Muon Chamber and Channel Numbering

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1 Introduction

For purposes of record keeping, defining chamber locations, and mapping raw hits to detector elements, we need a muon system numbering scheme. This scheme must:

1. be simple to use,
2. identify all the chambers and their locations, and
3. unambiguously identify all the readout channels.

Recall that for the pad chambers we readout both the pads and the anode wires. The numbering scheme presented here does not define the chamber geometry. The task of assigning coordinates to a readout channel is left to the Monte Carlo and reconstruction software writers.

A channel is denoted by a 6 character symbol:

M[readout type][superlayer].[layer]-[chamber].[channel]

where

- *readout type* designates the type of readout of the chamber, tube (t), pad (p), or pixel (x),
- *superlayer* designates which of the 4 muon superlayers the chamber resides in,
- *layer* designates the layer within a superlayer (The combination of readout type, superlayer and layer define the z coordinate of the chamber, whether the chamber is above or below the beam, and the chamber orientation (angle) for tube chambers.),
- *chamber* designates the number of the chamber, or the front end card for a pixel chamber,
- *channel* designates the readout channel number.

To identify a chamber, the channel number can be omitted. For a pixel chamber, the chamber number is used to denote a front end card and this can also be omitted.

There are (and probably always will be) two conventions for channel numbers: one where the first channel is number 1, widely used when working around the hardware; and a second where the first channel is number 0, often used in DAQ and software. Since this note is largely a hardware description, I will adhere to the hardware numbering scheme and number the first channel, first chamber, etc. as 1. It is a rather straightforward task to subtract 1 and convert to the software convention.

2 Tube and Pad Chambers

The tube chambers in superlayers 1 and 2 have 3 orientations, 0° (vertical), and $\pm 20^\circ$. Dividing each into up and down chamber groups, as shown in Figs. 1-2, requires 6 layer numbers.

The pad chambers are all vertical and need only 2 layer numbers, see Fig. 3. Information is gathered from both the anode wires (tube) and cathode walls (pad) of the pad chambers, such that the two designations Mp4.1-1 and Mt4.1-1 refer to the same chamber, but the first indicates pad readout and the second indicates tube readout. The first notation is preferred when referring to a pad chamber, however the second is needed to unambiguously refer to the wire readout of the chamber.

The wire readouts of the tube and pad chambers are numbered from 1 to 32. As shown in Fig. 4, there are two orientations to the numbering, distinguished by whether the even or odd numbered wires are first in z. While the tube chambers numbers always increase in the $+x$ direction, the channel numbers increase (decrease) in the $+x$ direction for lower (upper) chambers. For reference, this information is summarized in Table 1.

Layer	angle	y location	orientation	increasing channel number
Mt1.1	0°	upper	1	$-x$
Mt1.2	0°	lower	2	$+x$
Mt1.3	-20°	upper	1	$-x$
Mt1.4	-20°	lower	2	$+x$
Mt1.5	$+20^\circ$	upper	1	$-x$
Mt1.6	$+20^\circ$	lower	2	$+x$
Mt2.1	0°	upper	1	$-x$
Mt2.2	0°	lower	2	$+x$
Mt2.3	-20°	upper	1	$-x$
Mt2.4	-20°	lower	2	$+x$
Mt2.5	$+20^\circ$	upper	1	$-x$
Mt2.6	$+20^\circ$	lower	2	$+x$
Mt3.1	0°	upper	1	$-x$
Mt3.2	0°	lower	1	$+x$
Mt4.1	0°	upper	1	$-x$
Mt4.2	0°	lower	1	$+x$

Table 1: Information about the channel numbering for the tube readouts.

The pad readouts of the pad chambers are numbered from 1 to 32 in two columns, as

