



## WP3 Satellite meeting Status of MQYY

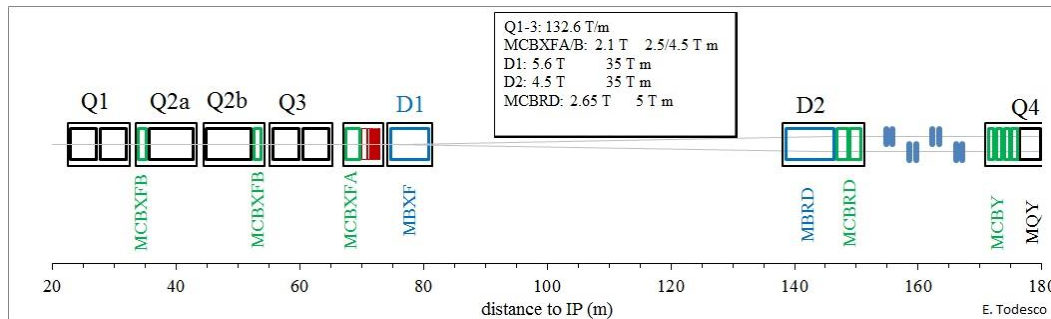
**Helene Felice** for the MQYY team

**CEA:** D. Simon, M. Segreti, J.M. Rifflet, A. Madur, S. Somsom, R. Machado-Correia, J.J Goc, J.M. Gheller, D. Bouziat, A. Acker, P. Graffin, H. Neyrial

**CERN:** E. Todesco, A Foussat, J.C. Perez, L. Fiscarelli, O. Dunkel, P. Viret

**QUACO team:** M. Lossasso, I. Bejar-Alonso, F. Toral, T. Martinez, P. Krawczyk, R. Nietubic

# History of MQYY development



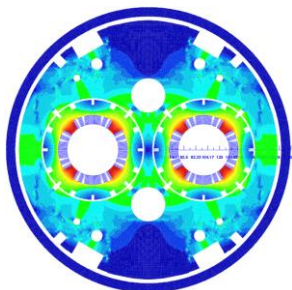
Q4 is the LHC MQY, double aperture quadrupole with 70 mm aperture

Layout of the magnets close to the interaction point

Initial HL-LHC baseline was to use MQYY, a new double aperture quadrupole with 90 mm aperture (see talk from E. Todesco)

- **2011**: development starts with a CEA- CERN initiative (J.M. Rifflet et M. Segreti) within the High Lumi design study (FR contribution)
- **March 2014**: collaboration agreement between CERN and CEA including activities on MQYY (WP2 of the agreement)
- **September 2015**: Formal decision to change the cable

# Zoom on cable change in 2015



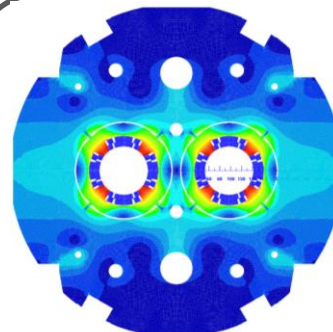
## From 2011 to 2015

- Design study (2011-2013)
- single layer coil
- LHC MB outer layer cable (15 mm wide)

## Reasons

- Use available cable
- CEA considerable experience with this cable for the MQ

Aperture	90 mm
Nominal Gradient	115 T/m
Magnetic length at 1,9 K	3,8 m
<b>1st design Nominal Current</b>	<b>15650 A</b>
Peak Field	6,1 T
Margin on the loadline	20 %
Differential inductance	2 x 2,9 mH
Cable type	MQ (MB outer layer)



## September 2015:

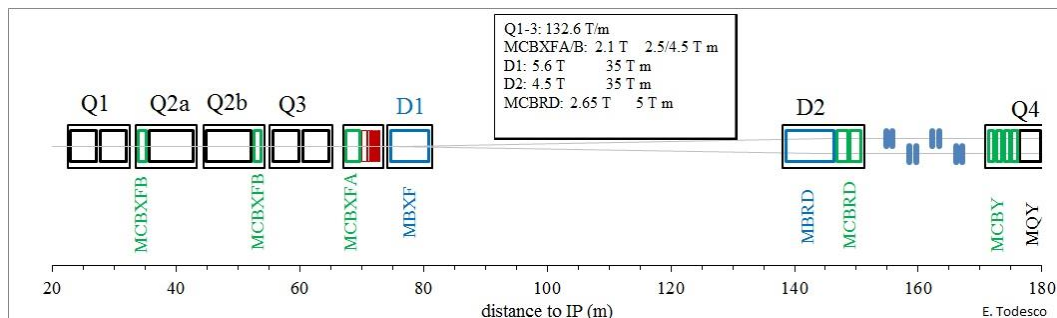
- Two layer coil
- LHC MQM cable (8.8 mm wide)

