Status
of
Accelerator Facility
of
Kyushu University

Nov. 13, 2012. FFAG-WS at Osaka University

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KYUSHU
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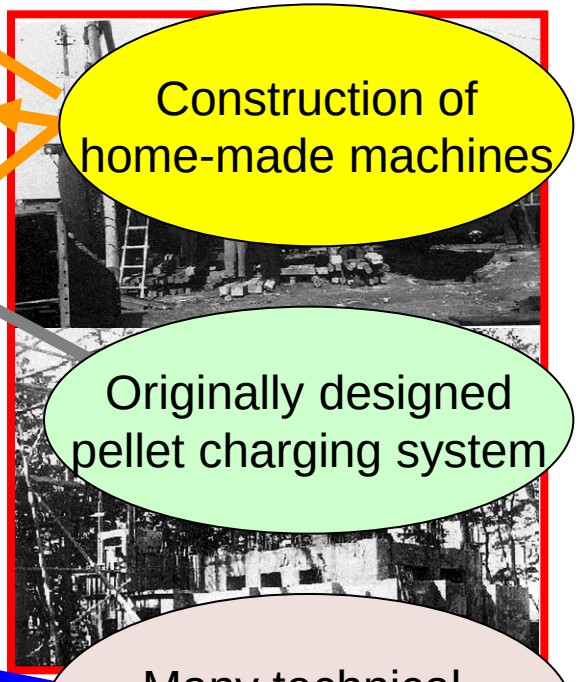
Contents

- Brief history and present accelerator activities at Kyusyu University
- Construction of the tandem-FFAG accelerator facility in new campus
- Uses and requirements

Brief History of Accelerators in Kyushu University

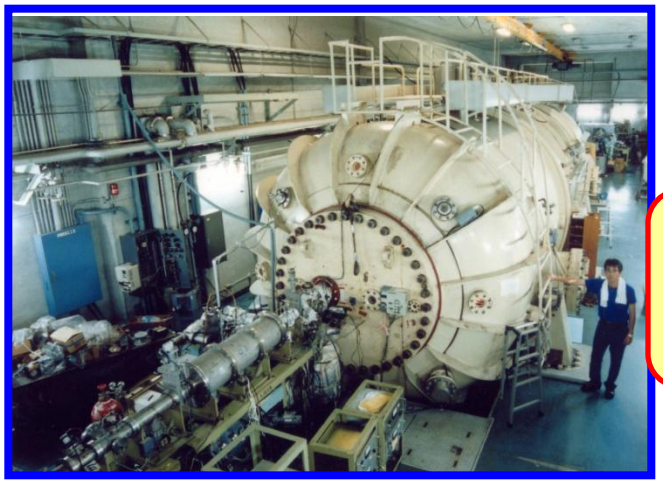
- 1943 Construction of Van de Graaff accelerator
  Terminal Voltage : 3 MV (1952)
- 1959 Construction of Cock Croft Walton accelerator
  Acceleration energy : 500 kV (1962)
- 1963 Original pellet Chain Development (VdG)
  Terminal Voltage : 7.5 MV (1970)
- 1972 Construction of Tandem accelerator
  Terminal Voltage : 11 MV (1980)
- Present activities with the Tandem accelerator
  - ☐ Few-nucleon systems
  - ☐ ^{12}C-AMS
  - ☐ Astro-nuclear reaction (α+12C→16O+γ)

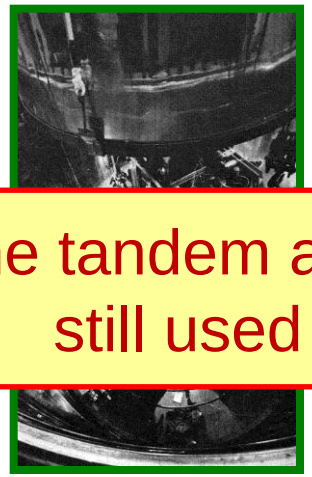


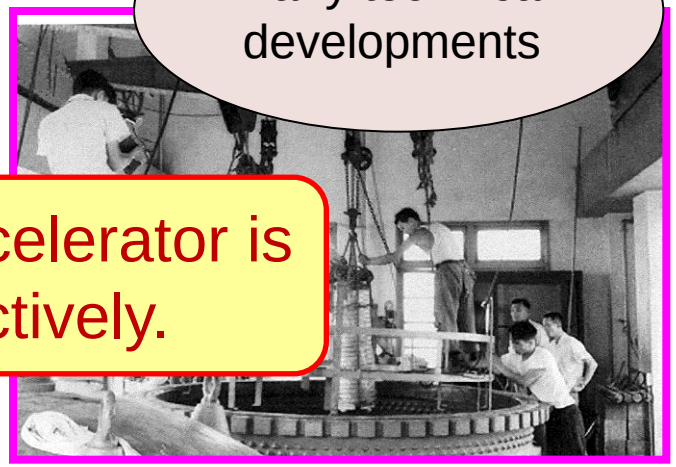
Construction of home-made machines

Originally designed pellet charging system

Many technical developments







The tandem accelerator is still used actively.

Campus movement and construction of new facility

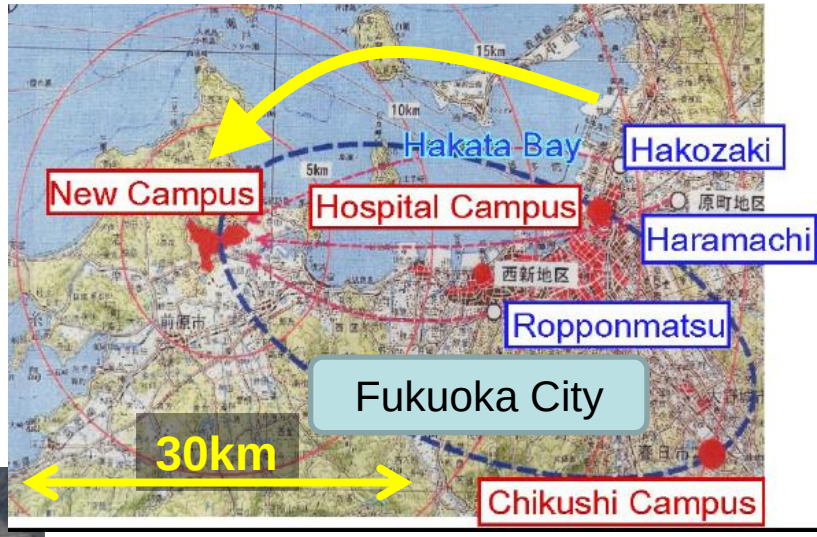
Schedule of the movement

2005-6：Faculty of Engineering

2015：Faculty of Science

(The schedule was recently fixed)

The present tandem accelerator is forced to shut down in 2014.



New accelerator facility is being constructed.

