Quantum-stochasticity-induced asymmetry in the angular distribution of electrons in a quasiclassical regime

Paper: Hu et al, Phys Rev A 102, 042218 (2020)
Notebook: Óscar Amaro, February 2023 @ GoLP-EPP

Introduction

Quantum stochastic angular broadening in electron-LP laser scattering.
We compare this notebook's implementation with data retrieved from the paper (with WebPlotDigitizer).

Figures 4, 5 and 6

In[1]:=
```
SetDirectory[NotebookDirectory[]];
Clear[Δθy, Δθx, Δθi, Δθp, ϵ0, γ, m, τ, T0, σy, W0, a0, δ,
 ΔθQ, imgsz, asp, fig4alst, fig4alst2, fig4blst, fig4blst2]
asp = 1 / 2; imgsz = 300;

(* fixed parameters, beginning of section IV *)
γ = ϵ0 / 0.511;
Δθi = 0.001; (*[rad]*)
T0 = 1;
(* ϵ0=300 MeV, W0=3 μm, τ=8 T0, σy=0.3 μm *)

(* equations *)
Δθy = Sqrt[(Δθi)^2 + (Δθp)^2];(*14*)
Δθp = 1.07 a0^2 σy τ / (γ^2 W0^2 T0);(*15*)
(*ΔθQ = 2Sqrt[2Log[2]σpx] / (m γ);(*16*)*)
ΔθQ = (3.3 × 10^-6) (a0^2.26) (γ^-0.24) (τ / T0)^0.5;(*17*)
Δθx = Sqrt[ΔθQ^2 + Δθy^2];(* 19 *)
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δ = Δθx / Δθy // Simplify;(*Sqrt[1+ΔθQ^2/(Δθi)^2+(Δθp)^2]*)

Print["FIG. 4"]
(*Fig4 a*)
fig4alst =
  Table[{(1000 Δθx /. {ϵ0 → 300, W0 → 3, τ → 8, σy → 0.3}), a0}, {a0, 10, 100, 1}];
fig4alst2 = Table[{-(1000 Δθx /. {ϵ0 → 300, W0 → 3, τ → 8, σy → 0.3}), a0},
   {a0, 10, 100, 1}];
Show[{ListPlot[{fig4alst, fig4alst2}, Joined → True,
   PlotRange → {{-100, +100}, {10, 100}}, Frame → True, FrameLabel → {"θx", "a0"},
   FrameTicks → {{{30, 50, 70, 90}, None}, {{-75, -50, -25, 0, 25, 50, 75}, None}},
   GridLines → {{-75, -50, -25, 0, 25, 50, 75}, {30, 50, 70, 90}},
   ImageSize → imgsz, AspectRatio → asp, PlotStyle → {{Black, Dashed}},
   PlotLabel → "FIG. 4 (a)"], ListPlot[Import["data/fig4a_estimate.csv"],
   PlotStyle → {Cyan, Opacity[0.3]}, PlotLegends → "Cyan Estimate"],
  ListPlot[Import["data/fig4a_numerical.csv"],
   PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red Numerical"]}]

(*Fig4 b*)
fig4blst =
  Table[{(1000 Δθy /. {ϵ0 → 300, W0 → 3, τ → 8, σy → 0.3}), a0}, {a0, 10, 100, 1}];
fig4blst2 = Table[{-(1000 Δθy /. {ϵ0 → 300, W0 → 3, τ → 8, σy → 0.3}), a0},
   {a0, 10, 100, 1}];
Show[{ListPlot[{fig4blst, fig4blst2}, Joined → True,
   PlotRange → {{-100, +100}, {10, 100}}, Frame → True, FrameLabel → {"θy", "a0"},
   FrameTicks → {{{30, 50, 70, 90}, None}, {{-75, -50, -25, 0, 25, 50, 75}, None}},
   GridLines → {{-75, -50, -25, 0, 25, 50, 75}, {30, 50, 70, 90}},
   ImageSize → imgsz, AspectRatio → asp, PlotStyle → {{Black, Dashed}},
   PlotLabel → "FIG. 4 (b)"], ListPlot[Import["data/fig4b_estimate.csv"],
   PlotStyle → {Cyan, Opacity[0.3]}, PlotLegends → "Cyan Estimate"],
  ListPlot[Import["data/fig4b_numerical.csv"],
   PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red Numerical"]}]

(*Fig4 c*)
Show[{Plot[(1000 ΔθQ /. {ϵ0 → 300, W0 → 3, τ → 8, σy → 0.3}), {a0, 10, 100},
   PlotRange → {{10, 100}, {0, 100}}, Frame → True, FrameLabel → {"a0", "ΔθQ"},
   FrameTicks → {{{0, 25, 50, 75, 100}, None}, {{10, 30, 50, 70, 90}, None}},
