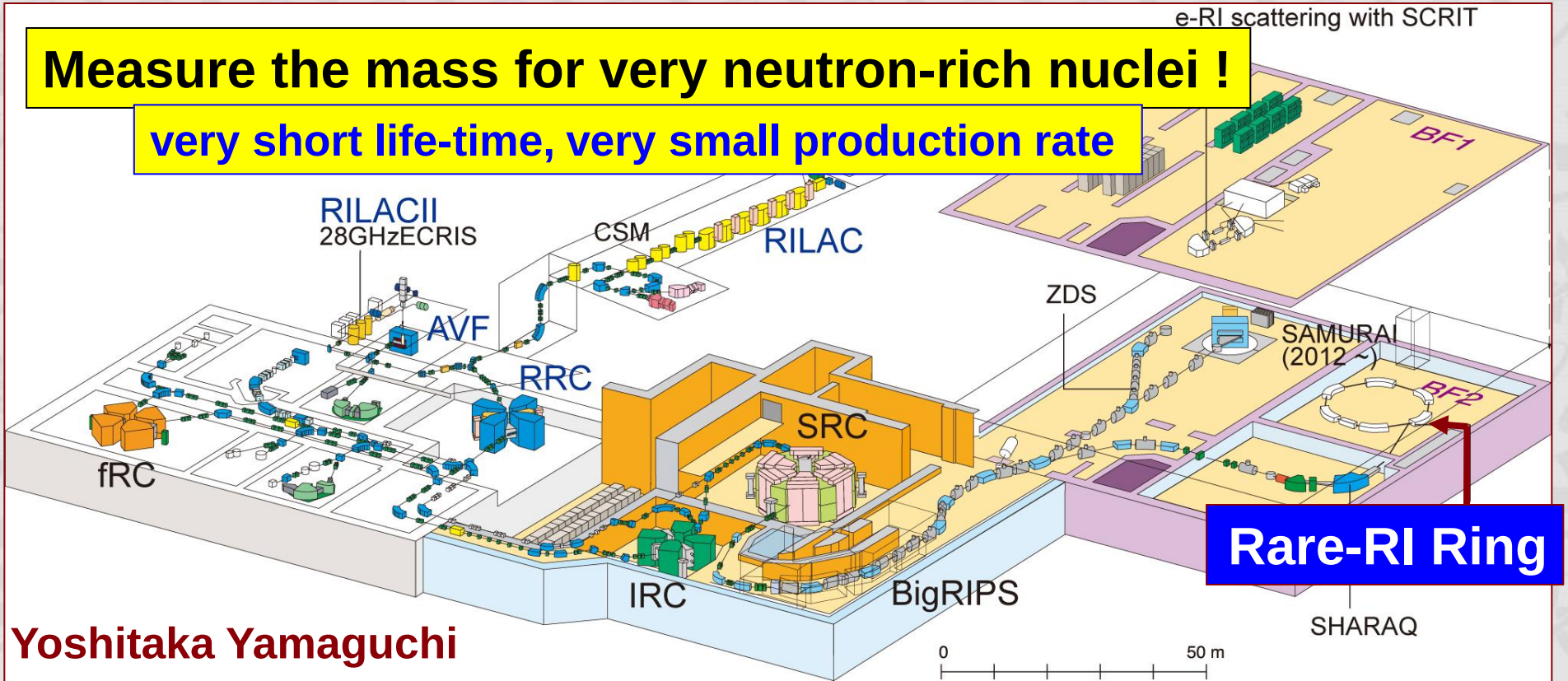
Construction of Rare-RI Ring at RIKEN RI beam factory

1. Introduction
   concept, principle, scheme
2. Kicker system
3. Trim coil
4. Construction status
5. Summary

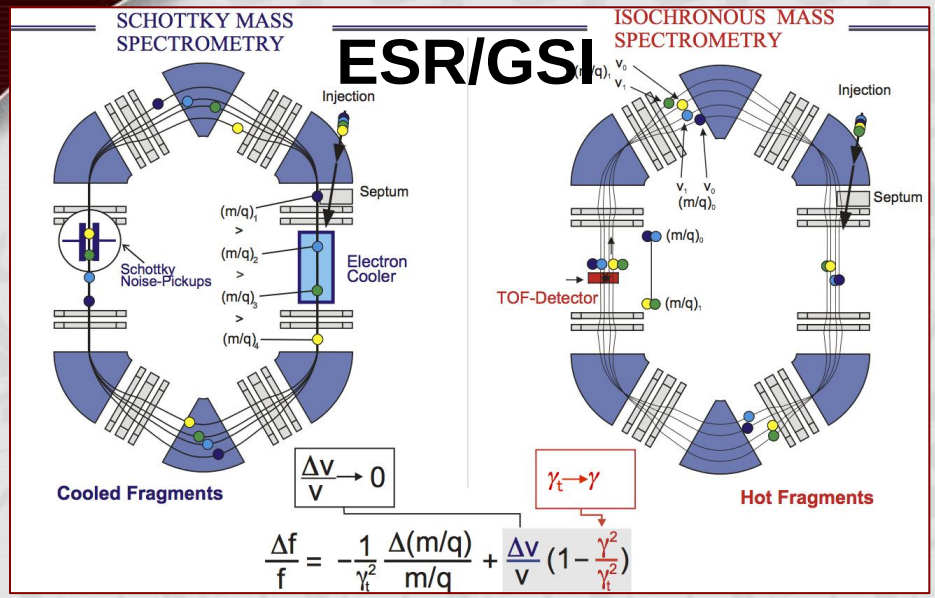
Measure the mass for very neutron-rich nuclei !

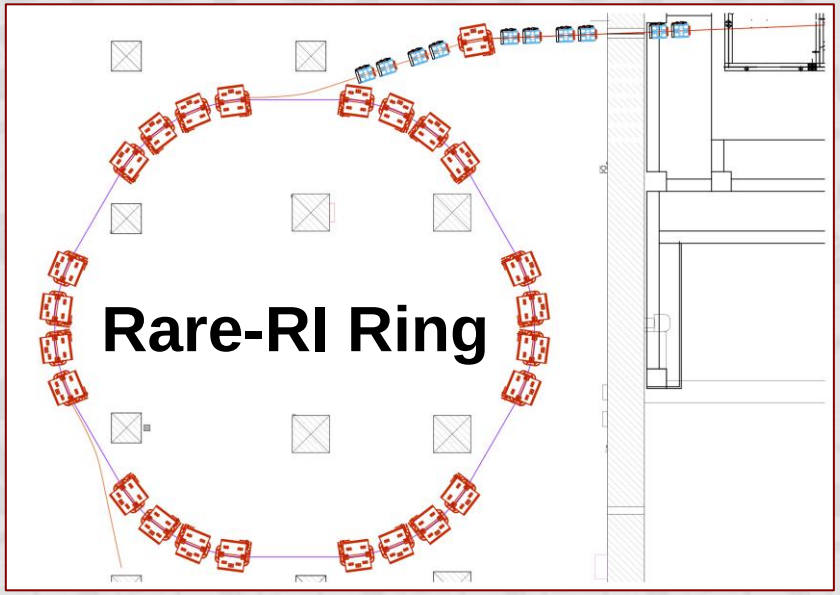
very short life-time, very small production rate



Yoshitaka Yamaguchi

Concept





	ESR/GSI (IMS)	Rare-RI Ring
Measurement time	< 1 ms	< 1 ms
δm/m	~10^{-5}	~10^{-6} (goal)
m/q acceptance	10^{-2}	10^{-2}
Momentum acceptance	10^{-3}	10^{-2}
Particle ID	No	Possible

Principle

Based on $f_c = \frac{1}{2\pi}\frac{qB}{m}$ **cyclotron frequency**

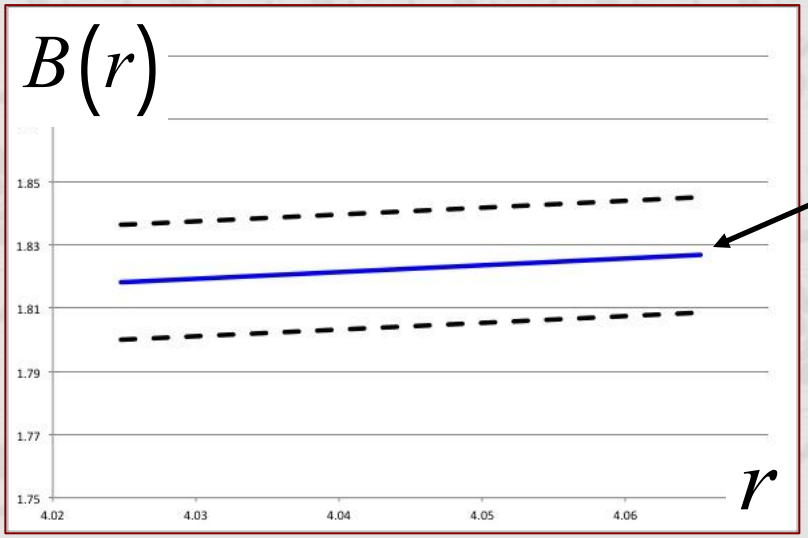
$$T = 2\pi\frac{m}{q}\frac{1}{B}\gamma = 2\pi\frac{m}{q}\frac{1}{B_0}$$