## Reasons

- Reduce operational current
- Saving on power converters and links

Aperture	90 mm
Nominal Gradient	120 T/m
Magnetic length at 1,9 K	3,7 m
<b>MQYY Nominal Current</b>	<b>4590 A</b>
Peak field	6,4 T
Margin on the loadline	23 %
Differential inductance	2 x 37,5 mH
Cable type	MQM

# History of MQYY development

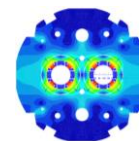


Q4 is the LHC MQY, double aperture quadrupole with 70 mm aperture

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- **March 2014**: collaboration agreement between CERN and CEA including activities on MQYY (WP2 of the agreement)
- **September 2015**: Formal decision to change the cable
- **June 2016**:
  - Decision to keep MQY to reduce cost
  - Decision to continue with the development of MQYY short model and prototype
  - Updated CEA-CERN collaboration content: [Single aperture model MQYYM](#) developed by CEA and CERN
- Parallel development: [two prototypes](#) developed in the QUACO initiative

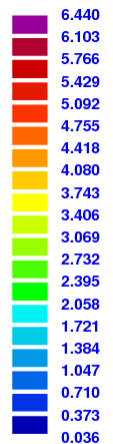
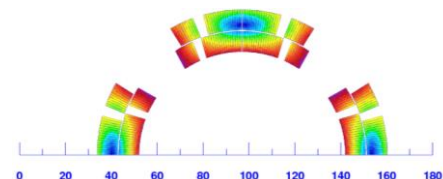
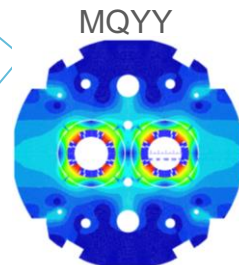


# Status on magnetic optimization

09/2015

Magnetic reoptimization 2D of the double aperture with MQM cable

COMPLETED



ROXIE<sub>10.2</sub>

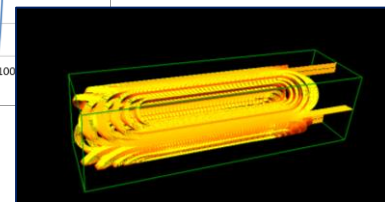
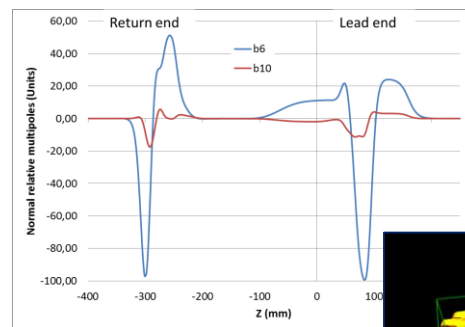
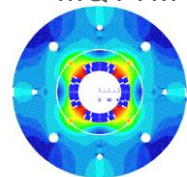
05/2016

## Magnet Design

- Fine tuning of the magnetic design (2D + 3D) in ROXIE
- Implementation of the cross-section in the single aperture model

COMPLETED

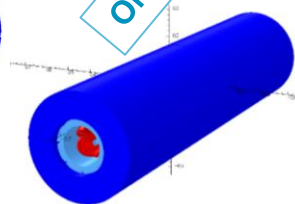
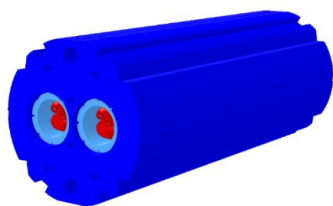
MQYYM



