MIPP Drift Chamber Safety Review

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# 1 System Overview

Fermilab's Experiment E907, or MIPP (**M***ain* **I***njector* **P***article* **P***roduction*), is designed to study minimum bias particle production in a fixed target experiment at MC7. The primary beam is 120 GeV/c protons from the Main Injector. A variety of secondary beams and targets will be used for the different measurements. Almost all detector elements of E907 are recycled from previous experiments. The system described in this document was first constructed for E690.

The MIPP Drift Chamber System consists of 3 small aperture beam chambers, or *BCs*, and 4 large aperture drift chambers, or *DCs*, and their associated electronics, high voltage, cables, and flamable gas systems. An overview of the chambers and their locations is given in Table 1. Each chamber, both

| **Chamber** | **z-Position w.r.t. Target (m)** | **Aperture ($cm^2$)** | **Gas Volume ($cm^3$)** | **Channel Count** |
|---|---|---|---|---|
| BC1 | -38.1 | $15.2 \times 10.2$ | $4.6 \times 10^{+2}$ | 640 |
| BC2 | -12.2 | $15.2 \times 10.2$ | $4.6 \times 10^{+2}$ | 640 |
| BC3 | -3.0 | $15.2 \times 10.2$ | $4.6 \times 10^{+2}$ | 640 |
| DC1 | +2.3 | $182.9 \times 121.9$ | $6.6 \times 10^{+4}$ | 2048 |
| DC1 | +4.0 | $152.4 \times 101.6$ | $4.6 \times 10^{+4}$ | 1920 |
| DC1 | +4.9 | $152.4 \times 101.6$ | $4.6 \times 10^{+4}$ | 1920 |
| DC1 | +8.8 | $152.4 \times 101.6$ | $4.6 \times 10^{+4}$ | 1920 |

Table 1: Summary of E907 Beam Chamber and Drift Chamber

BC and DC, are constructed of two wire ground planes sandwiching interleaved cathode and anode planes. The four anode planes are held at ground and have four different stereo angles. The cathode planes are held at negative high voltage. Using the symbols: "g" for ground, "c" for cathode, and "a" for anode, the planes for each chamber along the z-axis are in order g-c-a-c-a-c-a-c-a-c-g. A summary of the chamber construction and required electronics is given in Table 2.

Each anode wire is read out through a chain of electronics. An 8–channel PreAmplifier, is mounted on the chamber, amplifies the individual wire signals, and outputs pulses for each wire. This signal is transported along 13 pair twist–and–flat cable to a 32–channel Discriminator card. Here the signal is compared to a threshold voltage to discriminate against possible noise. Both PreAmplifiers and Discriminators, are original electronics from E690. The differential ECL signals at the output of the Discriminators is then read out from standard LeCroy Research Systems 4291B TDCs. A block diagram of the readout scheme for each detector is shown in Fig. 1. The shaded boxes in the figure indicate parts of the system which are described in this document for the purpose of mitigating potential hazards.

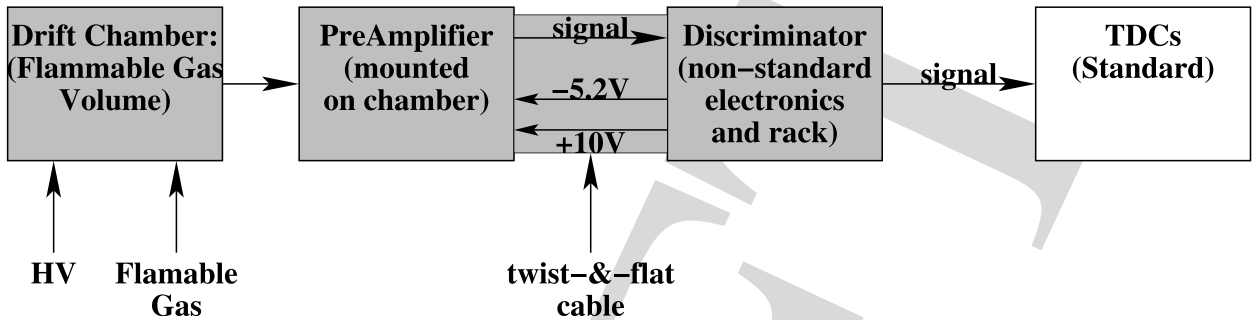


Figure 1: Block diagram of readout chain. The shaded boxes indicate devices addressed in this document.