Isochronous optics

$$B = B_0\gamma$$

Isochronous field for reference

$$B(r) = B_0\gamma = \frac{B_0}{\sqrt{1-\beta^2}} = \frac{B_0}{\sqrt{1-(qrB_0/m_0c)^2}} = \frac{B_0}{\sqrt{1-(\beta_0 r/r_0)^2}}$$



Adjustment with trim coil

$\delta B_{(r)}/B_{(r)} \sim 10^{-6}$ **(goal)**

Monitoring B_0 by NMR probe

Principle

Mass is determined relatively.

$$\frac{m_1}{q_1} = \frac{m_0}{q_0} + d\left(\frac{m_0}{q_0}\right)$$

$$\frac{m_1}{q_1} = \left(\frac{m_0}{q_0}\right)\frac{T_1}{T_0}\frac{g_0}{g_1} = \left(\frac{m_0}{q_0}\right)\frac{T_1}{T_0}\sqrt{\frac{1-b_1^2}{1-\left(\frac{T_1}{T_0}\right)^2 b_1^2}}$$

$$\frac{d(m_1/q_1)}{m_1/q_1} = \frac{d(m_0/q_0)}{m_0/q_0} + \frac{d(T_1/T_0)}{T_1/T_0} + k\frac{db_1}{b_1} \quad \Rightarrow \quad 10^{-6}$$

$$k = -\frac{b_1^2}{1-b_1^2} + \left(\frac{T_1}{T_0}\right)^2 \frac{b_1^2}{1-\left(T_1/T_0\right)^2 b_1^2}$$

reference
< 10^{-6}

measurement
< 10^{-6}

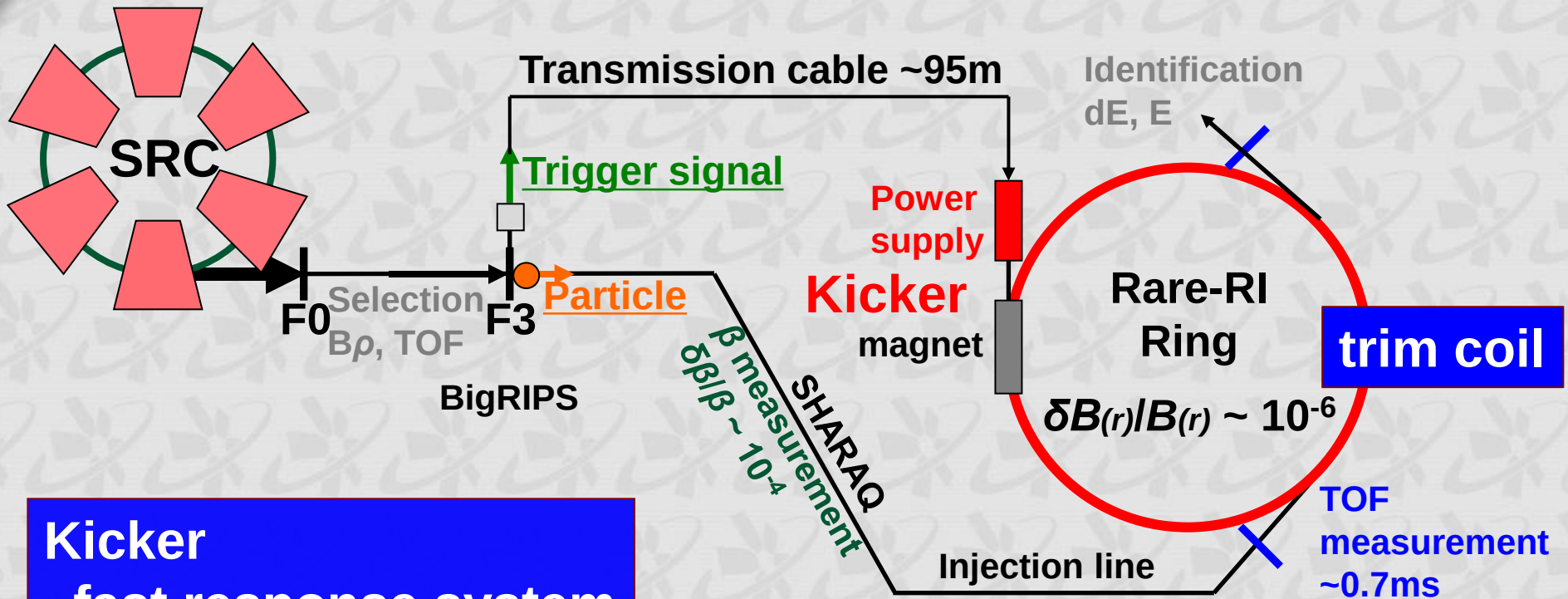
measurement
$\beta \sim 10^{-4}$

k **~ 10^{-2}**
difference of T ~ 1%
(difference of *m/q* ~ 1%)

Scheme for mass measurements

Self-trigger individual injection

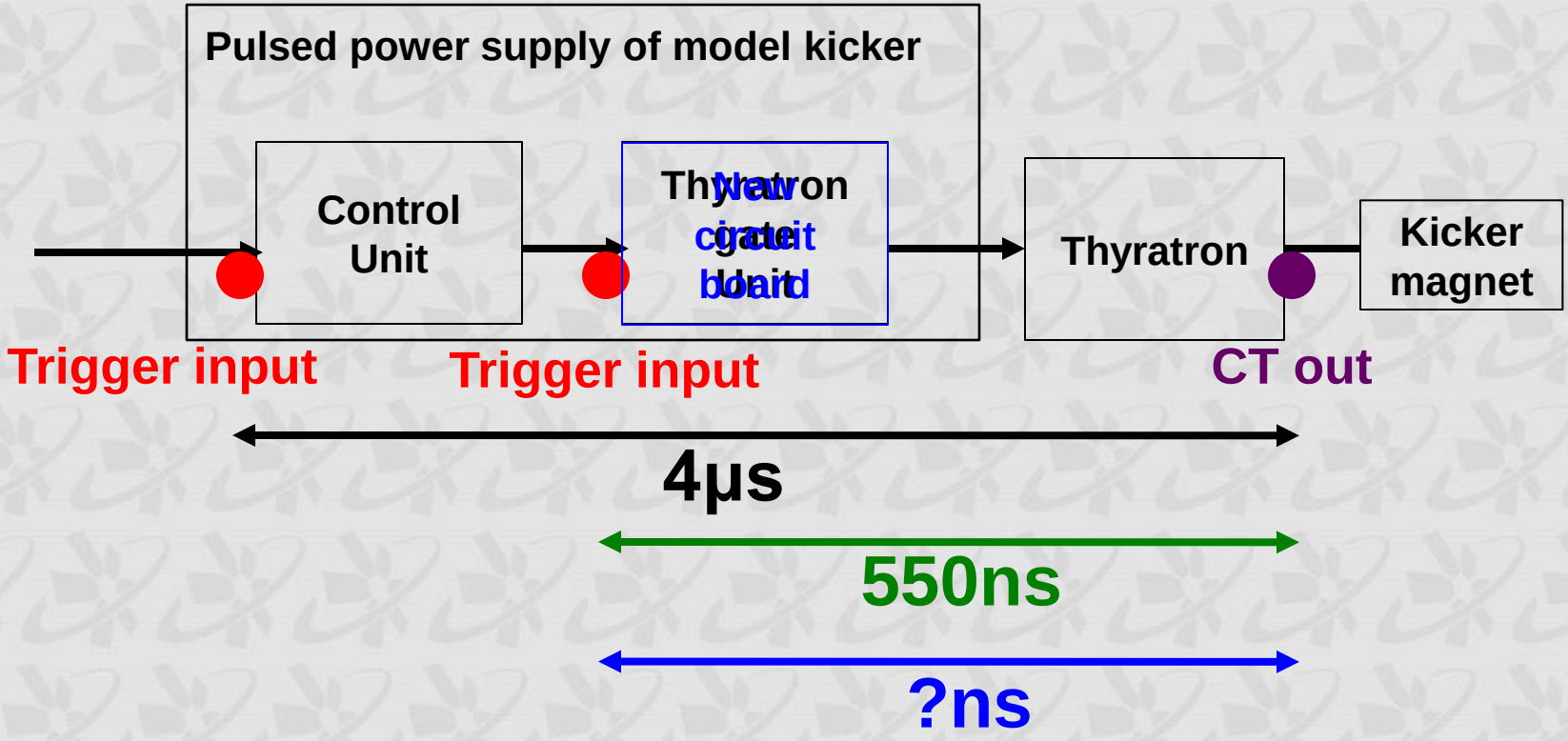
Meshkov et al.:
Nucl. Instrum. Methods Phys. Res. A 523, 262 (2004).



