

```
In[1200]:= SetDirectory[
  "/Users/yonehara/helios2/code/mathematica/logbook/2022/Dec/analyze_slope"]
```

```
Out[1200]:= /Users/yonehara/helios2/code/mathematica/logbook/2022/Dec/analyze_slope
```

```
In[1201]:= fn = FileNames["*.csv"]
```

```
Out[1201]:= {raw_data_beam_scan_2019-12-12.csv}
```

```
In[1202]:= scan = Import[fn[[1]], "CSV"];
```

```
In[1203]:= Take[scan, 5]
```

```
Out[1203]:= {{tt;ave_hptgt;ave_vptgt;ave_hp121;ave_vp121;hornI;beamI;mm1xav;mm1yav;mm2xav;
  mm2yav;mm3xav;mm3yav;time;x_trgt;y_trgt;mm1xav_mm;mm1yav_mm;mm2xav_mm;
  mm2yav_mm;mm3xav_mm;mm3yav_mm},
  {0;1576166401169;-0.28355;-0.70965;-0.434767;-0.759633;-198.4;38.85;0.593078;-
  1.09752;0.825388;0.158082;1.43003;0.608785;2019-12-12
  10:00:01.168999936;-0.181478525;-0.675911475;15.064181199999998;-27.877008;
  20.9648552;4.0152828;36.322762;15.463139},
  {1;1576166402500;-0.255667;-0.602867;-0.425983;-0.707817;-198.36;38.73;0.588259;-
  1.15731;0.814649;0.13327;1.39658;0.667905;2019-12-12
  10:00:02.500000000;-0.14070369999999993;-0.53202575000000001;14.9417786;-
  29.395674;20.692084599999998;3.385058;35.473132;16.964786999999998},
  {2;1576166403831;-0.264483;-0.8316;-0.412417;-0.81685;-198.4;38.95;0.586425;-
  1.10155;0.816002;0.196768;1.38651;0.543399;2019-12-12
  10:00:03.831000064;-0.16462755000000004;-0.84155625;14.895195;-27.97937;
  20.7264508;4.997907199999999;35.21735399999999;13.802334599999998},
  {3;1576166405166;-0.289867;-0.912467;-0.439617;-0.883083;-198.38;38.86;0.600804;-
  1.04562;0.817675;0.219419;1.3972;0.519592;2019-12-12
  10:00:05.165999872;-0.18878574999999997;-0.9323012;15.260421599999999;-
  26.558747999999998;20.768945;5.5732425999999995;35.488879999999995;
  13.197636800000002}}
```

```
In[1204]:= split = ToExpression[Table[StringSplit[scan[[n]], ";"], {n, 2, Length[scan]}]]];
```

```
ToExpression::sntx: Invalid syntax in or before "2019-12-12 10:00:01.168999936".
```

```
ToExpression::sntx: Invalid syntax in or before "2019-12-12 10:00:02.500000000".
```

```
ToExpression::sntx: Invalid syntax in or before "2019-12-12 10:00:03.831000064".
```

```
General::stop: Further output of ToExpression::sntx will be suppressed during this calculation.
```

```

In[1205]:= Take[split, 5]
Out[1205]= {{{0, 1576166401169, -0.28355, -0.70965, -0.434767, -0.759633, -198.4, 38.85,
0.593078, -1.09752, 0.825388, 0.158082, 1.43003, 0.608785, $Failed,
-0.181479, -0.675911, 15.0642, -27.877, 20.9649, 4.01528, 36.3228, 15.4631}}},
{{1, 1576166402500, -0.255667, -0.602867, -0.425983, -0.707817, -198.36,
38.73, 0.588259, -1.15731, 0.814649, 0.13327, 1.39658, 0.667905, $Failed,
-0.140704, -0.532026, 14.9418, -29.3957, 20.6921, 3.38506, 35.4731, 16.9648}}},
{{2, 1576166403831, -0.264483, -0.8316, -0.412417, -0.81685, -198.4,
38.95, 0.586425, -1.10155, 0.816002, 0.196768, 1.38651, 0.543399, $Failed,
-0.164628, -0.841556, 14.8952, -27.9794, 20.7265, 4.99791, 35.2174, 13.8023}}},
{{3, 1576166405166, -0.289867, -0.912467, -0.439617, -0.883083, -198.38,
38.86, 0.600804, -1.04562, 0.817675, 0.219419, 1.3972, 0.519592, $Failed,
-0.188786, -0.932301, 15.2604, -26.5587, 20.7689, 5.57324, 35.4889, 13.1976}}},
{{4, 1576166406498, -0.316583, -0.785333, -0.4619, -0.818867, -198.38,
38.74, 0.600723, -1.08765, 0.816474, 0.172589, 1.44568, 0.532948, $Failed,
-0.218494, -0.762698, 15.2584, -27.6263, 20.7384, 4.38376, 36.7203, 13.5369}}}}

In[1206]:= split[[1, 1]]
Out[1206]= {0, 1576166401169, -0.28355, -0.70965, -0.434767, -0.759633, -198.4,
38.85, 0.593078, -1.09752, 0.825388, 0.158082, 1.43003, 0.608785, $Failed,
-0.181479, -0.675911, 15.0642, -27.877, 20.9649, 4.01528, 36.3228, 15.4631}

In[1207]:= split[[2, 1]]
Out[1207]= {1, 1576166402500, -0.255667, -0.602867, -0.425983, -0.707817, -198.36,
38.73, 0.588259, -1.15731, 0.814649, 0.13327, 1.39658, 0.667905, $Failed,
-0.140704, -0.532026, 14.9418, -29.3957, 20.6921, 3.38506, 35.4731, 16.9648}

In[1208]:= Length[split]
Out[1208]= 8074

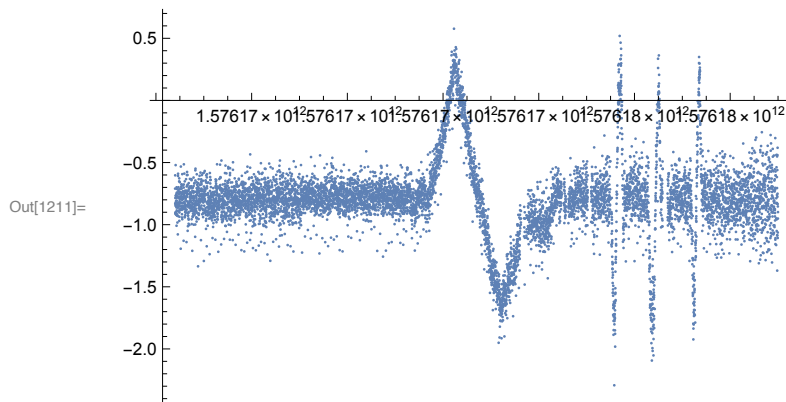
In[1209]:= msp = Table[split[[n, 1]], {n, 1, Length[split]};

