DUKHEP01-12-06

Gas Flow Rate Measurement in TRT Barrel Module Straws

Seog Oh, Doug Benjamin, Chiho Wang
Department of Physics
Duke University
Durham, NC, 27708

Introduction

Because straws are isolated from each other in the TRT, the ionization gas is fed to all straws in parallel through a buffer volume. In the barrel modules, the buffer volume is the space between the tension plate and HV plate. For proper module operation, a uniform gas flow rate through all straws is necessary.

In the module, there are four gas inlets and four outlets. The present plan is to use two inlets and two outlets and seal up the rest. At the end of gas feed (or exhaust) plugs, there are three small holes to generate fast gas stream.

A few years ago, the flow rate was measured using a prototype Type 1 barrel module. The result was reported in the X-ray paper. We found that the flow rate in straws is uniform within ~30%. Unlike the present production modules, it had only one inlet and one outlet and the plugs were without the three small holes.

In this paper, we report on the gas flow rate measurement using a production Type 2 module (2.11). For other production types, the work is in progress.

Data taking

The technique to measure the gas flow rate is to detect the gain change as the gas composition changes. After a module is flushed out with a mixture of gas (baseline mixture), the composition of the input gas is slightly changed. In this experiment, the baseline mixture is Ar-CO_2 (70-30%), and it is changed to 73-27% composition. The change typically lasts about 5 minutes and then it returns to the baseline mixture.
The gain shift due to this change is about 10% and easily measurable using our X-ray scanner.

While the change in the gas mixture is made, the gain at two points (let us call them A and B) separated by 20 cm along the straws are measured every 100 seconds. The first point (A) is 10 cm from the gas inlet side and the second point (B) is at 30 cm. As the new gas mixture passes the first point, the gain would increase and eventually return to the baseline gain. The same will happen at the second point but at somewhat later time. By measuring the time difference when the gain shift occurs at the two points, and the distance between two points (20 cm), the speed of the gas flow is calculated.

Figure 1 shows typical gain map plots as a function of time. There are two histograms corresponding to the data from A and B. As expected there is an increase in the gain as the new gas mixture passes the points. The shape is fitted with a Gaussian function to get the time when the peak occurs. The peak of the second curve appears a little later and the width is wider compared to the first curve. The widening of the peak is due to the diffusion process. From the difference of the peak times and the distance between A and B, the speed of gas flow is calculated. Because only 16 channels can be measured at one time in this experiment, this process is repeated every hour using different set of 16 channels.

