Tipp 2014 - Third International Conference on Technology and Instrumentation in Particle Physics

Contribution ID: **155** Type: **Poster**

Recent Achievements of the ATLAS Upgrade Planar Pixel Sensors R&D Project

In the framework of the HL-LHC upgrade, the ATLAS experiment plans to introduce an all-silicon inner tracker with the HL-LHC upgrade to cope with the elevated occupancy.

To investigate the suitability of pixel sensors using the proven planar technology for the upgraded tracker, the ATLAS Planar Pixel Sensor R&D Project was established comprising 19 institutes and more than 90 scientists. Main areas of research are
- performance assessment and improvement of planar pixel sensors at HL-LHC fluences
- the achievement of slim or active edges to provide low geometric inefficiencies without the need for shingling of modules
- establishment of reliable device simulations for severely radiation-damaged pixel detectors
- the exploration of possibilities for cost reduction to enable the instrumentation of large areas with pixel detectors

The presentation will give an overview of the R&D project and highlight some accomplishments, among them
- beam test results with planar sensors up to innermost layer fluences
- measurements obtained with irradiated thin edgeless n-in-p pixel assemblies
- recent studies of the SCP technique to obtain almost active edges by post-processing already existing sensors based on scribing, cleaving and edge passivation
- update on prototyping efforts for large areas: sensor design improvements, 6”wafer production experience, 8”wafer production possibilities, concepts for low-cost hybridisation

Together, these results will allow an assessment of the state-of-the-art with respect to radiation-hard position-sensitive tracking detectors suited for the instrumentation of large areas.

Summary

To extend the physics reach of the LHC, upgrades to the accelerator are planned to increase the peak luminosity by a factor 5 to 10 which will enable the experiments to collect up to 3000 fb-1 of data. This, however, will lead to increased occupancy and radiation damage of the inner trackers, approaching fluences of a few 10ˆ16 neq/cm2 at the innermost layer and still some 10ˆ15 neq/cm2 at the outer pixel layers.

The ATLAS experiment plans to introduce an all-silicon inner tracker with the HL-LHC upgrade to cope with the elevated occupancy. With silicon, the occupancy can be adjusted by using the unit size (pixel, strip or short strip sensors) appropriate for the radiation environment. For radiation damage reasons, only electron-collecting sensors designs are considered (n-in-p and n-in-n): Beyond a fluence of about 10ˆ15 neq/cm2, trapping becomes the dominant radiation effect and electrons are trapped significantly less than holes.

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It has been demonstrated with sensors from different vendors that planar pixel sensors can be operated and still yield more than 5000 electrons of signal charge even above 1016 neq/cm2; hit efficiencies of well above 97% were obtained.

Special slim-edge designs have been implemented and tested and show a reduction of the inactive edges from 1100 µm in the current ATLAS Pixel Detector to only about ˜200 µm. Further improvements towards fully active edges by SCP (scribe-cleave-passivate) and DRIE etching techniques have been prototyped and look promising.

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Track Classification: Sensors: 1b) Semiconductor Detectors