PRISM R&D Status

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Outline

- What is PRISM?
- Motivation
- Design
- R&D Status
- Summary

What is PRISM?

- PRISM = Phase Rotation Intense Slow Muon Source
  - Muon intensity: 10^{11}~10^{12} /sec
    (now: ~10^{8} /sec)
  - Central Muon Momentum: 68MeV/c
  - Momentum Spread width: ±3%
    - by Phase Rotation
  - pion contamination: 10^{-18}

LOI to J-PARC

A pulsed proton beam is required

PRISM Working Group Members

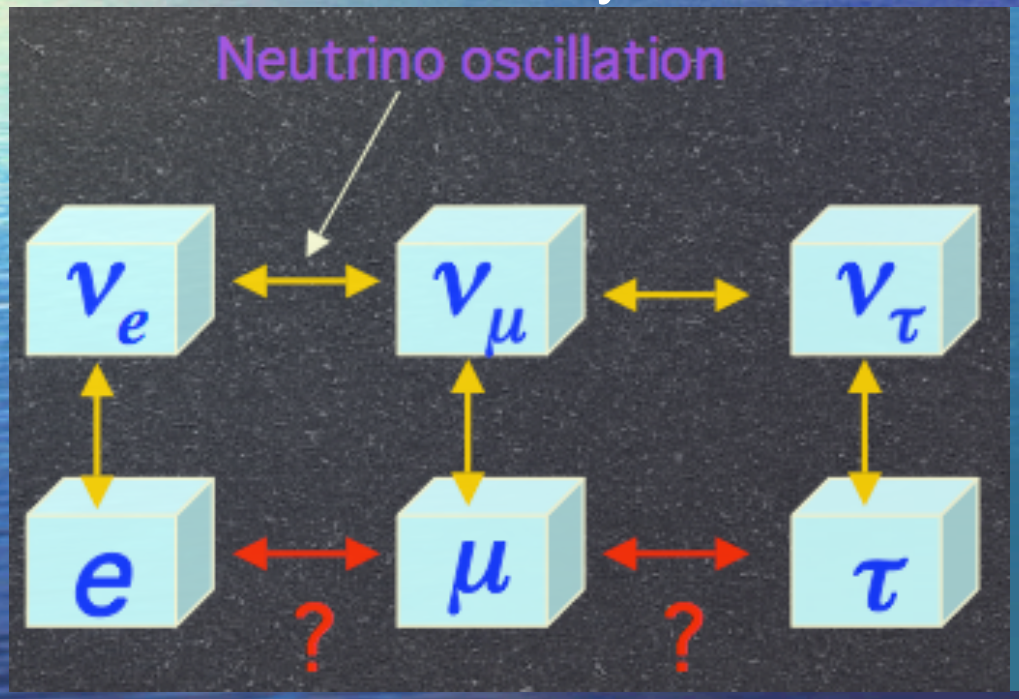
- *KEK Accelerator Laboratory*
  - Machida, Mori*, Ohmori, Yokoi
- *KEK Cryogenics Science Center*
  - Nakamoto, Ogitsu, Yamamoto
- *Kyoto Univ. Department of Physics*
  - Sasao*
- *Kyoto Univ. Accelerator Laboratory, Institute for Chemical Research*
  - Iwashita
- *Kyushu Univ. Graduate School of Engineering*
  - *Ohnishi*
- *Osaka Univ. Graduate School of Science*
  - Aoki, Kuno*, Sato, Arimoto, Yoshida, Takubo, **Kuriyama**, Nakahara, Sakamoto, Nakaoka, Horikoshi

*contact person

Why we need PRISM?

- charged Lepton Flavor Violation

Beyond the Standard Model



◆Example: $\mu^+ \rightarrow e^+\gamma$

muon flavor	-1	0
electron flavor	0	-1

Not be observed yet!

◆Example: $\mu^+ \rightarrow e^+e^-e^+$

muon flavor	-1	0
electron flavor	0	-1

Not be observed yet!

Why the Muon ?

Reaction	90 % CL upper limit
$B(\mu^+ \to e\gamma)$	4.2×10^{-11}
$B(\mu^+ \to e^+e^-e^+)$	1.0×10^{-12}
$B(\mu\ \mathrm{Ti} \to e^-\mathrm{Ti})$	6.1×10^{-13}
$B(\mu^-\mathrm{Pb} \to e^-\mathrm{Pb})$	4.6×10^{-11}
$B(\mu^-\mathrm{Ti} \to e^+\mathrm{Ca})$	1.7×10^{-12}
$B(\mu^+e^- \to \mu^-e^+)$	$G_{MM} < 3 \times 10^{-3}\ G_F$
$B(\tau \to e\gamma)$	2.7×10^{-6}
$B(\tau \to \mu\gamma)$	3.0×10^{-6}
$B(\tau \to \mu\mu\mu)$	1.9×10^{-6}
$B(\tau \to eee)$	3.3×10^{-6}
$B(K_L \to \mu e)$	5.0×10^{-11}
$B(K^+ \to \pi^+\mu^+e^-)$	4.0×10^{-11}
$B(K_L \to \pi^+\mu^+e^-)$	3.2×10^{-9}
$B(D^0 \to \mu e)$	1.9×10^{-5}
$B(D^0 \to \tau e)$	5.3×10^{-4}
$B(D^0 \to \Phi\mu e)$	3.4×10^{-5}
$B(B \to \mu e)$	5.9×10^{-6}
$B(B \to K\mu e)$	1.8×10^{-5}
$B(Z^0 \to \mu e)$	2.3×10^{-6}
$B(Z^0 \to \tau e)$	7.3×10^{-6}
$B(Z^0 \to \tau\mu)$	1.0×10^{-5}

beam will increase by 10^4

beam will increase by 10^2

The muon might be the best

LFV catalog for the muons

- $\Delta L=1$
  - $\mu^+ \rightarrow e^+\gamma$
  - $\mu^+ \rightarrow e^+e^-e^+$
  - $\mu^-+N(A,Z) \rightarrow e^-+N(A,Z)$

