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RD8 Status Report - Addendum

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1 Brief Review of Progress

In response to requests from the DRDC for further information, the following is a brief summary of the understanding achieved by the RD8 collaboration of the radiation hardness of GaAs detectors subjected to gamma-ray and neutron irradiation.
In examining the merits of GaAs with respect to increasingly optimistic assessments of the capabilities of silicon microstrip detectors, it is perhaps worth emphasising that, to our knowledge, the maximum tolerable neutron dose for silicon detectors is still not much higher than about $10^{14}n/cm^2$, at least without very considerable operational penalties. Recent results of simulation of the dose expected at nominal LHC luminosities [1], if correct, confirm the requirement for higher levels of radiation resistance.
For the example of the forward tracker "wheels" proposed for the ATLAS detector, we believe it would be wise to aim for radiation hardness at the level of $5 \times 10^{14}n/cm^2$ at least.

Our typical GaAs detectors have been shown to suffer from incomplete collection of the charge released by a traversing minimum ionising particle. This is attributable to the presence of trapping centres in the semi-insulating (SI) substrate material used in their manufacture. (Detectors fabricated in high quality liquid - phase epitaxially grown (LPE) layers do not suffer significantly from such charge collection inefficiency, but are considerably more expensive.) Simple Schottky barrier detectors have been fabricated with charge collection efficiencies exceeding 80%, however, both in the University of Glasgow and, commercially, by ALENIA SpA in Italy. Samples of Glasgow (Aachen) detectors have been exposed to gamma - ray doses exceeding 20 MRad (100 MRad) and to neutron doses up to $2 \times 10^{15}n/cm^2$ as shown in Figure 1. We are presently measuring the effects of a neutron dose of $10^{14}n/cm^2$ on simple "pad" detectors from Alenia. Present indications are that these detectors have a charge collection efficiency exceeding 65% after irradiation at this fluence. (As shown in Figure 2, similar detectors have achieved values of 80% for this parameter before irradiation.)

Our research has concentrated during the last year on understanding something of the nature of the processes causing the loss in charge collection efficiency and we believe that we have made important progress in that time. In particular, we believe that the physically desirable goal of reducing to a minimum the detector thickness is exactly consistent with achieving the best performance of the detector in terms of charge collection efficiency, ϵ_c. Figure 3 shows how the charge signal is expected to vary with detector thickness and the best performance obtained by us to date. Figure 4 shows a comparison between the measured pulse height spectrum due to minimum ionising particles in a Schottky diode detector and a Monte Carlo simulation of the spectrum, based on a model of the charge collection derived from our investigations this year [2].

In order to achieve an adequate signal/noise ratio with existing read-out electronics, it seems that a GaAs thickness of around 200 microns is satisfactory. The charge signal from this thickness with $\epsilon_c = 80\%$ is equivalent to that from a silicon detector of around 250 microns in thickness, and after $10^{14}n/cm^2$ the equivalent charge signal would be around 17000 electrons, assuming the figure of 65% quoted above for the irradiated ϵ_c. No change in the detector biasing is required. The leakage current density remains at around $2\mu amp/cm^2$, corresponding to a leakage current of 60 nA per strip for the 5cm long, $60\mu m$ pitch microstrip detectors of the ATLAS wheels cited above. There is no need for special cooling of the detector below room temperature - in fact, our present evidence is that the value of ϵ_c increases with temperature increase.

2 Proposed Programme

Our primary goals during the next twelve months are
(1) to achieve performance figures in microstrip detectors of LHC dimensions which are comparable to the best obtained with simple pad detectors and
(2) to continue our studies of charge loss mechanisms, with the aim of identifying possible methods of improving the performance of commercially - available material, e.g. by suitable annealing treatment;
(3) to investigate in more detail the radiation hardness of the detectors and how it may be extended to higher neutron doses. This study will surely benefit from the very extensive programme already carried out on similar structures in silicon, but is nevertheless likely to be demanding and time - consuming.

