Single Event Effect and Beam Diagnostic Studies at the CBM Proton Test Beam

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Introduction

Radiation damages to electronic components are an important issue for FAIR accelerator, FAIR experiments and the used equipment there. For the experiments one of the preferred technology for Application Specific Integrated Circuit (ASIC) developments is the 180 nm UMC CMOS process. In this regard the ASIC design group of the GSI Electronics department (CSEE) has been launched a research project, including the development of the *GRISU* ASIC with the main goal to characterise the Single Event Effects (SEE) on this process [1].

Within the CBM collaboration a SEE test with 2 GeV protons was realised in August 2012 at the particle accelerator COSY at Jülich [2]. Two aspects were tested: mobile beam diagnostic devices and the SEE characterisation itself.

Beam Diagnostic Devices

For the SEE cross section measurement it is essential to know the intensity and the position of the particle beam. The number of proton particles is measured via an ionising chamber [3], read out with a Charge to Frequency Converter ASIC (QFW) [4]. An online measurement of the proton beam position is done with a YAG:Ce scintillating screen and an attached CCD camera [5]. The entire setup is mounted on a moveable XY-table and alignment is done with the feedback from the online beam profile measurement. Once the system is aligned the scintillating screen is pneumatically moved out of the proton beam. In addition, the beam position has been approved by a self-developing dosimetry film [6]. A photography of the GSI test system at COSY is shown in Figure 1 as well as a typical corresponding measured beam profile.

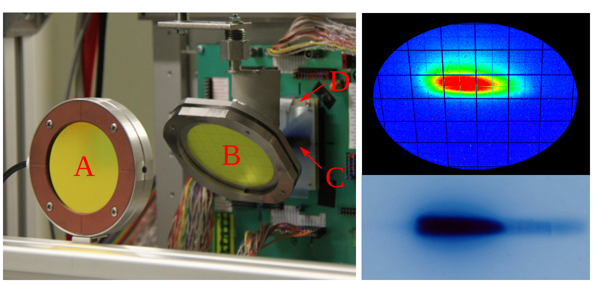

Figure 1: Left: SEE beam test system. A) ionising chamber, B) scintillating screen, C) dosimetry film, D) device under test. Right: beam position and dosimetry film.

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Single Event Effects induced by Protons

Single Event Effects (SEE) is the main generic term for immediate effects in semiconductor devices triggered by the impact of particles. Of great interest are the so-called Single Event Upset (SEU) and Single Event Transient (SET) effects. These effects were studied in detail with heavy ions at the *GRISU* ASIC between 2008 and 2011 [1].

For proton radiation the SEE mechanism is different. Within the 2012 CBM proton test beam campaign at COSY the SEE cross sections of all *GRISU* circuits are tested. At a proton energy of 2.0 GeV and a fluence of $4.9 \cdot 10^{12}$ p/cm^2 in total 456 SEE are measured. Figure 2 shows exemplary the SET cross section data as well as its corresponding Weibull fit of a minimum sized inverter obtained from measurements with heavy ions. In the same diagram the saturated SET cross section region for proton radiation is drawn. This results for this inverter device in a ratio of maximum cross section between heavy ion and proton radiation of $\sigma_{\rm sat,hi} / \sigma_{\rm sat,p} \approx 4500$.

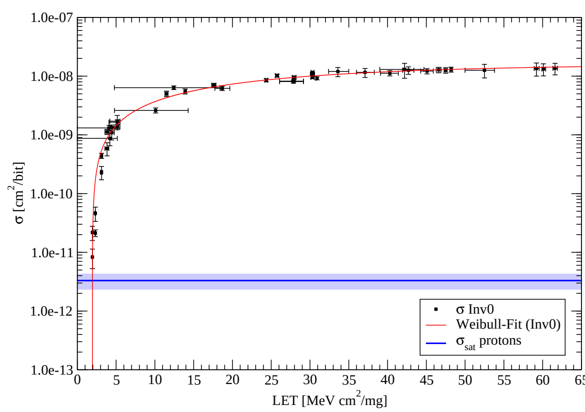

Figure 2: SET cross section for a minimum sized inverter.

References

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[3] GSI Detector Laboratory department (RBDL)

[4] H. Flemming, E. Badura, "A High Dynamic Charge to Frequency Converter ASIC", GSI Scientific Report 2004

[5] GSI Beam Instrumentation department (LOBI)

[6] GAFCHROMIC EBT self-developing dosimetry film, Sensitive dose range from about 1 cGy to 800 cGy