Calculation of the proton bremsstrahlung

https://github.com/gramolin/esepp/

The FeynCalc package:

```
In[1]:= << HighEnergyPhysics`FeynCalc`
```

The squares of the four-momenta:

```
In[2]:= ScalarProduct[l, l] = m^2;
        ScalarProduct[p, p] = M^2;
        ScalarProduct[l', l'] = m^2;
        ScalarProduct[p', p'] = M^2;
        ScalarProduct[k, k] = 0;
```

The lepton tensor:

```
In[7]:= L = 1/2 Tr[(GS[l] + m).GA[ν].(GS[l'] + m).GA[μ]];
```

The proton tensor:

```
In[8]:= P1 = 1/2 Tr[(GS[p'] + M).((F10 + F20) GA[α] - F20/(2 M) (FourVector[2 p' + k, α] - GA[α].(GS[p' + k] - M))).
          (GS[p' + k] + M)/(2 ScalarProduct[k, p']).((F12 + F22) GA[μ] - F22/(2 M) (FourVector[p + p' + k, μ] - (GS[p' + k] - M).GA[μ])).
          (GS[p] + M).((F10 + F20) GA[α] - F20/(2 M) (FourVector[2 p - k, α] - GA[α].(GS[p - k] - M))).
          (GS[p - k] + M)/(2 ScalarProduct[k, p]).((F12 + F22) GA[ν] - F22/(2 M) (FourVector[p + p' - k, ν] - (GS[p - k] - M).GA[ν]))];
```

In[9]:=
$$P_2 = -\frac{1}{2}\,\mathrm{Tr}\Big[(\mathrm{GS}[p'] + M).\Big((F10 + F20)\,\mathrm{GA}[\alpha] - \frac{F20}{2M}\,(\mathrm{FourVector}[2p' + k, \alpha] - \mathrm{GA}[\alpha].(\mathrm{GS}[p' + k] - M))\Big).$$
$$\frac{\mathrm{GS}[p' + k] + M}{2\,\mathrm{ScalarProduct}[k, p']}.\Big((F12 + F22).\mathrm{GA}[\mu] - \frac{F22}{2M}\,(\mathrm{FourVector}[p + p' + k, \mu] - (\mathrm{GS}[p' + k] - M).\mathrm{GA}[\mu])\Big).$$
$$(\mathrm{GS}[p] + M).\Big((F12 + F22).\mathrm{GA}[\nu] - \frac{F22}{2M}\,(\mathrm{FourVector}[p + p' + k, \nu] - \mathrm{GA}[\nu].(\mathrm{GS}[p' + k] - M))\Big).$$
$$\frac{\mathrm{GS}[p' + k] + M}{2\,\mathrm{ScalarProduct}[k, p']}.\Big((F10 + F20)\,\mathrm{GA}[\alpha] - \frac{F20}{2M}\,(\mathrm{FourVector}[2p' + k, \alpha] - (\mathrm{GS}[p' + k] - M).\mathrm{GA}[\alpha])\Big)\Big];$$

In[10]:=
```
P3 = P1 /. {p → -p', p' → -p};
```

In[11]:=
```
P4 = P2 /. {p → -p', p' → -p};
```

Contraction of the lepton and proton tensors:

In[12]:=
```
Output = Simplify[Contract[L P1] + Contract[L P2] + Contract[L P3] + Contract[L P4]];
```

Convenient notations for the products of the four-momenta:

In[13]:=
```
ScalarProduct[k, l] = kfli;
ScalarProduct[k, l'] = kflf;
ScalarProduct[k, p] = kfpi;
ScalarProduct[k, p'] = kfpf;
ScalarProduct[l, l'] = lilf;
ScalarProduct[l, p] = lipi;
ScalarProduct[l, p'] = lipf;
ScalarProduct[p, p'] = pipf;
ScalarProduct[l', p] = lfpi;
ScalarProduct[l', p'] = lfpf;
```

Output to the text file:

In[23]:=
```
CForm[Output] >> "cform_proton.txt";
```