FuSuMaTech

Future Superconducting Magnet Technology

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Grant Agreement Number n° 766974

DELIVERABLE D 5.6

SYNTHESIS AND ORIENTATION REPORT FOR DEVELOPMENT OF TECHNOLOGY AND INDUSTRIAL APPLICATIONS

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PROJECT DELIVERABLE INFORMATION SHEET		
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1. INTRODUCTION

This report is analyzing the overall process of the Work Package 5 of FuSuMaTech Phase 1 “Setting up technology Pilots” and give a feedback on the methodology. This report contributes to foster innovation in the domain by setting up new situations for synergy between Academic Research and Industry.

Technology development relies on two pilars:

-Basic knowledge of phenomena and material properties usually called under the R&D acronym.
-Realisation of technology pilots or prototypes based on functional specifications in view of applications.

These two ways of progress are complementary and FuSuMaTech has been oriented from the beginning to use them both.

2. ARCHITECTURE OF WP5

The present deliverable is a synthesis of this second pilar in FuSuMaTech.
WP5 - Setting up technology Pilots

The architecture of FuSuMaTech WP5 is the following:

T5.1: Preparation of proposal for MgB2 Technology demonstrator
Task leader: Sigmaphi

T5.2: Preparation of proposal for Frontier edge High-field MRI 16 T concept magnet
Task leader: CEA

T5.3: Preparation of proposal for investigation of innovative magnetic configurations for emerging MRI applications
Task leader: ELYTT

T5.4: Preparation of proposal for technology demonstrator of an HTS insert for HFML
Task leader: BNG

T5.5: Preparation of proposal for gradient coils technology for high-field MRI, over 10 T
Task leader: Tesla

3. ORGANISATIONAL GUIDELINES OF FUSUMATECH WP5

The organisation guidelines of FuSuMaTech WP5 are the following:

- All the task leaders of WP5 belong to Industry (except the task 5.2 led by CEA for a more than challenging project but it includes major industry partners).
- As defined at the origin of FuSuMaTech, main applications are medical applications with high field.
- Development of SC conductors is not directly included in WP5 as far as other actions have been already implemented in particular by CERN.
- No prototyping in the high field accelerator magnets is included as this programme is already developed by CERN.

4. SYNTHESIS OF PROPOSALS

The 5 proposals (Deliverables from 5.1 to 5.5) are presented according to the following summary.

1. EXCELLENCE
1.1 Context and Objectives
1.2 Description
1.3 Ambition (Innovation, technological breakdown)
1.4 Concept and Methodology (Integration in the FuSuMaTech Initiative Methodology, Collaboration between Academics, Links with other FuSuMaTech Sub-Projects)

2. IMPACT
2.1 Expected Impact
2.2 Potential Applications / market

3. IMPLEMENTATION
3.1 Technology Status (State of the art / project choices)
3.2 Work plan and Roadmap for development
3.2.1 List of Sub-Task
3.2.1.1 Sub-Task Description
3.2.1.2 Sub-Task Resources (Manpower and material)
3.2.2 Roadmap (including milestones / deliverables)
3.3 Consortium (Role, activity of each Partner within the Project)
3.4 IP Matrix Review and status

The estimation of the necessary funding is presented in the following table :

Task	5.1	5.2	5.3	5.4	5.5
Technology Pilot	MgB2 Dipole	MRI 16T	Mammo Magnet	HTS Insert	Gradient Coils
Estimated Budget	1844.K€	3450.K€	1575.K€	8205.K€	1422.K€
Remark	Functional magnet	Initial R&D Phase only	Initial R&D Phase only	Functional magnet	Initial R&D Phase only

5. COMMENTS ON THE WP5 OUTCOME TASK PER TASK

5.1. *MgB2 TECHNOLOGY PILOT*

The initial idea was to build up a 5 Teslas solenoid. As far as this development has almost already been carried out, the task has been reoriented with a ”Gantry Dipole”. The MgB_2 conductor characteristics and availability remain the central constraint of this task. The proposal De 5.1 has a very high degree of maturity.

