Present Status of the J-PARC MR IPM System and other Monitors (DCCT, BLM): Proposal for Gated IPM for J-PARC

US-Japan workshop on Accelerators and Beam Equipment for High Intensity Neutrino Beams
9-10/11/2016

J-PARC MR beam monitor G
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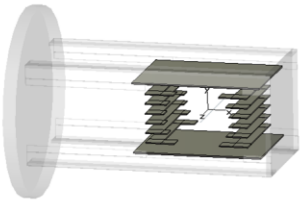
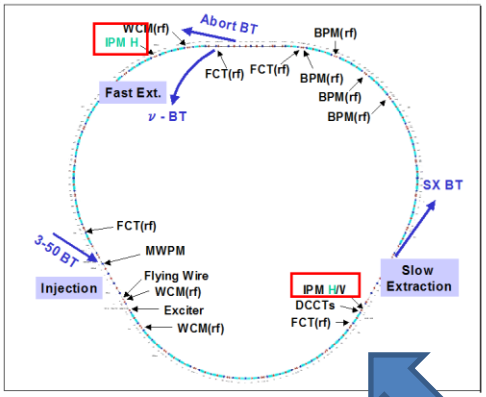
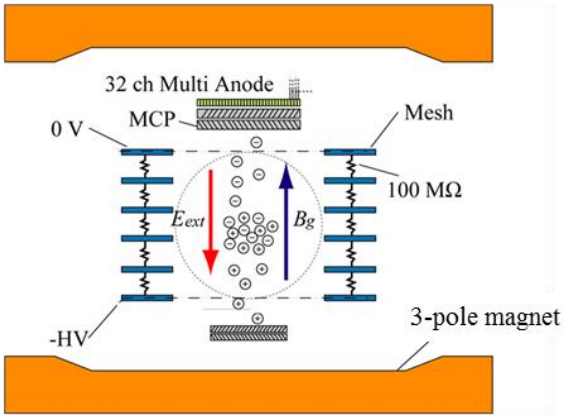
IPM system at present

MR IPM specification





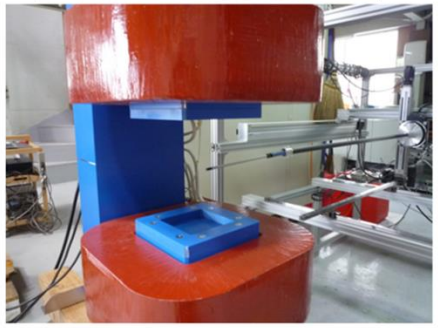
MR IPM specification	
Number	3
Twiss parameter	Vertical βx=12.1m, βy=27.3m,η=0m Horizontal βx=13.1m, βy=21.6m,η=0m Horizontal βx=8.4m, βy=15.5m,η=2.0m
Gap size	130mm
Maximum HV	50kV
Operation voltage	<30kV
w/w.o. Magnet	D2H: w. D2V,D3H:w.o.
Detector	1 chevron MCP
Current pickup	32ch strip anode
Anode width	2.5mm
MCP calibration source	Cold electron source: EGA

