Silicon sensors for the LumiCal – prototype design

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Abstract

The silicon-tungsten calorimeter LumiCal, located in very forward region of the future detector at the International Linear Collider, is proposed for the precise luminosity measurements based on the Bhabha scattering process. For this purpose, the precise measurement of the scattering polar angles is crucial. A silicon–tungsten sandwich calorimeter with fine–segmented silicon sensors has been designed for this purpose. This paper describes current design of silicon sensors for the LumiCal prototype based on available silicon technologies and intends to freeze for a moment sensors design development. It is necessary to proceed detailed MC simulations for one version of detector segmentation.

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1 Introduction

In the future detector for the International Linear Collider ILC [1], the very forward region is a particularly challenging area for instrumentation. The LumiCal detector [2] is expected to give the required precision of 10^{-4} luminosity measurement and to extend calorimetric coverage of small angles from ~40 to ~80 mrad. The luminosity measurement will be based on detection of Bhabha event rate. The precise measurement of the scattering polar angles [3] requires fine segmented silicon sensors and an ultimate precision in detector mechanical construction and metrology [4].

2 Mechanical Structure

The two LumiCal detectors will be build as the silicon-tungsten sandwich calorimeters. Segmented silicon sensors are interspersed into tungsten half-disks of one radiation lenght (3.5 mm). The gap for sensors is foreseen to be 1 mm. A possible mechanical structure is shown in Fig. 1.

