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Status report and plan of the Japanese contribution to HL-LHC.

Executive summary:

This document summarizes the planned Japanese contribution to the HL-LHC projects. The Japanese group led by KEK will contribute to various areas in the project; i.e. the construction of the beam separation magnets (D1) for the LHC accelerator, in-kind contributions to the FineMet magnetic alloy for the PS booster, and ATLAS upgrades for the inner tracker and muon trigger systems.

1. INTRODUCTION

WP1 covers the LHC exploitation and upgrades in particular linking to the planned Japanese contributions to these projects, as well as R&D for future hadron machines at higher intensity or energy. The LHC has been running at almost full energy since 2015, and Japanese researchers participate in the operation, in physics analysis, and in various upgrade projects for both the accelerator and the detectors. Ongoing R&D efforts are described in a separate document [1,2]. In this report, the planned Japanese contributions to the HL-LHC accelerator, to its injectors and to the upgrade of the ATLAS detector are summarized briefly.

2. JAPANESE CONTRIBUTION TO THE HL-LHC ACCELERATOR

The R&D on high-field magnets is central for the LHC luminosity upgrade (HL-LHC) and for later higher-energy hadron colliders. HL-LHC is aimed at allowing set of beam parameters for a machine in the LHC tunnel to reach the following targets: $L_{peak} = 5\times10^{34}$ cm^{-2}s^{-1} with levelling, and allowing an integrated luminosity of 250 fb^{-1} per year, enabling the goal of $L_{int} = 3000$ fb^{-1} twelve years after the upgrade.

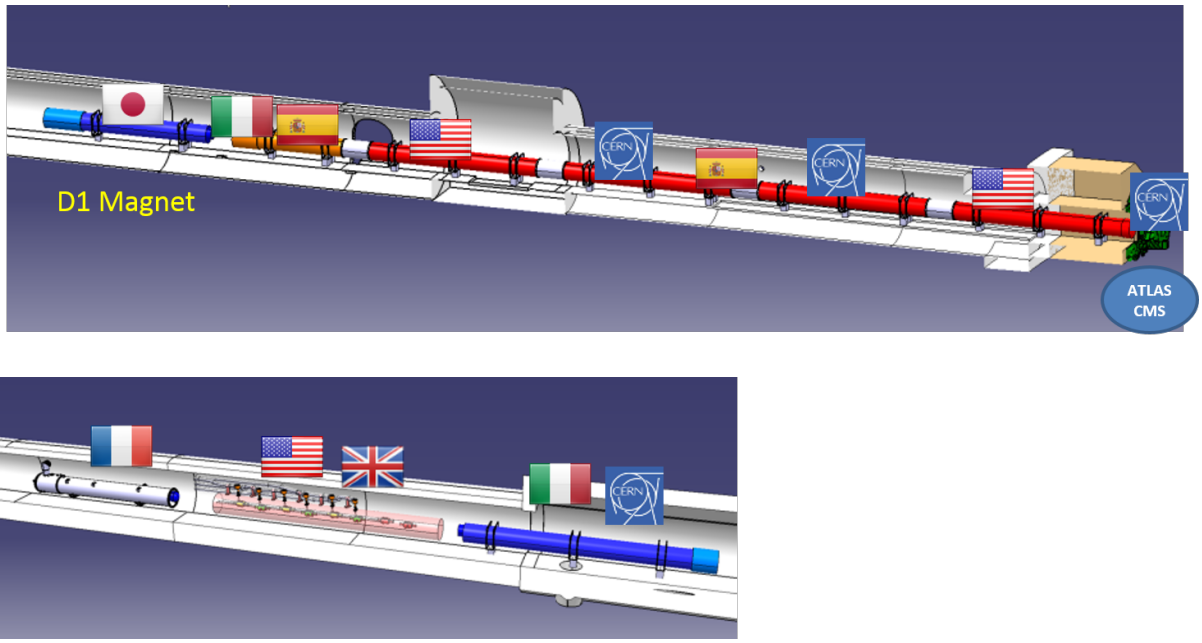

Figure 1: The HiLumi LHC interaction region. The contributions from various partners are also indicated .