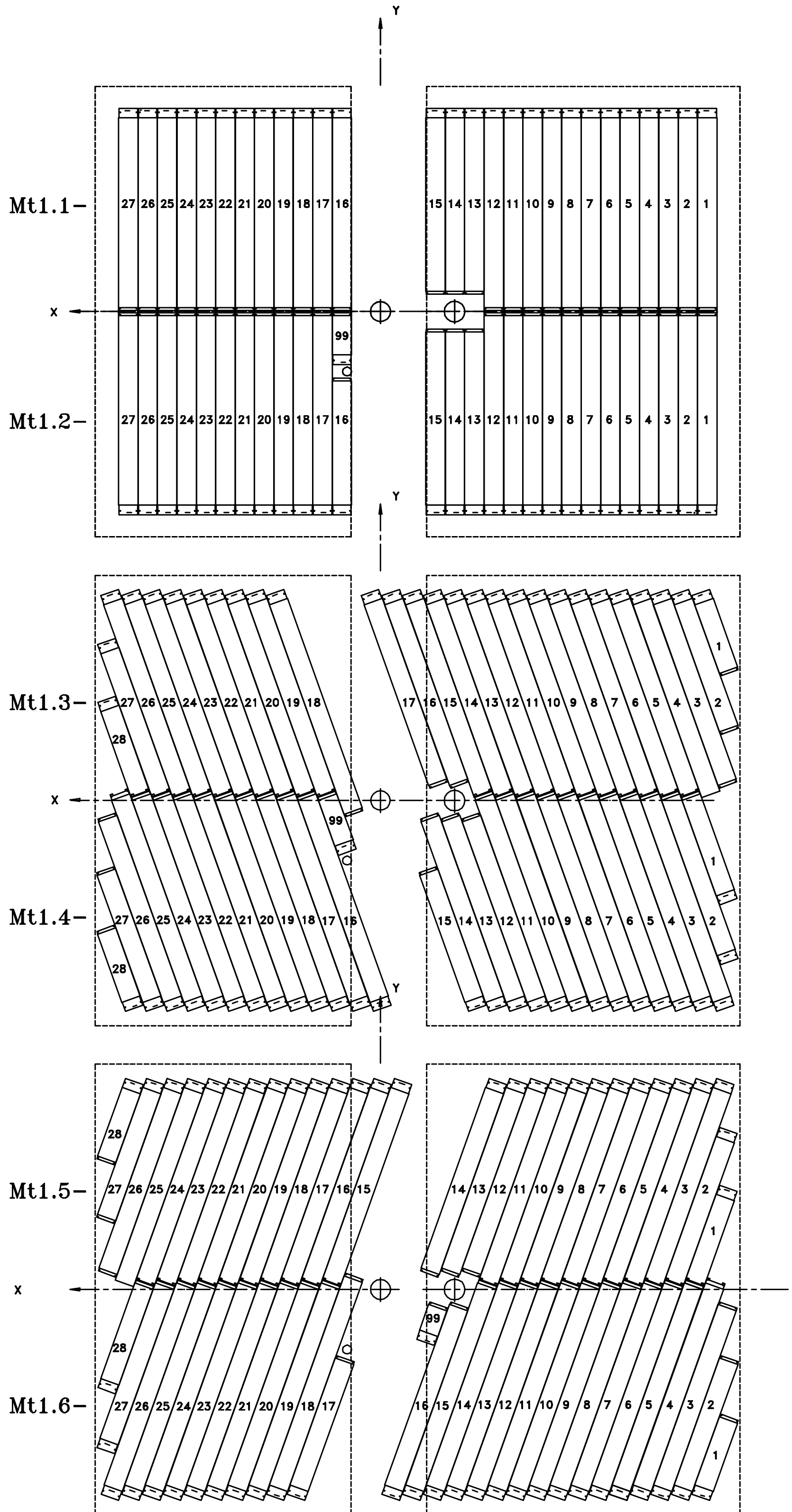

Figure 1: The layer numbers for the 3 tube orientations and the upper and lower halves in the first superlayer.

