KOBELCO
KOBE STEEL GROUP

JASTEC
SUPERCONDUCTOR

The way Nb_3Sn wire was developed and improved for ITER Project

Japan Superconductor Technology, Inc.
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2018/12/14　ITER/BA　成果報告会

OUTLINE

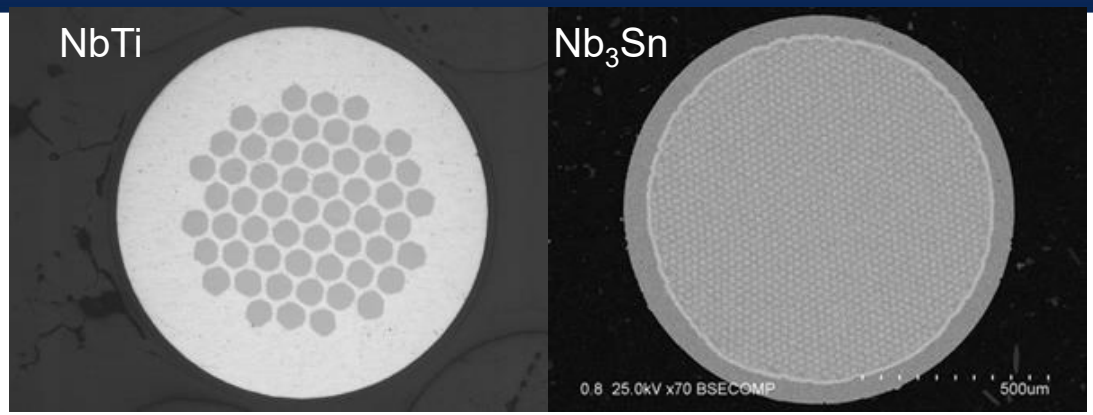
- About JASTEC (Japan Superconductor Technology, Inc.)
- Contribution to ITER: Superconducting magnet
- Contribution to ITER: Superconducting wire
- Development for future

- Originated from Research Laboratory in Kobe Steel LTD
- Established in 2002
- Products ; Superconducting wire and magnet
- Manufacturing and Sales of High field magnet and superconducting wire for the magnet

Products lineup in JASTEC

Superconducting wire

- ✓ NbTi⇒ low magnetic field
- ✓ Nb_3Sn⇒high magnetic field



Superconducting magnet

- ✓ Biology/Chemical Analysis : NMR
- ✓ Medical Imaging : MRI
- ✓ Silicon Crystal Growth : MCZ
- ✓ Gyrotron: High power Microwave radiation

Contribution to ITER –Superconducting magnet-

Cryo-cooler cooled magnet

Magnet for superconducting wire evaluation

Max Field 15T（150000 Gauss）

Bore size 170mm

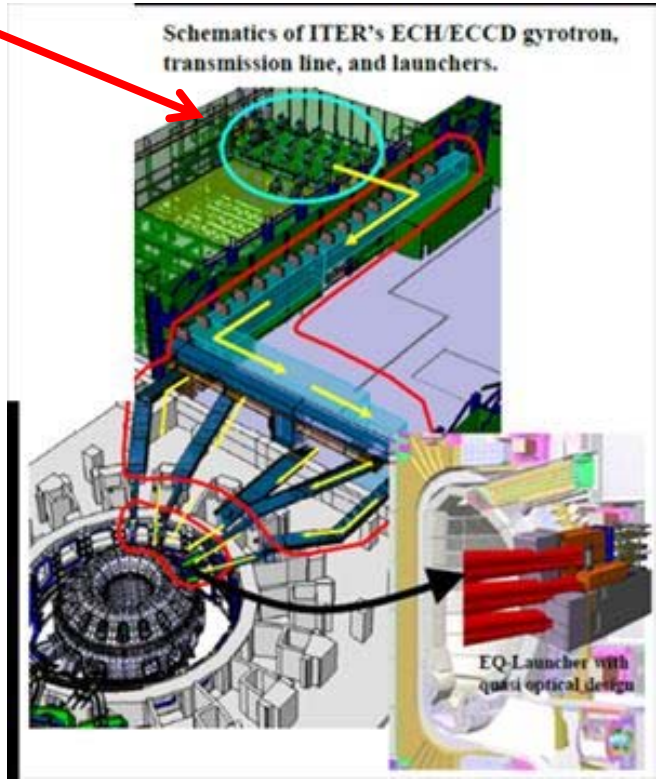
Delivery in May 2005 at QST, Four GM-cryocoolers installed

