FFAG DEVELOPMENTS IN JAPAN

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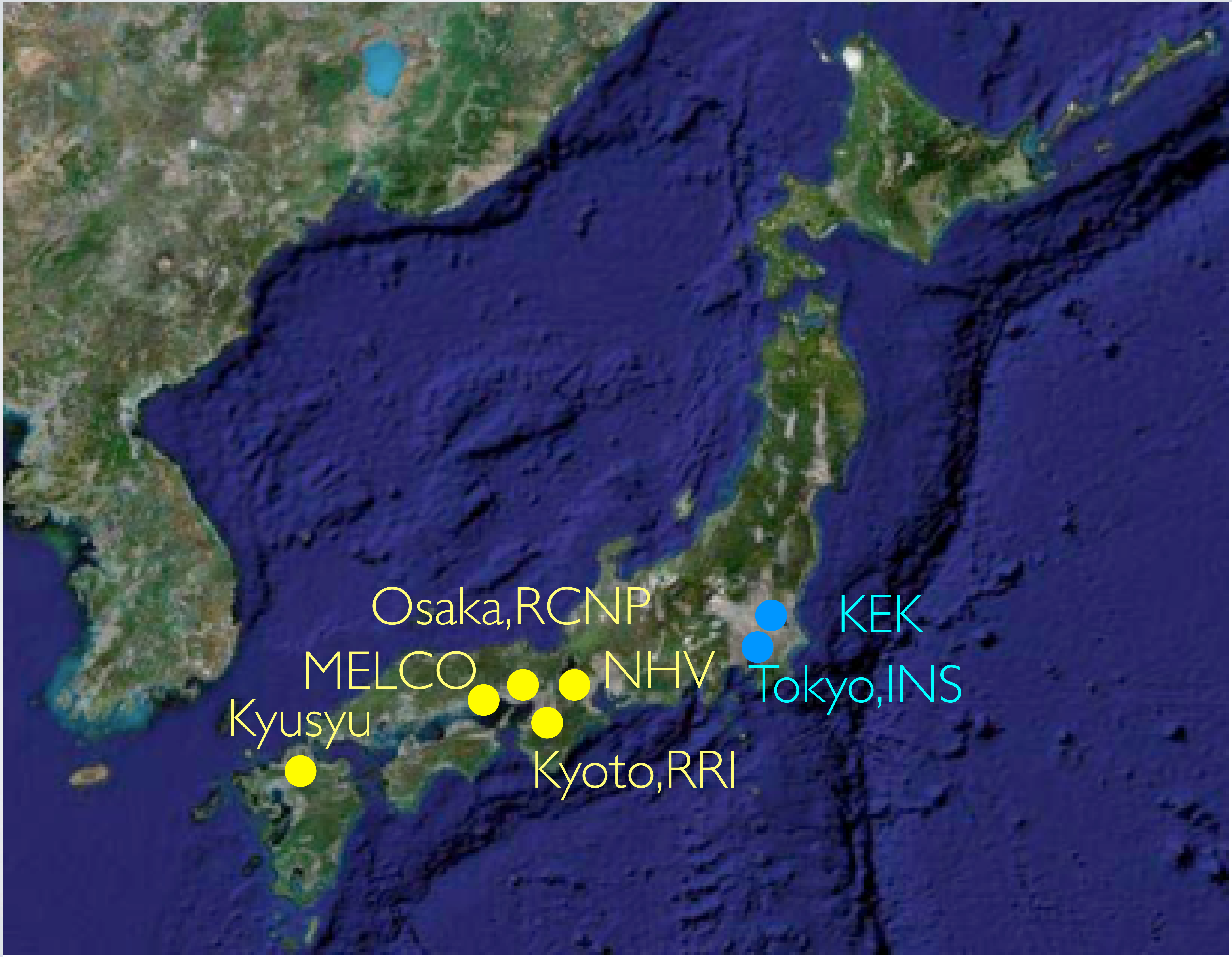
CONTENTS

- Introduction
- Lepton acceleration
  - Muon
    - Osaka University
    - Kyoto University
  - Electron
    - NHV Co.
- Hadron acceleration
  - Proton & Ion
    - Kyoto University
    - Kyusyu Univerisity
- Summary

DEVELOPMENTS OF FFAG IN JAPAN

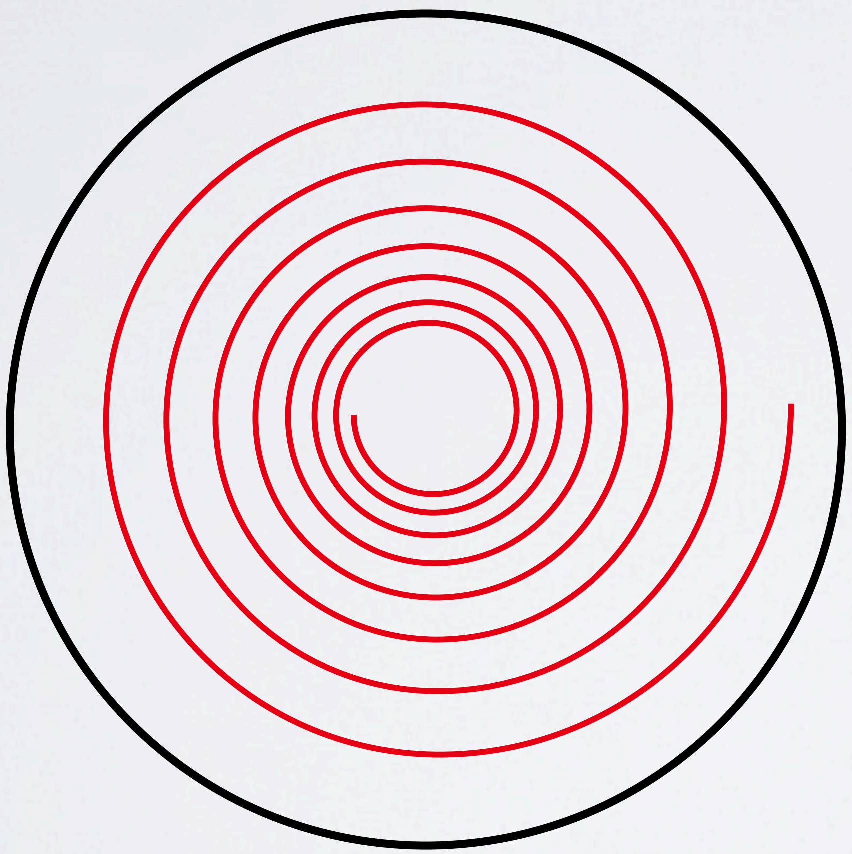


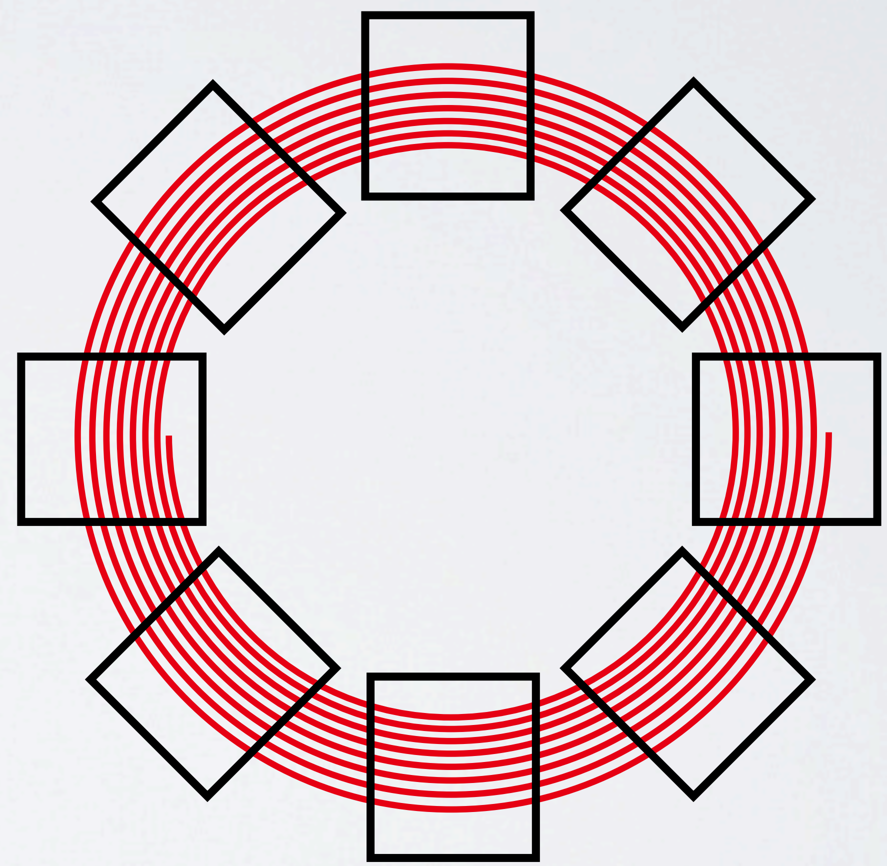
FFAG

- Strong focusing in 3-D: AG-focus in transverse and phase focus in longitudinal directions
  - It is like synchrotron.
  - Large acceptance
  - Various longitudinal RF gymnastics become possible.
    - Bunching, Stacking, Coalescing, etc.
- Static magnetic field: small orbit excursion.
  - It is like cyclotron, but not much orbit excursion
  - Fast acceleration
    - Fixed magnetic field allows the beam acceleration only by RF pattern.
    - No needs of synchronization between RF and magnets.
  - Large repetition rate
    - Space charge and collective effects are below threshold.

FIELD INDEX
ORBIT EXCURSION

Field Index → $k = -\frac{r}{B}\frac{\partial B}{\partial r}$





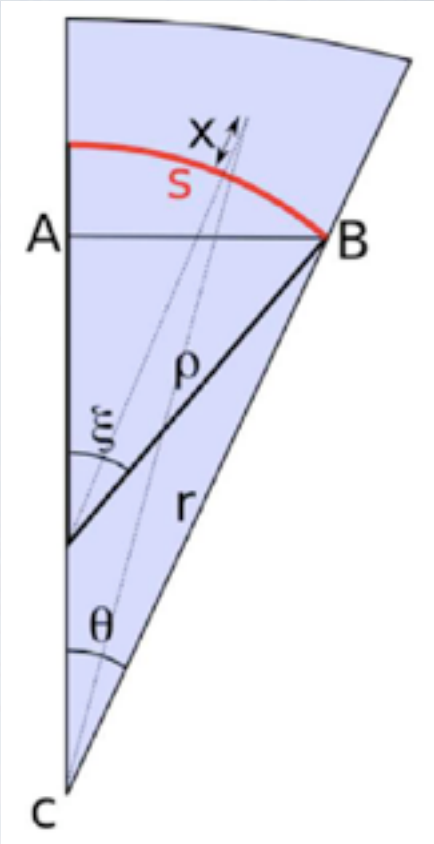
$k \approx 0$ — Cyclotron

$k >> 1$ — FFAG

TYPES OF FFAG OPTICS

- Zero chromaticity : Scaling FFAG
  - Betatron tunes during acceleration are constant.
  - Free from resonance crossing.
  - Orbit configurations for different beam momentum(energy) are (nearly) similar.
  - Very Large momentum acceptance : $\Delta p/p > \pm 100\%$
- Non-zero chromaticity : Non-scaling FFAG
  - Optical elements are all linear : dipole and quadrupole magnets.
  - Betatron tunes are varied during acceleration.
  - Need fast resonance crossing : very fast acceleration.
  - Large dynamic aperture

ZERO CHROMATICITY SCALING FFAG RING



- Betatron oscillation (cylindrical coordinate)

$$\frac{d^2x}{d\theta^2}+\frac{r^2}{\rho^2}\left(1-K\rho^2\right)x=0$$

$$\frac{d^2z}{d\theta^2}+\frac{r^2}{\rho^2}\left(K\rho^2\right)z=0$$

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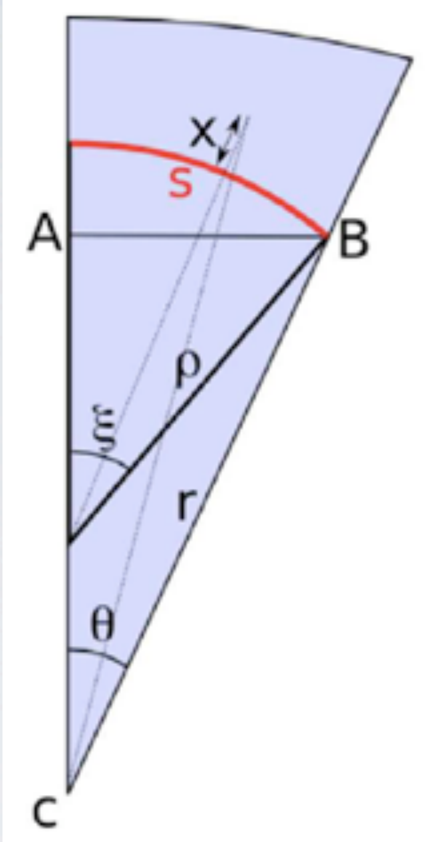

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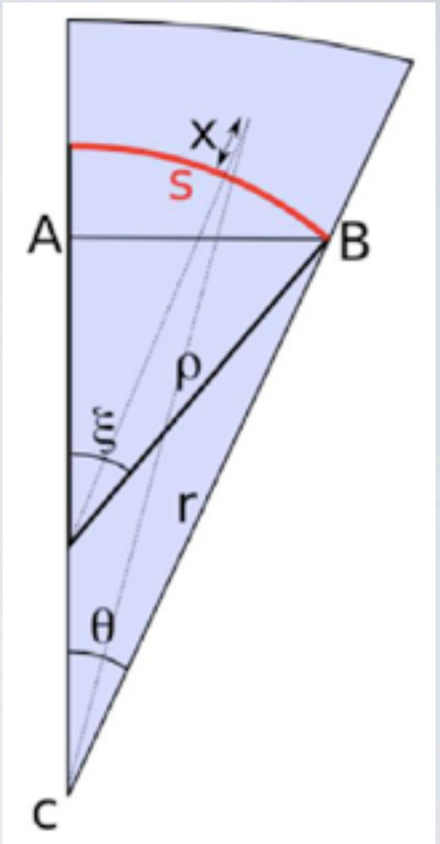

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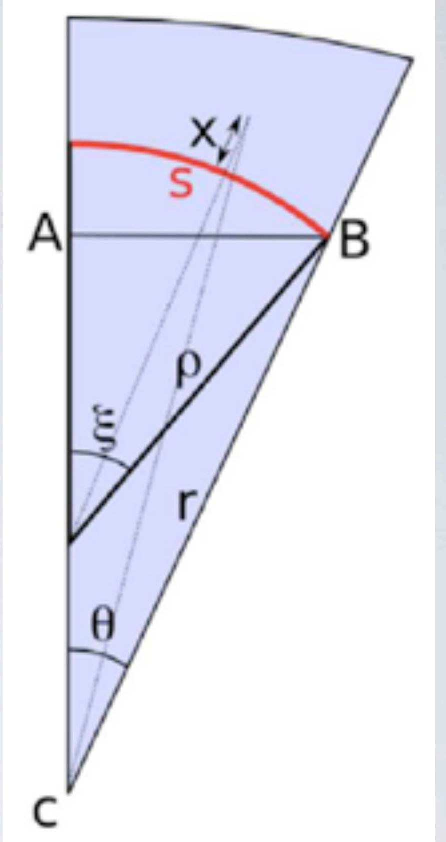

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$$\longrightarrow \begin{cases} r \propto \rho \\ \frac{r}{B}\left[\frac{\partial B_z}{\partial r}\right]_{z=0} = k \end{cases}$$

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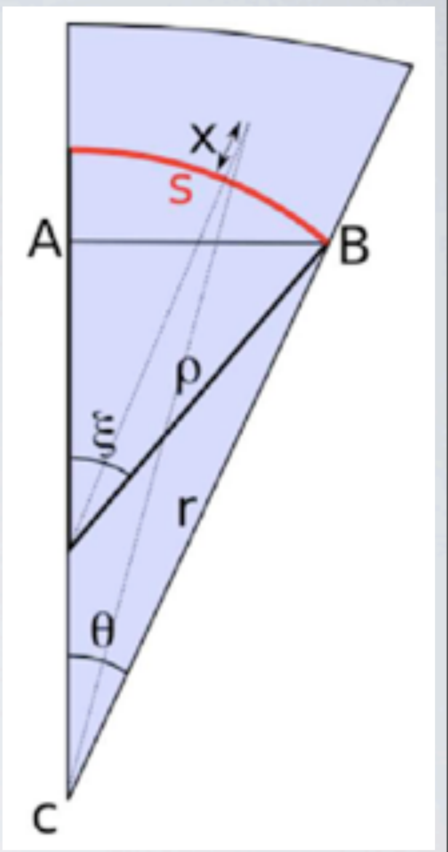

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AG FOCUSING LATTICE OF SCALING FFAG RING

$$B_z = B_0 \left(\frac{r}{r_0} \right)^k f(\theta)$$

- AG focusing : FODO lattice
- Radial sector
  - F: positive bend
  - D:negative bend

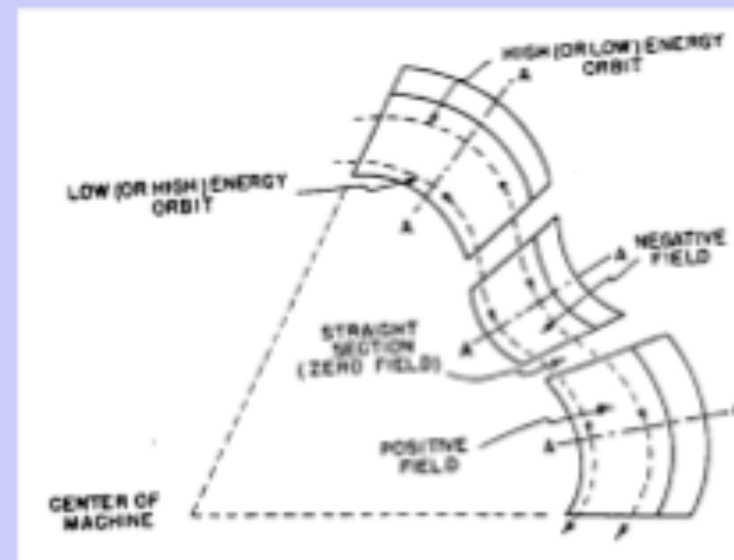


FIG. 2. Plan view of radial-sector magnets.

- Spiral sector
  - F: positive bending
  - D: edge focusing

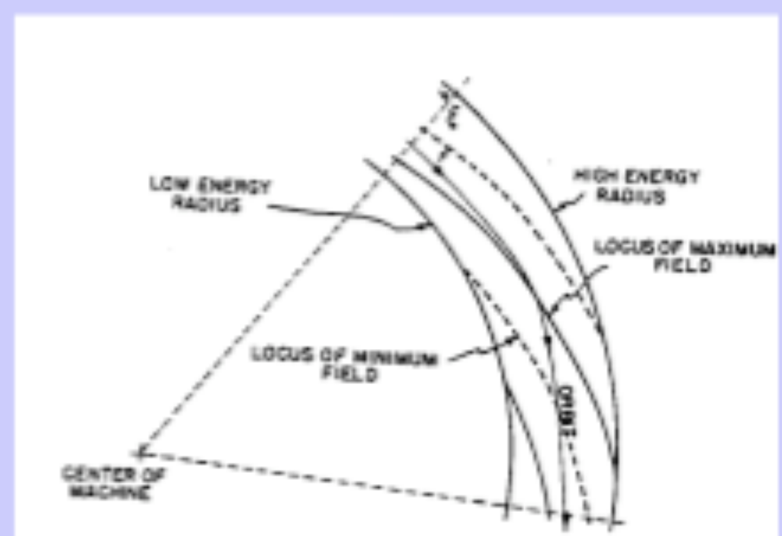


FIG. 3. Spiral-sector configuration.

ADVANCED SCALING FFAG ACCELERATOR
- FFAG STRAIGHT LINE -

- Symmetric circular scaling FFAG
- Cons/
  - Large dispersion:orbit excursion becomes large
    - Large horizontal aperture magnet
    - Large horizontal aperture rf cavity → Low frequency rf system is needed.
  - Short straight section
    - Small space for injection/extraction → Kicker/septum require large aperture.
    - Small space for rf cavity → High gradient rf is needed.
- We need a long straight line with small dispersion keeping "Zero-chromaticity".
- Is it possible to make a scaling FFAG straight line(lattice)?
  - Keeping a scaling law : zero chromaticity
  - Reducing dispersion : dispersion suppressor
  - Making a good match with circular FFAG ring : insertion
- What is a configuration of the magnetic field for scaling FFAG straight line? Obviously,

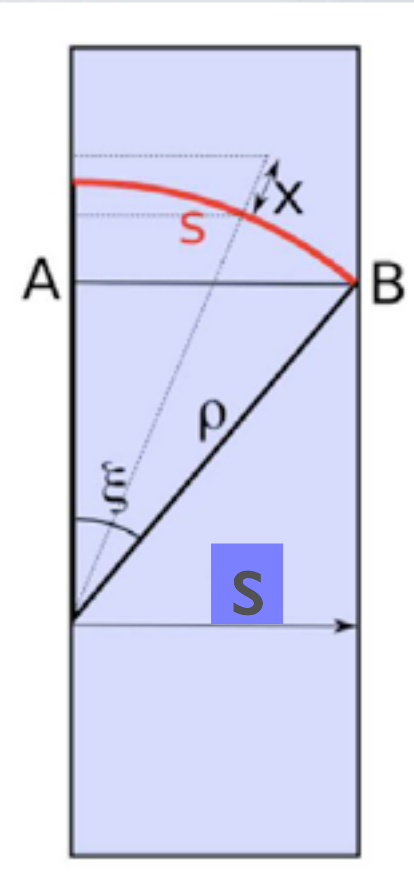
$$B_z \neq B_0 \left(\frac{r}{r_0}\right)^k f(\theta)$$

ZERO CHROMATICITY SCALING FFAG STRAIGHT LINE

- Betatron oscillation (linear coordinate)

$$\frac{d^2x}{ds^2} + \frac{1}{\rho^2}\left(1 - K\rho^2\right)x = 0$$

$$\frac{d^2z}{ds^2} + \frac{1}{\rho^2}\left(K\rho^2\right)z = 0 \qquad K = -\frac{1}{B\rho}\frac{\partial B}{\partial x}$$



- Zero chromaticity : constant betatron tunes for various beam momentum

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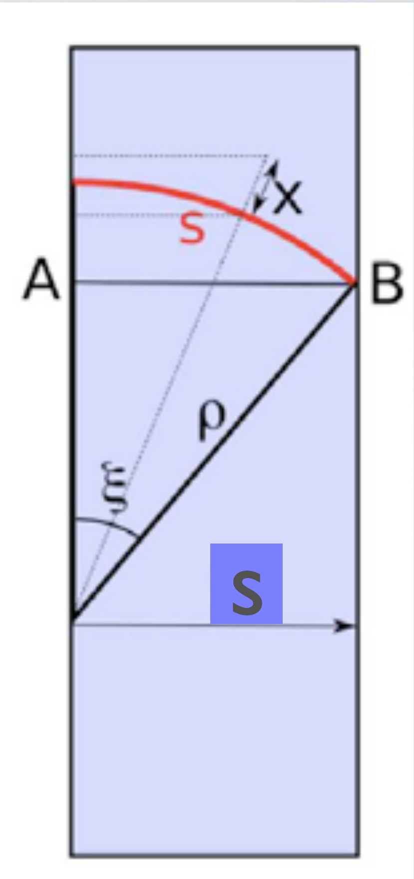

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$$\frac{d\left(1/\rho^2\right)}{dp} = 0$$

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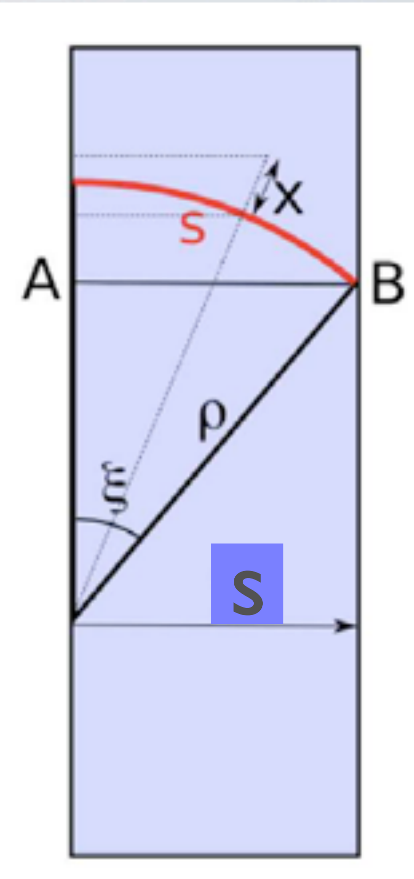

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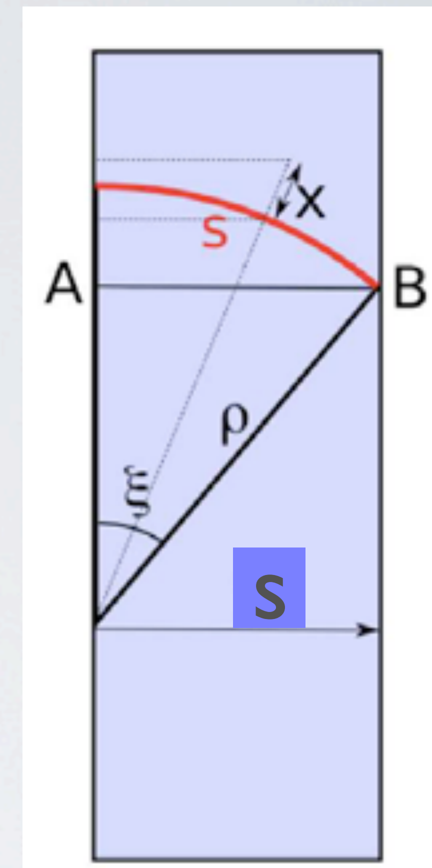

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$$\frac{d\left(1/\rho^2\right)}{dp} = 0$$

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$$\longrightarrow \begin{cases} \rho = const. \\ \dfrac{1}{B}\left[\dfrac{\partial B_z}{\partial x}\right]_{z=0} = \dfrac{n}{\rho} \end{cases}$$

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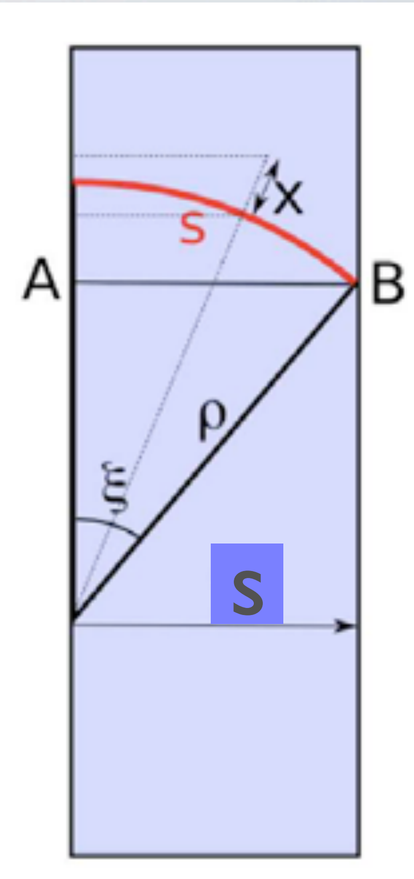

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$$B_z = B_0 \exp\left[\frac{n}{\rho}x\right]$$

SCALING FFAG STRAIGHT LINE

- Scaling(zero-chromatic) FFAG straight line (JB. Lagrange)
  - Example
    - Proton beam
    - Energy range : E=80~200MeV

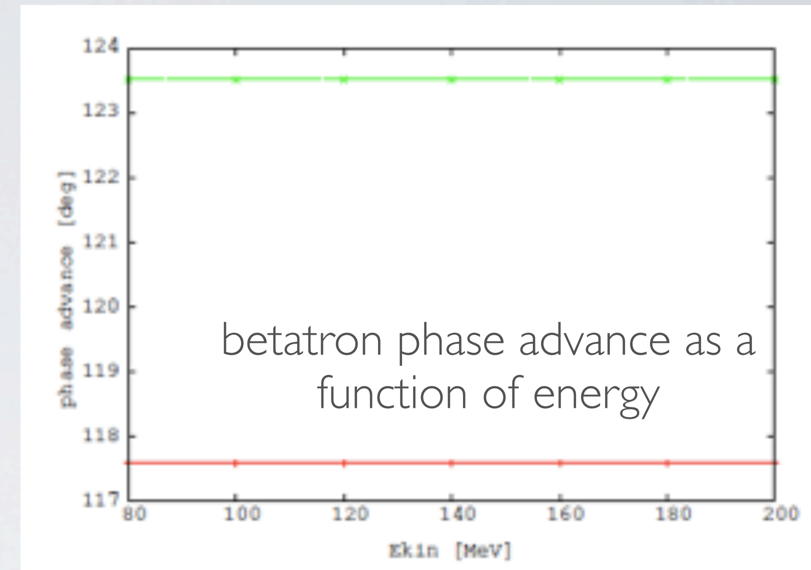
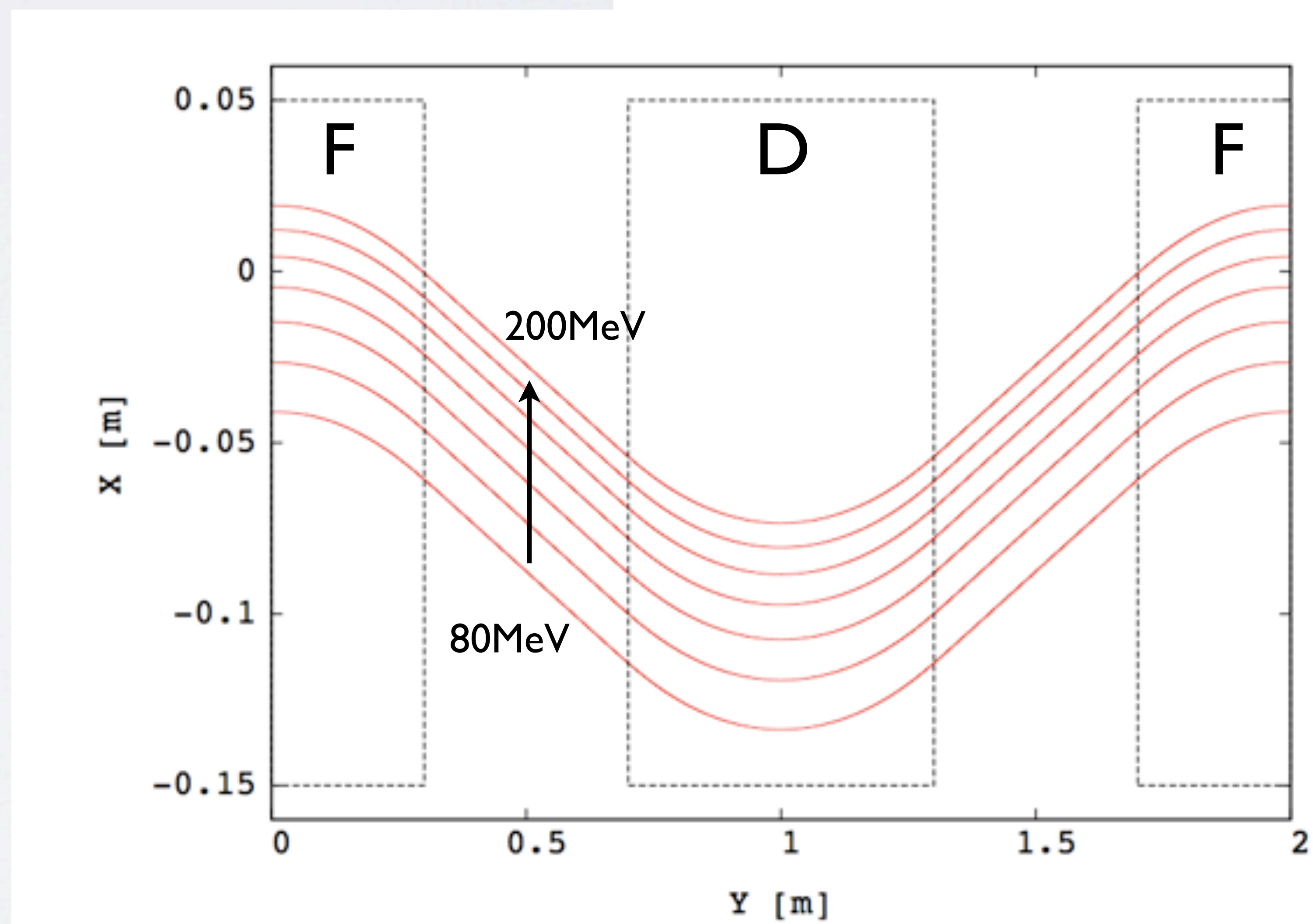


Table 1: Tracking parameters

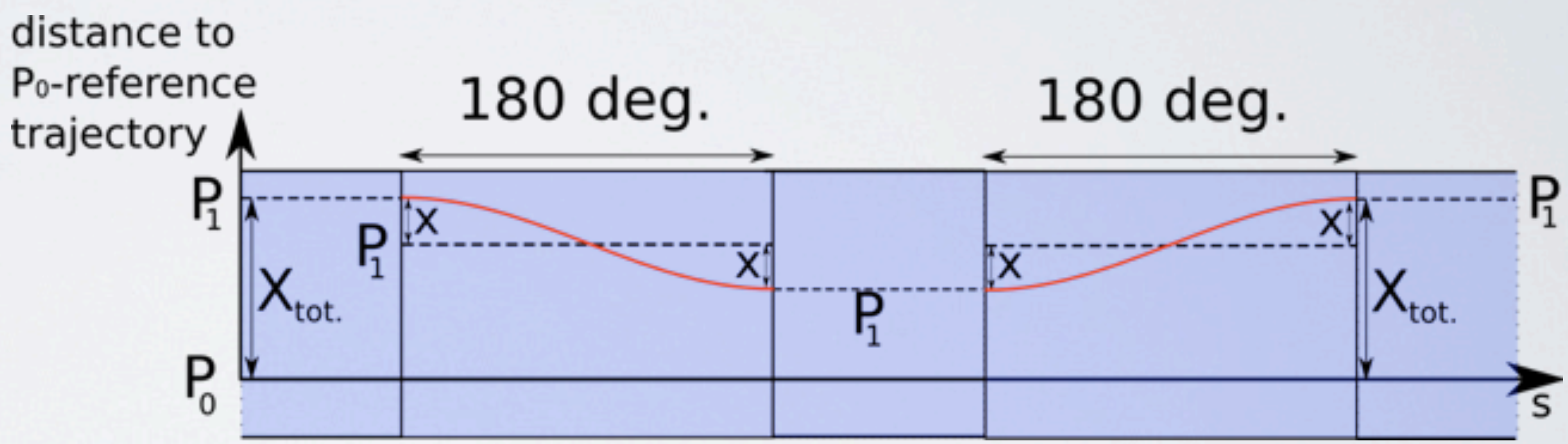
Length of the magnets	60 cm
Drift	40 cm
Kinetic energy range	80 to 200 MeV
Field index	17
Local curvature radius	2.1 m
Step size	1 mm
Phase advances:	
horizontal μ_x	104.8 deg.
vertical μ_z	112.5 deg.



