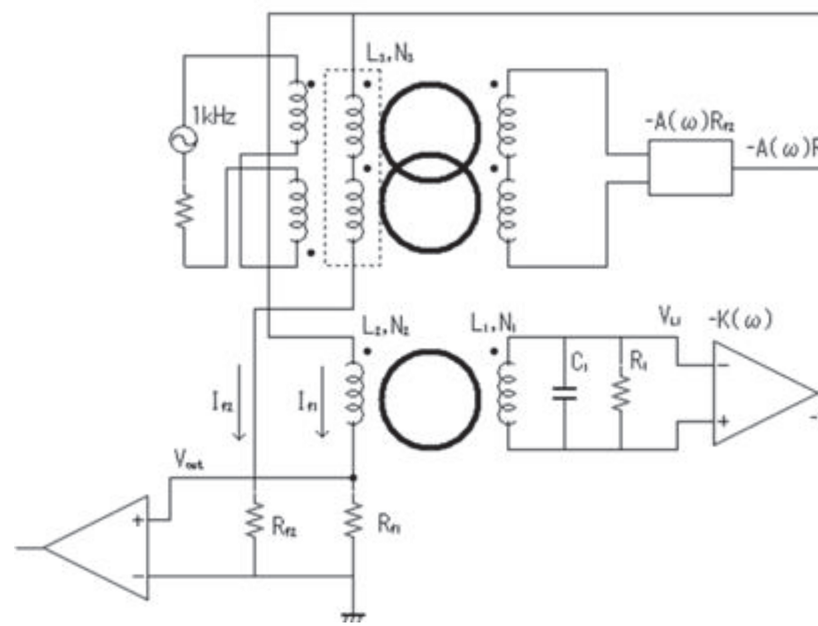


ths of the DCCT and the active CT cross at ~ 5 Hz

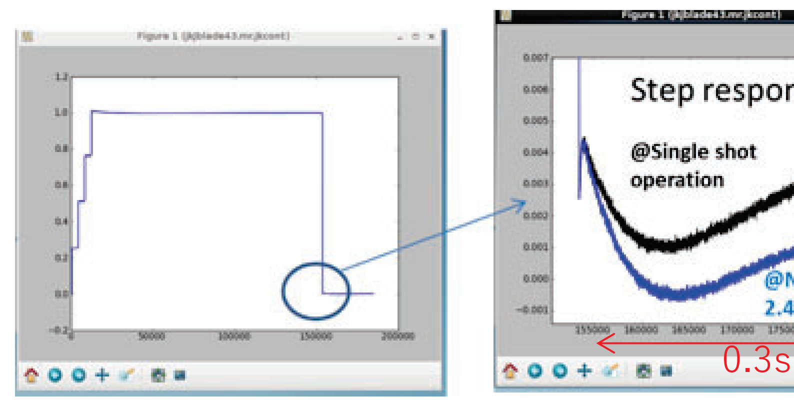
ching is very sensitive to the errors of feedback resistors



Open and closed loop gain



Parallel feed back DCCT



Step responses is corrected.

K. Satou et al., "PRESENT PERFORMANCE OF A DCCT FOR J-PARC MR", PA

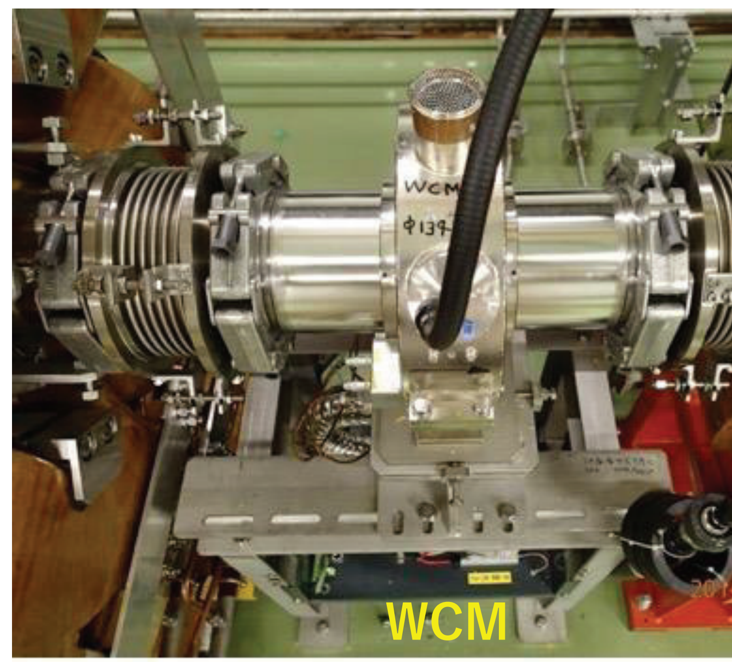
K. Satou, US-Japan collaboration mini-workshop, Nov. 9-10, 2016.

FCT and WCM

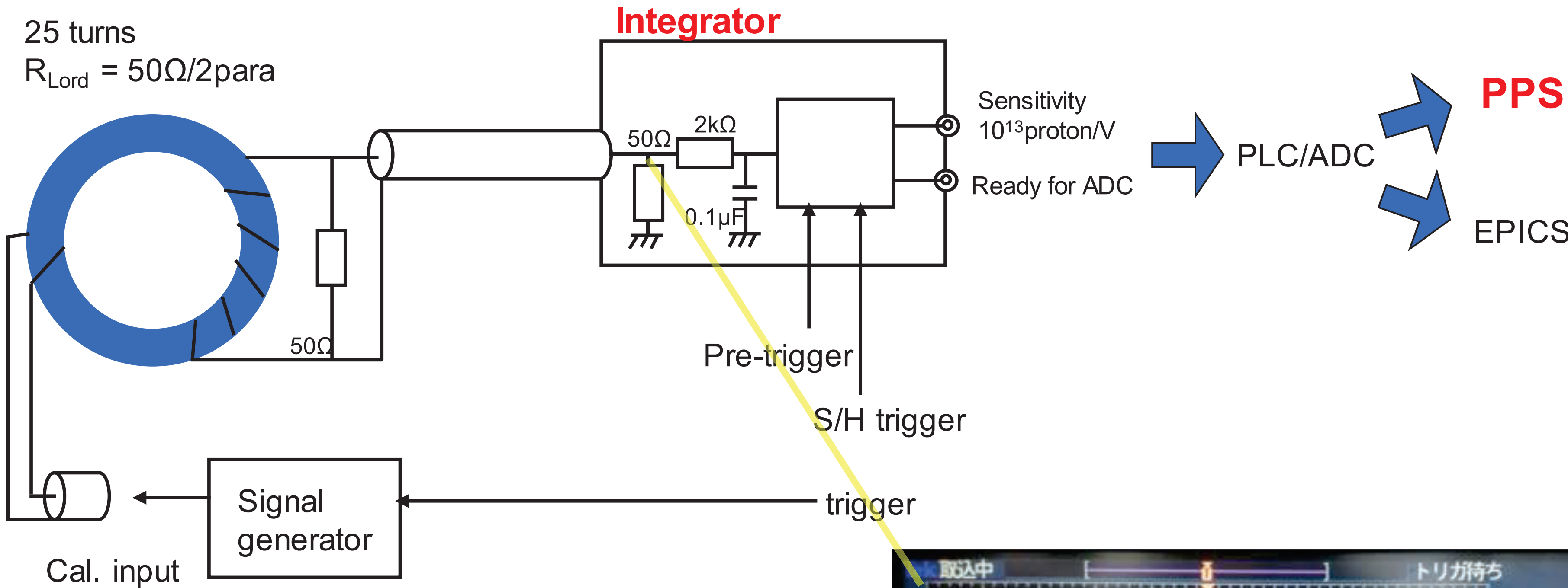
CT Coil: 50 turns
Frequency bandwidth: ~20 Hz - 180MHz

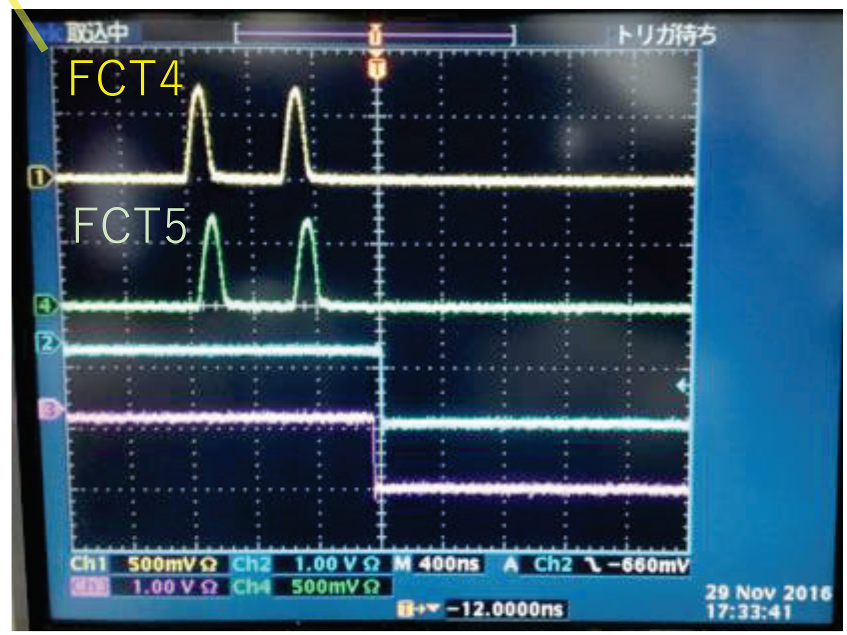
Shunt impedances 0.1 ohm(13 ohm*130 para)
Frequency bandwidth > a few 100 Hz

signal was acquired with the "sequence mode": 0.2 ms data at every 40 ms
10^{14} ppp, 426 kW

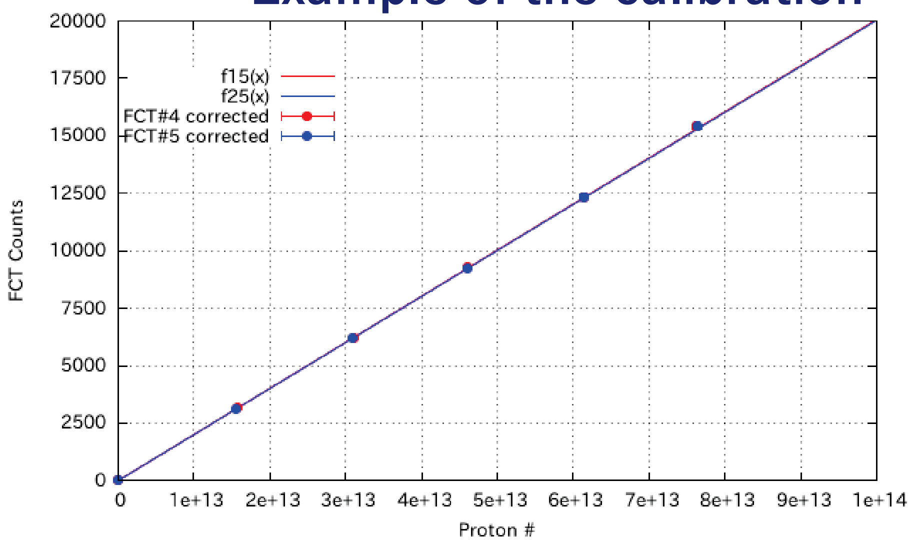


3-50BT PPS-FCT (ICT)





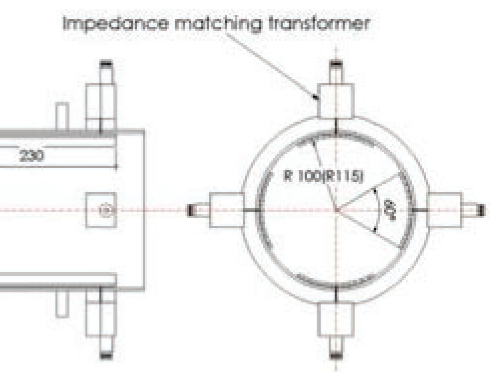
Example of the calibration



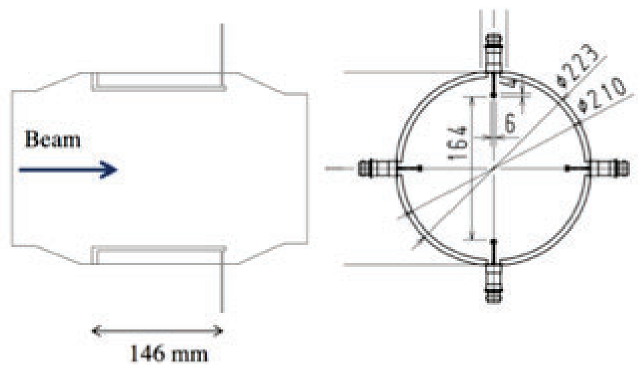
BPM / 350BT & MR

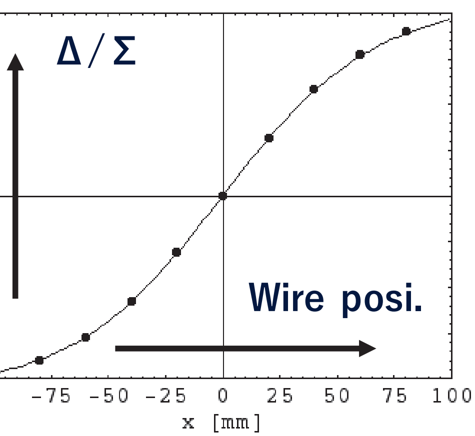
350BT

ameter sizes: ϕ230 (#1, 2)
nd ϕ200 mm (#3, #7 - #17)



loop-coupler BPM: #4, #5, #6
(Collimator section)

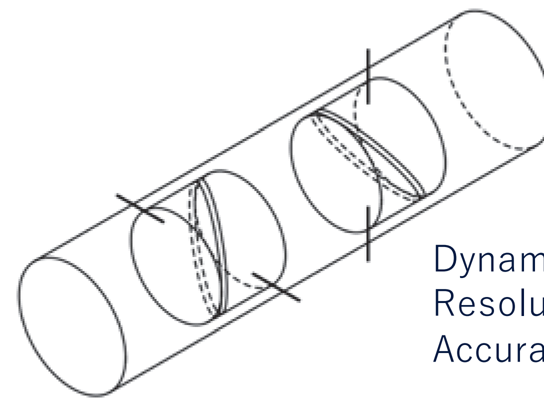




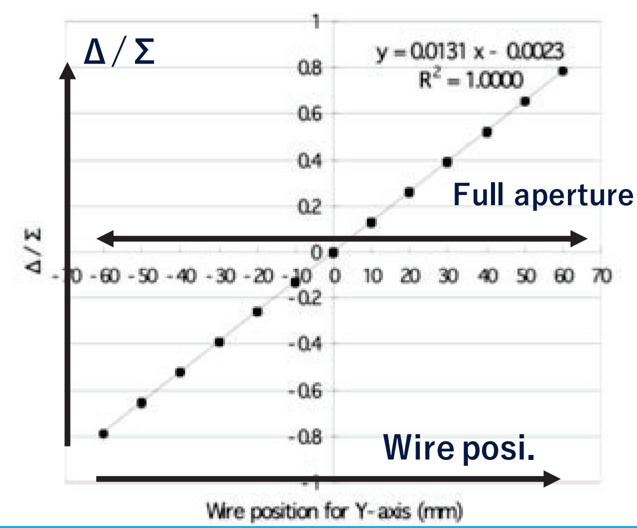
Precision ~ 300 μm

MR

ESM
diameter sizes: ϕ130mm(standard)
ϕ134, 165, 200, 257, 140x302mm(s

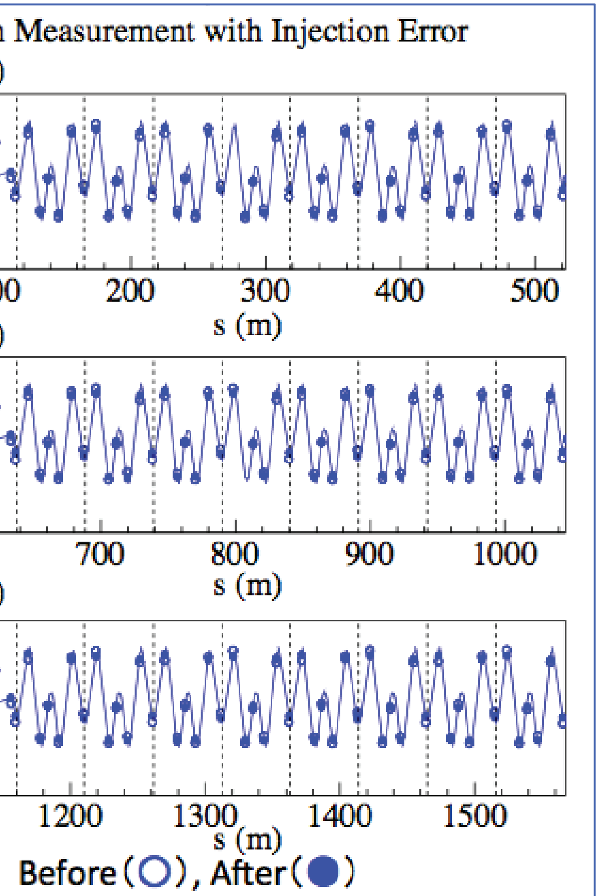


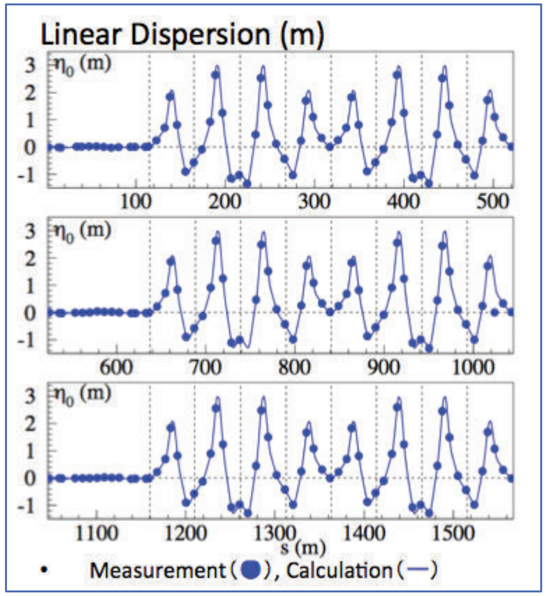
Dynamic range < ~4.4
Resolution ~ 30 μm
Accuracy ~ 300 μm

