Topological optimization for accelerators R&D

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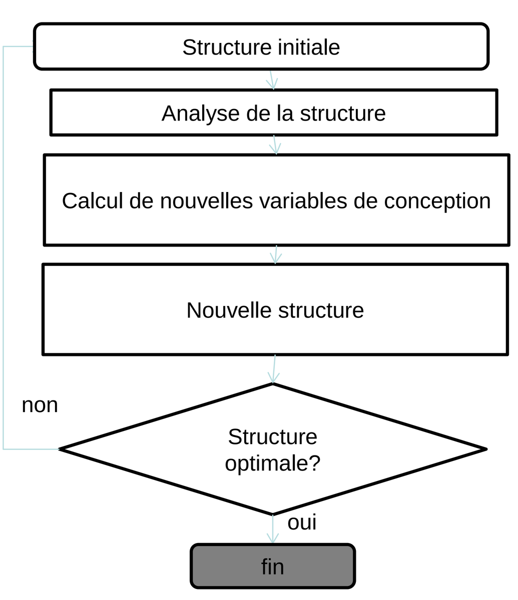
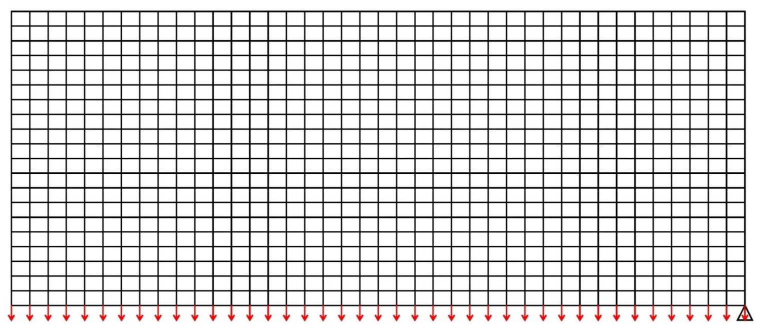
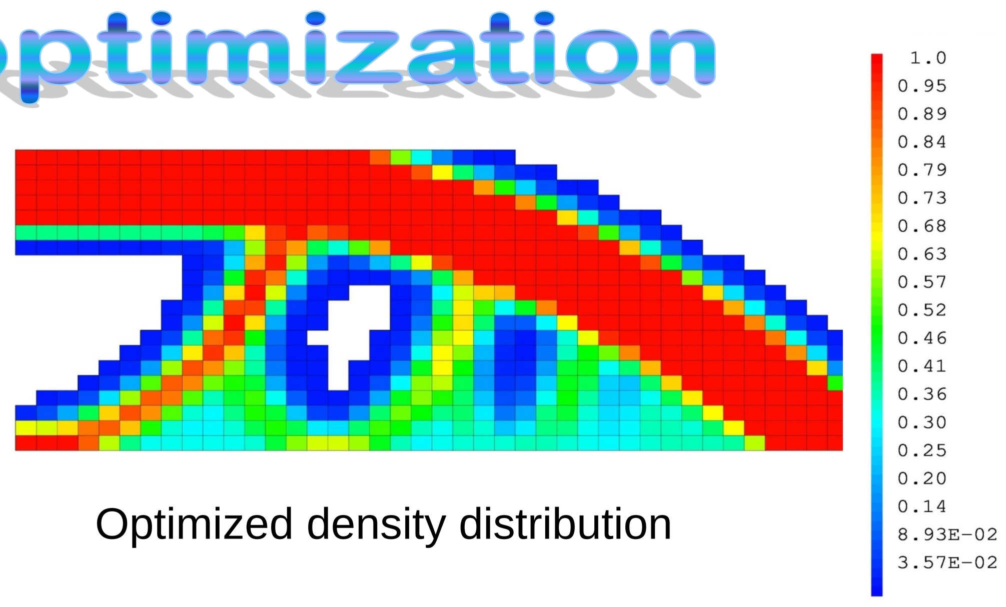
Within the program of 3D metal printing supported by in2p3 [1], the studies by topological optimization for the accelerator components have been associated [2]. This innovative activity is challenging for R&D accelerator. For example, the design of superconducting cavities for accelerator should always take into account the compromise between the cavities stiffness as well as a reduction of Niobium consummation which is potential interest of 3D metal additive manufacturing. To perform topology optimization tasks, some simulation codes have been evaluated. The simulations are performed on a 9 cell 1,3 GHz niobium prototype. The topological optimization associated with 3D metal additive manufacturing project has promising interest in terms of reduction of Niobium thickness and the cost of stiffening system.