11/2016

- Comparison with Opera

ONGOING



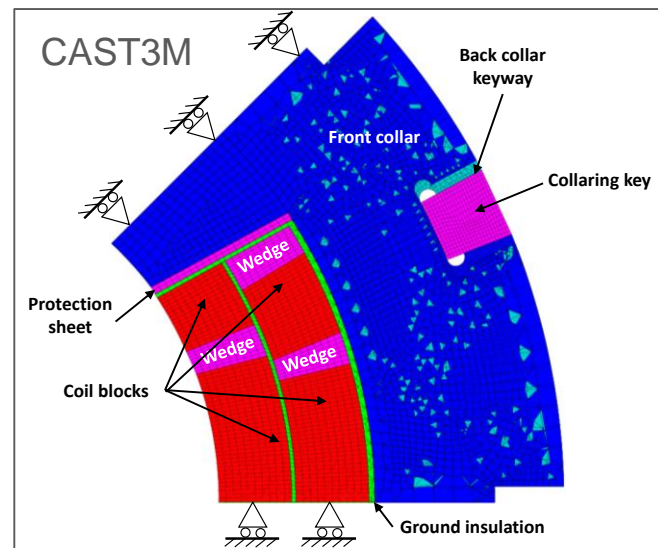
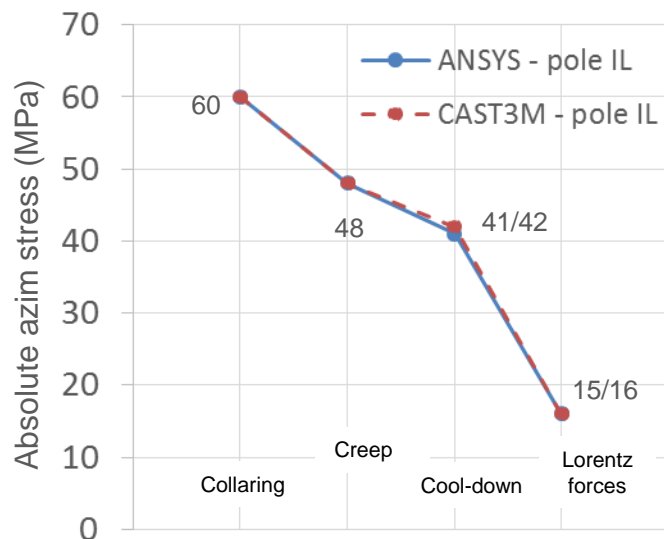
Aperture	90 mm
Nominal Gradient	120 T/m
MQYY Magn. length at 1,9 K (MQYYM)	3,7 m (1,2 m)
<b>MQYY Nominal Current (MQYYM)</b>	<b>4590 A (4550)</b>
Peak field	6,4 T
Margin on the loadline	23 %
Differential inductance	2 x 37,5 mH
Cable type	MQM
MQYYM / MQYY outer diameter	360 / 614 mm

# Status on mechanical design

09/2015

CAST3M  
Mechanical 2D  
design

Completed

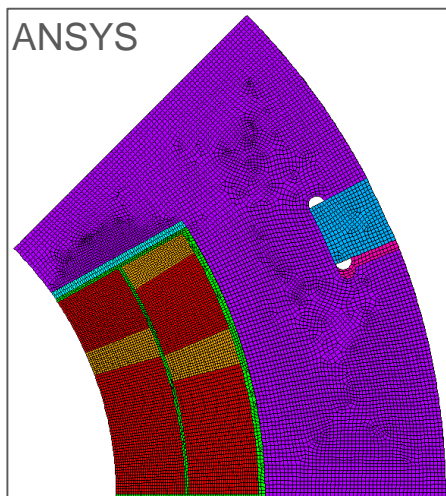


05/2016

SHORT MODEL

ANSYS/CAST3M  
comparison

Ongoing

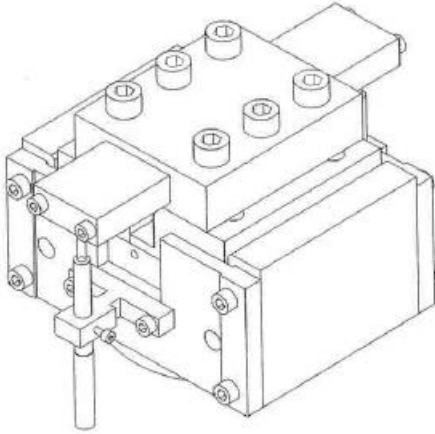


- Self standing collar structure
- Required stress during assembly: 60 MPa
- Very good agreement between CAST3M and ANSYS
- Validation of cable material properties is ongoing

