A few details related to the LUX TPC high voltage design

Abstract
In this note, I am trying to understand the LUX connection to HV power supplies. Analyzing the situation and contacting two power supply companies (SRS and CAEN), one must say that the LUX TPC works because: (a) TPC runs very small cathode HV, (b) there is an internal sink resistor inside SRS PS-350 PS, and (c) because the LUX resistor chain draws a very small current. However, if the internal PS resistor would fail, or cable to PS is accidentally disconnected, the cathode HV voltage would appear at the gate wire plane. If one would run at 100kV, it would mean a lot of damage.

CRID TPC sink resistor
Best way to describe the issue related to the sink resistor is to use an example of CRID HV design [1], shown on Fig.1.

Two 300MΩ sink resistors, ensuring that the “bottom” TPC voltage does not go to a cathode voltage, if a cable or PS fails, and also that no current flows into the power supply.

Fig. 1 CRID HV design from point of view of external sink resistor.

It was known to me at that time that it is not recommended to sink current into CAEN power supply, which controls low voltage end of TPC. Therefore the TPC resistor chain ended with an external sink resistor, which was located inside the vessel on the TPC itself (each TPC had one). There were actually two sink resistors in parallel to increase the redundancy for safety, and what is important, they were protected by two spark gaps.
This was the essential safety feature. In case of accidental overvoltage, the sink resistors were protected. Any damage to the sink resistor would be a disaster because a full cathode voltage would appear at the detector end – a guaranteed way to break many anode wires, not to speak about safety issues. In case that the bottom power supply $V_{\text{Bot}}$ is disconnected, or fails or trips, the TPC low voltage end will stay at a "parking" voltage of about -1.6 kV, assuming that $V_{\text{top}}$ stays at -55 kV.

**LUX TPC HV sink resistor**

In LBL meeting on 5/28/2015 I realized that LUX does not have an explicit sink resistor on low voltage side of TPC, located outside of the HV power supply. This means that the resistor chain current has to sink to ground inside of the PS-350 power supply. I mentioned this to several people at that meeting. Since then I looked in detail to what LUX actually has, including contacting the SRS company\(^1\). I concluded that the present LUX HV concept works only because the resistor chain current is extremely small (at a level of $<$200 nA for the present voltages (see Fig.3a), and therefore the extra power loading to the PS-350 inner sink resistor is very small (see Fig.3b). The PS-350 power supply has the internal sink resistor of $\sim$20 M$\Omega$ resistor (see Appendix for actual circuit and sink current path inside the PS-350 power supply).

![Fig. 2](image_url) (a) A diagram, sent to me by Tom, which includes filter resistors. (b) A simplified diagram (omitting filter circuits, which are not important for this discussion), but including the internal $\sim$20 M$\Omega$ sink resistor inside the SRS PS-350 power supply. Detailed circuit is shown in Appendix Figs. 4&5.

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\(^1\) I contacted the SRS company, had many e-mails exchanged with them, and I got a very clear message from Kevin McKee: “Do not use the SRS PS-350 to sink the current. Use it only to source the current. The sink resistor should be outside of the PS. We would suggest something on the order of 1-5 M$\Omega$. The maximum power rating for the chain is $\sim$2-3 Watts. However if you operate them above their normal 1.2W operating condition, the voltage accuracy will suffer.”
Feedback from CAEN company

HV channels of R1470 have an impedance to ground of about 300 MΩ. Company suggests to use a parallel resistor to sink the current. Even if there is no issue on the channel safety if all the current gets sunk by the HV channel itself, it would help in having a better voltage control and correctly recognize the overvoltage conditions.

Conclusion

My conclusion is that I do not see any serious issue with the present LUX design, which would cause a poor voltage control.

Even though that the present connection scheme works, I believe it is not a good design from a safety point of view, as any interruption in the sink current path outside of TPC vessel, either inside or outside of PS-350, would mean to have a full cathode voltage on the gate wire plane, and possibly all the way inside the PC-350 power supply.

References

Appendix: Details of PS350 HV power supply circuit.

**Fig. 4** LUX SRS PS-350 HV power supply circuit details. Figure 5 shows details of the sink current path.
Fig. 5 LUX sink current path in PS-350 goes through $8 \times 2.49 \, \text{M} \Omega$ resistors, which represent a total value of $\sim 20 \, \text{M} \Omega$. The maximum power rating for the chain is $\sim 2-3$ Watts. However if one operates them above the normal $\sim 1.2$ Watt operating condition, the voltage accuracy will suffer.