Construction of the 6 MV Tandem Accelerator System for Various Ion Beam Applications at the University of Tsukuba

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UTTAC
Tandem Accelerator Center
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10 Sep. 2015
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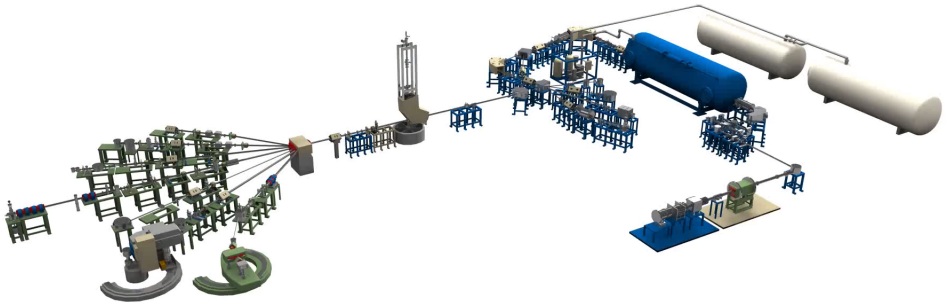

10 Sep. 2015
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Outline

1. Introduction

- UTTAC: University of Tsukuba, Tandem Accelerator Center 12UD Pelletron tandem accelerator
- Disaster Reconstruction Project for the Great East Japan Earthquake, 11 March. 2011.

2. Construction of the 6 MV Tandem Accelerator

- Repair of the facility
- Design and development of the 6 MV tandem accelerator
- Ion sources & Control system

3. Research projects

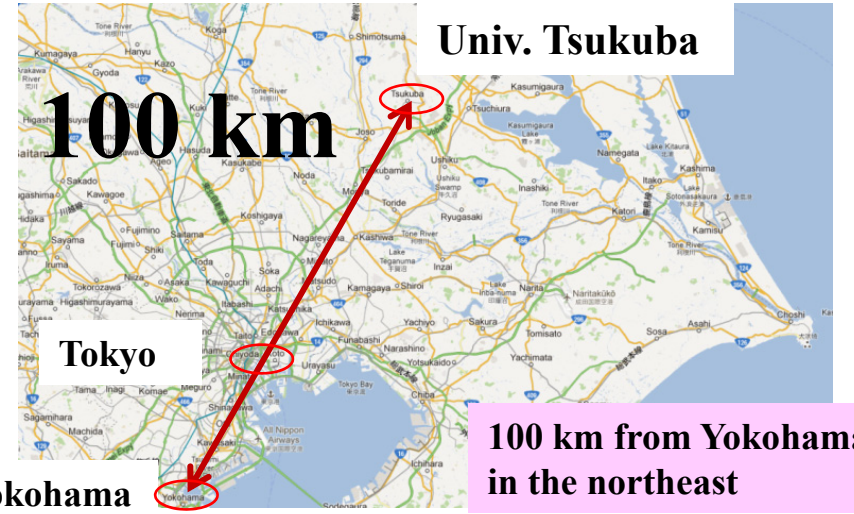
- Beam lines
- Ion beam applications

4. Summary

筑波大学 University of Tsukuba UTTAC

University of Tsukuba

Tsukuba science city

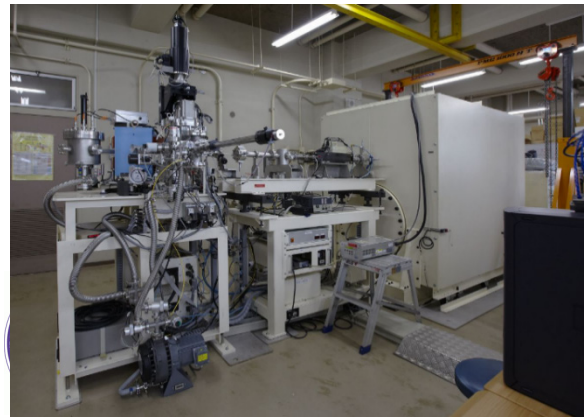


100 km from Yokohama in the northeast

University of Tsukuba,
Tandem Accelerator Center (UTTAC)

Major center of ion beam research in Japan

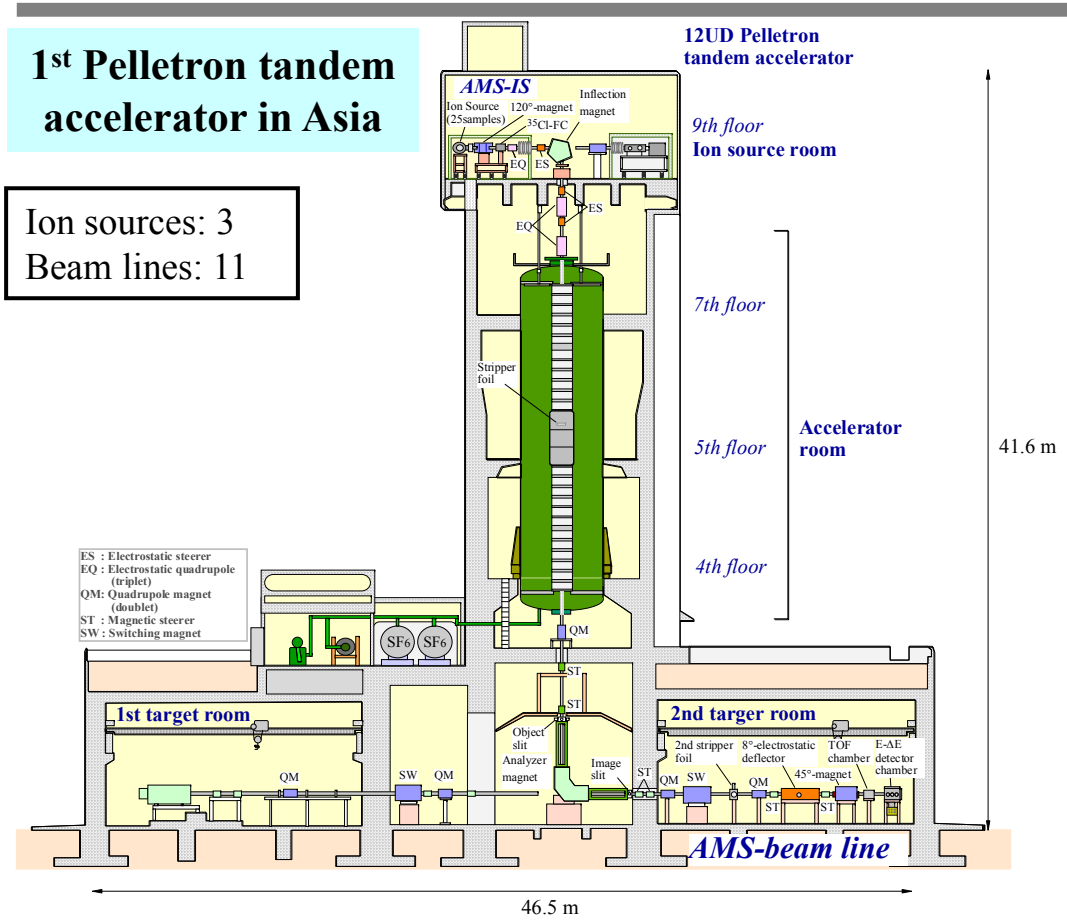
- 12UD Tandem (1975-2011)
- 1 MV Tandetron (1987)
- Positron accelerator (2012)
- 1 MV HR-RBS (2012)
- 6 MVTandem (2015)



12UD Pelletron tandem accelerator

1st Pelletron tandem accelerator in Asia

Ion sources: 3
Beam lines: 11



University of Tsukuba, Japan (1975-2011)

MODEL : Vertical Tandem Van de Graaff
Terminal voltage range: 2.0 - 12.0 MV
Insulation Gas : SF_6 pressure: 0.6 MPa
Accelerator Tank : Height: 17.9 m
Diameter: 4.8 m
Volume: 350 m^3
Total weight: 120 ton

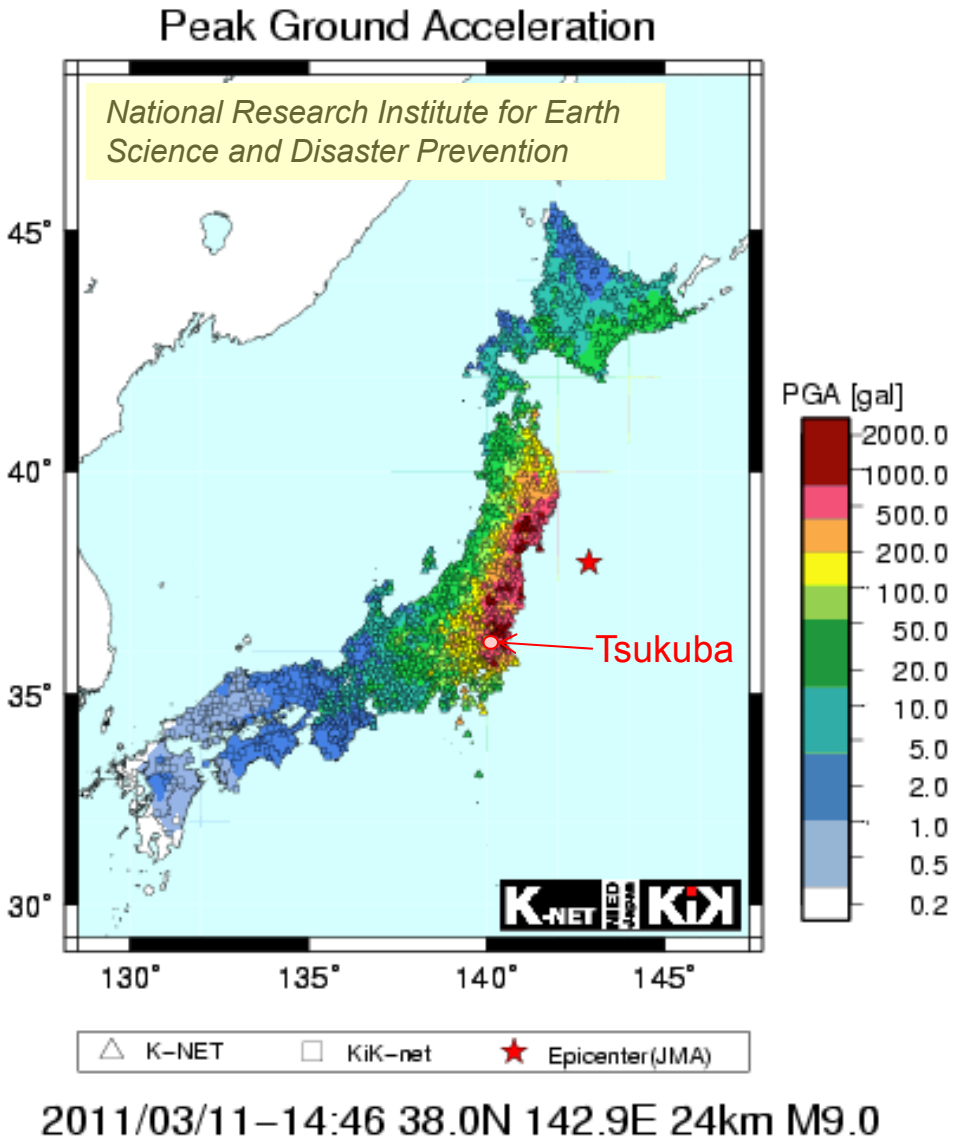
Acceleration column NEC, USA in 1975

12UD at Tsukuba University

大学
Tsukuba

Great East Japan Earthquake on 11 Mar. 2011

At 2:46 p.m. on March 11, 2011.
In Sanriku, Miyagi Prefecture.



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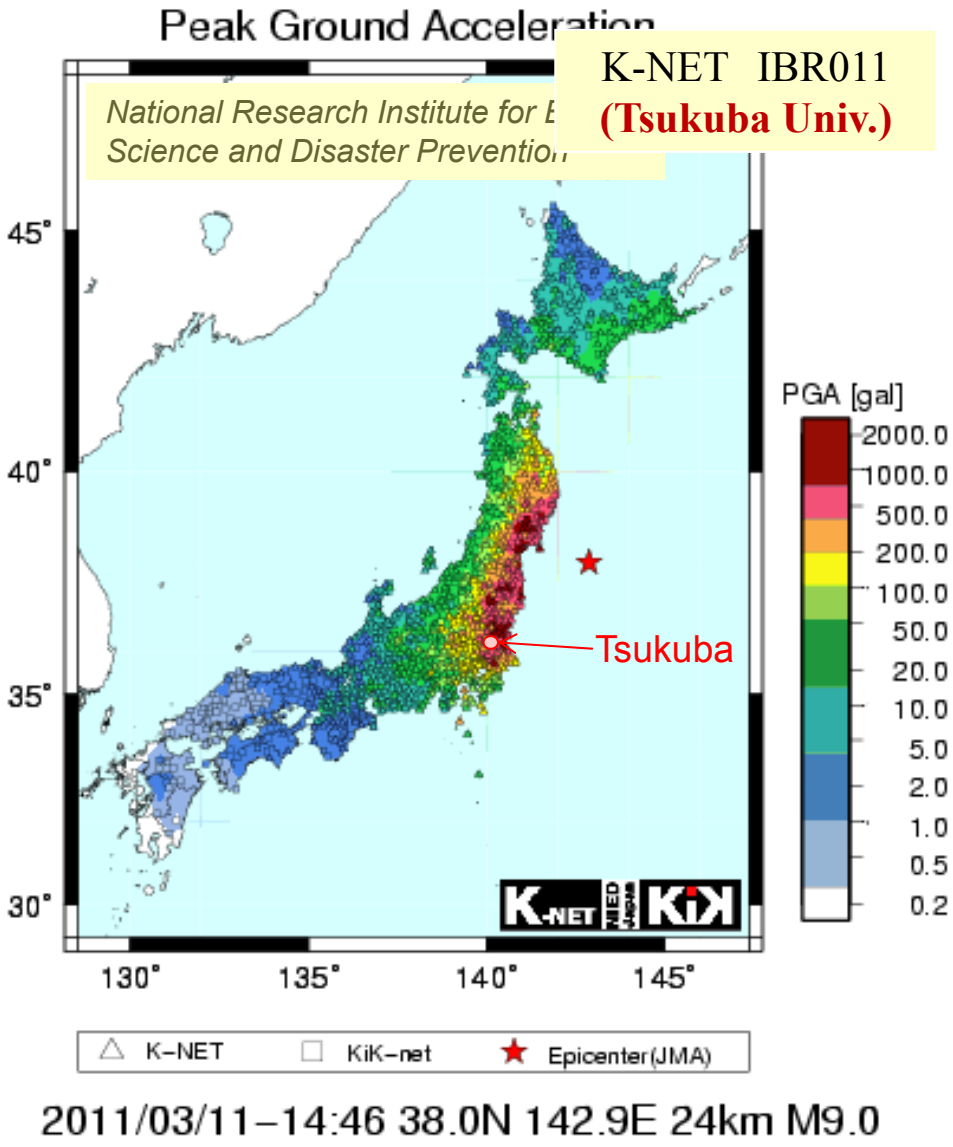
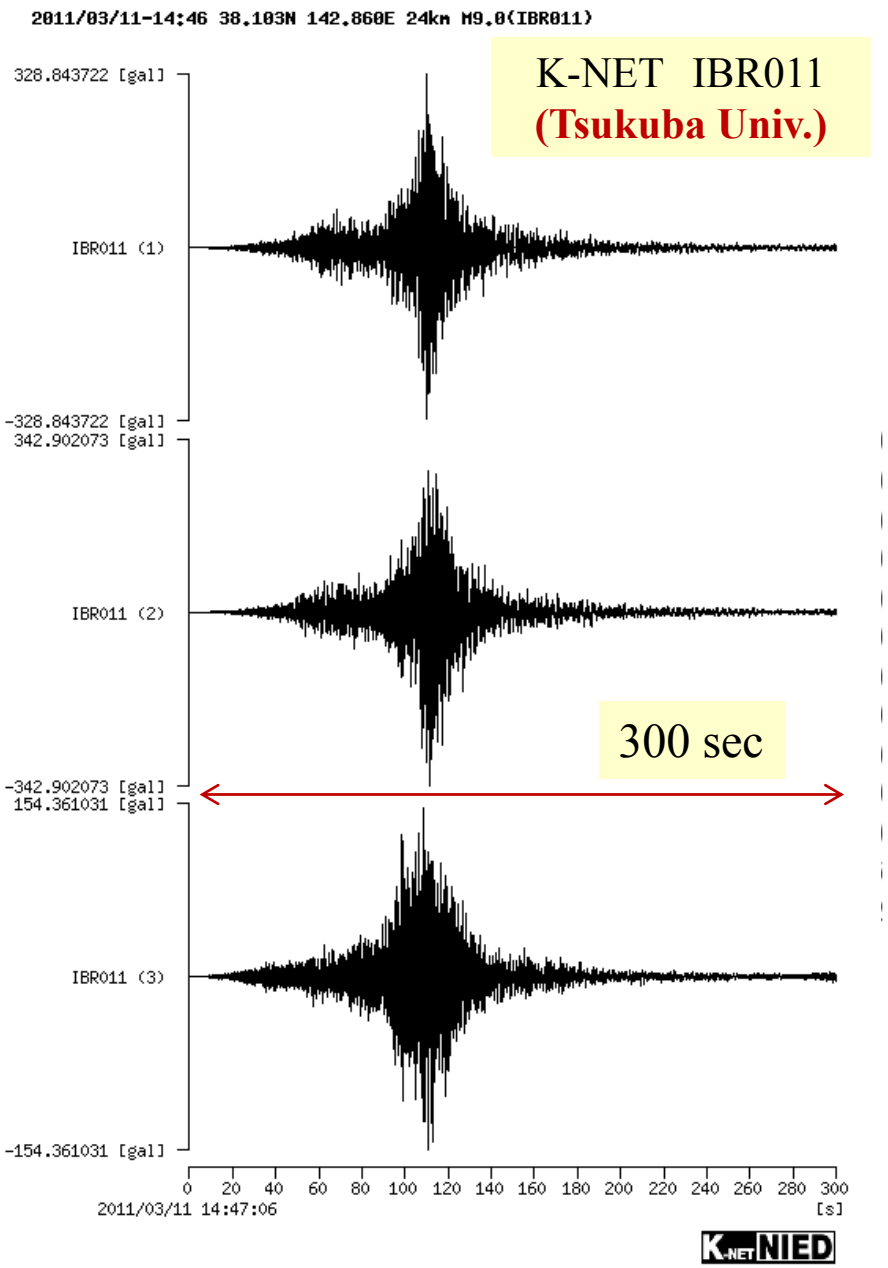