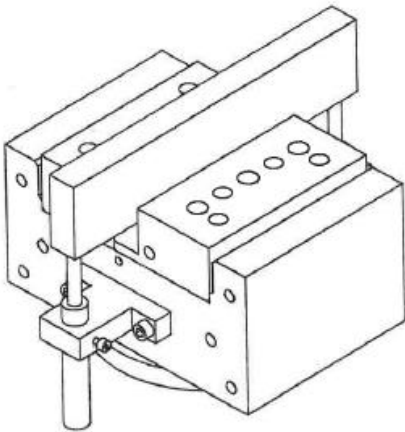
10/2016



# Mechanical measurements of MQM cable for the short model



*Curing mould, courtesy of M. Durante*



*Compression tooling, courtesy of M. Durante*

- Mechanical data on MQM cable are not available
- Plan to proceed with Young modulus measurements at CEA
- Adaptation of existing tooling is ongoing
- Measurements are foreseen **early 2017**

# Status on quench protection

09/2015

Magnetic reoptimization 2D

Mechanical 2D design

## Magnet Design

- Fine tuning of the magnetic design (2D + 3D) in ROXIE
- Opera Modeling
- Quench protection study

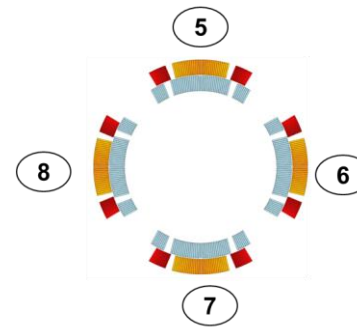
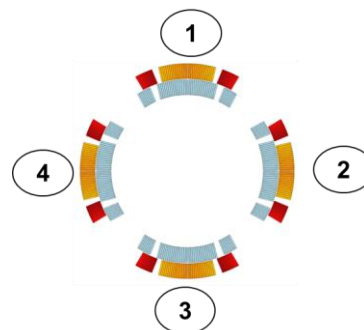
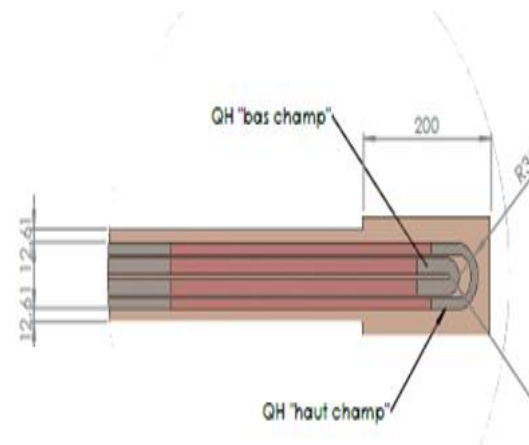
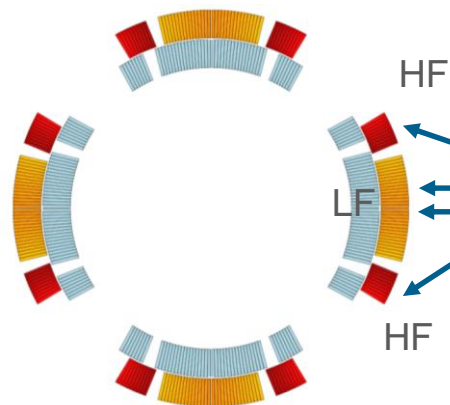
ONGOING – To be completed by 11/2016

05/2016

- Protection ensured via quench heaters
- Energy extraction option discarded
- Heater design ongoing

10/2016

SHORT MODEL



First power supply: 1H; 2H; 5H; 6H  
 Second power supply: 1L; 3L; 5L; 7L  
 Third power supply: 3H; 4H; 7H; 8H  
 Fourth power supply: 2L; 4L; 6L; 8L



