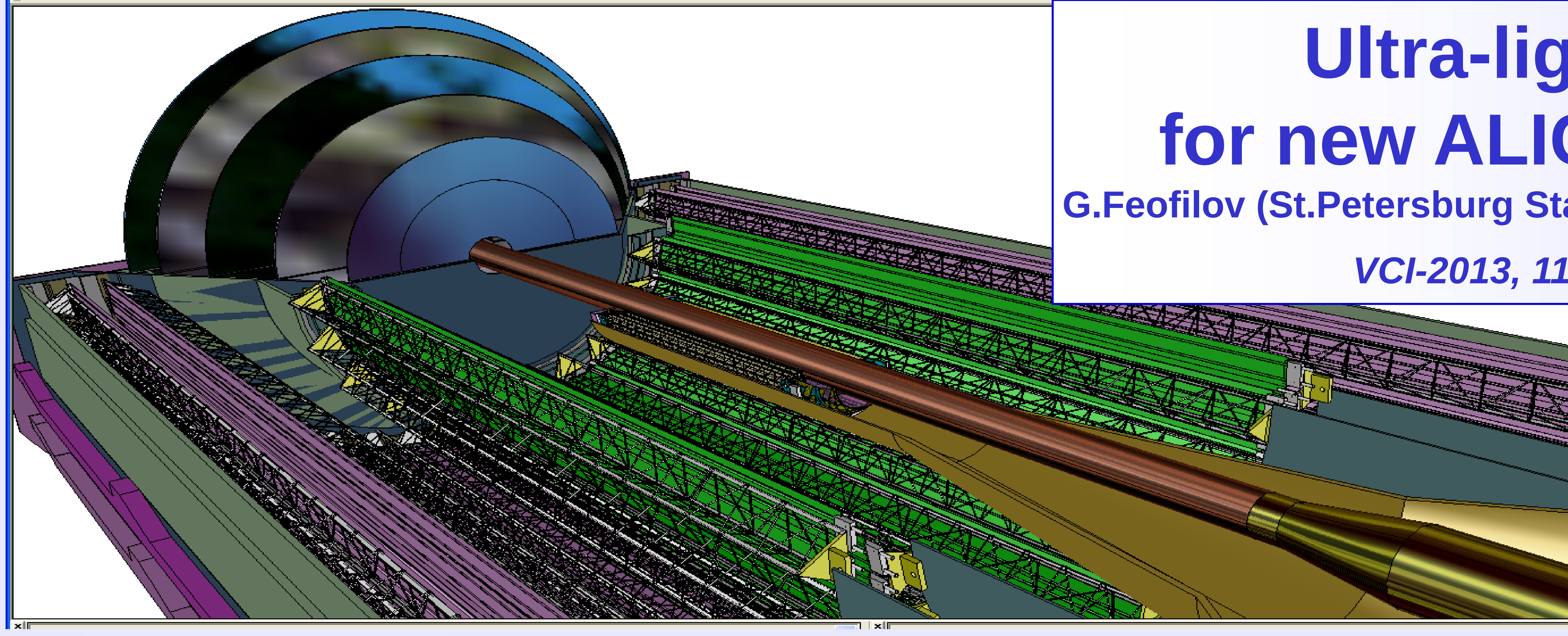

Ultra-lightweight systems for new ALICE Inner Tracker

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Abstract

We present practical solutions, design and examples of technologies of the low-mass, low-Z structures with various integrated cooling systems to be used for Monolithic arrays of pixel detectors (MAPS) for ALICE [1] at the LHC. These promising, high speed, precise, high granularity, 50 m thin pixel detectors will be used for particle tracking and vertex determination in the upgraded ALICE Inner Tracking System (ITS). The ALICE physics requirements are imposing a number of severe constraints in terms of mass minimization of all mechanical, cooling and signal cables structures, and in terms of precision and stability of the detector support structure.

Several technologies are presented. They include air-cooling and liquid cooling options: extremely low-mass (about 1.4 g) 30cm length Carbon Fiber (CF) based support structures with cooling ducts, CF Wound Truss Structure plus Carbon Plate with Embedded Pipes, Silicon micro-channels, Polyimide micro-channel cooling ducts.