5.2. *FRONTIER EDGE HIGH FIELD MRI 16T CONCEPT MAGNET*

Ultrahigh field MRI is now really emerging and a prospective for a 16 T MRI is relevant.
The task description is concentrated on the following technical aspects:

- SC conductor development
- Winding technology in liaison with magnetic design
- Mechanical structure

Considering the very high level of technical challenges of the project, starting long time ahead of a realisation sounds the more realistic way.

5.3. *SOCIAL MAGNET, OPEN MRI MAGNET, MAMMO MAGNET (CONCEPTUAL DESIGN)*

Starting MRI magnet design from a simple list of functional requirements is a real challenge. Several structures have been envisaged for the two applications:

- Social magnet
- Mammo magnet

A three-year process of preliminary design is still required.

5.4. *HIGH TEMPERATURE SUPERCONDUCTING INSERTS FOR HIGH-FIELD MAGNETS*

This subject is strategic for the development of high field magnets in Europe both for:

- Accelerator magnets where the concept of HTS insert in a background field produced by LTS conductors is promising.
- High field magnets developed in the frame of the European collaboration EMFL.

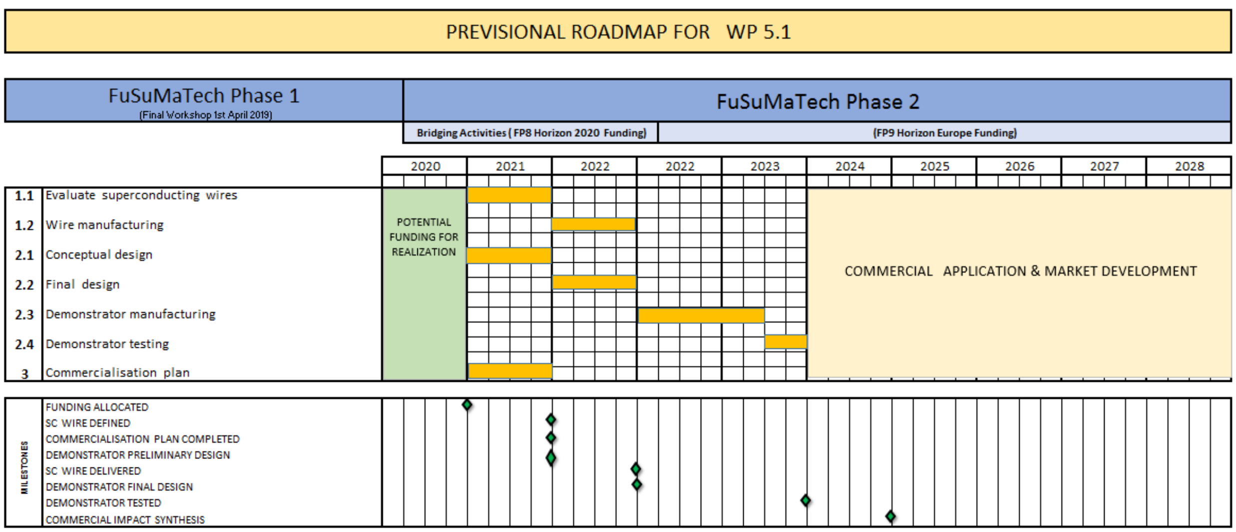
The partners of the Task 5.4 have been working together for a few years on R&D subject related to HTS behaviour especially in the situation of magnet quenching.
The outcome of this task 5.4 is a very mature proposal and can be considered as ready for implementation.