```

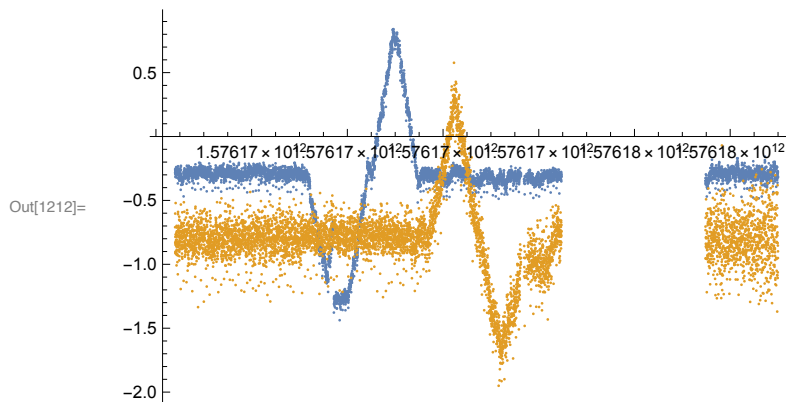
In[1210]:= **Take[msp, 5]**

```
Out[1210]= {{0, 1576166401169, -0.28355, -0.70965, -0.434767, -0.759633, -198.4,
  38.85, 0.593078, -1.09752, 0.825388, 0.158082, 1.43003, 0.608785, $Failed,
  -0.181479, -0.675911, 15.0642, -27.877, 20.9649, 4.01528, 36.3228, 15.4631},
 {1, 1576166402500, -0.255667, -0.602867, -0.425983, -0.707817, -198.36,
  38.73, 0.588259, -1.15731, 0.814649, 0.13327, 1.39658, 0.667905, $Failed,
  -0.140704, -0.532026, 14.9418, -29.3957, 20.6921, 3.38506, 35.4731, 16.9648},
 {2, 1576166403831, -0.264483, -0.8316, -0.412417, -0.81685, -198.4,
  38.95, 0.586425, -1.10155, 0.816002, 0.196768, 1.38651, 0.543399, $Failed,
  -0.164628, -0.841556, 14.8952, -27.9794, 20.7265, 4.99791, 35.2174, 13.8023},
 {3, 1576166405166, -0.289867, -0.912467, -0.439617, -0.883083, -198.38,
  38.86, 0.600804, -1.04562, 0.817675, 0.219419, 1.3972, 0.519592, $Failed,
  -0.188786, -0.932301, 15.2604, -26.5587, 20.7689, 5.57324, 35.4889, 13.1976},
 {4, 1576166406498, -0.316583, -0.785333, -0.4619, -0.818867, -198.38,
  38.74, 0.600723, -1.08765, 0.816474, 0.172589, 1.44568, 0.532948, $Failed,
  -0.218494, -0.762698, 15.2584, -27.6263, 20.7384, 4.38376, 36.7203, 13.5369}}
```

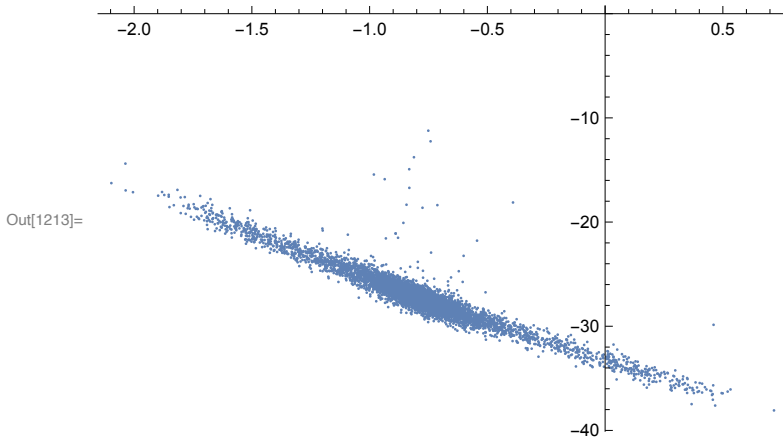
In[1211]:= **ListPlot[Map[{{#[[2]], #[[4]]} &, Select[msp, -199 < #[[7]] < 0 &]], PlotRange -> All]**



In[1212]:= **ListPlot[{Map[{{#[[2]], #[[3]]} &, Select[msp, -199 < #[[7]] < -197 &]], Map[{{#[[2]], #[[4]]} &, Select[msp, -199 < #[[7]] < -197 &]]}, PlotRange -> All]**



```
In[1213]:= ListPlot[
  {Map[#[[17]], #[[19]]] &, Select[msp, -199 < #[[7]] < -197 &]}, PlotRange -> All]
```



```
In[1214]:= mm1y = NonlinearModelFit[
  Map[#[[17]], #[[19]]] &, Select[msp, -199 < #[[7]] < -197 &], a x + b, {a, b}, x]
```

```
Out[1214]= FittedModel[ -33.6475 - 8.17025 x ]
```

```
In[1215]:= mm1y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-8.17025	0.0326195	{-8.23419, -8.1063}
b	-33.6475	0.0278324	{-33.702, -33.5929}

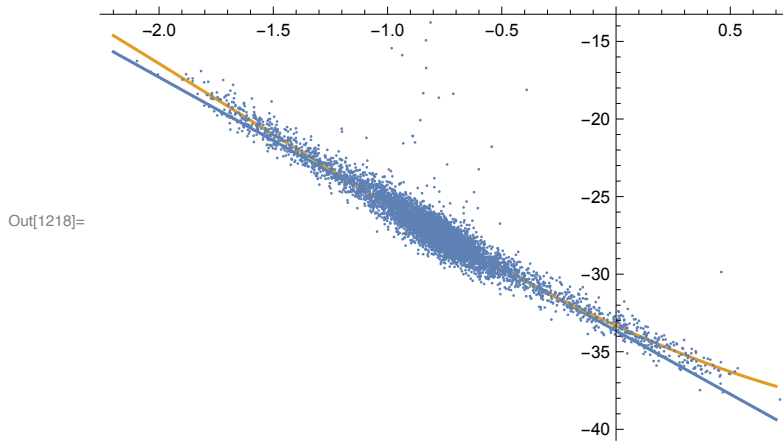
```
In[1216]:= mm1yPol = NonlinearModelFit[Map[#[[17]], #[[19]]] &,
  Select[msp, -199 < #[[7]] < -197 &], a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

```
Out[1216]= FittedModel[ -33.3242 - 6.70329 x + 1.42225 x^2 + 0.27509 x^3 ]
```

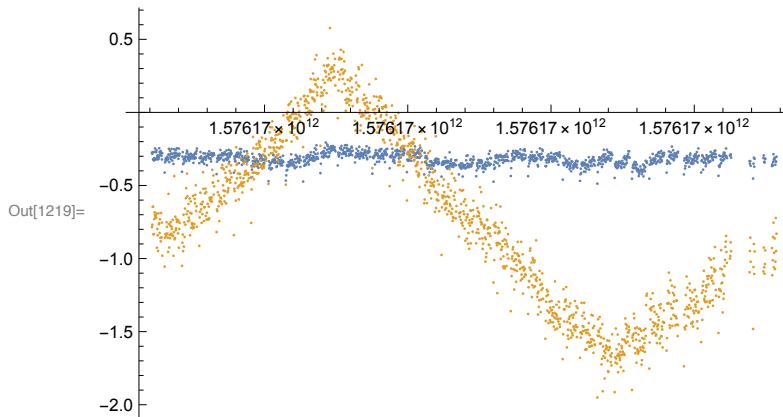
```
In[1217]:= mm1yPol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.27509	0.0786745	{0.120861, 0.429319}
b	1.42225	0.173958	{1.08124, 1.76327}
c	-6.70329	0.10303	{-6.90526, -6.50132}
d	-33.3242	0.0340525	{-33.3909, -33.2574}

```
In[1218]:= Show[Plot[{mm1y[x], mm1ypol[x]}, {x, -2.2, 0.7}], ListPlot[
  {Map[#[[17]], #[[19]]] &, Select[msp, -199 < #[[7]] < -197 &]}, PlotRange -> All]
```



```
In[1219]:= ListPlot[
  {Map[#[[2]], #[[3]]] &, Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &]},
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &]},
  PlotRange -> All]
```



```
In[1220]:= mm1y = NonlinearModelFit[Map[#[[17]], #[[19]]] &,
  Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &], a x + b, {a, b}, x]
```

Out[1220]= FittedModel[$-33.3679 - 8.06276 x$]

```
In[1221]:= mm1y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-8.06276	0.0328564	{-8.12721, -7.9983}
b	-33.3679	0.0316142	{-33.4299, -33.3059}

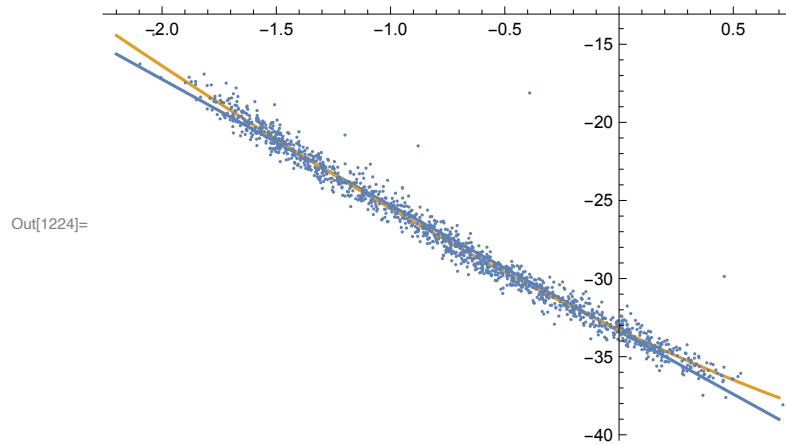
```
In[1222]:= mm1ypol = NonlinearModelFit[
  Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1222]= FittedModel[$-33.2727 - 6.91084 x + 0.929379 x^2 + 0.0811872 x^3$]

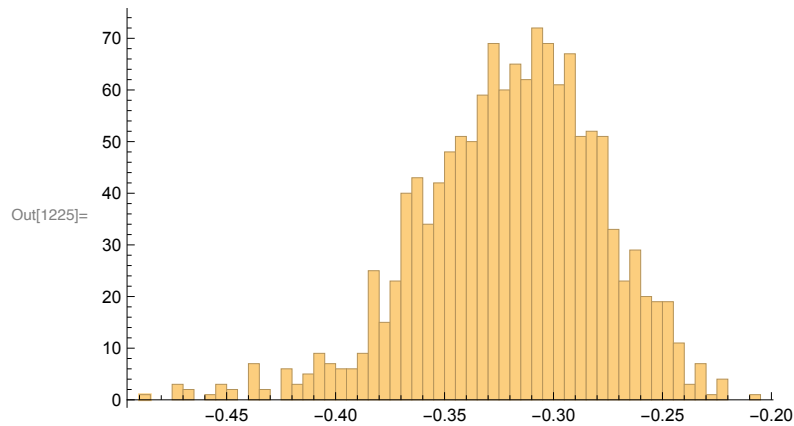
In[1223]:= **mm1ypol["ParameterConfidenceInterval"]**

	Estimate	Standard Error	Confidence Interval
a	0.0811872	0.0842058	{-0.0840016, 0.246376}
b	0.929379	0.18391	{0.568598, 1.29016}
c	-6.91084	0.101824	{-7.1106, -6.71109}
d	-33.2727	0.0333007	{-33.338, -33.2074}

In[1224]:= **Show[Plot[{mm1y[x], mm1ypol[x]}, {x, -2.2, 0.7}], ListPlot[{Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &]}], PlotRange -> All]**



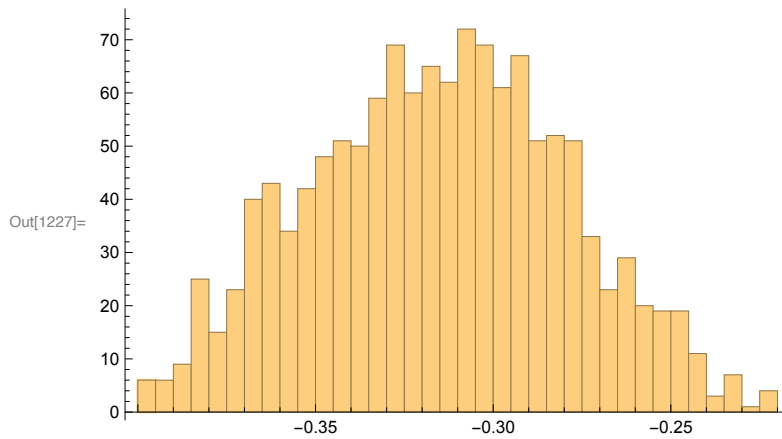
In[1225]:= **Histogram[Map[#[[3]] &, Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &]], 50]**



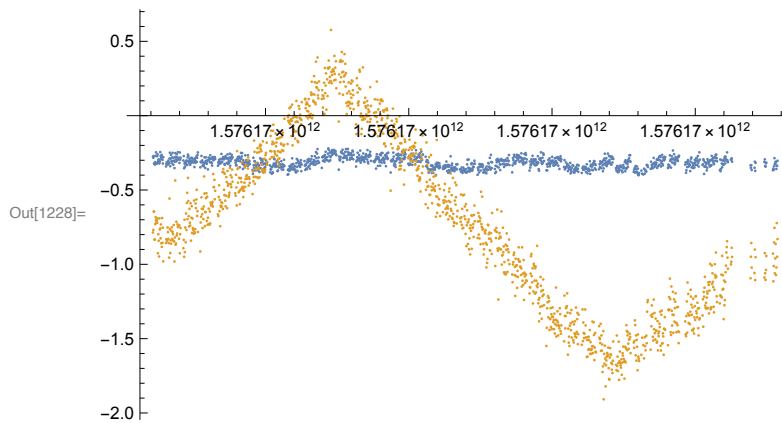
In[1226]:= **Mean[Map[#[[3]] &, Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 &]]]**

Out[1226]= -0.319553

```
In[1227]:= Histogram[Map[#[[3]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.4 < #[[3]] < -0.22 &]], 50]
```



```
In[1228]:= ListPlot[{Map[#[[2]], #[[3]]] &,
  Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 && -0.4 < #[[3]] < -0.22 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.4 < #[[3]] < -0.22 &]], PlotRange -> All]
```



```
In[1229]:= mm1y = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.4 < #[[3]] < -0.22 &]], a x + b, {a, b}, x]
```

Out[1229]= FittedModel[$-33.3546 - 8.02618 x$]

```
In[1230]:= mm1y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-8.02618	0.0332804	{-8.09147, -7.96089}
b	-33.3546	0.031317	{-33.4161, -33.2932}

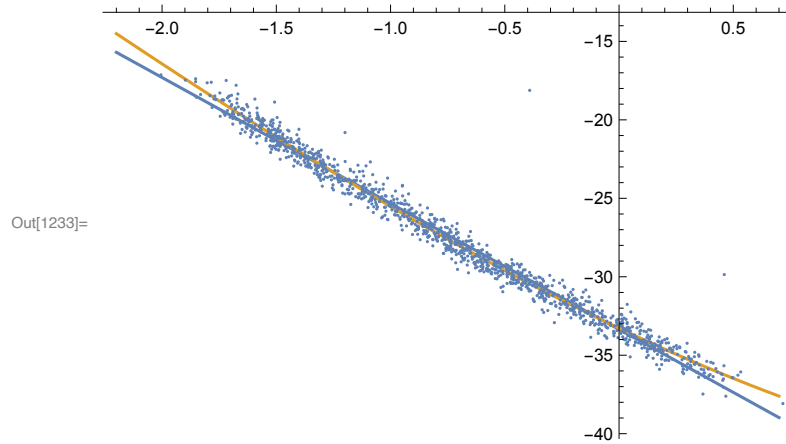
```
In[1231]:= mm1ypol = NonlinearModelFit[Map[#[[17]], #[[19]]] &,
  Select[Take[msp, {3450, 4800}], -199 < #[[7]] < -197 && -0.4 < #[[3]] < -0.22 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1231]= FittedModel[$-33.2752 - 6.89949 x + 0.954489 x^2 + 0.0966192 x^3$]

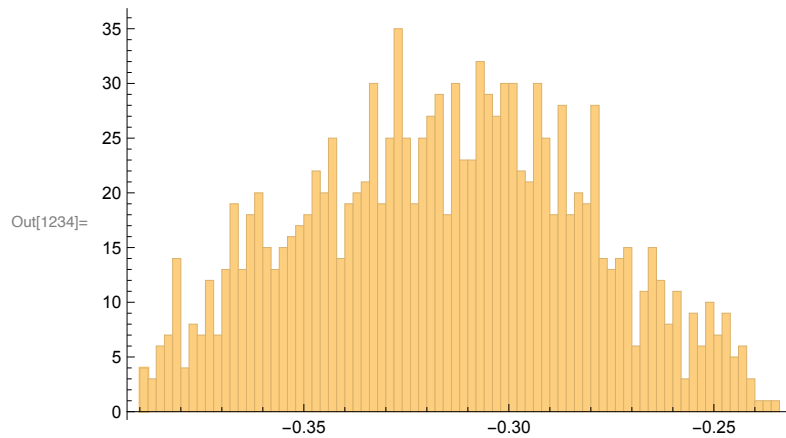
```
In[1232]:= mm1ypol["ParameterConfidenceInterval"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0966192	0.0911663	{-0.0822305, 0.275469}
b	0.954489	0.192301	{0.577233, 1.33175}
c	-6.89949	0.101414	{-7.09845, -6.70054}
d	-33.2752	0.0334036	{-33.3408, -33.2097}

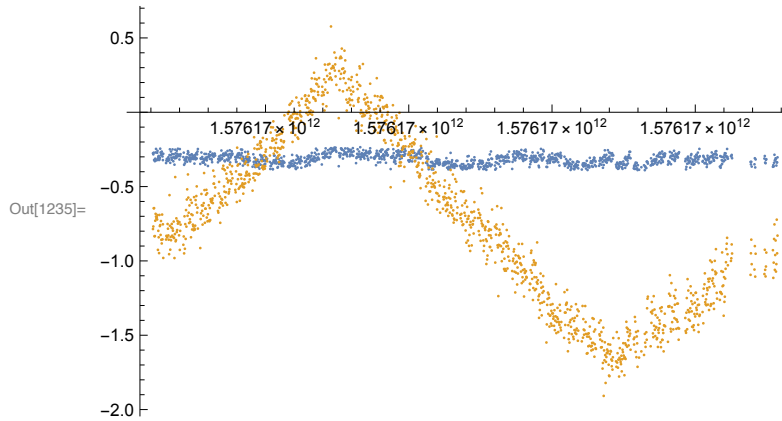
```
In[1233]:= Show[Plot[{mm1y[x], mm1ypol[x]}, {x, -2.2, 0.7}],
  ListPlot[{Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
    -199 < #[[7]] < -197 && -0.4 < #[[3]] < -0.22 &]], PlotRange -> All]
```



```
In[1234]:= Histogram[Map[#[[3]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.39 < #[[3]] < -0.235 &]], 50]
```




```
In[1235]:= ListPlot[Map[#[[2]], #[[3]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.39 < #[[3]] < -0.235 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.39 < #[[3]] < -0.235 &]], PlotRange -> All]
```



```
In[1236]:= mm1y = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.39 < #[[3]] < -0.235 &]], a x + b, {a, b}, x]
```

Out[1236]= FittedModel[$-33.362 - 8.03185 x$]

```
In[1237]:= mm1y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-8.03185	0.0340982	{-8.09875, -7.96496}
b	-33.362	0.0321249	{-33.425, -33.2989}

```
In[1238]:= mm1ypol = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[
  Take[msp, {3450, 4800}], -199 < #[[7]] < -197 && -0.39 < #[[3]] < -0.235 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

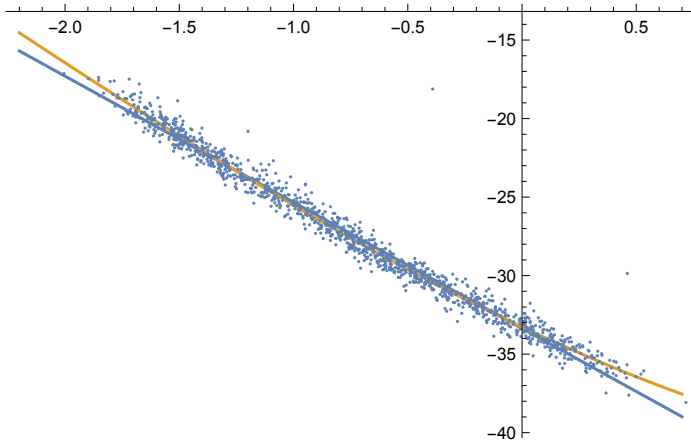
Out[1238]= FittedModel[$-33.2717 - 6.86632 x + 1.00458 x^2 + 0.115836 x^3$]

```
In[1239]:= mm1ypol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.115836	0.09418	{-0.0689291, 0.300602}
b	1.00458	0.200324	{0.611581, 1.39758}
c	-6.86632	0.107135	{-7.0765, -6.65614}
d	-33.2717	0.0340816	{-33.3386, -33.2049}

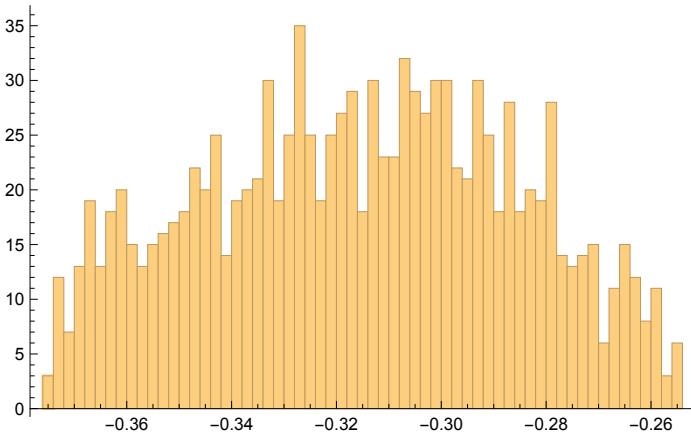
```
In[1240]:= Show[Plot[{mm1y[x], mm1ypol[x]}, {x, -2.2, 0.7}],
  ListPlot[{Map[{#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
    -199 < #[[7]] < -197 && -0.39 < #[[3]] < -0.235 &]}], PlotRange -> All]]
```

Out[1240]=

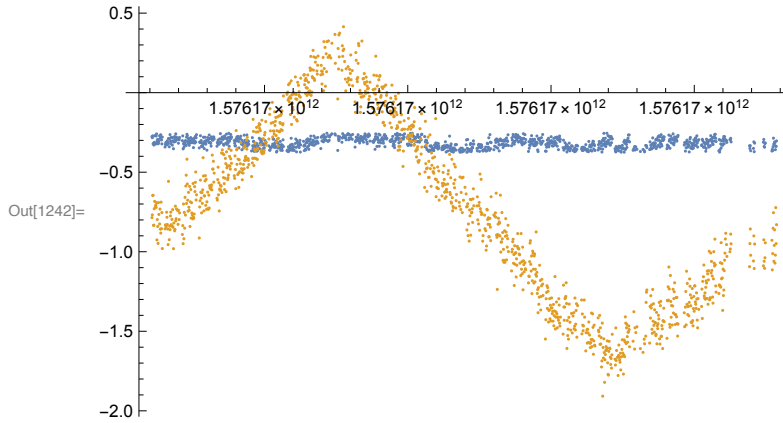


```
In[1241]:= Histogram[Map[#[[3]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], 50]
```

Out[1241]=



```
In[1242]:= ListPlot[Map[#[[2]], #[[3]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], PlotRange -> All]
```



```
In[1243]:= mm1y = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
  -199 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

```
Out[1243]= FittedModel[ -33.3965 - 8.06336 x ]
```

```
In[1244]:= mm1y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-8.06336	0.0350832	{-8.13219, -7.99452}
b	-33.3965	0.0332096	{-33.4616, -33.3313}

```
In[1245]:= mm1ypol = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[
  Take[msp, {3450, 4800}], -199 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

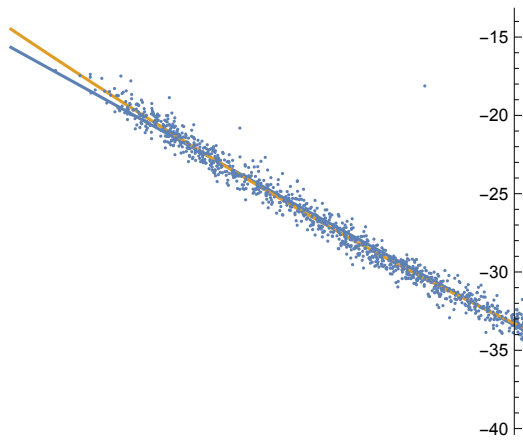
```
Out[1245]= FittedModel[ -33.2719 - 6.97064 x + 0.849055 x^2 + 0.0623291 x^3 ]
```

```
In[1246]:= mm1ypol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0623291	0.104132	{-0.141978, 0.266636}
b	0.849055	0.22851	{0.400718, 1.29739}
c	-6.97064	0.127338	{-7.22048, -6.7208}
d	-33.2719	0.035049	{-33.3406, -33.2031}

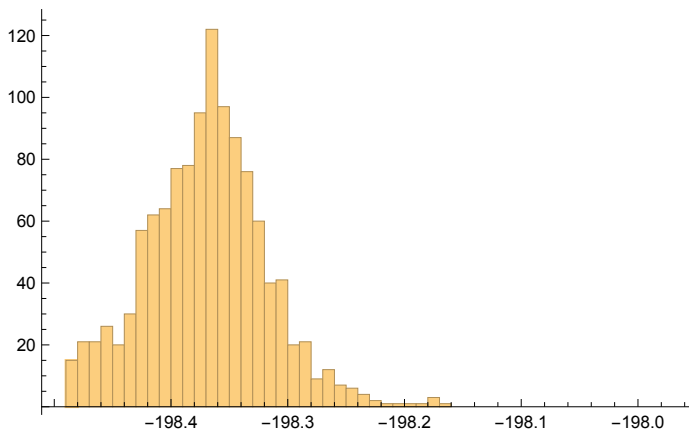
```
In[1247]:= Show[Plot[{mm1y[x], mm1ypol[x]}, {x, -2.2, 0.7}],  
  ListPlot[{Map[{#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],  
    -199 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]}], PlotRange -> All]]
```

Out[1247]=

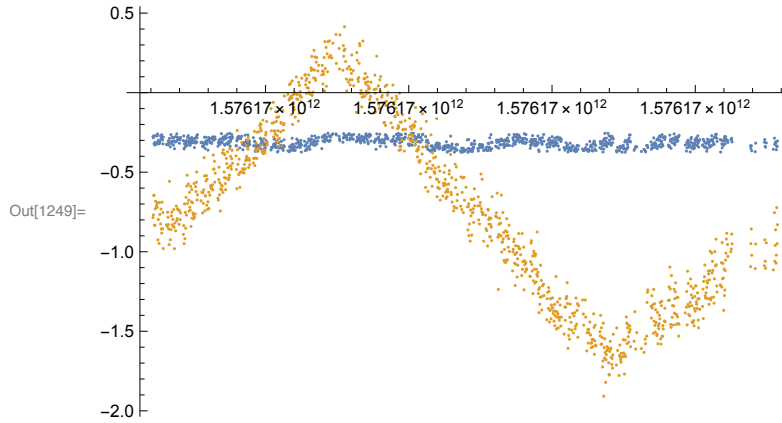


```
In[1248]:= Histogram[  
  Map[{#[[7]]] &, Select[Take[msp, {3450, 4800}], -198.5 < #[[7]] < -197 &]}, 50]
```

Out[1248]=



```
In[1249]:= ListPlot[Map[#[[2]], #[[3]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], PlotRange -> All]
```



```
In[1250]:= mm1y = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

```
Out[1250]= FittedModel[ $-33.3752 - 8.04386 x$ ]
```

```
In[1251]:= mm1y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-8.04386	0.0377322	{-8.1179, -7.96982}
b	-33.3752	0.0357541	{-33.4454, -33.3051}

```
In[1252]:= mm1ypol = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[
  Take[msp, {3450, 4800}], -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

```
Out[1252]= FittedModel[ $-33.2576 - 6.93162 x + 0.92269 x^2 + 0.0992816 x^3$ ]
```

```
In[1253]:= mm1ypol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0992816	0.111387	{-0.119287, 0.31785}
b	0.92269	0.243797	{0.4443, 1.40108}
c	-6.93162	0.135247	{-7.197, -6.66623}
d	-33.2576	0.0378863	{-33.3319, -33.1832}

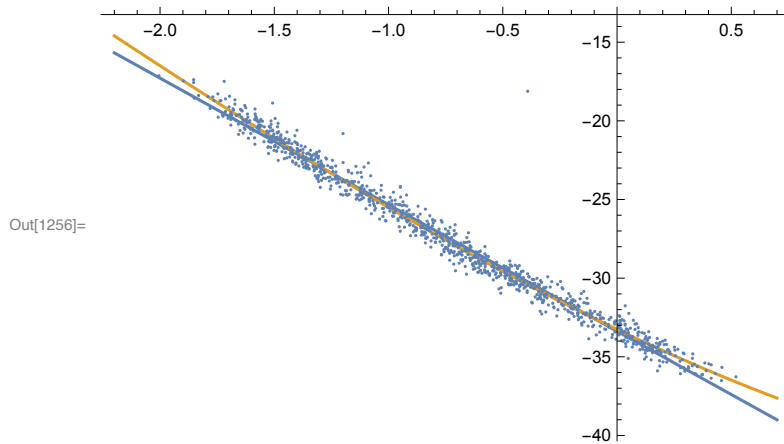
```
In[1254]:= mm1y200 = NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

```
Out[1254]= FittedModel[ $-33.3752 - 8.04386 x$ ]
```

```
In[1255]:= mmlypol200 =
  NonlinearModelFit[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
    -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

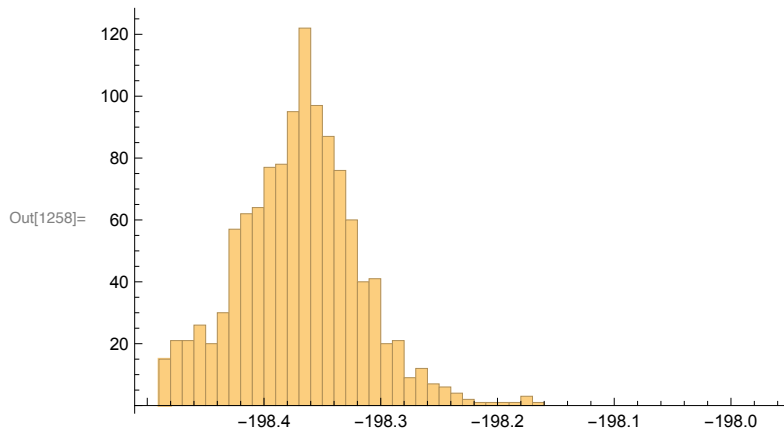
```
Out[1255]= FittedModel[ -33.2576 - 6.93162 x + 0.92269 x2 + 0.0992816 x3 ]
```

```
In[1256]:= Show[Plot[{mml1y[x], mmlypol[x]}, {x, -2.2, 0.7}],
  ListPlot[Map[#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
    -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], PlotRange -> All]]
```

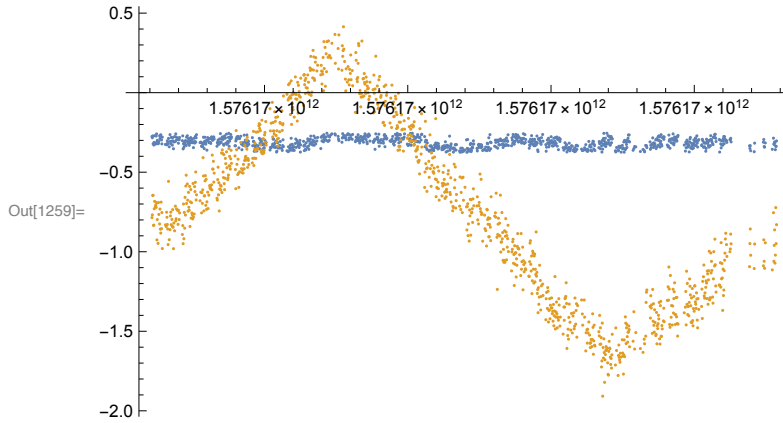


```
In[1257]:=
```

```
In[1258]:= Histogram[
  Map[#[[7]] &, Select[Take[msp, {3450, 4800}], -198.5 < #[[7]] < -197 &]], 50]
```



```
In[1259]:= ListPlot[Map[#[[2]], #[[3]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], PlotRange -> All]
```



```
In[1260]:= mm2y = NonlinearModelFit[Map[#[[17]], #[[21]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

```
Out[1260]= FittedModel[1.37904 - 5.10023 x]
```

```
In[1261]:= mm2y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-5.10023	0.0198634	{-5.1392, -5.06125}
b	1.37904	0.0188221	{1.34211, 1.41597}

```
In[1262]:= mm2ypol = NonlinearModelFit[Map[#[[17]], #[[21]]] &, Select[
  Take[msp, {3450, 4800}], -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

```
Out[1262]= FittedModel[1.53862 - 3.44869 x + 1.47635 x^2 + 0.216572 x^3]
```

```
In[1263]:= mm2ypol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.216572	0.0273021	{0.162999, 0.270146}
b	1.47635	0.0597572	{1.3591, 1.59361}
c	-3.44869	0.0331506	{-3.51374, -3.38364}
d	1.53862	0.00928636	{1.5204, 1.55684}

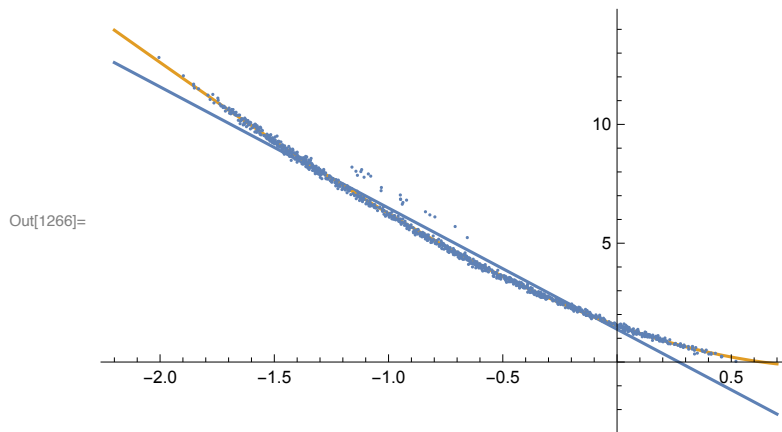
```
In[1264]:= mm2y200 = NonlinearModelFit[Map[#[[17]], #[[21]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

```
Out[1264]= FittedModel[1.37904 - 5.10023 x]
```

```
In[1265]:= mm2ypol200 =
  NonlinearModelFit[Map[#[[17]], #[[21]]] &, Select[Take[msp, {3450, 4800}],
    -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

```
Out[1265]= FittedModel [ 1.53862 - 3.44869 x + 1.47635 x2 + 0.216572 x3 ]
```

```
In[1266]:= Show[Plot[{mm2y[x], mm2ypol[x]}, {x, -2.2, 0.7}],
  ListPlot[Map[#[[17]], #[[21]]] &, Select[Take[msp, {3450, 4800}],
    -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], PlotRange -> All]]
```



```
In[1267]:= mm3y = NonlinearModelFit[Map[#[[17]], #[[23]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

```
Out[1267]= FittedModel [ 21.2486 + 8.30301 x ]
```

```
In[1268]:= mm3y["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	8.30301	0.0404452	{8.22365, 8.38238}
b	21.2486	0.0383249	{21.1734, 21.3238}

```
In[1269]:= mm3ypol = NonlinearModelFit[Map[#[[17]], #[[23]]] &, Select[
  Take[msp, {3450, 4800}], -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
  a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

```
Out[1269]= FittedModel [ 21.5034 + 10.7174 x + 2.00673 x2 + 0.218003 x3 ]
```

```
In[1270]:= mm3ypol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.218003	0.0942481	{0.0330648, 0.402941}
b	2.00673	0.206285	{1.60195, 2.41151}
c	10.7174	0.114437	{10.4928, 10.9419}
d	21.5034	0.032057	{21.4405, 21.5663}


```
In[1271]= mm3y200 = NonlinearModelFit[Map[{{#[[17]], #[[23]]} &, Select[Take[msp, {3450, 4800}],
-198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], a x + b, {a, b}, x]
```

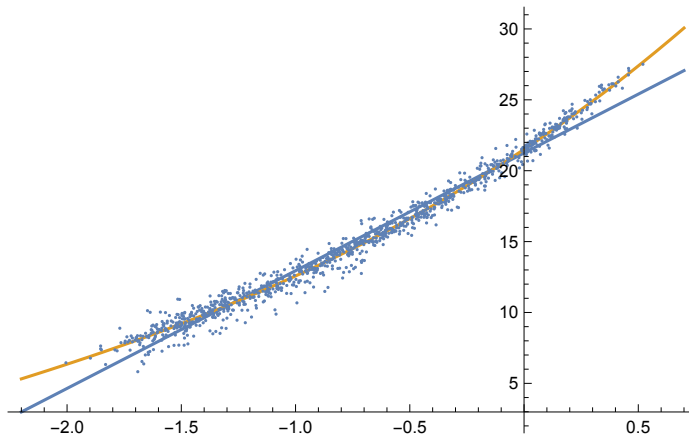
```
Out[1271]= FittedModel[ 21.2486 + 8.30301 x ]
```

```
In[1272]= mm3ypol200 =
NonlinearModelFit[Map[{{#[[17]], #[[23]]} &, Select[Take[msp, {3450, 4800}],
-198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]],
a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

```
Out[1272]= FittedModel[ 21.5034 + 10.7174 x + 2.00673 x2 + 0.218003 x3 ]
```

```
In[1273]= Show[Plot[{mm3y[x], mm3ypol[x]}, {x, -2.2, 0.7}],
ListPlot[Map[{{#[[17]], #[[23]]} &, Select[Take[msp, {3450, 4800}],
-198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]], PlotRange -> All]]]
```

```
Out[1273]=
```



```

In[1275]= Show[Plot[{mm1y[x], mm2y[x], mm3y[x]}, {x, -2.2, 0.7},
  PlotStyle -> {Blue, Orange, Green}], Plot[{mm1ypol[x], mm2ypol[x], mm3ypol[x]},
  {x, -2.2, 0.7}, PlotStyle -> {{Blue, Dashed}, {Orange, Dashed}, {Green, Dashed}}],
ListPlot[{Map[{#[[17]], #[[19]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]},
  Map[{#[[17]], #[[21]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]},
  Map[{#[[17]], #[[23]]] &, Select[Take[msp, {3450, 4800}],
  -198.5 < #[[7]] < -197 && -0.375 < #[[3]] < -0.255 &]}],
  PlotRange -> All, PlotStyle -> {Blue, Orange, Green}], GridLines -> Automatic,
ImageSize -> 700, AspectRatio -> 0.7, Frame -> True,
FrameStyle -> Directive[Thick, 24],
FrameLabel -> {"Vertical proton beam position at target (mm)",
  "Vertical beam centroid at muon monitor (mm)"}, PlotRange -> {All, {-40, 30}}]

```

Out[1275]=

