Report from Japan

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Outline

- International Collaboration
  - MUCOOL in NFMCC
  - MICE
- (Scaling) FFAG Studies in Japan
  - ERIT FFAG for neutron sources at KURRI, Kyoto University
  - PRISM FFAG for muon phase rotation at Osaka University
- Summary

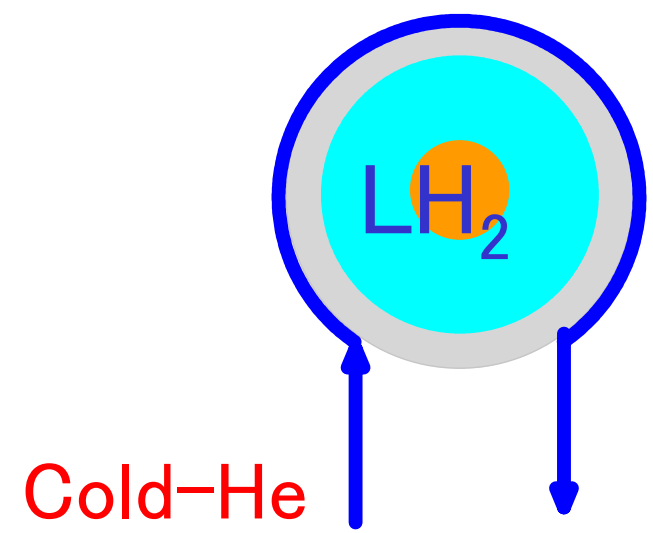
International Collaboration

- NFMCC
  - The Japanese group has joined the MUCOOL studies since 2000.
  - Major contributions are the development of liquid hydrogen absorbers of convection type.
- MICE
  - The Japanese group has joined the MICE collaboration from the beginning.
- ISS/IDS Studies

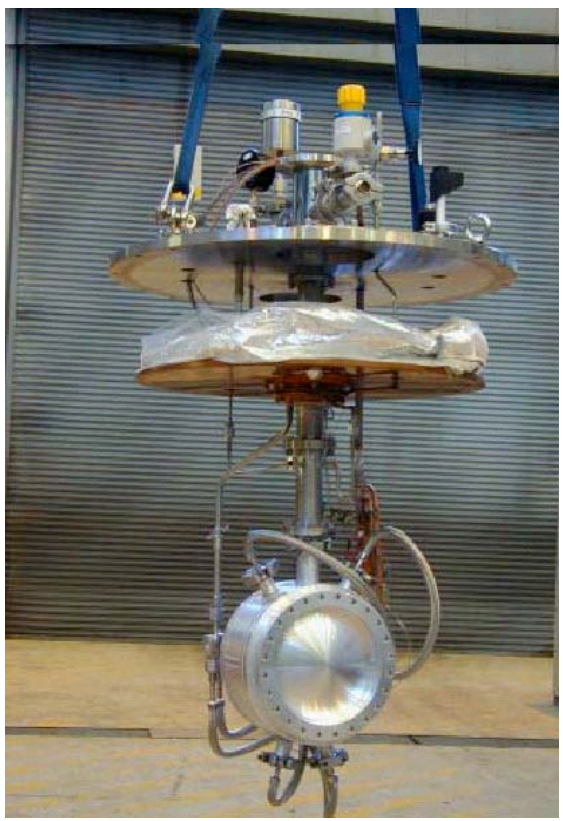
MUCOOL

Contribution to NFMCC

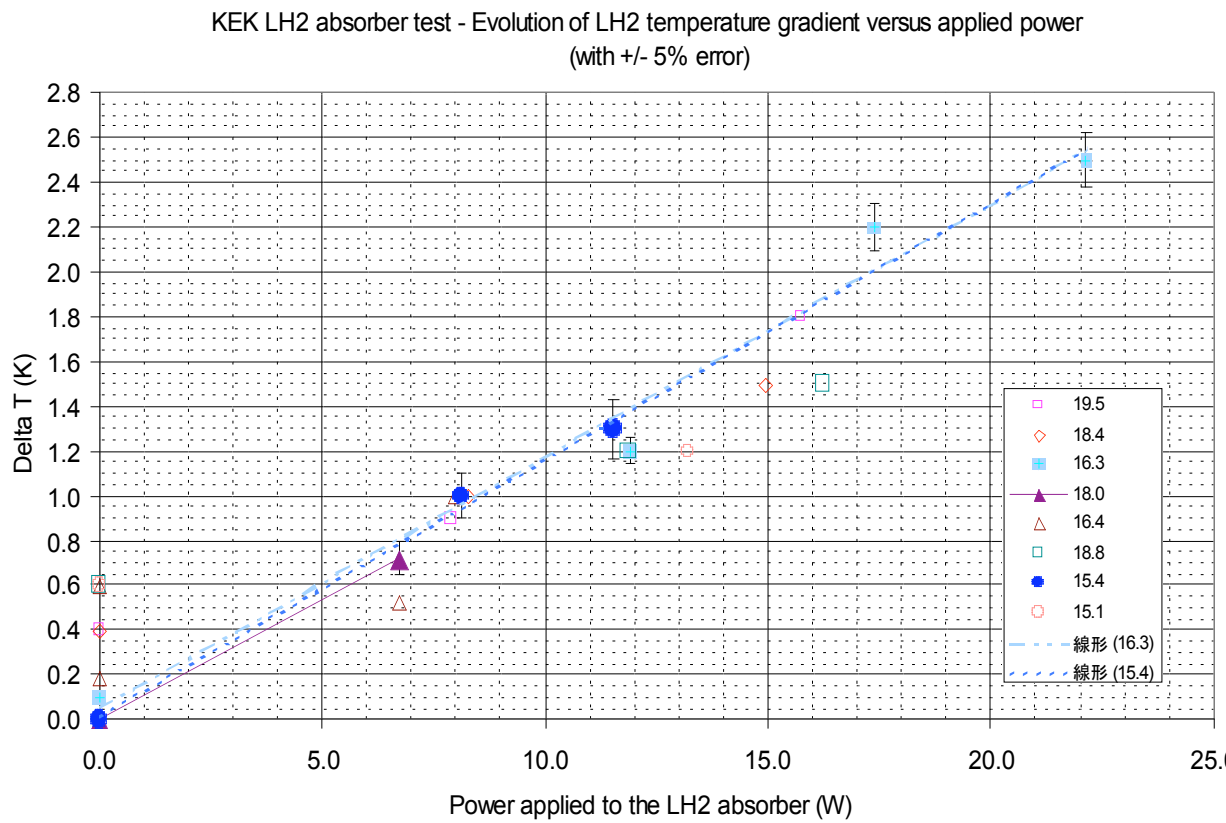
- The Japanese group has participated in NFMCC since 2000. using the US-Japan Collaboration Program.
  - Major area of our contribution is the construction of liquid hydrogen (LH2) absorber for MUCOOL
- Convection type absorber
  - He gas exchanger removes heats from the absorber wall.
  - Advantages:
    - simple, less LH2
  - Disadvantages:
    - less cooling power (need prototype.
    - MICE uses convection type.



Cooling Test at MTA@FNAL



Temperature rise of 2.4 K for 20 W, and LH2 has 9 K range.



Temperature gradient (TC-106-H - TC-110-H) versus applied heat for several LH2 absorber bath temperatures.

dT=2.3 K for 20 W → dT=9 K for 78 W
(T_{max}=23K, T_{min}=14K)

Heat road up to 70 kW can be taken by convection cooling.

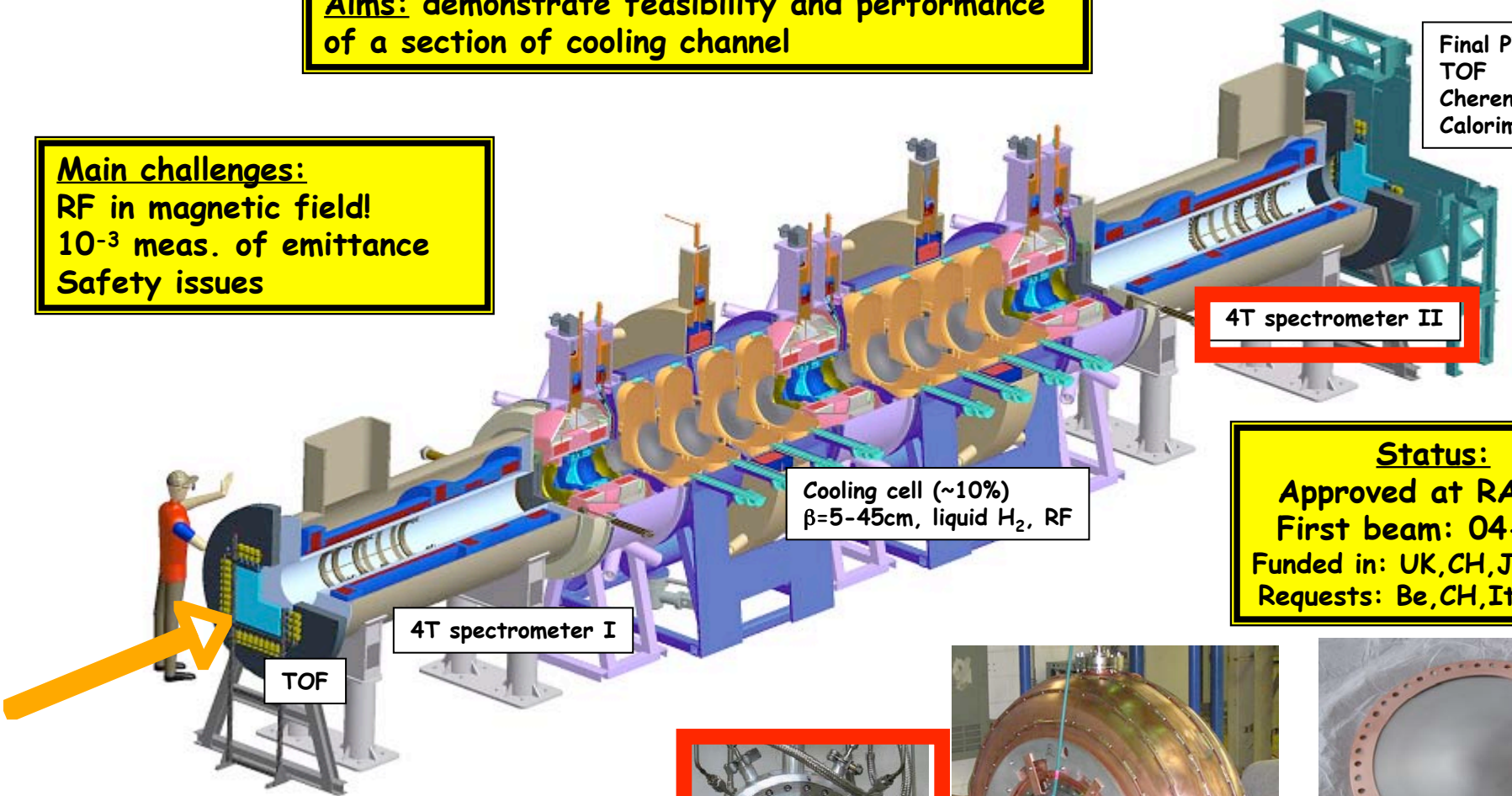
US-Japan Program

- We obtained the budget from the US-Japan program (between DOE and MEXT in Japan, and funded by MEXT) since JFY 2000.
- Our proposal for JFY 2008 is also turned down.
  - Since JFY 2007, the total budget of the US-Japan became half and the competition became harder.
- Need to looking for other budgets ?

