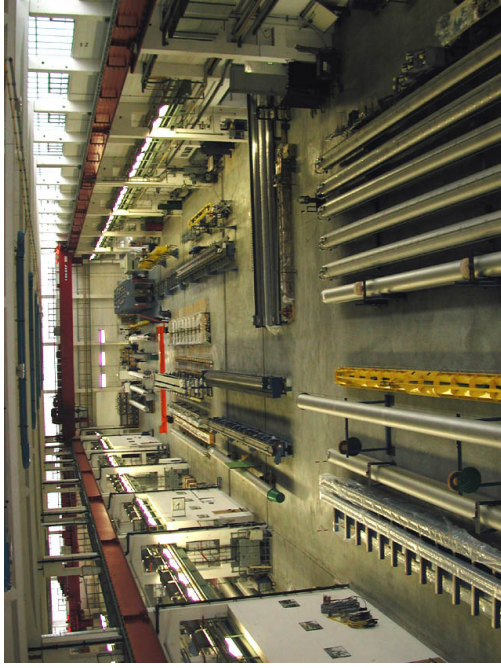


Series manufacture of the LHC main dipole magnets



Notes about the CERN
approach to industrial
production

C.Wyss & L.Rossi / CERN

LHC main dipole magnets

- **1232 +16 units, 8.3 T nominal field, 9 T ultimate field, 2 x 56 mm coil apertures, 15 m long, 28 t heavy**
- **Total value before cryostating: about 1BCHF (800 M\$)**
- **Design and model work (1-m length) at CERN**
- **Full-length prototype collared coils made in industry (3 vendors)**
- **All prototype cold mass assembled at CERN**
- **Pre-series contracts for 3 x 30 cold masses**
- **Assembly of the first 2-4 pre-series cold masses / vendor at CERN, to train industry personnel**
- **Series contracts for 3 x 416 cold masses, after full testing of 2 pre-series units/vendor and manufacture of 6-8 pre-series units/vendor**

LHC main dipole magnets

- **Highest magnet uniformity (10^{-4}) necessary for best machine performance and simplest installation sequence in the tunnel**
- **For the pre-series, all main components were directly procured by CERN, providing thus the contractors' qualification by CERN**
- **For series production, nearly all main components were directly procured by CERN (45 contracts, 4 inter-laboratory agreements - India, Russia, USA)**
- ⇒ **Double source for critical items: SC cables, fine-blanked parts (collars and laminations) and corrector magnets**
- ⇒ **All other CERN provided materials and components are from a single source**
- ⇒ **Number of contracts minimized to achieve economies of scale and minimize the amount of CERN resources for close follow-up**

LHC main dipole magnets

- ⇒ **Heavy tooling designed and procured by CERN, except for coil winding machines and coil curing presses**
- ⇒ **Essential quality control equipment (coil e-module, geometrical, electrical, field quality) designed and supplied by CERN**
- ⇒ **Maximum sharing of know-how among the CERN staff in charge of contract follow-up**

