



# Development of Analyzing Capability of React and Wind Process based on Strand Trace and Inter-Strand Resistance Measurement System for Cable-In-Conduit Conductor

Sophia University

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on Magnet Technology

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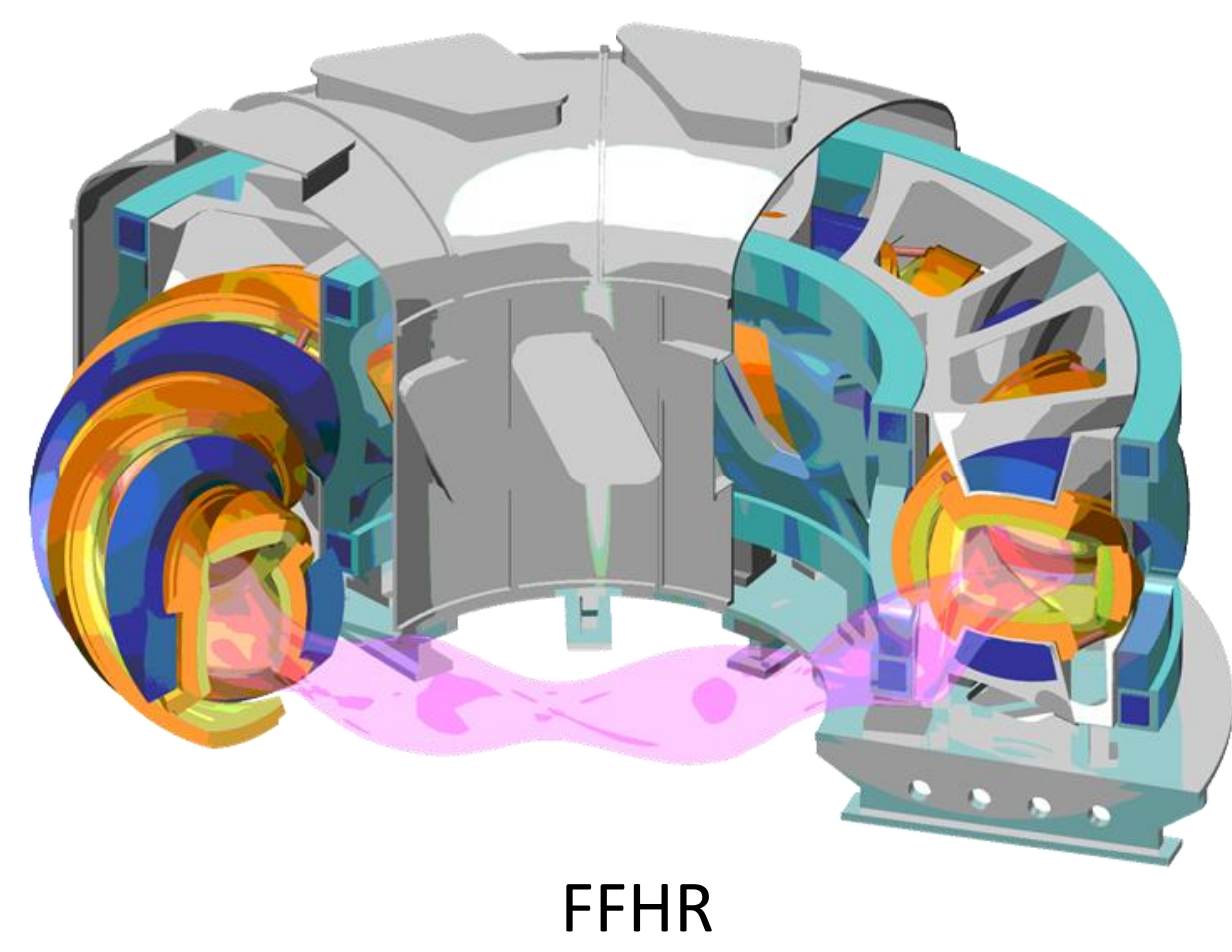
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## Introduction

- CICC is the most promising conductor for large scale magnets.
- To fabricate the magnets for fusion devices, we usually use the “Wind and React” method to prevent the degradation of the performance of the conductor made of thousands of Nb<sub>3</sub>Sn strands.
- For the next generation device, larger magnets will be needed, this means “React and Wind” method has to be introduced because of the fragile mechanical property of Nb<sub>3</sub>Sn strands.
- Our aim is to evaluate the performance of “curved” conductor after heat treatment by the structural mechanical analysis based on the measured strand traces.

