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Silicon Detectors for the LPTPC Test Beam

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Abstract

The Silicon for the Linear Collider (SiLC) collaboration will participate at the Large Prototype TPC (LPTPC) at the EUDET facility in DESY. The SiLC collaboration will design, build and install position sensitive silicon strip sensors in the small gap between the LPTPC and its surrounding magnet with the primary goal to provide precise tracking information for the LPTPC. In addition it will be possible to test different silicon sensors and readout chips. This setup will allow testing a first prototype of a silicon external layer with the TPC prototype. The current status and first test results of the silicon detector modules and the SiLC DAQ will be presented.

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1 Introduction

The Linear Collider TPC (LCTPC) collaboration is formed of several groups world-wide and stands in close relationship to the ILD detector concept. Their goal is to evaluate different TPC designs for the ILC [1]. At the moment the second R&D phase is running – the so-called Consolidation Phase. The goal of this phase is to design, build and operate a Large Prototype TPC (LPTPC) at the EUDET facility at DESY [2].
The Silicon for the Linear Collider (SiLC) collaboration will design, build and install position sensitive silicon strip sensors close to the LPTPC with the primary goal to provide precise tracking information for the TPC. In addition it will be possible to test different silicon sensors and readout chips. This setup will allow testing a first prototype of a silicon external layer with the TPC prototype.
The overall setup, the magnet and the TPC are described in details in [3]. Here, only short updates to some parts are given. A detailed overview of the individual silicon detector components is given in [4]. The most emphasis is given to first test results of the silicon detectors and the concept of the silicon readout system.

