Magnetic Diagnostics for Ignitor

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Introduction

- All the electromagnetic diagnostics commonly used in present experiments to measure plasma parameters such as current, loop voltage, horizontal and vertical position, plasma beta, toroidal and poloidal modes, etc., are adopted for Ignitor. The moderate neutron fluence and very intense neutron flux expected in Ignitor demand the use of fully inorganic insulating materials, for which permanent radiation damage should be limited, but transient, reversible effects cannot be excluded. More data is needed to verify the sensitivity of the chosen materials to the radiation background, but in the meantime, an R\&D program has started with the purpose of selecting insulator materials, testing impregnation techniques, verification of installation feasibility for all types of magnetic diagnostic coils. Full size prototypes are being manufactured.
- The magnetic coils system must be closely integrated with the plasma chamber as it requires early installation. While the initial positioning of the in-vessel components should be possible with relative ease (before the welding of the individual sectors of the plasma chamber), their replacement and maintenance in the course of the experimental life of the machine can be problematic. Therefore, an adequate level of redundancy is being considered.

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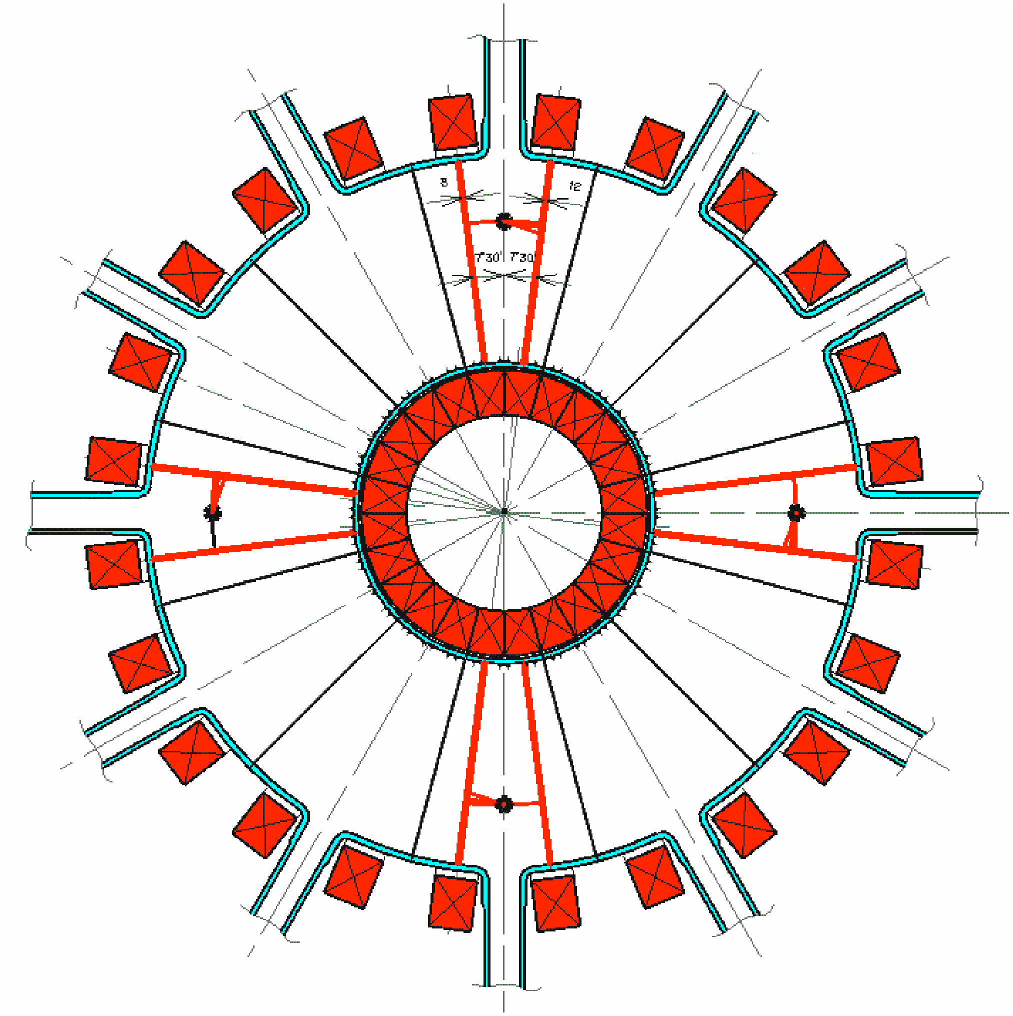
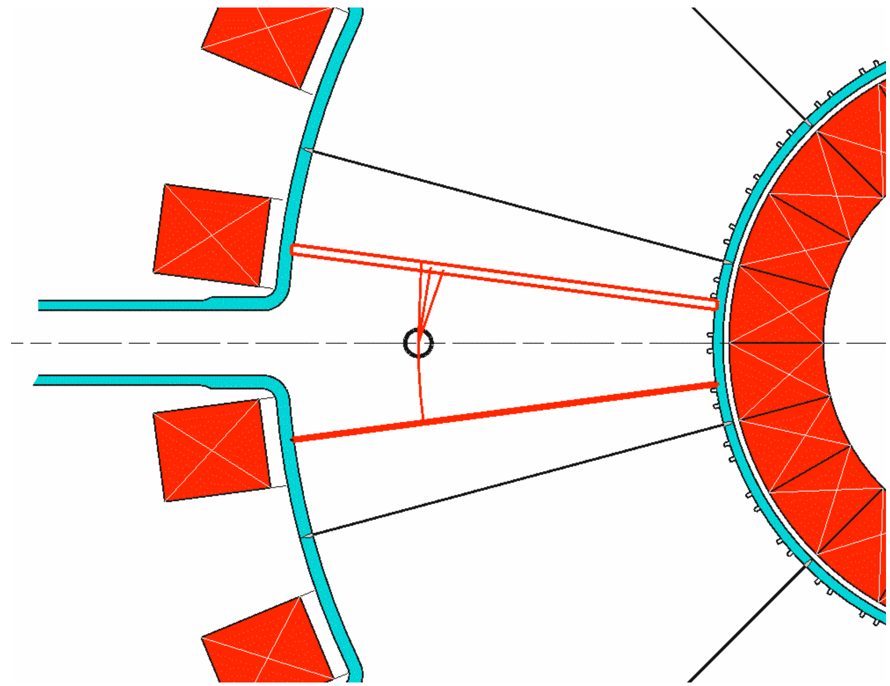
Purpose	Number of coils	Location	Dimensions
B_{pol}	16×4 toroidal sectors	Center of sector, poloidally equispaced in Boozer coordinates	Toroidal width: 40 mm Radial thickness: 9 mm Poloidal length: 50 mm 270 turns (2 layers)
B_{tor}	16 × 4 toroidal sectors	7.5° from center of sector, poloidally equispaced in Boozer coordinates	Poloidal width: 30 mm Radial thickness: 9 mm Toroidal length: 20 mm ~160 turns (2 layers)
Saddle coils	16 × 4 toroidal sectors	15° across the sector center, poloidally equispaced in Boozer coordinates	Poloidal width: variable Radial thickness: 9 mm Toroidal length: to cover 15°, ~12 turns
Rogowsky	1× 4 toroidal sectors		Support: ϕ=6 mm ~32000 turns (2 layers)
Diamagnetic loops	3 × 4 toroidal sectors: 2 compensating coils, 1 plasma flux coil		Radial thickness: 9 mm Toroidal width: 25 mm Compensating coils: ~120 turns (2 layer) Plasma flux: 12 turns (1 layer)