Results of the first heat drain tests are showing that these ultra-lightweight systems are meeting the basic requirements in terms of cooling up to 0.5 Watt/cm2. The design [1] ensures the radiation transparency at the level of about 0.31% of X0 per layer for the 3 innermost layers forming the Inner Barrel.

References

[1] The ALICE Collaboration, "Upgrade of the Inner Tracking System Conceptual Design Report", CERN-LHCC-2012-013 (LHCC-P-005) September 11, 2012

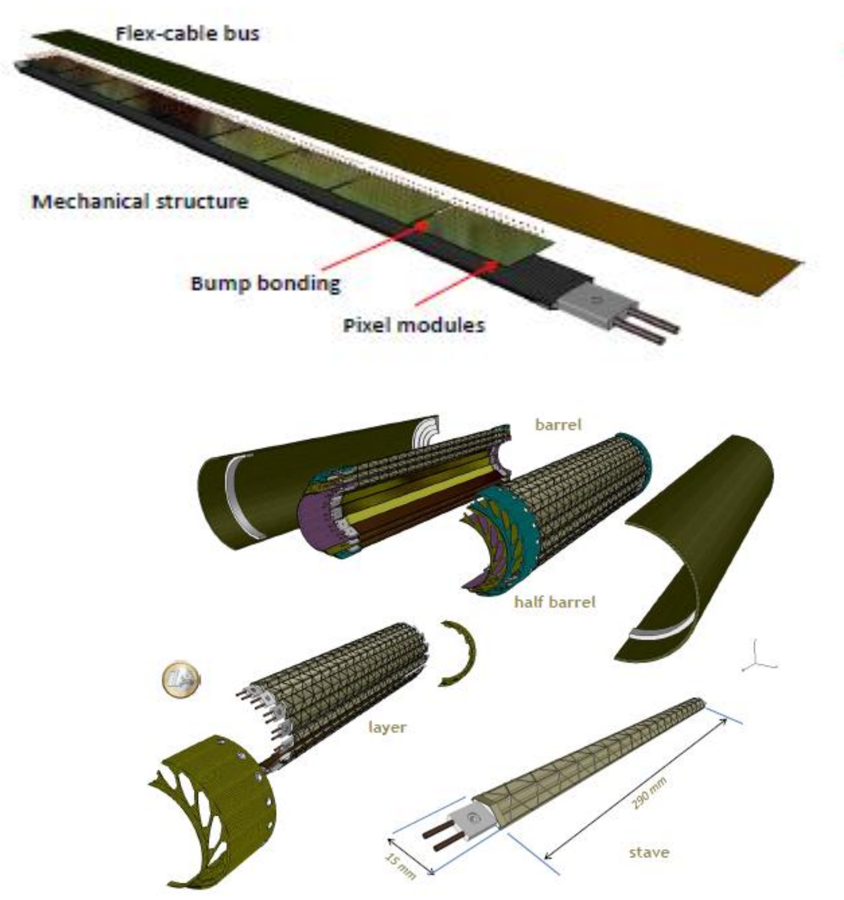
Table 1. Requirements for the ITS upgrade

Parameters	Inner Barrel	Outer Barrel
Beampipe outer radius (mm)	20	-
Beampipe wall tickness (mm)	0.8	-
Detector Technology	Pixel	Pixel−Strip
Number layers	3	4
Mean radial positions (mm)	22, 28, 36	200, 220, 410, 430
Stave length in z (mm)	270, 270, 270	843, 843, 1475, 1475
Power consumption (W/cm^2)	0.3 ÷ 0.5	≤ 0.5 mW/strip
Total material budget per layer (% of X_0)	≈ 0.3	≤ 1.0
Working temperature (°C)	≈ 30	≈ 30

