



Grant Agreement No: 645479

# E-JADE

Europe-Japan Accelerator Development Exchange Programme  
Horizon 2020 / Marie Skłodowska-Curie Research and Innovation Staff Exchange  
(RISE)

## DELIVERABLE REPORT

### [HADRONS AT HIGH INTENSITY AND ENERGY]

---

<b>Document identifier:</b>	E-JADE.Deliverable.WP1.D2.v1.docx
<b>Due date:</b>	31 December 2016
<b>Report release date:</b>	18/5/2018
<b>Document status:</b>	Final / public

---

#### Delivery Slip

	Name	Date
<b>Authored by</b>	S. Stapnes (CERN)	10/05/18
<b>Edited by</b>	K. Tokushuku (KEK) T. Schörner-Sadenius (DESY)	11/05/18
<b>Approved by</b>	E-JADE General Assembly	18/05/18

## Deliverable

Month 25: “Hadrons at high intensity and energy”:  
Report describing R&D results on FCC and J- PARC related activities.

### Executive summary

There is a substantial amount of developments and important contributions from Japanese researchers and industries to the LHC injector complex upgrade. The development and production of FineMet cavities for the PS booster, development and radiations tests of a solid state amplifier, and work on a damper cavity for coupled bunch instabilities in the CERN PS are all progressing very well. The experience from J-PARC, and the use of similar methods there for damping, highlights the beneficial connections between the LHC injector work done in collaboration Europe-Japan and J-PARC.

There is broad activity on superconducting magnets in Japan, at KEK, in universities and in industry. Several programmes are ongoing with work on Nb<sub>3</sub>Sn and HTS the most significant. Other programmes, for example using MgB<sub>2</sub>, are being set up. Furthermore, the ongoing work at KEK for the HiLumi separation dipoles and crab cavities, the SuperKEKb luminosity performance optimisation, as well as the SCRF modules for ILC, are all relevant for HE-LHC and FCC.

## Introduction

E-JADE work package (WP) 1 covers the LHC exploitation and upgrades, in particular linking to the planned Japanese contributions to these projects, as well as R&D for a future hadron machine at higher intensity or energy.

LHC will run near its full energy from 2015, and Japanese researchers participate in operation, analysis and upgrade projects for both accelerator and detectors. R&D on high field magnets and wideband magnetic alloy RF systems carried out in Japan is a key ingredient for upgrading the LHC itself as well as its injectors – through the LHC Injectors Upgrade project – and for reaching the performance goals of the High-Luminosity LHC (HL-LHC) project. This is also relevant for the J-PARC upgrades and, at a later stage, for a potential very large collider as studied in the Future Circular Collider (FCC) programme. The main objective for this work-package is the integration of the European and Japanese efforts (involving also other regions) on the LHC High-Luminosity upgrade into a construction project for the upgrade hardware.

### WP1 covers the following tasks:

**Task 1.1:** LHC operation and analysis (CERN, KEK & UoT): Integrate Japanese efforts in operation of LHC machines and detectors at full energy; expected to provide important guidance for future accelerator developments in Europe and Japan.

**Task 1.2:** The HL-LHC project (CERN & KEK): Engineering design and validation of two short prototype separation superconducting dipoles (D1) followed by construction preparation, construction and test of the 4 final (plus two spare) D1 dipoles for the upgraded LHC insertion regions. Studies for the crab cavities (CC) for the LHC luminosity upgrade, benefitting from operational experience of CC at KEK.

**Task 1.3:** High field magnet R&D and preparation of future hadron injectors and colliders (CERN & KEK): R&D on the viability of HTS magnets of accelerator/collider quality. Enhance the exchange of staff between CERN and KEK in the context of the LIU project and the J- PARC intensity upgrade studies. Technologies of special interest are Wideband Cavities using Magnetic Alloy, Solid State Amplifiers and Low Level RF.

## Developments for the LHC injectors with relevance for J-PARC, and visa-versa

The PS booster at CERN is being upgraded with a new RF cavity system (see Fig. 1). The PS Booster's new acceleration system is based on radio-frequency cavities built using a composite magnetic material called FineMet (Fig. 2) developed by the Japanese firm Hitachi Metals. The upgrade project is a collaboration between CERN and KEK. The Japanese laboratory had already developed wide-band cavities for KEK accelerators and J-PARC and has cooperated with Hitachi Metals to develop magnetic alloys for these accelerators. The PS booster development built on these experiences. KEK

has financed 132 of the 340 magnetic discs at the heart of the PS Booster's new cavities, and was responsible for testing the components delivered.

