The Japanese Programs

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MUTAC review,
Brookhaven National Laboratory
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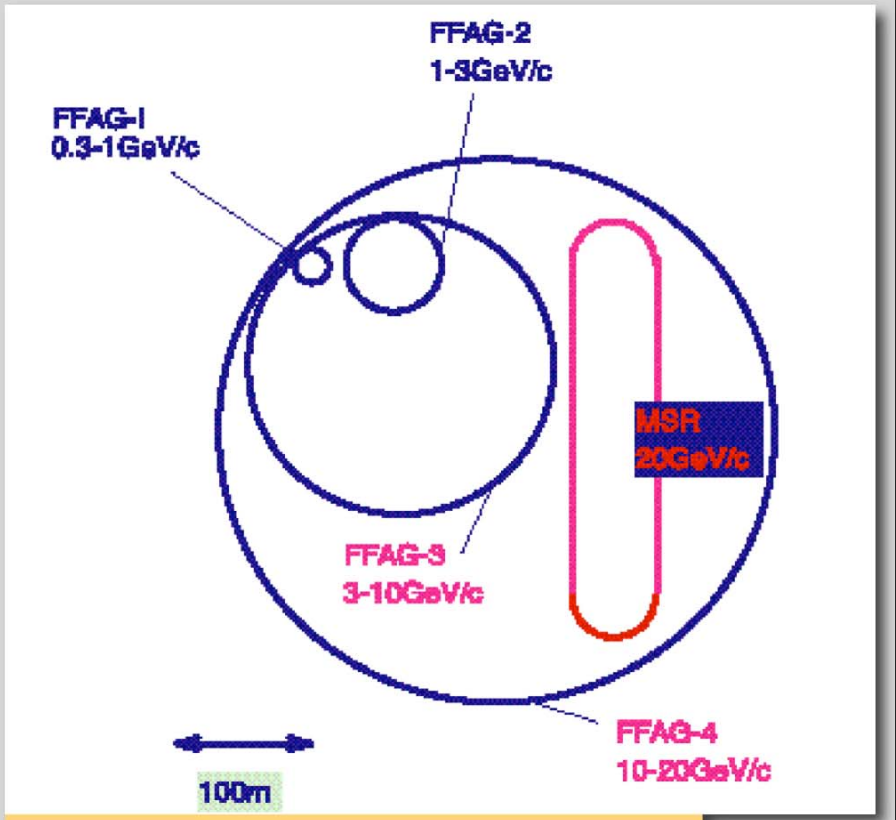
Outline

- FFAG-based muon acceleration for a Neutrino Factory
- International Collaboration
  - MUCOOL in NFMCC
  - MICE
- Domestic Studies in Japan
  - (Scaling) FFAG R&D in Japan
    - ADS FFAG at KURRI
    - ERIT FFAG at KURRI
    - PRISM at Osaka
- Summary

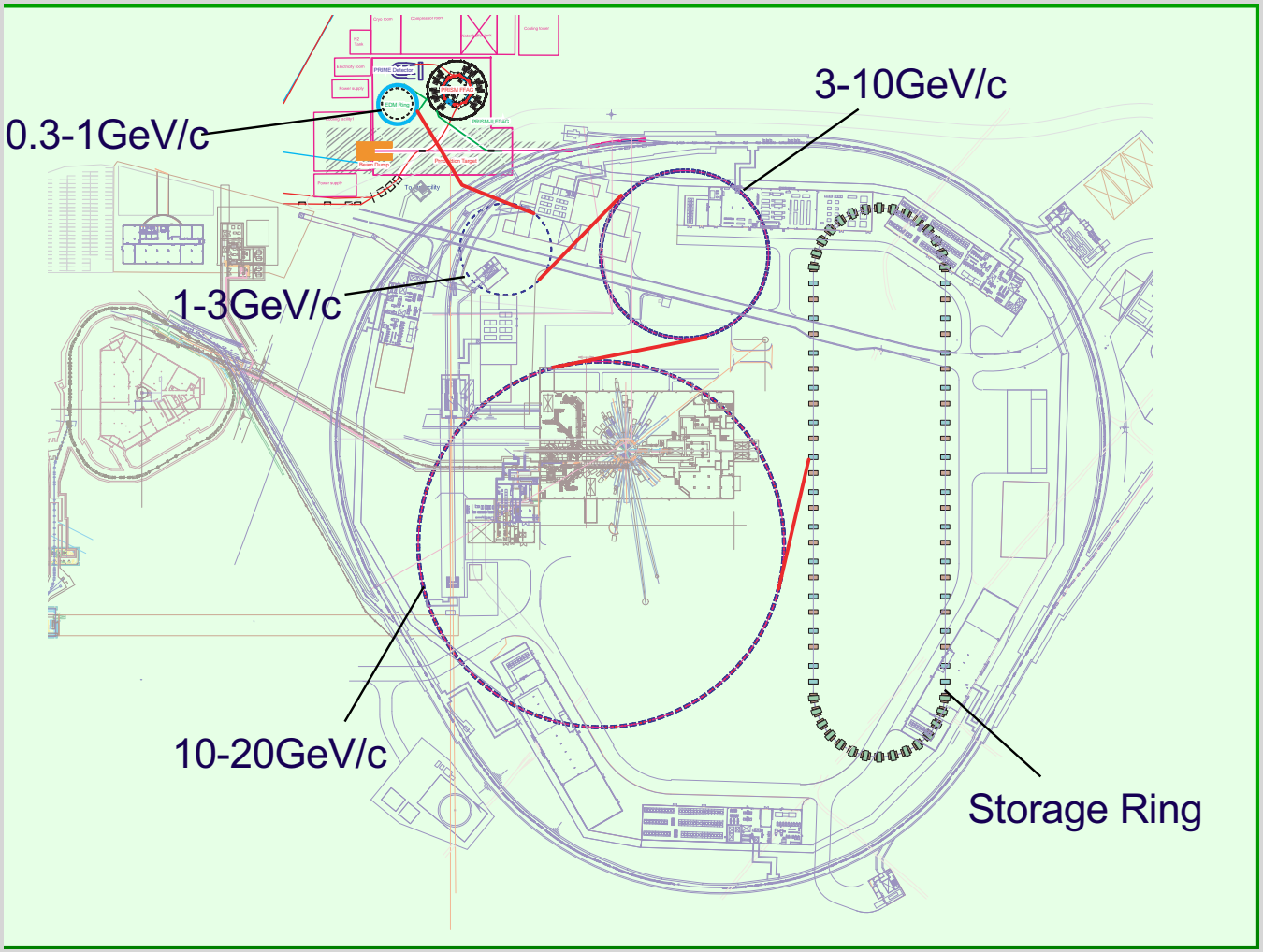
FFAG-based Scheme

- 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.

Historical Remark

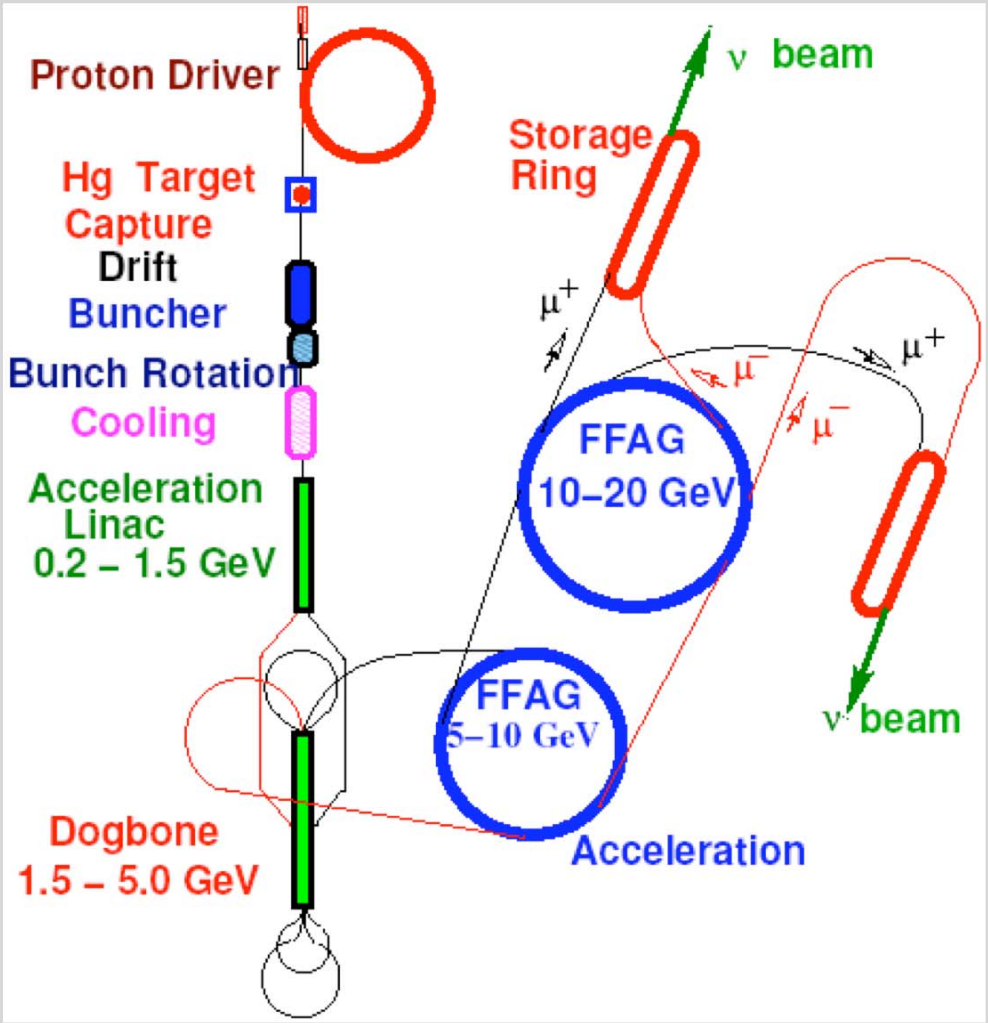


Muon Acceleration based on a series of FFAGs



NuFACT-J at J-PARC

Possible schematic layout at J-PARC. They are underground. No consideration since 2001.



ISS Baseline Design

non-scaling FFAGs

International Collaboration

International Collaboration

- NFMCC
  - The Japanese group has joined the MUCOOL studies for the past 7 years.
  - Major contributions are the development of liquid hydrogen absorbers of convection type.
- MICE
  - The Japanese group has joined the MICE collaboration from the beginning.
- MERIT
- ISS/IDS Studies

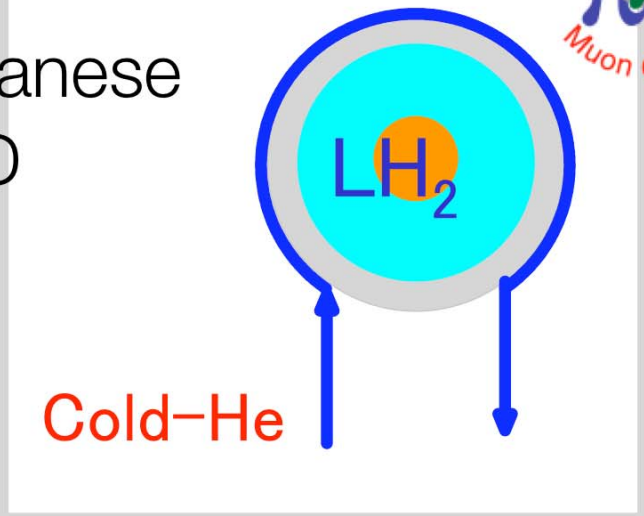
LH2 Absorber R&D for MUCOOL

Liquid Hydrogen Absorbers

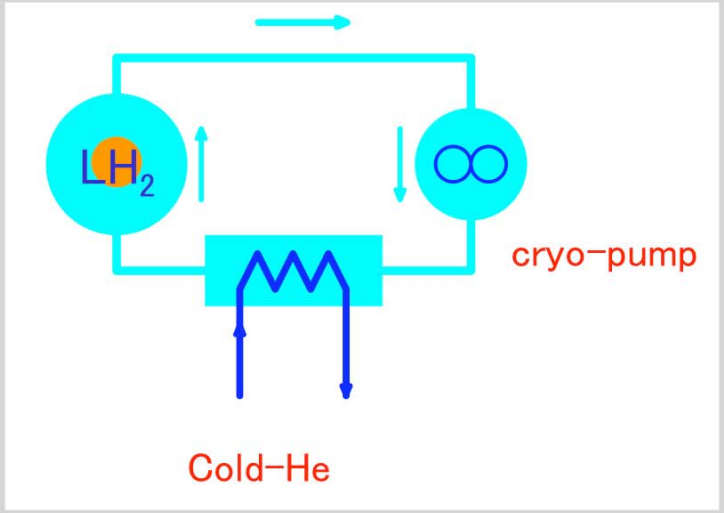
- Absorbers need long radiation length.
  - The best candidate is liquid hydrogen.
- Two types of cooling : convection type and forced flow type.
- Japanese contribution is for the convection driven type.
- PI is Shigeru Ishimoto (KEK).