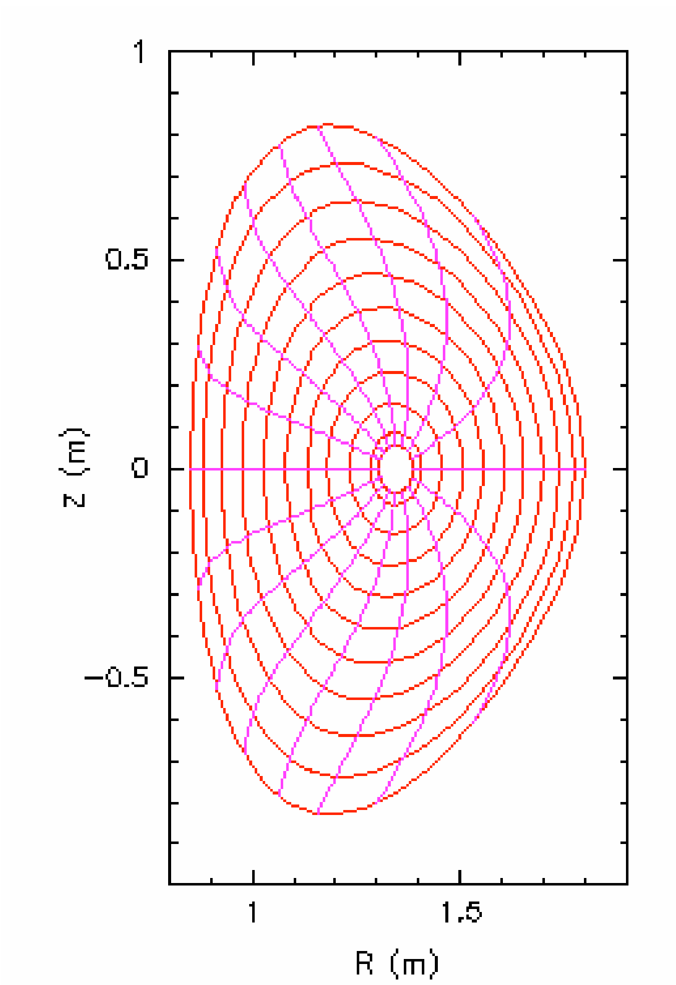
Full sets of coil systems are placed at 90^{o} on 4 sectors



