Production and manufacturing Infrastructure (Models for Manufacturing)

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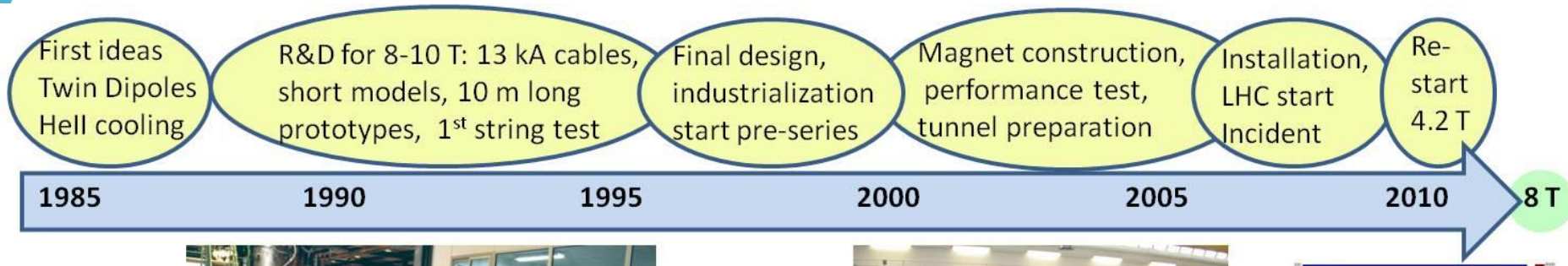
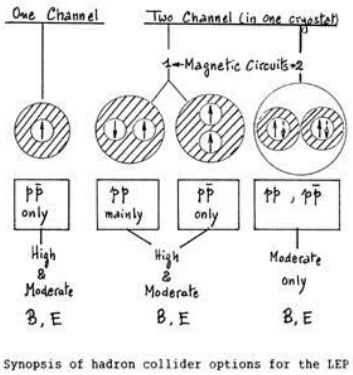
FCC WEEK 2016 – Rome, 13 April 2016

LHC Magnet (dipole) timeline



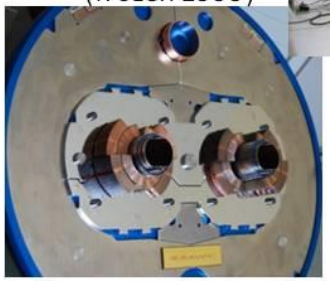
Magnet designs at first LHC workshop, 1984



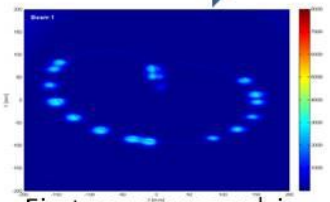
Synopsis of hadron collider options for the LEP tu

First LHC dipole prototype on the test bench (June1994)

Final dipole cross section (frozen 1999)