Generates 15 Tesla magnetic field without Liquid Helium

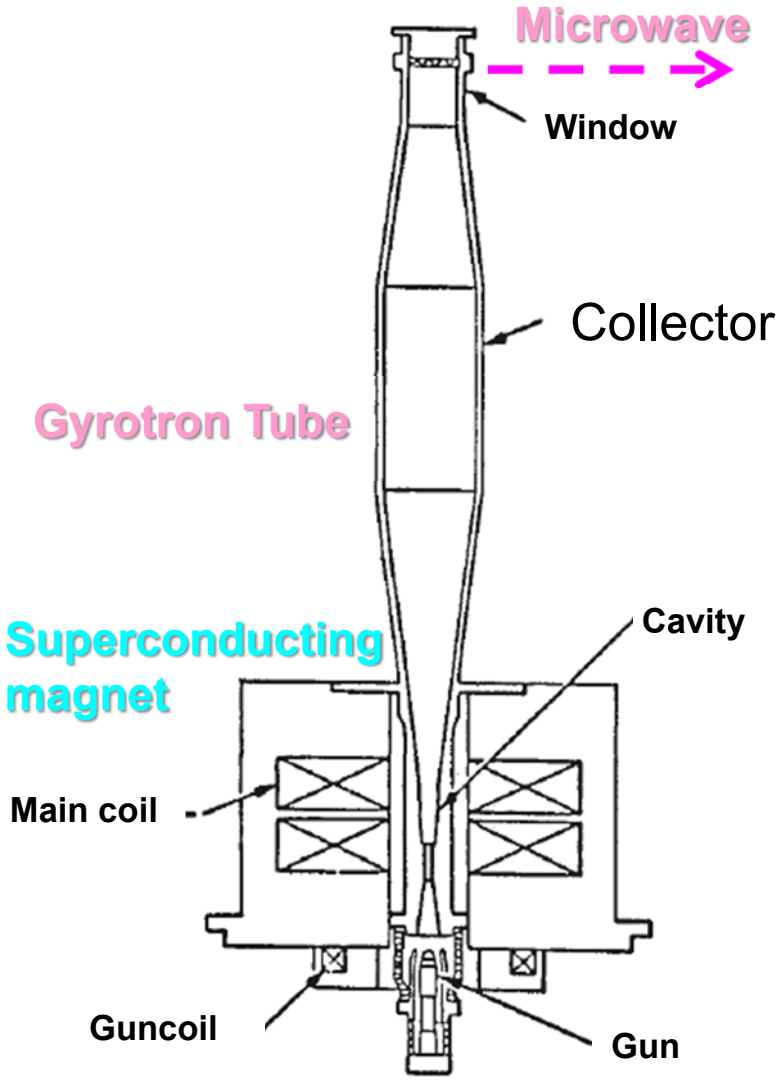
Magnet for Gyrotron

Installed in Microwave generation for plasma heating

Generates 6-7 Tesla



About Gyrotron （How Superconducting magnet works）



Gyrotron

What is Gyrotron?

- High power microwave generator by ultra high speed rotation of electron. For the rotational movement of electron, high magnetic field required.
- Electron heating and current controlling for fusion plasma is enabled by high power microwave

How Superconducting magnet works

- Supply magnetic field for electron rotation
- Generates magnetic field distribution suitable for gyrotron
  e.g. Higher filed at cavity, lower field at collector

Development history of 7T240 for Gyrotron

- 2006 Prototyping
  Superconducting gun coil is installed.
  Fast field distribution change by sweep coil
  Presentation in MT-20 at Philadelphia

- 2011 Type Ⅱ installed in KSTAR Korea
  Two compensation coils could change field distribution
  Presentation in MT-22 at Marseille

- 2011,2013 Two Type Ⅱ delivered for JT-60SA

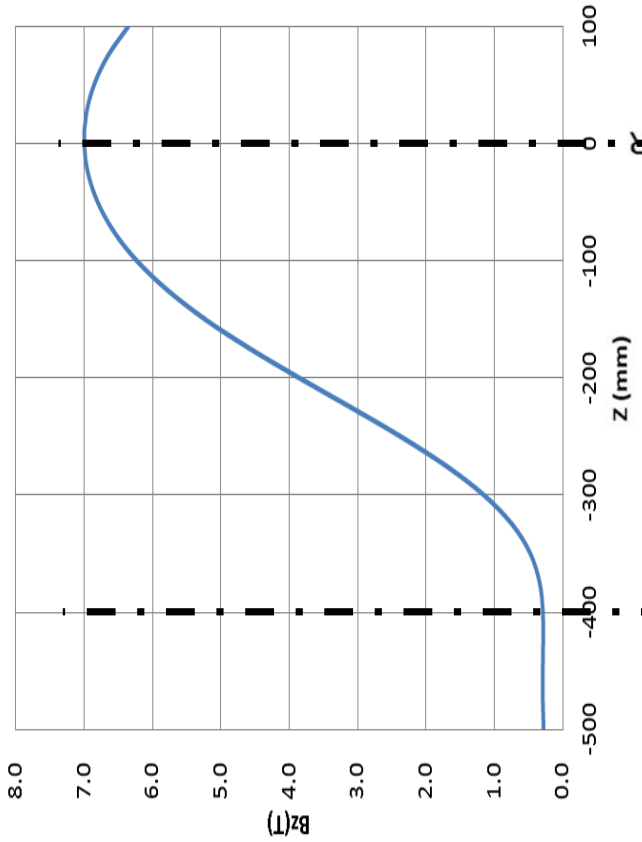
- 2011,2014 Two 6.5T260 magnets delivered to NIFS（Tsukuba Univ.)