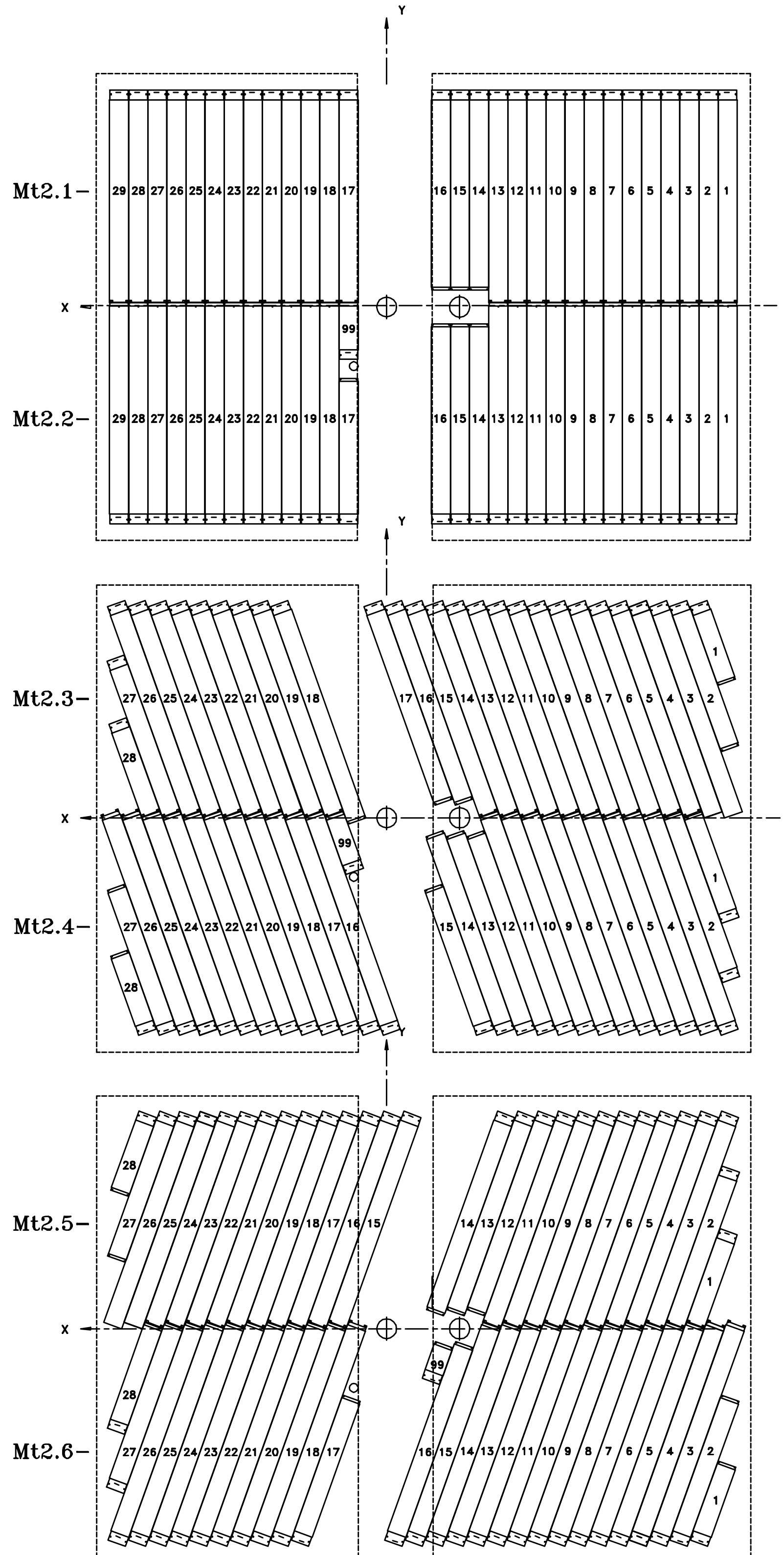

Figure 2: The layer numbers for the 3 tube orientations and the upper and lower halves in the second superlayer.

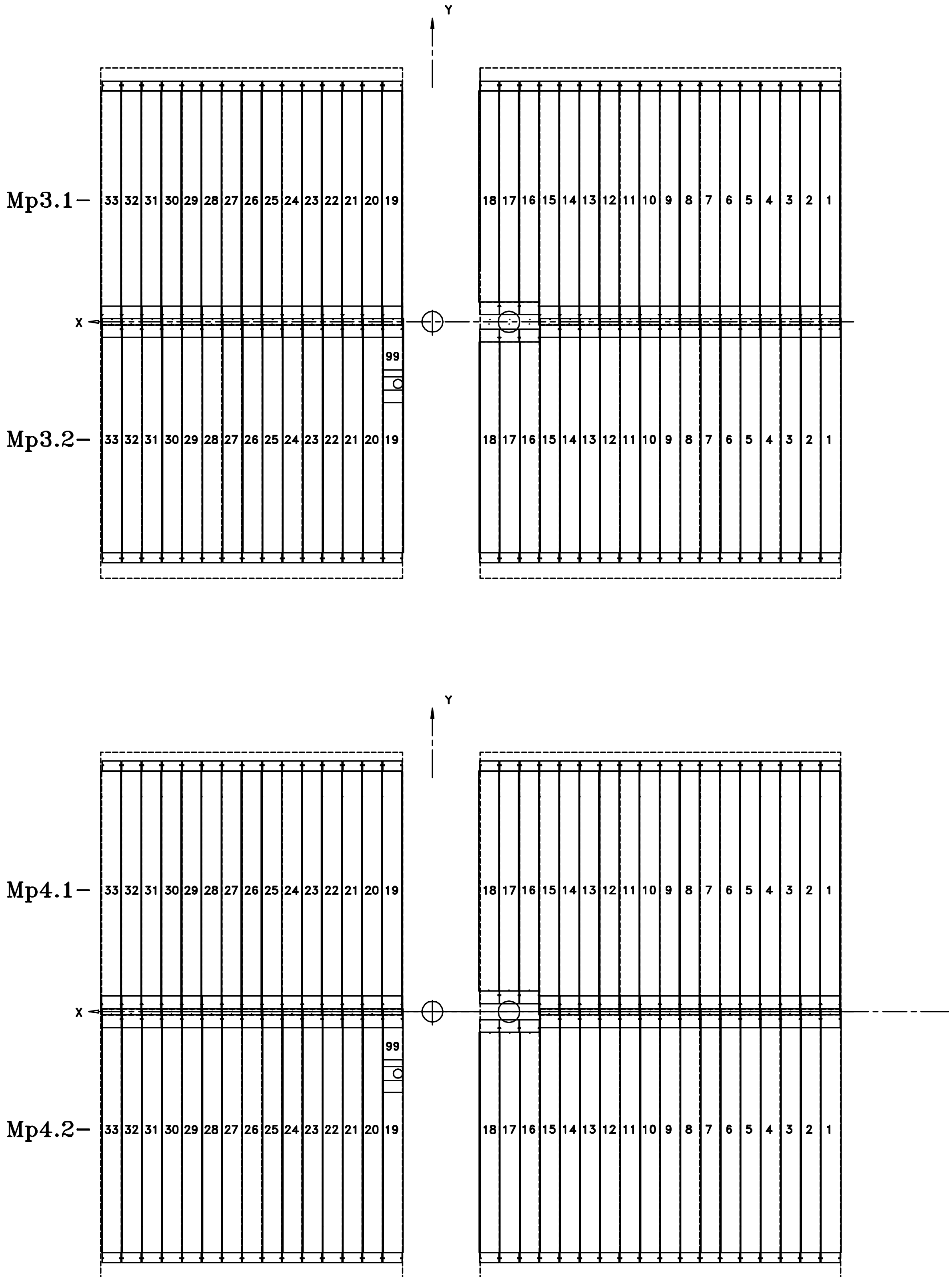

Figure 3: For the pad chambers, layer numbers identify up and down.