The key development project at KEK for HL-LHC is the beam separation magnet D1 (MBXF) (Fig. 1). The magnet is a 150 mm single aperture, 35 Tm (5.6 T x 6.3 m), Nb-Ti technology dipole. As described in Ref [1]., KEK built 2-m model coils in 2016 and has successfully energized them up to the required current.

KEK has committed to produce an improved version of the 2-m model coil in 2018 and to start preparatory work for a full-scale prototype. Although the funding negotiations are still

ongoing, KEK has expressed its intention to contribute all six D1 magnets and the full-scale prototype for the HL-LHC as an in-kind contribution.

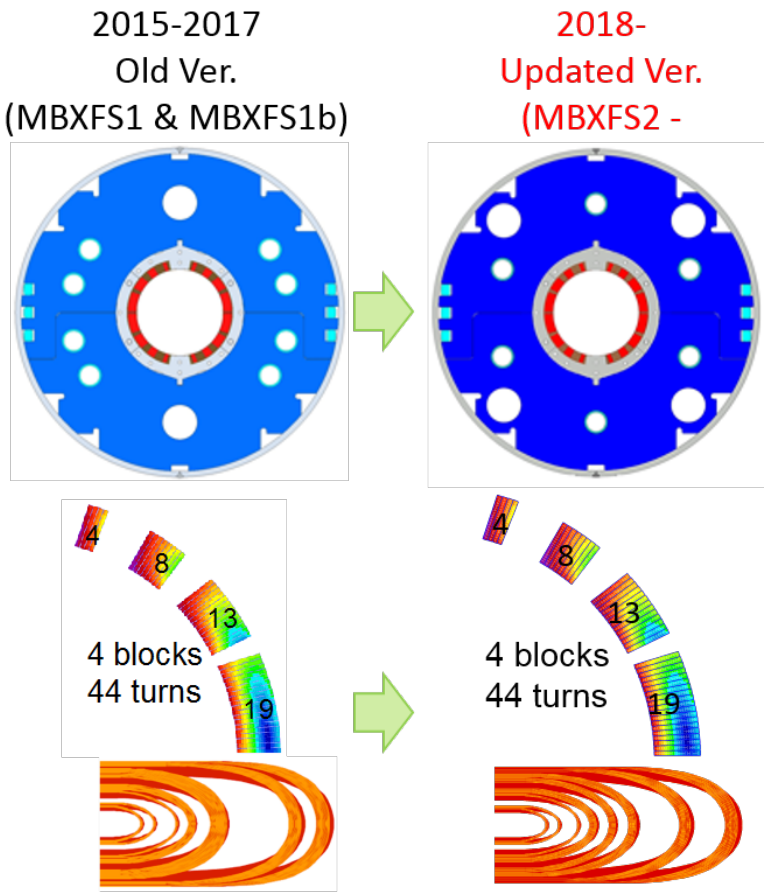

Figure 2: The old and new design of the D1 magnet.

3. JAPANESE CONTRIBUTIONS TO LHC INJECTOR UPGRADE

Various refurbishments of the CERN accelerator complex are needed to provide more intense and better quality proton beams to the HL-LHC. This includes the total replacement of the acceleration system of the PS Booster – the second link in the accelerator chain. The PS Booster's new acceleration system is based on radio-frequency cavities built using a composite magnetic material called FineMet and developed by the Japanese firm Hitachi Metals. As KEK had already developed the wide-band cavities for the J-PARC accelerators and was cooperating with Hitachi Metals to develop the magnetic alloys, a collaboration with KEK began in 2012.