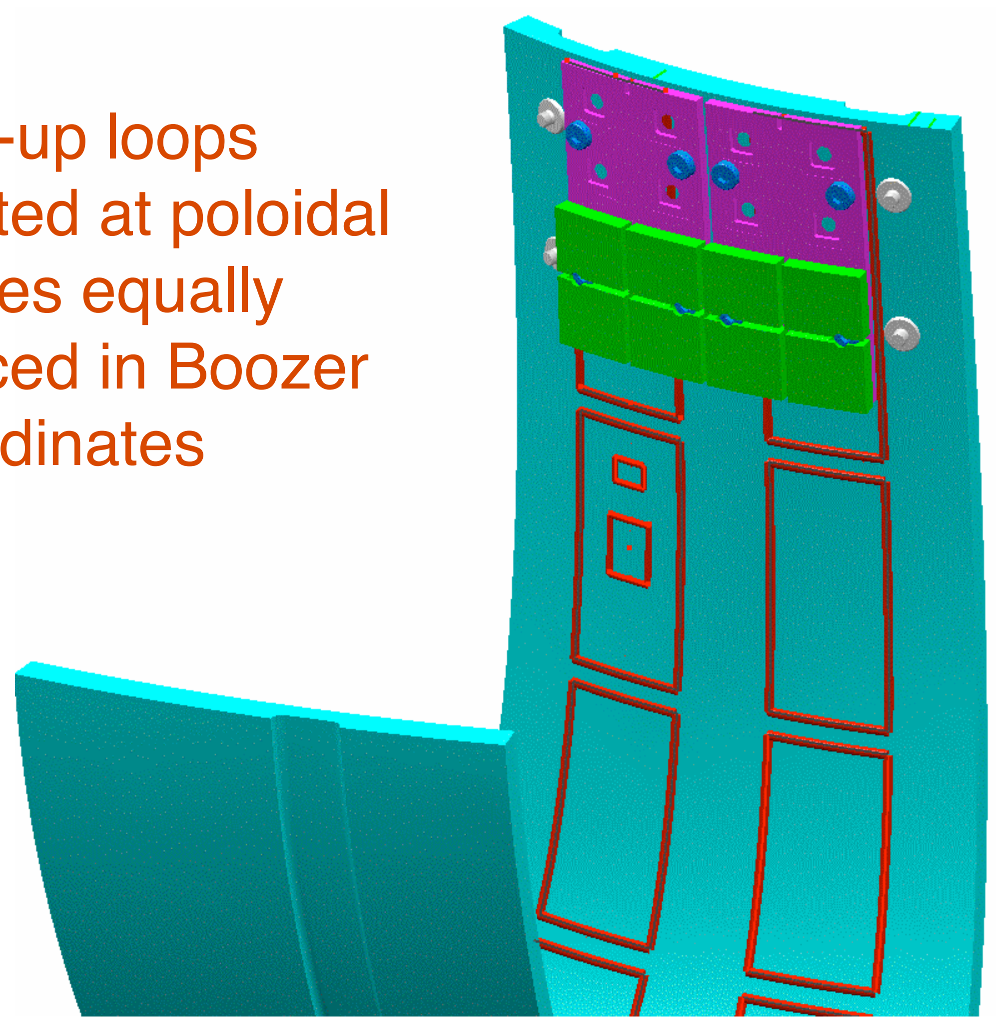
A. Cucchiaro

The whole magnetic coil diagnostic system is closely integrated with the plasma chamber.

All the in-vessel coils are attached to the wall of the plasma chamber under the first wall TZM tiles

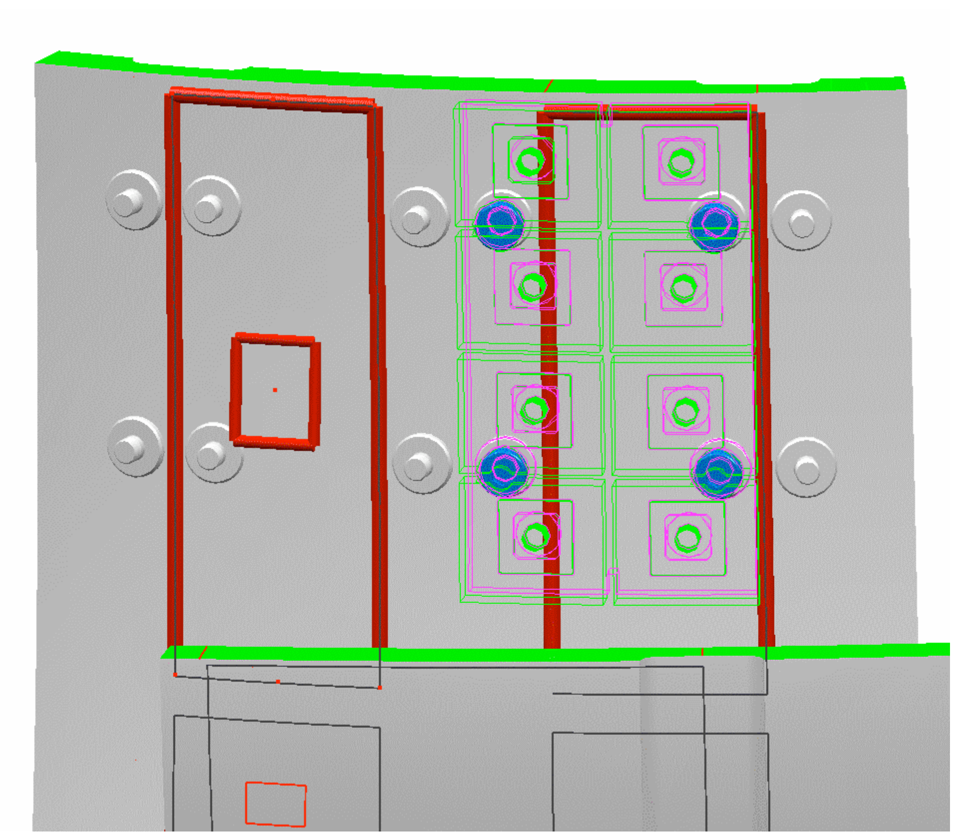


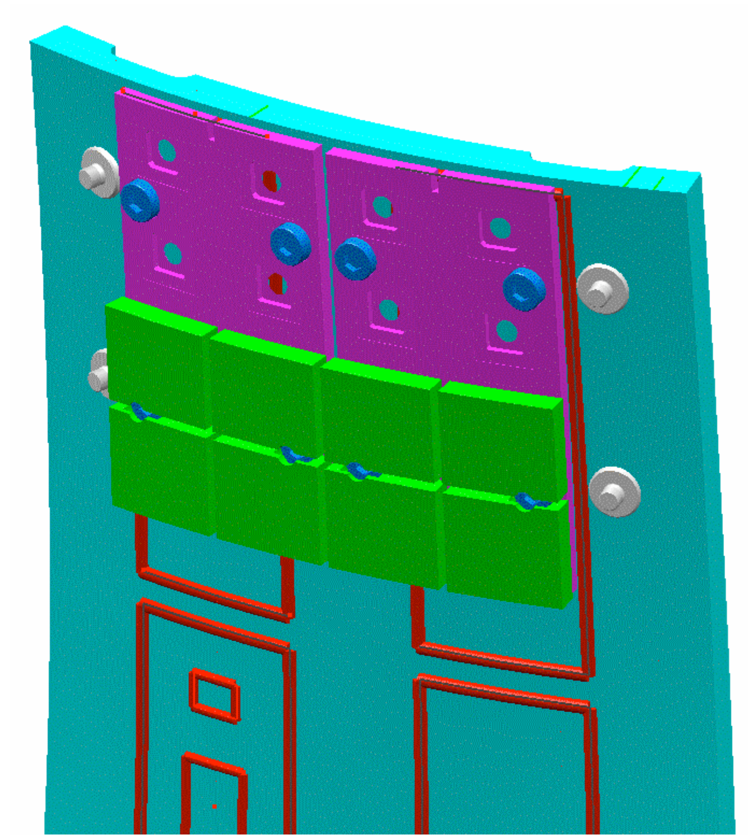
Pick-up loops located at poloidal angles equally spaced in Boozer coordinates



A. Cucchiaro

Diamagnetic flux loops and Rogowsky coils need to be compatible with the presence of studs, tile carriers attachments, weldings, etc.