- 2013 8T240 magnets delivered
  Development of higher field magnet. Enabling beyond ITER specification

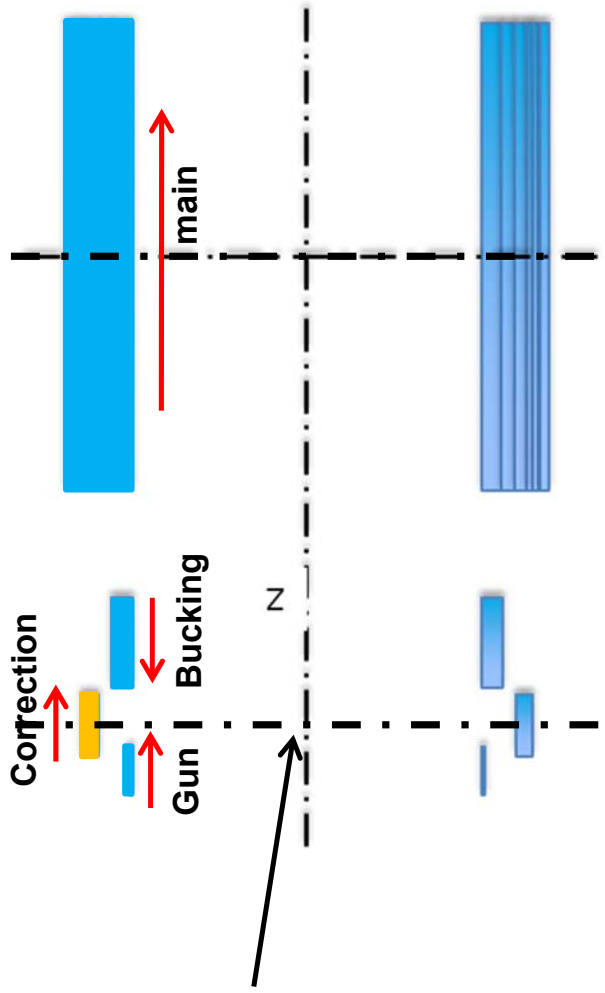
- 2015～2017 Eight Type Ⅲ magnets delivered
  Realized large cost down by reducing cryocooler, homemade power supply
  Updated design criteria could reduce training quench