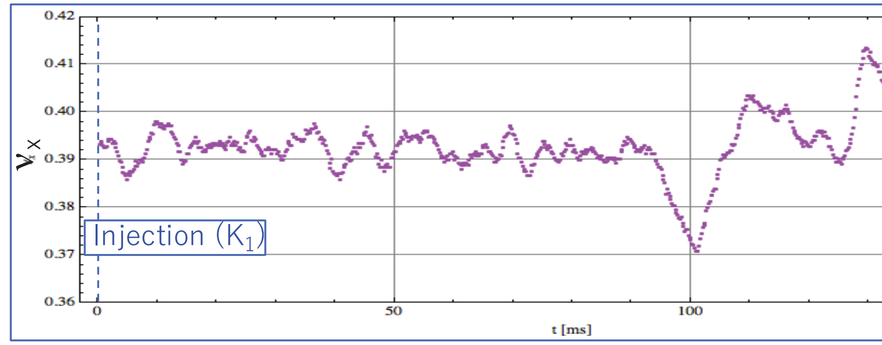


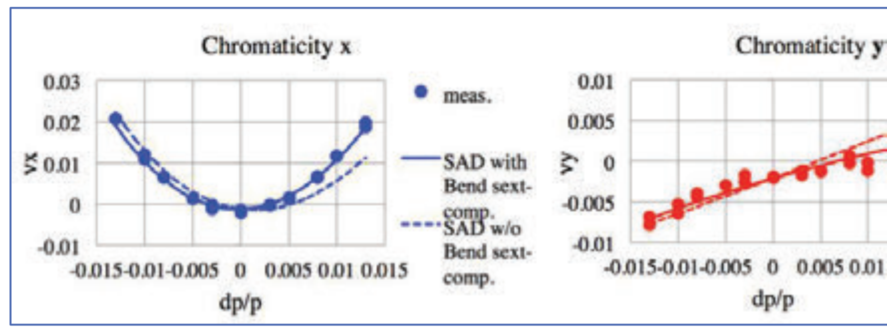
BPM @ MR

from MR data









BLM

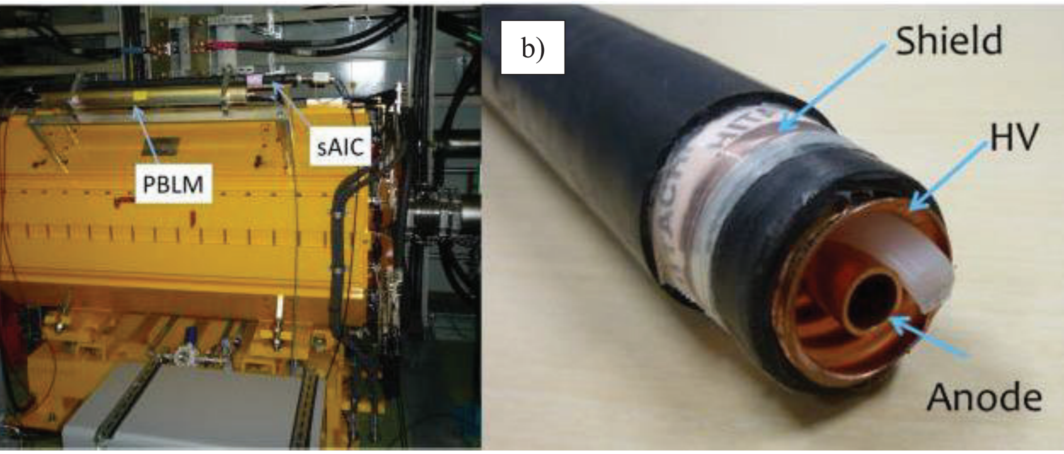
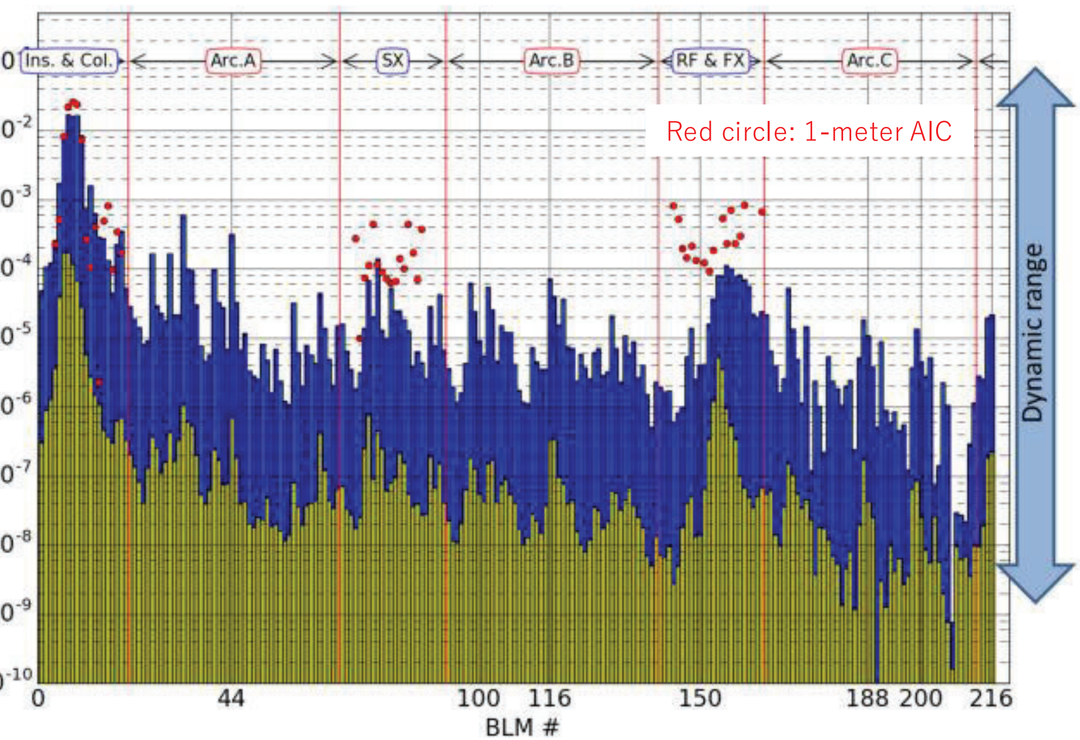


Figure 1. a) Photo of the PBLM and sAIC. b) Cable structure used for AIC.



3. Integrated charge plot. The beam loss signals from PBLMs and sAICs are shown as blue
d red solid circles, respectively. The yellow bars show the residual dose.

Day-one signal processing circuits are
replaced upgraded system in FY2016-2

Absolute amount of the beam loss is c
to the DCCT value or residual radiation

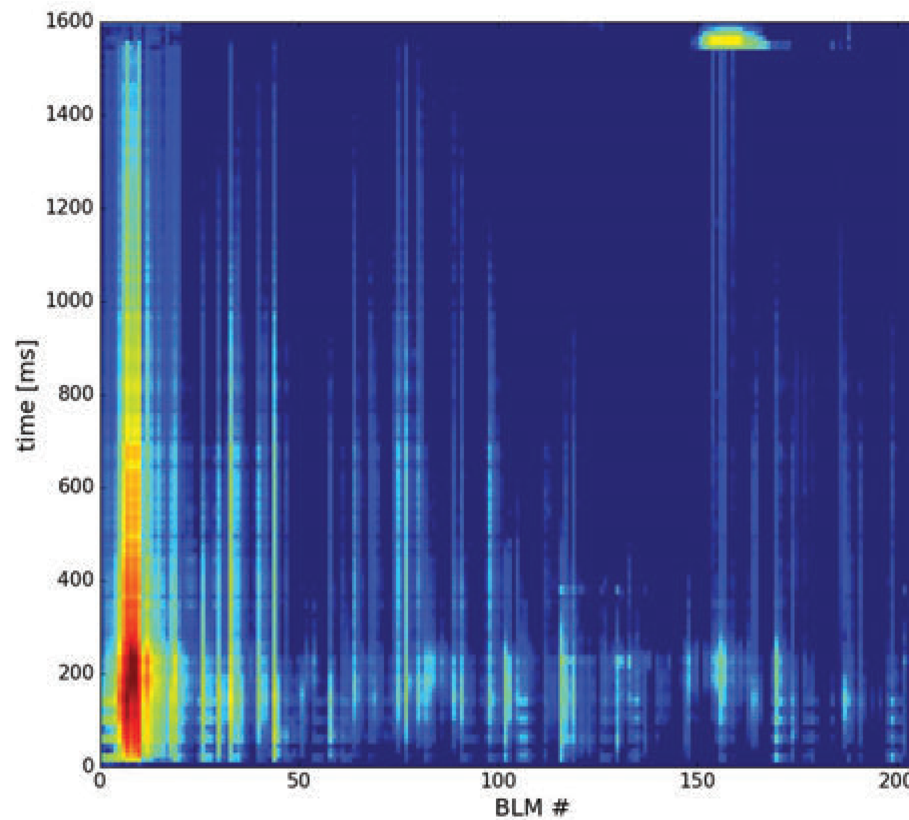
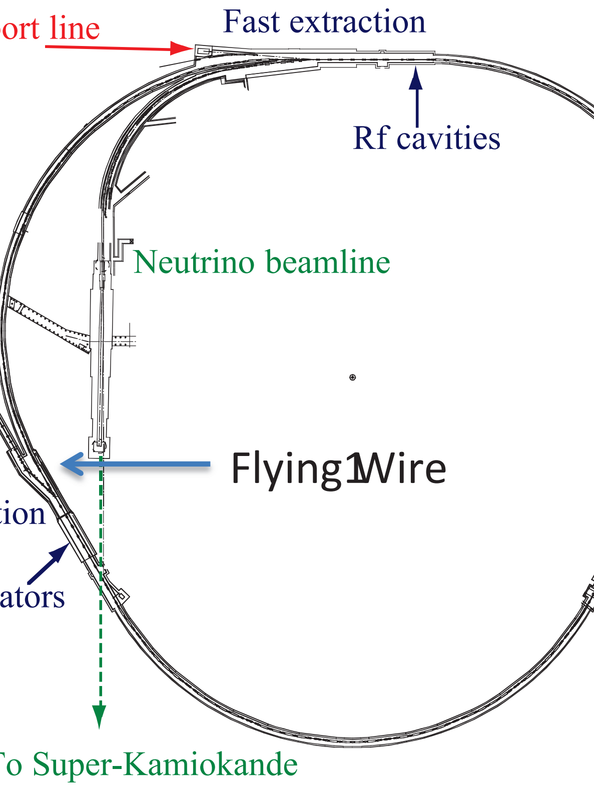
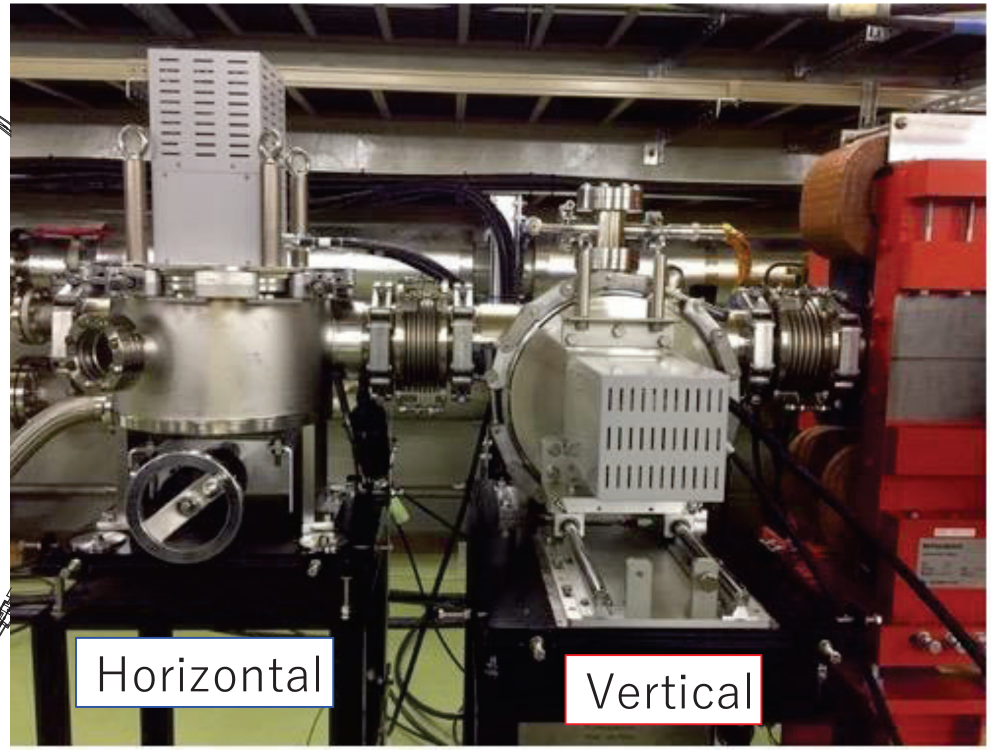


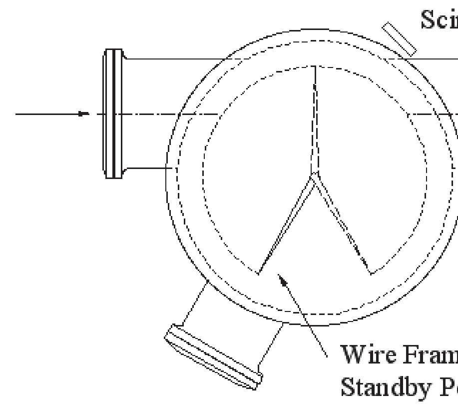
Figure 4. Contour plot of the waveforms from the PBLMs.

K Satou *et al* 2017 *J. Phys.: Conf. Ser.* **874** 012087
K. Satou *et al.*, NIM, A 887 (2018) 174–183

Flying Wire

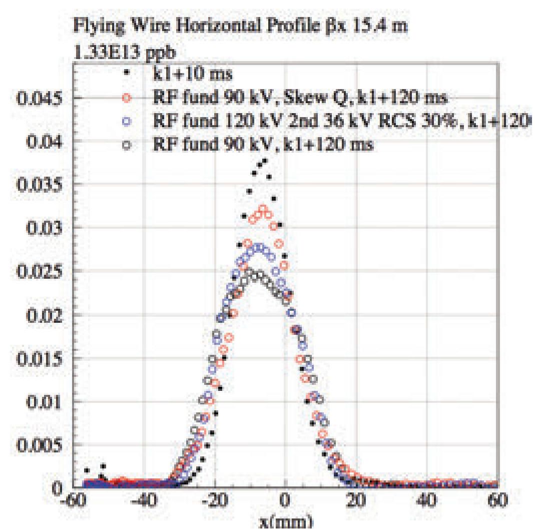


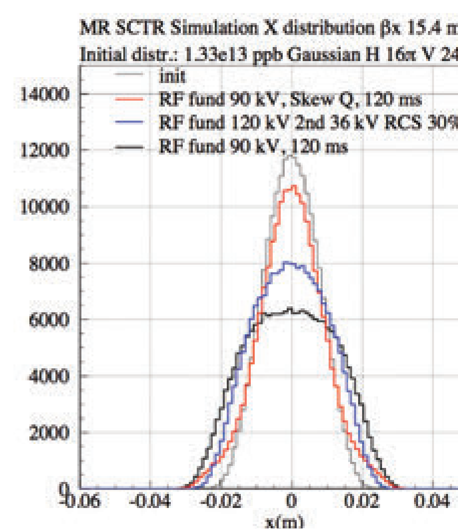




horizontal, one vertical
on wire of 7 μ m diameter
speed: 10m/s
ation < 4.4 x 10^{13} p / 2 bunches

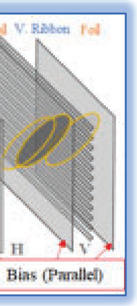
hi, et al., IPAC2011, p. 1239

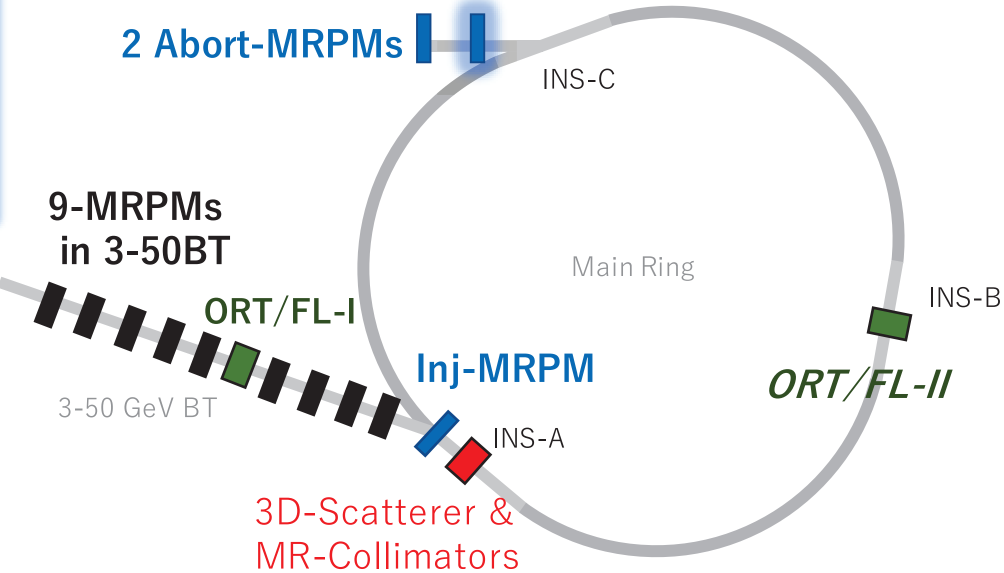




Abort MRPM

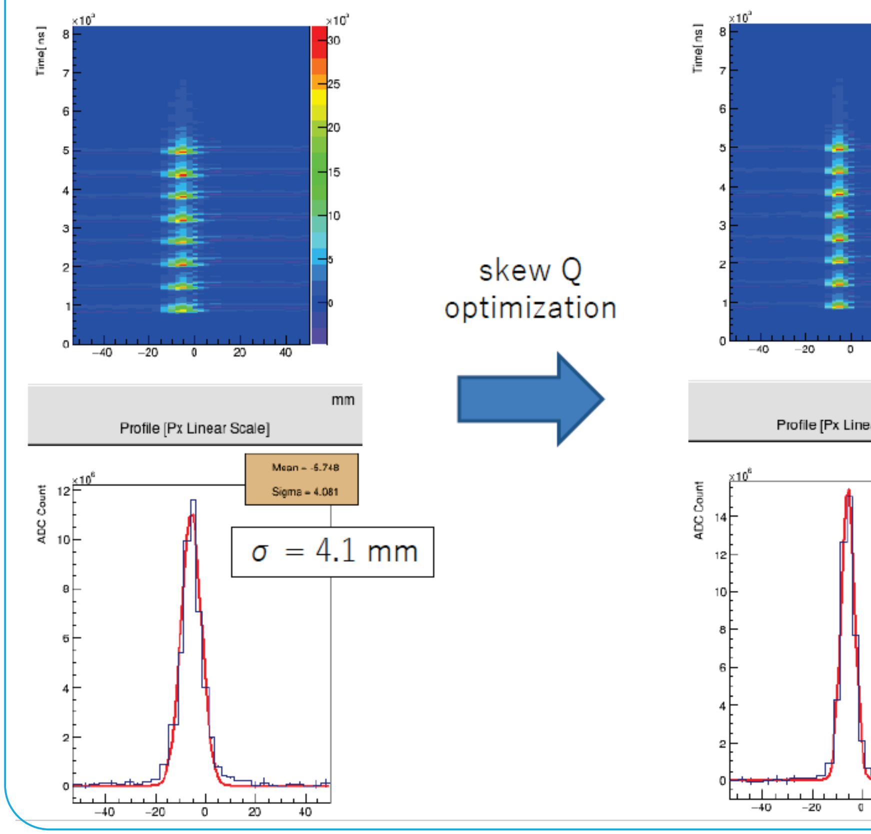
Y. Hashimoto, H. Sak





Measurements @SX

M. To
R. Mu



on profile monitor in the abort line (JFY2019~)