Topology optimization





Distribued charge on a bridge,



Optimized density distribution

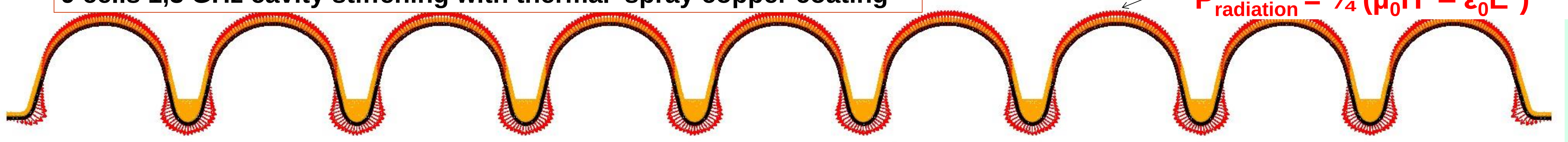
The reduction of material is essential for industriel production of an instrument. The validation of our topological optimization is realized for a bridge. The simulation code [3] is based on optimal criteria which take as the objective function to be minimized the compliance under mechanical constraint [4]. The optimized mass distribution is illustrated with a volumic density of 0,3.

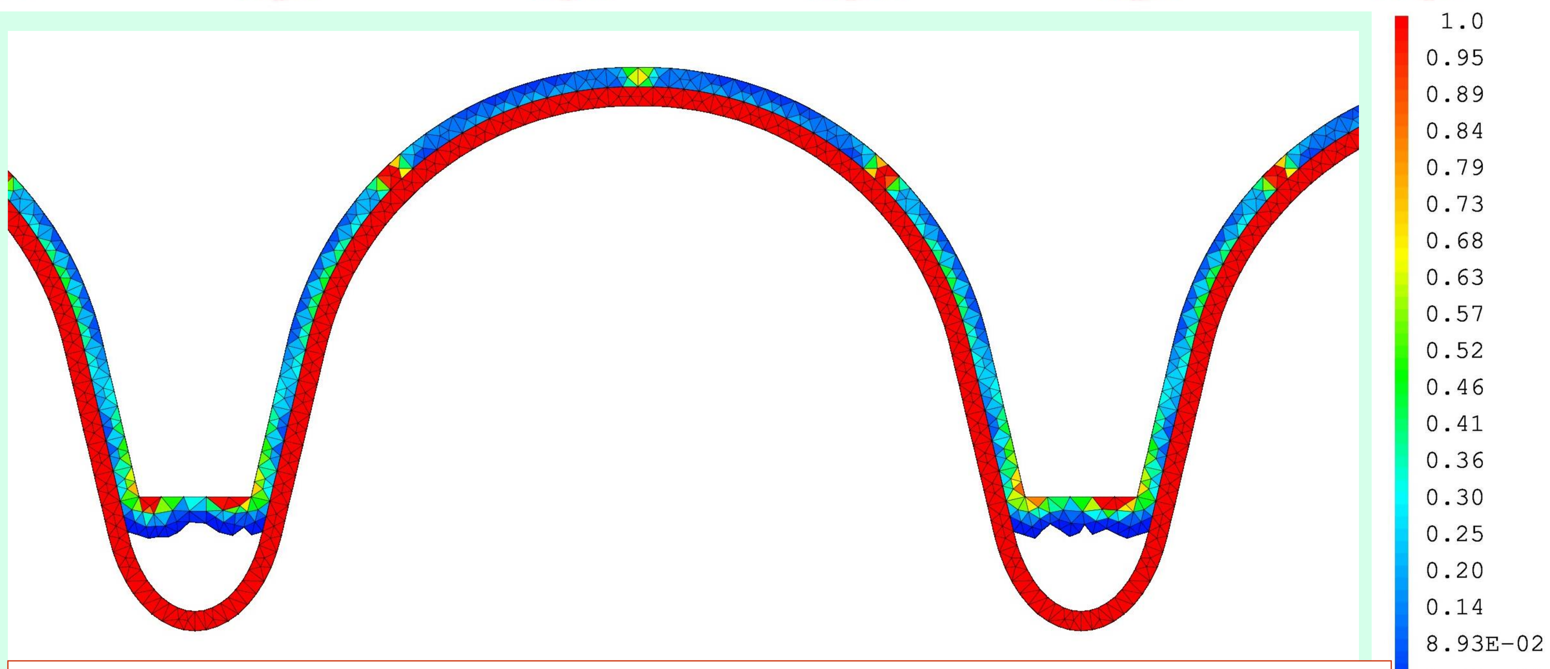
R&D accelerator: topology optimization and 3D metal printing

