A Study of PBG Cavity Systems : some devices for accelerating high energy, high intensity beams

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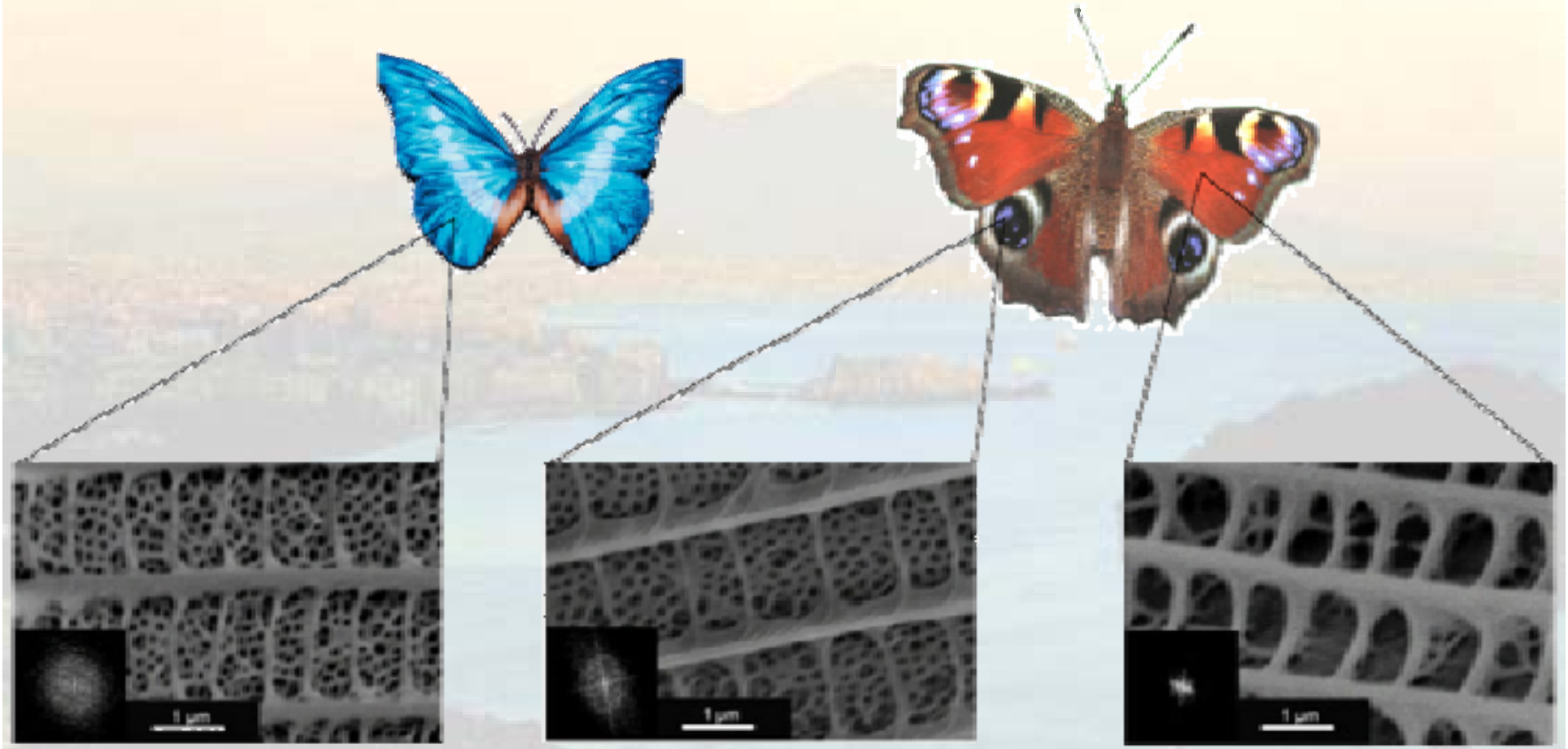
Photonic Band Gap Accelerator Cavities

Natural photonic band gap structures

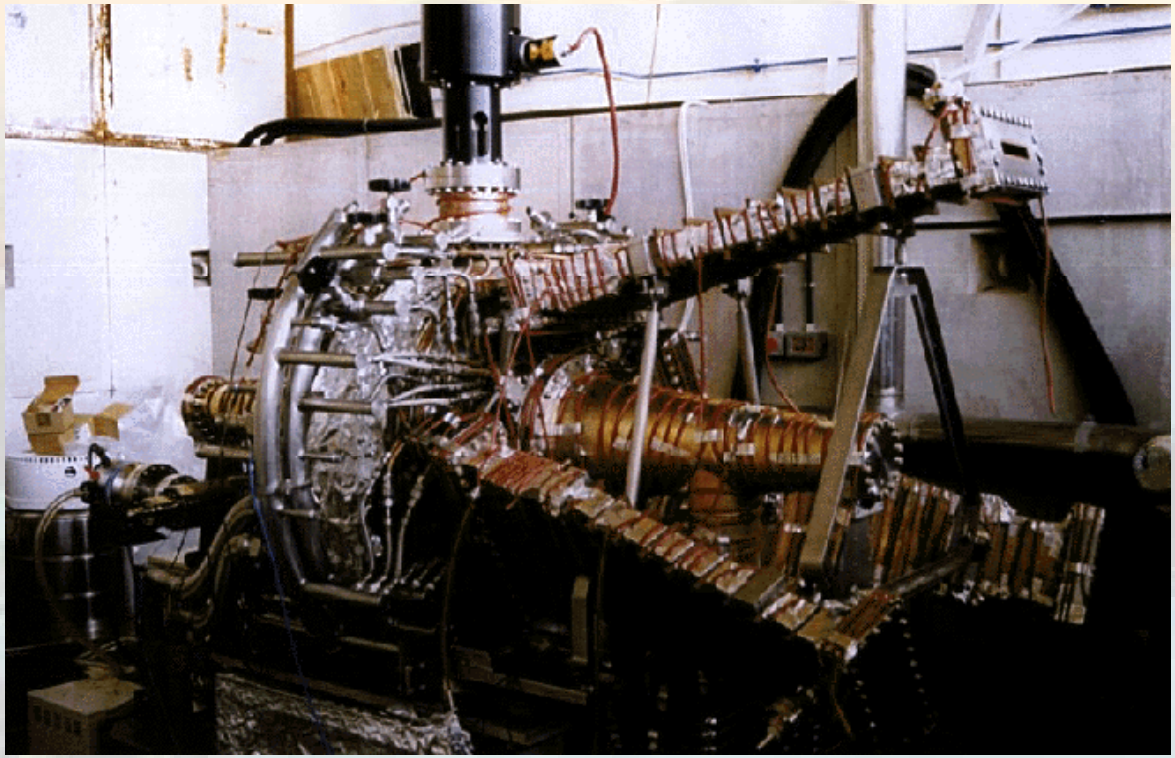


The Bragg diffraction induced by photonic structured butterfly wings filters the light spectrum reflecting the wavelenghts in the band gap: this produces various color effects

In Quest of Monomodal Cavities…….

Brute Force:

