Exercise sheet 8
Simple parton energy loss model

Mika Holzem

July 2023

a)

An absolute constant energy loss of

$$p_T = p'_T - \Delta \tag{1}$$

is assumed.
Further, the spectra are expressed in the form

$$\frac{dN}{dp_T \cdot p_T} \propto p_T^{-n} \quad . \tag{2}$$

Using Eq. (1), allows expressing the yield of particles for a given centrality class and a given particle with transverse momentum p_T as the yield at $p_T + \Delta = p'_T$ (when the particle was created and did not suffer from energy loss yet):

$$\frac{dN_{afterloss}}{dp_T \cdot p_T} = \frac{dN}{dp'_T \cdot p'_T} \tag{3}$$

The spectra when the particles are created are expected to follow the relation mention in Eq. (2).
R_{AA} is given by the equation

$$R_{AA}(p_T) = \frac{\frac{dN_{afterloss}}{dp_T \cdot p_T}}{\frac{T_{AA} \cdot d\sigma_{inv}^{pp}}{dp_T \cdot p_T}} \quad . \tag{4}$$

Here T_{AA} is the nuclear overlap function, and $\frac{d\sigma_{inv}^{pp}}{dp_T \cdot p_T}$ is the invariant cross-section for proton-proton collisions, which is also related to Eq. (2).

Combining the latter remarks yields the equation

$$R_{AA}(p_T) = \frac{\frac{dN}{dp'_T \cdot p'_T}}{\frac{T_{AA} \cdot d\sigma_{inv}^{pp}}{dp_T \cdot p_T}} = \kappa \cdot \frac{(p_T + \Delta)^{-n}}{p_T^{-n}} = \kappa \cdot (1 + \Delta/p_T)^{-n} \tag{5}$$

for R_{AA}. The proportionality factor κ is a parameter, which we set to 1, so that for no energy loss the equation $R_{AA} = 1$ holds.

b)

The Equation (5) is used to fit the data recorded by the CMS collaboration (arXiv:1611.01664v1) for Pb-Pb collisions, which can be found as a download here.

The function (5) is fitted to the data for the most central collisions (0-5%) which is displayed in Fig. 1.

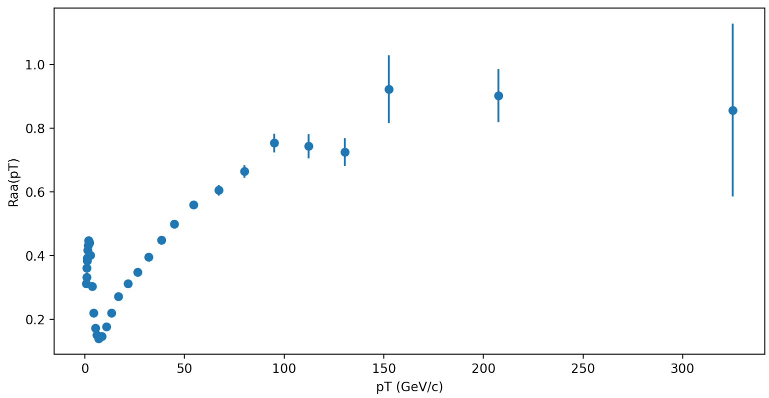

Figure 1: Raw HEP-data of nuclear modification factor R_{AA} in dependance of transverse momentum p_T for most central (0-5%) Pb-Pb collisions

The fit is done for $p_T \geq 25$ GeV/c and can be seen in Fig. 2.

