Beam Diagnostics for RIBF in RIKEN

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Cyclotrons 2010
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Ning-Wo-Zhuang Hotel, Lanzhou, China

RIBF:
Radio
Isotope
Beam
Factory

Can we watch a beam?

Purpose and importance of beam diagnostics

- What is the purpose of beam diagnostics?
  - These systems are our sense organ showing
    - (1) what properties a beam has;
    - (2) how it behaves in a machine.
- Why do we need diagnostics?

Why ?

  - If we don't use beam diagnostics,
    - (1) one would blindly grope around in the dark;
    - (2) improvements are hardly achievable.
- Accelerator is just as good as its diagnostics !

Preview

- Purpose and importance of beam diagnostics
- Accelerator complex of RIBF
- Monitors used in beam transport line
- Monitors used in cyclotron
- Newly developed monitors
- Summary

Accelerator complex of RIBF

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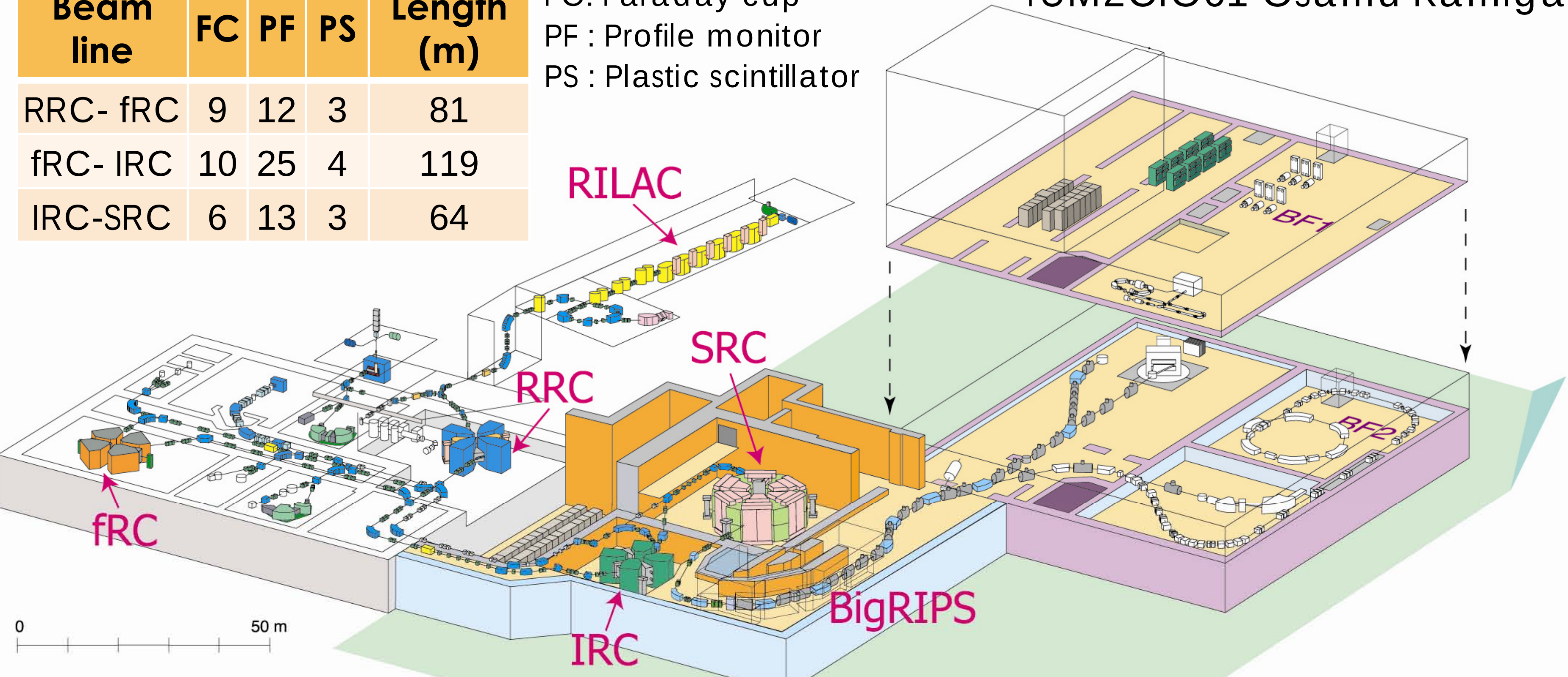
TUM2CIO01 Osamu Kamigaito

Beam line	FC	PF	PS	Length (m)
RRC- fRC	9	12	3	81
fRC- IRC	10	25	4	119
IRC-SRC	6	13	3	64

FC: Faraday cup
PF : Profile monitor
PS : Plastic scintillator



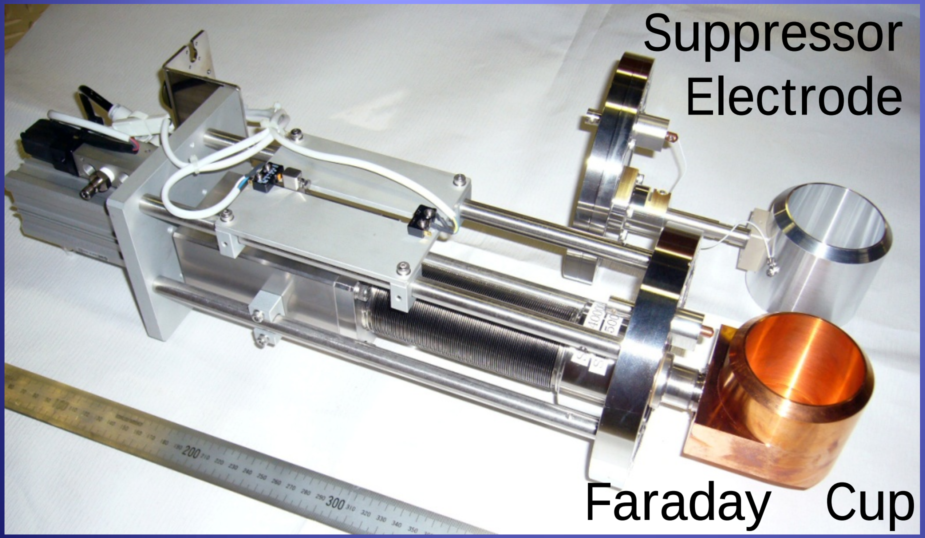
1 Linac + 4 Cyclotrons+
BigRIPS (Superconducting RI Separator)

- Succeeded in accelerating a U beam to 345 MeV/u in 2007
- Discovery of a new RI, a neutron-rich Pd 125, in same year
- Search for new isotopes in-flight fission of the 345 MeV/u U beam
- Discovery of new 45 neutron rich RIs in 2008

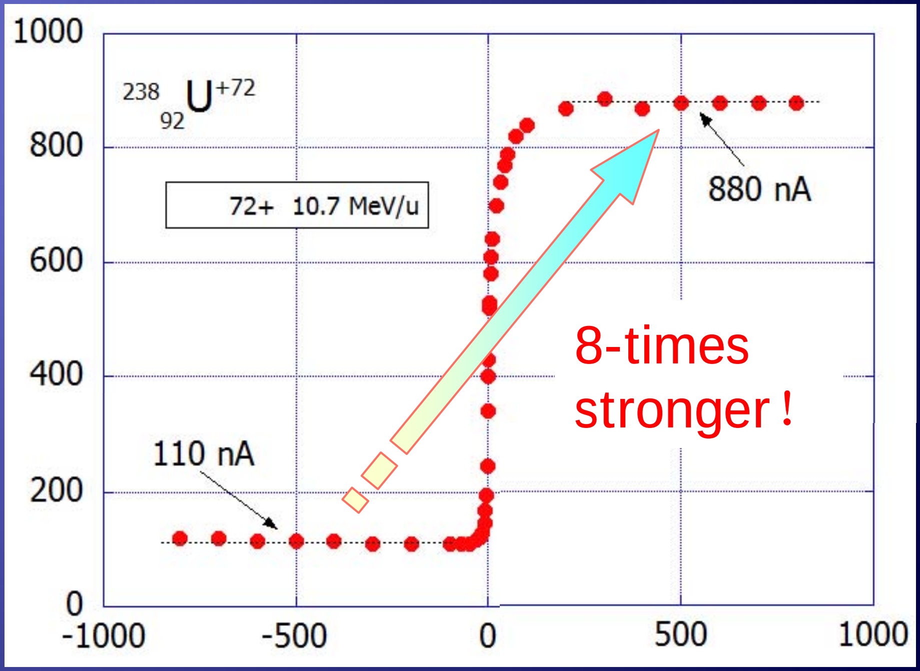
- Accelerator complex of RIBF
- Monitors used in beam transport line

Technical issues of Faraday cup

- Difficulty of suppressing of high energy secondary electrons



Beam current (enA)



Applied Suppressor Voltage (V)

