Construction of the Rare RI Ring (R3) at the RIKEN RI Beam Factory

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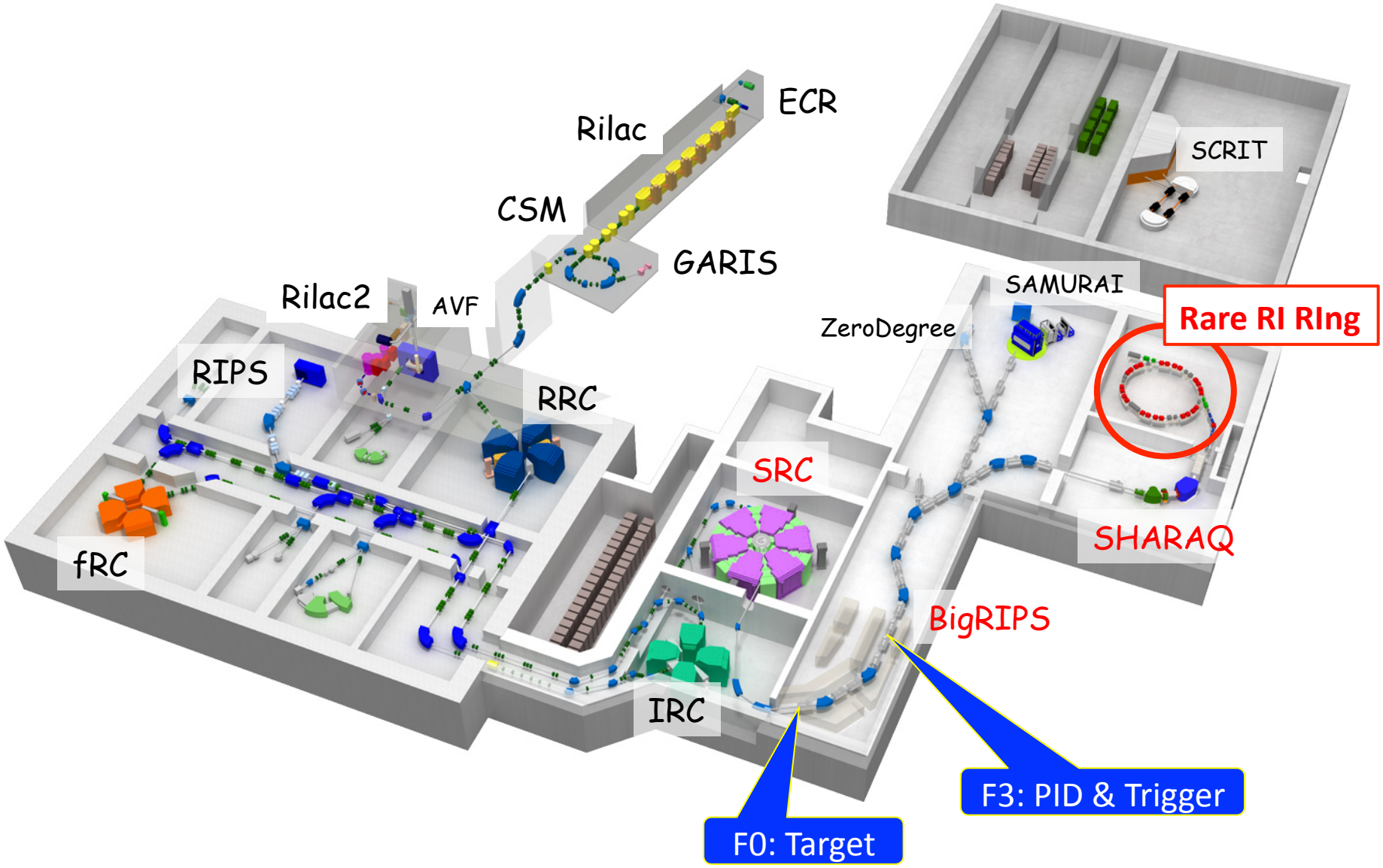
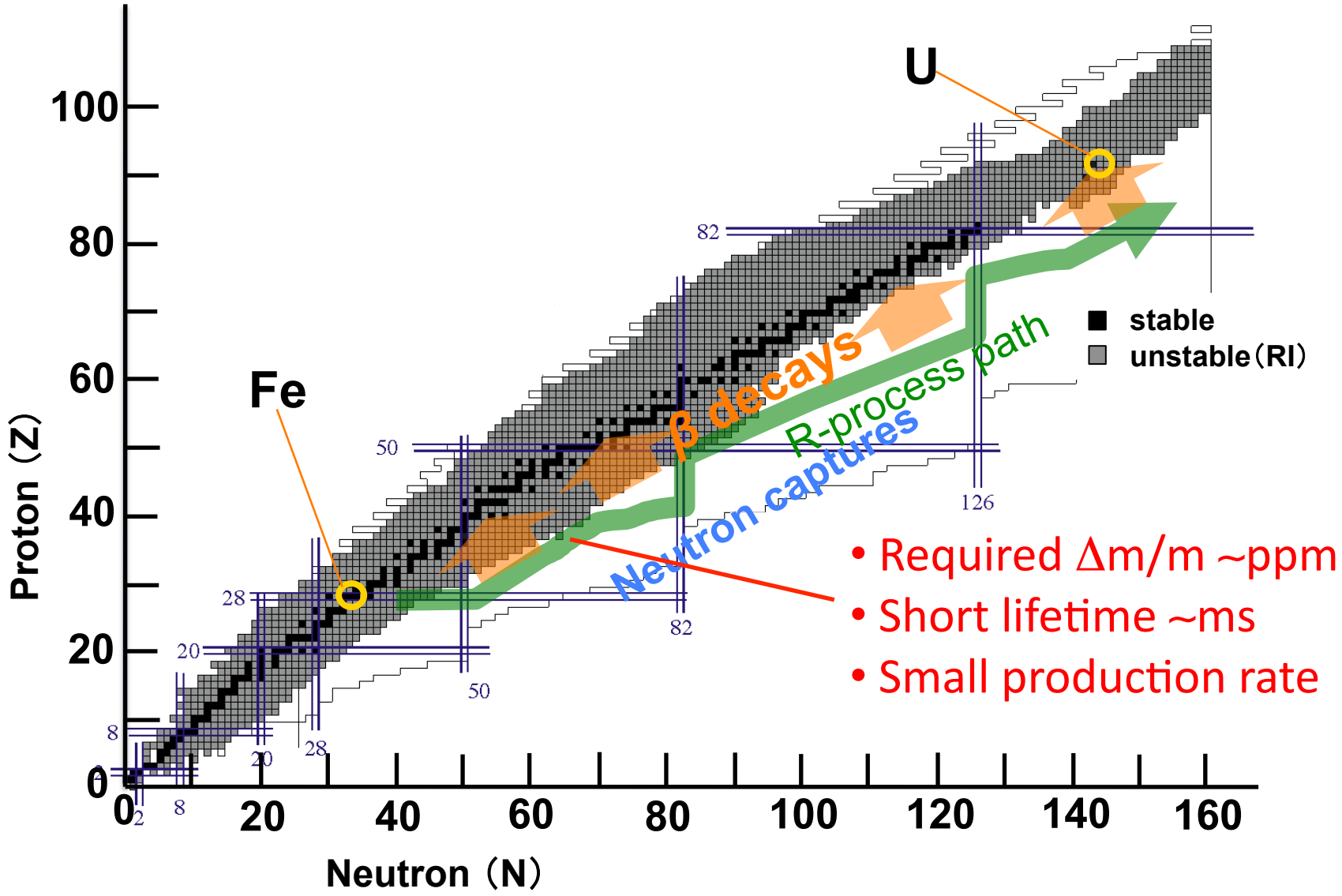
Location of R3 in the RIKEN RI Beam Factory