Cavity with External Waveguides. Not exportable to high frequencies

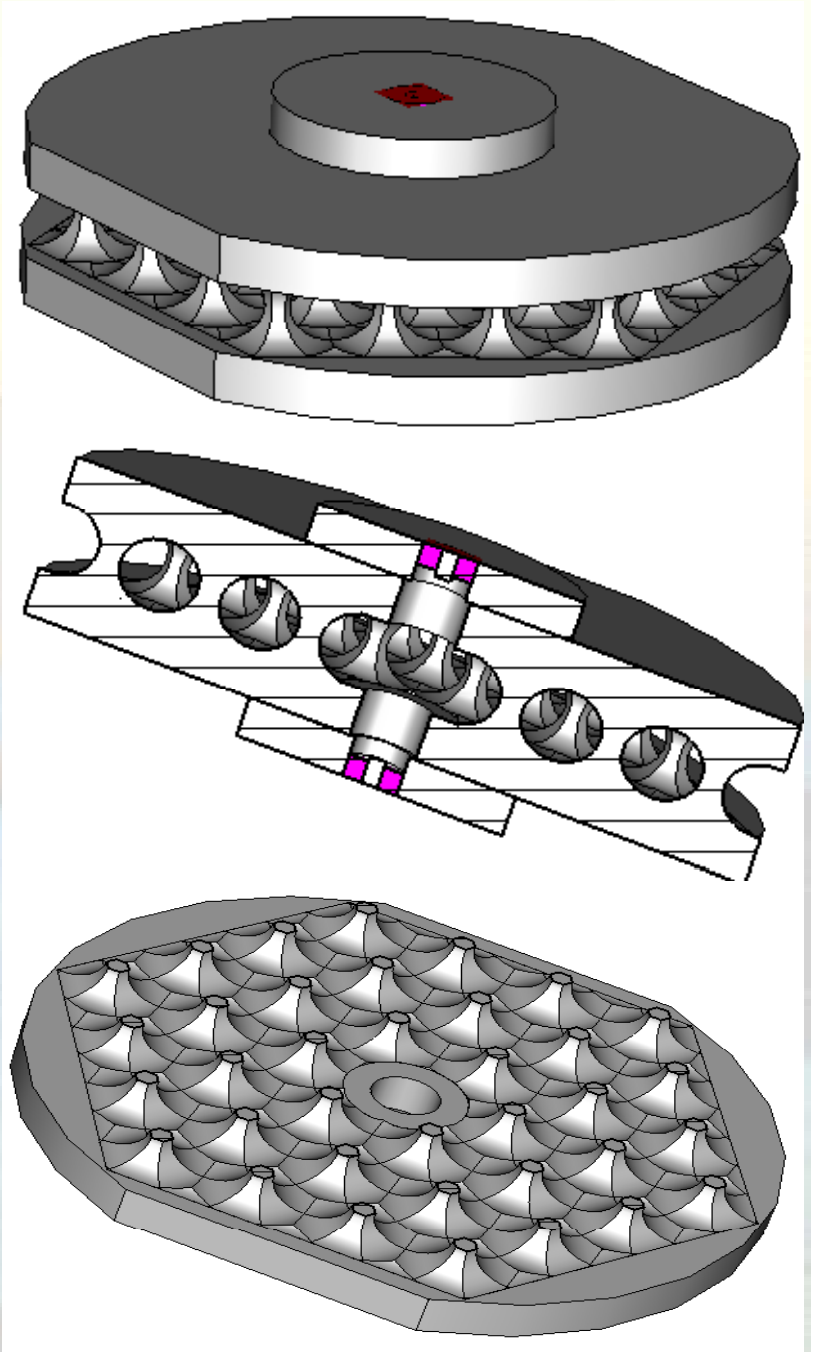


A DAΦNE accelerating cavity

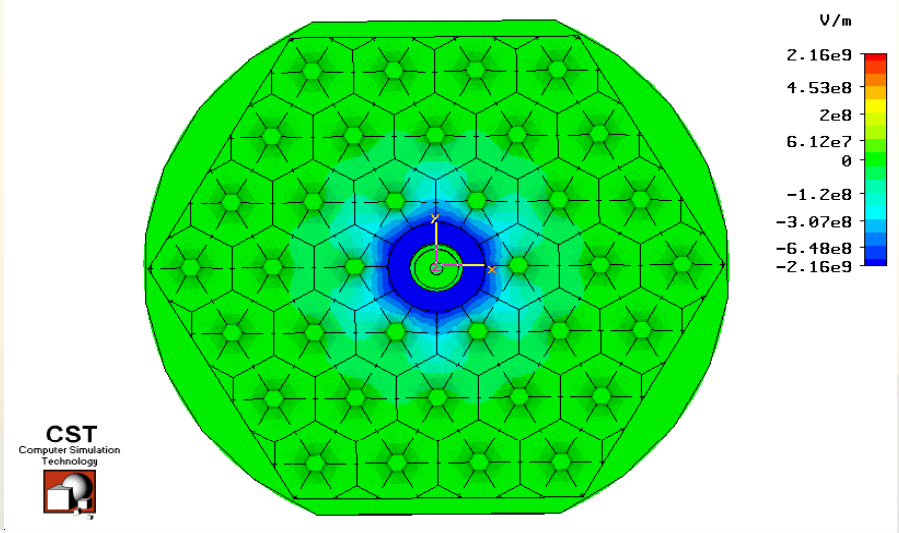
From the lattice of the crystals a First Solution:

a Metallic Cavity from bulk material

Cavity parameters	Dimensions [mm]
Lattice pitch (b)	7.5
Column thickness (a)	0.75
Column height	5.0
Bore radius	2.5
Defect zone width	14.25



SIMULATIONS RESULTS

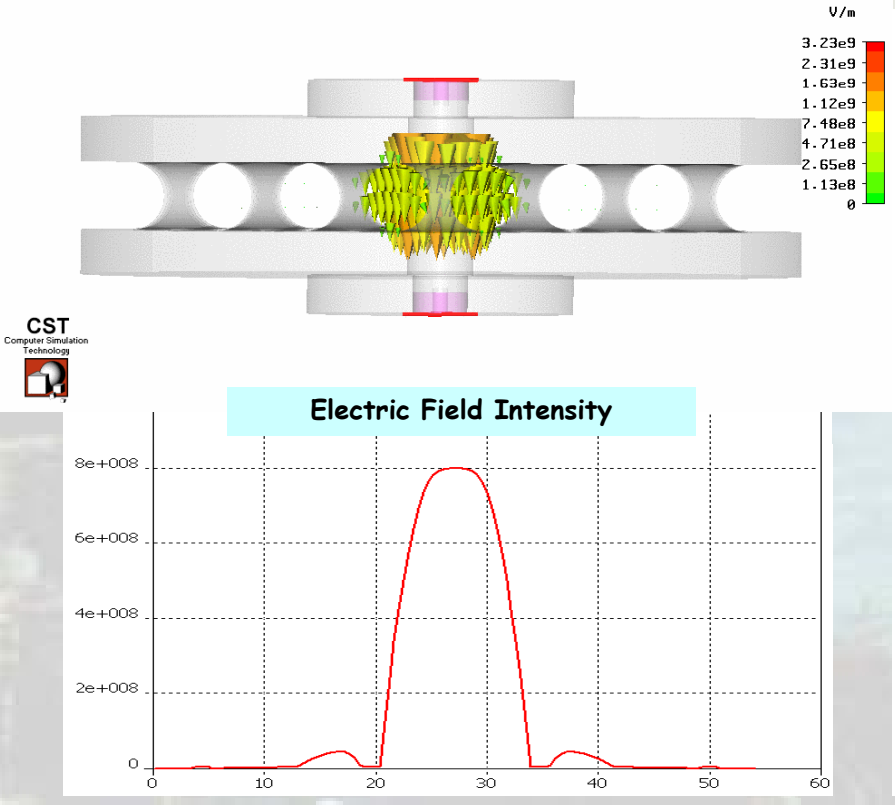


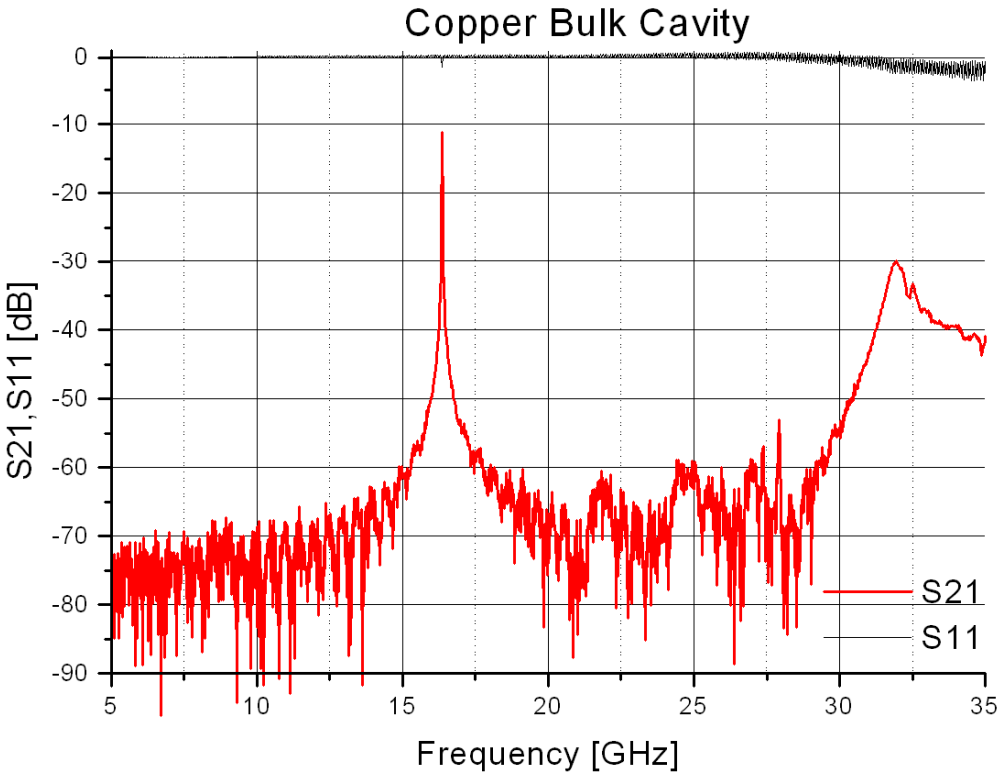
Fundamental mode

- confined in the defective zone
- resonance frequency: 16.28 GHz

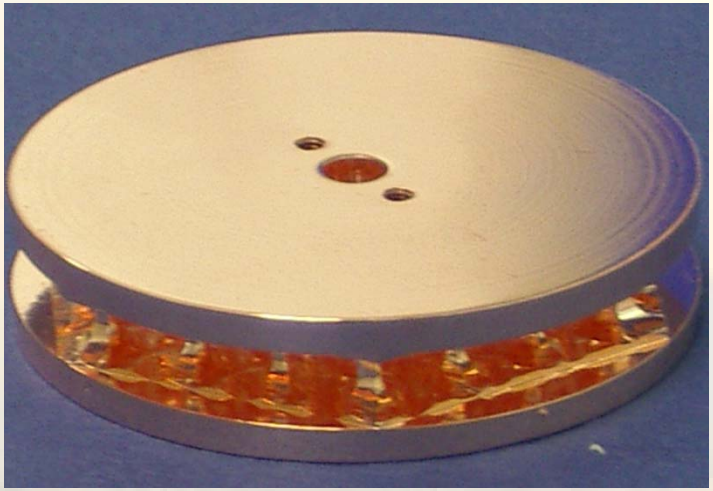
Higher frequency modes

- at least 20dB below the first mode





Niobium and Copper prototypes



The machining technique from a single piece of bulk material ensures that no conducting losses, due to poor electrical contact or local surface defects, are present.

The prototypes were tested in a wide range of temperature and at very low temperature.

