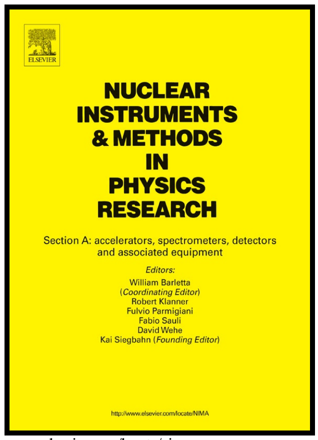


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# Thermal and hydrodynamic studies for micro-channel cooling for large area silicon sensors in high energy physics experiments

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**Abstract**

Micro-channel cooling initially aiming at small-sized high-power integrated circuits is being transferred to the field of high energy physics. Today's prospects of micro-fabricating silicon opens a door to a more direct cooling of detector modules. The challenge in high energy physics is to save material in the detector construction and to cool large areas. In this paper, we are investigating micro-channel cooling as a candidate for a future cooling system for silicon detectors in a generic research and development approach. The work presented in this paper includes the production and the hydrodynamic and thermal testing of a micro-channel equipped prototype optimized to achieve a homogeneous flow distribution. Furthermore, the device was simulated using finite element methods.

*Keywords:* micro-channel, cooling, HEP, silicon sensors, ANSYS, CFX, OpenFoam, microfluidics, heat sink, DESY, IMB-CNM, heat



## 1. Introduction

As electronic devices are becoming smaller and smaller their power density is increasing and cooling becomes more important than ever before. The small dimensions of today's integrated circuits demand for a down scaling of heat sinks. The first cooling of electronics through micro-channel flows was accomplished in 1981 by Tuckerman and Pease [1]. The endeavor to achieve a better understanding of heat and mass transfer through micro-channels has led to an ever growing number of approaches. Using varying channel geometries, different fluids and multi-phase flows helped to increase the efficiency of micro-channel cooling and led to tailor-made solutions in various fields of applications [2].
The attractiveness of this technology to high energy physics (HEP) is less its capability to handle high power densities, but its potential to provide a direct and homogeneous cooling, to save material and to satisfy tight restrictions on the choice of materials, regarding radiation hardness and thermal expansion.
In HEP experiments like the ones of the LHC, the silicon detectors, which are positioned very close to the interaction point, receive considerable radiation doses. The sensors in tracking detectors, equipped with readout electronics, have to be kept at low temperatures around 0 °C and in some cases much less [3]. This is mainly to keep the leakage current - introduced by radiation damage - low and to avoid thermal runaway. The cooling system typically adds a significant amount of material to the detector, leading to multiple scattering of charged particle tracks and conversions of photons into electron-positron pairs when passing through the material.
Saving material is essential to maintaining a good momentum resolution especially for low momentum particles. To do so, the heat sinks for the sensors, the readout electronics and the rest of the detector have to be within a certain radiation length, to limit multiple scattering and conversions. Moreover, the difference of the coefficient of thermal expansion (CTE) between sensor and heat sink must be kept small to avoid mechanical stress occurring by undergoing temperature cycles during production, installation and operation.
The micro-channel system presented in this paper is built upon a channel array etched in silicon, closed with a Pyrex layer and operated with a single-phase hydrofluoroether coolant [4]. Pyrex was chosen for the purpose of the studies presented here, because it provides the ability to visually inspect the channel array for impurities and empty channels. A design has been developed to maintain a homogeneous distribution of the coolant across the micro-channel layout. For thermal