7T240 magnet for ITER Gyrotron

Field distribution



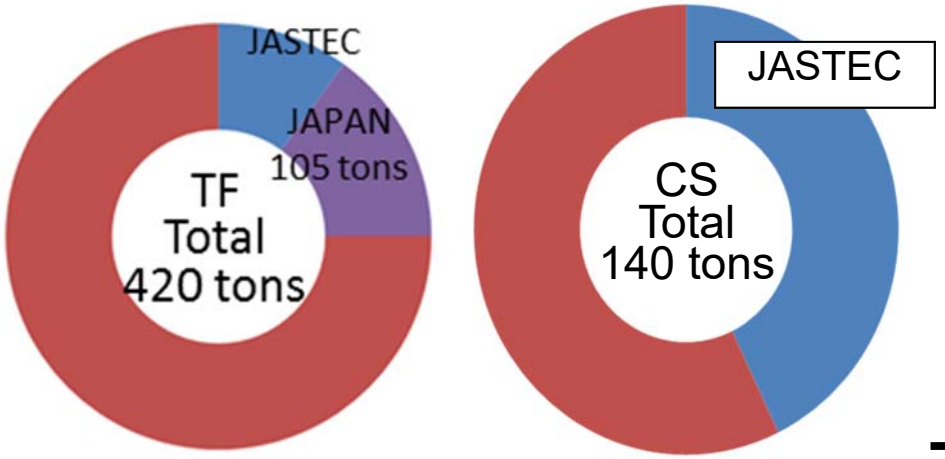
Magnet cross section

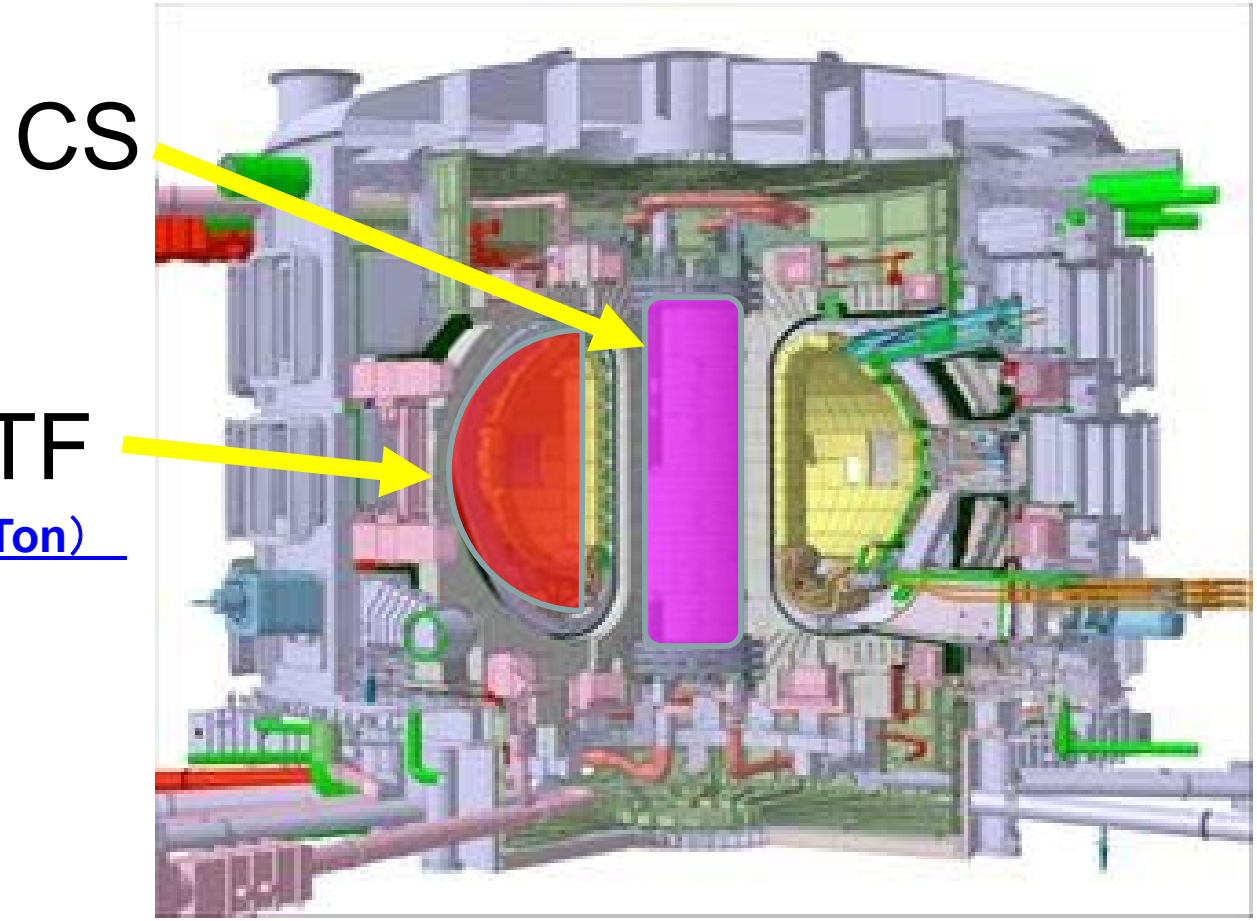


Variable 0.24-0.34T

7T240 SCM installed in QST

Contribution to ITER –Superconducting wire-





■ TF Coil：420 Ton （**Japan supplies 105 Ton**）

(For Tokamak plasma confinement)

Wire procurement ：2009～2012

#2,3: JASTEC #1,4,5:Hitachi

■ CS Coil：140 Ton（**Japan supplies all**）

(For Tokamak plasma current induction)

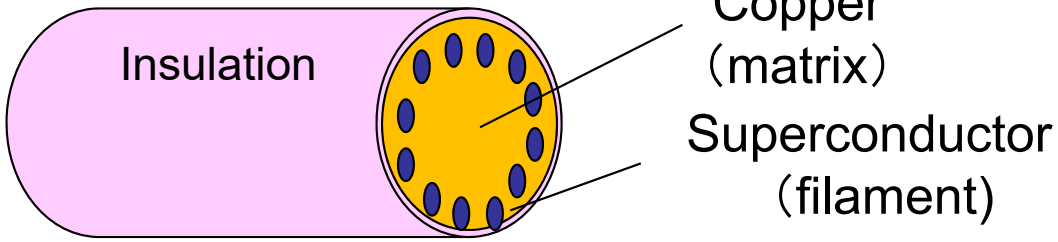
Cable procurement ：2012～2016

#1,2,6: JASTEC

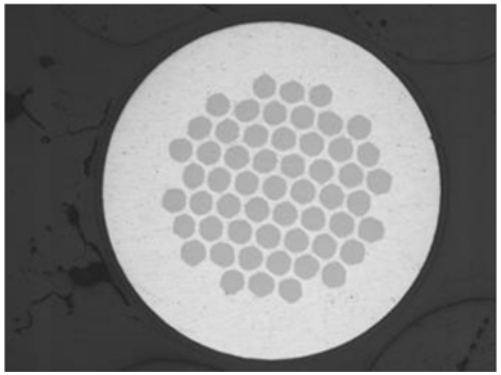
#3,7:Furukawa #4,5:KAT (Korea)

