High-resolution modeling of non-linear Compton scattering in focused laser pulses

C. F. Nielsen, R. Holtzapple, and B. King, PhysRevD **106** 013010 (2022), arXiv:2109.09490v2
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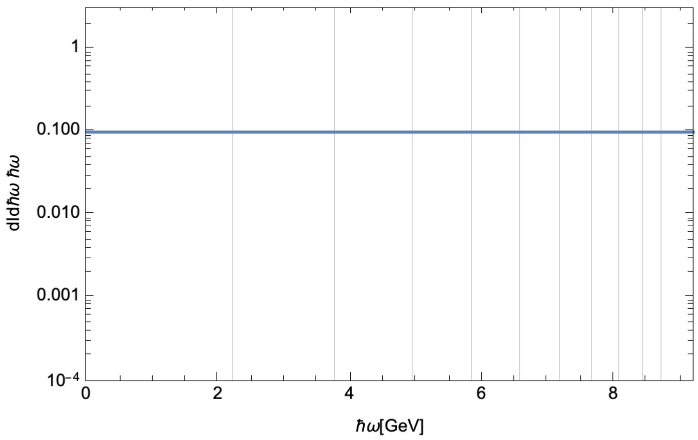
Introduction

In this notebook we reproduce some results from the paper.

Figure 1

In[127]:=
```
Clear[ħω, ϵ, m, a0, s, ħωGeV]
Clear[c, ħ, m, ħωsGeV, λμm, ωL, e]

c = 3 × 10^8; (*[m/s]*)
ħ = 1.05 × 10^-34; (*[Js]*)
m = 9.1 × 10^-31; (*[Kg]*)
e = 1.6 10 ^-19; (*[C]*)

ωL = (2 π c)/(λμm 10^-6); (*[1/s]*)

mGeV = 0.511 × 10^-3; (*[GeV]*)
ϵGeV = 13; (*[GeV]*)
ħωGeV = (ħ ωL)/e 10^-9; (*[GeV?]*)

(* showing harmonics as GridLines *)
a0 = 1;
ħωsGeV =
  Table[((4 s ħωGeV ϵGeV^2)/(mGeV^2 (1 + a0^2 / 2) + 4 s ħωGeV ϵGeV) //. {λμm → 0.8}) // N, {s, 1, 10}];
LogPlot[{0.1}, {ħω, 0, 9.2}, GridLines → {ħωsGeV, None},
 PlotRange → {{0, 9.2}, {10^-4, 10^0.5}}, Frame → True,
 FrameLabel → {"ħω[GeV]", "dIdħω ħω"}]

ħωsGeV = Table[((4 s ħωGeV ϵGeV^2)/(mGeV^2 (1 + a0^2 / 2) + 4 s ħωGeV ϵGeV) //. {λμm → 8}) // N, {s, 1, 10}];
LogPlot[{0.1}, {ħω, 0, 2}, GridLines → {ħωsGeV, None},
 PlotRange → {{0, 2}, {10^-4.5, 10^-0.5}}, Frame → True,
 FrameLabel → {"ħω[GeV]", "dIdħω ħω"}]
```

Out[132]=



Out[134]=

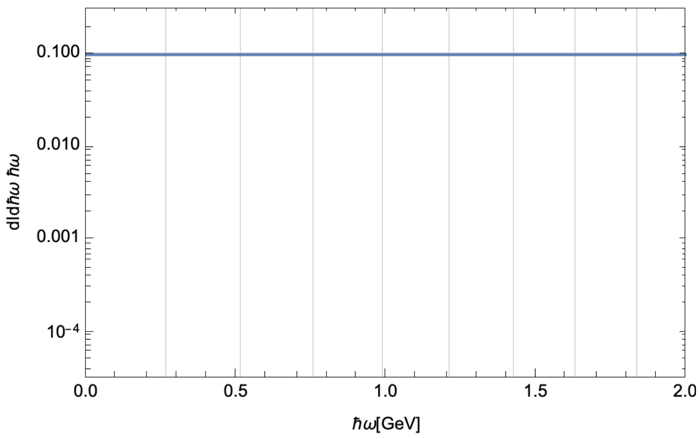
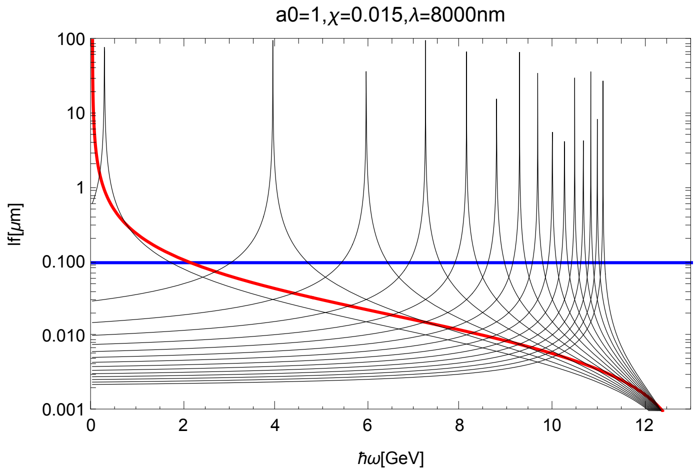