MICE

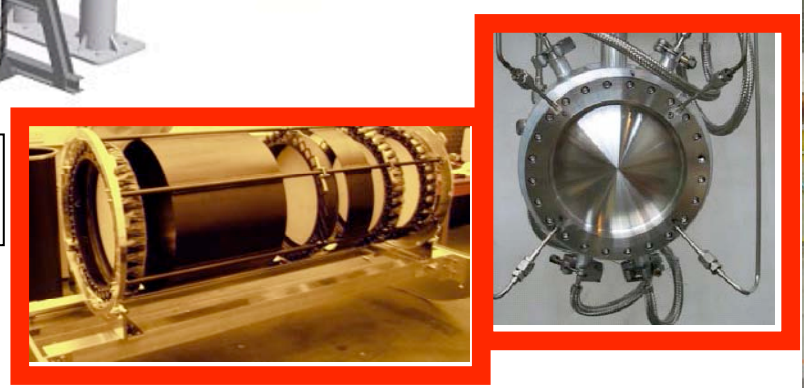
Aims: demonstrate feasibility and performance of a section of cooling channel

Main challenges:
RF in magnetic field!
10^{-3} meas. of emittance
Safety issues



Status:
Approved at RAL(UK)
First beam: 04-2007
Funded in: UK,CH,JP,NL,US
Requests: Be,CH,It,JP,US

Single-μ beam
~200 MeV/c



DAQ
Control

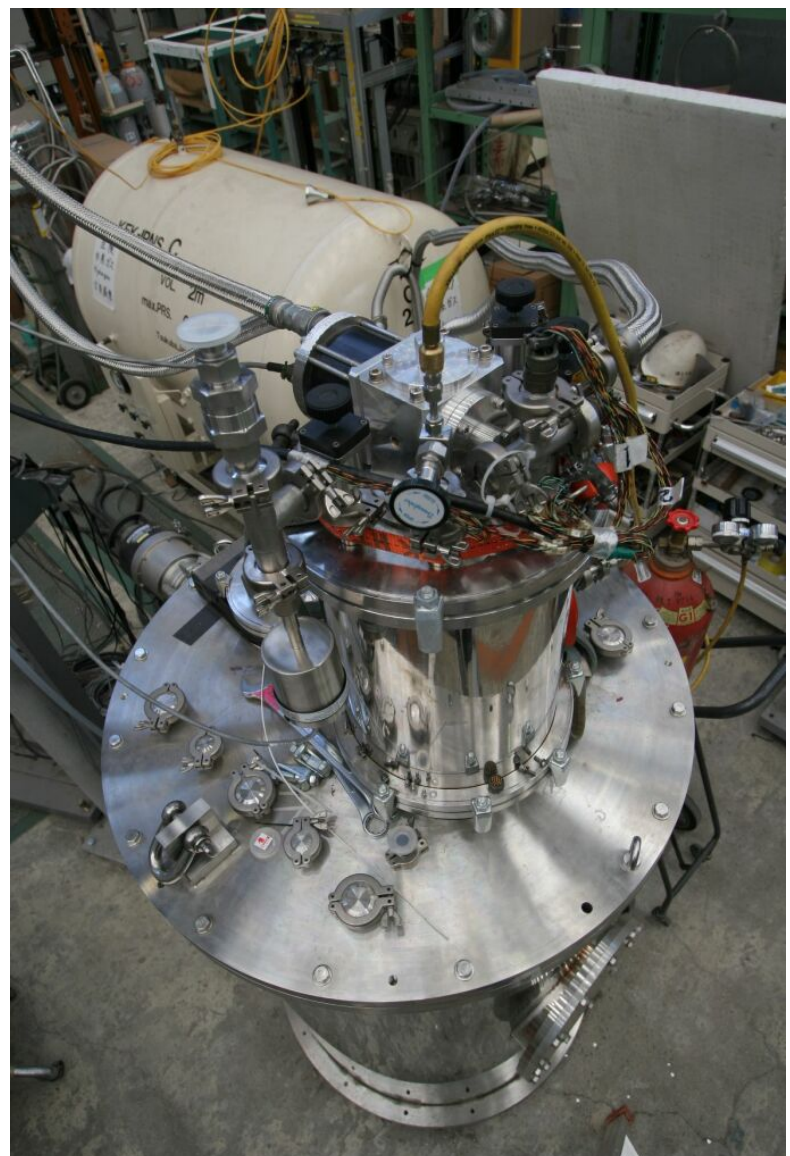
Japanese Contributions

MICE Test LH2 Absorber at KEK

Cryocooler

TMP

H2 press. transducer



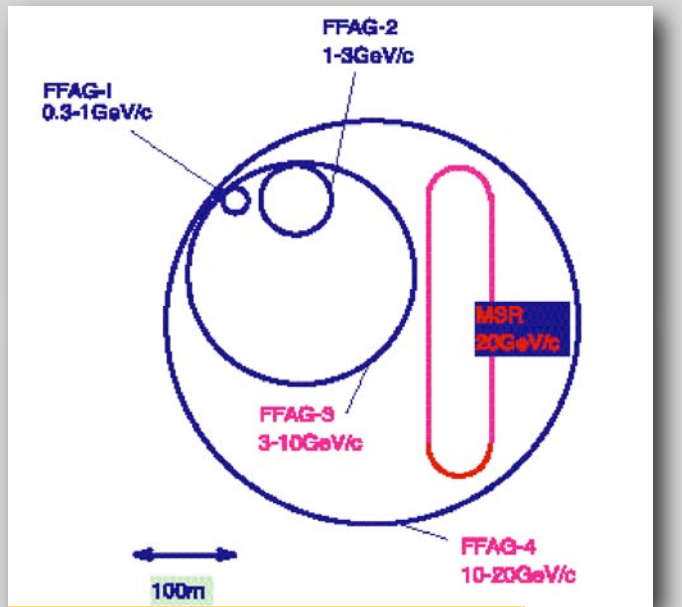
H2 gas tank (2000 l)

Bendix 18 pin connector x2

(Scaling) FFAG R&D

FFAG-based Scheme

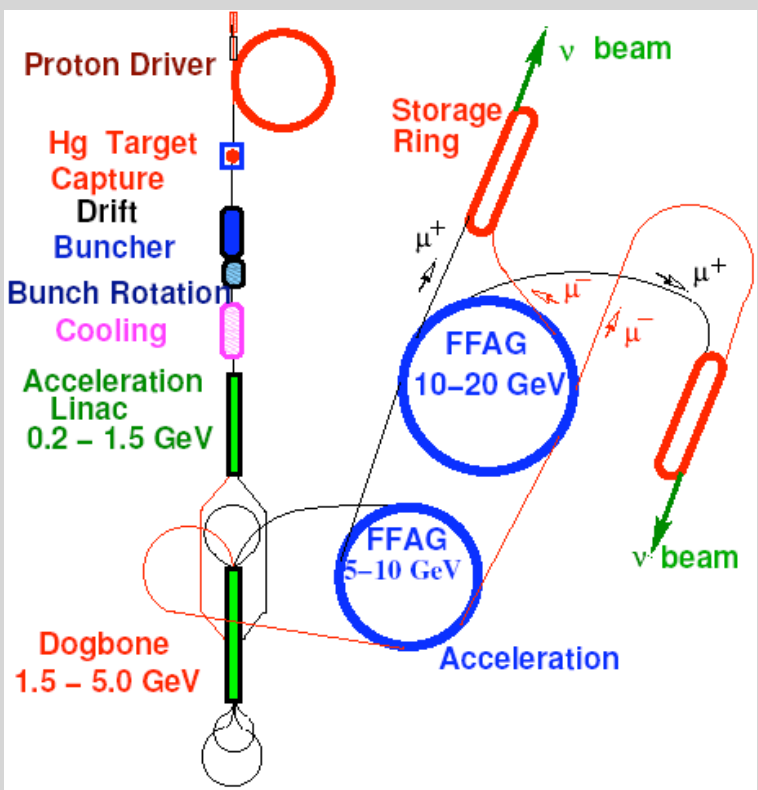
- Japanese scheme of a neutrino factory is based on scaling FFAGs.
  - proposed in 2000.
  - a study report in 2001.
- series of FFAG rings
  - 0.3-1/1-3/3-10/10-20 GeV/c
- Advantages
  - large acceptance
  - quick acceleration
  - cooling is not a must (but better if cooling is available.