2 LPTPC Setup

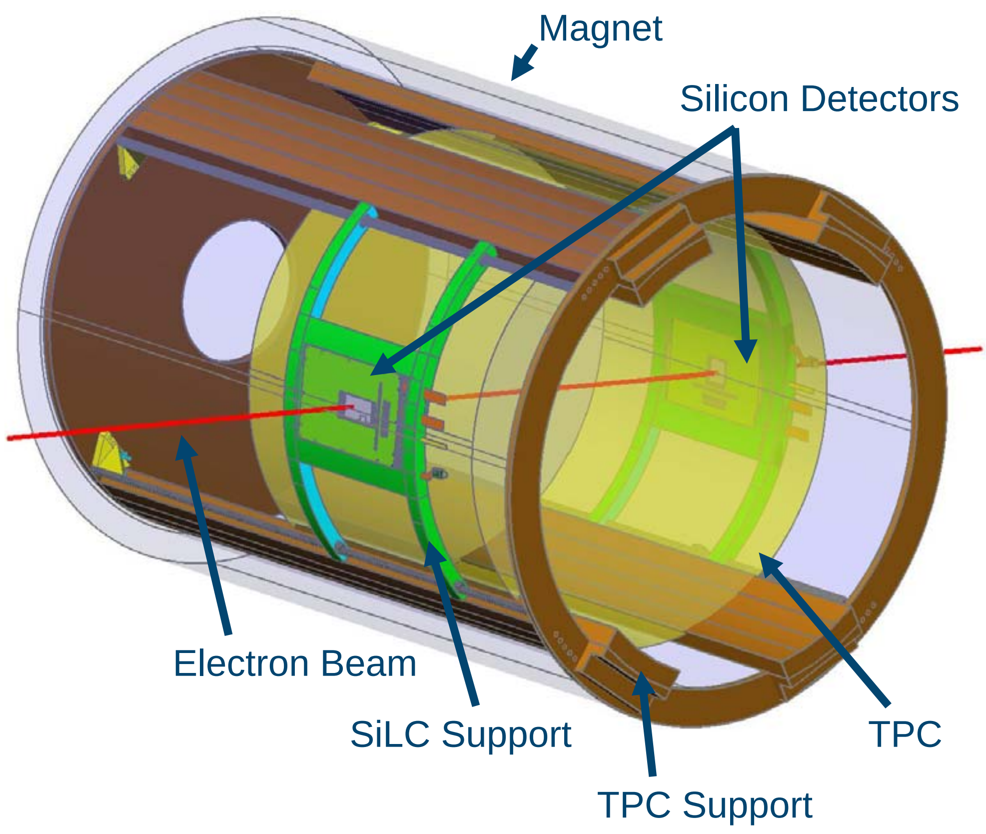

Figure 1: Overview of the LPTPC Setup

The TPC (in yellow) with its support structure (brown) and the silicon detectors with support structure (green) inside the magnet (blue) are shown in Figure 1. The space between magnet and TPC is just 35 mm on radius leaving very little space for the silicon. In addition it must be possible to move the silicon detectors in both z- (TPC axis) and phi-direction, because the silicon has to stay inside the electron beam when the magnet moves. Magnet and TPC movements are foreseen to enable a scanning of the TPC.

3 The Detectors Modules

The detector modules as sketched in Figure 2 will provide very precise 2D space points just outside the TPC. The silicon sensors have a spatial resolution of 9 μm which was determined in June 2008 during the SiLC test beam at the SPS in CERN [5]. To provide this resolution in both, phi- and z-direction, two sensors crossed at an angle of 90 degree on both sides of the TPC will be mounted in each detector module. Both horizontal silicon detectors consist of two daisy-chained sensors and are located closer to the magnet than the one sensor detectors. The sensors were designed by the SiLC collaboration and produced by Hamamatsu Photonics, Japan, details of the sensors can be found in [6].

