

# Notes on SHMS drift chambers

Jure Bericic

March 23, 2017

## Abstract

The SHMS drift chambers were build by the Hampton University team. This document includes some notes pertaining to the assembly of the chambers and the `hcana` replay parameters.

## 1 Introduction

The SHMS drift chambers were build by the Hampton University team. This document gathers some notes and gotchas that were encountered during the preparation of the `hcana` parameter files [1][2]. It is not intended as a comprehensive overview. A compilation of additional information about the chambers can be found on the Hall C wiki [3].

## 2 Chamber assembly

To lower the production costs, the SHMS drift chambers were assembled from just two base board designs [4] (for wire planes), that is from a U board and an X board (see Figure 1). The wires on the X board are oriented horizontally, while the wires on U board are positioned with a  $60^\circ$  angle relative to the X board.

By rotating both boards by  $180^\circ$  about the axis piercing the paper ( $X \rightarrow \bar{X}$ ,  $U \rightarrow \bar{U}$ ), the same wire orientation is obtained, but the wires are offset for half a cell width. Rotating the U board for  $180^\circ$  about the vertical axis ( $U \rightarrow U'$ ) flips the wire orientation. This transformation ( $X \rightarrow X'$ ) does not affect the wires in the X plane.

The SHMS drift chamber package is constructed from a pair of drift identical drift chambers, DC1 and DC2, where DC2 is just rotated about the vertical axis. Each of the drift chambers is again assembled from a pair of identical subchambers, SC, which are in turn a combination of two U boards and an X board.

$$\begin{aligned} \text{SC} : [U] + [U]' + [X] &= [U \ U' \ X] \\ \text{DC1} : [\text{SC}] + [\overline{\text{SC}}]' &= [U \ U' \ X \ \bar{X}' \ \bar{U} \ \bar{U}'] \\ \text{DC2} : [\text{DC1}]' &= [U' \ U \ X' \ \bar{X} \ \bar{U}' \ \bar{U}] \end{aligned}$$

However, as installed, the wire chambers have an additional rotation for  $180^\circ$  about the axis piercing the paper, i.e., they were installed on their head compared to the design. That is,  $DC1 \rightarrow \overline{DC1}$  and  $DC2 \rightarrow \overline{DC2}$ . This does not affect the wires orientation, but it influences the numbering scheme and wire staggering.

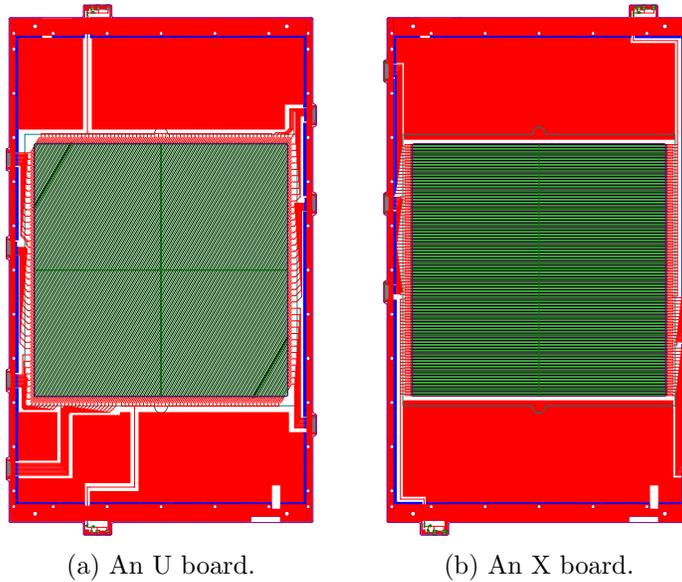


Figure 1: Technical drawings of U and X boards as seen from the front side. [4]

Figures 2 and 3 show the designed and installed drift chamber assembly, as seen from a particle perspective. The red dot marks the front side of the top-right corner of the U and X boards, as they are depicted in Figure 1. The blue dot marks the back side of the same physical corner.