| | $+21.6°$ | | | $-21.6°$ | | | $+7.8°$ | | | $-7.8°$ | | | **W** | **P** | **D** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chamber** | **W** | **P** | **D** | **W** | **P** | **D** | **W** | **P** | **D** | **W** | **P** | **D** | **Total** | **Total** | **Total** |
| BC1 | 160 | 20 | 5 | 160 | 20 | 5 | 160 | 20 | 5 | 160 | 20 | 5 | 640 | 80 | 20 |
| BC2 | 160 | 20 | 5 | 160 | 20 | 5 | 160 | 20 | 5 | 160 | 20 | 5 | 640 | 80 | 20 |
| BC3 | 160 | 20 | 5 | 160 | 20 | 5 | 160 | 20 | 5 | 160 | 20 | 5 | 640 | 80 | 20 |
| | | | | | | | | | | **Subtotal** | | | 1920 | 240 | 60 |
| DC1 | 512 | 64 | 16 | 512 | 64 | 16 | 512 | 64 | 16 | 512 | 64 | 16 | 2048 | 256 | 64 |
| DC2 | 448 | 56 | 14 | 512 | 64 | 16 | 512 | 64 | 16 | 448 | 56 | 14 | 1920 | 240 | 60 |
| DC3 | 448 | 56 | 14 | 512 | 64 | 16 | 512 | 64 | 16 | 448 | 56 | 14 | 1920 | 240 | 60 |
| DC4 | 448 | 56 | 14 | 512 | 64 | 16 | 512 | 64 | 16 | 448 | 56 | 14 | 1920 | 240 | 60 |
| | | | | | | | | | | **Subtotal** | | | 7808 | 976 | 244 |
| | | | | | | | | | | **Total** | | | **9728** | **1216** | **304** |

Table 2: Channel Count for E907 Chambers: "**W**" is wire count, "**P**" is PreAmp count, and "**D**" is Discriminator count. The angles given are the anode wire angles.

# 2 Electronics

## 2.1 PreAmplifiers

Each 8–channel PreAmplifier requires +10V and -5.2V for operation. The +10V powers the transistors in the initial stages of amplification, and the -5.2V is used for powering the differential MECL MC10116 chip at the output stage. Each PreAmplifier card requires 0.9mA at +10V and 60mA at -5.2V. The circuit diagram for the PreAmplifier is shown in Fig. 2. Four 8–channel PreAmplifiers are connected to a single Discriminator card with 13 pair, 24AWG, twist–and–flat cable. Power for the PreAmplifiers is carried on the twist–and–flat cable on pairs 1 and 13 for +10V and 2 and 12 for -5.2V. This means that 30mA is carried on each -5.2V line. Should one of the -5.2V lines but cut, 60mA still does not exceed the IEEE standard which is ???mA for 7 strand 24AWG. The remaining pairs of wires, other than the $7^{th}$ pair, carry the signals from the PreAmplifiers to the Discriminiator. The Discriminators are fused with 1.5A fuses on both the +10V and the -5.2V feedthrough lines to the PreAmplifier to provide protection for the power leads.

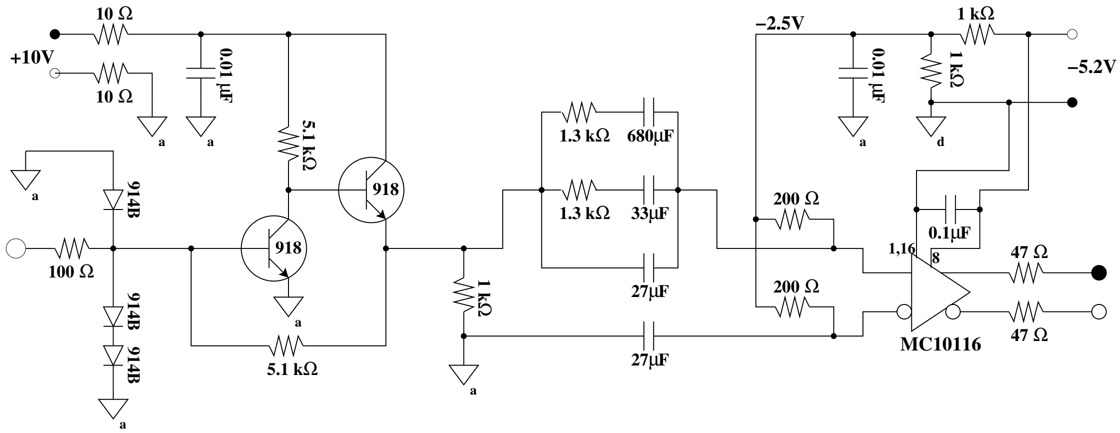


Figure 2: Circuit diagram for one channel of E907 PreAmplifier. There are eight identical channels on each board.

The PreAmplifiers are mounted directly on the Drift Chamber chassis. Table 2 gives a count of how many PreAmplifiers are required for each chamber.

## 2.2 Discriminators

Each 32–channel Discriminator requires 5A at -5.2V for operation. This current requirement includes the 60mA at -5.2V for each of the four PreAmplifiers. Since the current requirement is so high for the Discriminator cards, 200A power supplies, see Sec. 2.3.1, are used in the system. This leads to the possibility of smoldering or burning of the printed circuit boards should a short circuit be created.

We tested for the possiblitiy of self–fusing on the boards by putting large currents across the largest trace on the board. We chose the largest trace, as it would potentially carry the largest current should an accidental short be created. We found that at 70A, the trace began to smolder, and deemed that it was not sufficiently self–fusing. We have since modified each Discriminator board by cutting this trace at the input of the Discriminator card and putting a 10A fuse across the cut trace.

