IR Magnets for an LHeC

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Electrons for the LHC: Workshop on the LHeC, FCC-eh and PERLE

24-25 October 2019

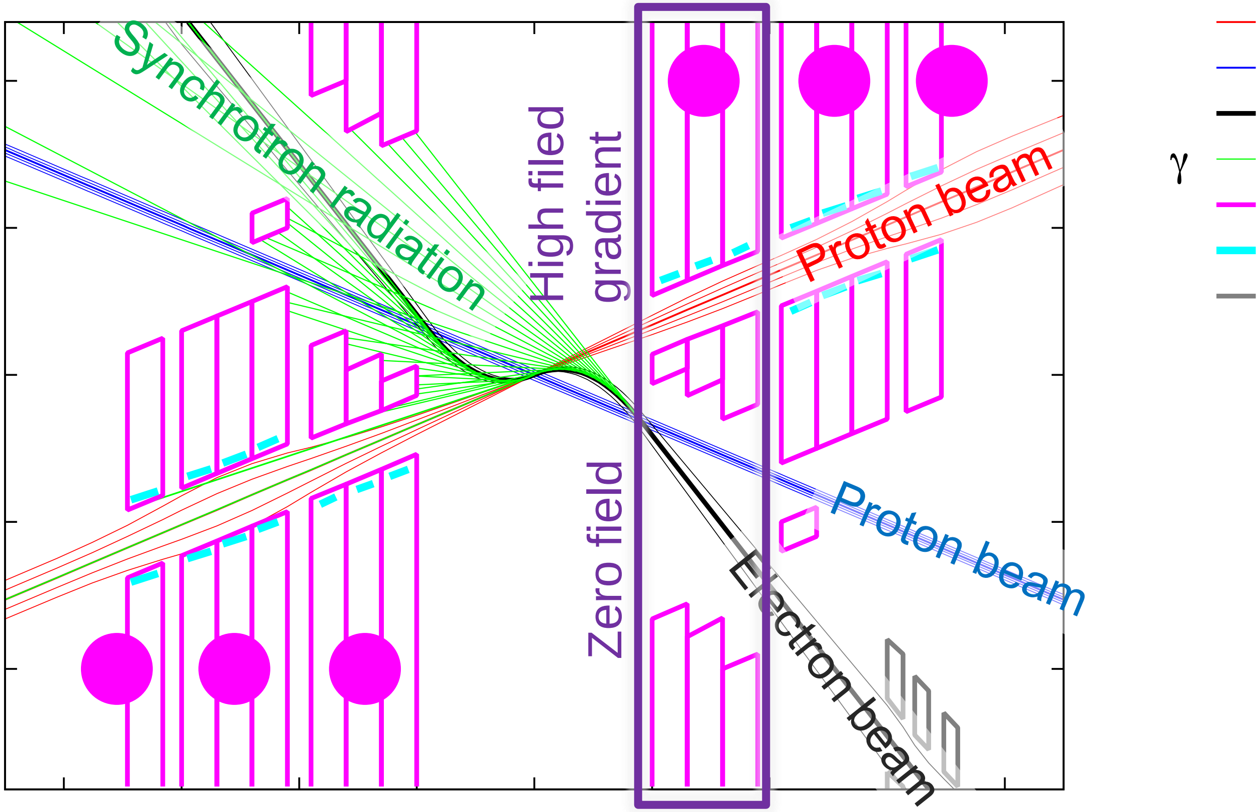
Chavannes de Bogis

Outline

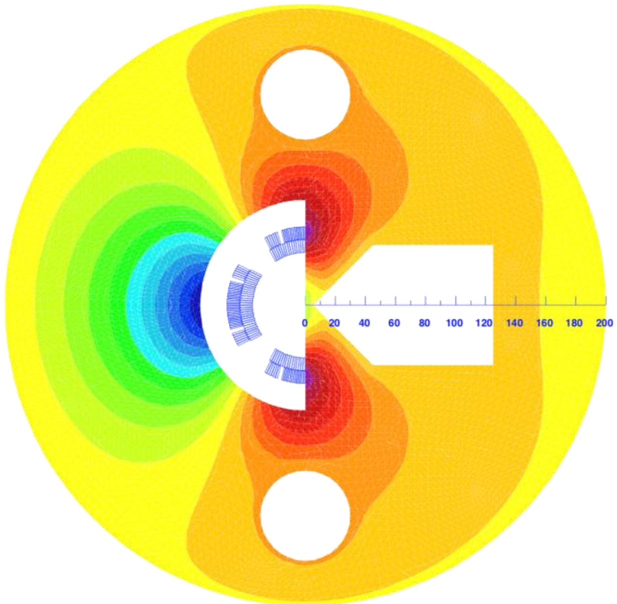
- What magnets ?
- What are the challenges ?
- A development plan
- Summary and conclusions

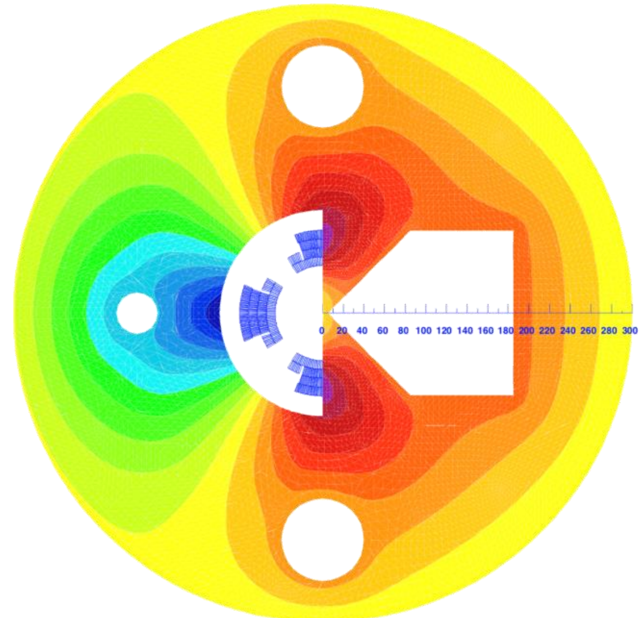
What magnets ?

