Report of Activities in Japan

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Osaka University
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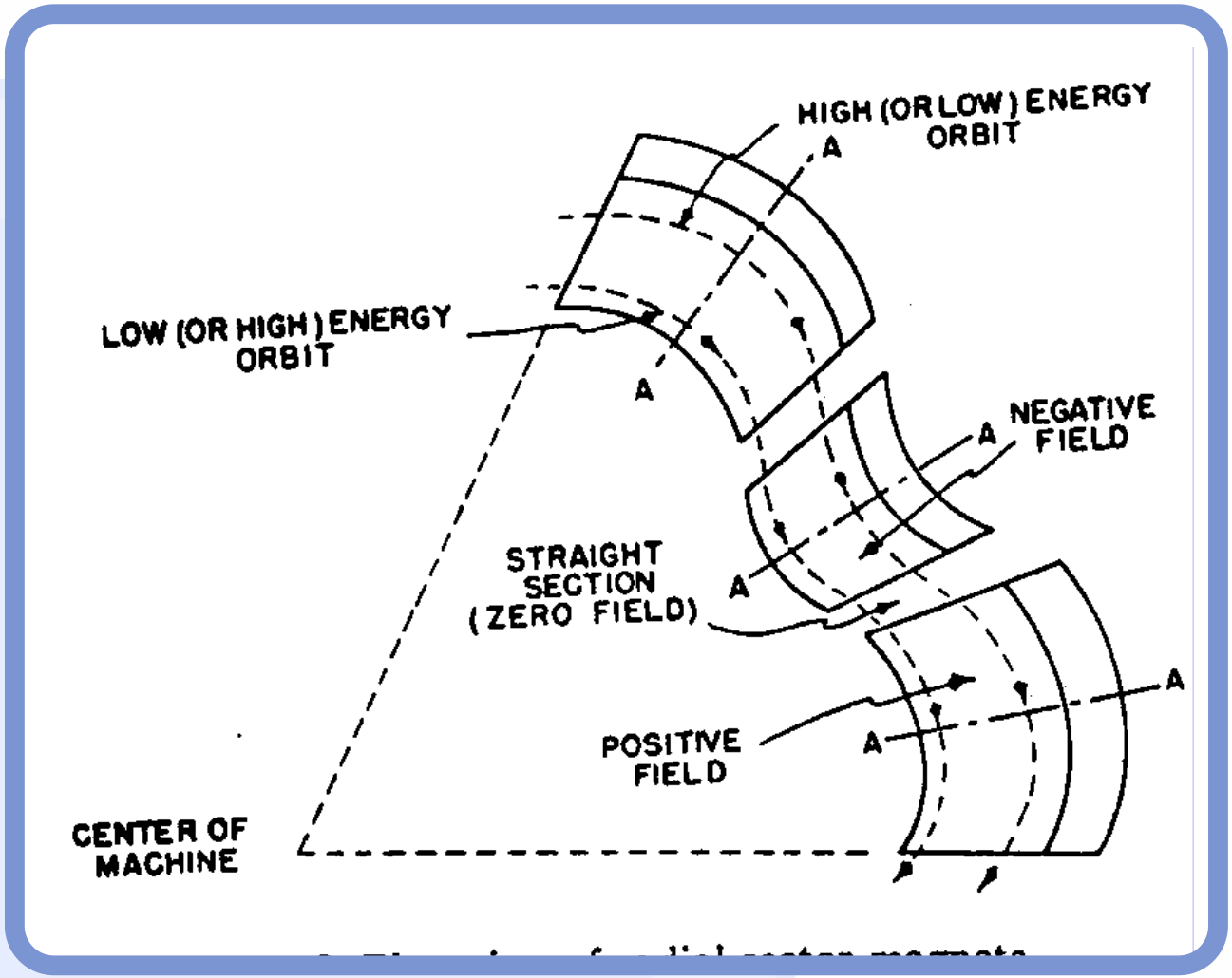
Berkeley, April 26, 2005

Outline

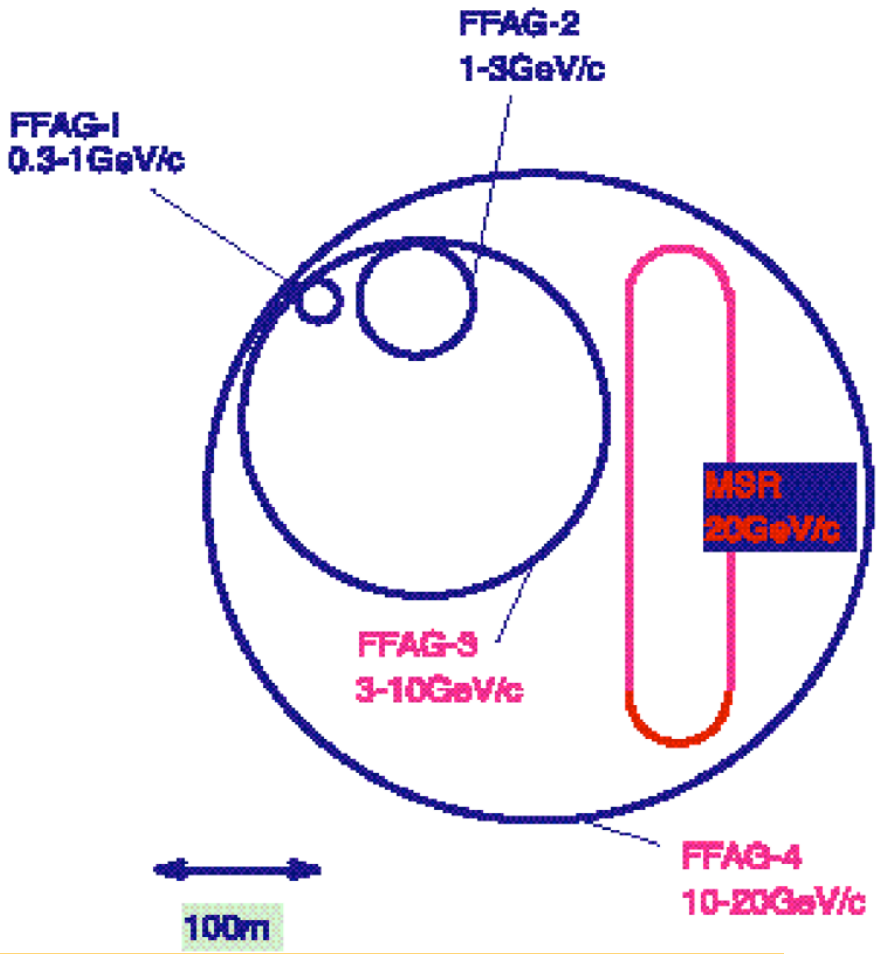
- FFAG-based Neutrino Factory
- R&D
  - International Collaboration
    - MUCOOL and MICE
  - FFAG
    - Proton FFAG and PRISM
- Summary



FFAG-based Scheme

FFAG-based Scheme

- Japanese scheme of a neutrino factory is based on muon acceleration by FFAGs.
  - Large acceptance (trans. and vert.)
  - Quick Acceleration
  - cooling is not a must. (better if available)



Muon Acceleration based on a series of FFAGs

Design

The design has not been changed since 2003.

	Energy		comments
1st Ring	0.3 - 1.0 GeV/c	DFD	PRISM-II ?
2nd Ring	1 - 3 GeV/c	DFD	
3rd Ring	3 - 10 GeV/c	FD	
4th Ring	10 - 20 GeV/c	FD	low frequency RF (25 MHz)

The details of the design is available in the past presentations.

Staging Approach

- Staging scenario (with FFAG)
  - Muon Factory (PRISM)
    - For stopped muon experiments
  - Muon Factory-II (PRISM-II)
    - Muon moments (g-2, EDM)
  - Neutrino Factory-I
    - Based on 1 MW proton beam
  - Neutrino Factory-II
    - Based on 4.4 MW proton beam
  - Muon Collider

70 MeV/c
PRISM

0.3-1 GeV/c

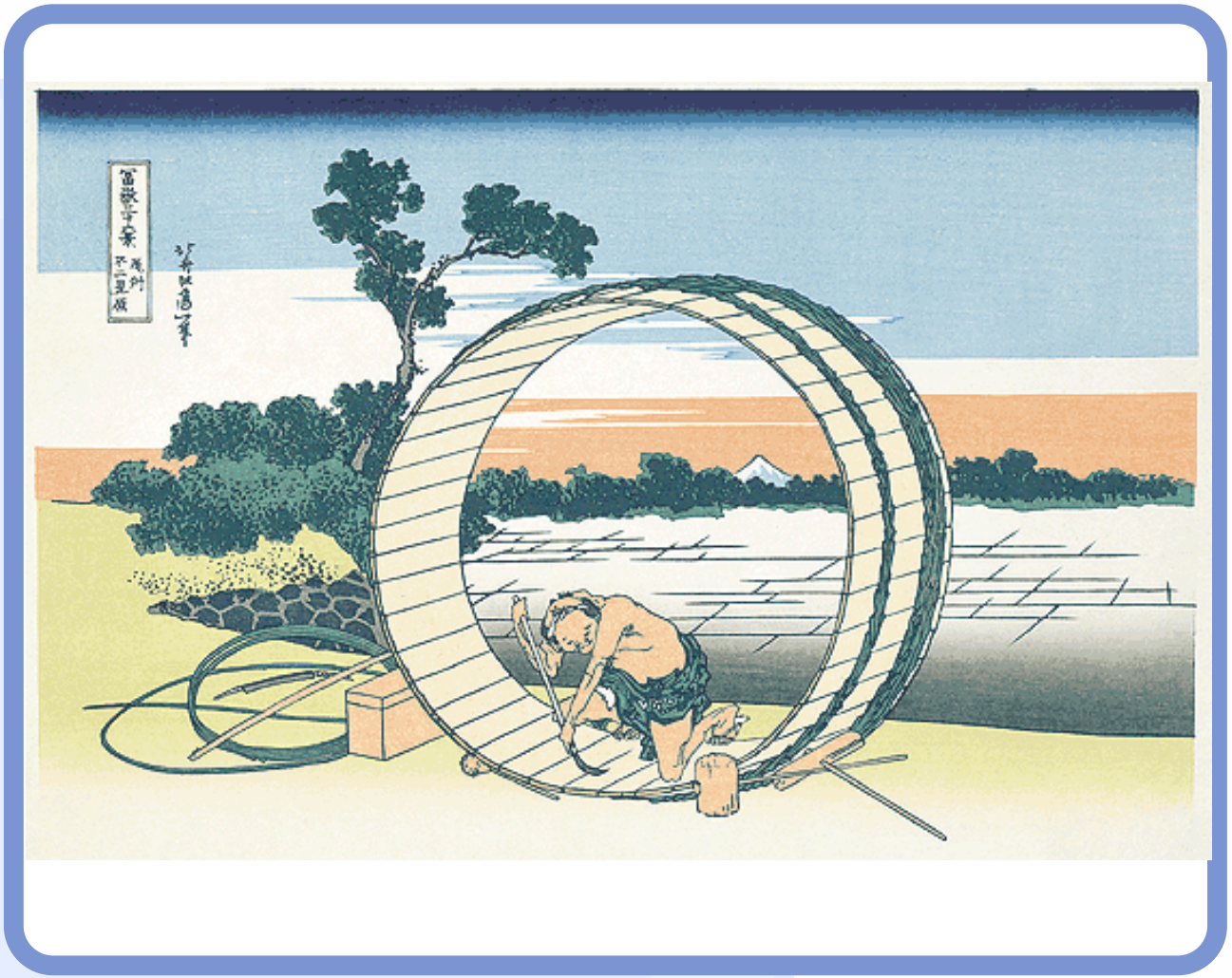
1-3 GeV/c
PRISM-II

3-10 GeV/c
Nufact-I

10-20 GeV/c
Nufact-II

Muon
Storage Ring

Physics outcome
at each stage



Japanese Activities

R&D Overview

- MUCOOL
  - LH2 Absorber
- MICE
  - Scintillating Fiber (SciFi) Trackers
  - LH2 Absorber
- FFAG
  - Proton FFAG
  - PRISM
  - FFAG workshop / Telephone Conf.
- Targetry R&D
- Pion Capture SC magnet design