Precision Mass Measurement for RIs around R-process pass



Principal of Isochronous Mass Spectrometry at R3, I

(R3: Cyclotron-Based Lattice Structure)

Momentum $\frac{m_0}{q_0}\gamma_0\,\beta_0 = \frac{m_1}{q_1}\gamma_1\,\beta_1$ Flight pass length $T_0\,\beta_0 = T_1\,\beta_1$

Mass $$\frac{m_1}{q_1} = \left(\frac{m_0}{q_0}\right)\frac{1}{T_0}\,T_1\sqrt{\frac{1-\beta_1^2}{1-\left\{(T_1/T_0)\beta_1\right\}^2}} = \left(\frac{m_0}{q_0}\right)\frac{T_{1corr}}{T_0}$$

Uncertainty $$\frac{\delta(m_1/q_1)}{m_1/q_1} = \frac{\delta(m_0/q_0)}{m_0/q_0} + \frac{\delta(T_1/T_0)}{T_1/T_0} + k\frac{\delta\beta_1}{\beta_1}$$ ➔ ~ppm

Known Mass $< 10^{-6}$

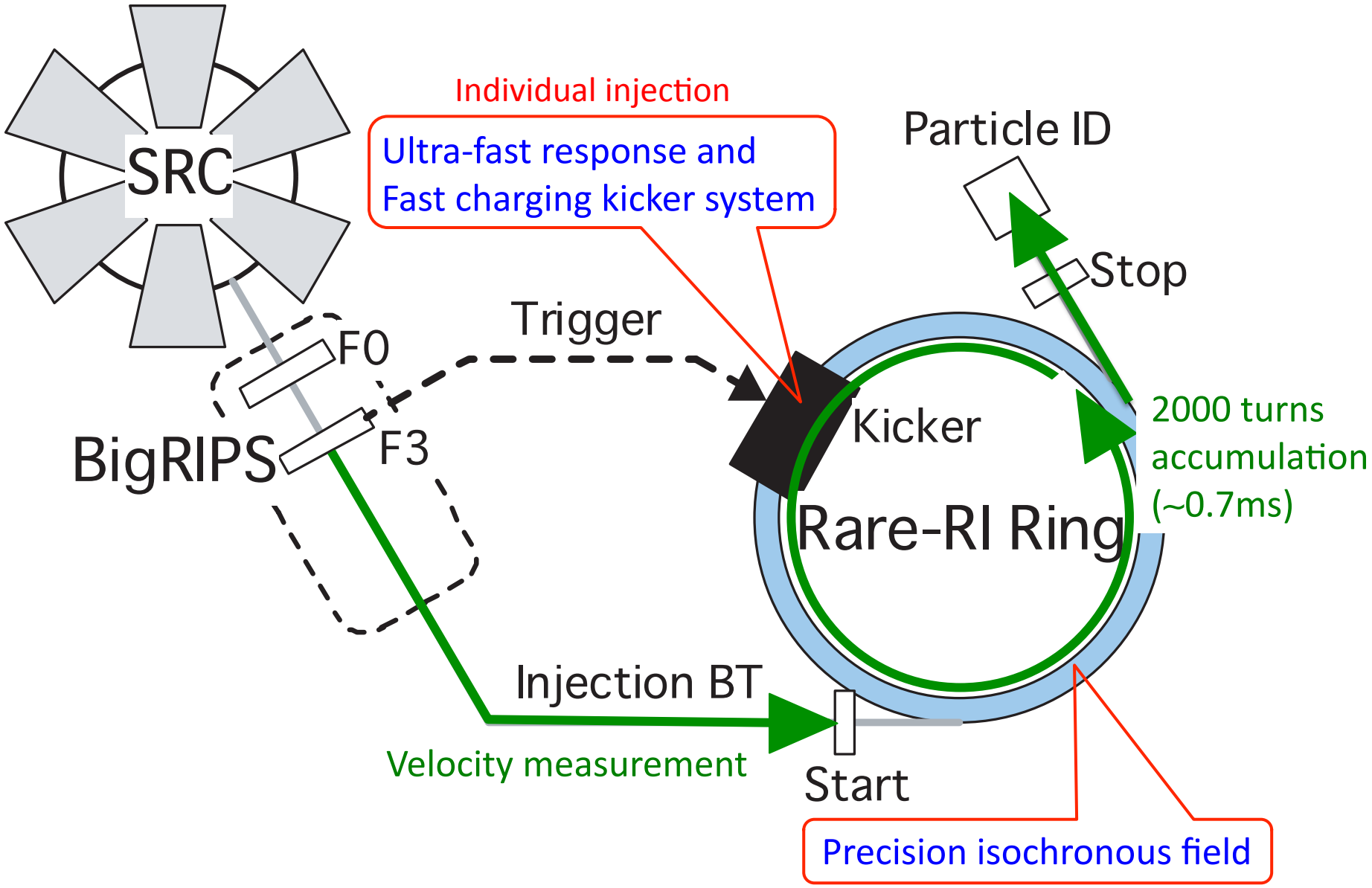
TOF Measurement $< 10^{-6}$

β_1 measurement $\sim 10^{-4}$ **(k~ 10^{-2})**

$$k = -\frac{\beta_1^2}{1-\beta_1^2} + \left(\frac{T_1}{T_0}\right)^2 \frac{\beta_1^2}{1-(T_1/T_0)^2\beta_1^2}$$

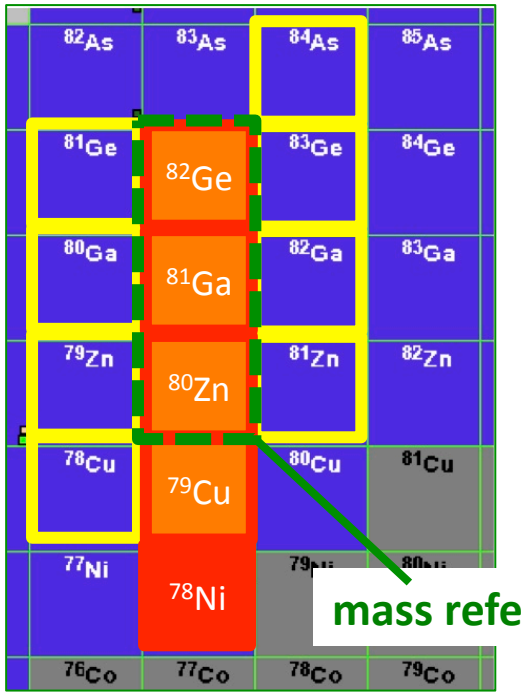
Measurements of T_1, T_0 and β_1 are essential