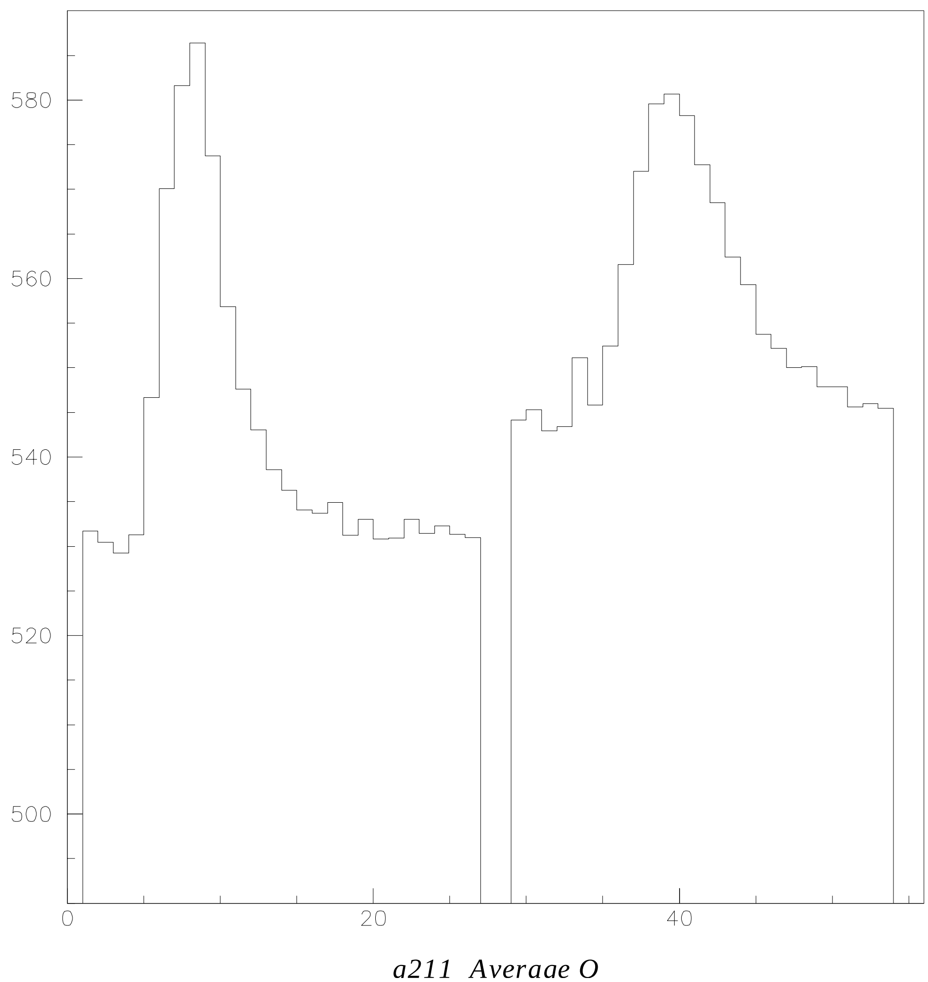

Figure 1. Gain plots measured as a function of time at two locations, A (left plot) and B (right plot). Plot B is shifted by 29 bins. The first point of A is t=0 and the first point of B is t=50 sec. The bin width is 100 seconds. The difference between two peaks corresponds to the time for gas to flow 20 cm, the distance between A and B.

Figure 2 shows the flow speed distribution for most of the straws in a Type 2 module. It is centered at 2.5 cm/min with 0.3 cm sigma. This is somewhat higher than the expected

2.3 cm/min calculated from the input gas flow. Figure 3 shows a Lego plot of the gas flow speed. The locations for the two gas inlets are at the rightmost corner and the leftmost corner. There is slightly more gas flow around the input inlets and less gas flow at the other corners. Other that that feature, the gas flow rate is fairly uniform.

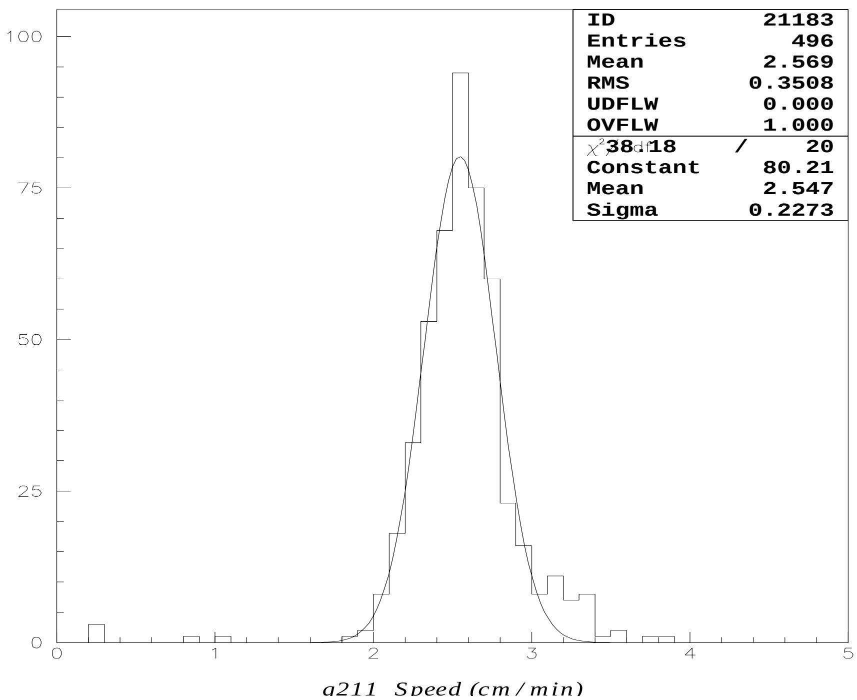

Figure 2. The flow speed distribution from module Type 2.11.