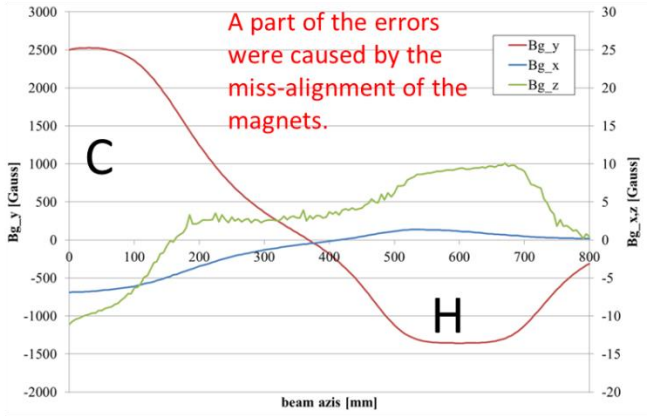


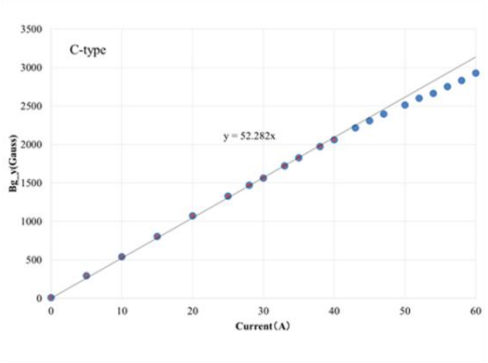
Magnet performance

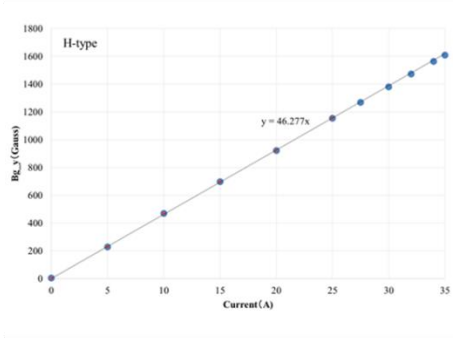
Requirements of magnets

Type	Pole gap[mm]	B at center [T]	Effective area [mm]	Error fields, Bx/By, Bz/By	Flatness	Cooling
C	220	0.25	(x,y,z)=-45~45, 40~40, 20~20	<1%	<5%	Water
H	130	0.13	(x,y,z)=-45~45, 40~40, 20~20	<1%	<5%	Air



