

```
In[1102]:= SetDirectory[
    "/Users/yonehara/helios2/code/mathematica/logbook/2022/Dec/analyze_slope"]
```

```
Out[1102]:= /Users/yonehara/helios2/code/mathematica/logbook/2022/Dec/analyze_slope
```

```
In[1103]:= fn = FileNames["*.csv"]
```

```
Out[1103]:= {raw_data_beam_scan_2019-12-12.csv}
```

```
In[1104]:= scan = Import[fn[[1]], "CSV"];
```

```
In[1105]:= Take[scan, 5]
```

```
Out[1105]:= {{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[1106]:= 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[1107]:= Take[split, 5]
```

```
Out[1107]= {{{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[1108]:= split[[1, 1]]
```

```
Out[1108]= {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[1109]:= split[[2, 1]]
```

```
Out[1109]= {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[1110]:= Length[split]
```

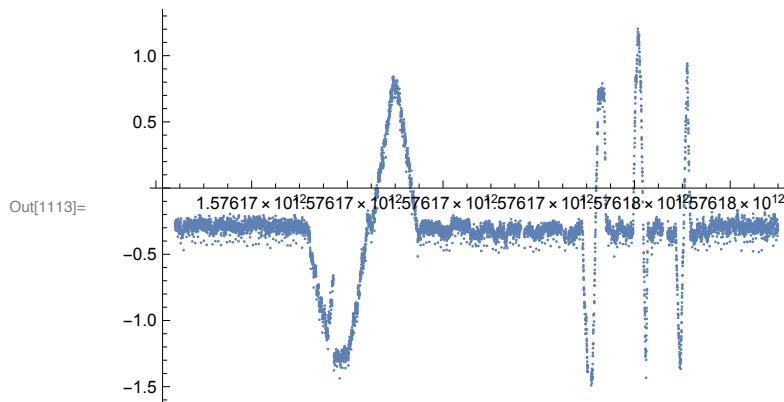
```
Out[1110]= 8074
```

```
In[1111]:= msp = Table[split[[n, 1]], {n, 1, Length[split]}];
```

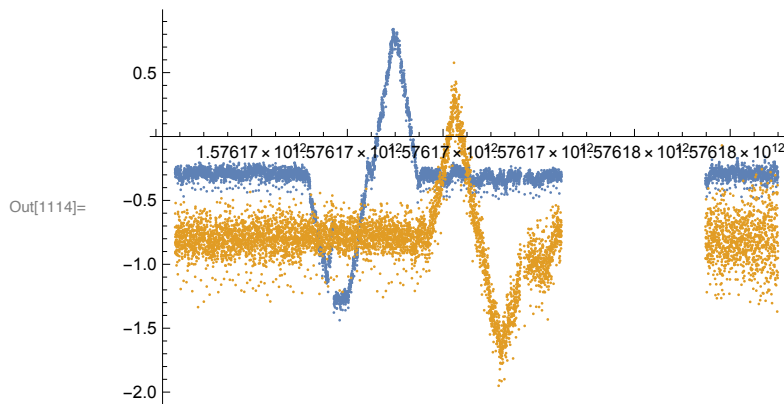
In[1112]:= **Take[msp, 5]**

```
Out[1112]:= {{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}}
```

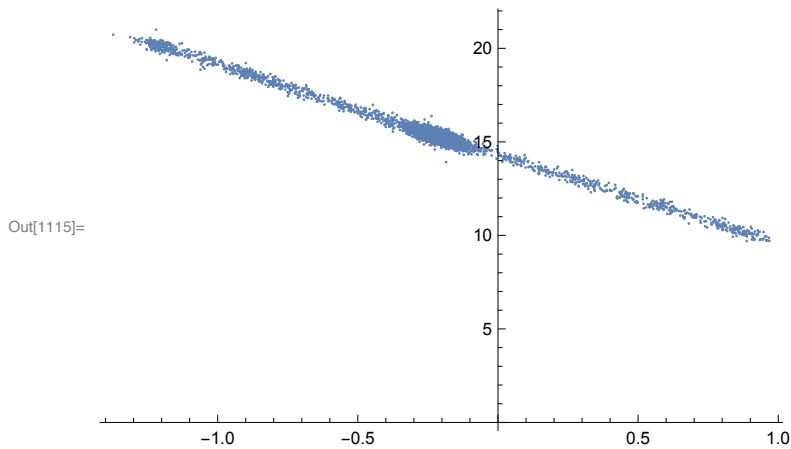
In[1113]:= **ListPlot[Map[{{#[[2]], #[[3]]} &, Select[msp, -199 < #[[7]] < 0 &]], PlotRange -> All]**



In[1114]:= **ListPlot[{Map[{{#[[2]], #[[3]]} &, Select[msp, -199 < #[[7]] < -197 &]], Map[{{#[[2]], #[[4]]} &, Select[msp, -199 < #[[7]] < -197 &]]}, PlotRange -> All]**



```
In[1115]:= ListPlot[
  {Map[#[[16]], #[[18]]] &, Select[msp, -199 < #[[7]] < -197 &]}, PlotRange -> All]
```



```
In[1116]:= mm1x = NonlinearModelFit[
  Map[#[[16]], #[[18]]] &, Select[msp, -199 < #[[7]] < -197 &], a x + b, {a, b}, x]
```

Out[1116]= FittedModel [14.2713 - 4.80017 x]

```
In[1117]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.80017	0.00688767	{-4.81367, -4.78666}
b	14.2713	0.00282007	{14.2658, 14.2769}

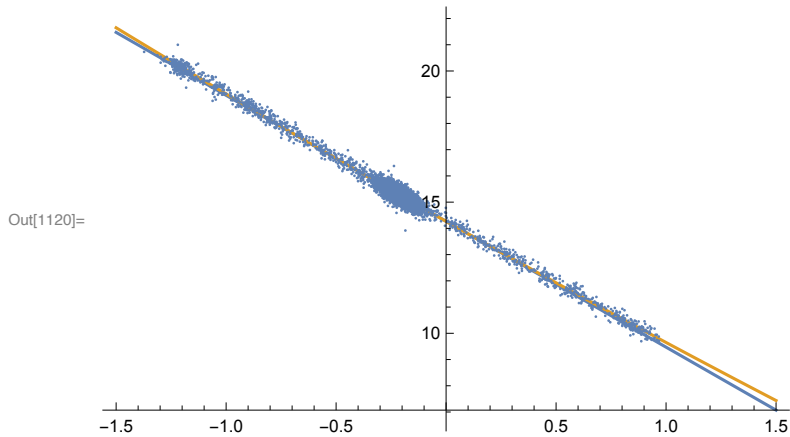
```
In[1118]:= mm1xpol = NonlinearModelFit[Map[#[[16]], #[[18]]] &,
  Select[msp, -199 < #[[7]] < -197 &], a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1118]= FittedModel [14.2648 - 4.73948 x + 0.123277 x^2 + 0.0011894 x^3]

```
In[1119]:= mm1xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0011894	0.0200736	{-0.0381618, 0.0405406}
b	0.123277	0.014324	{0.0951975, 0.151357}
c	-4.73948	0.015803	{-4.77046, -4.70851}
d	14.2648	0.00425448	{14.2565, 14.2732}

```
In[1120]:= Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}], ListPlot[
  Map[{{#[[16]], #[[18]]} &, Select[msp, -199 < #[[7]] < -197 &]}], PlotRange -> All]]
```



```
In[1121]:= mm3x = NonlinearModelFit[
  Map[{{#[[16]], #[[22]]} &, Select[msp, -199 < #[[7]] < -197 &]}], a x + b, {a, b}, x]
```

Out[1121]= FittedModel [37.6419 + 11.0544 x]

```
In[1122]:= mm3x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	11.0544	0.0222707	{11.0107, 11.098}
b	37.6419	0.00911843	{37.624, 37.6598}

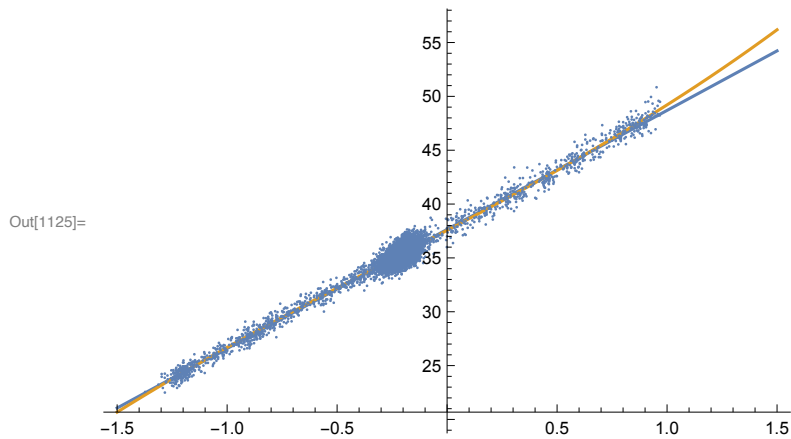
```
In[1123]:= mm3xpol = NonlinearModelFit[Map[{{#[[16]], #[[22]]} &,
  Select[msp, -199 < #[[7]] < -197 &]}], a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1123]= FittedModel [37.5625 + 10.801 x + 0.386226 x^2 + 0.459637 x^3]

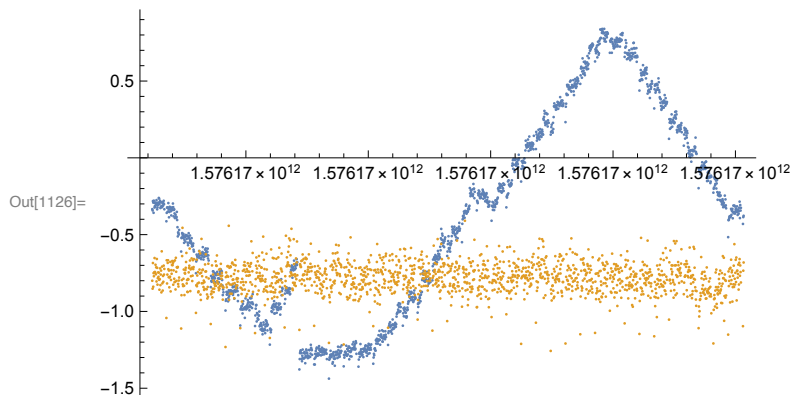
```
In[1124]:= mm3xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.459637	0.0656788	{0.330884, 0.58839}
b	0.386226	0.0468667	{0.294351, 0.478101}
c	10.801	0.0517058	{10.6996, 10.9023}
d	37.5625	0.0139202	{37.5353, 37.5898}

```
In[1125]:= Show[Plot[{mm3x[x], mm3xpol[x]}, {x, -1.5, 1.5}], ListPlot[
  {Map[#[[16]], #[[22]]] &, Select[msp, -199 < #[[7]] < -197 &]}], PlotRange -> All]
```



```
In[1126]:= ListPlot[
  {Map[#[[2]], #[[3]]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]},
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]}],
  PlotRange -> All]
```



```
In[1127]:= mm1x = NonlinearModelFit[Map[#[[16]], #[[18]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]], a x + b, {a, b}, x]
```

Out[1127]= FittedModel [14.3354 - 4.79395 x]

```
In[1128]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.79395	0.00647936	{-4.80666, -4.78124}
b	14.3354	0.0046795	{14.3262, 14.3445}

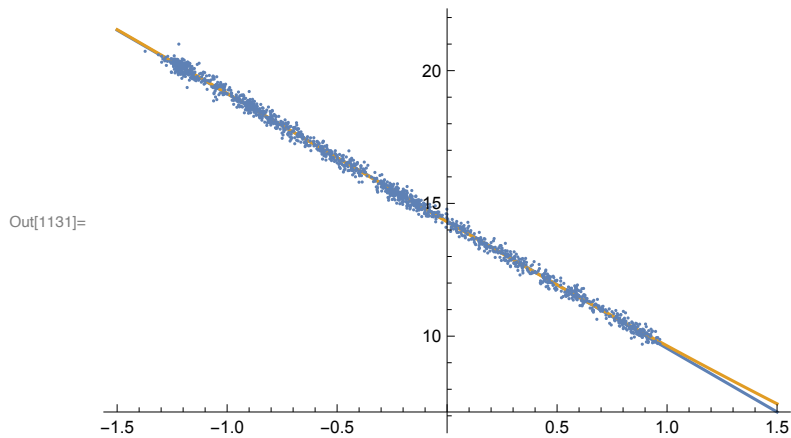
```
In[1129]:= mm1xpol = NonlinearModelFit[
  Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1129]= FittedModel [14.3043 - 4.79895 x + 0.0865291 x^2 + 0.0451319 x^3]

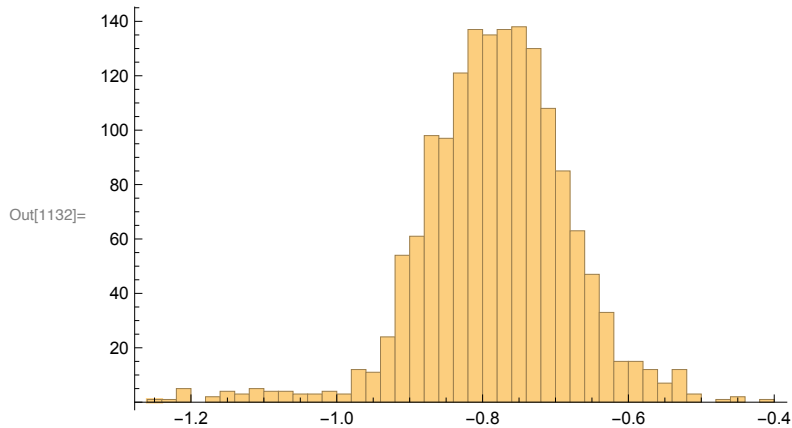
In[1130]:= **mm1xpol["ParameterConfidenceInterval"]**

	Estimate	Standard Error	Confidence Interval
a	0.0451319	0.0195629	{0.00676017, 0.0835036}
b	0.0865291	0.0156821	{0.0557694, 0.117289}
c	-4.79895	0.0156389	{-4.82963, -4.76828}
d	14.3043	0.00704468	{14.2905, 14.3181}

In[1131]:= **Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}], ListPlot[{Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]}], PlotRange → All]]**



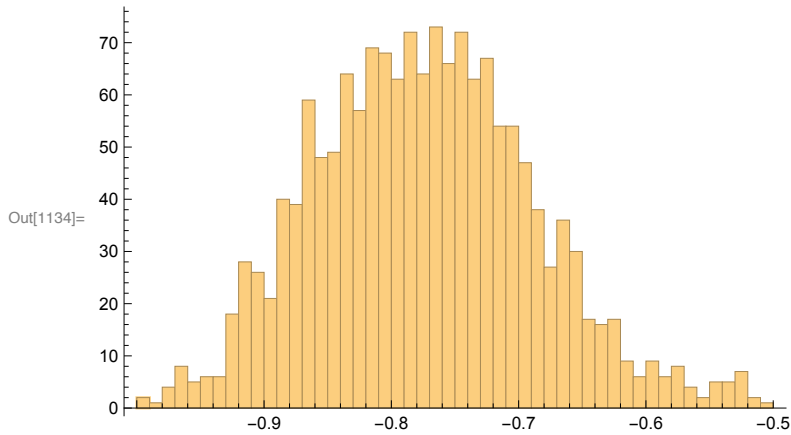
In[1132]:= **Histogram[Map[#[[4]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]], 50]**



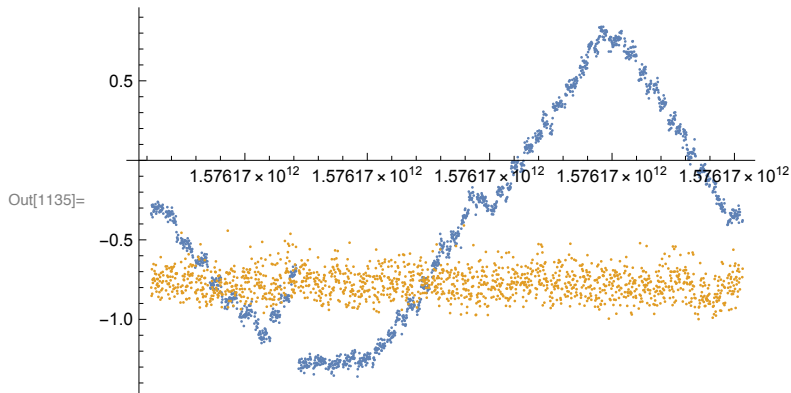
In[1133]:= **Mean[Map[#[[4]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]]]**

Out[1133]= -0.781256

```
In[1134]:= Histogram[Map[#[[4]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -1.0 < #[[4]] < -0.5 &]], 50]
```



```
In[1135]:= ListPlot[{Map[#[[2]], #[[3]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -1.0 < #[[4]] < -0.5 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -1.0 < #[[4]] < -0.4 &]], PlotRange -> All]
```



```
In[1136]:= mm1x = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -1.0 < #[[4]] < -0.4 &]], a x + b, {a, b}, x]
```

Out[1136]= FittedModel [14.3336 - 4.79718 x]

```
In[1137]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.79718	0.00655341	{-4.81003, -4.78432}
b	14.3336	0.00472577	{14.3243, 14.3428}

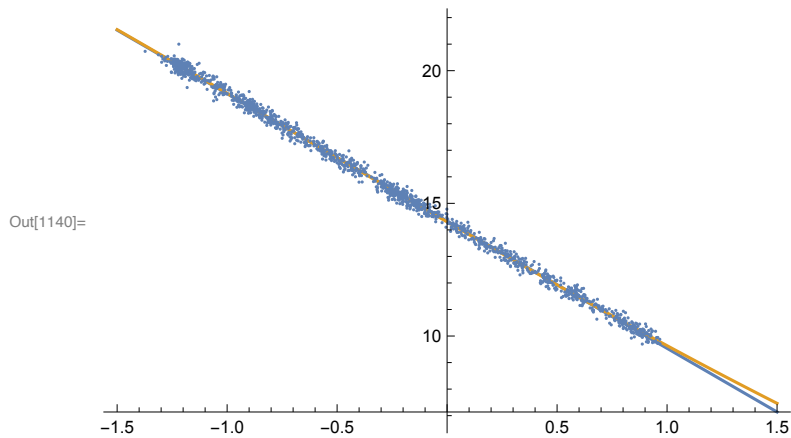
```
In[1138]:= mm1xpol = NonlinearModelFit[Map[#[[16]], #[[18]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -1.0 < #[[4]] < -0.4 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1138]= FittedModel [14.3009 - 4.80388 x + 0.0908457 x^2 + 0.048586 x^3]

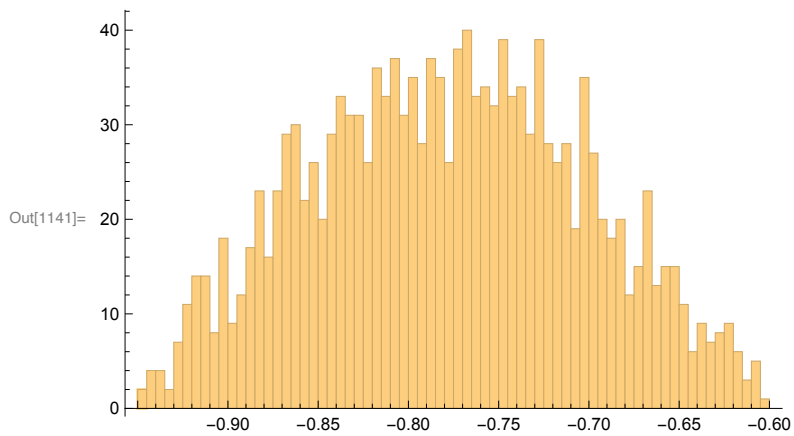
In[1139]:= `mm1xpol["ParameterConfidenceInterval"]`

	Estimate	Standard Error	Confidence Interval
a	0.048586	0.0198543	{0.009642, 0.08753}
b	0.0908457	0.0157688	{0.0599153, 0.121776}
c	-4.80388	0.0158747	{-4.83502, -4.77275}
d	14.3009	0.00711375	{14.2869, 14.3148}

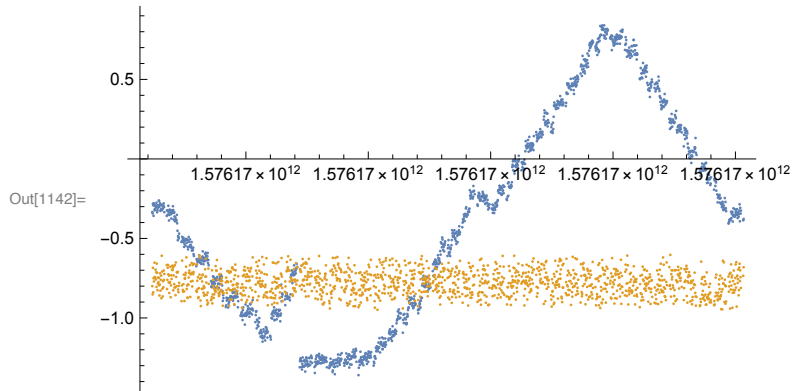
In[1140]:= `Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}], ListPlot[{Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]}], PlotRange -> All]`



In[1141]:= `Histogram[Map[#[[4]] &, Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.95 < #[[4]] < -0.6 &]], 50]`



```
In[1142]:= ListPlot[Map[#[[2]], #[[3]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.95 < #[[4]] < -0.6 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.95 < #[[4]] < -0.6 &]], PlotRange -> All]
```



```
In[1143]:= mm1x = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.95 < #[[4]] < -0.6 &]], a x + b, {a, b}, x]
```

Out[1143]= FittedModel[$14.3346 - 4.79779x$]

```
In[1144]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.79779	0.00665744	{-4.81085, -4.78473}
b	14.3346	0.00482734	{14.3251, 14.3441}

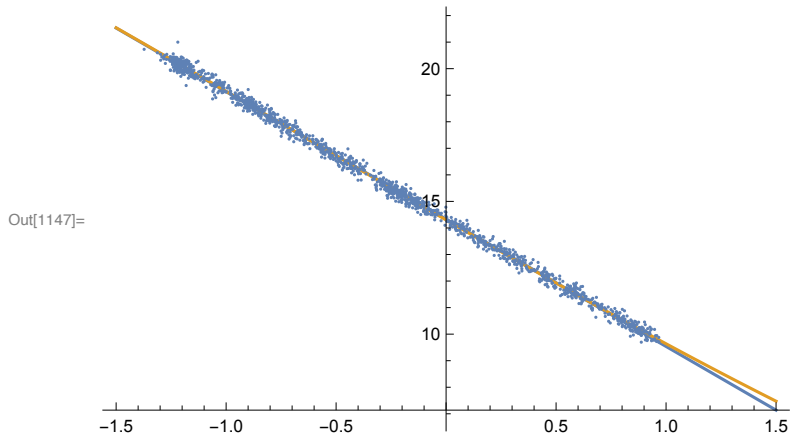
```
In[1145]:= mm1xpol = NonlinearModelFit[Map[#[[16]], #[[18]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.95 < #[[4]] < -0.6 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1145]= FittedModel[$14.3015 - 4.80919x + 0.0915896x^2 + 0.0535787x^3$]

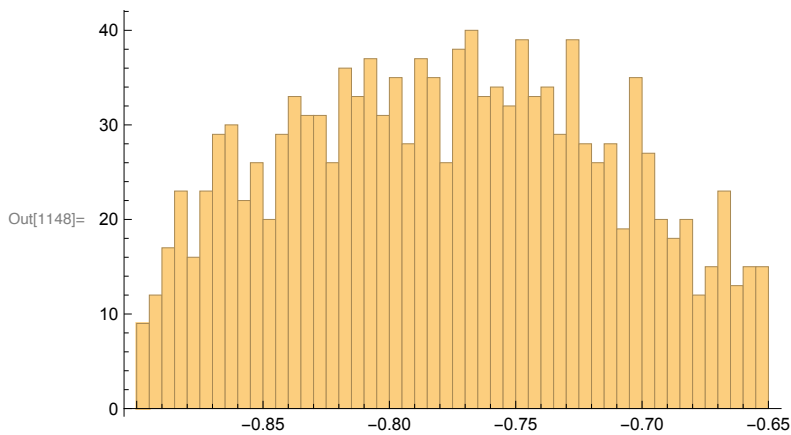
```
In[1146]:= mm1xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0535787	0.0201905	{0.0139738, 0.0931836}
b	0.0915896	0.0160177	{0.0601699, 0.123009}
c	-4.80919	0.0162302	{-4.84103, -4.77735}
d	14.3015	0.00729329	{14.2872, 14.3158}

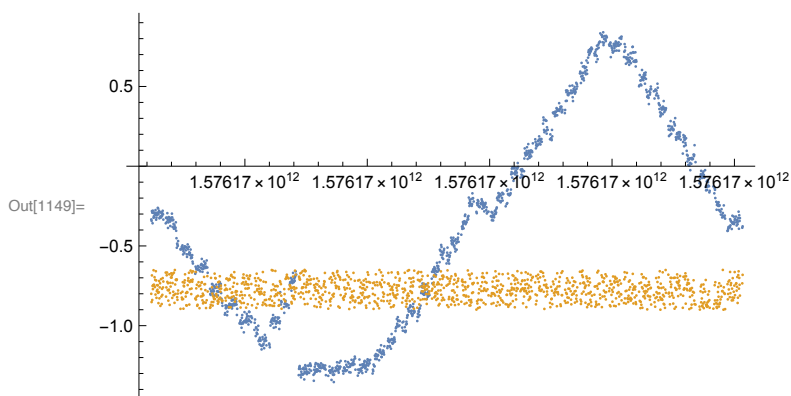
```
In[1147]:= Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}], ListPlot[{Map[#[[16]], #[[18]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]}], PlotRange -> All]
```



```
In[1148]:= Histogram[Map[#[[4]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], 50]
```



```
In[1149]:= ListPlot[{Map[#[[2]], #[[3]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]}], PlotRange -> All]
```



```
In[1150]:= mm1x = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
-199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

```
Out[1150]= FittedModel[ 14.334 - 4.80053 x ]
```

```
In[1151]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.80053	0.00708123	{-4.81442, -4.78664}
b	14.334	0.00510814	{14.3239, 14.344}

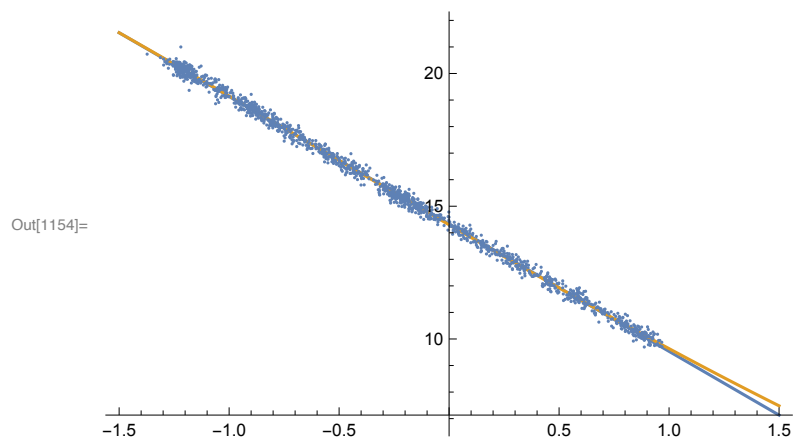
```
In[1152]:= mm1xpol = NonlinearModelFit[Map[#[[16]], #[[18]]] &,
Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

```
Out[1152]= FittedModel[ 14.3012 - 4.81617 x + 0.0923962 x^2 + 0.0585928 x^3 ]
```

```
In[1153]:= mm1xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0585928	0.0215037	{0.0164081, 0.100778}
b	0.0923962	0.0171157	{0.0588197, 0.125973}
c	-4.81617	0.0171709	{-4.84985, -4.78248}
d	14.3012	0.00772477	{14.286, 14.3163}

```
In[1154]:= Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}], ListPlot[Map[#[[16]], #[[18]]] &,
Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]], PlotRange -> All]
```



```
In[1155]:= mm3x = NonlinearModelFit[Map[#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
-199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

```
Out[1155]= FittedModel[ 37.6717 + 11.0812 x ]
```

```
In[1156]:= mm3x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	11.0812	0.0241021	{11.0339, 11.1285}
b	37.6717	0.0173863	{37.6375, 37.7058}

```
In[1157]:= mm3xpol = NonlinearModelFit[Map[#[[16]], #[[22]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

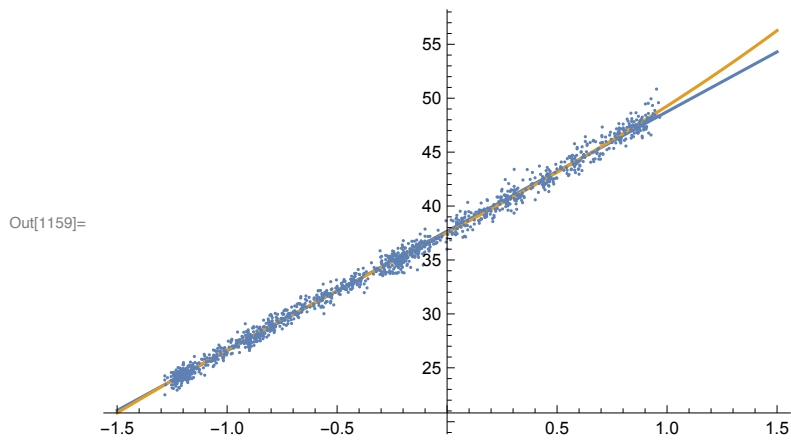
```
Out[1157]= FittedModel[ 37.517 + 10.8853 x + 0.45616 x^2 + 0.415023 x^3 ]
```

```
In[1158]:= mm3xpol["ParameterConfidenceIntervalTable"]
```

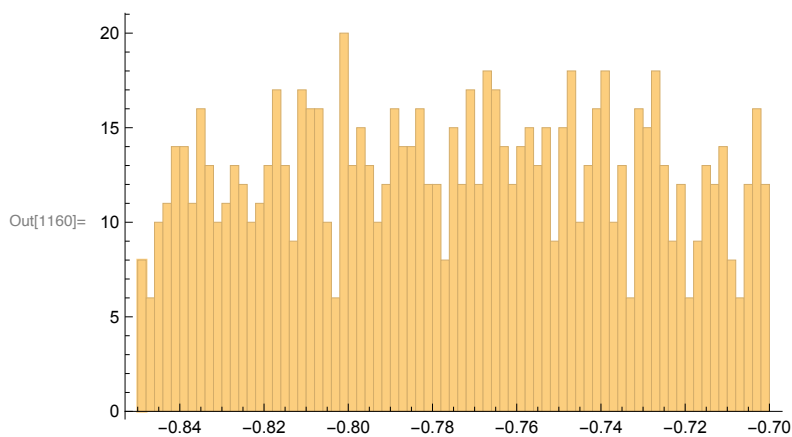
	Estimate	Standard Error	Confidence Interval
a	0.415023	0.0724009	{0.272991, 0.557055}
b	0.45616	0.0576268	{0.343112, 0.569209}
c	10.8853	0.0578127	{10.7718, 10.9987}
d	37.517	0.0260085	{37.466, 37.568}

```
Out[1158]=
```

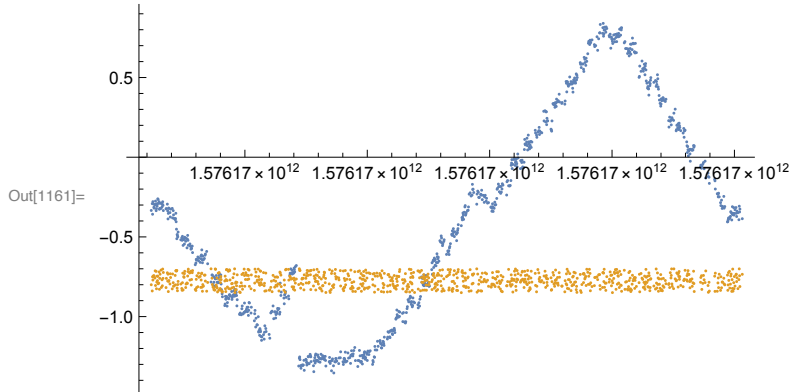
```
In[1159]:= Show[Plot[{mm3x[x], mm3xpol[x]}, {x, -1.5, 1.5}],
  ListPlot[Map[#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], PlotRange -> All]]
```



```
In[1160]:= Histogram[Map[#[[4]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]], 50]
```



```
In[1161]:= ListPlot[Map[#[[2]], #[[3]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]], PlotRange -> All]
```



```
In[1162]:= mm1x = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]], a x + b, {a, b}, x]
```

Out[1162]= FittedModel [14.3307 - 4.80181 x]

```
In[1163]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.80181	0.00839067	{-4.81827, -4.78534}
b	14.3307	0.00610655	{14.3187, 14.3427}

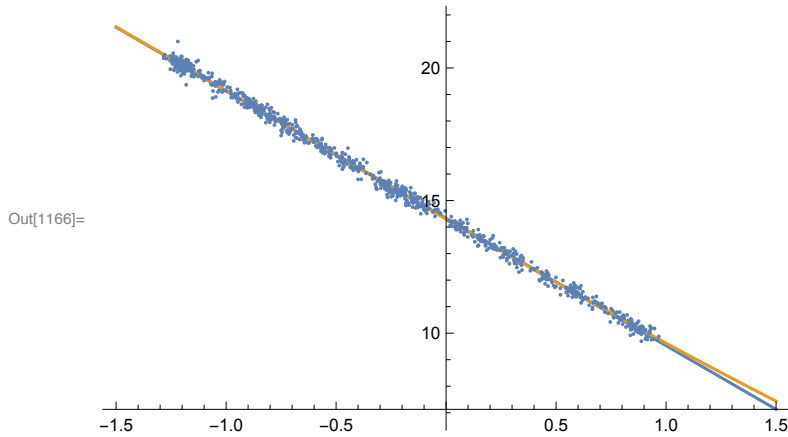
```
In[1164]:= mm1xpol = NonlinearModelFit[Map[#[[16]], #[[18]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1164]= FittedModel [14.2997 - 4.8103 x + 0.0854216 x^2 + 0.0479927 x^3]

```
In[1165]:= mm1xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0479927	0.0254781	{-0.00200708, 0.0979925}
b	0.0854216	0.0206286	{0.0449387, 0.125904}
c	-4.8103	0.0202288	{-4.85, -4.77061}
d	14.2997	0.00935275	{14.2813, 14.318}

```
In[1166]:= Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}],
  ListPlot[Map[#{#[[16]], #[[18]]} &, Select[Take[msp, {1800, 3400}],
    -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]], PlotRange -> All]]
```



```
In[1167]:= mm3x = NonlinearModelFit[Map[#{#[[16]], #[[22]]} &, Select[Take[msp, {1800, 3400}],
  -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]], a x + b, {a, b}, x]
```

Out[1167]= FittedModel [37.6812 + 11.0622 x]

```
In[1168]:= mm3x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	11.0622	0.0279248	{11.0074, 11.1117}
b	37.6812	0.0203231	{37.6413, 37.7211}

```
In[1169]:= mm3xpol = NonlinearModelFit[Map[#{#[[16]], #[[22]]} &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

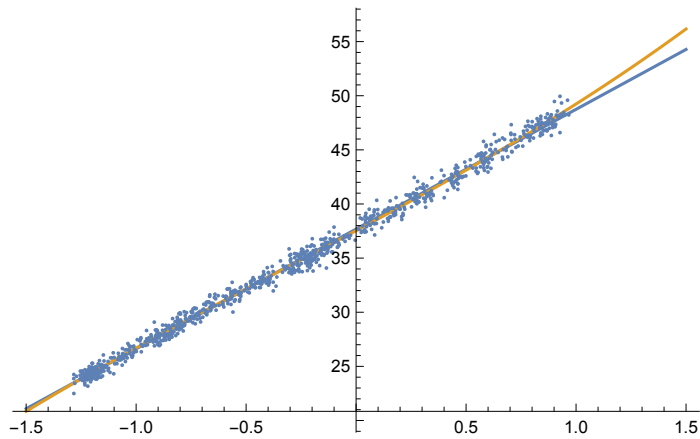
Out[1169]= FittedModel [37.5336 + 10.8685 x + 0.431778 x^2 + 0.402061 x^3]

```
In[1170]:= mm3xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.402061	0.0839315	{0.237349, 0.566773}
b	0.431778	0.0679561	{0.298417, 0.565139}
c	10.8685	0.0666388	{10.7378, 10.9993}
d	37.5336	0.0308104	{37.4732, 37.5941}

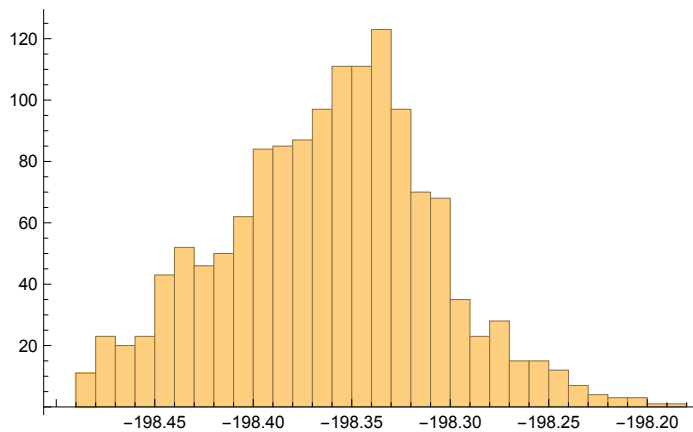
```
In[1171]:= Show[Plot[{mm3x[x], mm3xpol[x]}, {x, -1.5, 1.5}],
  ListPlot[{Map[#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
    -199 < #[[7]] < -197 && -0.85 < #[[4]] < -0.7 &]], PlotRange -> All]]
```

Out[1171]=



```
In[1172]:= Histogram[
  Map[#[[7]] &, Select[Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 &]], 50]
```

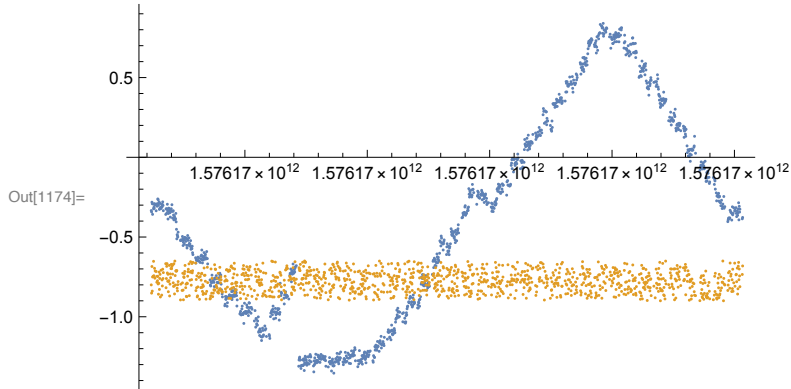
Out[1172]=



```
In[1173]:= {Mean[Map[#[[7]] &, Select[Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 &]],
  StandardDeviation[
    Map[#[[7]] &, Select[Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 &]]]}
```

Out[1173]= {-198.366, 0.0539548}


```
In[1174]:= ListPlot[Map[#[[2]], #[[3]]] &, Select[
  Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], PlotRange -> All]
```



```
In[1175]:= mm1x200 = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

Out[1175]= FittedModel[$14.3316 - 4.80554 x$]

```
In[1176]:= mm1xpol200 =
  NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1176]= FittedModel[$14.3004 - 4.82008 x + 0.0875743 x^2 + 0.0556999 x^3$]

```
In[1177]:= mm1x = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

Out[1177]= FittedModel[$14.3316 - 4.80554 x$]

```
In[1178]:= mm1x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	-4.80554	0.00739213	{-4.82004, -4.79104}
b	14.3316	0.00538308	{14.321, 14.3421}

Out[1178]=

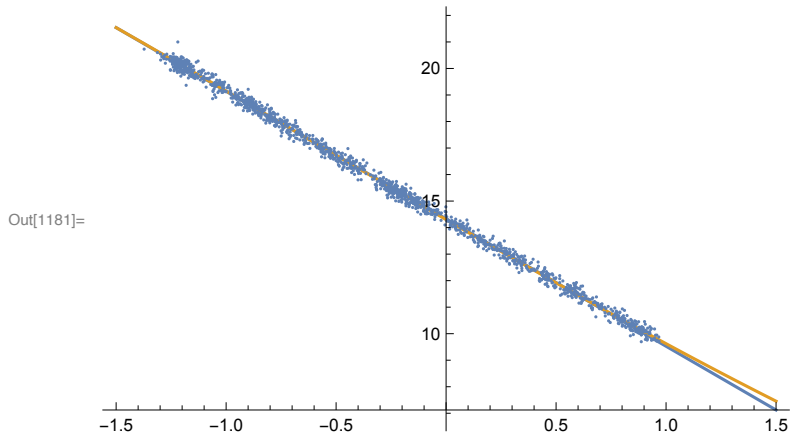
```
In[1179]:= mm1xpol = NonlinearModelFit[Map[#[[16]], #[[18]]] &, Select[
  Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

Out[1179]= FittedModel[$14.3004 - 4.82008 x + 0.0875743 x^2 + 0.0556999 x^3$]

```
In[1180]:= mm1xpol["ParameterConfidenceInterval"]
```

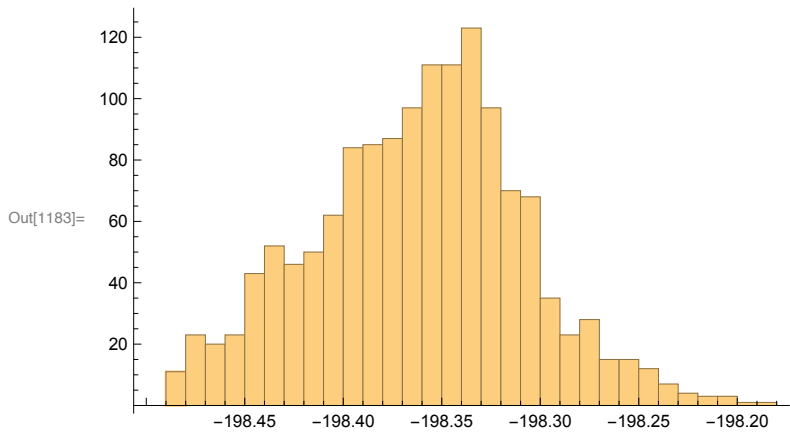
	Estimate	Standard Error	Confidence Interval
a	0.0556999	0.0225006	{0.0115556, 0.0998443}
b	0.0875743	0.0181629	{0.0519401, 0.123208}
c	-4.82008	0.0179188	{-4.85524, -4.78493}
d	14.3004	0.00819244	{14.2843, 14.3165}

```
In[1181]:= Show[Plot[{mm1x[x], mm1xpol[x]}, {x, -1.5, 1.5}], ListPlot[{Map[#[[16]], #[[18]]] &,
    Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]}], PlotRange -> All]]
```

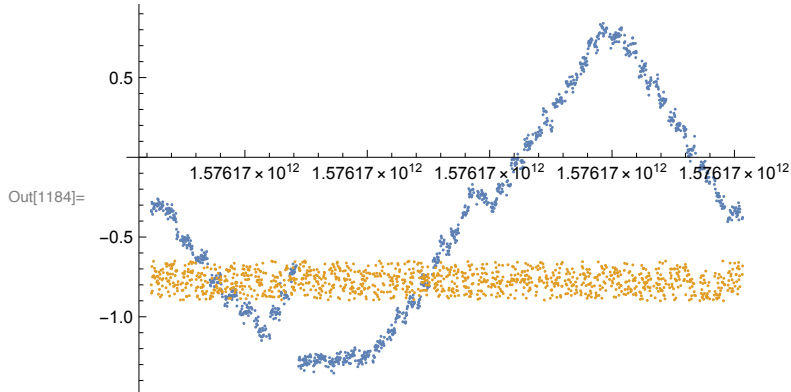


```
In[1182]:=
```

```
In[1183]:= Histogram[
    Map[#[[7]] &, Select[Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 &]], 50]
```



```
In[1184]:= ListPlot[Map[#[[2]], #[[3]]] &, Select[
  Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  Map[#[[2]], #[[4]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], PlotRange -> All]
```



```
In[1185]:= mm2x = NonlinearModelFit[Map[#[[16]], #[[20]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

```
Out[1185]= FittedModel[ 20.7673 + 0.539032 x ]
```

```
In[1186]:= mm2x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.539032	0.00403042	{0.531124, 0.546939}
b	20.7673	0.00293502	{20.7615, 20.7731}

```
In[1187]:= mm2xpol = NonlinearModelFit[Map[#[[16]], #[[20]]] &, Select[
  Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  a x^3 + b x^2 + c x + d, {a, b, c, d}, x]
```

```
Out[1187]= FittedModel[ 20.7422 + 0.491925 x + 0.0762946 x^2 + 0.0846885 x^3 ]
```

```
In[1188]:= mm2xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.0846885	0.0120833	{0.0609821, 0.108395}
b	0.0762946	0.00975385	{0.0571584, 0.0954309}
c	0.491925	0.00962273	{0.473046, 0.510804}
d	20.7422	0.0043995	{20.7336, 20.7509}

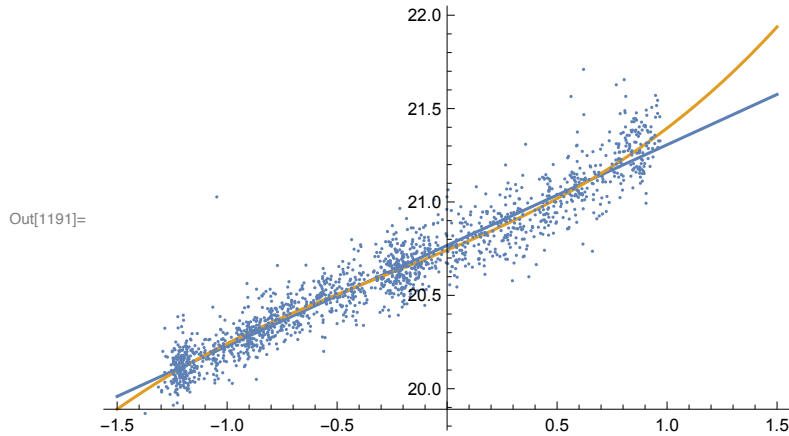
```
In[1189]:= mm2x200 = NonlinearModelFit[Map[#[[16]], #[[20]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

```
Out[1189]= FittedModel[ 20.7673 + 0.539032 x ]
```

```
In[1190]:= mm2xpol200 =
  NonlinearModelFit[Map[#[[16]], #[[20]]] &, Select[Take[msp, {1800, 3400}],
    -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &],
    a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

```
Out[1190]:= FittedModel [ 20.7422 + 0.491925 x + 0.0762946 x2 + 0.0846885 x3 ]
```

```
In[1191]:= Show[Plot[{mm2x[x], mm2xpol[x]}, {x, -1.5, 1.5}], ListPlot[{Map[#[[16]], #[[20]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]}], PlotRange -> All]
```



```
In[1192]:= mm3x = NonlinearModelFit[Map[#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &], a x + b, {a, b}, x]
```

```
Out[1192]:= FittedModel [ 37.6757 + 11.0807 x ]
```

```
In[1193]:= mm3x["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	11.0807	0.0250922	{11.0315, 11.13}
b	37.6757	0.0182726	{37.6398, 37.7115}

```
In[1194]:= mm3xpol = NonlinearModelFit[Map[#[[16]], #[[22]]] &, Select[
  Take[msp, {1800, 3400}], -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &],
  a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

```
Out[1194]:= FittedModel [ 37.5261 + 10.8849 x + 0.441224 x2 + 0.409283 x3 ]
```

```
In[1195]:= mm3xpol["ParameterConfidenceIntervalTable"]
```

	Estimate	Standard Error	Confidence Interval
a	0.409283	0.0755822	{0.260997, 0.557569}
b	0.441224	0.0610114	{0.321524, 0.560924}
c	10.8849	0.0601913	{10.7669, 11.003}
d	37.5261	0.0275194	{37.4721, 37.5801}

```
In[1196]:= mm3x200 = NonlinearModelFit[Map[#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]], a x + b, {a, b}, x]
```

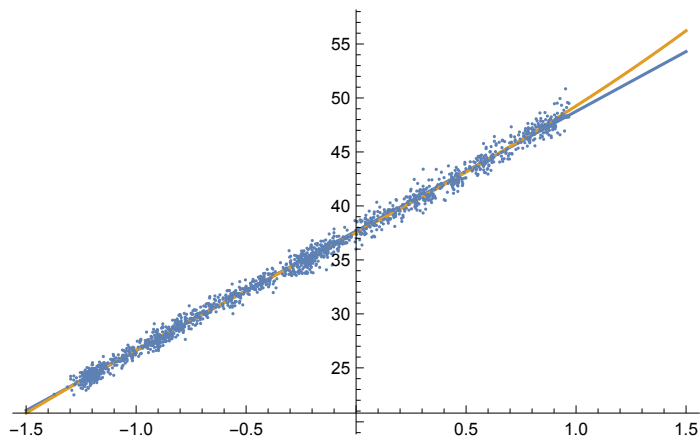
```
Out[1196]= FittedModel[ 37.6757 + 11.0807 x ]
```

```
In[1197]:= mm3xpol200 =
  NonlinearModelFit[Map[#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
    -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
    a x3 + b x2 + c x + d, {a, b, c, d}, x]
```

```
Out[1197]= FittedModel[ 37.5261 + 10.8849 x + 0.441224 x2 + 0.409283 x3 ]
```

```
In[1198]:= Show[Plot[{mm3x[x], mm3xpol[x]}, {x, -1.5, 1.5}], ListPlot[Map[#[[16]], #[[22]]] &,
  Select[Take[msp, {1800, 3400}], -199 < #[[7]] < -197 &]], PlotRange -> All]
```

```
Out[1198]=
```



```

In[1199]:= Show[Plot[{mm1x[x], mm2x[x], mm3x[x]}, {x, -1.5, 1.5},
  PlotStyle -> {Blue, Orange, Green}], Plot[{mm1xpol[x], mm2xpol[x], mm3xpol[x]},
  {x, -1.5, 1.5}, PlotStyle -> {{Blue, Dashed}, {Orange, Dashed}, {Green, Dashed}}],
ListPlot[{Map[{#[[16]], #[[18]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  Map[{#[[16]], #[[20]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]],
  Map[{#[[16]], #[[22]]] &, Select[Take[msp, {1800, 3400}],
  -198.5 < #[[7]] < -197 && -0.9 < #[[4]] < -0.65 &]]},
  PlotRange -> All, PlotStyle -> {Blue, Orange, Green}], GridLines -> Automatic,
ImageSize -> 700, AspectRatio -> 0.7, Frame -> True,
FrameStyle -> Directive[Thick, 24],
FrameLabel -> {"Horizontal proton beam position at target (mm)",
  "Horizontal beam centroid at muon monitor (mm)", PlotRange -> {All, {0, 60}}]

```