Let us take the Q1 as a good example…



Q1 in LHeC CDR - 2012





Nb-Ti Q1 option
R = 46 (mm)
G = 145 (T/m)
B_{max} = 8 (T)

Nb_3Sn Q1 option
R = 46 mm
G = 175 (T/m)
B_{max} = 10 (T)

Seven LHeC IR Magnet Options

Septum saturates for |B| much above 1 T

Low

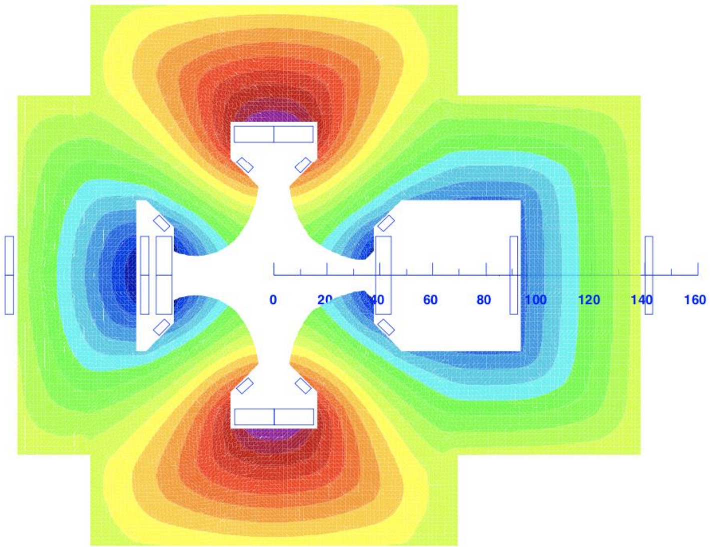
- ~~High~~ gradient Magnetic Septum Quadrupoles (MSQ).
- Open yoke "MSQ" with integrated correctors. ← Clumsy
- Combined function magnet septum magnets.
- Actively shielded high gradient quadrupoles.
- Extended Sweet Spot quadrupole designs. ← Clumsy
- High gradient block coil designs that also may incorporate "Sweet Spot" regions.
- External field cancel coils as for SuperKEKB.

