High performance engineering technology for accelerator devices

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(Masa)

Metal Technology Co. Ltd. (JAPAN)

Metal Technology Co. Ltd.

Outline

- Introduction of Metal Technology Co. Ltd.
- HIP technology
- Engineering division
- Key parts for accelerator devices
- Compact accelerator development

About us – Company Vision

"Our core desire is to help, not only our customers, but the society we are part of….

…We seek to use our knowledge and expertise in the field of engineering, to find the 'metal solution', which is the best solution for all parties involved."

"The guiding ethos of the company is 'respecting and maintaining harmony' and this has been unchanged since we were first established."

About us – At a glance

the metal solution

1

Beginning

MTC was founded in **1960**.

Initially in Heat Treatment.

2

Core business

Hot Isostatic Pressing, Bonding, Brazing, and Additive manufacturing.

3

Plants/Offices

8 plants in Japan

&

1 in China.

4

Annual Sales

Approx. –

86 Million Euros

(¥10,818,346,569)

About us - Our Locations

Korea Sales representative

ISO 9001 ISO 14001 JIS Q 9100

Toki Plant

Gunma Plant

ISO 9001 ISO 14001

Ibaraki Plant

ISO 9001 ISO 14001

US sales representative

Himeji Plant

Kanagawa Plant / Technical center

ISO 9001 ISO 14001

Suzhou Plant (China)

Shiga Plant

ISO 9001 ISO 14001 JIS Q 9100

Chiba Plant

ISO 9001 JIS Q 9100

Narita Plant

Federal Aviation Administration

About us - Timeline of capability

1970

MTC's first Vacuum Furnace was installed. In 1977 obtained Boeing specification

1980

In 1984 MTC installed our first HIP unit in Shiga Factory

1990

A rapid period of expansion in the 1990s.
MEGA HIP, SPF, EBW, Vacuum Hot presses & Machining Centres were installed.

2000

In 2001 we began Additive Manufacturing.
In 2006 MTC's Technical center was established at Kanagawa factory

2010

Major Milestones reached
- Giga HIP installed
- **Engineering Division established**
- China Factory opened
- Entered the MRO business

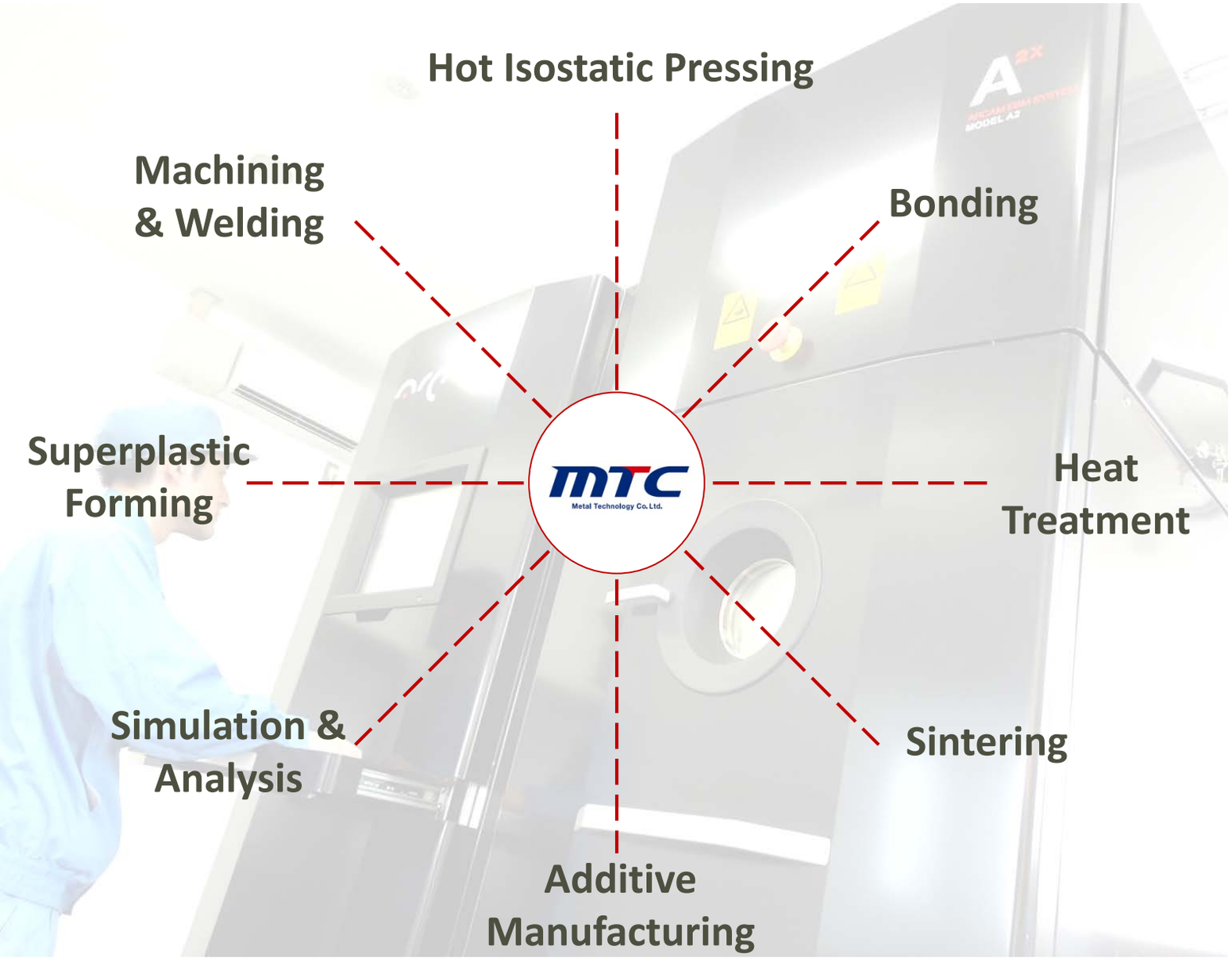
2013

EBM & DMLS AM Units FAA/EASA approved

2017-18

Toki factory opened
Arcam Level three operator
4th 3D Printer installed
NADCAP for HIP process

About us - Overall capabilities



Metal Technology Co. Ltd.

We are constantly taking on the challenges of new ideas with a combination of reliable technical knowledge and state-of-the-art equipment.

Core Competencies

PROCESSES

Processes - HIP Technology

Mega-HIP
Dia. 1,100mm X H2,100mm

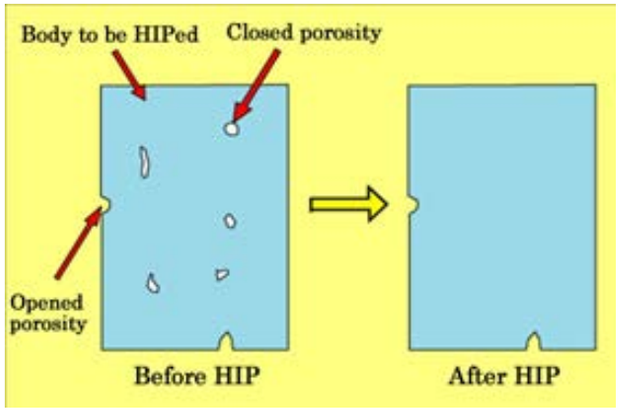
Metal Technology has the second largest HIP capability in the world

- 18 HIP units in operation including the world's largest HIP unit, Giga-HIP.
- Processing size ranges from Dia.200mm x H300 up to Dia.2050 x H4200.
- Max. temperature - 2000 degrees Celsius.
- Max. pressure 196 MPa.

（HIP）Technology

Giga-HIP

Removal of Internal Defects

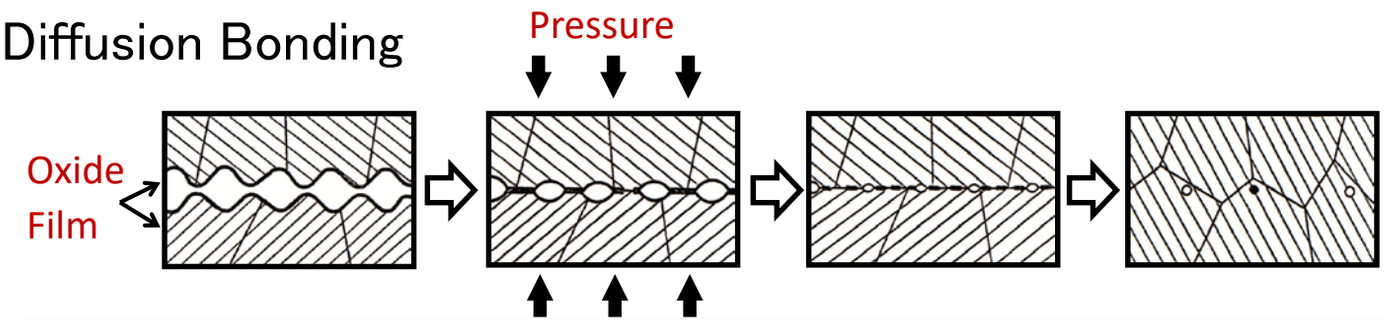


Turbine Blades

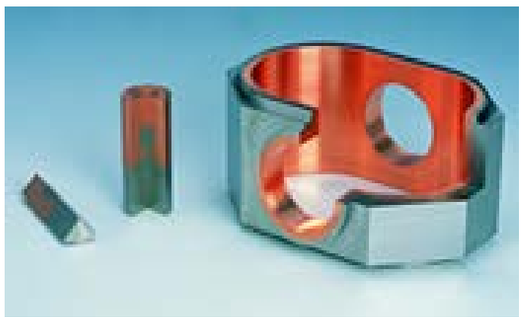
Work Size : ϕ2,050 x 4,200㎜
***Largest Class in The World**
Max. Weight: 28 ton
Max. temp: 1,350 Degree C
Max. Pressure: 118 MPa

Aluminum Body + Stainless Tube

Diffusion Bonding



Stainless Steel + Copper



Powder Metallurgy for a Subsea Valve Body

Material:

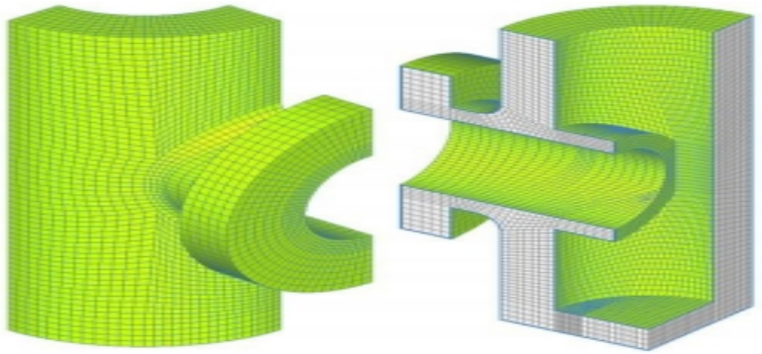
Super Duplex Stainless Steel UNS S32505
Acc. to ASTM A988 for HIP production

Part Size:

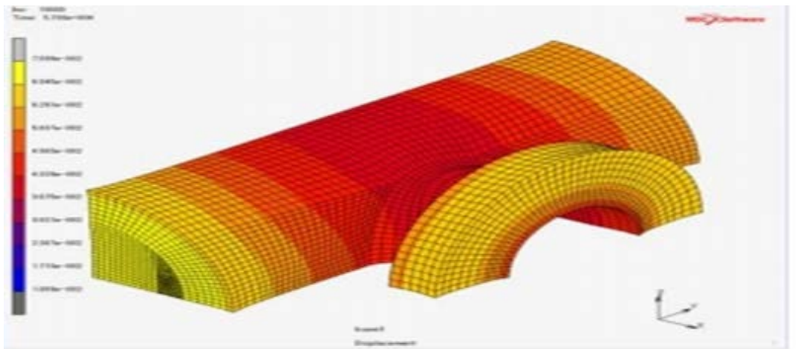
W 1,200mm x H 1,000mm

Simulation:

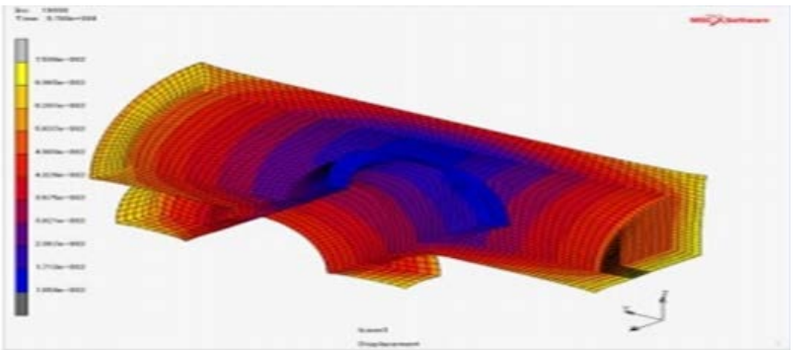
3D analytical model



External displacement



Internal surface displacement



Processes - Heat Treatment

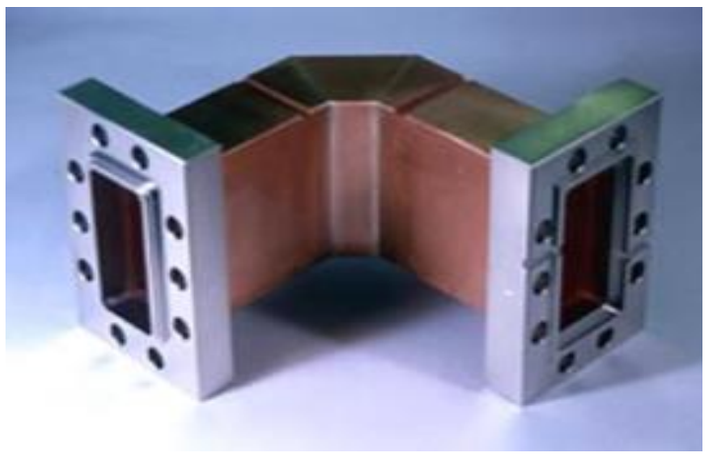
- Various sizes of equipment available including the largest vacuum furnace in Japan
- 36 Vacuum Furnace units and 25 Atmosphere Furnaces in operation
- High productivity utilizing multiple chamber vacuum furnaces
- Various certifications including NADCAP
- 24-hour operation

Aircraft part: Ti-6Al-4V
Brazing and Stress relief

Processes - Brazing

- Larger parts can be brazed.
- Brazing on active metals.
- Step brazing applied for bonding metals to ceramics.
- Material combinations including ceramics and carbon can be brazed.

