Report on FCC Conductor Workshop at CERN

A. Ballarino - CERN

FCC Week 2018, Amsterdam

FCC Conductor development workshop, 5-6 March 2018, CERN

FCC Conductor Development Workshop at CERN, 5-6 March 2018

Scope: **summarize results** of conductor development after about one year of activities performed in the framework of collaboration agreements between CERN and industry or academic institutions; **create a momentum** for constructive iterations and focus on evaluation of present/future developments

Participants: representatives from industry and laboratories/universities world - wide
~ 40 invited participants
21 oral contributions

Workshop Chair: A. Ballarino (CERN)
Scientific secretary: S. Hopkins (CERN)

Review panel (CERN): R. Flukiger (chair), L. Bottura, A. Devred, H. Ten Kate, L. Rossi

Organization: several plenary open presentations and six closed meetings
Two full days of meetings – included visits of conductor and magnets CERN facilities

FCC Conductor Development Workshop at CERN, 5-6 March 2018

Participants

Switzerland

CERN

Japan

KEK

FURUKAWA ELECTRIC

JASTEC SUPERCONDUCTOR

Russia

BOCHVAR INSTITUTE OF INORGANIC MATERIALS JSC VNIINM

FUEL COMPANY OF ROSATOM TVEL

Korea

Kiswire

China

Western Superconducting Technologies Co., Ltd.

Austria

TU WIEN

Germany

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

Italy

Columbus Superconductors

Finland/USA

LUVATA SPECIAL PRODUCTS

Italy

SPIN

Switzerland

UNIVERSITÉ DE GENÈVE

7 companies, two universities and two national research institutes

FCC Conductor Development Program

Scope of the conductor development program:

- Provide feedback on possibility of achieving beyond state-of-the-art **HL-LHC Nb_3Sn high-field performance** (J_c @ 16 T) to enable design of compact and cost effective 16 T magnets;

- Foster **Nb_3Sn conductor development in industry** and support the industrial development with academic **activities** (material studies and characterization) **in laboratories and institutes world-wide**;

- **Procure** (and cable) **Nb_3Sn conductor** to feed the on-going magnet model-coil activity (~ 6 tons in the next 5 years). This procurement, parallel with the R&D activity, will enable production of promising conductors in large quantity – and validation in model coils.

- Investigate potentials of **other superconductors** (feasibility of developments for high fields, potential in terms of low cost)

FCC Conductor Development Program – Nb_3Sn

CERN Targets, IEEE Trans. Appl. Supercond., 2015		Final	Today
Wire diameter	mm	**~ 1**	
Non-Cu Jc (16 T, 4.2 K)*	A/mm^2	**≥ 1500**	**Focus is on Jc**
μoΔM(1 T, 4.2 K)	mT	**≤ 150**	
Deff	μm	**≤ 20**	≤ **60** (as for HL-LHC)
RRR	-	**≥ 150**	
Unit length	km	**≥ 5**	**≥ 0.1**
Cost	Euro/kA m**	**≤ 5**	

*Je ~ 600 A/mm^2

** 16 T, 4.2 K

Choice of processes that should enable scalability and show potentials for low cost large scale production

Starting with a 4 years program. On-going agreements include production of about 20 km of R&D wire, as well as evaluation of cost of processes/production for a future industrialization.

FCC Conductor Development Program – Participants

Conductor activities for FCC started in 2017:

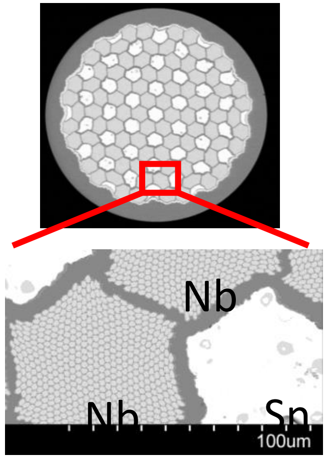
- **Bochvar Institute** (conductor produced at **TVEL**), **Russia**
- **KEK** (**Jastec** and **Furukawa**), **Japan**
- **KAT**, **Korea**
- **Columbus, Italy**
- **University of Geneva**, **Switzerland**
- **Technical University of Vienna**, **Austria**
- **SPIN**, **Italy**
- **University of Freiberg, Germany**

Effort done to support development in industry with activities in laboratories and universities - and at CERN