A. Cucchiaro

BP experiments pose demanding conditions on materials used for magnetic measurements:

Neutron Compatibility

- RIC (Conductivity under n flux)
- RIED (Conductivity degradation)
- RIEMF (Electromotive forces)
- RITES (Thermoelectrical sensitivity)

Good Insulation @

- 1000 volt
- 300 °C
- Electromechanical Stress

As well as:

- Thin wire diameters
- Small curvature radii (<6 mm)
- High reliability

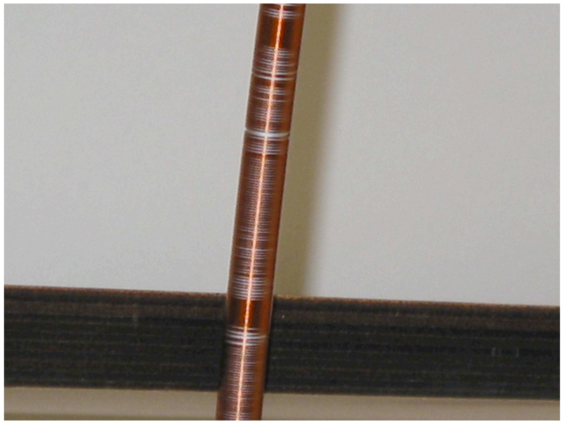
A program to assess the feasibility for all the types of magnetic diagnostics inside the plasma chamber is underway.

The purpose is to establish materials and fabrication techniques for the magnetic diagnostics that fulfill the requirements of the Ignitor experiment.

Full size wood model of one sector of the Ignitor plasma chamber.

Rogowsky coils

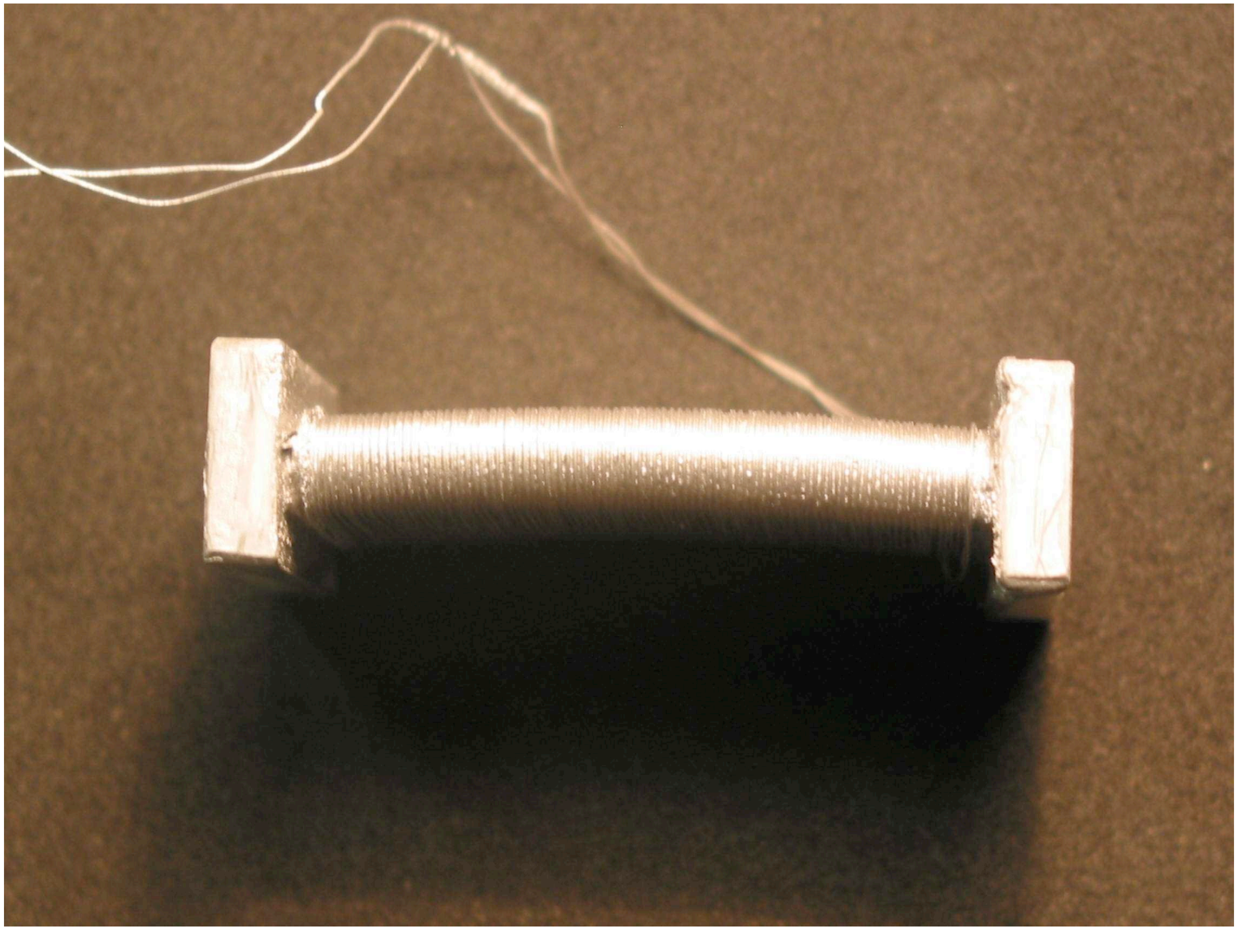
- Square or round cross-section?
- Wire diameter?