# Status on quench protection

09/2015

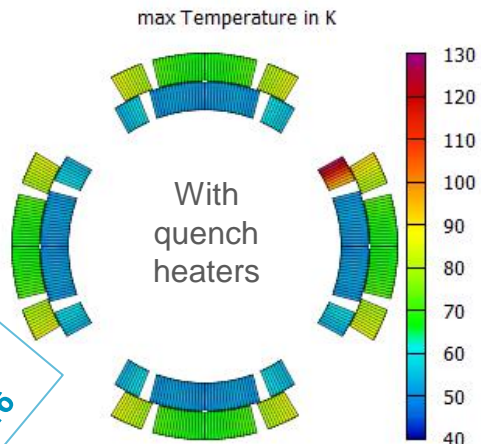
Magnetic reoptimization 2D

Mechanical 2D design

## **Magnet Design**

- Fine tuning of the magnetic design (2D + 3D) in ROXIE
- Opera Modeling
- Quench protection study

ONGOING – To be completed by 11/2016



## ROXIE RESULTS

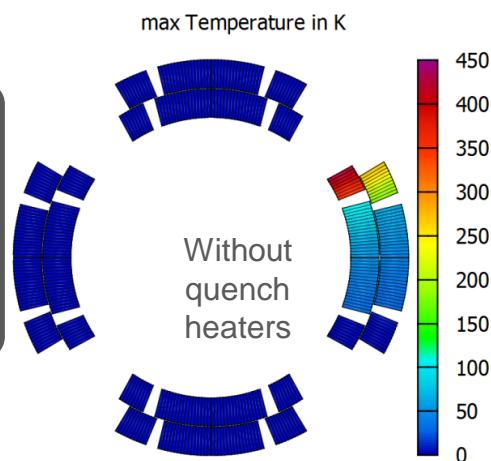
### With protection heaters

Hot Spot	≈130K
Voltage to ground	≈135V

05/2016

SHORT MODEL

- Protection ensured via quench heaters
- Energy extraction option discarded
- Heater design ongoing



## ROXIE RESULTS

### Without PH

Hot Spot	≈450K
Voltage to ground	≈700V

### With half of the PH

Hot Spot	≈160K
Voltage to ground	≈145V

10/2016

# Status of winding tests

09/2015

## 2 mock-ups fabricated:

- Mock-up # 1: ABSPlus 3 printed layer 1 parts (fab at CEA)
  - Winding only at CEA
- Mock-up # 2: Blue-stone epoxy layer 1 and 2 (fab at CERN)
  - Winding L1 and L2 **and curing** L1 at CEA

⇒ Layer jump chosen with  $R_{\text{bend}} = 300 \text{ mm}$

05/2016

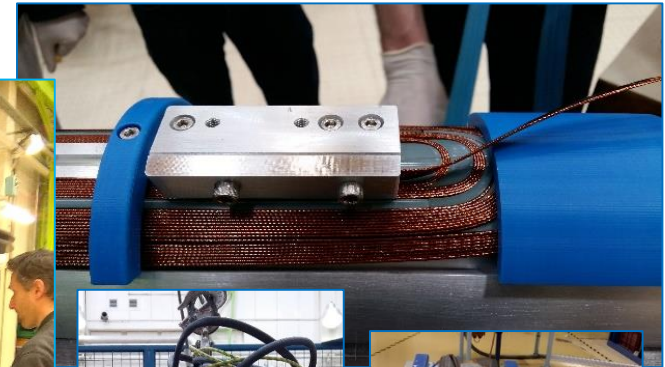
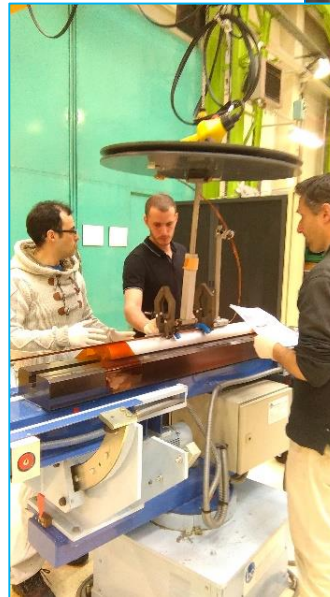
SHORT MODEL

### *Tooling Design and Fabrication*

- Mock-ups fabrication
- Coil fab tooling design ready for RFT
- Agreement on assembly location and tooling design strategy