DISPERSION SUPPRESSOR/ INSERTION MATCHING

- Dispersion suppressor
  - Successive π-cells in the horizontal plane can suppress the dispersion.
  - Help to reduce the size of apertures of the magnet and rf cavity.

$$x = \ln\left(\frac{P_1}{P_0}\right)\left(\frac{\rho_0}{n_0} - \frac{\rho_1}{n_1}\right)$$



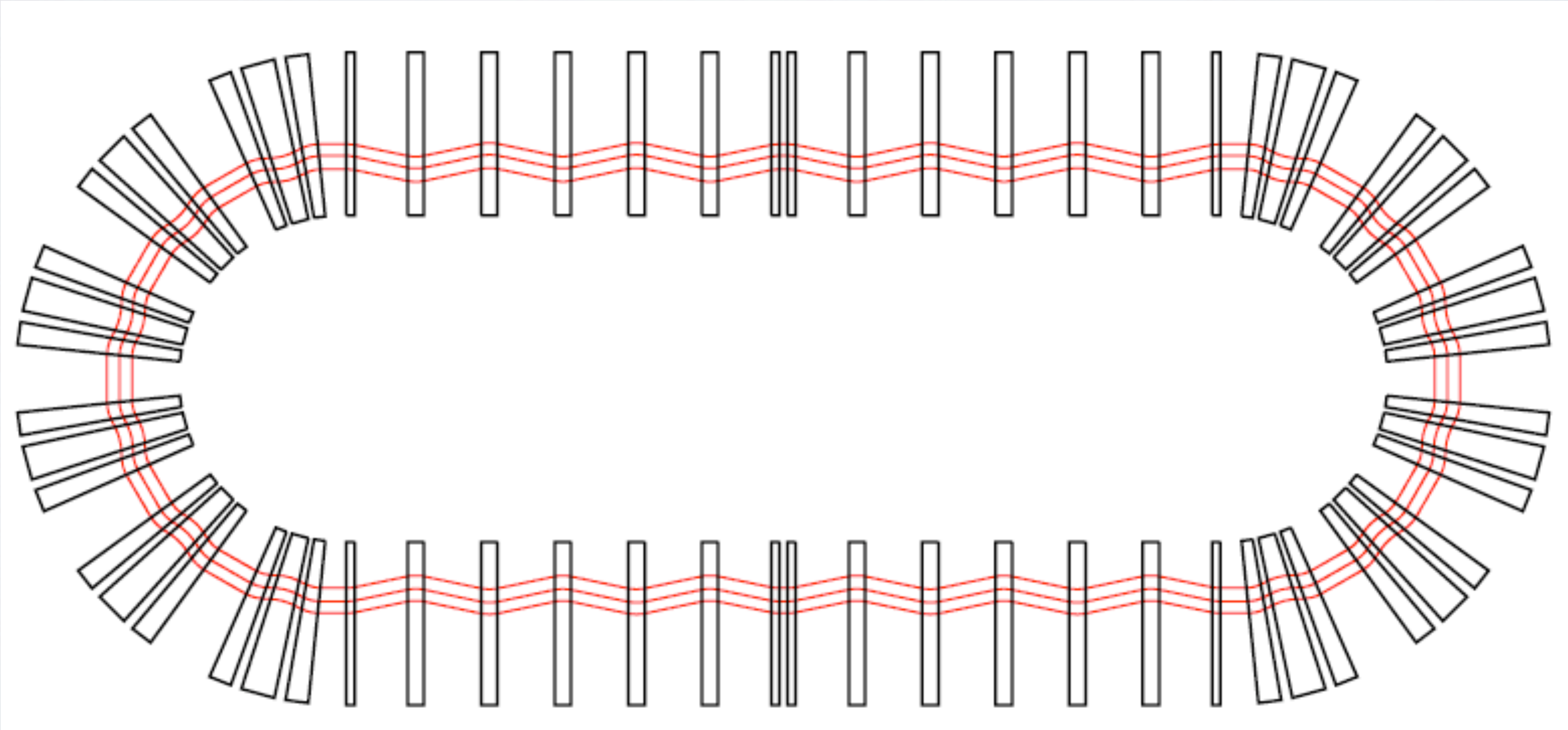
- Insertion matching
  - Matching condition for closed orbit between ring and straight line

ring — linear line

$$\left(1 + \frac{x}{r_m}\right)^{k+1} = \exp\left(\frac{n}{\rho}x\right) \quad \Rightarrow \quad \boxed{\frac{k+1}{r_m} = \frac{n}{\rho}}$$

← 1st order

ADVANCEMENT OF SCALING FFAG



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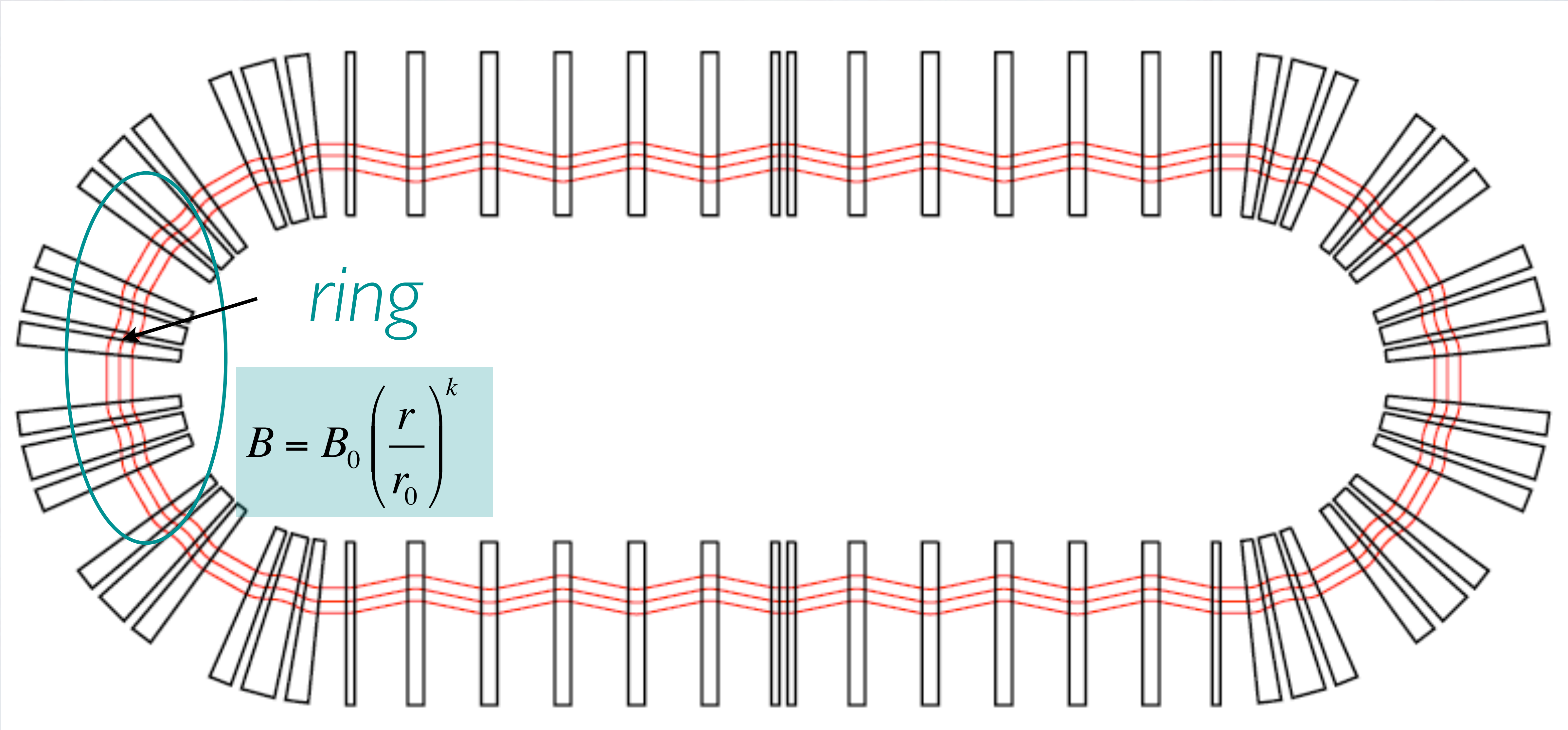
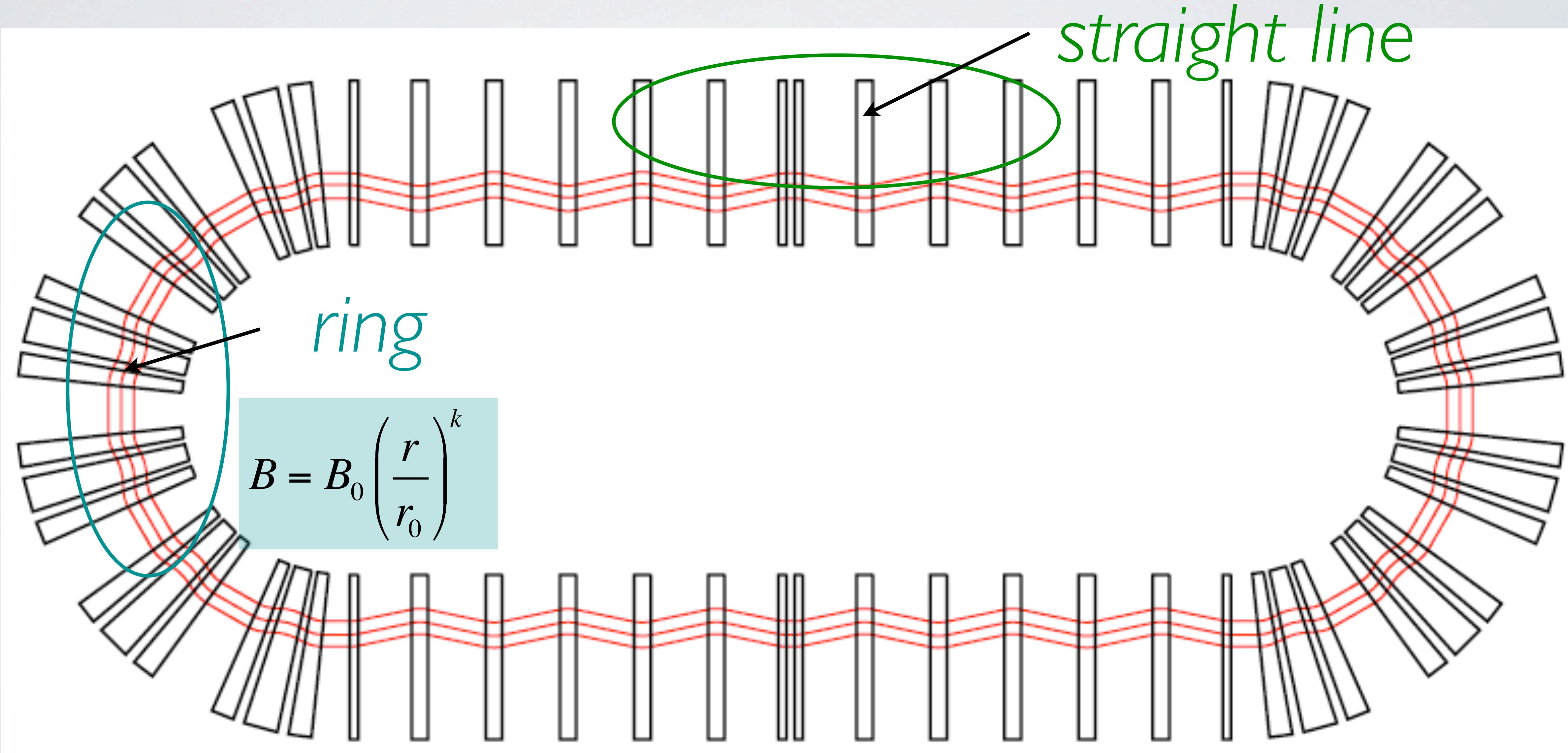


$$B = B_0 \left(\frac{r}{r_0} \right)^k$$

ADVANCEMENT OF SCALING FFAG

$$B_z = B_0 \exp\left[\frac{n}{\rho} x\right]$$



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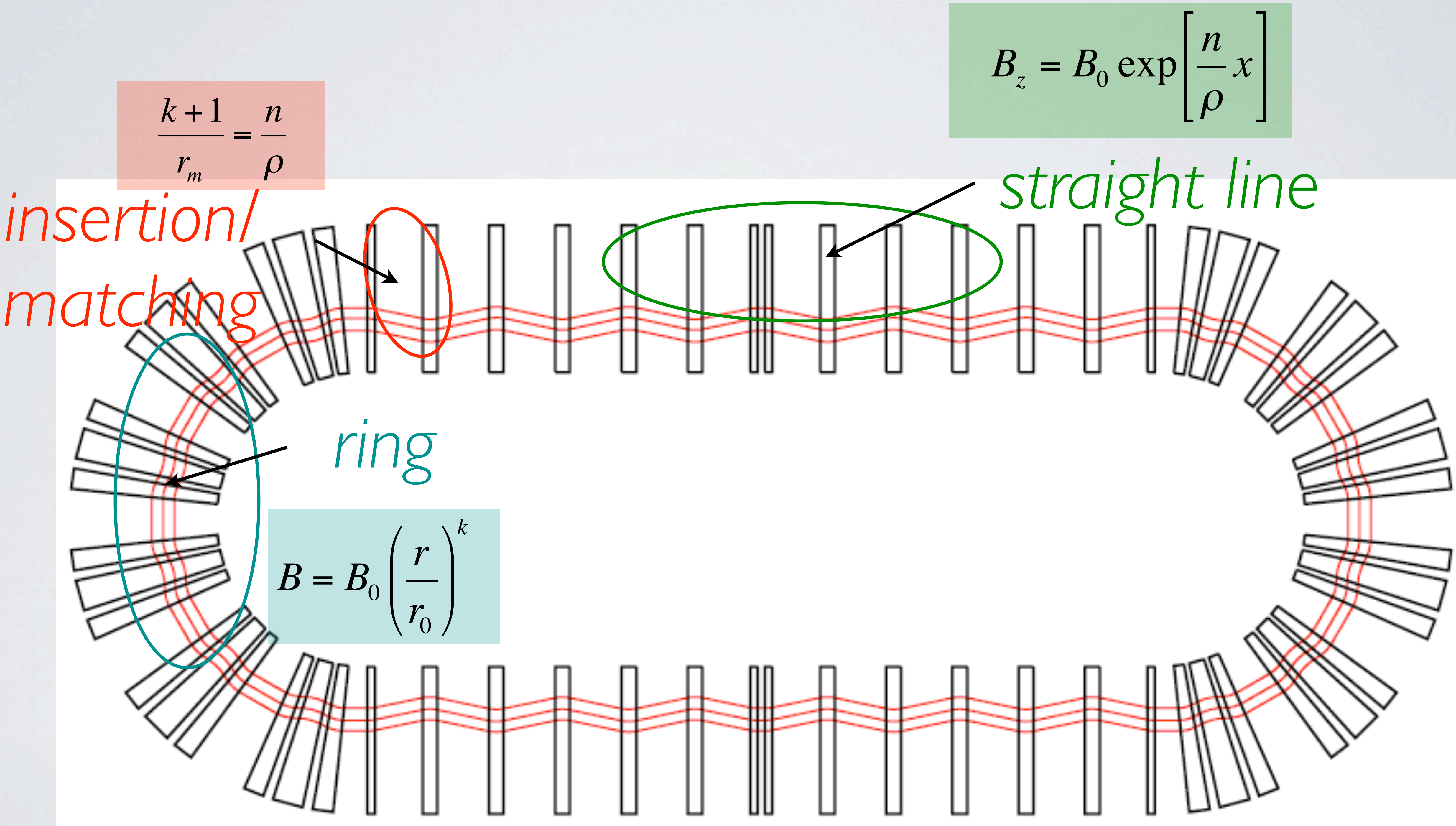

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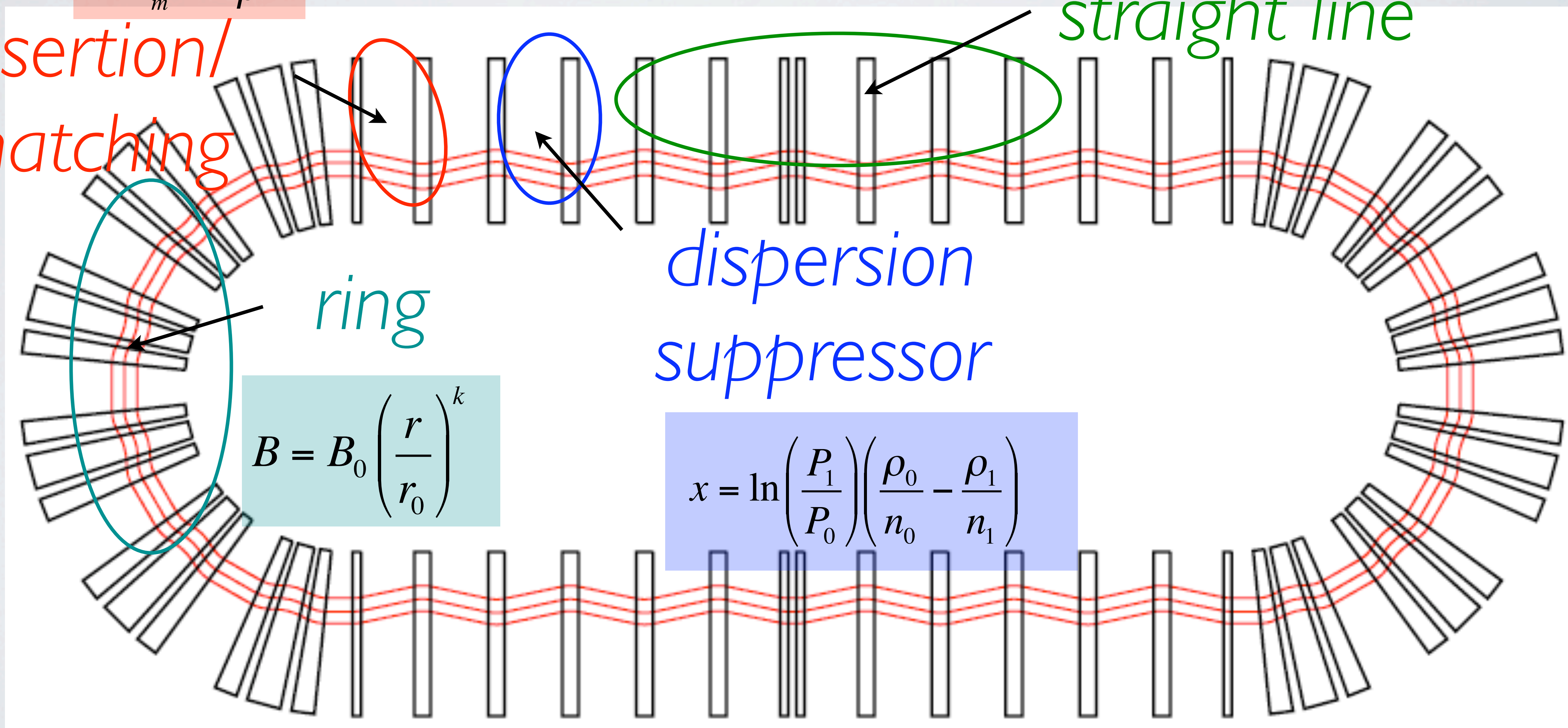

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ADVANCEMENT OF SCALING FFAG - RF ACCELERATION -

- Beam acceleration in the scaling FFAG has varieties.
  - Momentum compaction is constant during acceleration
  - Variable frequency rf acceleration
    - Broad-band rf cavity
      - MA(magnetic alloy) cavity : Q~1
  - Fixed frequency rf acceleration
    - Stationary bucket
    - Serpentine bucket
    - Harmonic number jump

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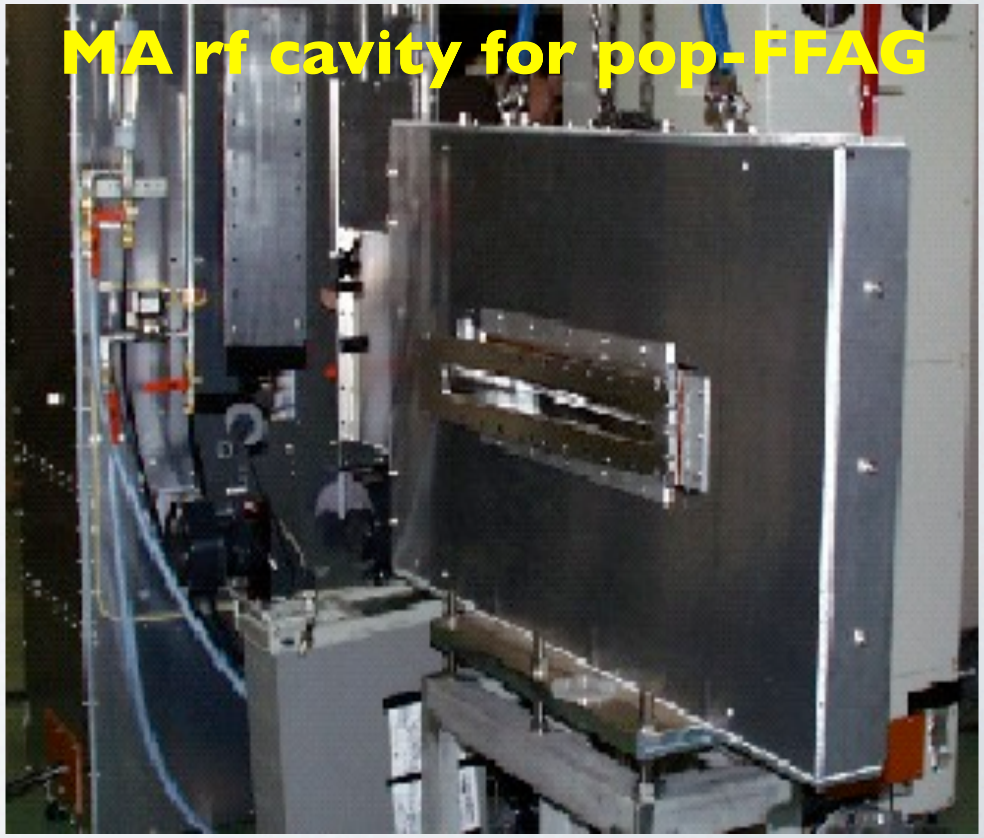

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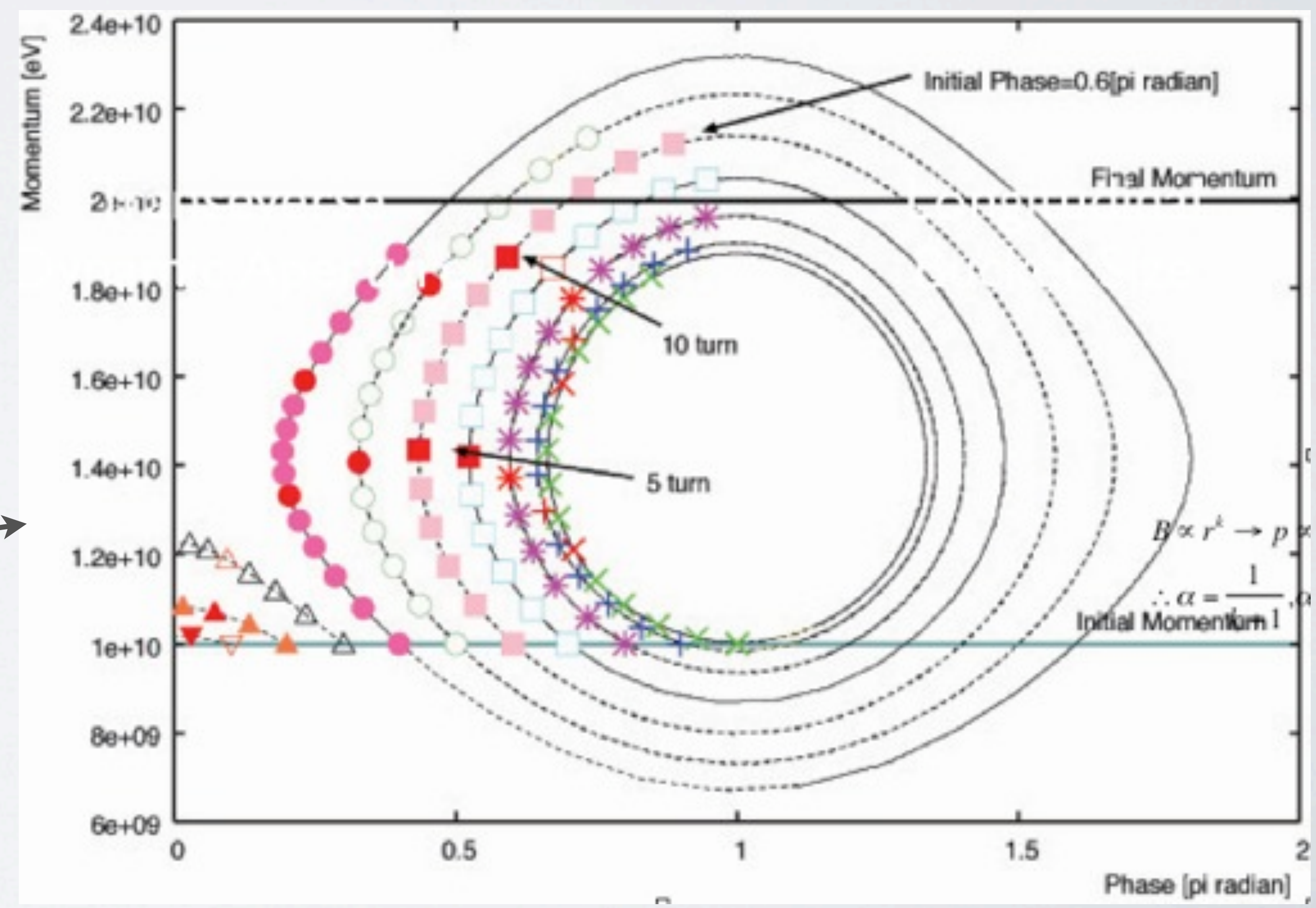

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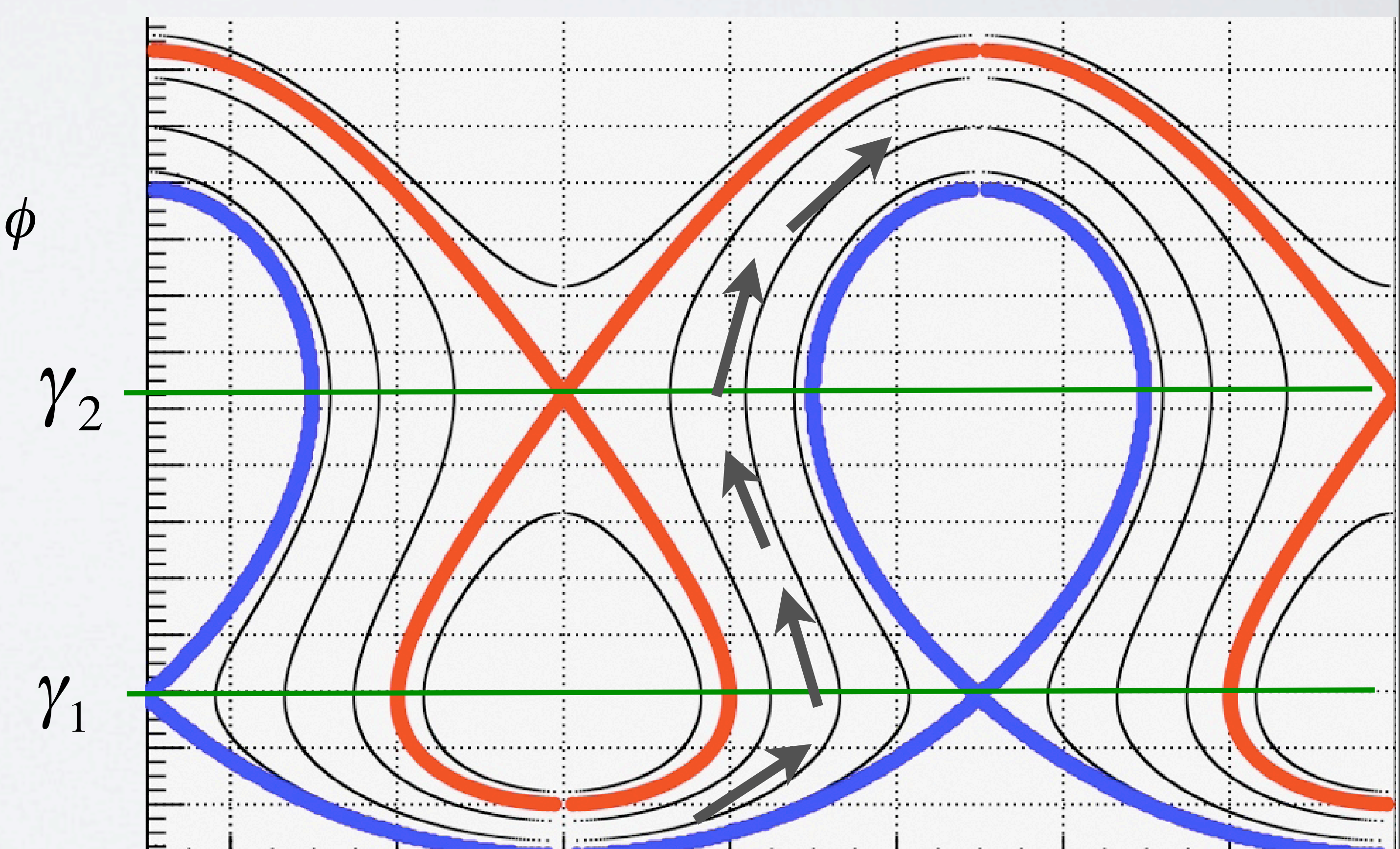
FIXED FREQUENCY RF ACCELERATION -SERPENTINE BUCKET-