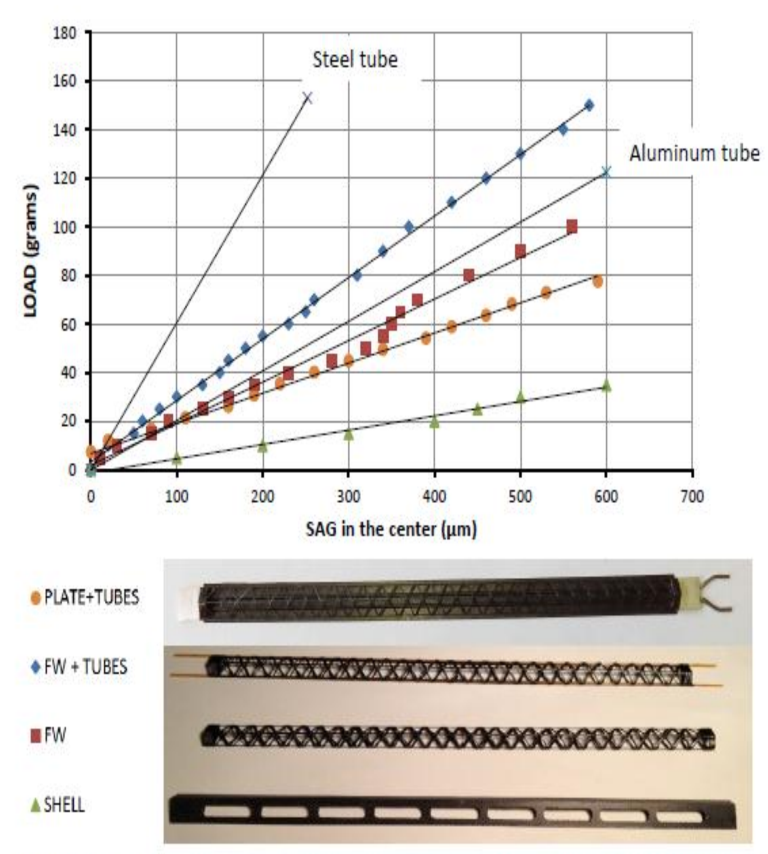
Technical constrains to the new ITS design

- MAPS sensors of 50 m thickness as one of the demanding options for all 7 ITS layers
- SINGLE-SIDED services (cables and cooling tubes and/or air ducts).
- Radiation length limitation: X/Xo per Si layer < 0.3– 0.8% (for inner – outer layers)
- High positional stability of detectors (< 100 microns)
- Capability to ensure up to 24kW of total heat power drain (or up to 0.5 Watt/cm2)

Drawings of the three innermost layers of new ITS



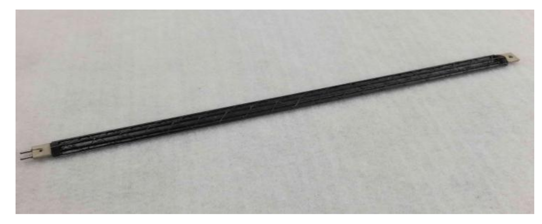
Bending tests of new ultralight structures