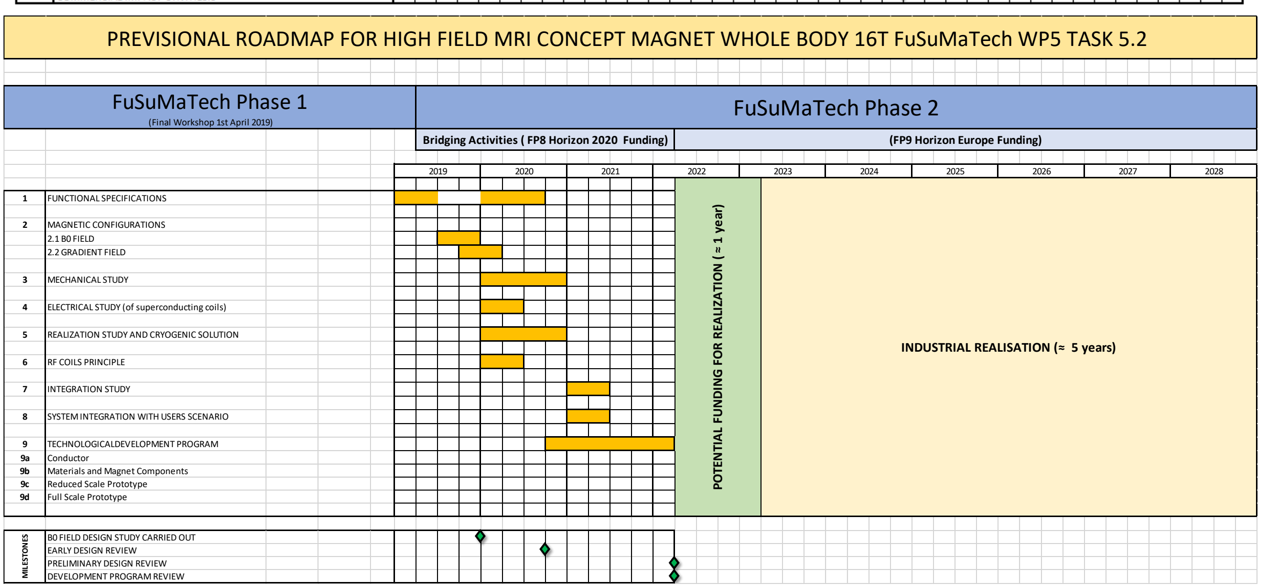
5.5. *GRADIENT COIL TECHNOLOGY FOR HIGH FIELD MRI, OVER 10T*

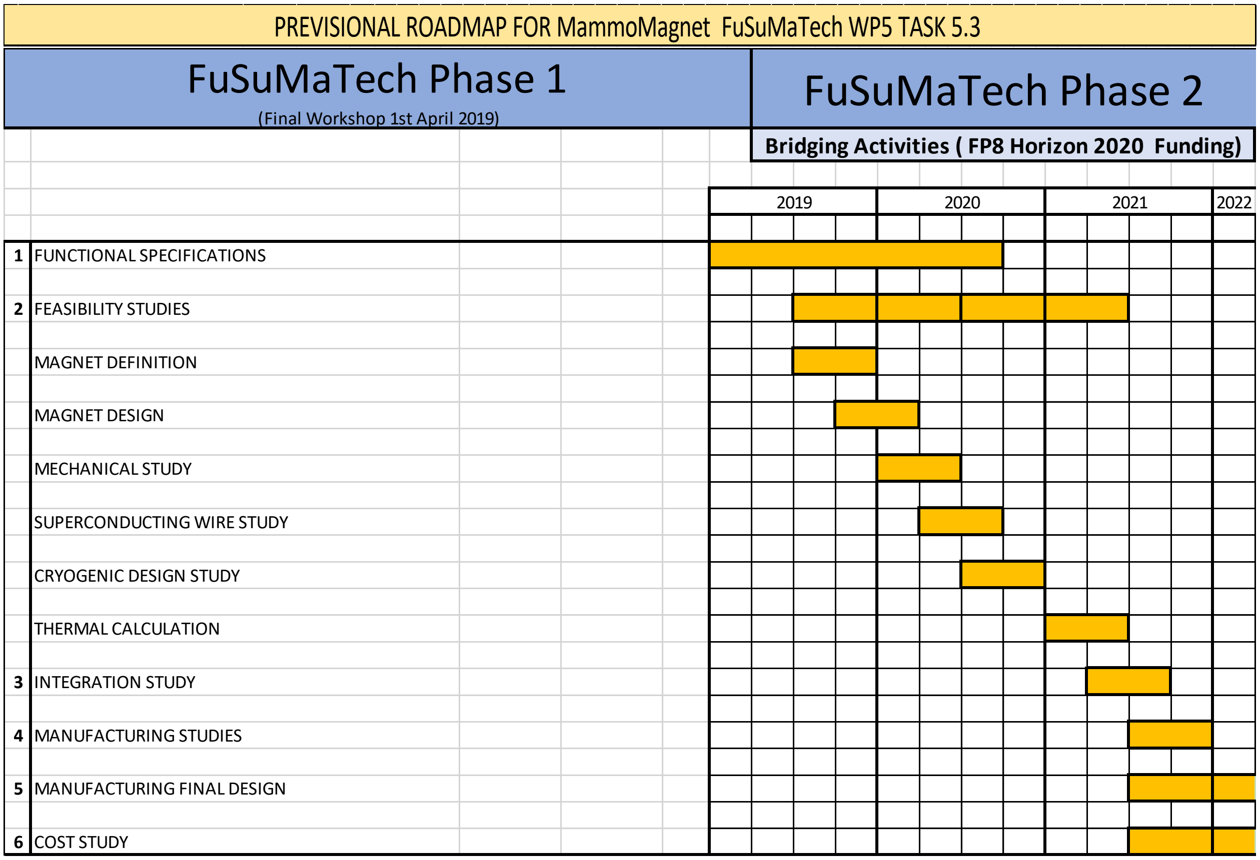
The FuSuMaTech Phase 1 has stimulated operational contacts between the final users of the high field MRI ISEULT and European Gradient coils designer and manufacturer TESLA. These contacts have made possible the establishment of functional specifications and are opening the way for an R&D&I action.