- Two rf buckets below and above the transition energy are interfered in the strong focusing machine. Serpentine path between two buckets exist. (Sessler, Symon)
- In the scaling FFAG, hamiltonian of longitudinal motion can be obtained analytically. (Yamakawa, Uesugi, Mori)
  - Either relativistic or non-relativistic beam can be accelerated with fixed frequency rf cavity

$$H = 2\pi m_0 c^2 \left[\frac{\left(\gamma_s^2 - 1\right)^{\lambda}}{2\gamma_s} \frac{\left(\gamma^2 - 1\right)^{-\lambda+1}}{(1-\lambda)} + \gamma \right] + e\frac{V_{rf}}{h} f_0 \cos\phi$$

$$\lambda = \frac{k}{2(k+1)}$$

$$\frac{dp}{dT} = 0 : \quad p = \gamma_1 \text{ and } \gamma_2$$



HISTORY

- Idea
  - 1950s Okawa(Japan), Kerst-Symon(USA), Kolomenskii (USSR)
- Developments
  - 1960s MURA project (USA) Electron models
  - 2000 POP-FFAG (KEK, Japan) First proton FFAG
  - 2004 150-MeV proton FFAGs (KEK, Kyusyu, Japan)
  - 2005 R&Ds for various applications:RACAAM(Grenoble, France), PD(FNAL, USA), etc.
  - 2008 Proton FFAGs for ADSR (Kyoto, Japan)
  - 2008 PRISM-FFAG for muon (Osaka, Japan)
  - 2009 e-FFAG(NHV, Japan)
  - 2010 EMMA(Daresbury, England) First non-scaling FFAG

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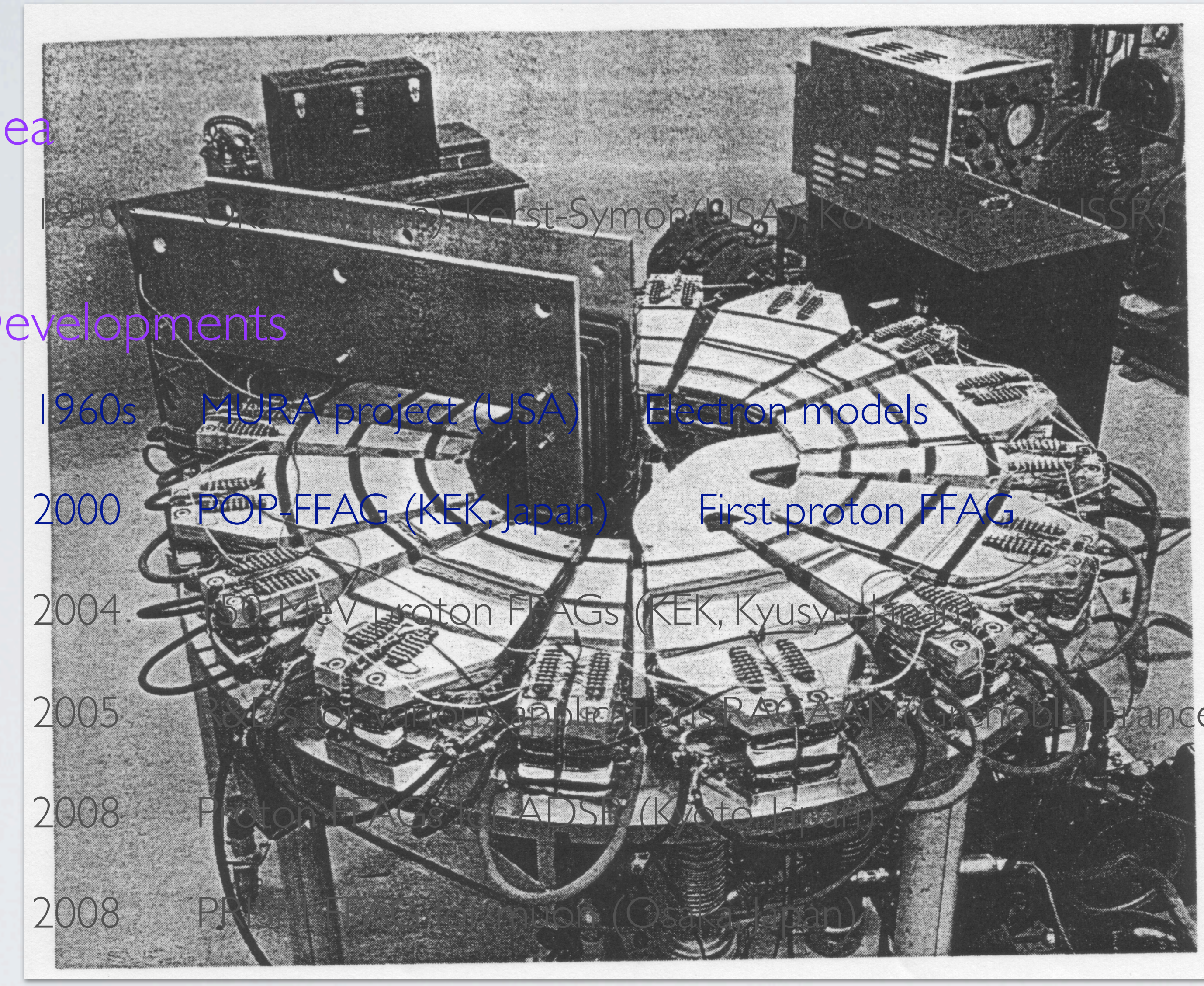
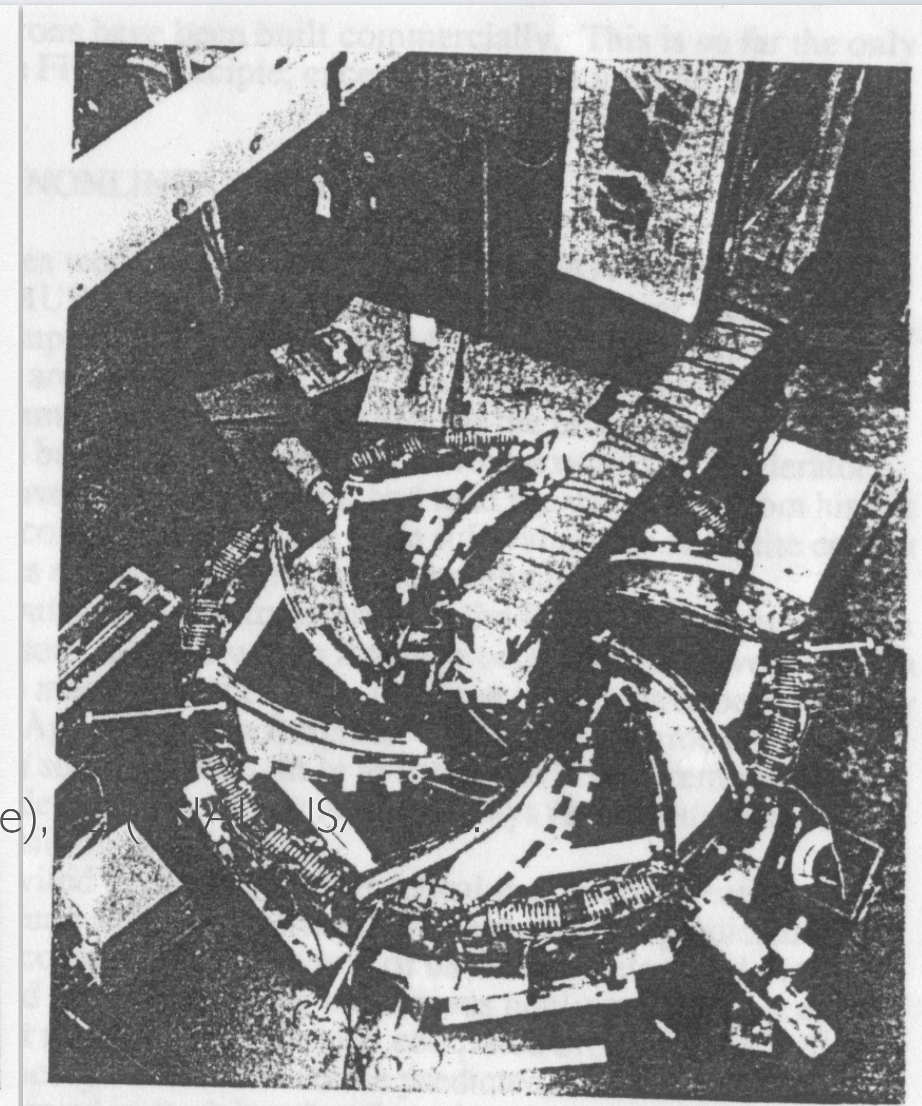

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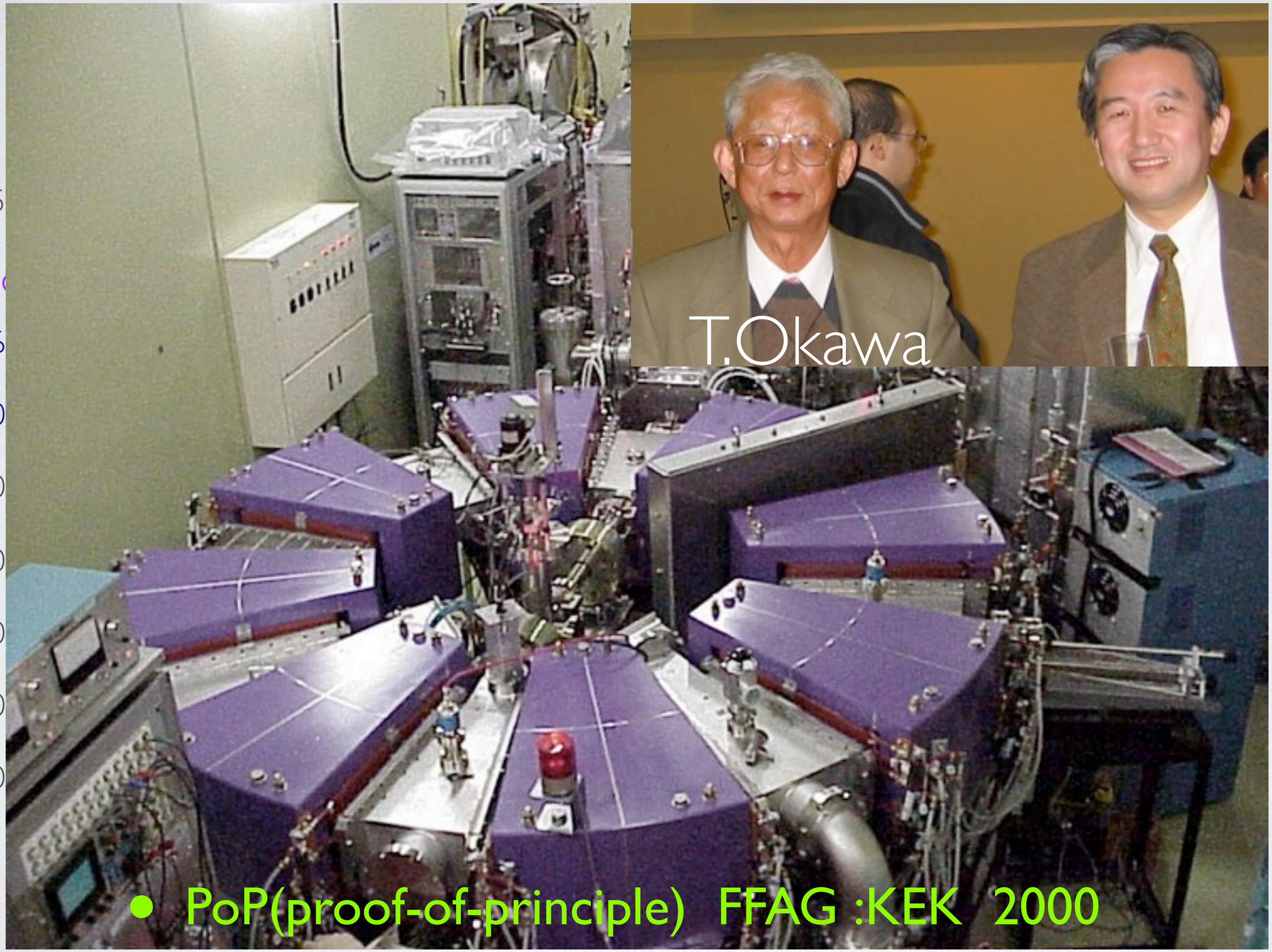
HISTORY

- Idea
  - 195
- Devel
  - 196
  - 200
  - 200
  - 200
  - 200
  - 200
  - 200
  - 201



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  - 2010 EMMA(Daresbury, England) First non-scaling FFAG

HISTORY

EMMA:Electron Model for Muon Accelerator under constraction at UK

- Idea
  - 19
- Deve
  - 19
  - 20
  - 20
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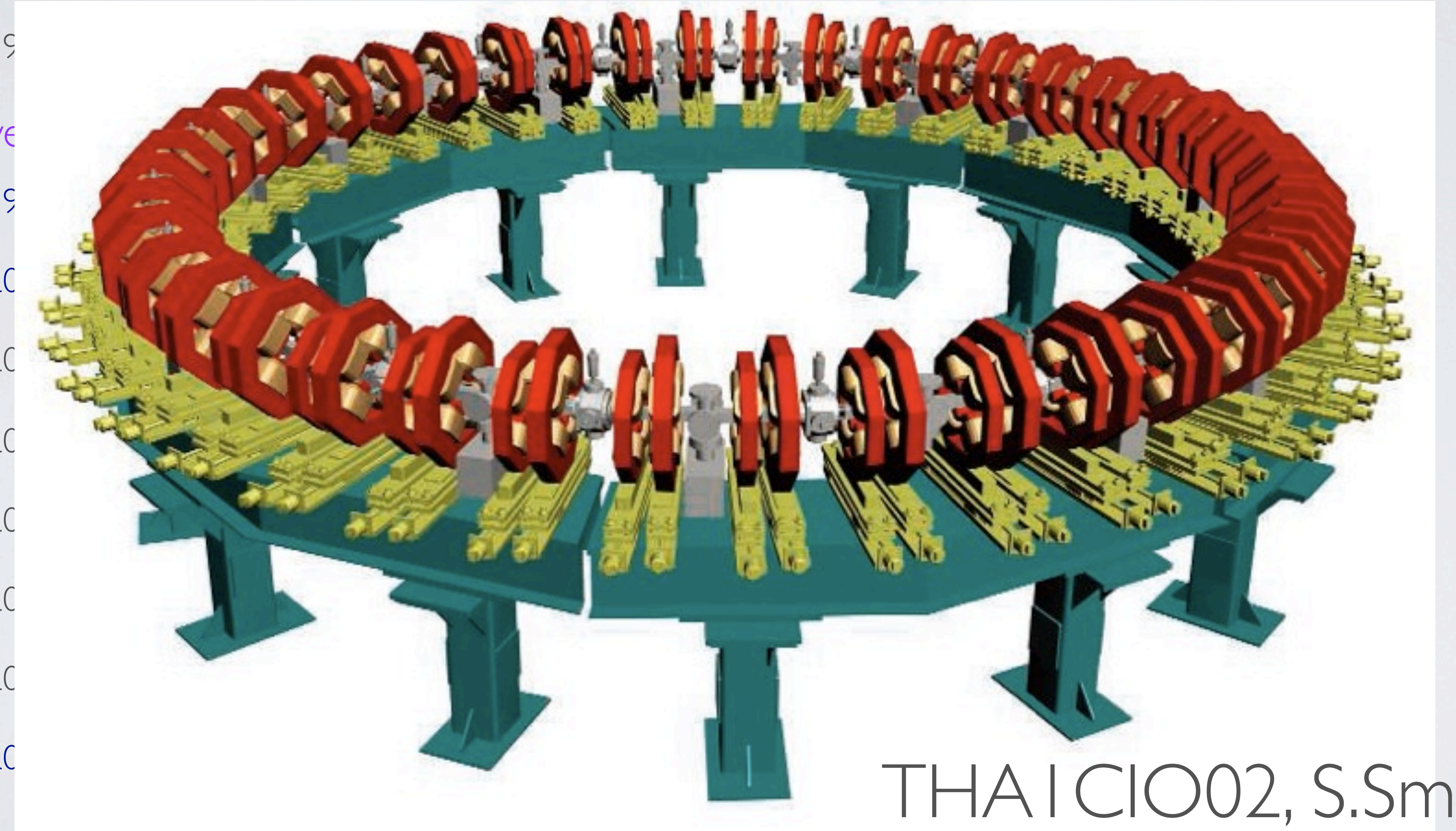
  - 20
  - 20
  - 20



THA1CIO02, S.Smith

FFAGS FOR LEPTON BEAM ACCELERATION IN JAPAN

- Muon
  - Osaka University
  - Kyoto University
- Electron
  - NHV Co.

OSAKA UNIVERSITY

Y.Kuno, A.Sato

- **MOTIVATION**
- Research for new physics beyond Standard Theory with **μ**-e conversion rare event experiment

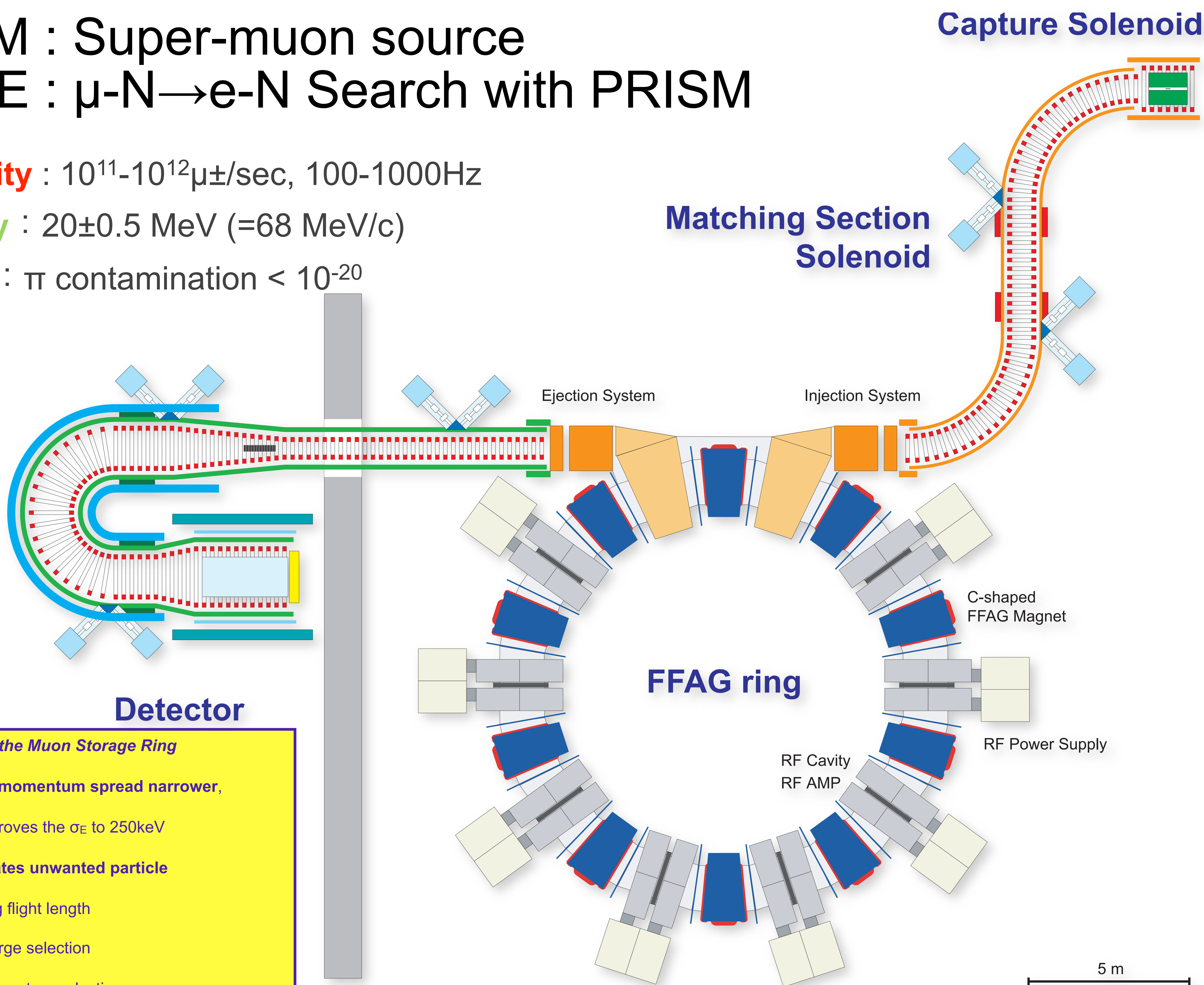
$$B(\mu^- + Ti \rightarrow e^- + Ti) < 10^{-18}$$

- To do this,

●with a muon storage ring to reduce the energy spread and pion background.
●with a fast-extracted pulsed proton beam.
●need a new beamline and experimental hall.
●Ultimate search

PRISM : Super-muon source
PRIME : μ-N→e-N Search with PRISM

- **Intensity** : 10^{11}-10^{12}μ±/sec, 100-1000Hz
- **Energy** : 20±0.5 MeV (=68 MeV/c)
- **Purity** : π contamination < 10^{-20}



Functions of the Muon Storage Ring

- **Makes momentum spread narrower,**
  - improves the σ_E to 250keV
- **Eliminates unwanted particle**
  - long flight length
  - charge selection
  - momentum selection

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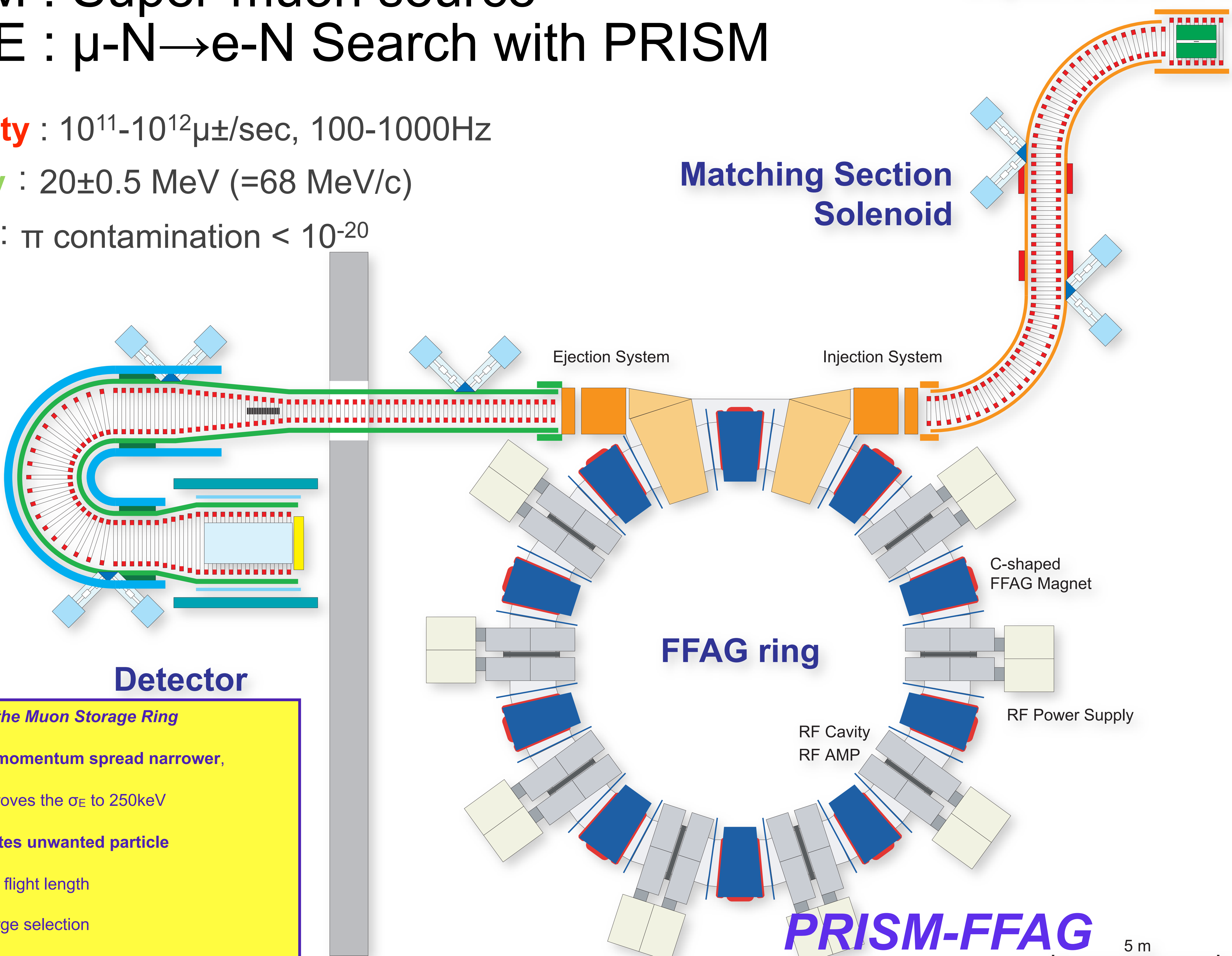

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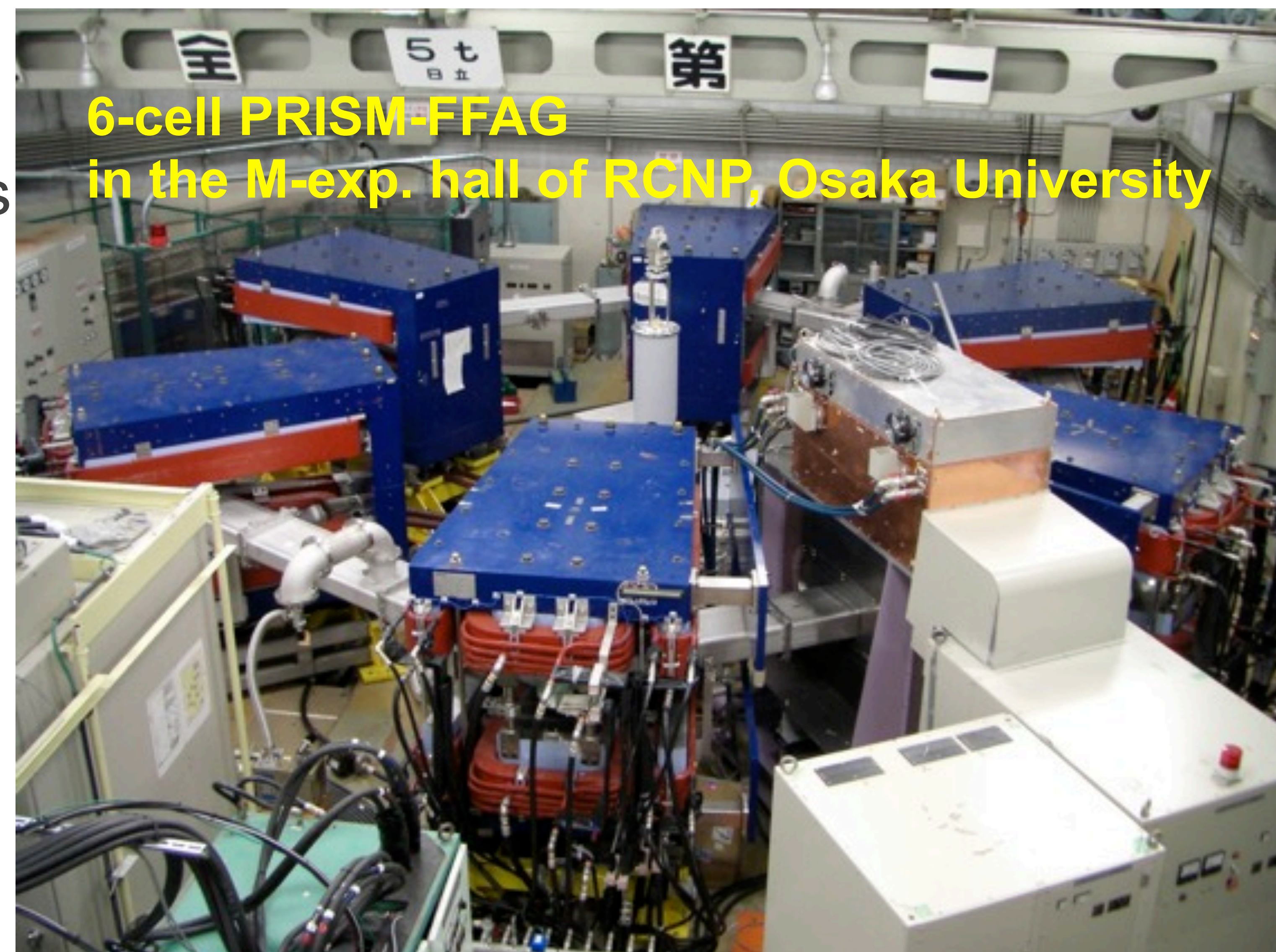
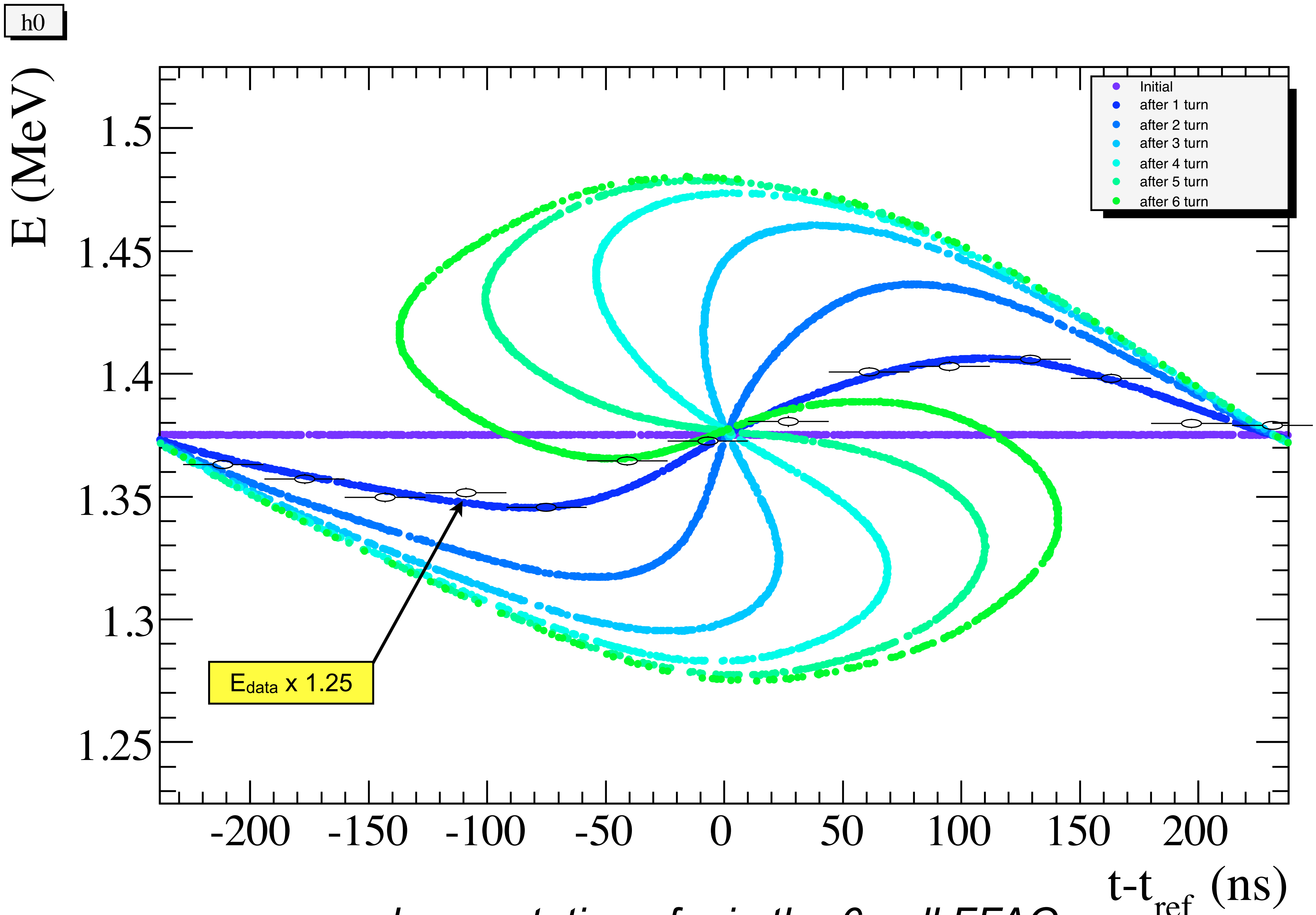
Demo. of Phase Rotation with α-particles

