Fast ramped dipole and DC quadrupoles design for the Beam Test Facility upgrade

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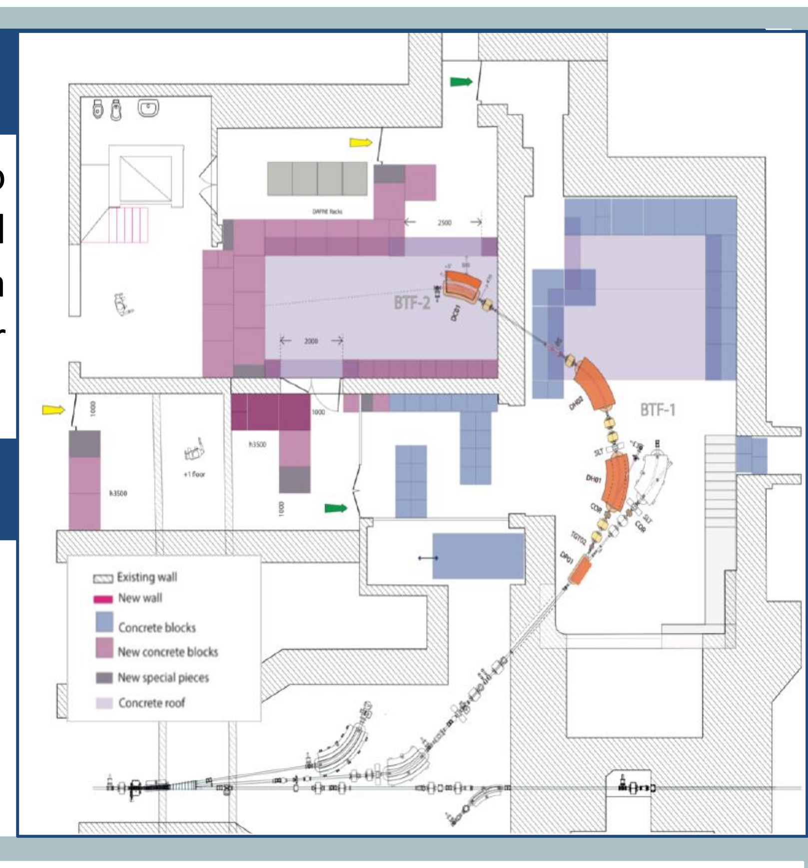
Background

The Beam Test Facility is part of the DAFNE accelerators system of INFN-LNF. It will be upgraded by adding a new branch to the present transfer line, in order to have two different beam lines into two experimental halls. For this purpose, the crucial element of the new configuration is a dipole driving the beam alternatively in one of the two lines (BTF-1 and BTF-2) with a bending angle of 15 degrees. The dipole switching time must be short enough with the minimum dead-time. This poster shows the design of the fast ramped dipole and of the quadrupoles. The other magnets are described in Poster [12].



