

Resistance Measurement of GEM's in Low Pressure

August 26, 2015

During measurements the GEM's were installed inside of a vacuum chamber with a pressure of $1.65 \cdot 10^{-6}$ mbar.

The resistance was measured separately for every GEM. High voltage was applied to the anode while the cathode was grounded.

Applying a voltage of 750V caused a discharge, then during all the following measurements a voltage of 500V and 200V was alternately applied.

1 Middle GEM

A series of current measurements was taken on the middle GEM.

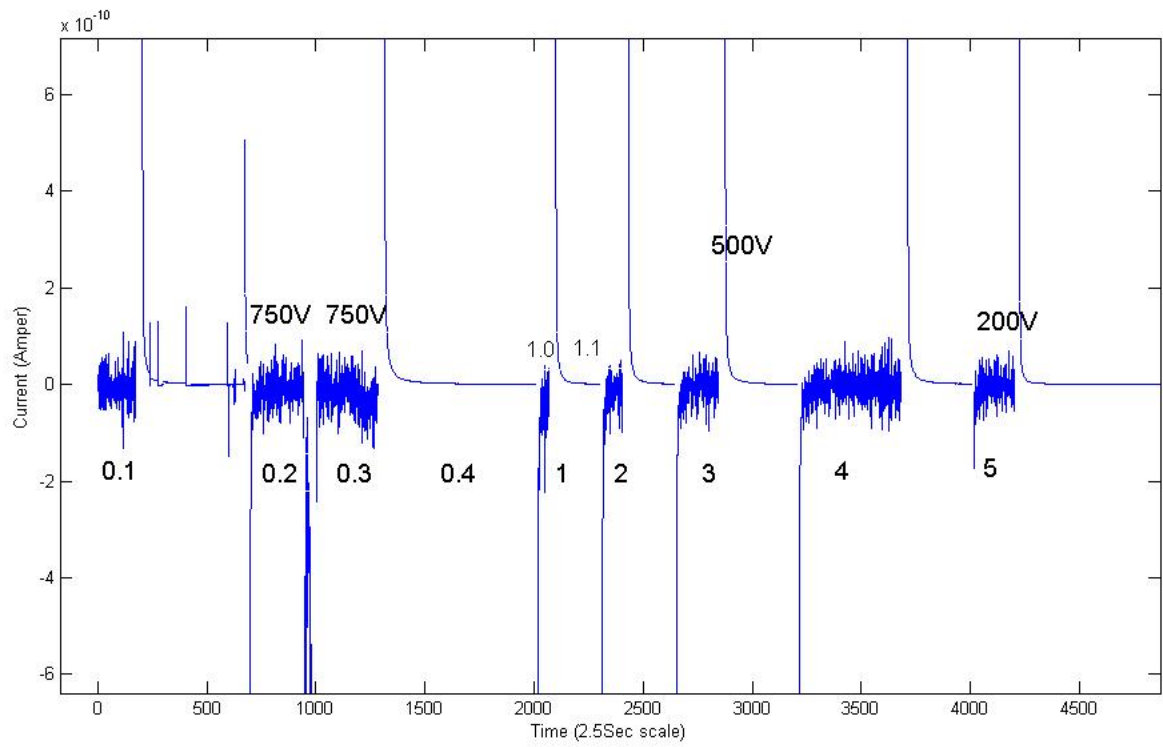


Figure 1: Current Measurements

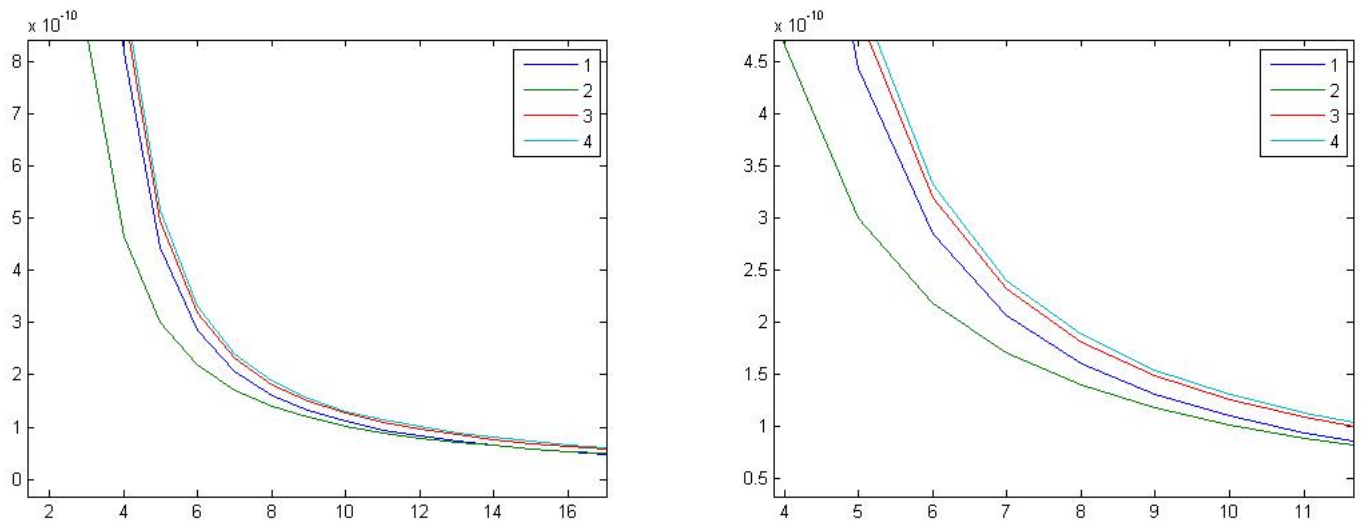


Figure 2: Slope Comparison

1.1 Resistance

1.1.1 200V

$$\begin{aligned} R_{5.0-5.1} &= \frac{200}{5.837 \cdot 10^{-13} - (-1.9357 \cdot 10^{-13})} \\ &= \mathbf{2.573 \cdot 10^{14}} \\ \frac{\sigma_{I_{5.0}}}{\sqrt{N}} &= \frac{1.4337 \cdot 10^{-13}}{\sqrt{101}} = 1.426 \cdot 10^{-14} \\ \frac{\sigma_{I_{5.1}}}{\sqrt{N}} &= \frac{9.5236 \cdot 10^{-14}}{\sqrt{401}} = 4.755 \cdot 10^{-15} \end{aligned}$$

1.1.2 500V

$$\begin{aligned} R_{0.4-0.1} &= \frac{500}{8.4240 \cdot 10^{-13} - (-4.2755 \cdot 10^{-12})} \\ &= \mathbf{9.7696 \cdot 10^{13}} \\ \frac{\sigma_{I_1}}{\sqrt{N}} &= \frac{3.607 \cdot 10^{-11}}{\sqrt{141}} = 3.03764 \cdot 10^{-12} \\ R_{1.0-1.1} &= \frac{500}{1.4468 \cdot 10^{-12} - (-2.7785 \cdot 10^{-11})} \\ &= \mathbf{1.7104 \cdot 10^{13}} \end{aligned}$$

$$\begin{aligned} R_{2.0-2.1} &= \frac{500}{1.7194 \cdot 10^{-12} - (-1.1838e \cdot 10^{-11})} \\ &= \mathbf{1.47499 \cdot 10^{13}} \end{aligned}$$

1.1.3 750V

$$\begin{aligned} R_{0.4-0.2} &= \frac{750}{8.4240 \cdot 10^{-13} - (-8.4508 \cdot 10^{-12})} \\ &= \mathbf{8.07041 \cdot 10^{13}} \\ \frac{\sigma_{I_{0.2}}}{\sqrt{N}} &= \frac{3.2264 \cdot 10^{-11}}{\sqrt{181}} = 2.39816 \cdot 10^{-12} \\ R_{0.4-0.3} &= \frac{750}{8.4240 \cdot 10^{-13} - (-1.9796 \cdot 10^{-11})} \\ &= \mathbf{3.6340 \cdot 10^{13}} \\ \frac{\sigma_{I_{0.4}}}{\sqrt{N}} &= \frac{2.5624 \cdot 10^{-13}}{\sqrt{251}} = 1.61737 \cdot 10^{-14} \\ \frac{\sigma_{I_{0.3}}}{\sqrt{N}} &= \frac{3.8781 \cdot 10^{-11}}{\sqrt{241}} = 2.4981 \cdot 10^{-12} \end{aligned}$$

1.2 Curve Fitting Discharging graph

The most successful attempts to fit a curve were using a power law or a stretched exponential. We also tried separate the slope into to parts and fit a 2 terms exponential function. We failed to find any relation between the constants describing the discharge graph to those describing the charging graph.