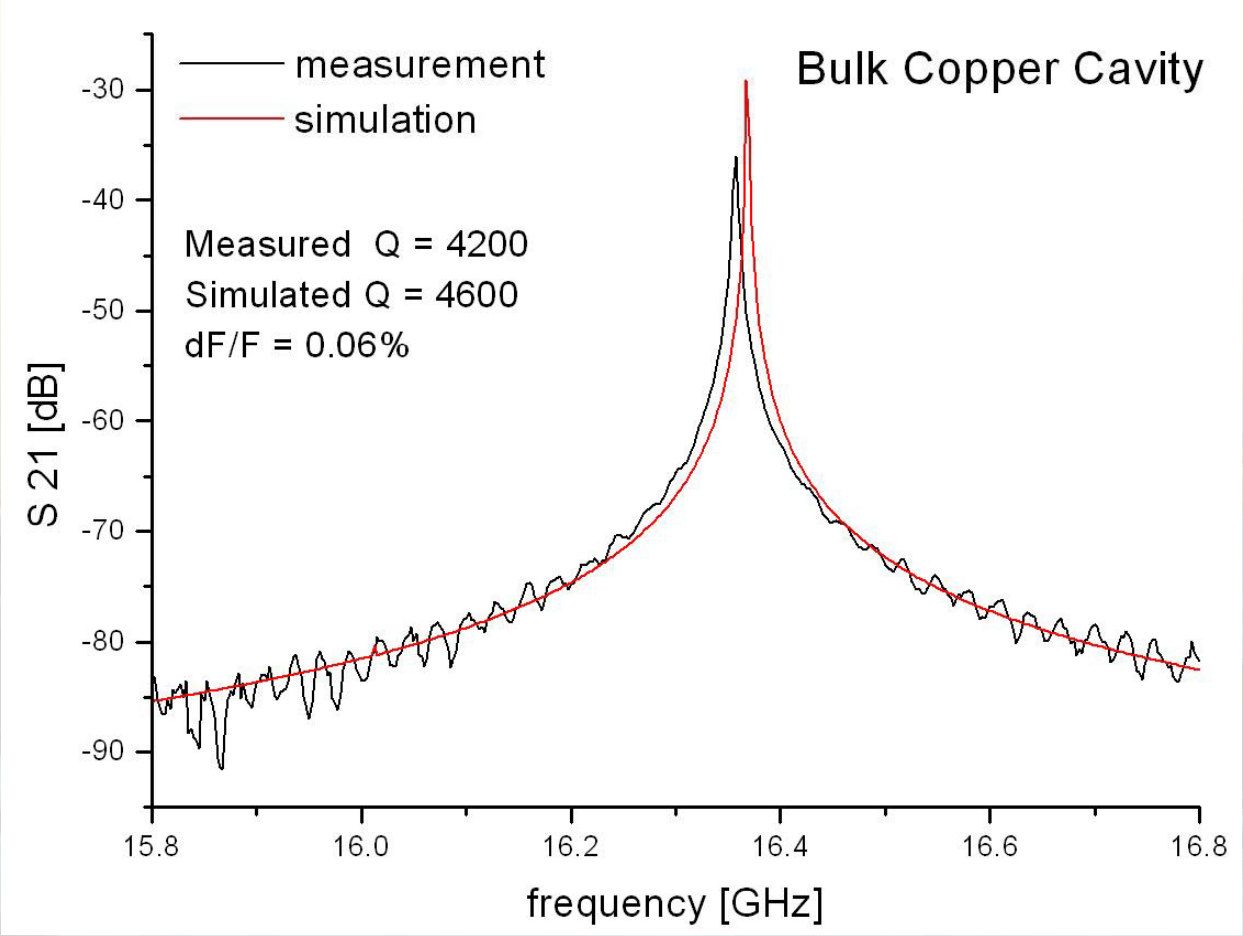
COPPER

f_0 = 16,356 GHz

NIOBIUM

f_0 = 16,068 GHz

Copper prototype



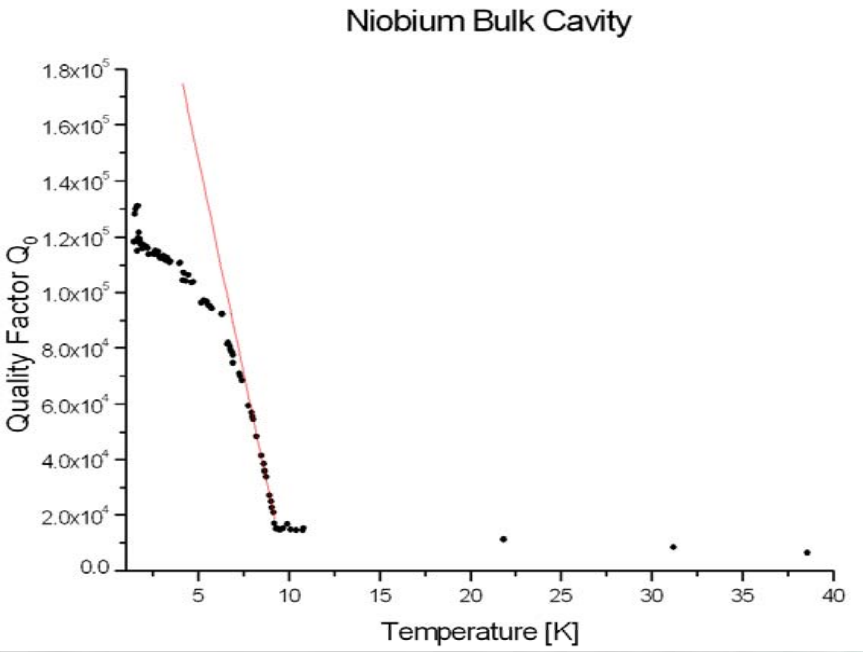
Measured and simulated transmission coefficient at room temperature

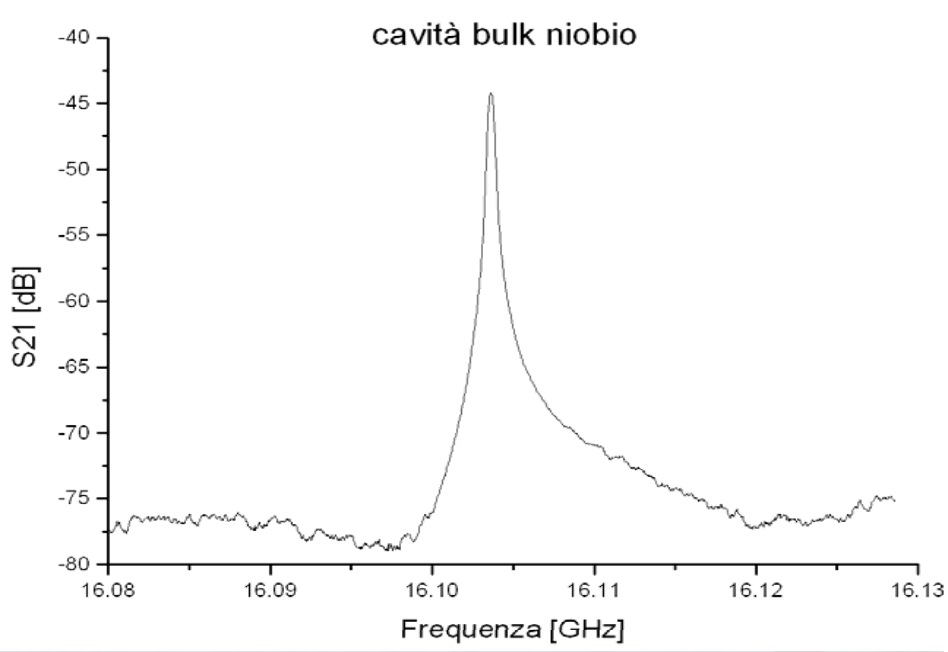
Niobium cavity : Cryogenic measurements (down to 1.5 K)

Max quality factor $Q_m = 1.2 \cdot 10^5$ ($Q_{th} = 1.35 \cdot 10^5$)

$$\frac{1}{Q_m} = \frac{1}{Q_c} + \frac{1}{Q_r} \approx \frac{1}{Q_r}$$

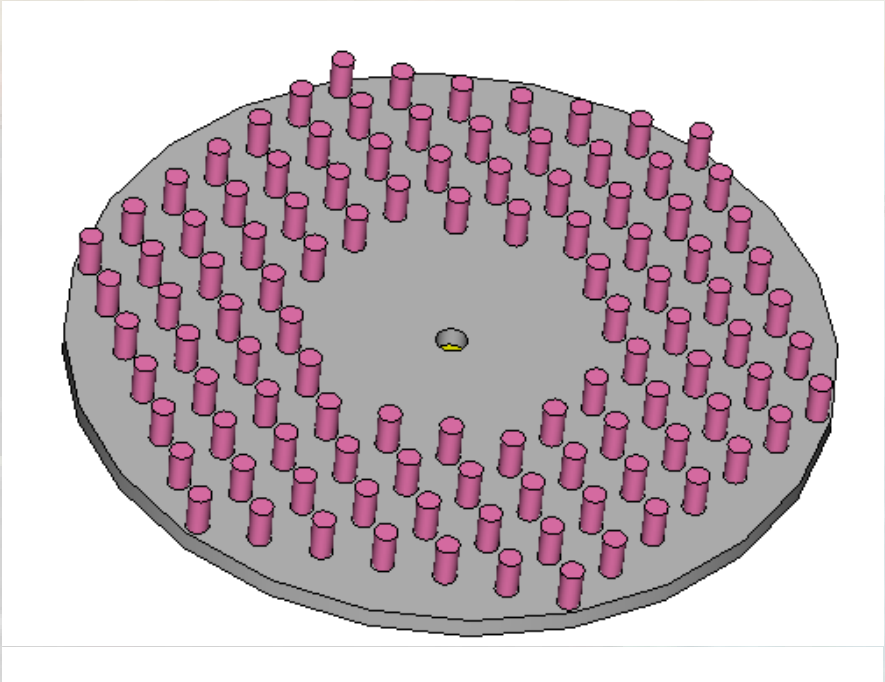
The philosophy of the measurement was to verify the numerical results obtained for a PEC structure. In the superconducting state the Q is limited by radiative losses only.

