On the Commissioning of the 12 GeV HMS Drift Chambers, Electronics/Computer Dead Time Monitoring and Overview of the D(e,e'p)n Experimental Run Plan

Carlos Yero
October 30, 2017

Abstract

Three separate topics, all of equal importance, are briefly discussed. The new (12 GeV Era) HMS Drift Chambers are ready to be put in the HMS detector stack, in place of the old HMS Chambers. Several efficcinecy tests were performed on one of the chambers during the second week of October 2017. The efficciecies were determined to be better than 99%. The second chamber has not been tested yet, but it is expected to behave the same since both chambers were tested under similar conditions in the past. Dead time studies are currently in progress to determine how many physics events (triggers) are actually lost due to computer and electronic deadtime inherent in our experimental equipment. There had been some technical issues found related to the computer livetime that are being addressed by the Jefferson Lab DAQ group. The experimental run plan of my thesis experiment, the electro-disintegration of Deuteron, is briefly discussed as the kinematics have slightly changed and new simulations had to be done.

I. INTRODUCTION

On March 7-10 of 2017, a 5 μA electron beam was delivered to a BeO and Carbon targets for the first time to experimental Hall C since the 12 GeV upgrade. The beam was delivered as part of the Key Performance Parameters (KPP) required by the Department of Energy (DOE) to demonstrate the operability of the High Momentum Spectrometer (HMS) and Super HMS (SHMS). Hall C was able to demonstrate KPP in four days of beam time before an important component of the accelerator was damaged which caused to accelerator to shut down for repair. The accelerator is expected to be operational starting December 4, 2017. As a result of this delay, the commissioning experiments that were scheduled to run on Fall 2017 have now shifted to Spring 2018. This time window has allowed the Hall C collaboration to work extensively in preparation for the commissioning of the spectrometers on December.

One of the projects I have been involved in is the ongoing work on testing and commissioning the 12 GeV HMS Drift Chambers. The chambers were constructed at Hampton University by Dr. Liguang Tang and his graduate students in 2016. They were made the same design as the SHMS chambers, but slightly different size. The chambers were transported to Jefferson Lab on November 2016, where they underwent extensive tests as part of conditioning the chambers to sustain High Voltages using a gas mixture[1] of 75:25 Argon/CO_2 by volume. The chambers were found to be operational below 1850 V which is below the expected value[2] of 1940 V. At high voltages above 1850 V, the chambers drew a significant amount of dark current which made the signals from the chamber noisy. It was determined that the most likely cause of the large currents drawn was the gas mixture[Ar/CO_2] being used, so the one of the chambers (HMS DC II) was transported to the experimental Hall C where a gas mixture of 50:50 Argon/Ethane by volume was used. A test stand for the chamber was set up in the HMS hut, where it has been tested and verified to be operational with the new gas mixture. The other chamber (HMS DC I) exhibited similar symptoms as the first with the addition that it had a few missing channels due to a bad connection between the sense wires and the discriminator cards. The second chamber is now ready to be transported to Hall C for further tests with the Argon/Ethane gas mixture before it can be put in the detector stack.

A second project I am currently involved in is the determination of electronic and computer dead times. In nuclear/particle physics experiments, the number of physics events (triggers) are counted via nuclear electronic modules. These triggers ultimately get processed by the DAQ before being written to tape. The deadtime refers to the time window in which the modules are unable to process triggers and physics events are lost. The electronic deadtime contribution comes from the electronic modules having a maximum rate capability. Typically, the electronic modules in Hall C can achieve rates from a few MHz to few hundred MHz. Once the modules reach their limit, a pileup of signals can occur which contributes to the total dead time. The computer deadtime contribution comes from finite processing time of the DAQ. These rates are typically on the order of a few kHz, therefore, the dominant contribution of total dead time comes from the DAQ, since it takes a few kHz of data before physics events are lost. These measurements are important for the determination of high precision cross section measurements in Hall C, since knowing how many events are actually lost can make a significant difference in the uncertainty of the cross section.