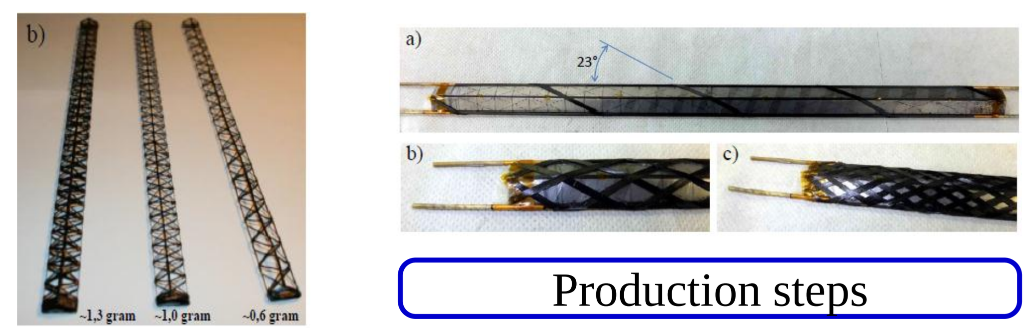
Advanced Carbon Fiber Technology

Table 2. List of carbon fibers used for the prototypes

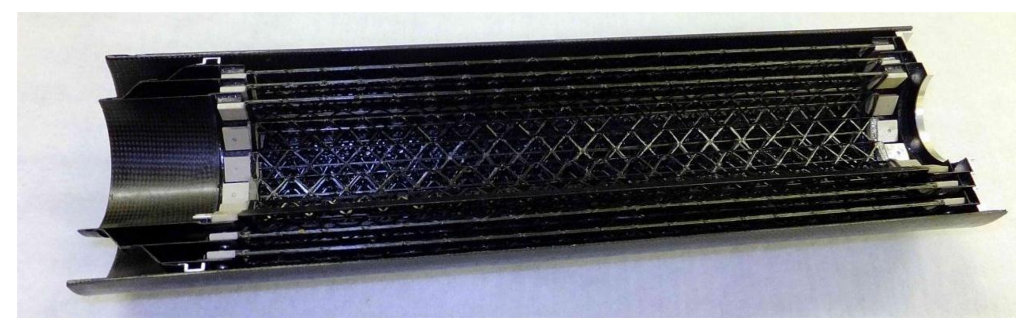
Composite type	Composite material	Young modulus (GPa)	Tensile strength (GPa)	Density	Thermal conductivity (W/m K)	Dimension (mm)
Unidirectional prepreg	K13D2U-2k	560	2.2	115 g/m^2	≈ 450	0.07
Impregnated thread	M60J-3K	365	2.9	0.15 g/m	≈ 95	D = 0.3
Impregnated thread	M55J-6K	340	2.1	0.32 g/m	≈ 100	D = 0.5
Fabric (0/90)	T300	-	-	207 g/m^2	-	0.12
CF Paper	FGS003	-	-	48 g/m^2	≈1000	0.03
Carbon fleece	-	-	-	8 g/m^2	-	0.02



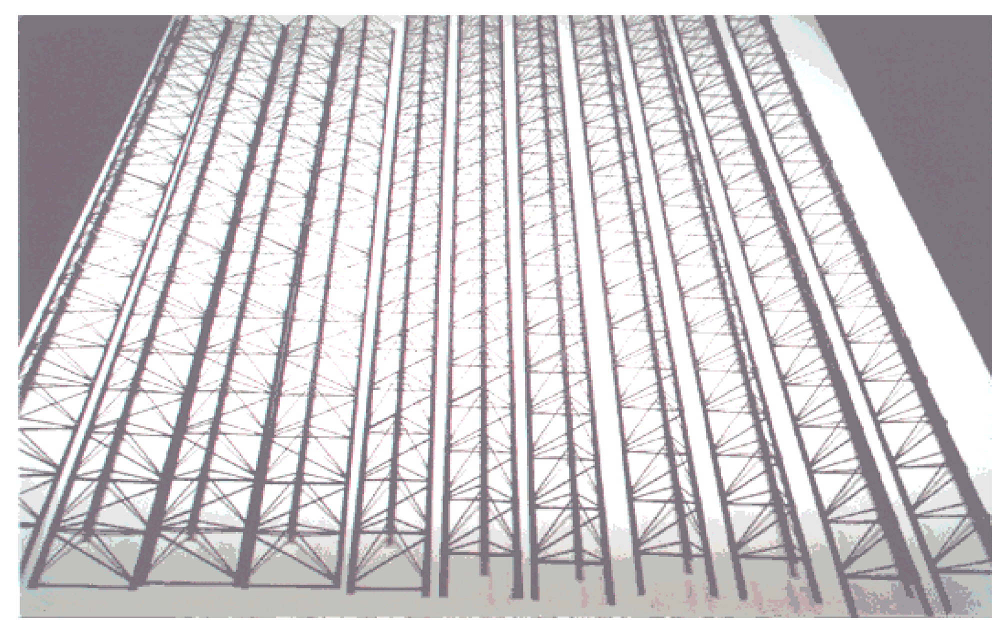
Low-mass (1.5g, L=30mm), CF structure with integrated cooling system (polyimide tubes diam.1mm)



Production steps



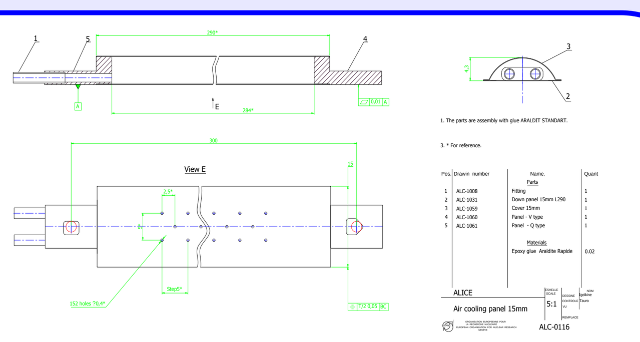
Full scale CF mechanical prototype of 3 innermost pixel layers



