Exercises to Lecture 5: Experimental Basics

Exercise 12 (Luminosity):

The luminosity $\mathcal{L}$ of the LHC can be calculated from its beam parameters by:

$\mathcal{L} = \frac{f N^2}{4\pi\sigma^2} F(\theta)$

with the following parameters:

- f corresponding to the bunch crossing frequency ($\rightarrow 40\ \mathrm{MHz}$),
- N corresponding to the number of protons per bunch ($\rightarrow 10^{11}$),
- σ corresponding to the mean diameter of the beam ($\rightarrow 17\ \mu\mathrm{m}$).
- $F(\theta)$ corresponding to a reduction function, which depends e.g. on the crossing angle of the two beams ($\rightarrow 0.85$).

(Values given for nominal running in design configuration at 14 TeV.)

a)
Calculate the nominal luminosity of the LHC at a center of mass energy at 14 TeV. (Cross sections in particle physics are calculated in "barn". One barn corresponds to $1\mathrm{b} = 10^{-28}\mathrm{cm}^{-2}$. Give the value of the luminosity in $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and in $\mu\mathrm{b}^{-1}$.)

b)
The total inelastic cross section at 14 TeV is $\sigma_{\mathrm{inel}}(pp) \approx 85\,\mathrm{mb}$. Calculate the number of pp collisions per second. How many pp collisions does this correspond to per bunch crossing?

c)
In the following the cross section for a few more interesting inelastic scattering processes are given:

- $\sigma(pp \rightarrow Z + X, Z \rightarrow \ell\ell) = 3380\,\mathrm{pb}$ (cross section per lepton flavor),
- $\sigma(pp \rightarrow W + X, W \rightarrow \ell\nu) = 21872\,\mathrm{pb}$ (cross section per lepton flavor),
- $\sigma(pp \rightarrow t\bar{t}) = 880\,\mathrm{pb}$ (inclusive),
- $\sigma(pp \rightarrow H + X) = 53\,\mathrm{pb}$ (gluon fusion only, for a SM Higgs boson with $m_H = 125\,\mathrm{GeV}$).

A typical beam lifetime during physics data taking is 15 hours. Calculate how many of the corresponding particles are produced during one beam cycle in the collision point at CMS.

d)
Assume that you have simulated 100'000 events of type $pp \rightarrow H + X$ (gluon fusion only, for a SM Higgs boson with $m_H = 125\,\mathrm{GeV}$) and 100'000 events of type $pp \rightarrow Z + X, Z \rightarrow \ell\ell$ with a MC event generator. To what integrated luminosity do these numbers of generated events correspond to?