My thesis experiment, the *Electro-Disintegration of Deuteron at Very High Missing Momenta* is projected to run towards the end of February 2018, and will receive a total of six days of beam time. The experiment will be done at four

[1]This gas mixture is non-flammable and at lower cost compared to the gas mixture that the chambers run on during an experiment, which is why it is preferred during the testing phase of the detector.

[2]The HMS chambers are the same design as the SHMS chambers, which operate at $\sim$ 1940 V.

different spectrometer configurations. The kinematic setting have changed slightly from the original proposal, and will be briefly discussed in this paper.

II. 12 GeV HMS Drift Chambers

A. *Design and Operation of the Chambers*

The new HMS Drift Chambers were designed to be geometrically the same as the SHMS Drift Chambers. Each chamber consists of 6 wire planes and each wire plane is located between two cathode planes. The wire planes consist of alternating field and sense wires. The U, U', V and V' planes consist of 96 sense wires each and are oriented 60^o relative to the +y-coordinate. The X and X' planes consist of 102 sense wires and are oriented perpendicular to the x-axis (See Figures 1 and 2). The cathode planes and field

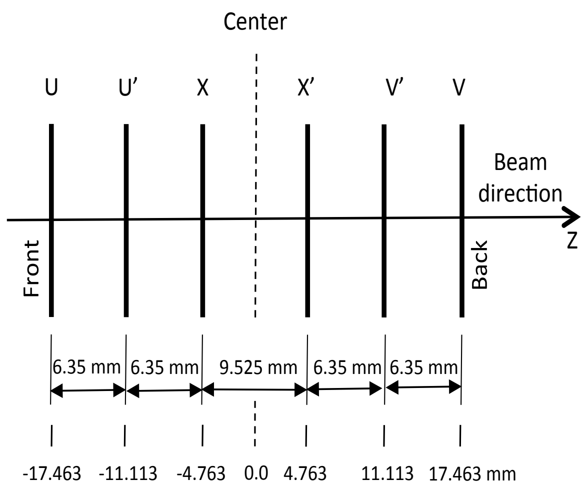

Fig. 1: HMS Drift Chamber 1 wire planes.

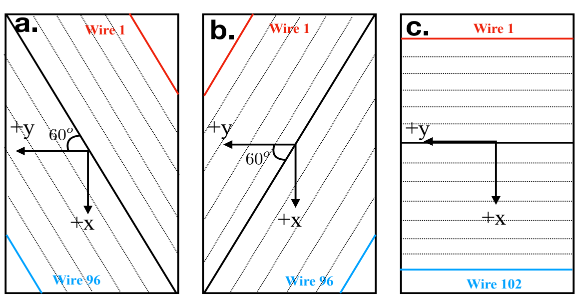

Fig. 2: HMS Drift Chamber wire orientation for planes a) U, U', b) V, V' and c) X, X' where the direction of the beam (+z) is into the plane of the paper.

wires are held at a negative high voltage and the sense wires are grounded which establihses a potential gradient causing an electric field between high voltage and grounded wires. Each chamber is filled with a gas mixture[3] of Argon with either CO_2 or Ethane. As the particles traverse the chamber, the free electrons from ionized Argon drift towards the sense wires producing a detectable signal which is read out via discriminator cards and into electronic modules.

[3]Argon is mixed with CO_2 or Ethane, where Argon is the ionizing agent the particles interact with, and Ethane/CO_2 are the quenching elements to control avalanche produced by secondary ionization

B. *HMS Drift Chamber Cosmic Tests*

To determine the operatility of the HMS Drift Chambers, several cosmic tests were performed on the chambers in the Experimental Storage Building (ESB) before being transported to Hall C. The chambers did not held the High Voltage beyond 1850 V without drawing a significant amount of current ($\geq$ 10 μA) using a gas mixture of 75:25 Ar/CO_2 by volume. When Drift Chamber II (DCII) was transported to Hall C, the gas mixture was changed to 50:50 Ar/Ethane and a High Voltage scan was done (See Figure 3)

