

protoDUNE DP lifetime analysis

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Introduction

The variables quoted below on the analysis output are obtained as follows:

```
double E1 = VC/1.8; // V/cm (cathode-cathode/grid)
double E2 = VA*0.948/47.; // V/cm cathode/grid-anode/grid
double E3 = VA*0.052/0.79; // V/cm anode/grid-anode

double T12=1.;
if (E2<E1) T12 = E2/E1;

double T23 = 1.;
if (E3<E2) T23 = E3/E2;

// ... compute drift time
double tdc = 1.8/FUNC->ElectronDriftVelocity(E1);
double tda = 0.8/FUNC->ElectronDriftVelocity(E3);

// ... computing purity
double T = T12*T23;
double QC = Y[min1_index];
double QA = Y[min2_index];
double PUR = -(X[min2_index]-X[min1_index])/log(QA/T/QC);
```

Lifetime monitor data from 02 dec 2019

new oscilloscope

cathode=300 V anode=3000V

cathode, anode separated signal analysis

```
=> VOLTAGES: Cathode=300.000000 (V) Anode=3000.000000 (V)
=> DRIFT times tdc=26.528134 (micro sec) tda=10.383455 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=60.510638 (V/cm) E3=197.468354 (V/cm)
=> TRANSMISSION FACTORS: T12=0.363064 T23=1.000000 T=T12*T13=0.363064
=> PEAK SIGNALS: vCmax=-2.887841 vAmax=-0.900989
=> TIMES (microsec): tC=-12.000000 tA=1416.600000 dt=1428.600000
=> PURITY = 9.423832 (milisec)
```

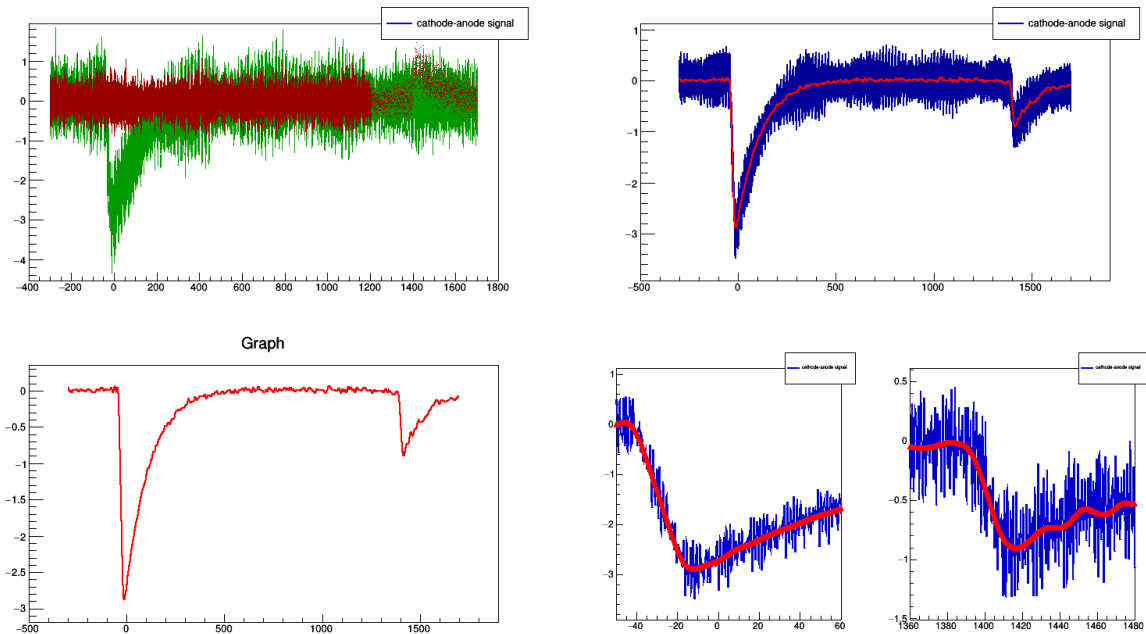


Figure 1:

cathode-anode oscilloscope subtracted signal analysis

```
=> VOLTAGES: Cathode=300.000000 (V) Anode=3000.000000 (V)
=> DRIFT times tdc=26.528134 (micro sec) tda=10.383455 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=60.510638 (V/cm) E3=197.468354 (V/cm)
=> TRANSMISSION FACTORS: T12=0.363064 T23=1.000000 T=T12*T13=0.363064
=> PEAK SIGNALS: vCmax=-2.894866 vAmax=-0.897527
=> TIMES (microsec): tC=-12.400000 tA=1417.000000 dt=1429.400000
=> PURITY = 9.054026 (milisec)
```

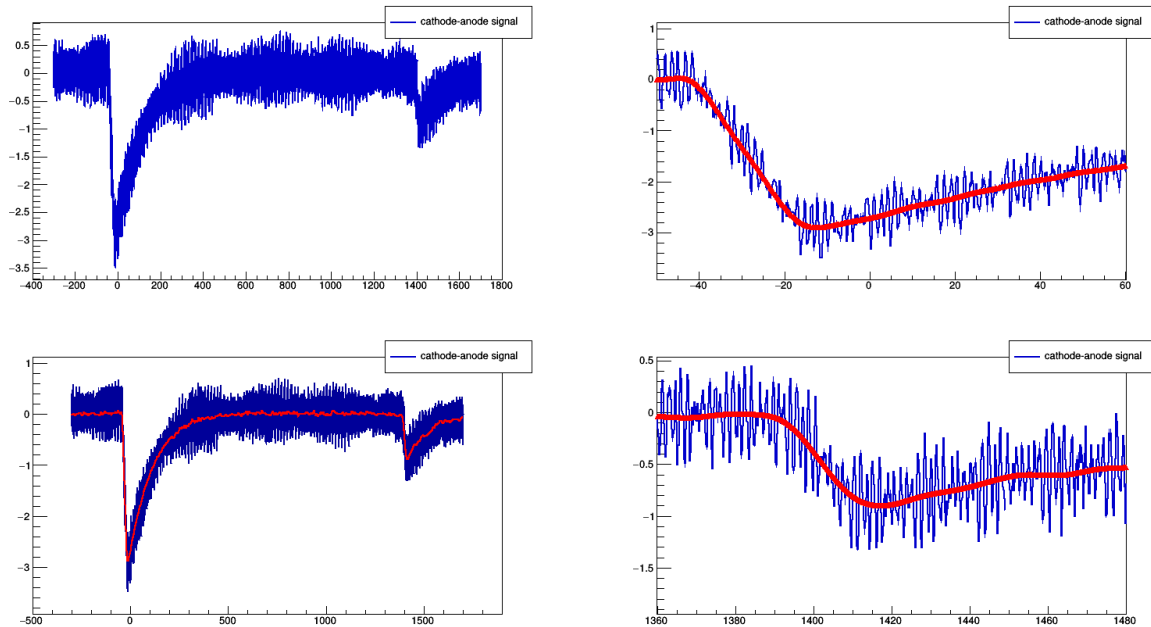


Figure 2:

cathode=255 V anode=3000V

cathode, anode separated signal analysis

```
=> VOLTAGES: Cathode=255.000000 (V) Anode=3000.000000 (V)
=> DRIFT times tdc=30.109870 (micro sec) tda=10.383455 (micro sec)
=> E FIELD: E1=141.666667 (V/cm) E2=60.510638 (V/cm) E3=197.468354 (V/cm)
=> TRANSMISSION FACTORS: T12=0.427134 T23=1.000000 T=T12*T13=0.427134
=> PEAK SIGNALS: vCmax=-2.564222 vAmax=-0.923818
=> TIMES (microsec): tC=-7.800000 tA=1424.600000 dt=1432.400000
=> PURITY = 8.414146 (milisec)
```

cathode-anode oscilloscope subtracted signal analysis

```
=> VOLTAGES: Cathode=255.000000 (V) Anode=3000.000000 (V)
=> DRIFT times tdc=30.109870 (micro sec) tda=10.383455 (micro sec)
=> E FIELD: E1=141.666667 (V/cm) E2=60.510638 (V/cm) E3=197.468354 (V/cm)
=> TRANSMISSION FACTORS: T12=0.427134 T23=1.000000 T=T12*T13=0.427134
=> PEAK SIGNALS: vCmax=-2.570565 vAmax=-0.918529
=> TIMES (microsec): tC=-8.000000 tA=1419.800000 dt=1427.800000
=> PURITY = 8.001111 (milisec)
```