In the following table, the results are summarized. For the flow rates 110 cc/min and 180 cc/min, only ~160 straws are measured. Figure 4 and 5 show the gain measurement as a function of time at the location A and B for the two flow rates respectiveily.

Input Flow (speed)	**Inlet holes**	**Outlet holes**	**Measured Average Flow speed**
110 cc/min (1.8 cm/min)	A and C	A and C	2.2+/-0.1 cm/min
140 cc/min (2.3 cm/min)	A and C	A and C	2.6+/-0.1 cm/min
180 cc/min (3.0 cm/min)	A and C	A and C	3.0+/-0.1 cm/min

Table 1. The gas inlets are labeled A,B,C and D. A (B) and C (D) are diagonal. A is the one near the acute corner.

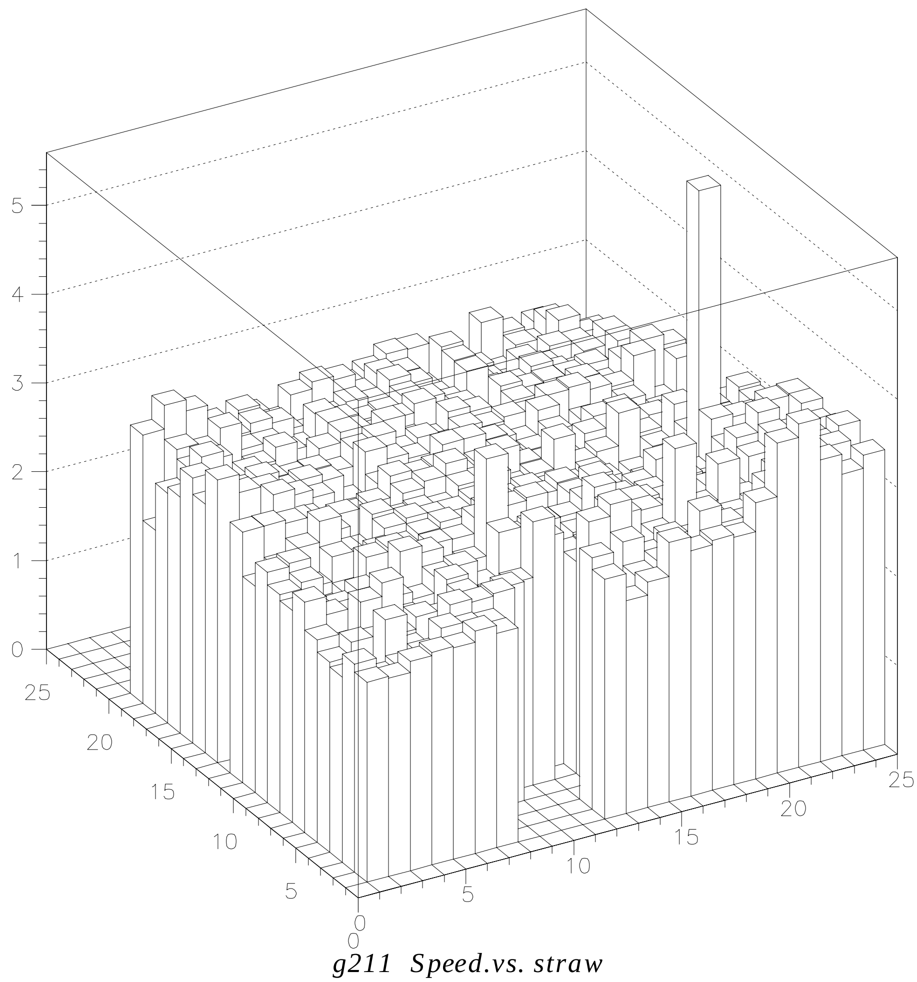

Figure 3. The vertical axis is the flow speed (cm/min). The grids on the horizontal plane represent the straw location on the tension plate. The two gas inlets are at the rightmost corner and leftmost corner. There is a slight increase of gas speed (~3 cm/min) in the straws around the gas inlets. The flow speed is low (~ 2.2cm/min) at the other corners. There are a couple of channels with high values. These are due to bad fits to the gain distributions (Figure 1).