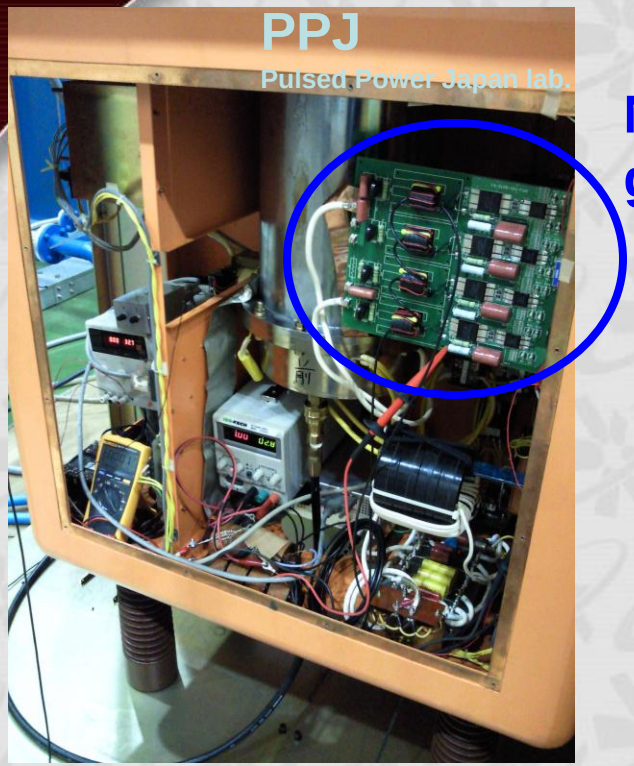
Kicker
- fast response system
- fast charging system

Fast response kicker system

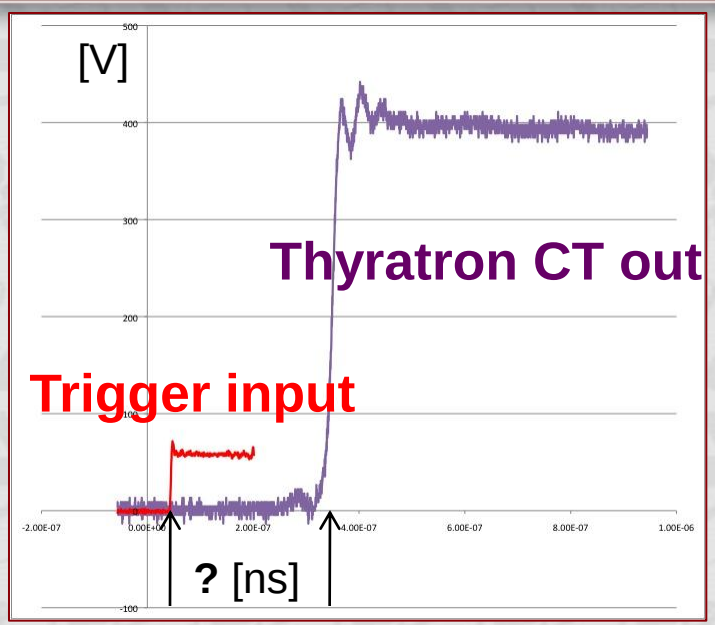
Response time of kicker power supply < 290ns
to establish the self-trigger individual injection method

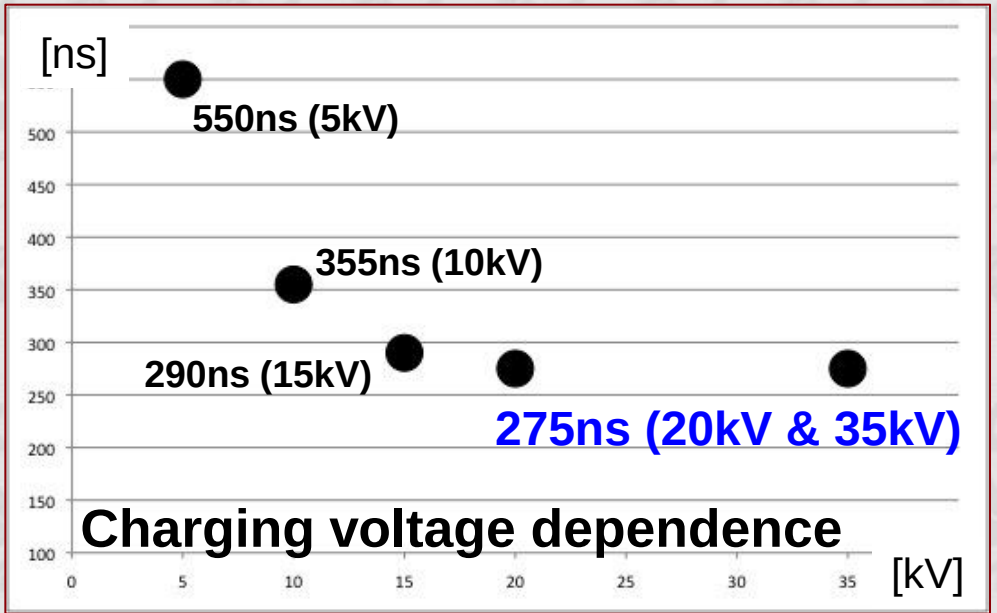


Fast response kicker system



New thyratron gate board

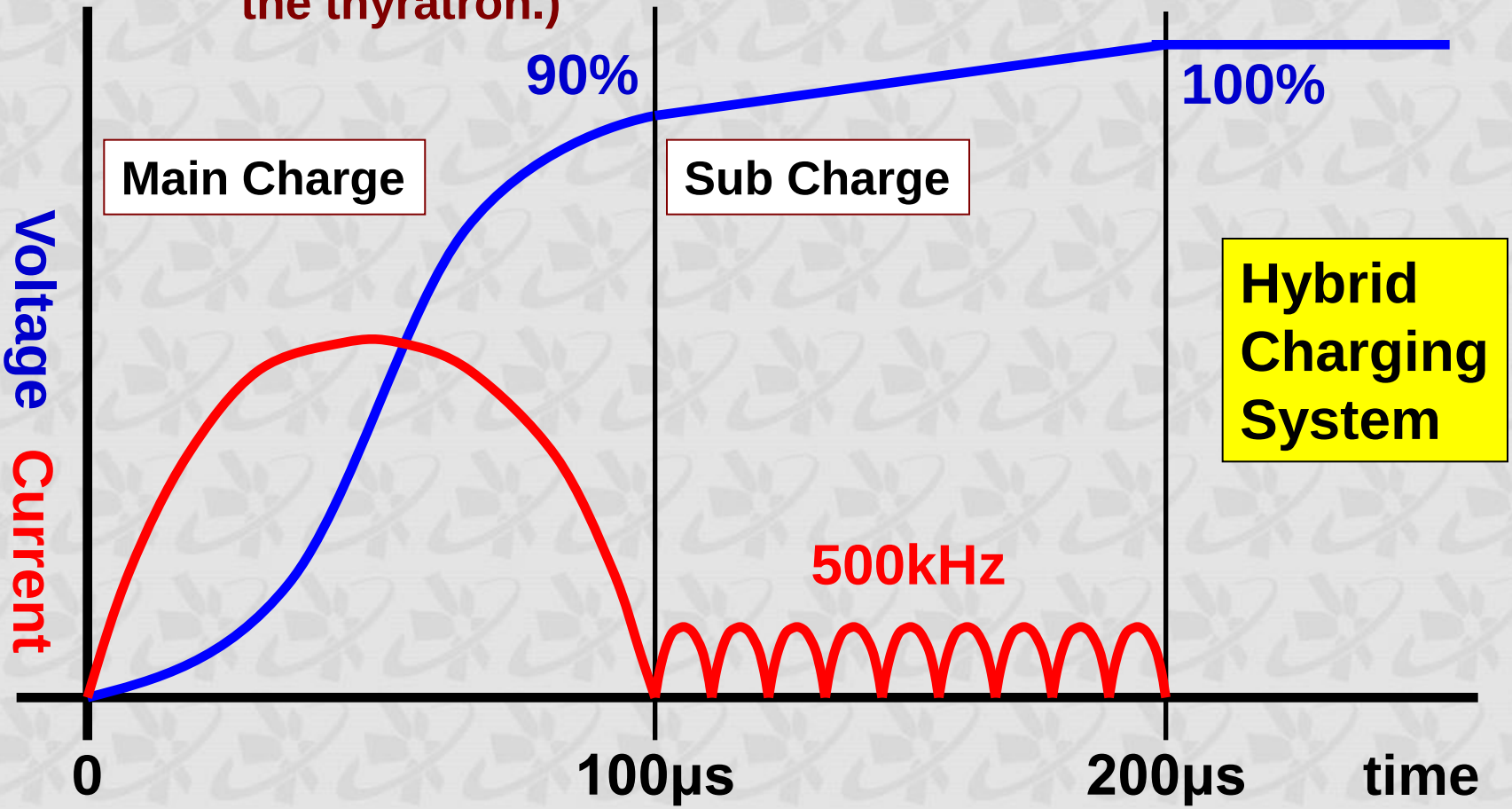




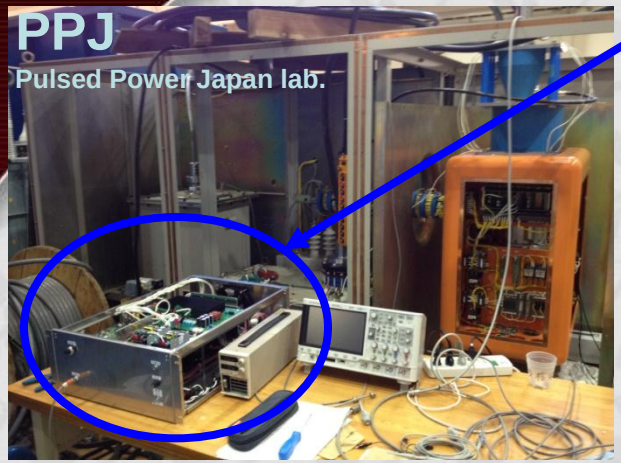
2010

Fast charging kicker system

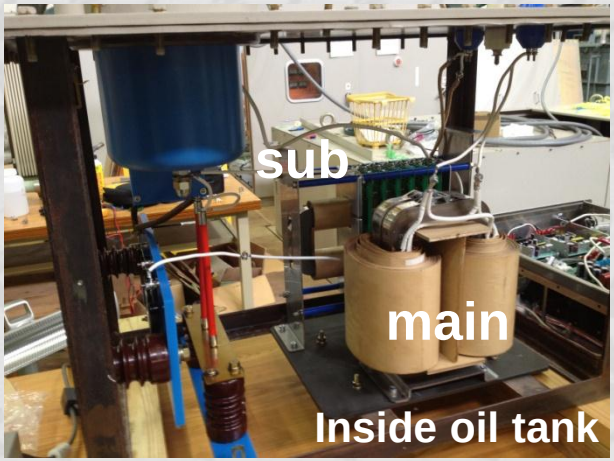
Charging time < 200μs to extract a particle from the ring
~0.7ms (2000 turn) later by using same kicker.
(The remaining 0.5ms is assigned to the recovery time of the thyratron.)