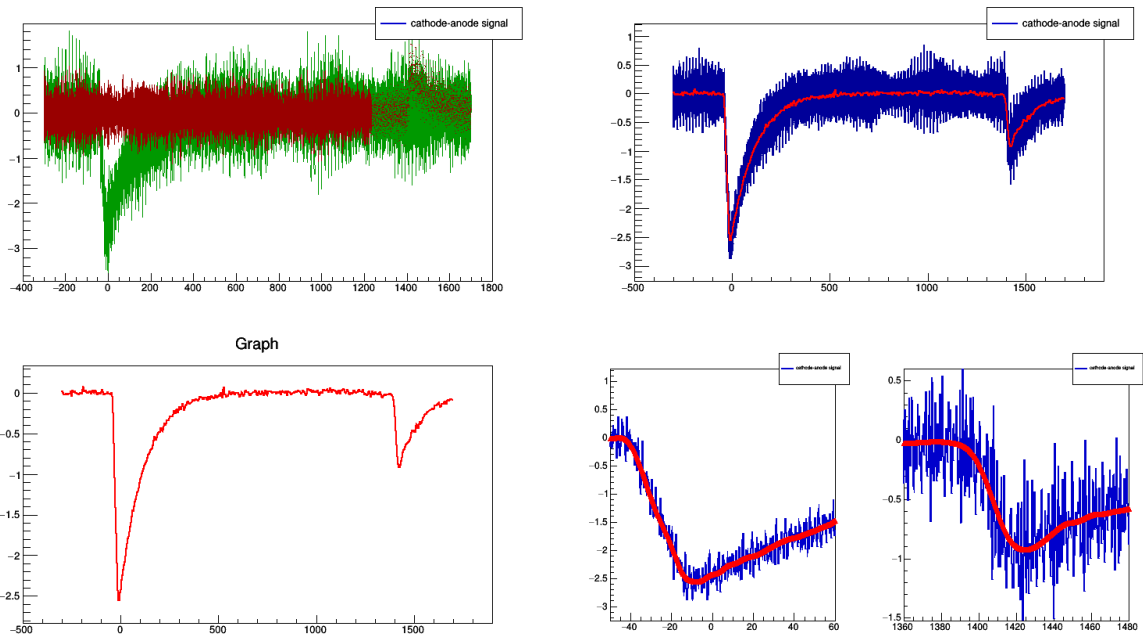


Figure 3:

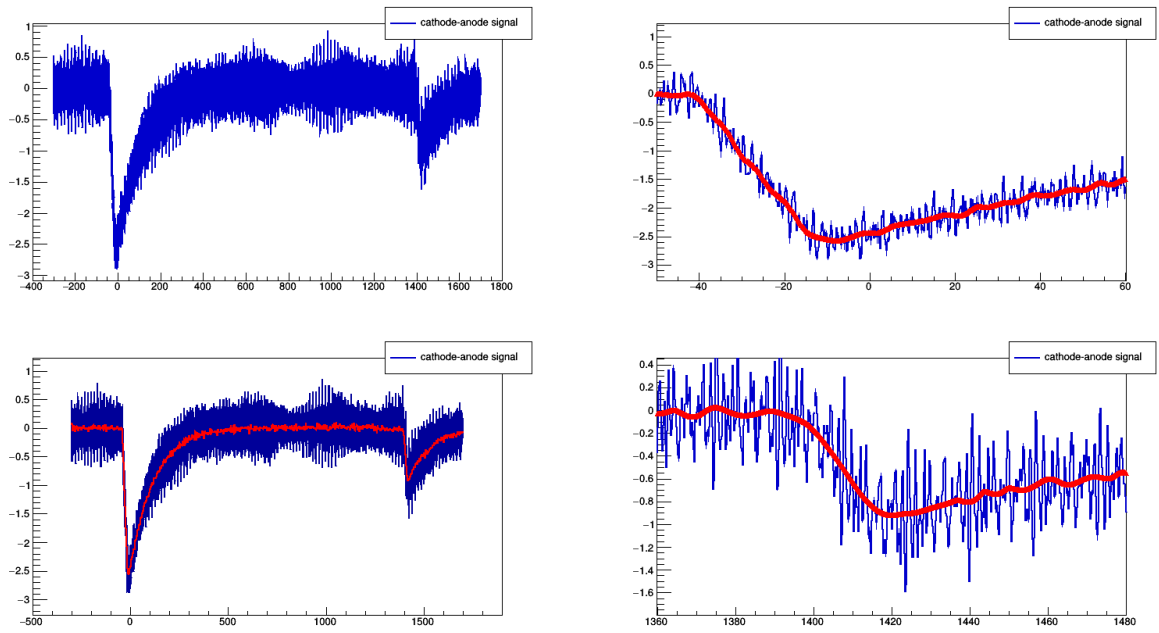


Figure 4:

cathode=255 V anode=4000V

cathode, anode separated signal analysis

```
=> VOLTAGES: Cathode=255.000000 (V) Anode=4000.000000 (V)
=> DRIFT times tdc=30.109870 (micro sec) tda=8.466319 (micro sec)
=> E FIELD: E1=141.666667 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)
=> TRANSMISSION FACTORS: T12=0.569512 T23=1.000000 T=T12*T13=0.569512
=> PEAK SIGNALS: vCmax=-2.604896 vAmax=-1.282665
=> TIMES (microsec): tC=-10.200000 tA=1078.200000 dt=1088.400000
=> PURITY = 7.481587 (milisec)
```

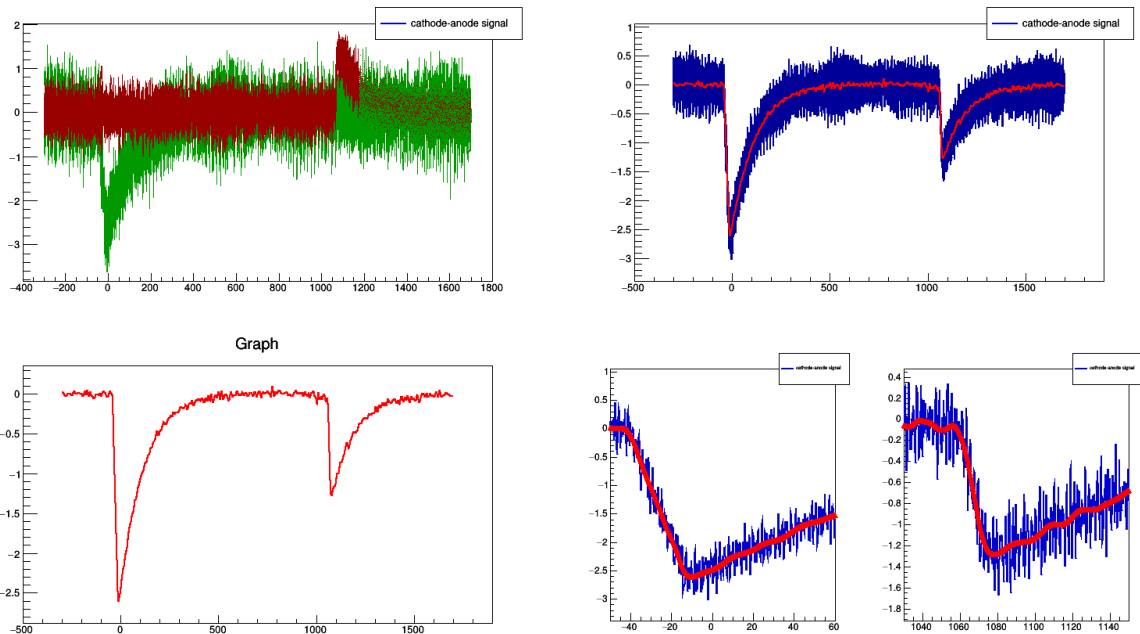


Figure 5:

cathode-anode oscilloscope subtracted signal analysis

```
=> VOLTAGES: Cathode=255.000000 (V) Anode=4000.000000 (V)
=> DRIFT times tdc=30.109870 (micro sec) tda=8.466319 (micro sec)
=> E FIELD: E1=141.666667 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)
=> TRANSMISSION FACTORS: T12=0.569512 T23=1.000000 T=T12*T13=0.569512
=> PEAK SIGNALS: vCmax=-2.598234 vAmax=-1.285844
=> TIMES (microsec): tC=-8.800000 tA=1078.800000 dt=1087.600000
=> PURITY = 7.744182 (milisec)
```

