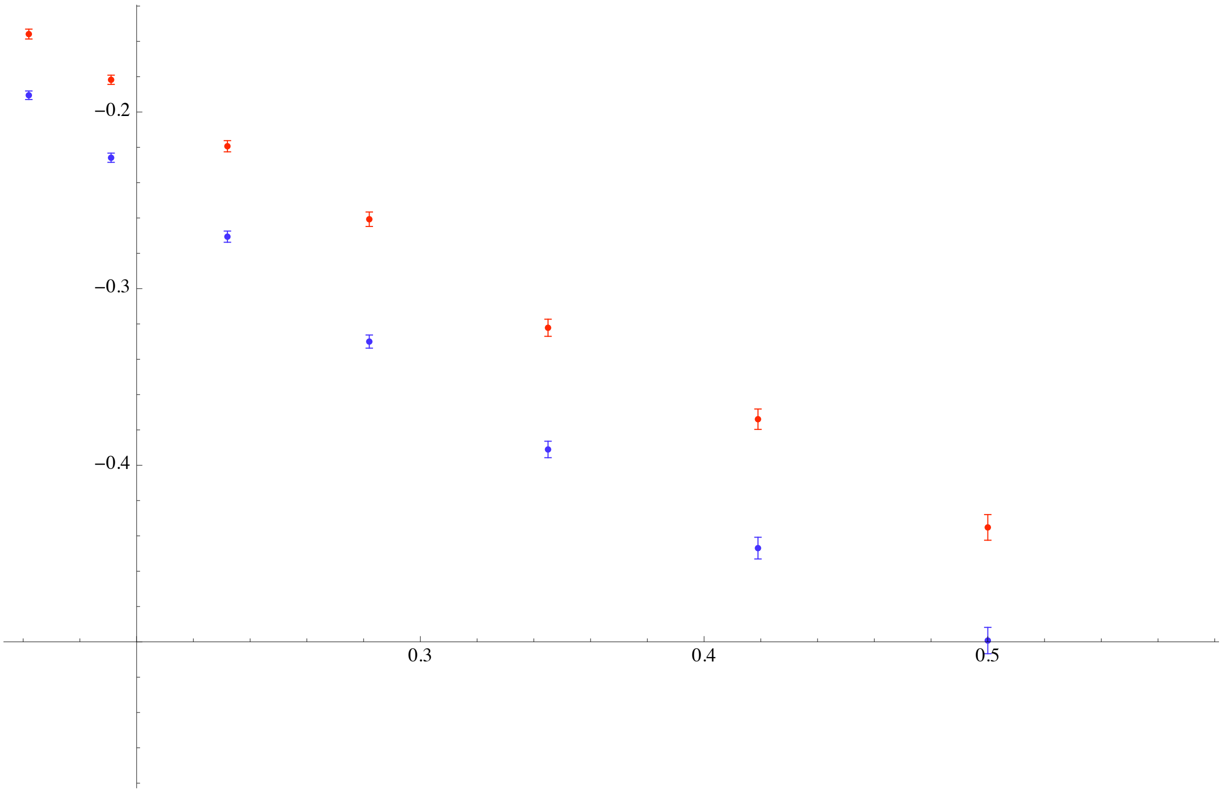
```
Needs["ErrorBarPlots`"]
```

MIT Bates Data

```
PbPt = 0.537;

DataLeft = {{0.162, -0.0837, 0.0015}, {0.191, -0.0976, 0.0014},
   {0.232, -0.1178, 0.0017}, {0.282, -0.1400, 0.0022}, {0.345, -0.1730, 0.0026},
   {0.419, -0.2008, 0.0031}, {0.500, -0.2337, 0.0039}, {0.591, -0.2612, 0.0054}};

DataRight = {{0.162, -0.1023, 0.0013}, {0.191, -0.1213, 0.0014},
   {0.232, -0.1453, 0.0017}, {0.282, -0.1772, 0.002}, {0.345, -0.2100, 0.0025},
   {0.419, -0.2400, 0.0033}, {0.500, -0.2681, 0.0040}, {0.591, -0.2999, 0.0057}};

MITResultsLeft = Map[{{#[[1]], #[[2]]/PbPt}, ErrorBar[#[[3]]/PbPt]} &, DataLeft];

MITResultsRight = Map[{{#[[1]], #[[2]]/PbPt}, ErrorBar[#[[3]]/PbPt]} &, DataRight];

plotMIT = Show[ErrorListPlot[MITResultsLeft, PlotStyle → Hue[0]],
  ErrorListPlot[MITResultsRight, PlotStyle → Hue[0.7]], ImageSize → {600, 400}, ]
```