Assembly of 15 m long coils in industry, 2003

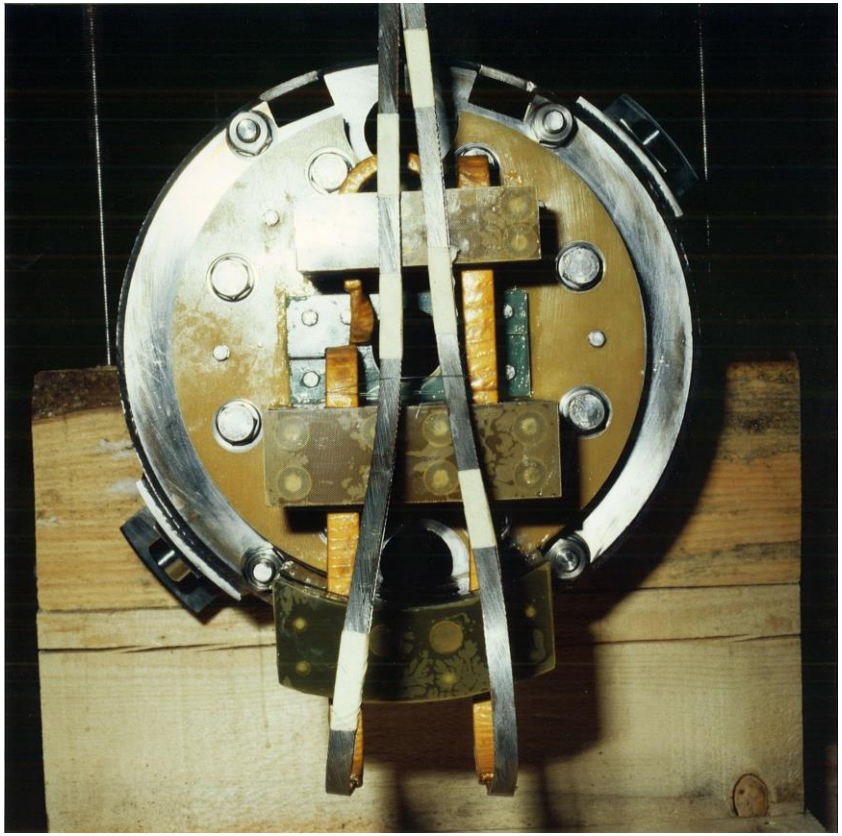


First energy record in the proton beam, December 2009

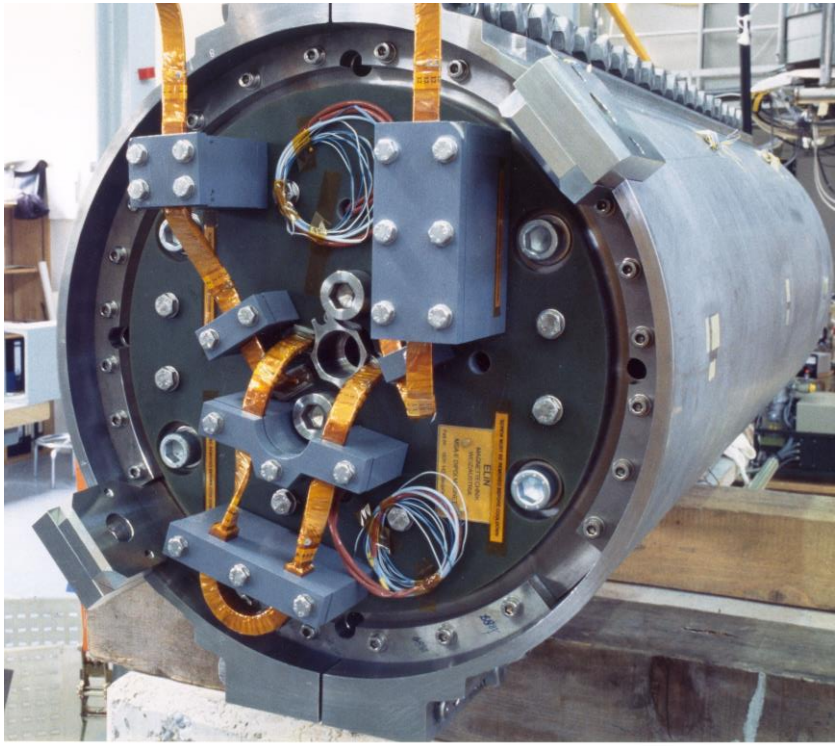
Continuous magnet line installed in the 27 km LHC tunnel, 2006