Mass Measurement Scheme in IMS at R3

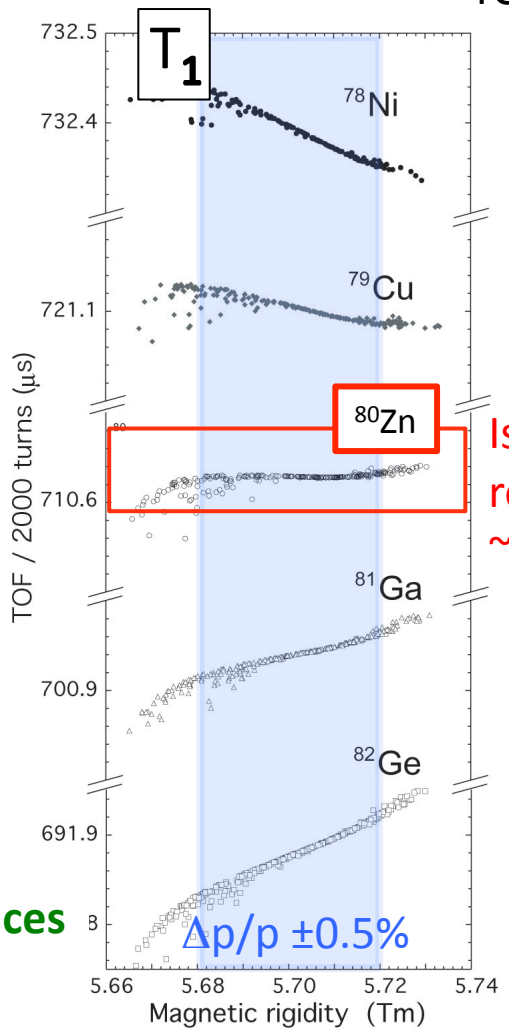


Principal of Isochronous Mass Spectrometry at R3, II

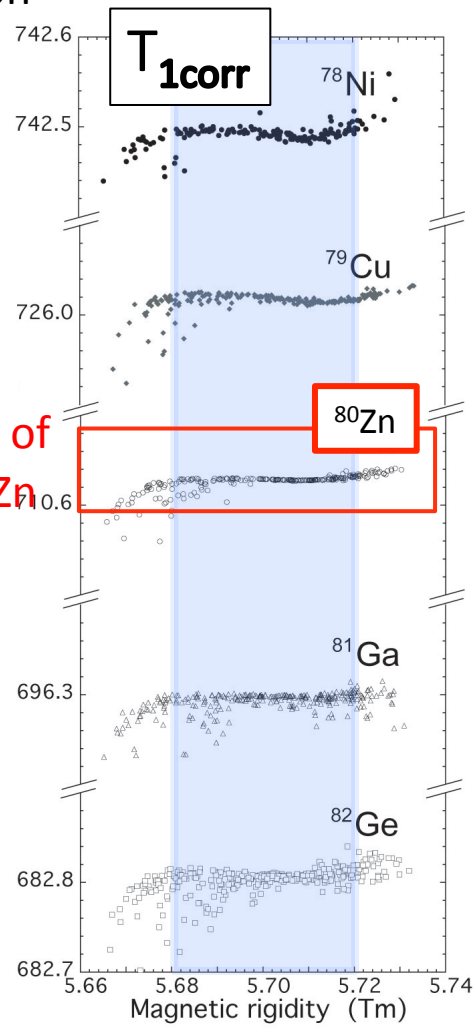
- Many RIs are accepted in the given machine condition.
- One of them (^{80}Zn) is reference for tuning of isochronism.
- Some of them are references for mass determination.



