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Addendum to Development of Diamond Tracking Detectors for High Luminosity Experiments at the LHC

The RD42 Collaboration

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◇ Spokespersons

Abstract

In this addendum to the RD42 status report [1] we present recent progress on diamond pixel detectors. Specifically we present the first beam test results with CMS diamond pixel devices read out with the full CMS electronics chain. These results were not available in time to be included in the RD42 status report and the LHCC presentation.

During the past year the highest priority of RD42 has been to develop CVD diamond material for applications in LHC detectors. To accomplish this goal we have taken the highest quality CVD diamond available and constructed pixel detectors for ATLAS, CMS, and BTEV. Previously our first successful test of a diamond pixel detector was performed in collaboration with the ATLAS group [2]. Recently we fabricated diamond pixel detectors to the specifications of the CMS pixel readout chip. The CMS members of RD42 tested it using the full CMS readout chain in a test beam at Fermilab. This test also included silicon pixel detectors with which the diamonds may be compared.

The pixel electronics used in this test was designed by the CMS group at PSI [3] and produced at Honeywell in their radiation hard technology. The bump bonding was performed at University of California at Davis [4]. The procedure used indium bumps deposited on both the electronics and the detector. The bump deposition efficiency was 100 % as determined by visual inspection. The diamond detector was fabricated with 100 μm $\times$ 100 μm size pixels on a 125 μm $\times$ 125 μm pitch. The electronics was capable of triggering at thresholds as low as 1500 e.

The analysis presented here is very preliminary and as such we only infer general qualities from the data. Fig. 1 shows the overall hit map for the silicon (left) and diamond (right) pixel detector for hits on tracks. One observes that almost all pixels have hits on tracks in both detectors. If we compare the central region of the silicon with that of diamond we find that the diamond is very efficient relative to the silicon detector.

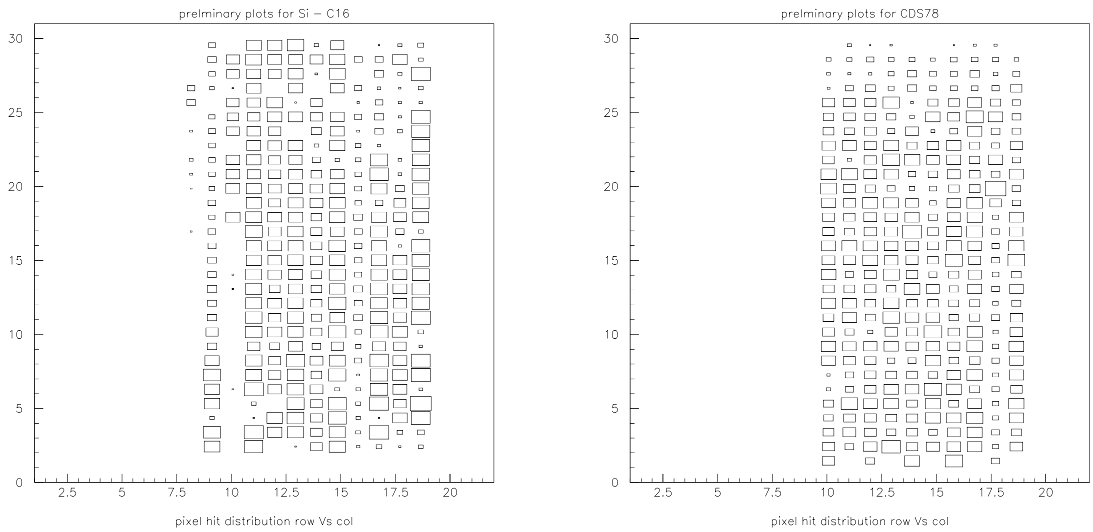

Figure 1: Hit map in the silicon pixel detector (left) and in the diamond pixel detector (right).

Fig. 2 shows the uncorrected pulse height spectrum from the diamond detector. For normal tracks most of the hits (> 90 %) in the CMS pixel device are single hits. The pixel pad width of 100 μm is comparable with the 90 μm wide strips on the same diamond tested earlier as a strip detector in a beam test. Fig. 3 shows the distribution of the single strip charge in the strip detector. Only those signals are included that were found as hits inside the region containing 90 μm wide strips. Comparing these distributions we estimate that the threshold on the diamond pixel detector was below 1500 e.

Fig. 4 shows the track correlations in both dimensions for the diamond pixel detector. This correlation indicates a well working device. Finally in Fig. 5 we present the resolutions in both dimensions for the diamond pixel detector. The spatial resolution is 125 μm/$\sqrt{12}$

which is the spatial resolution expected for single pixel hits.

This preliminary result demonstrates that diamond pixel detectors can be produced to provide very efficient tracking. In combination with results from measurements of radiation hardness of the most recent diamond samples from De Beers presented in the RD42 status report [1] and recent progress in radiation hardness of deep sub-micron CMOS technologies one can predict that layers of diamond pixel detectors can be employed at the innermost radii close to the beam pipe with excellent tracking performance and long survival at the highest luminosities. This may be of significant importance for the physics performance of LHC experiments.