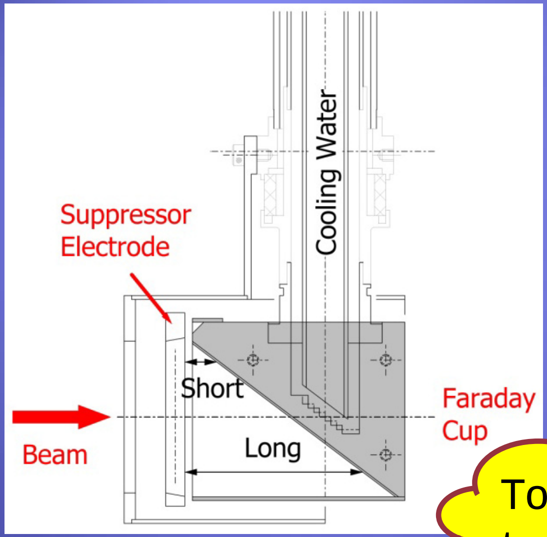
- Transmission efficiency

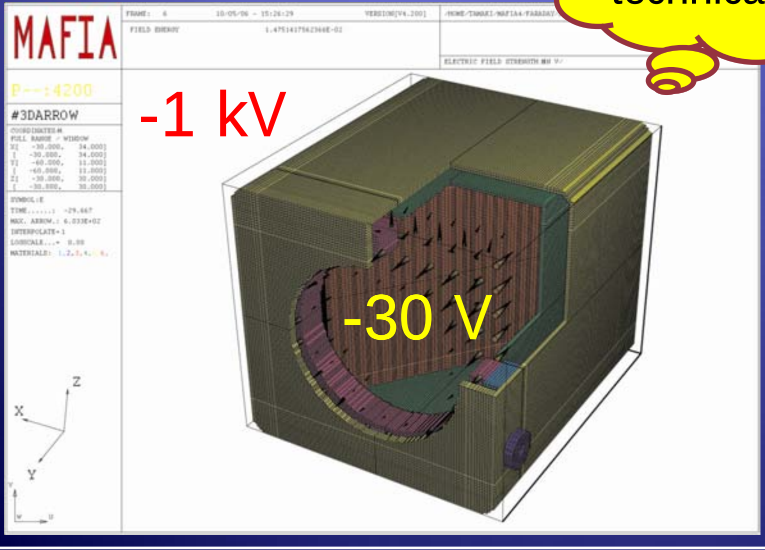
-> 50 Faraday cups

TUM2CIO01 : Osamu Kamigaito

Modification of Faraday cup

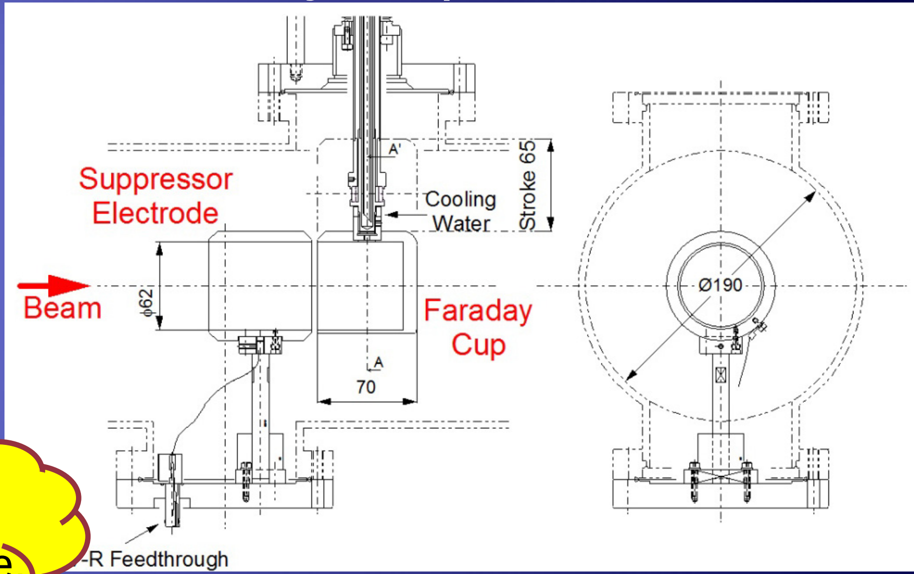
- Faraday cup used in 2007

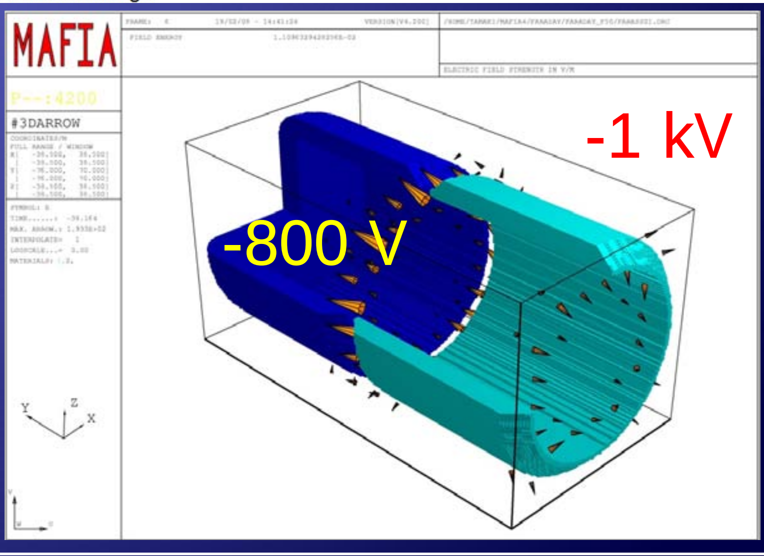




To solve this technical issue,

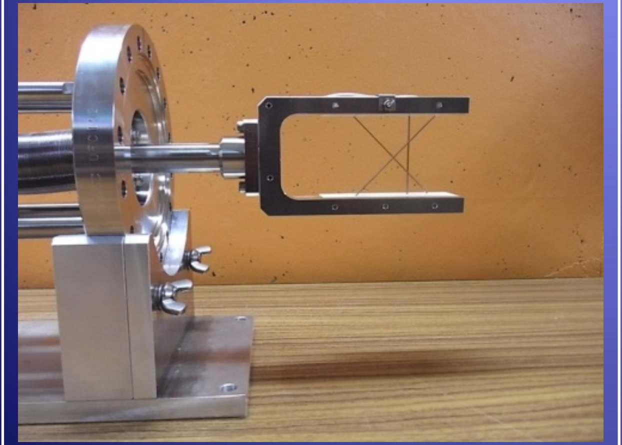