: Ti ribbon (1.2 μm thick)

dary electron emission

urability against radiation

rements during acceleration, 3 – 30GeV, time resolution 200 ns

or

rements of temporal evolution of the beam profile

of fast extraction: timing and orbit

of slow extraction: **SkewQ**, Debunching parameters of acc. RF

Ribbon spacing →

dth: 1 mm / 2.5 mm

Horizontal		
3.5 mm spacing 22 ch	2.5mm 21ch	3.5 mm 22 ch
77 mm	52.5 mm	77 mm

Vertical		
3.5 mm pitch 12 ch	2.5mm 9 ch	3.5 mm 12 ch
42 mm	22.5 mm	42 mm

Kiwamu Sato *et al* 2019 *J. Phys.: Conf. Ser.*

beam position monitor (BPM) system

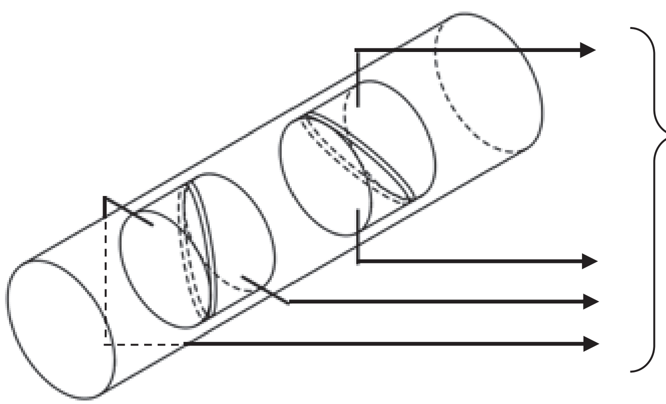
to accurately measure beam trajectories

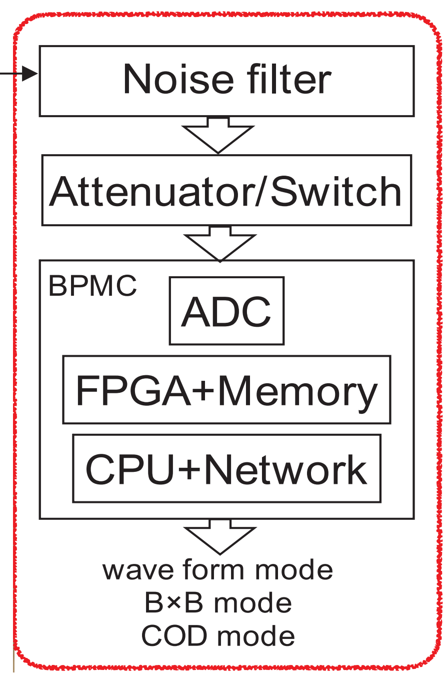
unctions (< 1 %) by updating the signal processing circuits.

osition uncertainties (σ)

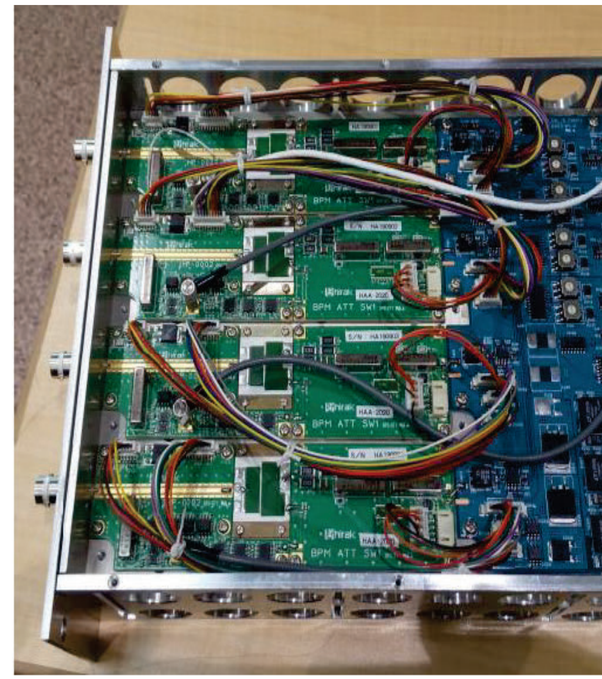
m → ≲ 10 μm for COD mode

μm → ≲ 100 μm for bunch-by-bunch mode





The test has been conducted since last De



Test module under test

Variable input impedance -> Z_{in} r

Attenuator: 12dB+(10dB, through

SFDR: >80dB

K. Satou et

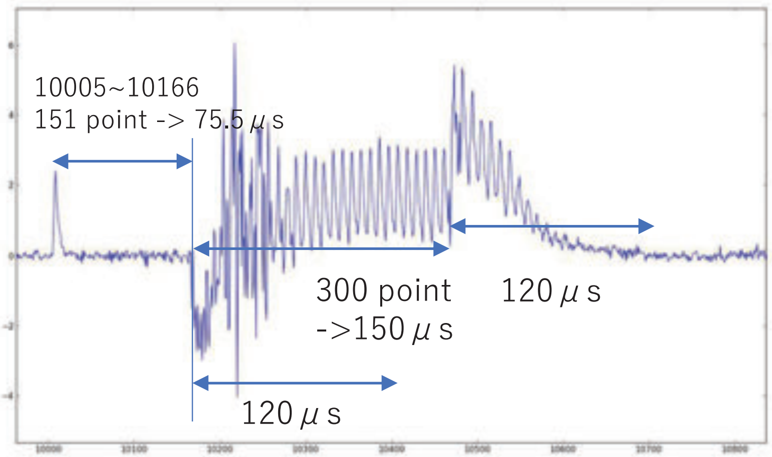
"Gated" IPM system for MR

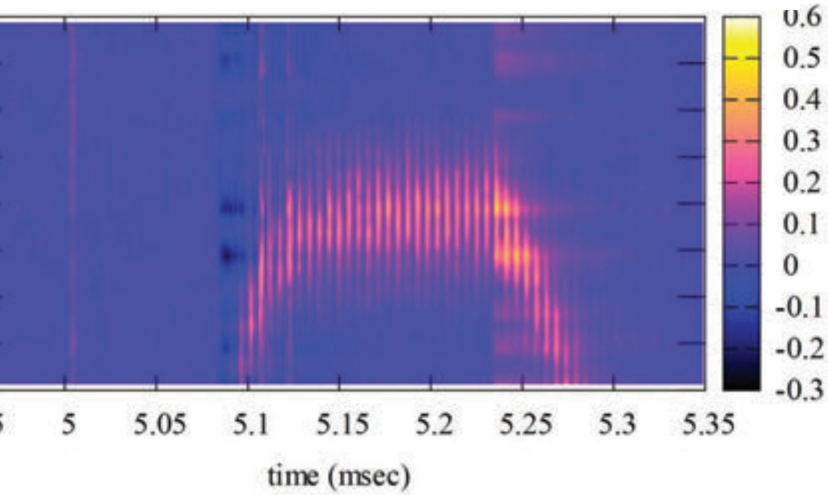
d" IPM

ching the HV, only the required particles can be selected and multiplied by the MCP
e will be extended much longer than that in the case of non-gated system

AB-CONF-14-332-AD

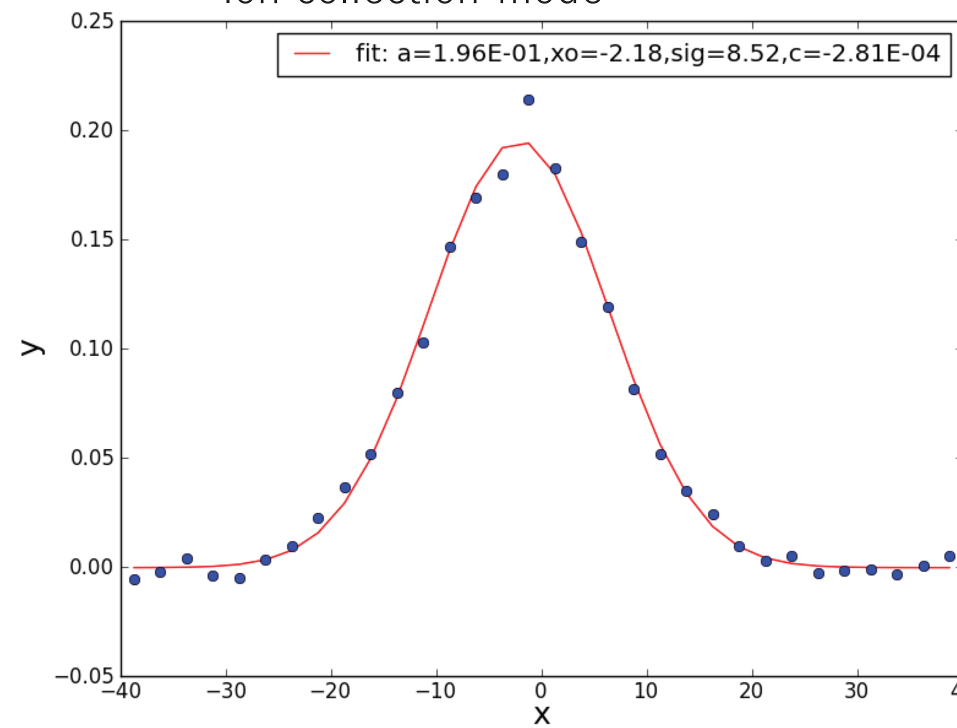
ntal 1st test of the "Gated IPM" @ Dec. 11 – 12, 2020





e have a similar results for the vertical plane

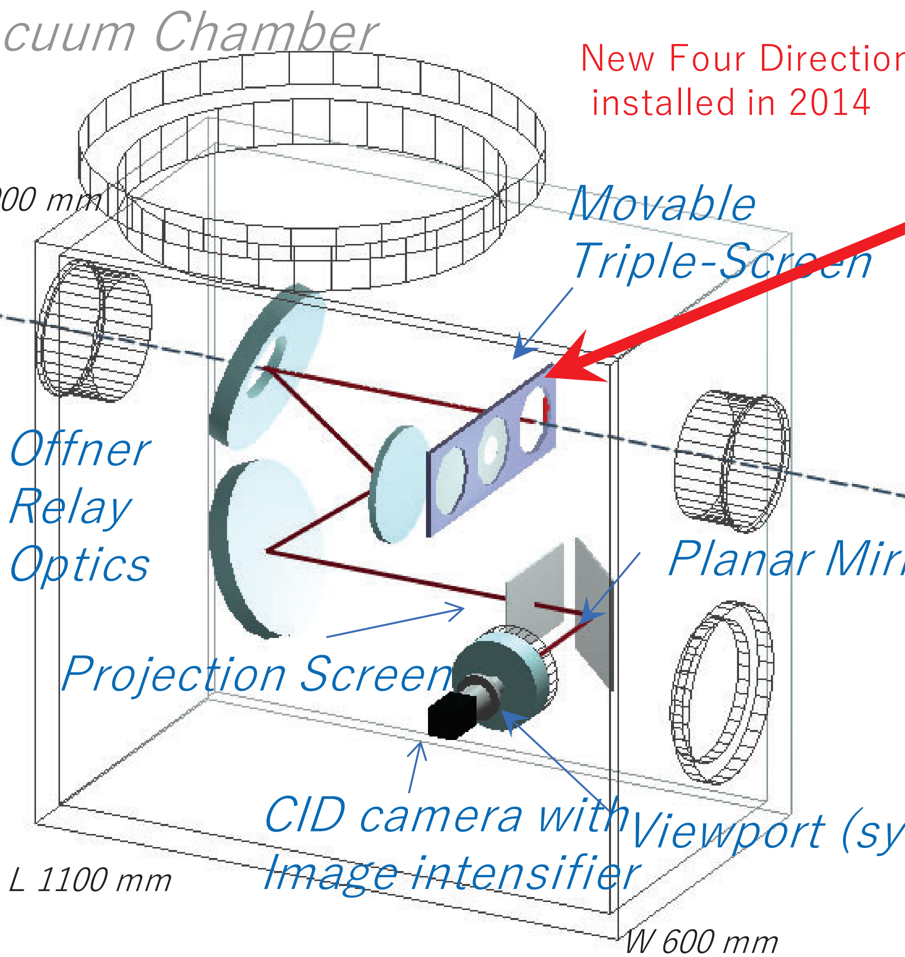
MR injection (3 GeV)
HV switching: 10 kV, 150 μs
N_B = 2.1E+12 p/bunch, 1 bunch
Ion collection mode



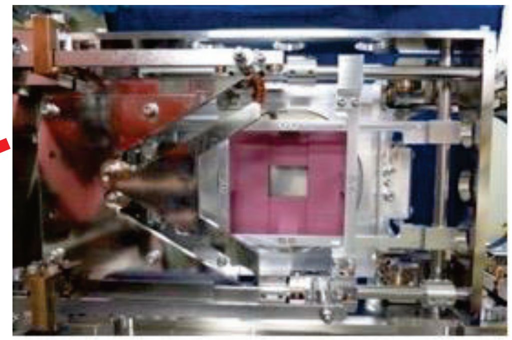
Averaged profile from 10382th – 10456th p

OTR/FL monitor

MULTI-SCREEN BEAM PROFILE MONITOR

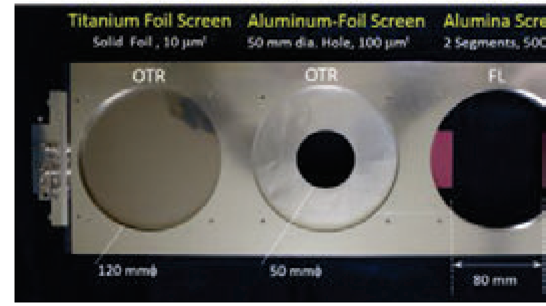


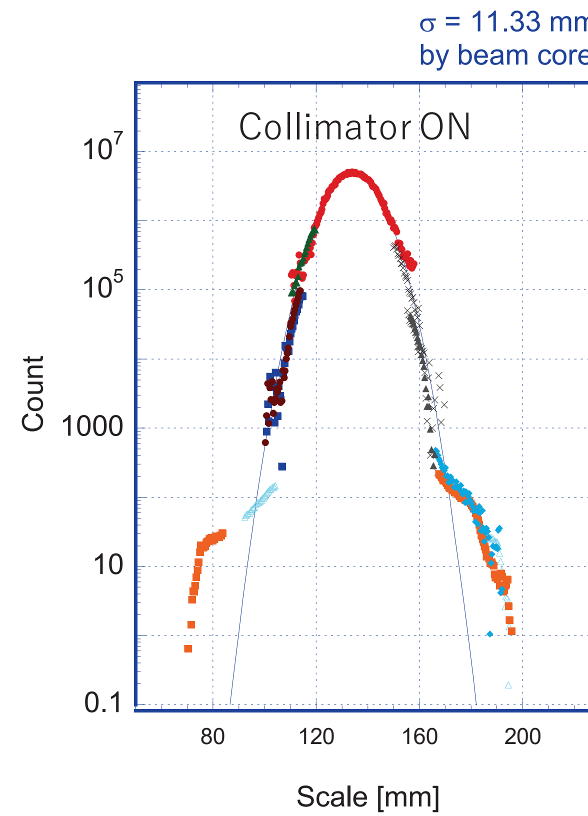
New Four Direction Alumina Screen was installed in 2014



Pre-existing triple screen

→ Inserted just after four direction sc



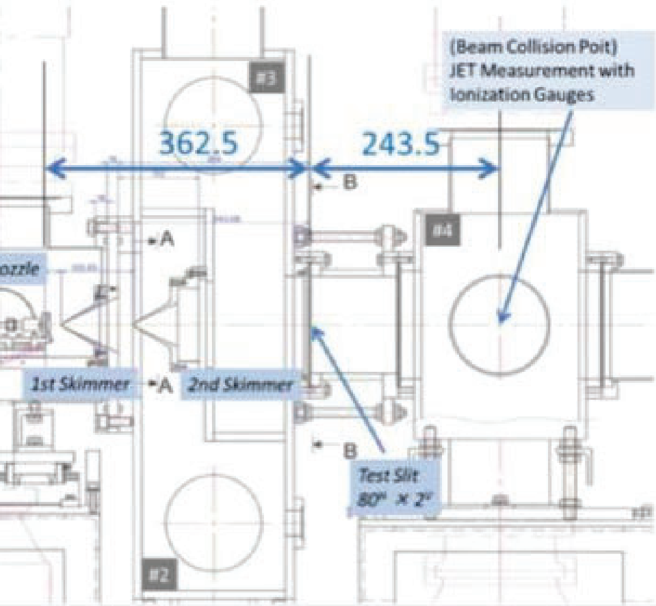


peration at the 3-50 BT since 2013

to, M.Tejima, T.Mitsuhashi et al., HB2014, TUO2AB04

New OTR/FL system is in preparation for the M

Gas-jet Profile Monitor



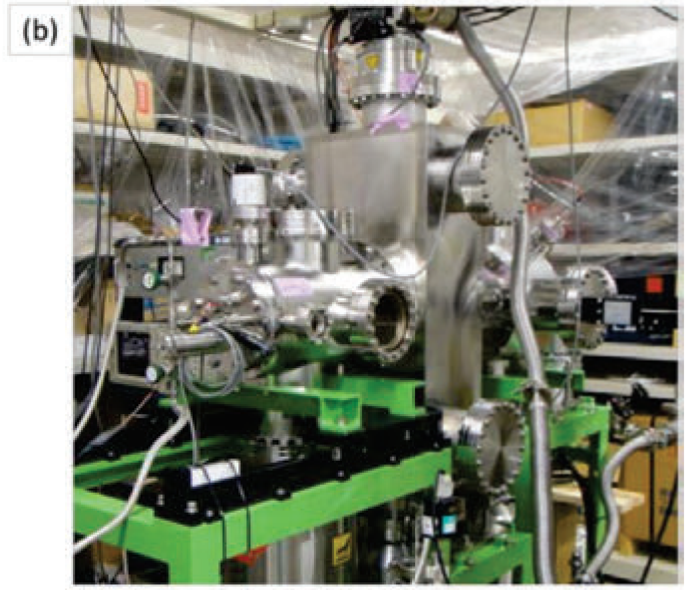


Table 1: Specification of the Jet Generator

Parameter	Value
Pulse Duration	100-1000 μs
Source Pressure	1.0 MPa
Nozzle Size	1.83 mm dia.
1st/2nd Skimmer Size	$6.0^{H} \times 3.0^{V}/20^{H} \times 5^{V}$ mm^2
Slit #3-4	$80^{H} \times 1.5^{V}$ mm^2