Materials

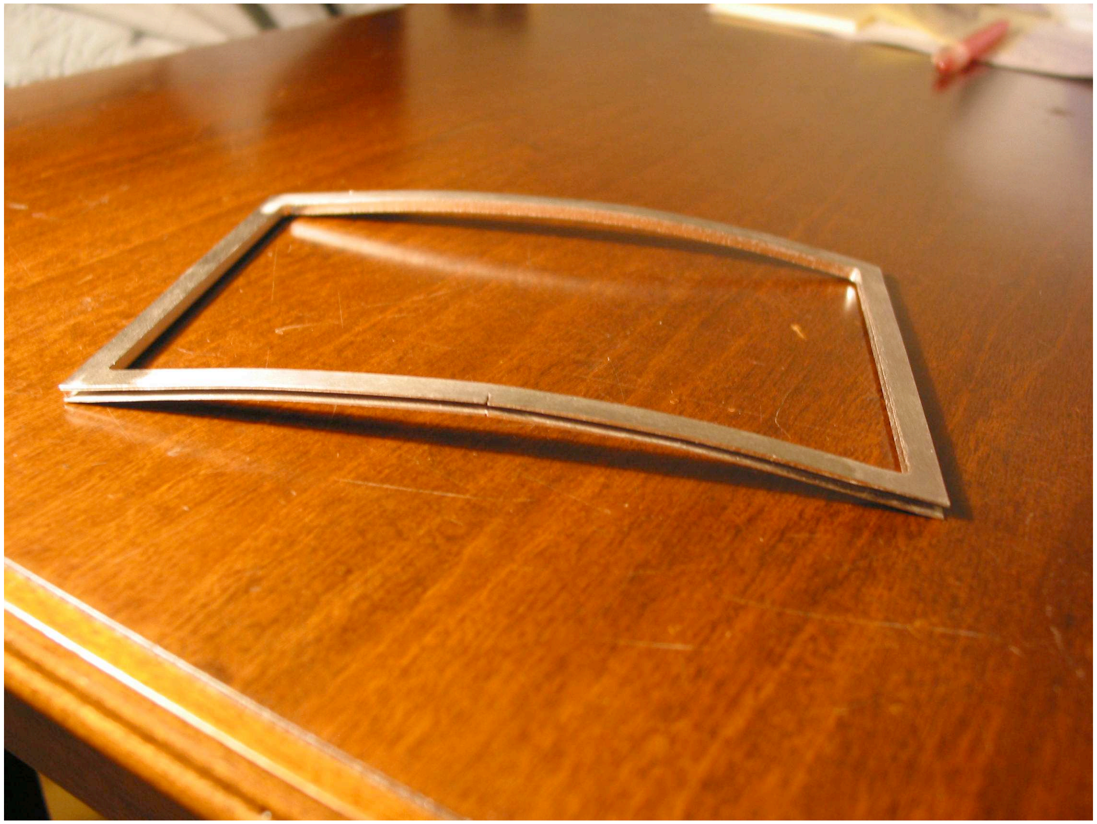
- The original idea was to use Pt wire (0.3 mm) with a Macor coating. This, however, turns out to be very expensive, the insulation breaks up when wound at small radii (6 mm), and the wire easily deforms with temperature.
- Commercially available Ni coated wire performs better but insulation level is insufficient.
- An R&D program is underway, with the support of SALENTEC (*Lecce, Italy*) to test different insulating techniques for the small B_{pol}, B_{tor} pick-up coils and the larger saddle coils.

Sample of pick-up coil



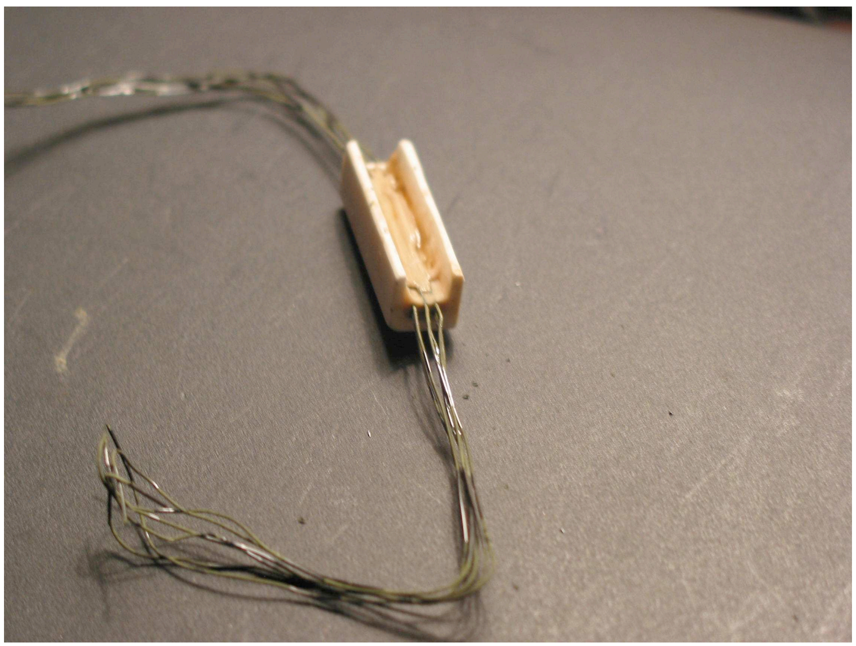
Ni insulated wire (Ceramawire) on Macor support

The support for the saddle coils can be built in Inconel (same as the vessel) or...



...IN PLASTIC ALUMINA

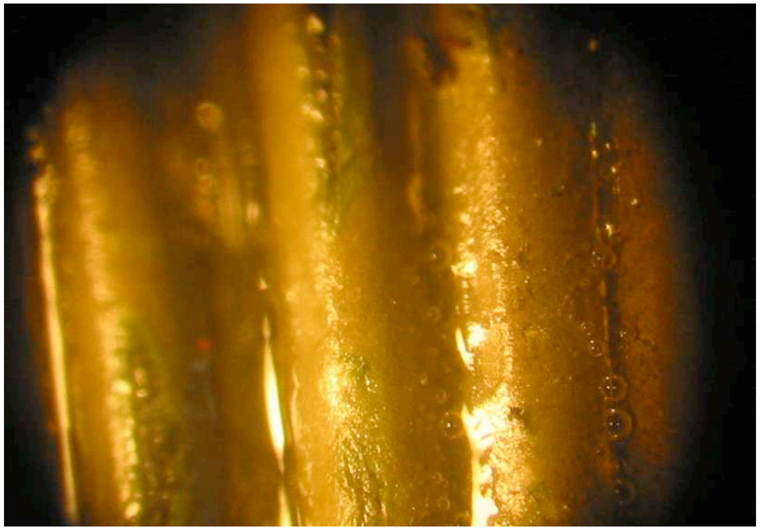
This material allows to cast the conduit in any shape, also curved ones.



