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RADNEXT Transnational Access Summary Report

Project title	*EXP28 - Proton Test (EXP28-PT)*
Project TA identifier	*TA05-101*
General application	*High-energy physics*
Type of test	*SEE*
Group leader, Institute	*Giulio Borghello, CERN*
Date of the experiment	*07/12/2022*
Facility	*TRIUMF BL1B*
Amount of access granted	*12 hours*

Objectives of the experiments

In the context of the Strategic R&D on Technologies for Future Experiment, the IC Technology Work Package 5 at CERN (WP5) has targeted 28 nm bulk CMOS process as common technology for the most advanced developments for HEP application. WP5 is currently evaluating performance and radiation tolerance in this process node. For this reason, a family of 3 ASICs [EXPloit28 (EXP28)] has been designed to study radiation effects on 28 nm CMOS technology.

Each EXP28 chip has a size of 2 mm × 2 mm.
The chip used in the proton test at TRIUMF is called EXP28-SEE.

EXP28-SEE contains structures for studying:
SINGLE EVENT TRANSIENT (SET), based on a vernier detector that allows measuring the cross section for transients, estimate transient length vs LET and detect multiple-transient.
SINGLE EVENT UPSET (SEU) ON SEQUENTIAL ELEMENTS: 7 matrices of 4096 D-Flip-Flop (DFF) are used to evaluate the rate and cross section of SEUs.
SEU ON FOUNDRY SRAMS: 4 different foundry SRAM type cover a total active area of 0.76 mm^2 on the chip.

This test follows a test with heavy ions made in the facility in Louvain-la-Neuve (BE), also obtained through RADNEXT. The purpose of this irradiation campaign is to evaluate single event effects (SEEs) at the fluences expected in high-energy physics (HEP) environments. This step is essential to provide guidelines to the HEP community for future ASIC developments using this 28 nm CMOS technology.

A universal test system was designed in order to interface with all the EXP28 chips. The test system is made of a Genesys 2 FPGA development board running a Microblaze LWIP server, an interface board and a carrier board that hosts the chip. The Genesys 2 board communicates with the test chip through the interface board. The test chip is wire-bonded on the carrier board, which connects to the interface board with the FMC cable.

One of the advantages of this system is its extreme compactness, as well as its ease of use, which makes preparing and performing the test significantly less demanding. Fig. 1 shows the carrier board with the chip whereas Fig. 2 shows the interface board.