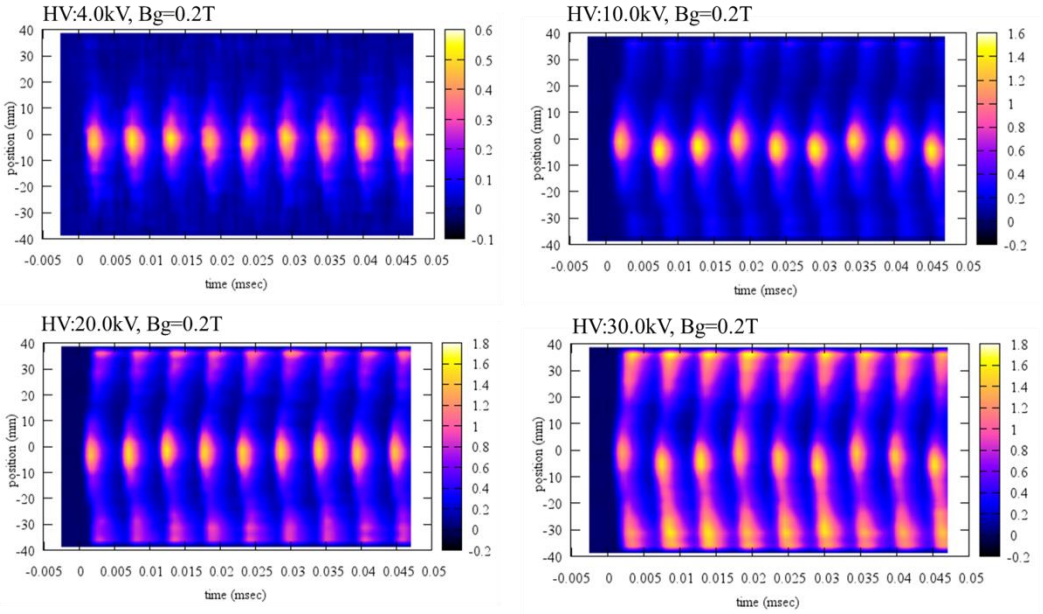


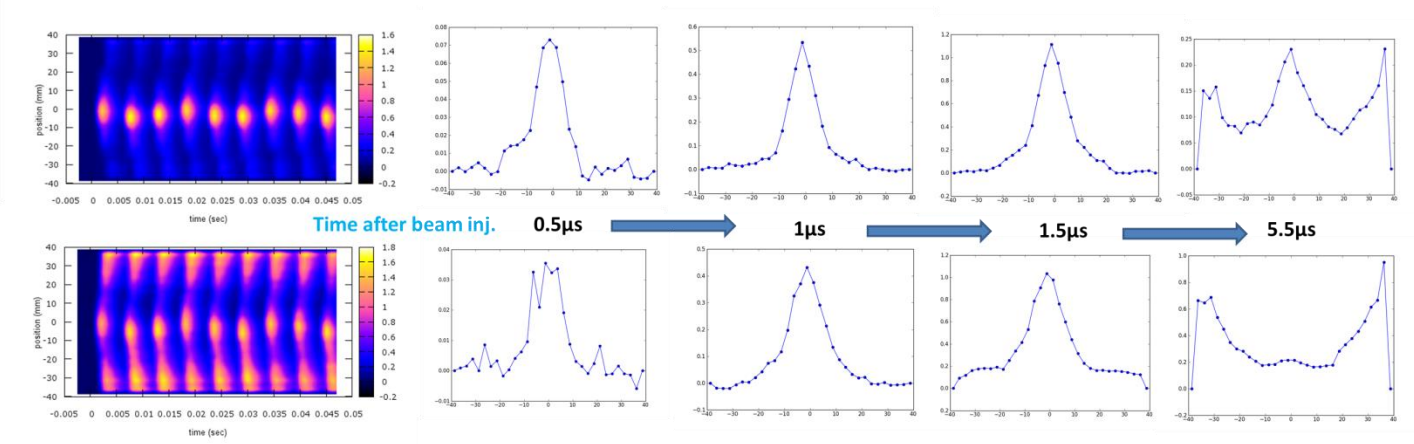




Test results: Electron collection with the magnetic field

- The first test ware made just before this summer shutdown, only 30 minutes × 2!!: Beam condition was 3 GeV 5E12 ppb 1 bunch inj.
- The turn by turn profile showed beam induced contamination, and it depends on HV
- The contaminant electrons appeared ~1.5 μs after the beam passage
- Mechanism of this contamination issue is under investigation

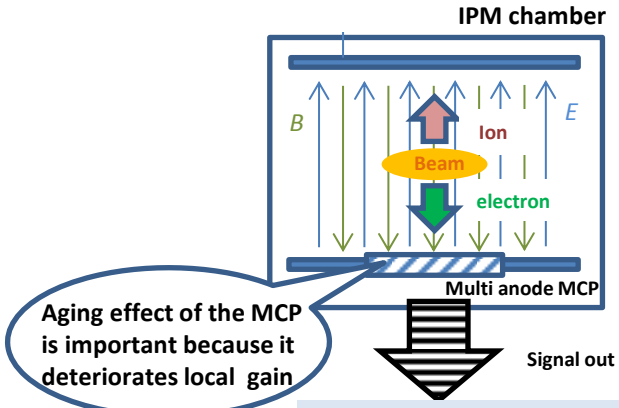


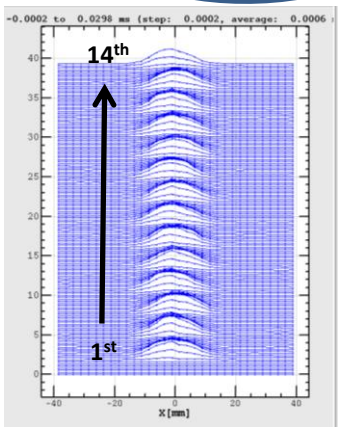


Sliced profile at selected time, 0.5, 1, 1.5, and 5.5 μs after the beam injection

Proposal for
New Gated IPM system for J-PARC MR

- Gated IPM system was installed in main injector of FERMI lab
  - ※FERMILAB-CONF-14-332-AD
- Gated system will effectively reduce the MCP operation time -> MCP life will be improved
- This work includes,,,,
  - Development of a HV switching module
  - Install in the existing system
  - Performance test at FERMI and(or) J-PARC MR





1st to 14th turn profile

Turn by turn profile have been utilized for injection tunings

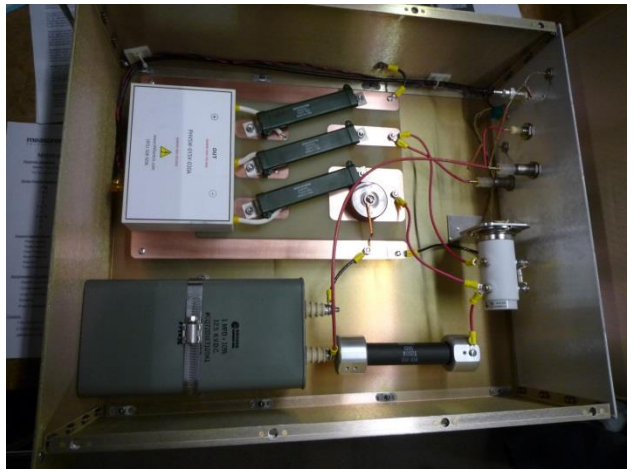
◎Non-Gated IPM
From Inj. to Ext. (1.5s), all ionized particles are multiplied by the MCP detector

