We investigated the efficiency of superconducting MgB$_2$ and superimposed MgB$_2$/Fe systems consisting of cylindrical cups with an aspect ratio of height/radius close to unity. At first, the shielding capability of these systems was measured as a function of the external magnetic field and position by means of cryogenic Hall probes mounted on a custom-designed stage, moveable with micrometric resolution [1]. Then, the experimental data were successfully reproduced by using a finite element method based on a vector potential formalism [2,3].

Starting from these results, further bi- and multi-layer SC/FM superimposed systems were studied in order to achieve additional improvements in their shielding efficiency, optimizing the relative shaping and sizing of both SC and FM layers [4,5]. It turned out that the presence of a height difference between the edge of the SC/FM cups, as well as a suitable choice of the lateral gap between the cups, makes the multilayer shields the configuration with the highest efficiency both at low and high magnetic field [4,5].

### Why SC and SC/FM shields?

- Magnetic field shielding is crucial for several applications requiring an ultralow magnetic field environment (e.g., biomedical applications) or the mitigation of the magnetic field produced by an electronic device in order to guarantee electromagnetic compatibility with the surrounding environment or to prevent possible health hazards (e.g. workers safety).
- Superconductors represent an excellent solution for creating a perfect magnetic shield [1-4].
- Ferromagnetic materials can improve the superconductor shielding capability [10]. It was experimentally confirmed that specially designed superconducting/ferromagnetic bilayers can display uniform static magnetic field [11,12].

### The starting point

Our study deals with the shielding potential of superconducting superimposed SC/FM systems with an aspect ratio of height/radius close to unity.

- The shielding potential in situations where it is necessary to minimize the amount of space occupied by the shield.
- The shielding factor of the superimposed SC/FM structures is not a simple combination of the components [1] but must be evaluated by means of dedicated experiments or modelling.

### Samples

- The shields consist of SC and FM cylindrical cups.
- The superconducting cup is made of MgB$_2$.
- The superimposed cup is made of Fe.
- The shielding capability was measured as a function of the external magnetic field and position by means of cryogenic Hall probes mounted on a custom-designed stage, moveable with micrometric resolution.
- The experimental data were successfully reproduced by using a finite element method based on a vector potential formalism [2,3].

### Experimental results and model validation

The multilayer shields were modelled starting from the experimental BH curve.

- High magnetic fields: enhancement of the SF in the superimposed configuration.
- Low magnetic fields: the SC solution is the most efficient.
- Parameters: the SF and the SC/FM cup are half the size of those of the superimposed configurations. Outer and inner diameters of the whole structure are the same as those of the bilayer arrangements 6 and 7.

### Towards new shielding configurations

#### Multilayer configurations: higher shielding efficiency both at low and at high applied fields

### In conclusion

- The presence of the FM layer tunes the shielding efficiency of the SC in a very weakly dependent on the aspect ratio of the system.
- In the investigated geometry a key factor to achieve a competitive hybrid arrangement is the presence of a height difference between the SC and FM vessels.
- Multilayer structures are expected to show the best shielding performances.

### References