Great East Japan Earthquake on 11 Mar. 2011

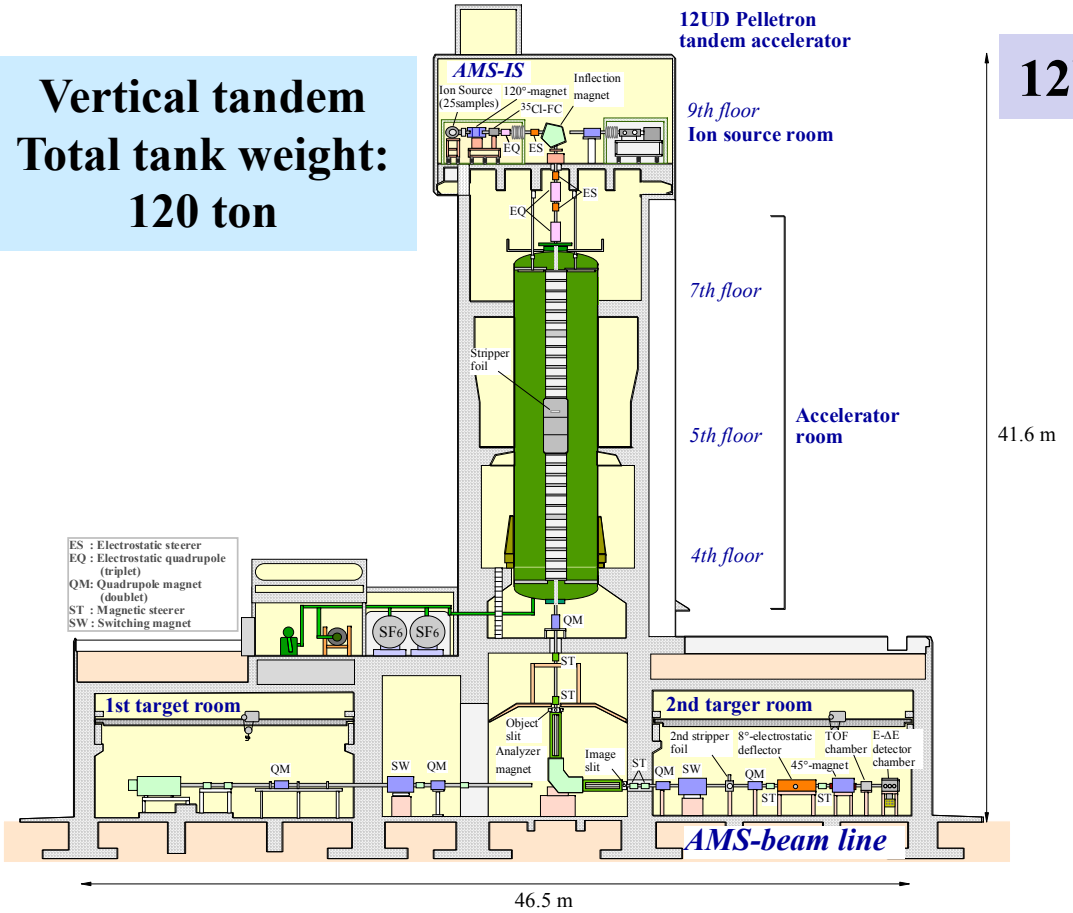
At 2:46 p.m. on March 11, 2011.
In Sanriku, Miyagi Prefecture.

Maximum acceleration:
371.7 cm/s^2 (gal)
at Univ. Tsukuba
Duration time: 300 sec.



Disaster situation of the Great East Japan Earthquake at UTTAC

Vertical tandem
Total tank weight:
120 ton



12UD Pelletron tandem accelerator

University of Tsukuba
UTTAC

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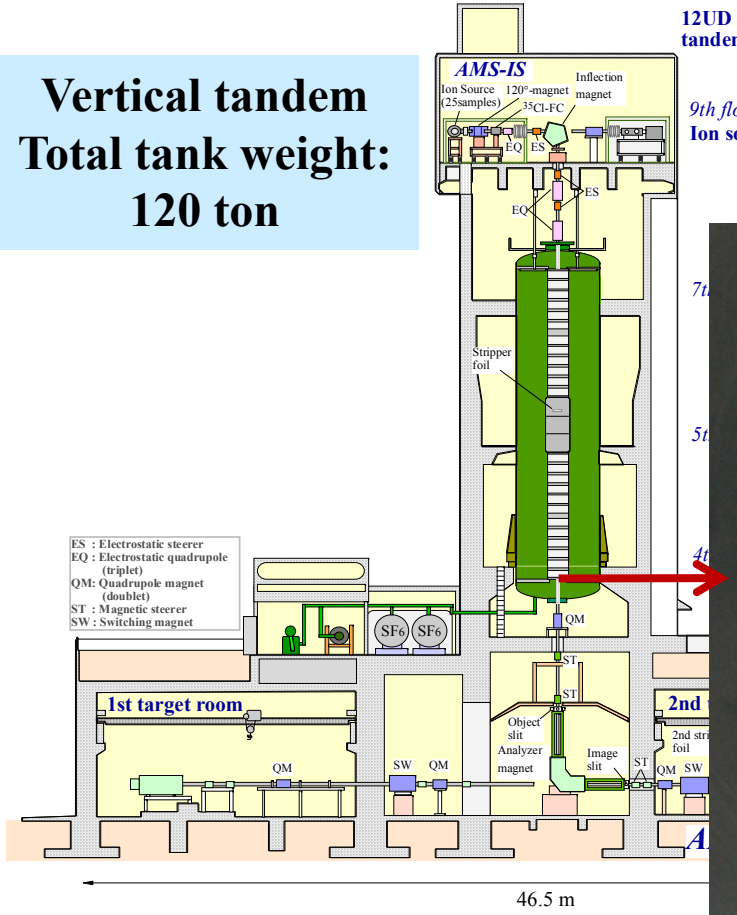

12UD Pelletron tandem accelerator

Collapsed accelerator column (Total weight: 10 ton)

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Disaster situation of the Great East Japan Earthquake at UTTAC

Vertical tandem
Total tank weight:
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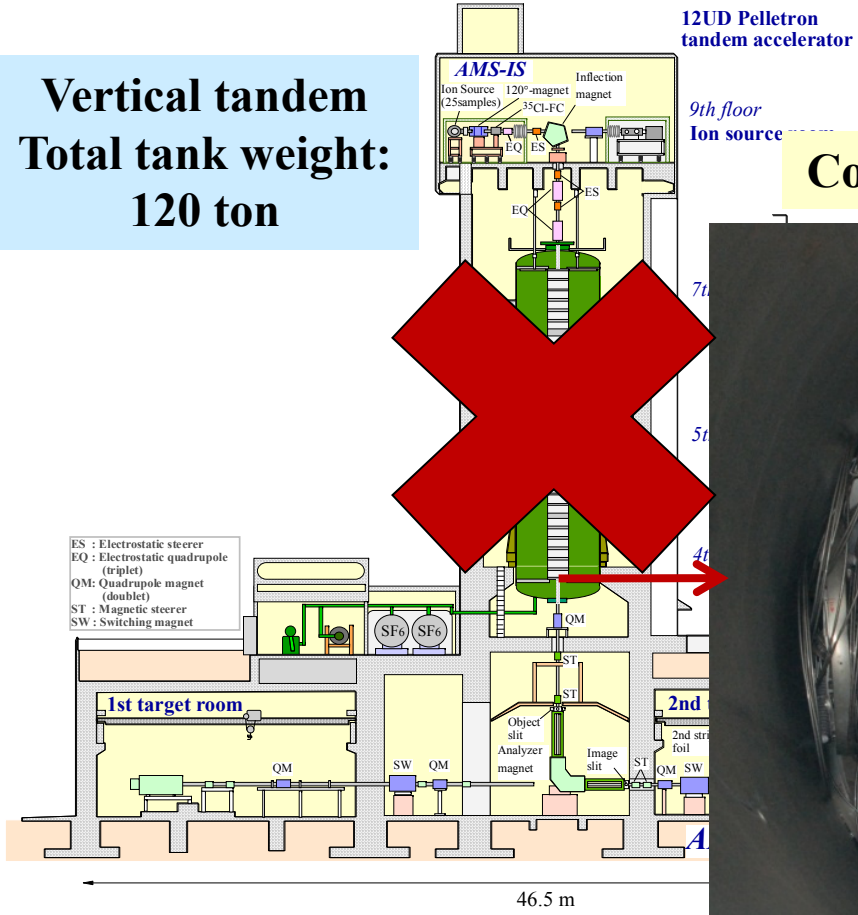

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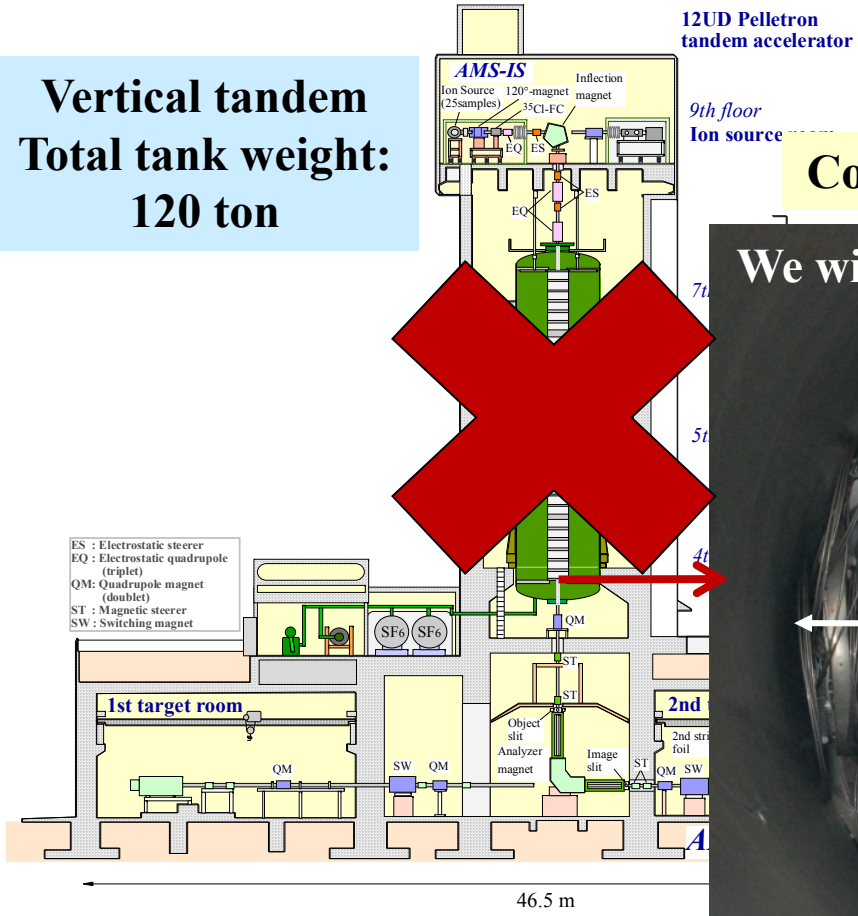

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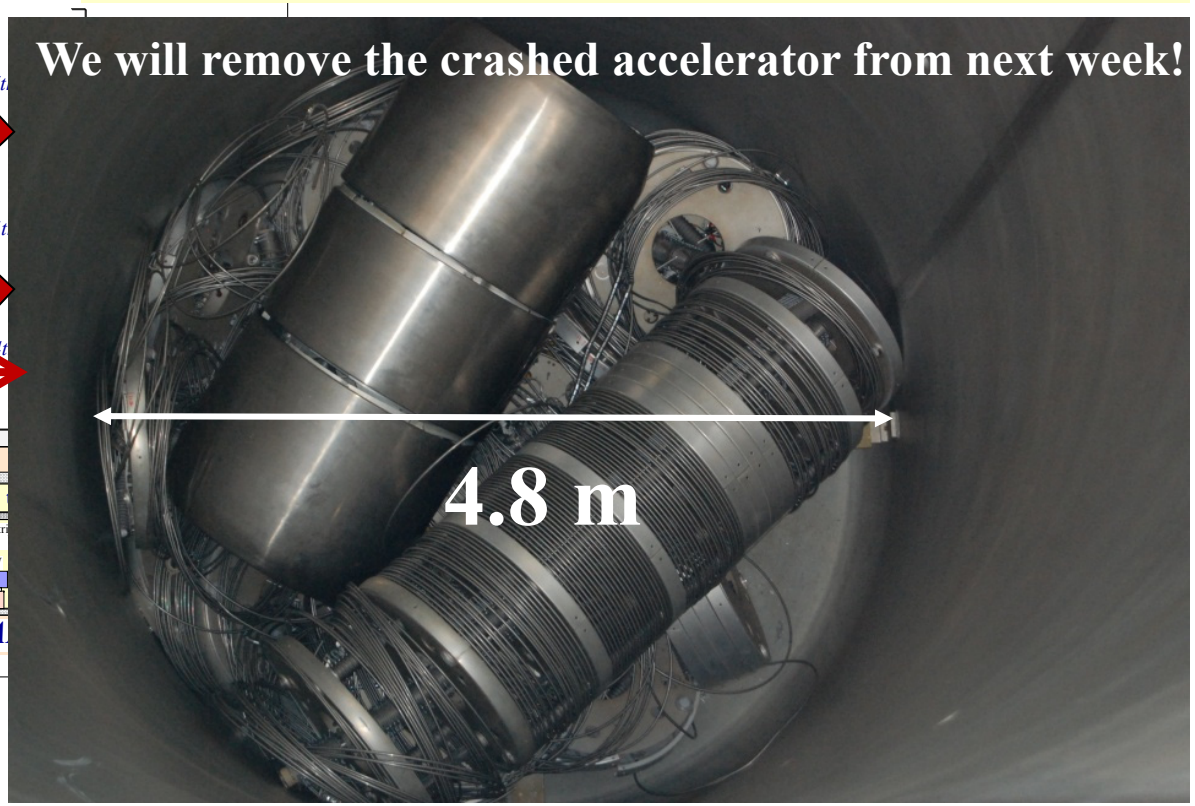

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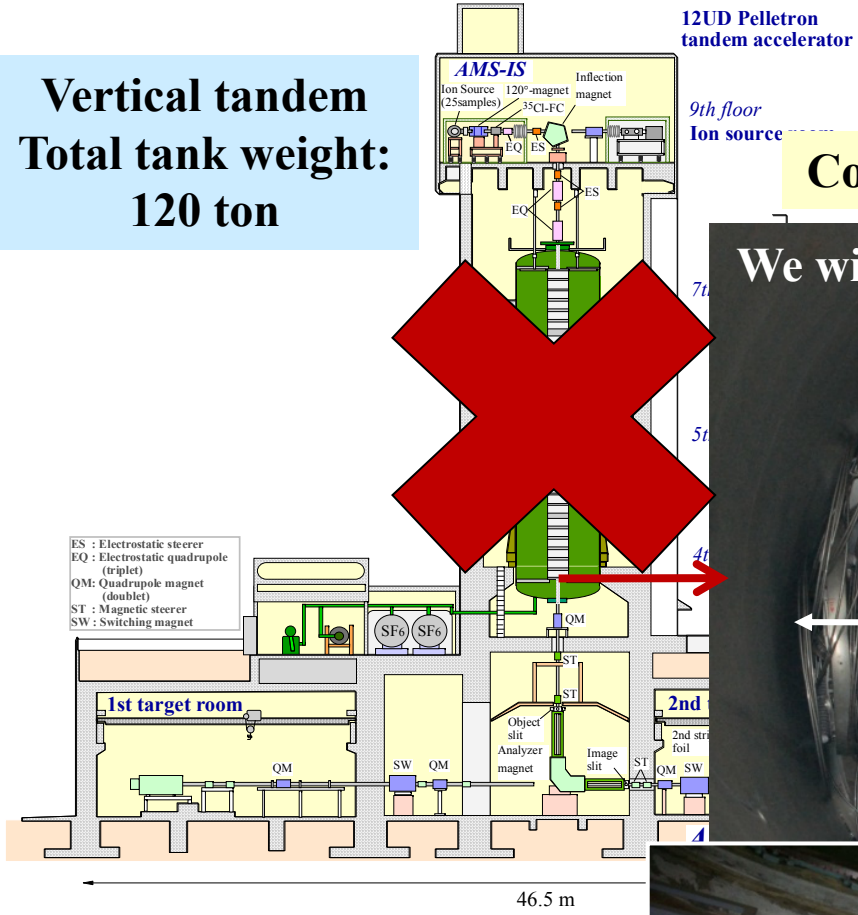

12UD Pelletron tandem accelerator

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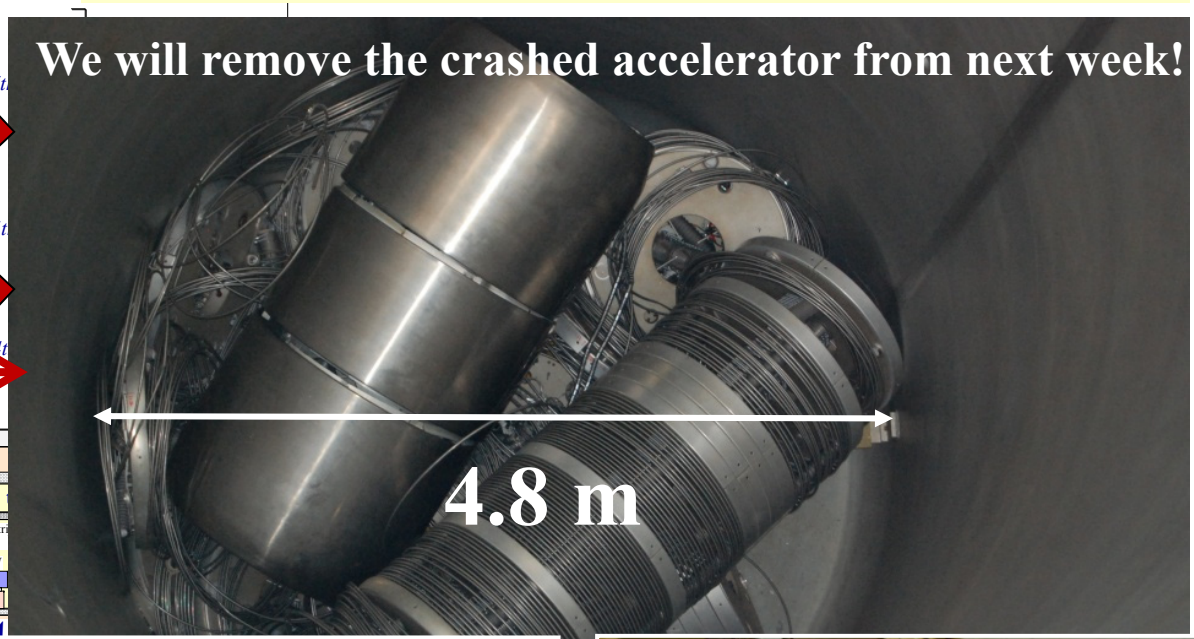