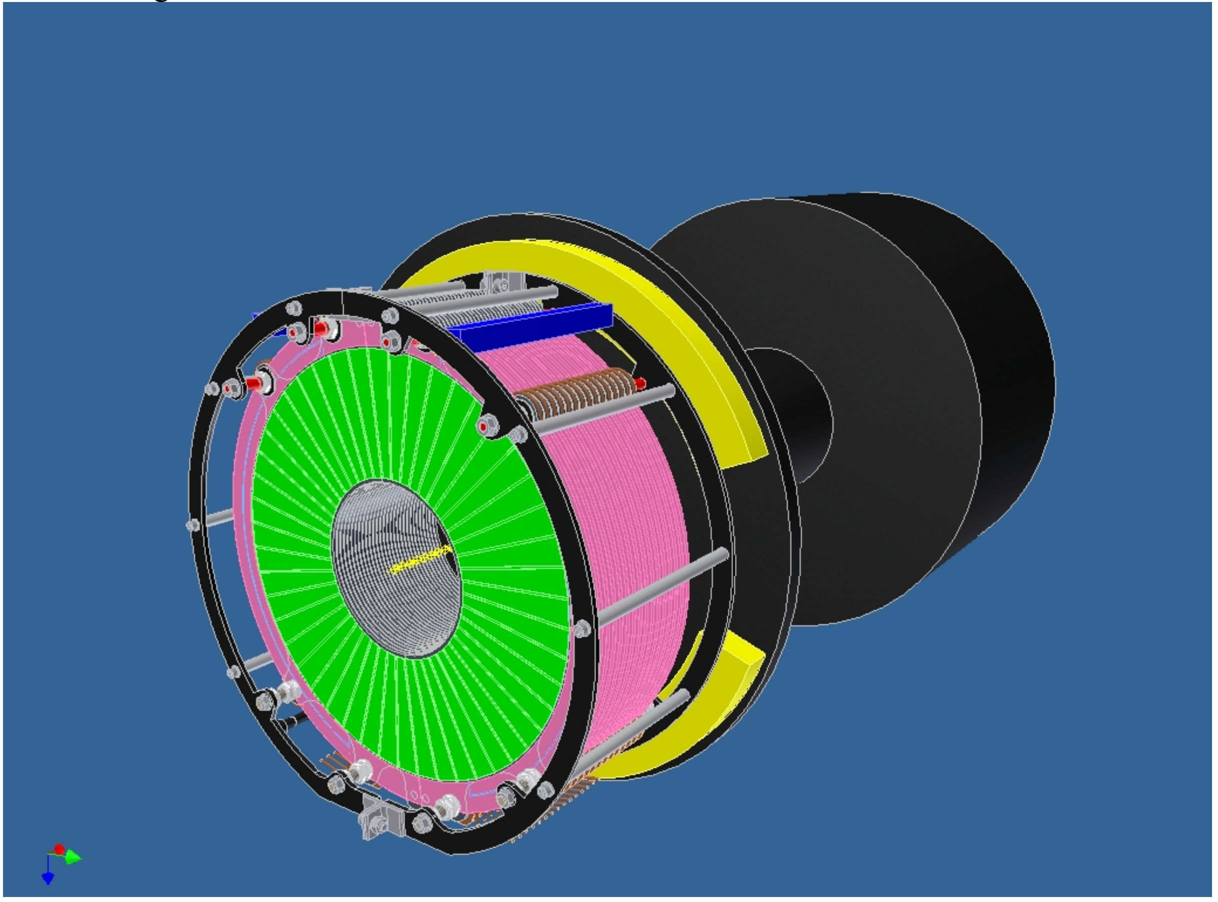

Fig.1. The proposed mechanical structure of the one LumiCal a bit more details.

The two half barrels can be clamped on the closed beam pipe. The position of the two parts of the detector with respect to each other will be fixed by the help of precise pins placed at the top and bottom of each C shaped steel frame. The latter stabilizes the structure and carries the heavy tungsten disks by the bolts. The silicon sensors are glued to the tungsten surface with capton foil insulation. The gravitation sag of tungsten absorber can be kept in required tolerances [5]. The silicon sensors of 320 μm thickness are glued on a 100 μm thick capton foil. The thickness of each glue surface seems to be in order of 100 μm. The fan out traces are placed on a thin 100 μm capton foil glued to the silicon sensor surface. The electric contact between fan out traces and sensor pads will be done by bump bonding or direct gluing with conductive glue via the holes in capton foil. The bump bonding or gluing will take 100 µm at maximum and 180 µm space is left for clearance. The place for readout electronics, connectors and cooling is foreseen at the outer radius of the calorimeter as shown in Fig. 2.