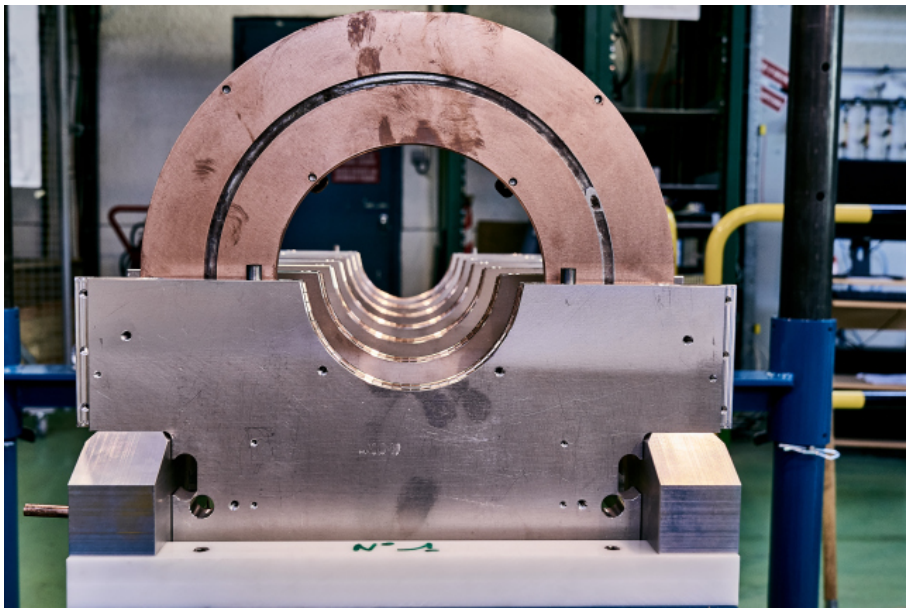

Figure 3: One of the PS Booster's new radiofrequency cavities being assembled.

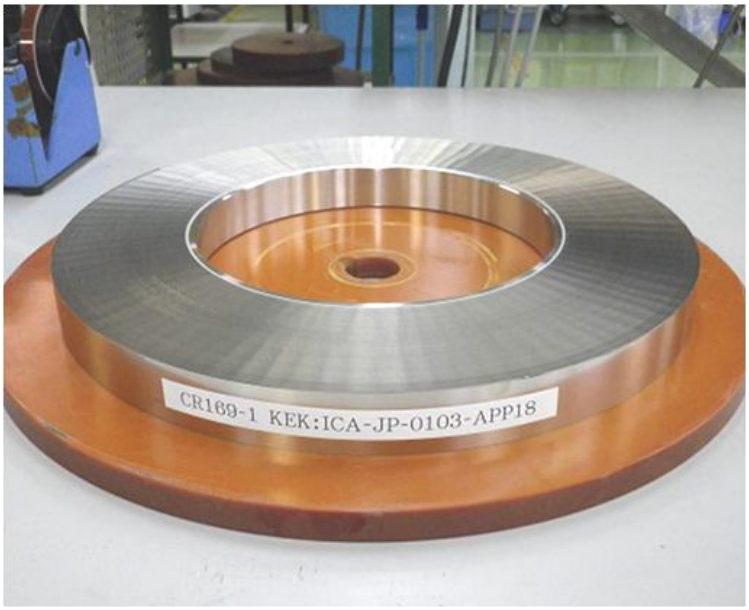

Figure 4: A FineMet metal alloy disc delivered by KEK.

After the intense communication and cooperation between the KEK and CERN accelerator researchers with the help of E-JADE and a Japanese travel fund supported by the JSPS, KEK's contribution on the PS-booster was defined. KEK financed 132 of the 340 magnetic discs at the heart of the PS Booster's new cavities and delivered them to CERN in 2017. KEK was also responsible for testing the components. In June 2017, the KEK and CERN teams celebrated an important milestone: the completion of the assembly of the first new-generation accelerating cavity [3].

4. JAPANESE CONTRIBUTION TO THE ATLAS UPGRADE

The ATLAS Japan Group was primarily responsible for the construction of several subsystems of the ATLAS detector, such as the superconducting solenoid magnet, the muon trigger system in the end-cap regions with the detector called thin-gap chamber (TGC), and the semiconductor tracker (SCT) in the central region. All of these detector components showed excellent performance since the start of the experiment, and many important physics results have been produced as described in Ref. [2].