Large region to compensate, excessive cross talk and no independent operation. 4

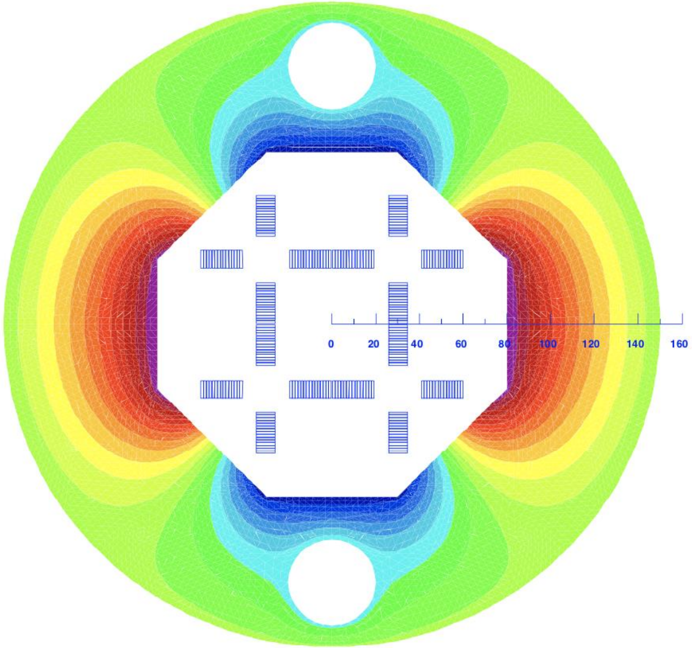
Electron Ion Collider – eRHIC

Options …

Super-ferric

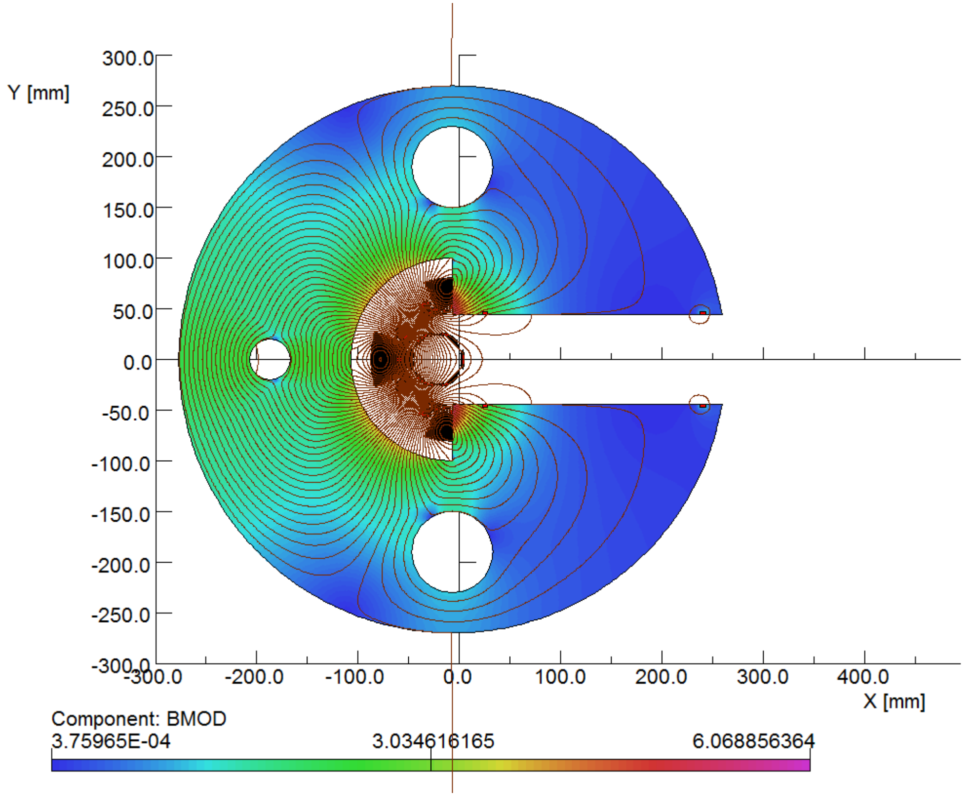


Block-coil quadrupole

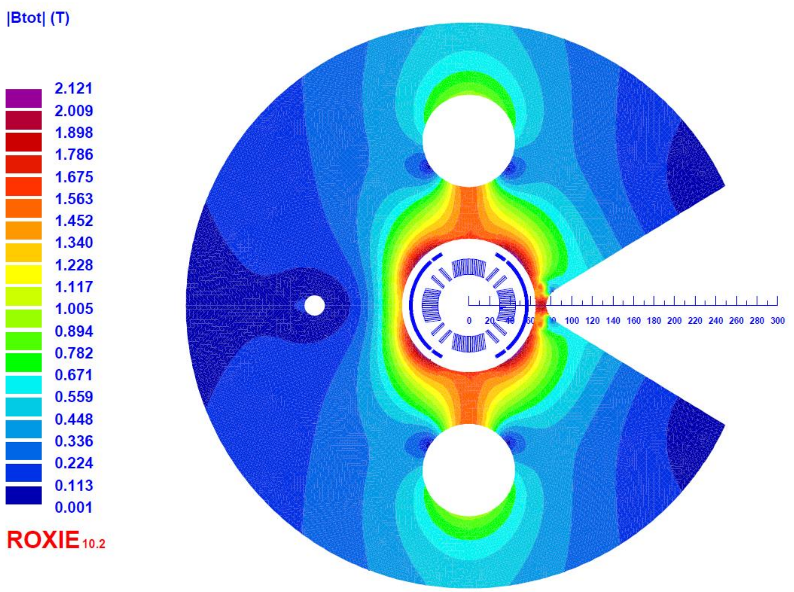


… more options …

Alternative iron cut-outs and compensation coils in field-free volume