Scattering angle calculation

```
ScatAngle[Qsq_, Eng_, M_] := 2 * ArcSin[Sqrt[Qsq / (2 (2 Eng^2 - Qsq Eng / M))]]
```

```
ScatAngle[0.345, 0.850, 0.93827]
```

0.801886

Theta* Calculation

```
StarAngles[Qsq_, θTg_] := Module[
  {EBeam = 0.850, M = 0.93827},
  θL = ScatAngle[Qsq, EBeam, M];
  vecTargetSpinDirection = {Sin[θTg], 0, Cos[θTg]};
  ELeft = EBeam / (1 + EBeam/M (1 - Cos[θL]));
  vecEBeam = {0, 0, EBeam};
  vecELeft = {ELeft * Sin[θL], 0, ELeft * Cos[θL]};
  Print[vecELeft ];
  vecq = vecEBeam - vecELeft;
  Print[vecq];
  vecN = Cross[vecEBeam, vecELeft];
  Print[vecN];
  vecNS = Cross[vecq, vecTargetSpinDirection ];
  Print[Dot[vecq, vecTargetSpinDirection ]];
  θStar = ArcCos[Dot[vecq, vecTargetSpinDirection ] / (Norm[vecq] Norm[vecTargetSpinDirection ])];
  ϕStar = ArcCos[Dot[vecN, vecNS ] / (Norm[vecN] Norm[vecNS ])];
  {θL, θStar, ϕStar}
 ]
```

```
StarAngles[0.162, 48 * π/180]
```

{0.369413, 0, 0.668377}

{-0.369413, 0, 0.181623}

{0., 0.314001, 0.}

-0.152997

$\{0.504915, 1.95161, 1.49012 \times 10^{-8}\}$

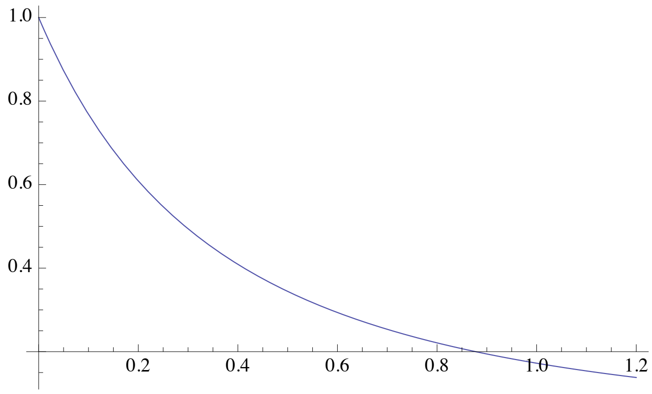
Theoretical Calculation

$$\text{GDipole[Q2\_]} := \frac{1}{\left(1 + \frac{\text{Abs[Q2]}}{0.71}\right)^2}$$

```
GEp[Q2_] := GDipole[Q2]
GMp[Q2_] := 2.79 GDipole[Q2]
GMn[Q2_] := -1.91 GDipole[Q2]
```