NuFACT-J

Muon Acceleration based on a series of FFAGs

ISS Design (2006)



Types of FFAG

- Scaling type FFAG
  - betatron tune : constant (zero chromaticity)
  - non-linear field elements
- Non-scaling type FFAG
  - betatron tune : not constant
  - linear field elements

Scaling FFAG

$$B(r,\theta) = B_i \left(\frac{r}{r_i}\right)^k F\left(\theta - \eta \ln \frac{r}{r_i}\right)$$

Radial-sector

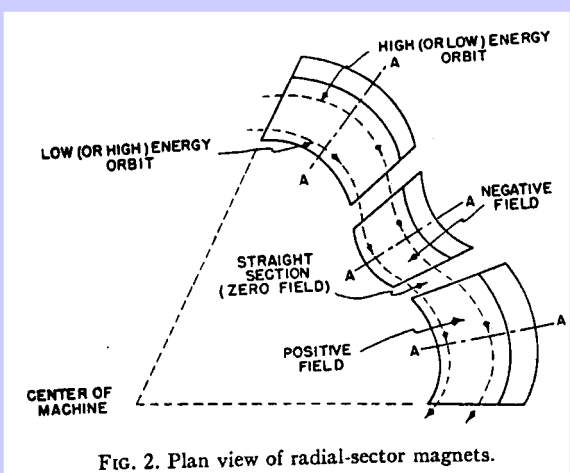


FIG. 2. Plan view of radial-sector magnets.

Spiral

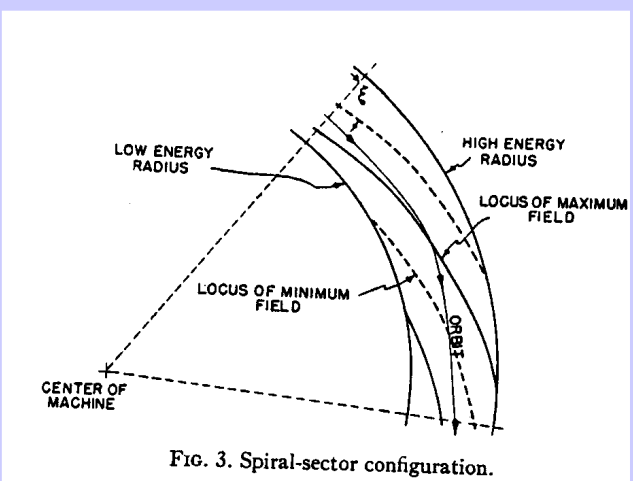


FIG. 3. Spiral-sector configuration.

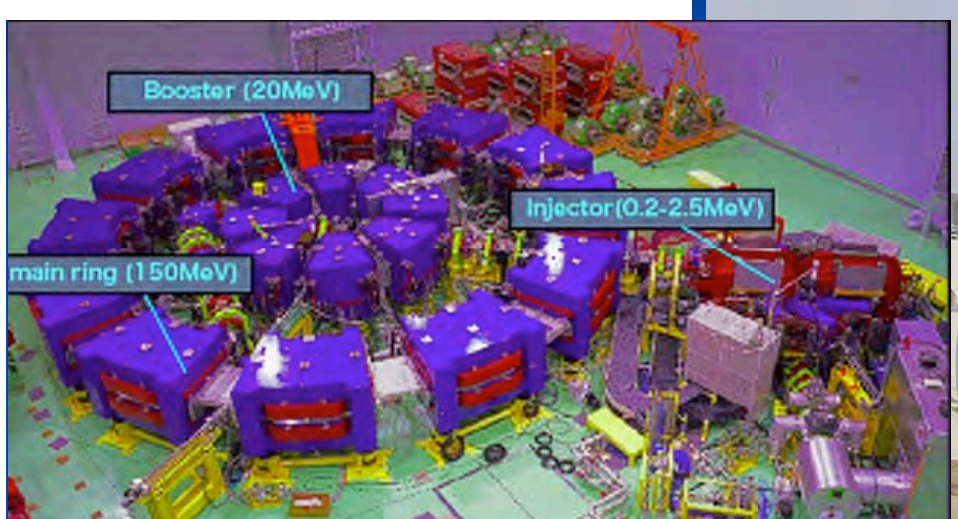
Scaling FFAG R&D in Japan

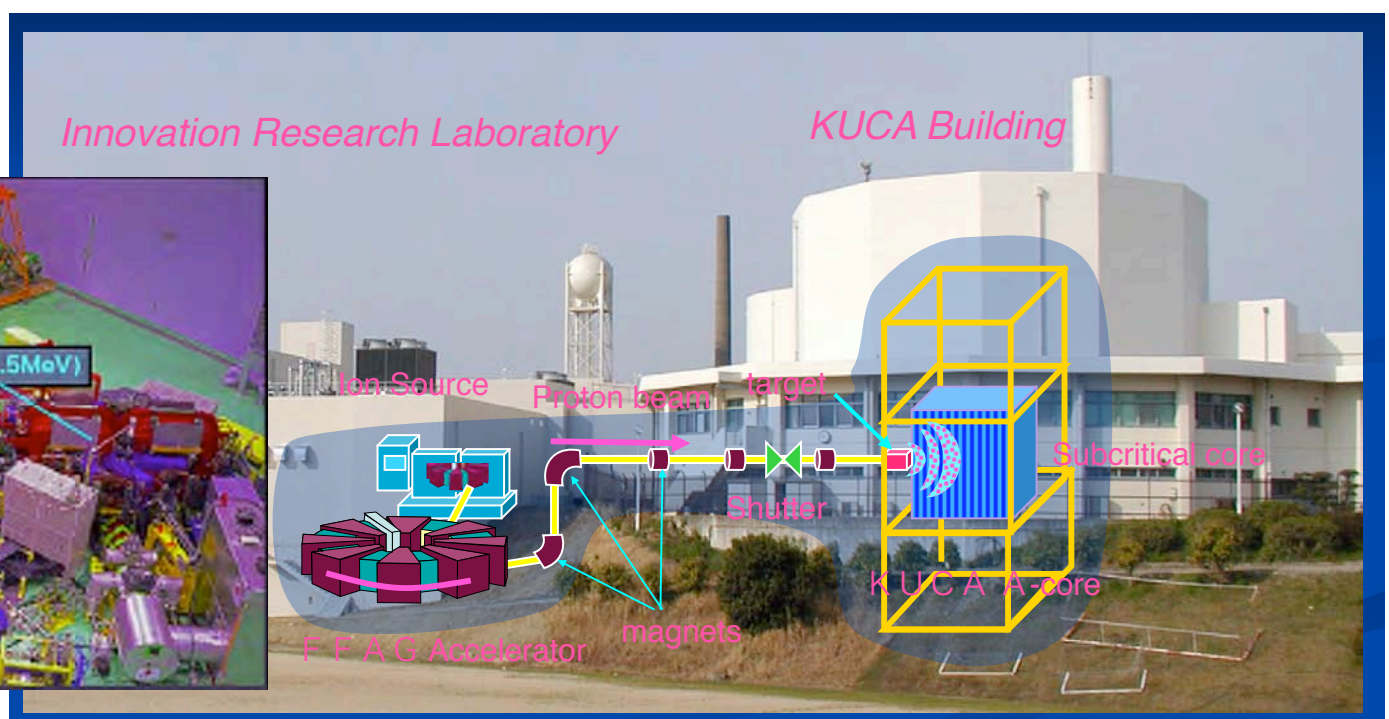
- Past
  - KEK
    - 500 keV Proof-of-Principle (POP) machine (2000)
    - 150 MeV proton FFAG (2006)
- Present
  - KURRI, Kyoto University
    - Accelerator Driven System (ADS) (2007)
      - 3 FFAG rings + reactor
    - FFAG for neutron sources (ABNS) (2008)
      - ERIT (emittance/energy recovery internal target)
        - storage ring + internal target
  - Osaka University
    - PRISM FFAG for muon storage ring (2008)

FFAGs at KURRI, Kyoto University

Status of ADS FFAG

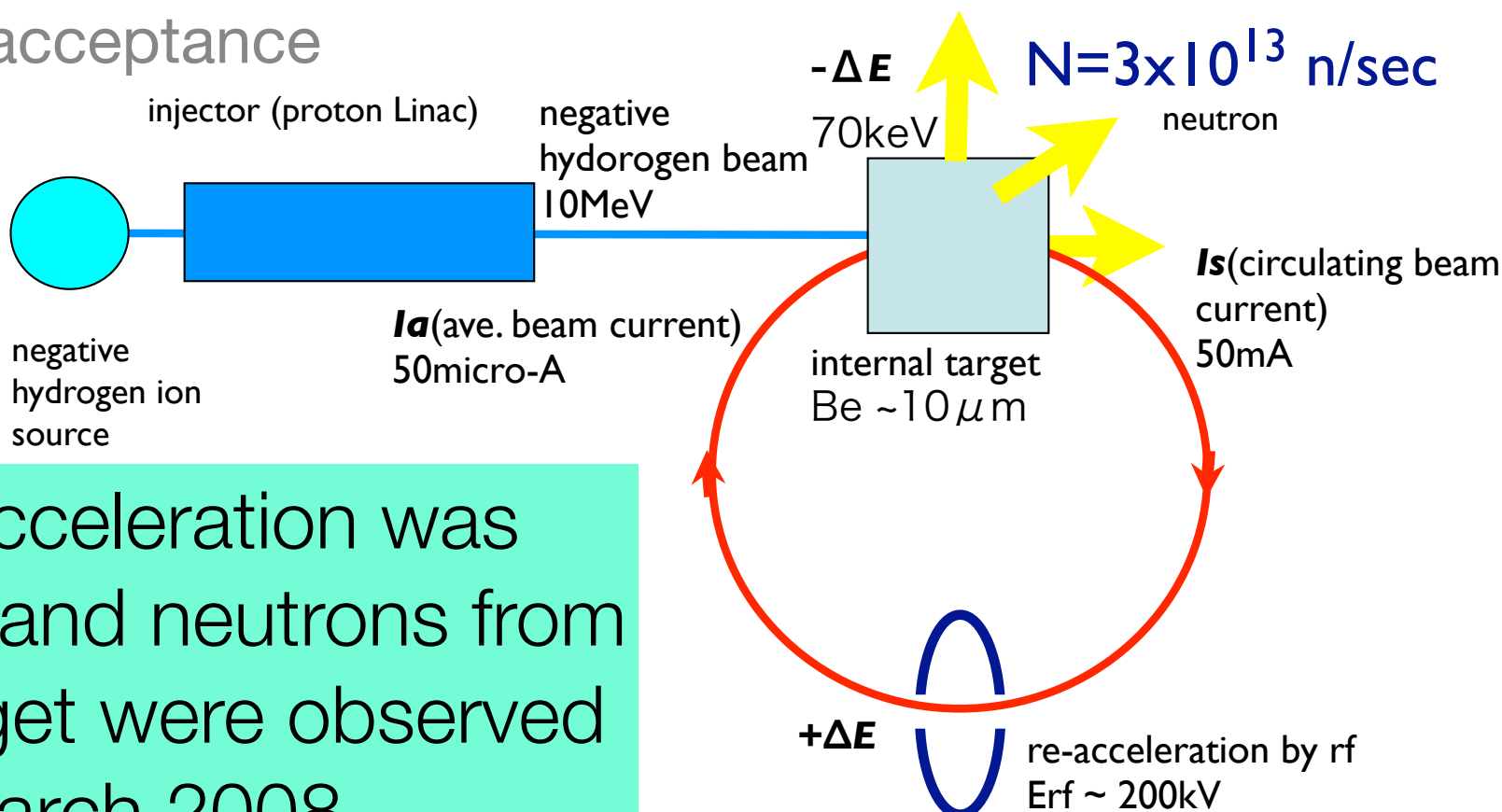
- Injector Ring (Spiral-induction FFAG)
  - completed in Jan., 2006.
  - E=1.2 MeV, I=50 nA
- Booster Ring
  - completed June, 2006.
  - E=11.5 MeV, I=0.8 nA
- Main Ring
  - under commissioning