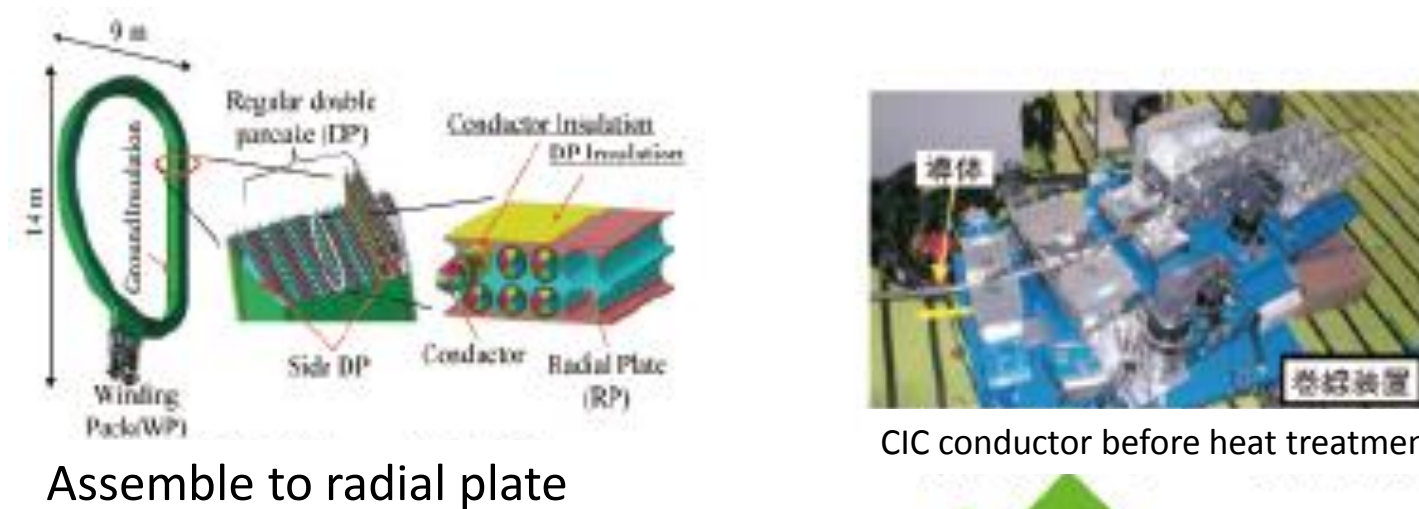
## Overview



FFHR

Performance of FFHR

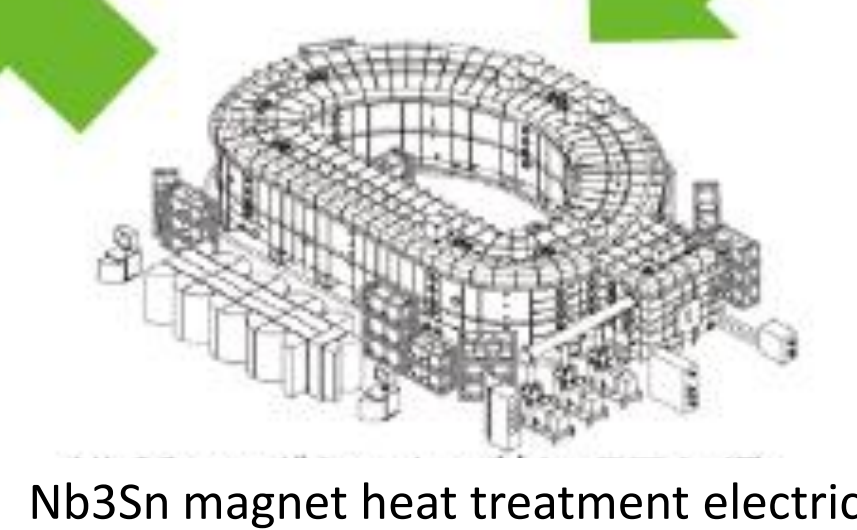
	LHD	FFHR
Major radius	3.9m	15.6m
Center magnetic field	3T	4~6T
Coil conductor current	13kA	~100kA
Coil maximum magnetic field	6.9T	~12T
Total energy	0.9GJ	160GJ