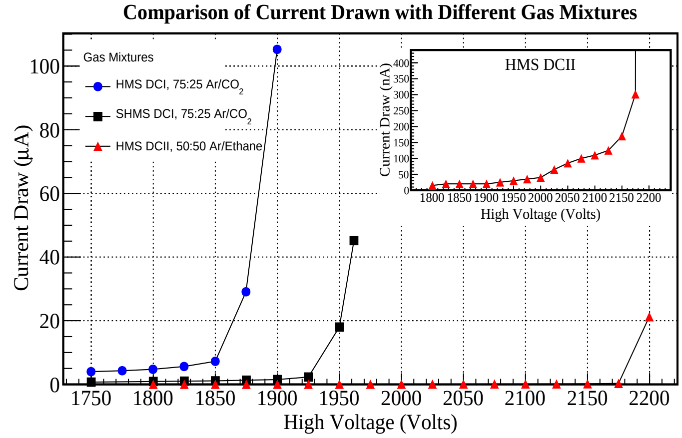

Fig. 3: Comparison of the current drawn in the HMS and SHMS chambers for different gas mixtures. The subplot shows a zoomed version of the Argon/Ethane gas mixture used in HMS DC II plot on a nanoampere scale.

Figure 3 shows a decrease is the current drawn by the HMS chambers by three orders of magnitude smaller, from a few μA to a few nA of current drawn. This indicates that Ethane is a better quenching gas, as it kept the secondary electron ionization small for a broader range of High Voltages, up to $\sim$2100 Volts. There is still the unresolved issue of why the HMS and SHMS chambers behave differently with the same gas mixture, since they both have the same design. The broad High Voltage range achieved by DC II without significant current drawn allows for a better determination of the *Plateau Region* of the chambers, which is a region in which the chamber efficiencies have little sensitivity to relatively large High Voltage variations.

To determine the plateau region of HMS DC II, a cosmic test stand was set up in the HMS detector hut (See Figure 4). The setup consists of two scintillator paddles on the top and two on bottom of the chamber. The top two are completely overlapped while the bottom two are only partially overlapped. Each scintillator paddle is wrapped around a light tight material known as Tedlar, and is coupled to a Photomultiplier Tube (PMT) via a light guide. To ensure that only cosmic rays pass through the chamber, a coincidence between the top and bottom PMTs is made. It is required that the top two PMTs detect a signal to reduce the probability of instrinsic noise being interpreted as a cosmic signal. The bottom scintillators are partially overlapped to achieve full coverage of the chamber active area, and a less restrictive requirement was made by requiring that either of the bottom PMTs detect a signal. A final requirement was made so that the top and bottom PMTs would detect a signal within a certain time window. This requirement ensures a correlation between the top and bottom PMT signals, making it highly probable that the signal was produced by a cosmic ray. The correlated signal between the top and bottom PMTs is defined as the *trigger*. The efficiency of the i^{th} plane, ϵ_i, can then be defined as follows,

$$\epsilon_i = \frac{\#\text{ triggers that } did \text{ hit the } i^{th} \text{ plane}}{\#\text{ triggers that } should \text{ have hit the } i^{th} \text{ plane}} \qquad (1)$$

given that the other five planes received at least one hit from the cosmic.

To make a reliable efficiency measurement, it has to be ensured from the geometry of the cosmic set-up, that any cosmic passing though the top and bottom scintillators also traverses every plane in the chamber to make the efficiency measurements unbiased to the scintllators orientation.

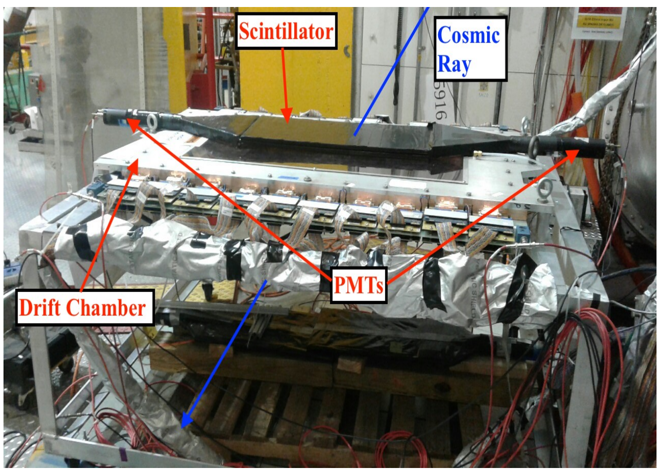

Fig. 4: Cosmic test stand setup in Hall C detector hut.