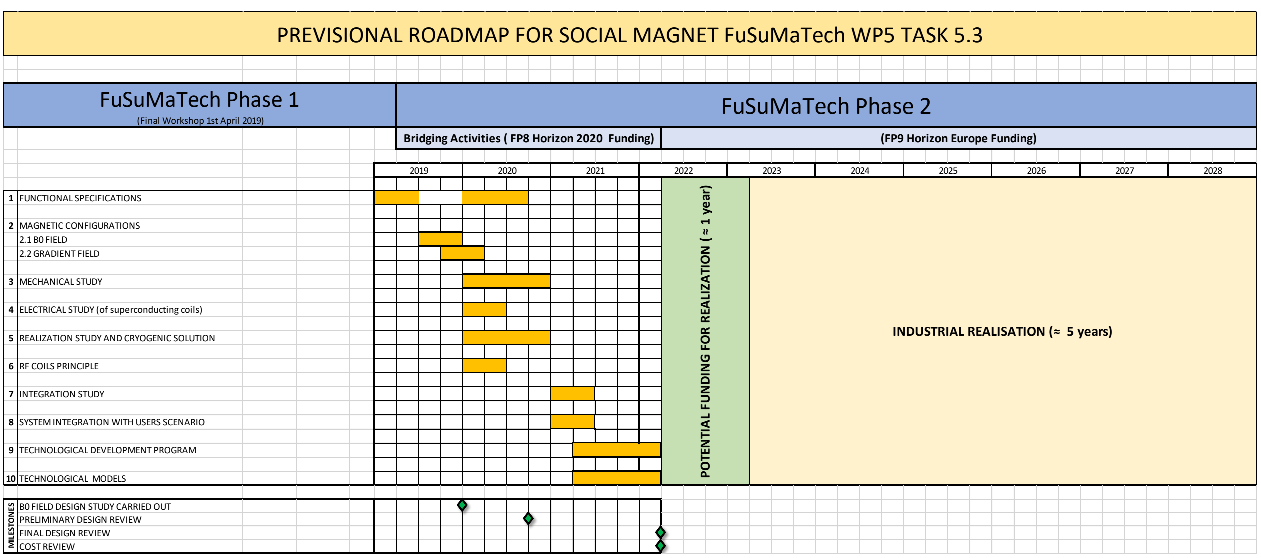
6. OVERALL ROADMAP

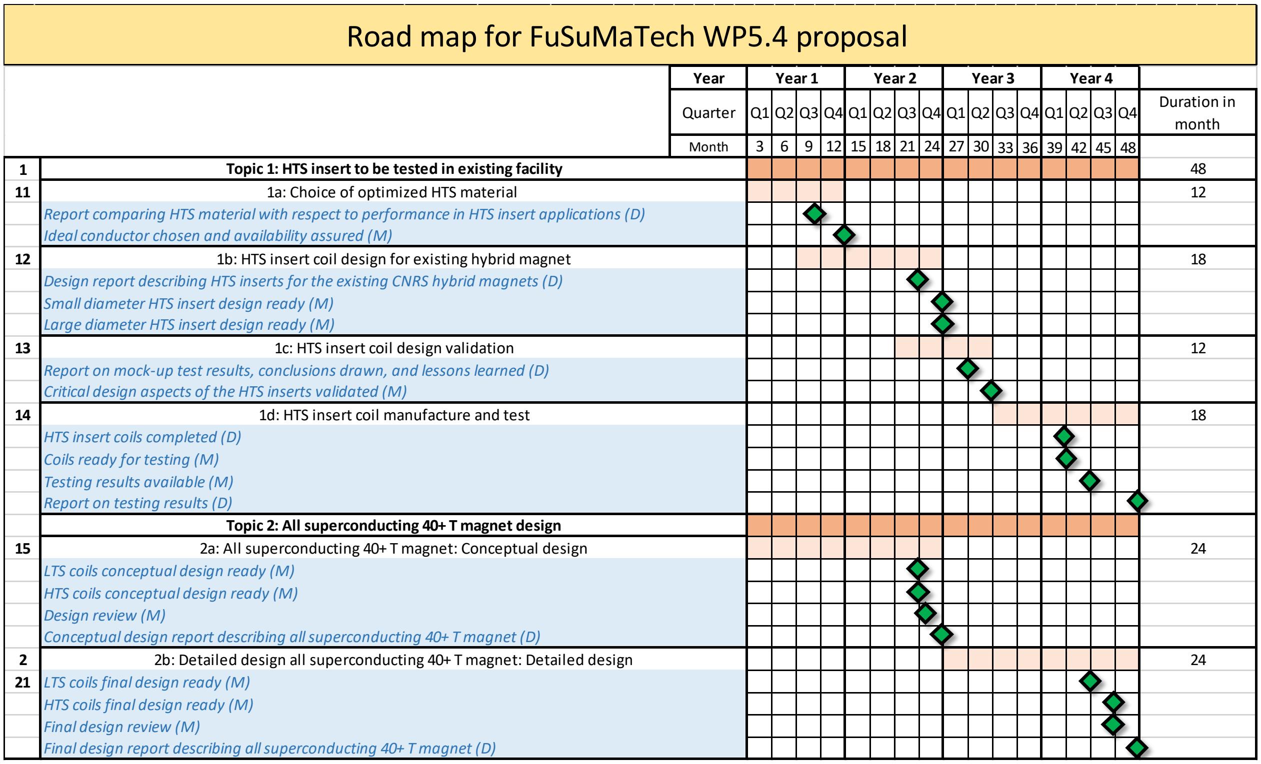
The following table is an overall roadmap of the 5 Technology pilot actions.