QF parameters	Values
Oprerating T	2 K
E_{acc}	25 MV/m
E_{pk}/E_{acc}	2
B_{pk}/E_{acc}	4,26 mT/(MV/m)
Q_0	$5x10^9$
G	270 Ω
frequency	1,3 GHz
β	1

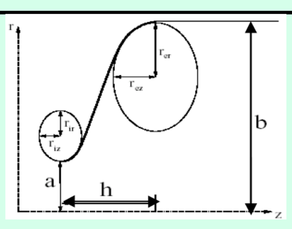
Example of optimization	
Objectif function	Compliance minimization
contraint	Distributed pression
Mass density	0,6

9 cells 1,3 GHz cavity stiffening with thermal spray copper coating





Topological optimization for 3D metal additive manufacturing

Unit: mm 	Outer ½ cell pick up side	Inner ½ cells	Outer ½ cell tuner side
External radius	103,3	103,3	103,3
Iris radius	35	39	39
length	57,7	56	57
Ellipse_equator Rer	55.7	44.7	39.5
Ellipse_equator Rez	53	47.1	41.6
Ellipse_iris Rir	12,8	19	13,5
Ellipse_iris Riz	9,	12	10,

The stiffening system of 9 multicell 1,3GHz cavity is made of the stiffering rings at maximal deformation positions calculated by multiphysics simulations. With topological simulations, the optimal stiffering positions are automatically find. Comparing to stifening system realized by thermal spray coating technology, topological simulations show that 3D metal printing technology can save material and represent a more advangageous one step solution. However, Niobium-based 3D printing is still challenging since it is still a confidential research subject. It started at CERN from 2018 [2]. Other investigations are necessary to improve niobium 3D additive manufacturing technology for cavities performances.

Conclusions: in terms of structure design, the 3D additive manufacturing change the way of simulation. The goal is to find a good distribution of the material for given boundary condition with single load case or multi load cases. Since several years, many finite element codes have implemented some topology optimization routines, especially the linkage with CAD code. These activities are still in development as 3D additive manufacturing.

Références:
[1] « Prospective sur la FA à l'IN2P3 », S. Jenzer, journées accélérateurs de la SFP, oct. 2017
[2] Colloque fabrication additive Physique des deux infinis, Orsay, déc. 2018
[3] Cast3M, http://www-cast3m.cea.fr
[4] « A 99 line topology optimization code written in Matlab, Structural and Multidisciplinary Optimization », O. Sigmund, 21 (2001) 120-127