SALENTEC Advanced Technologies

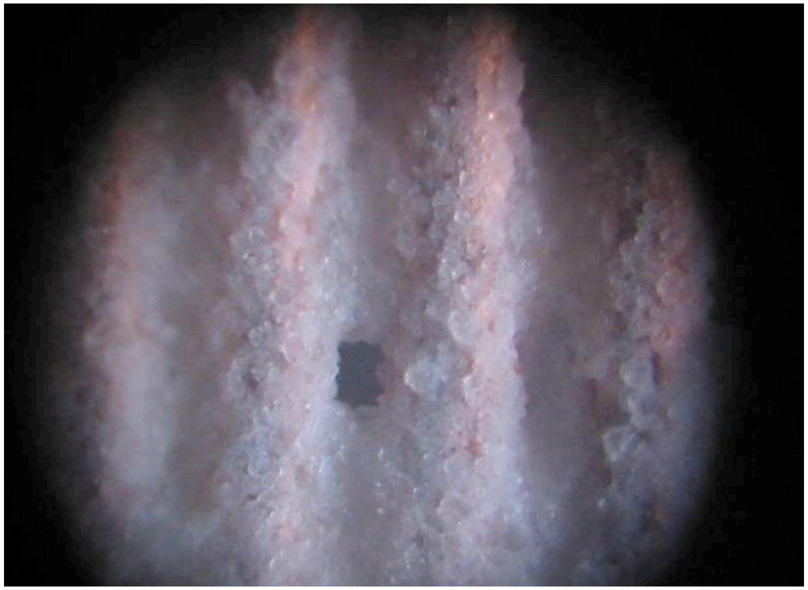
Different types of wire insulation have been tested

fused SiO2



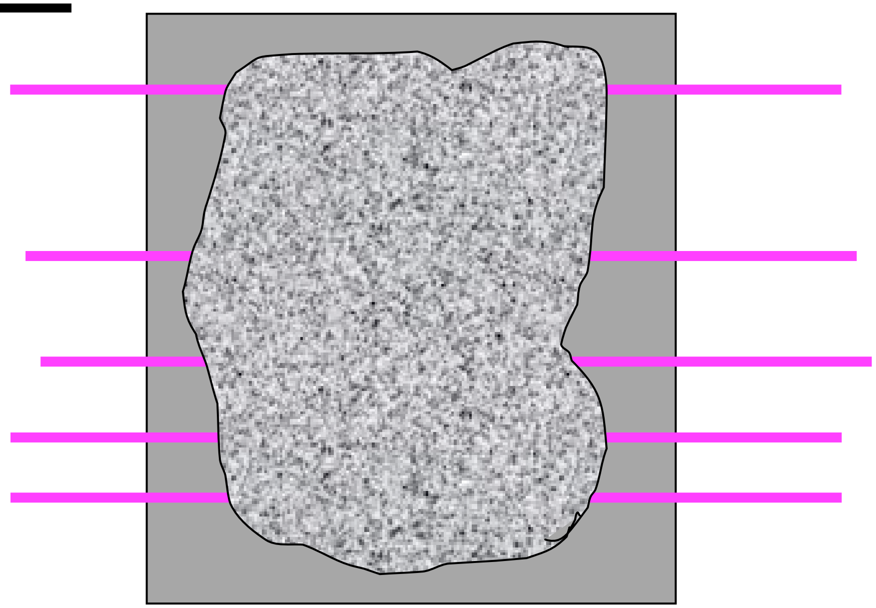
Ni wires immersed in plastic alumina infiltration

alumina powder



First issues addressed:

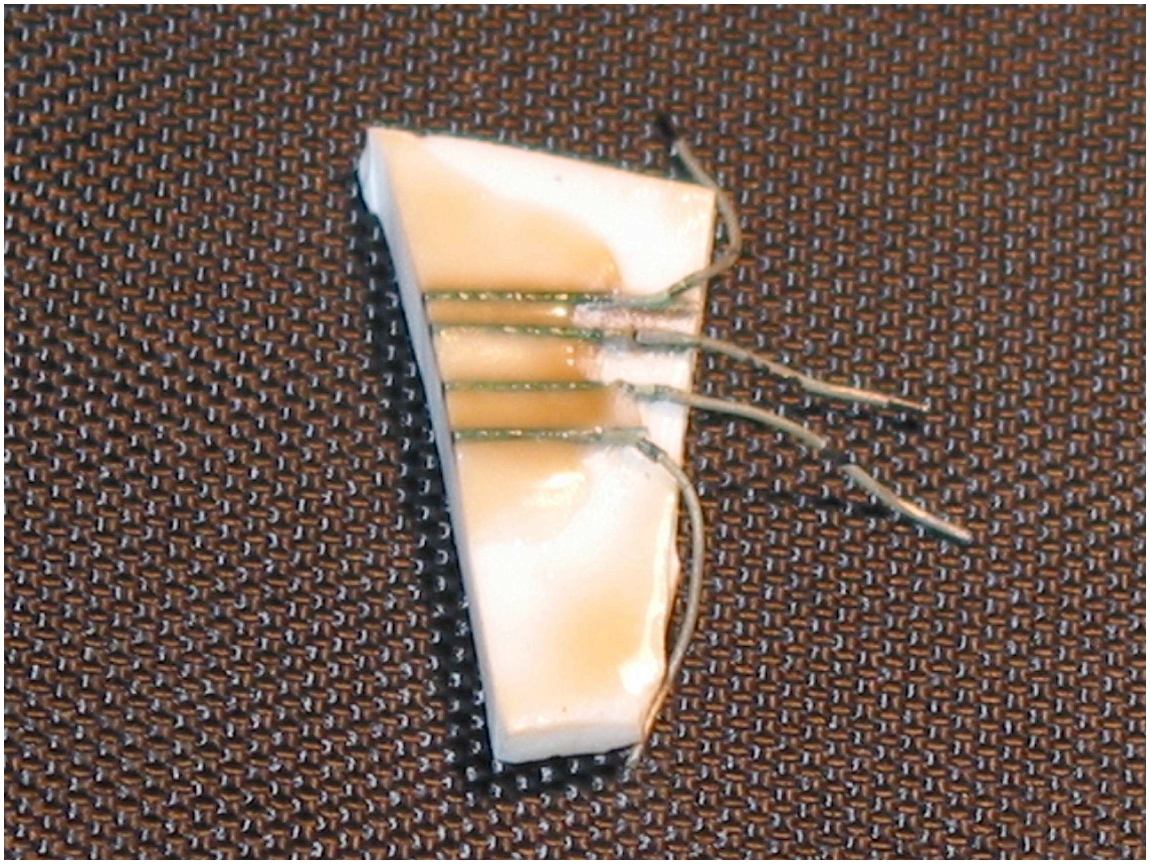
- Tensioning of Ni at high temperature
- Deposition of Ni over Al2O3 slab
- Baking with powder and **short fiber** Al2O3
- Infiltration of **lanthanids**
- Final sinterization