The No.1 Nb_3Sn supplier for ITER in the world

Aspects of superconducting wire



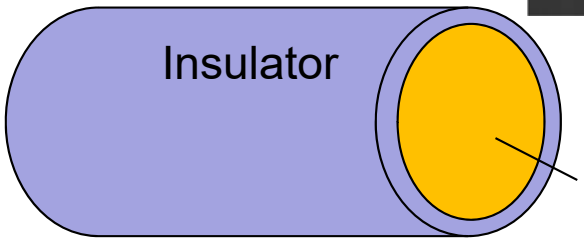
Superconducting wire



Superconducting wire

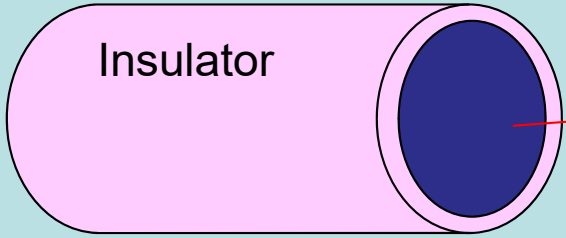
Superconducting filaments are embedded in copper matrix.

Current flows only in the filaments, not in the matrix. “Multi fine filament structure” is inevitable for practical superconducting wire.



Normal wire

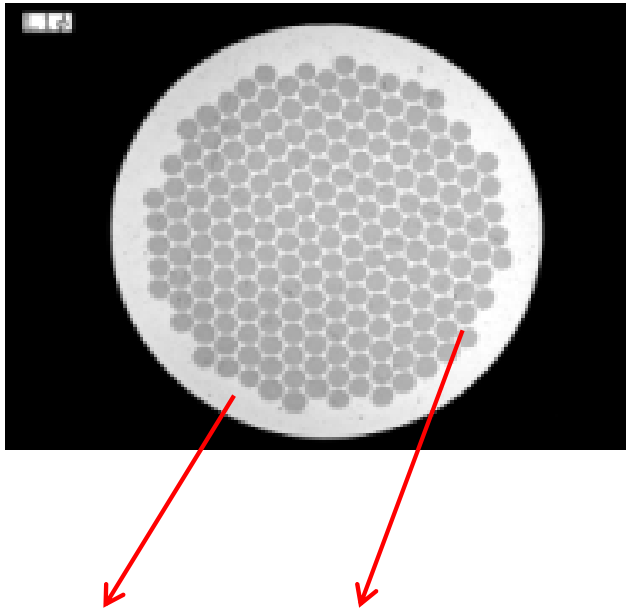
Very small current flows in the superconducting wire in early stage



Superconducting wire in early stage

Structure of superconducting wire

NbTi wire

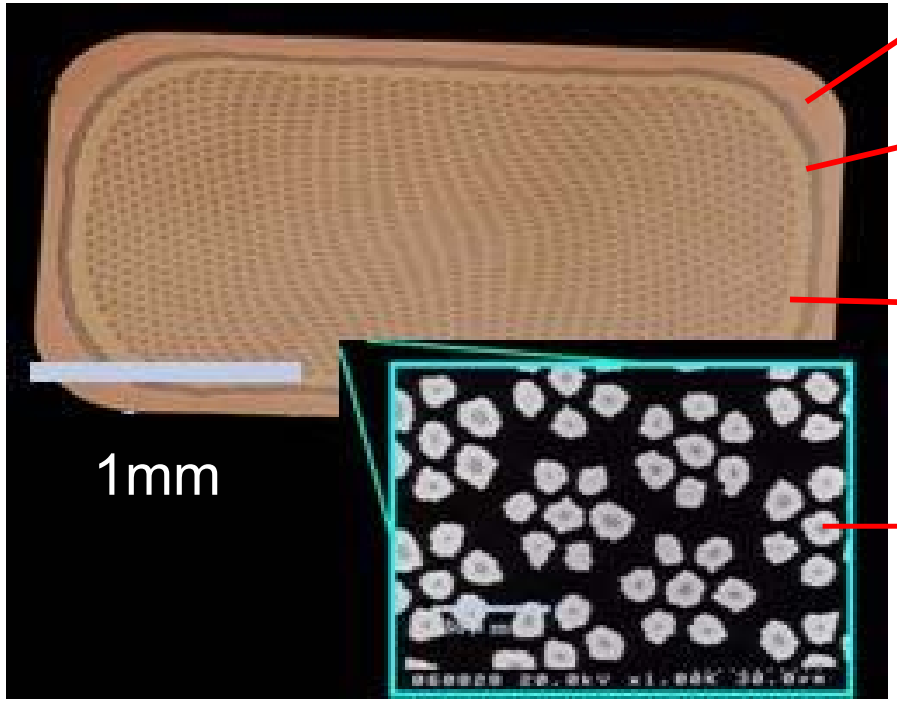


Niobium-Titanium filaments are embedded in oxygen free copper matrix.