Lifetime monitor data from 29 nov 2019

cathode=350 V anode=4000V

cathode-anode signal analysis

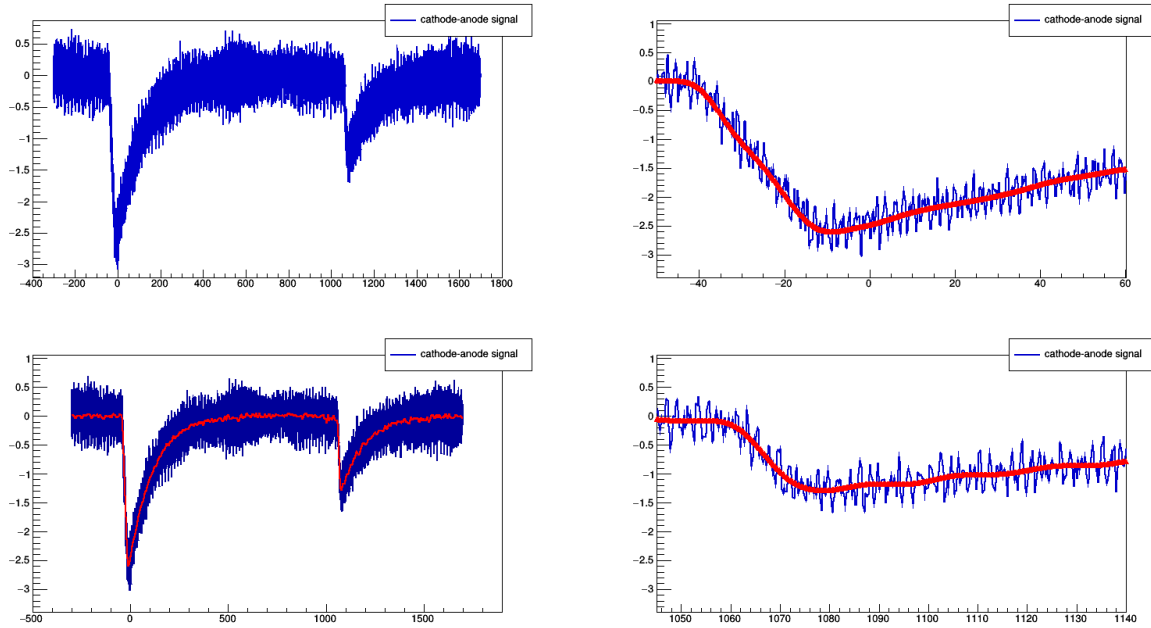


Figure 6:

analysed signal (F1) from new LeCroy oscilloscope already subtracted

Finding EMD minima (N=10002)...

after EMD subtraction: minima index = 1420 6865 / values = -3.298737 -1.178920 -1.178920 times = -16.200000

E=194.444444 Temp=87.300000 vel=0.076176 (cm/microsec)

E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)

PURITY lifetime calculation...

=> VOLTAGES: Cathode=350.000000 (V) Anode=4000.000000 (V)

=> DRIFT times tdc=23.629494 (micro sec) tda=8.466319 (micro sec)

=> E FIELD: E1=194.444444 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)

=> TRANSMISSION FACTORS: T12=0.414930 T23=1.000000 T=T12*T13=0.414930

=> PEAK SIGNALS: vCmax=-3.298737 vAmax=-1.178920

=> TIMES (microsec): tC=-16.200000 tA=1072.800000 dt=1089.000000

=> PURITY = 7.294254 (milisec)

cathode,anode signal analysis

subtraction cathode (C3) and anode (C4) was made by me

Finding EMD minima (N=10002)...

after EMD subtraction: minima index = 1427 6859 / values = -3.289770 -1.199799 -1.199799 times = -14.800000

E=194.444444 Temp=87.300000 vel=0.076176 (cm/microsec)

E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)

PURITY lifetime calculation...

=> DRIFT times tdc=23.629494 (micro sec) tda=8.466319 (micro sec)

=> E FIELD: E1=194.444444 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)

=> TRANSMISSION FACTORS: T12=0.414930 T23=1.000000 T=T12*T13=0.414930

=> PEAK SIGNALS: vCmax=-3.289770 vAmax=-1.199799

=> TIMES (microsec): tC=-14.800000 tA=1071.600000 dt=1086.400000

=> PURITY = 8.420503 (milisec)

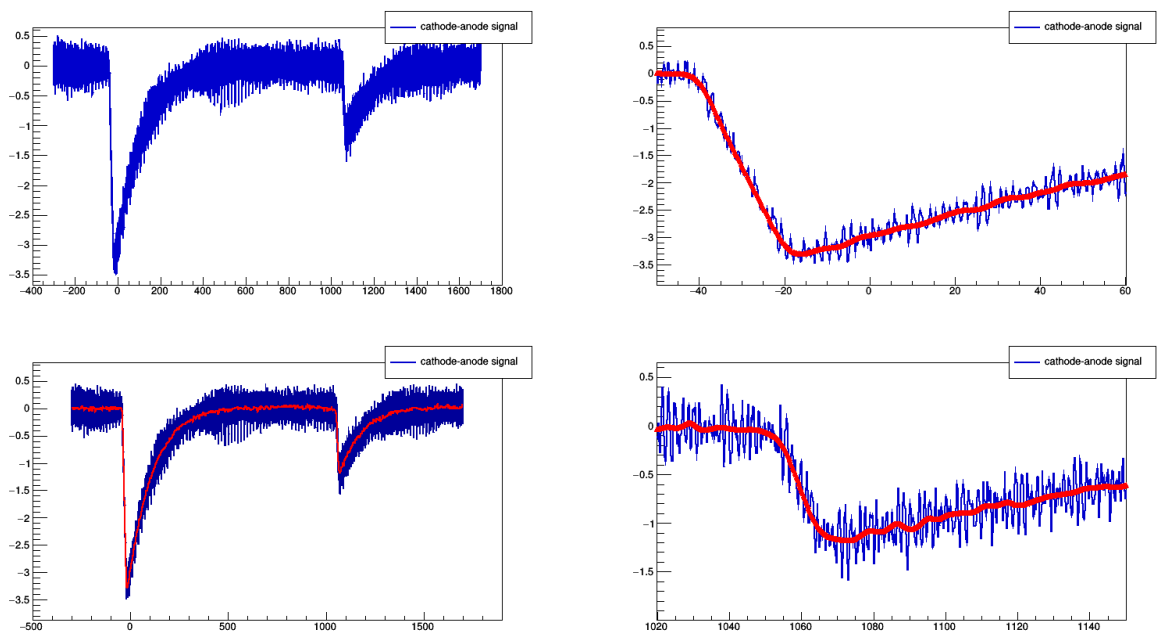


Figure 7:

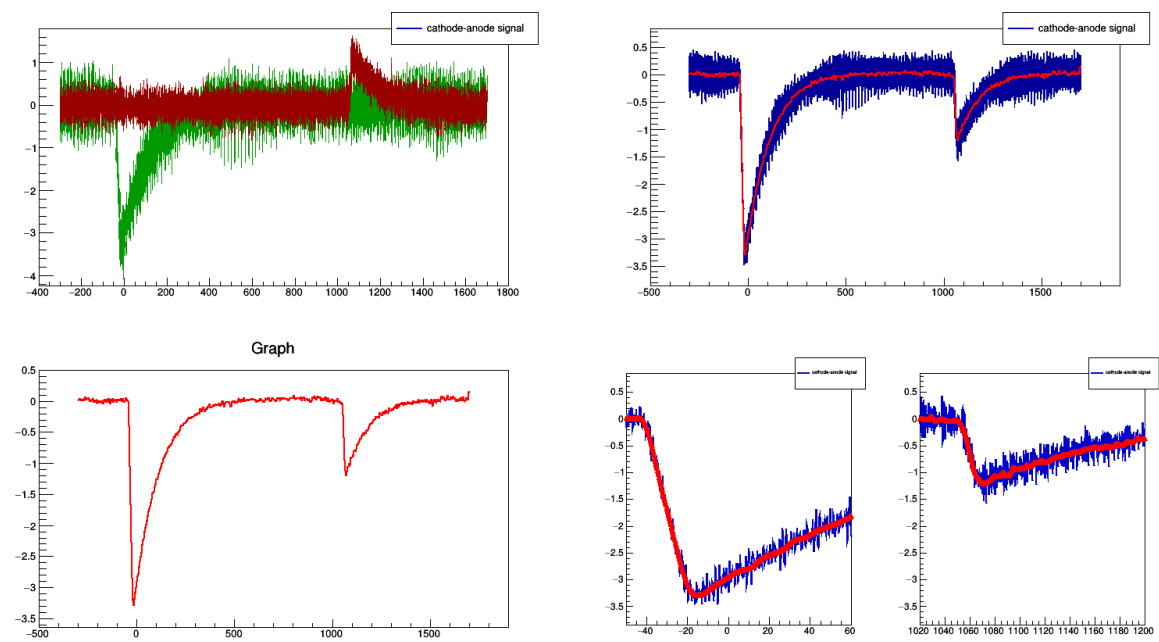


Figure 8:

Lifetime monitor data from 26 nov 2019

RUNS:

cathode=300 V anode=4000V camera ON (NOISY STUFF)

cathode=300 V anode=4000V camera OFF

cathode=400 V anode=4000V camera OFF

cathode=300 V anode=3000V camera OFF

26 Nov 2019: cathode=300 V anode=4000V camera ON (NOISY STUFF)

using Cathode-anode signal already subtracted: noise extraction applied to order 6

```
after EMD subtraction: maxima index = 2250 13086 / values = 2.892700 1.146027 1.146027 times = 29.000000
E=166.666667 Temp=87.300000 vel=0.067852 (cm/microsec)
E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)
PURITY lifetime calculation...
=> VOLTAGES: Cathode=300.000000 (V) Anode=4000.000000 (V)
=> DRIFT times tdc=26.528134 (micro sec) tda=8.466319 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)
=> TRANSMISSION FACTORS: T12=0.484085 T23=1.000000 T=T12*T13=0.484085
=> PEAK SIGNALS: vCmax=2.892700 vAmax=1.146027
=> TIMES: tC=29.000000 tA=1112.600000 dt=1083.600000
=> PURITY = 5.407334 (msec)
```

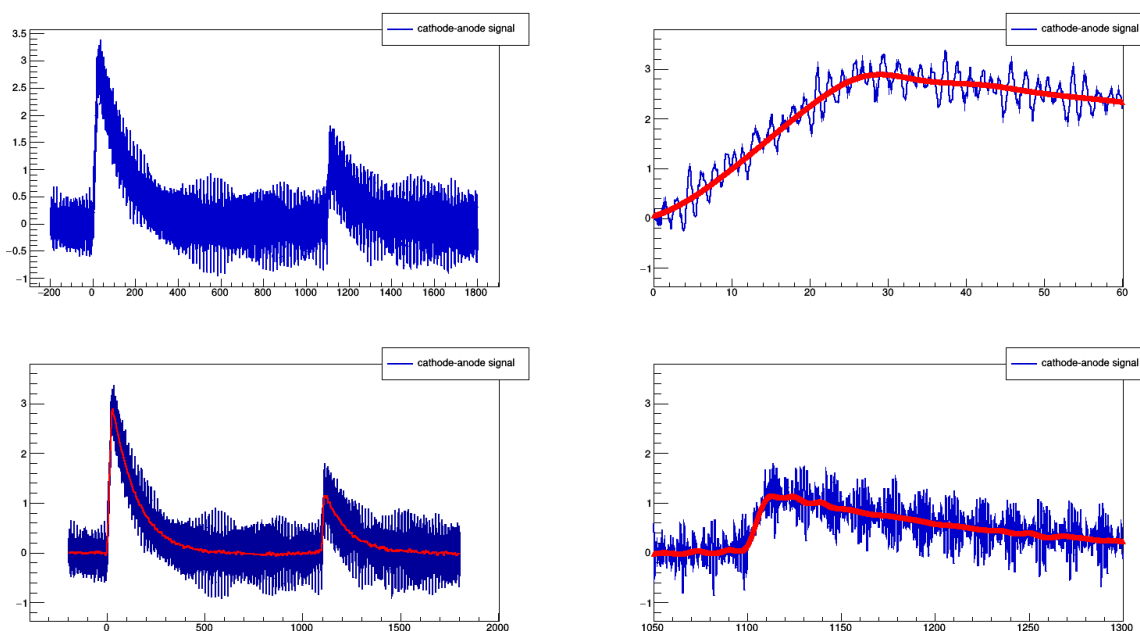


Figure 9:

using Cathode, Anode signals separated and subtracted on analysis: noise extraction applied to order 6

```
after EMD subtraction: minima index = 2267 13134 / values = -1.122418 -0.659395 -0.659395 times = 30.600000
E=166.666667 Temp=87.300000 vel=0.067852 (cm/microsec)
E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)
PURITY lifetime calculation...
=> DRIFT times tdc=26.528134 (micro sec) tda=8.466319 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)
=> TRANSMISSION FACTORS: T12=0.484085 T23=1.000000 T=T12*T13=0.484085
=> PEAK SIGNALS: vCmax=-1.122418 vAmax=-0.659395
=> TIMES (microsec): tC=30.600000 tA=1117.300000 dt=1086.700000
=> PURITY = -5.613795 (milisec)
```

why lifetime is negative?

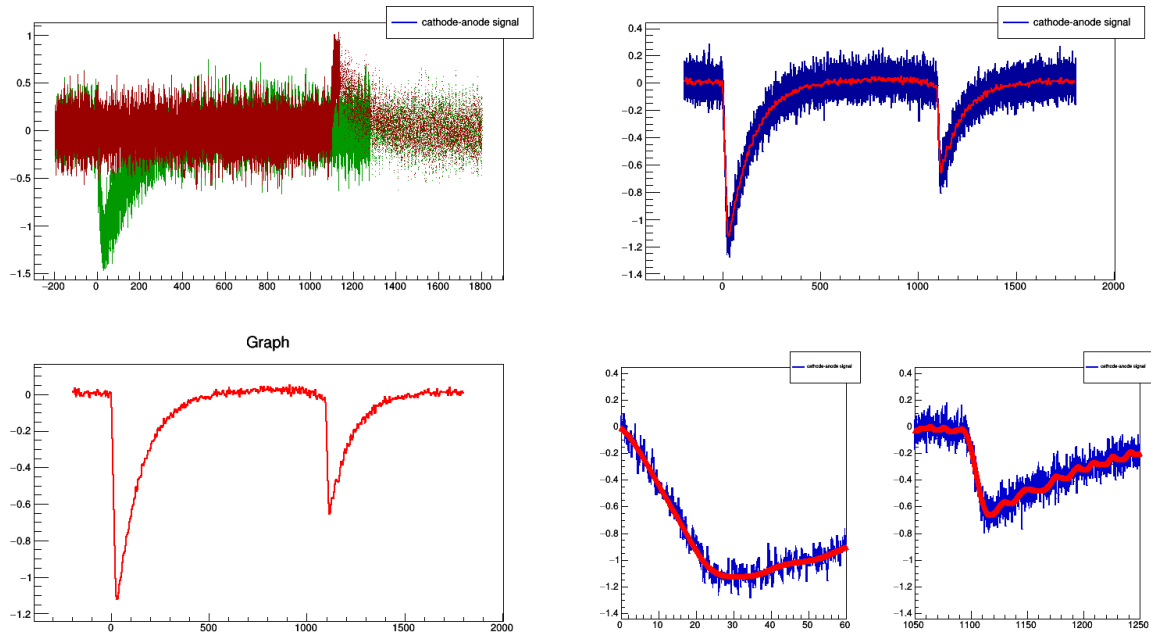


Figure 10:

26 Nov 2019: cathode=300 V anode=4000V camera OFF

using Cathode-anode signal already subtracted: noise extraction applied to order 5

```

after EMD subtraction: maxima index = 2236 13110 / values = 2.897323 1.222241 1.222241 times = 27.600000
E=166.666667 Temp=87.300000 vel=0.067852 (cm/microsec)
E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)
PURITY lifetime calculation...
=> VOLTAGES: Cathode=300.000000 (V) Anode=4000.000000 (V)
=> DRIFT times tdc=26.528134 (micro sec) tda=8.466319 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)
=> TRANSMISSION FACTORS: T12=0.484085 T23=1.000000 T=T12*T13=0.484085
=> PEAK SIGNALS: vCmax=2.897323 vAmax=1.222241
=> TIMES (microsec): tC=27.600000 tA=1115.000000 dt=1087.400000
=> PURITY = 7.902209 (milisec)

```

using Cathode, Anode signals separated and subtracted on analysis: noise extraction applied to order 5

```

after EMD subtraction: minima index = 2236 13121 / values = -2.074203 -0.915082 -0.915082 times = 27.500000
E=166.666667 Temp=87.300000 vel=0.067852 (cm/microsec)
E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)
PURITY lifetime calculation...
=> DRIFT times tdc=26.528134 (micro sec) tda=8.466319 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)
=> TRANSMISSION FACTORS: T12=0.484085 T23=1.000000 T=T12*T13=0.484085
=> PEAK SIGNALS: vCmax=-2.074203 vAmax=-0.915082
=> TIMES (microsec): tC=27.500000 tA=1116.000000 dt=1088.500000
=> PURITY = 11.726393 (milisec)

