Layer0 Support and Cooling

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Outline

- Design Requirements
- Upgrade of Support Structure
- Experimental data setup (History)
- Present Works
- Future Works

Design Requirements

Mechanics

- Light (long radiation length) so the particle trajectories are unaffected $X \leq 0.3\ \%\ X_0$;
- Stiff (high Young Modulus, E) to minimize susceptibility to vibrations;
- Radiation resistant;
- Insensitive to temperature variations (low Coefficient of Thermal Expansion, CTE);
- Insensitive to humidity variation (low Coefficient of Moisture Expansion, CME, and moisture absorption);
- Stable with time;

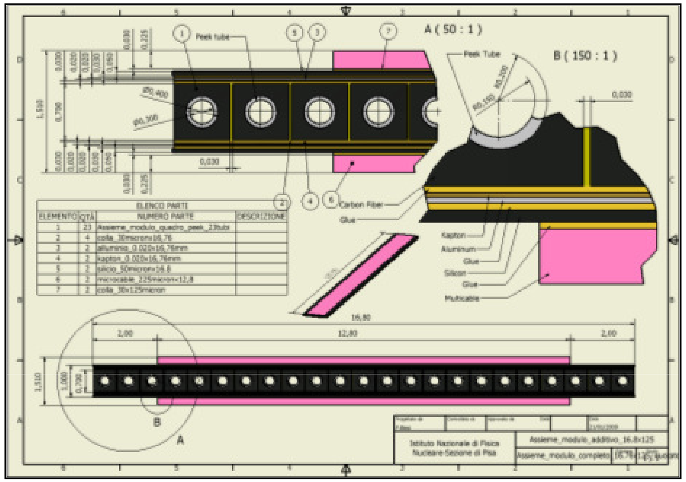
Layer 0 Power Dissipation

- Power density: 2 W/cm^2 → Total Power: 210 W / layer;
- Electronics Working Temperature range: 0 °C < T < 50 °C.

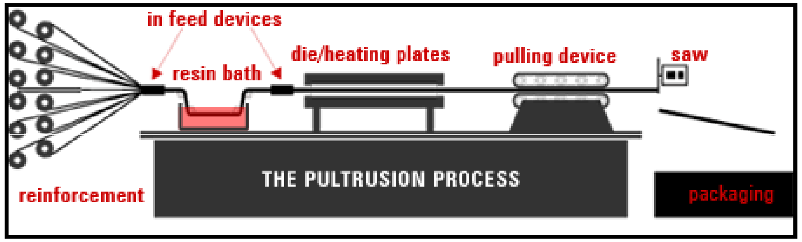
Support Structure / 1

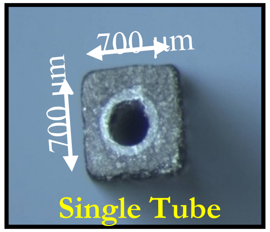
"Candidate" Support Structure

The Design:

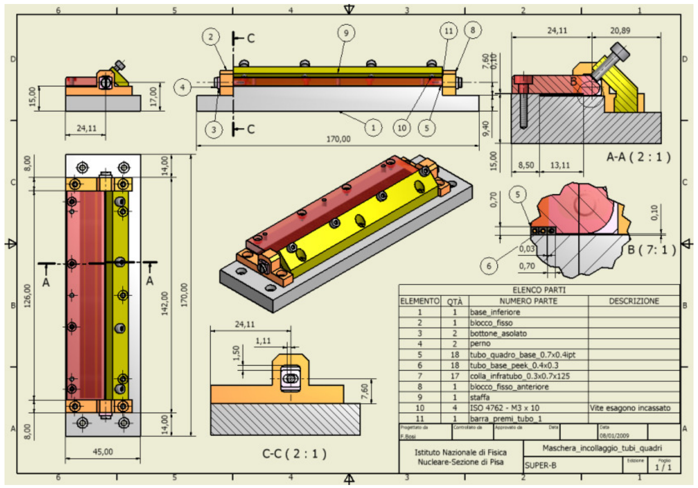


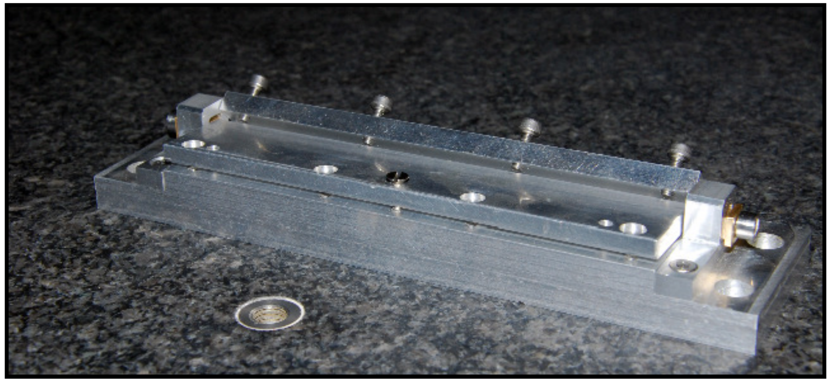
The candidate support structure is made by CFRP (Carbon Fibers Reinforced Plastic). The structure is assembled with 18 glued poltruded tubes with peek internal protection (moisture absorption problems). The fibers used are not high thermal conductive fibers and the resin is epoxy.