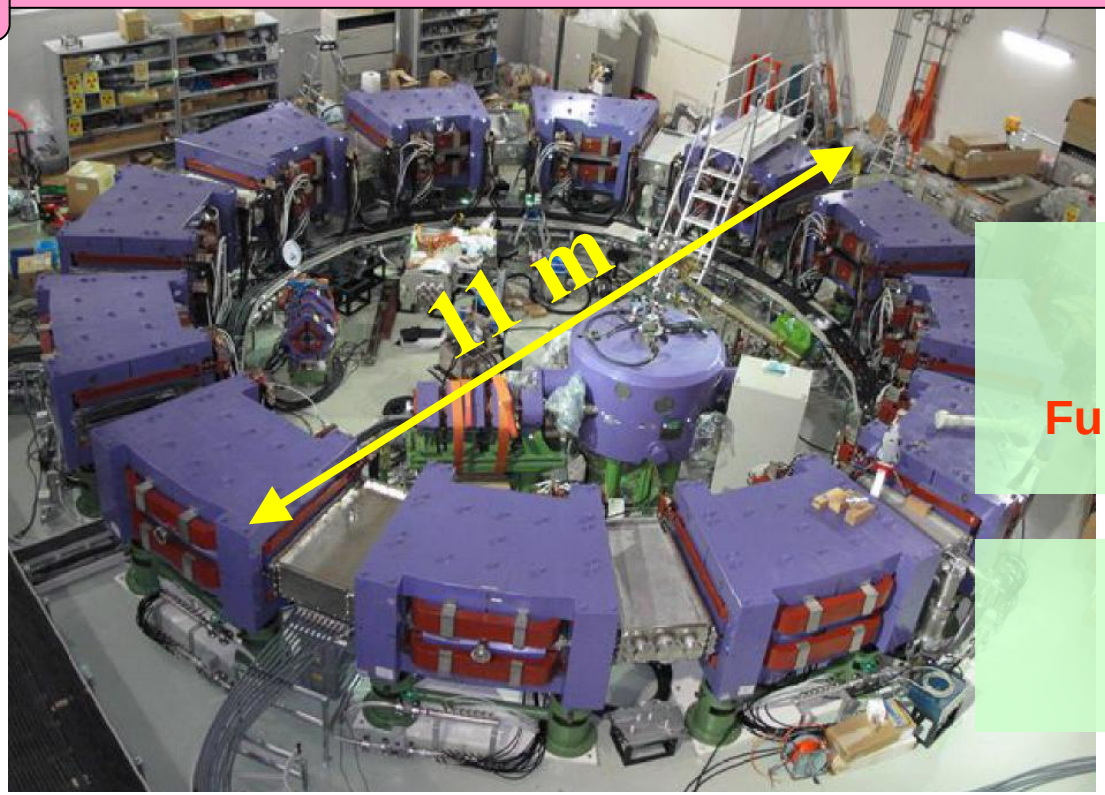
- Only an accelerator hall exists.
- Experimental area will be constructed as a part of the campus movement.

New accelerator center at Kyushu Univ.

"Center for accelerator and beam applied science"

Main accelerator : FFAG Synchrotron

The test machine that Prof. Mori developed was transferred and reinstalled.

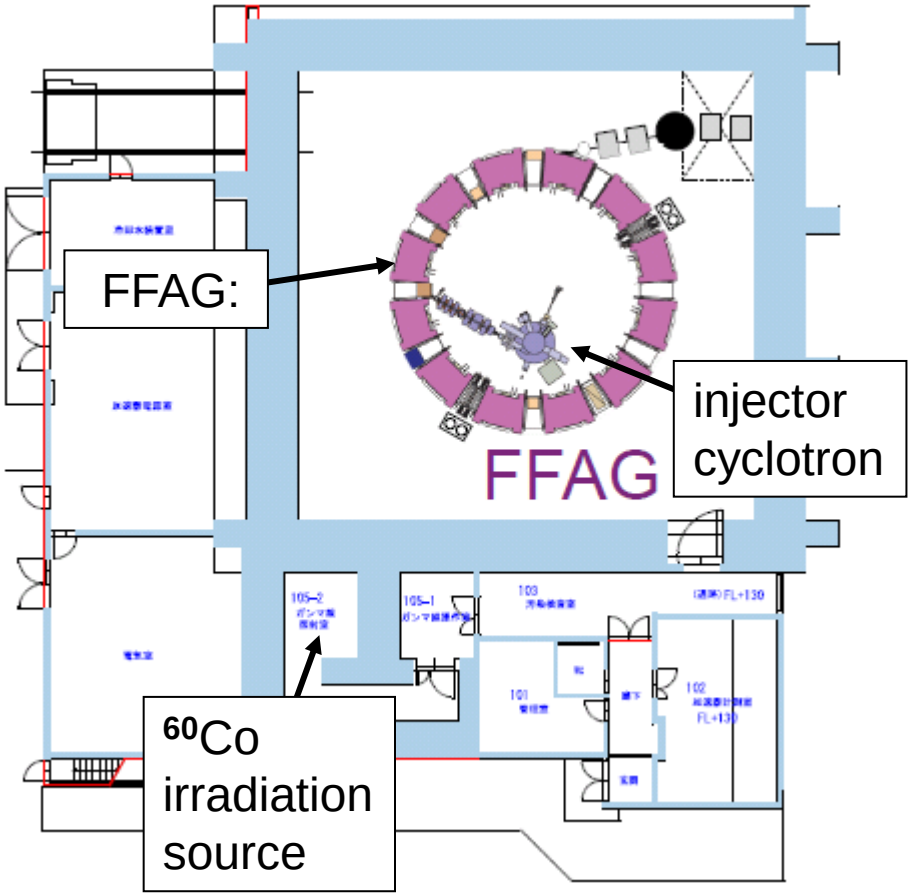


Newly constructed machine
still under development
Further development at Kyushu

A machine with
various possibilities
Challenges for new usage

Present (1st stage) FFAG accelerator facility

Accelerator and Beam Applied Science, Kyushu Univ.

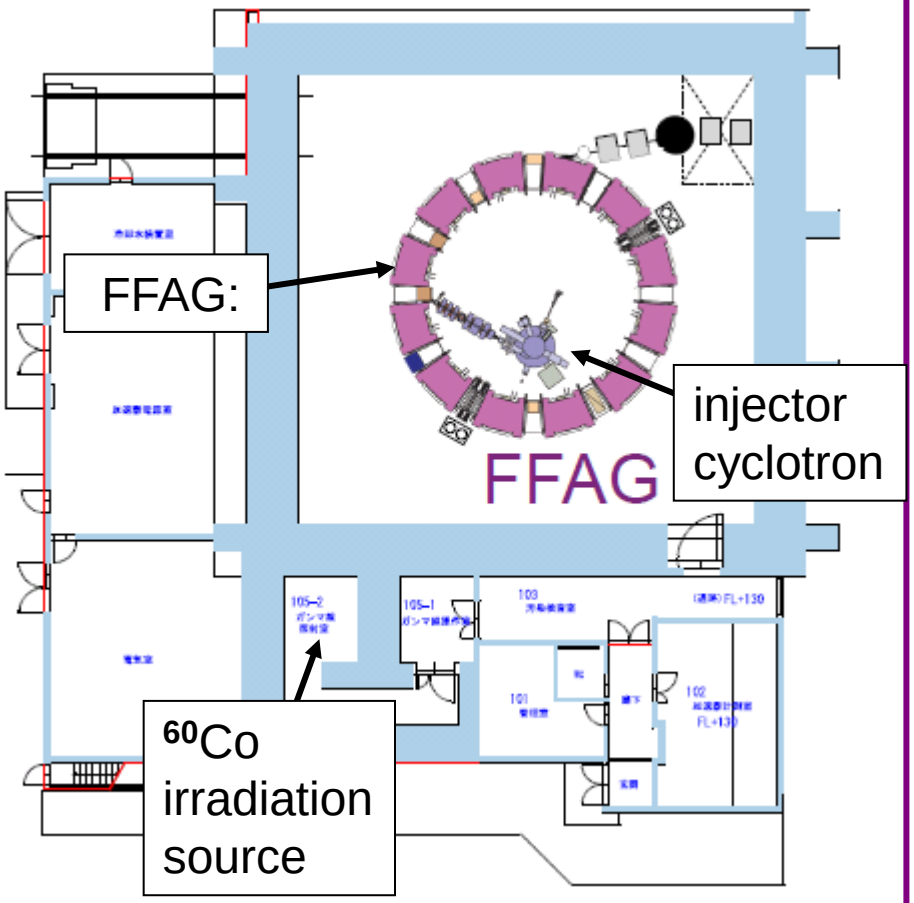


Design values of the FFAG

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

Present (1st stage) FFAG accelerator facility

Accelerator and Beam Applied Science, Kyushu Univ.



