FROM RESEARCH TO INDUSTRY

Madmax project meeting
MPI - CEA

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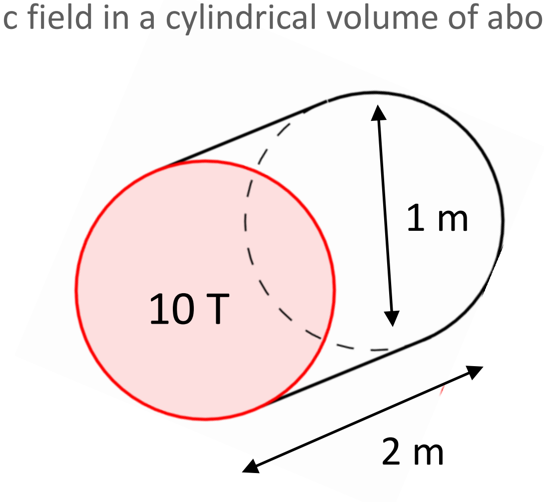
Introduction

Framework of the MadMax experiment project:

In order to try to detect dark matter and demonstrate the existence of axions, the Max Planck Institute has launched an innovation partnership with the goal of manufacturing a dipole magnet with an assessment factor of 100 T^2m^2 over a length of 2m.

Main requirements for the magnet:

- $\left|\vec{B}\right|^2 A \geq 100\, T^2 \cdot m^2$ → 10 T magnetic field in a cylindrical volume of about 1 m diameter and 2 m length

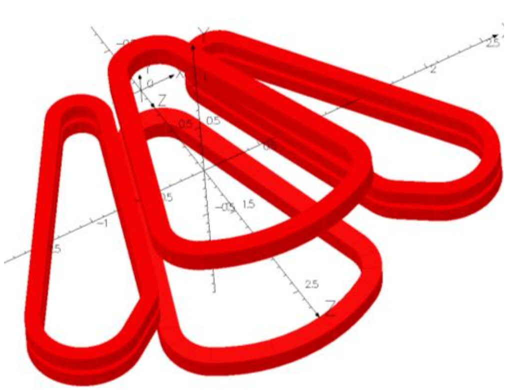


- Low stray field in order to allow safe work around the magnet
- Base design superconductor material : Nb3Sn

CEA first proposal

Leading parameters :

- Magnetic field perpendicular to the magnet aperture axes → Dipole coil
- 2 m length → Racetrack coils
- 10 T + low stray field → Several hundred tons of iron (unrealistic) → Active shielding (close to R3B concept)
- $\left|\vec{B}\right|^2 A \geq 100\,T^2 \cdot m^2$ + 2 m length → 160 MJ of magnetic energy → ~ 340 MJ of magnet stored energy (Iseult, 11.7 T)



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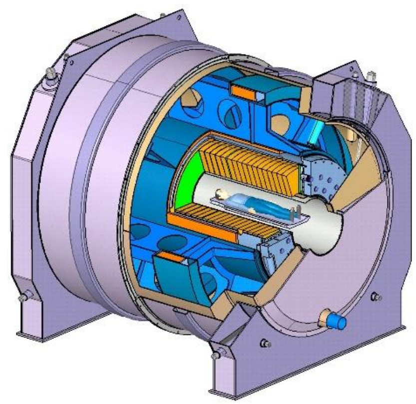

