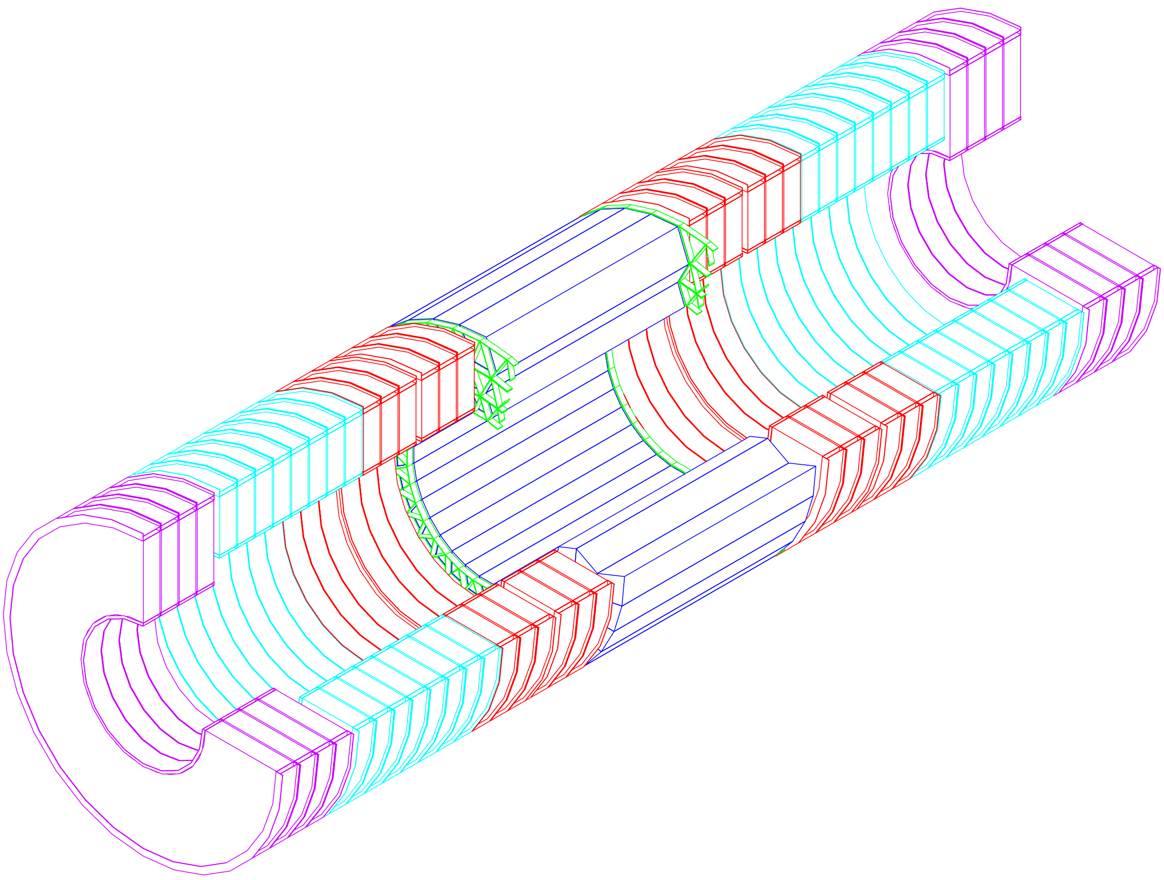
Grounding and Power Distribution for the ATLAS TRT Detector