- FFAG-ring
  - PRISM-FFAG Magnet x 6、RF x 1
- Beam : α-particles from radioactive isotopes
  - ^{241}Am 5.48MeV(200MeV/c) → degrade to 100MeV/c
  - small emittance by collimators
  - pulsing by electrostatic kickers
- Detector : Solid state detector
  - energy
  - timing

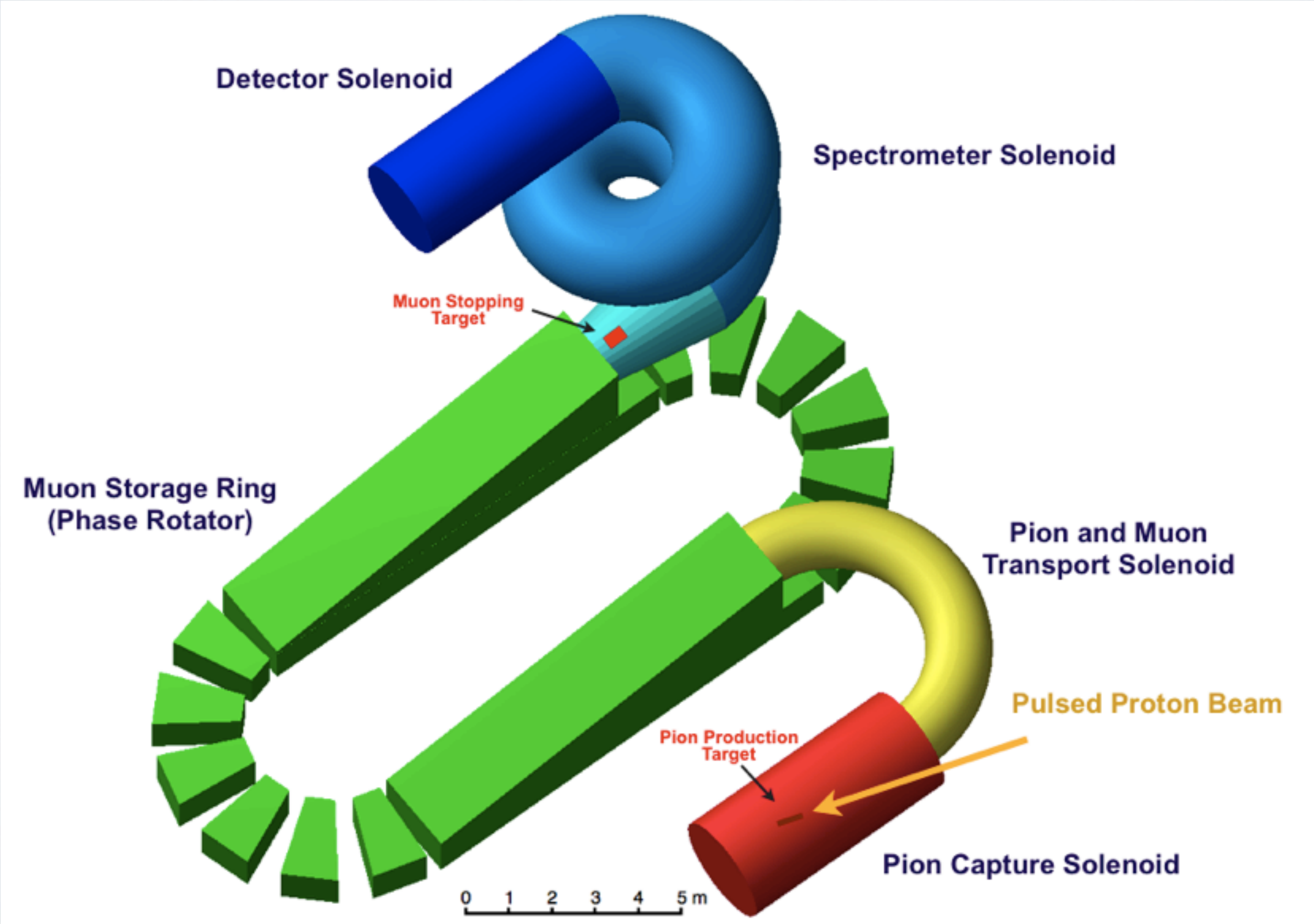


Comparison b/w data and simulation



phase rotation of α in the 6-cell FFAG

SCHEMATIC LAYOUT OF PRISM WITH ADVANCED FFAG



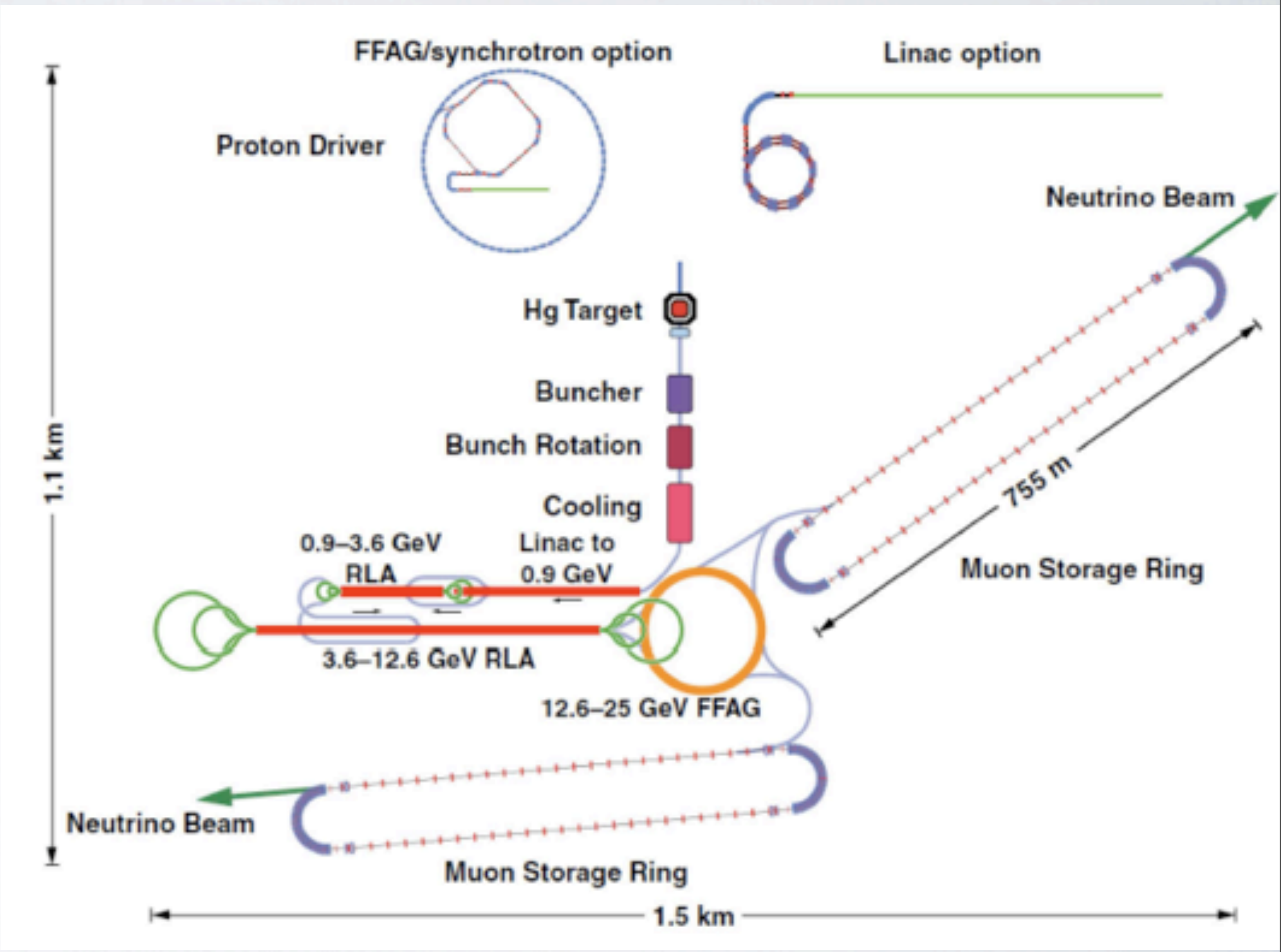
KYOTO UNIVERSITY RESEARCH REACTOR INSTITUTE

T.Planche, JB Lagrange, Y.Mori

- Muon accelerator for Neutrino Factory
- Advanced scaling FFAG for PRISM

MUON ACCELERATOR FOR NEUTRINO FACTORY

- Motivation
- To replace RLA(recirculating linac) to scaling FFAG
  - Cost effective
  - Large acceptance :
    - Transverse >30πmm.rad
    - Longitudinal > 150mm
  - Free from longitudinal emittance degradation caused by TOF dependence of transverse beam emittance



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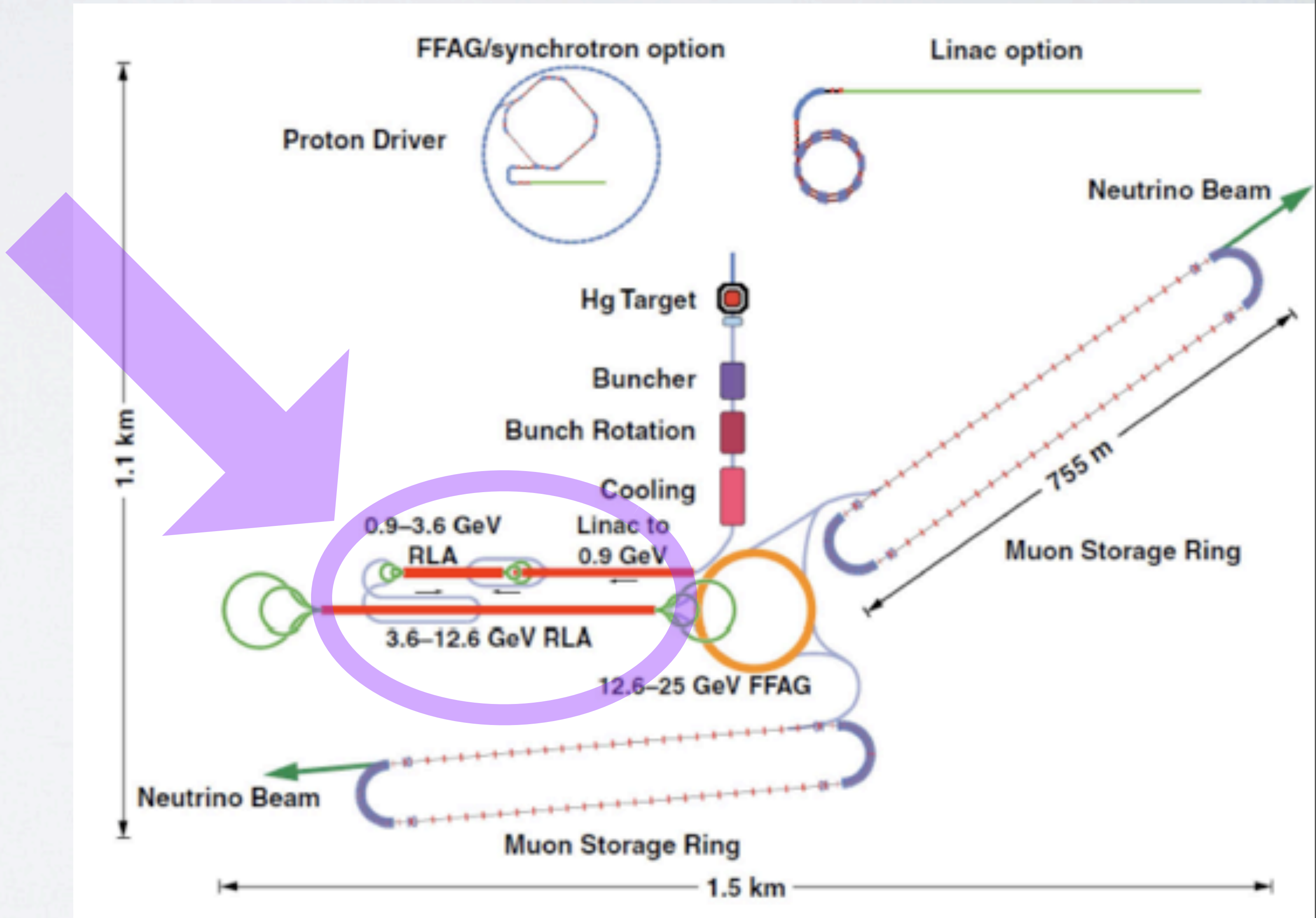


RING PARAMETERS OF A 3.6-12.6GEV MUON RING

Lattice type	FDF triplet
Injection/extraction energy	3.6/12.6 GeV
RF frequency	200 MHz
Number of turns	6
RF peak voltage (per turn)	1.8 GV
Synchronous energy	8.04 GeV
Mean radius	$\sim$160.9 m
B_{max}(@ 12.6 GeV)	3.9 T
Field index k	1390
Total orbit excursion	14.3 cm
Harmonic number h	675
Number of cells	225
Long drift length	$\sim$1.5 m
Horiz. phase adv. per cell	85.86 deg.
Vert. phase adv. per cell	33.81 deg.

Table 1 - Example of 3.6 to 12.6 GeV muon scaling FFAG ring parameters.

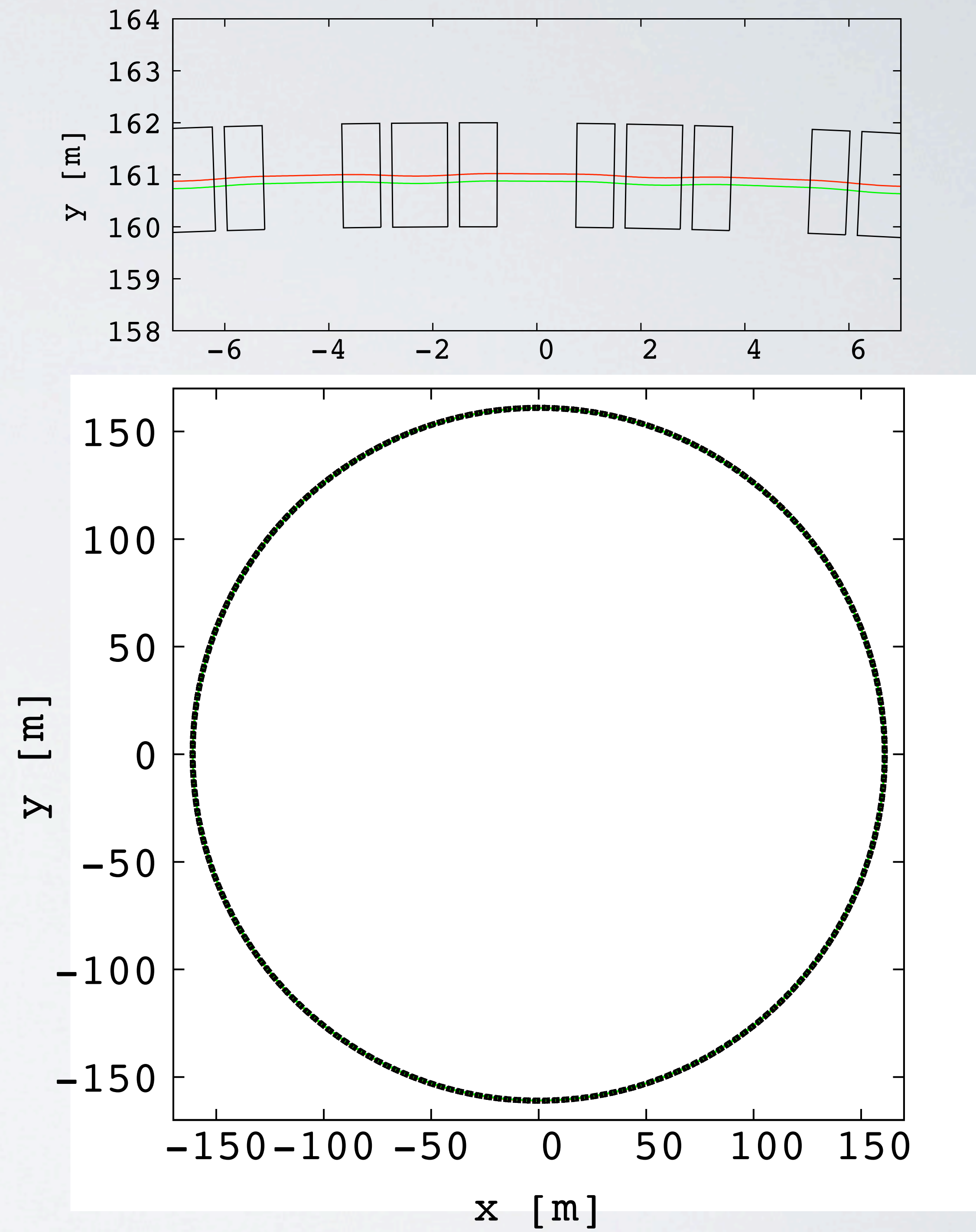
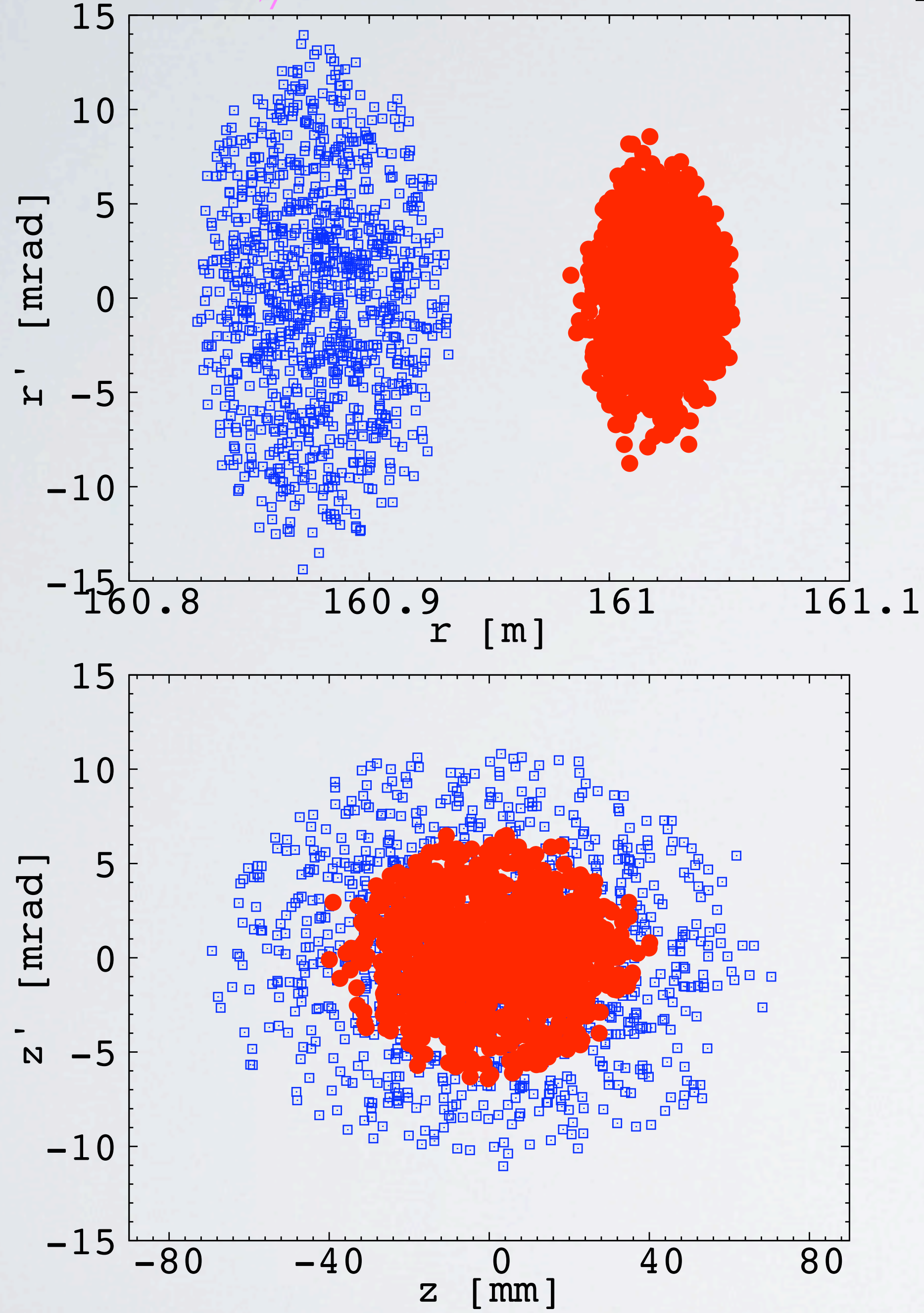


Figure 3 - Ring layout.

FULL ACCELERATION CYCLE - 6D TRACKING

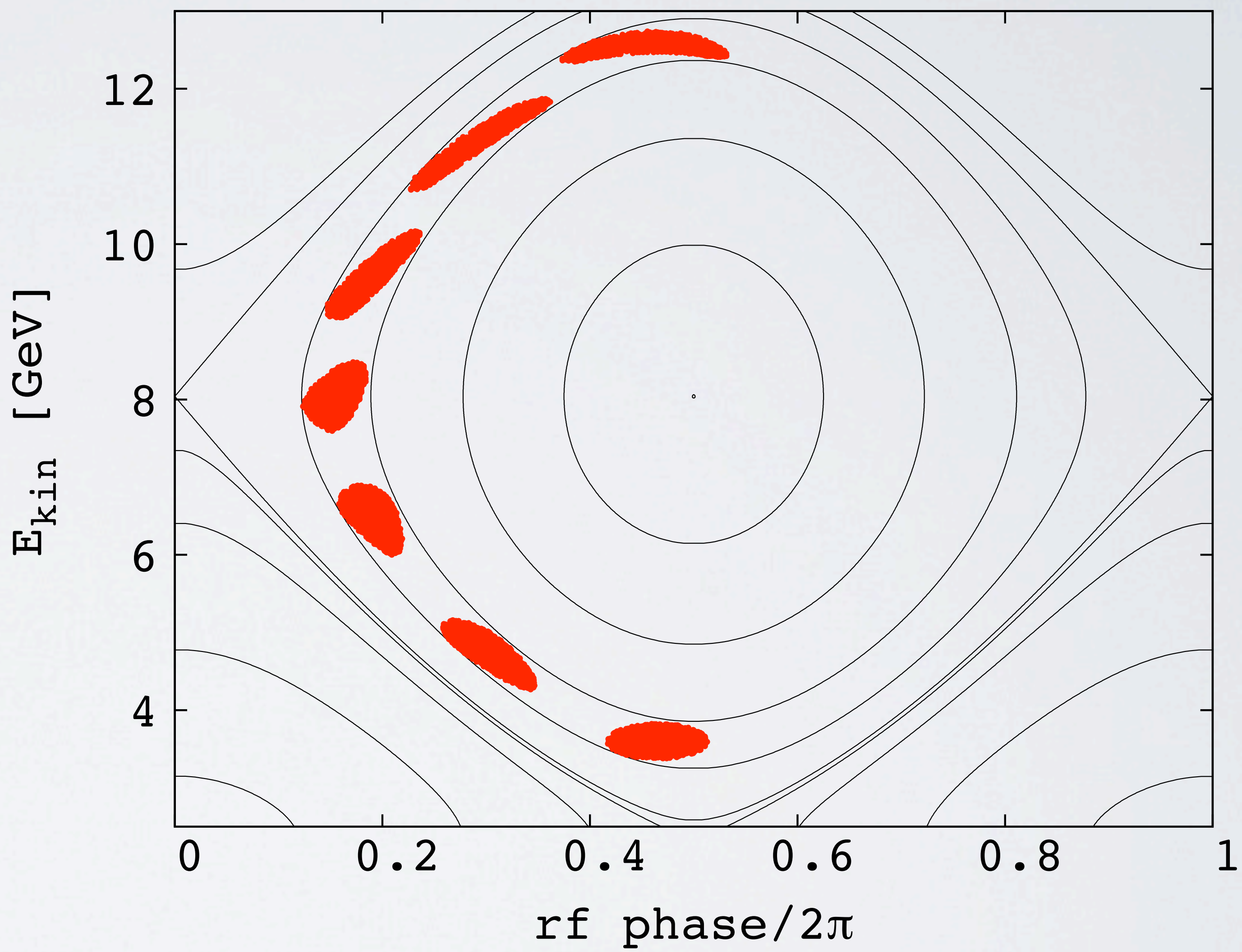
- Tracking results -

$\varepsilon_{x,y}$=30πmm.rad



Initial (blue) and final (red) particles distribution in the horizontal (top), and vertical (bottom) phase space.

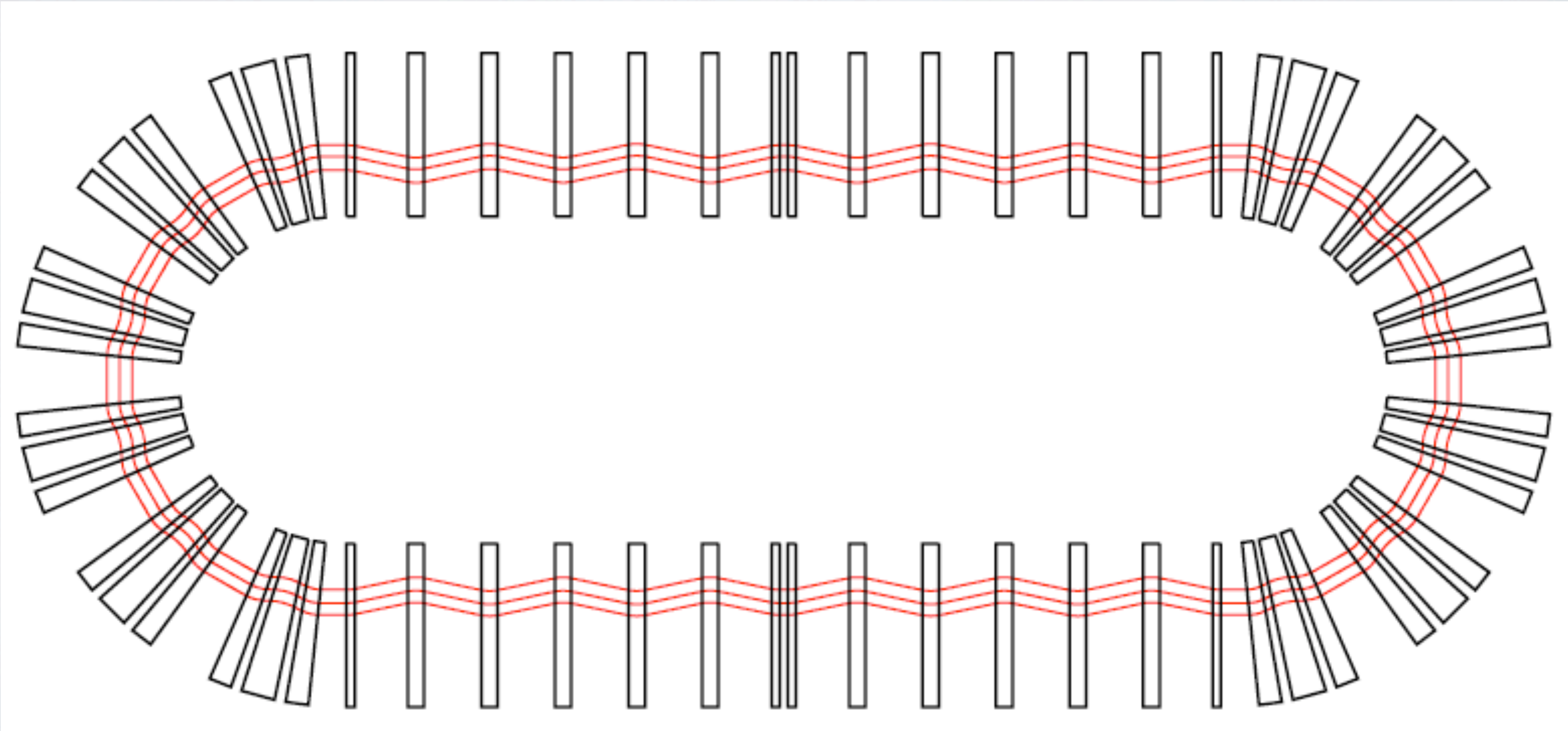
ε_z=150mm



Longitudinal phase space plot showing a 6-turn acceleration cycle. Hamiltonian contours are superimposed.