Assemble to radial plate



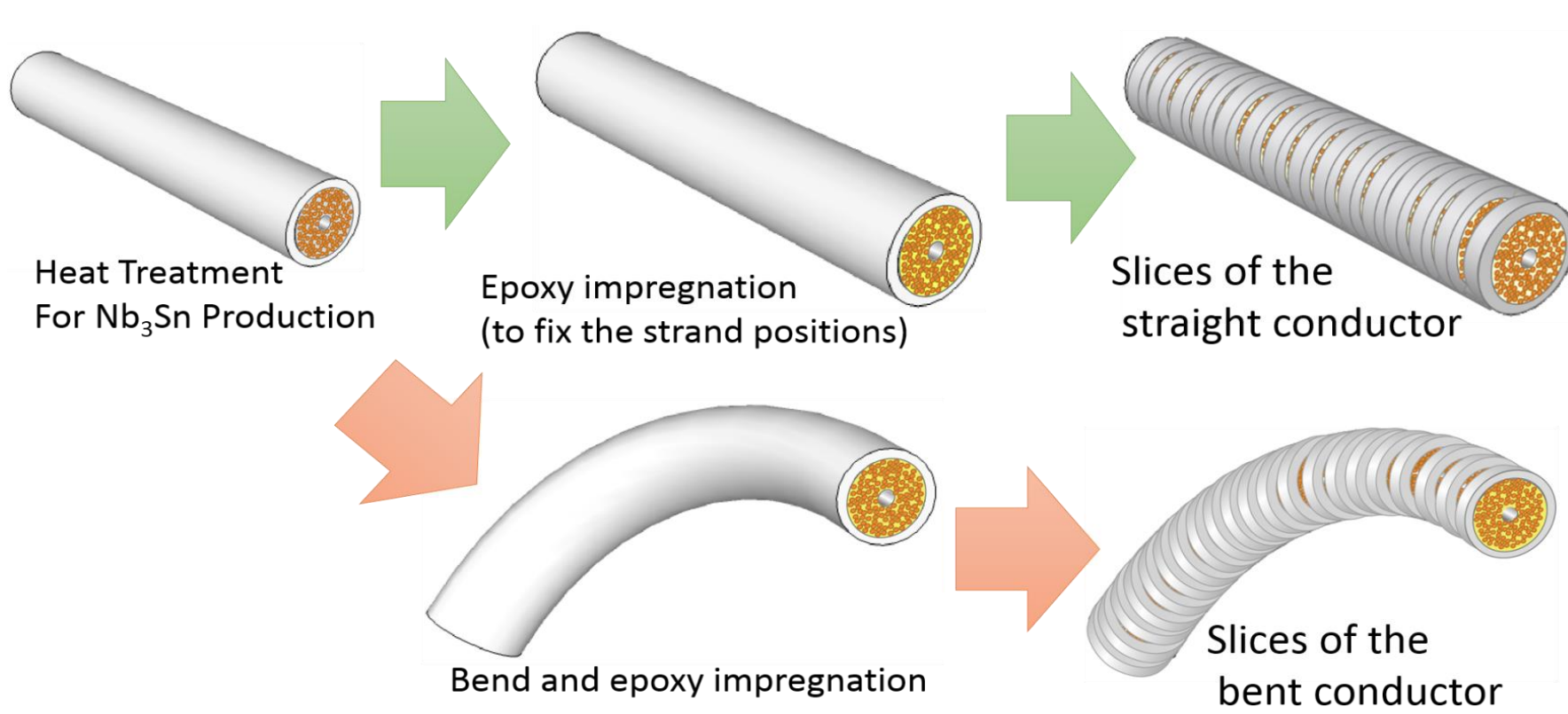
CIC conductor before heat treatment

Nb<sub>3</sub>Sn magnet heat treatment electric furnace

Dimensional error of radial plate  
Conductor length  $\pm 0.025\%$

Increasing size of  
helical and tokamak coil

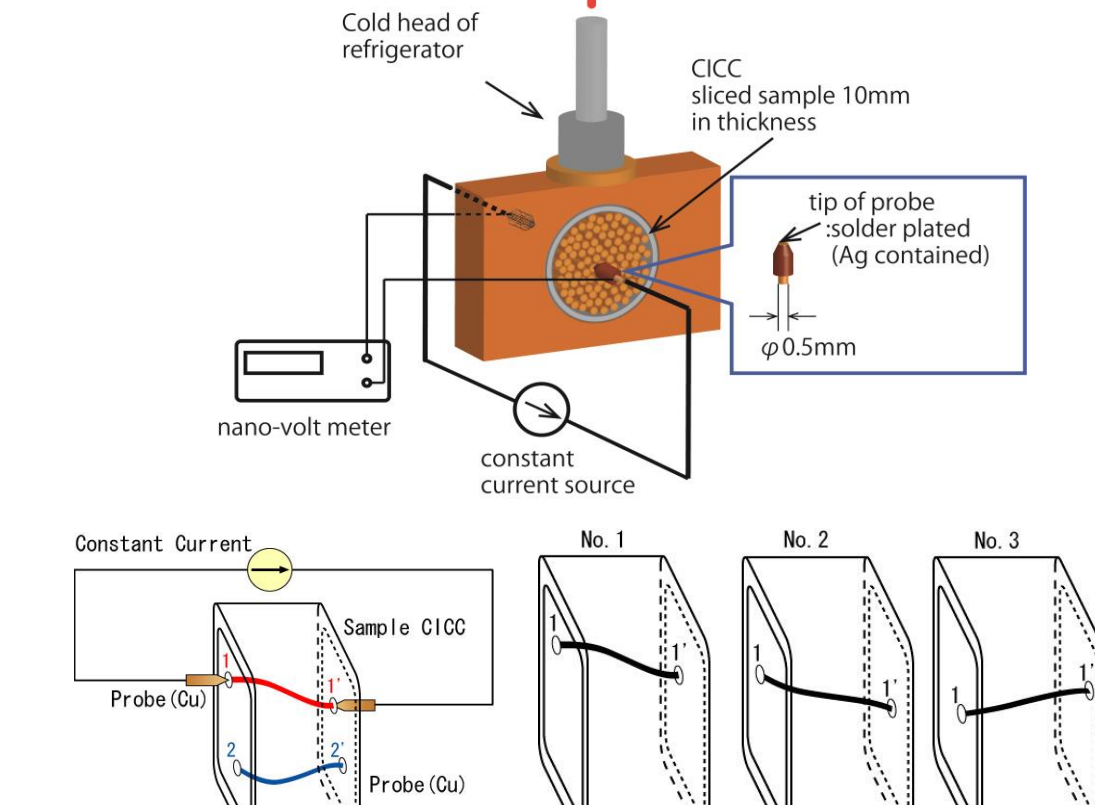
1,2

Heat Treatment For Nb<sub>3</sub>Sn Production

Epoxy impregnation (to fix the strand positions)

Bend and epoxy impregnation

3



Cold head of refrigerator

CICC strand sample 10mm in thickness

tip of probe - solder plated (Ag containing)