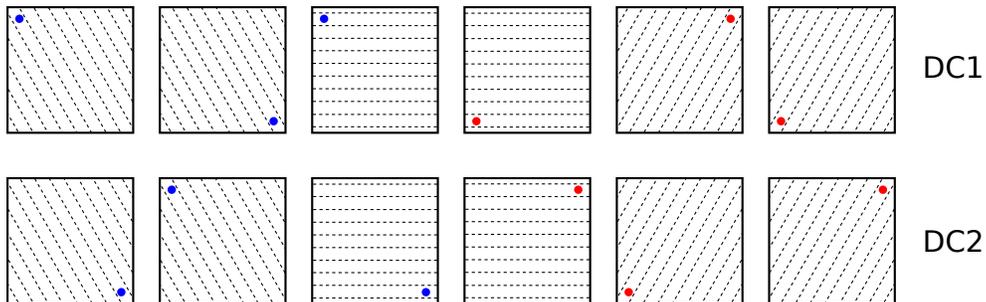


Figure 2: The designed assembly of drift chambers from upstream to downstream. The red dot marks the front side of the top-right corner of the U and X boards, as they are depicted in Figure 1. The blue dot marks the back side of the same physical corner.

### 3 Numbering scheme

The U board is designed for 109 sense wires and the X board for 80. The sense wires are interspersed with field wires. However, some of the edge wires are not surrounded by the field wires on both sides and as such would not work properly (see Figure 4). These edge wires were not strung. So the U planes are left with only 107 wires, and the X planes with 79 wires.

The detector builder's documents usually number the wires starting with 0, i.e., 0-106 for U planes and 0-78 for X planes. However, in `hcana`, the signals are numbered from 1, i.e., 1-107 for U and

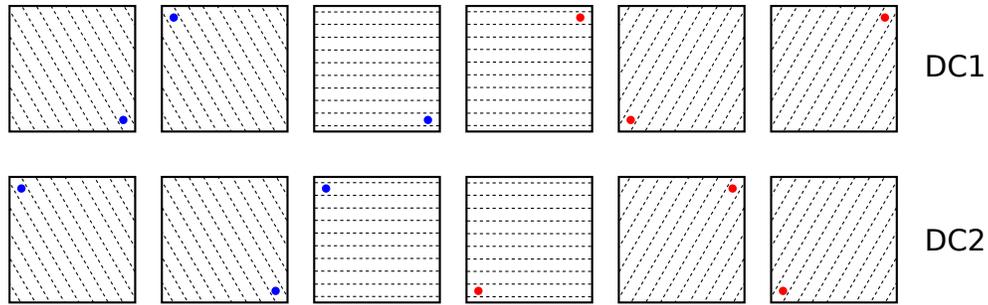


Figure 3: The installed assembly of drift chambers as seen by a particle traversing the detector stack. Compared to Figure 2, each plane is rotated by  $180^\circ$  about the axis piercing the paper.

1-79 for X planes. A care needs to be taken to avoid an off-by-one error when translating between the two.

For all planes in Figure 2, the lowest numbered wire is located on the top of the frame. Equally, for all planes in Figure 3, the lowest numbered wire is located on the bottom of the frame, due to the rotation.

See also Figure 4.

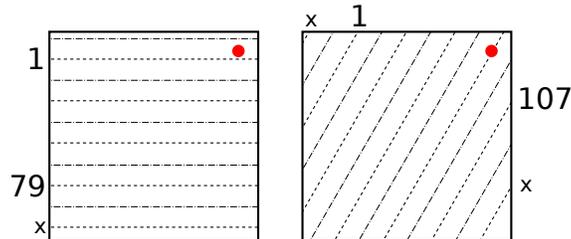


Figure 4: Dashed lines represent the signal wires and dash-dot lines represent the field wires. The bottom signal wire of the X plane does not have a field wire on both sides, so it was not strung. Same for both edge signal wires in U plane. Other wires are numbered from 1 to 79 for the X and 1 to 107 for the U plane, where the lowest number is always associated with the top wire, relative to the design scheme, i.e., Figure 2.