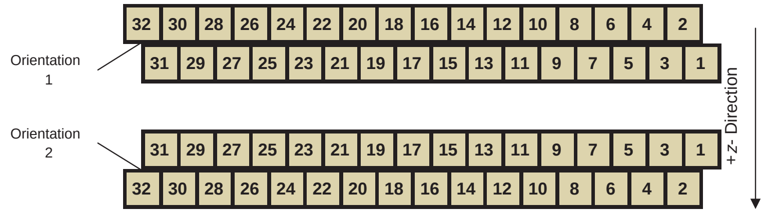

Figure 4: The channel numbering of the wire readouts when looking end on at a tube or pad chamber. Which of the two orientations to use depends on the z position of the even and odd numbered wires.

shown in Fig. 5. To distinguish the two columns, we append a $-x$ or $+x$ to the channels, with the notation obviously indicating the x location of the column of pads relative to the other column in that chamber. In some instances it is easier to refer to the columns by the readout card they are connected to, top (t) or bottom (b). The top and bottom cards are referenced to the chamber mounting plate: the bottom card is closest to the mounting plate, and the top card is further away. For the lower pad chambers Mp3.2 and Mp4.2, the bottom card is connected to the $-x$ column and the top card is connected to the $+x$ column. For the upper pad chambers Mp3.1 and Mp4.1, the connections are reversed.

Please note that there is no physical pad for readout channels 1 and 17, that is, those channels are not connected to a detector component. There are 30 pads in a column, and the readout comes in units of 8, so there are 2 extra readout channels per chamber. And in the MU4 pad chambers, pad number 32 doesn't exist either.

2.1 Signal Cables

In some instances it is convenient to refer to groups of channels carried by a particular signal cable. For tube readouts, the cables are referred to as A and B, with A carrying channels 1 to 16, and B carrying channels 17 to 32. For pad readouts, the cables are referred to as A, B, C, and D, with the channels grouped as shown in Fig. 5.

3 Pixel Chambers

The pixel chambers come in a high density and low density types. For simplicity, we will start running with low density type chambers, and therefore I will neglect the high density types in the discussion below. The pixel chambers need 4 layer numbers which simply refer to each of the 4 chambers in a superlayer, as shown in Fig. 6. Since the layer number now refers to a chamber, we will use the chamber number to refer to a particular readout card. The readout cards are numbered according to their position in the pixel backplane – from 1 to 24 starting with the innermost card. Only the Mx4 chambers have 24 cards, the others have 23. Finally, the channel number will refer to a channel on the readout card, counting from 1 to 16.

The mapping from a readout channel to a pixel location is complex. There are three different mappings, one for Mx1 and Mx2 (Fig. 7), one for Mx3 (Fig. 8), and one for Mx4(Fig. 9). On these drawings, groups of pixels connected to the same readout card are filled with the same color. The number of the same color appearing above, or sometimes below, the drawing

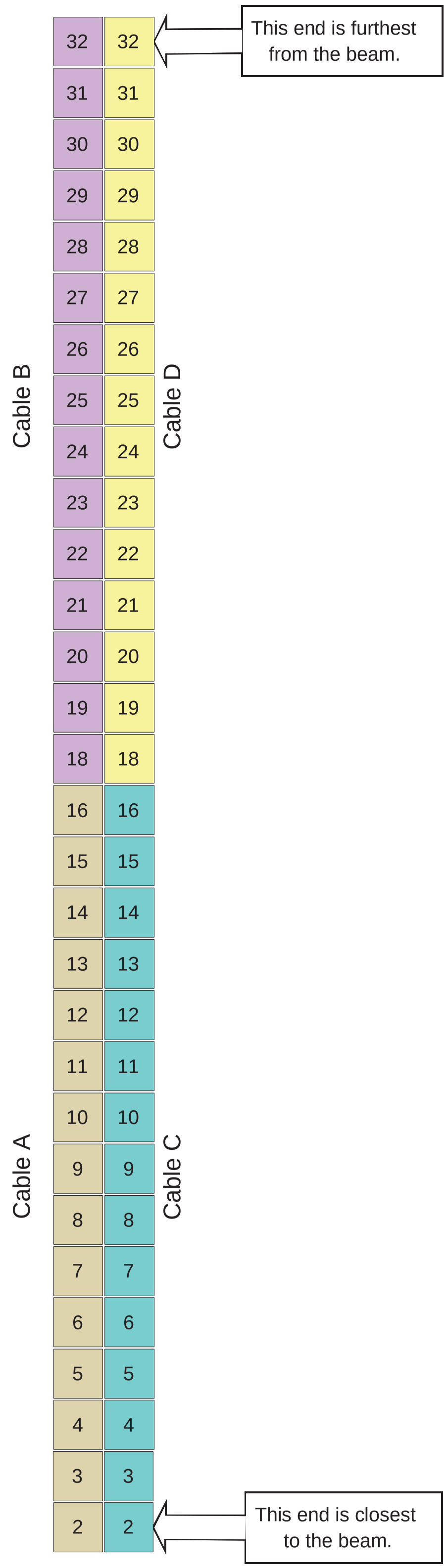

Figure 5: The pad channel numbers of a pad chamber, looking in the $+z$ direction. Each chamber has two columns of pads, differentiated by their relative x locations. Note that pad numbers 1 and 17 do <u>n</u>ot exist, and in the MU4 layer, neither does pad number 32.