The Discriminator cards are installed in custom crates. The circuit diagram for the Discriminator boards is shown in Fig. 3.

## 2.3 Electronics Crates and Power Requirements

The Discriminator crates are custom built for E690. They have been refurbished and modified to meet present, more stringent, safety requirements for use with E907. From Tables 1 and 2, the required Discriminator crates and current drawn for each crate is summarized in Table 3.

The BCs each have a single crate with 24 slots for Discriminator cards. The Discriminator crate is mounted in a standard 19” relay rack. As these racks have non-standard electronics, the racks will have the sides closed with doors and/or blank panels, and the rack will be fitted with smoke detection at the top of the rack.

The DCs have custom racks, or *towers*, which house 2 or 4 38 slot Discriminator crates. There are two types of these racks, two 4–crate types and a one 2–crate type. The 64 DC1 Discriminators are in the two center crates of a four–crate rack. Both DC2 and DC3 share the four crates of a second

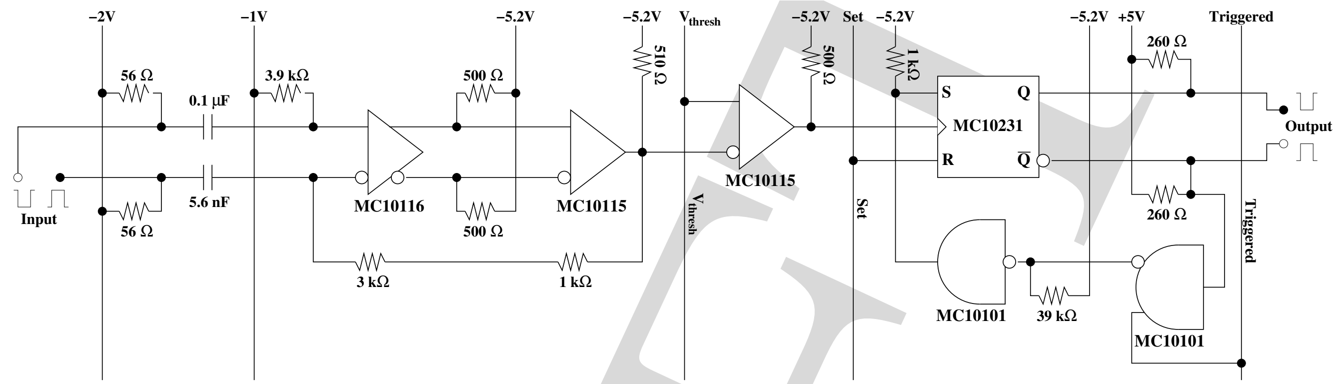


Figure 3: Circuit diagram for one channel of E907 Discriminator. There are 32 identical channels on each board.

| **Chamber** | **D Total** | **24-Card Crates** | **38-Card Crates** | **TDC Cards** | **TDC Crates** | **-5.2V Current** | **+10V** Current |
|---|---|---|---|---|---|---|---|
| BC1 | 20 | 1 | | 20 | 1 | 100 A | 18 mA |
| BC2 | 20 | 1 | | 20 | 1 | 100 A | 18 mA |
| BC3 | 20 | 1 | | 20 | 1 | 100 A | 18 mA |
| DC1 | 64 | | 2 | 64 | 3 | 320 A | 288 mA |
| DC2 | 60 | | $\frac{1}{2}$ of 4 | 60 | 3 | 300 A | 270 mA |
| DC3 | 60 | | $\frac{1}{2}$ of 4 | 60 | 3 | 300 A | 270 mA |
| DC4 | 60 | | 3 | 60 | 3 | 300 A | 270 mA |

Table 3: Crate Count for E907 Chambers: "**D**" is Discriminator count. DC2 and DC3 will share 4 Discriminator crates by using $\frac{1}{2}$ of each crate.

four–crate rack with 15 Discriminator cards in each crate. The 60 Discriminator cards for DC4 are installed in the two–crate rack. The DC1 and DC2/DC3 racks are installed on the east side of the beamline between the two analysis magnets. The DC4 rack is also on the east side of the beamline, immediately downstream of the second analysis magnet.

Each DC tower includes integrated air ducts for a blower system which serves to cool the Discriminator cards, see Sec. 2.3.3.

### 2.3.1 Low Voltage Power Supplies

Each BC has a single -5.2V 300A and two +10V 1.2A power supplies mounted in the Discriminator crate. The DC1 and DC2/DC3 racks each have 4 -5.2V 200A and 1 +10V 18A supplies. The DC4 rack has 2 -5.2V 200A and 1 +10V 18A supplies. Wiring diagrams for the low voltage power supplies are shown in Figs. 4, 5, and 6.

The AC for the BCs is ???

Each of the DC racks is powered by its own 3–phase 220V circuit; each of these circuits has its own ??? A circuit breaker. The circuit breaker box is located along the east wall of MC7.