1.2.1 slope #1, 500V

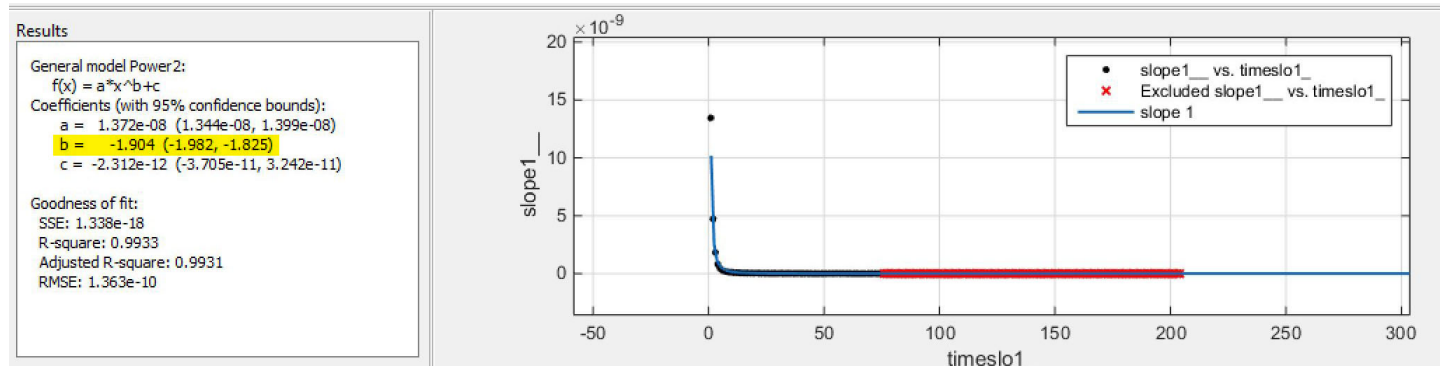


Figure 3: Power Law

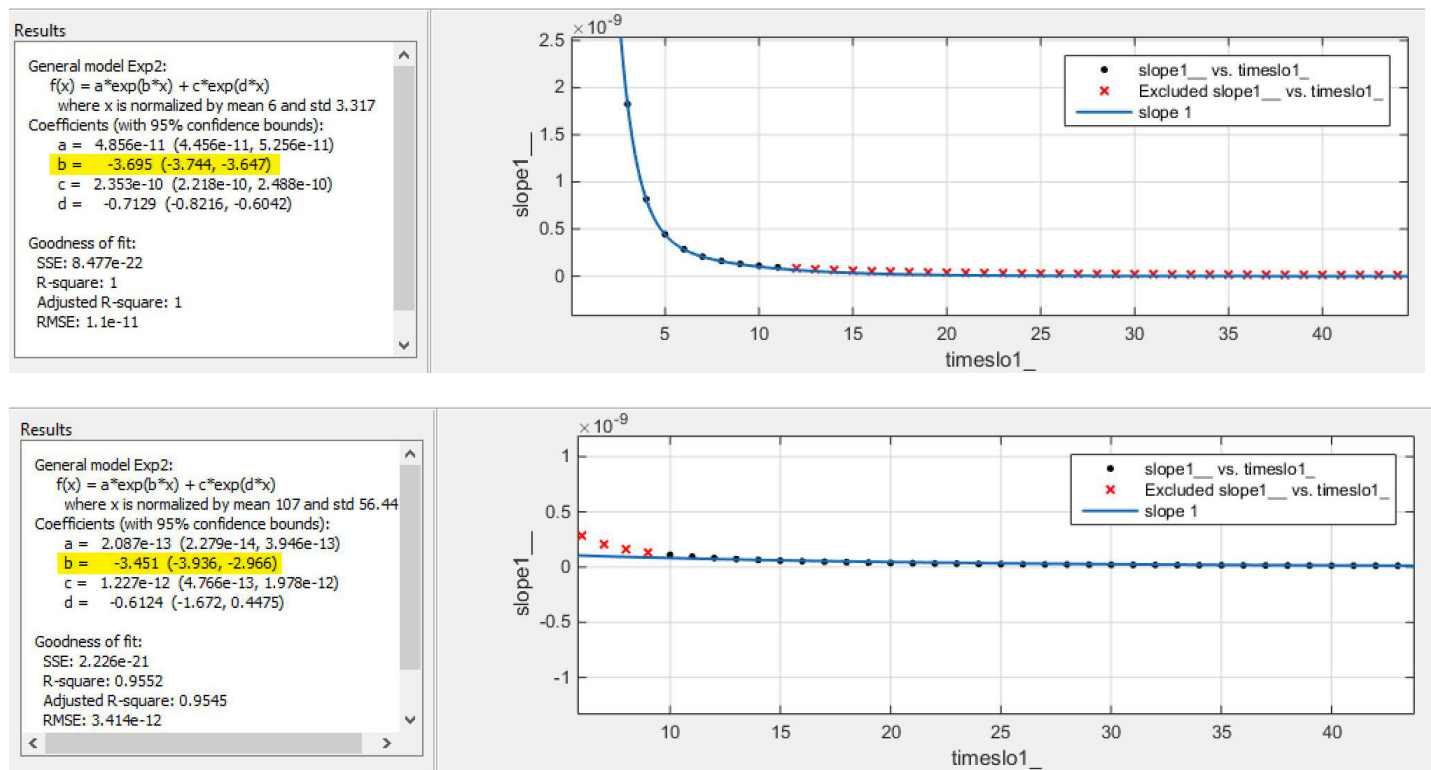


Figure 4: Exponential fitting

1.2.2 slope #2, 500V

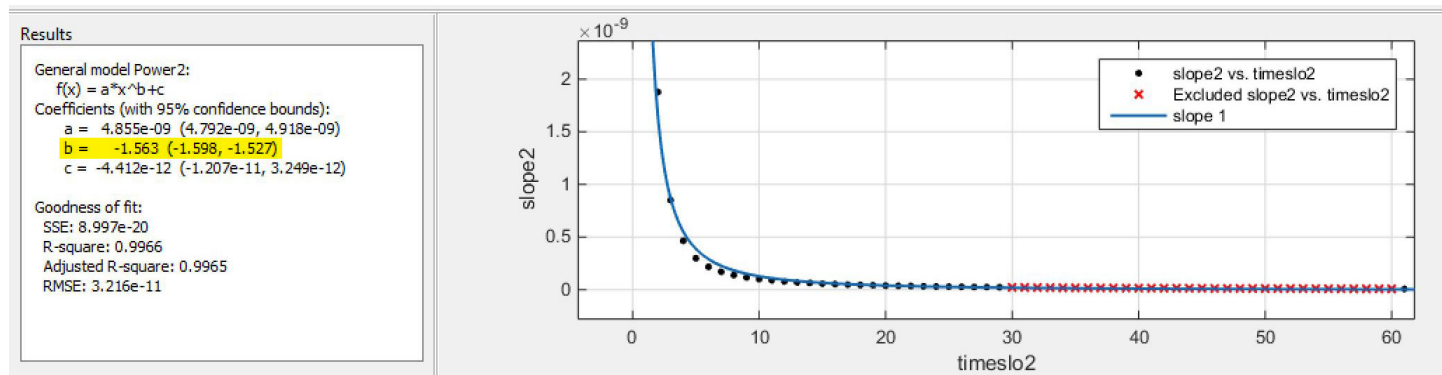


Figure 5: Power Law

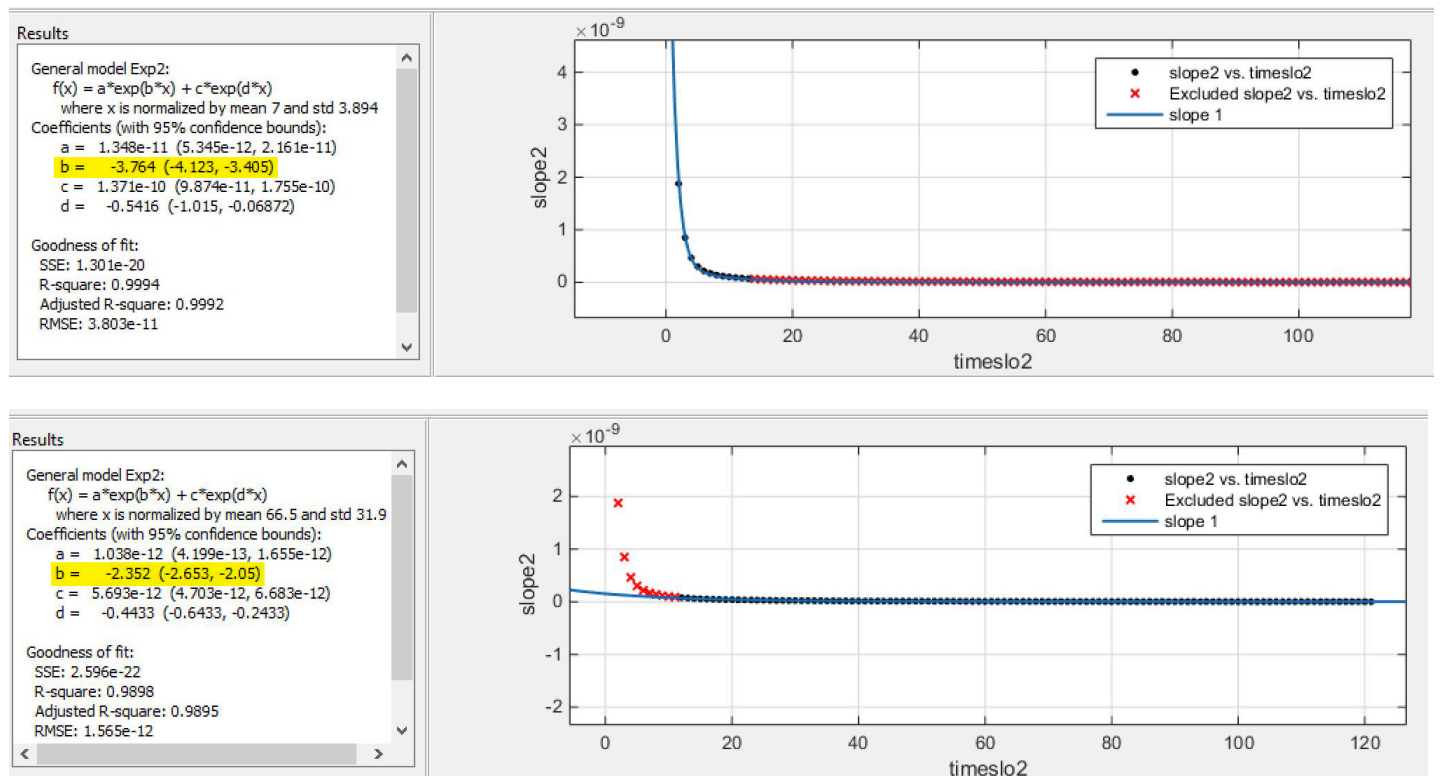


Figure 6: Exponential fitting

2 A series of measurements

A series of measurements was taken to all three GEMs. We applied a voltage of 500V waited ~20 min for each GEM to get charged and then dropped the voltage to 0 and waited about the same time while it discharged.

