Event Monitoring Software for the Heavy Photon Search Experiment

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Introduction

The Heavy Photon Search (HPS), an experiment at Thomas Jefferson National Accelerator Facility (JLab) to search for massive photons, is in need of an event monitoring display software. This software is an important addition to the HPS experiment due to its real-time indication of unexpected and general quality of data. The data that must be monitored in this experiment is centered around the location of specific particle hits on the Electromagnetic Calorimeter (ECal) as well as on the Silicon Vertex Tracker (SVT). The energies of these hits can be displayed visually in a clear and precise manner so that physicists on site can clearly monitor how the experiment is progressing.

Heavy Photon Search

The HPS[1] is a new experiment with the goal of finding what experts in the field call the "**heavy photon**". The heavy photon is a massive photon-like particle known as a heavy vector boson. With theoretical support, physicists believe that these heavy photons will help extend the standard model and lead to a further understanding of dark matter and dark energy. Theoretical research suggests that the heavy photon may be used to explain electron/positron features in cosmic rays as well as dark matter annihilations.

The heavy photon has been suggested to couple with an electric charge because of mixing with the photon. Due to this coupling, a heavy photon could be detected since it would be able to travel a suitable distance for measurement before it would decay into an electron-positron pair or a muon. These particles will have a mass of approximately 100 MeV and will be produced by a process similar to photon bremsstrahlung, which produces a photon from a collision of two electrons.

The heavy photon will then decay to a charged particle pair. The HPS exploits the fact that heavy photons can be detected over a wide range of couplings in that the experiment will be conducted over multiple energy ranges and detectors. This experiment uses the ECal, SVT, and a muon detector to search for a heavy photon in the range of 20 MeV to 1000 MeV.

Experimental Setup for HPS

This experiment will be measuring the mass of A' (heavy photon) decay products as well as the position of the decay. For the most detailed information to be obtained, the experiment uses the setup in Figure 1, which is located in Hall B at JLab where the data will be collected.

Features of the experimental setup include the beam, target (of tungsten foil), SVT system, ECal, and muon detector. The beam will hit the target and the latter three detectors will then measure information such as energy, mass, and position of decay products. The detectors, as displayed in Figure 1, listed in order of downstream location from target:

Silicon Vertex Tracker-

- Vertex tracking
- For pattern recognition of scattering from A' decay products immediately downstream of the target
- "Dead Zone" to avoid beam electrons from causing damage to the detectors

Electromagnetic Calorimeter-

- Triggering for data acquisition
- Electron identification downstream from tracker
- "Dead Zone" to avoid damage to detector from beam electrons, radiated electrons, and bremsstrahlung photons

Muon Detector-

- Detects muon products of A' decay

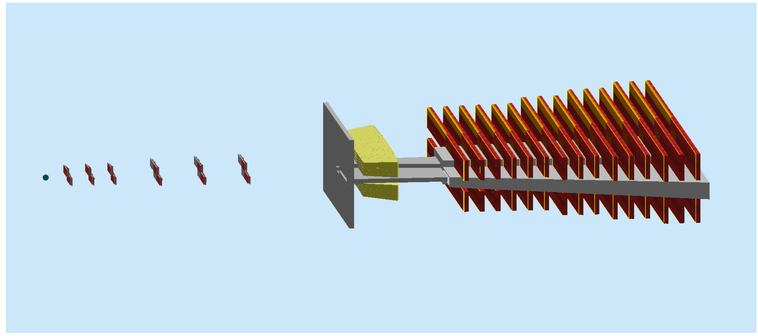

Figure 1: GEMC-generated Experimental Setup for HPS located in Hall B at Jlab with target, SVT, ECal, and muon detector from left to right

Event Monitoring Software

An **event monitoring software** is an essential addition to real time experiments in a counting house. This software would allow physicists running the experiment to see a visual representation of the experimental particle hits occurring shortly after run-time. The software will be closely connected to the raw data stream in a way that would quickly identify any problems or inconsistencies that may occur at run-time with the detectors.

I modified a pre-existing java software[2] for a wire drift chamber in Hall B in order to best fit the purposes of the HPS experiment. The event monitoring software is currently in a form where it has two specific data displaying functions which each have distinct advantages and sub-functions. The first is a monitoring system for the **ECal** and the second is a monitoring system for the **SVT**. The data used to develop this software is data from a test run of the HPS which occurred at JLab in May 2012.