## 4 Wire staggering

Both the U and X boards were designed such, that rotating them for  $180^\circ$  about the  $z$  axis displaces the wires for half a cell width. It is important to know for each DC plane, whether the top or the bottom wire is closest to its respective edge.

As can be seen in Figure 4 for the X plane, the wire numbered as 1 (top) is closer to the edge of the frame than the wire 79 (bottom). Similarly, the wire 1 is closer to the frame corner (top-left) than wire 107 is to the opposite corner (bottom-left) for the U plane in same figure.

## 5 Replay parameters

The `hcana` requires a host of parameters to detail all aspects of the drift chambers (see [2]). This section describes three of them that needs to be set simultaneously:

- `alpha_angle`,
- `central_wire`,
- `wire_counting`.

### 5.1 `alpha_angle`

This parameter is one of a triplet, together with `beta_angle` and `gamma_angle`, that define the orientation of the local measurement coordinate system with respect to the transport system. Angle  $\beta$  describes the pitch of the chambers,  $\gamma$  measures yaw, and  $\alpha$  is connected to roll of the chambers and orientation of the wires in each plane. A more detailed overview on all three is given in [5] and [6].

The definition of the  $\alpha$  angle is shown in Figure 5. I find it a bit awkward and prefer to use its complementary angle  $\alpha'$ , which describes the angle between the  $x''$ - and  $\psi$ -axis. The doubly-primed coordinate system describes the orientation of the drift chamber after taking into account pitch and yaw. The  $\psi$ -axis is the coordinate measuring axis, which is perpendicular to the direction of the wires, while the  $\chi$ -axis is parallel to the wires.

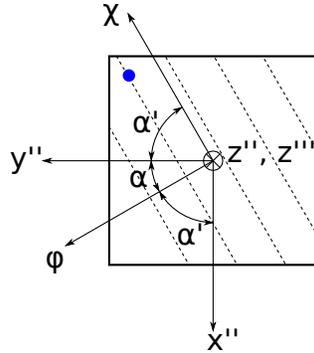


Figure 5: The  $\alpha$  angle describes a negative rotation about the  $z''$  axis. It is the angle between the  $y''$ - and  $\psi$ -axis. Complementary angle  $\alpha'$  describes a positive rotation between the doubly-primed coordinate system and  $(\psi, \chi, z''')$ .

### 5.2 `central_wire`

This parameter represents the number of an imaginary wire that goes through the center of the chamber, i.e.,  $(\psi, \chi) = (0, 0)$ . Because of how wire staggering was designed in the SHMS drift chambers, these numbers should always end in .75 or .25. In the case of an X plane, as shown in Figure 4, the central wire is 40.25, and in the case of a U plane in same figure, it is 54.25.

### 5.3 wire\_counting

This parameter describes how the wires are numbered in each plane. Together with the central wire, wire pitch and number of wires in the plane, it is used to calculate the center of a wire as:

$$\text{wire\_counting} == 0 : \quad \text{center} = (\text{wire} - \text{central\_wire}) \cdot \text{pitch} \quad (2a)$$

$$\text{wire\_counting} == 1 : \quad \text{center} = (\text{nr\_wire} + 1 - \text{wire} - \text{central\_wire}) \cdot \text{pitch} \quad (2b)$$

where `wire` is the current wire number and `nr_wire` is the number of wires in the plane. It follows from this, that the `wire_counting` should be 0 if the first wire is at the negative  $\psi$  side, and 1 if it is at the positive. However, both cases are not treated symmetrical.