Gas-jet densit

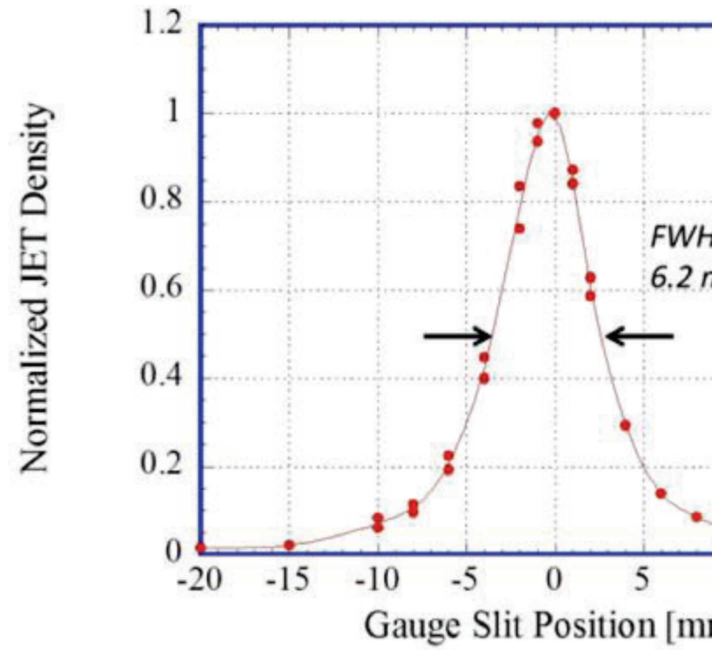
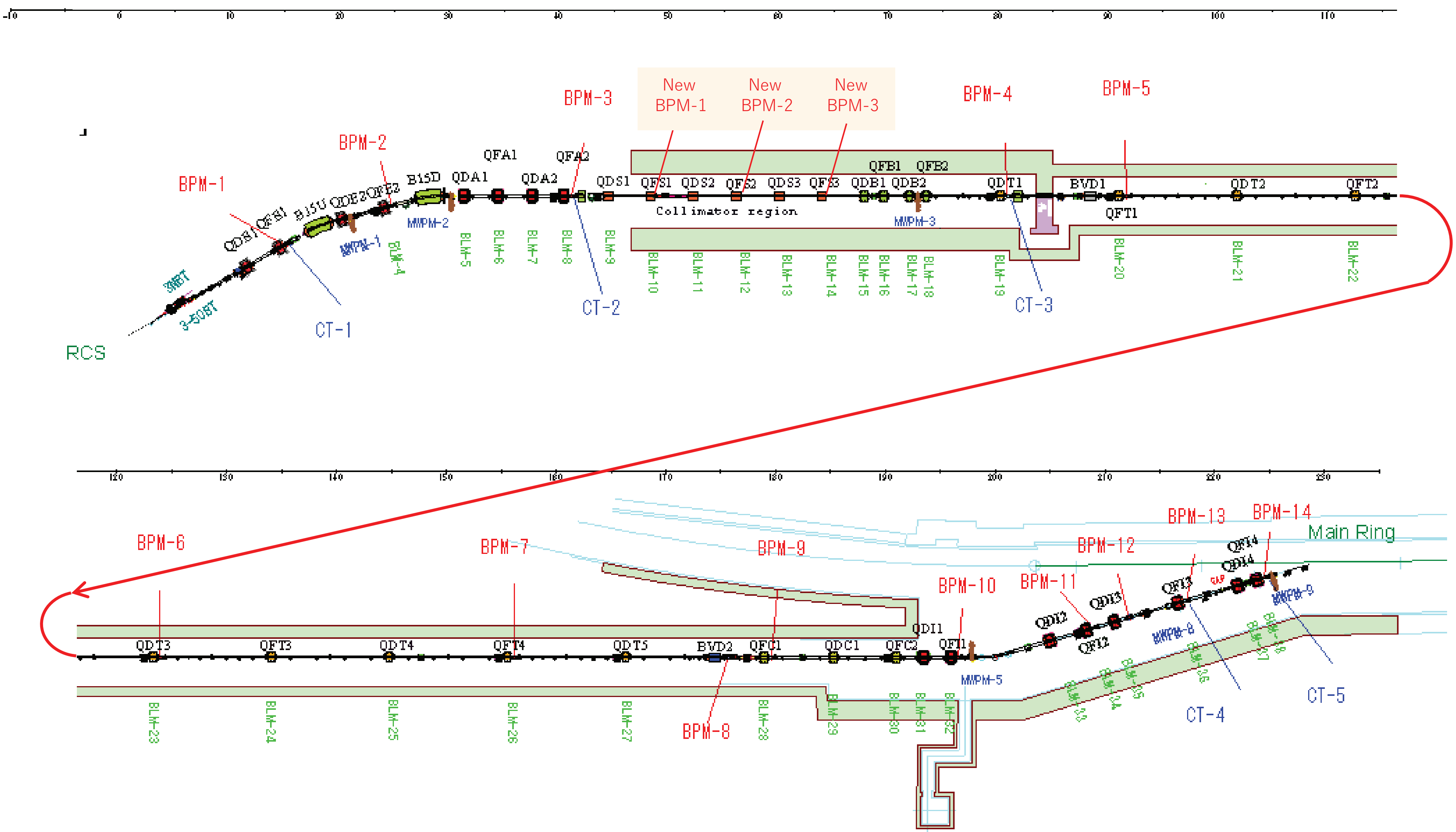


Figure 7: A vertical density distribution at

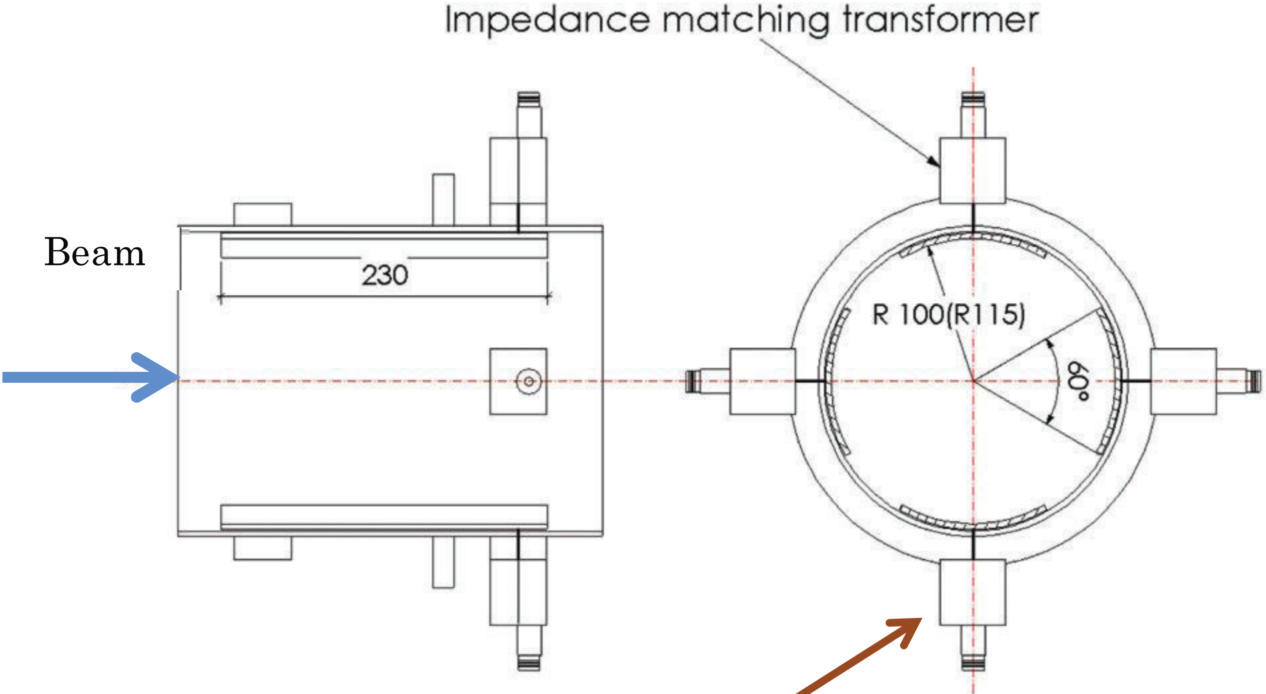
et al., "DEVELOPMENT OF A BEAM PROFILE MONITOR USING A NITROGEN - MOLECULAR JET FOR THE J-PARC MR", IBIC2013, p.848.

"Non-invasive" diagnostics

Beam position and emittance measurements a
Beam Transport line to MR (3-50BT)

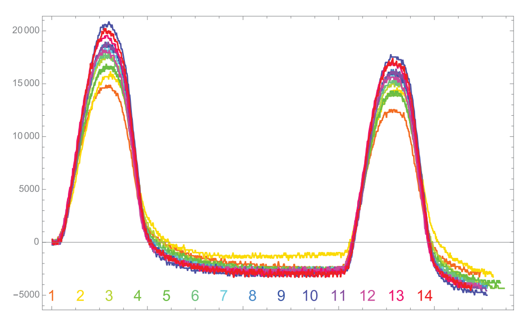


Original BPM in the 350 BT

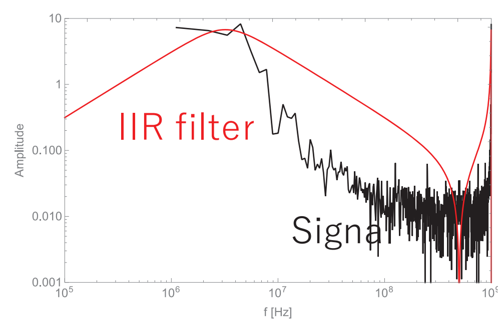


Transformer 15:2
50 Ω → 2.8 kΩ

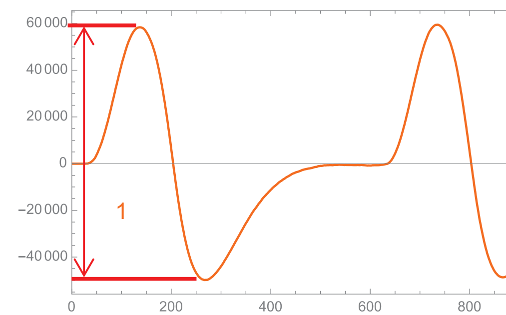
Oscillos
(DSO6
8 bit, 1(



Raw signal

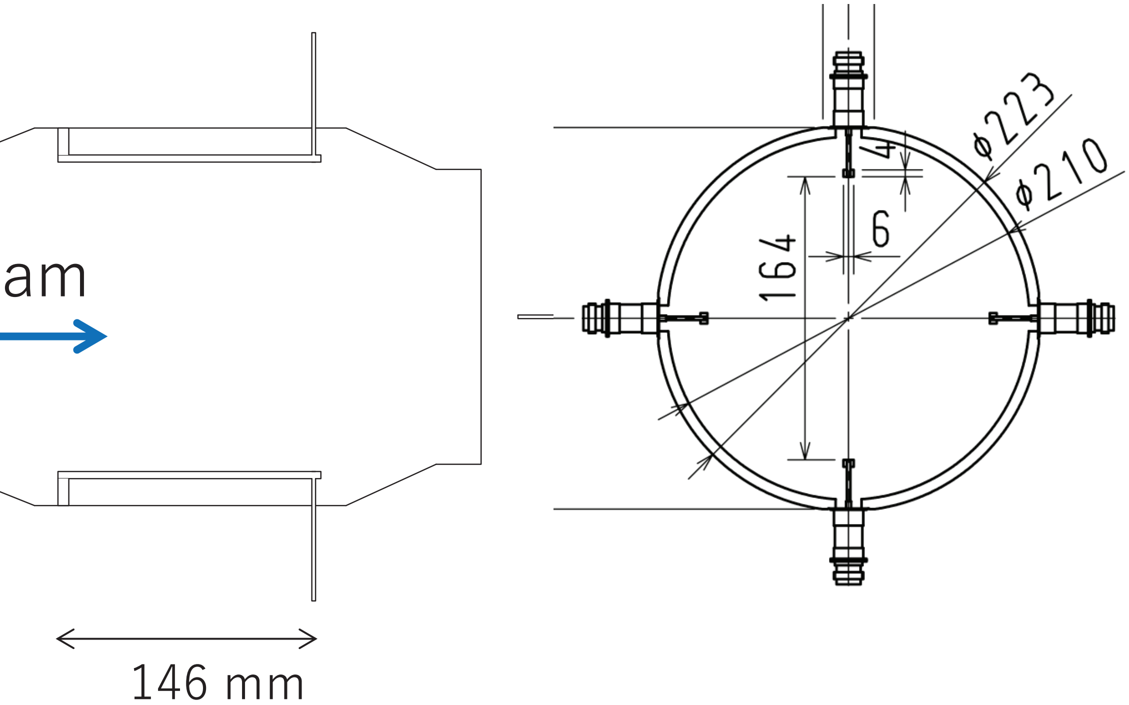


IIR filter

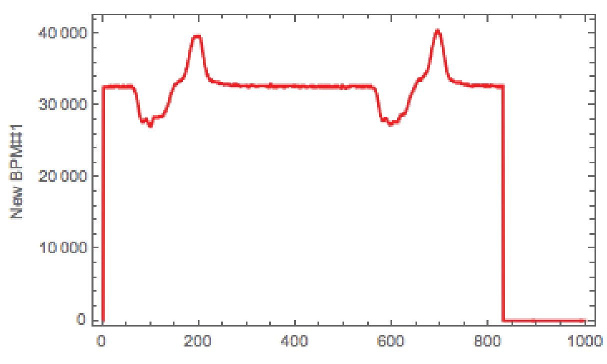


Filtered signal

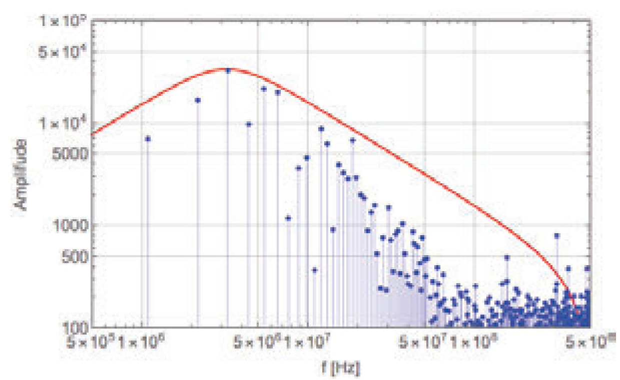
Additionally installed BPM in the 350BT collimator region



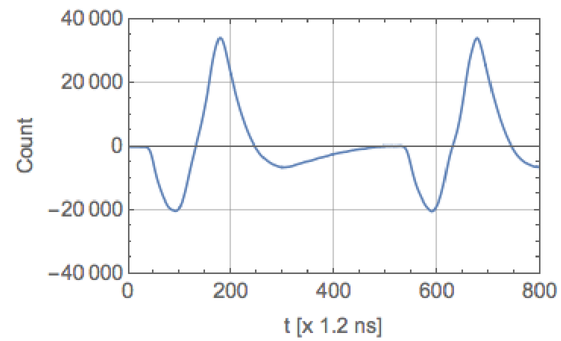
- ✓ Electrodes with small surface area were selected.
- ✓ The signal may suffer from secondary electron emission at the electrode surface due to lost particles.



Raw signal



IIR filter



Filtered signal

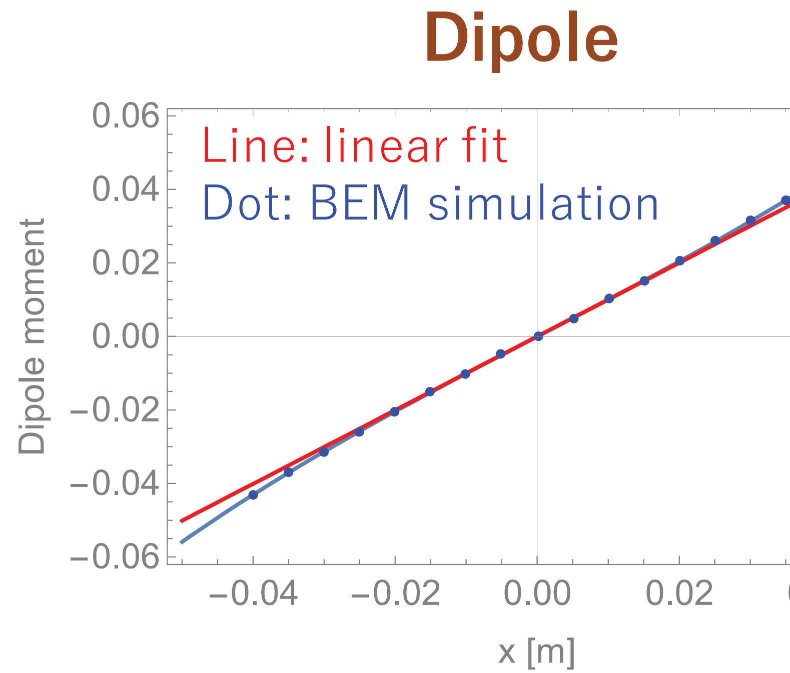
pole and quadrupole moment

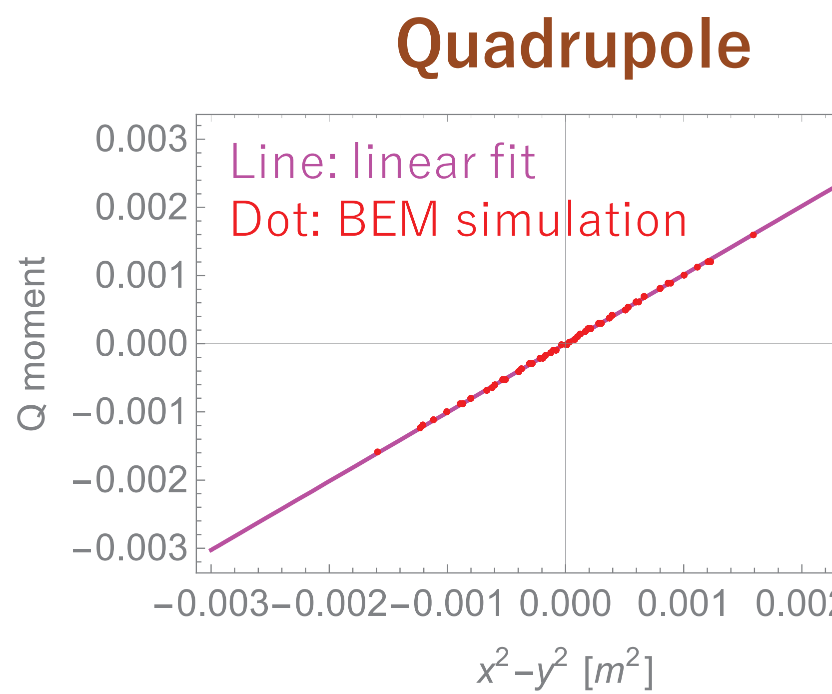
a function of the "pencil" beam

V$_2$, V$_3$, V$_4$ → Moments

$$\begin{pmatrix} \ldots_B \\ \ldots x> \\ \ldots y> \\ \ldots - y^2 > \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} & c_{13} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \end{pmatrix} \begin{pmatrix} V_{x+} \\ V_{x-} \\ V_{y+} \\ V_{y-} \end{pmatrix}$$

$$- \sigma_y^2 = \left\langle x^2 - y^2 \right\rangle - \left\{ \left\langle x \right\rangle^2 - \left\langle y \right\rangle^2 \right\}$$