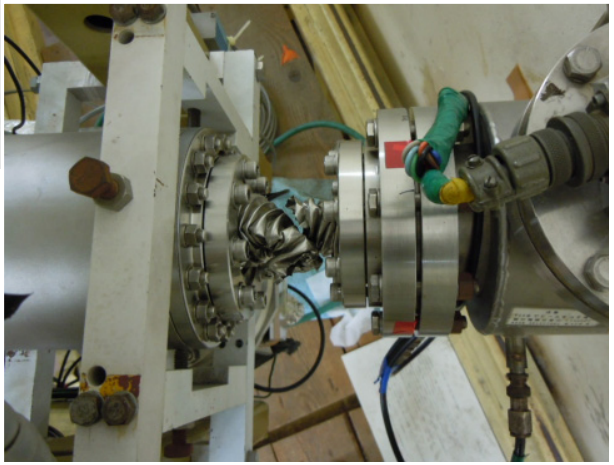

Disaster situation of the Great East Japan Earthquake at UTTAC

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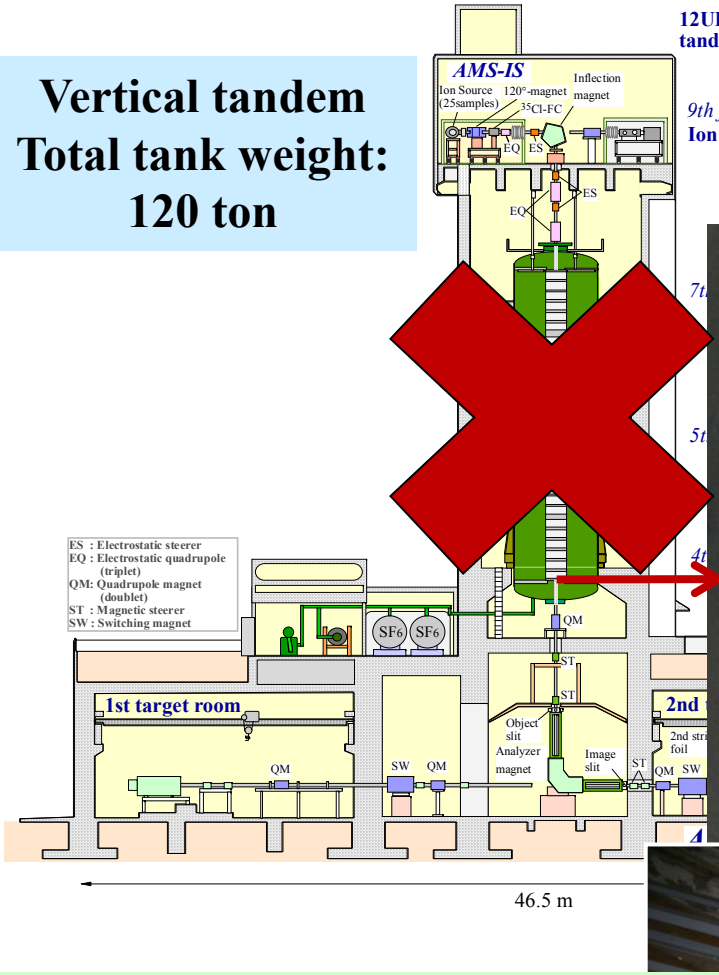
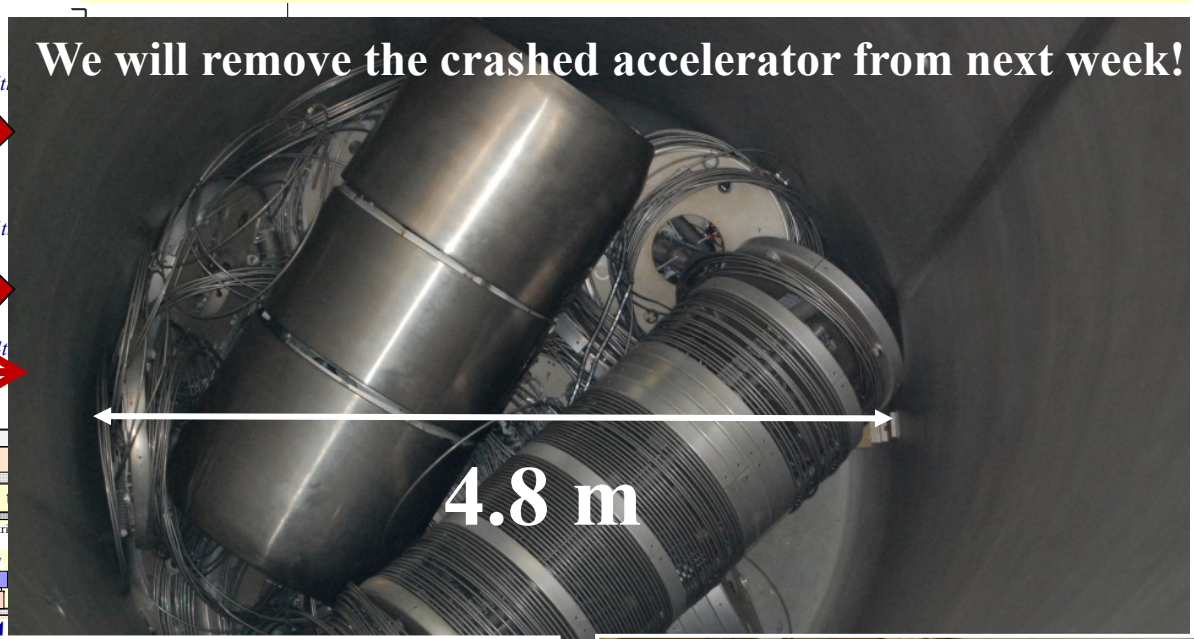
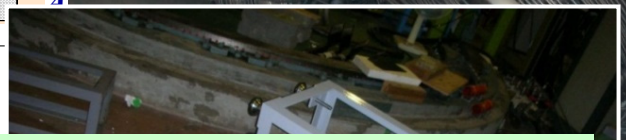
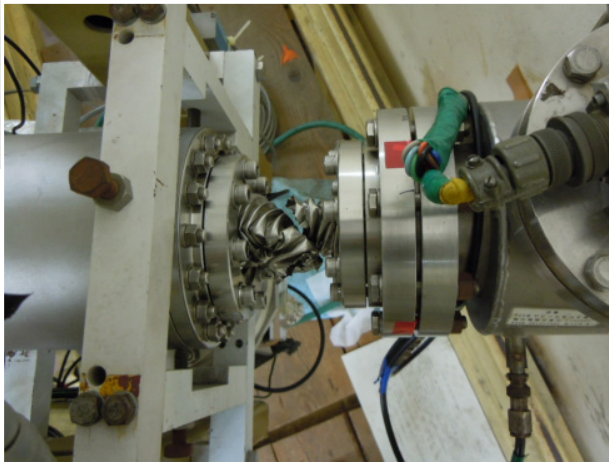


12UD Pelletron tandem accelerator

Collapsed accelerator column (Total weight: 10 ton)







- **Total financial damage at Univ. Tsukuba:**
  7 billion JPY ($ 58.5 million)
  including accelerator damage:
  1.2 billion JPY ($ 10 million)

Reconstruction project at UTTAC since 2011

We decided to shut down the 12UD Pelletron tandem in 2011.

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University of Tsukuba
UTTAC

Reconstruction project at UTTAC since 2011

We decided to shut down the 12UD Pelletron tandem in 2011.

System design concept of the new accelerator

- **Multi-purpose tandem accelerator**
  - **Nuclear physics: Low energy nuclear reaction, nuclear astrophysics etc.**
  - **Ion beam applications: AMS, IBA, Ion irradiation, etc.**
- **Horizontal middle-sized tandem accelerator**
- **Reusing of existing infrastructures, beam lines and Polarized ion source**
- **New dedicated AMS system**
  - **Radionuclide-AMS: ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, ^{129}I etc.**
  - **Especially for ^{36}Cl.**

6 MV Pelletron tandem accelerator

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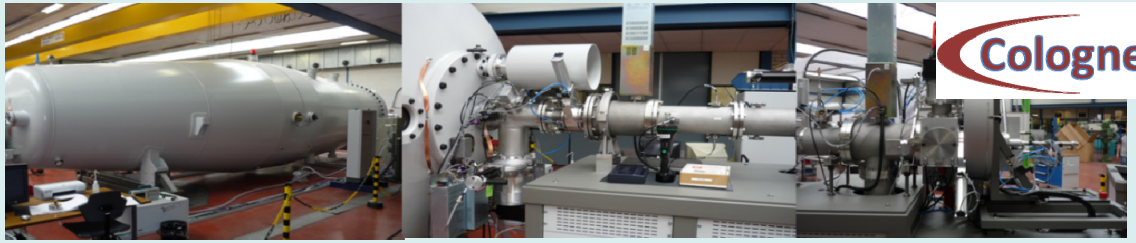
Advanced large electrostatic accelerators in the world

6 MV tandem accelerator for AMS & ion beam analysis (IBA) from the 2010s onward

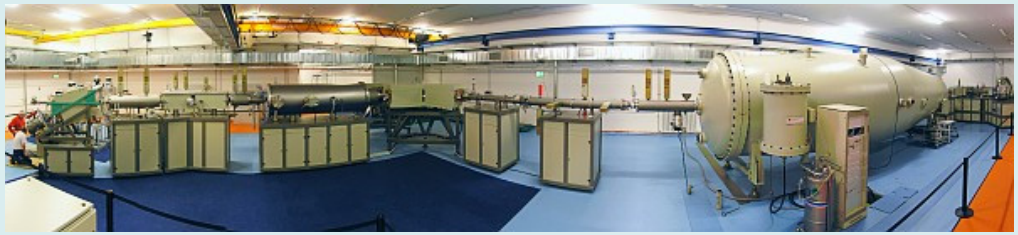
A new HVEE 6 MV AMS system at the University of Cologne, Germany



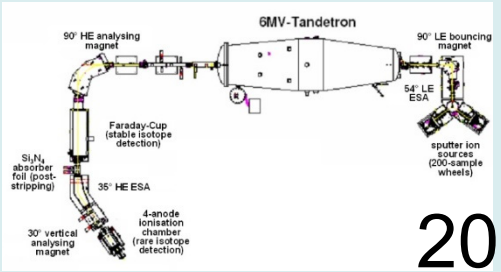
CologneAMS — University of Cologne - Centre for Accelerator Mass Spectrometry

AMS 2011

The 6 MV DREsden AMS facility: DREAMS HZDR-AMS, Germany



AMS



2012

6-MV KIST Tandem Ion Accelerator
Korea Institute of Science and Technology (KIST), Korea

2012 **AMS & IBA**

ANSTO :
Australian Nuclear Science and Technology Organisation
The 6MV SIRIUS Tandem Accelerator

2015 **AMS & IBA**

2. Construction of the 6 MV Tandem Accelerator system

- Repair of the facility
- Design and development of the 6 MV tandem accelerator
- Ion sources & Control system

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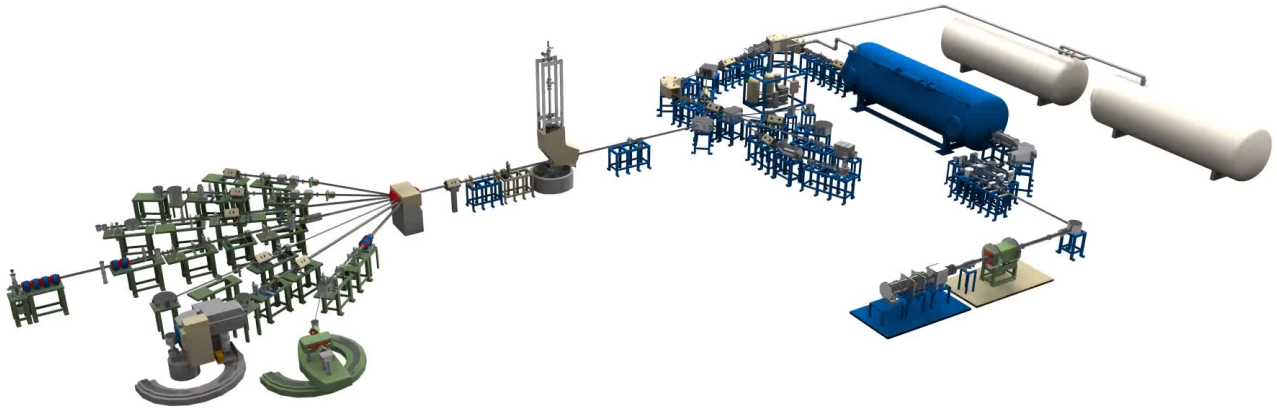
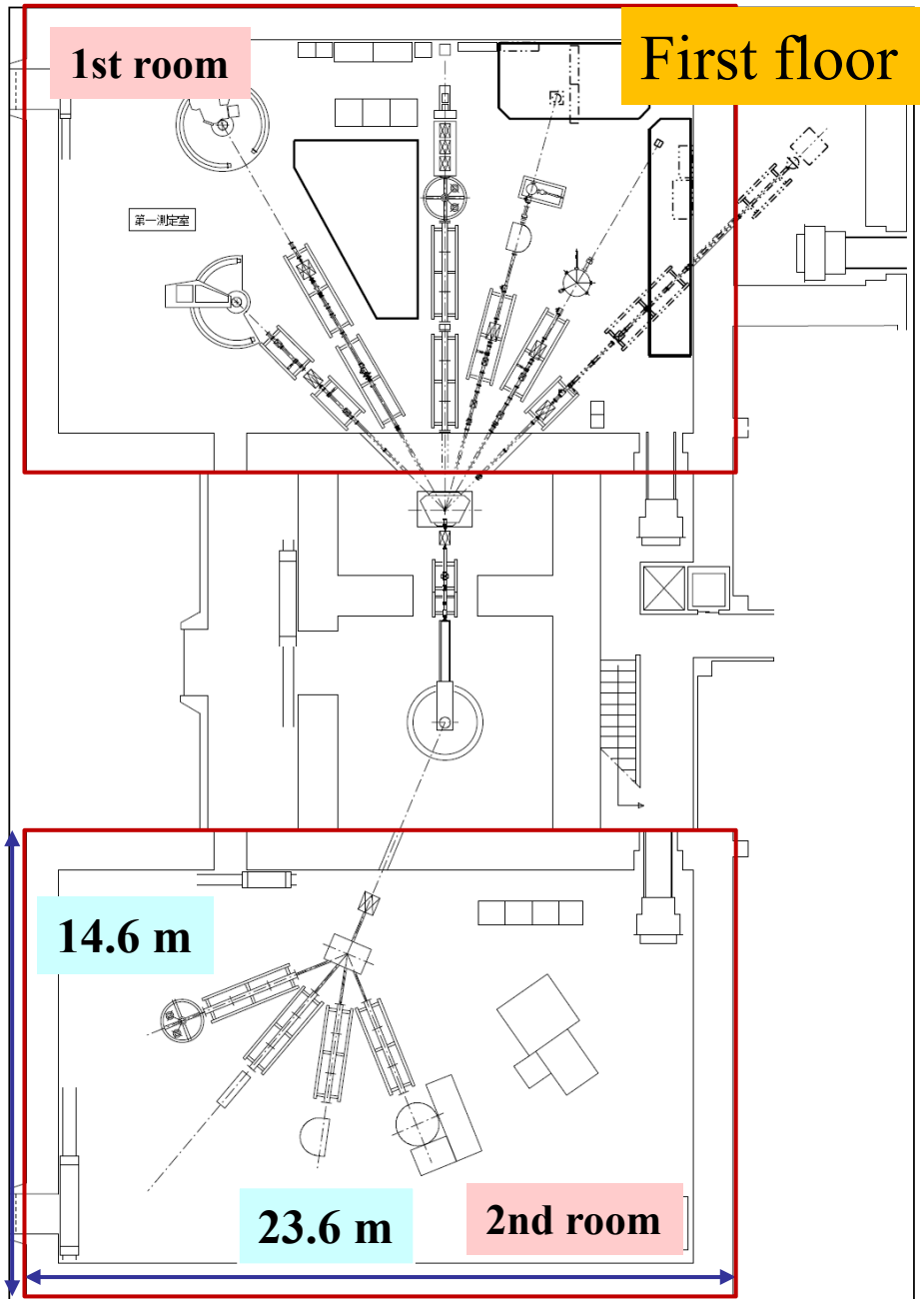


Repair of the facility



Past layout

2 experimental rooms:
$23.6 \times 14.6\ m^2$

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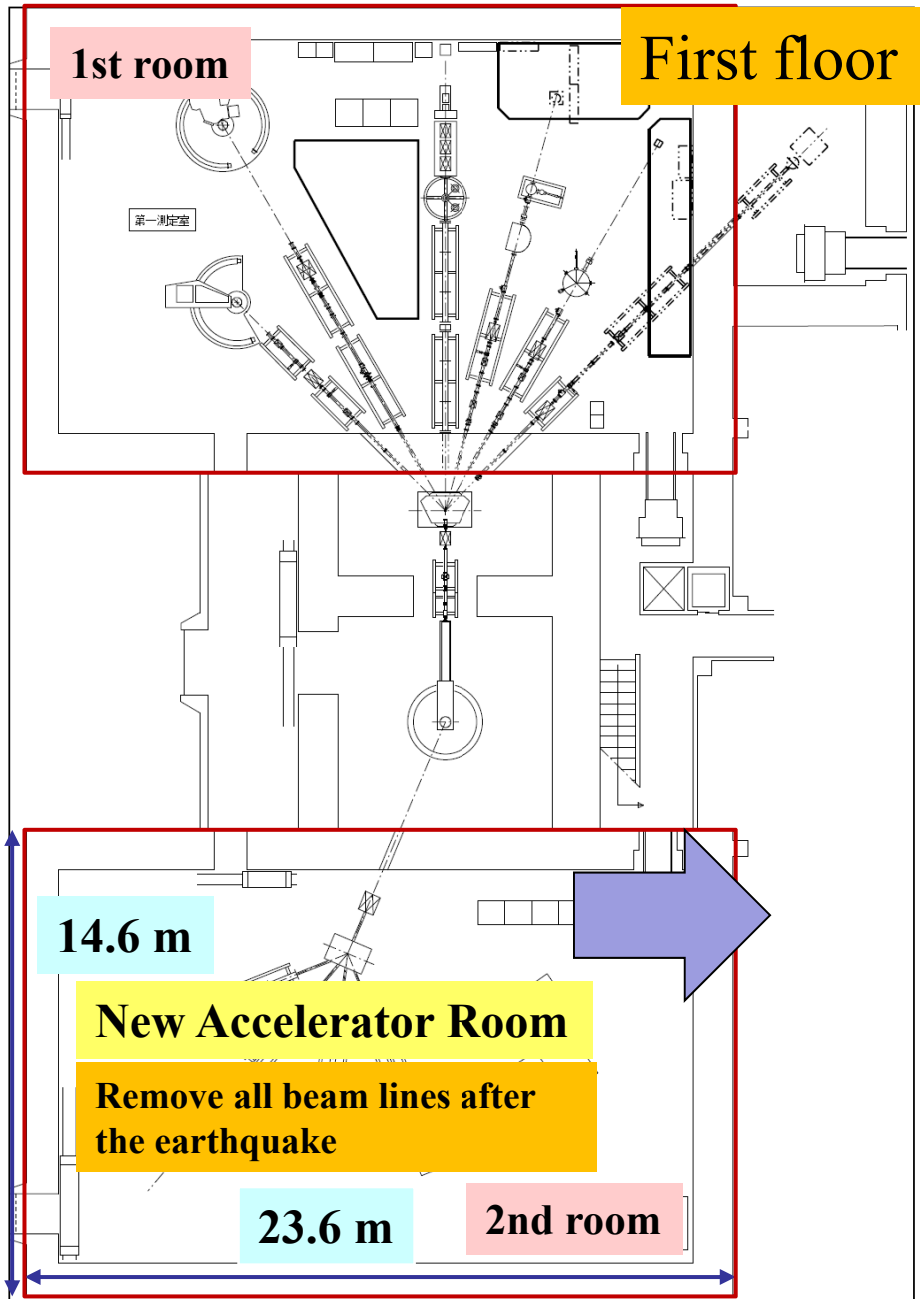
Repair of the facility