   GridLines → {{10, 30, 50, 70, 90}, {0, 25, 50, 75, 100}}, ImageSize → imgsz,
   AspectRatio → asp, PlotStyle → {{Black, Dashed}}, PlotLabel → "FIG. 4 (c)"],
  ListPlot[Import["data/fig4c_estimate.csv"], PlotStyle → {Black, Opacity[0.3]},
   PlotLegends → "Black Estimate"], ListPlot[Import["data/fig4c_numerical.csv"],
   PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red Numerical"]}]

(*Fig4 d*)
Show[{Plot[(δ /. {ϵ0 → 300, W0 → 3, τ → 8, σy → 0.3}), {a0, 10, 100},
   PlotRange → {{10, 100}, {0, 6}}, GridLines → Automatic, Frame → True,
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    FrameLabel → {"a0", "δ"}, ImageSize → imgsz, AspectRatio → asp,
    PlotStyle → {{Black, Dashed}}, PlotLabel → "FIG. 4 (d)"],
   ListPlot[Import["data/fig4d_estimate.csv"], PlotStyle → {Black, Opacity[0.3]},
    PlotLegends → "Black Estimate"], ListPlot[Import["data/fig4d_numerical.csv"],
    PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red Numerical"]}]

Print["FIG. 5"]
(*Fig5 a*)
Show[{Plot[(δ /. {a0 → 30, ϵ0 → 300, W0 → 3, σy → 0.3}), {τ, 4, 40},
    PlotRange → {{4, 40}, {0, 4}}, Frame → True, FrameLabel → {"τ/T0", "δ"},
    FrameTicks → {{{1, 2, 3, 4}, None}, {Table[x, {x, 4, 41, 4}], None}},
    GridLines → {Table[x, {x, 4, 41, 4}], {1, 2, 3, 4}}, ImageSize → imgsz,
    AspectRatio → asp, PlotStyle → {{Black, Dashed}}, PlotLabel → "FIG. 5 (a)"],
   ListPlot[Import["data/fig5a_estimate.csv"], PlotStyle → {Black, Opacity[0.3]},
    PlotLegends → "Black Estimate"], ListPlot[Import["data/fig5a_MCM.csv"],
    PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red MCM"]}]

Print["FIG. 6"]
(*Fig6 a*)
Show[{Plot[(δ /. {a0 → 30, W0 → 3, τ → 8, σy → 0.3}), {ϵ0, 100, 1000},
    PlotRange → {{100, 1000}, {0, 4.5}}, Frame → True, FrameLabel → {"ϵ0[MeV]", "δ"},
    FrameTicks → {{{1, 2, 3, 4}, None}, {Table[x, {x, 100, 1001, 100}], None}},
    GridLines → {Table[x, {x, 100, 1001, 100}], {1, 2, 3, 4}}, ImageSize → imgsz,
    AspectRatio → asp, PlotStyle → {{Black, Dashed}}, PlotLabel → "FIG. 6 (a)"],
   ListPlot[Import["data/fig6a_estimate.csv"], PlotStyle → {Black, Opacity[0.3]},
    PlotLegends → "Black Estimate"], ListPlot[Import["data/fig6a_MCM.csv"],
    PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red MCM"]}]

(*Fig6 b*)
Show[{Plot[(δ /. {a0 → 30, ϵ0 → 300, τ → 8, σy → 0.1 W0}), {W0, 2, 10},
    PlotRange → {{2, 10}, {0, 5}}, Frame → True, FrameLabel → {"W0[μm]", "δ"},
    FrameTicks → {{{1, 2, 3, 4}, None}, {Table[x, {x, 2, 11, 1}], None}},
    GridLines → {Table[x, {x, 2, 11, 1}], {1, 2, 3, 4}}, ImageSize → imgsz,
    AspectRatio → asp, PlotStyle → {{Black, Dashed}}, PlotLabel → "FIG. 6 (b)"],
   ListPlot[Import["data/fig6b_estimate.csv"], PlotStyle → {Black, Opacity[0.3]},
    PlotLegends → "Black Estimate"], ListPlot[Import["data/fig6b_MCM.csv"],
    PlotStyle → {Red, Opacity[0.3]}, PlotLegends → "Red MCM"]}]
FIG. 4
```
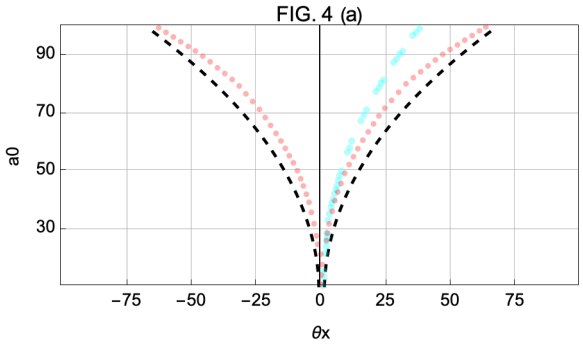
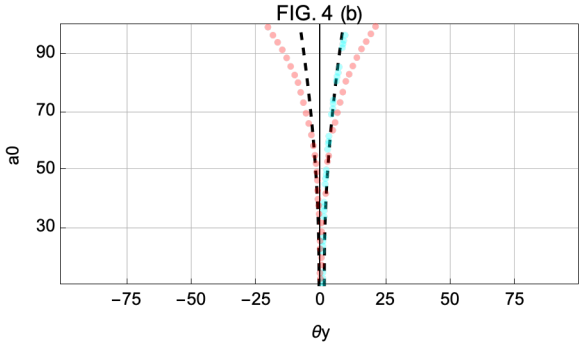