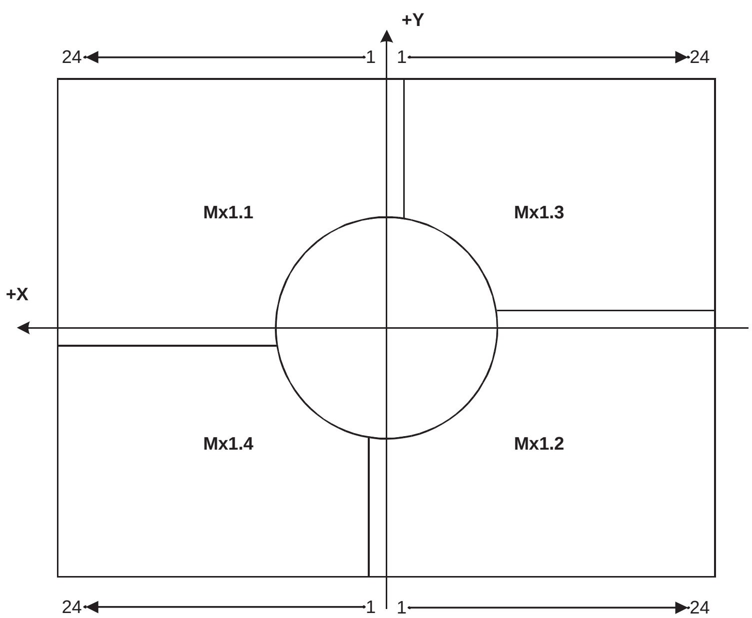

Figure 6: The layer numbers for the pixel chambers refer to an individual chamber. The numbering for superlayer 1 is shown, the other superlayers follow the same convention. Chambers Mx1.1 and Mx1.2 are at smaller z than Mx1.3 and Mx1.4. The chamber number refers to the pixel backplane slot number of the readout card for a particular group of pixels. For each chamber, card number 1 is closest to the beam.

is the backplane slot number of that group of pixels. The number inside a pixel is its channel number.

As for the tube and pad readout numbering, the pixel numbering does not directly provide the location of a pixel, as needed by Monte Carlo and reconstruction routines. However, in some instances we will want to refer to pixels by their relative location, for instance, row and column. Row and column numbers are included in Figs. 7-9 along the top and left of the pixels. Row numbers are indicated in red, column numbers in blue. We count rows and columns starting from those closest to the proton beam – then a rough coordinate system can be created by applying negative signs to the row or column number as appropriate for the particular quadrant. It is recommend to precede the row number by "r" and the column number by "c" to avoid confusion. In this scheme, pixel Mx3.1r5c23 is the same as readout channel Mx3.1-13.7.