+ Nb3Sn

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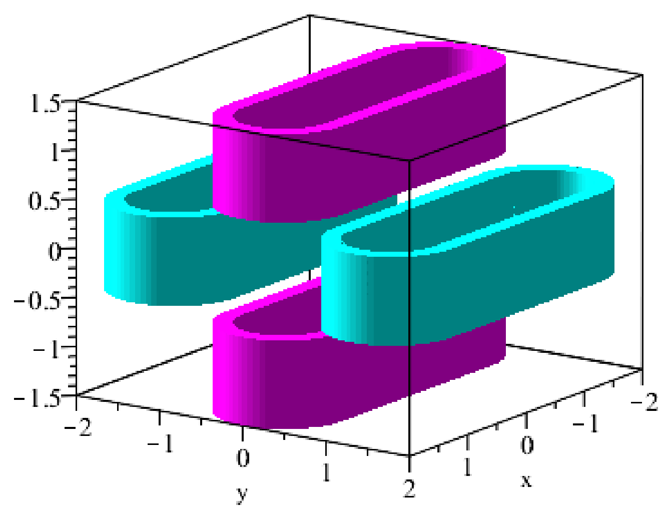
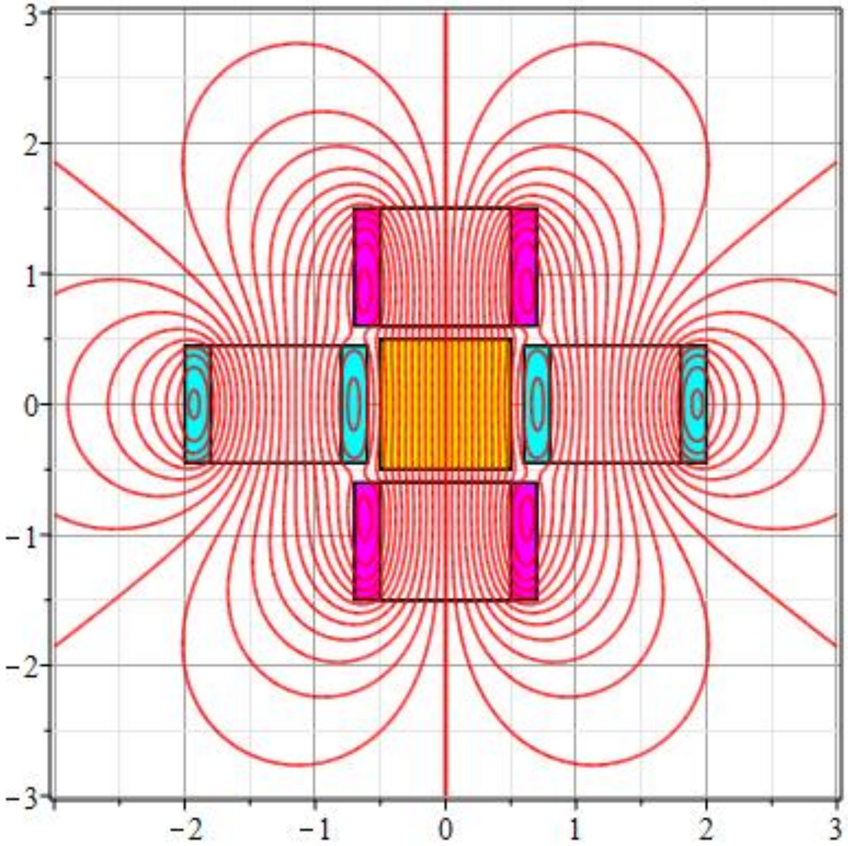


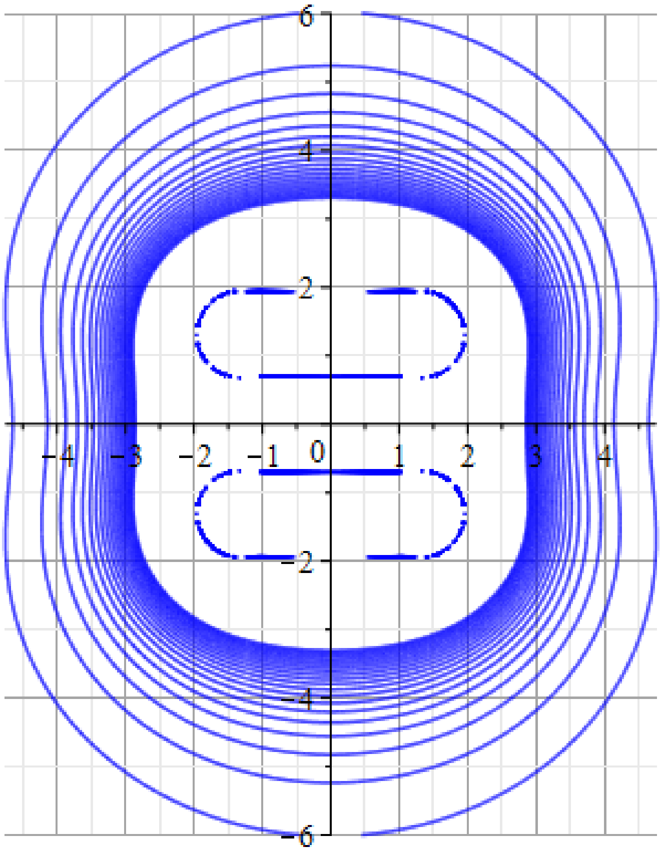
Actively shielded magnet with 4 racetrack coils