```

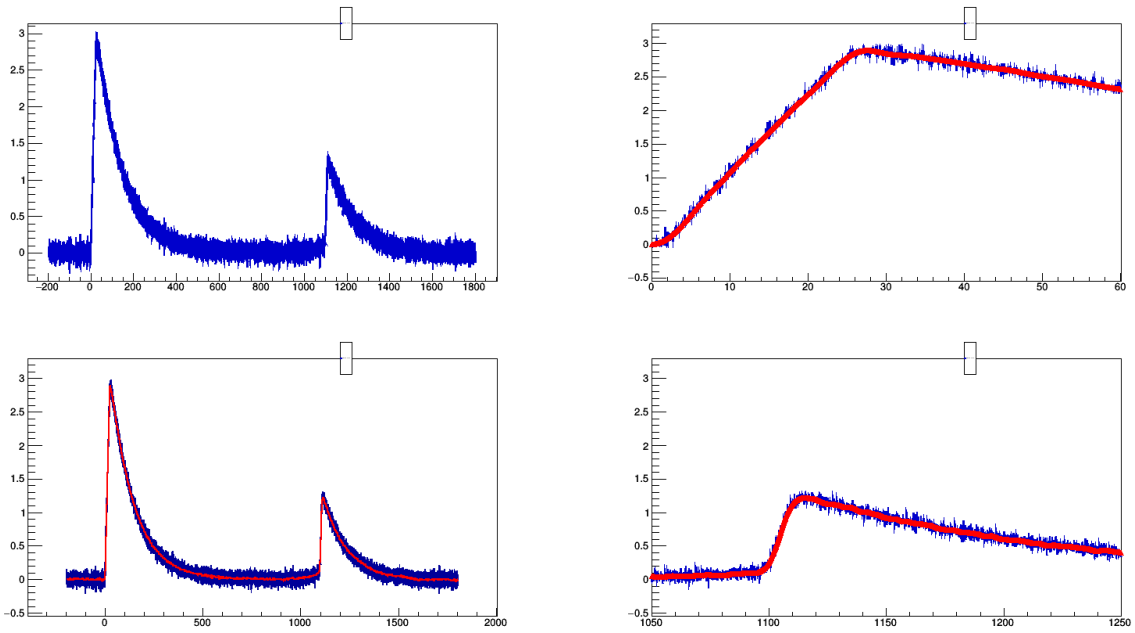


Figure 11:

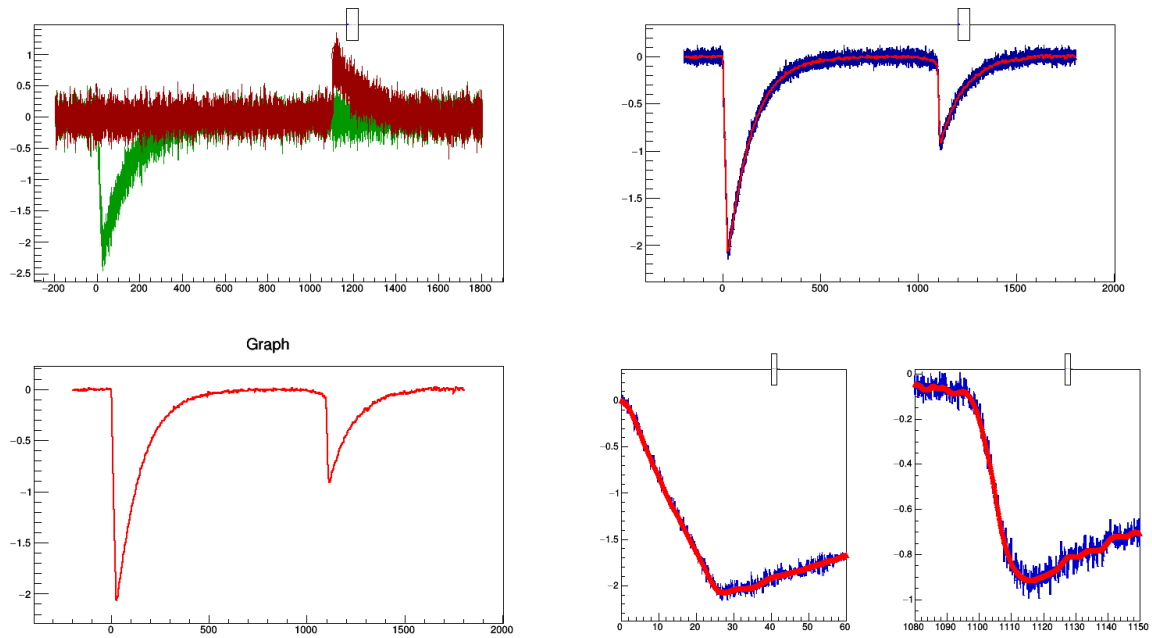


Figure 12:

26 Nov 2019: cathode=400 V anode=4000V camera OFF

using Cathode-anode signal already subtracted

after EMD subtraction: maxima index = 2192 13042 / values = 3.511824 1.114054 1.114054 times = 23.200000

E=222.222222 Temp=87.300000 vel=0.083923 (cm/microsec)

E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)

PURITY lifetime calculation...

=> VOLTAGES: Cathode=400.000000 (V) Anode=4000.000000 (V)

=> DRIFT times tdc=21.448194 (micro sec) tda=8.466319 (micro sec)

=> E FIELD: E1=222.222222 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)

=> TRANSMISSION FACTORS: T12=0.363064 T23=1.000000 T=T12*T13=0.363064

order 5

=> PEAK SIGNALS: vCmax=3.511824 vAmax=1.114054

=> TIMES (microsec): tC=23.200000 tA=1108.200000 dt=1085.000000

=> PURITY = 8.039805 (milisec)

order 6

=> PEAK SIGNALS: vCmax=3.497201 vAmax=1.108050

=> TIMES (microsec): tC=24.800000 tA=1108.200000 dt=1083.400000

=> PURITY = 7.955367 (milisec)

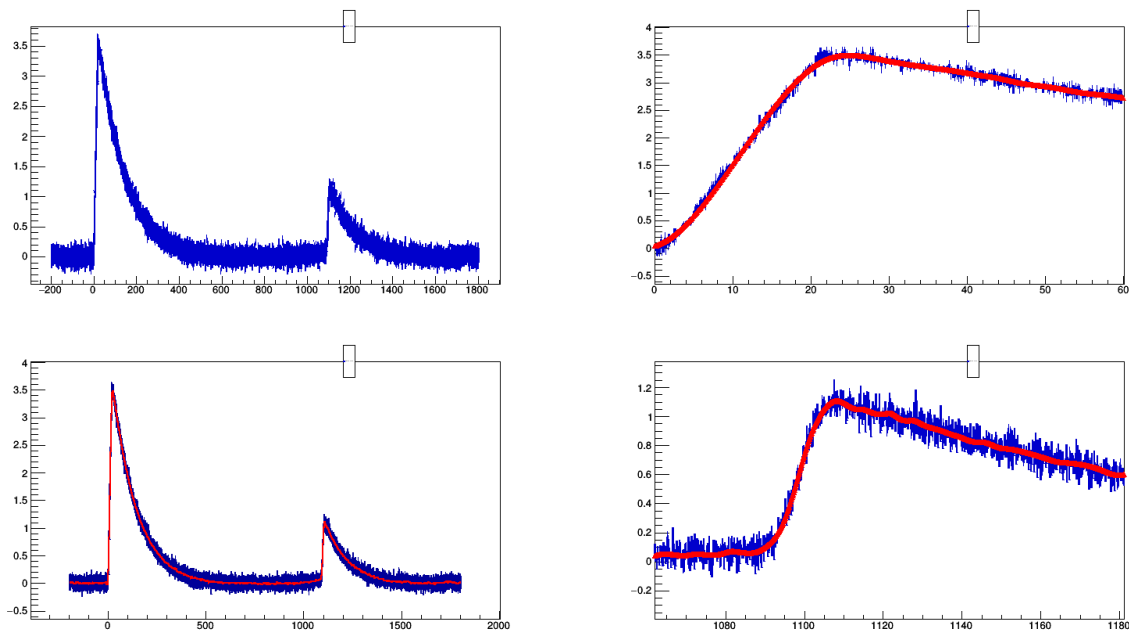


Figure 13:

**using Cathode, Anode signals separated and subtracted on analysis

order 5

=> PEAK SIGNALS: vCmax=3.511824 vAmax=1.114054
=> TIMES (microsec): tC=23.200000 tA=1108.200000 dt=1085.000000
=> PURITY = 8.039805 (milisec)

order 6

=> PEAK SIGNALS: vCmax=-2.606002 vAmax=-0.825289
=> TIMES (microsec): tC=24.700000 tA=1108.600000 dt=1083.900000
=> PURITY = 7.931210 (milisec)