$$\text{GEn[Q2\_, } \tau\text{\_]} := \frac{1.91\,\tau}{1 + 5.6\,\tau}\ \text{GDipole[Q2]}$$

```
Show[Plot[GEp[Q2], {Q2, 0, 1.2}, PlotRange → All]]
```




```
ProtonRelCS[Q2_, MTg_, θe_] := Module[{},
```
$$\tau = -\frac{Q2}{4\,MTg^2};$$
$$CS = \frac{1}{(1+\tau)}\left(GEp[Q2]^2 + GMp[Q2]^2\left(\tau + 2\,\tau\,(1+\tau)\,Tan\left[\frac{\theta e}{2}\right]^2\right)\right)$$
```
]
```

```
NeutronRelCS[Q2_, MTg_, θe_] := Module[{},
```
$$\tau = -\frac{Q2}{4\,MTg^2};$$
$$CS = \frac{1}{(1+\tau)}\left(GEn[Q2, \tau]^2 + GMn[Q2]^2\left(\tau + 2\,\tau\,(1+\tau)\,Tan\left[\frac{\theta e}{2}\right]^2\right)\right)$$
```
]
```

$$fp[Q2\_, \theta e\_] := \frac{2\,ProtonRelCS[Q2, 0.93827, \theta e]}{(2\,ProtonRelCS[Q2, 0.93827, \theta e] + NeutronRelCS[Q2, 0.939, \theta e])}$$

```
fp[-0.35, 14.5 π/180]
```

0.902358

```
ProtonAsymmetryNew[{Q2_, MTg_, θe_, θstar_, ϕstar_, σPhi_}] := Module[{},
  τ = - Q2/(4 MTg^2);
  vL = 1/(1 + τ)^2;
  vT = 1/2 1/(1 + τ) + Tan[θe/2]^2 ;
  vTb = Tan[θe/2] Sqrt[1/(1 + τ) + Tan[θe/2]^2] ;
  vTLb = - 1/Sqrt[2] 1/(1 + τ) Tan[θe/2];
  Ap = - (Cos[θstar] vTb 2 τ GMp[Q2]^2 -
        Sin[θstar] If[σPhi == 0, Cos[ϕstar], 1/4 ((2 σPhi + Sin[2 σPhi])/Sin[σPhi])] vTLb 2
        Sqrt[2 τ (1 + τ)] GEp[Q2] GMp[Q2]) / (vL (1 + τ) GEp[Q2]^2 + vT 2 τ GMp[Q2]^2)
 ]
```

```
ProtonAsymmetryNew[{-0.35, 0.93827, 40 * π/180, 99.0641, 0, 0}]
```

0.301225

```
ScatAngle[0.21, 0.720, 0.93827]
```

0.707208

```
ProtonAsymmetryNew[{-0.21, 0.93827, 0.707, 90 * π/180, 0, 0}]
```

-0.32387

```
N[27 / 32 * Sqrt[3/2]]
```

1.03338

0.84375

Comparison of MIT data with Theory

```
TheoryInputLeft =
 Map[Flatten[{-#[[1]], 0.93827, StarAngles[#[[1]], 48 * π/180]}] &, DataLeft]
```

```
{{-0.162, 0.93827, 0.504915, 1.95161, 1.49012 × 10^-8},
 {-0.191, 0.93827, 0.555116, 1.91108, 0.},
 {-0.232, 0.93827, 0.623021, 1.85813, 0.}, {-0.282, 0.93827, 0.702961, 1.79856, 0.},
 {-0.345, 0.93827, 0.801886, 1.729, 1.49012 × 10^-8},
 {-0.419, 0.93827, 0.918859, 1.65252, 0.},
 {-0.5, 0.93827, 1.05182, 1.57274, 0.}, {-0.591, 0.93827, 1.21294, 1.48532, 0.}}
```

```
TheoryInputRight =
 Map[Flatten[{-#[[1]], 0.93827, StarAngles[#[[1]], -48 * π/180]}] &, DataLeft]
```

```
{{-0.162, 0.93827, 0.504915, 0.27609, 0.}, {-0.191, 0.93827, 0.555116, 0.235569, 0.},
 {-0.232, 0.93827, 0.623021, 0.182609, 0.}, {-0.282, 0.93827, 0.702961, 0.123041, 0.},
 {-0.345, 0.93827, 0.801886, 0.0534804, 1.49012 × 10^-8},
 {-0.419, 0.93827, 0.918859, 0.022997, 3.14159},
 {-0.5, 0.93827, 1.05182, 0.102772, 3.14159},
 {-0.591, 0.93827, 1.21294, 0.190191, 3.14159}}
```

```
TheoryResultsLeft =
 Map[{-#[[1]], ProtonAsymmetryNew[{#[[1]], #[[2]], #[[3]], #[[4]], #[[5]], 0}]} &,
  TheoryInputLeft]
```

```
{{0.162, -0.156615}, {0.191, -0.182316}, {0.232, -0.218167}, {0.282, -0.261267},
 {0.345, -0.314662}, {0.419, -0.375847}, {0.5, -0.440184}, {0.591, -0.507685}}
```

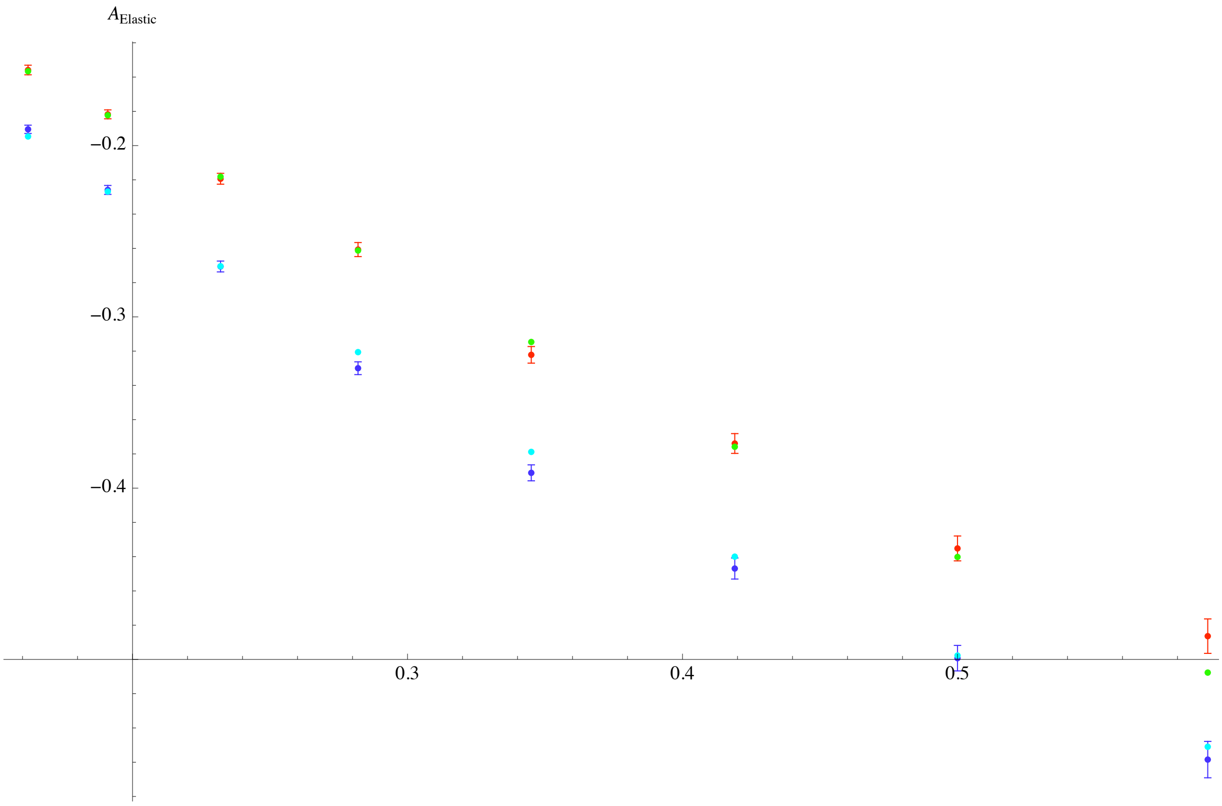
```
TheoryResultsRight =
 Map[{-#[[1]], ProtonAsymmetryNew[{#[[1]], #[[2]], #[[3]], #[[4]], #[[5]], 0}]} &,
  TheoryInputRight]
```

```
{{0.162, -0.194675}, {0.191, -0.226834}, {0.232, -0.27045}, {0.282, -0.320591},
 {0.345, -0.378828}, {0.419, -0.439986}, {0.5, -0.497734}, {0.591, -0.550985}}
```

```
TheoryPlotLeft = ListPlot[TheoryResultsLeft, PlotStyle → Hue[0.3]];
```

```
TheoryPlotRight = ListPlot[TheoryResultsRight, PlotStyle → Hue[0.5]];
```

```
fig1 = Show[plotMIT, TheoryPlotLeft, TheoryPlotRight, AxesLabel → {"-Q²", "A_Elastic"}]
```



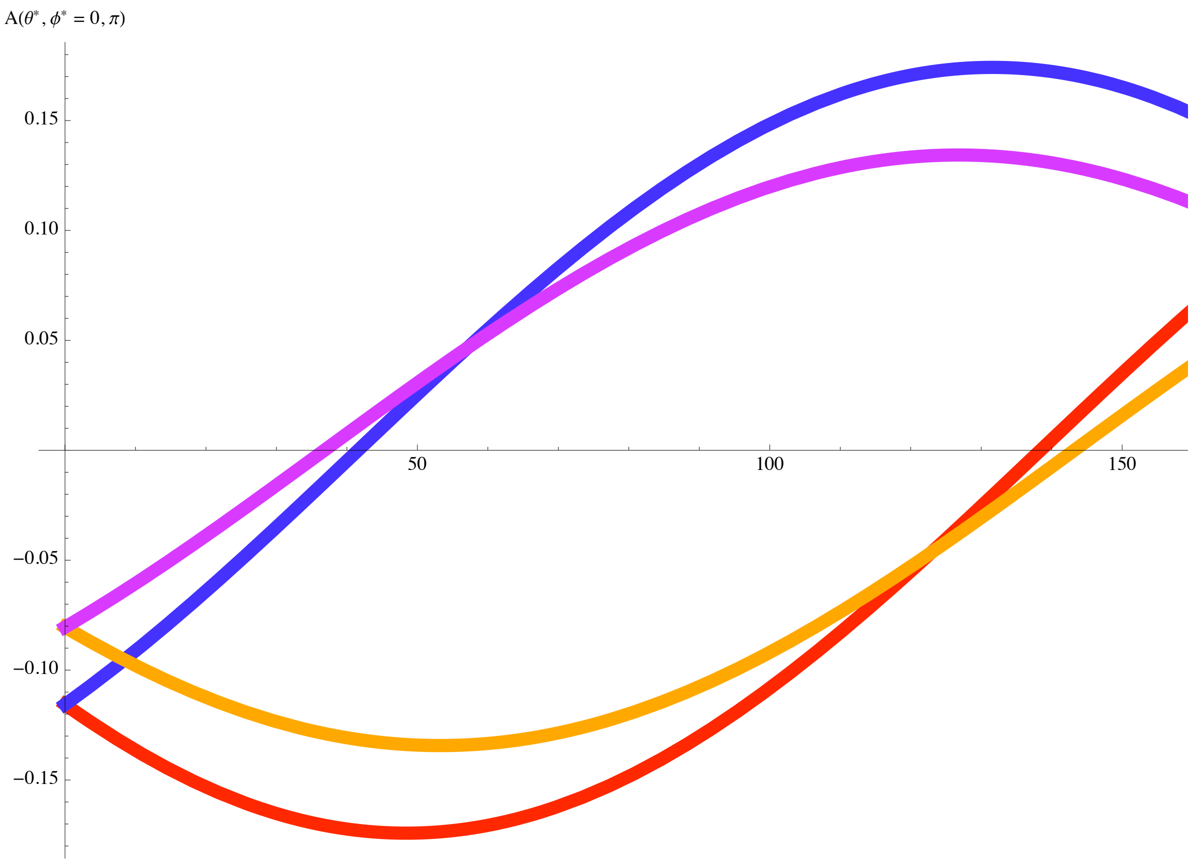

```
Export["~/Desktop/figDoug.pdf", fig1]
```

~/Desktop/figDoug.pdf

Asymmetries As function of θ^*

```
fig3 = Show[Plot[ProtonAsymmetryNew[{-0.35, 0.93827, 14.5 π/180, x * π/180, 0, 0}],
    {x, 0.0, 180}, PlotRange → All, PlotStyle → {Thickness[0.01], Hue[0.]}],
   Plot[ProtonAsymmetryNew[{-0.35, 0.93827, 14.5 π/180, x π/180, π, 0}],
    {x, 0.0, 180}, PlotRange → All, PlotStyle → {Thickness[0.01], Hue[0.7]}],
   AxesLabel → {"θ*[deg]", "A(θ*, ϕ* = 0, π)"}, ImageSize → {700, 400}];

fig4 = Show[Plot[ProtonAsymmetryNew[{-0.25, 0.93827, 12.5 π/180, x * π/180, 0, 0}],
    {x, 0.0, 180}, PlotRange → All, PlotStyle → {Thickness[0.01], Hue[0.1]}],
   Plot[ProtonAsymmetryNew[{-0.25, 0.93827, 12.5 π/180, x π/180, π, 0}],
    {x, 0.0, 180}, PlotRange → All, PlotStyle → {Thickness[0.01], Hue[0.8]}],
   AxesLabel → {"θ*[deg]", "A(θ*, ϕ* = 0, π)"}, ImageSize → {700, 400}];
```

```
fig5 = Show[fig3, fig4]
```




```
Export["~/Desktop/fig5.png", fig5]
```

Mean value of the ϕ^*

$$N\left[\frac{\text{Integrate}\left[\text{Cos}[x]^2, \{x, -\sigma, \sigma\}\right]}{\text{Integrate}[\text{Cos}[x], \{x, -\sigma, \sigma\}]} \;/.\; \left\{\sigma \to 40\,\frac{\pi}{180}\right\}\right]$$

0.926072

$$\frac{\text{Integrate}\left[\text{Cos}[x]^2, \{x, -\sigma, \sigma\}\right]}{\text{Integrate}[\text{Cos}[x], \{x, -\sigma, \sigma\}]}$$

$$\frac{1}{2}\,\text{Csc}[\sigma]\,(\sigma + \text{Cos}[\sigma]\,\text{Sin}[\sigma])$$

$$N\left[\frac{1}{4}\left(\frac{2\,\sigma + \text{Sin}[2\,\sigma]}{\text{Sin}[\sigma]}\right) \;/.\; \left\{\sigma \to 40\,\frac{\pi}{180}\right\}\right]$$