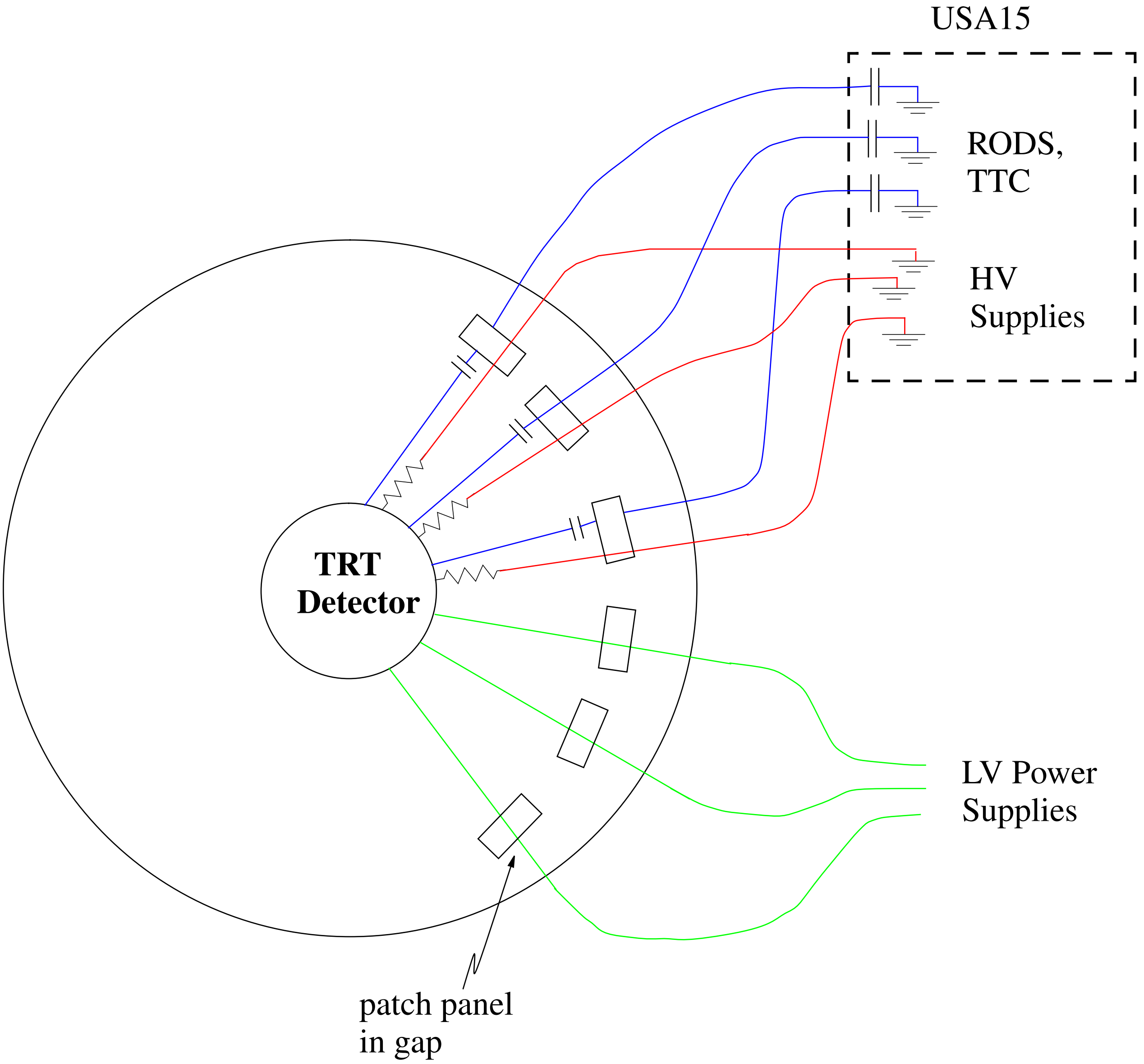
TRT Collaboration

1.0 Overview

The TRT detector consists of two “end cap wheel sections” and a barrel section as shown in Figure 1. It exists in close proximity to the SCT, Pixel, and Liquid Argon systems. We outline here the tentative plan for grounding and power distribution for the TRT “independent” of these other systems. Because of the large capacitive coupling to these other systems, we believe that it may be desirable to make the primary grounds of these systems in a similar way at a similar point. Initial discussions indicate that at least the Liquid Argon, Muon, TRT, and Tile Calorimeter systems intend to make their “ground connection” in USA15 via a relatively small number of dedicated cables.