R&D Collaboration

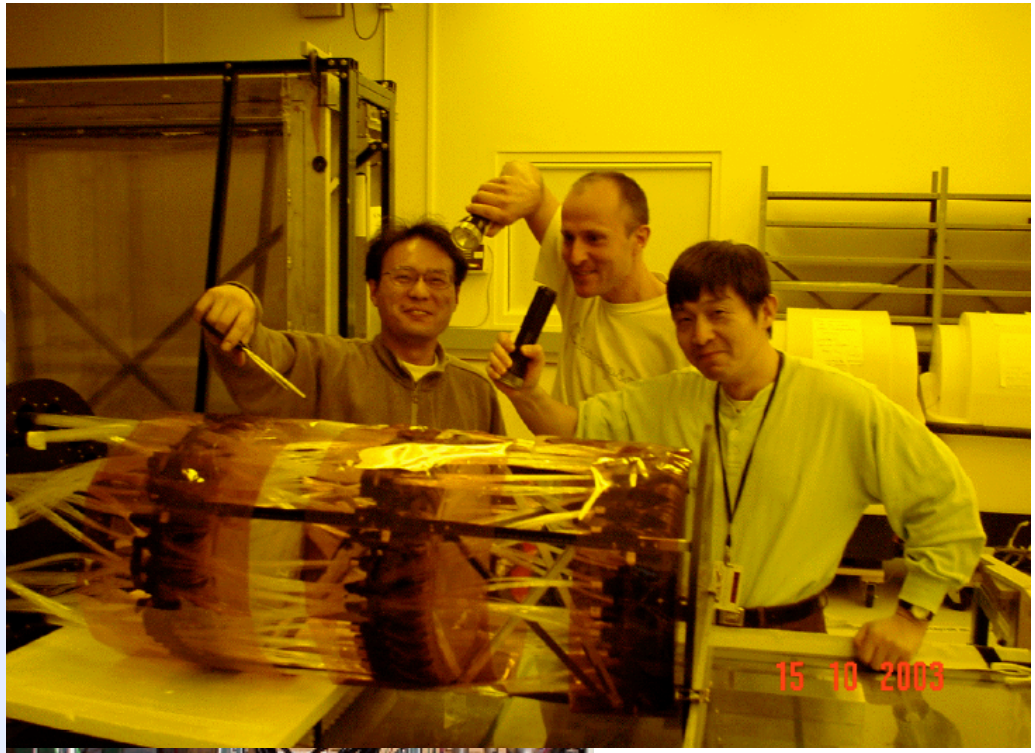
LH2 Absorber R&D

- For MUCOOL
- under the US-Japan Program ("muon source")
- Convection-driven cooling
- Successful LH2 filling test done at MTA/FNAL in 2004
  - gas heater
- 2nd test in 2005
- Proton beam test ?

See Shigeru Ishimoto's talk.

SciFi Tracker R&D

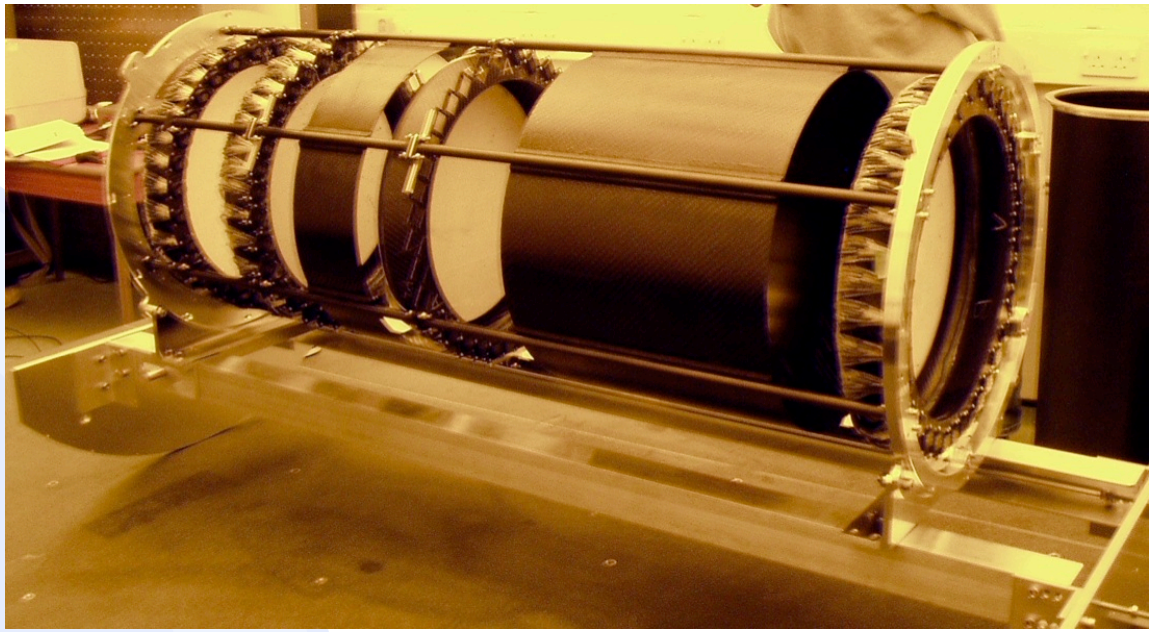
- For MICE
- Design and construction of Scintillating Fiber (SciFi) trackers
  - with FNAL and UK
  - fiber supply
- VLPC cryostat construction
  - with FNAL and UK
  - cryo-cooler cooling

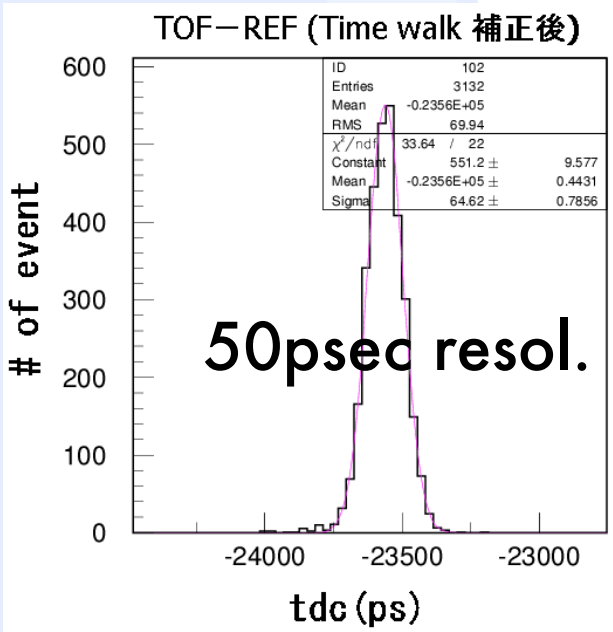


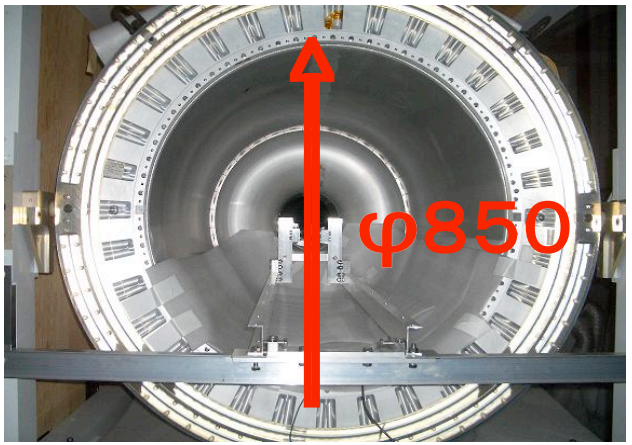
cosmic ray test at the D0 Stand at Fermilab

SciFi Tests at KEK

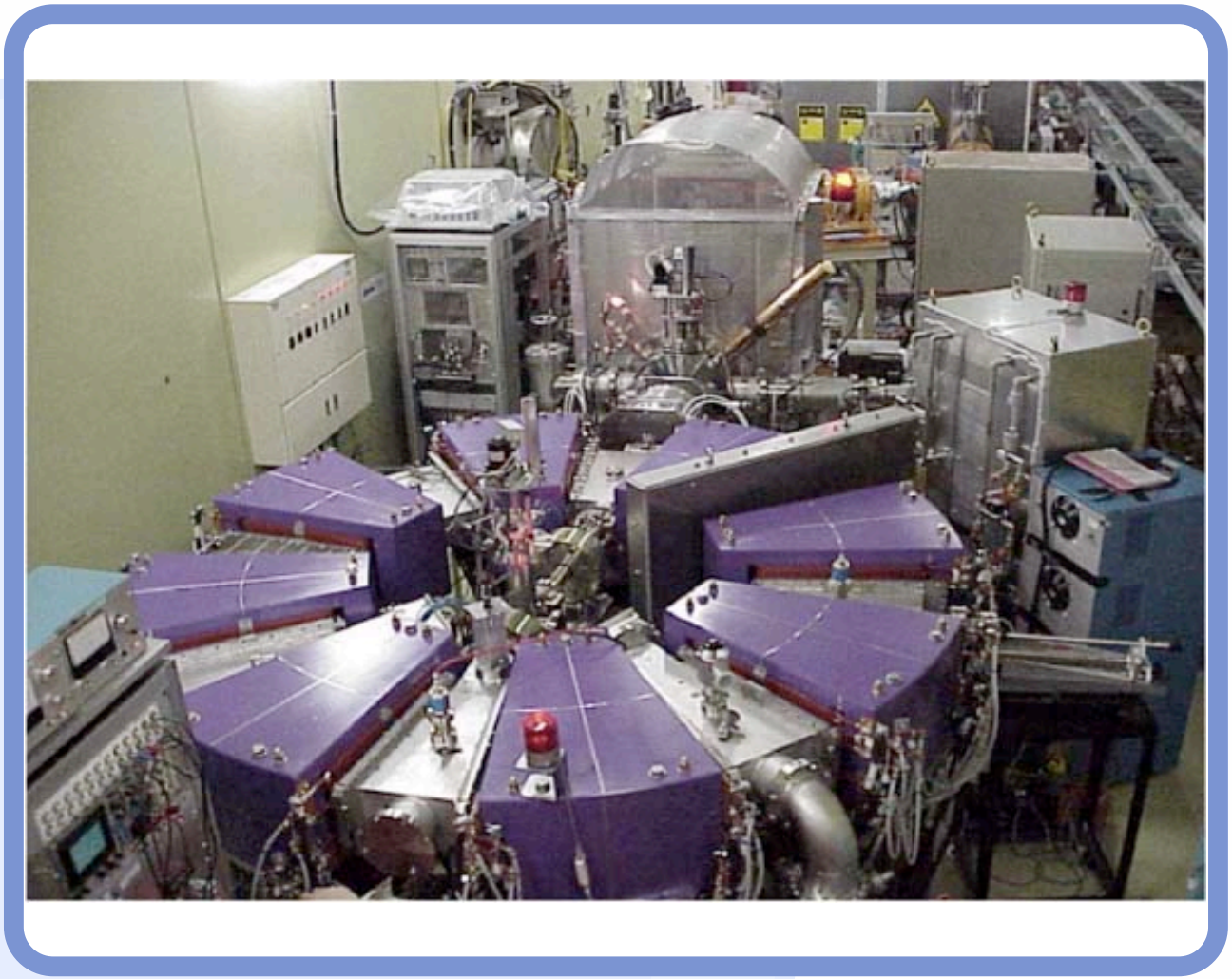
- For MICE
- will test the scifi system with a beam at KEK (2005).
  - 4 SciFi stations
  - VLPC cryostat cooled by a cryo-cooler.
  - solenoid mag. field (1T)
  - TOF&ACC for PID







Super JACEE Magnet



FFAG R&D

Types of FFAG

- Scaling type FFAG
  - betatron tube : 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

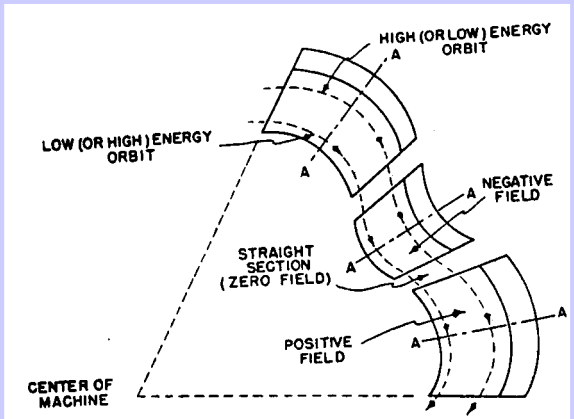


FIG. 2. Plan view of radial-sector magnets.