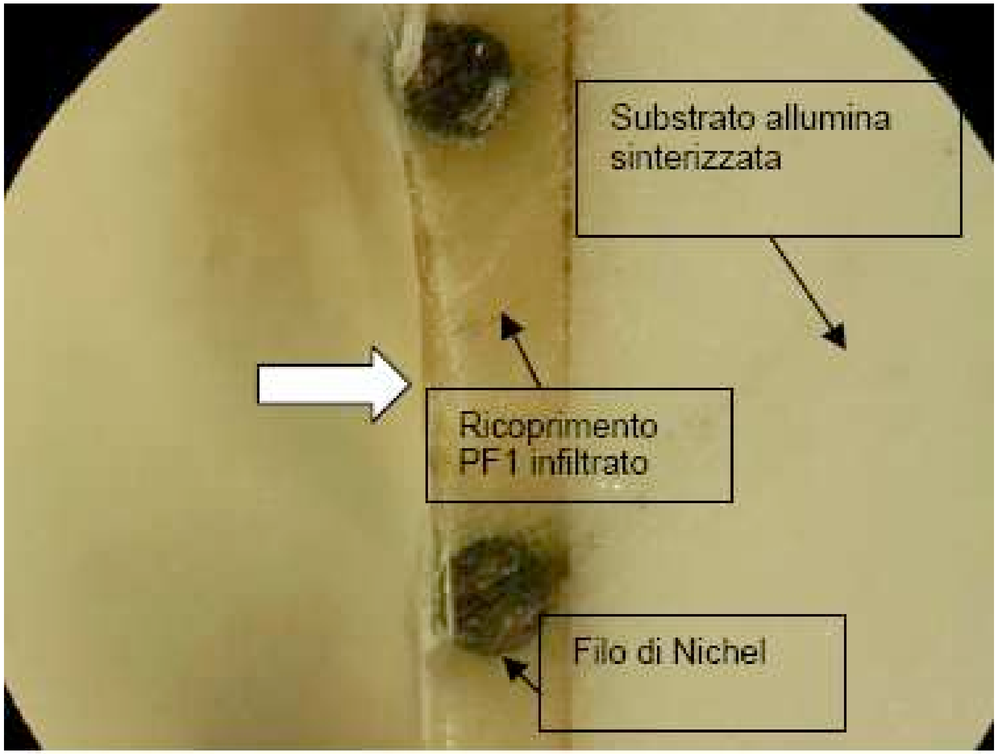


Insulation of Ni wire with alumina and lanthanids over an alumina slab

- 400 micron wires
- Separation 1-3 mm

- **Withstands 1.000 volt**

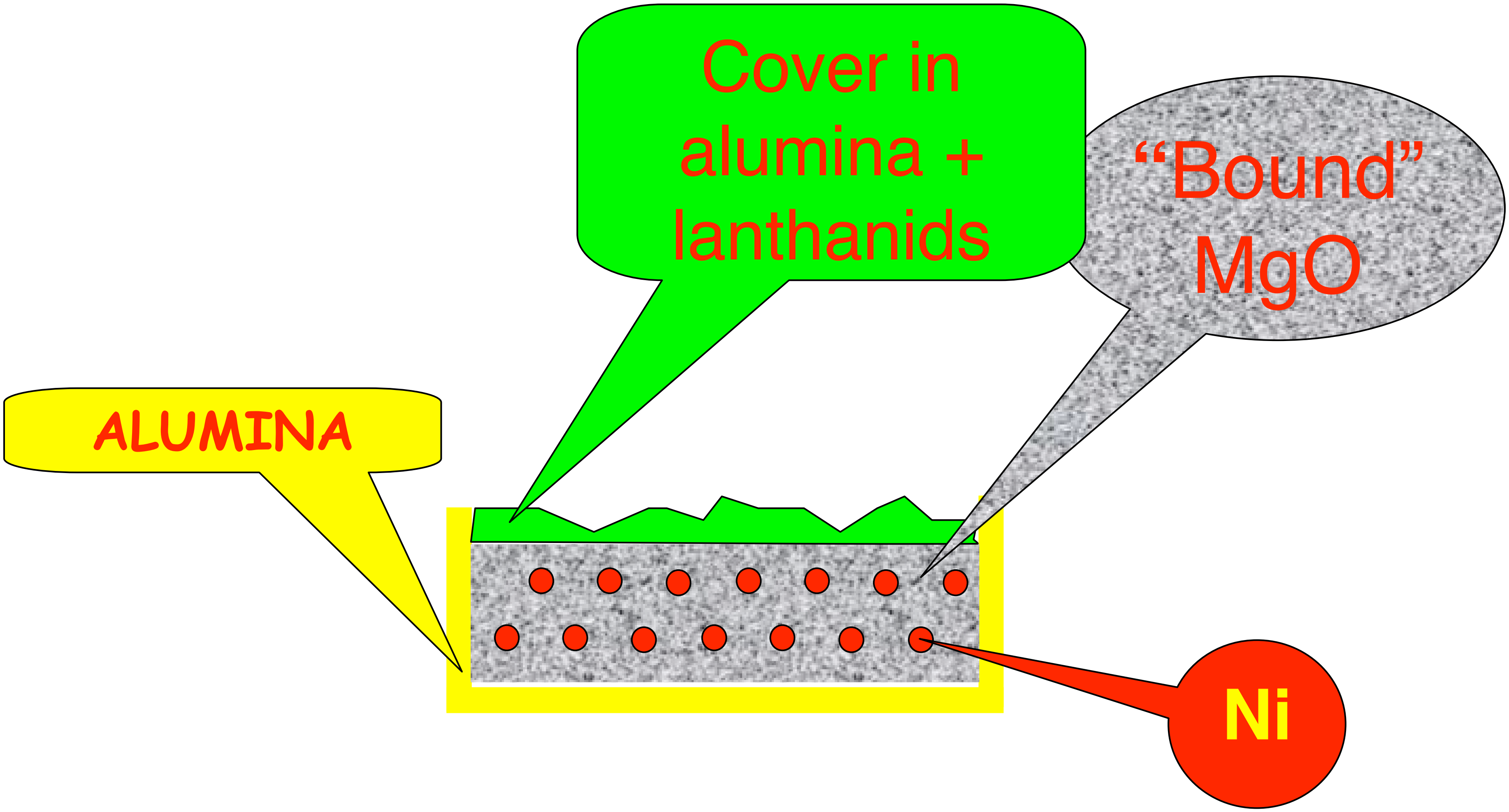




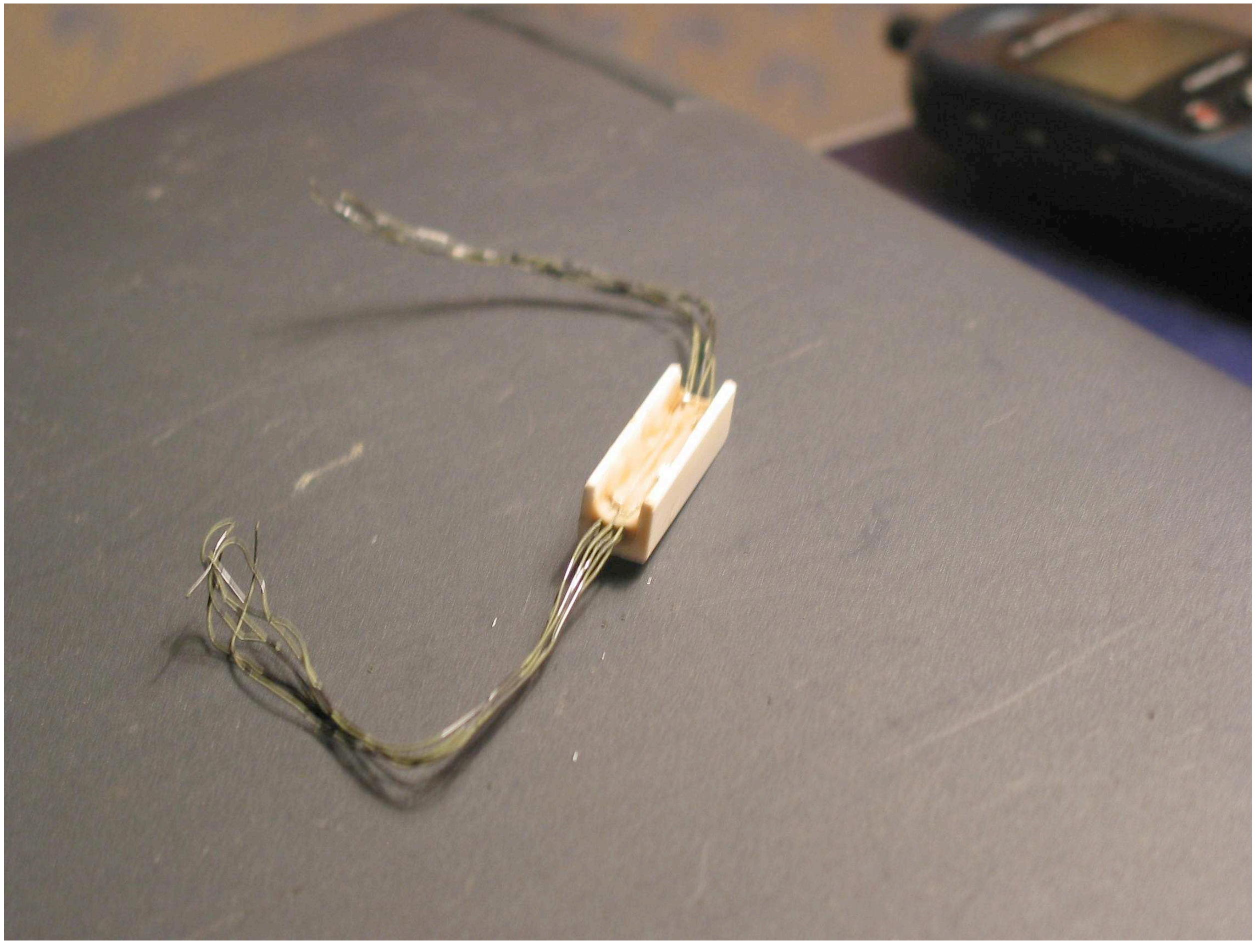
Cross section of Ni wires

It is possible to obtain a better insulation by infiltration techniques and a “filler” that can be added to increase the breakdown voltage.

Latest idea:



Prototype of Ni wire enbedded in an alumina conduit with lanthanids and alumina insulation



A thin sleeve in Al2O3 can be used to cover the tails

Next steps

- Replace Al2O3 with MgO
- Technological issues to “bound” MgO have been investigated and materials have been acquired
- Test thinner wire
- Produce a prototype coil to test on existing experiment
- Characterize materials for neutron environment