In the LHC the work was first in Industry in 1986-1990

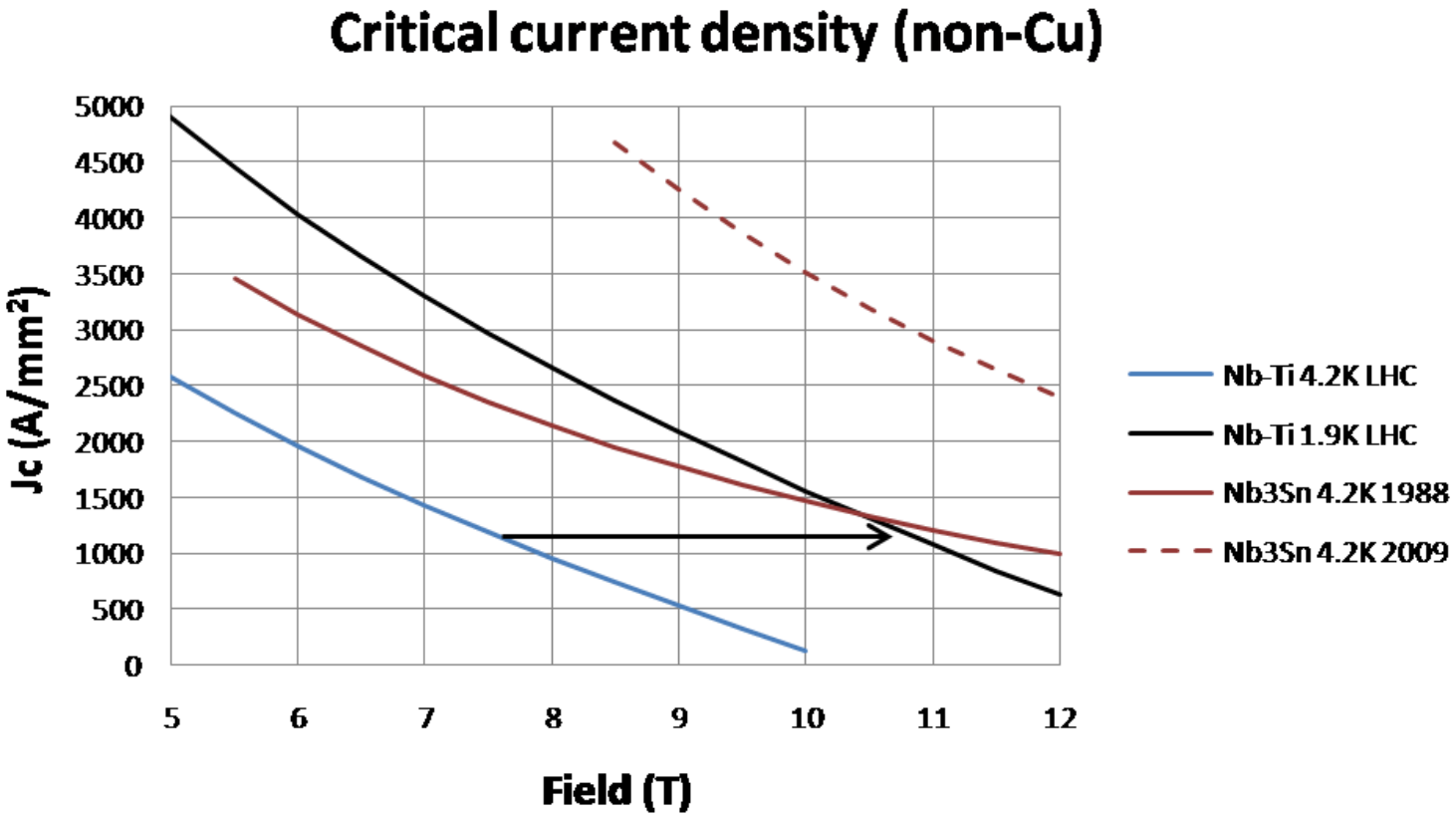
A 9 T Nb-Ti dipole manufactured in Ansaldo with CERN design & cable