convection

Japanese R&D

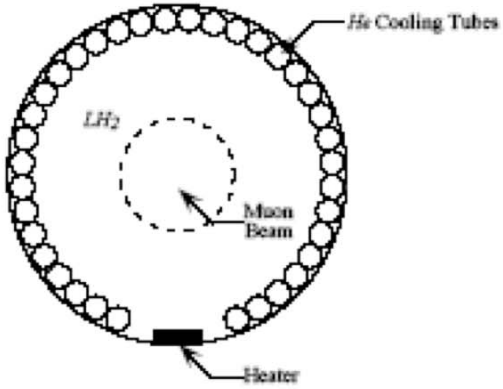


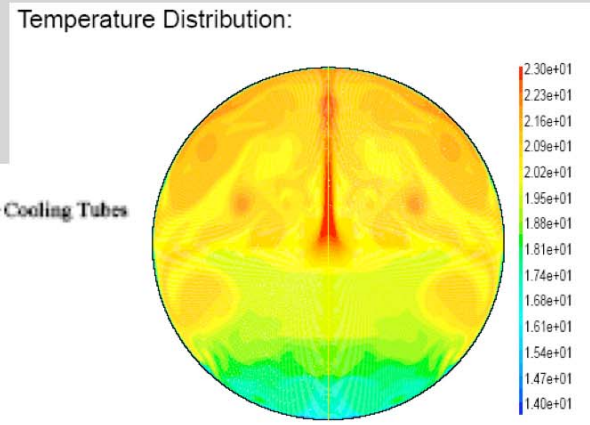
forced flow



Convection Absorber

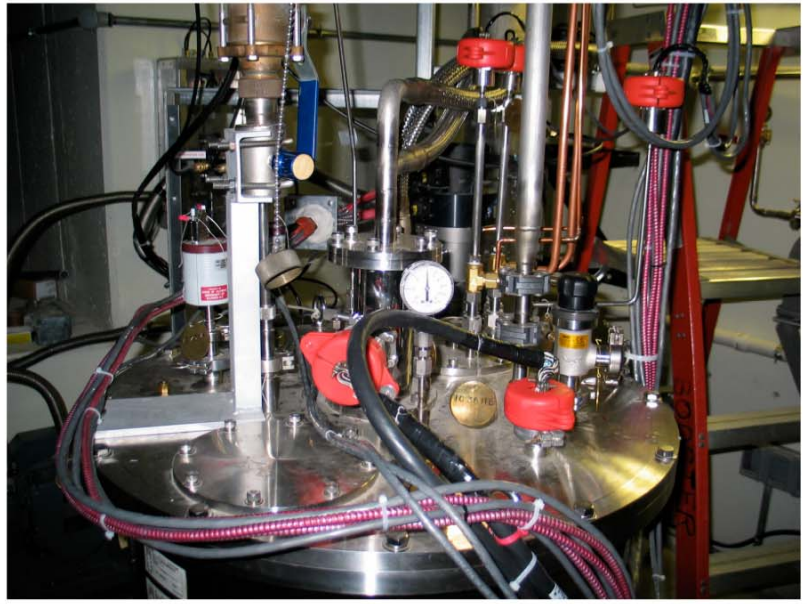
- Convection is driven by beam power and internal heaters.
- Helium gas exchanger removes heats from the absorber wall.
- Advantages:
  - simple, less LH2
- Disadvantages:
  - less cooling power.
  - need prototype tests.
  - MICE uses convection type.





Electric cabinet purged by G-N_2

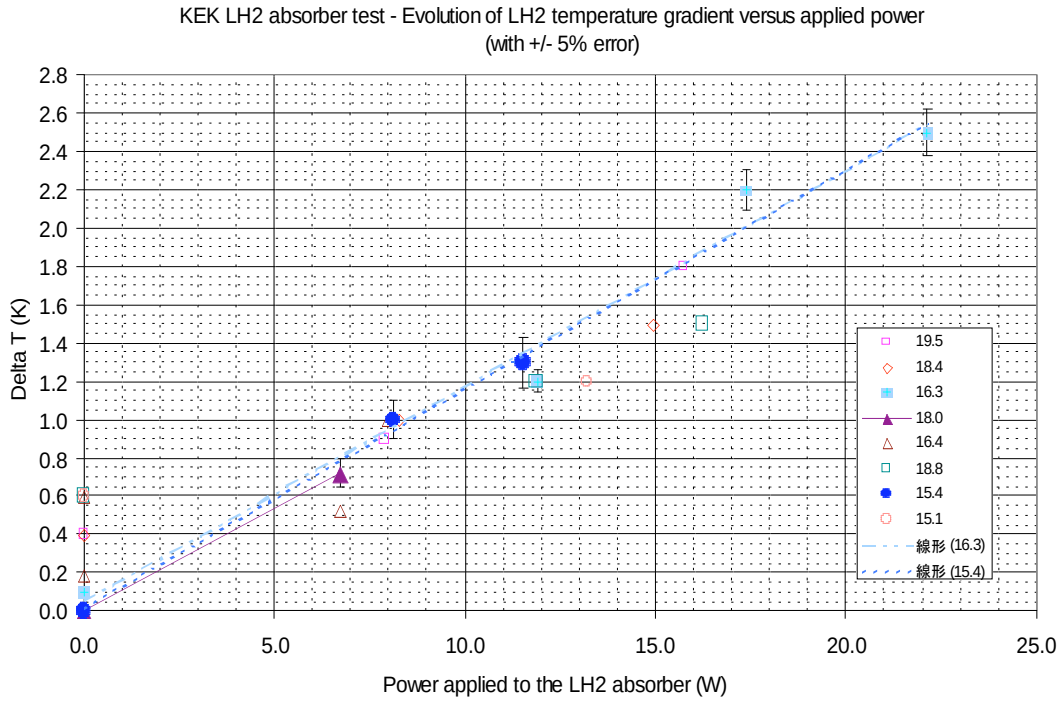
Top flange of absorber test cryostat



Set-up of absorber test cryostat

1st Cooling Test at MTA/ FNAL

Results of 1st Cooling Test at MTA/FNAL



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

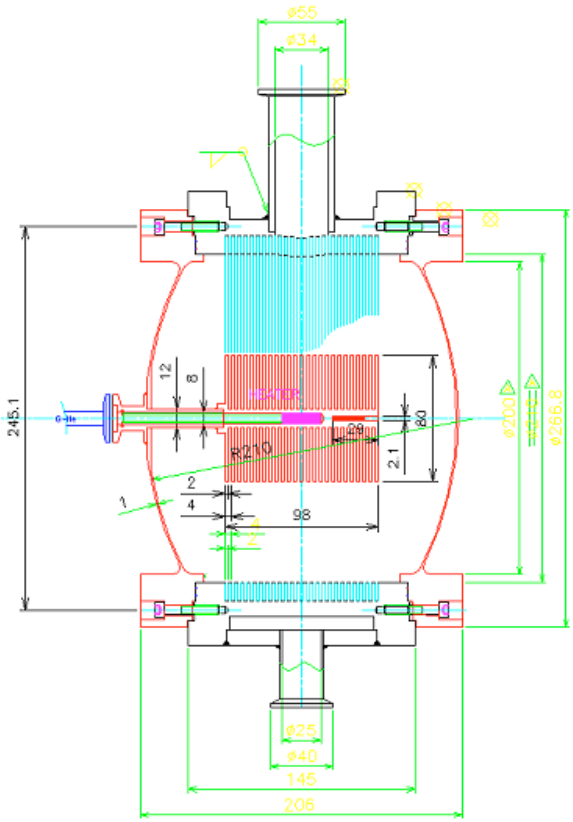
dT=2.3 K for 20 W → dT=9 K for 78 W
(T_{max}=23K, T_{min}=14K)

- The 1st test of LH2 filling test was done at MTA in 2004.
- The test showed that the temperature rise of 2.4 K for 20 W.
- LH2 has 9 K range (Tmin=14K, Tmax=23K).
- Heat of about 70 W can be taken.

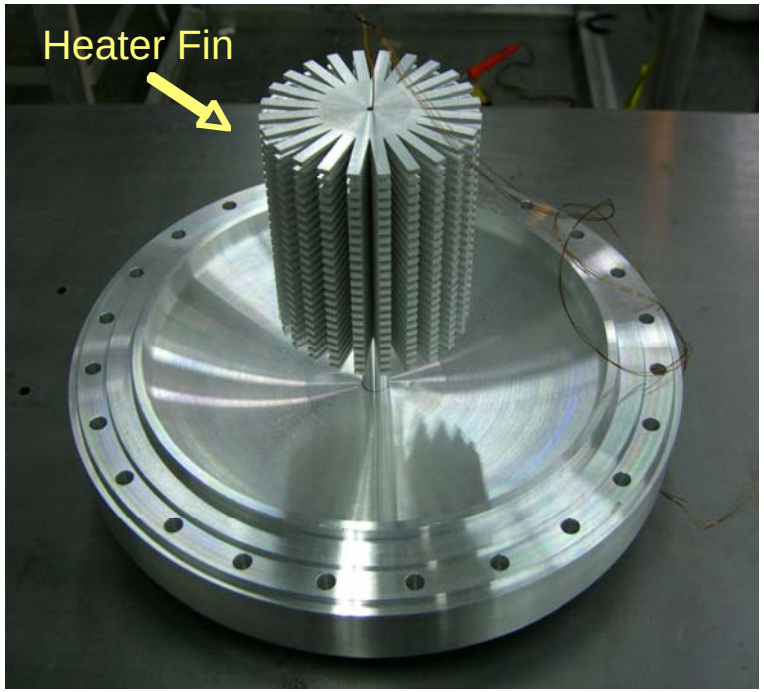
2nd LH2 Filling Test at MTA

- Purpose :
  - demonstration of 70 W or more cooling power.
  - measurement of temperature and LH2 level more precisely.
  - forced convection
- Improvements :
  - electric heaters (instead of gas heaters)
  - a shorter He transfer line
  - more thermometers
  - liquid level meter for LH2
- Wait for safety approval .....

LH2 Absorber with Heaters for 2nd Test (2006)



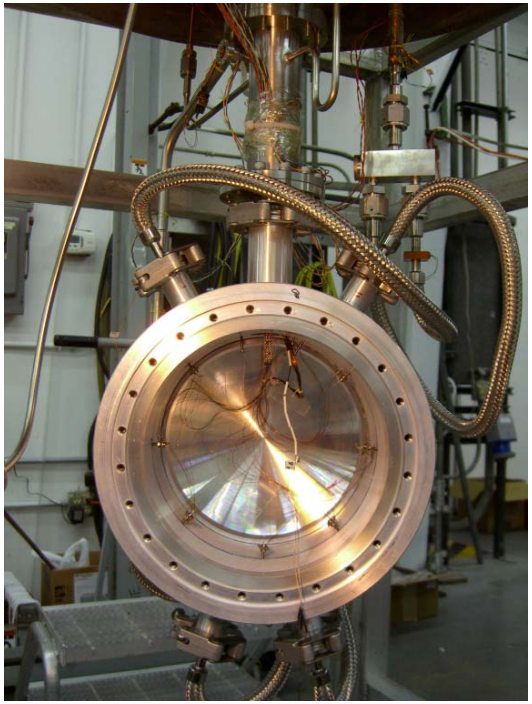
Window with Heater & Fun

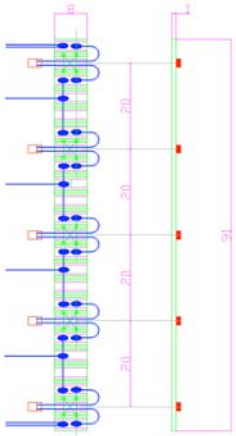


Electric heater installed

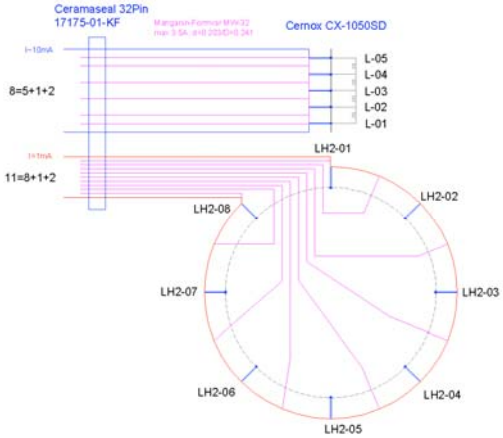
Heater 100W max.

