Problem 13: HBT correlations for an extended static source

For an extended static spatial distribution $\rho(\vec{x})$ of incoherent sources (with $\int \mathrm{d}^3x\rho(\vec{x}) = 1$) the probability to detect a pair of pions with momenta $\vec{k}_1$ and $\vec{k}_2$ is given by

$$P(\vec{k}_1, \vec{k}_2) = \frac{1}{2} \int \mathrm{d}^3x_1 \mathrm{d}^3x_2 \, \rho(\vec{x}_1)\rho(\vec{x}_2)|\psi(\vec{k}_1, \vec{k}_2)|^2$$

where $|\psi(\vec{k}_1, \vec{k}_2)|^2 = \frac{1}{V^2}(1 + \cos(\Delta\vec{k} \cdot \Delta\vec{x}))$. Show that the correlation function $C_2 = \frac{2P(\vec{k}_1,\vec{k}_2)}{P(\vec{k}_1)P(\vec{k}_2)}$ is given by

$$C_2 = 1 + |\tilde{\rho}(\Delta\vec{k})|^2$$

where $\tilde{\rho}(\vec{k}) = \int \mathrm{d}^3x\rho(\vec{x})e^{i\vec{k}\vec{x}}$ is the Fourier transform of $\rho(\vec{x})$.

Problem 14: Simple energy loss model

a) Find the formula for the charged-hadron $R_{\mathrm{AA}}(p_T)$ for a transverse momentum spectrum described by $1/p_T \, \mathrm{d}n/\mathrm{d}p_T \sim 1/p_T^n$ assuming a constant absolute energy loss Δ of the partons.

b) Determine the value Δ which describes the $R_{\mathrm{AA}}(p_T)$ measured in central (0–5%) Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02\,\mathrm{TeV}$ (arXiv:1611.01664) for $p_T \gtrsim 25\,\mathrm{GeV}/c$ best by extending the jupyter notebook charged_hadron_Raa_homework.ipynb. This notebook reads a data file obtained from hepdata.net.

Problem 15: Moving thermal photon source

A photon source at rest emits photons in the directions of a detector with an energy spectrum

$$\frac{\mathrm{d}n_\gamma}{\mathrm{d}E^*} \propto \frac{E^{*2}}{\exp\left(E^*/T\right) - 1} \, .$$

What energy spectrum $\mathrm{d}n_\gamma/\mathrm{d}E$ is measured in the detector if the photon source moves with a velocity β towards the detector? Plot the energy spectrum $\mathrm{d}n_\gamma/\mathrm{d}E$ for $\beta = 0$ and $\beta = 0.6$.