EP R&D on Experimental Technologies

WP8

Magnet Detector R&D

21st June 2022

Benoit CURE – EP/CMX

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EP R&D WP8 Activities

→ *WP8 on Magnet Detector R&D launched in 2020 with **3 major R&D areas** (scope reduced compared to the initial plan to meet the available budget).*

Scope for years 2020-2024

8.1 Advanced Magnet Powering

***8.2 Reinforced Super-Conductors and Cold Masses* ..... On hold**

***8.3 Ultra-Light Cryostat Studies* ..... Integrated into WP4**

8.4 New 4-Tesla General Purpose Magnet Facility for Detector Testing

8.5 Innovation in Magnet Controls, Safety Systems & Instrumentation

WP8 organisation

Program started at the time of the **Covid pandemic** :

- **Still possible to begin the activities** with one fellow and one technical student**,** but it was **a slow start due to Covid.**

Over the Covid period, the works **were adapted to the conditions:**

- Prototyping delayed until access to CERN was granted, following CERN recommendations regarding on-site presence,
- First focusing more on studies, but with limited internet speed for remote connections.

We selected highly motivated candidates with **excellent** background in mechanical and electrical engineering, cryogenics, instrumentation.

- Candidates were selected to have **complementary scientific backgrounds** in the team, but few of the applicants had full university education in the field of superconductivity.
- The works were also adapted to enable the fellows & students to learn in this field.

WP8 organisation – period 2020-2022

Members of the team:

Fellows: Shuvay Singh, Anna Vaskuri

Technical Students: Filip Malinowski, Michela Neroni, Weronika Głuchowska, Robert Jurco

Staff: Alexey Dudarev, Matthias Mentink, Nicola Pacifico, Benoit Cure

+ support from :

Atlas Magnet Team Fellow: Nikkie Deelen

Trainees: Tonke Boelens, Pieter Kruyt, Dennis Klaassen

WP8 organisation

In the frame of our activities we have received the welcome (and appreciated) support from:

- **TE-CRG Cryolab** for test facility design and testing (snubber, 5-T small coil),
- **EP-DT-DI** magnet control section (b180 new test facility control system),
- **EP-DT-TP** for contribution to instrumentation studies,
- **TE-VSC-SCC** for material analysis,
- **EN-MME** for material testing,
- **EN-EL** for the electrical distribution of b180 new test facility,
- **ATLAS** (and **CMS**) support team for technical activities.

Many thanks to them for their useful collaboration !

WP 8.1 - Advanced Magnet Powering

Original workplan

Scope for years 2020-2024

- Magnet powering and protection
- Free wheel systems and persistent mode current switch
- Energy extraction studies and quench protection
- Studies applied to WP8.4.

Resources: (½ fellow + 1 technical student) / year over 2020-2022

Deliverable 2020 – mid 2022:

- Feasibility studies and reports.
- Conceptual Design reports based on simulation, technical designs, construction of demonstrator models and testing.

Results

Activities 2020- mid 2022

1. Quench protection studies and modelling, applied to the 4-T magnet studies,
2. Snubber studies for implementation on Atlas Barrel Toroid,
3. Commissioning of CMS free wheel system,
4. Study of persistent mode current switch,
5. Study of flux pump.

Resources: (½ fellow + 1 technical student + trainee) / year over 2020-2022

Results 2020 – mid 2022:

- Feasibility studies and reports : done (1-2-4-5)
- Computational simulations: done (1-2-4-5)
- Conceptual design reports based on simulation: done (2-4-5); construction of demonstrator models and testing : done (2), in progress (5)
- Implementation and final testing campaign : done (2-3)

WP 8.4 - New 4-Tesla Magnet Facility

Original workplan

Scope for years 2020-2024

- Conceptual design study of a 4-T magnet for a test beam facility

Resources: ½ fellow / year over 2020-2022

Deliverable 2020 – mid 2022:

- Magnet design.
- Magnet subsystem design (cryogenics, powering, cryostat, yoke, support system)

Results

Activities 2020- mid 2022

1. Definition of technical requirements,
2. Studies of magnet layout and stray field
3. Definition of conductor and cold mass
4. Study of cryogenics

Resources: ½ fellow (2020-22)+ 1 technical student (2021)

Results 2020 – mid 2022:

- Magnet concepts: done, reported and published.

  Two options studied, Split coil solenoid and Dipole (Magnadon*).
  Conductor and winding defined: pancake winding of reinforced Al-stabilized NbTi conductor.

- Magnet subsystem studies on:

  Inner cryogenics, powering system, yoke.
  In progress: cryostat, support system.