Spiral

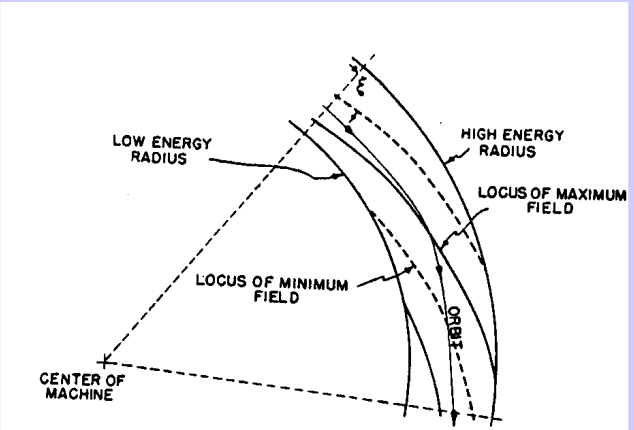


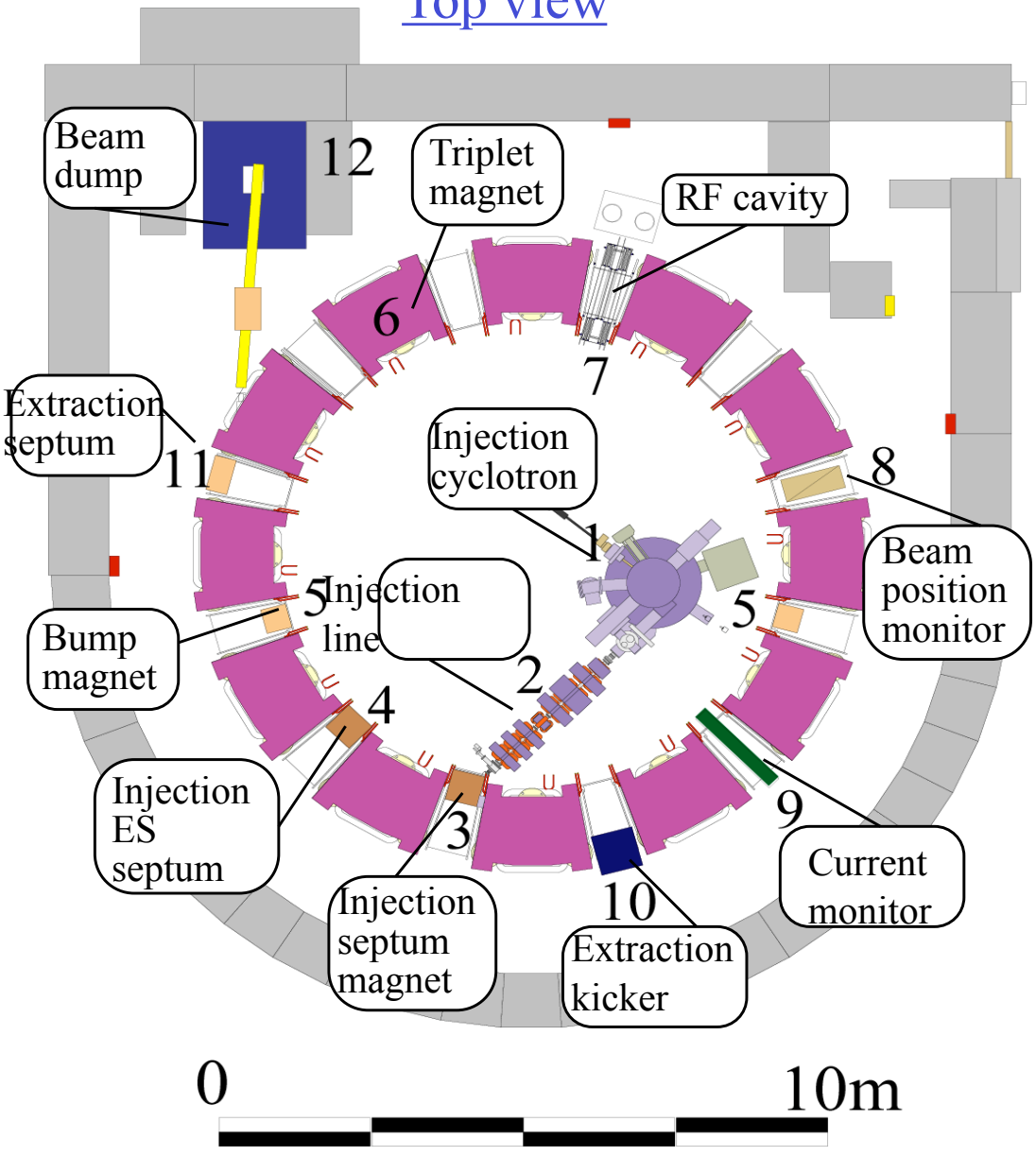
FIG. 3. Spiral-sector configuration.

FFAG R&D in Japan

- Past
  - POP machine
- On-going Projects
  - 150-MeV Proton FFAG (KEK)
  - FFAG for ADS (Kyoto U.,KURRI)
  - PRISM (Osaka U.)
- Planned Projects
  - FFAG for Hadron therapy (Ibaraki)
  - Neutron source for Boron-captured neutron therapy (Kyoto U., KURRI)

150-MeV Proton FFAG

Top view



Design parameter

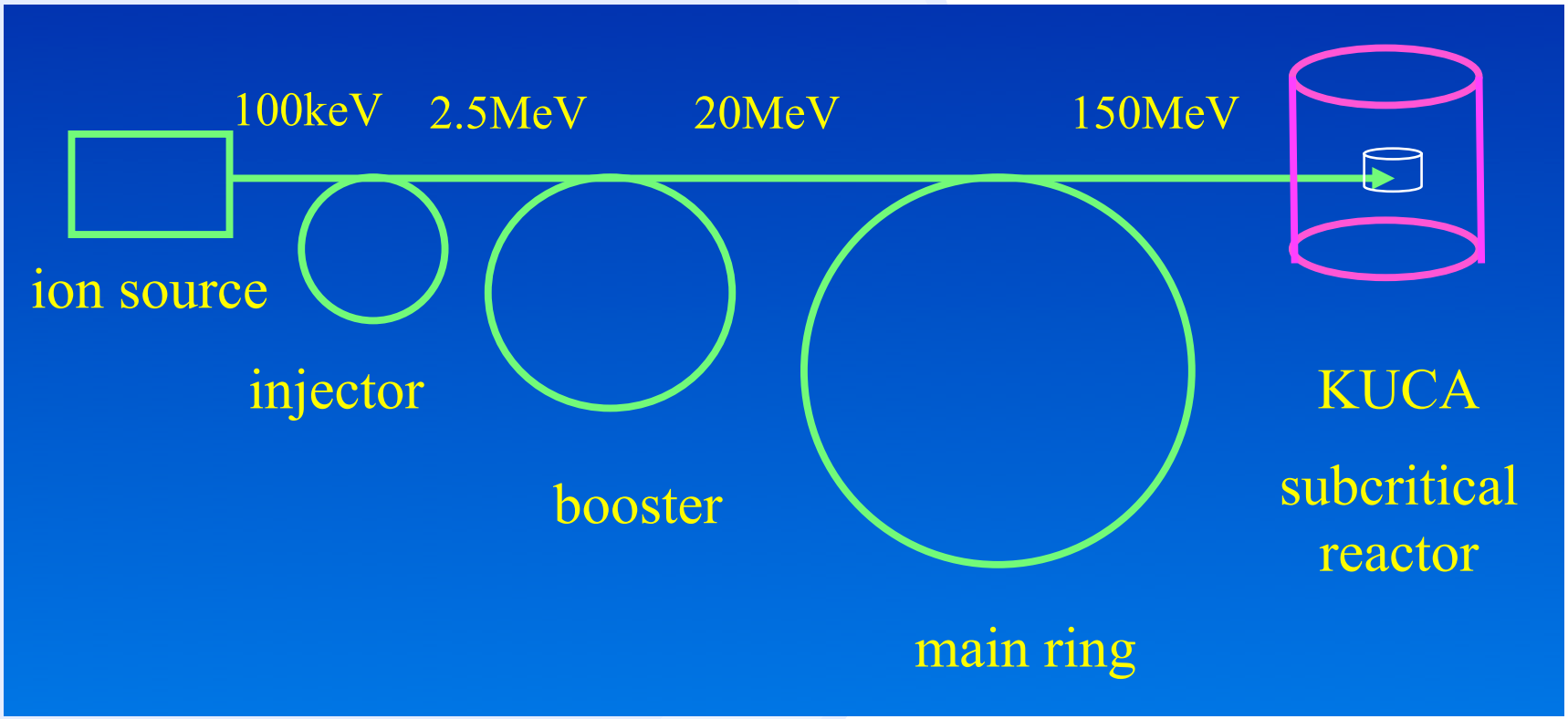
Magnet	radial sector type (DFD triplet)
Num. of cell	12
k-value	7.6
Ek	12 => 150MeV (10 => 125MeV)
Av. radius	4.47 => 5.20m
betatron tune	hor. : 3.69 ~ 3.80 ver. : 1.14 ~ 1.30
Peak Field (@beam orbit)	F-mag. : 1.63T D-mag. : 0.78T
revolution	1.55 ~ 4.56MHz
repetition	250Hz

150-MeV Proton FFAG

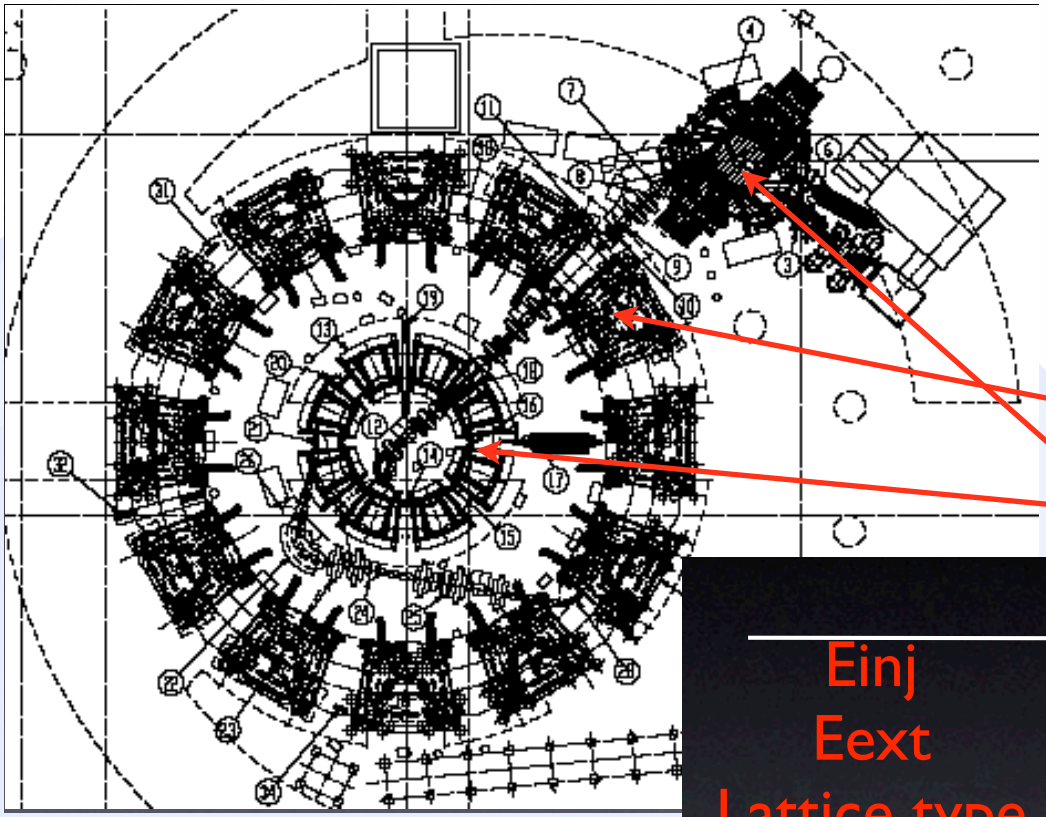
successfully accelerate protons up to about 150 MeV
study resonance crossing
study beam extraction / spot scanning