3 Requests for Resources

As indicated in our Status Report, we are increasingly handicapped by the loss of laboratory facilities and technical support previously supplied via the LAA project. This has been forcibly re-emphasised during our recent test-beam period. Collaboration members from outside laboratories have a real need for a relatively clean area in which to mount and test detector prototypes before their installation in a beam line. Very recent proposals at CERN make it possible that this need will be satisfied for semiconductor detectors generally, so that the RD8-specific request would become unnecessary.

From the outset of our collaboration, it has been one of our primary aims to encourage industrial interest in the prospects of GaAs detectors for future use in HEP. We believe that we have achieved a reasonable measure of success in this aim. To enable commercial organisations to make realistic offers for the fabrication of potentially large - area detectors, they need to be given the opportunity to acquire experience in the requirements (and budget limitations!) of the HEP community, through fabrication of prototype detectors in particular. For this reason, we have bid for a contribution from CERN towards these costs at a level commensurate with contributions which we have up to now succeeded in extracting from our local funding agencies. The 30k CHF which was requested for purchase of commercial prototypes is around the minimum required to make serious work possible with industry. It would be used to obtain a small number (around 10) of microstrip detectors from at least two suppliers, (probably G.E.C.-Marconi and Alenia, who have already shown interest in commercial fabrication). This bid represents the only critical component of our original request - support from the DRDC would greatly enhance the prospects for successful commercial GaAs detectors within the next year.

The RD8 collaboration was formed originally by the CERN - based LAA group, including the Universities of Bologna and Florence, and a U.K. group including members from the Universities of Lancaster, Sheffield and Glasgow. Since then, the collaboration has expanded to include groups from ANSTO (Sydney), Freiburg and Aachen Universities. We have very recently agreed to accept an offer from the Protvino group to join our collaboration.
The level of funding obtained by these groups from local funding agencies over the last two years has been in excess of 300 kCHF per year. It is worth re - stating that the non

- LAA groups have received no direct funding contribution from the LAA project, other than through "grace and favour" access to lab. and technical facilities, which no longer exist. The Italian groups in RD8 are now funded via INFN.

References

[1] *Radiation dose expected in lHC inner detectors: an update*, T.Mouthuy, CPPM Marseille internal ATLAS note, 1993.
ATlAS internal note 2 September 1993

[2] M.Toporowsky, RD8 internal note, July 1993

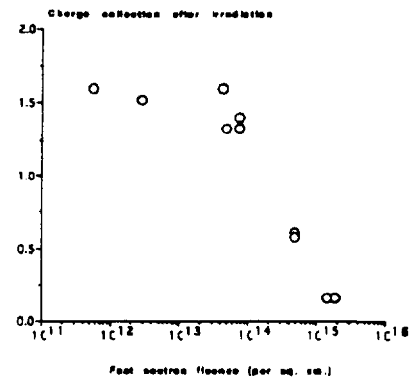

Figure 1: Variation of charge collection efficiency with neutron dose

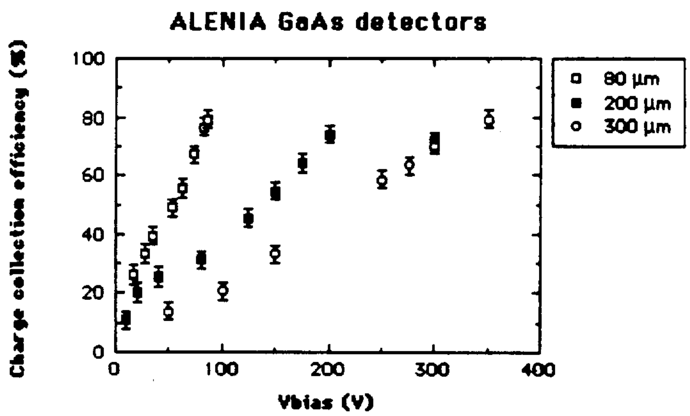

Figure 2: Charge collection efficiency versus reverse bias for three different thicknesses of simple pad detector from ALENIA SpA

