



Beam Diagnostics at the First Beam Commissioning of the J-PARC MR

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KEK / J-PARC

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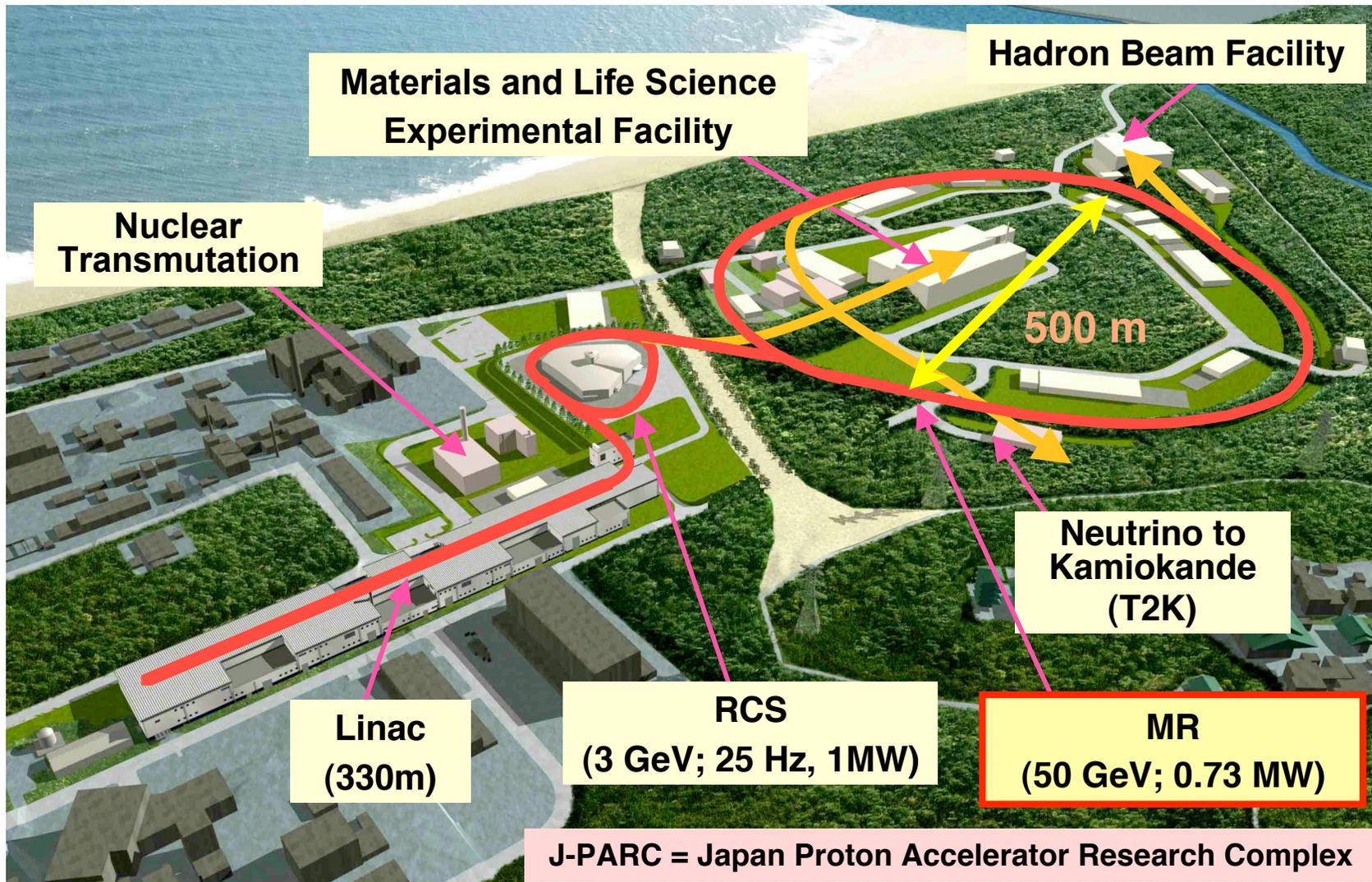
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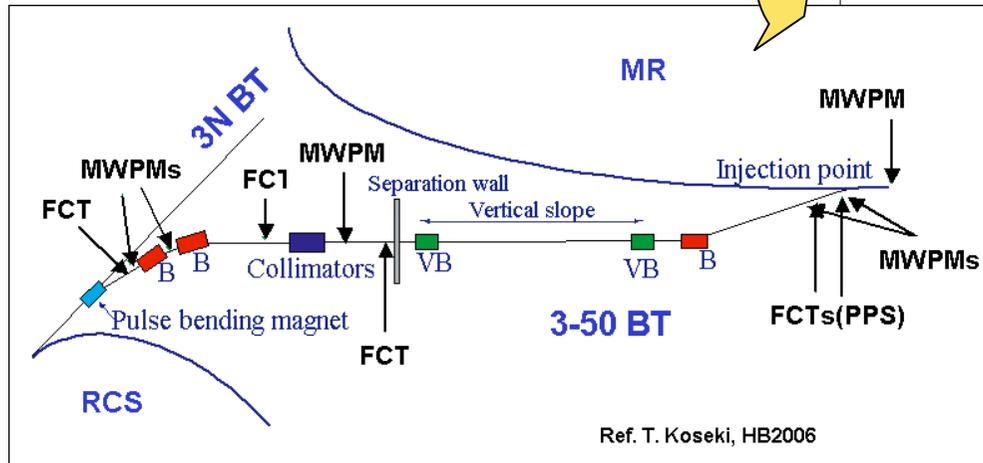
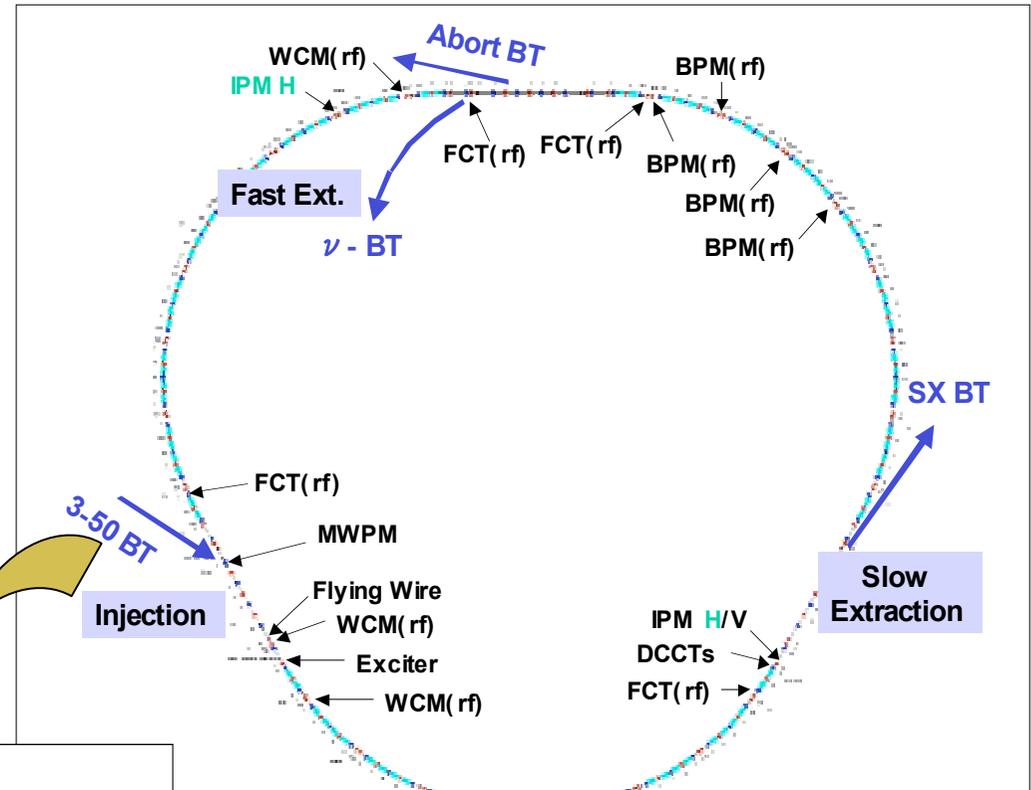
Overview of J-PARC



Location of instrumentations

List of ring monitor (Blue:future plan)

Monitors	Number
BPM	186
Single-pass BPM	2
Dump/abort BPM	2 + 2
WCM(>100MHz)	3
FCT(~20MHz)	6 + 1 (v-BT)
DCCT(DC-30kHz)	2
MWPM	1 (inj.), 2 (SX, Abort BT)
Flying Wire (H/V)	1 / 1
IPM (H/V)	1, 1 / 1
BLM	Proportional type 238 Air ion chamber 18