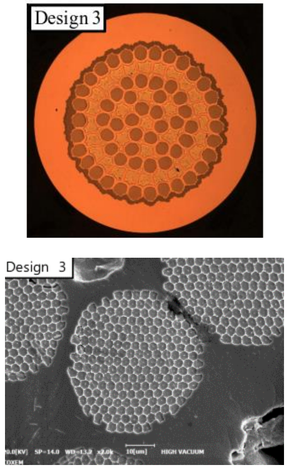
In addition, being finalized agreements with:

- **Bruker (Germany)**
- **Luvata Pori (Finland)**

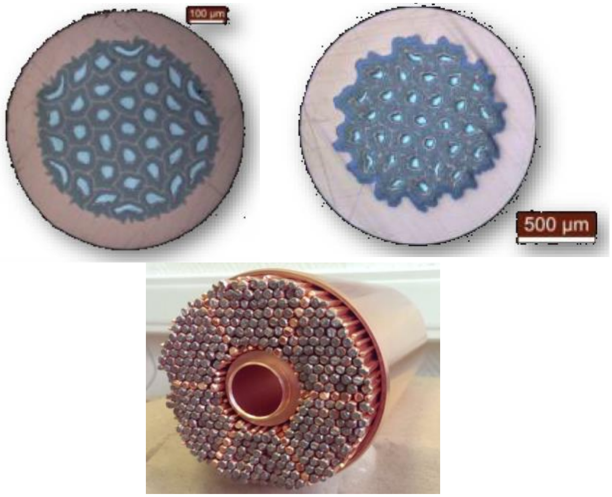
Outcome – Nb_3Sn development



KEK/Jastec - Japan



Kiswire KAT - Korea



Bochvar/TVEL - Russia

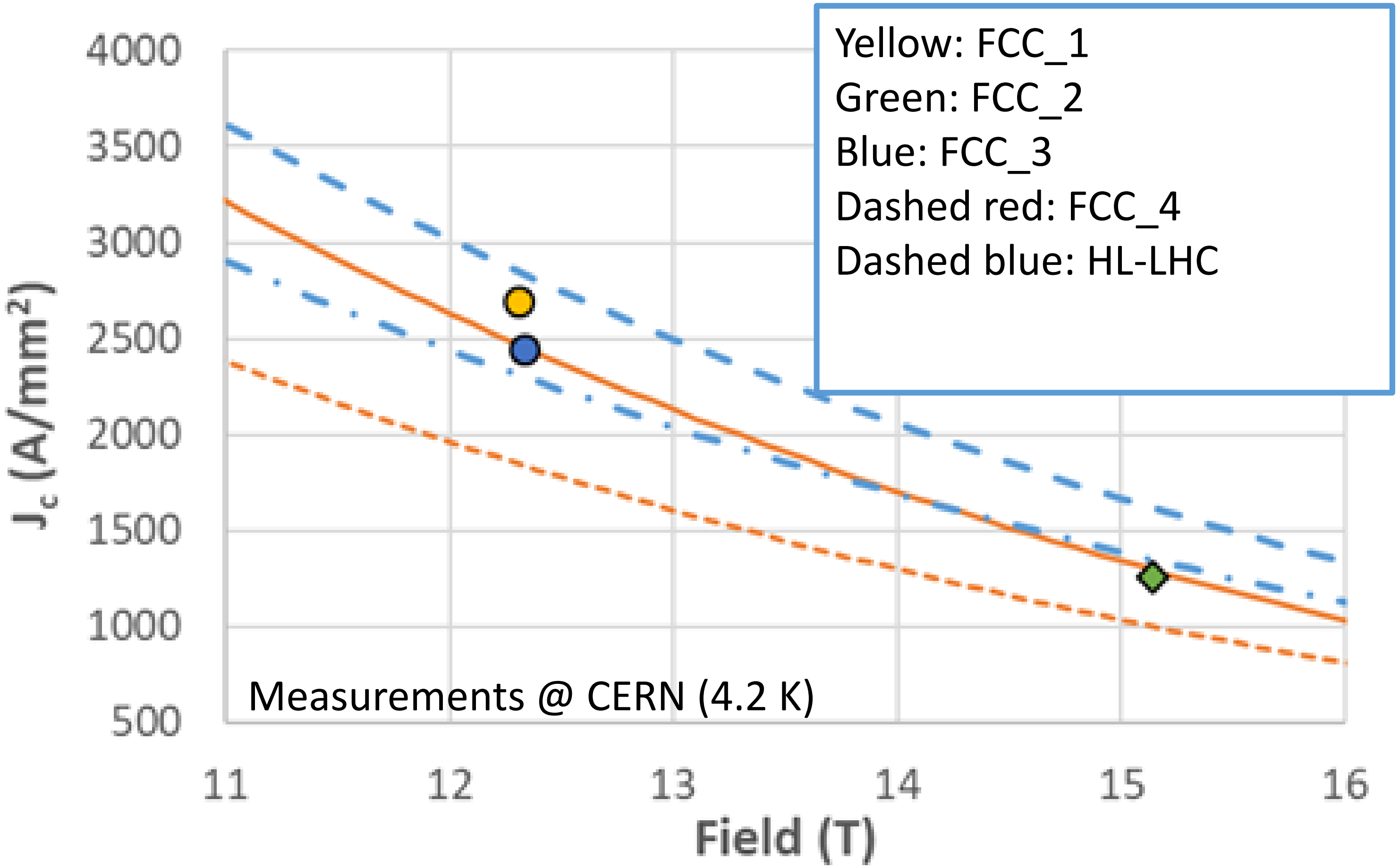
See following presentations:
S. Hopkins, T. Ogitsu, V. Pantsyrny, J. Kim