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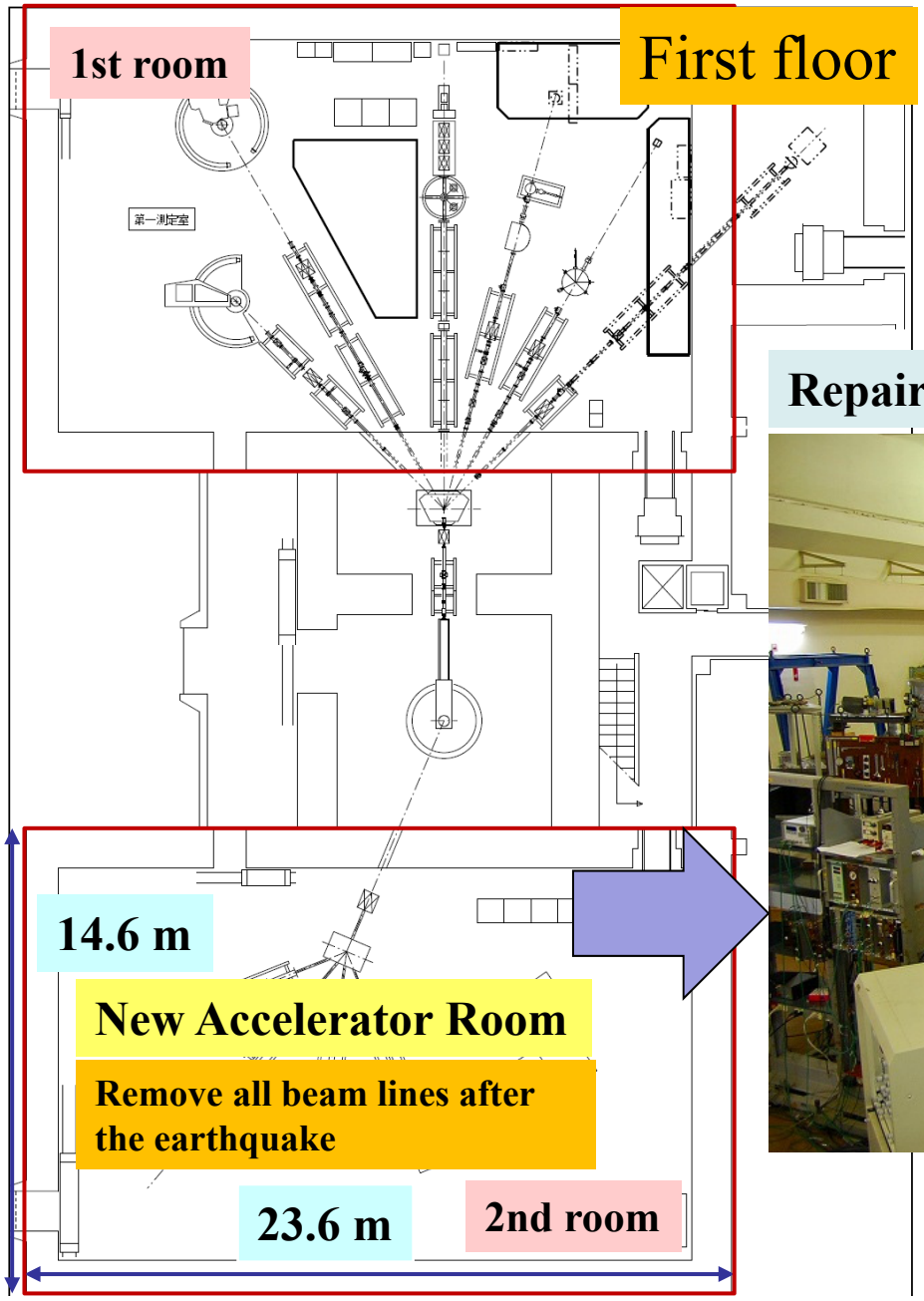

Past layout

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Repair & relocation

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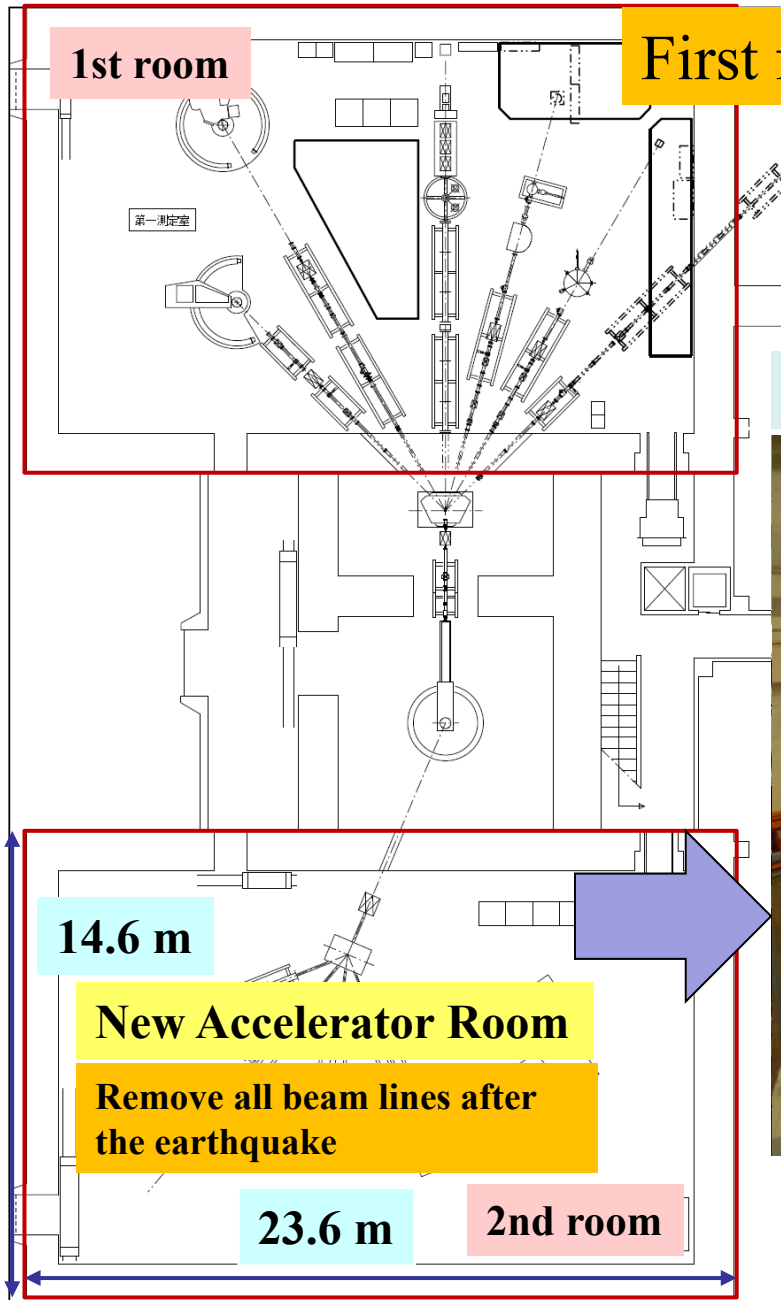
Repair of the facility



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Repair & relocation

University of Tsukuba
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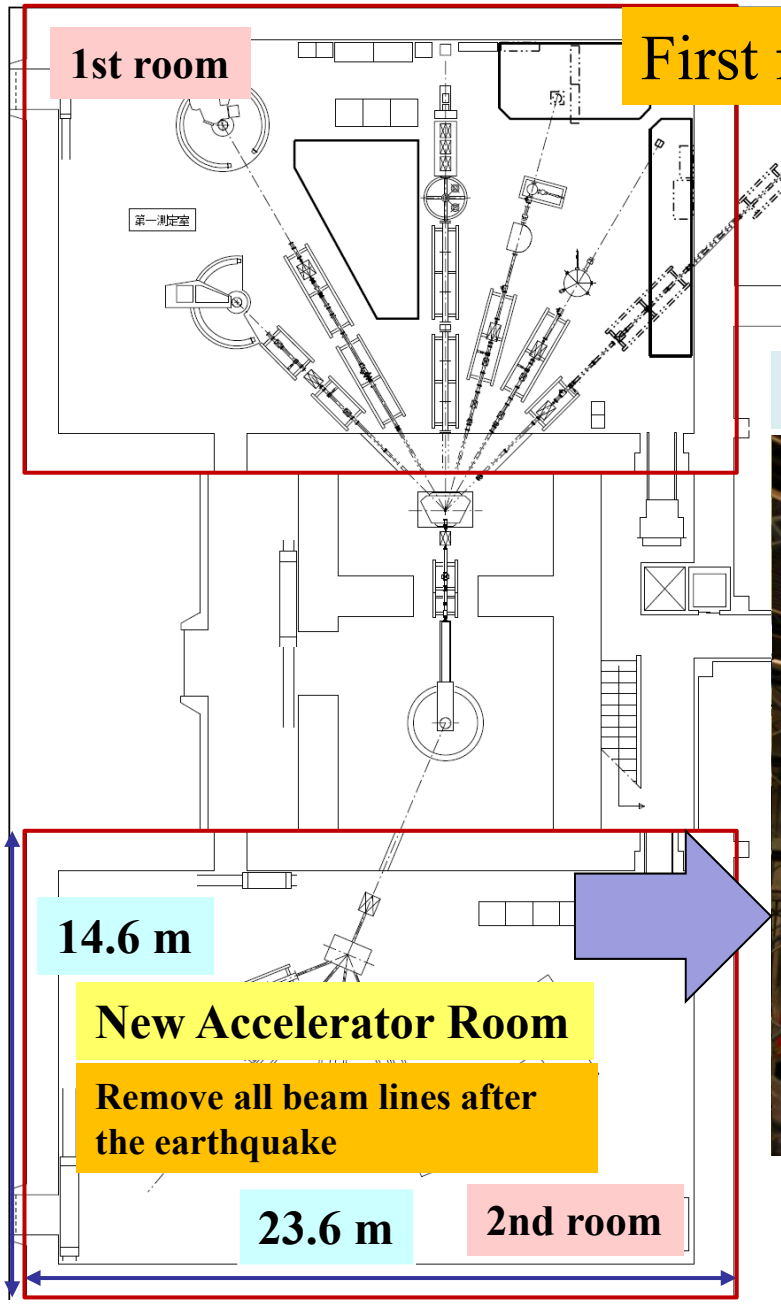
Repair of the facility



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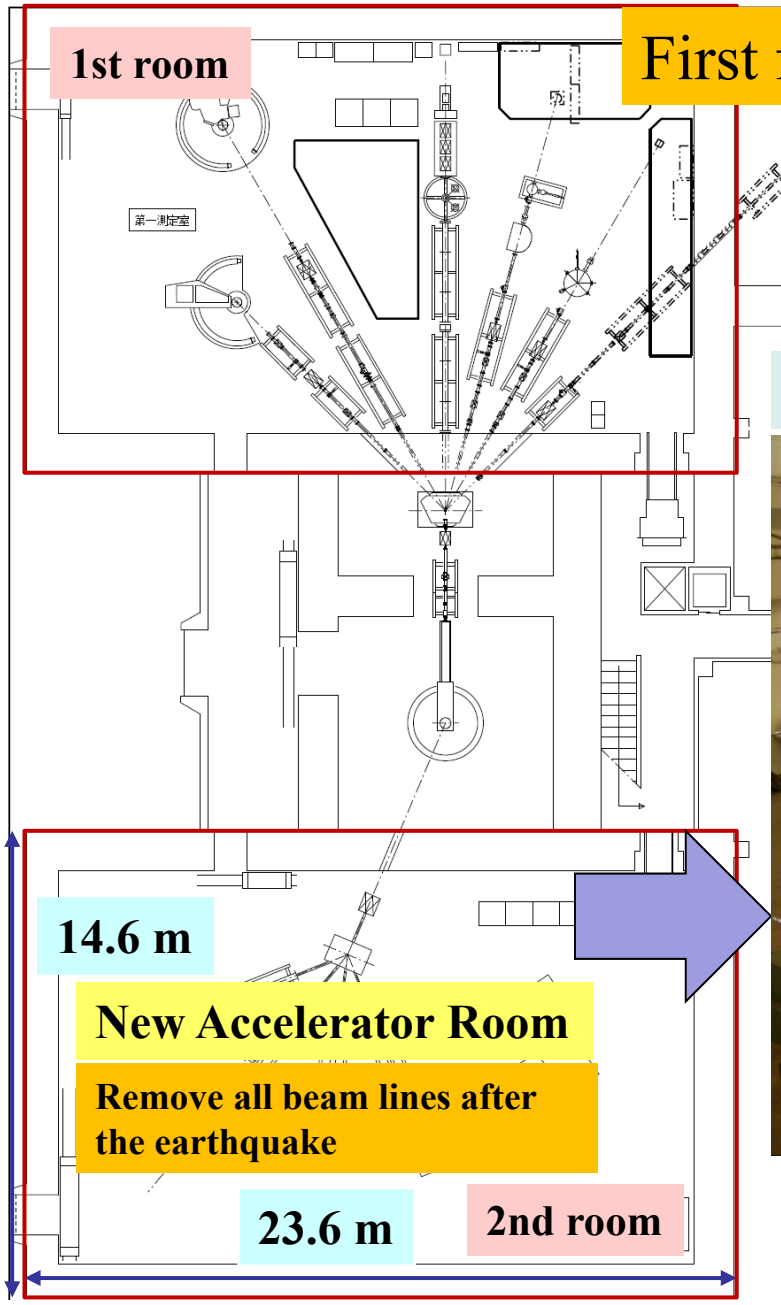
Repair of the facility



Past layout

2 experimental rooms:
$23.6 \times 14.6\ m^2$

Repair & relocation

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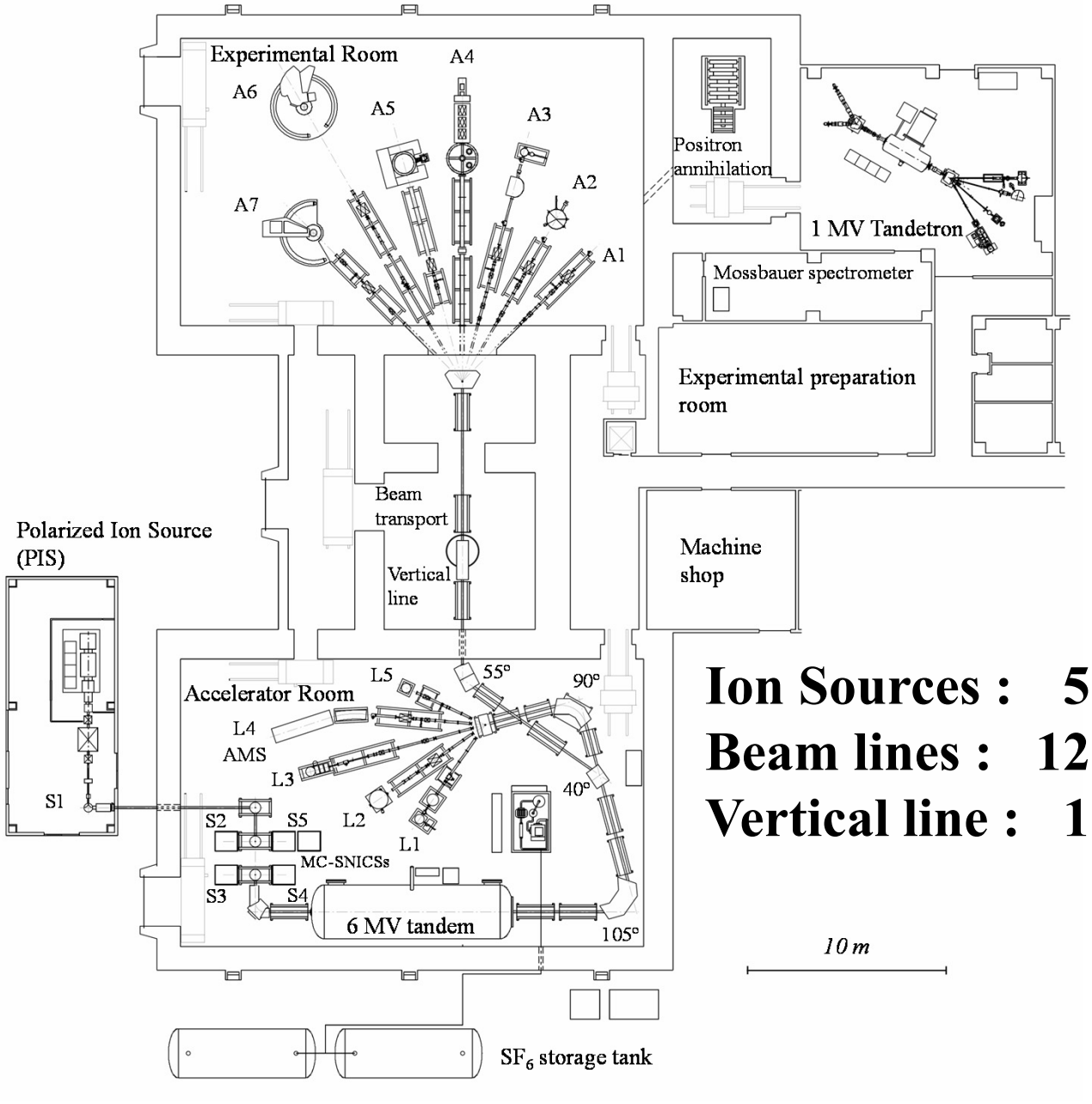
Accelerator room
Mar. 2013