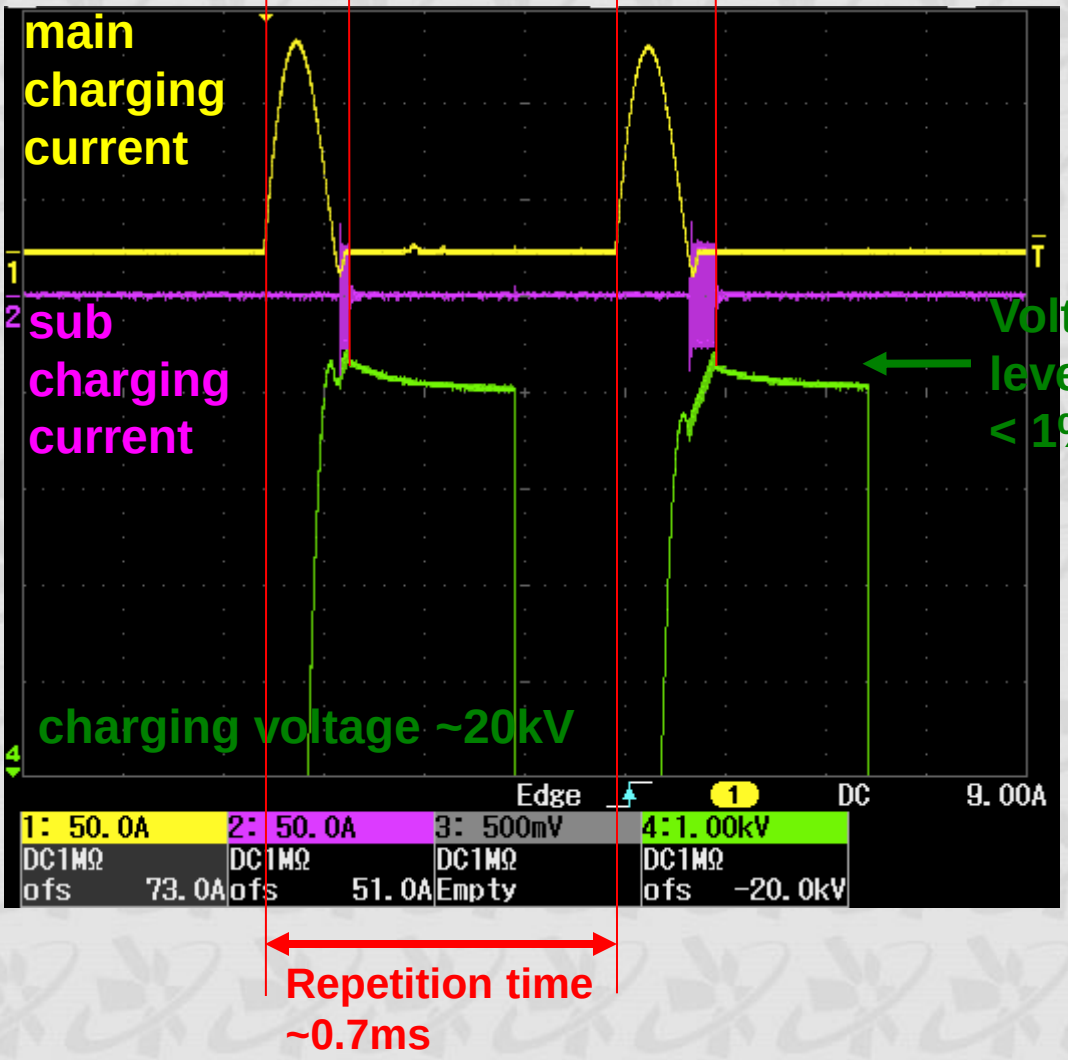


Fast charging kicker system

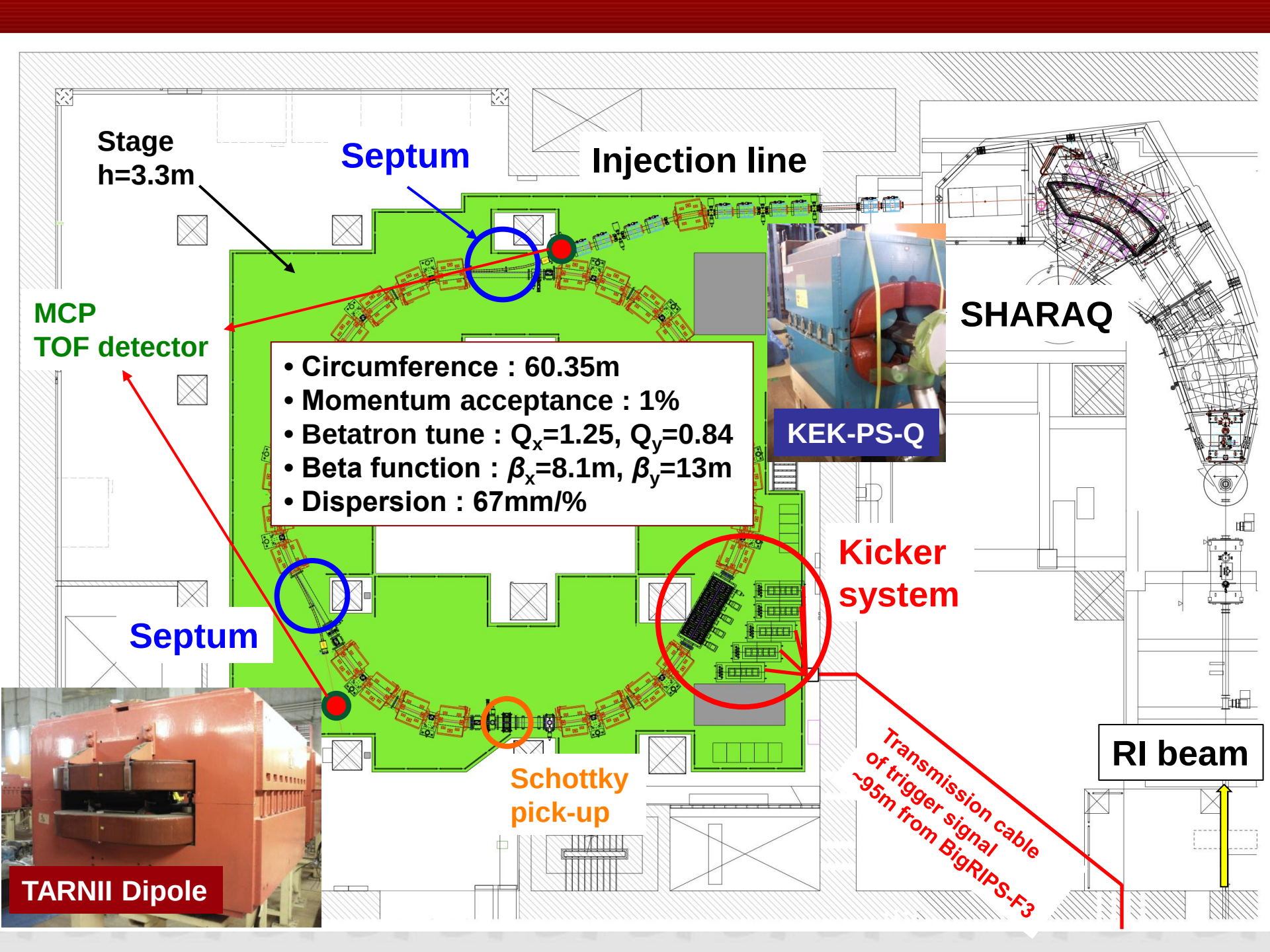


Control unit

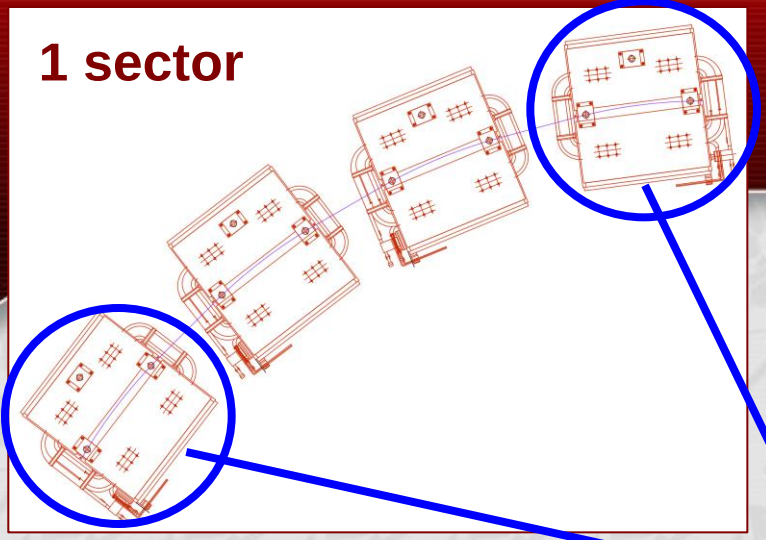




2011

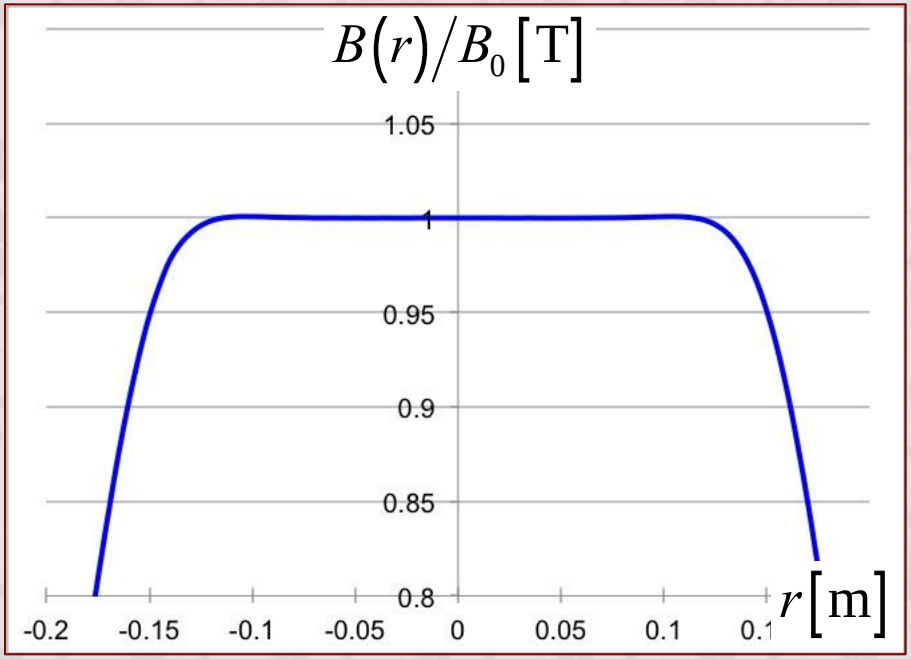

Stage
h=3.3m
Septum
Injection line
MCP
TOF detector
• Circumference : 60.35m
• Momentum acceptance : 1%