- Faraday cup used in 2008





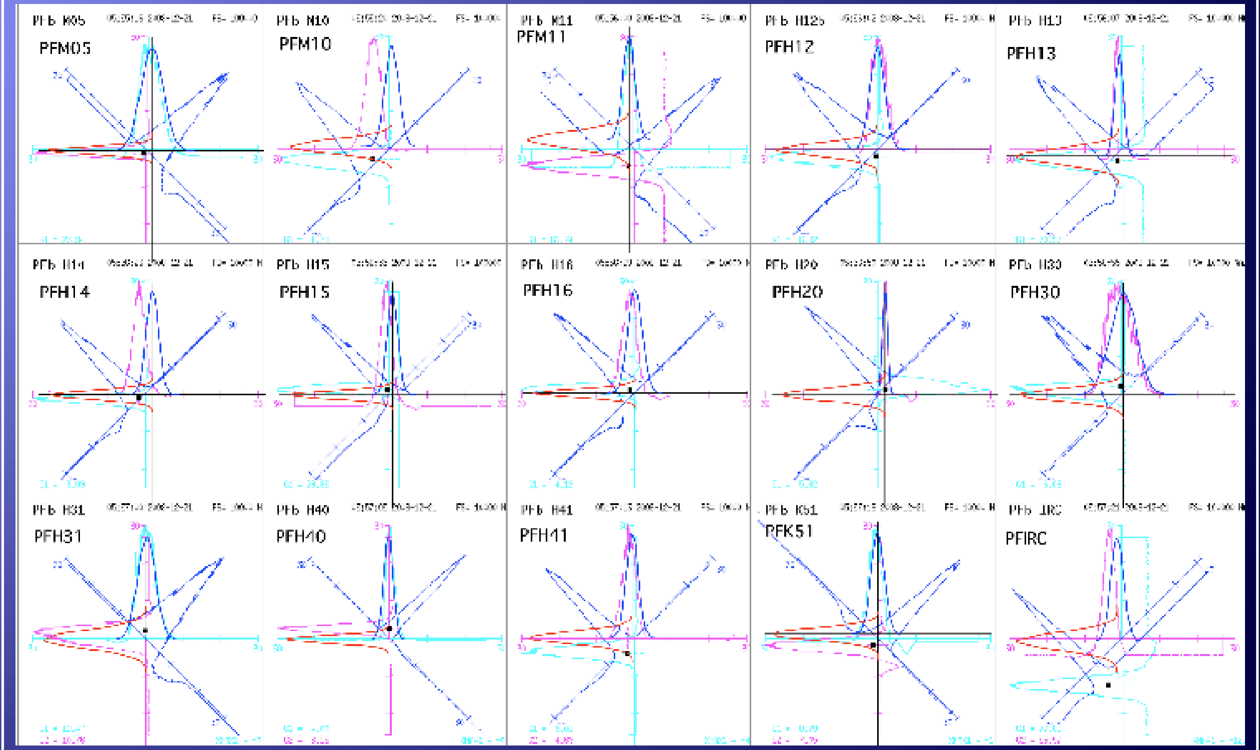
Comparison of Beam Profile

- Beam profile monitor



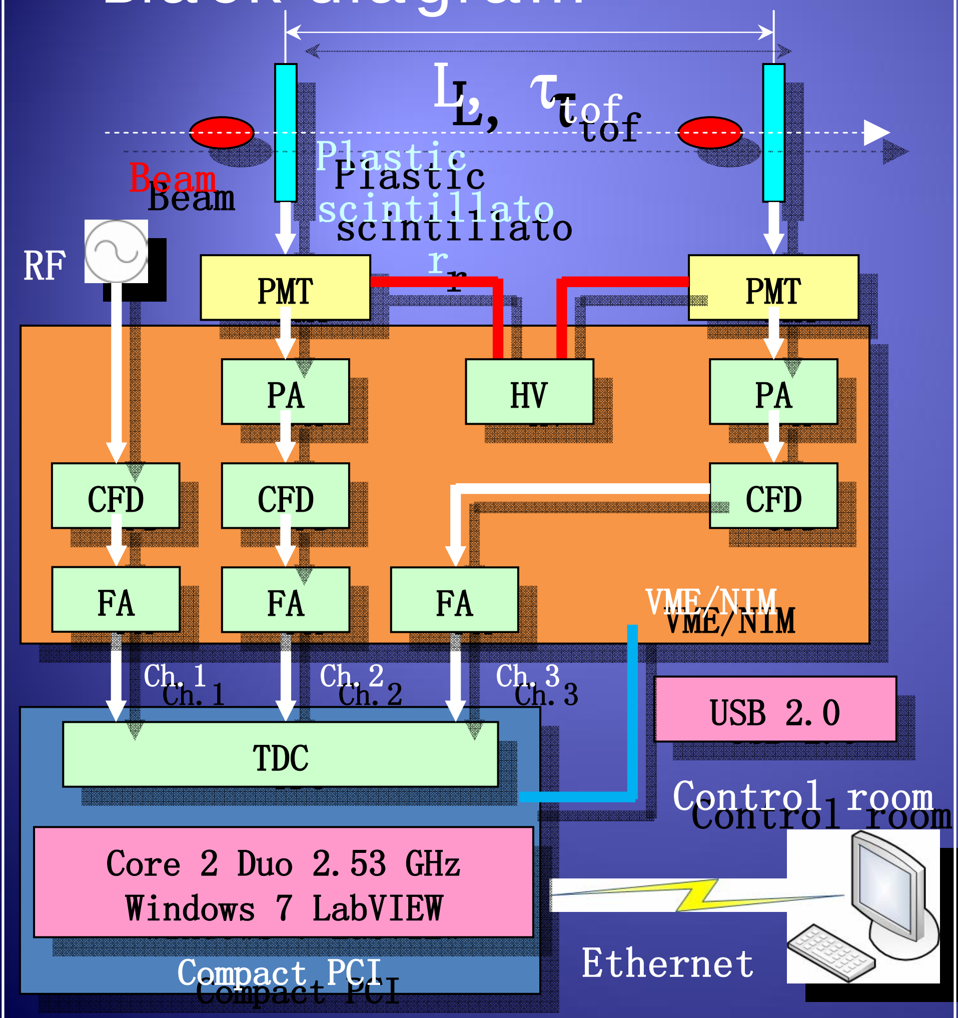
3 wires-scanner type

- ^{48}Ca beam on IRC-injection line

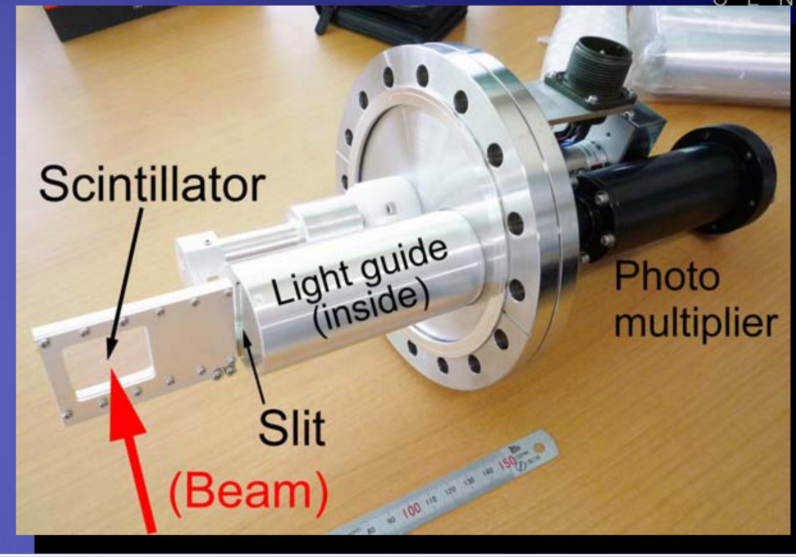


Plastic scintillation monitor

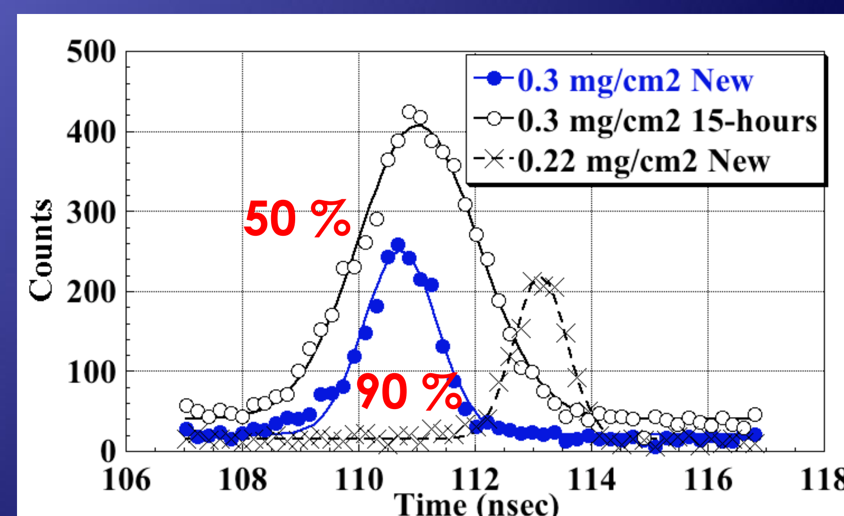
Black diagram

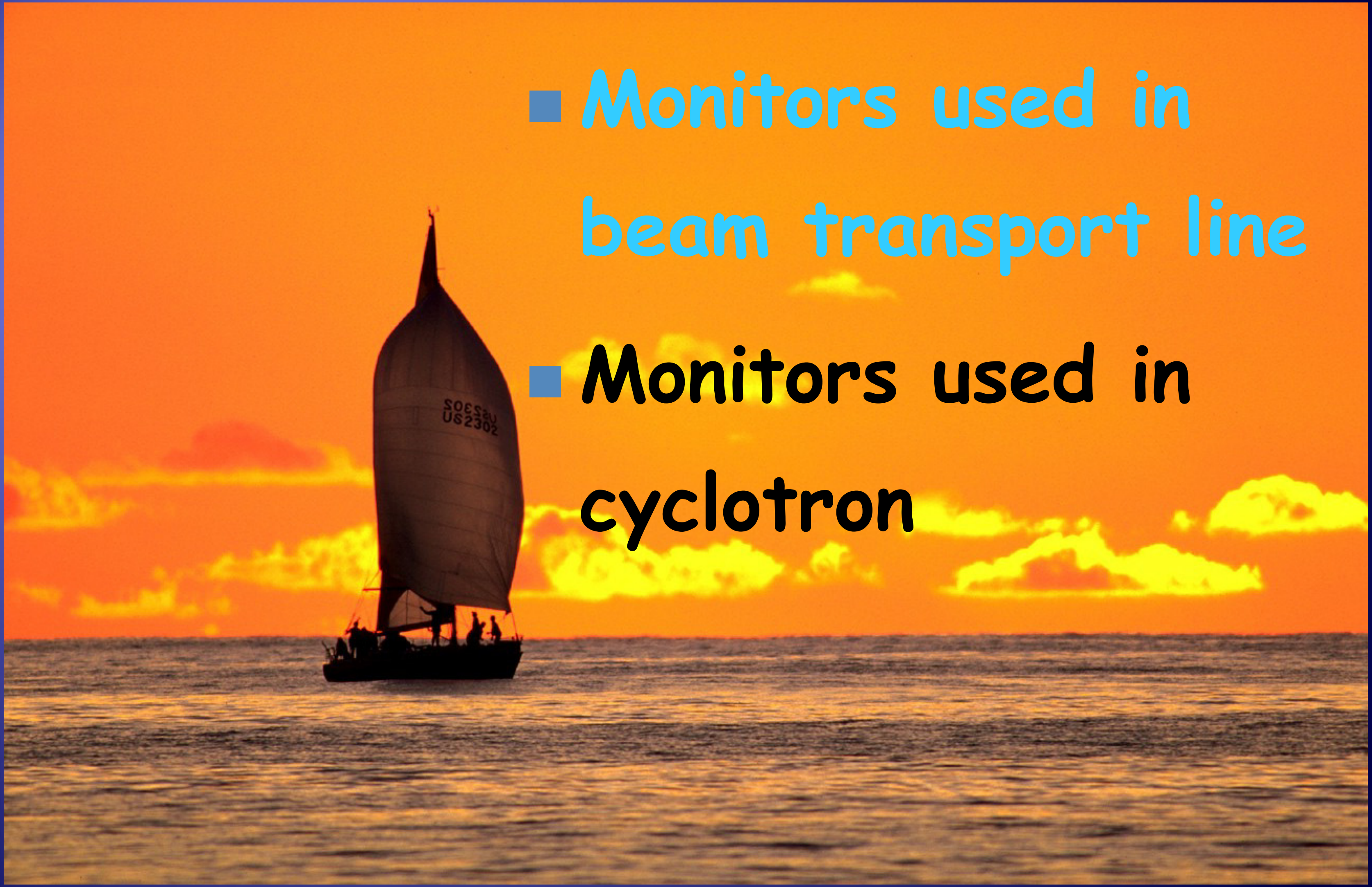