List of 3-50 BT monitor

Monitors	Number
Single-pass BPM	14
FCT(~20MHz)	5
MWPM (SEEM)	3 + 6
BLM	Proportional type 50 Air ion chamber 3

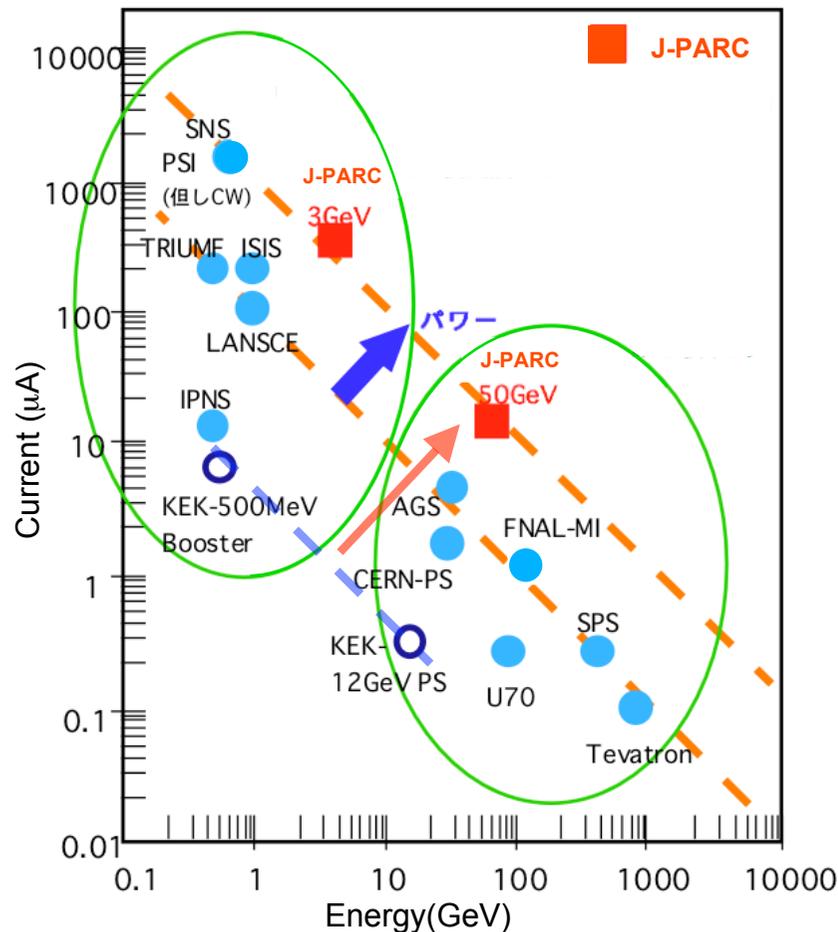
Requirements for beam monitors

J-PARC MR Beam power > 100×(KEK-PS beam power)

However,

Beam loss criteria: **0.5 W/m same as KEK-PS!!**

This criteria corresponds to 1.8% (3GeV)~0.1%(50GeV) beam loss



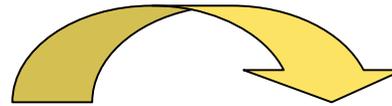
- Beam loss monitoring covering < 0.1% to 100%
- Beam halo monitoring
- Beam current monitoring with wide band and wide dynamic range

Beam monitoring system with wide dynamic range over 10^3 level.
Challenging and essential issue!!

Day-one beam parameters

(May, Jun., Dec. 2008, Jan., Feb., Apr. 2009)

- 3 GeV DC mode
- 30 GeV acceleration mode
- 1/100 particle per bunch
- single bunch injection



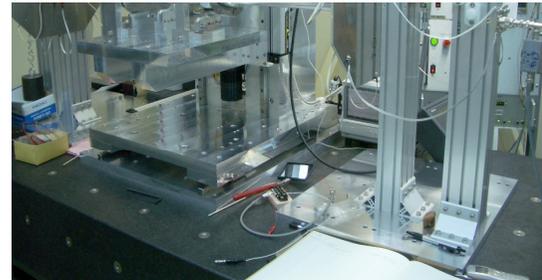
	Design	Day-one	
Particle per pulse	3.3×10^{14} (8 bunches)	$1 \sim 4 \times 10^{11}$ (single bunch)	ppp
Peak current	41.3-220	0.5 - 6	A
Circulating current	~13	0.003-0.012	A
velocity (β)	0.9712-0.9998	0.9712-0.9998	1/c
Bunch half width	180-33.7	35-20	ns
Emittance	54	~15	μmmrad (unnormalized, 3 GeV)
Revolution frequency	186-191	186-191	kHz
period	5.38-5.24	5.38-5.24	μs
RF frequency	1.67-1.72	1.67-1.72	MHz
period	599-581	599-581	ns

BPM

Electrostatic type BPMs are installed near almost all QM

Ring BPM:

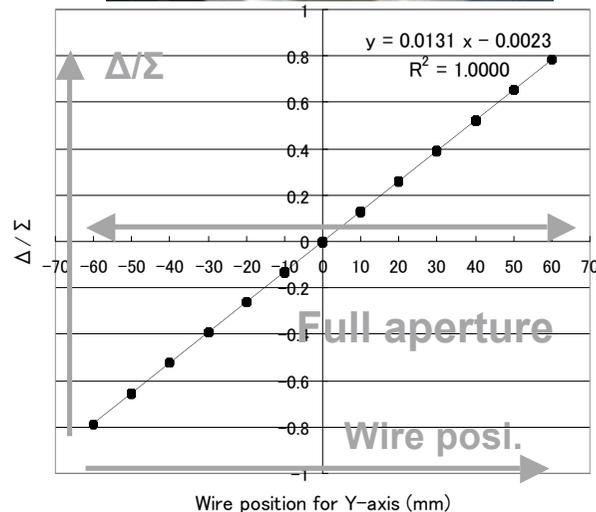
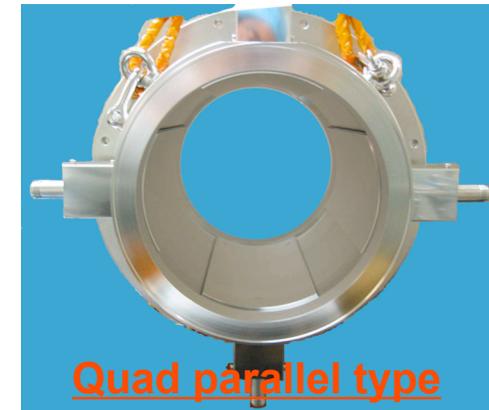
- Mainly used in the ring
- Good linear response covering full aperture
- Bore: $\Phi 130\text{mm}$ (standard), $\Phi 134, 165, 200, 257, 140 \times 302\text{mm}$ (special)



Calibration : wire method

Single pass BPM:

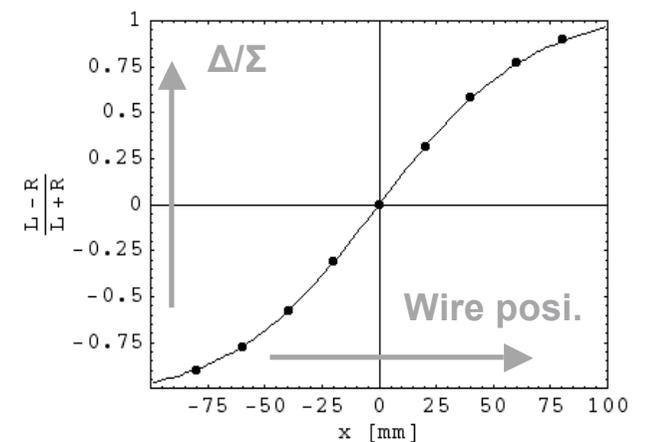
- Mainly used at 3-50BT
- Bore: $\Phi 230, 200\text{mm}$



Errors (in rms unit)