φ0.5mm

nano-volt meter

constant current source

No. 1

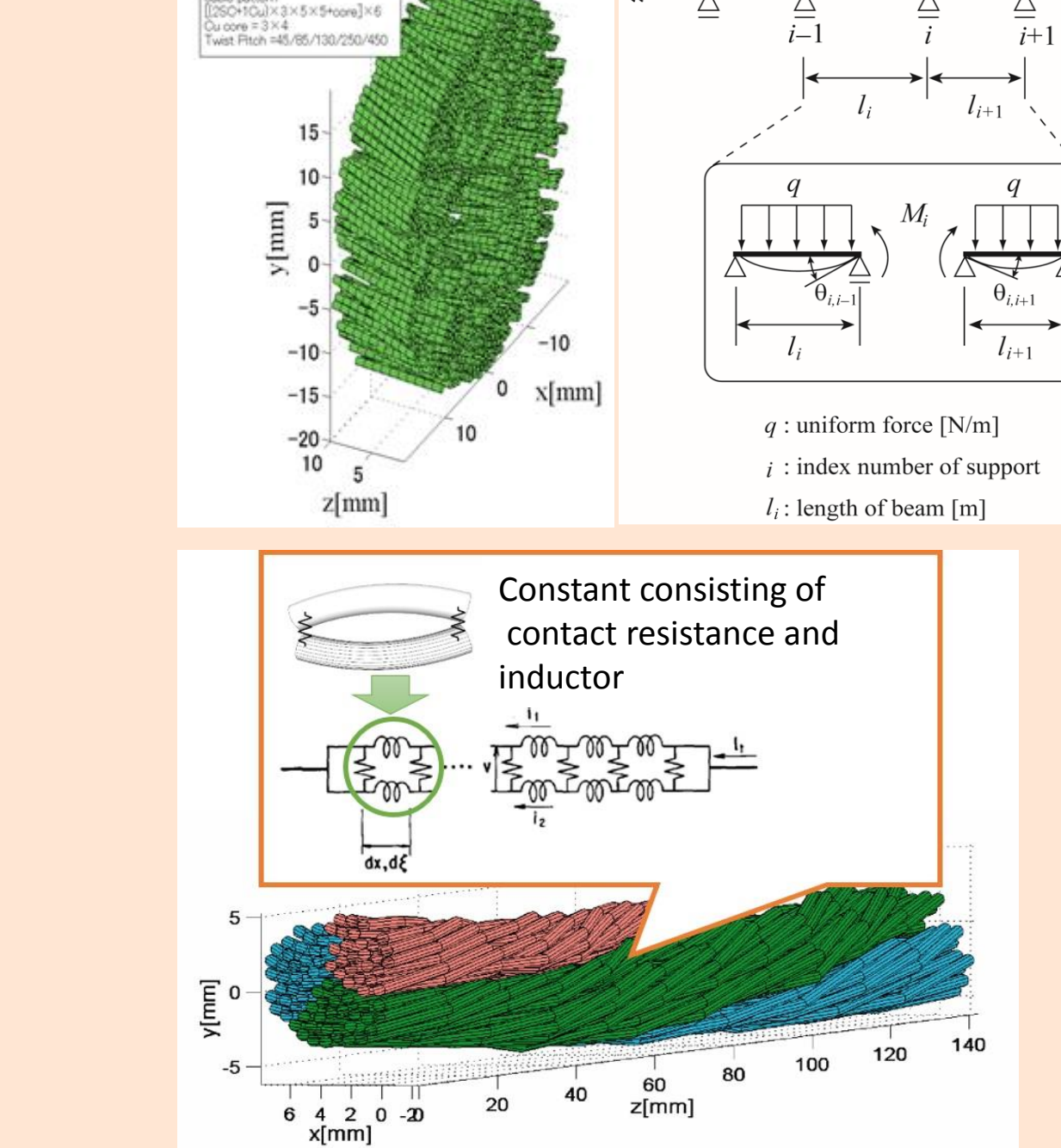
No. 2

No. 3

Probe (in)