Gold brazing for aerospace related parts



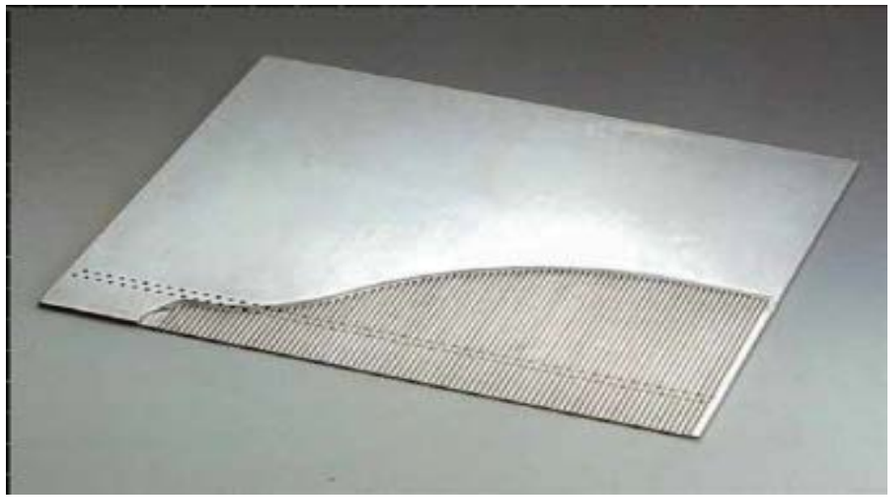
Brazing for waveguide part

Brazing for insulation tubes with materials of stainless steel and ceramics

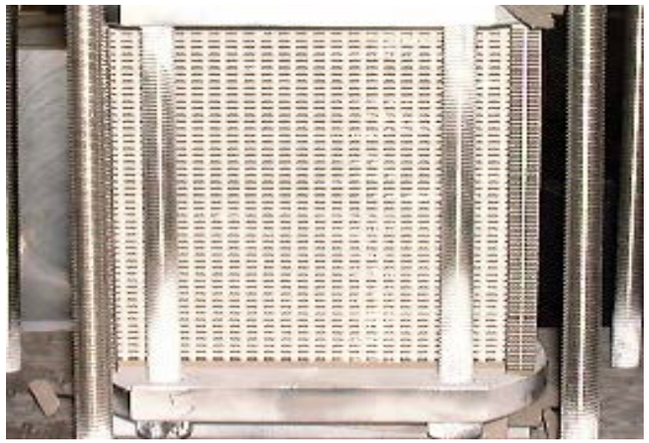
Processes - Vacuum Hot Press

Ti Alloy diffusion bonding

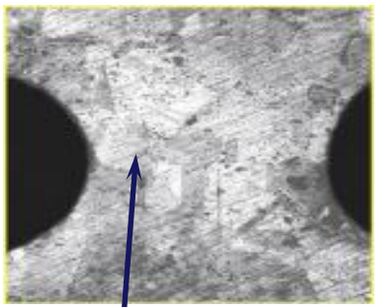
12 axes vacuum hot press unit



Ni based alloy diffusion bonding



Heat exchanger



Diffusion bonded section

Processes - Machining

Vertical

Horizontal

5 Axis

Lathes

5 Surface

Additive Manufacturing-MTC's Current Units

EOSINT M280

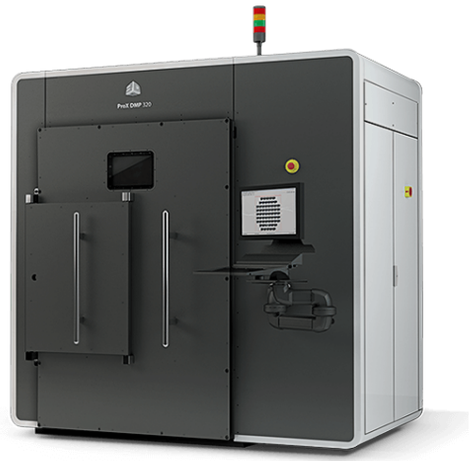
Material:
Ti6Al4V
Inconel718
Work Zone:
W250 × L250 × H325

Arcam Q20

Material:
Ti6Al4V
Work Zone:
Φ350 × H380

Arcam A2X

Material:
Ti6Al4V
TiAl
SUS 316L
Work Zones:
W200 × L200 × H350 (Ti6Al4V)
W150 × L150 × H300 (TiAl)



ProX DMP 320

Material:
Ti6Al4V
Inconel718
Work Zone:
W275 × L275 × H420
Oxygen Concentration in AM process:
Less than 25 ppm.

Processes - Additive Manufacturing

EBM

Aviation

Turbine blades additively manufactured from Titanium aluminide, TiAl. An example of three stages: As built, HIPed, and Machine finished. This is part of the SIP program planned to run from 2014 to 2018. Supporting the Investigation into the development of heat resistant alloys and intermetallic compounds.

※ *Manufactured as a part of Cross-ministerial strategic innovation promotion program (SIP)*

GS Cup Medical devices marketing license number : 22600BZX00463000

EBM

Medical care

An acetabular cup with a complex design and shape The acetabular cup is the component which is placed into the acetabulum (hip socket). for medical care. This piece was made by additive manufacturing and HIPing.

※*Photo credit: Teijin Nakashima medical*

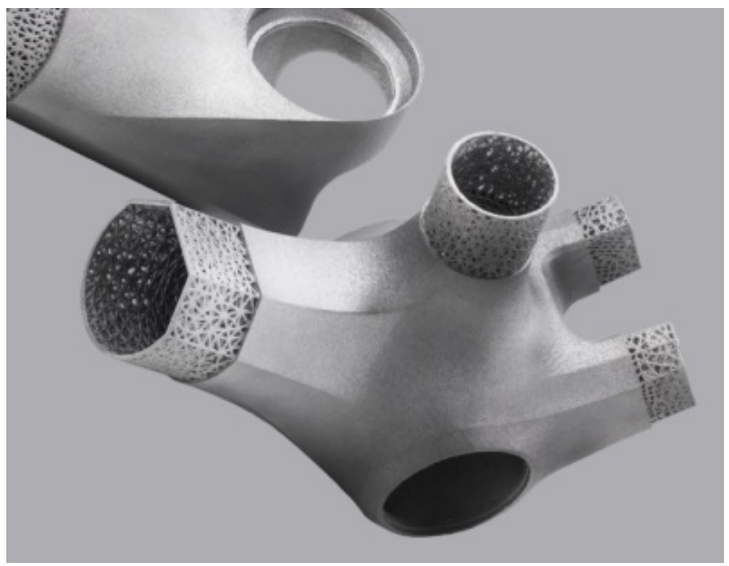
Processes - Additive Manufacturing

DMLS

Interior design

Additively manufactured interior design for lights, expressing organic shapes through additive manufacturing. The design was chosen for additive manufacturing due to being difficult to create using existing or traditional methods.

※ *Photo credit: Triple Bottom Line*



DMLS

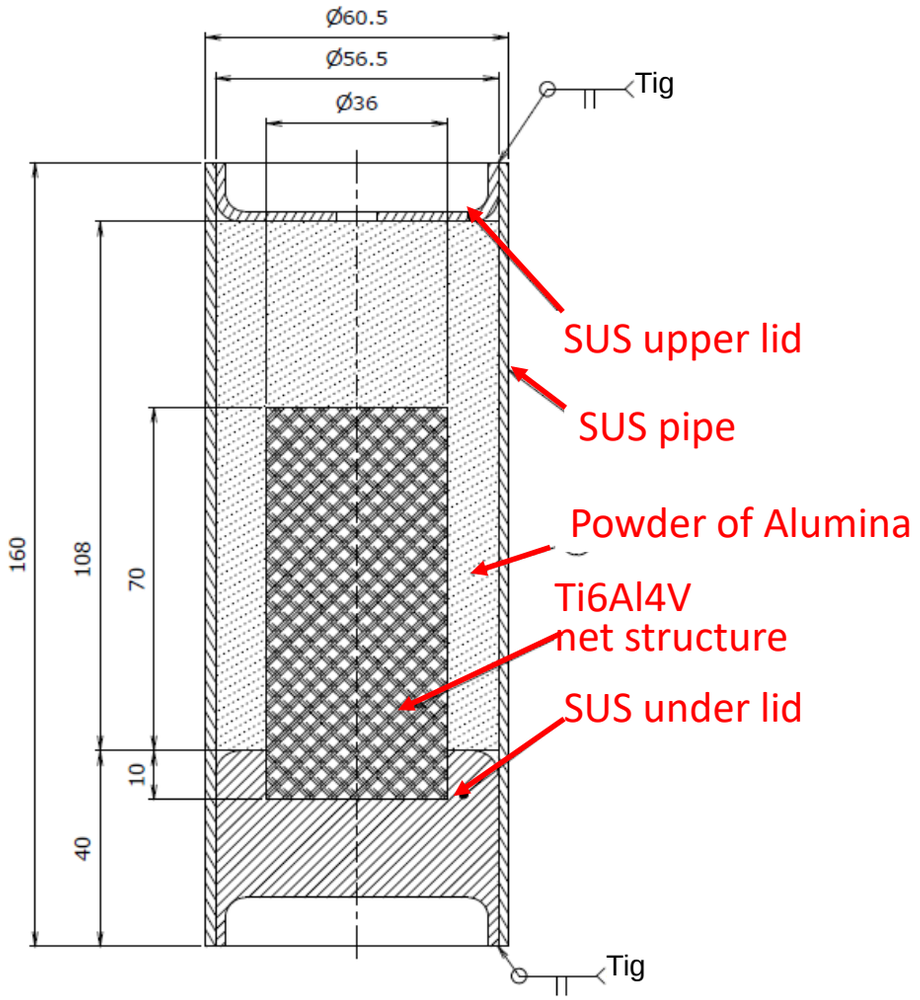
Bicycle

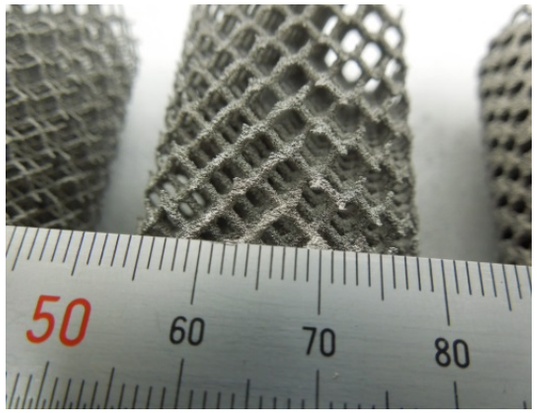
Bicycle parts additively manufactured to achieve a reduction of weight using a 3D lattice structure with a 0.5mm thickness plate and high elasticity.

※*Photo credit: Triple Bottom Line & CEREVO*

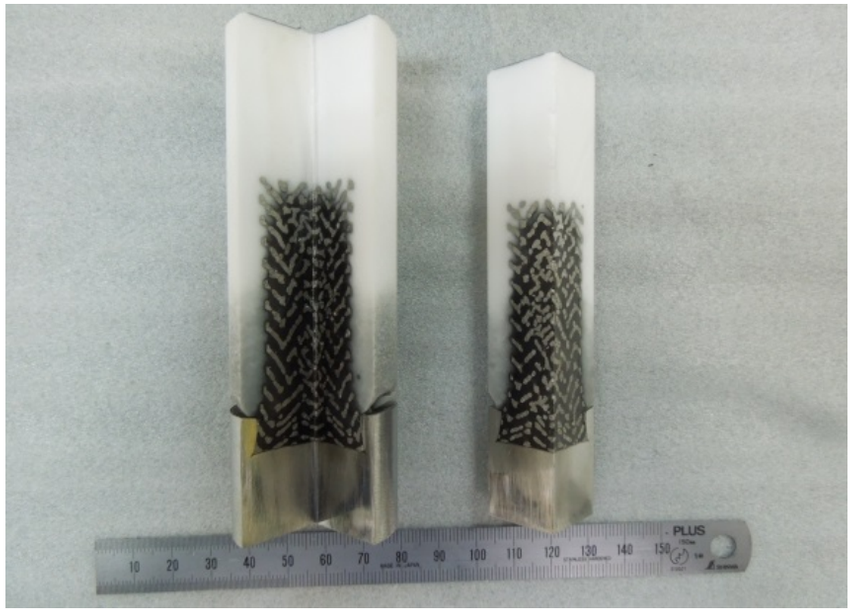
Combination Processes – AM+HIP sintering

AM parts + Alumina(Al2O3)





Shape of Ti6Al4V net structure



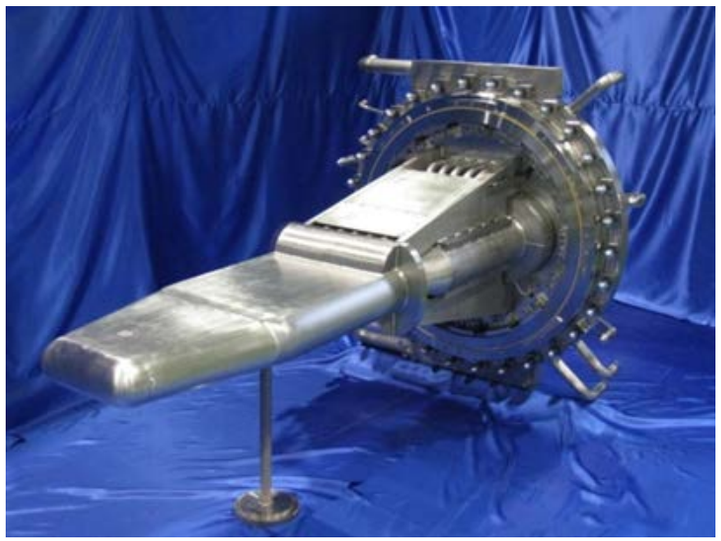
Sintered body (Upgrading for brittleness of ceramics)

MTC engineers

R&D

The Engineering Division

“The Engineering Division specializes in products related to accelerators, neutron sources, and nuclear fusion technology.”