History of the re-installation :

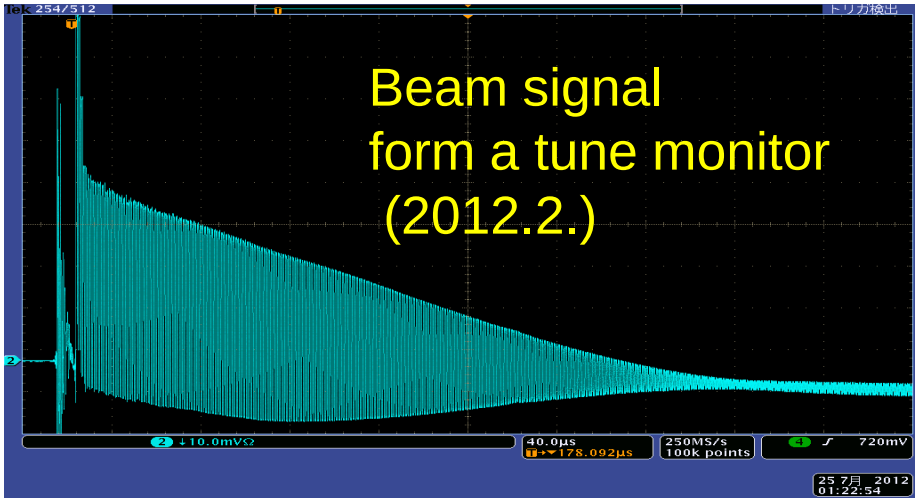
2008- Hardware reconstruction

2011- Commissioning of the injector cyclotron

2011- Commissioning of the FFAG accelerator

2011.12.2. One turn circulation was observed.

2012.11.- Installation of the RF cavities.



The 1st stage injector : cyclotron

Type	AVF cyclotron
Beam Energy	10 MeV
Ion Source	Internal PIG (LaB_6 Cathode)
Extraction Radius	300 mm
Magnetic Field	Max. 1.54 T
RF Dee Voltage	40 kV
RF Frequency	47 MHz (2nd harmonic acceleration)
Beam Current	2 μA (Duty 4%, 100Hz)

Limitations :

- Proton (and deuteron) beam only.
- 10MeV is the maximum. (12 MeV is required for 150 MeV acceleration.)
- Time structure does not match the FFAG synchrotron.

→ Replacement of the injector is preferable.

Expected activities of the new facility at Kyushu Univ.

- Development research on the FFAG accelerator
  - various kinds of application
- Extension of present accelerator activities
  - low-energy nuclear physics → astro-nuclear physics
  - AMS
- General purpose use in various fields
  - energy science, material science, life science, medical science (basic)

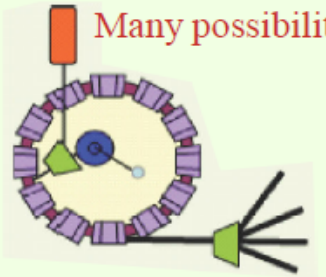
As a general purpose accelerator facility …

FFAG development

Accelerator science

Under-developed machine just born.

Many possibilities no other machines have.

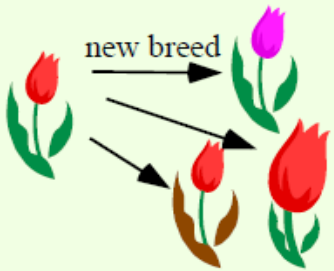


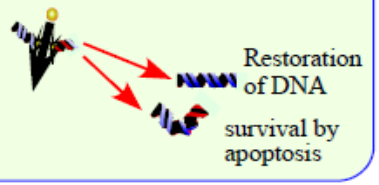
- Flexible beam time-structure
- Large acceptance, multi-beam
- possibility as a beam delayer
- Acceleration of various beams
- High intensity by fast repetition

DNA processing, breed improvement

Life science

Environment science

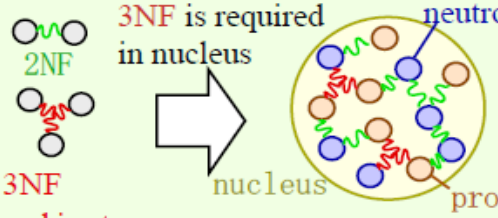




3-body force, nuclear data

Hadron science

Energy science



working to
3 nucleons
simultaneously

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

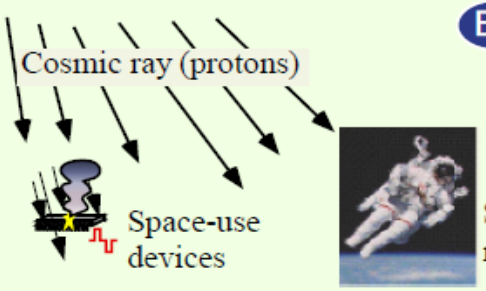
Space simulation

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

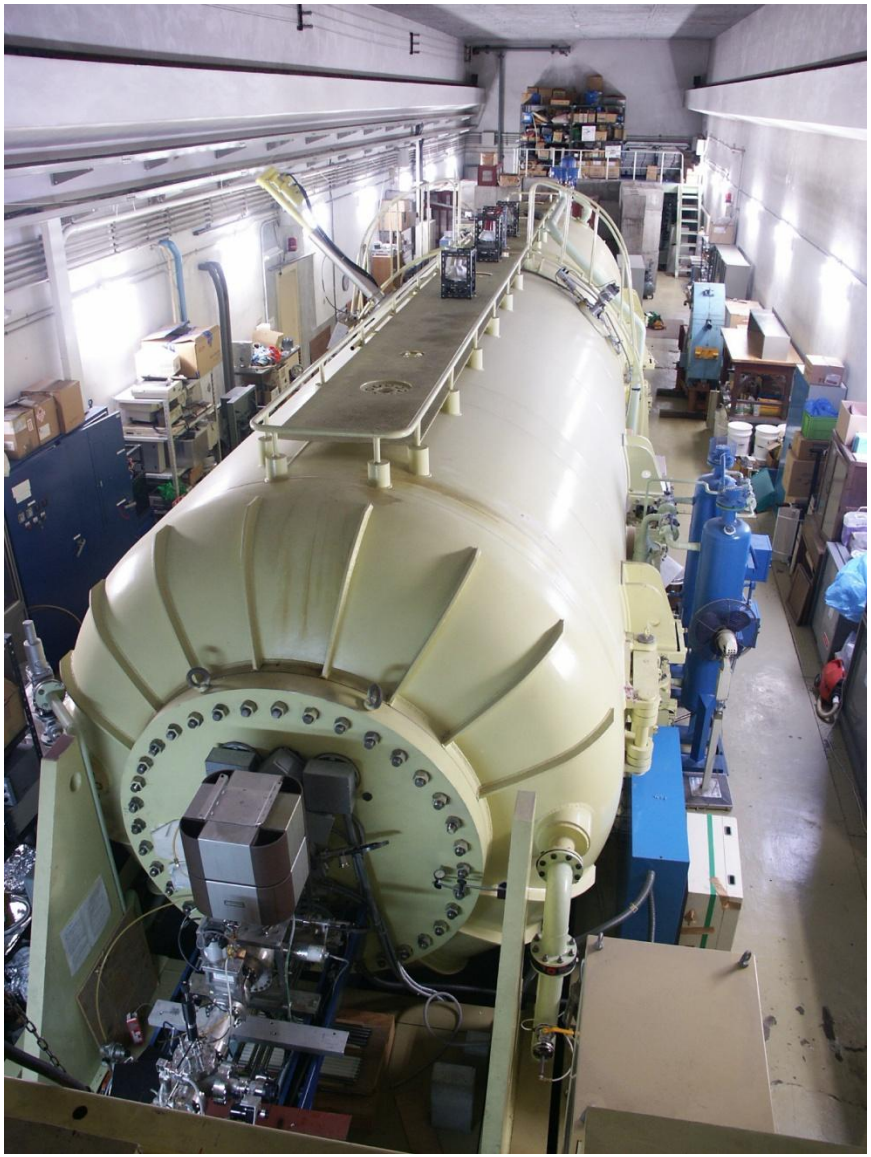
Expected activities of the accelerator facility at Kyushu Univ.