Before discussing in detail each of the data, TTC, service, slow control, and mechanical interfaces to the TRT, and the techniques proposed to maintain electrical isolation, we note that there are four primary locations where the nature of the connections to ground must be considered: the detector itself, the “receiver/driver” boxes located in the gap between the barrel and endcap calorimeter, the low voltage supplies located in the cavern (or possibly in US15), and the high voltage supplies and off-detector electronics located in USA15. These four locations are schematically illustrated in Figure 2. The existence of the power return lines which are attached to local detector ground, and shields on the twisted pair used to carry signals to USA15 allow the possibility for the "primary ground" connection to be made in any of these locations. However, to avoid ground loops, a direct connection to ground must be made in only one of these locations. We note that it is generally argued that the only reason a "direct connection to ground" must be made in any of these locations is for safety reasons. We also note that because the rock in which the cavern is located has very poor conductivity, it is planned that the primary "earth" connection for the cavern and USA15 will be via 100m cables to the surface. While in principle any of the four locations noted above could be selected for the primary safety ground,, we present the issues leading to a preferred choice.



2.0 The Primary Ground Connection: Where is it?

- Ground connection in USA15- While it may be argued that USA15 is located relatively far (80m) from the detector, it is important that the absolute potential of the local detector ground and the potential of the local ground at the receivers in USA15 be not too far apart (< a few hundred millivolts difference) because of the limited common mode range of some receivers. A connection from the "local detector ground" to the "local receiver ground" of USA15 can and should be made with a small number of cables so that the connection may be selectively removed if desired and so that currents flowing in this connection can be monitored. In a properly designed system, there should be almost no current flowing in the connection.
- Ground connection at the LV power supplies - In a system in which the power supplies were all located in one location, and the power cables from the detector followed the same path, it might be quite reasonable to make the ground connection at the LV supplies. However, in order to minimize cable lengths, it is likely that the power supplies will be located in different areas of the cavern (even if primarily on one side of the detector). In any event, the power cables must follow significantly different routes, spread out in phi as shown in Figure 2, since they come from different parts of the detector and in order to fit through the crack. Ground connections at power supplies located in different locations would not produce ground loops if each of the detector "modules" were isolated from one another. However, for the TRT (unlike the case for the SCT), it is believed to be difficult to effectively isolate the different parts of the endcap wheels, or even the barrel modules. Initial discussions with safety representatives (and the experience of NA48), indicate that power supply returns can be completely isolated from ground, without safety problems, as long as the voltages are less than 50 volts. This seems very attractive to us. Aside from completely avoiding ground loops due to LV power supply connections, it has the added virtue of forcing the low voltage current to return to each supply thus preveting uncontrolled currents from this source.
- Ground connection at the "receiver/driver" boxes located in the gap between the central and endcap tile calorimeters. A possible argument for making a "solid" connection to earth at the receiver/driver boxes is that this would allow for shunting to ground any noise that is picked up on the shields of the data, clock & control, HV, and LV cables. However, in point of fact it is not possible to make a "solid ground" connection (unless one considers it to be to be rest of the detector, which violates the isolation philosophy) since the "earth reference" in the cavern is a 100m cable to the surface. as noted above.
- Ground connection directly to the *local detector ground*. In practice this could be accomplished either by connecting locally to the Liquid Argon cryostat (which grossly violates the subsystem isolation philsophy) , or via a cable which exits through the gap between the calorimeters. The latter still leaves open the question of where this cable is connected to a "ground reference". In reality it either goes to a cable in the cavern which goes directly to the surface or it can go to USA15 where it connects to a cable going to the surface.

- The potential of local detector ground must be within a few hundred millivolts of the local ground reference at the receiver/driver boxes in order for the LVDS signals to remain within the common mode range. This is presumably not difficult to accomplish given the short distance between the two. As noted above a more challenging requirement is that the reference ground at the receiver/driver boxes must be within a few 100 mV of the reference ground at the receivers in USA15. Since there is no "solid ground" in the cavern in any event, and since it is deirable to maintain the detector and the USA15 ground reference at the same potential, it seems logical to connect the detector ground to that of USA15.