A (almost) 10 T dipole in Nb3Sn CERN-Elin at 4.2 K. Technology not mature



Early decision for Nb-Ti He II cooling made things moving

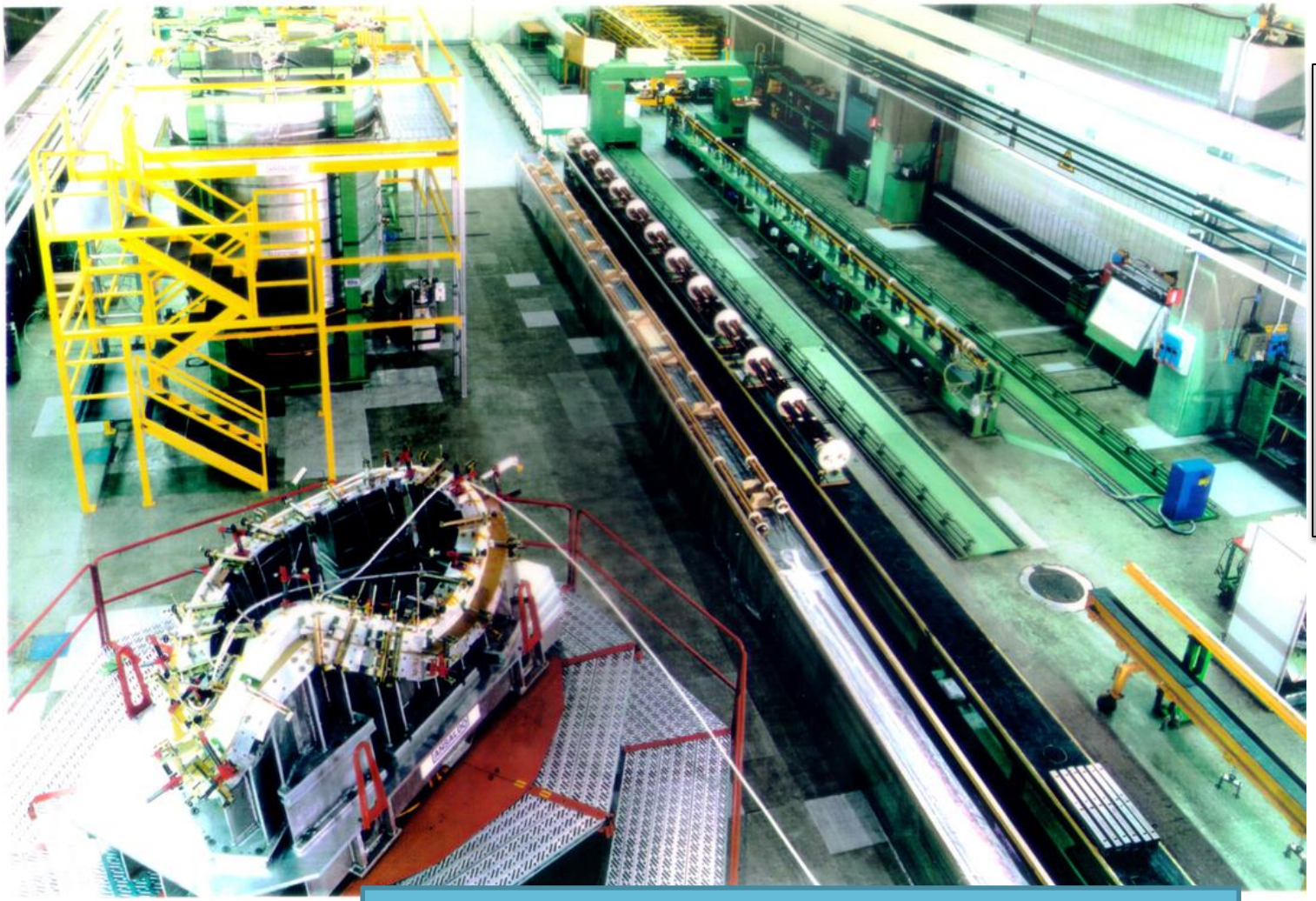


And then the R&D and even pre-industrialization was re-internalized

- A few Twin 1 m long dipole Models were manufactured in INDUSTRY
- Followed by the 2 INFN and 4 CERN 10 m long dipoles (1989-1994)
- Meanwhile the 927 Magnet lab was set up (1992-95)
- The LHC Magnet facility (B.181) was set up, too, in 1995-98, while Indistry was kept busy wiht 10 and 15 m long prototypes
- The 15 m magnets, (EXCEPT the CERN-INFN first proto of 1998) were done partly in Industry (collared coil and partly at CERN in B.181 by CERN-Industry)
- CERN had for 4-5 Industries producing long magnets for almost ten years (reduced to 3 after 1994).

The LHC Magnet Facility B.181 in 1999.

Industry had large facility and many projects going on; LHC profited of this…



Magnet Facility of Ansaldo (now ASG-Gruppo Malacalza) in 1998 (courtesy of ASG)

Accelerators: LHC dipole prototype (right)
Fusion: W7X prototype (front)
Detector: BaBar solenoid (back)

Now all is concentrated in the LMF of B.180 (courtesy of F. Lackner, 11 T review Apr.2016) 5,500 m2 (+1500 m2 of mechanical shop)

Finishing benches Geometrical measurements

15m Welding press

15m Collaring press

Pressure/leak bench

Nb3Sn Reaction furnace

"Winding house"

Yoke assembly bench

Impregnation chamber

Welding press for 2m models

Half Yoke returning bench

Cold mass assembly bench

Collared coil returning bench

Collared coil magnetic measurement bench

Cold mass magnetic measurement bench

Expansion of the «winding house»