Figure 2 + Figure 5 (continuation) Formation length

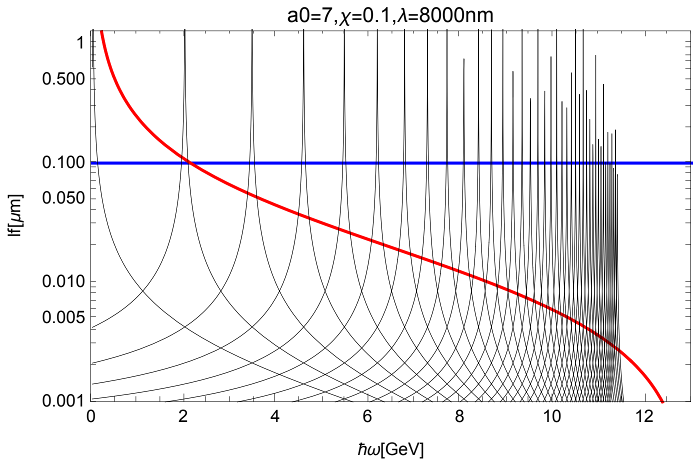
In[111]:=
```
(* "The values
  of s are not equidistant and are chosen to represent the entire spectrum." *)
Clear[lf, lf39, lf41, a0, ω, ϵ, γ, s, c, ħ, e, m, ωl, lf39fun, lf41fun, ħωGeV, λ]
c = 3 × 10^8; (*[m/s]*)
ħ = 1.05 × 10^-34; (*[Js]*)
e = 1.6 × 10^-19; (*[C]*)
m = 9.1 × 10^-31; (*[Kg]*)

(* eq 39 *)
lf39 = 2 γ^2 (ϵ - ħ ω)/(ϵ ω);

(* equation 41: LMA effective formation length. use Abs *)
lf41 = 2 γ^2 / Abs[(ϵ ω (1+a0^2/2))/(ϵ-ħ ω) - 4 γ^2 s ωl];

ϵ = 13 × 10^9 e; (*[eV]*)
γ = ϵ / (511 × 10^3 e); (*[] ~25000 → 13GeV *)
ωl = 2 π c / λ // N;
(*[s^-1] ωl is frequency of plane wave background*)


(* Figure 2 *)
λ = 8000 × 10^-9; (*[m] *)
lf39fun = 0.3 × 10^9 × 10^6 lf39 /. {ω → 10^9 e ħωGeV/ħ};
lf41fun = 0.3 × 10^9 × 10^6 lf41 /. {ω → 10^9 e ħωGeV/ħ};
a0 = 1; (*[]*)
```

```
Show[{LogPlot[{0.1, lf39fun}, {ℏωGeV, 0, 13}, Frame → True,
    FrameLabel → {"ℏω[GeV]", "lf[μm]"}, PlotStyle → {Blue, Red, Black},
    PlotRange → {{0, 13}, {10^-3, 10^2}}, PlotLabel → "a0=1,χ=0.015,λ=8000nm"],
  LogPlot[Table[lf41fun, {s, 1, 300, 20}], {ℏωGeV, 0, 13},
    PlotStyle → {{Black, Thickness[0.001]}}, PlotRange → {{0, 13}, {10^-3, 10^2}}]}]
a0 = 7;
Show[{LogPlot[{0.1, lf39fun}, {ℏωGeV, 0, 13}, Frame → True,
    FrameLabel → {"ℏω[GeV]", "lf[μm]"}, PlotStyle → {Blue, Red},
    PlotRange → {{0, 13}, {10^-3, 10^0.1}}, PlotLabel → "a0=7,χ=0.1,λ=8000nm"],
  LogPlot[Table[lf41fun, {s, 1, 6000, 150}], {ℏωGeV, 0, 13},
    PlotStyle → {{Black, Thickness[0.001]}}, PlotRange → {{0, 13}, {10^-3, 10^2}}]}]


(* Figure 5 *)
Clear[lf39fun, lf41fun, lf39, lf41]
λ = 800 × 10^-9; (*[m] *)
lf39 = 2 γ^2 (ϵ - ℏ ω)/(ϵ ω);
lf41 = (2 γ^2)/(Abs[(ϵ ω (1+a0^2/2))/(ϵ-ℏ ω) - 4 γ^2 s ωl]);
lf39fun = 0.3 × 10^9 × 10^6 lf39 /. {ω → 10^9 e ℏωGeV/ℏ};
lf41fun = 0.3 × 10^9 × 10^6 lf41 /. {ω → 10^9 e ℏωGeV/ℏ};
a0 = 1.97; (*[]*)
Show[{LogPlot[{2.4, lf39fun}, {ℏωGeV, 0, 13}, Frame → True,
    FrameLabel → {"ℏω[GeV]", "lf[μm]"}, PlotStyle → {Blue, Red, Black},
    PlotRange → {{0, 13}, {10^-4, 10^2}}, PlotLabel → "a0=1.97,χ=0.30,λ=800nm"],
  LogPlot[Table[lf41fun, {s, 1, 300, 10}], {ℏωGeV, 0, 13},
    PlotStyle → {{Black, Thickness[0.001]}}, PlotRange → {{0, 13}, {10^-4, 10^2}}]}]
a0 = 10.81;
Show[{LogPlot[{2.4, lf39fun}, {ℏωGeV, 0, 13}, Frame → True,
    FrameLabel → {"ℏω[GeV]", "lf[μm]"}, PlotStyle → {Blue, Red},
    PlotRange → {{0, 13}, {10^-4, 10^2}}, PlotLabel → "a0=10.81,χ=1.67,λ=800nm"],
  LogPlot[Table[lf41fun, {s, 1, 3000, 50}], {ℏωGeV, 0, 13},
    PlotStyle → {{Black, Thickness[0.001]}}, PlotRange → {{0, 13}, {10^-4, 10^2}}]}]
```

