Contribution ID: **30** Type: **Contributed Talk**

A Program to Determine the Feasibility of MCz silicon as a Detector Material for Super-LHC Tracker Volumes

Wednesday 17 February 2010 16:30 (25 minutes)

With an expected ten-fold increase in luminosity, the radiation environment in S-LHC tracking volumes will be considerably harsher for silicon-based detectors. Since 2007, a collaboration of CMS institutes has been exploring the use of Magnetic Czochralski (MCz) silicon as a detector element for the strip tracker layers of planned S-LHC detectors. Both n-type and p-type MCz sensors have been characterized, irradiated with proton and neutron sources, assembled into modules, and tested in the CERN H2 beam line. There have been three beam studies to date and preliminary results suggest that both n-type and p-type MCz silicon are sufficiently radiation hard for the R>25 cm regions of S-LHC tracking volumes. However, the Silicon Beam Telescope (SiBT) group also seeks to understand the observed charge collection efficiency in the context of trapping models and in that regard has worked closely with the RD39 and RD50 collaborations. The SiBT group has also explored application of a current injection operating mode for MCz sensors. CID detectors would require a -40 deg. C or colder operating temperature, but offer a potential factor of two improvement (for highly irradiated detectors) in charge collection efficiency over the standard reverse bias operating mode.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

The CMS Silicon Beam Telescope (SiBT) group has now had three successful beam studies in the SPS H2 line and is currently analyzing the data from the summer 2009 run. At the present time there are four institutes that are participating in the analysis and in planning future activities. These are Brown, FNAL, Helsinki, Karlsruhe, and Rochester. Paanja Luukka (Helsinki) is the spokesperson for the group. The SiBT home page can be viewed at

http://www.hip.fi/research/cms/tracker/SiBT/php/home.php

The beam telescope, the CMSSW based analysis, and results from the first two beam tests have been published

1) Silicon Beam Telescope for LHC Upgrade Tests, Nuclear Inst. and Methods in Physics A, 593 (2008)

2) Off-line collaboration and data analysis for the silicon beam telescope on the CERN H2 beam, Nuclear Inst. and Methods in Physics A, 602 (2009)

3) TCT and test beam results of irradiated magnetic Czochralski silicon (MCz-Si), Nuclear Inst. and Methods in Physics Research A, 604 (2009)

4) Test beam results of heavily irradiated magnetic Czochralski silicon (MCz-Si) strip detectors, Nuclear Inst. and Methods in Physics Research A, (available online since August 2009)

and there has been one note on Charge Injection Detectors (CID)

Test beam results of a heavily irradiated Current Injected Detector (CID), Nuclear Inst. and Methods in Physics Research A,

which represents work done in collaboration with other groups.

The major conclusions to date of our R&D are

1) That n-type MCz silicon has acceptable signal-to-noise performance up to 1E15 1 MeV neutron equivalents/cm^2 and as such is a feasible solution for the strip layers in S-LHC. There is some indication from the recent beam test that p-type MCz silicon may be even more radiation hard, but this is preliminary and in the end one would need to consider other factors such as the ease of fabrication for the different sensor types and practical limits on the bias voltage.

2) For higher fluences (up to 5E15) CID detectors appear to improve on the charge collection efficiency over n(p)-type MCz silicon by a factor of two. However, the CID operating mode requires a -40 deg. C sensor

temperature, which could be achieved through the use of liquid CO2 although this would require significant engineering.

Future studies will focus on

1) Completing the n(p) MCz program.

2) Thin sensors (less than 200 microns).

3) Testing HPK sensors that have been requisitioned by CMS for upgrade studies.

There are also some tentative plans to upgrade the older CMS DAQ system to the present version so that the telescope could be integrated with other CMS systems, such as HCAL in the H2 beam line and could operate in a magnetic field.

Results from the beam tests and other measurements have been reported in the Sensor Upgrade meetings within the framework of the Tracker upgrade project and in CMS Upgrade workshops as well. The SiBT group also has a close connection with the CERN RD50 and RD39 collaborations and has given updates in these venues as well. Results have also been presented in conferences, such as the 4th Trento Workshop on Advanced Silicon Radiation Detectors (3D and P-type Technologies) earlier this year.

The hardware used in the beam studies was largely recycled from the Tracker construction period: The "Vienna" cold box, from the CMS module long-term test stand, is used to house 8 reference modules and 1-2 DUTs. The reference modules were constructed using left-over TOB hybrids and Run IIb HPK sensors donated by the D0 collaboration.

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Session Classification: Semiconductor Detectors 4