Design of the 6 MV tandem accelerator system



Ion Sources : 5

Beam lines : 12

Vertical line : 1

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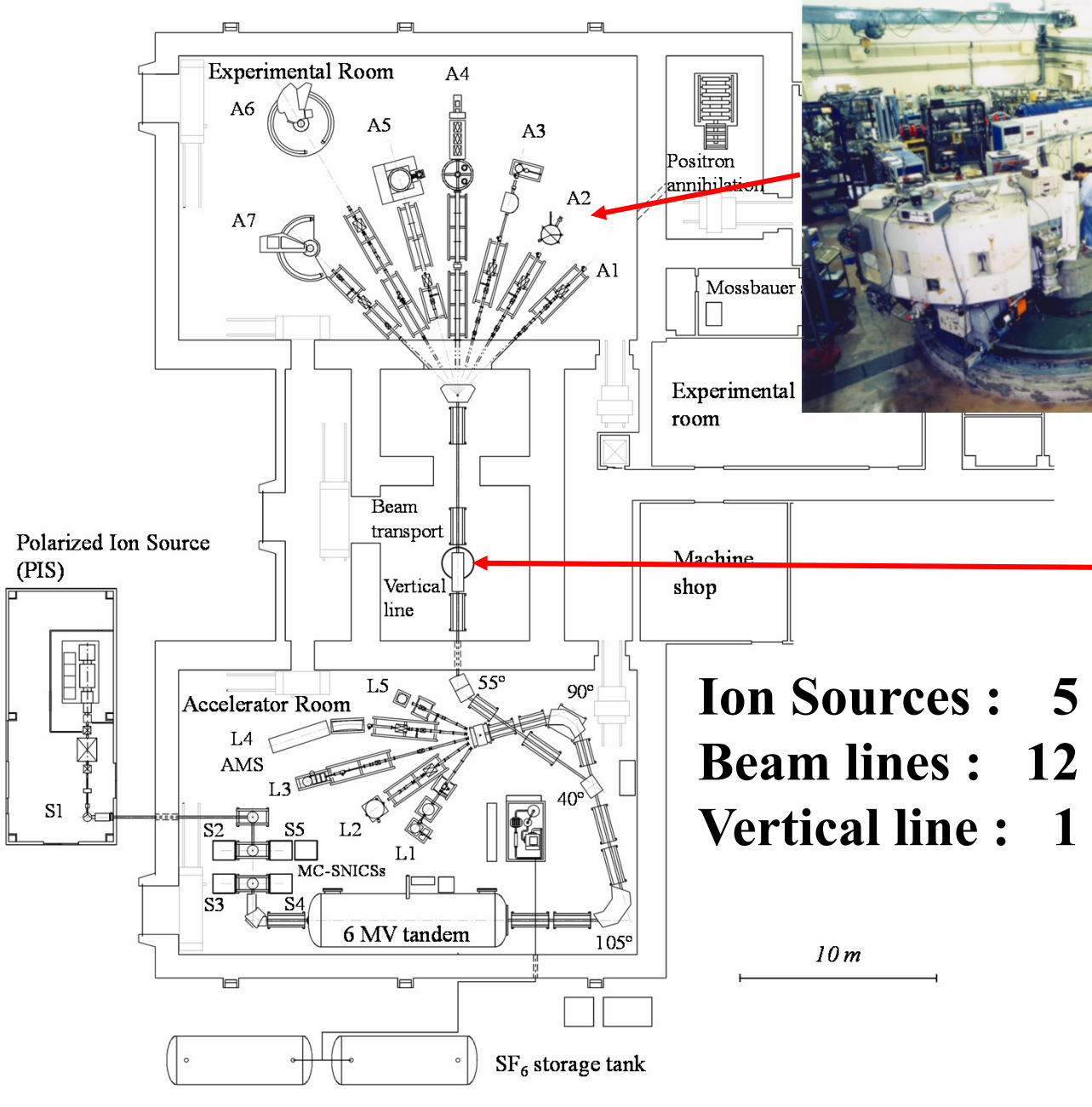
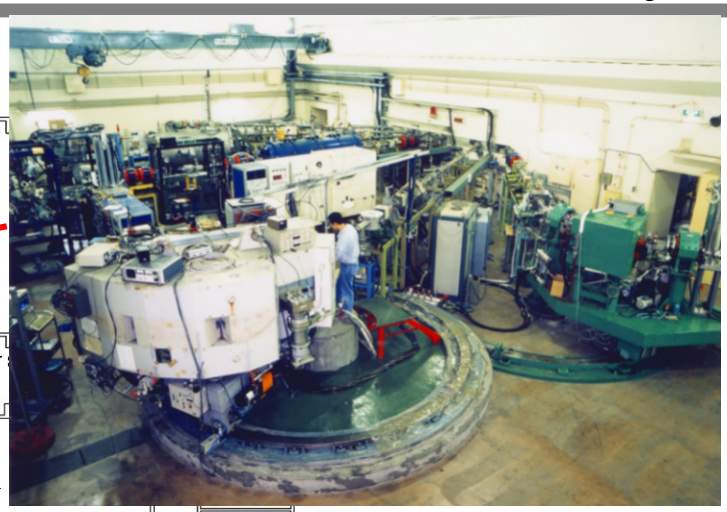
Design of the 6 MV tandem accelerator system





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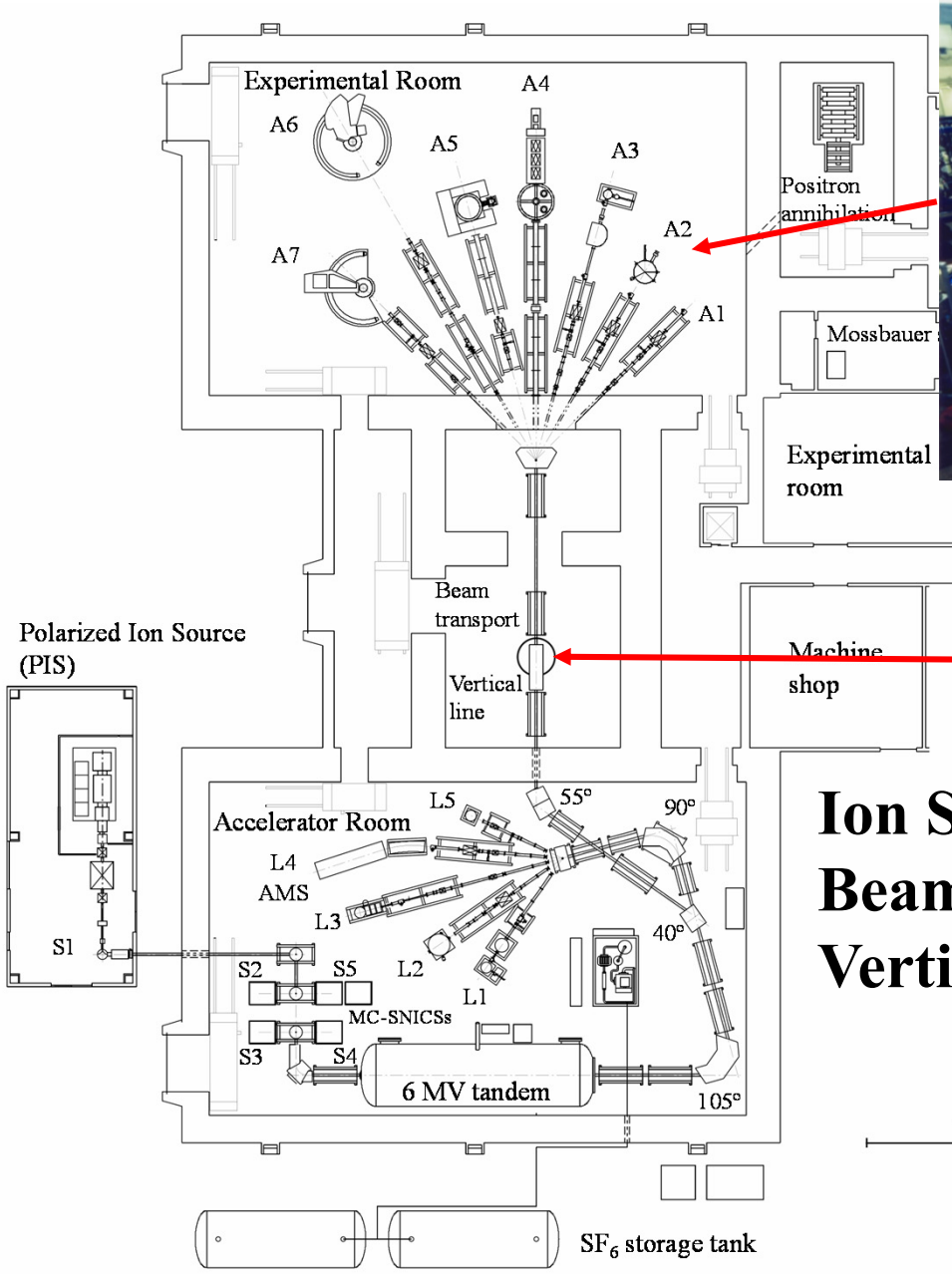
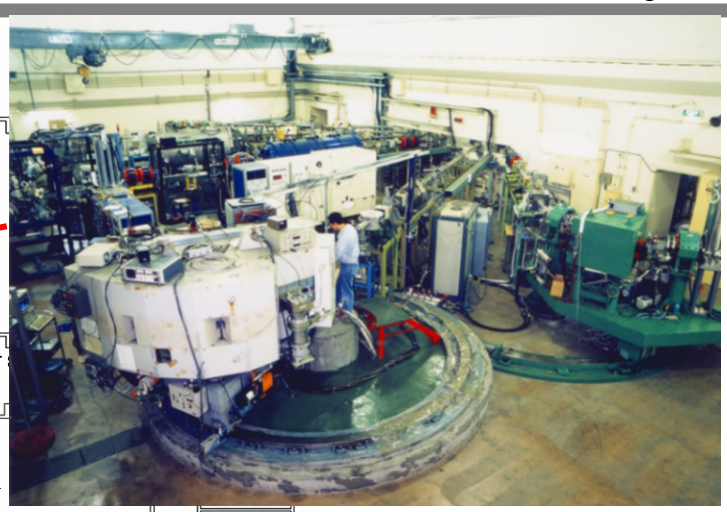
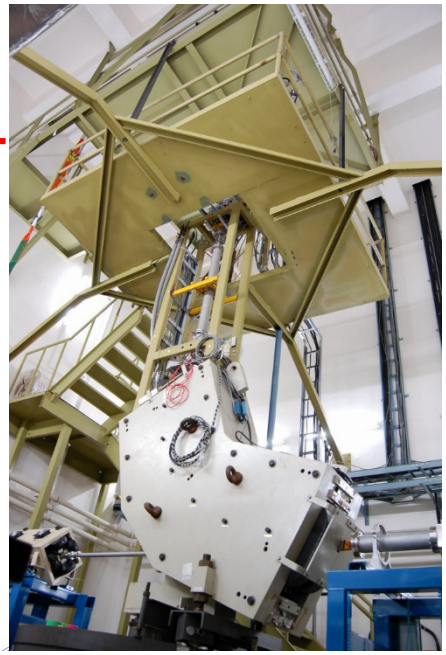
Design of the 6 MV tandem accelerator system







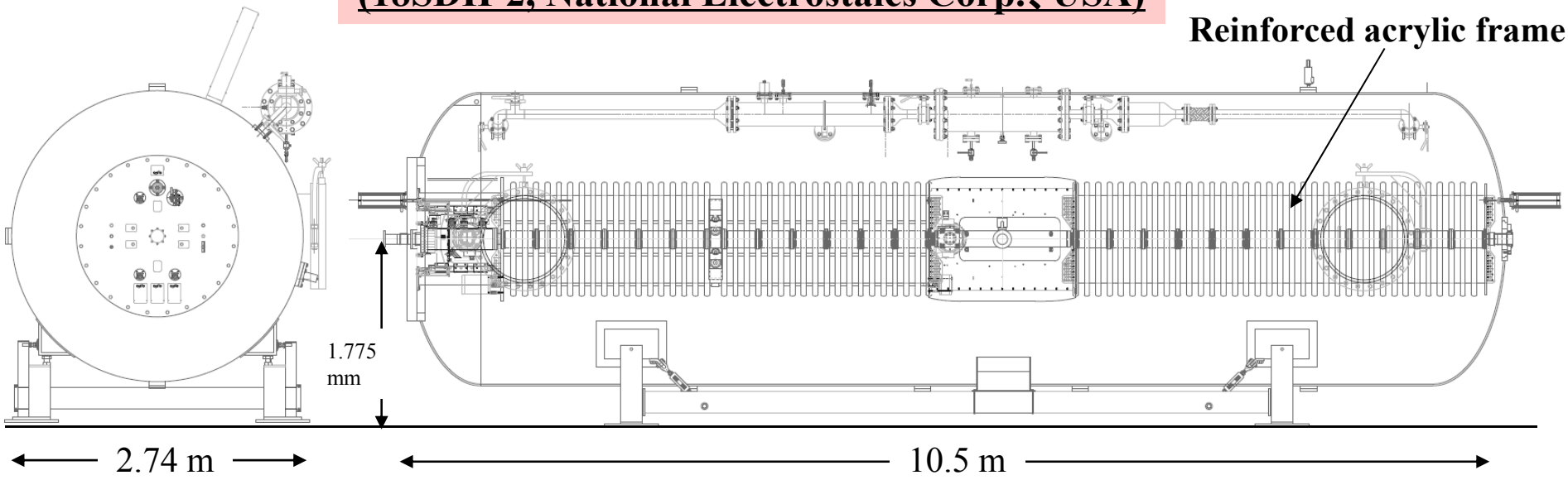
Ion Sources : 5
Beam lines : 12
Vertical line : 1

Vertical beam line for life science

UTTAC

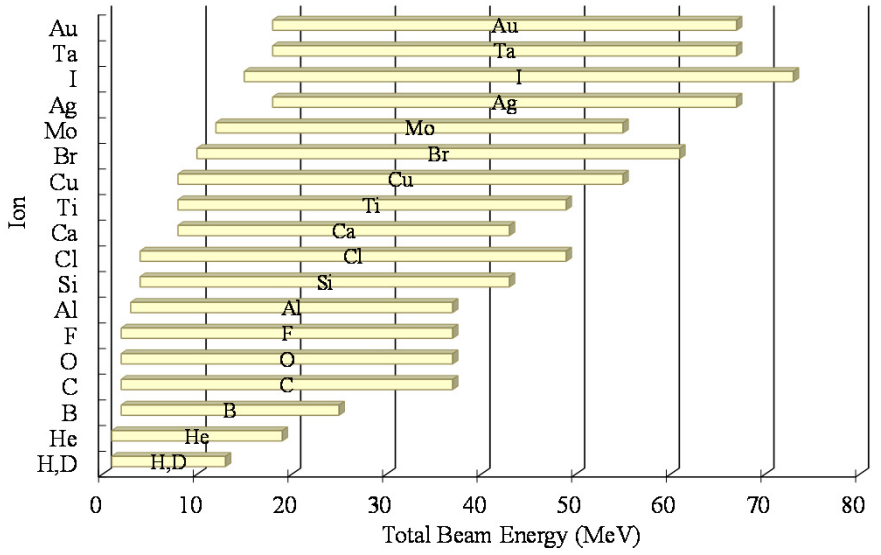
Main accelerator design

6 MV Pelletron tandem
(18SDH-2, National Electrostaics Corp., USA)



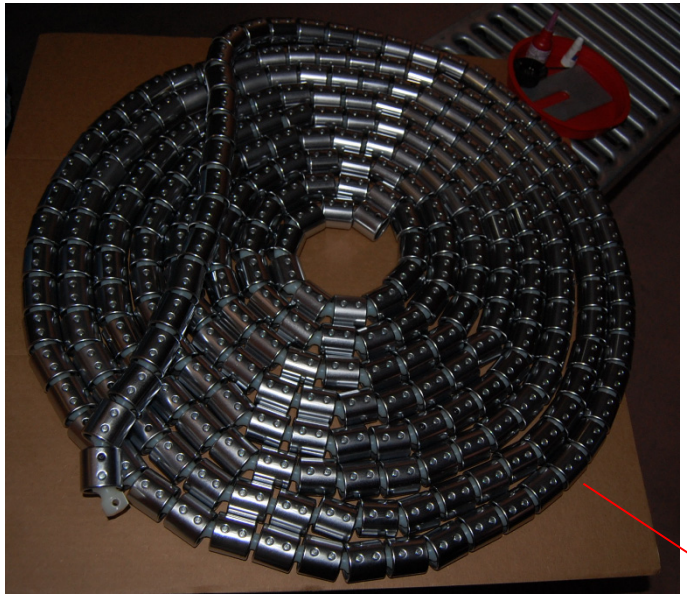
- **Accelerator tank size: Length: 10.5 m**
  Diameter: 2.74 m
  Beam line height: 1,775 mm
- **GVM and Slit current feedback system**
- **Terminal Voltage: 0.5 - 6.3 MV**
- **Voltage stability: < 1 kV V_{p-p} at 6.0 MV**
- **Maximum beam current: H : 3 μA**
  (DC) Heavy ions: ~50 μA

Ion Beam Energy Range



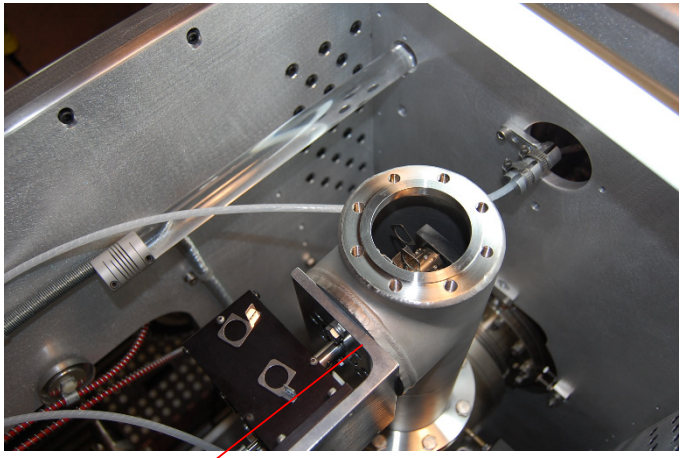
Install of the 6 MV accelerator tank (6 Mar, 2014)