In parallel to the detector operation and physics analysis, KEK, together with the other 15 ATLAS institutes at Japanese universities, has extensively been pushing R&D for the detector upgrades for the HL-LHC (so called “phase-II upgrade”. The main scope of the Japanese contribution is to maintain its significant engagement in the areas of the current involvement, i.e. to the muon trigger upgrade and to the upgrade of the inner tracker. A general description of the phase-II upgrade project is given in Ref. [4].

The ATLAS Japan Group is responsible for delivering the Level-0 trigger for the end-cap regions. In the current system, the trigger information is derived from a single detector, the aforementioned TGC. In order to cope with the high rates expected at the HL-LHC from real and fake muons, it is necessary to combine information from various other muon detectors including the drift tube detectors. The Japanese group will contribute on the new trigger electronics, replacing the current system (see Fig. 5). The detailed design is described in the technical design report of the muon system upgrade [5] and the TDAQ upgrade (to be published in 2018).

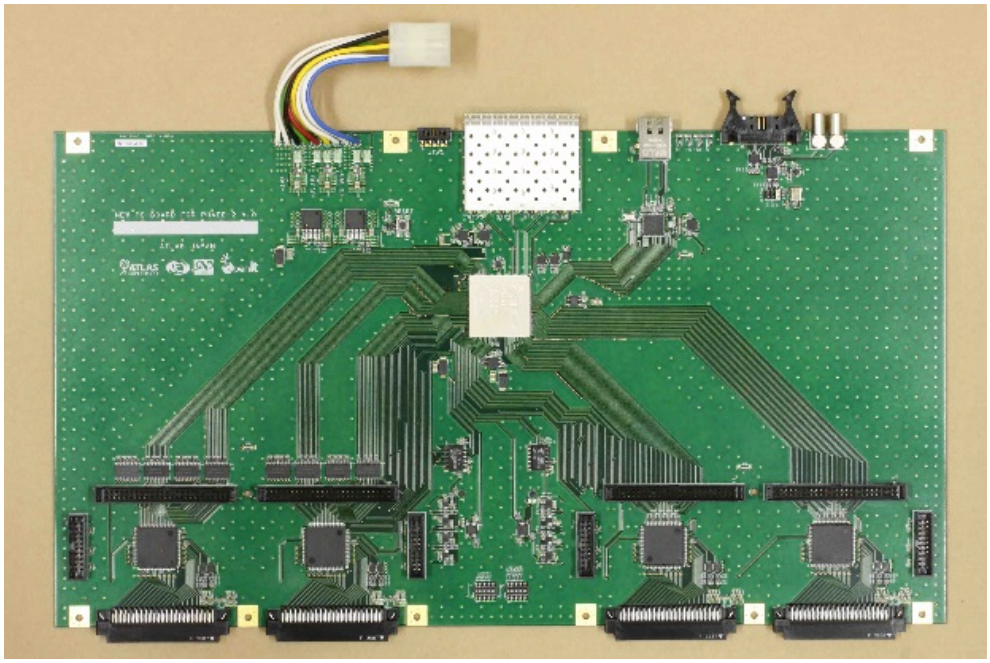

Figure 5: A prototype board for the muon trigger upgrade.