NEW PRISM RING WITH ADVANCED SCALING FFAG

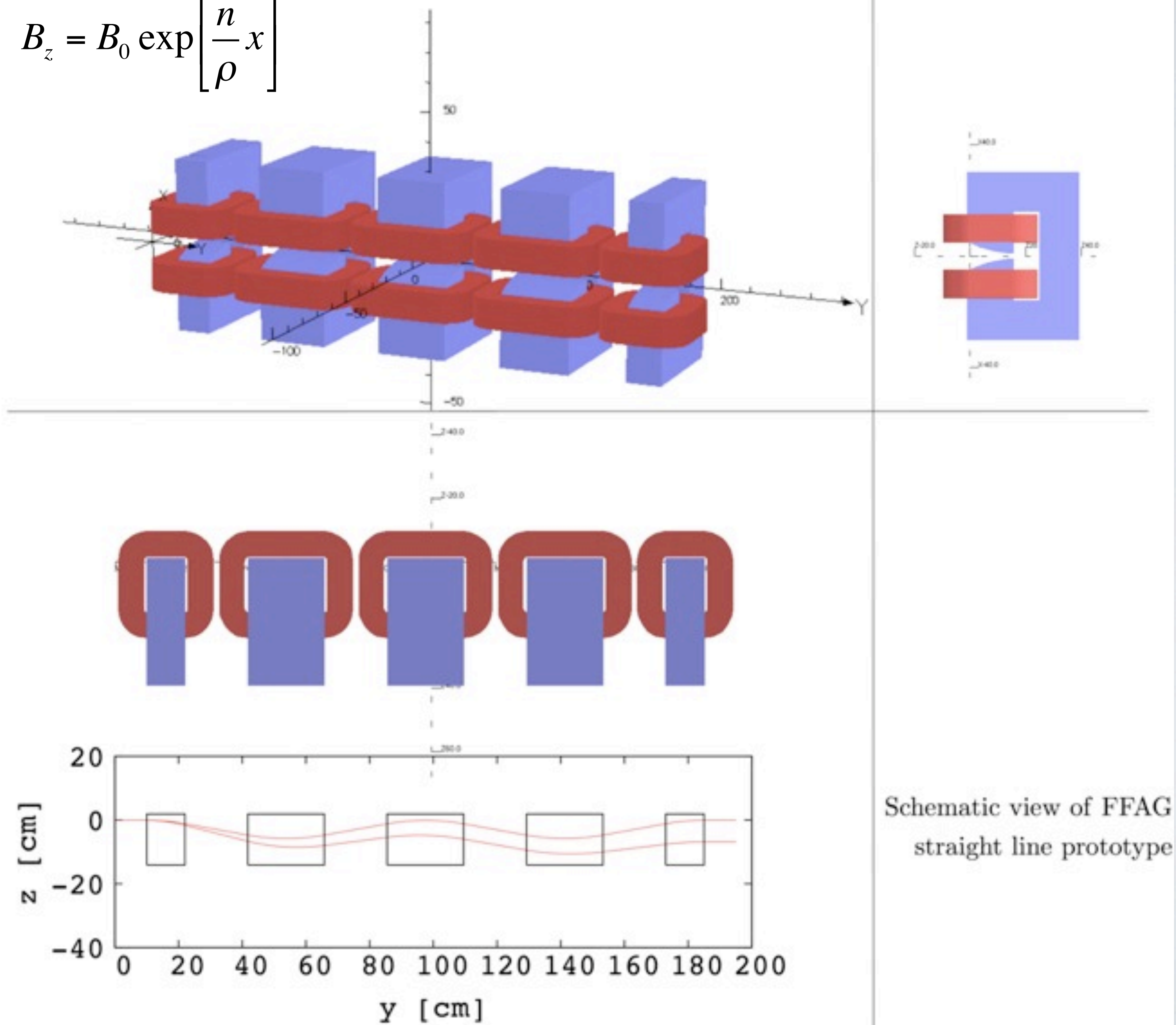
- Race-track ring for beam injection/extraction and rf cavity



EXPERIMENT OF SCALING FFAG STRAIGHT LINE

- Clarify the FFAG straight line experimentally with π-section
  - Dispersion suppressor
  - Insertion matching
- Momentum range
  - 0.0811 - 0.1441 GeV/c
  - H- ion beam

$$B_z = B_0 \exp\left[\frac{n}{\rho}x\right]$$



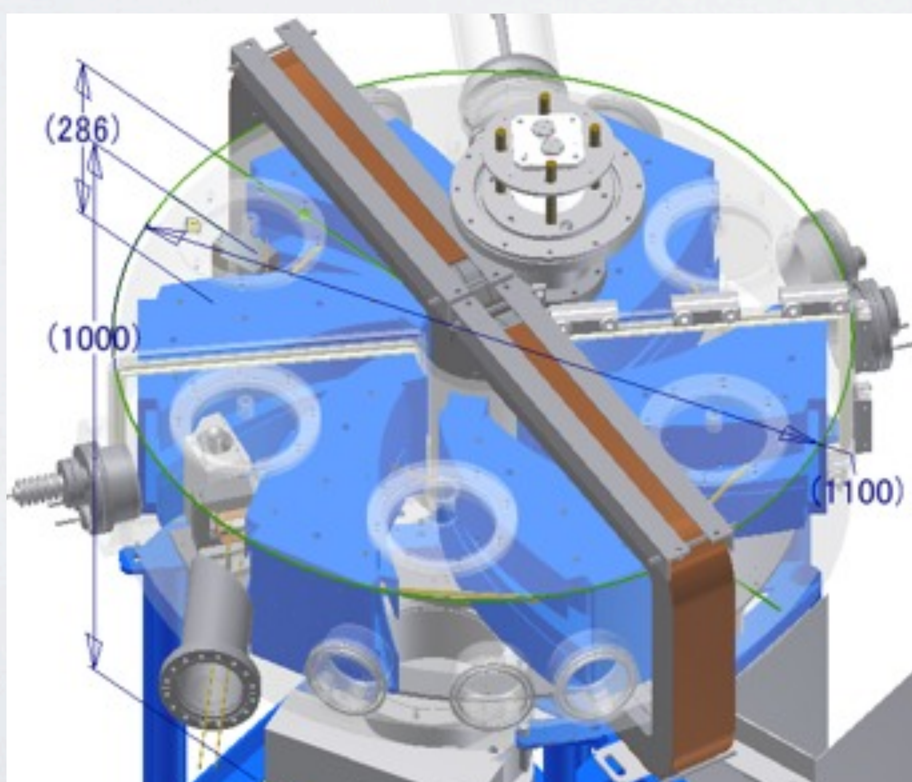
Schematic view of FFAG straight line prototype

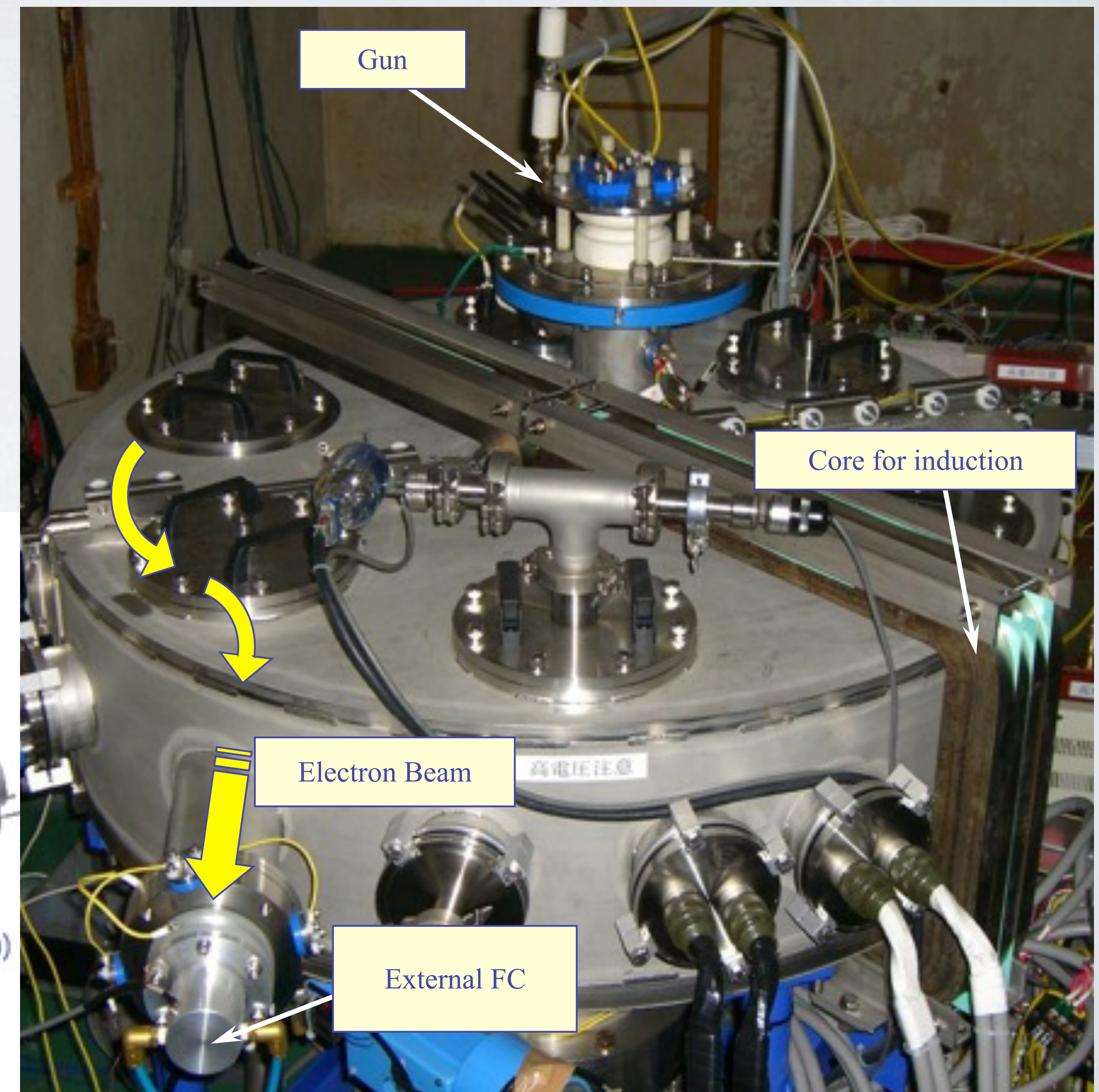
NHV CO.

T.Baba, M.Yuasa

Prototype of FFAG Electron Accelerator: sterilization etc.

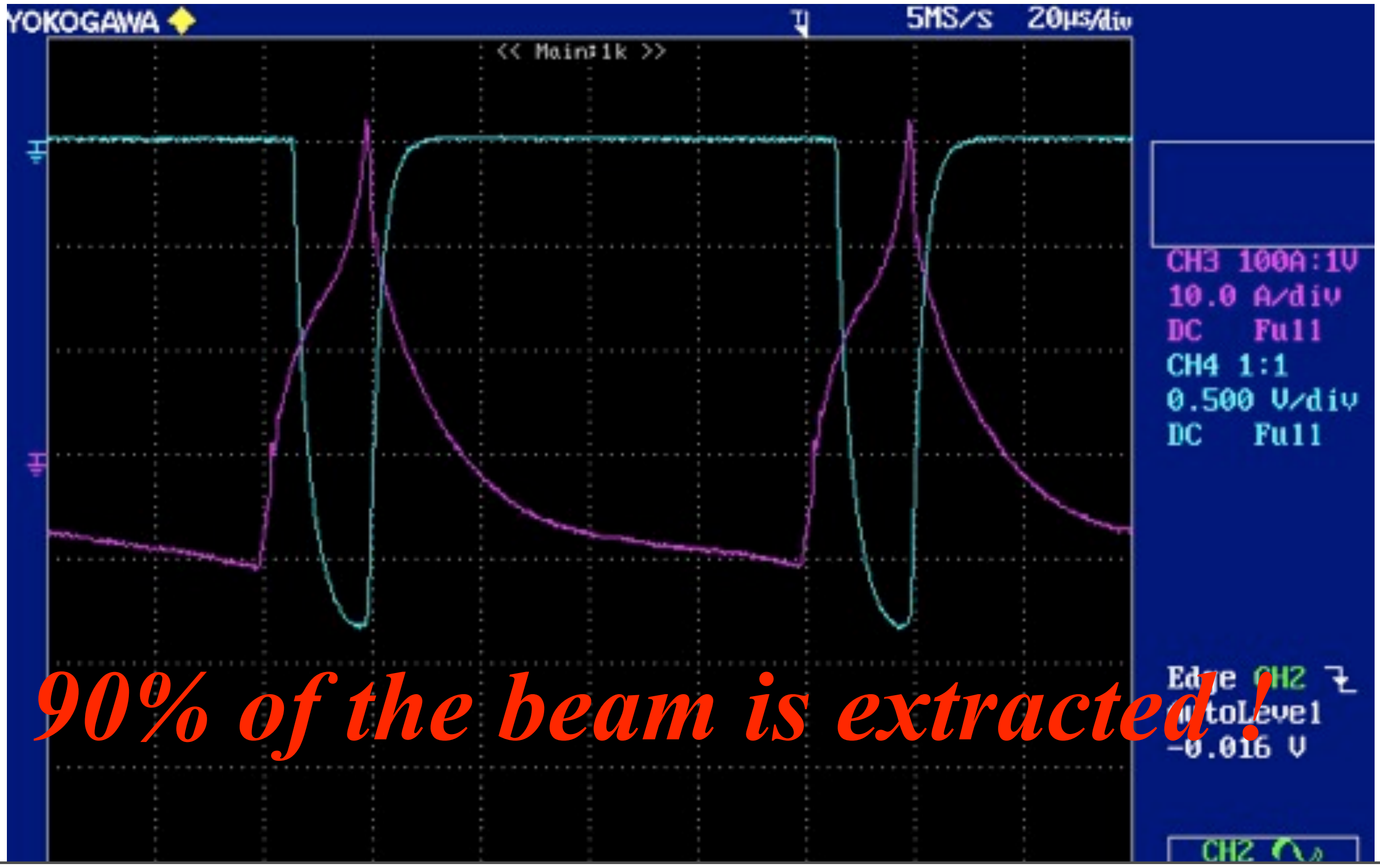
Energy Inj. / Ext.	50 / 500keV
Orbit radius Inj. / Ext.	0.19 / 0.44m
Acceleration frequency	10kHz
Beam Current	100mA peak
Duty	20%
Outer diameter	1.1m





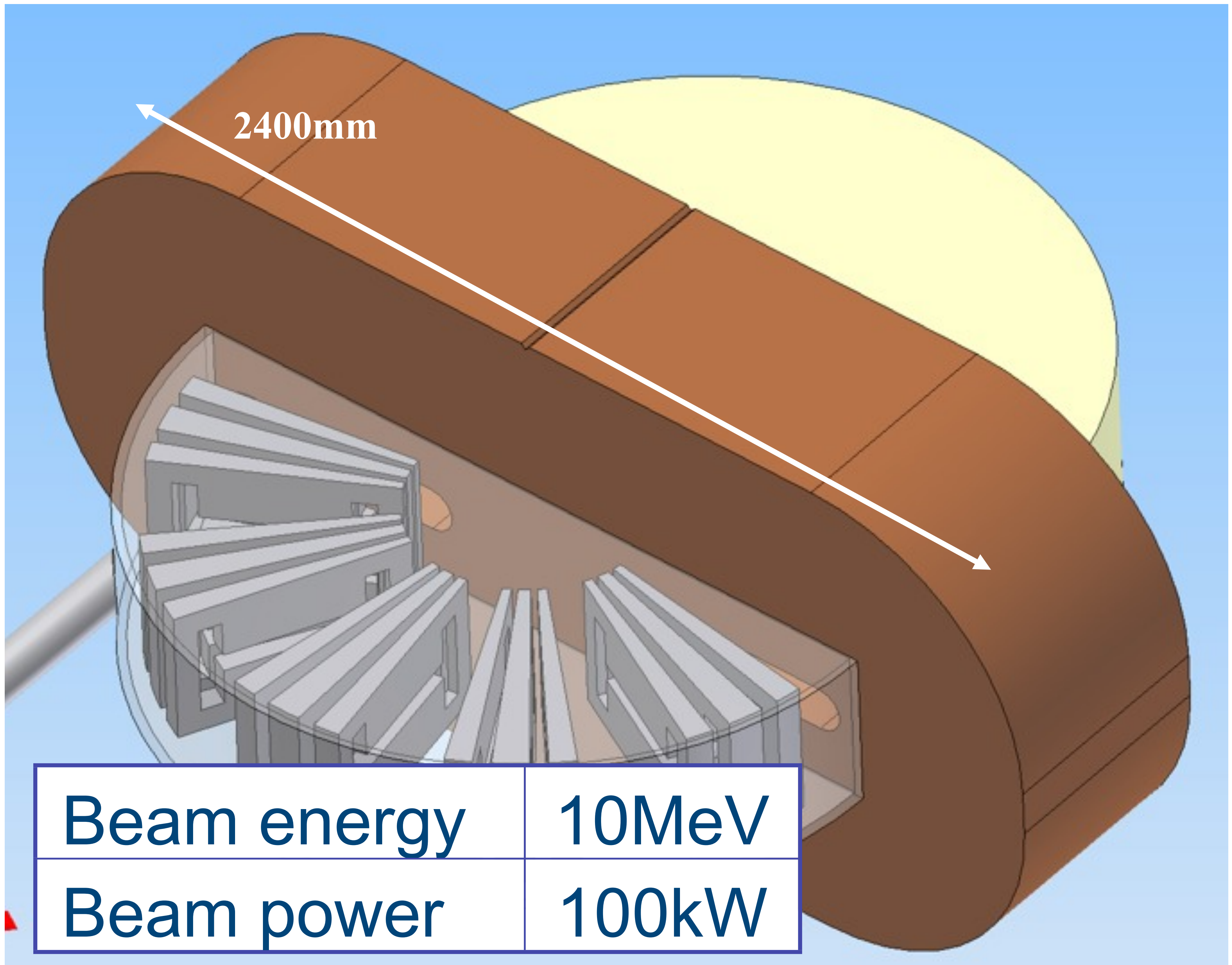
Results of the Development

- Accelerator assembling is completed.
- Beam injection and acceleration are successful.
- 90% of the beam is extracted form FFAG ring.
- Extracted beam energy is measured as same as the specified energy.



NHV Corporation

10MeV Electron Accelerator



Beam energy	10MeV
Beam power	100kW

NHV Corporation

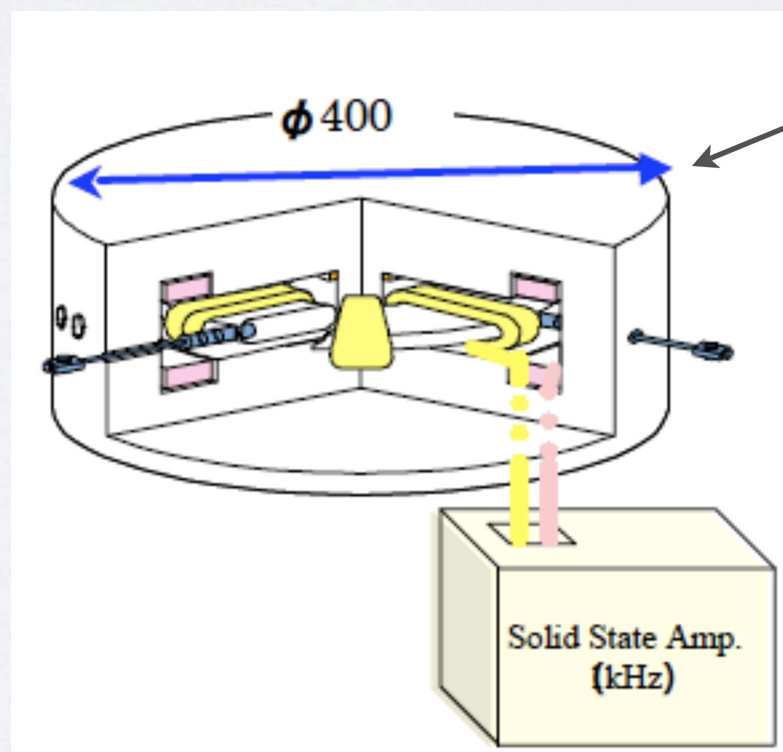
MITSUBISHI ELECTRIC CO.

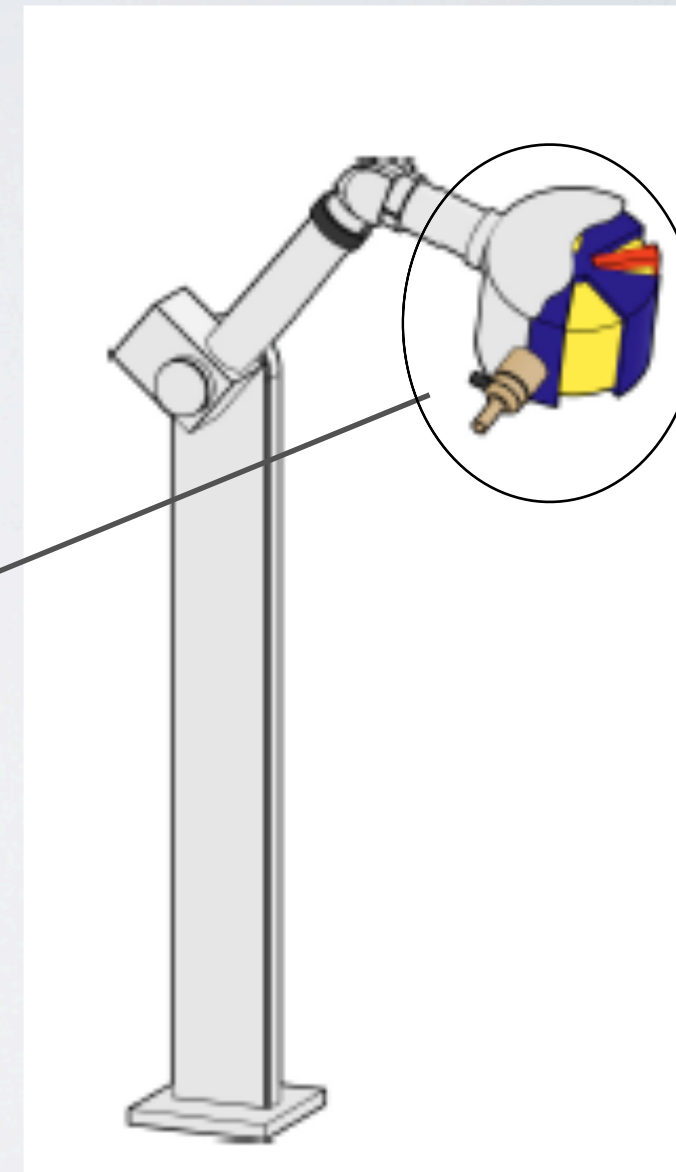
F.Tanaka-CYCLOTRON 2004

- LAPTOP Electron accelerator
  - FFAG(injection/extraction)+Betatron(acceleration)

Proto-type Machine

Injection Energy	50 [keV]
Acceleration Energy	6 [MeV]
Injection Radius	0.1 [m]
Extraction Radius	0.125[m]
K value	2～3
Magnet	Spiral Sector Magnet
Repetition	1 [kHz]
Duty	2 [%]
Energy after injection	50～250[keV]





FFAGS FOR HADRON BEAM ACCELERATION IN JAPAN

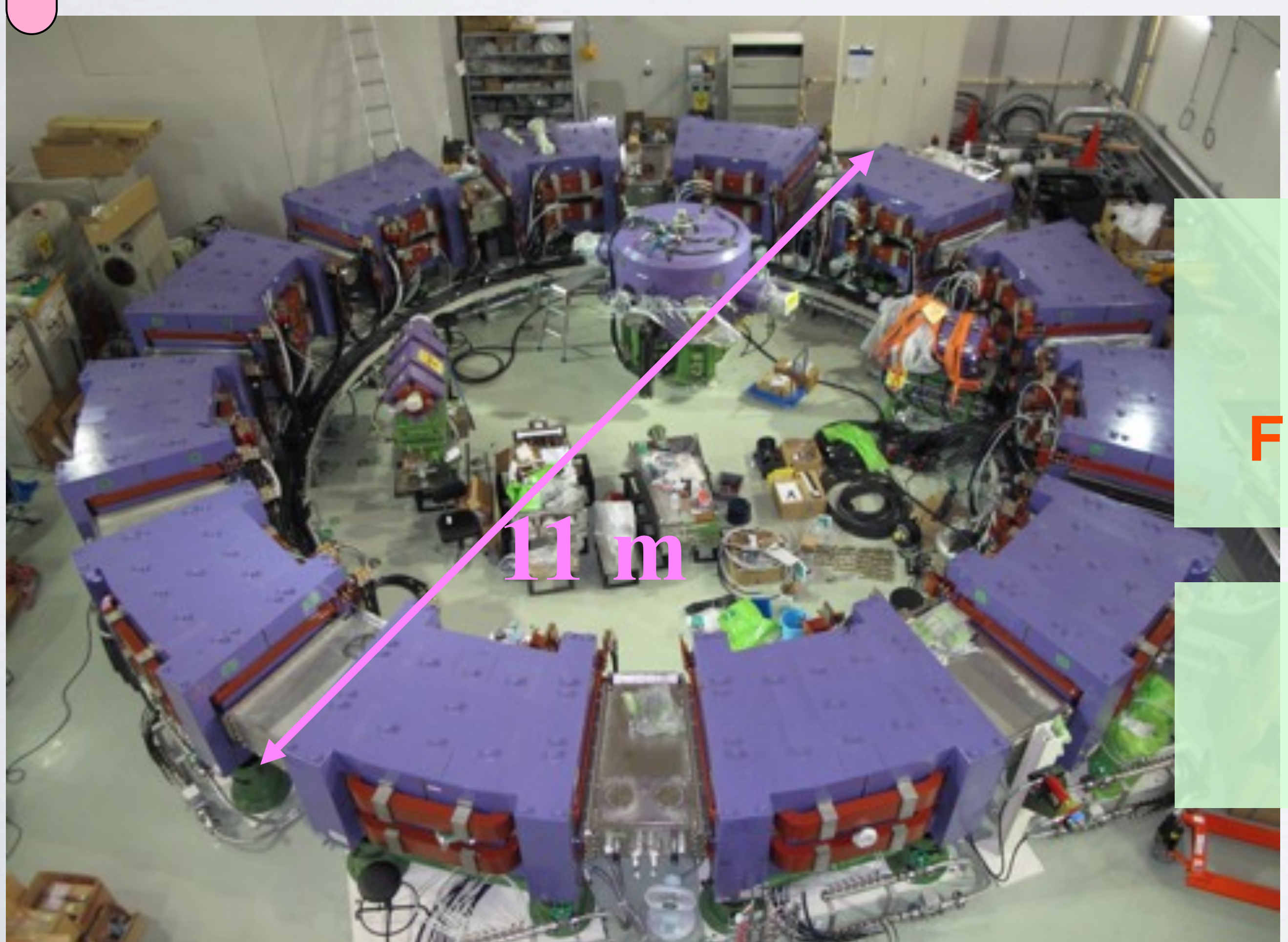
- Proton & Ions
  - Kyusyu University
  - Kyoto University

KYUSYU UNIVERSITY

Construction of new accelerator center

Main accelerator : FFAG Synchrotron

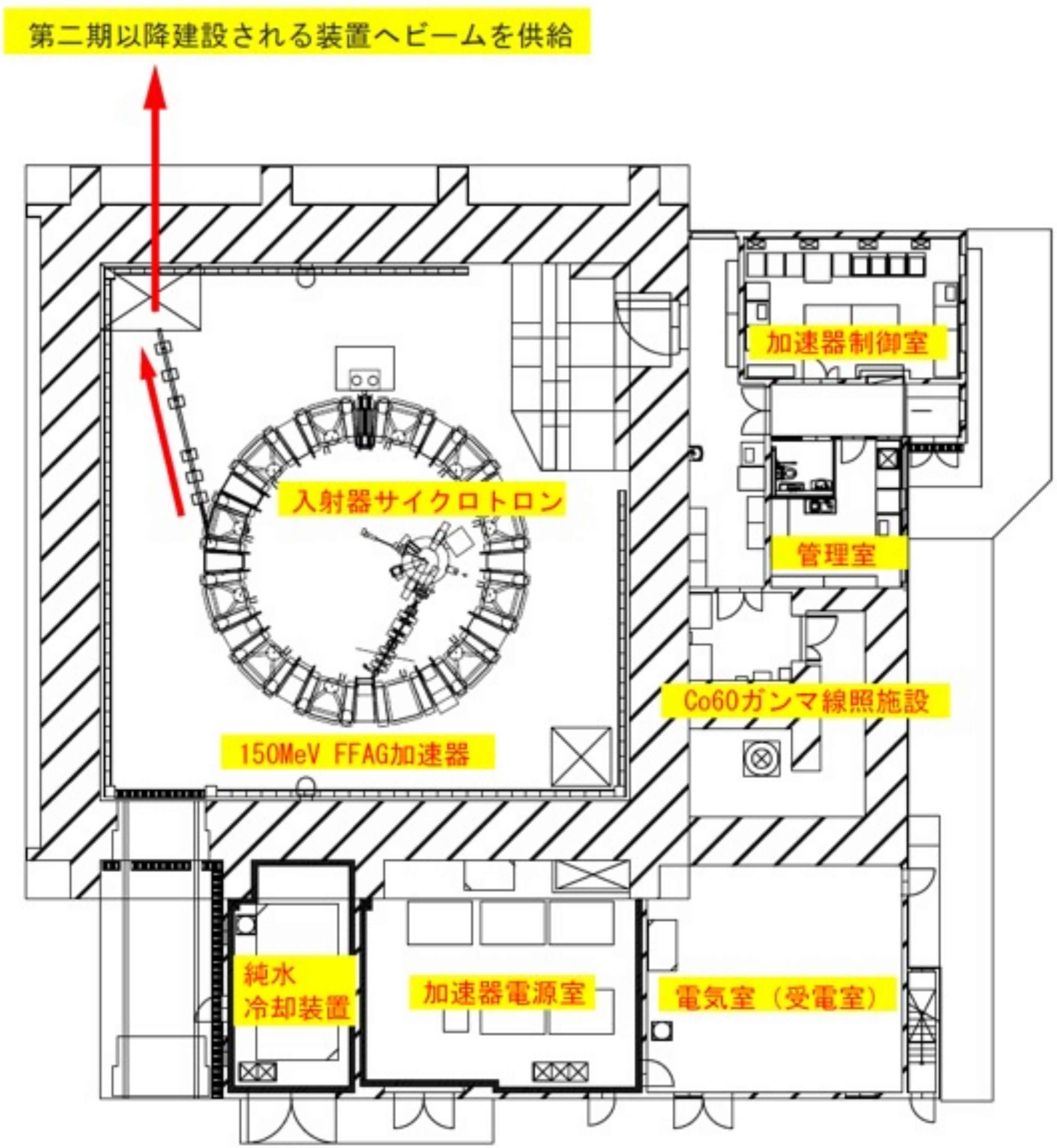
The test machine that Mori's group developed is under re-installation.



Newly constructed machine
still under development
Further development at Kyushu

A machine with
various possibilities
Challenges for new usage

Design values of the FFAG Synchrotron

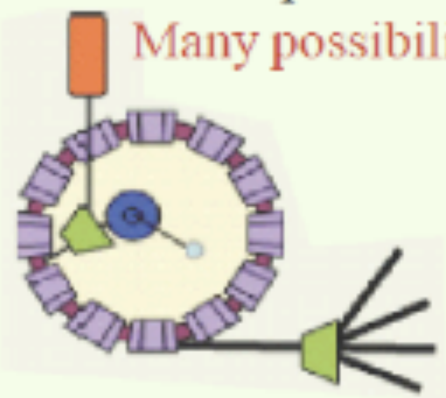


magnet	Radial sector type (DFD-triplet)
Cell	12
K-value	7.62
Beam energy	12 ⇒150 MeV (10 ⇒ 125 MeV)
Radius	4.47 ⇒ 5.20 m
Betatron tune	H: 3.69〜3.80 V: 1.14〜1.30
Max. field	F-field: 1.63 T
(along orbit)	D-field: 0.78 T
Circ. freq.	1.55〜4.56 MHz
Repetition	100 Hz

Various field studied with FFAG

FFAG development — Accelerator science

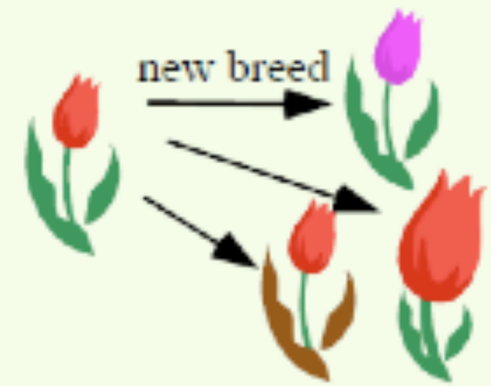
Under-developed machine just born.



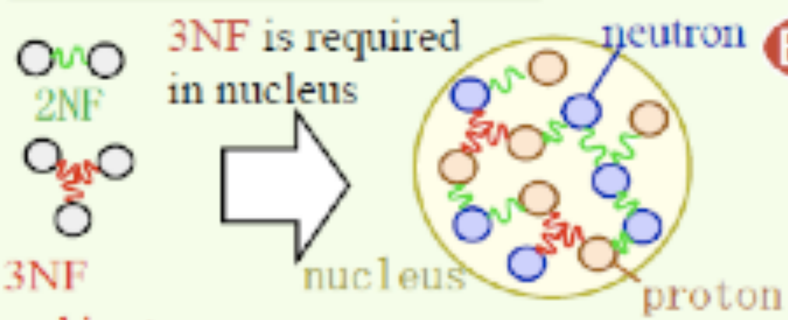
Many possibilities no other machines have.

