A Readout and Data Sparsification System for the Heavy Flavor Tracker at STAR

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We are conducting research and development with the goal of constructing a Heavy Flavor Tracker (HFT) for the STAR experiment at RHIC. A complete description of our motivations and methods can be found in our proposal. [1]

The basic unit of the HFT detector is a 20 cm long by 2 cm wide ladder that mounts ten 2 cm x 2 cm CMOS sensors. Each sensor is a 640 x 640 array of 30 micron square CMOS active pixels with two analog readout ports at 50 MHz. These ladders are arranged in 2 concentric cylindrical arrays enclosing the beam interaction region from $-1 < \eta < 1$. The ladders are identical. A drawing showing this arrangement of 24 ladders is shown as figure 1.

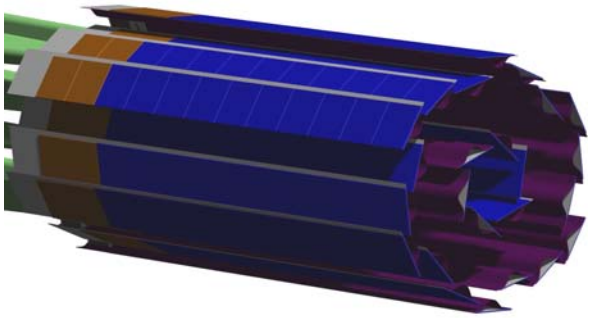

Figure 1: HFT Structure

The HFT is an upgrade detector system proposed for the STAR experiment. It thus needs to fit easily into the STAR environment. The requirements to integrate this detector system into STAR are;

- Triggered detector system fitting into existing STAR infrastructure and interfaces to the existing Trigger and DAQ systems.
- Deliver full frame events to the STAR DAQ for event building at approximately the same rate as the TPC.
- Provide a total data rate to STAR at a manageable level (< TPC rate)

The data flow consists of a synchronous parallel system of electronics for each sensor culminating in readout to DAQ at the ladder level. The analog data from each individual sensor is driven off of the ladder to readout electronics where is it digitized in a 12 bit ADC. The ADC sample is subtracted from the previous stored value for that pixel providing correlated double sampling, reducing the required resolution to 8 bits. This value is then fed into a high / low threshold discriminator and the results of that discriminator fed into a cluster finder. The sensor serial data output is a repeating resorted raster scan. This allows us to identify clusters by doing threshold pattern recognition in a field programmable gate array (FPGA) over a synchronous window that examines a sequential 3 x 3 array of pixels. When a cluster is detected, only the center pixel address is read out. This provides the bulk of the data reduction required. Cluster address data from each chip is read out into a multiple buffered system that then delivers events at the ladder level to the STAR DAQ system via the CERN developed ALICE RORC (Read Out Receiver Card) and DDL (Detector Data Link). This multiple simultaneous event buffering allows us to take up to 1000 events / s despite having a 4 ms. / frame readout time. The hardware designed to accomplish this data flow is shown schematically (for one ladder) as figure 2.

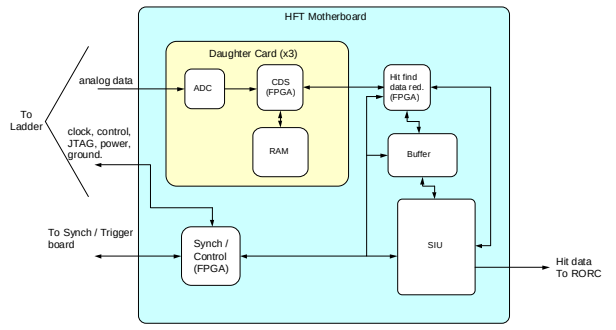

Figure 2: Readout for 1 ladder of HFT detector. All ladders are read out in parallel.

The raw data rate out of the ADCs at the front end is approximately 123 GB/s. Our calculated occupancy is 100 clusters / detector on the outer detectors and 500 clusters / detector on the inner detectors. By doing cluster identification and reading out only the cluster central address we reduce the data rate from 123 GB / s to 106 MB / s. This is shown schematically for the stages of the readout in figure 3.

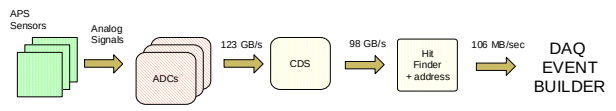

Figure 3: Data rates at the various stages of the HFT readout

This readout scheme reduces the raw data rate by a factor of ~ 1000. This reduces the data rate of the HFT detector system to much less than that of the STAR TPC. Furthermore it is a triggered system fitting well into the STAR environment and thus meets the system requirements.

REFERENCES

[1] A Heavy Flavor Tracker for STAR, LBNL-PUB-5509, Lawrence Berkeley National Laboratory (2006).