Probe (out)

4



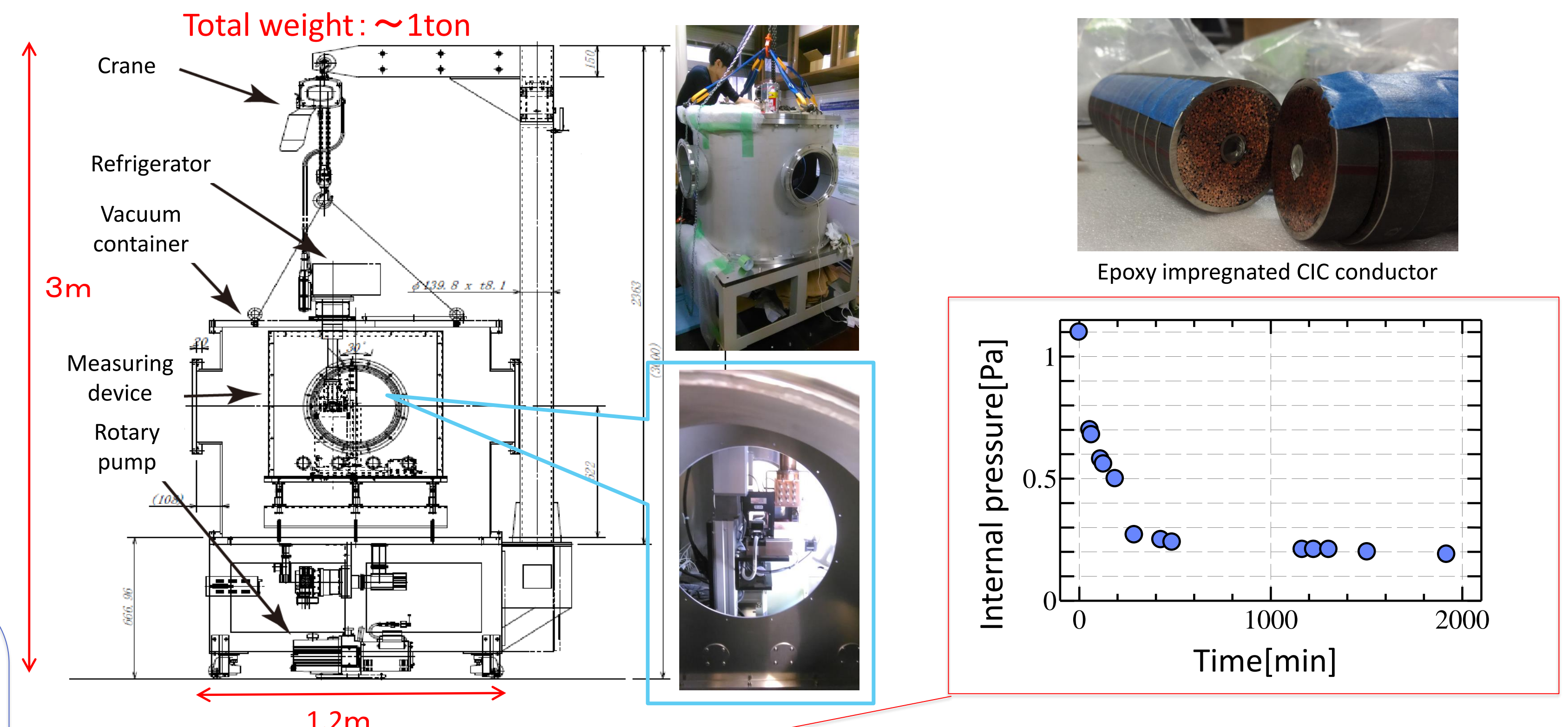
✓ Structural Mechanics Approach  
✓ Statistics · Electro circuit Approach