- Flexible beam time-structure
- Large acceptance, multi-beam
- possibility as a beam delayer
- Acceleration of various beams
- High intensity by fast repetition

DNA processing, breed improvement — Life science, Environment science



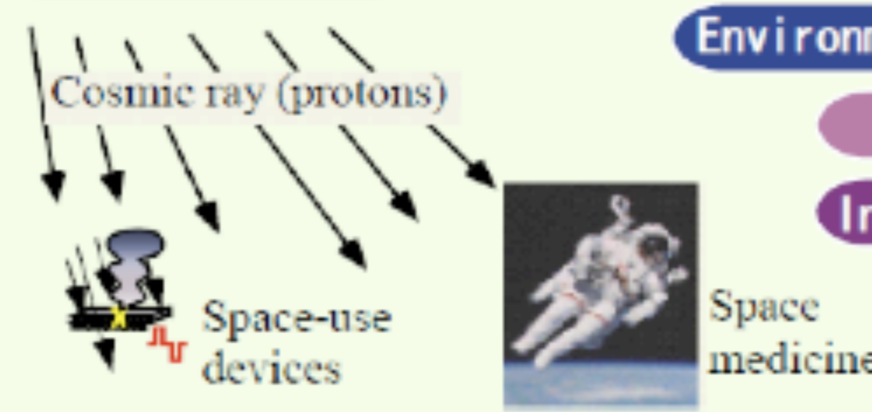
3-body force, nuclear data — Hadron science, Energy science



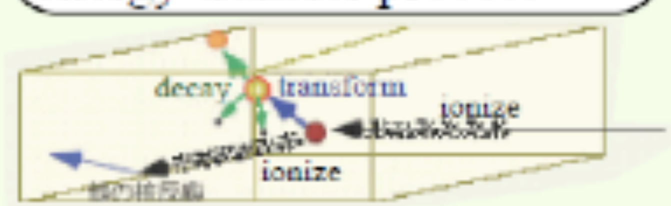
3NF working to 3 nucleons simultaneously

1936:Yukawa predicted 2NF
1994:Sagara found exp. evideence of 3NF

Space simulation — Life science, Environment science, Fronteer, Industry use



biological irradiation effect energy-transfer process — Energy science, Life science, Material science, Medical use (basic)



30% of incident energy are converted to other radiation

→ High quality radiation treatment
→ Radiation damage process of semiconductor devices

Monochro./white neutron field — Hadron science, Material science, Environment science, Industry use

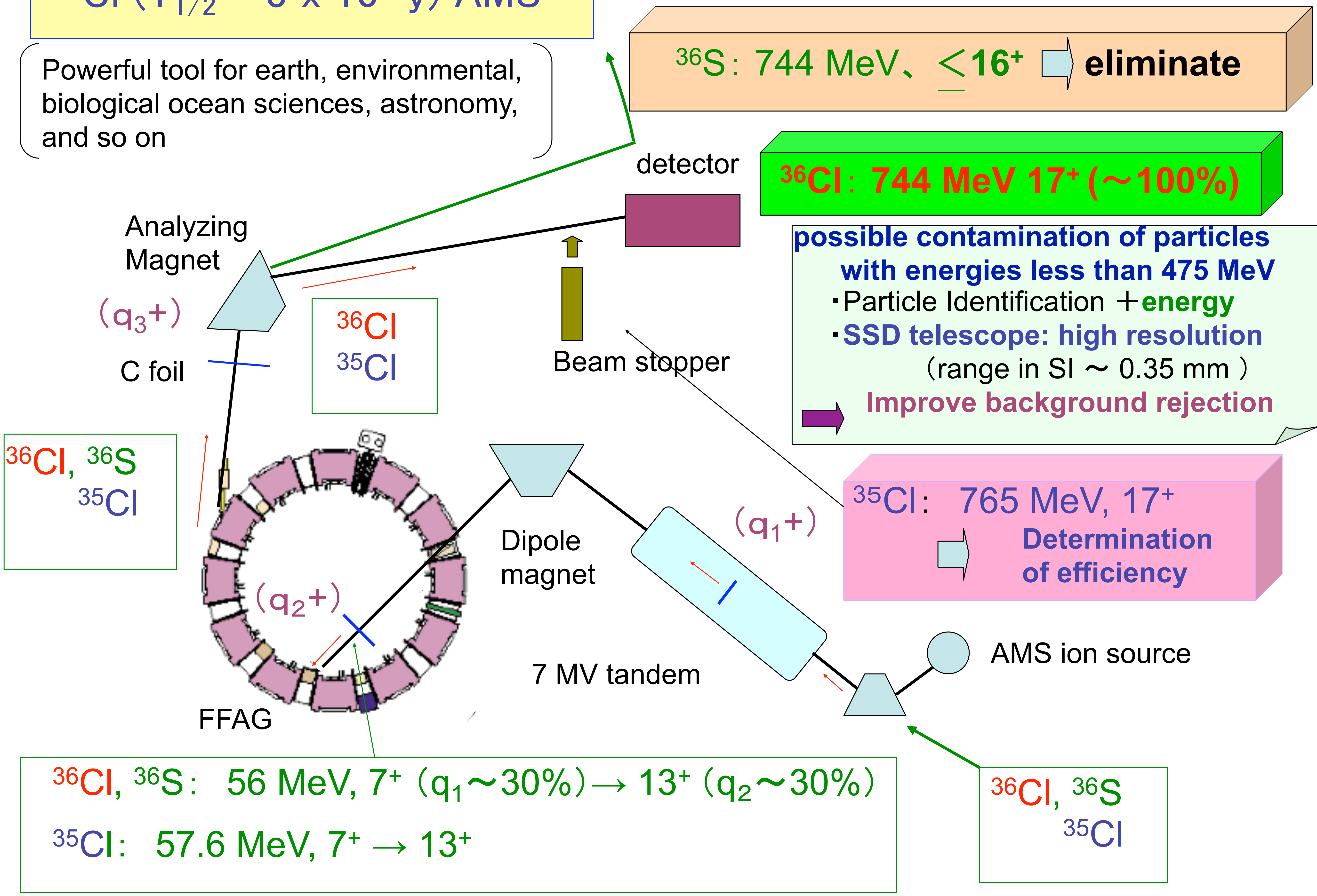
Reactor material
Calibration of neutron detectors
Bacic data for acc. driven reactor / nuclear waste

? ? ? — ? ? ? science

New field

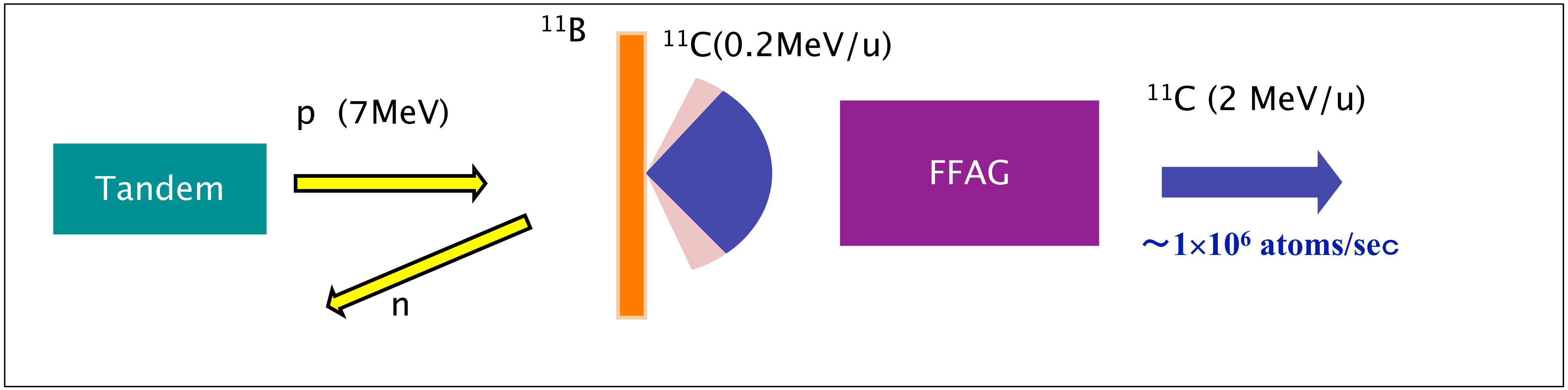
^{36}Cl ($T_{1/2}$ = 3 x 10^5 y) AMS

Powerful tool for earth, environmental, biological ocean sciences, astronomy, and so on



Acceleration of unstable nuclei and isomers

***Acceleration of unstable nuclei**



***Acceleration of isomers**

^{16}O + ^{39}K → ^{52m}Fe + p,n,n
(40MeV) (10MeV)
⇒ (100MeV)

^{18}O + ^{9}Be → ^{24m}Ne + p,n,n
(35MeV) (20MeV)
⇒ (200MeV)

Advantage:
- High quality unstable beam for all elements

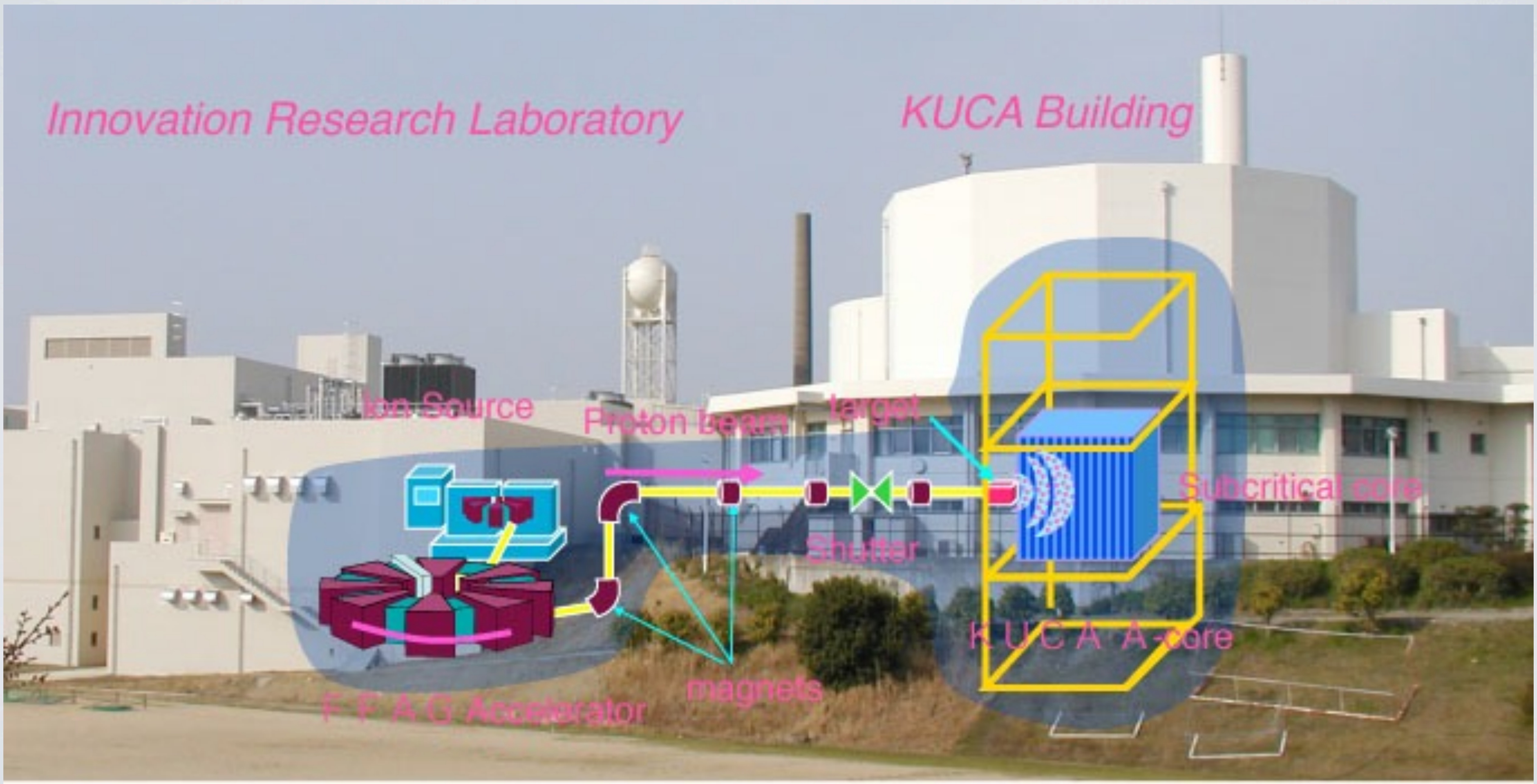
Subjects
- Structure of high-spin isomer, Astro-nuclear data
- Diffusion process in material

Requirement to accelerator
- Large acceptance (longitudinal and transverse)

KYOTO UNIVERSITY RESEARCH REACTOR INSTITUTE (KURRI) FFAG-ADSR PROJECT

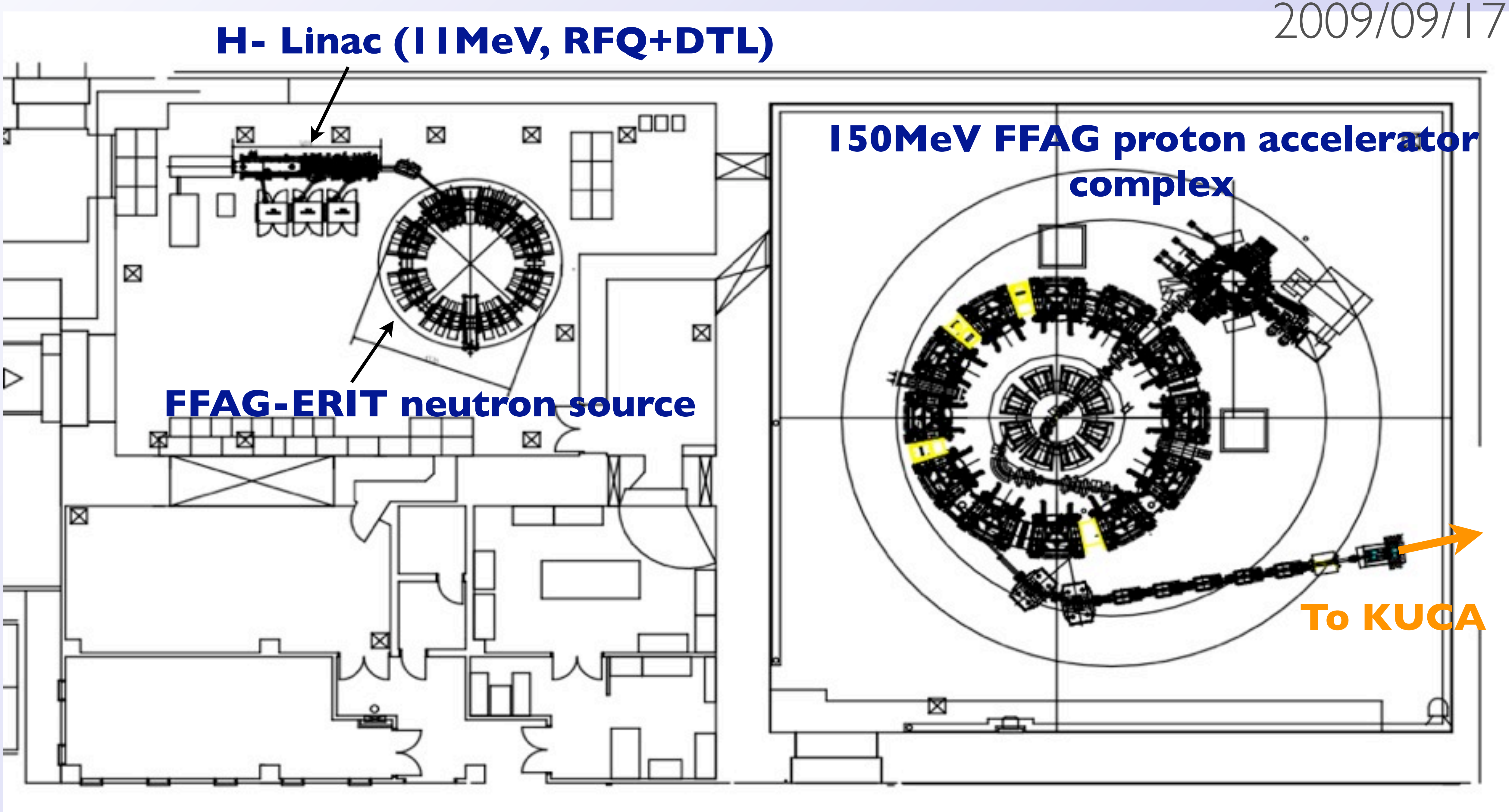
- Purpose of the project
  - Basic study of ADSR(Accelerator Driven Sub-critical Reactor) with FFAG accelerator and KUCA(Kyoto University Critical Assembly)
- KUCA
  - Output power ~100W
  - Neutron amplification : $\alpha=1/(1-k_{eff})$. If $k_{eff}=0.99$, $\alpha=100$
  - Beam power should not exceed < 1W!!
  - Beam power is also limited by radiation safety because the beam passes only 1m away from office.
    - cf. For 100MeV proton beam, I<10nA
- FFAG Accelerator Complex
  - Beam energy 100-150MeV (variable)
  - Beam current 1nA

FFAG-KUCA ADSR PROJECT AT KURRI

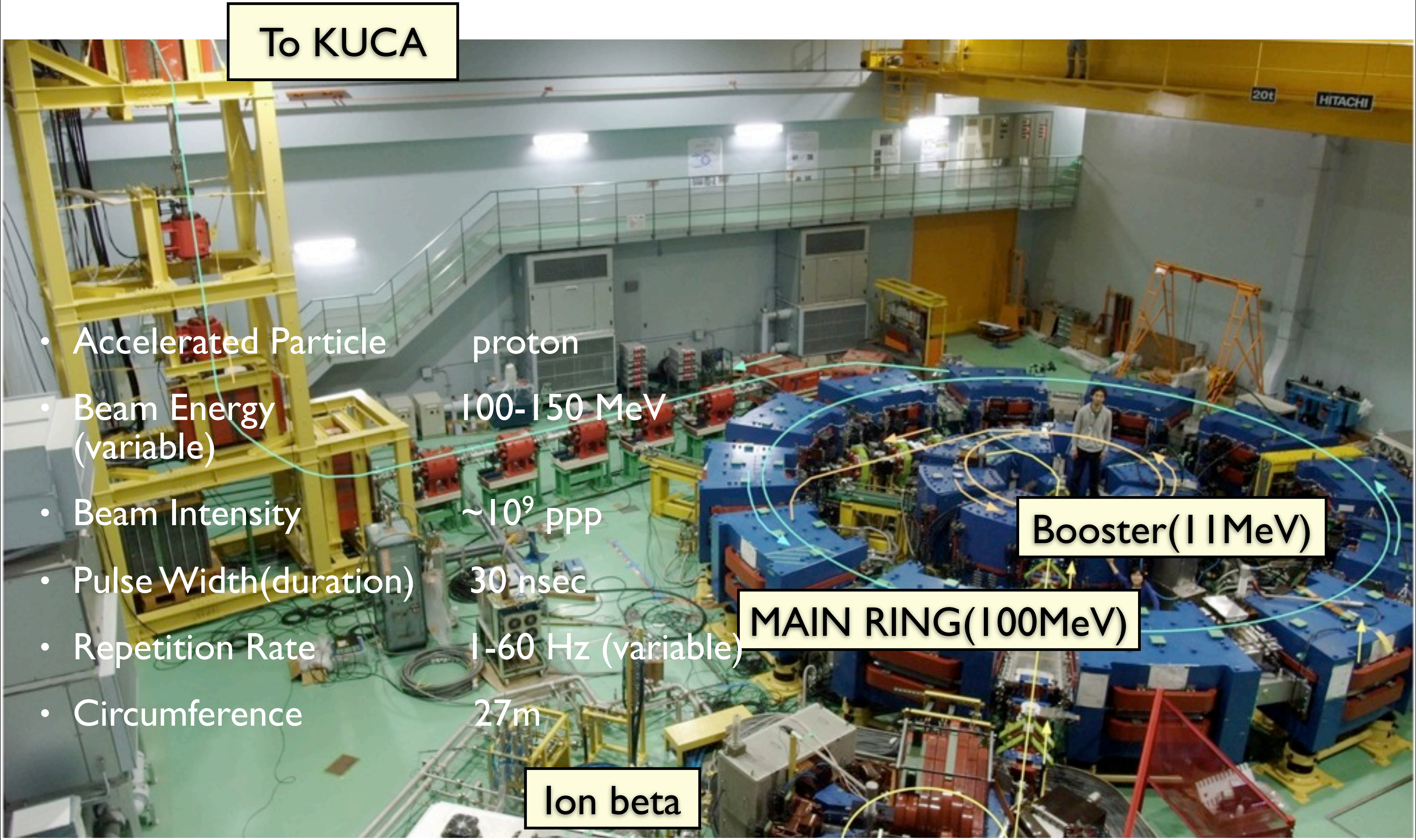


Layout of FFAG Accelerators in Innovation Laboratory

2009/09/17



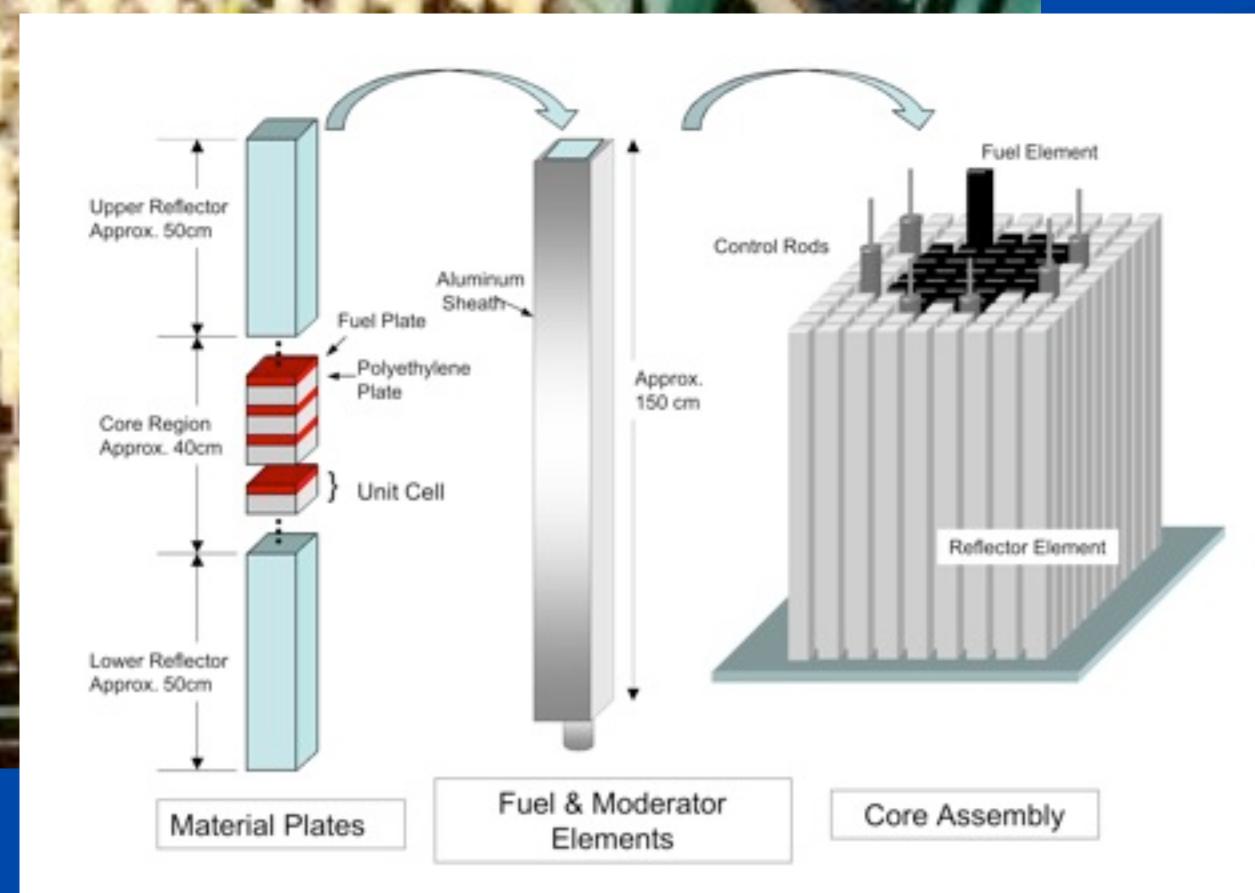
FFAG accelerator complex



- Accelerated Particle: proton
- Beam Energy (variable): 100-150 MeV
- Beam Intensity: ~10^9 ppp
- Pulse Width(duration): 30 nsec
- Repetition Rate: 1-60 Hz (variable)
- Circumference: 27m

KUCA-A Core - solid moderated and reflected -

- Items of ADSR experimental study
  - High energy neutron spectrum
  - Reactivity distribution, neutron distribution and proton profile at the reactor core
  - Reactor response for abrupt changes in reactivity: beam trip, negative reactivity introduction, etc.
  - Sub-criticality measurement with pulsed neutron method
  - Dynamical behaviors with Feynman-α method



ADSR EXPERIMENT

WORLD FIRST ADSR EXPERIMENT WITH SPALLATION NEUTRONS

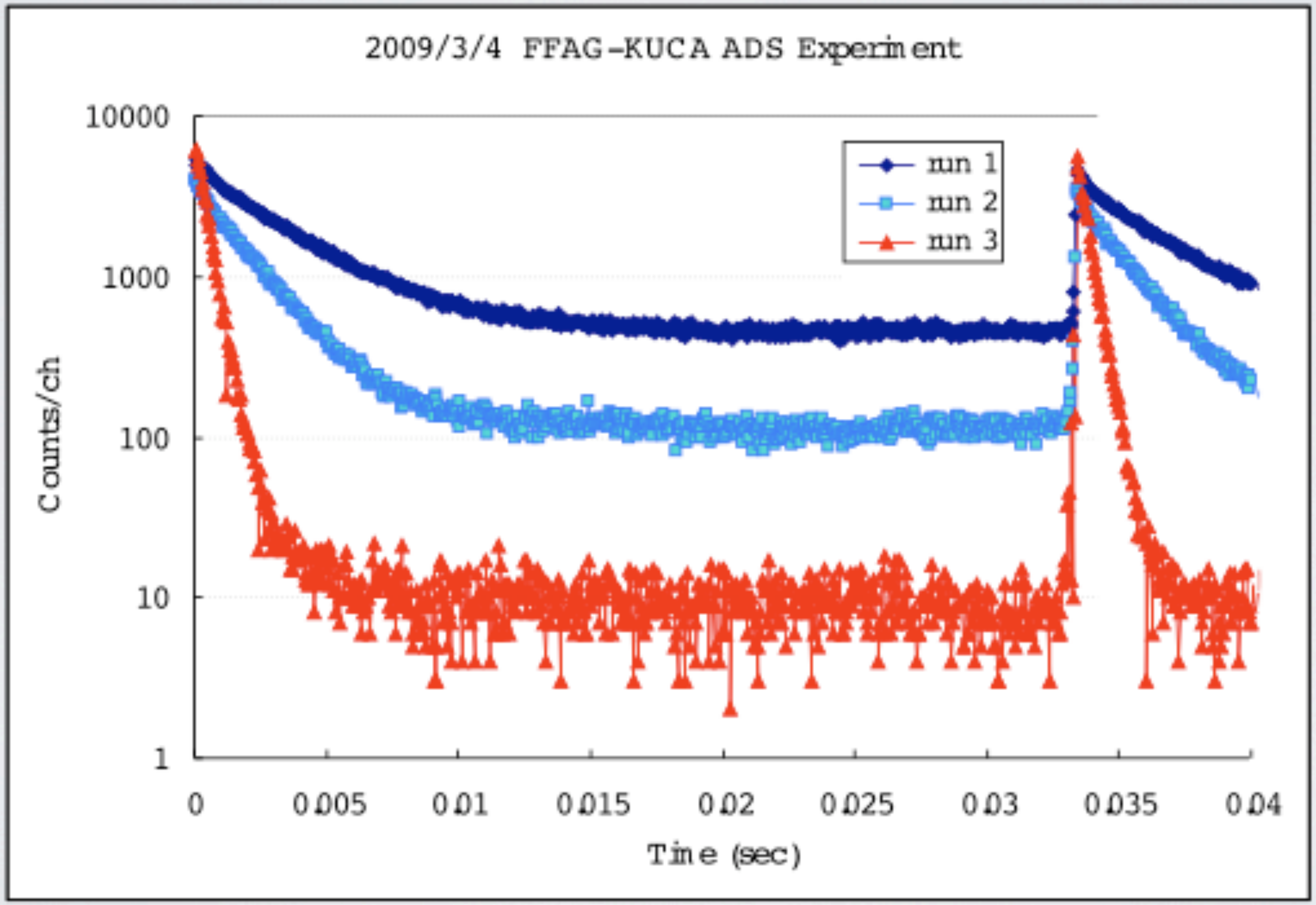
-THE FIRST FFAG USED FOR APPLICATION-

- *March 4, 2009: The first beam from FFAG was successfully delivered to KUCA.*

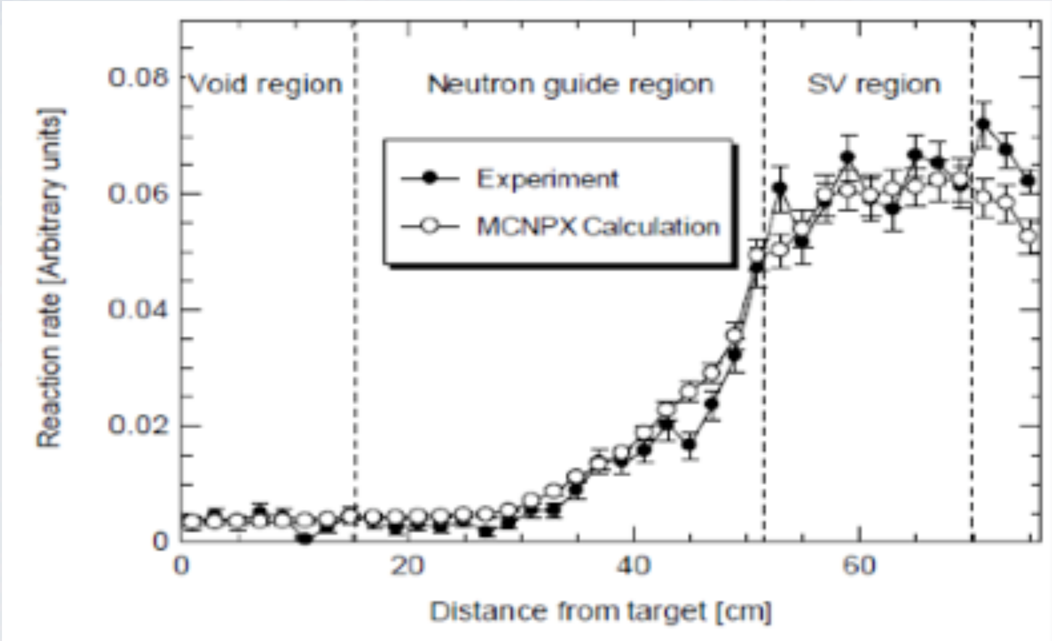
FIRST DATA

Journal of Nuclear Science and Technology, Vol.46 No.12, pp.1091-1093(2009).