CEA first proposal

Field lines in the yOz plan



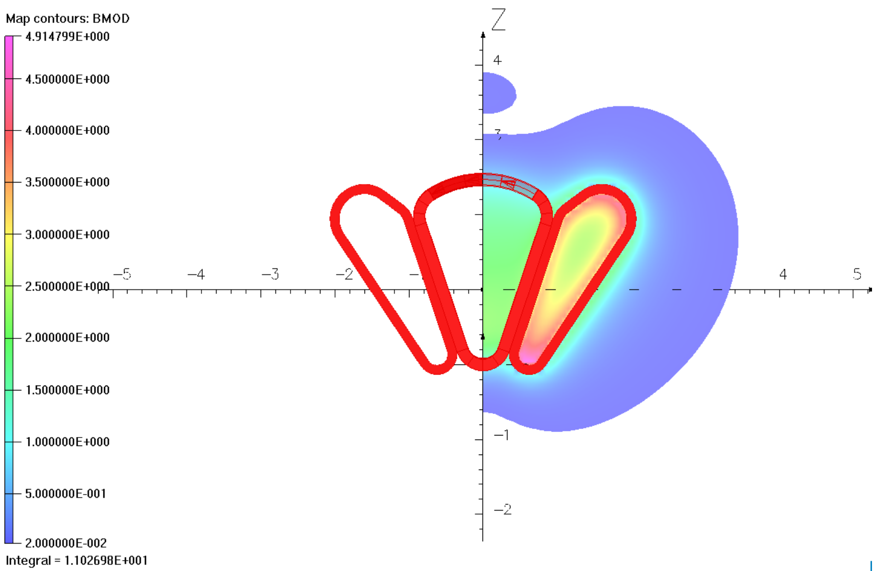
Stray field (0.5 T – 25 mT) in the xOy plan

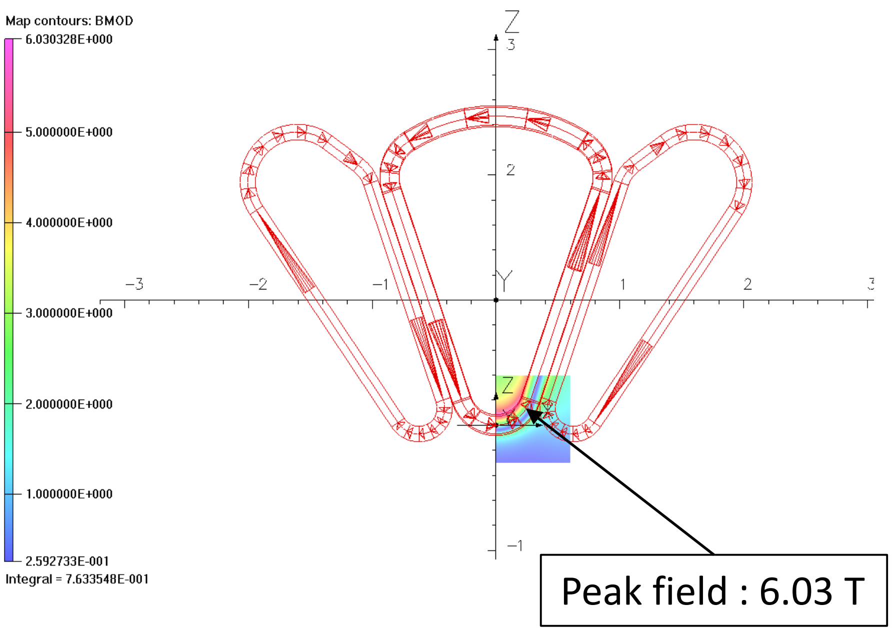


Study plan: Nb3Sn magnet concept design

Magnetic design:

The objective of the work will be to optimize the field quality, to minimize the stray field, to minimize the superconductor mass and the whole magnet mass. A particular attention will be given to the study of the peak field area which is a key point of the design. The magnetic design will be followed by electrical studies (current leads, insulation requirements), magnetic stability (AC losses), and quench protection requirements. The quench protection study will investigate several concepts (internal or external protection, electrical circuit).



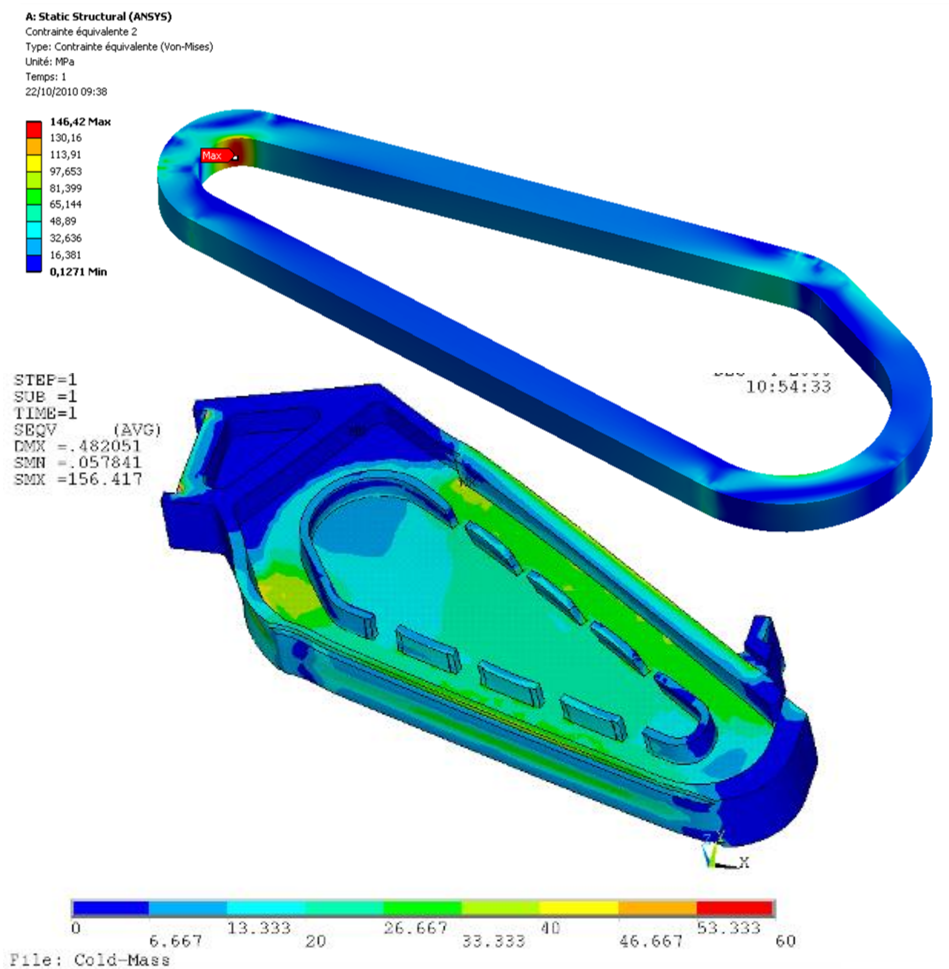


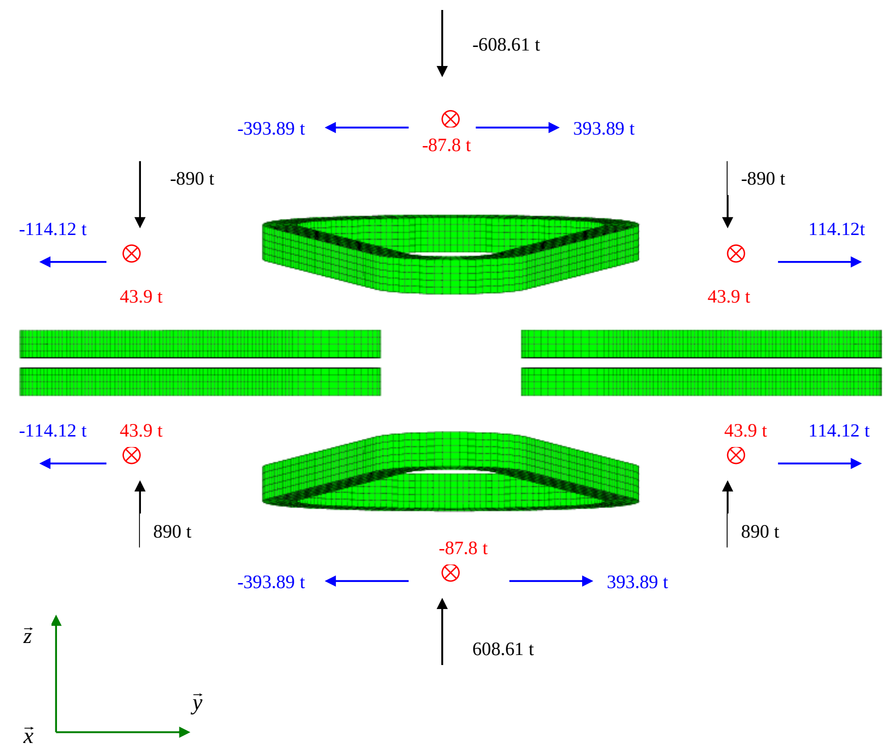
Computations examples from the R3B project

Study plan: Nb3Sn magnet concept design

Mechanical & cryostat design:

In this part a special attention will be accorded to the stress analysis in order to determine the maximum stress level that can be supported by the winding. The principle of the cold mass structure, thermal screen, vacuum vessel, and internal supporting structure will be designed.