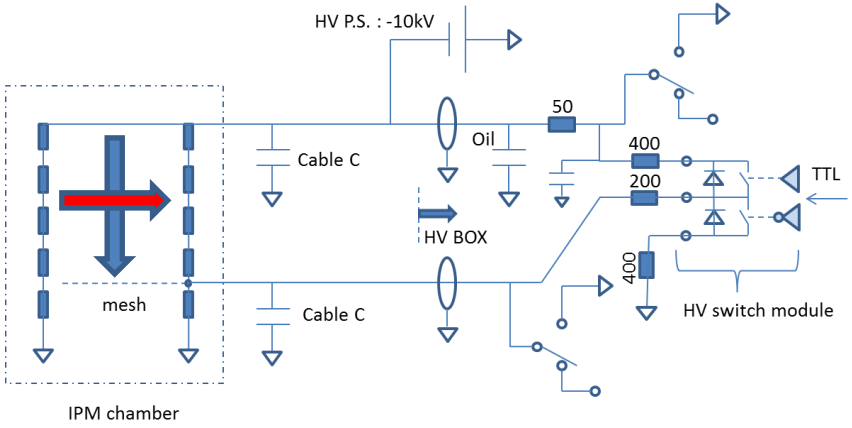
◎New Gated IPM
By switching the HV, only the required particles can be selected and multiplied by the MCP

When 100Hz 1% duty switching operation is used , only 20 turn profiles will be selected for each pulse. MCP life will be extended to 100 times longer than that in the case of non-gated system

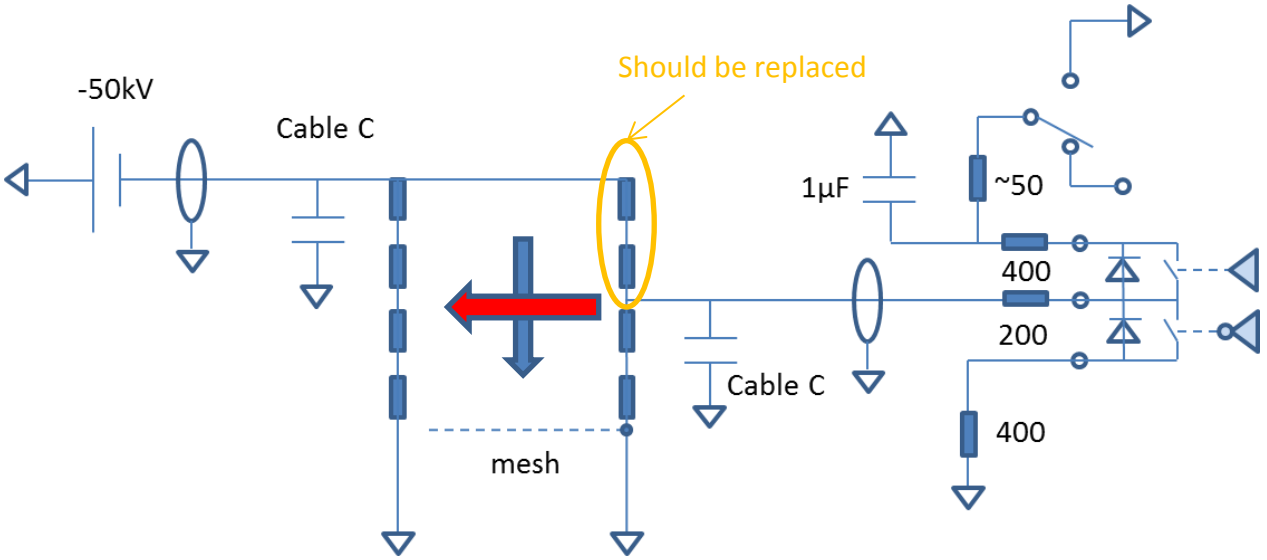
Gated system for FNAL

- Thanks to FNAL group, we could learn,,,
  - Details of the switching system
  - Components
  - How does it works
  - When the “Gate Off,” horizontal E field is generated and the B and E cross term force will sweep away the charges out from the effective area
- In our case, the maximum HV is ±50kV, collecting both ions (+HV) and electrons (-HV), thus if we use the same design,,,,
  - All the components will be bigger than these of the FNAL case -> 5 times??
  - Need more careful design
  - And above all, we should find a “special” resister for the last resister in chain, between mesh and ground, on which the HV=50kV can be applied





