THE MICRO-COOLED LIGHT SUPPORT OF THE PIXEL MODULES FOR THE SUPERB EXPERIMENT

SuperB

INFN Sezione di Pisa

In HEP experiments the use of pixel detectors requires that high power density in the sensitive area should be carried away by efficient thermal systems.

Micro-channel cooling technology is featured by high efficient thermal exchange and it can profit by miniaturization technique applied on composite material (CFRP).

The key concept

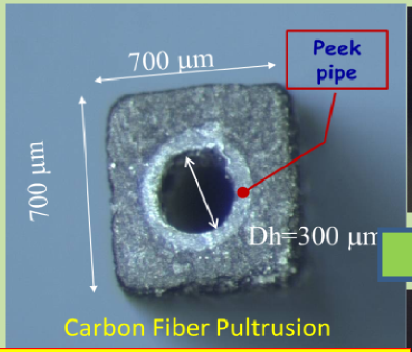
In a thermal convective exchange the h film coefficient is:
Nu = Nusselt number
k = Conductive heat transfer coefficient of the liquid
D_h = Hydraulic Diameter of the cooling channel

$$h = \frac{Nu \cdot k}{D_h} \quad (1)$$

$$Q = h\,S\,(T_w - T_f) \quad (2)$$

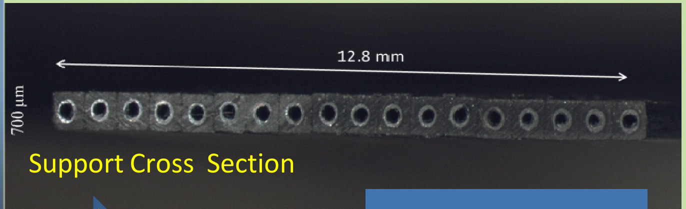
From formulas (1) and (2), for a Laminar flow fully developed, (Nu=constant), to maximize the thermal exchange Q → to maximize h → to minimize the hydraulic diameter : all these considerations brings to the micro-channel technology .

D_h minimization → high pressure drop → (needed a compromise between pressure drops and film coefficient value).

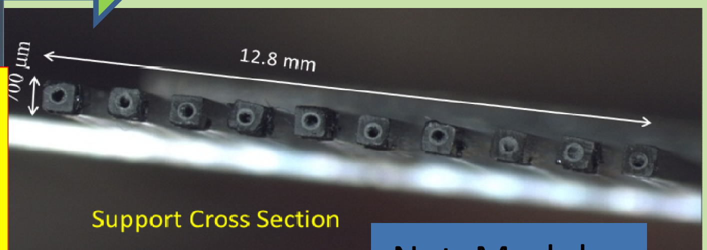


Single base micro-channel unit

A square CF micro-tube with an internal peek tube 50 µm thick used to avoid moisture on carbon fiber



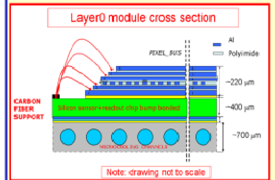
Full Module

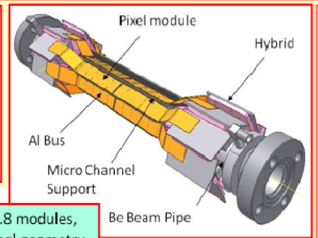


Net Module

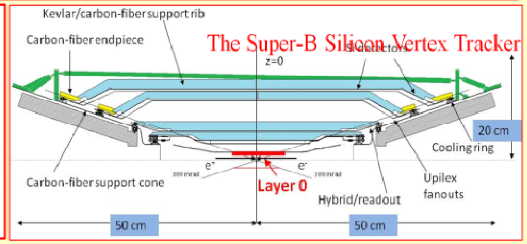
Super-B Silicon Vertex Tracker

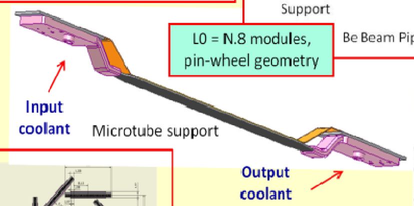
The micro-channel mechanical support is designed to match the specifications for the planned pixel upgrade of the most internal layer (L0) of the Silicon Vertex Tracker of the Super-B experiment :
- To evacuate the heat dissipated by the electronics (specific power up to 2 W/cm^2) and operating temperature of the sensors below 50°C
- Material budget of the pixel support structure and cooling(w/o cables/sensors) below 0.30% X_0.