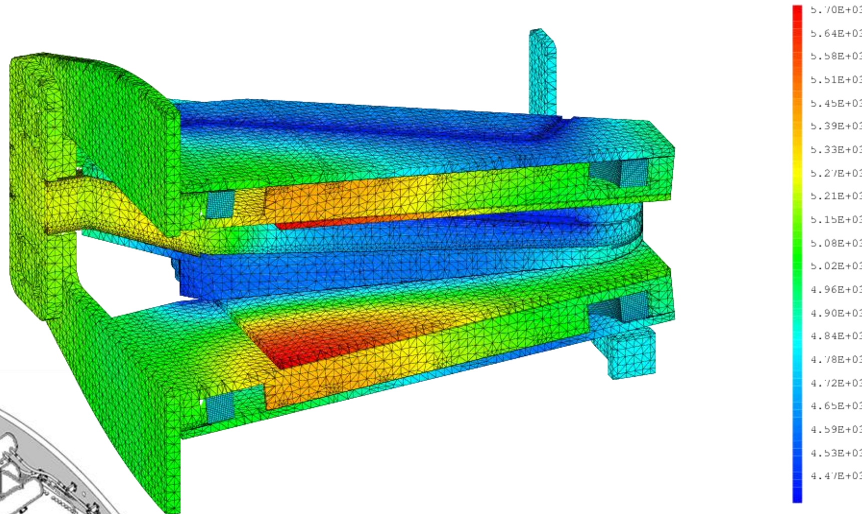


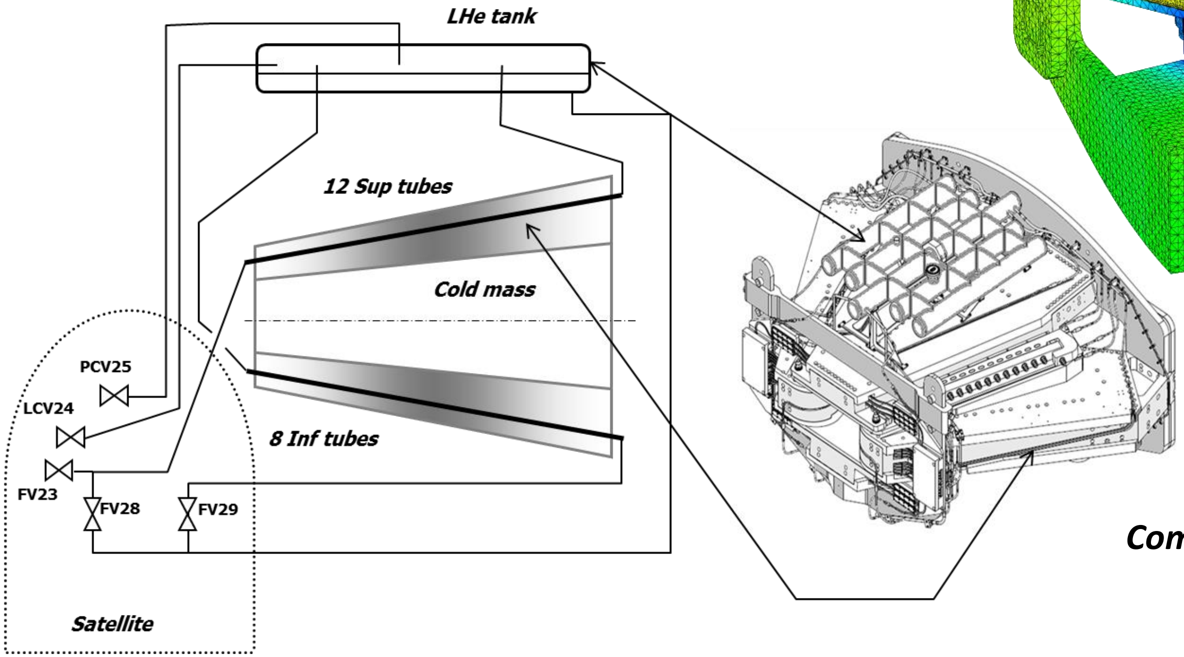
Computations examples from the R3B project

Study plan: Nb3Sn magnet concept design

Cooling concept:

Different kinds of cooling concept (He free, closed loop thermosiphon, He bath, CICC) will be investigated taking into account the MPI cooling requirement. The cooling time, and quench time recovery will also be investigated. 3D Thermal analysis will be made.





