The Q4 magnet (MQYY) cold mass Series open items on for Hi Lumi-LHC

Impact of QUACO scheme

CEA-CERN meeting, 19th May 2016

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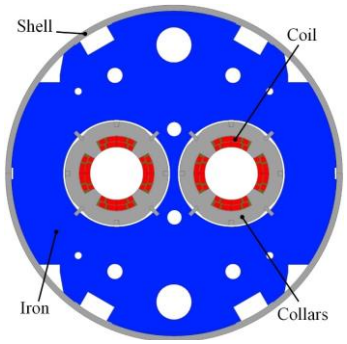
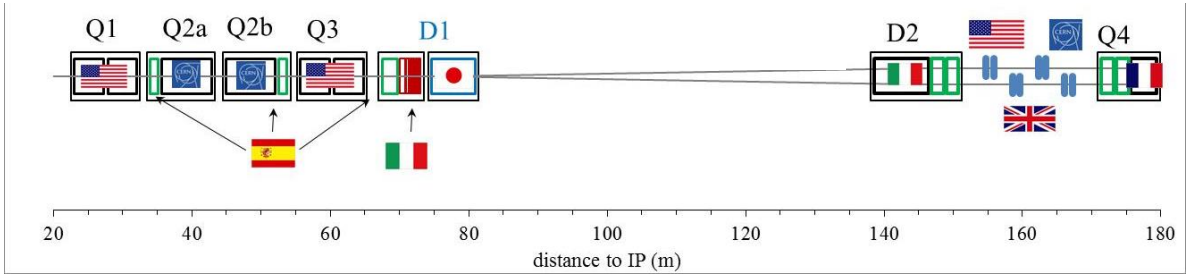
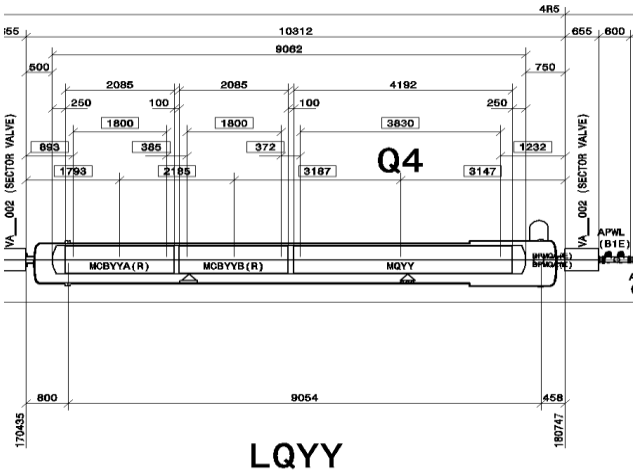
Q4 features & lattice layout

- Double aperture Nb-Ti matching section magnet:

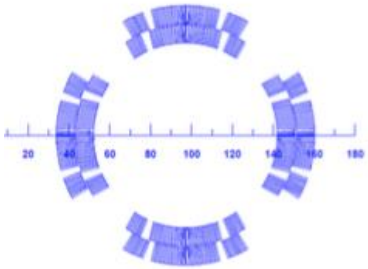
2 individual apertures powered independently in a common yoke (2PS per Q4)







Double layer cos2θ Quadrupole
Aperture: 90 mm
Integrated gradient : 440 T
Nominal gradient = 120 T/m
1,9 K Magnetic length : 3.67 m
Nominal gradient : 120 T/m
Temperature : 1.9 K
Nominal current : 4590 A
Stored energy : 0.81 MJ



2 layers of MQM cable
Inner blocks: 17 + 8 turns
Outer blocks: 16 +10 turns

Q4 procurement

- One SINGLE APERTURE SHORT MODEL developed at CEA to be completed by end 2017
- Two PROTOTYPES magnets (First-of-a-kind), double aperture and full length
  - Scope of QuaCo from 03/2016 to 03/2020
  - Options of design are open to contractors
  - Q1: status of the resources plan (CEA, CERN, QUACO members) to perform follow up, deadlines shall be adapted and finalised in the PMT workpackages document
  - QUACO «Buyers group » Consortium (CERN, CEA, CIEMAT, NCBG) provide possible magnetic design of the Q4, a configuration of coil ends and quench protection scheme based on CEA-CERN know-how.
  - The technical solutions chosen by the awarded companies will be evaluated during each of the 3 phases;
- 4 SERIES double aperture magnets + 2 spares; from 2020-2023
  - The question of the facility where to perform the cold test is still open. There are some discussion between CEA and CERN (new collaboration contract covering 2017-2020) but no decision
  - So far based on LHC experience it is unlikely that a prototype magnets can be integrated in the machine
  - Series production plan based on deliverables-based industrial packages to be started considering the lead time for tools procurement and series first of kind manufacture procedure preparation.