2.1 1st GEM

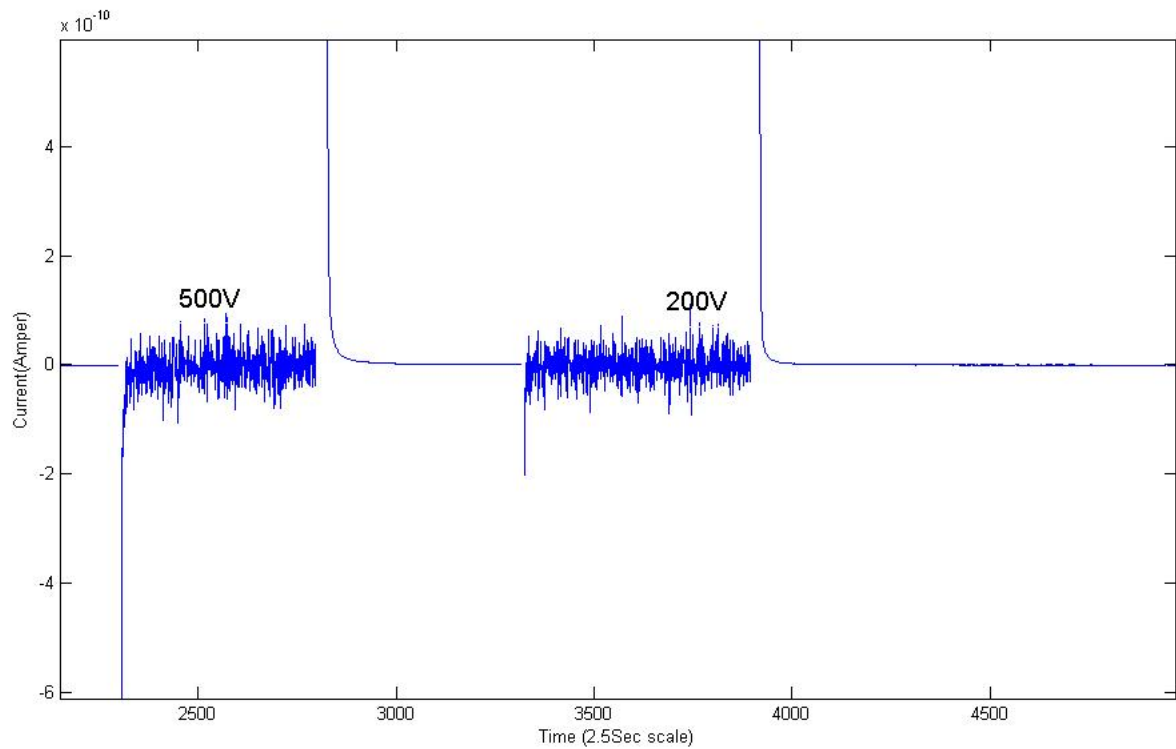


Figure 7: 1st GEM Current Measurement

2.1.1 500V, 1250Sec

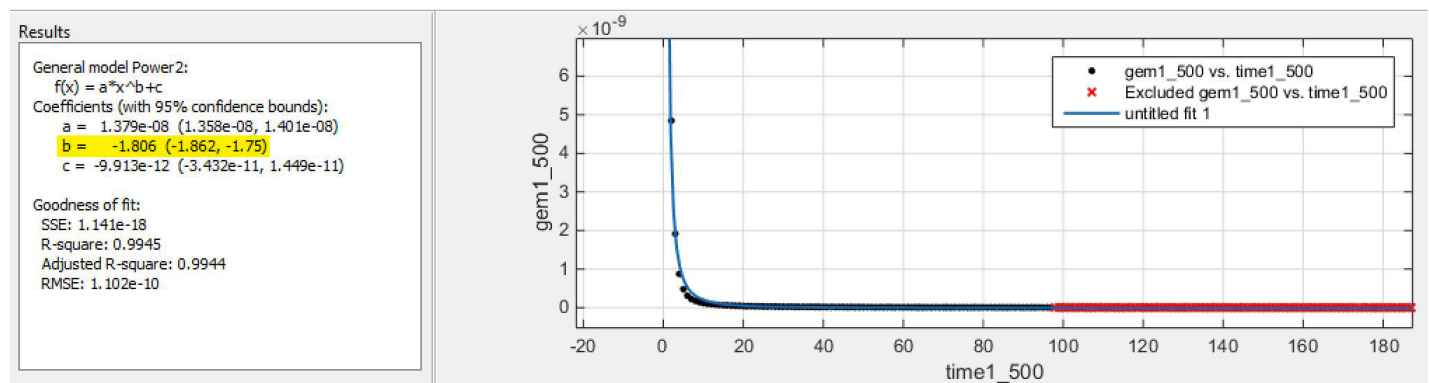


Figure 8: Power Law

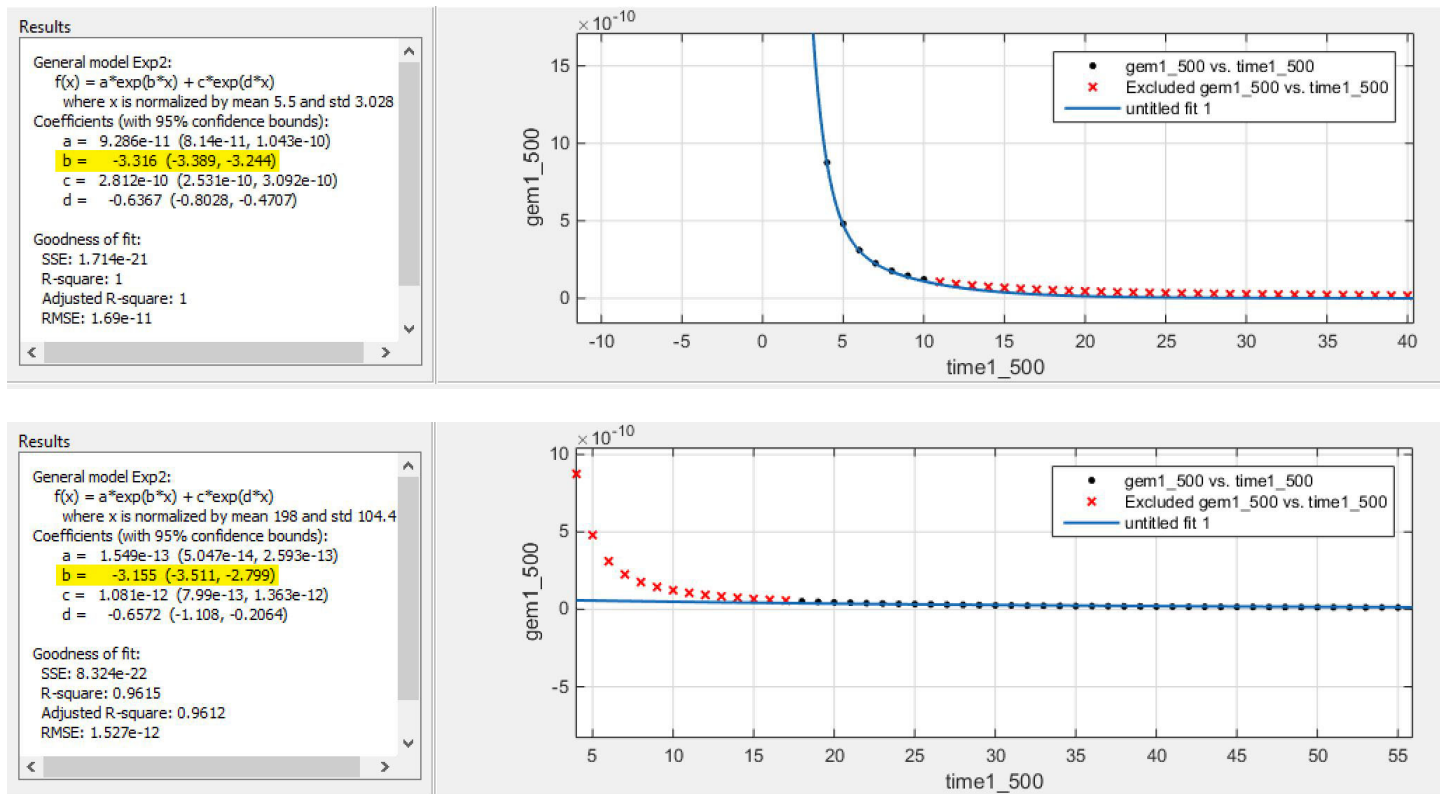


Figure 9: Exponential fitting

2.1.2 Resistance

$$\begin{aligned}
 R &= \frac{500}{7.3126 \cdot 10^{-13} - (-2.808 \cdot 10^{-12})} \\
 &= 1.4127 \cdot 10^{14} \\
 \frac{\sigma_{I_1}}{\sqrt{N}} &= \frac{3.3822 \cdot 10^{-11}}{\sqrt{351}} = 1.8052 \cdot 10^{-12} \\
 \frac{\sigma_{I_{10}}}{\sqrt{N}} &= \frac{3.5298 \cdot 10^{-13}}{\sqrt{251}} = 2.2279 \cdot 10^{-14}