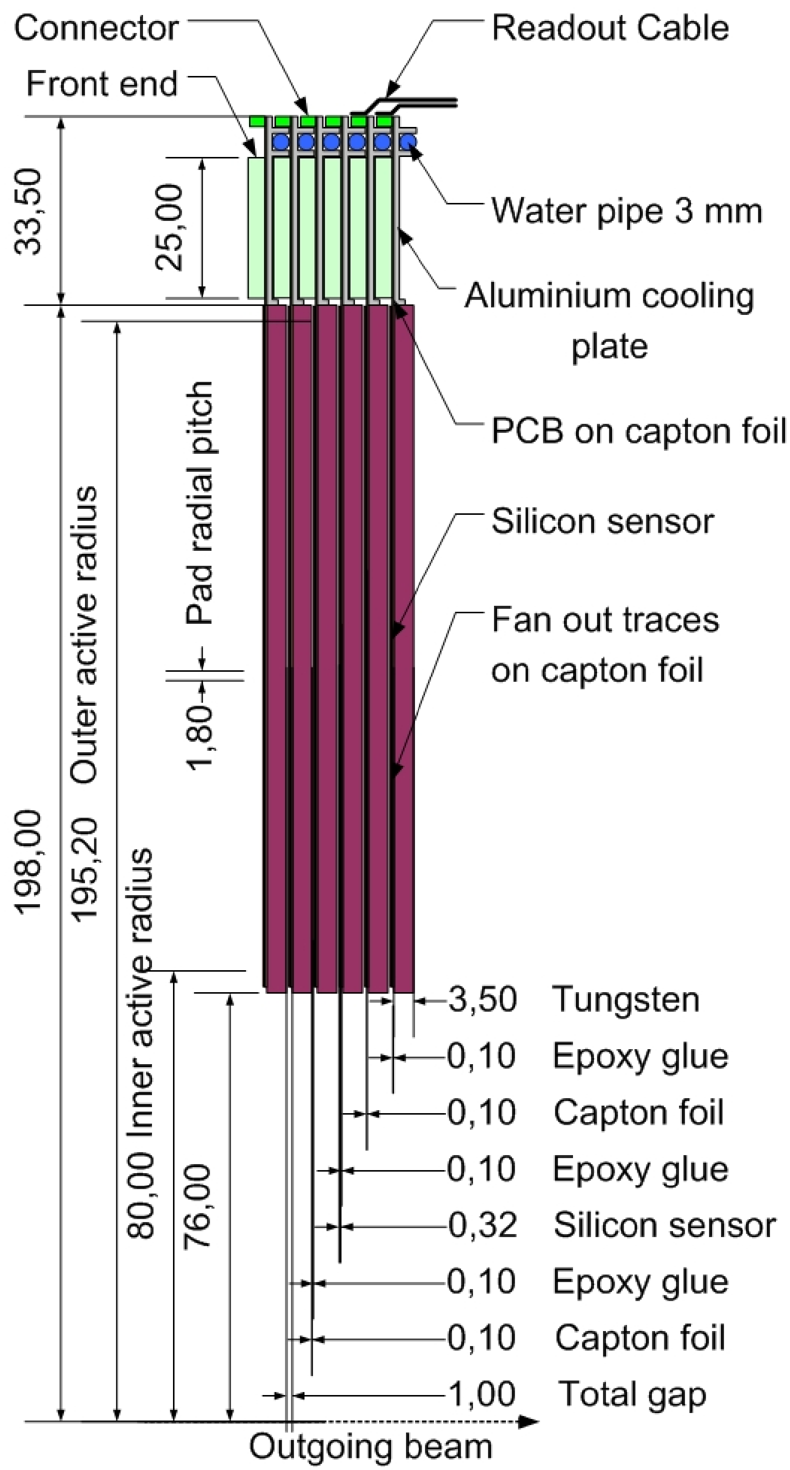

Fig.2. The cross section of the LumiCal.

The thin water pipes goes around the outer detector diameter are pressed into aluminium profiles to provide heat exchange from front-end electronics.
Detailed drawing of the connection between silicon sensor and front-end electronics is shown in Fig. 3.

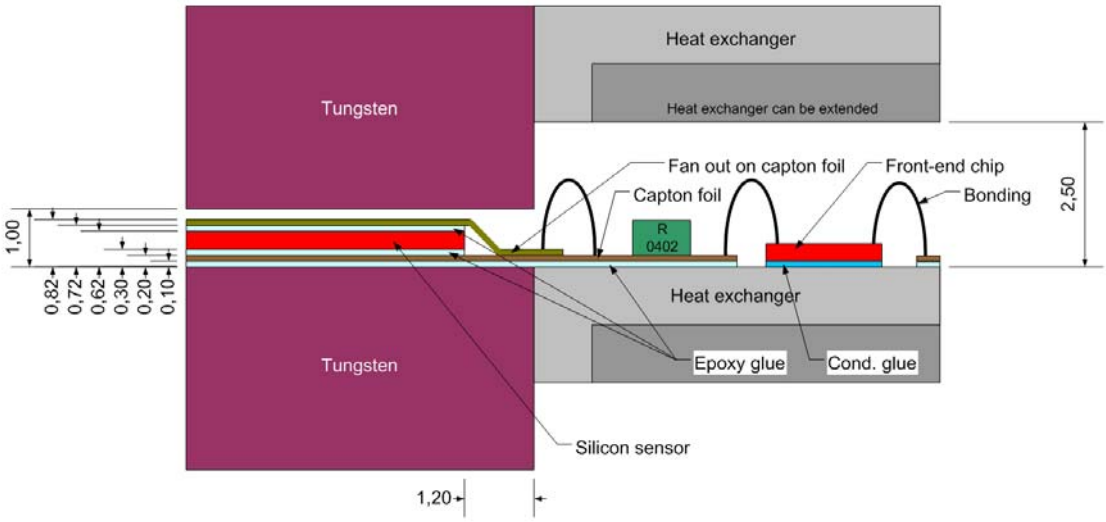

Fig. 3. Detailed cross section of the connection between silicon sensor and front-end electronics.