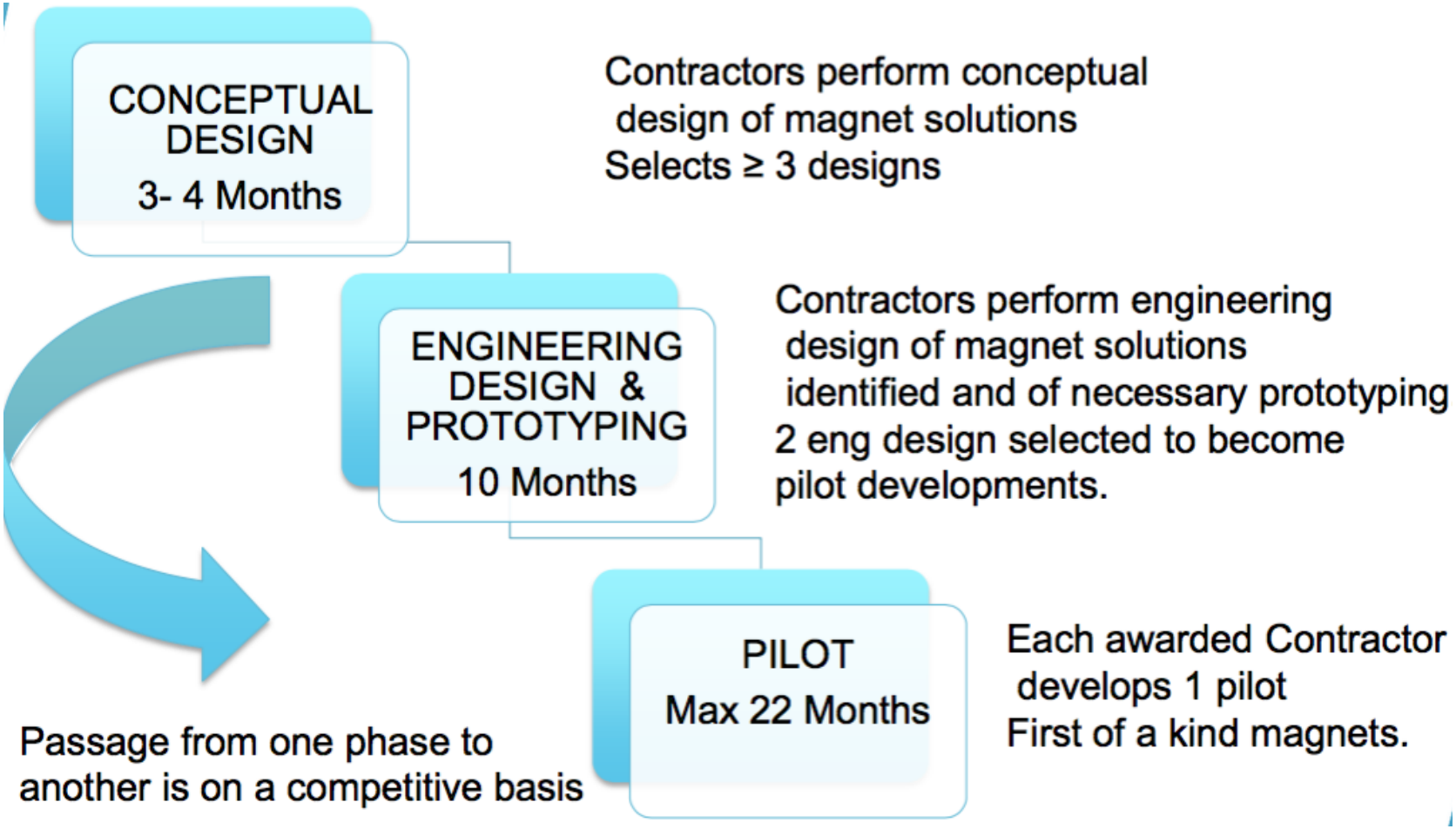
Short model schedule

- Detailed design phase: ongoing @ CEA Saclay
  - Drawings, Mock-ups. Status of Prototype CAD model for next exchange
  - Single aperture, RT coil length = 1350 mm , RT Magnetic length = 1217 mm
  - Self supporting austenitic collars
  - Non laminated yoke to speed up fabrication and lower cost
  - Q1: can we test the manufacture of Q4 iron laminations on SM and assembly?
- Procurement of tooling and components: April to Dec 2016
- Coil fabrication should start in Fall 2016, work affected by QUACO as limited CEA resources
- Collaring at CERN with CEA team in May 2017
  - Use of Vertical collaring press in 927
  - Q2: To which extend CERN is providing collaring support, what is the work arrangement ?
  - Need to put in place a interface working group on SM. Effective feedback onto QUACO and series;
- Yoking in Spring 2017, location to be defined
- Cold test at Saclay in Summer 2017

QUACO procurement scheme

- The QUAdrupoleCOrrector (QuaCo) project is funded by the European Union's Horizon 2020 COFUND (PCP)
  - Total QUACO budget 6.5M€. Total procurement budget 4.6M€
- Ultimate goal is to manufacture two first-of-a-kind quadrupole magnet (MQYY) with two 90 mm aperture and a magnetic length of 3.67 m operating at 1.9 K.
- Duplication in industry of magnet manufacture toolings
- Development of the Q4 prototypes in 3 phases:
  - *Phase I: 'Solution Design' = Conceptual Design (4 months)*
  - *Phase II: Engineering Design & « CAD Prototyping » (10 months):*
    - Completion of the engineering detail design
