CERN HTS program: Next steps

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Challenges

Field view

- Accelerator dipole development is on the brink of reaching 16 T in a usable aperture , in a few mm aperture it was already achieved twice
- Above 16 T is uncharted territory
- We think that at B > 16 T Nb_3Sn will run quickly out of steam, technically and economically
- For B> 16 T we will have to apply some type of HTS conductor

Challenges (2)

HEP view "whatever your problem is, a magnet is the solution"

- If higher energy (E_{cm}>>14 TeV) proton-proton colliders are needed, then we can identify the following CERN options:
  - C_{ring}= 27 km, B= 16 T, E_{cm} = 26 TeV | "HE-LHC"
  - C_{ring}= 27 km, B= 20 T, E_{cm} = 33 TeV |
  - C_{ring}= 80 km, B= 16 T, E_{cm} = 80 TeV | "FCC"
  - C_{ring}= 80 km, B= 20 T, E_{cm} = 100 TeV |
  - C_{ring}= 100 km, B= 16 T, E_{cm} = 100 TeV |
  - C_{ring}= 100 km, B= 20 T, E_{cm} = 125 TeV |

- It is likely that we will have to maximize E_{cm} and hence B in the smallest possible ring, for cost, complexity and timing reasons:
  - HE-LHC is a real option as the next step (whatever the step after will be)

Challenges (3)

- Experience (reality kicks in !)
  - It took 22 years (1986-2008) from the first LHC main dipole coil design to the first beam
  - It is planned to take (2004-2025) 21 years for the HILUMI quadrupole from first coil designs to the beam

==> We have to start now to be able to apply HTS accelerator magnets in the mid-2030 decade

- The last 5%: even in a 16 T Nb_3Sn machine, a few HTS magnets are probably needed in some special places:
  - Low beta quadrupoles
  - Collimation space
  - Separation magnets
  - Sextupoles

The (draft) CERN HTS program 2017-2024

Aims:

1. Develop usable REBCO tape conductors and cables with cable currents in the 10 kA-20 kA range to operate around 20 T or with cable currents of a few kA for other accelerator magnets.
2. Show the feasibility of 20 T dipole magnets using REBCO conductor either single or graded with other conductors
3. Show the feasibility of quadrupole and corrector magnets using REBCO conductor

With:

- Using the developments from EuCARD and EuCARD2 (*)
- Complete and complement the EuCARD2 Feather magnet series

Extending and building up:

- A wide range of collaborations with institutes, universities and key industries

(* continuity !)

The program in an eye blink (1)

- The HTS magnet development program is divided into 5 groups of topics

1. General: the management of the program

2. Conductor development and procurement
   - Development of the REBCO conductor (tape and cable), including ARIES
   - Study (solve) some conductor related issues like splicing, basic quench behaviour, current redistribution, etc.
   - Procurement of the conductor for the models

3. Enabling Technologies
   - Complete the EuCARD2 models
   - Study how to use HTS magnets in accelerators
   - Study magnet related issues like insulation, coil splicing, quench protection
   - Develop basic coil manufacturing in sub-scale models

The program in an eye blink (2)

- The HTS magnet development program is divided into 5 groups of topics

4. Model Dipole Magnet
   - Go through the steps : conceptual design, detailed design and construction of a 20 T accelerator dipole model
   - As support, intermediate reduced-size models can be made as well

5. Other types of HTS magnets
   - Quadrupole design study
   - Corrector magnet design study

And 2 KT type activities:

- Space spectrometer design study and model coil
- Medical magnet design study

Proposal for “work-packaging”