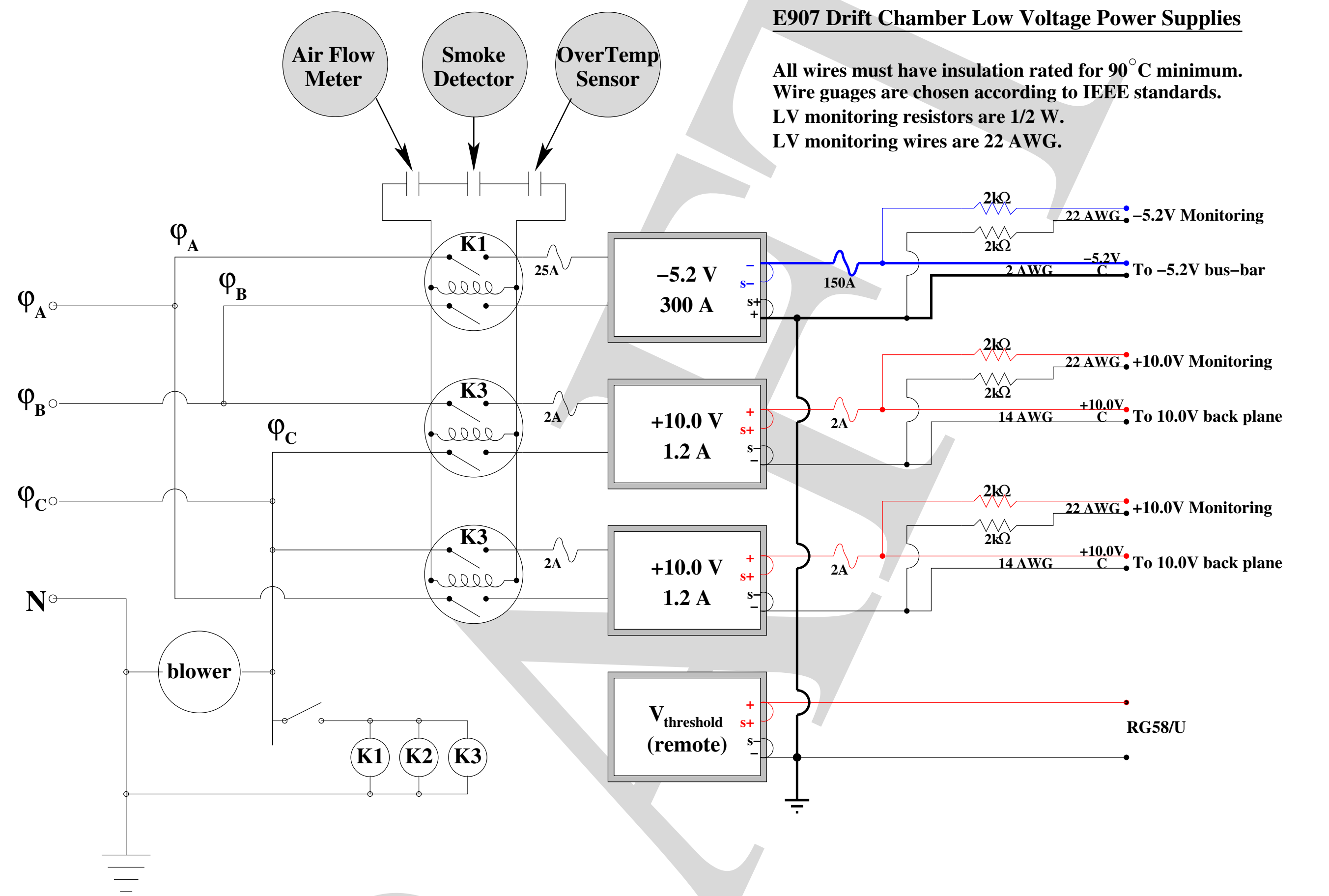


Figure 4: Wiring diagram for MIPP BC low voltage power supplies



All wire gauges are chosen to meet IEEE standards and all are rated for 90° C. The wire gauges are shown in Figs. 4, 5, and  6.

### 2.3.2 Cables

Under certain circumstances, bundled cables create a hazard by generating too much heat. Given the size of our bundles, the current carried on the wires, and the gauge of the wire, the bundled cables are well within safety specs as given by ???.

Since the cables between the PreAmplifiers and Discriminators carry power for the PreAmplifiers, there may be a concern of misorienting the cables which would short the power supplies. By the design of the PreAmplifiers, there is no danger of this, as the power and channel signals reverse sides of the board when flipped. In short, there is no possibility of causing a short circuit by misorienting the cables at either the PreAmplifier or Discriminator ends.

### 2.3.3 Discriminator Crate Cooling

At -5.2V volts and  5A, each Discriminator card dissipates  26W of power. With a maximum of 38 Discriminators in a crate, this becomes close to 1kW per crate. To keep the electronics cool, a blower system is built into the custom racks.

As the BC racks have only 20 Discriminator cards each, cooling is provided by 3–pack muffin fans mounted directly above the crates.