Number of filament; 30～200

Filament diameter 20 ～40μm

Nb_3Sn wire



Niobium filaments are embedded in Copper- Tin alloy

Barrier (Niobium/Tantalum) raps the alloy and there is coper matrix most outer layer.

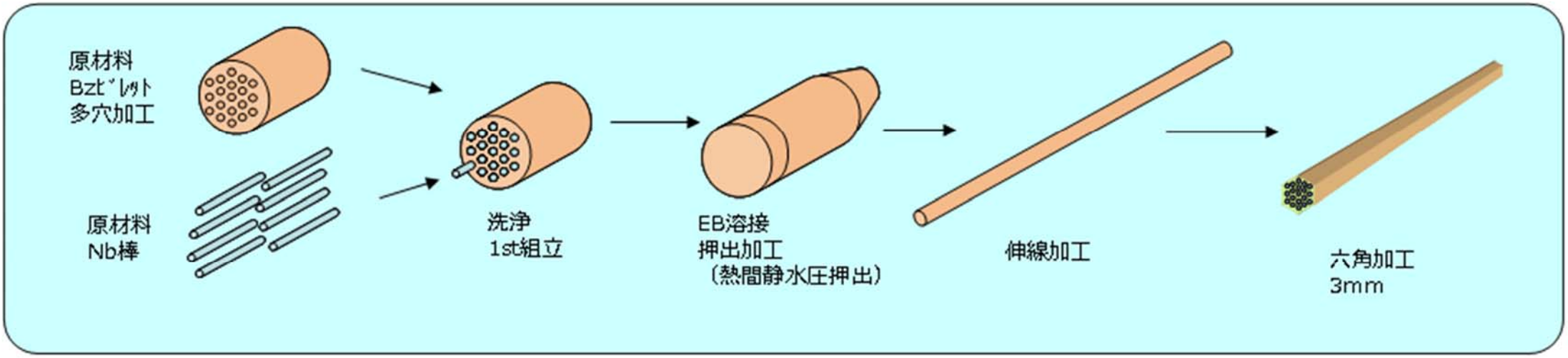
Nb3Ti is synthesized from Niobium and Tin by heat reaction process

Number of filament; 20000～40000

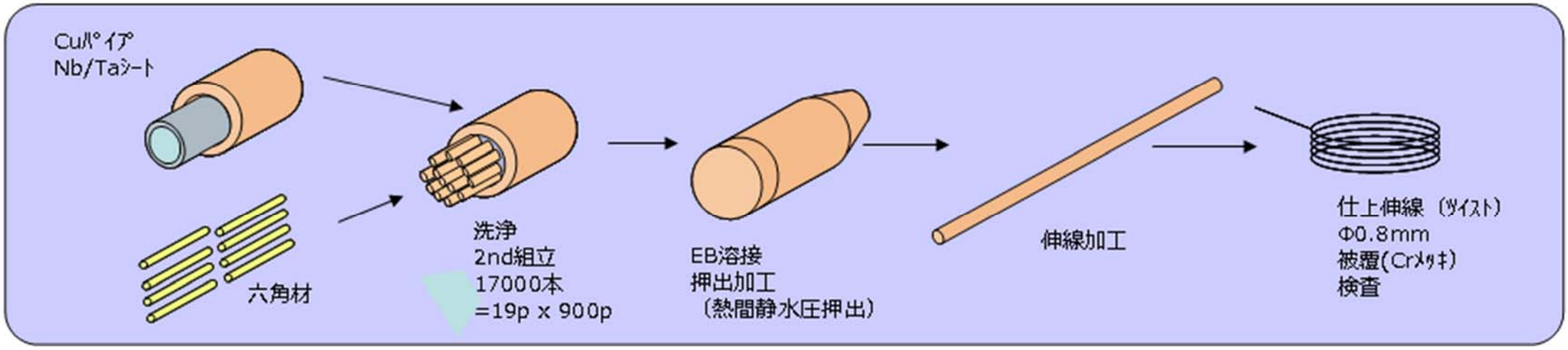
Filament diameter 2 ～6μm ⟶ 1/10 size of human hair