A possible solution for J-PARC IPM



- This solution can make required switching voltage decrees and make design works rather easier and simpler
- Some resisters in the IPM chamber should be replaced by ones which is excellent in dielectric breakdown voltage
- This will also make the horizontal E when “Gated Off”, but it will be rather deformed and asymmetric than the FNAL case
- However, the transversal beam E field can help sweeping out the charges during the beam passage, and this effect is likely to be essential for the particles generated around 1σ area in a beam profile
- Need detail simulations on charge motions in the “Gated Off” field and the beam fields as well

Present schedule

- This fiscal year, 2016, start form Apr.
  - Design works on <- we are here
    - Switching system
    - Circuit
    - Production cost estimates
  - Simulation on charge motions
- Next fiscal year, 2017
  - Discussion on simulation works with FNAL group
  - Parts procurement
    - HV switch, HV C, resister
  - Construction
  - Test @J-PARC or @FERMI
  - IPM chamber modification during summer shutdown: resister replacements and any other changes will make
- The fiscal year, 2018
  - Install a HV gated BOX in our system and test
  - Discussion on performance tests with FNAL group @ mini-workshop??

The others collaboration works on IPM: Simulation code

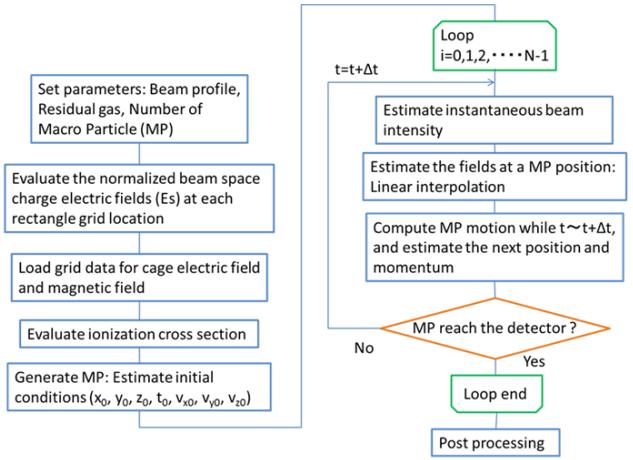
- IPM simulation code collaboration had begun from 2015 followed by the first collaboration meeting at CERN in 2016
- J-PARC, GSI, CERN, FNAL, IFMIF, RAL, ESS, CEA
- Please visit the web site, https://twiki.cern.ch/twiki/bin/view/IPMSim

The first meeting of the collaboration took place at CERN in March 2016

Name/Lab	Language	Ionization	Guiding field	shape	Beam field	Tracking
GSI code	C++	simple DDCS	uniform E,B	parabolic 3D	3D analytic relativ.	numeric R-K 4th order
PyECLOUD-BGI /CERN	python	realistic DDCS	uniform E,B	Gauss 3D	2D analytic relativ. only	analytic
FNAL	MATLAB	simple SDCS	3D map E,B	arbitrary	3D numeric relativ. (E and B)	num. MATLAB rel. eq. of motion
ISIS	C++	at rest	CST map E only	arbitrary (CST)	2D numeric (CST) non-relativ.	numeric Euler 2nd order
IFMIF	C++	at rest	Lorenz-3E map E only	General. Gauss	numeric (Lorenz-3E) non-relativ.	
ESS	MATLAB	at rest	uniform E,B	Gauss 3D	3D numeric (MATLAB) relativ.	numeric MATLAB R-K
IPMSim3D /J-PARC	python	realistic DDCS	2D/3Dmap E, B	Gauss 3D	2D numeric (SOR) relativ. only	numeric R-K 4th order