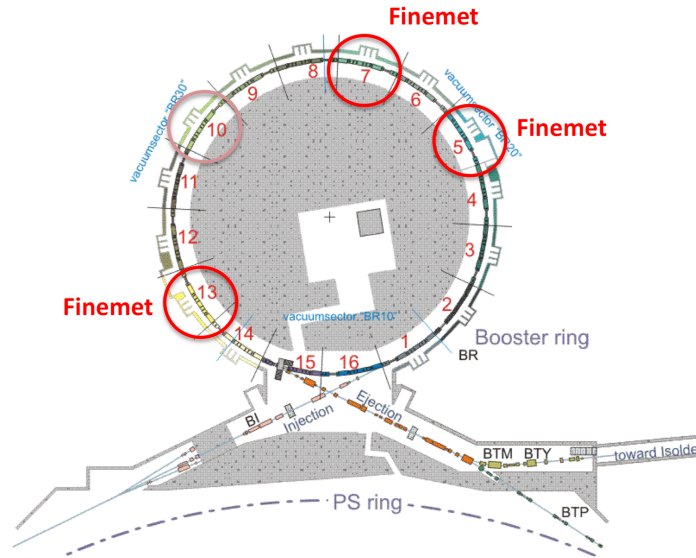


Figure 1: The FineMet cavities in the PS booster

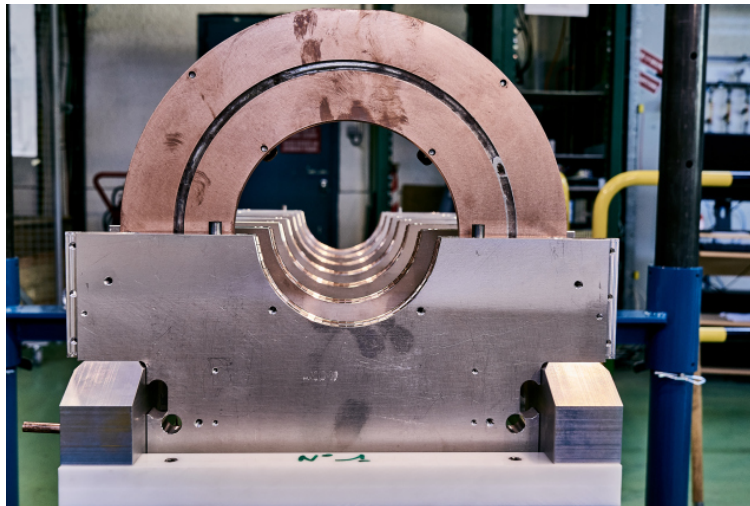
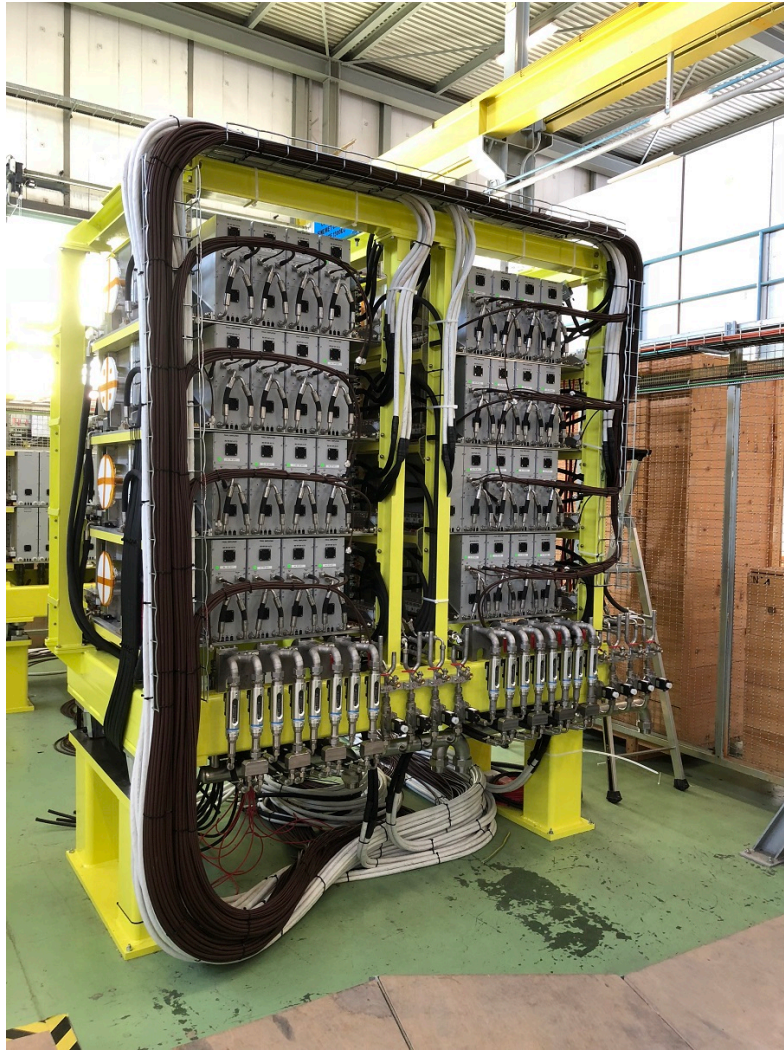