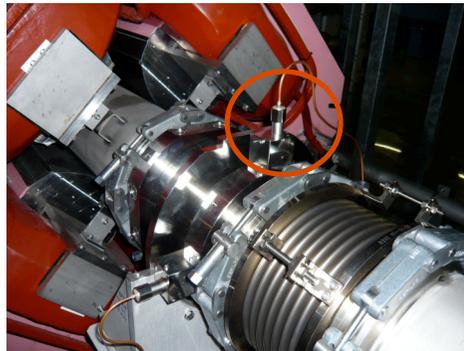
- Sensitivity: $\pm 0.3\%$
- Offset: $\pm 0.12\text{ mm}$
- Rotation: $\pm 3.6\text{mrad}$

corrected
on the computer

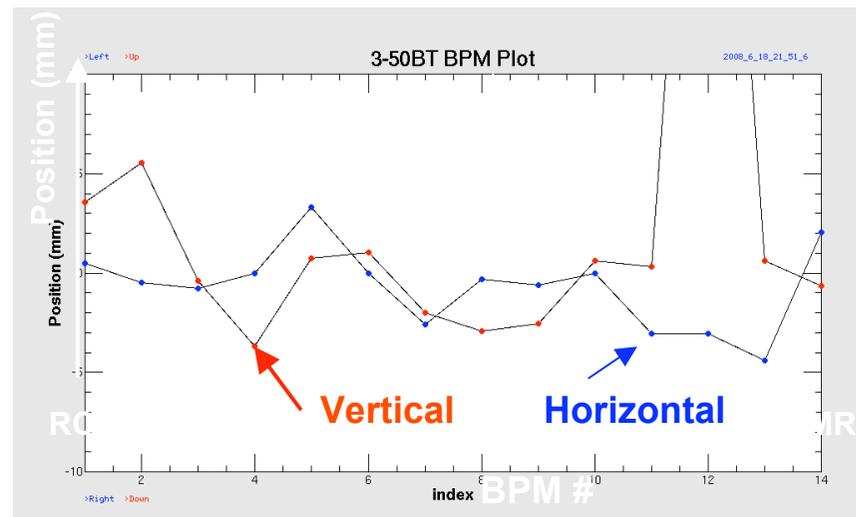
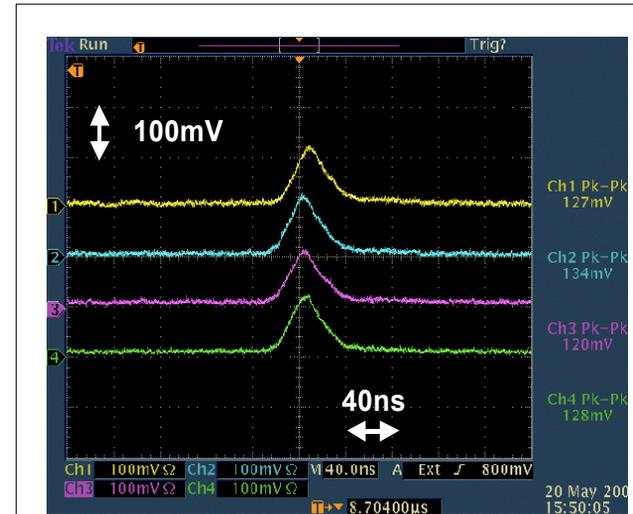


Single-pass BPM (3-50BT)

- To expand lower cut-off frequency, a transformer has installed at an output connector \Rightarrow 230kHz
- 8 bit, 100MHz, 2GS/s ADC
- Q-mode measurement (**future plan**)

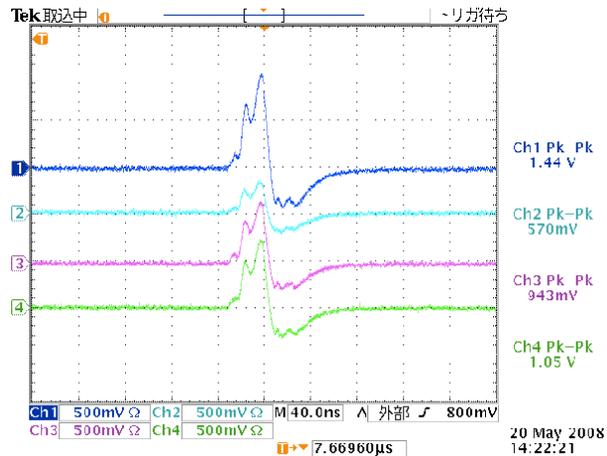


2:15 transformer at output connector

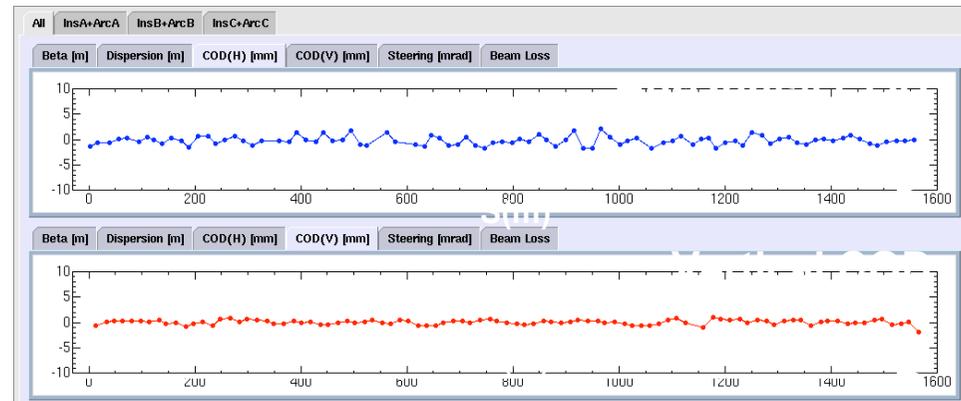


Ring BPM

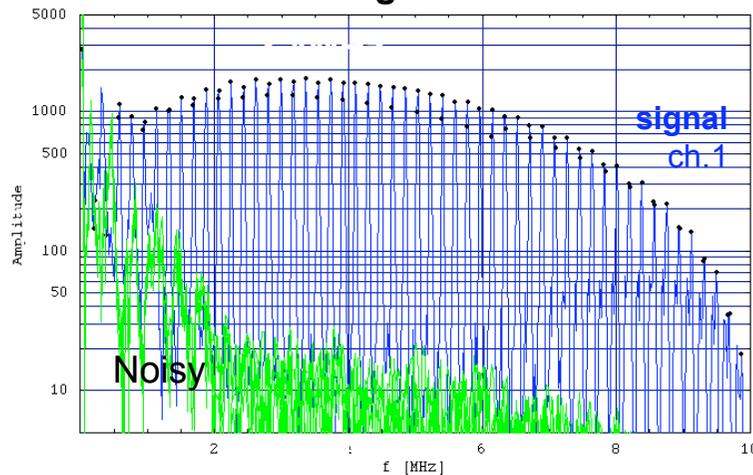
- Lower cut-off frequency is 17MHz \Rightarrow differential wave form
- 14 bit, 10MHz, 80 MS/s ADC
- Off-line position calc. (COD mode): Raw signal (4096 point) \Rightarrow average over 4 data (1024 point) \Rightarrow FFT \Rightarrow peak search ($3.4\text{MHz}=2 \times f_{\text{rf}}$) \Rightarrow Position



Raw signals



Measured COD



FFT of the raw signal

Blue: Signal+noise
Green: noise

Installation error (in rms unit)

- Offset: $\Delta x = 0.41 \pm 0.96 \text{ mm}$, $\Delta y = -0.35 \pm 0.50 \text{ mm}$
- Rotation: $0.96 \pm 3.3 \text{ mrad}$
- \Rightarrow corrected on the computer

position resolution:

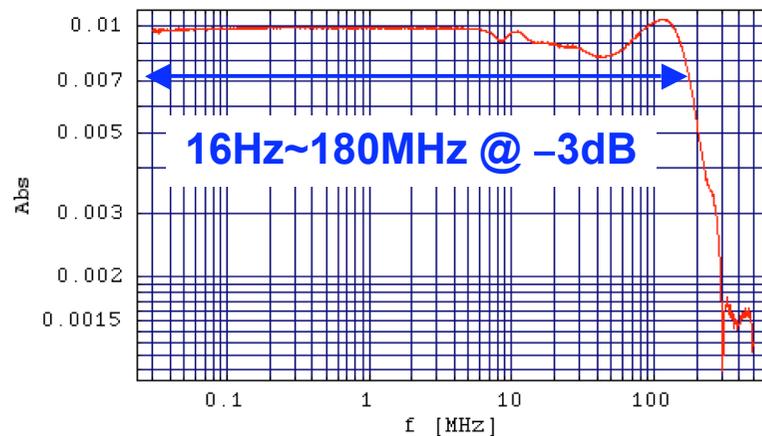
$< \pm 0.5 \text{ mm}$ / three BPM correlation
(3.5×10^{11} protons/bunch, single bunch)