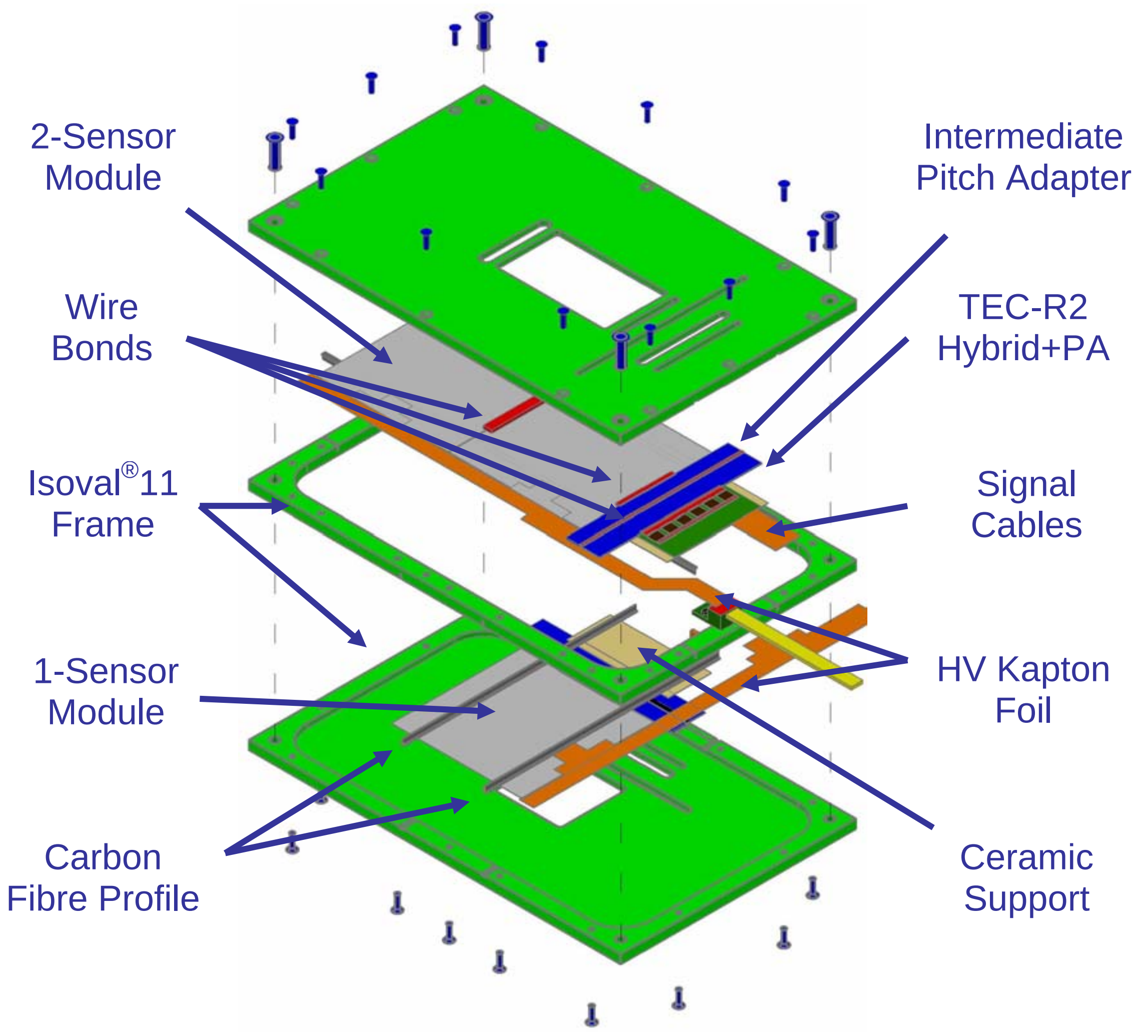

Figure 2: Exploded Drawing of a silicon detector

Figure 3 shows one, nearly finished, detector module; only a light-tight adhesive foil is missing, which is needed because the area between magnet and TPC is not dark. Including this foil the modules will have a thickness of about 20 mm which leaves sufficient space for the needed support structure. In Figure 4 the same module is shown with the top cover of the Isoval®11 frame removed; on the left side with the one-sensor detector and on the right sensor with the two-sensor detector on top.

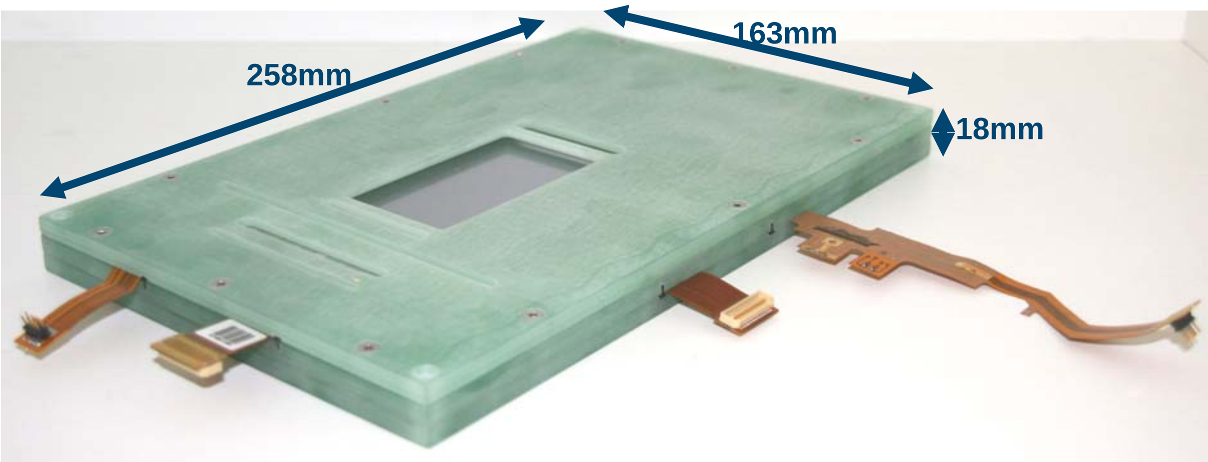

Figure 3: Closed silicon detector module (without light-tight adhesive foil)

Figure 4: Open detector module with the one-sensor detector on top (left) and the two-sensor detector on top (right)

3.1 Electrical Tests of the Sensors

To build the two detector modules all together six silicon strip sensors are needed. These Sensors were electrical tested at HEPHY prior their assembly. The results of these measurements have been re-validated by IEKP. The results are shown in Figure 5 and verify that the sensors are fully functional and can safely be operated at 100 V.