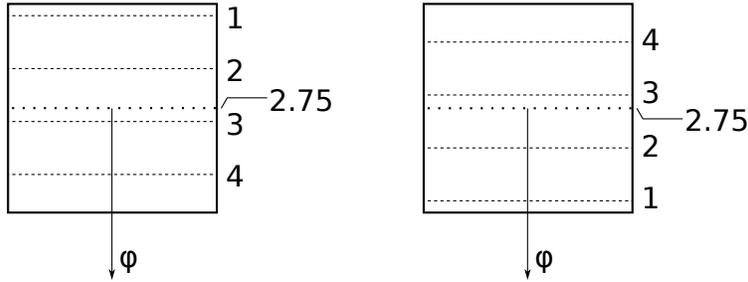


Figure 6: This toy model is composed of two identical wire planes, one of which is rotated by  $180^\circ$ . Wire centers for both have the same magnitude but opposite sign.

The wire chambers shown in Figure 6 are identical, just that one is rotated. The central wire and alpha angle are the same, but the wire numbering is reversed because of the rotation. The centers of the wires have the same magnitude but opposite sign. Because first wire in the left plane is at a negative  $\psi$ , `wire_counting` should be 0. For the right plane, the first wire is at a positive  $\psi$ , so `wire_counting` should be 1. Using this in Equations 2 yields:

$$0 : \quad (1 - 2.75) \cdot 1 \text{ cm} = -1.75 \text{ cm} \quad 1 : \quad (4 + 1 - 1 - 2.75) \cdot 1 \text{ cm} = 1.25 \text{ cm} \quad (3a)$$

$$(2 - 2.75) \cdot 1 \text{ cm} = -0.75 \text{ cm} \quad (4 + 1 - 2 - 2.75) \cdot 1 \text{ cm} = 0.25 \text{ cm} \quad (3b)$$

$$(3 - 2.75) \cdot 1 \text{ cm} = 0.25 \text{ cm} \quad (4 + 1 - 3 - 2.75) \cdot 1 \text{ cm} = -0.75 \text{ cm} \quad (3c)$$

$$(4 - 2.75) \cdot 1 \text{ cm} = 1.25 \text{ cm} \quad (4 + 1 - 4 - 2.75) \cdot 1 \text{ cm} = -1.75 \text{ cm} \quad (3d)$$

where `nr_wire` = 4 and `pitch` = 1 cm were used. An offset of 0.5 cm is observed for the second case, as compared to the first case and to the model.

Instead of Equations 2, the following set should be used:

$$\text{wire\_counting} == 0 : \quad \text{center} = (\text{wire} - \text{central\_wire}) \cdot \text{pitch} \quad (4a)$$

$$\text{wire\_counting} == 1 : \quad \text{center} = (\text{central\_wire} - \text{wire}) \cdot \text{pitch} \quad (4b)$$

This set treats both cases symmetrically and yields correct results for the toy model:

$$0 : \quad (1 - 2.75) \cdot 1 \text{ cm} = -1.75 \text{ cm} \quad 1 : \quad (2.75 - 1) \cdot 1 \text{ cm} = 1.75 \text{ cm} \quad (5a)$$

$$(2 - 2.75) \cdot 1 \text{ cm} = -0.75 \text{ cm} \quad (2.75 - 2) \cdot 1 \text{ cm} = 0.75 \text{ cm} \quad (5b)$$

$$(3 - 2.75) \cdot 1 \text{ cm} = 0.25 \text{ cm} \quad (2.75 - 3) \cdot 1 \text{ cm} = -0.25 \text{ cm} \quad (5c)$$

$$(4 - 2.75) \cdot 1 \text{ cm} = 1.25 \text{ cm} \quad (2.75 - 4) \cdot 1 \text{ cm} = -1.25 \text{ cm} \quad (5d)$$

## 5.4 Setting the parameters

As seen in previous subsection, the `wire_counting` parameter does not work as expected in the case of 1. One solution is to fix the calculation of the wire center, but this might break for older parameter files which might be tuned to the current formula, e.g., for HMS or SOS.

Another solution is to tweak the `central_wire` to correct the offset introduced by the formula. However, the central wire is defined by the board design and it would be pragmatical to leave it at the physical value.

