One of the necessary conditions for being a certified gain mapping device is that the gain variation along a straw length has to be reproducible. For the study, we used one of the recently strung modules, M2.15. It turns out that ~30% of straws have wires with diameter variation problem. Because of the problem, there are a lot of straws with large gain variation, which is good for the repeatability study.

Two data sets (only from the front of the module) were taken over a period of three days. The first data set was taken on April 14 and 15, the second data set was taken on April 15 and 16. The Figure 1 shows the dG distribution and there are two peaks. One corresponds to the ‘normal’ wires (peak at ~2%), and the other corresponds to the ‘problem’ wires (peak at ~5%). The problem wires are with varying wire diameter.

Figure 1. dG plot of M2.15. Some of wires in this module have wire diameter problem.
Figure 2 shows the two dimensional plot $dG$ vs. $rms$. This plot clearly shows that the straws with $dG > 4\%$ have normal $rms$ values, which is an indication that these straws have wires with fluctuating wire diameter.

Figure 2. $dG$ vs. $rms$

Figure 3 shows the average gain of all straws along the straw length. First let me point out that we have a slight problem with the first and the last data points. This was because we tried to take data too close to the HV plate and mid-wire support and the sudden dips (not very obvious for the first point) were the indication. From the figure, we can conclude that the average gain variation along the straw length is $\sim 1\%$. This could be due to electronics or temperature variation along the module. There are two plots in Figure 3. The left one is from the first data set, and the right one is from the second data set. They are quite similar in shape. No correction to take out the slope is made in the analysis.
Figure 3. The average gain variation of all straws from the two data sets. There is about ~1% gain shift from the beginning to the end. The difference in the absolute height is likely due to pressure and/or temperature change between the two data sets.

In Figure 4, we plot the difference between dG of straws from the first measurement (dG₁) and the second measurement (dG₂). If the reproducibility is perfect, this should be exactly 0.0. The curve is fitted with a Gaussian and sigma of 0.48% was obtained. Since this is the difference between two measurements, the reproducibility should be better then 0.48%. The exact value is not important since this is more than adequate for being certified.

However there are some straws with the difference more than 2%. They are investigated separately (see below), and we conclude these straws are due to one bad measurement or fit and should not affect the final wire list because these cases are quite easy to determine from the detail plots (gain and width variation plots along the straw) whether to include in the final wire list or not.
Figure 4. dG₁-dG₂ distribution. There are some straws with the difference more than 2%. These straws are analyzed separately later.

Figure 5 shows a two dimensional plot. Plotted is dG₁ (x-axis) versus dG₂ (y-axis). There is a very good correlation.
In Table 1, we list the straws with difference between dG₁ and dG₂ greater than 2%. There are 6 straws. For these straws, we show the gain variation and width variation plots from two data sets below. The reason for the difference is quite obvious (see the comments with each straw).

<table>
<thead>
<tr>
<th>Straw #</th>
<th>dG₁</th>
<th>dG₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>4.8%</td>
<td>9.1%</td>
</tr>
<tr>
<td>103</td>
<td>1.7%</td>
<td>4.4%</td>
</tr>
<tr>
<td>268</td>
<td>7.2%</td>
<td>4.4%</td>
</tr>
<tr>
<td>443</td>
<td>2.6%</td>
<td>4.9%</td>
</tr>
<tr>
<td>519</td>
<td>2.4%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

Table 1. The list of straws with absolute value of dG₁-dG₂ greater than 2%

In summary, the repeatability of dG of the Duke X-ray scanner is better than 0.5%. But, there are random straws with the difference between the two measurements greater than 2%. These straws are investigated and the main cause is one bad data point which distorts the dG value. These straws should pose no problem in making the final wire list. We conclude that Duke X-ray scanner can be certified.
Straw # 23. The top two plots are from the first data set, and the bottom two plots are from the second data set. The two left plots are the gain variation along the straw length and the two right plots are the width variation along the straw length. This straw has $dG_1-dG_2=4.3\%$ and the difference is due to the dip near the end of the plot.
Straw # 103. The second set (two left plots) has gentle slope while the first set do not. The reason is unknown.
Straw #268. The difference is the 4th point from the end (compare the two left plots).
Straw # 443. The difference is the first point.
Straw # 519. The difference is the first point.