Sensor	Vdepl [V]	I300V [nA]	I400V [nA]
27	55	262	277
34	58	230	256
19	50	198	221
05	53	195	216
01	53	196	210
23	50	174	193

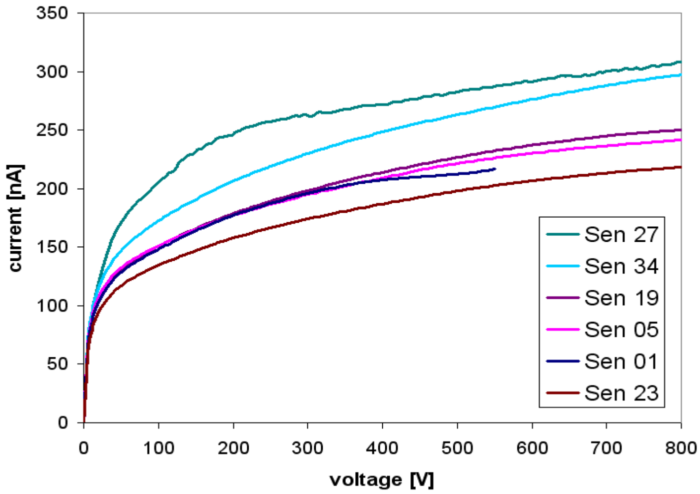

Figure 5: The table displays the depletion voltage (Vdepl) and the leakage current at 300 V (I300V) and 400 V (I400V) of the six sensors. The plot shows the IV-curves of these sensors.

3.2 Electrical Tests of the Modules with the ARC-System

The APV Readout Controller System was developed by RWTH Aachen for the CMS silicon strip module production quality assurance. Since the first version of the detector modules contain CMS front end hybrids as front end electronics, the modules can rather easy be tested with the ARC-System in Vienna, as displayed in Figure 5. This is a first electrical test performed after the assembly and bonding of the modules, before they get shipped to IEKP Karlsruhe for their final electrical tests with the adopted CMS readout system that will be used for the LPTPC setup.

3.2.1 Short description of the ARC-System

The ARC system provides full hybrid support like power, trigger, clock and slow control. It consists of a Windows PC which acts as a control device of a so-called ARC board, connected to the front end hybrid via an ARC front end adapter. In addition the system contains a LED controller, which can induce charge in the sensors using diodes emitting infrared light. A high voltage controller (DEPP) supplies the sensors with the required bias voltage. The modules can be tested inside a light-tight, humidity controlled test box which serves as electromagnetic shield.

With the ARC system it is possible to perform different tests to verify the functionality of the silicon strip modules. An IV measurement of the silicon sensors can reveal gross failures, caused by sensor damages or by micro discharges, which are indicated by an increase in the bias current. The functionality of the integrated circuits on the front-end hybrid can be checked. In addition a set of tests can be performed to detect single channel faults like opens, shorts, pinholes and saturated channels.

Figure 5: The ARC setup in Vienna with a look inside the test box on the right side, which is indicated by the blue ellipse in the left picture.

3.2.2 First electrical tests at HEPHY

Twisted pair cables with a length of two meters will be used to route the APV signals to the readout electronics outside the PCMAG. New adapter cards had to be designed to connect these cables to the CMS hybrids. A schematic of these cards and a picture of them connected to a twisted pair cable are shown in Figure 6. For the electrical tests in Vienna these cables were used and the differences in the measurements due to higher capacitances and losses in the connectors are displayed in Figure 7.

