Forum on Tracking Detector Mechanics 2015

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Book of Abstracts

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Advanced Engineering Plastics in High-Tech applications – material selection guidelines

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High tech applications mostly demand high-tech materials. As engineering plastics have evolved over time, they have become a great alternative to traditional materials such as metals in many applications. However each polymer has its specific advantages & limitations, and the use of fillers can even more influence the specific properties. During this presentation, I would like to provide technical-oriented & straightforward steps in the material selection of Advanced Engineering Plastics. Topics covered are wear resistance, temperature effects, dimensional stability, X-ray radiation transparency, radiation resistance (UV & Gamma), radiation shielding (neutrons only), outgassing in high vacuum, ESD properties, bonding and machine-ability / possible tolerances.

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Advanced Materials and Tools Research at Berkeley

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Over the past two years a variety of topics in advanced materials and tools for instrumentation have been under study at LBNL. This talk will present results on thermally enhanced polymers and laminates, low mass foams, air cooling, and precision metrology for inspection and defect location. A broad survey of filler materials has been conducted, a protocol for thermal measurement developed, and outstanding performance has been observed for certain additives. Practical application in laminates has been studied. Carbon foams with low density and high conductivity have been known for some time. A new hollow ligand foam has been studied and evaluated for an air flow cooling application. Precision microscopy using line scan cameras and confocal scanners has been applied to a variety of 2D and 3D inspection applications.

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CMS FPIX Phase I Progress

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A new forward pixel detector for the CMS experiment is currently under construction, for installation during the extended year end shutdown 2016/2017. I am reporting on the latest developments in mechanics and cryogenics, and progress with construction.

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CMS Phase 2 silicon pixel-strip thermal mock-up module - building and testing

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The talk will discuss the thermal tests of a CMS Phase 2 prototype pixel-strip module carried out at Fermilab. The prototype is based on the common design and assembled using the same raw materials as foreseen for the production module. A rod support structure was also built to carry the prototype and provide a realistic cooling scheme via the CO2 test stand at Fermilab. Data results at various heat loads will be discussed and compared with simulations.

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Closeout

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Developments for future tracking systems based on Medipix based read-out chips

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The developments within the Medipix collaboration on hybrid pixel detectors for many applications outside the world of high energy physics over the last decade have led to interesting design features that are now being considered or even applied in tracking systems for ATLAS and LHCb. Especially, the development of chips with timing capabilities such as Timepix3 has triggered this return to high energy physics. The Timepix3 chip can be applied for gaseous tracking systems in e.g. ATLAS, while a descendent of the Timepix3 chip, the Velopix chip is being designed for the upgrade of the LHCb vertex detector. In this contribution, the next generation is contemplated. What are the requirements we want to aim for and how do we deal with the possibilities new technologies like 3D integration offer us and the implications of increasing complexity such as the increase of power density and the necessary cooling?

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Double-Sided Metrology of Strip-Modules for the CMS Phase2-Upgrade

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For the Phase2-Upgrade of the CMS Silicon Tracker new double-sided modules are foreseen, providing track information to the first trigger stage of CMS. Hence two strip sensors, positioned on top of each other at a small distance (~3 mm), will be part of a single module, allowing for a combined readout using a single front-end-chip. From the correlation between hits in both layers within one front-end, tracks can be filtered on their transverse momentum for the first trigger stage (min. 2

GeV). In this schema, the relative sensor-to-sensor alignment within one module plays a crucial role, since for the first trigger stage it cannot be corrected using software alignment techniques. Therefore all modules will be required to fulfil rigorous quality criteria.

To verify the assembly accuracy, especially the relative sensor placement, it is required to relate measurements from the opposite sides of the module with high accuracy to each other. In absence of a commercially available solution, a prototype for a double-sided metrology machine has been developed at RWTH Aachen University. Apart from the general measurement method, results on achieved accuracies will be presented, as well as the ongoing work on a full scale double-sided metrology set-up. Furthermore the potential usage during the module production will be discussed, in conjunction with possible module assembly strategies.

