All-Optical Radiation Reaction at 10^21 W/cm^2

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Introduction

In this notebook we reproduce figure 3.

Figure 3: Electron beam energy loss

(In the units chosen in the paper, the classical electron radius, present in the Thompson cross section, is re = $\frac{e^2}{m c^2}$ while in SI `re` = $\frac{1}{4 \pi \epsilon 0} \frac{e^2}{m c^2}$)

In[1003]:=

```
(* LP PW laser colliding against a relativistic electron *)
Clear[γ, γf, γ0, k, k3, η, EGeV, τ0, τ0fs, e, m, c, λ, a0, ω0, ΔEE, χ, ΔEEχ, ϵ0]

(* equation 3 *)
γf = γ0 / (1 + k γ0);(*[] final electron energy *)
```

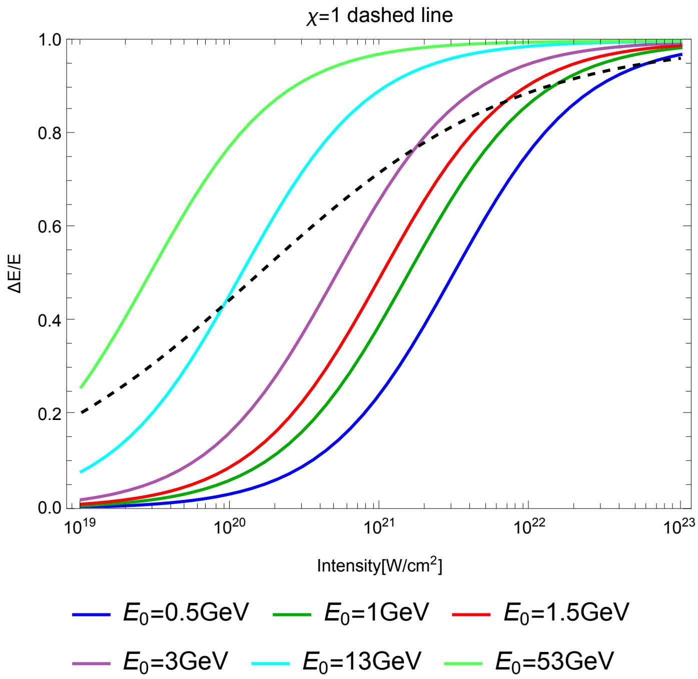
$$k3 = \frac{1}{4\pi\epsilon 0}(1-\mathrm{Cos}[\pi])^2\,\frac{\eta}{3}\,\frac{e^2\,\omega 0^2}{m\,c^3}\,a0^2\,\tau 0;$$ (*[] CRR k factor from equation 3 *)

```
k = (1 - Cos[π])^2 3.2×10^-5 (I 10^-22) τ0fs;(*[] CRR k factor Engineering formula *)
ΔEE = (γ0 - γf) / γ0;(*[] 0≤energy loss≤1 *)

(* χ=1: χ~2 γ0 a0/aS *)
(*Solve[γf==γ0/(1+k γ0),γ0][[1,1,2]]*)
γ = Solve[1 == 2 γ a0 / (411823), γ][[1, 1, 2]];
ΔEEχ = ΔEE //. {γ0 → γ};

(* physical constants *)
e = 1.6×10^-19;(*[C]*)
m = 9.1×10^-31;(*[Kg]*)
c = 3×10^8;(*[m/s]*)
ϵ0 = 8.854×10^-12;(*[F/m] vacuum permittivity*)

(* parameters *)
η = 0.4;(*[] temporal profiles *)
τ0 = 26.5×10^-15;(*[s]*)
τ0fs = τ0 10^15;(*[fs]*)
λ = 1;(*[μm] laser central wavelength *)
ω0 = 2 π c / (λ 10^-6) // N;(*[1/s] laser frequency *)
a0 = 0.855 Sqrt[I 10^-18] λ;(*[] laser a0 *)
γ0 = EGeV / (0.511×10^-3);(*[] electron γ from GeV to boost *)

(* compare the CRR k factors of equation 3 and the "engineering formula" *)
k3
k
(*k ~ 4.64 10^-7 a0^2 for these parameters *)

(* plot *)
LogLinearPlot[{ΔEE /. {EGeV → 0.5}, ΔEE /. {EGeV → 1}, ΔEE /. {EGeV → 1.5},
  ΔEE /. {EGeV → 3}, ΔEE /. {EGeV → 13}, ΔEE /. {EGeV → 53}, ΔEEχ},
 {I, 10^19, 10^23}, Frame → True, FrameLabel → {"Intensity[W/cm^2]", "ΔE/E"},
 PlotRange → {0, 1}, PlotStyle → {Blue, Darker[Green], Red,
   Lighter[Purple], Cyan, Lighter[Green], {Dashed, Black}}, PlotLegends →
  {"E_0=0.5GeV", "E_0=1GeV", "E_0=1.5GeV", "E_0=3GeV", "E_0=13GeV", "E_0=53GeV"},
 AspectRatio → 3 / 4, PlotLabel → "χ=1 dashed line"]
```

Out[1021]= $3.43767\times10^{-25}\,\mathrm{I}$

Out[1022]= $3.392\times10^{-25}\,\mathrm{I}$

Out[1023]=



χ=1 dashed line
1.0
0.8
0.6
0.4
0.2
0.0
ΔE/E
10^{19}
10^{20}
10^{21}
10^{22}
10^{23}
Intensity[W/cm^2]
E_0=0.5GeV
E_0=1GeV
E_0=1.5GeV
E_0=3GeV
E_0=13GeV
E_0=53GeV