Beam current monitors

DCCT

S. Hiramatsu *et. al*

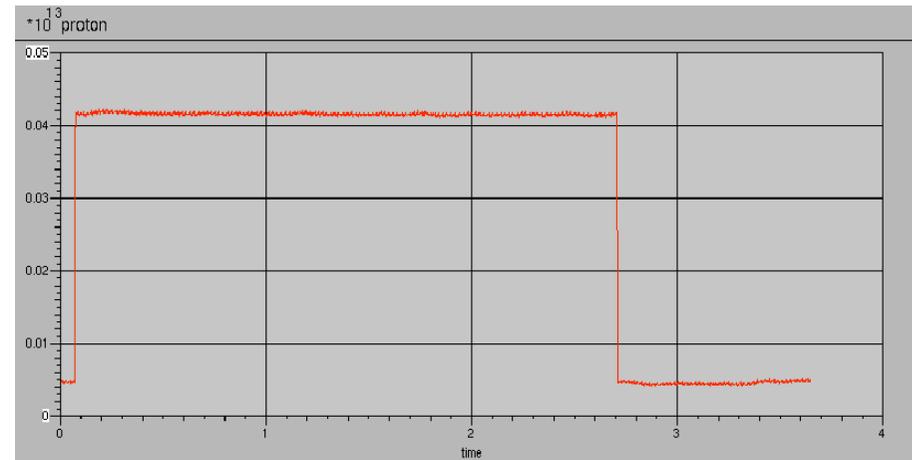
- FINEMET (HITACHI metal Ltd.) core
- Frequency band: DC~20kHz
- Gain selection: 0.2A, 2A, 20A
- $\Delta I < 100\mu A \Rightarrow \Delta N_B \sim 6.5 \times 10^9$ ppp(rms)



WCM

D. Arakawa *et. al*

- FINEMET (HITACHI metal Ltd.) core
- Lower cut-off frequency: 150, 380, 400 Hz
- Shunt impedance: 92m Ω
- Heat load on resister is 40-50 W
 \Rightarrow Air blow system is needed
- RF feedforward



FCT

D. Arakawa *et. al*

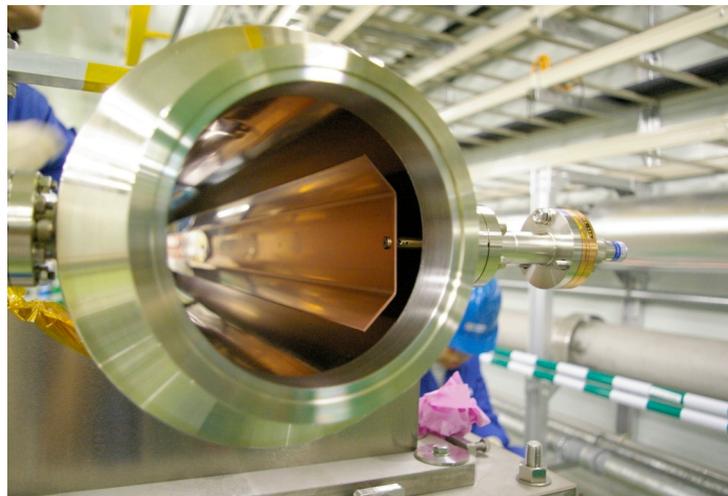
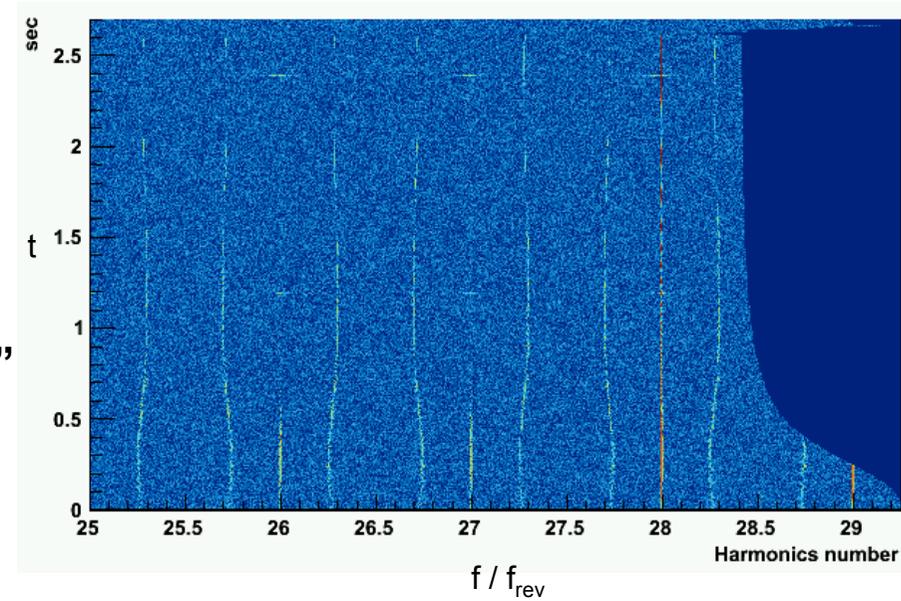
- FINEMET (HITACHI metal Ltd.) core
- Frequency band: 16Hz~180MHz
- RF feedback