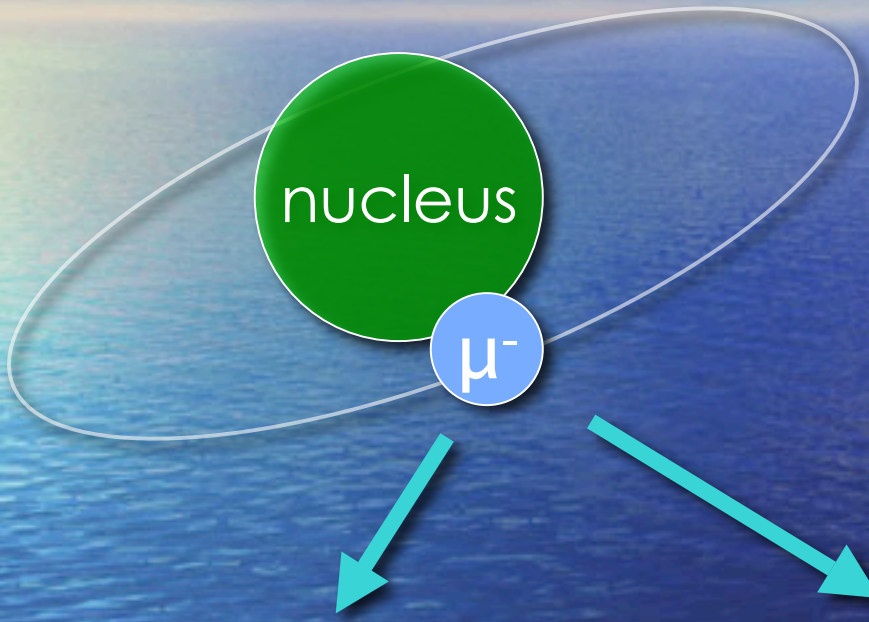
    μ–e conversion in a muonic atom
- $\Delta L=2$
  - $\mu^+e^- \rightarrow \mu^-e^+$

etc...

Which Muon LFV Process Next?

	issue	Beam Requirement
μ→eγ	detector limited	a continuos beam
μ→eee	detector limited	a continuos beam
μN→eN	beam limited	a plused beam

What is μ-e conversion?



Neutrino-less muon nuclear capture
(=μ-e conversion)
$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$

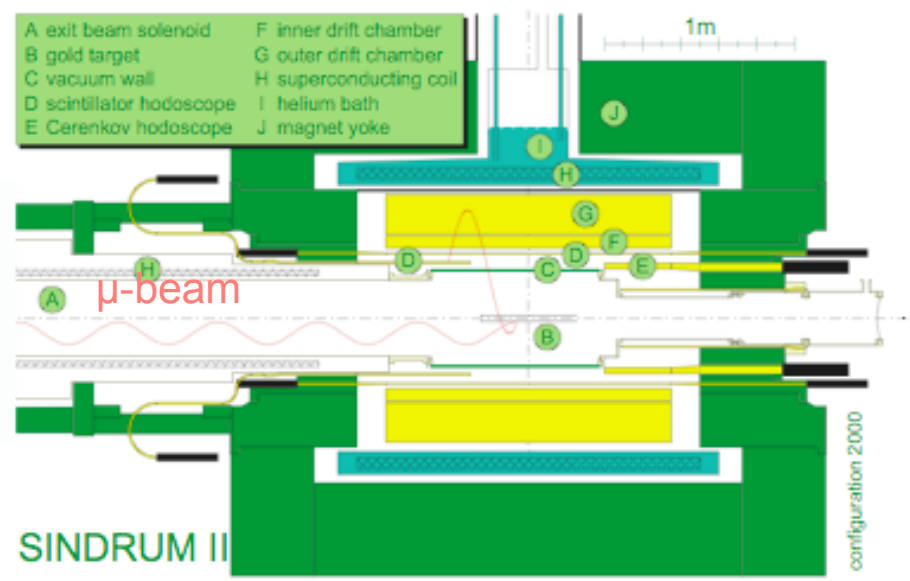
$$B(\mu N \rightarrow eN) = \frac{\Gamma(\mu N \rightarrow eN)}{\Gamma(\mu N \rightarrow \nu N)}$$

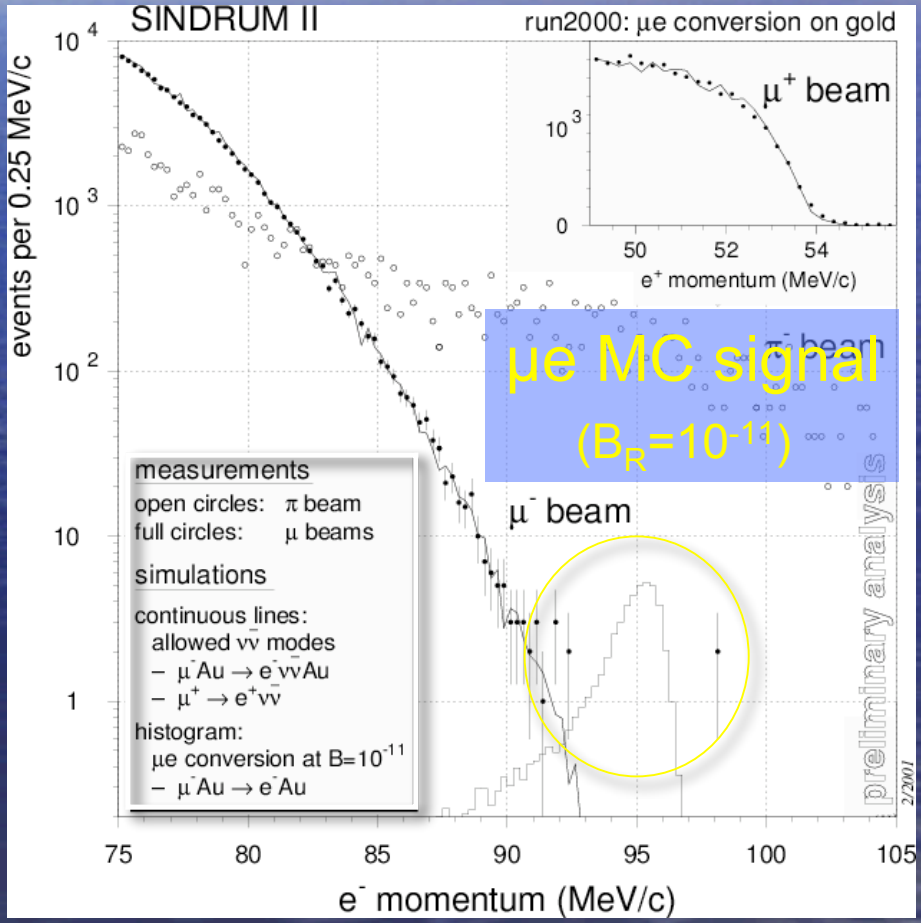
nuclear muon capture
$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$

muon decay in orbit
$\mu \rightarrow e^- \nu_e \nu_\mu$

μ-e conversion Signal & Background

Sindrum-Ⅱ Result (target: gold)