1. Work-package group: General
   - WP1: Project management
2. Work-package group: Conductor development and procurement
   - WPA1: Sub-conductor development
   - WPA2: Cable development
   - WPA3: Conductor current re-distribution and quench propagation studies
   - WPA4: Conductor and cable electrical joints development
   - WPA5: Conductor test and characterisation
   - WPA6: Conductor procurement for model magnets
3. Work-package group: Enabling Technologies
   - WPB1: Insulation development
   - WPB2: Quench protection
   - WPB3: HTS magnet operation in accelerators
   - WPB4: Feather0 and Feather2 models
   - WPB5: Insert and sub-scale tests in stand-alone and in background field
   - WPB6: Coil joining technology and cable validation in sub-scale structures

Proposal for “work-packaging”

3. Work-package group: Model Dipole Magnet
   - WPC1: Conceptual design of dipole models
   - WPC2: Design and construction of reduced size HTS models
   - WPC3: Design of 20 T dipole magnets
   - WPC4: Construction of 20 T dipole magnets
   - WPC5: Model test and infrastructures

5. Work-package group: Other types of HTS magnets
   - WPD1: Design of a quadrupole and other HTS magnet for HEP
   - WPD2: Design study for HTS magnets for space applications
   - WPD3: Design study for HTS magnets for medical applications

The program in time

8 year program starting 2017 ending end 2023

General

WP1	Project management

Conductor

WPA1	sub-conductor development
WPA2	Cable development
WPA3	Conductor current re-distribution and quench propagation studies
WPA4	Conductor and cable electrical joints development
WPA5	Conductor test and characterisation
WPA6	conductor procurement

Enabling technologies

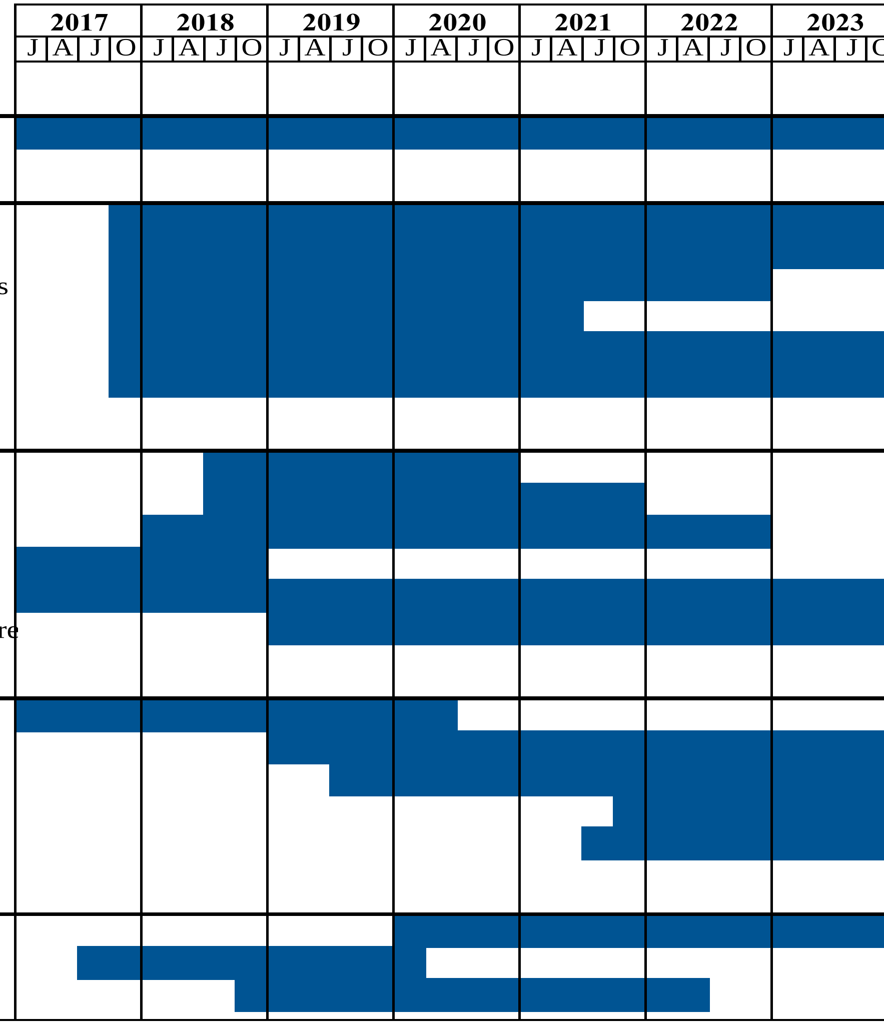
WPB1	Insulation development
WPB2	Quench protection
WPB3	HTS Magnet operation in accelerators
WPB4	Feather0 and Feather2 models
WPB5	Insert and sub-scale tests in stand-alone and in background field
WPB6	Coil joining technology and cable validation in sub-scale structure