ting of

$_y$, $\sigma_{\Delta p/p}$

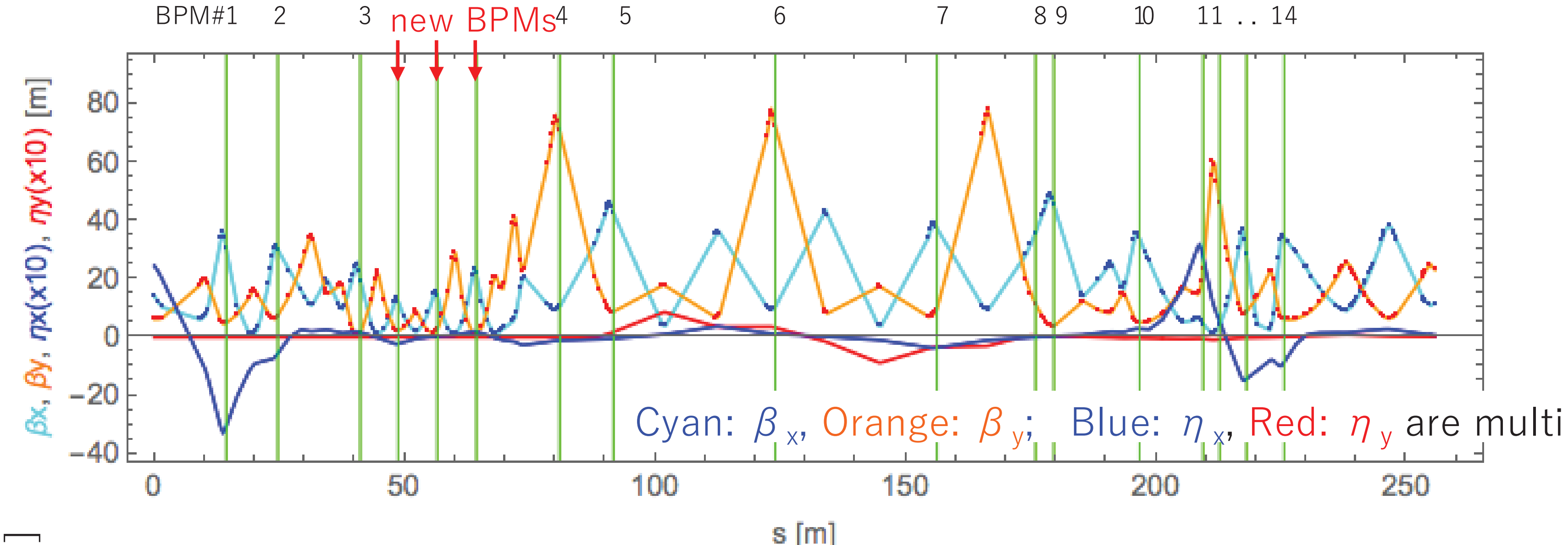
$\sigma_y^2[i]$

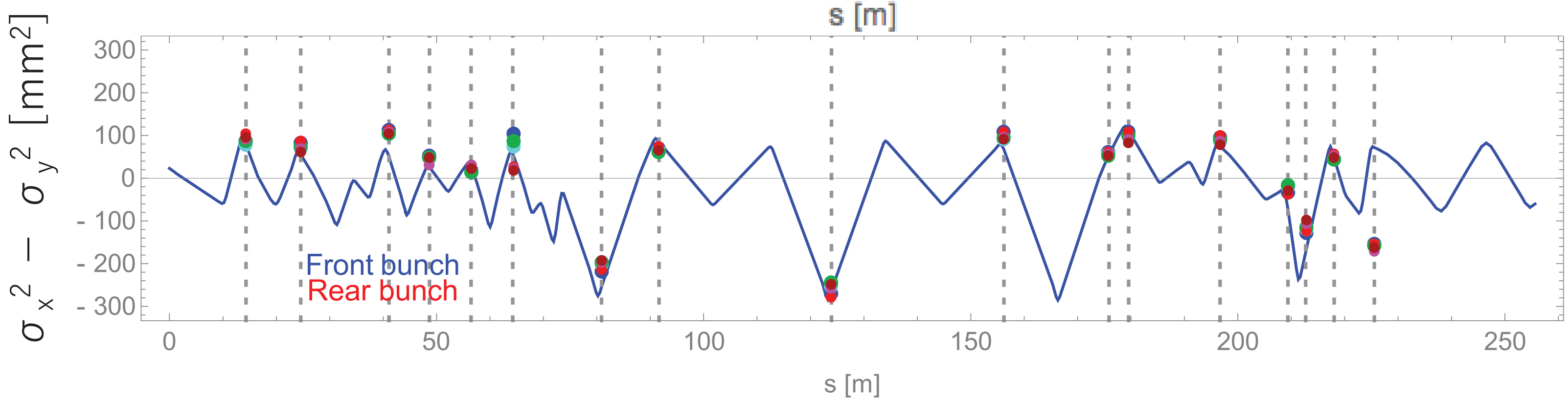
$\varepsilon_x - \beta_y[i]\cdot\varepsilon_y$

$-\eta_y[i]^2\big)\cdot\sigma_{\Delta p/p}^2$

PM#)

3-50 BT lattice for Fast Extraction mode





Blue solid line:

ε_x ~ 2.8 π mm・mmrad (σ)

ε_y ~ 4.0 π mm・mmrad (σ)

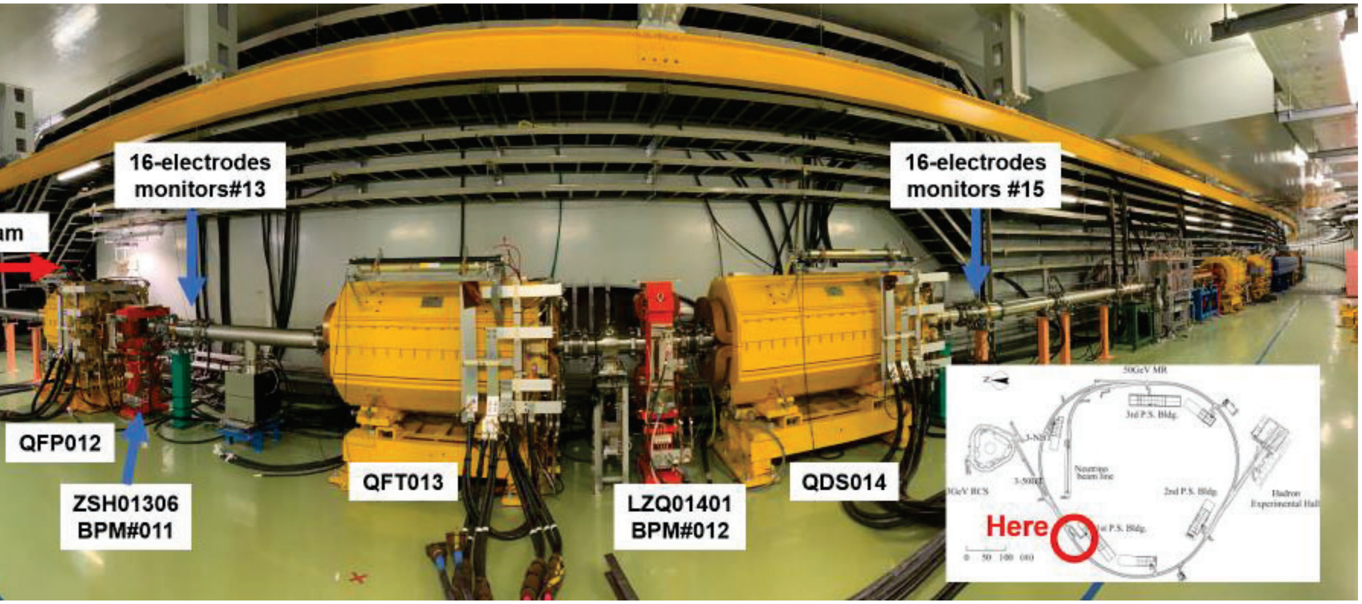
$\sigma_{\Delta p/p}$ ~ 0.12 %

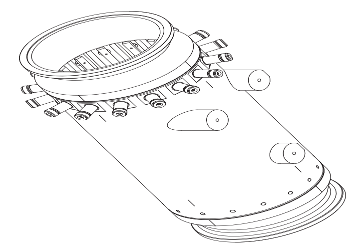
Dots

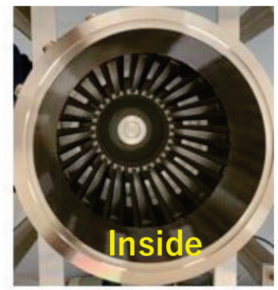
2018. 4.11, 19, 24

~ 2.4E+14 p/8 bunches (FX operatio

16-electrodes monitor

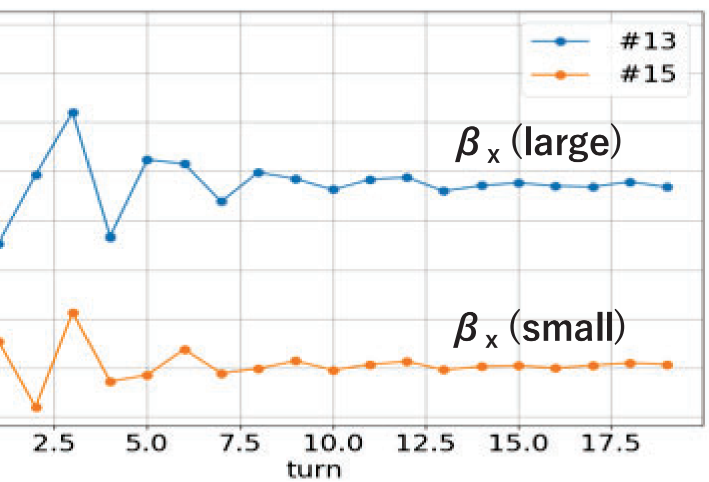


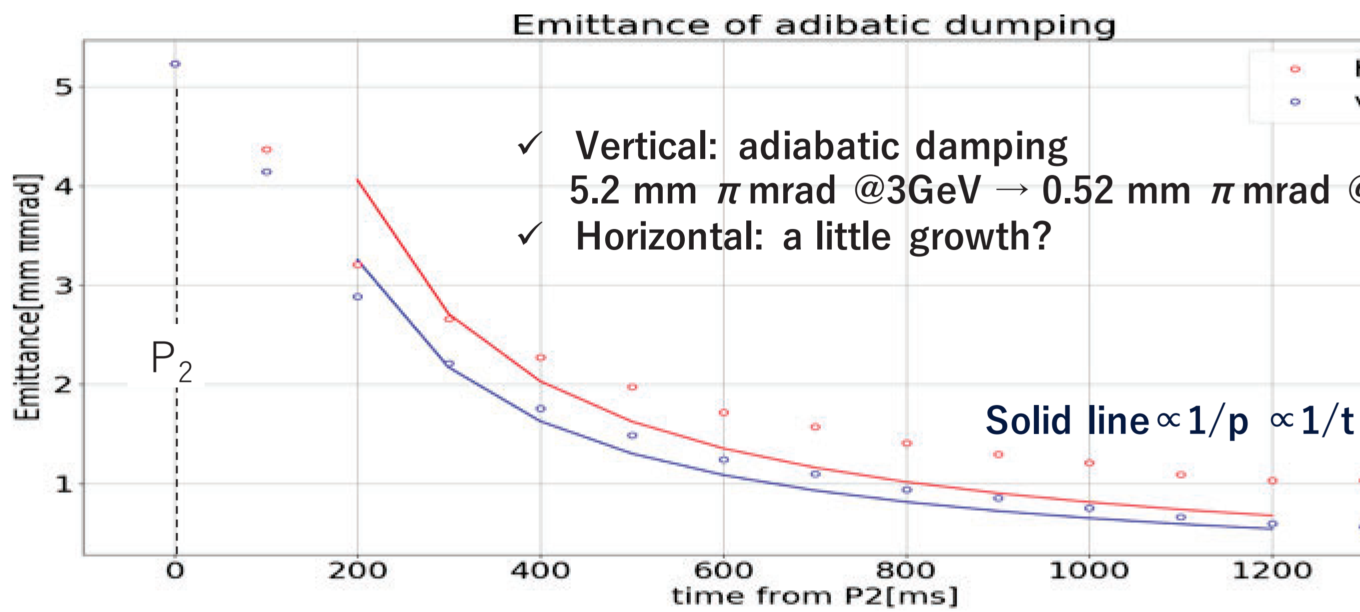




Inconsistency i
by comparing
with the MWPM
still investigatin
reason

ect of the horizontal Twiss mismatch





M. Tajima, Master thesis 2020.

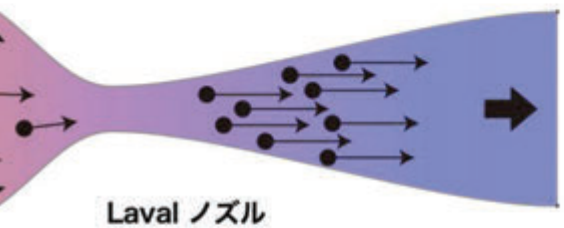
Gas sheet profile monitor

generation

先行研究

体力学）ノズルの利用

温度（相対運動）低下 + 運動方向の統一化



us flow

Supersonic flow,
ful sheet distribution

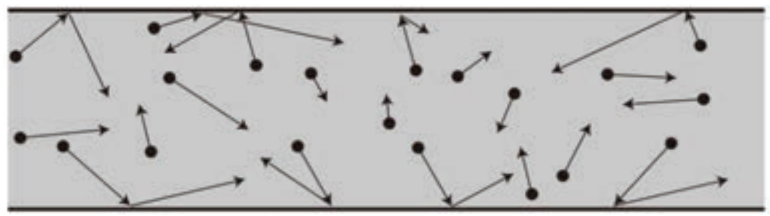
rit: The device is large
s flow control is
lt.

本研究*

分子流（希薄気体力学 or 真空工学）

=> 定義「ガス間衝突（相互作用） 無視可能」

+ 流路壁面での特殊な反射過程



Molecular flow

Merit: Simple equipment, easy gas pressure control

Demerit: Includes thermal velocity error in profile

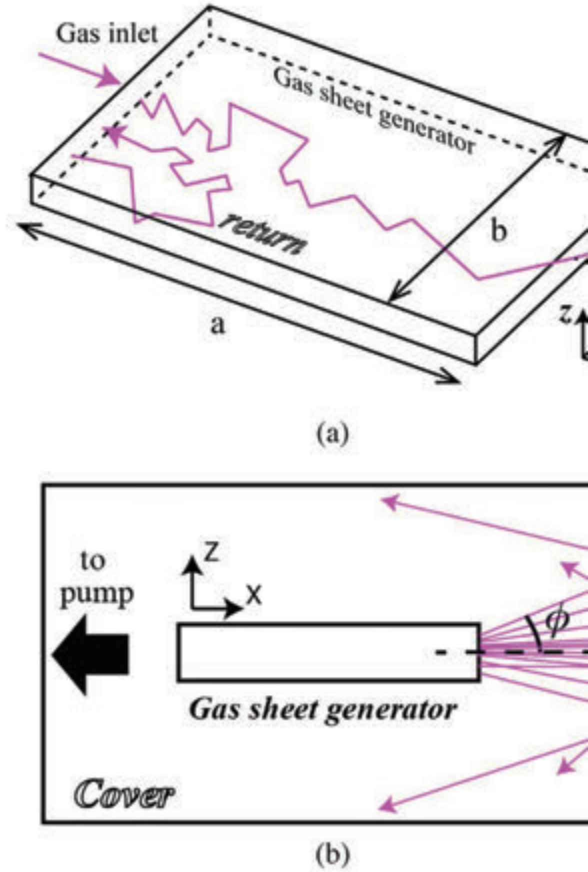


FIG. 3. Schematic diagrams of the formation prin
sheet. (a) A thin and long gas conduit makes a ga
cover slit eliminates the gas molecules that have l

Yama

@ 3 MeV MEBT test bench

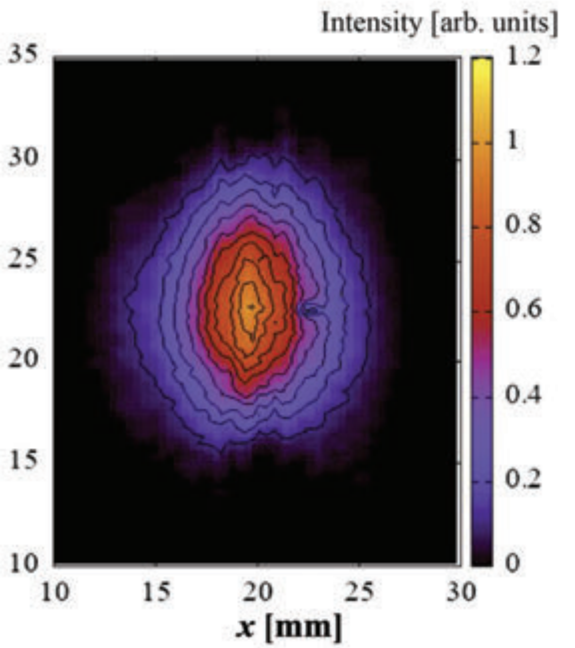
H- beam

ions were done:

ensity spatial distribution

ion efficiency spatial distribution of

oton detector system



. A two-dimensional mapping of the transverse beam of Fig. 12.

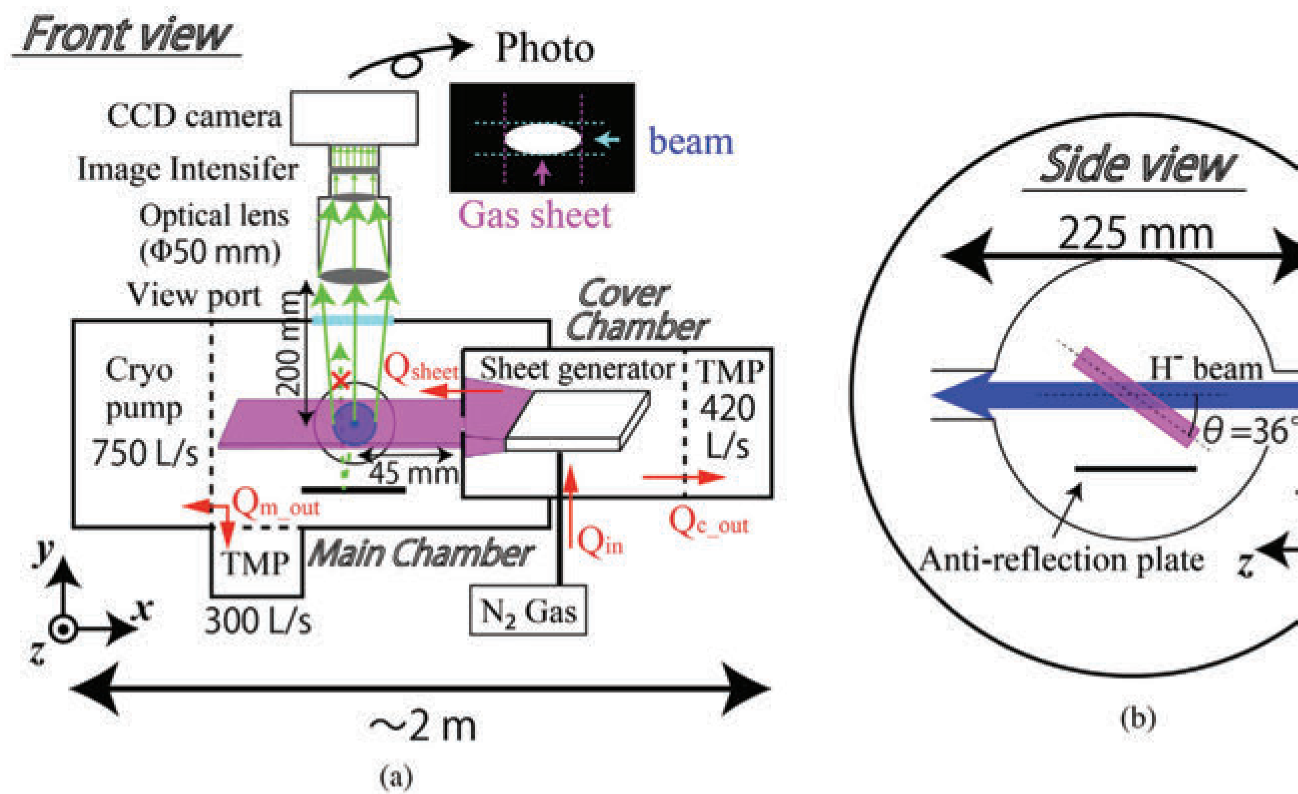
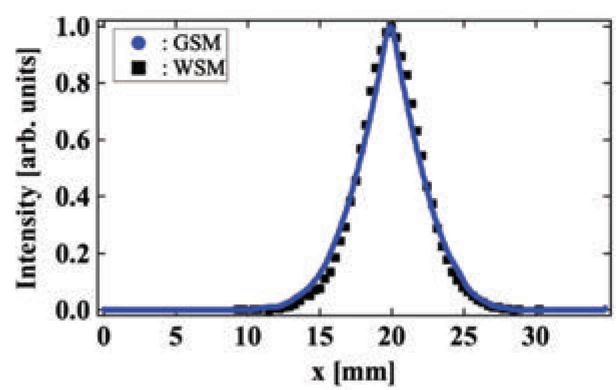
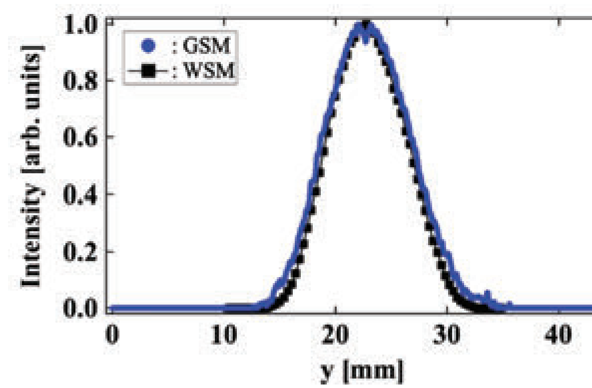


FIG. 7. The gas sheet monitor system: (a) the front view and (b) the side view. The system consists of a main chamb beam line, a gas sheet generator attached to a cover chamber that consists of a 0.5 mm × 50 mm slit and a TMP, two va a photon detector system consisting of optical lenses, an image intensifier, a CCD camera, and an antireflection plate. 36 degrees from the beam.