Absorber Assembly at FNAL Lab-6 (Jan. 2007)





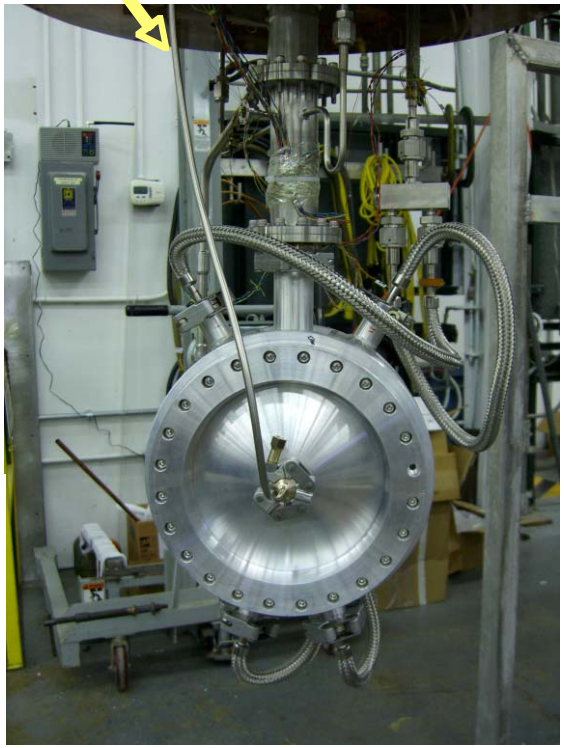
L-H2/LHe Level sensor in absorber

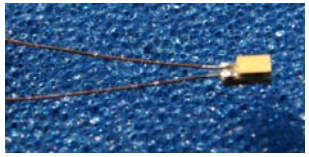


Temp sensors

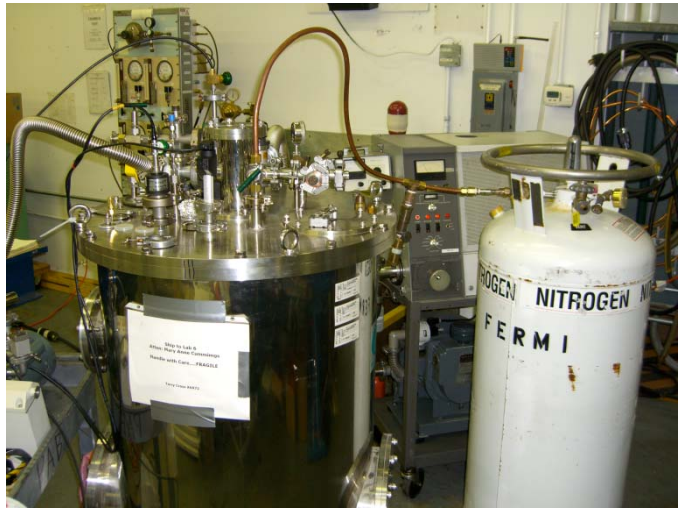
CX-1050-SD

GHe Shield Pipe for Heater Wires





Pressure/ He Leak Test at FNAL Lab-6 (Jan. 2007)



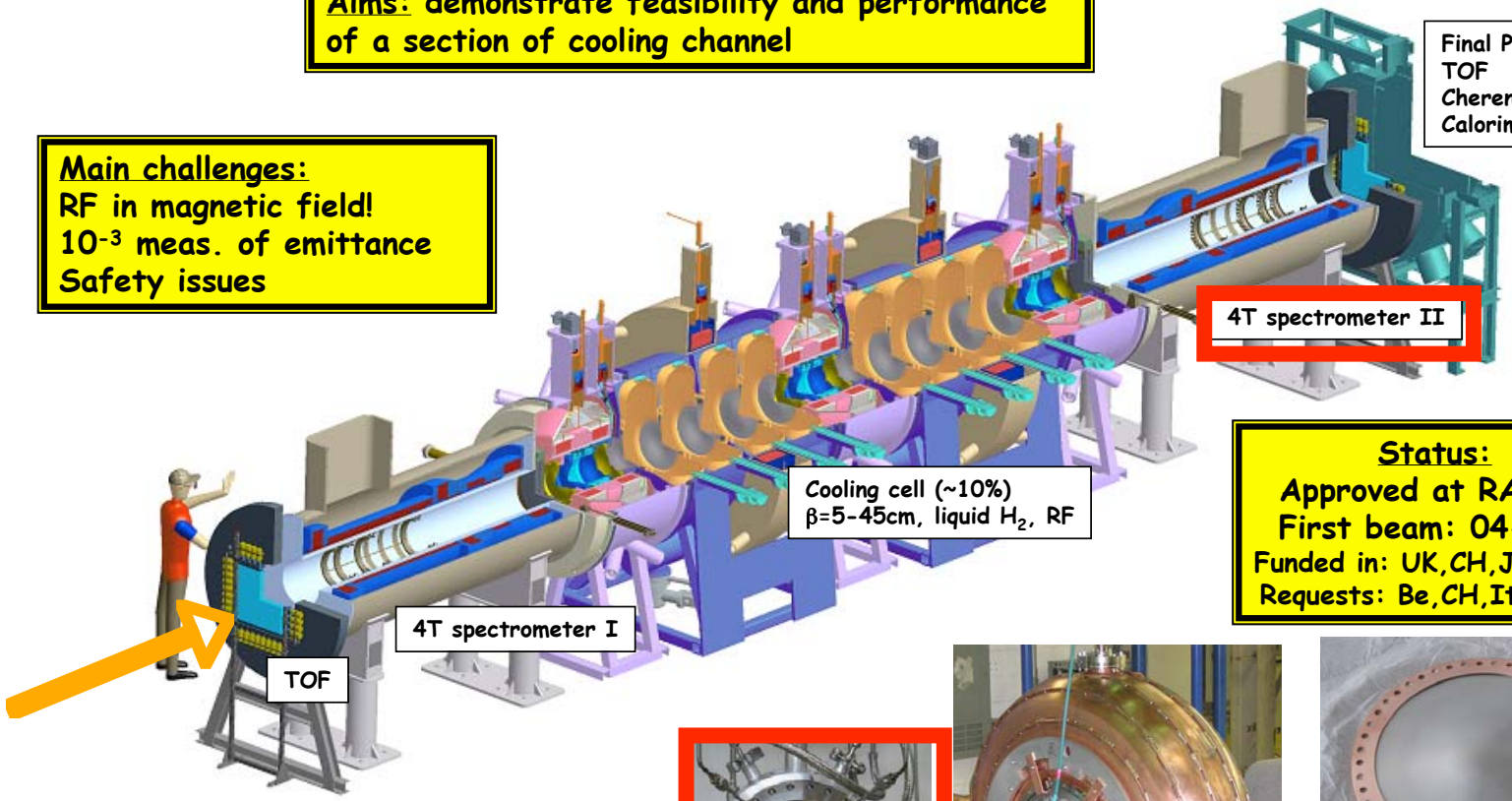
US-Japan Program

- We got budget from the US-Japan program (between DOE and MEXT in Japan, and funded by MEXT).
- In JFY2007, the US-Japan program has been jeopardized. The whole budget became about a half, from 8 oku yen to 4 oku yen (oku=10^8).
- Our application on MUCOOL for the US-Japan program (PI is Shigeru Ishimoto) for JFY 2007 has been turned down.
  - It is mainly for R&D for LH2 absorbers.
    - However, can keep the KEK group (Shigeru Ishimoto et al.) working on MUCOOL and MICE, but no budget,
  - The program has continued for the past 7 years.
  - And, need to consider a new “good” proposal ....

MICE

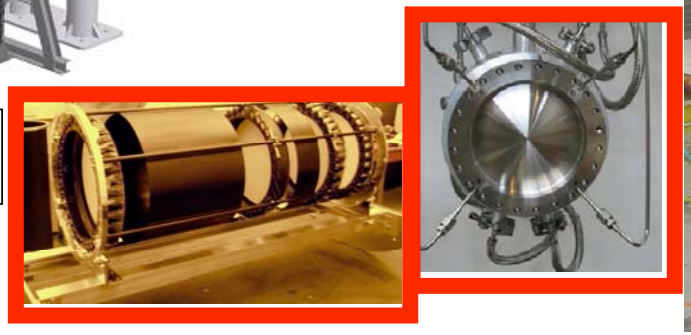
Aims: demonstrate feasibility and performance of a section of cooling channel

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

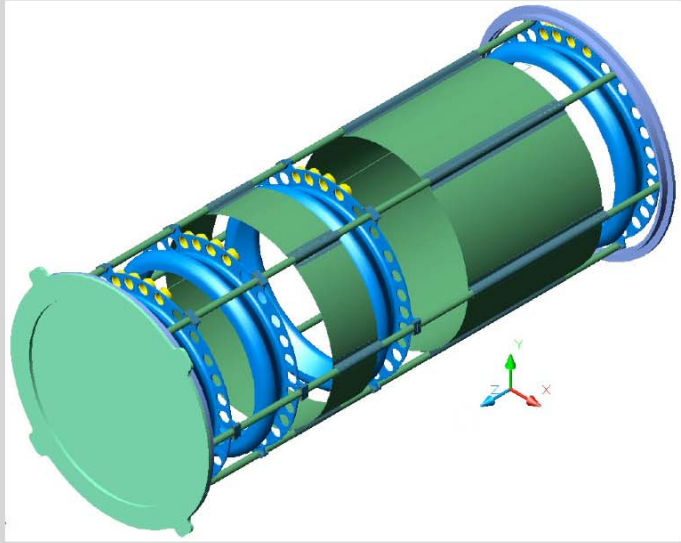


DAQ
Control

Japanese Contributions

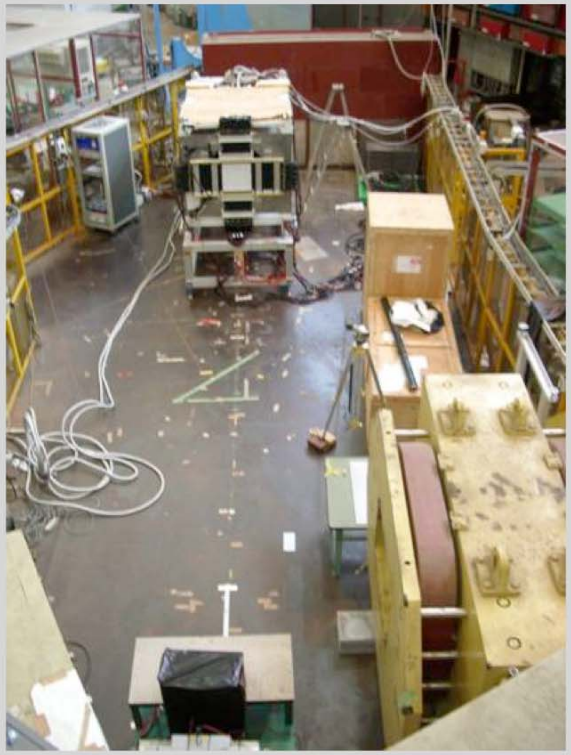
SciFi Tracker R&D

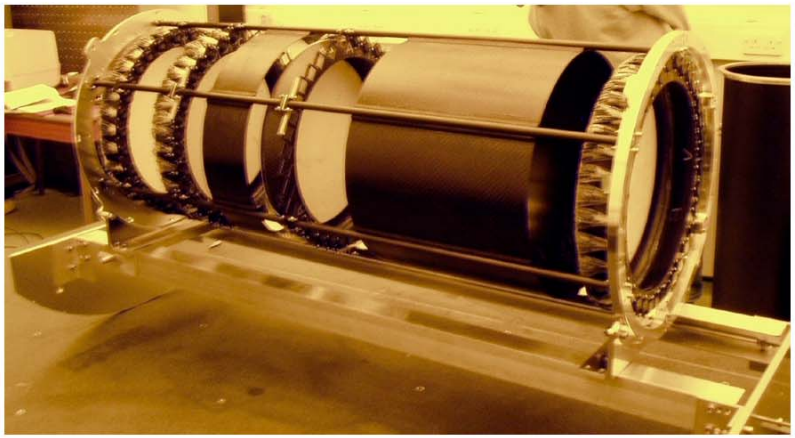
- JP-MICE (Osaka, KEK) participates in SciFi trackers, and LH2 absorber (together with UK & US).
- Design and construction of Scintillating Fiber (SciFi) trackers
  - with FNAL and UK
  - fiber supply
- VLPC cryostat construction
  - with FNAL and UK
  - cryo-cooler cooling