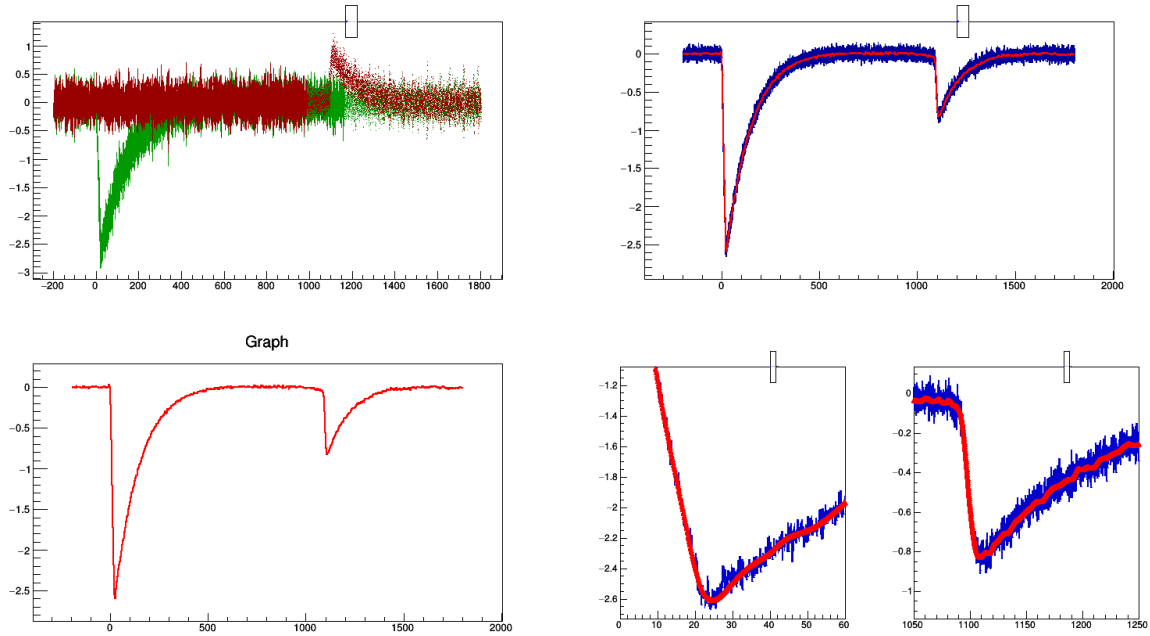


Figure 14:

26 Nov 2019: cathode=300 V anode=3000V camera OFF

using Cathode-anode signal already subtracted

```
Finding EMD maxima (N=20001)...
after EMD subtraction: maxima index = 2242 16533 / values = 2.876383 0.810016 0.810016 times = 28.200000
E=166.666667 Temp=87.300000 vel=0.067852 (cm/microsec)
E=197.468354 Temp=87.300000 vel=0.077046 (cm/microsec)
PURITY lifetime calculation...
=> VOLTAGES: Cathode=300.000000 (V) Anode=3000.000000 (V)
=> DRIFT times tdc=26.528134 (micro sec) tda=10.383455 (micro sec)
=> E FIELD: E1=166.666667 (V/cm) E2=60.510638 (V/cm) E3=197.468354 (V/cm)
=> TRANSMISSION FACTORS: T12=0.363064 T23=1.000000 T=T12*T13=0.363064
```

order 5

```
=> PEAK SIGNALS: vCmax=2.876383 vAmax=0.810016
=> TIMES (microsec): tC=28.200000 tA=1457.300000 dt=1429.100000
=> PURITY = 5.625096 (milisec)
```

order 6

```
=> PEAK SIGNALS: vCmax=2.848563 vAmax=0.808713
=> TIMES (microsec): tC=29.800000 tA=1458.000000 dt=1428.200000
=> PURITY = 5.806879 (milisec)
```

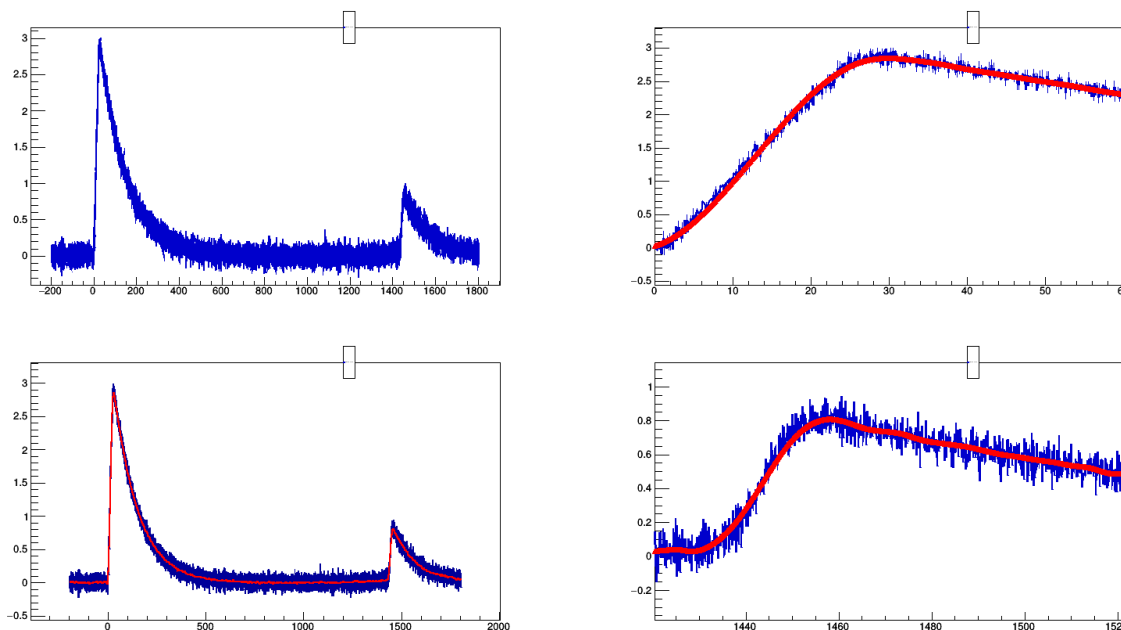


Figure 15:

using Cathode, Anode signals separated and subtracted on analysis

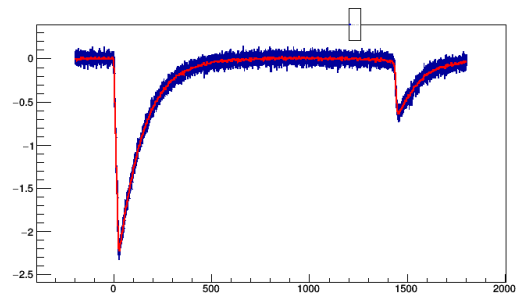
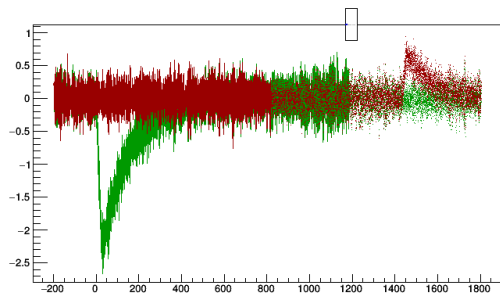
order 5

=> PEAK SIGNALS: vCmax=-2.235385 vAmax=-0.641924
=> TIMES (microsec): tC=28.700000 tA=1454.200000 dt=1425.500000
=> PURITY = 6.078325 (milisec)

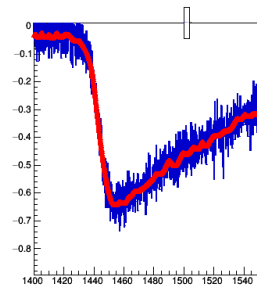
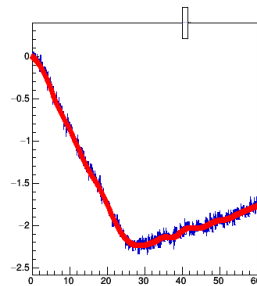
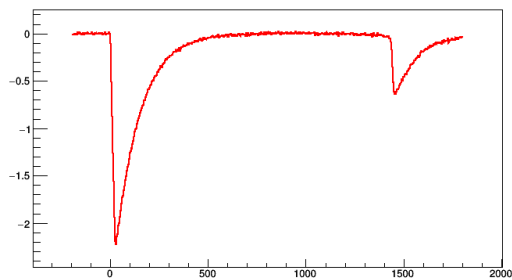
order 5 seems better for anode peak!

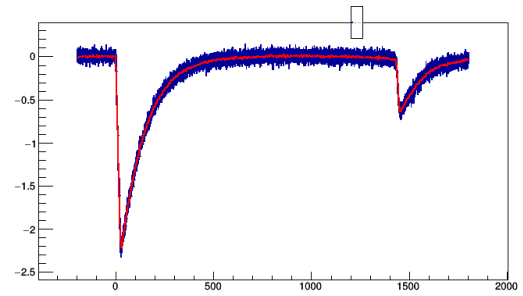
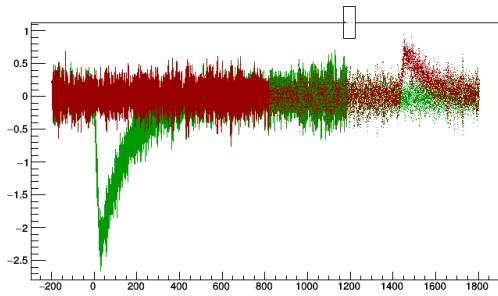
order 6

=> PEAK SIGNALS: vCmax=-2.214923 vAmax=-0.642888
=> TIMES (microsec): tC=30.600000 tA=1456.600000 dt=1426.000000
=> PURITY = 6.371028 (milisec)

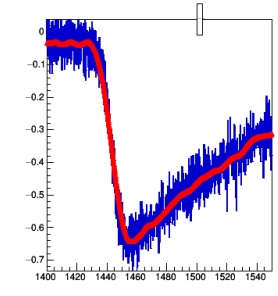
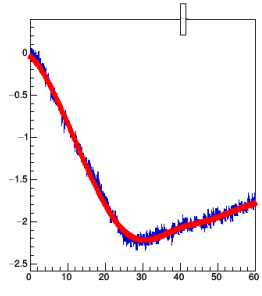
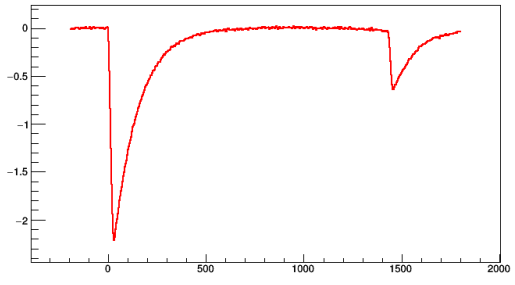


Graph





Graph



Lifetime monitor data from 22 nov 2019

cathode=350 V anode=4000V

Cathode-anode signal analysis: noise extraction applied to order 6

The analysis has been applied to cathode and anode separated signals.