3.0 Modularity of the Detector

How many such ground connections there are depends on how many "independent" modules there are. Each end-cap wheel is an integral mechanical structure with straws running radially between inner and outer carbon fiber rings. The electronics is planned to have a modularity of 1/32 in phi; that is the power supply voltages, readout, etc is grouped such that the "ground reference" on the front end printed circuit boards can be independent for each 1/32 unit. We can refer to these as "virtual" detector modules. Then one has 1152 virtual end cap modules. Similarly the barrel is one integral unit mechanically but can be divided into 96 virtual detector modules electrically. One could maintain the isolation of each of these virtual modules in which case the approach would be very similar to that of the SCT and Pixel systems. However, because of the large capacitance between the straws, it is believed to be difficult to effectively isolate these "virtual modules" in practice. In addition, because of the potential sensitivity of the straws to pickup, it is intended to include the detector in a Faraday cage. Because of the requirement of minimizing material and not absorbing the transition radiation photons, it is probable that the finest granularity of Faraday cages would be: the entire barrel system, and three groupings of endcap wheels on each side (e.g. wheels of type A, B, ;and C). It has not been decided at this point what modularity to try to maintain, but it is likely that for the purpose of a ground connection from the detector to USA15, the detector will be treated as seven "supermodules"

4.0 Electrical Isolation of all other interfaces to the TRT

In order to avoid ground loops, all connections to the TRT other than the primary ground connection(s), must be electrically isolated from ground as well as possible. We list below each of the interfaces to the TRT and the technique envisaged to provide electrical isolation.

- Mechanical Support - insulation
- Cooling pipes - insulation
- Data, Clk & Control, Parameter Readback

  shielded twisted pair with direct connection at one end and capacitive connection at the other end (provision for an open connection at one end will be provided although that is not expected to be the optimal solution)
- Temperature readback - shielded twisted pair as for Data or optical isolation
- Low Voltage Power - power return floating. If the power cables are shielded, then the shield is connected at one end only or as for the data transmission.
- High Voltage Power - HV return connected via resistor at detector end, probably directly connected to ground at HV supply. Bundles of HV coaxial cables will share a common ground to reduce noise on the HV return. This shield would be connected as for the data transmission cables.

As the LV power returns can be completely floating and the HV return can be isolated at the detector by a relatively large resistance (order 1 kohm), the primary issue for avoiding ground loops is likely to be the treatment of the shields for the twisted pairs, and for the HV and LV if shields are also used on these cables.

5.0 Schematic of Ground Connections

We present in Figure 2 a schematic diagram showing one possible scheme for making all ground connections. This figure shows the connections of shields for the twisted pairs, and the power returns for the LV and HV. A more detailed diagram of the connections at each location is shown in Figure 3. .In the approach which we have adopted as described above, the primary remaining uncertainties are (1) at which end is the direct connection of cable shields to ground made, and (2) what value of capacitance should be used in connecting the ground shield at the other end. As noted above,. to obtain the best shielding at high frequencies, it is advisable to connect the shield via a capacitor. The presumption is that variations in magnetic fields that could cause ground loop problems would mostly occur at lower frequencies. We expect that further analysis and experience in test beams and system tests will lead to the optimal choice prior to installation of the detector. However, it would be wise, and probably not too costly, to allow for the connection of the shields to ground to be changed even after installation has begun if it is shown to be strongly desirable. Figures 2 and 3 do not show the “explicit” ground connections that would be made from the detector reference ground to USA15. While such a connection could be made simply by making a DC connection at each end of the twisted pair for one particular 1/32 in phi, it is more likely that a separate, well identified connection would be made. In this way the “safety ground connection” to the detector itself would not be undone accidentally if data cables were disconnected. Conversely, if one wanted to remove this connection in a controlled fashion, for checking for accidental connections that cause ground loops for example, it is preferable to be able to remove a single (or small number) of connections.