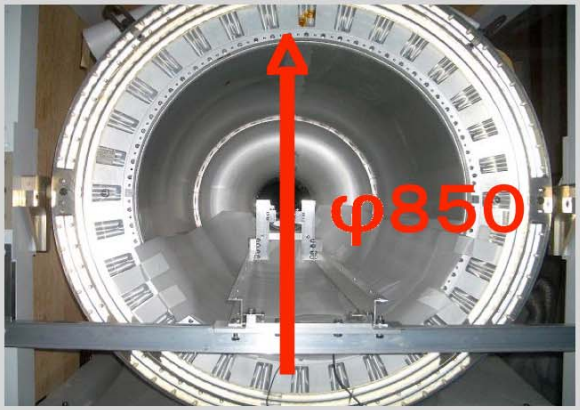


SciFi Tests at KEK

- Beam test at KEK-PS was done in fall, 2005.
  - 4 SciFi stations
  - VLPC cryostat with a cryo-cooler.
  - solenoid mag. field (1T)
  - TOF&ACC for PID

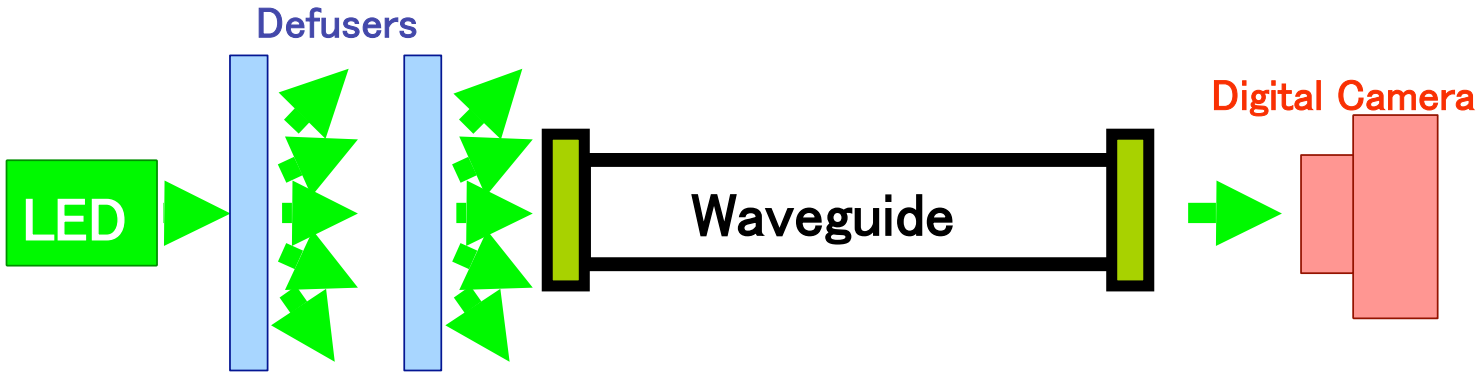




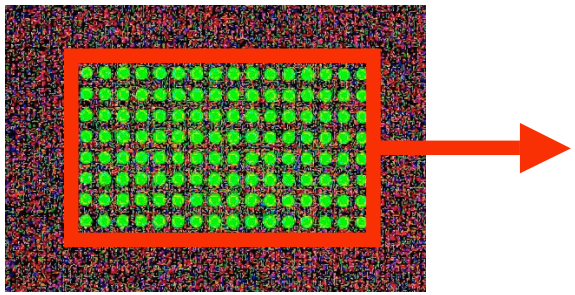


Super JACEE Magnet

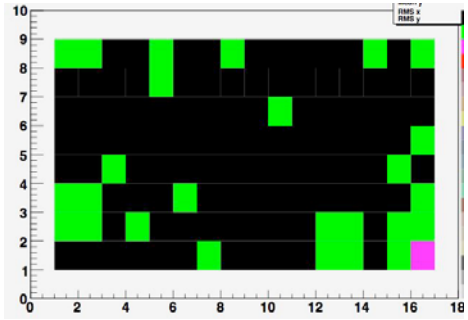
Transmission QA for Fiber Waveguide



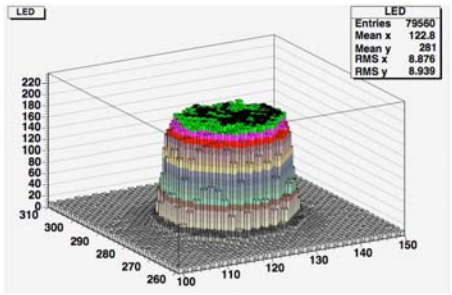
LED : Wave length=525nm(3HF : Wave length=520nm)



LED photo data (RAW format)
of a connecter



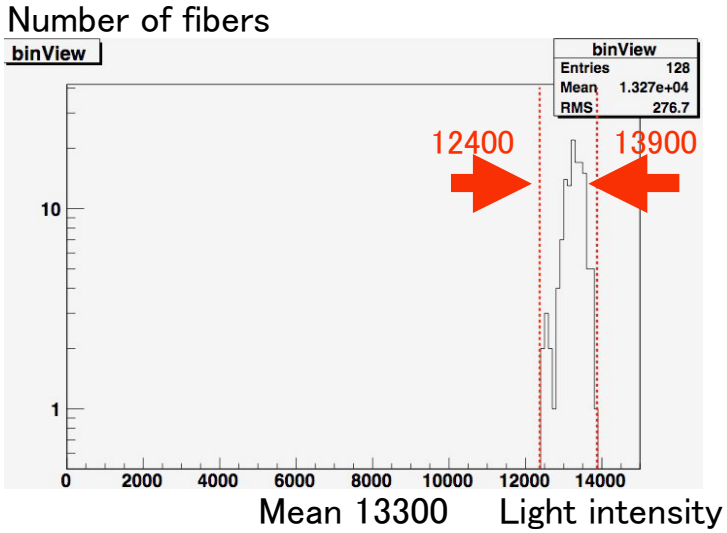
Intensity mapping data
of a connecter

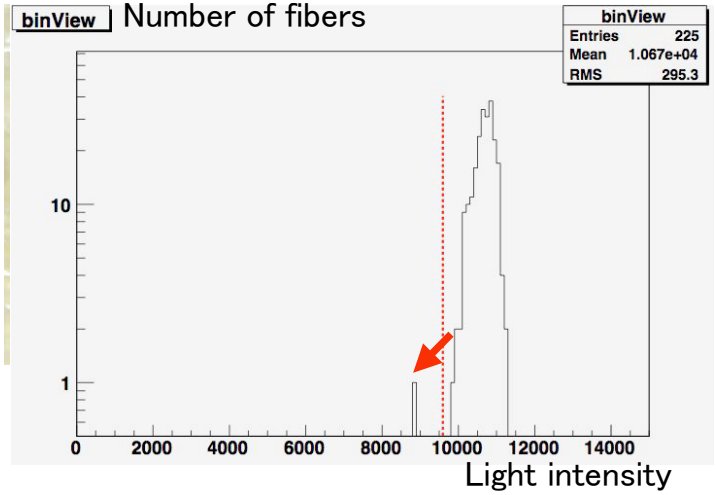


CCD readings of a fiber

QA Test Preliminary

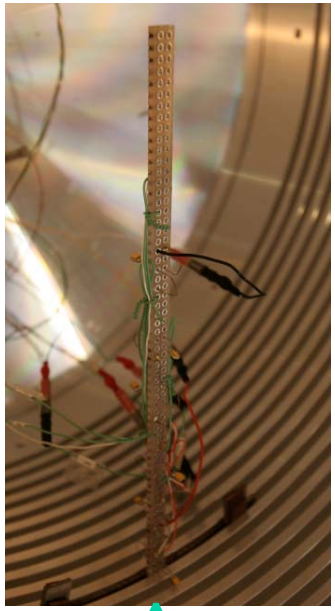
- QA procedure for transmission has been established.
- All the clear fibers and connectors are in hand.
- Production of wave guilds (made by clear fibers) will start soon.