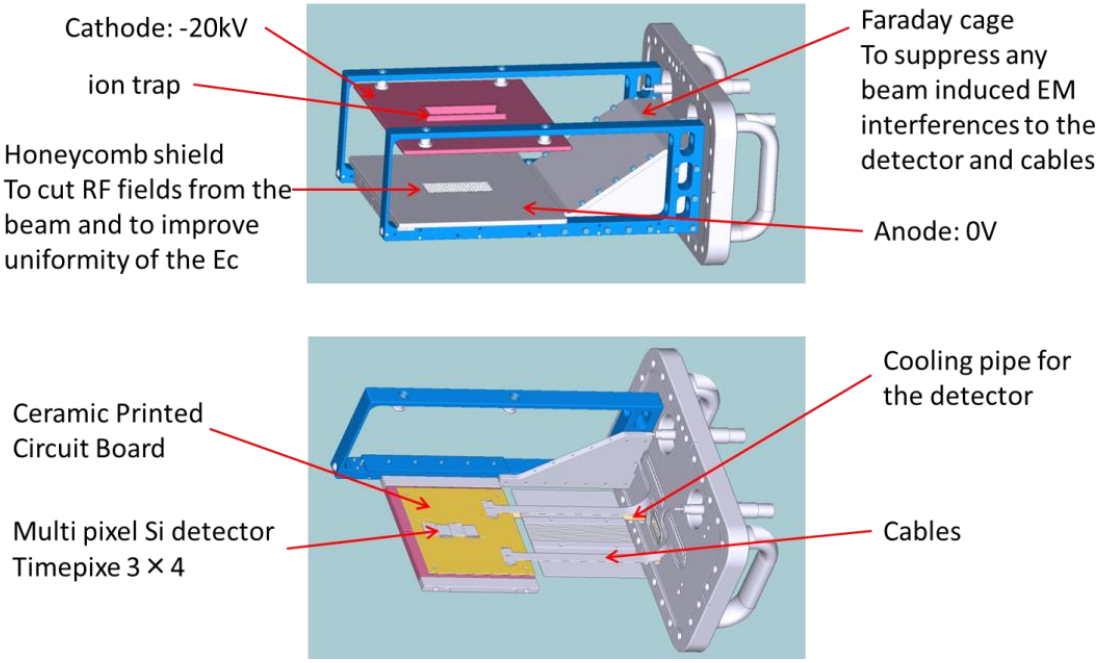
Different kinds of IPM codes: Courtesy of M. Sapinski

See also TUPG71, IBIC16



Flow chart of the J-PARC code, IPMsim3D

The others collaboration works on IPM: CERN-PS IPM



- The collaboration works on next IPM for CERN-PS is now in progress
- Timepixe 3 position sensitive Si detector is used for charged particle detection
- We have proposed an ion trap structure to suppress ion collisions thus secondary electron generation on electrode surface
  - If it works well, we will use the same ion trap structure in our system, next year???
- Design works were finished by 2015 and construction of magnet system is now ongoing
- We are waiting for the installing and the first data

New BLM system

- Air ionization chambers (ion chamber) were installed near old BLMs, proportional counter type BLM
- The dual system will cover wide range of beam loss
- New BLM amp and data-taking system was installed and started operation from 2 weeks ago

AIC and P-BLM: Dual system

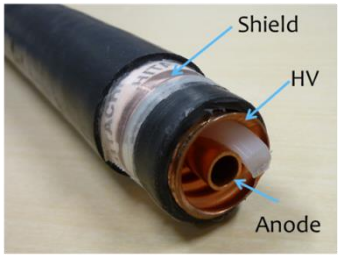
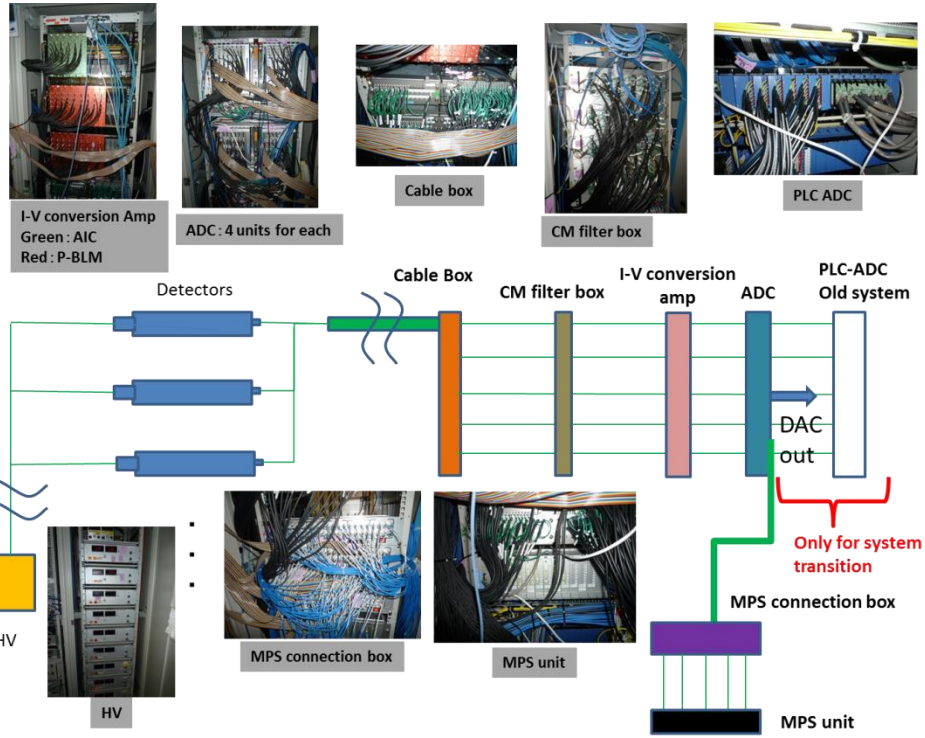
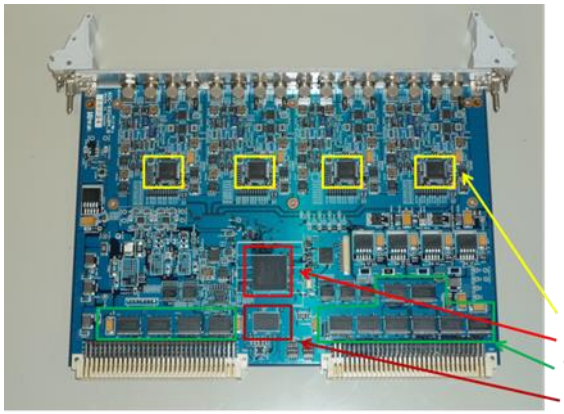