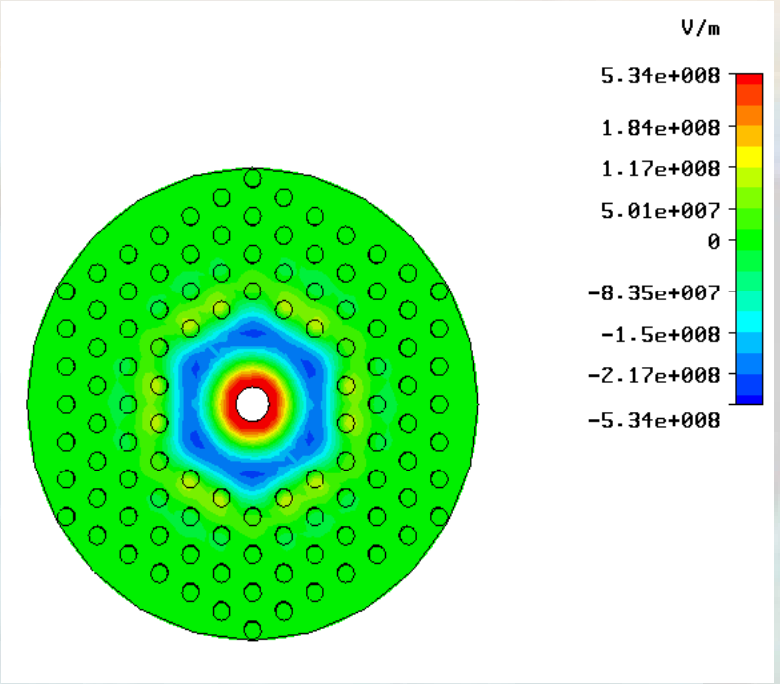




From the lattice of the crystals a Second Solution:

dielectric colonnade sandwiched between two metal plates (Hybrid PBG)





Peculiarities of Hybrid PBG

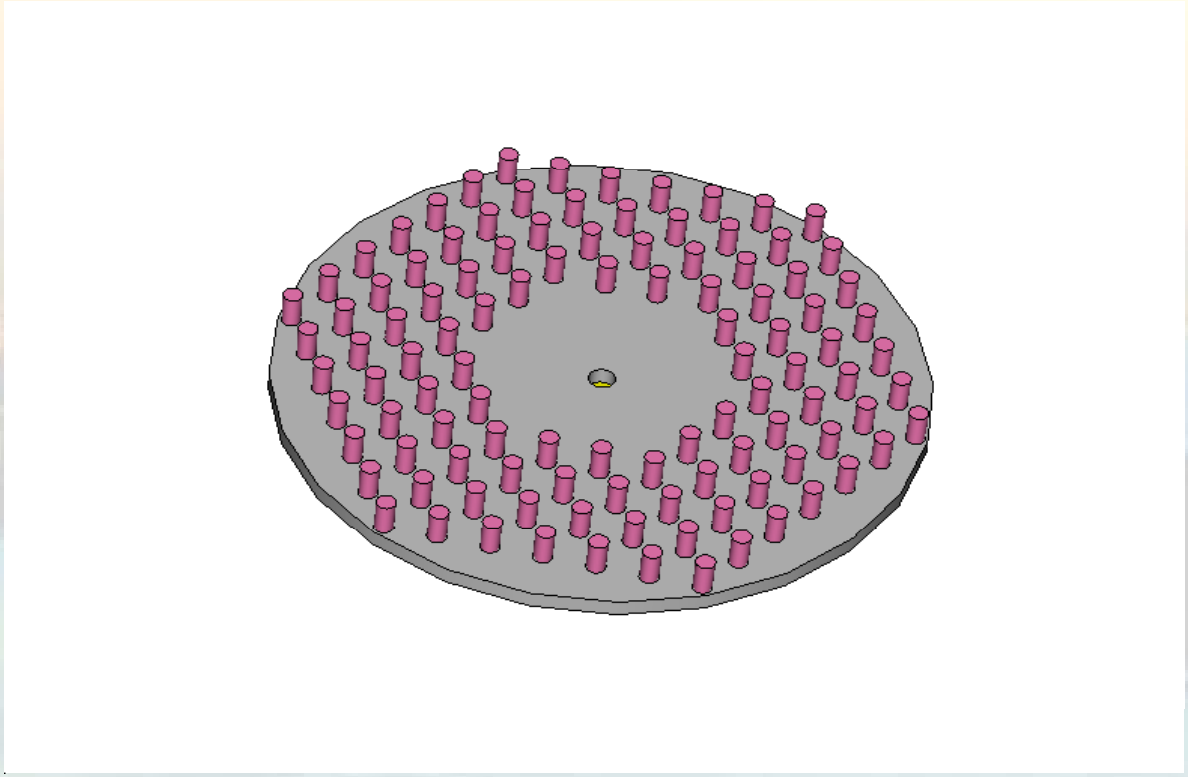
- Even if the fabrication requires sofisticated tools, the device may easily reach higher performances: components may consist in long dielectric cylinders traversing metallic plates. If possible one may resort to superconductive material.
- However, this is a technology to which one cannot resort in home-made production

Hybrid PBG: Prototype Parameters

Dielectric cylinder radius	a = 0.15 cm
Lattice pitch	b = 0.8 cm
Dielectric constant of cylinders	ε = 9.7
Height of the cylinders	h = 0.6 cm
Plate diameter	d = 12 cm

Central Defect

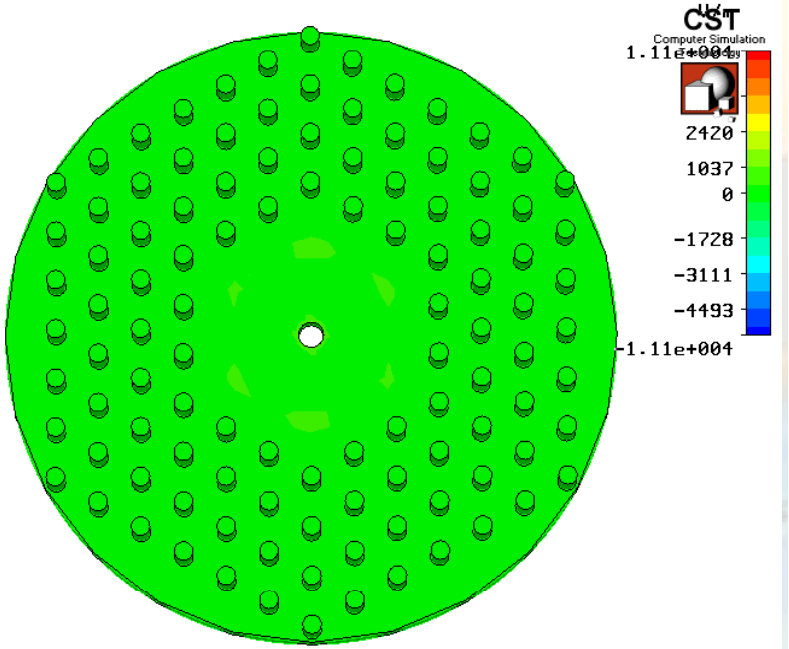
Dimension of the defect: $6b - 2a = 2\lambda$