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Endcap mechanics and cooling for the CMS tracker upgrade

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The extreme pile-up conditions expected in the CMS detector during operation in the High Luminosity LHC (HL-LHC) necessitate the replacement of the entire tracking system during long shutdown 3 (LS3). New silicon modules with higher radiation tolerance and enhanced functionality will be installed. To further improve radiation resistance, the tracker will be operated at a lower temperature (-20℃) with respect to the current detector. In addition, it is highly desirable that the overall mass of the tracker be reduced. Progress towards achieving these aims for the endcap region of the outer tracker will be presented. To reduce mass, the silicon modules will be attached directly to the endcap disks, rather than to intermediate structures ('petals') as in the current endcaps. Individual lightweight conductors will replace relatively heavy printed circuit boards. Furthermore, cooling of the modules will be achieved using two-phase CO2, a low-density fluid which allows the use of small diameter pipework. The status of the endcap mechanics, including disk design, module layout, services routing and cooling, will be presented, together with results from initial prototyping of the disk mechanics and cooling circuits.

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LHCb SciFi Detector and Read-out box

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The upgrade of the complete LHCb detector will extend the physics reach of the experiment, by allowing it to run at higher luminosity with increased trigger efficiency. The tracking system behind the magnet will be replaced by a new Scintillating Fibre Tracker (SciFi), a modular array of 5 m long layers of scintillating fibers, consisting of six densely packed layers of round fibers with a diameter of 250 μm. The fibers will be read out by Silicon Photomultipliers (SiPMs) housed in the so-called "Read-out Boxes" at the top and bottom of each fiber module.

We will present a summary of the main SciFi design choices, and discuss in detail the specific challenges posed by the design of the Read-out Boxes (where fiber modules, photon detectors and on-detector readout electronics are integrated) stemming from thermal expansion and contraction (different CTE's in combination with ΔT's of 90℃), condensation and frost prevention, and high posi-

tioning accuracies.

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Mass flow rate measurements for CO2 cooling systems: methods and results

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In CO2 evaporative detector cooling systems, the measurement of the mass flow rate is not always trivial. Not many instruments can be used in magnetic field or radiation environment and few of them can measure CO2 in two phase. After a brief review of the existing measurement techniques reported in literature, the presentation highlights the experience gained so far at CERN with a few mass flow meter models available on the market or designed by the team. Three measuring principles are investigated: Coriolis, thermal and differential pressure. Data on the use of the three types are shown and compared in order to suggest the best possible instrument for the various application cases.

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Material Challenges for Metallic 3D-Printed Parts

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Additive manufacturing of metals offers great opportunities for the aerospace and high-tech industry, however it also faces serious challenges. Some of these challenges lie in the field of material science and quality control. This presentation gives an overview of the state of the technique, current applications in aerospace and the challenges that are being tackled in the Netherlands.

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Mechanics and Cooling for the LHCb Upstream Tracker Detector

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The LHCb Detector will undergo an upgrade during the LHC shutdown in 2019. The UT (Upgrade Tracker) is a silicon strip tracking detector being designed and constructed as part of this upgrade. The UT will provide a fast momentum measurement for the trigger as well as function as part of the overall tracking system where it will severely reduce the presence of "ghost" tracks.

The UT Tracker consists of ~10x10 cm2 silicon strip sensors, with custom ASIC readout chips (SALT) arranged as modules containing flex circuits and ceramic substrates. These modules are to be mounted on staves, lightweight CFRP and foam sandwich structure supports with integrated CO2 cooling. The cooling tube follows a snake-shaped routing which allows the tube to run under all the ASICs and provide efficient cooling. Construction is planned to start this year. The design details of the UT Tracker staves and modules will be presented, including prototype results, mechanical component tests, thermo-mechanical simulations, and other R&D activities.

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Micro-channel cooling for high precision vertex detectors: status and perspectives

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For future Vertex detectors, where the requirements on material budget minimization and performance optimization will push at the limit the design and technology choices, thermal management solutions based on ultra-thin micro-channel heat exchangers are being envisaged.

The NA62 GTK detector, launched in operation at the end of 2104 has demonstrated for the first time the practical feasibility of the direct cooling of a pixel detector module by a micro-fabricated silicon device circulating single-phase liquid refrigerant. The very advanced studies in preparation of the "phase-I" upgrade of the LHCb VELO detector (detailed in a separate presentation) suggest that the thermo-physical characteristics of CO2 are very favourable for its use in connection with evaporative flow in micro-channel devices. On the other hand, a recently presented study on a possible application of this technology to the upgrade of the ALICE ITS detector provided the first demonstration of two devices hydraulically interconnected through an integrated micro-fluidic distribution line, allowing for controlled evaporation of C4F10 in both micro-devices.