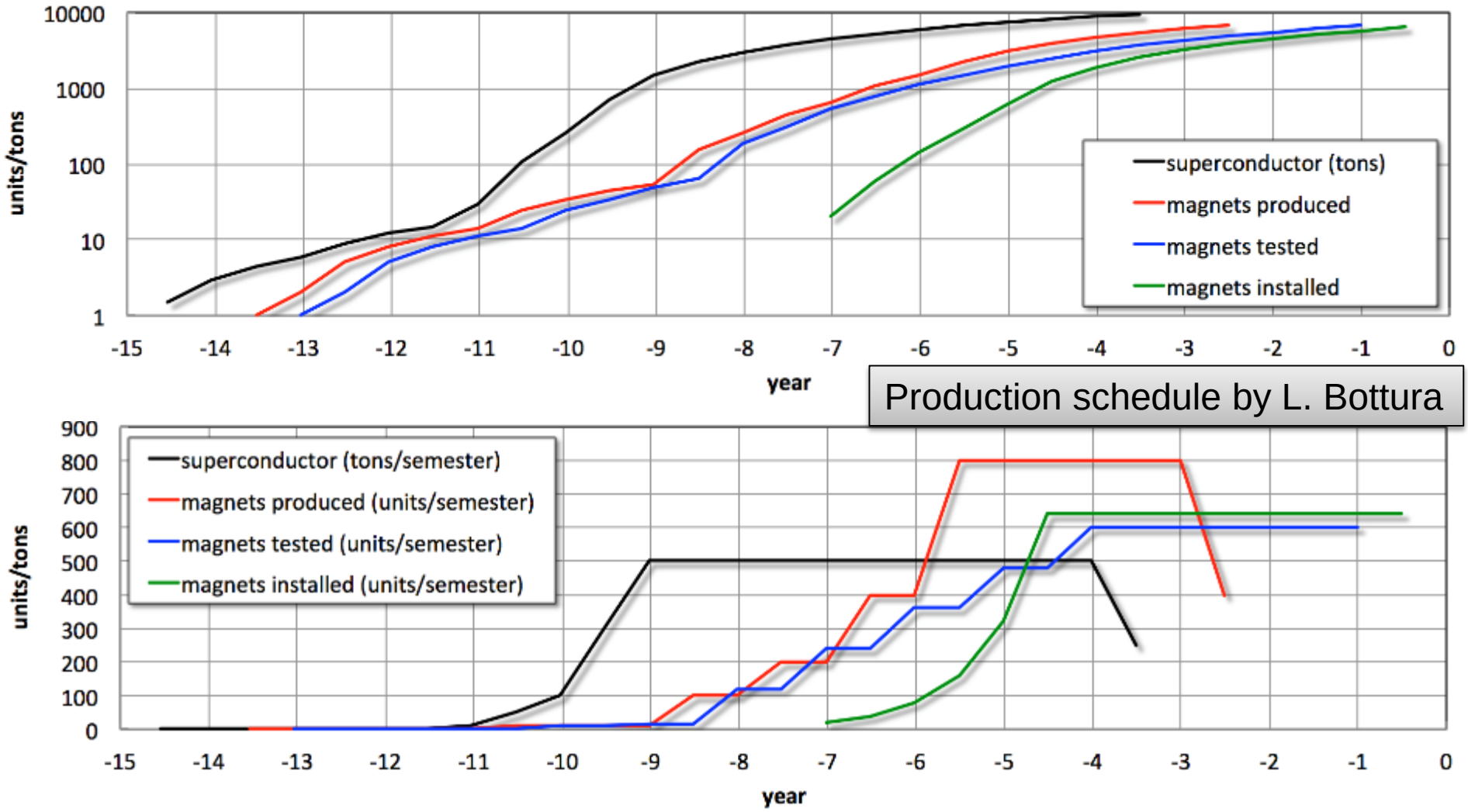
Present scope of CERN LMF

- LHC Magnets maintenance, repair, revamping…
- HiLumi prototyping and – partly – construction
- **In future**
- Natural place to start industrialization for FCC magnets with short and full size prototypes

HiLumi needs 58 main magnets – 40 in Nb_3Sn (in two types: MQXF quads and 11 T dips)

- R&D and short models in house B.927 lab (+10y LARP)
- Parallel development of long magnets in B.181 with sharing of technology and people
- The numbers, the variants (MQXF is in two lenghts), the time scale (some magnets are needed for LS2 in 2019, while long demo not yet tested) and in-kind contribution (USA) make involvement of Industry not straightforward
- However:
  - (mutual) knowledge transfer si already active (TE-MSC is managing four service contracts of magnet companies)
  - HiLumi will try to manufacture in Industry as much as reasonable especially for LS3
  - **HiLumi is the technological preparation to FCC** so wahtever is learnt by Industry is relevant for FCC. It is the SC material technology, rather than field level that dictates, process and tooling

The challange: how to manufacture some 6600 large magnets in time and to the qualitiy?