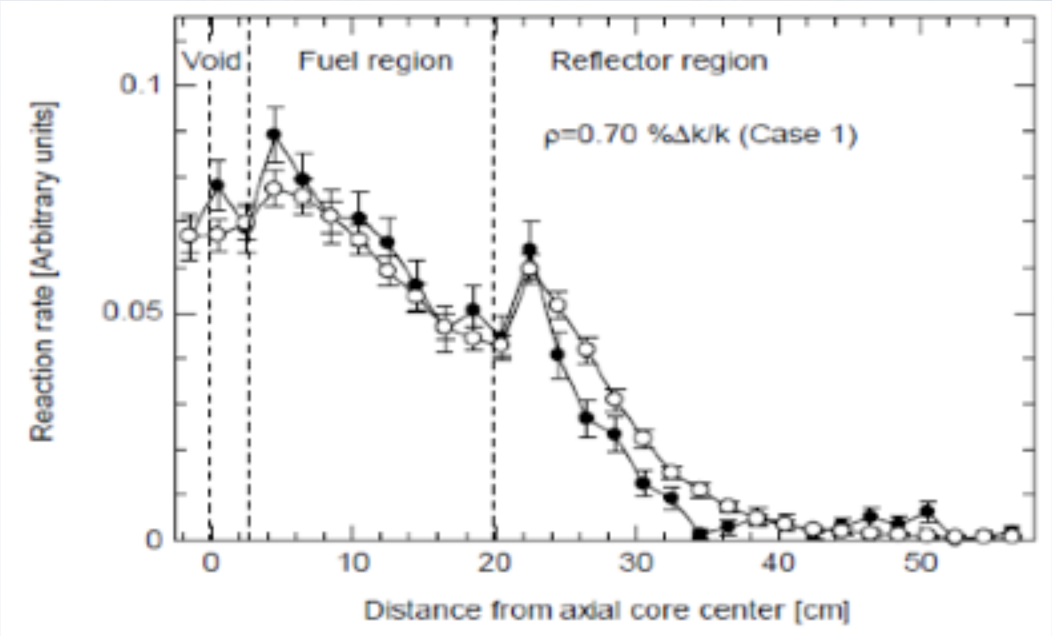
- Measurement of neutron multiplication



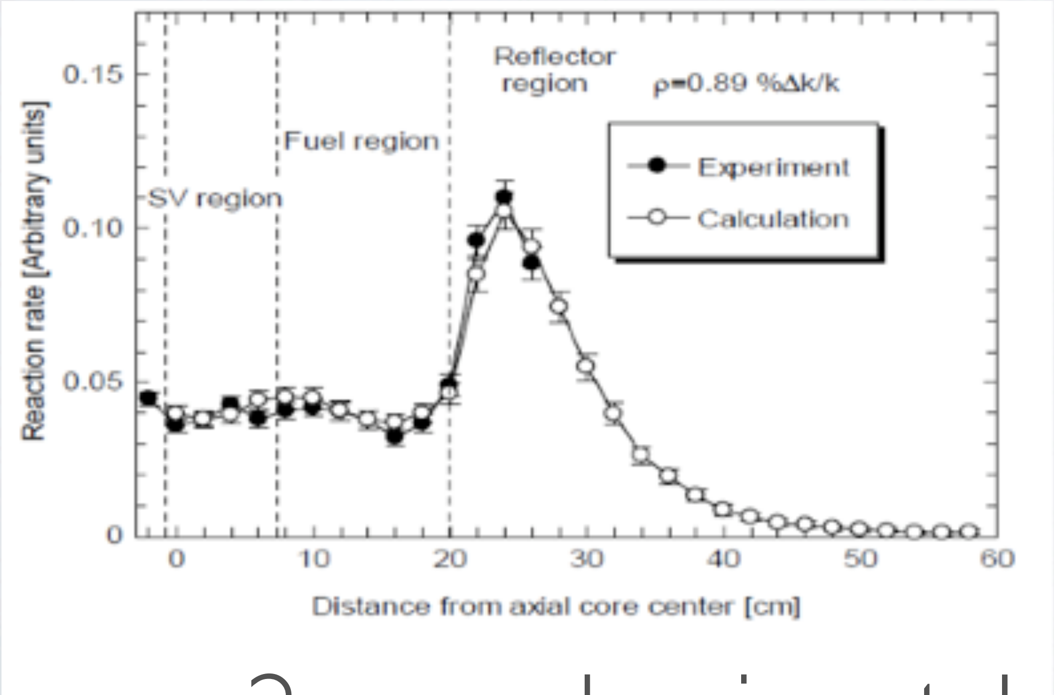
REACTIVITY DISTRIBUTION



core1: beam duct



core1: core-axial

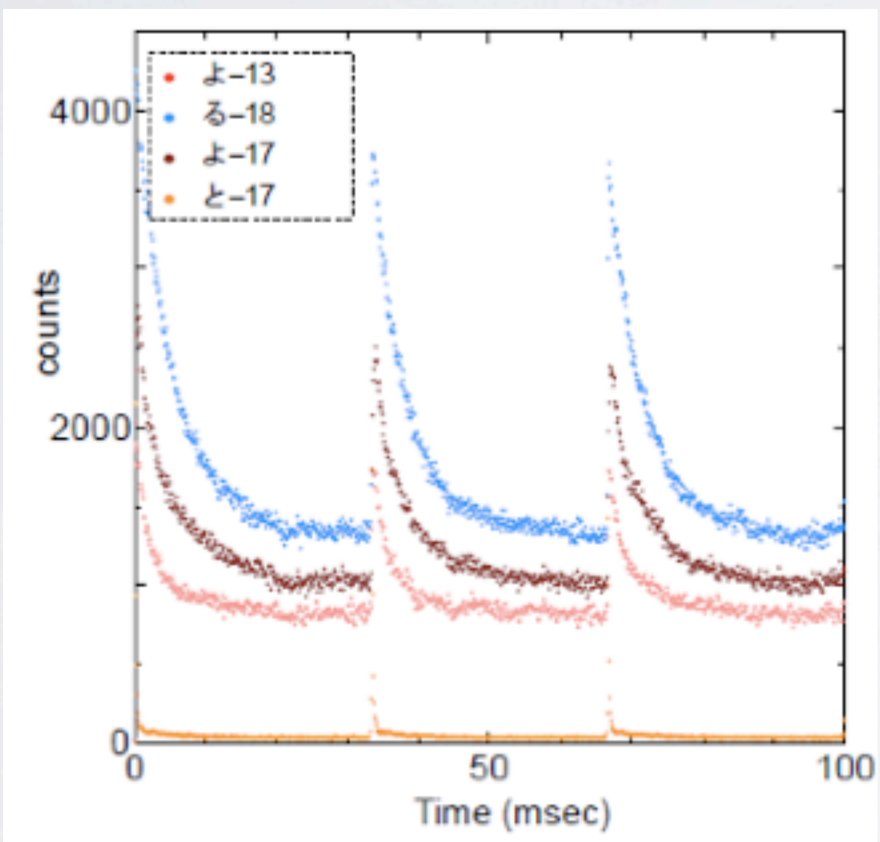


core2: core-horizontal

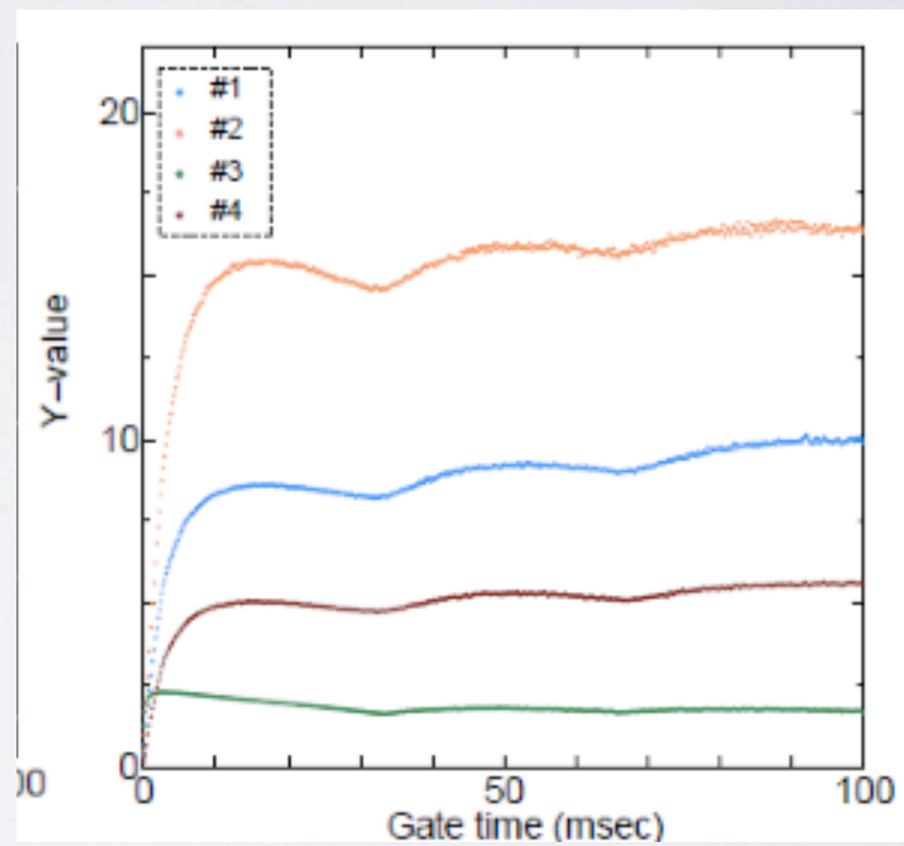
Good agreement with the MCNPX predictions

SUB-CRITICALITY & DYNAMICAL BEHAVIOR

PNM and Feynman-α were both useful for detecting the sub-criticality during operation.



pulsed neutron method



Feynman-α

THORIUM LOADED CORE

MAR. 3, 2010

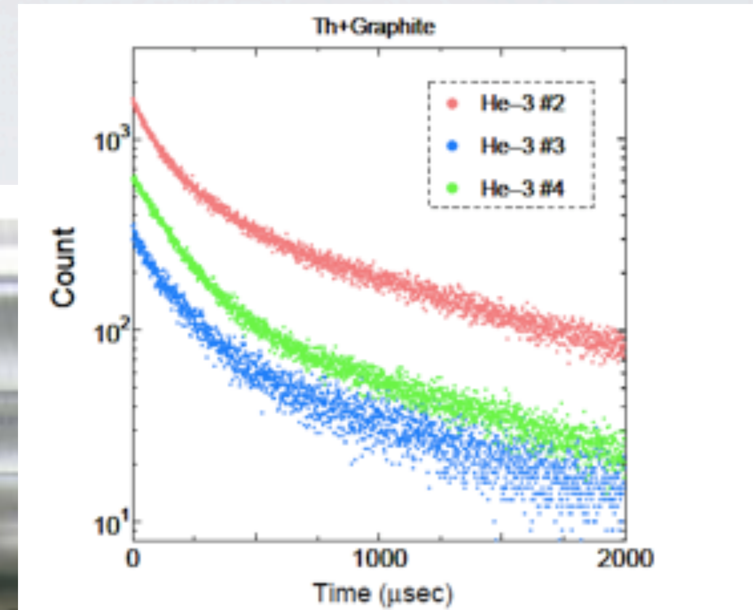
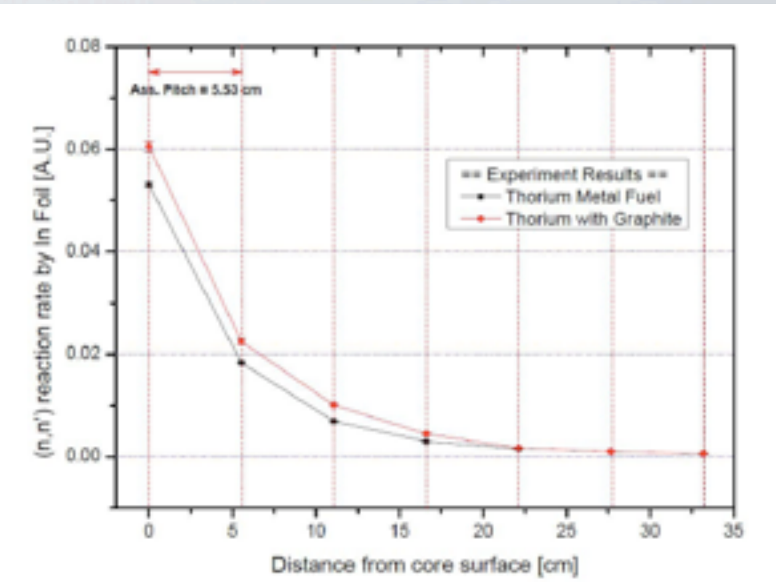


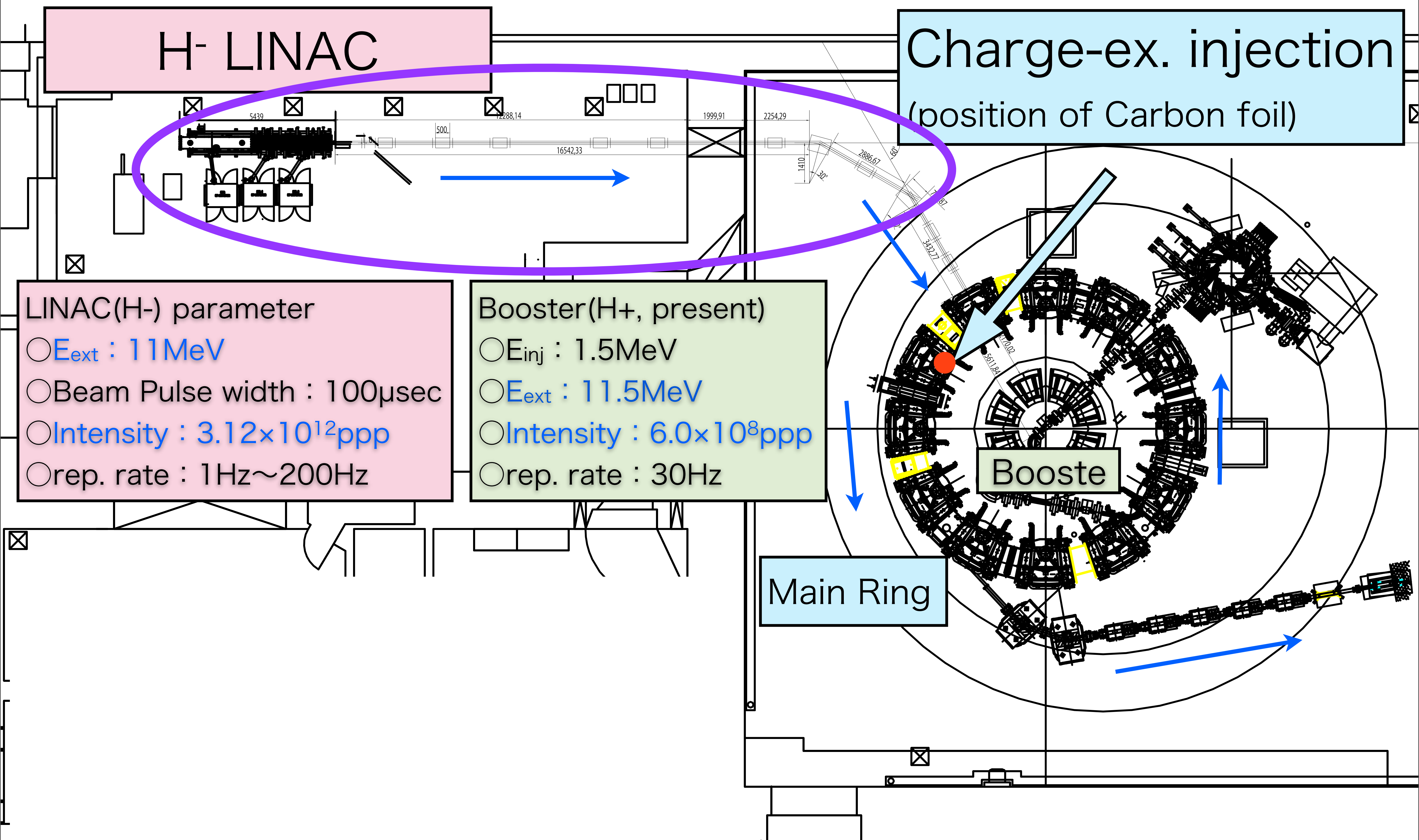
Fig. Results of pulsed neutron method at Th-Graphite core



SCIENCE PROJECTS WITH INTENSITY UPGRADED FFAG

- ADSR engineering experiment with a new "high-power sub-critical system" (not reactor)
  - Output power (SC) ~10kW: proton beam power >kW
  - Engineering study: cooling(heat transfer), materials, control of reactivity, etc.
- Nuclear data taking
  - Energy range of neutrons 0.1-10MeV : complementary for e-Linac
  - Pulsed beam 30nsec, 60Hz
  - Neutron yield: 5×10^{13} n/sec @60Hz operation
- Pulsed spallation neutron source
  - Beam power ~1kW
  - Pulsed beam 30nsec, 15(30)Hz
  - Innovated neutron target -> cf. 2nd target at Rutherford Lab.

Beam intensity upgrade of FFAG accelerator at KURRI



LINAC(H-) parameter

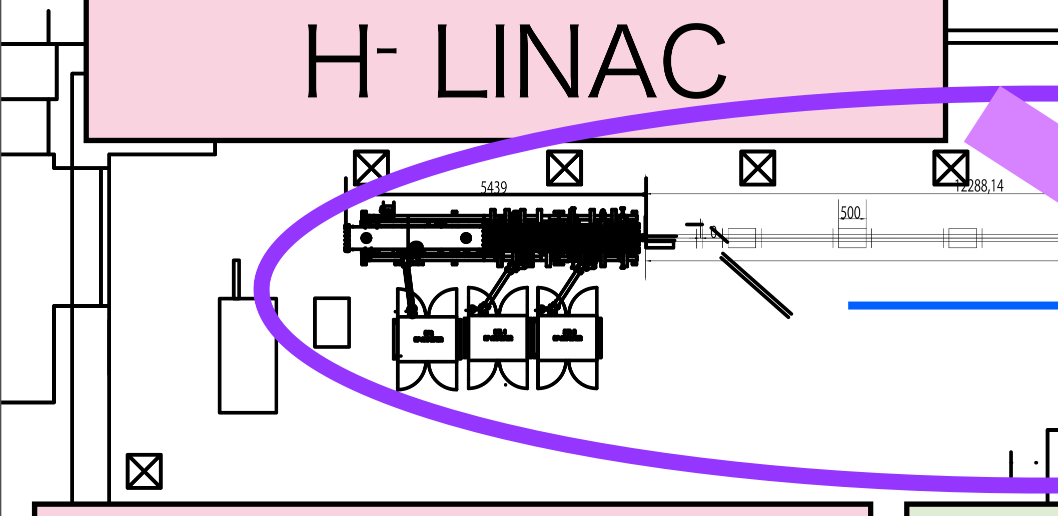
- ○E_{ext} : 11MeV
- ○Beam Pulse width : 100μsec
- ○Intensity : 3.12×10^{12}ppp
- ○rep. rate : 1Hz～200Hz

Booster(H+, present)

- ○E_{inj} : 1.5MeV
- ○E_{ext} : 11.5MeV
- ○Intensity : 6.0×10^{8}ppp
- ○rep. rate : 30Hz

Beam intensity upgrade of FFAG accelerator at KURRI

H- LINAC



LINAC(H-) parameter

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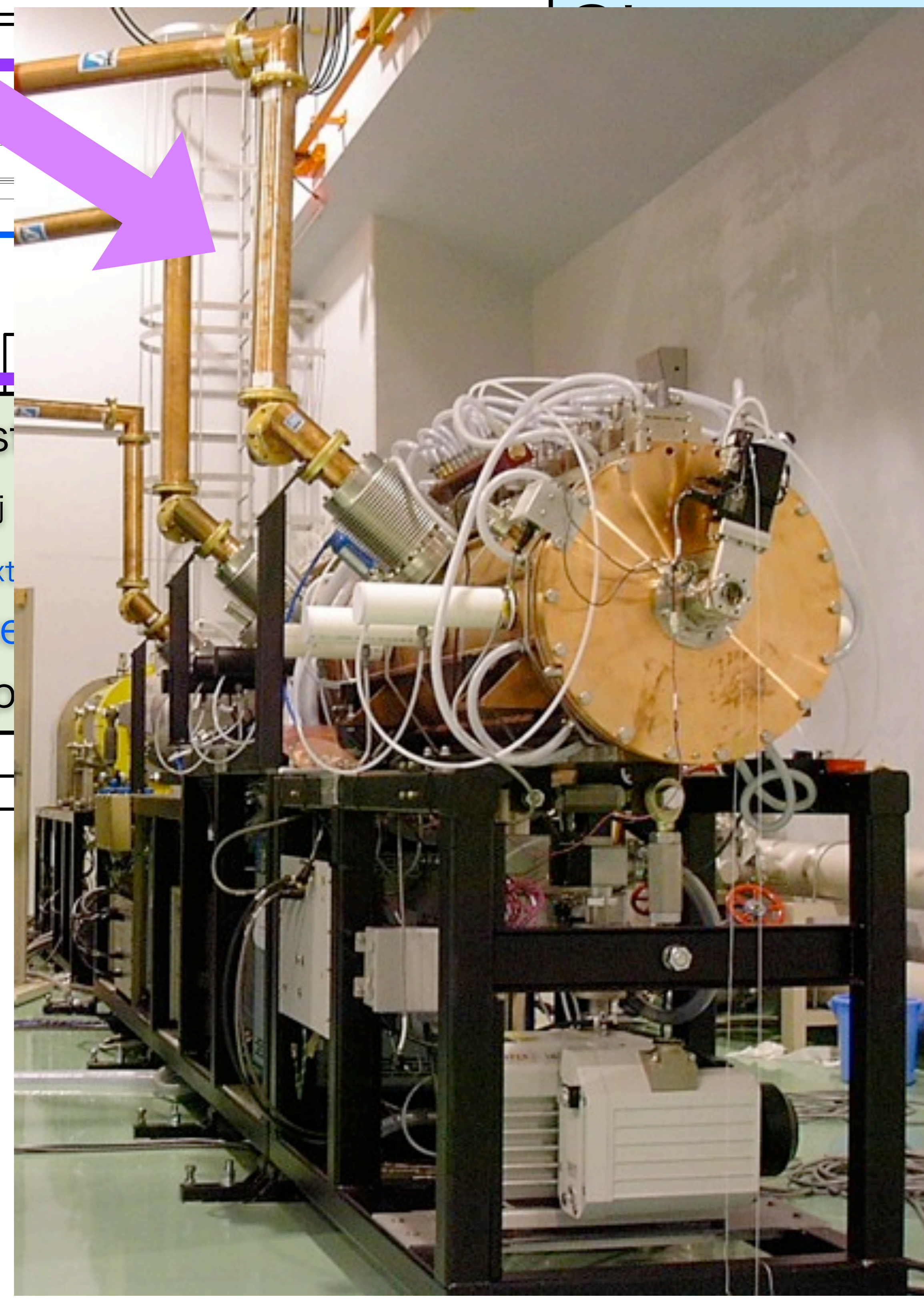
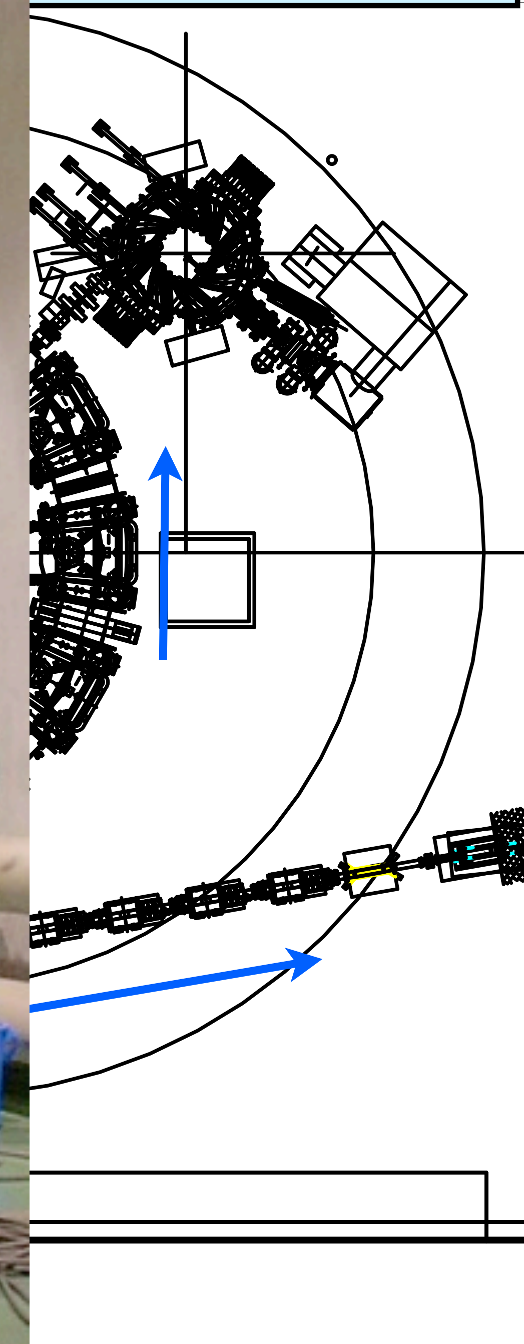
Boos

- ○E_{inj}
- ○E_{ext}
- ○Inte
- ○rep

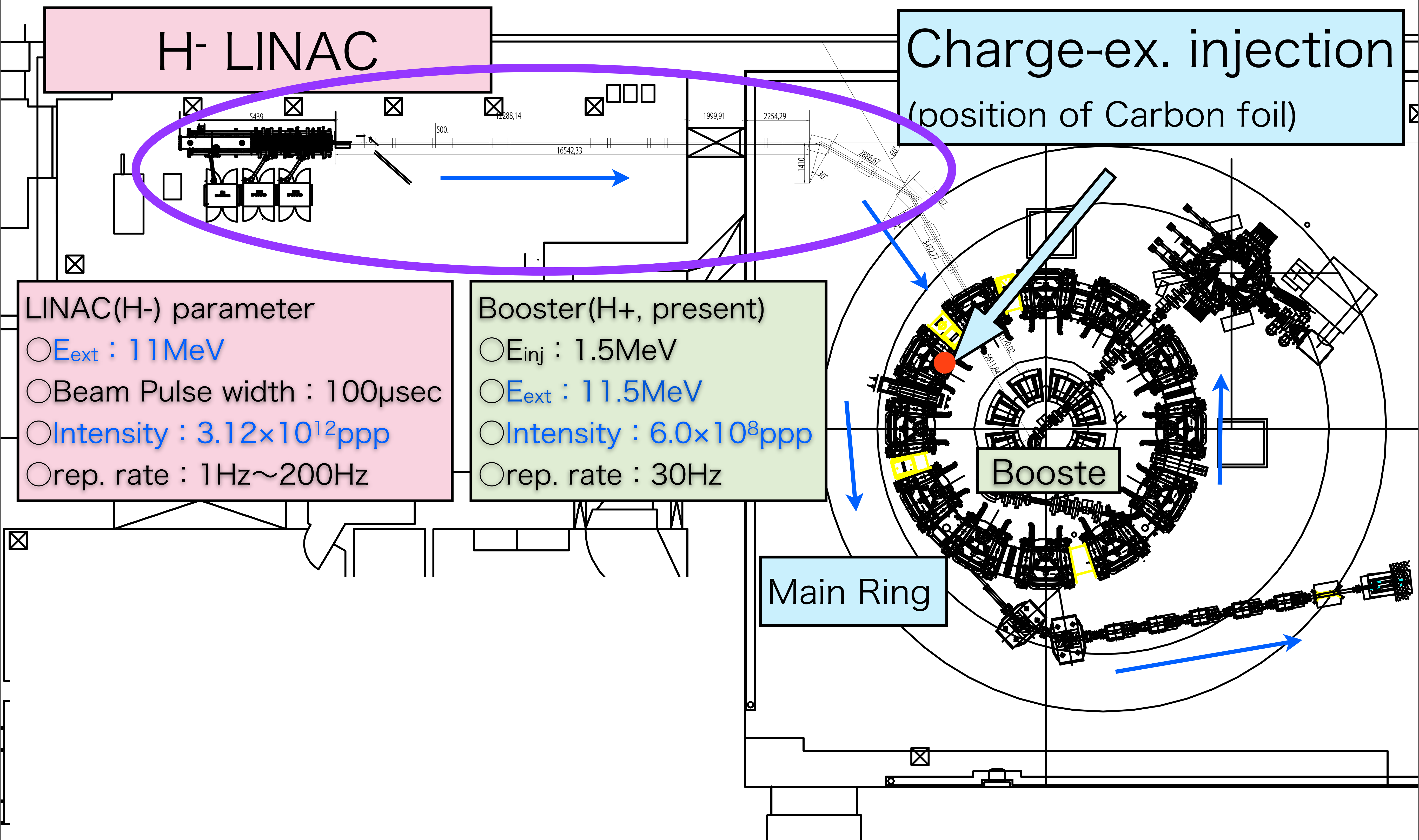


x. injection

rbon foil)



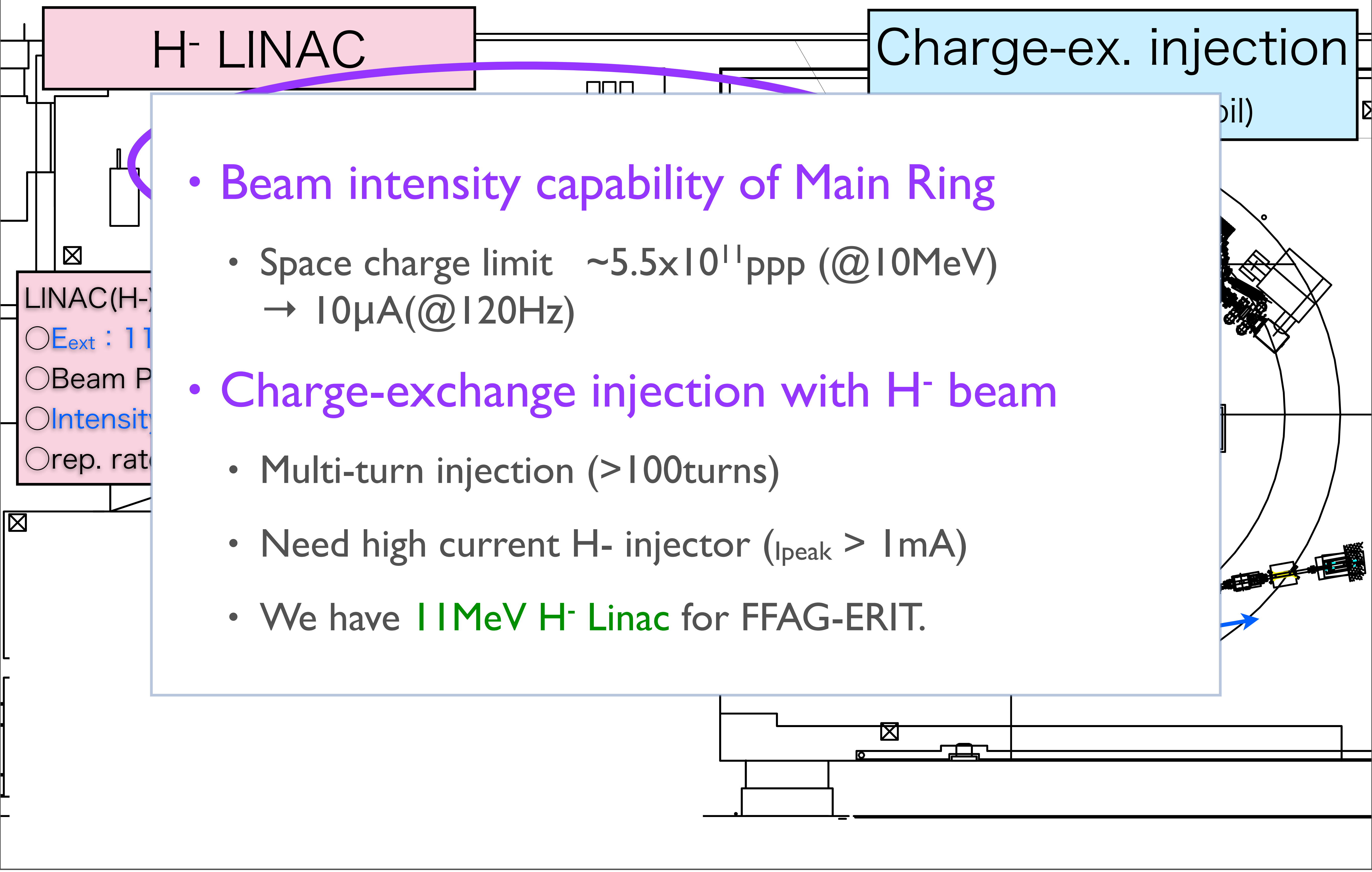
Beam intensity upgrade of FFAG accelerator at KURRI



LINAC(H-) parameter
- ○E_{ext} : 11MeV
- ○Beam Pulse width : 100μsec
- ○Intensity : 3.12×10^{12}ppp
- ○rep. rate : 1Hz～200Hz

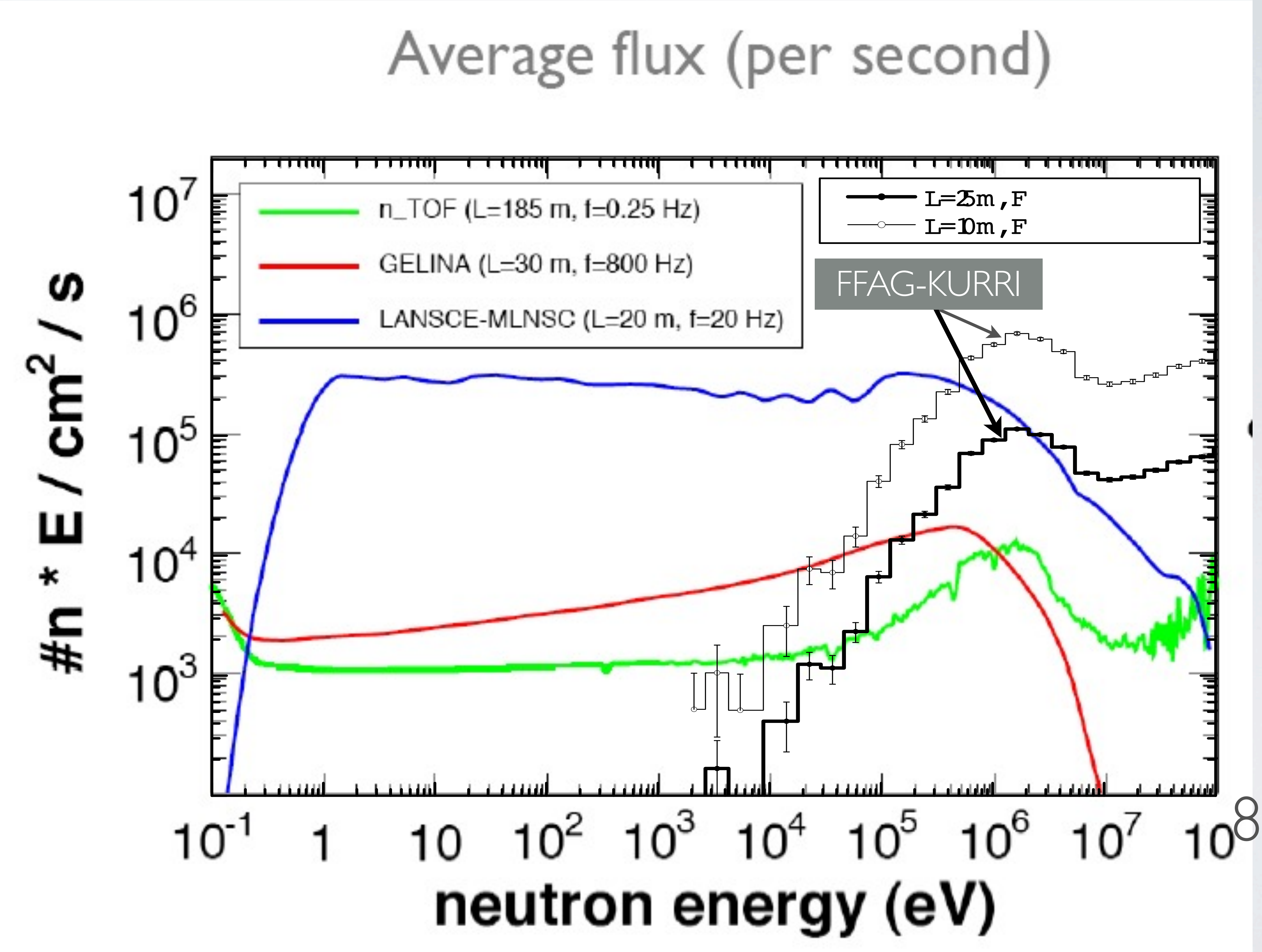
Booster(H+, present)
- ○E_{inj} : 1.5MeV
- ○E_{ext} : 11.5MeV
- ○Intensity : 6.0×10^{8}ppp
- ○rep. rate : 30Hz

Beam intensity upgrade of FFAG accelerator at KURRI



- Beam intensity capability of Main Ring
  - Space charge limit ~5.5×10^{11}ppp (@10MeV) → 10μA(@120Hz)
- Charge-exchange injection with H^- beam
  - Multi-turn injection (>100turns)
  - Need high current H- injector (I_{peak} > 1mA)
  - We have 11MeV H^- Linac for FFAG-ERIT.

