Forum on Tracking Detector Mechanics 2014

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Book of Abstracts

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Evaporative CO2 cooling in silicon micro-channels for the LHCb VELO

Author: Lars Eklund[1]

[1] *University of Glasgow (GB)*

Corresponding Authors: pawel.jalocha@cern.ch, lars.eklund@cern.ch

The LHCb Vertex Detector (VELO) will be upgraded in 2018 to a lightweight, pixel detector capable of 40 MHz readout and operation in very close proximity to the LHC beams. The thermal management of the system will be provided by evaporative CO2 circulating in microchannels embedded within thin silicon plates. This solution has been selected due to the excellent thermal efficiency, the absence of thermal expansion mismatch with silicon ASIC's and sensors, the radiation hardness of CO2, and very low contribution to the material budget.

Although microchannel cooling is gaining considerable attention for applications related to microelectronics, it is still a novel technology for particle physics experiments, in particular when combined with evaporative CO2 cooling. The R&D effort for LHCb is focusing on the design and layout of the channels together with a fluidic connector and its attachment to withstand pressures in excess of 200 bars. This talk will describe the design and optimization of the cooling system for LHCb together with latest prototyping results.
Even distribution of the coolant is ensured by means of the use of restrictions implemented before the entrance to a race-track layout of the main cooling channels. The coolant flow and pressure drop has been simulated together with the thermal performance of the device. The results can be compared to the cooling performance of prototype plates operating in vacuum. The design of a suitable low mass connector, together with the bonding technique to the cooling plate will be described.

Long term reliability as well as resistance to extremes of pressure and temperature is of prime importance. The setup and operation of a cyclic stress test of the prototype cooling channel designs will be described.

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Cooling studies for the CLIC vertex detector

Author: Fernando Duarte Ramos[1]

[1] *CERN*

Corresponding Author: fernando.duarte.ramos@cern.ch

The strict requirements in terms of material budget for the CLIC vertex detector (0.2% X0 per detection layer, including cables and supports) require the use of a dry gas for the cooling of the respective sensors. This, in conjunction with the compactness of the inner volumes, poses several challenges for the design of a cooling system that is able to fulfill the required detector specifications. This presentation introduces a detector cooling strategy using dry air as a coolant and shows the results of computational fluid dynamics simulations and experimental measurements used to validate the proposed strategy.

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Optimisation studies and tests of low-mass support structures for the CLIC vertex detector

Author: Francois-Xavier Nuiry[1]

[1] *CERN*

Corresponding Author: francois-xavier.nuiry@cern.ch

This talk follows the first one proposed by Fernando Ramos about the CLIC Vertex detector design, general requirements and thermal aspects.

A vertex detector with a barrel and an end-cap section, both composed of three double layers, is under development for CLIC. The strict requirements in terms of material budget (2 x 0.2% X0 per double layer, including 2 x 0.1% X0 of silicon for the sensors and readout) necessitate the development of novel low-mass support structures. This presentation focuses on optimisation studies and tests of ultralight full sandwich and open structures (staves) for the CLIC vertex barrel detector. Particular emphasis is put on stave stiffness studies (optimisation and measurements through 3-point bending tests) in view of the maximization of its eigenfrequencies. The mechanical studies, spanning from the stave prototyping program to vibrations studies in a wind tunnel, are shown. Mechanical simulations are compared with measurements on prototypes. In particular high modulus carbon fibres and low-density core materials are studied, as well as the corresponding assembly processes. The amount of material in terms of radiation length is calculated and compared for different stave designs and materials.

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The ultralight mechanics and cooling system of a DEPFET-based pixel detector

Authors: Carlos Lacasta Llacer[1]; Carlos Marinas Pardo[2]; Laci Andricek[3]; Marcel Vos[4]

[1] *IFIC-Valencia*

[2] *Universitaet Bonn (DE)*

[3] *Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D*

[4] *IFIC Valencia (ES)*

Corresponding Author: carlosmarinas@gmail.com

The DEPFET Collaboration develops highly granular, ultra-thin active pixel detectors for high-performance vertex reconstruction at future collider experiments. A fully engineered vertex detector design, including all the necessary supports and services and a novel ladder design with excellent thermo-mechanical properties, is being developed for the Belle II experiment. The self-supporting all-silicon ladder combined with the low power density of the DEPFET array and a cooling strategy that relies on forced convection of cold air to cool the active area allow for a very thin detector (0.2% X0). In the contribution, a detailed description of the full engineering system will be explained, including the latest finite-element simulations as well as thermal mockup measurements. In addition, a novel cooling concept based on wafer integrated micro-mechanized channel cooling will be presented.