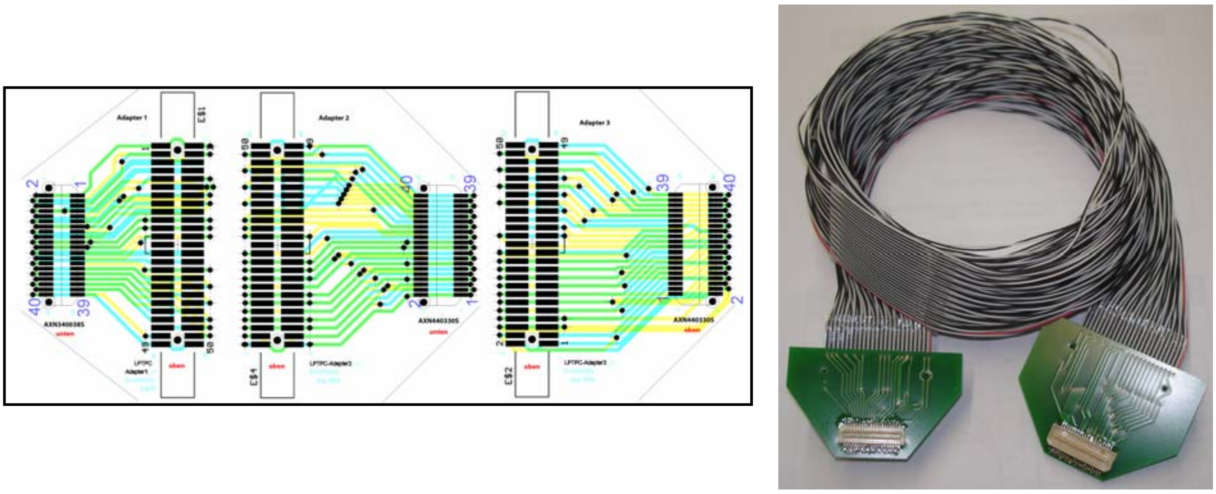

Figure 6: Schematic of the three needed adapter cards, one to connect the CMS hybrids to the twisted pair cables (left) and two for the connection of the twisted pair cables to the ICC Board (middle and right). The right photo shows two connected adapter cards.

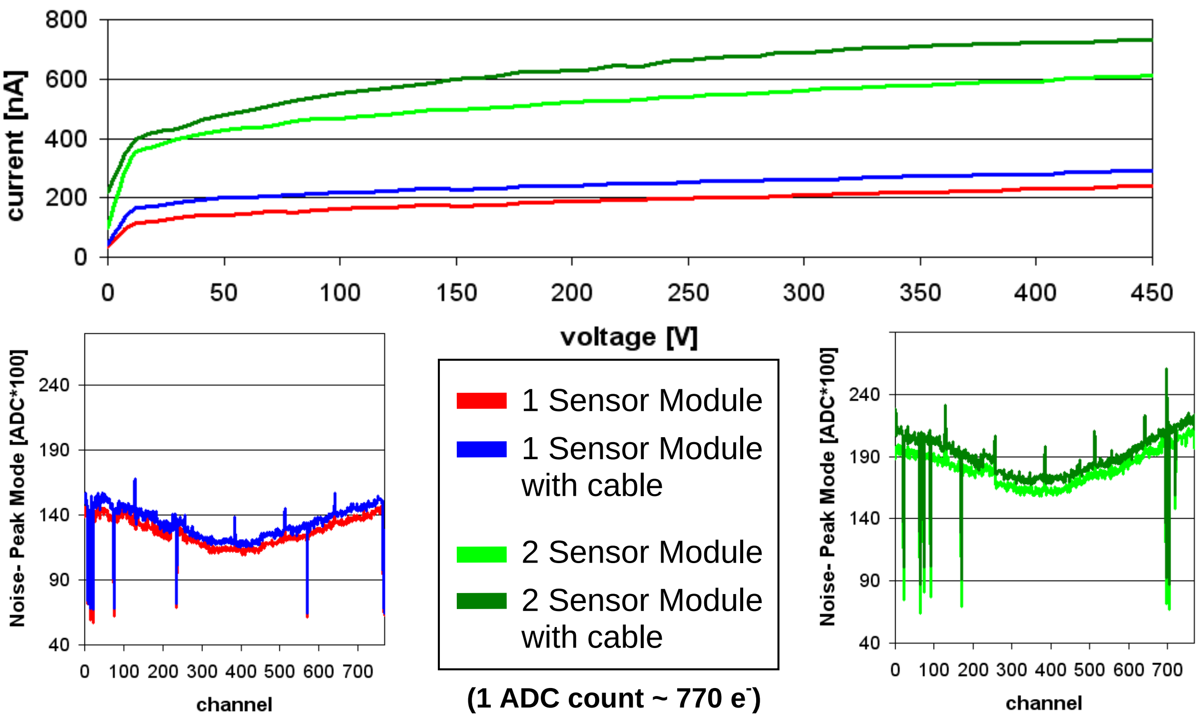

Figure 7: The top plot shows the IV curves of the two first detectors in the first built detector module, both with and without twisted pair cable. The two bottom plots show the noise of the detectors: the one sensor detector left and the two sensor detector right, again with and without cable.