The blower system used in the DC1 and DC2/DC3 racks is ??? which is mounted external to the racks. The air is supplied to each of the racks using flexible ??? hose; once at the rack, tapered ducts on the racks provides uniform air flow over each crate. The blower provides ??? air flow.

The DC4 blower system is mounted directly to the DC4 Discriminator tower. The blower is ???, which provides ??? air flow.

For each Discriminator crate, blank panels will cover the unused slots to force the air over the cards. In the DC1 tower, both the upper and lower, unused crates will have the air flow dammed to force the air over the middle two instrumented crates.

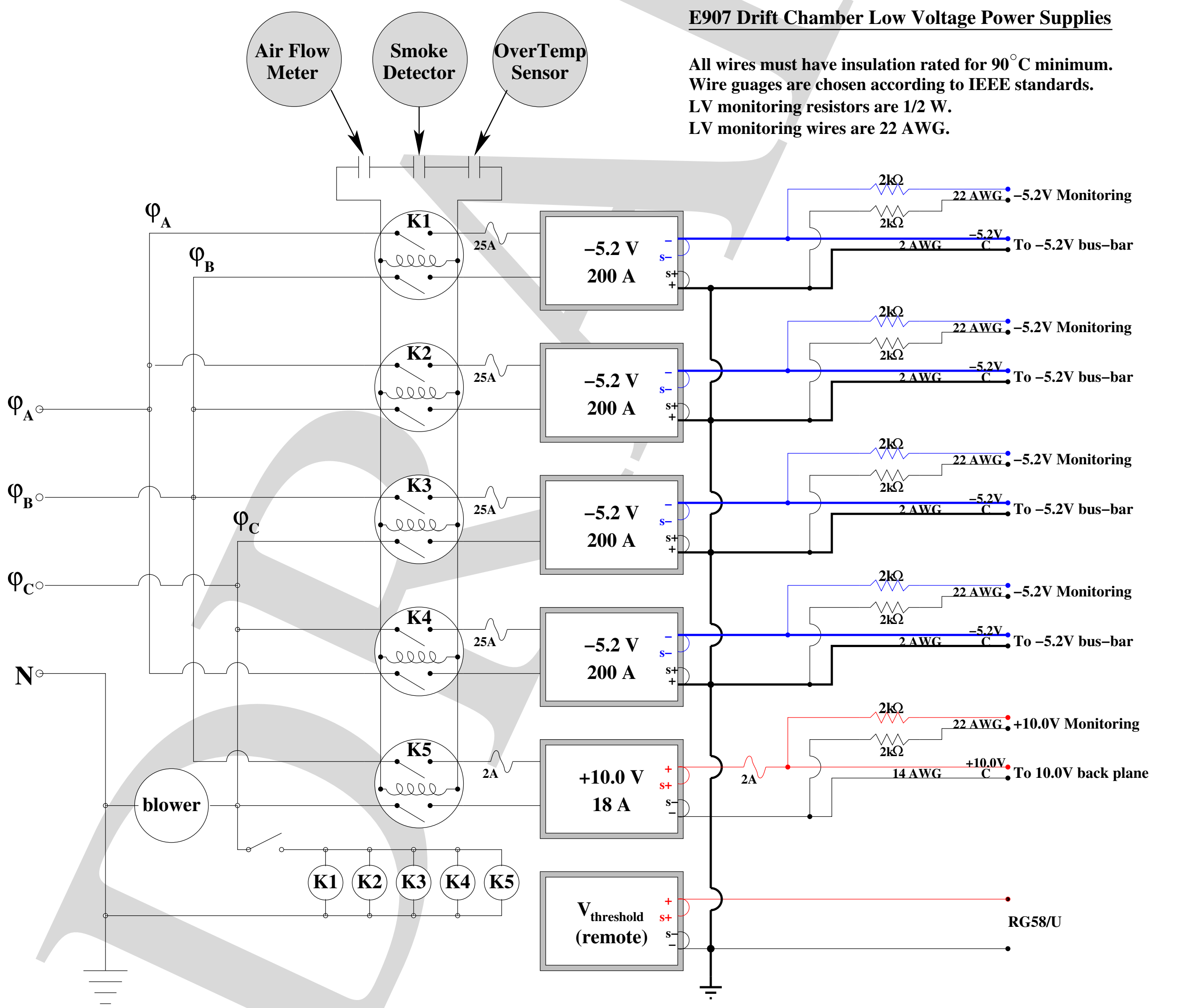


Figure 5: Wiring diagram for MIPP DC1, DC2, and DC3 low voltage power supplies

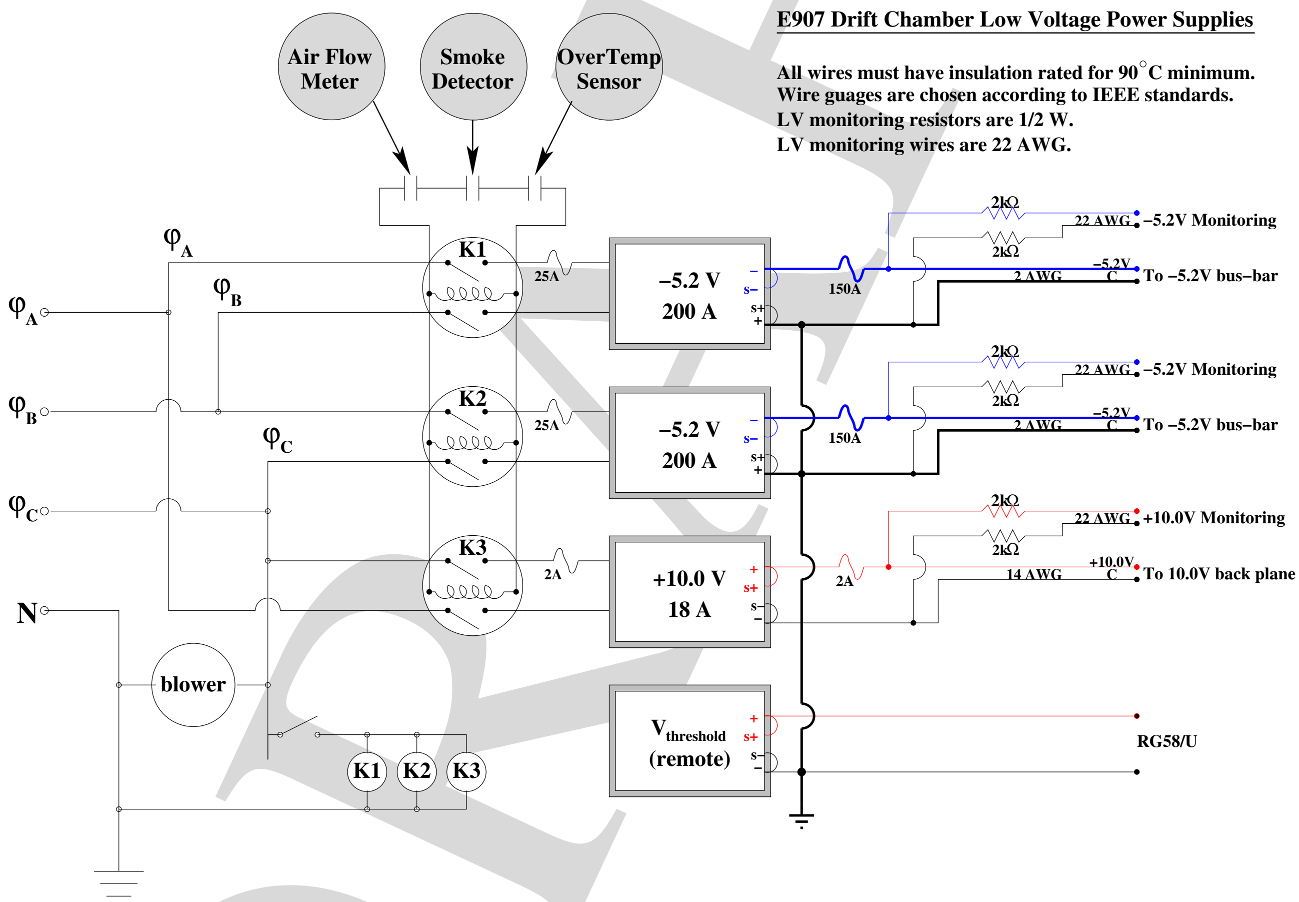


Figure 6: Wiring diagram for MIPP DC4 low voltage power supplies