Neutron Sources with Internal Target : FFAG-ERIT at KURRI, Kyoto University

- ERIT = Emittance / Energy Recovery Internal Target
- neutron source from internal target in the proton FFAG
- internal target (Be foil) and RF
- need large acceptance

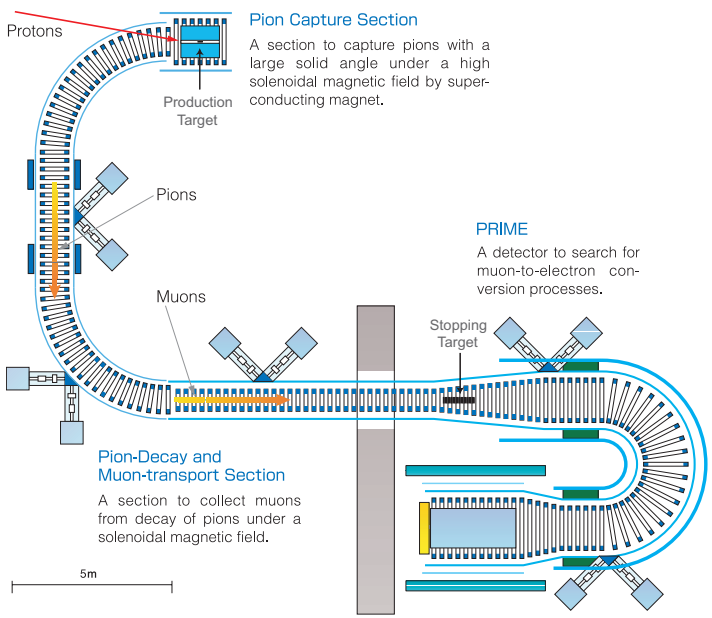


Proton acceleration was completed, and neutrons from internal target were observed in March 2008.

PRISM-FFAG for Muons

COMET/PRISM Projects in Japan

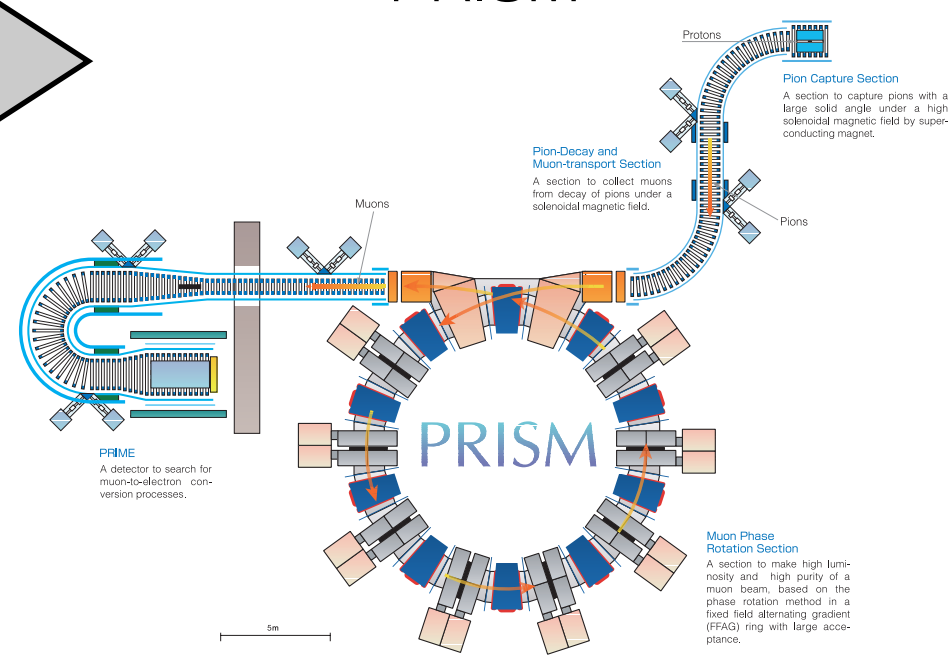
COMET



$$B(\mu^- + Al \rightarrow e^- + Al) < 10^{-16}$$

- without a muon storage ring.
- with a slowly-extracted pulsed proton beam.
- doable at the J-PARC NP Hall.
- regarded as the first phase / MECO type
- Early realization

PRISM



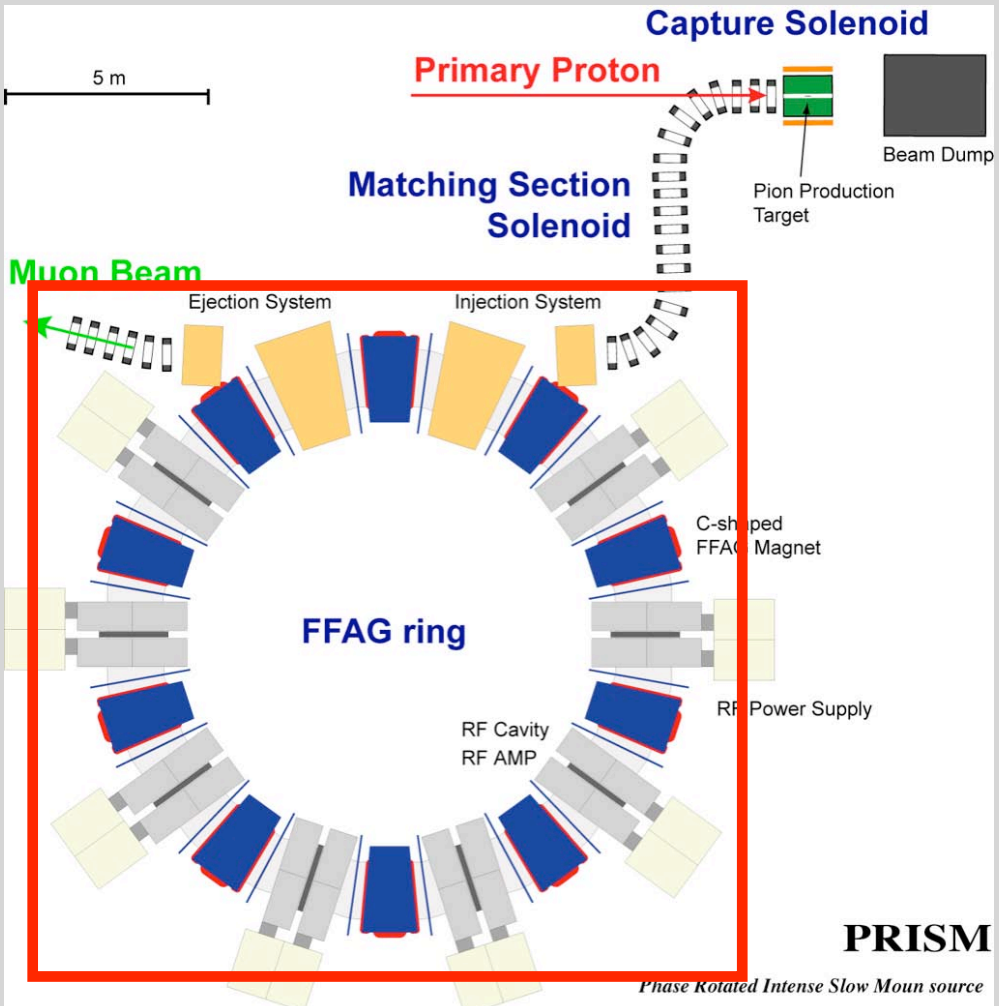
$$B(\mu^- + Ti \rightarrow e^- + Ti) < 10^{-18}$$

- with a muon storage ring.
- with a fast-extracted pulsed proton beam.
- need a new beam line and experimental hall.
- regarded as the second phase.
- Ultimate search

PRISM FFAG Ring

- use a FFAG ring to store muons.
  - phase rotation to make narrow energy spread
  - eliminate pions.
- being constructed at Osaka University for 2003-2007.
- a scaling FFAG
  - large acceptance