Mercury Target Container

Some of the leading projects we have been part of:

QST / Quantum and Radiological Science and Technology

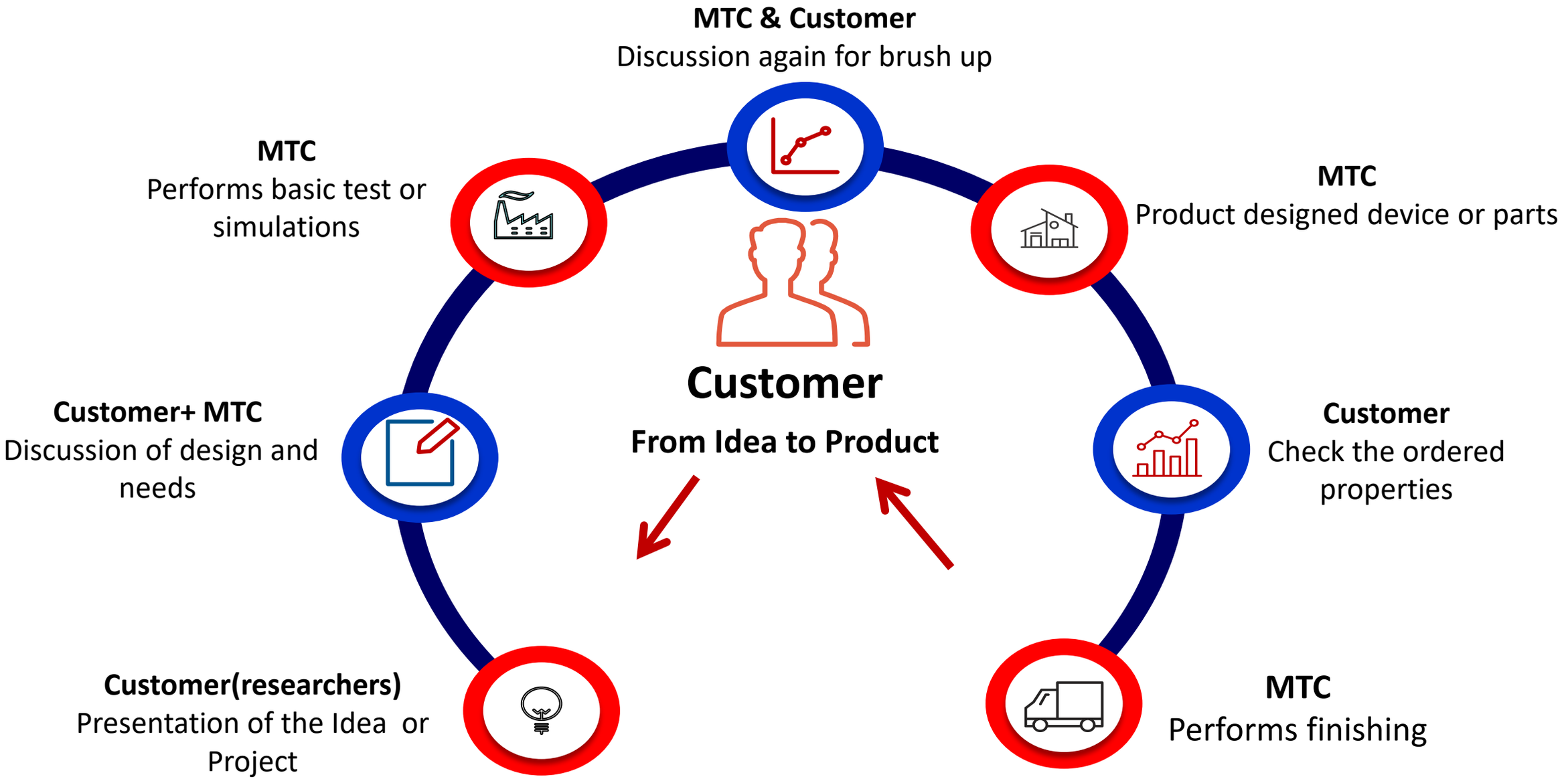
JAEA / Japan Atomic Energy Agency

J-PARC / Japan Proton Accelerator Research Complex

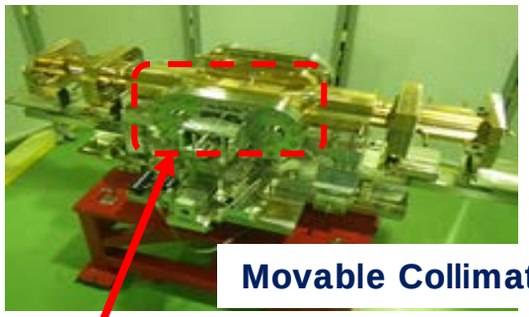
KEK / High Energy Accelerator Research Organization

RIKEN/ Rikagaku-Kenkyujo for Physics and Chemistry Research Centre.

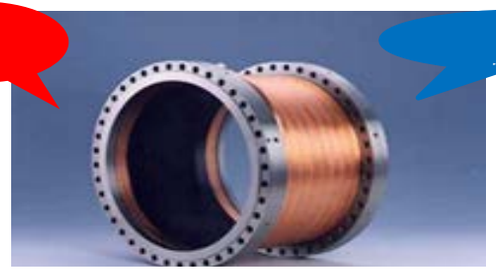
The Process and Operation



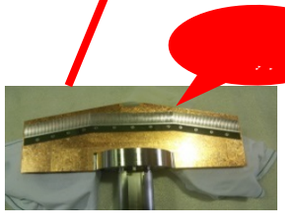
Engineering (Accelerator)

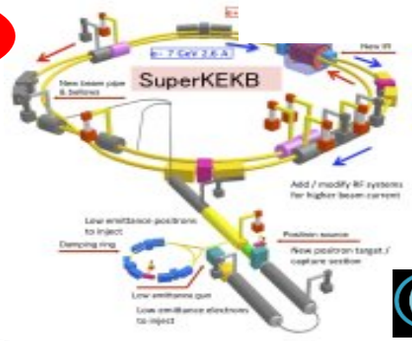


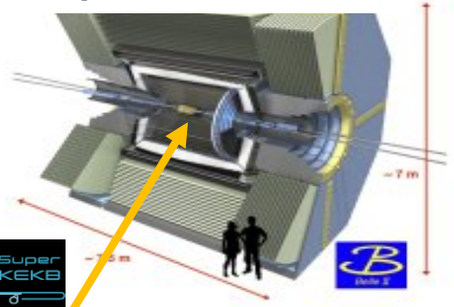
Movable Collimator



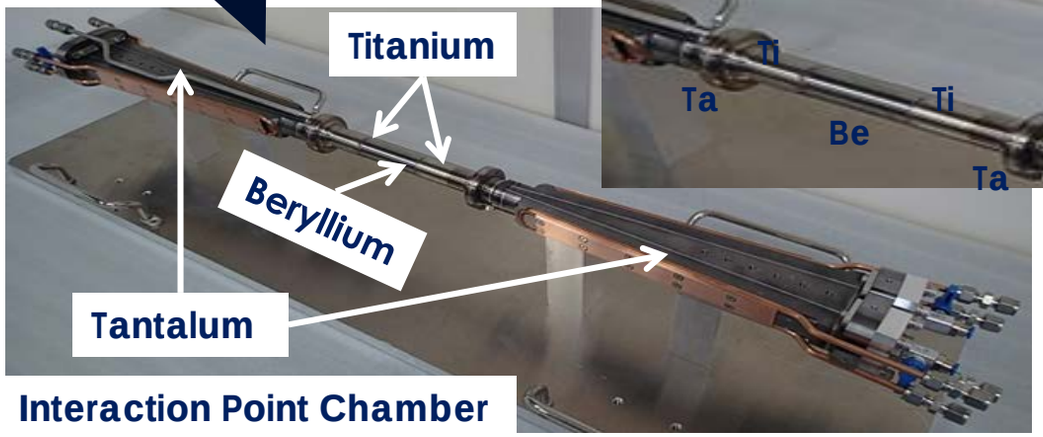
HOM (Higher Order Mode) Damper



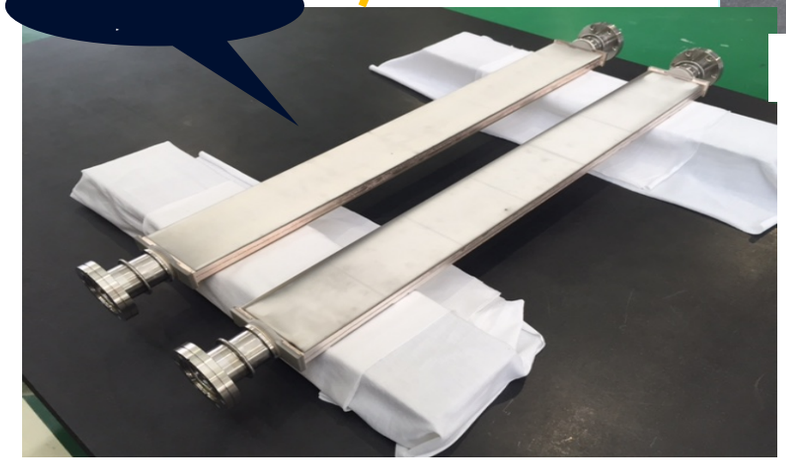




BPM Bellows Chamber

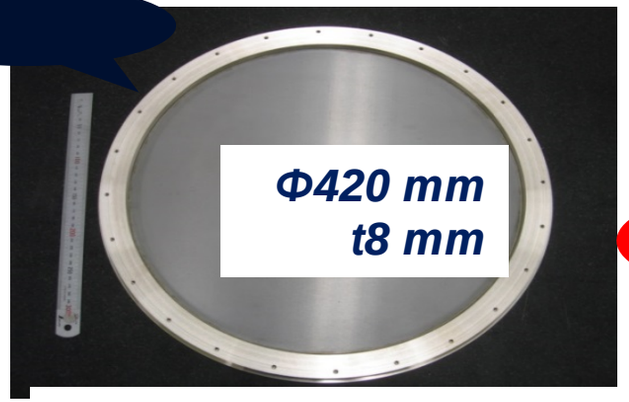


Interaction Point Chamber

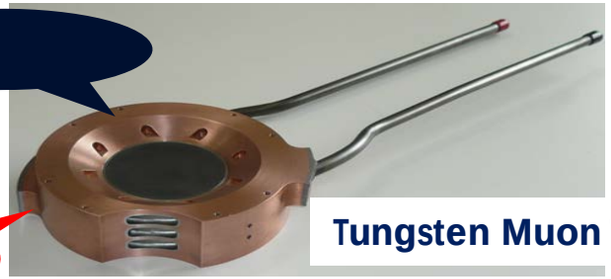


Ceramic Chamber (*Completely Non-magnetic)

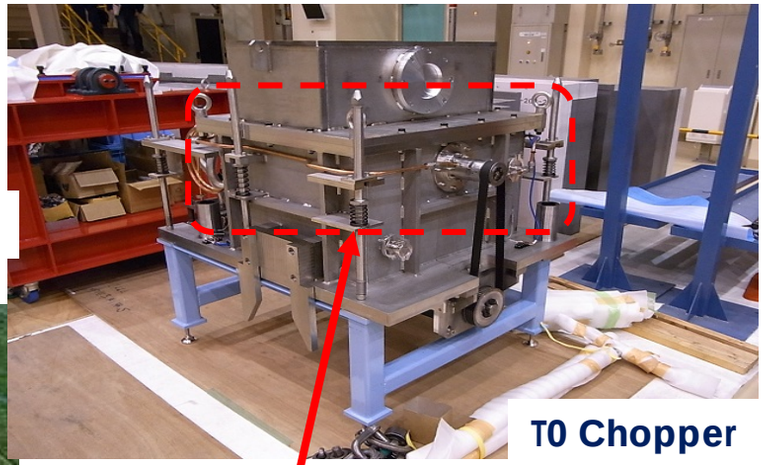
Engineering (Accelerator)



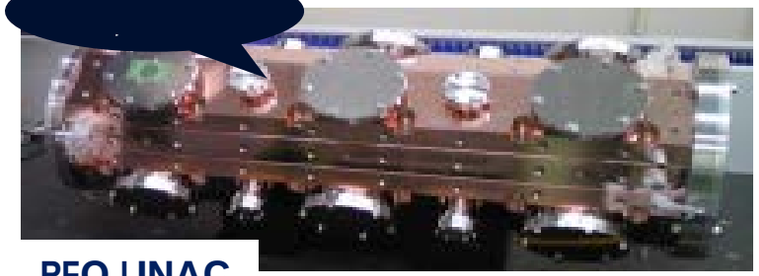
Large Beryllium Beam Window



Tungsten Muon Target

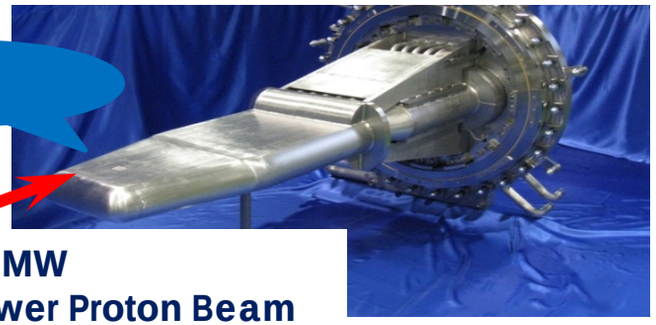


T0 Chopper



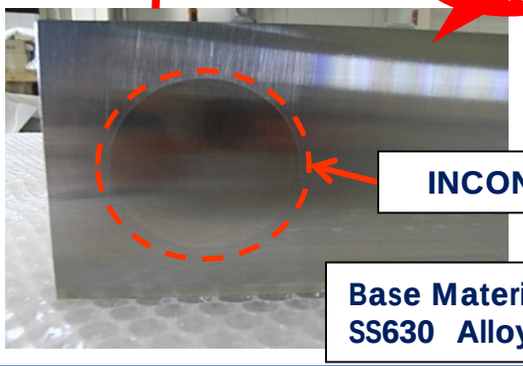
RFQ LINAC

Mercury Neutron Spallation Target



3GeV, 1MW
High Power Proton Beam

Large Vacuum Chamber of Neutron Diffractometer



Analytical Tools

- **ANSYS Mechanical**

Structural and Heat Transmission Analysis

Structural analysis under external force, own weight and Heat conditions

- **MARC**

Structural Analysis of Nonlinear Condition

Nonlinear dynamics such as SPF (Superplastic Forming), Material behavior under high temperature condition etc.