## Estimation of conductor Ic

1. Heat treatment of other 2 short sample CICC's
  - One - epoxy impregnated (**straight shape**)
  - The other - bend, then impregnated (**curved shape**)
2. Slice with the 10mm thickness of the 2 samples.
3. Measure the strand traces and inter strand contact resistance distribution (@LHe temperature)
4. Analyze the mechanical properties and evaluate the Ic of conductor assuming the operational conditions.

**Automatic measurement with actual conductors**

## Experimental device under development



### Vacuum Insulation

Currently in progress

### Cooling

By the end of 2017

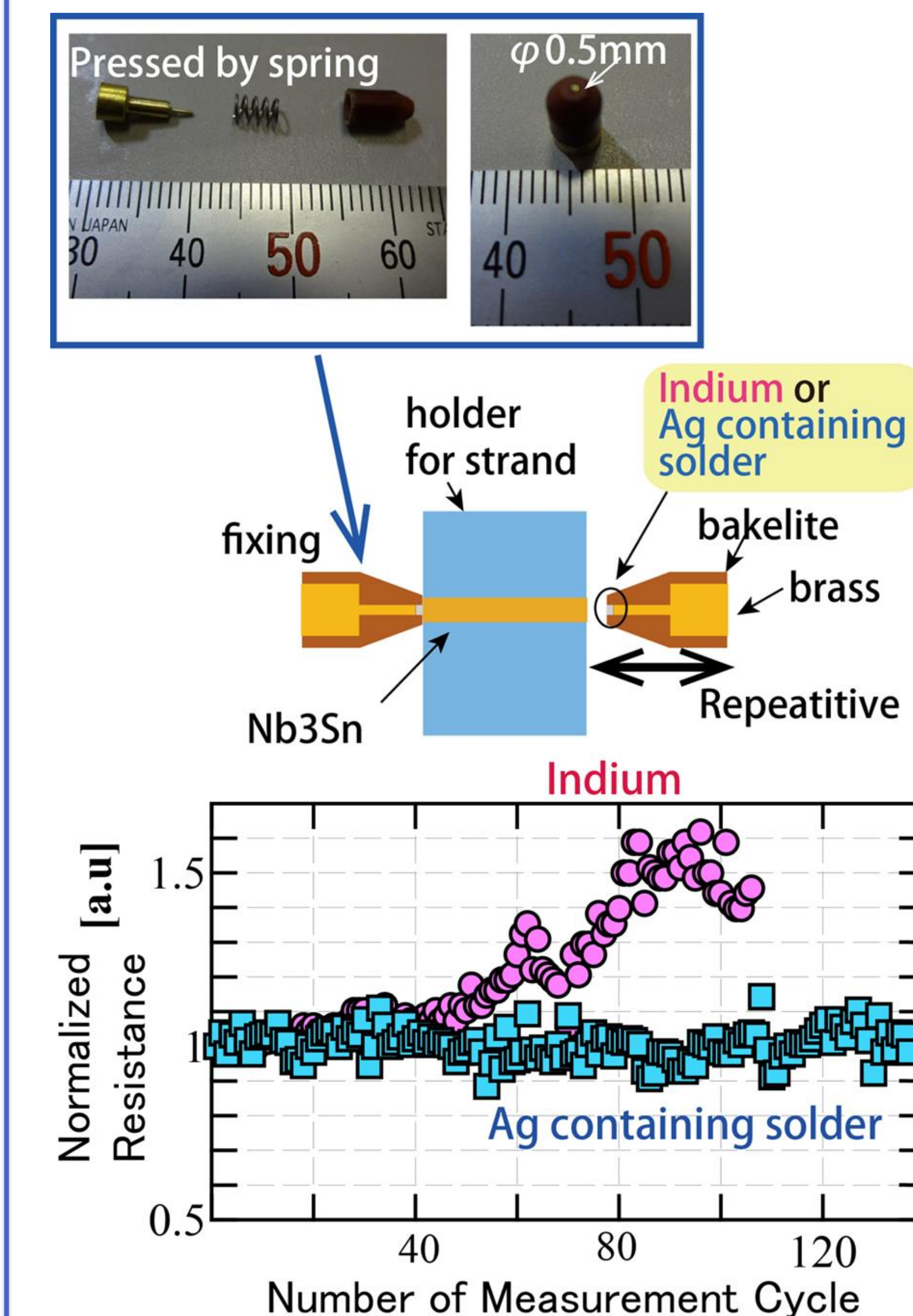
### Commissioning

### Things necessary for measurement

- Probe that can withstand cold and long-term measurement
- Know the effect of epoxy impregnation on measurement
- Discrimination of strands in case of perfect contact