A leakage current of less than 1 µA at 450 Volts is very low and verifies the excellent quality of the sensor. In the two noise plots some channels with a much lower noise than the others can easily be seen. These channels are opens, channels where the aluminium readout strip on the sensor is not connected to the appropriate channel of the readout electronic. This rather high amount of opens results most probably from the imperfect glass pitch adapters produced by HIP. The first production run was a complete loss, with some fabrication problems as displayed in Figure 8 (right). Out of the 20 pitch adapters we received from the second production run, only two had no visible faults, but opens of only one micron width, as displayed in Figure 9, could easily be overlooked. Since there are no clusters of opens in the central region of the sensors the sensor modules can be used without concern.

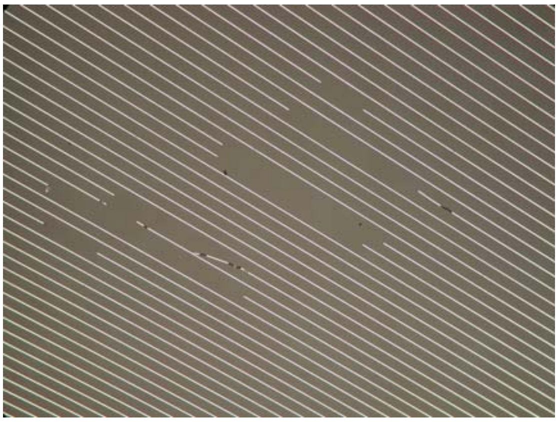

Figure 8: In the first production run problems like adhesion failures between glass and aluminium occurred.

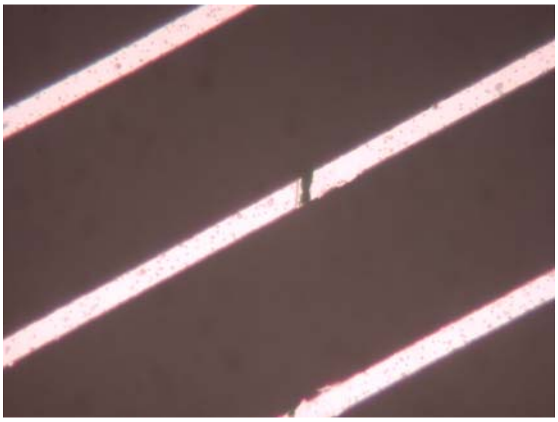

Figure 9: Such small opens in the pitch adapter lines are not easy to find. (width of the Aluminium line is 10mm)

4 Mechanical Support for the SiLC Modules

Since the magnet will be moveable w.r.t. the beam and the TPC will be moveable inside the magnet the modules have to compensate these movements to keep the active sensor areas inside the beam spot. In addition the two modules have to move independent from each other to compensate different deviations of the beam due to different magnetic fields. This, and the very limited space, makes the design of the modules and their support very challenging. A first very important step was to include threaded holes in the design of the TPC support structure; their positions are indicated by green circles in Figure 10.