Starting from these achievements, the presentation will review the latest technical progresses and the open issues to be addressed in view of the challenges posed by the next generation of detectors. Different lines of investigations will be discussed, in particular in view of the 4-years networking activity to be soon launched in the context of the recently approved AIDA-2020 programme; and different options will be examined from a detector engineering point of view. Finally, some preliminary ideas will be presented for long-term developments, requiring a level of technology not available today for operational implementation, yet ready for interesting early feasibility studies.

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Module Designs and Assembly for CMS Tracker Phase 2 Upgrade

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PS (Pixel-Strip) modules and 2S (Strip-Strip) modules will be the detection devices used for the future phase 2 upgrade of the CMS Tracker. 7084 PS modules and 8424 2S modules would be integrated on different parts of the detector (TBPS, TB2S, Endcap Double-Disc) for more than 218 m^2 of active silicon sensor surface. Both modules are designed to be as light as possible to ensure minimal impact on tracking from the material budget. However, the modules must also have sufficient strength, a high mechanical precision, and efficient heat removal to support/cooling structures and thus materials such as carbon-fibre/polymer and aluminium/carbon-fibre composites are being employed. The assembly of the modules must at the same time allow for high throughput as well as mechanical precision (especially the silicon sensors) and thus tooling and assembly procedures must be well conceived.

The presentation summarizes the current status of the module designs and also describes some of the prototype jigs needed to build them.

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Poster: 3D monitoring of the LHCb Inner trackers

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The positions of the Inner Tracker (IT) detectors of the LHCb experiment installed in the LHC at CERN are impacted by the LHCb dipole magnet powering. In the past the movements of the stations have been measured using standard survey methods during magnet tests in shutdown periods. But the survey targets are visible only in very narrow spaces and the access to the IT is very difficult, even impossible in the central region when the detector is closed. Finally the precision of the standard survey measurement is affected by the poor configuration.
In 2013 and 2014, during the first long shutdown of the LHC (LS1), the CERN Survey team (EN/MEF-SU) in collaboration with the LHCb Technical Coordination and the EPFL (Ecole Polytechnique Fédérale de LAUSANNE, CH), developed a permanent monitoring system which has been tested and installed in order to allow the 3D position measurement of the IT stations, even during the run periods, with a precision of 100 microns at 1 sigma level.
The 3D Monitoring system of the LHCb IT stations is based on opto-electronic BCAM (Brandeis CCD Angle Monitor) sensors, precise low material retro-reflective targets and mechanical elements. This paper summarizes the studies of the proposed system, its configuration and integration in the experiment, as well as the first results obtained.

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Progress on the LHCb VELO microchannel cooling

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The LHCb Vertex Detector (VELO) will be upgraded in 2019 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 vacuum-resident system will be provided by bi-phase CO_2 circulating in micro channels embedded within thin silicon substrates onto which active elements are placed. This solution has been selected due to the excellent thermal efficiency, the absence of thermal expansion mismatch with silicon ASICs, the radiation hardness of CO_2, and very low contribution to the material budget. The R&D effort for LHCb is focusing on the design and layout of the channels together with a fluidic connector and its attachment which must withstand pressures in excess of 200 bars. 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.

In this talk,a characterisation of a realistic microchannel prototype will be presented and compared to simulation. The design of a suitable fluidic connector, together with the vacuum soldering technique will be described.

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Radiation tolerant fiber optic sensors for long-term humidity monitoring in the CMS experiment

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Relative humidity (RH) monitoring has a significant impact in various application fields and many sensing schemes and solutions have been proposed according to the specific applications. Here we concentrate our attention on the use of RH fiber optic sensors (FOS) recently developed for application in the CMS experiment. Any humidity sensor to be introduced in the volume of a Tracking detector should comply with many requirements in terms of radiation resistance (required up to 1 MGy for regions close to the Interaction Point), insensitivity to strong magnetic field, small dimensions and low mass, operation at very low temperatures, reliable readings across long distances and reduced number of wires for operation. In this scenario, FOS-based thermo-hygrometers appear as a good alternative to the conventional instruments. Indeed, the fiber itself, if properly selected, can tolerate a very high level of radiation, optical fiber transmission is insensitive to magnetic field and electromagnetic noise and perfectly suited for read-out over very long distances. After a few years of development, 72 FOS thermo-hygrometers, based on polyimide-coated Fiber Bragg Gratings (FBG) organized in multi-sensors arrays, have been installed in CMS in December 2013 and are currently providing constant monitoring of temperature and RH. However, experience in operation has shown some limitations of the polyimide coated FBG sensors which will be thoroughly discussed An alternative to overcome the FBGs' limitations, might come from an innovative class of RH-FOS, based on high-sensitivity titanium dioxide coated Long Period Grating (LPG). Preliminary results obtained on samples produced in-house are very encouraging. In this contribution we present results from the first application of FBG thermo-hygrometers in CMS and we discuss the status of the R&D on the new generation of LPG sensors.

