

DETECTOR STRUCTURE DEVELOPMENT USING ACTIVE AND PASSIVE THERMOGRAPHY

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Abstract

During the development and production of the mechanical support structures of the PANDA-Micro-Vertex-Detector(MVD)* experiment passive and active thermography were applied and are shown. The combination of mostly carbon-based materials enables the development of lightweight structures, which satisfy the mechanical stability and thermal conductivity requirements. The carrier structure of the MVD stripe detector is mainly composed of carbon foams, high fiber content CFC materials and PMI-based foams. This enables to selectively cool areas where heat is generated and to decouple them from the temperature-sensitive areas of the sensor system. Passive thermography is used during our development work mainly to validate the results of thermal simulations, for design optimization and for the functional control of the carrier structure. Additionally active thermography allows us to identify anomalies and thermal disturbances, which would remain unnoticed in static processes. Also the investigation and characterization of adhesive layers are possible. For this purpose we developed special software algorithms which are sensitive to small-scale differences in heat conductivity.

INTRODUCTION

The PANDA Experiment will be one of the key experiments at the Facility for Antiproton and Ion Research (FAIR) which is under construction and currently being built on the area of the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, Germany. The central part of FAIR is a synchrotron complex providing intense proton beam will then be filled into the High Energy pulsed ion beams. Antiprotons produced by a primary Storage

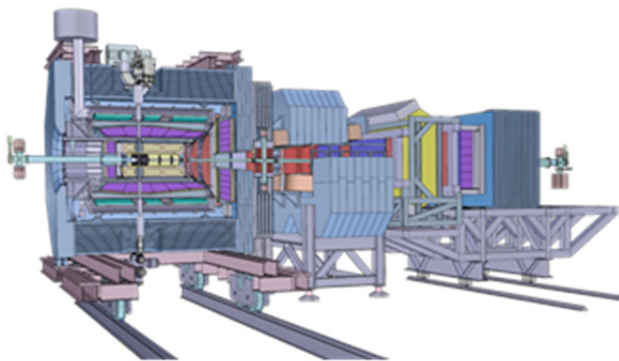


Figure 1: Design of PANDA detector [1].

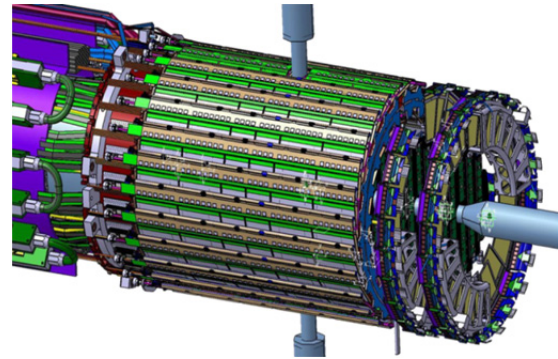


Figure 2: Design of the Micro-Vertex-Detector (MVD), inner part of PANDA 2: Design of PANDA detector.

Ring (HESR) which collide with the fixed target inside the PANDA Detector (Fig. 1). The word PANDA actually is an acronym which stands for Anti – Proton ANnihilation at Darmstadt. The PANDA Micro-Vertex-Detector (MVD) is situated in the target spectrometer and is the closest detector part with respect to the primary interaction vertex. The MVD is a tracking device for charged particles and thus essential for a very precise determination of secondary decay vertices of short-lived particles such as hyperons or mesons with charm or strangeness content. Due to the target pipe crossing the MVD volume, the detector has a half-shell and half-disk structure for the barrel and the forward part, respectively. In the current MVD design four barrel layers and six disks are foreseen (Fig. 2). While the two innermost barrel layers are equipped with pixel detectors, for the two outermost layers double sided silicon strip detectors (DSSD) are foreseen. Due to the high track density in the forward direction pixel sensors will be used in all six disks. The last two disks are equipped with both pixel detectors and DSSD in the inner and outer part, respectively [1].

To achieve the demanding spatial resolution required for the MVD, it is of utmost importance to reduce as far as possible the thickness of the detector measured in radiation lengths. This imposes high demands also on the support and cooling structures, which have to be on one hand as lightweight as possible and on the other hand very stiff.

The development and the production of the support and cooling structures for the strip part of the barrel and strip-disc is done by the ZEA-1, organized by the IKP. Both institutes belong to the Forschungszentrum Jülich.

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NOVEL CARBON BASED MATERIALS AND THE BENEFIT OF PASSIVE AND ACTIVE THERMOGRAPHY

In particular the carrier structure of the Panda MVD detector is mainly composed of carbon foams, high fiber content CFRP materials and PMI-based foams. The combination of these materials enables the development of structures, which satisfy mechanical stability and thermal requirements as well as the physical demands on a modern particle detector framework. The barrel part of the MVD consists of several shells, which are composed of individual Staves, which overlap like fish scales. The staves carry both the sensors as well as the front-end

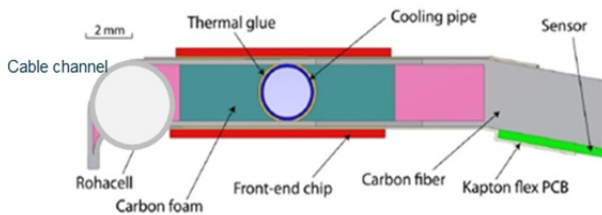


Figure 3: Cross section of a barrel layer holding structure (Stave).