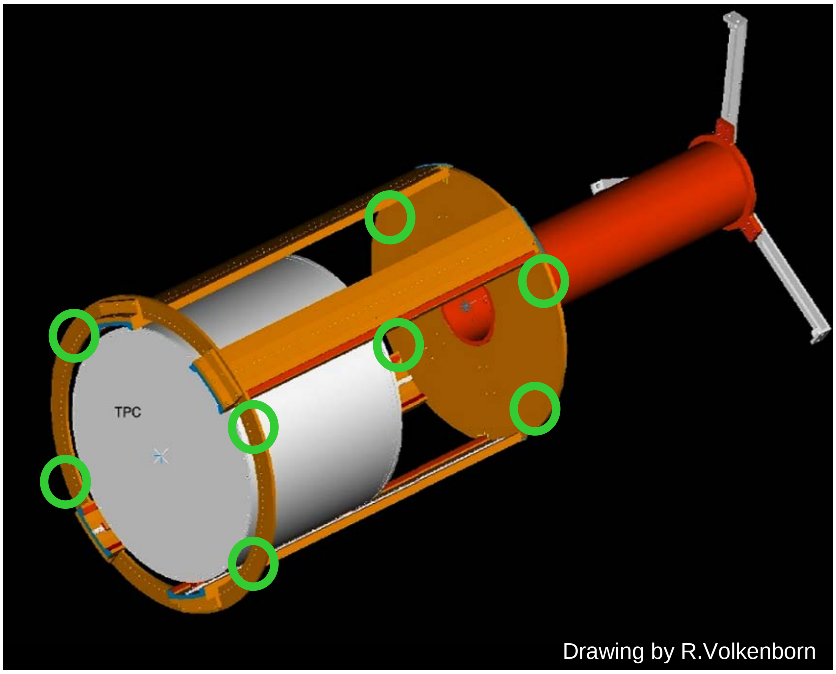

Figure 10: TPC support structure including threaded holes (indicated by green rings) for the SiLC support.

5 Adopted CMS Readout System

Since the initially proposed readout chip [8] for the sensors is not yet available, it was decided to use CMS R2 front end hybrids, including APV25 readout chips, with an adopted CMS readout system as preliminary solution. Later on it is foreseen to use the new developed readout chips with its appropriate DAQ.

5.1 CMS Tracker Readout

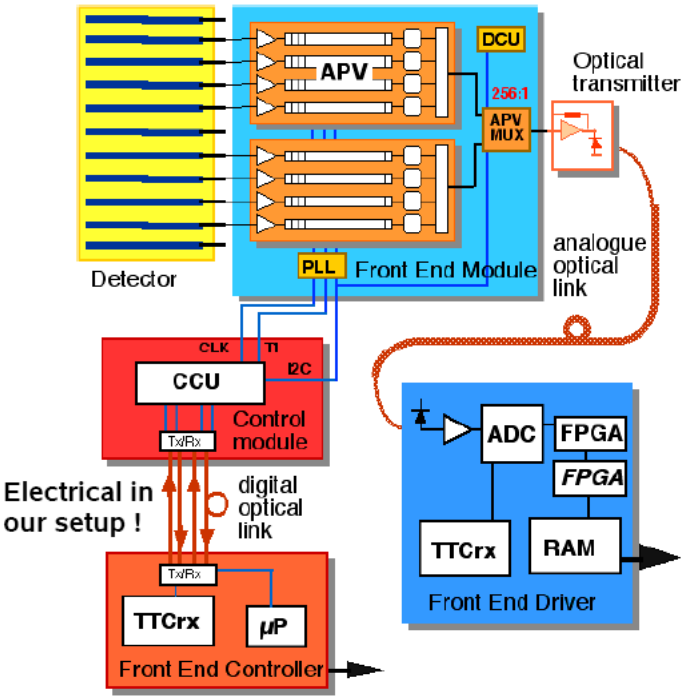

Figure 11: Schematic of the CMS Tracker Readout System

A detailed description of the CMS readout system can be found in [7], here only a brief description is given. A schematic diagram of the CMS Silicon Tracker readout system is shown in Figure 11. The signals of the silicon sensors are processed and stored on the APV25 chips. Each APV serves 128 silicon strips and keeps the data from each strip separately in an analogue pipeline until the decision from the trigger system is received. On a positive decision, the data from pairs of APVs get multiplexed and converted into analogue optical signals in the Analogue OptoHybrids (AOH). Their output is transmitted at 40 MHz serially by analogue optical links to the Front End Driver (FED) cards.
The Front End Controller (FEC) cards receive clock and trigger signals from the global Timing Trigger and Command (TTC) system and distribute those as well as control signals via digital optical links and the Digital OptoHybrids (DOH). One Communication and Control Units (CCU) is mounted on a CCU Module (CCUM) and is dedicated to a set of detector modules. A combined clock and trigger signal is distributed to Phase Locked Loop (PLL) chips on each front end module while the industry standard I^2C protocol is used to send control signals to the APV chips.