FFAG for ADS

- at Kyoto University Research Reactor Institute (KURRI)
- feasibility study (2002-2006) for accelerator-driven (Reactor) system
  - accelerator, reactor, reactor physics



FFAG for ADS

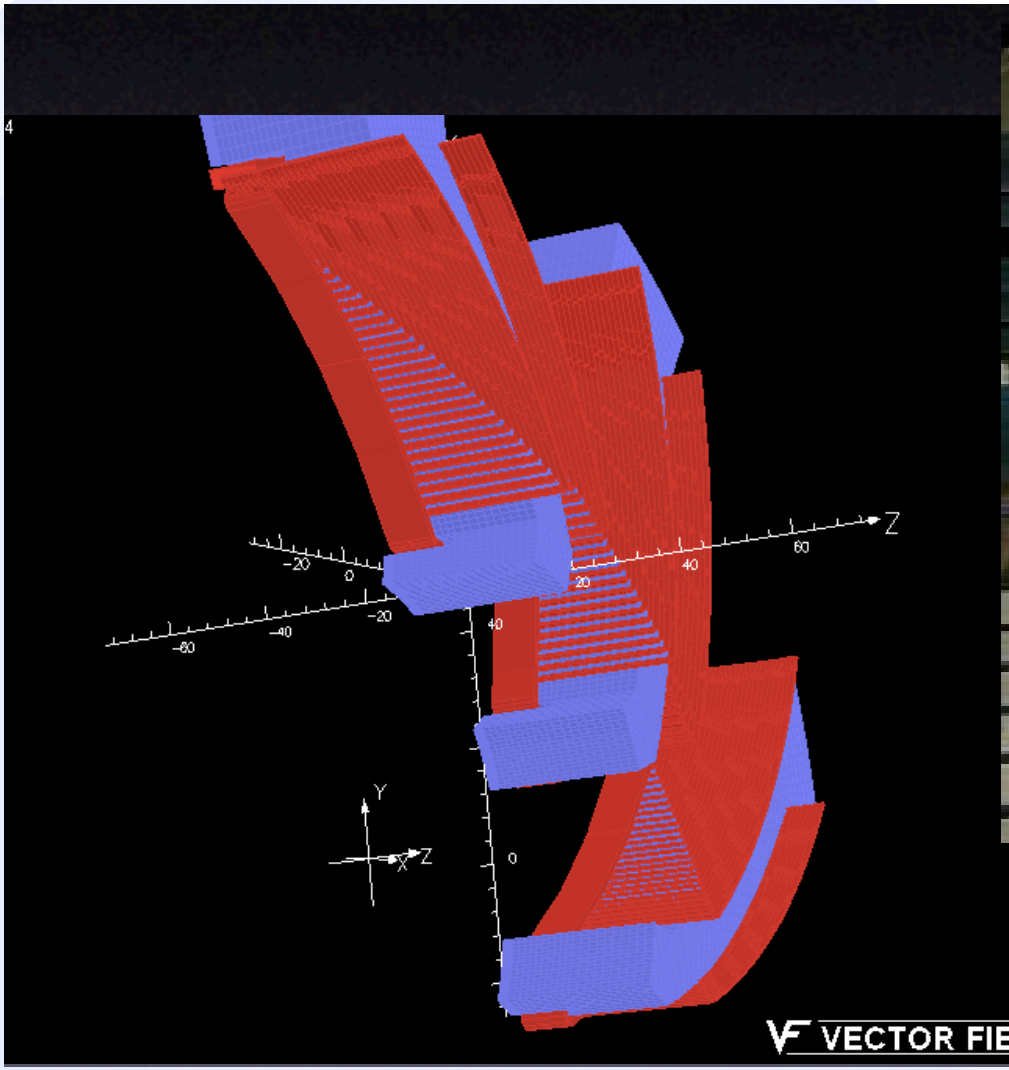


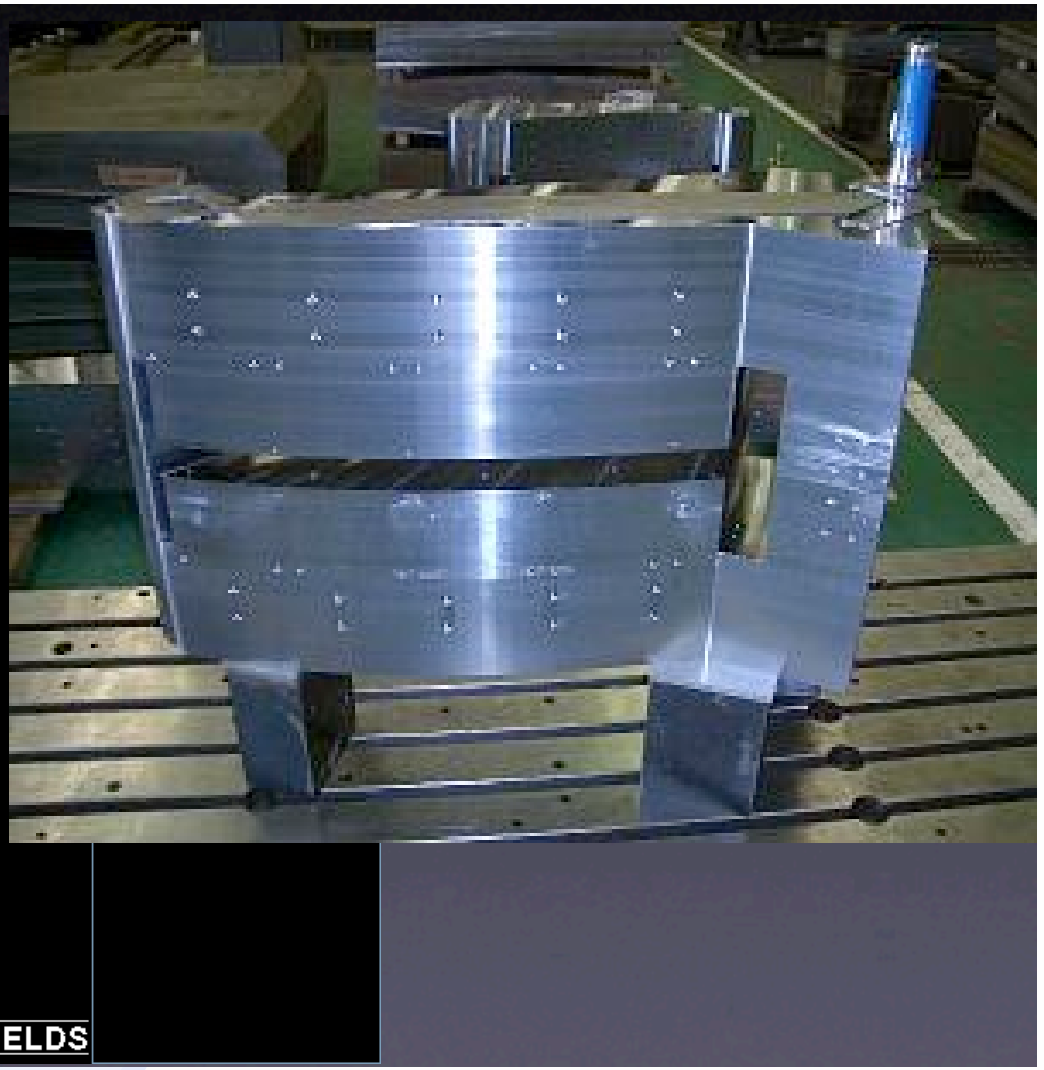
FFAG Ring Parameters

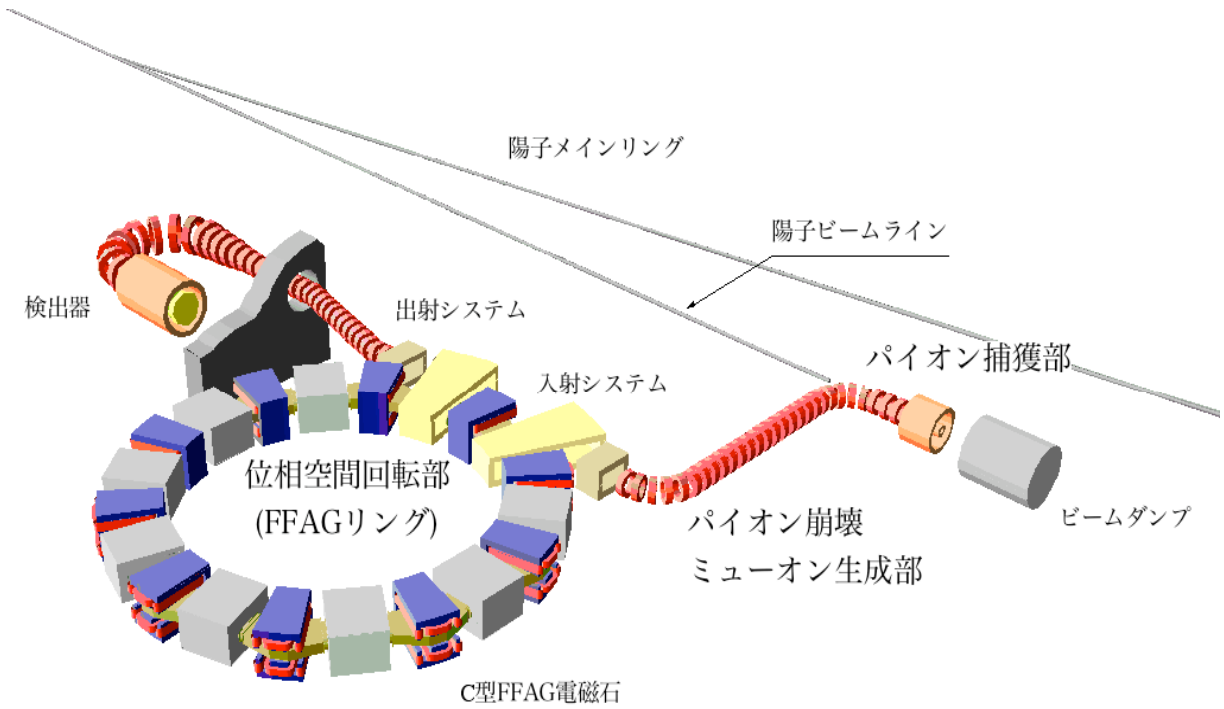
	Injector	Booster	Main ring
Einj	100keV	2.5MeV	20MeV
Eext	2.5MeV	20MeV	150MeV
Lattice type	Spiral	Radial DFD	Radial DFD
Acc. scheme	Induction	rf	rf
# of cells	8	8	12
k value	2.5	4.5	7.6
coil/pole	coil	coil	pole
Pext/Pinj	5.00	2.84	2.83
Rinj	0.60m	1.42m	4.54m
Rext	0.99m	1.71m	5.12m