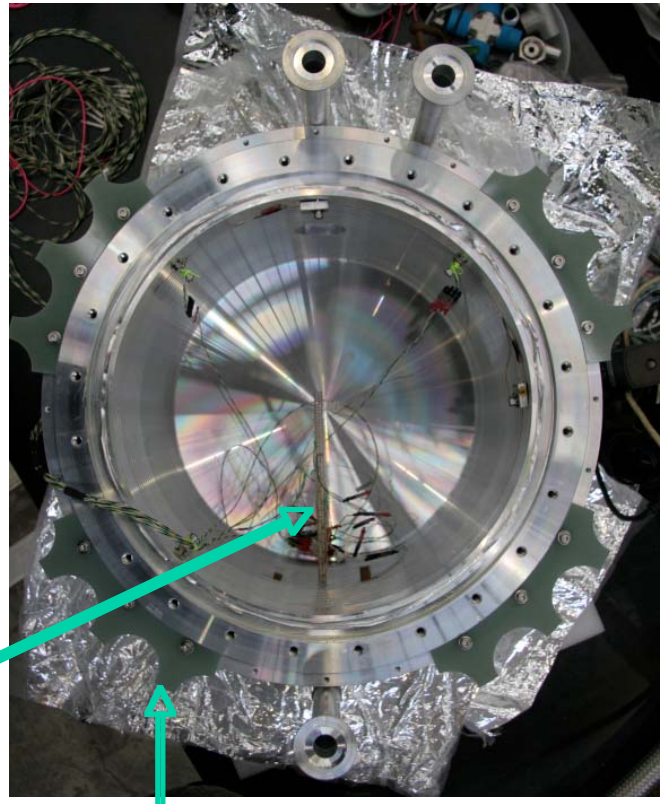




LH2 Absorber R&D for MICE

20 litter absorber R&D at KEK



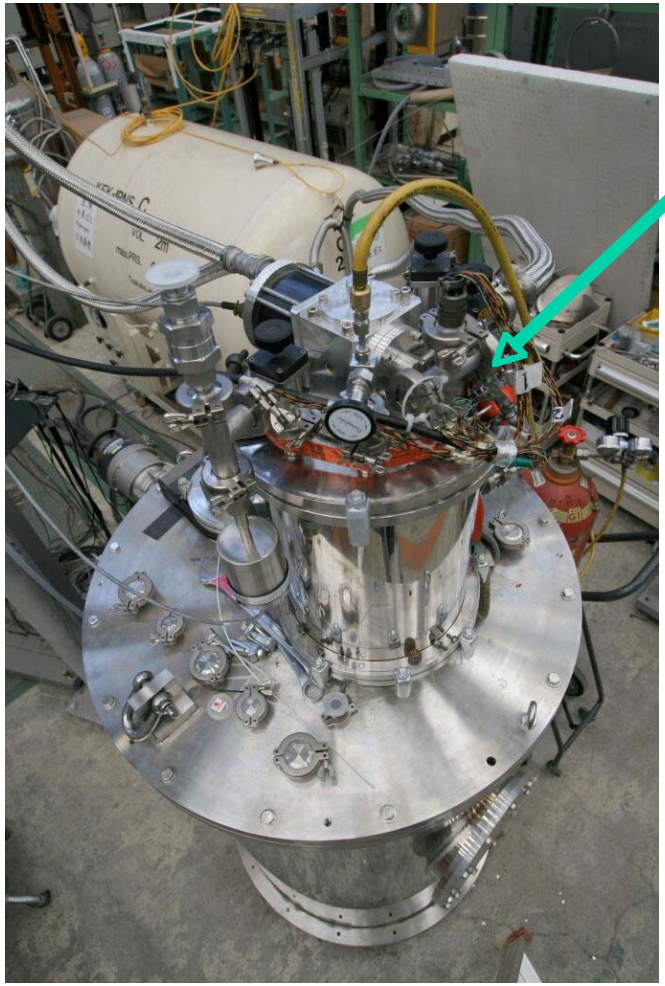


Level Sensor

G-10

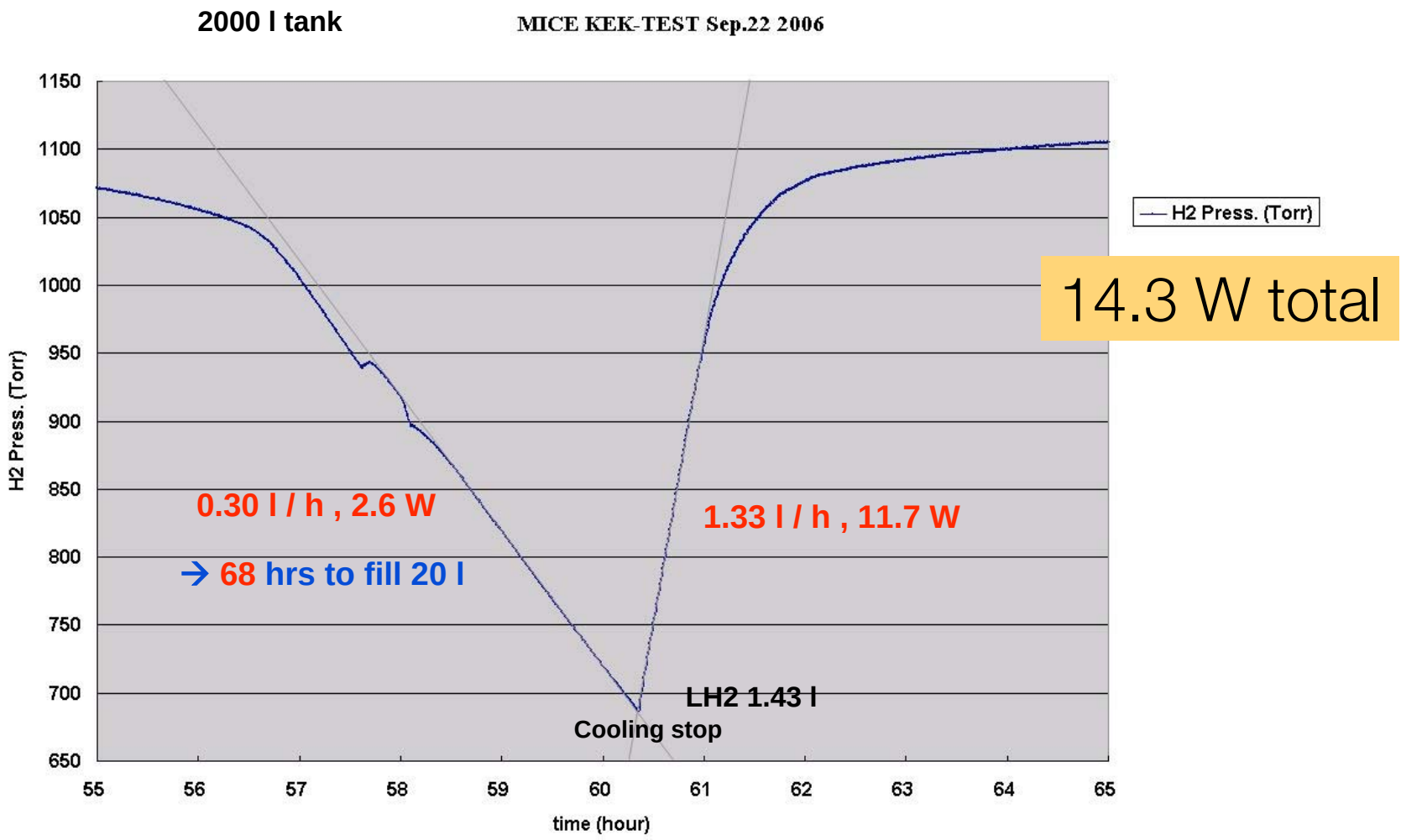
M.L.I.

LH2 Absorber Cryostat at KEK



Cryocooler
1.5W@4.2K

Cooling Power Test



FFAG R&D in Japan

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

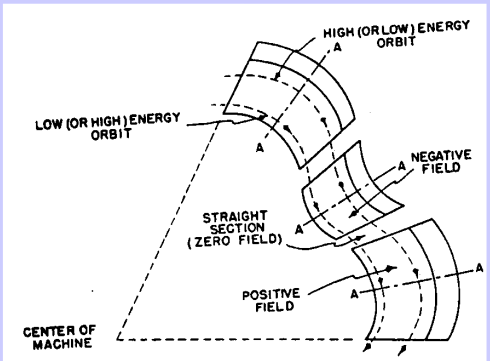


FIG. 2. Plan view of radial-sector magnets.

Spiral

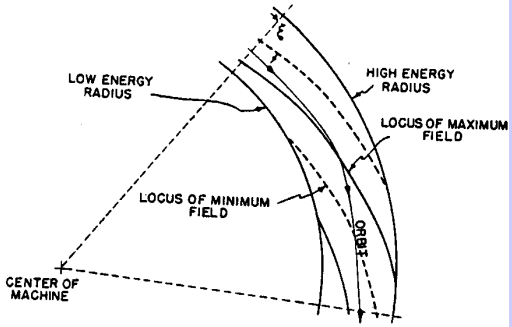
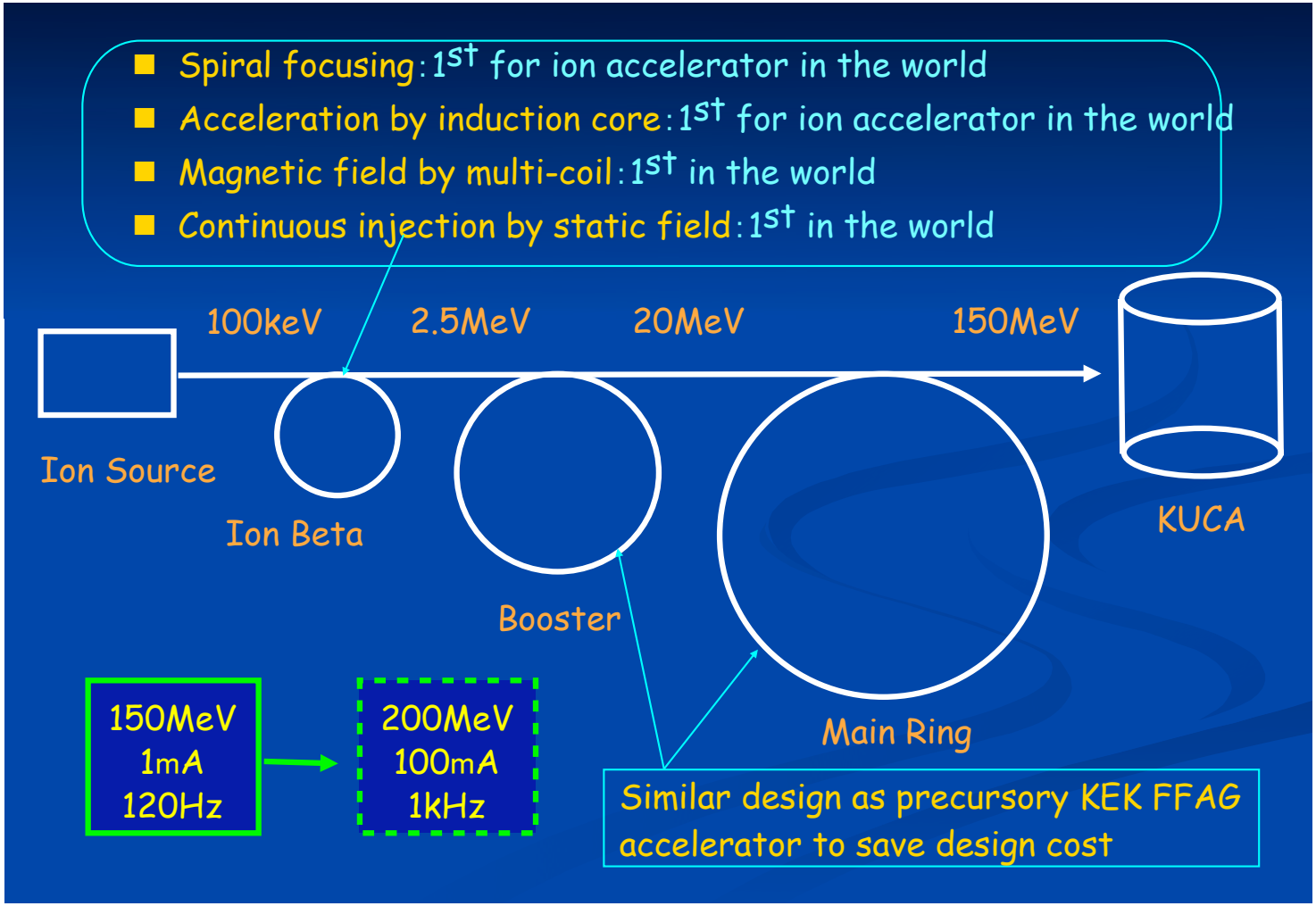


FIG. 3. Spiral-sector configuration.

Scaling FFAG R&D in Japan

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

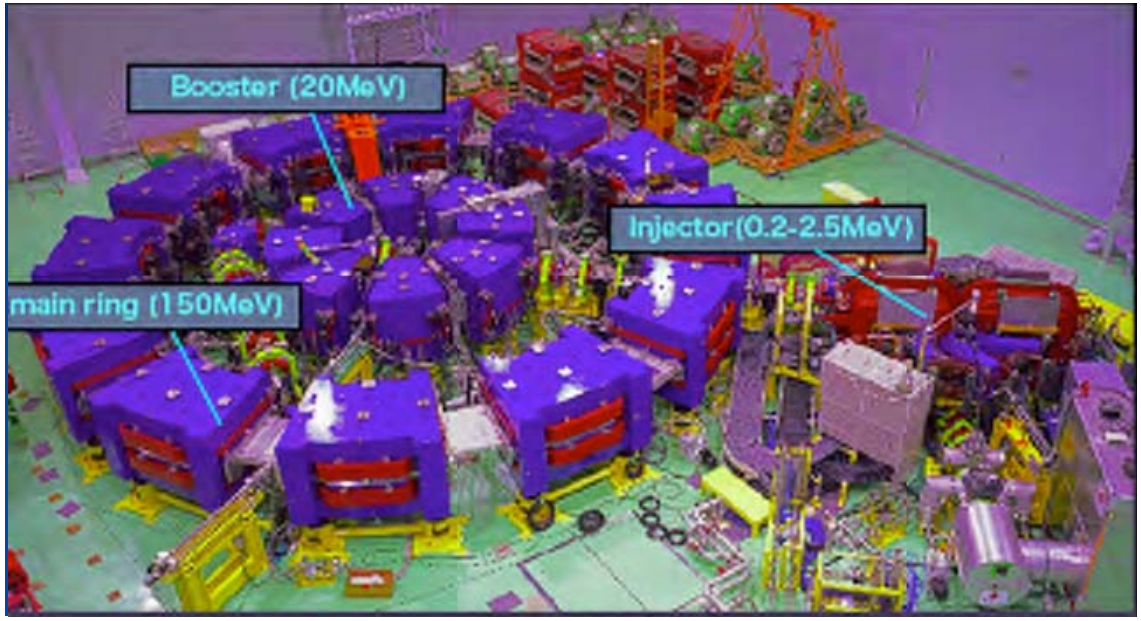
FFAG Configuration for ADS system at KURII, Kyoto University