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Requirements and Specifications for metal cooling tubes for evaporative CO2 cooling

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As part of our R&D on cooling tubes for the barrel strip system of the ATLAS phase II tracker upgrade we have identified requirements and specifications for these tubes. One of the most important of these is the understanding of the pressure requirements. For this definitions and the subsequent calculations of required wall thickness by design by formula (DBF) we follow EN and ASME standards, as much as they are applicable. Because of the special constraints the cooling tube will be subjected to within the local support staves we have backed up these calculations by FEA studies of the stresses in the tubes (design by analysis - DBA). We have a preference for metallic tubes and our R&D has focused on stainless steel and titanium, and we will present the calculations for these materials, but the approach can easily be generalized.

In this presentation we will list all requirements and their inputs under special consideration of the relevant parts of the EN and ASME standards.

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

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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} n_{eq}/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 the pre-production phase we are constructing the precursor of the second MVD station. The project addresses a double-sided integration of 15 MIMOSA-26 sensors onto a 8x8 cm^2 CVD diamond carrier featuring a thickness of 150 µm. The sensors are arranged in ladders composed of 3 sensors each

This contribution summarizes the activities undertaken to construct a precursor of a quadrant of the second MVD station, in particular:

- Vacuum-compatible gluing procedures
- Positioning of ultra-thin sensors using dedicated jigs
- Development of low material budget, copper-based flex-print cables
- Thermal management studies in vacuum
- Sensor commissioning and bonding

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The SLIM proposal for the ATLAS ITK pixel barrel

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The Pixel ITK mechanics after having defined the engineering requirements is now considering new options for module and service local support for the barrel region. While targeting for a material budget as low as possible and a layout that ensures the perfect hermeticity, the module have to be able to safely operate with respect to the thermal run away effect in the silicon sensor whatever technology is considered. The SLIM (Stiff Longeron for ITK Modules) concept is a novel approach that tries to combine interesting features that was proposed so far. The SLIM concept is based on a layout that allows a silicon surface optimization using barrel sensor orientation combined with tilted modules with respect to eta. It is also proposed to combine a modular approach on a self-supported structures designed for thermo-mechanical performances. It will be showed that the material budget which is one of the key parameters can be optimized and scaled according to the thermal requirements while not degrading the tracking performances and the mechanical stability. This talk will presents and describes the engineering solutions chosen and the performances achieved.

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

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The DEPFET Collaboration develops highly granular, ultra-thin active pixel detectors for high-performance vertex reconstruction at future e+e- 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 and a low mass petal solution for the forward region of the ILC detector concepts will be presented.

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The vacuum envelope of the upgraded LHCb VELO detector

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The LHCb vertex detector (VELO) is shielded from the LHC beam by a thin envelope called the RF box. Tight constraints on maximum thickness, vacuum tightness, conductivity and rigidity make the construction of the RF box a challenge. We discuss progress in the construction of the RF box for the upgraded VELO detector, which is planned for installation in 2018.

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Thermal mock-up studies for the Belle II vertex detector

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The cooling system of the BelleII vertex detector is based on the 2-phase accumulator controlled loop method with CO2 as the coolant. The DESY group is in charge of building a thermal mock-up in order to study and optimize the cooling system. This talk shows the design for this thermal mock-up and some results for the preliminary measurements.