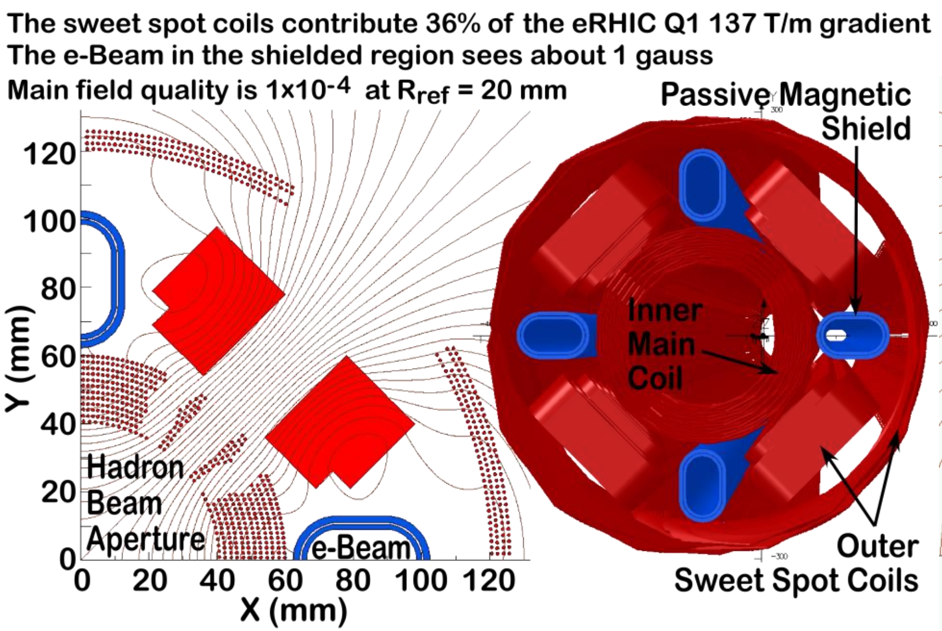


Direct wind compensation coil and optimized magnetic mirror

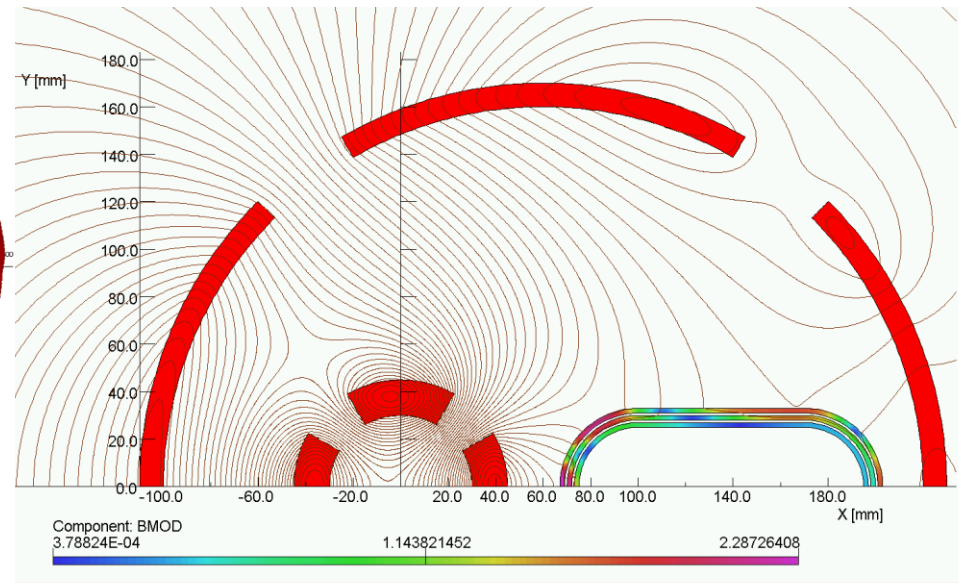


… and more options …

eRHIC *sweet spot* design

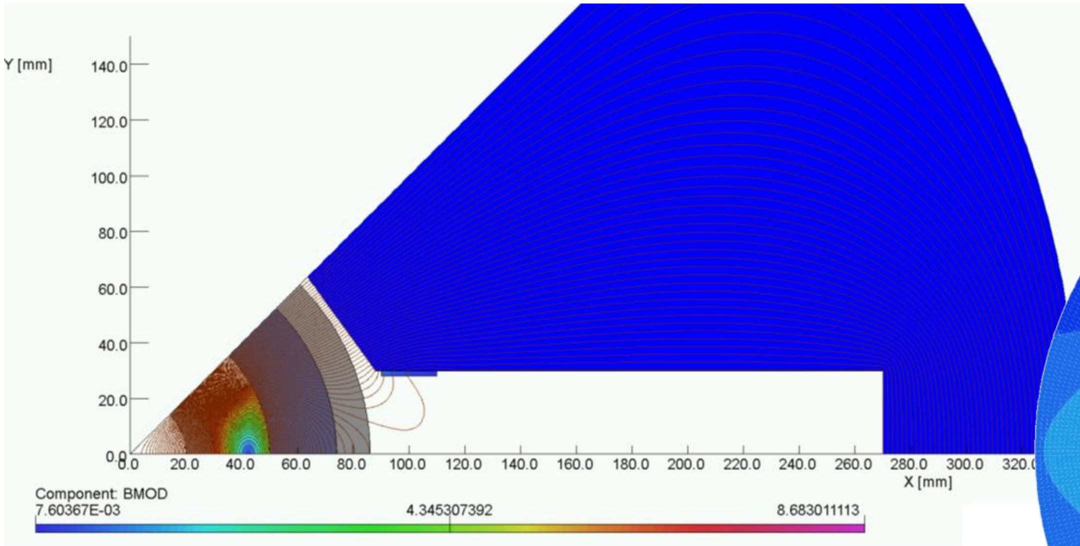


LHeC *sweet spot* design



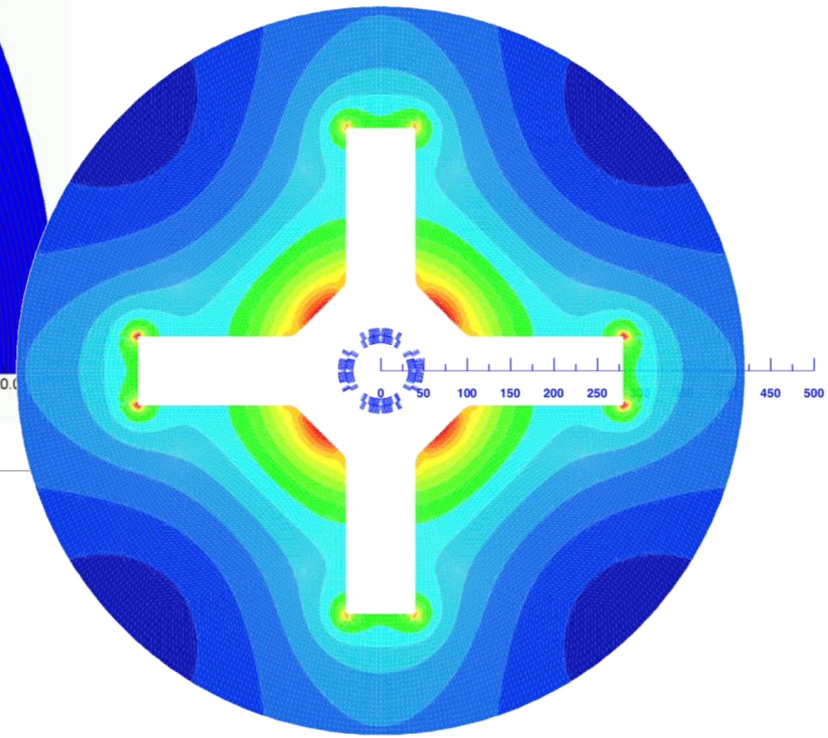
… and yet more options !