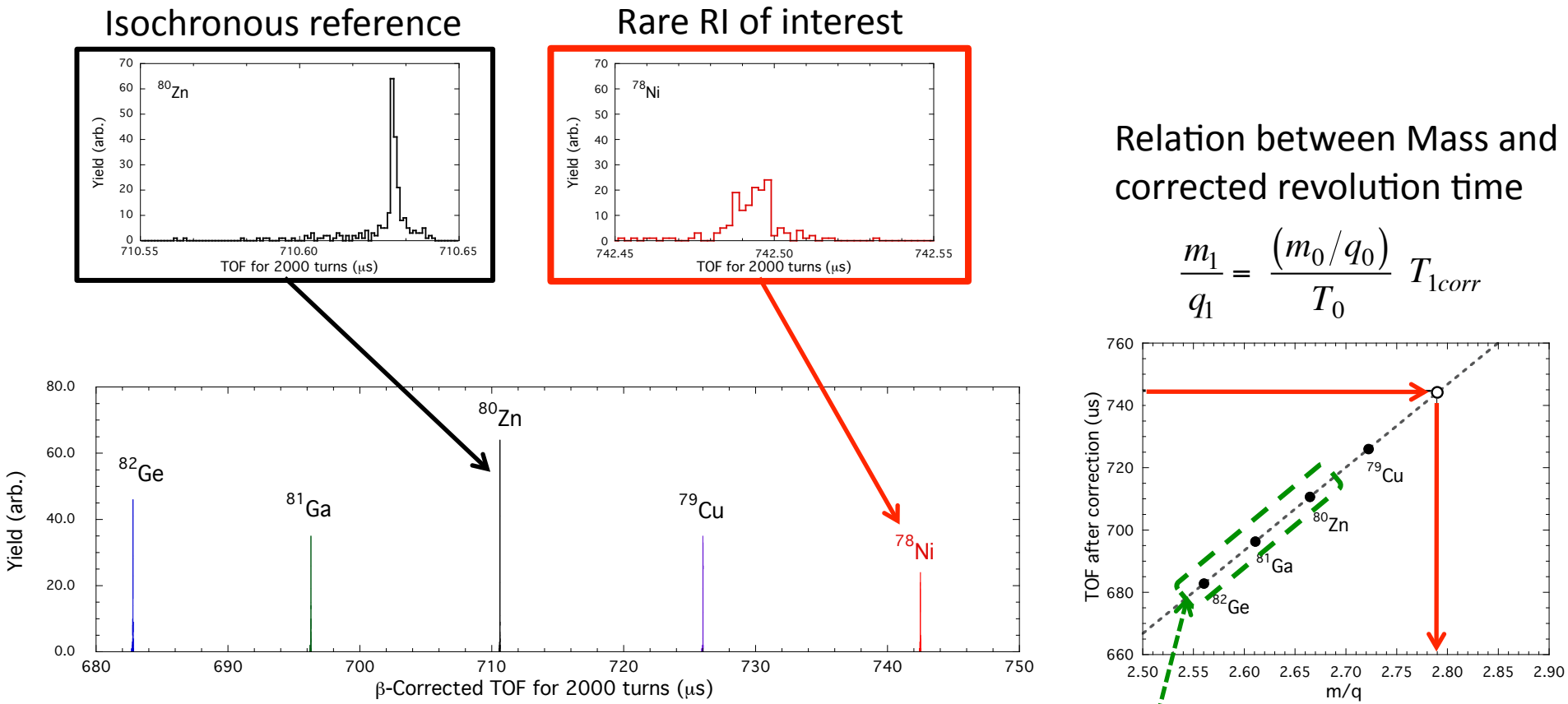
TOF correction



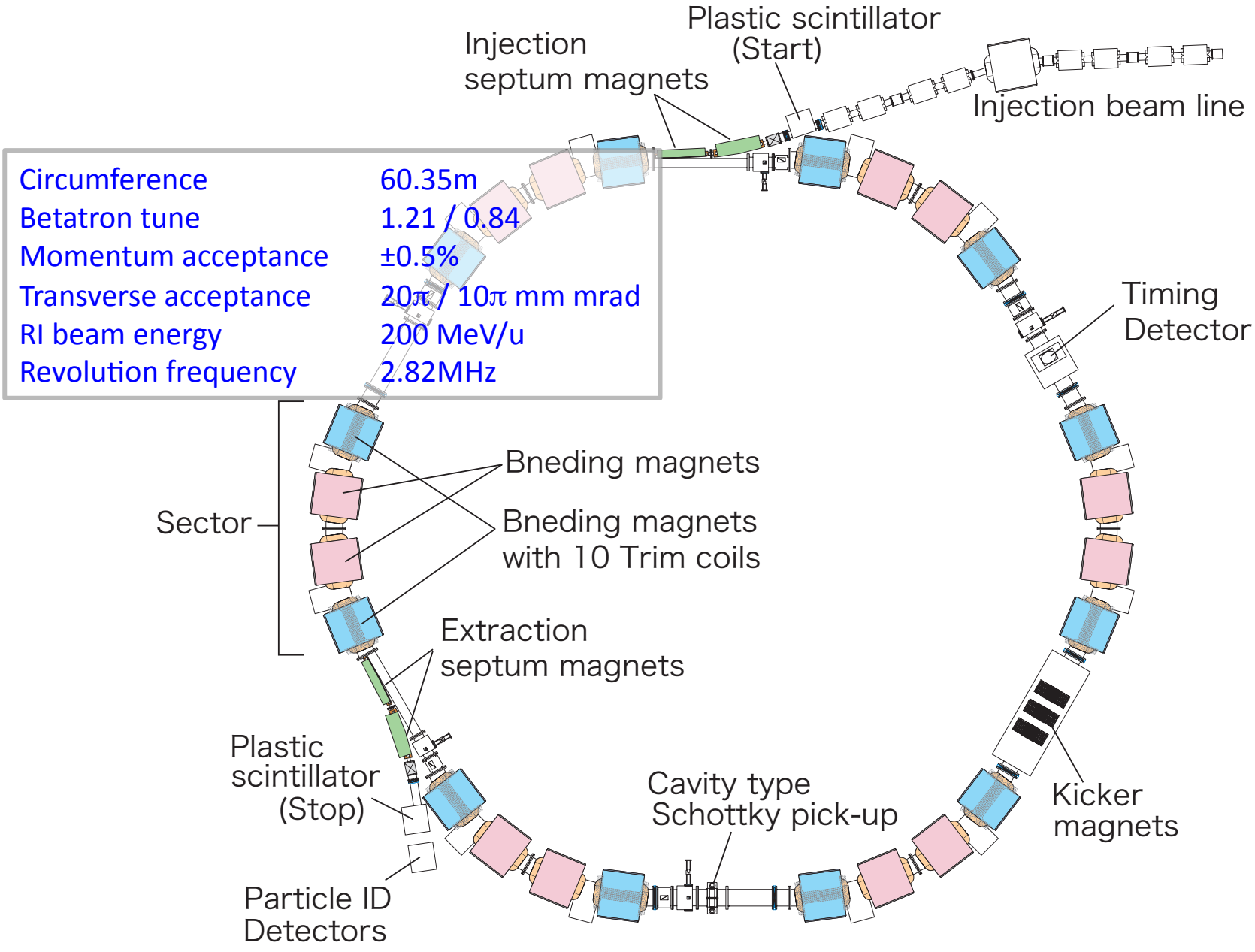
Isochronism of reference ^{80}Zn ~ 2×10^{-6}