2 Silicon sensors

The proposed LumiCal detector will consists of 30 layers of tungsten of 1 radiation length thickness and 320 μm silicon sensors layers. The sensitive region extends from 80 mm to 195.2 mm in radius. Each such layer will include 48 azimuthal sectors. The sector will be segmented into 64 radial pads with a constant pitch of 1.8 mm. The sensor plane will be built from a few tiles because the current technology is based on 6-inch wafers.
The tiles of the silicon sensors will be glued to a thin capton foil placed directly on a tungsten surface for electrical insulation. Reference marks are foreseen on the detector surface for precision positioning. The layout of the sensors and the mechanical design of the calorimeter does not allow sensor to overlap. To reduce of the impact of the gaps odd and even planes are rotated by 3.75°. The silicon diodes will be usual planar high resistive silicon sensors.
Figure 4. shows one silicon detector of the proposed structure of 4 sectors and 64 pads in radius. To cover one full plane of the LumiCal 12 silicon tiles with 3072 pads are needed.
The mechanical gap (clearance) between every two tiles is foreseen to be 0.1 mm as shown in Fig. 5. Counting also the guard rings of 0.6 mm wide and roughly 0.6 mm clearance for wafer cutting, the inactive gap between the tiles has a width of ~2.5 mm. This gap width has to be taken into account in the MC simulations. The azimuthal gaps are staggered by rotation for odd and even layers of the detector.