0.926072

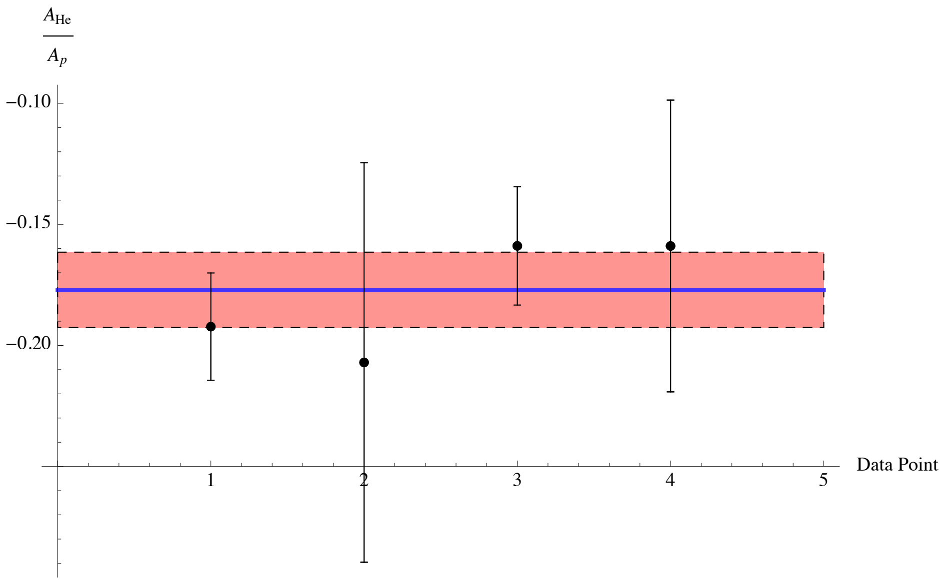
New Analysis @ JLab

```
DataPoints = {
  {{-0.2961, 0.93827, (14.5 - 1.285) * π/180,
    67.0 * π/180, 0.0, 0.0 * π/180}, 0.02777, 0.0032},
  {{-0.2973, 0.93827, (14.5 - 1.259) * π/180, 156.1 * π/180, 0.0, 2 * 16.64 * π/180},
   -0.00878, 0.0035},
  {{-0.2253, 0.93827, (12.5 - 1.086) * π/180, 69.01 * π/180, 0.0, 0.0 * π/180},
   0.0182, 0.0028},
  {{-0.2246, 0.93827, (12.5 - 1.103) * π/180, 157.7 * π/180, 0.0, 0.0 * 35.0 * π/180},
   -0.00422, 0.0016}
 };

ProtonAsymmetryNew[{-0.2961, 0.93827, (14.5 - 1.285) * π/180, 67.0 * π/180, 0.0, 0.0}]

-0.144467

Flatten[DataPoints[[1]]]

{-0.2961, 0.93827, 0.230645, 1.16937, 0., 0., 0.02777, 0.0032}

Map[ProtonAsymmetryNew[#[[1]]] &, DataPoints]

{-0.144467, 0.0424078, -0.114552, 0.0265537}

resdata = Map[{(#[[2]] / ProtonAsymmetryNew[#[[1]]]),
    Abs[#[[3]]/#[[2]] (#[[2]] / ProtonAsymmetryNew[#[[1]]])]} &, DataPoints]

{{-0.192224, 0.0221504}, {-0.207037, 0.0825319},
 {-0.158879, 0.024443}, {-0.158923, 0.0602553}}
```

$$\text{MeanRatio} = \left\{ \frac{\sum_{i=1}^{\text{Length[resdata]}} \frac{\text{resdata[[i,1]]}}{\text{resdata[[i,2]]}^2}}{\sum_{i=1}^{\text{Length[resdata]}} \frac{1}{\text{resdata[[i,2]]}^2}}, \sqrt{\frac{1}{\sum_{i=1}^{\text{Length[resdata]}} \frac{1}{\text{resdata[[i,2]]}^2}}} \right\}$$

```
{-0.177032, 0.0155528}

PlotData = Map[{{#[[1]]}, ErrorBar[#[[2]]]} &, resdata]

{{{-0.192224}, ErrorBar[0.0221504]}, {{-0.207037}, ErrorBar[0.0825319]},
 {{-0.158879}, ErrorBar[0.024443]}, {{-0.158923}, ErrorBar[0.0602553]}}
```

```
finalplot = Show[ErrorListPlot[{{{1, -0.19222422305308}, ErrorBar[0.02215043261684791]},
    {{2, -0.2070371945650625}, ErrorBar[0.0825319112730887]},
    {{3, -0.1588793846964430}, ErrorBar[0.02444298226099123]},
    {{4, -0.158923465378785}, ErrorBar[0.06025534232371003]}},
   PlotStyle → {Black, PointSize[0.012]}], Graphics[{EdgeForm[Dashed], Pink, Rectangle[
     {0, MeanRatio[[1]] - MeanRatio[[2]]}, {5, MeanRatio[[1]] + MeanRatio[[2]]}]}],
  Plot[MeanRatio[[1]], {x, 0, 5}, PlotStyle → {Hue[0.7], Thickness[0.005]}],
  ErrorListPlot[{{{1, -0.19222422305308}, ErrorBar[0.02215043261684791]},
    {{2, -0.2070371945650625}, ErrorBar[0.0825319112730887]},
    {{3, -0.1588793846964430}, ErrorBar[0.02444298226099123]},
    {{4, -0.158923465378785}, ErrorBar[0.06025534232371003]}},
   PlotStyle → {Black, PointSize[0.012]}], AxesLabel → {"Data Point", "A_He/A_p"}]
```




```
Export["~/Desktop/figDoug2.pdf", finalplot]
```

~/Desktop/figDoug2.pdf