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Tour

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Ultra-Light Weight Mechanics and Cooling of the Mu3e Experiment

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The Mu3e collaboration is setting up an experiment to study the decay of a muon into three electrons μ+⟶e+e-e+ . Any observation of this decay with the Mu3e experiment would point to physical processes so far not described in the standard model, mediated by the exchange of very heavy particles. The Mu3e Experiment is a combination of three detector technologies. The main part is a High Voltage – Monolithic Active Pixel Sensor (HV-MAPS) Tracker combined with a Fiber Tracker and a Tile Detector. The Experiment is sub segmented into five stations.

A main requirement is to reach a very low material budget (of 0.1% X/X0 per layer). Therefore the mechanics use an ultra-light weight support structure to fulfill this requirement. A folded 25 μm thick KaptonTM foil is used as a base support structure for the silicon chips. At the ends segmented support rings made out PEI give further stability to the system and serve in addition as a distribution for the gaseous Helium cooling. In this talk an overview of the extensive R&D concerning choice of materials and their mechanical properties as well as the development of the He-cooling will be presented.
Summary

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Understanding the deformation issue of the ATLAS IBL detector

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The ATLAS cosmics run over the last month has revealed a stability issue in the mechanics of IBL detector. In particular a global and coherent rotation of the Z=0 detector cross section has been observed analyzing the alignment parameters of the muon tracks. Such instability affects the overall tracking performances. Understanding the causes of the deformation allows to set operation conditions meant to mitigate the deformation and reestablish the nominal detector performances. The talk collects the experimental evidences of the distortion and provides the mechanical explanation.

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Vacuum flex lines design, production, qualification and tests for the ATLAS IBL CO2 cooling system

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The Insertable B-Layer (IBL) is the innermost layer of the ATLAS pixel detector; it has been installed on a new beam pipe with reduced diameter and successfully inserted in the Inner Detector (ID) volume. The IBL is a fundamental detector to improve the vertex reconstruction and to provide an additional tracking layer in case of failure or radiation damage in the other three layers of the Pixel Detector of ATLAS. To extract the 1.5 kW power dissipated by its on-detector electronics, the IBL is equipped with an evaporative CO2 cooling system based on a 2-PACL (2-Phase Accumulator Controlled Loop) cooling concept. The cooling plant is connected to the IBL thanks to a long vacuum transfer line of about 90 m that reaches the Muon sector 5 of ATLAS where a junction box, provided with a dummy load and a distribution manifold, are installed. From the manifold box the fluid is distributed to the detector thanks to 14 vacuum flex lines. Vacuum is a very effective thermal insulation system and in cryogenic installation vacuum is quite commonly used to reduce the heat transfer by convection. In our case this choice was fundamental in order to transfer the coolant through a volume in which the dew point is just a few degrees below the ambient temperature and the humidity level could become a serious problem. The 11 meter long stainless steel flex lines are constituted of 3 concentric pipes: starting from the smaller we find the inlet liquid capillary (ø 1.6x0.3 mm), the outlet gas pipe (ø 4x0.5mm) and the vacuum hose (ø 17.2mm). They are made of commercial and customized components. The flex lines concept was mechanically and thermally tested in the laboratory by bending the lines to check if and how this may affect the mechanical stability and thermal insulation. The design criteria were mainly driven by the results of these tests and on the assembly sequence of the parts. The construction of the flex lines was done according to a precise sequence of operations and quality checks; it took about 12 weeks starting from the orbital welding parameters optimization to the final flow tests. The quality criteria were very carefully defined to guarantee the reliability of the lines given that each one cools 7 % of the IBL. This paper is about the concept design, production and qualification of the 14 vacuum concentric flex lines that were successfully installed and are now fully operational. We will present the details of the mechanical assembly process, the solutions we adopted, the tooling preparation and the qualification tests that were carried out in order to guarantee the best performance and long term stability.

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Welcome at NIKHEF

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Welcome by the organizers

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X0 : CAD estimation material

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Obtaining accurate and quick estimates of the amount of material represented by a detector is essential in the design phase, especially for tracking detectors. It allows the designers to have a quick feed-back of the effect of the design choices on important aspects of the physics performance. The best available information on the detector geometry is the 3D CAD mockup. We will show through several examples (IBL, ITK, ID services, and also LArg calorimeter) how the 3D CAD mockup can be used efficiently to produce this information under Catia , by using a Visual basic macro able to access the geometrical information inside Catia. The presentation will cover the internal logic of the macro, the preparation of the CAD mockup for adequate analysis. Results obtained will be shown and discussed, including limitations on amount of information that can be extracted.