Computations examples from the R3B project

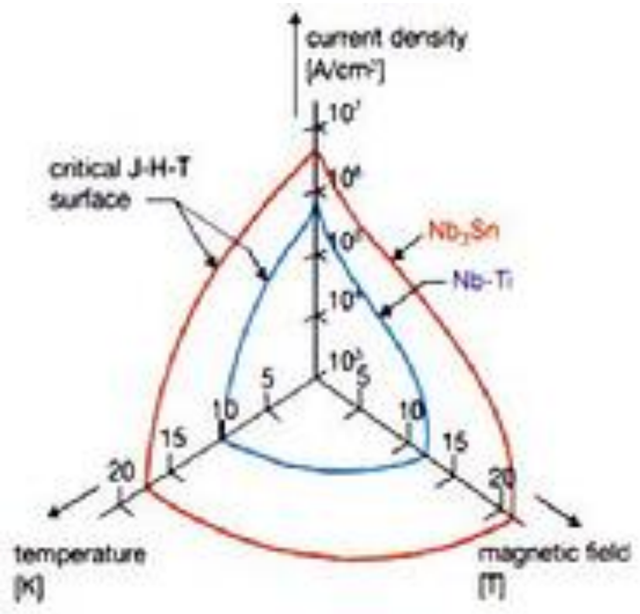
Study plan: NbTi magnet concept

Maximum FoM with NbTi:

A NbTi conductor design will be performed with the objective to use a standard production if possible. This design will be based on the expected operating margin and the maximum NbTi achievable performances. The study will take into account work and achievements obtained on other NbTi high field magnets.