FFAG for ADS at KURRI, Kyoto University

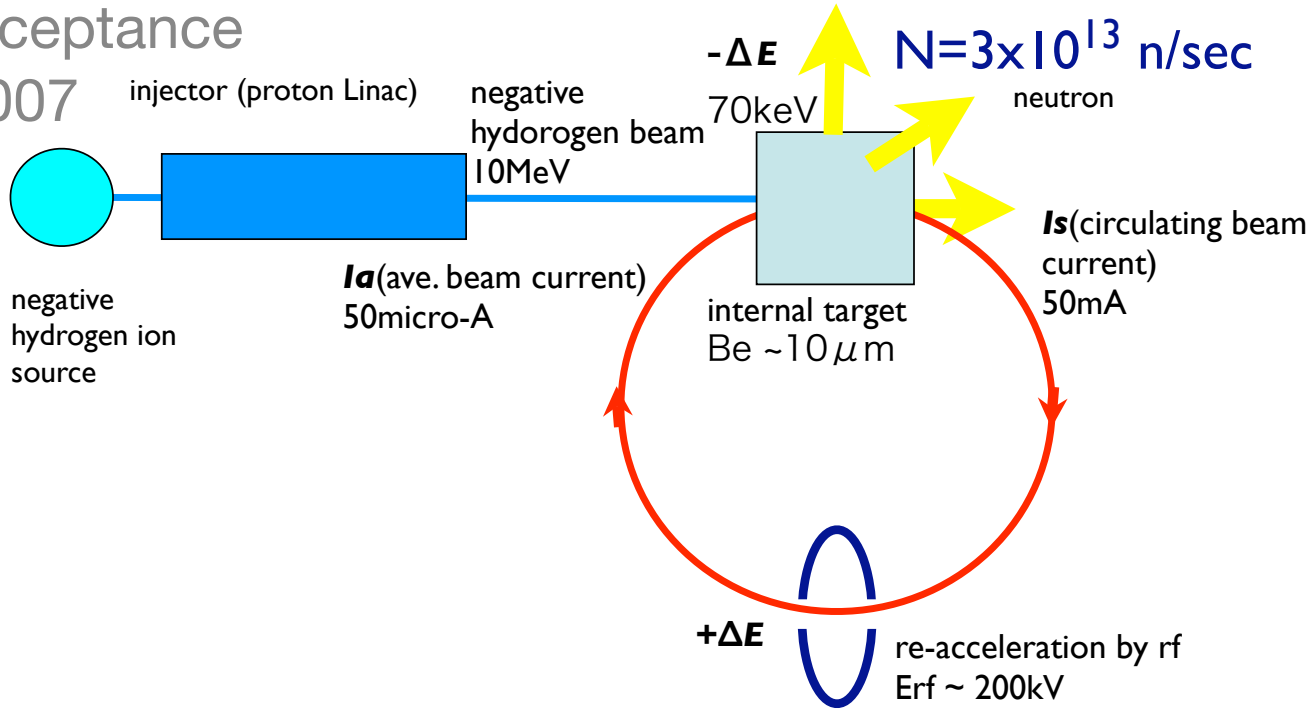
Status of ADS FFAG Commissioning

- Injector Ring (Spiral-induction FFAG)
  - completed in January, 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

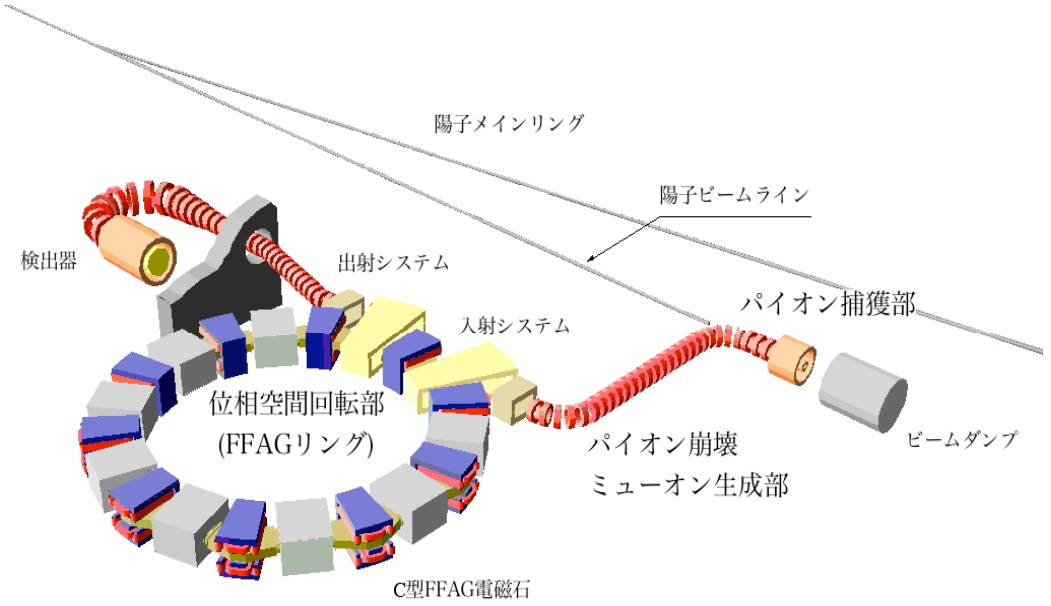


ABNS with Internal Target : FFAG-ERIT

- Accelerator based neutron source (ABNS)
- ERIT = Emittance/Energy Recovery Internal Target
- proton storage ring with cooling
- internal target
- need large acceptance
- JFY 2005 - 2007



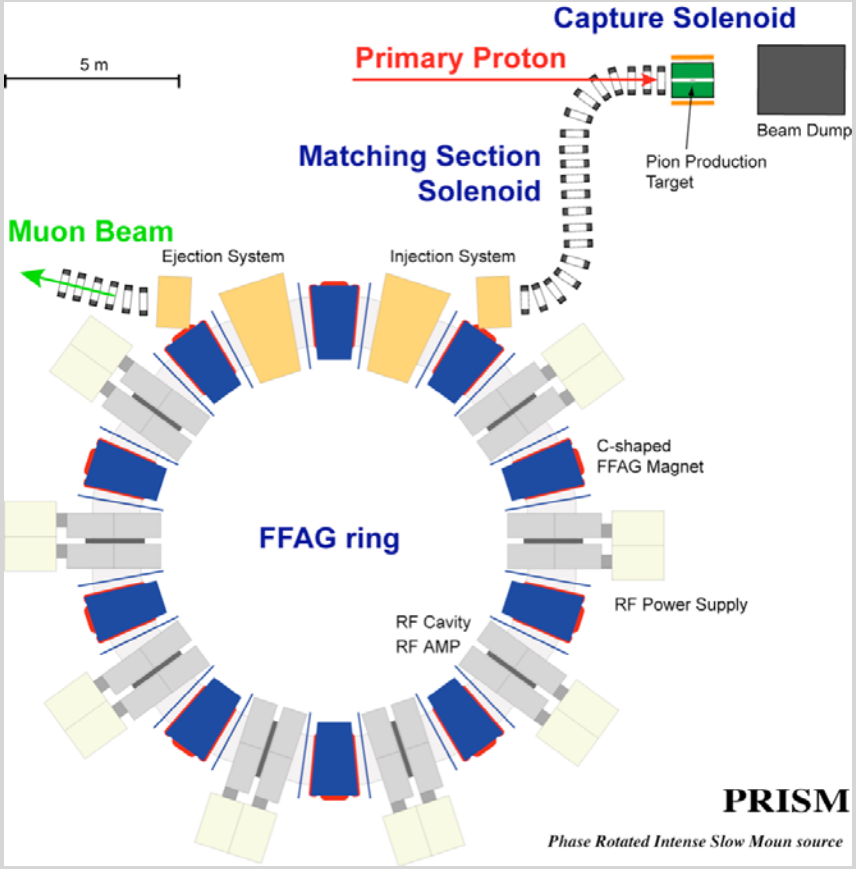
FFAG for Muon Storage Ring



PRISM

- High muon intensity
  - 10^{11}-10^{12}/sec
- High luminosity
  - phase rotation
- High muon purity
  - no pions
- Low energy
  - 68 MeV/c
- primarily, for a search for charged-lepton mixing (a muon-to-electron conversion process).

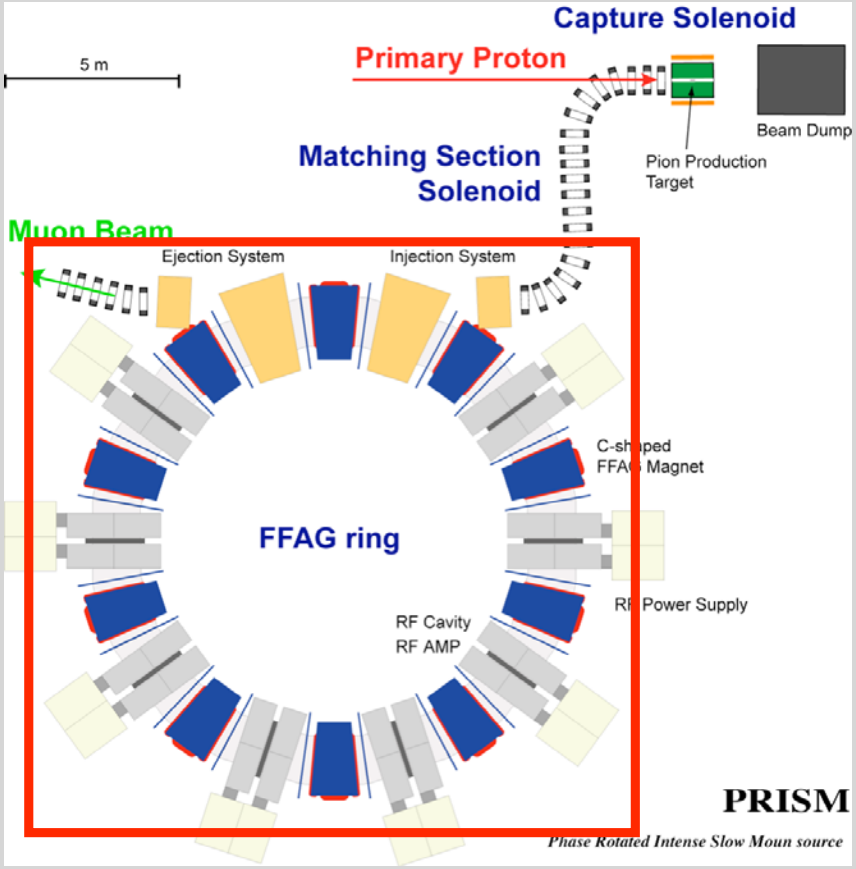
Phase Rotated Intense Slow Muon source



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

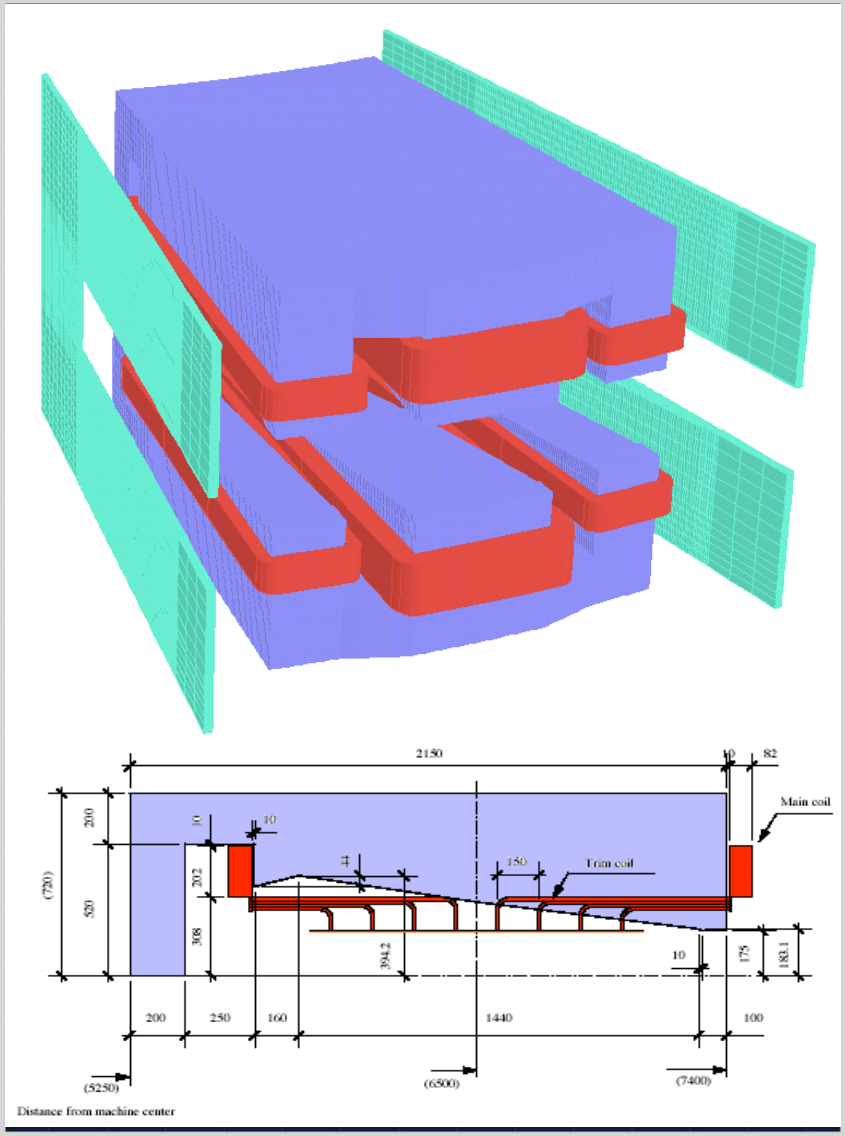
Phase Rotated Intense Slow Muon source



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
- Construction underway.