Production process of Nb_3Sn superconducting wire

First multi stack process

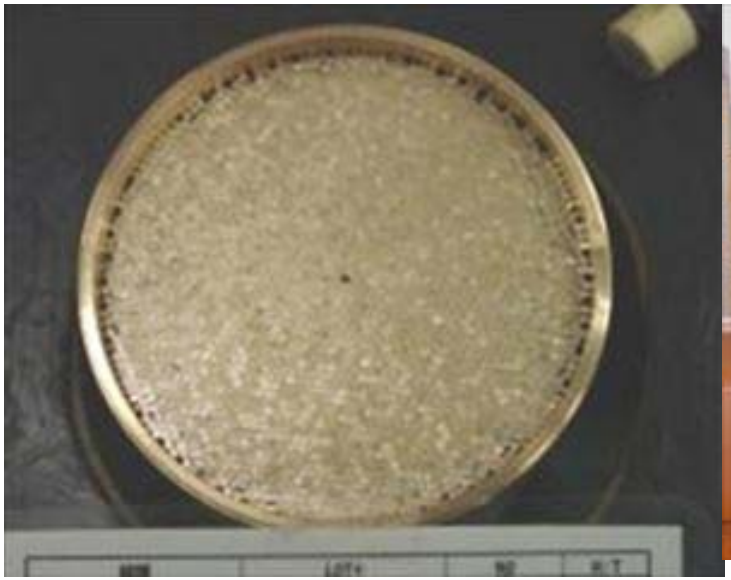


Second multi stack process



Landscape in Superconducting wire factory


熱間静水押出し装置



Challenge ; Wire breakage during production

Superconducting wire＝Composite metal material of sophisticated structure

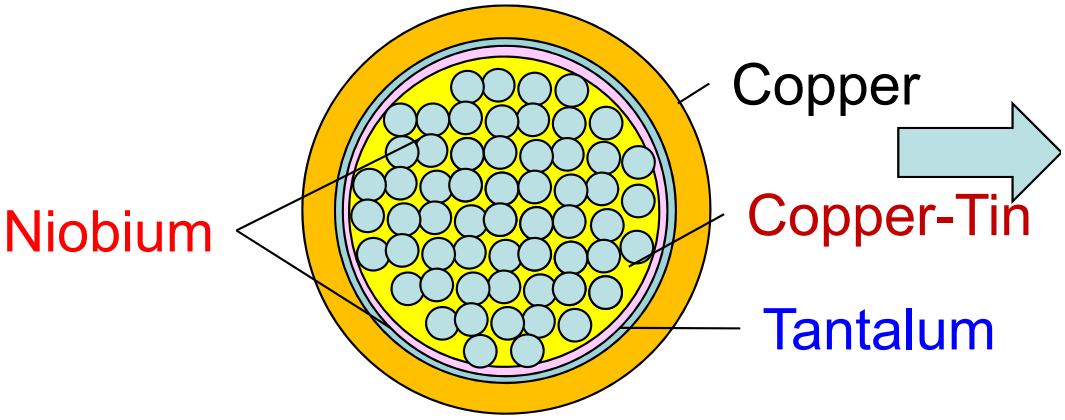
Challenge：Drawing the metals of different hardness as a composite

Diameter from150㎜ to 0.8㎜ ⇒1/200, Area ⇒1/40000

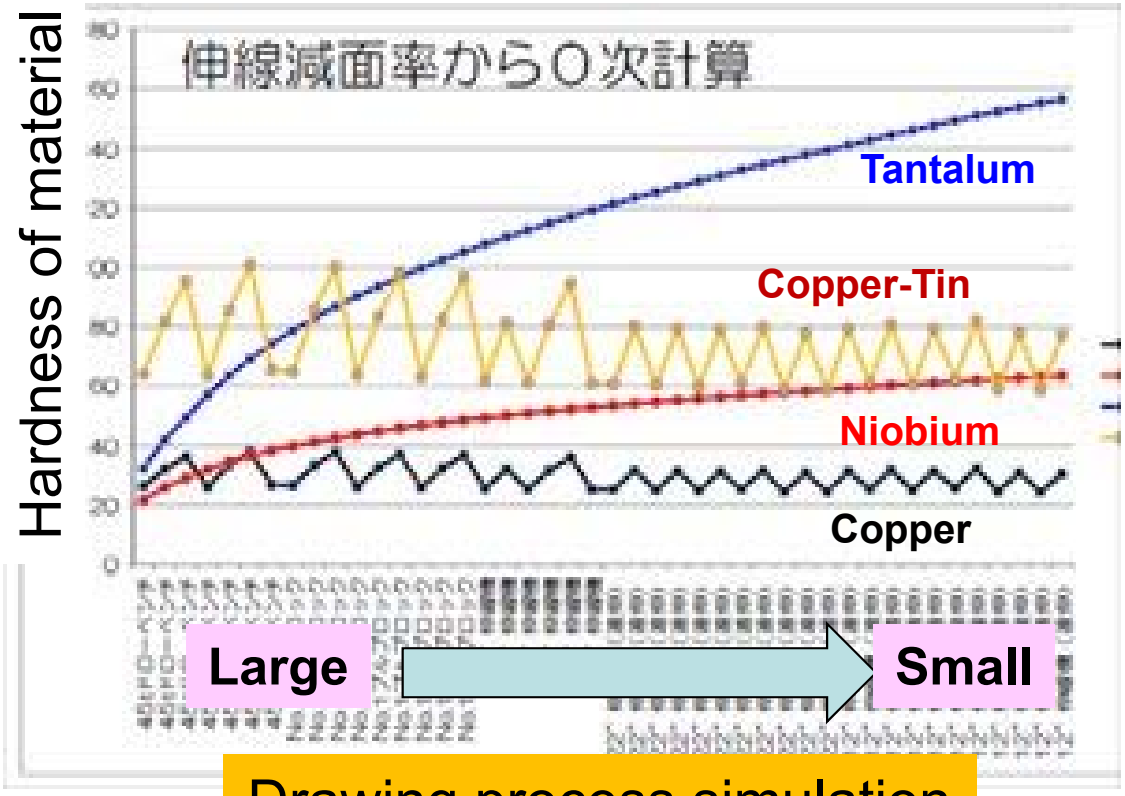
Soft metals are drawn easily, Hard metals are NOT.