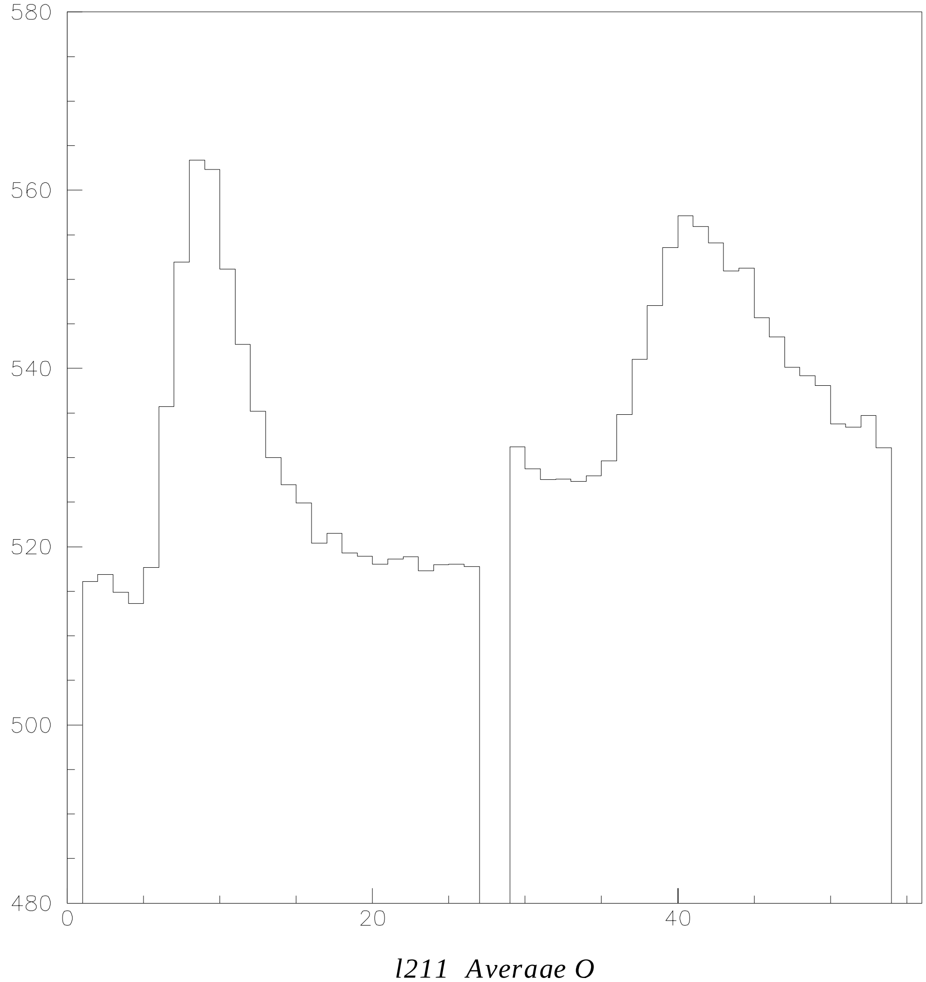

Figure 4. Same as Figure 1, except the flow rate is 110 cc/min.