Other innovative layouts also being studied

- Production of several R&D billets by industrial partners
- Delivery of samples for measurements at CERN by most of the partner
- Delivery of 12 km of wire from Bochvar/TVEL

*"The review panel enthusiastically welcomes the **encouraging progress** achieved by participants in the short time for which the programme has been running"*

Outcome – Nb_3Sn development



"After a short project time, industrial Nb_3Sn wires with J_c values between 850 and 1'100 A/mm^2 at 4.2K/16T have been reached, i.e. ***approaching the level specified for HL-LHC****"*

Outcome – Nb_3Sn specification

*"The **project is structured logically, with a staged approach and clearly defined intermediate steps (J_c, RRR, D_{eff}, robustness and cost).** We support a procurement of wires satisfying HL-LHC performance for use as well for cable qualification as in magnet R&D, also to demonstrate a solid interest in the result"*

*"Wire diameter and effective filament diameter specifications have been defined in combination with magnet design. It is **acceptable to retain 60 microns** as an intermediate specification, but it is **urgent to conduct a study to define requirements**. An integrated conductor programme considering cabling degradation, stability and margin issues should be established"*

*"The panel supports to **test the Internal Oxidation approach** and to consider processes compatible with this technique"*

Outcome – Nb_3Sn timeline

"If the present FCC timescale is retained, it is expected that the results of the conductor development programme will not be complete in time for the short model coil programme, but should be available for implementation at the time foreseen for production of long model coils.

It is recommended that the ***short model coil programme should be extended*** *to run in parallel with the period foreseen for the production of long model magnets, to allow the validation of results achieved by the conductor development programme"*

Outcome – Nb_3Sn cost

"The ***cost target is ambitious****: from the present review it seems difficult, but* ***realistic****, as was considered* ***by more than one participant in a reasonable timescale****"*

Outcome – Other superconductors

*"The panel **acknowledges the effort and interesting ideas** that are being pursued towards the development of **MgB_2, BSCCO 2212 and iron-based** superconductors, but emphasises that this is a basic materials programme, and that these materials are clearly on a **different priority with respect to Nb3Sn**. It supports the necessity to further evaluate the potential of these materials and recommends to identify the opportunities for accelerator magnets so that target specifications can be defined (e.g. use of MgB_2 magnets requiring a high temperature margin).*

*It is recommended that the application for each potential conductor in the context of the FCC Study should be defined, and **suitable targets specified**"*

Conclusions

Significantly results achieved by several collaborators during the first year of development.

The **HL-LHC intermediate target (~ 1000 A/mm^2 at 16 T)** seems to be **within reach in a short time schedule**. Larger production of the wire recently developed by several industrial partners will enable consolidation of the results.

The **final target (1500 A/mm^2)** is challenging. **Innovative processes are required, e.g. internal oxydation, Ti + Ta additions, or both.** Partners are moving in these directions, e.g. proposing layouts that could enable implementation of internal oxidation processes in industrial production.

The **time scale** is clearly longer than four years (8-10 years), and the FCC magnet development program ingrates this requirement in the model coil program.

More exciting results to come in the next years

Many thanks to all participants to the review panel !

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