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Electrical tapes for the ATLAS phase II barrel strip tracker upgrade

Authors: Anthony Weidberg[1]; Roy Wastie[None]

[1] *University of Oxford (GB)*

We report on R&D on the electrical bus tapes for the barrel strip tracker of the of the ATLAS phase II upgrade. In this system electrical connections (HV and LV supply, data, control and DCS) are distributed locally on the local supports by 130x12cm2 large multi-layer Kapton/Cu flex circuits, which are co-cured with the carbon fibre facesheets of the support structure. The tape design has been carefully optimized to minimize multiple scattering material.

We will describe the design and the manufacture of full-size prototype tapes, and the lessons learned. We will discuss the dimensional accuracy of these large-area flex circuits. We will also outline the co-curing process and the issues encountered in developing the right process for this technique. In preparation for the final mass production we have also developed a fully automated tape testing robot which is used to test the tapes at various production stages and we will describe this system in our presentation.

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The Mechanical Design of the Belle II Silicon Vertex Detector

Author: Florian Buchsteiner[1]

[1] *HEPHY Vienna*

Belle II will be the only experiment at the SuperKEKB collider in Tsukuba, Japan. Its innermost part surrounding the beam pipe - the "Vertex Detector" (VXD) - is composed of a 2-layer "Pixel Detector" (PXD) and a 4-layer "Silicon Vertex Detector" (SVD) made from double-sided silicon strip detectors. Because of the relatively low collision energy (10.58 GeV), multiple scattering and thus material budget are of utmost importance.

The Belle II SVD uses the largest available silicon sensors (made from 6" wafers) in order to reduce the number of structural elements. The sensors are mounted onto ladders, which are cylindrically arranged around the collision point. The main structure of the ladders are "ribs" made from a sandwich composite of carbon fiber plies with an Airex foam core. All the heavy materials are assembled outside of the 17…150° polar angle acceptance region. Inside, the averaged material budget of the ladders is 0.6% X0, which is dominated by the sensor material and also includes the highly efficient two-phase CO2 cooling.

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HFT PXL Vertex Detector Mechanics

Author: H. Wieman[1]

[1] *Lawrence Berkley National Laboratory*

The HFT PXL detector is a new two layer, inner, vertex detector which has just been installed in the STAR experiment at RHIC. This is the first time that a vertex detector based on MAPS[1] technology has been used in a collider experiment. The MAPS silicon chips have 20.7 micron square pixels and are thinned to 50 microns to reduce multiple coulomb scattering. The detector is configured in two layers with one layer at 2.8 cm radius and the other layer at 8.0 cm radius from the beam. The small pixel size, thinned silicon and small radius provides the opportunity to achieve the excellent pointing resolution required to topologically identify D mesons in the high track density environment of Au Au collisions at RHIC. The mechanics have been designed to take advantage of this potential providing a stable low radiation length structure. Air cooling, thin very rigid carbon composite support structures and aluminum flex cables are used to achieve a radiation length of 0.4% at the inner layer for non-angled tracks. The mechanics are also designed for detector withdrawal and replacement within a day should this be required mid run in the event of a beam excursion accident. We will report on design details and testing addressing the successful control of thermal deformations,

air induced vibrations and other stability issues. We will also cover the CMM methods that were developed to fully map the silicon surfaces and pixel locations. As planned from the beginning this mapping is used because fabrication of the very thin structures cannot be done to the mechanical tolerance required for our pointing resolution. The system designed for insertion and closure of the detector around the central beam pipe to a locked in position will be presented. Initial cosmic ray testing of the PXL detector installed in STAR demonstrates a 3D hit determination of better than 8 microns RMS.