• Betatron tune : Q_x=1.25, Q_y=0.84
• Beta function : β_x=8.1m, β_y=13m
• Dispersion : 67mm/%
KEK-PS-Q
SHARAQ
Kicker
system
Septum
Schottky
pick-up
Transmission cable
of trigger signal
~95m from BigRIPS-F3
RI beam
TARNII Dipole

Isochronous design



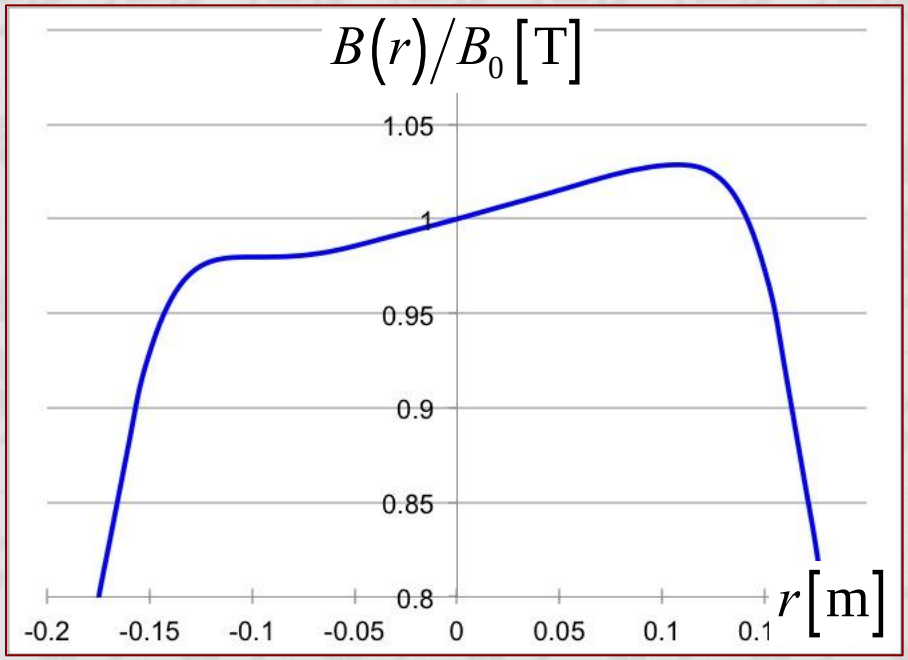
Put trim coil into outer 2 dipoles to adjust an isochronism.