Finding EMD minima (N=20002)...

after EMD subtraction: minima index = 2235 13085 / values = -2.619120 -0.878814 -0.878814 times = 27.400000

E=194.444444 Temp=87.300000 vel=0.076176 (cm/microsec)

E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)

PURITY lifetime calculation...

=> DRIFT times tdc=23.629494 (micro sec) tda=8.466319 (micro sec)

=> E1=194.444444 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)

=> vCmax=-2.619120 vAmax=-0.878814 T12=0.414930 T23=1.000000 T=0.414930

=> tC=27.400000 tA=1112.400000 dt=1085.000000

=> PURITY = 5.108879 (msec)

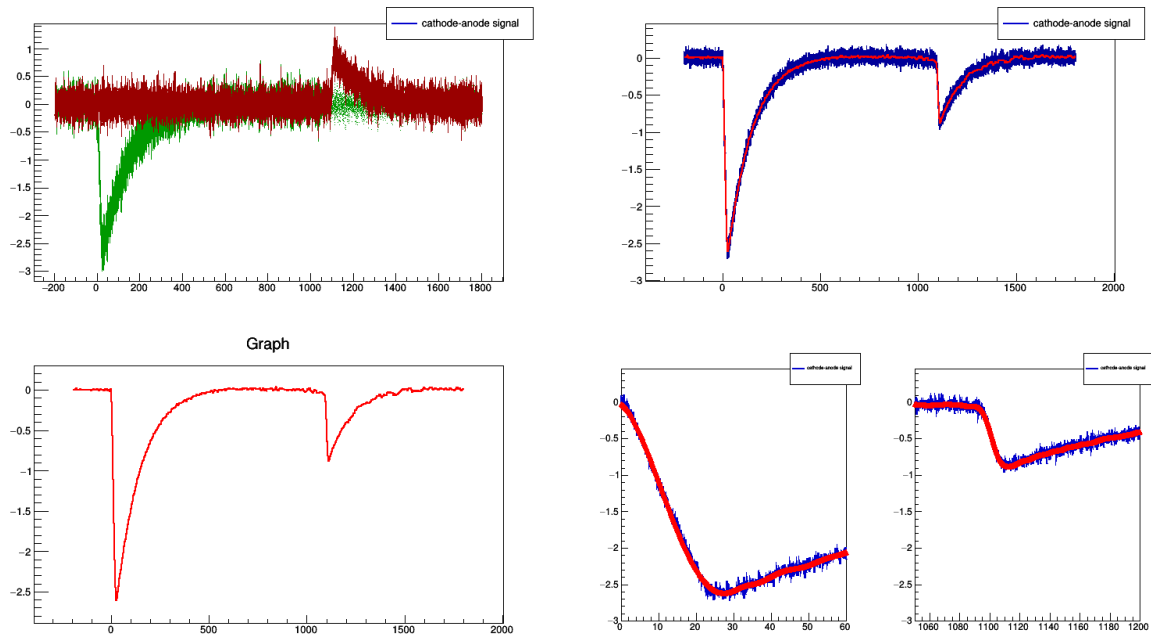


Figure 16:

*

*Cathode-anode signal analysis: noise extraction applied to order 5**

The analysis has been applied to cathode and anode separated signals.

Finding EMD minima (N=20002)...

after EMD subtraction: minima index = 2217 13076 / values = -2.632379 -0.866963 -0.866963 times = 25.600000

E=194.444444 Temp=87.300000 vel=0.076176 (cm/microsec)

E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)

PURITY lifetime calculation...

=> DRIFT times tdc=23.629494 (micro sec) tda=8.466319 (micro sec)

=> E1=194.444444 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)

=> vCmax=-2.632379 vAmax=-0.866963 T12=0.414930 T23=1.000000 T=0.414930

=> tC=25.600000 tA=1111.500000 dt=1085.900000

=> PURITY = 4.700838 (msec)

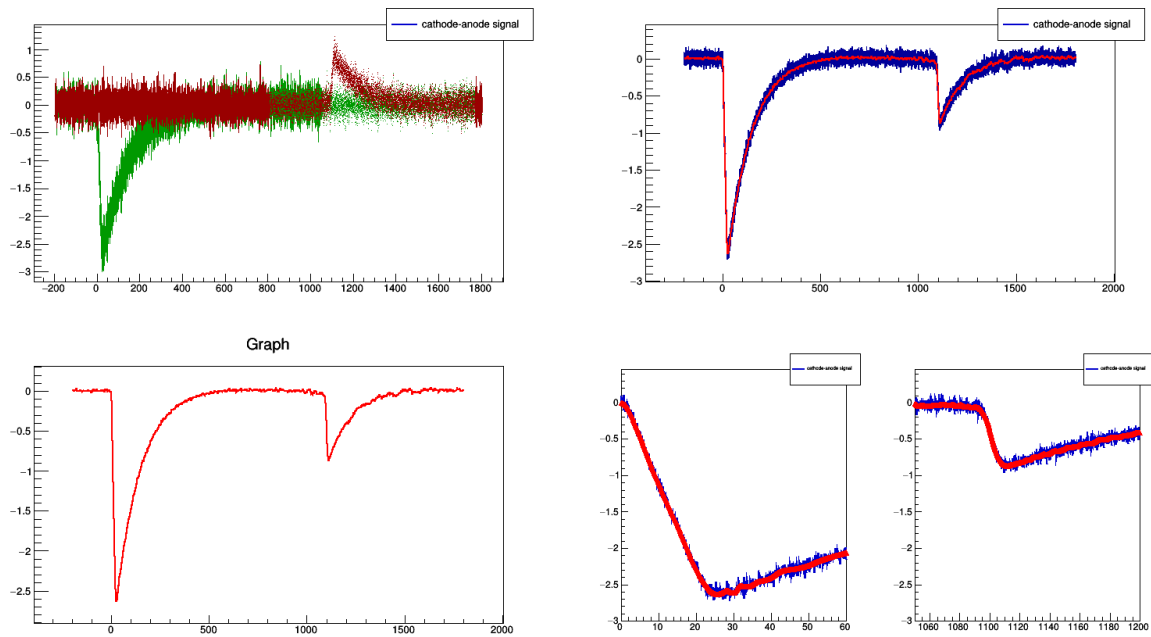


Figure 17:

*

*Cathode-anode signal analysis: noise extraction applied to order 6**

The analysis has been applied to an already subtracted cathode-anode signal.

Finding EMD maxima (N=20001)...

after EMD subtraction: maxima index = 2222 13068 / values = 3.163783 1.023368 1.023368 times = 26.200000

E=194.444444 Temp=87.300000 vel=0.076176 (cm/microsec)

E=263.291139 Temp=87.300000 vel=0.094492 (cm/microsec)

PURITY lifetime calculation...