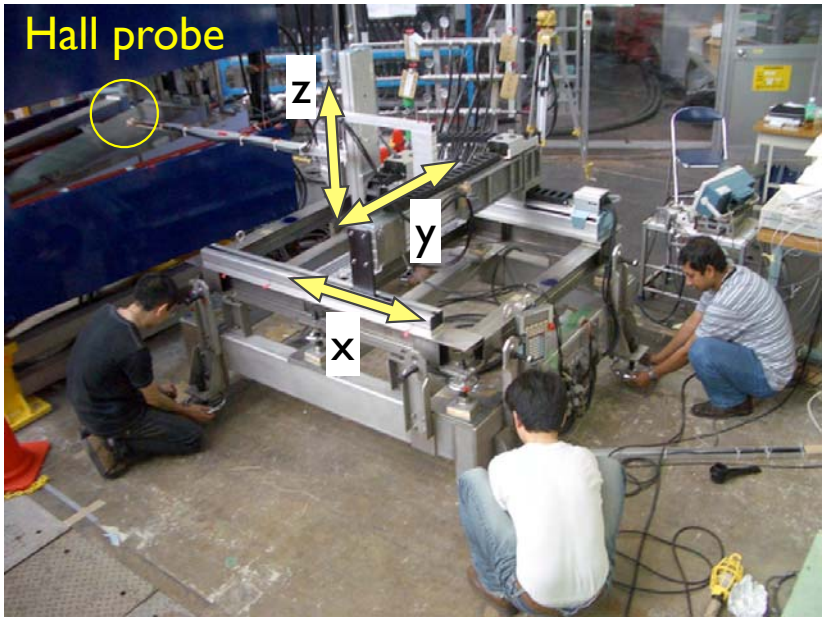


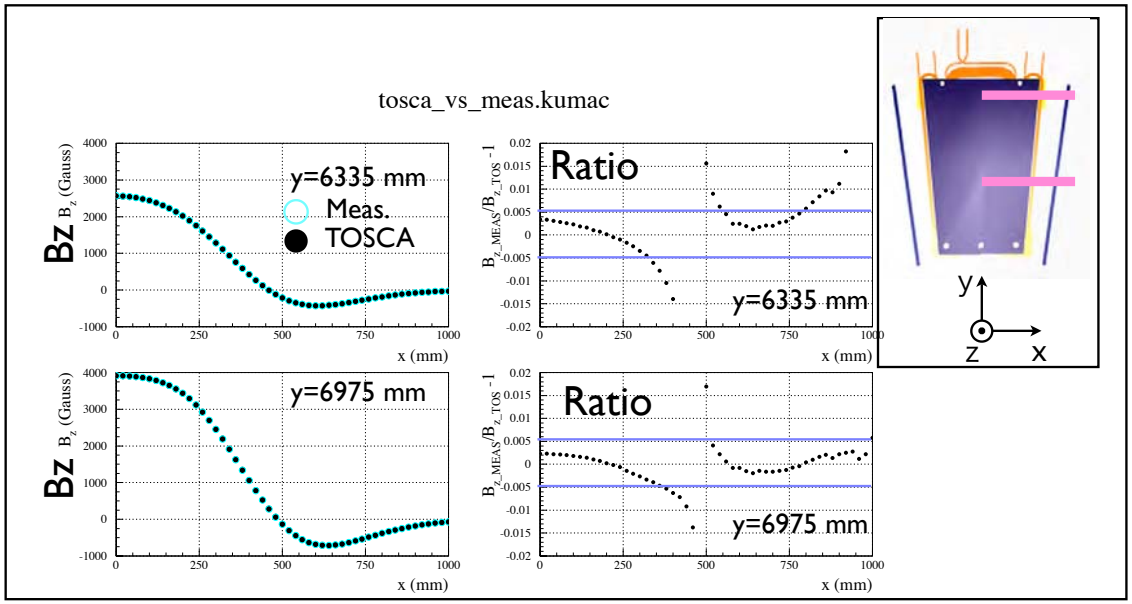
PRISM FFAG Magnet Construction

5 magnets have been completed.
One more magnet will be constructed now.

Magnetic Field Measurements

- Magnetic field measurements for PRISM FFAG magnet has been made in spring, 2006.
- The measured field distribution has been compared with TOSCA calculation.
- Differences between them are less than 0,5%. It is within tolerance.

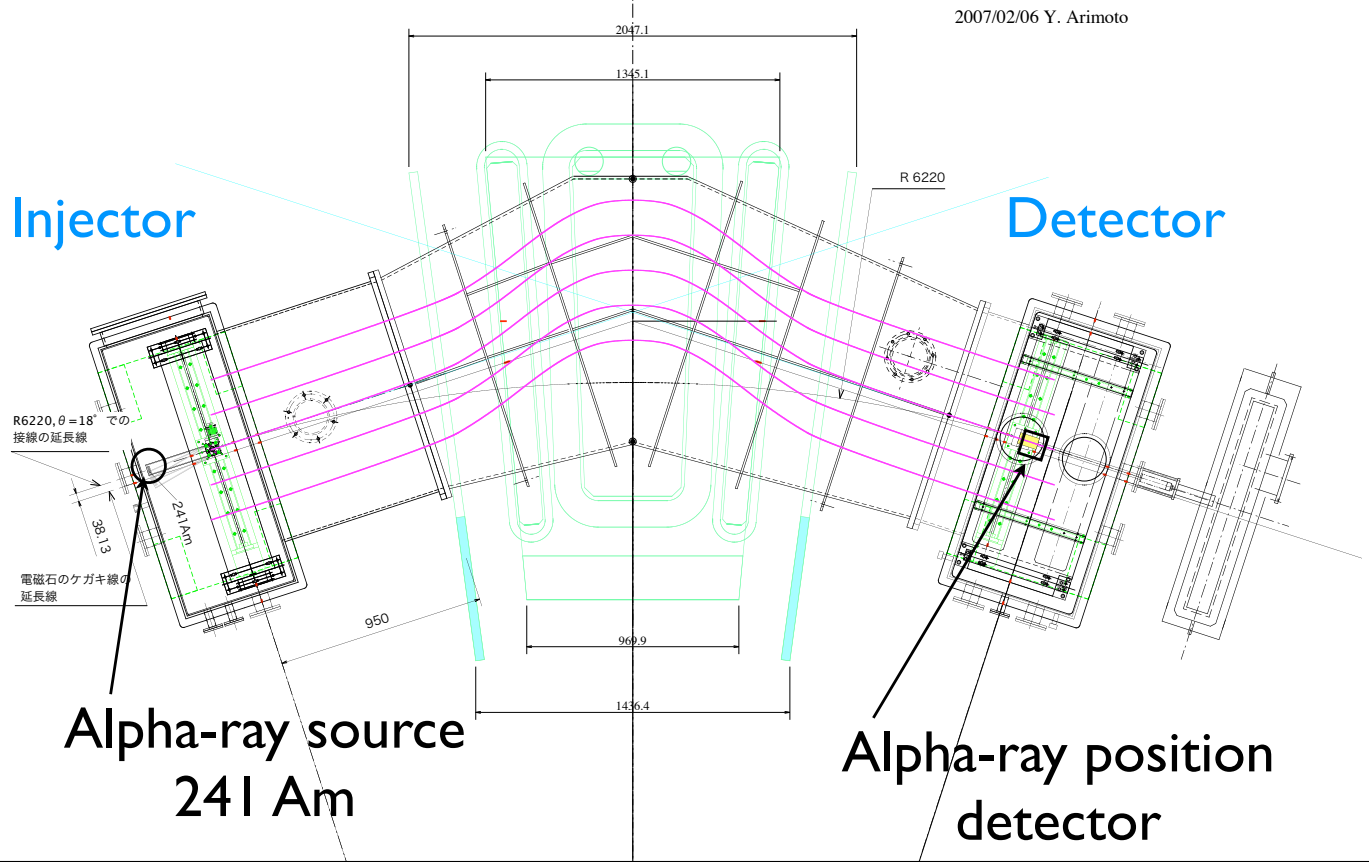




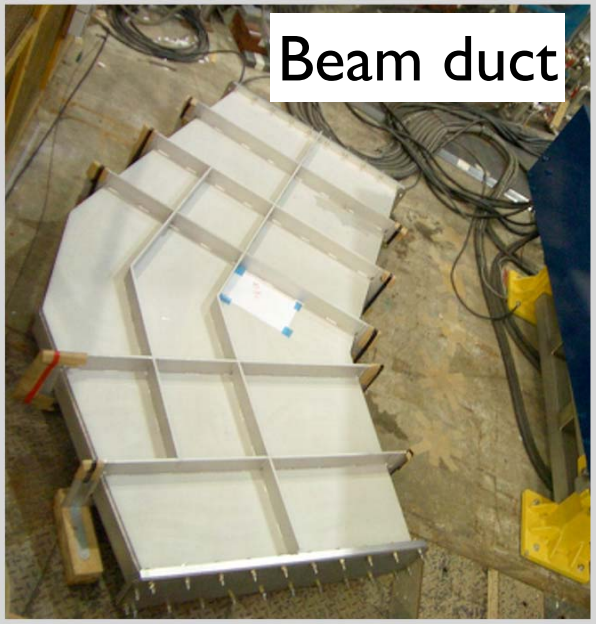
Alpha Particle Tracking with One Magnet Cell

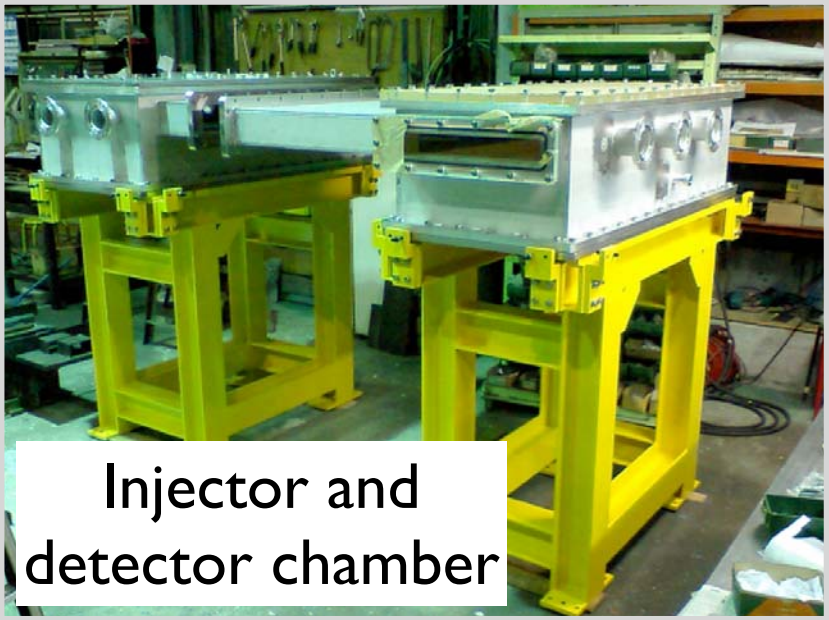
Purpose: study beam dynamics at large amplitudes (non-linearity) by determining a transfer mapping between in and out.