Principal of Isochronous Mass Spectrometry at R3, III

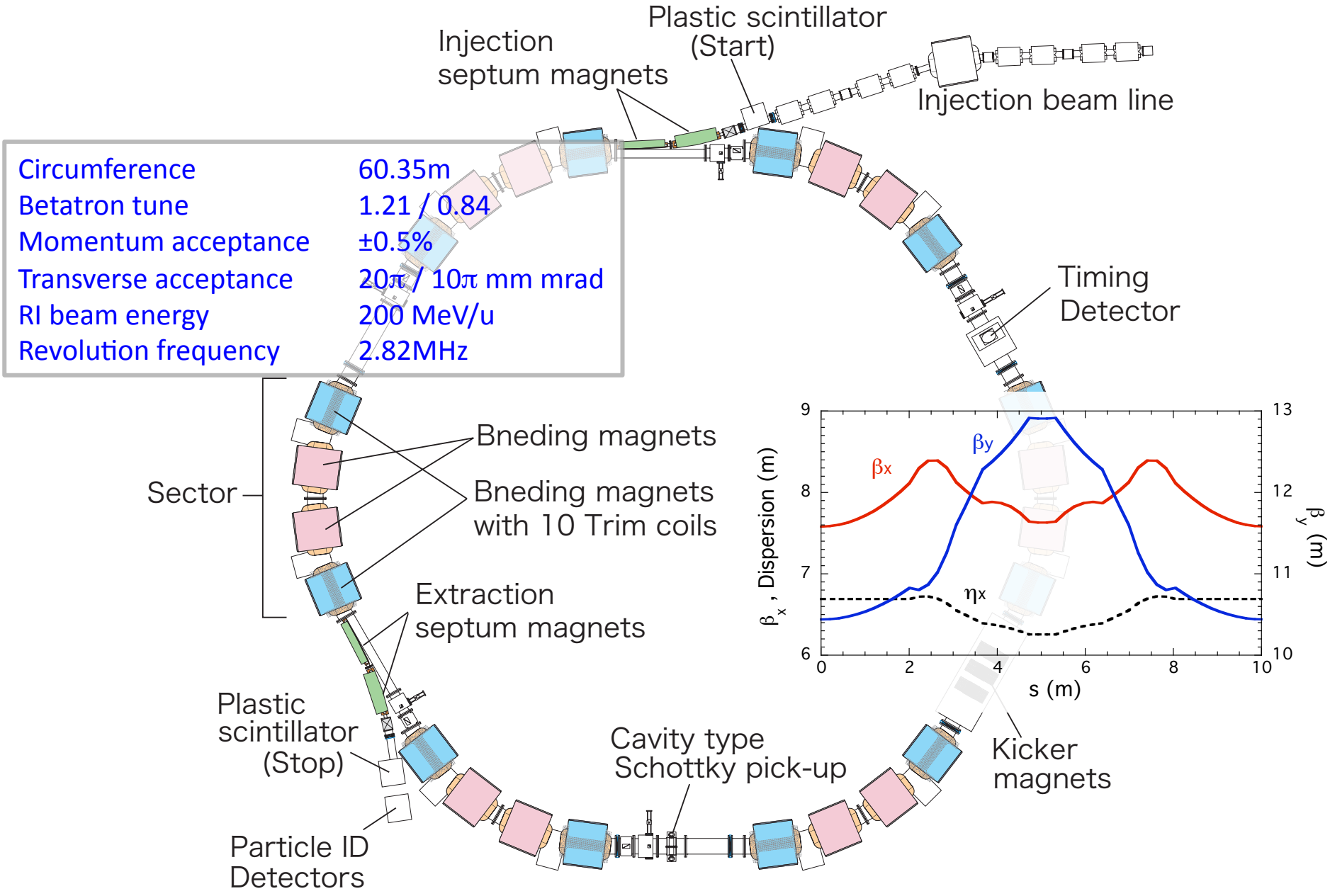


R3 Structure



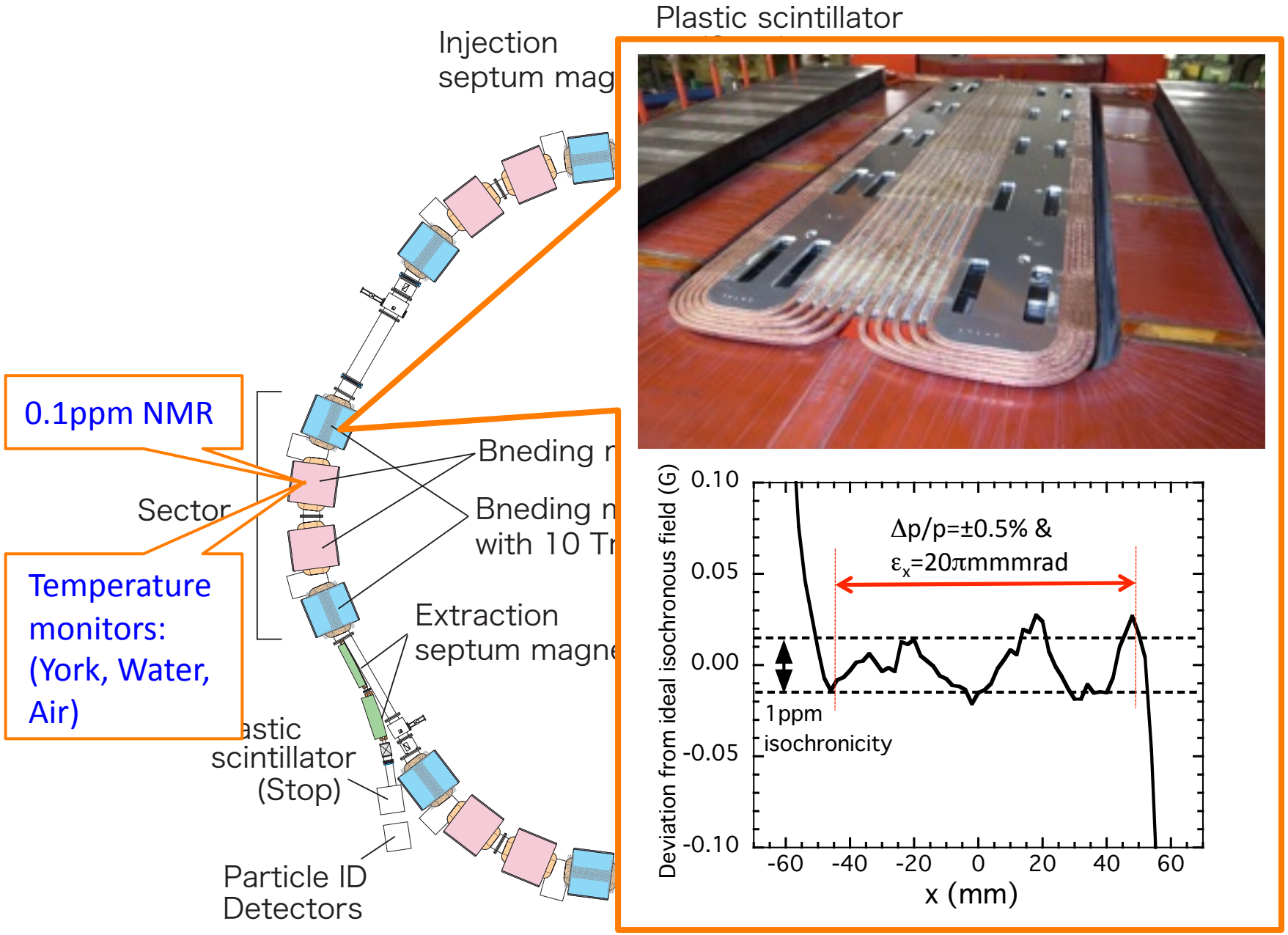
Circumference	60.35m
Betatron tune	1.21 / 0.84
Momentum acceptance	±0.5%
Transverse acceptance	20π / 10π mm mrad
RI beam energy	200 MeV/u
Revolution frequency	2.82MHz

R3 Structure



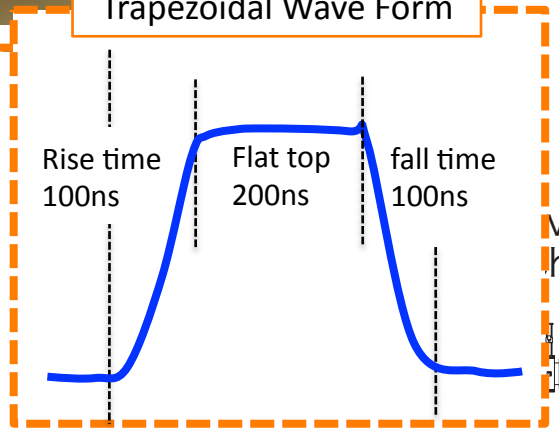
Circumference	60.35m
Betatron tune	1.21 / 0.84
Momentum acceptance	±0.5%
Transverse acceptance	20π / 10π mm mrad
RI beam energy	200 MeV/u
Revolution frequency	2.82MHz

