Proton tracking UFXC32k Hybrid Pixel Detector

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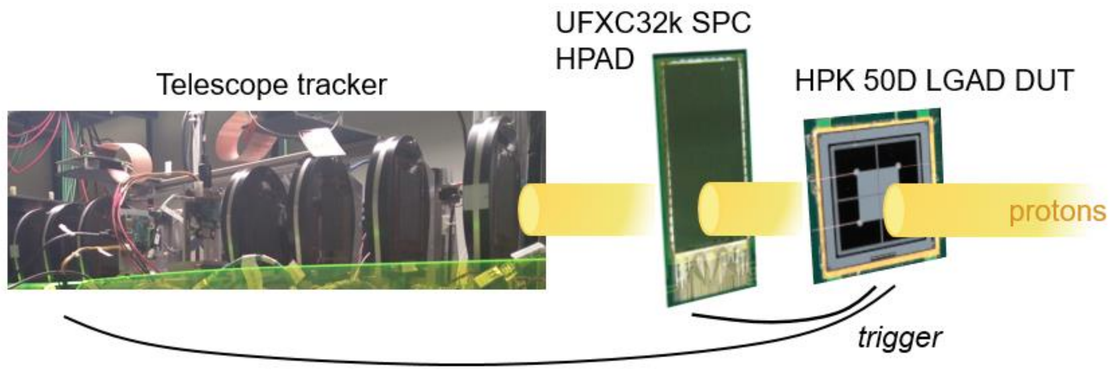
Introduction

Test beam at the Fermilab Test Beam Facility (FTBF), US, provide a unique possibility to characterize prototype detectors (DUTs), such as Low Gain Avalanche Diodes (LGADs), with proton particles. Knowing **the coordinates** of the high energy particles' impact on the detector surface it is possible to perform device characterizations.

In this work, we present **the design and measuring results of proton tracking system** built with the use of **single photon counting hybrid pixel array detector**. The system uses the UFXC32k detector capable of operating with very high photon flux of over 1 Mcps/pixel and avery **high frame rate of 50 kfps**. Having such a characteristic, it makes it possible to apply it not only in X-ray photon detection, but also in a proton tracking system.