Photo of inside electrodes of AIC

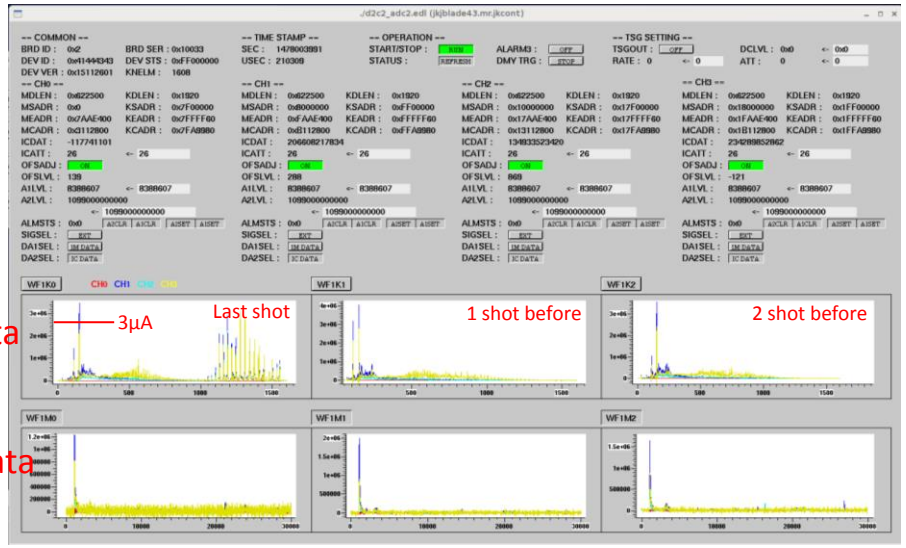


BLM2

- New I-V conversion amp
  - Installed at PS building: cable C=10nF-30nF
  - Conversion impedance: 1MΩ, 10 times higher than the old one
  - 50kHz (now limited down to 20kHz): ~50 times faster
  - Isolation
- New ADC system
  - VME based system
  - 1MS/s 24bit ADC: old one is 100 times conversions per pulse with 4000 points resolution in full scale
  - Shot by shot offset subtraction
  - Ring buffer like storage for >20s data length
  - Digital WF integration
  - Digital comparator for MPS system: Waveform data and integrated data
  - 2 DAC outputs