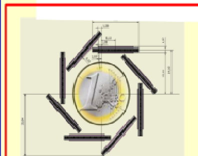




L0 = N.8 modules, pin-wheel geometry

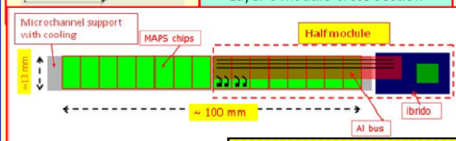


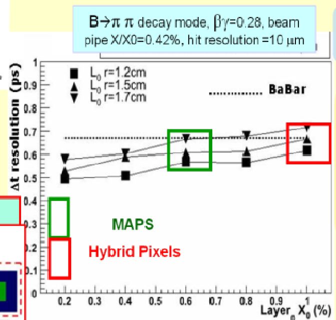




Comparing Layer 0 & beam pipe dimensions

Layer 0 module cross section





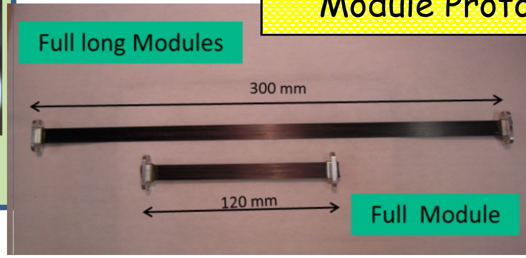
SuperB SVT based on Babar SVT design for R>3cm. BUT:

1) reduced beam energy asymmetry (7x4 GeV vs. 9x3.1 GeV) requires an improved vertex resolution (~factor 2)
- Layer0 very close to IP (@1.5 cm) with low material budget (<1% X_0) and fine granularity (50 µm pitch)
- Layer0 area 100 cm^2

2) bkg levels depend steeply on radius
- Layer0 needs to be fast and rad hard (>20x5 MHz/cm^2, >3x5 MRad/yr)

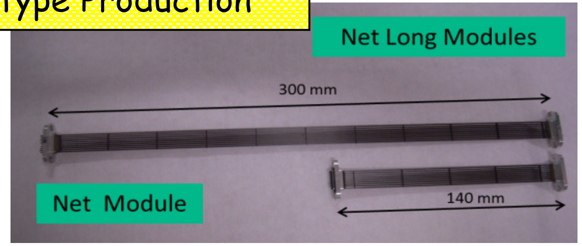
Module Prototype Production

Full long Modules



Full Module

Net Long Modules



Net Module

F.Bosi, INFN Pisa, 12th Pisa Meeting on Advanced Detectors

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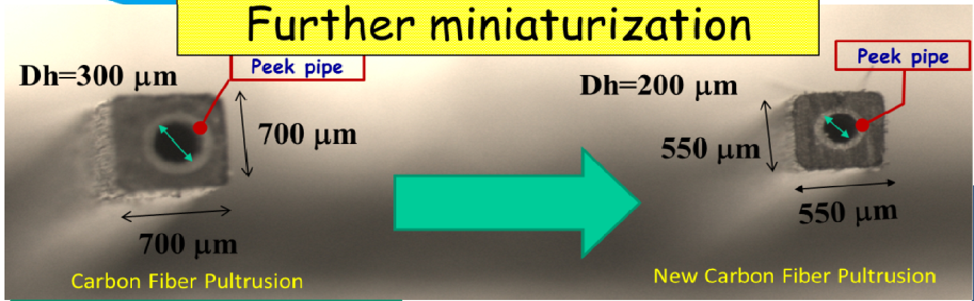
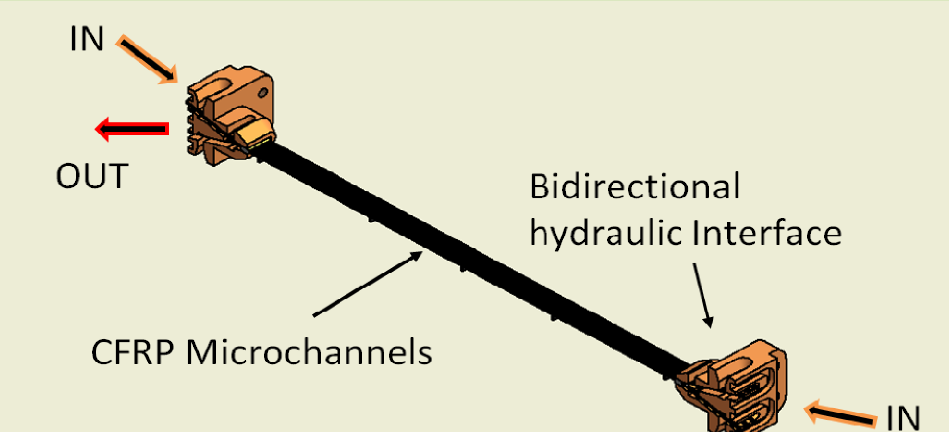
Further miniaturization

