WP4 – Radiation Hard Semiconductor Detectors: Annual Report 2009

The work package comprises the development and characterization of silicon sensor technologies which are best suited for the upgraded inner tracking systems of the S-LHC experiments and is performed in close collaboration with the ATLAS, CMS, RD42 and RD50 collaborations. Along with the R&D activities silicon sensor characterization and test tools are produced as CERN common infrastructure. A major research activity is the study of recently developed new silicon sensor materials and their application in conventional and new detector concepts. This comprises the study of Czochralski (CZ), Floating Zone (FZ) and Epitaxial (EPI) silicon of n- and p-type in form of ministrip-, pixel- and diode- structures in planar and so-called 3D sensor configuration.

In the framework of the **Pixel Sensors R&D** the noise and signal behavior of different sensor types and layouts was studied in order to optimize the signal-to-threshold performance before and after irradiation. The study includes planar silicon sensors manufactured by CiS, 3D silicon sensors from Stanford, Sintef, FBK and CNM and CVD diamond sensors manufactured by Diamond Detectors Ltd. Particular emphasis was put on testing 3D Silicon sensors fabricated at FBK-irst with the Double-side Double Type Column (DDTC) approach and columnar electrodes only partially etched through the p-type substrate. They were tested with γ-sources and a Sr^{90} β-source in the laboratory as well as in a 1.6 Tesla magnetic field with a 180 GeV pion test beam at the CERN SPS. Towards the end of 2009 several devices were irradiated with 23 GeV protons at the CERN PS Irradiation Facility up to $3.5x10^{15}$ p/cm^2 and will be analyzed in 2010. Some selected results obtained with 3D FBK-irst sensors during the test beam are summarized below, while a detailed description of the overall performed work on pixel sensors can be found in [1]. Figure 1 shows the hit efficiency of a 3D sensor (3E-type) with B field on at 0° and 15° beam incidence angle. To visualize the hit efficiency as function of the track position all tracks have been folded into a 2x2 sensor cell (800μ*m* x 100μ*m*). The electrodes of both doping types are clearly visible when the tracks are normal to sensor surface (0°) as low efficiency regions. The hit efficiency becomes more uniform when the tracks are inclined (15°), thus demonstrating that the inefficiency of the columns can be overcome by tilting the sensors. Figure 2 shows the pulse height distribution for a 3E-type sensor with B field off/on and 0°/15° angle of incidence. It can be seen that the magnetic field does not have a relevant effect on the charge distribution.

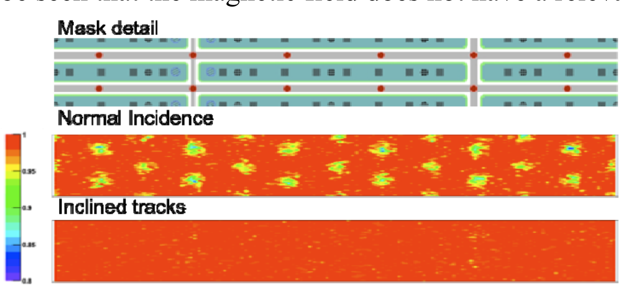

Figure 1. Hit efficiency of an non irradiated 3D sensor (3E type, FBK) with 1.6 T magnetic field at 0 and 15 degrees incident angle.

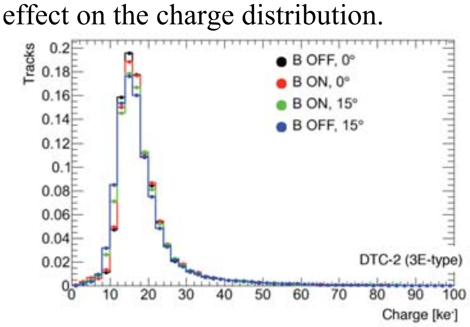

Figure 2. Pulse height distribution with 1.6 T magnetic field on/off and 0/15 degrees of incident angle.

In the framework of the **Strip sensors R&D** several ministrip sensors originating from RD50 projects have been irradiated with protons and neutrons and subsequently characterized with the CV/IV methods and a newly designed Charge Collection Efficiency (CCE) measurement system based on the LHCb Beetle chip (ALIBAVA system). The results were presented on RD50 workshops [2] and are an integrative part of the overall RD50 work program. In the framework of the CMS tracker upgrade program [3] the mask layout for a sensor production at Hamamatsu

Photonics (HPK) was finalized and a detailed work plan for 2010 including irradiations and annealing experiments was worked out. Additional measurement equipment was installed and partly commissioned in the CERN DSF that will allow the CERN CMS & WP4 team to play a major role in the upcoming characterization campaign.

In terms of **generic R&D** on silicon sensors the emphasis of the experimental work performed at CERN was set on p-type epitaxial silicon materials of various thickness (50 to 150 μm) and the evaluation of MCZ n-type ministrip sensors which show promising features in mixed irradiation fields containing protons and neutrons. In the framework of the RD50 collaboration [2] further proof was delivered that charge multiplication mechanisms lead to an improved radiation tolerance of planar silicon sensors with n-type readout electrode after very high hadron fluences. This result gives further confidence in the improved radiation tolerance of n-in-p type silicon strip sensors compared to the presently used p-in-n type sensors. Operation of this kind of devices at 500V seems feasible under Super-LHC conditions provided the strip length (scaling with the noise) is adopted to the expected radiation environment.

Finally, and in line with the R&D activities, **new sensor characterization tools** were produced in the labs in bldgs. 28 and 301 and in the silicon facility (DSF): An LHCb Beetle chip based CCE system for strip sensors with beta source, a multichannel TCT with a picoseconds laser system, a cold chuck system and a further CV/IV probe station. Existing measurement systems were refurbished and upgraded. These tools were partly made available as **service** to groups not participating in the work package. Furthermore, strong support was provided for ATLAS, CMS, RD42 and RD50 test beam and irradiation activities at CERN.

List of References

[1] WP4 - Pixel R&D: https://twiki.cern.ch/twiki/bin/view/Main/CernAtlasPixelSensorsRD
[2] RD50 collaboration (see 2009 & 2010 publications); https://rd50.web.cern.ch/rd50/
[3] CMS Tracker upgrade: http://cms-tracker.web.cern.ch/cms-tracker/TKSLHC/