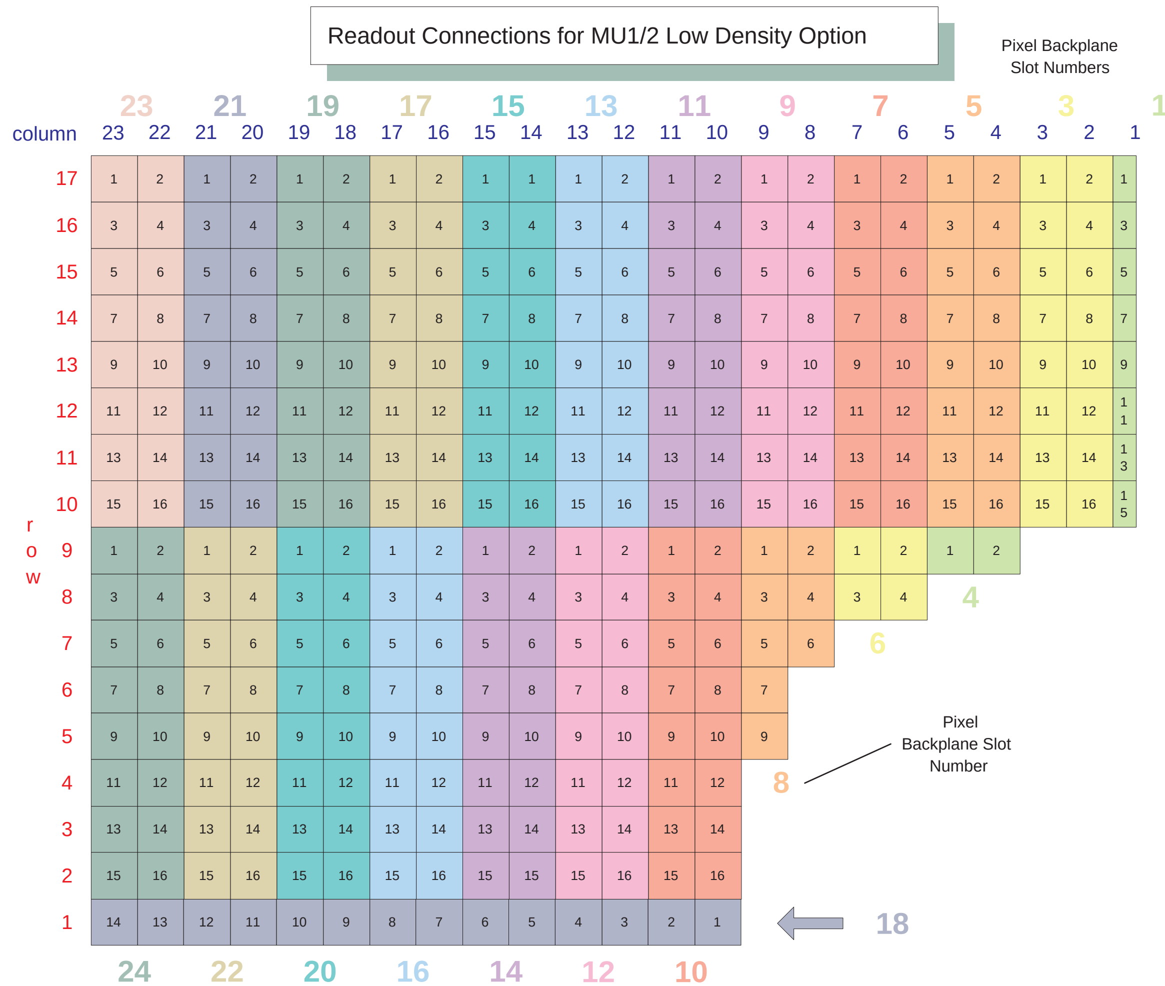

Figure 7: The readout channel map for the Mx1 and Mx2 pixel chambers. A full color version of this drawing is available from the Muon web page.