- Development research on the FFAG accelerator
  - various kinds of application
- Extension of present accelerator activities
  - nuclear physics
  - AMS
- General purpose use in various fields
  - energy science, material science, life science, medical science (basic)

⇒ A variety of beams are to be requested.

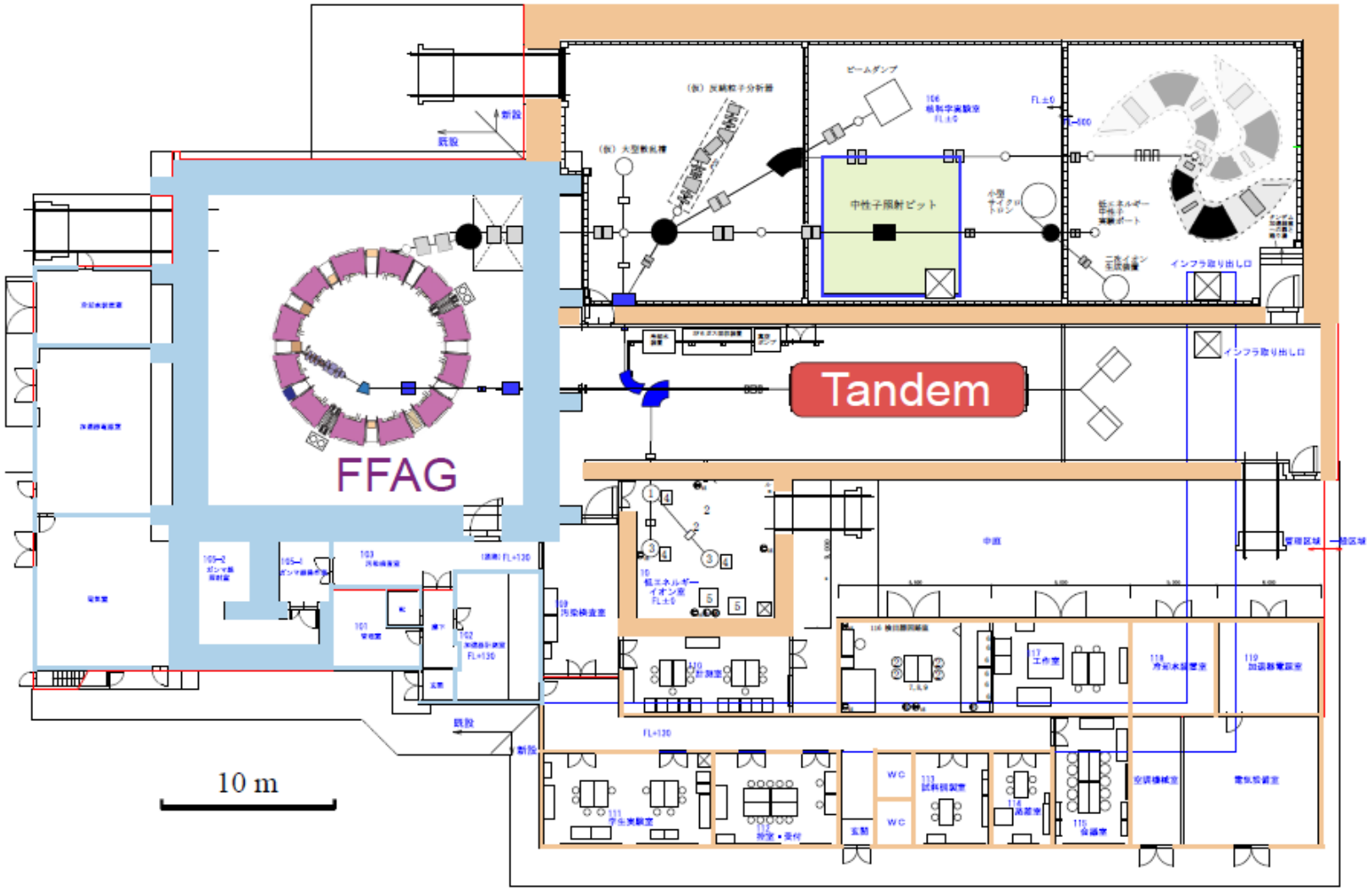
⇒ Introduction of Tandem accelerator, as an injector and for separate use, is preferable.

Transfer of the tandem accelerator from Kyoto Univ.



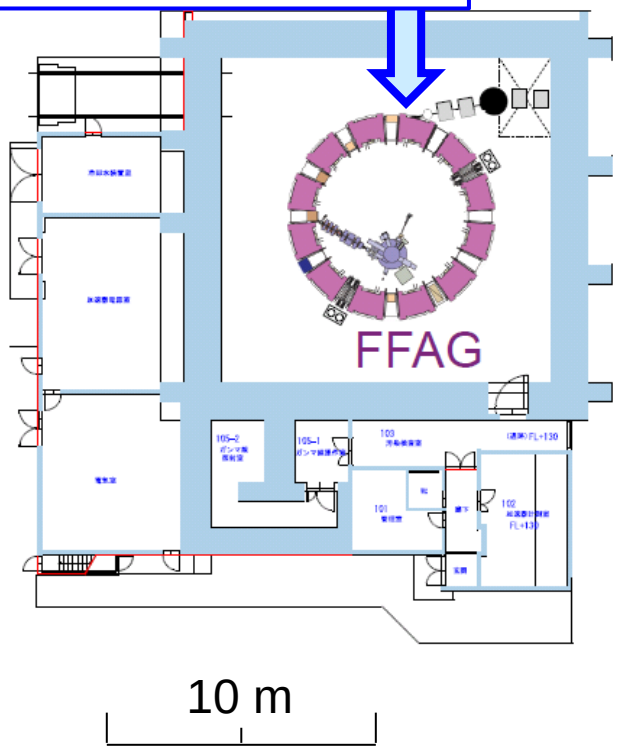
Type	8UD Pelletron (NEC)
Terminal Voltage	8 MeV
Ion Source	SNICS II (→ MC SNICS) ALPHATROS
Injection Voltage	−200 kV → −80 kV
Pellet Current	150 μA × 2
Charge Stripper	C-foil and N_2-gas
Tank size	3 m^D x 13.6 m
Gas	5 atm SF_6

Plan view of the accelerator facility at Kyushu Univ.



Construction of the accelerator facility

1st phase:
FFAG (E_p=120~150MeV)
（from KEK：2008-2009）



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Mar. 11, 2012
tandem prefab. and
FFAG bldg.