Cost evaluation for both Nb3Sn and NbTi magnet concepts

Concept design of an NbTi magnet [optional study]

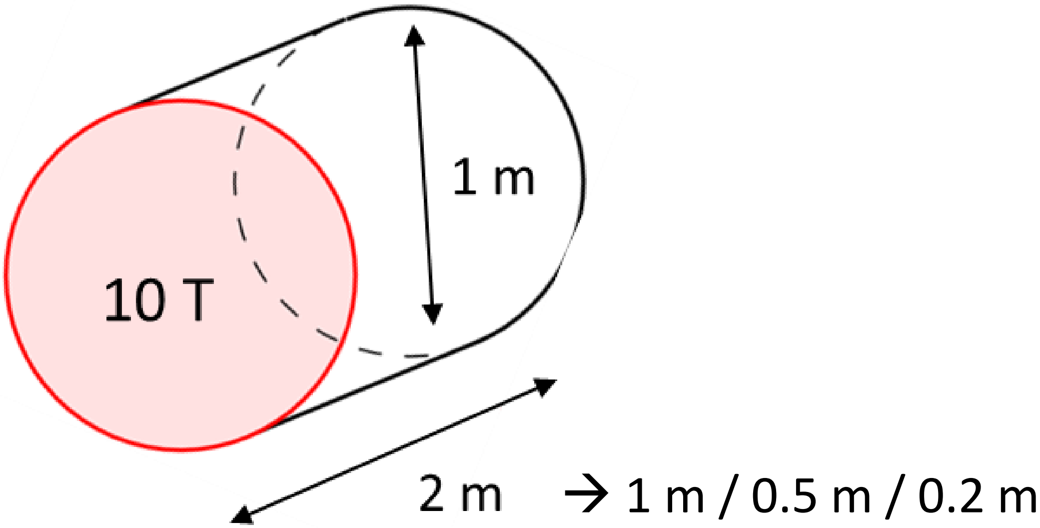


Study plan: reduced length study

Design update:

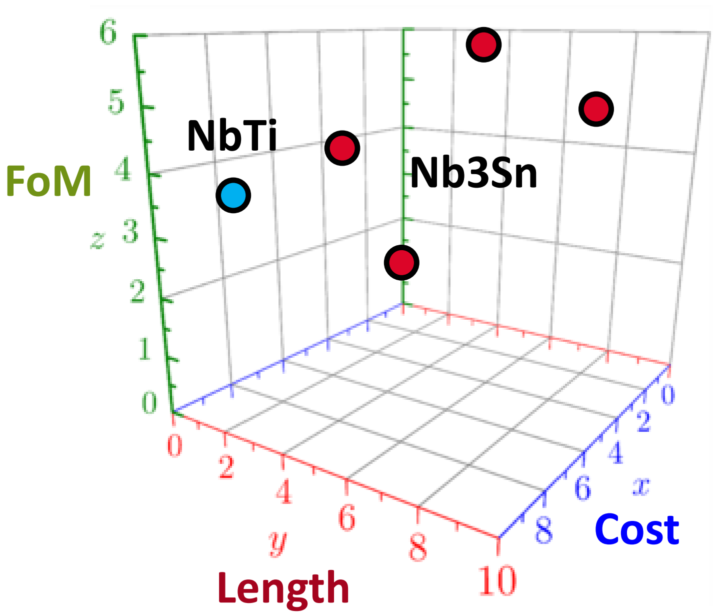
Update of the magnetic & mechanical computations for 3 new magnet lengths: 100 cm, 50 cm, 20 cm. This study will be made only for Nb3Sn concept.

