Very Forward Detectors for ILC and LHC

Sergej Schuwalow (on behalf of FCAL collaboration)
DESY, Platanenallee 6, 15738 Zeuthen, Germany

Radiation hard solid state sensors are necessary to instrument the very forward region of LHC and future ILC detectors. We report the results of recent studies of GaAs, Diamond and Sapphire sensors and their applications for Beam Condition Monitor at LHC CMS Detector and Beam Calorimeter at ILD detector for ILC.

1 Radiation Hard Sensors

For the very forward region of ILC detectors special calorimeters are needed. They will be hit by a large fraction of e^+e^- pairs originating from beamstrahlung. Sensors have to withstand a very high radiation level up to several MGy per year. Similar conditions we face at LHC for detectors near the beam pipe. Radiation hardness of several sensor material candidates is tested experimentally and reported below.

Single crystal diamond sensors are grown using Chemical Vapor Deposition method by Diamond Detector Ltd company. They show very low leakage current (at pA level) and very good radiation hardness. Initial charge collection efficiency is close to 100%, after 10 MGy dose sensor still has above 10% of initial CCE (see Fig. 1).

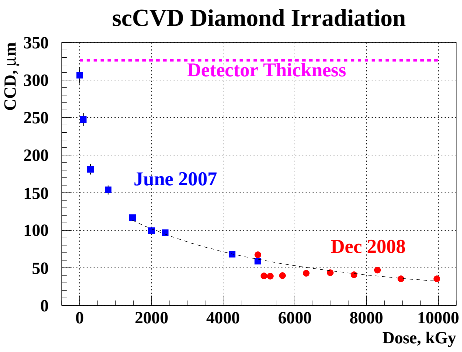

Figure 1: (Color online) Charge Collection Distance of single crystal Diamond sensor as a function of the absorbed dose. Two different irradiation periods are shown by different colors

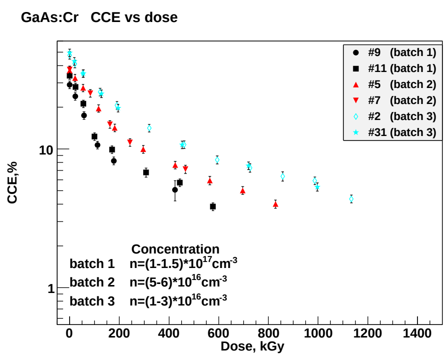

Figure 2: (Color online) Charge Collection Efficiency of GaAs sensor as a function of the absorbed dose for different Cr dopant concentration.

Large area GaAs sensors are obtained from Siberian Institute of Technology. They are produced using the liquid encapsulated Czochralski method and are doped with tin and tellur as shallow donors and chromium as a deep acceptor. Three batches with different concentration of the dopants are irradiated up to 1.2 MGy and the charge collection efficiency, CCE, is measured as a function of the absorbed dose (see Fig. 2). The sensors with a lower acceptor concentration show a larger initial charge collection efficiency and better radiation hardness.

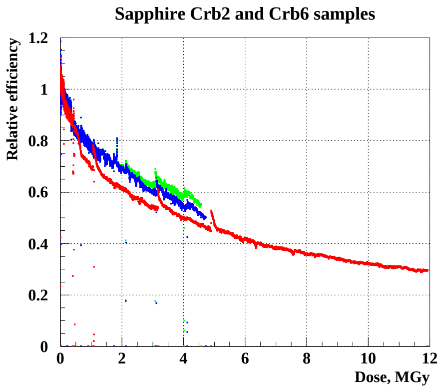

Figure 3: (Color online) Relative charge collection efficiency of single crystal Sapphire sensor as a function of the absorbed dose (see text).

Optical grade single crystal sapphire sensors are created using the Czochralski process. They show initially low (about 2%) CCE, but extremely high radiation tolerance (see Fig. 3). Since the signal from the detector is too small to observe it directly, CCE was extracted from the detector current measurements during irradiation. Crystals of better purity have to be tested.

2 Application examples at LHC and ILC

In the CMS detector at LHC a series of beam condition monitors [1] were installed and are in operation for measuring radiation doses and preventing possible damages to the detector in case of beam losses. The Fast Beam Condition Monitor, BCM1F, consists of two modules, with 4 scCVD diamond sensors each, located 1.8 m away from the IP, on both sides, and was designed to give a fast response measuring beam-halo on a bunch-by-bunch basis. Figure 4 shows a photo of one of the installed BCM1F stations and a photo of single module prototype.

