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

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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

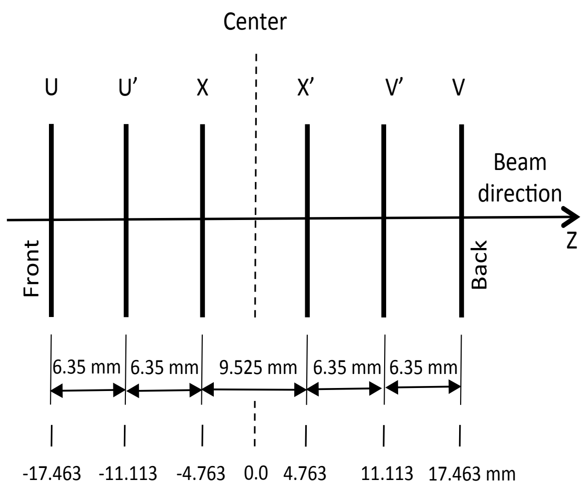

Fig. 1: HMS Drift Chamber 1 wire planes.

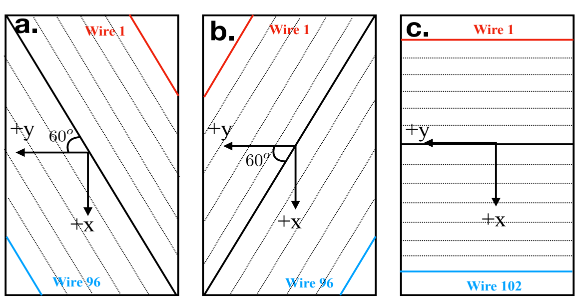

Fig. 2: HMS Drift Chamber wire orientation for planes a) U, U', b) V, V' and c) X, X' where the direction of the beam (+z) is into the plane of the paper.

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)

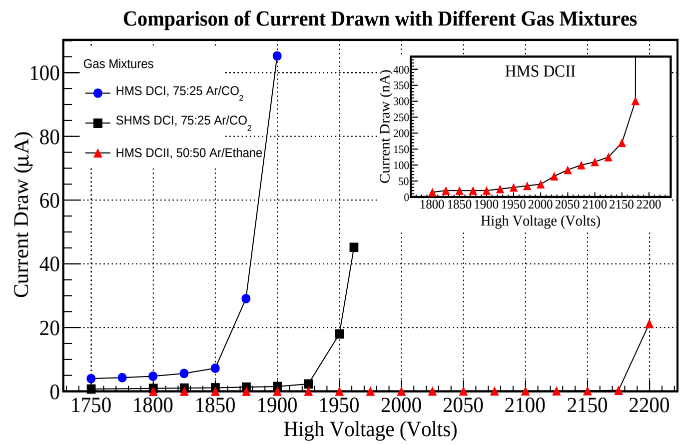

Fig. 3: Comparison of the current drawn in the HMS and SHMS chambers for different gas mixtures. The subplot shows a zoomed version of the HMS DC II plot on a small scale.

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 efficinecies have little sensitivity to relatively large High Voltage variations of $\sim$40 V.

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.

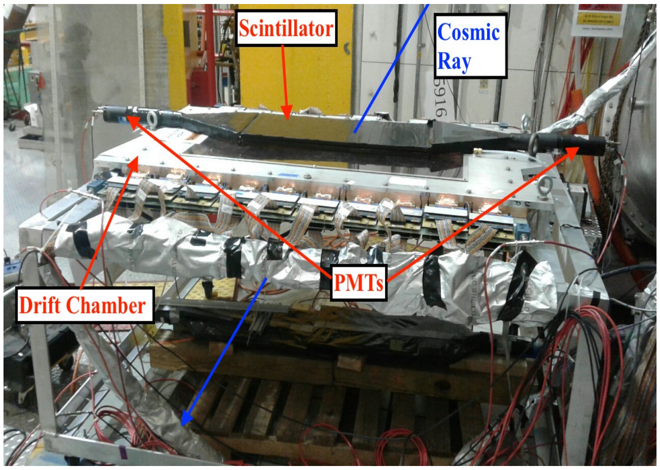

Fig. 4: Cosmic test stand setup in Hall C detector hut.

When cosmic data was taken, to ensure that all (or at leas 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).