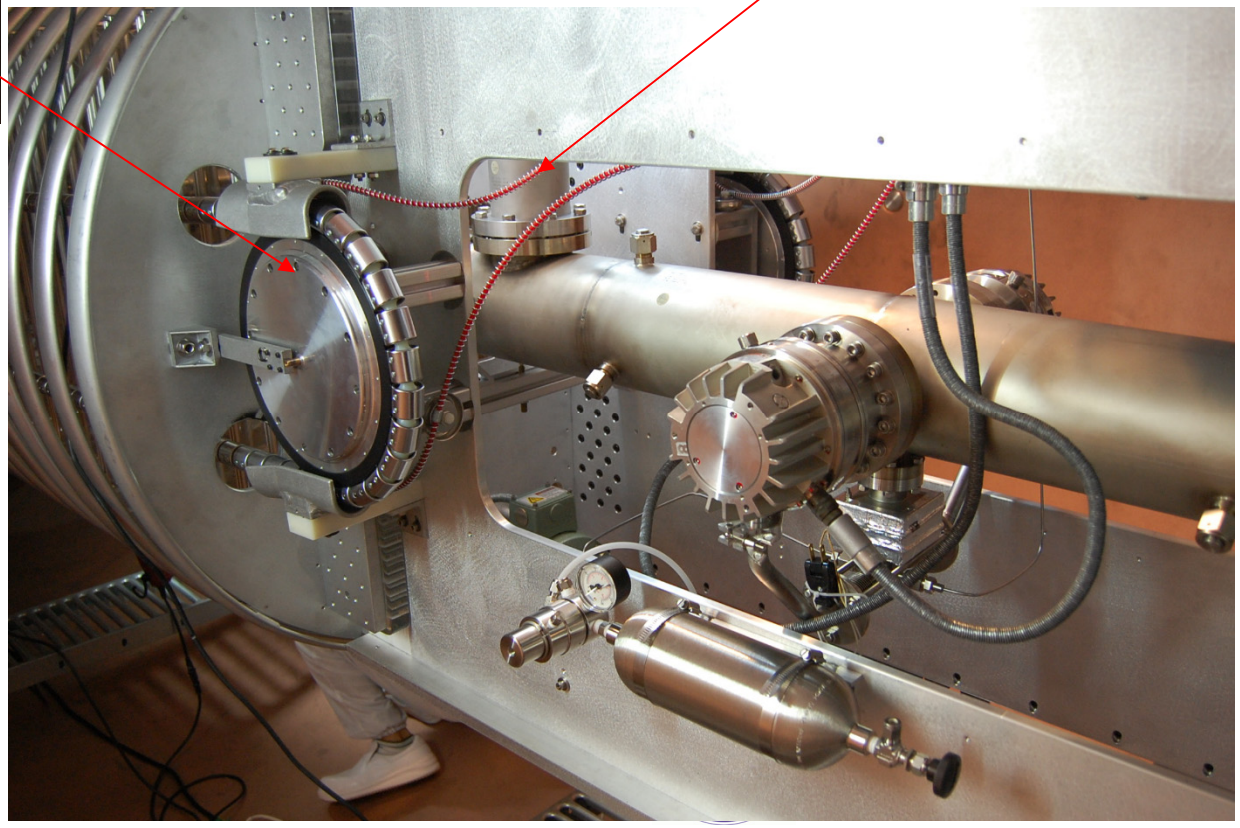
Accelerator Terminal



Double- Pelletron charging chain :
Up to 250 μA

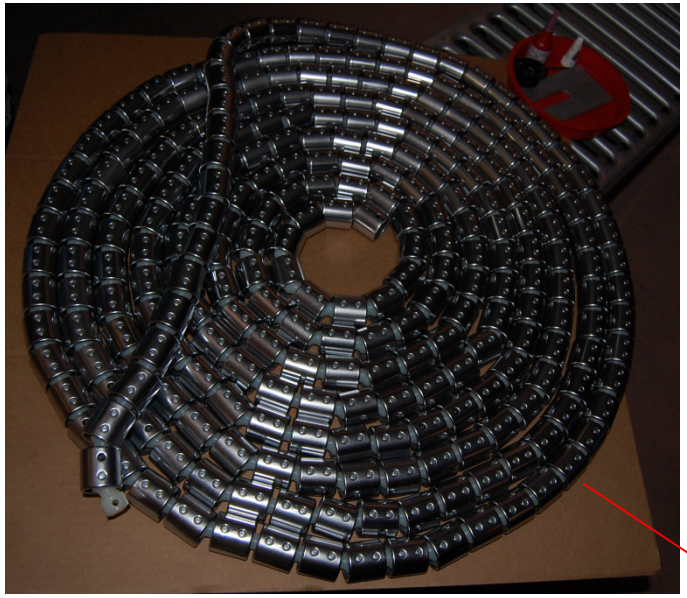
80 stripper foils:
(3 ~ 10 μg/cm^2)

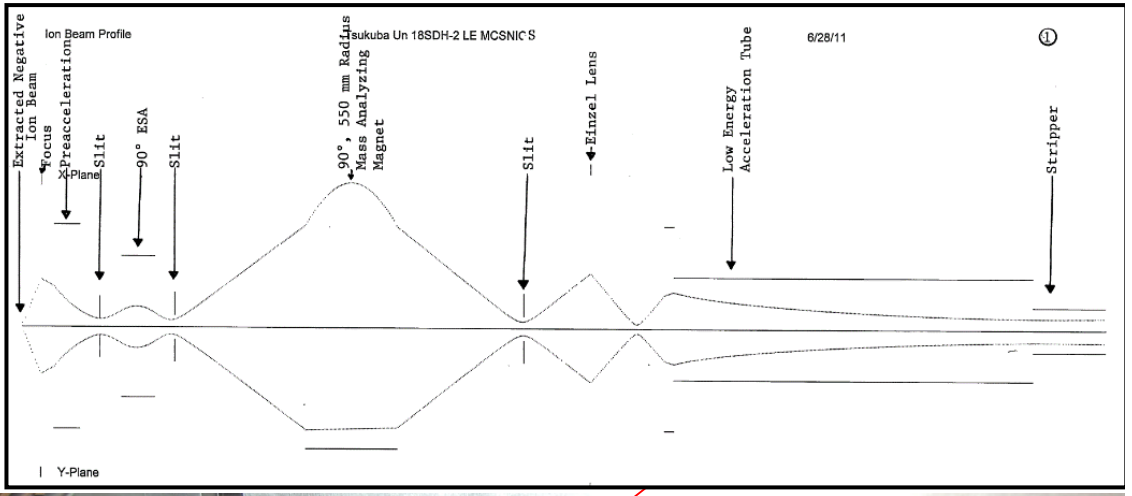


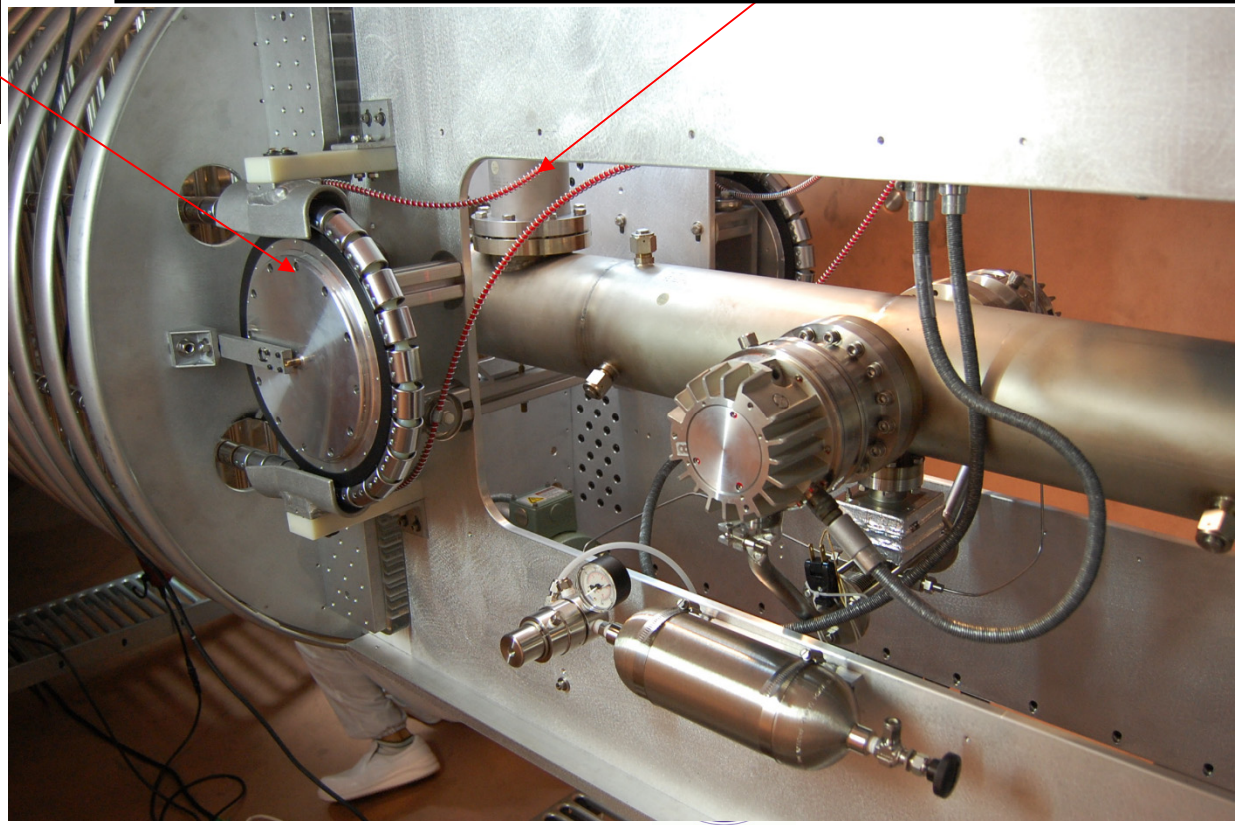


Gas stripper tube assembly
Stripper gas : Ar
Canal size: 10 mm in diameter
950 mm long
Gas circulation system with two TMPs

Accelerator Terminal







Double- Pelletron charging chain :
Up to 250 μA

Gas stripper tube assembly
Stripper gas : Ar
Canal size: 10 mm in diameter
950 mm long
Gas circulation system with two TMPs

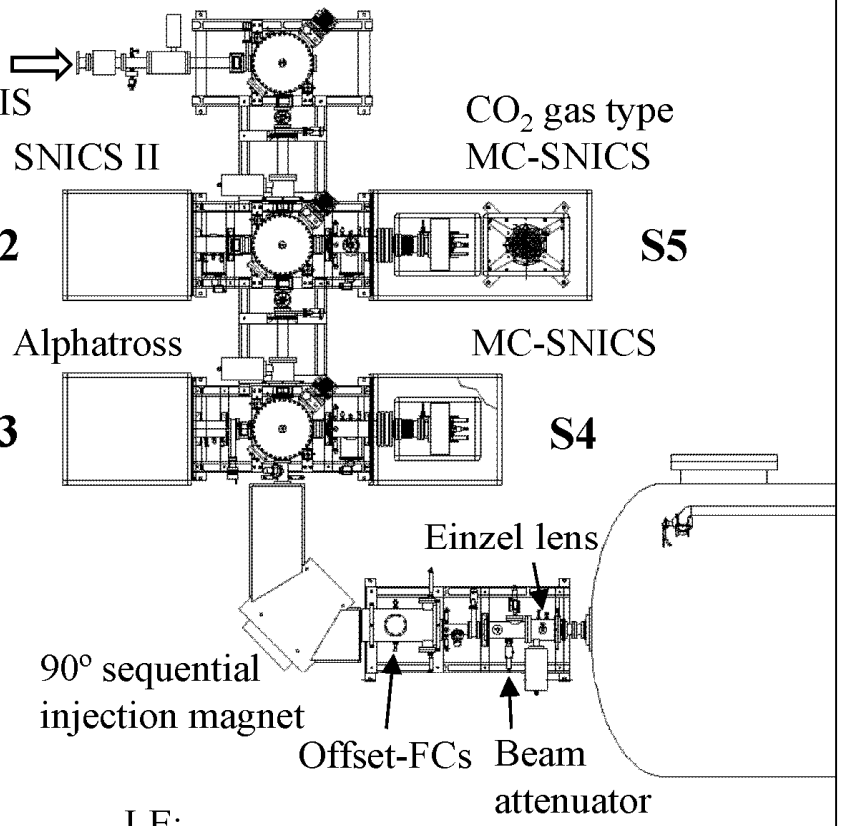
Low energy side (Ion sources)

Ion sources: 5

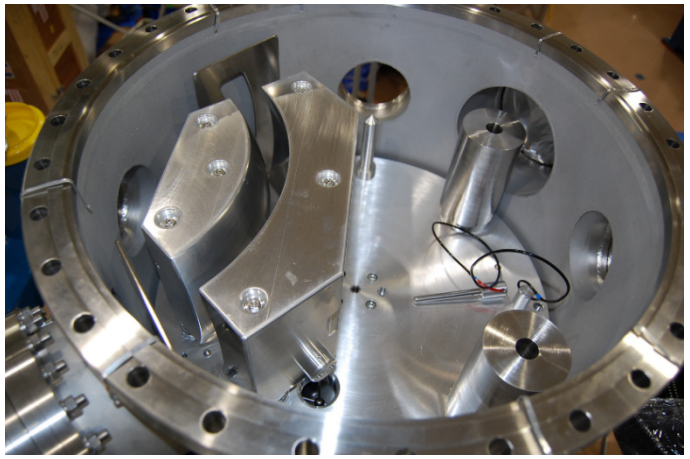
Injection system

Three 90° rotational Electrostatics Spherical Analyzers (ESAs)

Polarized DC
H^- & D^- ion
~ 500 nA from PIS



LE:
$ME/q^2 = 15$ amu-MeV



Rotational 90° ESA
(200 mm radius, 35 mm plate separation)

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Low energy side (Ion sources)

Ion sources: 5

Injection system

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H^- & D^- ion
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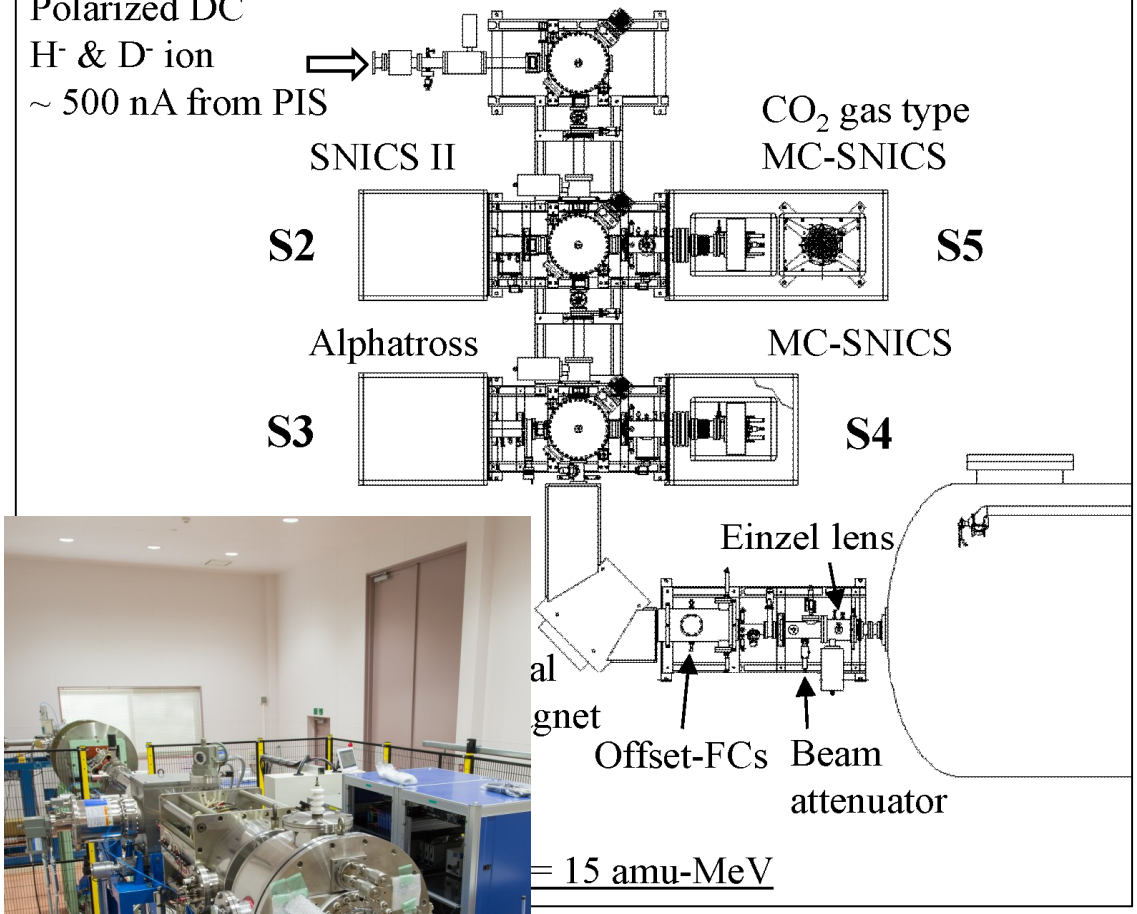
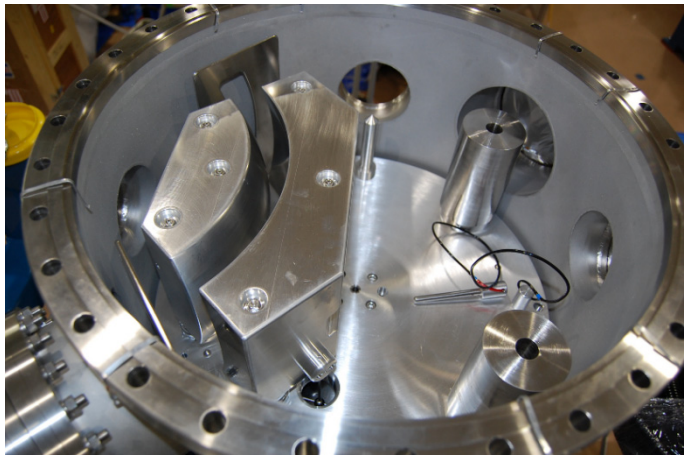


Lamb-shift PIS



Rotational 90° ESA
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~ 500 nA from PIS