without trim coil



Measurement data

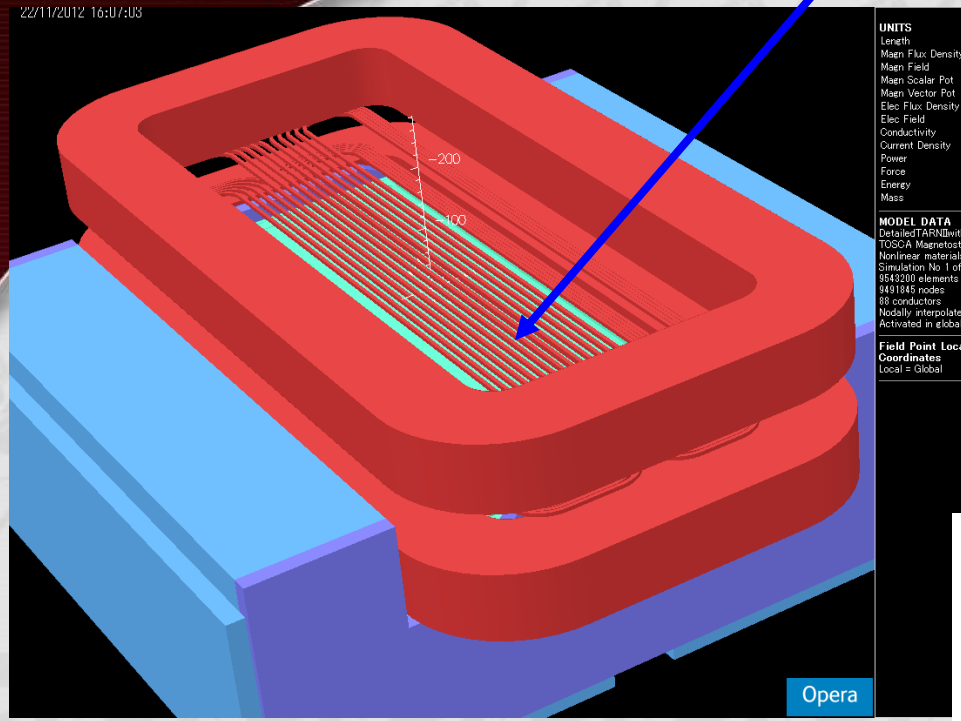
with trim coil

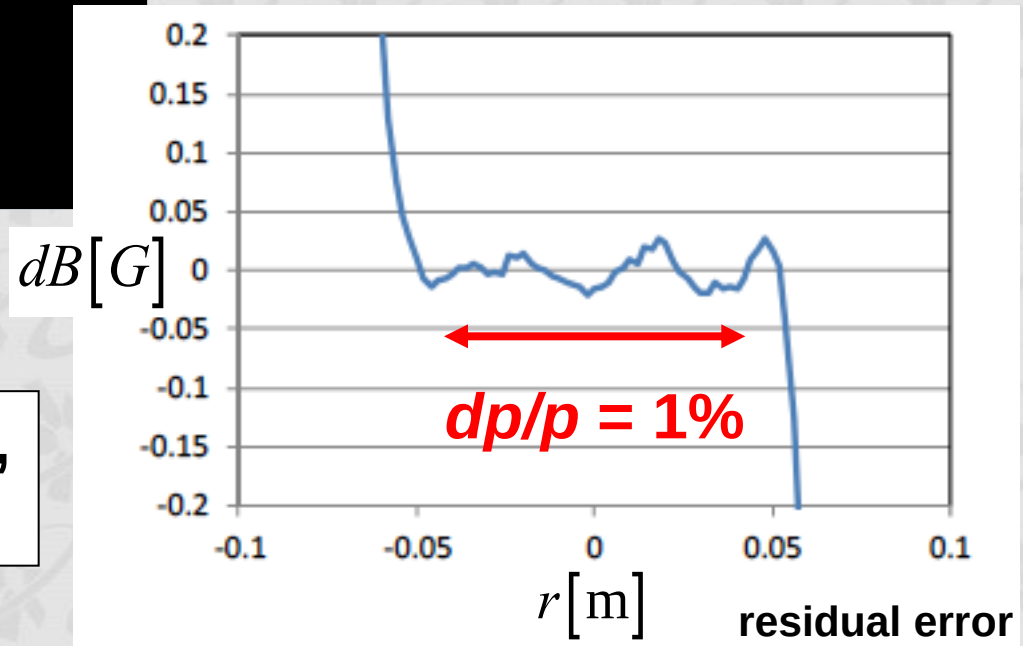


TOSCA result

Isochronous design

10 trim coils



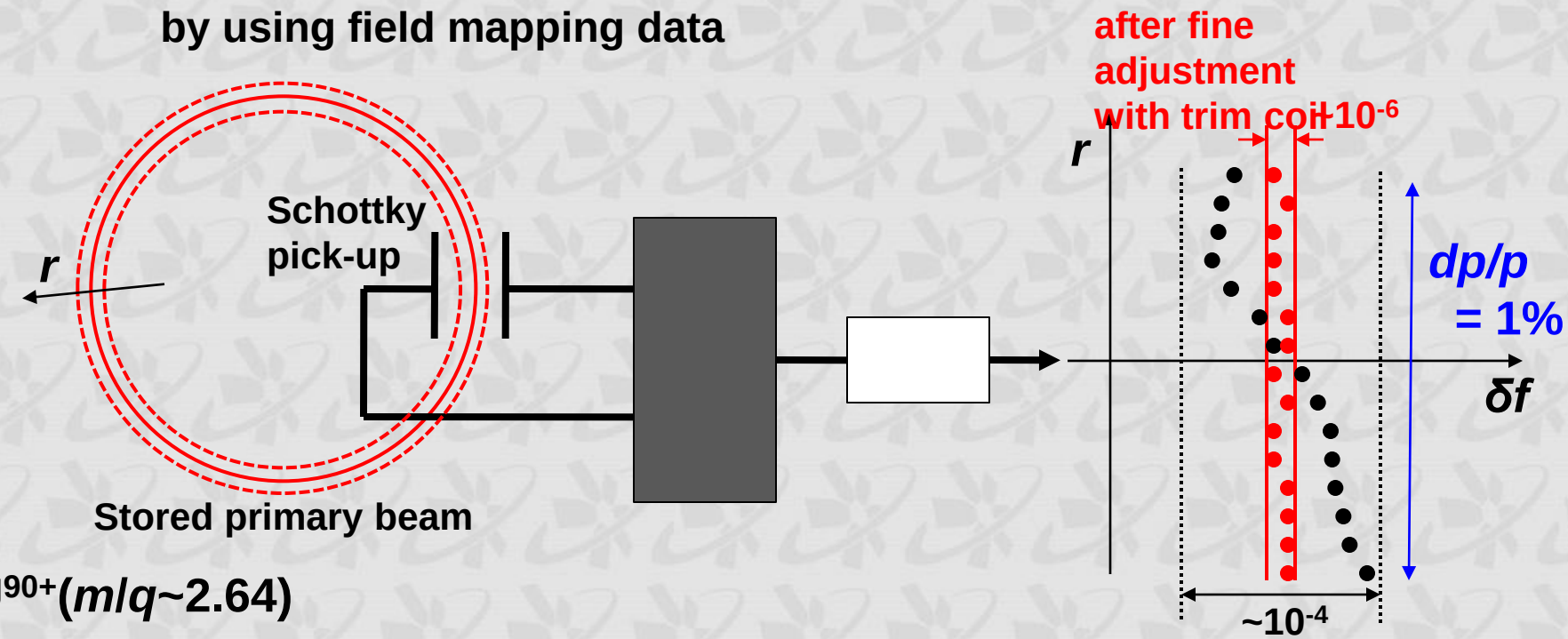


Since central field B_0 is 1.5T, isochronism is ~2×10^{-6}.

How to check the isochronism ?

1. Circulation of energy-degraded (~200 *A* MeV) primary beam (~10^3/circulation)
2. Measurements of frequency by schottky pick-up system

Isochronism ~10^{-4}
by using field mapping data



$^{238}U^{90+}$(*m*/*q*~2.64)

Construction status

Construction status

Construction status

Construction status

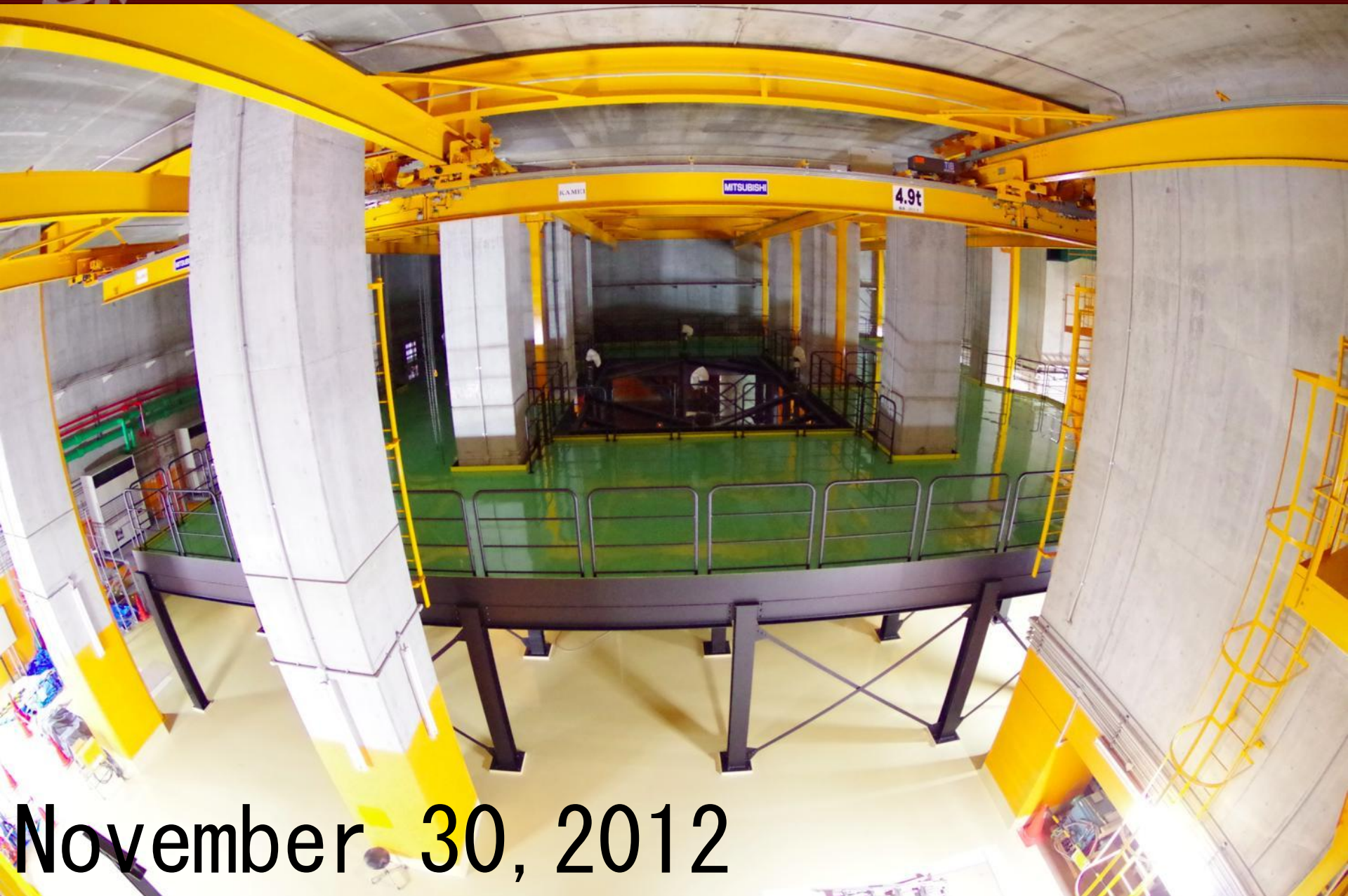
Construction status

Construction status

Construction status

October 27, 2012

Construction status



November 30, 2012

Schedule

2012 / 12 ~ 2013 / 3	2013	2014	2015
Construction	**Construction / Preparation**	**Preparation / Commissioning**	**Mass measurements**
~~・Overhead traveling crane~~ ~~・Stage~~ ・Water system ・AC generator ・DC power supply ・Kicker magnets ・Septum magnets ・Trim coil ・Beam monitors ・Vacuum chamber ・Vacuum pumps ・Installation ・Wiring etc…	・Magnetic field measurements → mapping data ・Chamber baking ・Beam monitor calibration ・R&D Schottky system Kicker system TOF detector ・Connection to SHARAQ ・Circuits ・Control etc…	Primary beam injection Check of isochronism	^{78}Ni & nuclei near to A=80

Summary

- **Construction of Rare-RI Ring started from this August.**

- **We realize the self-trigger individual injection method for the first time.**

  (feasibility study for the kicker system was completed !)

- **We measure the mass of Rare-RI with good resolution 10^{-6}.**

  Key issue :

  1. establishment of the adjustment technique with trim coil

  2. keep the form of the isochronous magnetic field

Thank you very much for your attention !