Ultralight (22g , L=1.1m) CF space frames produced in St.Petersburg for the currently running ALICE/ITS

Advanced cooling schemes are under evaluation

Air cooling



Requirements:
Gas temperature at the inlet--- preferably +14 deg.C
Gas temperature at the outlet - + 30-deg.C
Working gas – dry air , Cp = 1

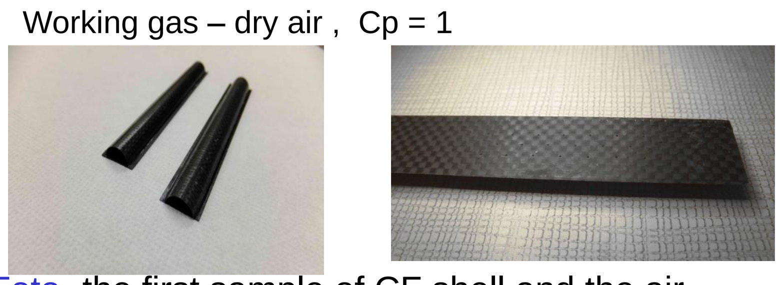
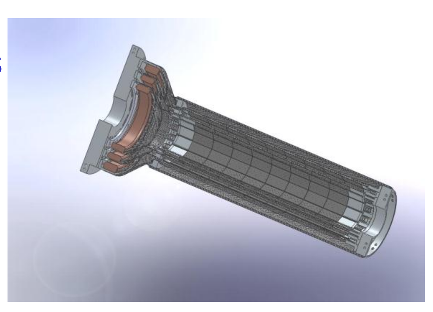


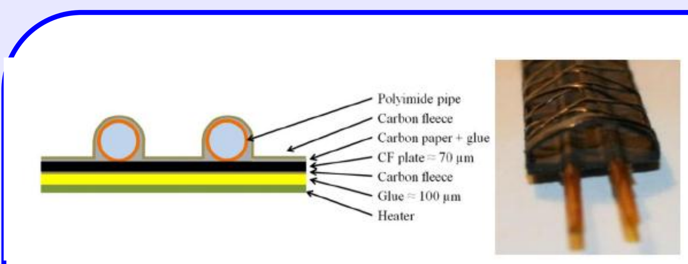
Foto- the first sample of CF shell and the air-cooling panel.

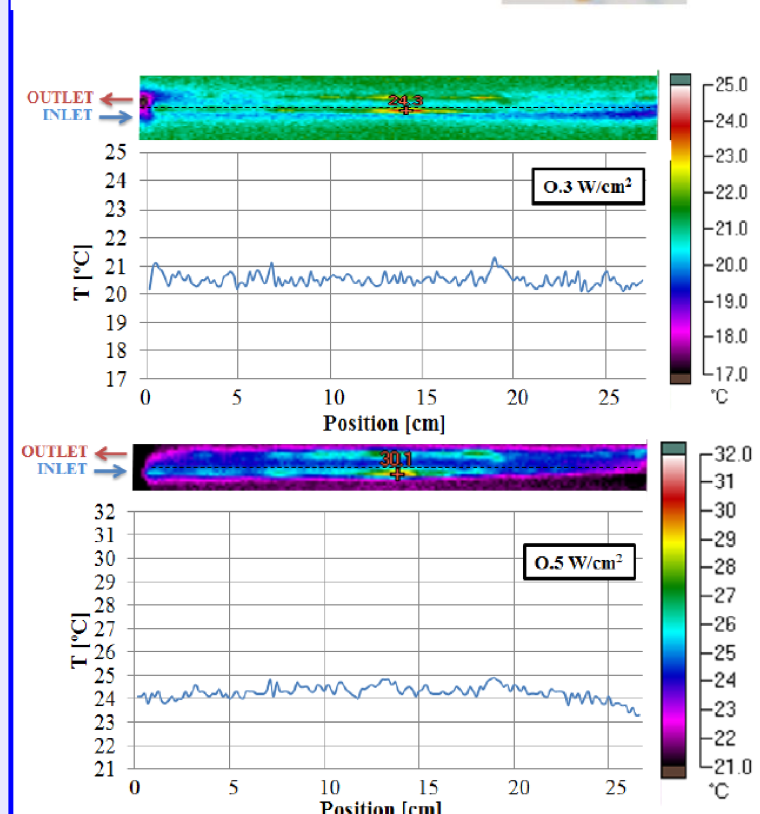
Calculations:
0,25 W/cm2 to 0,5 W/cm2 heat drain is feasible at a flow rate of air to about or 0,8 ... .1,2 l/s.
The air output temperature - 25C.
The pressure inside the C-fiber shell - (0,05 ... 0,1 kg/cm2).