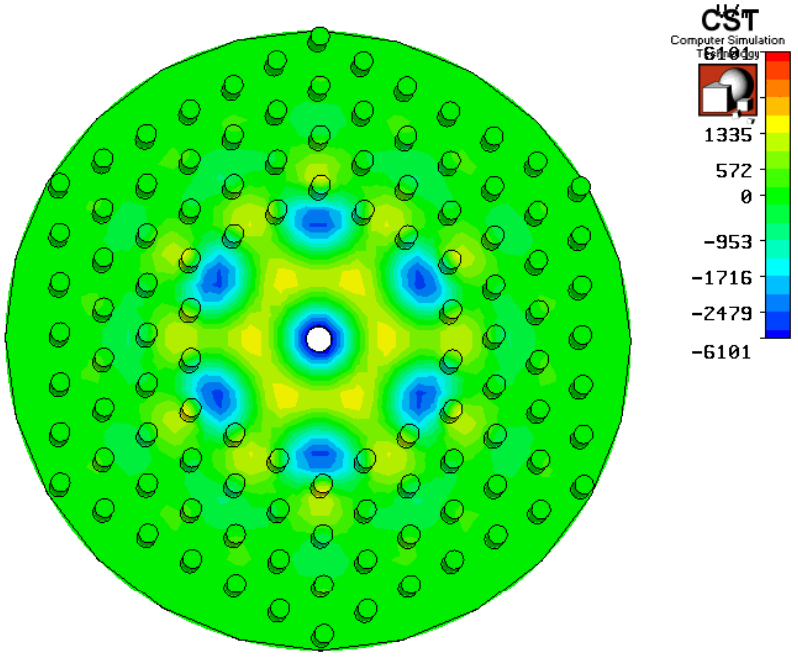


Confinement of
Mode TM_{02}: good for acceleration

Simulations: the first two modes

Modal analysis



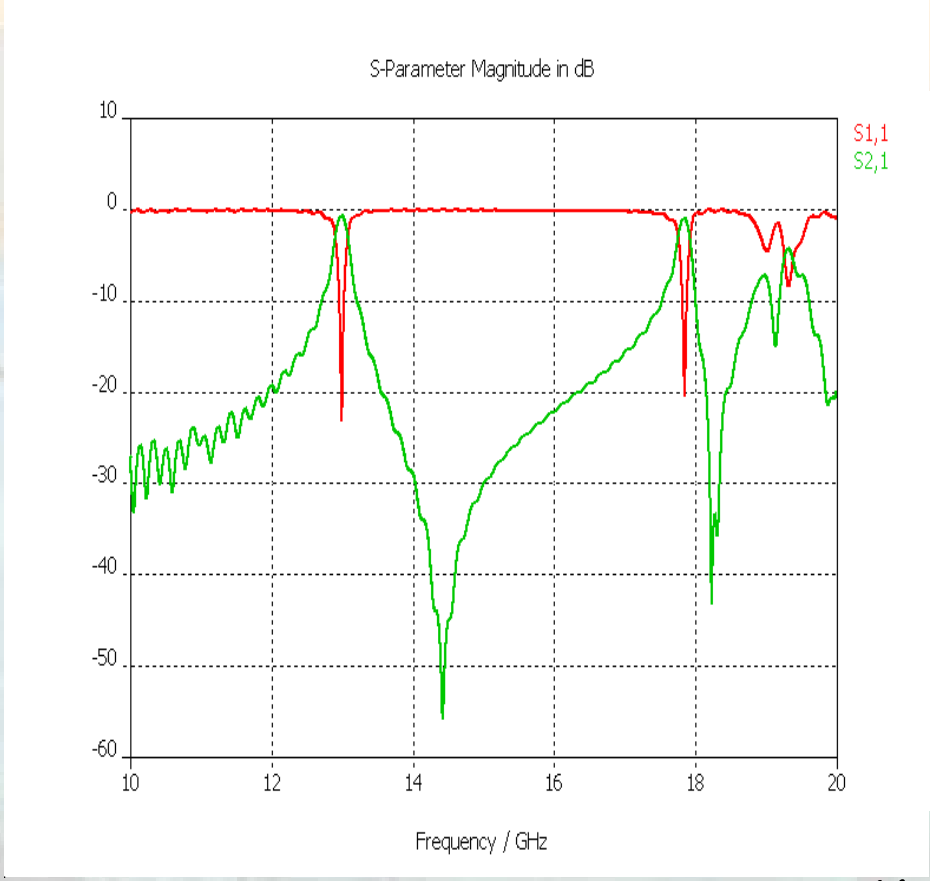


f = 12.9845 GHz

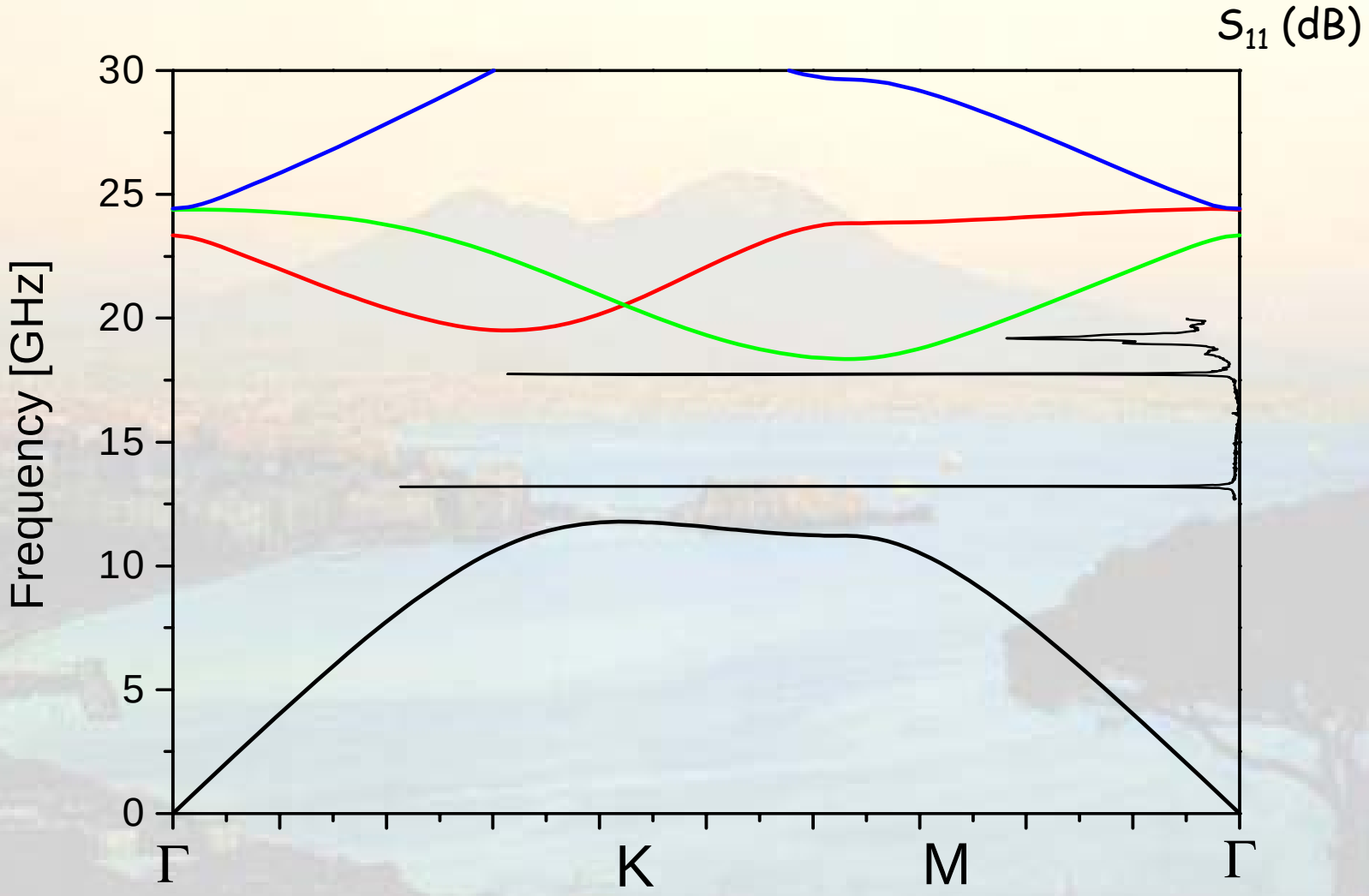
f = 17.813 GHz

Scattering parameters from the simulations

Lenght of the pin in the simulation = 0.4 cm



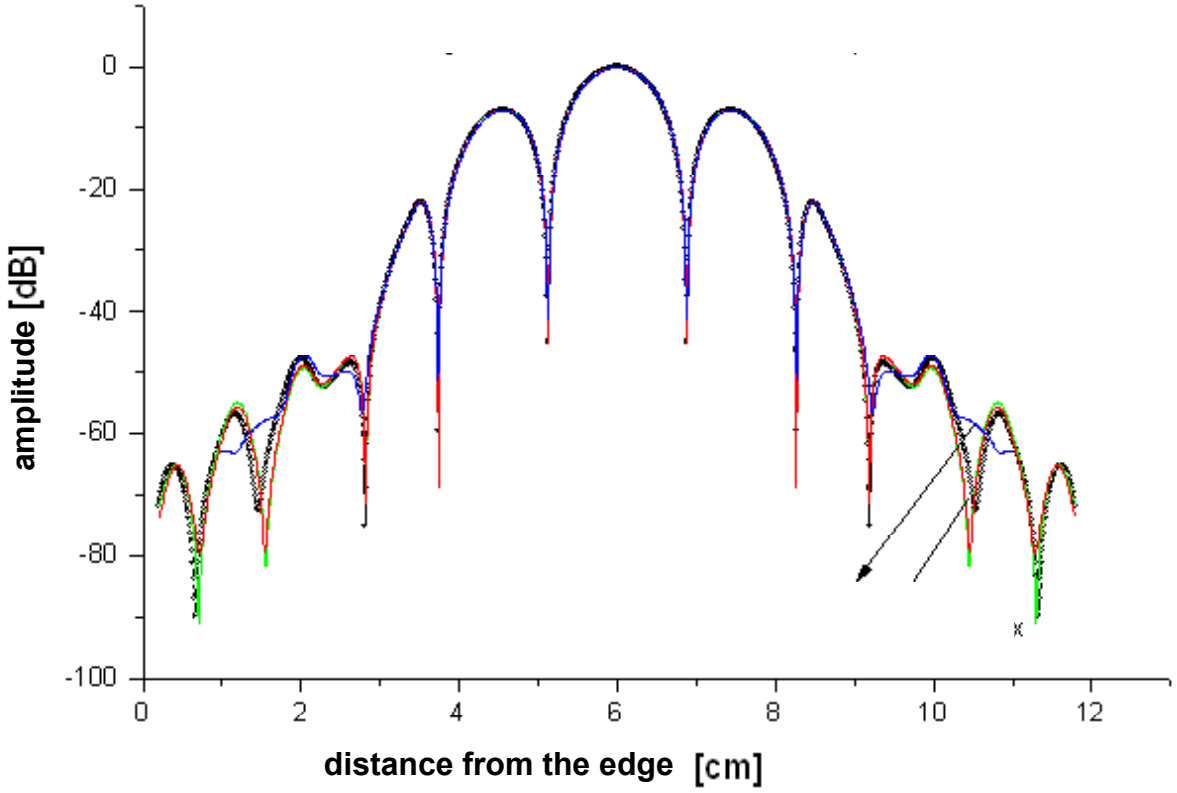
The Brillouin diagram of the hybrid PBG cavity (TM polarisation)