Production schedule by L. Bottura

Can we scale up the LHC model?

- 3 MB manufacturers (cold mass)
  - Alstom (nowe GE Alstom)
  - ASG (former Ansaldo, now in Malacalza Group)
  - BNG (now BiLFINGER group)
  - (Oxford Ins., Elin and Holec were in early R&D)
- 1 MQ manufacturer (LSS cold mass)
  - Accel (then Bruker and now closed)

- Each company manufactured ~ **400 units**
  - **In 4 years of peak production (100 units/y)**

LHC scaled up – Intense model
4 large magnet manufacturers

- Limiting the number of contratcors,, i.e. keeping more or less the same numbers of manufacturers than in LHC
  - **Might be actractive in terms of cost reduction**
  - NOT realistic: **too big singularity for the company**
  - **Risk of a lot of subcontracting by the main contratctor(s)**
  - Risk, in case of failure of one manufacturer
  - If this is to be pursued, is more advantageous one or more «ad hoc» facility, a FCC Magnet Facility of 10-20,000 m2 with clean areas and cranes
    - CERN + Industrial partners
    - Institution 2 + Industrial partners
    - …

LHC scaled up – Extended model
4 x 3 large magnet manufacturers

- Reproduce the LHC models in EACH region:
  - EU (+Russia)
  - America(s)
  - Asia/Pacific
- Can be done if magnets are built to print and to process.
- Differences and larger performance spread than LHC.
- Production must be guided by Institutes that have to reach the same understanding through R&D phase. The first thing is to share the R&D!
- The components can (**must?**) be purchased by a unique component center (components are as important as process for the quality) to secure quality, safety stock, flexibility

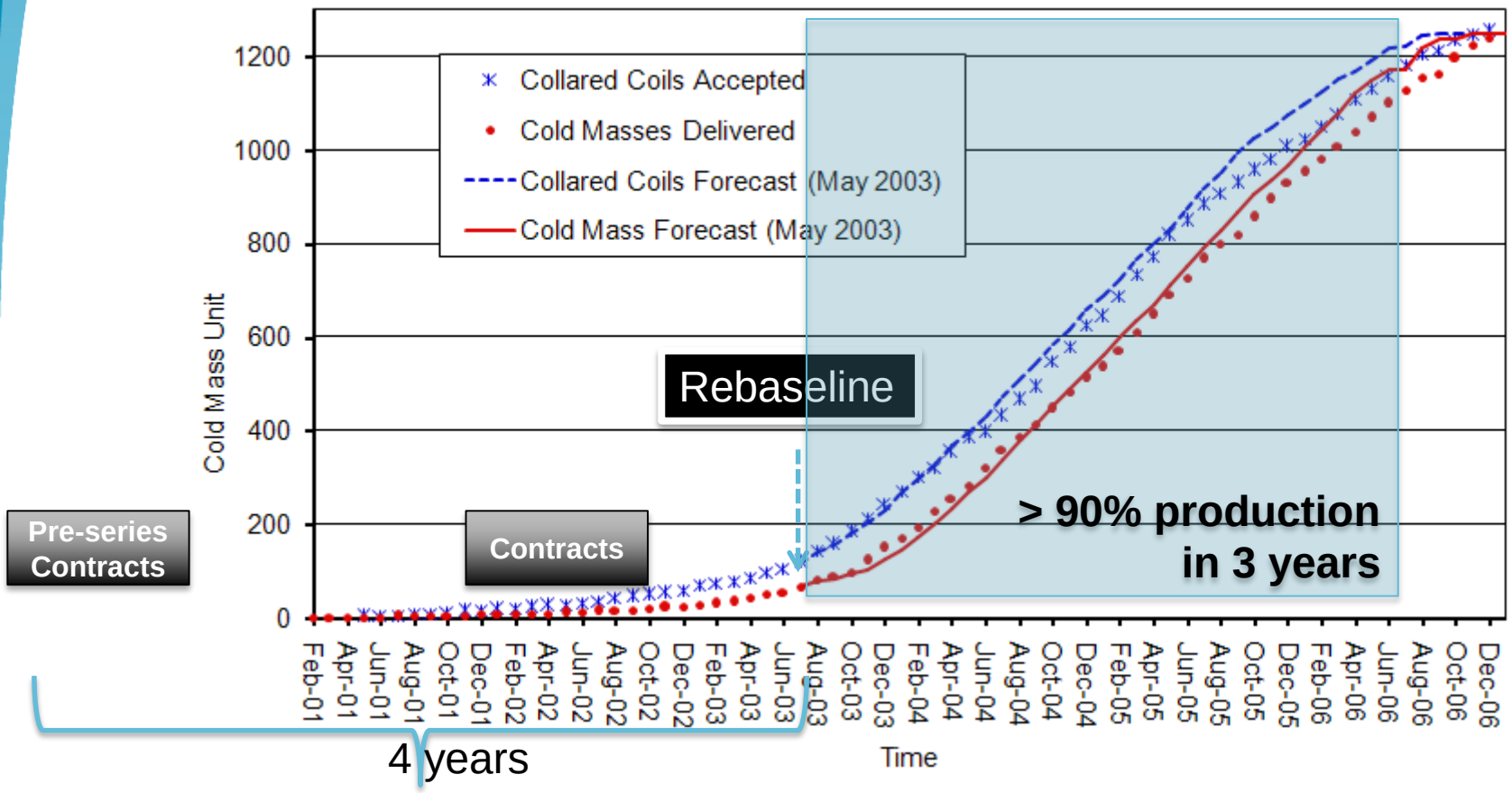
LHC scaled up – Extended (cont.)
4 x 3 large magnet manufcturers