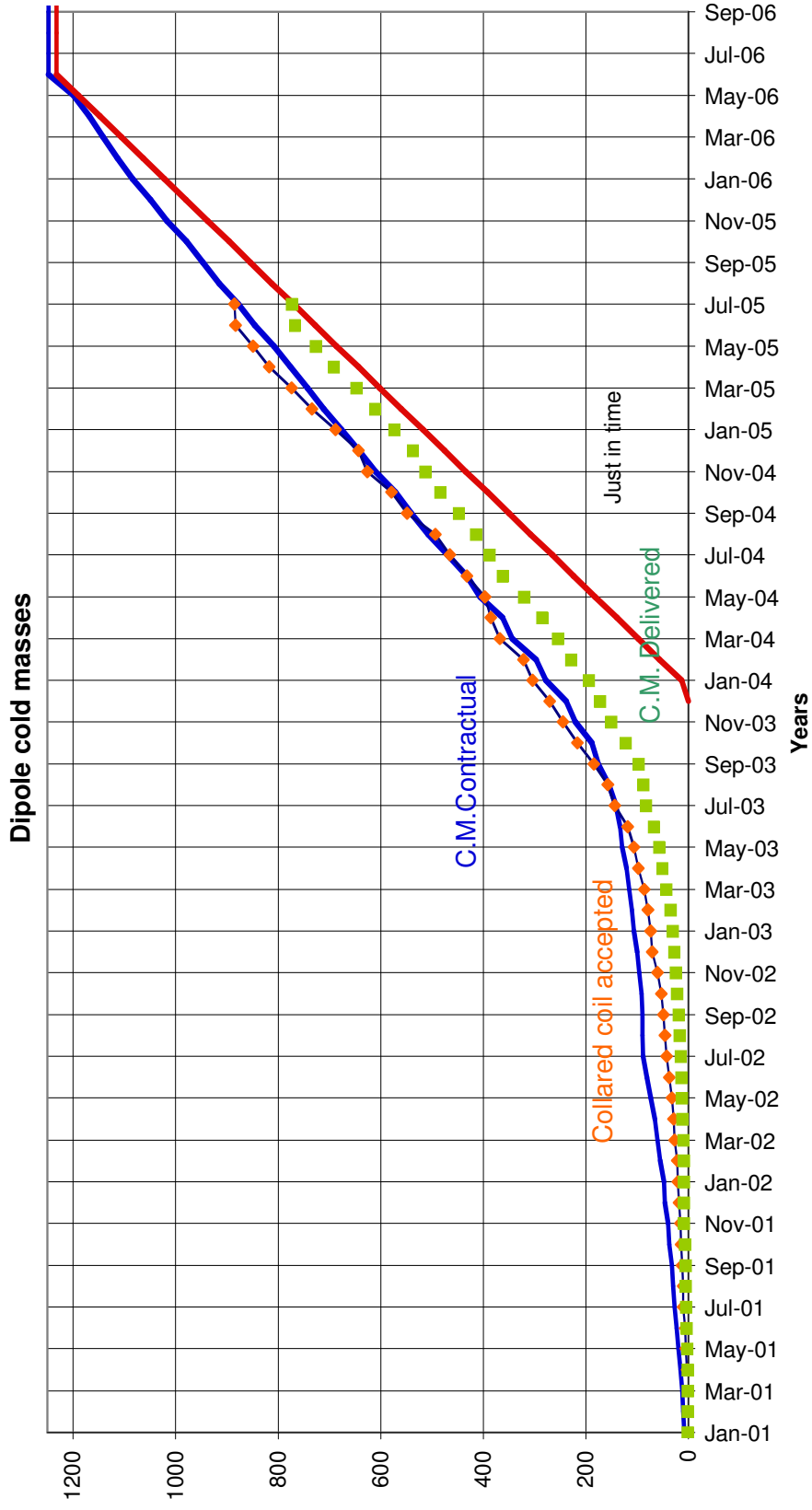
- **Implementation of Statistical Process Control (SPC) for the properties of materials, components, sub-assemblies and of the warm and cold tested magnets.**
- **Resident inspectors under CERN contract at the vendors' premises**

LHC main dipole magnets

- **Responsibility for design and performance with CERN**
- **Responsibility for faultless assembly with the vendors**
- **Responsibility for operation and maintenance of the tooling with the owners of the tooling design**
- **Quality checks after completion of each main assembly step to intercept errors at the earliest moment and minimize the loss of added value**
- **Bonus (1%) for magnets needing no more than three quenches to reach 9 T (reduced test time and hence cost for CERN)**

LHC main dipole magnets

Status on June 30, 2005



LHC main dipole magnets

- **Status on June 30, 2005:**
 - **883 (71 %) collared coils accepted**
 - **767 (61 %) cold masses delivered**
 - **647 (51%) cryomagnets cold tested**
- **Rejected cold masses: 26**
 - **14 for unsatisfactory quench performance**
 - **10 for electrical failure (mostly quench heaters)**
 - **2 for mechanical non-conformities**

LHC main dipole magnets

- **11 cold masses repaired without magnet disassembly**
- **15 cold masses were disassembled (9 for quench performance, 6 for electrical failure)**
- **Out of the 26 rejected cold masses, 25 were repaired and only one was scrapped**
- **About 60% of the defaults could be clearly ascribed to assembly errors or to the non-respect of agreed procedures**
- **For the remaining 40 %, the responsibility was shared between CERN and the vendor**
- **The ramping up of series manufacture is the period where most errors occurred, because of the training of additional staff**