  - *Phase III: Two First-of-a-kind (22 months)*:
    - Fabricate two Q4 prototype magnets
    - Baseline solution is based on self supporting collar structure
    - Alternative solution is based on shell–based support structure (alternative Bladders and keys)
    - There is a technological R&D interest to make a different technology based prototype although probably not mature enough for an accelerator type series coil.
    - If contractor choose to develop shell based support structure he would need ot develop frist a First of kind Single aperture which is not compatible with ptresent PCP phasing .

QUACO phasing



Prototype Quaco scheme, risk

Magnet key parameters

- Double aperture
- RT/1,9K Magnetic length = 3681 / 3670 mm

Tender documents:

- Functional specification co-written by CEA and CERN (WP3)
- Call for tender Annexes with selection/award table criteria based on Top Management Plan merit

Specificity of Pre-commercialization procurement (PCP), inherent risk

- EU finances 70% of the project but strong constraints on implementation
- Activity divided in 3 phases: conceptual design, engineering design, first-of-a-kind fabrication
- Firms in competition from one phase to the next: 4/3/2 firms selected in phases 1/2/3
- No garantee that the final company selected for the production participates in the Engineering phase
- QUACO committee to review all deliverables, assess the bidding offers at each phase
- Risk of procuring same tools at prototype and later series phases in different companies
- Tools property is part of companies
- Not a Built-to-Print