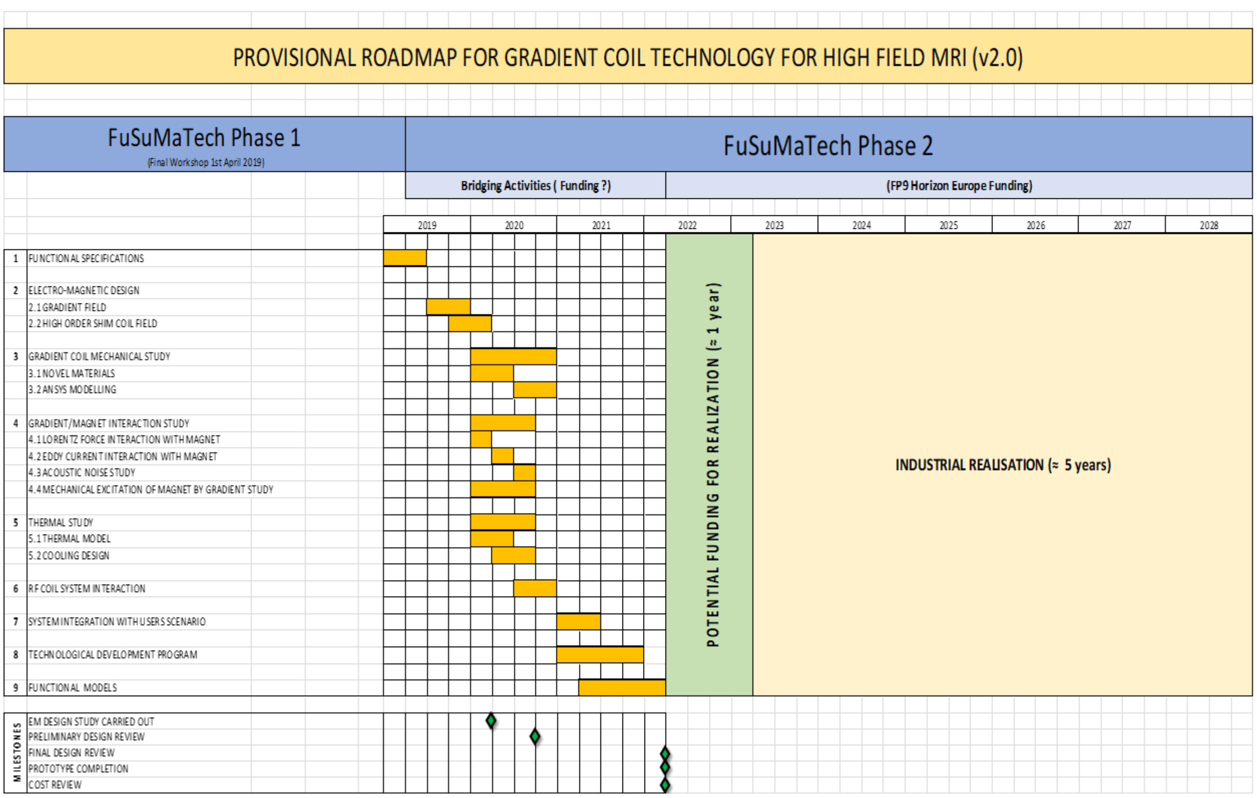





PREVISIONAL ROADMAP FOR MammoMagnet FuSuMaTech WP5 TASK 5.3
FuSuMaTech Phase 1
(Final Workshop 1st April 2019)
FuSuMaTech Phase 2
Bridging Activities (FP8 Horizon 2020 Funding)
2019
2020
2021
2022
1 FUNCTIONAL SPECIFICATIONS
2 FEASIBILITY STUDIES
MAGNET DEFINITION
MAGNET DESIGN
MECHANICAL STUDY
SUPERCONDUCTING WIRE STUDY
CRYOGENIC DESIGN STUDY
THERMAL CALCULATION
3 INTEGRATION STUDY
4 MANUFACTURING STUDIES
5 MANUFACTURING FINAL DESIGN
6 COST STUDY