 \end{aligned}$$

2.1.3 200V, 1250Sec

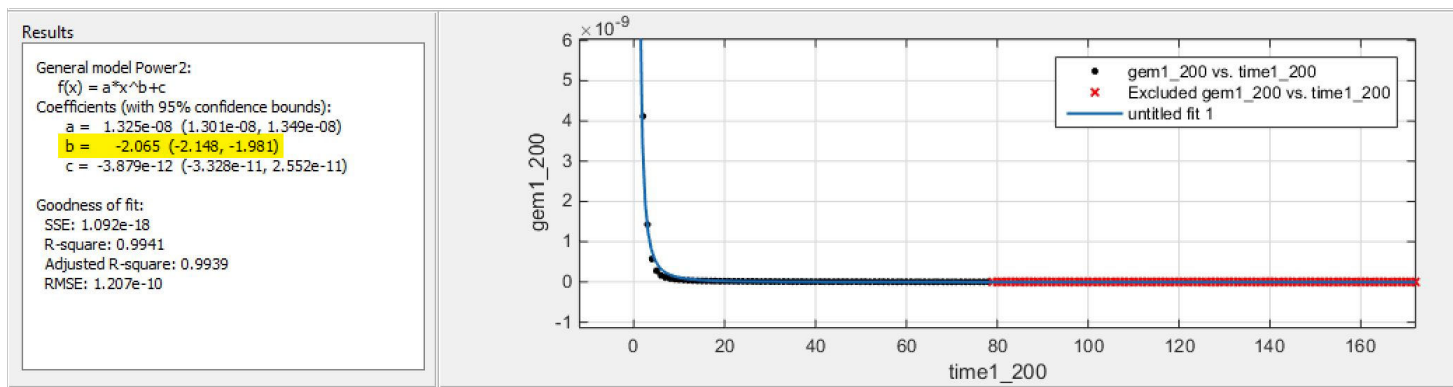


Figure 10: Power Law

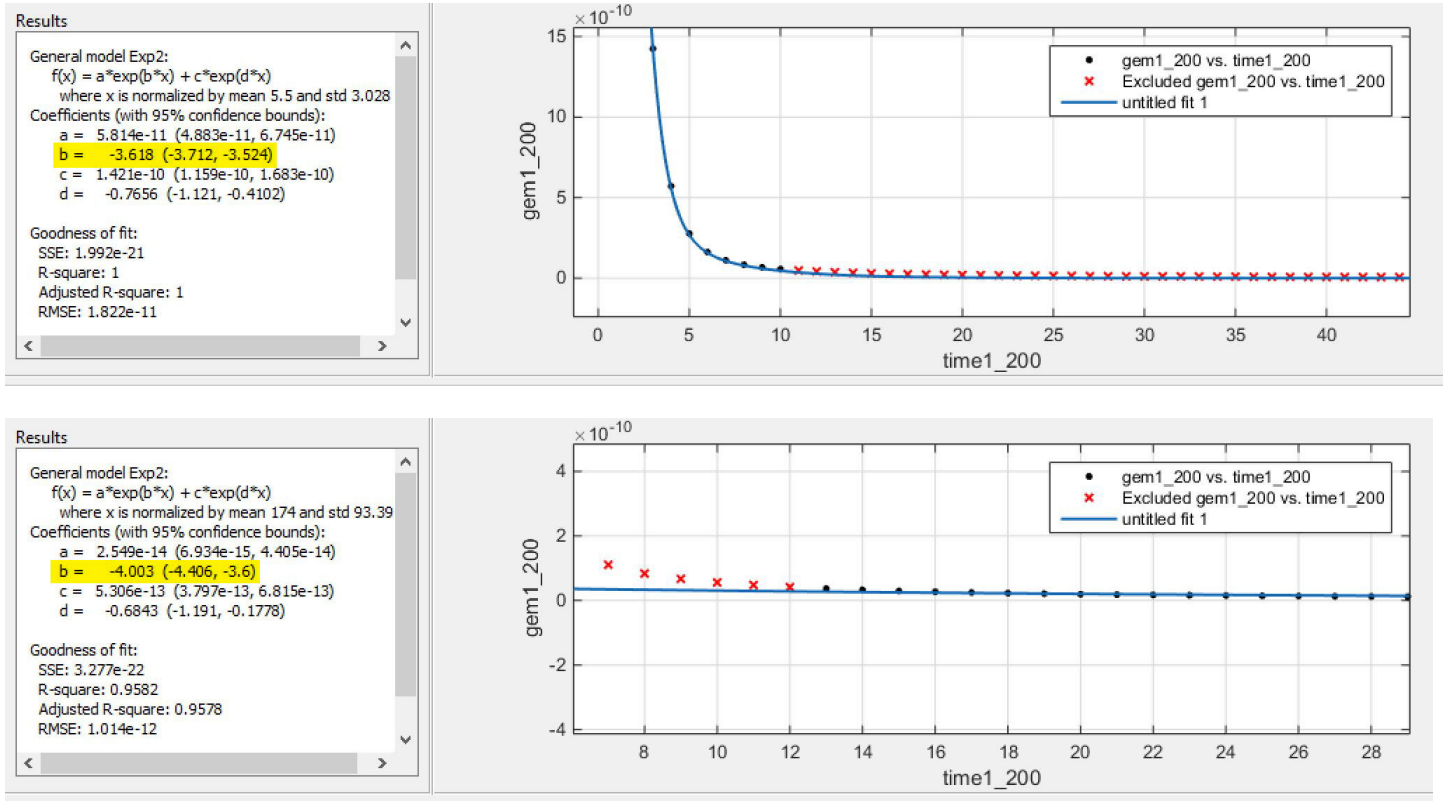


Figure 11: Exponential fitting

2.1.4 Resistance

$$\begin{aligned}
 R &= \left| \frac{200}{-1.6762 \cdot 10^{-12} - (-9.4347 \cdot 10^{-14})} \right| \\
 &= 1.26433 \cdot 10^{14} \\
 \frac{\sigma_{I_1}}{\sqrt{N}} &= \frac{3.0258 \cdot 10^{-11}}{\sqrt{401}} = 1.511 \cdot 10^{-12} \\
 \frac{\sigma_{I_{10}}}{\sqrt{N}} &= \frac{9.9655 \cdot 10^{-14}}{\sqrt{401}} = 4.9765 \cdot 10^{-15}
 \end{aligned}$$