** discussed with MADMAX collaboration as potential application.*

WP 8.5 - Innovation in Magnet Controls, Safety Systems & Instrumentation

Original workplan

Scope for years 2020-2024

- Quench protection in HTS: fast detection, sensitivity, low voltage;
- Magnet controls : requirements, identification of future systems;
- Instrumentation: magnetic measurement, interfaces CAN FD.
- Applied to the 4-T magnet beam test facility to test and qualify these systems.

Resources: activity starting from mid 2021 with 1 fellow + 1 technical student

Deliverable mid 2021 – mid 2022:

- Magnet control system needs.
- Testing and reporting.
- Simulation, prototyping with new instrumentation.

Results

Activities 2021 - mid 2022

1. New testing setups for HTS tape characterisations.
2. Assembly of a new low-T test bench facility with SC magnet for SC cable measurements and further prototype testing.
3. Scrutiny of emerging optical technologies in position measurement for potential application to fieldmapping.
4. Study of an innovative insulation system.

Resources: 1 fellow / year from Oct. 2021 + 1 TS (2022)

Results 2021 – mid 2022:

- HTS studies: in progress

  Computational simulations,
  Construction of cable demonstrator models and testing.
- Test bench facility installation : in good progress.
- New magnet control system to be implemented on new test facility (with EP-DT magnet control team).
- Report on optical technologies with discussion on applications and level of accuracy: done.

The 2021 ECFA Detector Research and Development Roadmap

Detector Research and Development Themes (DRDTs) identified in the Roadmap report.

DRDT 8.1: *Develop Novel Magnet Systems*

in Chapter 8 - Integration ; 8.3 - Key technologies

Integration (Task Force 8)

DRDT 8.1 - Develop novel magnet systems.

Magnet requirements are very specific to the design of the detector. Considering the very long lead time, generic R&D programmes must be established and maintained on dedicated conductors and prototyping to achieve the variety of magnet specifications.

The 2021 ECFA Detector Research and Development Roadmap

DRDT 8.1: *Develop Novel Magnet Systems*

Some examples of future magnet systems that represent the spectrum of engineering challenges and R&D needs for this topic :

Accelerator	Detector	B [T]	R[m]	L[m]	I [kA]	E [GJ]	comment	
LHC	CMS	4	3	13	20	2.7	scaling up	reference
LHC	ATLAS solenoid	2	1.2	5.3	7.8	0.04	scaling up	
FCC-ee [Ch8-1]	CLD	2	3.7	7.4	20-30	0.5	scaling up	
	IDEA	2	2.1	6	20	0.2	ultra light	
CLIC [Ch8-2]	CLIC-detector	4	3.5	7.8	20	2.5	scaling up	
FCC-hh [Ch8-3]	main solenoid	4	5	19	30	12.5	new scaling up	
	forward solenoid	4	2.6	3.4	30	0.4	scaling up	
IAXO [Ch8-4]	8 coil toroid	2.5	8x0.6	22	10	0.7	new toroid	
MadMax [Ch8-5]	dipole	9	1.3	6.9	25	0.6	large volume	

Table 8.1: Examples of magnets for future experiments that represent the engineering and R&D challenges. The dimensions and fields refer to the free bore. The magnets for ATLAS and CMS are given for reference.