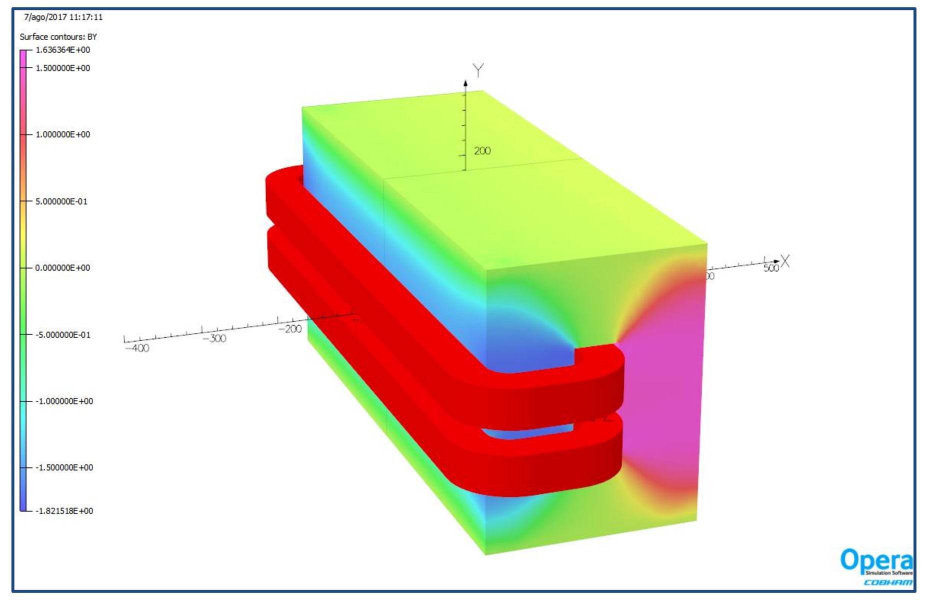
Objectives

- The main goal is to perform the complete design of the magnets for the BTF upgrade within the INFN, taking advantage of the long term expertise of Physicists and Engineers of the Accelerator Division and Technical Division of the Frascati National Laboratory, LNF.
- Boost the involvement of local Small and Medium Enterprises in the manufacturing of prototypes and small series of magnets, giving them the occasion of acquiring specific experience in magnet technology.

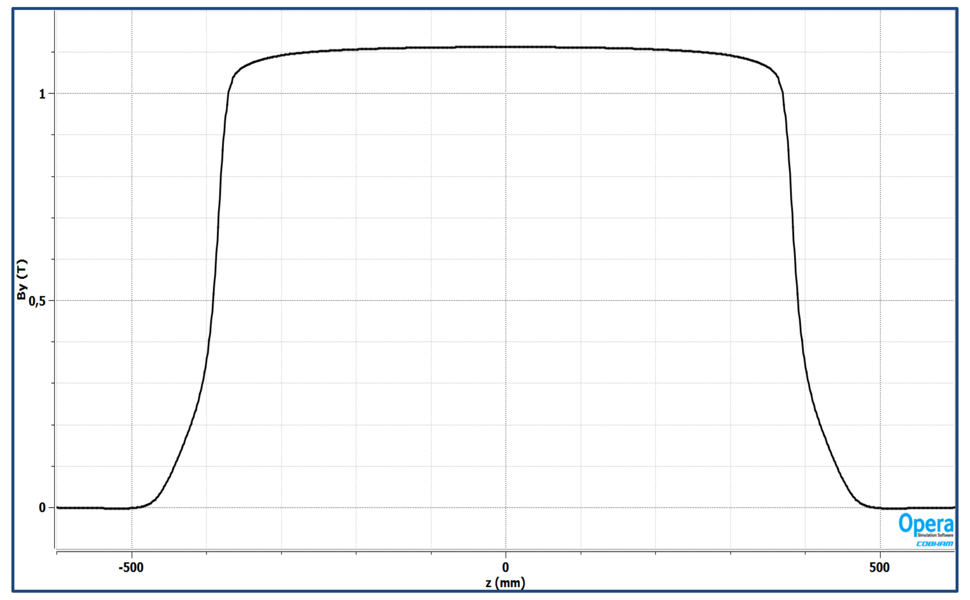
Fast Ramped Dipole

Electromagnetic design

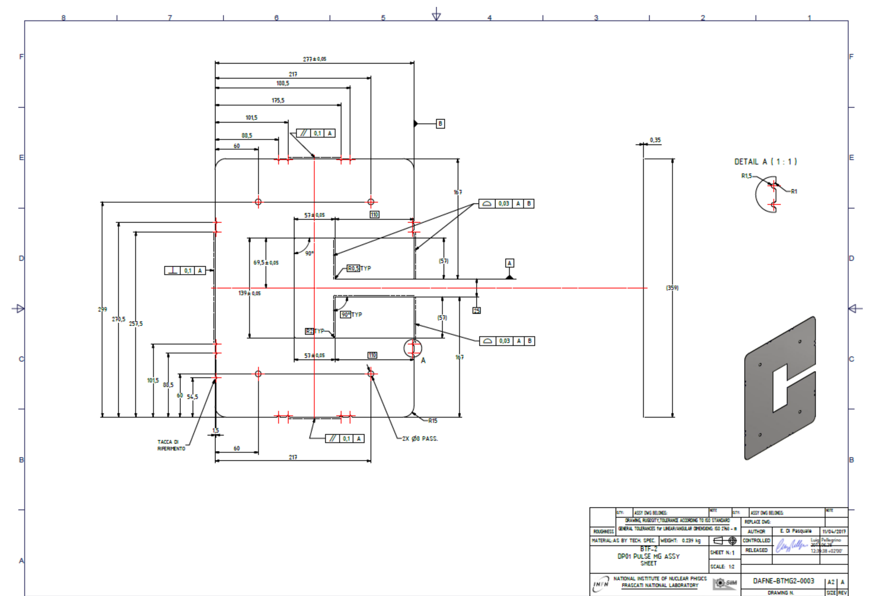
The general parameters of the magnet have been set by the study of the beam dynamics. Electromagnetic FEA simulations have been performed both with 2D and 3D software. The electromagnetic study allowed the optimization of pole size and length in order to comply with the requirements of integrated magnetic field and field quality. Error analysis both on transversal and longitudinal directions has been performed to fix the required manufacturing tolerances.