The solution currently used for setting the SHMS drift chamber parameters is to set the  $\alpha$  in such way, that the `wire_counting` is 0. This angle is connected to the wire orientation in each plane, however, it is only uniquely defined up to modulus  $180^\circ$ . Looking at the second case in Figure 6,  $\alpha$  is  $90^\circ$ . Adding  $180^\circ$  to it would still describe the same wire orientation, except that the  $\psi$ -axis would be pointing in the opposite direction, as shown in Figure 7. This means that `wire_counting` of 0 should be used and with that the correct calculation of the wire center.

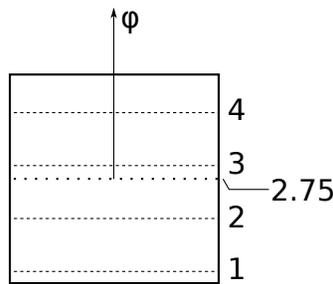


Figure 7: This model is the same as shown in Figure 6 right, except that  $\alpha$  is  $270^\circ$  inserted of  $90^\circ$ .

Using this solution is fitting for the SHMS drift chambers, which were indeed rotated by  $180^\circ$  when installed, as compared to the design models (see Section 2).

## 6 Plane naming

The names of the drift chamber planes were selected such, that they described the direction of wires as the chambers were constructed. The "x" is naming the horizontal orientation, the "u" is describing wires going from top-left to bottom-right and the "v" is for the planes with wires oriented from bottom-left to top-right. The full naming scheme is:

```
DC1 :    1u1  1u2  1x1  1x2  1v1  1v2
DC2 :    2v2  2v1  2x2  2x1  2u2  2u1
```

The names of the second drift chambers planes are reversed since DC2 is identical to DC1, just rotated about the vertical axis (see Figure 2). This, however, also changes the orientation of the wires. The 2v planes have the same orientation as the 1u planes and the 2u same as the 1v planes. This means, that the naming scheme does not correspond to the direction of the wires anymore.

Additional problem is with internal naming of the planes in the `EVe_HallC`. This program was written at first for the HMS, with the names of the planes hardcoded in. It would have been too

cumbersome and error prone to rename everything, so the HMS infrastructure was just hijacked for the SHMS. Following is the wire plane translation table for the SHMS drift chambers:

HMS :	x	y	u	v	y'	x'
SHMS DC1 :	u1	u2	x1	x2	v1	v2
SHMS DC2 :	v2	v1	x2	x1	u2	u1

## References

- [1] <https://github.com/JeffersonLab/hcana> (23 March 2017)
- [2] [https://github.com/JeffersonLab/hallc\\_replay](https://github.com/JeffersonLab/hallc_replay), (23 March 2017).
- [3] [https://hallcweb.jlab.org/wiki/index.php/SHMS\\_Drift\\_Chambers](https://hallcweb.jlab.org/wiki/index.php/SHMS_Drift_Chambers), (23 March 2017).
- [4] M. E. Christy, P. Monaghan, N. Kalantarians, D. Biswas, *Hall C Reference - SHMS Drift Chambers*, 11 July 2016. [https://hallcweb.jlab.org/document/howtos/shms\\_drift\\_chambers.pdf](https://hallcweb.jlab.org/document/howtos/shms_drift_chambers.pdf), (23 March 2017).
- [5] D. F. Geesaman, *Tracking in the SOS Spectrometer*, 14 September 1993. [https://hallcweb.jlab.org/DocDB/0008/000812/001/SOS\\_Tracking.pdf](https://hallcweb.jlab.org/DocDB/0008/000812/001/SOS_Tracking.pdf), (23 March 2017).
- [6] J. Bericic, *Drift chamber orientation in hcana*, 23 March 2017. [https://hallcweb.jlab.org/DocDB/0008/000845/001/DC\\_orientation.pdf](https://hallcweb.jlab.org/DocDB/0008/000845/001/DC_orientation.pdf), (23 March 2017).
- [7] Hall C, *EVe\_HallC: Hall C Event Display*, [https://github.com/JeffersonLab/EVe\\_HallC](https://github.com/JeffersonLab/EVe_HallC), (23 March 2017).