The Gluing Mask:

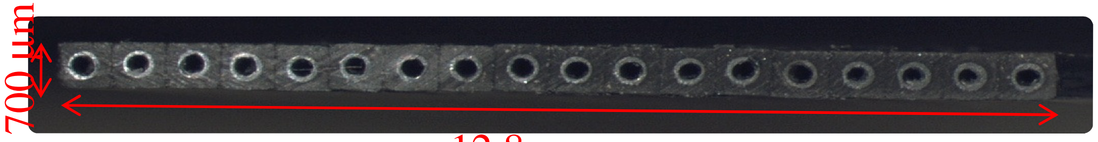




With this gluing mask we can realize support structure with a length of 100 mm. We are going to design a new mask that allows us to assembly structures with "final" dimensions of the module (with support for the hybrid, total length ≈ 250 mm)

Support Structure / 2

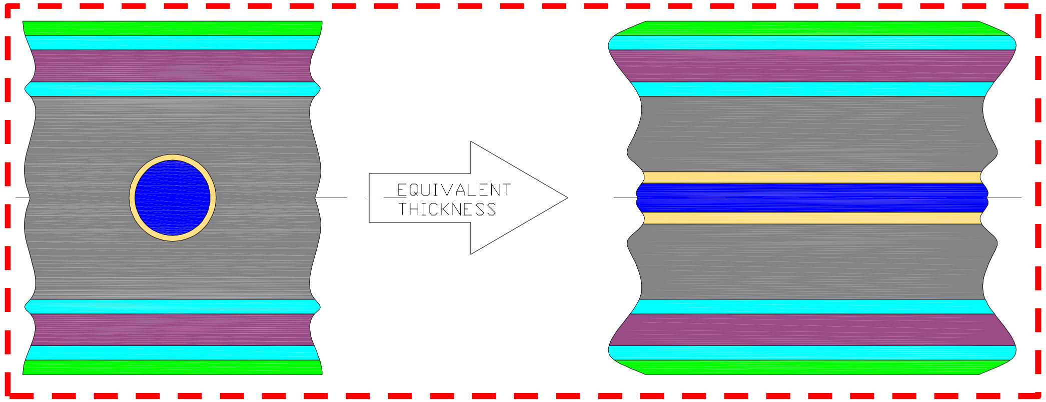
The Micro-Channel Prototype:



> ***Remarks****: With this kind of support structure the material is uniformly distributed all over the solid angle*

We've evaluated the average thickness in radiation length of the support structure by uniformly distributing the different volumes along the section of the support structure.

The scheme used is:



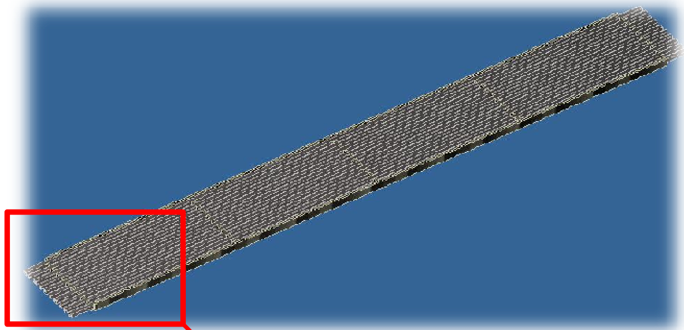
<u>The radiation length of the support structure (CFRP + peek tube + Water) is</u>:

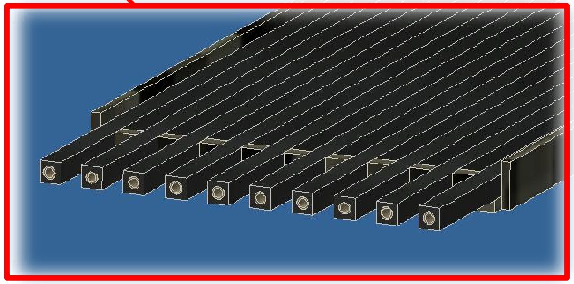
$$X = 0.28\ \%\ X_0$$

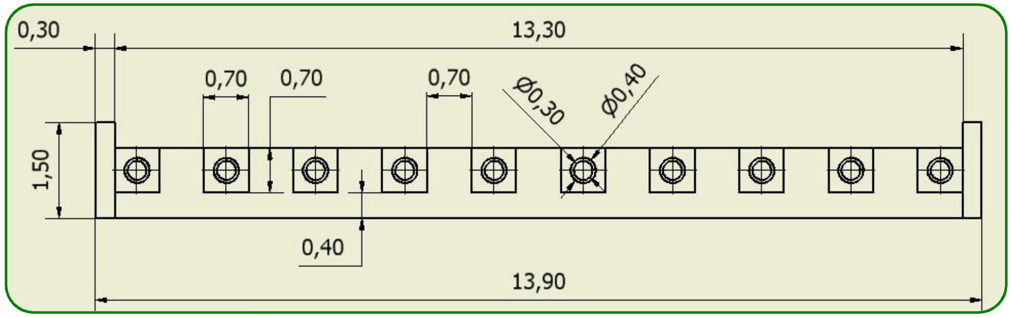
The micro-channel technology with Carbon Fibers tubes allows us to match the tightening requirements driven by Mechanics and Power dissipation.

Support Structure / 3

"Upgraded" Support Structure







The idea (radiation length driven) is to have a vacancy between the tubes in order to minimize the radiation length of the support structure. The module is assembled with 10 CFRP tubes, 2 longitudinal stiffeners and 5 transversal stiffeners

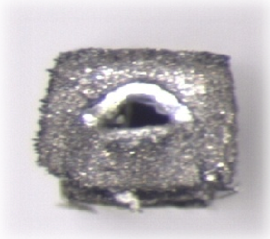
REMARKS: Naturally, it's important to maintain the efficiency of the cooling!!!

The radiation length of the support structure (CFRP + peek tube + Water + Stiffeners) is:

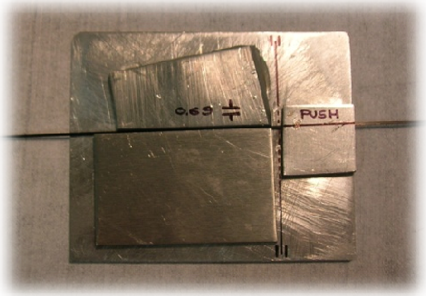
$$X = 0.2\ \%\ X_0$$

Support Structure / 4

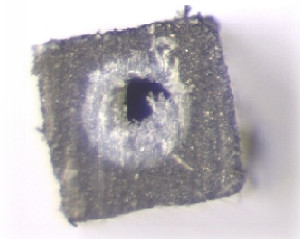
We have found some problems cutting the tubes with a “simple” cutter.

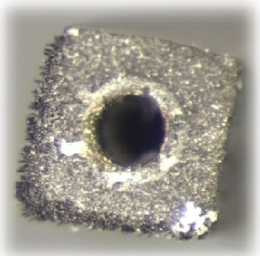


We have a better cut using high cutting velocity (16000 rpm), a cutting jig and a wire with a diameter of 200 μm in order to “clean” the cutting edges.