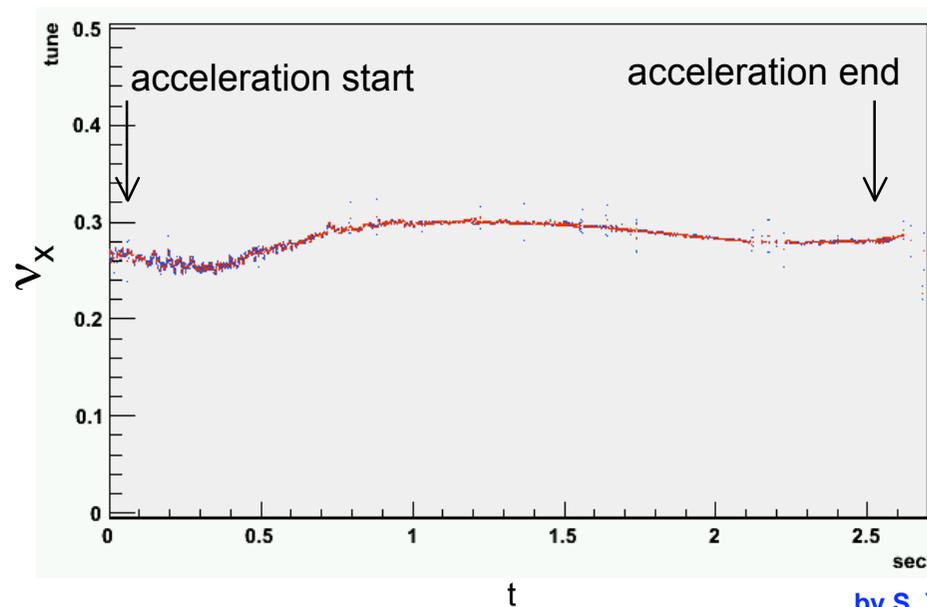
Air blow system

Tune meter

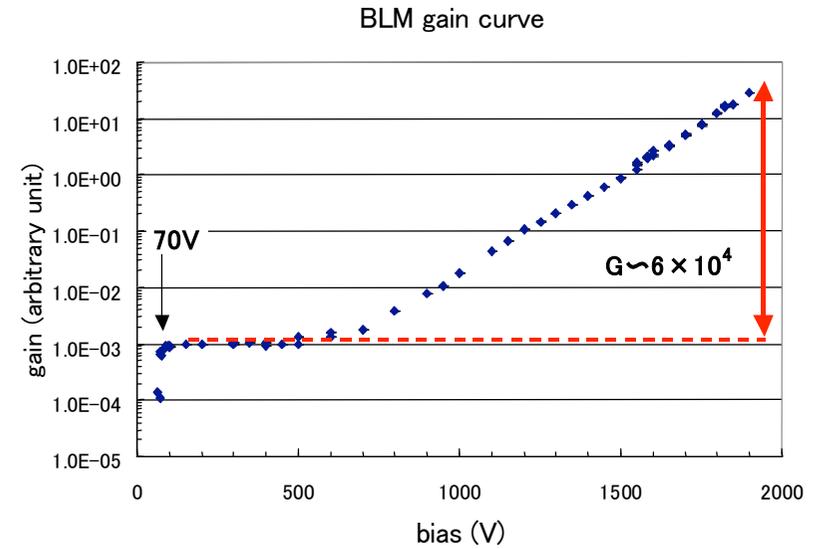
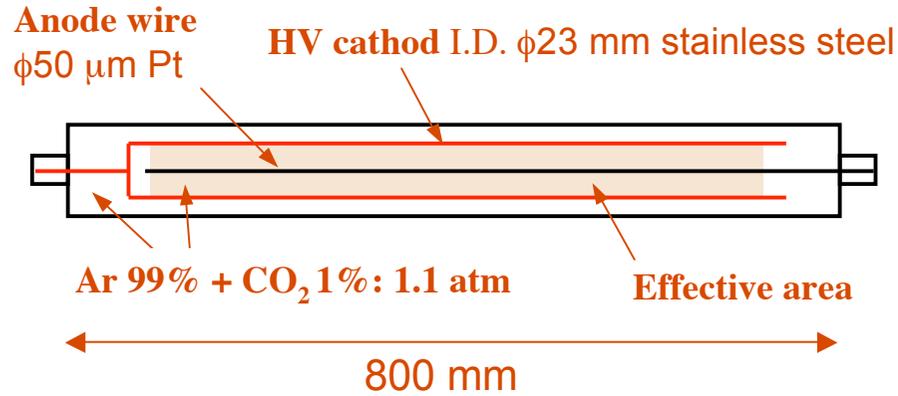
- Horizontal and Vertical exciters
50Ω striplines
max. power: 2x1 kW
white noise (1-2MHz)
- Beam oscillation is analyzed
by “Real-time spectrum analyzer”



Exciter



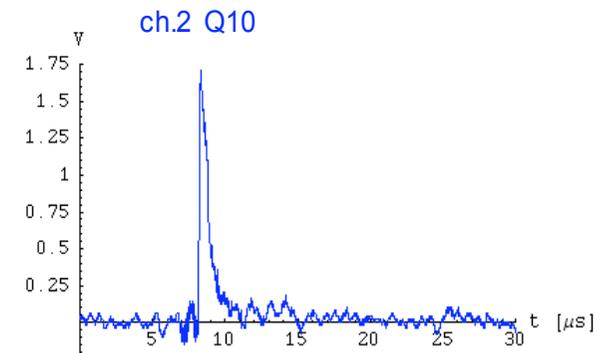
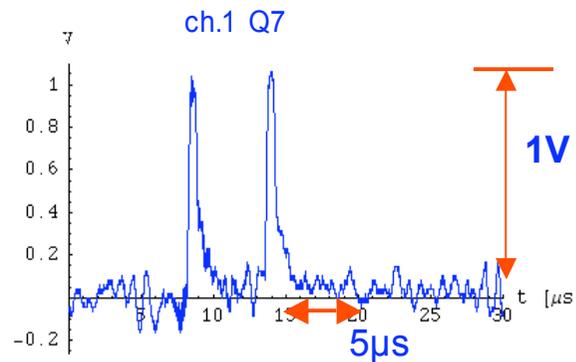
Proportional type BLM(1)



Gain curve of the BLM measured by using secondary cosmic rays, mainly muon



BLMs have been installed at each QM



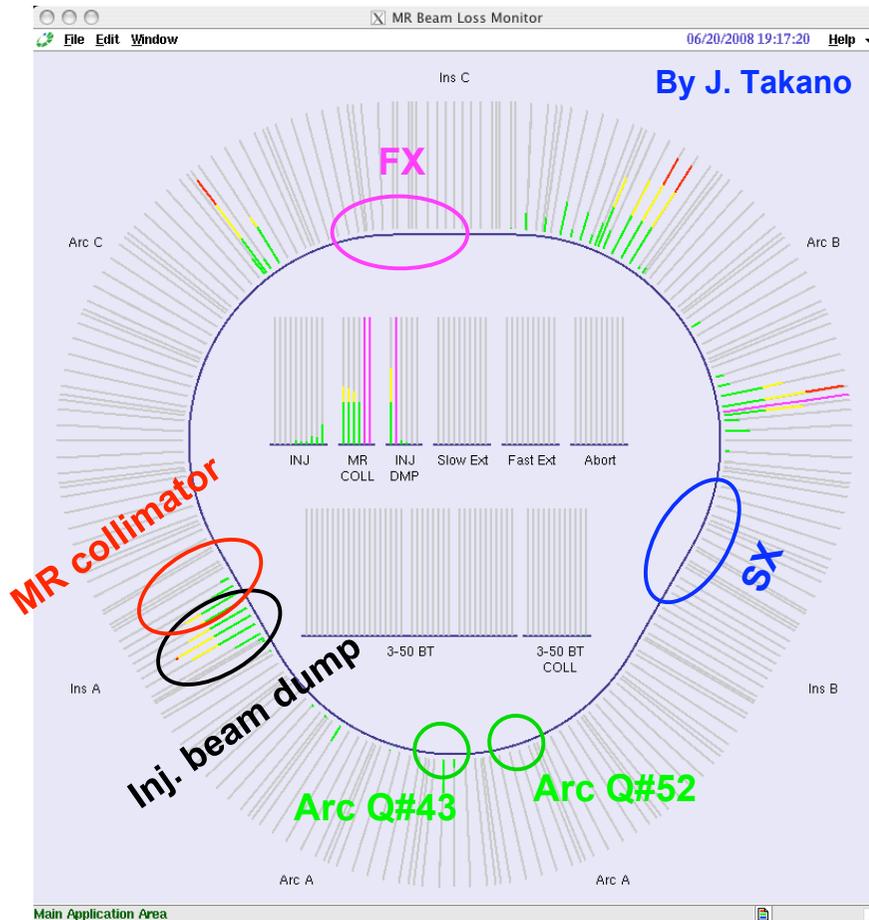
Raw signal

bias: 1.6kV, Z_{in} of amp: 50Ω , amp gain: $\times 10$

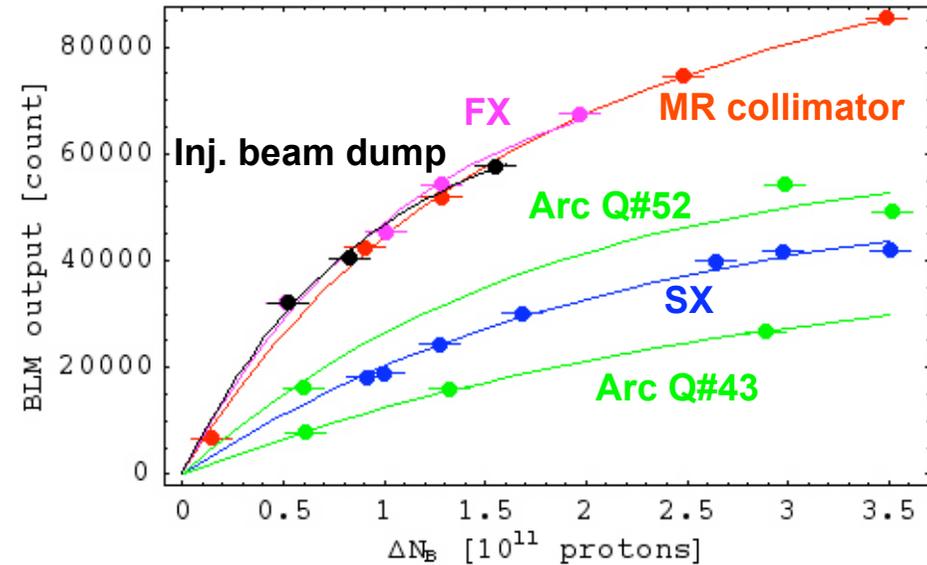
Proportional type BLM (2)

K. Satou *et. al*

- Sum of beam loss signals from inj. to ext.
- Loss signals are just shown in arbitrary unit, not yet in number of lost particles



Beam loss distribution



Correlation between the sum of the local BLM integrated signals and a number of loss particle

to be compared with the simulation

⊙ Beam loss criteria

0.5W/m for 0.75MW, 3.3×10^{14} ppp

0.1% for 50 GeV $\Rightarrow 3.3 \times 10^{11}$ ppp

1.8% for 3 GeV $\Rightarrow 5.9 \times 10^{12}$ ppp

Meet the beam loss criteria

But nonlinear behaviour

Further investigation should be made !!