Self-contained coil plus quad-yoke



protons

electrons



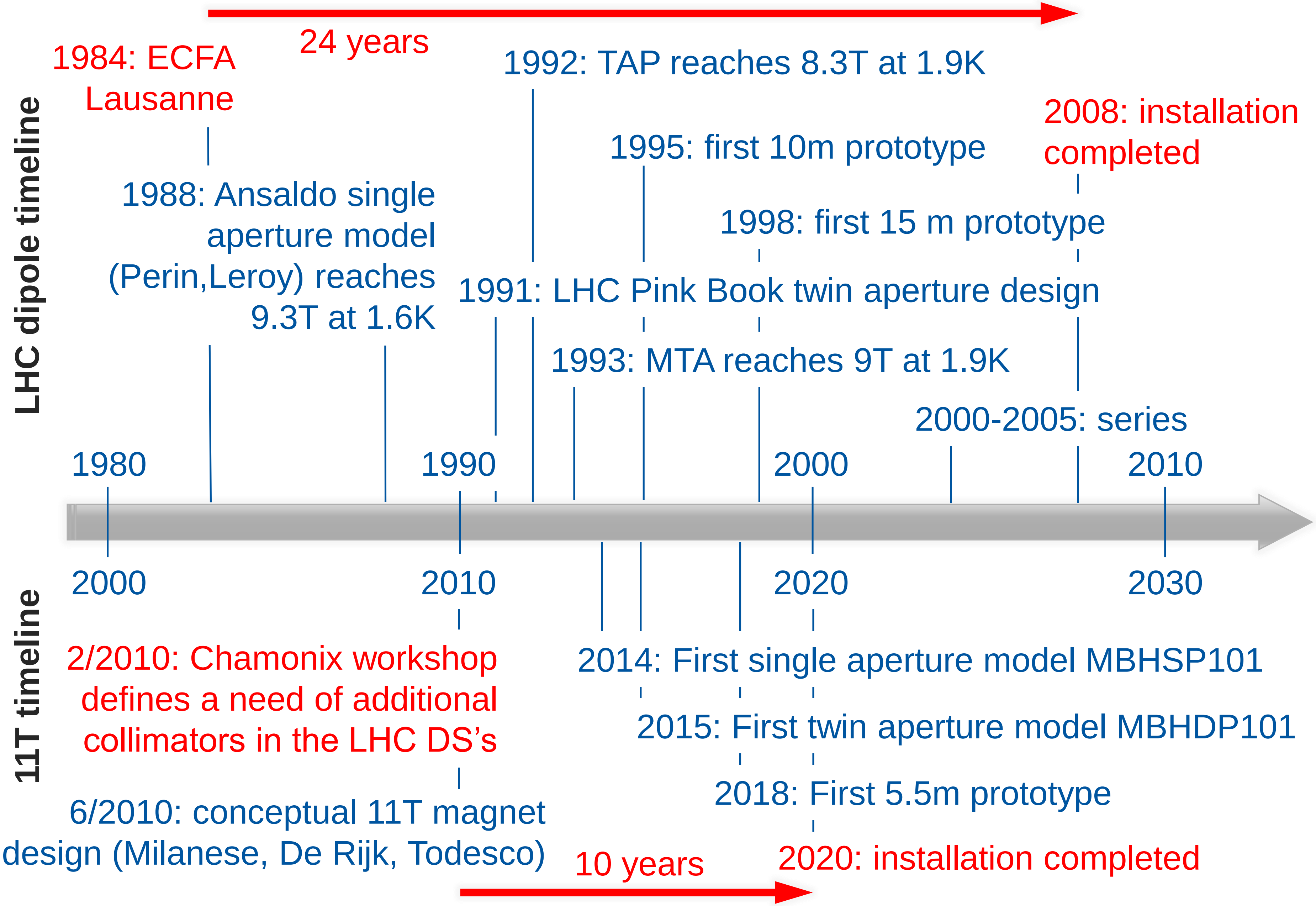
LHeC Q1 magnet recalculation
after B.Parker by S. Russenschuck

What are the challenges ?

- Concept and design of a high-field magnet with such anomalous requirements (*field-free* region, lack of symmetry, ...)
- Training and performance of Nb_3Sn magnets in the range of 10T
- Forces (non-symmetric configurations) and stresses (limited to 150 MPa) on a brittle conductor
- Stored energy, quench detection, quench protection, voltages
- Field quality and residual field in the *field-free* region