- **ANSYS CFX/CFD**

Fluid Analysis

Fluid such as cooling water and so on including laminar flow, turbulent flow, multi-phase flow and free surface flow

- **ANSYS Maxwell**

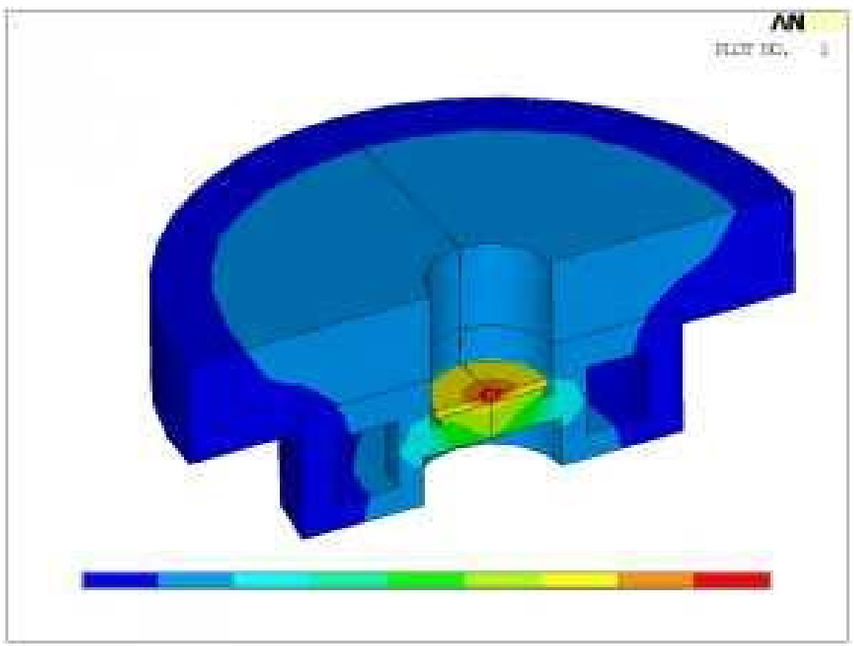
Electromagnetic Force Analysis

Structural analysis including the electromagnetic forces not only for steady state analysis but also transient phenomena

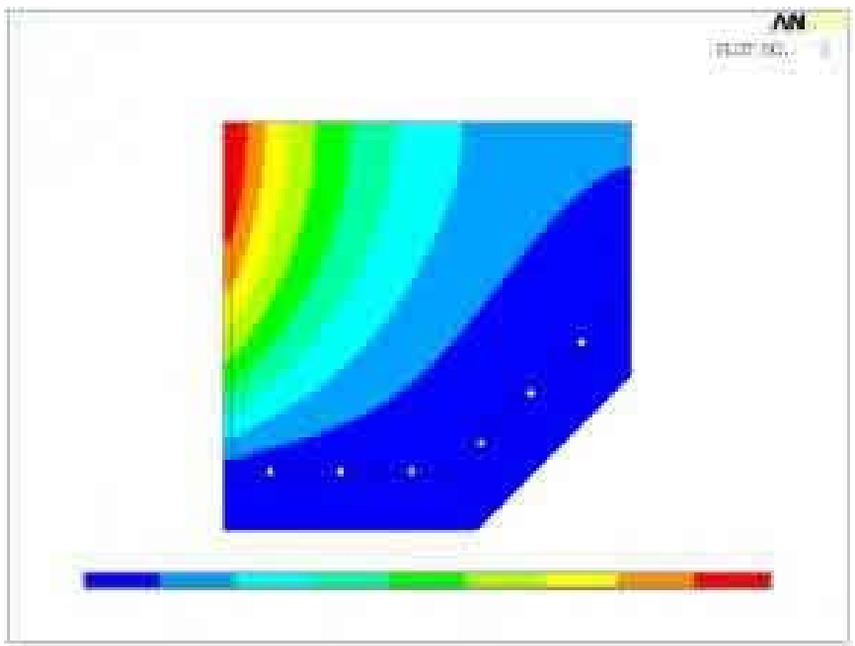
MTC can provide only the analysis work

Examples of Heat Transmission Analysis

- Heat Analysis (Heat transmission, Radiation heat, degree of superheat) for designing the cooling structures such as a heat exchanger or cooling plates to create a uniformed cooling performance.



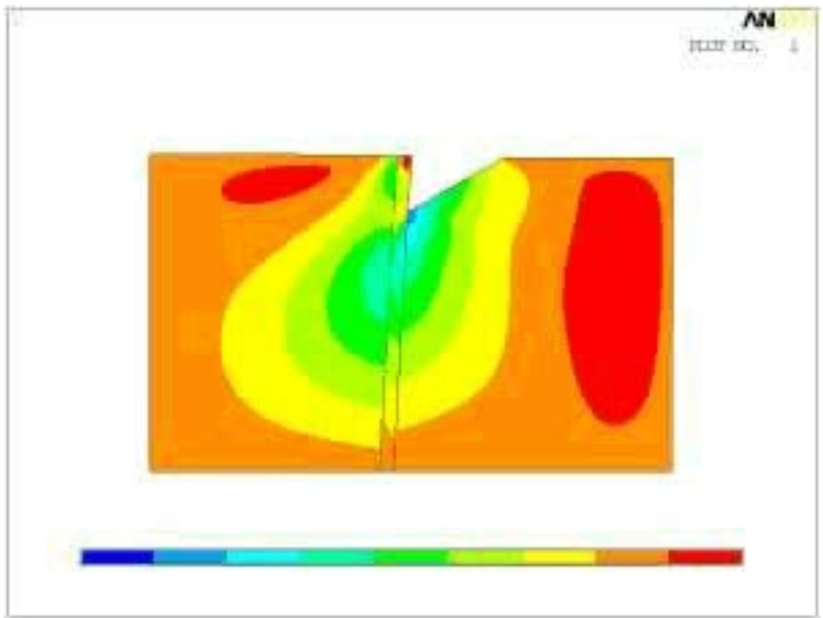
Heat and heat transmission of brazing



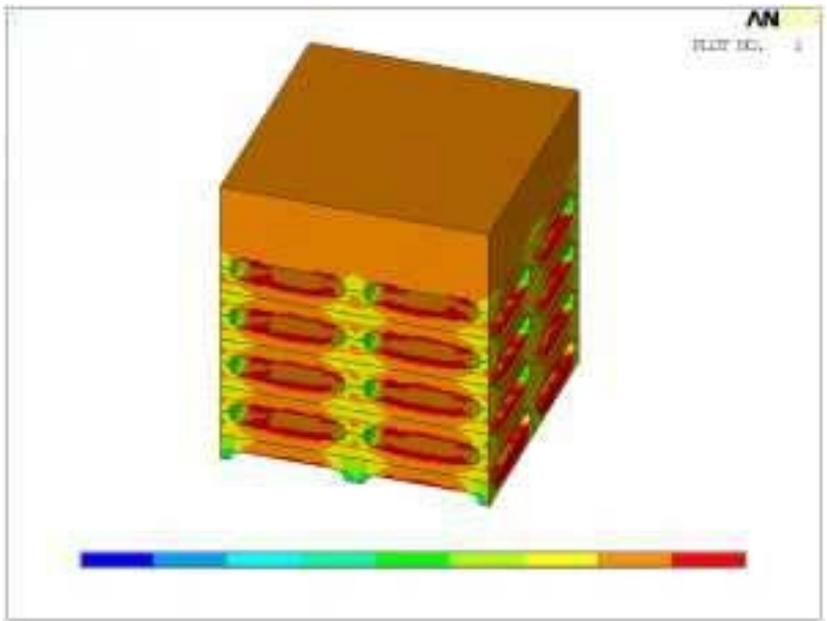
Cooling performance of cooling plate

Examples of Stress Analysis

- Heat Stress, Distortion and Thermal Expansion Analysis for designing the brazing, diffusion bonding of different materials



Heat stress of brazing process

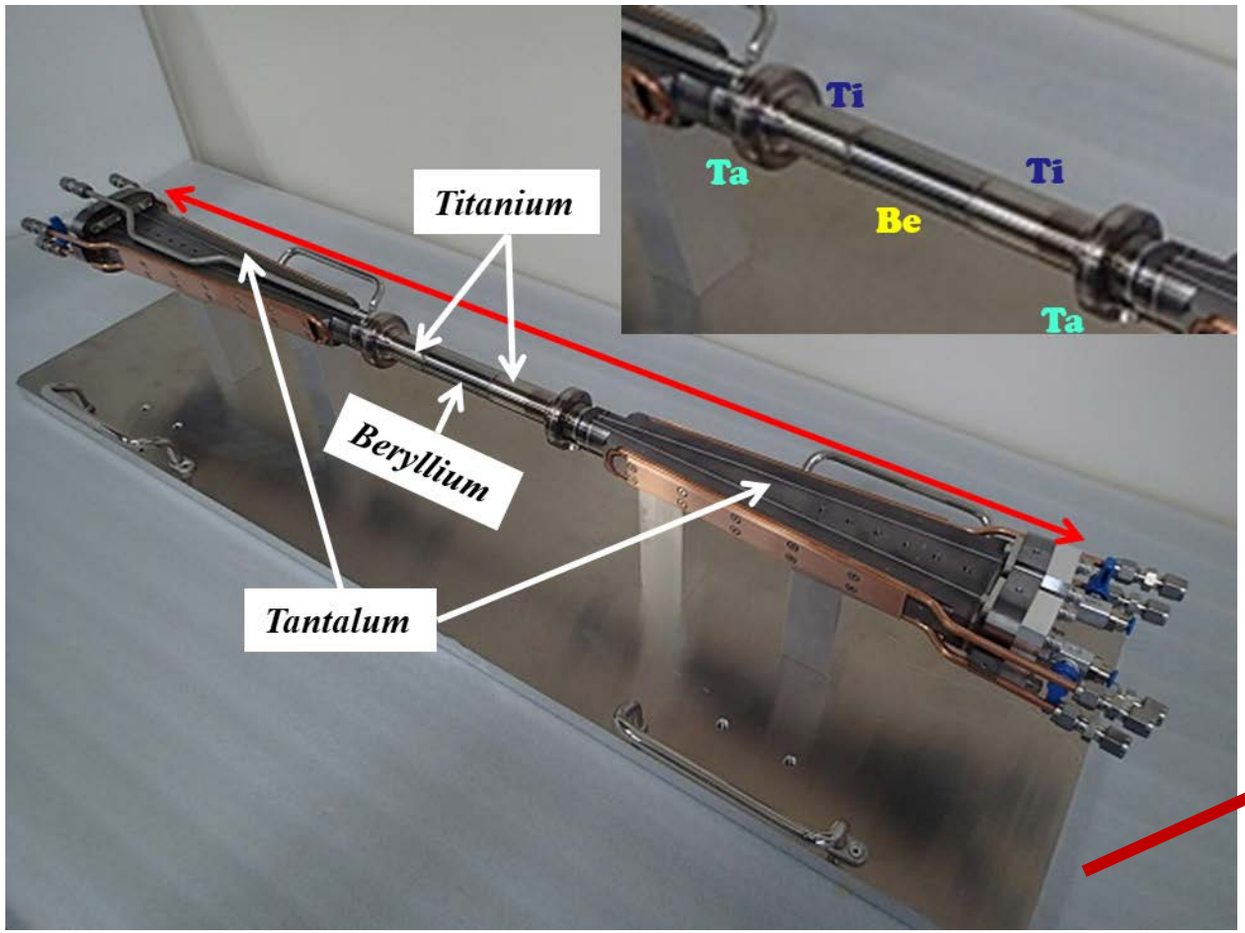


Stress on the boundary of diffusion bonding process

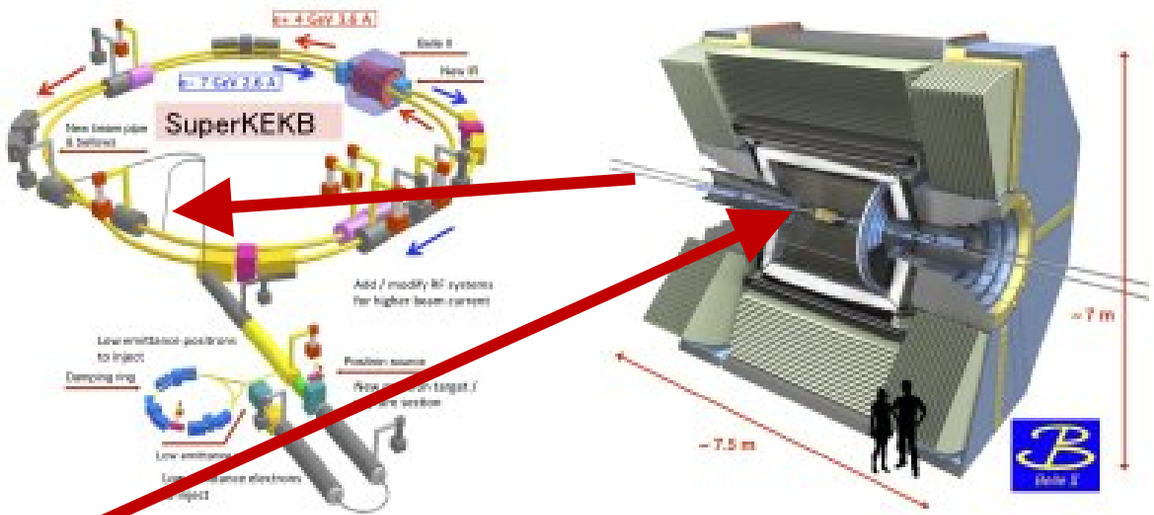
Accelerator Related Equipment

Metal Technology Co. Ltd.