[1] The cmos MAPS pixel chips were developed at IPHC by Marc Winters group.

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Module assembly and metrology for the Phase-2 Upgrade of the Strip tracking detector of the ATLAS experiment

Authors: Marc Manuel Hauser[1]; Susanne Kuehn[1]

[1] *Albert-Ludwigs-Universitaet Freiburg (DE)*

Corresponding Authors: marc.hauser@cern.ch, susanne.kuehn@cern.ch

For the phase-2 upgrade of the LHC in about ten years from now, several detector components of the ATLAS experiment will be replaced. The planned ten times higher LHC design luminosity will result in severe radiation dose and high particle rates. The current inner detector of the ATLAS experiment will be replaced by an all silicon tracking detector.
The layout of the upgrade silicon tracking detector envisages low mass and modular double-sided structures for the barrel and forward region. Modules, consisting of a silicon sensor and readout electronics, are foreseen to be assembled double-sided on larger carbon-core structures. Detailed plans are layout and prototyping of many components is ongoing. The talk will show the status of prototyping, assembly procedures and mechanical results of the prototypes. Both requirements and results on modules and larger structures, called stavelets and petalets, will be presented.
In addition, the experience of the prototyping and metrology results will be discussed.

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Concentric vacuum insulated transfer lines: feedback from Atlas and CMS newly installed systems

Author: Paola Tropea[1]

Co-authors: Bart Verlaat [2]; Claudio Bortolin [3]; Hans Postema [1]; Jan Godlewski [1]; Jerome Daguin [1]; Lukasz Zwalinski [1]; Marek Leslaw Gutt-Mostowy [1]; Nicola Bacchetta [4]; Paolo Petagna [1]; Thomas Eisel [1]; Tomasz Piotr Blaszczyk [5]

[1] *CERN*

[2] *NIKHEF (NL)*

[3] *University of Innsbruck (AT)*

[4] *Universita e INFN (IT)*

[5] *AGH University of Science and Technology (PL)*

Corresponding Author: paola.tropea@cern.ch

In order to transfer CO2 coolant from the cooling systems to the detector, coaxial vacuum insulated transfer lines have been chosen by both ATLAS IBL and CMS Pixel Phase I Upgrade. This work summarize the recent installation experience in both experiments, the issues encountered and gives some preliminary results on the performances.

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STUDIES ON THE MECHANICS AND COOLING OF THE ALICE ITS UPGRADE BASED ON CARBON FIBRE STRUCTURES

Author: Corrado Gargiulo[1]

[1] *CERN*

Corresponding Author: corrado.gargiulo@cern.ch

STUDIES ON THE MECHANICS AND COOLING OF THE ALICE ITS UPGRADE BASED ON CARBON FIBRE STRUCTURES

Corrado Gargiulo (1)

on behalf of ALICE Collaboration

(1) European Centre for Nuclear Research (CERN), Geneva CH-1211

ABSTRACT

A key item of the LS2 upgrade for the ALICE Experiment is the construction of a new, high-resolution, low mass 7-layer silicon tracker based on monolithic pixel detectors. A large effort is being devoted to the design and prototyping of the lightest possible mechanical supports that will maintain the silicon sensors in an accurate position while providing the cooling to remove the heat dissipated by the sensors.
The design choices that foresees the use of carbon fiber materials and non-standard production process are presented.

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THERMAL PERFORMANCE OF LIGHTWEIGHT COOLING SYSTEMS FOR THE ALICE ITS UPGRADE

Author: Manuel Gomez Marzoa[1]

Co-author: Corrado Gargiulo [2]

[1] *Ecole Polytechnique Federale de Lausanne (CH)*

[2] *CERN*

Corresponding Author: corrado.gargiulo@cern.ch

THERMAL PERFORMANCE OF LIGHTWEIGHT COOLING SYSTEMS FOR THE ALICE ITS UPGRADE

Manuel Gómez Marzoa (1)(2), Corrado Gargiulo (1)

on behalf of ALICE Collaboration

(1) European Centre for Nuclear Research (CERN), Geneva CH-1211
(2) Laboratoire de Transfert de Chaleur et de Masse (LTCM), École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, CH-1015