Background

- muon decay in orbit
- nuclear muon capture
- Beam, Cosmic ray

Beam Requirements for μ-e conversion

Beam is critical element for μ-e conversion

- Higher muon intensity
  - more than 10^{12} μ^-/sec
- pulsed beam
  - rejection of background from proton beam
  - Narrow energy spread
    - allow a thinner muon stopping target

    ➔better e^- resolution and acceptance


PRISM

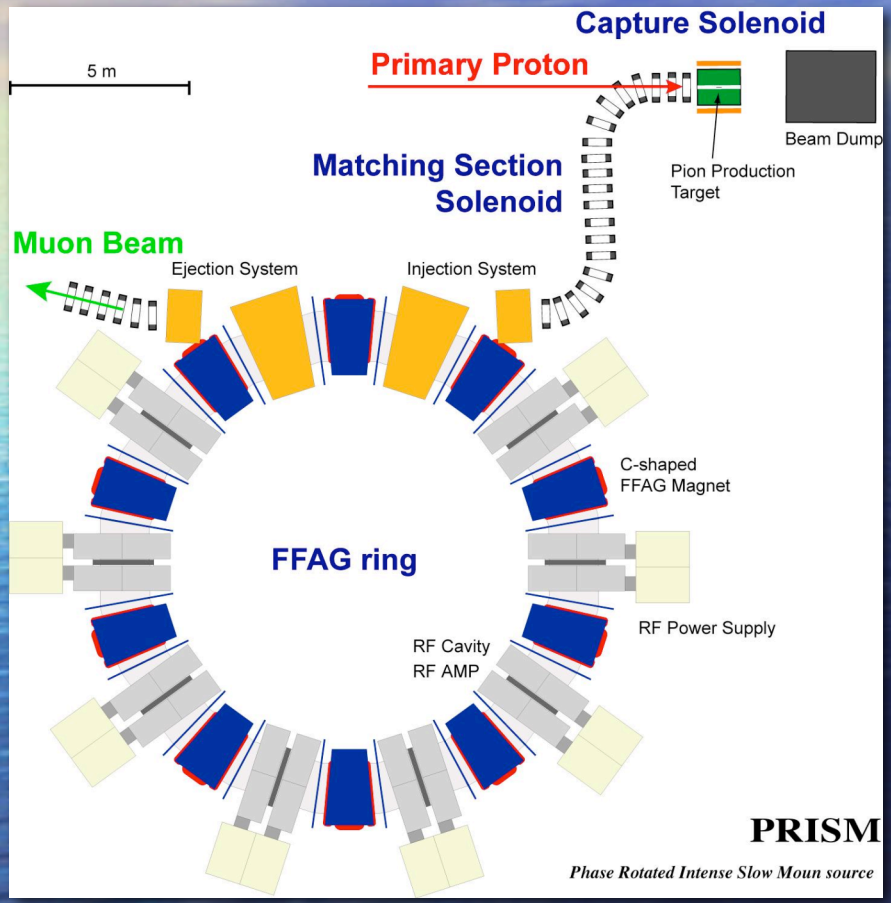
What is PRISM? once more...

- Muon intensity: 10^{11}~10^{12}/sec
- Central Muon Momentum: 68MeV/c
- Momentum Spread width: ±3%

  20% ➔ 3% by Phase Rotation
- Pion contamination: 10^{-18}

  for 150m in PRISM-FFAG Ring
- Repetition: 100Hz

PRISM overview



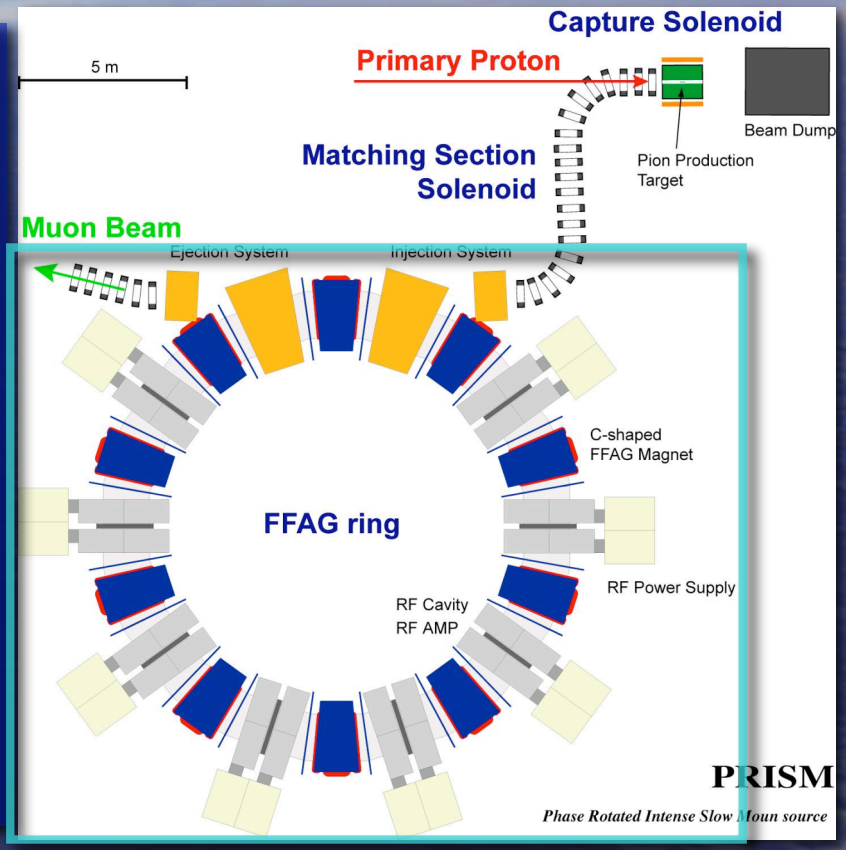
PRISM consists of

- (Proton beam)
- Pion Production Target
- Pion Capture
- Transport
- Injection & Ejection
- FFAG Ring

  for phase rotation
  - Magnet
  - RF

PRISM-FFAG ring construction

- PRISM ring construction has been approved in JFY2003.
  - 5 year plan
    - 3 year construction
    - 2 year test



What is FFAG ?