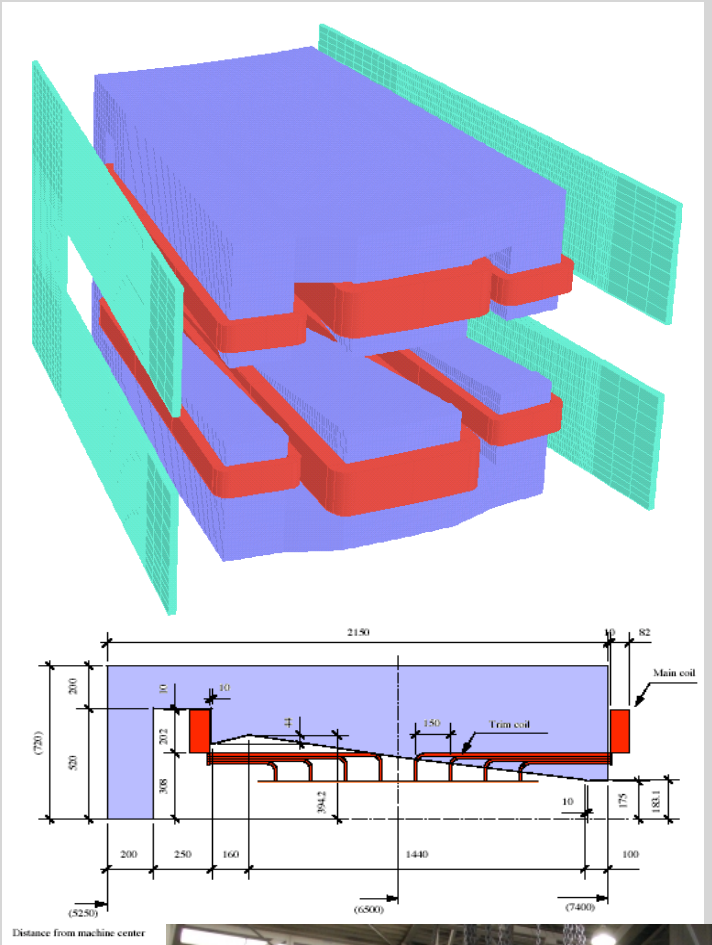
Phase Rotated Intense Slow Muon source



PRISM FFAG ring construction has been started in 2003.

PRISM FFAG Magnets

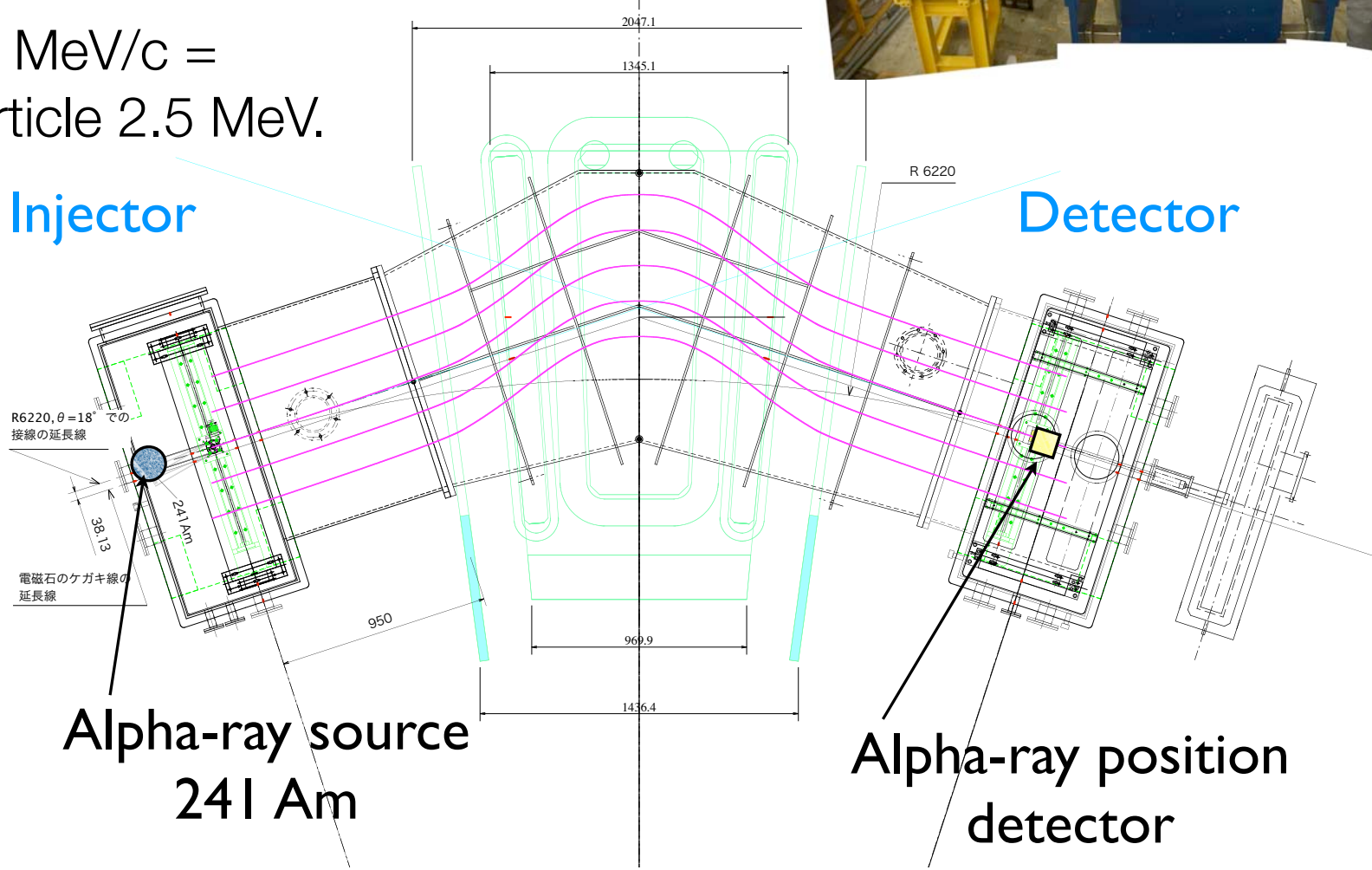
- radial sector with C-type yoke
  - D-F-D triplet
- machined pole shape to create field gradient (k)
- trim coils for variable k values (future)
- vertical tune : F/D
- horizontal tune : k value
- magnetic field design : TOSCA



Alpha Particle Tracking with One Magnet Cell

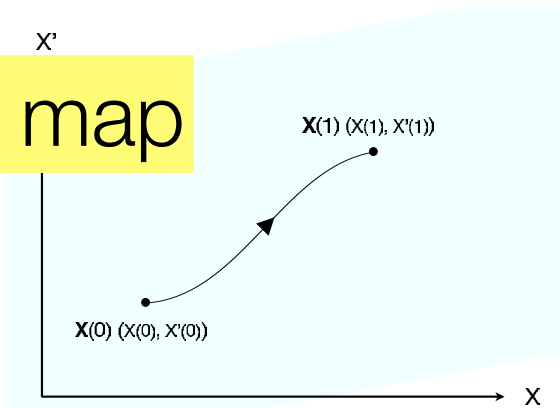
Purpose: study beam dynamics at large amplitudes (non-linearity) by determining a transfer mapping between in and out.

muon 68 MeV/c =
alpha particle 2.5 MeV.



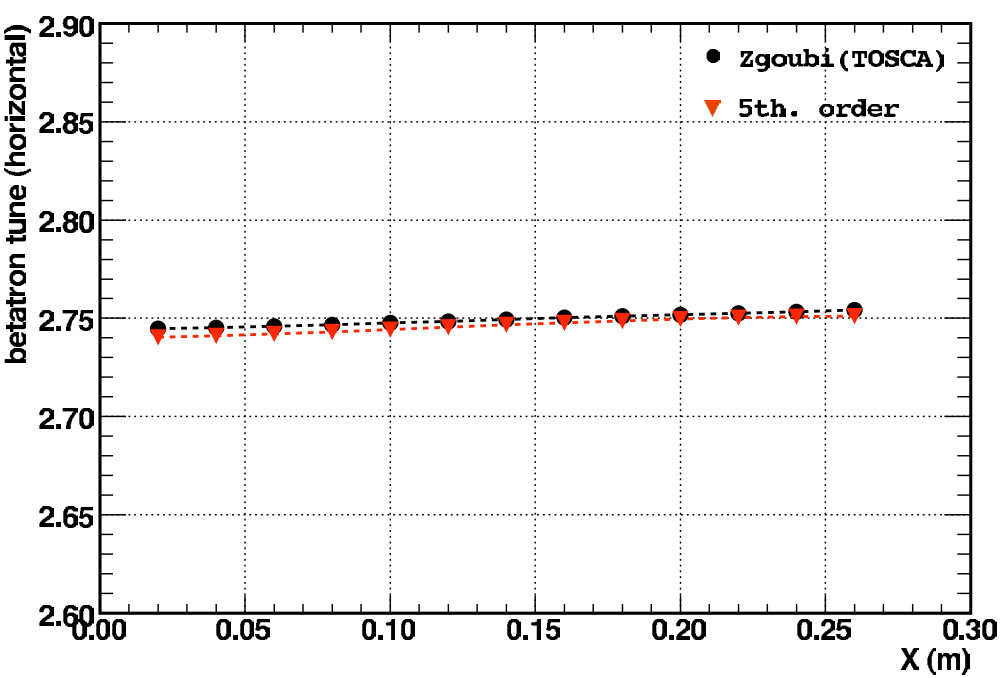
Transfer Map with Truncated Taylor Expansion

Transfer map



truncated Taylor expansion of higher orders to include non-linearity

$$X_a(1) = \sum_b R_{ab} X_b(0) + \sum_{b,c} T_{abc} X_b(0) X_c(0) + \sum_{b,c,d} U_{abcd} X_b(0) X_c(0) X_d(0) + \cdots ,$$



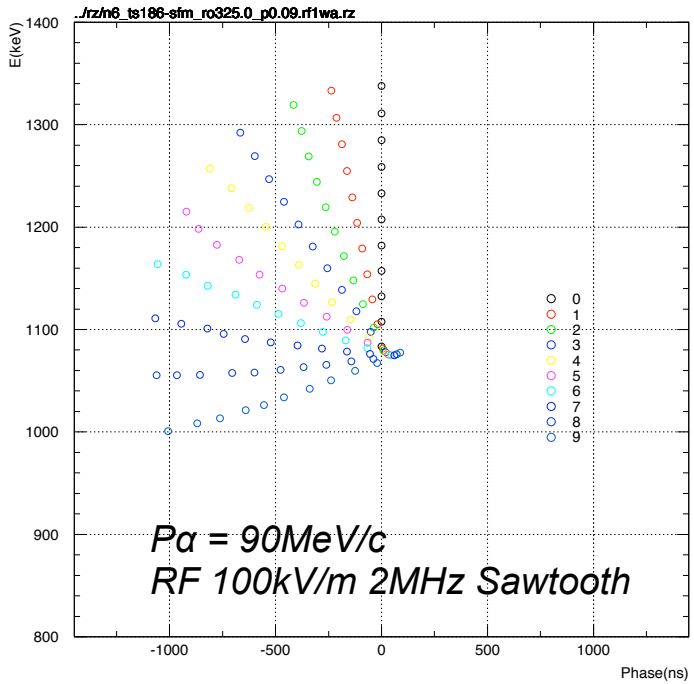
Tunes (and amplitude dependence) from transfer map and Zgoubi agree one another.