PMT : Photomultiplier tube
TDC : Time-to-digital conversion



Longitudinal beam width

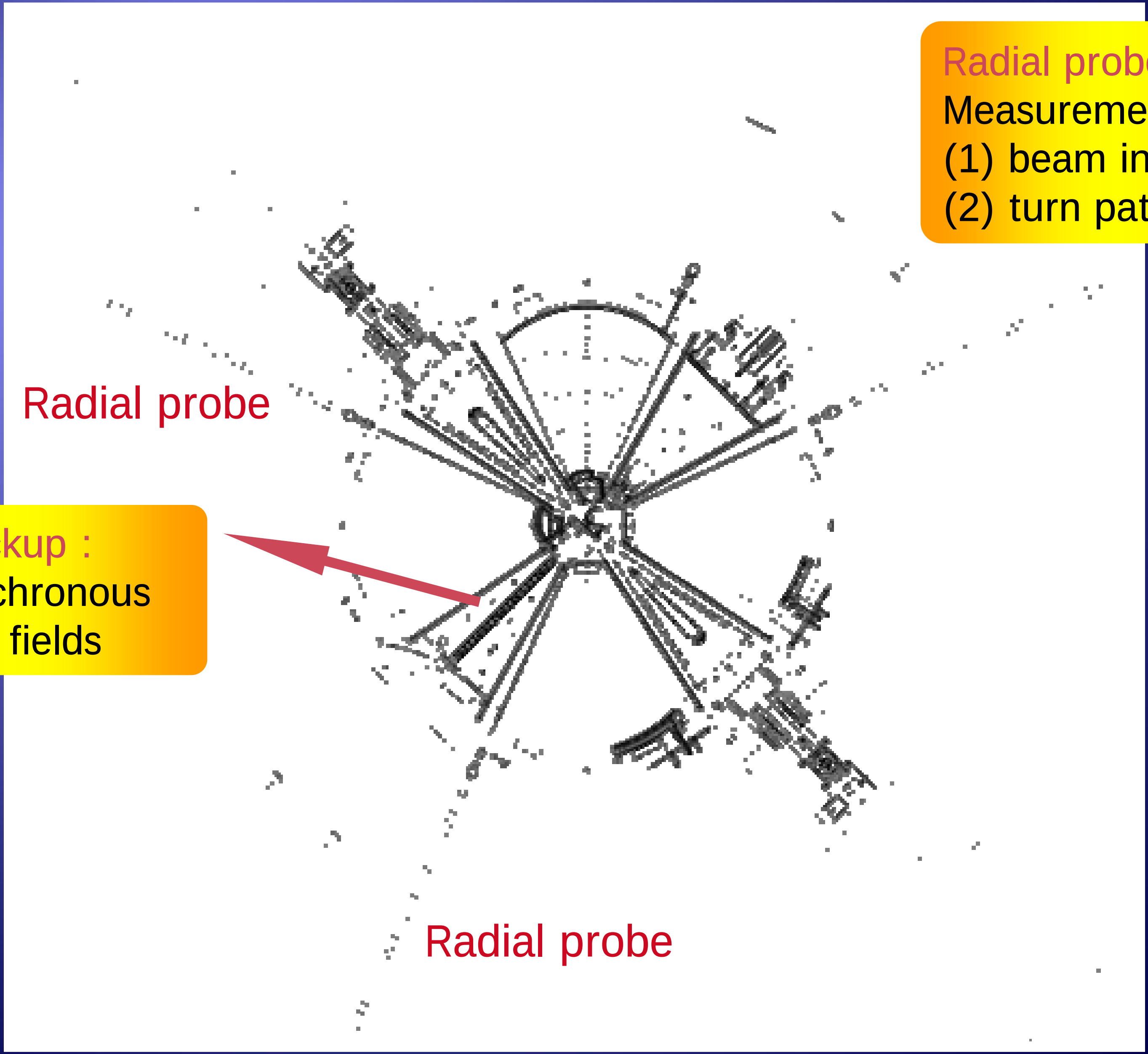




- Monitors used in beam transport line
- Monitors used in cyclotron

Radial probe & phase pickup

Radial probe :
Measurement of
(1) beam intensity;
(2) turn pattern



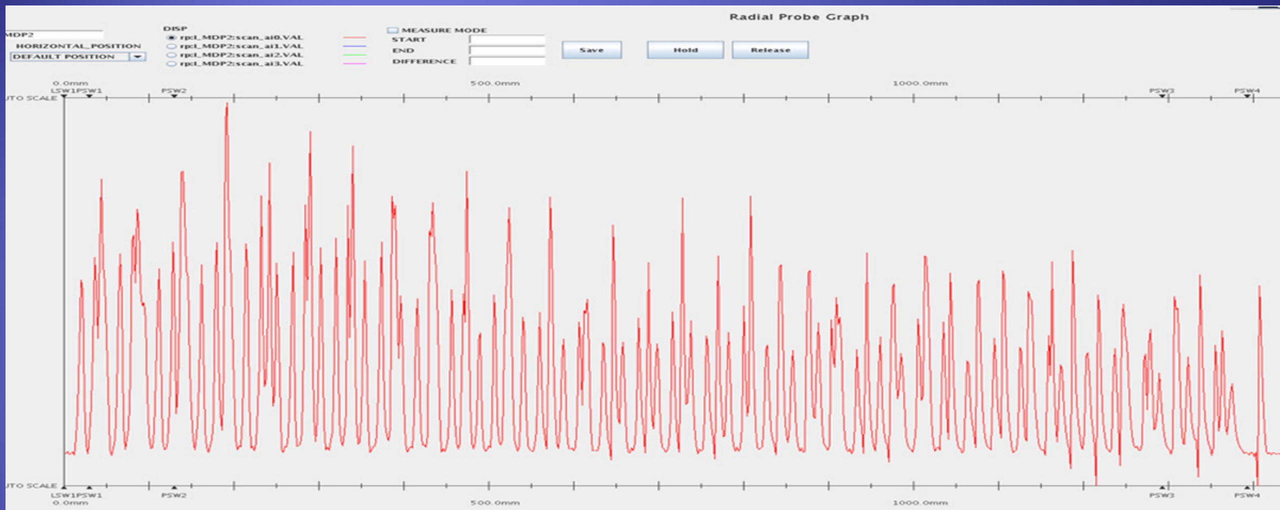
Phase pickup :
Good isochronous
magnetic fields