Confinement analysis of the fundamental mode

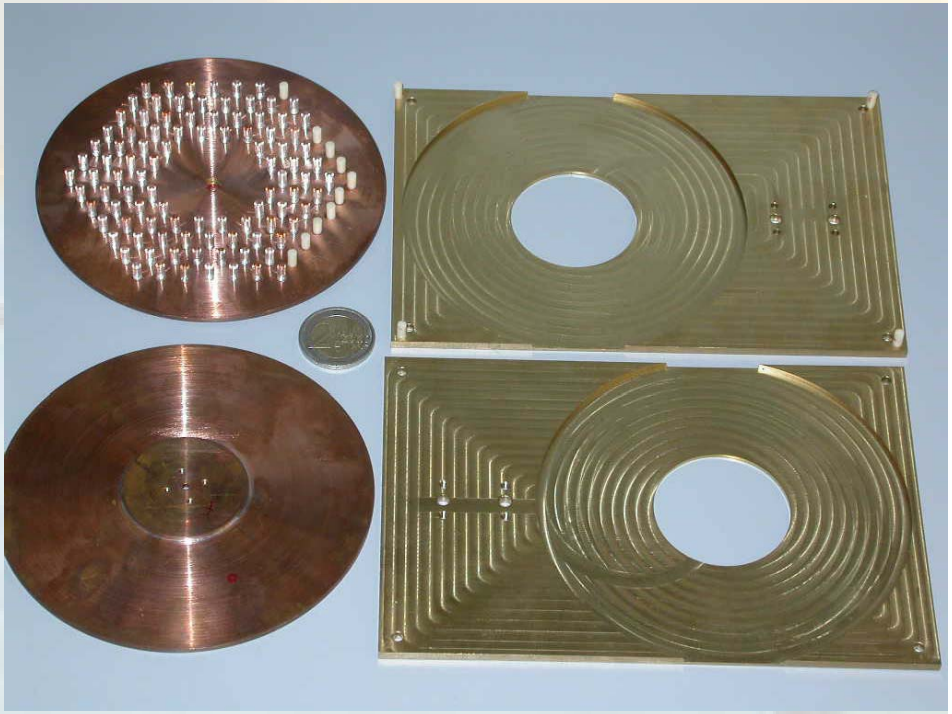
Field Pattern Sensitivity to "box" dimensions and to presence of one more ring

- **4rings. Small box**
- **5rings. Small box**
- **5rings. Medium box**
- **5rings. Large box**