- Each manufatcurer may actually be a consortium
  - LHC example
    - 2 companies did all in house (in two separated halls), ASG in Genova and Accel in Troisdorf (Bonn)
    - 1 was a consortium: Jeumont (Areva) made coils; Alstom assembled coils and cold mass
    - 1, BNG, had two separated sites, for collared cois (Wurzburg) and cold mass (Zeitz).
- Each manufacturer: 3-5000 m2 for CC + 3-5000 m^2 of suitable space for CM assembly: clean for CC and reasonable for CM assembly (and space for storage)
- Cleaning, humidity and temperature controlled.
- $\Rightarrow$ **Each region has to provide some 15-30,000 m^2.**
- In industrialization, space can be times less.
- **Cranes for 5 to 50 tons is a necessary asset**

Few pictures from LHC magnet manufact.

When to start Industry production? 7 years before end.Few years of R&D/Industrialization are necessary

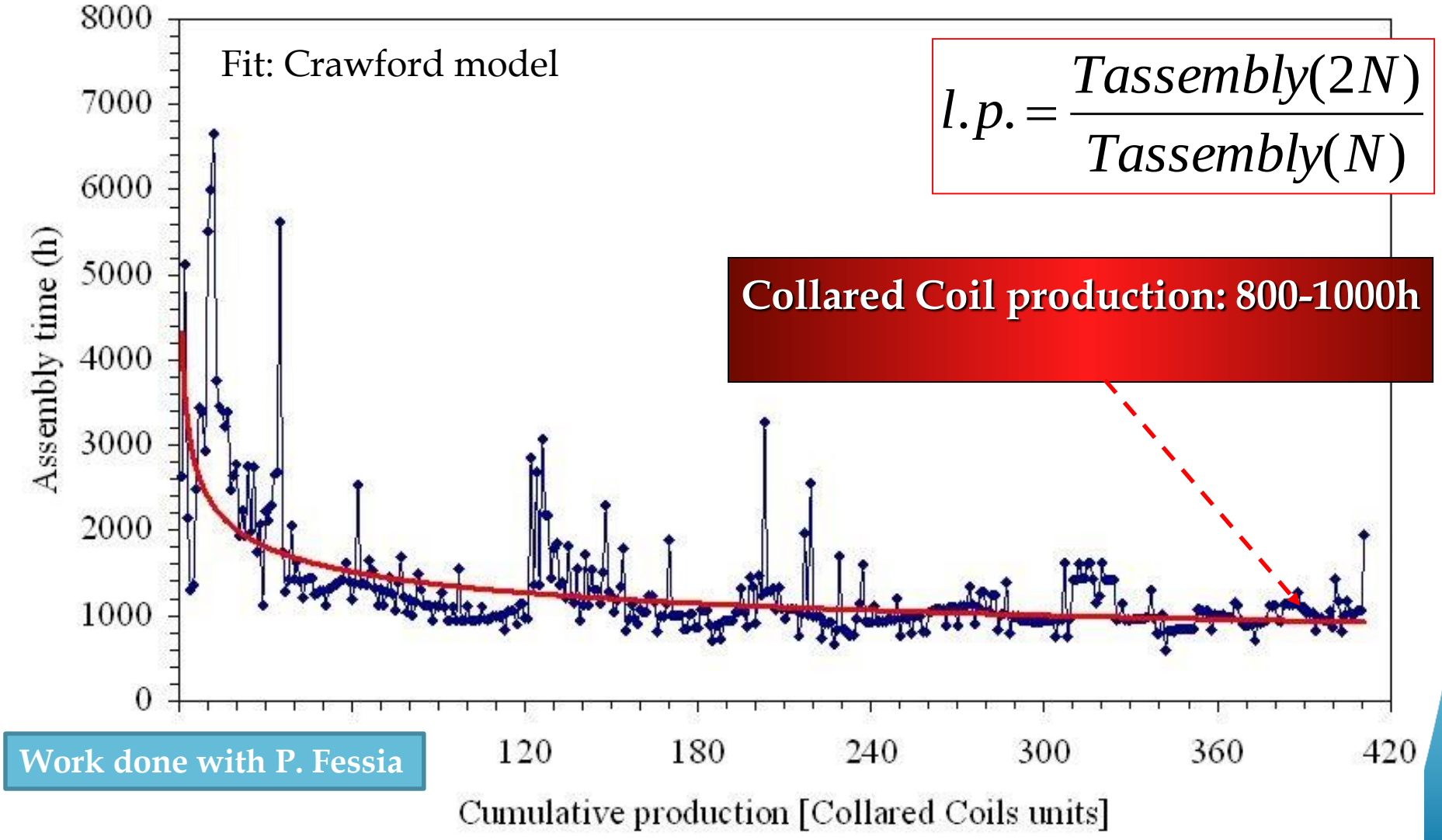
- LHC main dipole production



2nd Option: a magnet as sequence of assembly with Project-Labs taking full responsibility

- Subcontracting different assembly steps to various companies, choppi g the work as much as convenient.
- Coils winding
- Thermal treatment and impregnation
- Coil assembly & Collaring
- Assembly of longitudinal cold mass
- Extremities and enclosure
- (re-thinking to) Cryostating (@4.2K would be easier)
- …

Exploiting learning curved to the maximum (more automatic tooling may bee rewarding)



Work done with P. Fessia

An (incomplete) comparison between models

A company responsible for the manufacturing (global supplier)
LHC scale up Intense or extended