FFAG = *Fixed Field Alternating Gradient Synchrotron*

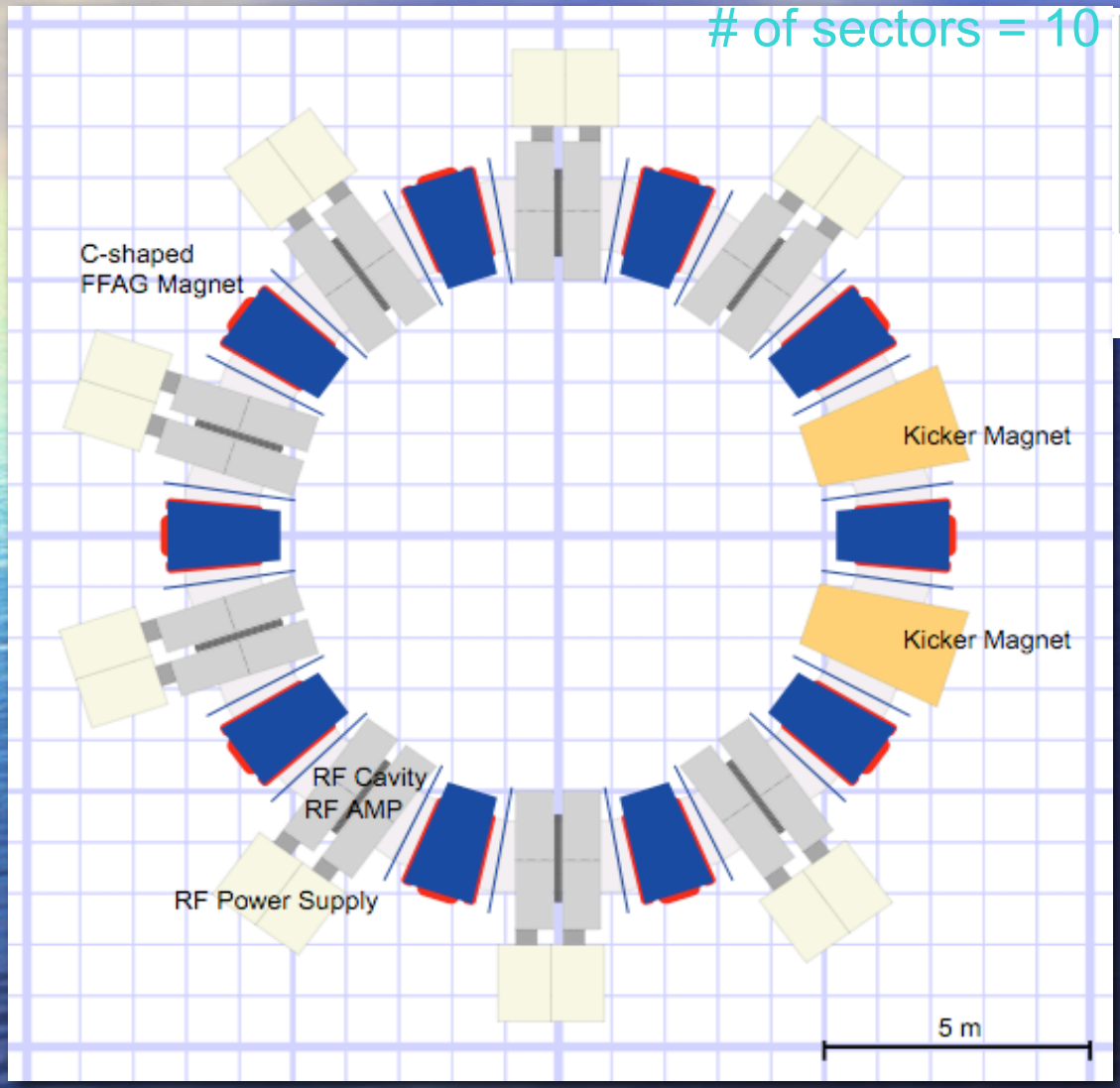
FFAG field

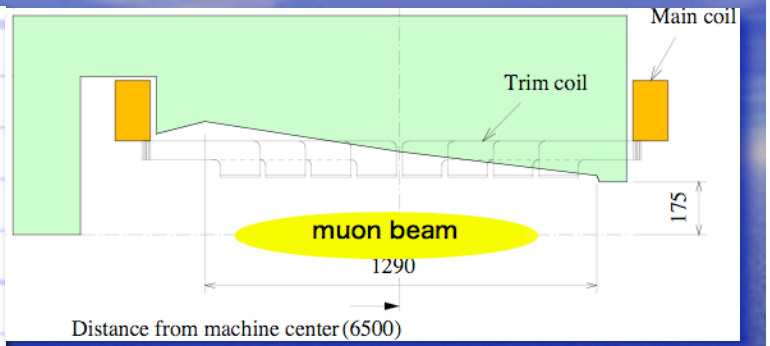
$$B(r) = B_0 \left(\frac{r}{r_0} \right)^k$$

- FFAG Advantage
  - Large Acceptance
    - Both Longitudinal and Transverse directions
    - strong focusing
  - Fast Acceleration
    - due to fix magnetic field