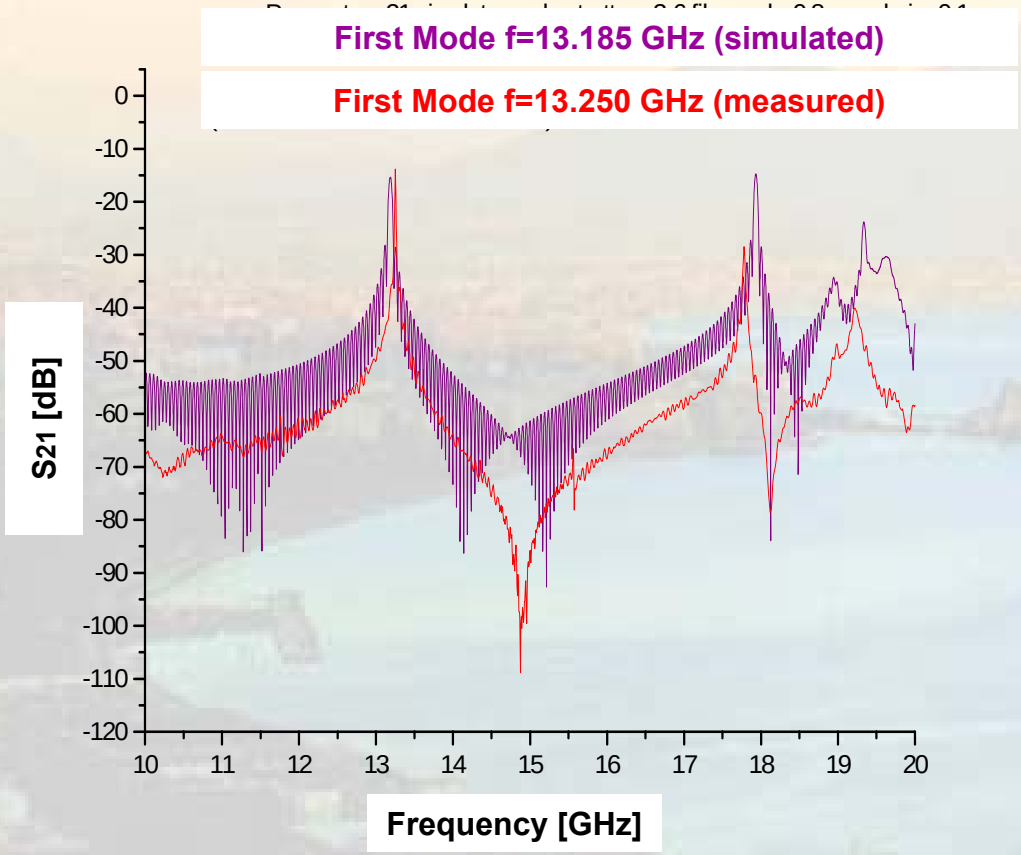


The experimental setup

- Scattering Parameters Measurement



Measurement-Simulations Confrontation



- Good agreement between simulation and measurement

Measured Q = 2400

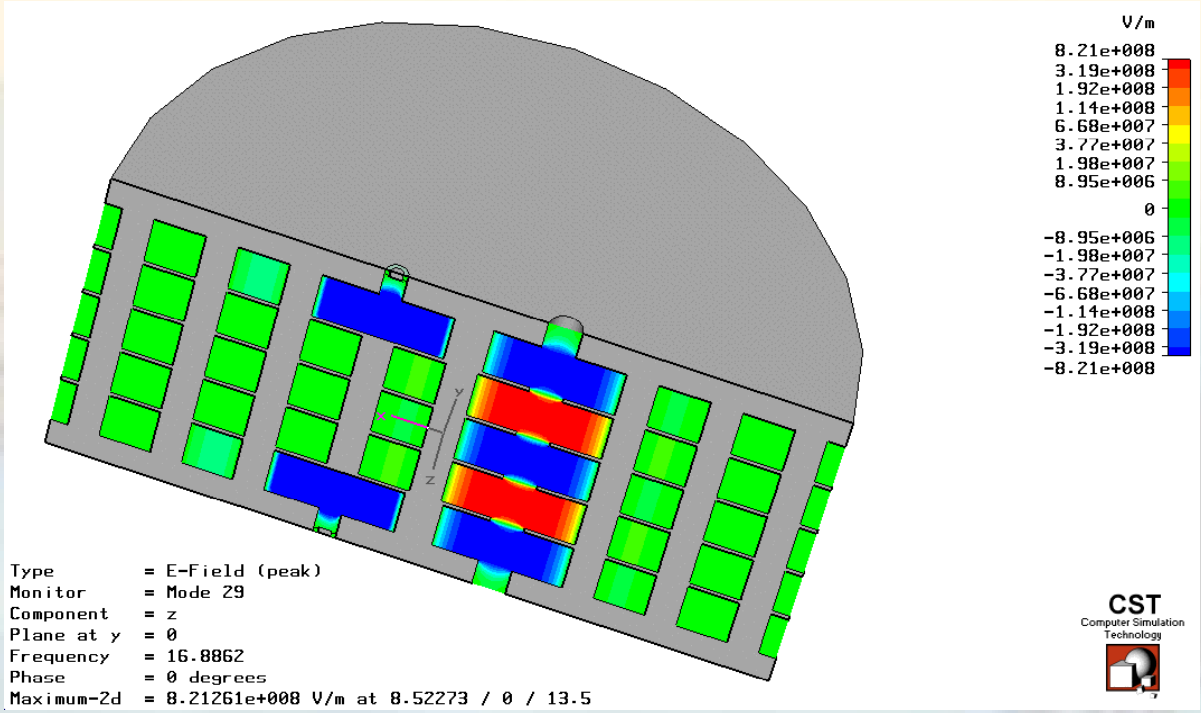
Simulated Q = 10100

An example of 5 layers stack

2 coupling cells + 5 accelerating cells

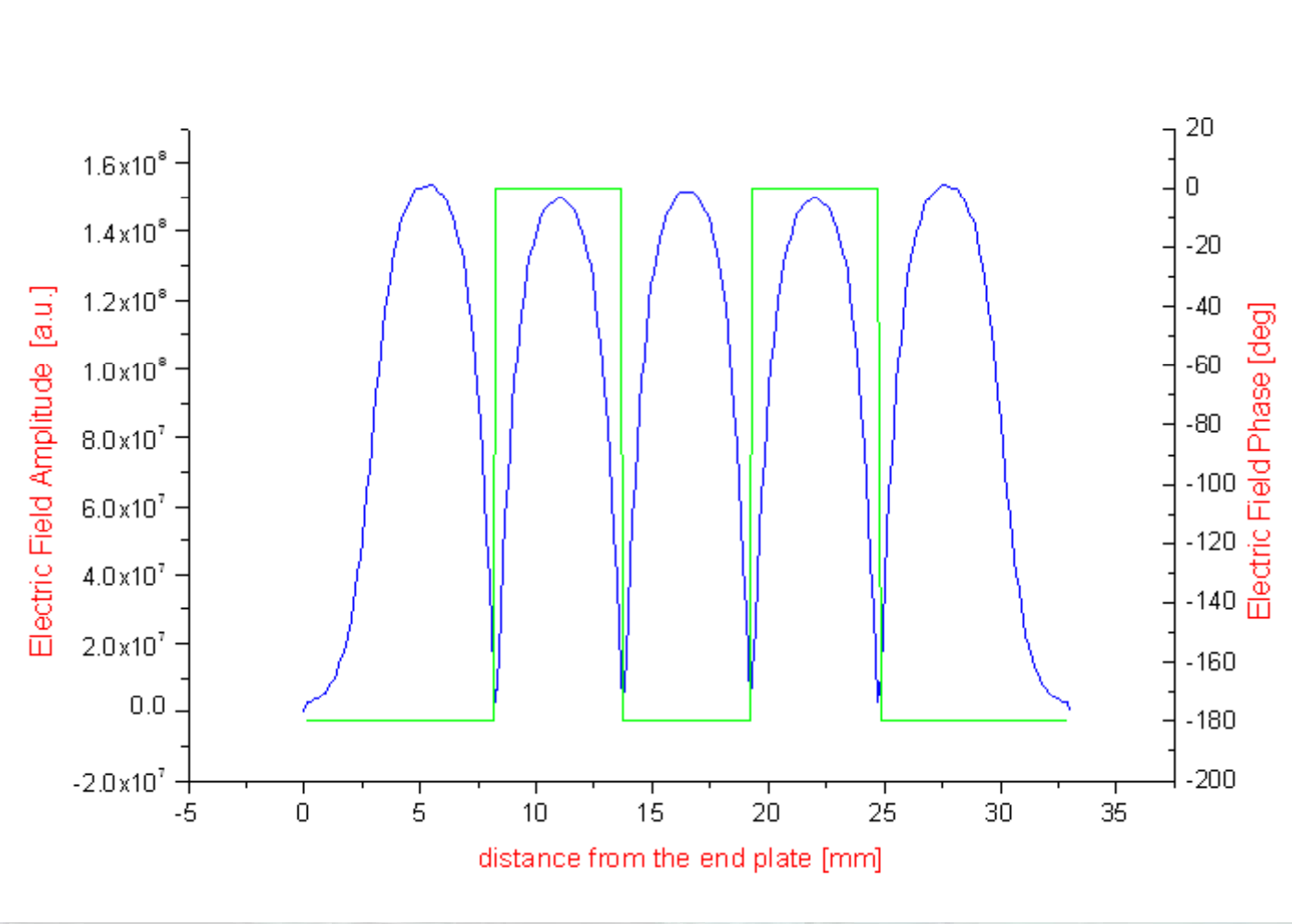
π-Mode excited

The accelerating cells coupled via the bore of the accelerating channel



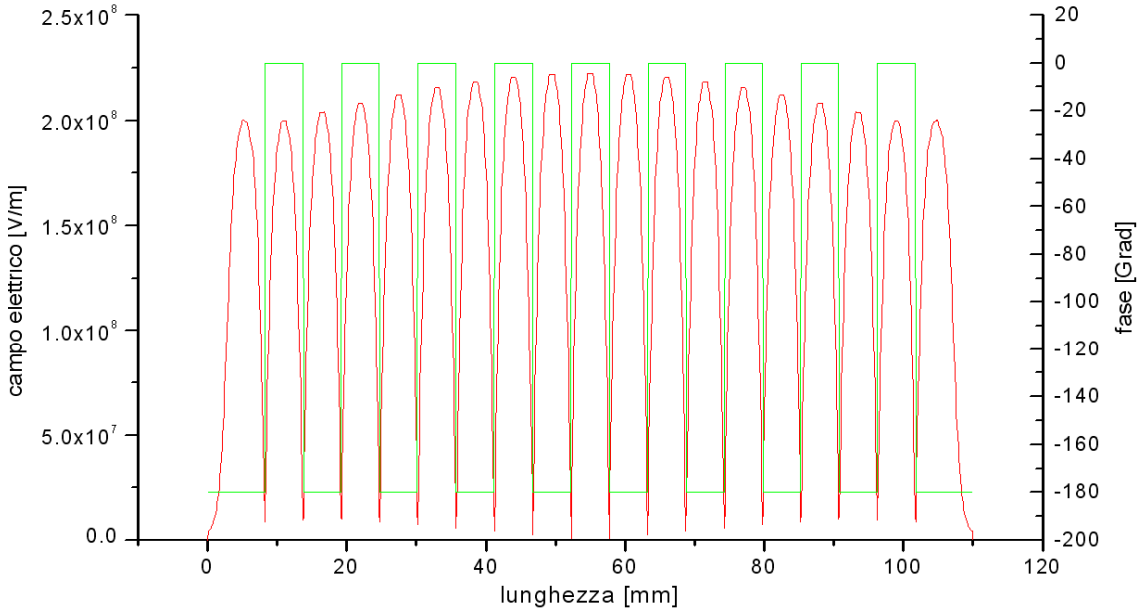
Field Pattern in the module

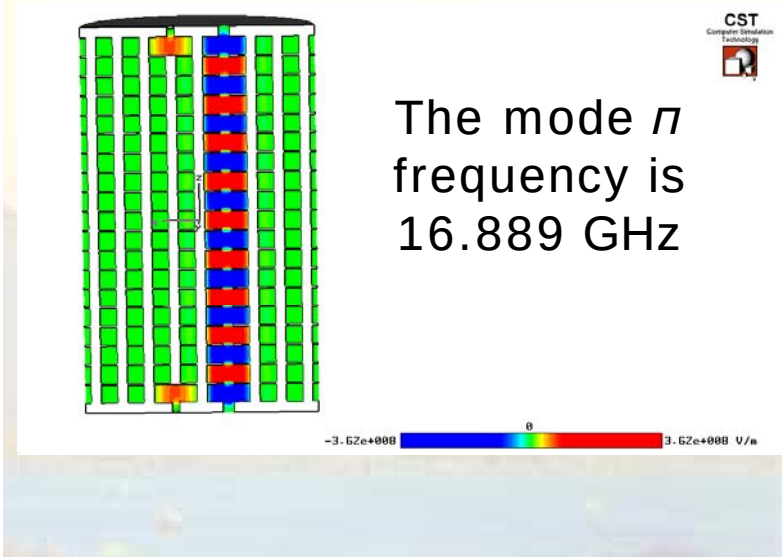
excellent field uniformity



19 accelerating cavities

Optimization of the structure



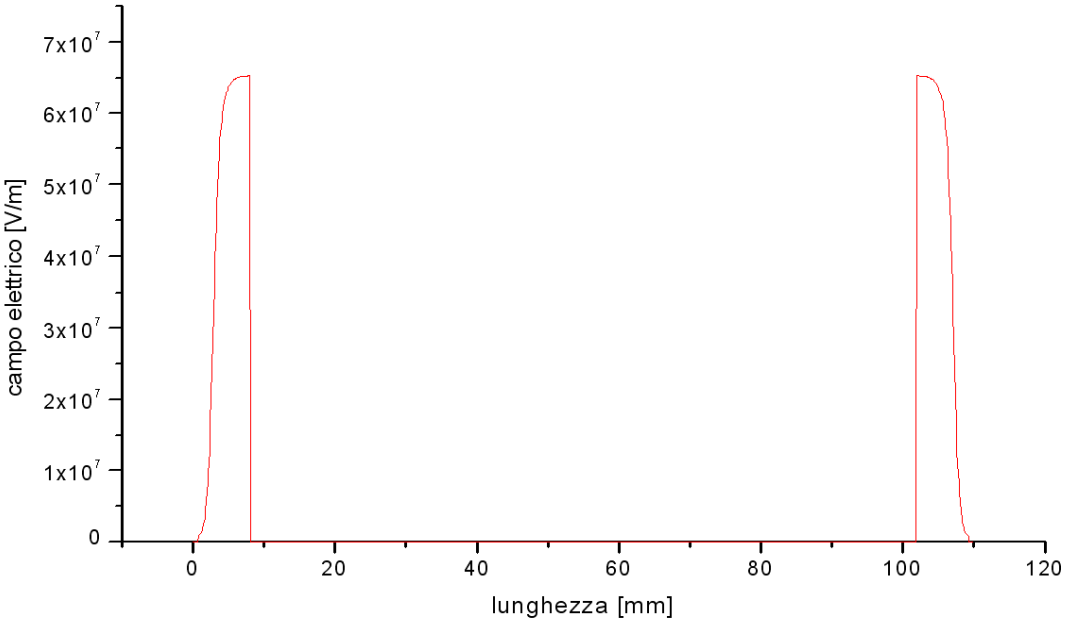


The mode π frequency is 16.889 GHz

Diameter= 2.96 mm

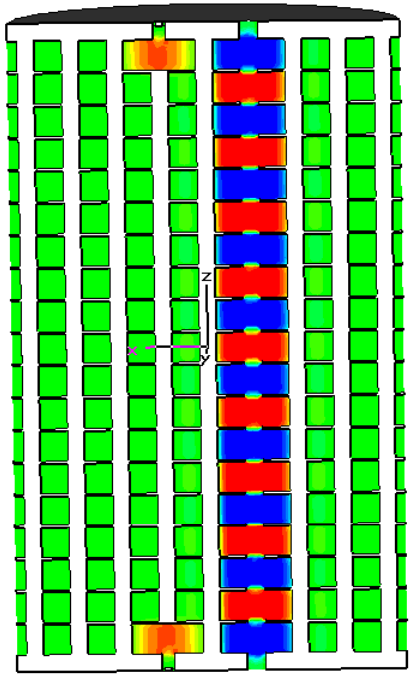
The field in the feeding cavities is smaller than the accelerating ones