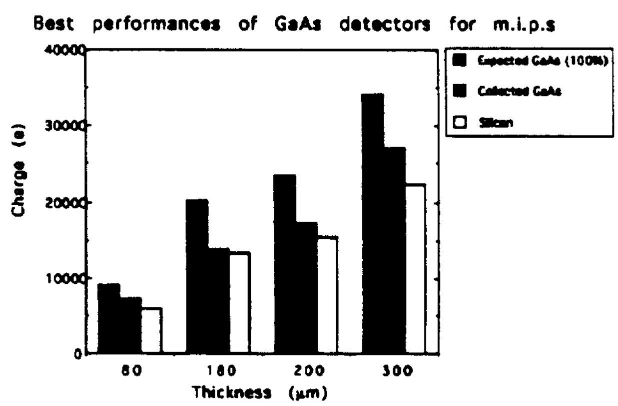

Figure 3: Variation of expected charge signal with detector thickness for silicon and GaAs, compared with the best performance measured to date

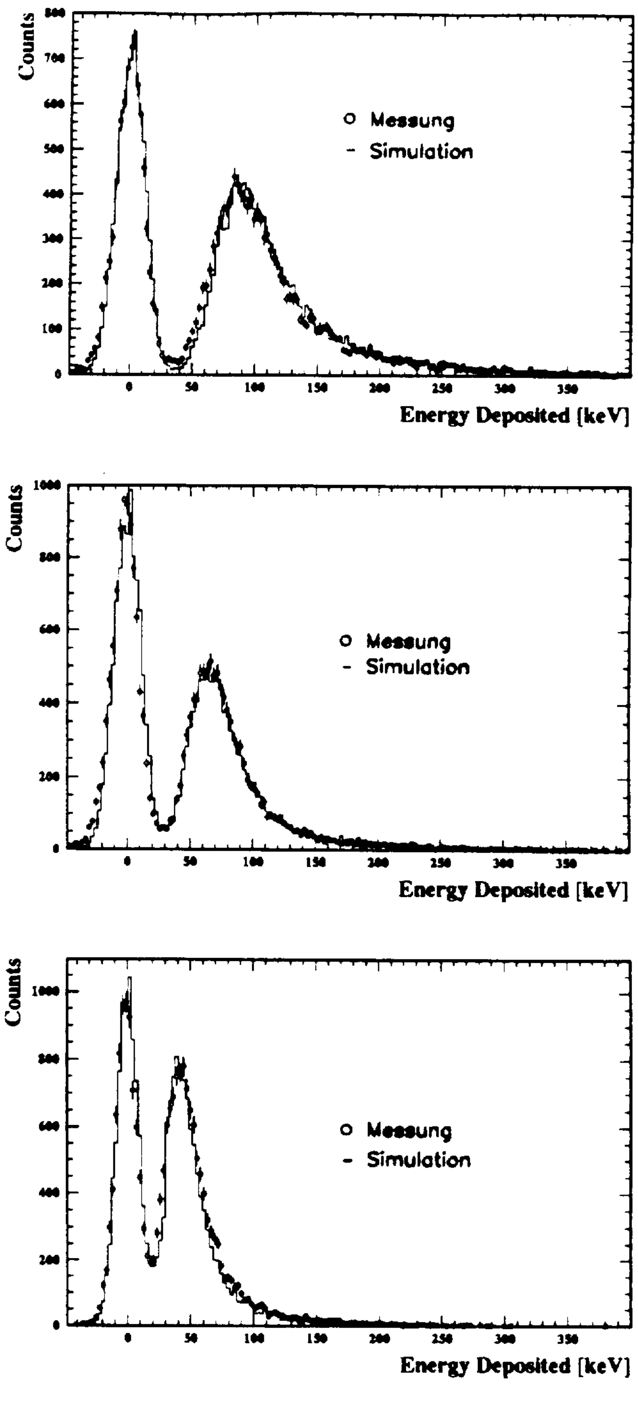

Figure 4: Pulse height spectrum of minimum ionising particles in a $350\mu m$ thick Aachen detector, compared with Monte Carlo simulation of the response. The spectra are taken at 200, 300 and 400V bias, respectively