5.2 Adopted CMS Readout

An adopted CMS readout was chosen as backup solution for the readout since it was very important that it could be built up fast and that it does not cost a lot of money. HEPHY has a few fully assembled CMS R2 hybrids as leftovers from the CMS module production and IEKP could manage to organise most parts of a CMS petal test readout system. Only the Inter Circuit Cards (ICC) had to be newly designed and produced.

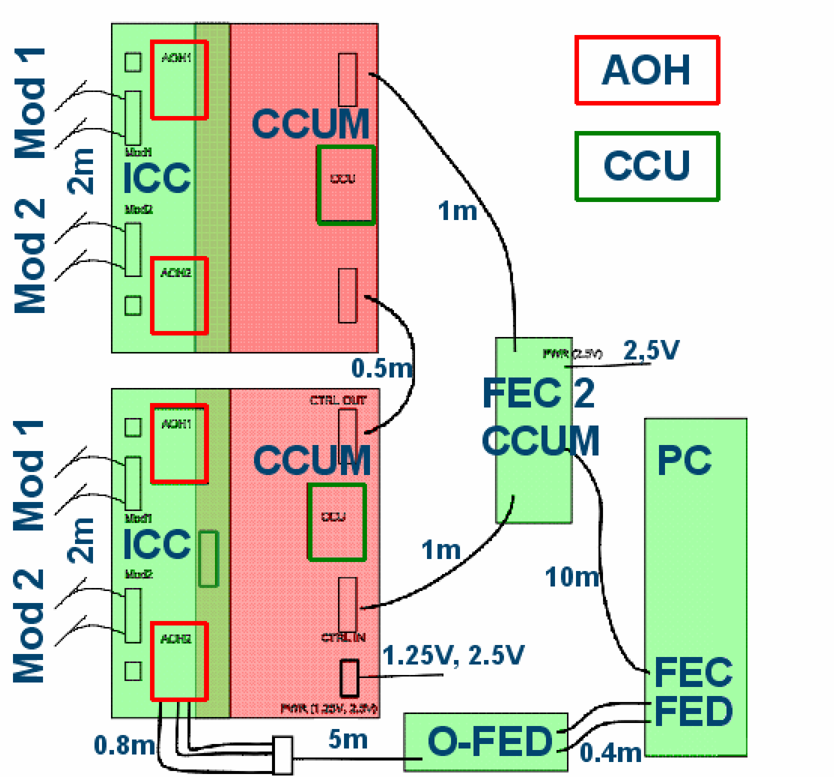

Figure 12: Schematic of the adopted CMS Tracker Readout System

Figure 12 shows a schematic of the readout system that will be used in the LPTPC setup until the new designed readout chip, including an associated DAQ, of the SiLC collaboration is ready for operation. The CMS R2 front end hybrids are included into the silicon modules and read the signals from the silicon sensors. The electrical signals from the hybrids are brought to the new designed Inter Connect Cards (ICC) via four 2m long twisted pair cables (Figure 6) and get converted to analogue optical signals in the Analogue OptoHybrids (AOH). These signals are transferred via five meter long optical links to the Optical Front End Driver (O-FED) where they get re-converted to electrical signals and delivered to the FED card in the PC, which is located in the control hut. The readout is controlled from the same PC via a Front End Control (FEC) card. This FEC steers the Central Control Units (CCU) sitting on the Central Control Unit Modules (CCUM) via a ten meter long electrical cable. The CCUs provide I^2C control sequence and clock for the APV readout and controls which get transferred via the ICC cards and the two meter long twisted pair cables. The FECs receive clock and trigger signals via the so-called Distributor Box (DB) from the Trigger Logic Unit (TLU).

6 Outlook

According to the schedule end of 2008 first cosmic Muons will be measured with the TPC. Also first beam tests are foreseen until the beam shutdown at 12th of December. In the beginning of 2009 the silicon modules will be installed in inside the beam line with a sliding carriage that enables both z- and phi- movements of the modules.

References

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