Suitable for muon acceleration

PRSIM-FFAG ring design

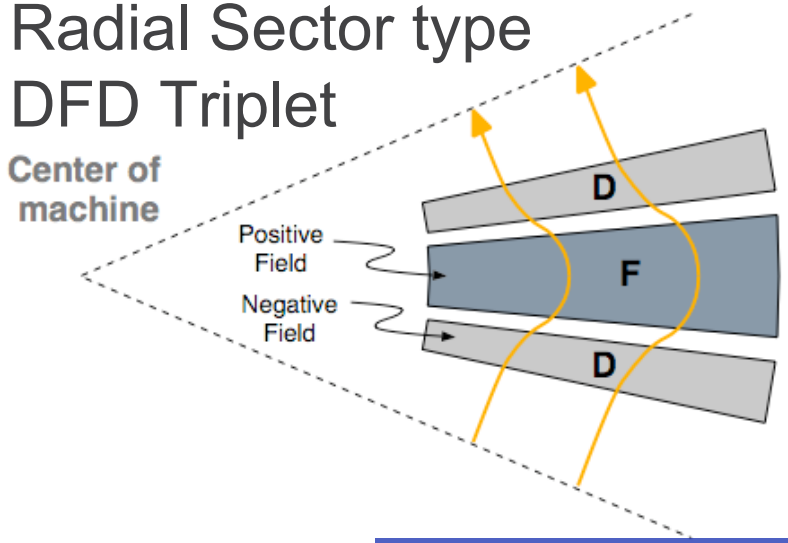


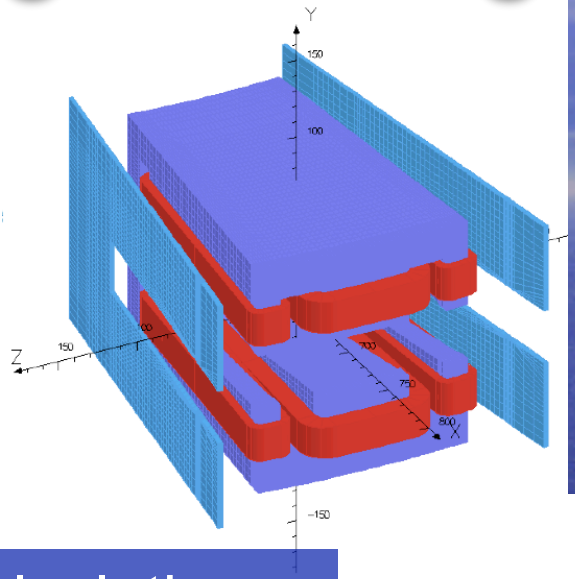


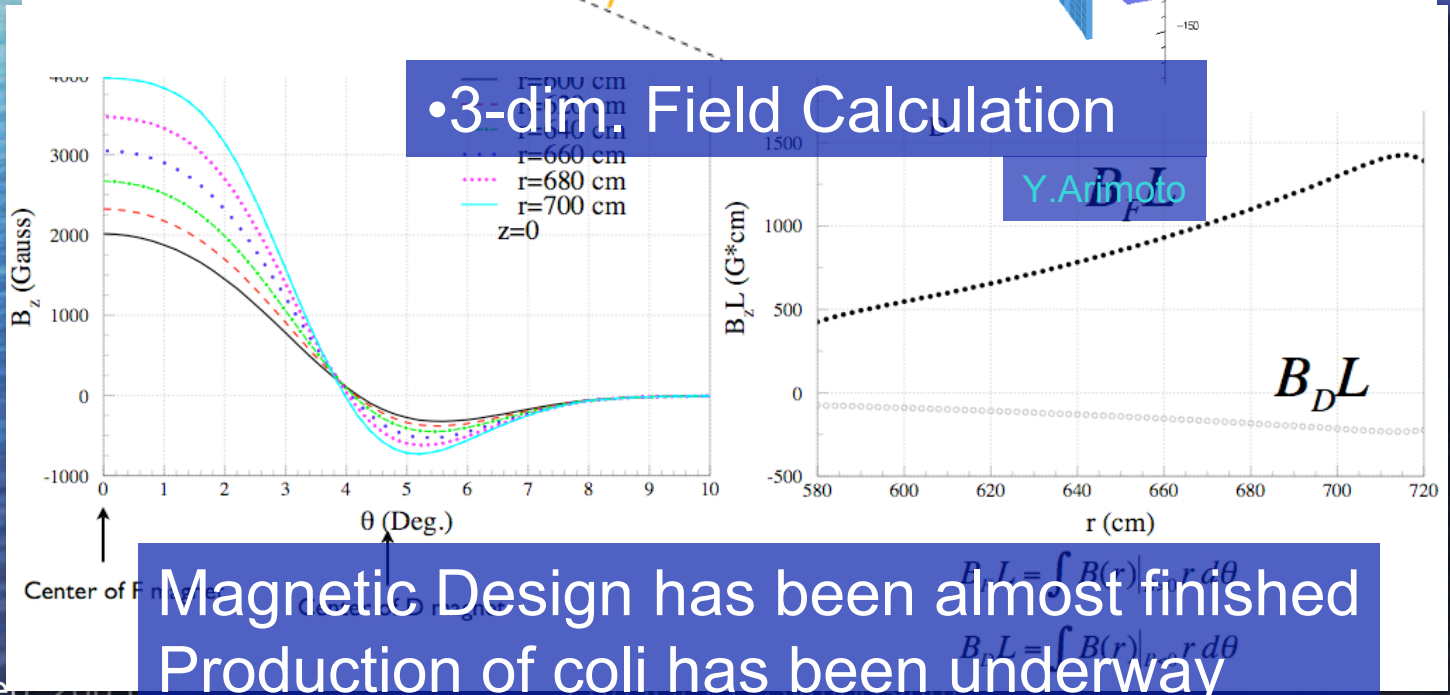
- N=10
- K=4.4-5.2
- F/D(BL)=4-8
- R_0=6.5m @68MeV/c
- Aperture Size
  - Horizontal 100cm
  - Vertical 30cm