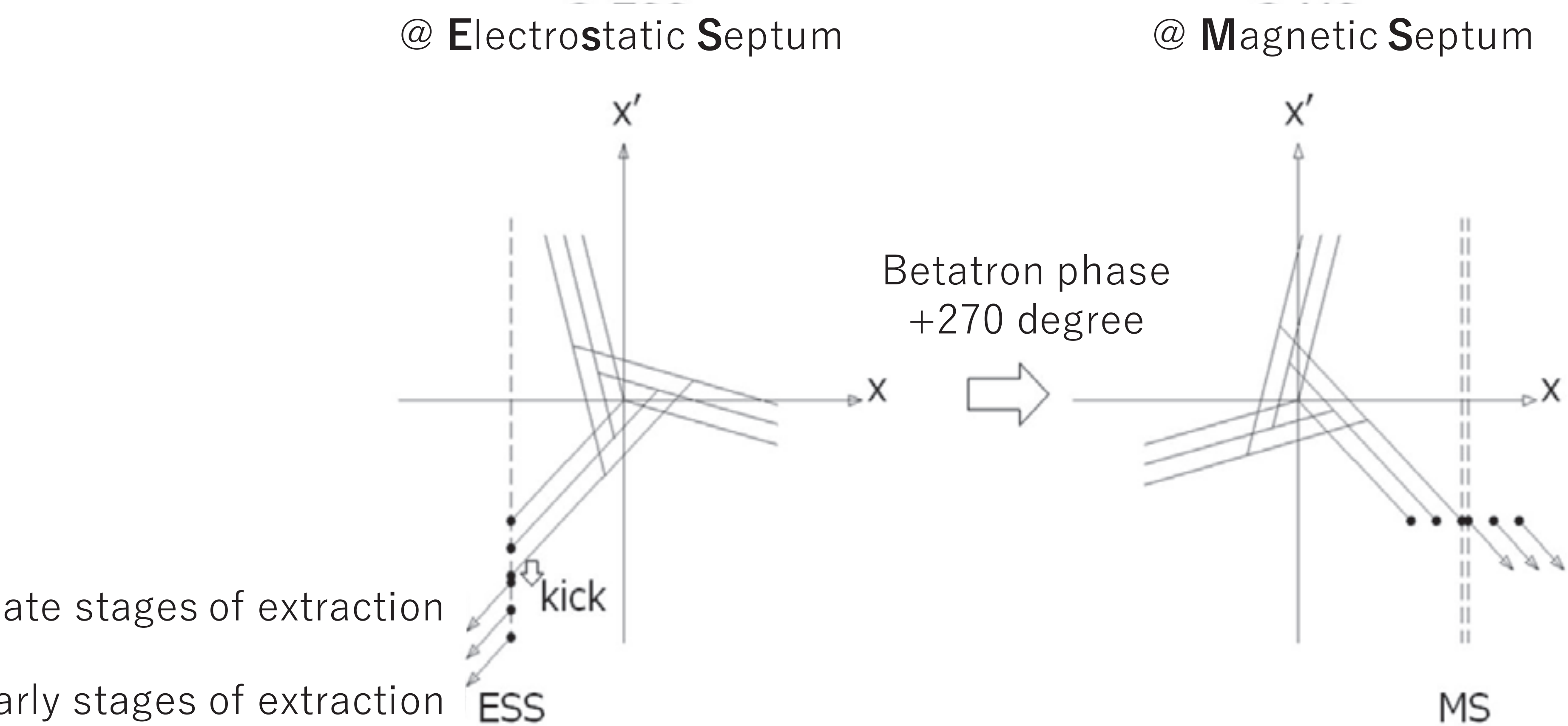
Yama

Beam diagnostics for the MPS

(examples related to targets)

extraction of a coasting beam

1. Make third-integer resonance with sextupole magnets, make a separatrix
2. Make a separatrix shrinked by changing the betatron tune slowly
3. Spilled protons are extracted along the phase space flow line



Mut

old target incident during slow extraction at the hadron experimental facility
11:55, May 23, 2013

ction Quadrupole" (EQ) malfunctioned:

ormally large command value was output.

supply reached its max. current

erted overvoltage. → MPS stopped the beam.

protons were extracted in 5 ms.

rget was instantaneously heated up

ry high temperature and

y melted or evaporated.

tion fans were turned on

ce airborne radiation dose rate in the HD hall.

um total exposure dose of the workers

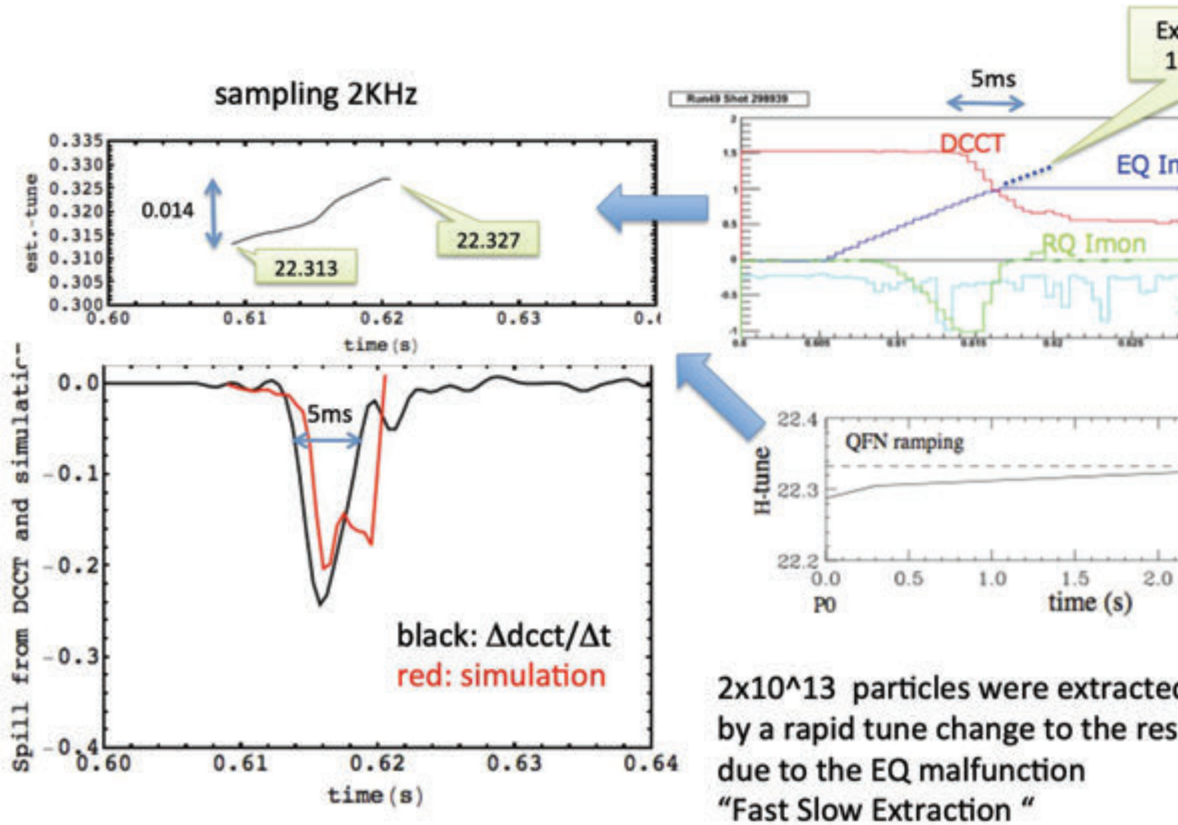
HD hall was 1.7 mSv

aximum integrated radiation dose

site boundary is estimated to be 0.17 μSv

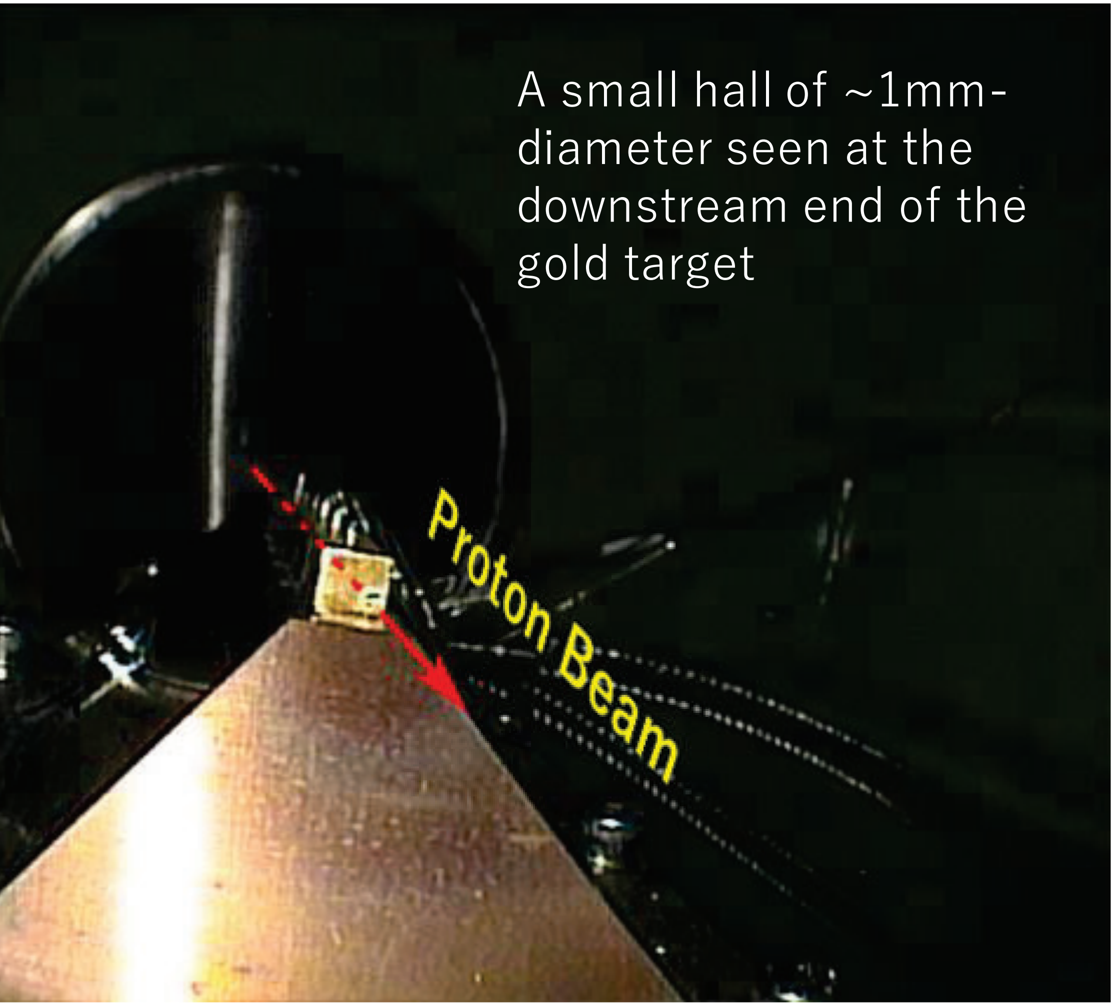
cation close to the HD hall.

Spill and Simulation

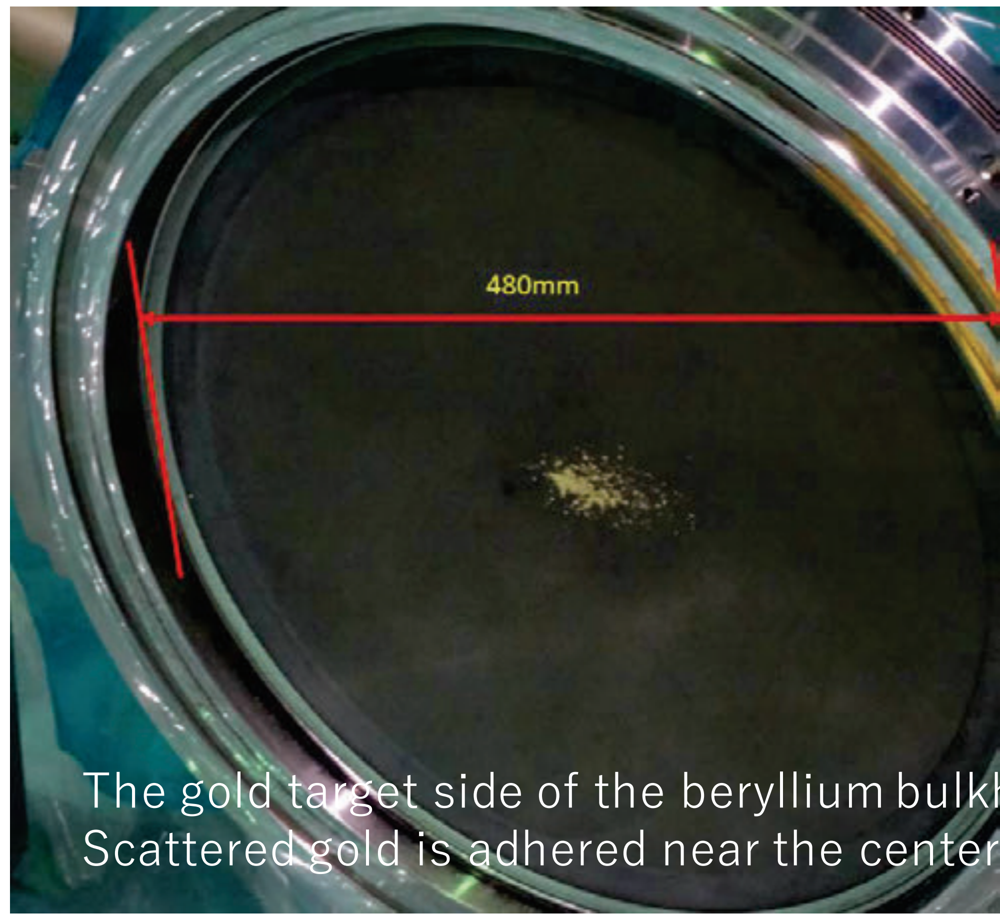


2x10^13 particles were extracte
by a rapid tune change to the res
due to the EQ malfunction
"Fast Slow Extraction "

Tom

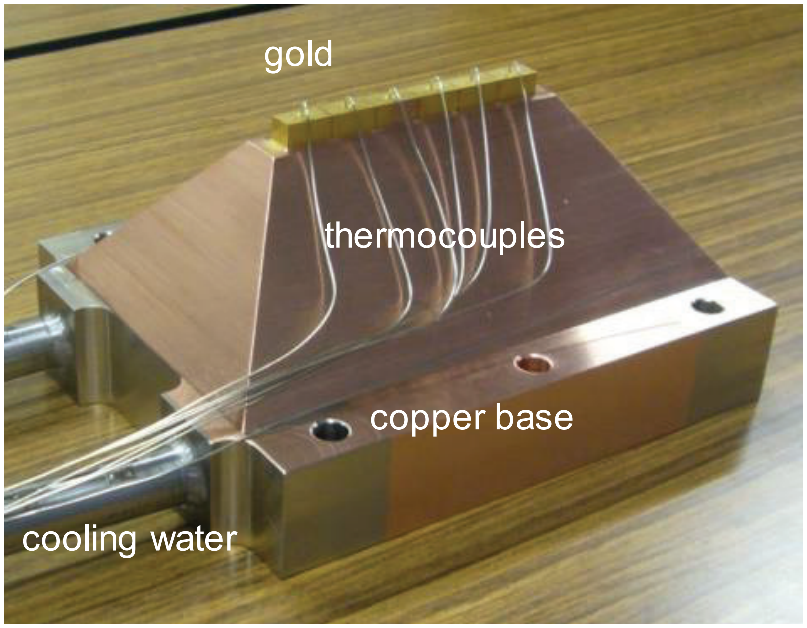


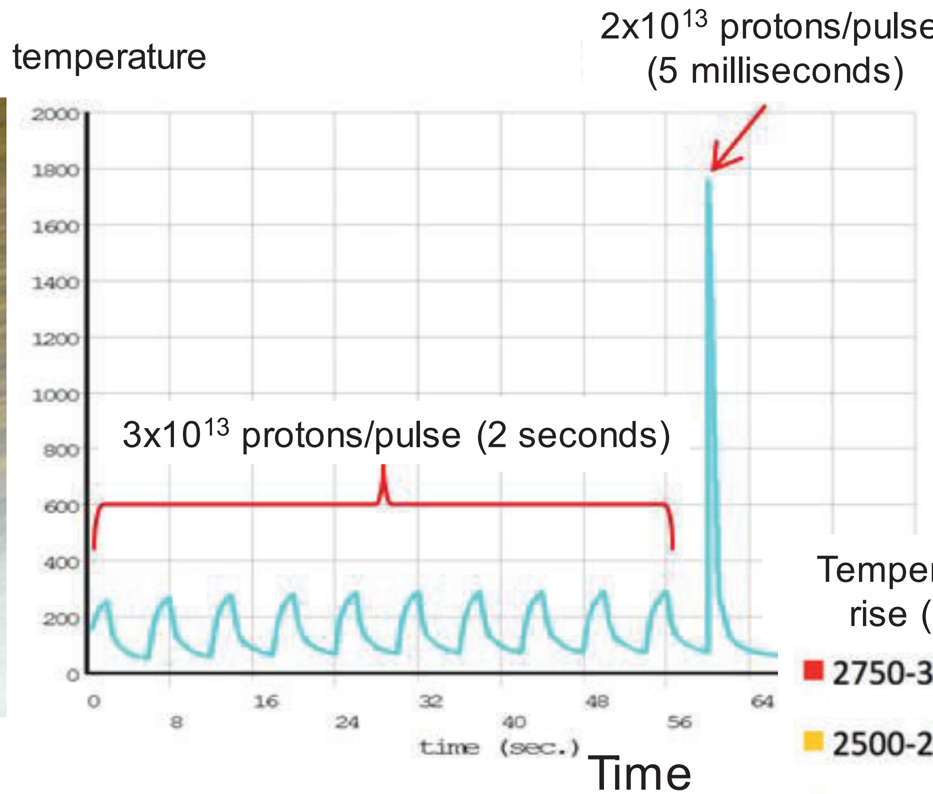
A small hall of ~1mm-diameter seen at the downstream end of the gold target