Isochronous Field Formed by 10 Trim Coils

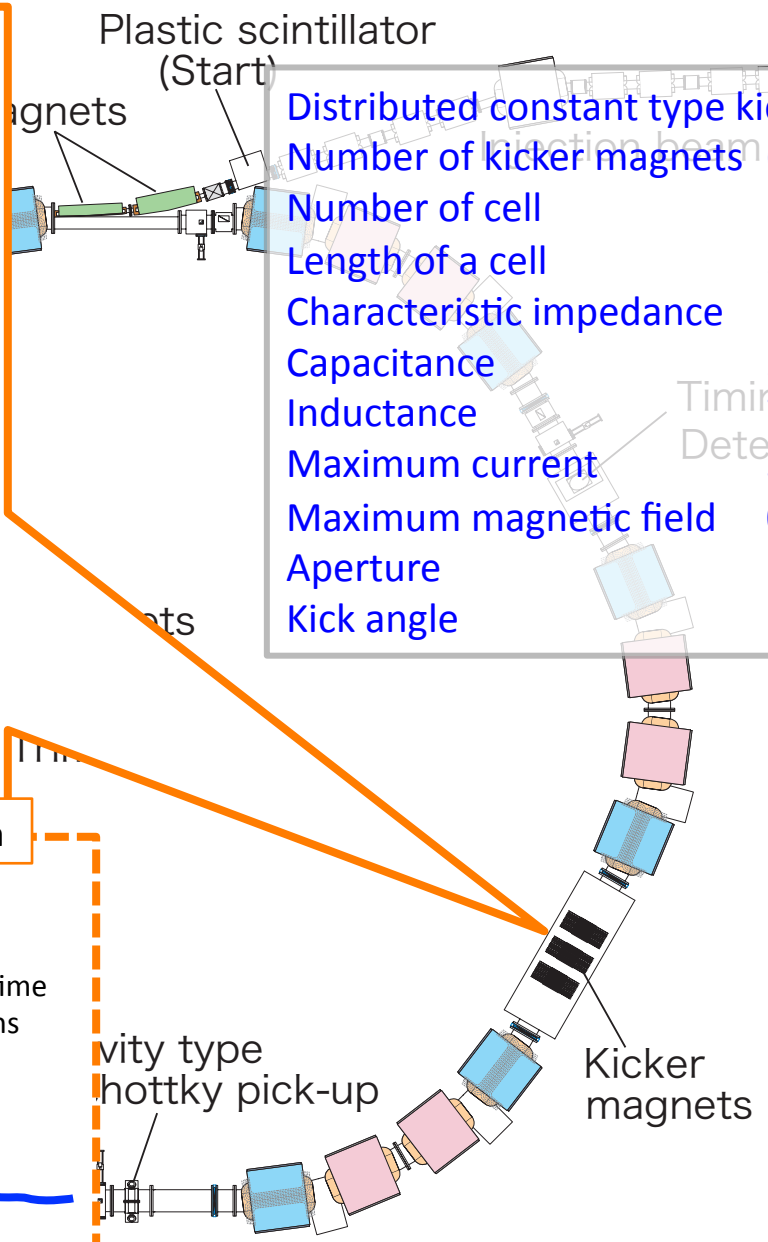


Kicker Magnets

Trapezoidal Wave Form



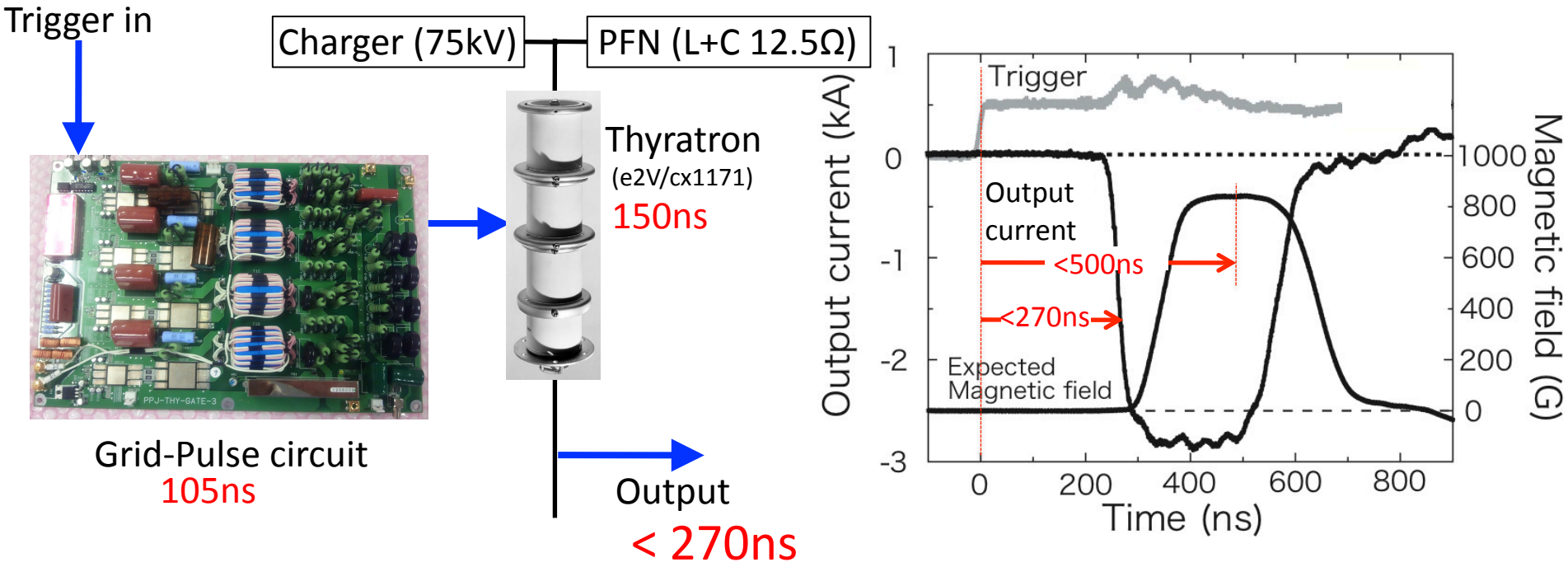
Distributed constant type kicker magnets	
Number of kicker magnets	6
Number of cell	13
Length of a cell	25mm
Characteristic impedance	12.5Ω
Capacitance	240pF/cell
Inductance	75nH/cell
Maximum current	3000A/35kV
Maximum magnetic field	0.094T
Aperture	180×40mm^2
Kick angle	12.8mrad



Fast Response Kicker System

(for establishing individual injection scheme)

F3	Flight time 950ns				Kicker
	Trigger transmission 430ns	Kicker PS Required <290ns	Output 30ns	Field activation 200ns	



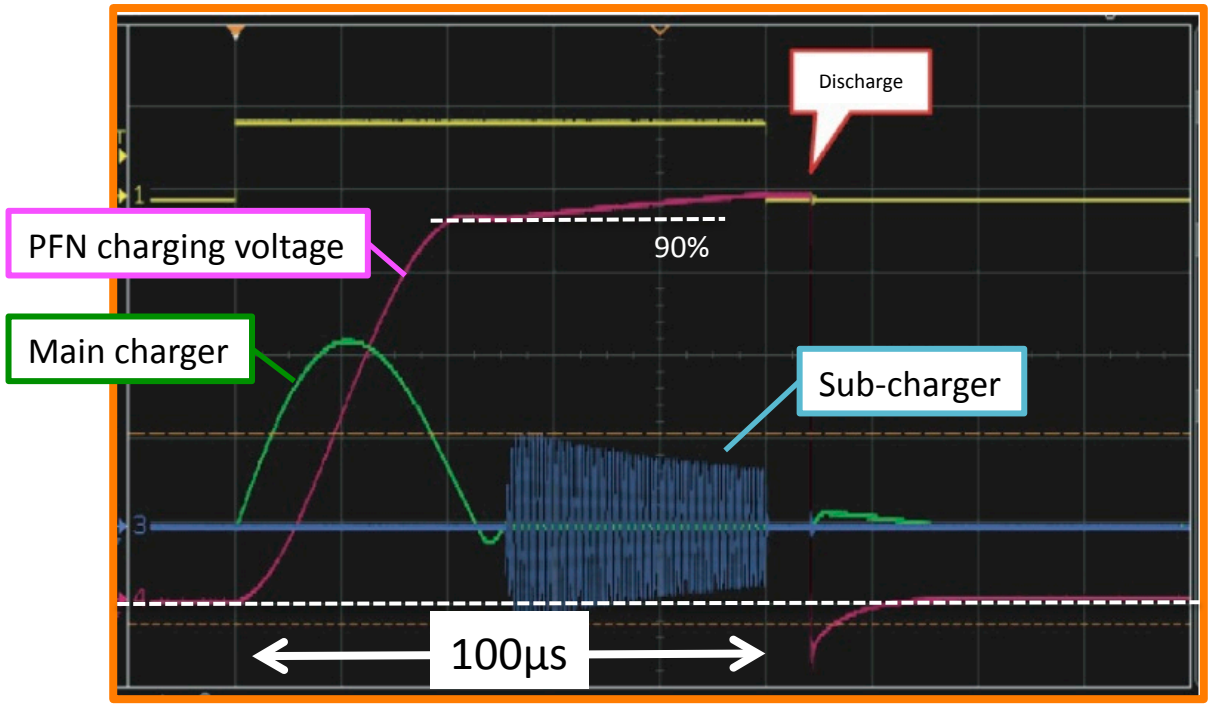
Fast & Precision Charging and Full-Time Charging of Kicker System

(for extraction of RI after 2000 turns (0.7ms)
for accepting RIs unpredictably produced)

Hybrid Charging System

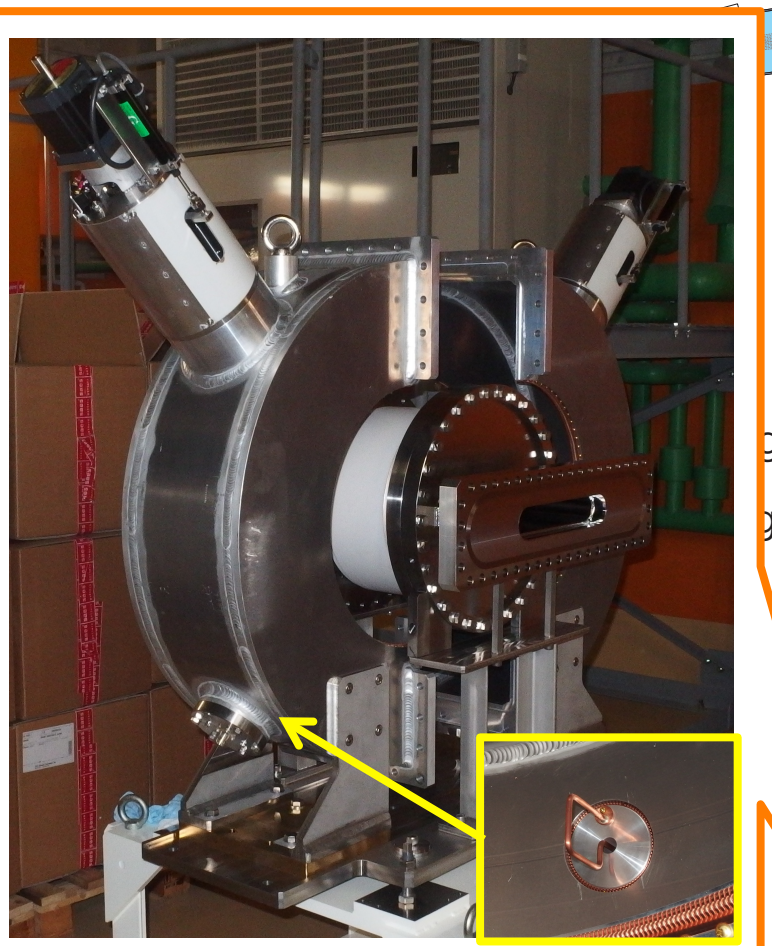
Main Charger : 90% charging

Sub-Charger : 10% charging & keep charging voltage ±1%

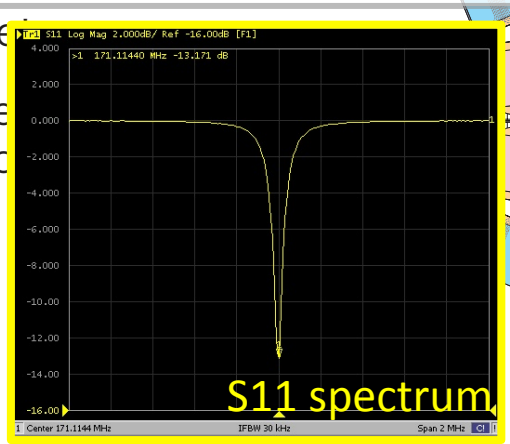


Highly-Sensitive Beam Diagnostic Devices I

Cavity type Schottky pick-up



Resonance frequency	172MHz (TM_{010})
Harmonic number	61
Tuning range	±0.5MHz
Q value	5365 (designed)/6100(actual)
Shunt impedance	276kΩ (designed)
Gap	40mm
Ceramic tube	290mmΦ, 10mm thickness

