The Stability Measurement of Barrel TRT with Xe-CO$_2$ Mixtures

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One of the criteria in choosing the ionization gas for the TRT is the stability of the chamber operation at very high rate with offsetted wire. The baseline gas mixture for the TRT is Xe-CO$_2$-CF$_4$ (70-10-20%), which has a very good property of quenching the onset of ‘arching’.

Because of the uncertainty in the noise level, the nominal gas gain (25,000) may have to be increased. In other words, the operating high voltage may have to be increased in case the noise level is higher than expected. However increasing the high voltage could put the chamber into an ‘arching’ region and trip the high voltage.

The mixture of Xe-CO$_2$ (65-35%) is one possible back up ionization gas mixture. This mixture has some advantages compared to the baseline gas mixture, but the range of the operating voltage (operationally stability region) is much narrower than the baseline gas mixture. Recently there is renewed interest in this gas because of the wire-joint problem. We have re-measured the stability property of the gas mixtures using the exiting Duke test module being used for the aging study.

The offsetted wire inside straw reduces the range of the operational stability. The gain along the straws is mapped to measure the offset. A typical gain map is shown in Figure 1. From the gain maps, we estimate that all straws (thirteen in total for this measurement) are aligned better than 250 microns.

Because there is no exact definition of the operational stability, the following definition is used in this paper. The current draw from a straw tube (or a set of straws) is measured as a function of the applied high voltage. When ‘arching’ is observed (sudden jump in the current draw or high voltage trip) or the straw tube goes into a continuous discharge mode or the current draw increases dramatically, we define that the straw tube has entered the unstable operating region.
Figure 1. The gain map along a straw for a channel in the test module. The x-axis is in the step of ~3.5 cm.

Figure 2. The voltage distribution when straws go into ‘unstable’ operating region. The channel with 1880 volts is the straw number 15. There is no obvious alignment problem with this straw.
First, this measurement was done with 13 separate straws with no external radiation. The HV was increased in 10 volts step and the current draw was monitored. In all straws, arcing appeared suddenly. As the HV increased further, the frequency of arcing increased without substantial increase of the current. As Figure 2 shows a distribution of the voltage when the first arcing appeared. Although there was some difference in the current draw before arcing, the typical current draw from a straw tube was less than a micro-amp.

The next measurement was done with radiation sources. The same 10 sources used for the aging test was used for the radiation. They were eight 10 milli-curie and two 50 milli-curie Sr$^{90}$ sources. The two stronger sources were positioned near the wire-joints. First, the two stronger sources were closed (the rest was open) and the high voltage was raised until the unstable operating region (arcing) was reached. Figure 3 shows the current draw as a function of the high voltage. The occasional arcing started to appear at 1760 volts.

![Figure 3. The current draw (µA) from 13 straws as a function of the high voltage. Only eight 10 milli-curie sources are opened. The onset of occasional arcing was observed at HV=1760. The gas gain doubles every ~70 volts.](image)

This measurement was repeated with all sources opened. For this configuration, the onset of occasional arcing was observed at 1700 volts. At 1690 Volts, the chamber was stable (without any arcing for hours). At 1720 volts, the frequency of arcing was about five per hour. The stable voltage (1690) is about 140 volts higher than the nominal operating voltage. We estimate that the average rate around the wire-joints (~ +/-15 cm, where the two stronger sources are positioned) is similar to the expected rate at the full LHC luminosity. The gas gain at this voltage is about 100,000.

In conclusion, we believe that the barrel module should be stably operable with high voltage upto around 1690 Volts at the full LHC rate with Xe-CO$_2$ (65-35) mixture. The gas gain at this voltage is about 100,000. However this voltage could change depending on the straw alignment in the final barrel modules. One final note is that this study does not include the effect of heavily ionizing particles.