PRISM-FFAG Magnet design

Radial Sector type
DFD Triplet







- 3-dim. Field Calculation

Y.Arimoto

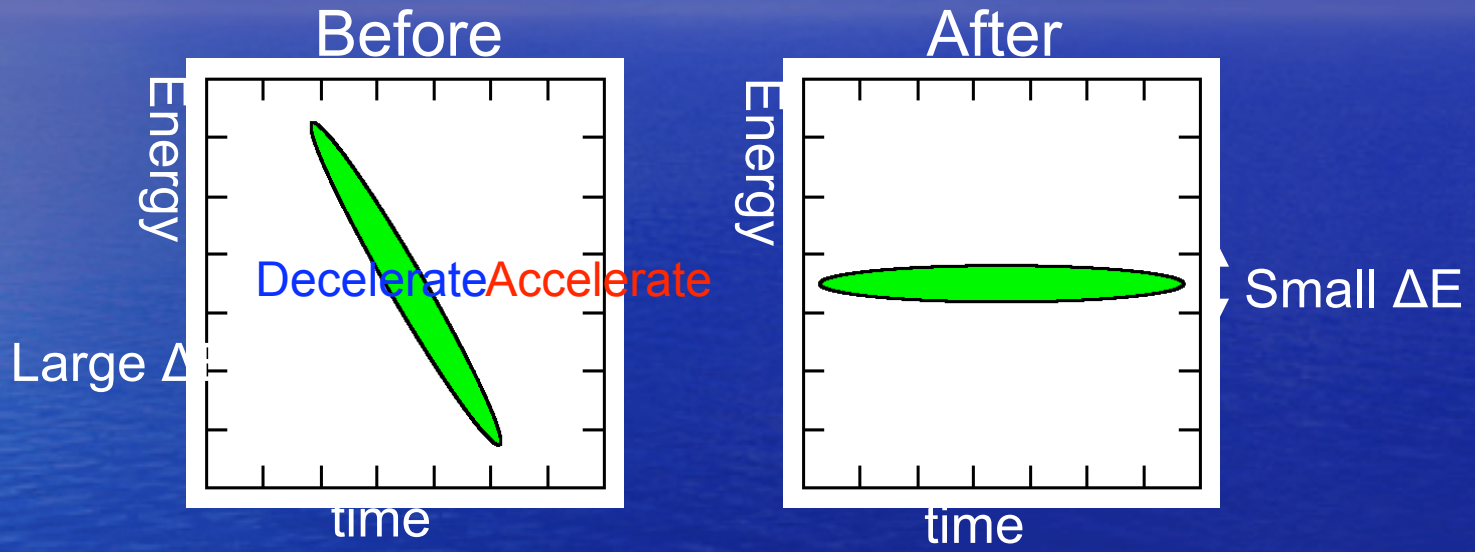
$$B_F L = \int B(r)|_{r=r_F} \, r \, d\theta$$

$$B_D L = \int B(r)|_{r=r_D} \, r \, d\theta$$

Magnetic Design has been almost finished
Production of coli has been underway

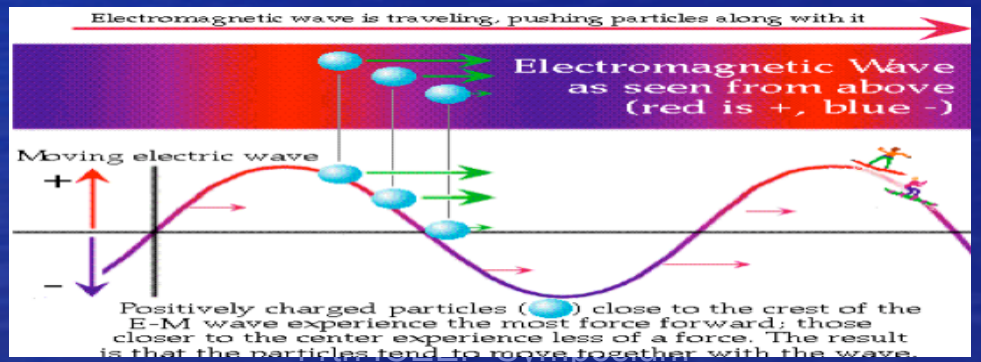
What is Phase Rotation ?

Phase Rotation = decelerate particle with high energy and accelerate particle with low energy by high-field RF

