In[3]:=
```
Needs["ErrorBarPlots`"]
```

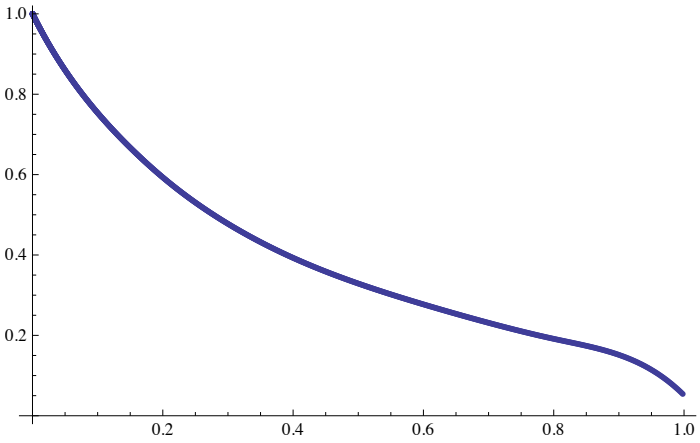
In[4]:=
```
SetDirectory[NotebookDirectory[]]
```

Out[4]=
```
/Users/miham/Desktop/ISR/RadiusFit
```

In[5]:=
```
GEparam = {-0.482595542345, -0.128546517269, -0.143915206116,
    -0.0707915928433, -0.120344362658, -0.0725995689361, -0.0967010500022,
    -0.0795875516334, -0.306355578219, 0.285410628132, 0.666347535185, 0.0};
GMparam = {0.291619218385, -0.119536433529, 0.0138813241395, 0.0539795485351,
  0.0736318819094, 0.0961249406462, 0.050817085997, 0.00975127318037,
  -0.0341580765641, 0.0249794642243, -0.104345799964, 0.0};
knots = {0., 0., 0., 0., 0.25, 0.5, 0.75, 1., 1.5, 3., 5., 10., 40., 40., 40., 40.};
ftbl = Table[BSplineBasis[{3, knots}, i, x], {i, 0, 11}];
GEswvk[x_] = (1 + Total[GEparam ftbl] x) (1 + x/0.71)^-2;
GMswvk[x_] = (1 + Total[GMparam ftbl] x) (1 + x/0.71)^-2;
```

In[118]:=
```
spline = ListPlot[Select[Map[{#[[1]], #[[2]]} &, Import["Spline.dat"]], #[[1]] < 1 &]]
```

Out[118]=



In[11]:=
```
GD[x_, a_, n_] := 1/(1 + x/a)^2 * n
```

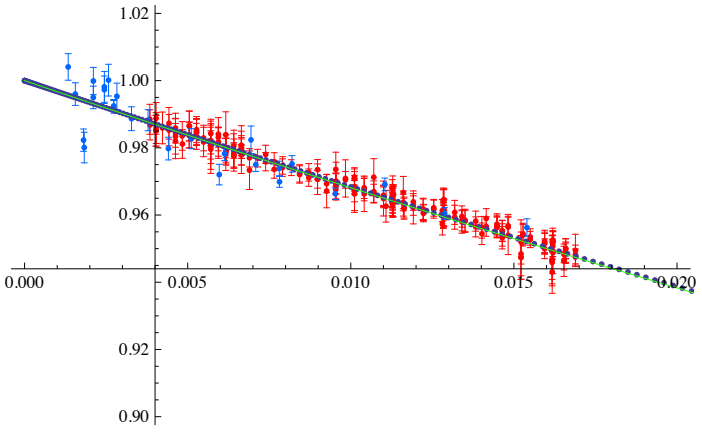
In[132]:=
```
data1 = Select[Map[{#[[1]], Sqrt[#[[2]]] * GD[#[[1]], 0.71, 1.00], #[[3]]} &,
     Import["BernauerCS.dat"]], #[[1]] < 1 &];
data2 = Select[Map[{#[[1]], #[[2]], #[[3]]} &, Import["ISRFormFactor.dat"]],
   #[[1]] < 0.017 &];


data2;
```

In[192]:=
```
data = Join[Select[data1, #[[1]] < 0.017 &]];
```

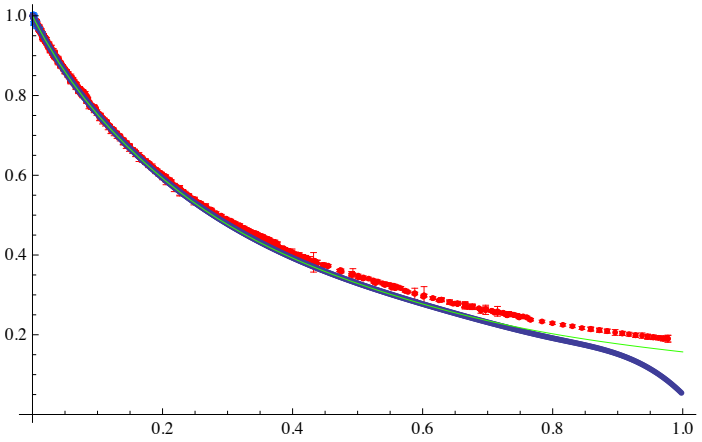
In[193]:=
```
s1 = Show[
  ErrorListPlot[Map[{{#[[1]], #[[2]]}, ErrorBar[#[[3]]]} &, data], PlotStyle → Hue[0]],
  ErrorListPlot[Map[{{#[[1]], #[[2]]}, ErrorBar[#[[3]]]} &, data2],
   PlotStyle → Hue[0.6]], spline, Plot[GEswvk[x], {x, 0, 0.06},
   PlotStyle → Hue[0.3]], PlotRange → {{0, 0.02}, {0.9, 1.02}}]
```

Out[193]=



In[136]:=
```
Show[ErrorListPlot[Map[{{#[[1]], #[[2]]}, ErrorBar[#[[3]]]} &, data1],
  PlotStyle → Hue[0]], ErrorListPlot[
  Map[{{#[[1]], #[[2]]}, ErrorBar[#[[3]]]} &, data2], PlotStyle → Hue[0.6]],
 spline, Plot[GEswvk[x], {x, 0, 1}, PlotStyle → Hue[0.3]], PlotRange → All]
```

Out[136]=

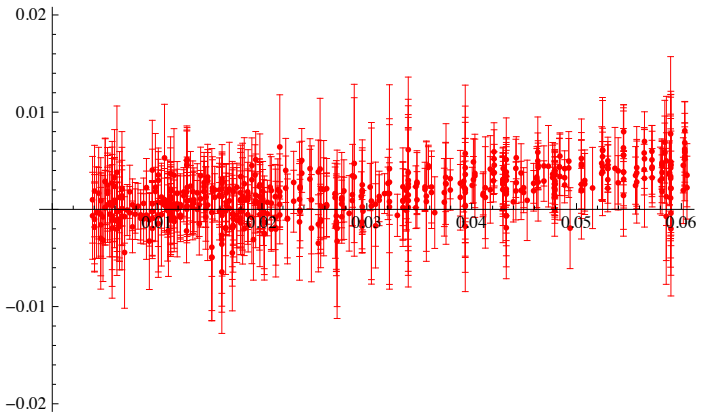


Difference

In[137]:=
```
diff = Map[{#[[1]], #[[2]] - GEswvk[#[[1]]], #[[3]]} &, data1];
```

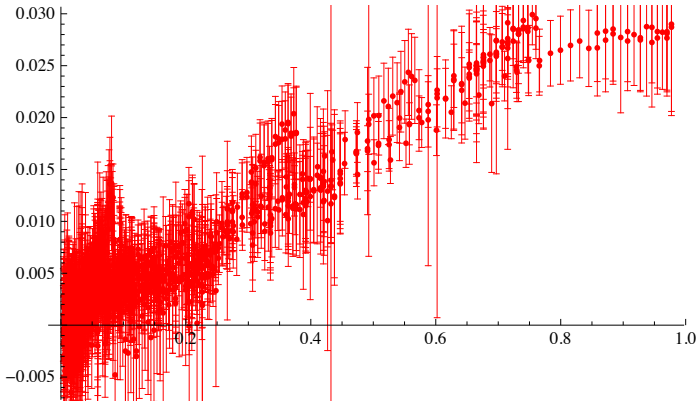
In[138]:=
```
Show[ErrorListPlot[Map[{{#[[1]], #[[2]]}, ErrorBar[#[[3]]]} &, diff],
  PlotStyle → Hue[0]], PlotRange → {{0, 0.06}, {-0.02, 0.02}}]
```

Out[138]=



In[139]:=
```
Show[
 ErrorListPlot[Map[{{#[[1]], #[[2]]}, ErrorBar[#[[3]]]} &, diff], PlotStyle → Hue[0]]]
```

Out[139]=



Uncostrained Dipole Fit

In[194]:=
```
Clear[n]
```

In[195]:=
```
errors = Map[#[[3]] &, data];
nlm = NonlinearModelFit[Map[{#[[1]], #[[2]]} &, data], GD[x, a, n],
    {a, n}, {x}, Weights → 1/errors^2, VarianceEstimatorFunction → (1 &)];
fd1 = nlm["BestFitParameters"]
```

Out[197]=
```
{a → 0.63946, n → 0.999264}
```

In[198]:=
```
nlm["EstimatedVariance"]
```

Out[198]=
```
1
```

In[199]:=
```
nlm["ParameterConfidenceIntervals"]
```

Out[199]=
```
{{0.610444, 0.668477}, {0.997648, 1.00088}}
```

In[200]:=
```
nlm["ParameterTable"]
```

Out[200]=

	Estimate	Standard Error	t-Statistic	P-Value
a	0.63946	0.0147104	43.47	1.13589×10^{-100}
n	0.999264	0.000819337	1219.6	$7.193263214443627\times10^{-372}$

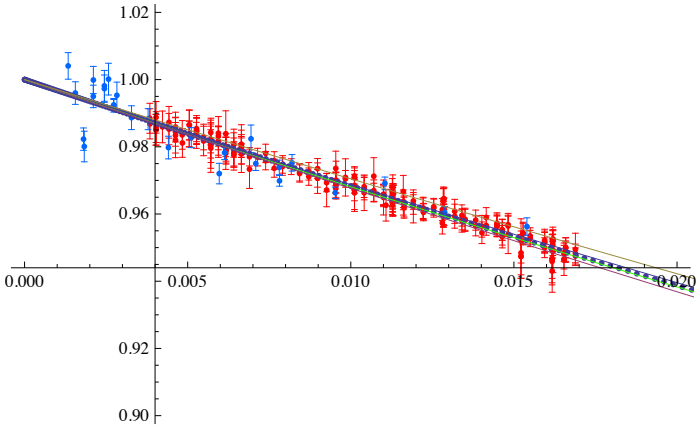
In[201]:=
```
nlm["ANOVATable"]
```

Out[201]=

	DF	SS	MS
Model	2	1.564×10^{7}	7.81998×10^{6}
Error	190	40.5539	0.213442
Uncorrected Total	192	1.564×10^{7}	
Corrected Total	191	1990.21	

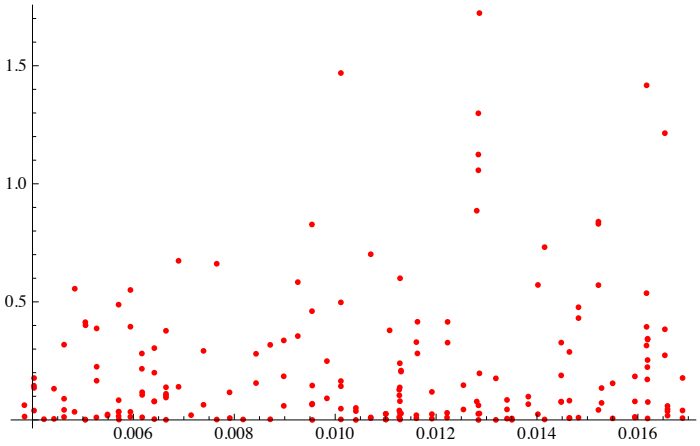
In[202]:=
```
Show[s1, Plot[
  {GD[x, a, n] /. fd1, GD[x, 0.603371130, 1] /. fd1, GD[x, 0.66220324, 1]}, {x, 0, 0.03}]]
```

Out[202]=



In[203]:=
```
s2 = Show[ListPlot[Map[{#[[1]], (#[[2]] - GD[#[[1]], a, n] /. fd1)^2/#[[3]]} &, data],
   PlotStyle → Hue[0], PlotStyle → Hue[0.6]], PlotRange → All]
```

Out[203]=



In[204]:=
```
dd = D[GD[x, a, n], x] /. {x → 0}
r = Sqrt[-6 * 0.197326^2 * dd]
```

Out[204]=
$$-\frac{2\,n}{a}$$

Out[205]=
$$0.683557\sqrt{\frac{n}{a}}$$

In[206]:=
```
r /. fd1
```

Out[206]=
```
0.854493
```

In[207]:=
```
cc = nlm["CovarianceMatrix"];
cc // MatrixForm
```

Out[208]//MatrixForm=
$$\begin{pmatrix} 0.000216396 & -0.0000114653 \\ -0.0000114653 & 6.71313\times 10^{-7} \end{pmatrix}$$

In[209]:=
```
dr = Sqrt[(D[r, a])^2 cc[[1, 1]] + (D[r, n])^2 cc[[2, 2]]] /. fd1
```

Out[209]=
```
0.00983478
```

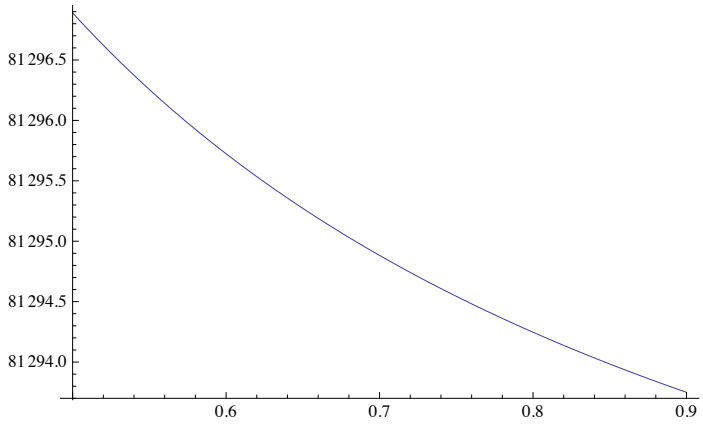
In[210]:=
```
Total[Map[((#[[2]] - GD[#[[1]], a, 1])/#[[3]])^2 &, data]] /. fd1
```

Out[210]=
```
49.0271
```

In[211]:=
$$\text{Chi2}[a\_, n\_] := \frac{1}{\text{Length}[\text{data}]}\ \text{Total}\left[\text{Map}\left[\left(\frac{\#[[2]] - \text{GD}[\#[[1]], a, n]}{\#[[3]]}\right)^2 \&, \text{data}\right]\right]$$

In[212]:=
```
Plot[Chi2[a, 0.001], {a, 0.5, 0.9}]
```

Out[212]=



In[213]:=
$$\text{Solve}\left[0.683557315308\ \sqrt{\frac{1}{a}} == 0.84, a\right]$$

Out[213]=
```
{{a → 0.662203}}
```

- **Systematics (only normalization is affected)**

In[214]:=
```
Sqrt[(D[r, n])^2 0.01^2] /. fd1
```

Out[214]=
```
0.00427561
```

Manual Fit with Chi2

In[222]:=
$$\text{Chi2b}[a\_, c\_, \text{data}\_] := \frac{1}{\text{Length}[\text{data}] - 2}\ \text{Sum}\left[\frac{(\text{GD}[\text{data}[[i, 1]], a, 1] - c * \text{data}[[i, 2]])^2}{c^2 * \text{data}[[i, 3]]^2}, \{i, 1, \text{Length}[\text{data}]\}\right]$$

In[223]:=
```
min = FindMinimum[Chi2b[aa, ccc, data], {aa, ccc}]
```

FindMinimum::lstol :
The line search decreased the step size to within the tolerance specified by AccuracyGoal and PrecisionGoal but was unable to find a sufficient decrease in the function. You may need more than MachinePrecision digits of working precision to meet these tolerances. ≫

Out[223]=
```
{0.213442, {aa → 0.63946, ccc → 1.00074}}
```

In[224]:=
$$\alpha 2[\text{data}\_, \text{aa}\_, \text{ccc}\_] := \text{Sum}\left[\frac{1}{\text{data}[[i, 3]]^2}\right.$$
$$\left\{\left\{D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], a\right] D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], a\right],\ D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], a\right] D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], c\right]\right\},\right.$$
$$\left.\left.\left\{D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], c\right] D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], a\right], D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], c\right] D\left[\text{GD}\left[Q2, a, \frac{1}{c}\right], c\right]\right\}\right\} /.$$
$$\left.\{a \to \text{aa},\ c \to \text{ccc},\ Q2 \to \text{data}[[i, 1]]\}, \{i, 1, \text{Length}[\text{data}]\}\right]$$

In[225]:=
```
Cov = Inverse[α2[data, aa, ccc] /. min[[2]]]
```

Out[225]=
$$\left\{\{0.000216396, 0.0000114822\}, \left\{0.0000114822, 6.73292 \times 10^{-7}\right\}\right\}$$

In[226]:=
```
{Sqrt[Cov[[1, 1]]], Sqrt[Cov[[2, 2]]]}
```

Out[226]=
```
{0.0147104, 0.000820543}
```

In[227]:=
```
RadiusGD2[{a_, n_}, cc_] := Module[{},
  dd = D[GD[x, a1, 1], x] /. {x → 0};
  r = Sqrt[-6 * 0.197326^2 * dd];
  dr = Sqrt[(D[r, a1])^2 cc[[1, 1]]];
  {r, dr, n1, Sqrt[cc[[2, 2]]]} /. {a1 → a, n1 → n}
 ]
```

In[228]:=
```
RadiusGD2[{aa, ccc} /. min[[2]], Cov]
```

Out[228]=
```
{0.854807, 0.00983216, 1.00074, 0.000820543}
```

Manual Form - Factor Error band

```
da = Sqrt[Cov[[1, 1]]]
```

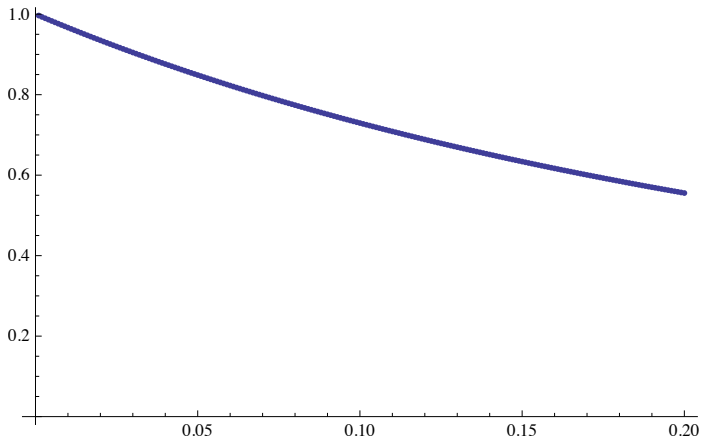
```
0.0239316
```

```
FormFactor[Q2_, NN_, a_, n_, da_, dn_] := Module[{},
  aList = RandomVariate[NormalDistribution[a, da], NN];
  FF = Map[GD[Q2, #, 1] &, aList];
  mean = Mean[FF];
  sigma = Sqrt[Variance[FF]];
  {Q2, mean, sigma}
 ]
```

```
FormFactor[0.01, 100, aa /. min[[2]], 1, da, 0]
```

```
{0.01, 0.966768, 0.00143494}
```

```
FFTable =
  Table[FormFactor[Q2, 100 000, aa /. min[[2]], 1, da, 0], {Q2, 0.001, 0.2, 0.001}];
ListPlot[Map[{#[[1]], #[[2]]} &, FFTable]]
```




```
Export["ResultsISRStandAloneManual.dat", FFTable];
```