- advantages of this method
  - 3D magnetic field measurement is not needed.
  - Only one magnet would give the performance of the ring.

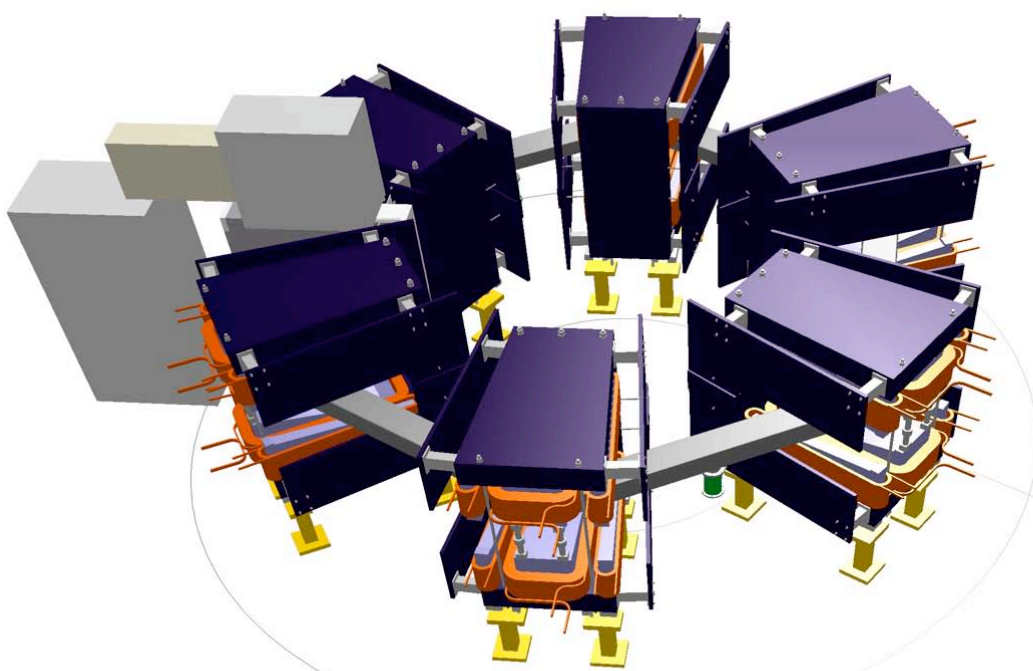
6 Sector PRISM-FFAG

Demo. of Phase Rotation with α-particles

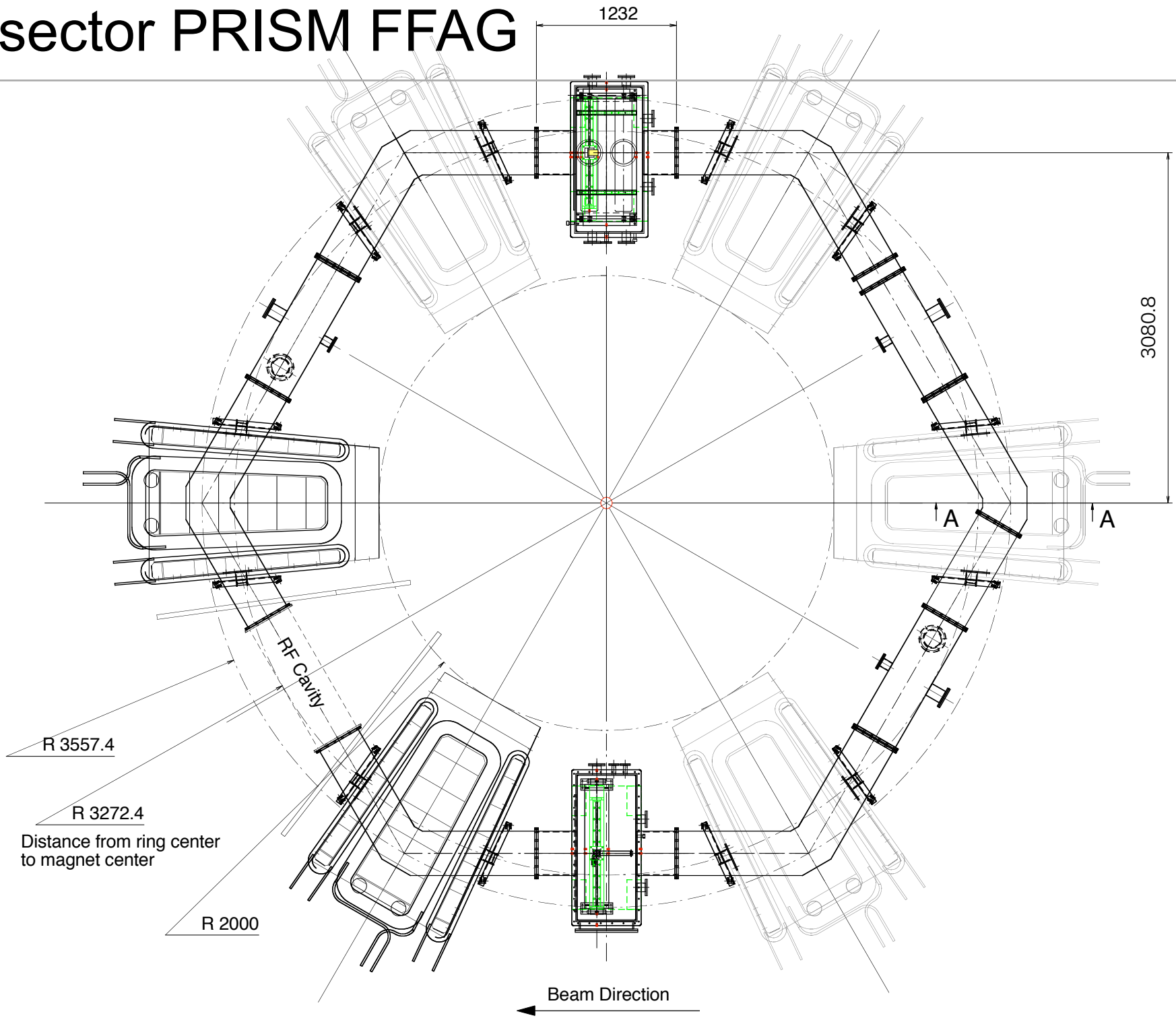
Purpose: study demonstration of phase rotation with a 6-cell ring with one RF cavity by single alpha particle tracking.



- 6-sector FFAG ring
  - PRISM-FFAG Magnet x 6、RF x 1
- Beam : α-particles from radioactive isotopes
  - ^{241}Am 5.48MeV(200MeV/c)
  - → degrade to 85MeV/c
  - small emittance by collimators
  - pulsing by electrostatic kickers
- Detector :
  - Scintillator
    - position
  - Solid state detector
    - energy (50 kV resolution)
    - timing (50 nsec)