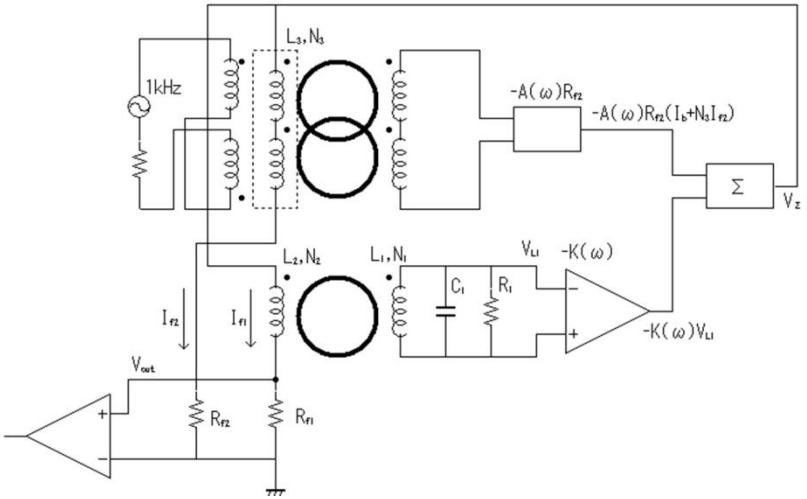


Photos of the new ADC board for BLM system

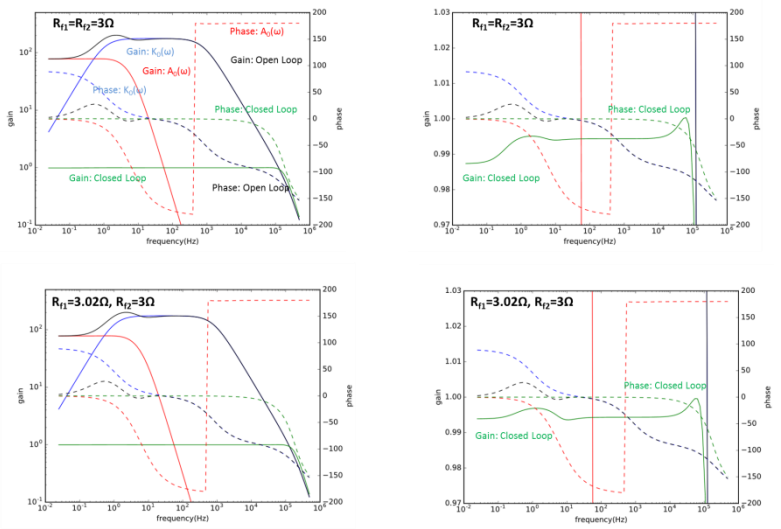


DCCT

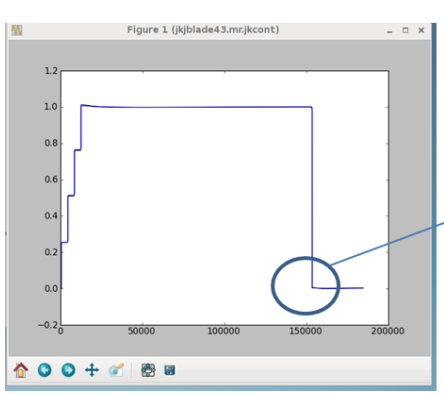
- DCCT for J-PARC MR was firstly designed to obtain 1% accuracy, and the thus the present performance is 0.1% in precision but 0.6% in accuracy, due to limited open loop gain and imperfect matching of two current sensing resisters in 2 feed back loops
- We would like to improve this DCCT to measure beam power loss in more good accuracy, within 0.1% level

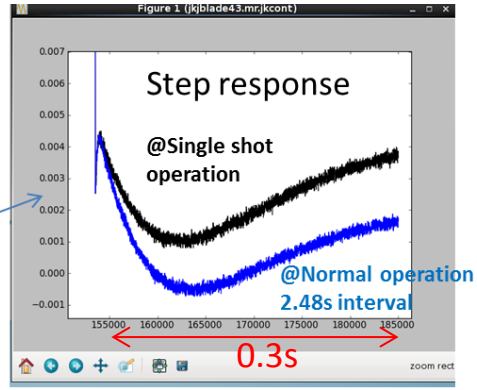


Parallel feed back DCCT



Open and closed loop gain





Step responses should be same, but,,,

Summary

- IPM
  - The magnet system was installed at one IPM system out of three and first test was done just before this summer shut down
  - The beam induced electron contamination issue is now on investigation
  - The HV gated system was proposed, and start working from last week with the great helps from FNAL IPM group
  - The possible solution for the switching system for J-PARC was presented
- BLM
  - The new data taking system had been developing, and about 2 weeks ago, the system started operation
- DCCT
  - The parallel feed-back type DCCT is used for our system
  - Its accuracy is 0.6%, and this limitation is mainly due to the limited open loop gain and mismatching of the 2 I-V conversion resisters in 2 different feed back loops
  - The < 0.1% in resolution and also in precision is needed, on the beam commissioning point of view, to identify the beam power loss in detail -> < 100W @ inj. @1MW ope.