6.0 Interaction with other Systems

We note that the TRT is likely to be capacitively coupled rather strongly to the SCT/Pixel detectors or their power cables and to the cryostat. It is our experience that large “floating” conductors near the TRT become efficient couplers of noise into the TRT electronics. Thus it is desirable that both the SCT/Pixel systems and the cryostat be at a stable potential with respect to the TRT local detector ground. Thus there should be a solid connection to earth for each of these systems at some point. We do not believe that it will be acceptable for these systems to be “completely electrically isolated” from ground in normal operation. That is, a “safety connection” which provides high impedance to ground during normal operation and allows relatively high frequency excursions of the potential of these systems could well allow them to beome a significant noise source.While a single point connection to ground for these systems could in principle be made at at number of different locations (at the LV power supplies, in the USA15 couting room, or a direct connection to ground in the cavern), we imagine that it may be advantageous for the TRT, liquid argon, and SCT/Pixels to follow the same basic philosphy. As noted above, this is the case at present for the TRT and liquid argon systems. If the SCT/Pixel detectors choose to make the “ground connection” for each module at the corresponding power supply, if the power supplies are located other than in USA 15, it would seem to be desirable for this ground to be derived from that in USA15..

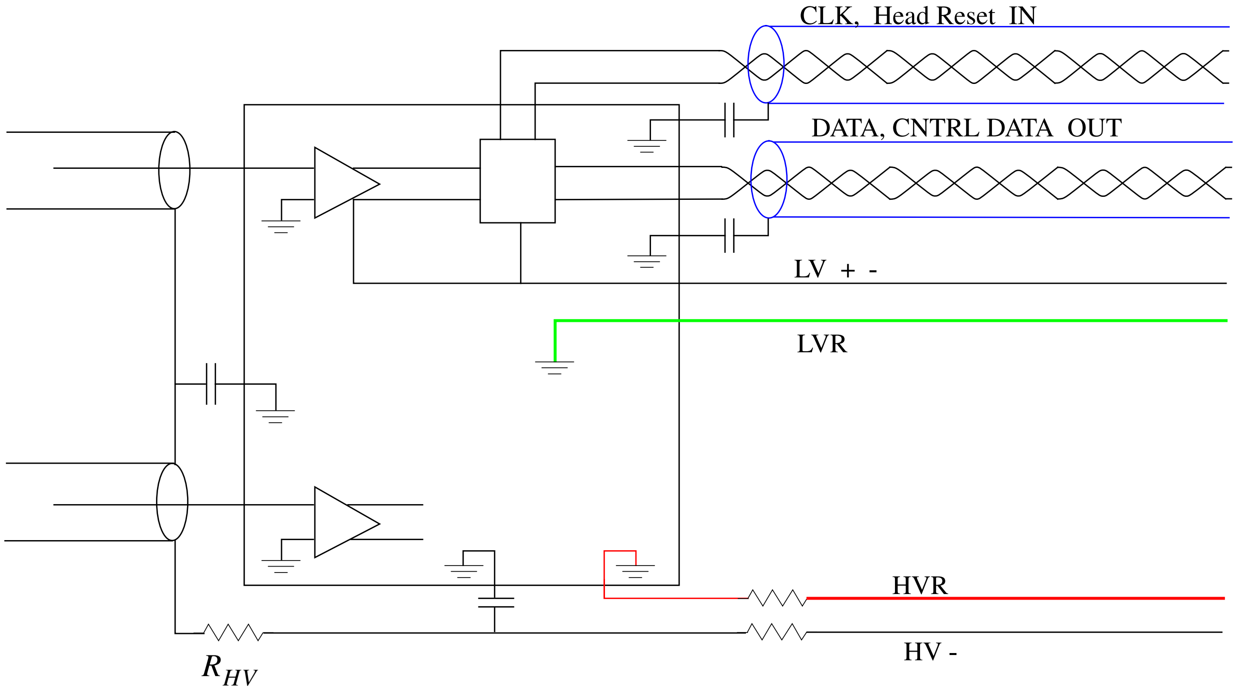
7.0 Outstanding Issues

One of the primary issues to be resolved, which does not seem to us to be fundamental, is the insulation of the mechanical support and the cooling and gas ionisation pipes.