Specialized Vacuum Chambers

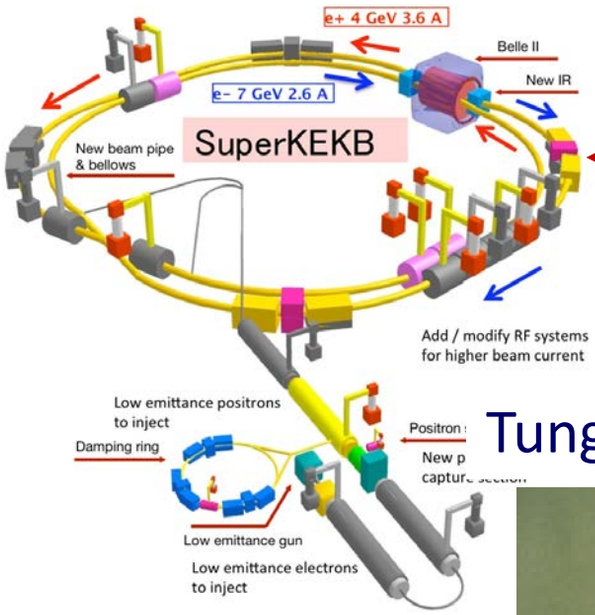


SuperKEKB Accelerator and Belle II detector

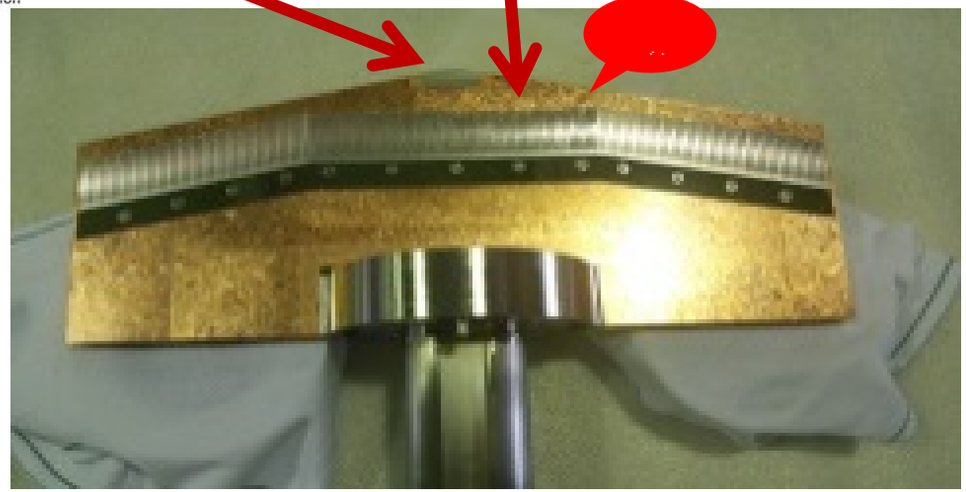


Beam Pipe for Interaction Point

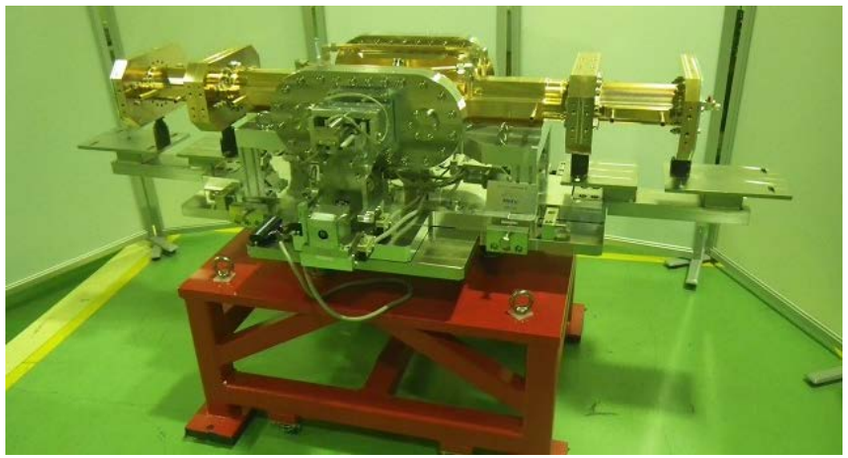
Specialized Vacuum Chambers



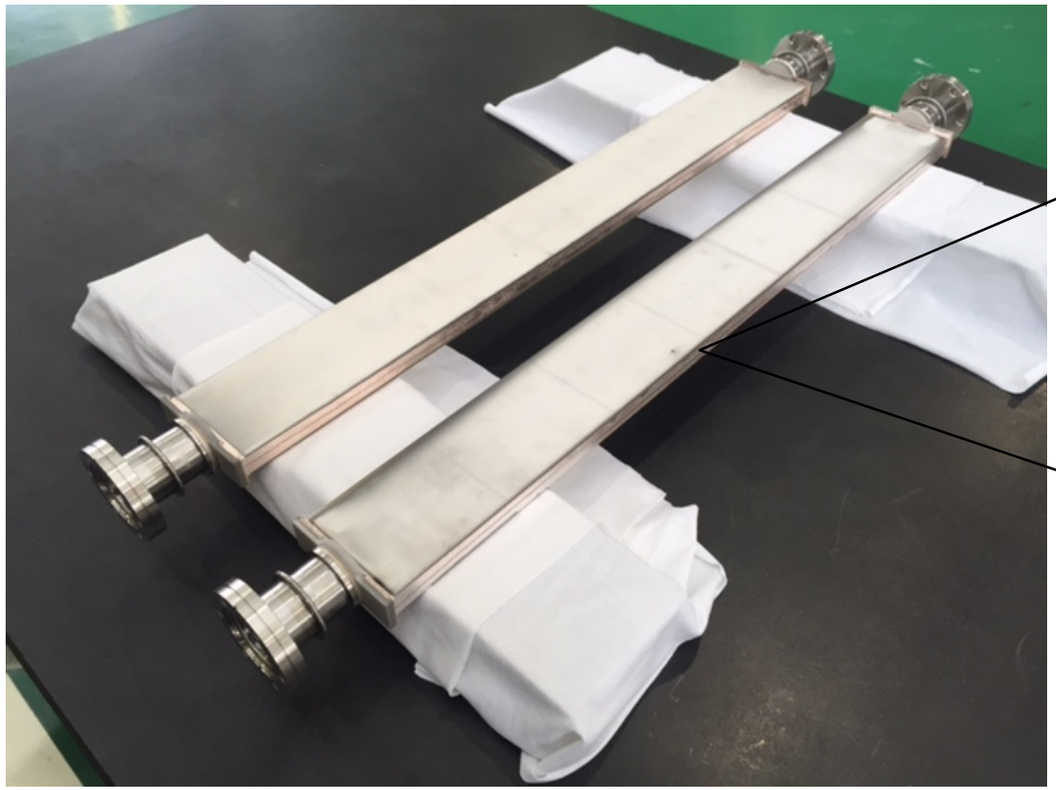
SuperKEKB Accelerator



Collimator for Horizontal Direction



Specialized Vacuum Chambers



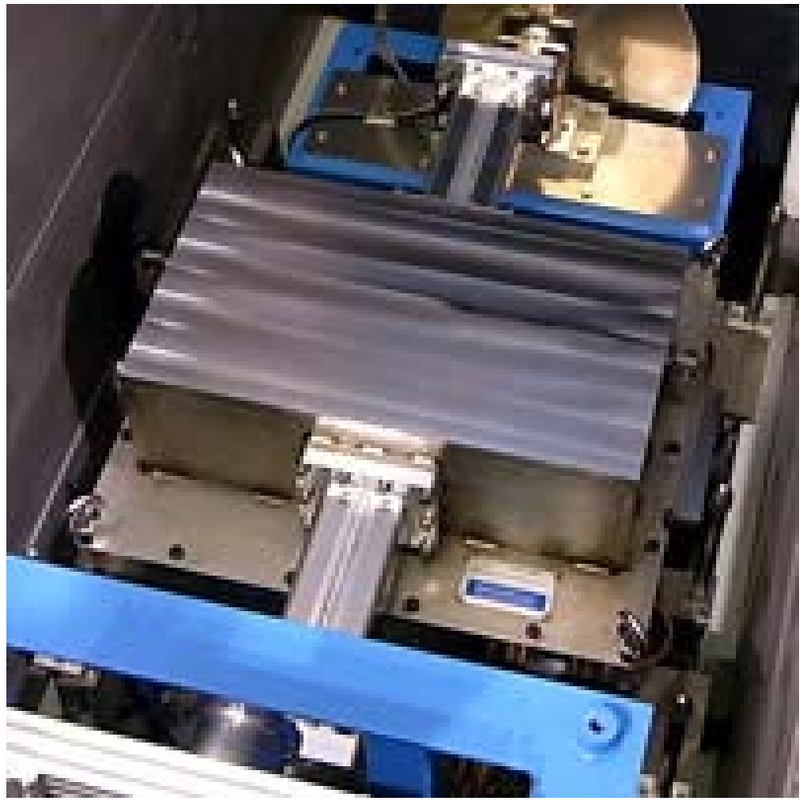
Ceramic Vacuum Duct with absolute non-magnetic for SACLA

The ceramic vacuum ducts used for SACLA.
They are installed on the pulsed electromagnet for the function to distribute electron beams.

- The size of the duct is 830mm long
- Ceramic is 18 x 80 x 718mm
- It's a race-track shaped cross section of 10 x 33mm.
- High-purity alumina ceramic is used.

Because brazing metal and coating materials which have magnetic characteristics were never used in our manufacturing process, the our ceramic ducts have achieved the absolute non-magnetic characteristic.

T0 Chopper System ~ J-PARC ~

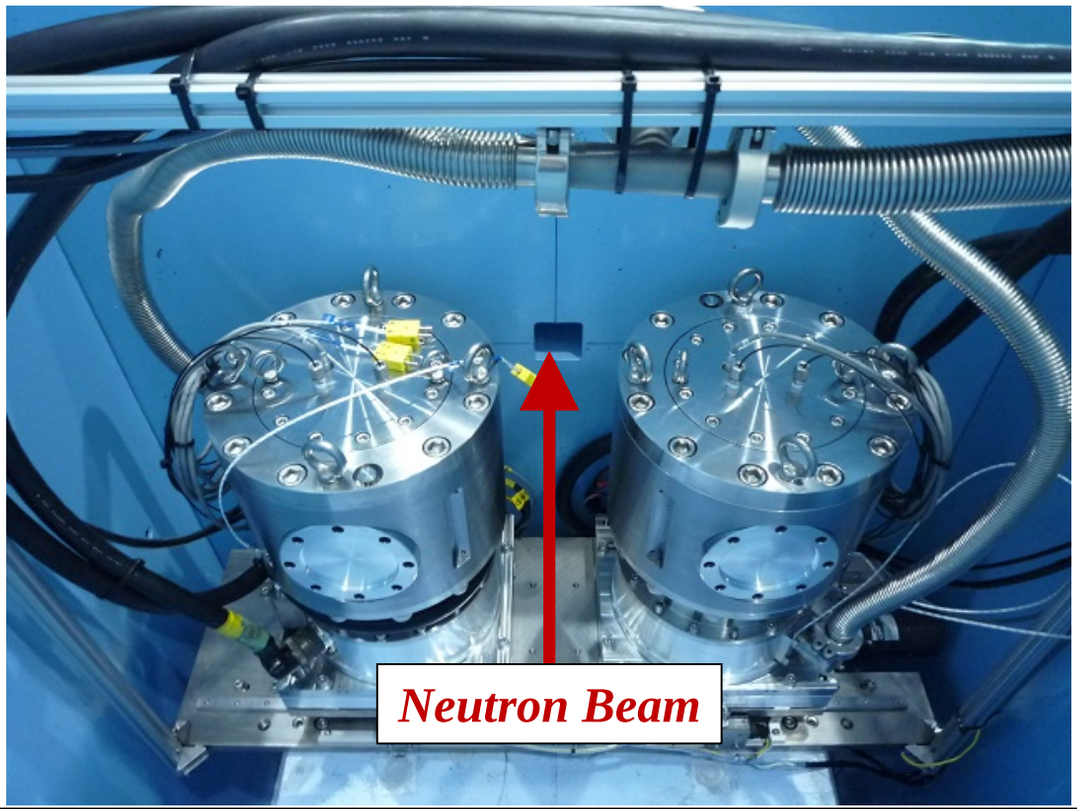


FY2007	BL04 Beam Line, T0 Chopper, 100 Hz
FY2008	BL04 Beam Line, Rotor parts T0 Chopper *HIP process
FY2009	BL12 Beam Line, T0 Chopper, 100 Hz
FY2009	BL21 Beam Line, T0 Chopper, 50 Hz
FY2010	BL16 Beam Line, T0 Chopper, 25 Hz
FY2011	BL23 Beam Line, T0 Chopper, 100 Hz
FY2012	BL12 Beam Line, T0 Chopper No2, 100 Hz
FY2013	BL22 Beam Line, T0 Chopper, 25 Hz
FY2014	BL09 Beam Line, Second T0 Chopper, 50 Hz

MTC can provide T0 Chopper which achieve 100Hz Rotation!

- Several types of T0 Chopper systems are introduced at J-PARC MLF beam lines as a neutron spectrometer of the fast neutron measurement system.
- A spinning rotor (up 100kg) is made from Inconel X750 and SUS630 which are bonded by HIP diffusion bonding process. Compared to the traditional all Inconel rotor, this fabrication method achieves a significant cost reduction.
- A high-speed type of 100Hz needs high accuracy of machining to achieve concentricity within 0.01mm in the rotation axis.

Fermi Chopper System ~ J-PARC ~



Two types of Fermi Chopper will be changed for the purpose of the experiment.

- 5 systems are introduced at J-PARC MLF beam lines as a neutron spectrometer to extract monochromatic energy neutrons.
- Fermi chopper has a high speed rotating rotor achieving a synchronization accuracy of 0.3μs or less at the rotation speed of 600Hz.
- A rotor is a heap of bended slits and grids of fixed curvature, which is designed to endure the centrifugal force of 600Hz.

MTC is only provider of Fermi Chopper in Japan!