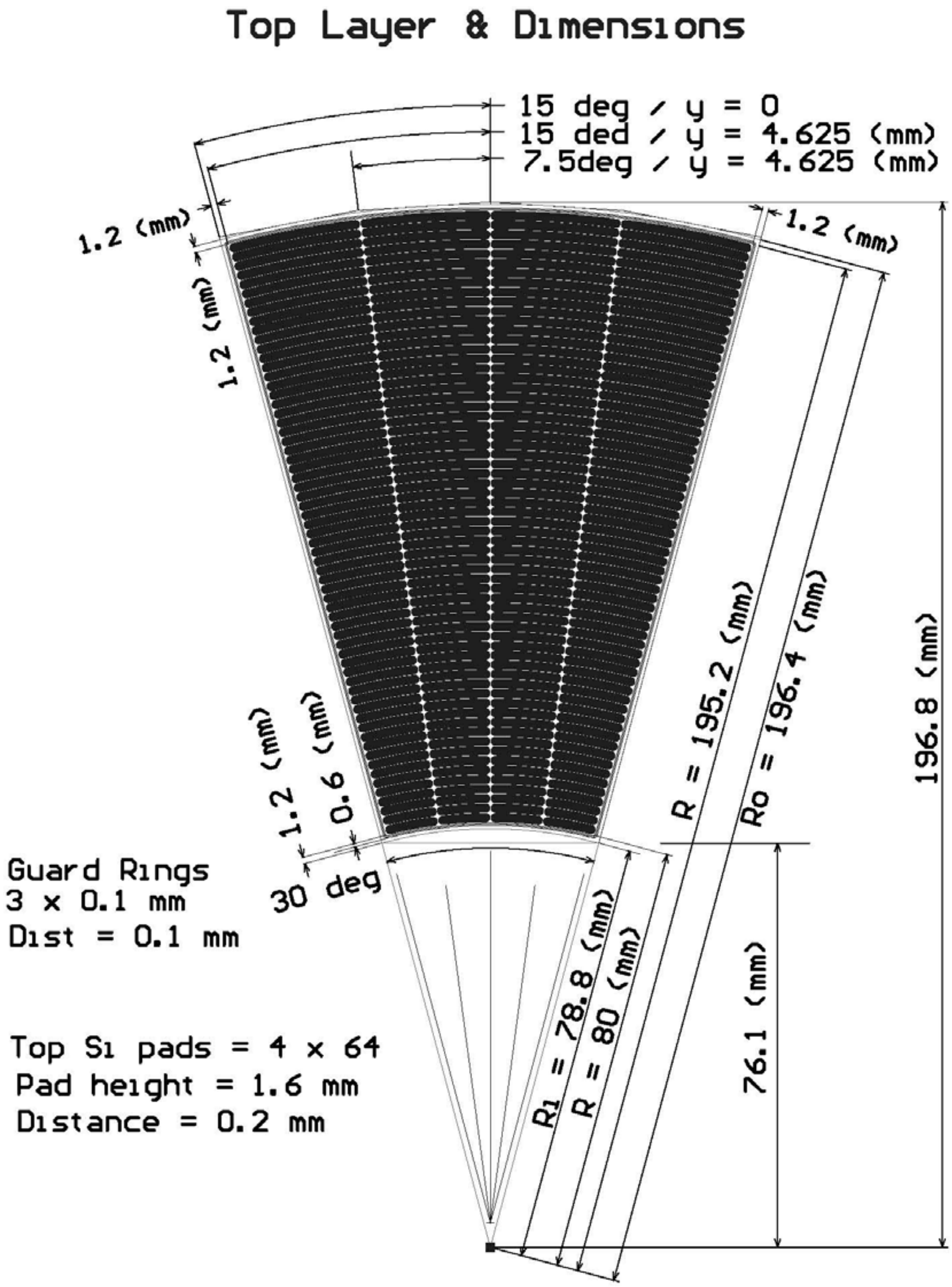

Fig.4. The proposed segmentation of the silicon sensor.