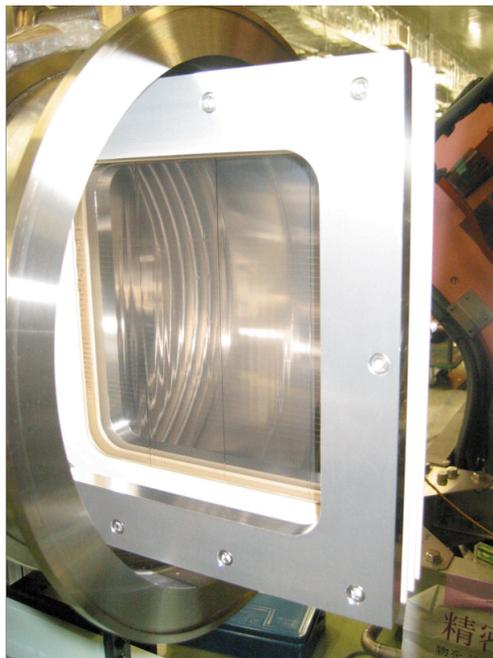
Preparing Ar ionization chambers

Multi-wire profile monitor:

SEEM
(secondary electron emission monitor)

3-50 BT
Injection
Abort
SX

5 (upstream 3, downstream 2)
1 just after septum
1 (Ti foil)
5 screens for day-one, 1 SEEM (C ribbon)



Tungsten wire

ϕ 30 μ m

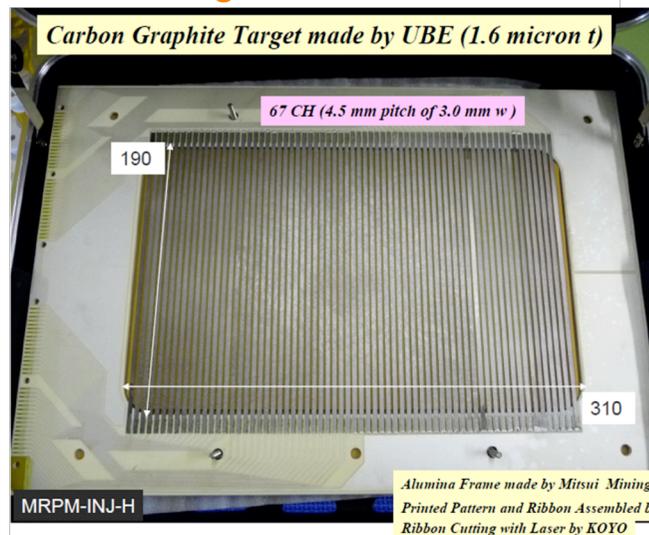
pitch 2.5, 3.5, 4 mm

(depends on design beam size)

Day-one



Low beam loss
High rad-resistant

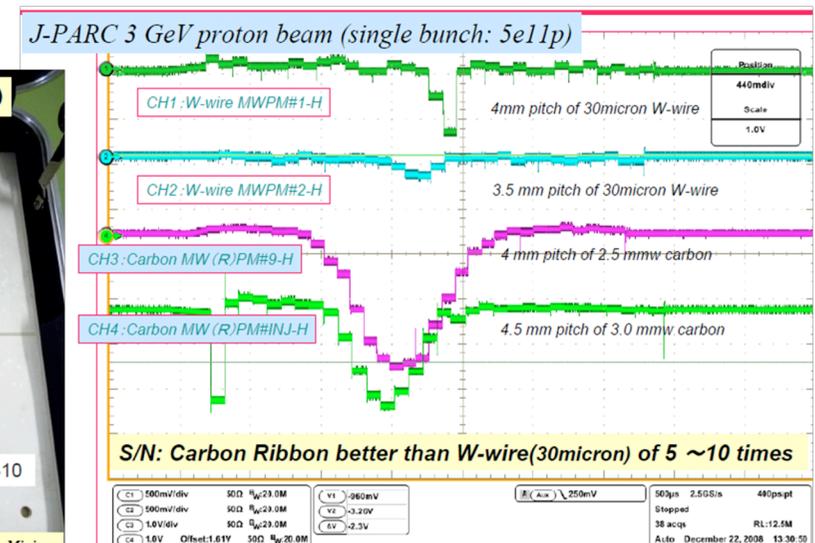


Carbon-graphite ribbon

t 1.6 μ m

width 3.0 mm, pitch 4.5 mm, 67 ch.

Being replaced



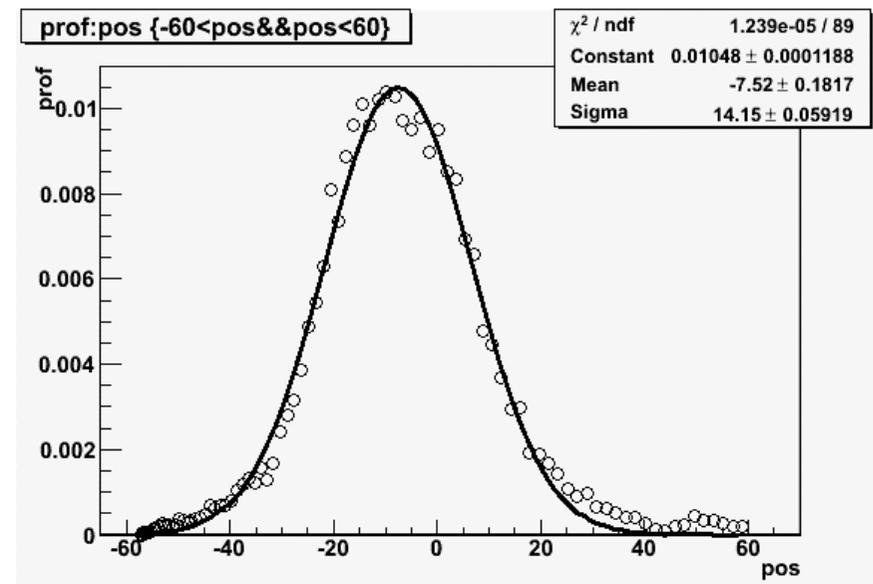
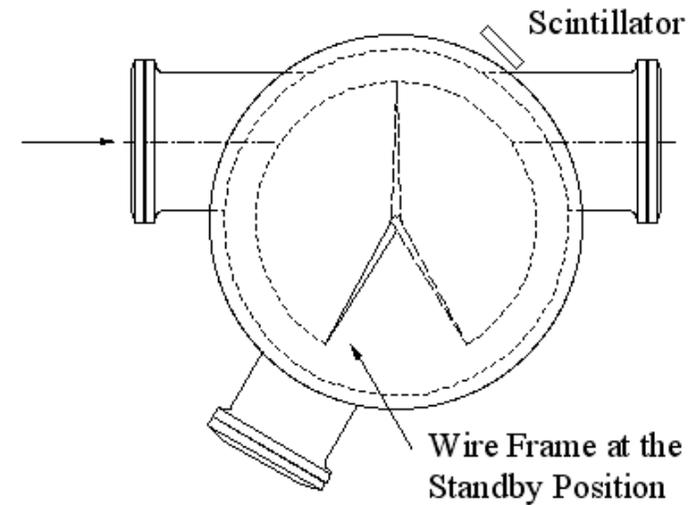
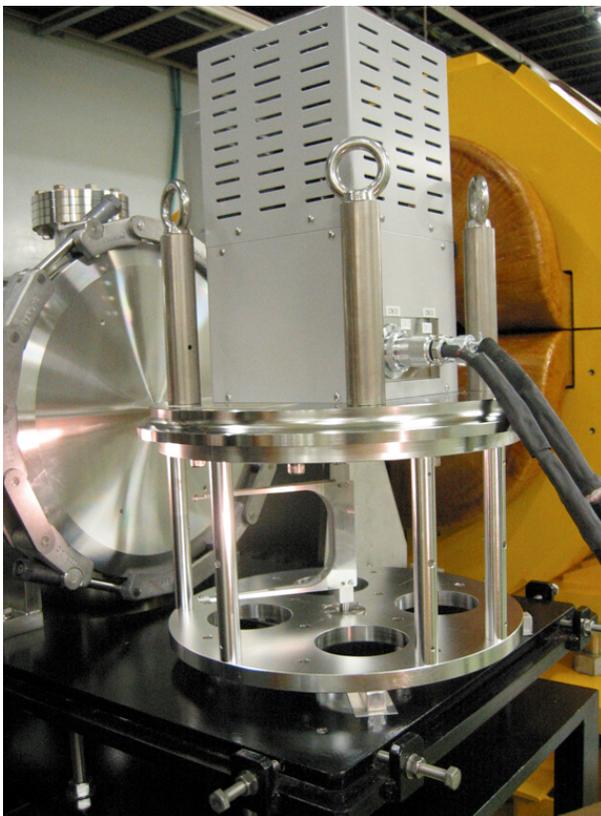
Upper two traces : W wire

Lower two tarces : carbon-graphite ribbon

Measured profiles

Flying wire profile monitor

- One horizontal type for day-one
- Vertical one is now under development
- Wire: Carbon fiber of $\phi 7\mu\text{m}$
- Wire speed: 10m/s



Residual gas ionization profile monitor: IPM

Ion collection with HV

- 35kV for day-one ⇒ will be upgraded to 50kV

Electron collection with magnetic field

- Required for 0.75MW beam profile measurement
- ⇒ future plan

Micro Channel Plate (MCP) for signal read out device

- 2 stage MCP assembly with 32 ch strip anode
- Active area: 31×81 mm²
- Width of each anode: 2.5 mm
- Gain: ~10⁶

Calibration devise for MCP gain balance

- Electron generator arrays ⇒ Photonis Ltd.