Neutron Detector

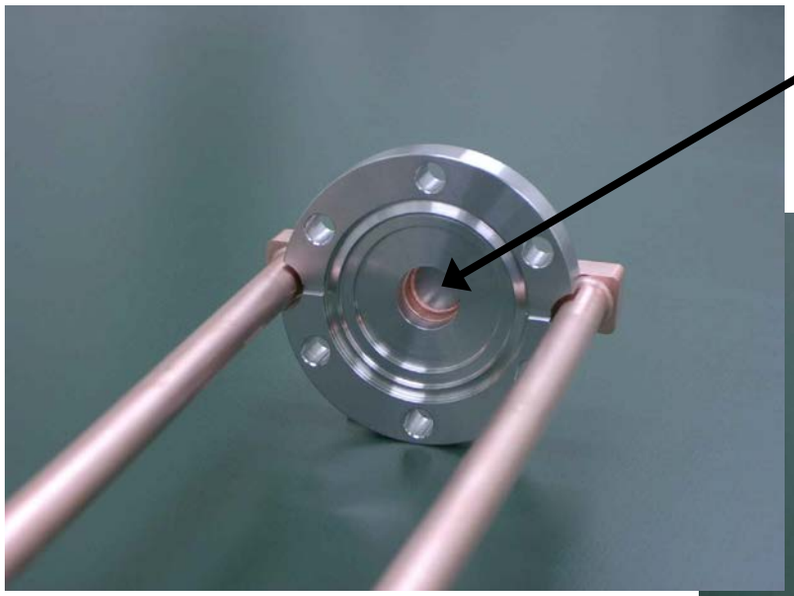
Position sensitive neutron detector
Made by Aluminum Alloy

- ϕ12 mm x L600 mm (t0.5 mm)
- Filled with He3 gas of 20 atm
- Anode center line made by NiCr

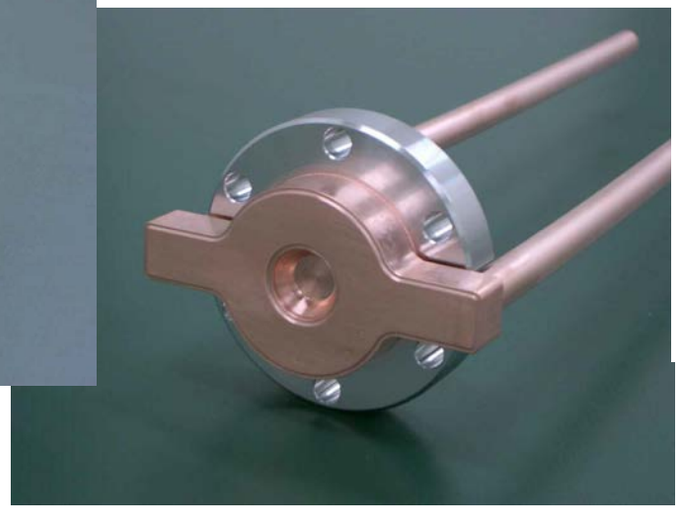
The edge part is also applied aluminum alloy treated with MTC's special HIP material.

MTC is only provider for the neutron detector which has aluminum alloy sheath!

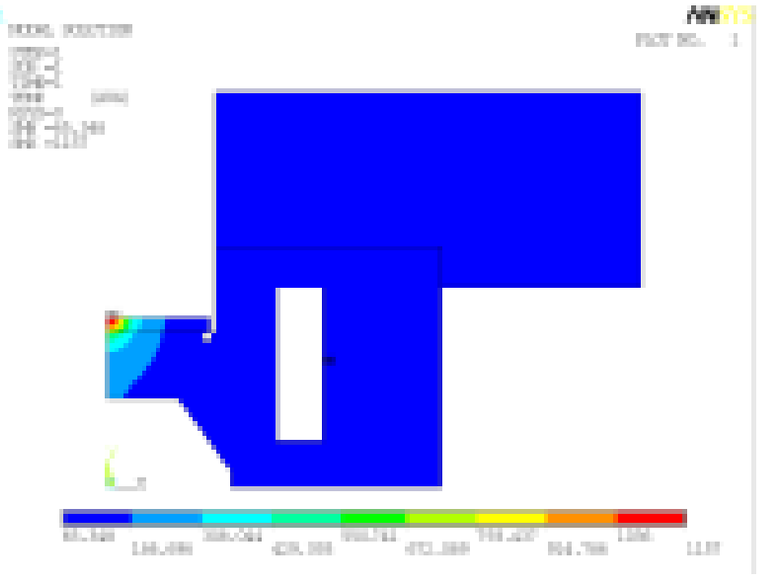
X-Ray Target



Tungsten target is brazed to the stainless steel flange.



X-ray Target



Temperature distribution by FEM analysis

The X-ray target generates bremsstrahlung (Brake Radiation) caused by high energy electron beam. The electron beam power of 1 kW is irradiated on the target center region of 2mm in diameter.

In order to prevent overheating of the target, the X-ray target was designed to efficient cooling system based on FEM analysis, and it was manufactured using MTC's machining and brazing technology.

Muon Target (MLF, J-PARC)

Product Overview

- A muon target is used to generate muon particles when accelerated protons hit the graphite target.
  This equipment is installed at MLF (Materials and Life Science Facility), in J-PARC (Japan Proton Accelerator Research Complex).

Manufacturing Technology

- HIP diffusion bonding of copper frame body, stainless steel pipe and a stainless steel part is used.
  Vacuum brazing is used for graphite and copper frame.

HOM Damper (KEKB and ERL at KEK)

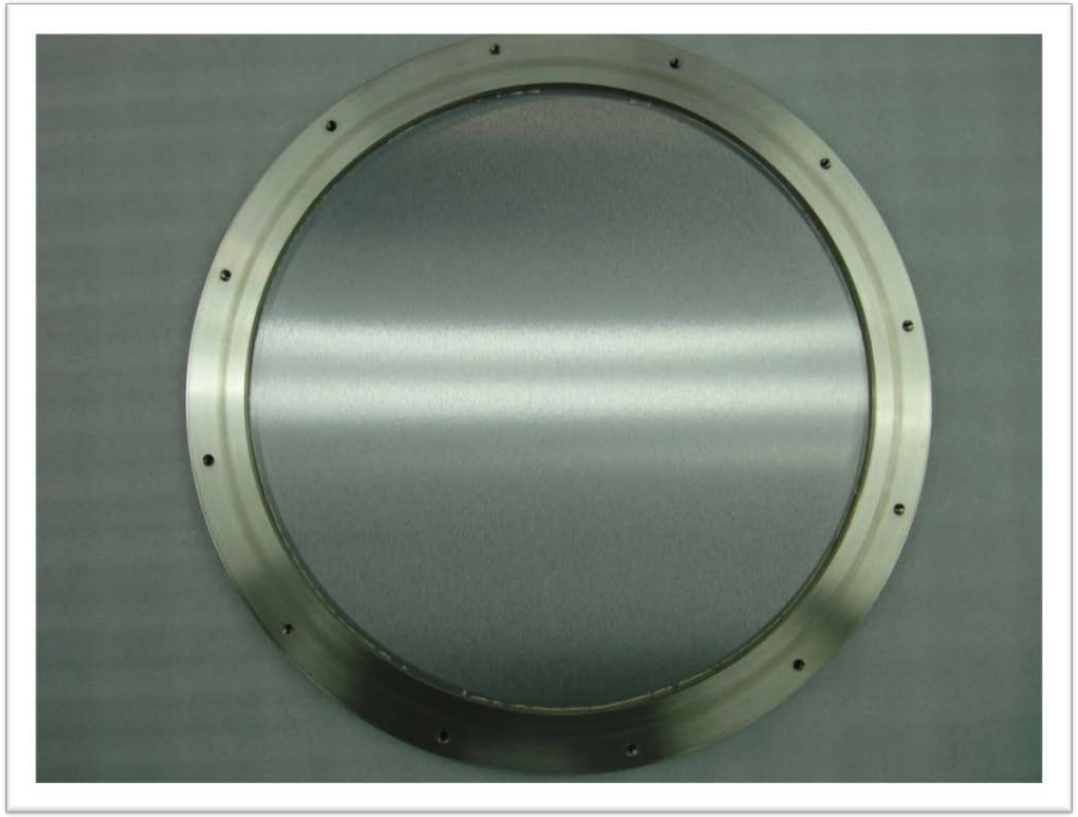
Product Overview

- HOM (Higher Order Mode) damper is used to absorb higher order mode of resonant frequency of accelerator tube, consisting of a copper body for cooling and ferrite core for absorber.

Manufacturing Technology

- Ferrite powder is sintered and bonded to a copper body by a single HIP process.
  Vacuum brazing is also used to attach outer stainless tube and copper main body.

Large Beryllium windows (J-PARC)



Product Overview

For high energy particle and X-ray source, beryllium window is often used.
The left photo shows the largest window in the world whose diameter is ϕ460mm.

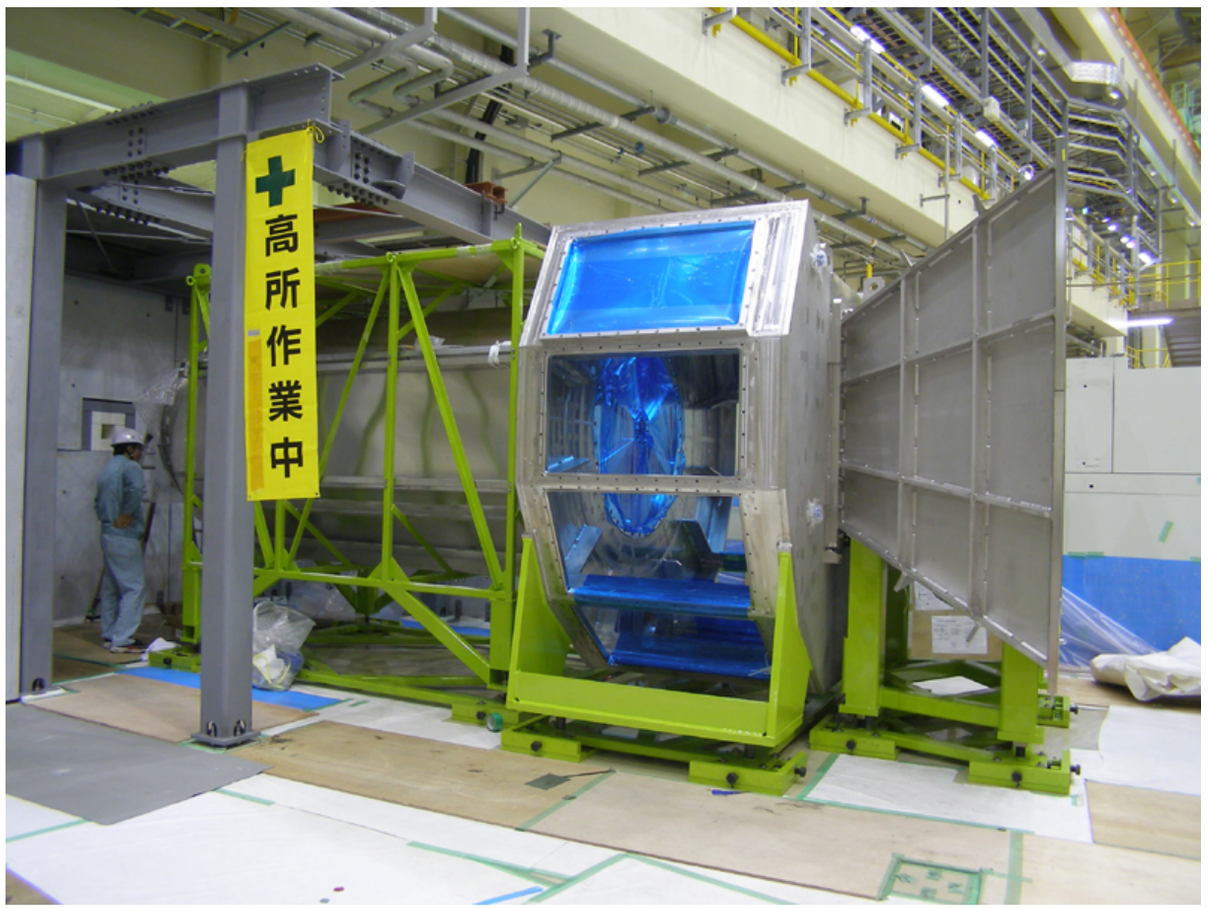
Fabrication Technology

A strength evaluation using FEM analysis tool makes it possible to manufacture the larger window by brazing technique.

Plant Related Equipment

Metal Technology Co. Ltd.

Large Vacuum Chamber of Diffractometer



- The large vacuum chambers are the main components of the neutron diffractometer, which consist of two stainless steel chambers and one aluminum alloy chamber.
- Besides large structures of 3m x 3m x 7m, the aluminum wall is designed to have t1.0mm for good penetration of neutron.
- A FEM structural strength evaluation based on material data and both high-precision machining and little-distortion welding are applied on this production.

Mercury Target Vessel (J-PARC)

Specification: Triple container of SUS316L for mercury, helium and heavy water.
Length: 2.3 m
Weight: 1.6 ton

- The mercury target vessel is located in the center of MLF (Materials and Life Science Facility) of J-PARC. The vessel contains mercury as a neutron spallation source, with which a proton beam of high intensity is irradiated. In order to contain mercury tightly and to cool down efficiently, the vessel is made of triple stainless steel container, for which production advanced welding and bonding technologies of high accuracy is required.

- Total 5 vessels are delivered by MTC for now and the upgrade design has been applied step by step regarding with beam current increase.

Accelerator equipment

Metal Technology Co. Ltd.

Compact Accelerator Development

PPL and MTC signed the technical alliance agreement about MICROTRON in March 2016.

In cooperation with PPL, MTC is now developing small and high power MICROTRON for Electron Irradiation use such as sterilization of medical equipment, material reforming, etc.

光発生技術で未来を拓く 光子研
Photon Production Laboratory, Ltd.

＋

Metal Technology Co. Ltd.