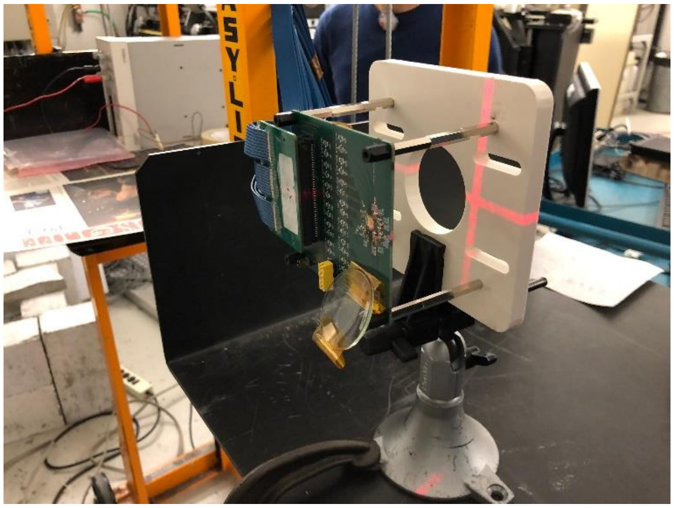

Fig. 1: interface board

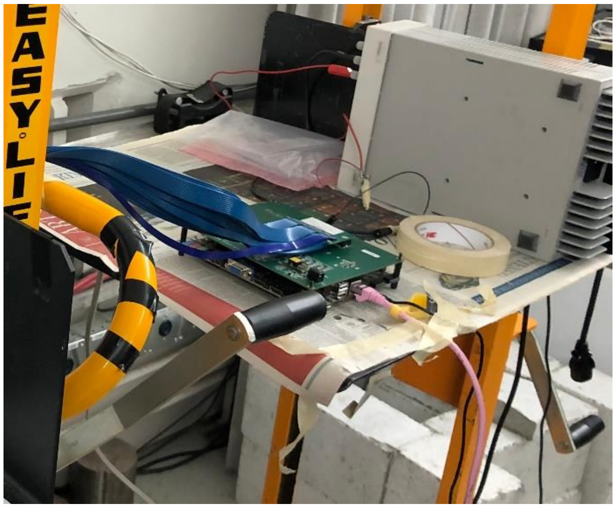

Fig. 2: carrier board

To be able to achieve the required fluences, the chip had to be positioned very close to the source, as depict by Fig. 3.

The interface board was connected to a PC in the control room through an ethernet cable.
The results were monitored in real time, as shown in Fig. 4.

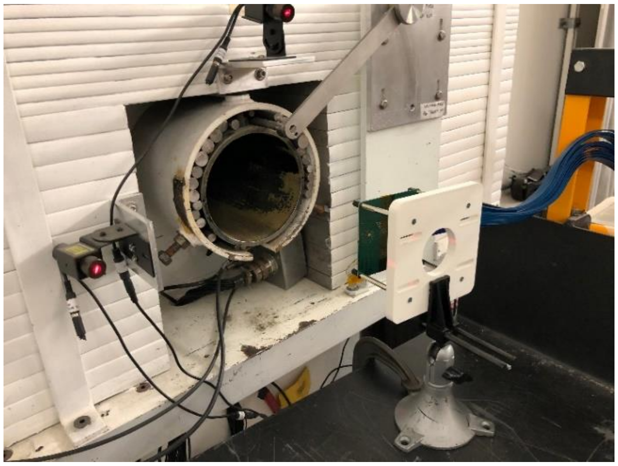

Fig. 3: position of chip and source

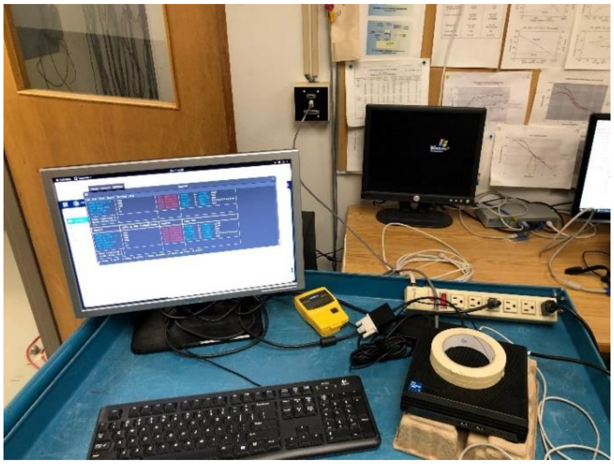

Fig. 4: PC in the control room

Experiment test report

We tested 2 EXP28-SEE chips in different conditions of energy, flux and fluence as reported in the tables below.

test n.	1	2	3	4	5	6	7
chip	A	A	A	A	B	B	B
energy [MeV]	480	480	480	480	480	480	480
fluence [$cm^{-2} \times 10^9$]	174	182	184	184	183	184	184
flux [$cm^{-2} \times 10^6/s$]	520	130	1300	1300	1300	1300	1300

test n.	8	9	10	11	12	13	14	15	16	17	18
chip	B	B	B	B	B	B	A	A	A	A	A
energy [MeV]	350	350	350	350	350	350	350	350	350	350	350
fluence [$cm^{-2} \times 10^9$]	90	183	183	184	184	90	184	184	64	385	385
flux [$cm^{-2} \times 10^6/s$]	256	256	640	640	640	128	640	640	128	640	640

SEU ON FOUNDRY SRAMS:
Fig. 5 shows the cross section for the 4 SRAMs available in EXP28-SEE.

Managing to place the chip in the center of the beam turned out to be an extremely complicated operation. The laser was designed to have its focus several meters behind the position of the carrier board. This difficult positioning explains why measurements 3 and 4 have an obviously lower cross section than the others. For these measurements, the flux was increased (Table 1), which tends to slightly displace the proton beam. If the chip is in the center of the beam, this shift is negligible. However, if the positioning was not done correctly and the chip is at the edge of the beam, small deviations may lead to large variations in the results.