Cost evaluation of the magnet for each length assumption



Study plan: Prototype design

All studies results



CEA/MPI meeting:
Choice of only 1 magnet concept

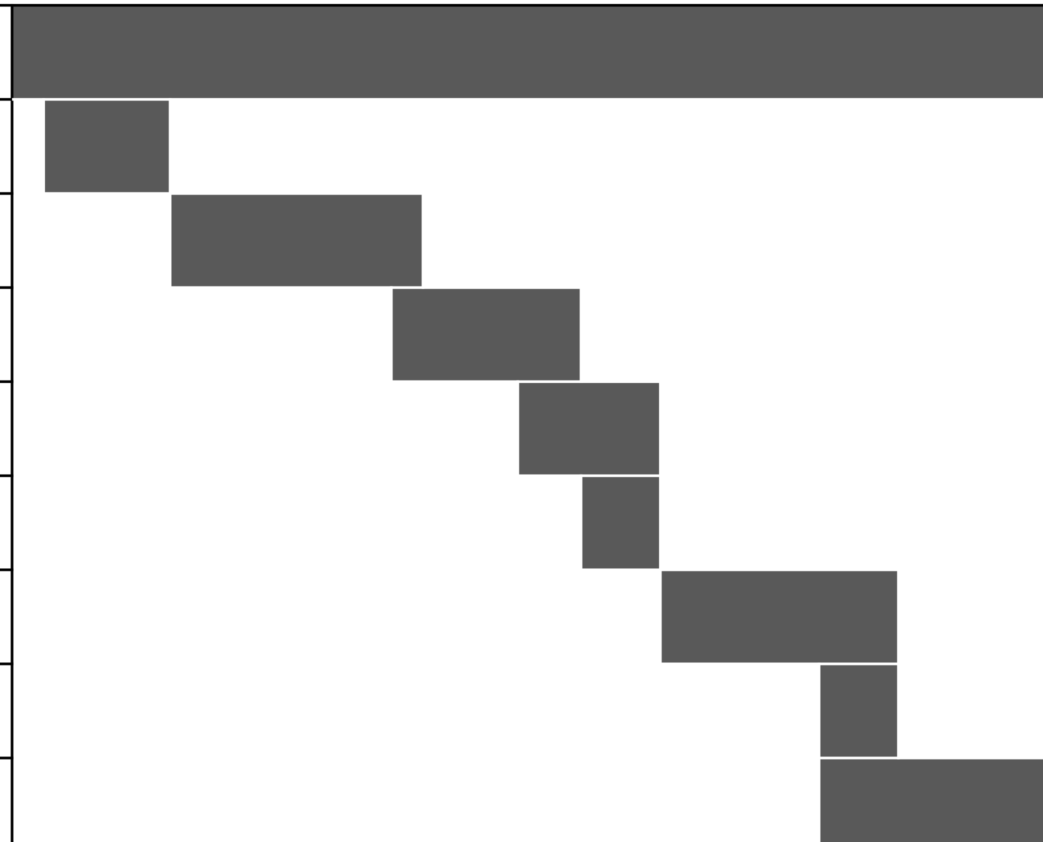
Prototype magnet design

The final chosen magnet concept will be used as a basis for making the design of a prototype able to demonstrate a FoM of 10 T^2m^2. This design will include: magnetic field calculations, protection and quench study, mechanical structure layout, cooling concept, geometrical dimensions.

Time schedule for final magnet manufacturing

Global implementation of the project: step 1

WP	WP title	DL	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
0	Management, follow up and reporting	T0+15															
1	Definition of technical requirements	T0+2.5															
2	Concept design of the Nb3Sn magnet	T0+6.5															
3	Maximum FoM with NbTi	T0+9															
4	Cost evaluation for both solutions	T0+10															
5	Reduced length cost evaluation	T0+10															
6	Prototype magnet study	T0+13															
7	Time schedule for manufacturing	T0+13															
8	Conceptual design review	T0+15															



Global implementation of the project: steps 2 & 3

Project step	Work phase	DL	S1	S2	S3	S4	S5	S6	S7	S8
2	Prototype detailed design	T1+1								
2	Prototype call for tender	T1+1								
2	Prototype Manufacturing	T1+3								
2	Prototype characterization	T1+4								
3	Magnet final design	T2+0.5								
3	Magnet call for tender	T2+0.5								
3	Magnet manufacturing	T2+2								
3	Magnet characterization	T2+2.5								
3	Magnet integration	T2+3.5								
3	Magnet commissioning	T2+4								

Questions ?

[CEA] : Send to MPI a list of technical requirements