FFAG for ADS

Model for the Injector Magnet





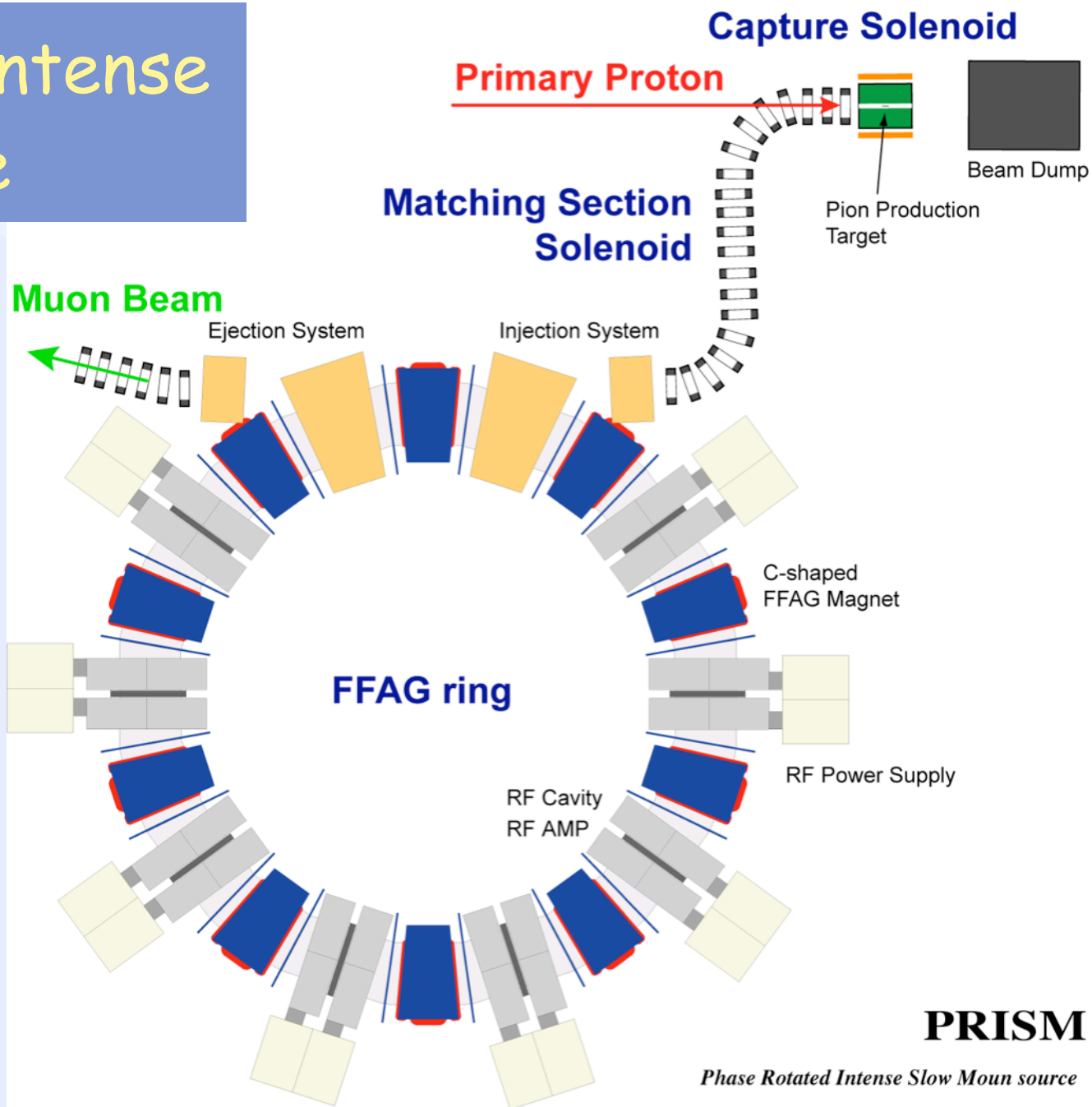

陽子メインリング
陽子ビームライン
検出器
出射システム
入射システム
パイオン捕獲部
位相空間回転部
(FFAGリング)
パイオン崩壊
ミューオン生成部
ビームダンプ
C型FFAG電磁石

PRISM R&D

PRISM

=Phase Rotated Intense Slow Muon source

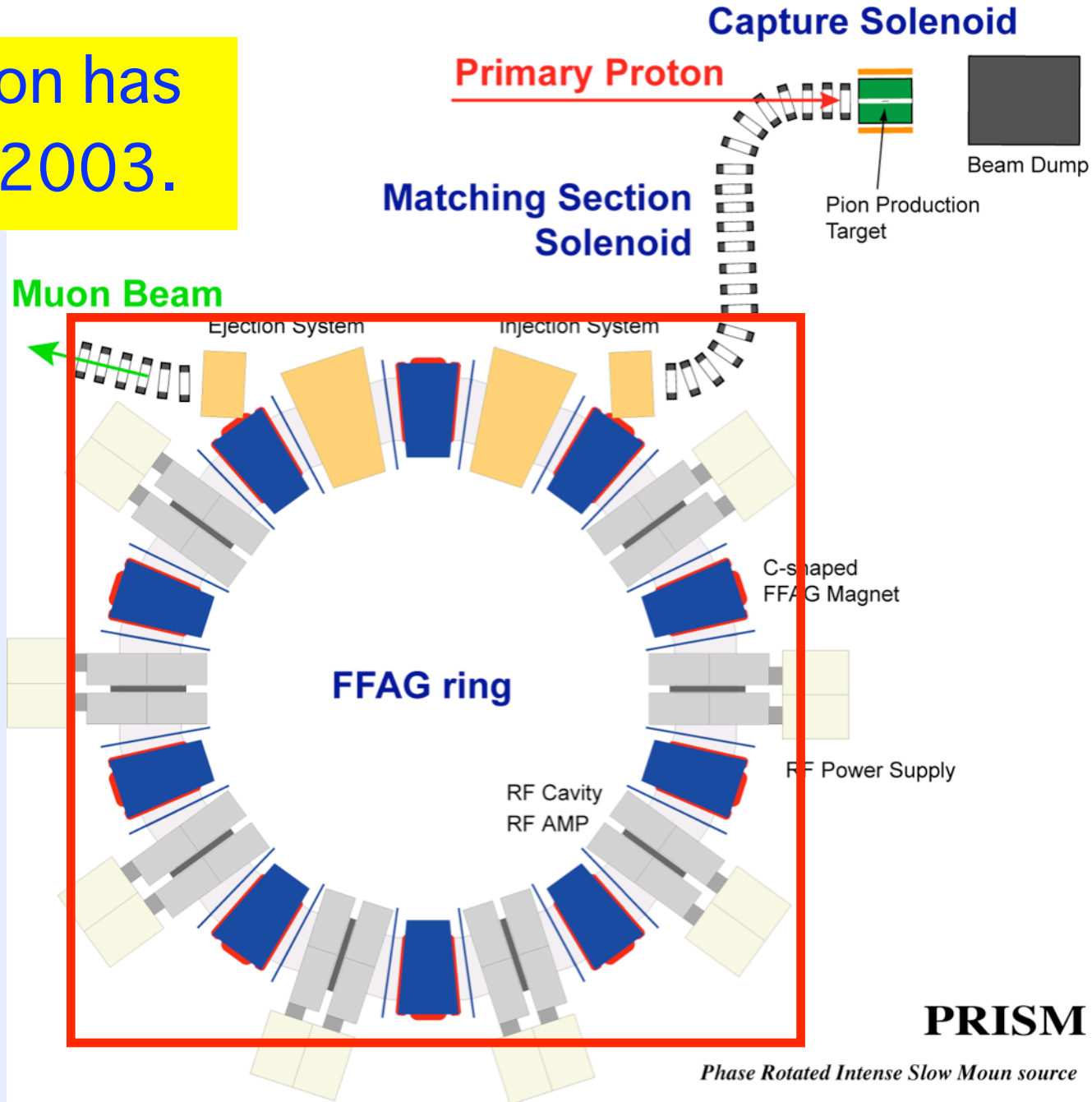
- High-intensity
  - 10^{11}-10^{12}/sec
- High-luminosity
  - phase rotation
- Low energy
  - 68 MeV/c
- search for charged-lepton mixing.



PRISM Construction

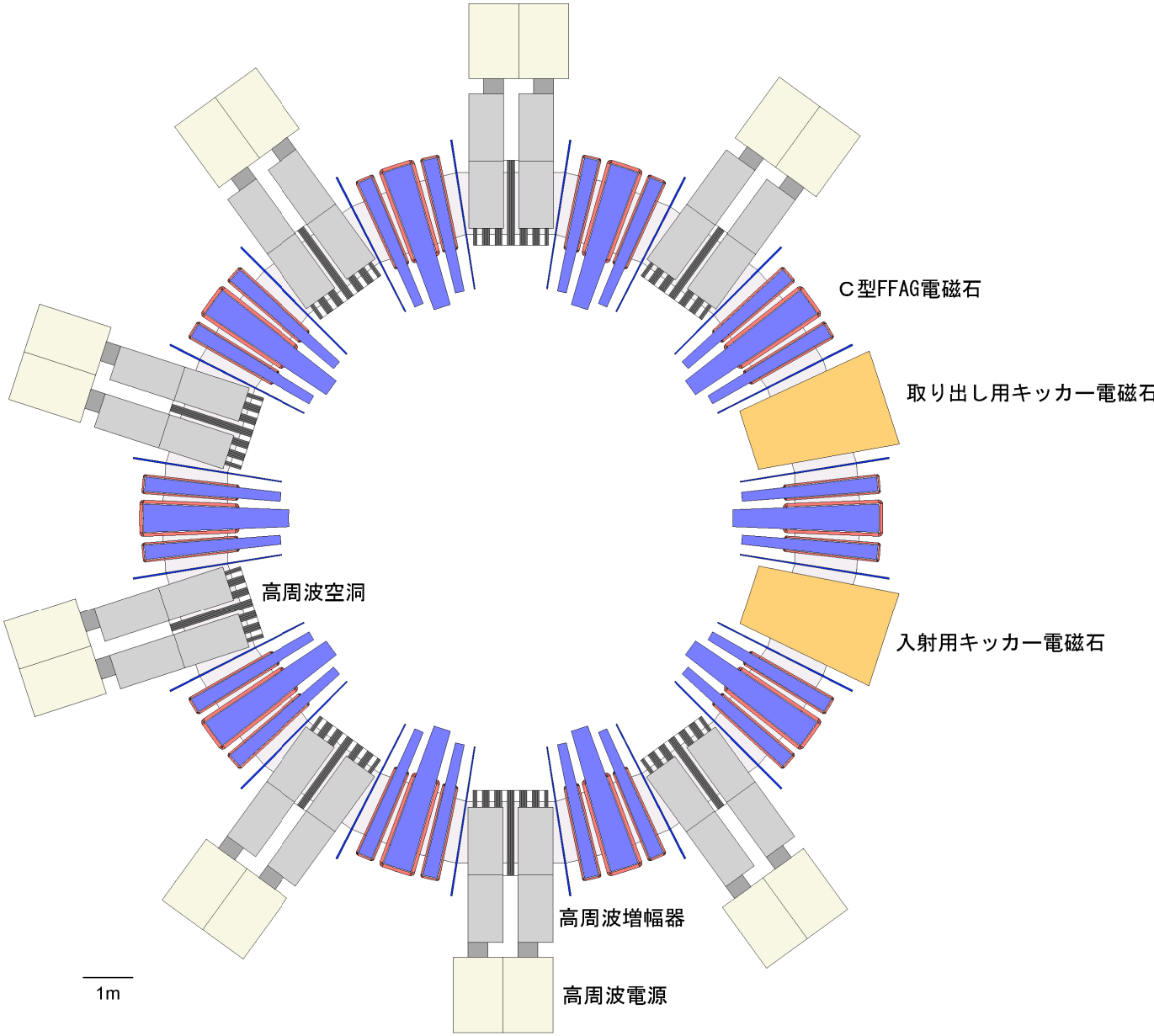
PRISM ring construction has been approved in JFY2003.