### 2.3.4 Discriminator Crate Backplane

The Discriminator Crate backplanes for the BC crates is made of tinned copper clad G10. From Fig. 4, the power is supplied to xxx. A diagram of the backplane map is shown in Fig. 7.

The Discriminator Crate backplanes for the DC crates is made of copper clad G10. From Fig. 5 and Fig. 6, a $2'' \times \frac{1}{4}''$ bus bar. A diagram of the backplane map is shown in Fig. 7.

On the inside of each crate, female card edge connectors distribute power to each Discriminator card. Each card slides into the crate on rails, such that it is almost impossible to misorient a card and short circuit the power supplies. Installation of the Discriminator cards is performed with the power off to avoid blowing the PreAmplifier fuses and possible accidents of shorting power supplies. Once installed in the card edge connector, each card is screwed into place so that it can no longer be moved within the crate.

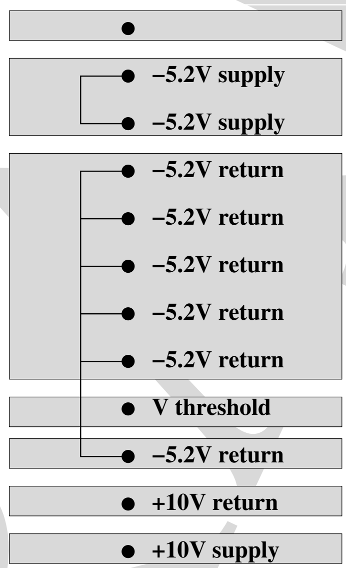


Figure 7: Backplane map for Discriminator crates.