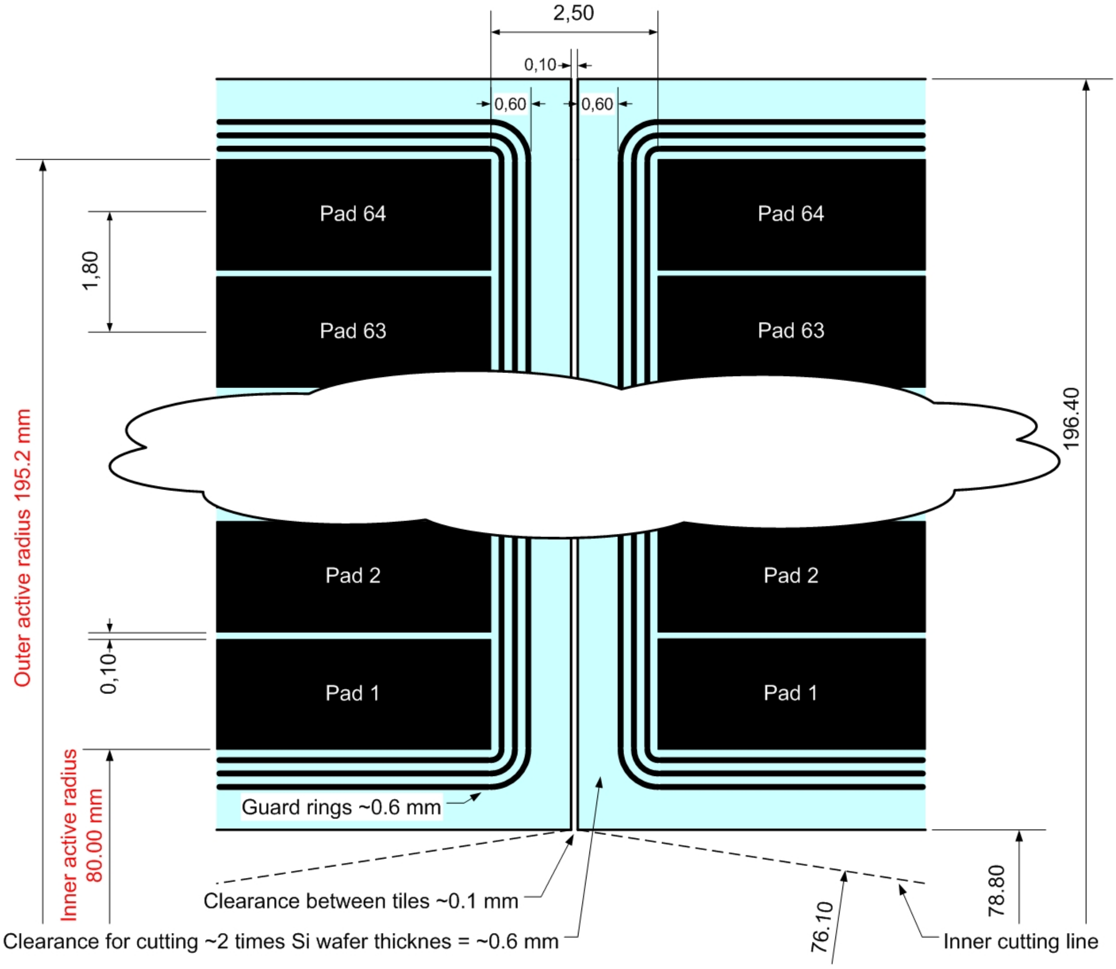

Fig. 5. Gap between tiles detailed drawing.

Placement of proposed silicon sensor tile on the 6 inch wafer is shown in Fig. 6.

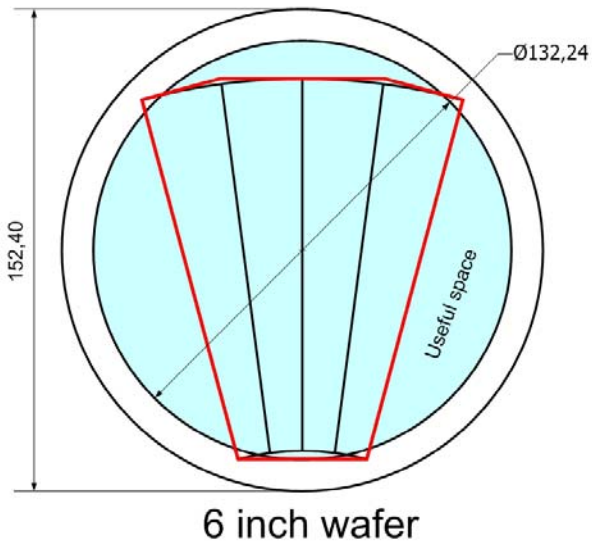

Fig. 6. Placement of silicon sensor tile on the 6” wafer.

3 Summary

The design of the silicon sensors presented in this paper looks very promising but many details have to be investigated carefully for the final design. The new geometry and segmentation have to be implemented in MC simulations. The influence of the proposed design to the precision of the luminosity measurement has to be studied finally, especially the problem of the gaps between sensor tiles. Previous MC simulation shows, that the gap width up to 2 mm does not degrade luminosity measurement precision, but in that design we have to count the gap to be 2.5 mm.
Design of the LumiCal silicon sensors has been sent to Hamamatsu Company to manufacture first prototypes. We are also discussing with Hamamatsu possibility to reduce the gap between tiles (i.e. lowering clearance for cutting).
Table 1. summarizes parameters of proposed LumiCal prototype.

Beam crossing angle	14 mrad
Centre of LumiCal	Centred on outgoing beam axis
Number of layers	30
Tungsten thickness	3.5 mm
Gap between tungsten absorbers	1.0 mm
Silicon sensor thickness	320 µm
Insulation capton foil thickness	100 µm
Fan out capton foil thickness	100 µm
Epoxy glue (total)	300 µm
Estimated air in the gap between tungsten	180 µm
Inner active radius	80 mm
Outer active radius	195.2 mm
Number of sectors	48
Number of radial pads in each sector	64
Pads radial pitch	1.8 mm
Inactive gap between silicon tiles (Fig.5.)	2.5 mm
Total number of channels for one LumiCal	92 160
Proposed ADC	10 bit

Table 1.LumiCal parameters

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