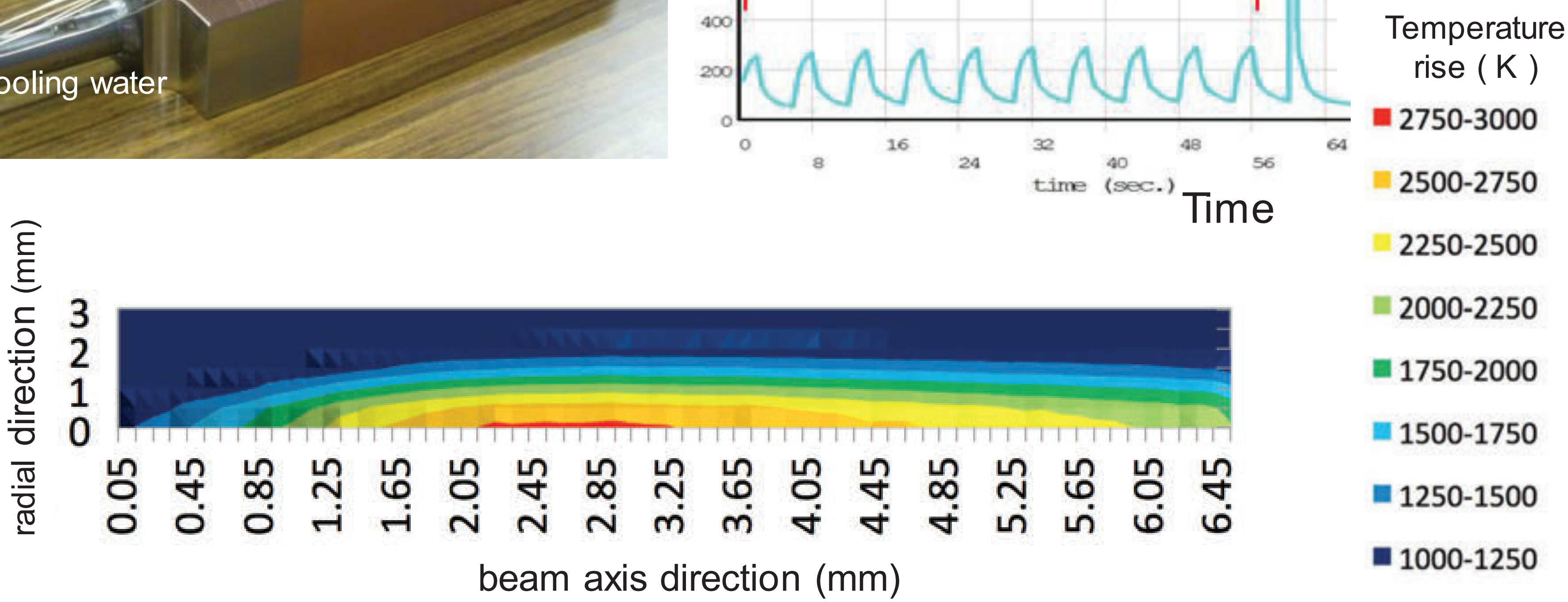


The gold target side of the beryllium bulkh
Scattered gold is adhered near the center

Target Temperature（Simulation Results）

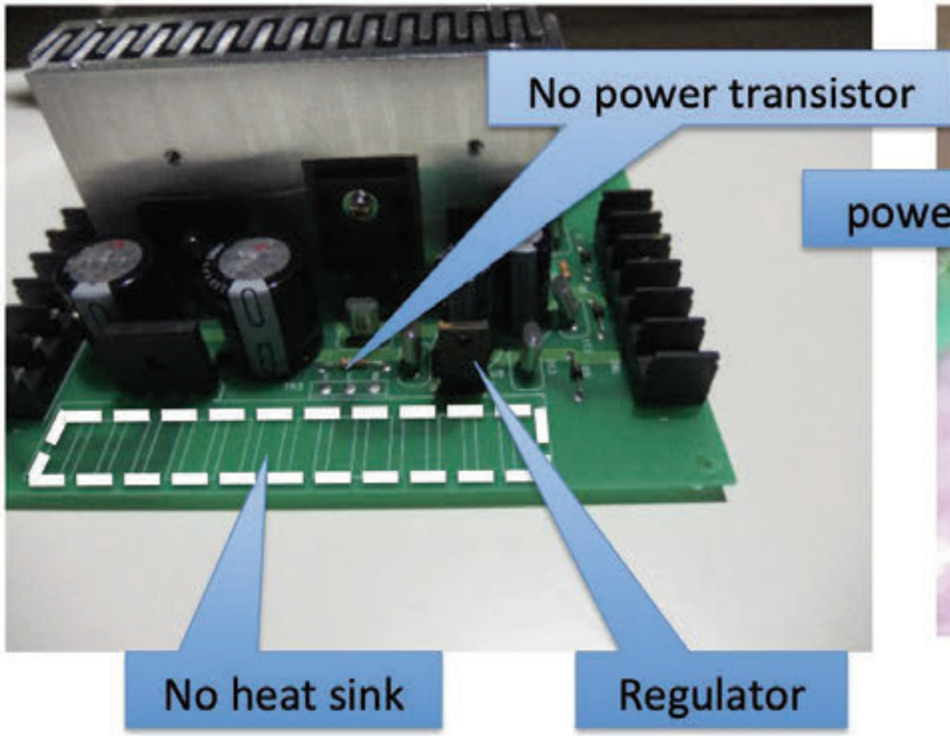




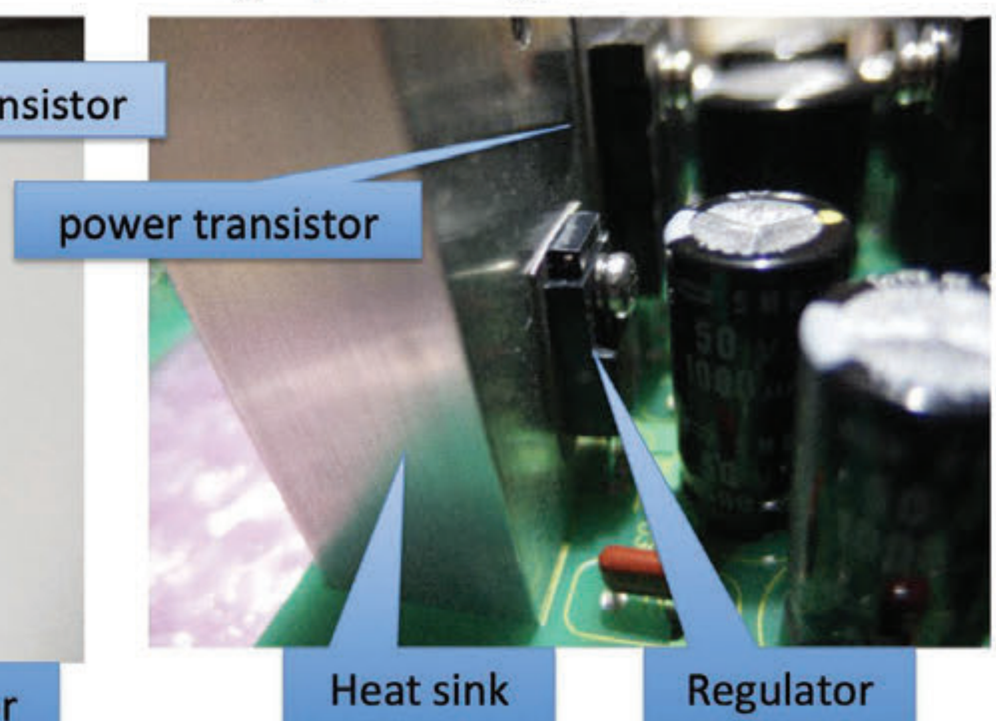


5V supply Board for digital signal transmission (photo-coupler) in EQ P.S.

Low power type



high power type



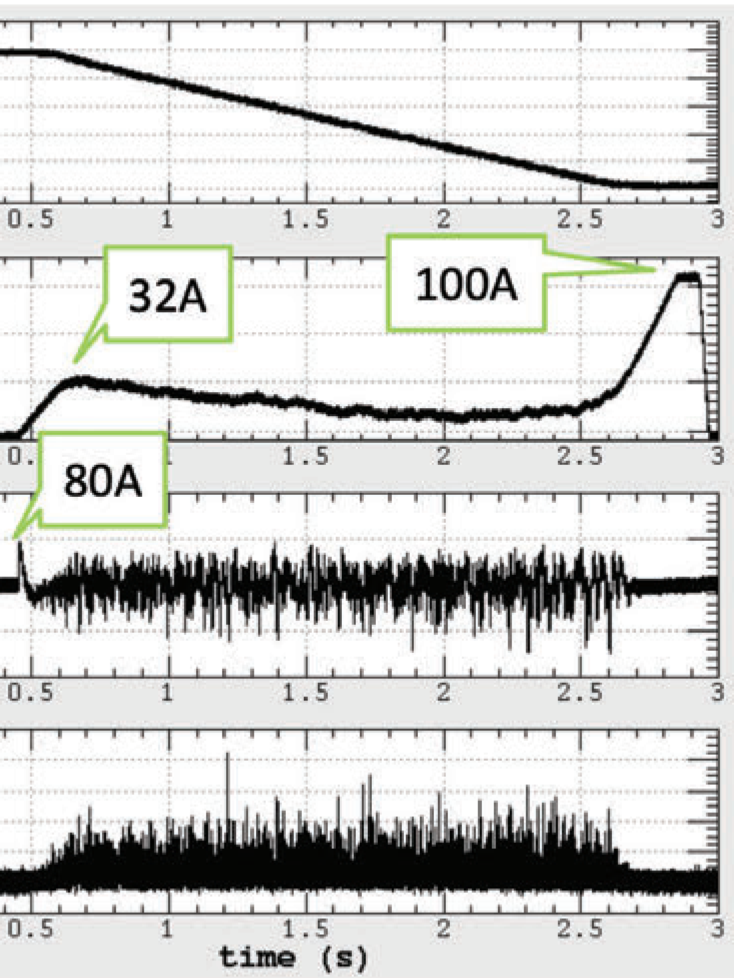
Low-power type board had been misused in the EQ power supply.

Long operation under overheat of the regulator
caused an unstable voltage drop,
which made transmission of the digital signals unstable.

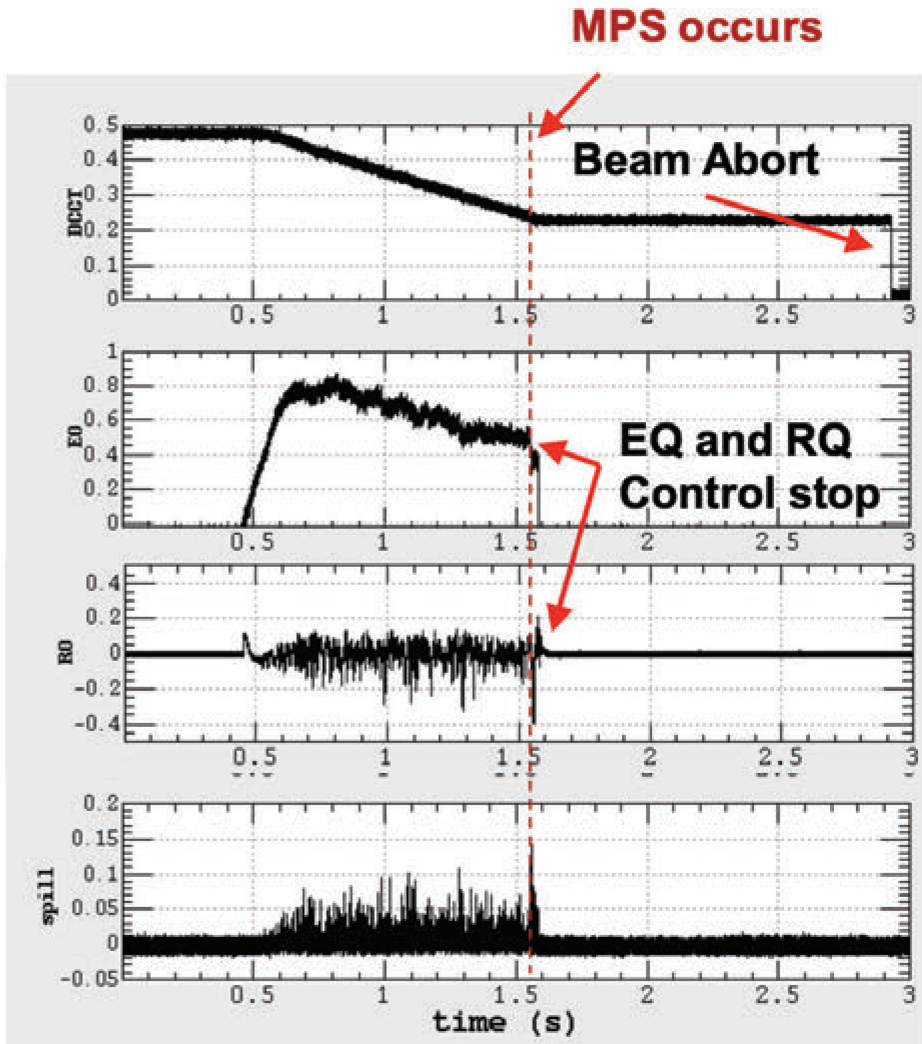
Behavior at the malfunction can be understood.