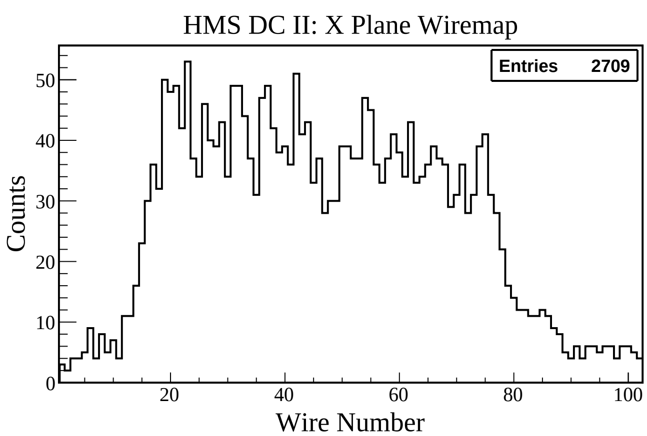

Fig. 5: Wiremap distribution of the X Plane in DC II shows occupancy in all wires.

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. The optimal HV setting was determined to be 1940 V. A threshold scan was then performed at 1940 V to determine the optimal threshold. The results are shown in Figures

[4]The threshold set on the chamber is used to filter cosmic signals from noise by requiring that the signals to be a certain size before discriminating them as logic signals, which are read out by the electronic modules.

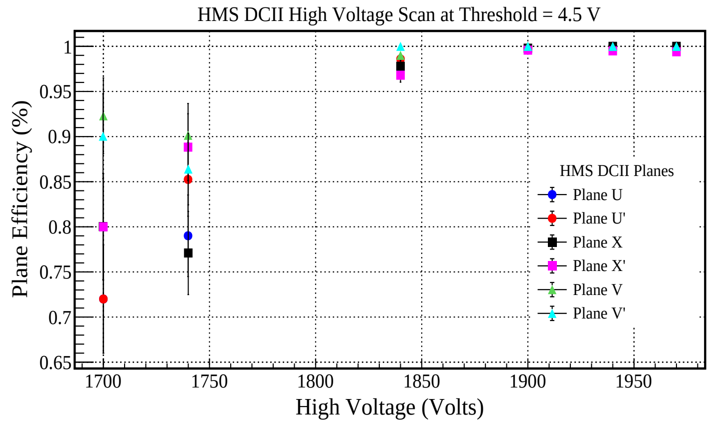

Fig. 6: Wiremap distribution of the X Plane in DC II shows occupancy in all wires.

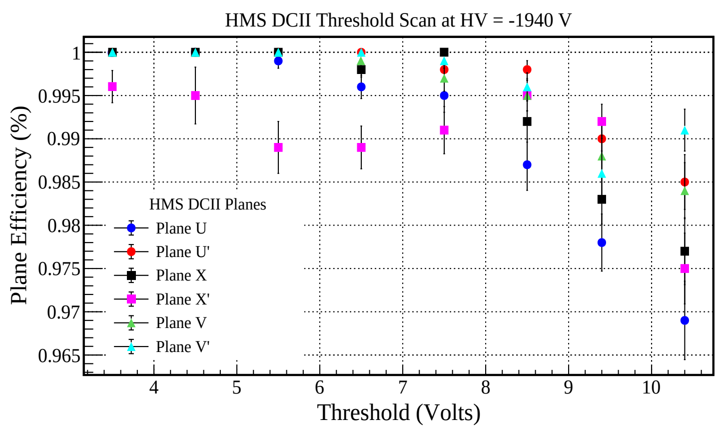

Fig. 7: Wiremap distribution of the X Plane in DC II shows occupancy in all wires.

III. MATH

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Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. *Units*

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as Ò3.5-inch disk driveÓ.

- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
- Do not mix complete spellings and abbreviations of units: ÒWb/m2Ó or Òwebers per square meterÓ, not Òwebers/m2Ó. Spell out units when they appear in text: Ò. . . a few henriesÓ, not Ò. . . a few HÓ.
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$$\alpha + \beta = \chi \tag{1}$$

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- The word ÒdataÓ is plural, not singular. [1]
- The subscript for the permeability of vacuum ?0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter ÒoÓ.
- In American English, commas, semi-/colons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
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A. Headings, etc

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Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation ÒFig. 1Ó, even at the beginning of a sentence.

TABLE I: An Example of a Table

One	Two
Three	Four

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

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi TIFF or EPS file, with all fonts embedded) because, in an document, this method is somewhat more stable than directly inserting a picture.

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

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

V. CONCLUSIONS

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

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References are important to the reader; therefore, each citation must be complete and correct. If at all possible, references should be commonly available publications.

References

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