=> DRIFT times tdc=23.629494 (micro sec) tda=8.466319 (micro sec)

=> E1=194.444444 (V/cm) E2=80.680851 (V/cm) E3=263.291139 (V/cm)

=> vCmax=3.163783 vAmax=1.023368 T12=0.414930 T23=1.000000 T=0.414930

=> tC=26.200000 tA=1110.800000 dt=1084.600000

=> PURITY = 4.355396 (msec)

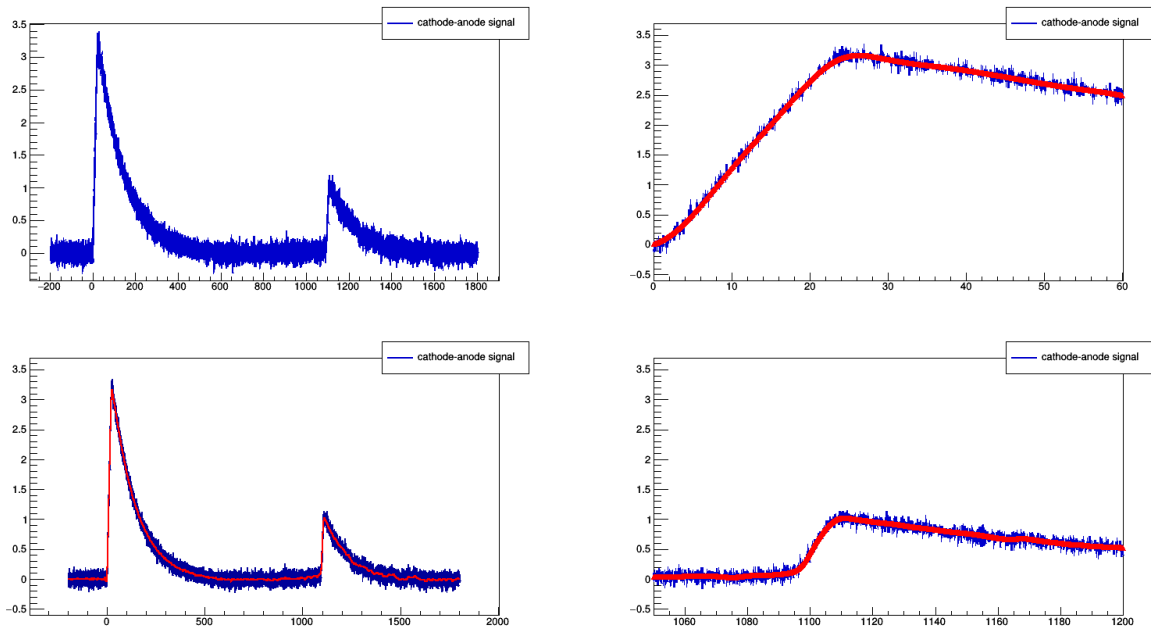


Figure 18:

cathode=350 V anode=3500V

Finding EMD maxima (N=20001)...

after EMD subtraction: maxima index = 2216 14525 / values = 3.164944 0.813235 0.813235 times = 25.600000

E=194.444444 Temp=87.300000 vel=0.076176 (cm/microsec)

E=230.379747 Temp=87.300000 vel=0.086101 (cm/microsec)

PURITY lifetime calculation...

=> VOLTAGES: Cathode=350.000000 (V) Anode=3500.000000 (V)

=> DRIFT times tdc=23.629494 (micro sec) tda=9.291385 (micro sec)

=> E1=194.444444 (V/cm) E2=70.595745 (V/cm) E3=230.379747 (V/cm)

=> vCmax=3.164944 vAmax=0.813235 T12=0.363064 T23=1.000000 T=0.363064

=> tC=25.600000 tA=1256.500000 dt=1230.900000

=> PURITY = 3.560666 (msec)

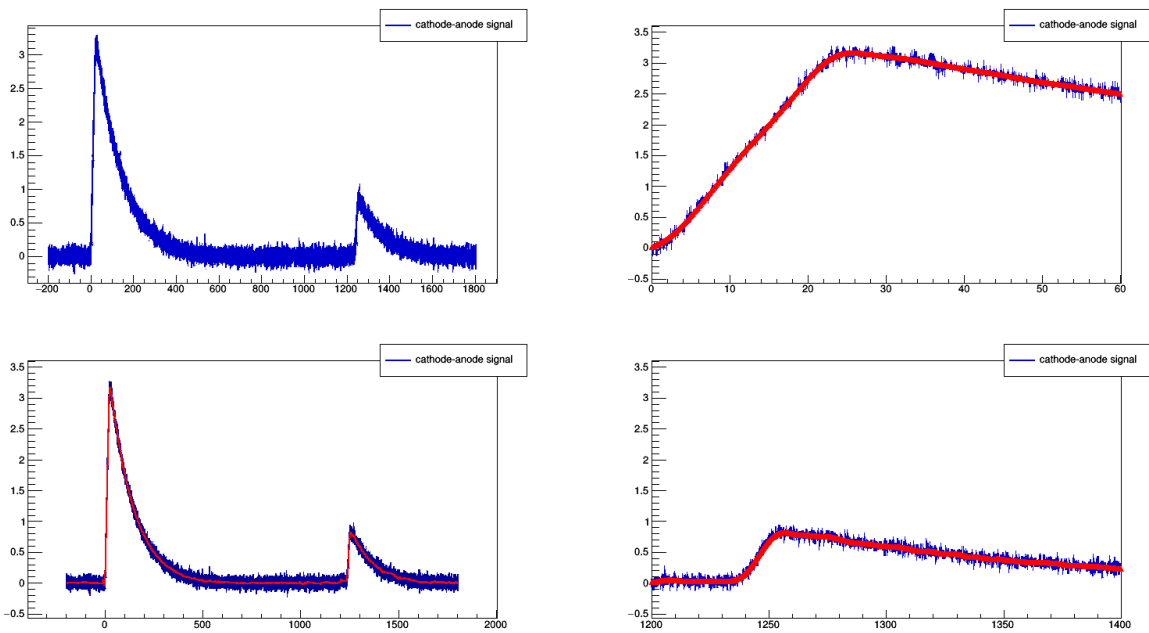


Figure 19:

cathode=400 V anode=3000V

Finding EMD maxima (N=20001)...

after EMD subtraction: maxima index = 2215 16444 / values = 3.456878 0.644679 0.644679 times = 25.500000

E=222.222222 Temp=87.300000 vel=0.083923 (cm/microsec)

E=197.468354 Temp=87.300000 vel=0.077046 (cm/microsec)

PURITY lifetime calculation...

=> VOLTAGES: Cathode=400.000000 (V) Anode=3000.000000 (V)

=> DRIFT times tdc=21.448194 (micro sec) tda=10.383455 (micro sec)

=> E1=222.222222 (V/cm) E2=60.510638 (V/cm) E3=197.468354 (V/cm)

=> vCmax=3.456878 vAmax=0.644679 T12=0.272298 T23=1.000000 T=0.272298

=> tC=25.500000 tA=1448.400000 dt=1422.900000

=> PURITY = 3.759211 (msec)

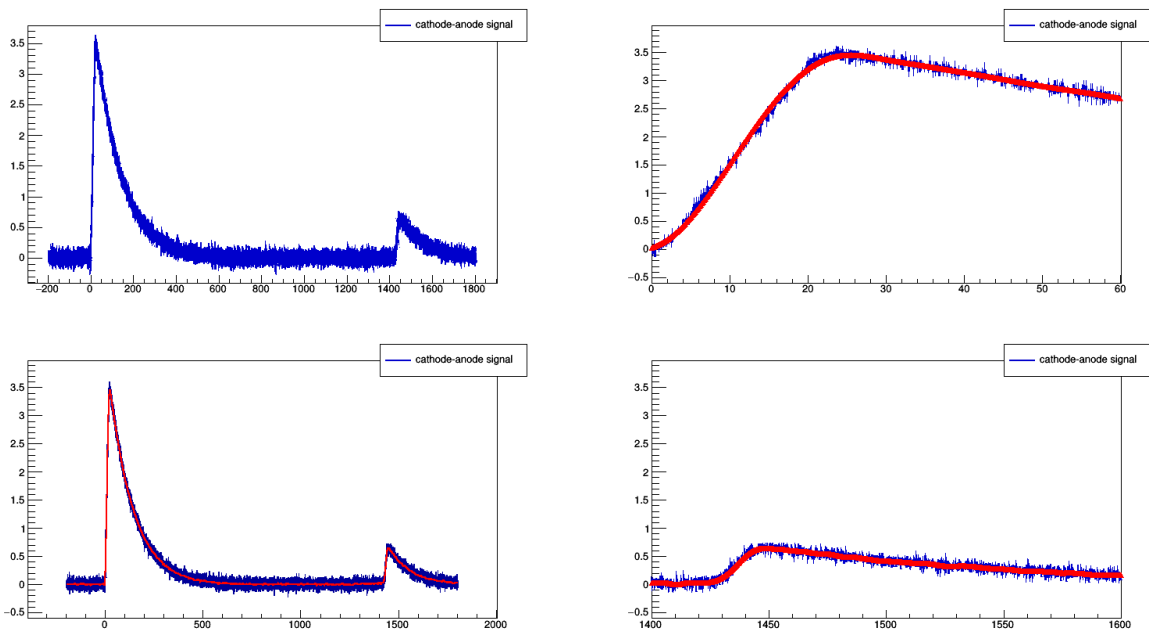


Figure 20:

Résumé pf the Lifetimes obtained the 22 Nov 2019

| K voltage (V) | A voltage (V) | signal | EMD | lifetime (musec) |

350	4000	K,A signals	6	5.1
350	4000	K,A signals	5	4.7
350	4000	K-A signal	6	4.4
350	3500	K-A signal	6	3.6
400	3000	K-A signal	6	3.8