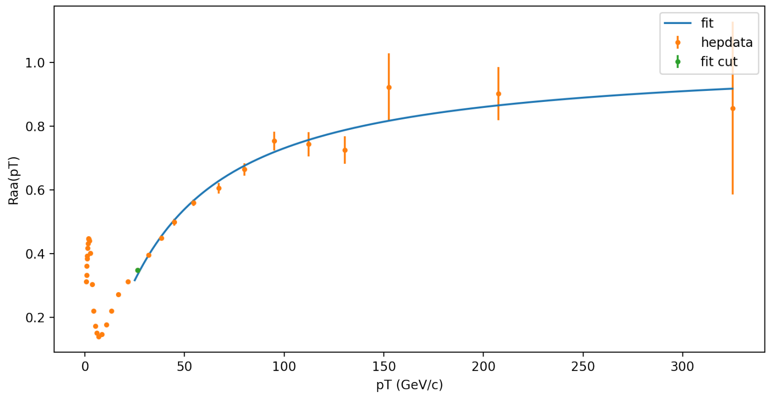

Figure 2: Fit of function (5) to HEP-data. The orange dots represent the HEP-data, the blue line is the best fit and the green point displays the data point at 26.4 GeV/c from which on is fitted.

The best fit value for Eq. (5) is given for $n = 1.9 \pm 0.3$ and $\Delta = (20 \pm 4)$ GeV/c, with $\chi^2_{red} = 0.80$.

c)

For the next part the factor n will be determined first using a pp-spectrum. The pp-spectrum is retrieved from the HEP-data here.

The pp spectrum is fitted with a function

$$f(p_T) = \frac{A}{p_T^n} \quad . \tag{6}$$

The resulting fit can be seen in Fig. 3.

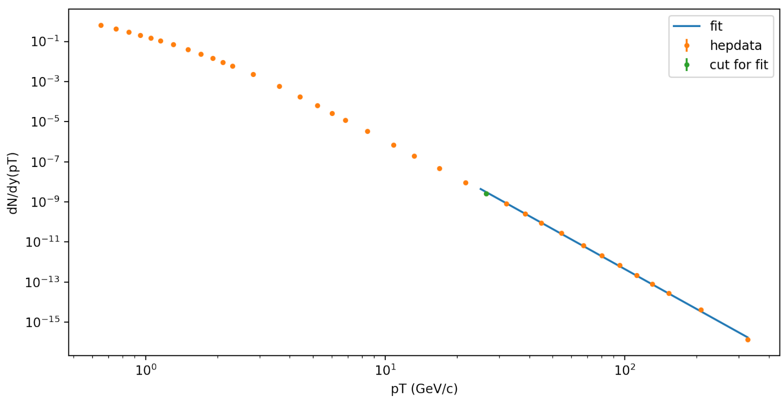

Figure 3: Fit of pp-spectra with the fit function (6). The green marker indicates the lower cut of $pt = 26.4$ GeV/c from which on was fitted

This resulted in a value of $n = 6.64 \pm 0.04$.
This value was now used as a parameter for the fit, thus only Δ was varied (see Fig. 4)

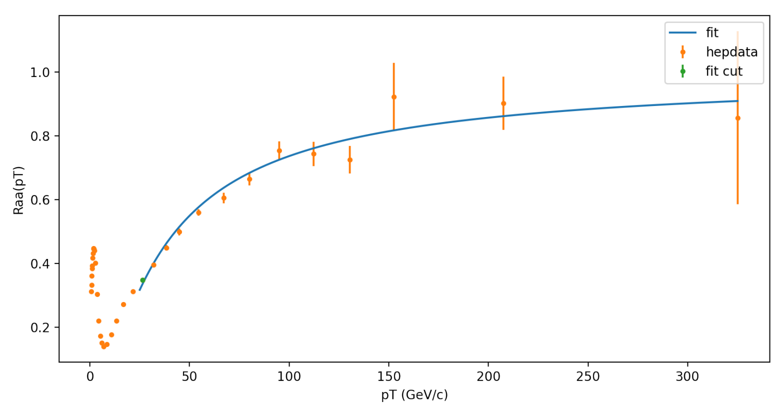

Figure 4: Fit of function (5) to HEP-data. The orange dots represent the HEP-data, the blue line is the best fit and the green point displays the data point at 26.4 GeV/c from which on is fitted. Only Δ was varied in this plot.

The best fit value for Eq. (5) is now given for $\Delta = (4.72 \pm 0.06)$ GeV/c, with $\chi^2_{red} = 2.4$.