When cosmic data was taken, to ensure that all (or at least most) of the sense wires in each plane were present (and had not been damaged by transporting the chamber), the wiremap distribution was a looked at first. The distributions show full occupancy for all wire planes in DC II (See Figure 5).

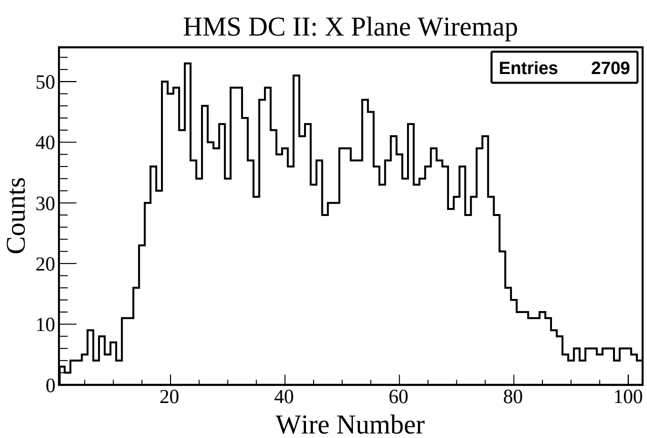

Fig. 5: Wiremap distribution of the X Plane in DC II shows occupancy in all wires.

Once all planes of the chamber were verified to have full occupancy, a High Voltage and threshold[4] scan was done to determine the plateau region. A high voltage scan was done first by setting the threshold fixed at 4.5 V to determine the optimal HV setting. A threshold scan was then performed at 1940 V to determine the optimal threshold. The results are shown in Figures 6 and 7. The high voltage scan in Figure 6 shows the plateau region starting at 1900 V. The chamber operational high voltage was chosen to be 1940 V since the efficiencies seem to be stable and better than 99% over a $\sim \pm 40$ Volt range about this central setting.

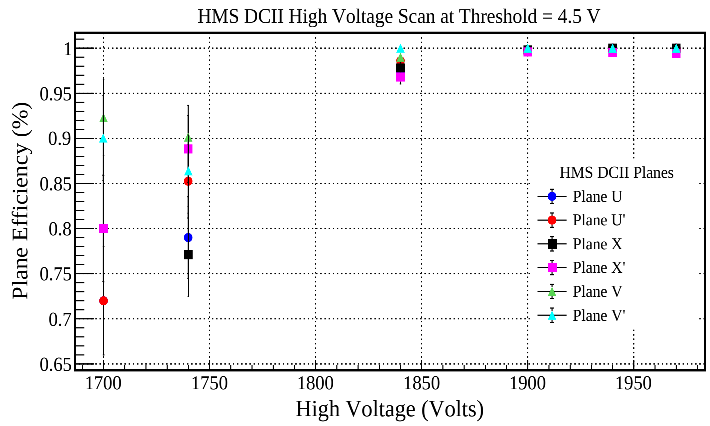

Fig. 6: High Voltage scan of DC II over a broad range at a Threshold of 4.5 Volts.