Out[15]=



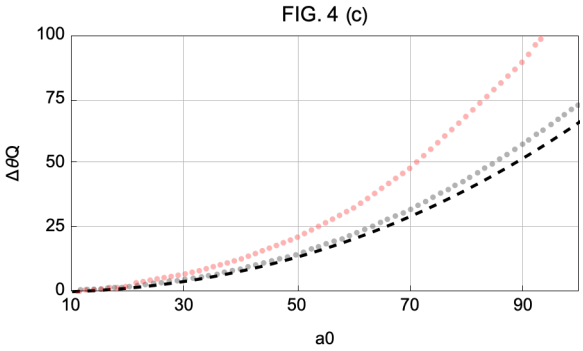
Cyan Estimate
Red Numerical

Out[18]=



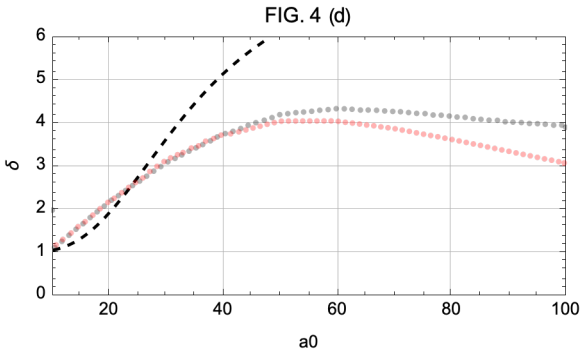
Cyan Estimate
Red Numerical

Out[19]=



Black Estimate
Red Numerical

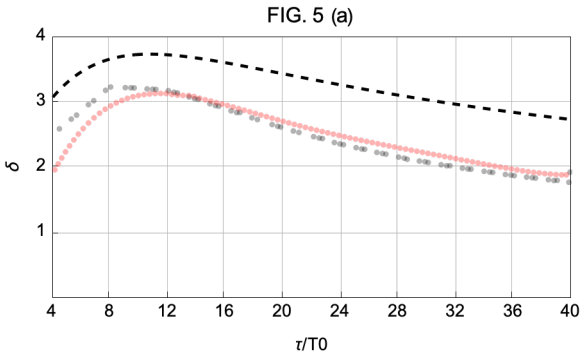
Out[20]=



Black Estimate
Red Numerical

FIG. 5

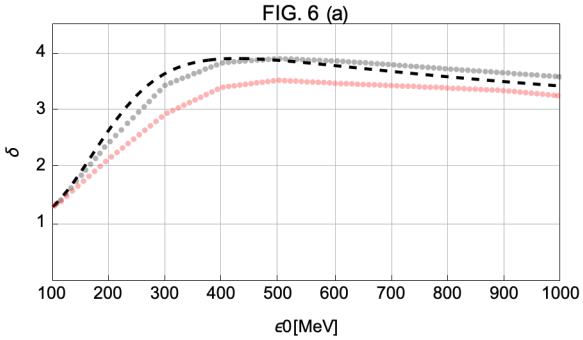
Out[22]=



Black Estimate
Red MCM

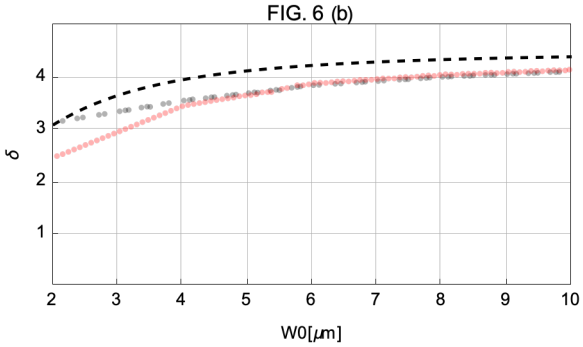
FIG. 6

Out[24]=



Black Estimate
Red MCM

Out[25]=



Black Estimate
Red MCM