Time Frame

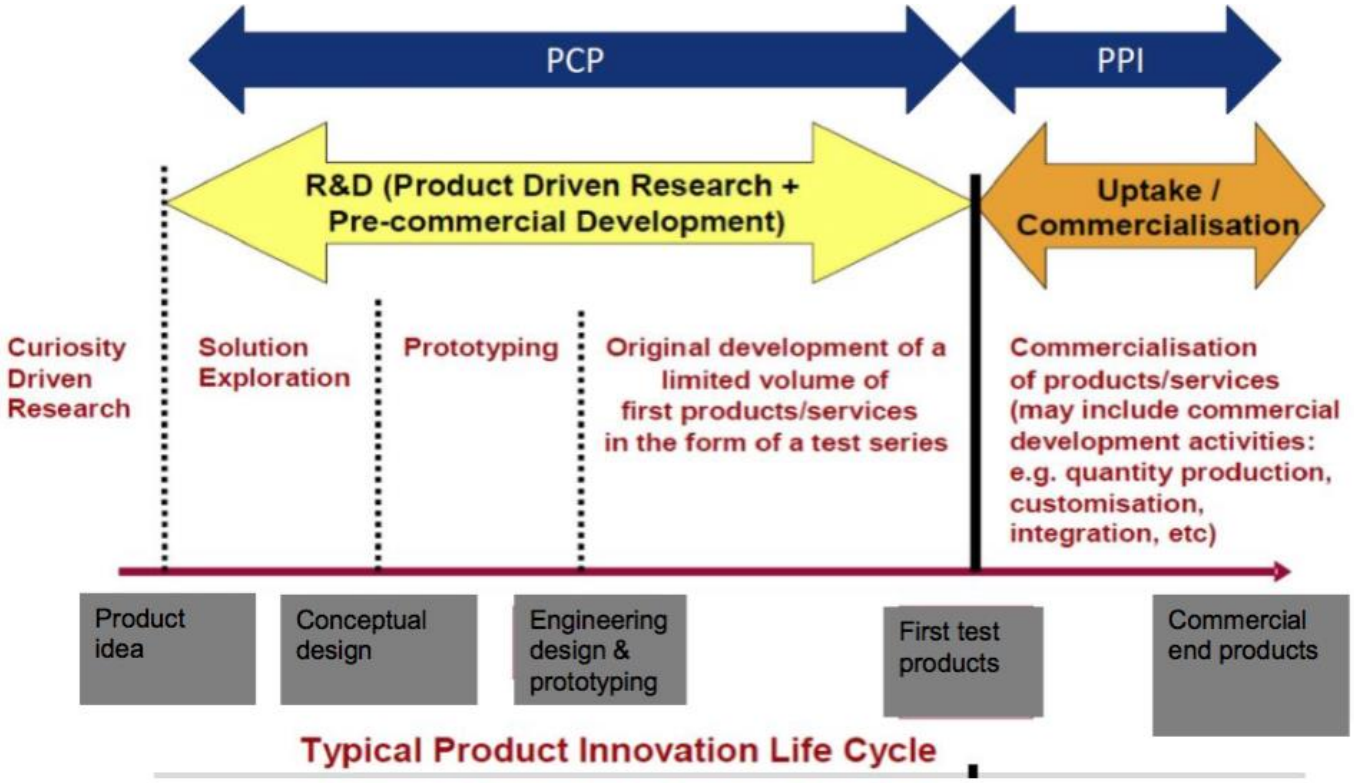
- RFT in May 2016 – Decision on organisation of follow up collaboration team,
- Start of the work in January 2017, attempt to start earlier in 11/2016 before CERN finance committee
- Prototypes delivered for testing in Feb 2020

Spare LHC magnets procurement

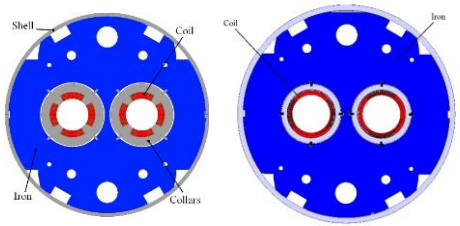
- In case of failure, short straight sections currently in the LHC machine would need to be removed from the tunnel. Building a stock of spare quadrupoles is considered to allow faster repair of SSS, if needed.
- 5 MQ magnets, 2020-2023
  - Double aperture, 3.1 m magnetic length at 1.9 K, 56 mm aperture
- 5 MQY magnets, 2023-2025
  - Double aperture, 3.4 m magnetic length at 4.5 K, 70 mm aperture
- The procurement of those coils spares shall be in line with the Q4, D2 series procurement strategy.