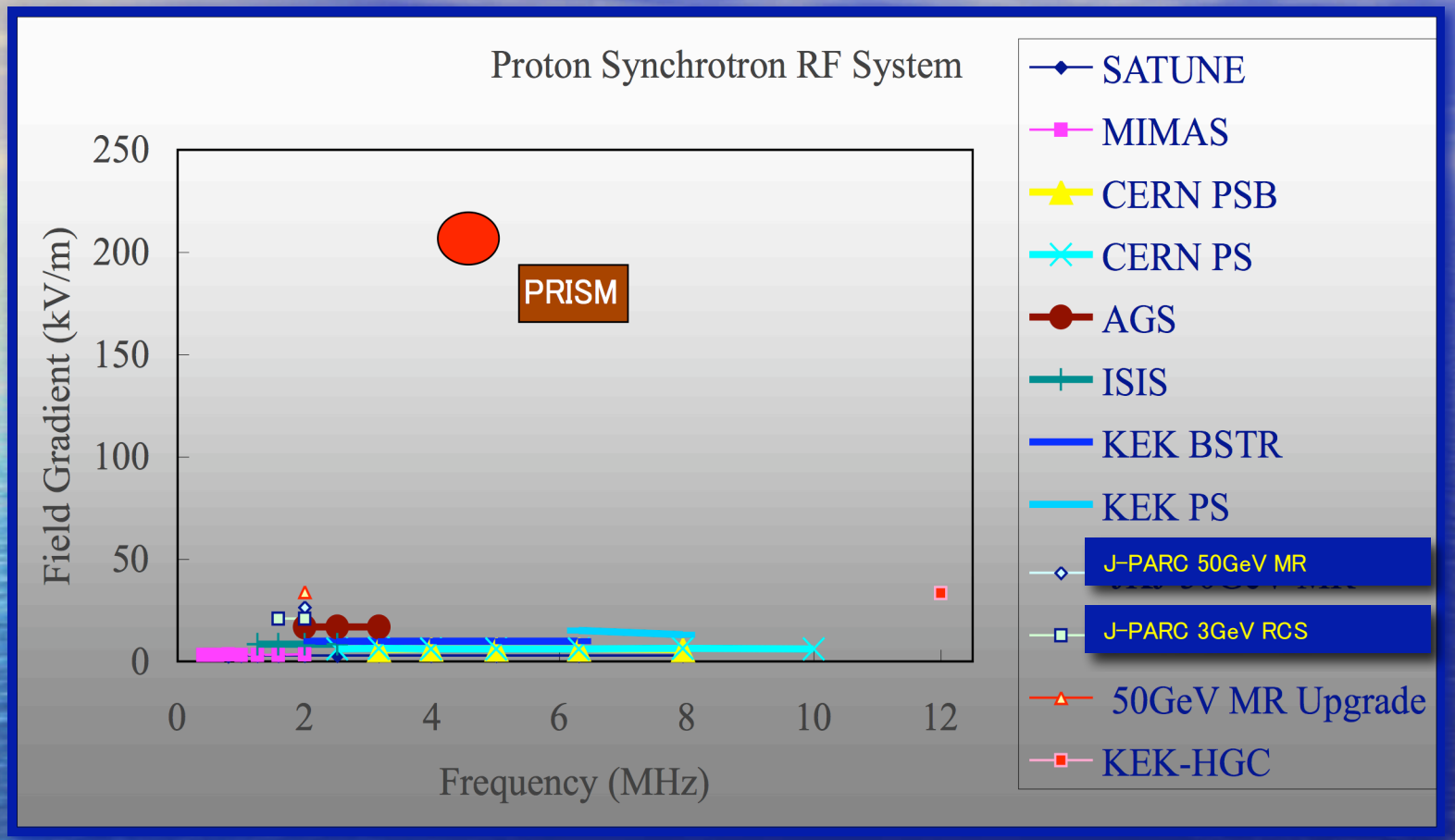


Δp/p = ±20%

Δp/p = ±3%



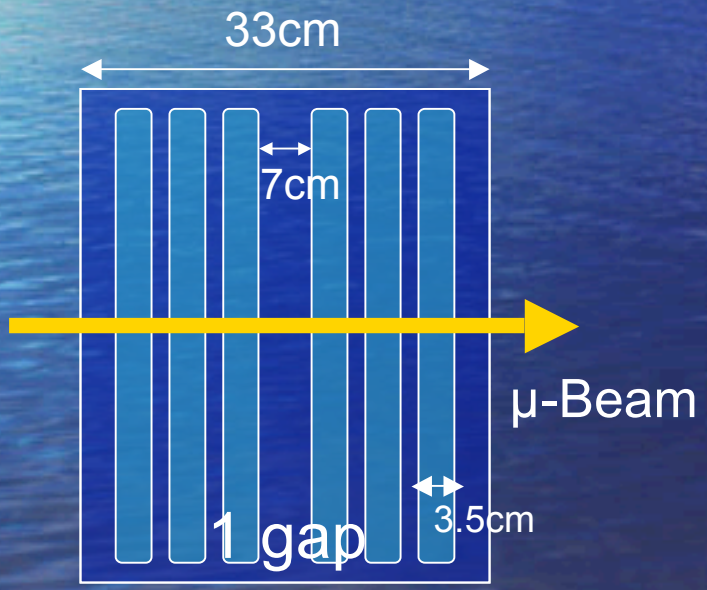
PRISM RF Requirement

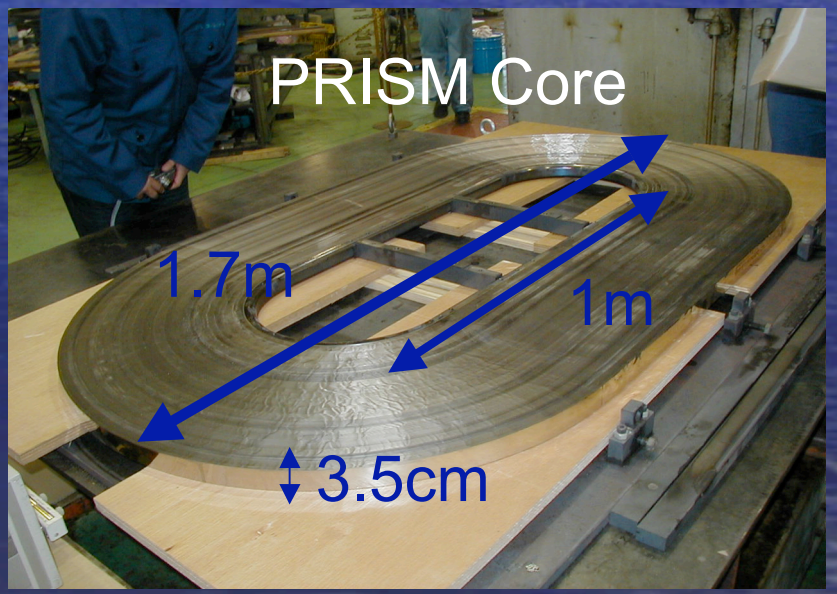


High Gradient RF system is required for Rapid Phase Rotation

PRISM RF system

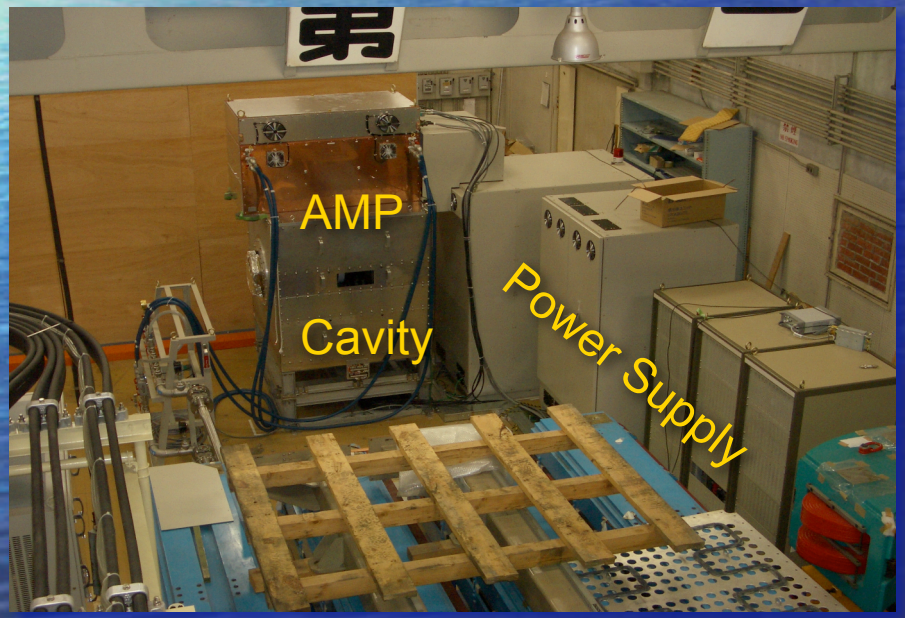
- Install RF cavity 8 straight sections
- One cavity consists of 5 gaps and 1 gap includes 6 cores



