Recommendations towards a standardisation
of the macroscopic parameter measurements
Part II: MIP CCE measurements

1. Charge Collection Efficiency (CCE) measurements considered here are assumed to study the effects of carrier trapping only. Other reasons for the CCE losses, e.g. an insufficient integration time (sometimes called "ballistic deficit"), are not considered here and are supposed to be appropriately cared for by experimentalists.

2. The recommendations are aimed at the CCE measurements relevant for High Energy Physics (HEP) experiments, where detected particles are Minimum Ionizing Particles (MIPs). The CCE measurement for other applications (e.g. X-ray detection) are not considered here.

3. The charge induction on signal electrodes depends on their geometry (see Shockley-Ramo theorem). Appendix A illustrates the relation between different carrier contributions to a MIP signal in a strip detector. Thus the only straightforward way to measure relevant CCE is to do it with MIPs crossing a detector with the electrode geometry close to that of the strip or pixel detector one wants to study.

4. Measurements with planar diodes where contributions from both carriers to the MIP signal are equal give the CCE for **pad detectors only**. Substantial additional information is needed to obtain the CCE for a strip or pixel detector from these results because the effects of the electron and hole trapping are different in a highly segmented detector compared with a planar diode.

5. MIPs can be produced either by a radioactive source or by accelerator. The latter option is not considered here as being too specific. Among the sources ^{90}Sr is recommended because of the following advantages: a) long half-life time of 28.5 years: b) sufficiently high maximum energy of 2.28 MeV of the

electrons emitted in the daughter nuclide ^{90}Y β^- decay; c) no gammas produced in either ^{90}Sr or ^{90}Y decays. Recommendations on β-particle collimation are given in Appendix B.

6. An alternative way to measure the CCE for a segmented detector is to measure the trapping time for electrons and holes separately. This information can then be used as input for the CCE calculation based on the electric and weighting fields in a real detector. The advantage of this approach is that the results are relevant for any detector geometry. The drawback is that the actual electric field in a heavily irradiated detector can differ from the one used in the CCE calculations.

7. The trapping time for electron and holes separately can be measured by illuminating a planar diode from either side by a source producing short range ionisation e.g. alpha particles or short red light pulses. The latter is preferable because of: a) easy triggering; b) absence of so-called plasma effects related to the high density of the deposited ionization. Note however that for the light source windows should be provided at both electrodes.

8. The light wavelength in the range 675-830 nm is recommended. This corresponds to the absorption length λ in Si from 4 to 13 μm respectively. Shorter λ makes the signal too sensitive to details of the electric field at the edge of the detector sensitive area while longer λ (and hence the length of the initial ionization deposition) complicates the data analysis.

9. The most advanced method of trapping time measurement is based on the Transient Current Technique (TCT) with the current pulse corrected for the carrier trapping. The details can be found in T.J.Brodbeck et al., **NIM A455 (2000) 645** and G.Kramberger et al., **NIM A476 (2002) 645**.

Compiled by A.Chilingarov

To be discussed at the 4th RD50 Workshop 5-7.05.2004

Suggestions and comments to a.chilingarov@lancaster.ac.uk

Appendix A

Consider a MIP crossing a strip detector normally to its plane and producing electrons and holes uniformly along the track. In a typical case with the strip pitch p noticeably smaller than the active detector thickness w the signal on the strip is induced mainly by the carriers moving toward the strip. For $p<<w$ the contribution of the carriers moving from the strip is about proportional to the ratio p/w.