Tom

SX Abort



Normal



SX Abort

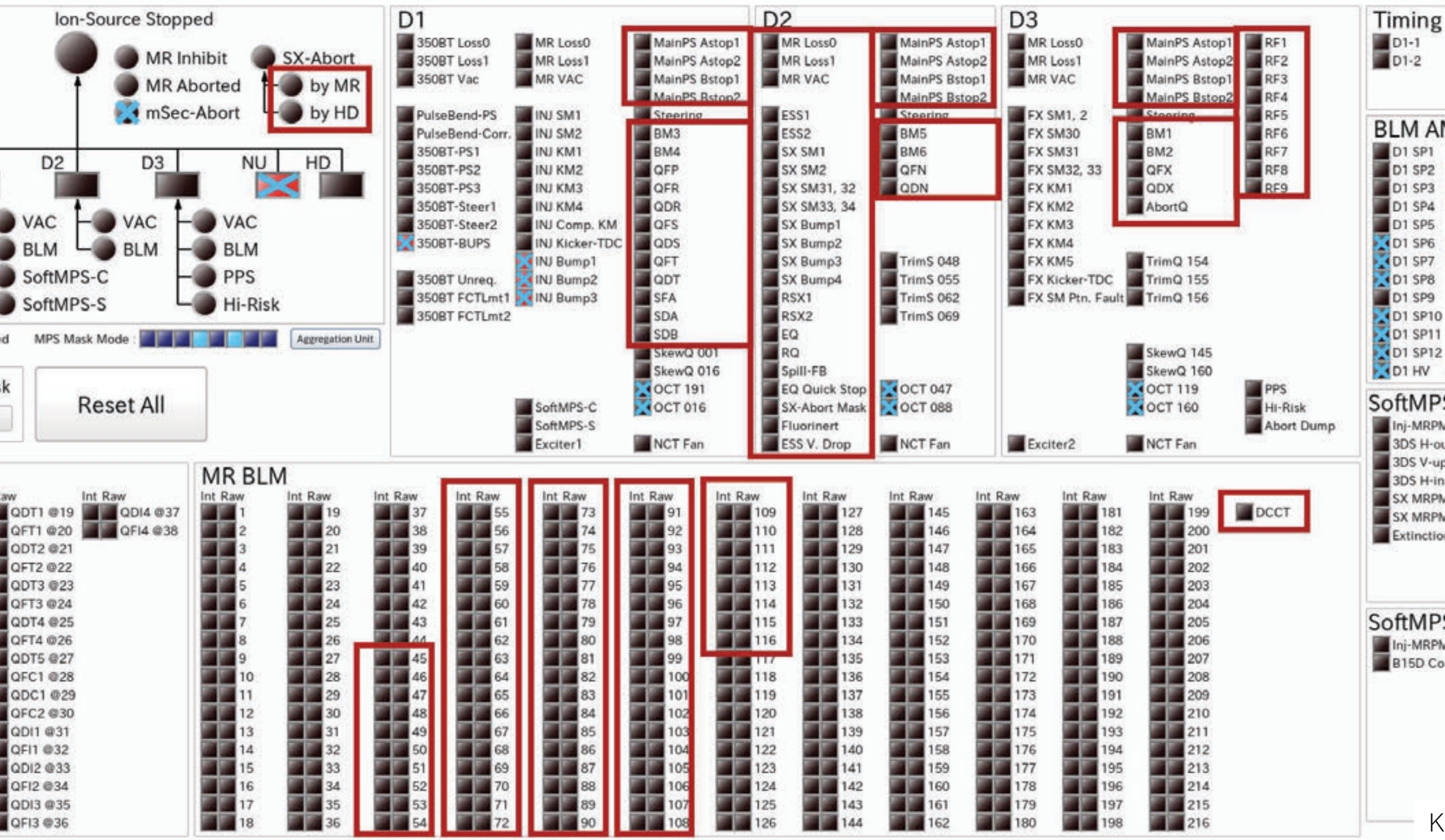
・Stop SX compo
immediately

・SX is stopped a
the beam continu
circulate in MR

・The kickers ab
at scheduled tim

Kimura

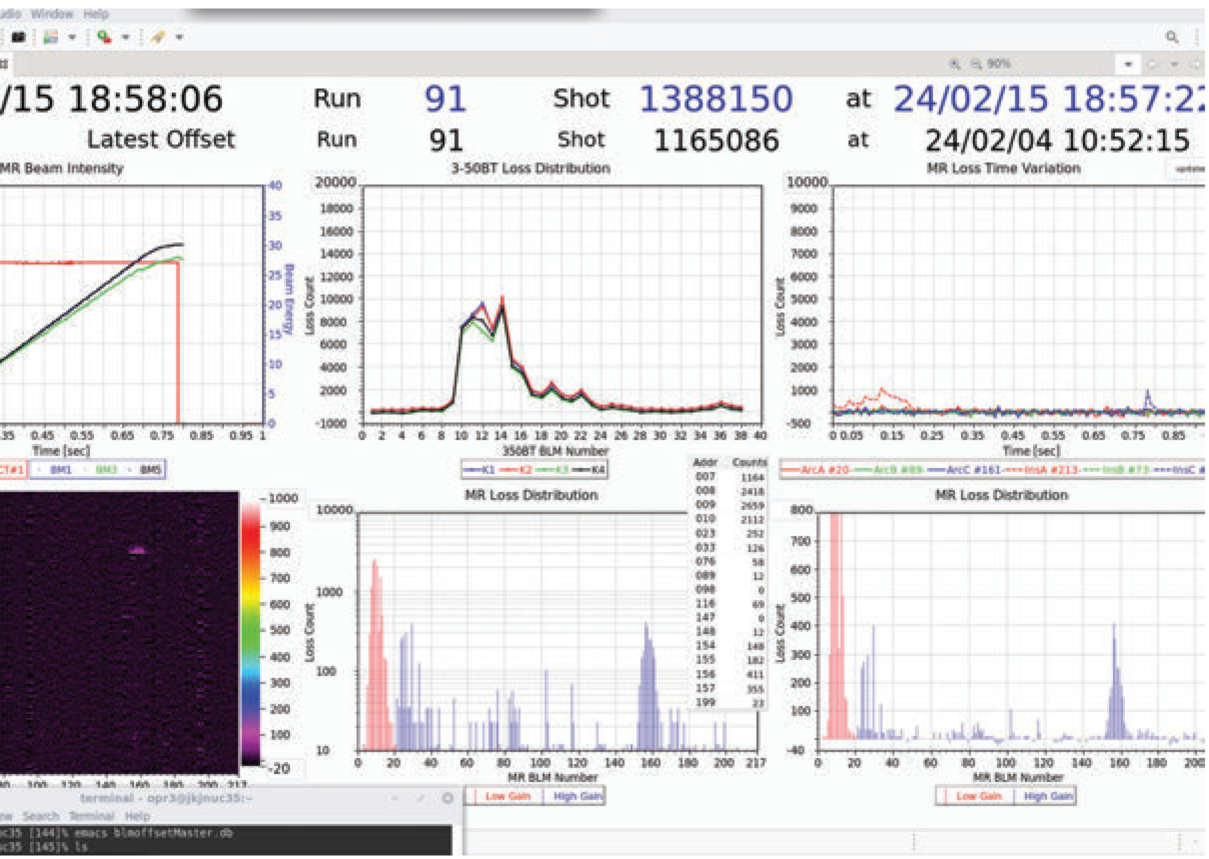
Equipment requiring SX Abort

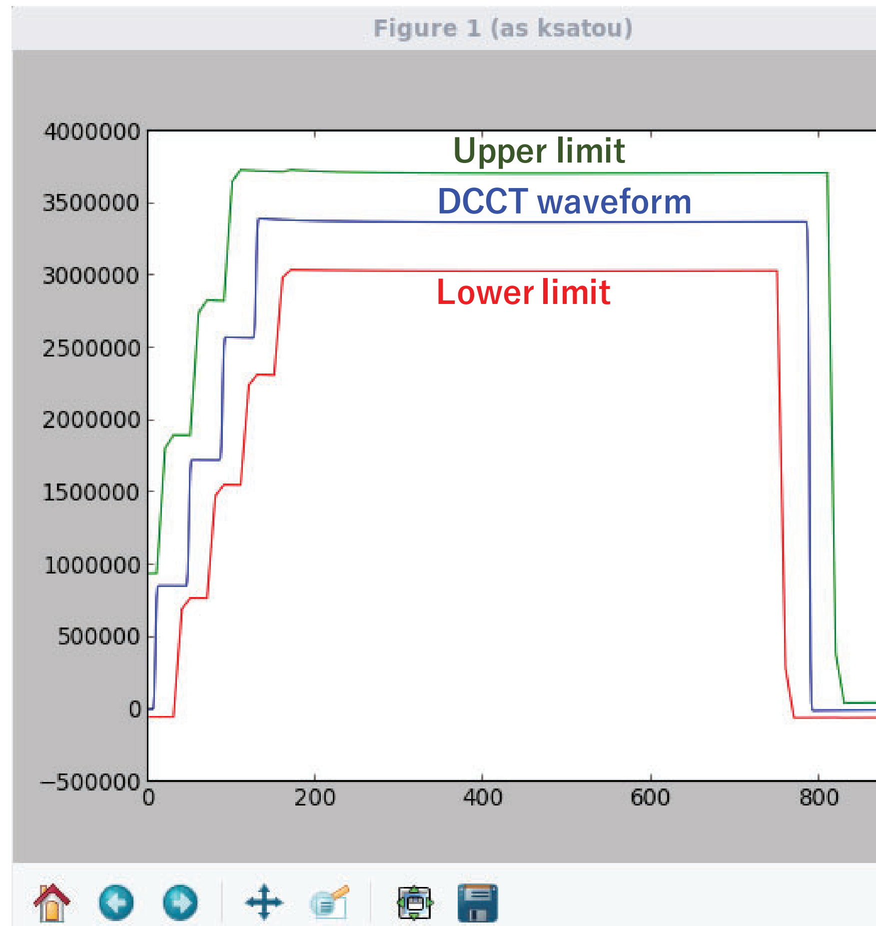


K

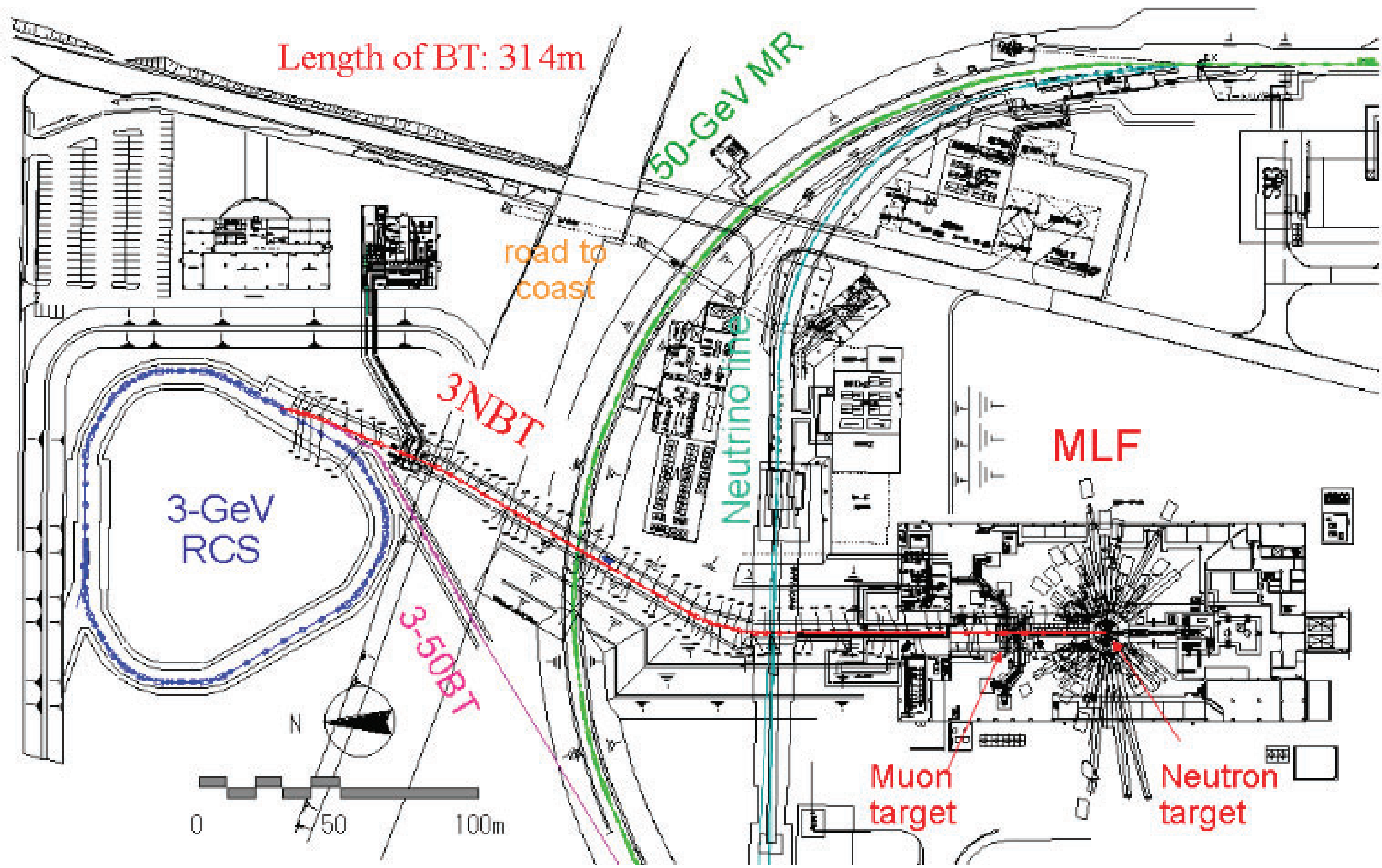
'S of DCCT

event is generated by capturing glitches of DCCT waveform



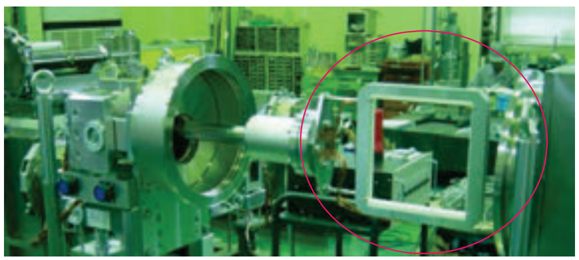


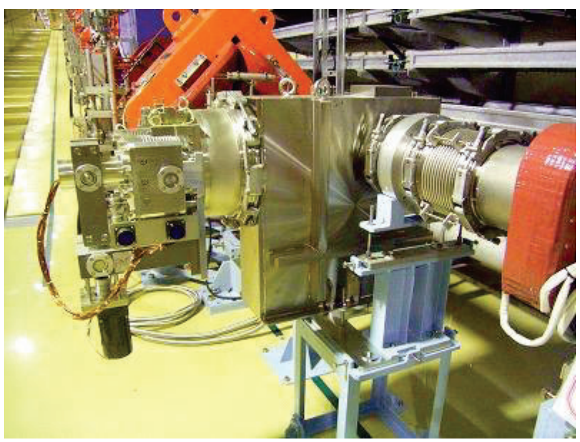
MPS protecting the MLF target



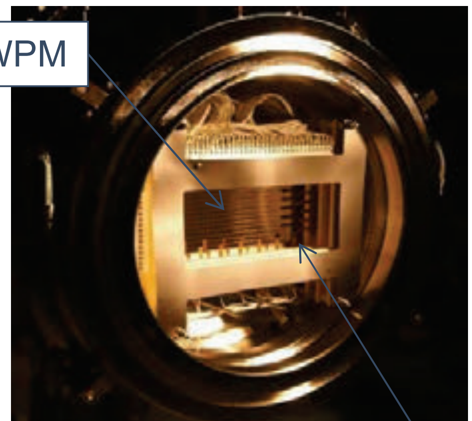
Monitors for the beam transport line from 3 GeV RCS to the MLF target (3N-BT)

- [illegible]
  - [illegible]
- [illegible]
- [illegible]
- [illegible]

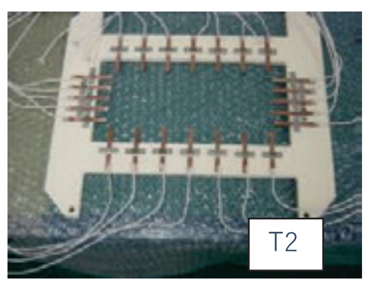




MWPM



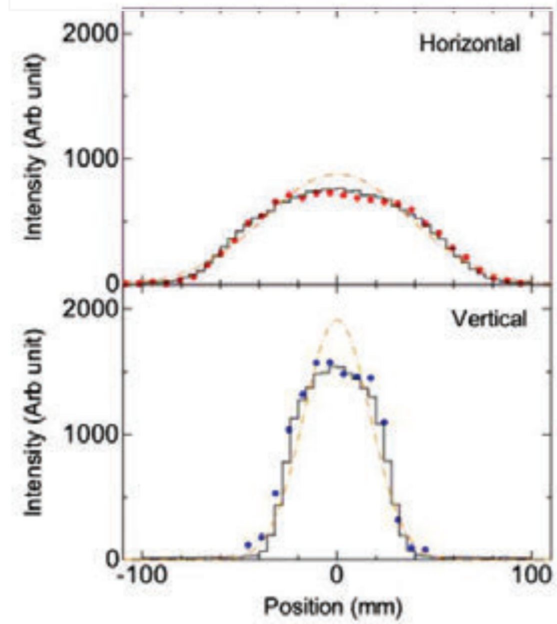
MWPM



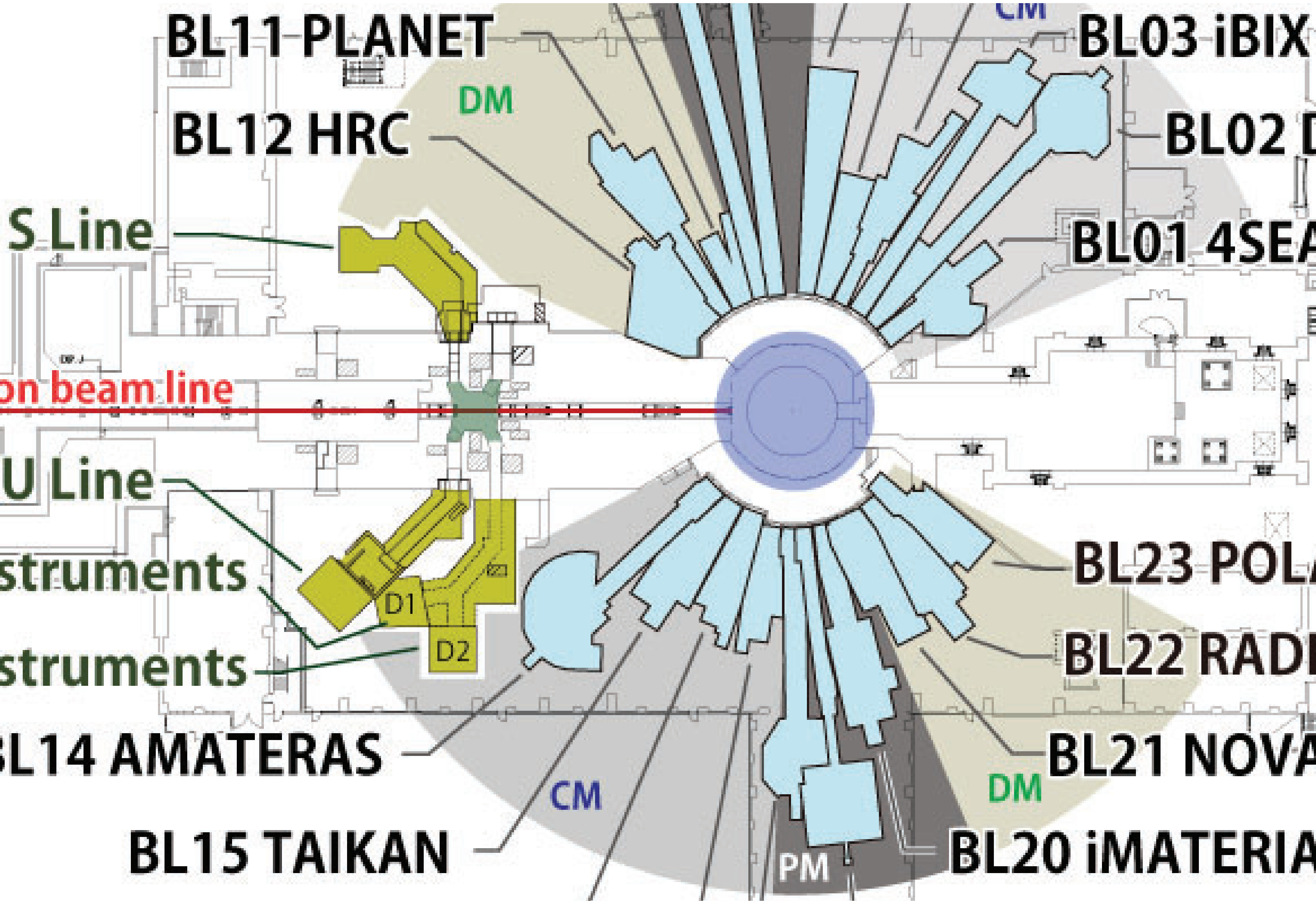
Halo monitor
・SEC(Secondary electron emission)
・TC (Thermo coulpe)

Monitors at Proton Beam Window (PBW) (1.8 m from neutron target)

[illegible]

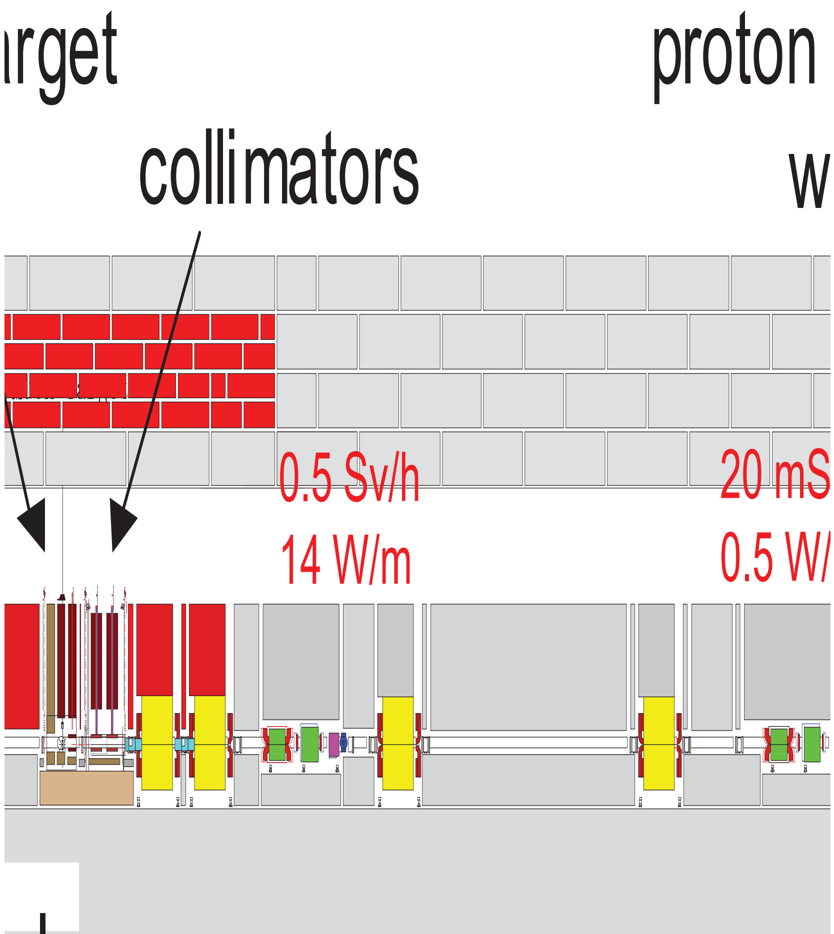


[illegible]



BL11 PLANET
CM
BL03 iBIX
DM
BL12 HRC
BL02 D
S Line
BL01 4SEA
on beam line
U Line
struments
D1
struments
D2
BL23 POLA
BL22 RADI
BL14 AMATERAS
BL21 NOVA
CM
DM
BL15 TAIKAN
BL20 iMATERIA
PM

as quantitatively observed by
ained by dosimeter for 500 k



eam loss aroused due to n
e beam loss at hands on ma
ning more flat shape, star s
g with large aperture is insta

Me

event @ May 27, 2018

halo monitor @PBW Alerts if temperature exceeds limit value (~ 5 min at 25 Hz op
MWPM Alerts when peak current density exceeds a certain value (quick res

ayer short at the coil of one quadrupole magnet in the transport line, "3N-BT"
30% of the quadrupole magnetic field was lost.
he magnetic center was displaced, causing the beam on the target to be displaced
pproximately 20 mm in horizontal and vertical position.
he beam halo monitor immediately detected the abnormality
nd stopped the beam without any problems.

e event
also initiated by position excursion detected by the MWPM

Summary

- J-PARC achieved the design beam powers (conditionally)
  - 1 MW at RCS and 750 kW at MR
- Next targets are
  - 1.5 MW at RCS and 1.3 MW at MR
- Beam diagnostic instruments are reviewed
- Two "non-invasive" diagnostic methods were introduced
- Two MPS cases related to the target were described

Thank you for your attention