Model dipole magnets

WPC1	Conceptual design of dipole models
WPC2	Design and construction of reduced size HTS models
WPC3	Design of 20T dipole magnets
WPC4	Construction of 20T dipole magnets
WPC5	Model test and infrastructures

Other types of HTS magnets

WPD1	Design of a quadrupole and other HTS magnet for HEP
WPD2	Design study for HTS magnets for space applications
WPD3	Design study for HTS magnets for medical applications



General – program management

- The program is managed by CERN in the TE-MSC group.
- Collaborations with other institutes will be continued / developed
- Initially CERN will organise meetings with potential partners to keep the community informed on the progress of the work and stimulate interest for taking up part of the work. (**Meetings starting in the next weeks**)
- The program is intended to be a smooth continuation of previous projects like EuCARD and EuCARD2. The HTS part of the ARIES project will be considered part of this program.

Conductor development and procurement

- The first aim of the conductor program is to develop REBCO tape with J_e>600 A/mm^2@20 T and 4.2 K.

- The second aim is to develop several cable types using REBCO tape with currents in the 10 kA- 20 kA range. New cable concepts are to be tried (invented ?)

- Additional aims are the development of the basic splicing technology for the tapes and cables. The detailed understanding of the conductor in terms of current redistribution and quench is also included.

- The procurement of the cables for the model programs will be assured during the duration of the program

Enabling Technologies

- In preparation for the actual design of a 20 T dipole magnet a number of developments have to be done.

- The full exploitation of the models of the EuCARD2 project is an essential starting point to understand how to use REBCO conductor in magnets

- These consist of sub-system development
  - Insulation
  - magnet protection technology,
  - joints inside and between coils,
  - sub-scale models for cable and coil technology validation
  - studies on how HTS magnets can be used in an accelerator.
    - Study of operation of HTS magnets in accelerators,
    - Dynamic effect studies of HTS magnets,
    - Special correction schemes
    - Demonstration in a beam line
- The sub-scale tests (Feather0-1 etc) in stand-alone or inside outsert magnets (Fresca2, SULTAN, etc)

Model Dipole Magnets

- The design and construction of a demonstrator model for 20 T passes by:
  - a conceptual study that scans all possibilities and then selects a few (1-3) feasible layouts.
  - reduced scale models to be designed and built that represent the main features of the high field HTS core of the magnet.
  - 20T models detailed design
  - 20T Model manufacturing
  - Model testing

Other type of HTS magnets

- HTS quadrupole magnets conceptual design
- HTS corrector magnets conceptual design

+ two KT type activities:

- Space magnets (with ASI):

  To develop design and advanced HTS technology suitable for high field magnets to be used for high resolution spectrometer space experiment.
- Design study for HTS magnets for medical applications (eg. Gantry magnets)

Getting the program to run...

- In the next 2 months we will take the necessary steps to get the program accepted at CERN
- In parallel we will start to contact other institutes for collaborative actions

- Already started and running:
  - Feather program in EuCARD2 will move naturally into the program on 1st May
  - The conceptual study for the 20T dipole started on 1 Dec 2016 (Jeroen van Nugteren)
  - Sub-scale testing is already being set-up (CERN, INFN-LASA, EPFL-SPC)

- The resources: to be revealed when we get approved