COMPLETED

10/2016



# Tooling design, Assembly plan and Procurement

## • Assembly Tooling Design



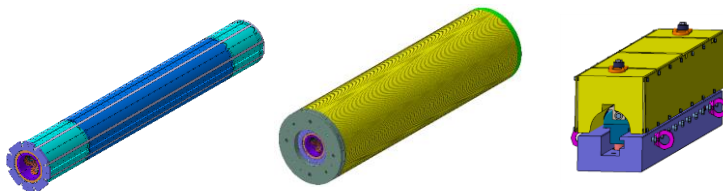
## • Procurement

- If >5 k€ procurement through CERN
  - Nordine Azizi / Arnaud Foussat (CERN)
  - Hubert Neyrial / Helene Felice (CEA)
- **Coil fabrication tooling:** order placed
- **End spacers:** first 2 sets: order placed
- **Angular wedges:** order placed
- **Collars:** Tender in preparation
  - Material:  
Nippon YUS130 in stock  
( X8CrMnNiN 19-11-6 grade )

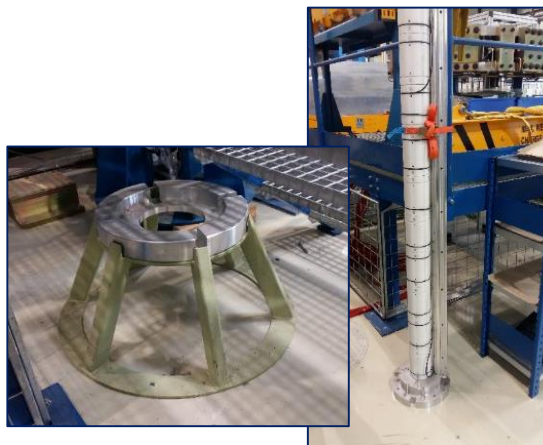


## • Remaining component design

- Connection box
- Protection heater
- Ground plane insulation
- Instrumentation
- Complete integration



- ⇒ **Collaring** at CERN by a CEA team assisted by CERN
- ⇒ **Yoking** at CERN by a CEA team assisted by CERN
- ⇒ **Interface tooling** and **assembly tooling**
  - ⇒ has been designed based on existing models and drawings provided by CERN.
  - ⇒ will be ordered