SNICS II

CO_2 gas type MC-SNICS

S2

S5

Alphatross

MC-SNICS

S3

S4

Einzel lens

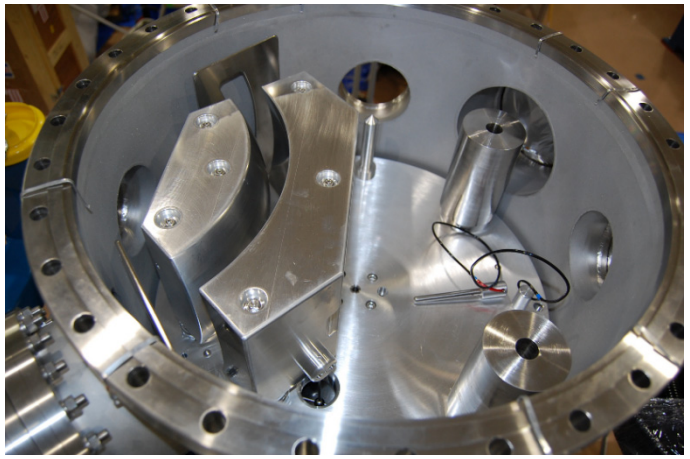
al

gnet

Offset-FCs

Beam attenuator

= 15 amu-MeV



Rotational 90° ESA
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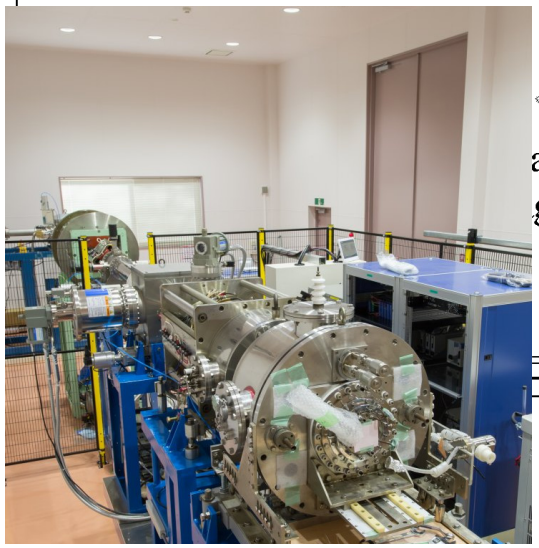
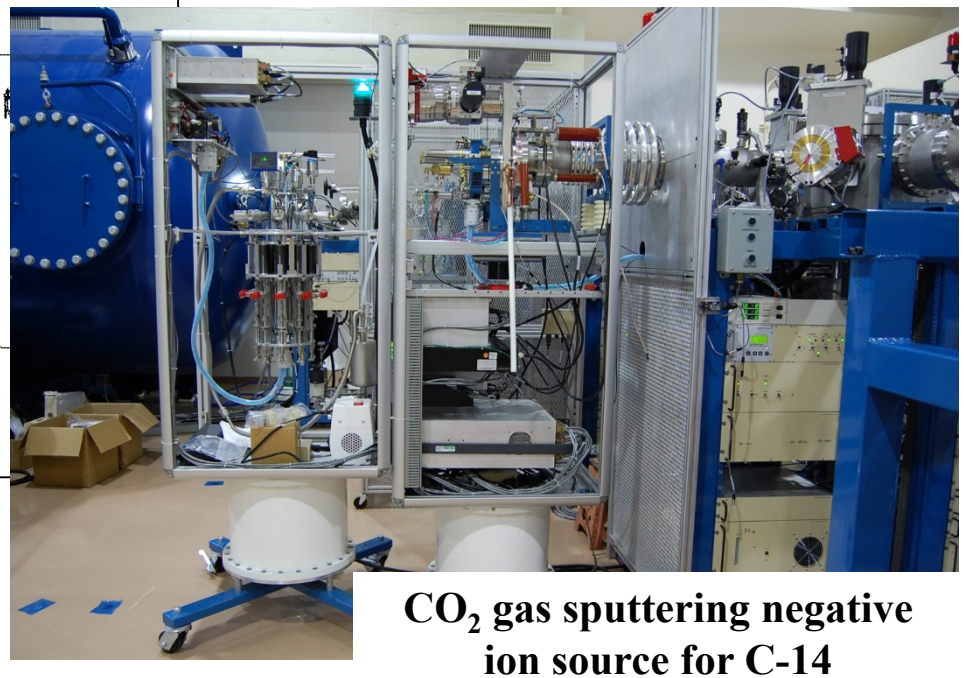


Lamb-shift PIS



CO_2 gas sputtering negative ion source for C-14

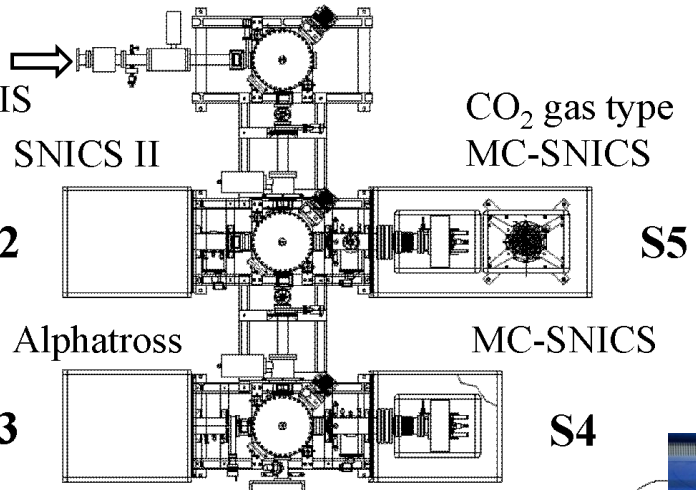
Low energy side (Ion sources)

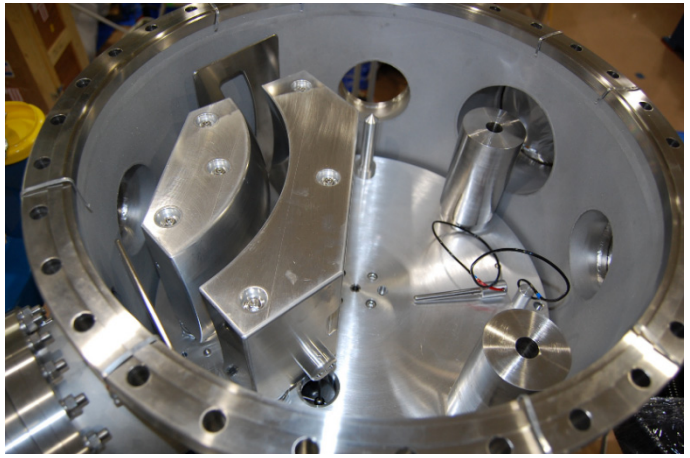
Ion sources: 5

Injection system

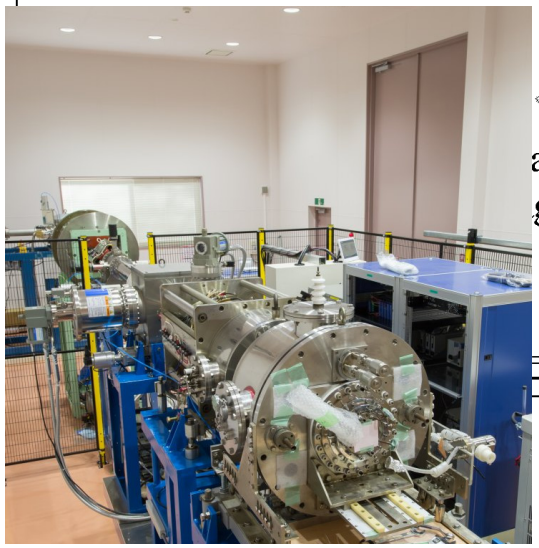
Three 90° rotational Electrostatics Spherical Analyzers (ESAs)

Polarized DC
H^- & D^- ion
~ 500 nA from PIS

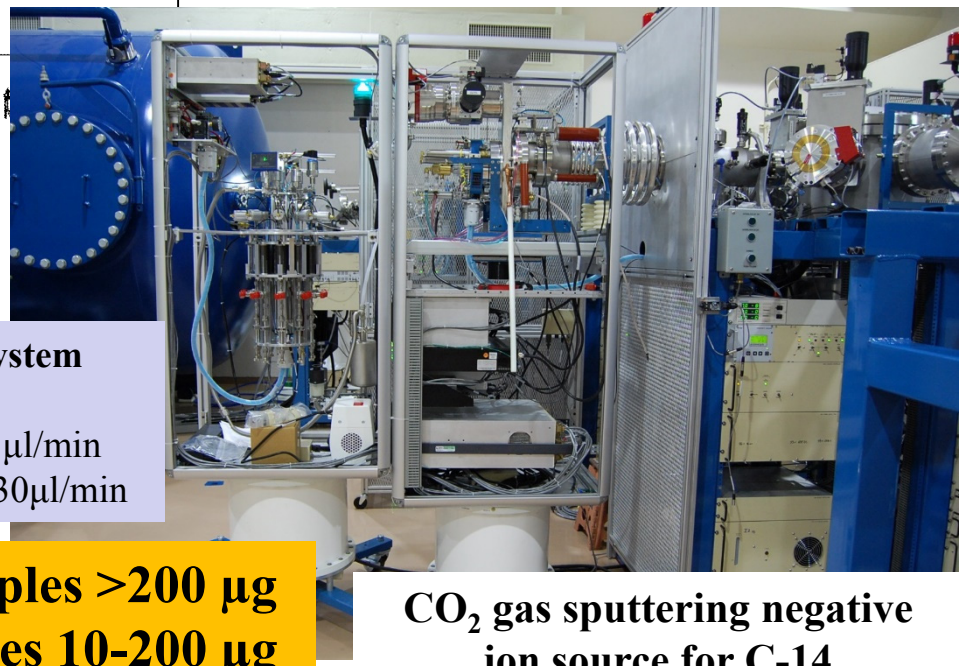




Rotational 90° ESA
(200 mm radius, 35 mm plate separation)



Lamb-shift PIS



CO_2 gas handling system
- CO_2 gas lines: 10
- CO_2 gas flux: 1-2 µl/min
- He gas flux: < 130µl/min

0.5% for samples >200 µg
1% for samples 10-200 µg

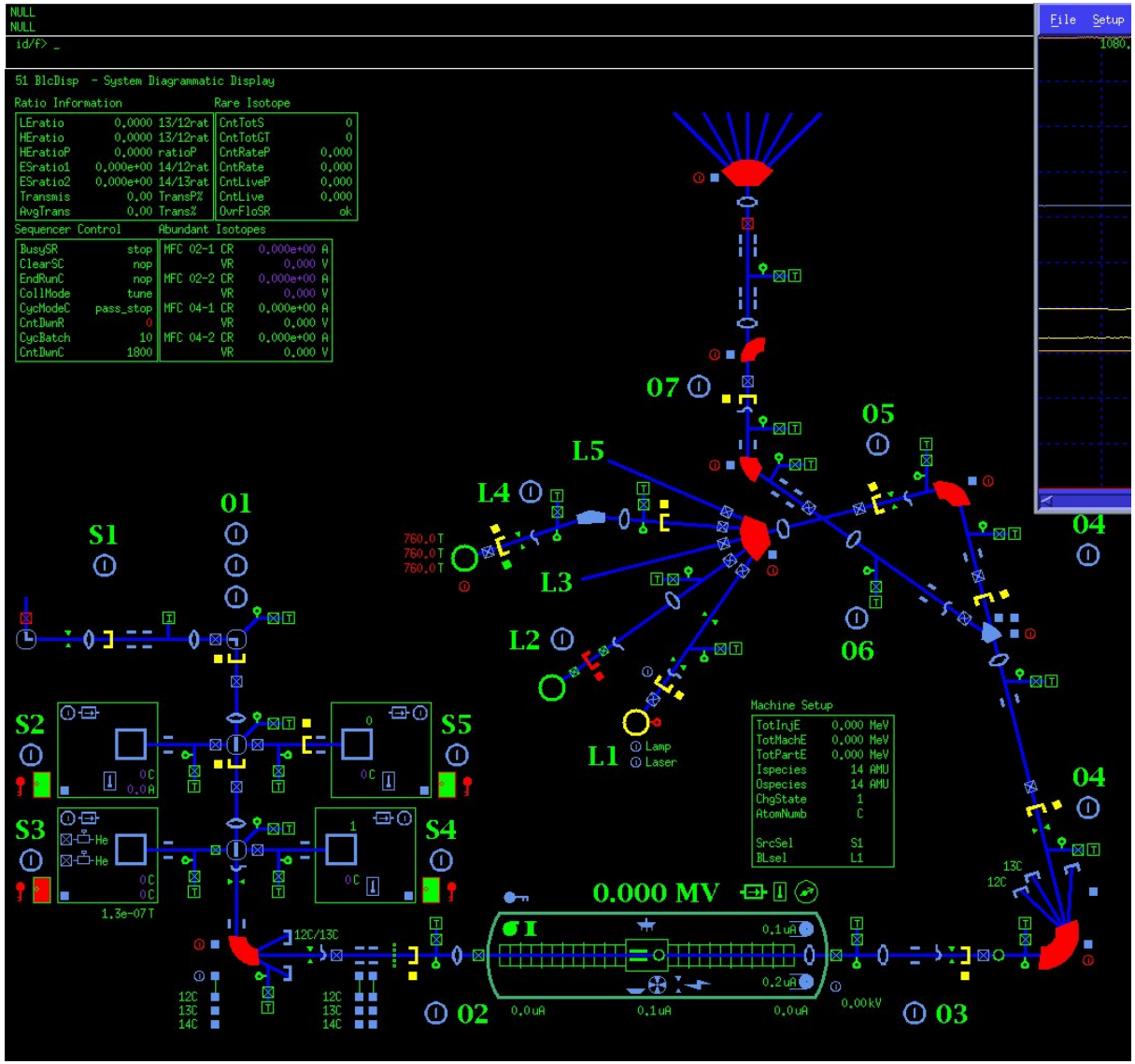
CO_2 gas sputtering negative ion source for C-14

Construction of the 6 MV tandem accelerator in 2014

6 MV tandem accelerator at the Univ. of Tsukuba

Control of the 6 MV tandem accelerator system

Control room



Control console on BSD

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3. Research projects of 6 MV tandem accelerator

- Beam lines
- Ion beam applications

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3. Research projects of 6 MV tandem accelerator

- Beam lines
- Ion beam applications

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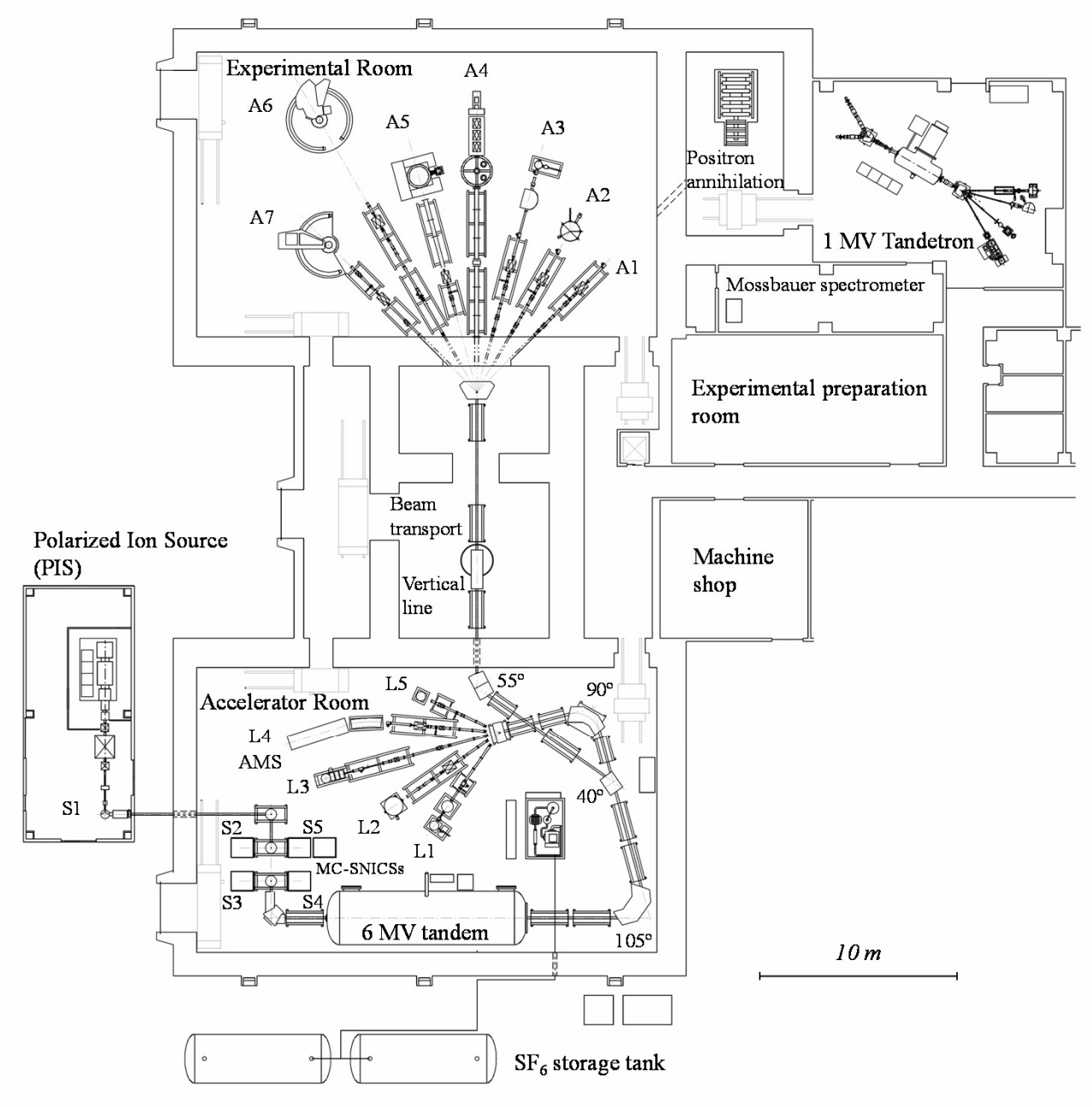
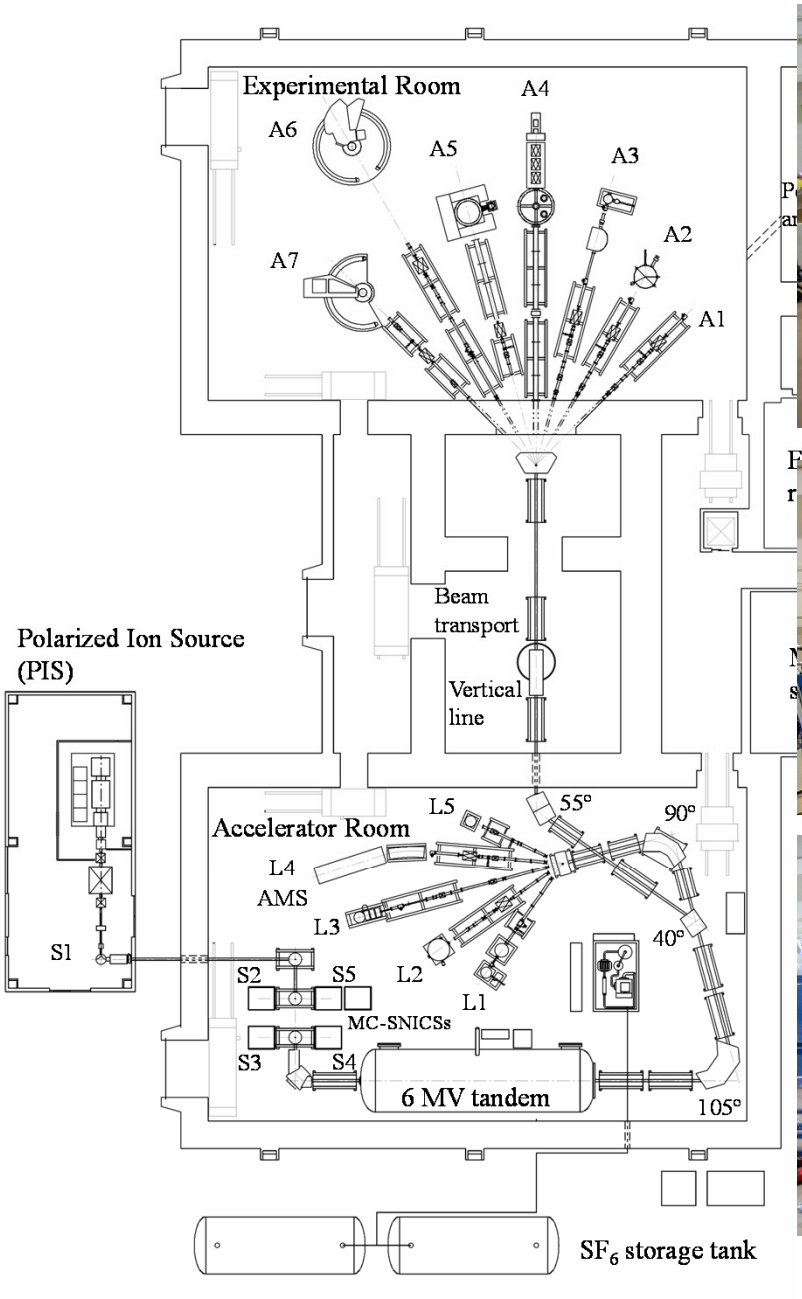
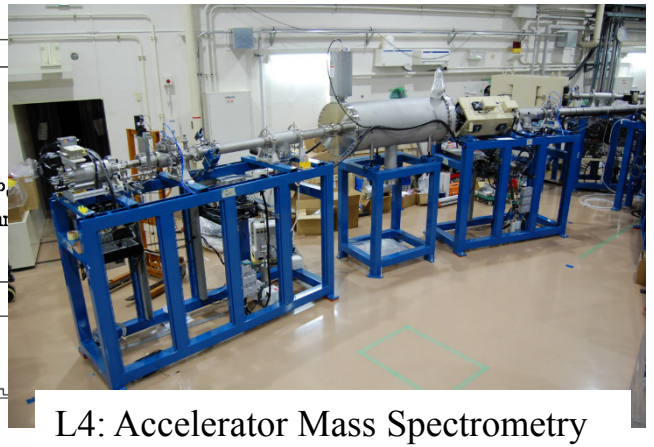
Beam lines