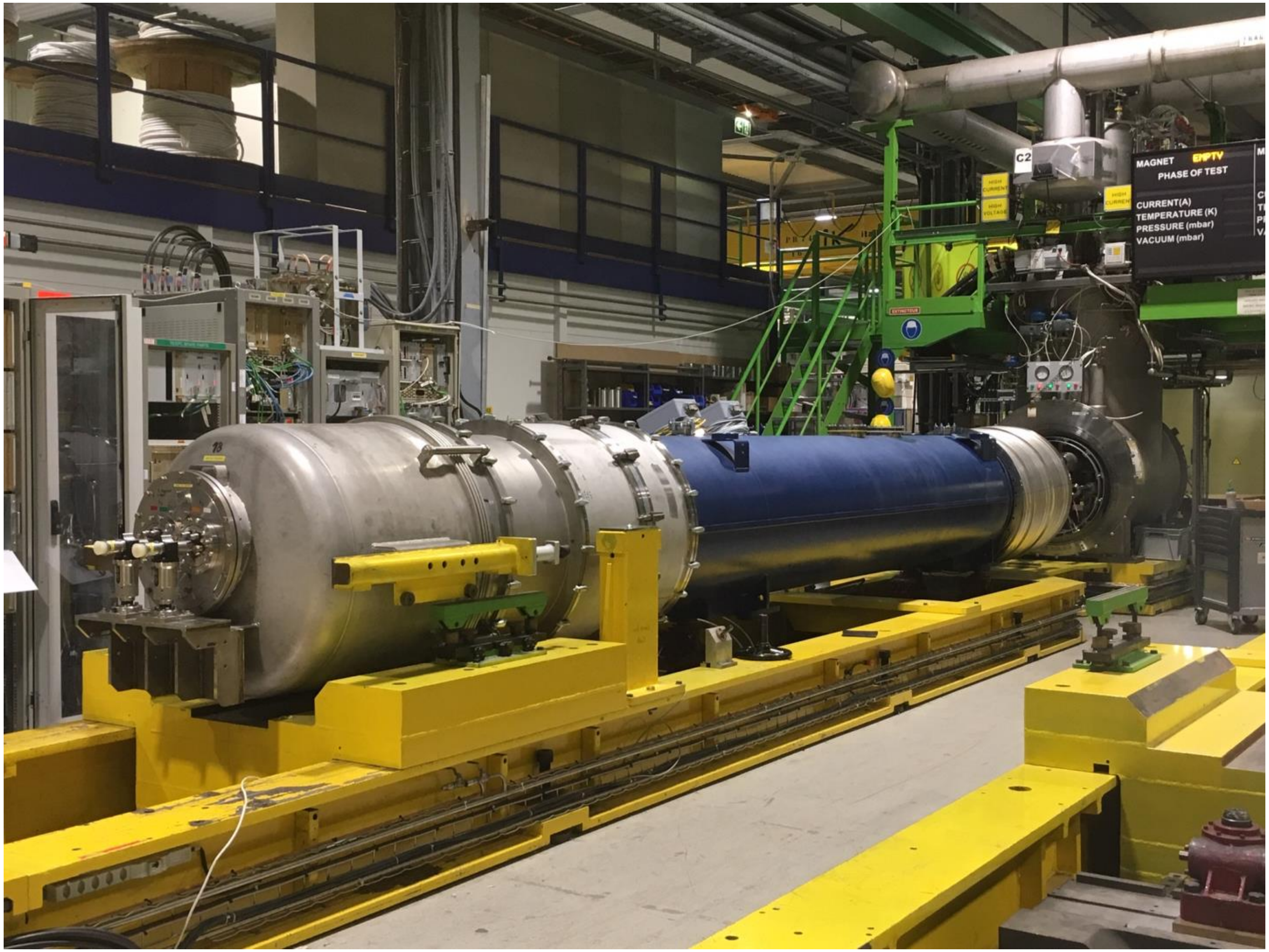
Get moving !

It will take typically 10 (optimistic) to 15 (realistic) years from the time the decision is taken, to the first accelerator magnet of this type

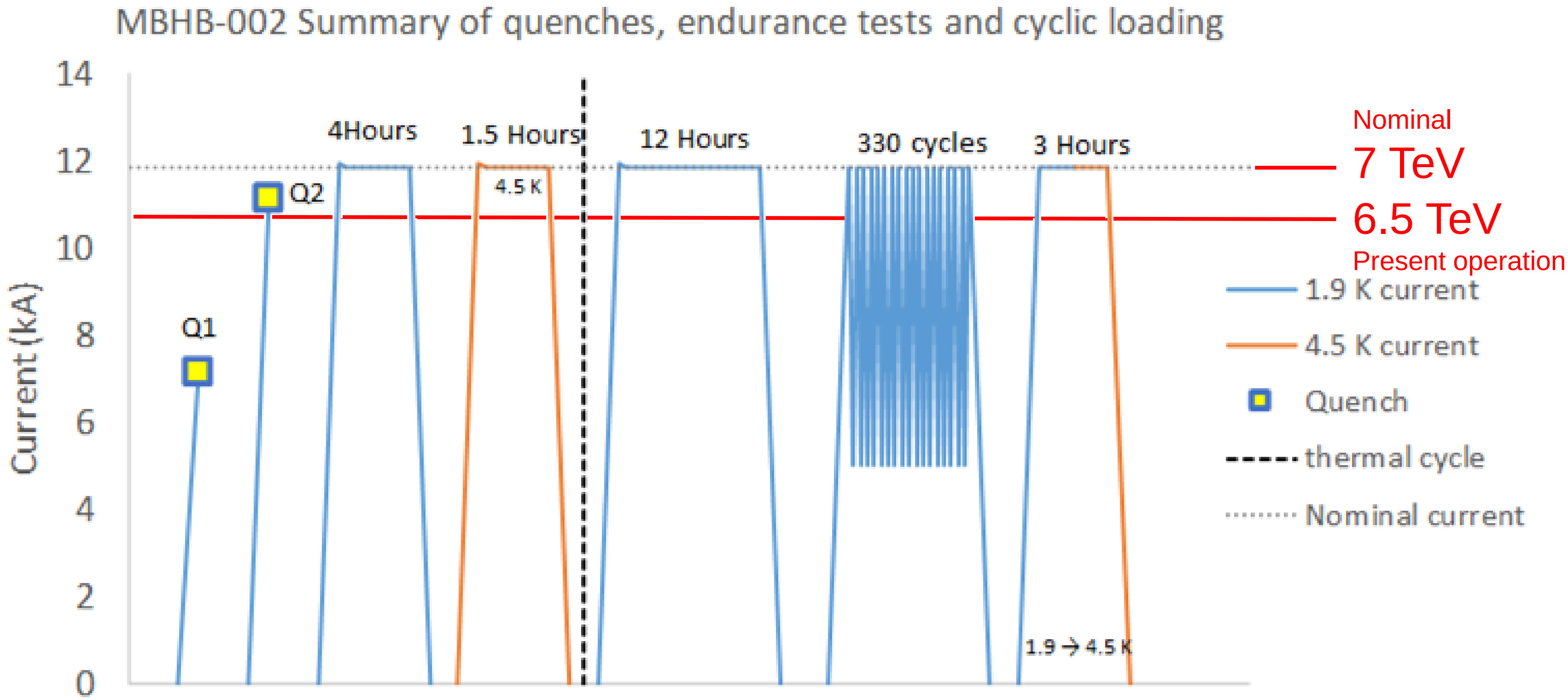


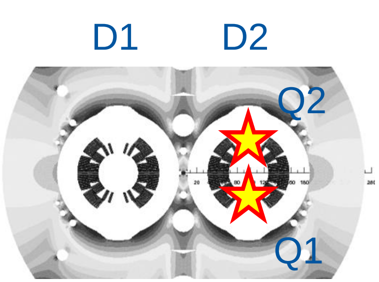
The Nb_3Sn development for the 11T HL-LHC was fast !