Horizontal plane: 1 IPM ($\eta=0$)

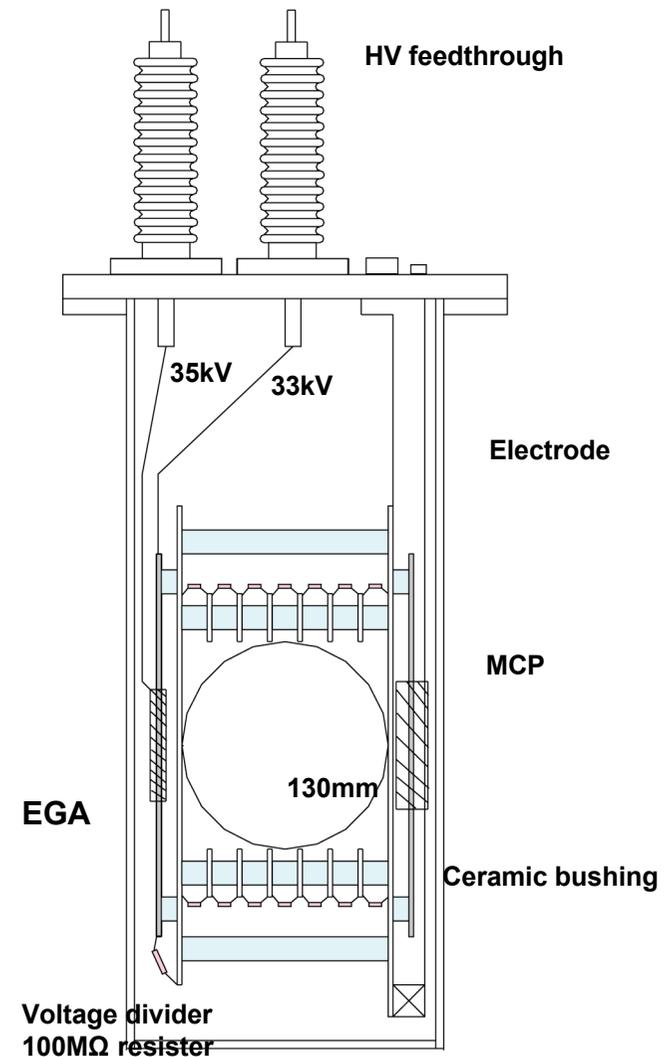
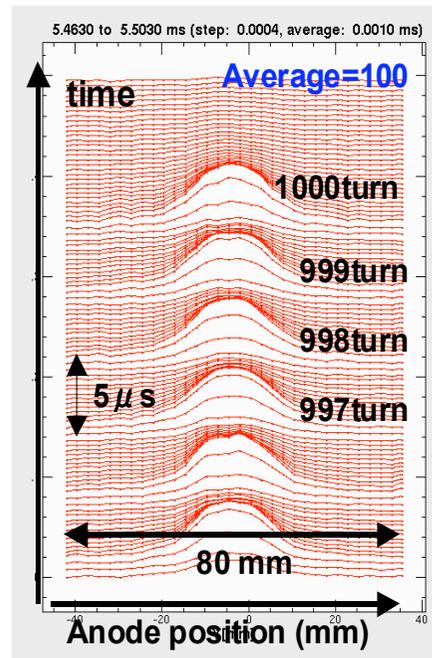
Vertical plane: 1 IPM



One more will be installed at an arc section ($\eta=2m$)

LPF: ~5μsec

Digitizer: 200MHz, 100kS/s, 1 Mwords



Cross section of V-IPM

Summary

- Various instrumentations are installed and used on the day-one beam commissioning
 - 3 GeV one-pass to the injection beam dump, and storage
 - Acceleration up to 30 GeV,
extracted to the abort beam dump, hadron beam dump and neutrino target
- The beam current was $\sim 1\%$ of designed value,
however, the system shows good performances
- Some monitors will be ready until the October machine operation
 - Horizontal IPM arc section ($\eta=2.0\text{m}$)
 - W target SEEM \Rightarrow carbon-graphite target
 - Feedback damper system
- For higher intensities:
 - BPM's will be attached attenuators
 - low sensitive BLM's, Ar ionization chambers, will be installed
at the high radiation areas like collimators and the slow extraction section
 - IPM's should realize electron collection
 - Beam based alignment of the BPM's
 - a quadrupole mode measurement

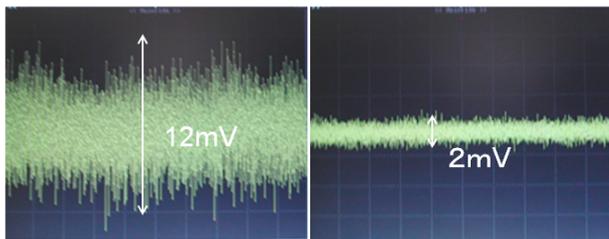
Backup

Countermeasures against noise problem

- High shielded cables tested radiational hardness at Co60 yray facility of Takasaki lab./JAEA
- Grounding copper plates along the ring
- Noise cut trans on an AC line
- Common mode choke coil on a signal line

