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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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**Abstract**

In this addendum we elaborate on the RD42 position for future plans especially pixel detectors as requested at the September 1995 LHCC closed session. We outline our understanding of the current state of the art pixel readout electronics, our plans to study pixel-type sensors in RD42 and our proposal to read these first sensors out. For completeness we re-iterate our intentions for using diamonds in LHC experiments such as ALICE, ATLAS, CMS and LHC-B which we believe will not be limited solely to pixel-type devices.

During the past year the highest priority of RD42 has been to develop and characterise diamond material with the goal developing an LHC tracking detector. To accomplish this goal we first test each piece of diamond by metalising a simple 5mm diameter pad detector. Since the metalisation pattern on the diamond is removable, those diamonds with the highest signal charge are then re-evaluated as strip detectors with low noise electronics. This method could be extended taking those strip detectors with the best performance and producing pixel detectors. Below we discuss the feasibility of producing prototype pixel detectors in the next year.

Members of our collaboration have already begun preparing pixel-type devices. Those who are also members of RD19 plan to provide a pixel mask suitable for readout with Omega-type electronics. However, our understanding of the current state of the art in pixel readout electronics makes this a low priority in RD42. Figure 1 from reference [1] highlights the difficulties of operating any "true" diamond pixel detector in the next few years. Although the single channel noise in a pixel pre-amplifier is very low (left distribution in fig. 1), on the order of 200 $e^-$ Equivalent Noise Charge, the channel-to-channel variation in sparsification threshold, due to variations in the CMOS processing over the area of a readout chip are currently about 1000 $e^-$. In order to provide efficient sparsification given such a spread in thresholds, the average threshold has been designed to be 6,000 $e^-$ (the open distribution in fig. 1). If it were much lower many channels would record hits from noise fluctuations resulting in a prohibitively large occupancy. For such a threshold distribution reasonable efficiency can only be obtained for signals in excess of 10,000 $e^-$. The Omega3/LHC1 readout chip is being re-designed to have a lower threshold spread and consequently a lower average threshold (the second distribution from the left in fig. 1) however this is "unlikely to be attained in the first iterations with the new SACMOS1 technology" [1]. When this chip is available it will still require diamond material with a most probable signal in excess of 7,000 $e^-$ (c.f. the lower Landau distribution, with dark shading, in fig. 1) in order to obtain an efficient diamond pixel detector.

In our minds this precludes pursuing a "true" pixel detector with the CVD diamond avaliable today. At this stage, we have concentrated on developing devices with one-dimensional readout geometry. From our strip trackers we are learning about effects near the end of readout strips and in the gaps between strips. An alternative approach to looking at pixel-like devices has already been proposed in RD42. In the absence of a readout chip adapted to this geometry it has been suggested that we instrument a limited area of such a detector with the analog readout electronics we currently use to readout strip trackers. One advantage of such an approach is that the analog information may be invaluable to us to better understand charge sharing among cells and the effect of the more complicated cell boundary structure. By close-packing 4 VA readout chips it should be possible readout an array of $16 \times 32$ cells. We are investigating ways of routing the signals from these 512 cells to the edge of the detector (where they can be bonded to readout chips) using technology similar to the double metal approach, now successfully used in double sided silicon detectors. However, if the pixels are small enough a simpler approach may be to use a series of varying length bond-wires to retrieve signals from pads which are not along the edge of the array.

In addition to our interest in studying the charge collection properties of pixel-type detectors on CVD diamond sensors, we would like to stress that we believe it is by no means a foregone conclusion that diamond strip trackers will not have their place in an LHC experiment. Since the expertise of much of our group lies in this area it has been natural to pursue this while continuing to improve the diamond material. In the coming year we intend to study the pattern recognition implications of using a strip tracker at small radii in several LHC experiments. It is

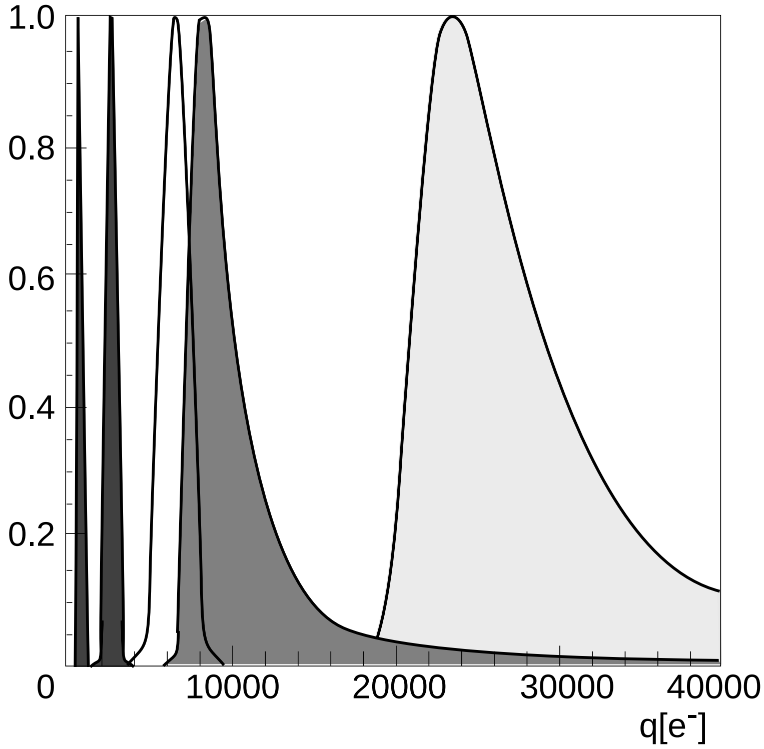


Figure 1: Distributions (from left to right) of the noise of the pixel readout amplifier, a projected threshold distributions (2000 $e^-$ average) for the Omega3/LHC readout chip, the threshold distribution for the existing Omega2 chip (6000 $e^-$ average) and the signal distributions for a 100 $\mu$m thick silicon detector (similar to our goal for a 300 $\mu$m thick diamond detector) and a 300 $\mu$m thick silicon detector.

our view that making a case for the added physics potential a diamond strip tracker may turn out to be a more fruitful way to interest LHC experiments in this very promising radiation hard technology.

## References

[1] Erik H. M. Heijne *et al.*, "The next steps in pixel detectors" Contributed paper to the EPS High Energy Physics conference Brussels, 1995.