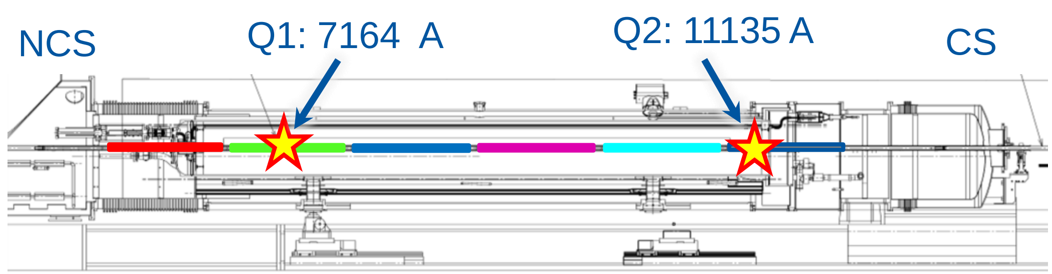
LMBHB0002


MAGNET
EMPTY
PHASE OF TEST
CURRENT(A)
TEMPERATURE (K)
PRESSURE (mbar)
VACUUM (mbar)

LMBHB002 powering tests

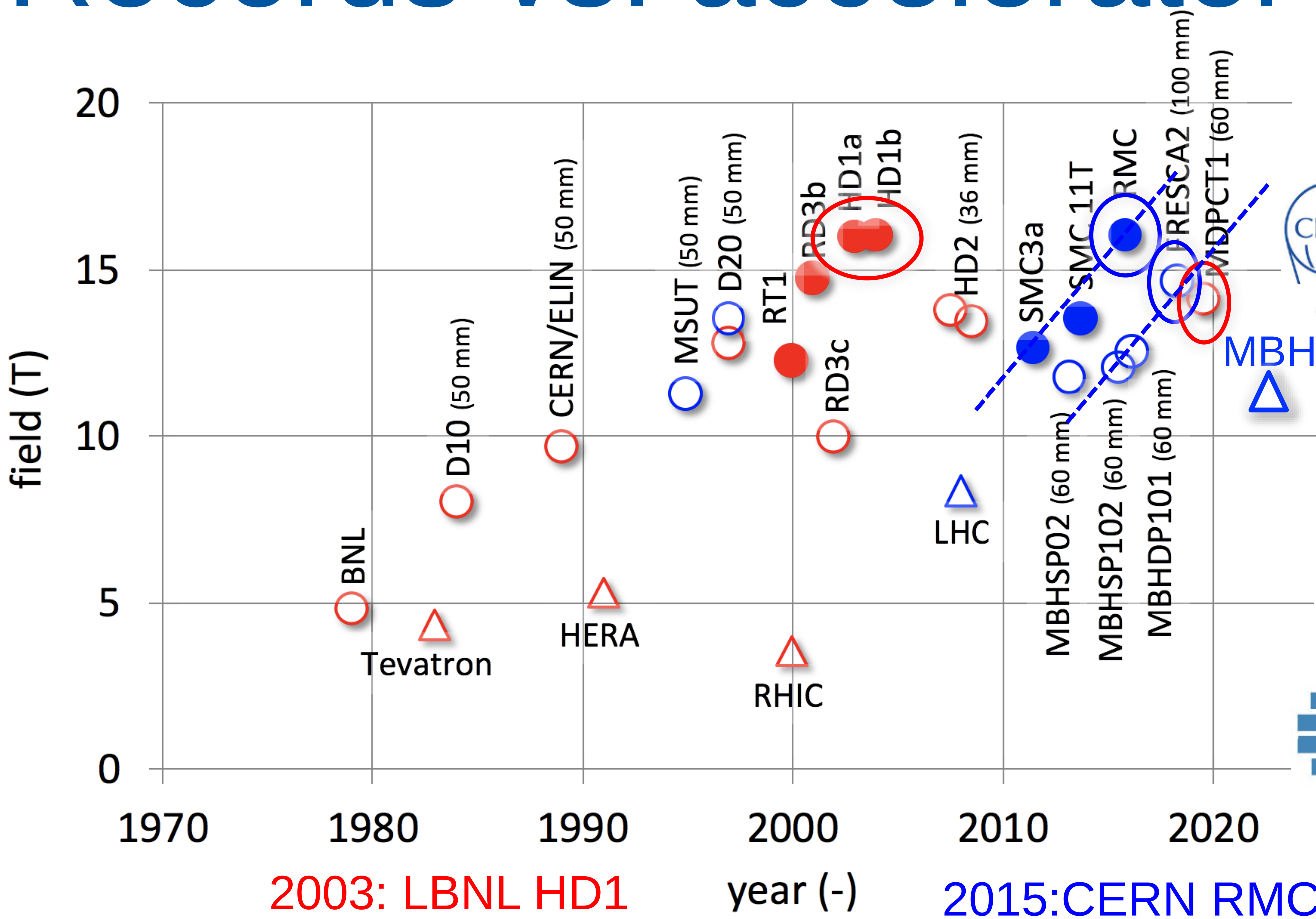






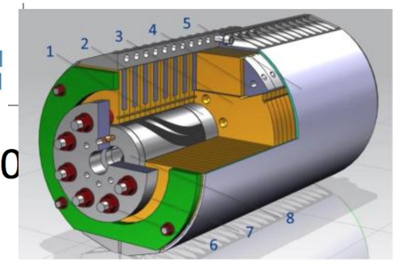
This is an accelerator worthy dipole !