⇒ Hardness should be averaged by “Integration”

If not, wire will be broken



Cross section model of CS wire



Drawing process simulation

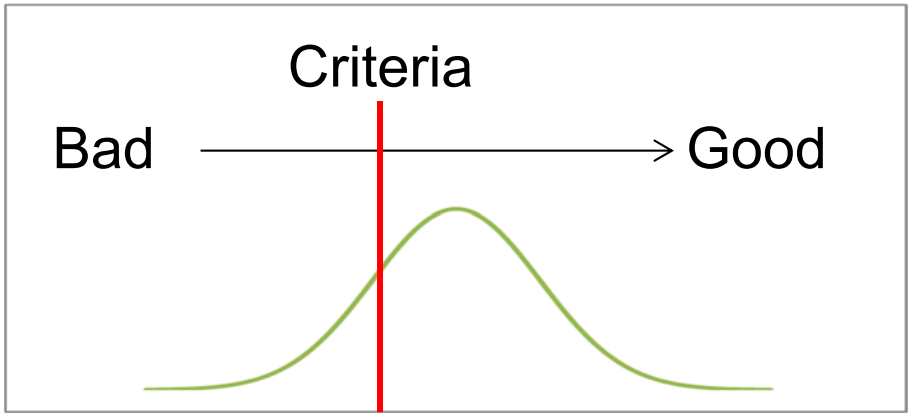
Improvement Action

In CS Nb_3Sn wire manufacturing,
Suffering from frequent wire breakage

Design ： Cross section , Size

Material ： Mechanical property

Process ： Environment, Control



Yield rate before improve action

There are good and bad

Large deviation is the problem

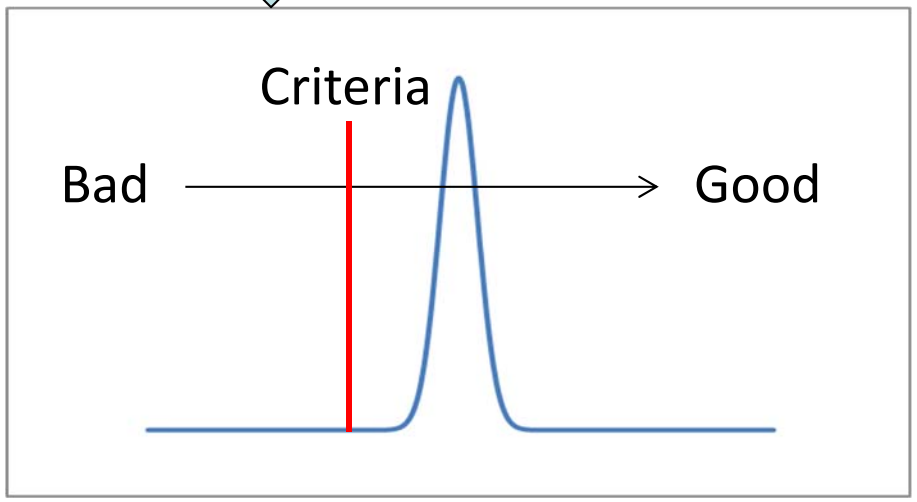
Had a big crisis by low yield, lack of products

Tackled to address the problem with a lot of help

Yield rate improvement

Average 20% up

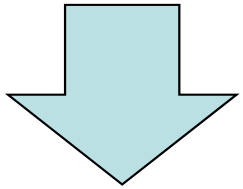
Deviation 1/20



Yield rate after improve action

For future

- JASTEC has contributed to ITER project by suppling both superconducting wire and magnet.
- Especially for Niobium Tin superconducting wire, JASTEC supplied more than 100 Ton as the world No.1 supplier.
- JASTEC will continue to produce next generation superconducting products using the cutting edge technology which was developed in ITER project.



Fusion, Industrial application（Semiconductor process）

Science, HEP, MRI, NMR　etc.

Thank you for your attention