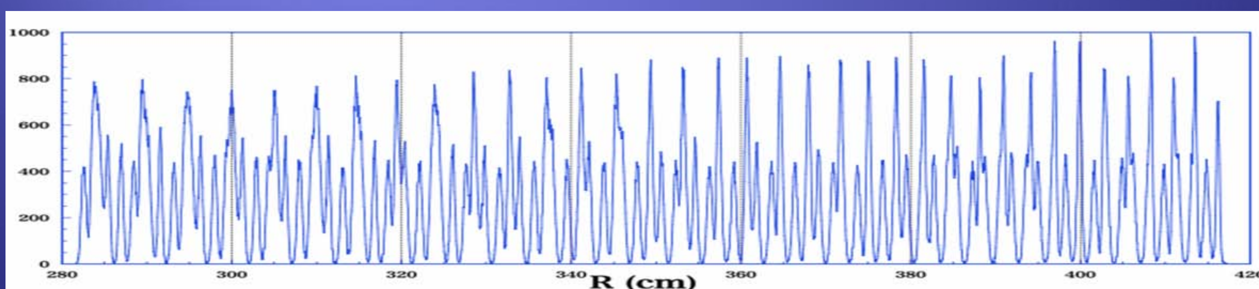
Turn pattern comparison

$^{238}U^{86+}$

@ IRC-MDP2

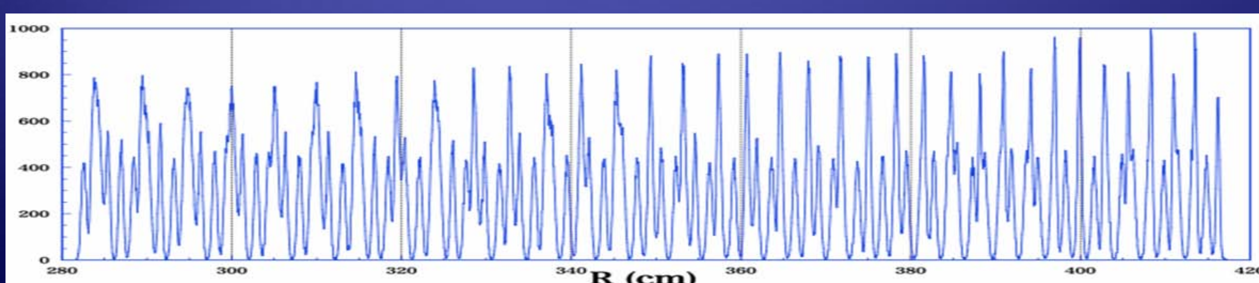
- Measured Result



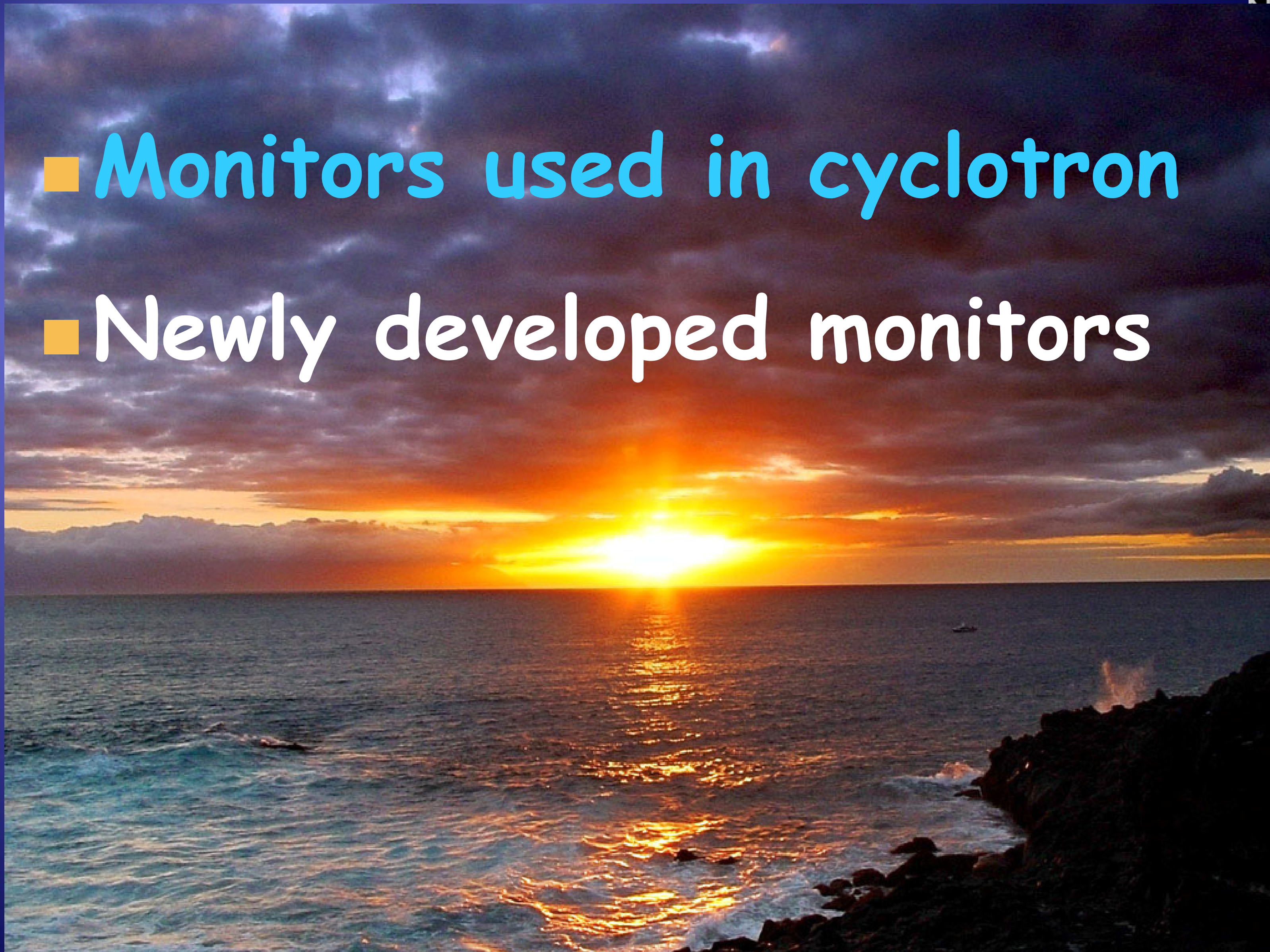


$\Delta p/p$=0.20%

- Simulation

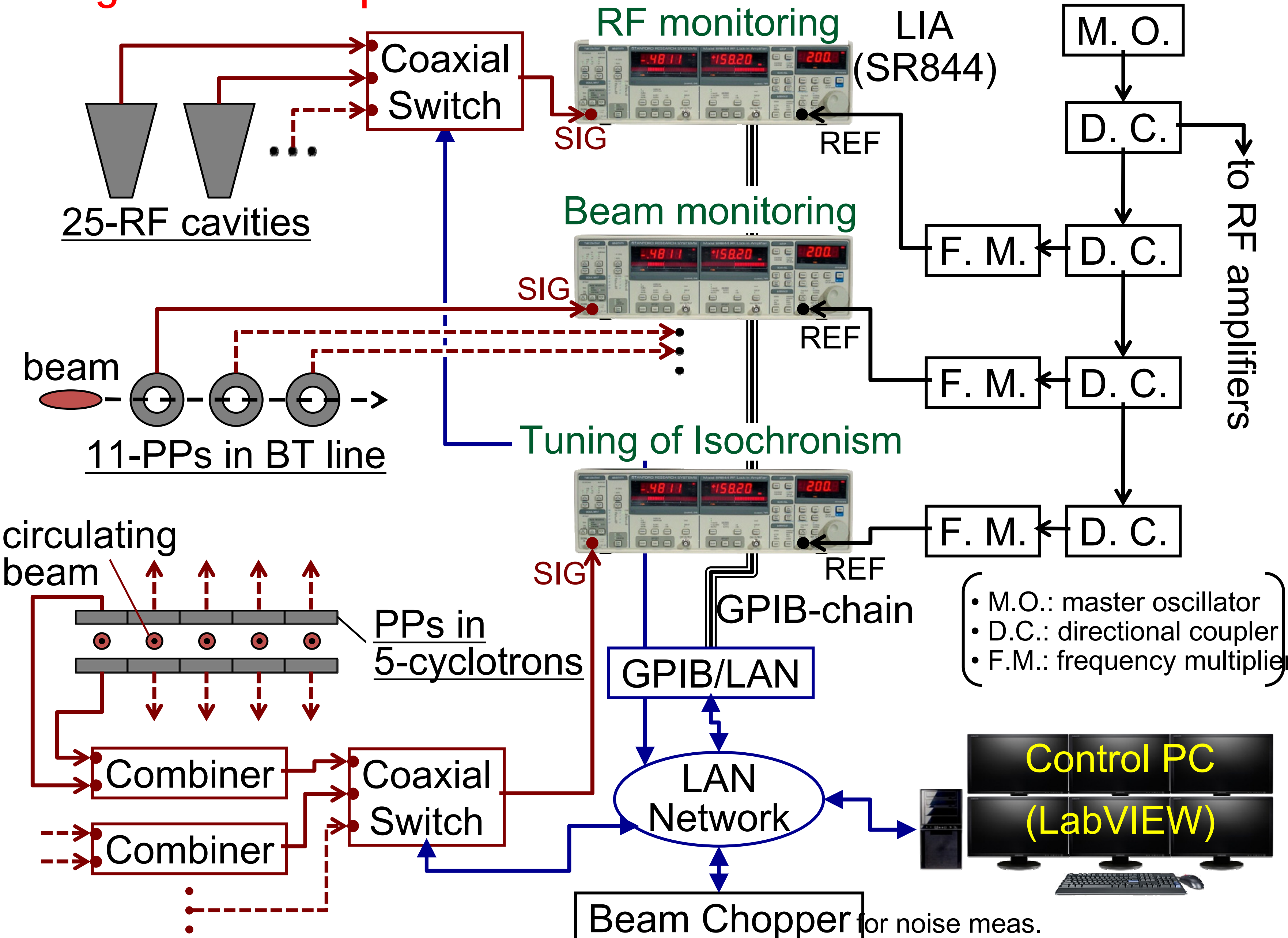


$\Delta p/p$=0.22%


Monitors used in cyclotron
Newly developed monitors

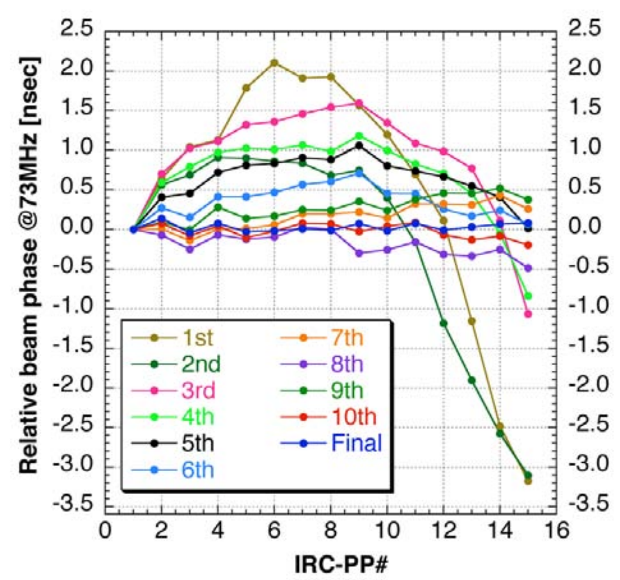
Block diagram of phase measurements by using Lock in amplifier