Records vs. accelerator magnets



2018: FRESCA2
(14.6T at 1.9 K, 100 mm)

2019: FNAL MDPCT1
(14.1 T at 4.2 K)



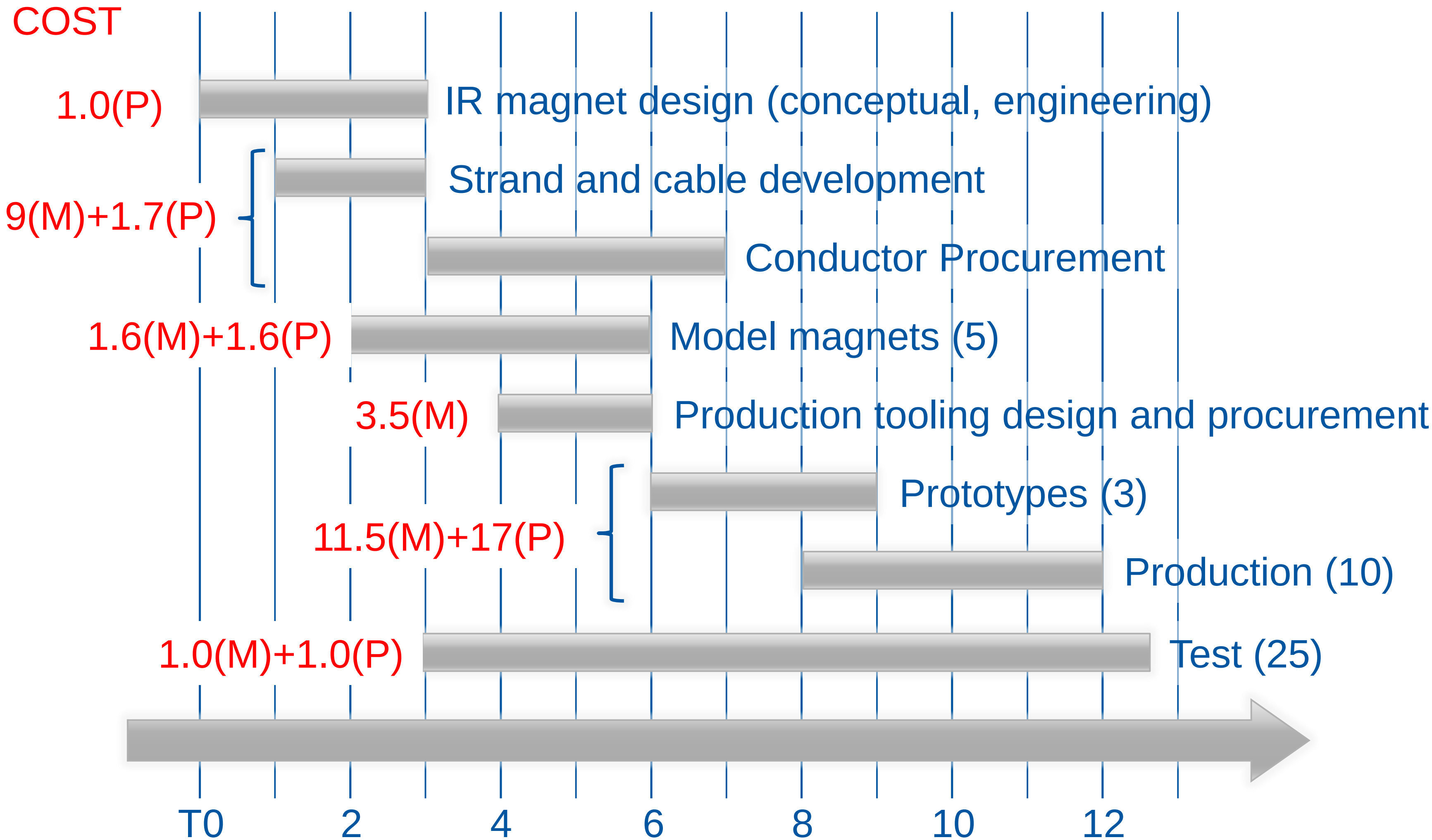
2003: LBNL HD1
(16 T at 4.2 K)

2015:CERN RMC
(16.2 T at 1.9 K)

Other examples

- MQXC IR for the LHC Luminosity Upgrade Phase-I: **11 years**
  - 2002 – LHC Project Report 626
  - 2008 – SLHC-pp
  - 2013 – model magnet test
- FRESCA2: **12 years**
  - 2004 – EU-FP6 NED JRA
  - 2009 – EU FP7 EuCARD
  - 2018 – magnet test (14.6 T)

A development plan (12y, 50M)



DISCLAIMER: the content of this slide is non-committal

Summary and conclusions

- The IR magnets for an LHeC pose challenges that have relevance to future developments, and are comparable to the HL-LHC magnets

Yes, we are interested !

- Though the technical challenges are significant, there are some very good ideas on the table as to how to address and solve them

Yes, we can do it !

- The main challenge, in fact, is to get a reality check through a suitable magnet development program

Get going, time is running !

CERN