ABSTRACT

The thermal performance of lightweight cooling systems proposed as baseline for the Inner and Outer Barrel modules of the ITS upgrade of the ALICE Experiment at CERN is reported. In order to provide minimum negative impact over the detector resolution, the cooling systems consist of a minimal amount of specific materials and refrigerants. Experimental heat transfer tests with water in single phase and boiling per-fluorocarbon (C_4F_{10}) refrigerant were carried out with the goal of thermally characterizing the prototypes. Maximum temperature, temperature uniformity and refrigerant pressure drop are the main parameters of interest in this study. The prototypes are capable

to keep the detector temperature within its operational limits (below 30℃) for power densities as high as 0.3 W cm-2, meeting the requirements of material budget at the same time This is possible thanks to the use of lightweight, high-conductive materials for the structure and innovative thin wall plastic tubes for the refrigerant flow.

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Detector Modules for the CMS Phase II Outer Tracker

Author: Andreas Mussgiller[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Author: andreas.mussgiller@cern.ch

For the high-luminosity LHC (HL-LHC), CMS will install a new silicon tracker. As a result of the expected increase in instantaneous luminosity by a factor of five compared to the LHC design value, the granularity will be significantly increased in order to cope with the higher track density. Moreover, the expected radiation dose requires the use of more radiation hard sensor material that has to be cooled to temperatures below -20℃. It is also planned to use information from the tracker in the Level-1 trigger of CMS. For this purpose the detector modules will consist of a stack of two silicon sensors that will allow for the determination of the transverse momentum and the generation of a trigger signal directly on the module and at each bunch crossing. Currently two different module types are foreseen, a stack of two silicon strip sensors at large radii and a stack of a pixel and a strip sensor at inner radii. The contribution will discuss the module designs and the status of the ongoing R&D activities.

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Lessons learnt from aligning the CMS silicon tracker

Author: Frank Meier[1]

[1] *University of Nebraska (US)*

Corresponding Author: marco.musich@cern.ch

The alignment of the CMS silicon tracker reached a remarkable precision and it is only based on track-based algorithms. This talk will present the strategies used, methods to validate the results and the results itself. An emphasis will be put on lessons learned and their application to future silicon trackers.

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Movements monitoring of CMS Tracker detector during cooling procedure with the Laser Alignment System

Author: Adrian Perieanu[1]

[1] *Rheinisch-Westfaelische Tech. Hoch. (DE)*

Corresponding Author: ostap@physik.rwth-aachen.de

The Laser Alignment System (LAS) of the CMS Tracker detector monitors the position variation of its components with a rate of five minutes. A precision of 1 micrometer for the x and y translations, and 1.1 microradians rotation around z-axis was achieved. For rotations around x- and y-axis the achieved precision is 3.7 and 2.6 microradians, respectively.

During the cooling down test performed in November 2013, the Tracker internal structure was monitored and movements of thermal nature were observed. With the tracks based alignment algorithm, Millepede, the observed LAS alignment parameter variations were cross-checked using cosmic rays.

The results obtained from both alignment strategies, LAS and tracks based, are presented. The consistency of the alignment parameters variations is discussed.

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Large moment of inertia structures to reduce mass and improve performance of silicon detectors

Author: Neal David Hartman[1]

Co-authors: Eric Anderssen [1]; Mauricio Garcia-Sciveres [1]; Murdock Gilchriese [1]

[1] *Lawrence Berkeley National Lab. (US)*

Corresponding Author: neal.hartman@cern.ch

While HEP silicon detectors have embraced next generation materials, including carbon fibers, foams, and advanced resin systems, they have been slow to capitalize on the design freedom offered by composite fabrication techniques. In particular, limited use has been made of large moment of inertia structures for coupling sensors together in anything but simple shells. By creating high inertia, thin section substructures that are self-supporting, silicon detectors can reduce mass while simultaneously increasing stiffness and stability, and even obviate the need for redundant or global support structures. Design paradigms and figures of merit for such high inertia structures will be presented, In addition to potential novel fabrication techniques, such as Resin Transfer Molding, which may be ideally suited to this genre of fabrication.