- Model has made its proof (LHC)
- Responsibility more clear and easier to check
- Likely less people needed for contract follow up
- Easier to get support for in-kind from Institutes (maybe)

Subdivision in many contracts (distributed manufacturing)

- Specialized centers may be more cost effective, avoiding using high cost labour for simple operation
- More companies can be involved using best skill
- Uniformity of production may be better
- This model requires a vigorous action SOON

Last (but not least)
Facilitities for R&D and KTT

- Are the CERN LMF/magnet Labo and facilities in USA and Asia sufficent to train people and for transfer of technology?
- Probably **not** given the fact that Hilumi will keep them busy for a few years, still. But time can cure this.
- **However, probably an extension of LMF would be necessary; the problem of staffing it, is also important**
- **USA and ASIA/Pacific would need to upgrade/built their facilities and staffing them, if as serious participation is to be foreseen**
- Staffing with personnel from Industry would be an excellent preparation: knowledge tranfer is mainly through people…

Conclusion

- Start worrying about magnet construction infrastructure 15 years before end of delivery is not too early. Plan must be done in next two years.
- The investement may depends on the strategy for construction.
  - Global supplier model (LHC scaled up)
  - Distributed manufacturing model
- For an FCC the CERN LMF is not enough also **for Prototyping/Industrialization phase**.
  - More in EU
  - MORE IN OTHER REGIONS


HiLumi
HL-LHC PROJECT