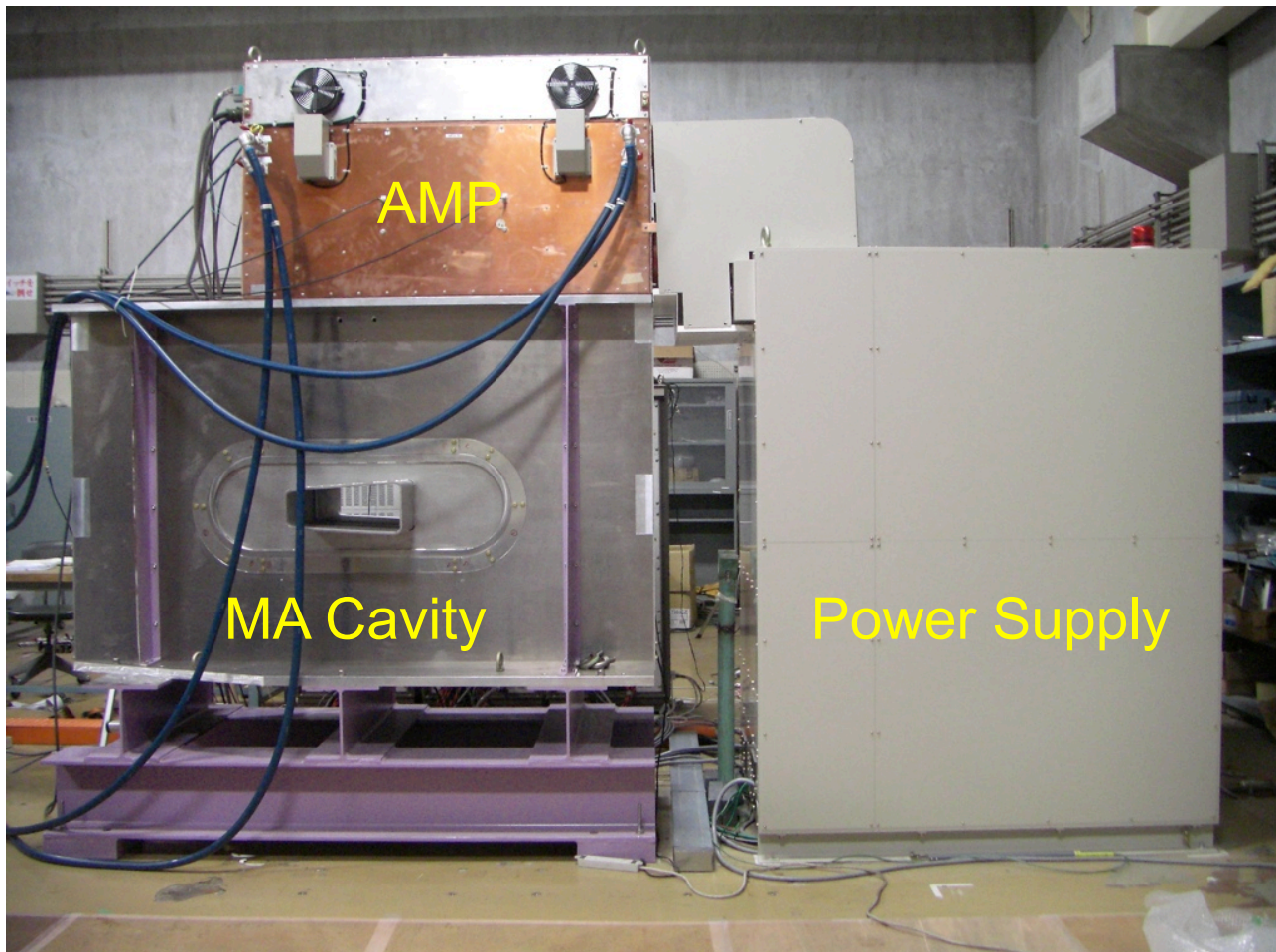


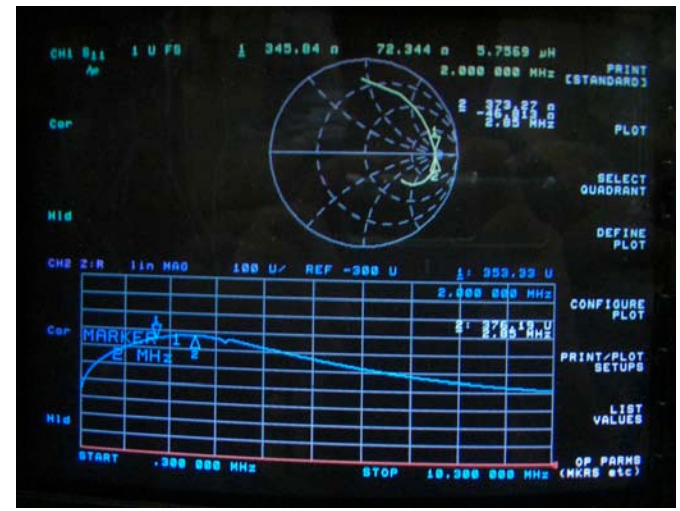
6-sector PRISM FFAG

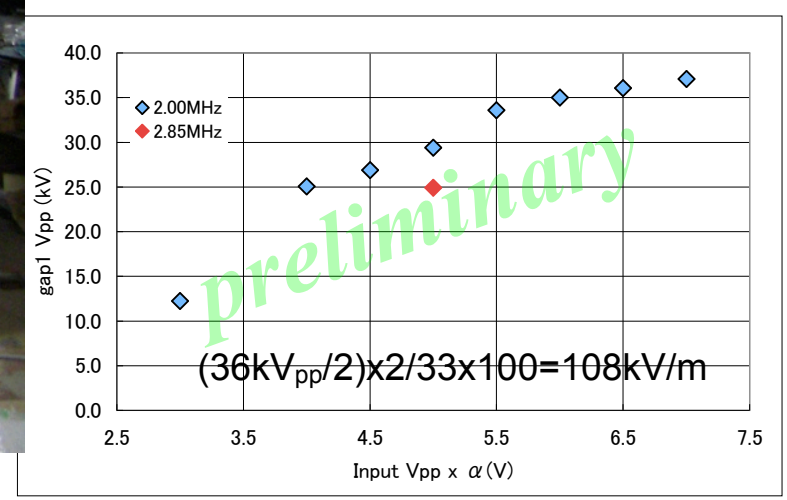


6-sector PRISM FFAG Ring at the M-Exp Hall, RCNP, Osaka University.

RF for 6-sector PRISM FFAG



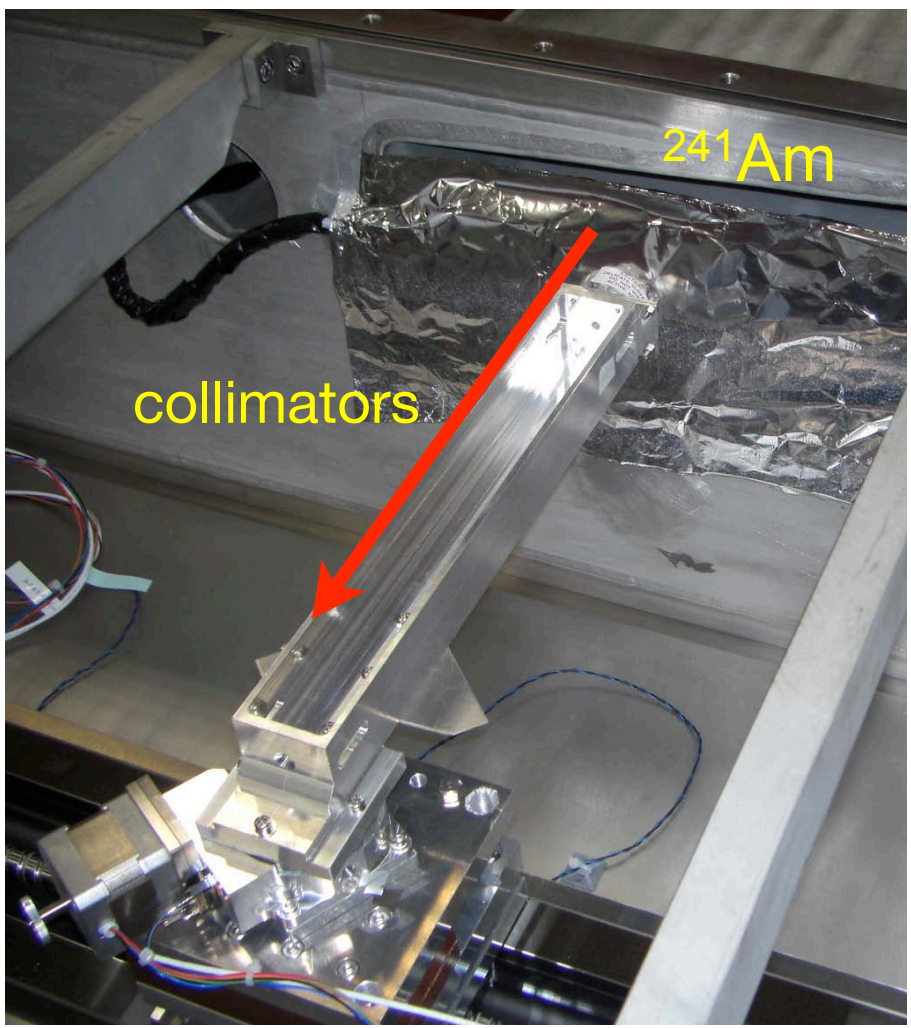




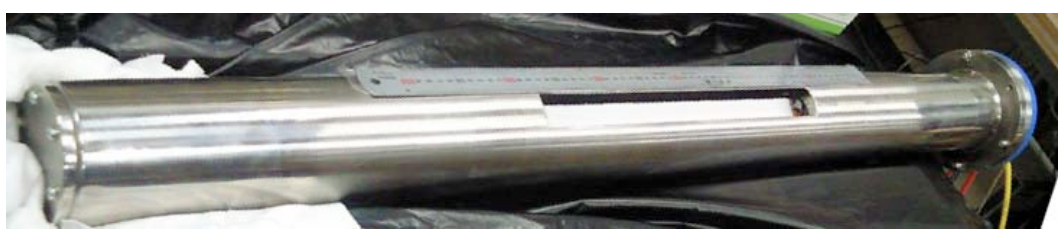
RF system for 6 sector PRISM-FFAG has been developed.
100kV/m @ 2MHz is promising.