Schematic view of the magnet showing the saturation level.



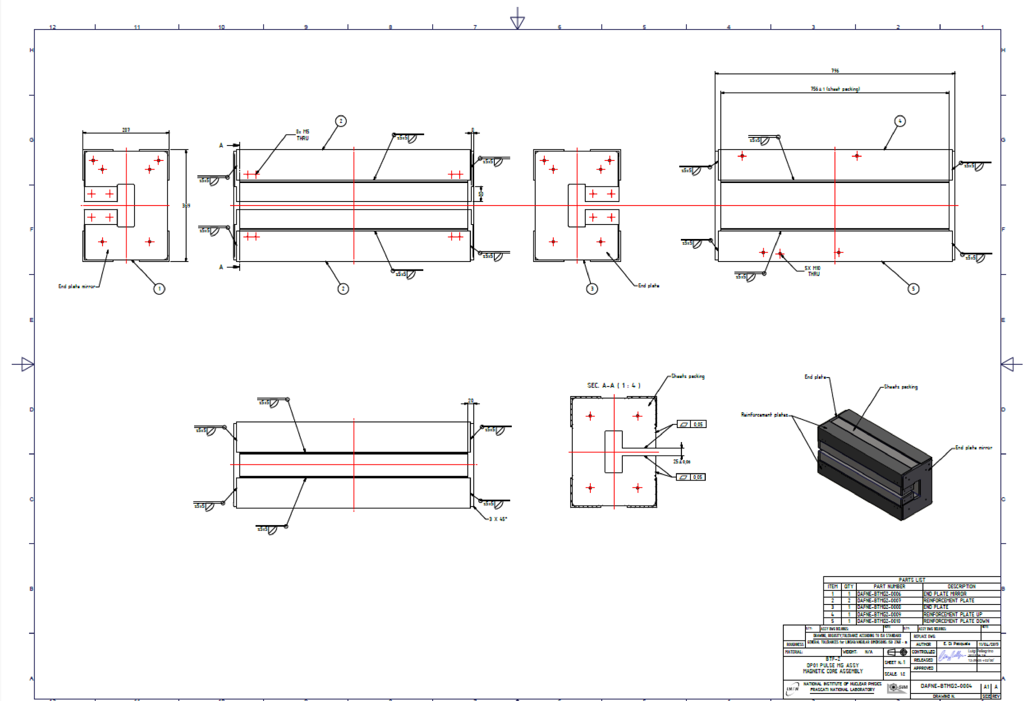
Longitudinal profile of the vertical field.



Drawing of the lamination with manufacturing tolerances.