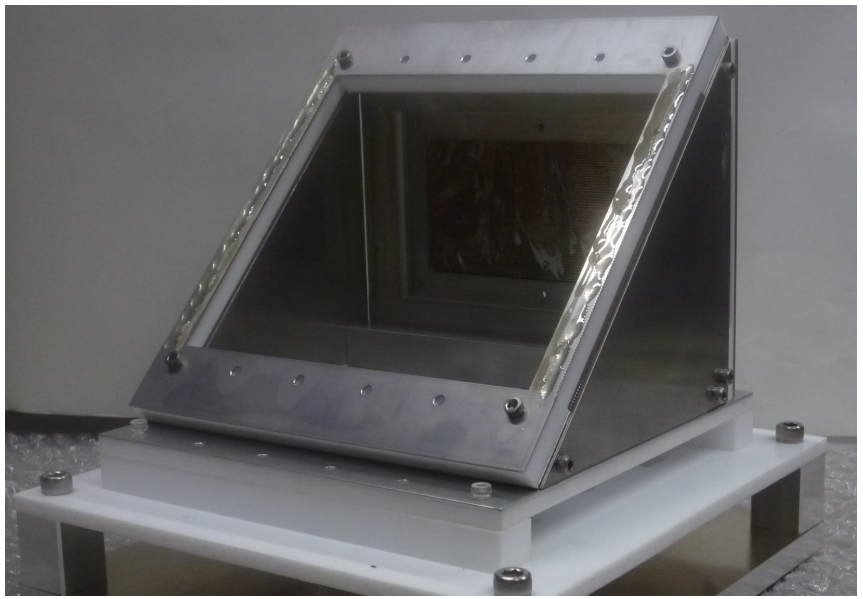


S11 spectrum

Single particle (q>15)
circulation is detectable

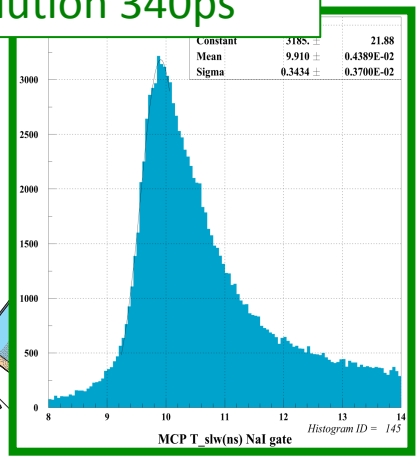
Highly-Sensitive Beam Diagnostic Devices II

C-Foil Timing Monitor



Monitor for first 1000 turns
60μg/cm² C foil
MCP secondary electron detector
Window size : 100×50 mm²
Position sensitivity : less than 10mm
Efficiency : 75 %

Test with ^{84}Kr 200MeV/u
Time resolution 340ps



R3 Construction Status

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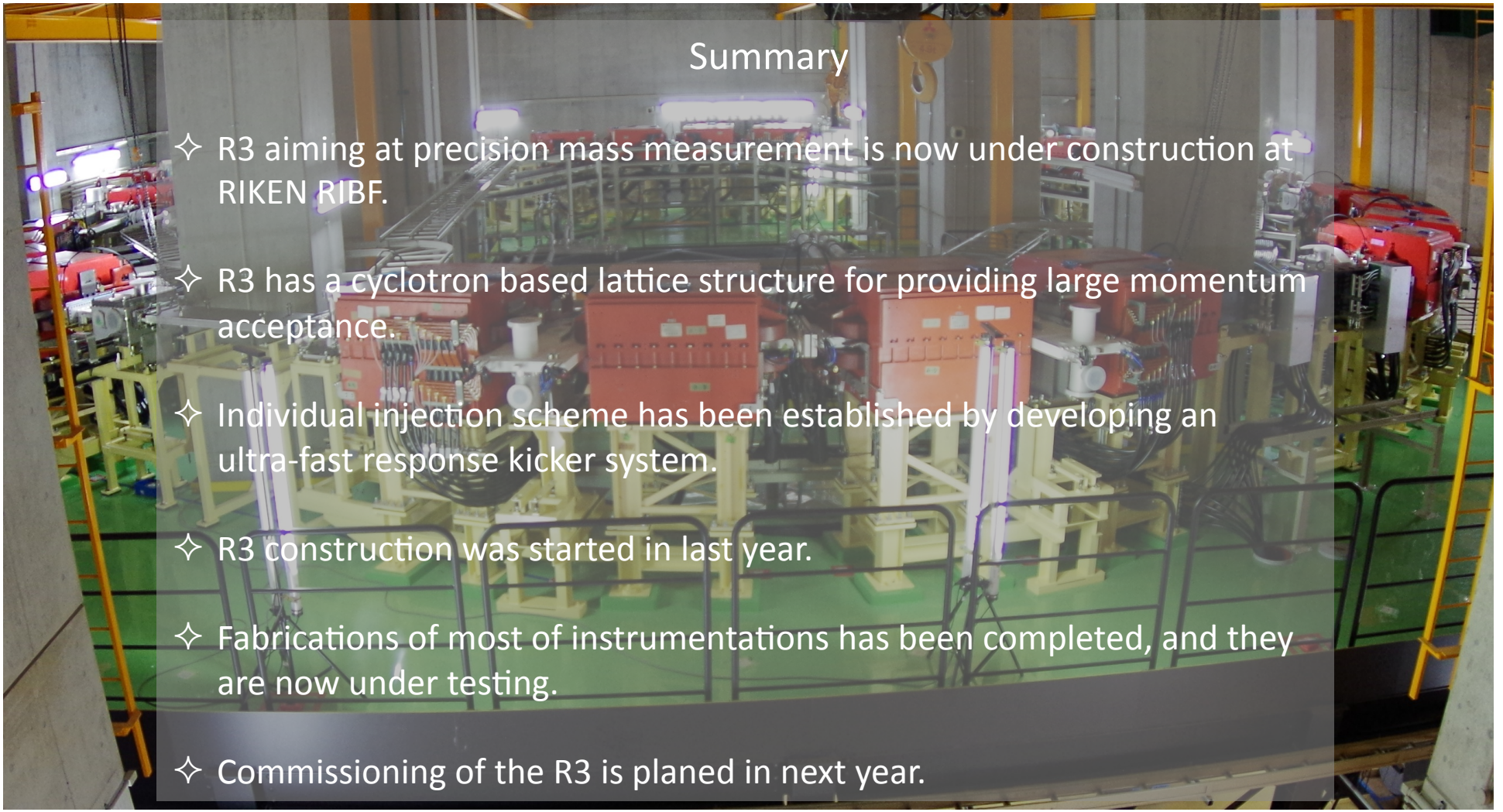
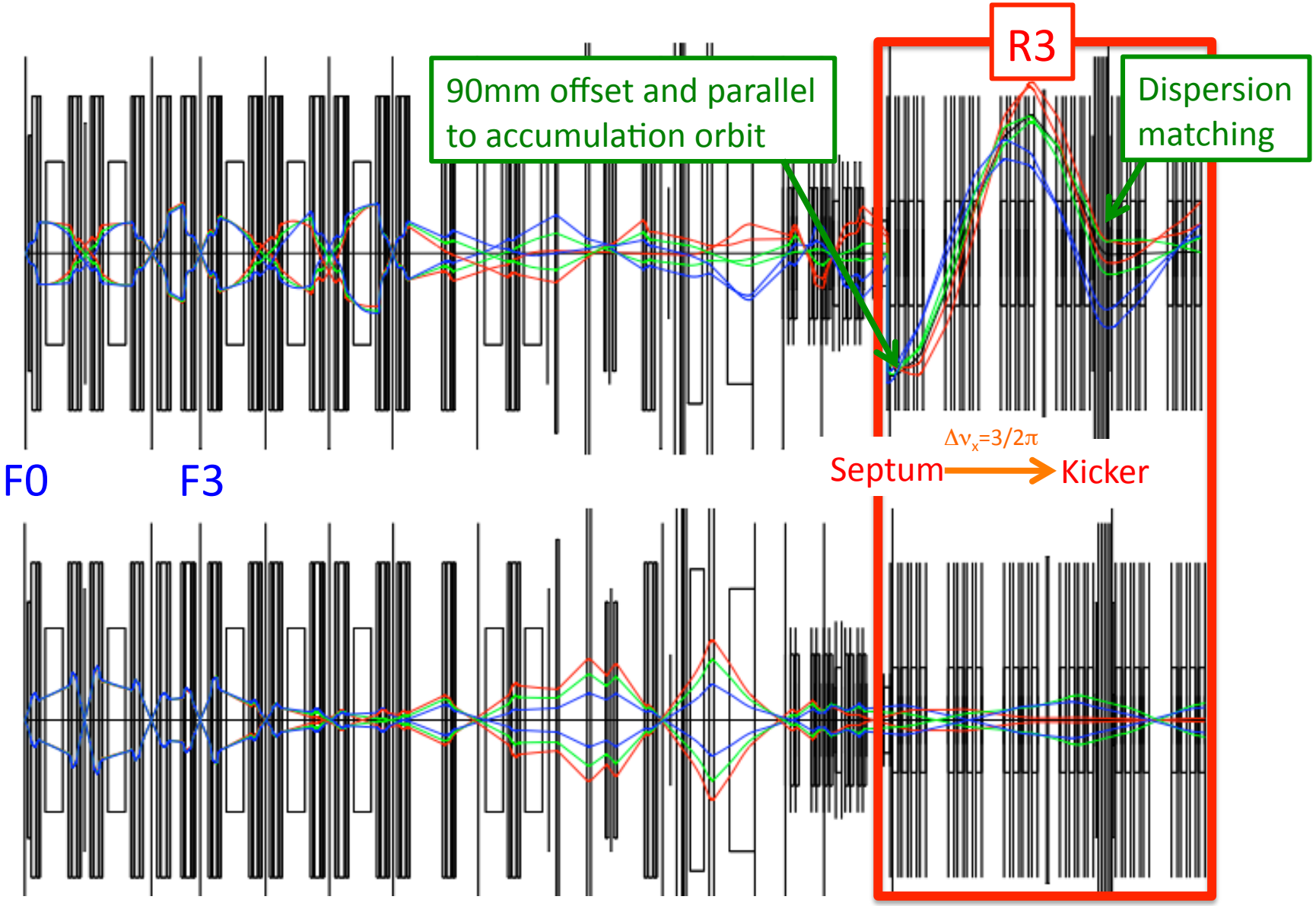