Alpha Particle Injector and Detector

Alpha particle injector



Alpha particle detectors

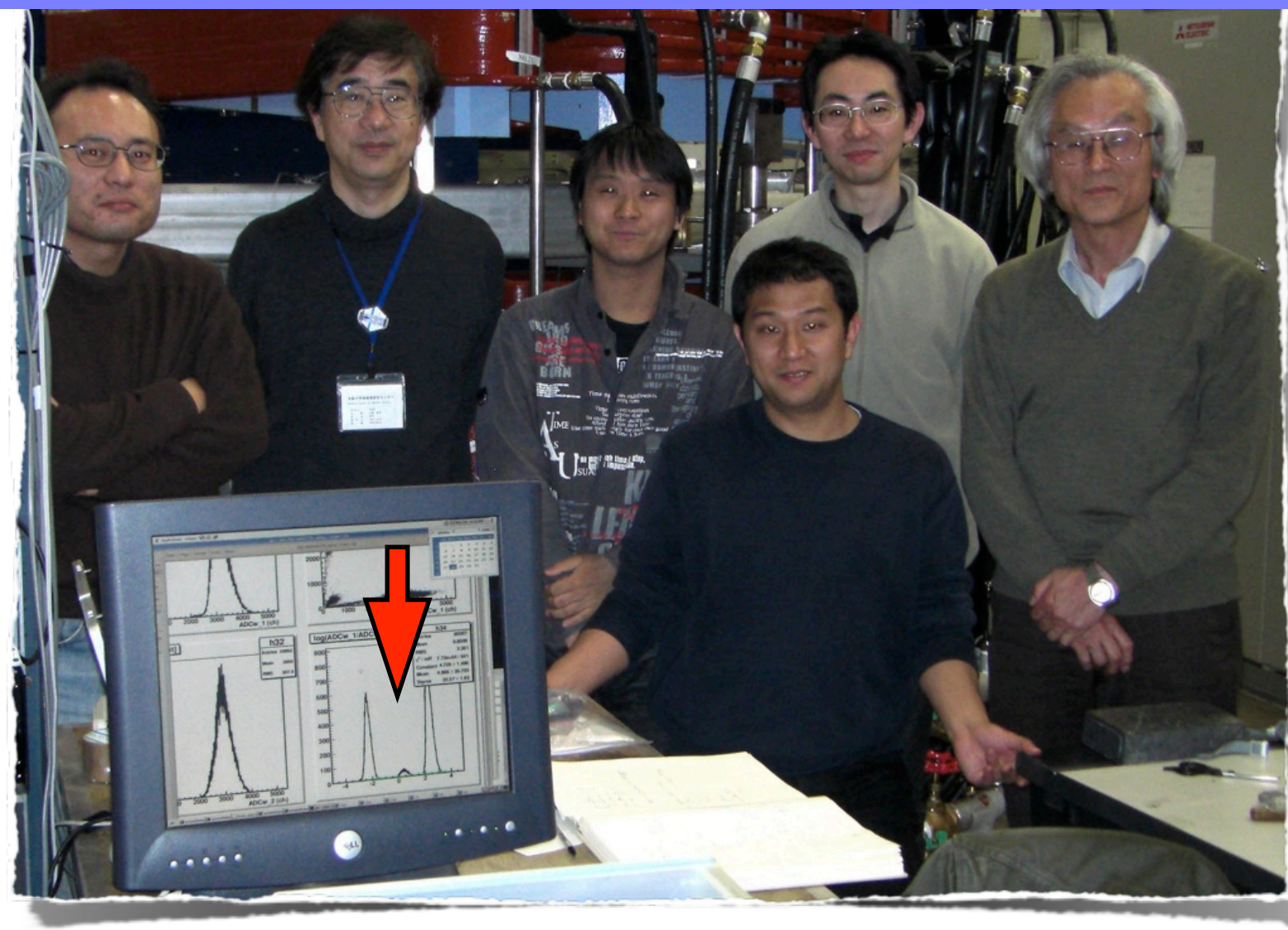


Plastic scintillator with ZnS with both-end readout for position measurement

In addition, a SSD detector for energy measurement

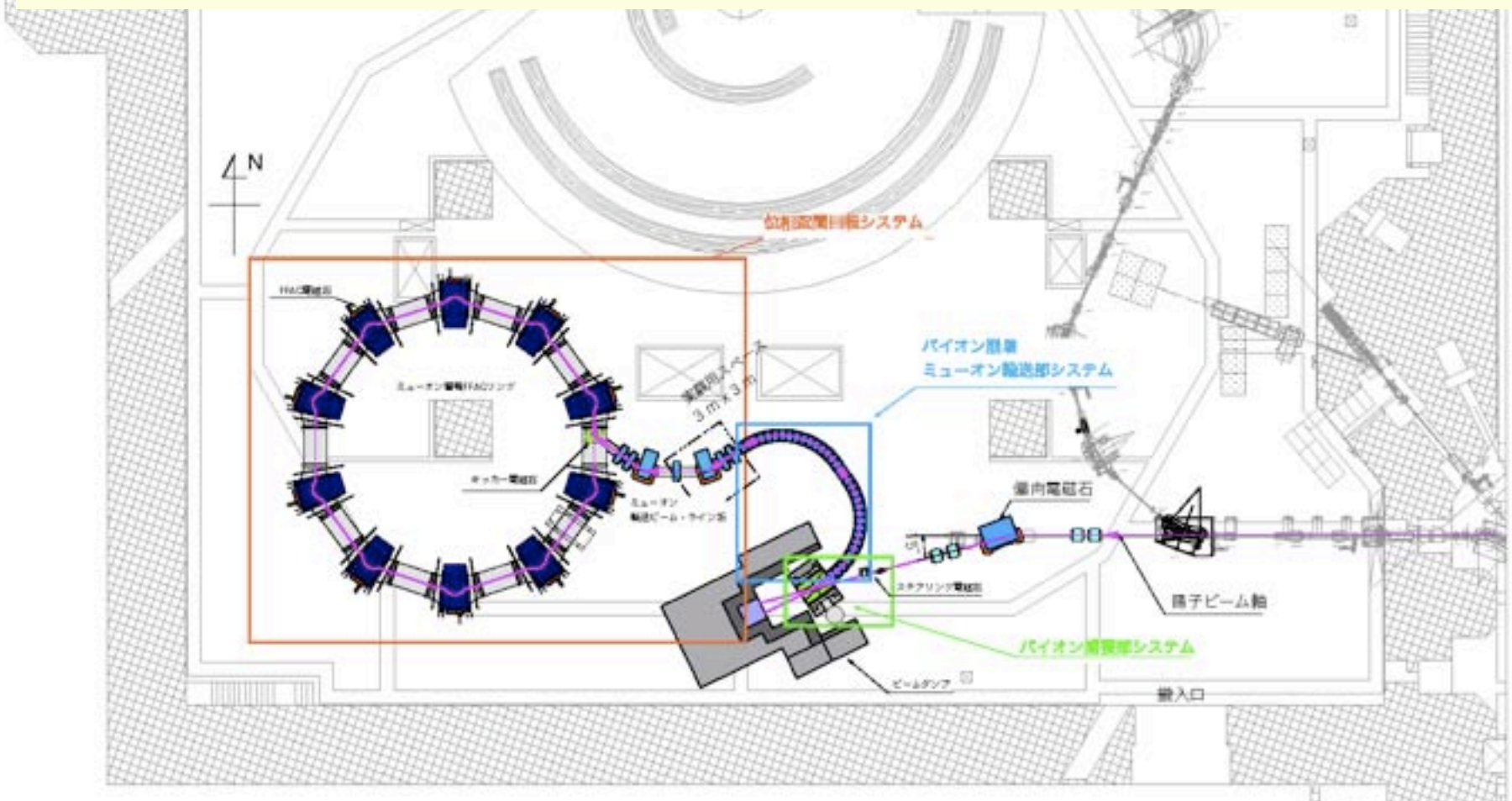
The First Alpha Events in the 6-Cell PRISM-FFAG Ring.

The first alpha events were detected on the 28 March, 2008.

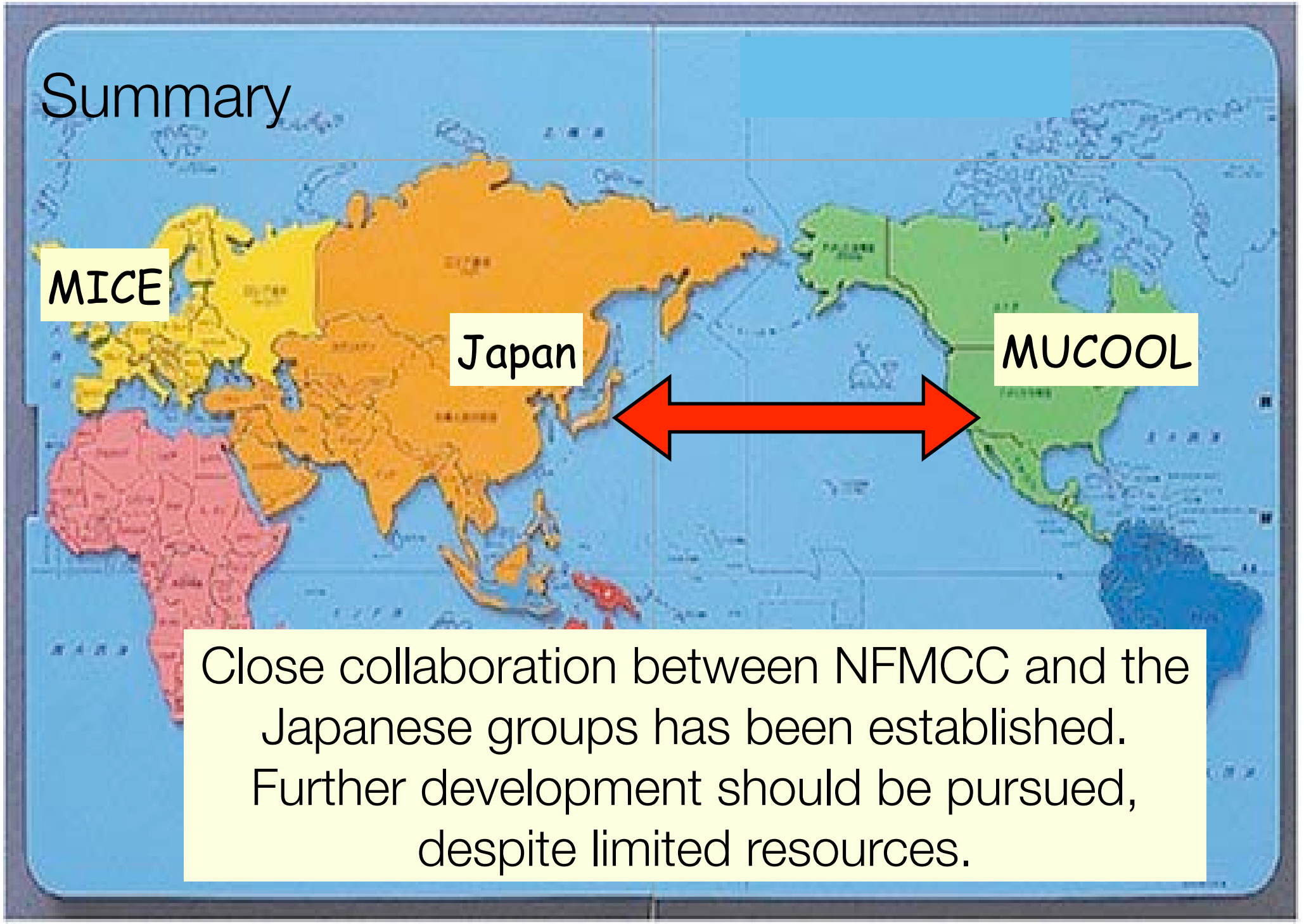


PRISM FFAG Test at RCNP, Osaka University

- Research Center for Nuclear Physics (RCNP), Osaka University has a cyclotron of 420 MeV. The energy is above pion threshold.
- The plan is to install the PRISM FFAG ring at RCNP to produce muons.
- Budget request is under preparation



Summary



Close collaboration between NFMCC and the Japanese groups has been established. Further development should be pursued, despite limited resources.

End of My Talk.