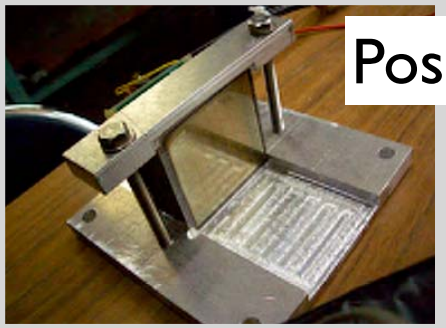
muon 68 MeV/c = alpha particle 2.5 MeV.



One-cell Test Stand under Preparation


Beam duct


Injector and detector chamber

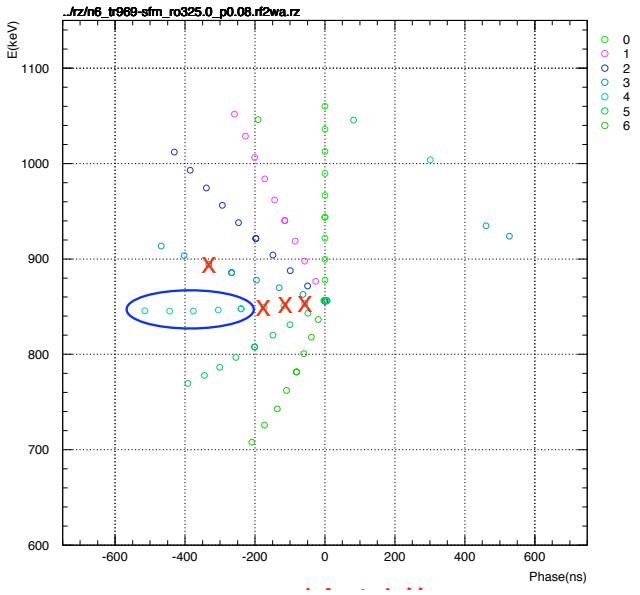

Position detector

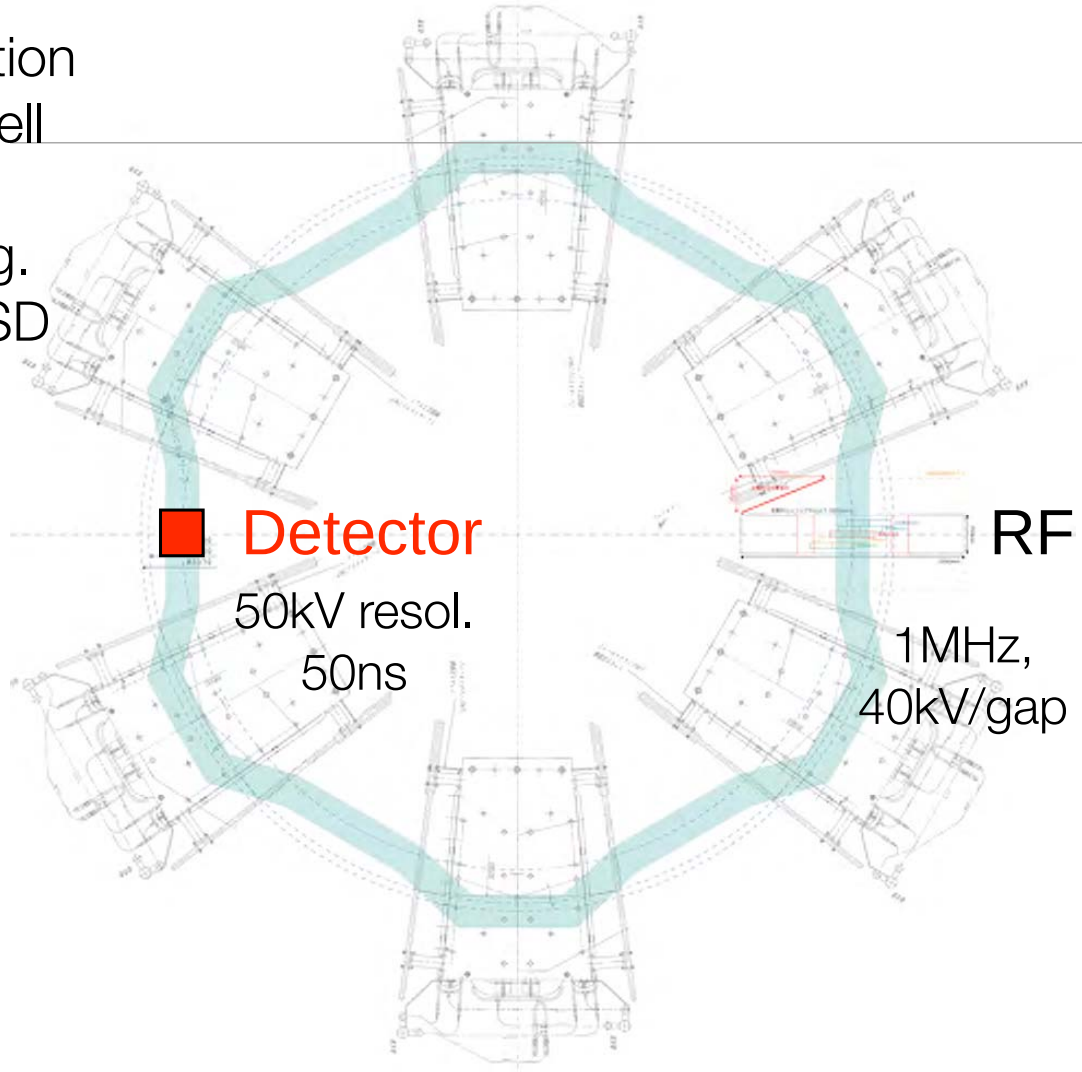

Injector collimator

The test will start soon.

Alpha Particle Tracking with 6 Magnet Cells

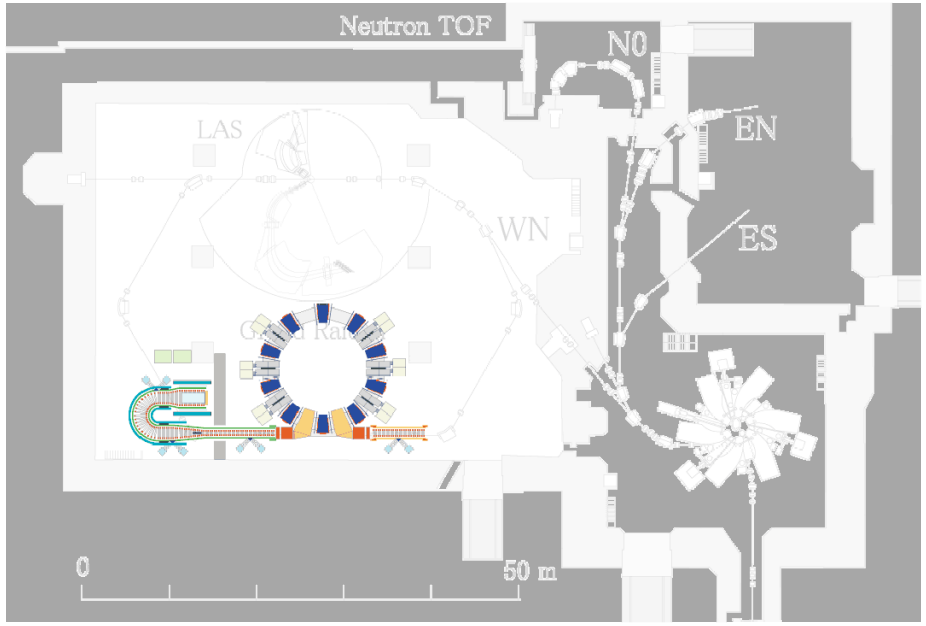
Purpose: study demonstration of phase rotation with a 6-cell ring with one RF cavity by single alpha particle tracking. Electric static kicker plus SSD detectors are needed.



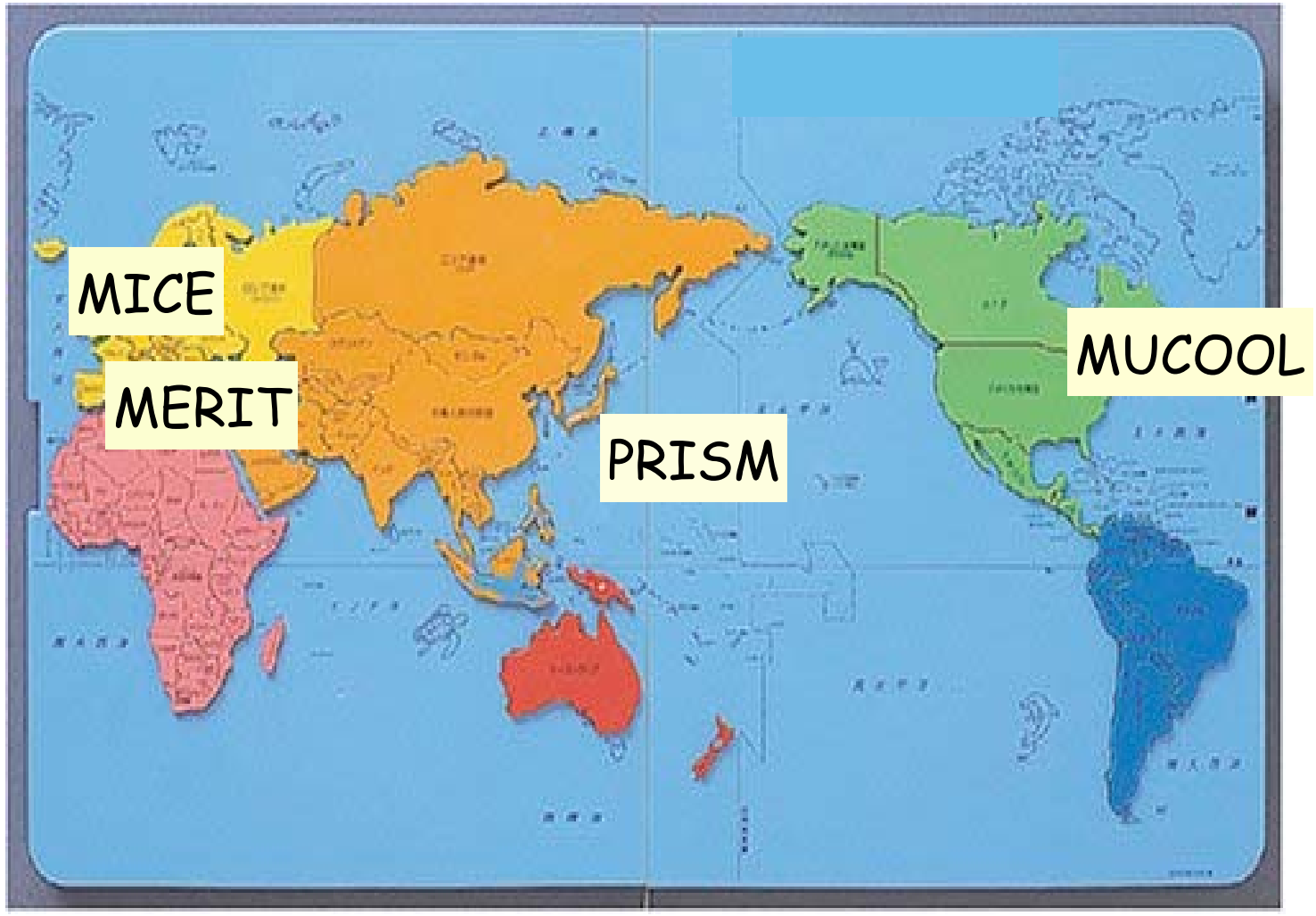


PRISM FFAG Test at Osaka University

- Research Center for Nuclear Physics (RCNP), Osaka University has a cyclotron of 420 MeV. The energy is above pion threshold.
- A plan is to install the PRISM FFAG ring at RCNP, and inject muons, although a muon rate is small.
- Wait for funding.



International Collaboration



Summary

- The Japanese groups participate in the international collaboration on NuFACT R&Ds:
  - MUCOOL, MICE, MERIT and ISS/IDS.
- FFAG-based muon acceleration for a neutrino factory was originally proposed in 2000, in Japan.
- Constructions and studies of various scaling-FFAGs are going in Japan.
  - ADS FFAG in KURRI,
  - ERIT FFAG in KURII,
  - PRISM FFAG at Osaka.
- Consider a new proposal to the US-Japan program.

End of My Talk.