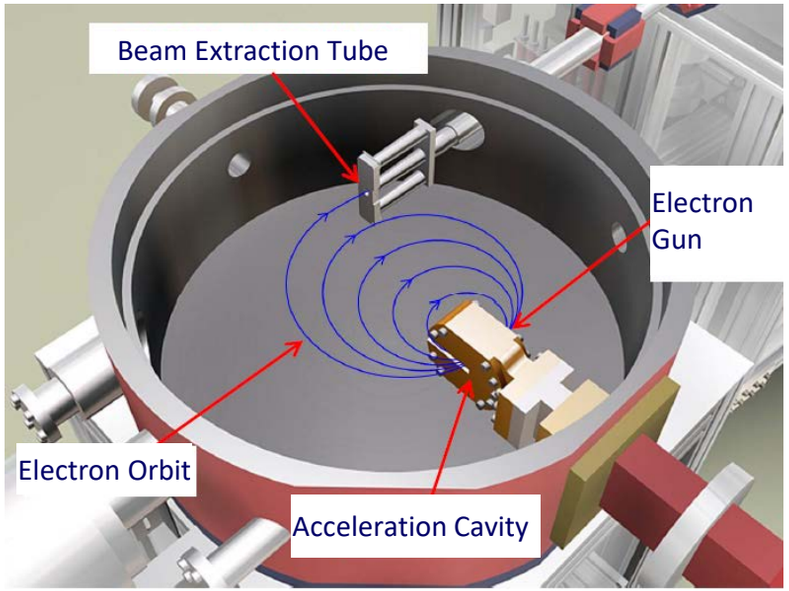
PPL Business: Non Destructive Testing (NDT) with High-energy electron accelerator

※ With compared to conventional NDT using conventional X-ray tubes, PPL can provide high quality X-ray images, since they uses MeV class electron accelerator

X-ray CT

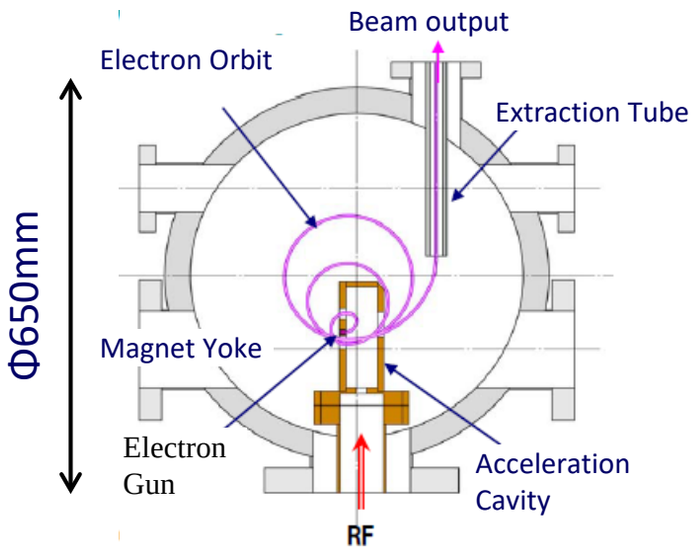
http://www.photon-production.co.jp/common1/ref/JAPI_2016.pdf

MICROTRON Electron Accelerator



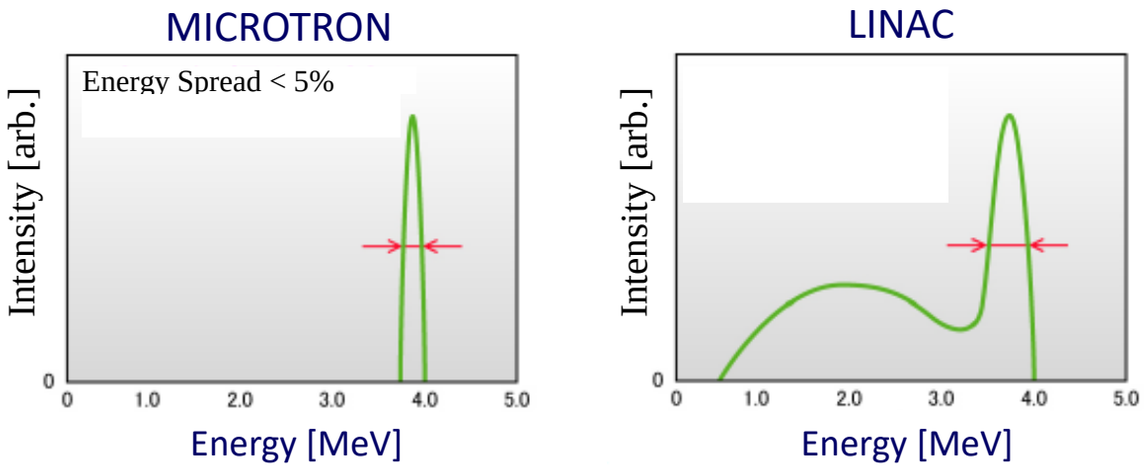
Features of MICROTRON

- ✓Electron Accelerator
- ✓Single Cavity in Uniform Magnetic Field
- ✓Repetition Acceleration with Single Cavity
- ✓Simple and Small Structure
- ✓Easy Acceleration to Several MeV
- ✓Small Energy Spread



MICROTRON : Energy 6 – 10 MeV

Comparison of Energy Spectrum



*Reference : PPL data

Radiation Sterilization Example

MTC would like to provide high power compact Electron accelerator “MICROTRON” for several irradiation applications.

Medical Equipment

—Syringe
—Catheter
—Glove for Operation
—First-aid adhesive tape
—Cotton Swab
—Clamp … etc.

Sanitary Material

—Gloves
—Wear
—Deodorants
—Mask
—Gauze
—Bandage…etc.

Clinical Inspection Instruments

—Dish
—Rubber Stopper
—Sterile Bag
—Bovine serum
—Clinical Inspection Instruments…etc.

Container (Medical / Cosmetics)

—Eye Drops Container点眼
—Mascara
—Drug Container
—Ampoule…etc.

Food Container

—Margarine Container
—Bottle Cap
—Processed Meat Net
—Yogurt Container
—Cotton Cloth
—Wine Cork
—wrapping Paper
…etc.

Material of Drug, Cosmetic and Crude drug

—Hyaluronic Acid
—Polyglutamic Acid
—Collagen
—Drug Substance
—Crude Drug…etc.

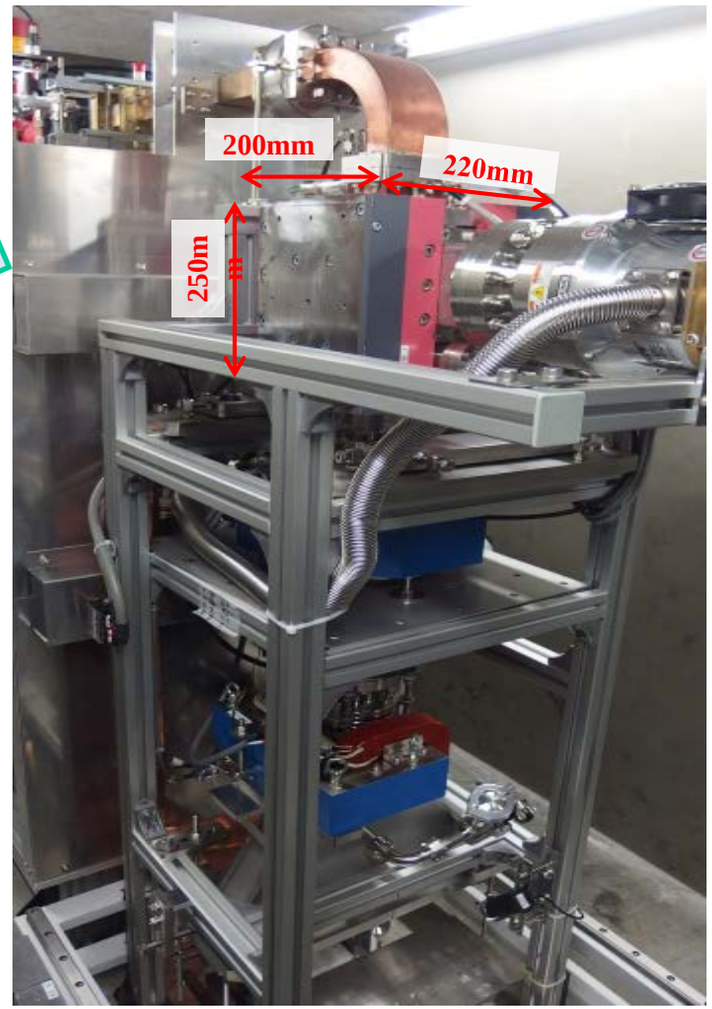
Animal experimentation and Agricultural / livestock-related

—Veterinary Medical Equipment
—Experimental Animal Feed
—Mouse Cage
—Paper Towel
—Bedding
…etc.

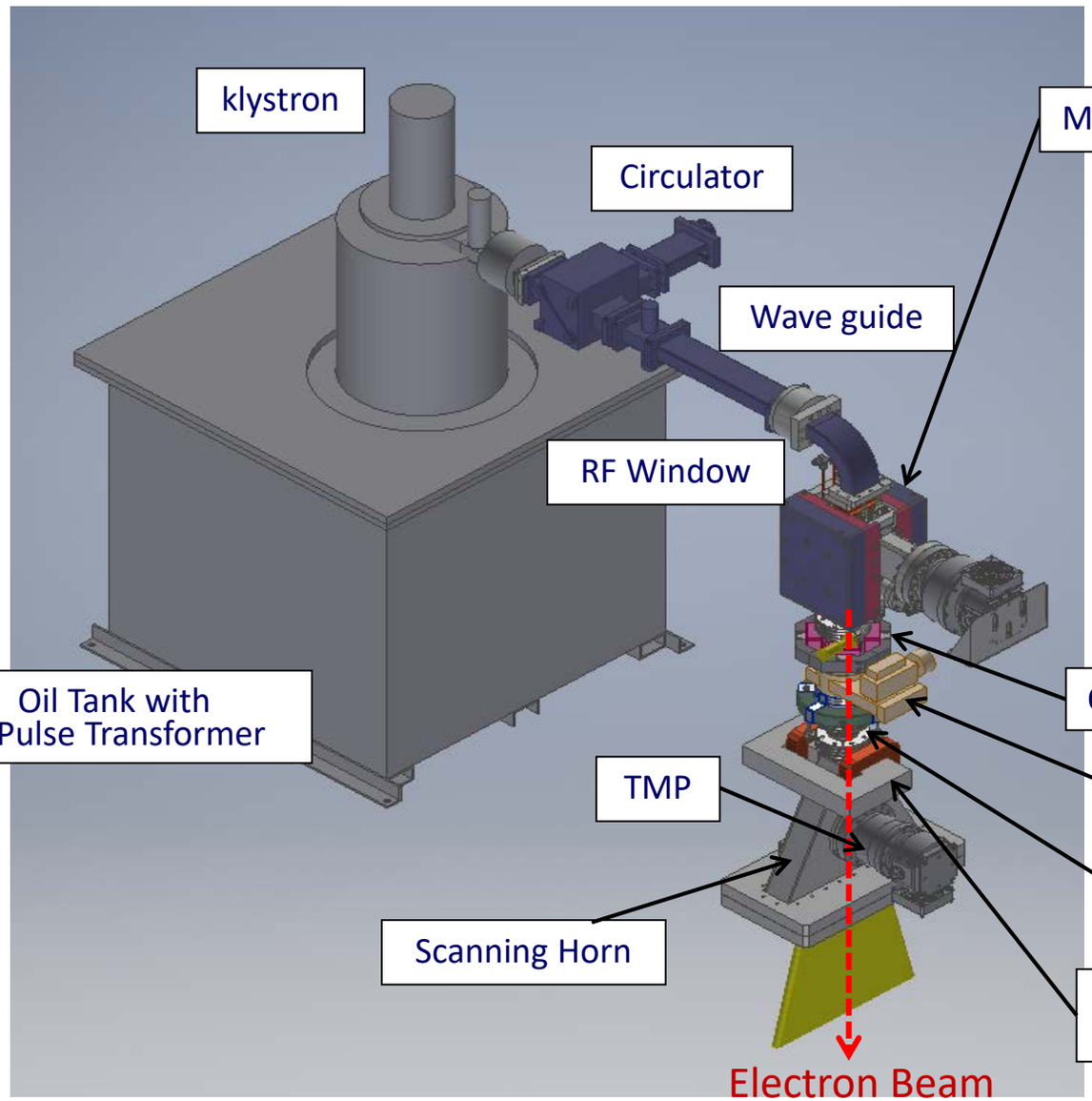
MIC1 Test Machine

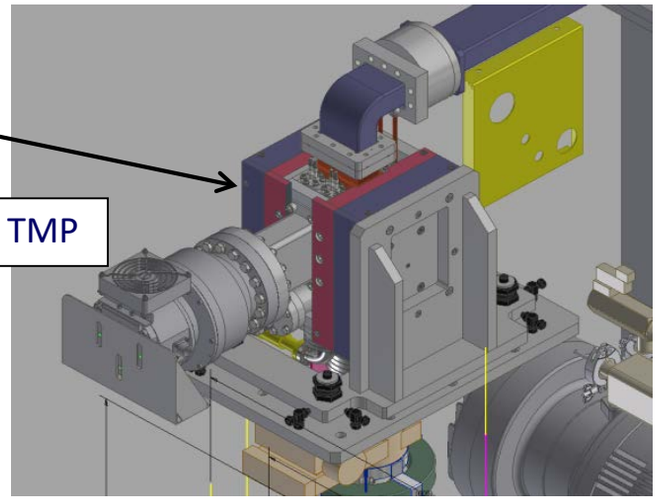
Name	MIC1
Energy	0.95 MeV
Beam Current (Peak)	300 mA
RF Frequency	2856 MHz
Pulse Width (FWHM)	1.5 μs
Repetition Rate	1,000 pps
Body Size	250mm x 200mm x H220mm