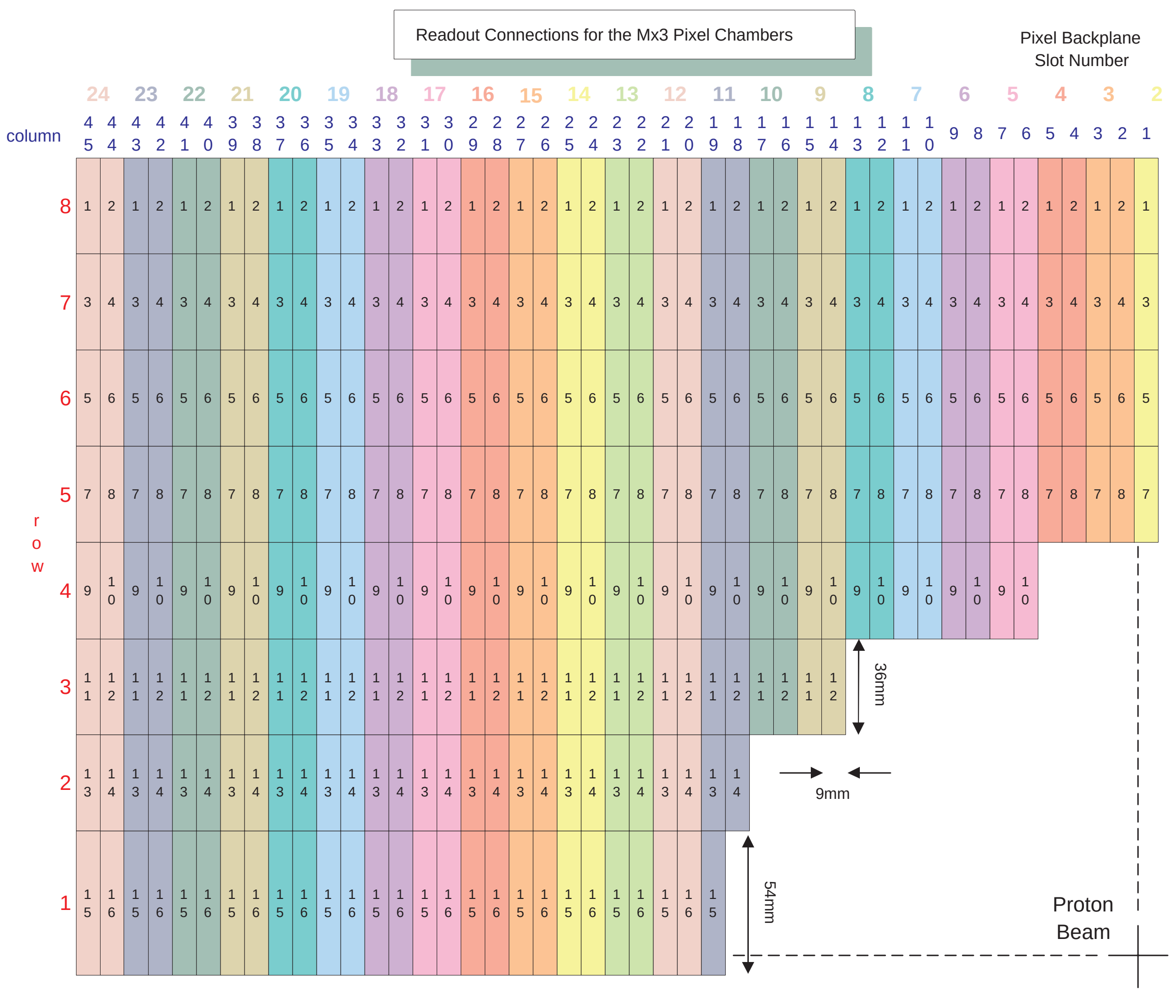

Figure 8: The readout channel map for the Mx3 pixel chambers. A full color version of this drawing is available from the Muon web page.

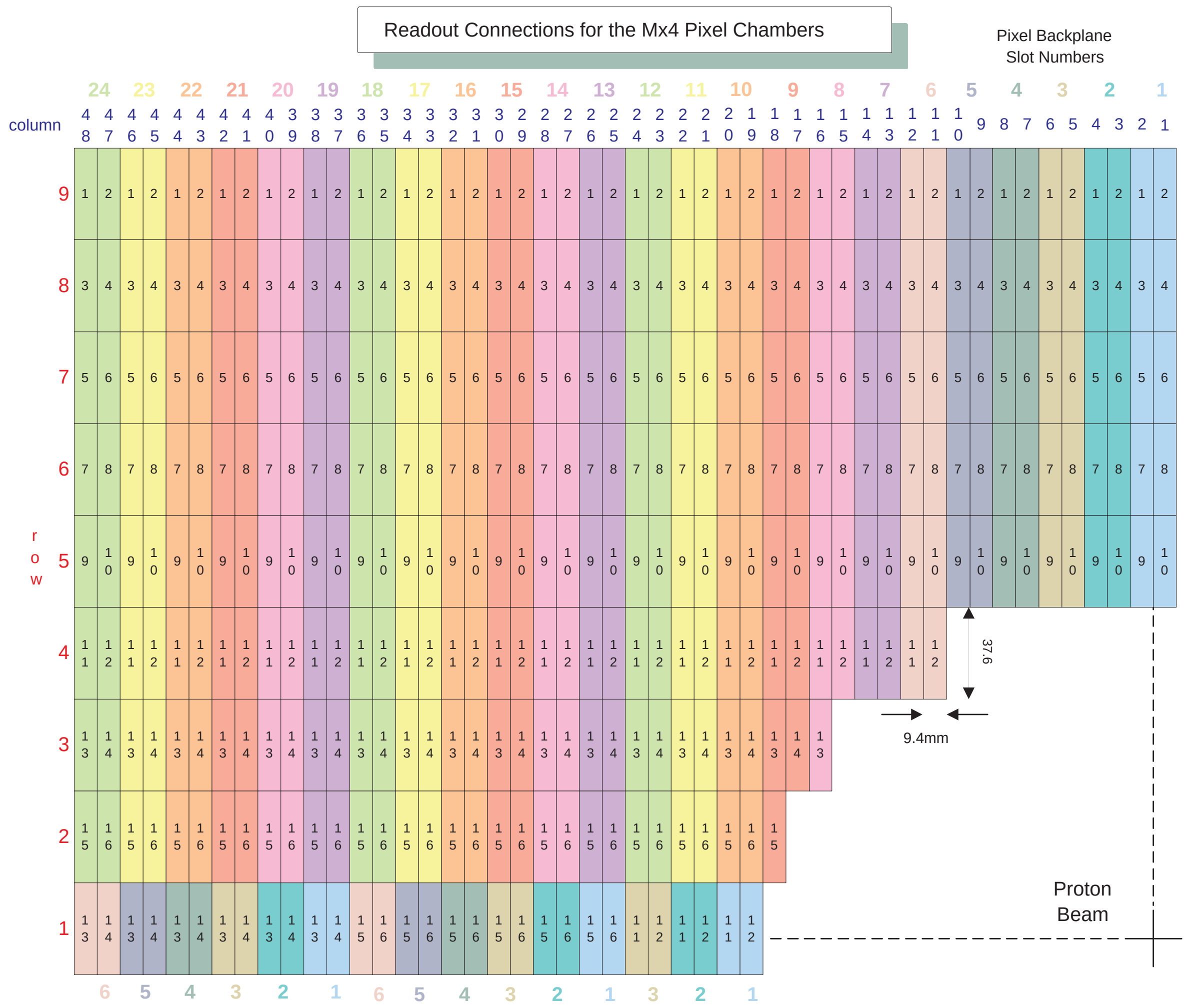

Figure 9: The readout channel map for the Mx4 pixel chambers. Note that the bottom row of pixels are connected to readout cards 1 to 6. A full color version of this drawing is available from the Muon web page.