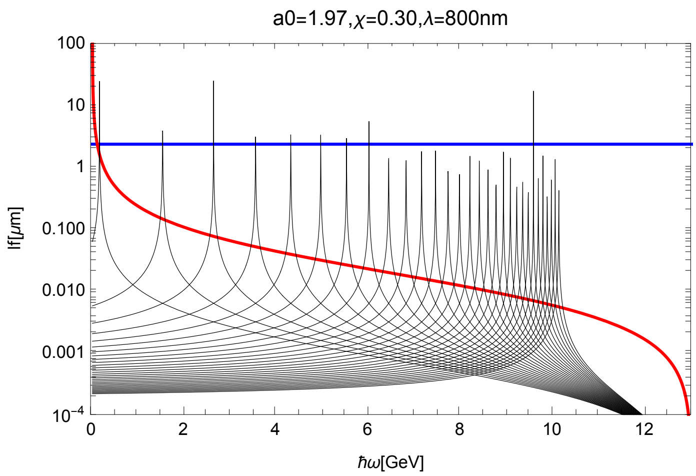
Out[116]=



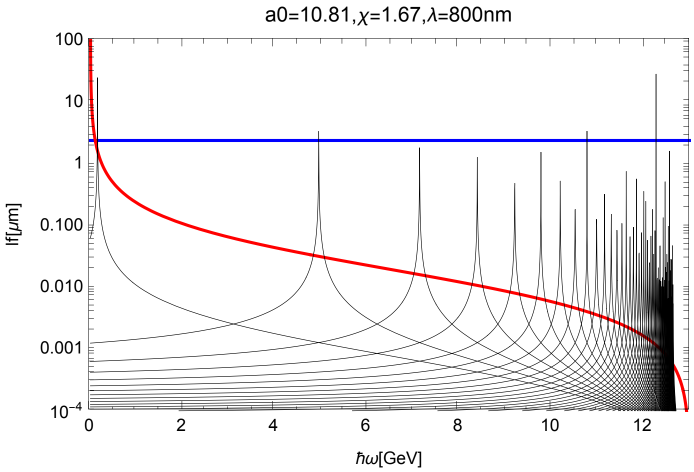
Out[118]=



Out[124]=



Out[126]=


a0=10.81,χ=1.67,λ=800nm
lf[μm]
ħω[GeV]
100
10
1
0.100
0.010
0.001
10^-4
0
2
4
6
8
10
12