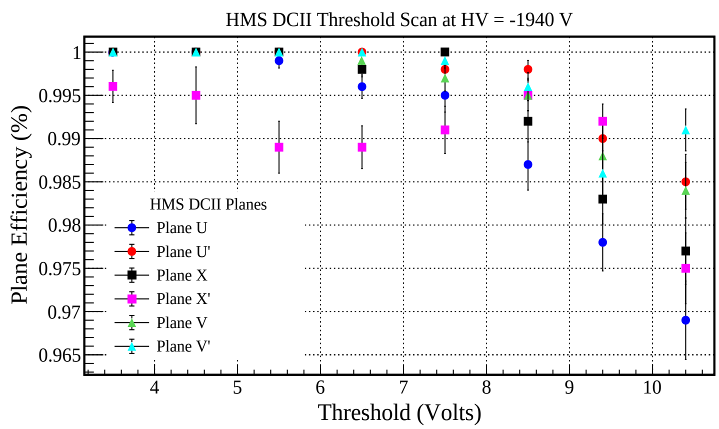

Fig. 7: Threshold scan over a broad range at a HV setting of 1940 V.

From the threshold scan results in Figure 7, there is a 3% decrease in the plane efficiencies over a 6 Volt range. The operational threshold voltage was determined to be 4.5 Volts, where the efficiencies are better than 99%, over a $\sim$ 1 Volt range. The high voltage and threshold settings determined from the scans were chosen based on the high efficiency region and its small sensitivity over a voltage range.

III. Electronic and Computer Deadtime Studies

The procedure to determine the computer and electronic dead times is currently in the development stage in Hall C.

[4]The threshold set on the chamber is used to filter cosmic signals from noise by requiring the signal amplitude to cross a threshold before discriminating them to produce logic signals, which are read out by the electronic modules.

The general idea is to use a pulse generator to produce a fixed frequency pulse and feed it as early as possible into the electronic modules being used in the experimental setup. This pulse will interfere wth the actual signals produced by physics, but its rate can be set orders of magnitude smaller such that its interference will be minimal and will have insignificant contribution to the deadtime. By counting the number of pulses generated before sending them to the electronics chain, compared to the number of pulses that actually make it to the end of the chain and are accepted by the TI (Trigger Interface) module, one may determine the dead time as follows:

$$\text{dead time} = 1 - \frac{\#\text{ of accepted pulses}}{\#\text{ of generated pulses}} \tag{2}$$

This is the total deadtime from the electronics and computer (TI module) that arises due to the finite processing time of the modules. The computer live time alone is calculated by the TI module since it has an internal scaler which counts the number of input and output signals, and takes the ratio to determine the computer live time. This calculation can also be done externally as a cross-check by counting the number of signals that make it to the TI via a scaler module, and comparing it to the number of accepted signals which is outputted by the TI and determined during the data analysis stage. The electronics deadtime is investigated by keeping the computer live time near 100% and increasing the pulse generator rate to probe the rate limits of the electronics modules. One might argue that such high rates can reduce the computer live time itself which is true, however, such high rates can be pre-scaled by the TI by orders of magnitude, such that the computer live time is preserved. For example, for every 10,000 counts/sec., (10 KHz), the TI counts 100 Hz., so that the rate is pre-scaled by a factor of 10^3. Using this technique, one can investigate the effects of high rates on the electronic modules. In this limitng case, the total live time measured will be the electronics live time, since the computer live time will be fixed.

The electronic and computer live time measurements have not been completed as there had been some issues encountered with the TI module that is currently being investgated by DAQ experts. These issues were uncovered during the initial stages of the deadtime studies in which a pulse generator at various rates was used to probe the limits of the modules.

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$$\alpha + \beta = \chi \tag{1}$$

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Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity ÒMagnetizationÓ, or ÒMagnetization, MÓ, not just ÒMÓ. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write ÒMagnetization (A/m)Ó or ÒMagnetization A[m(1)]Ó, not just ÒA/mÓ. Do not label axes with a ratio of quantities and units. For example, write ÒTemperature (K)Ó, not ÒTemperature/K.Ó

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Three	Four

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Fig. 8: Inductance of oscillation winding on amorphous magnetic core versus DC bias magnetic field

V. CONCLUSIONS

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APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

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REFERENCES

[1] W. Leo, *Techniques for Nuclear and Particle Physics Experiments: A How-to-Approach*. New York: Springer-Verlag New York, LLC, 1987.