The need to place the chip as much as possible in the center of the beam led to several corrections of the chip position. These adjustments are indicated in the figure by the magenta-colored dashed vertical lines.

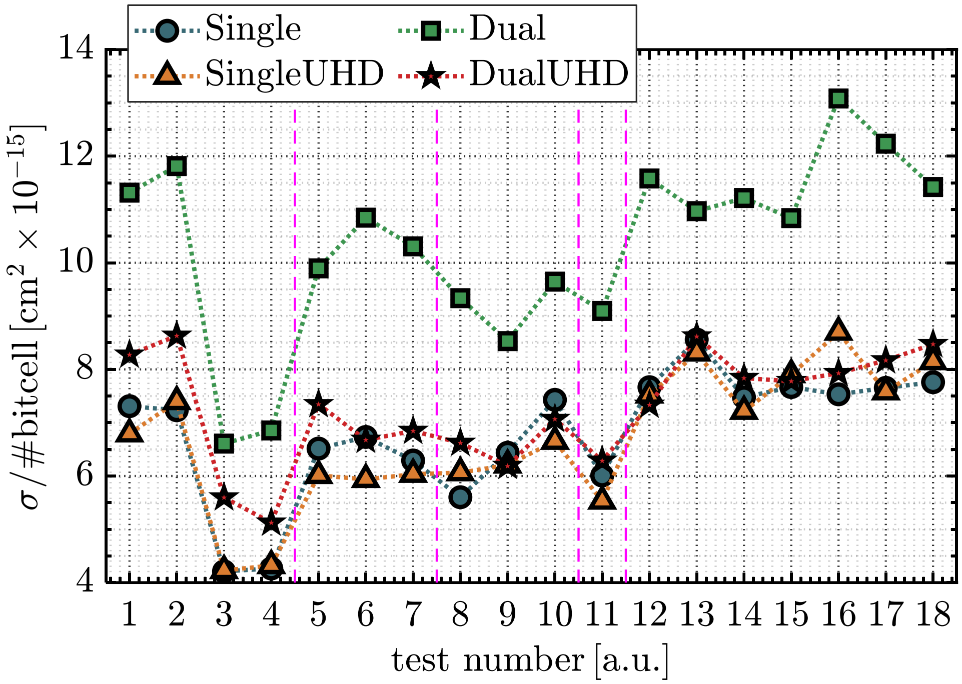

Fig. 5: Cross section SRAMs

In order to achieve a better positioning, we used a radiochromic film placed in front of the chip (Fig. 6).

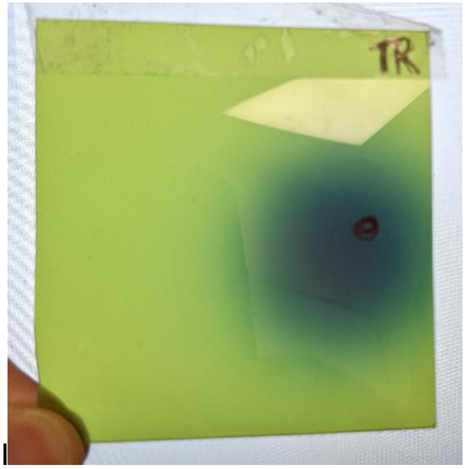

Fig. 6: radiochromic film

The small black dot indicates the position of the chip.

The final position was reached at measurement 12. After that, the holder of the carrier board was no further moved. The variability of measurements 12-18 is relatively small, with the only exception of measures 13 and 16 where the low fluence achieved and the resulting small number of errors caused greater statistical fluctuation in the results.

All other test structures have produced interesting data. Their results are still being studied.

Outcome of the experiments

Please indicate what the experiment is likely to lead to by putting an ‘X’ next to one or more of the possible outcomes below.

Journal publication	X
Data for Thesis	
Follow-up experiment at same facility	
Follow-up experiment at another facility	
Other (report)	X

As a RADNEXT user, we encourage you to submit the scientific results of your experiments to journals as well as to the NSREC and RADECS data workshops. Please remember to include the RADNEXT acknowledgment into your publications!

RADNEXT acknowledgment:

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