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Irradiation test for BETSEE at CSNS for ATLAs ITk strip upgrade

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ITk strip module is the basic unit in ITk strip upgrade. To do an irradiation test for module with smaller size, the collaboration developed a board called BETSEE. We finish BETSEE test with all latest version of ASICs using proton beam at China Spallation Neutron Source, which is the first time using 10(Mrad/h) level dose rate. From our result, SEE effect is acceptable but TID effect become quite significant, and the system become very unstable during TID peak. The powerboard even get broken with both communication and power supply. Our results could help the collaboration to check all ASICs' reliability.

Summary (500 words)

ITk strip upgrade project is a very important job for ATLAS collaboration, and irradiation test for strip module is the only way to ensure our ASIC design is reliable. Our work is the first and the only time in collaboration to successfully finish BETSEE test with proton beam after upgrading all ASICs. Because of the high flux in CSNS, we even find some unexpected problems for the system, which makes this work more valuable to let people know.

The BETSEE test is much more challenge than it looks like. The board is shown is Fig.1. First, BETSEE need to run two DAQ software parallel. ITSDAQ for "hybrid" data (only have one HCC and one ABC chip), and powertools for two powerboards data. Since all ASICs are also upgrade during these time, code for BETSEE test also has many bugs without maintaining in time. So, there is lots of work to do just to successfully run the setup. Besides, the datas for BETSEE is also complicate, we need to be quite familiar with all kinds of ASICs to finally get meaningful results. And it even need more knowledge to understand the results and clarify their connections.

In general, irradiation beam could cause different effects on the electrics, including SEE (Single Event Effect), and TID (Total Ionising Dose) effect. SEE mainly manifested as storage bit flips inside the chips and TID could be observed by current increase from chips and some other system variables. In our ASICs, TMR (Triple Modular Redundancy) is highly used on digital circuit part to take against with SEE. And all chips have been pre-irradiated to avoid a destructive TID current.

After analyzing the result, we could see that TMR has done a good protection for all ASICs from SEE. With about 27 Mrad irradiation in total, only one real SEU was found only on AMAC while we could see corrected SEU recorded in SEU Counter register increase as we expect. The status for register is shown in Fig.2. However, TID current is still too huge under such a big flux, which cause the system running unstable. The high current period last for about 30 minutes, which could be seen in Fig.3. During this range, we could get lots of packet error, SEU, and LCB (signals between HCC and ABC) errors for "hybrid". Details is in Fig.4. Luckily, these errors could recover with the current drops to normal. But after about 21 Mrad irradiation, the powerboard was discovered damaged on both EndeavourCom communication and even the output power. In specific, the communication was off once beam turns on, and the power would be down under 2.6 Mrad/h but recover when lower the flux to 0.57 Mrad/h.

Our talk will show all results in details. Although our test environment may not be so typical to the real environment in LHC, some serious damage happened after all. We believe the result still need people's concentration and do more study to make sure the ASICs, especially powerboard's reliability under irradiation.

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