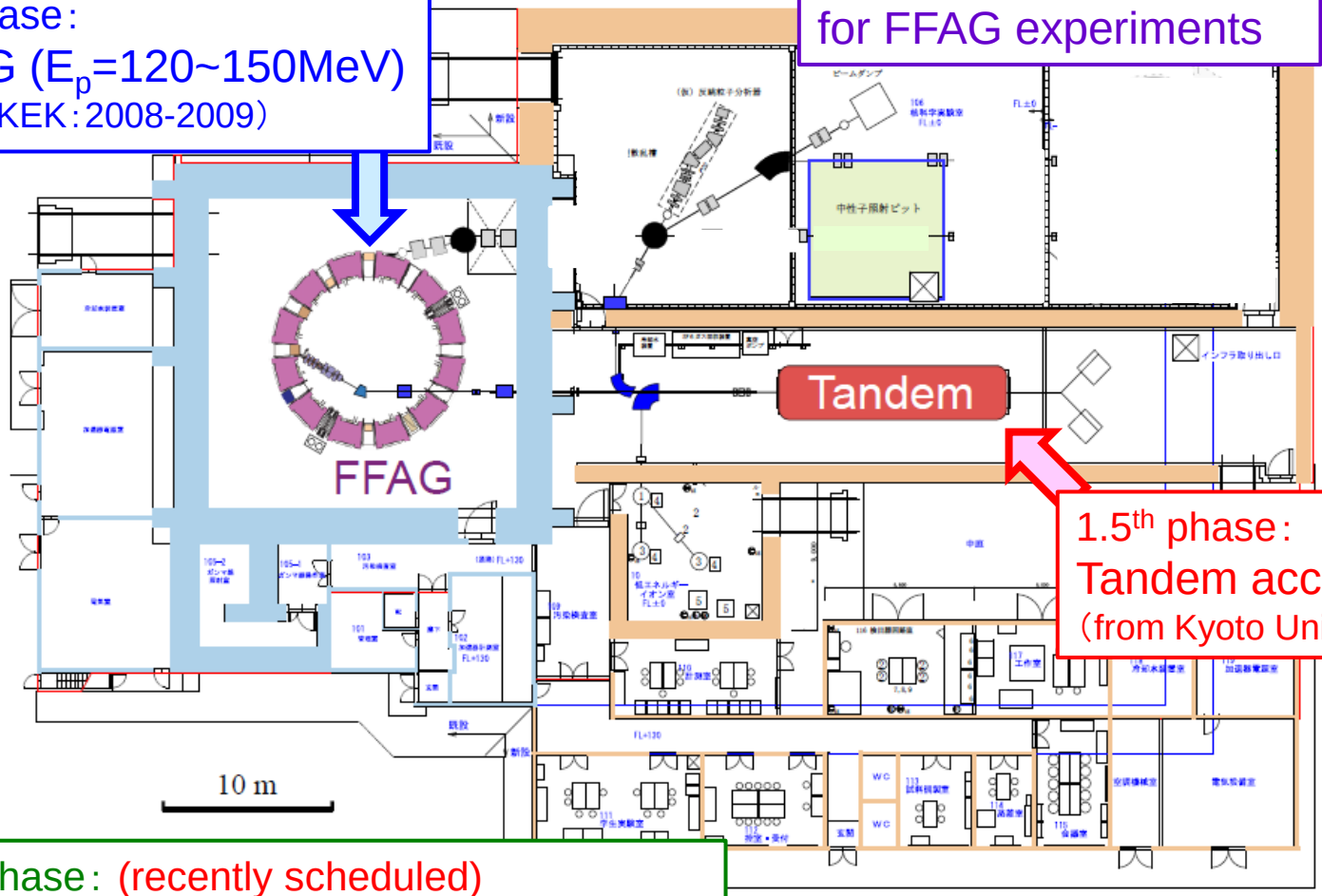
Feb. 18, 2012
Installation of accelerator tank

Re-fabrication of the accelerator is in progress

Construction of the accelerator facility

1st phase:
FFAG (E_p=120~150MeV)
(from KEK:2008-2009)

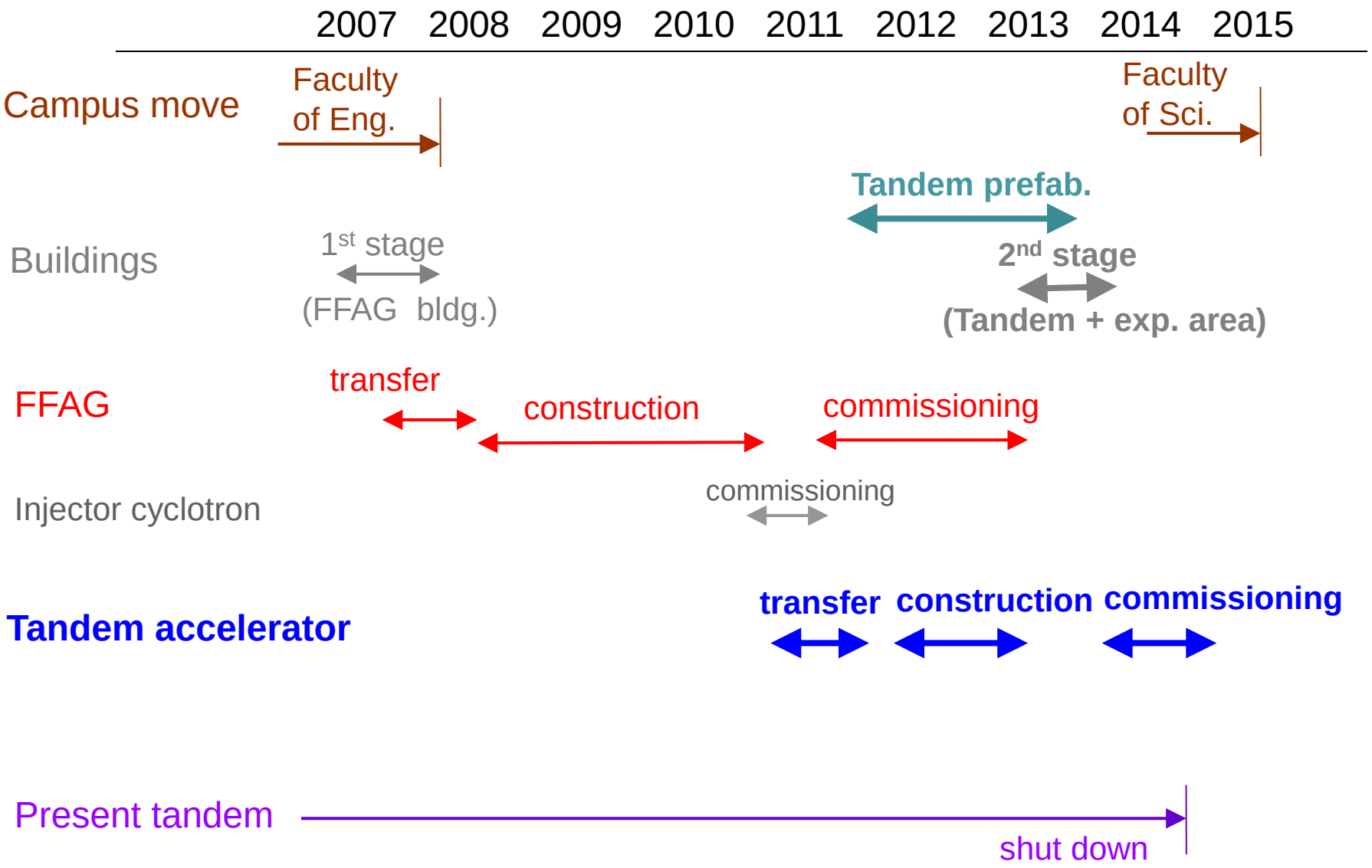
?th phase (not scheduled):
Experimental apparatus
for FFAG experiments