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Large Area Inspection and Metrology for High Performance Integrated Structure

Author: Carl Haber[1]

Co-authors: Brian Amadio [2]; Haichen Wang [1]; Sergio Diez Cornell [1]

[1] *Lawrence Berkeley National Lab. (US)*

[2] *LBNL*

Corresponding Authors: carl.haber@cern.ch, eric.anderssen@cern.ch

A variety of new tools and methods have become available which provide fast and accurate metrological data in an efficient and scalable way. These include high speed line scanners, laser, and confocal surface probes.

We will report on studies made, using these methods, of
1) precision metrology of large electro-mechanical co-cured laminates
2) non-contact imaging of hidden defects in precision laminates

3) development of scalable inspection systems which would be appropriate for fabrication workflow in the HL-LHC detector assembly process.

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Parametric studies of materials for improved thermal performance

Author: Eric Anderssen[1]

Co-authors: Carl Haber [1]; Joseph Silber [2]

[1] *Lawrence Berkeley National Lab. (US)*

[2] *LBNL*

Corresponding Author: eric.anderssen@cern.ch

Recent results on nano-particle modified lamination resins for improved thermal conductivity, including processing techniques, lessons learned and preliminary results.
Paramaterization of conductive foams for use as a heat transfer media in air flows

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Development of Low Mass Integrated Local Supports for the ATLAS Tracker Upgrade

Author: Tim Jones[1]

Co-authors: Carl Haber [2]; David Lynn [3]; Georg Viehhauser [4]; Peter Sutcliffe [5]; Qing Yang [4]; William Emmet [6]

[1] *University of Liverpool (GB)*

[2] *Lawrence Berkeley National Lab. (US)*

[3] *Brookhaven National Laboratory (US)*

[4] *University of Oxford (GB)*

[5] *University of Liverpool*

[6] *Yale University*

Corresponding Authors: peter@hep.ph.liv.ac.uk, peter.sutcliffe@cern.ch, tim.jones@cern.ch

The silicon tracker of the ATLAS experiment will be replaced in 10 years'time in readiness for the high luminosity operation of the LHC. The replacement tracker will cover 200m2 and will consist of 10,000 detector modules mounted onto a mechanical support structure. Central to the design of the support structure is the concept of a highly integrated local support (or stave) onto which 26 modules are mounted. The stave provides the necessary mechanical support, cooling and electrical interfaces required by the modules for implementation in ATLAS. In this paper we describe the current status of the design of the local supports together with the results of finite element analyses and measurements from prototypes and discuss the applicability of the design to the mass manufacture of a large number of staves.

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Studies of Adhesives for HL-LHC Tracking Detectors

Author: Tim Jones[1]

Co-author: Simon Canfer [2]

[1] *University of Liverpool (GB)*

[2] *STFC - Rutherford Appleton Lab. (GB)*

Corresponding Author: tim.jones@cern.ch

The quest for low mass tracking systems for the next generation of experiments at the LHC requires extensive use of low density polymeric materials. Such materials take the form of plastics, resins in CFRP and adhesives. In this paper we attempt to summarise the results of experimental investigations into such materials within the context of developments for the LHC and other similar activities. Initial results of a new flexible detector epoxy developed at STFC-RAL will be presented, including post irradiation studies. Finally we present the current status of our attempts to document these results in a database with the intention of making these data available throughout the community.

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Construction of an actively cooled MAPS device operated in vacuum near a storage ring beam

Author: Prometeusz Jasinski[1]

Co-author: Leithoff Heinrich [1]

[1] *Helmholtzinstitut Mainz*

Corresponding Author: jasinski@kph.uni-mainz.de

The Luminosity Detector for the PANDA experiment at FAIR/Darmstadt is a tracking device 11m downstream of the interaction point. Since we are measuring elastic pbar-p scattering as a reference channel to determine the luminosity, we need to reconstruct tracks near the non interacting antiproton beam which is stored in the HESR (high energy storage ring). We would like to share our experience in the construction of a prototype which involves:

- a stiff rectangular vacuum box for very low pressure down to 10-9 mbar
- construction of a conical laminate from very thin aluminum and mylar
- differential pumping to protect a thin transition foil from bursting
- moving heavy tracking devices precisely in vacuum
- cooling of active silicon pixel sensors in vacuum
- construction of very thin tracking layers
- issues of large CVD-diamond wafers
- thermal contacts of passive heat conductors to actively cooled heat sinks
- leaky connections, Swadgelok experiences, cooling with ethanol at -25℃
- alignment of detectors in vacuum in respect to the experiment

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On the use of Fiber Optic Sensors for structural and enviromental monitoring of the Belle-II vertex detector

Authors: David Moya Martin[1]; Ivan Vila Alvarez[1]

Co-author: Malte Frovel [2]

[1] *Universidad de Cantabria (ES)*

[2] *INTA*

Corresponding Authors: david.moya.martin@cern.ch, ivan.vila@cern.ch

The DEPFET vertex detector at Belle-II incorporates a structural (vibrations and displacement) and environmental (temperature and humidity) monitor based on Fiber Bragg Gratting (FBG) optical sensors. The basic layout and principles of the monitoring system will be reviewed including results from the 2014 PXD-SVD combined testbeam and a detailed description of the FBG packaging, radiation hardness assessment and calibration procedures to make the FBG sensors a suitable technology for HEP applications.

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Concept of a Tilted Barrel for the CMS Tracker Phase 2 Upgrade

Authors: Antti Onnela[1]; Kamil Norbert Cichy[2]

Co-authors: Alan Honma [1]; Antonio Conde Garcia [1]; Duccio Abbaneo [1]; Giovanni Bianchi [1]; Pierre Rose [3]; Stefano Martina [4]; Stefano Mersi [1]

[1] *CERN*

[2] *Cracow University of Technology (PL)*

[3] *Ministere des affaires etrangeres et europeennes (FR)*

[4] *Universita e INFN (IT)*

Corresponding Author: antti.onnela@cern.ch

A novel detector design with tilted silicon strip/pixel detector modules is being considered for the Inner Barrel section of the CMS Tracker Phase 2 Upgrade. By tilting the modules towards the interaction point the angular coverage of the modules is increased, leading to less modules needed. The layout and a support structure concept for such tilted geometry are presented.

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The MVD of the CBM experiment at FAIR: Selected Aspects of Mechanical Integration

Author: Michal KOZIEL[1]

[1] *IKF Frankfurt am Main*

The Compressed Baryonic Matter experiment (CBM) at the future FAIR facility at Darmstadt (Germany) explores the phase diagram of strongly interacting matter in the regime of highest net baryon densities with numerous probes, among them open charm. Open charm reconstruction requires a vacuum compatible Micro-Vertex Detector (MVD) with unprecedented properties, arranged in (up to) four planar detector stations in close vicinity of the (fixed) target. The CBM-MVD requires sensors featuring a spatial resolution of < 5 μm, a non-ionizing radiation tolerance of > 10^{13}neq/cm^2, an ionizing radiation tolerance of 3 Mrad, a readout speed of few
10 s/frame, and the integration in detector planes with several per mille X0 material budget only.

In our contribution we will address aspects related to the mechanical integration of the CBM-MVD, among those: Vacuum compatibility, glue development, commissioning of the 50 μm thin CMOS sensors with standard probe cards, lithography on CVD diamond.

The prototyping phase of the MVD addressed several issues related to sensor integration into the vertex detector [1], however, the vacuum compatibility of the approach used has not been studied up to now. To do so, assembled beam telescope stations were placed inside a vacuum chamber and successfully run for several days at the pressure of about $2{\cdot}10^{-6}$ mbar. Despite the first results are very promising, a full validation of vacuum compatibility requires further tests which are currently addressed. Regarding the electrical connectivity of the sensors we study option to guide electrical traces close to the sensors with minimum material budget (dedicated flex, lithography on carrier material), as well as dedicated feed-throughs for a vacuum chamber.