Cutting Jig



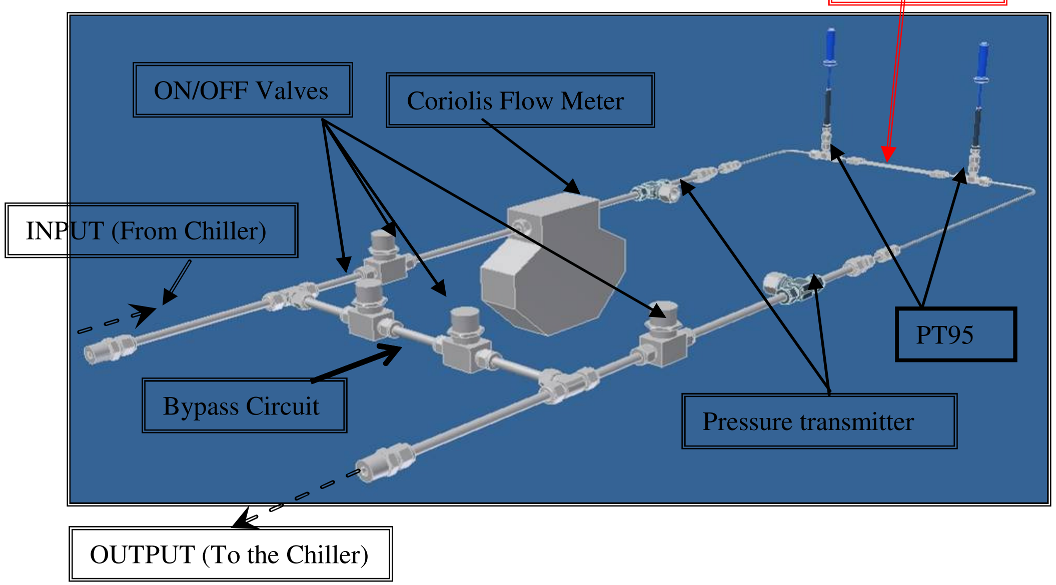



Support structure and hydraulic interface

The next step is to design and realize a fixture that allow us to use a very high speed cutting turbine (85000 rpm) with diamond tools (already ordered and received)

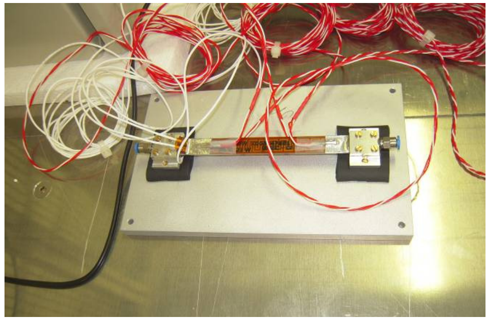
Experimental Setup (History) / 1

Cooling Circuit Schematic View:

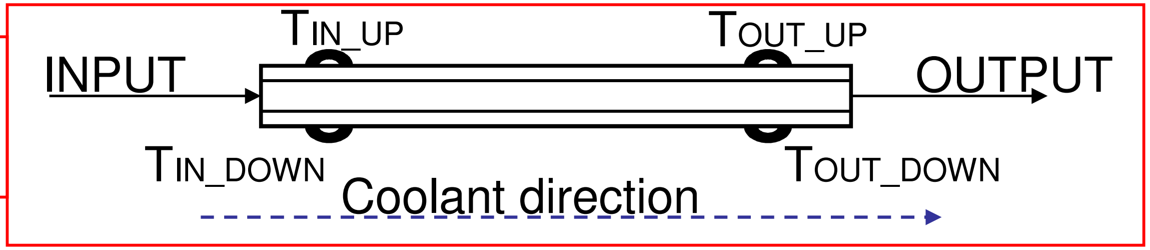


DAQ System:

Test Section:



Longitudinal sample section



Experimental Setup (History) / 2

The ***direct measures*** read during the tests are:

- Total power consumption of the heater
- Flow rate
- Fluid temperature inside the Coriolis
- Fluid temperature upstream the module
- Fluid temperature downstream the module
- Tin_up: temperature on the top of the input section
- Tout_up: temperature on the top of the output section
- Tin_down: temperature on the bottom of the input section
- Tout_down: temperature on the bottom of the output section
- P_in: pressure in the entrance section
- P_out: pressure in the output section

The ***indirect measures*** obtained from the tests are:

- ΔT fluid between input and output (longitudinal direction)
- ΔTup and ΔTdown, longitudinal ΔT evaluated on the top and on the bottom
- Fluid velocity evaluated as the ratio between flow rate and cross section
- Reynolds Number $Re = (\rho\ V\ D)/m$
- Pressure drop, difference between P_IN and P_OUT
- Nusselt Number
- Film coefficient $h = Nu\ K/D_h$
- Transversal ΔT between fluid and top (or bottom) of the module in input and output sections.

We are trying to change something in the cooling circuit in order to minimize the errors on the measures. This is possible replacing the temperature probes and taking measures closer to the test section.

Until now we have debugged the system and we've got the experience in handling of support structures and in data acquisition.

Present Works

- Design and realization of gluing mask to obtain a module with a length of 250 mm.
- Design and realization of jigs for cutting the single tubes.
- Realization of several micro-channel support structures. This is needed in order to have a family of modules to test. This kind of modules must be very close to the final module with the correct "thermal resistances" → that means the correct thickness of various materials. This realization allows us to study the behavior of different modules with same boundary conditions.
- We are also studying the positions of the temperature probes in order to read the temperature value in each layer of material.
- About the "upgraded" model: The first Ansys simulations show a difference in temperature of: 6 ÷ 8 °C. We are realizing the first "upgraded" prototype to test it.

Future Works

- Realize a prototype using thermoplastic resins in order to “build” a 3d shape.
- Go ahead with experimental tests and validation changing the boundary conditions on the “candidate” support structure (Temperature inlet, power density etc).
- Study the behavior of models realized with different fibers (different Thermal conductivity values).
- Design and realize a new hydraulic interface in order to have an easier assembly of the structure on flanges.