- FFAG ring
- 2003-2007
- Constructed at Osaka University
- Tests with proton/muons
- phase rotation/ muon cooling

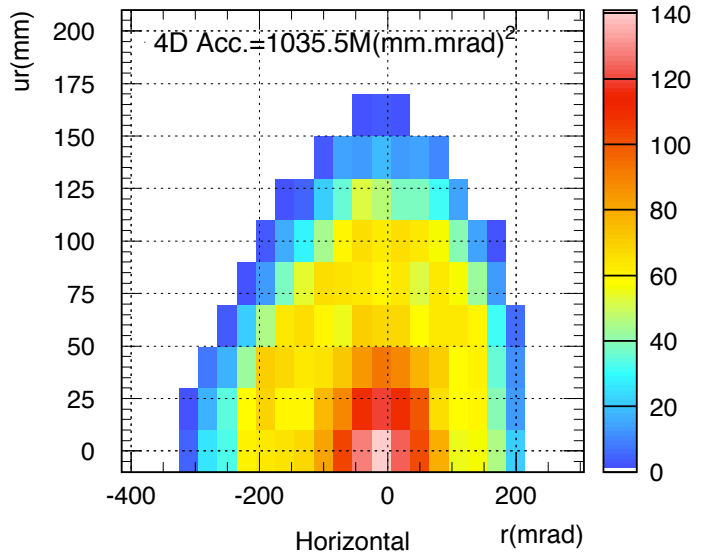


PRISM-FFAG Ring Parameters

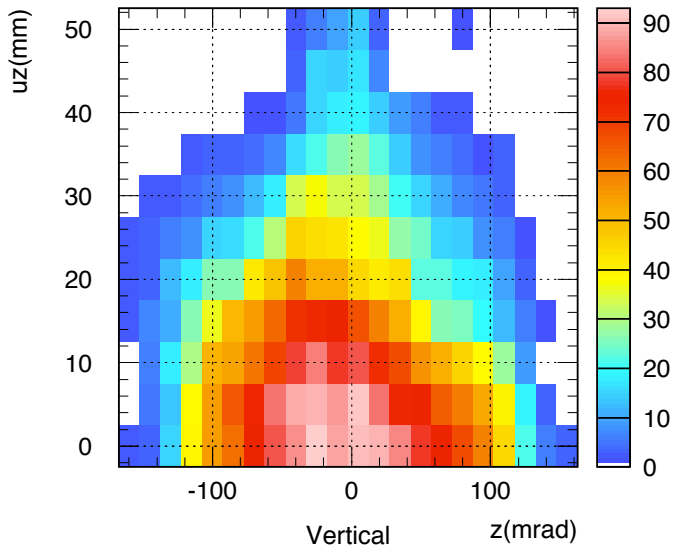
- N=10
- k=5(4.6-5.2)
- F/D(BL)=8
- r0=6.5m for 68MeV/c
- half gap = 15cm
- mag. size 110cm @ F center
- Triplet
  - θ_F=4.40deg
  - θ_D=1.86deg
- tune
  - h : 2.86
  - v : 1.44
- acceptance
  - h : 40000 π mm mrad
  - v : 6500 π mm mrad



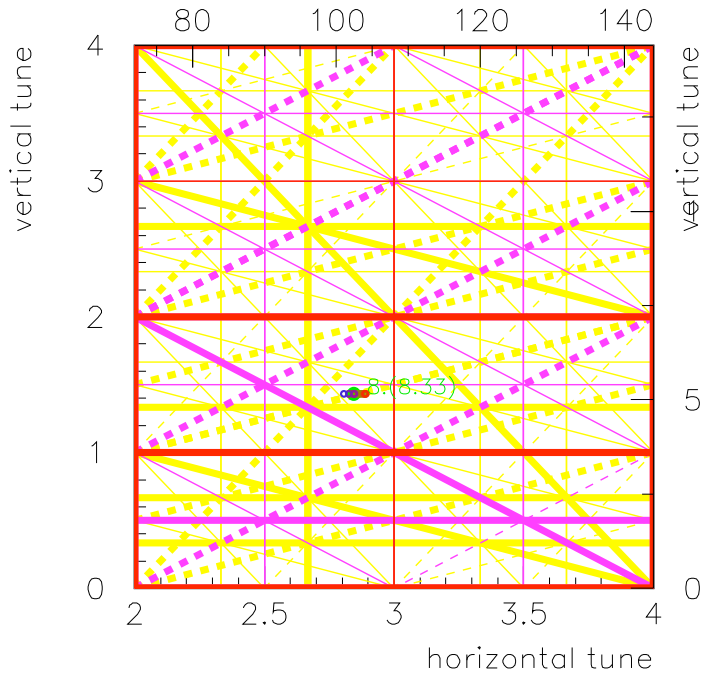
PRISM-FFAG Acceptance

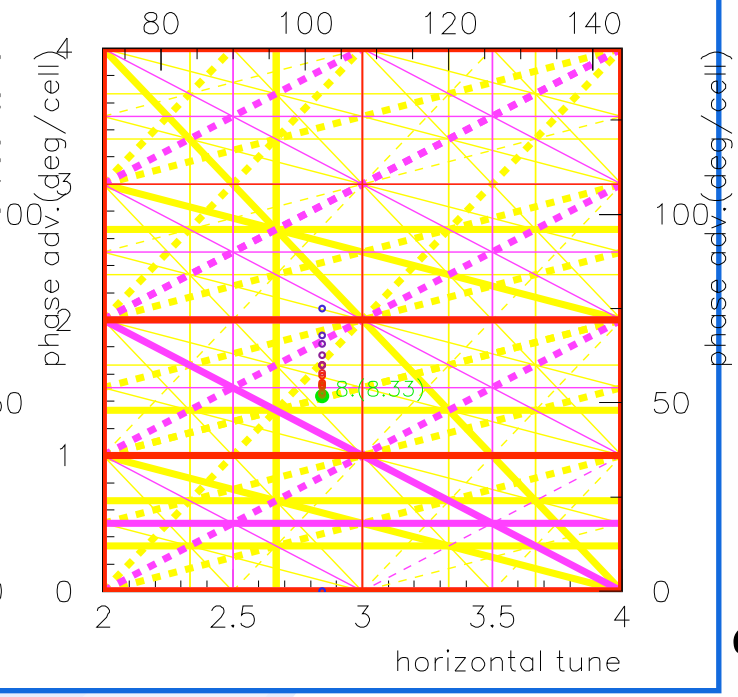


Horizontal Acceptance
40000π mm mrad



Vertical Acceptance
6500π mm mrad





N=10
F/D=8
k=5
r0=6.5m
H:2.86
V:144

Geant tracking with TOSCA field.

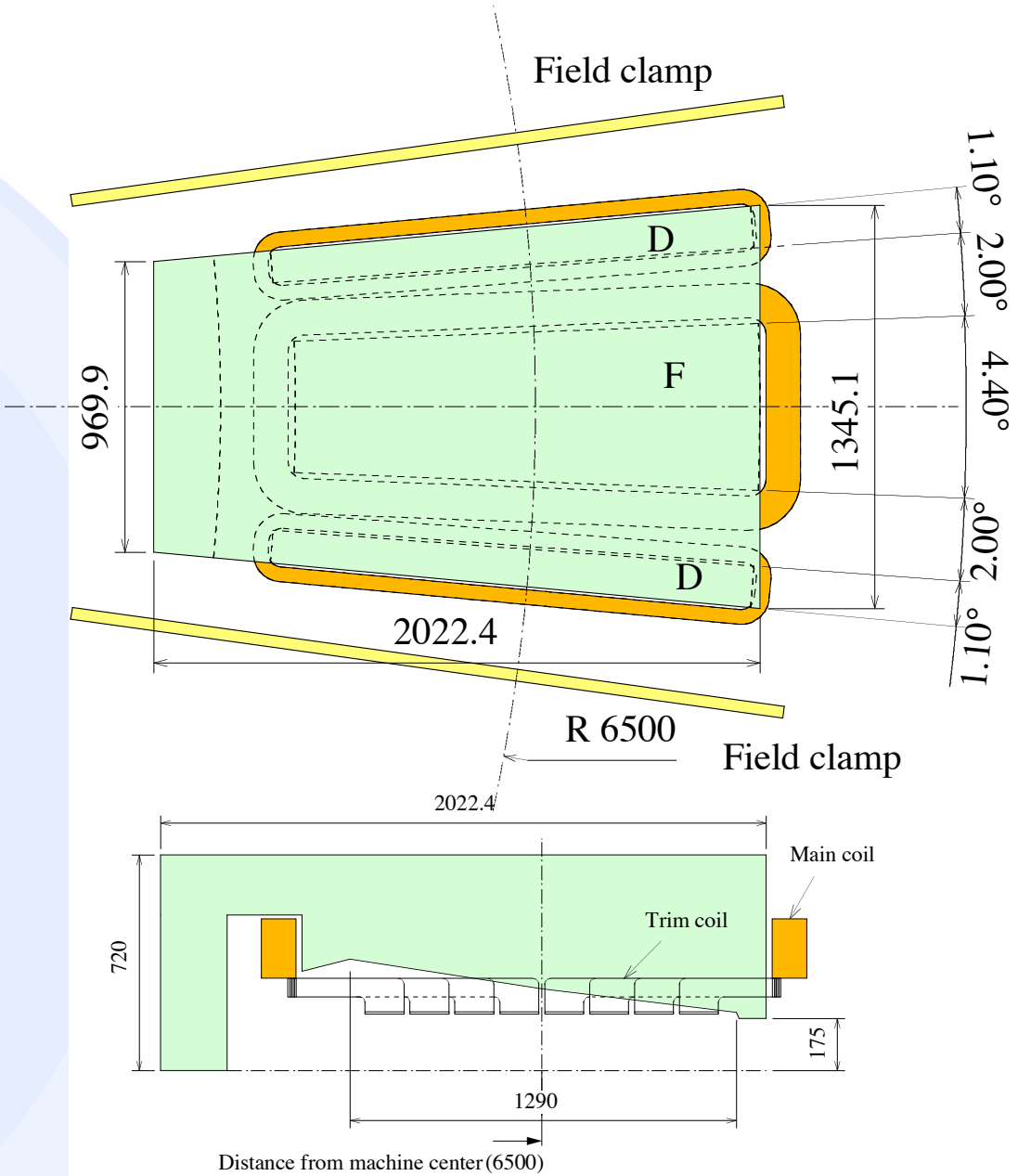
h : 40000 π mm mrad
v : 6500 π mm mrad

a la Akira Sato (Osaka)

PRISM-FFAG Magnet

- Radial type DFD triplet
- Scaling FFAG

- Aperture
  - 100cm (H)
  - 30cm (V)
- Field gradient produced by pole shape
- Trim coil to adjust field gradient index.
- C-shape magnet