Figure 2: A new PS booster cavity being assembled



**Figure 3: 4-story PS booster cavity**

In early June 2017 an important milestone was reached: the completion of the assembly of the first new-generation accelerating cavity (Fig. 3). Another 27 cavities are currently in production at CERN. They will be installed in the accelerator during the Long Shutdown 2 in 2019-2020. Once they are in place, the PS Booster will be capable of accelerating higher-intensity beams and at a higher energy of up to 2 GeV, compared with just 1.4 GeV today. In parallel development and testing of a solid-state amplifier is showing good results in radiation tests, well above the levels expected for use in the PS booster.

Another common development is equipping the PS with a 6-cell FineMet cavity for the damping of coupled bunch instabilities (CBI). Such instabilities are also observed in the J-PARC main ring and can be reproduced with simulation software developed by CERN. Work is on-going to improve the CBI damping in J-PARC.



More information about both projects can be found in references [1] and [2].

## Developments with relevance for FCC

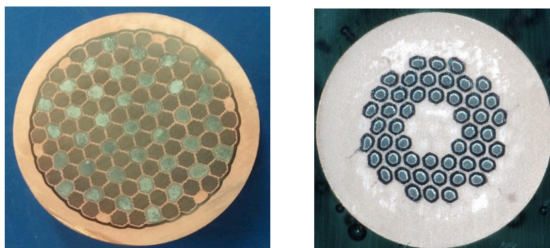
There are many FCC relevant developments reported elsewhere for E-JADE. The work for HiLumi LHC (WP1), separation dipoles and crab cavities, optimizing the interaction regions are directly relevant for HE-LHC and FCC-hh [3].

The SuperKEKb studies – on the accelerator side – are very relevant for FCC-ee (WP2). The superconducting RF developments for ILC in WP3 have relevance for the FCC RF systems, although the parameters and use will be quite different [4]. Visits in the framework of E-JADE support this knowledge exchange.

In this report we only add information about generic magnet technology development for future colliders (see Fig. 4).

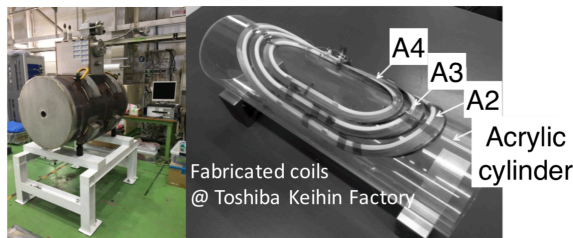
The most prominent programme is related to Nb<sub>3</sub>Sn developments as a joint R&D activity between CERN, KEK and Tohoku & Tokai Universities with Japanese companies [5]. The programme is planned over 4 years and the two manufacturers are already active. Conductors are provided to KEK, CERN and Tokai University for further characterization. The use of Nb<sub>3</sub>Sn is essential for the FCC magnets, and a wide industrial involvement is important.

The second programme is R&D on radiation-resistant HTS magnets. The HTS programme covers use of new materials, process R&D and irradiation for qualification and tests. More information can be found in [5]. Magnets built with this material (ReBCO tape) are aimed at very high fields (~20 Tesla) and radiation tolerance.



Nb<sub>3</sub>Sn conductor by JASTEC & Furukawa

Figure 4: Examples of superconducting magnet R&D



Fabricated coils @ Toshiba Keihin Factory  
HTS 3T Dipole with COSθ windings

## References

- [1] [KEK report on their work on the LHC injectors, Nov 2017](#)
- [2] [CERN bulletin report on the PBS status](#)
- [3] [KEK report on the separation dipoles for HiLumi LHC, Nov 2017](#)
- [4] [Collaboration on SCRF between CERN and KEK, Nov 2017](#)
- [5] [Programmes exploring new superconducting materials, Nov 2017](#)