Summary

- ✧ R3 aiming at precision mass measurement is now under construction at RIKEN RIBF.
- ✧ R3 has a cyclotron based lattice structure for providing large momentum acceptance.
- ✧ Individual injection scheme has been established by developing an ultra-fast response kicker system.
- ✧ R3 construction was started in last year.
- ✧ Fabrications of most of instrumentations has been completed, and they are now under testing.
- ✧ Commissioning of the R3 is planed in next year.

Optics of Injection Line and R3



High-Precision and Fast Mass Measurement

Methods

① Ion-Trapping Based Method

② Schottky Mass Spectrometry

$\Delta m/m < 1$ ppm, $T_{measure} > 1$s

③ Isochronous Mass Spectrometry → $\Delta m/m > 10$ ppm, $T_{measure} \sim$ ms

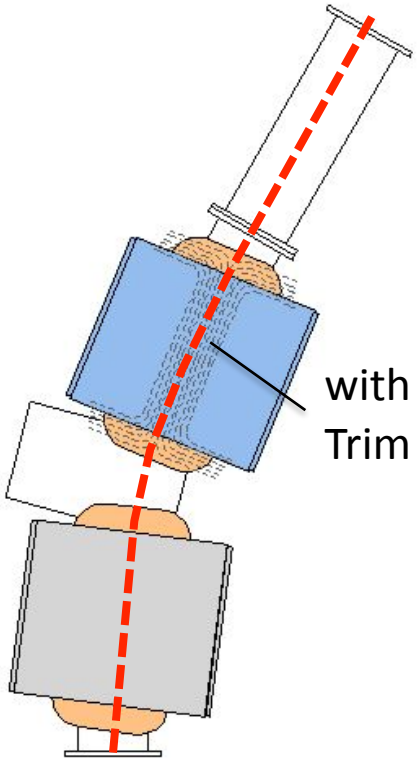
Isochronous Mass Spectrometry at Cyclotron Type Storage Ring

for precision measurement

- Providing large momentum acceptance
- Velocity measurement

Calculation of Isochronous Field

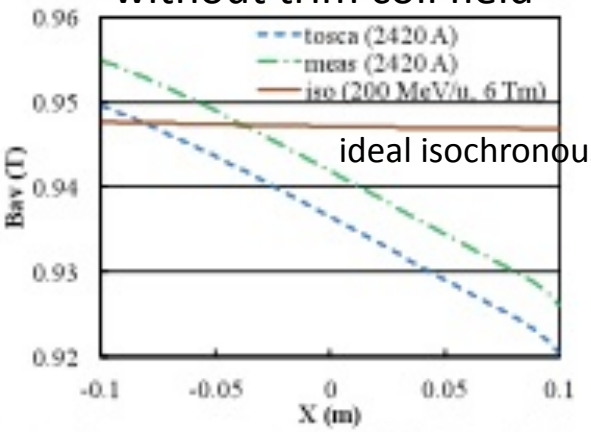
Half of a sector



with
Trim coils

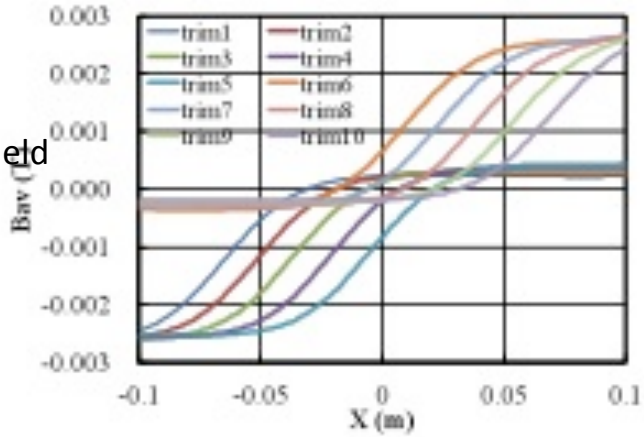
Averaged magnetic field $B_{av} = \dfrac{\int_s B_z ds}{\int_s ds}$

without trim coil field



ideal isochronous field

10 trim coil field



Deviation of tuned B_{av} from ideal isochronous field