Post PCP

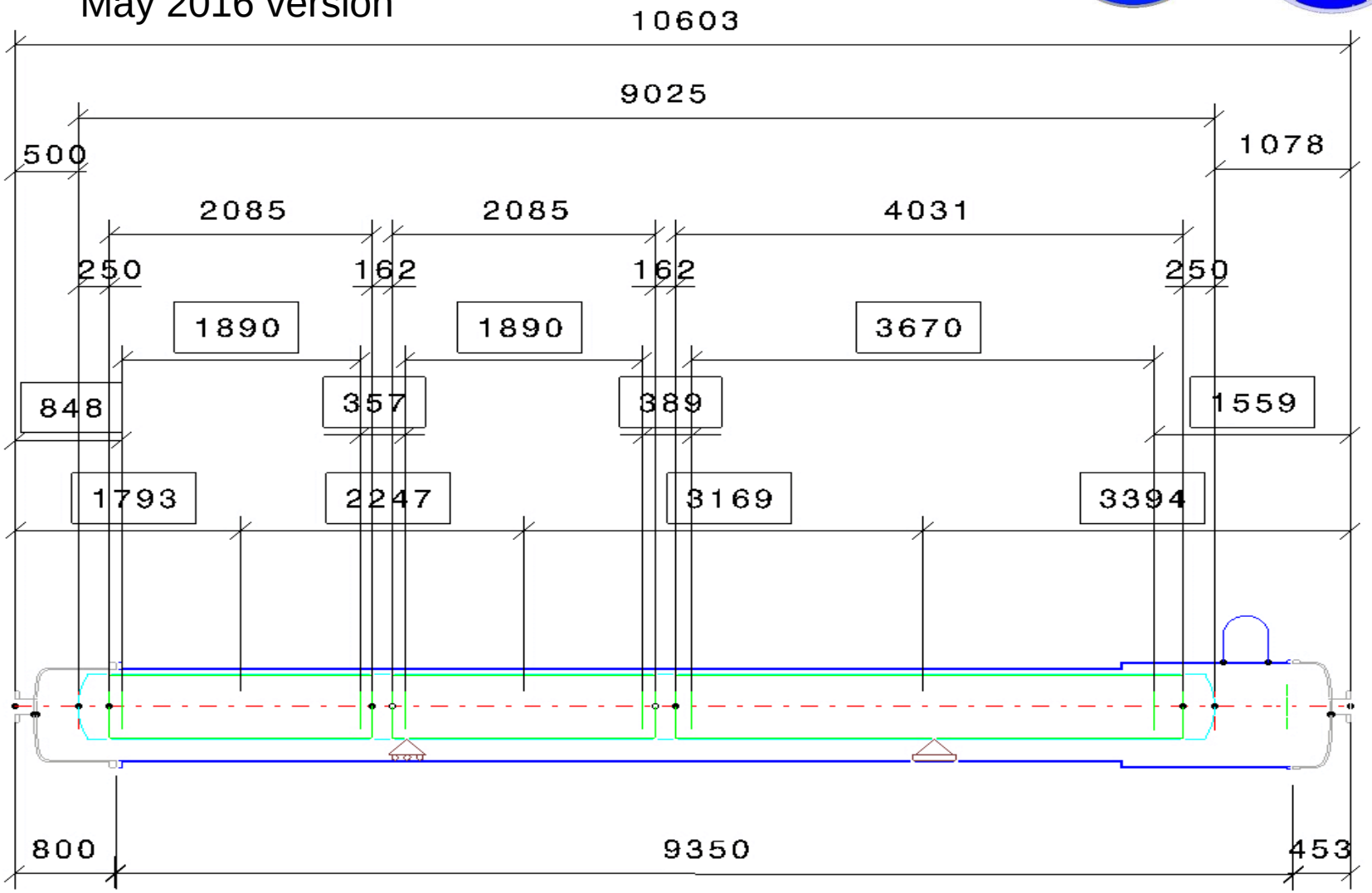
- Depending on QUACO success and timing, there is a proposal to launch the EC PPI to procure the Q4 series
- Progress from R&D of pilots magnets to small series production → Public Procurement of Innovation (PPI) is expected to allow small series production following of the Quaco project (see schedule impacts)