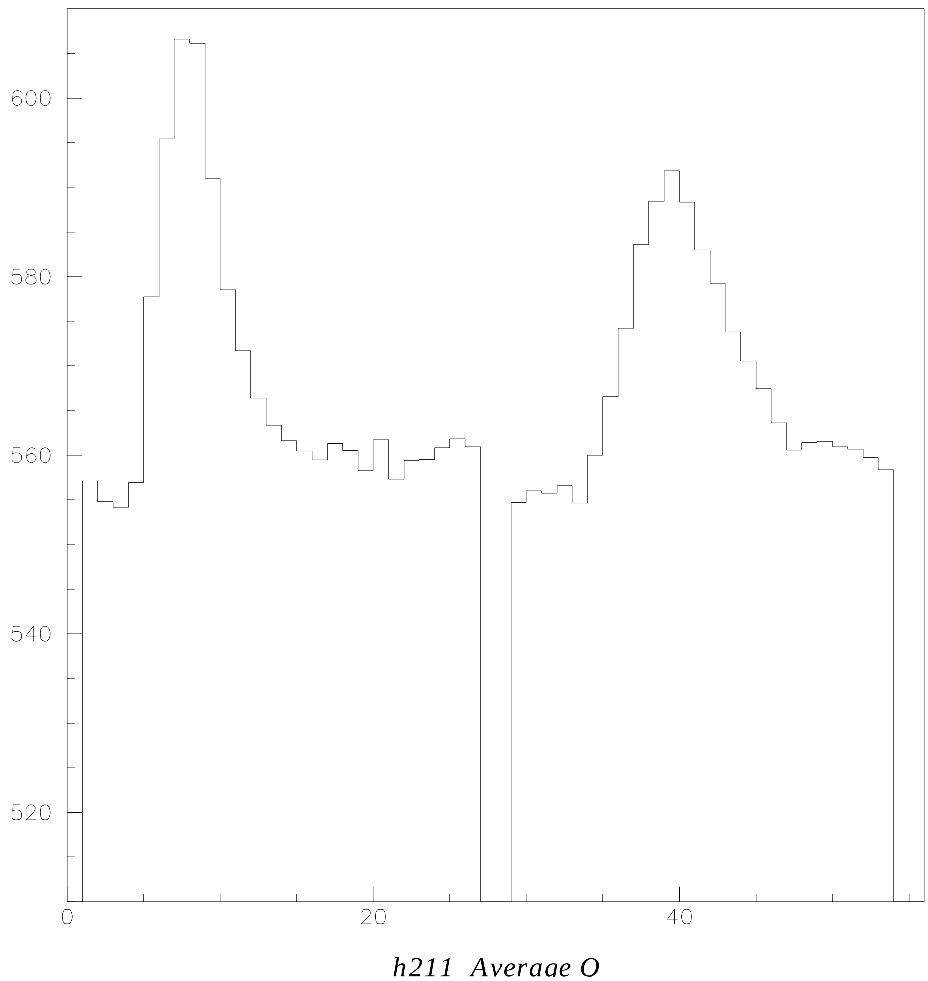

Figure 5. Same as Figure 1 except the flow rate is 180 cc/min.

Discussion

In this experiment, a pulse of gas (with different concentration) is injected to into the end of a straw. The length of the pulse is about 6 minutes or 15 cm (for the 2.5 cm/minutes flow speed). The pulse moves along the straw because of continuous gas input and diffusion process. And since the pulse diffuses as it travels down, the pulse shape looks like a Gaussian rather than a rectangular shape. The width of the Gaussian-like-shape increases as it travels along the straw (as shown in Figures 1, 4 and 5). By measuring the time that the pulse travels 20 cm, the speed of gas flow is calculated.

Using this technique, the flow rate in the straws in a module Type 2 is measured and shown that the gas flow speed in straws is uniform within ~+/-20% level. The flow rate for the straws around the gas inlet is slightly higher than the average.

We also find that the measured flow speeds are somewhat higher than the expected flow speeds. The difference between the two gets larger as the flow rate decreases. We believe that the difference is due to the diffusion effect.

The typical value for the diffusion coefficient (D) is 0.2 cm^2/sec. If one injects N number of type A molecules in the middle of a straw filled with B at t=0, then the concentration of gas A along the length of straw is expressed with a Gaussian function with $\sigma = (Dt)^{1/2}$ where t is in second. After one minute (ten minutes), the σ of the distribution is about 3.5 cm (11 cm). This is comparable to the expected nominal flow speed and it is not unexpected that we see the diffusion effect in the measured speed.