The plot below shows the ratio of the charges induced at the signal strip by the carriers moving from (Q_{from}) and toward (Q_{toward}) the strip as a function of the p/w ratio. The curve is calculated for a MIP crossing the detector normally through the strip centre. An analytic calculation was made for the case of the strip width s equal to the pitch p. For the more realistic case of the aspect ratio $s/p<1$, which can't be calculated analytically and needs a simulation, the curve will be lower but only slightly.
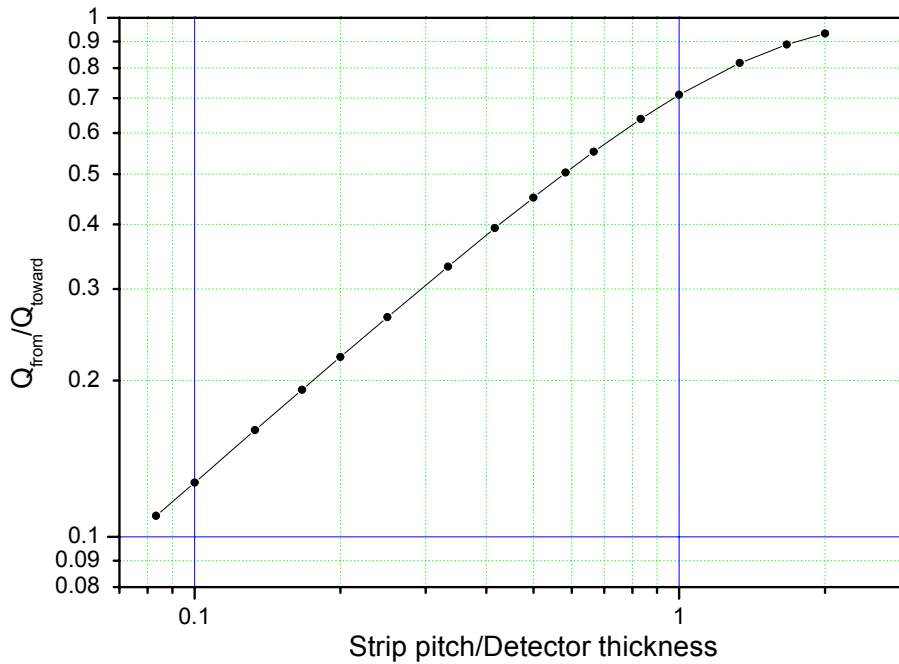
Appendix B. Collimation of ^{90}Sr β-particles

The ^{90}Sr ($\to^{90}$Y) radioactive source produces β-particles with the maximum energy of 0.55 (2.28) MeV in respective decays. The higher energy component can be used as a source of MIP particles. Another commonly used radioactive source ^{106}Ru (^{106}Rh) emits electrons with maximum energy of 3.54 MeV but also the 0.51 and 0.62 MeV photons in comparable quantity. The latter actively produce background electrons via photo-effect and Compton scattering in the β-particle collimator material. The advantage of ^{90}Sr is that no photons are produced either in primary or in secondary β-decays.

Recommended collimation scheme looks as follows.

Collimator

Two scintillator
counters

^{90}Sr

Detector
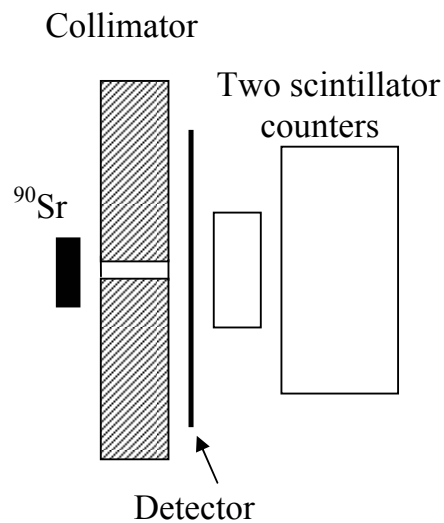
The collimator should be made of low Z material to minimize bremsstrahlung photon production. The coincidence between two scintillator counters further suppresses signal from photons and allows background free trigger for β particles crossing detector under study. The amount of material in the first scintillator counter and the threshold in the second one set the threshold energy for the trigger. An example of successful operation of this scheme can be found in L.Beattie et al. **NIM A412 (1998) 238.**

Below are the plots for electron ionisation loss (dE/dx) and the range in Al (which may also be used for Si) and Polyethylene, which may also be used for plastic scintillators and other plastic materials like Perspex (Plexiglas), PTFE (Teflon) etc.

Electron dE/dx vs kinetic energy

Total electron range vs kinetic energy