2.2 2nd GEM

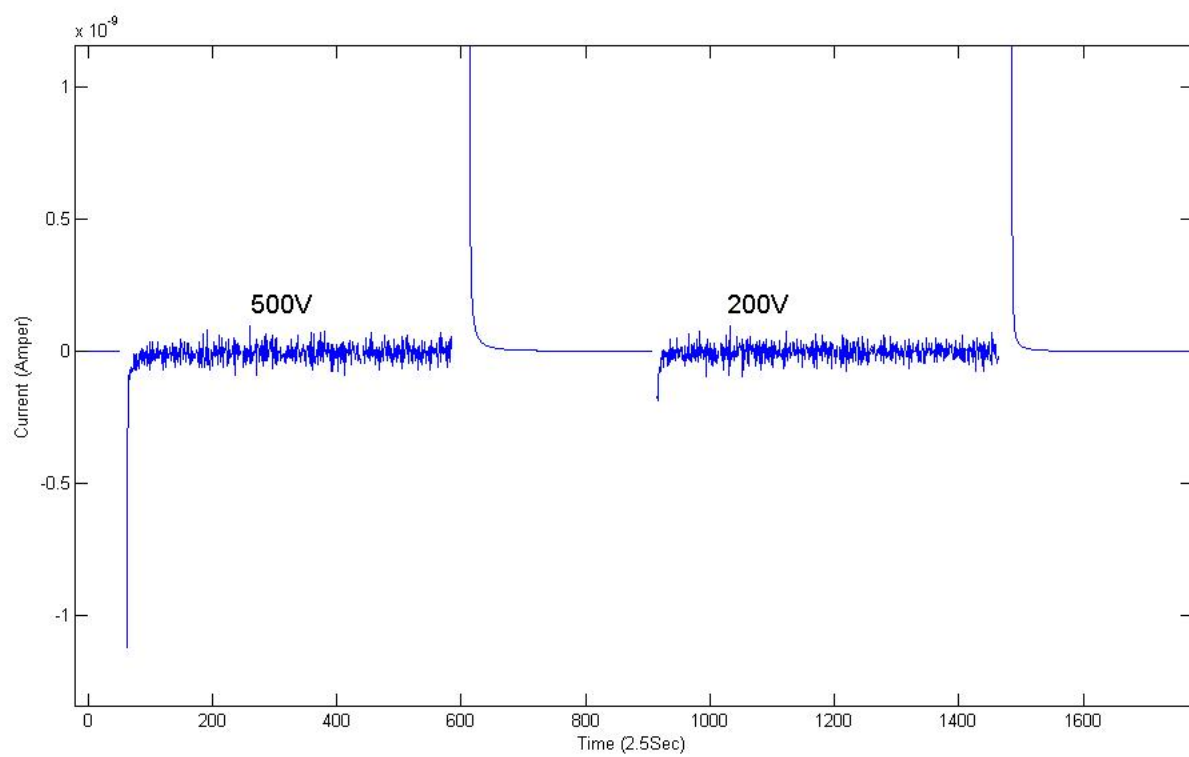


Figure 12: 2nd GEM Current Measurement

2.2.1 500V, 1250Sec

In this part we used a curve fitting of a stretched exponential $\sim e^{-\left(\frac{t}{\tau_0}\right)^\beta}$ - i.e taking the logarithmic scale and then looking for a power law

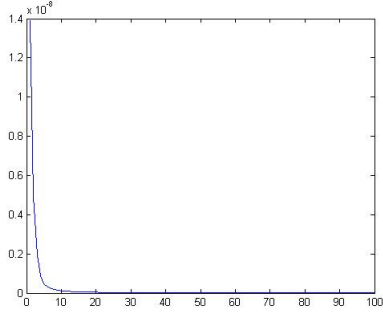


Figure 13: plain data

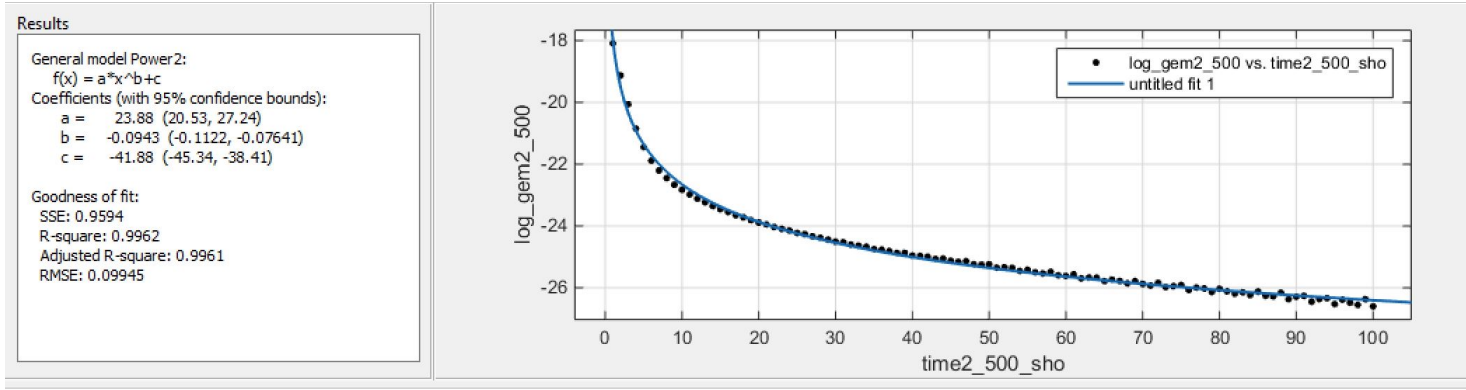


Figure 14: power law for logarithmic scale

$$I(t) \sim e^{-41.88} e^{23.88t^{-0.0943}}$$

2.2.2 Resistance

$$\begin{aligned} R &= \frac{500}{1.4202 \cdot 10^{-12} - (-4.0676 \cdot 10^{-12})} \\ &= 9.111 \cdot 10^{13} \\ \frac{\sigma_{I_2}}{\sqrt{N}} &= \frac{3.2265 \cdot 10^{-11}}{\sqrt{401}} = 1.61124 \cdot 10^{-12} \\ \frac{\sigma_{I_{20}}}{\sqrt{N}} &= \frac{2.7717 \cdot 10^{-13}}{\sqrt{101}} = 2.75794 \cdot 10^{-14} \end{aligned}$$

2.2.3 200V, 1250Sec

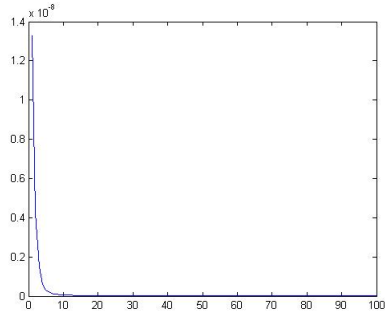


Figure 15: plain data

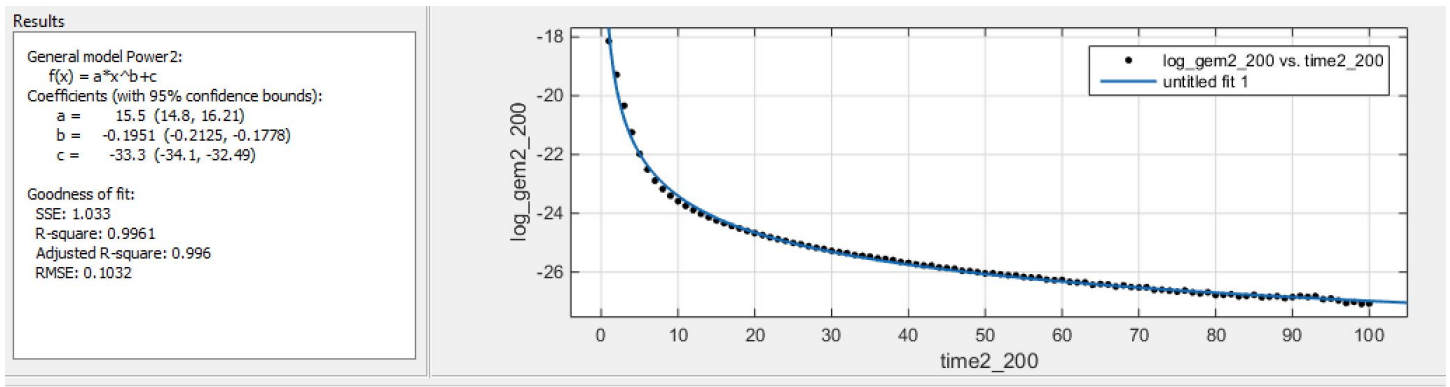


Figure 16: power law for logarithmic scale

$$I(t) \sim e^{-33.3} e^{15.5t^{-0.1951}}$$

2.2.4 Resistance

$$\begin{aligned} R &= \left| \frac{200}{1.2088 \cdot 10^{-12} - (-5.4937 \cdot 10^{-14})} \right| \\ &= \mathbf{1.5826 \cdot 10^{14}} \\ \frac{\sigma_{I_1}}{\sqrt{N}} &= \frac{2.9518 \cdot 10^{-11}}{\sqrt{401}} = 1.47406 \cdot 10^{-12} \\ \frac{\sigma_{I_{10}}}{\sqrt{N}} &= \frac{5.1686 \cdot 10^{-13}}{\sqrt{141}} = 4.35275 \cdot 10^{-14} \end{aligned}$$