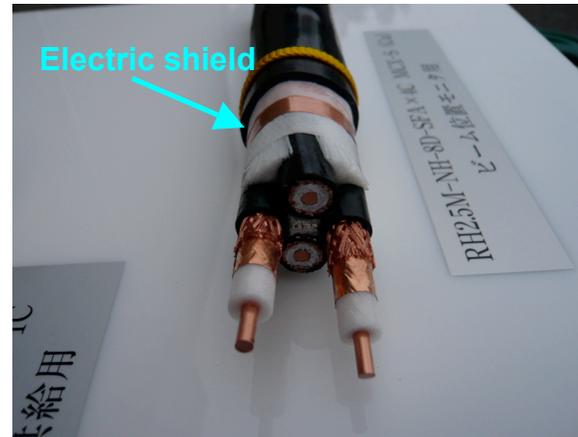


Grounding copper plate

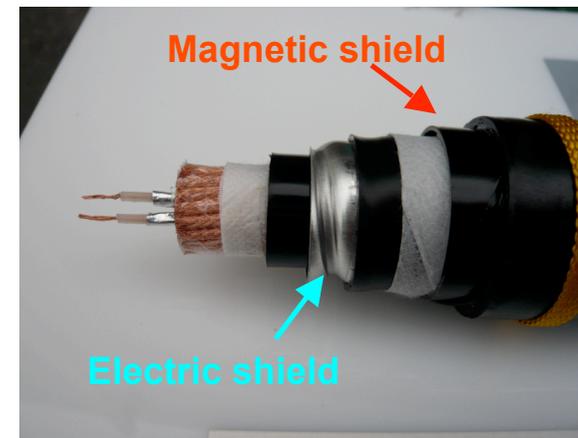


1/6

Connect a electric shield to a grounding copper plate



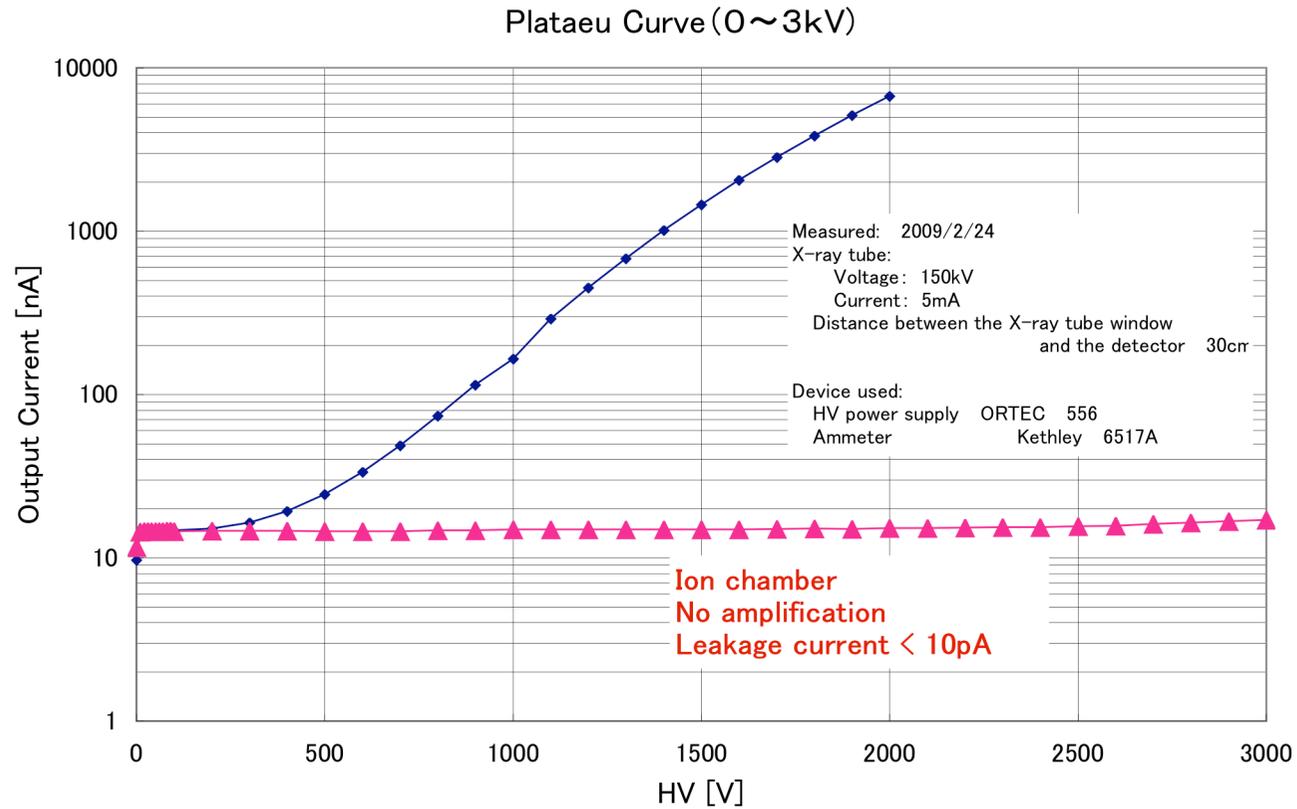
4 in 1 coaxial cable for BPM



34 in 1 coaxial cable for MWPM and IPM

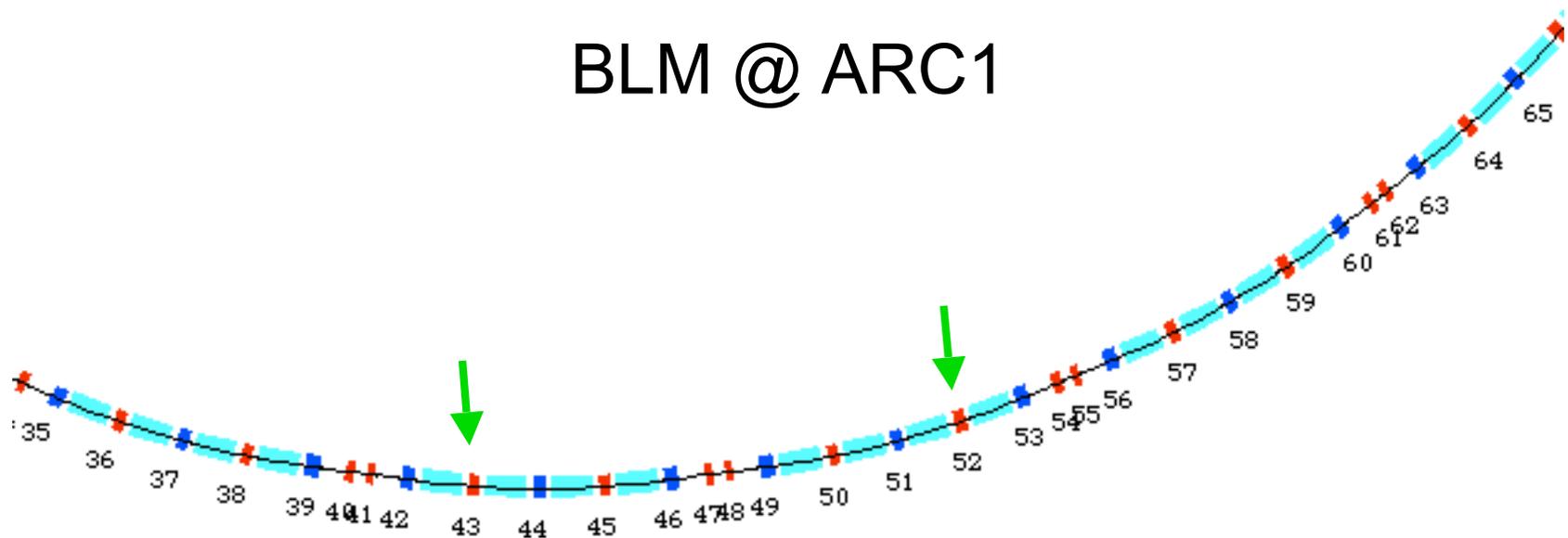
High shielded cables with radiational hardness (<2.5MGy) for J-PARC Fujikura Ltd.

BLM - Ionization Chamber

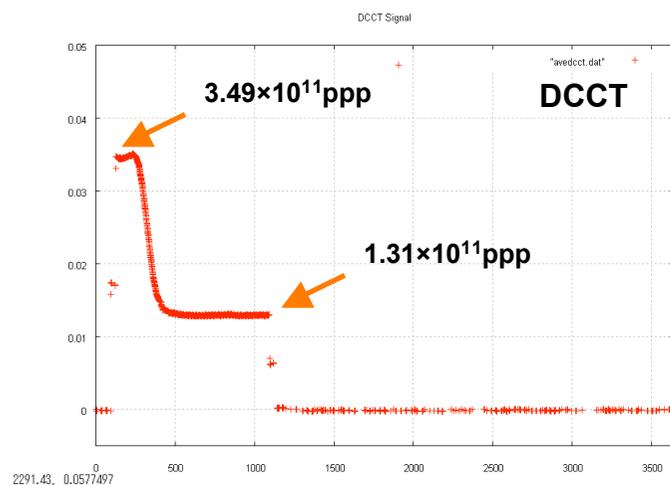
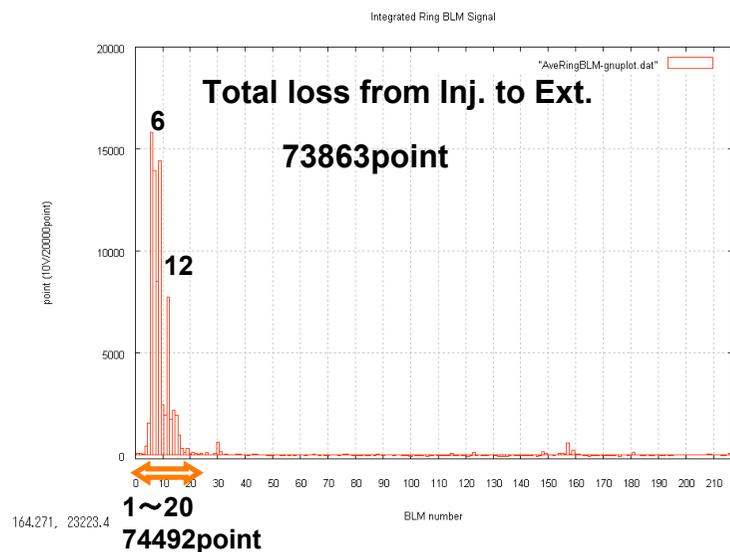


Irradiation test will be held in summer with ^{60}Co

BLM @ ARC1



Beam loss at collimators(local bump=40mm)



IPM data processing

Digitizer: 200MHz, 100kS/s, 1 Mwords

Aaveraged over 100 pulses to reduce
high frequency noise,
statistical error due to small number of detected ions,
signal level fluctuation due to broad gain distribution of the MCP.

MCP gain at the proportional mode :

$$f(g) = f_0 e^{-g/\langle g \rangle}$$

$\langle g \rangle$: average gain