The 2021 ECFA Detector Research and Development Roadmap

DRDT 8.1: ***Develop Novel Magnet Systems***

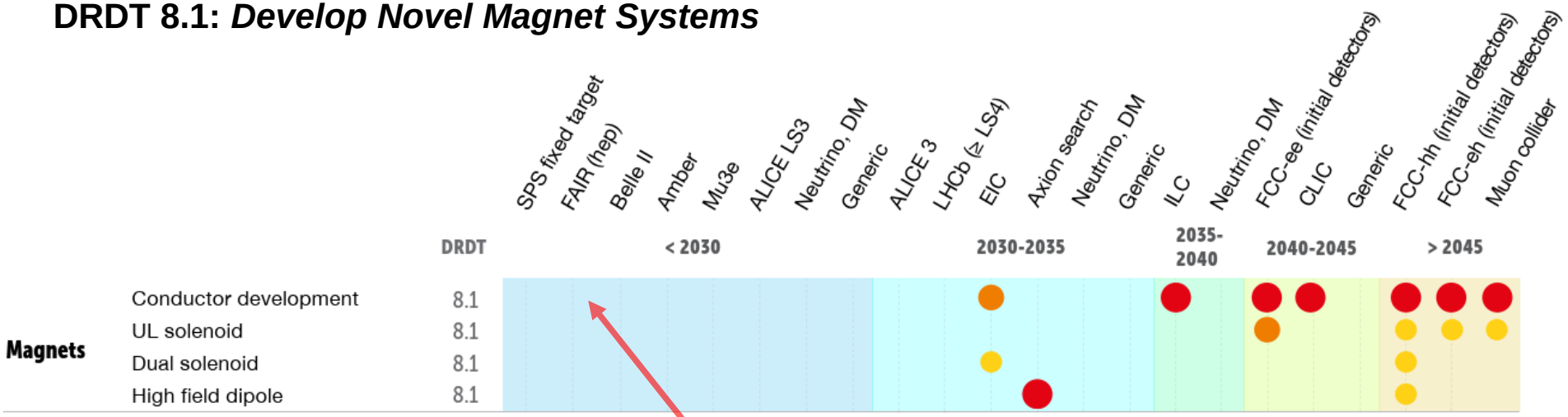

Figure 8.1: Schematic timeline of categories of diverse R&D topics [...]

Given the time required for ***procurement, conductor manufacturing, coil and detector assembly****,* ***the availability of the superconductor*** *comes quite early in the project plans****.***

R&D on superconductors must be achieved well in advance of detector completion (minimum ~ 5 to 7 years).

The 2021 ECFA Detector Research and Development Roadmap

DRDT 8.1: ***Develop Novel Magnet Systems –***

Summary of the key technologies needed, as listed in the ECFA report :

Magnets for collider experiments:

- Development of next generation of Al-stabilized high-yield strength Rutherford cable superconductors and prototyping for 30-40 kA large coils placed behind calorimeters.
- R&D on conductors and prototyping for thin conductors Al/Cu/NbTi for small coils placed in front of the calorimeters.
- Long term: development of high temperature superconductors for coils and current leads.
- R&D for assemblies with dual solenoids for magnetic shielding.

Magnet for non-collider experiments:

- large volume magnets for axion searches […], *and high field*

Development of quench protection, energy extraction and high voltage designs for coils with high energy/mass ratios is also needed.

WP8 workplan for second half of R&D program

Workplan to be continued according to the reduced initial scope.

WP 8.1 – Advanced Magnet Powering

Continue on powering system demonstrators and testing.

WP 8.4 - New 4-Tesla Magnet Facility

Plan to build a demonstrator coil including concepts with potential use for future magnets.

WP 8.5 - Innovation in Magnet Controls, Safety Systems & Instrumentation

Implement a specific instrumentation and test system for HTS superconductor cables.

Continue prototyping and testing of these HTS cables, including the use of a new insulation.

More details in the next presentation by Matthias Mentink

WP8 request for R&D program extension from 2023 onwards

- **To keep plans of EP R&D WP8 in line with ECFA DRDT 8.1:**

→ **Enlarge the scope of activities on superconductor R&D, for period 2023-2027**

- **Strong need identified** for aluminum stabilized superconductor prototyping & pre-industrialization, for **CERN programs and associated projects:**
  - BabyIaxo, Alice3, FCC-ee (ultra-thin and conventional), CLICdp, FCC-hh.

⇒ **Request the EP R&D Committee to consider activating the WP8.2** on reinforced superconductors and cold masses from 2023 onwards, with resources to be defined.

WP8 request for R&D program extension from 2023 onwards

WP 8.2 workplans reported earlier (blue report CERN-OPEN-2018-006)

Scope given: to identify and propose manufacturing routes, in view of producing sample lengths with industry that can be adapted for scaling up to production for future detector magnet conductors.

To be discussed in a specific meeting.

Initial workplan proposed:

R&D work plan — WG: 8 - Detector Magnets — **Avtivity**: 8.2

Short description:	Reinforced Super Conductors and Cold Masses
Long description:	Design goal is a 2-4T solenoid cold mass with radiation length less than 1 X0. This requires very high yield strength Al stabilized and reinforced NbTi/Cu conductors. The project comprises cold mass and conductor mechanical design, quench dumps studies, conductor development and demonstrator tests.

Deliverables (max. 5)

date (count month from start of R&D)	item
12	Review study reinforcement options, thin cold mass design report.
24	Short sample productions, welding technology, and characterization
36	Short sample productions, welding technology, and characterization.
48	Selected conductor unit length production and coiling/bending test.
60	Reporting, evaluation and outlook.

Milestones (max. 5)

12	Review study report.
24	Short sample test reports.
36	Short sample test reports.
48	Long unit test report.
60	Test coil report, final report, batch of samples made.

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