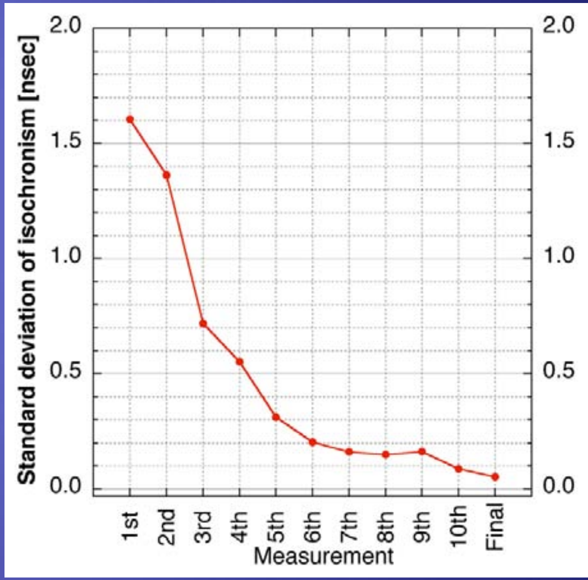
MOPCP094 Ryo Koyama



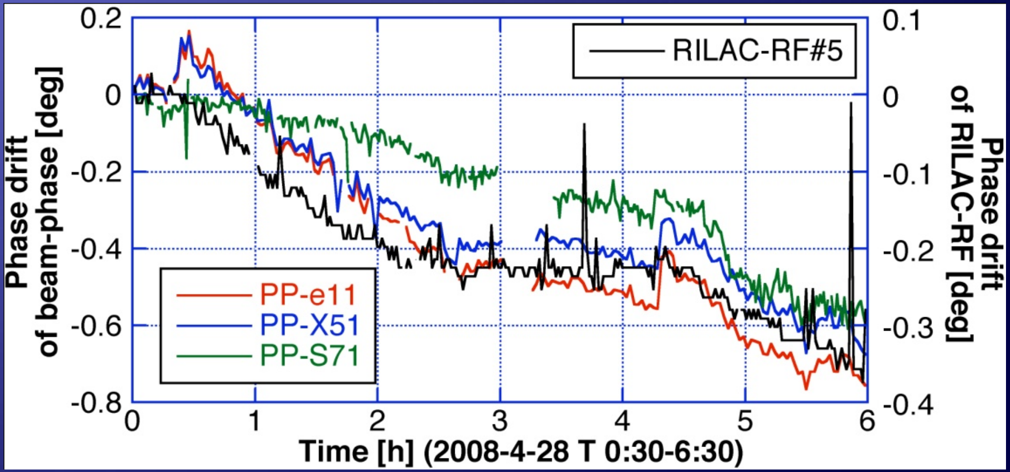
Measured Result by LIA

- Good isochronous magnetic fields





- Correlation between observed beam phases and acceleration RF

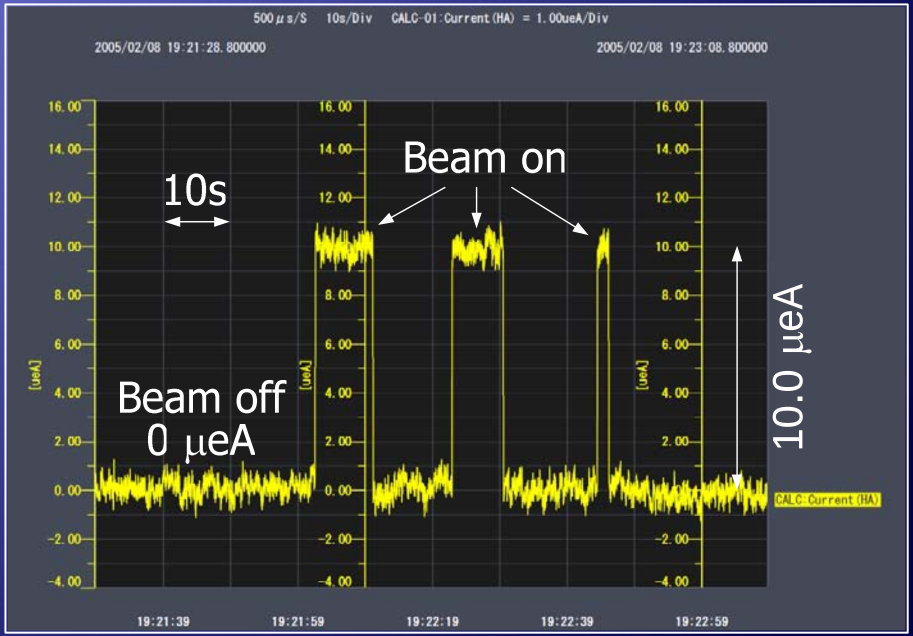


Successful measurements using ion beams -SQUID monitor-

RF cavity:
Max. 0.6 MW
Main magnetic field:
Max. 1.7 T

Radiation dose (1 year):
3.0 Sv for gamma radiation
25.5 Sv for neutrons

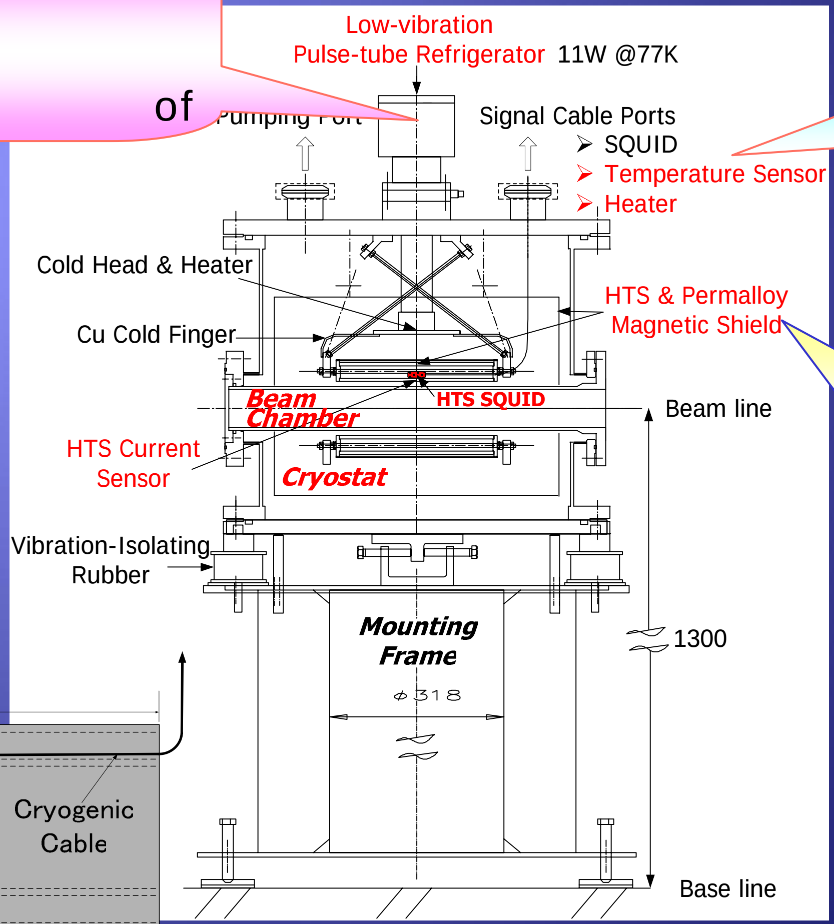
Beam $^{40}Ar^{+15}$ (63 MeV/u)



HTc SQUID Monitor System

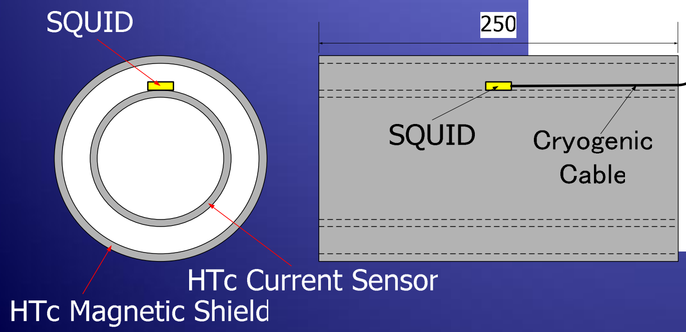
Reduction of ;
- Running costs
- Frequency of maintenance

SQUID Gradiometer



SQUID temperature
$\Delta T < 5$ mK 18h
(PID control)

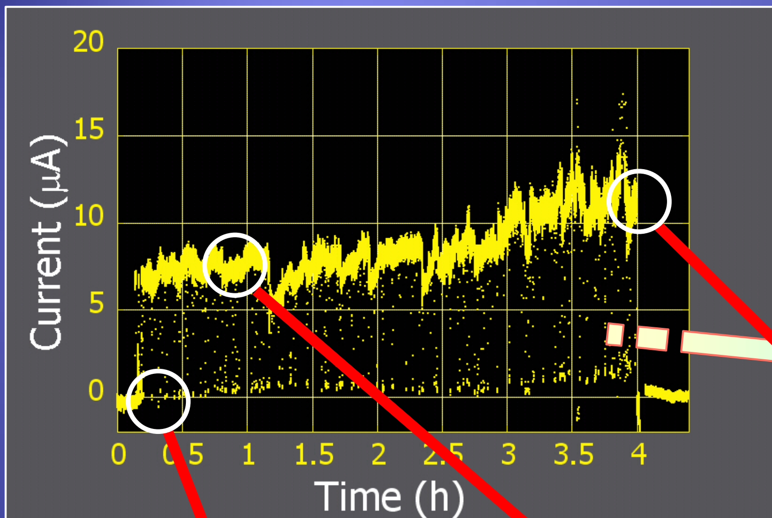
Environmental magnetic noise can be reduced
1/1,000,000