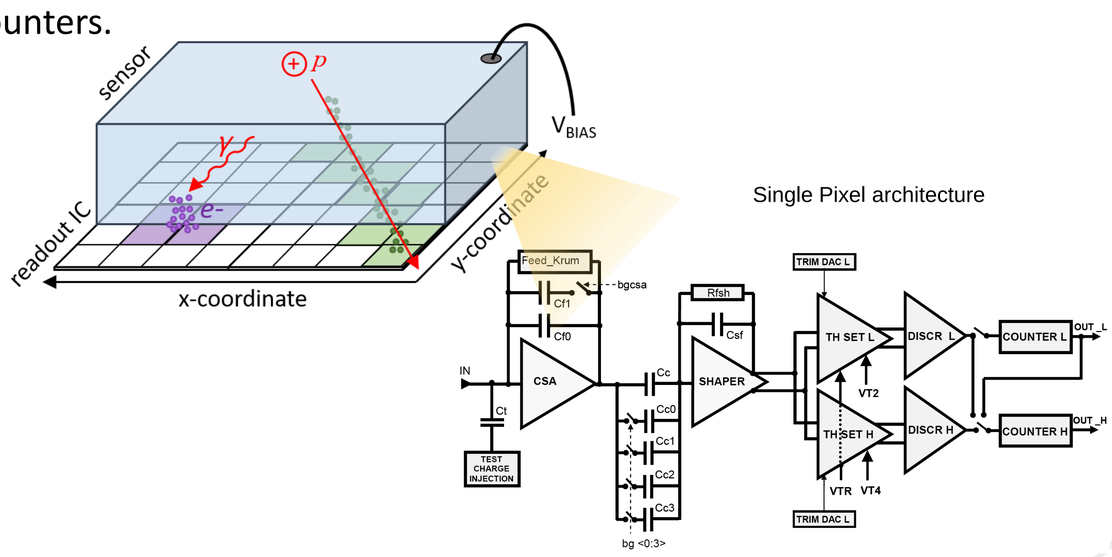
Measurement Setup



The proton tracking system was tested at Fermilab Test Beam Facility (FTBF) with 120 GeV proton beam generated by linear accelerator. The measurement setup consisted of **three layers of different detectors**: LGAD DUT, UFXC32k-based single layer detection system, and current FTBF telescope proton tracker. The first layer, LGAD DUT, is 4-channel high-time resolution detector that produced a trigger to two remaining layers when its channels detected protons. This triggering signal was used by UFXC32k-based detector to pick up a frame from 50 kfps data stream – the frame which should have registered proton indicated by the DUT. The trigger was also used by the telescope tracker for further comparison of the proton transition coordinates registered UFXC-based system.

UFXC32k IC

The UFXC32k [1] is a single photon counting (SPC) hybrid pixel array detector (HPAD) capable to work with different types of semiconductor sensors. The detector consists of 128 x 256 matrix of square pixels with a side of 75 µm. Every pixel contains analog and digital blocks dedicated to signal processing: charge amplifier, shaper and two independent discriminators followed by two independent counters.



Measurement Results

Below: example patterns registered after transition of nine proton particles through UFXC32k detector.

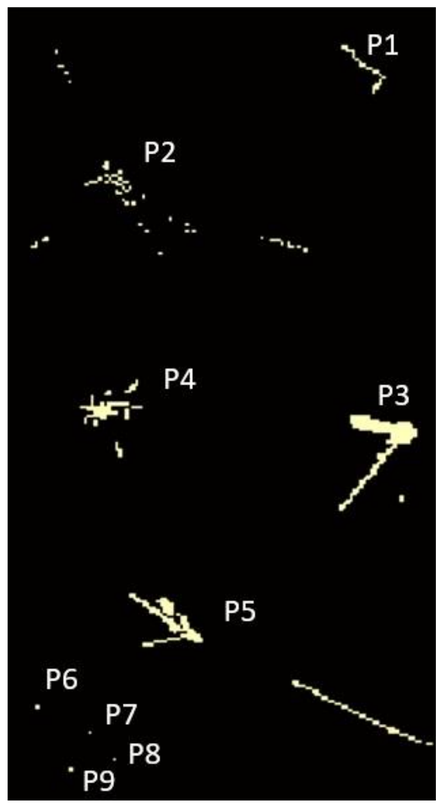
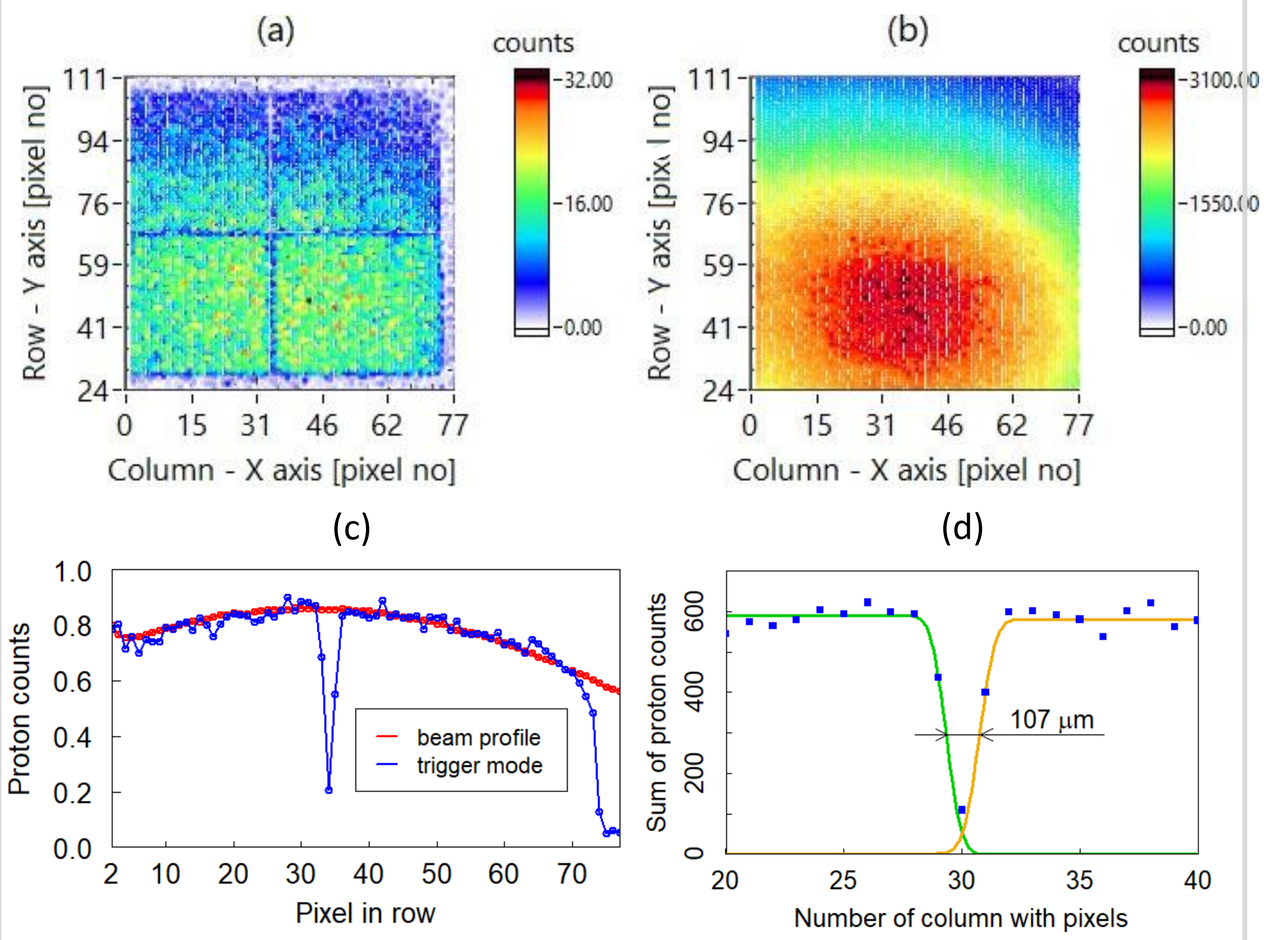