# 3 High Voltage

Negative high voltage *or HV* is supplied to the cathode planes of each chamber. The HV supplies are standard NIM Droegie supplies which are mounted in the counting house north of the experimental hall. The HV is conducted to the chambers using standard RG58/U HV cable with SHV connectors.

# 4 Grounding

The grounding scheme for a complete BC and DC system is shown in Fig. 8.

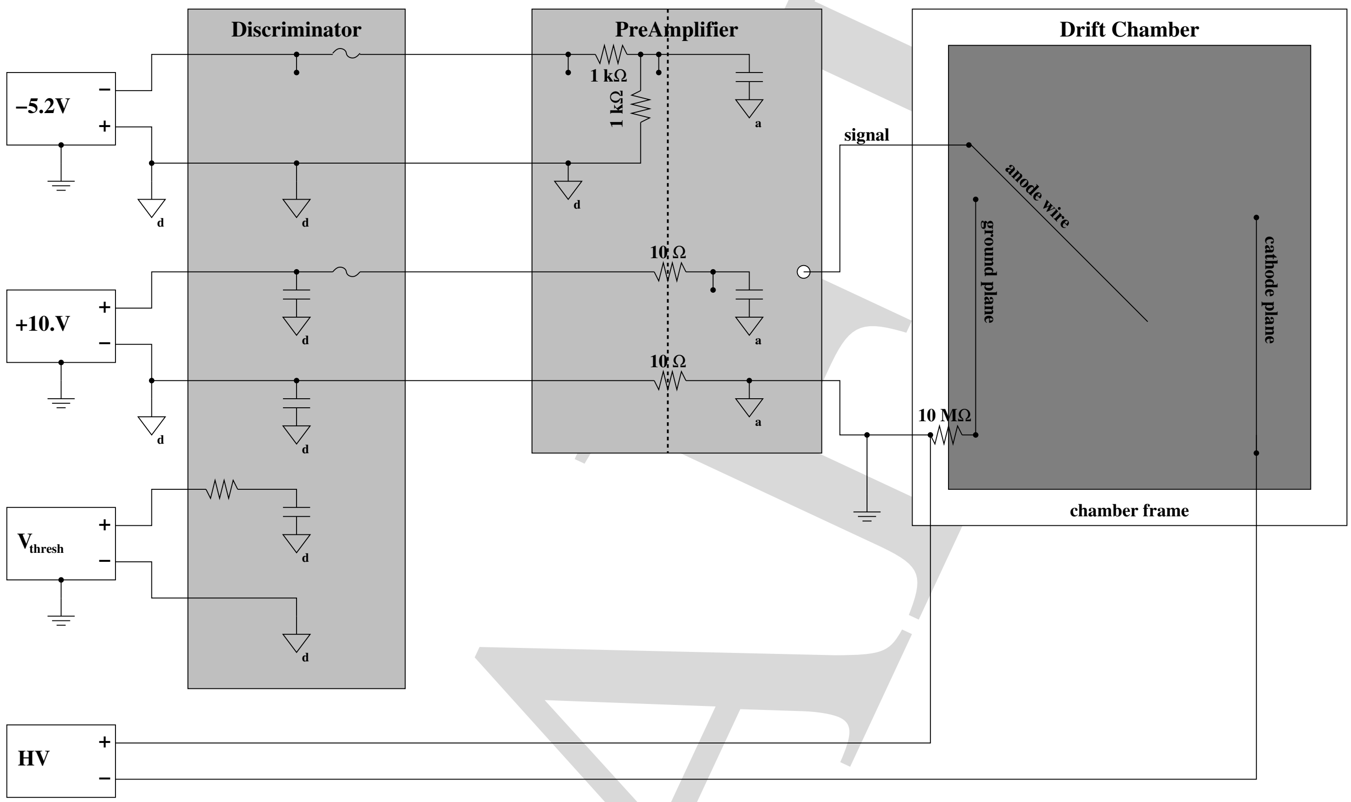


Figure 8: Grounding scheme for each BC and DC

# 5 Flamable Gas

For initial testing of BC1, BC2, BC3, and DC1, DC2, and DC3, E907 will use a single bottle of 50-50 Argon/Ethane in MC7. The volume of gas in the bottle, chambers, and piping leads to a hydrogen equivalence of 0.556 kg which is less than the 0.6 kg limit for a FESHM Risk Class Zero installation. All exhaust for the system is vented outside of MC7. A diagram of the temporary gas system for the BC and DC systems is show in Fig. 9.

Figure 9: Gas system diagram for BCs and DCs.

Safety features include a flow restricting orifice that limits the flow of Argon/Ethane from the bottle to 3 SCFH and a flammable gas detector with a local display at each chamber. Prior to the introduction of flammable gas, chambers are purged with nitrogen from a dewar located downstream in the MC8 gas shed.