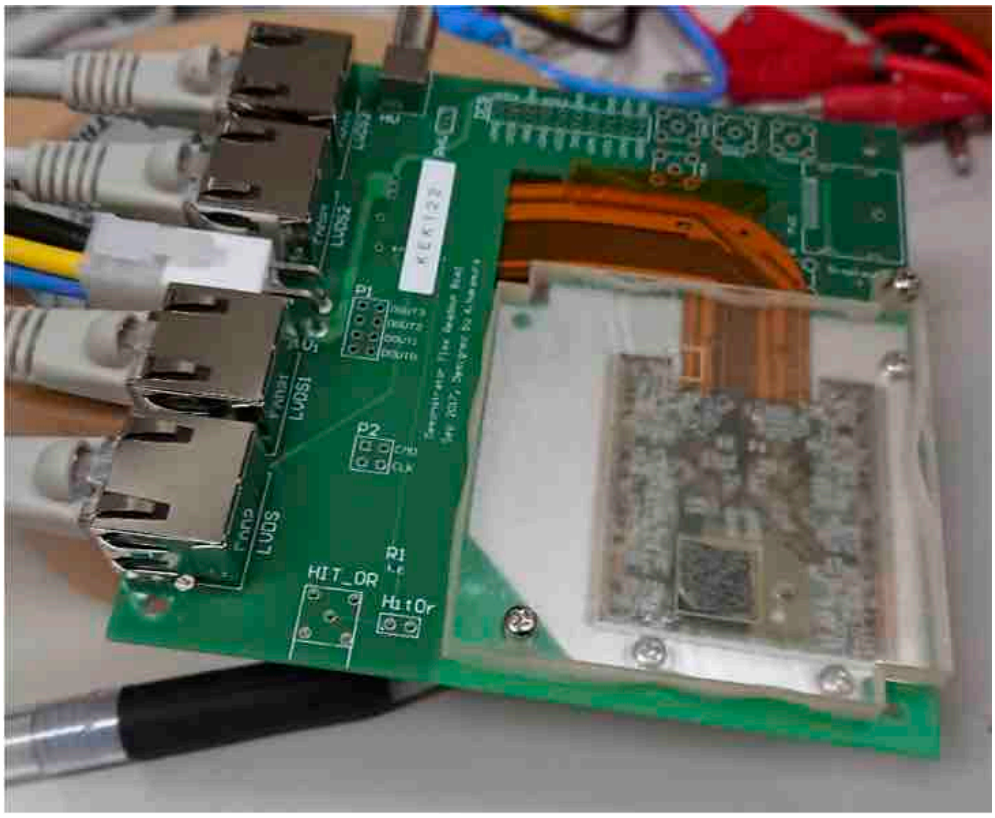

Figure 6: A test system for the prototype pixel detector.

Another and very expensive upgrade is the replacement of the inner tracker system. The Japanese contribution to the construction of the current detector ("SCT") was on its barrel part. After the upgrade, the inner detectors are all made from silicon detectors; strips and pixels. KEK has been working extensively on the development of new types of the radiation-hard pixel sensors and on the realization of the integration of the sensor and readout electronics [6] (see Fig. 6). It is intended that, after successful negotiations within the ATLAS collaboration, the Japanese group will contribute to the sensor production of the strip detectors and the outer layers of the pixel detector, in collaborations with numerous ATLAS institutes in the other countries. A detailed description of the project can be found in the strip detector TDR [7]. The corresponding pixel part will be published in 2018.

The budget proposed by the ATLAS Japan group for the HL-LHC programme has not yet been fully secured. However, KEK and the funding agency are informed on the detailed plan. KEK prepares the start-up funding, which will be sufficient for coming year, and will continue the effort to secure the full funding. Because of the nature of the Japanese funding system, which follows a single-year accounting, it is impossible to secure the full budget covering multiple fiscal years. KEK will continue to request the funding to cover the full budget.

5. SUMMARY

The Japanese contributions to the HL-LHC and ATLAS are by now well defined, and the corresponding R&D is well underway. It concentrates on the beam separation magnet D1 (MBXF) for the LH-LHC accelerator, of which KEK intends to produce all necessary units, 132 of the 340 magnetic discs at the heart of the PS Booster's new cavities (which were delivered to CERN already in 2017), and significant contributions to the ATLAS muon trigger and the inner tracker barrel upgrades.

With these contributions, Japan will maintains it high visibility and at CERN and in the LHC project, and it will help secure invaluable physics output for the future running periods of the accelerator flagship LHC.

REFERENCES

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