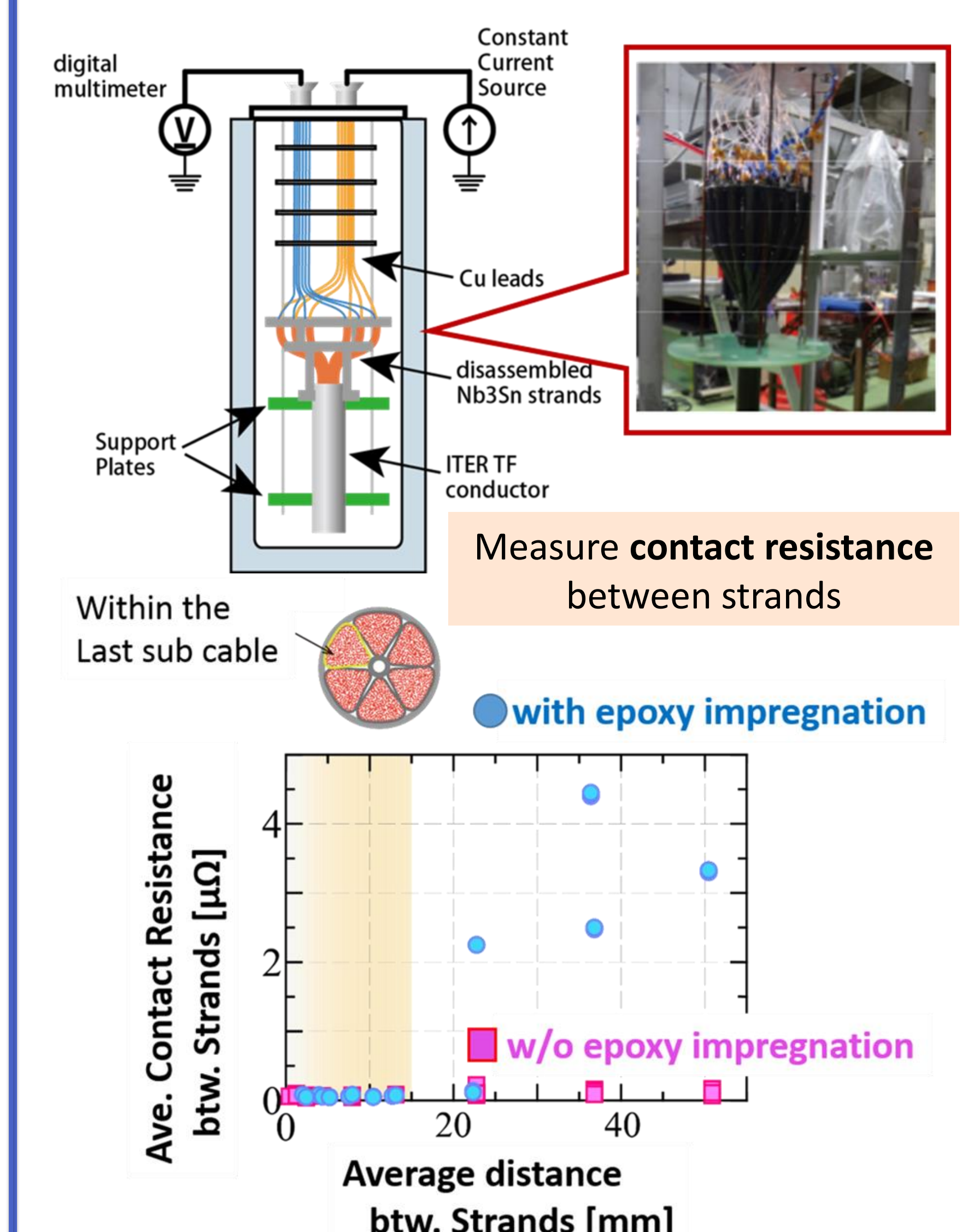
## Component Technology

### (a) Development of probe



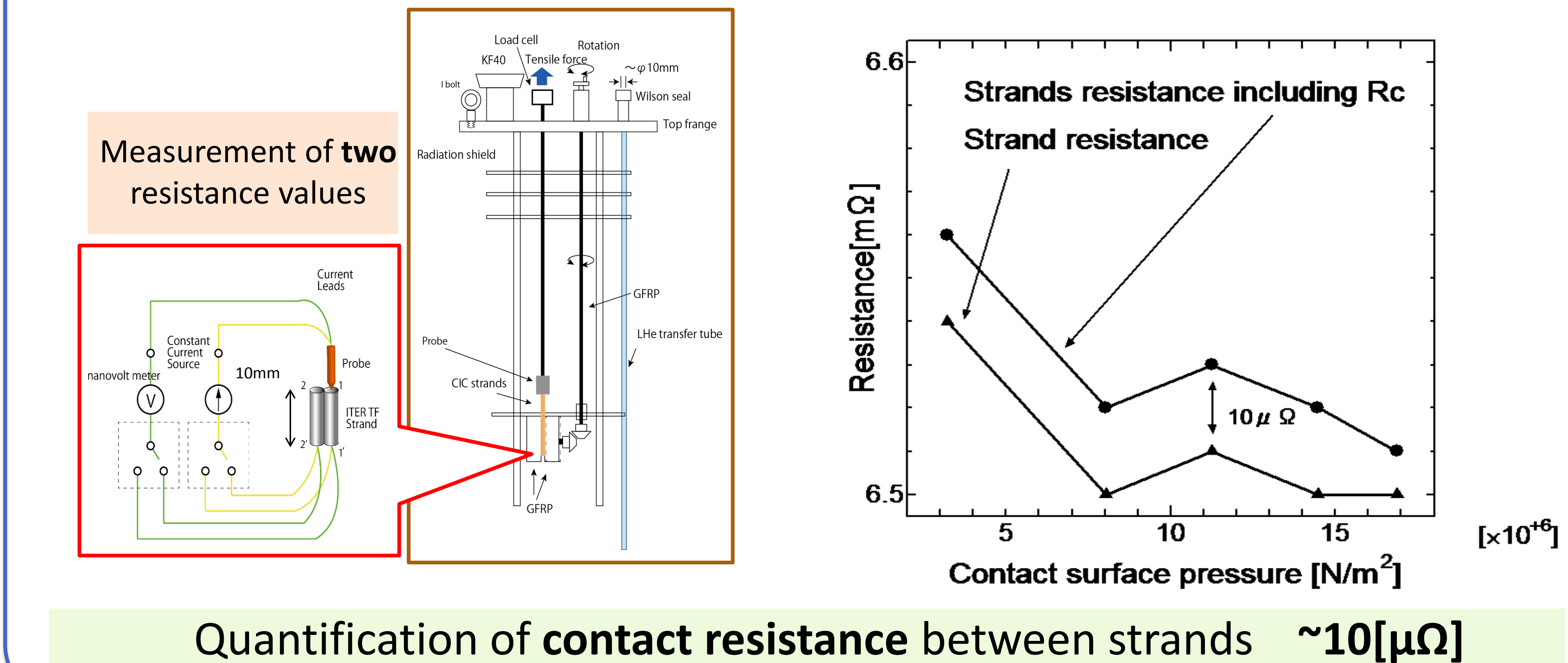
Ag containing solder can withstand many times of measurement

### (b) Influence of epoxy impregnation



No effect on contact resistance between strands with or without epoxy impregnation

### (c) Measure contact resistance between strands



## Summary

- ✓ To fabricate large scale magnets with **Wind and React** using conventional CICC, we need a **strand traces** and detailed **contact resistance** between strands
- ✓ **Structural Mechanics** and **Statistics · Electric circuit analysis** will be carried out

### Acknowledgement

This work has been performed under the LHD Project Collaboration Research (research code NIFS15K0BA030).