4 Chamber Distribution

The construction of the muon front end electronics is such that four tube chamber or pad chamber cards receive their power and control signals through one power distribution card (PDC). Four PDC's connect to a single controller card (CC), which serves to locally monitor voltages, currents, and temperatures, and interfaces to the host computer system.

East or +X platform							
readout	number of						
layer	chambers	channels	FEE	PDC	CC	PLB	TLB
Mt1.1	12	384	12	3	1	0	1
Mt1.2	13	416	13	4	1	0	1
Mt1.3	11	352	11	3	1	0	1
Mt1.4	14	448	14	4	1	0	1.25
Mt1.5	14	448	14	4	1	0	1.25
Mt1.6	12	384	12	3	1	0	1
Mt2.1	13	416	13	4	1	0	0
Mt2.2	14	448	14	4	1	0	0
Mt2.3	11	352	11	3	1	0	0
Mt2.4	14	448	14	4	1	0	0
Mt2.5	14	448	14	4	1	0	0
Mt2.6	12	384	12	3	1	0	0
Mp3.1	15	900	30	8	2	4	0
Mt3.1	15	480	15	4	1	0	1.25
Mp3.2	16	960	31	8	2	4	0
Mt3.2	16	512	16	4	1	0	1.25
Mp4.1	15	900	30	8	2	4	0
Mt4.1	15	480	15	4	1	0	1.25
Mp4.2	16	960	31	8	2	4	0
Mt4.2	16	512	16	4	1	0	1.25
totals							
tube	154	6912	216	91	24	16	15
pad	62	3844	122				

Table 2: The distribution of chambers on the +X platform.

In the Hera-B coordinate system, $\hat{z}$ points along the direction of the proton beam, $\hat{y}$ points up, and $\hat{x}$ points to the center of the Hera ring, from West to East. Chambers are numbered in ascending order along $\hat{x}$. This means, for any layer, chamber number 1 is the outermost chamber on the rear or West platform. Please notice that the channel numbers for a chamber are determined by the orientation of the front end card. For lower tube chambers the channel order is the same as the chamber order, but for upper tube chambers, the channel order is opposite the chamber order.

The muon front end drivers (FED's) receive and buffer the muon data. The muon front end drivers come in crates capable of handling 1024 channels of data (32 tube, or pad cards (TCFE or PCFE), or 64 low density pixel cards. A crate contains up to 4 – 256 channel FED

West or -X platform							
readout	number of						
layer	chambers	channels	FEE	PDC	CC	PLB	TLB
Mt1.1	15	480	15	4	1	0	1.25
Mt1.2	15	480	15	4	1	0	1.25
Mt1.3	17	544	17	4^a	1^a	0	1.75
Mt1.4	15	480	15	4^b	1^b	0	1.5 (?)
Mt1.5	14	448	14	4^a	1^a	0	1.5
Mt1.6	17	544	17	4^b	1^b	0	1.875 (?)
Mx1.1	1	324	23	1	1	0	2.5
Mx1.2	1	324	23	1	1	0	2.5
Mx1.3	1	324	23	1	1	0	2.5
Mx1.4	1	324	23	1	1	0	2.5
Mt2.1	16	512	16	4	1	0	0
Mt2.2	16	512	16	4	1	0	0
Mt2.3	17	544	17	4^c	1^c	0	0
Mt2.4	15	480	15	4^d	1^d	0	0
Mt2.5	14	448	14	4^c	1^c	0	0
Mt2.6	17	544	17	4^d	1^d	0	0
Mx2.1	1	324	23	1	1	0	0
Mx2.2	1	324	23	1	1	0	0
Mx2.3	1	324	23	1	1	0	0
Mx2.4	1	324	23	1	1	0	0
Mp3.1	18	1116	36	9	2^e	4.5	0
Mt3.1	18	576	18	5	2	0	1.5
Mp3.2	18	1116	36	9	3^e	4.5	0
Mt3.2	18	576	18	5	2	0	1.5
Mx3.1	1	306	23	1	1	0.5	1
Mx3.2	1	306	23	1	1	0.5	1
Mx3.3	1	306	23	1	1	0.5	1
Mx3.4	1	306	23	1	1	0.5	1
Mp4.1	18	1116	36	9	2^f	4.5	0
Mt4.1	18	576	18	5	2	0	1.5
Mp4.2	18	1116	36	9	3^f	4.5	0
Mt4.2	18	576	18	5	2	0	1.5
Mx4.1	1	372	24	1	1	0.5	1.5
Mx4.2	1	372	24	1	1	0.5	1.5
Mx4.3	1	372	24	1	1	0.5	1.5
Mx4.4	1	372	24	1	1	0.5	1.5
totals							
tube	188	8320	260	104	30	18	18
pad	70	4464	144				
pixel	16	5304	372	16	16	4	20

Table 3: The distribution of chambers on the -X platform. Items marked with superscript letters a through f are shared to save on the number of PDC's and CC's needed in the system.

daughter cards, one FED mother card, an FCS daughter card, and up to 6 trigger boards.

The 338 TCFE and PCFE cards on the +X platform require 12 FED crates. On the -X platform we use 24 FED crates. Three more crates are required were we to implement the high-density readout of the Mx1 and Mx2 pixel chambers.