electronic. Therefore special emphasis was placed on thermal decoupling between the sensors and the electronic part. Figure 3 shows schematically the section of a Stave. A cooling tube is embedded in carbon foam and runs just below the front-end electronic (Fig. 3). The heat conductivity of the foam is not homogenous. The foam is oriented so that the heat conductivity between the electronic part and the cooling line (z-direction) is twice higher than the heat conductivity between the electronic part and the sensors (in plane). The orientation of the foam

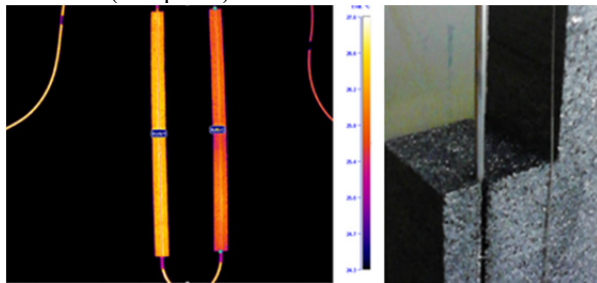


Figure 4: Thermography of carbon foam inlays (left) and the integration of the cooling pipe inside the foam during the manufacturing process.

before the manufacturing process is carried out with active pulse thermography. To largely prevent heat conduction in plane, between the sensors and the front end electronics the carbon foam is followed by a lightweight foam with high temperature resistance (Rohacel). In order to test the thermal properties of the manufactured components we use passive thermography systems with a large spatial resolution (Fig. 4). Passive thermography is also applied during the development process mainly to validate the results of thermal simulations, as well as design

optimization. Additional active thermography allows us to identify anomalies and thermal disturbances which remain unrecognized in static processes. For this purpose we developed a special experimental setup and adapted software algorithms which are sensitive to small-scale differences in temperature conductivity.

QUALITY CONTROL USING PULSE THERMOGRAPHY AND ADAPTED PROCESSING METHODS BASED ON LASER FLASH ANALYSIS

In addition to a large spatial resolution, newly thermography cameras also have a high temporal resolution capacity. We make use of this by combining the method of laser flash analysis with that of active pulse thermography. Therefore the CFC compound sample is positioned between a high-power flash lamp and a high-speed thermography camera. Thermal aperture prevents direct or reflected heat during the flash at the place of the camera. The energy of electromagnetic pulse of the flash lamp should be as large as possible, whereas the time duration of the pulse must be short as possible. If the pulse energy hits the front side of the probe, it is suddenly heated up. In Form of a thermal wave the energy travels through the sample body until it can be detected on the back side as a temperature rise. The running time of the thermal wave is depending on the thickness of the sample, its thermal conductivity, density and specific heat capacity. The temperature run of the back side of the probe is recorded as fast as possible to achieve a high contrast of the analyze image later on. From the resulting image series, a temperature-time plot is created for each pixel. Each of these plots passes through a curve fit, from whose parameters a value result which is proportional to thermal diffusivity of the area beneath the appropriate pixel. Based on these values RGB-data are calculated which are combined into the final analysis image. Figure 5 shows on the right side a 1.5mm thick CFRP | Rohacel | CFRP Sandwich test object with a 500µm steel inlay in diameter and for comparison a part of a 5ct piece below. Not shown is a foam cavity with the same dimensions (Fig. 4). Both defects are about 10mm deep. The test object was examined with pulse thermography, with a pulse length of 2milliseconds and a pulse energy of 6000J. The temperature sequence of the backside of the plate was measured with a FLIR SC6000 high-speed thermography camera with a framerate of 3000fps. On the left side of Fig. 5 the outcome of the thermography analysis is shown. With a clear contrast the steel inlay is represented and even the cavity can be recognized. Which shows that defect in a size of 0.5mm inside the foam layer of a CFRP compound can be identified using a combination of high speed pulse thermography and adapted analysis process, based on laser flash analysis.

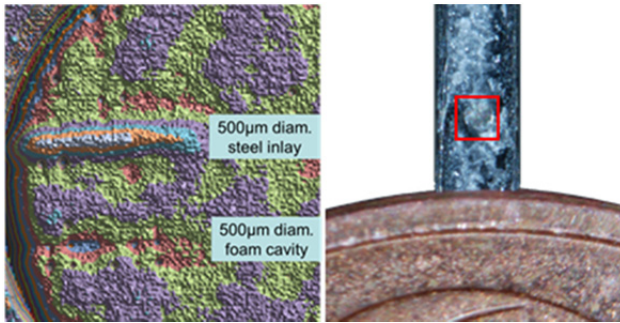


Figure 5: (right) 1.5mm thick Sandwich test object with 500µm diam. steel inlay and a part of a 5ct piece below; (left) active pulse thermography analysis of the test object.

CONCLUSIONS

A modern detector framework not only meets the requirements for mechanical stability, but also has an extended range of functions. For example, it contributes to the thermal management of the detector system. Active and passive thermography methods are an important component during development work and are major tools for quality assurance. Combining high areal and temporal resolution of modern thermography cameras, a specific experimental setup and adapted analysis algorithms we could achieve a localization of defects in a size of 0.5 mm inside the foam layer of a CFRP compound.

REFERENCE

- [1] PANDA Collaboration, <https://panda.gsi.de>