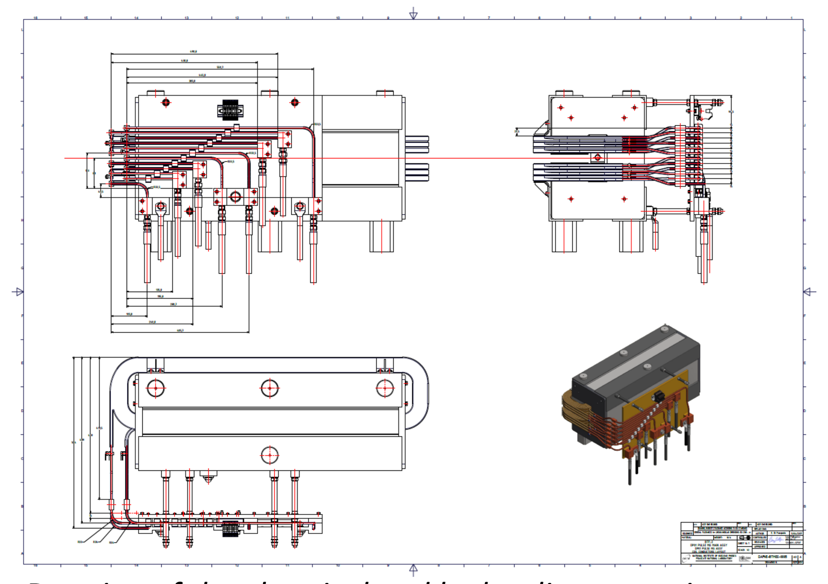
The magnet must be compliant with the pre-existing timing of the DAFNE accelerator. For that reason, and in order to comply with the dead time, the rise time must be of 100ms. Hence the yoke will be realized with laminations instead of full iron. The lamination thickness has been studied in detail.

The yoke is designed with about 2000 laminations of 350μm thickness. The insulation and bonding is going to be obtained with Stabolit 70. End plates of a-magnetic material have been designed in order to reduce eddy currents. Packing method has been studied in detail, taking into accounts the forces acting between the laminations.



Drawing of the assembled yoke.

Thermo-hydraulic design



Drawing of the electrical and hydraulic connections.

The cooling system of the magnet must be compliant with the present BTF plant. Hence the dimensioning of the hydraulic system has been performed in order to have a 3 bar pressure drop. The details of the cooling have been fixed.

The detailed list of parameters is reported in Table:

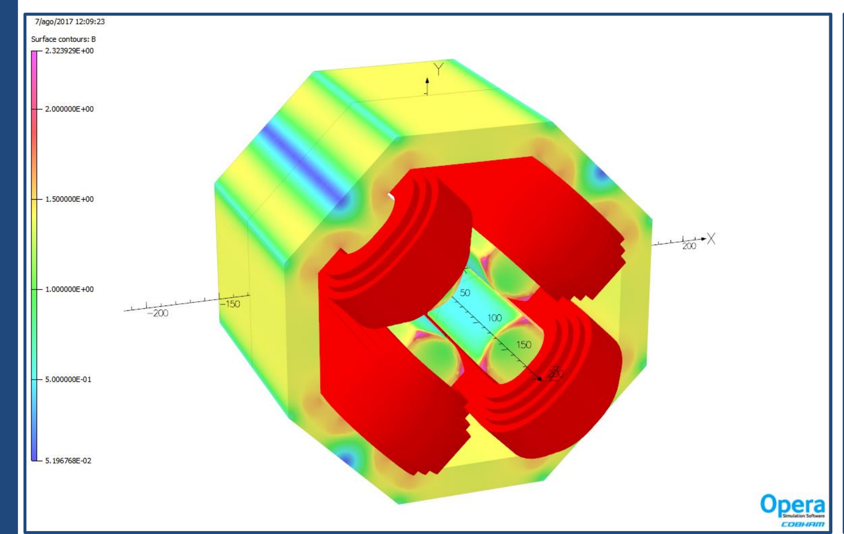
	Unit	Value
MAIN SPECIFICATION		
Beam energy	GeV	1
Nominal Magnetic Field	T	1.11
Bending angle	°	15
Pole iron gap	mm	25
Pole base width	mm	110
Magnetic length	mm	786
Yoke material		M270-35A
Integrated field quality (over ±15mm)		$2\ 10^{-3}$
COIL DATA		
Conductor dimensions	mm x mm	7x7 / bore ϕ 4mm
Number of turns per pole		36
Cooling water pressure drop	bar	3
ELECTRICAL INTERFACE		
Nominal Current	A	316
Magnet Resistance	mΩ	78
Magnet Inductance	mH	29
Nominal Voltage	V	122
Power	KW	7.8

