Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 579 (2007) 718–722
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Noise performance of the D0 layer 0 silicon detector

M. Johnson, For the D0 Collaboration

Fermilab, MS 357, P.O. Box 500, Batavia, IL 60510-500, USA

Available online 25 May 2007

Abstract

A new inner detector called Layer 0 has been added to the existing silicon detector for the DZero colliding beams experiment [V.M. Abazoz et al., Nucl. Instr. and Meth. A 565 (2006) 463]. This detector has an all carbon fiber support structure that employs thin copper clad Kapton sheets embedded in the surface of the carbon fiber structure to improve the grounding of the structure and a readout system that fully isolates the local detector ground from the rest of the detector. Initial measurements show efficiencies greater than 90% and 0.3 ADC count (240 e) common mode contribution to the signal noise. The total detector capacitance is 24 pF so this corresponds to 2 μV of common mode voltage.

PACS: 29.40.Wk

Keywords: Silicon tracker; Carbon fiber; Detector grounding

1. Introduction

The original silicon detector for the D0 experiment had four layers of silicon. A new radiation hard inner layer (L0) [1] was added to improve the resolution for displaced vertices and also provide increased redundancy for failures in the existing detector. Because the main barrel part of the existing detector could not be removed, this new detector had to be designed for insertion into the existing detector. This placed severe constraints on the design. Table 1 shows the detailed specifications.

The overall length and small diameter required the use of very high modulus carbon fiber. It also made it very difficult to provide a dielectric break in the structure. High modulus carbon fiber is quite conductive at high frequencies so there is a classic ground loop formed by the grounded electronics at each end, the carbon fiber support tube and the rest of the detector. In order to eliminate this ground loop, we developed a readout system that isolates the local detector ground from the rest of the detector. We achieved isolation greater than10 Ω per end at 10 MHz.

The small diameter of the detector did not allow the direct mounting of the readout chips on the sensors so we were forced to use a Kapton flex circuit cable (called the analog cable) between 200 and 360 mm long to bring the detector signal to the readout electronics. The capacitance of this cable (0.35 pF/cm) doubled the detector capacitance, which then doubles the intrinsic noise of the detector.

2. Mechanical design

The L0 support structure can be divided up into three major regions (Fig. 1). The first region, occupying the central 760 mm of the structure, is the silicon sensor mounting outer shell with the precision sensor mounting surfaces. The other two regions are the 450 mm long hexagonal hybrid mounting outer shells at each end of the structure. Cooling distribution manifold assemblies at each end also act as the support and connecting points for L0. All of these components are connected together via a long dodecagonal inner shell.

The inner shell, the sensor mounting shell and the hybrid mounting shells are all made from unidirectional Mitsubishi Chemical K13C2U carbon fiber pre-impregnated with RS-24 MOD resin supplied by YLA Inc. This fiber has a Young's modulus 900 GPa This material has a pre-cure

E-mail address: mjohnson@fnal.gov

0168-9002/$ - see front matter
doi:10.1016/j.nima.2007.05.281

weight of 66 g/m^2 and resin content of 39 wt%. The nominal thickness is 63.5 μm.

The inner shell spans the full length of the support structure (1660 mm) and has an inscribed diameter of 31.7 mm. It is made of three layers of pre-preg with a 0°/90°/0° arrangement. In another words, fibers are along the long axis in the two outside layers and are in the azimuth direction in the middle layer. The nominal cured thickness is 195 μm. The sensor mounting and hybrid mounting outer shells are both made of five layers of the same carbon fiber material with a symmetrical fiber orientation of +20°/−20°/0°/−20°/+20°. An outer layer of Kapton® with copper mesh and gold plated contacts is co-cured with the outer shells giving a combined cured thickness is 325 μm. The sensor mounting outer shell has a six-sided shape that allows for mounting of the silicon sensors at two different radial locations.

We increased the conductivity of the carbon fiber [2] by covering the outer layer of carbon fiber on the sensor mounting surfaces with a layer of copper clad Kapton film (25 μm Kapton, 5 μm copper). The copper is etched in a mesh pattern (234 μm trace width, 1.45 mm pitch, 30% copper coverage) to reduce the amount of added material.

This film is applied to the outer layer of carbon fiber on the sensor mounting surfaces, and is bonded to the shell during the cure process. The copper mesh is facing the carbon fiber. This process forced the copper mesh into good electrical contact with the conductive carbon fibers.

Table 1
Specifications for the L0 detector

Over all length	1660 mm
Minimum diameter	31.7 mm
Sensor pitch	71 or 81 μm
Length of sensors	70 or 120 mm
Number of sensors in longitudinal direction	8
Number of sensors in azimuth direction	6
Sensor thickness	0.3 mm

We used the same techniques as we used for the plies of carbon fiber with special care to ensure that the Kapton/Cu-mesh conformed to the surface features of the castellated shell with no corner air gaps. Contact to the copper mesh is made by plated through holes in the Kapton and gold pads on the outer surface. For the B-layer sensors that mount on the top of the castellations a flexible grounding strap is bonded to the ground circuit on the bottom of the castellation to make contact with the underside of the sensor.

3. Electrical design

The electrical design was dominated by the need to eliminate common mode noise. Because of the added capacitance of the analog cable and the use of 300 μm thick detectors, even a small amount of common mode noise could seriously affect the performance of the detector. In addition the analog cable can act as a good antenna for picking up common mode noise. The overall philosophy is two fold. First, we isolate the detector grounds from the rest of the world to prevent any ground loops through the body of the detector. Second, we provide low impedance connections between the sensor and the SVX 4 [3] chip. So that there is little relative voltage between them at all frequencies in the pass band of the SVX 4.

Fig. 2 shows a simplified schematic of the detector readout electronics. Every circuit has an input path and a return path. The input path to the SVX 4 is from the reversed bias diode through the analog cable and into the preamp in the SVX 4. There are no local ground traces on the analog cable (done to minimize input capacitance) so detector pulses will couple into neighboring channels. However, the time constants for this AC coupling are much smaller than the integration time for the SVX 4 so almost all the charge flows back into main channel before the end of the charge integration time. There is a trade off between the capacitance between the cable and the ground plane

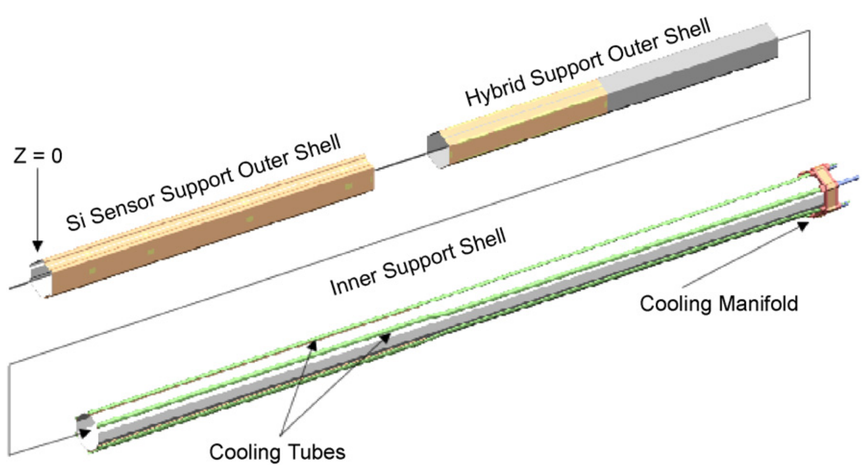

Fig. 1. Drawing of the L0 detector showing the sensor mounting shell, the hybrid mounting shell and the inner support shell.