Construction of the CBM-MVD station with minimum material budget of 0.3% x/X0 for the 1'st station up to 0.5% x/X0 for the 4'th station is an ambitioned task. Therefore, developing a dedicated thin read-out flex is mandatory. In addition, together with our partner institutions (GSI Darmstadt and Hochschule RheinMain Russelsheim), we have addressed studies aiming at verifying a feasibility of employing Al traces on a CVD diamond carrier using photolithography methods. Here, we report on "phase-1" of the project, which focuses on placing aluminum traces on CVD diamond.

Imperfections in CMOS process as well as further dicing and thinning procedures may reduce the final yield of sensors to be mounted in the detector stations to about 60-70%. To select sensors with the best characteristics, probe-testing prior to integration is mandatory. Due to the fact that the MVD sensors are thinned to 50 um, which is not a standard industrial thickness, feasibility of needle tests of such thin devices was addressed at IKF with a CMOS sensor named MIMOSA-26 [2]. A dedicated probe-card hosts 65 tungsten needles with minimum pitch of 120 μm provides all necessary signal lines to operate the sensors and read a data stream out. The first successful tests of 50 μm thin precursors of final CBM-MVD sensors will be discussed here.

[1] M. Koziel et al., Nuclear Instruments and Methods in Physics Research A 732 (2013), pp. 515–518C.

[2] G. Voutsinas et al, Nuclear Physics B - Proceedings Supplements, Vol. 215, Issue 1, (2011), pp. 48-50.

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The integration of the PANDA Micro-Vertex-Detector

Author: Tommaso Quagli[1]

Co-authors: Daniela Calvo [2]; Dirk Grunwald [3]; Giuseppe Giraudo [2]; Hans Georg Zaunick [1]; Kai-Thomas Brinkmann [1]; Paolo De Remigis [2]; Robert Schnell [1]; Rosenthal Eberhard [4]; Silvia Coli [2]; Tobias Stockmanns [3]; Vincenzo Fracassi [3]

[1] *Justus-Liebig-Universität Gießen*

[2] *Universita e INFN (IT)*

[3] *Forschungszentrum Jülich GmbH*

[4] *Foschungszentrum Jülich GmbH*

PANDA is a key experiment of the future FAIR facility, under construction in Darmstadt, Germany. It will study the collisions between an antiproton beam and a fixed proton or nuclear target. The Micro Vertex Detector (MVD) is the innermost detector of the apparatus and its main task is the identification of primary and secondary vertices. The central requirements include high spatial and time resolution, trigger-less readout with high rate capability, good radiation tolerance and low material budget.
To meet these requirements, the detector will be composed of four concentric barrels and six forward disks. The inner layers will be instrumented with silicon hybrid pixel detectors, while for the outer two barrels and for the outer part of the last two disks double-sided silicon microstrip detectors were chosen.

Because of the compact layout of the system, its integration poses significant challenges. The detectors will be supported by a composite structure of carbon fiber and carbon foam, which will ensure the precise positioning of the sensitive elements while keeping the material budget low. A water-based cooling system embedded in the carbon mechanical supports will be used to remove the excess heat from the readout electronics. The fixed target setup of the experiment requires all the services to be routed in the backward direction, traversing the sensitive volume. The use of light aluminum cables and busses for power and data transmission within the detector has been therefore studied to minimize the impact of the cabling on the material budget.
In this contribution the design of the detector and the ongoing development of the hardware components related to its integration will be presented.

Supported by BMBF, HIC for FAIR, INFN and JCHP.

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The development of common thermo-mechanical facilites

Author: Carlos Lacasta Llacer[1]

[1] *IFIC-Valencia*

Corresponding Author: carlos.lacasta@cern.ch

The requirements imposed by the Physics of the new particle and nuclear physics experiments and the upgrades of the existing ones on the detector trackers are more and more challenging. The required degree of expertise of the institutes participating in the design and construction of the trackers whittles down the range of possible activities that can be efficiently tackled both in terms of personal and equipment by a single group. In the last years we have witnessed an increased degree of collaboration among very geographically spread research groups as a response to the increasing complexity of the systems that have to be built. This has generated a substantial knowledge and a number of institutions have considerably improved their equipment. In this talk we explore the possibilities offered by a model in which the know-how acquired is made available as a set of common building blocks and recommendations and some of those improved facilities are made accessible to the community.

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Welcome

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Conference close-out