PREVISIONAL ROADMAP FOR SOCIAL MAGNET FuSuMaTech WP5 TASK 5.3
FuSuMaTech Phase 1
(Final Workshop 1st April 2019)
FuSuMaTech Phase 2
Bridging Activities (FP8 Horizon 2020 Funding)
(FP9 Horizon Europe Funding)
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
1 FUNCTIONAL SPECIFICATIONS
2 MAGNETIC CONFIGURATIONS
2.1 B0 FIELD
2.2 GRADIENT FIELD
3 MECHANICAL STUDY
4 ELECTRICAL STUDY (of superconducting coils)
5 REALIZATION STUDY AND CRYOGENIC SOLUTION
6 RF COILS PRINCIPLE
7 INTEGRATION STUDY
8 SYSTEM INTEGRATION WITH USERS SCENARIO
9 TECHNOLOGICAL DEVELOPMENT PROGRAM
10 TECHNOLOGICAL MODELS
POTENTIAL FUNDING FOR REALIZATION (≈ 1 year)
INDUSTRIAL REALISATION (≈ 5 years)
MILESTONES
B0 FIELD DESIGN STUDY CARRIED OUT
PRELIMINARY DESIGN REVIEW
FINAL DESIGN REVIEW
COST REVIEW


Road map for FuSuMaTech WP5.4 proposal
Year
Year 1
Year 2
Year 3
Year 4
Quarter
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Month
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
Duration in month
1 Topic 1: HTS insert to be tested in existing facility 48
11 1a: Choice of optimized HTS material 12
Report comparing HTS material with respect to performance in HTS insert applications (D)
Ideal conductor chosen and availability assured (M)
12 1b: HTS insert coil design for existing hybrid magnet 18
Design report describing HTS inserts for the existing CNRS hybrid magnets (D)
Small diameter HTS insert design ready (M)
Large diameter HTS insert design ready (M)
13 1c: HTS insert coil design validation 12
Report on mock-up test results, conclusions drawn, and lessons learned (D)
Critical design aspects of the HTS inserts validated (M)
14 1d: HTS insert coil manufacture and test 18
HTS insert coils completed (D)
Coils ready for testing (M)
Testing results available (M)
Report on testing results (D)
Topic 2: All superconducting 40+ T magnet design
15 2a: All superconducting 40+ T magnet: Conceptual design 24
LTS coils conceptual design ready (M)
HTS coils conceptual design ready (M)
Design review (M)
Conceptual design report describing all superconducting 40+ T magnet (D)
2 2b: Detailed design all superconducting 40+ T magnet: Detailed design 24
21 LTS coils final design ready (M)
HTS coils final design ready (M)
Final design review (M)
Final design report describing all superconducting 40+ T magnet (D)


PROVISIONAL ROADMAP FOR GRADIENT COIL TECHNOLOGY FOR HIGH FIELD MRI (v2.0)
FuSuMaTech Phase 1
(Final Workshop 1st April 2019)
FuSuMaTech Phase 2
Bridging Activities (Funding ?)
(FP9 Horizon Europe Funding)
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
1 FUNCTIONAL SPECIFICATIONS
2 ELECTRO-MAGNETIC DESIGN
2.1 GRADIENT FIELD
2.2 HIGH ORDER SHIM COIL FIELD
3 GRADIENT COIL MECHANICAL STUDY
3.1 NOVEL MATERIALS
3.2 ANSYS MODELLING
4 GRADIENT/MAGNET INTERACTION STUDY
4.1 LORENTZ FORCE INTERACTION WITH MAGNET
4.2 EDDY CURRENT INTERACTION WITH MAGNET
4.3 ACOUSTIC NOISE STUDY
4.4 MECHANICAL EXCITATION OF MAGNET BY GRADIENT STUDY
5 THERMAL STUDY
5.1 THERMAL MODEL
5.2 COOLING DESIGN
6 RF COIL SYSTEM INTERACTION
7 SYSTEM INTEGRATION WITH USERS SCENARIO
8 TECHNOLOGICAL DEVELOPMENT PROGRAM
9 FUNCTIONAL MODELS
POTENTIAL FUNDING FOR REALIZATION (≈ 1 year)
INDUSTRIAL REALISATION (≈ 5 years)
MILESTONES
EM DESIGN STUDY CARRIED OUT
PRELIMINARY DESIGN REVIEW
FINAL DESIGN REVIEW
PROTOTYPE COMPLETION
COST REVIEW

7. CONCLUSION

All the tasks of WP5 are resulting in promising proposals with high degree of maturity.
Contacts with EU are planned to select adequate calls in view of implementation in the 2 or 3 coming years.