Conclusions

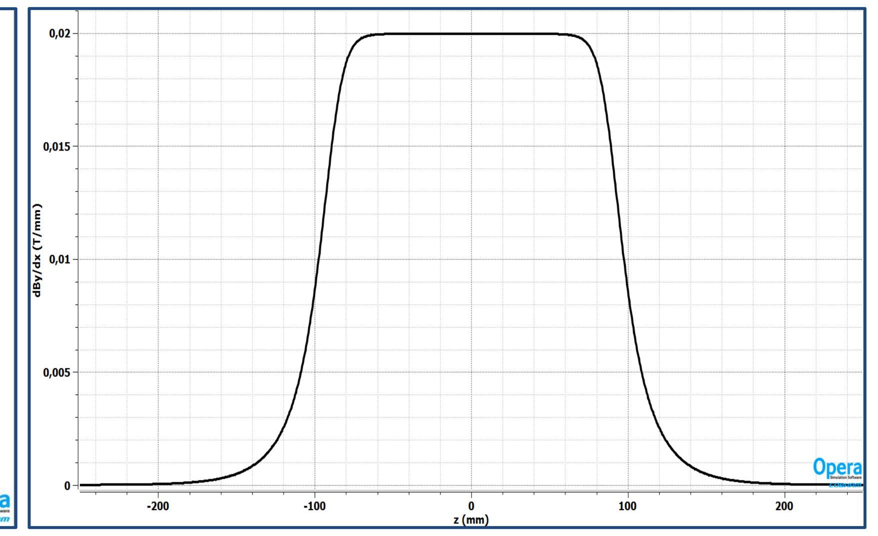
- The design of the magnets has been completely performed at INFN, including electromagnetic, mechanical, thermal and hydraulic aspects. A complete set of detailed CAD drawings has been produced.
- The manufacturing processes have been studied in detail in order to reduce the fabrication costs.
- The fast ramped dipole has been already commissioned to an Italian industry. The delivery is foreseen in winter 2018. The design of quadrupoles is going to be finalized in fall 2017.
- Magnetic measurements will be performed at INFN-LNF. The magnetic measurements laboratory is equipped with a Hall digital teslameter with a 5 axes movement device mounted on a granite bench, a rotating coil, a nuclear magnetic resonance teslameter.
- Installation and commissioning are planned in Spring 2018.

Quadrupoles

The quadrupoles will be realized in full iron AME. Preliminary calculations led to the choice of the main parameters needed to obtain the required gradient. 2D simulations have been used to optimize the pole profile, with facetted hyperbolic shape. 3D simulations have been performed to fix the yoke length taking into account the desired magnetic length.



Schematic view of the magnet.



Longitudinal profile of the field gradient at radial position x=10mm.