R&D is in progress



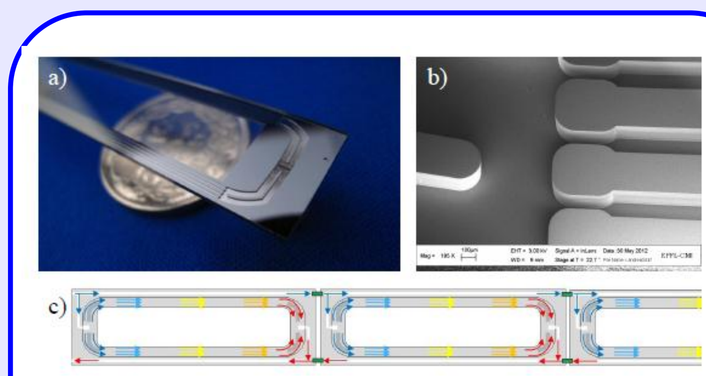
Liquid cooling





The first thermal Tests of one of the CF cooling for MAPS.

Silicon micro-channels



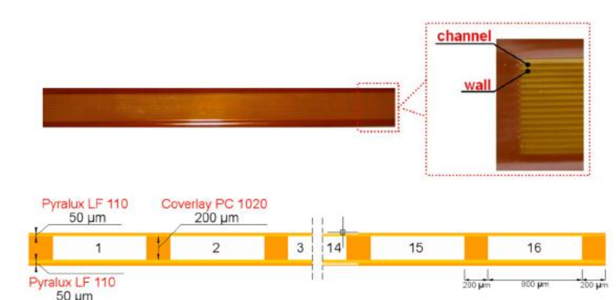
a) Picture of a silicon microchannel frame.
b) B)Zoom of the inlet manifold
c) Cscetch of frame interconnections

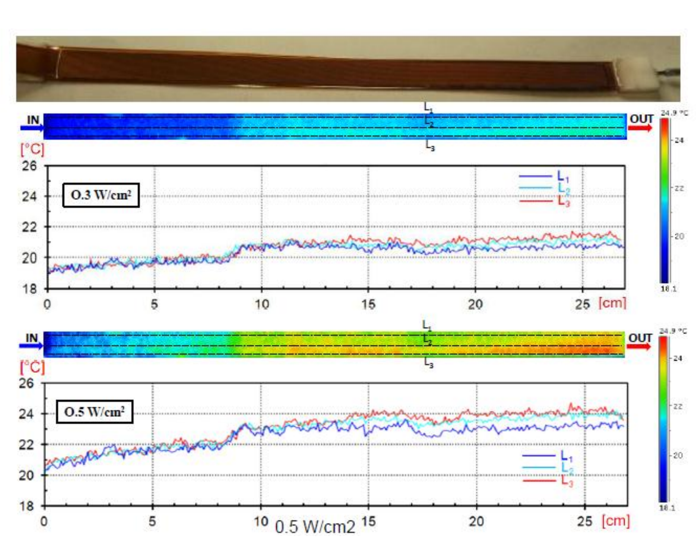
Option is being studied in the Framework of Cooling Project of the PH-DT group at CERN in cooperation with Microsystems Laboratory of EPFL in Lausanne and CSEM in Neuchatel.

The 1st prototype: Si-wafer 4 inches diameter was used, thickness 30 m, 0.1-0.5 Ohm,*cm p-type. The microchannels are covered by 50 m thick Si layer.

The R&D is in progress.

Polyimide microchannel cooling





Thermographic images and temperature profiles of the heater surface glued on the polyimide microchannel plate at 0.3 and 0.5 W/cm2.
Water flow rate 4.8l/h.

The R&D is in progress.