8.0 Shielding of the TRT

In addition to choosing electrical connections which minimise group loops, and to the use of low level differential signals to minimise noise generation by the TRT itself, we anticipate that the TRT electronics and detectors will be surrounded by some kind of Faraday cage as noted above.. For the end cap wheels, the connections from the straws to the front end amplifier chips (ASDBLR circuits) are contained within conducting surfaces which yield a reasonably good Faraday cage. Alternatively, a more explicit conducting plane between the FEB containing the front end amplifier chips and the FEB containing the digital chips could be utilized. The exact design is still under dicussion. An added constraint for the endcap wheels is that it must be done in a way which does not absorb the TR photons. Thus it is likely that the 18 end cap wheels at each end of the detector would be grouped into three independent Faraday cages.

For the barrel modules, if the carbon fibre shells are sufficiently conducting at high frequencies, the modules themselves (together with the ground plane on the tension plate or roof board at the end of the modules) could yield an adequate Faraday cage. Tests will be carried out in the near future to verify whether this is true.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DATA, CNTRL DATA OUT
LV + -
LVR
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HV -
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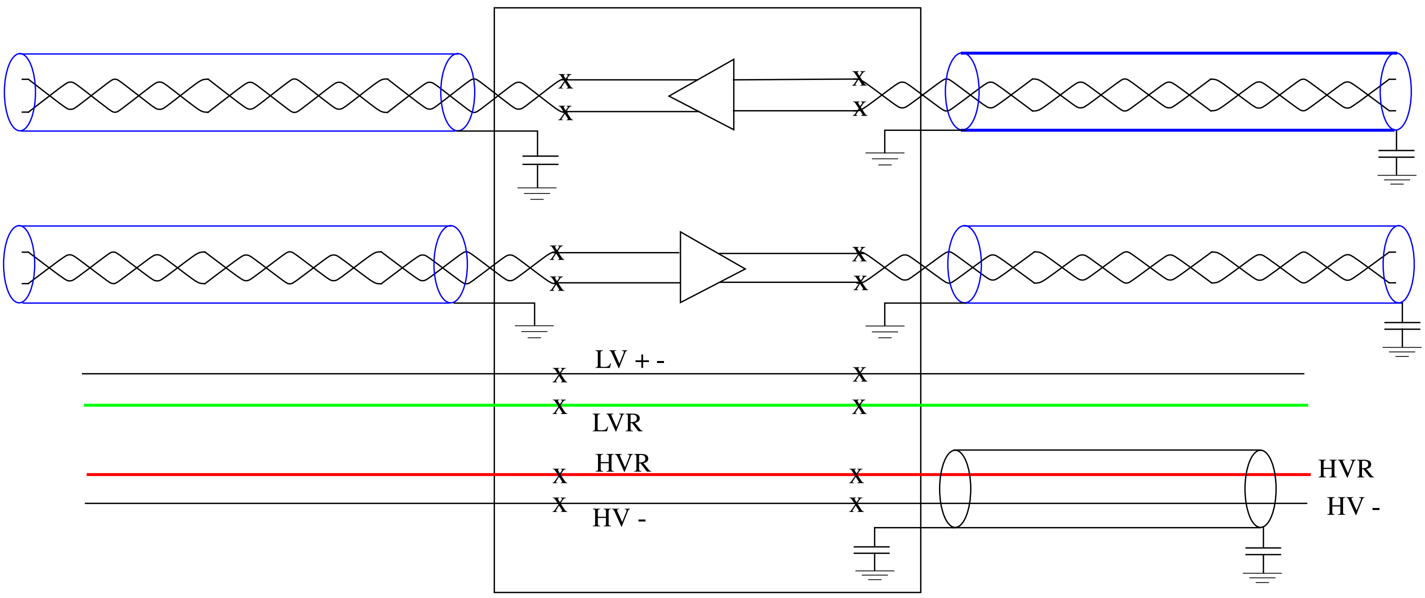
LV + -
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