Rare-RI Ring Collaboration

Spokespersons: T.Uesaka (RIKEN) and A.Ozawa (Univ. of Tsukuba)
Project manager: M.Wakasugi (RIKEN)
Research group:

A.Ozawa (Co-leader), T.Uesaka (Co-leader),
T.Yamaguchi, T.Suzuki, F.Suzaki (Saitama Univ.)
Y. Abe, T.Komatsubara, D.Nagae (Univ. of Tsukuba)
J.Zenihiro (RIKEN), Y.J.Yuan, H.S.Xu (IMP),
T.Ohtsubo (Niigata Univ.)

Detector development group:

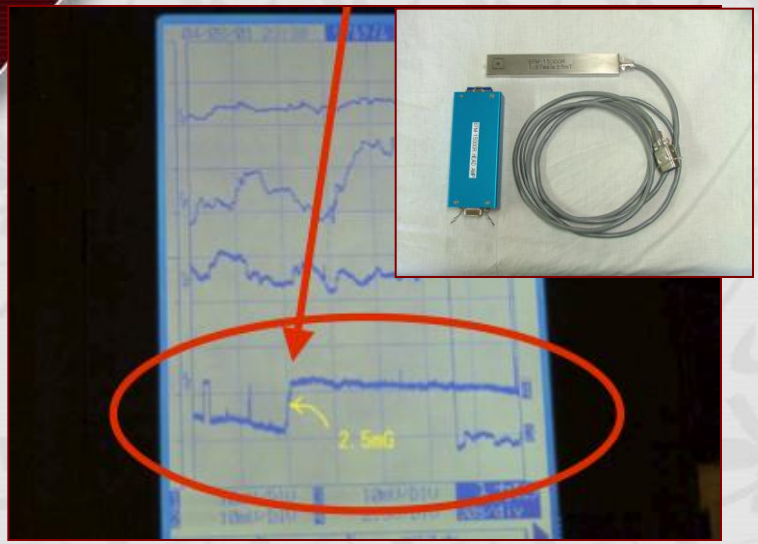
T.Yamaguchi (Leader), Y. Abe, D.Nagae, J.Zenihiro

Construction group:

M.Wakasugi (Leader), Y.Yamaguchi, O.Kamigaito, N.Fukunishi,
J.Ohnishi, K.Kumagai, M.Kase, T.Fujinawa, T.Kubo, N.Inabe,
K.Yoshida, K.Kusaka, H.Sato (RIKEN),
T.Kikuchi, A.Tokuchi (Nagaoka Univ. of Technology)

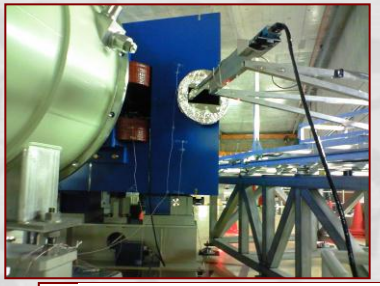
High-precision NMR probe

Developed for MRI
2.5mG observed in 1.5T

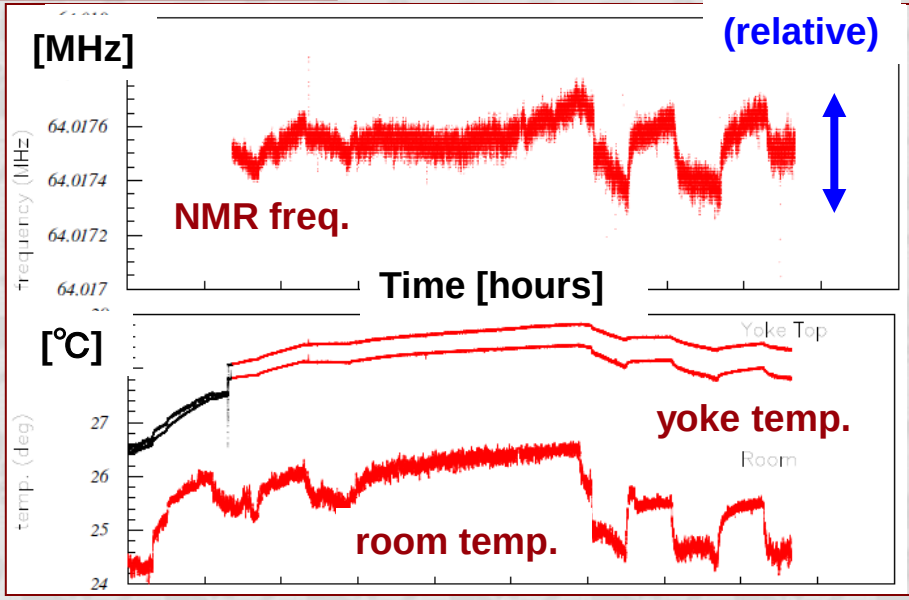


Precision ~10^{-7}

Checking the long-term field stability of ZDS-D8 (~180 hours)



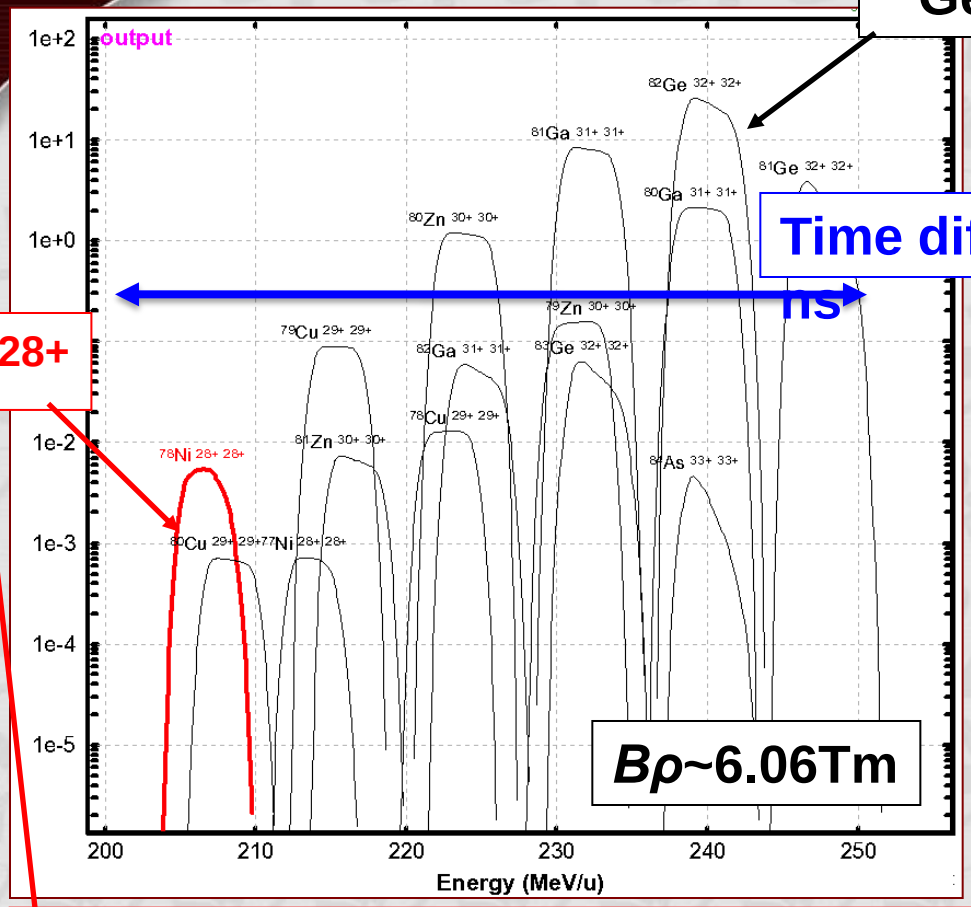
RMS
3 x 10^{-6}
(relative)



Long-term field stability was affected
by room temperature (yoke temperature) mainly.
Keep K4 room temperature!