Q4 Layout drawing



May 2016 version

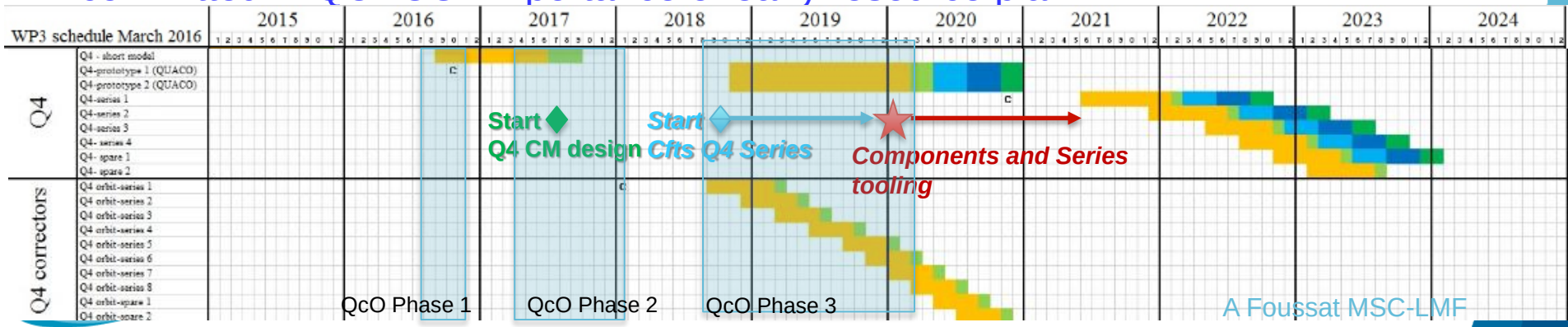


Design Interfaces

- Recent progress on MCBYY final yoke shape, lifting feature, HEX tube alignmed with Q4
- CERN wish to study and integrate Q4 cold mass CAD model of prototype interface items, proposal for shared study workpackages:
  - Main busbars routing, decision on cross section, fixed point, lyra compensation loops, instrumentation wires, PH leads layout
  - QQS cryogenic interface connections, thermal shields, cryostating
  - Tooling vertical handling, lifting interfaces

Schedule of Q4 Cold mass assembly, analysis

- Expected delivery Q4 prototype by Feb 2020
- QUACO schedule impacted by intrinsic overhead in regular deliverables and updated offers assessments.
- Risk from the estimate of industrial tooling procurement time and its compliance with final series design, to be confirmed ONLY at start of Phase 3 (late milestone).
- Considering estimate series production starting from 04/2021 and lead time of tools procurement, in worst case, the CfTs of Q4 series and new tools should be launched in 10/2018. Series schedule to be consolidated as highly parallelised
  - Specific series tooling procurement then would start from 02/2020 (timescale not yet compatible with possible PPI procurement scheme)
- Assembly sequence schedule strongly depend on MCBYY correctors availability, does not seem an issue on the production schedule (see talk by Torschanoff, Cold masses of Main Quadrupole in 04/2004)
- Strategy on series to be validated by management as CEA and CERN strongly committed in QUACO. Importance of early resource plan



Specific tooling issues on prototype and Q4 series

- Adaptation plan of B927 collaring press for the construction of the CEA short model (WP3)
  - Next interface meeting on 2nd June at CERN. Clarification of work resources, action plan
- How to guarantee compliance and value for allocated budget of prototype tools ?
- Winding machine for series should be identical to QUACO prototypes tool (need a First of kind on the series)
  - Cft Specifications for new series tooling shall be ready by 09/2018
  - Option to combine winding facility procurement with Hi Lumi development tools in industry to maintain know how on Nb3sn coils (ex: MQXF)
- The Q4 He containment shells do not require preload and the assembly could be performed by contractor either at CERN site or external site.
  - Horizontal assembly of 3 magnets (MQYY+2 MCBYY) by developed longitudinal shells MIG /MAG welding method.

Open questions / items

- Series production sites choice are not guaranteed until end of PCP (04/2020). This is a pending risk onto the series schedule.
- Either Quaco built-to-print is ready on time (mid 2019) for the series or a mitigation plan has to be implemented. This alternate plan includes a detailed design completed by 09/2018 so to anticipate the design completion of Q4 design file (see schedule).
- Risk identified in case prototype feature differ from final series production specification
- How to implement the feedback from prototype production ending beg. 2020 on the next series phase.
- Due to strong parallelism of Q4 CMs production and common integration with correctors, we would benefit from integration site at CERN, preferably performed on standard tools with industrial resources.
  - On the field QC and technical support CERN and partner teams
  - Optimisation of CERN resources for in house workpackages follow up
  - Winding of series could be performed by external company using QUACO tools development or third party bidder company. Such industrial resources could be coupled to possible external outsourced Nb3Sn magnet production efforts.
  - A decision on the Q4 cold test station location shall be taken by end 2016 to plan related budget and the necessary test station upgrade work.

Thank you