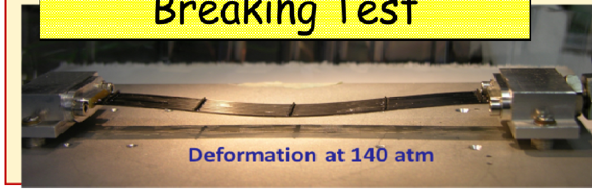


Carbon Fiber Pultrusion	New Carbon Fiber Pultrusion
Full Module $X = 0.28\ \%\ X_0$	Full Module $X = 0.22\ \%\ X_0$
Net Module $X = 0.15\ \%\ X_0$	Net Module $X = 0.11\ \%\ X_0$

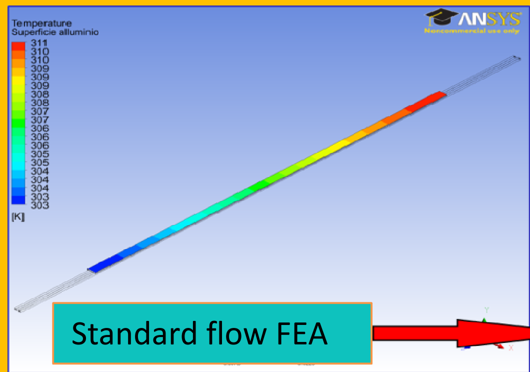


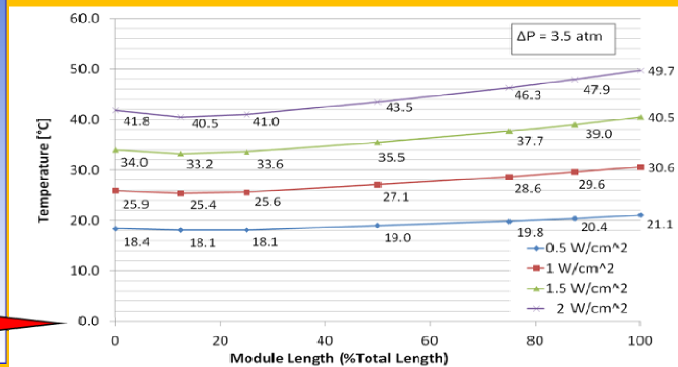
Net Module sample (L= 120 mm - D_h=200 μm th= 550 μm) - coolant water-glycol @ 10 °C

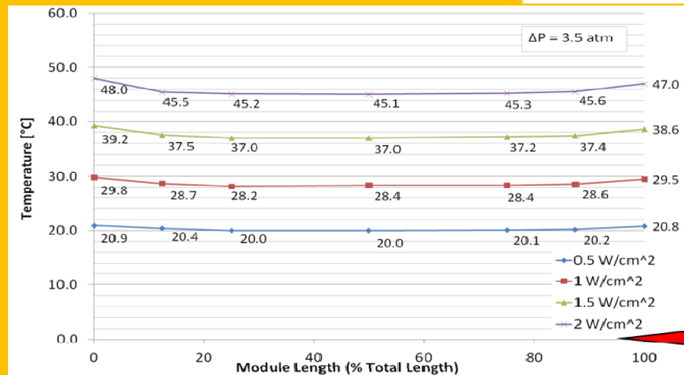
Breaking Test

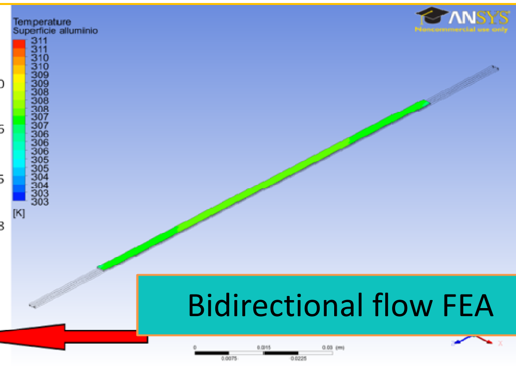


Structural test was realized on Net Module and Full Module prototypes. The test has been performed up to 140 atm . At this pressure the flanges of hydraulic interface were deformed to extrude the seal and produced the failure.









The micro-channel CFRP prototypes match the Super-B Layer 0 pixel detector requirements on material thickness (X_0). An efficient heat evacuation has been achieved by micro-channel technology through liquid forced convection.
The experimental results show that the Net Module is able to cool sensors with a power density up to 1.5 W/cm^2 with a X_0 value of 0.11 % and keep the sensor below 50 °C, as requested from specs. Moreover, with bidirectional coolant flow, it is possible to reduce the ΔT along the sensor below 2°C . Further optimization currently under development at the TFD Pisa laboratory: in progress the set-up for transition phase CO_2 cooling on CFRP micro-channels.

F.Bosi, INFN Pisa, 12th Pisa Meeting on Advanced Detectors