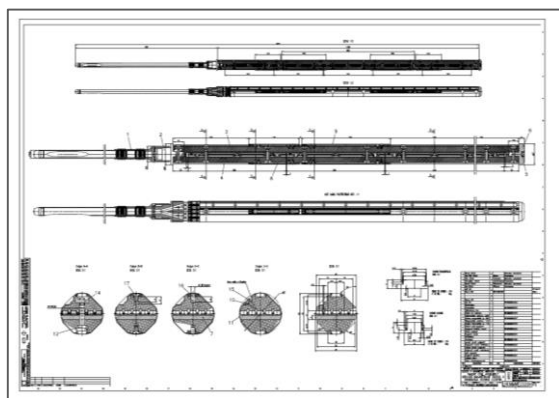
# Test of MQYYM

09/2015

05/2016

10/2016

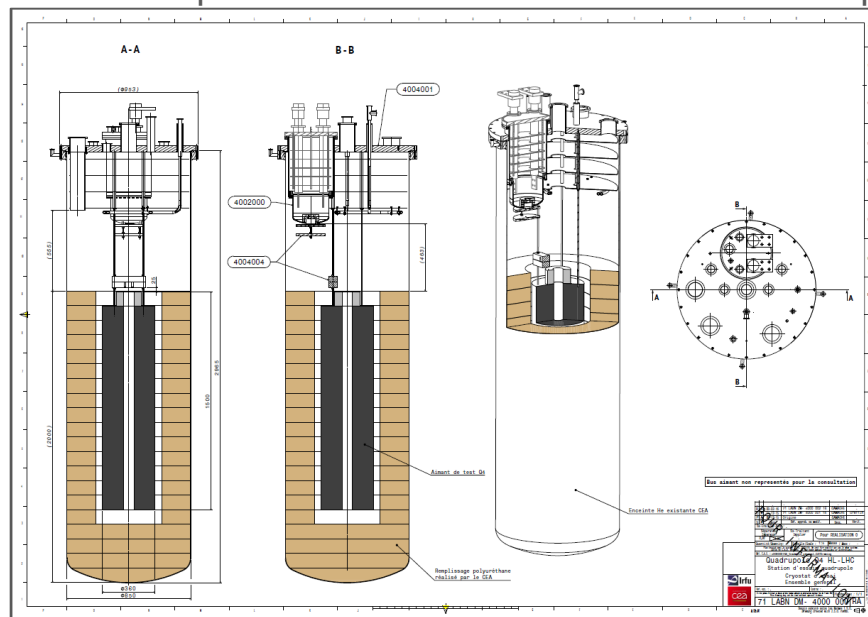
SHORT MODEL



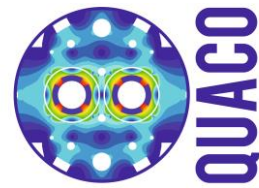
Start of Test preparation

ONGOING – To be  
Completed by  
September 2017

- **Test of MQYYM in the vertical cryostat at CEA-Saclay**
  - ⇒ 8 m cryostat equipped with a 3 m long « sock » (tank)
  - ⇒ Adaptation of an existing top plate
  - ⇒ Saturated LHe bath at 1,9 K 23 mbar
- ⇒ Magnetic measurements
  - ⇒ Cold system provided by CERN
  - ⇒ Adaptation on CEA test station under development



# Towards the prototype: QUACO



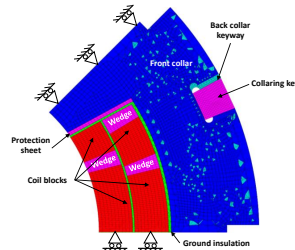
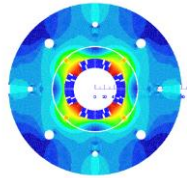
- In 2015 a program to build two prototypes in the industry using EU funds has been launched (M. Losasso, I. Bejar Alonso)
  - QUACO is a PreCommercial Procurement (PCP)
- Principle:
  - **R&D project** in industry lead by a consortium of EU labs: CEA, CIEMAT, NCBJ and CERN
  - Industries are in **competition** in 3 phases. At each end of phase, a company is eliminated.
  - In **Spring 2020** two companies will have produced two prototypes (one per company)
  - The **magnetic design and protection** are given, mechanical structure and tooling have to be proposed by the company



# Short Model and Prototypes

## 2 different paths

**MQYYM** Expected to be completed by end of 2017 – early 2018



11/2016

03/2018

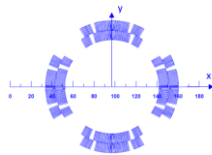
05/2020



**Concept. Design  
PHASE 1**  
4 months  
11/2016 to 03/2017

**Engineering Design  
PHASE 2**  
13 months  
07/2017 to 08/2018

**Manufacturing  
PHASE 3**  
18 months  
11/2018 to 05/2020



- Baseline magnetic design **provided but not imposed**
- ROXIE provided without the BEM FEM module
- Mechanical support structure design **up to companies**





# Main Technical Difficulties

- The prototype might / will be different from the short model
  - Not a build-to-print
  - Minimum amount of info fed into the prototype to ensure « compatibility to PCP spirit »
- The information we need to provide to the companies is not always mature/ ready
  - cable mechanical measurement for instance
- Concerns on tooling procurement:
  - Shortness of the last phase (18 months) to procure all the tooling (including infrastructure) and complete the prototype

=> Potential increase of technical risk for the project

# Status of QUACO

- Start of QUACO in **March 2016** with the preparation of the functional specification and the Request for Tender documents
- Request for Tender launched on 31/05/2016
- 4 selected offers approved by Quaco Steering Committee on 28/09/2013
  - All offers within the budget estimated envelope

# Status of QUACO

- The four contracts have been signed by the companies for Phase 1:
  - Antec-Tecnalia consortium, Spain
  - Elytt, Spain
  - Sigmaphi, Spain
  - Tesla, UK
- Kick-off meetings: 3rd and 4th of November 2016
- Face-to-face meetings are scheduled to visit the company workshops in the next three weeks

# Next steps and Milestones

## ■ Short Model MQYYM

- Fabrication of 1st coil at CEA: **early 2017**
- Aperture collaring and yoking at CERN: **late spring 2017**
- Test at CEA: **Fall 2017**

## ■ Prototype MQYY

- End of Phase 1: **March 2017**
- Selection of three companies to proceed to the engineering phase (phase II): **June 2017**