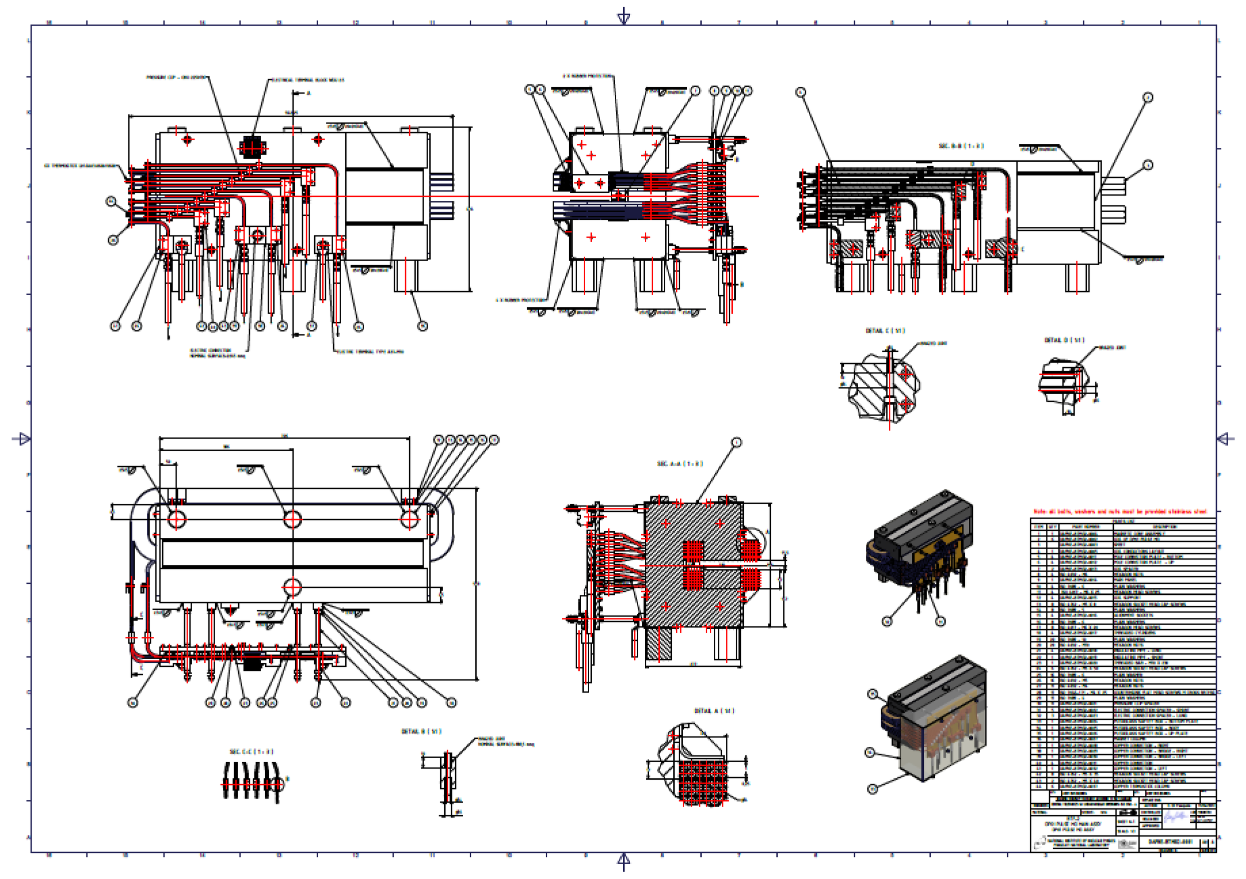
The electromagnetic design includes also the analysis of harmonic content and its optimization. In particular, detailed study of the chamfering needed to reduce the 12-pole term has been performed.

	Unit	Value
MAIN SPECIFICATION		
Nominal Gradient	T/m	20
Bore	mm	45
Magnetic length	mm	200
Pole width	mm	45
Integrated quality (r=15mm)		$5\ 10^{-3}$
COIL DATA		
Conductor dimensions	mm x mm	5x5 / bore ϕ 3mm
Number of turns per pole		46
Cooling water pressure drop	bar	3.5
ELECTRICAL INTERFACE		
Nominal Current	A	88
Magnet Resistance	mΩ	110
Magnet Inductance	mH	22
Nominal Voltage	V	11
Power	KW	0.97

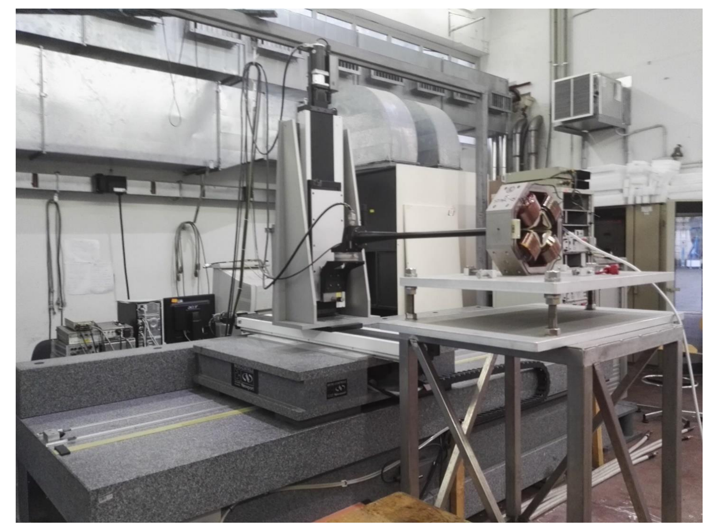
Mechanical design and Magnetic measurements

Detailed CAD Drawings

The result of the full design of the magnets is a complete set of CAD drawings. They describe in detail all the features of the magnets, including the yoke, the coils, the electrical and hydraulic connections. All the materials and tolerances have been defined. This work also aims to transfer our specific knowledge in magnet technology to the companies participating to the bid for the construction.



Magnetic Measurements Lab



Hall digital teslameter.

Rotating coil.

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