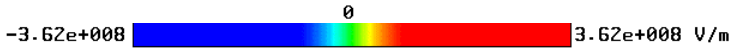
Field non-uniformity 4%



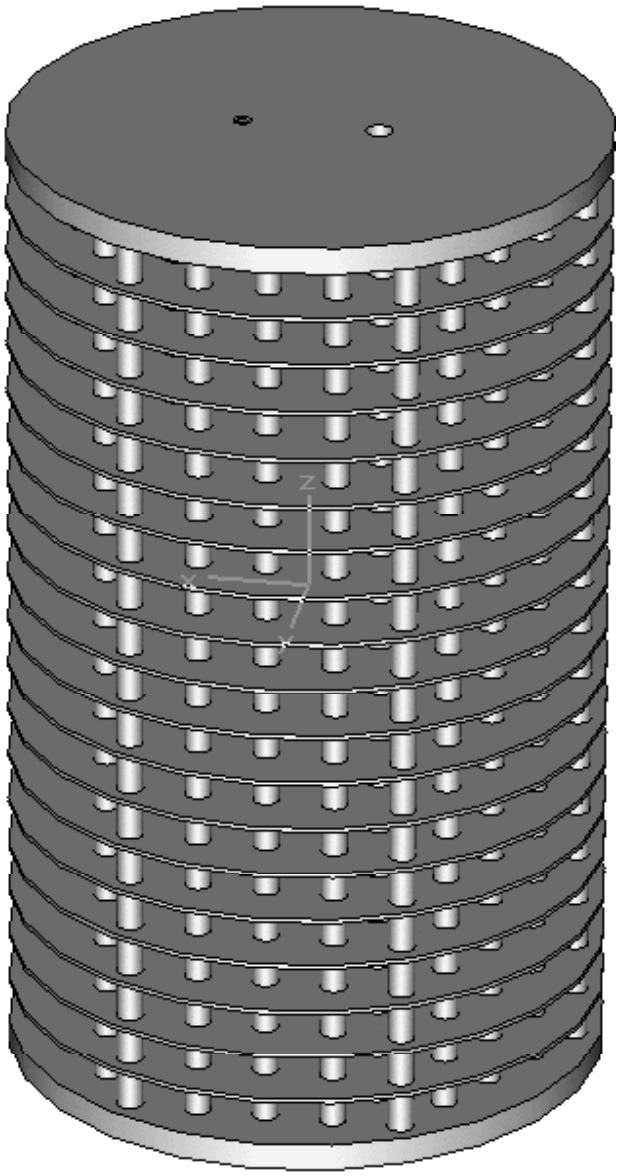
Sviluppi futuri

Realizzazione del prototipo relativo alla struttura a 19 cavità





Il modo π oscilla ad una frequenza di 16.889 GHz

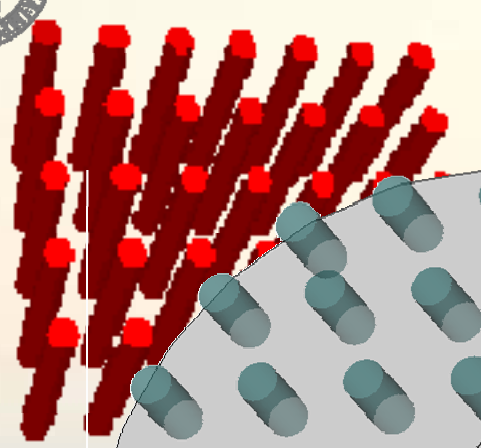


Conclusions

- Monomodal behaviour Optimization
- Good rejection of HO-Modes
- Good agreement between simulations and measurement
- Encouraging indications for fabrication of a multi-layered module
- Perspective of Viable Technology for Hybrid Structures


END

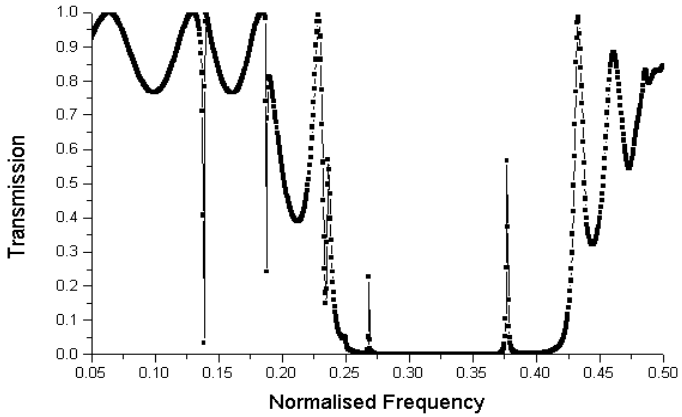
“Difetti” nei cristalli fotonici

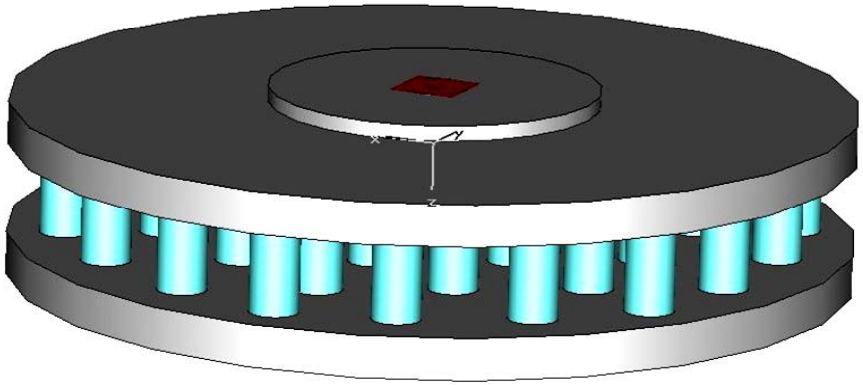


Possibile “difetto”

uzione di un difetto
nstaurarsi all’interno
oroibita di uno o più
almente confinati

Cavità risonante

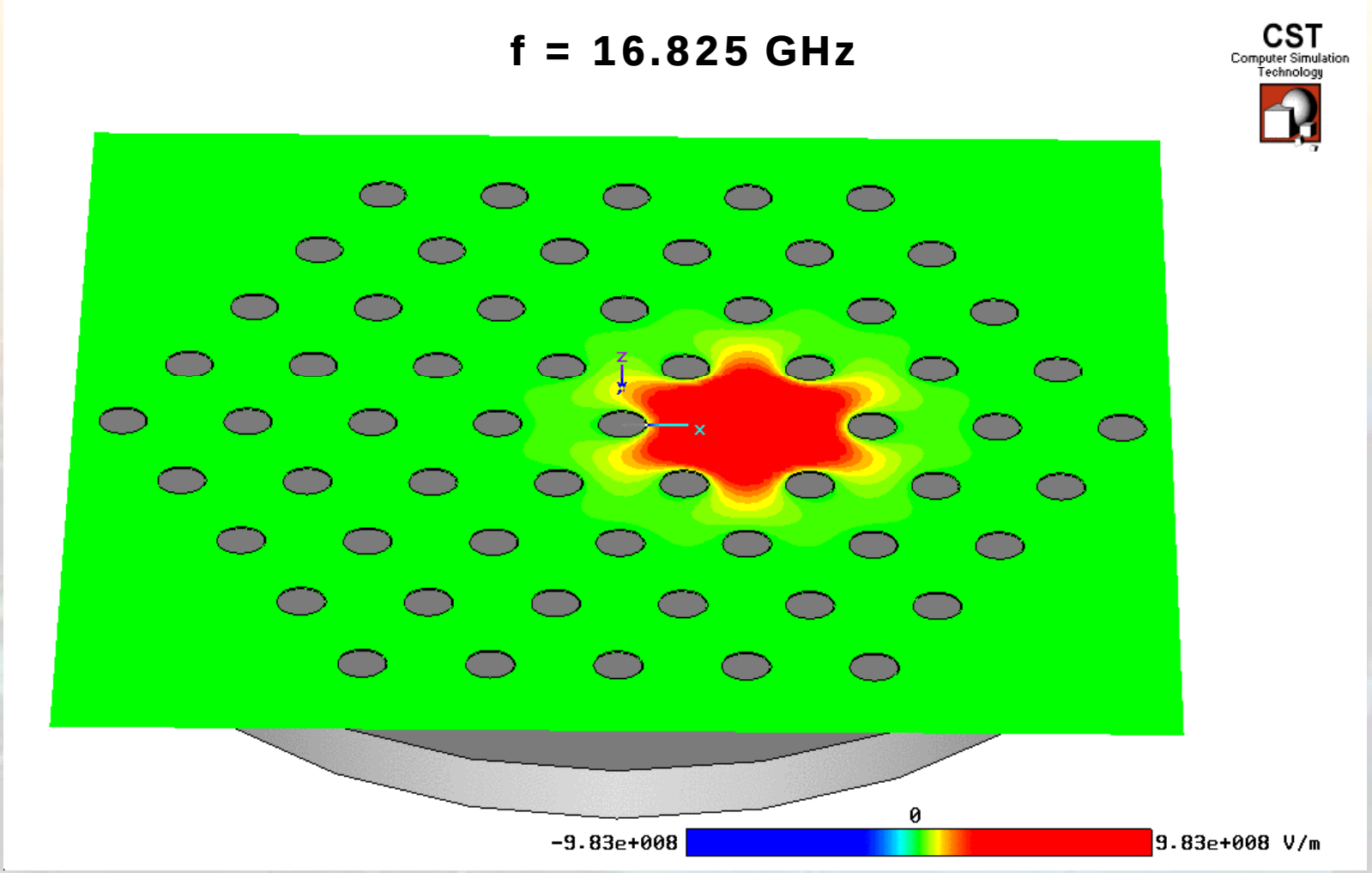




La geometria della cavità può essere facilmente scalata per poter lavorare a frequenze diverse senza cambiare le proprietà della struttura

Cavità accoppiate

La singola cavità spostata risuona ad una frequenza di



Hybrid PBG configuration

Results on metallic PBG cavities

- The Experimental Q factor is limited by radiative losses in the superconducting state
- The manifacture of a superconductive cavity is easy for prototype tests but it has fundamental limitations for practical applications
- In principle, it is possible to fabricate hybrid structures (stacks) that should meet special performances