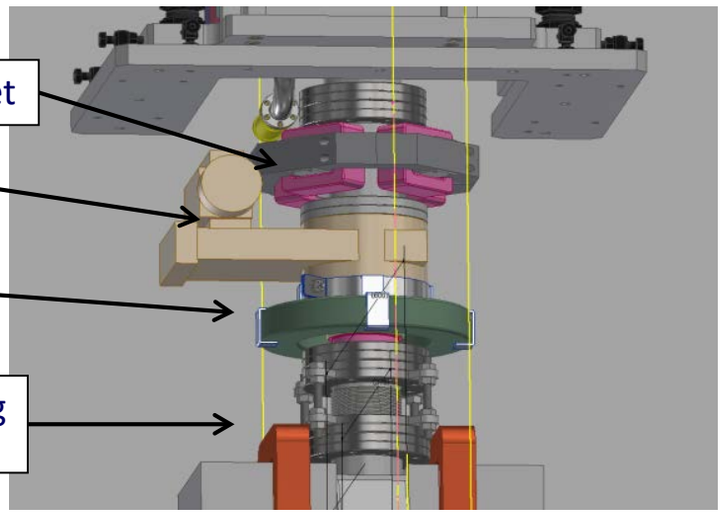
Movable Local Shield



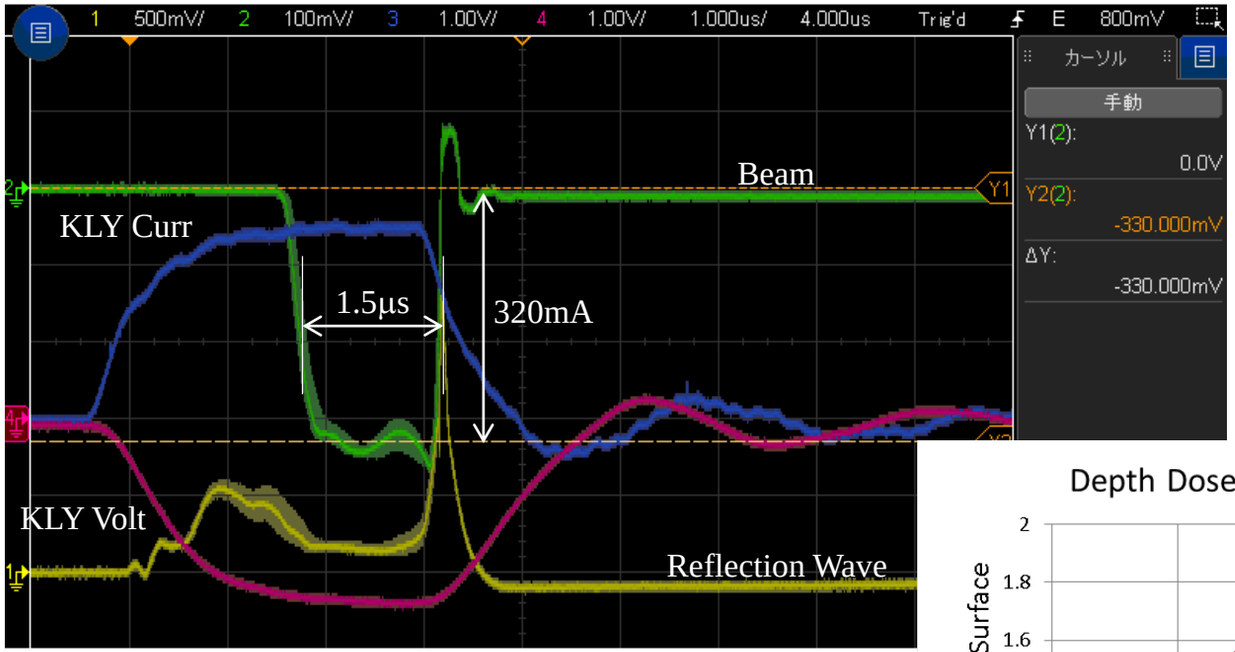
MIC1 Test Machine



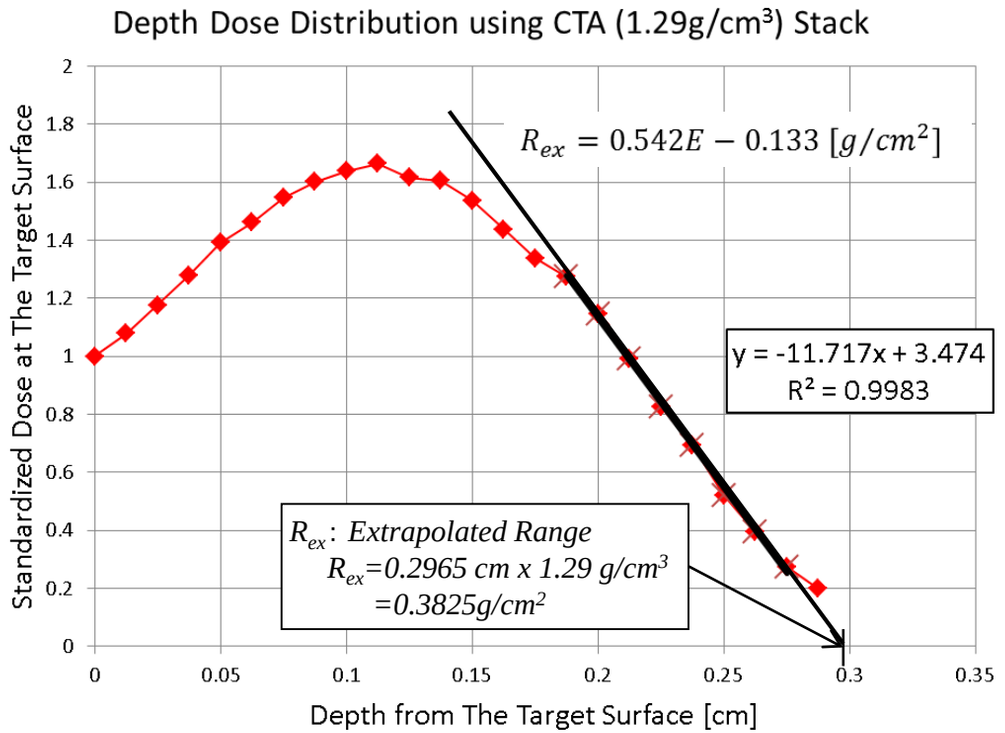




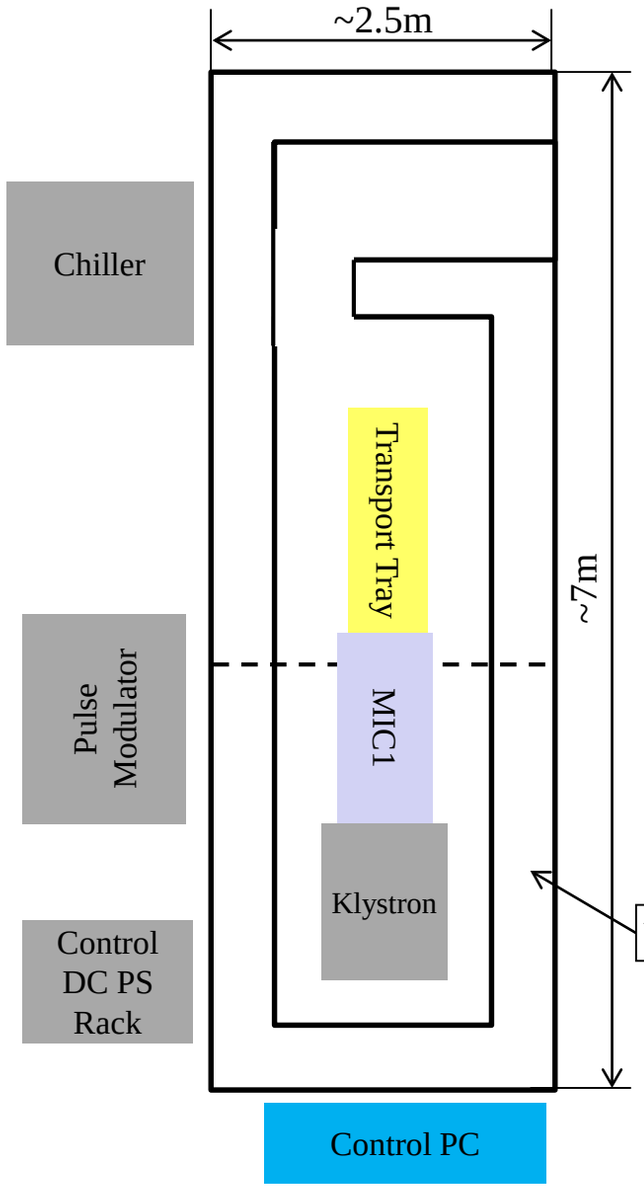
Beam Data



- Beam Current : 320mA
- Beam Pulse : ~1.5ms
- Beam Energy : 0.95MeV
  E = (0.3825 + 0.133) / 0.542 = 0.951 MeV
- Scanned Beam Width : ~ 300mm
  under 100mm from Ti Window
  *Scanned Beam dose distribution < ±5～10%

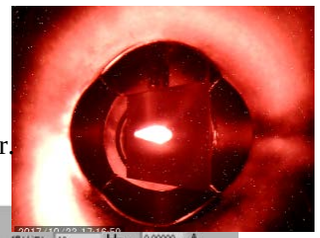


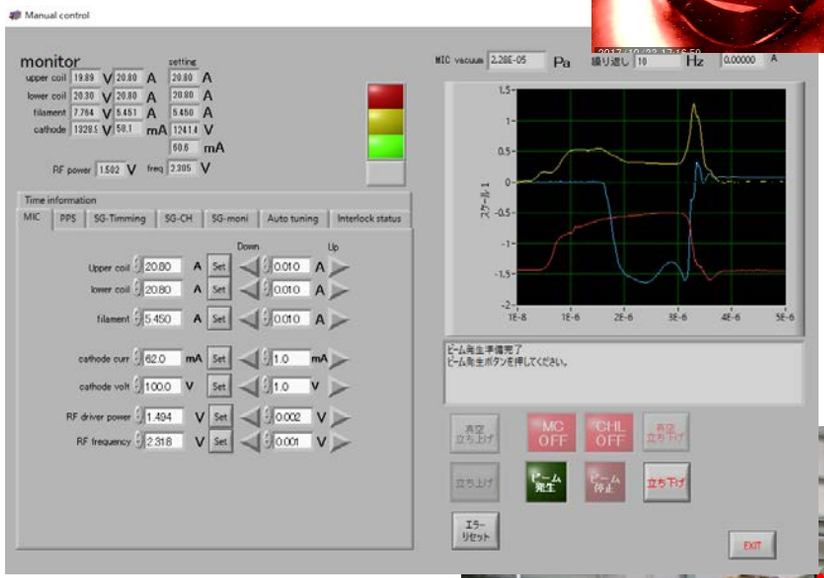
Main Equipment and Shielding Structure



Beam Size : ~ϕ15mm

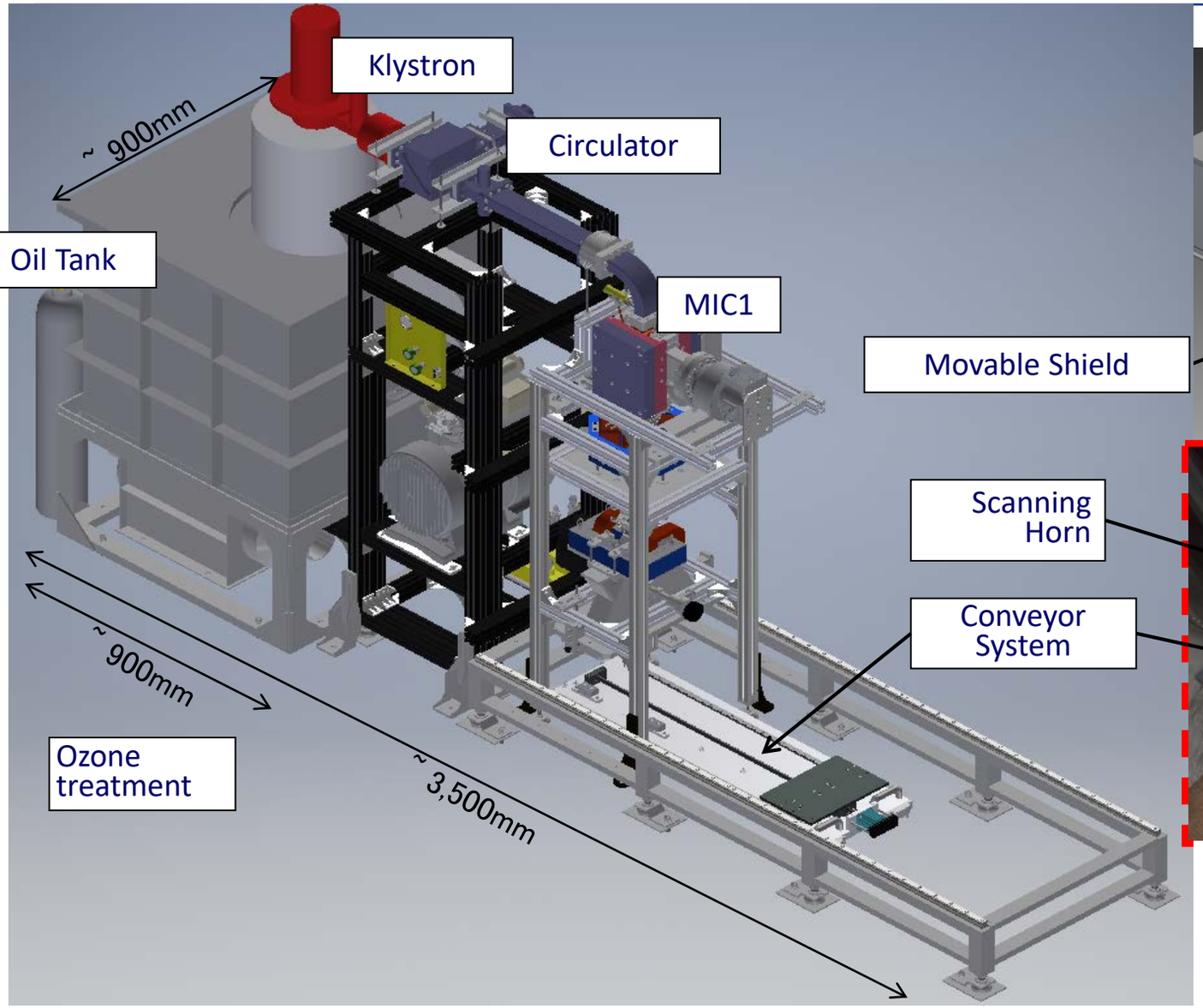
*Phosphor was 45 degree diagonally set in the chamber.

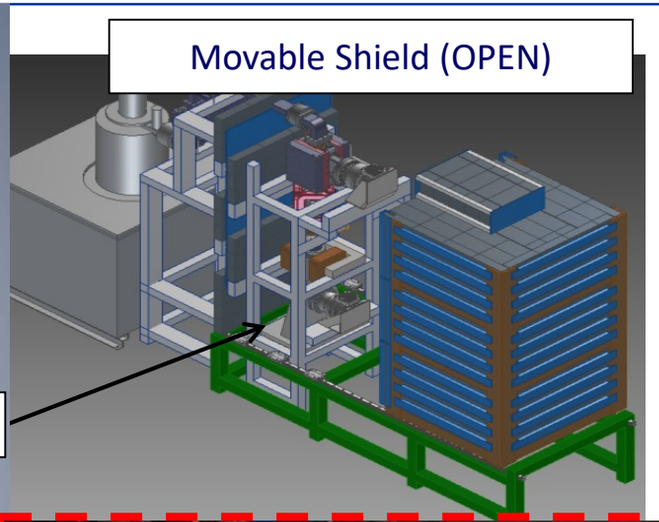




Test facility in MTC Shiga Plant

Sample Irradiation is available





Tray Size : 300 x 200 mm
Work Height : < 280 mm

"The metal solution"

For any equipment, even if it is still in the concept stage, MTC can find the best solution. Through our knowledge and experience in metal technology and processes we can reach a solution together.

- Thank you for your attention.


Metal Technology Co. Ltd.