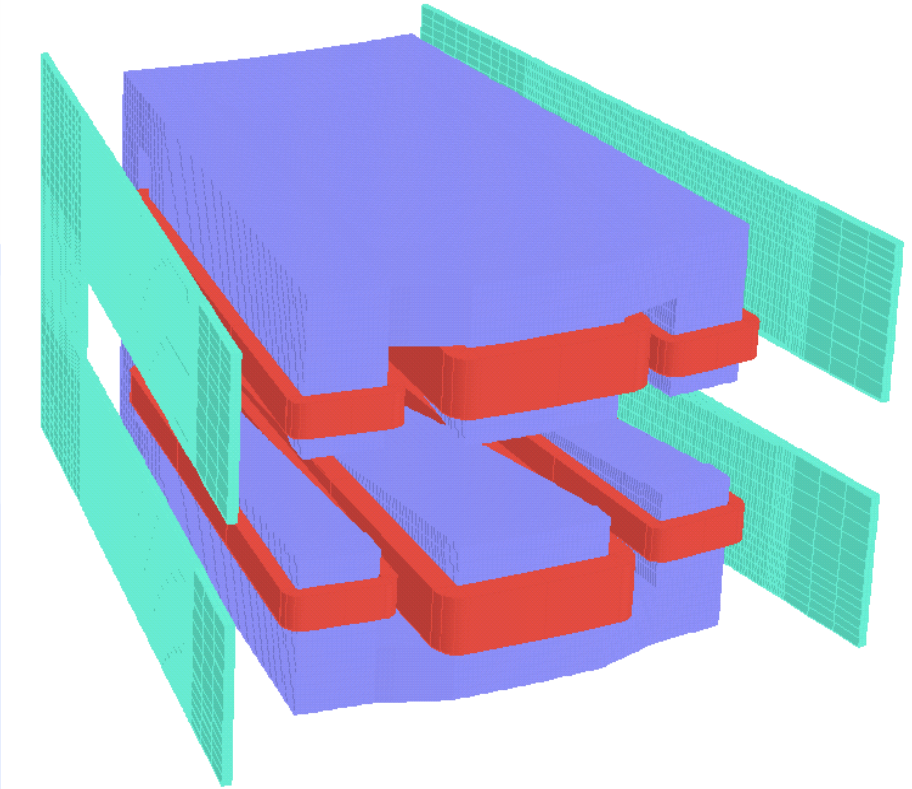


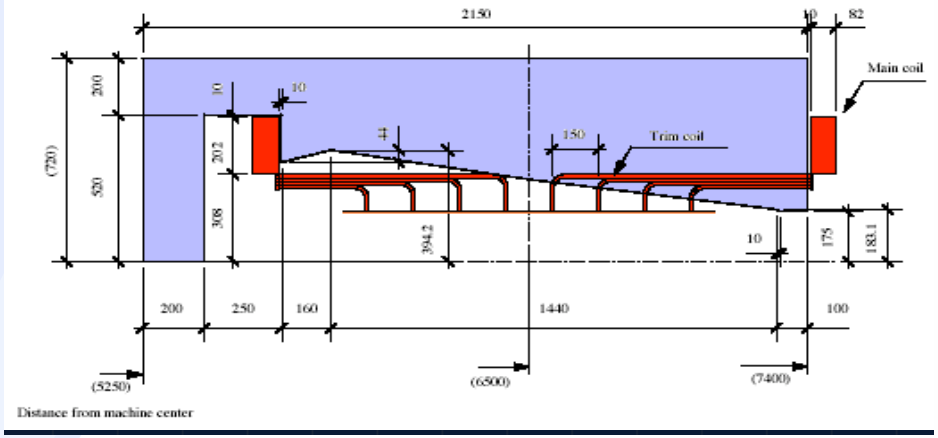
PRISM FFAG Coils

All 40 the D-coils are completed. 6 out of 20 the F coils are completed.

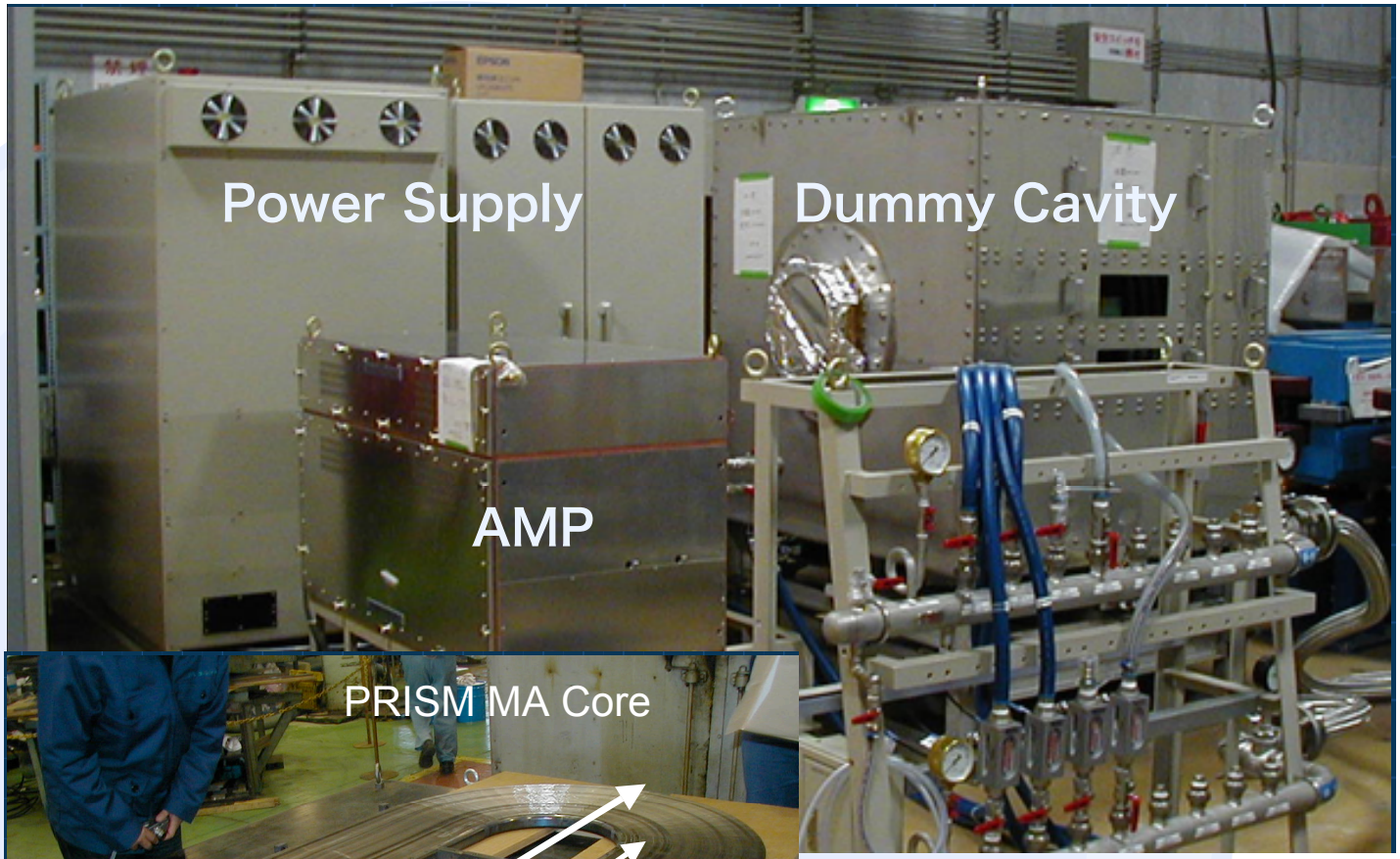
Magnet Yoke Const.

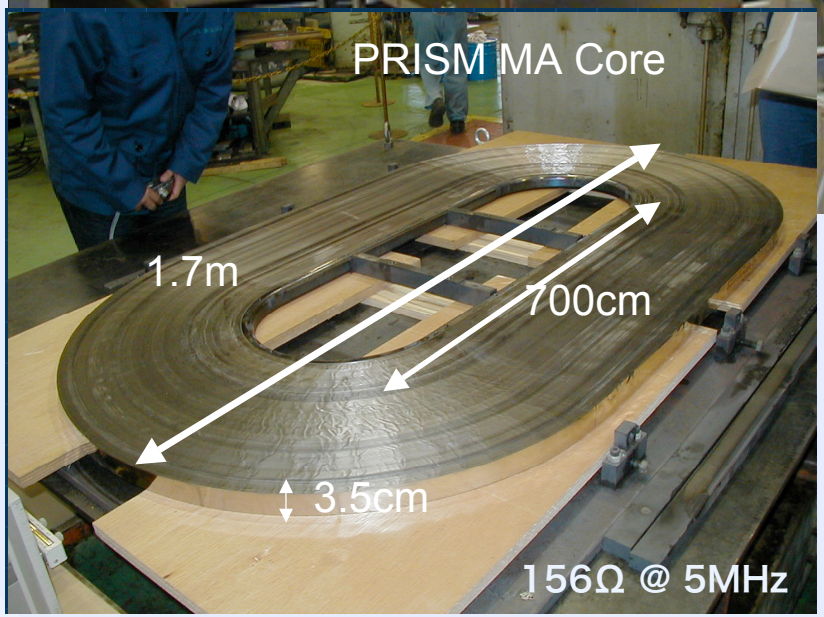
- Design of the PRISM FFAG magnets has been fixed.
  - TOSCA field
  - GEANT tracking
- Biding starts now.
- The construction takes from 2005 -2007.

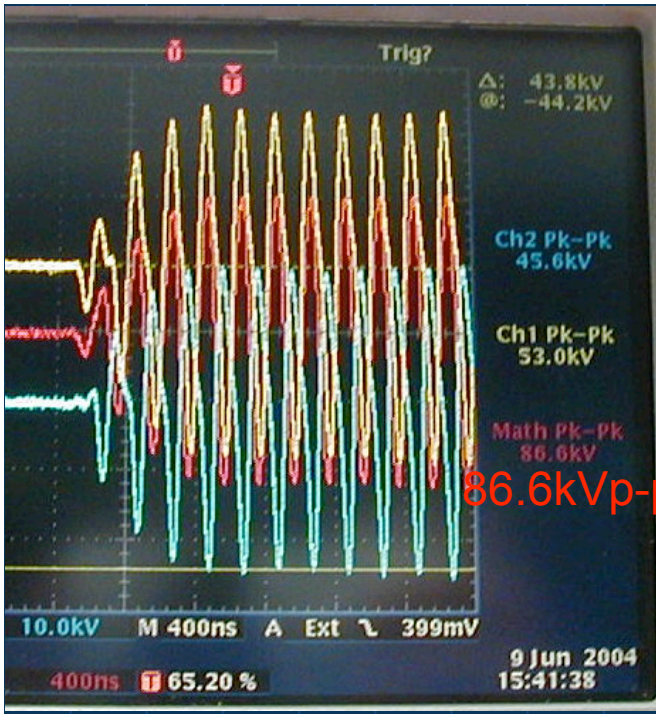




PRISM RF R&D





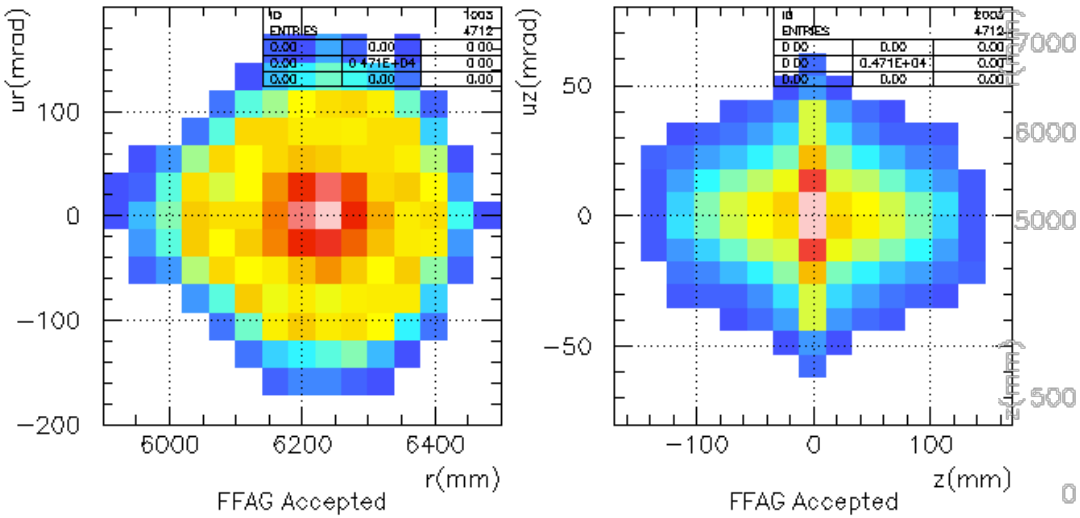


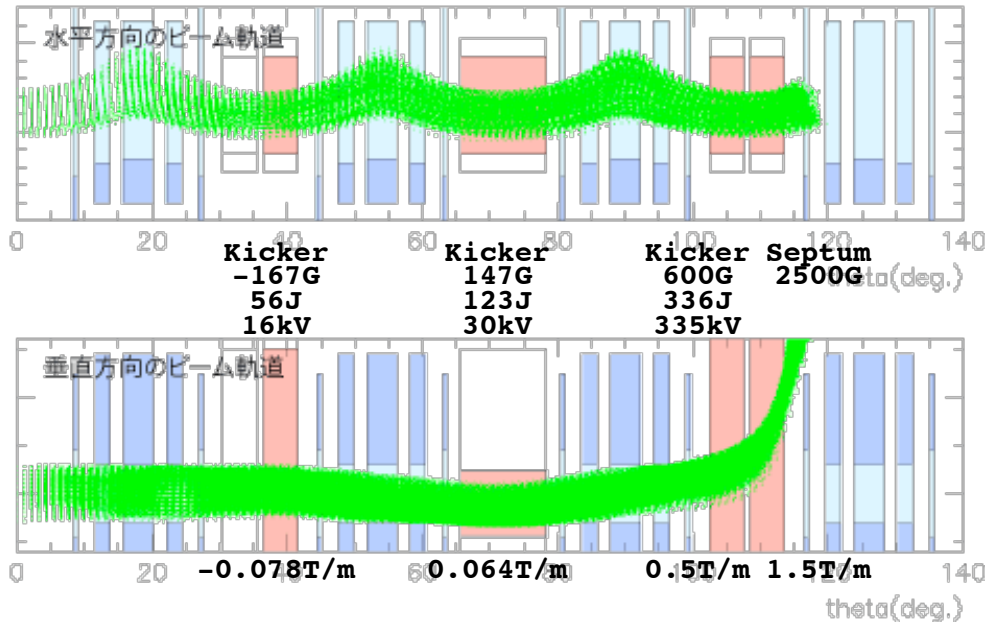
86kV/p-p @5MHz achieved with dummy RF cavity. It corresponds to 150 kV/m.