Faley M I *et al.* 2001 *IEEE Trans. Appl. Supercond.* **11** 1383

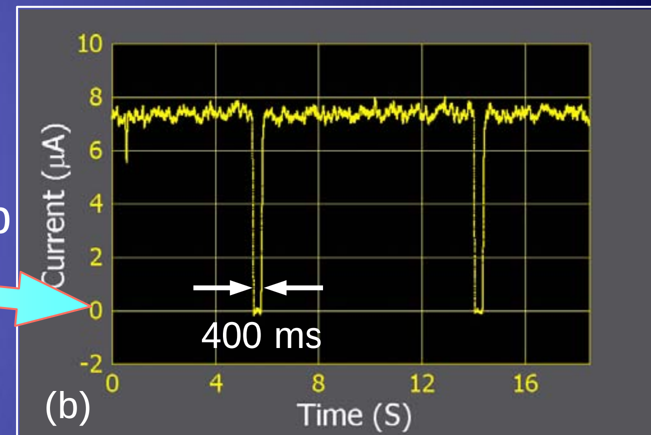
Real-time analysis

Beam $^{40}Ar^{+15}$ (63 MeV/u)

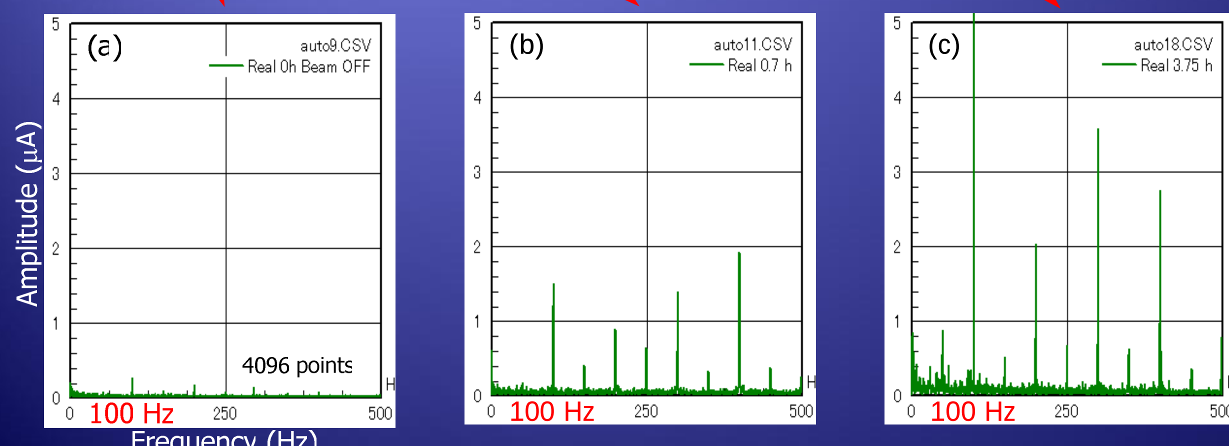


- Discharge of ECR ion source

Close up



- Amplitudes of ripples in modulated beam



0 hour (beam off) 0.7 h 3.8 h

- Measurements and analyses
- In real time
- Without interrupting beam user's experiments

Summary

- Purpose and importance of beam diagnostics
- Accelerator complex of RIBF
- Monitors used in beam transport line
- Monitors used in cyclotron
- Newly developed monitors

Can we
watch a beam ?

-> Yes, we can !

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Thank you for your kind attention

Tamaki Watanabe

Principle of HTc SQUID monitor

Irradiation of beam

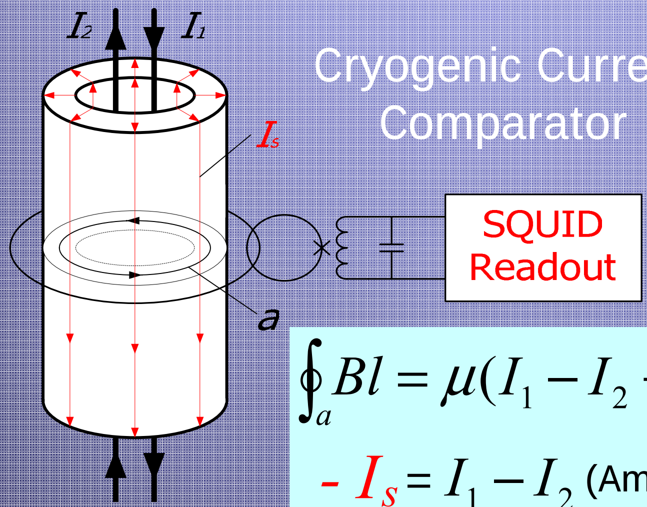
↓

Shielding current is produced by Meissner effect

↓

Designed to have a bridge circuit
Current is concentrated in bridge circuit
SQUID can detect Φ with high S/N ratio

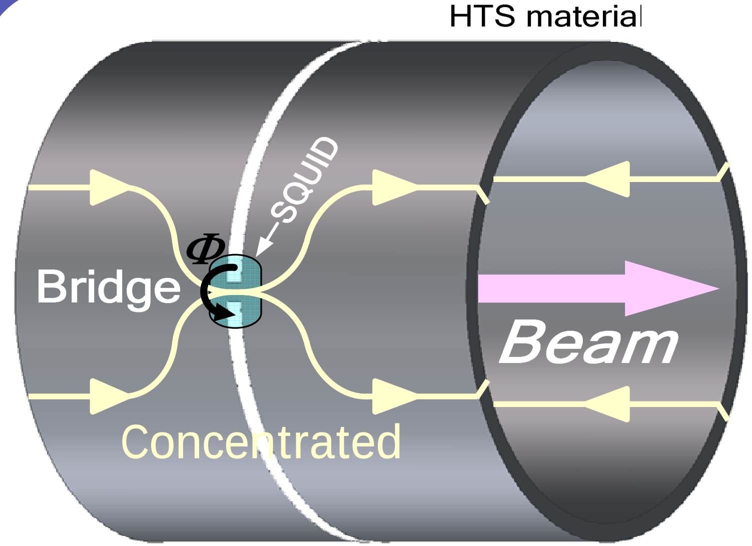
Cryogenic Current Comparator

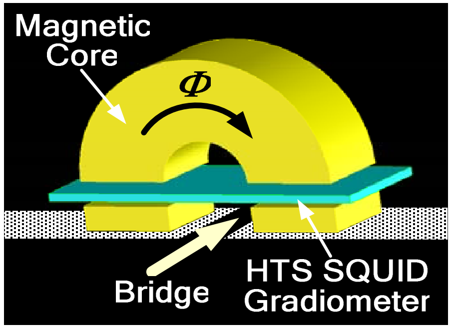


$$\oint_a Bl = \mu(I_1 - I_2 + I_s) = 0$$

$$-I_s = I_1 - I_2$$ (Ampere's low)

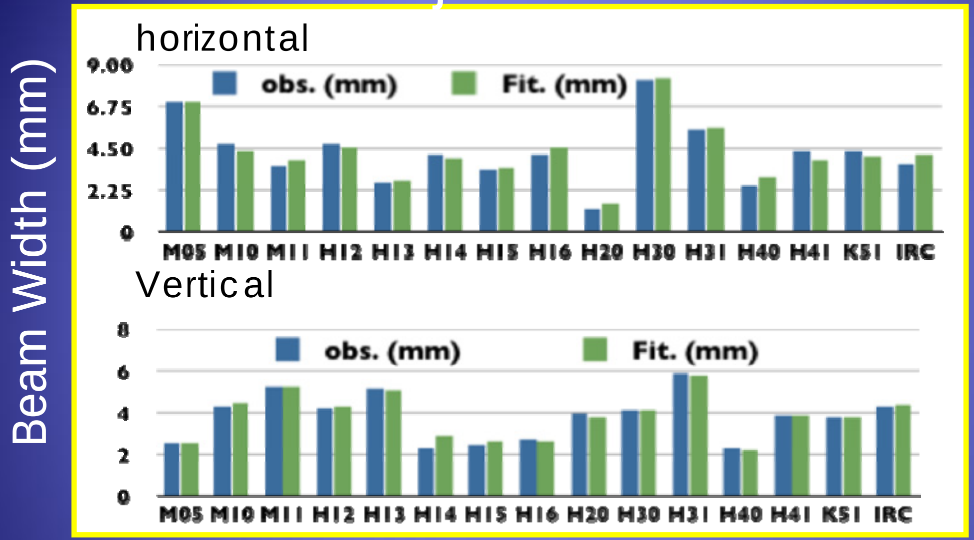
Superconductor: $Bi(Pb)_2$-Sr_2-Ca_2-Cu_3-O_x (Bi2223)
Substrate: 99.9% MgO ceramic