Electromagnetic Calorimeter (ECal)

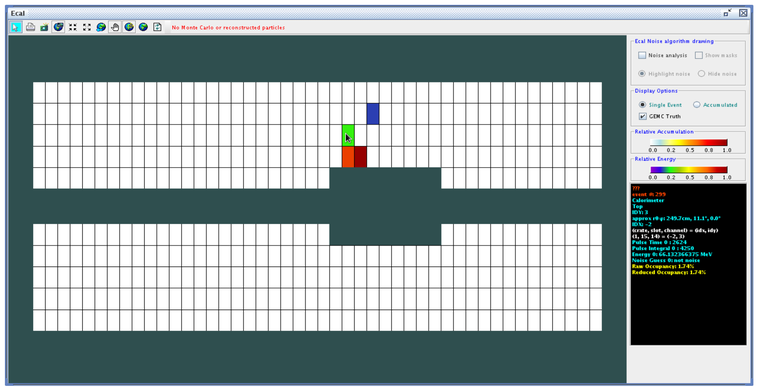

Figure 2: One event from HPS test run data for ECal. Note hit location, relative energy color indications, and energy and pulse time information

I converted the original wire drift chamber display to a calorimeter with the geometry of the Ecal which would interpret the data specifically for this experiment.

The ECal display utilizes test run data from a bank-based data structure and converts a crate, slot, channel structure to a display of physical location. This display will be used to display the energies, pulse information, and locations of charged particle pairs that hit the detector. In addition to single event plotting capabilities, this software is currently equipped with an accumulation option in order to visually display an occupancy plot for many events.

Visually, the ECal displays the location of pairs with a color scale that may be changed to logarithmic or scalar as well as a maximum energy that can be set such that all other energies are scaled accordingly. As well, this display has the ability to automatically cycle through the data to give a better visual representation.

Silicon Vertex Tracker (SVT)

The SVT display utilizes data from the same file format as the ECal and displays one event at a time. This can be used to visually see which channels of the tracker have reported to have hits during a specific event. This will be used by experimentalists to have a detailed view of the location as well as information regarding the sample which help to separate time-overlapping hits.

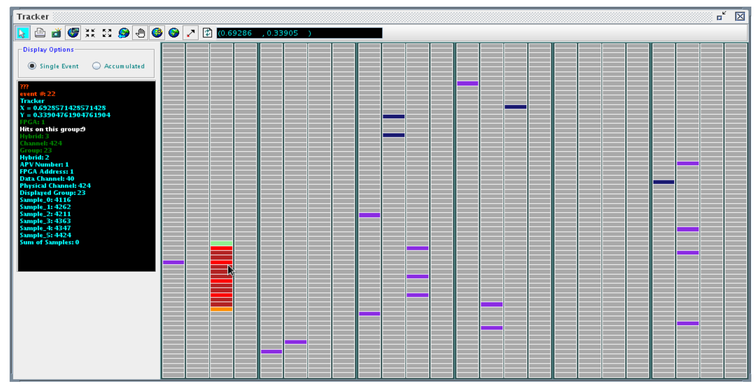

Figure 3: One set of event data displayed from HPS test run data for SVT. Note physical and data hit locations

Conclusion and Future Features

There are other important features to the event Monitoring Software that will need to be added in order for it to run at its fullest capacity and be of the most use at JLab in the counting house:

- Second SVT display – a geometric representation of the tracker display in order to visually inspect tracks
- Improved visual features – to include:
  - Accumulation for both SVT and ECal
  - ET ring – to allow the software to gather data directly from the data stream as opposed to a file

Scientists during an experiment seek to have a quick and easy way to observe data directly at run-time. An event display of the ECal and the SVT is an essential tool for scientists on the HPS experiment to use to identify problems or unusual behavior with regards to particle hits as well as indicate the quality of data.

Acknowledgements and References

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[1] A. Grillo *et al.* [HPS Collaboration], Heavy Photon Search Proposal to Search for Massive Photons at Jefferson Laboratory, (2010).

[2] D. Heddle, java code CED, Christopher Newport University, (2012).