References

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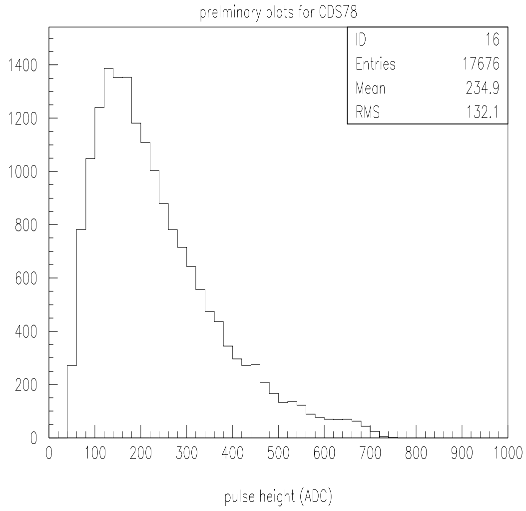

Figure 2: Diamond pixel detector: distribution of charge signals.

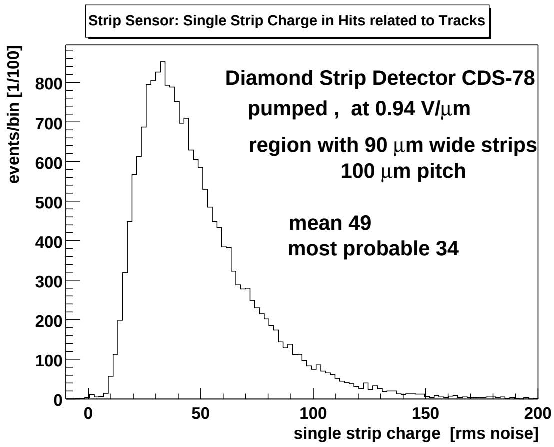

Figure 3: Diamond strip detector (same sensor material as for pixel sensor): distribution of single strip charge signals.

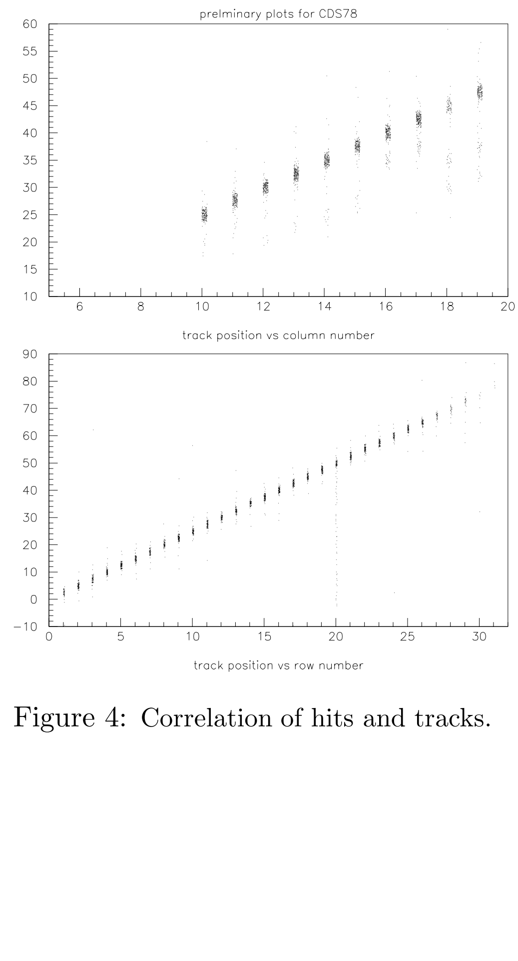

Figure 4: Correlation of hits and tracks.

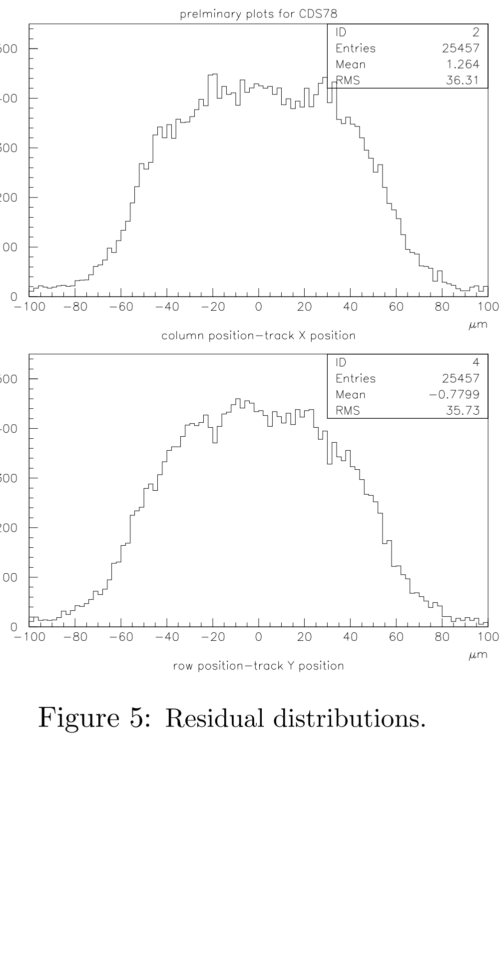

Figure 5: Residual distributions.