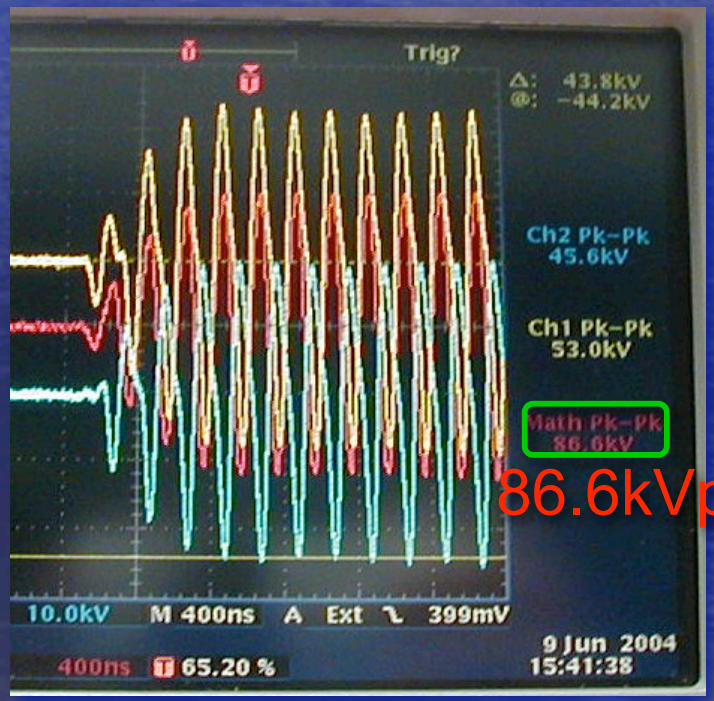


PRISM RF R&D

- AMP, PS, D-AMP and MA Cores have been produced
- AMP Test with test cavity has done.
- Achieved 43kV/gap @5Mhz ➔ 165kV/m (expected)
  (using 60A ps, 700Ω Cavity w/ PRISM RF Cavity(900Ω)



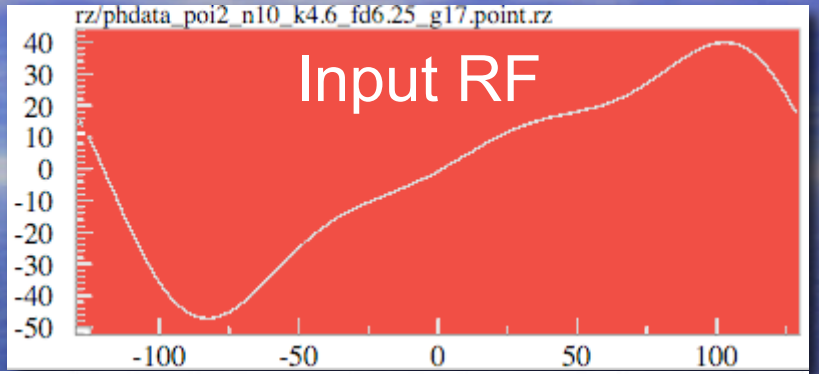
M-Experimental Hall, RCNP,Osaka-Univ.

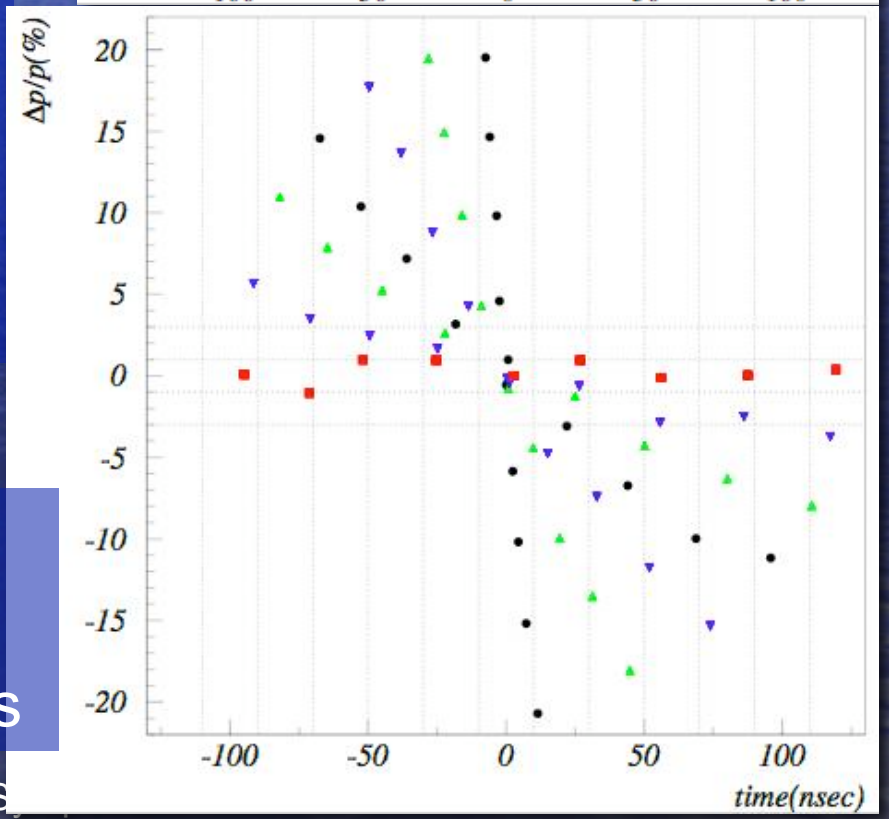


86.6kVp-p

Phase Rotation Simulation

Simulation condition
- Initial phase
  - 10m TOF
  - ±20% momentum spread
- RF
  - 45kV/gap (Total 1,800kV)
  - 8sector*5=40gaps
  - $V_{rf} = V_1\sin\theta + V_2\sin 2\theta + V_3\sin 3\theta$
- w/ TOSCA Magnet Field





Result:
±20% Momentum Acceptance
Momentum Spread ±2%@6turns

Summary

- PRISM-FFAG ring construction has started
- Magnet
  - Magnet design has been almost finished
  - Production of coil has been underway
- RF
  - RF-AMP has been tested using test cavity and obtained 43kV gap voltage (it's a design goal)
  - 1st PRISM RF cavity will be produced next month
- Phase Rotation simulation has been started and obtained ±2% momentum spread after 6 turns

Construction Schedule

- JFY2003
  - RF Amp. Production
- JFY2004
  - RF cavity and FFAG Magnet construction
- JFY2005
  - FFAG Magnet production continue
  - Test PRISM RF System
- JFY2006
  - FFAG Magnet production complete
- JFY2007
  - Test Beam Acceleration and Phase Rotation