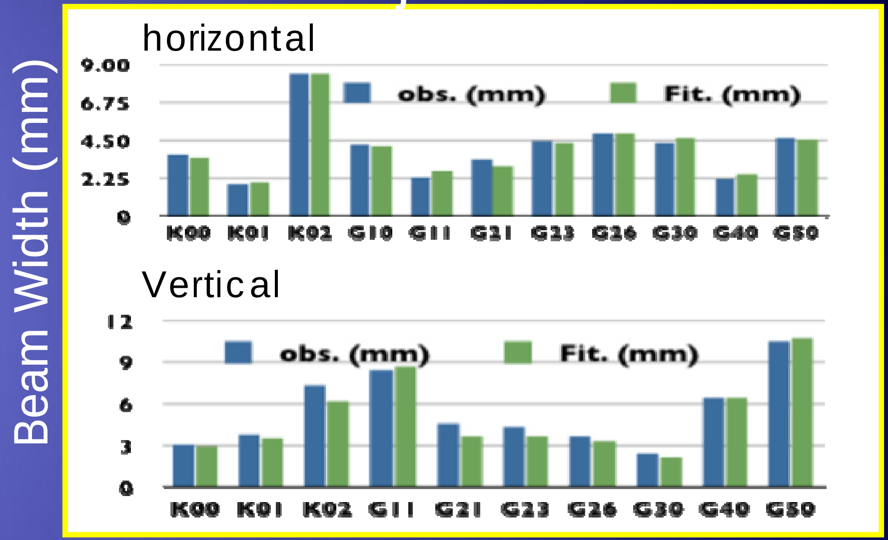


Emittance analysis of ^{48}Ca beam

IRC-injected beam



SRC-injected beam

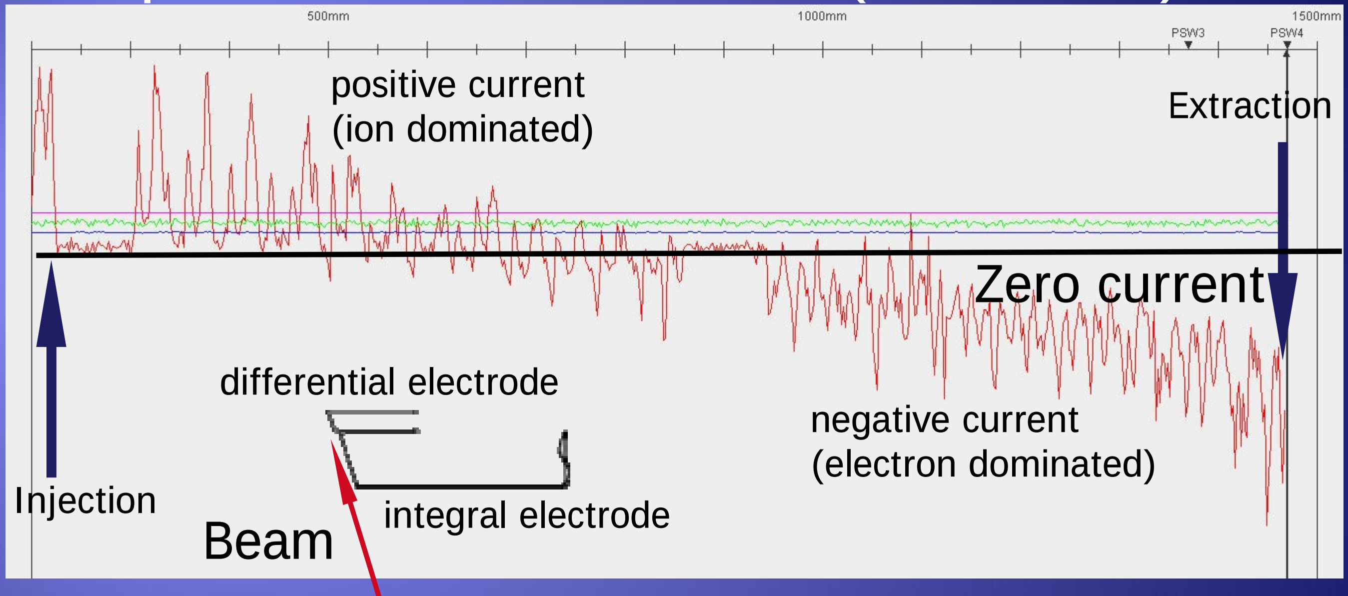


Utilizing the data of beam widths obtained by beam profile monitors, we estimated beam emittances based on the first order ion optics.

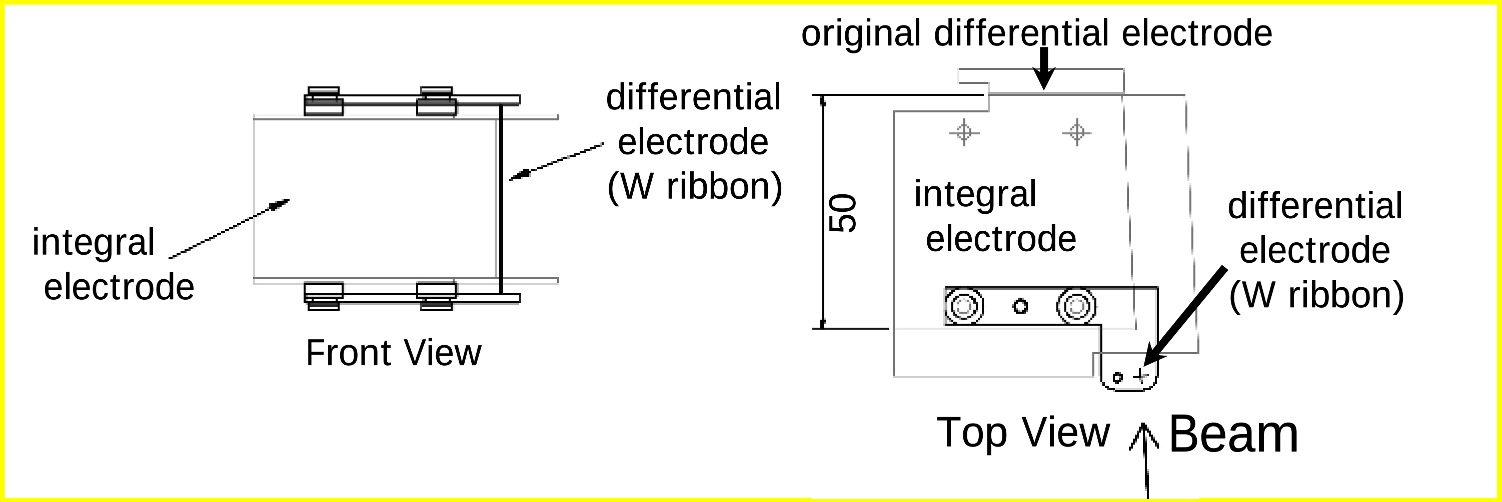
- Emittance (IRC-injected beam) = 2.2 ~ 2.3 π mm mrad (unnormalized, within 4 σ region)
- Emittance (SRC-injected beam) = ~1.7 π mm mrad (unnormalized, within 4 σ region)
- No notable emittance growth was observed.
- Corresponding normalized-RMS emittance is 0.19 π mm mrad.

Effect of secondary electrons

- Turn pattern of IRC-MDP1 (07/05/22)



- Modification of SRC-MDP



Effect of secondary electrons

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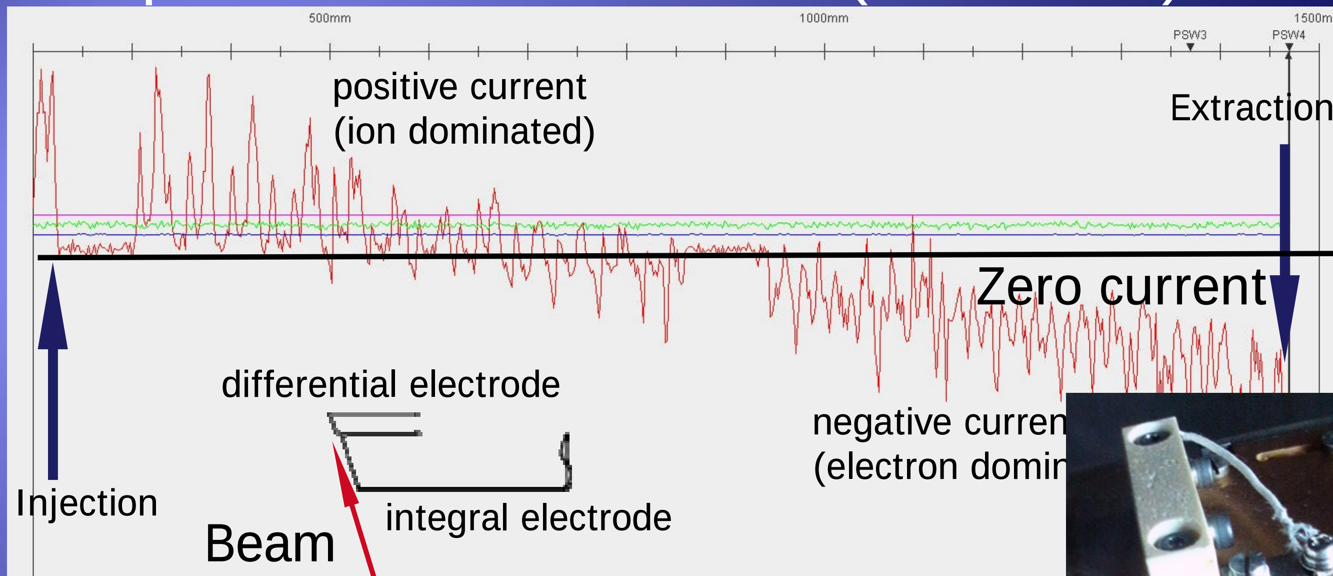

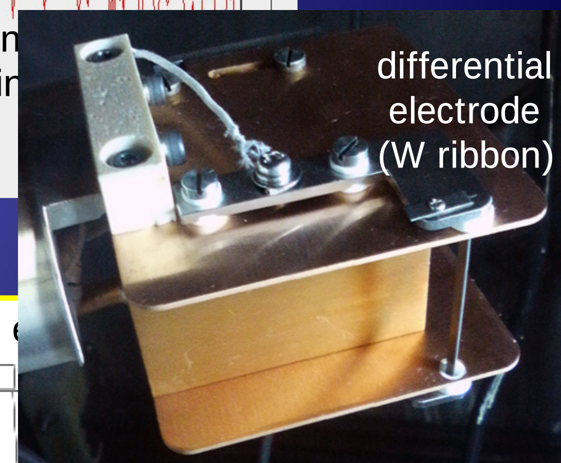

- Modification of SRC-MDP