2.3 3rd GEM

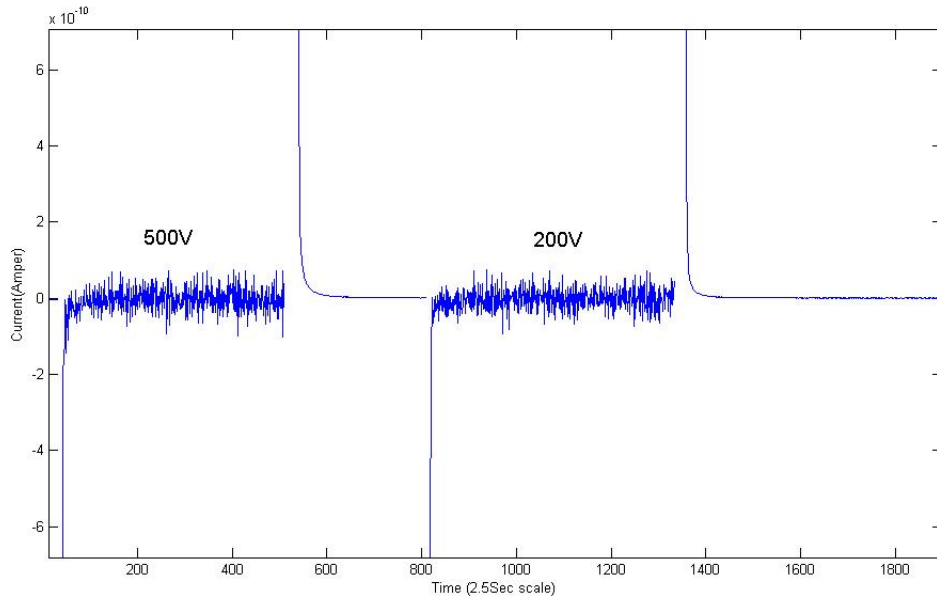


Figure 17: 3rd GEM Current Measurement

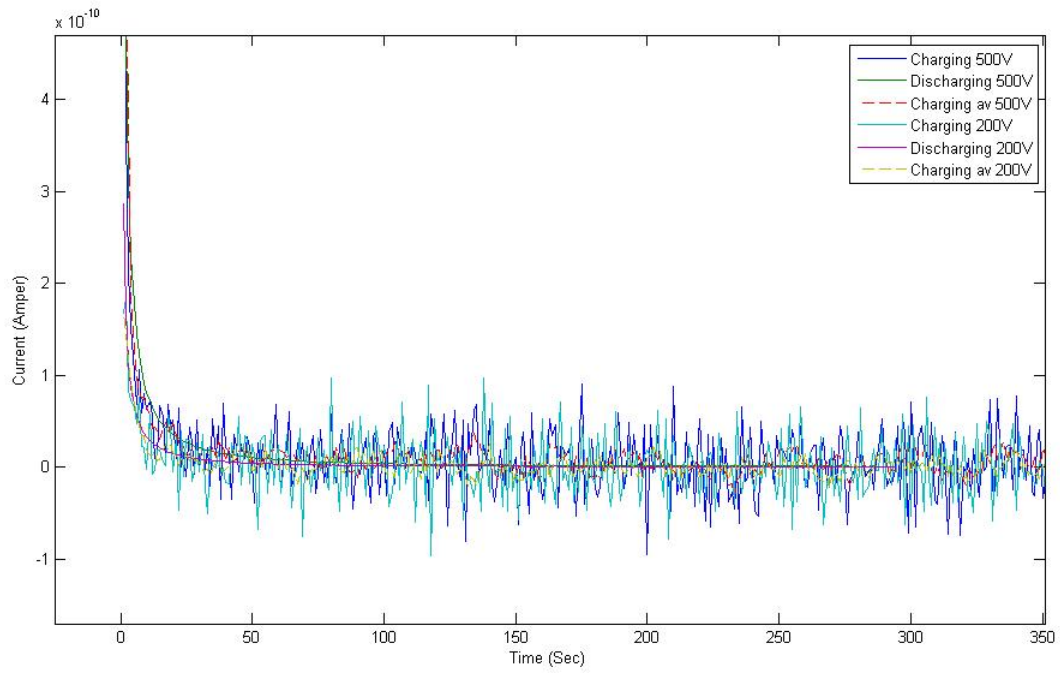


Figure 18: Discharging and Charging Overlapping

2.3.1 500V, 1250Sec

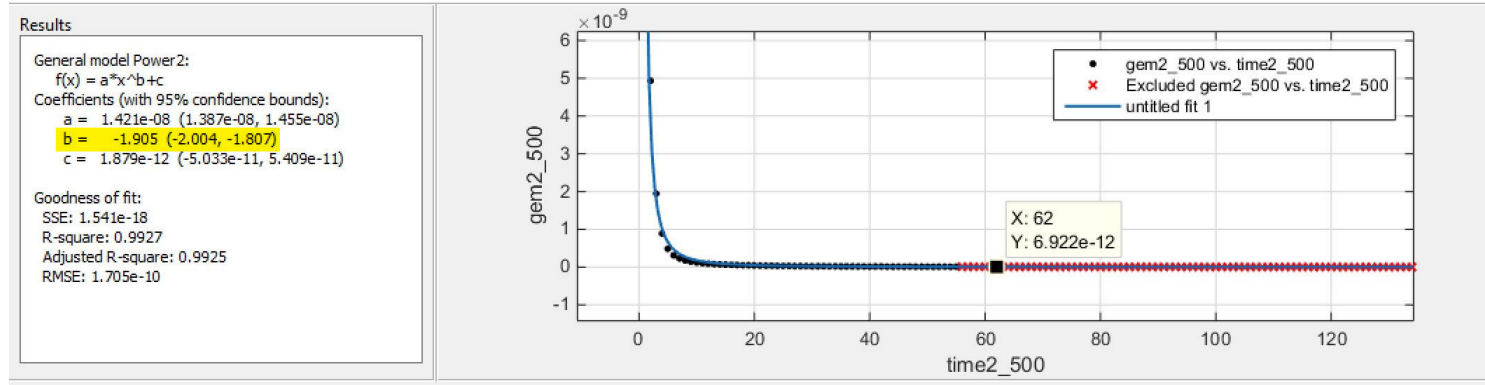


Figure 19: Power Law

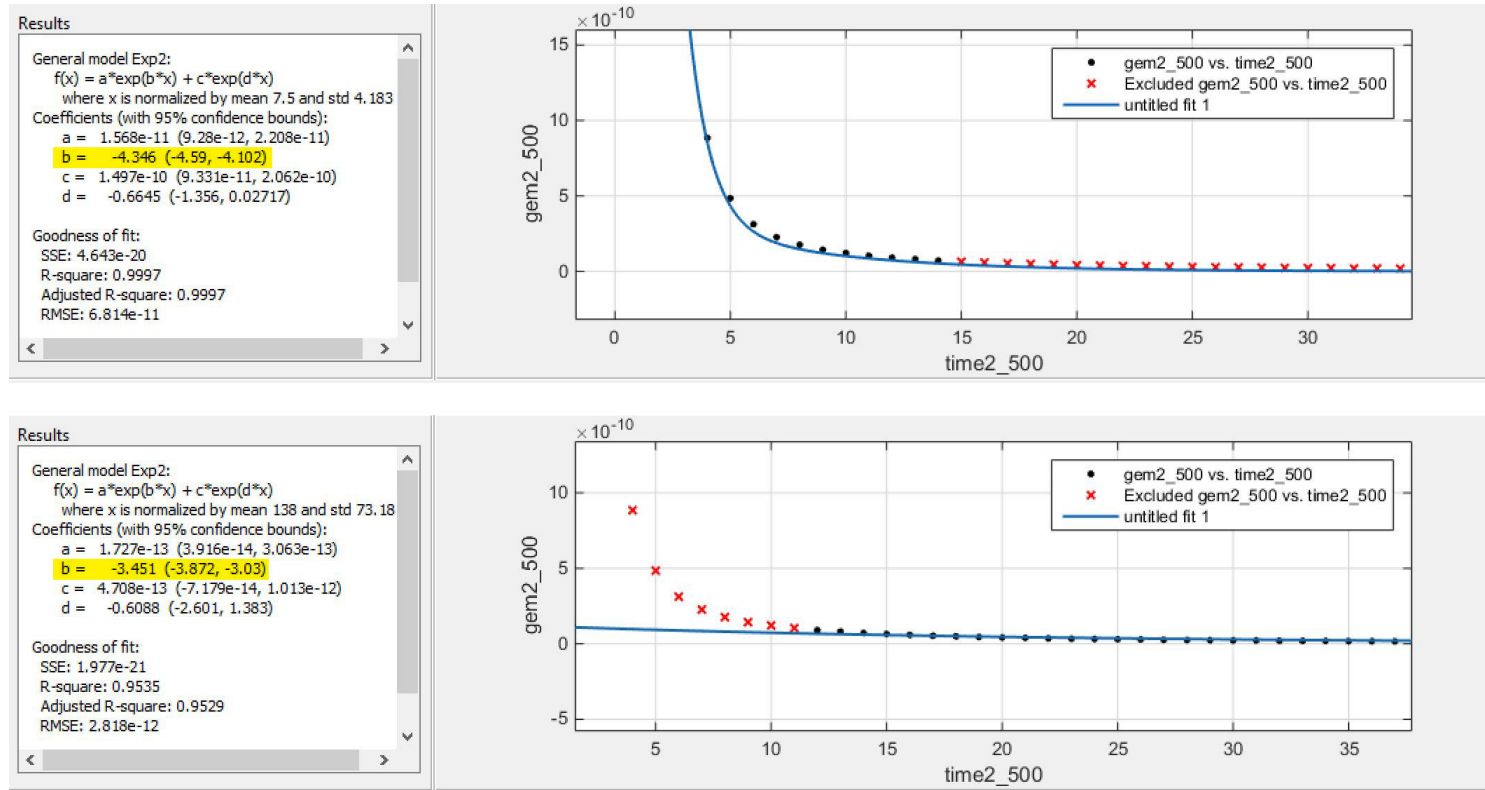


Figure 20: Exponential fitting

2.3.2 Resistance

$$R = \frac{500}{8.0289 \cdot 10^{-13} - (-2.3525 \cdot 10^{-12})}$$

$$= 1.58459 \cdot 10^{14}$$

$$\frac{\sigma_{I_3}}{\sqrt{N}} = \frac{3.1719 \cdot 10^{-11}}{\sqrt{351}} = 1.6930 \cdot 10^{-12}$$