1.5th phase:
Tandem accelerator
(from Kyoto Univ.: 2011-2014)

2nd phase: (recently scheduled)
Experimental area and
apparatus for Tandem experiments
(campus movement of Faculty of Sci. 2013-2015)

Construction schedule



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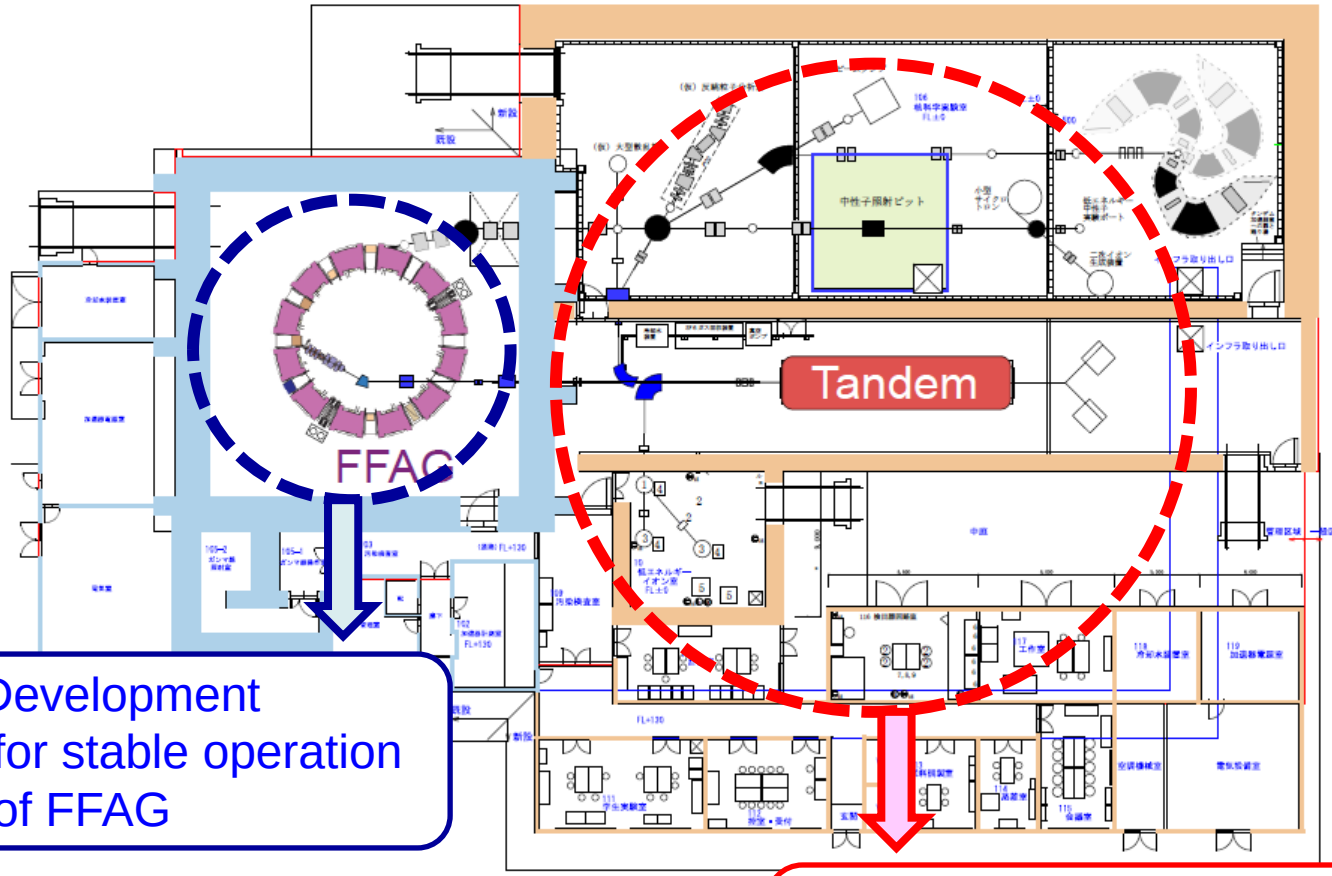
Uses and requirements

① Early stage



Development
for stable operation
of FFAG

Separate use of tandem-beams

- Astro-nuclear physics
- AMS etc.

② General uses of FFAG-tandem system

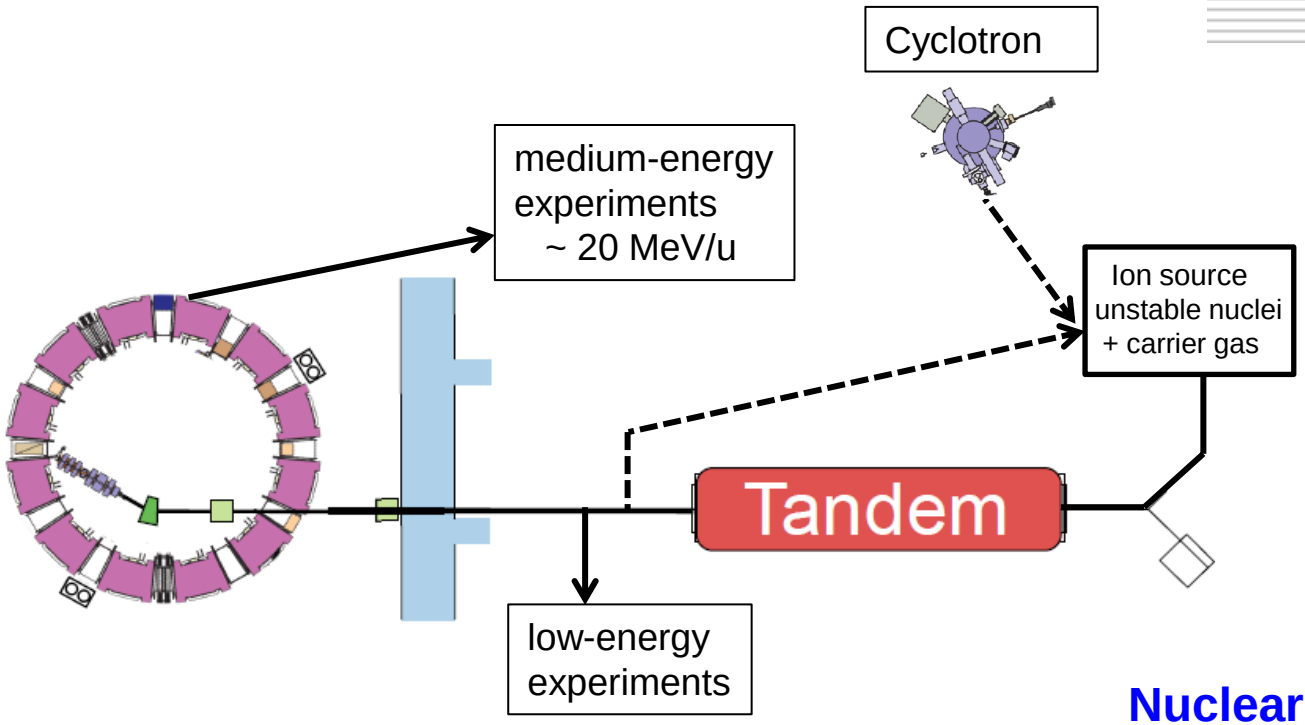
Requirements :

- Moderate intense beam, at least

  - Matching of FFAG (AC) and tandem (DC) is required.
  - One way is to use pulsed ion sources.
    (100 Hz of FFAG beams is much faster
    than the time-constant of the tandem terminal.)

- Slow extraction
  - Essential for nuclear-scattering experiment.

③ RI production and acceleration



Produced RI (life > 1 min)

t, ^{7}**Be,** ^{10}**Be,** ^{11}**C,** ^{14}**C,** ^{13}**N,** ^{15}**O,** ^{17,18}**F, ...**

Accelerator and production reactions:

10 MeV cyclotron (p,n) reactions,

8MV tandem accelerator (p,n), (d,X) reactions

Nuclear spectroscopy by Low energy resonance and transfer reactions.

Unstable nuclei

Astro-nuclear phys.

・systematic studies

・technical developments

Requirement for RI acceleration or AMS

- Almost 100% injection of DC beams

  ← Charge exchange injection with ionization cooling

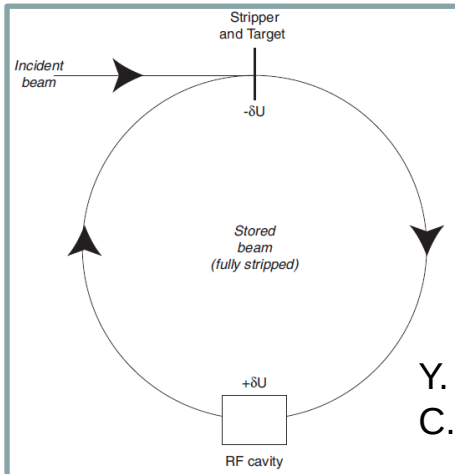
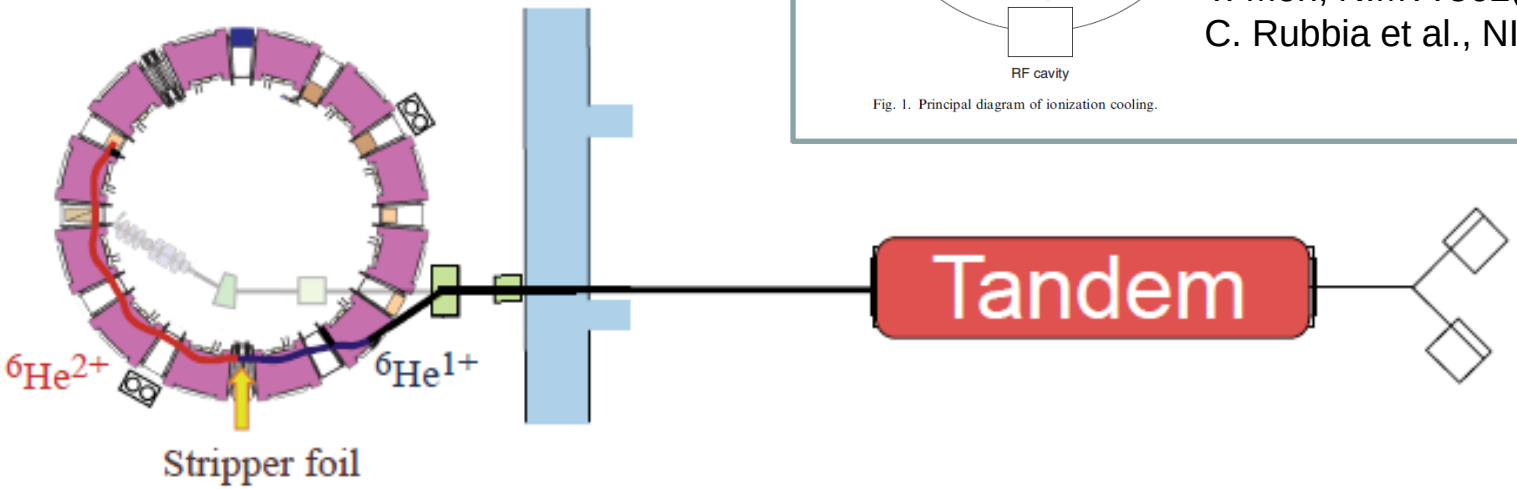


Fig. 1. Principal diagram of ionization cooling.

Ionization cooling :

Compensation of longitudinal energy-loss in a foil by RF acceleration

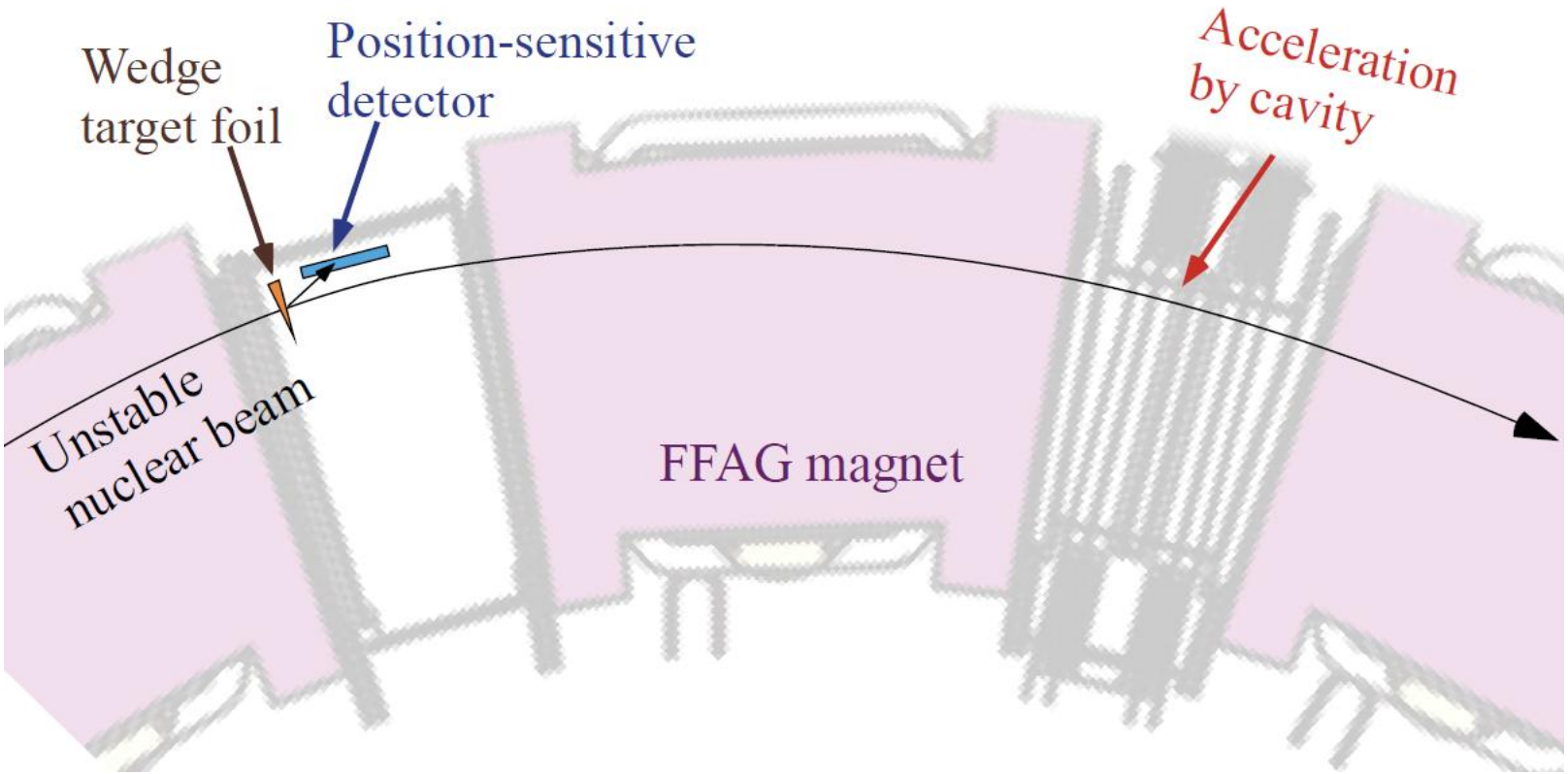
Y. Mori, NIM A 562(2006)591.
C. Rubbia et al., NIM A 568(2006)475.



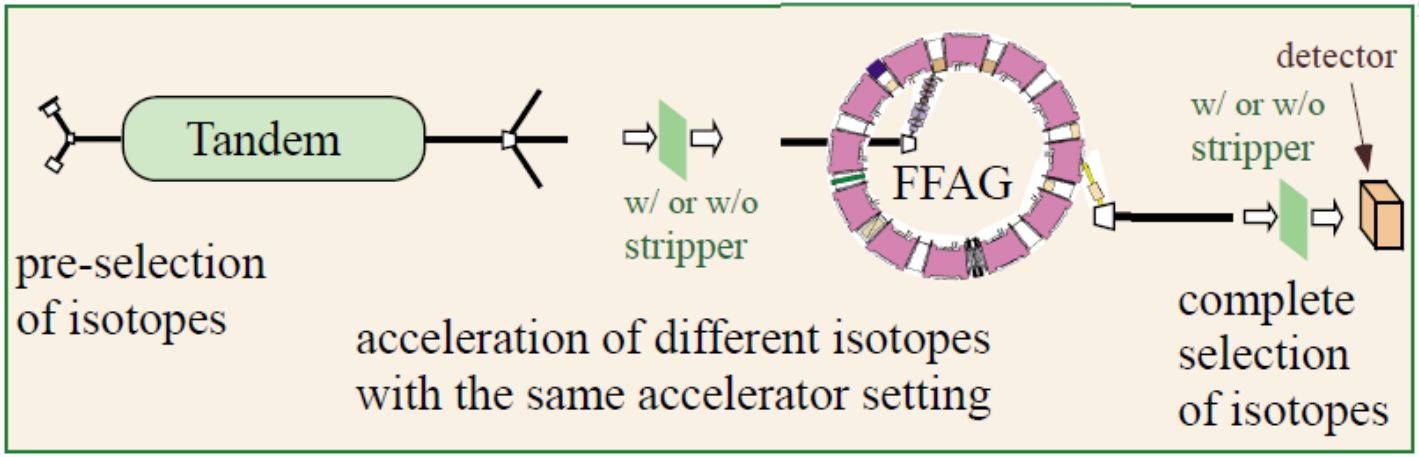
(Ray-tracing by Miyaoki)

③’ Internal target experiment with ionization cooling

- Luminosity is drastically increased
  by 3-dimensional cooling using a wedge target



④ AMS with post-acceleration



e.g. ^{36}Cl 350MeV Full-strip ion beam with 2.5% efficiency*
or 12+ ion beam with 10% efficiency*

^{41}Ca 400MeV 13+ beam with 10% efficiency*

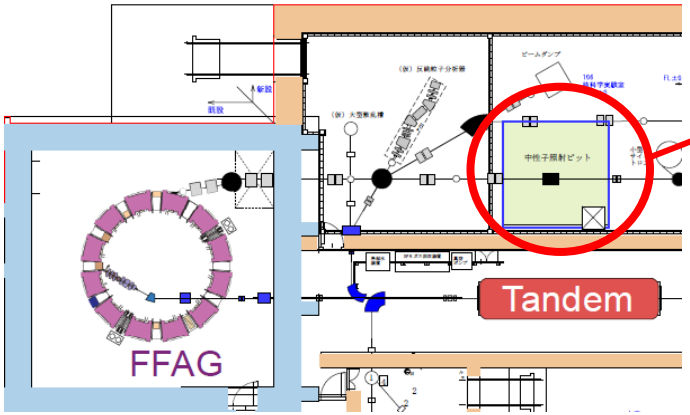
*Except FFAG efficiency

Advantage:
- Easy isotope separation for heavy elements

Subjects
- Archeology, Earth science, Life science, ...

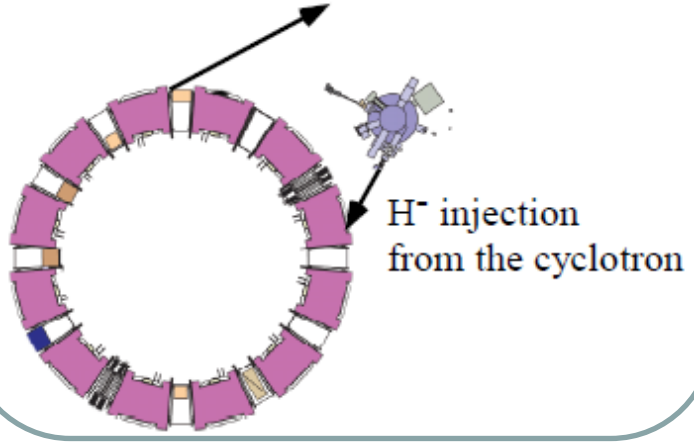
Requirement to accelerator
- Acceleration of different isotopes with same parameters
- Charge-exchange injection with ionization cooling

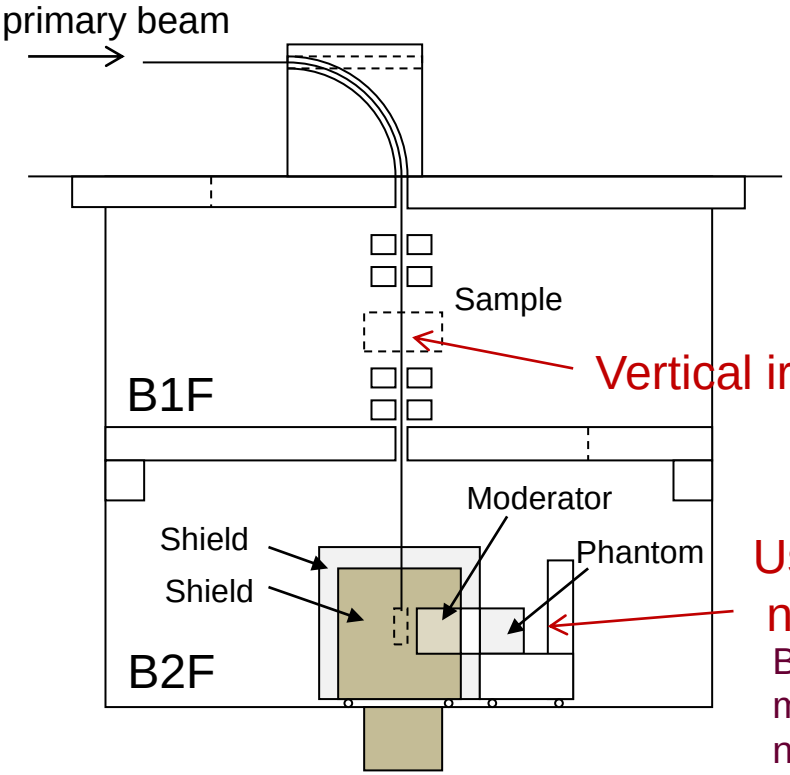
⑤ Irradiation of vertical beams and neutrons



8m deep pit

Intense primary beams will be given by negative-ion injection





Vertical irradiation

Use of spallation neutrons

BNCT
material science
nuclear data etc.

Brief summary

- A FFAG-tandem accelerator facility is under construction

  Construction of the tandem building and movement of Hakozaki facility was decided recently.

- Many kinds of development works and challenges are required for full use of the facility

I would like to thank Mori-san and other accelerator people for their support.