Injection/Extraction

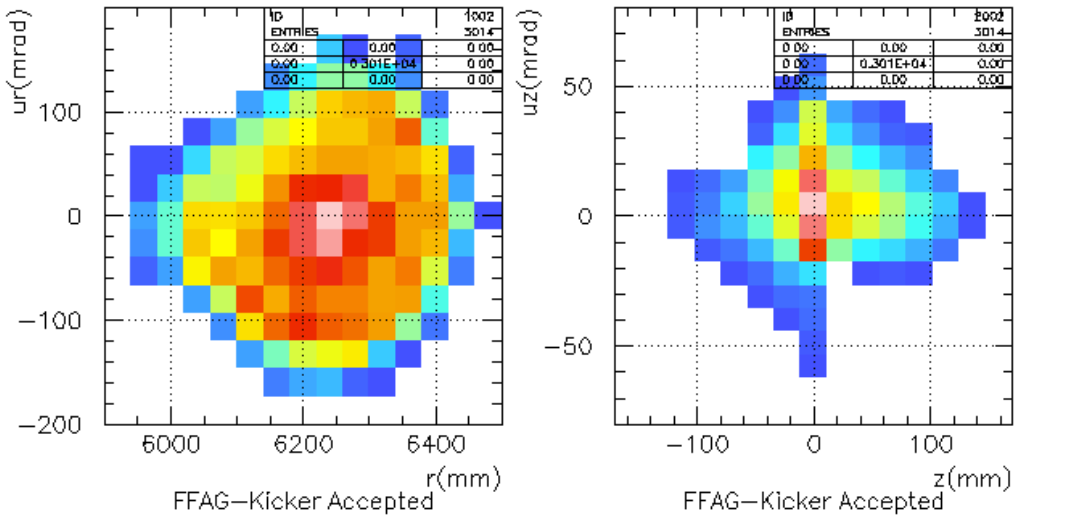
Vertical injection/extraction scheme proposed by R. Palmer.

FFAGの4D Acc. : 1.0G(mm mrad)^2





FFAG-Kickerの4D Acc. : 0.64G(mm mrad)^2

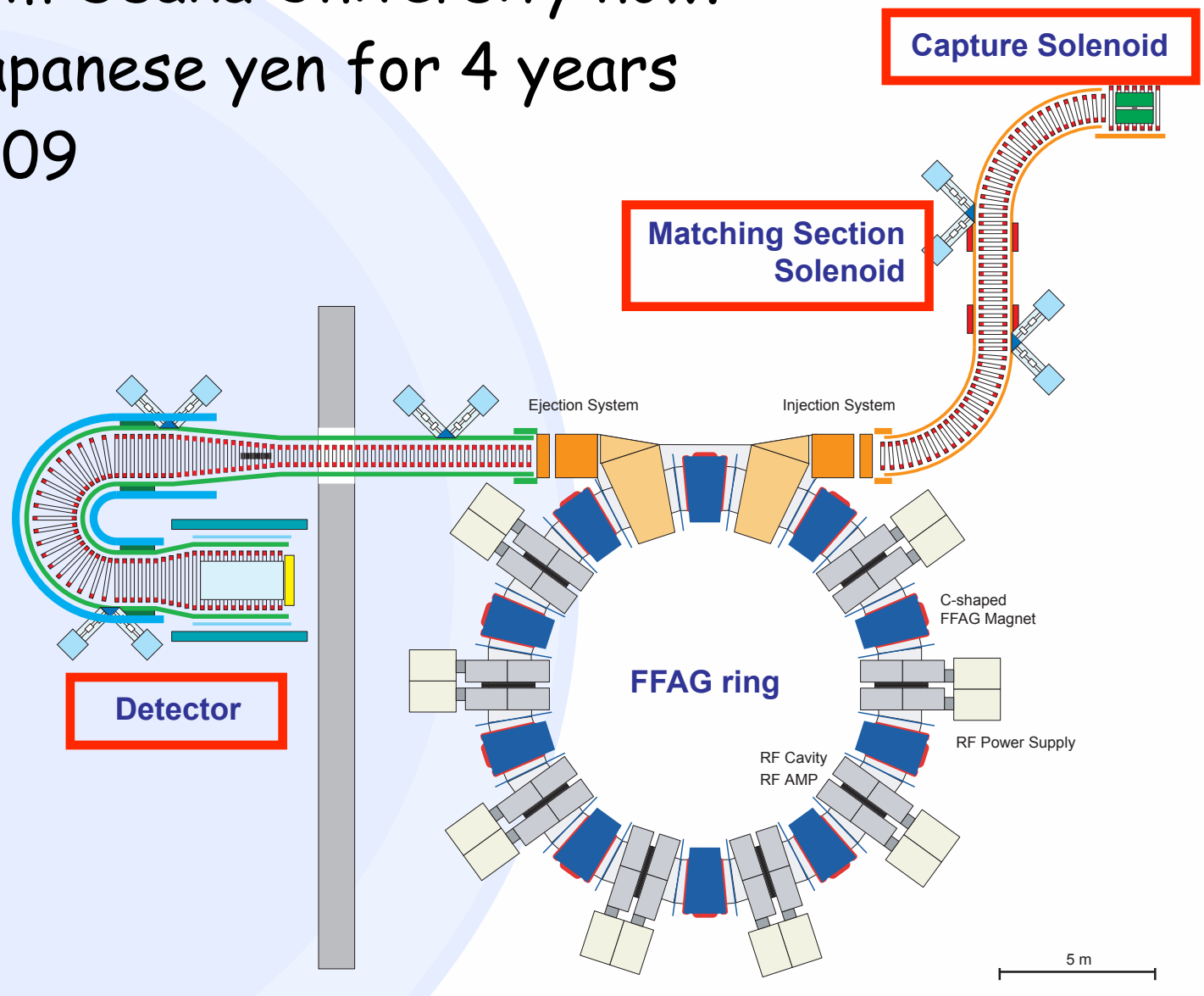


64% of the PRISM-FFAG maximum acceptance.
Further study is going on.

Next Step for PRISM

- We are preparing the budget request for the rest of PRISM from Osaka University now.
- 2 billion Japanese yen for 4 years
  - 2006-2009

(1) Pion Capture Solenoid
(2) Transfer Solenoid
(3) Kickers
(4) Detector for mu-e conversion

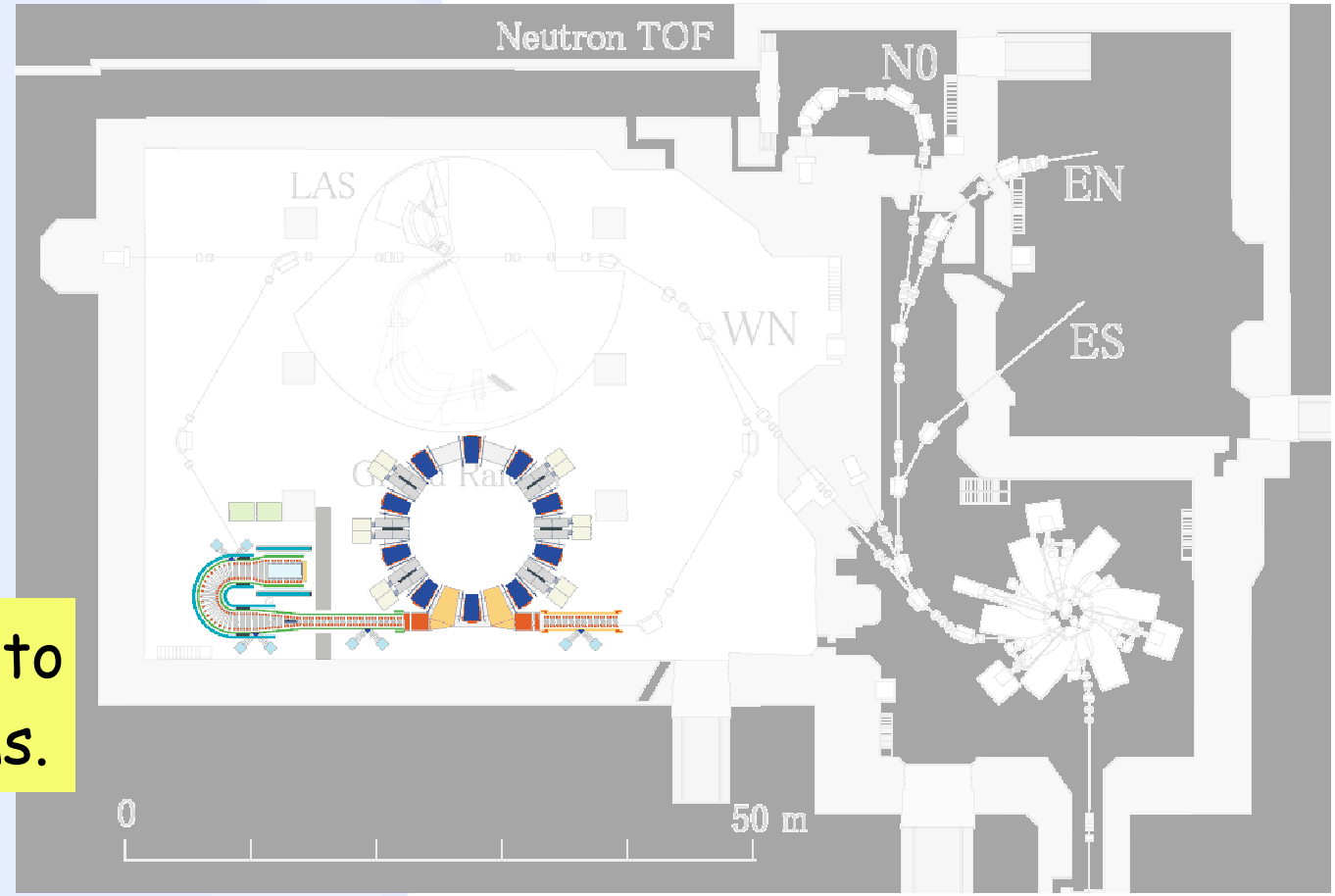


PRISM at RCNP

- Research Center for Nuclear Physics (RCNP), Osaka University
  - 400 MeV proton (above pion production threshold)
  - upto 5 micro A

Purpose : Test of fundamental performance of PRISM with muons.

Give good opportunity to study FFAG with muons.



World Collaboration

World Collaboration

Summary

- The neutrino factory scheme based on FFAG acceleration was proposed. Its preliminary design has been made.
- International contributions to MUCOOL and MICE has been made from Japan.
- Constructions and studies of various scaling-FFAGs are going. Experience and knowledge are being accumulated.
- The funding for the whole PRISM is being requested. International collaboration is welcome.