$$\frac{\sigma_{I_{30}}}{\sqrt{N}} = \frac{3.1378 \cdot 10^{-13}}{\sqrt{81}} = 3.48644 \cdot 10^{-14}$$

2.3.3 200V, 1250Sec

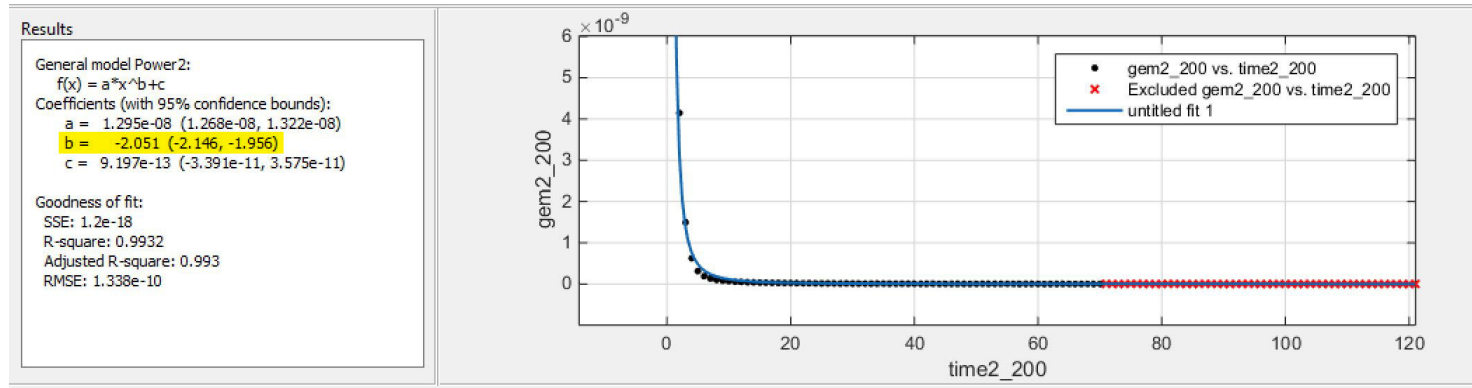


Figure 21: Power Law

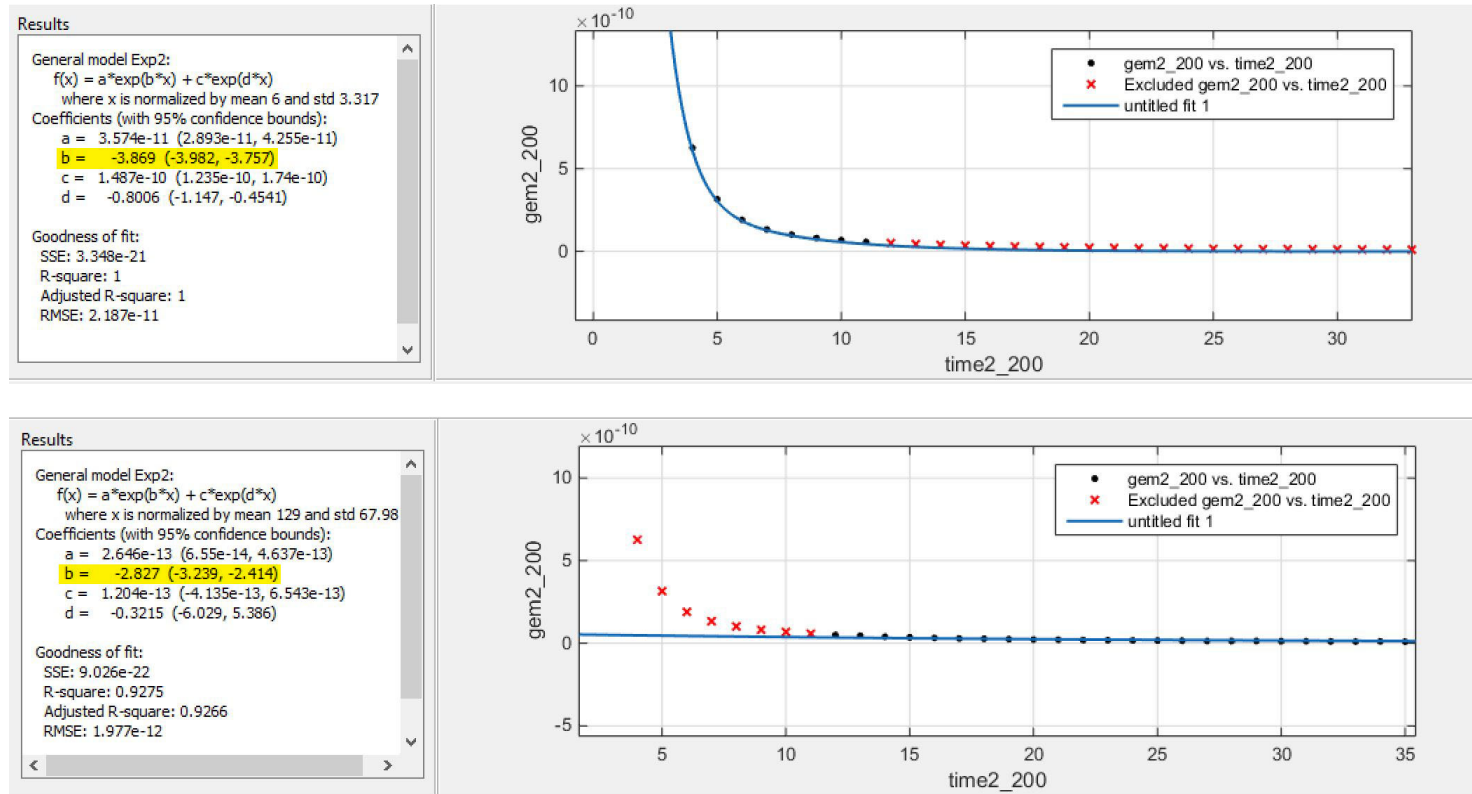


Figure 22: Exponential fitting

2.3.4 Resistance

$$\begin{aligned}
 R &= \frac{200}{3.64 \cdot 10^{-13} - (-1.4773 \cdot 10^{-12})} \\
 &= 1.0861 \cdot 10^{14} \\
 \frac{\sigma_{I_3}}{\sqrt{N}} &= \frac{2.9483 \cdot 10^{-11}}{\sqrt{401}} = 1.4723 \cdot 10^{-12} \\
 \frac{\sigma_{I_{30}}}{\sqrt{N}} &= \frac{3.5475 \cdot 10^{-13}}{\sqrt{301}} = 2.0447 \cdot 10^{-14}
 \end{aligned}$$

