Could an Active Pixel Sensor Withstand Radiation from a Collider?*

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STAR could explore a new physics dimension if it could detect charmed mesons. If we were to insert a high resolution and low mass detector inside the SVT, our simulations show that such a vertex detector can measure a charm signal with a factor of 100 less events then the current detector and that this detector could measure the D^0 invariant cross section in a typical RHIC year.

Active Pixel Sensors (APS) [1] have recently emerged as a competitor to CCDs and the hybrid technology for charged-particle pixel detectors. The APSs CMOS section has three layers. The top layer of the device has an n+ diffusion / n-well surrounded by a p-well region. Below it is a lightly doped (p^-) epitaxial (epi) silicon layer and then the p+ wafer silicon. As most of the epitaxial region is field free, electrons and holes diffuse in the epitaxial region.

To determine the effect of radiation, we exposed the chips to 55 MeV protons at the 88" Cyclotron. We measured effects on signal and noise using the charge deposited from an Fe^{55} source following techniques previously described. The measured degradation of signal and increased noise are shown in Fig. 1. We were able to measure a clear peak in the Fe^{55} spectra for all exposures except for the highest at 1.0×10^{13} p/cm^2. The data show a decrease in pulse height and a gradual increase of noise.

The radiation-induced leakage current can explain the increase of noise. Charge deposited in the n+ n-well is independent of radiation. Therefore, the radiation induced bulk damage in the epi layer can explain the loss of signal. The damage sites facilitate recombination of the signal electrons with holes shortening their lifetime preventing them from being from being collected by the APS diode.

We have annealed the chip and discovered that the leakage current returns to its nominal level while there is only a modest increase in collected charge. This technique could be used to recover from a radiation exposure.

In summary, our data show that APS technology is appropriate for a collider such as RHIC. However, damage to the silicon could be high if the beam accidentally strays. If necessary, the mechanical supports could be designed so that the silicon can be replaced easily.

Footnotes and References

*Adapted from LBNL-51760

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1. Yu. Gornushkin *et al.*, "Test results of monolithic active pixel sensors for charged particle tracking," *Nucl. Instrum. Meth*ods, vol. A478, pp. 311-315, 2002.

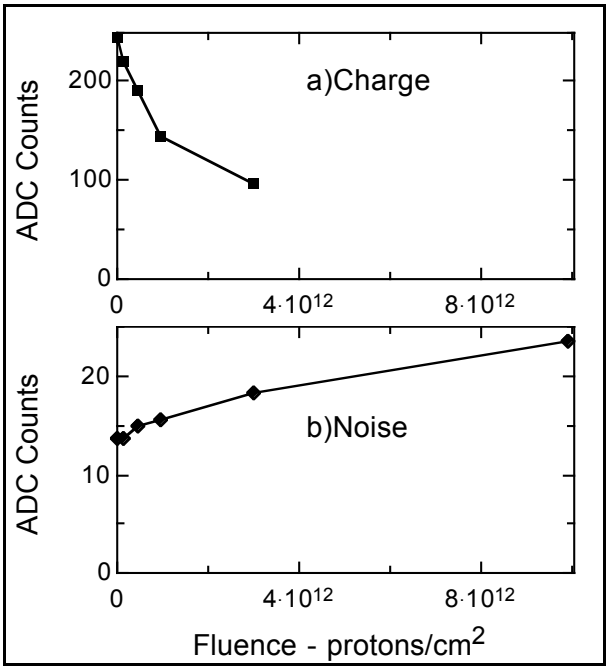

Fig. 1. The effect of radiation on the collected charge and noise for an APS chip. The exposure of 1 x 10^{12} represents a detector that had 122 years at RHIC I and 3.1 years at the proposed accelerator RHIC II.