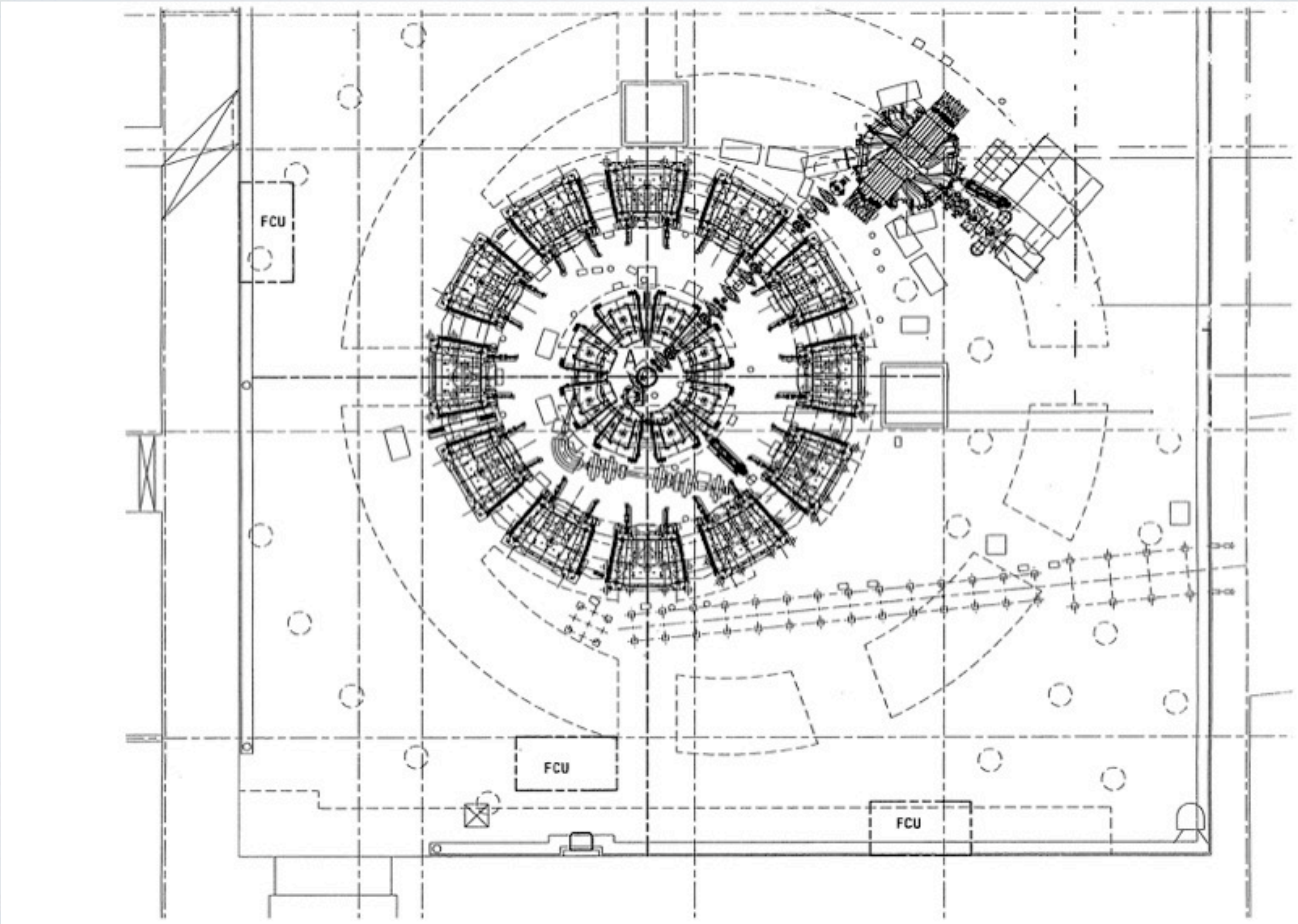
NEUTRON YIELD FOR NUCLEAR DATA TAKING



Reference: F. Gunsing, et al., Nucl. Instrum. Meth.,B 261, 925-929 (2007).

FUTURE

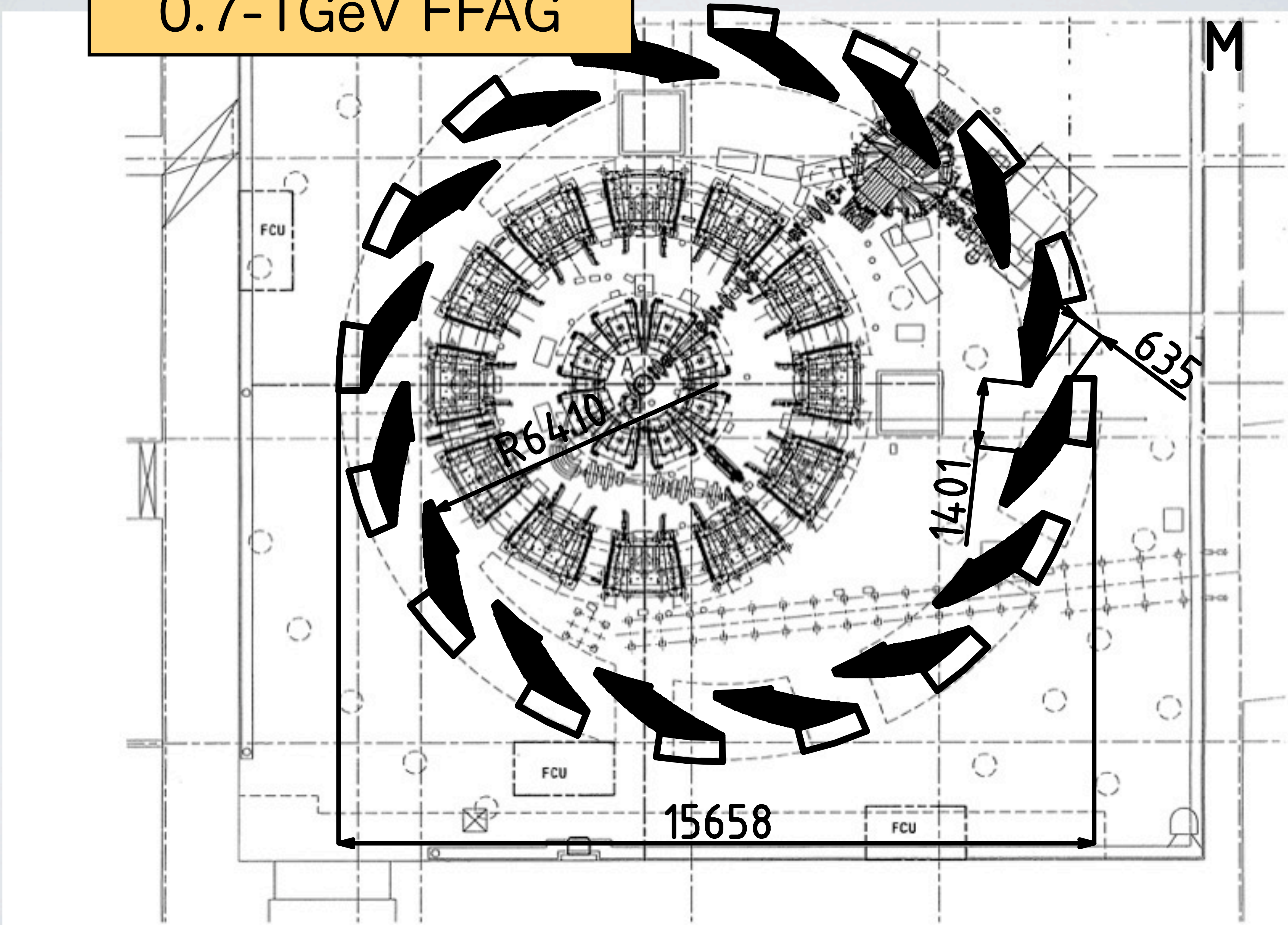
0.7-1GEV -B. QIN(THIS CONFERENCE)-



FUTURE

0.7-1GEV -B. QIN(THIS CONFERENCE)-

0.7-1GeV FFAG



FUTURE

0.7-1GEV -B. QIN(THIS CONFERENCE)-

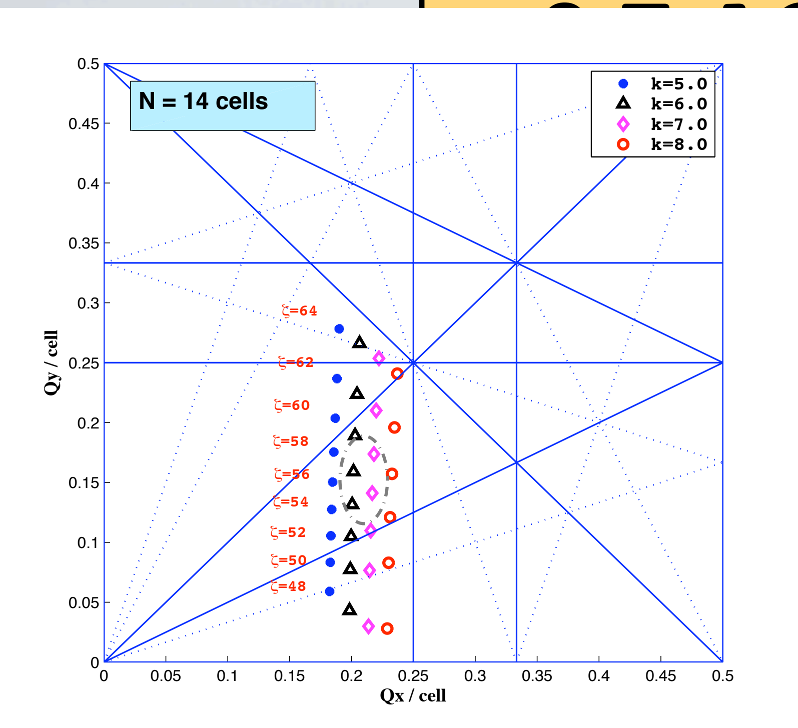
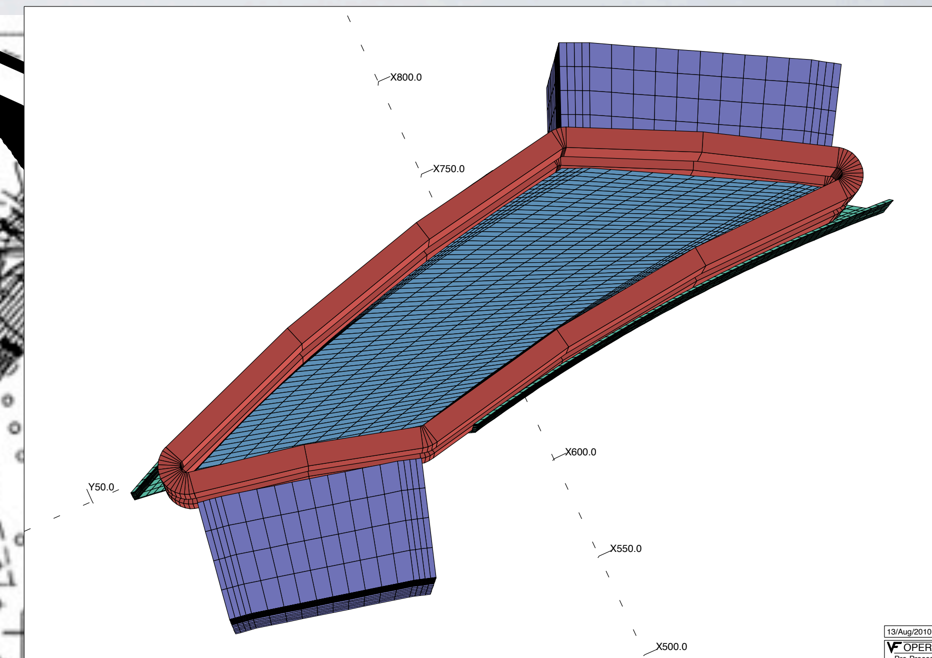
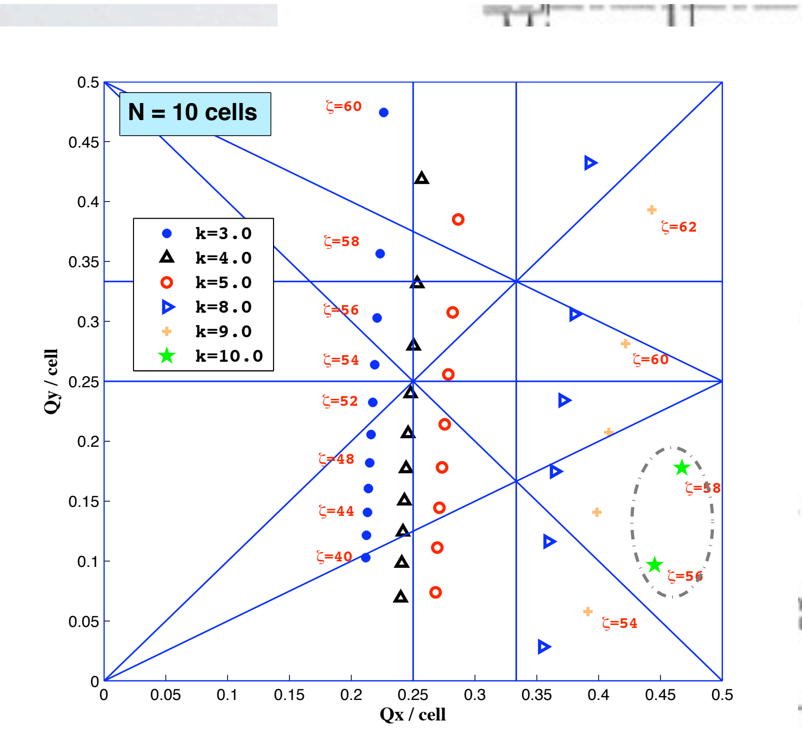
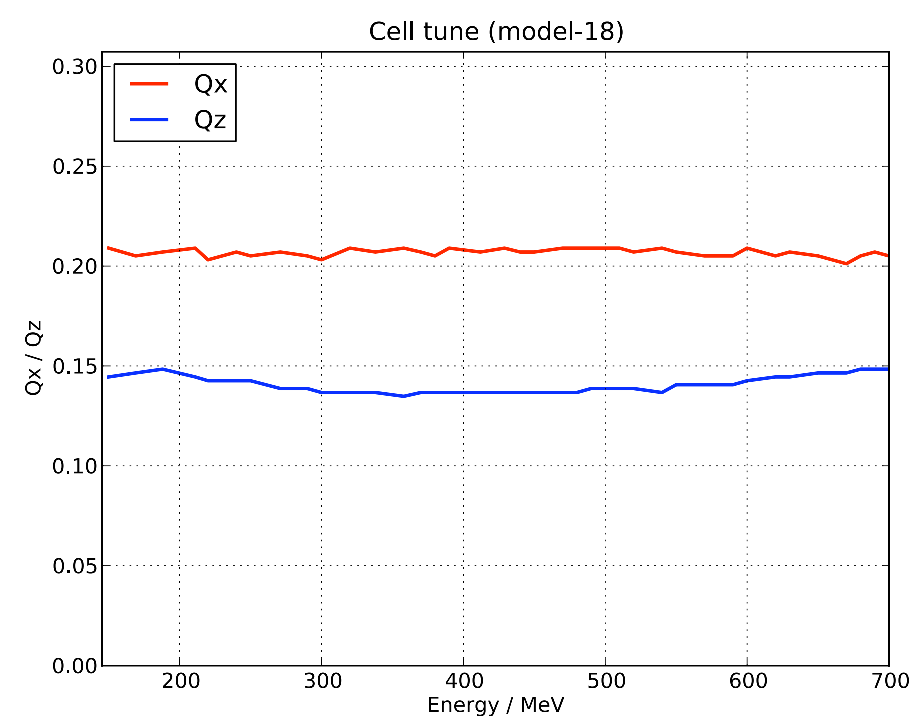


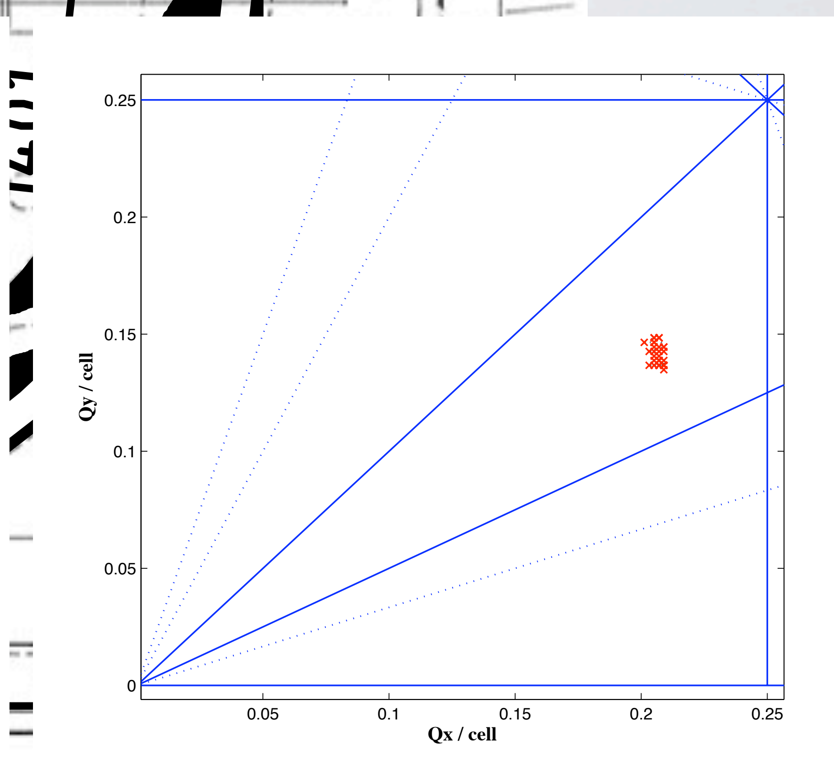
Table 1: Ring and optics parameters of the model

lattice type	spiral, scaling
gap geometry	variable gap with only main coil
number of cell	14
k	7.0
ζ	58°
R_0	6.9m
packing factor	0.36
$B\rho_{inj}$, B_{inj}	1.839$T\cdot m$ (150MeV), 0.666T
$B\rho_{ext}$, B_{ext}	4.48$T\cdot m$ (700MeV), 1.452T
R_{ext}	7.71m
radius excursion	0.81m
Pole inner radius	6.7m
Pole outer radius	7.92m
ν_x	0.22
ν_z	0.14
β_z min, max	1.4 / 4.0 (m)
D_x min, max	0.65/1.0 (m)



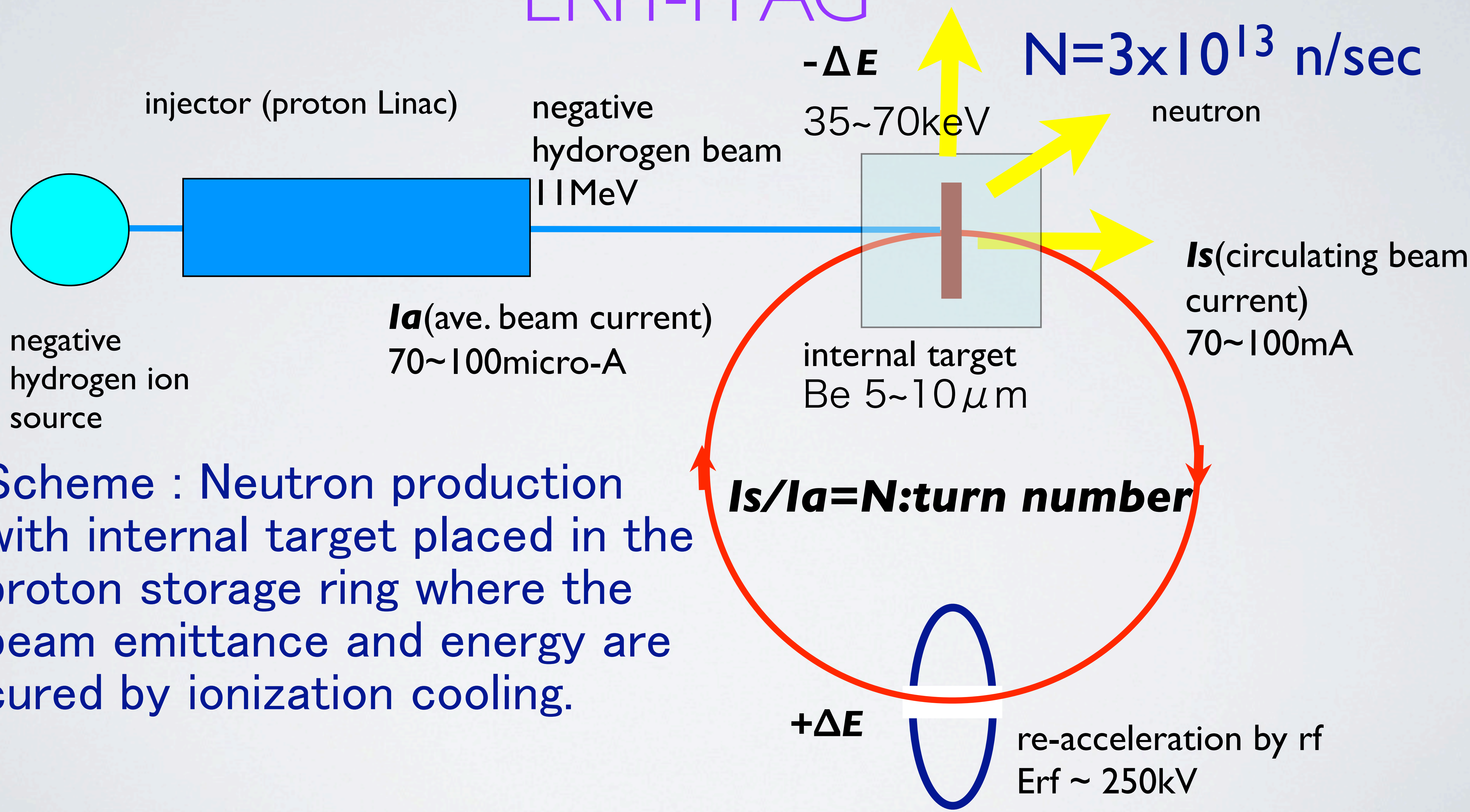






NEUTRON SOURCE WITH EMITTANCE RECOVERY INTERNAL TARGET

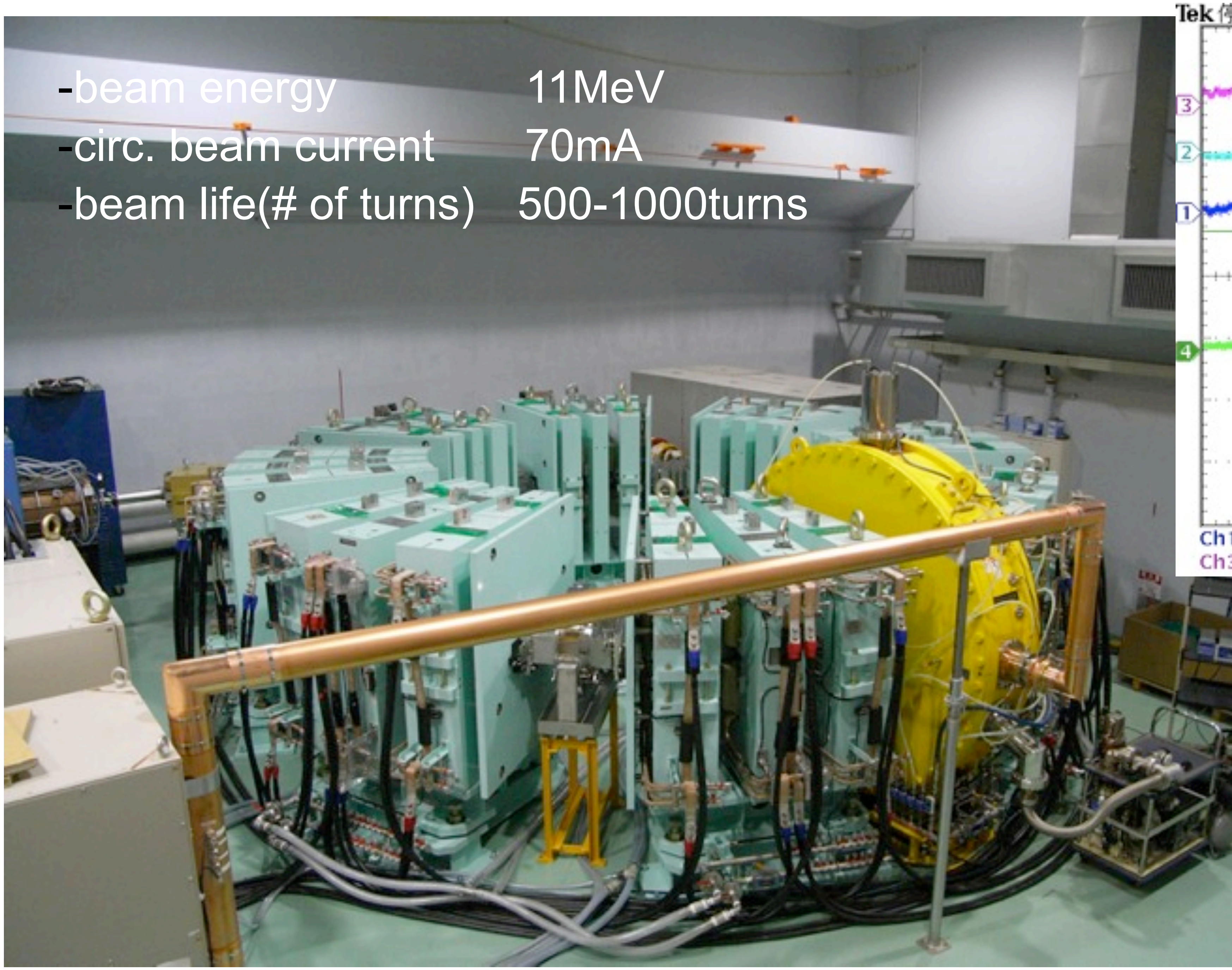
ERIT-FFAG

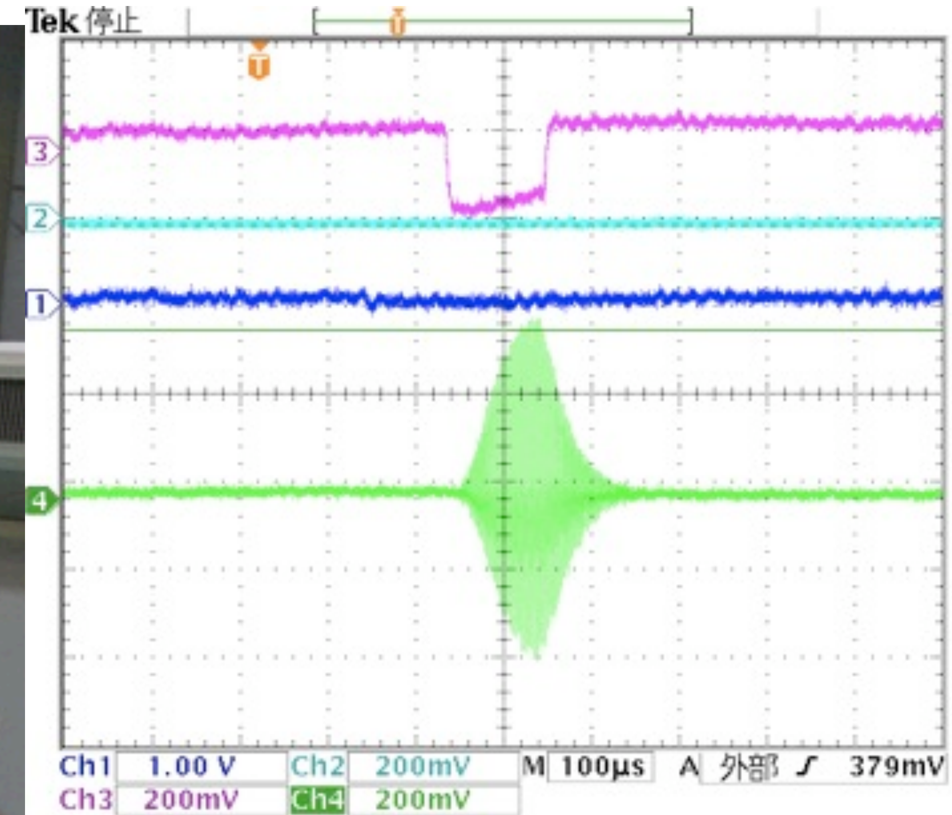


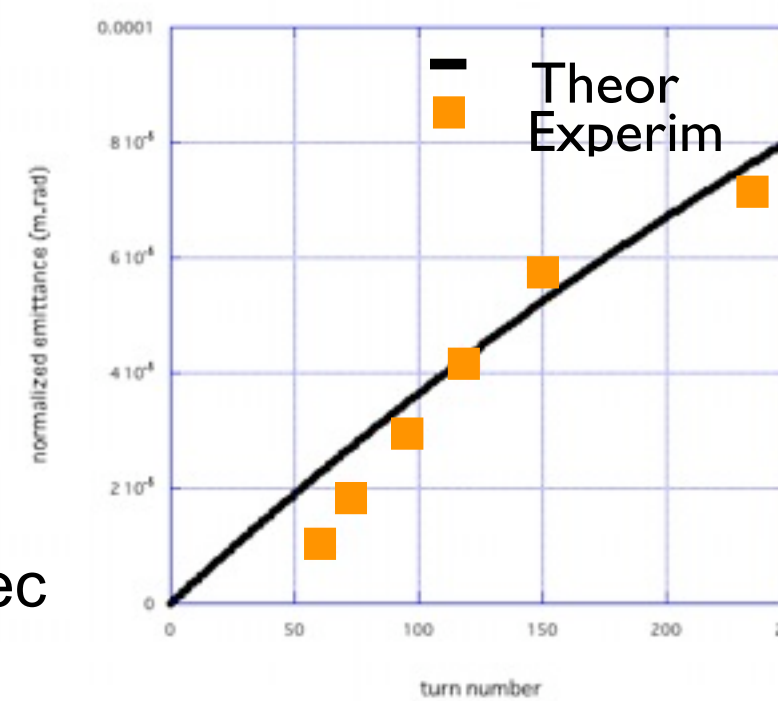
Scheme : Neutron production with internal target placed in the proton storage ring where the beam emittance and energy are cured by ionization cooling.

FFAG-ERIT RING

-beam energy 11MeV
-circ. beam current 70mA
-beam life(# of turns) 500-1000turns







-acceptance Av>3000mm.mrad,
dp/p>+-5%(full)

-ν_x, ν_y 1.77, 2.27

Neutron Yield > 10^{13}n/sec

- Thanks to
- Y. Kuno, A.Sato (Osaka Univ.)
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- T.Baba,M.Yuasa (NHV Co.)
- F.Tanaka(Mitsubishi Electric Co.)
- H.Unesaki, K.Hori(KURRI) and KUCA group at KURRI
- All members of FFAG group at KURRI

FFAG'10

Kyoto Univ. Research Reactor Institute (KURRI)

Osaka, Japan

Oct. 26-31

- FFAG Accelerator School Oct. 26-27
- International Workshop on FFAG Accelerator (FFAG'10) Oct. 28-31

Students and young scientists are very welcome!