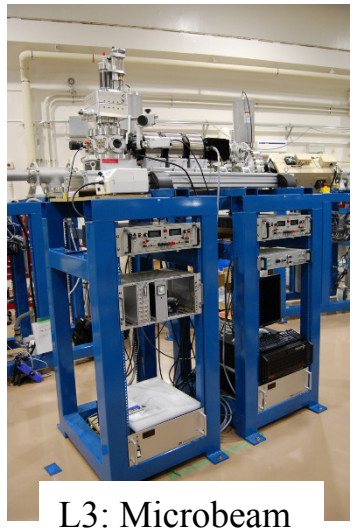


Beam lines

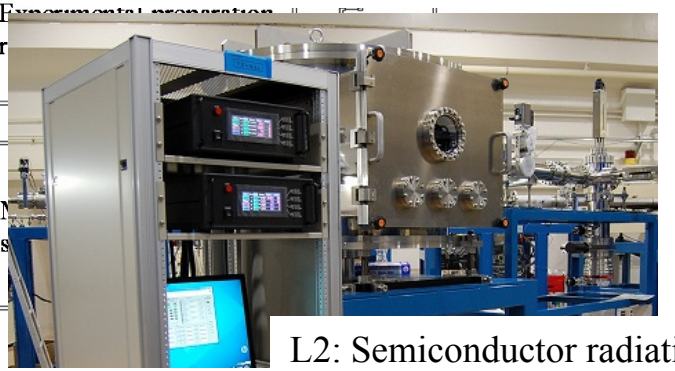




L4: Accelerator Mass Spectrometry



L3: Microbeam



L2: Semiconductor radiation resistance test

L1: Ion Beam Analysis for Materials

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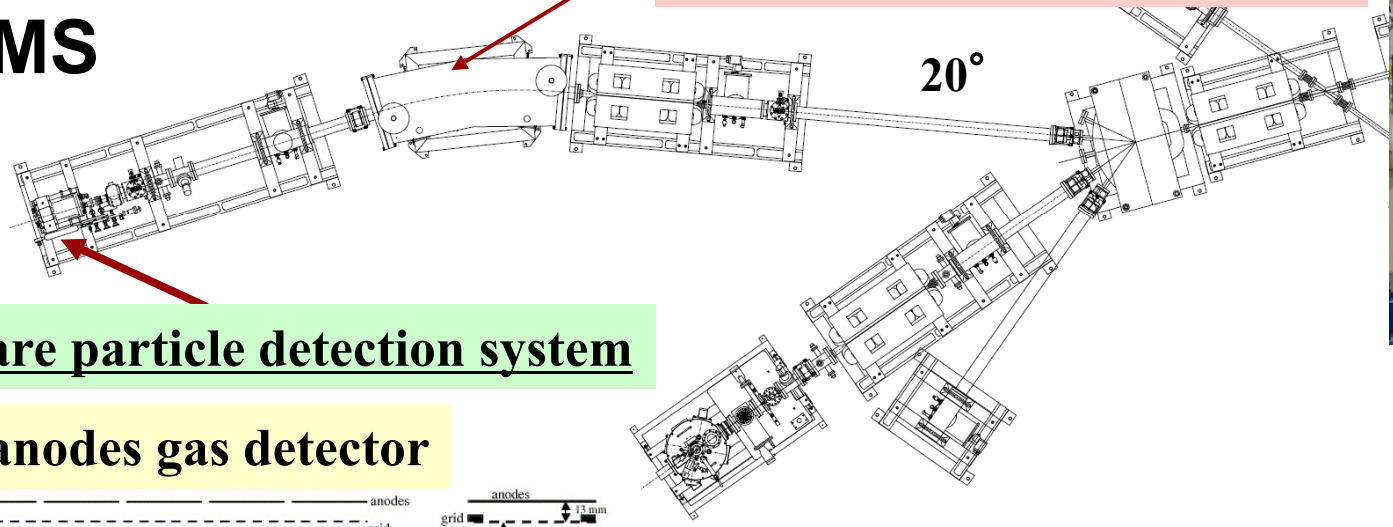
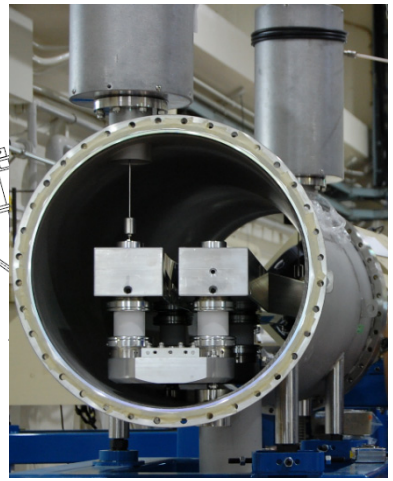
Multi-nuclide Accelerator Mass Spectrometry

22.5° ESA with a 3.81 m radius
and a resolution of E/ΔE = 200.

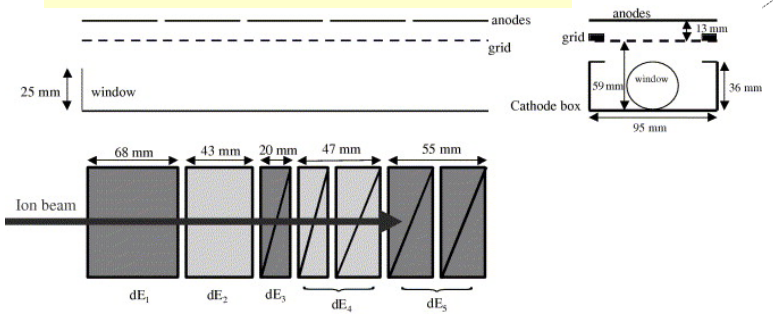
AMS

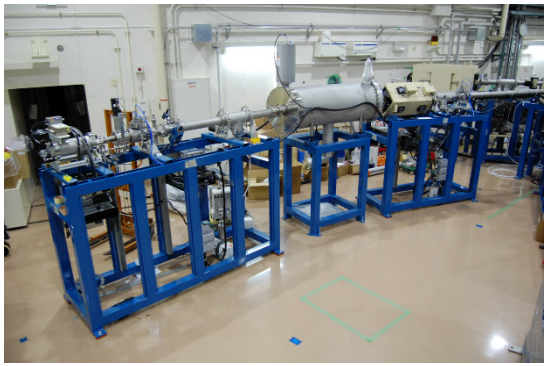




Rare particle detection system

5 anodes gas detector





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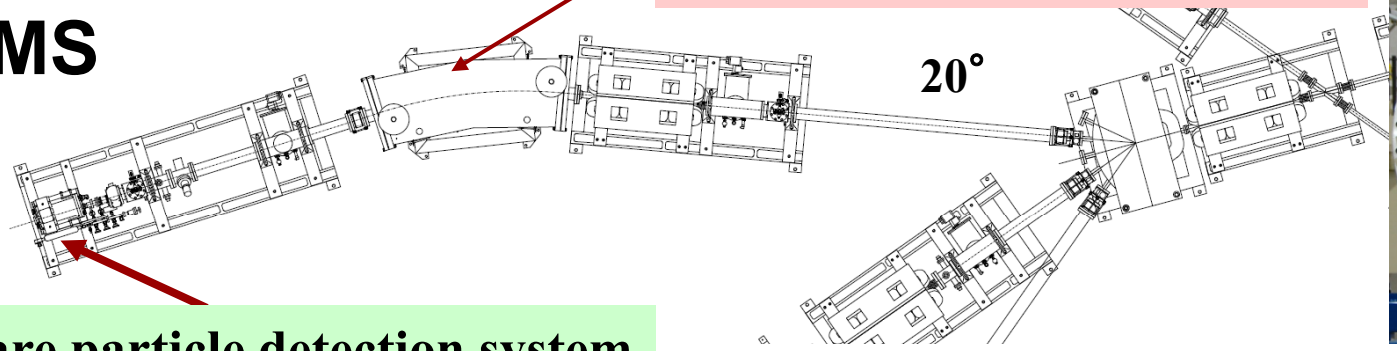
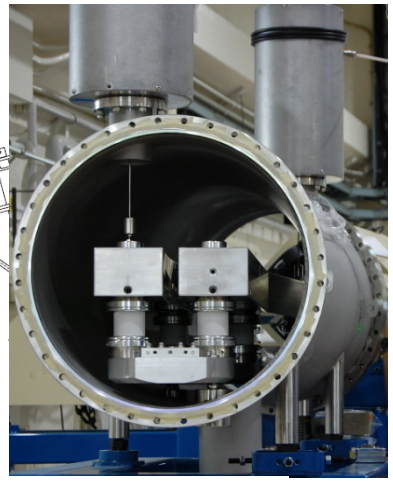
Multi-nuclide Accelerator Mass Spectrometry

AMS

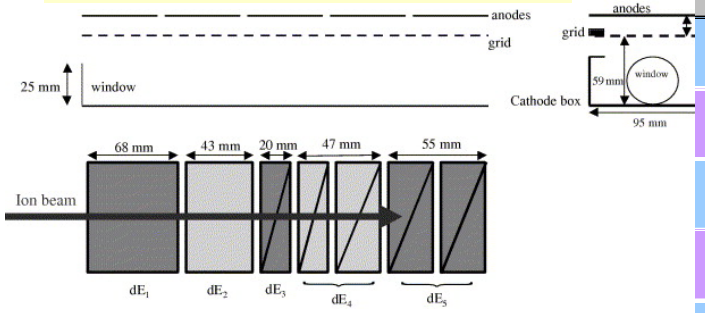
22.5° ESA with a 3.81 m radius and a resolution of E/ΔE = 200.

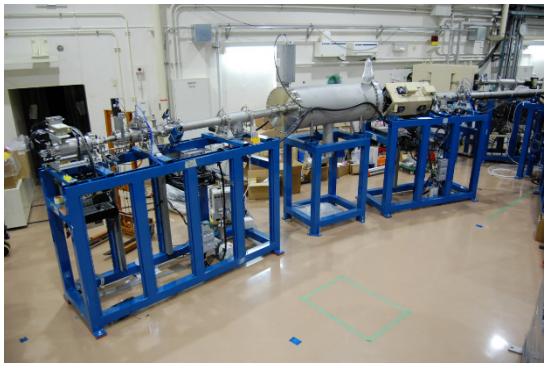




Rare particle detection system

5 anodes gas detector





Radionuclides-AMS performance

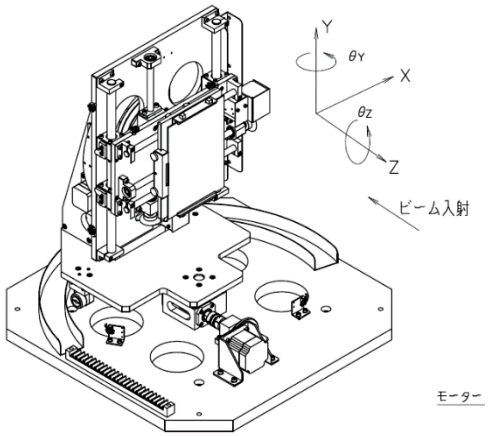
Isotopes	^{10}Be	^{14}C	^{26}Al	^{36}Cl	^{41}Ca	^{129}I
Target	BeO	Graphite	Al_2O_3	AgCl	CaF_2	AgI
Injected Ion	BeO^-	C^-	Al^-	Cl^-	CaF_3^-	I^-
Injectable Ion Current	4 μA	50 μA	1 μA	30 μA	0.3 μA	20 μA
Detected ion / Stripper	$^{10}Be^{3+}$ (Gas)	$^{14}C^{4+}$ (Gas)	$^{26}Al^{3+}$ (Gas)	$^{36}Cl^{7+}$ (Foil)	$^{41}Ca^{5+}$ (Gas)	$^{129}I^{4+}$ (Gas)
Terminal Voltage	4.5 MV	4.5 MV	4.3 MV	6 MV	5 MV	3.5 MV
Transmission	20%	55%	20%	20%	5%	8%
Background	2×10^{-15}	5×10^{-16}	5×10^{-15}	1×10^{-15}	3×10^{-14}	1×10^{-13}
Precision	3%	0.3%	3%	3%	3%	3%

Radio isotope detection limit ~ 10^{-15}

Tsukuba

Semiconductor radiation resistance test

1. Radiation effect for semiconductor
2. Heavy ion irradiation
3. Detector calibration
4. Cosmic ray effect for climate change



4-axis target holder

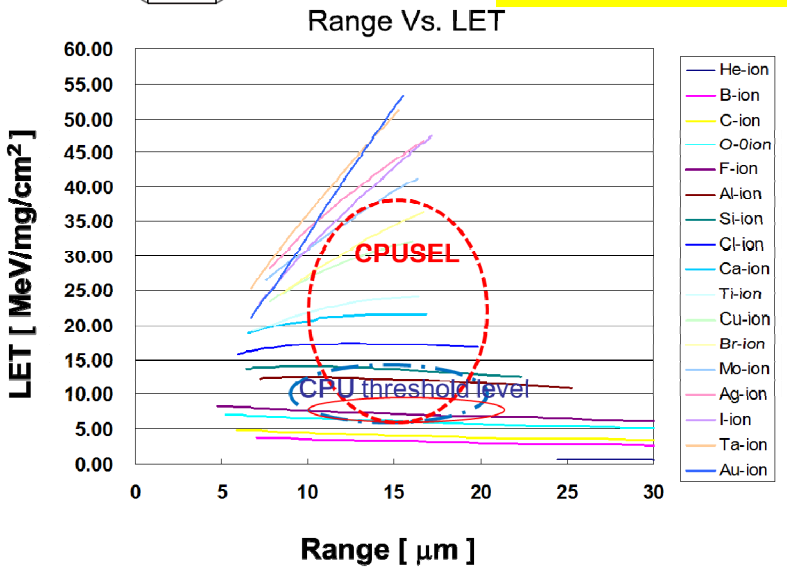
148×210 mm

・X：±74mm

・Y：±105mm

・θy：+30-90°

・θz：±30°



大学
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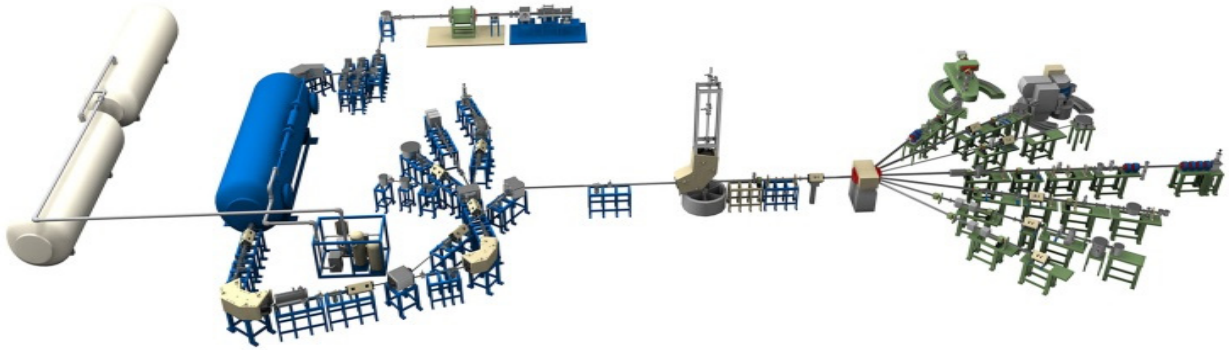
Summary

1. **The 12UD Pelletron tandem accelerator was shut down due to the Great East Japan Earthquake in 2011.**
2. **The 6 MV tandem accelerator was installed at the University of Tsukuba in 2014.**
3. **Multi-purpose tandem accelerator will be used for AMS, IBA, Ion irradiation, Nuclear physics and so on.**
4. **Radionuclides of ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca and ^{129}I will be routinely analyzed by the new Tsukuba AMS system.**
5. **The new system will start routine experiments on ion beam applications in 2015.**

Thank you for your kind attention !



6 MV tandem accelerator at UTTAC since 2015

Acknowledgements

**This project is supported by MEXT, Japan.
We thank UTTAC staff, NEC, Hakuto Co. for their help and support.**