Low polar angle Beam Calorimeter [2] for the detector at future Linear Collider is designed as a compact highly segmented sampling calorimeter with tungsten absorber (see Fig. 5). Thin sensor planes between absorber plates should provide a fast response and operate in the harsh radiation environment.

References

[1] A. Bell *et al.*, NIM **A614** 433 (2010).
[2] H. Abramowicz *et al.*, IEEE Trans.Nucl.Sci **51** (2004) 2983.

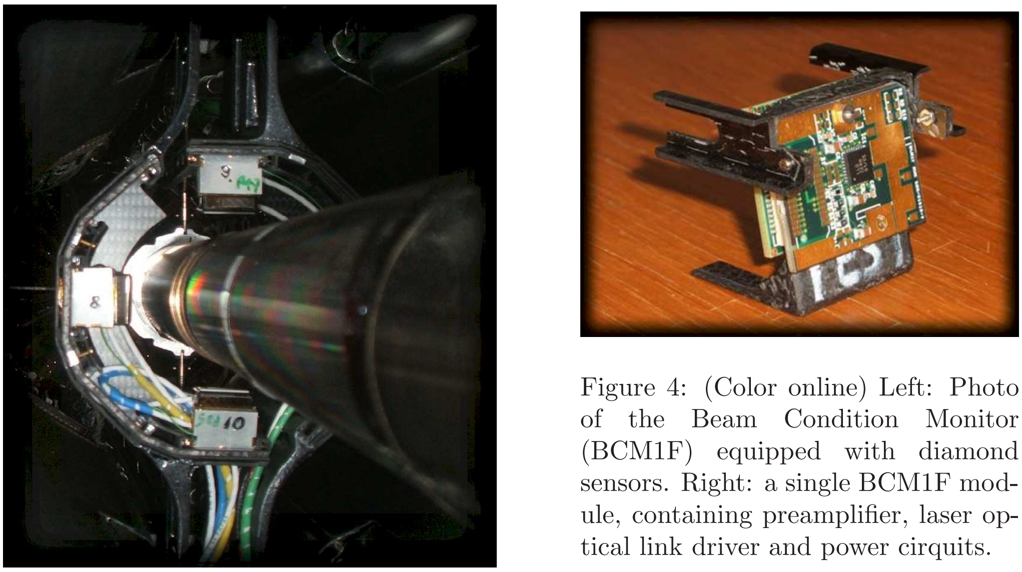

Figure 4: (Color online) Left: Photo of the Beam Condition Monitor (BCM1F) equipped with diamond sensors. Right: a single BCM1F module, containing preamplifier, laser optical link driver and power cirquits.

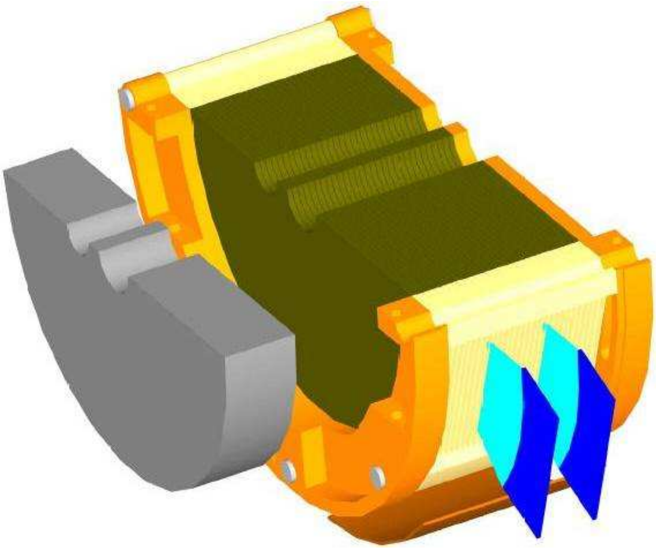

Figure 5: (Color online) Beam Calorimeter for the ILD detector is located at 3.5 m distance from the IP. Graphite block in front of BeamCal protects tracking detectors from backsplash particles.