Each DC has inlet bubblers to protect the chamber from overpressure and an outlet bubbler to maintain a slight positive pressure; this ensures the ambient air does not leak into the chamber and create a combustible atmosphere. Each chamber has its own flow meter.

The BC, as they are have a much smaller gas volume and are more robust, share input and exhaust bubblers. A single flow meter is used for the BCs, as they connected in series.

For more details regarding gas systems safety, refer to [**?**].

# 6 Safety Interlocks

Several scenarios can be envisioned which would lead to potentially hazardous circumstances such as outgassing toxic gases when electronics smolders, burning of components, or gas explosions. Though it is unlikely that one can imagine and prevent each disaster, efforts have been made to mitigate the most likely hazardous scenarios. The methods employed ultimately power down the system

In addition to monitoring various characteristics of the Drift Chamber system, see Sec. 8, we will also have an interlock system to shut off power to the Discriminator crates

1. Smoke Detection
2. Air flow
3. $T_{max}$
4. Over Current
5. Gas Leak

This is accomplished through a system of relays as shown in Figs. 4, 5, and 6.

## 6.1 Smoke Detection

Each Discriminator rack is fitted with ??? smoke detection device. We chose this type as it is sensitive to both ions and ???. Since the smoke detectors are mounted in the exhaust manifold of the air flow, see Sec. 2.3.3, the ??? type of smoke detector is not sensitive to the turbulance.

The smoke detector for each rack is put in series with other interlocking systems to cut power to the low voltage power supplies, see Sec. 2.3.1.

## 6.2 Air Flow

All DC towers are equiped with ??? airflow vanes. These are set to trip when the airflow falls below 1000 linear feet per minute.

## 6.3 Over Temperature

??? Klixons are installed on the exhaust port of each of the air flow ducts. These are set to trip at $T_{max} = 125F^{\circ}$, and have a reset of $T_{max} = 95F^{\circ}$.

## 6.4 Over Current

Over current protection is provided by fusing. These are shown in Figs. 4, 5, and 6.

## 6.5 Gas Monitoriing

At present, we have no interlock between the gas system and the Discriminator crate power.

# 7 Operation Instructions

With all of the interlock systems in place and operational, there is no danger of creating a hazard by turning on any of the devices. Operation of the beam chambers and drift chambers is reduced to: 1) verifying that each system is on and 2) turning on devices that are not on

That being stated, in order to protect the chambers and electronics from potential damage, there are some checks that are required before turning on devices.

## 7.1 Chamber Gas Verification

For the chambers themselves, it is important to check that gas is flowing through them before turning on HV. This prevents arcing which could potentially break wires. To check the gas flow, the operator must verify that visible bubbles are produced at the bubblers on the output line of each DCs. These bubblers are found on the west side of DC1, DC2, and DC4, and on the east side of DC3.

Since the beam chambers are connected in series, the operator is required to check gas flow at the output of the BCs which is found in the gas rack in MC7. When the permanent gas system is in place, there will be an electronic means of verifying gas flow in each of the chambers.

Note that if gas is not flowing, *Do not turn on HV to the chambers!*. The operator must notify a chamber expert, since the chamber may need to be purged before turning on the HV.

## 7.2 Cooling Air Verification for BCs

Since each of the discriminator cards dissipates $\sim$ 25W of power, air cooling is crucial to the safe operation of the electronics. For the DCs, the air flow in the discriminator racks is interlocked. For the BCs, the discriminator crates are mounted in racks with other electronics, such that the entire rack dissipates a large amount of power. Each of these racks is equipped with a fan at the top of the rack. The operator must verify that each of these fans is operational in each rack.

## 7.3 Startup Procedures

### 7.3.1 Beam Chamber Startup

Once these verifications are accomplished, the procedure for turning on the BCs is:

1. Check gas flow
2. Check that upper rack exhaust fan is turned on
3. Turn on HV
4. Turn on Discriminator Crate:
   - Turn on discriminator crate toggle switch
   - Press and hold push button switch for 3 seconds
5. Turn on all TDC CAMAC crates

The wait period when pushing the switch is to give the discriminator crate cooling fan time to engage.

### 7.3.2 Drift Chamber Startup

The procedure for turning on the DCs is:

1. Check gas flow
2. Turn on HV
3. Turn on Discriminator Crate:
   - Turn on discriminator crate toggle switch
   - Press and hold push button switch for 3 seconds
4. Turn on all TDC CAMAC crates

# 8 Monitoring

*I still need to finish this section*
Want to monitor:

1. -5.2V voltage for each discriminator crate
2. +10V voltage for each discriminiator crate
3. Threshold voltage for each discriminiator crate
4. HV
5. Gas pressure
6. Gas mixture
7. Air flow
8. Temperature difference: $T_{electronics} - T_{ambiant}$

These will be read out in slow monitoring systems of the DAQ.

# 9 Conclusions

We have made considerable effort to mitigate all reasonable sources of hazards in the E907 Drift Chamber System. We believe that implementation of the safety systems described above will allow us to operate our system safely, remotely, and without direct human monitoring.