3 Overnight measurement

3.1 Resistance

$$\begin{aligned} R_1 &= \frac{500}{2.70 \cdot 10^{-14} - (-3.8060 \cdot 10^{-13})} \\ &= \mathbf{1.226 \cdot 10^{15}} \end{aligned}$$

$$\begin{aligned} R_2 &= \frac{500}{-1.688 \cdot 10^{-13} - (-2.9633 \cdot 10^{-13})} \\ &= \mathbf{3.9206 \cdot 10^{15}} \end{aligned}$$

$$\begin{aligned} \left| \frac{\sigma_R}{R} \right| &= \left| \frac{\sigma_I}{I} \right| \\ &\sim \frac{1.7146 \cdot 10^{-11}}{2.9633 \cdot 10^{-13}} \sim 57.86 \\ \frac{\sigma_{I_2}}{\sqrt{N}} &= \frac{1.7146 \cdot 10^{-11}}{\sqrt{26001}} = 1.063 \cdot 10^{-13} \\ \frac{\sigma_{I_{20}}}{\sqrt{N}} &= \frac{1.7937 \cdot 10^{-13}}{\sqrt{8001}} = 2.005 \cdot 10^{-15} \end{aligned}$$

4 Resistance Summery Table

GEM#	V	R	Mean
1	200V	$1.26433 \cdot 10^{14}$	
	500V	$1.4127 \cdot 10^{14}$	
2	200V	$9.111 \cdot 10^{13}$	
	500V	$1.5826 \cdot 10^{14}$	
	750V	$8.07041 \cdot 10^{13}$	
	750V	$3.634 \cdot 10^{13}$	
	500V	$9.7696 \cdot 10^{13}$	
	500V	$1.7104 \cdot 10^{13}$	
	500V	$1.47499 \cdot 10^{13}$	
	200V	$2.573 \cdot 10^{14}$	Over 500V - $7.19524 \cdot 10^{14}$
	500V over night	$1.226 \cdot 10^{15}$	
	500V over night	$3.9206 \cdot 10^{15}$	
3	200V	$1.0861 \cdot 10^{14}$	
	500V	$1.58459 \cdot 10^{14}$	

5 Odd measurements

We had a series of strange results when we reversed the field applied in the GEM. We couldn't repeat the result, so we conclude that there was probably some problem with the measure apparatus.

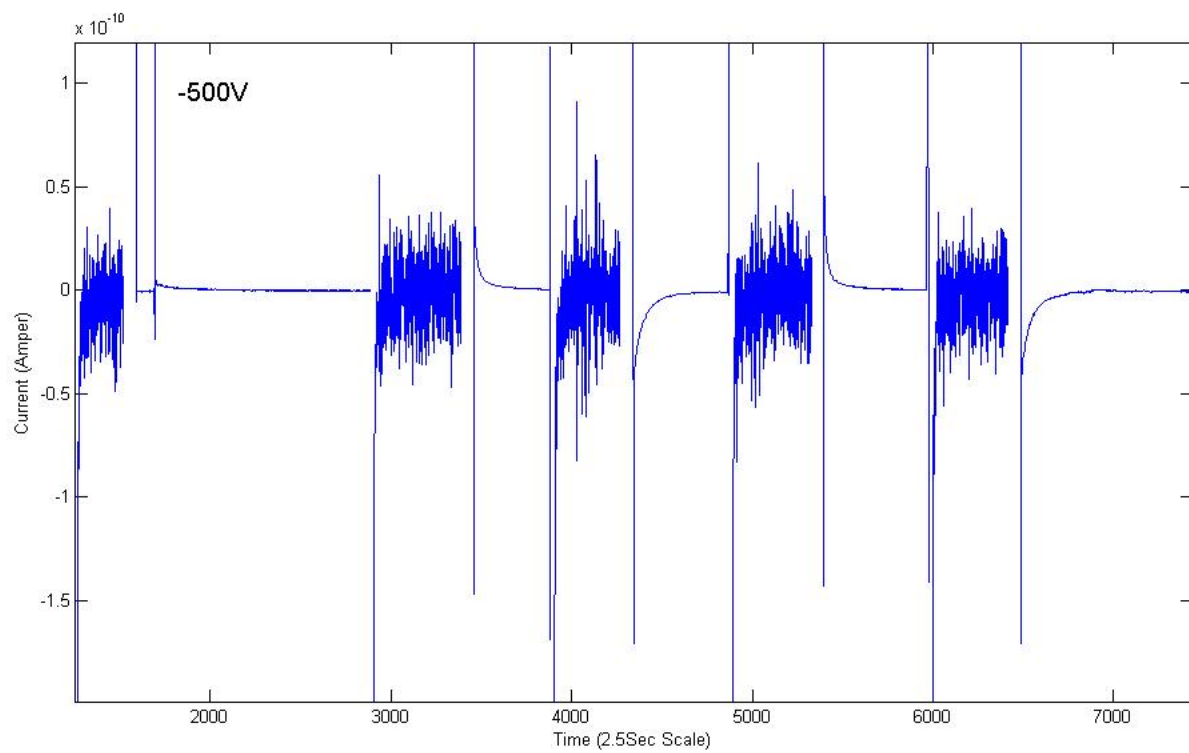
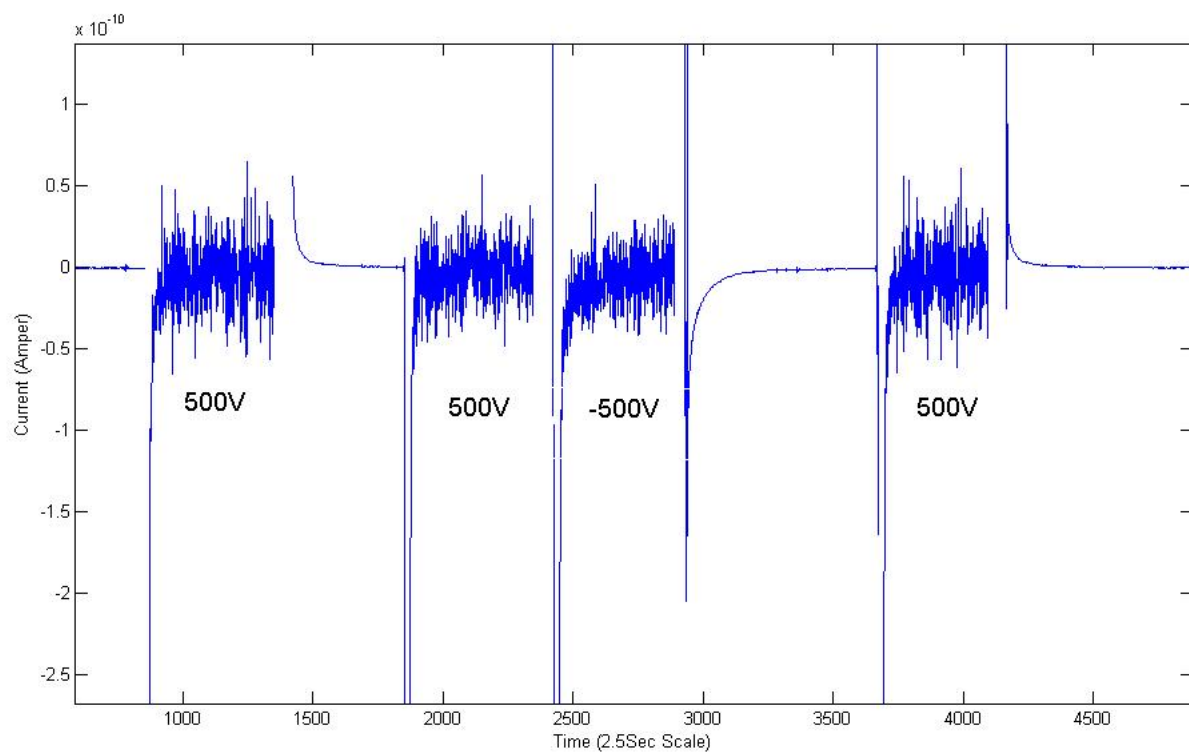


Figure 23: