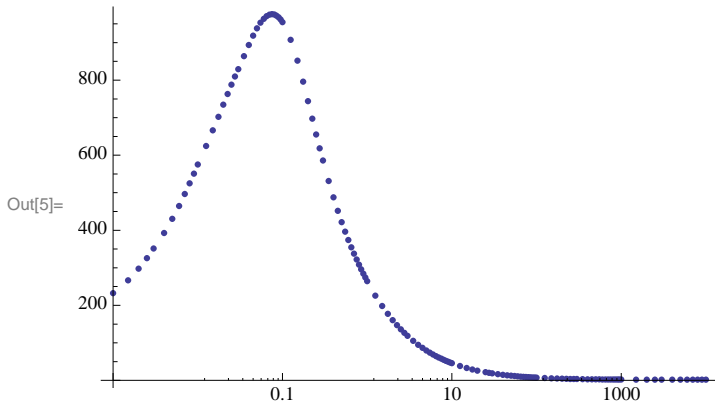


```

In[1]:= Needs["Histograms`"]
In[2]:= tocke = Import["~/Desktop/EdEPoints.dat"];
In[3]:= data = Import["~/Desktop/PLossData.dat"];
In[4]:= EnergyLossData = Map[{{#[[1]], #[[2]]} &, data];
In[5]:= ListLogLinearPlot[EnergyLossData]

```



Calculation

```

In[26]:= K = 0.307075;
z = 1;
ZoverA = 0.54141;
ρ = 1.032;
II = 64.7 * 10-6;

```

```

In[58]:= beta[En_, M_] := 
$$\frac{\text{Sqrt}[En^2 - M^2]}{En}$$

T[En_, M_] := En - M
FullE[Tn_, M_] := Tn + M
gamma[En_, M_] := 
$$\frac{M}{En}$$

Tmax[En_, M_] := 
$$\frac{2 * 0.511 * \text{beta}[En, M]^2 * \text{gamma}[En, M]^2}{1 + 2 * \text{gamma}[En, M] * \frac{0.511}{M} + \left(\frac{0.511}{M}\right)^2}$$


```

```

In[48]:= Tmax[1000, 938.27]

```

```

Out[48]= 0.107541

```

```

In[49]:= beta[1000, 938.27]

```

```

Out[49]= 0.345904

```

```

In[50]:= gamma[1000, 938.27]

```

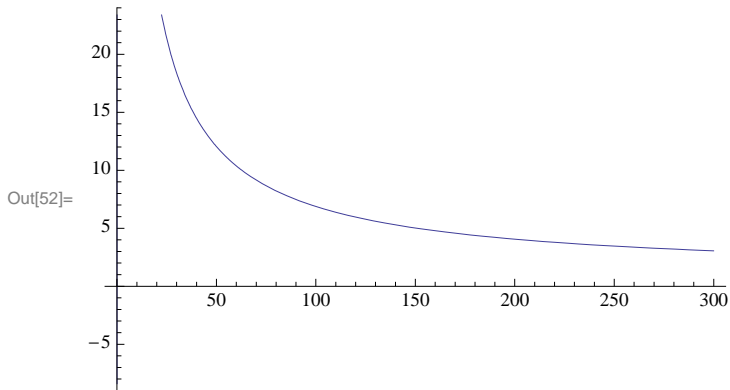
```

Out[50]= 0.93827

```

```
In[51]:= dEdx[En_, M_] := -K * z^2 * ZoverA *  $\frac{1}{\text{beta}[En, M]^2}$ 
 $\left( \frac{1}{2} \text{Log} \left[ \frac{2 * 0.511 \text{beta}[En, M]^2 \text{gamma}[En, M]^2 \text{Tmax}[En, M]}{\text{II}^2} \right] - \text{beta}[En, M]^2 \right)$ 
```

```
In[52]:= Plot[-dEdx[FullE[Tn, 938.27], 938.27], {Tn, 0, 300}]
```



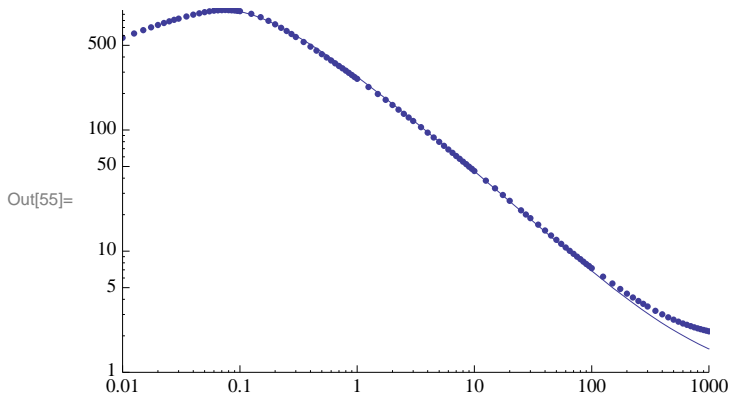
```
In[53]:= dEdx[FullE[150, 938.27], 938.27]
```

Out[53]= -5.0224

```
In[55]:= Show[ListLogLogPlot[EnergyLossData, PlotRange -> {{0.01, 1000}, {0, 300}}],
LogLogPlot[-dEdx[FullE[Tn, 938.27], 938.27], {Tn, 0.1, 1000}, PlotRange -> All]]
```

LogLogPlot::excl : {1.93377 × 10²⁰ Im[$\frac{(-\ll 18 \gg + \ll 1 \gg)^2}{(\ll 7 \gg + \ll 1 \gg)^8 (\ll 19 \gg + \ll 1 \gg)}$] - 0}

must be a list of equalities or real-valued functions. >>



```
In[63]:= dLdx[En_, M_, L0_, kBirks_] := L0 *  $\frac{-dEdx[En, M]}{1 + \text{kBirks} * (-dEdx[En, M])}$ 
```

```
In[64]:= dLdx[FullE[280, 938.27], 938.27, 1, 1]
```

Out[64]= 0.762085

Light Output

```

In[635]:= SimulateEdEPlot[p_, M_, th_] := Module[{},
  Tn0 = T[Sqrt[p^2 + M^2], M];
  (*Print[Tn0]*);
  OffsetX = 220;
  OffsetY = 250;
  kB = 0.01;
  L01 = 180;
  L02 = 39;
  dx = 0.005;
  X01 = 0.3 / Cos[th];
  X02 = 3.0 / Cos[th];
  x = 0;
  Tn = Tn0;
  L1 = 0;
  While[x < X01 && Tn > 0.1,
    x = x + dx;
    L1 = L1 + dLdx[FullE[Tn, M], M, L01, kB] * dx;
    Tn = Tn + dEdx[FullE[Tn, M], M] * dx;
  ];
  (*Print[{x,Tn, Tn0 - Tn,L1}];*)
  x = 0;
  L2 = 0;
  While[x < X02 && Tn > 0.1,
    x = x + dx;
    L2 = L2 + dLdx[FullE[Tn, M], M, L02, kB] * dx;
    Tn = Tn + dEdx[FullE[Tn, M], M] * dx;
  ];
  (*Print[{x,Tn, Tn0 - Tn,L2}];*)
  (*Print[{L1,L2}];*)
  {L2 + OffsetX, L1 + OffsetY}

```

```

In[393]:= SimulateEdEPlot[300, 938.27, 0]

```

```

Out[393]:= {1643.71, 914.441}

```

```

(*results=Table[SimulateEdEPlot[p],{p,100,600,25}];*)

```

```

In[636]:= results = Map[SimulateEdEPlot[#, 938.27, 0] &, {20, 40, 60, 80, 100, 130, 150, 160, 165, 170,
  172, 174, 190, 195, 200, 210, 220, 230, 240, 250, 270, 280, 290, 300, 310, 320, 330,
  344, 350, 360, 370, 380, 400, 440, 480, 500, 600, 650, 700, 800, 900, 1000, 1500}];

```

```

In[372]:= SimulateEdEPlot[280, 938.27, 0]

```

```

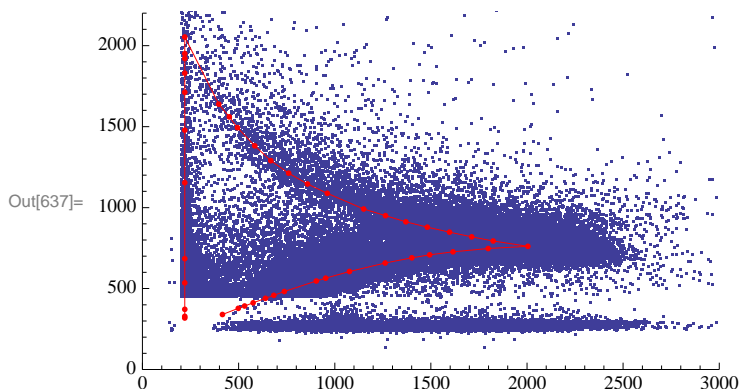
Out[372]:= {1370.65, 869.463}

```

```

In[637]:= Show[ListPlot[Take[tocke, 30 000], PlotStyle -> {PointSize[0.001]}], ListPlot[Take[tocke2
  , 30 000], PlotStyle -> {PointSize[0.0002]}],
  ListPlot[Take[tocke4, 30 000], PlotStyle -> {PointSize[0.0002]}],
  ListPlot[results, PlotStyle -> {PointSize[0.01], Hue[0]}],
  ListPlot[results, PlotJoined -> True, PlotStyle -> Hue[0],
  PlotRange -> {{0, 3000}, {0, 2200}}]

```



Results

```

In[80]:= ppp = {SimulateEdEPlot[344, 938.27, 0],
  SimulateEdEPlot[500, 938.27, 0], SimulateEdEPlot[200, 938.27, 0]}
Out[80]= {{2082.35, 760.77}, {939.359, 546.5}, {488.396, 1497.15}}

In[81]:= ddd = {SimulateEdEPlot[300, 1876.12, 0], SimulateEdEPlot[500, 1876.12, 0],
  SimulateEdEPlot[200, 1876.12, 0], SimulateEdEPlot[400, 1876.12, 0]}
Out[81]= {{308.529, 2184.01}, {1935.5, 1061.7}, {220, 1024.85}, {1065.63, 1390.06}}

In[645]:= ReferencePointsProton = Table[{p, SimulateEdEPlot[p, 938.27, 0]}, {p, 50, 1000, 1}];
In[673]:= ReferencePointsDeuteron = Table[{p, SimulateEdEPlot[p, 1876.12, 0]}, {p, 50, 1000, 1}];
In[183]:= ExportTockeProton = Map[{#[[1]], #[[2, 1]], #[[2, 2]]} &, ReferencePointsProton];
In[188]:= ExportTockeDeuteron = Map[{#[[1]], #[[2, 1]], #[[2, 2]]} &, ReferencePointsDeuteron];
In[672]:= Export["~/Desktop/SimEdEPointsProton2.dat", ExportTockeProton];
In[674]:= Export["~/Desktop/SimEdEPointsDeuteron2.dat", ExportTockeDeuteron];

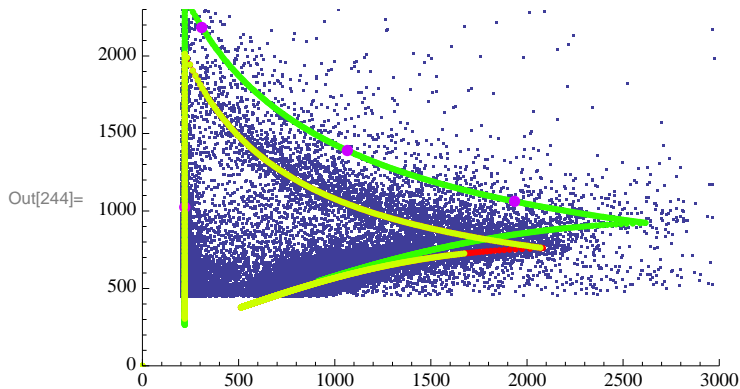
In[242]:= ReferencePointsProtonExcluded =
  Map[If[#[[1]] < 344 || #[[1]] > 360, #, {#[[1]], {-1, -1}}] &, ReferencePointsProton];

In[646]:= Maximum = Max[Map[First[Last[#]] &, ReferencePointsProton]]
Out[646]= 2004.16

In[647]:= plottockeProton = Map[#[[2]] &, ReferencePointsProton];
In[222]:= plottockeDeuteron = Map[#[[2]] &, ReferencePointsDeuteron];
In[243]:= plottockeProtonExcluded = Map[#[[2]] &, ReferencePointsProtonExcluded];
In[236]:= Last[plottockeProtonExcluded]
Out[236]= {512.519, 377.717}

```

```
In[244]:= Show[ListPlot[Take[tocke, 30 000], PlotStyle -> {PointSize[0.001]}],
ListPlot[plottockeProton, PlotStyle -> {Hue[0]}, PlotJoined -> True],
ListPlot[plottockeDeuteron, PlotStyle -> Hue[0.3]],
ListPlot[plottockeDeuteron, PlotStyle -> Hue[0.3], PlotJoined -> True],
ListPlot[ddd, PlotStyle -> {Hue[0.8], PointSize[0.02]}],
ListPlot[plottockeProtonExcluded, PlotStyle -> Hue[0.2]],
PlotRange -> {{0, 3000}, {0, 2300}}]
```



```
In[102]:= CalcDistance[{x1_, y1_}, {x2_, y2_}] := Sqrt[(x1 - x2)^2 + (y1 - y2)^2]
```

```
In[654]:= SelectPoint[{xT_, yT_}] := Module[{},
MinDistance = 10 000;
FinalMomentum = -1;
For[i = 1, i <= Length[ReferencePointsProton], i++,
CurrentDistance = CalcDistance[Last[ReferencePointsProton[[i]]], {xT, yT}];
If[CurrentDistance < MinDistance && xT < 1900 && yT < 2100 && yT > 450,
MinDistance = CurrentDistance;
FinalMomentum = First[ReferencePointsProton[[i]]];
]
];
{MinDistance, FinalMomentum}
]
```

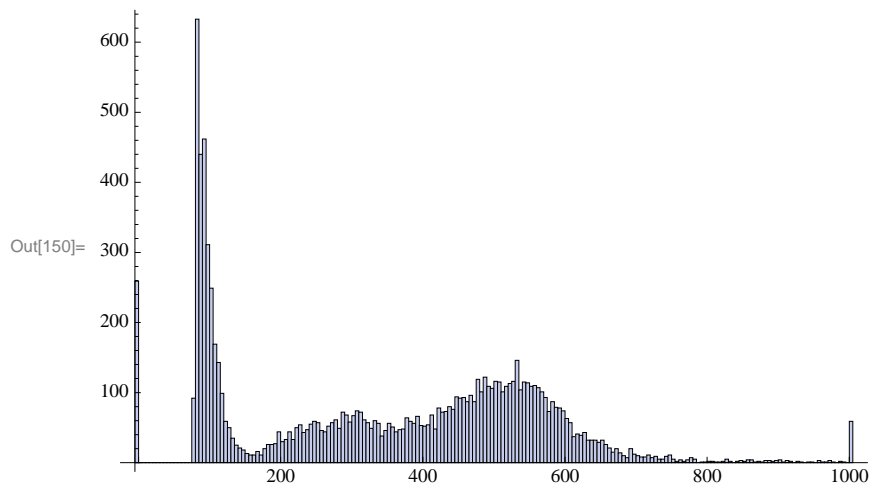
```
In[658]:= SelectMomentumPoint[{xT_, yT_, q_}] := Module[{},
MinDistance = 10 000;
FinalMomentum = -1;
For[i = 1, i <= Length[ReferencePointsProton], i++,
CurrentDistance = CalcDistance[Last[ReferencePointsProton[[i]]], {xT, yT}];
If[CurrentDistance < MinDistance && xT < 1900 && yT < 2100 && yT > 450,
MinDistance = CurrentDistance;
FinalMomentum = First[ReferencePointsProton[[i]]];
]
];
{MinDistance, FinalMomentum, q}
]
```

```
In[537]:= SelectPoint[{1000, 600}]
```

```
Out[537]= {36.3206, 465}
```

```
In[149]:= momentumRes1 = Map[Last[SelectPoint[#]] &, Take[tocke, 10 000]];
```

```
In[150]:= Histogram[momentumRes1, HistogramCategories -> 200]
```



Elastic

```
In[91]:= tocke2a = Import["~/Desktop/EdEPointsHydrogenElastic1.dat"];
```

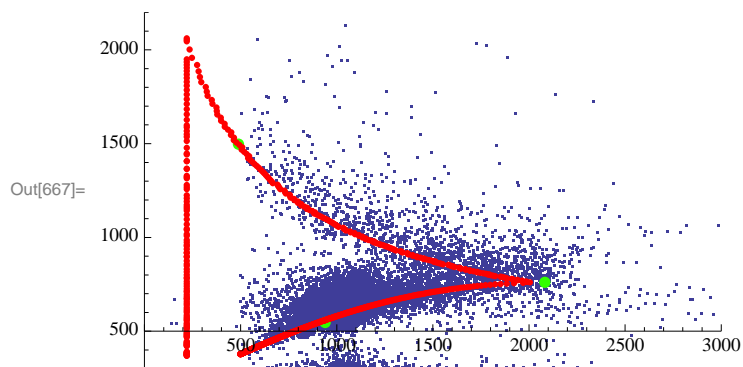
```
In[93]:= tocke2 = Map[#[[1]], #[[2]]] &, tocke2a];
```

```
In[101]:= First[tocke2]
```

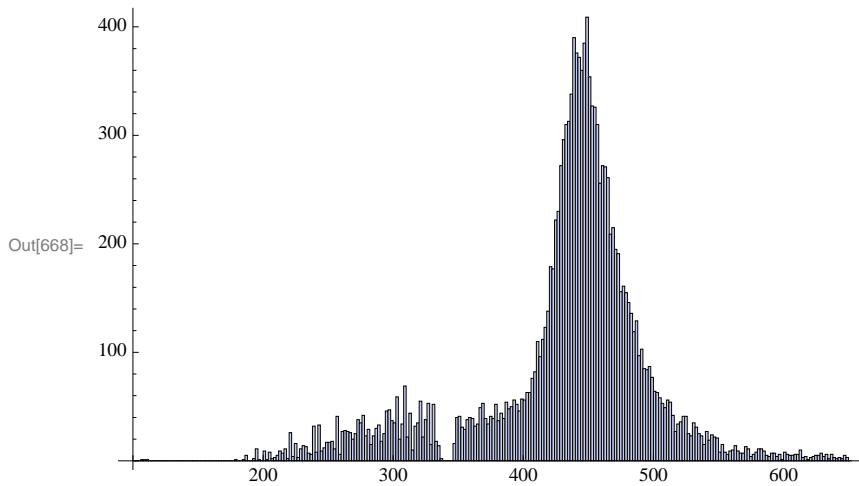
Out[101]= {983.5, 258.5}

```
In[666]:= momentumRes2 = Map[Last[SelectPoint[#]] &, Take[tocke2, 30 000]];
```

```
In[667]:= Show[ListPlot[Take[tocke2, 30 000], PlotStyle -> {PointSize[0.0002]}],
  ListPlot[ppp, PlotStyle -> {Hue[0.3], PointSize[0.02]}],
  ListPlot[plottockeProton, PlotStyle -> Hue[0]], PlotRange -> {{0, 3000}, {300, 2200}}]
```



```
In[668]:= Histogram[momentumRes2, HistogramCategories -> 300, HistogramRange -> {100, 650}]
```

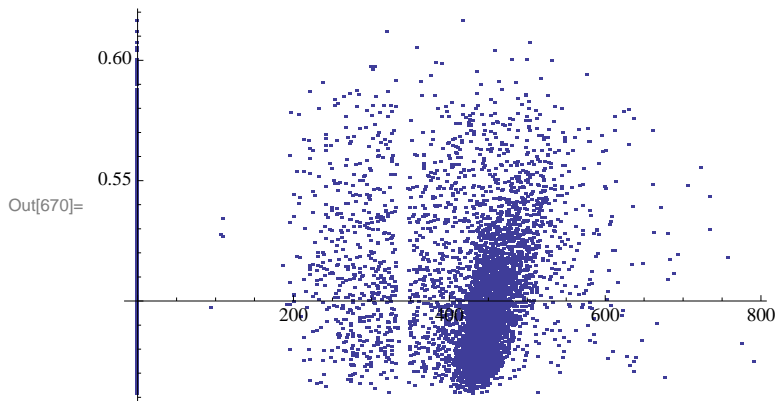


```
In[669]:= momentumRes2Mom = Map[SelectMomentumPoint[#] &, Take[tocke2a, 10 000]];
```

```
In[136]:= First[momentumRes2Mom]
```

```
Out[136]= {10 000, -1, 0.497778}
```

```
In[670]:= s1 = ListPlot[Map[{#[[2]], #[[3]]} &, momentumRes2Mom], PlotStyle -> {PointSize[0.005]}, PlotRange -> All]
```



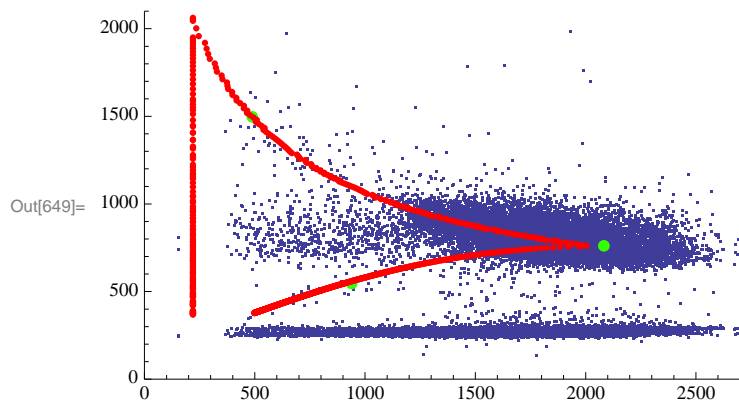
Elastic proton #2

```
In[118]:= tocke4a = Import["~/Desktop/EdEPointsHydrogenElastic2.dat"];
```

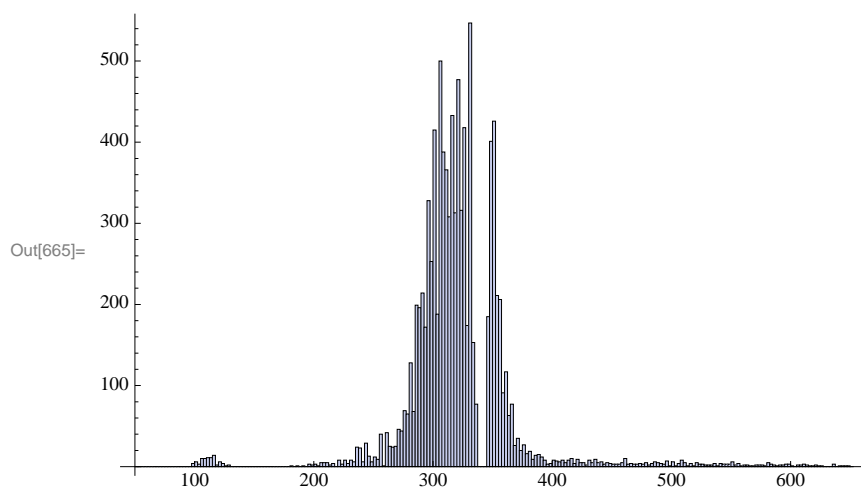
```
In[119]:= tocke4 = Map[{#[[1]], #[[2]]} &, tocke4a];
```

```
In[664]:= momentumRes4 = Map[Last[SelectPoint[#]] &, Take[tocke4, 30 000]];
```

```
In[649]:= Show[ListPlot[Take[tocke4, 30 000], PlotStyle -> {PointSize[0.0002]}],
ListPlot[ppp, PlotStyle -> {Hue[0.3], PointSize[0.02]}],
ListPlot[plottockeProton, PlotStyle -> Hue[0]], PlotRange -> {{0, 2700}, {0, 2100}}]
```



```
In[665]:= Histogram[momentumRes4, HistogramCategories -> 200, HistogramRange -> {50, 650}]
```

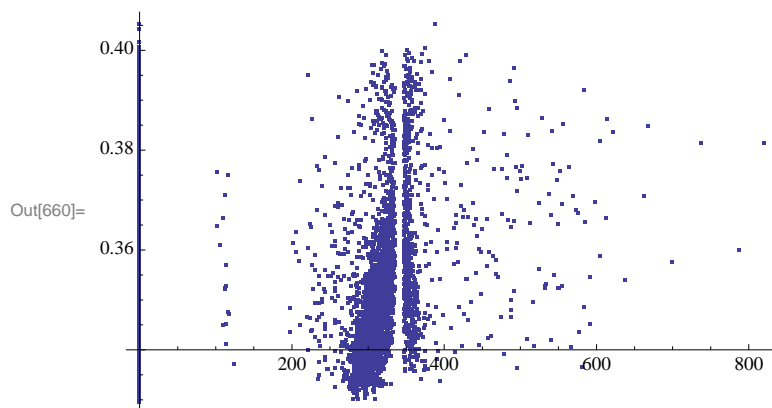


```
In[659]:= momentumRes4Mom = Map[SelectMomentumPoint[#] &, Take[tocke4a, 10 000]];
```

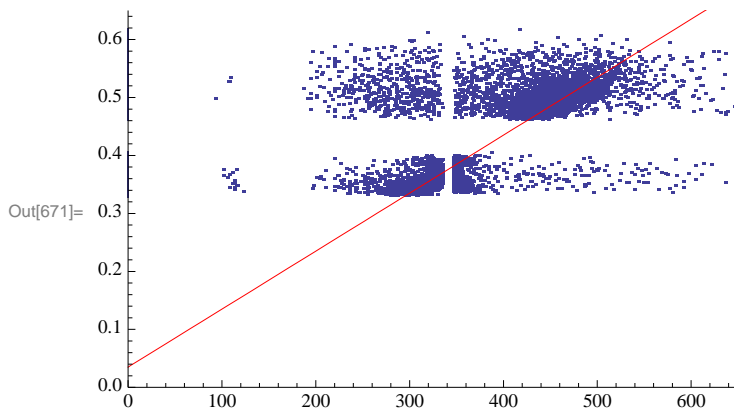
```
In[439]:= First[momentumRes4Mom]
```

```
Out[439]= {10 000, -1, 0.364359}
```

```
In[660]:= s2 = ListPlot[Map[{#[[2]], #[[3]]} &, momentumRes4Mom], PlotStyle -> {PointSize[0.005]}]
```




```
In[671]:= Show[s1, s2, Plot[x / 1000
+ 0.035, {x, 0, 650}, PlotStyle -> Hue[0]], PlotRange -> {{0, 650}, {0, 0.650}}]
```



Elastic Deuteron

```
In[201]:= SelectPointDeuteron[{xT_, yT_}] := Module[{},
  MinDistance = 10 000;
  FinalMomentum = -1;
  For[i = 1, i ≤ Length[ReferencePointsDeuteron], i++,
    CurrentDistance = CalcDistance[Last[ReferencePointsDeuteron[[i]]], {xT, yT}];
    If[CurrentDistance < MinDistance && xT < 2700 && yT < 2700 && yT > 450,
      MinDistance = CurrentDistance;
      FinalMomentum = First[ReferencePointsDeuteron[[i]]];
    ]
  ];
  {MinDistance, FinalMomentum}
]
```

```
In[213]:= SelectMomentumPointDeuteron[{xT_, yT_, q_}] := Module[{},
  MinDistance = 10 000;
  FinalMomentum = -1;
  For[i = 1, i ≤ Length[ReferencePointsDeuteron], i++,
    CurrentDistance = CalcDistance[Last[ReferencePointsDeuteron[[i]]], {xT, yT}];
    If[CurrentDistance < MinDistance && xT < 2700 && yT < 2700 && yT > 450,
      MinDistance = CurrentDistance;
      FinalMomentum = First[ReferencePointsDeuteron[[i]]];
    ]
  ];
  {MinDistance, FinalMomentum, q}
]
```

```
In[208]:= SelectPointDeuteron[{2000, 1000}]
```

```
Out[208]= {44.4818, 508}
```

```
In[202]:= tocke3a = Import["~/Desktop/EdEPointsDeuteronElastic1.dat"];
```

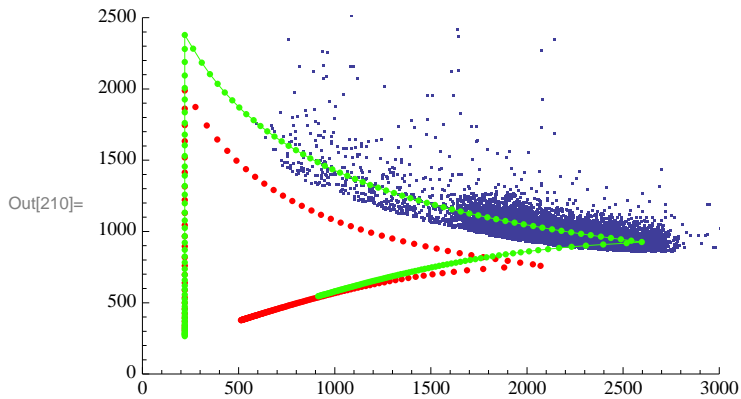
```
In[203]:= tocke3 = Map[#[[1]], #[[2]]] &, tocke3a;
```

```
In[206]:= momentumRes3 = Map[Last[SelectPointDeuteron[#]] &, Take[tocke3]];
```

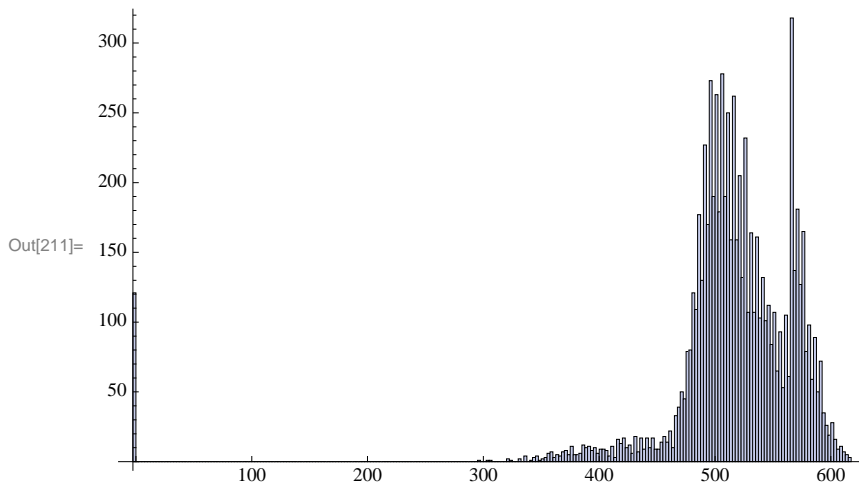
```
In[207]:= Last[momentumRes3]
```

```
Out[207]= 508
```

```
In[210]:= Show[ListPlot[Take[tocke3], PlotStyle -> {PointSize[0.0002]}],
ListPlot[plottockeProton, PlotStyle -> Hue[0]],
ListPlot[plottockeDeuteron, PlotStyle -> Hue[0.3]],
ListPlot[plottockeDeuteron, PlotStyle -> Hue[0.3], PlotJoined -> True],
PlotRange -> {{0, 3000}, {0, 2500}}
```



```
In[211]:= Histogram[momentumRes3, HistogramCategories -> 200]
```

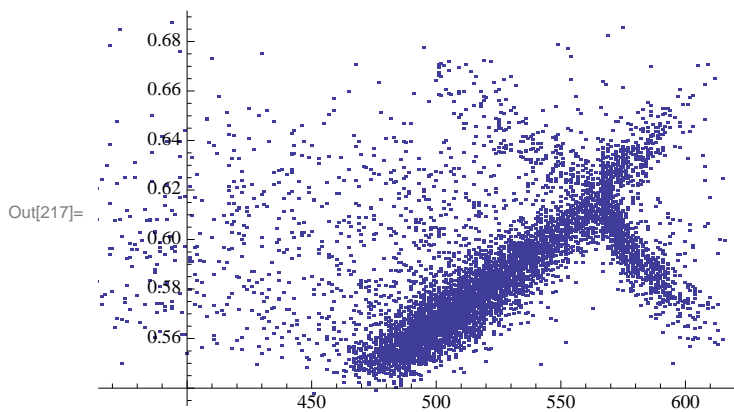


```
In[215]:= momentumRes3Mom = Map[SelectMomentumPointDeuteron[#] &, Take[tocke3a]];
```

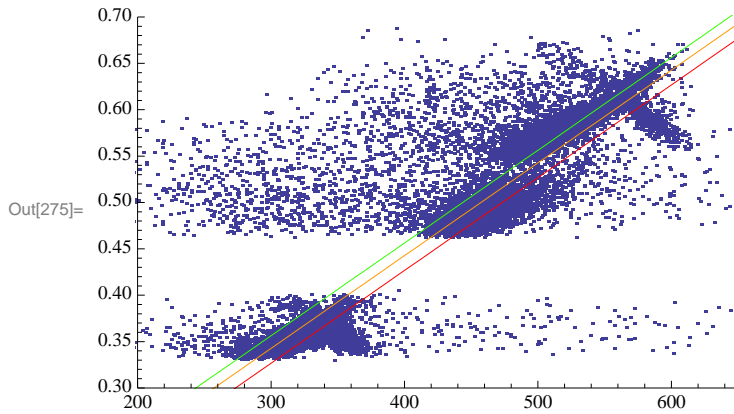
```
In[216]:= First[momentumRes3Mom]
```

```
Out[216]= {15.2843, 545, 0.594198}
```

```
In[217]:= s3 = ListPlot[Map[{#[[2]], #[[3]]} &, momentumRes3Mom], PlotStyle -> {PointSize[0.005]}]
```



```
In[275]:= Show[s1, s2, s3, Plot[x / 1000
+ 0.0267, {x, 0, 650}, PlotStyle -> Hue[0]], Plot[x / 1000
+ 0.0563, {x, 0, 650}, PlotStyle -> Hue[0.3]], Plot[x / 1000
+ 0.0427, {x, 0, 650}, PlotStyle -> Hue[0.1]], PlotRange -> {{200, 650}, {0.3, 0.70}}
```



```
In[273]:= T[Sqrt[360^2 + 938.27^2], 938.27]
```

Out[273]= 66.693

Corrected for ΔE

```
In[282]:= Show[
ListPlot[Map[#[[2]] + 42.7, #[[3]]] &, momentumRes4Mom], PlotStyle -> {PointSize[0.005]}],
ListPlot[Map[#[[2]] + 26.7, #[[3]]] &, momentumRes2Mom], PlotStyle -> {PointSize[0.005]}],
Plot[x / 1000, {x, 0, 650}, PlotStyle -> Hue[0.5]]]
```