2008

^{78}Ni



$^{82}Ge^{32+}$

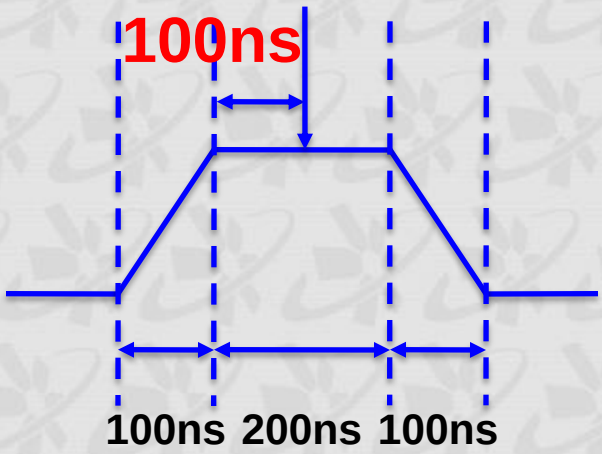
Time difference: 75 ns

$^{78}Ni^{28+}$

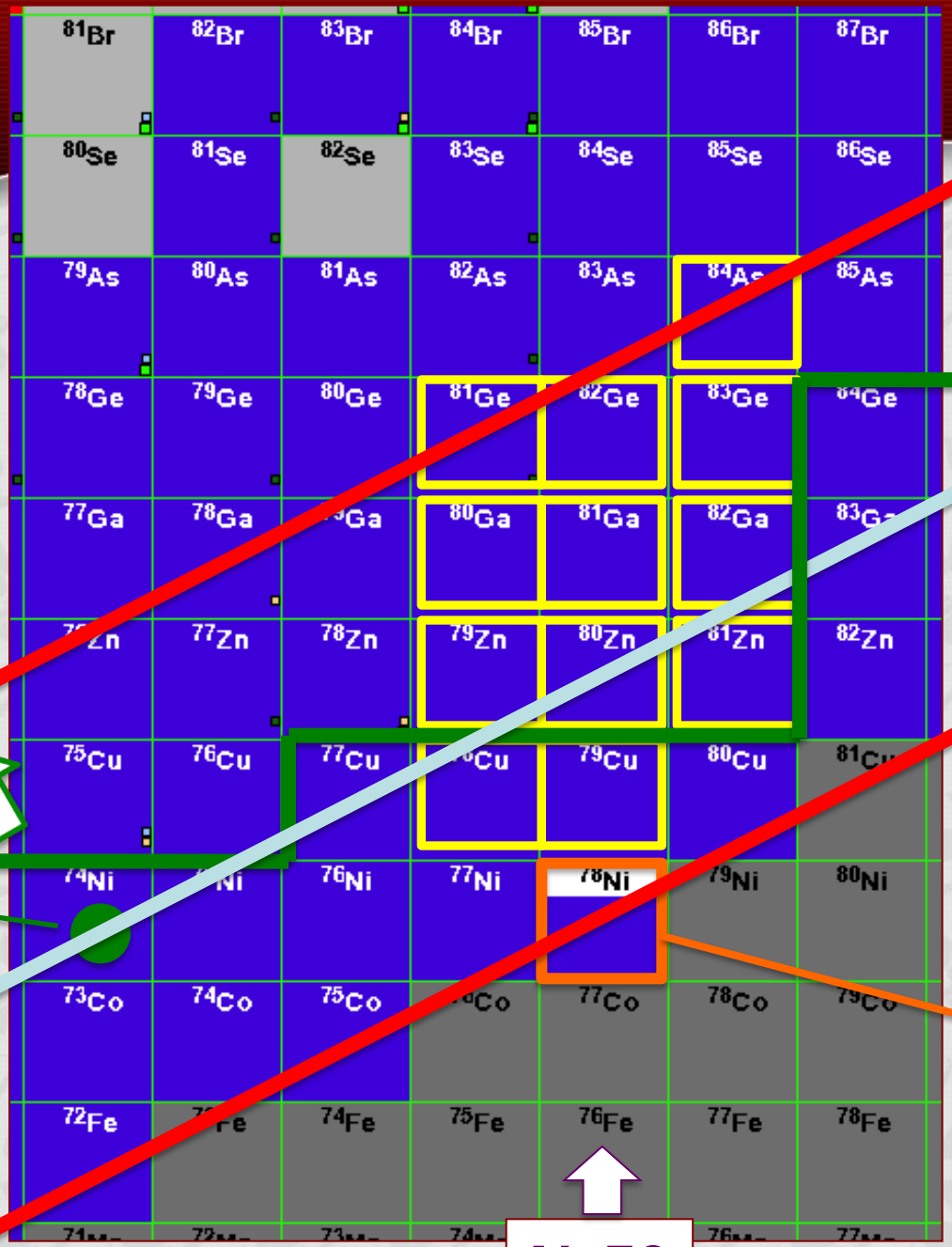
~0.005cps/pnA @BigRIPS (full acceptance)

Possible kicker timing

$^{78}Ni^{28+}$



^{78}Ni



~0.1 cps

~3 events/day

Known mass (AME2011)

Measured in NSCL(2011)

m/*q*~2.64

^{78}Ni

N=50

Yield estimation of ^{78}Ni

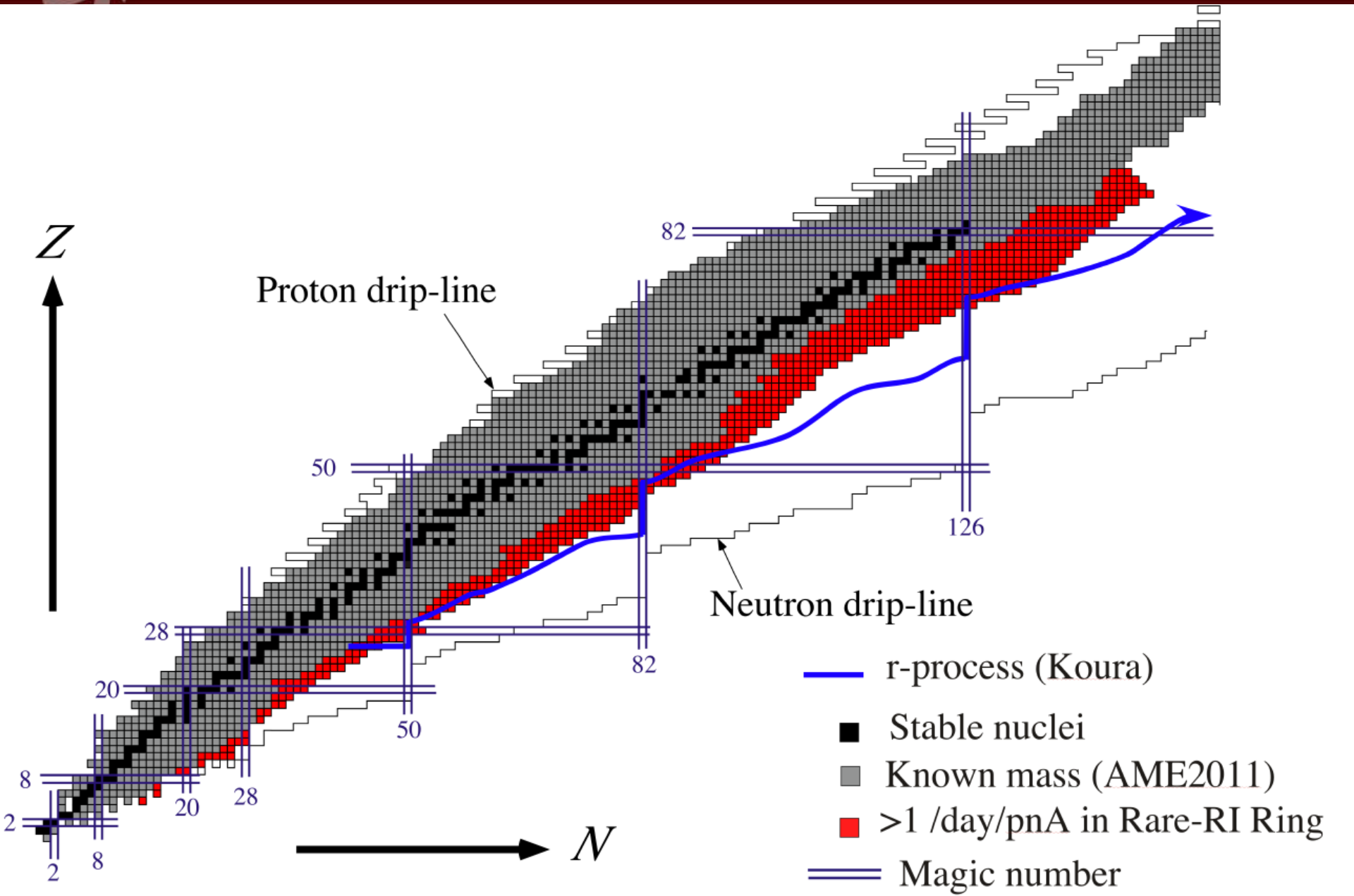
^{78}Ni : ~0.005cps/pnA @BigRIPS (full acceptance)

	Reduction factor from BigRIPS
Energy: ~290 *A* MeV → 200 *A* MeV	~0.9
Momentum acceptance 6% → 1%	1/6
Angular acceptance 80pmm mrad → ~20pmm mrad	~1/16
Transmission eff. at injection	~0.8
Total	~0.0075

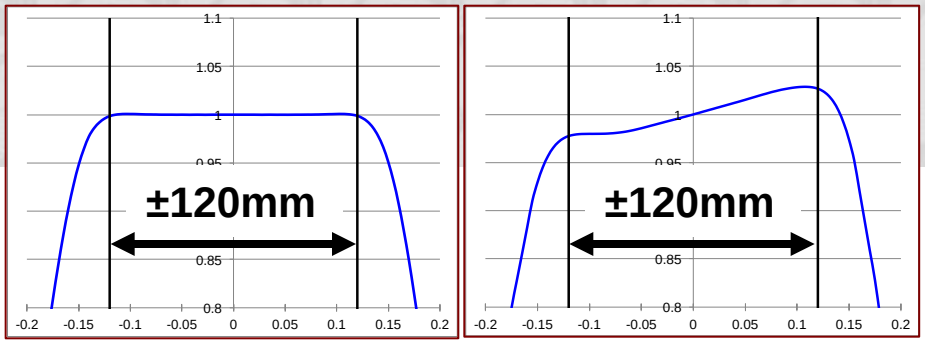
4×10^{-5} cps/pnA

~3 events/day/pnA in Rare-RI ring

Accessible area in Rare-RI Ring



Optics design for injection



a_0 = ±10mrad
(200 *A* MeV, *m*/*q*=2.78)

- 90mm outside offset
- Kick angle ~12mrad

Injection point

Fast response kicker system