Figure (a) presents transition points of protons registered during 30 minutes of triggered acquisition. Distinct square shapes match location and dimensions of four channels of HPK LGAD detector. The sides of two left channels are cut at the UFXC32k border due to the misalignment between the DUT and UFXC chip.

Measurements performed for several hours in continuous mode allowed to collect a clear beam profile. Registered beam profile, presented in **Figure (b)**, demonstrates that the gradient of counts visible in **Figure (a)** reflects the shape and intensity of the beam. **Figure (c)** presents horizontal total cross-section of the normalized images shown in Figure (a) and (b), which well overlap.



The inter-channel gap was used to estimate precision of UFXC32k detector (**Figure d**). The sigma of left and right channel fits equals 37 and 39 µm respectively. The value of sigma is expected to be influenced by the detector spatial resolution, as well as probable rotation between the two detectors and an effect of charge sharing. The inter-channel gap length was measured as a distance between the centers of both fits at 50% of their amplitude. The length equals 107 µm and it corresponds to the 110 µm observed previously with the use the current FTBF tracker [2].

[1]: P. Grybos et al, "*32k Channel Readout IC for Single Photon Counting Pixel Detectors with 75 um pitch, Dead Time of 85 ns, 9 e- rms Offset Spread and 2% rms Gain Spread*," IEEE TNS, vol. 63, no. 2, pp. 1155-1161, 2016
[2]: A. Apresyan et al., "*Studies of uniformity of 50 µm low-gain avalanche detectors at the Fermilab test beam*", Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip. 895 (2018) 158–172.

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